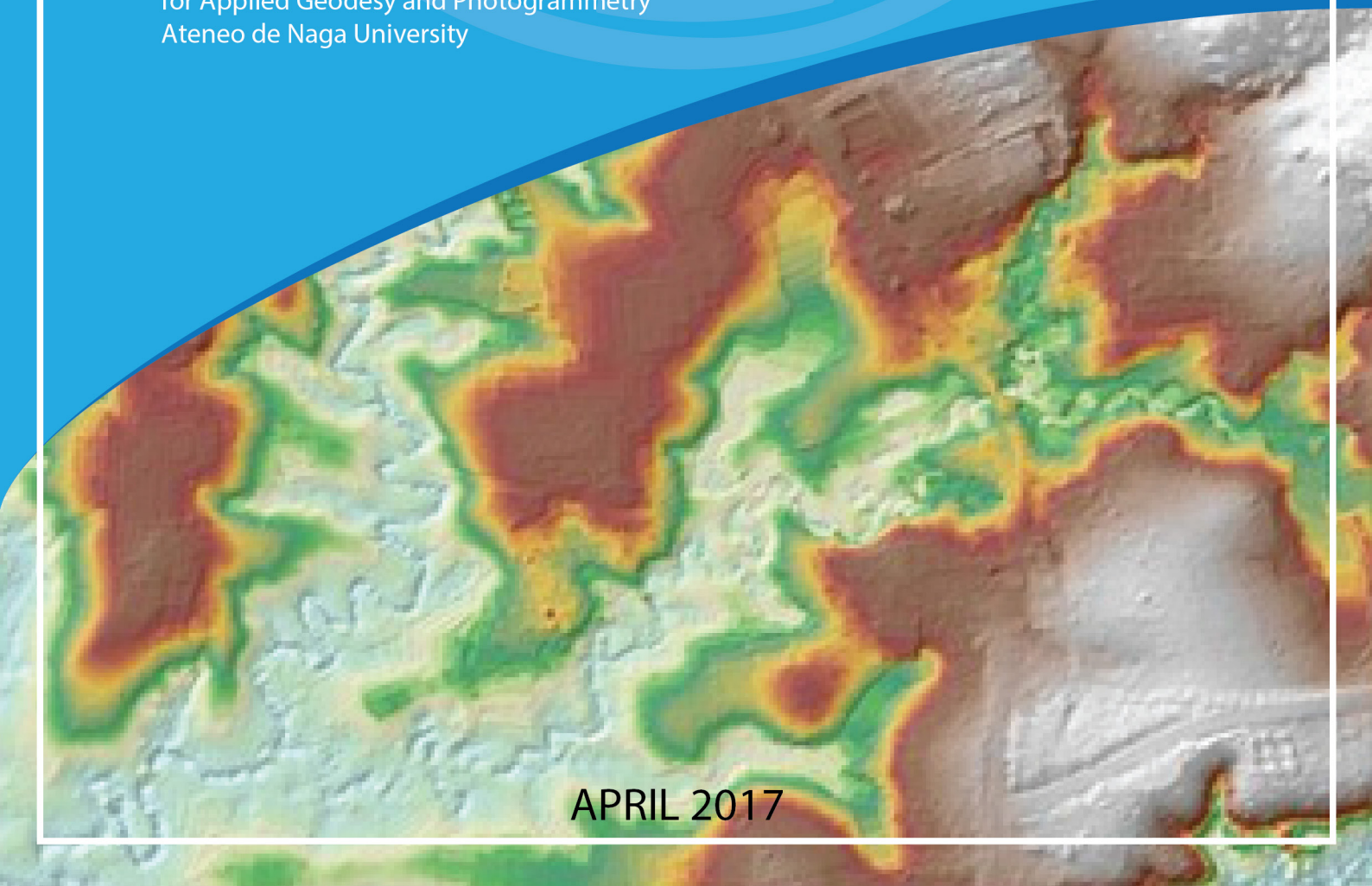
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Daraga River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADNU	Ateneo de Naga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA-BSWM	Department of Agriculture - Bureau of Soil and Water Management
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PSA	Philippine Statistics Authority
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 DARAGA RIVER

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 methods applied in this report are thoroughly described in a separate publiction entitled "FLOOD MAPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et al., 2017) available separately."

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga (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 in the Province of Camarines Sur.

1.2 Overview of Daraga River Basin

Daraga River Basin (RB) is within the jurisdiction of the towns of Daraga and Camalig, both first class municipalities, and Legazpi City, a component city. Daraga has a total population of 126,595 distributed in 54 barangays, while Camalig has 66,904 in its 50 barangays. Legazpi City has 196,639 in its 70 barangays. The major stream emptying this basin is the Daraga River which is 73.48 km long, and empties out to Albay Gulf. The surroundings of the Daraga RB also falls under the type II modified Corona Classification of climate resulting in no dry season and pronounced rainfall from November to January. The headwaters of Daraga River originates from the southern slope of Mt. Mayon. Thus, it is bound to the north by the very active volcano, which is also a protected area by virtue of Proclamation 412 signed in November 2000. Mayon Volcano reaches 2,463 mASL and last erupted in September 2014.

In terms of economy, the nearby areas are dedicated to agricultural practices with major products including rice, coconut, and various root crops. It is however, currently urbanizing and given a boost in economy by various infrastructures such as the future Bicol International Airport and presence of a mining industry; it is also being marketed and geared towards other industries such as business process outsourcing. Tourism is also a lucrative business, considering the presence of Mayon Volcano and several other destinations as sidetrips.

Typhoon Reming (Durian) devastated Albay in 2006, resulting in lost lives.

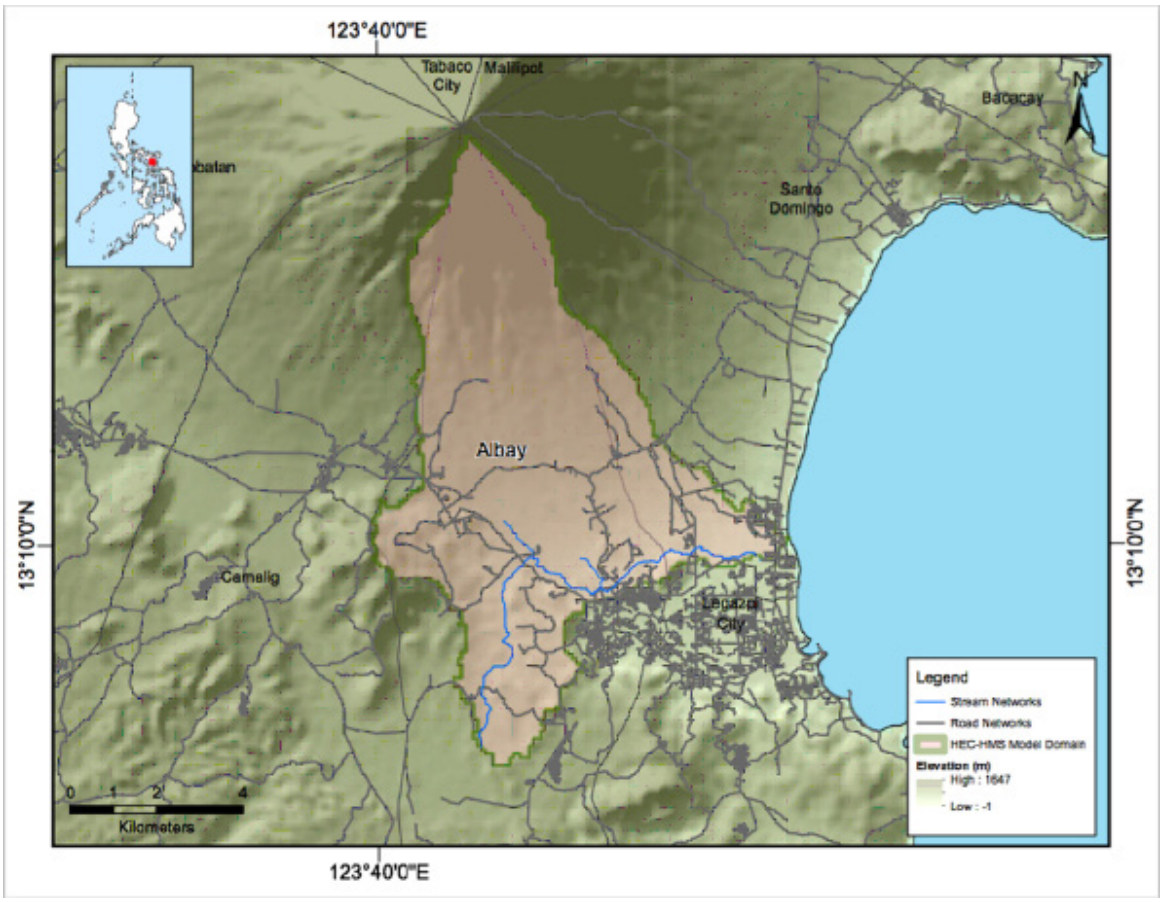

Figure 1. Map of the Daraga River Basin

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DARAGA 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

To initiate the LiDAR acquisition survey of the Daraga Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Daraga Floodplain in Albay, Camarines Sur, and Sorsogon. These missions were planned for 17 lines each, which ran for at most four and a half (4.5) hours including take-off, landing, and turning time (See Annex 1 for sensor specifications). The flight planning parameters for the LiDAR system is found in Table . Figure 2, on the other hand, shows the flight plan for Daraga Floodplain survey.

Table 1. Flight planning parameters for the Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK19A	1000	30	50	125	50	130	5
BLK19B	1000	30	50	125	50	130	5
BLK19C	1000	30	50	125	50	130	5
BLK19D	1000	30	50	125	50	130	5
BLK19E	1000	30	50	125	50	130	5
BLK19G	1000	30	50	125	50	130	5
BLK19I	1000	30	50	125	50	130	5
BLK19S	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5

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

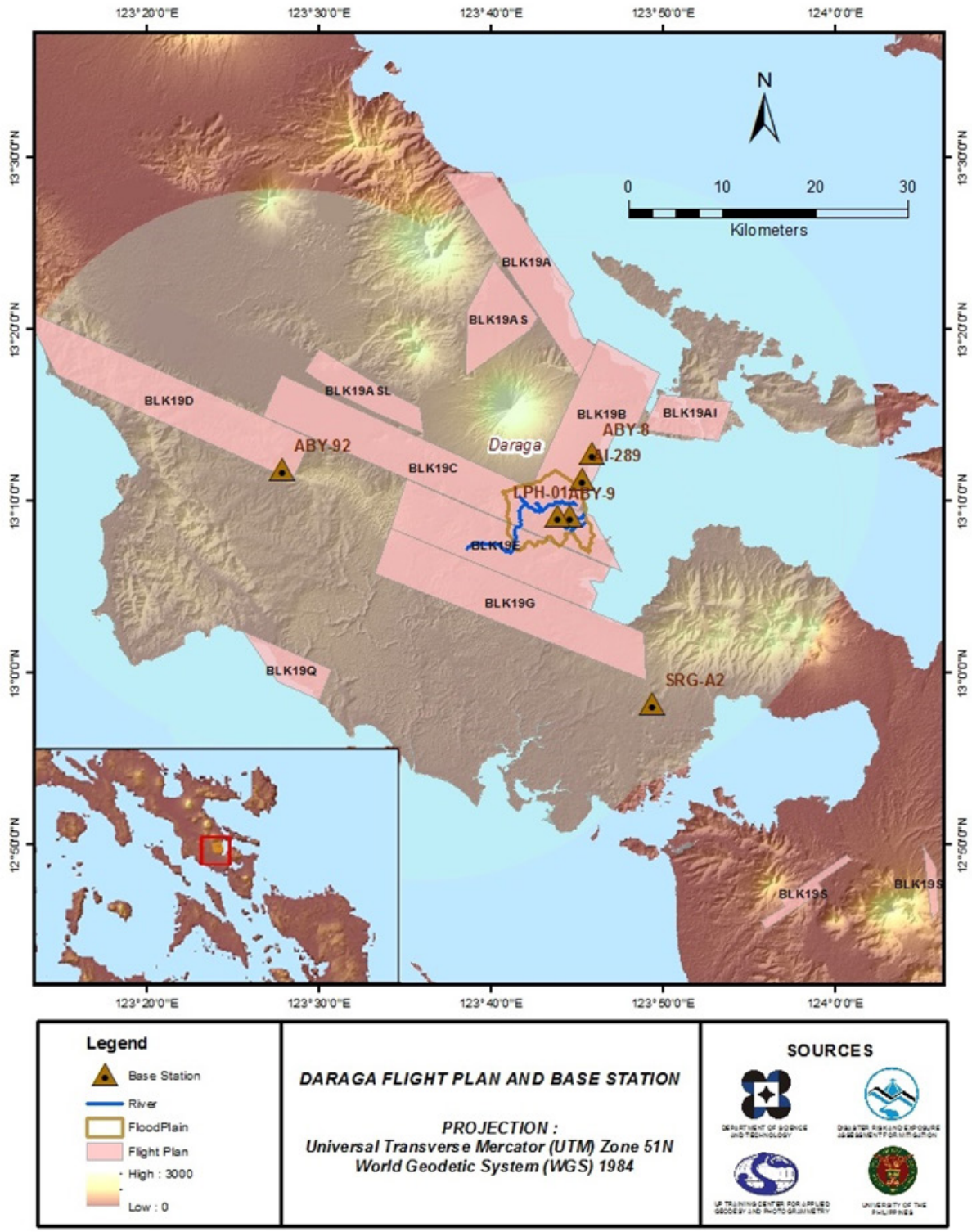

Figure 2. Flight plan and base stations used for Daraga Floodplain.

2.2 Ground Base Station

The field team for this undertaking was able to recover three (3) NAMRIA reference points: ABY-92 and ABY-08 (of second (2nd) order accuracy), and ABY-9 (of third (3rd) order accuracy). Also recovered was one (1) NAMRIA benchmark, AL-289, which is of second order accuracy. The project team established two (2) ground control points: LPH-1 and SRG-A2. The certifications for the base stations and benchmark are 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 (March 29 – April 28, 2014 and February 29– March 19, 2016). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 882, and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Daraga Floodplain are shown in Figure 2. For the list of team members, see Annex 4.

Figures 3 to 8 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 7 show the details about the following NAMRIA control stations and established points while Table 8 shows the list of all ground control points occupied during the acquisition with the corresponding dates of survey.

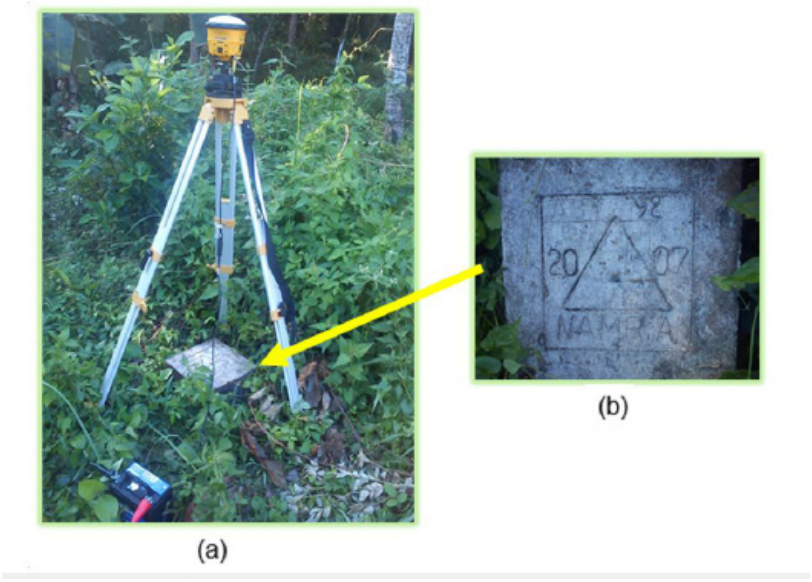

Figure 3. a) GPS set-up over ABY-92 beside the baseline of the basketball court at about 19 m from the barangay hall, and b) NAMRIA reference point ABY-92 as recovered by the field team.

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

Station Name	ABY-92	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 11’ 56.27238” North 123° 27’ 47.60156” East 127.309000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	550210.89 meters 1459605.458 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 11’ 51.38974” North 123° 27’ 52.59990” East 180.74900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	550193.31 meters 1459094.57 meters

(a) (b)

Figure 4. a) GPS set-up over ABY-8 at a center island in Mayon Riviera Subdivision, and b) NAMRIA reference point ABY-8 as established by the field team.

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

Station Name	ABY-8	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 12’ 51.92876” North 123° 45’ 45.95336” East 6.33900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	582675.867 meters 1461395.121 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 12’ 47.06720” North 123° 45’ 50.94829” East 60.47000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	582646.93 meters 1460883.61 meters

(a) (b)

Figure 5. a) GPS set-up over ABY-9 inside Legaspi Airport compound, and b) NAMRIA reference point ABY-9 as recovered by the field team.

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

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

(a)

(b)

Figure 6. a) GPS set-up over AL-289 located at Arimbay Bridge along the Tiwi-Legazpi National Road at Brgy. Bigaa, Legazpi City, Albay, and b) NAMRIA reference point AL-289 as recovered by the field team.

Table 5. Details of the recovered NAMRIA vertical control point AL-289 used as base station for the LiDAR acquisition with established coordinates.

Station Name	AL-289	
Order of Accuracy (benchmark)	2nd	
Elevation (Mean Sea Level)	8.9801 meters	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 11’ 22.18920” North 123° 45’ 09.03476” East 10.065 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 11’ 17.33275” North 123° 45’ 14.03173” East 64.238 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	581543.975 meters 1458123.495 meters

Figure 7. GPS set-up over LPH-01 located at the rooftop of La Piazza Hotel and Convention Center along Tahao Road, Legazpi, Albay.

Table 6. Details of established ground control point LPH-01 used as base station for the LiDAR acquisition.

Station Name	LPH-01	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 09' 13.3540" North 123° 44' 27.8894" East 11.01 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	580345.19416 meters 1454671.24009 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 09' 08.50554" North 123° 44' 32.88949" East 65.236 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	580467.016 meters 1454103.670 meters

(a)

(b)

Figure 8. a) GPS set-up over SRG-A2 beside the flag pole of San Rafael Barangay Hall, Castilla, Sorsogon near kilometer post 556, and b) NAMRIA reference point SRG-A2 as established by the field team.

Table 7. Details of the established ground control point SRG-A2 used as base station for the LiDAR acquisition.

Station Name	SRG-A2	
Order of Accuracy (benchmark)	3rd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 58’ 19.68256” North 123° 49’ 14.551238” East 50.561 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 58’ 14.88482” North 123° 49’ 19.56657” East 105.483 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	589012.581 meters 1434108.317 meters

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 29, 2014	7156GC	2BLK19E088A	ABY-9 & LPH-01
March 30, 2014	7158GC	2BLK19ES089A & 2BLK19G089A	ABY-9 & LPH-01
April 2, 2014	7165GC	2BLK19CS092A	ABY-08 & ABY-09
April 04, 2014	7169GC	2BLK19CS096A & 2BLK19D096A	ABY-9 & LPH-01
April 06, 2014	7172GC	2BLK19CS096A & 2BLK19D096A	ABY-92 & LPH-01
April 28, 2014	7216GC	2BLK19AS118A & VOIDS	ABY-08 & ABY-09
February 29, 2016	3827G	2BLK19ABS060A	ABY-08 & ABY-09
March 10, 2016	3869G	2BLK19ASBSI070A	ABY-08 & AL-289
March 16, 2016	3891G	2BLK19ACS076A	ABY-08 & AL-289
March 19, 2016	3903G	2BLK19S079A	ABY-09 & SRG-A2

Table 8. Ground control points used during LiDAR data acquisition

2.3 Flight Missions

Ten (10) missions were conducted to complete the LiDAR data acquisition in Daraga Floodplain, for a total of thirty seven hours and forty six minutes (37+46) of flying time for RP-C9322 and RP-C9022. All missions were acquired using the Gemini LiDAR system. Table 9. shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10.presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for LiDAR data acquisition in Daraga Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	Flying Hours	
						Hr	Min
March 29, 2014	7156GC	106.73	40.41	6.52	33.89	2	11
March 30, 2014	7158GC	241.81	282.19	4.88	277.30	4	29
April 2, 2014	7165GC	162.42	101.56	20.17	81.39	2	11
April 04, 2014	7169GC	107.61	125.03	14.24	110.80	3	17
April 06, 13	7172GC	162.42	362.55	40.24	322.32	4	35
April 28, 2014	7216GC	144.01	45.93	34.36	11.58	3	11
February 29, 2016	3827G	160.82	167.37	16.19	151.18	4	29
March 10, 2016	3869G	193.41	144.44	-	144.44	4	36
March 16, 2016	3891G	61.28	135.78	-	135.78	4	48
March 19, 2016	3903G	189.01	103.19	-	103.19	3	41
TOTAL		1529.51	1508.45	136.59	1371.86	37	46

Table 10. 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
7156GC	1000	35	40	100	50	130	5
7158GC	1000	35	40	100	50	130	5
7165GC	1000	45	40	100	50	130	5
7169GC	900	40	40	125	50	130	5
7172GC	1000	40	40	100	50	130	5
7216GC	1200	50	34	100	50	130	5
3827G	1100/850 /600	40	50	100/ 125	40	130	5
3869G	750	40	50	125	45	130	5
3891G	600/850	40	50	125	45	130	5
3903G	850	35	50	125	45	130	5

2.4 Survey Coverage

Daraga Floodplain is located in the Provinces of Albay, Camarines Sur, and Sorsogon with majority of the floodplain situated within Albay. The Municipality of Camalig and Legazpi City are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Daraga Floodplain is presented in Figure 9.

Table 11. List of municipalities and cities surveyed during Daraga Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)
Albay	Camalig	136.54	118.39	87%
	Legazpi City	153.18	130.51	85%
	Daraga	135.66	97.43	72%
	Santo Domingo	60.83	42.99	71%
	Bacacay	115.2	61.86	54%
	Guinobatan	174.07	80.07	46%
	Tabaco City	112.24	48.99	44%
	Malinao	106.78	41.6	39%
	Libon	222.82	73.55	33%
	Ligao City	258.51	74.7	29%
	Oas	239.58	57.27	24%
	Malilipot	45.42	9.06	20%
	Polangui	148.89	29.88	20%
	Jovellar	82.35	11.97	15%
	Tiwi	124.4	16.4	13%
	Pio Duran	133.24	12.28	9%
Camarines Sur	Bato	75.94	32.97	43%
	Balatan	59.84	21.91	37%
Sorsogon	Juban	127.78	12.77	10%
	Bulusan	93.11	6.76	7%
	Barcelona	58.77	3.8	6%
	Castilla	197.27	8.82	4%
	Donsol	153	5.82	4%
	Magallanes	117.6	2.78	2%
	Pilar	196.62	4.19	2%
	TOTAL	3329.64	1006.77	30.24%

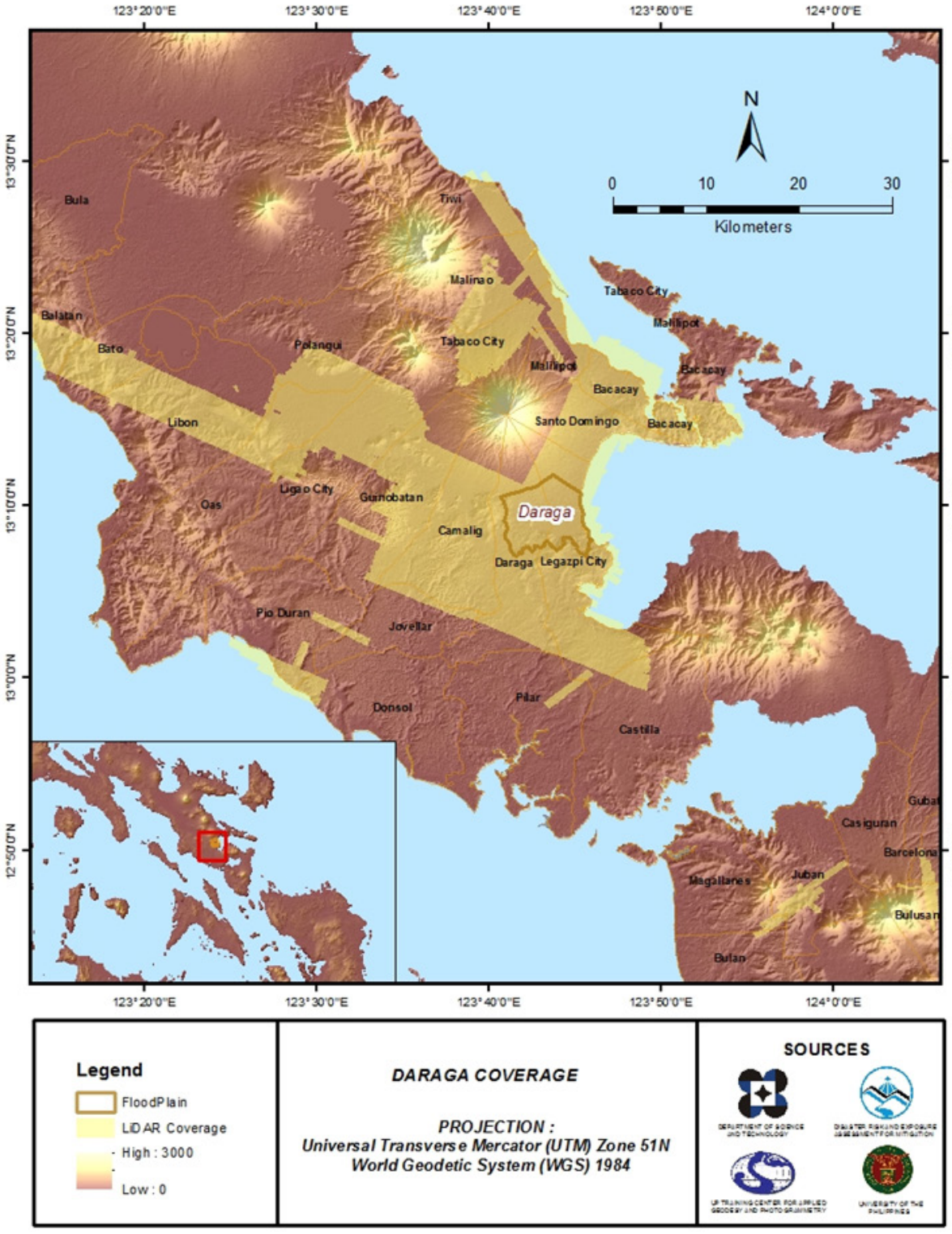

Figure 9. Actual LiDAR survey coverage for Daraga Floodplain.

CHAPTER 3: DATA PROCESSING FOR THE DARAGA FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

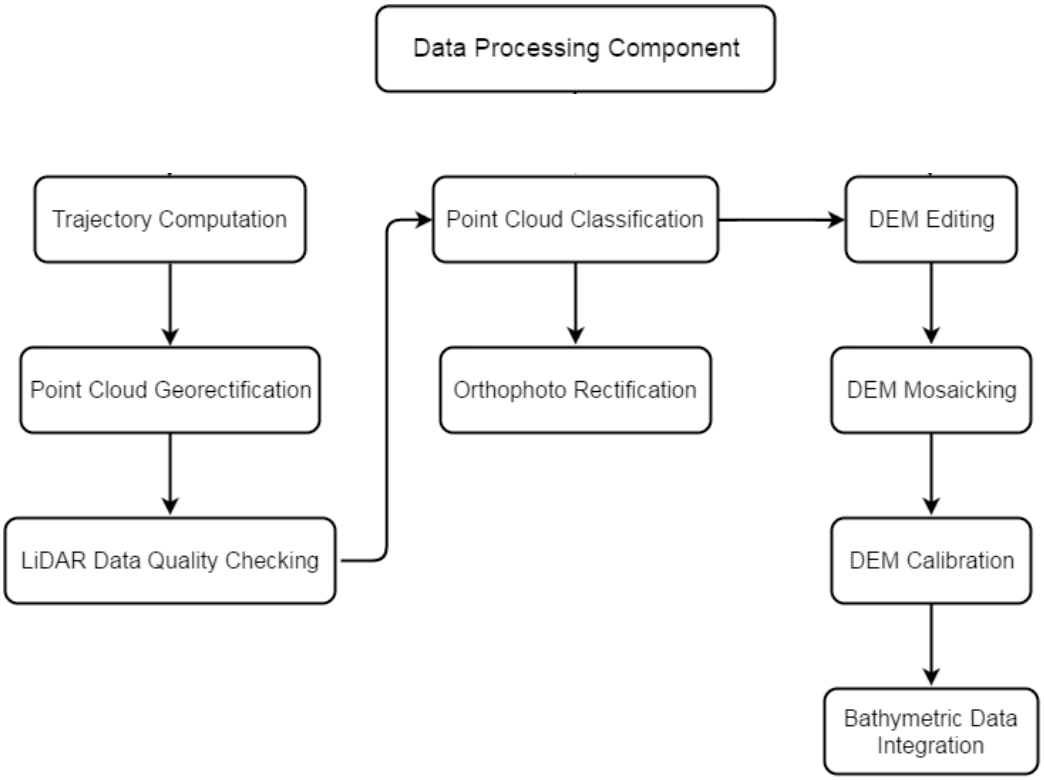

Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Daraga Floodplain can be found in Annex 5. Missions flown during the first and second survey conducted on March 2014 and February 2016 both used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System over Daraga and Legazpi City, Albay. The Data Acquisition Component (DAC) transferred a total of 187.75 gigabytes of range data, 1.77 gigabytes of POS data, 86.6 megabytes of GPS base station data, and 212.2 gigabytes of raw image data to the data server on October 29, 2014 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 Daraga was fully transferred on March 31, 2016, as indicated on the Data Transfer Sheets for Daraga Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 3891G, one of the Daraga flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on March 16, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

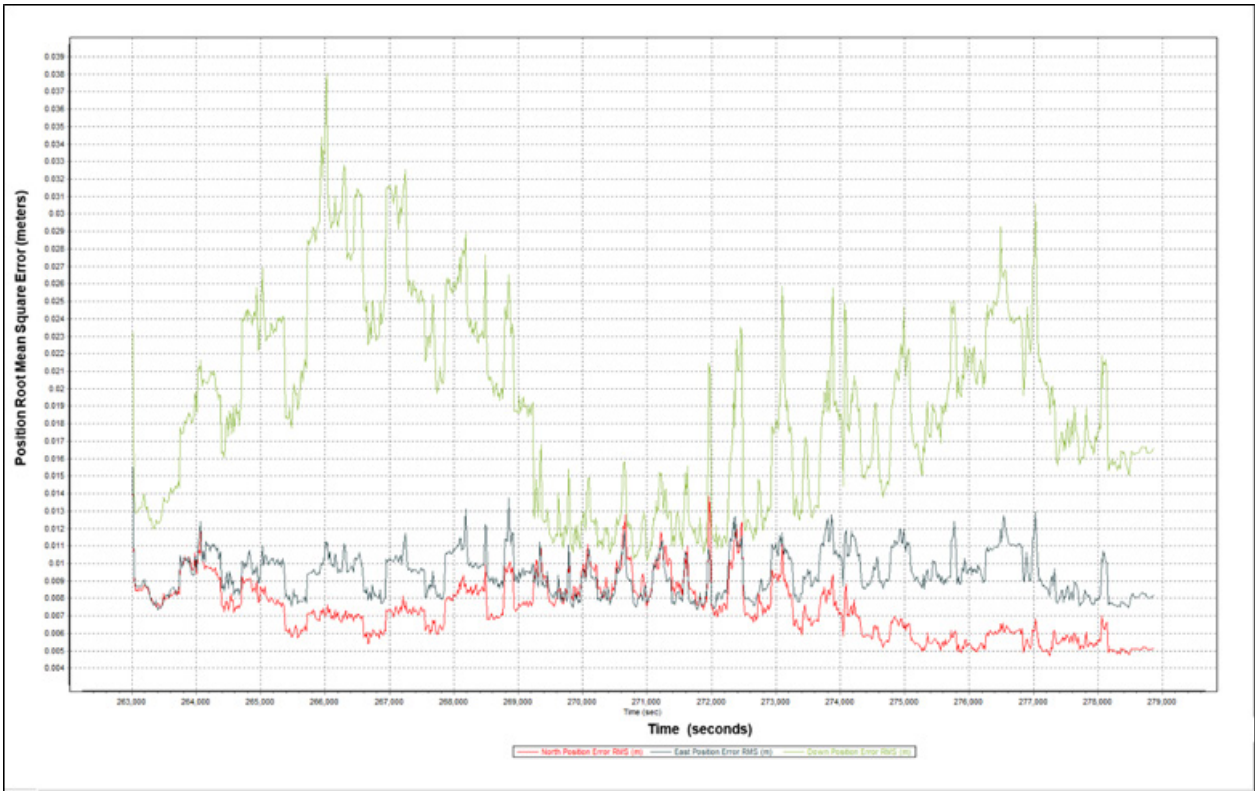

Figure 11. Smoothed Performance Metrics of Daraga Flight 3891G

The time of flight was from 263000 seconds to 279000 seconds, which corresponds to the morning of March 16, 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 minimize 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 12 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1.40 centimeters, and the Down position RMSE peaks at 3.80 centimeters, which are within the prescribed accuracies described in the methodology.

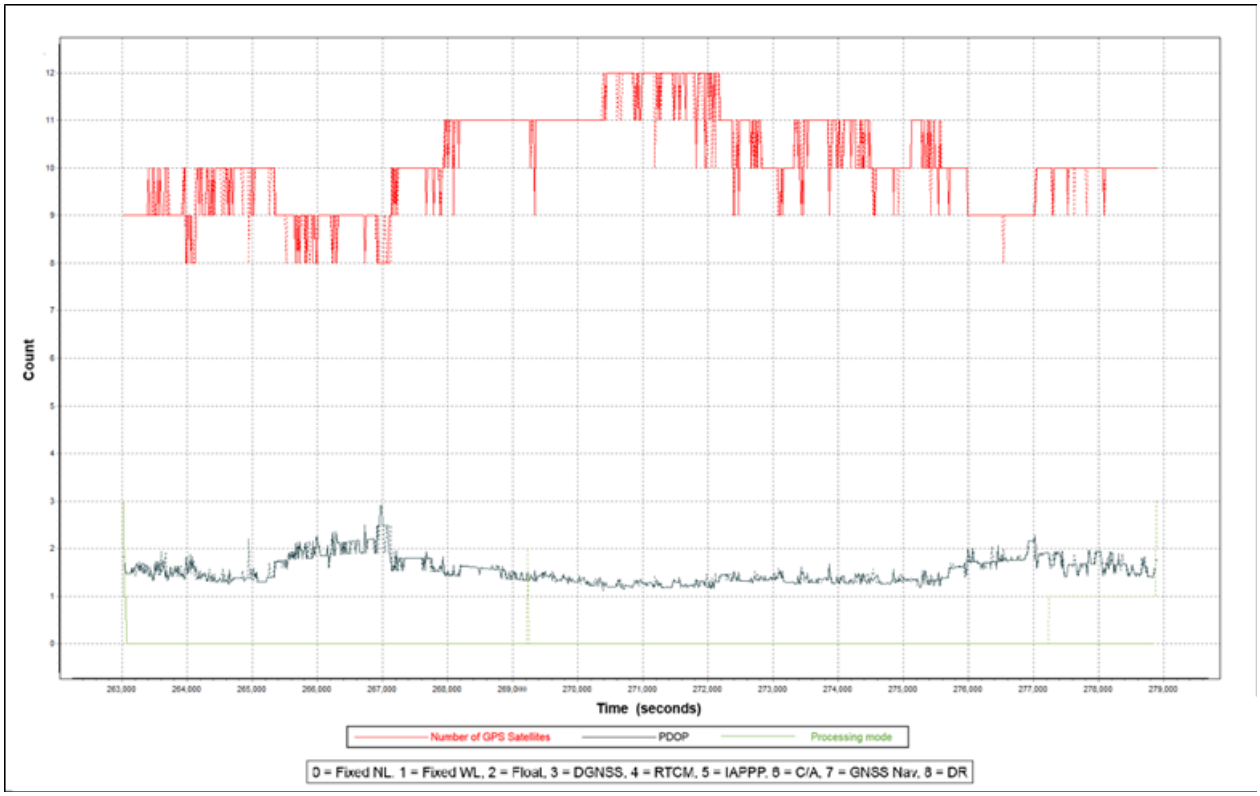

Figure 12. Solution Status Parameters of Daraga Flight 3891G.

The Solution Status parameters of Flight 3891G, one of the Daraga flights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 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 Daraga flights is shown in Figure 13.

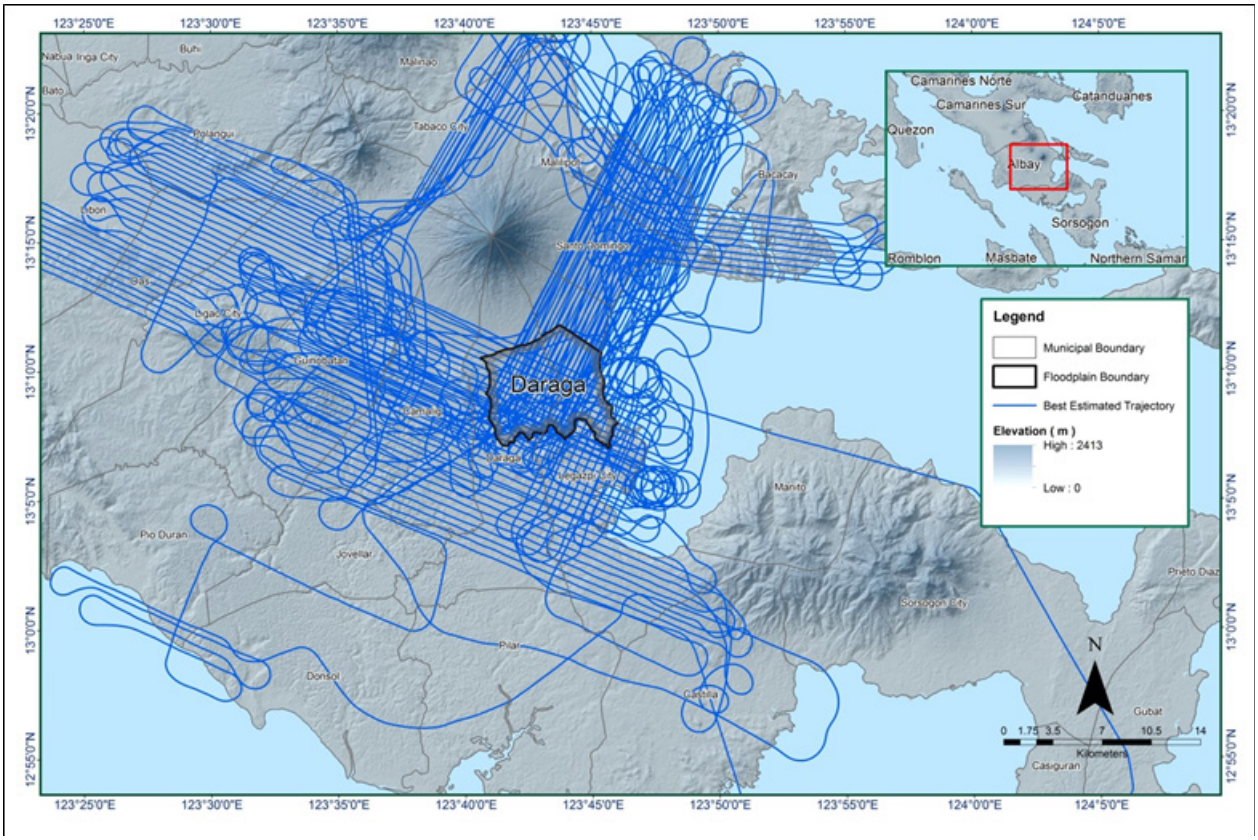

Figure 13. Best Estimated Trajectory of the LiDAR missions conducted over the Daraga Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 106 flight lines, with each flight line containing one channel, since the Gemini and AquariusSystems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Daraga Floodplain are given in Table 12.

Table 12. Self-Calibration Results values for Daraga flights.

Parameter	Value
Boresight Correction stdev (<0.001degrees)	0.000325
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000688
GPS Position Z-correction stdev (<0.01meters)	0.0094

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

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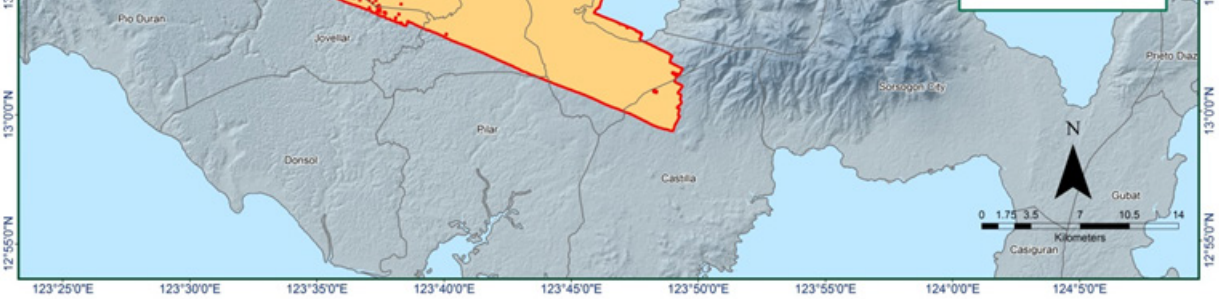


Figure 14. Boundary of the processed LiDAR data over Daraga Floodplain

The total area covered by the Daraga missions is 795.62 square kilometers that is comprised of nine (9) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Daraga Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Albay_Sorsogon_Blk19EG	7156GC	301.83
	7158GC	
	7216GC	
Albay_Sorsogon_Blk19C	7165GC	193.30
	7172GC	
Albay_Sorsogon_Blk19C_additional	7165GC	14.99
	7172GC	
Albay_Sorsogon_reflights_Blk19S	3903G	66.43
Albay_Sorsogon_reflights_Blk19C	3891G	11.25
Albay_Sorsogon_reflights_Blk19E	3891G	48.70
Albay_Sorsogon_reflights_Blk19B	3827G	129.88
Albay_Sorsogon_reflights_Blk19B_supplement	3869G	29.26
	TOTAL	**795.62 sq.km**

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

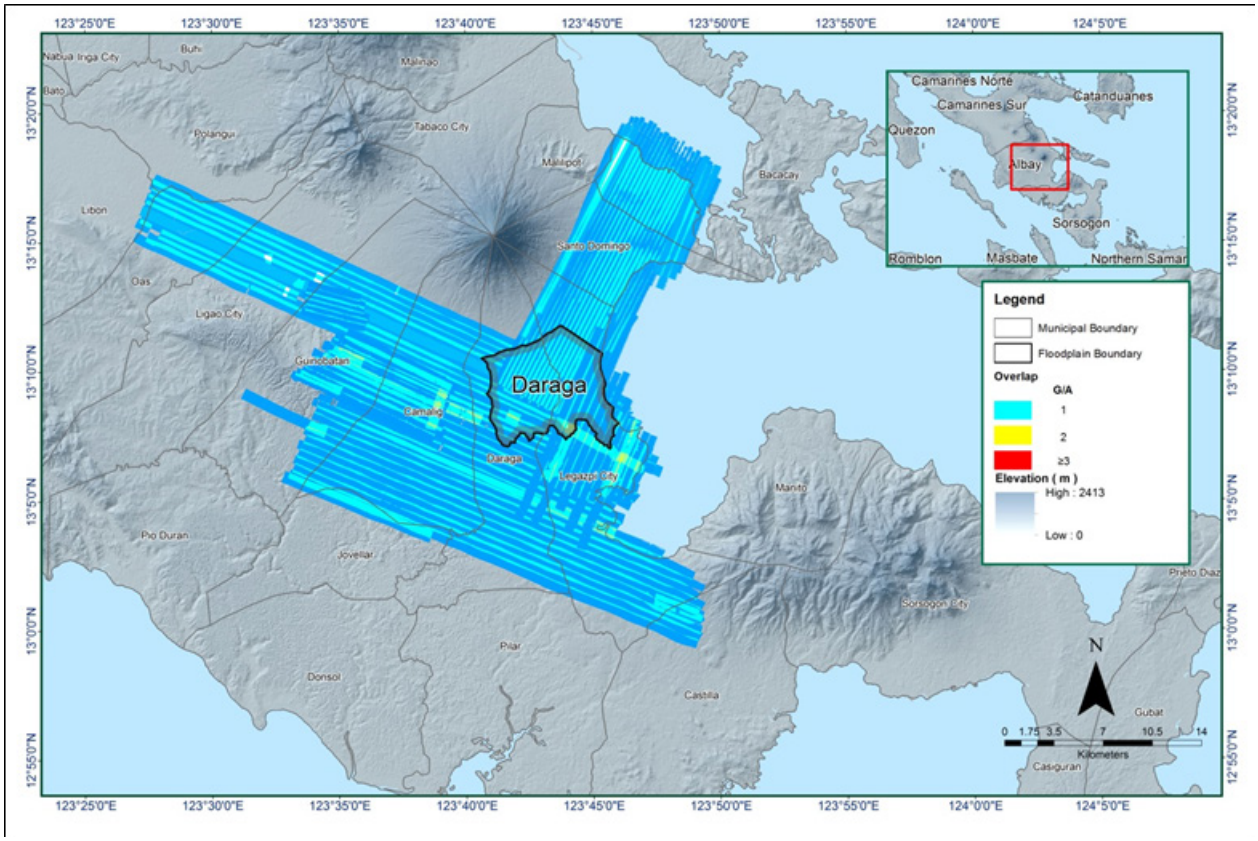


Figure 15. Image of data overlap for Daraga Floodplain.

The overlap statistics per block for the Daraga floodplain can be found in Annex B-1. Mission Summary Reports. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.43% and 41.33% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Daraga Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.31 points per square meter.

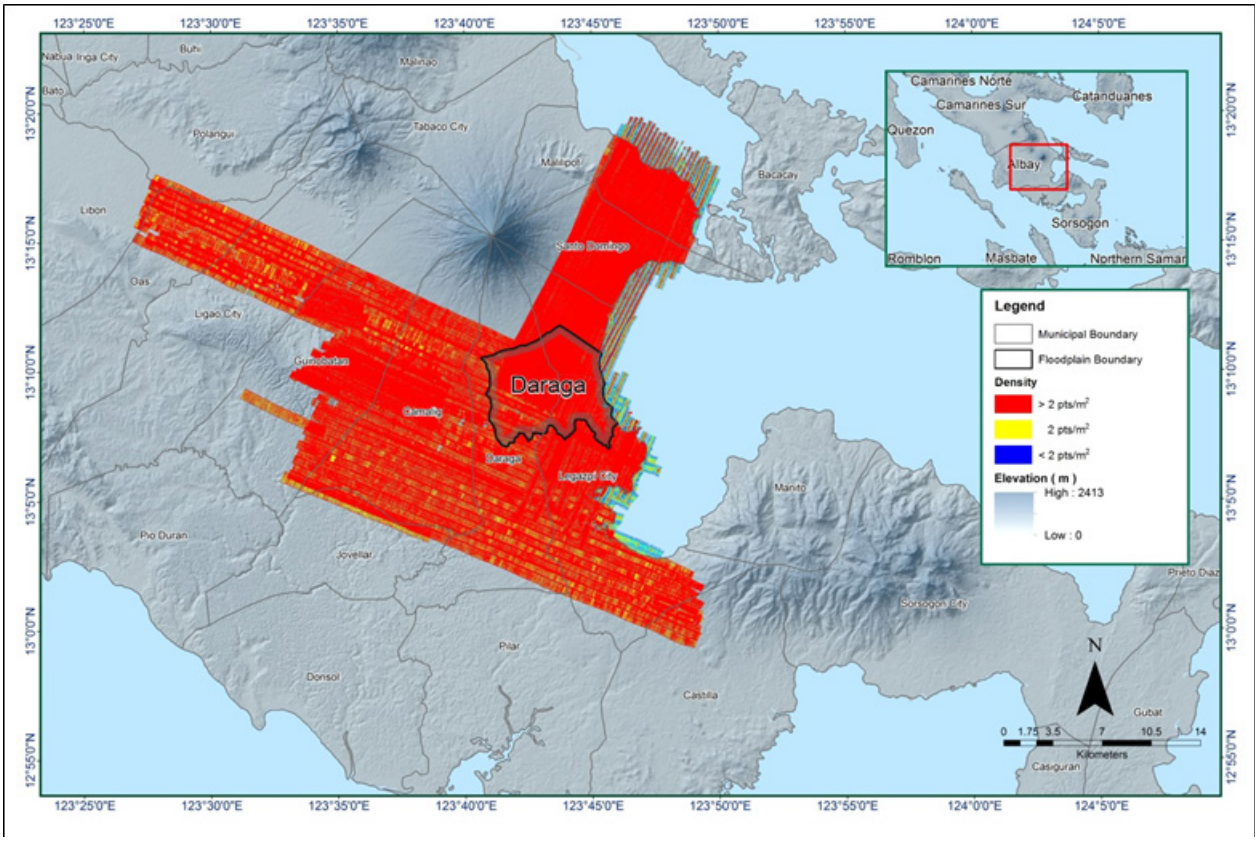


Figure 16. Pulse density map of merged LiDAR data for Daraga Floodplain.

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

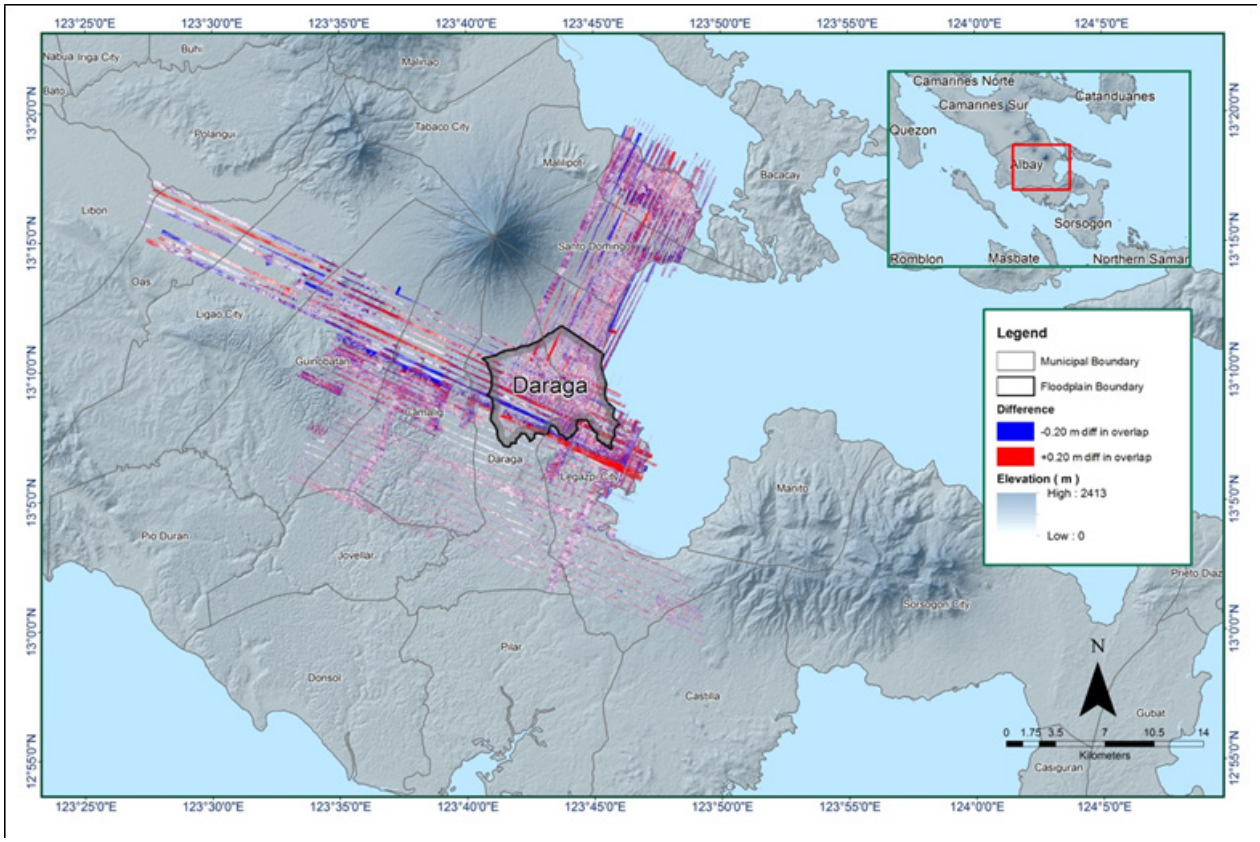


Figure 17. Elevation difference map between flight lines for Daraga Floodplain.

A screen capture of the processed LAS data from a Daraga Flight 3891G loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

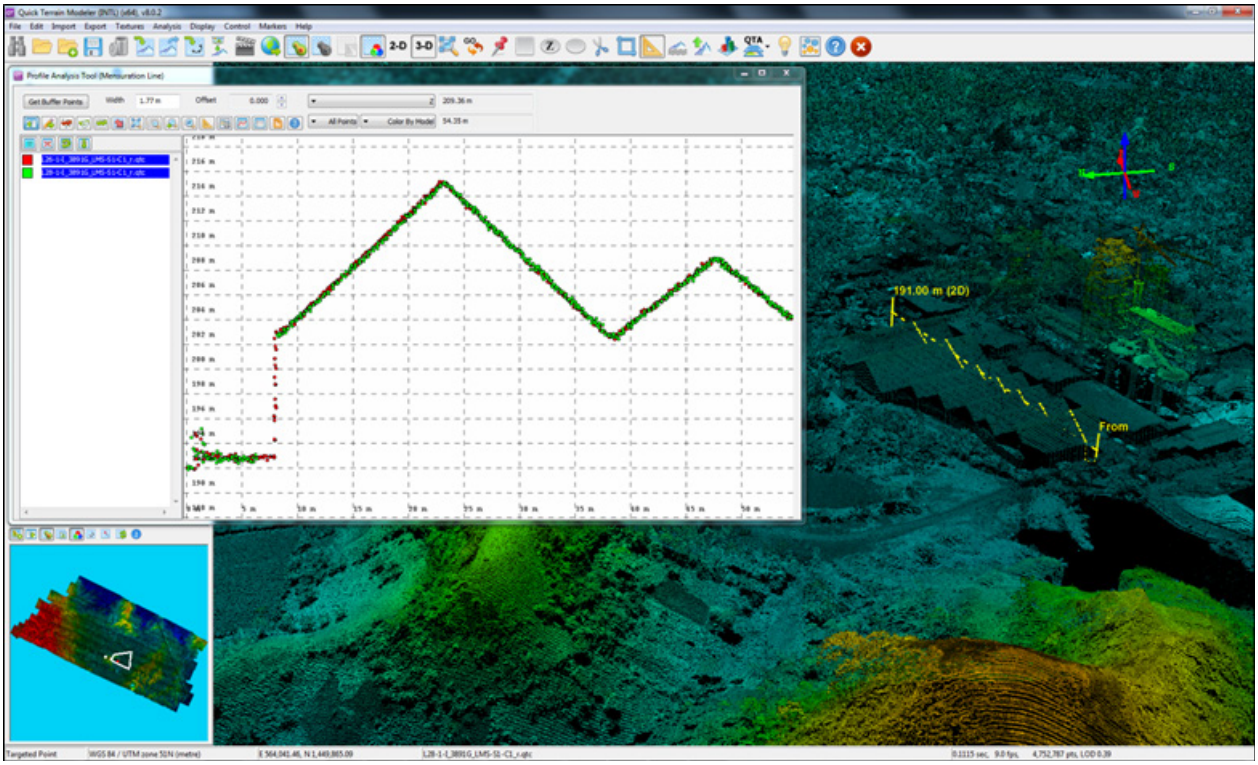


Figure 18. Quality checking for Daraga Flight 3891G using the Profile Tool of QT Modeler.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 m 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 0.20 m 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.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Daraga classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	401,131,234
Low Vegetation	417,888,330
Medium Vegetation	1,041,209,320
High Vegetation	1,442,735,454
Building	43,293,253

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Daraga Floodplain is shown in Figure B-10. A total of 1,414 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 472.65 meters and 51.3 meters respectively.

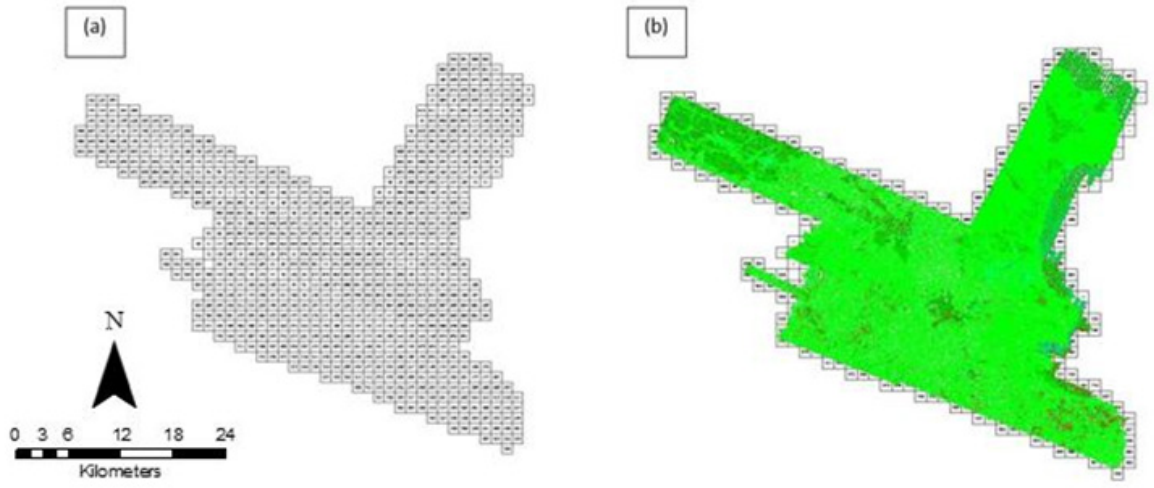


Figure 19. Tiles for Daraga Floodplain (a) and classification results (b) in TerraScan.

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.

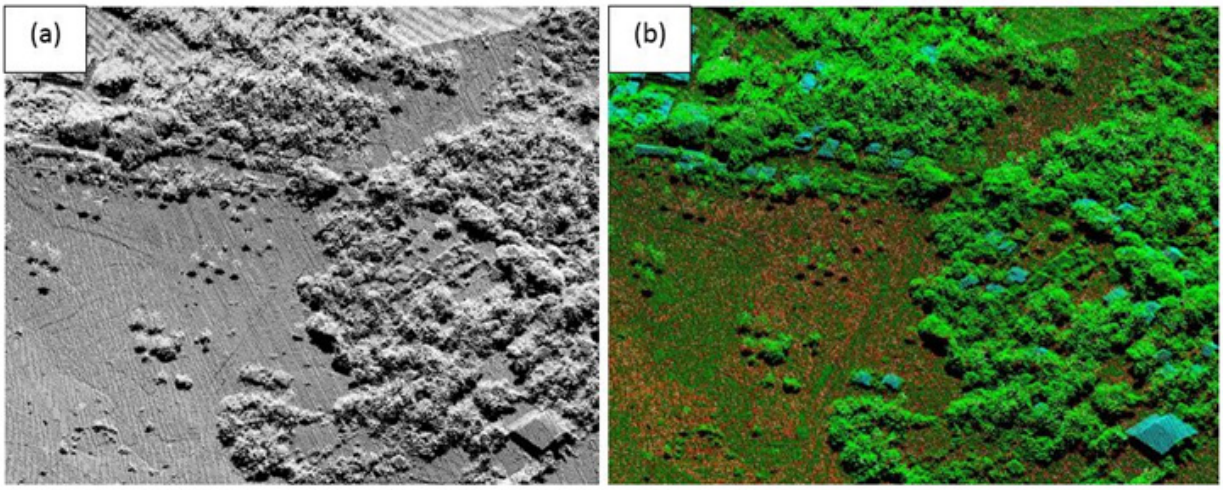


Figure 20. Point cloud before (a) and after (b) classification.

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

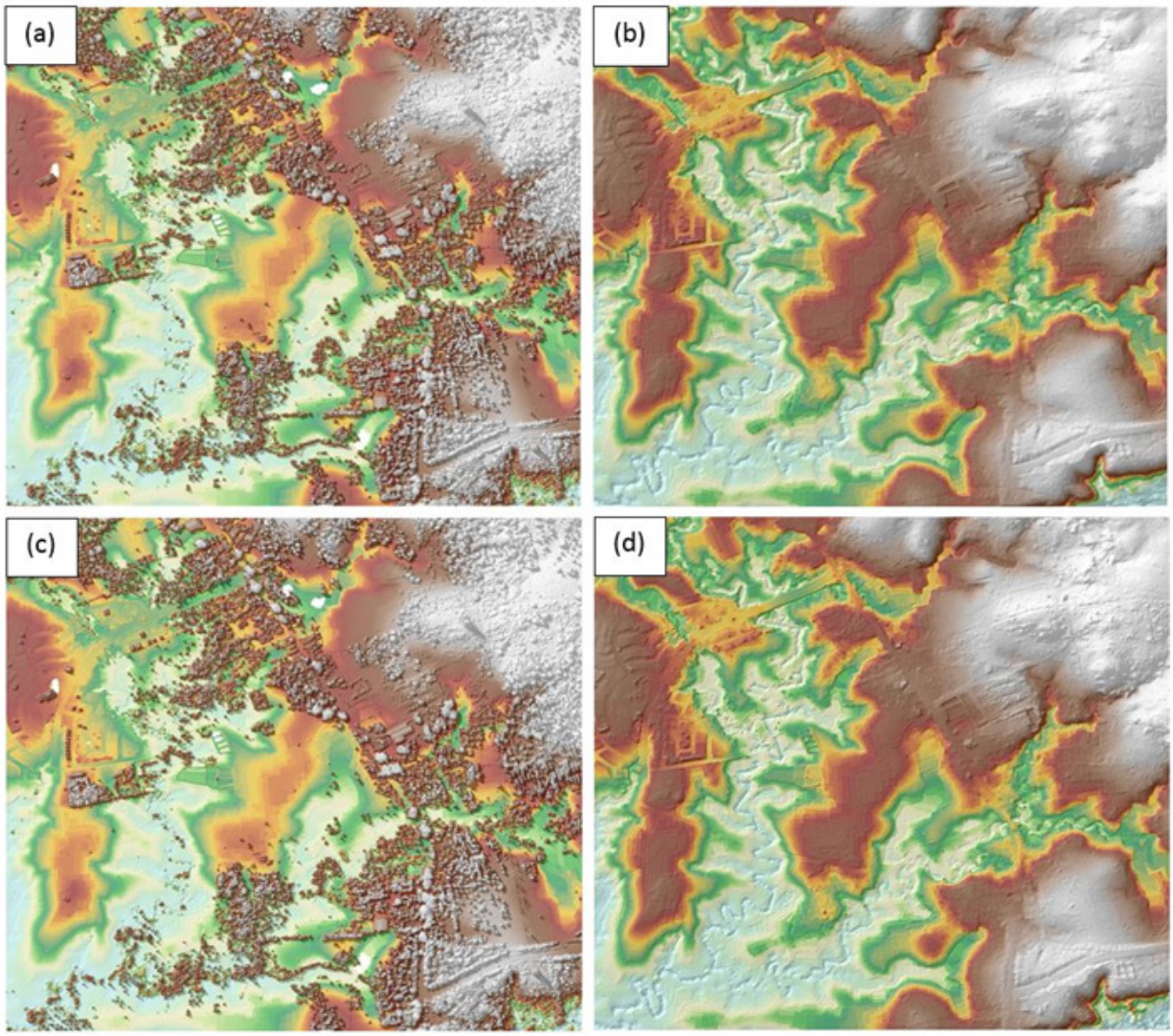


Figure 21. The Production of last return DSM (a) and DTM (b), first return DSM (c), and secondary DTM (d) in some portion of Daraga Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 m 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 0.20 m 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.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 273 1km by 1km tiles area covered by Daraga Floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Daraga Floodplain has a total of 161.07 square kilometers in orthophotogaph coverage comprised of 861 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

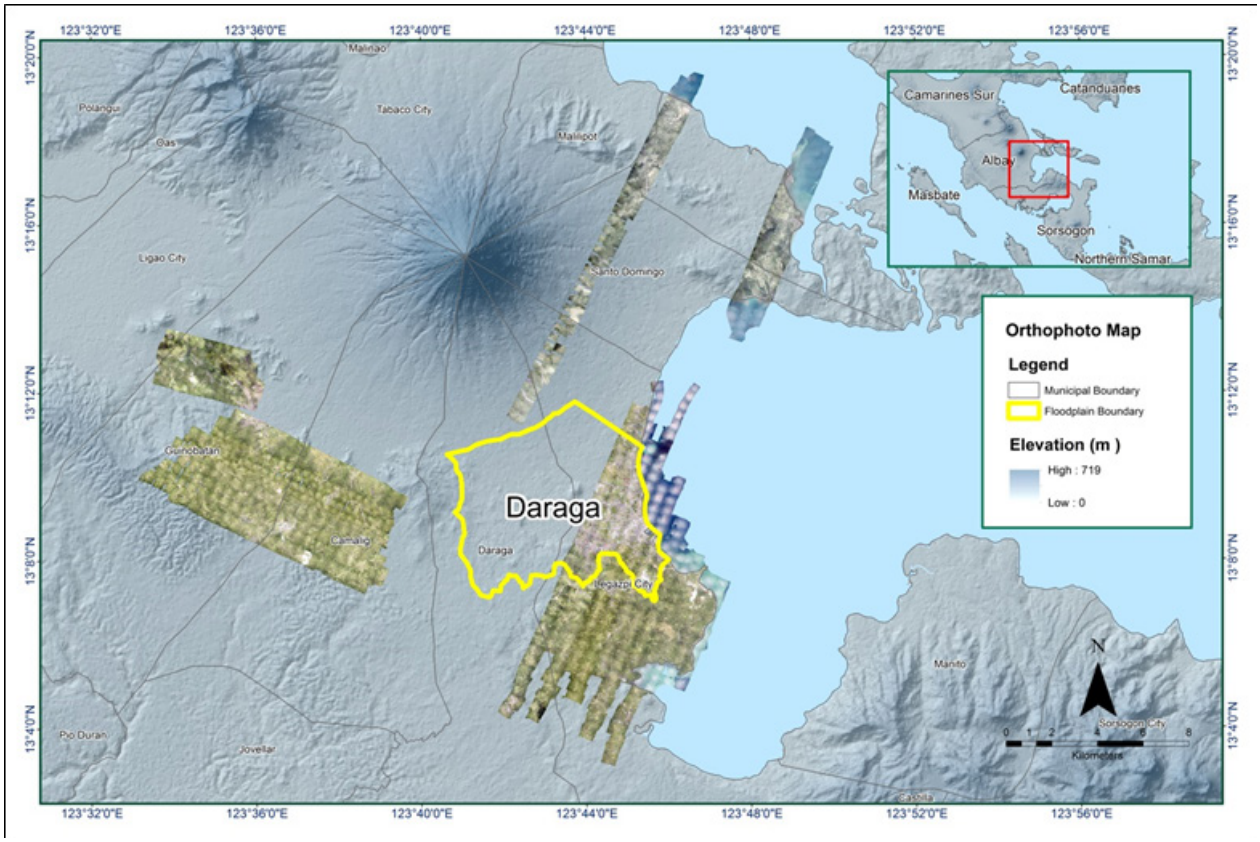


Figure 22. Daraga floodplain with available orthophotographs.

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.

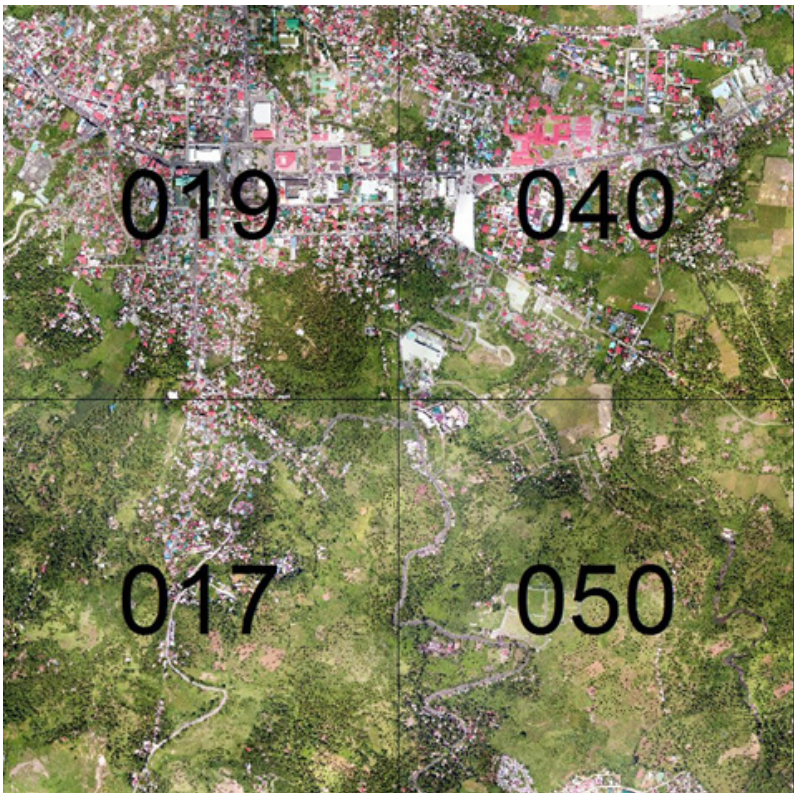


Figure 23. Sample orthophotograph tiles for Daraga Floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Daraga Floodplain. These blocks are composed of AlbaySorsogon blocks with a total area of 795.62 square kilometers. Table B-4 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Albay_Sorsogon_Blk19EG	301.83
Albay_Sorsogon_Blk19C	193.3
Albay_Sorsogon_Blk19C_additional	14.99
Albay_Sorsogon_reflights_Blk19S	68.43
Albay_Sorsogon_reflights_Blk19C	11.23
Albay_Sorsogon_reflights_Blk19E	48.70
Albay_Sorsogon_reflights_Blk19B	129.88
Albay_Sorsogon_reflights_Blk19B_supplement	29.26
TOTAL	**795.62 sq.km**

Figure 24 shows portions of DTM before and after manual editing. The river embankment (Figure 24a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 24b) to allow the correct flow of water. The two bridges (Figure 24c) are also considered to be an impedance to the flow of water along the river and has to be removed (Figure 24d) in order to hydrologically correct the river.

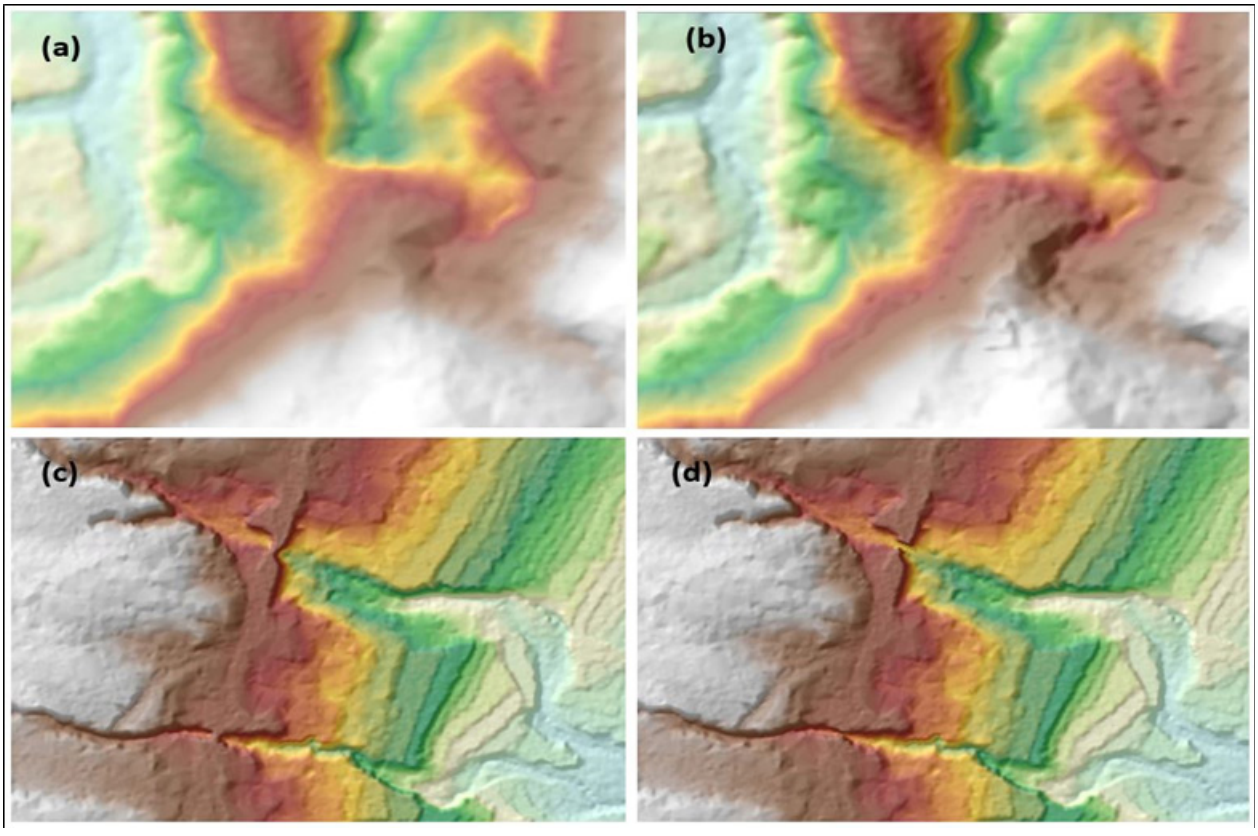


Figure 24. Portions in the DTM of Daraga floodplain –a mountain ridge before (a) and after (b) data retrieval; and a bridge before (c) and after (d) manual editing

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 16 shows the the shift values applied to each LiDAR block during mosaicking.

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

Table 16. Shift Values of each LiDAR Block of Daraga floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	Z
Albay_Sorsogon_Blk19EG	1	1.25	-1.34
Albay_Sorsogon_Blk19C	0.5	-1	-1.45
Albay_Sorsogon_Blk19C_additional	0.5	-1	-1.45
Albay_Sorsogon_reflights_Blk19S	-1.5	-2.2	-1.53
Albay_Sorsogon_reflights_Blk19C	-3	0	-1.85
Albay_Sorsogon_reflights_Blk19E	-1	-1	-1.90
Albay_Sorsogon_reflights_Blk19B	0	-1	-1.56
Albay_Sorsogon_reflights_Blk19B_supplement	-1.5	-1	-1.51

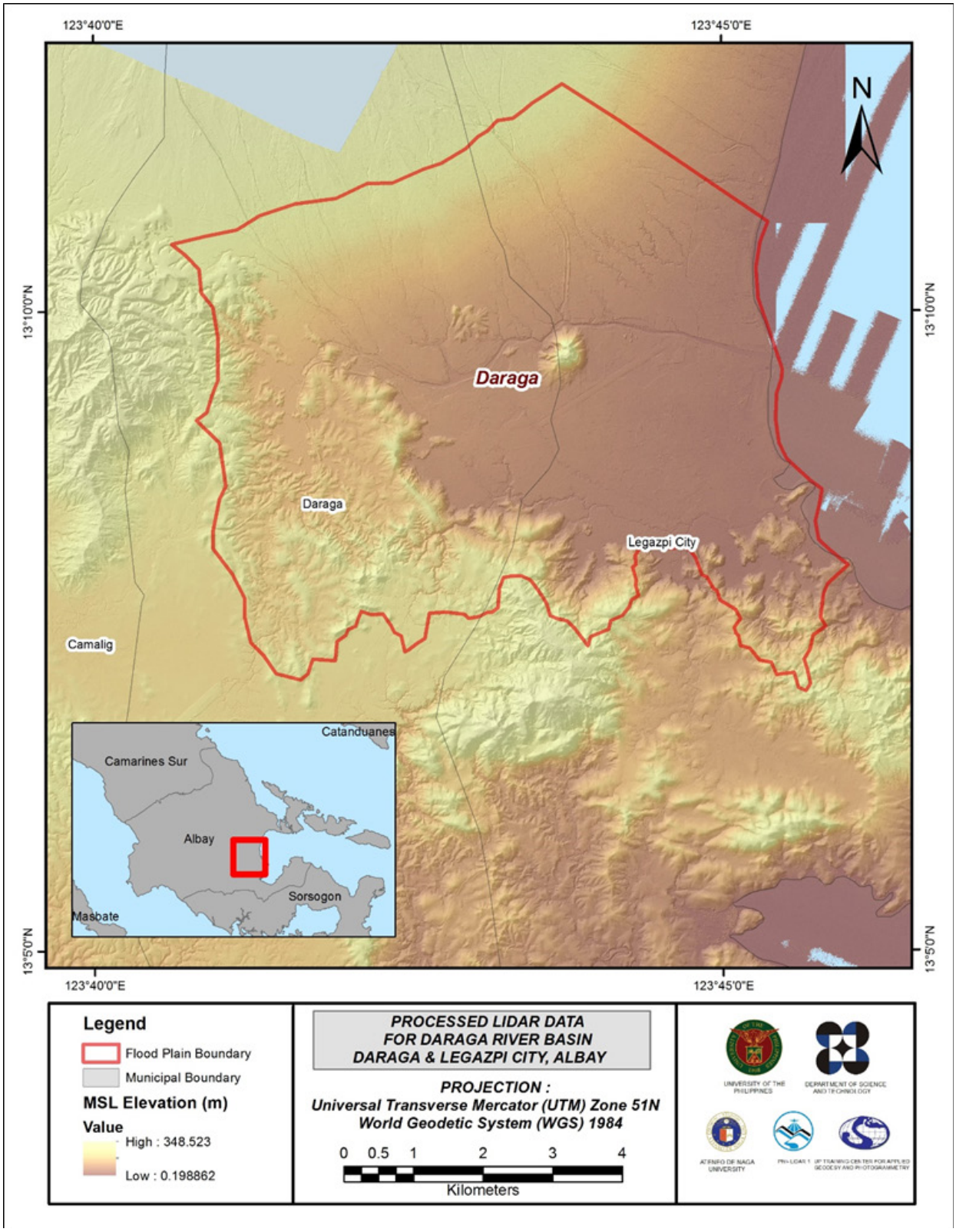


Figure 25. Map of Processed LiDAR Data for Daraga Floodplain.

