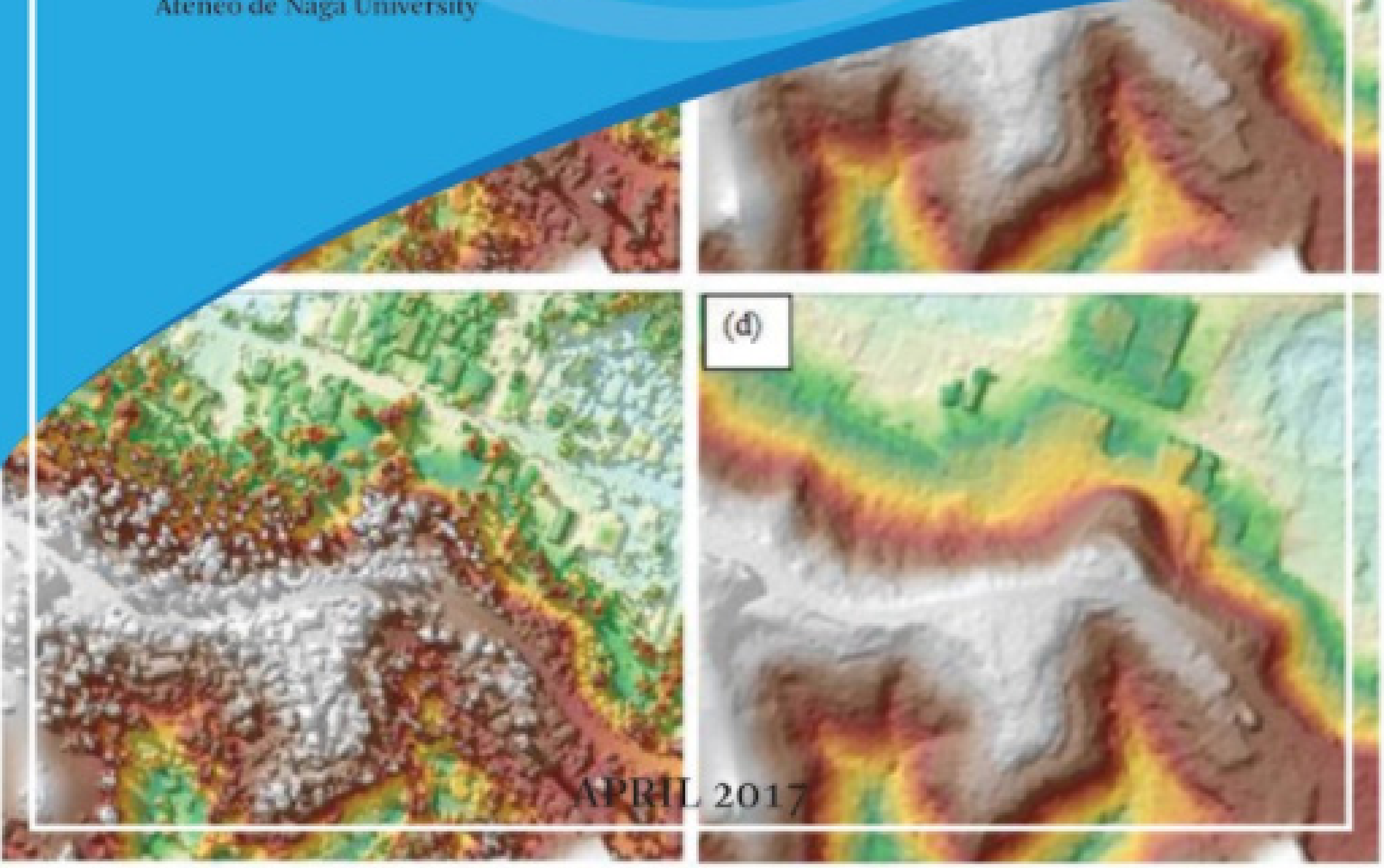
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND DONSOL RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga University (AdNU). AdNU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 24 river basins in the Bicol Region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Donsol River Basin

The Donsol River Basin is emptied by the markedly smaller Ogod River. It also empties out to the northern part of Ticao Pass. The Department of Environment and Natural Resources-River Basin Control Office identified the basin to have an approximately 396 km2 drainage area with an estimated annual runoff of 536 million cubic meters (MCM). The same hilly and rolling topography is found in the area. The municipalities with jurisdiction over the river basin include three (3) first class municipalities; the Municipalities of Pilar with a population of 74,564 based on the last 2015 census, Daraga (126,595 population) and Camalig (66,904 population); one (1) third class municipality, Donsol (47,563 population) and one (1) fourth class municipality, Jovellar (17, 308 population).

This river basin also experiences Type III climate based on the modified Corona classification, which is the same with the Ogod River Basin climate. The land cover in the river basin is mostly brushland with a few areas cultivated by small scale farmers. Very sparse mangrove thrives near the mouth of the river where fishponds are also established. The economic sources of the area are mostly from agricultural products such as coconuts, rice, and rootcrops. The area is also benefiting from tourism anchored on whaleshark interaction. coastline and swamp areas of the said barangays.

The Donsol River Basin's main stem, Donsol River, is part of the 24 river systems in Bicol Region. This major stream has a length of 54.5 km. It is a northwest-southeast oriented body of marine water that is bounded on the northeast by the Bicol Peninsula and on the southwest by the islands of Burias, Ticao, and Masbate. Its head water extends northwards into the province of Albay while its coastal waters is considered to be part of the Burias Pass. There is a total of 12,332 people residing within the immediate vicinity of the river which are distributed among thirteen (13) barangays in Municipality of Donsol according to the 2015 National Census conducted by National Statistics Office. Donsol is considered to be one of the most important nature-based tourist spots in the Province of Sorsogon, which is famous for its firefly sanctuary and luminous plankton river cruise. Donsol River is listed as one of the flood susceptible areas during the Typhoon Ruby (December 2014). The area is not only prone to flooding but also to landslide as reported by the Mines and Geosciences Bureau.