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 Daraga to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 11,856 survey points from the Bicol floodplain were used for calibration Daraga 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 27. 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 Daraga LiDAR data was done by adding the height difference value, 0.41 meters, to Daraga mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

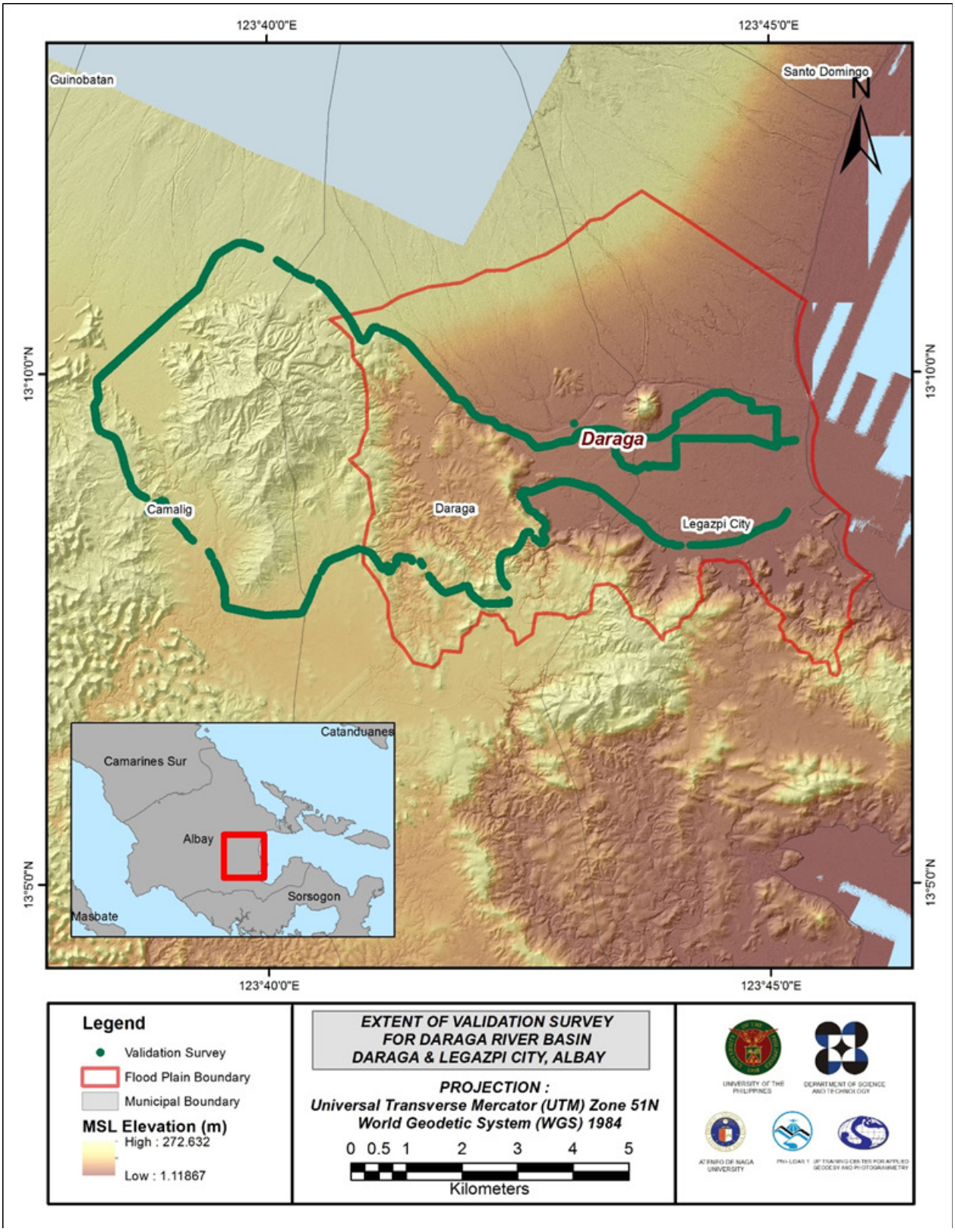


Figure 26. Map of Daraga Floodplain with validation survey points in green.

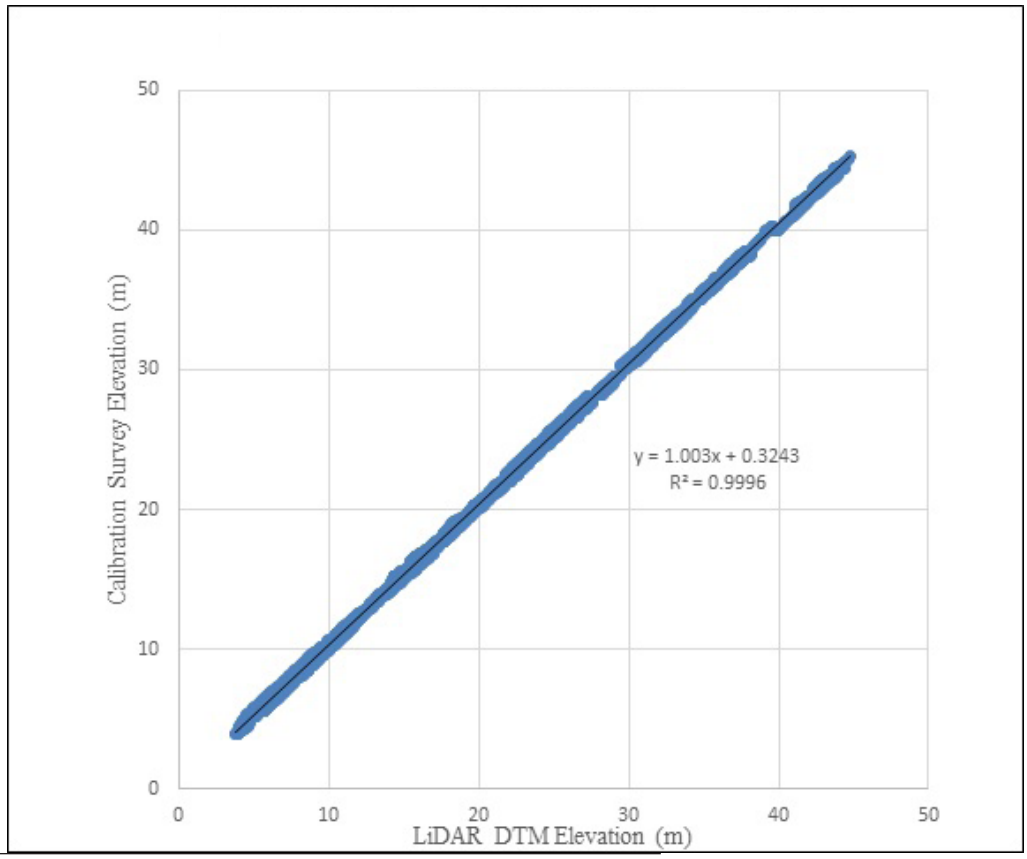


Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 17. 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 6,303 points were collected by DVBC for the Daraga river basin. Random selection of points within the floodplain boundary, resulting to 4432 points, were used for the validation of calibrated Daraga DTM. The 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19 meters with a standard deviation of 0.16 meters, as shown in Table 18.

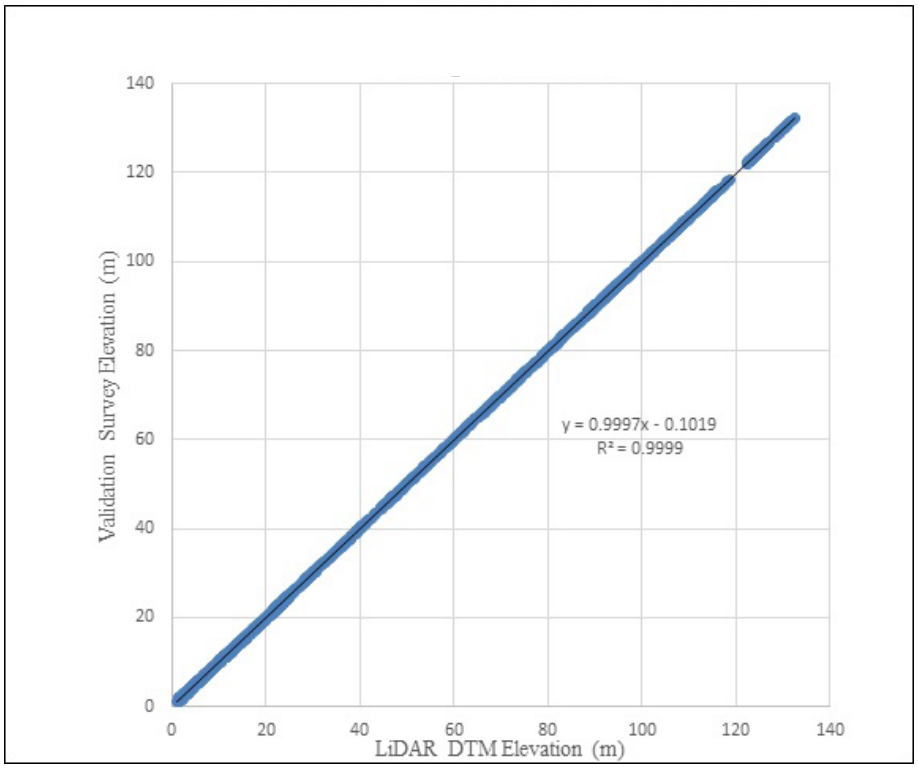


Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.16
Average	-0.11
Minimum	-0.46
Maximum	0.25

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Daraga with 694 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation Method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.025 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Daraga integrated with the processed LiDAR DEM is shown in Figure 29.

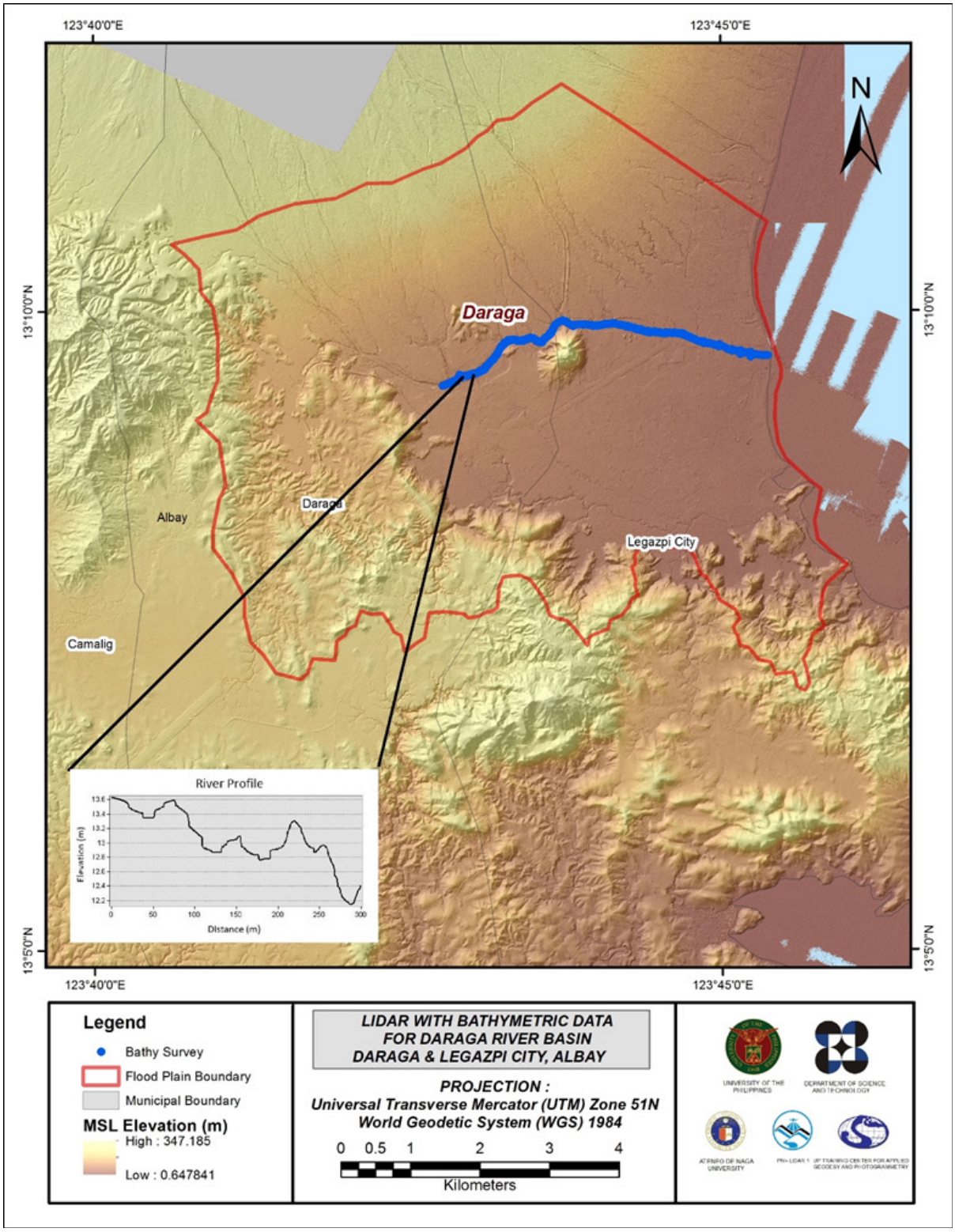


Figure 29. Map of Daraga Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Daraga Floodplain, including its 200 m buffer, has a total area of 54.18 square kilometers. For this area, a total of 5.0 square kilometers, corresponding to a total of 48,826 building features, are considered for QC. Figure 30 shows the QC points for Daraga Floodplain.

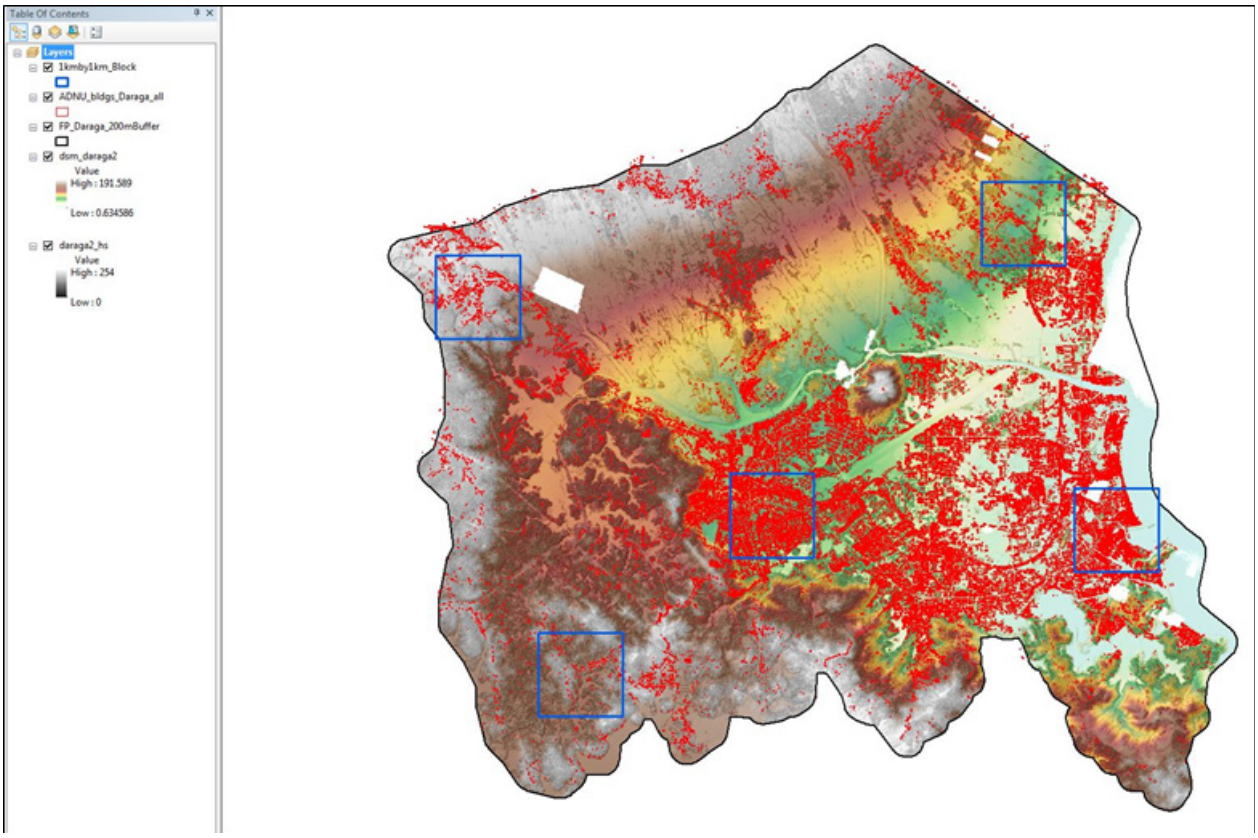


Figure 30. QC blocks for Daraga building features.

Quality checking of Daraga building features resulted in the ratings shown in Table 19.

Table 19. Quality Checking Ratings for Daraga Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Daraga	99.89	100.00	99.98	PASSED

3.12.2 Height Extraction

Height extraction was done for 49,299 building features in Daraga Floodplain. Of these building features, 603 were filtered out after height extraction, resulting to 47,199 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 21.59 m.

3.12.3 Feature Attribution

Feature Attribution was done for 48,696 building features in Daraga 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 local community with the premise that they 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 20 summarizes the number of building features per type. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Number of Building Features Extracted for Daraga Floodplain.

Facility Type	No. of Features
Residential	45,994
School	571
Market	73
Agricultural/Agro-Industrial Facilities	3
Medical Institutions	44
Barangay Hall	53
Military Institution	42
Sports Center/Gymnasium/Covered Court	27
Telecommunication Facilities	13
Transport Terminal	52
Warehouse	247
Power Plant/Substation	0
NGO/CSO Offices	8
Police Station	15
Water Supply/Sewerage	22
Religious Institutions	93
Bank	49
Factory	0
Gas Station	32
Fire Station	6
Other Government Offices	248
Other Commercial Establishments	1102
Demolished Building*	2
Total	**48,696**

. *Buildings which were present in the Digital Surface Model but were not found on the field.

Table 21. Total Length of Extracted Roads for Daraga Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Daraga	221.44	21.34	5.64	20.61	0.00	**269.02**

Table 22. Number of Extracted Water Bodies for Daraga Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Daraga	1	0	0	0	0	**1**

A total of 42 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 31 shows the Digital Surface Model (DSM) of Daraga Floodplain overlaid with its ground features.

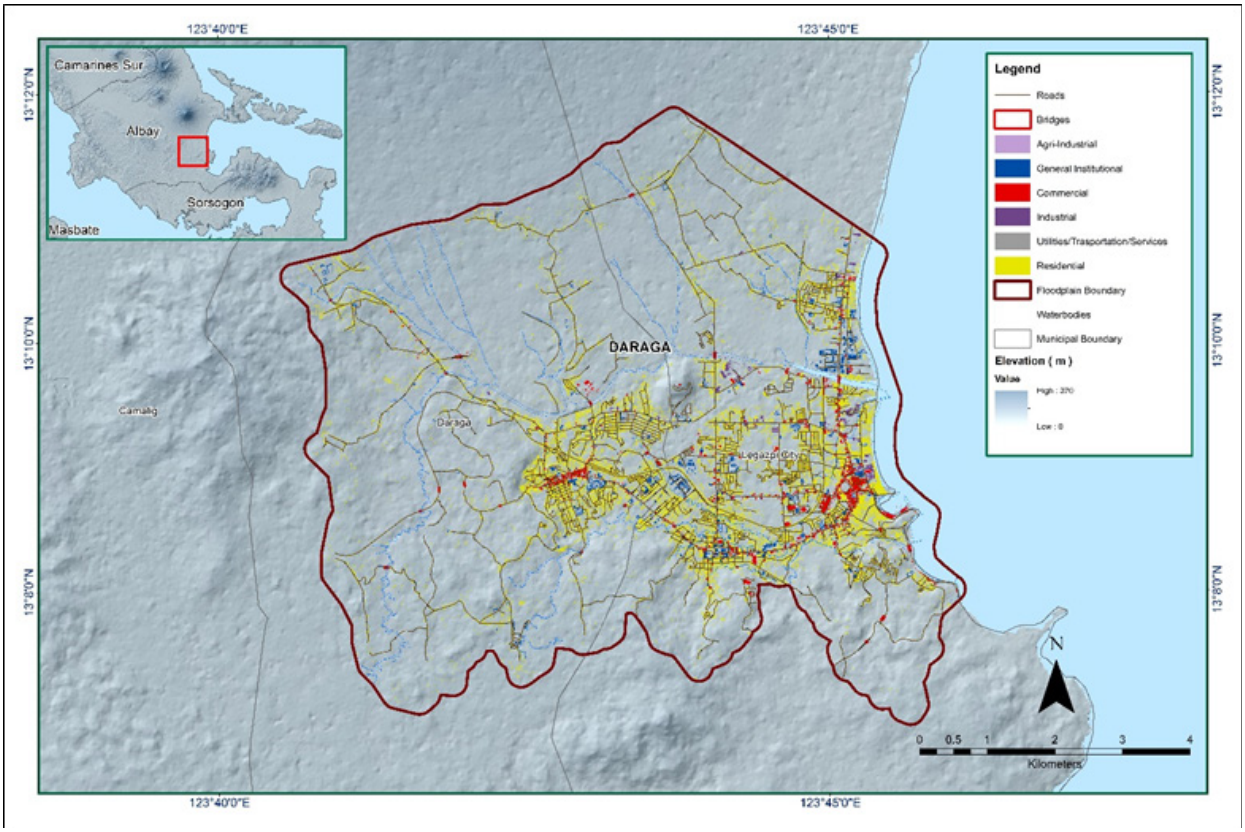


Figure 31. Extracted features for Daraga Floodplain.

CHAPTER 4: DATA VALIDATION MEASUREMENTS IN THE DARAGA 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 its field survey on August 11 to 20, 2015 for Daraga River in Albay with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built for Kilicao Bridge; ground validation data acquisition; and bathymetric survey with an estimated length of 5 km using GNSS PPK survey technique.

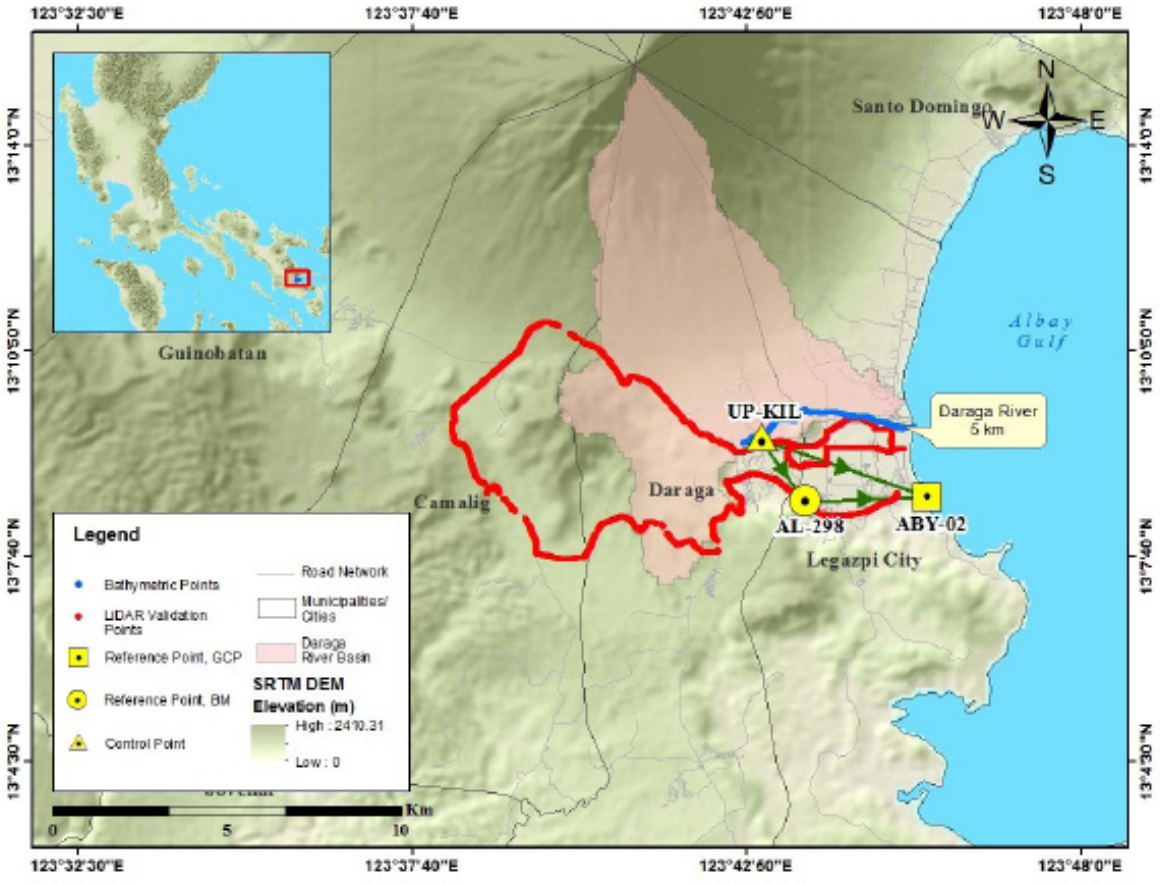


Figure 32. Extent of the bathymetric survey (in blue line) in Daraga River and the LiDAR data validation survey (red).

4.2 Control Survey

The GNSS network used for Daraga River Survey is composed of a single loop established on August 11-20, 2015 occupiying the following reference points: ABY2, a first order GCP, in Kapuntukan Hill (Sleeping Lion Hill), Brgy. Victory Village, Legazpi City, Albay; and AL – 298, a first order BM, in Sagpon Bridge, also in Albay.

A control point UP-KIL was established at the approach of Kilicao Bridge in Brgy. Binitayan, Daraga, Albay to use as marker during the survey.

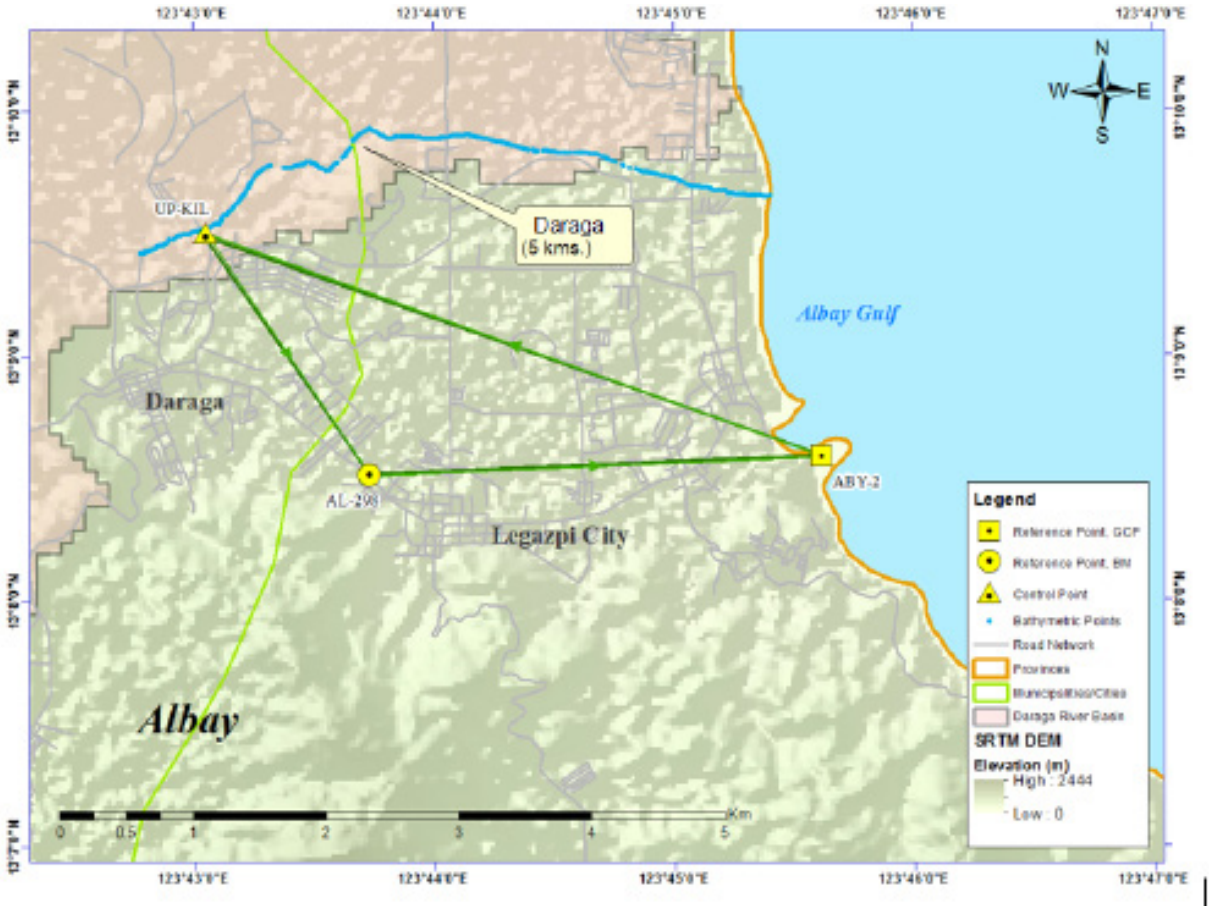


Figure 33. GNSS Network of Daraga River Basin Survey

Table 23. References used and control points established in the Daraga River Basin Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	BM Ortho (m)	Date Established
ABY-2	1st Order GCP	13°08'35.29707"	123°45'37.16782"	118.122		2009
AL-298	1st Order BM			65.015	11.696	2009
UP-KIL	UP Established					Aug 17, 2015

The GNSS set-up on ABY-2, AL 298 and established control UP-KIL in Albay are shown on Figure 34 to Figure 36:

Figure 34. GNSS receiver, Trimble® SPS882 set-up at ABY-2 in Victory Village, Legazpi City, Albay

Figure 35. GNSS base receiver Trimble® SPS852 at AL-298 in Sagpon Bridge, Legazpi City, Albay

Figure 36. GNSS base, Trimble® SPS852 base set-up at UP-KIL in Kilicao Bridge in Daraga, Albay

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within ± 20 cm and ± 10 cm requirement, respectively. In cases when one or more baselines did not meet all of these criteria, masking is performed. Masking is the removal or covering portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 24 presents the baseline processing result of control points in the Daraga River Basin, as generated by the TBC software.

Table 24. Baseline Processing Report for Daraga River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (m)	V. Prec (m)	Geodetic Az.	Ellipsoid Dist. (m)	Height (m)
UP-KIL---AL-298	Aug 17, 2015	Fixed	0.003	0.012	145°59'03"	2199.167	-10.776
AL-298---ABY-2	Aug 17, 2015	Fixed	0.003	0.019	87°40'22"	3415.565	53.121
UP-KIL---ABY-2	Aug 17, 2015	Fixed	0.003	0.012	109°56'08"	4938.965	42.318

As shown in Table , a total of three baselines were processed and all of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. Looking at the Adjusted Grid Coordinate 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 from:

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

Where:

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

For complete details, see the Network Adjustment Report shown in Tables 25 to 28:

The three (3) control points, ABY-02, AL-298, and UP-KIL were occupied and observed simultaneously to form a GNSS loop. Coordinates of ABY-2; and elevation value of AL-298 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 25. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ABY-2	Global	Fixed	Fixed		
AL-298	Grid				Fixed
Fixed = 0.000001(Meter)					

Likewise, 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 26. The fixed control CMS-110 has no values for grid errors while CS-461 has no value for elevation errors.

Table 26. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ABY-2	582405.288	?	1453089.242	?	64.864	0.032	LL
AL-298	578994.041	0.005	1452940.719	0.004	11.696	?	e
UP-KIL	577758.990	0.005	1454759.474	0.004	22.464	0.028	

The computation for the accuracy are as follows:

a. ABY-2
Horizontal accuracy = Fixed
Vertical accuracy = 3.2 cm < 10 cm

b. AL-298
Horizontal accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64 cm < 20 cm
Vertical accuracy = Fixed

c. UP-KIL
Horizontal accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64 cm < 20 cm
Vertical accuracy = 2.8 cm < 10 cm

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

Table 27. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
ABY-2	N13°08’35.29707”	E123°45’37.16782”	119.000	?	LLh
AL-298	N13°08’30.79075”	E123°43'43.85249"	67.901	0.025	
UP-KIL	N13°09’30.10812”	E123°43'03.00365"	76.677	0.021	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points used is indicated in Table 28.

Table 28. The reference and control points utilized in the Daraga River Survey, with its corresponding locations (Source: NAMRIA, UP-TCAGP)

Point ID	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ABY-2	1st order, GCP	13°08’35.29707”	123°45’37.16782”	118.122	1453089.242	582405.288	64.864
AL-298	1st order, BM	13°08’30.79067”	123°43’43.85242”	65.015	1452940.719	578994.041	11.696
UP-KIL	UP estab-lished	13°09’30.10805”	123°43’03.00357”	75.796	1454759.474	577758.99	22.464

4.5 Cross-section and Bridge-as-built survey and Water Level Marking

The cross Section and as-built survey were done on August 18, 2015 along the downstream side of Kilicao Bridge in Brgy. Binitayan, Daraga, Albay using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 37.

Figure 37. Cross-section of Daraga River under Kilicao Bridge

A total 25 points were gathered with an approximate length of 70 meters acquired using the control point UP-KIL as the GNSS base station. The Kilicao Bridge location map, cross-section diagram, and the bridge data form are shown in Figure 39 to Figure 41.

Bridge marking was done in Kilicao Bridge using GNSS point observation and differential levelling. The elevation in MSL of a point on the ground was determined using GPS PPK survey technique. The elevation obtained on the ground was used as a reference to determine the elevation of the bridge markings on the pier of the bridge using a Topcon DL 500 digital level. The pier has an existing bridge marking which was not referred from MSL. The leveling set-up is exhibited in Figure 42. Topcon DL 500 was used for differential levelling and Trimble® SPS 882 was used to get the reference elevation.

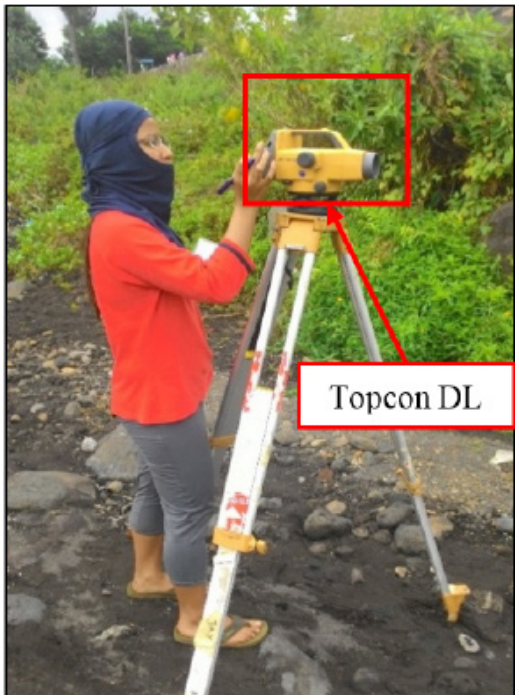


Figure 38. Leveling using a Topcon DL 500 for bridge marking in Kilicao Bridge, Daraga, Albay

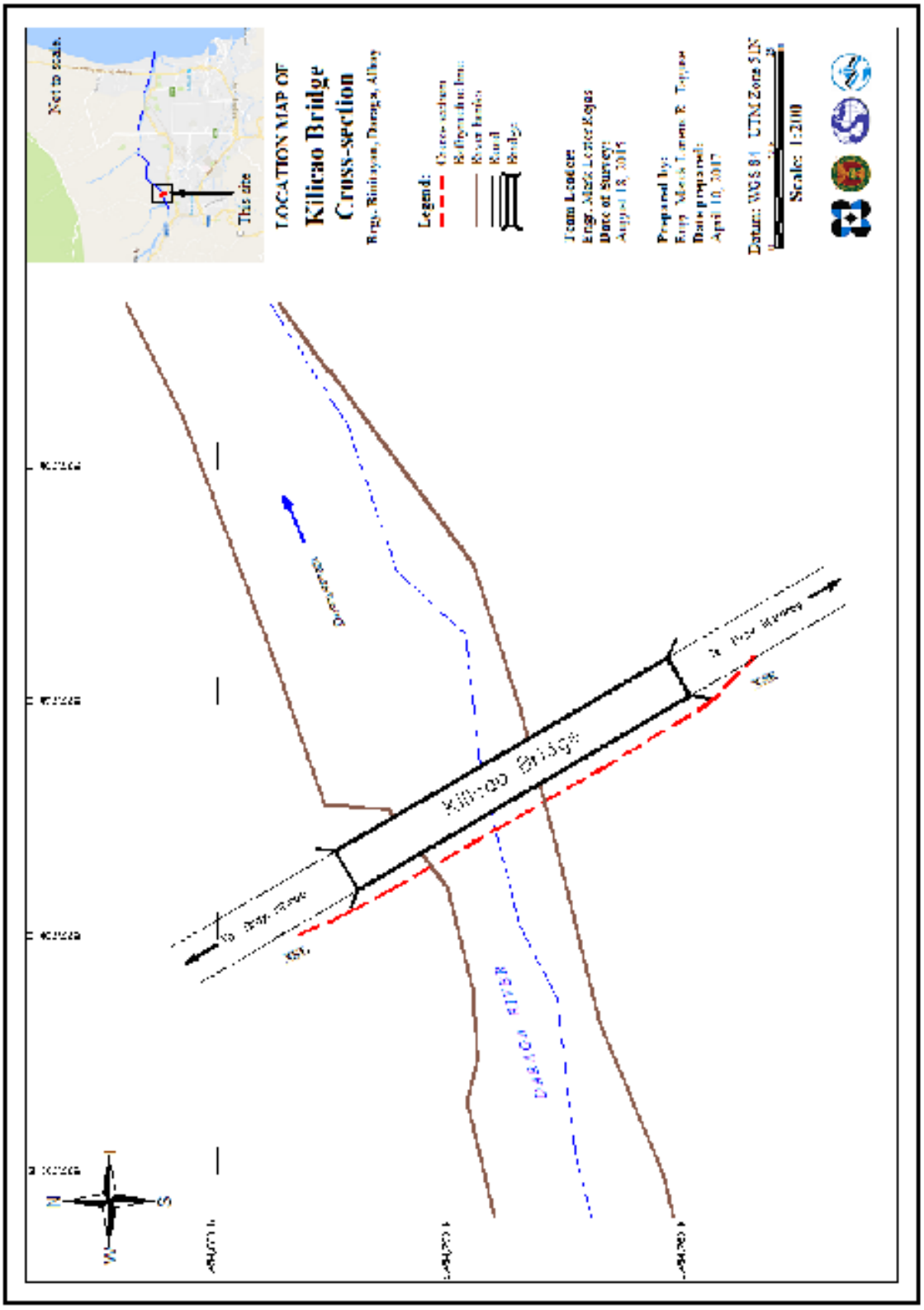


Figure 39. Kilicao Bridge cross-section location map

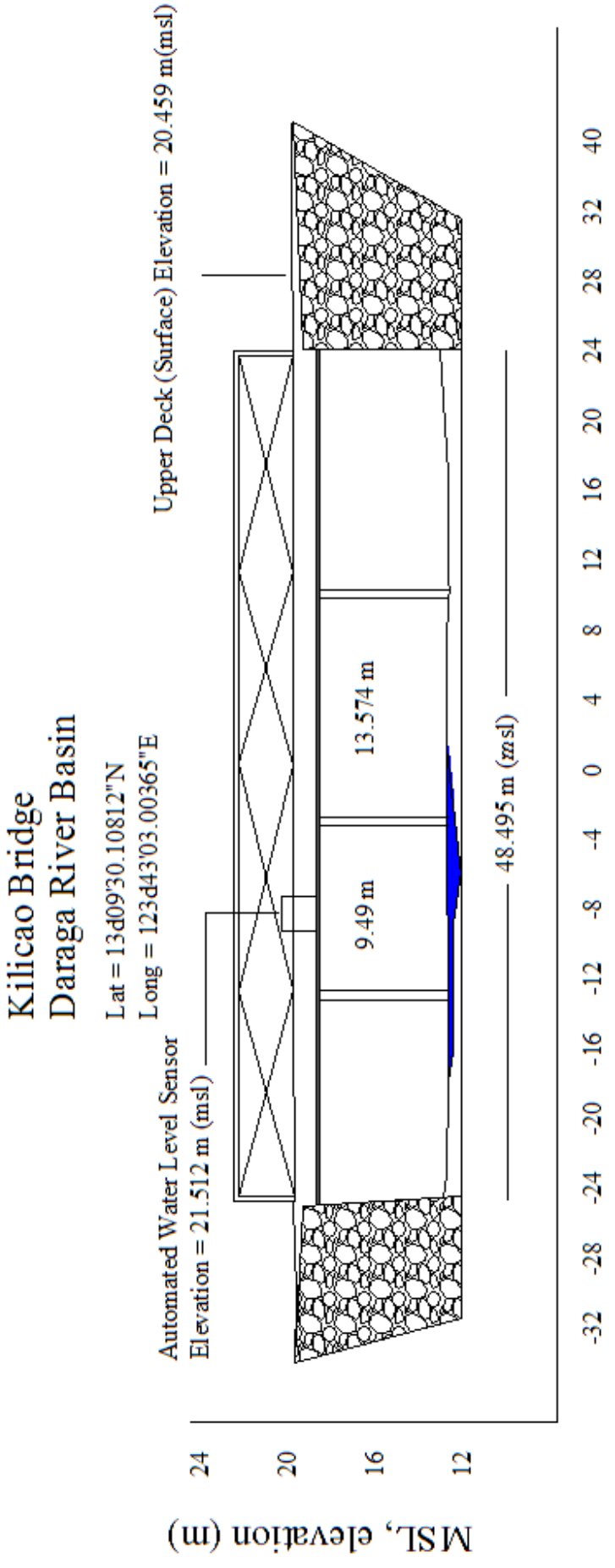


Figure 40. Cross section diagram at Kilicao Bridge in Daraga, Albay

Bridge Data Form

Bridge Name: KILICAO BRIDGE - Date: August 18, 2015

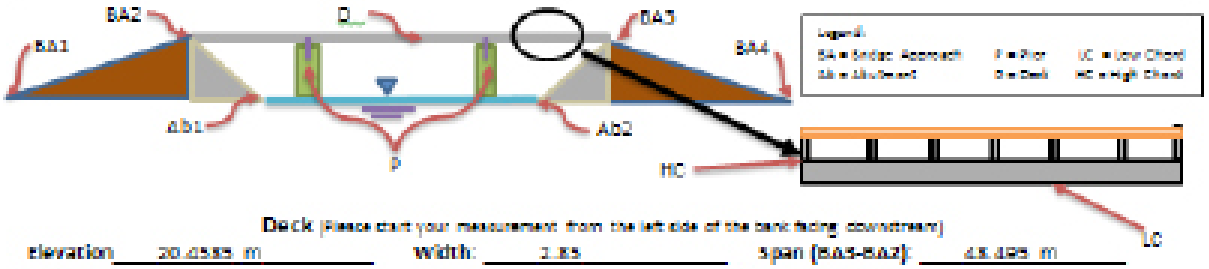
River Name: DARAGA RIVER Time: 7:15 AM

Location (Brgy. City. Region): Brgy. Binitayan, Municipality of Daraga, Albay

Survey Team: TEAM MARK

Flow condition: low (normal) high Weather Condition: (fair) rainy

Latitude: 13d09'30.10812"N Longitude: 123d43'03.00365"E



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

Elevation: 20.4585 m Width: 2.85 Span (BA3-BA2): 48.486 m

	Station	High Chord Elevation	Low Chord Elevation
1		20.4585	20.006
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	20.246	BA3	58.120	20.350
BA2	9.207	20.309	BA4	70.950	20.374

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: CYLINDRICAL STEEL PIER Number of Piers: 3 Height of column footing:

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	21.273	20.3535	46 cm
Pier 2	30.763	20.3685	46 cm
Pier 3	44.337	20.3685	46 cm
Pier 4			
Pier 5			
Pier 6			

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

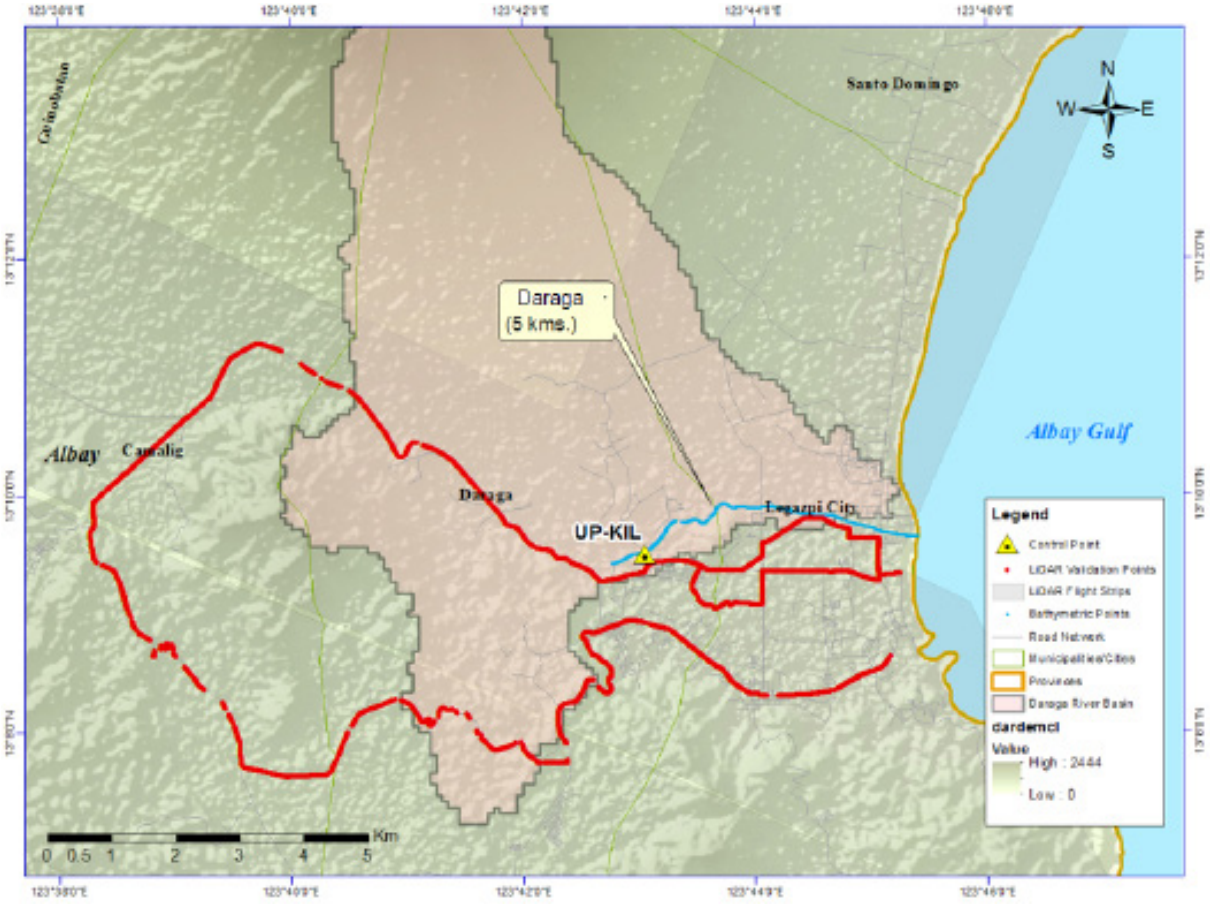
Figure 41. Bridge Data Form of Kilicao Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition was conducted on August 18, 2015 on national road along Municipalities of Legazpi, Daraga, and Camalig in Albay. A Trimble® SPS 882 was installed on top of the vehicle to gather LiDAR validation points as shown in Figure 42. The survey gathered a total of 6,348 ground validation points, covering an approximate length of 40 km using the base station UP-KIL.

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

The map on Figure 43 shows that the validation line covered the Municipalities of Legazpi, Daraga, and Camalig in the Province of Albay.



. Figure 43. LiDAR Ground Validation Survey along Daraga River Basin

4.7 Bathymetric Survey

A manual bathymetric survey was conducted on August 17 and 18, 2015. For two consecutive days, two teams simultaneously traversed the river by foot using a Trimble® SPS 882 mounted on a 2-m pole with base station at UP-KIL as shown in Figure 44. The survey started in Brgy. Bañag, Municipality of Daraga with coordinates 13°09'25.13209" 123°42'47.35421", traversed down the river by foot and ended at the mouth of the river in Brgy. Bonot, Legazpi City with coordinates 13°09'39.17087" 123°45'24.31111".

Figure 44. Manual bathymetric survey along Yawa River in Brgy. Binitaya, Daraga, Albay

A total of 534 points and an estimated length of five (5) kilometers starting from the upstream in Brgy. Bañag, Daraga down to the mouth of the river in Brgy. Bonot, Legazpi City, Albay, were gathered using the control point UP-KIL as the GNSS base station as shown in Figure . A CAD drawing was also produced to illustrate the Daraga riverbed profile. The change of elevation is around 12 meters from Kilicao Bridge in Brgy, Binitayan two kilometres down to Brgy. Bogtong as illustrated in Figure 45.

Figure 45. Bathymetric Survey of Daraga River

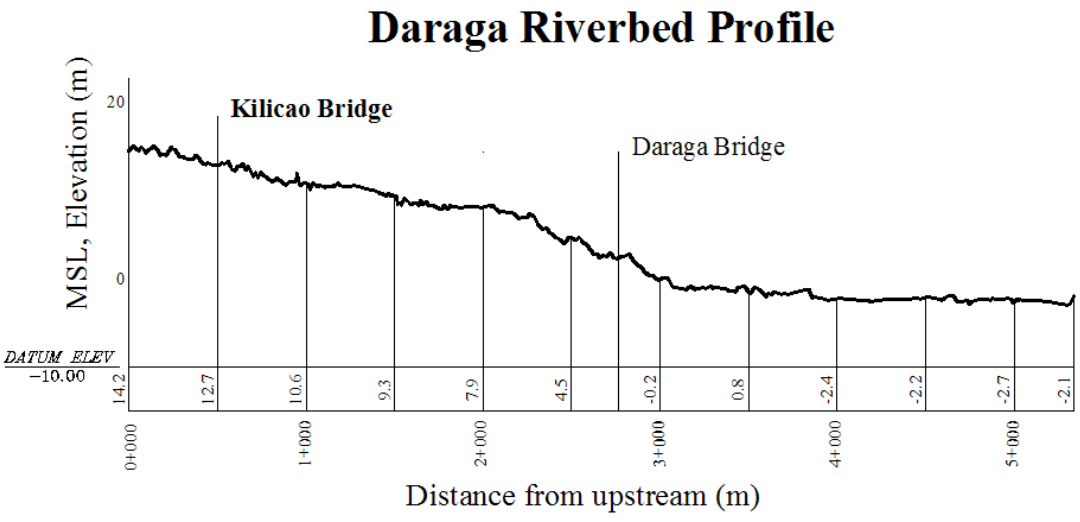


Figure 46. Riverbed Profile of Daraga River

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

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 Busay Bridge (Figure 47). The precipitation data collection started from October 16, 2015 at 7:30 AM to October 17, 2015 at 11:50 PM with a 10-minute recording interval.

The total precipitation for this event in Busay ARG is 57mm. It has a peak rainfall of 1.4mm on October 17, 2015 at 1:40 AM. The lag time between the peak rainfall and discharge is 7 hours and 10 minutes.

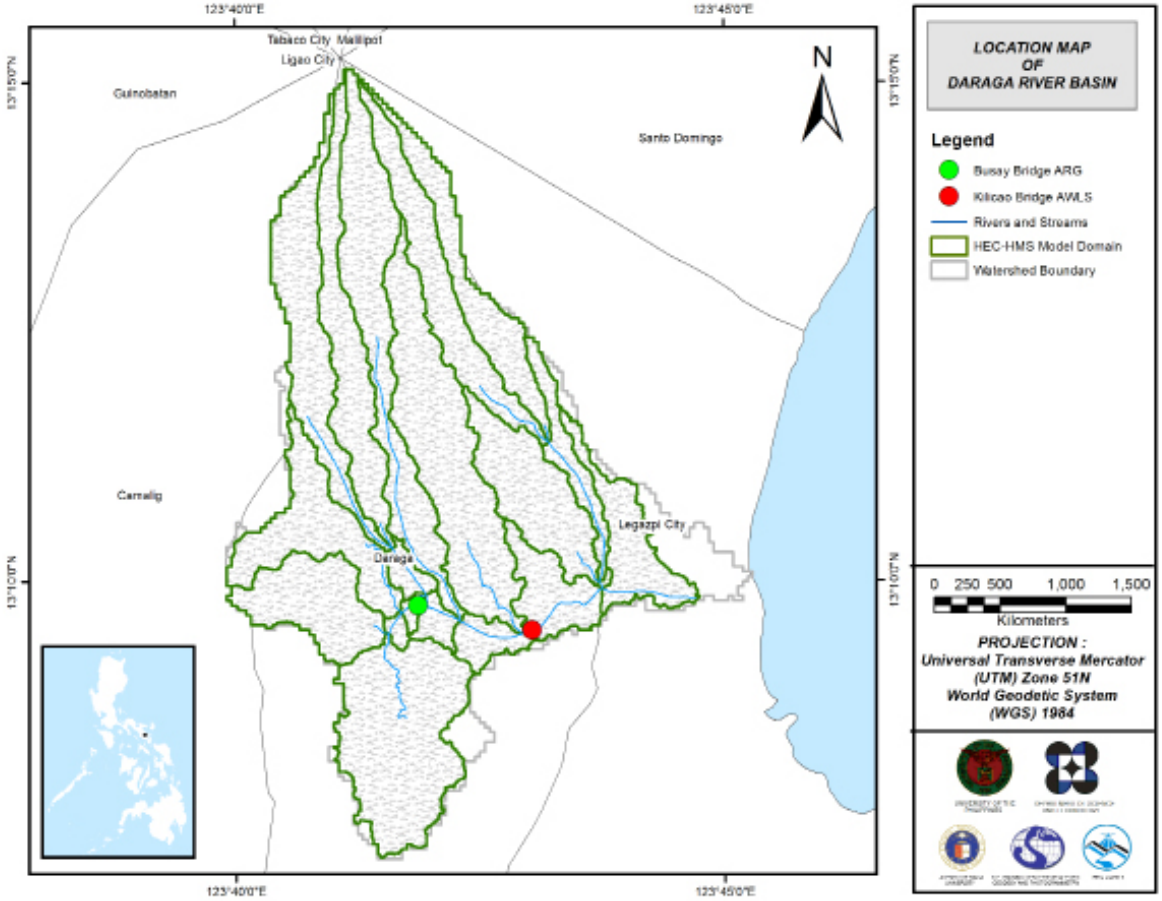


Figure 47. The location map of Daraga HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Kilicao Bridge, Daraga, Albay (13°9'30.6"N, 123°43'1.49"E). It gives the relationship between the observed water levels at Kilicao Bridge and outflow of the watershed at this location.

For Kilicao Bridge, the rating curve is expressed as Q = 5E-31e5.2217h as shown in Figure 49.

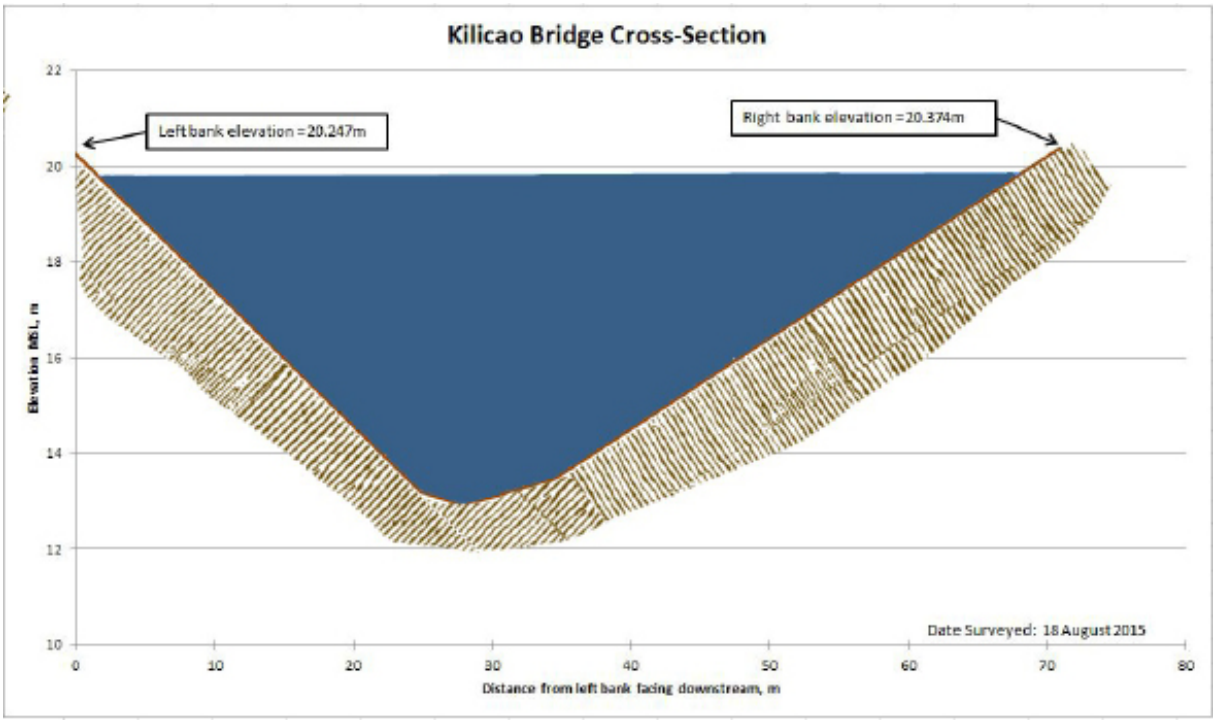


Figure 48. Cross-Section Plot of Kilicao Bridge

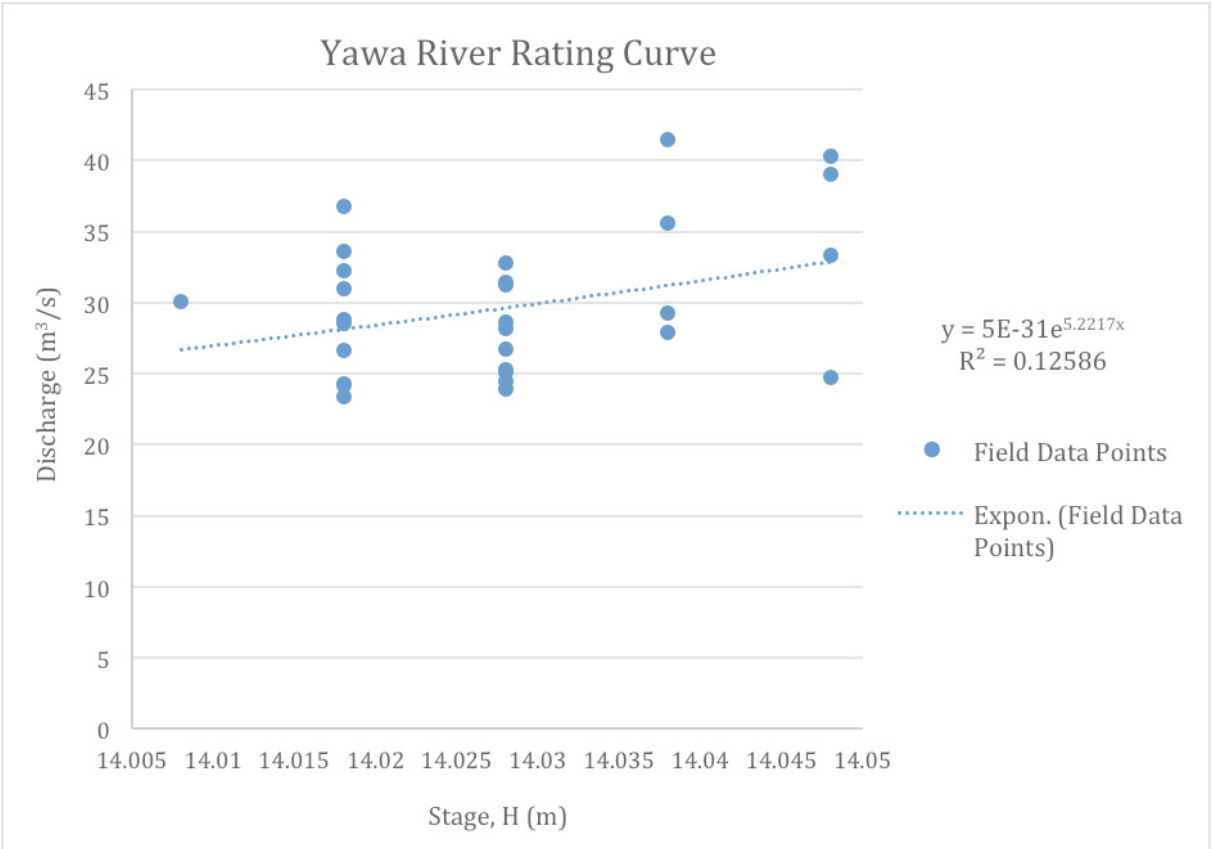


Figure 49. The rating curve of Kilicao Bridge in Daraga, Albay

This rating curve equation was used to compute the river outflow at Kilicao Bridge for the calibration of the HEC-HMS model shown in Figure 50. The total rainfall for this event is 57mm and the peak discharge is 42.1m3/s at 8:30 AM, October 17, 2015.

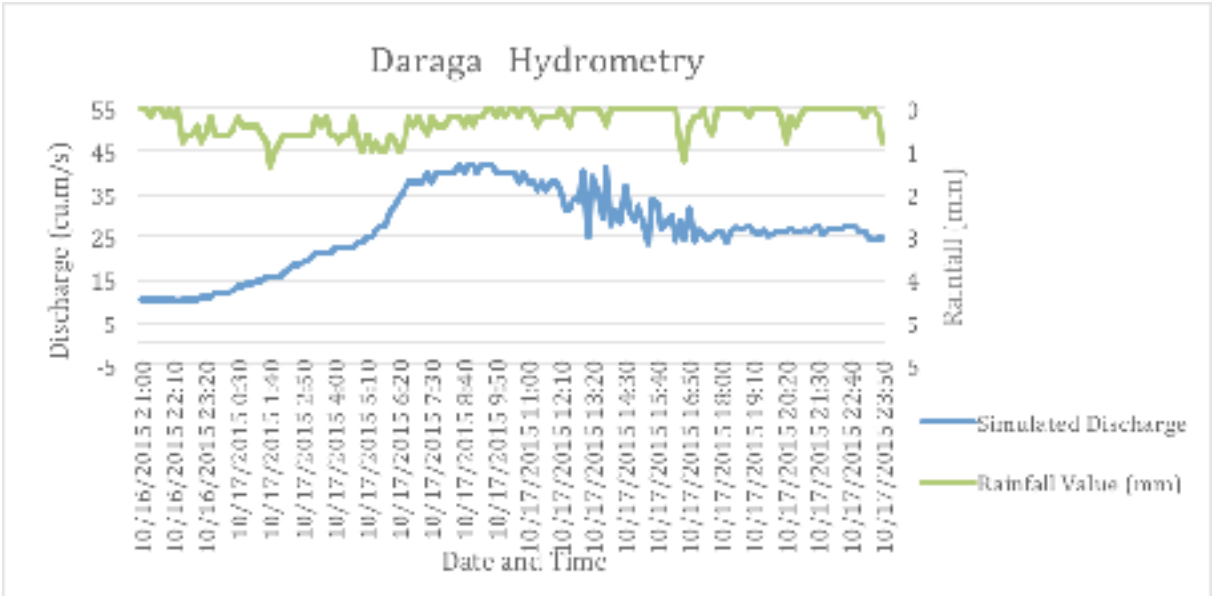


Figure 50. Rainfall and outflow data of the Daraga River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Legazpi RIDF (Figure 51). 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 (Figure 52). This station was selected based on its proximity to the Daraga watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 29. RIDF values for Daraga 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

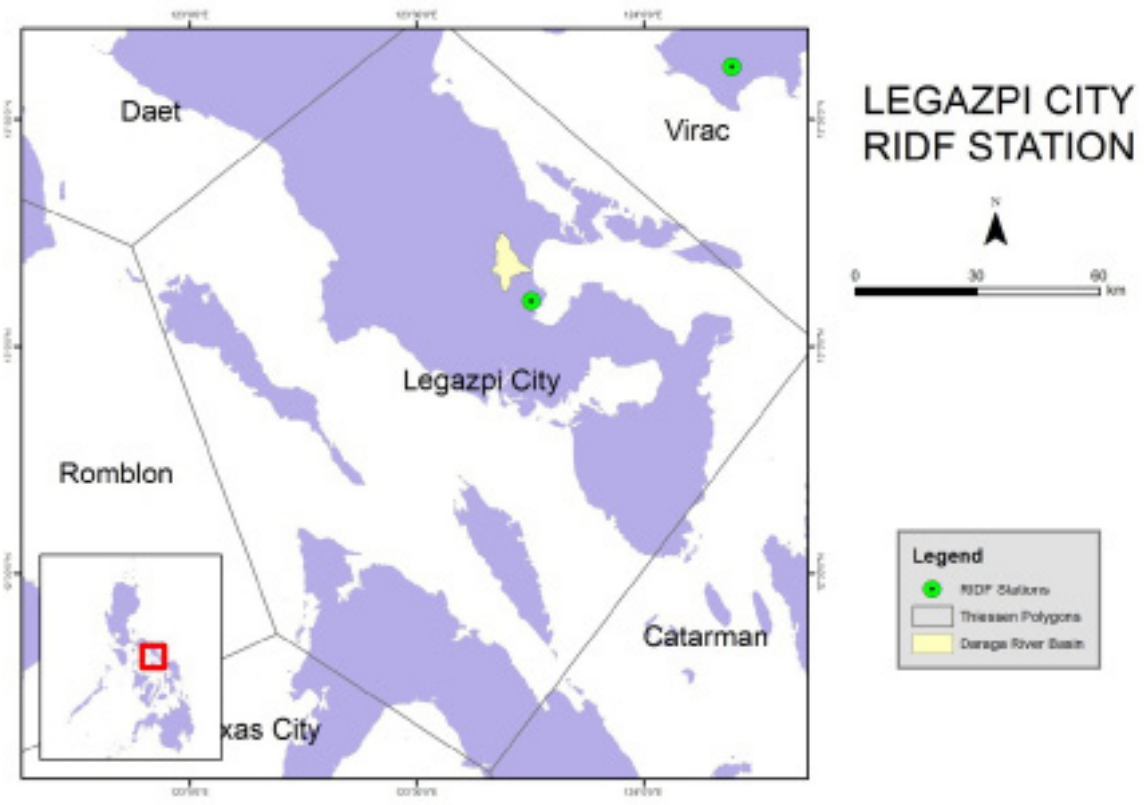


Figure 51. Location of the Legazpi City RIDF relative to the Daraga River Basin

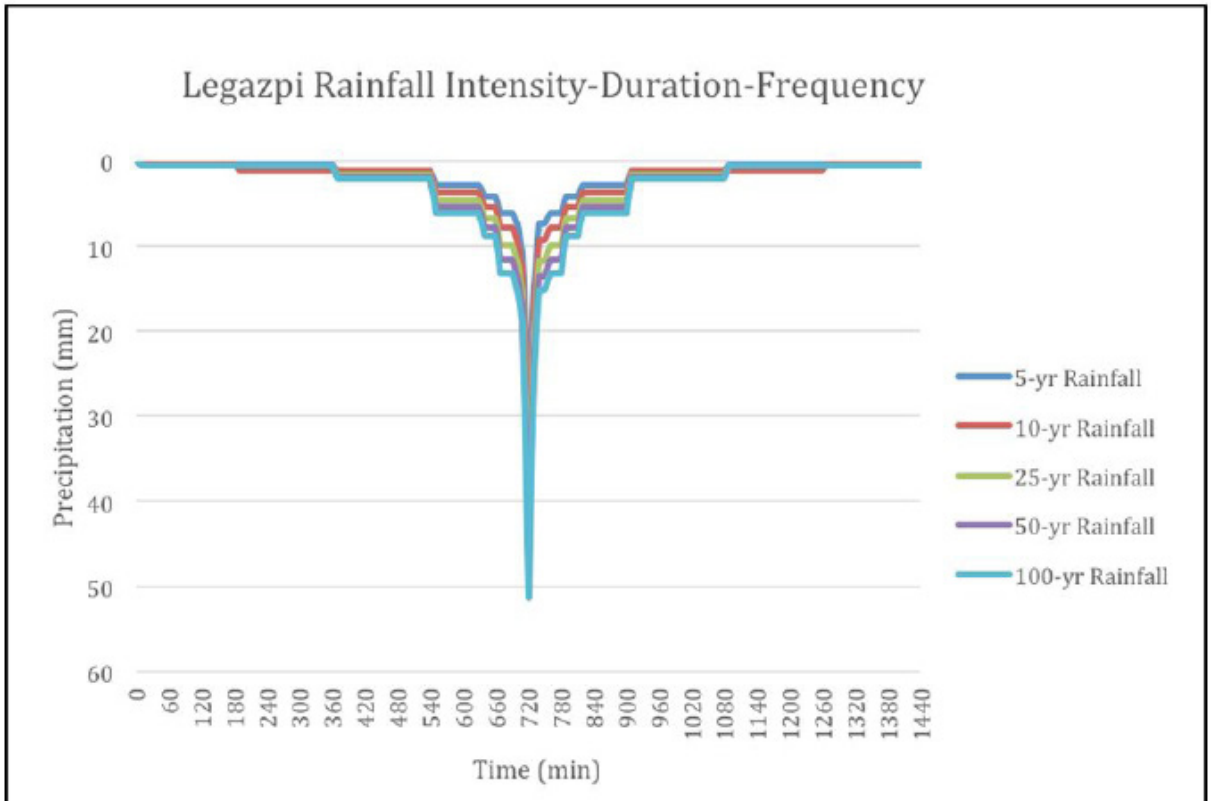


Figure 52. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

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

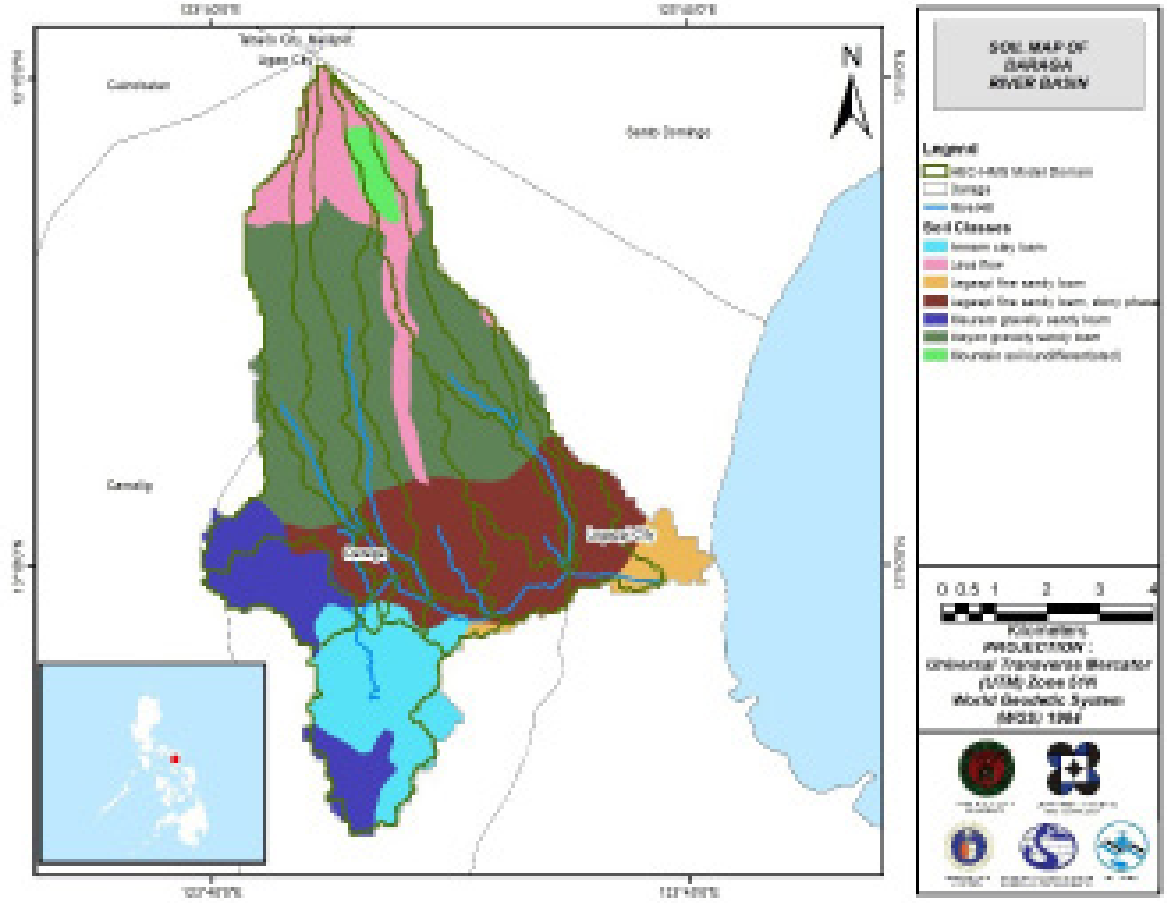


Figure 53. Soil Map of Daraga River Basin

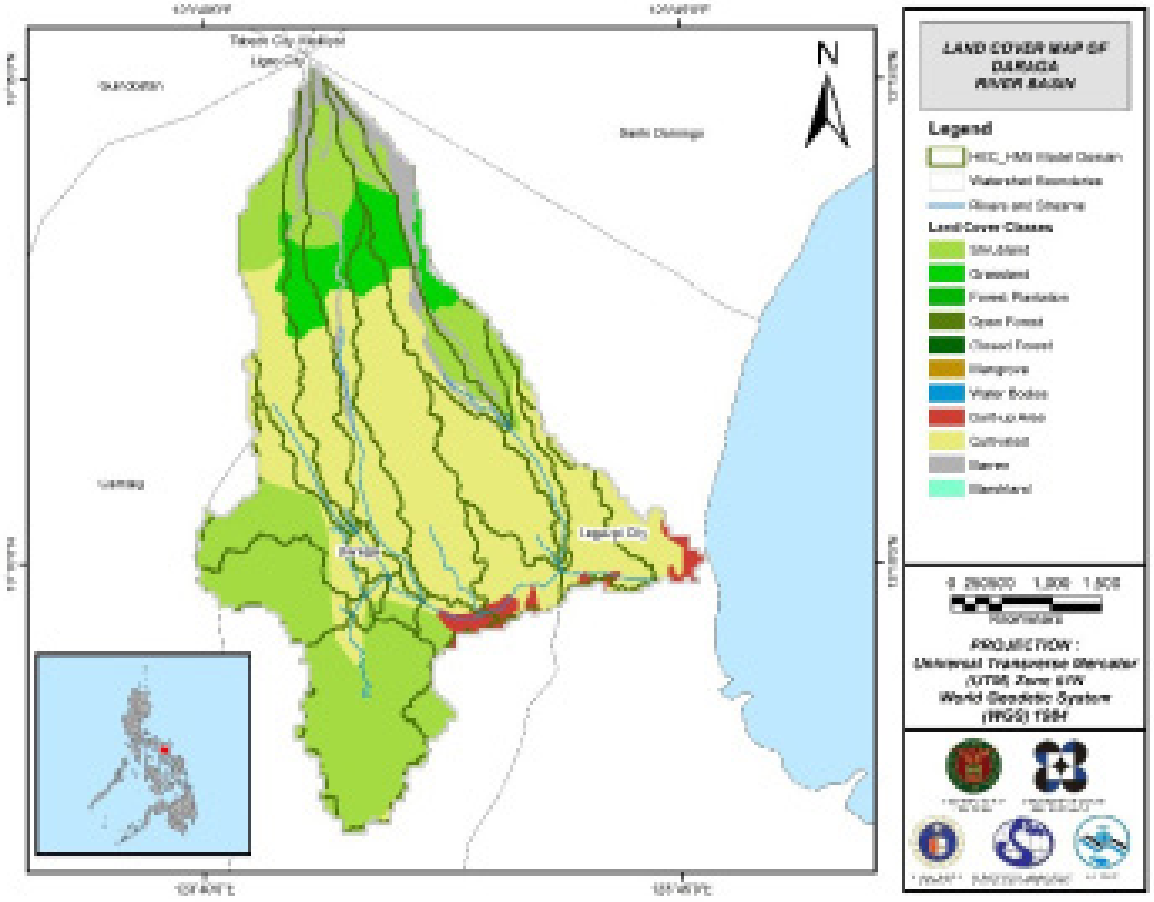


Figure 54. Land Cover Map of Daraga River Basin (Source: NAMRIA)

For Daraga, seven soil classes were identified. These are Annam clay loam, Legaspi fine sandy loam, Legaspi fine sandy loam (stony phase), Mauraro gravelly sandy loam, Mayon gravelly sandy loam, lava flow, and undifferentiated mountain soil. Moreover, four land cover classes were identified. These are shrubland, grassland, cultivated, and built-up areas.