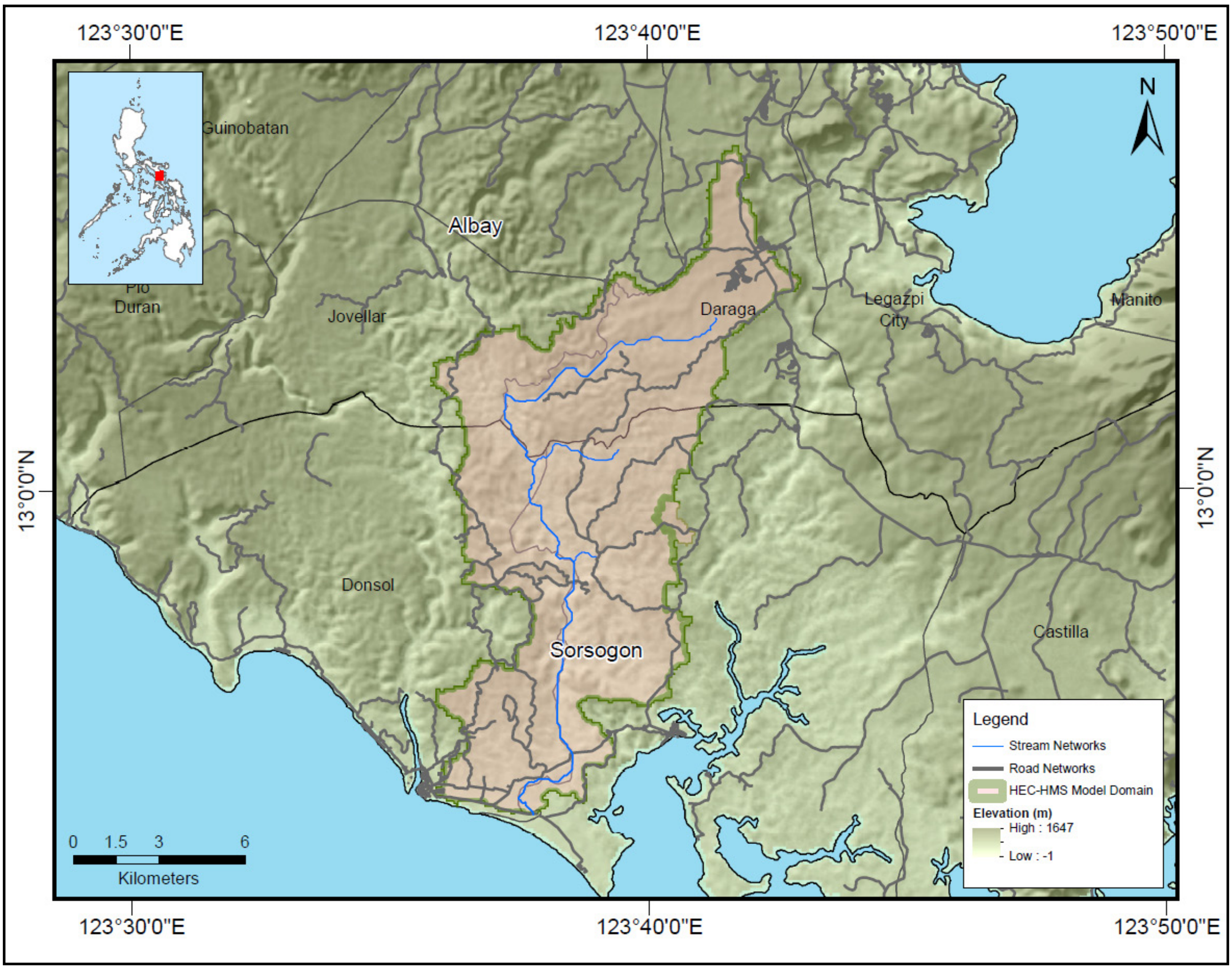

Figure 1. Map of the Donsol River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DONSOL FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Donsol floodplain in Sorsogon. Each flight mission has an average of fourteen (14) lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR System is found in Table 1. Figure 1 shows the flight plan for Donsol Floodplain.

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

Block Name	Flying Height	Overlap	Field of View	Pulse Repetition Frequency (PRF)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
	(m AGL)	(%)	(θ)	(kHz)	(Hz)	(kts)	
BLK19A	1000	30	40	100	50	130	5
BLK19E	1000	30	40	100	50	130	5
BLK19G	1000	30	40	100	50	130	5
BLK19F	1000	30	40	100	50	130	5
	650	30	40	125	50	130	5
BLK19I	1000	30	40	100	50	130	5
	650	30	40	125	50	130	5
BLK19J	650	30	40	125	50	130	5
BLK19K	1000	30	40	100	50	130	5
	900	30	40	125	50	130	5
BLK19L	1000	30	40	100	50	130	5
BLK19M	1000	30	40	100	50	130	5
BLK19Q	1000	30	40	100	50	130	5

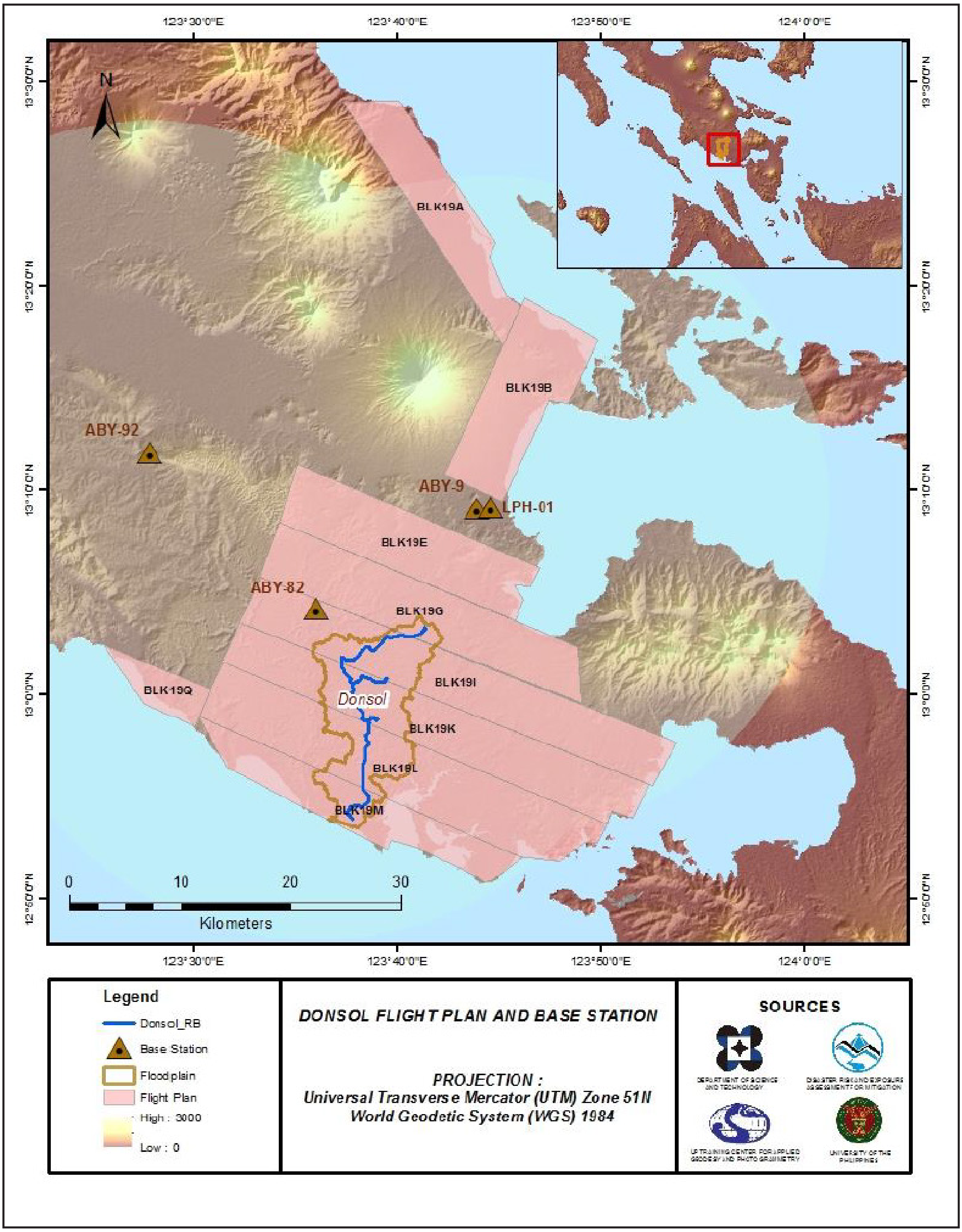

Figure 2. Flight Plan and base stations used for the Donsol Floodplain survey.

2.2 Ground Base Stations

The Project Team was able to recover two (2) NAMRIA reference points of second (2nd) order accuracy, ABY-92 and ABY-08, and one (1) of third (3rd) order accuracy, ABY-9. The Project Team established one (1) ground control point, LPH-1. The certification for the NAMRIA reference points are found in Annex 2 and the Baseline Processing Report for the established LPH-01 is 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 25 – March 31, 2016). Base stations were observed using Dual Frequency GPS receivers: TRIMBLE SPS 882, SPS 985 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Donsol Floodplain are shown in Figure 3.

Figures 4 to 6 show the recovered NAMRIA reference points within the area. In addition, Tables 2 to 5 show the details about the following NAMRIA control stations and established points, while table 6 shows the list of all ground control points occupied during the acquisition together with corresponding dates of utilization.