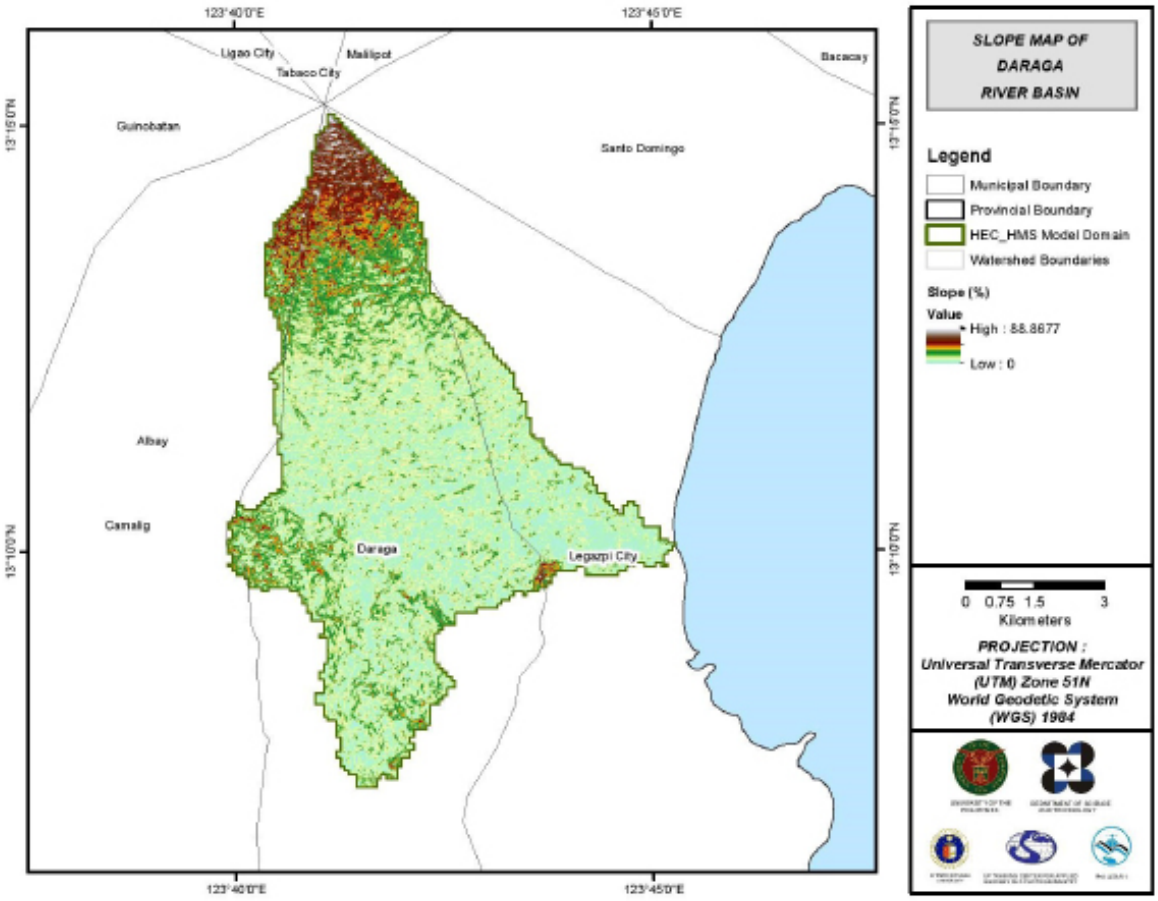


Figure 55. Slope Map of Daraga River Basin

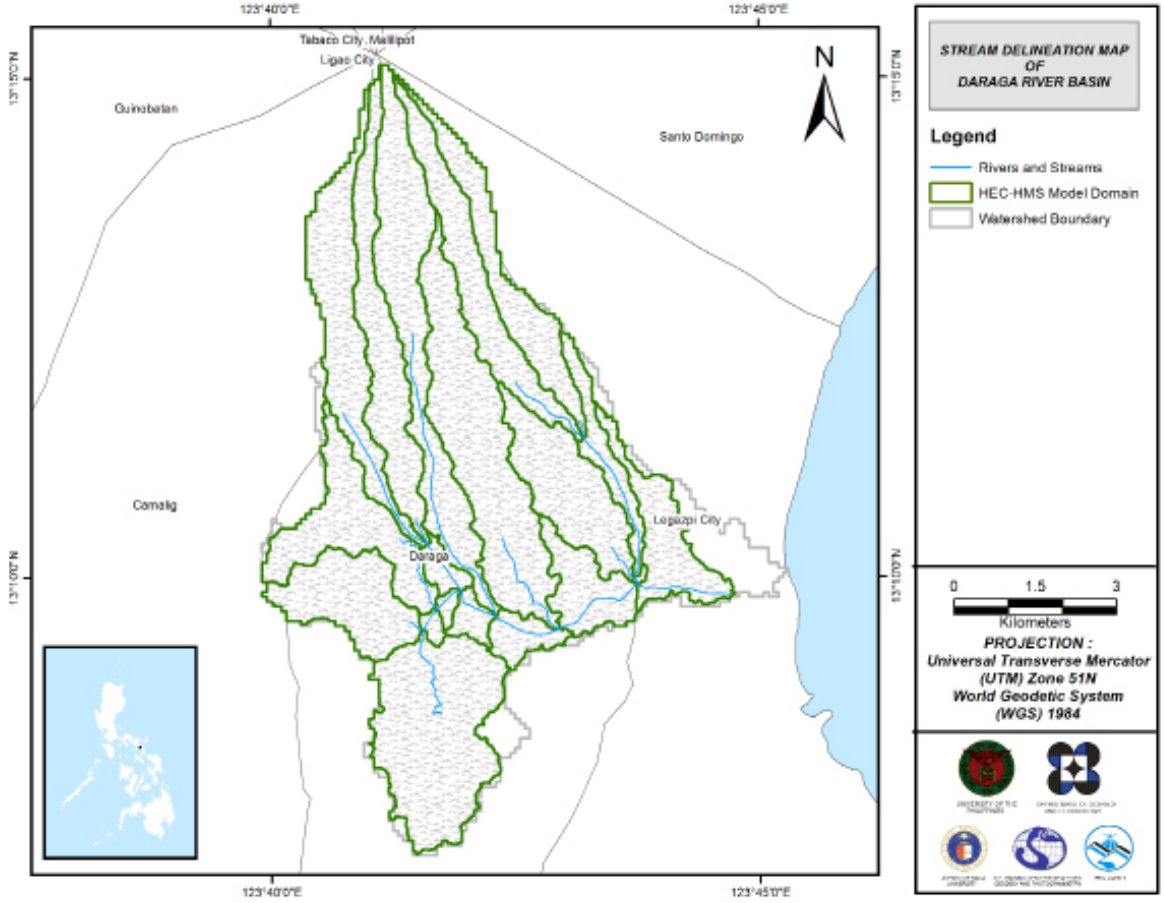


Figure 56. Stream delineation map of Daraga River Basin

Using the SAR-based DEM, the Daraga basin was delineated and further divided into subbasins. The model consists of 19 sub basins, 9 reaches, and 9 junctions, as shown in Figure 57 (See Annex 10). The main outlet is Kilicao Bridge.

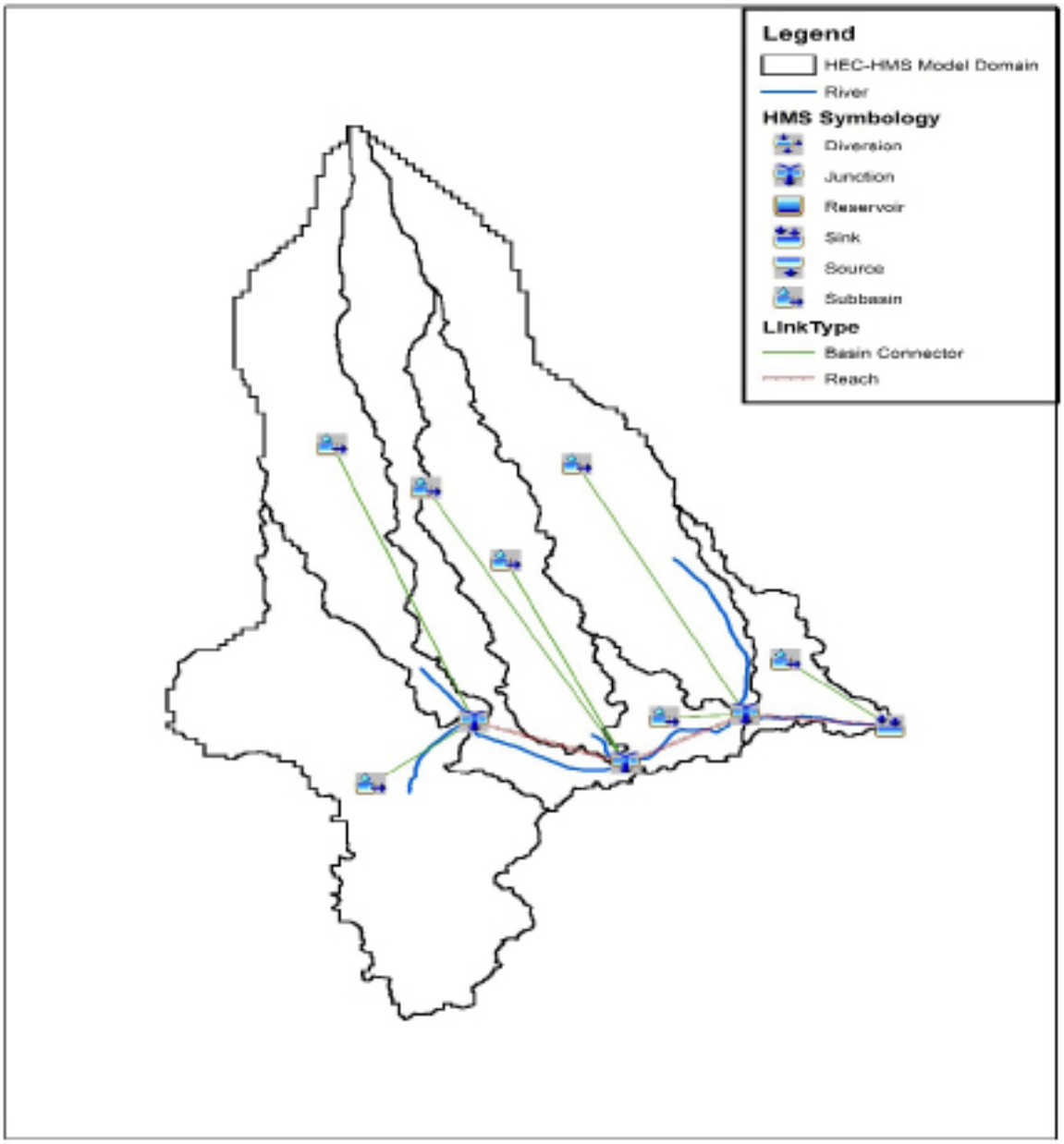


Figure 57. The Daraga River Basin model generated in HEC-HMS

5.4 Cross-Section Data

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

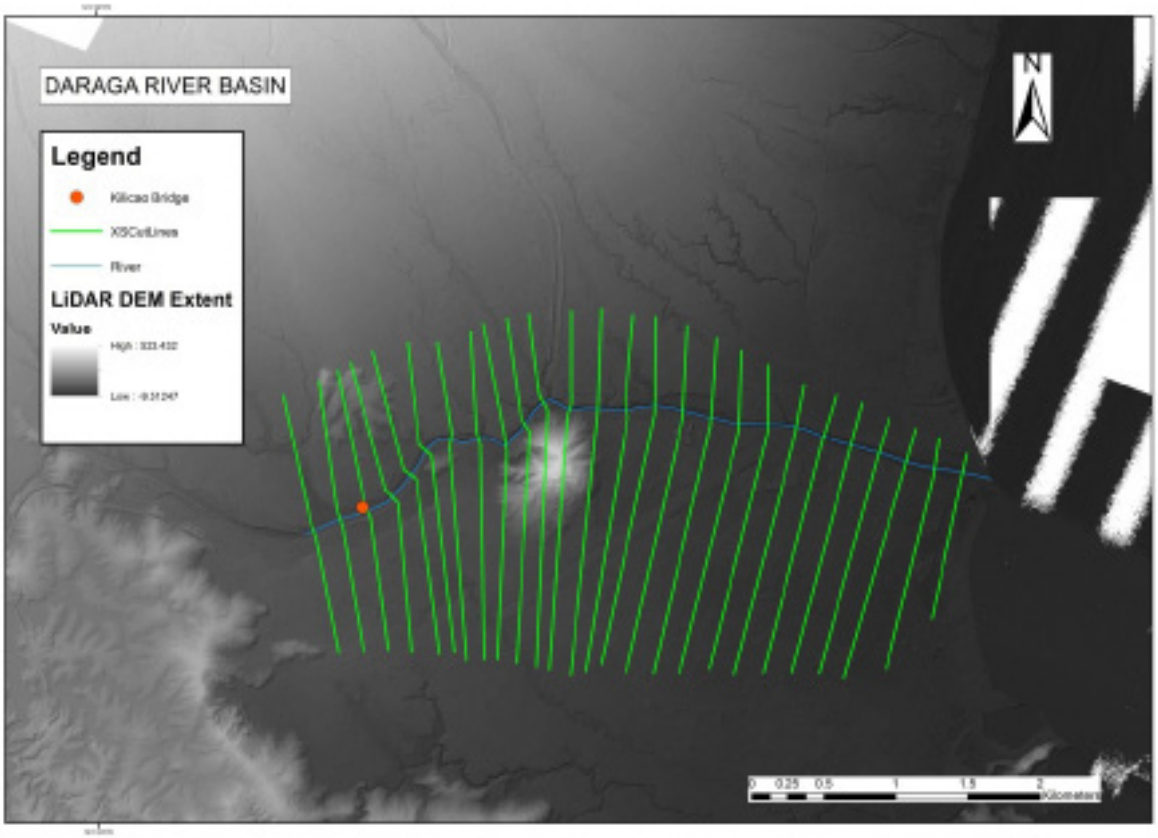


Figure 58. River cross-section of Daraga River generated through Arcmap HEC GeoRAS tool

Using the SAR-based DEM, the Daraga basin was delineated and further divided into subbasins. The model consists of 19 sub basins, 9 reaches, and 9 junctions, as shown in Figure 57 (See Annex 10). The main outlet is Kilicao Bridge.

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 north of the model to the southeast, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

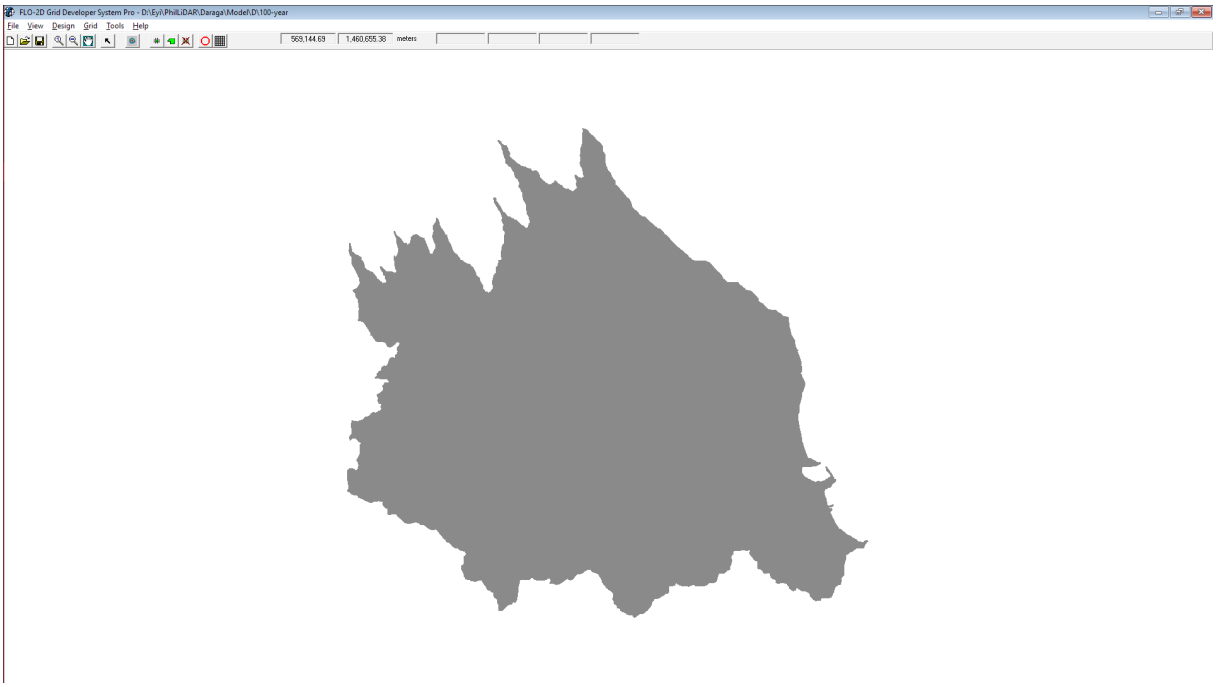


Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 31.38 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Daraga are in Figures 63, 65, and 67.

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 45,515,800.00 m2. The generated flood depth maps for Daraga are in Figures 64, 66, and 68.

There is a total of 21,514,269.83 m3 of water entering the model, of which 12,256,469.89 m3 is due to rainfall and 9,257,799.94 m3 is inflow from basins upstream. 3,749,856.50m3 of this water is lost to infiltration and interception, while 3,251,431.17m3 is stored by the flood plain. The rest, amounting up to 14,512,980.46 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Daraga HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

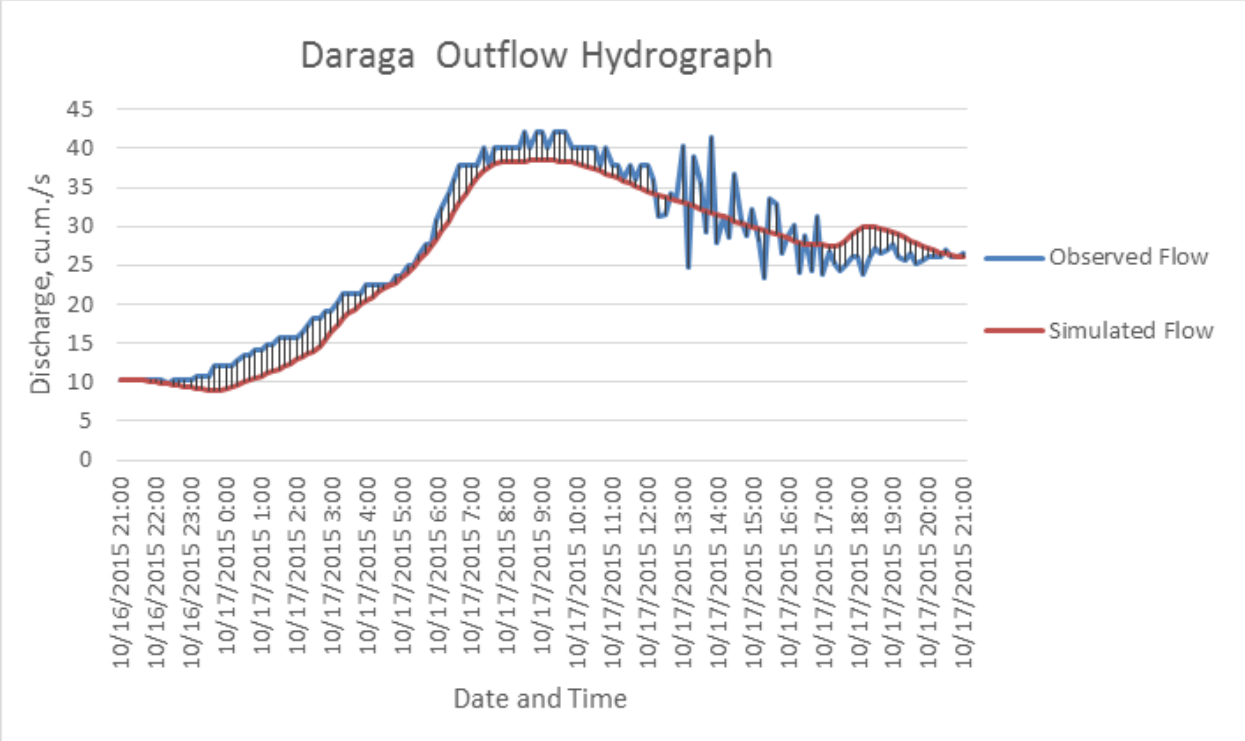


Figure 60. Outflow hydrograph of Daraga produced by the HEC-HMS model compared with observed outflow

Table 30 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of Calibrated Values for Daraga River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.4 - 14
			Curve Number	79 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1- 22
			Storage Coefficient (hr)	0.6 - 14
	Baseflow	Recession	Recession Con-stant	0.09 - 0.3
			Ratio to Peak	0.3 - 1
Reach	Routing	Muskingum-Cunge	Slope	0.003 - 0.03
			Manning's n	0.002 - 0.06

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 0.4 mm to 14 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 79 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Daraga, the basin mostly consists of cultivated land and the soil consists of Mayon gravelly sandy loam, Legaspi fine sandy loam, and Annam clay loam.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.1 hours to 22 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. For Daraga, it will take at least 15 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.057 corresponds to the common roughness in Daraga watershed, which is determined to be cultivated land of annual crop, with mature field crops (Brunner, 2010).

Table 31. Summary of the Efficiency Test of Daraga HMS Model

Accuracy Measure	Value
RMSE	2.88
r2	0.93
NSE	0.92
PBIAS	3.90
RSR	0.29

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 2.88 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.93.

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 0.92.

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 3.90.

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 0.29.

5.7 Calculated Outflow Hydrographs and Discharge Values for Different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Daraga 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 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 from 361.5m3/s in a 5-year return period to 723.4m3/s in a 100-year return period.

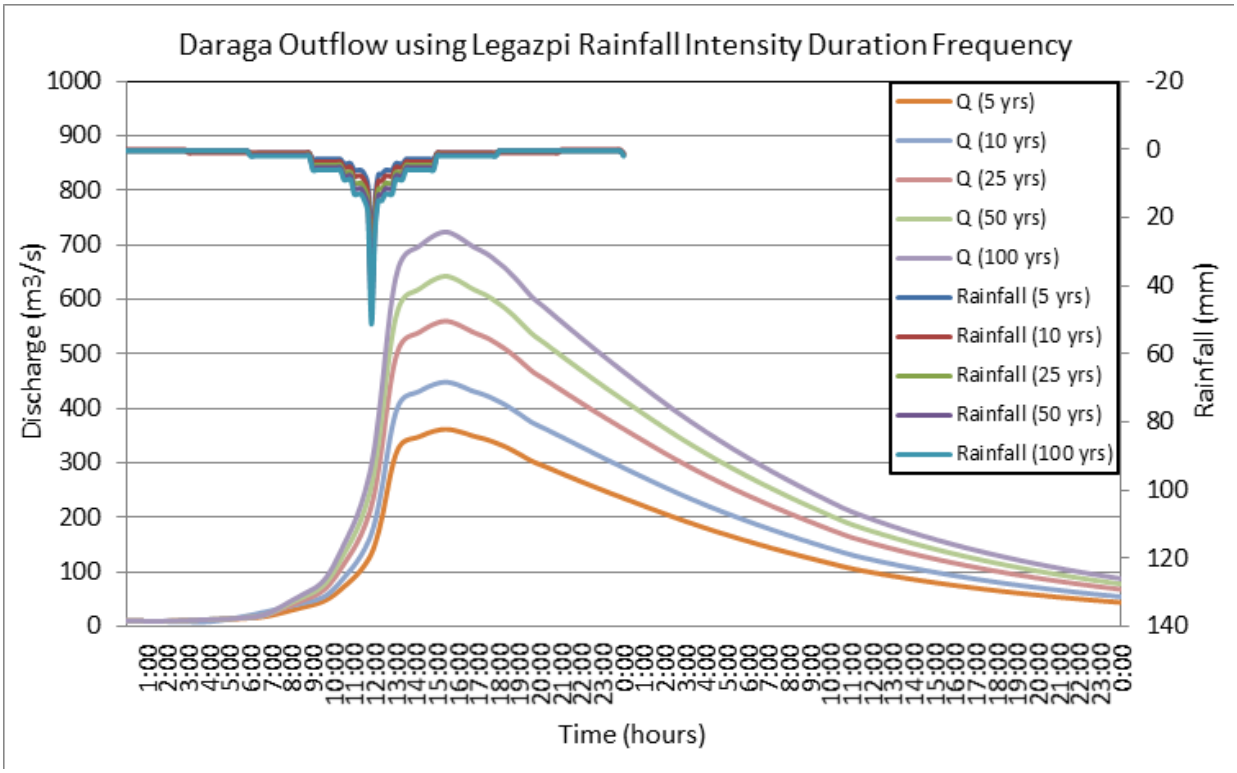


Figure 61. The Outflow hydrograph at the Daraga Station, generated using the simulated rain events for 24-hour period for Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Daraga discharge using the Legazpi RIDF in five different return periods is shown in Table 32.

Table 32. outlines the peak values of the Daraga HECHMS Model outflow using the Legazpi RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow	Range of Calibrated Values
(m 3/s)	Time to Peak	29.1	361.5	4 hours, 50 minutes
10-Year	316.10	34.5	448.1	4 hours, 40 minutes
25-Year	386.40	41.3	559.8	4 hours, 40 minutes
50-Year	438.40	46.3	642	4 hours, 50 minutes
100-Year	490.30	51.3	723.4	4 hours, 50 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. Figure 62 shows a generated sample map of the Daraga River using the calibrated HMS base flow.

Figure 62. Sample output map of the Daraga RAS Model

5.9 Flood Depth and Flood Hazard Maps

The resulting hazard and flow depth maps have a 10m resolution. Figures 63 to 68 show the 5-, 25-, and 100-year rain return scenarios of the Daraga Floodplain. The floodplain, with an area of 45.52km2, covers five (5) municipalities, namely Camalig, Daraga, Legazpi City, Malilipot, and Santo Domingo. Table 5 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Daraga Floodplain

Municipality	Total Area (km2)	Area Flooded (km2)	% Flooded
Camalig	136.54	3.18	2.35
Daraga	135.66	56	41.28
Legazpi City	153.18	36.04	23.53
Malilipot	45.42	0.0003	0.00007
Santo Domingo	60.83	0.02	0.04

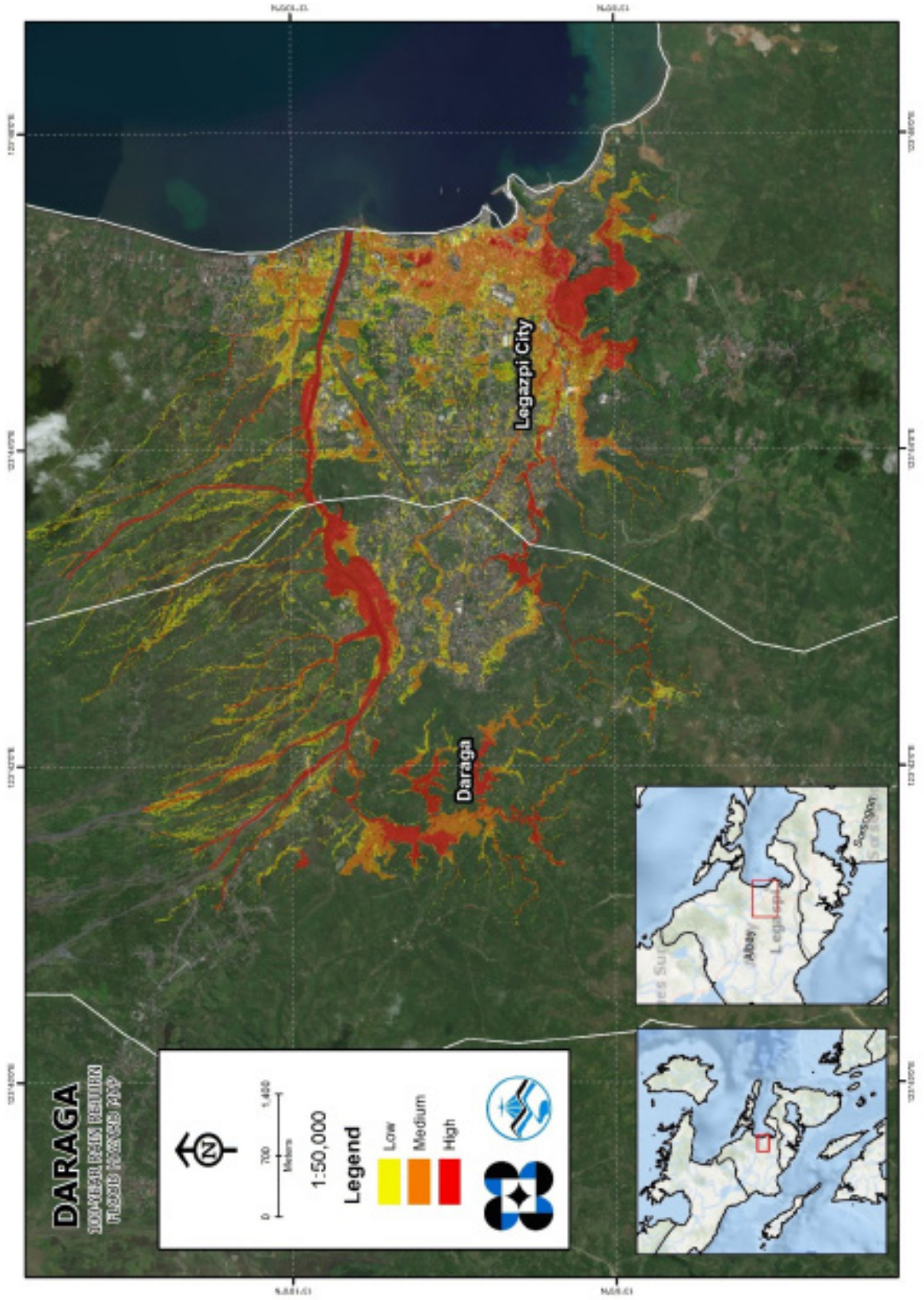


Figure 63. A 100-year flood hazard map for the Daraga Floodplain

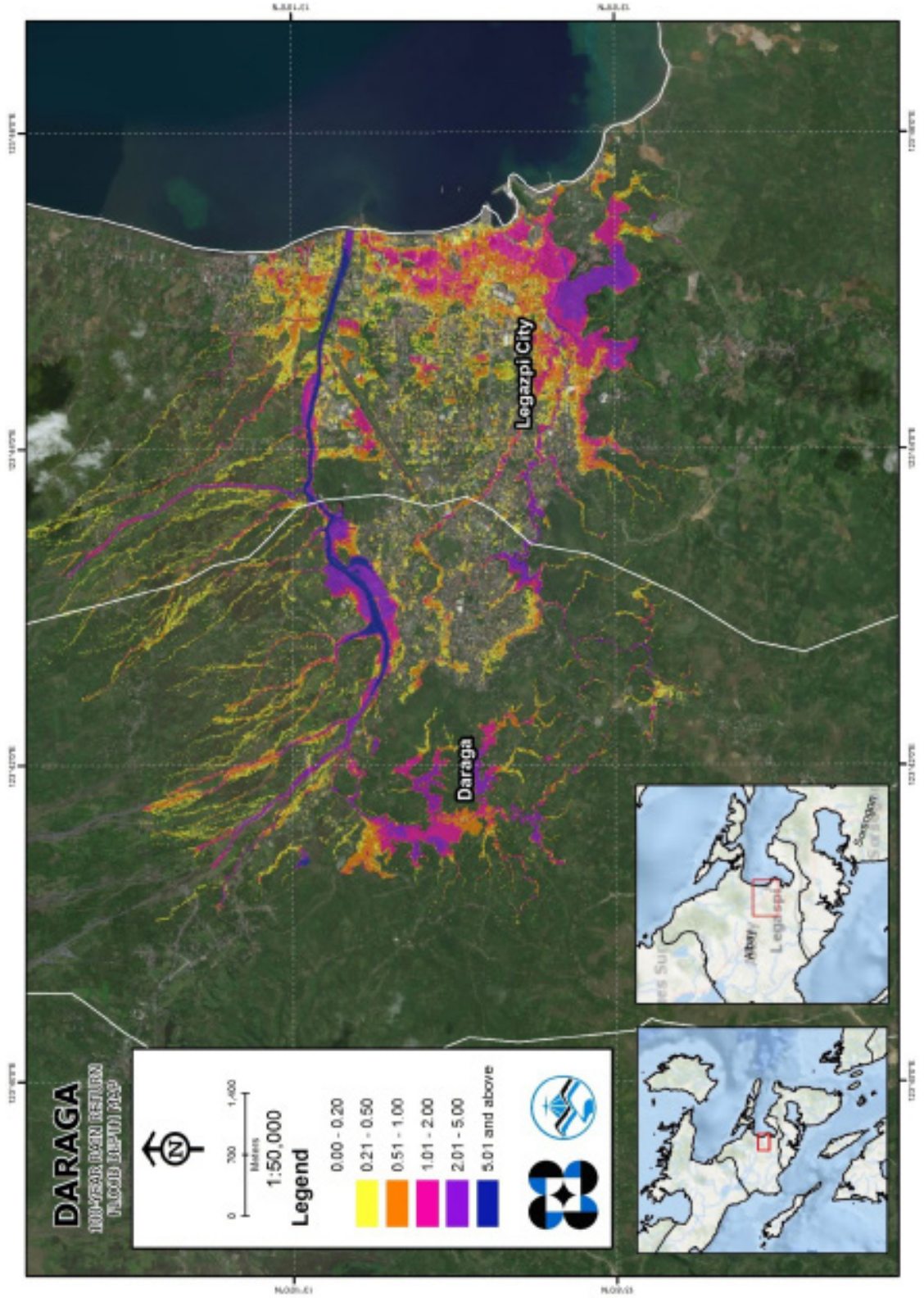


Figure 64. A 100-year flow depth map for Daraga Floodplain

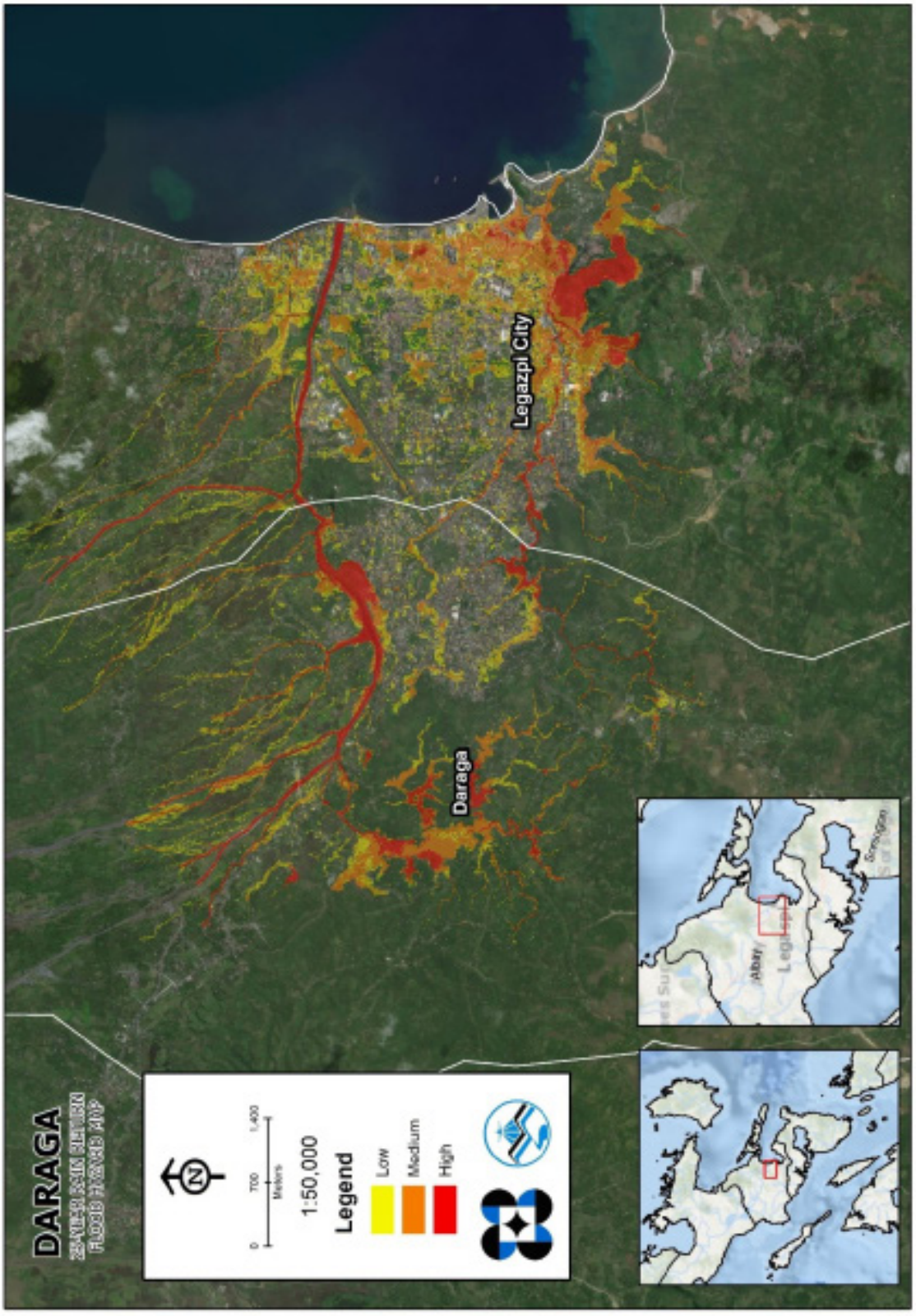


Figure 65. A 25-year flood hazard map for Daraga Floodplain

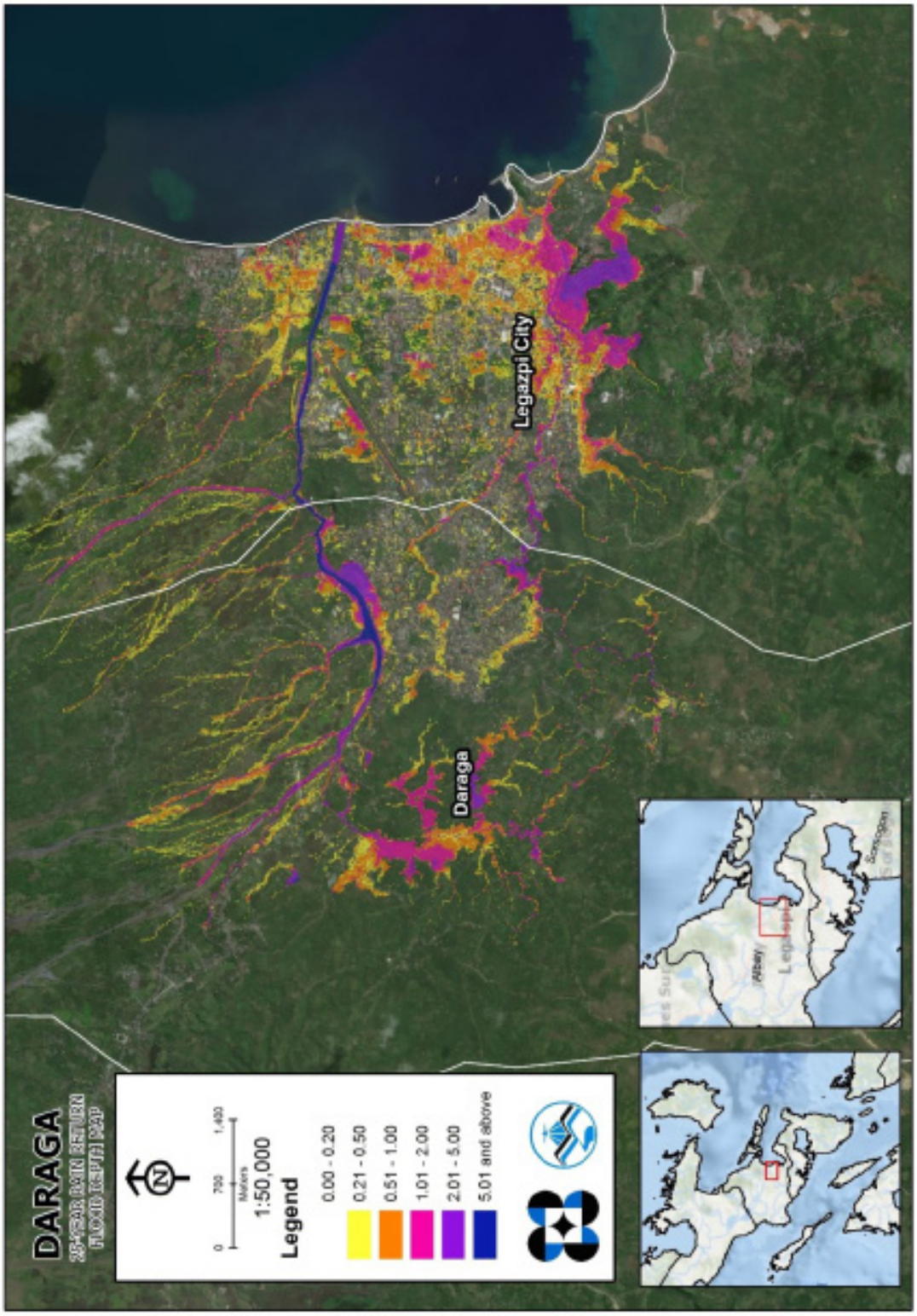


Figure 66. A 25-year flow depth map for Daraga Floodplain

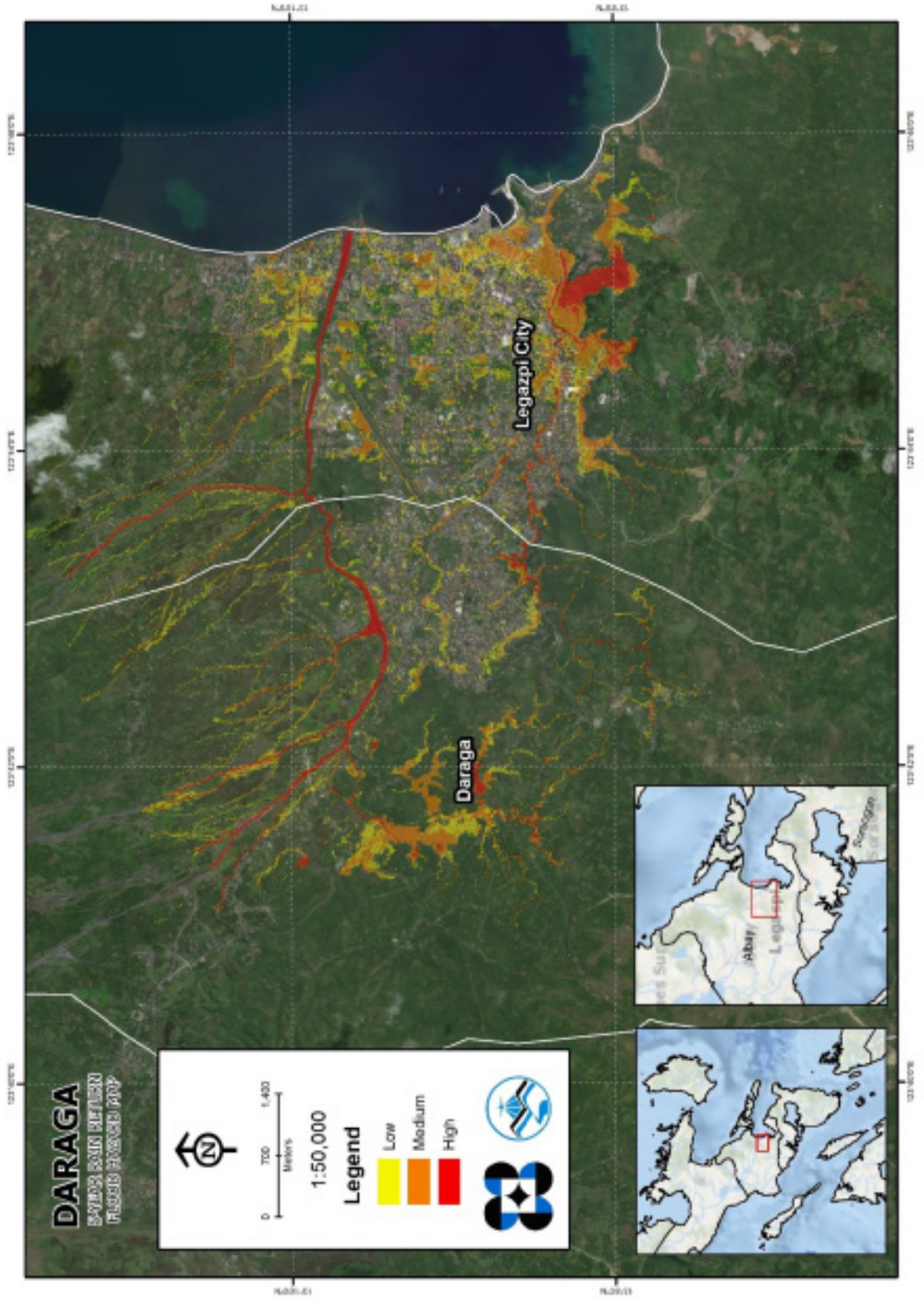


Figure 67. A 5-year flood hazard map for Daraga Floodplain

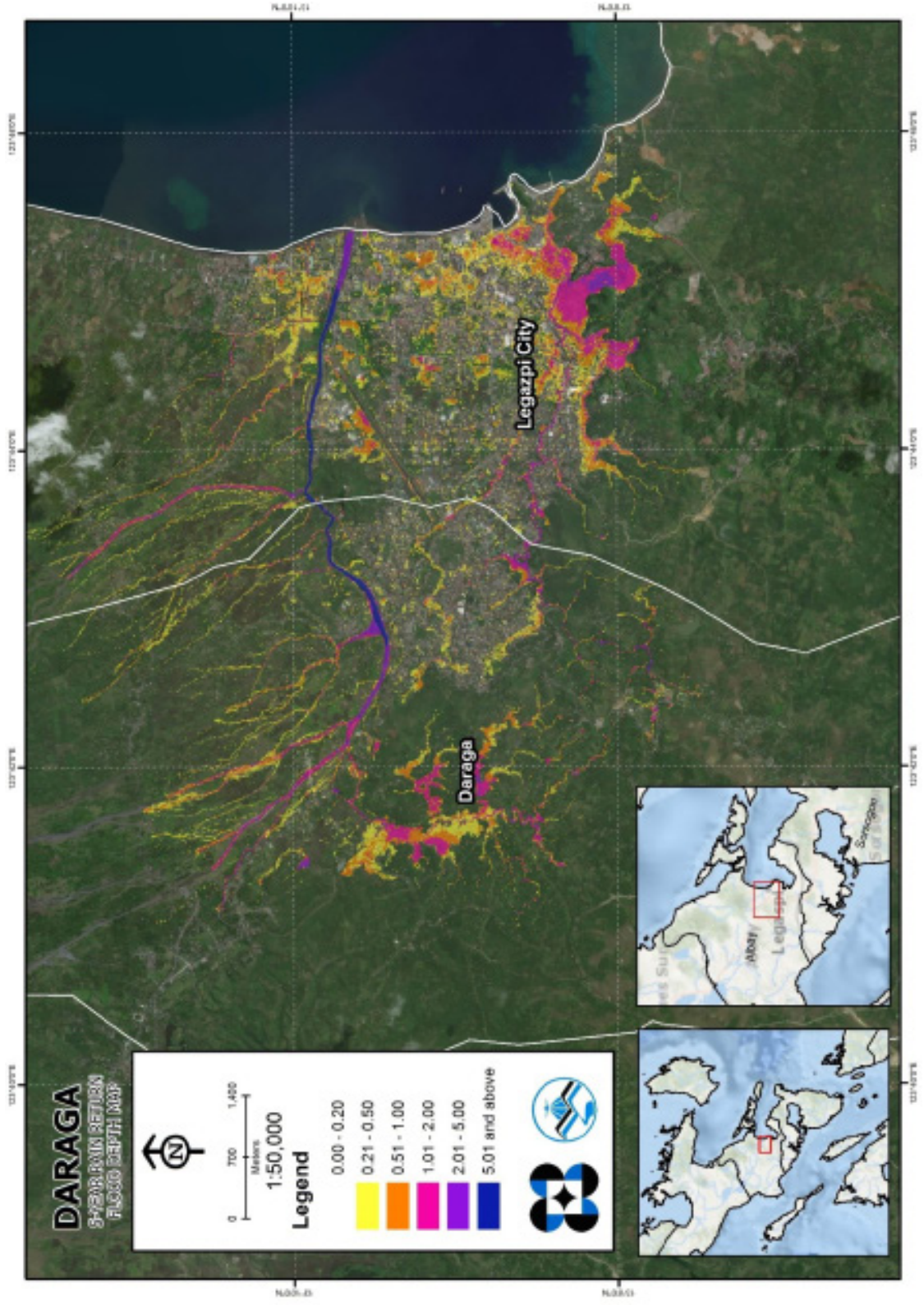


Figure 68. A 5-year flow depth map for Daraga Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Daraga River Basin, grouped accordingly by municipality. For the said basin, five (5) municipalities consisting of 102 barangays are expected to experience flooding when subjected to the three scenarios of rainfall return period scenarios.

For the 5-year rainfall return period, 2.23% of Camalig with an area of 136.54 square kilometers will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.03%, 0.01%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 34 depicts the affected areas in Camalig in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Camalig, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Camalig (in sq. km.)				
	Anoling	Cabagñan	Mina	Quirangay	Tinago
0.03-0.20	2.26	0.058	0.18	0.52	0.031
0.21-0.50	0.061	0.0085	0.0017	0.011	0
0.51-1.00	0.029	0.0006	0.0005	0.005	0
1.01-2.00	0.019	0	0	0.00035	0
2.01-5.00	0.0014	0	0	0	0
> 5.00	0	0	0	0	0

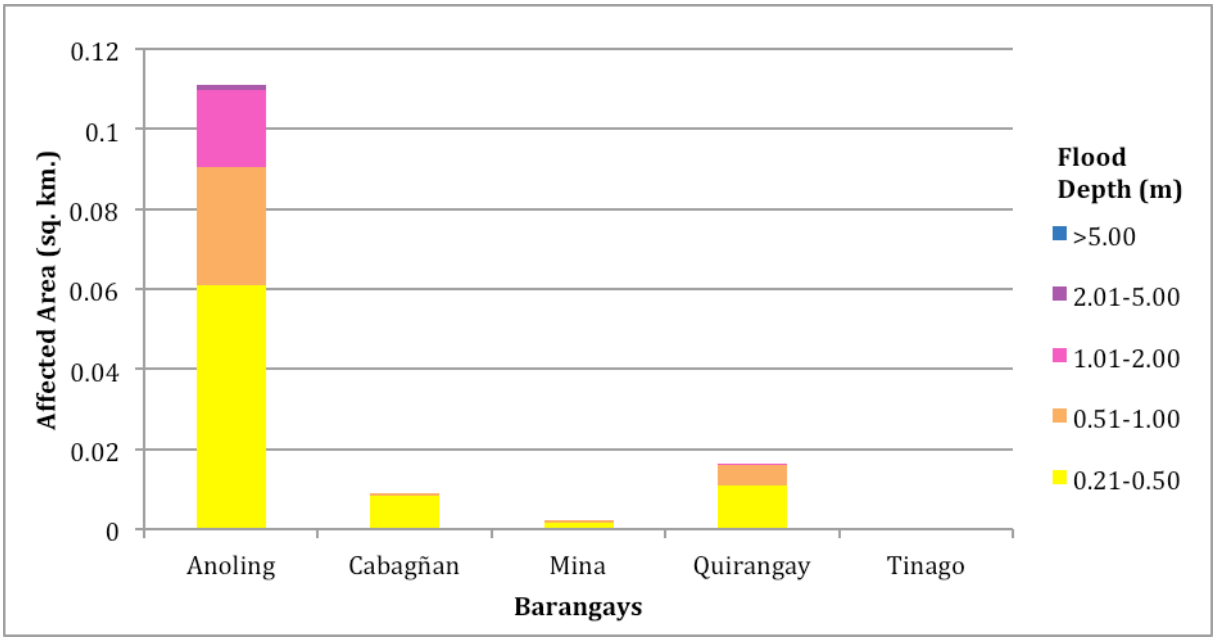


Figure 69. Affected Areas in Camalig, Albay during the 5-Year Rainfall Return Period

For the municipality of Daraga with an area of 135.66 square kilometers, 36.97% will experience flood levels of less than 0.20 meters. 2.2 % of the area will experience flood levels of 0.21 to 0.50 meters, while 1.2%, 0.61%, 0.22%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 35 to 37 depict the areas affected in Daraga in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)											
	Alcala	Alobo	Bagum-bayan	Balinad	Bañadero	Bañag	Bascaran	Binitayan	Bongalon	Budiao	Burgos	Busay
0.03-0.20	1.59	0.71	1.34	0.43	1.06	0.42	0.52	0.12	1.04	0.55	0.94	1.1
0.21-0.50	0.083	0.023	0.086	0.024	0.11	0.041	0.074	0.025	0.039	0.063	0.2	0.11
0.51-1.00	0.029	0.049	0.031	0.031	0.041	0.035	0.0099	0.039	0.056	0.0082	0.099	0.08
1.01-2.00	0	0.014	0.03	0.032	0.028	0.028	0.0001	0.033	0.055	0	0.0019	0.04
2.01-5.00	0	0.0005	0.0012	0.018	0.0001	0.045	0	0.047	0.0061	0	0	0.0088
> 5.00	0	0	0	0	0	0.018	0	0.055	0	0	0	0

Table 36. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)											
	Cullat	Dela Paz	Dinoronan	Gabawan	Gapo	Ilawod Area Poblacion	Kidaco	Kilicao	Kiman-tong	Kiwalo	Lacag	Malabog
0.03-0.20	1.05	1.02	0.62	0.061	0.85	0.18	0.63	1.02	0.62	0.62	1.38	3.39
0.21-0.50	0.14	0.029	0.025	0	0.031	0.003	0.041	0.09	0.022	0.014	0.1	0.15
0.51-1.00	0.065	0.019	0.016	0	0.03	0.00028	0.049	0.024	0.021	0.0061	0.13	0.1
1.01-2.00	0.051	0.0025	0.0051	0	0.031	0	0.041	0.0027	0.01	0.0024	0.063	0.077
2.01-5.00	0.026	0	0.0001	0	0.0004	0	0	0	0.0009	0	0.0023	0.0057
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

Table 37. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)												
	Malobago	Market Area Poblacion	Maroroy	Matnog	Mi-Isi	Pandan	Peña-francia	Sagpon	Salvacion	San Roque	Sipi	Tabon-Tabon	Tagas
0.03-0.20	0.75	0.12	0.36	1.65	17.42	1.47	0.76	1.04	1.91	0.58	0.51	1.61	0.73
0.21-0.50	0.047	0.0085	0.041	0.097	0.76	0.099	0.026	0.07	0.075	0.017	0.044	0.13	0.044
0.51-1.00	0.02	0.000019	0.011	0.0031	0.31	0.11	0.013	0.02	0.041	0.0055	0.03	0.065	0.029
1.01-2.00	0.012	0	0	0.00011	0.12	0.019	0.0037	0.02	0.03	0	0.006	0.023	0.045
2.01-5.00	0.008	0	0	0	0.016	0.0008	0.0003	0.0069	0.0045	0	0.001	0.0013	0.092
> 5.00	0.0012	0	0	0	0	0	0	0	0	0	0	0	0.045

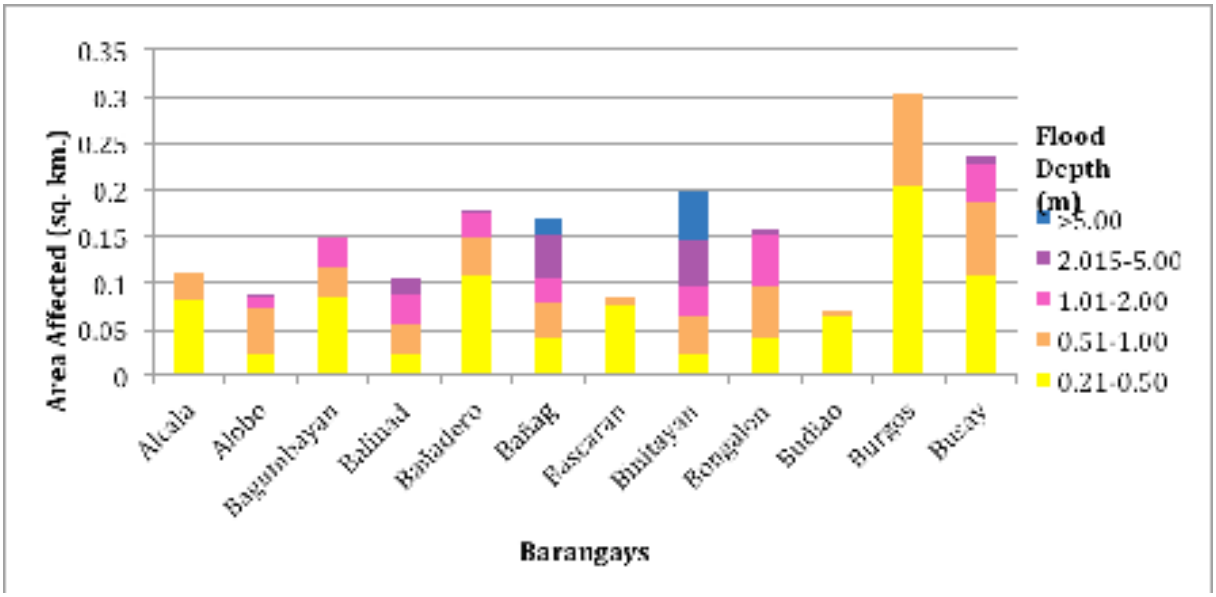


Figure 70. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

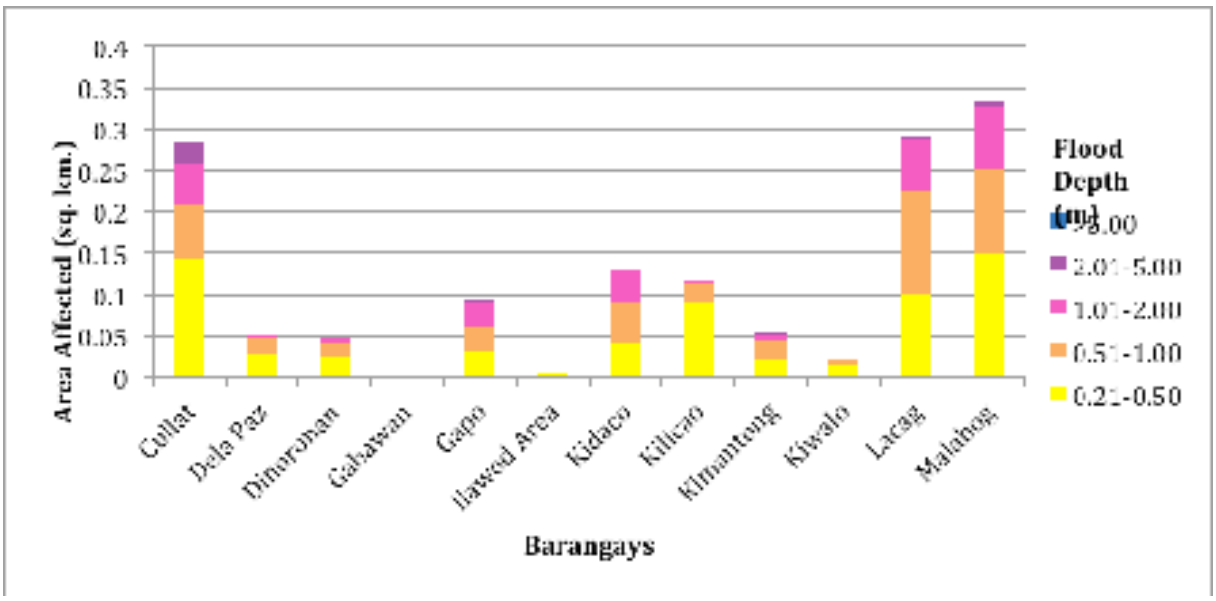


Figure 71. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

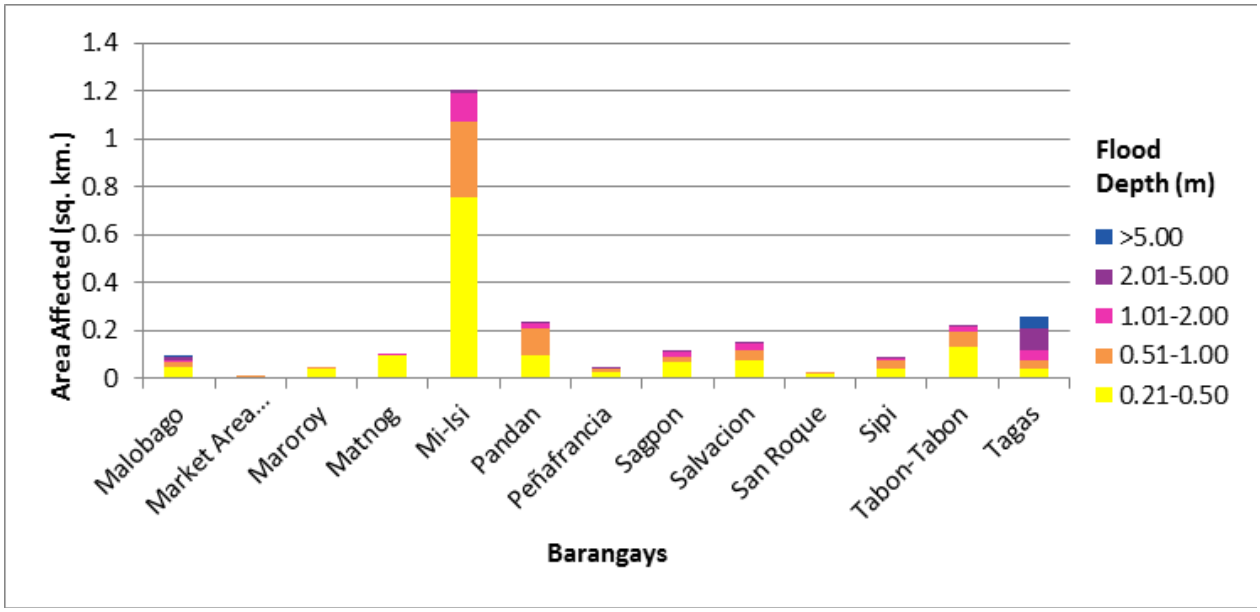


Figure 72. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

For Legazpi City with an area of 153.18 square kilometers., 19.07% will experience flood levels of less than 0.20 meters. 2.29% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.38%, 0.6%, 0.14%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 38 to 42 depict the areas affected in Legazpi City in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Legazpi, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 1 - Em's Barrio	Bgy. 10 - Cabugao	Bgy. 11 - Maoyod Poblacion	Bgy. 12 - Tula-Tula	Bgy. 13 - Ilawod West Poblacion	Bgy. 14 - Ilawod Poblacion	Bgy. 15 - Ilawod East Poblacion	Bgy. 16 - Kawit-East Washington Dr	Bgy. 17 - Rizal Sreet., Ilawod	Bgy. 18 - Cabagñan West	Bgy. 19 - Cabagñan
0.03-0.20	0.73	0.089	0.14	0.23	0.12	0.17	0.41	0.33	0.24	0.2	0.2
0.21-0.50	0.11	0.0005	0.0032	0.0059	0.0022	0.0022	0.012	0.066	0.09	0.066	0.0078
0.51-1.00	0.045	0	0	0	0.0004	0.0009	0.0052	0.042	0.0024	0.11	0.0034
1.01-2.00	0.026	0	0	0	0	0	0.0063	0	0	0.06	0.0072
2.01-5.00	0.0019	0	0	0	0	0	0.0013	0	0	0.0026	0.00088
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Table 39. Affected Areas in Legazpi, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 2 - Em's Barrio South	Bgy. 20 - Cabagñan East	Bgy. 21 - Binanuah-an West	Bgy. 22 - Binanua-han East	Bgy. 23 - Imperial Court Subd.	Bgy. 24 - Rizal Street	Bgy. 25 - Lapu-Lapu	Bgy. 26 - Dinagaan	Bgy. 27 - Victory Village South	Bgy. 28 - Victory Village North	Bgy. 29 - Sabang
0.03-0.20	0.48	0.2	0.068	0.2	0.13	0.12	0.17	0.15	0.13	0.18	0.077
0.21-0.50	0.0058	0.007	0.002	0.0032	0.007	0.0038	0.028	0.0027	0.0044	0.008	0.003
0.51-1.00	0.0004	0.022	0.018	0.0087	0.003	0.022	0.051	0.016	0.0038	0.0071	0.0098
1.01-2.00	0.0009	0.014	0.012	0.0025	0.014	0.052	0.021	0.041	0.0016	0.00042	0.00086
2.01-5.00	0.0002	0.0000034	0	0.0016	0	0.011	0.00024	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Table 40. Affected Areas in Legazpi, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 3 - Em's Barrio East	Bgy. 30 - Pigcale	Bgy. 31 - Centro-Baybay	Bgy. 33 - Pnr-Peñaranda St.-Iraya	Bgy. 34 - Oro Site-Magallanes St.	Bgy. 35 - Tinago	Bgy. 36 - Kapan-tawan	Bgy. 37 - Bitano	Bgy. 38 - Gogon	Bgy. 39 - Bonot	Bgy. 4 - Sagpon Poblacion
0.03-0.20	0.1	0.067	0.2	0.18	0.027	0.01	0.032	0.79	1.04	0.19	0.039
0.21-0.50	0.0032	0.003	0.059	0.061	0.048	0.00023	0.04	0.24	0.24	0.21	0.0063
0.51-1.00	0.001	0.0037	0.029	0.019	0.12	0.0013	0.11	0.15	0.12	0.18	0.0024
1.01-2.00	0	0.0059	0.0014	0.002	0.027	0.011	0.12	0.03	0.053	0.046	0.001
2.01-5.00	0	0	0	0	0	0.00097	0.0044	0	0.068	0.037	0
> 5.00	0	0	0	0	0	0	0	0	0.013	0	0

Table 41. Affected Areas in Legazpi, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 40 - Cruzada	Bgy. 41 - Bogtong	Bgy. 42 - Rawis	Bgy. 43 - Tamaoyan	Bgy. 44 - Pawa	Bgy. 45 - Dita	Bgy. 5 - Sagmin Poblacion	Bgy. 50 - Padang	Bgy. 52 - Matanag	Bgy. 53 - Bonga	Bgy. 54 - Mabinit
0.03-0.20	2.56	0.59	0.25	0.72	2.85	0.093	0.11	1.56	0.0028	1.28	2.66
0.21-0.50	0.41	0.16	0.16	0.18	0.18	0	0.022	0.048	0	0.089	0.14
0.51-1.00	0.045	0.093	0.089	0.095	0.12	0	0.025	0.0056	0	0.0043	0.062
1.01-2.00	0	0.058	0.015	0.0085	0.1	0	0.0021	0.0003	0	0.00027	0.049
2.01-5.00	0	0.0067	0	0.0061	0.062	0	0.0001	0	0	0	0.0023
> 5.00	0	0.002	0	0.0015	0.041	0	0	0	0	0	0

Table 42. Affected Areas in Legazpi, Albay during the 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 55 - Estanza	Bgy. 56 - Taysan	Bgy. 57 - Dap-dap	Bgy. 58 - Buragwis	Bgy. 59 - Puro	Bgy. 6 - Bañadero Poblacion	Bgy. 61 - Maslog	Bgy. 62 - Homapon	Bgy. 7 - Baño	Bgy. 8 - Bagum-bayan	Bgy. 9 - Pinaric
0.03-0.20	0.0077	5.95	0.28	0.06	0.22	0.26	1.79	0.00065	0.16	0.14	0.23
0.21-0.50	0	0.44	0.012	0	0.0022	0.0092	0.14	0	0.0085	0.15	0.0078
0.51-1.00	0	0.33	0.005	0	0.00095	0.055	0	0	0.019	0.049	0.0011
1.01-2.00	0	0.13	0.0013	0	0	0	0.0016	0	0.00072	0.0018	0
2.01-5.00	0	0.015	0	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

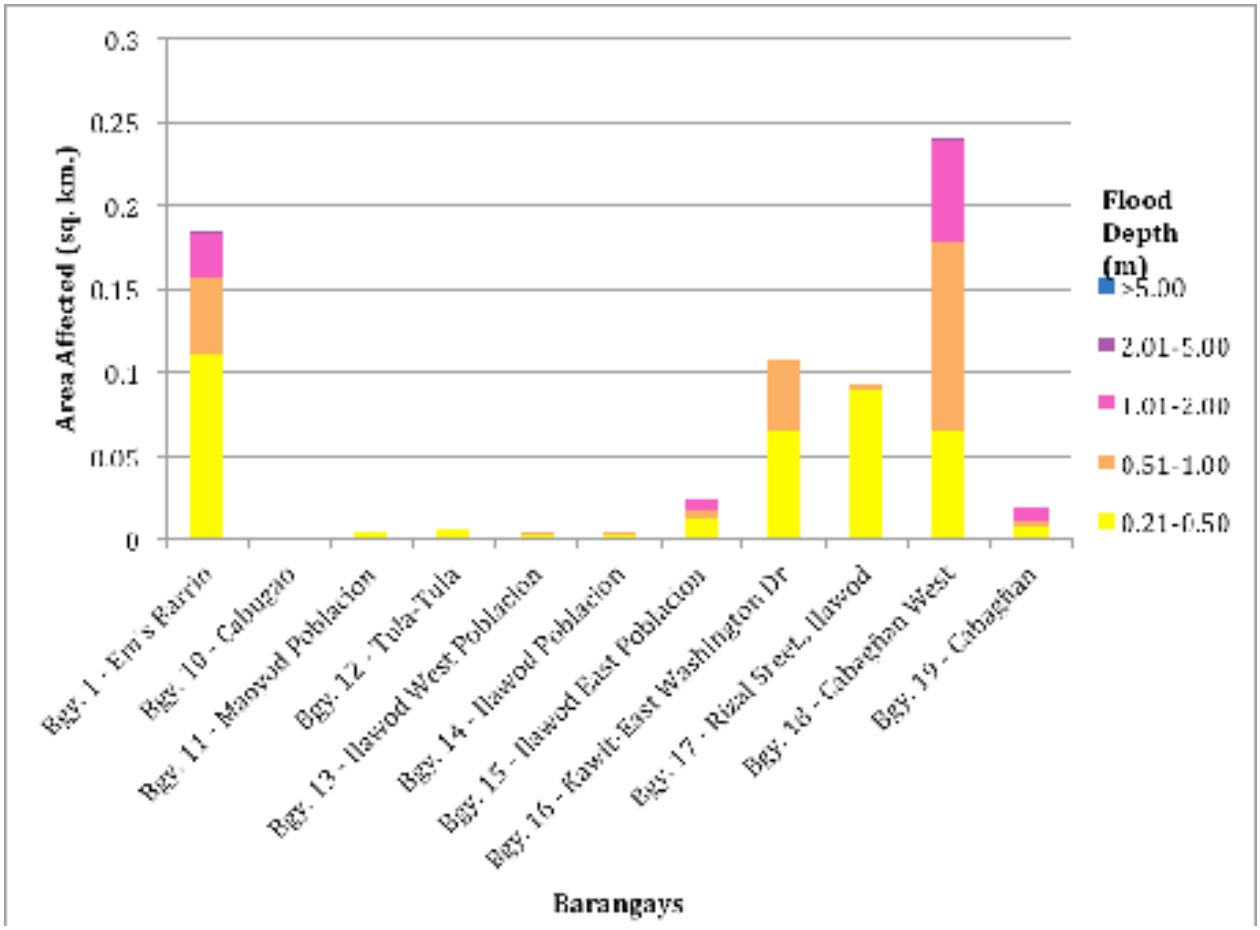


Figure 73. Affected Areas in Legazpi City, Albay during the 5-Year Rainfall Return Period

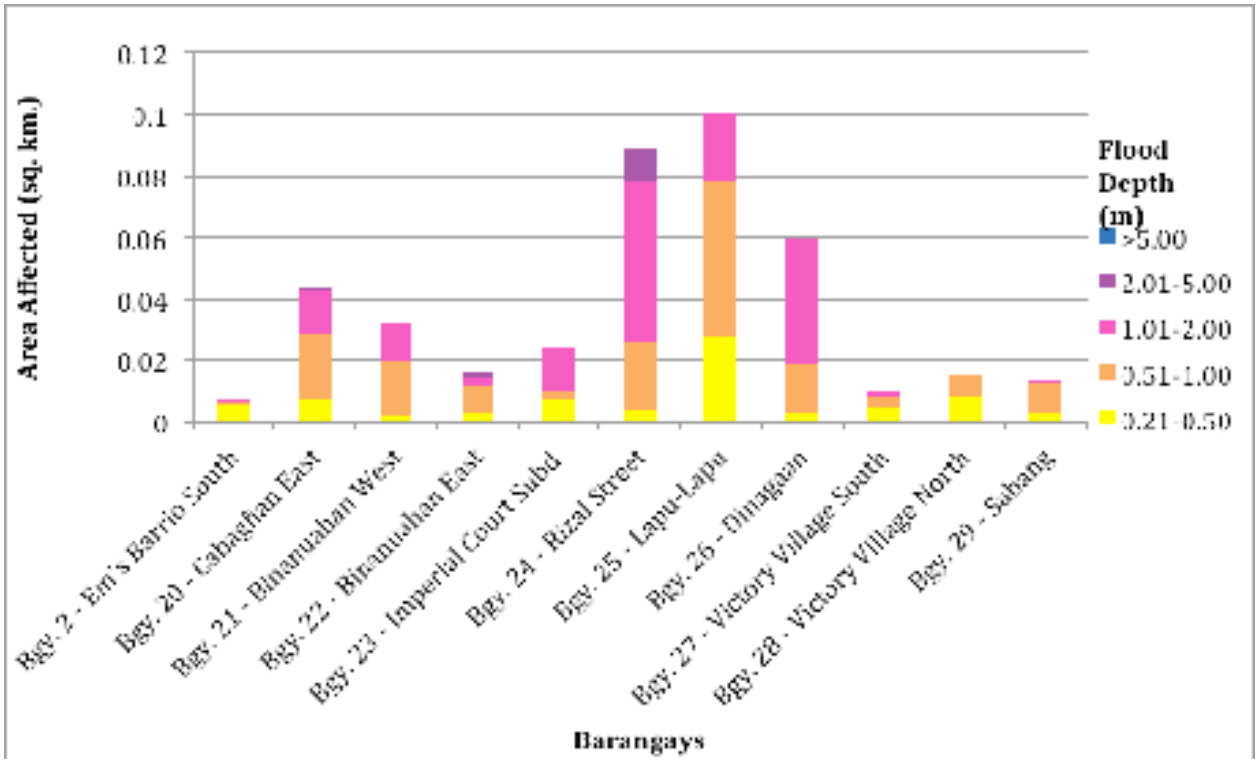


Figure 74. Affected Areas in Legazpi City, Albay during the 5-Year Rainfall Return Period

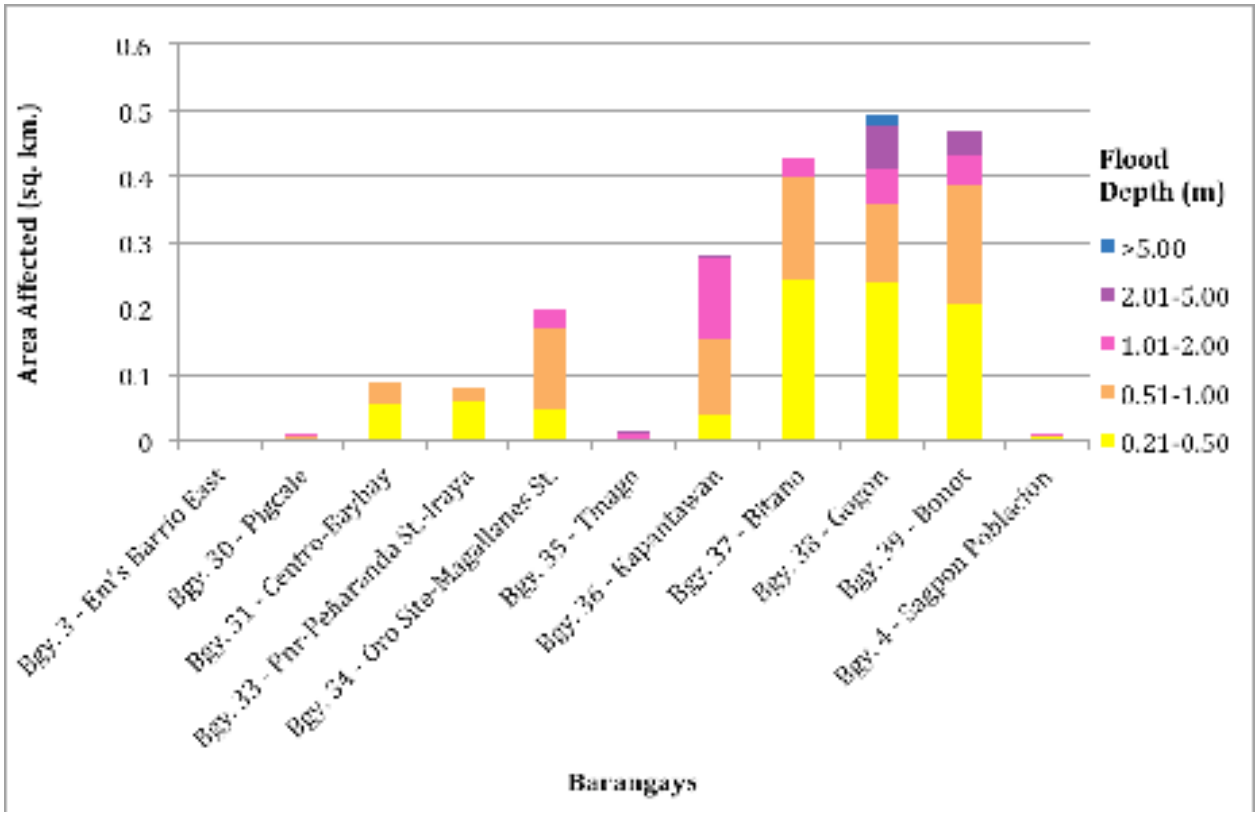


Figure 75. Affected Areas in Legazpi City, Albay during the 5-Year Rainfall Return Period

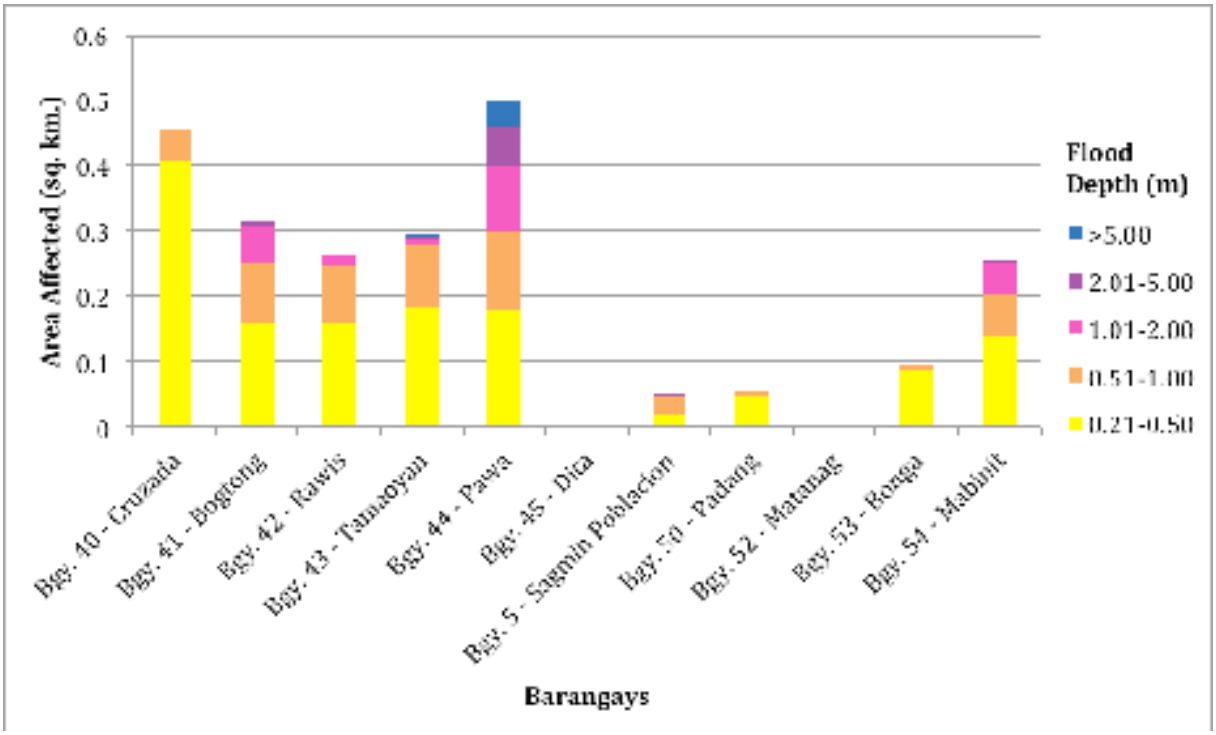


Figure 76. Affected Areas in Legazpi City, Albay during the 5-Year Rainfall Return Period

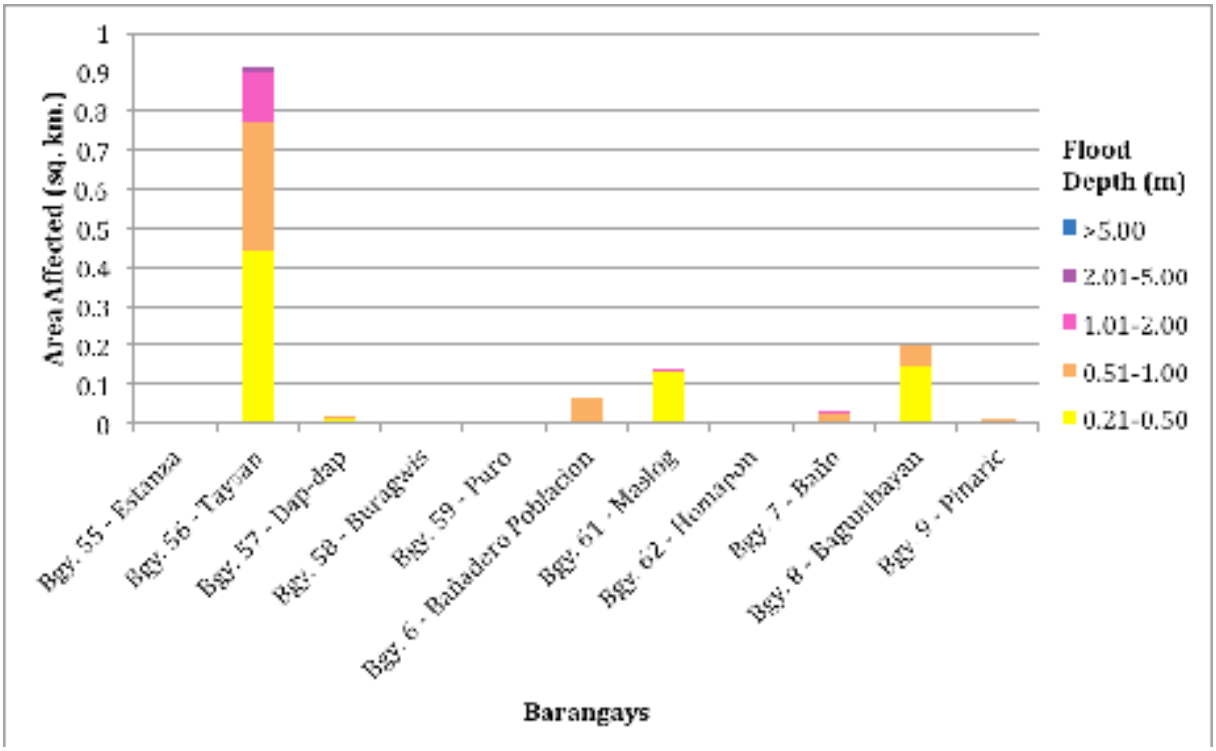


Figure 77. Affected Areas in Legazpi City, Albay during the 5-Year Rainfall Return Period

For the municipality of Malilipot with an area of 45.42 square kilometers., 0.0007% will experience flood levels of less than 0.20 meters.

For the municipality of Santo Domingo with an area of 60.83 square kilometers., 0.04% will experience flood levels of less than 0.20 meters.

For the 25-year rainfall return period, 2.2% of Camalig with an area of 136.54 square kilometers will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.03%, 0.02%, and 0.005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 43 depicts the areas affected in Camalig in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Camalig, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Camalig (in sq. km.)				
	Anoling	Cabagñan	Mina	Quirangay	Tinago
0.03-0.20	2.23	0.051	0.18	0.51	0.031
0.21-0.50	0.081	0.013	0.0023	0.015	0
0.51-1.00	0.03	0.0025	0.0006	0.0062	0
1.01-2.00	0.027	0.0001	0	0.0014	0
2.01-5.00	0.0063	0	0	0	0
> 5.00	0	0	0	0	0

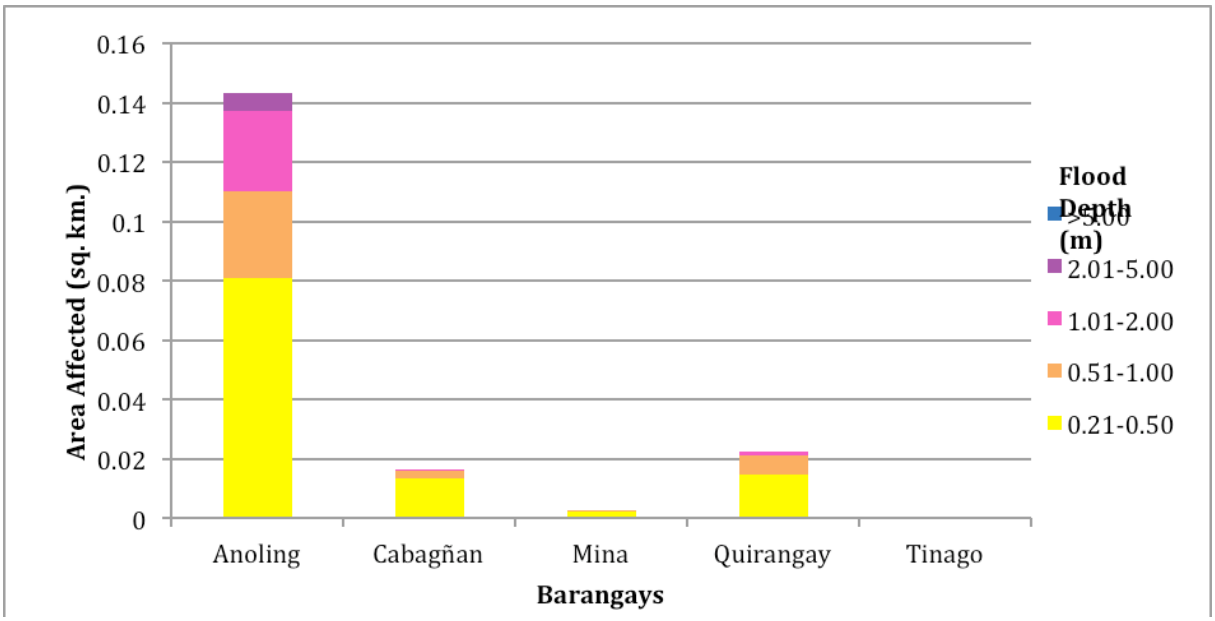


Figure 78. Affected Areas in Camalig, Albay during the 25-Year Rainfall Return Period

For the municipality of Daraga with an area of 135.66 square kilometers, 35.08% will experience flood levels of less than 0.20 meters. 2.96% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.6%, 1.07%, 0.42%, 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. Tables 44 to 46 depict the areas affected in Daraga in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Daraga, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)											
	Alcala	Alobo	Bagum-bayan	Balinad	Bañadero	Bañag	Bascaran	Binitayan	Bongalon	Budiao	Burgos	Busay
0.03-0.20	1.51	0.69	1.3	0.41	1.03	0.34	0.49	0.043	1.01	0.53	0.83	0.99
0.21-0.50	0.16	0.025	0.084	0.019	0.11	0.051	0.099	0.017	0.029	0.066	0.24	0.18
0.51-1.00	0.0009	0.025	0.065	0.027	0.062	0.047	0.018	0.045	0.049	0.028	0.17	0.095
1.01-2.00	0	0.03	0.05	0.042	0.041	0.052	0.0009	0.077	0.085	0	0.013	0.045
2.01-5.00	0	0.0047	0.008	0.042	0.0007	0.06	0	0.07	0.023	0	0	0.03
> 5.00	0	0	0	0	0	0.031	0	0.071	0	0	0	0

Table 45. Affected Areas in Daraga, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)											
	Cullat	Dela Paz	Dinoronan	Gabawan	Gapo	Ilawod Area Poblacion	Kidaco	Kilicao	Kiman-tong	Kiwalo	Lacag	Malabog
0.03-0.20	0.93	1.01	0.61	0.061	0.83	0.16	0.61	0.93	0.61	0.62	1.35	3.29
0.21-0.50	0.19	0.034	0.029	0	0.035	0.016	0.025	0.13	0.022	0.017	0.044	0.2
0.51-1.00	0.1	0.024	0.023	0	0.027	0.0005	0.057	0.038	0.025	0.0079	0.12	0.11
1.01-2.00	0.059	0.0077	0.0093	0	0.05	0	0.062	0.031	0.015	0.0037	0.15	0.099
2.01-5.00	0.05	0.0002	0.0004	0	0.001	0	0.0096	0.0092	0.0019	0.0000022	0.0085	0.026
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

Table 46. Affected Areas in Daraga, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)												
	Malobago	Market Area Poblacion	Maroroy	Matnog	Mi-Isi	Pandan	Peña-francia	Sagpon	Salvacion	San Roque	Sipi	Tabon-Tabon	Tagas
0.03-0.20	0.69	0.11	0.093	1.53	17.04	1.44	0.75	0.76	1.84	0.57	0.48	1.52	0.63
0.21-0.50	0.09	0.016	0.11	0.21	1	0.085	0.029	0.2	0.13	0.02	0.066	0.17	0.072
0.51-1.00	0.023	0.0002	0.14	0.0048	0.34	0.13	0.016	0.13	0.047	0.0073	0.031	0.081	0.044
1.01-2.00	0.018	0	0.065	0.0016	0.21	0.047	0.0083	0.043	0.04	0.0022	0.012	0.051	0.041
2.01-5.00	0.015	0	0.0002	0	0.036	0.0018	0.0009	0.022	0.011	0	0.0013	0.0037	0.13
> 5.00	0.0047	0	0	0	0	0	0	0	0	0	0	0	0.069

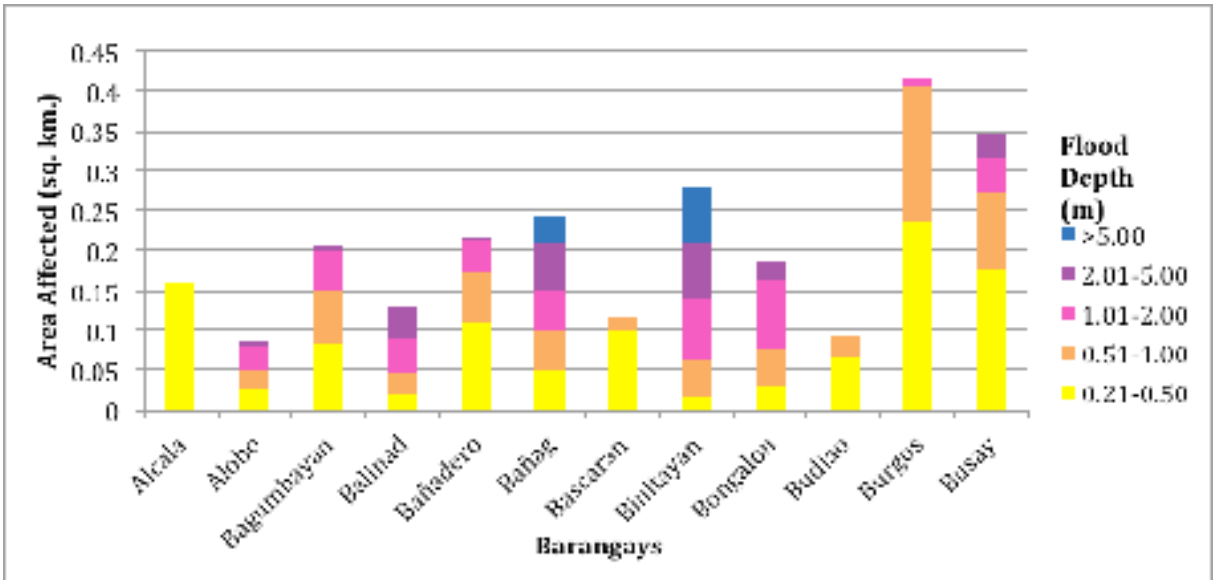


Figure 79. Affected Areas in Daraga, Albay during the 25-Year Rainfall Return Period

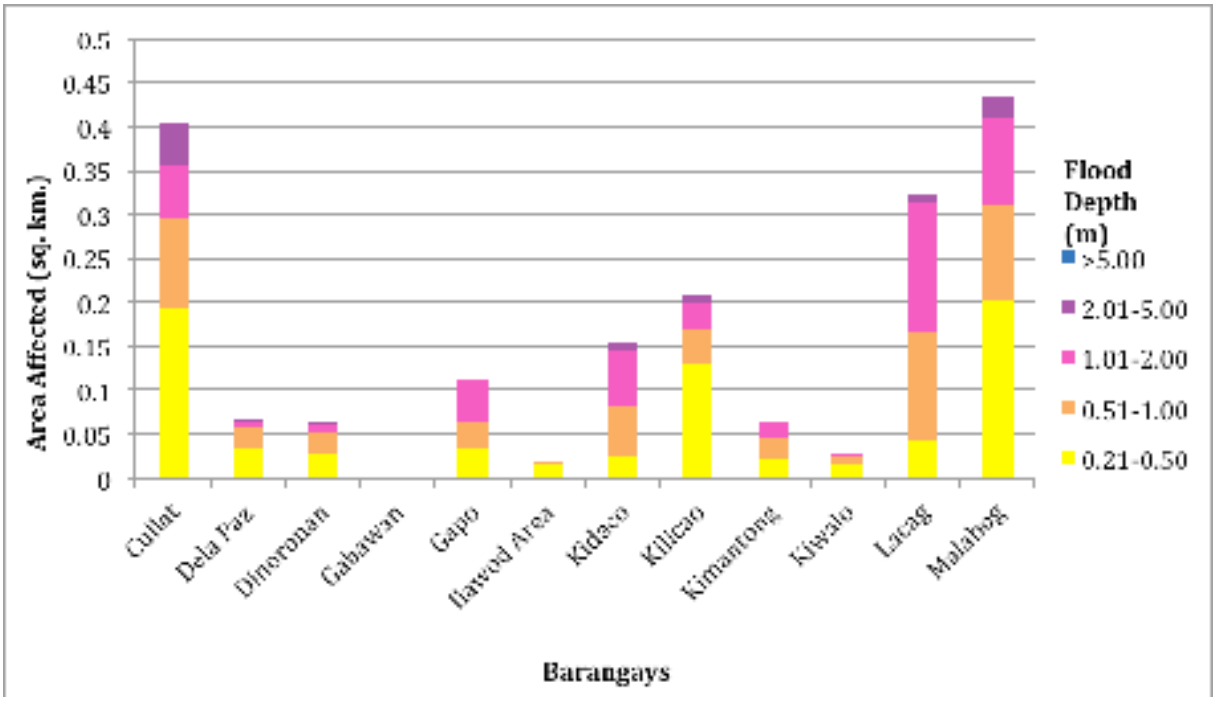


Figure 80. Affected Areas in Daraga, Albay during the 25-Year Rainfall Return Period

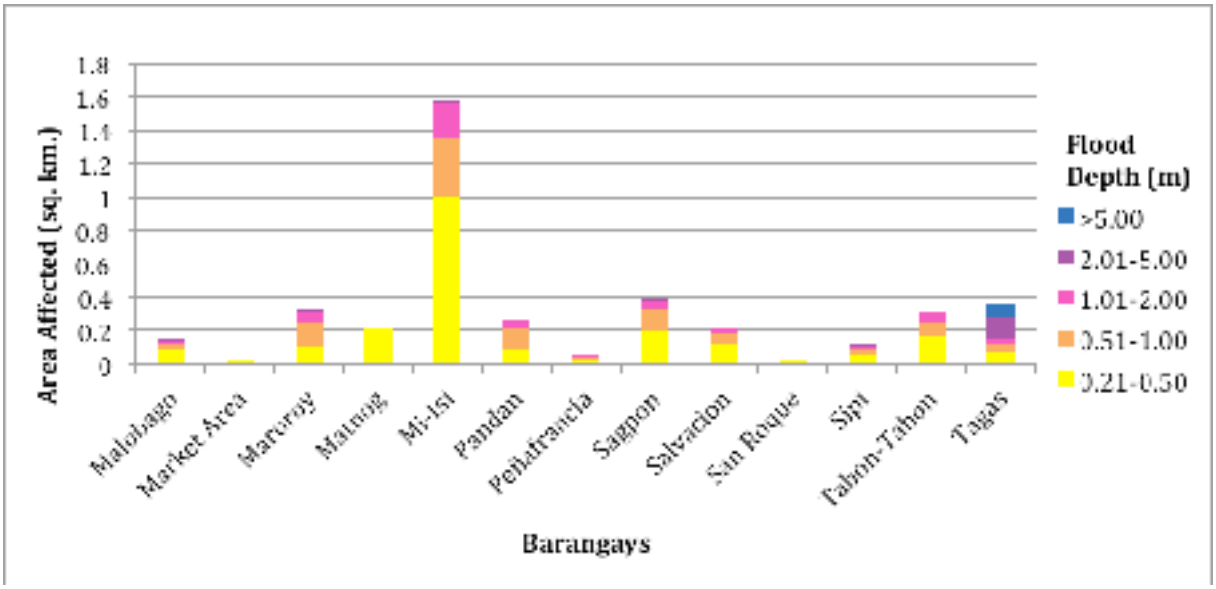


Figure 81. Affected Areas in Daraga, Albay during the 25-Year Rainfall Return Period

For Legazpi City with an area of 153.18 square kilometers., 17.18% will experience flood levels of less than 0.20 meters. 2.94% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.36%, 1.1%, 0.3%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 47 to 51 depict the areas affected in Legazpi City in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Legazpi, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 1 - Em's Barrio	Bgy. 10 - Cabugao	Bgy. 11 - Maoyod Poblacion	Bgy. 12 - Tula-Tula	Bgy. 13 - Ilawod West Poblacion	Bgy. 14 - Ilawod Poblacion	Bgy. 15 - Ilawod East Poblacion	Bgy. 16 - Kawit-East Washington Dr	Bgy. 17 - Rizal Sreet., Ilawod	Bgy. 18 - Cabagñan West	Bgy. 19 - Cabagñan
0.03-0.20	0.63	0.088	0.14	0.23	0.12	0.17	0.4	0.33	0.23	0.18	0.2
0.21-0.50	0.12	0.0009	0.0038	0.0077	0.0023	0.0025	0.016	0.02	0.085	0.027	0.0082
0.51-1.00	0.13	0	0.0002	0	0.001	0.0014	0.0067	0.09	0.022	0.09	0.0046
1.01-2.00	0.04	0	0	0	0	0	0.0067	0	0.0001	0.13	0.0078
2.01-5.00	0.0063	0	0	0	0	0	0.0039	0	0	0.0097	0.002
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Table 48. Affected Areas in Legazpi, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 2 - Em's Barrio South	Bgy. 20 - Cabagñan East	Bgy. 21 - Binanuah-an West	Bgy. 22 - Binanua-han East	Bgy. 23 - Imperial Court Subd.	Bgy. 24 - Rizal Street	Bgy. 25 - Lapu-Lapu	Bgy. 26 - Dinagaan	Bgy. 27 - Victory Village South	Bgy. 28 - Victory Village North	Bgy. 29 - Sabang
0.03-0.20	0.48	0.19	0.066	0.19	0.13	0.12	0.16	0.75	0.12	0.17	0.077
0.21-0.50	0.0078	0.0068	0.001	0.002	0.0068	0.003	0.016	0.0027	0.0048	0.01	0.0026
0.51-1.00	0.001	0.009	0.0027	0.0041	0.017	0.006	0.054	0.011	0.0041	0.0085	0.0084
1.01-2.00	0.001	0.033	0.03	0.01	0.023	0.061	0.034	0.033	0.0028	0.0031	0.0035
2.01-5.00	0.0005	0.0003	0.00004	0.0019	0.0008	0.024	0.0059	0.016	0	0	0
> 5.00	0	0	0	0.0003	0	0	0	0	0	0	0

Table 49. Affected Areas in Legazpi, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 3 - Em's Barrio East	Bgy. 30 - Pigcale	Bgy. 31 - Centro-Baybay	Bgy. 33 - Pnr-Peñaranda St.-Iraya	Bgy. 34 - Oro Site-Magallanes St.	Bgy. 35 - Tinago	Bgy. 36 - Kapan-tawan	Bgy. 37 - Bitano	Bgy. 38 - Gogon	Bgy. 39 - Bonot	Bgy. 4 - Sagpon Poblacion
0.03-0.20	0.1	0.063	0.17	0.11	0.01	0.0099	0.019	0.45	0.34	0.1	0.037
0.21-0.50	0.0041	0.0033	0.036	0.048	0.014	0.0003	0.013	0.32	0.77	0.12	0.0069
0.51-1.00	0.0017	0.0046	0.068	0.097	0.12	0.0006	0.093	0.32	0.24	0.3	0.0031
1.01-2.00	0	0.0073	0.014	0.0039	0.077	0.011	0.11	0.12	0.086	0.089	0.0014
2.01-5.00	0	0.0006	0	0	0.0009	0.0022	0.076	0.0088	0.073	0.045	0
> 5.00	0	0	0	0	0	0	0	0	0.018	0	0

Table 50. Affected Areas in Legazpi, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 40 - Cruzada	Bgy. 41 - Bogtong	Bgy. 42 - Rawis	Bgy. 43 - Tamaoyan	Bgy. 44 - Pawa	Bgy. 45 - Dita	Bgy. 5 - Sagmin Poblacion	Bgy. 50 - Padang	Bgy. 52 - Matanag	Bgy. 53 - Bonga	Bgy. 54 - Mabinit
0.03-0.20	1.56	0.42	0.17	0.62	2.68	0.093	0.11	1.53	0.0028	1.2	2.57
0.21-0.50	0.98	0.1	0.11	0.19	0.26	0	0.021	0.068	0	0.14	0.19
0.51-1.00	0.45	0.2	0.19	0.15	0.15	0	0.029	0.013	0	0.024	0.071
1.01-2.00	0.019	0.17	0.054	0.037	0.12	0	0.0068	0.0004	0	0.0009	0.062
2.01-5.00	0	0.019	0.0001	0.0073	0.099	0	0.0003	0	0	0	0.021
> 5.00	0	0.0032	0	0.0023	0.053	0	0	0	0	0	0

Table 51. Affected Areas in Legazpi, Albay during the 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 55 - Estanza	Bgy. 56 - Taysan	Bgy. 57 - Dap-dap	Bgy. 58 - Buragwis	Bgy. 59 - Puro	Bgy. 6 - Bañadero Poblacion	Bgy. 61 - Maslog	Bgy. 62 - Homapon	Bgy. 7 - Baño	Bgy. 8 - Bagum-bayan	Bgy. 9 - Pinaric
0.03-0.20	0.0077	5.75	0.28	0.06	0.22	0.25	1.74	0.0007	0.15	0.099	0.22
0.21-0.50	0	0.42	0.013	0.0003	0.0031	0.016	0.14	0	0.0068	0.15	0.0099
0.51-1.00	0	0.42	0.0064	0	0.0009	0.0003	0.086	0	0.018	0.081	0.0023
1.01-2.00	0	0.24	0.0029	0	0.000051	0	0.013	0	0.0067	0.01	0
2.01-5.00	0	0.04	0	0	0	0	0	0	0.000087	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

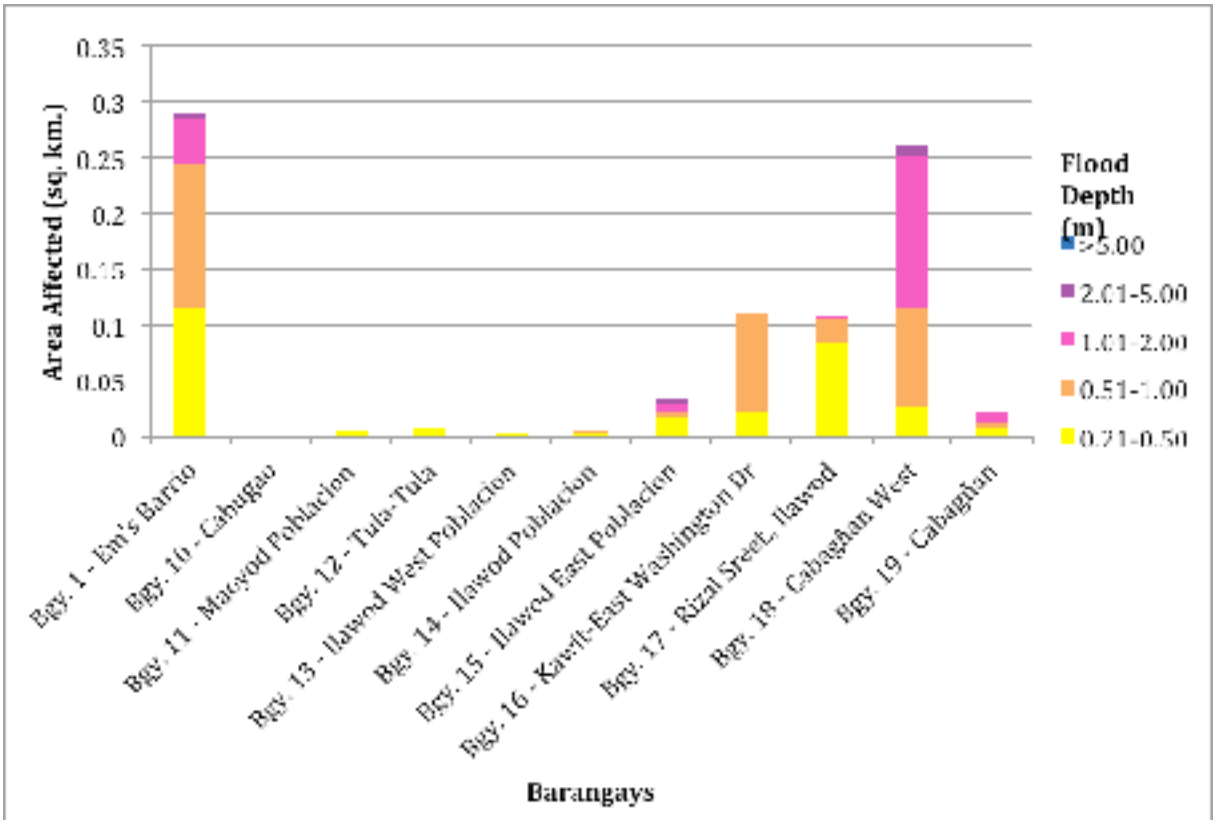


Figure 82. Affected Areas in Legazpi City, Albay during the 25-Year Rainfall Return Period

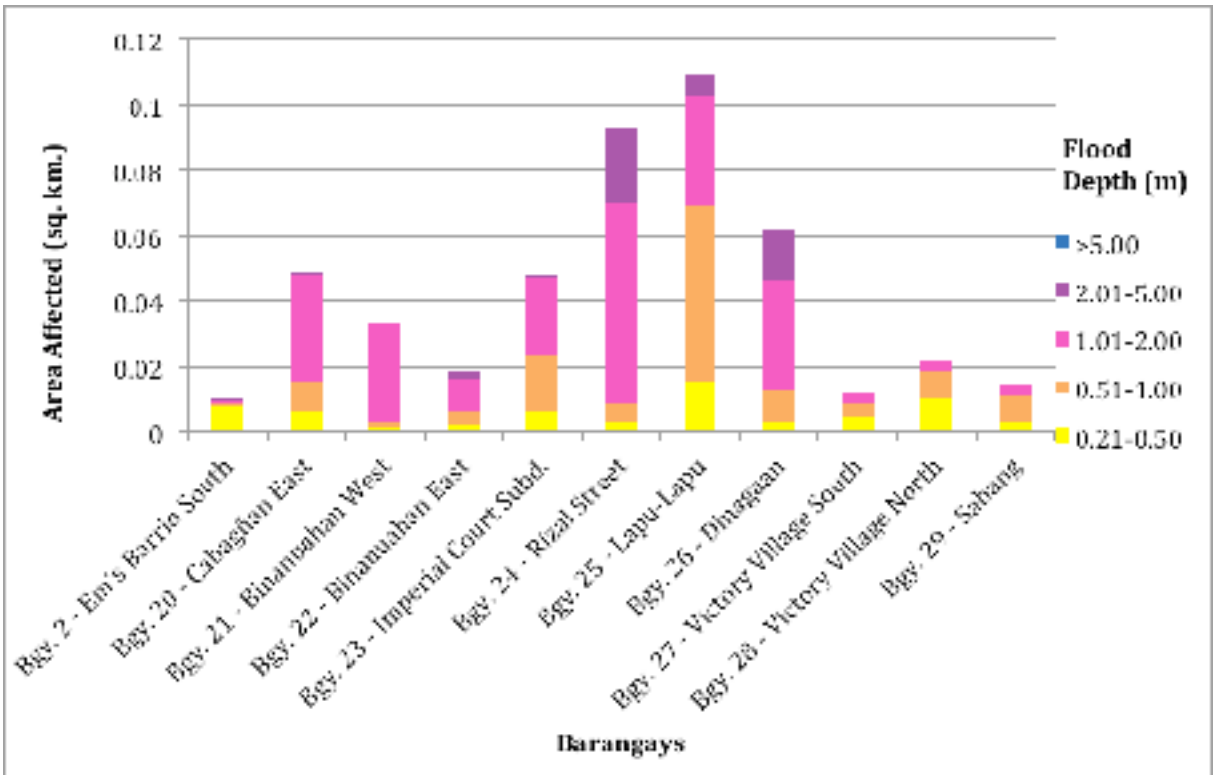


Figure 83. Affected Areas in Legazpi City, Albay during the 25-Year Rainfall Return Period

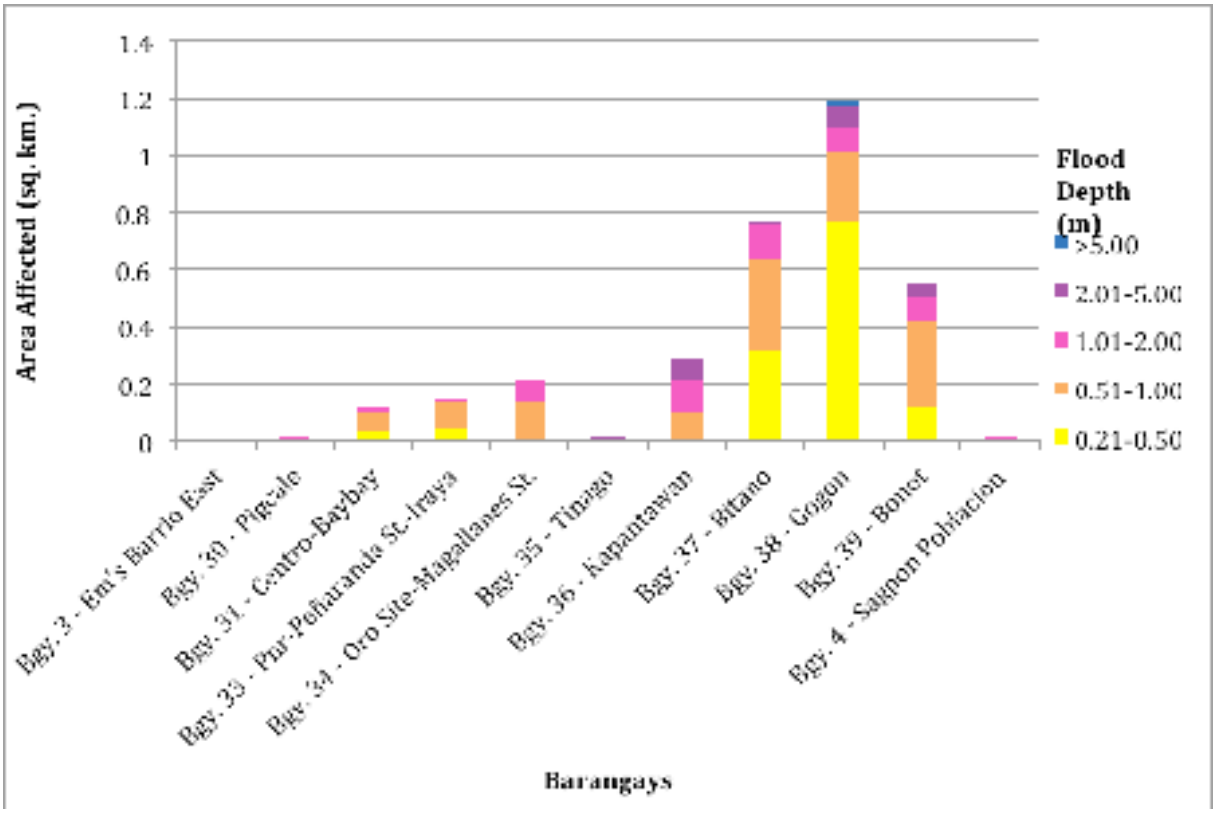


Figure 84. Affected Areas in Legazpi City, Albay during the 25-Year Rainfall Return Period

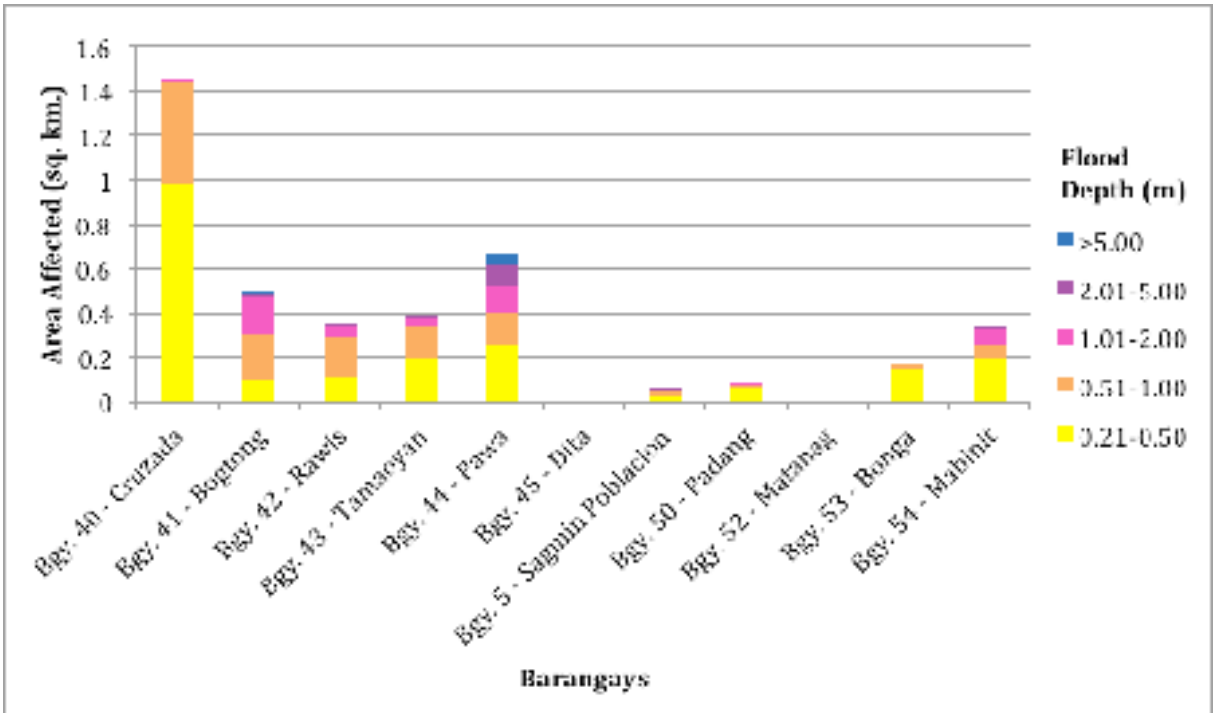


Figure 85. Affected Areas in Legazpi City, Albay during the 25-Year Rainfall Return Period

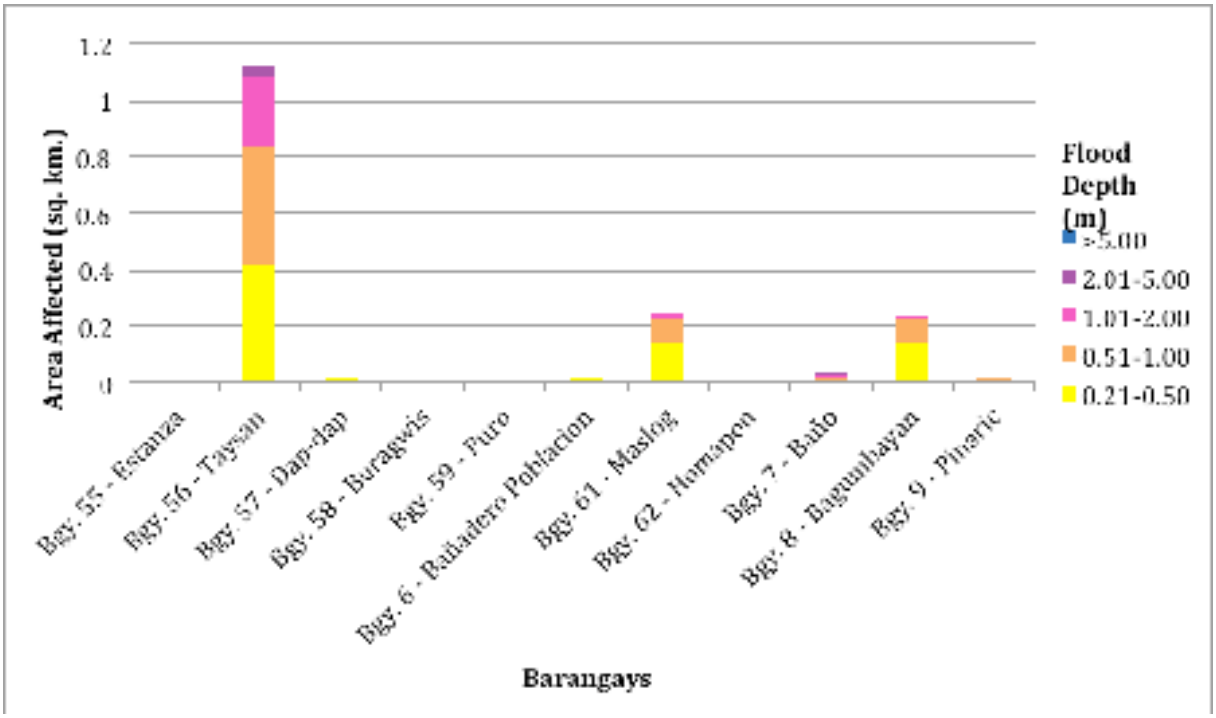


Figure 86. Affected Areas in Legazpi City, Albay during the 25-Year Rainfall Return Period

For the municipality of Malilipot with an area of 45.42 square kilometers., 0.0007% will experience flood levels of less than 0.20 meters.

For the municipality of Santo Domingo with an area of 60.83 square kilometers., 0.04% will experience flood levels of less than 0.20 meters.

For the 100-year rainfall return period, 2.18% of Camalig with an area of 136.54 square kilometers will experience flood levels of less than 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.03%, 0.02%, and 0.008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 56 depicts the areas affected in Camalig in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Camalig, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Camalig (in sq. km.)				
	Anoling	Cabagñan	Mina	Quirangay	Tinago
0.03-0.20	2.21	0.046	0.18	0.51	0.032
0.21-0.50	0.089	0.018	0.0026	0.016	0.00000094
0.51-1.00	0.032	0.0031	0.0007	0.0067	0
1.01-2.00	0.027	0.0001	0	0.002	0
2.01-5.00	0.011	0	0	0.000091	0
> 5.00	0	0	0	0	0

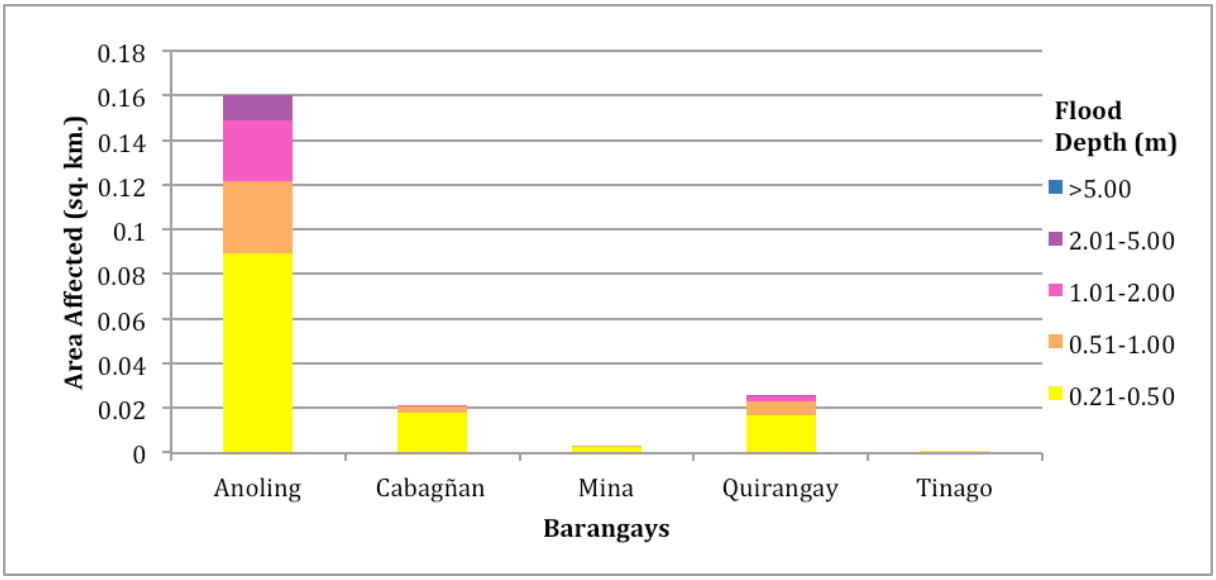


Figure 87. Affected Areas in Camalig, Albay during the 100-Year Rainfall Return Period

For the municipality of Daraga with an area of 135.66 square kilometers., 33.99% will experience flood levels of less than 0.20 meters. 3.28% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.77%, 1.39%, 0.67%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 53 to 55 depict the areas affected in Daraga in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)											
	Alcala	Alobo	Bagum-bayan	Balinad	Bañadero	Bañag	Bascaran	Binitayan	Bongalon	Budiao	Burgos	Busay
0.03-0.20	1.44	0.68	1.28	0.39	0.99	0.3	0.46	0.025	0.99	0.52	0.75	0.92
0.21-0.50	0.22	0.028	0.086	0.015	0.12	0.062	0.11	0.011	0.025	0.069	0.24	0.2
0.51-1.00	0.0042	0.025	0.064	0.026	0.079	0.043	0.034	0.028	0.04	0.039	0.22	0.11
1.01-2.00	0	0.039	0.056	0.038	0.047	0.065	0.0019	0.081	0.093	0	0.035	0.058
2.01-5.00	0	0.009	0.023	0.066	0.0046	0.075	0	0.099	0.045	0	0	0.041
> 5.00	0	0	0	0	0	0.04	0	0.078	0	0	0	0

Table 54. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)											
	Cullat	Dela Paz	Dinoronan	Gabawan	Gapo	Ilawod Area Poblacion	Kidaco	Kilicao	Kiman-tong	Kiwalo	Lacag	Malabog
0.03-0.20	0.84	1	0.6	0.061	0.82	0.15	0.6	0.87	0.6	0.61	1.33	3.22
0.21-0.50	0.22	0.036	0.029	0	0.035	0.027	0.021	0.17	0.021	0.019	0.039	0.23
0.51-1.00	0.14	0.027	0.026	0	0.026	0.0005	0.051	0.038	0.029	0.0079	0.065	0.11
1.01-2.00	0.074	0.01	0.012	0	0.043	0	0.071	0.038	0.018	0.0046	0.19	0.11
2.01-5.00	0.066	0.0007	0.001	0	0.019	0	0.022	0.023	0.0029	0.0003	0.041	0.047
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

Table 55. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Daraga (in sq. km.)												
	Malobago	Market Area Poblacion	Maroroy	Matnog	Mi-Isi	Pandan	Peña-francia	Sagpon	Salvacion	San Roque	Sipi	Tabon-Tabon	Tagas
0.03-0.20	0.63	0.11	0.031	1.47	16.82	1.41	0.74	0.64	1.78	0.57	0.44	1.46	0.58
0.21-0.50	0.13	0.021	0.053	0.27	1.12	0.09	0.034	0.15	0.17	0.02	0.1	0.19	0.074
0.51-1.00	0.026	0.0002	0.15	0.0092	0.36	0.13	0.018	0.22	0.051	0.0081	0.031	0.11	0.066
1.01-2.00	0.022	0	0.13	0.0024	0.26	0.072	0.01	0.1	0.045	0.0055	0.019	0.069	0.054
2.01-5.00	0.021	0	0.046	0	0.057	0.0027	0.0018	0.035	0.019	0.0002	0.0015	0.0078	0.13
> 5.00	0.0069	0	0	0	0.0003	0	0	0	0.0001	0	0	0	0.088

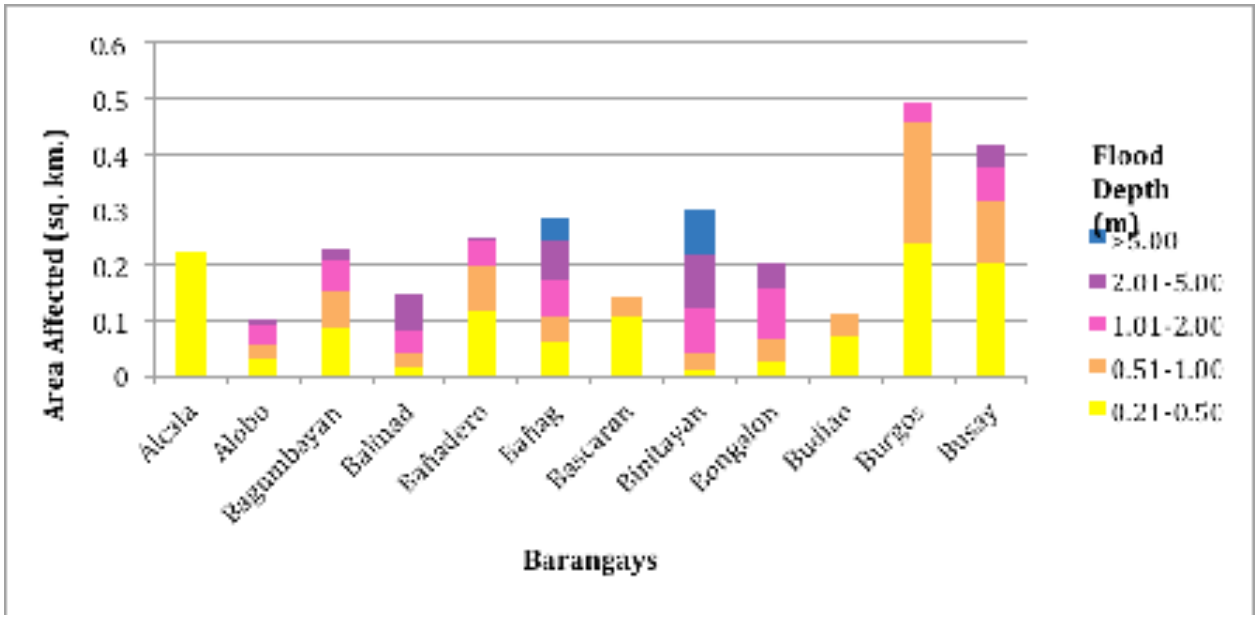


Figure 88. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

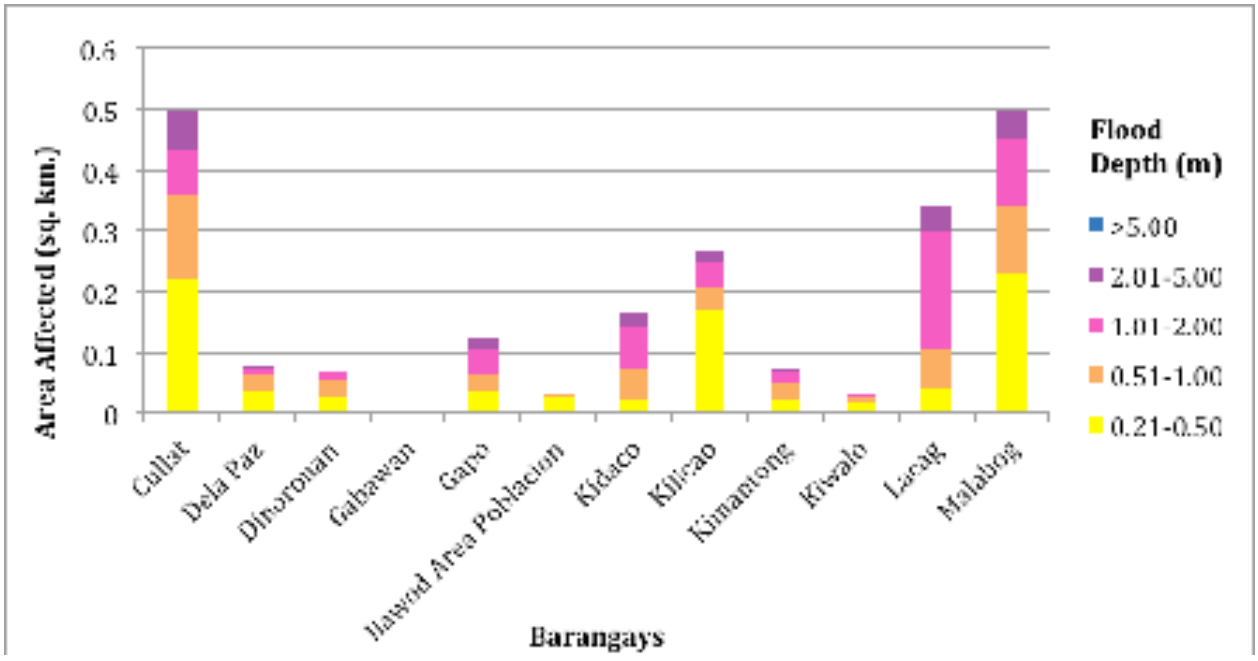


Figure 89. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

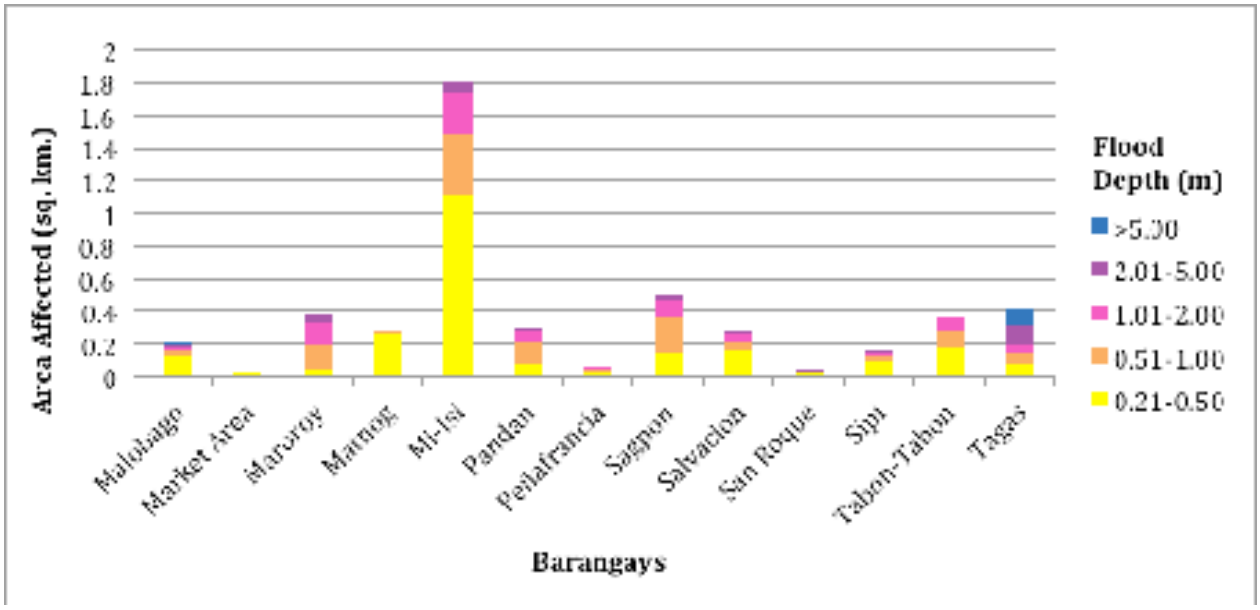


Figure 90. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

For Legazpi City with an area of 153.18 square kilometers, 9.96% will experience flood levels of less than 0.20 meters. 2.26% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.47%, 1.54%, 0.43%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 56 to 60 depict the areas affected in Legazpi City in square kilometers by flood depth per barangay.

Table 56. Affected Areas in Legazpi, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 1 - Em's Barrio	Bgy. 10 - Cabugao	Bgy. 11 - Maoyod Poblacion	Bgy. 12 - Tula-Tula	Bgy. 13 - Ilawod West Poblacion	Bgy. 14 - Ilawod Poblacion	Bgy. 15 - Ilawod East Poblacion	Bgy. 16 - Kawit-East Washington Dr	Bgy. 17 - Rizal Sreet., Ilawod	Bgy. 18 - Cabagñan West	Bgy. 19 - Cabagñan
0.03-0.20	0.58	0.088	0.14	0.23	0.12	0.17	0.4	0.33	0.22	0.17	0.2
0.21-0.50	0.071	0.0011	0.0035	0.0075	0.0024	0.0028	0.016	0.0067	0.041	0.015	0.0077
0.51-1.00	0.16	0	0.0008	0.0006	0.0011	0.0014	0.008	0.093	0.073	0.067	0.0051
1.01-2.00	0.099	0	0	0	0	0.0001	0.0061	0.013	0.0005	0.17	0.0087
2.01-5.00	0.012	0	0	0	0	0	0.0068	0	0	0.02	0.0025
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Table 57. Affected Areas in Legazpi, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 2 - Em's Barrio South	Bgy. 20 - Cabagñan East	Bgy. 21 - Binanuah-an West	Bgy. 22 - Binanua-han East	Bgy. 23 - Imperial Court Subd.	Bgy. 24 - Rizal Street	Bgy. 25 - Lapu-Lapu	Bgy. 26 - Dinagaan	Bgy. 27 - Victory Village South	Bgy. 28 - Victory Village North	Bgy. 29 - Sabang
0.03-0.20	0.47	0.19	0.065	0.19	0.12	0.11	0.16	0.15	0.12	0.16	0.076
0.21-0.50	0.0095	0.0048	0.0014	0.0019	0.0065	0.0027	0.012	0.0026	0.0045	0.013	0.002
0.51-1.00	0.0007	0.0048	0.0013	0.0024	0.016	0.0046	0.037	0.0059	0.0049	0.01	0.0073
1.01-2.00	0.0012	0.029	0.022	0.013	0.018	0.032	0.055	0.032	0.0036	0.0043	0.0059
2.01-5.00	0.001	0.013	0.01	0.0027	0.01	0.058	0.014	0.023	0	0	0
> 5.00	0	0	0	0.0003	0	0	0	0	0	0	0

Table 58. Affected Areas in Legazpi, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 3 - Em's Barrio East	Bgy. 30 - Pigcale	Bgy. 31 - Centro-Baybay	Bgy. 33 - Pnr-Peñaranda St.-Iraya	Bgy. 34 - Oro Site-Magallanes St.	Bgy. 35 - Tinago	Bgy. 36 - Kapan-tawan	Bgy. 37 - Bitano	Bgy. 38 - Gogon	Bgy. 39 - Bonot	Bgy. 4 - Sagpon Poblacion
0.03-0.20	0.099	0.06	0.14	0.074	0.0026	0.0097	0.018	0.24	0.17	0.074	0.037
0.21-0.50	0.0046	0.0051	0.038	0.035	0.0063	0.0002	0.0014	0.24	0.68	0.091	0.0068
0.51-1.00	0.0026	0.0038	0.06	0.077	0.027	0.0005	0.032	0.38	0.47	0.26	0.0033
1.01-2.00	0	0.0083	0.045	0.072	0.18	0.0049	0.15	0.35	0.12	0.18	0.0018
2.01-5.00	0	0.0023	0	0.0012	0.011	0.0083	0.11	0.019	0.076	0.053	0
> 5.00	0	0	0	0	0	0	0	0	0.02	0	0

Table 59. Affected Areas in Legazpi, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 40 - Cruzada	Bgy. 41 - Bogtong	Bgy. 42 - Rawis	Bgy. 43 - Tamaoyan	Bgy. 44 - Pawa	Bgy. 45 - Dita	Bgy. 5 - Sagmin Poblacion	Bgy. 50 - Padang	Bgy. 52 - Matanag	Bgy. 53 - Bonga	Bgy. 54 - Mabinit
0.03-0.20	0.88	0.38	0.14	0.55	2.55	0.092	0.1	1.51	0.0028	1.16	2.51
0.21-0.50	0.88	0.069	0.094	0.23	0.33	0.0007	0.02	0.081	0	0.18	0.23
0.51-1.00	1.1	0.17	0.2	0.16	0.17	0	0.031	0.016	0	0.034	0.079
1.01-2.00	0.15	0.25	0.079	0.067	0.13	0	0.011	0.0008	0	0.0011	0.069
2.01-5.00	0	0.037	0.0005	0.0084	0.13	0	0.0004	0.0001	0	0.00003	0.032
> 5.00	0	0.0035	0	0.0024	0.059	0	0	0	0	0	0

Table 60. Affected Areas in Legazpi, Albay during the 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Legazpi (in sq. km.)										
	Bgy. 55 - Estanza	Bgy. 56 - Taysan	Bgy. 57 - Dap-dap	Bgy. 58 - Buragwis	Bgy. 59 - Puro	Bgy. 6 - Bañadero Poblacion	Bgy. 61 - Maslog	Bgy. 62 - Homapon	Bgy. 7 - Baño	Bgy. 8 - Bagum-bayan	Bgy. 9 - Pinaric
0.03-0.20	0.0077	5.63	0.28	0.06	0.22	0.25	1.71	0.0007	0.15	0.064	0.22
0.21-0.50	0	0.4	0.013	0.0004	0.0034	0.02	0.15	0	0.0078	0.051	0.01
0.51-1.00	0	0.46	0.0067	0	0.001	0.0005	0.097	0	0.015	0.2	0.0036
1.01-2.00	0	0.31	0.0041	0	0.0002	0	0.023	0	0.011	0.02	0
2.01-5.00	0	0.068	0	0	0	0	0	0	0.0001	0	0
> 5.00	0	0.0001	0	0	0	0	0	0	0	0	0

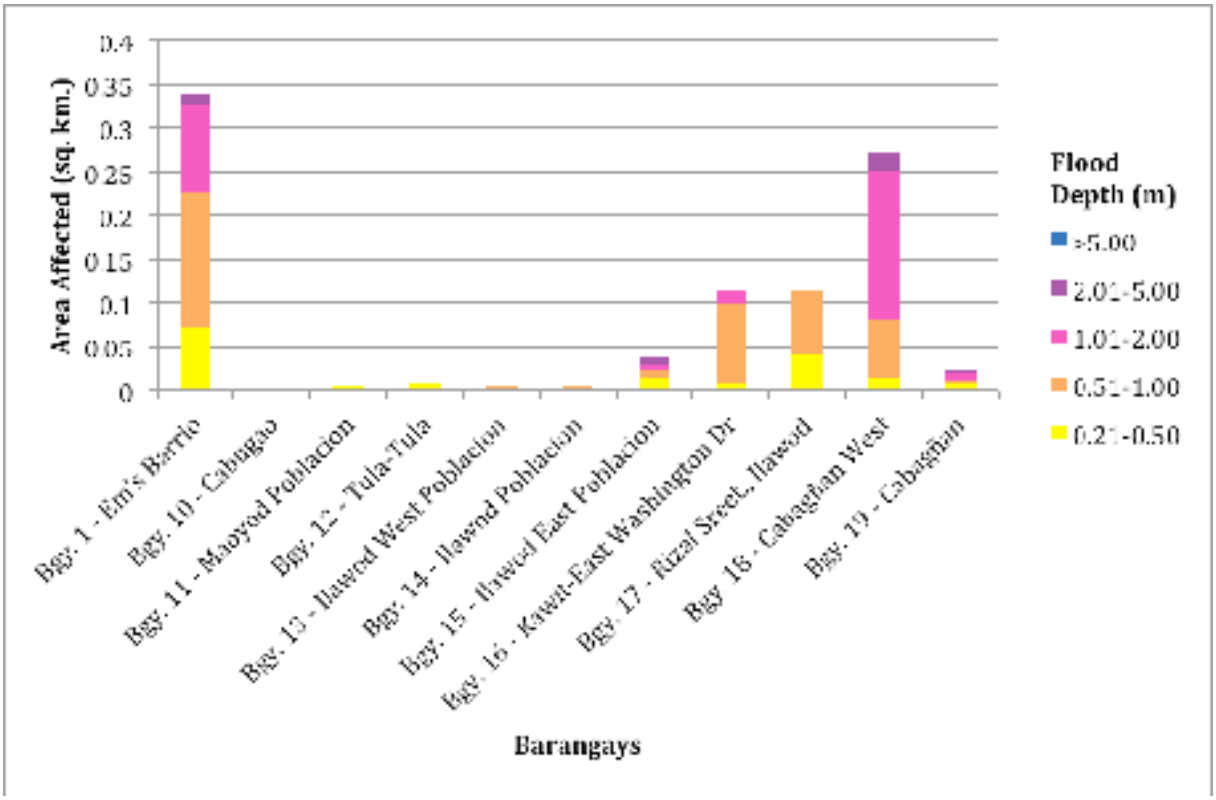


Figure 91. Affected Areas in Legazpi City, Albay during the 100-Year Rainfall Return Period

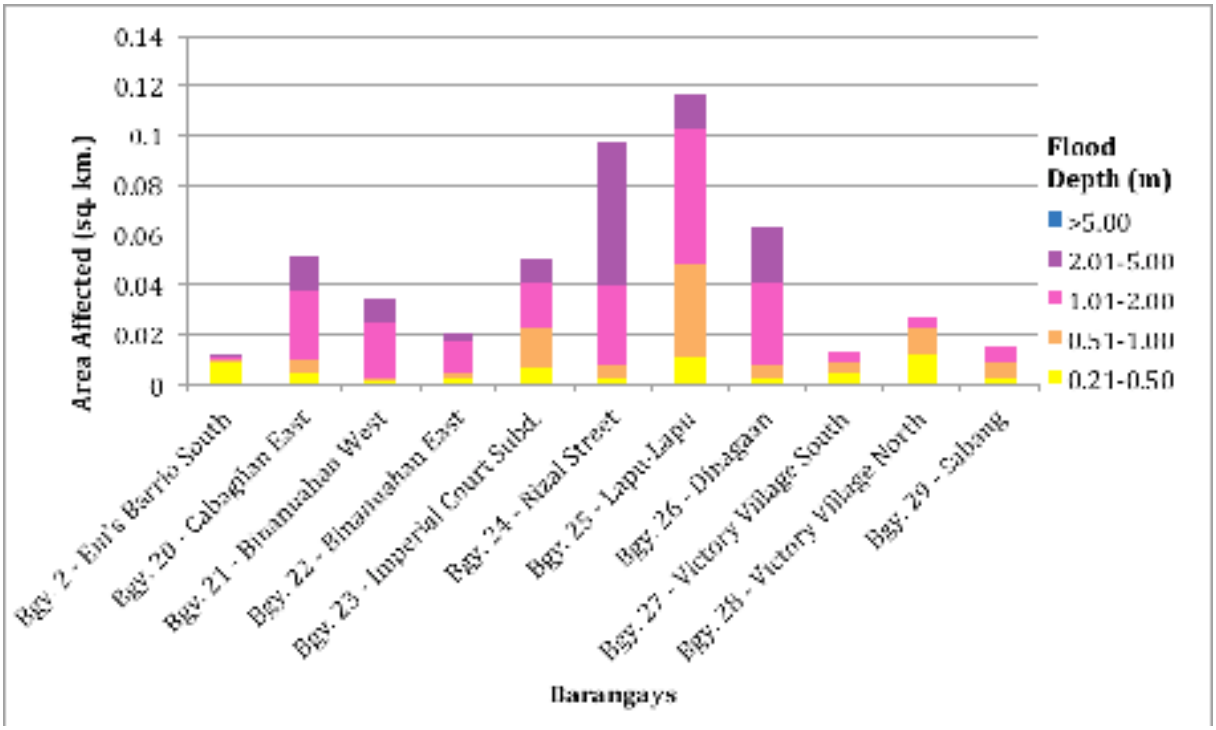


Figure 92. Affected Areas in Legazpi City, Albay during the 100-Year Rainfall Return Period

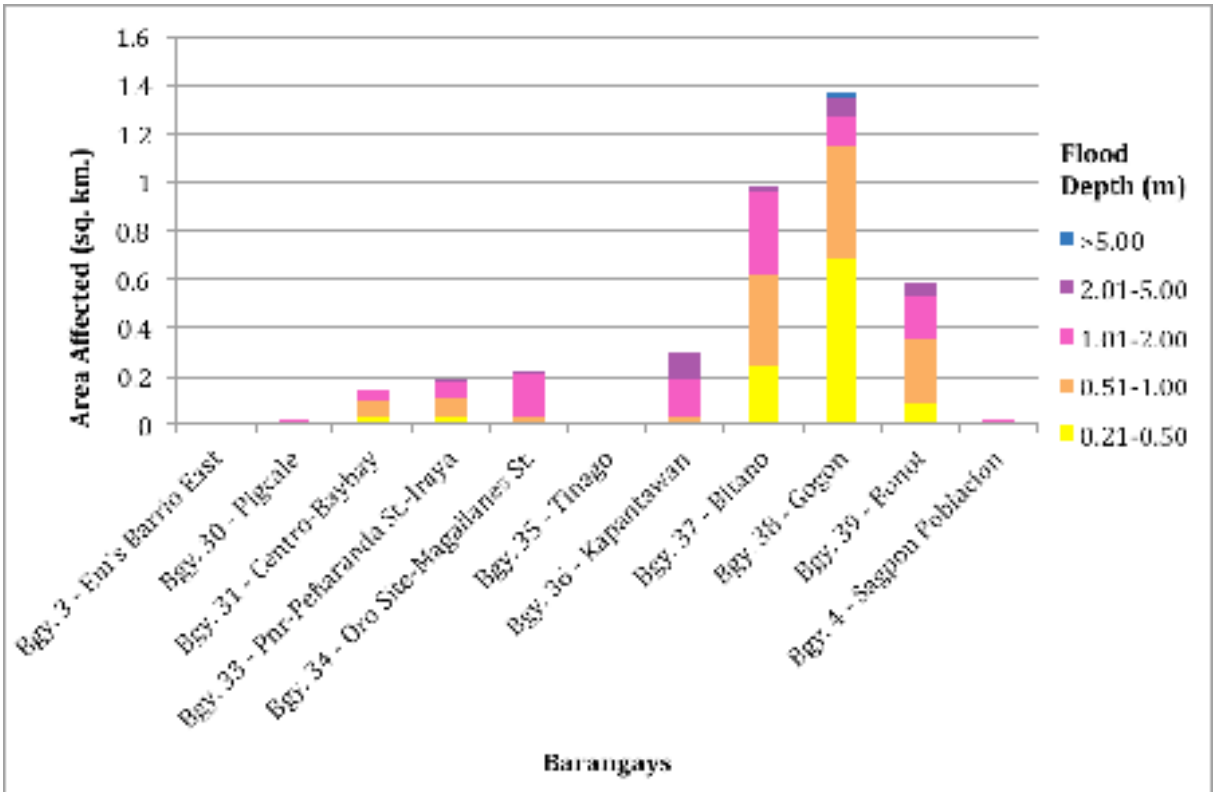


Figure 93. Affected Areas in Legazpi City, Albay during the 100-Year Rainfall Return Period

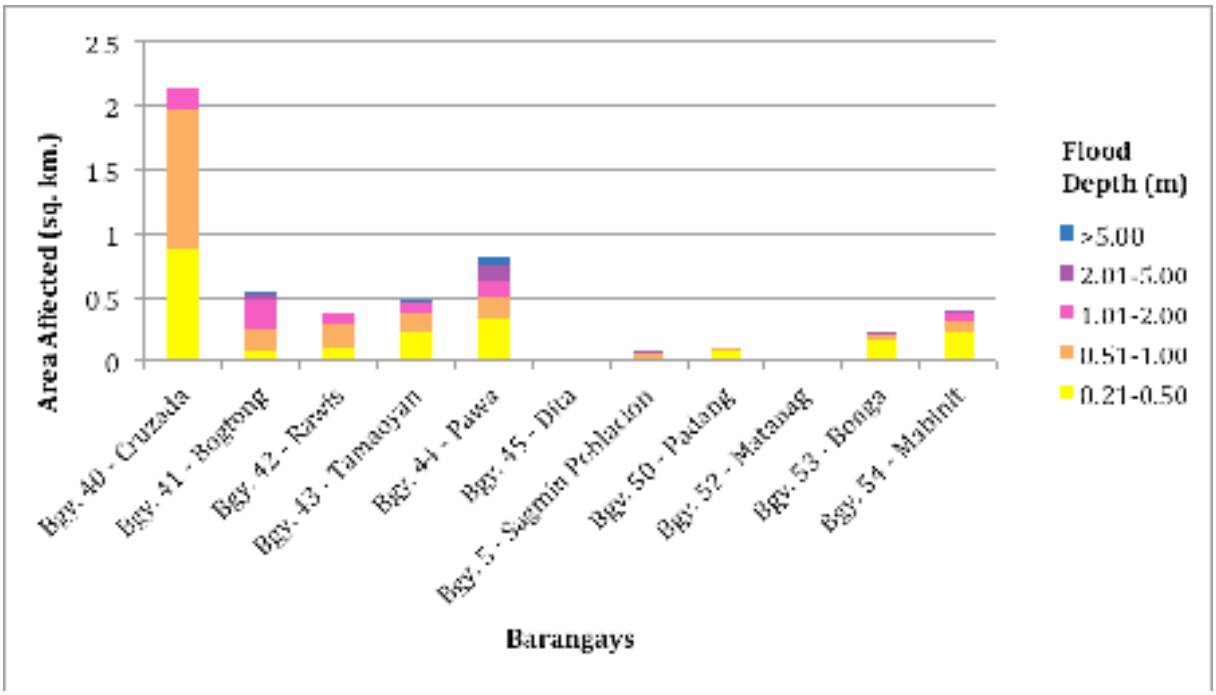


Figure 94. Affected Areas in Legazpi City, Albay during the 100-Year Rainfall Return Period

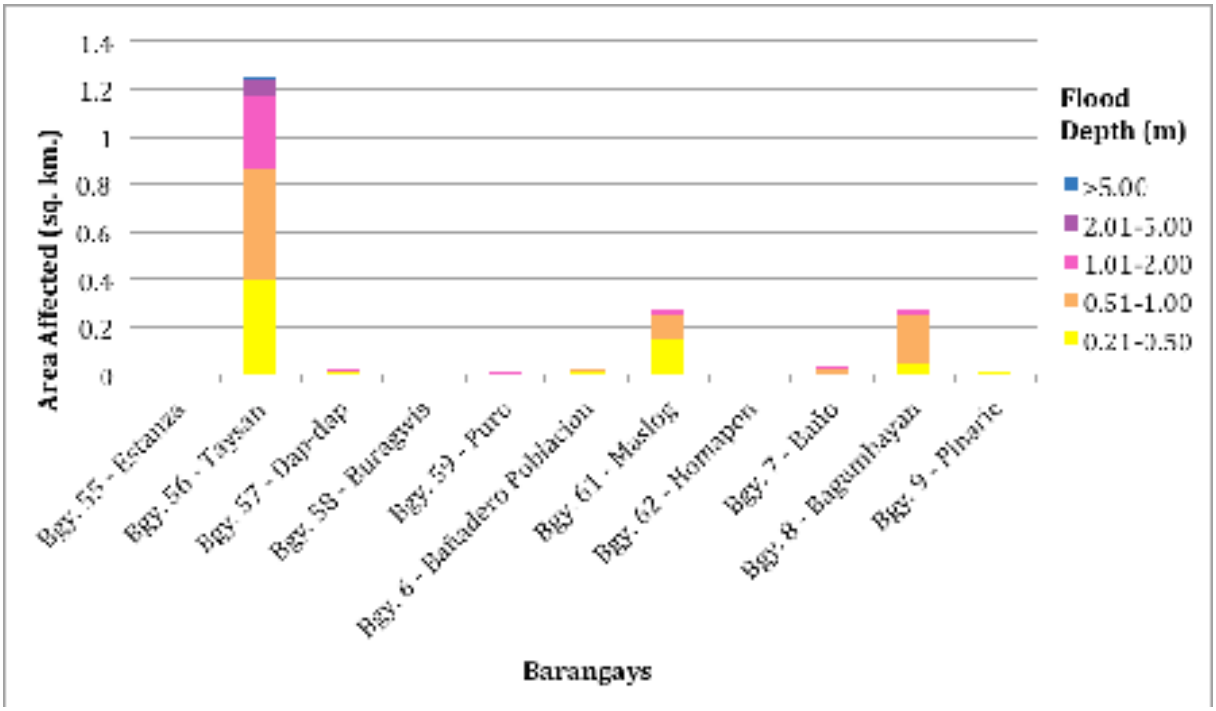


Figure 95. Affected Areas in Legazpi City, Albay during the 100-Year Rainfall Return Period

For the municipality of Malilipot with an area of 45.42 square kilometers., 0.0007% will experience flood levels of less than 0.20 meters. Table 65 depicts the areas affected in Malilipot in square kilometers by flood depth per barangay.

For the municipality of Santo Domingo with an area of 60.83 square kilometers, 0.04% will experience flood levels of less than 0.20 meters. Table 66 depicts the areas affected in Santo Domingo in square kilometers by flood depth per barangay.

Among the barangays in the Municipality of Camalig, Anoling is projected to have the highest percentage of area that will experience flood levels at 1.74%. Meanwhile, Quirangay posted the second highest percentage of area that may be affected by flood depths at 0.39%.

Among the barangays in the municipality of Daraga, Mi-Isi is projected to have the highest percentage of area that will experience flood levels at 13.73%. Meanwhile, Malabog posted the second highest percentage of area that may be affected by flood depths at 2.74%.

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Among the barangays in Legazpi City, Taysan is projected to have the highest percentage of area that will experience flood levels of at 6.87%. Meanwhile, Pawa posted the second highest percentage of area that may be affected by flood depths of at 3.36%.

Among the barangays in the Municipality of Malilipot, only Canaway is projected to experience flood levels at 0.0007%.

Among the barangays in the Municipality of Santo Domingo, Lidong is projected to have the highest percentage of area that will experience flood levels at 0.02%. Meanwhile, Fidel Surtida posted the second highest percentage of area that may be affected by flood depths at 0.01%.

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

Table 61. 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	6.52	8.65	8.76
Medium	4.70	7.65	10
High	1.97	3.08	4.04
Total	**13.19**	**19.38**	**22.8**

Of the 129 identified educational institutions in Daraga Floodplain, 33 were assessed to be exposed to low, 13 to medium, and none to high level flooding during the 5-year scenario. In the 25-year scenario, 19 were assessed to be exposed to low, 42 to medium, and 3 to high level flooding. In the 100-year scenario, 18 were assessed to be exposed to low, 51 to medium, and 5 to high level flooding.

Of the 47 identified medical institutions in Daraga Floodplain, 13 were assessed to be exposed to low, 7 to medium, and none to high level flooding in the 5-year scenario. In the 25-year scenario, 11 were assessed to be exposed to low, 16 to medium, and none to high level flooding. In the 100-year scenario, 5 were assessed to be exposed to low, 22 to medium, and 1 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 occurrences in the area within the major river system in the Philippines.

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

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

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

The flood validation consists of 199 points randomly selected all over the Daraga Floodplain. It has an RMSE value of 1.208651875.