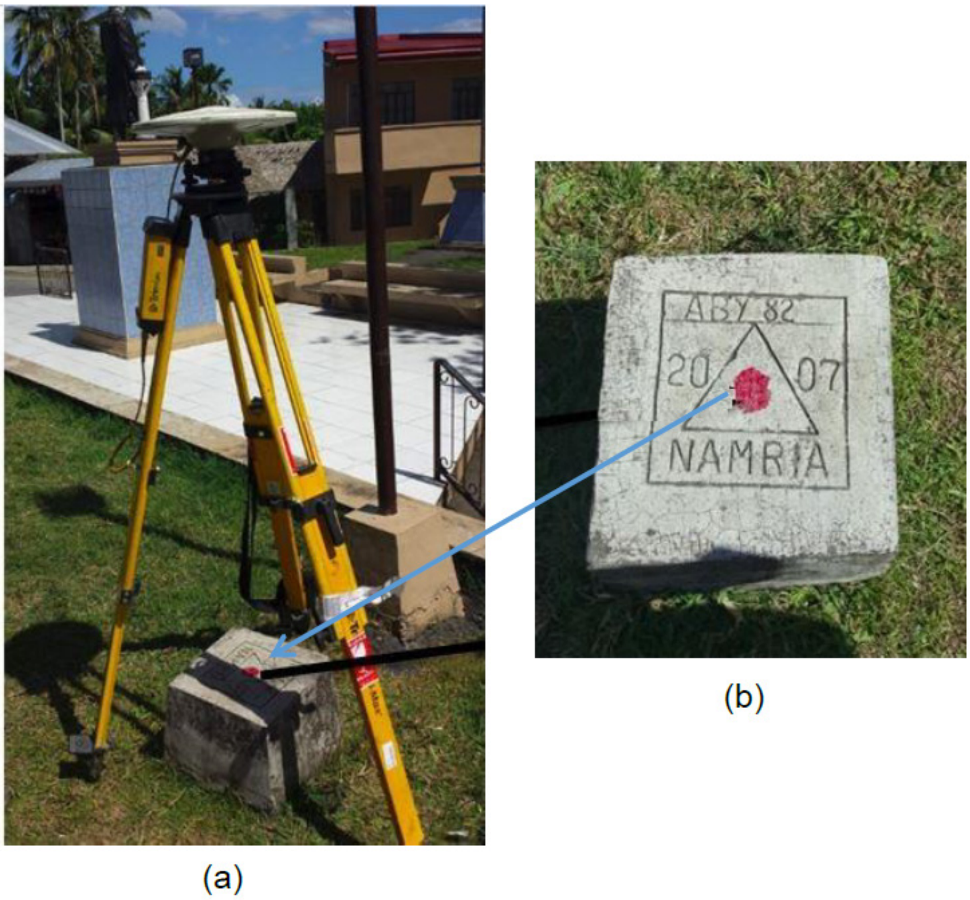

Figure 3. GPS set-up over ABY-82 located at about 12 meters from the right corner of the Rizal monument in front of Jovellar Catholic Church (a) and NAMRIA reference point SMR-53 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point ABY-82 used as base station for the LiDAR acquisition.

Station Name	ABY-82	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 4’ 16.27314” North
	Longitude	123° 35’ 53.17428” East
	Ellipsoidal Height	39.77600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Northing	1444995.02 meters
	Easting	564842.57 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 4’ 11.43271” North
	Longitude	123° 35’ 58.18268” East
	Ellipsoidal Height	93.89000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	564, 842.57 meters
	Northing	1,444,995.02 meters

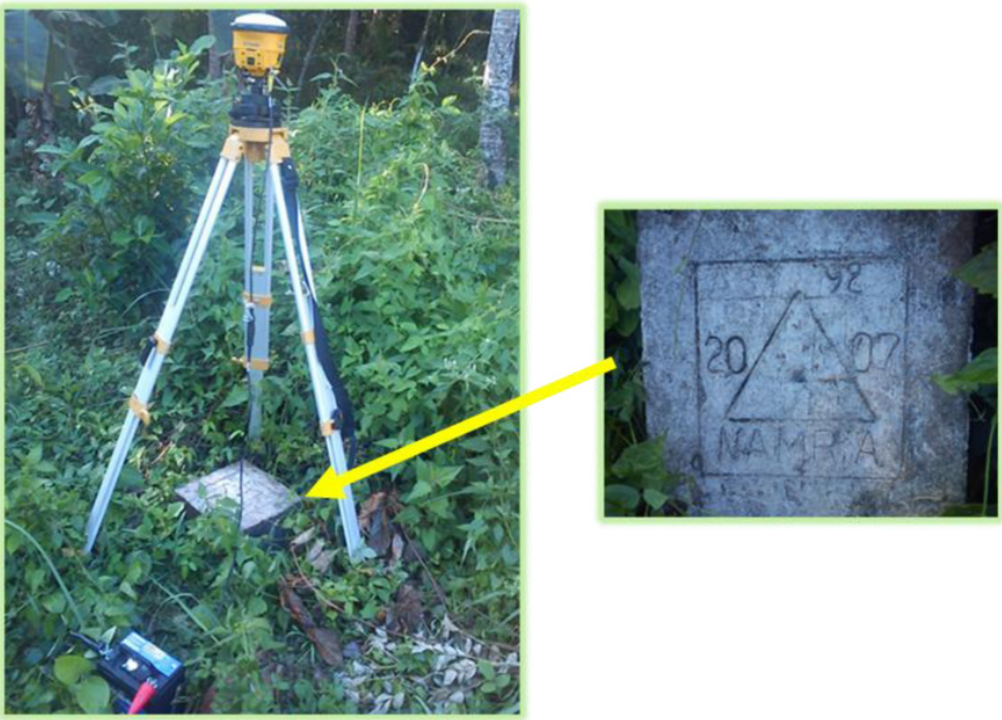

Figure 4. GPS set-up over ABY-92 located beside the baseline of the basketball court, about 19 meters from barangay hall in Brgy. Allang, Ligao City (a) and NAMRIA reference point ABY-92 (b) as recovered by the field team

Table 3. 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 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 11' 56.27238" North
	Longitude	123° 27' 47.60156" East
	Ellipsoidal Height	127.309000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	550210.89 meters
	Northing	1459605.458 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 11' 51.38974" North
	Longitude	123° 27' 52.59990" East
	Ellipsoidal Height	180.74900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	550193.31 meters
	Northing	1459094.57 meters