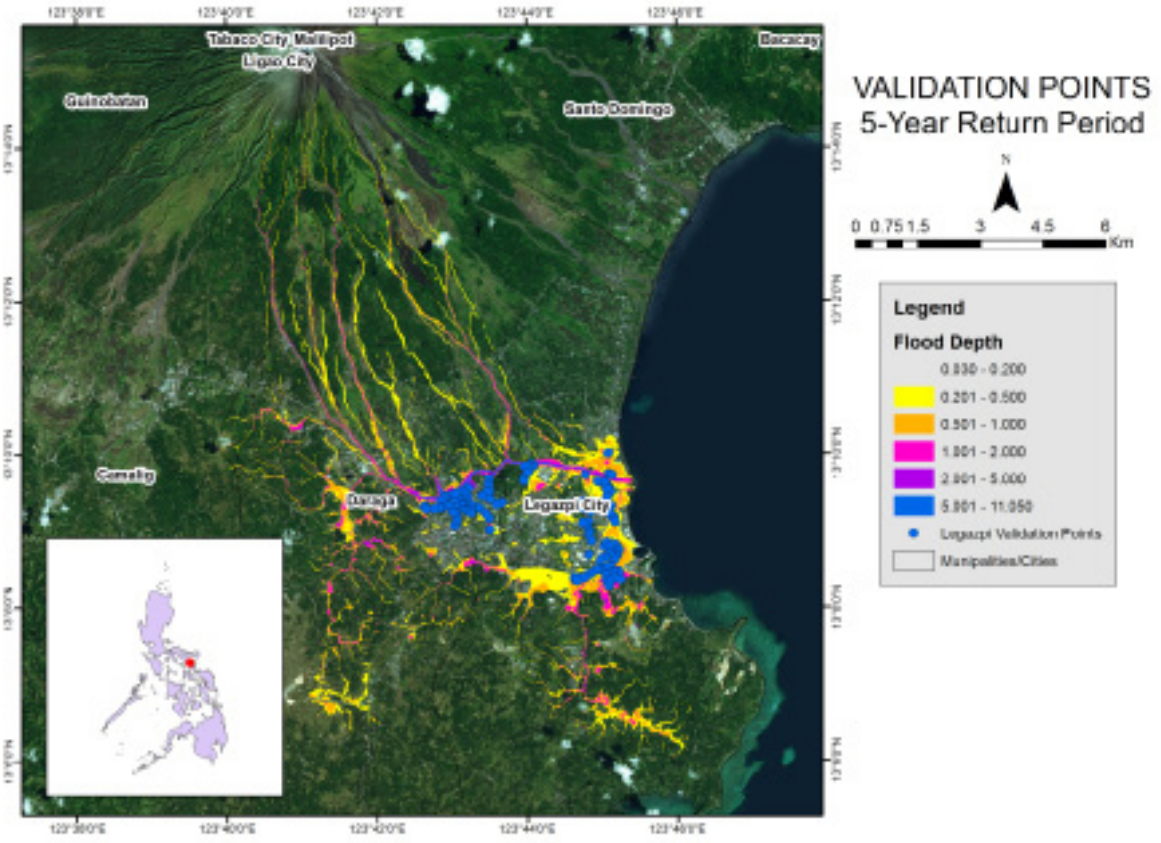


Figure 96. Validation points for the 5-Year flood depth map of the Daraga Floodplain

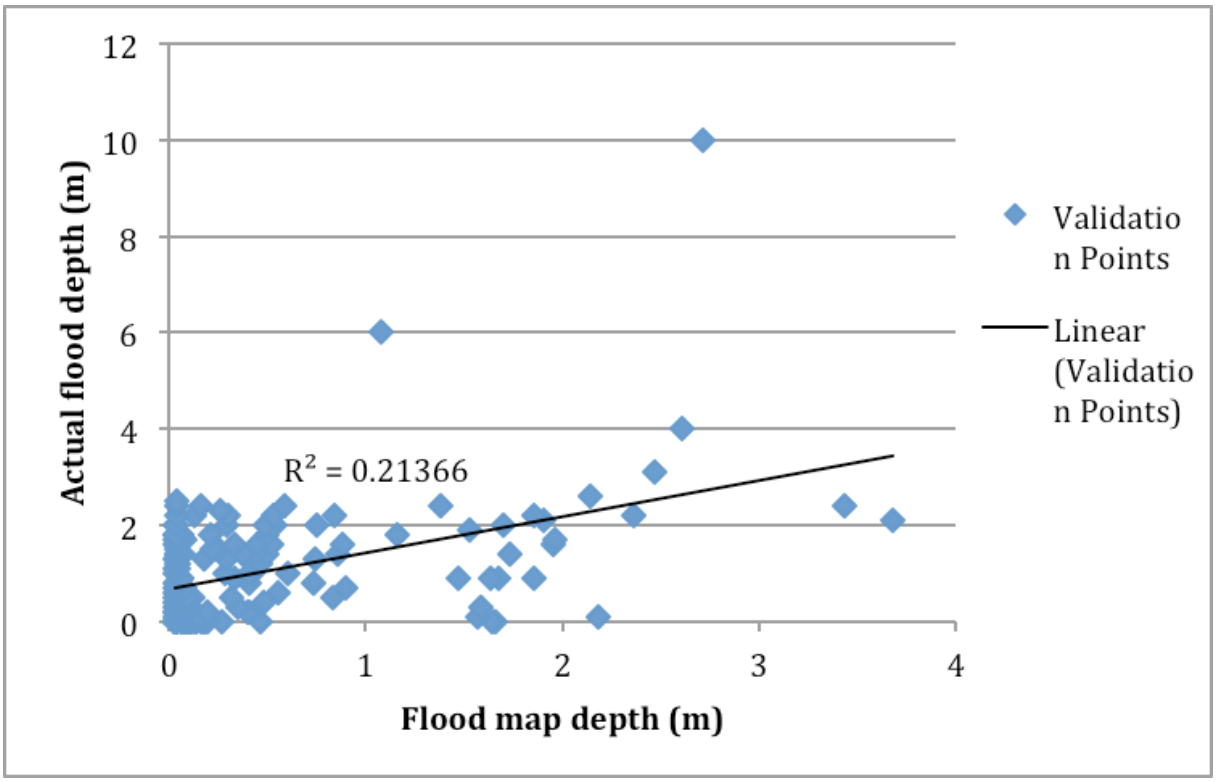


Figure 97. Flood map depth vs. Actual flood depth

Table 62. Actual flood vs. simulated flood depth in the Daraga River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	42	4	0	3	1	0	50
0.21-0.50	11	3	1	1	0	0	16
0.51-1.00	9	5	4	4	0	0	22
1.01-2.00	20	13	7	6	0	0	46
2.01-5.00	5	2	3	3	6	0	19
> 5.00	0	0	0	1	1	0	2
Total	87	27	15	18	8	0	155

On the whole, the overall accuracy generated by the flood model is estimated at 39.35%, with 61 points correctly matching the actual flood depths. In addition, there were 36 points estimated one level above and below the correct flood depths, while there were 27 points estimated two levels above and below, and 31 points estimated three or more levels above and below the correct flood depths. A total of 14 points were overestimated while a total of 80 points were underestimated in the modelled flood depths of Daraga. Table 63 depicts the summary of the Accuracy Assessment in the Daraga River Basin Flood Depth Map.

Table 63. Summary of Accuracy Assessment in the Daraga River Basin Survey

DARAGA	No. of Points	%
Correct	61	**39.35**
Overestimated	14	**9.03**
Underestimated	80	**51.61**
Total	155	**100**

REFERENCES

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

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

ANNEXES

Annex 1. Technical Specifications of the Gemini Sensor used in the Daraga Floodplain Survey

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. ABY-92

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

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

Island: **LUZON**
Municipality: **CITY OF LIGAO**
Barangay: **ALLANG**

PRS92 Coordinates

Latitude: **13° 11' 56.27238"** Longitude: **123° 27' 47.60156"** Ellipsoidal Hgt: **127.30900 m.**

WGS84 Coordinates

Latitude: **13° 11' 51.38974"** Longitude: **123° 27' 52.59990"** Ellipsoidal Hgt: **180.74900 m.**

PTM Coordinates

Northing: **1459605.458 m.** Easting: **550210.89 m.** Zone: **4**

UTM Coordinates

Northing: **1,459,094.57** Easting: **550,193.31** Zone: **51**

Location Description

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

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

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

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 96
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. ABY-08

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-8**
Order: **2nd**

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

PRS92 Coordinates

Latitude: **13° 12' 51.92876"** Longitude: **123° 45' 45.95336"** Ellipsoidal Hgt: **6.33900 m.**

WGS84 Coordinates

Latitude: **13° 12' 47.06720"** Longitude: **123° 45' 50.94829"** Ellipsoidal Hgt: **60.47000 m.**

PTM Coordinates

Northing: **1461395.121 m.** Easting: **582675.867 m.** Zone: **4**

UTM Coordinates

Northing: **1,460,883.61** Easting: **582,646.93** Zone: **51**

Location Description

ABY-8
From Legaspi Pier, Legaspi City, Travel towards Tabaco Albay for about 8.0 km. upon reaching Legaspi-Santo Domingo boundary post, travel for about 200 m. ahead, turn right to second T road intersection of Mayon Riviera Subdivision and travel about 0.90 km. The station is located at the center end of the island of Mayon Riviera Subdivision. Highest prominent mark is the electric timber post 9.50 m. SE of the station. Station mark is 12.50 mm. dia. steel bar centered on a triangle on a 0.30 m. x 0.30 m. concrete block protruding 0.05 m. above ground surface and mark with NAMRIA ABY-8, 1990. Reference mark is Electric Timber Post.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-831**

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. 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:	**579,064.86**	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, 36 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

9904102014141348

NAMRIA OFFICES:
Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. Nos.: (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

4. AL-289

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

April 14, 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: **ALBAY**
Station Name: **AL-289**

Island: **Luzon**	Municipality: **LEGAZPI CITY (CAPITAL)**	Barangay: **BGY. 49 - BIGAA**
Elevation: **8.9801 +/- 0.0175 m.**	Accuracy Class at 95% C.L: **2 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

AL-289 is in the Province of Albay, City of Legazpi, Brgy. Bigaa, Pppppurol 4 along the Tiwi-Legazpi Natinal Road. The station is located at the NW end of Arimbay Bridge wing at KM 536+100 and about 3.1 m NW of the centerline of the road.

A brass rod is set on a drilled hole and cemented flushed on top of a 15 cm x 15 cm cmenet putty with inscription "AL-289, 2009, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0914**

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

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

1. AL-289

ABY-8 - AL-289 (7:37:43 AM-12:53:25 PM) (S1)

Baseline observation:	ABY-8 --- AL-289 (B1)
Processed:	6/14/2016 11:05:20 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.011 m
RMS:	0.002 m
Maximum PDOP:	4.060
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/7/2016 7:37:43 AM (Local: UTC+8hr)
Processing stop time:	3/7/2016 12:53:25 PM (Local: UTC+8hr)
Processing duration:	05:15:42
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	ABY-8				
Grid		**Local**		**Global**	
Easting	582646.935 m	**Latitude**	N13°12'51.92887"	**Latitude**	N13°12'47.06720"
Northing	1460883.610 m	**Longitude**	E123°45'45.95355"	**Longitude**	E123°45'50.94829"
Elevation	7.322 m	**Height**	6.340 m	**Height**	60.470 m

To:	AL-289				
Grid		**Local**		**Global**	
Easting	581543.975 m	**Latitude**	N13°11'22.18920"	**Latitude**	N13°11'17.33275"
Northing	1458123.495 m	**Longitude**	E123°45'09.03476"	**Longitude**	E123°45'14.03173"
Elevation	11.032 m	**Height**	10.065 m	**Height**	64.238 m

Vector					
ΔEasting	-1102.960 m	**NS Fwd Azimuth**	201°57'22"	**ΔX**	572.158 m
ΔNorthing	-2760.115 m	**Ellipsoid Dist.**	2973.273 m	**ΔY**	1144.314 m
ΔElevation	3.710 m	**ΔHeight**	3.726 m	**ΔZ**	-2683.944 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.003 m
σ ΔNorthing	0.001 m	**σ Ellipsoid Dist.**	0.001 m	**σ ΔY**	0.005 m
σ ΔElevation	0.006 m	**σ ΔHeight**	0.006 m	**σ ΔZ**	0.002 m

2. LPH – 01

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

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

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

2

3. 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

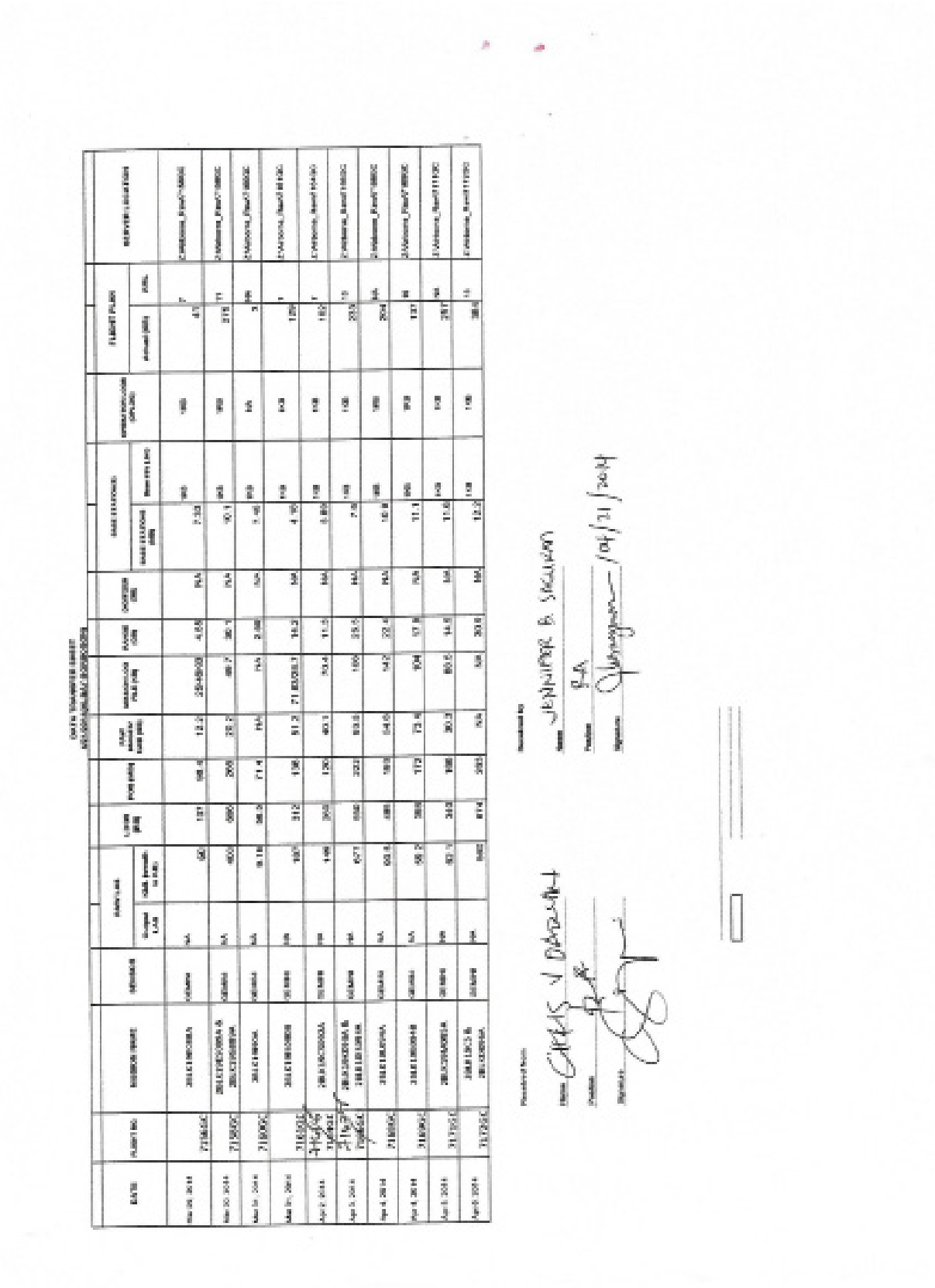
To:	SRG-A2				
Grid		Local		Global	
Easting	589012.581 m	Latitude	N12°58'19.68256"	Latitude	N12°58'14.88482"
Northing	1434108.317 m	Longitude	E123°49'14.55138"	Longitude	E123°49'19.56857"
Elevation	51.835 m	Height	50.561 m	Height	105.483 m

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

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALI-CANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA-PA-GADOR	UP-TCAGP
		CHRISTOPHER JOAQUIN	UP-TCAGP
LiDAR Operation	Research Associate (RA)	LARAH KRISELLE PARA-GAS	UP-TCAGP
		MA. VERLINA E. TONGA	
		MILLIE SHANE REYES	
		IRO NIEL ROXAS	
		KRISTINE ANDAYA	
		JERIEL PAUL ALAMBAN	
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
		JASMIN DOMINGO	
		LANCE KERWIN CINCO	
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJIE CARBOLLE-DO	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
	Pilot	CAPT. CESAR ALFONSO III	AAC
	Pilot	CAPT. RAUL CZ SAMAR II	AAC

Annex 5. Data Transfer Sheets for Daraga Floodplain



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

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	POS	RAW IMAGES(GB)	MISSION LOG FILES/CAS LOGS	RAW/BIL	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (DPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/20/2013	7200GC	2BLK19IS110A & 2BLK19N110A	GEMINI	NA	221KB	402KB	237MB	50.5	133	17.3	NA	7.61	1KB	1KB	151	24	Z:\Airborne_Raw\7200GC
4/22/2014	7204GC	2BLK19A112A	GEMINI	NA	130/23MB	959	206	NA	NA	15.1	N/A	1.14	1KB	1KB	384	7	Z:\Airborne_Raw\7204GC
4/26/2014	7212GC	2BLK19P116A & 2BLK190116A	GEMINI	NA	125	491	126	N/A	N/A	17.7	N/A	1.68	1KB	1KB	244	11	Z:\Airborne_Raw\7212GC
4/26/2014	7213GC	2BLK19O5116B & VOIDS	GEMINI	NA	33.6	263	141	N/A	N/A	8.77	N/A	1.88	1KB	1KB	311	3	Z:\Airborne_Raw\7213GC
4/28/2014	7216GC	2BLK19AS118A & VOIDS	GEMINI	NA	46.2	311	184	41.6	N/A	12.1	N/A	7.38	1KB	1KB	191	5kb/3kb	Z:\Airborne_Raw\7216P

Received from

Name [illegible]
Position
Signature

Received by

Name Benjamin Magalso
Position SWS
Signature
5/5/2014

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	6.35	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	38/29/30	376	Z:\DAC\RAW DATA
29-Feb-16	3829G	2BLK19FS 060B	GEMINI	NA	685	1.98	130	28.9	252	14	NA	11.7	1KB	1KB	38/32/29/30/3 0	NA	Z:\DAC\RAW DATA
4-Mar-16	3843G	2BLK19DS 064A	GEMINI	NA	042	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	687	183	28.7	227	16	NA	4.19	1KB	1KB	30/28/27	331	Z:\DAC\RAW DATA

Received from

Name F. PUNTO
Position RA
Signature

Received by

Name ACG Bayot
Position RPO
Signature 3/21/16

DATA TRANSFER SHEET

ALBAY/SORSOGON 3/28/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CAB	MISSION LOG FILE/CAB LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (await)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
7-Mar-16	3855G	2BLK19AS 057A	GEMINI	NA	NA	796	170	28.6	223	8.28	NA	11.5	1KB	1KB	36/30/28	NA	Z:\DAC\RAW DATA
9-Mar-16	3863G	2BLK19aC EFG069A	GEMINI	NA	545	1.34	282	40.6	360	26.9	NA	10.1	1KB	1KB	33211	NA	Z:\DAC\RAW 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\RAW DATA
11-Mar-16	3871G	2BLK19aC DGI071A	GEMINI	NA	1035	1.99	279	45.5	344	23.9	NA	10.8	1KB	1KB	33	NA	Z:\DAC\RAW DATA
11-Mar-16	3875G	2BLK19aH D71B	GEMINI	NA	952	749	180	35.4	250	17	NA	12.3	1KB	2KB	21.22	NA	Z:\DAC\RAW DATA
13-Mar-16	3879G	2BLK19aJ D73A	GEMINI	NA	669	1.14	267	52.7	404	26.8	NA	11.1	1KB	NA	18	4	Z:\DAC\RAW DATA
14-Mar-16	3883G	2BLK19JS KM074A	GEMINI	NA	1290	3.03	288	68.3	516	33.6	NA	15.5	1KB	1KB	17	1290	Z:\DAC\RAW DATA
14-Mar-16	3885G	2BLK19aK SMS074B	GEMINI	NA	70	1.79	197	17.2	161	19.2	NA	9.34	1KB	1KB	18	2	Z:\DAC\RAW DATA
15-Mar-16	3887G	2BLK19aK LS075A	GEMINI	NA	827	2.1	271	60.9	470	27.9	NA	17.8	1KB	1KB	15	4	Z:\DAC\RAW DATA
15-Mar-16	3889G	2BLK19aK LS075B	GEMINI	NA	239	1.4	196	22.3	187	10.4	NA	17.8	1KB	1KB	17	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO

Position RA

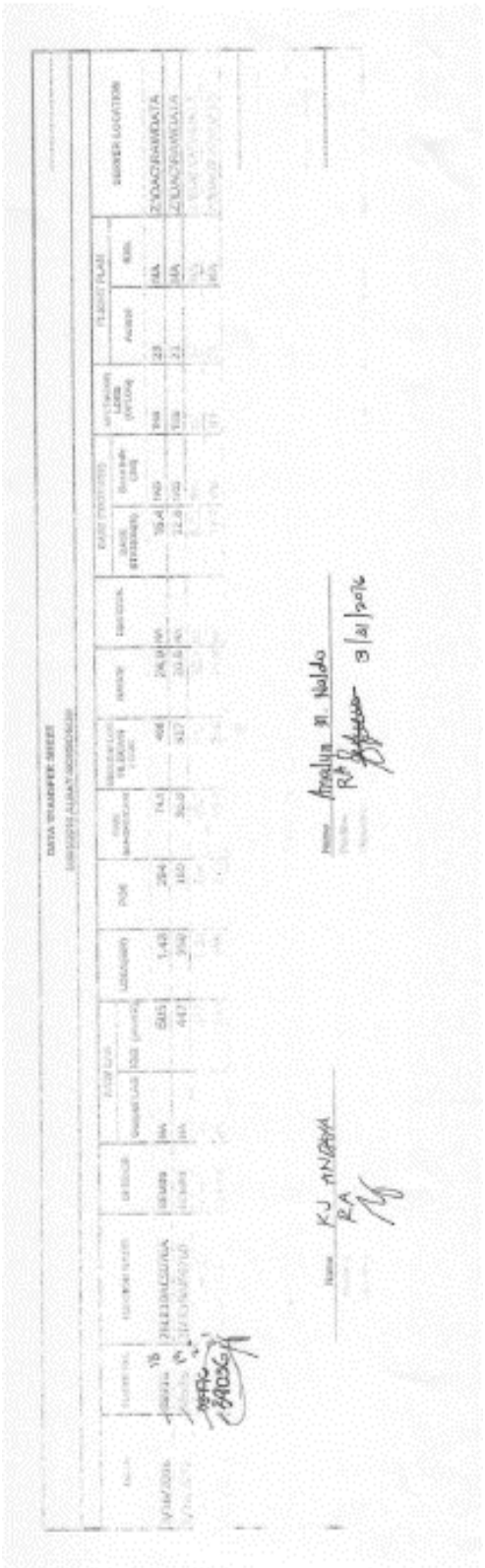
Signature

Received by

Name ANALYN M. NALDO

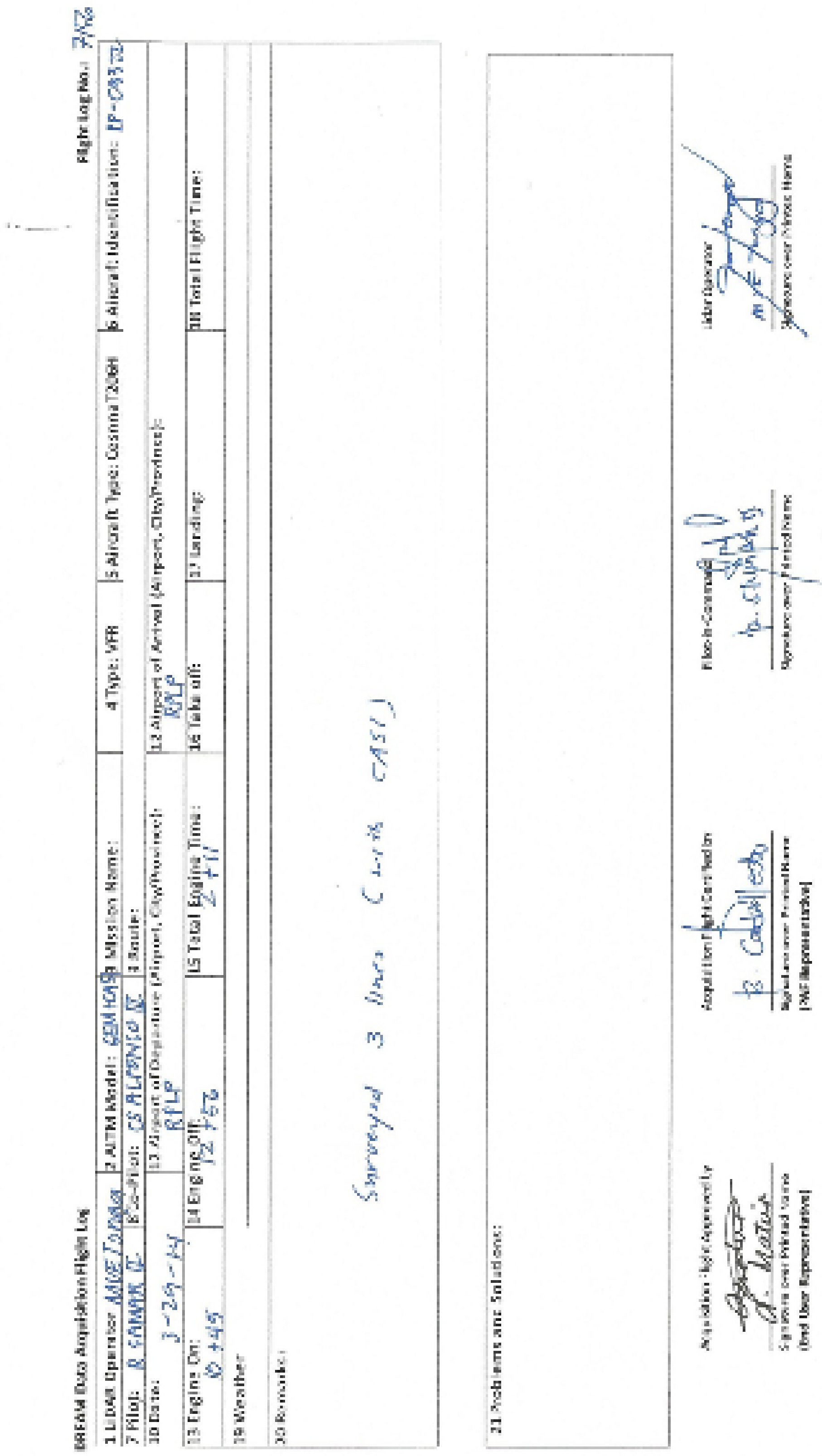
Position RA

Signature 3/31/2016



Annex 6. Flight Logs

1. Flight Log for 7156GC Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 7156

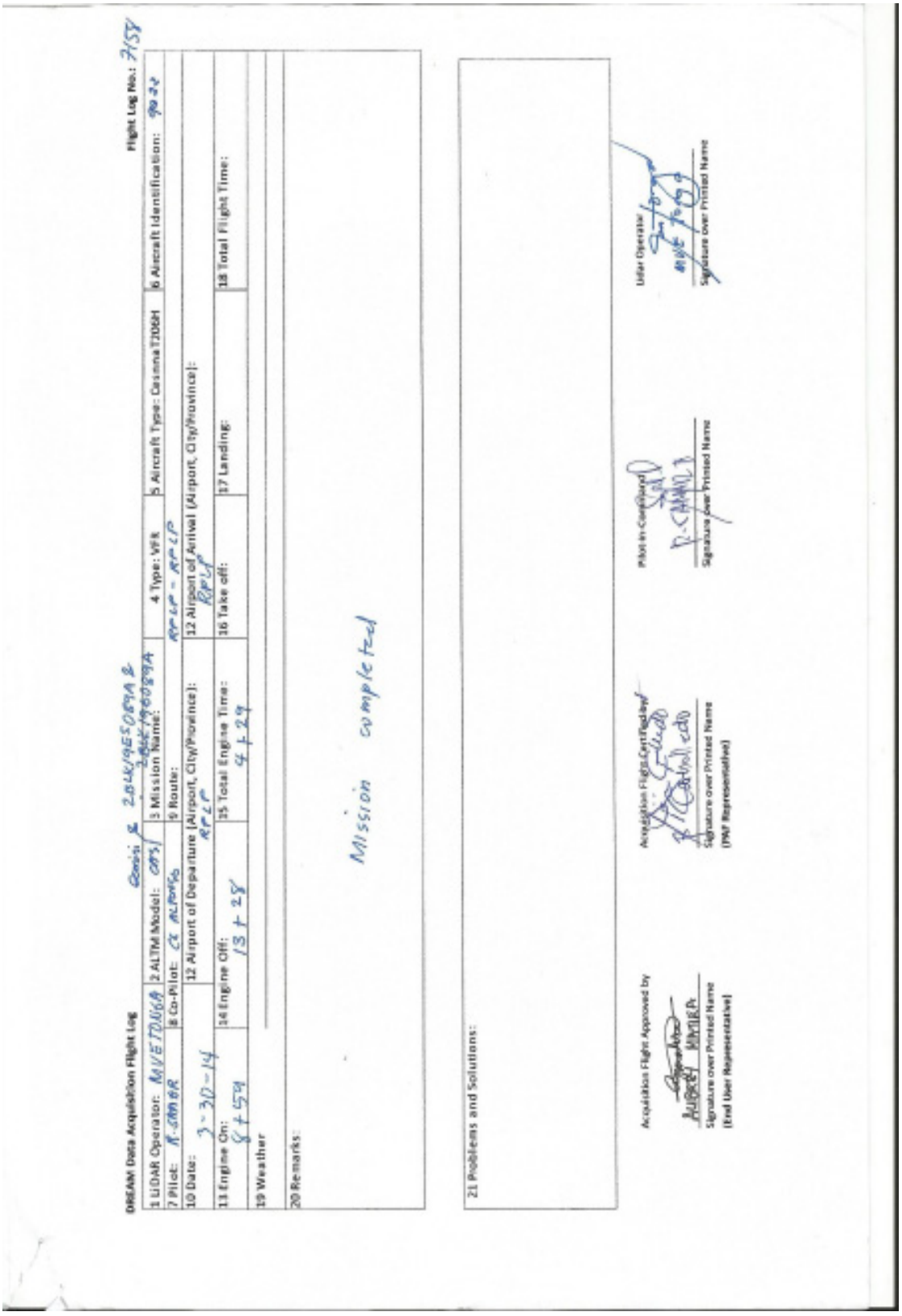
1 LiDAR Operator: AMIE TORAGA	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R SAMAR II	8 Co-Pilot: CS ALFONSO II	9 Route:			
10 Date: 3-29-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport,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

Surveyed 3 lines (with CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Matias	B. Caballeda	B. Chualgry?	M.E. Toraga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 7158GC Mission



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

1 LiDAR Operator: MVETOLOA	2 ALTM Model: GEMINI	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: PR 22
7 Pilot: M. SANDER	8 Co-Pilot: CR ALMARIO	9 Route:			
10 Date: 3-30-14	11 Airport of Departure [Airport, City/Province]:		12 Airport of Arrival [Airport, City/Province]:		
13 Engine On: 8:45	14 Engine Off: 13+25	15 Total Engine Time: 4.29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					
21 Problems and Solutions:					

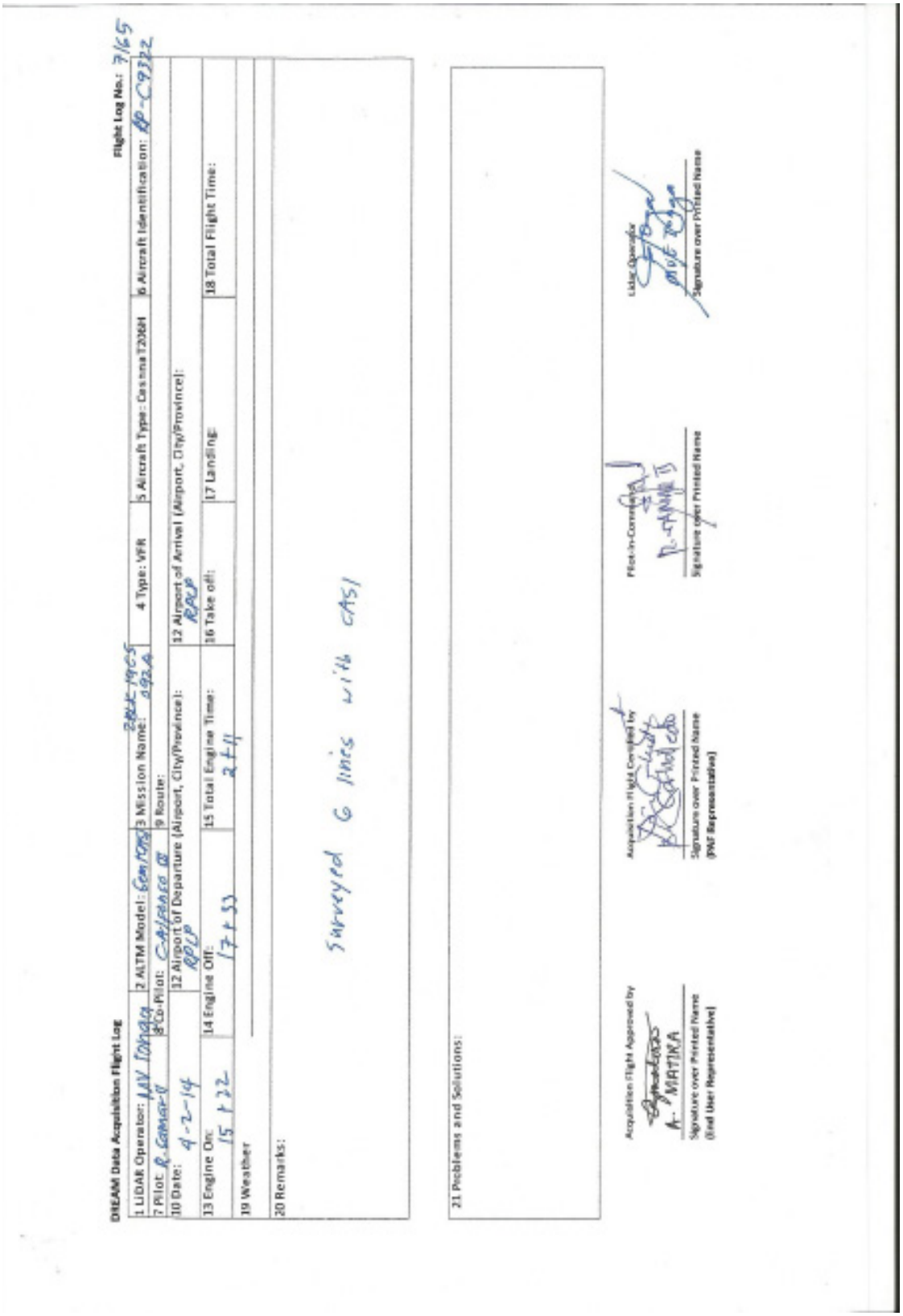
Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

3. Flight Log for 7165GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7165

1 LiDAR Operator: MV Fonoti	2 ALTM Model: Gemini	3 Mission Name: 2dec1965 a92a	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9262
7 Pilot: R. Gamarra	8 Co-Pilot: C. Arjonas	9 Route:			
10 Date: 4-2-14	11 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 15:22	14 Engine Off: 17:33	15 Total Engine Time: 2:11	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Surveyed 6 lines with CASI

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Completed by

Signature over Printed Name (PAF Representative)

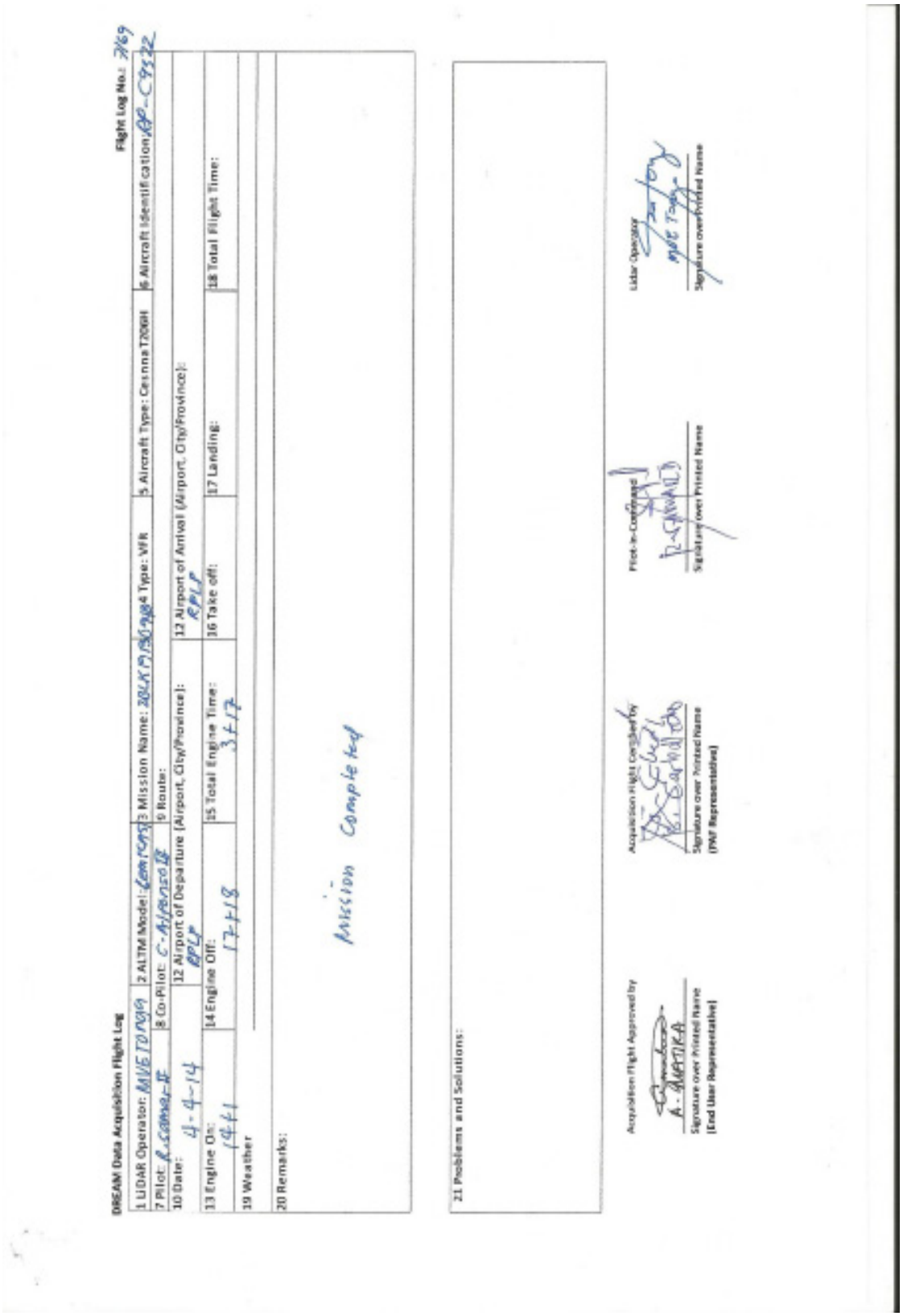
Pilot-in-Command

Signature over Printed Name

LiDAR Operator

Signature over Printed Name

4. Flight Log for 7169GC Missions



DREAM Data Acquisition Flight Log — Flight Log No.: 7169

1 LIDAR Operator: MVETO/NGP	2 ALTM Model: Gemini	3 Mission Name: 30AUG18A4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Cabrera	8 Co-Pilot: C. Alfonso	9 Route:		
10 Date: 4-4-14	11 Airport of Departure [Airport, City/Province]: RPLP		12 Airport of Arrival [Airport, City/Province]: RPLP	
13 Engine On: 1441	14 Engine Off: 17+18	15 Total Engine Time: 3.5.17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather				
20 Remarks: Mission Complete				
21 Problems and Solutions:				

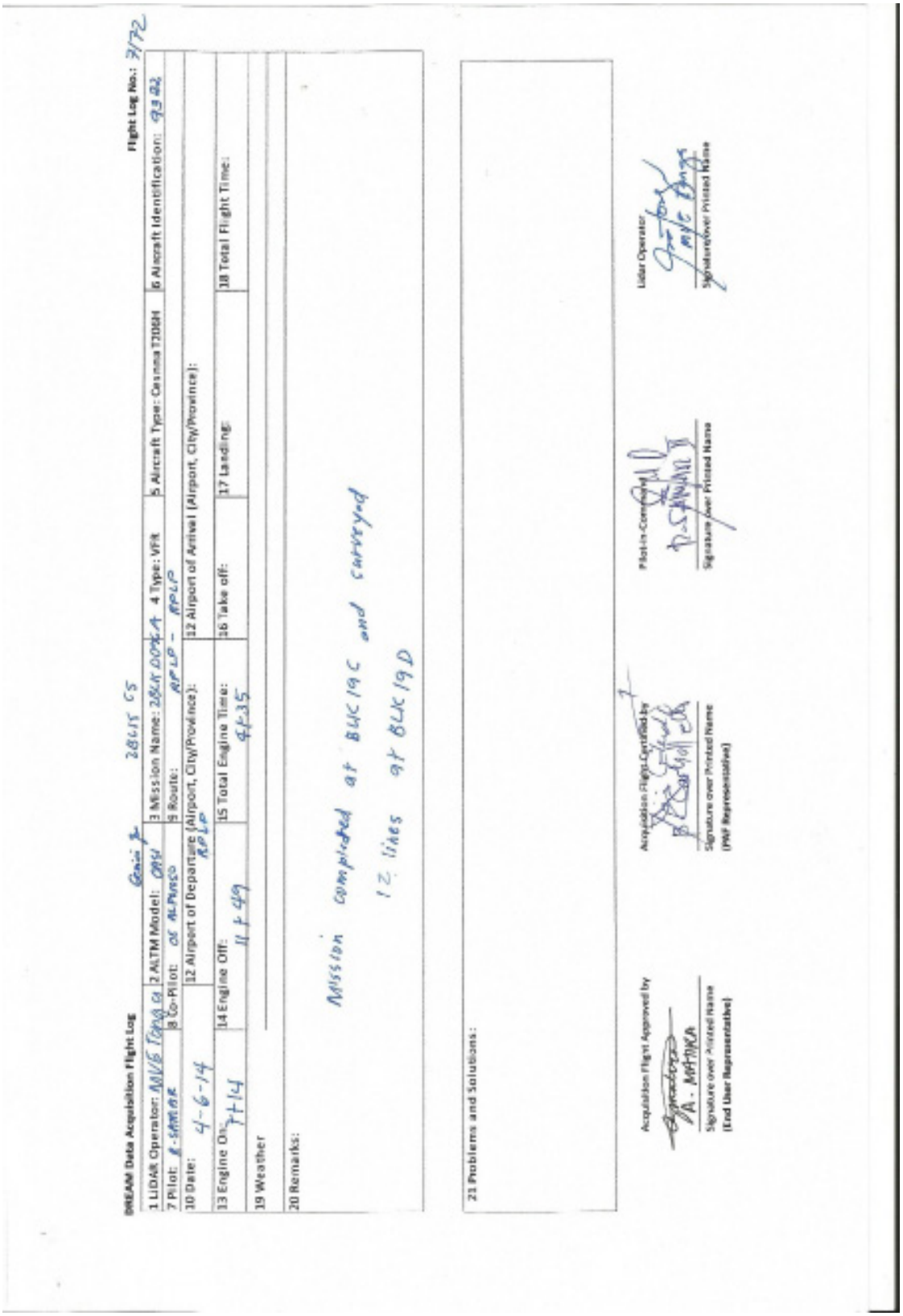
Acquisition Flight Approved by
Signature over Printed Name
[End User Representative]

Acquisition Flight Conforme by
Signature over Printed Name
[PNF Representative]

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

5. Flight Log for 7172GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 172

1 LiDAR Operator: AMVC Flying Co.	2 ALTM Model: ORION	3 Mission Name: 28415 GS	4 Type: VFR
5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9382		
7 Pilot: R. SAMSON	8 Co-Pilot: DE ALPUSO	9 Route: APLE – APLE	
10 Date: 4-6-14	11 Airport of Departure (Airport, City/Province): APLE	12 Airport of Arrival (Airport, City/Province):	
13 Engine On: 7:1-14	14 Engine Off: 11:49	15 Total Engine Time: 4:35	16 Take off:
17 Landing:	18 Total Flight Time:		
19 Weather			
20 Remarks: Mission completed at BLK 19C and surveyed 12 lines at BLK 19D			
21 Problems and Solutions:			

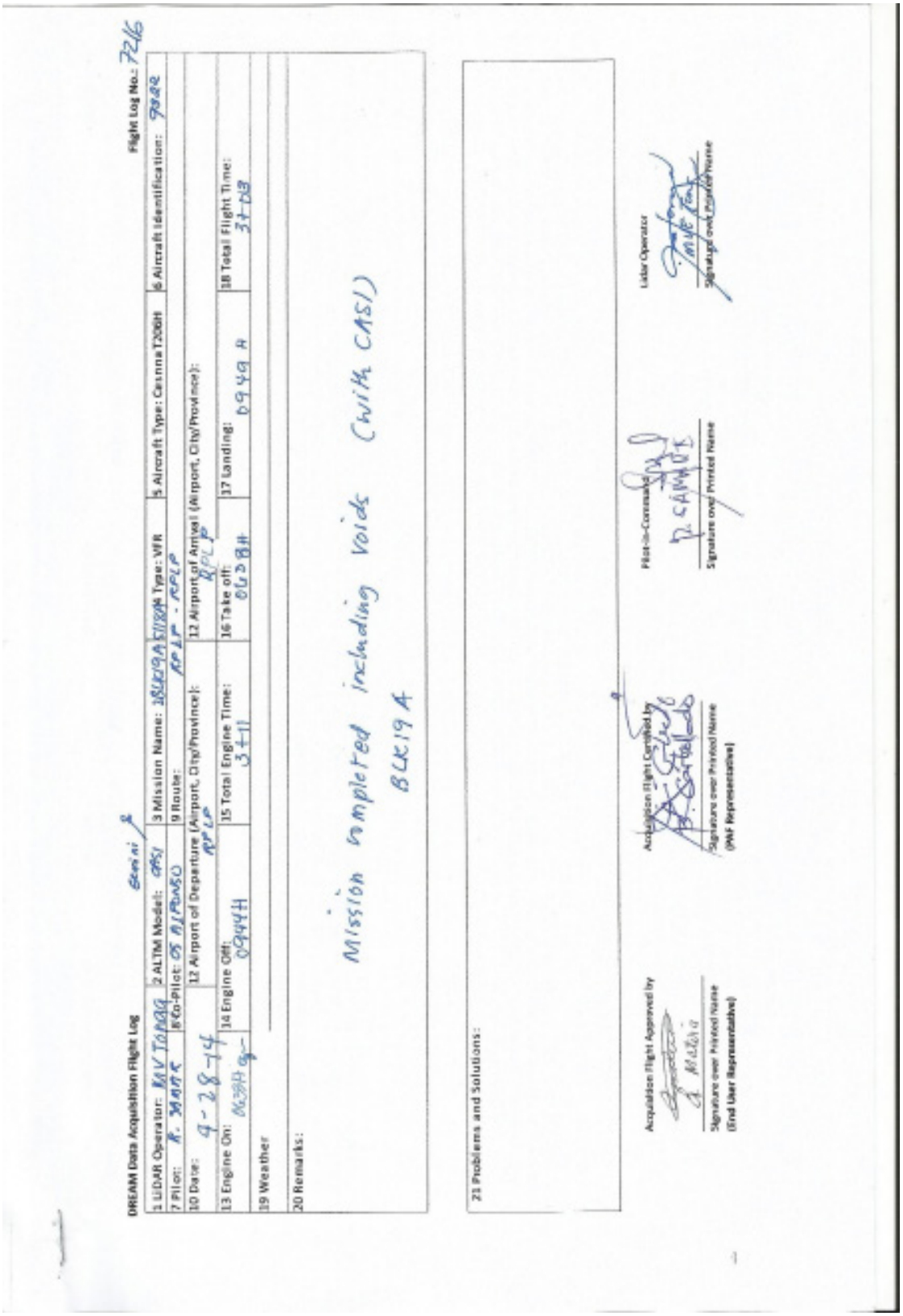
Acquisition Flight Approved by — Signature over Printed Name (End User Representative): A. MARTINEZ

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

Pilot-in-Command — Signature over Printed Name: R.S. SAMSON II

Lidar Operator — Signature over Printed Name

6. Flight Log for 7216GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7216

1 LiDAR Operator: RAY TORRAG	2 ALTM Model: GEMINI	3 Mission Name: BLK19A5 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 7216
7 Pilot: R. MARC	8 Co-Pilot: DS ALFONSO	9 Route: RPLP - RPLP		
10 Date: 4-28-14	12 Airport of Departure (Airport, City/Province): RPLP	12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0538H	14 Engine Off: 0944H	15 Total Engine Time: 3+11	16 Take off: 0638H	17 Landing: 0949 H
				18 Total Flight Time: 3+03

19 Weather

20 Remarks:

Mission completed including voids (with CASI)
BLK19A

21 Problems and Solutions:

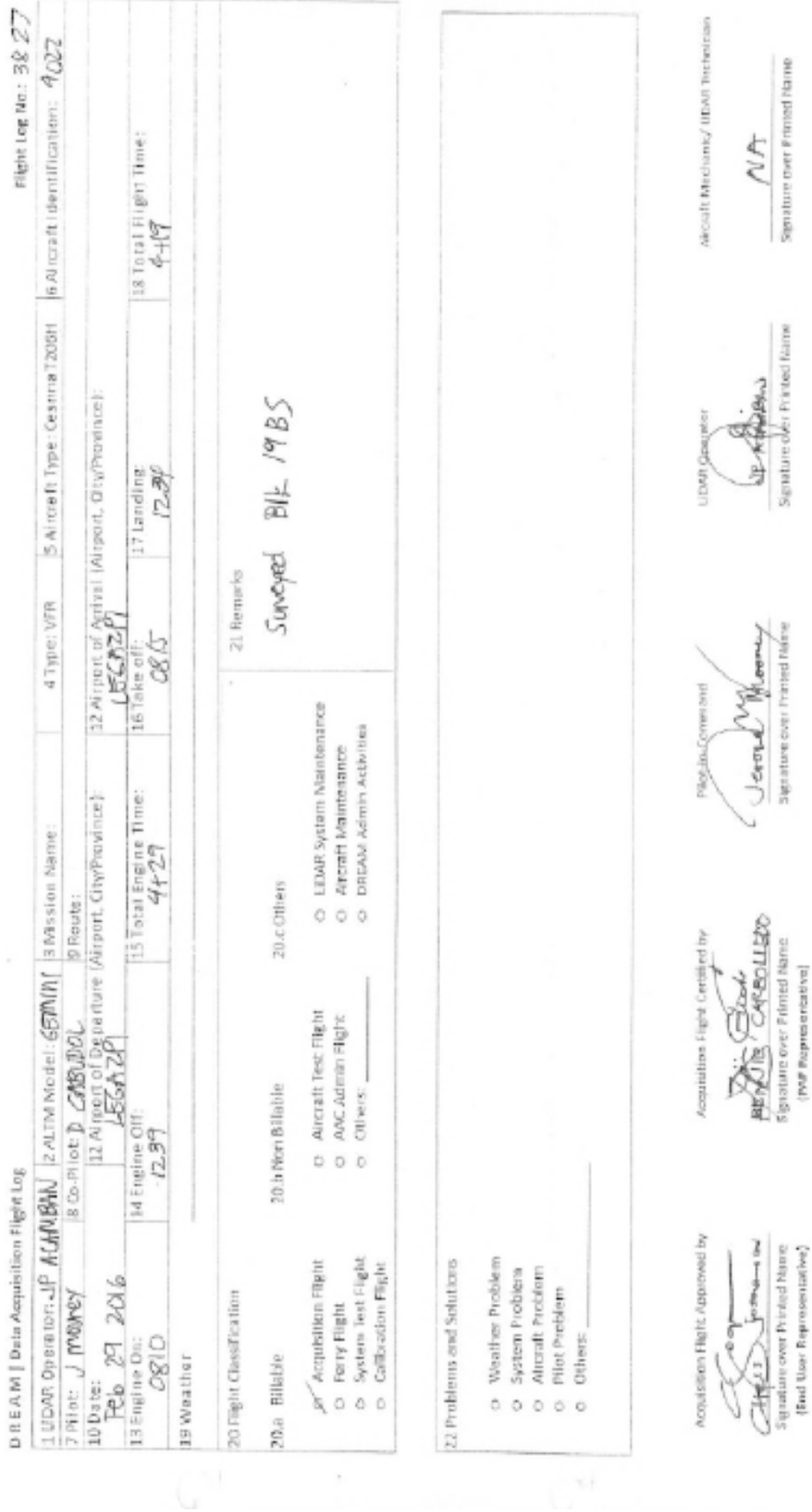
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

7. Flight Log for 3827G Mission



DREAM | Data Acquisition Flight Log

Flight Log No.: 38 27

1 LIDAR Operator: UP ALANBAN	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: J Mooney	8 Co-Pilot: D CABUDOL	9 Route:			
10 Date: Feb 29 2016	11 Airport of Departure (Airport, City/Province): LEGAZPI		12 Airport of Arrival (Airport, City/Province): LEGAZPI		
13 Engine On: 0810	14 Engine Off: 12:39	15 Total Engine Time: 4+29	16 Take off: 0815	17 Landing: 12:39	18 Total Flight Time: 4+19

19 Weather

20 Flight Classification

20a Billable

20b Non Billable

20c Others

- ☑ Acquisition Flight
- ☐ Ferry Flight
- ☐ System Test Flight
- ☐ Calibration Flight
- ☐ Aircraft Test Flight
- ☐ ABC Admin Flight
- ☐ Others: _____
- ☐ LiDAR System Maintenance
- ☐ Aircraft Maintenance
- ☐ DREAM Admin Activities

21 Remarks

Surveyed BIL 19 BS

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

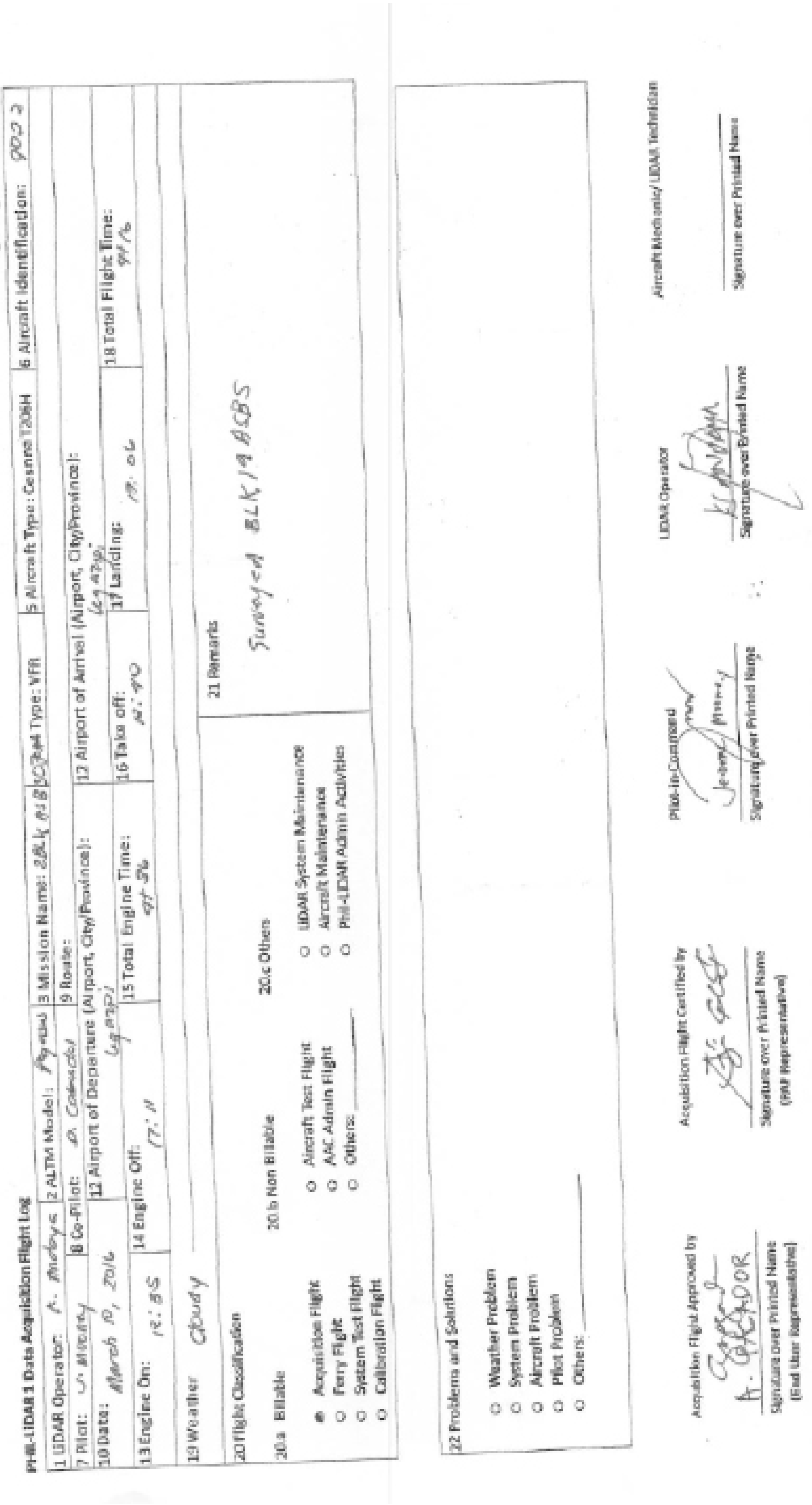
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician

N/A

Signature over Printed Name

8. Flight Log for 3869G Mission



Flight Log No.: 3869P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: A. Mudoyos	2 ALTM Model: Pegasus	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: J. Alburo	8 Co-Pilot: D. Camacho	9 Route:			
10 Date: March 10, 2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 12:35	14 Engine Off: 17:11	15 Total Engine Time: 4+36	16 Take off: 12:40	17 Landing: 17:06	18 Total Flight Time: 4+26
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 19 BCBS

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

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

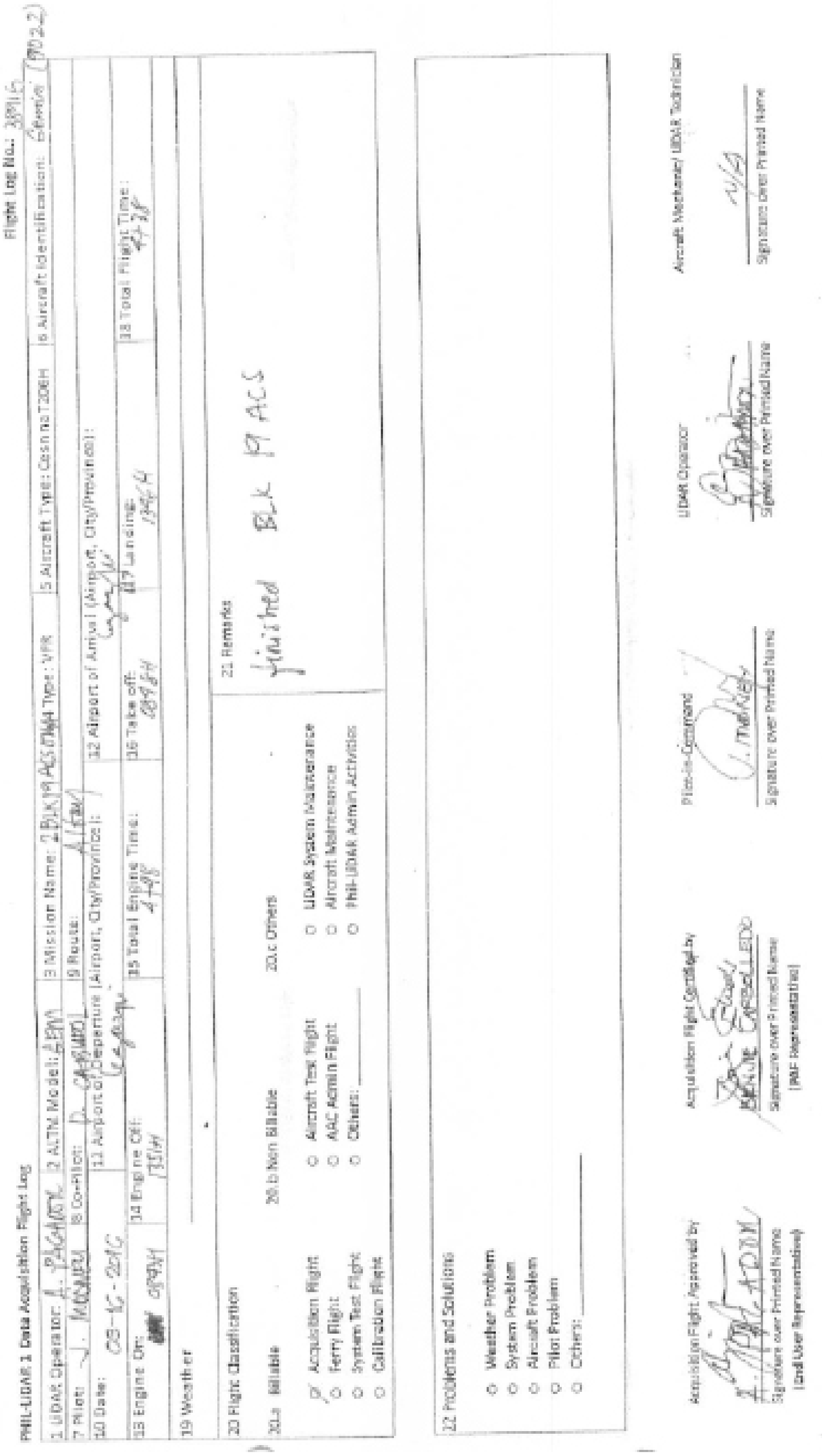
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

LIDAR Operator: Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

9. Flight Log for 3891G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3891G

1 LiDAR Operator: A. Pagaduan | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK19ACS | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: Gemini (9022)

7 Pilot: J. Mabanta | 8 Co-Pilot: D. Cabudol | 9 Route: Albay

10 Date: 03-16-2016 | 12 Airport of Departure (Airport, City/Province): Legazpi | 12 Airport of Arrival (Airport, City/Province): Legazpi

13 Engine On: 0854H | 14 Engine Off: 1351H | 15 Total Engine Time: 4+48 | 16 Take off: 0859H | 17 Landing: 1346H | 18 Total Flight Time: 4+38

19 Weather

20 Flight Classification

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

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

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

21 Remarks

finished BLK 19 ACS

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

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

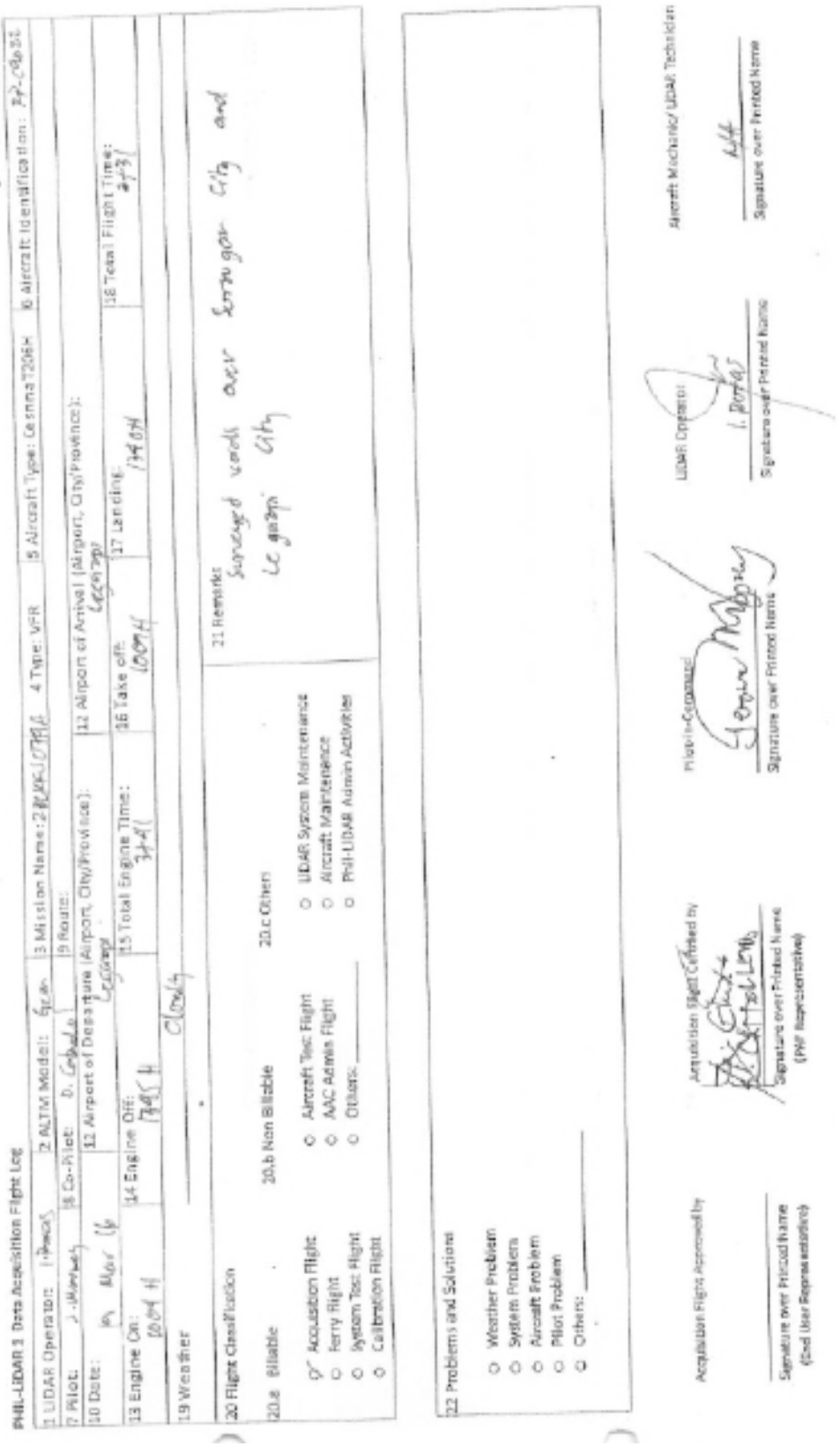
Acquisition Flight Certified by: Benjie Carbolledo, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

LiDAR Operator: Signature over Printed Name

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

10. Flight Log for 3903G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3903G

1 LIDAR Operator: [illegible] | 2 ALTM Model: [illegible] | 3 Mission Name: 2[illegible] | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: RP-C8838

7 Pilot: [illegible] | 8 Co-Pilot: [illegible] | 9 Route: [illegible]

10 Date: [illegible] | 11 Airport of Departure (Airport, City/Province): Legazpi | 12 Airport of Arrival (Airport, City/Province): Legazpi

13 Engine On: [illegible] | 14 Engine Off: [illegible] | 15 Total Engine Time: 3.4 | 16 Take off: [illegible] | 17 Landing: [illegible] | 18 Total Flight Time: 3.3

19 Weather: Cloudy

20 Flight Classification

20.a Billable | 20.b Non Billable | 20.c Others

- ○ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____
- ○ LIDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LIDAR Admin Activities

21 Remarks: Surveyed roads over Legazpi City and Legazpi 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

I. Bongat

Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician

Signature over Printed Name

Annex 7. Flight Status Report

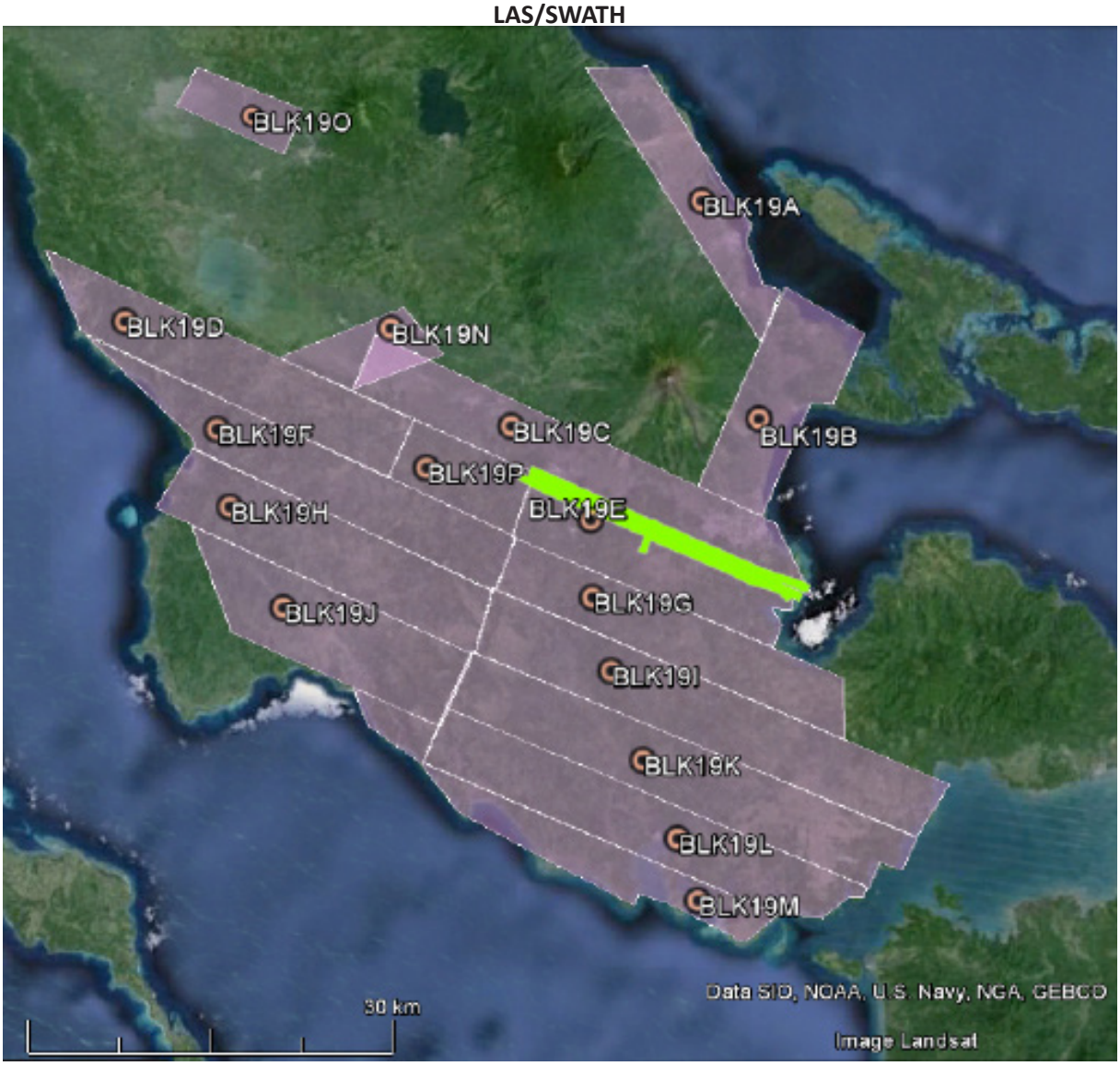
ALBAY AND SORSOGON
(March 26 – April 30, 2014 and February 24 – March 20, 2016)

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7156GC	BLK19E	2BLK19E088A	MVE TONGA	March 29, 2014	Surveyed 3 lines (with CASI)
7158GC	BLK19EG	2BLK19ES089A & 2BLK19G089A	MVE TONGA	March 30, 2014	Mission completed (with CASI)
7165GC	BLK19C	2BLK19CS092A	MVE TONGA	April 2, 2016	Surveyed 6 lines (with CASI)
7169GC	BLK19CD	2BLK19CS096A & 2BLK19D096A	MVE TONGA	April 4, 2016	Mission completed (with CASI)
7172GC	BLK19CD	2BLK19CS096A & 2BLK19D096A	MVE TONGA	April 6, 2014	Mission completed at BLKC and surveyed 12 lines at BLK19D (with CASI-corrupted hard drive)
7216GC	BLK19A	2BLK19AS118A & VOIDS	MVE TONGA	April 28, 2014	Surveyed 2 lines
3827G	BLK19AB	2BLK19ABS060A	J. ALAMBAN	February 29, 2016	Surveyed BLK19BS
3869G	BLK19AB	2BLK19ASBSI070A	KJ ANDAYA	March 10, 2016	Completed BLK19AS, BS, and AI
3891G	BLK19AC	2BLK19ACS076A	A PAGADOR	March 16, 2016	Finished voids over Ligao, Guinobatan; covered Polangui
3903G	BLK19S	2BLK19S079A	I ROXAS	March 19, 2016	Covered gap over Cadacan river basin then voids in Daraga river basin

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. : 7156GC
Area: BLK19E
Mission name: 2BLK19E088A
Parameters: Altitude: 1000m
Scan Frequency: 50Hz
Scan Angle: 20 degrees
Overlap: 35 %

LAS/SWATH



Flight No. : 7158GC
Area: BLK19E AND BLK19G
Mission name: 2BLK19ES089A & 2BLK19G089A
Parameters: Altitude: 1000m
Scan Frequency: 50Hz
Scan Angle: 20 degrees
Overlap: 35 %

LAS/SWATH

Flight No. : 7165GC
Area: BLK19C
Mission name: 2BLK19C092A
Parameters: Altitude: 1000m
Scan Frequency: 50Hz
Scan Angle: 20 degrees
Overlap: 35 %

LAS/SWATH

Flight No. : 7169GC
Area: BLK19
Mission name: 2BLK19B094B
Parameters: Altitude: 900m
Scan Frequency: 50Hz
Scan Angle: 20 degrees
Overlap: 40%

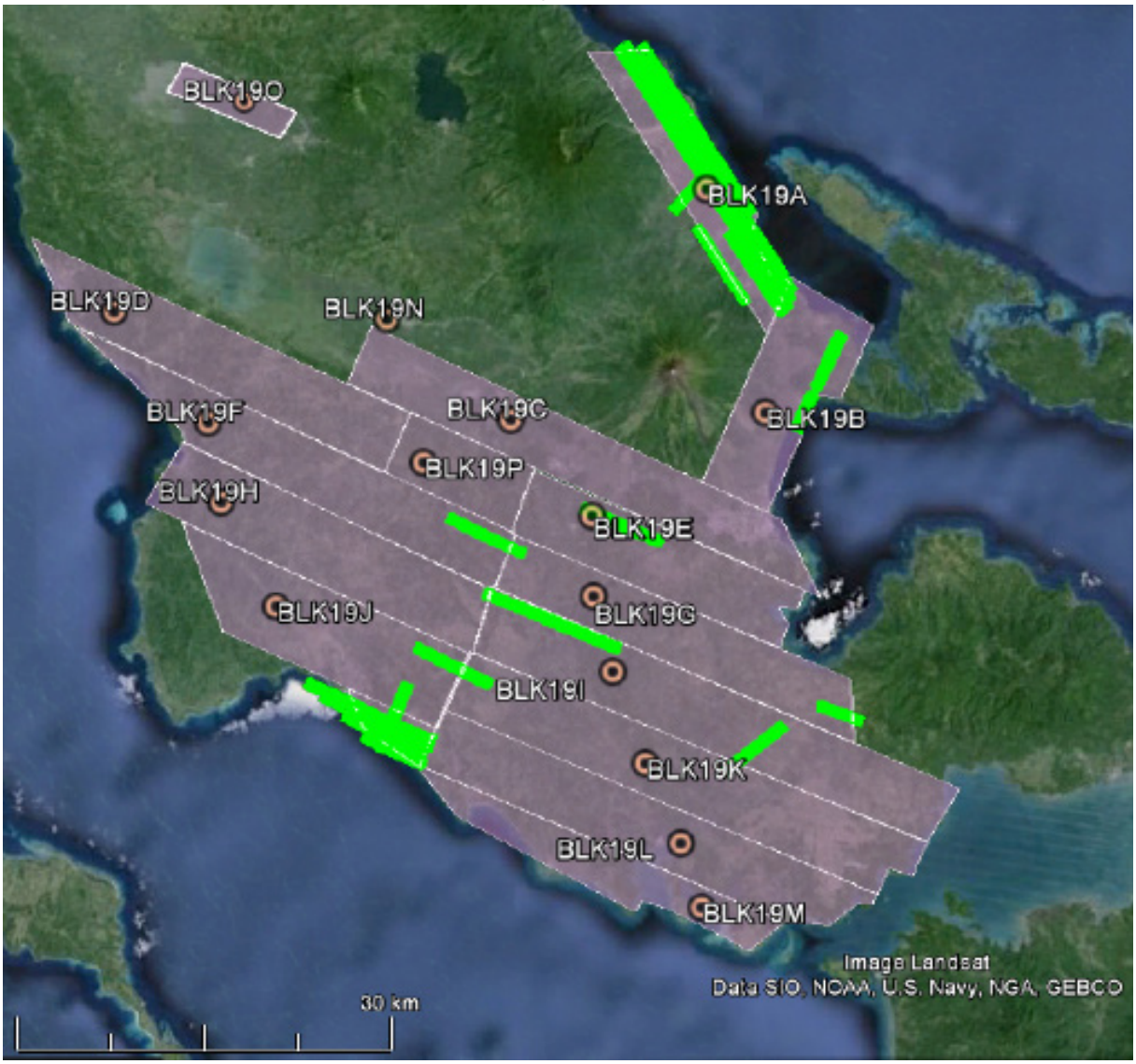
LAS/SWATH

Flight No. : 7172GC
Area: BLK19C AND BLK19D
Mission name: 2BLK19CS096A & 2BLK19D096A
Parameters: Altitude: 1000m
Scan Frequency: 50Hz
Scan Angle: 20 degrees
Overlap: 40%

LAS/SWATH

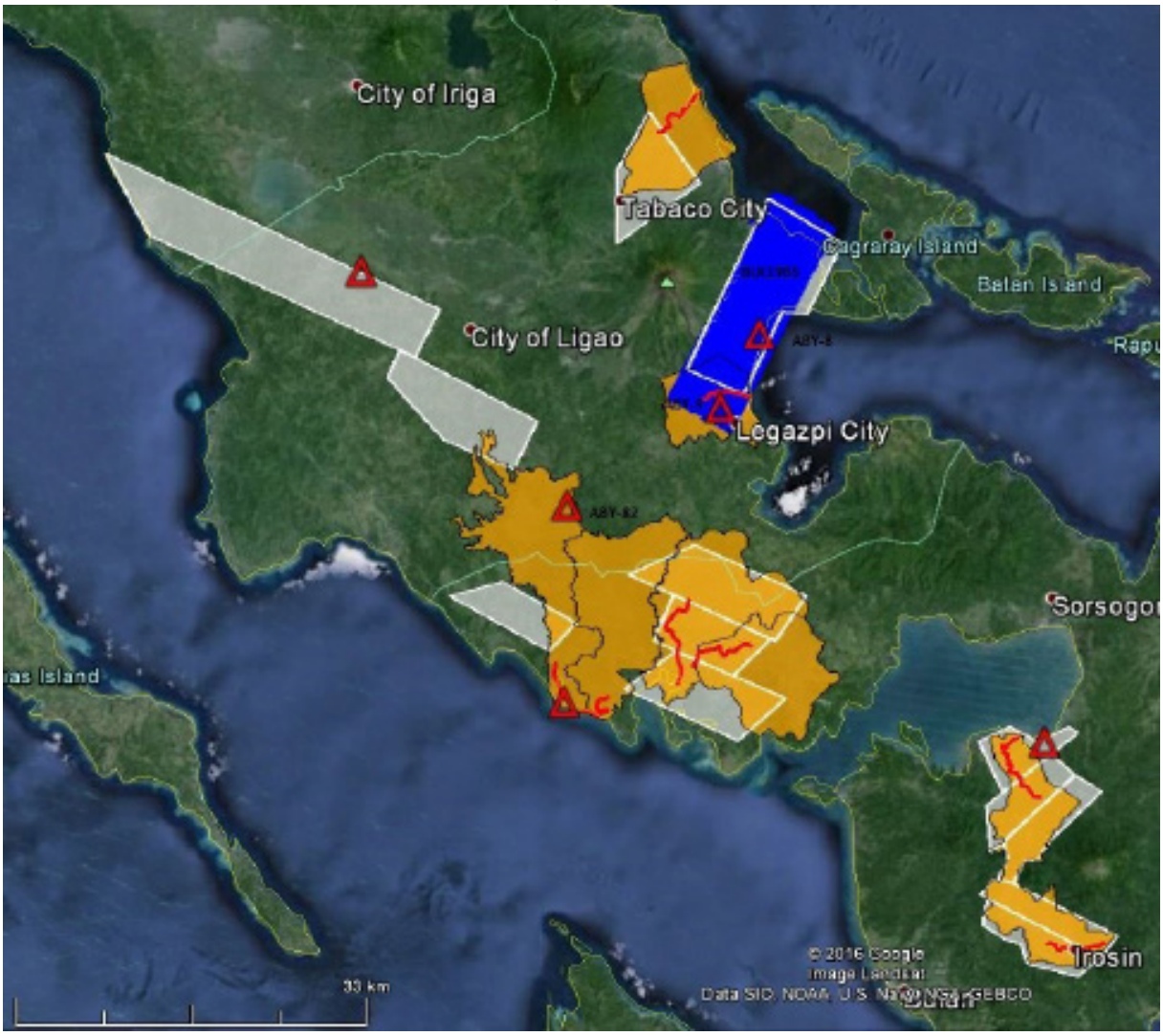
Flight No. : 7216GC
Area: BLK19A
Mission name: 2BLK19AS118A & VOIDS
Parameters: Altitude: 1200 meters
Scan Frequency: 50 Hz
Scan Angle: 17 degrees
Overlap: 50%

LAS/SWATH



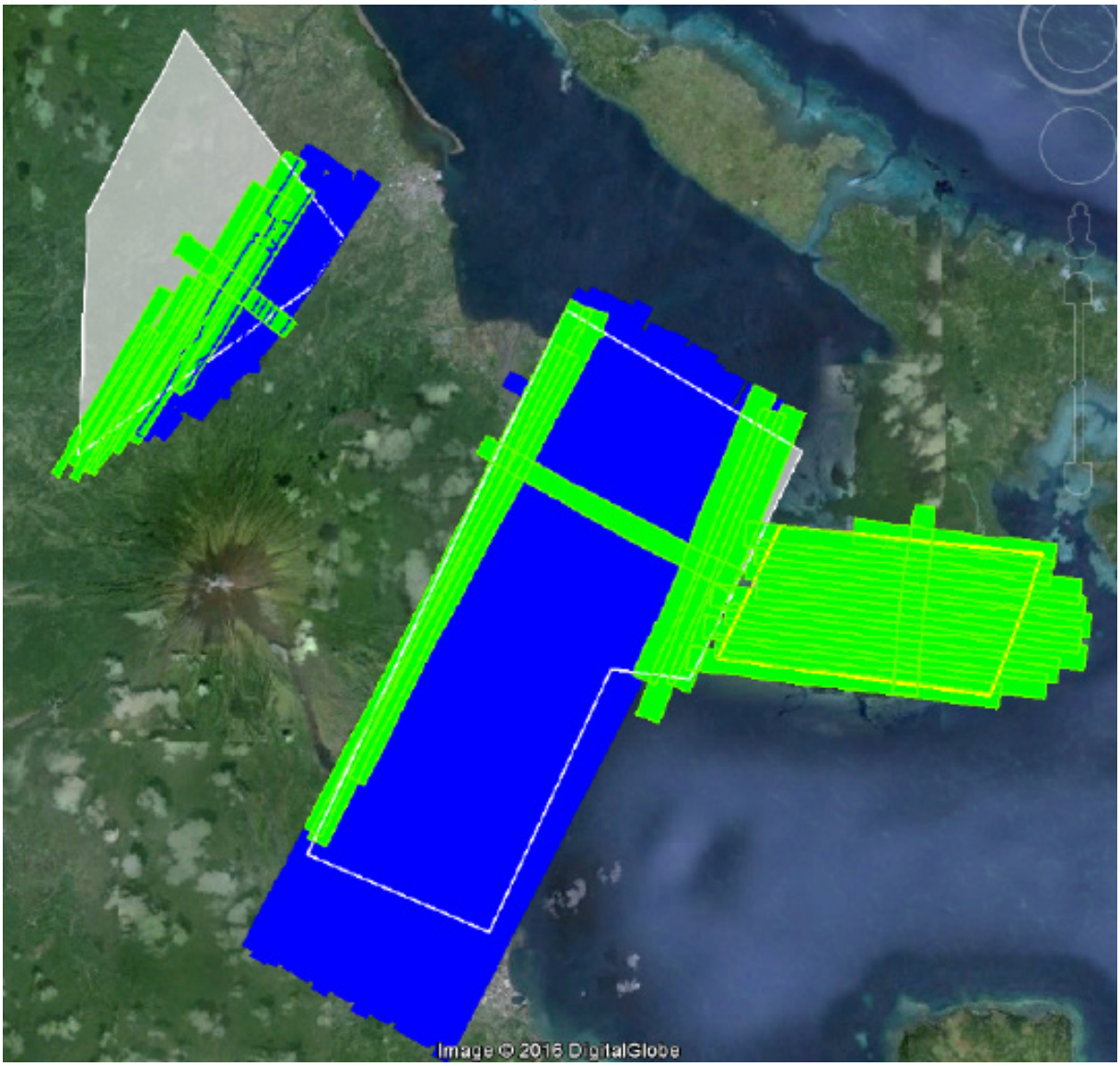
Flight No. : 3827G
Area: BLK19BS
Mission name: 2BLK19ABS060A
Parameters: Altitude: 1100/850/600 meters
Scan Frequency: 40Hz
Scan Angle: 25 degrees
Overlap: 20%

LAS/SWATH



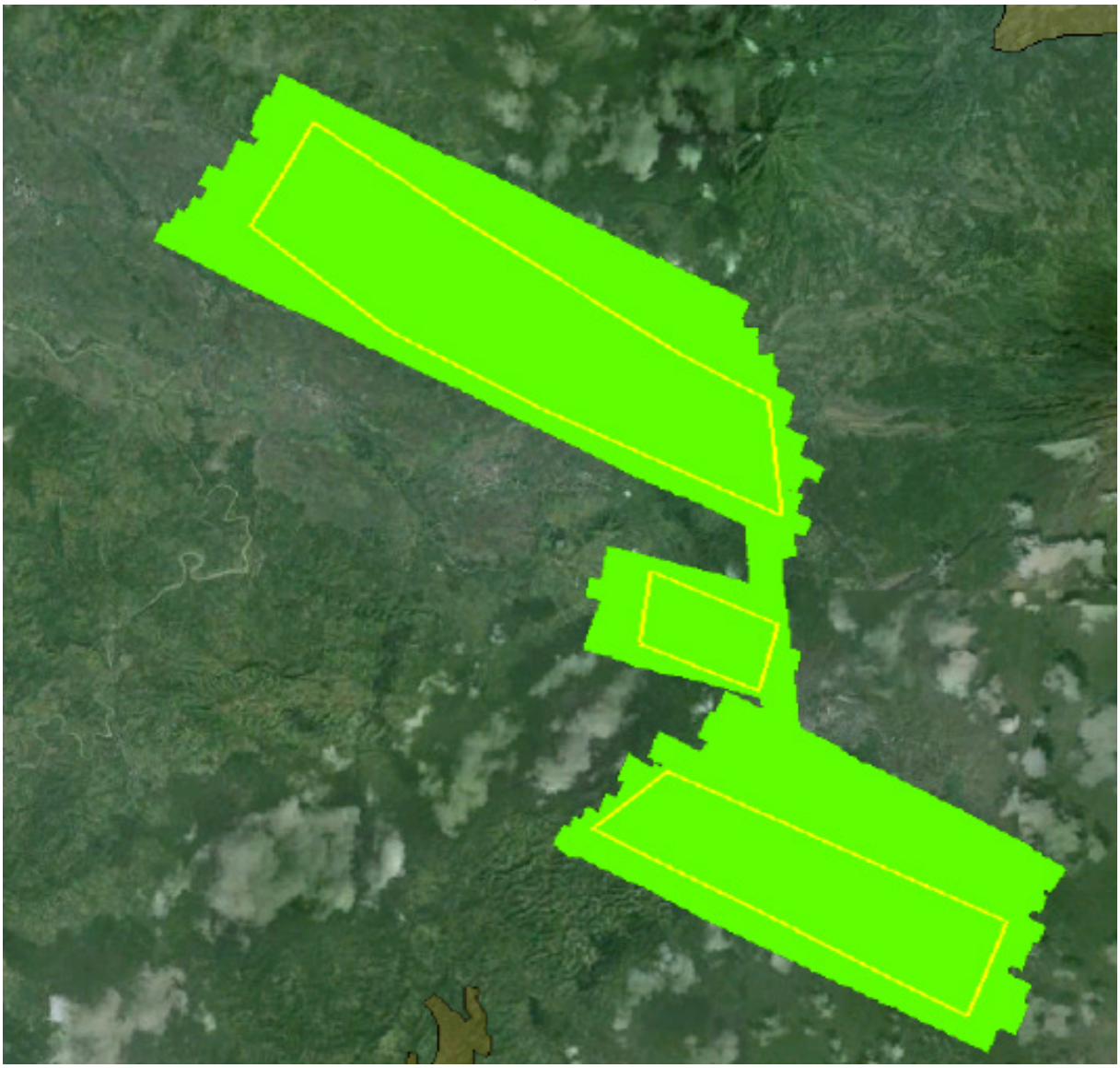
Flight No. : 3869G
Area: BLK19ASBSAI
Mission name: 2BLK19ASBSI070A
Parameters: Altitude: 750 meters
Scan Frequency: 45Hz
Scan Angle: 25 degrees
Overlap: 30%

LAS/SWATH



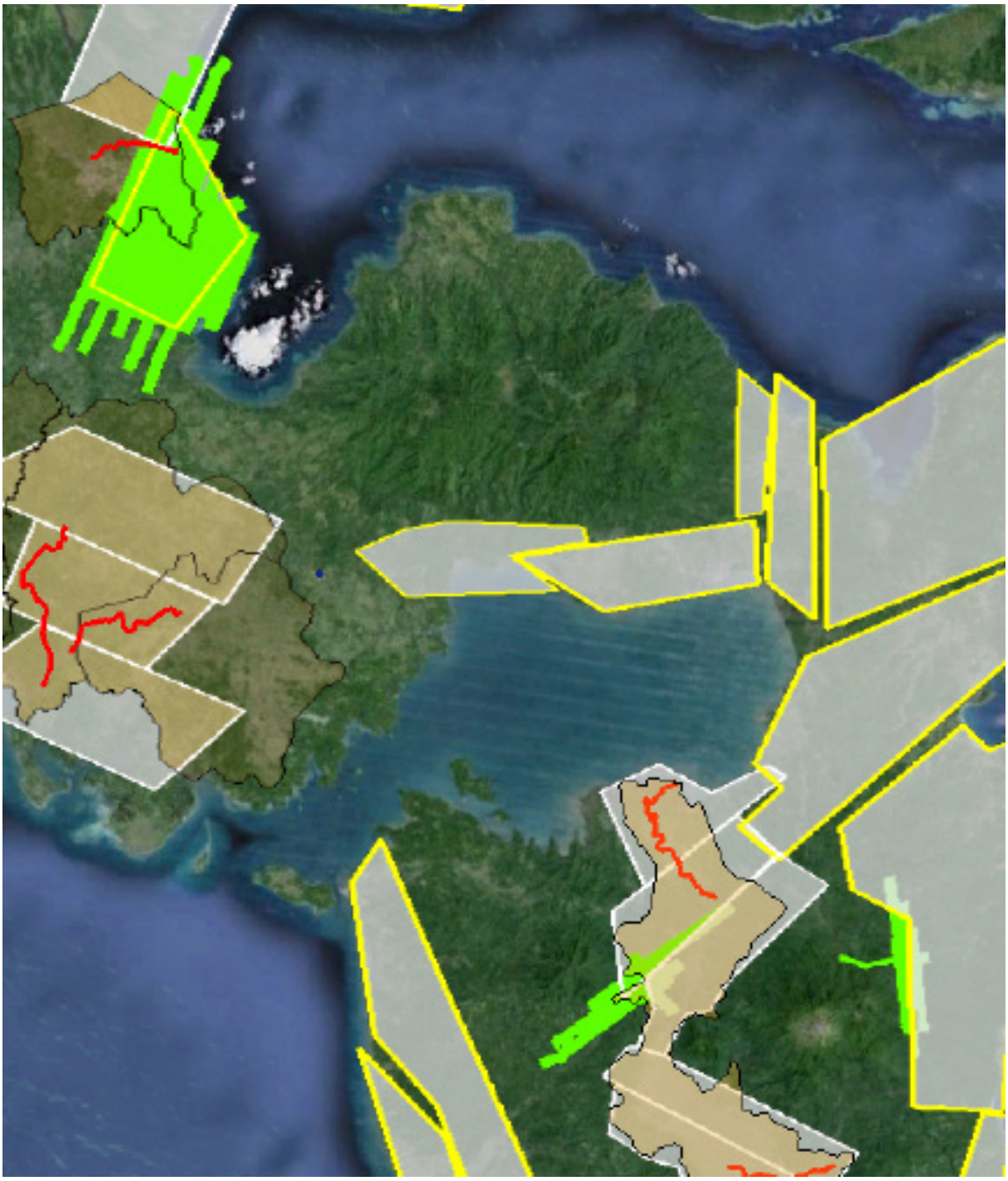
Flight No. : 3891G
Area: BLK19A and voids
Mission name: 2BLK19ACS076A
Parameters: Altitude: 600/850 meters
Scan Frequency: 45Hz
Scan Angle: 25 degrees
Overlap: 40%

LAS/SWATH



Flight No. : 3903G
Area: COVERED GAP OVER CADACAN, BULUSAN THEN VOIDS IN DARAGA
Mission name: 2BLK19S079A
Parameters: Altitude: 850 meters
Scan Frequency: 45Hz
Scan Angle: 25 degrees
Overlap: 30%

LAS/SWATH



Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk 19EG

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

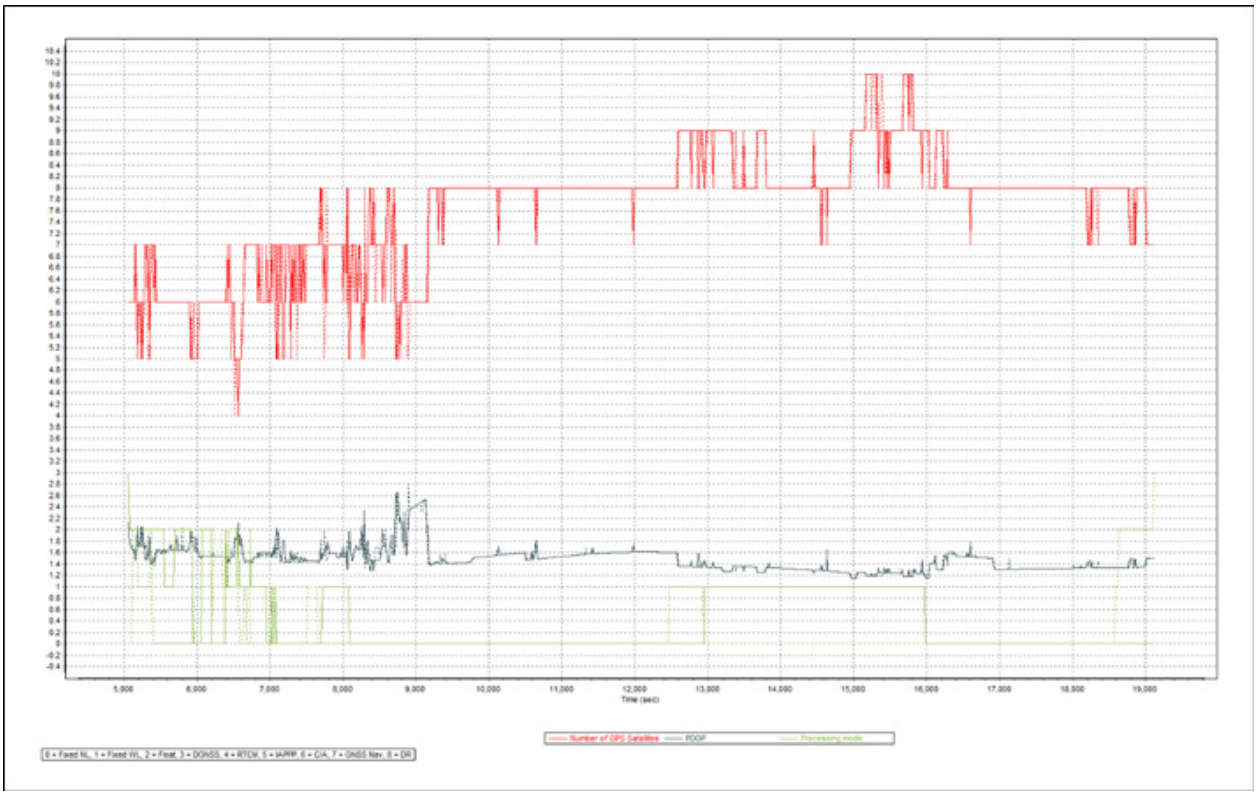


Figure A-8.1. Solution Status

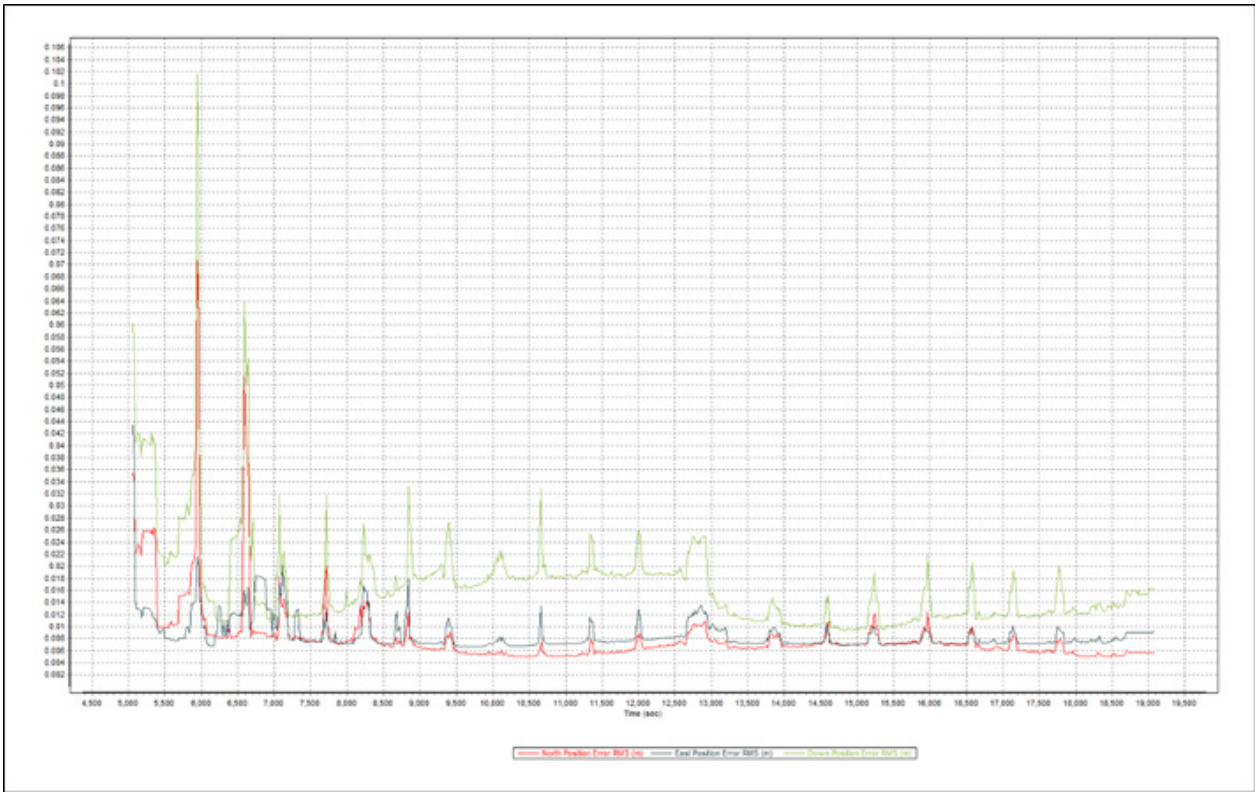


Figure A-8.2. Smoothed Performance Metric Parameters

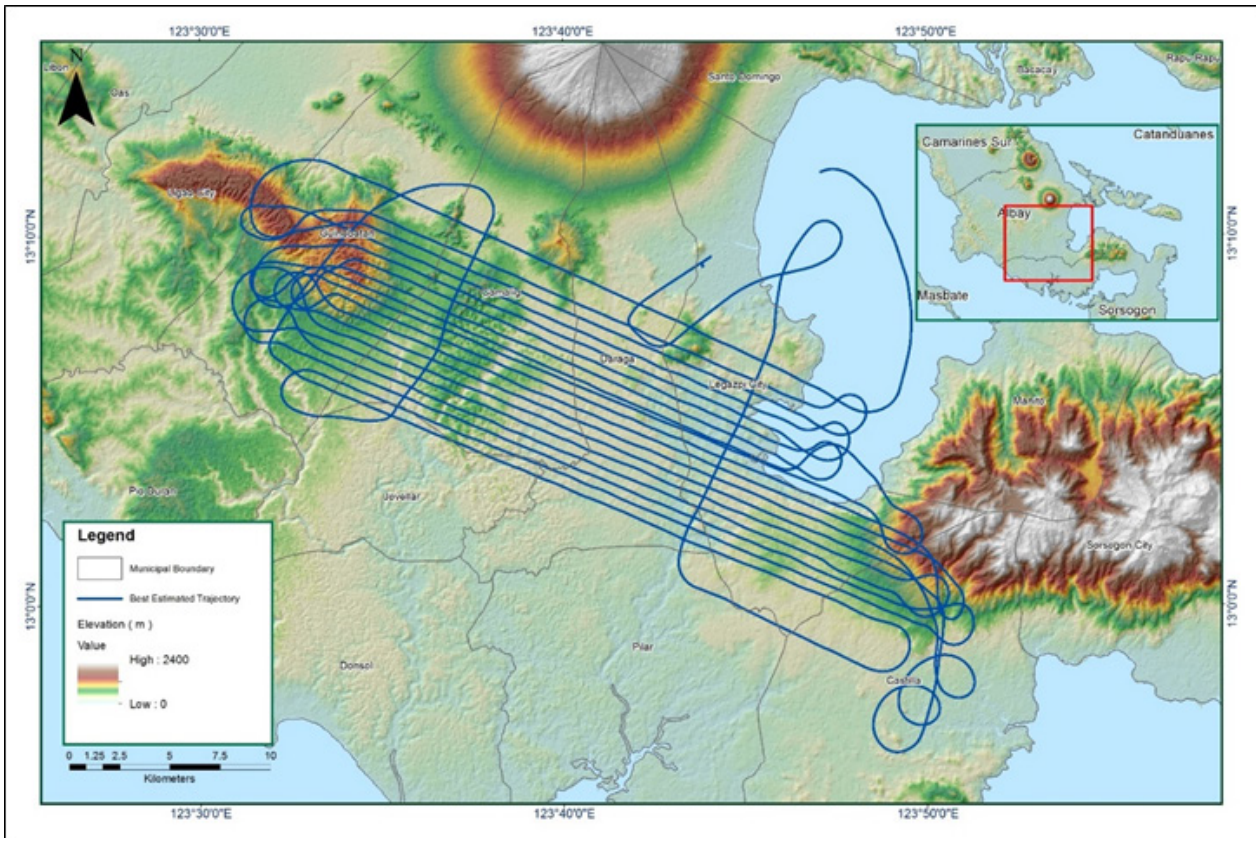


Figure A-8.3. Best Estimated Trajectory

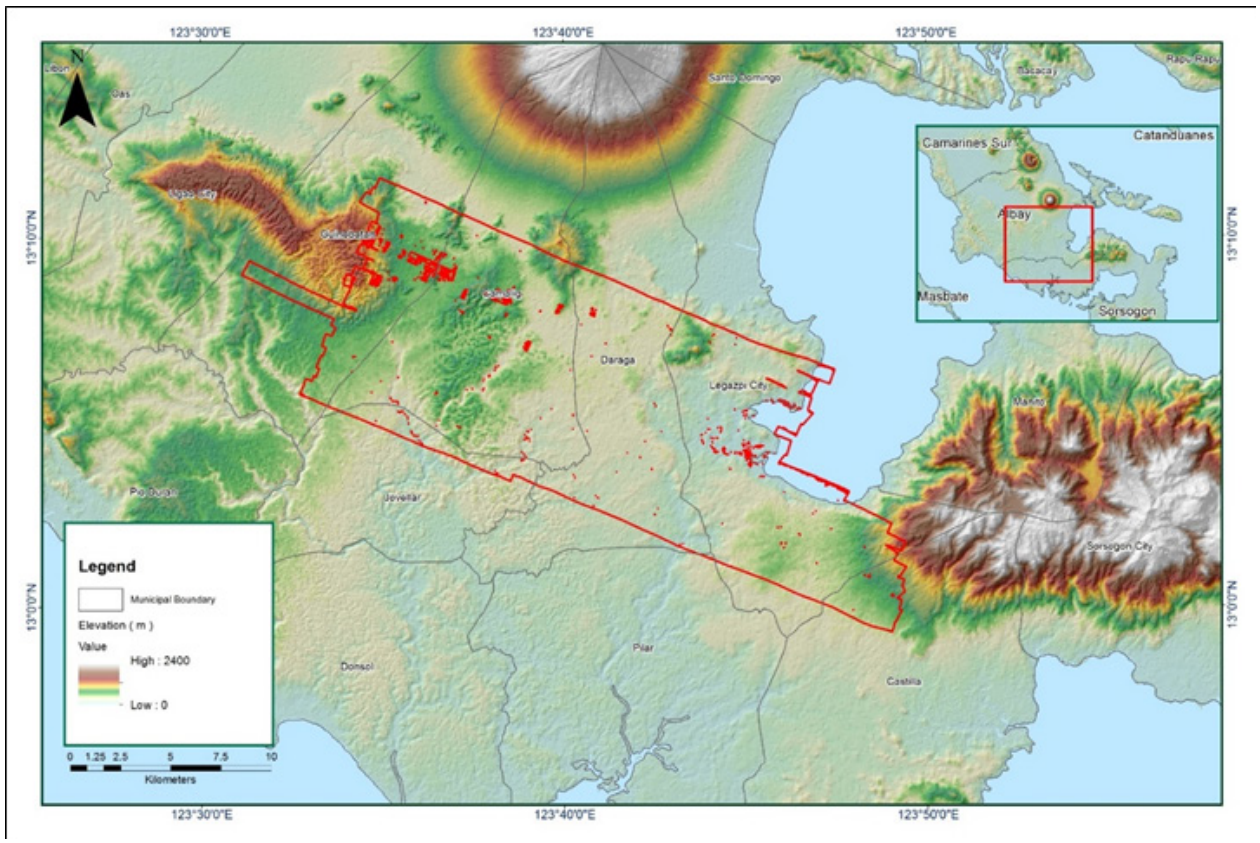


Figure A-8.4. Coverage of LiDAR data

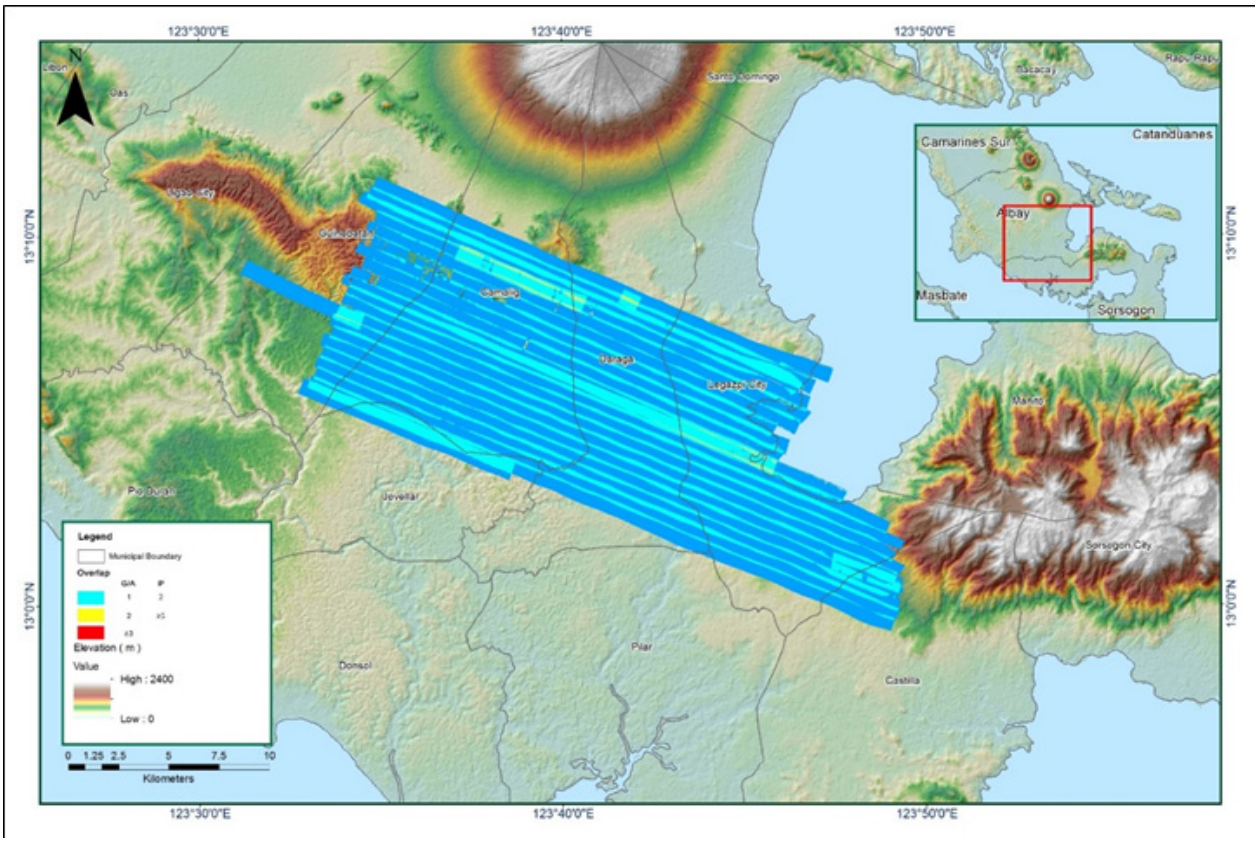


Figure A-8.5. Image of data overlap

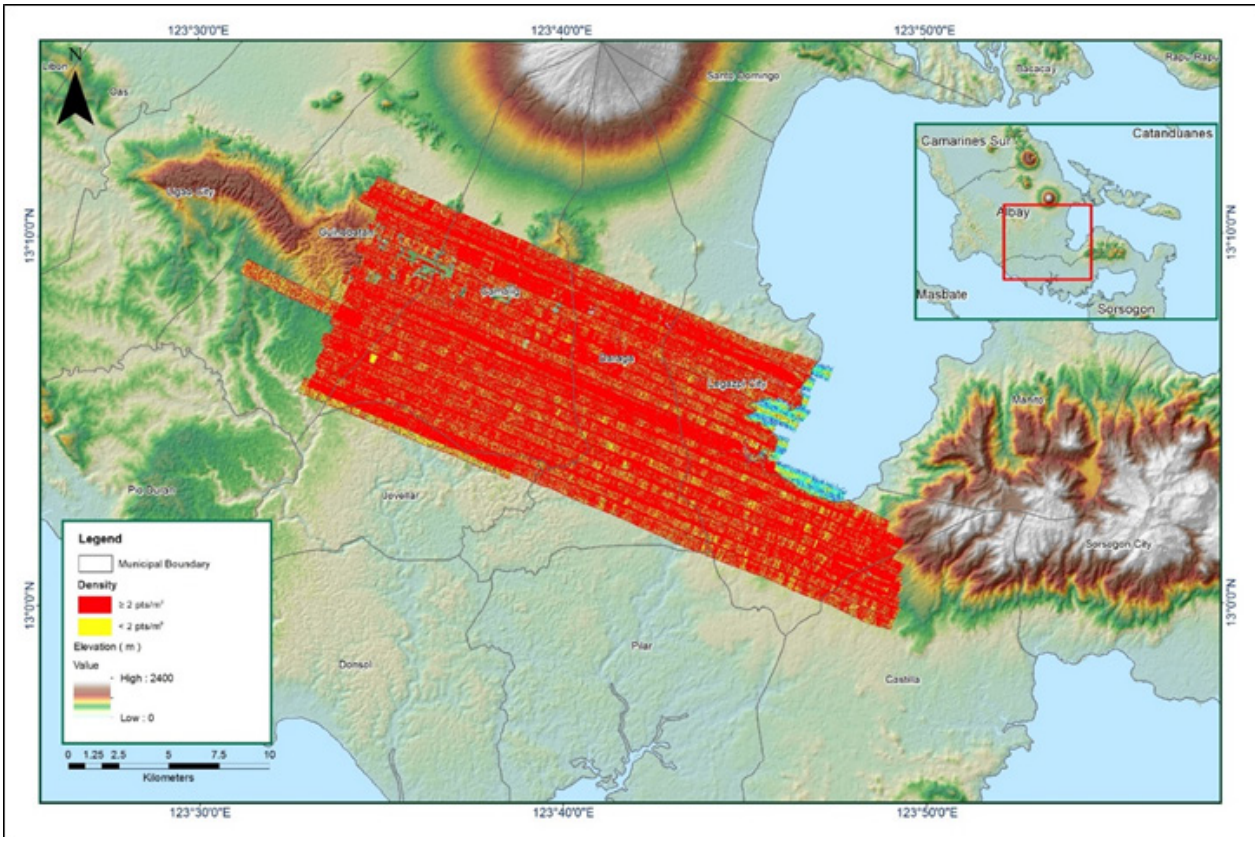


Figure A-8.6. Density map of merged LiDAR data

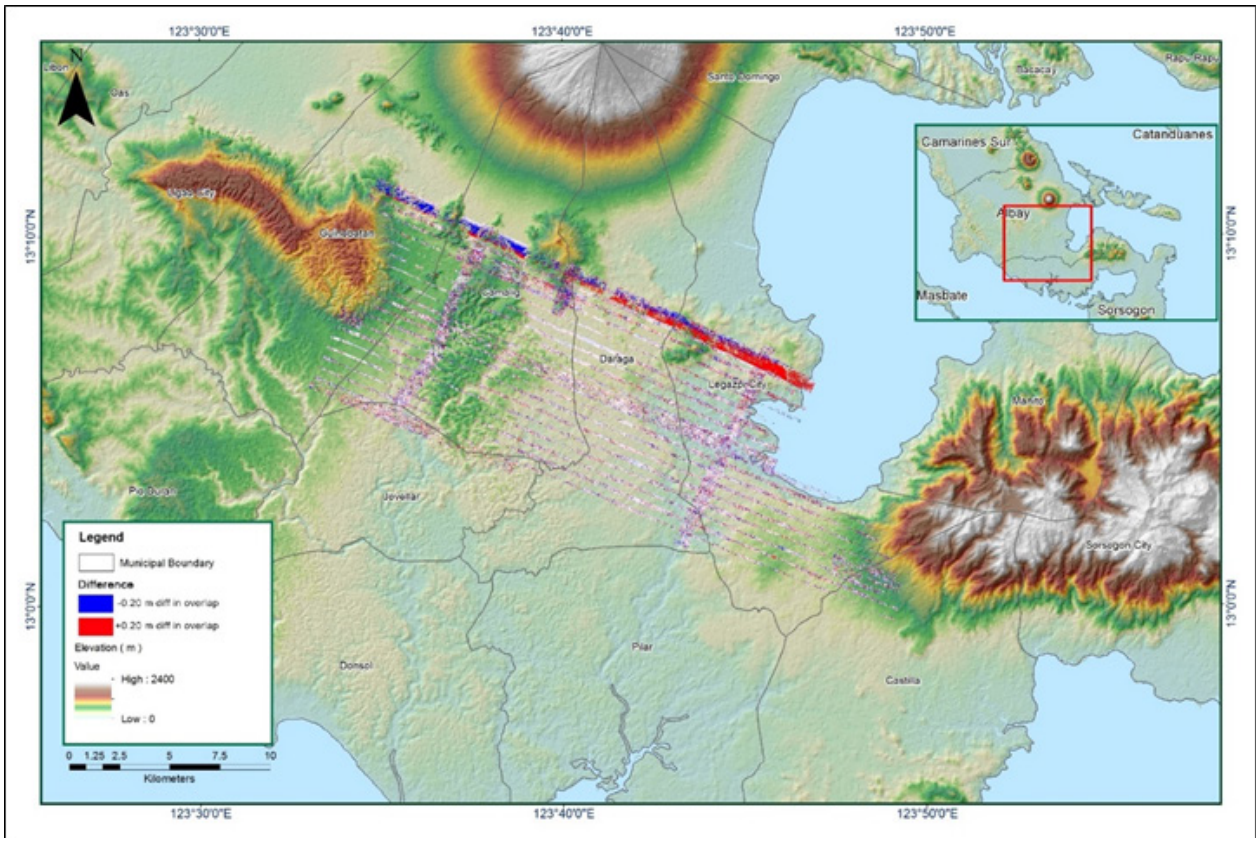


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk 19C

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19C
Inclusive Flights	7165GC, 7172GC
Range data size	42.2 GB
POS data size	383 MB
Base data size	18.09 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.35
RMSE for Down Position (<8.0 cm)	8.8
Boresight correction stdev (<0.001deg)	0.000290
IMU attitude correction stdev (<0.001deg)	0.001874
GPS position stdev (<0.01m)	0.0115
Minimum % overlap (>25)	36.45 %
Ave point cloud density per sq.m. (>2.0)	3.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	336
Maximum Height	443.49
Minimum Height	51.30
Classification (# of points)	
Ground	99,515,330
Low vegetation	120,077,260
Medium vegetation	146,813,275
High vegetation	212,558,899
Building	12,754,721
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga, Jr., Engr. Gladys Mae Apat

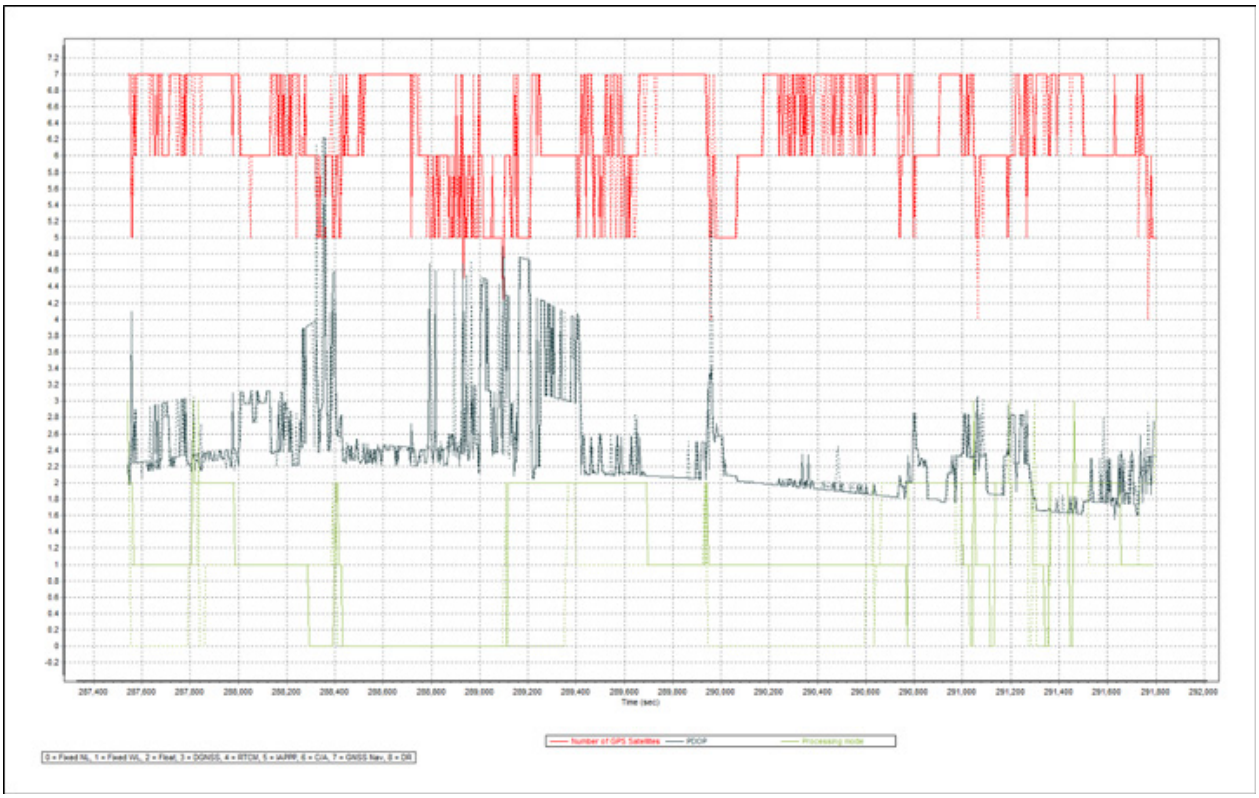


Figure A-8.8. Solution Status

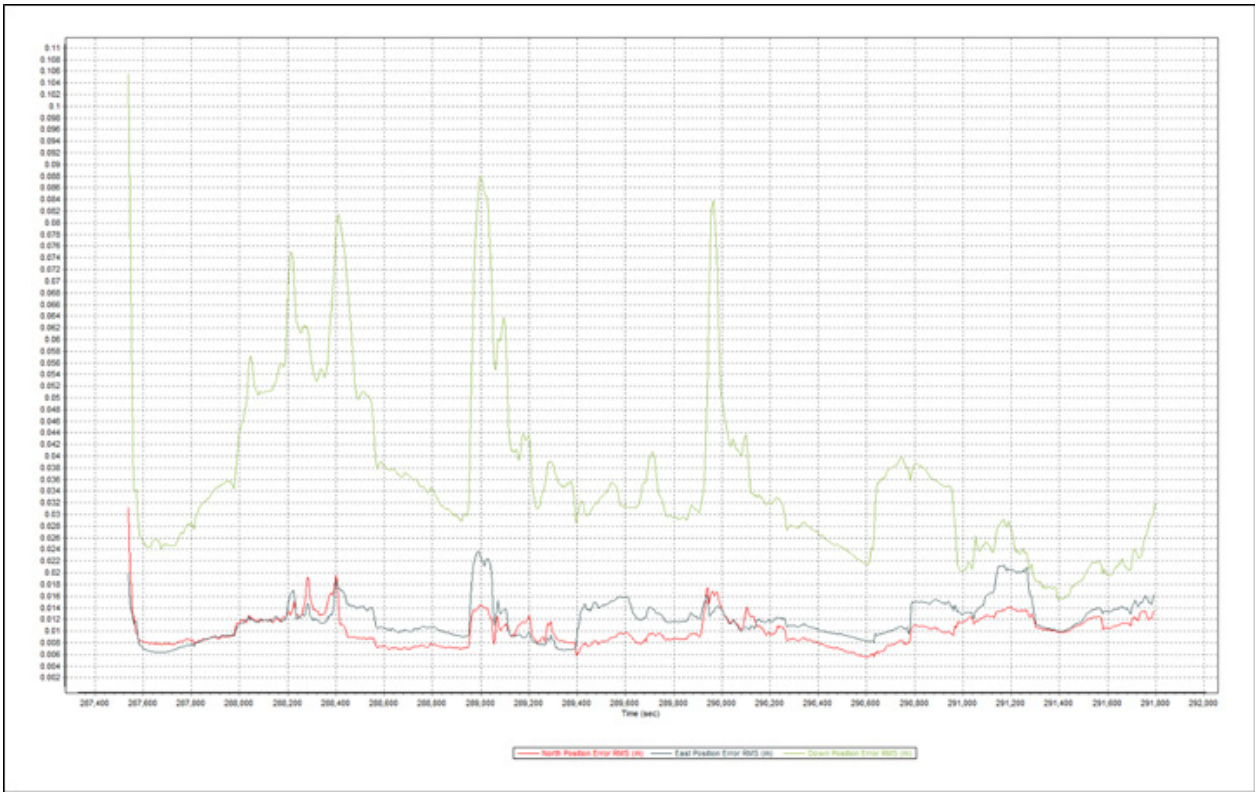


Figure A-8.9. Smoothed Performance Metric Parameters

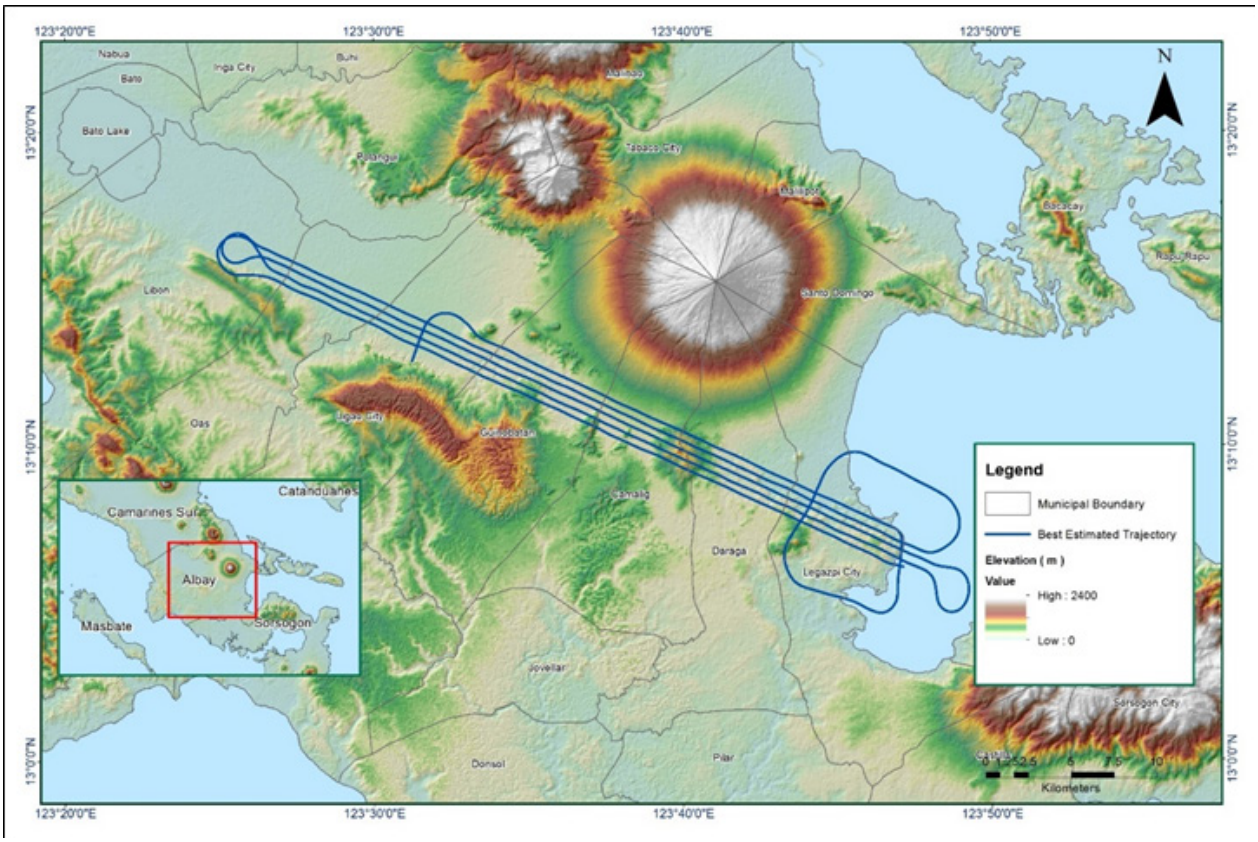


Figure A-8.10. Best Estimated Trajectory

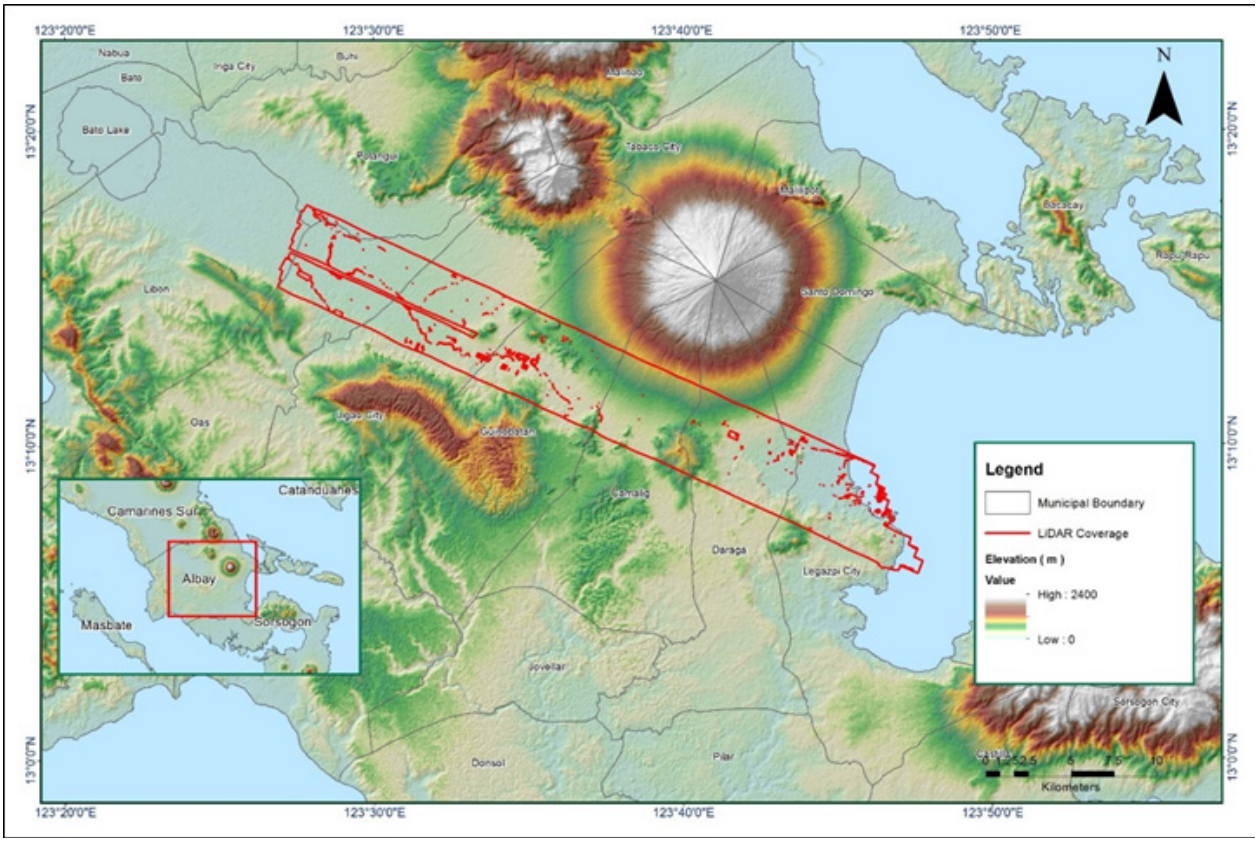


Figure A-8.11. Coverage of LiDAR data

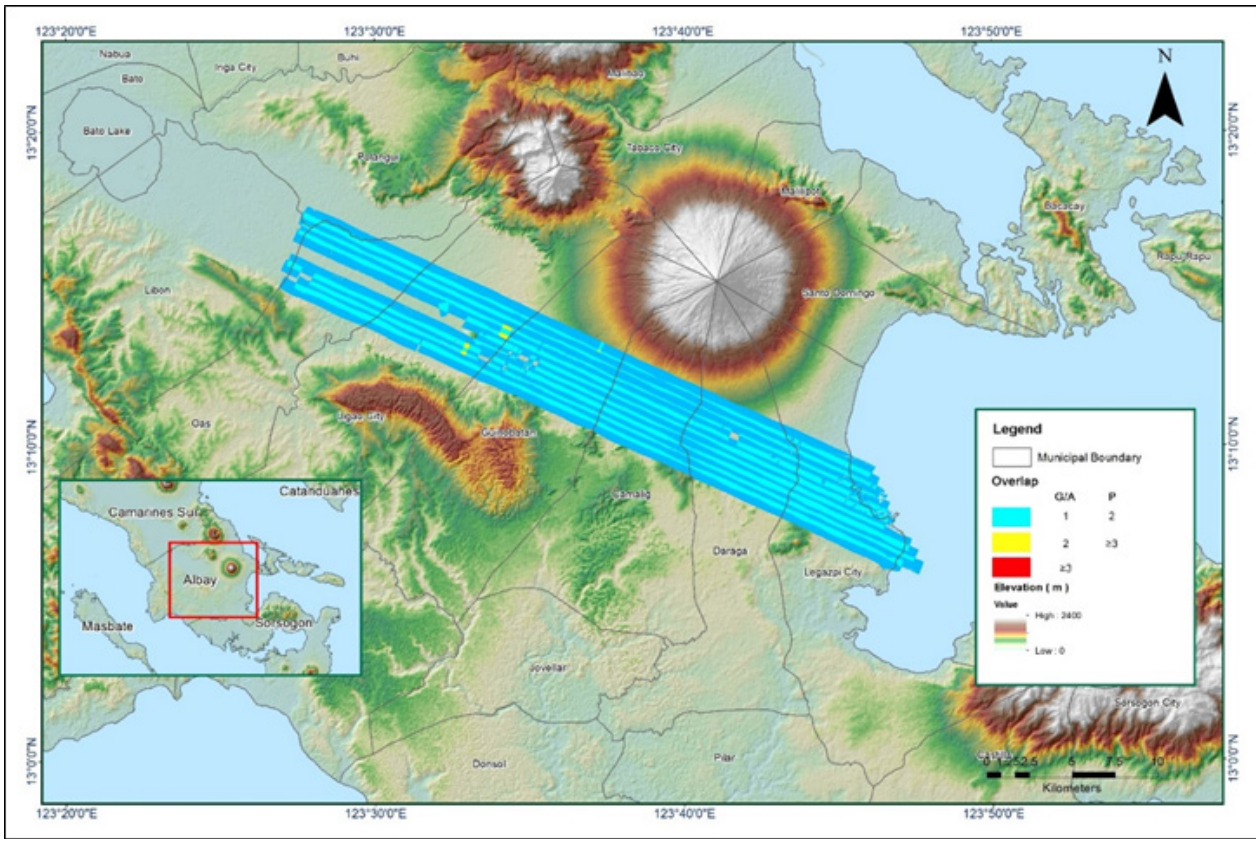


Figure A-8.12. Image of data overlap

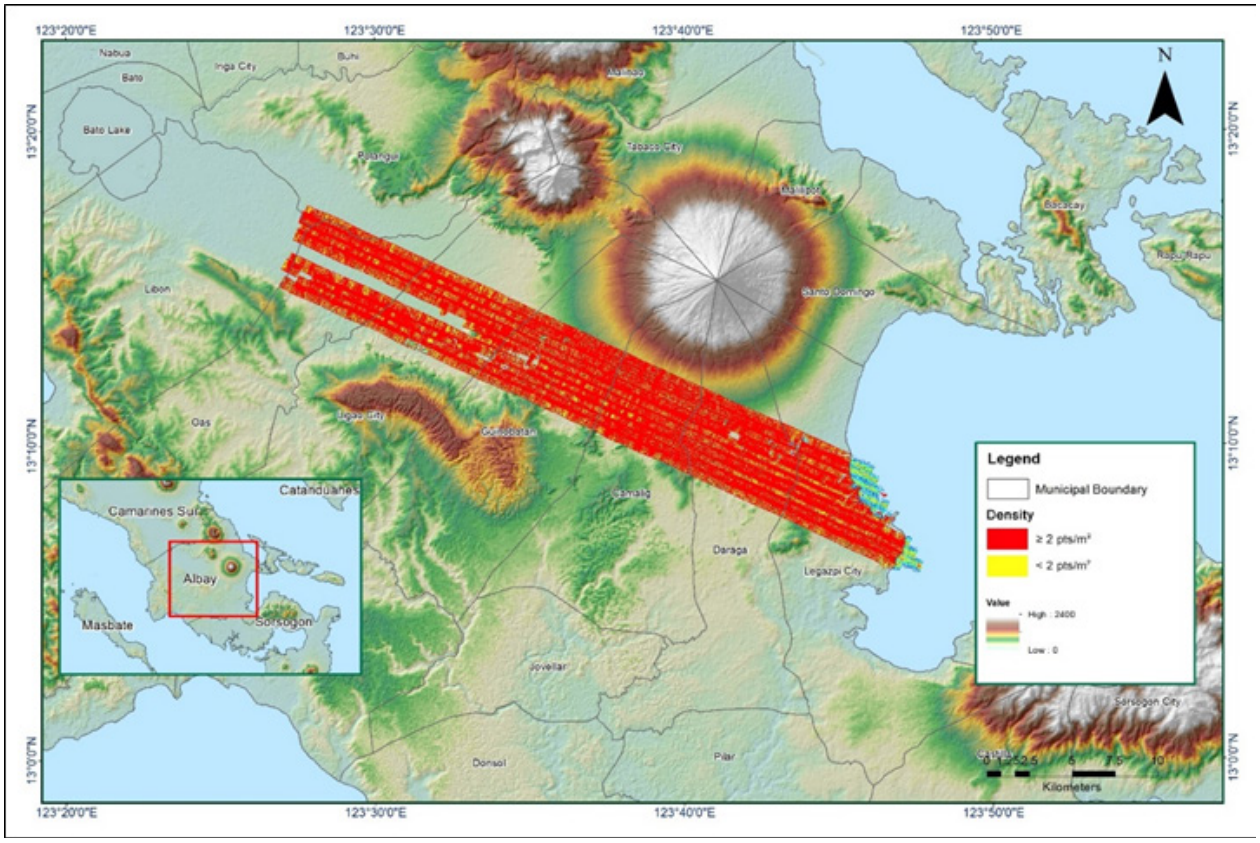


Figure A-8.13. Density map of merged LiDAR data

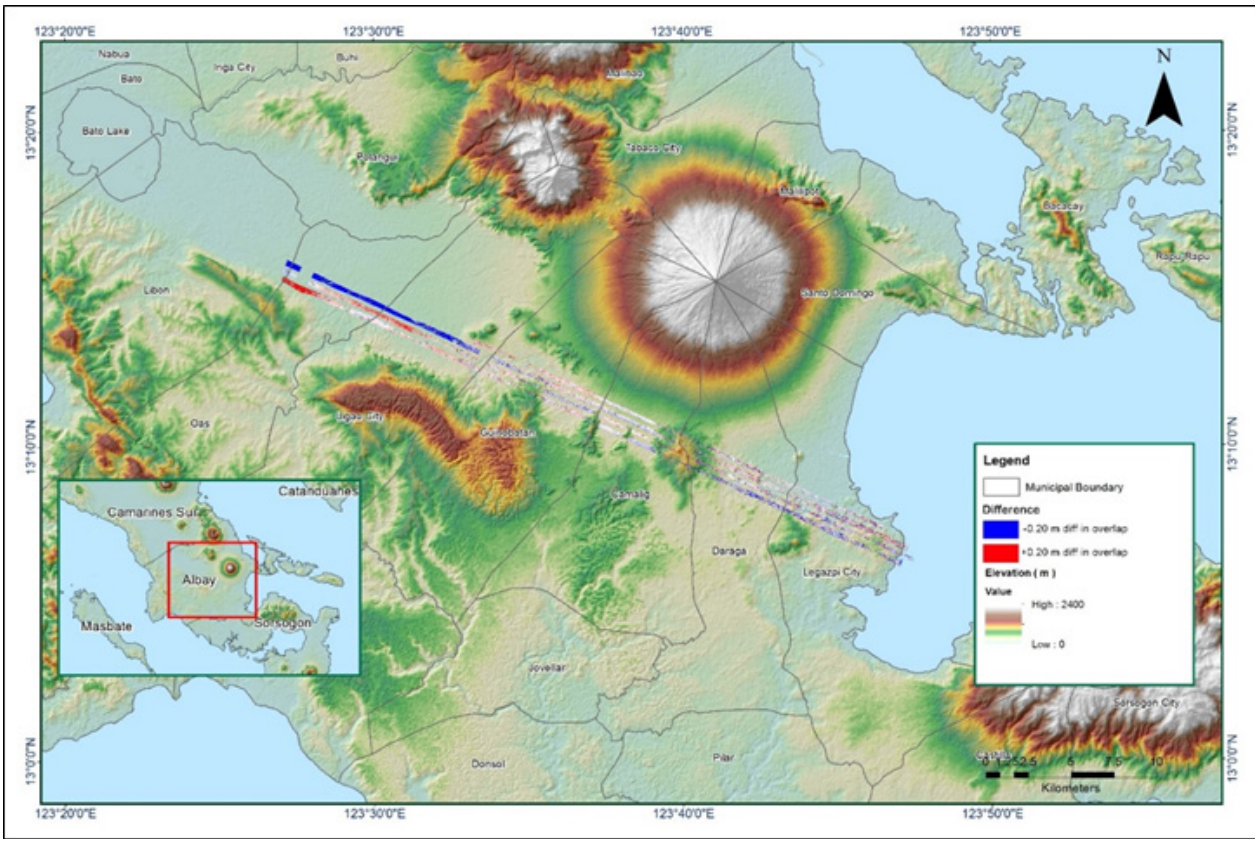


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk19C_additional

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19C_additional
Inclusive Flights	7165GC, 7172GC
Range data size	42.2 GB
POS data size	383 MB
Base data size	18.09 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.4
RMSE for East Position (<4.0 cm)	8.4
RMSE for Down Position (<8.0 cm)	17
Boresight correction stdev (<0.001deg)	0.000325
IMU attitude correction stdev (<0.001deg)	0.000688
GPS position stdev (<0.01m)	0.0094
Minimum % overlap (>25)	0.11 %
Ave point cloud density per sq.m. (>2.0)	1.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	77
Maximum Height	325.10 m
Minimum Height	54.50 m
Classification (# of points)	
Ground	5,320,261
Low vegetation	6,598,096
Medium vegetation	4,607,767
High vegetation	3,579,405
Building	282,144
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Christy Lubiano, Engr. Melissa Fernandez

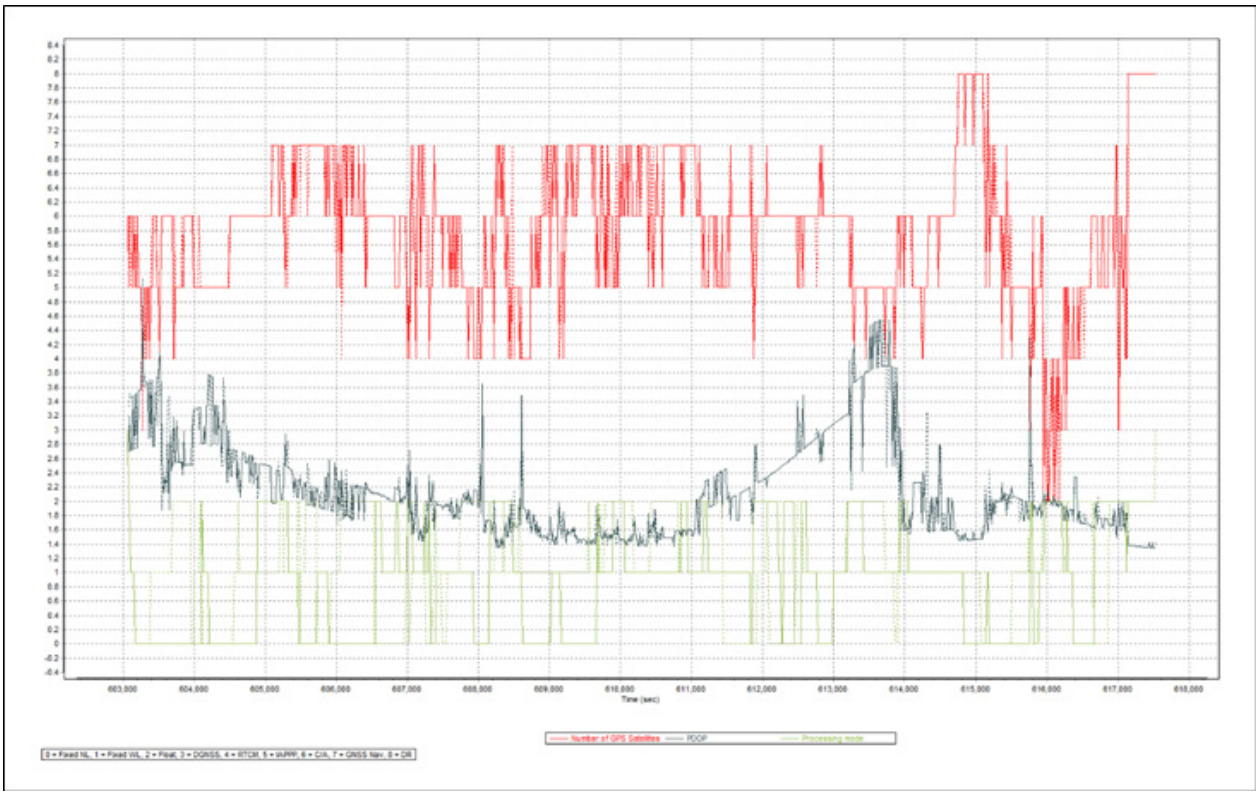


Figure A-8.15. Solution Status

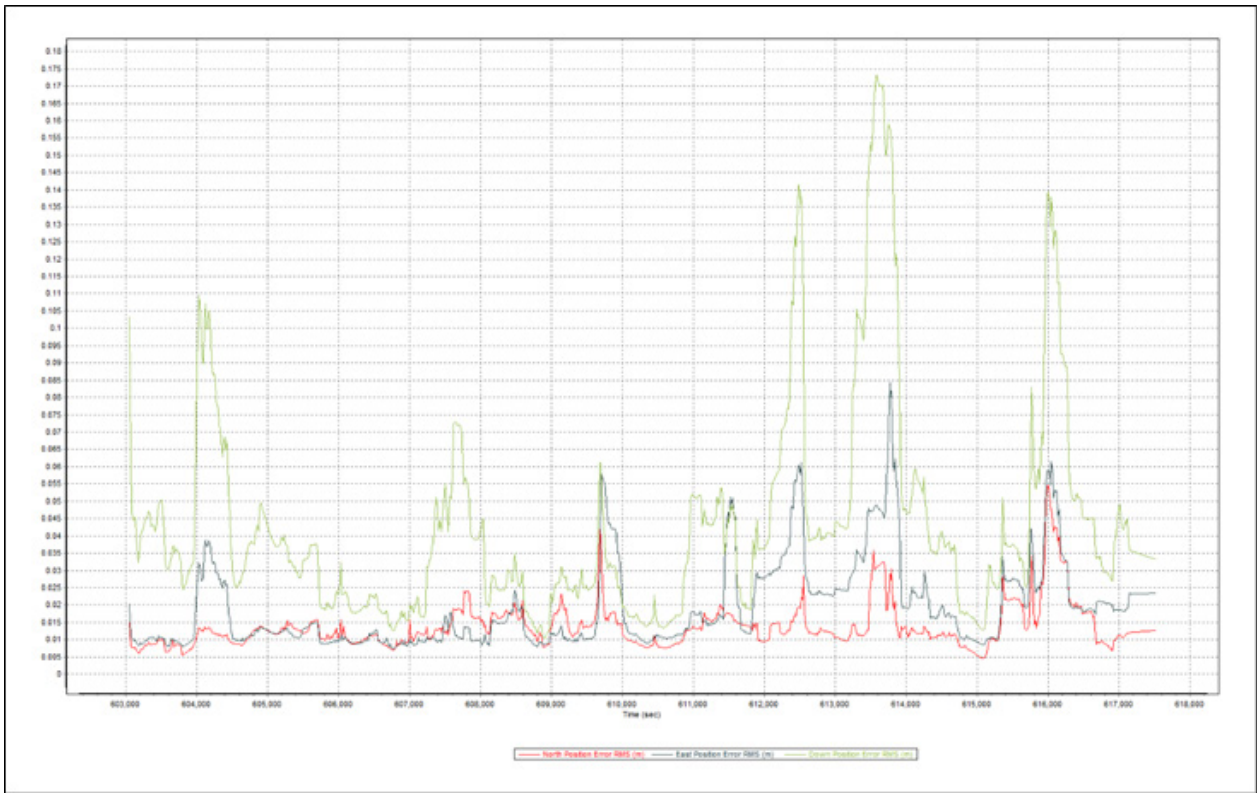


Figure A-8.16. Smoothed Performance Metric Parameters

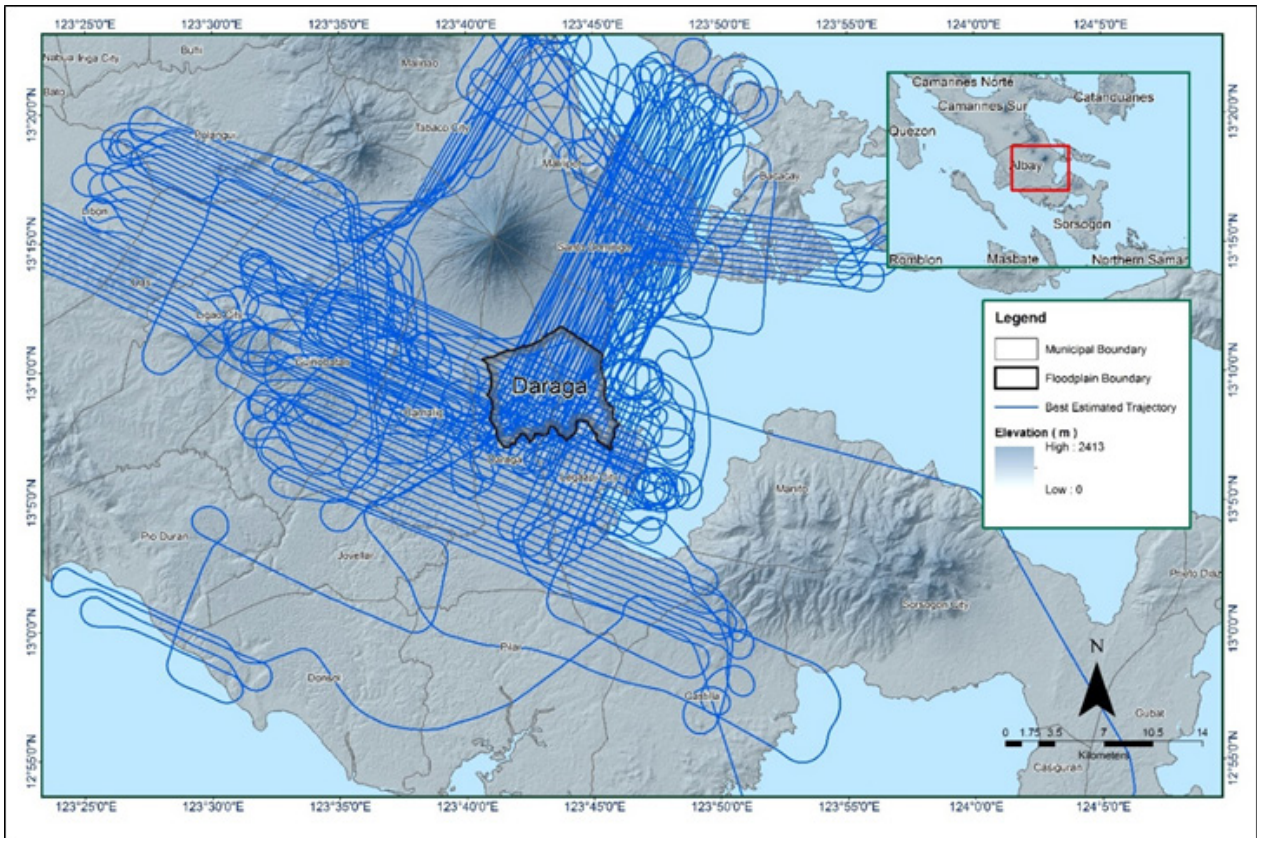


Figure A-8.17. Best Estimated Trajectory

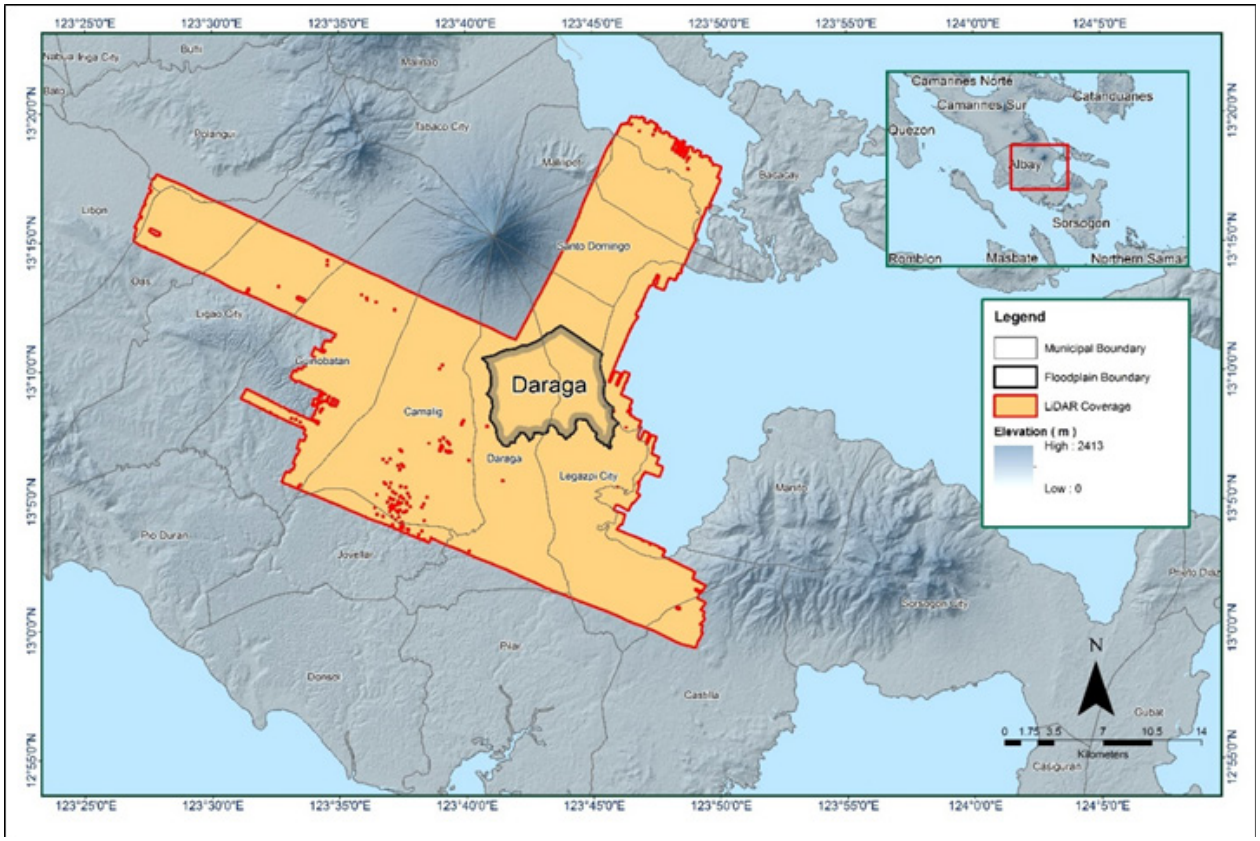


Figure A-8.18. Coverage of LiDAR data

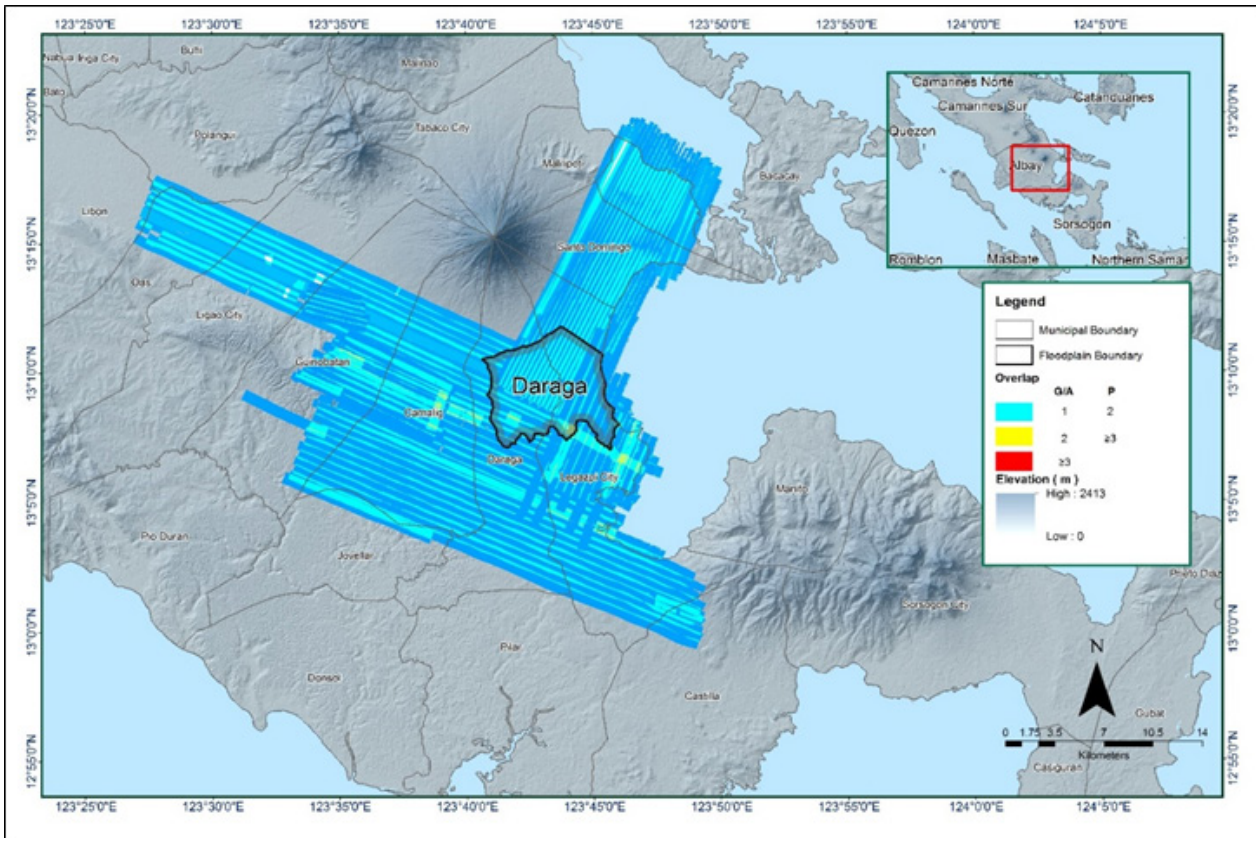


Figure A-8.19. Image of data overlap

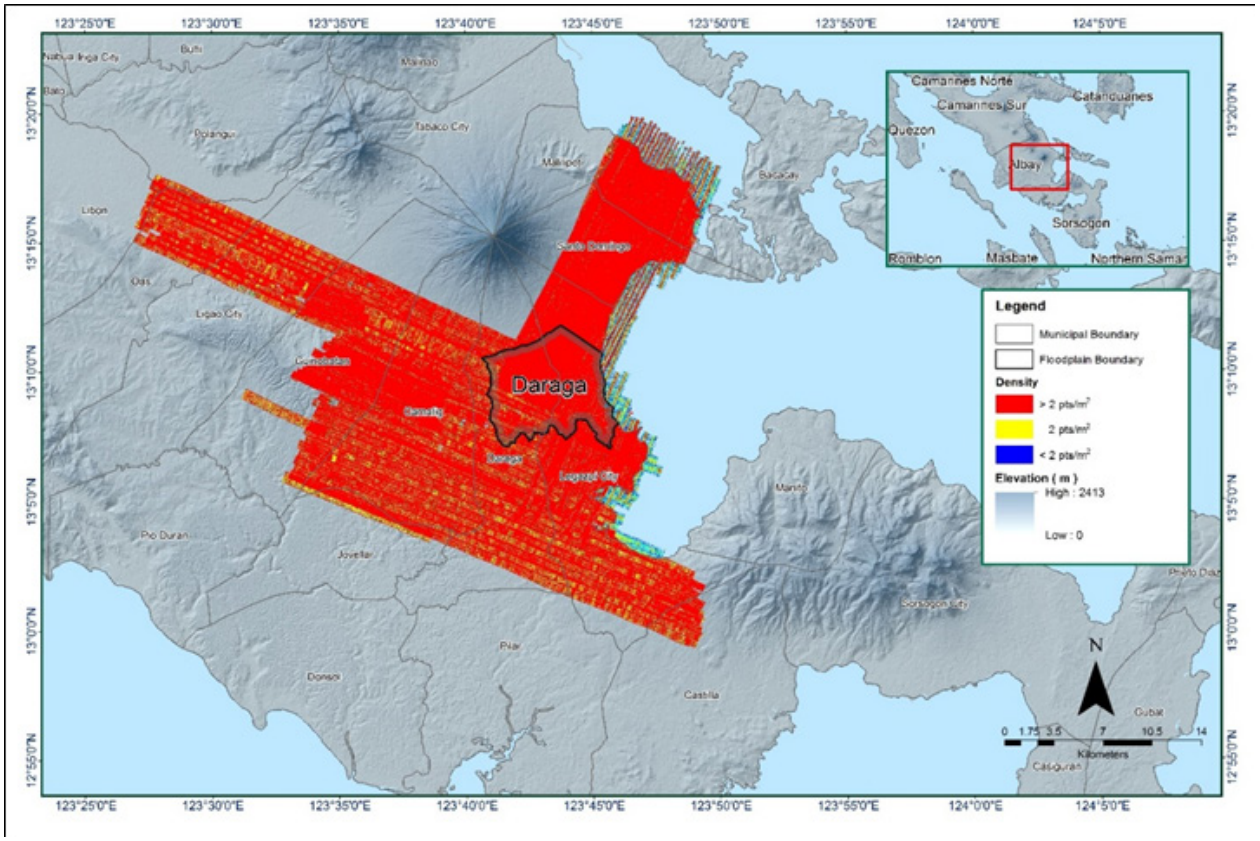


Figure A-8.20. Density map of merged LiDAR data

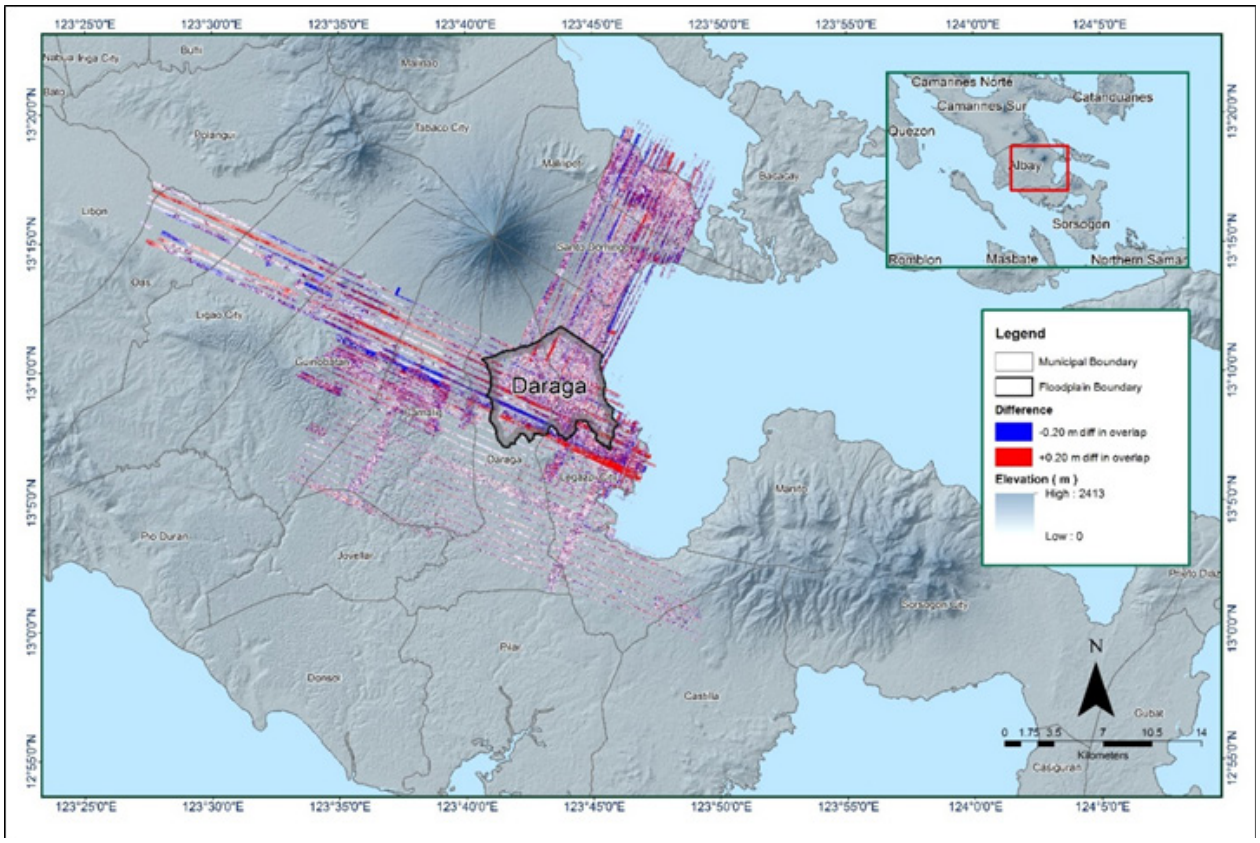


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk 19S

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19S
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)	1.68
RMSE for East Position (<4.0 cm)	1.52
RMSE for Down Position (<8.0 cm)	2.83
Boresight correction stdev (<0.001deg)	0.003201
IMU attitude correction stdev (<0.001deg)	0.017219
GPS position stdev (<0.01m)	0.0171
Minimum % overlap (>25)	25.43 %
Ave point cloud density per sq.m. (>2.0)	3.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	109
Maximum Height	400.49 m
Minimum Height	52.75 m
Classification (# of points)	
Ground	21,390,236
Low vegetation	19,781,346
Medium vegetation	107,811,221
High vegetation	99,654,273
Building	959,567
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Ma. Joanne Balaga, Engr. Melissa Fernandez