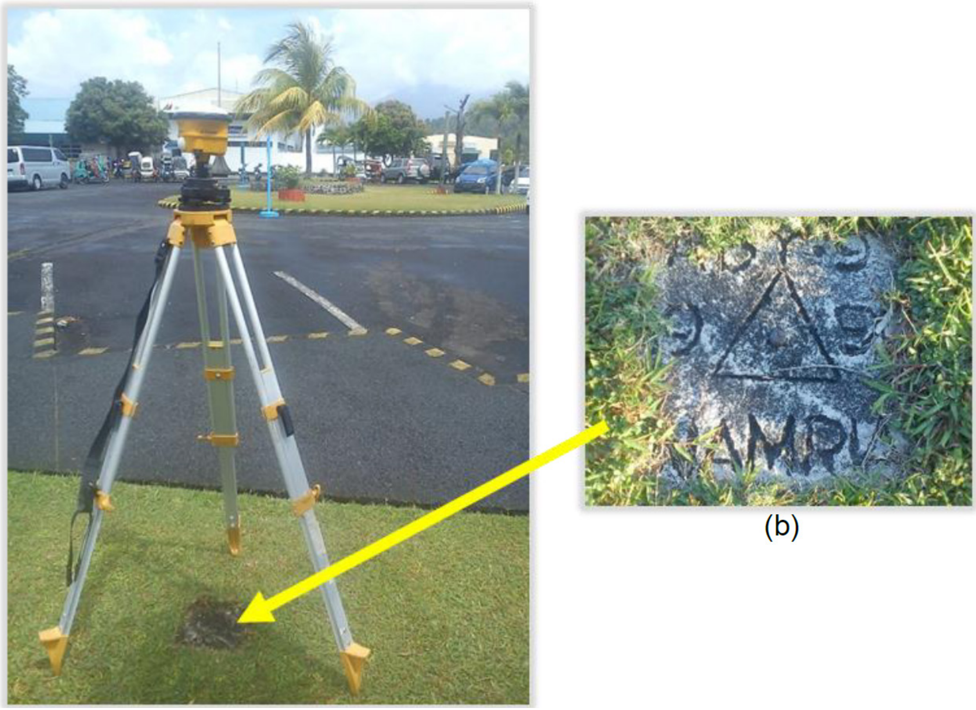

Figure 5. GPS set-up over ABY-9 at Legaspi Airport Compound (a) and NAMRIA reference point ABY-9 (b) as recovered by the field team

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	33d	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 9' 11.38733" North
	Longitude	123° 43' 45.95874" East
	Ellipsoidal Height	14.54010 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	579082.538 meters
	Northing	1454607.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 9' 6.53800" North
	Longitude	123° 43' 50.95900" East
	Ellipsoidal Height	68.754 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	579054.86 meters
	Northing	1454097.98 meters

Figure 6. GPS set-up over LPH-01 as established at the rooftop a building at La Piazza Hotel and Convention Center located at Tahao Road, Legazpi, Albay

Table 5. Details of the established 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	13° 09' 13.3540" North
	Longitude	123° 44' 27.8894" East
	Ellipsoidal Height	11.01 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	580345.19416 meters
	Northing	1454671.24009 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 09’ 08.50554” North
	Longitude	123° 44’ 32.88949” East
	Ellipsoidal Height	65.236 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	580467.016 meters
	Northing	1454103.670 meters

Table 6. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
29-Mar-14	7156GC	2BLK19E088A	ABY-09, LPH-01
30-Mar-14	7158GC	2BLK19ES089A & 2BLK19G089A	ABY-09, LPH-01
31-Mar-14	7167GC	2BLK19K093A & 2BLK10IS093A	ABY-09, LPH-01
31-Mar-14	7168GC	2BLK19L094A	ABY-09, LPH-01
03-Apr-14	7171GC	2BLK19M095A	ABY-92, LPH-01
04-Apr-14	7216GC	2BLK19AS118A & VOIDS (BLK19Q)	ABY-09, LPH-01
05-Apr-14	3813G	2BLK19IS056B	ABY-82
28-Apr-14	3815G	2BLK19KLS057A	ABY-82
06-Feb-16	3757G	2BLK34K037A	SMR-58 and SM-309
25-Feb-16	3825G	2BLK19JFS059B	ABY-82
26-Feb-16	7160GC	2BLK19I90A	ABY-09, LPH-01
28-Feb-16	7161GC	2BLK19IS090B	ABY-09, LPH-01

2.3 Flight Missions

Eleven (11) missions were conducted to complete the LiDAR Data acquisition in Donsol Floodplain, for a total of thirty five hours and thirty two minutes (35+32) of flying time for RP-C9322, RP-C9022. All missions were acquired using the Gemini LiDAR System.

Table 7 shows the actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Donsol Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within Floodplain (km2)	Area Surveyed Outside Floodplain (km2)	Flying Hours	
						Hr	Min
29-Mar-14	7156GC	106.73	40.41	-	40.41	2	11
30-Mar-14	7158GC	241.81	282.19	5.71	276.47	4	29
31-Mar-14	7160GC	171.14	19.42	2.64	16.78	1	35
31-Mar-14	7161GC	171.14	138.71	21.71	117	2	29
3-Apr-14	7167GC	179.98	247.35	50.89	196.46	3	53
4-Apr-14	7168GC	171.15	229.12	34.78	194.34	3	29
5-Apr-14	7171GC	75.7	119.2	13.56	105.64	2	59
28-Apr-14	7216GC	122.54	135.24	-	135.24	3	11
25-Feb-16	3813G	107.1	121.93	14.97	106.96	4	17
26-Feb-16	3815G	100.75	118.22	12.51	105.71	3	35
28-Feb-16	3825G	100.44	91.04	1.87	89.17	3	11
TOTAL		1548.47	1542.83	158.65	1384.18	35	32