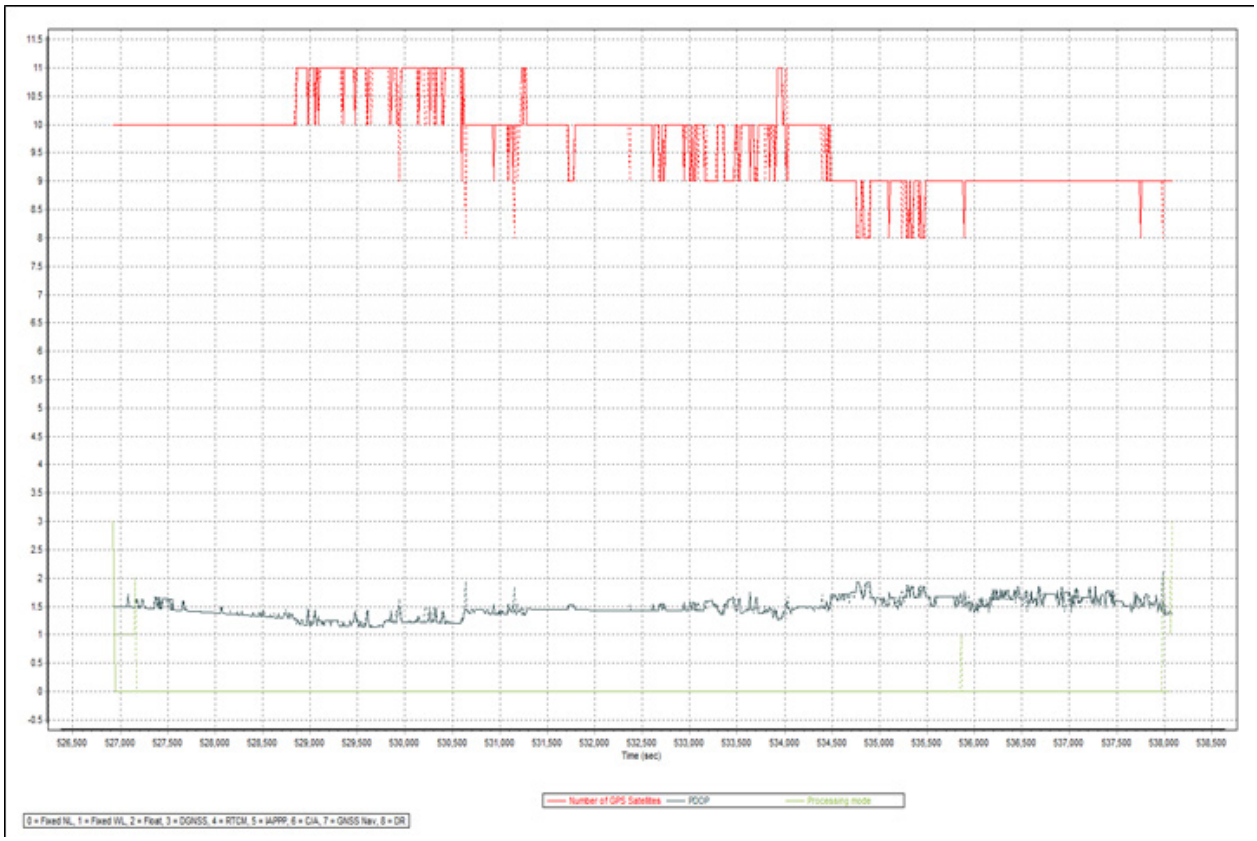


Figure A-8.22. Solution Status

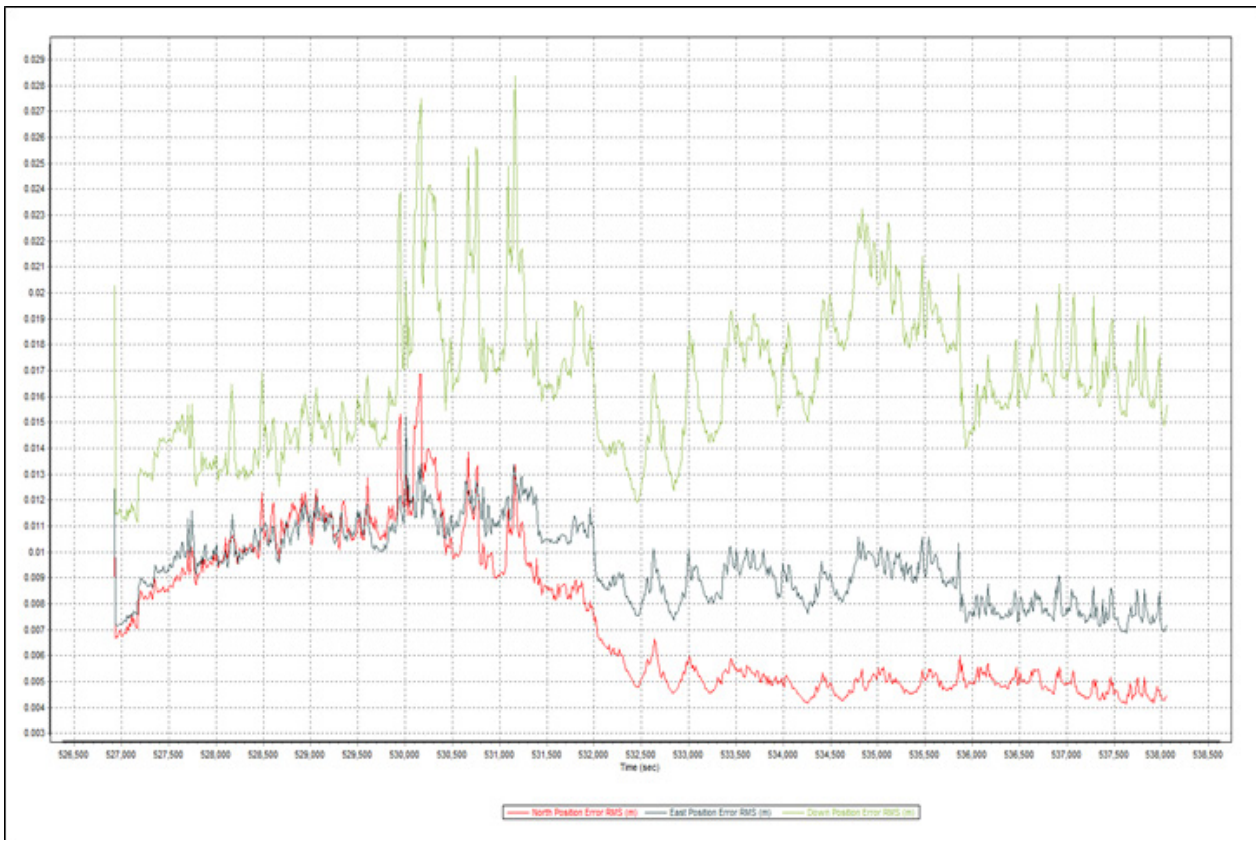


Figure A-8.23. Smoothed Performance Metric Parameters

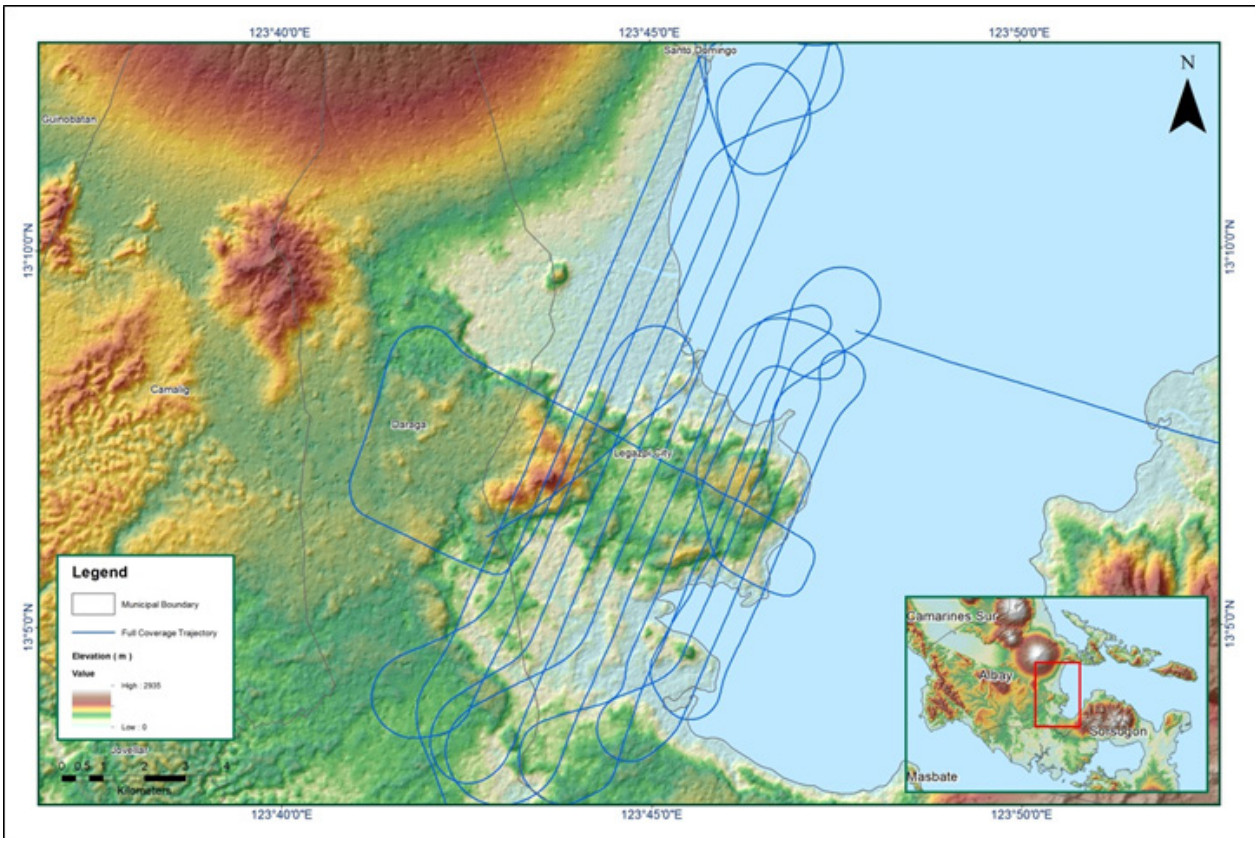


Figure A-8.24. Best Estimated Trajectory

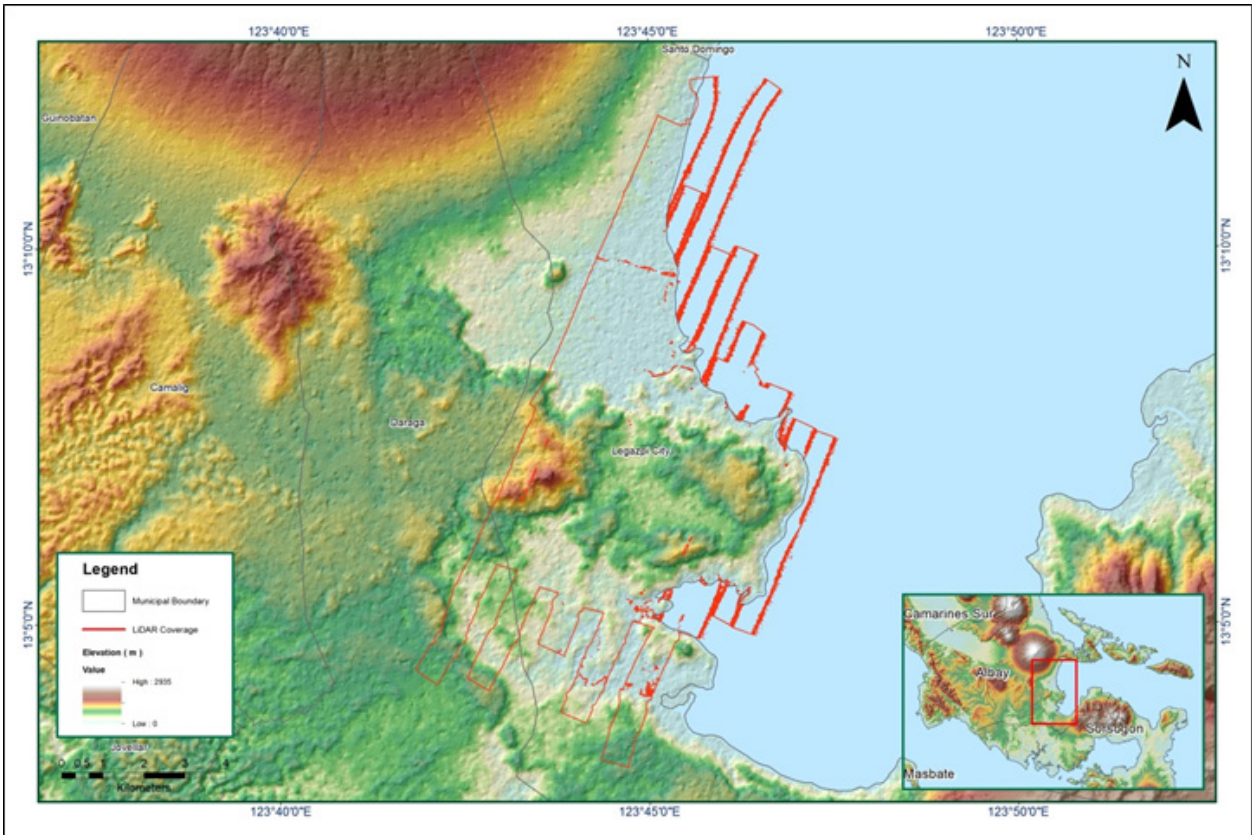


Figure A-8.25. Coverage of LiDAR data

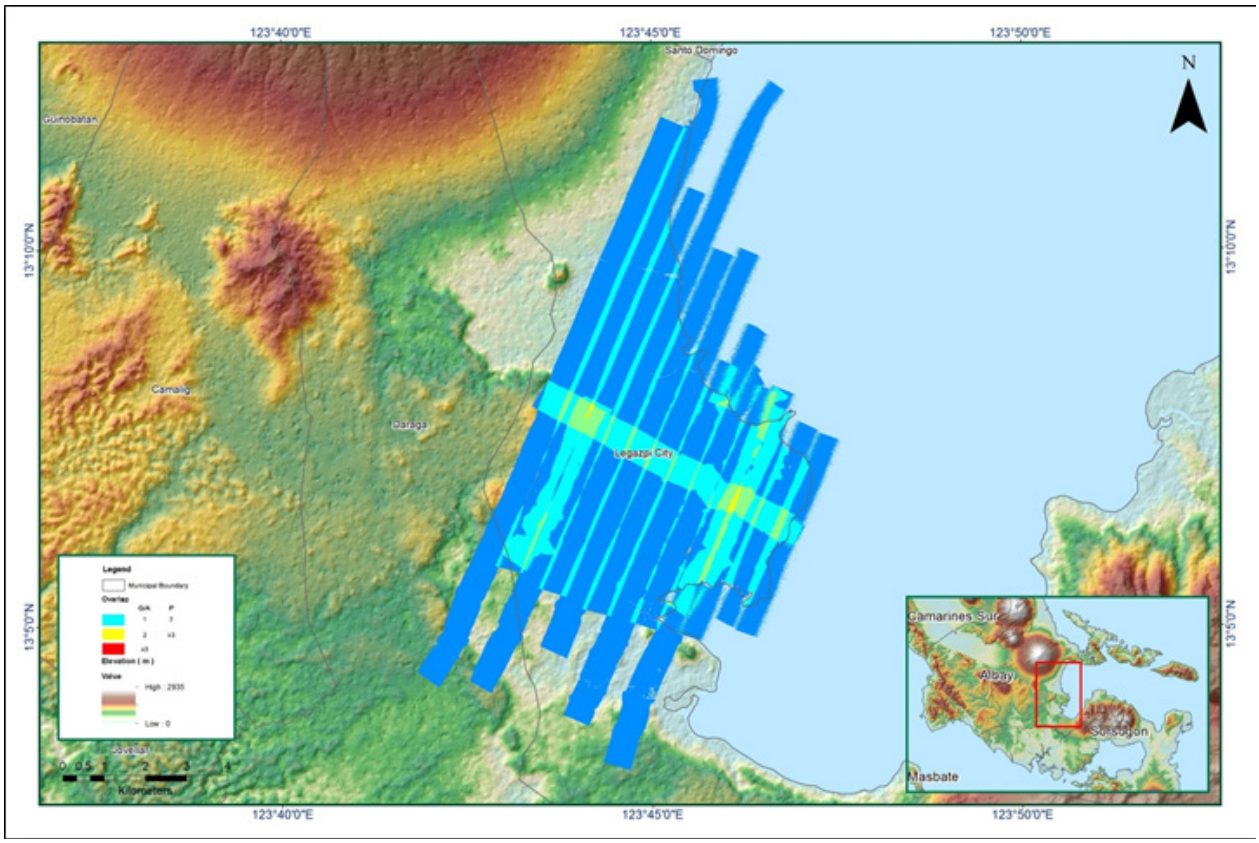


Figure A-8.26. Image of data overlap

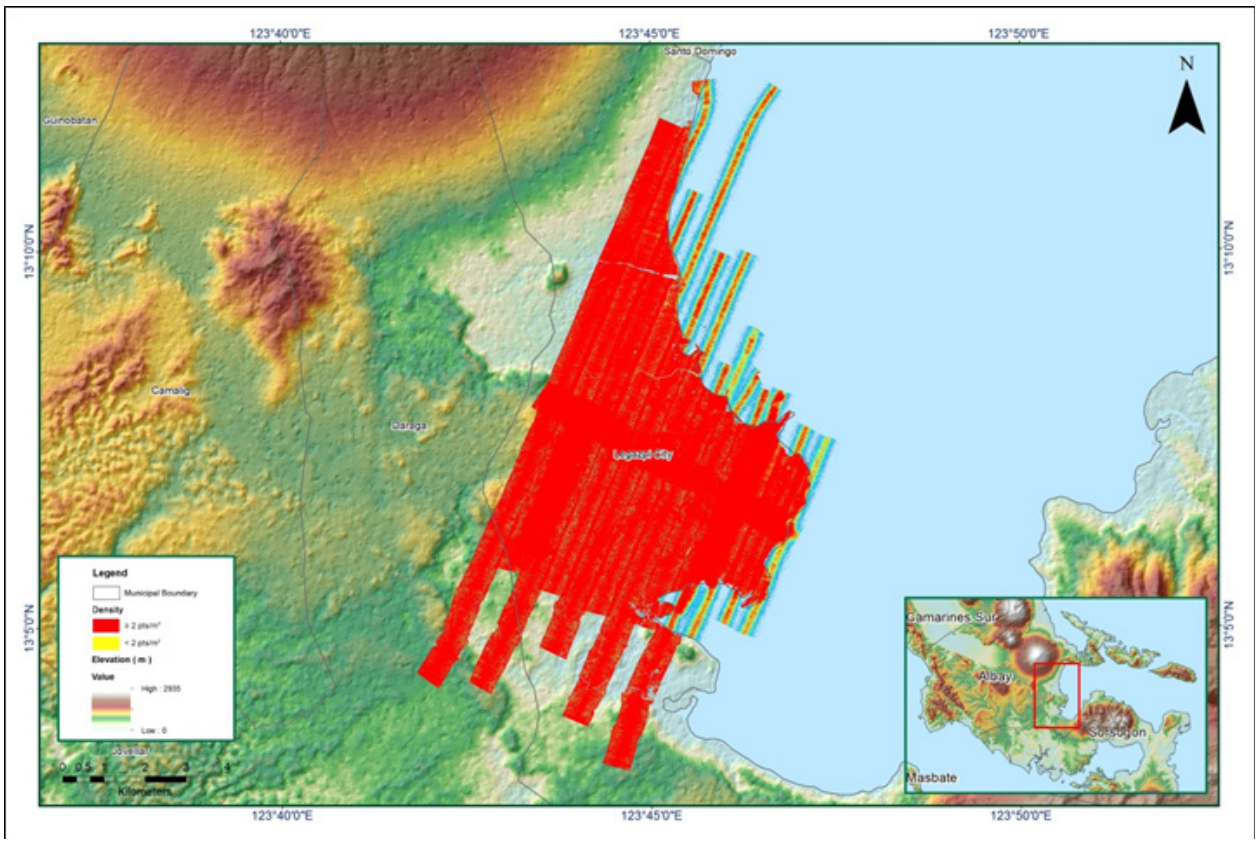


Figure A-8.27. Density map of merged LiDAR data

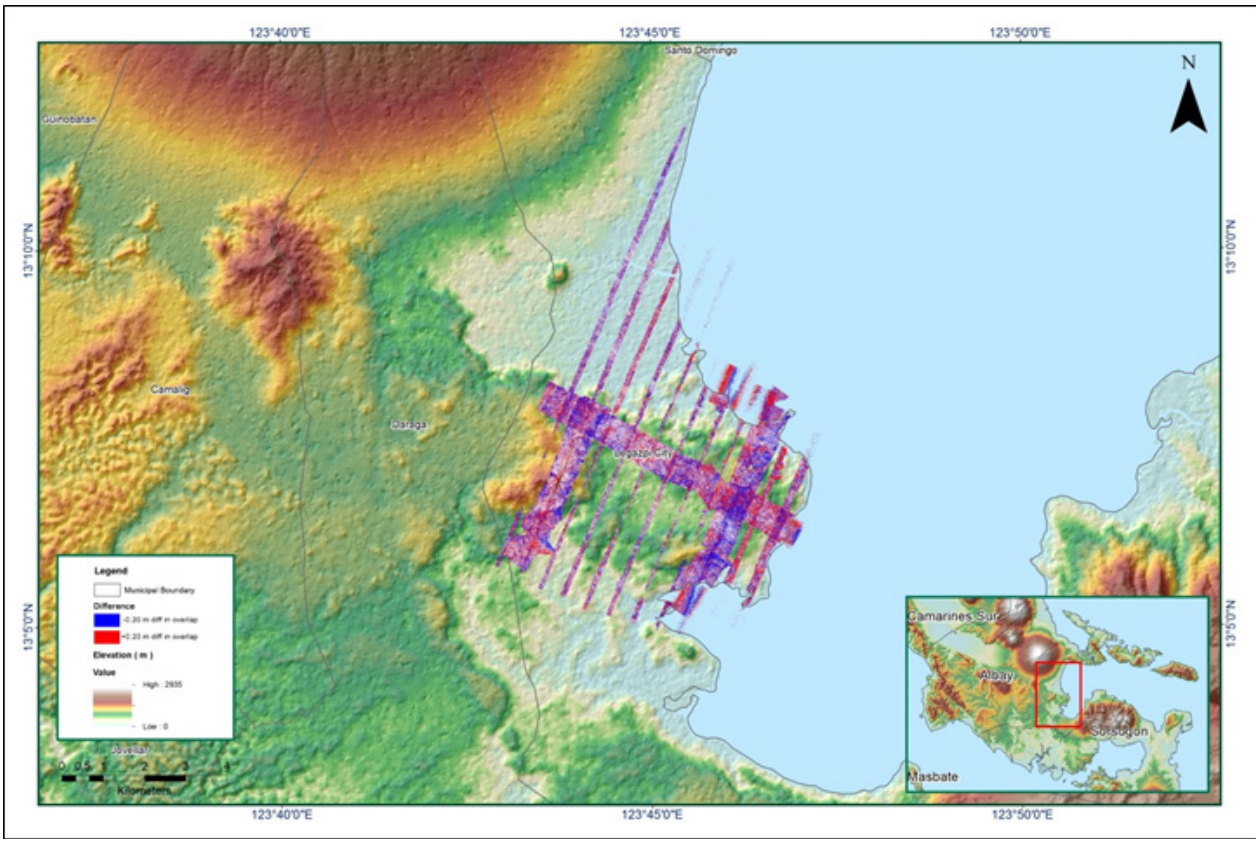


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk 19C

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19C
Inclusive Flights	3891G
Range data size	24.9 GB
POS data size	294 MB
Base data size	15.4 MB
Image	74.1 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)	1.682
RMSE for East Position (<4.0 cm)	1.422
RMSE for Down Position (<8.0 cm)	4.920
Boresight correction stdev (<0.001deg)	0.000488
IMU attitude correction stdev (<0.001deg)	0.011844
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	17.27 %
Ave point cloud density per sq.m. (>2.0)	5.72
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	22
Maximum Height	237.74 m
Minimum Height	101.52 m
Classification (# of points)	
Ground	4,581,832
Low vegetation	6,903,765
Medium vegetation	22,872,894
High vegetation	27,945,441
Building	627,594
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Mark Joshua Salvacion, Maria Tamsyn Malabanan

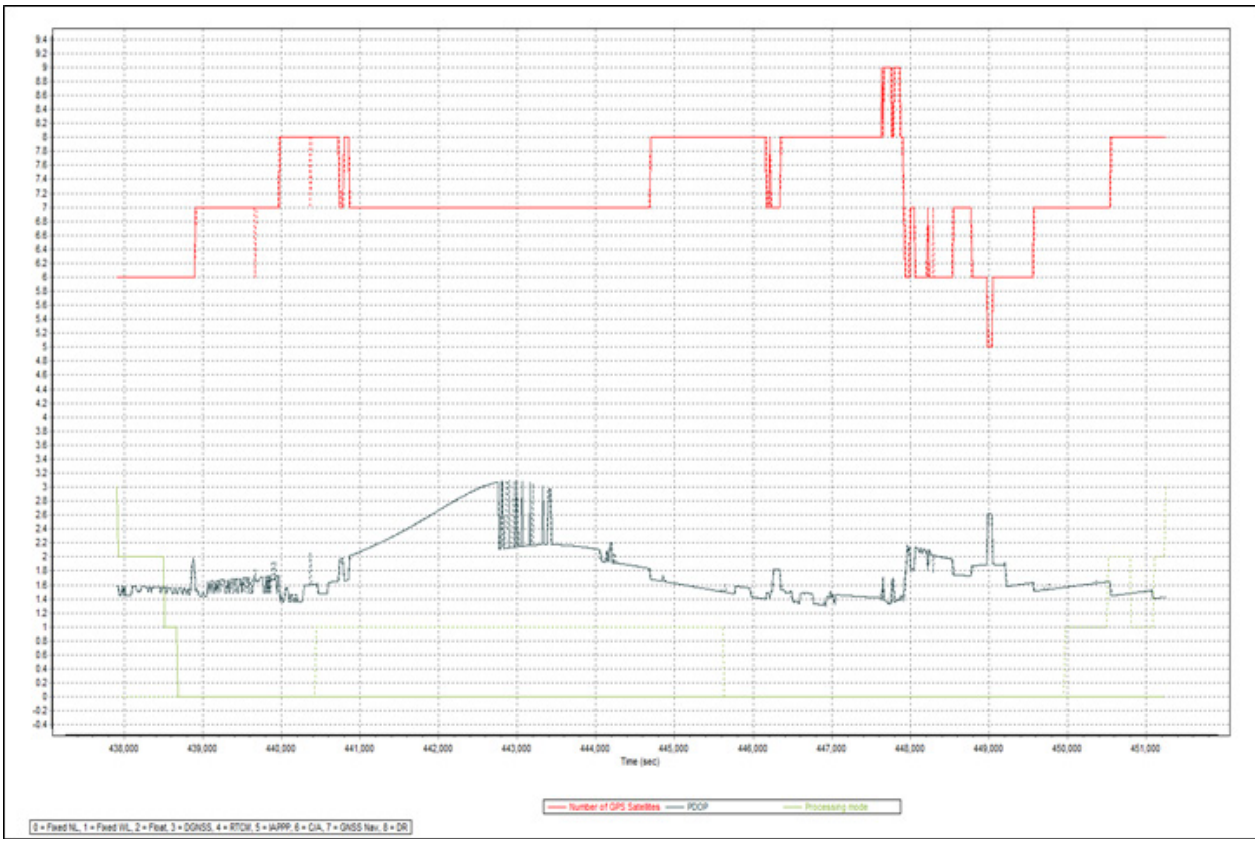


Figure A-8.29. Solution Status

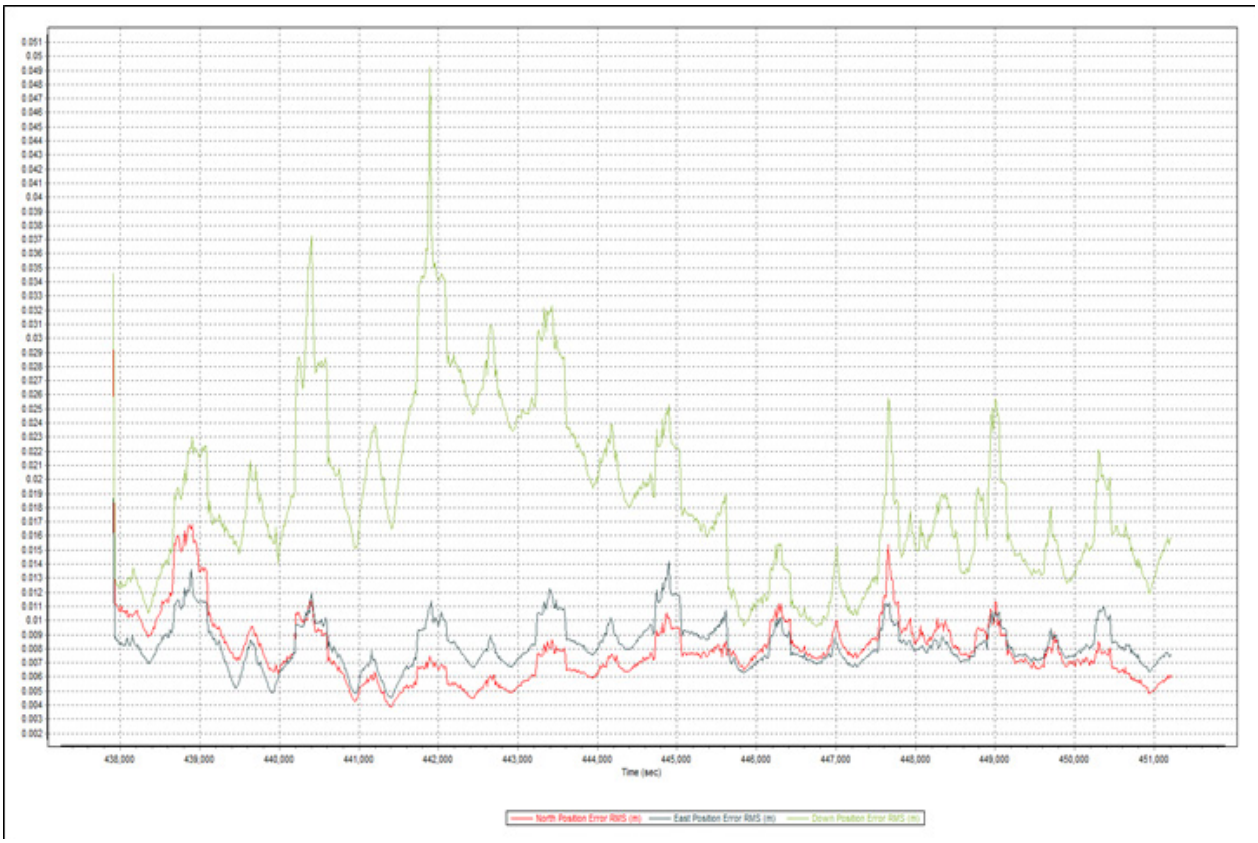


Figure A-8.30. Smoothed Performance Metric Parameters

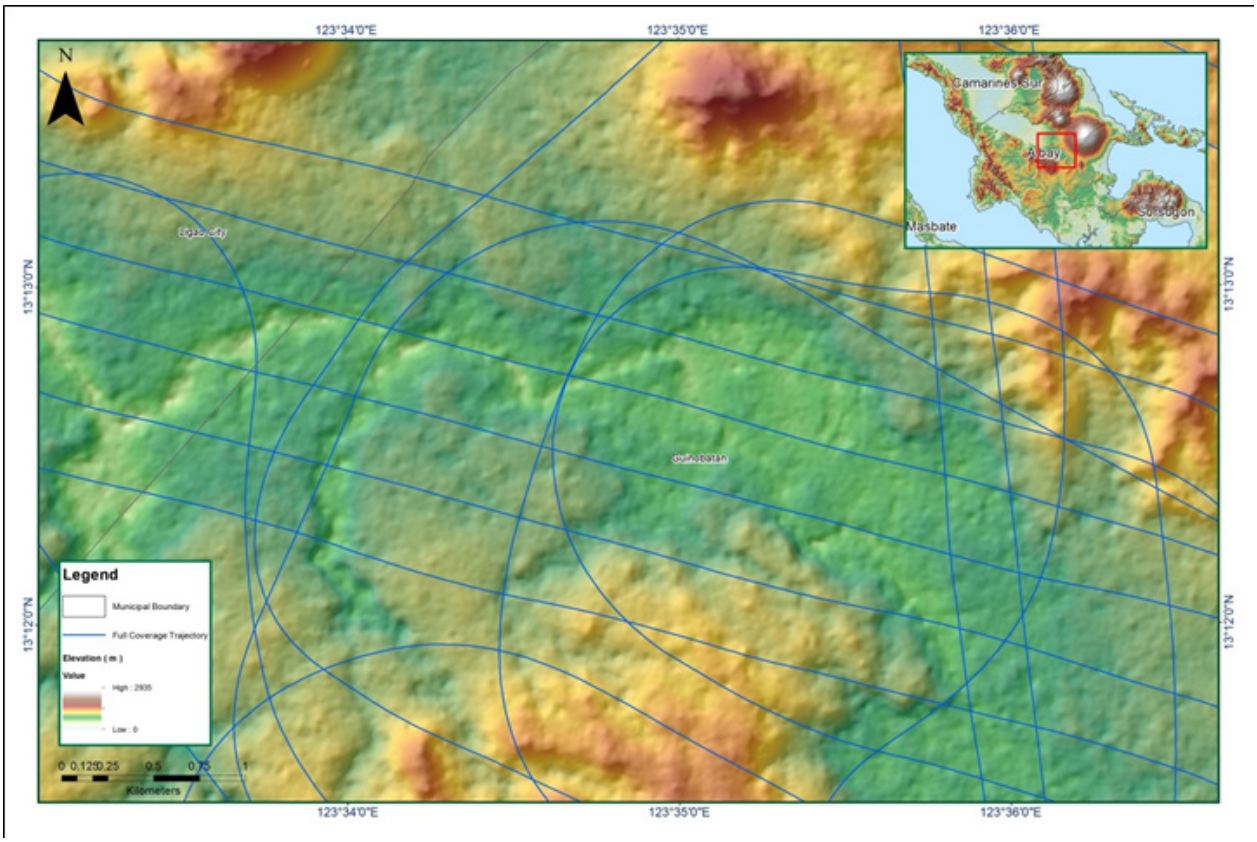


Figure A-8.31. Best Estimated Trajectory

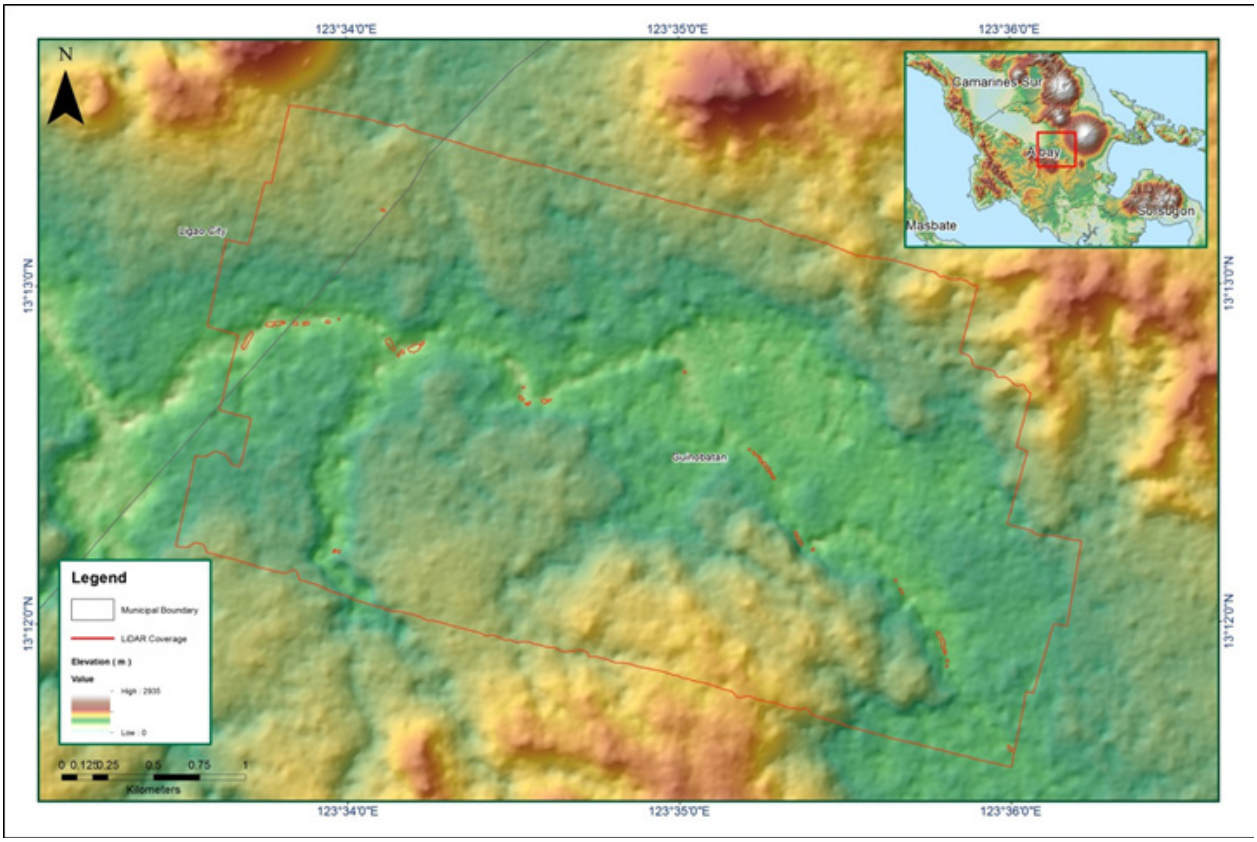


Figure A-8.32. Coverage of LiDAR data

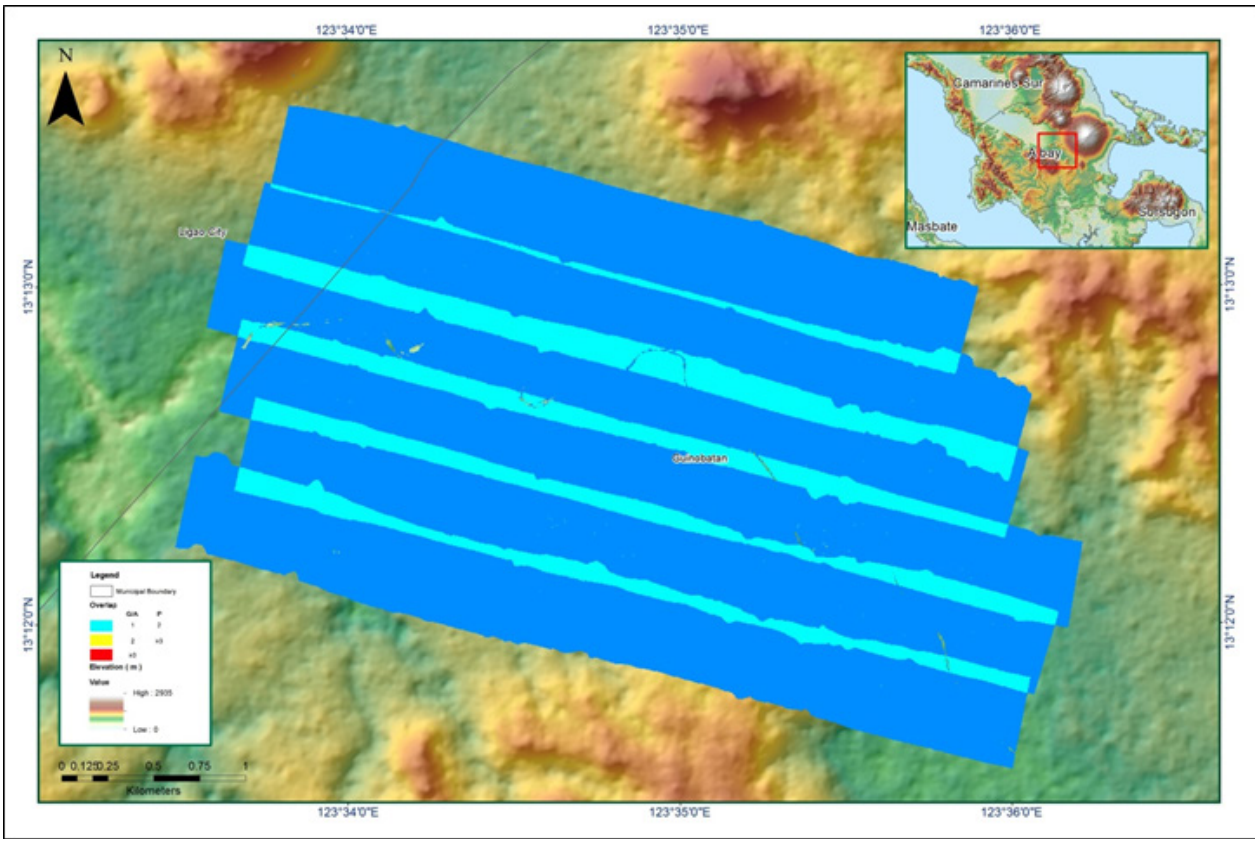


Figure A-8.33. Image of data overlap

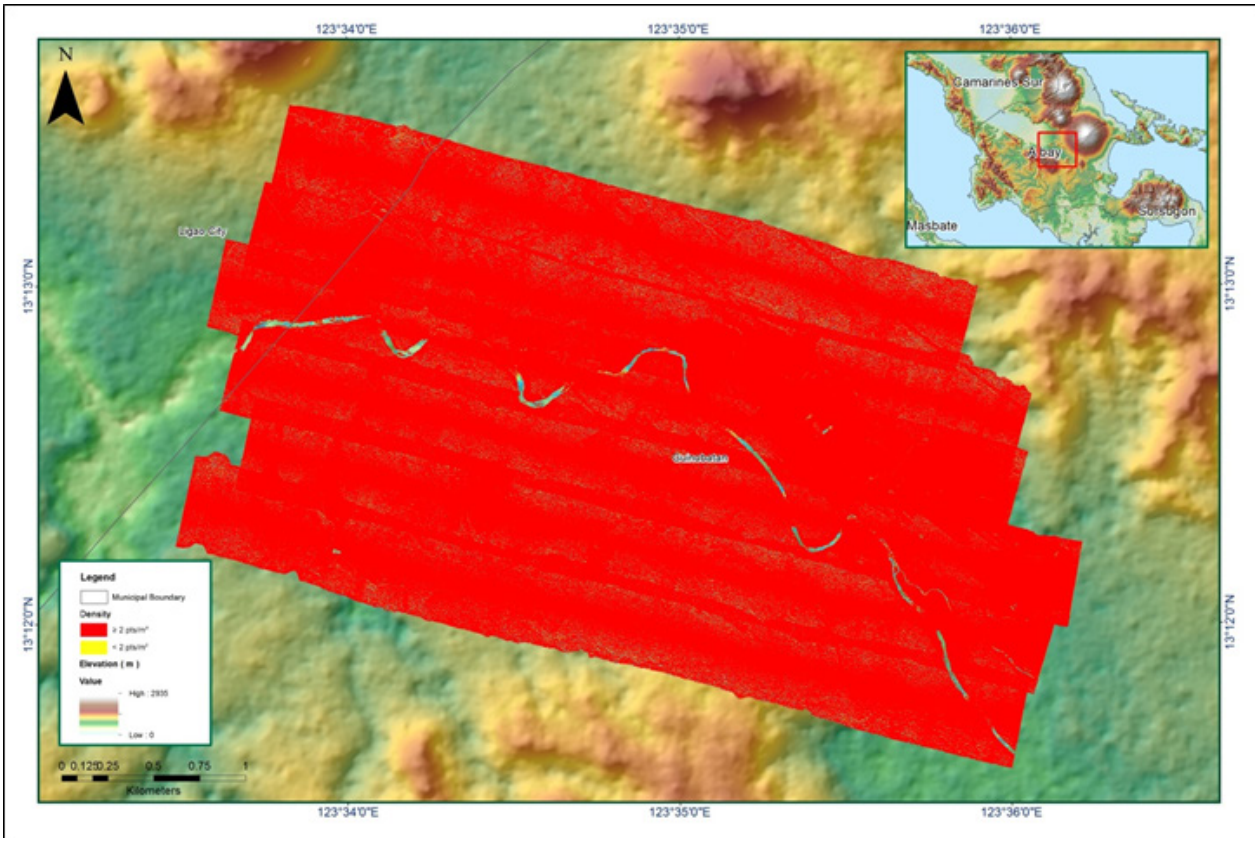


Figure A-8.34. Density map of merged LiDAR data

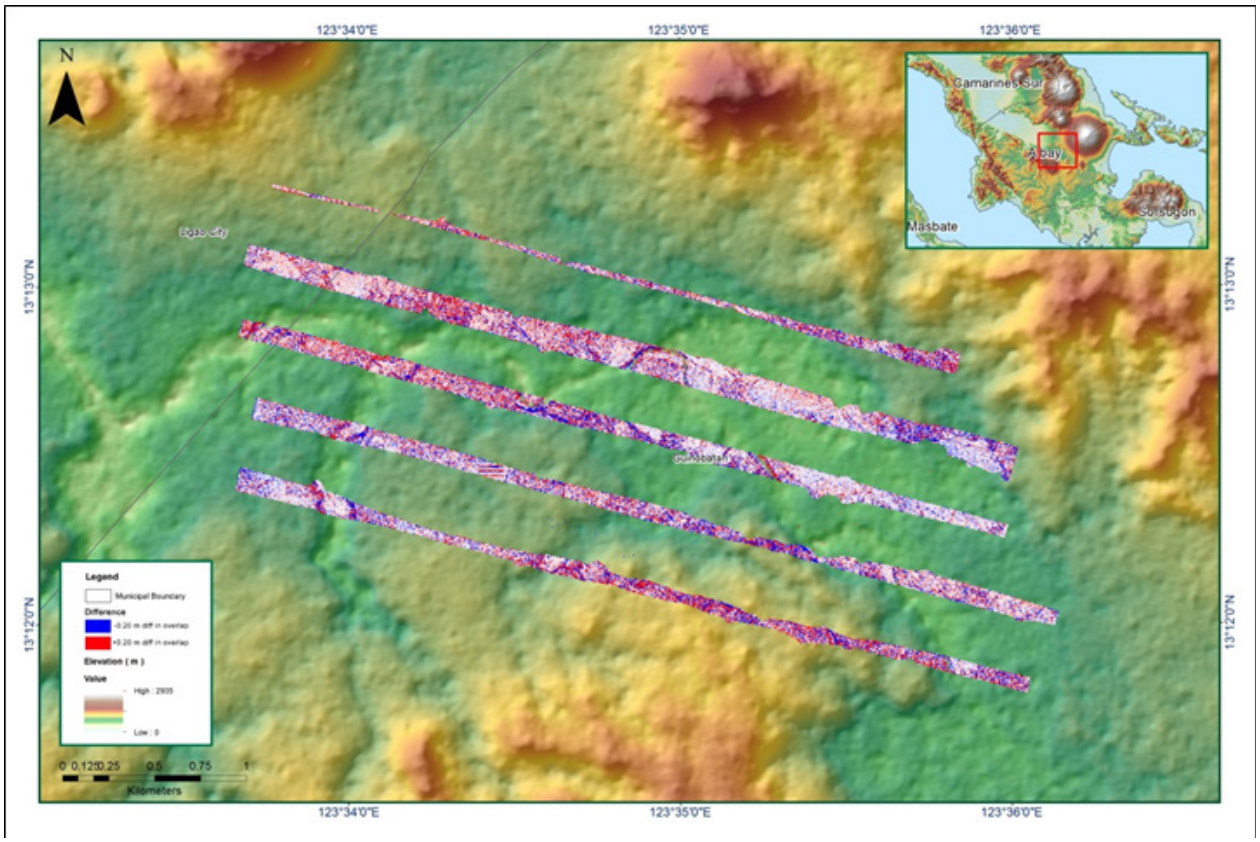


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk 19E

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19E
Inclusive Flights	3891G
Range data size	24.9 GB
POS data size	294 MB
Base data size	15.4 MB
Image	74.1 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)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	41.33 %
Ave point cloud density per sq.m. (>2.0)	5.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	70
Maximum Height	472.65 m
Minimum Height	121.45 m
Classification (# of points)	
Ground	25,302,214
Low vegetation	21,696,447
Medium vegetation	92,844,421
High vegetation	138,245,267
Building	1,233,020
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Velina Angela Bemida, Engr. Krisha Marie Bautista

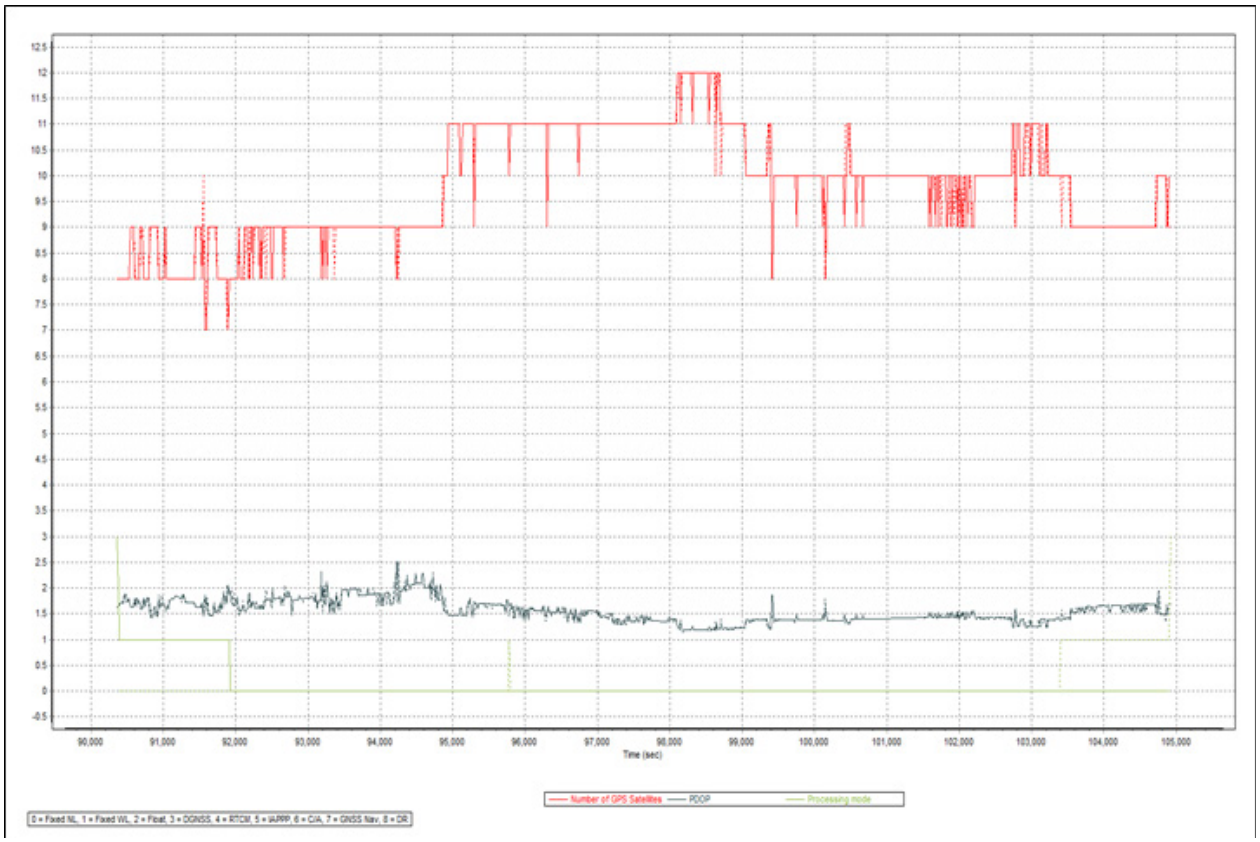


Figure A-8.36. Solution Status

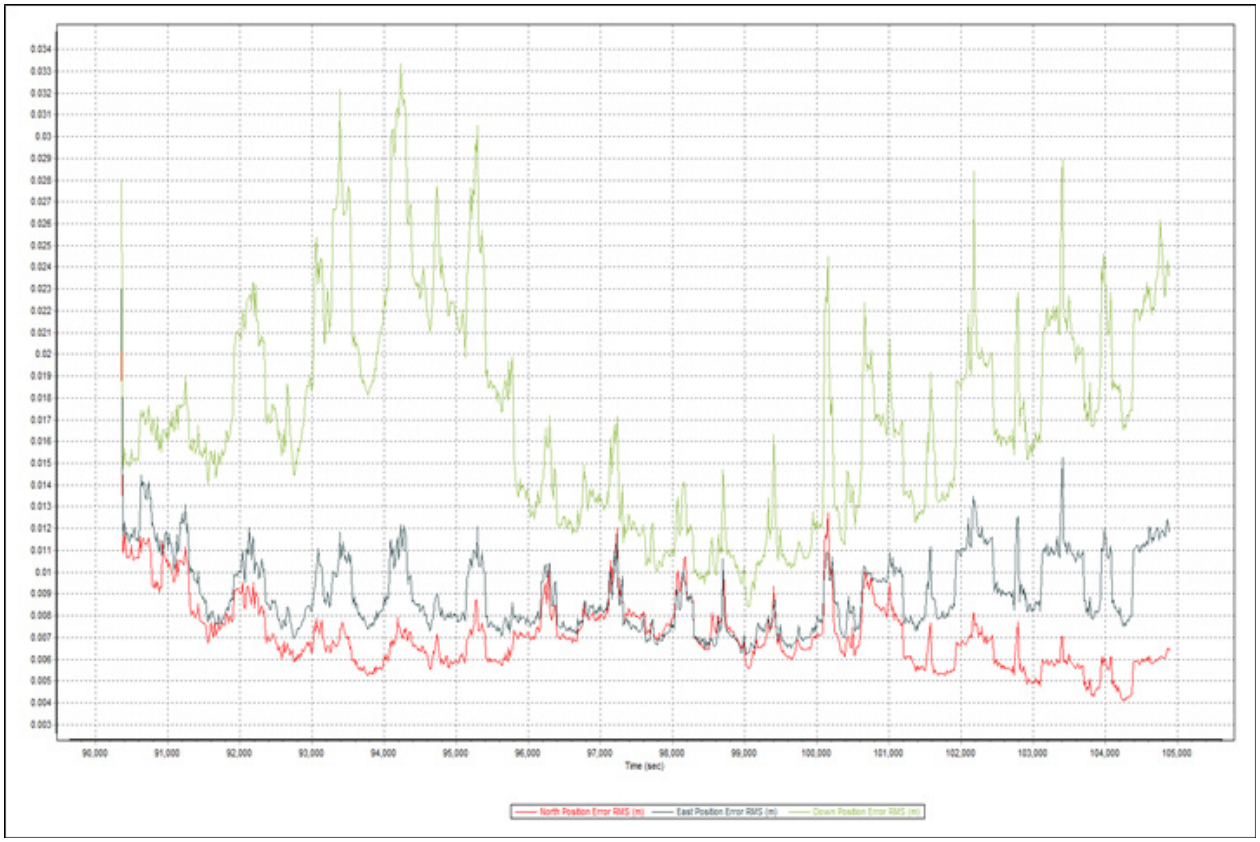


Figure A-8.37. Smoothed Performance Metric Parameters

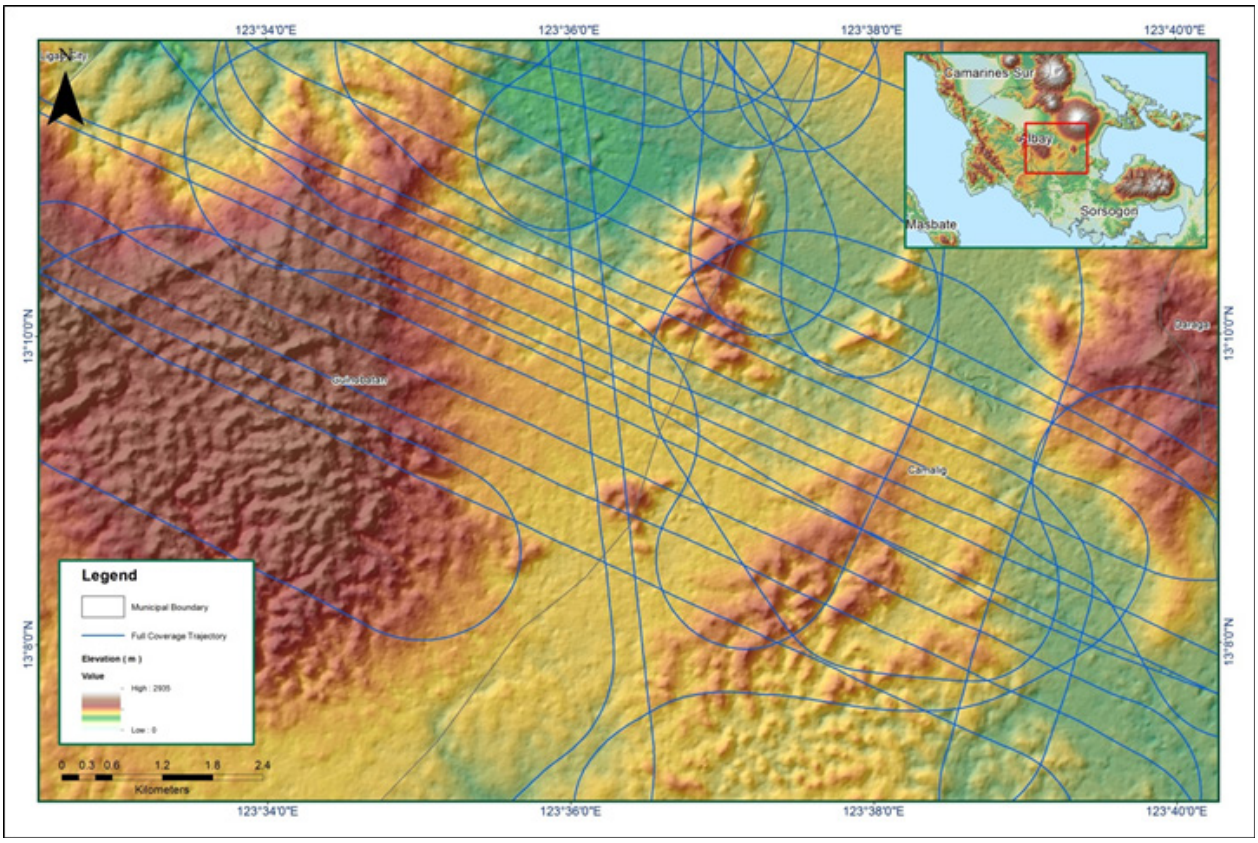


Figure A-8.38. Best Estimated Trajectory

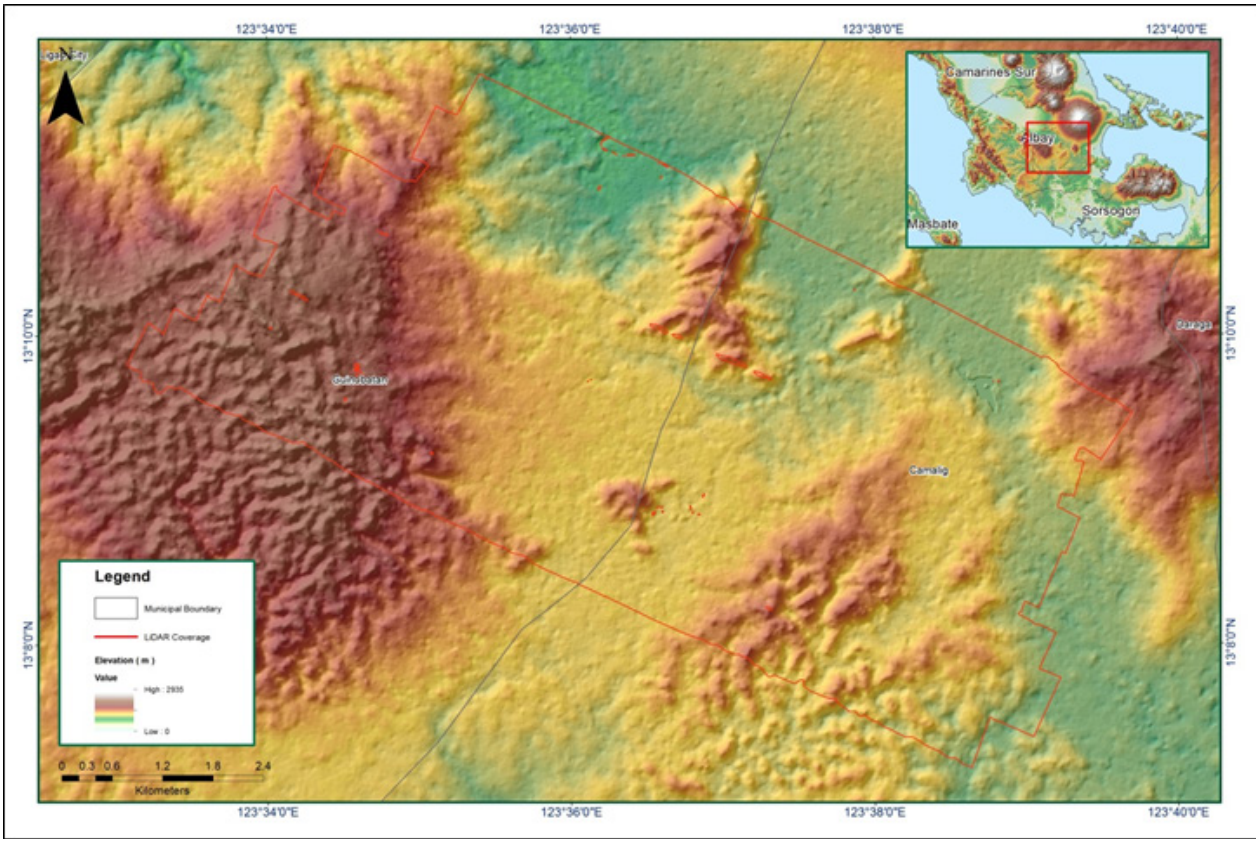


Figure A-8.39. Coverage of LiDAR data

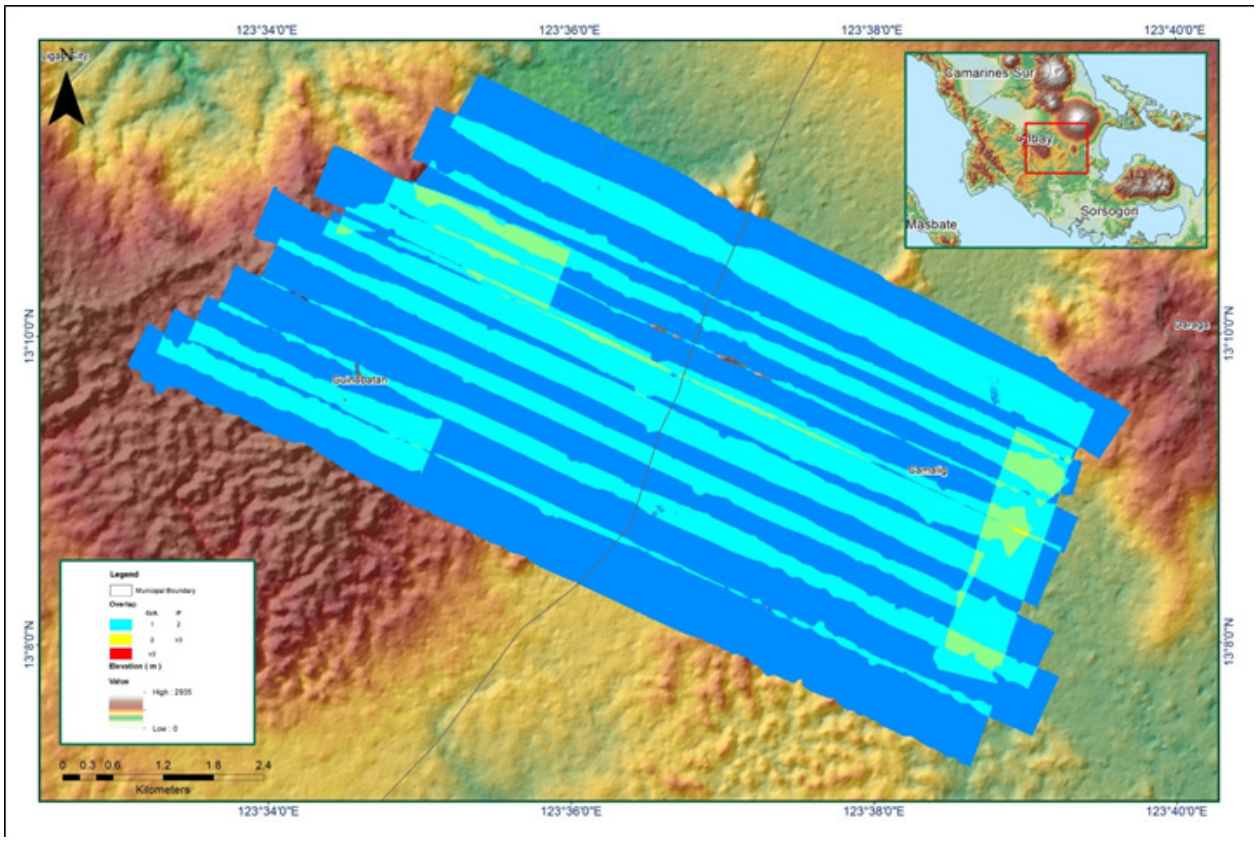


Figure A-8.40. Image of data overlap

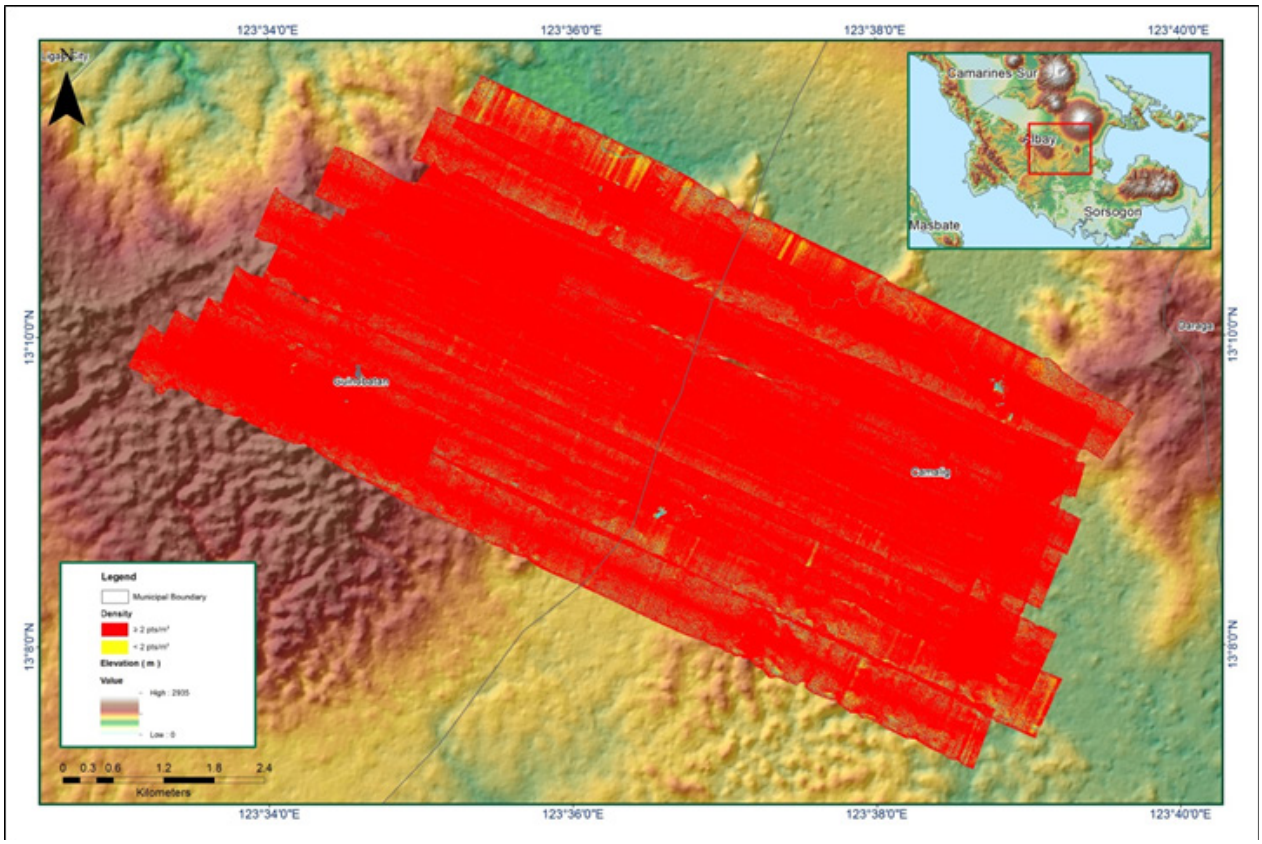


Figure A-8.41. Density map of merged LiDAR data

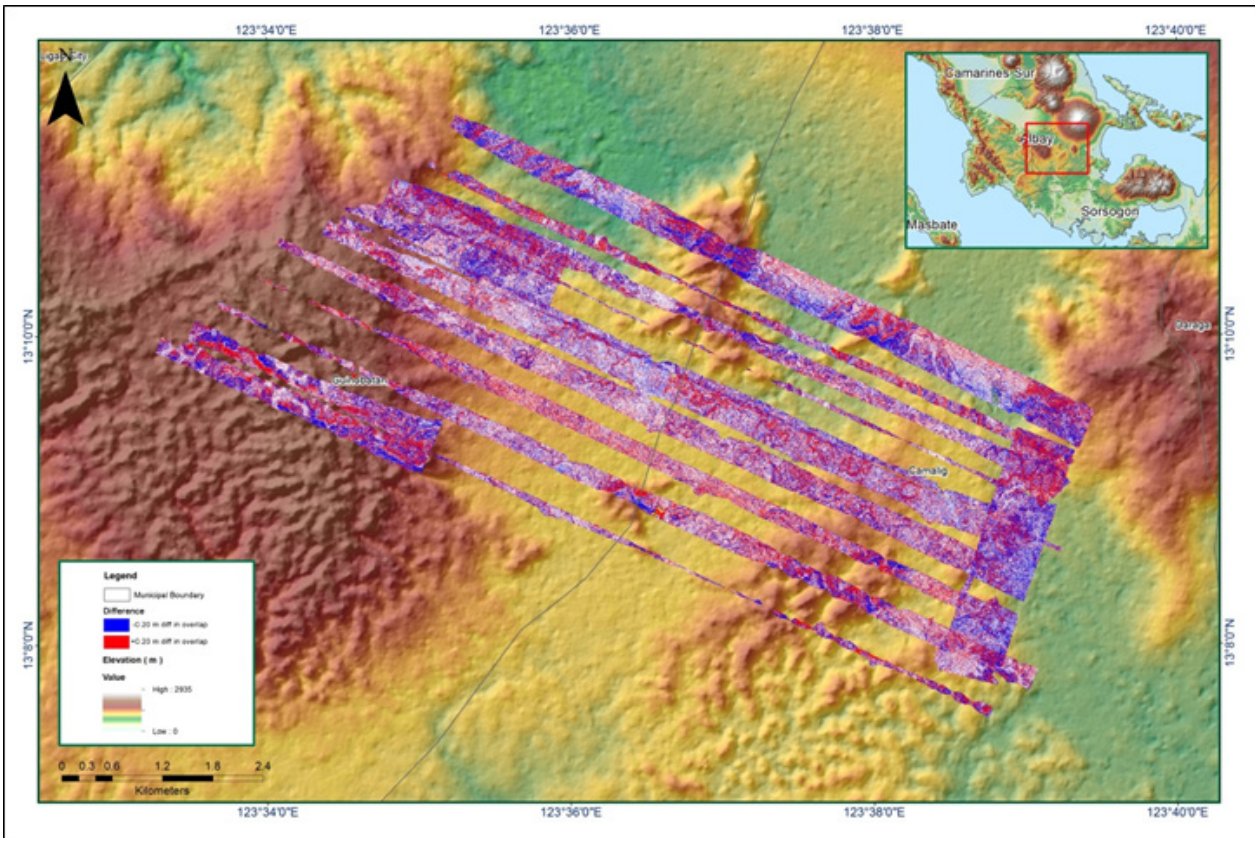


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk 19B

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19B
Inclusive Flights	3827G
Range data size	33.6 GB
POS data size	265 MB
Base data size	11.7 MB
Image	2.2 MB
Transfer date	March 21, 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)	1.134
RMSE for East Position (<4.0 cm)	1.390
RMSE for Down Position (<8.0 cm)	2.780
Boresight correction stdev (<0.001deg)	0.430905
IMU attitude correction stdev (<0.001deg)	0.0010
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	39.37 %
Ave point cloud density per sq.m. (>2.0)	6.05
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	190
Maximum Height	440.79 m
Minimum Height	52.27 m
Classification (# of points)	
Ground	56,173,397
Low vegetation	70,939,476
Medium vegetation	379,025,191
High vegetation	308,971,618
Building	15,256,745
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Justine Francisco, Jovy Narisma