Table 8. Actual parameters used during LiDAR data acquisition

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within Floodplain (km2)	Area Surveyed Outside Floodplain (km2)	Flying Hours	
						Hr	Min
7156GC	1100	35	40	100	50	130	5
7158GC	1100	35	40	100	50	130	5
7160GC	1000	45	40	100	50	130	5
7161GC	1000	45	40	100	50	130	5
7167GC	1000	40	40	100	50	130	5
7168GC	1100	40	40	100	50	130	5
7171GC	900	20	40	100	50	130	5
7216GC	1300	50	34 and 40	100	50	130	5
3813G	650	40	50	125	40	130	5
3815G	900	40	50	125	40	130	5
3825G	650	40	50	125	40	130	5
TOTAL		1548.47	1542.83	158.65	1384.18	35	32

2.4 Survey Coverage

The Donsol Floodplain is located in the Provinces of Albay and Sorsogon, with majority of the floodplain situated in Albay. The Municipalities of Donsol and Pilar are completely covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Donsol Floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during Donsol Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Albay	Jovellar	82.35	74.37	90%
	Camalig	136.54	94.69	69%
	Daraga	135.66	86.6	64%
	Legazpi City	153.18	88.6	58%
	Guinobatan	174.07	51.84	30%
	Malilipot	45.42	7.37	16%
	Malinao	106.78	15.33	14%
	Tiwi	124.4	16.4	13%
	Pio Duran	133.24	15.05	11%
	Tabaco City	112.24	8.59	8%
	Bacacay	115.2	5.27	5%
	Ligao City	258.51	9.74	4%
	Santo Domingo	60.83	2	3%
	Oas	239.58	2.8	1%
Sorsogon	Donsol	153	153	100%
	Pilar	196.62	196.28	100%
	Castilla	197.27	155.22	79%

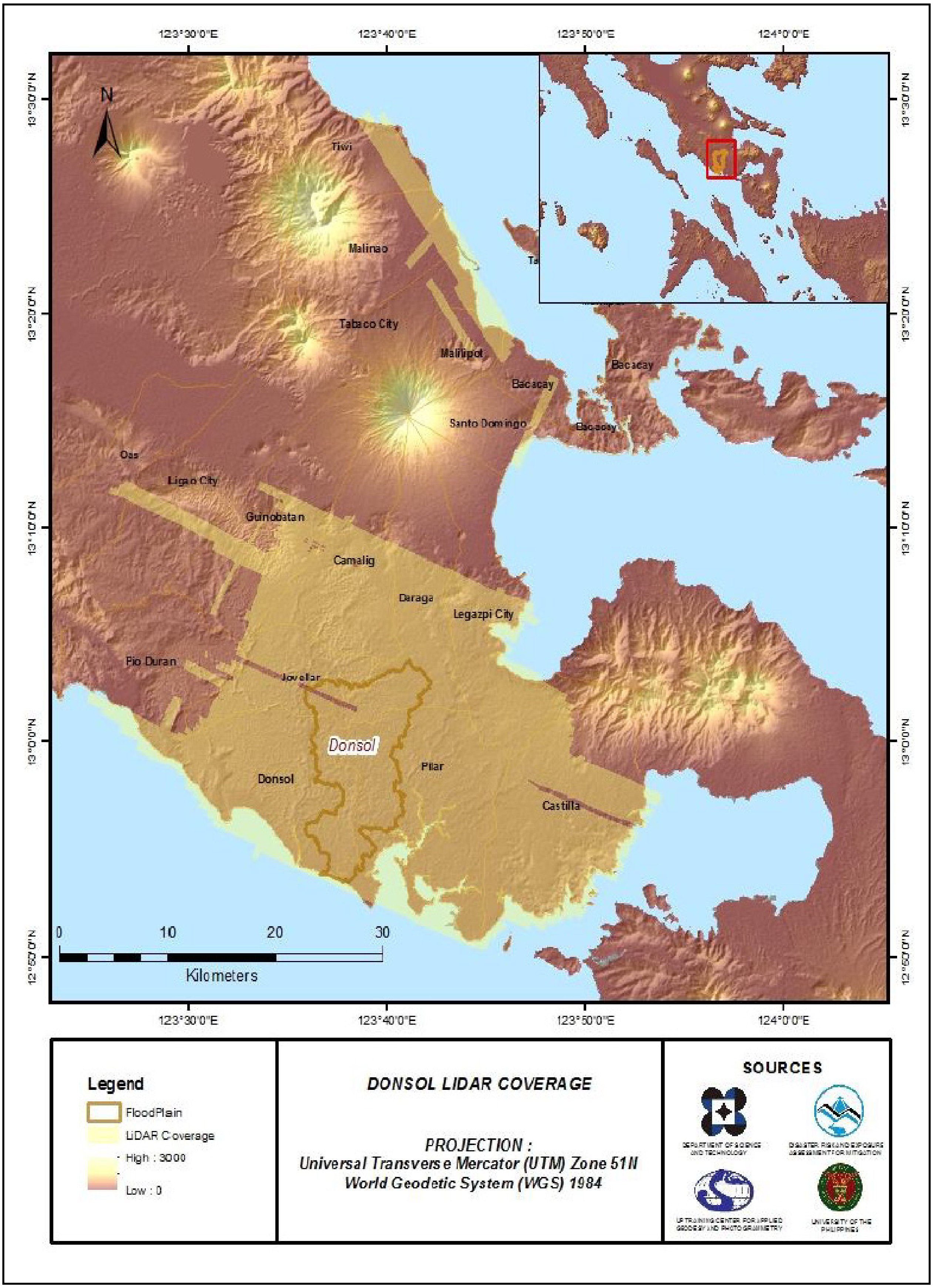

Figure 7. Actual LiDAR survey coverage for Donsol Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE DONSOL 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 LiDAR Data Processing for Donsol Floodplain

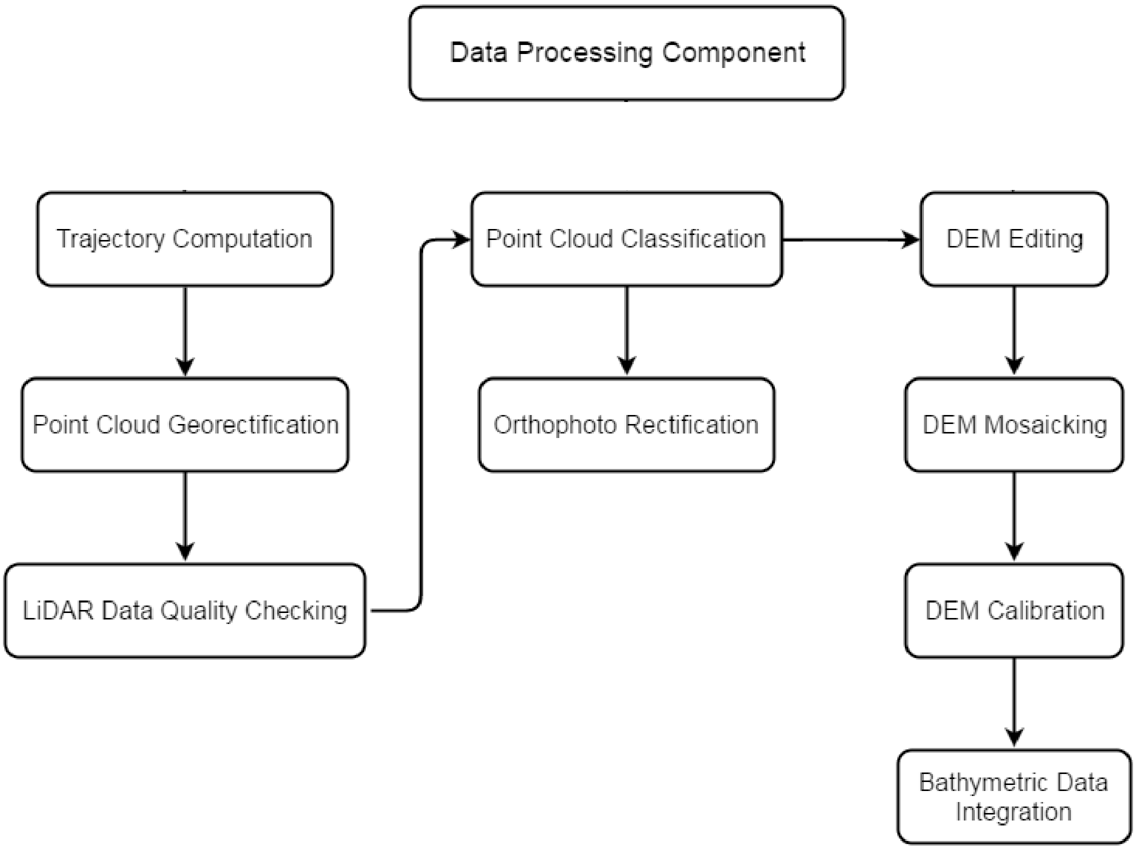


Figure 8. Schematic diagram for Data Pre-processing Component.

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality check to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were 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 were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data 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 8.

3.2 Transmittal of Acquired LiDAR Data

The Data Transfer Sheets for all the LiDAR missions for Donsol Floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on March 2014 and second survey conducted on February 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System and Gemini-CASI System, respectively over Donsol and Pilar, Sorsogon. The Data Acquisition Component (DAC) transferred a total of 194.24 Gigabytes of Range data, 1.92 Gigabytes of POS data, 85.48 Megabytes of GPS base station data, and 426.27 Gigabytes of raw image data to the data server on May 5, 2014 for the first survey, and on March 21, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Donsol was fully transferred on March 21, 2016 as indicated on the Data Transfer Sheets for Donsol Floodplain

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3815G one of the Donsol flights, which is the North, East, and Down position RMSE values are shown in Figure 9. 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 February 23, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