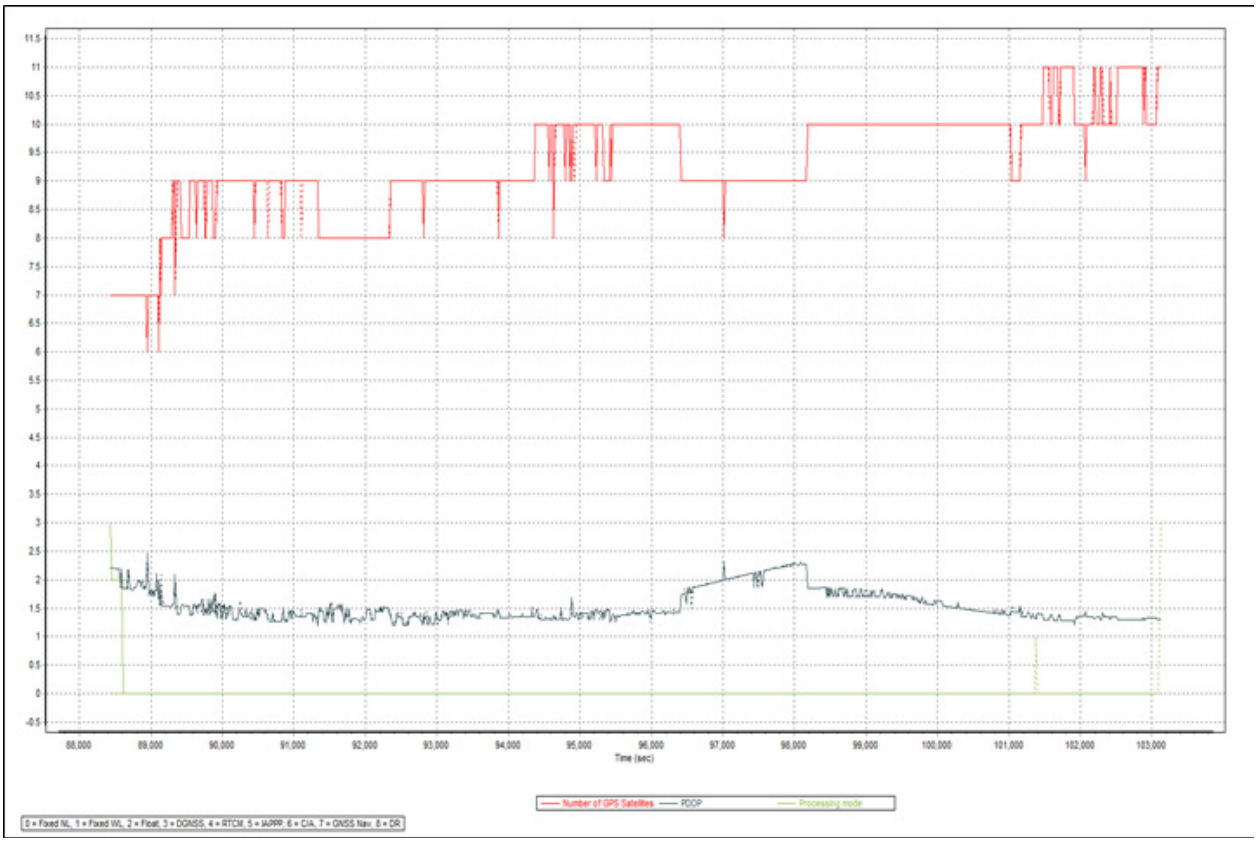


Figure A-8.43. Solution Status

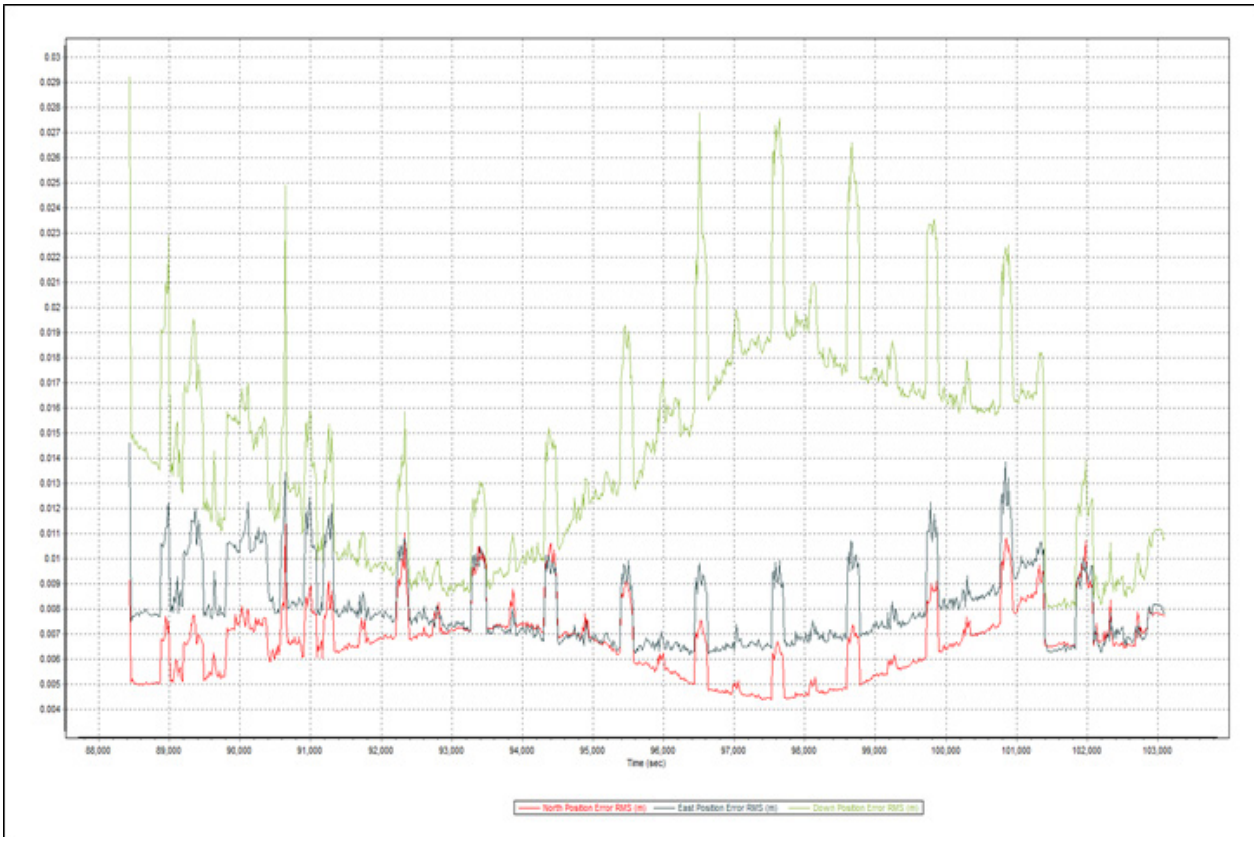


Figure A-8.44. Smoothed Performance Metric Parameters

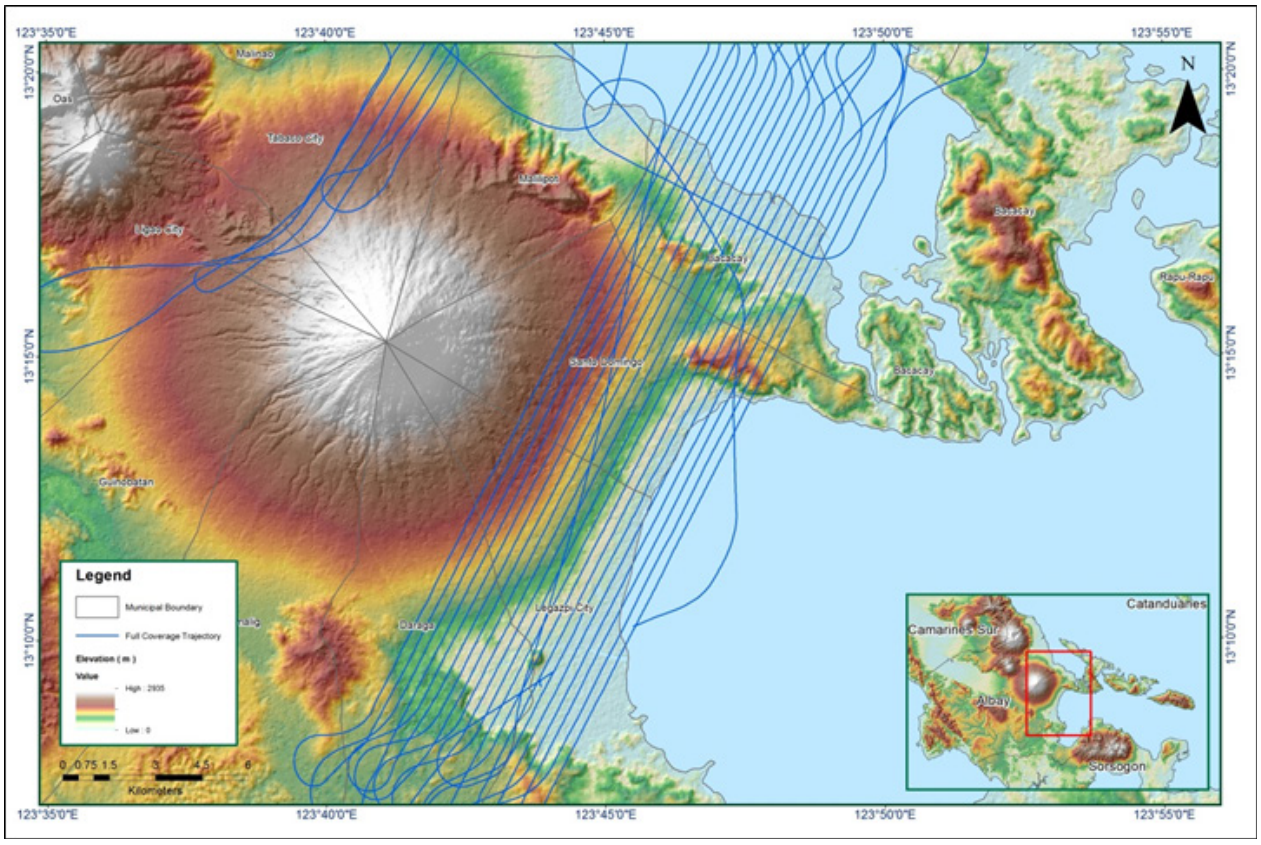


Figure A-8.45. Best Estimated Trajectory

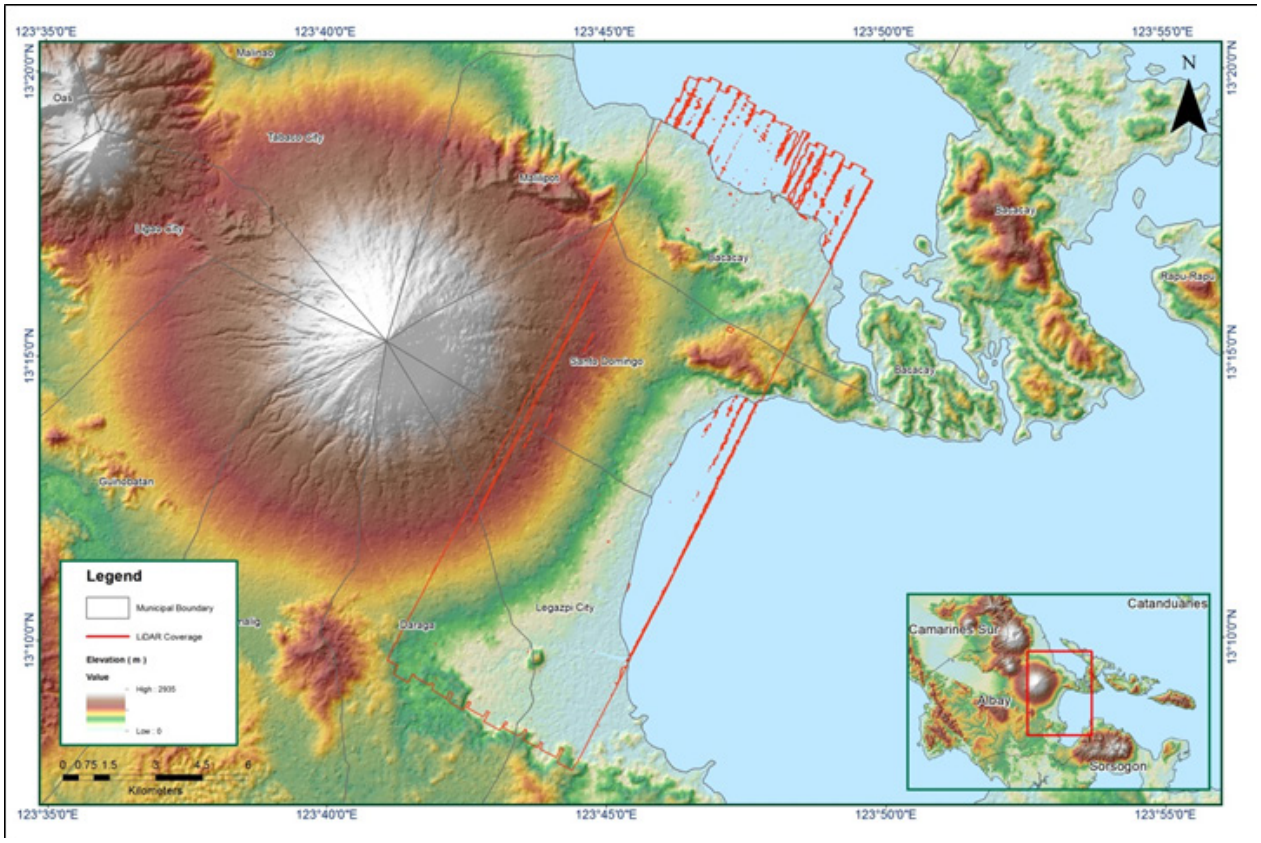


Figure A-8.46. Coverage of LiDAR data

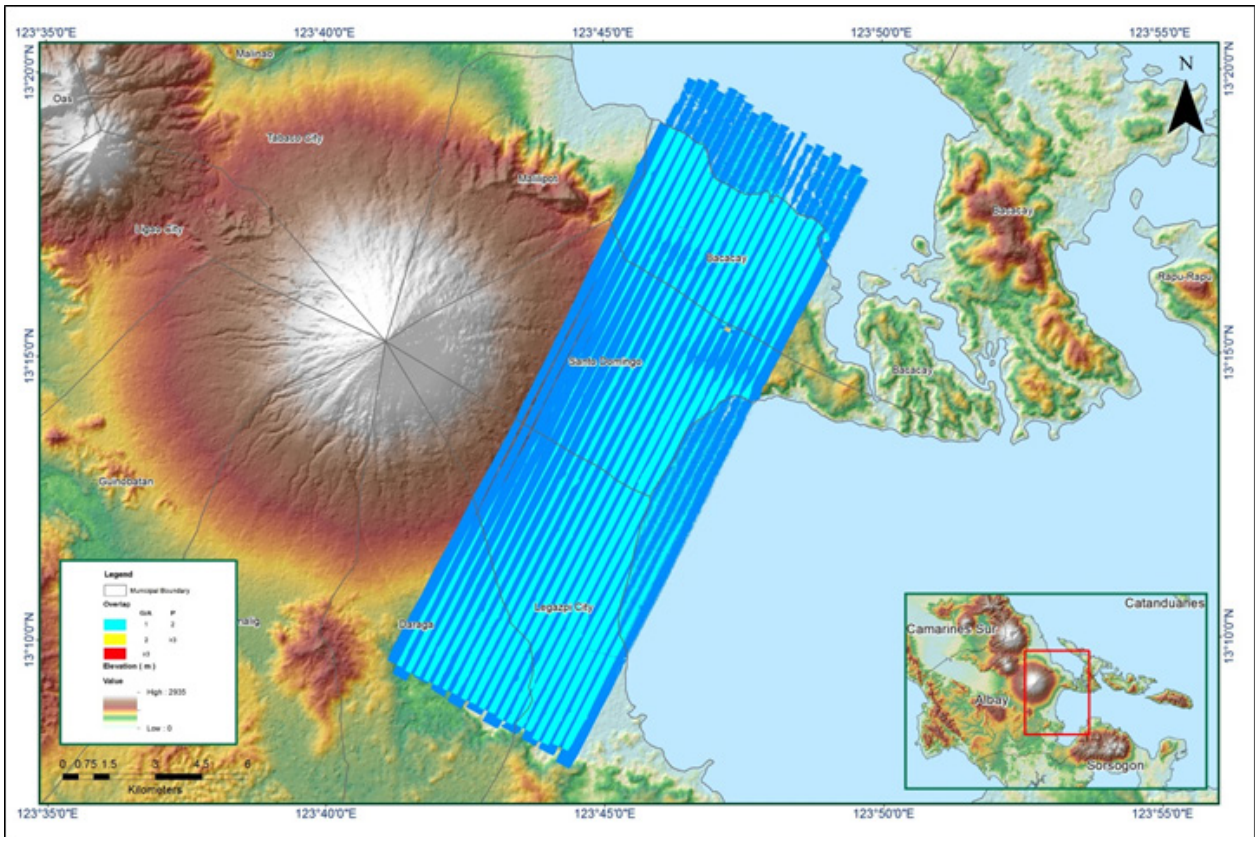


Figure A-8.47. Image of data overlap

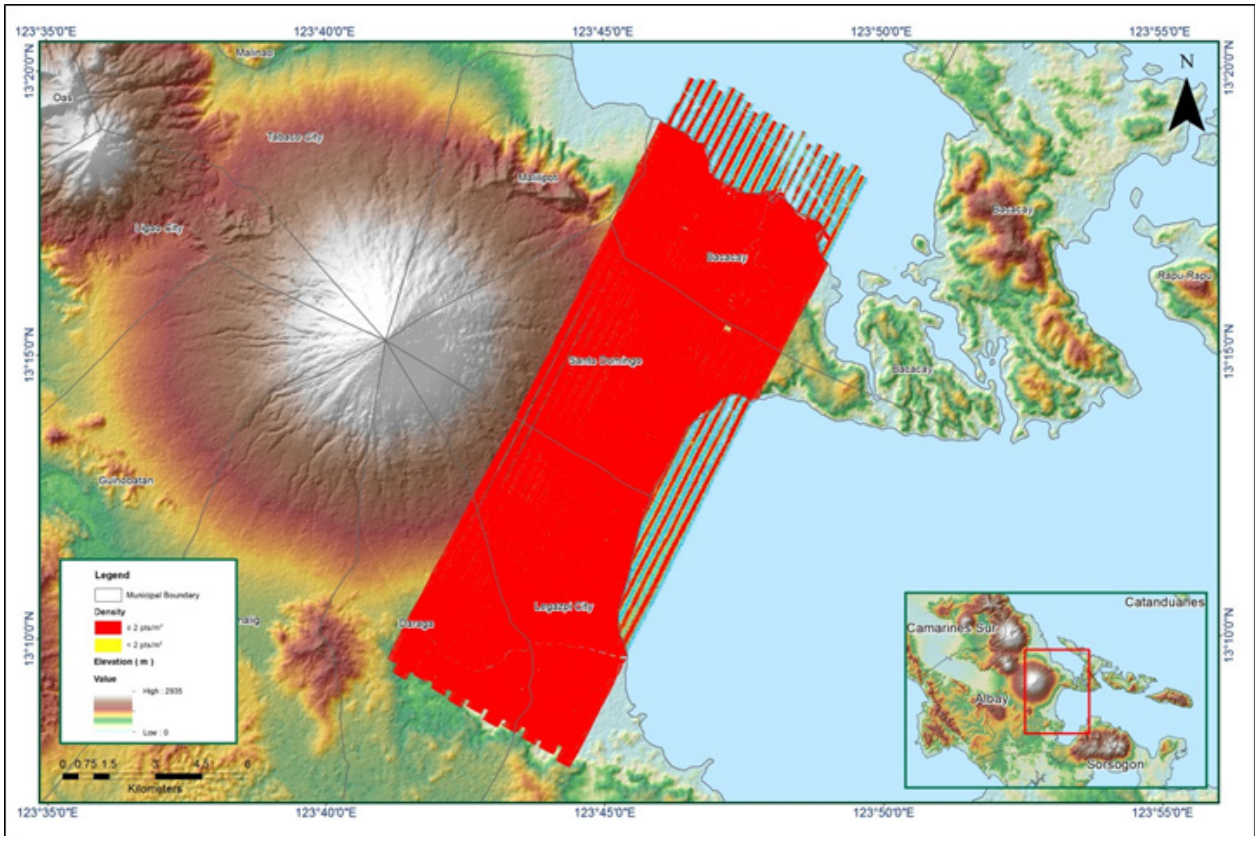


Figure A-8.48. Density map of merged LiDAR data

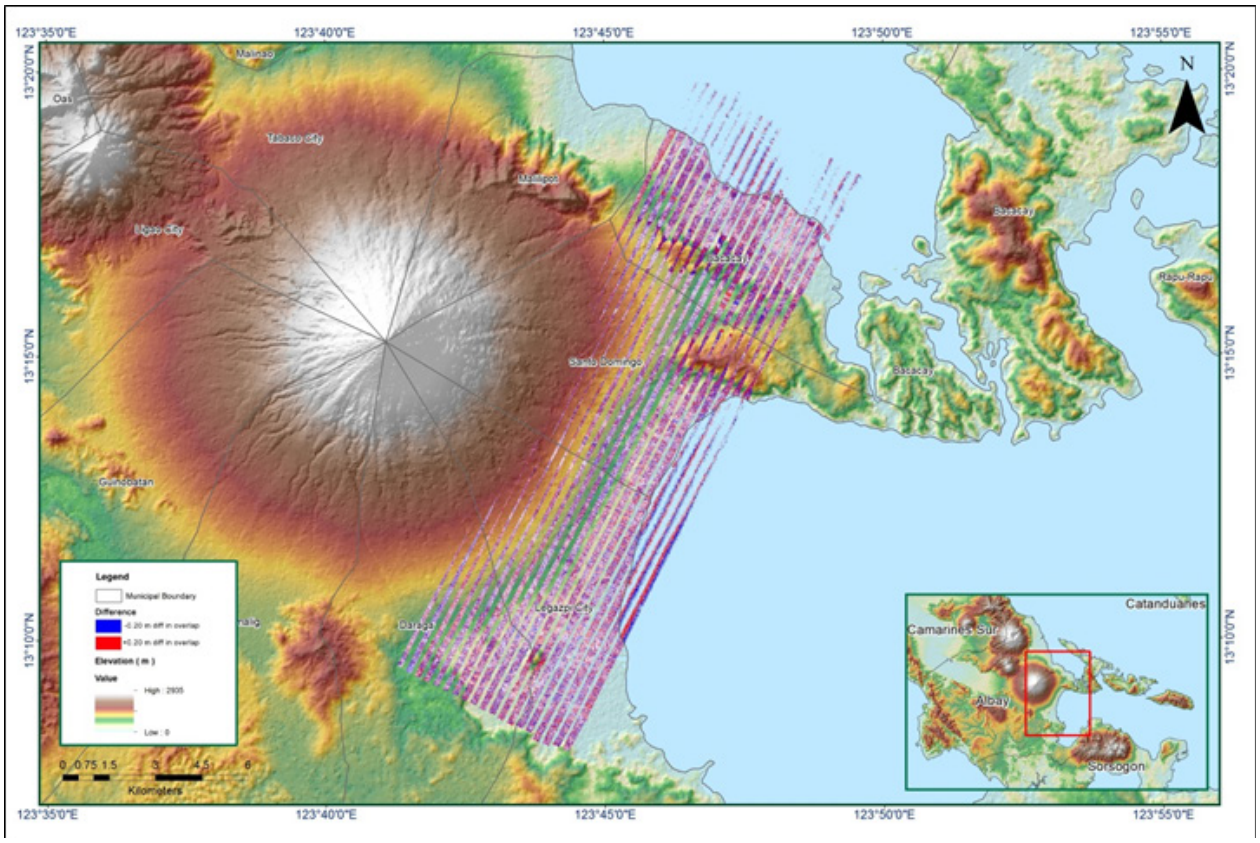


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk 19B_supplement

Flight Area	ALBAY/ SORSOGON
Mission Name	Blk 19B_supplement
Inclusive Flights	3869G
Range data size	18.9 GB
POS data size	283 MB
Base data size	10 MB
Image	32.5 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)	1.530
RMSE for East Position (<4.0 cm)	1.045
RMSE for Down Position (<8.0 cm)	4.425
Boresight correction stdev (<0.001deg)	0.001412
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	29.62 %
Ave point cloud density per sq.m. (>2.0)	5.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	77
Maximum Height	465.74 m
Minimum Height	52.01 m
Classification (# of points)	
Ground	9,697,590
Low vegetation	9,655,375
Medium vegetation	56,951,554
High vegetation	72,457,392
Building	686,658
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Merven Matthew Natino, Maria Tamsyn Malabanan

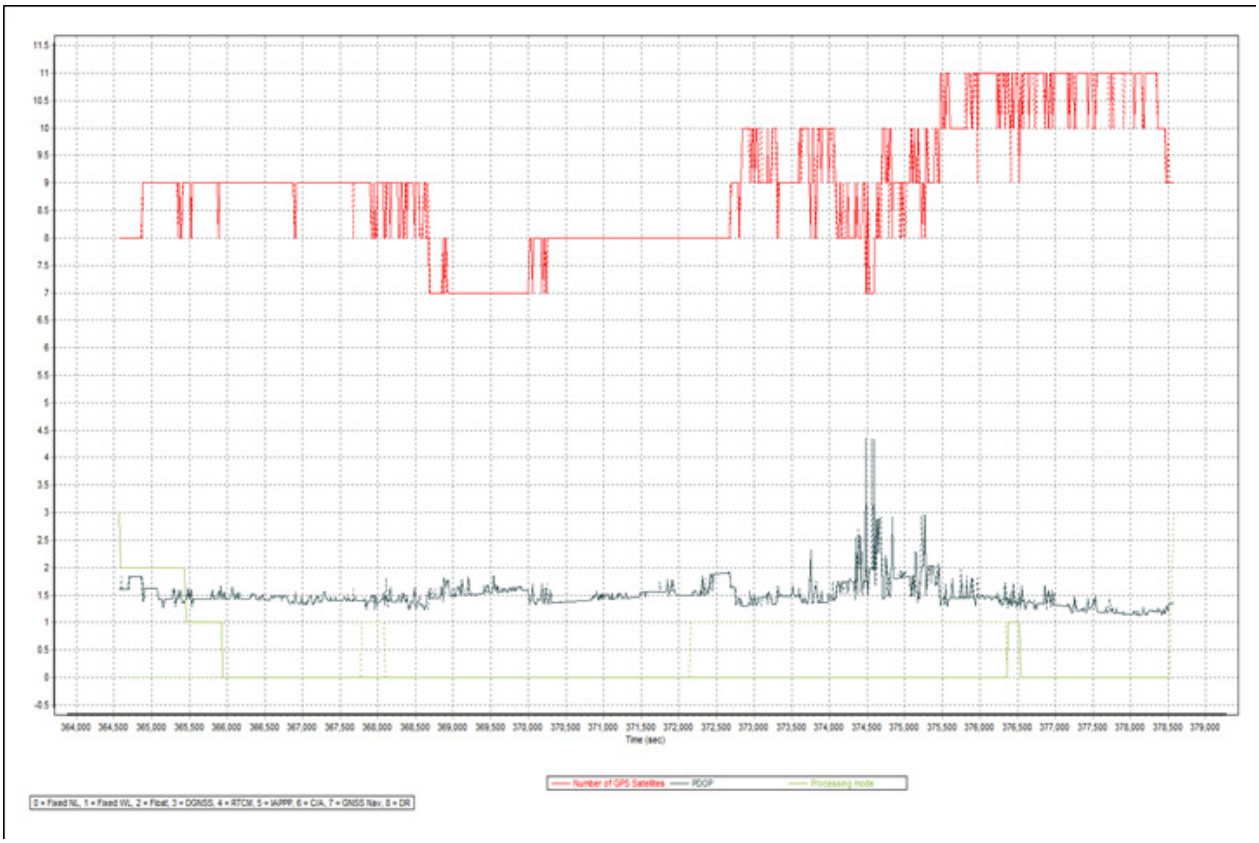


Figure A-8.50. Solution Status

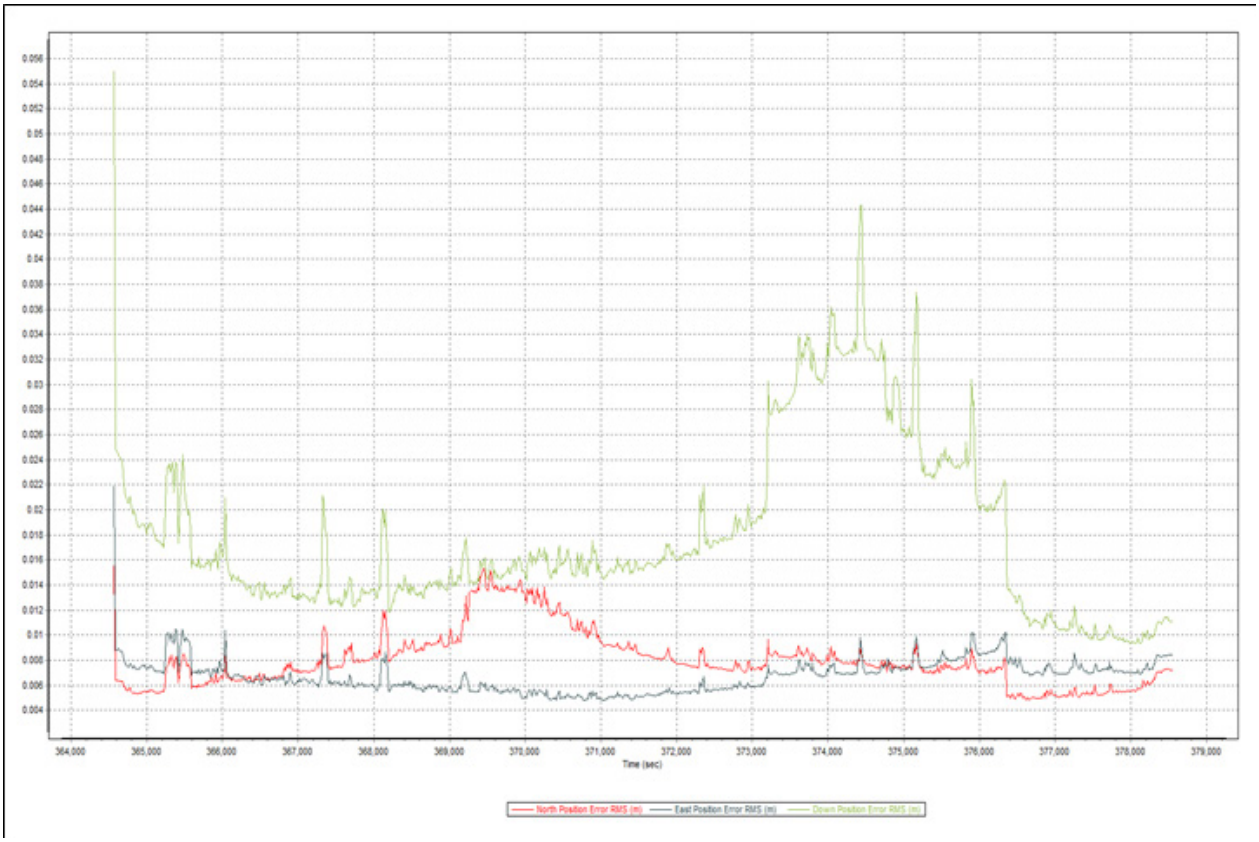


Figure A-8.51. Smoothed Performance Metric Parameters

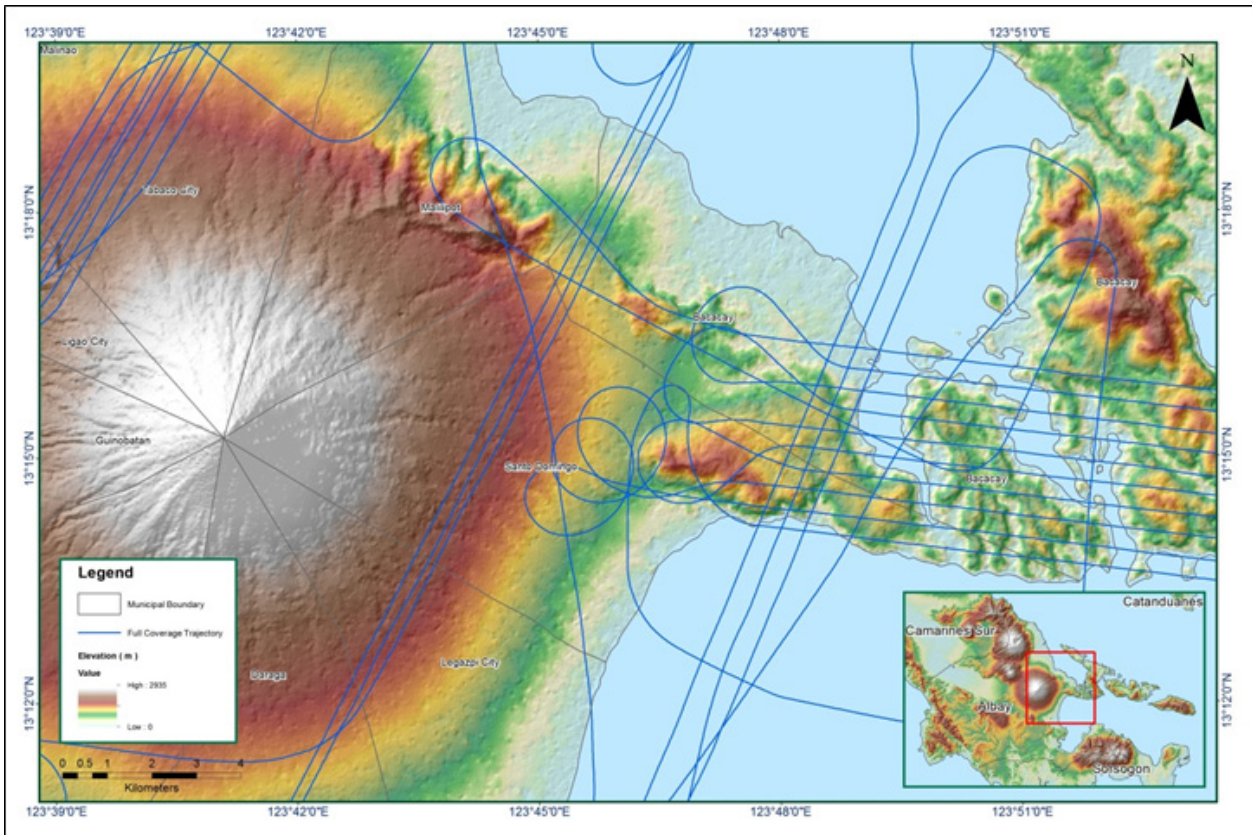


Figure A-8.52. Best Estimated Trajectory

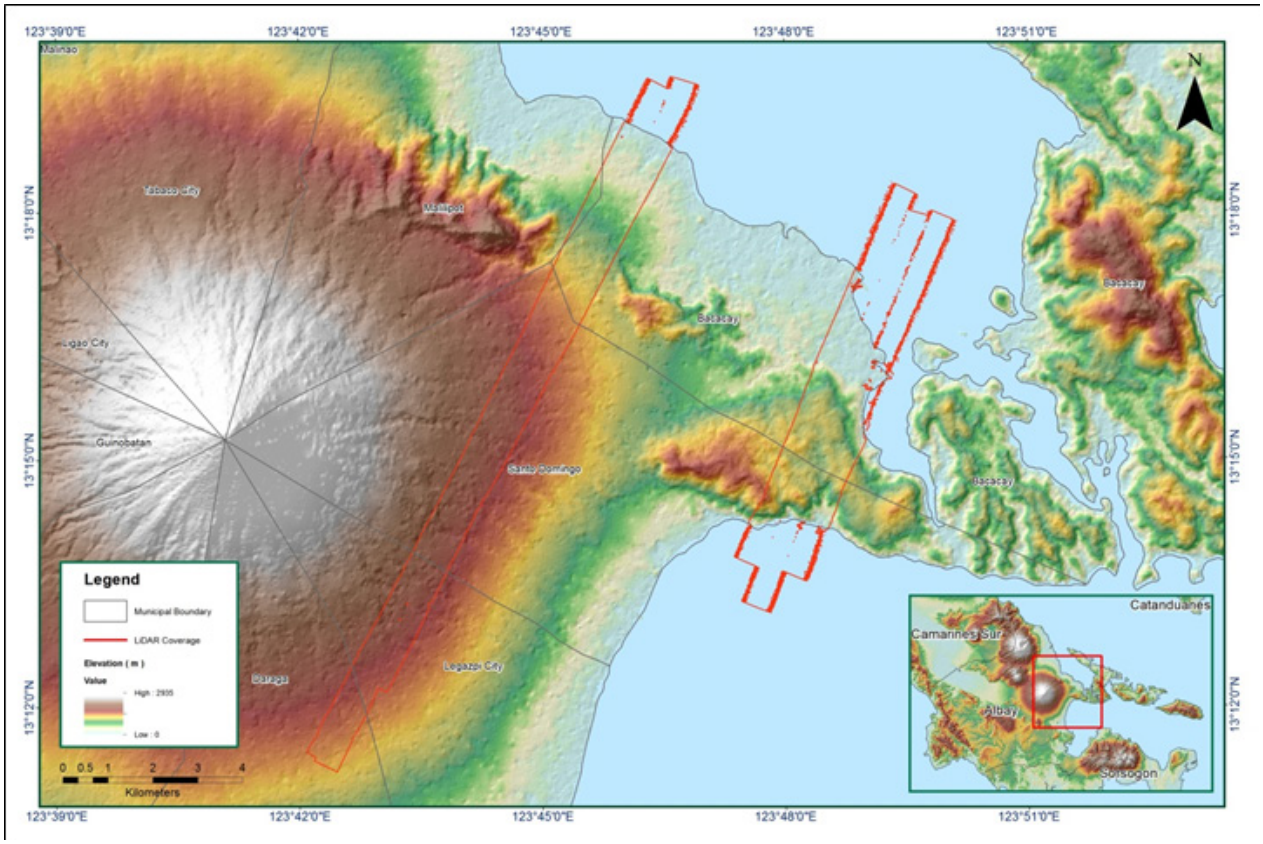


Figure A-8.53. Coverage of LiDAR data

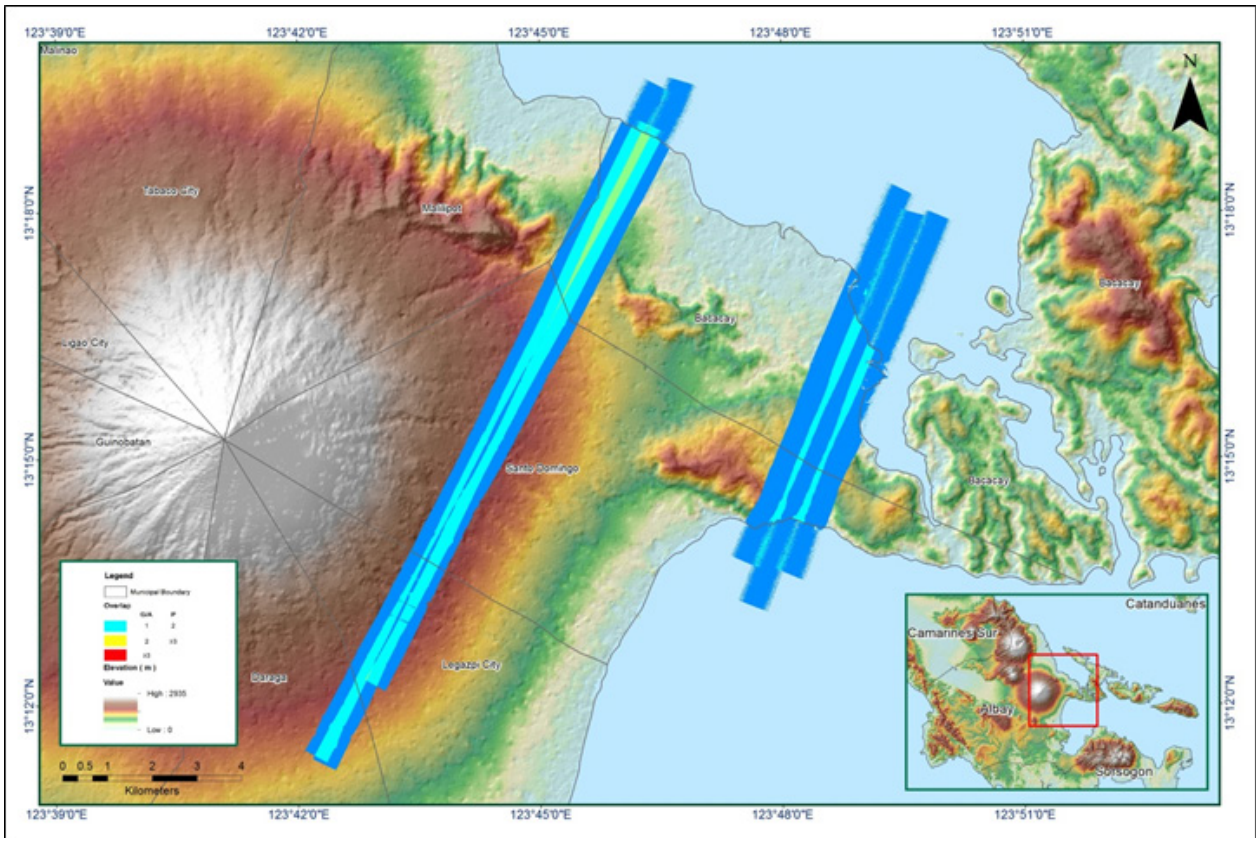


Figure A-8.54. Image of data overlap

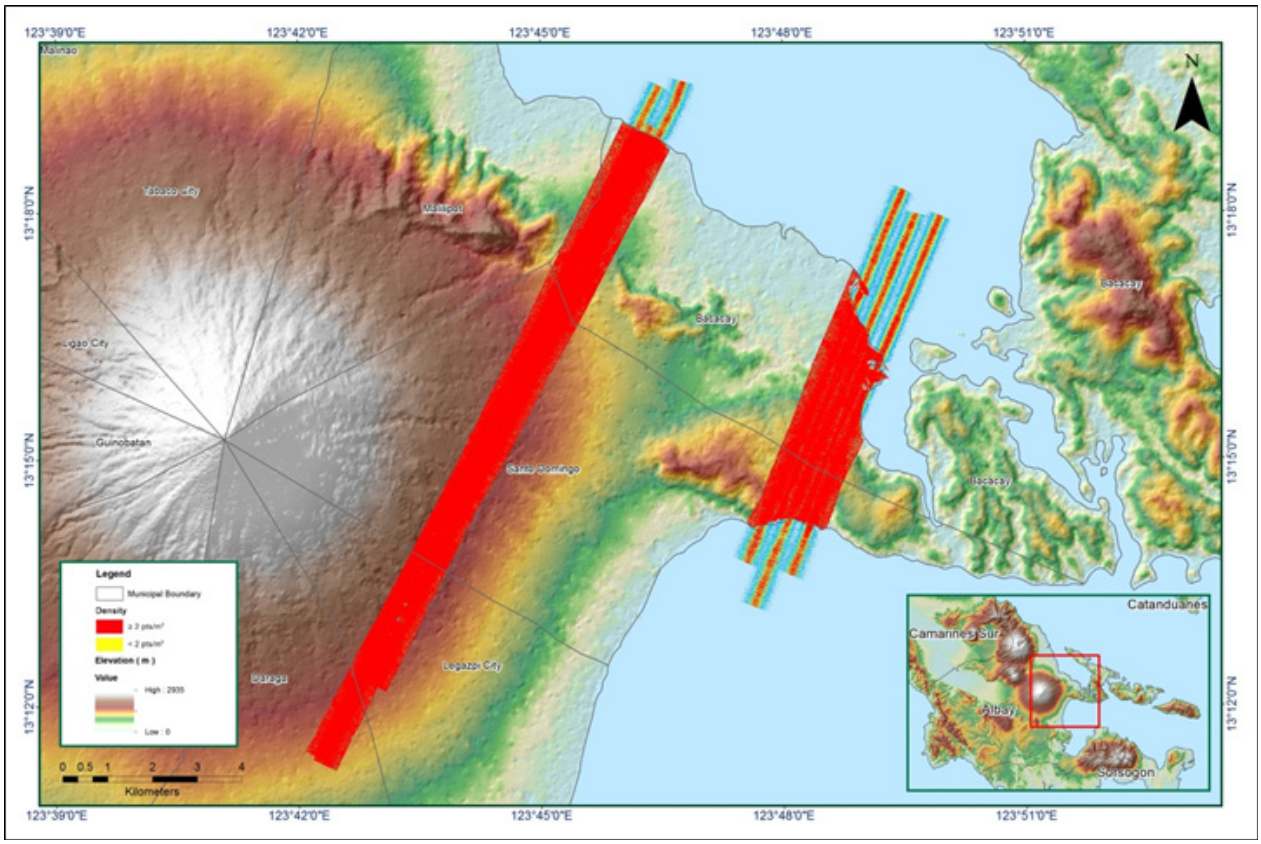


Figure A-8.55. Density map of merged LiDAR data

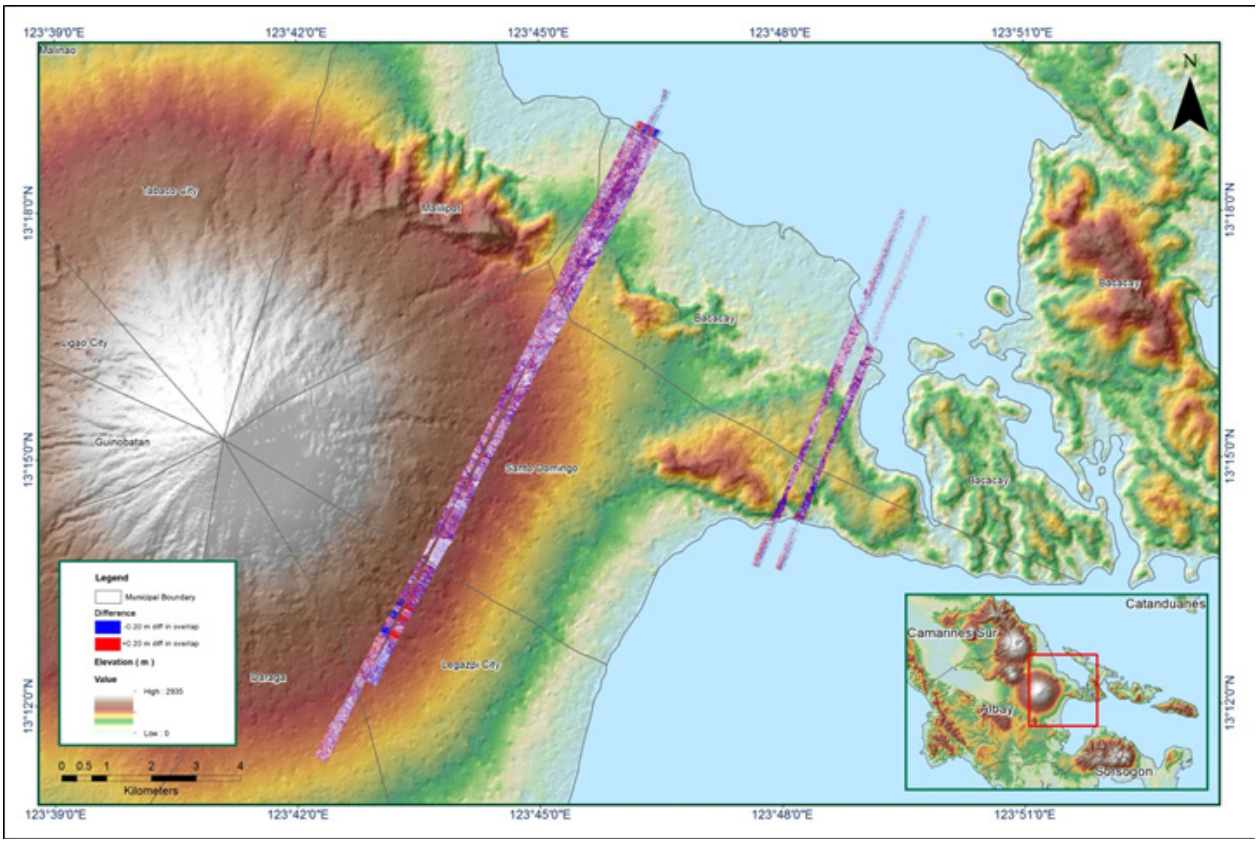


Figure A-8.56. Elevation difference between flight lines

Annex 9. Daraga 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	9.457	97.009	0	10.379	1.92880	Discharge	1.1407	0.13300	Ratio to Peak	0.96158
W210	9.313	98.213	0	3.113	2.92100	Discharge	0.6965	0.09020	Ratio to Peak	0.63829
W220	1.964	99.000	0	17.972	2.95790	Discharge	0.8481	0.29500	Ratio to Peak	0.96431
W230	9.457	99.000	0	3.776	1.94280	Discharge	0.5796	0.29500	Ratio to Peak	0.96780
W240	6.434	96.112	0	9.897	4.27950	Discharge	0.2609	0.09020	Ratio to Peak	0.43556
W250	1.935	98.750	0	21.890	1.30460	Discharge	0.7629	0.13500	Ratio to Peak	0.29481
W260	9.173	99.000	0	6.417	2.00170	Discharge	1.3507	0.19600	Ratio to Peak	0.64635
W270	0.396	98.428	0	1.322	1.26200	Discharge	0.7095	0.09020	Ratio to Peak	0.89295
W280	13.689	99.000	0	0.290	1.28060	Discharge	0.1039	0.09020	Ratio to Peak	0.29630
W290	4.181	99.000	0	0.147	2.54030	Discharge	0.6970	0.13500	Ratio to Peak	1.00000
W300	13.902	99.000	0	8.287	6.53210	Discharge	0.0092	0.13500	Ratio to Peak	0.43556
W310	1.965	99.000	0	5.731	2.95260	Discharge	0.4704	0.09020	Ratio to Peak	0.95771
W320	1.323	99.000	0	0.342	14.38200	Discharge	0.0373	0.20148	Ratio to Peak	1.00000
W330	1.323	88.375	0	0.858	1.93320	Discharge	0.1008	0.20149	Ratio to Peak	0.66935
W340	1.323	86.588	0	9.709	2.99040	Discharge	0.3772	0.20148	Ratio to Peak	0.98000
W350	2.947	99.000	0	0.141	9.63460	Discharge	0.0397	0.29618	Ratio to Peak	1.00000
W360	0.612	79.045	0	0.895	0.59729	Discharge	0.6232	0.20147	Ratio to Peak	0.65333
W370	1.323	89.460	0	0.306	9.93670	Discharge	0.1718	0.30073	Ratio to Peak	0.99999
W380	0.612	79.548	0	0.739	1.98290	Discharge	1.3205	0.29607	Ratio to Peak	0.46177

Annex 10. Daraga 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
R60	Automatic Fixed Interval	3075.6	0.03466	0.00722	Trapezoid	48.91	1
R70	Automatic Fixed Interval	144.9	0.01731	0.00229	Trapezoid	48.91	1
R80	Automatic Fixed Interval	1126.8	0.02684	0.02363	Trapezoid	48.91	1
R90	Automatic Fixed Interval	1855.1	0.02047	0.02588	Trapezoid	48.91	1
R110	Automatic Fixed Interval	590.8	0.00546	0.01179	Trapezoid	48.91	1
R120	Automatic Fixed Interval	920.1	0.01738	0.03758	Trapezoid	48.91	1
R150	Automatic Fixed Interval	1899.7	0.0034927	0.0167331	Trapezoid	48.91	1
R170	Automatic Fixed Interval	479.41	0.0062841	0.0569917	Trapezoid	48.91	1
R180	Automatic Fixed Interval	1378.1	0.0111376	0.0225394	Trapezoid	48.91	1

Annex 11. Daraga Field Validation Points

DARAGA				
ID	Latitude	Longitude	Depth	Accuracy (m)
1	13.15314	123.752514	2	4
2	13.15319	123.752361	1.6	2.5
3	13.1528	123.752395	1.8	6.5
4	13.15285	123.7526718	2	25.5
5	13.15187	123.7529111	2	3.5
6	13.15395	123.7516887	2.3	5
7	13.15512	123.7493034	2.5	2
8	13.15524	123.7486359	0.8	1.5
9	13.15551	123.7477525	1.8	2.5
10	13.15517	123.7472289	1.4	2
11	13.15474	123.7460224	0.5	2
12	13.15415	123.7475564	0.3	2
13	13.15193	123.7470725	0	2.5
14	13.15077	123.746899	0.3	2.5
15	13.15178	123.7456527	0	3
16	13.15008	123.7471833	0.7	2.5
17	13.14956	123.7473856	0.6	2.5
18	13.14906	123.7472097	0.9	4.5
19	13.14779	123.7477267	1.7	2.5
20	13.15625	123.7455488	0.4	2.5
21	13.15609	123.743996	0	3
22	13.16455	123.7343415	0	2
23	13.16405	123.7349762	0	2
24	13.16272	123.7335509	0	1.5
25	13.16126	123.7250778	2	2.5
26	13.15689	123.7251352	0.5	2
27	13.15777	123.7171007	0.9	2.5
28	13.16682	123.7514233	0	3
29	13.16236	123.7515568	0.5	3
30	13.16231	123.751667	0.4	3
31	13.16206	123.75227	0.2	4
32	13.1597	123.7512602	0	3
33	13.15906	123.7512165	0.1	3
34	13.15904	123.7514127	1.2	5
35	13.15908	123.7517549	1.2	3
36	13.15865	123.7515375	2	9
37	13.15868	123.7519881	1.8	3
38	13.15834	123.7519525	1.5	4
39	13.15703	123.7511687	1	6
40	13.157	123.7511271	1	3

DARAGA				
ID	Latitude	Longitude	Depth	Accuracy (m)
41	13.15626	123.7512265	1	3
42	13.15566	123.7513251	2.2	4
43	13.15564	123.7513721	1.5	3
44	13.15562	123.7514315	2.4	10
45	13.15539	123.7520265	1.3	3
46	13.15541	123.7520994	2	3
47	13.15565	123.7512638	2	10
48	13.15667	123.7511062	0.8	3
49	13.15743	123.751147	0.3	6
50	13.15919	123.7511363	0.8	3
51	13.16062	123.750506	1.3	3
52	13.16064	123.7491125	2.4	3
53	13.16213	123.746316	0.1	3
54	13.16393	123.7344125	0.3	3
55	13.16405	123.73363	0.5	3
56	13.164	123.732845	1	3
57	13.16157	123.7327913	0.5	8
58	13.16087	123.7326161	0.2	21
59	13.15612	123.7277979	0.5	3
60	13.1557	123.7266748	0	3
61	13.15016	123.7251341	0.1	18
62	13.15014	123.725259	0	3
63	13.1527	123.7250172	0.3	3
64	13.15359	123.7243662	0	3
65	13.15456	123.7231401	0	3
66	13.15515	123.7225394	0	3
67	13.15556	123.7209714	0	3
68	13.15474	123.7209514	0	3
69	13.15455	123.7209412	0	4
70	13.15395	123.7208707	0	3
71	13.15463	123.719682	0	3
72	13.15502	123.7192726	0	3
73	13.15603	123.7192127	0	3
74	13.15633	123.7193011	0	3
75	13.15658	123.7192656	0	3
76	13.15628	123.7185709	0	3
77	13.15125	123.7173824	0	3
78	13.15221	123.7177682	0	3
79	13.15311	123.7177662	0.2	3
80	13.15387	123.7174877	0.9	4

DARAGA				
ID	Latitude	Longitude	Depth	Accuracy (m)
81	13.15422	123.7169601	0.1	3
82	13.15573	123.7173719	0.6	3
83	13.16116	123.724985	2.2	2.700000048
84	13.157	123.72519	0.4	2.5
85	13.15742	123.7200283	0.2	2.400000095
86	13.15737	123.72011	0.2	2.400000095
87	13.1578	123.7169917	0.9	2.700000048
88	13.15762	123.7158017	2.4	2.400000095
89	13.15731	123.7153033	2.2	2.400000095
90	13.1571	123.7149667	2.4	2.099999905
91	13.15712	123.7176233	2.4	2.299999952
92	13.15685	123.7176267	0.2	3.5
93	13.15549	123.71545	0	3.900000095
94	13.15642	123.714355	1.5	3.299999952
95	13.40711	123.7129216	4.5	8
96	13.40655	123.71316	1.4	8
97	13.4077	123.7125285	0.6	8
98	13.40865	123.71209	1	4
99	13.40913	123.7122183	1.6	6
100	13.40917	123.7116985	1.7	6
101	13.40928	123.7055951	1	12
102	13.40785	123.7050793	1.4	4
103	13.40711	123.7042947	2	6
104	13.40514	123.7024012	0.8	8
105	13.40448	123.7013728	0.5	6
106	13.40466	123.7008503	1.4	12
107	13.40436	123.7005106	1.4	6
108	13.40428	123.7001491	0.7	6
109	13.40357	123.6991124	1	8
110	13.40329	123.698557	1.2	6
111	13.40278	123.6974516	0.8	6
112	13.40236	123.6988613	1	8
113	13.40219	123.6998297	1.6	12
114	13.40345	123.7007556	0.9	4
115	13.40331	123.7004864	1.1	6
116	13.40391	123.7012914	1.6	8
117	13.40223	123.7027469	0.7	8
118	13.40158	123.7027659	1.5	6
119	13.40136	123.7032228	1.9	6
120	13.39996	123.7032571	1.6	6

DARAGA				
ID	Latitude	Longitude	Depth	Accuracy (m)
121	13.39989	123.7037522	0.8	8
122	13.39734	123.70348	1.5	6
123	13.39746	123.7036743	1.7	8
124	13.39689	123.702524	1.8	4
125	13.40038	123.7060659	0.9	4
126	13.39977	123.705791	1.4	12
127	13.39909	123.7063381	1.4	6
128	13.39932	123.7064828	1.2	6
129	13.39822	123.706494	0.8	6
130	13.39836	123.7059553	1.4	8
131	13.39907	123.7043359	1.7	4
132	13.39865	123.7046713	1.5	8
133	13.39804	123.7044753	1.3	12
134	13.39783	123.7044472	1.3	4
135	13.39734	123.7047682	1.7	6
136	13.3972	123.7055691	2.1	4
137	13.397	123.705967	1.1	6
138	13.39703	123.7060507	1	12
139	13.13934	123.7438119	0.7	4
140	13.13984	123.7438067	2.2	4
141	13.13987	123.7442313	1.3	6
142	13.14472	123.7470602	1.6	8
143	13.14653	123.750603	0.9	16
144	13.1474	123.751046	1.2	6
145	13.14653	123.7518547	1.1	6
146	13.14687	123.7530273	1.4	12
147	13.14595	123.7536631	0.6	8
148	13.14543	123.7535643	1.6	4
149	13.14466	123.7533848	1.3	16
150	13.14433	123.7530632	1.4	6
151	13.14369	123.7527392	2.2	6
152	13.1448	123.7516101	1.6	4
153	13.14434	123.7508445	1.8	4
154	13.14407	123.7505159	1.4	4
155	13.14357	123.7496933	2.2	6
156	13.14175	123.750603	1.4	6
157	13.14233	123.751934	1.6	6
158	13.14221	123.751667	1.4	6
159	13.14074	123.7534041	1.9	6
160	13.14113	123.7537464	1.8	4

DARAGA				
ID	Latitude	Longitude	Depth	Accuracy (m)
161	13.14115	123.752763	0.9	6
162	13.14078	123.7524938	0.9	4
163	13.14062	123.7514971	1.4	4
164	13.14032	123.7508887	0.1	6
165	13.13938	123.750957	1.7	4
166	13.13875	123.7512993	1.6	6
167	13.13808	123.7515031	1.7	8
168	13.13923	123.7520712	2.1	6
169	13.13973	123.7530643	2.2	6
170	13.1394	123.7541407	2	4
171	13.14149	123.7492223	1.1	4
172	13.14154	123.7489917	1.8	8
173	13.14066	123.7475013	1.8	4
174	13.14007	123.7465133	1.8	6
175	13.13966	123.7458032	1.4	6
176	13.13911	123.7444827	0.8	6
177	13.16275	123.7335126	0	6
178	13.16027	123.7248821	0	4
179	13.15962	123.7250109	0	4
180	13.15867	123.725108	0.5	4
181	13.15853	123.7246579	0	6
182	13.15749	123.7232652	0.3	6
183	13.15739	123.7188962	0	8
184	13.1576	123.7189034	0.7	4
185	13.15868	123.7197958	2.6	4
186	13.1592	123.7203998	10	4
187	13.15817	123.7194901	6	4
188	13.15859	123.7188946	4	4
189	13.15837	123.7180401	2.1	4
190	13.15806	123.7174055	3.1	4
191	13.15562	123.7162753	1	6
192	13.15551	123.7156216	0	8
193	13.15519	123.7147172	0	4
194	13.15494	123.7141534	0	4
195	13.1549	123.713976	0	4
196	13.15486	123.7127689	0	6
197	13.15478	123.7108774	0	4
198	13.1553	123.7104651	0	8
199	13.1548	123.7109056	0	6

Annex 12. Educational Institutions Affected in Daraga Floodplain

ALBAY				
DARAGA				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Alcala Elementary School	Alcala			
Children International	Alcala			
Mabinet Eelementary School	Alcala			
Seminary	Bagumbayan			
Balintad elementary school	Balinad			
Bahoag Elementary School	Bañag	Low	Low	Low
Evangel Bible College	Bañag			
Simon of Cyrene	Bañag			
Binitayan Daycare Center	Binitayan	Medium	High	High
Binitayan Elementary School	Binitayan			
Kilicao Elementary School	Binitayan		Low	Medium
Paaralang Elementarya ng Bongalon	Bongalon			
Kidaco Elementary School	Kidaco			
Kilicao Elementary School	Kilicao			Low
Mater Salutis Major Seminary	Kiwalo			
Seminary	Kiwalo			
Paaralang Elementarya Ng Malabog	Malabog			
Paaralang Elementarya ng Malabog	Malabog			
Kilicao High School	Malobago			
Daraga Child Center	Market Area Poblacion			
Immaculate Conception College Albay	Market Area Poblacion			
Morante Development Academy	Market Area Poblacion			
Loving Care Learning Center	Maroroy			Low
Sunshine children museum	Maroroy			
Sunshine International School	Maroroy		Medium	Medium
Sunshine International School gymnasium	Maroroy		Low	Medium
Busay Elementary School	Pandan			
Penafrancia Elementary School	Peñafrancia			
Bagtang Elementary School	Sagpon		Medium	Medium
Basic Learning Center Cresche School inc	Sagpon			
Bicol College Graduate School	Sagpon			
Bicol University College of Social Sciences	Sagpon			
Bicol University East Campus College of Eng	Sagpon		Medium	Medium
Bicol University Main Campus	Sagpon	Low	Low	Low
College of Law	Sagpon			
Daraga National High School Community	Sagpon			

ALBAY				
DARAGA				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
Maroroy elementary school	Sagpon			Low
Mary's Child Science Oriented School	Sagpon			
United Institute/villamada hotel	Sagpon			
Bahoag Elementary School	San Roque	Low	Low	Low
Daraga Child Center	Sipi			
Daraga North Elementary	Sipi			Low
Harvest in Christ Academy Ministry	Sipi			
Immaculate Conception College Albay	Sipi			
Jun Go Technical Institute	Sipi			
Piamont Science Oriented for Dids	Sipi			
Seminary	Sipi			
Starminds School for Kids	Sipi		Low	Low
Penafrancia Oriented School	Tabon-Tabon			
Sunshine International School	Tagas		Medium	Medium
LEGASPI CITY				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
Daycare	Bgy. 1 - Em's Barrio	Medium	High	High
De Vera Institute of Technology Legaspi	Bgy. 1 - Em's Barrio	Medium	Medium	High
Kindergarten nazarene	Bgy. 1 - Em's Barrio	Low	Medium	Medium
Nazarene Elementary & Kindergarten School	Bgy. 1 - Em's Barrio	Medium	Medium	Medium
AMA College	Bgy. 16 - Kawit-East Washington Dr	Low	Medium	Medium
CAT College	Bgy. 16 - Kawit-East Washington Dr	Low	Medium	Medium
CCDI	Bgy. 16 - Kawit-East Washington Dr	Medium	Medium	Medium
Computer Communication Development Institute	Bgy. 16 - Kawit-East Washington Dr	Low	Medium	Medium
Divine Word College	Bgy. 16 - Kawit-East Washington Dr	Low	Medium	Medium
St Therese of the Child Jesus Learning Center	Bgy. 16 - Kawit-East Washington Dr	Medium	Medium	Medium
STI Legaspi Campus	Bgy. 16 - Kawit-East Washington Dr	Low	Medium	Medium
Saint Agnes Academy	Bgy. 17 - Rizal Sreet., Ilawod	Low	Medium	Medium
Saint Agnes Academy	Bgy. 18 - Cabagñan West	Low	Medium	Medium

ALBAY				
LEGASPI CITY				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
Buraguis elem school	Bgy. 24 - Rizal Street			
Buragwis elem school	Bgy. 24 - Rizal Street			
Buraguis elem school	Bgy. 25 - Lapu-Lapu			
Buragwis day care	Bgy. 25 - Lapu-Lapu			
Puro Elemntary School	Bgy. 28 - Victory Village North		Low	Low
Forbes College	Bgy. 31 - Centro-Baybay	Low	Medium	Medium
Meriam College of Technology, Inc / agri supplies	Bgy. 31 - Centro-Baybay	Low	Medium	High
Forbes Academy	Bgy. 33 - Pnr-Peñaranda St.-Iraya			Low
San Roque Elementary School	Bgy. 33 - Pnr-Peñaranda St.-Iraya		Low	Medium
Buragwis elem school	Bgy. 35 - Tinago			
Reyes Computer Oriented School	Bgy. 36 - Kapantawan	Medium	High	High
Saints Peter and Paul Early Childhood	Bgy. 36 - Kapantawan	Low	Medium	Medium
St Peter and Paul Early Chilhood Learning Center	Bgy. 36 - Kapantawan	Low	Medium	Medium
Aquinas University of Legaspi Professional Schools	Bgy. 37 - Bitano	Medium	Medium	Medium
Cabangan High School and Elementary School	Bgy. 37 - Bitano			Medium
Computer Systems Institute	Bgy. 37 - Bitano		Low	Medium
Hope Christian School	Bgy. 37 - Bitano			
Ibalong Elementary School	Bgy. 37 - Bitano	Low	Medium	Medium
Legazpi City High School	Bgy. 37 - Bitano			Low
Legazpi Port Elementary School	Bgy. 37 - Bitano	Low	Medium	Medium
Oro Site High School	Bgy. 37 - Bitano	Low	Medium	Medium
Saints Peter and Paul Early Childhood	Bgy. 37 - Bitano	Low	Medium	Medium
Southern Luzon Technological College	Bgy. 37 - Bitano	Low	Medium	Medium
St Peter and Paul Early Chilhood Learning Center	Bgy. 37 - Bitano	Low	Medium	Medium
St. Jude Catholic School	Bgy. 37 - Bitano		Low	Medium
St. Rafael Academy	Bgy. 37 - Bitano	Low	Medium	Medium
Tanchuling College	Bgy. 37 - Bitano	Low	Medium	Medium
Aquinas University	Bgy. 38 - Gogon	Medium	Medium	Medium
Forbes Academy	Bgy. 38 - Gogon			Low
Gogon Central School	Bgy. 38 - Gogon		Low	Low
Aquinas University	Bgy. 39 - Bonot	Low	Medium	Medium
San Roque Day Care	Bgy. 39 - Bonot	Medium	Medium	Medium
Albay Central School	Bgy. 40 - Cruzada	Low	Low	Medium

ALBAY				
LEGASPI				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Bagumbayan Central School	Bgy. 40 - Cruzada	Low	Low	Medium
Bicol University East Campus College of Eng	Bgy. 40 - Cruzada		Medium	Medium
CAT College	Bgy. 40 - Cruzada	Low	Medium	Medium
Computer Arts and Technological College	Bgy. 40 - Cruzada	Low	Medium	Medium
Divine Word College North Camp	Bgy. 40 - Cruzada		Low	Low
Heaven Door Academy	Bgy. 40 - Cruzada		Low	Medium
Saint Agnes Academy	Bgy. 40 - Cruzada	Low	Low	Medium
Smart Readers Learning Center	Bgy. 40 - Cruzada		Low	Low
St Therese of the Child Jesus Learning Center	Bgy. 40 - Cruzada	Low	Medium	Medium
The P.E.P. Foundation Inc.	Bgy. 40 - Cruzada			
Washington International School	Bgy. 40 - Cruzada		Medium	Medium
Bogtong Elementary School	Bgy. 41 - Bogtong	Low	Medium	Medium
Children International	Bgy. 41 - Bogtong		Low	Low
Aquinas University	Bgy. 42 - Rawis	Medium	Medium	Medium
Legazpi Div Center	Bgy. 42 - Rawis			
Mariners Polytechnic College	Bgy. 42 - Rawis	Low	Medium	Medium
Pag-Asa National High School	Bgy. 42 - Rawis			
Pag-asa national high School	Bgy. 42 - Rawis			Low
Pag-Asa National High School	Bgy. 42 - Rawis			
Aquinas University	Bgy. 43 - Tamaoyan	Medium	Medium	Medium
Pag-Asa National High School	Bgy. 43 - Tamaoyan			
Pag-Asa national high School	Bgy. 43 - Tamaoyan			Low
Pag-Asa National High School	Bgy. 43 - Tamaoyan			
Day care	Bgy. 44 - Pawa			
Pawa Elem Echool	Bgy. 44 - Pawa			
Pawa High school	Bgy. 44 - Pawa			
Dita Elem School	Bgy. 45 - Dita			
Dita elem school	Bgy. 45 - Dita			
Bogna Elem School	Bgy. 53 - Bonga			
Eskwela Ponics Reading Center	Bgy. 7 - Baño			
Bagumbayan Central School	Bgy. 8 - Bagumbayan	Low	Low	Medium
Daugthers of Saint Paul	Bgy. 8 - Bagumbayan			
Divine Word College	Bgy. 8 - Bagumbayan	Medium	Medium	Medium

Annex 13. Health Institutions Affected in Daraga Floodplain

ALBAY				
DARAGA				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
Clocson Medical Clinic	Bañag			
Wellness center, Swan Lake hometel	Bañag		Low	Medium
Bgry Health Center	Market Area Poblacion			
Daraga Lying In Clinic	Market Area Poblacion			
Bicol regional training & teaching hospital	Sagpon		Low	Medium
Central link lab and medical clinics	Sagpon			
Clinica pambata/Helen Onate m.d.	Sagpon			
CM Baldo dental clinic	Sagpon			
Dental Clinic	Sagpon			
Dental clinic Dr. Tan	Sagpon			
Clocson Medical Clinic	Bañag			
Wellness center, Swan Lake hometel	Bañag		Low	Medium
Bgry Health Center	Market Area Poblacion			
Daraga Lying In Clinic	Market Area Poblacion			
Bicol regional training & teaching hospital	Sagpon		Low	Medium
Central link lab and medical clinics	Sagpon			
Clinica pambata/Helen Onate m.d.	Sagpon			
CM Baldo dental clinic	Sagpon			
Dental Clinic	Sagpon			
Dental clinic Dr. Tan	Sagpon			
Oro Site High School	Bgy. 37 - Bitano	Low	Medium	Medium
Saints Peter and Paul Early Childhood	Bgy. 37 - Bitano	Low	Medium	Medium
LEGASPI CITY				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
Ago General Hospital	Bgy. 1 - Em's Barrio	Medium	Medium	Medium
AMEC-BCCM, Dr Eden Ago	Bgy. 1 - Em's Barrio			
BMSC Medical Imaging Center	Bgy. 1 - Em's Barrio	Low	Low	Medium
Children of Abrahan Puericulture/pcso	Bgy. 1 - Em's Barrio	Low	Medium	Medium
Ibalong Medical Center	Bgy. 16 - Kawit-East Washington Dr	Medium	Medium	Medium
Estevez Memorial hospital	Bgy. 17 - Rizal Sreet., Ilawod	Low	Low	Medium

ALBAY				
LEGASPI				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Sta. Teresita Hospital	Bgy. 18 - Cabagñan West	Medium	Medium	Medium
lim dental clinic	Bgy. 33 - Pnr-Peñaranda St.-Iraya	Low	Medium	Medium
Dental Clinic	Bgy. 36 - Kapantawan	Low	Medium	Medium
Albay Doctors Hospital	Bgy. 37 - Bitano	Medium	Medium	Medium
Baylon Chest Clinic	Bgy. 37 - Bitano	Medium	Medium	Medium
Dental Clinic	Bgy. 37 - Bitano			
Tanchuling Hospital	Bgy. 37 - Bitano		Medium	Medium
River of life Medical Clinic	Bgy. 39 - Bonot	Low	Low	Medium
Aquinas University hospital	Bgy. 40 - Cruzada	Low	Medium	Medium
Hospital	Bgy. 40 - Cruzada		Low	Low
Orense Maternity and Medical Clinic	Bgy. 40 - Cruzada	Low	Medium	Medium
Servant of Jesus Charity clinic	Bgy. 40 - Cruzada		Low	Medium
Ago general hospital	Bgy. 8 - Bagumbayan	Medium	Medium	High
Albay Poly Clinic	Bgy. 8 - Bagumbayan	Low	Low	Low
BMSC Medical Imaging Center	Bgy. 8 - Bagumbayan	Low	Low	Medium
Burce Dental Clinic	Bgy. 8 - Bagumbayan	Medium	Medium	Medium
Drug Testing Center	Bgy. 8 - Bagumbayan	Low	Medium	Medium
Marie Medical Clinic	Bgy. 8 - Bagumbayan	Low	Medium	Medium
St. Mecilia Maternity and Medical Clinic	Bgy. 8 - Bagumbayan	Low	Medium	Medium