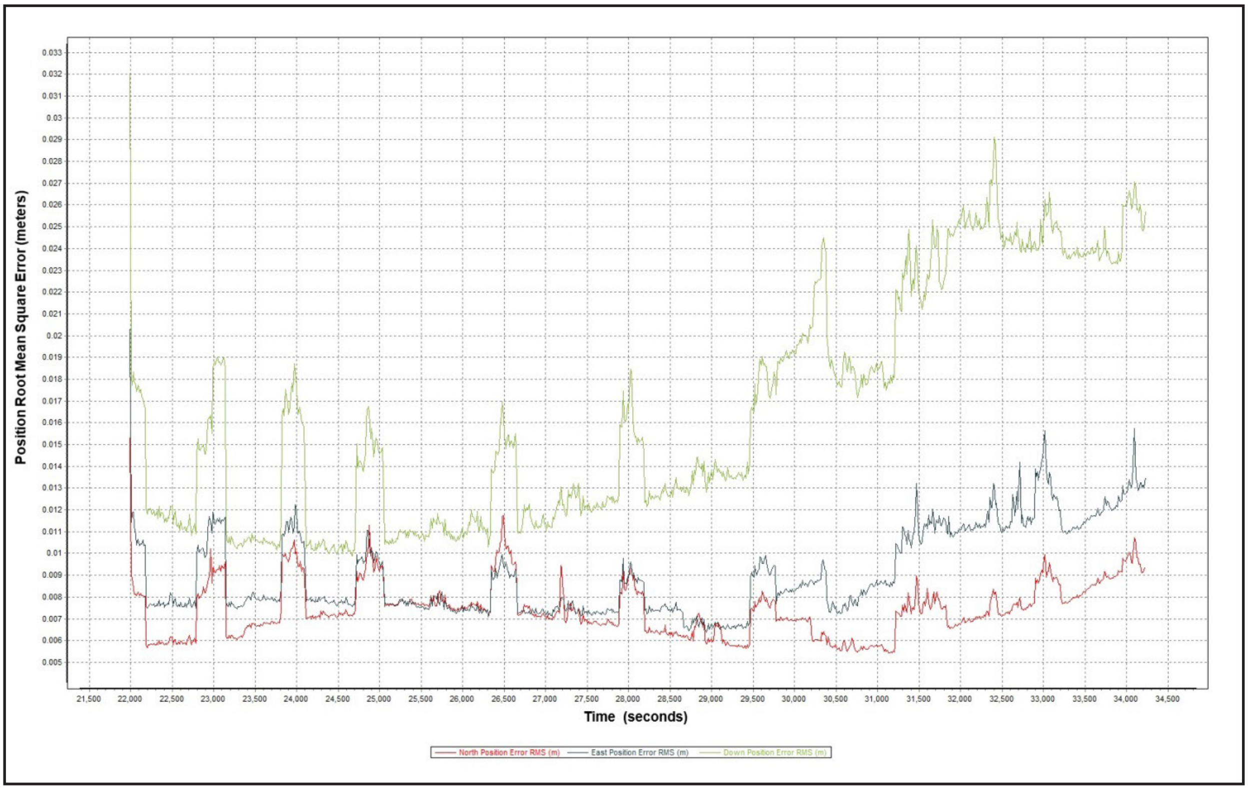


Figure 9. Smoothed Performance Metrics of a Donsol Flight 3815G

The time of flight was from 437,000 seconds to 447,500 seconds, which corresponds to morning of February 23, 2014. The initial spike seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and when the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft made a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1.71 centimeters, and the Down position RMSE peaks at 3.34 centimeters, which are within the prescribed accuracies described in the methodology.

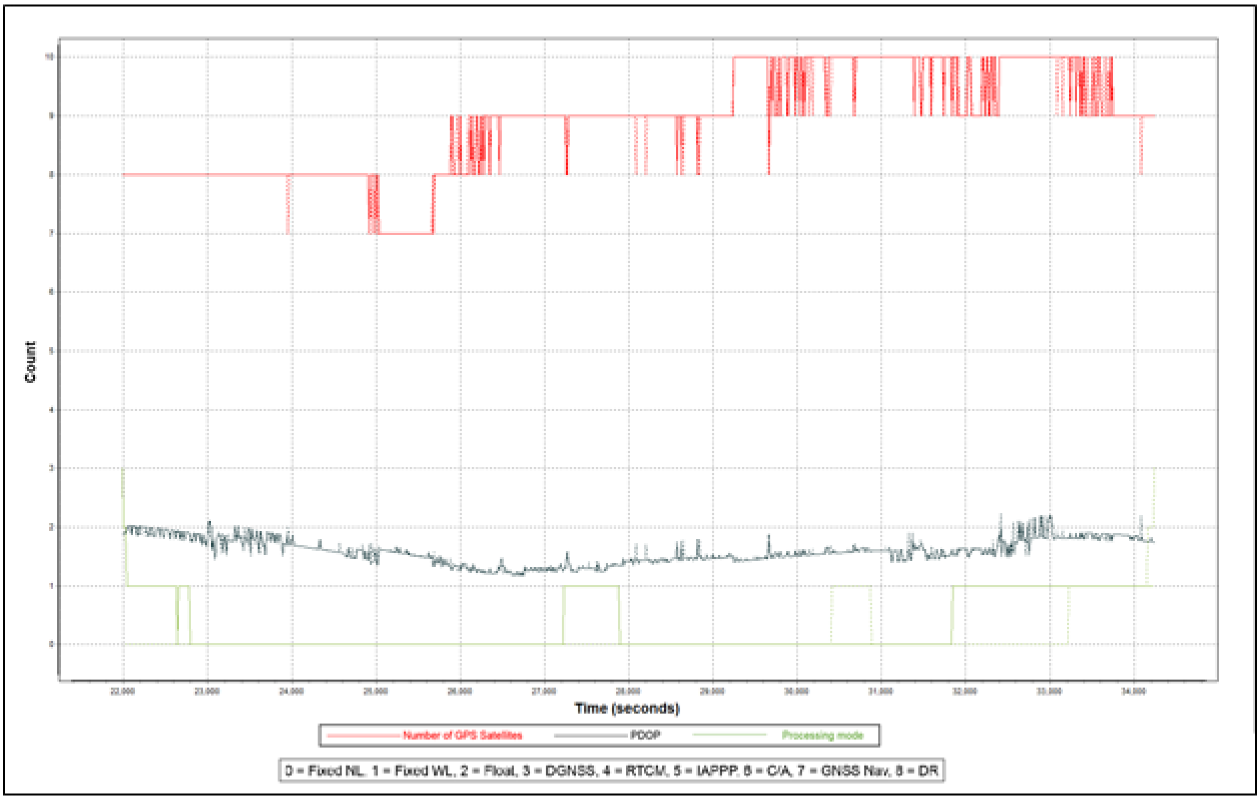


Figure 10. Solution Status Parameters of Donsol Flight 3815G

The Solution Status parameters of flight 3815G, one of the Donsol flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did go down to 6. Most of the time, the number of satellites tracked was between 7 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 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 Donsol flights is shown in Figure 11.

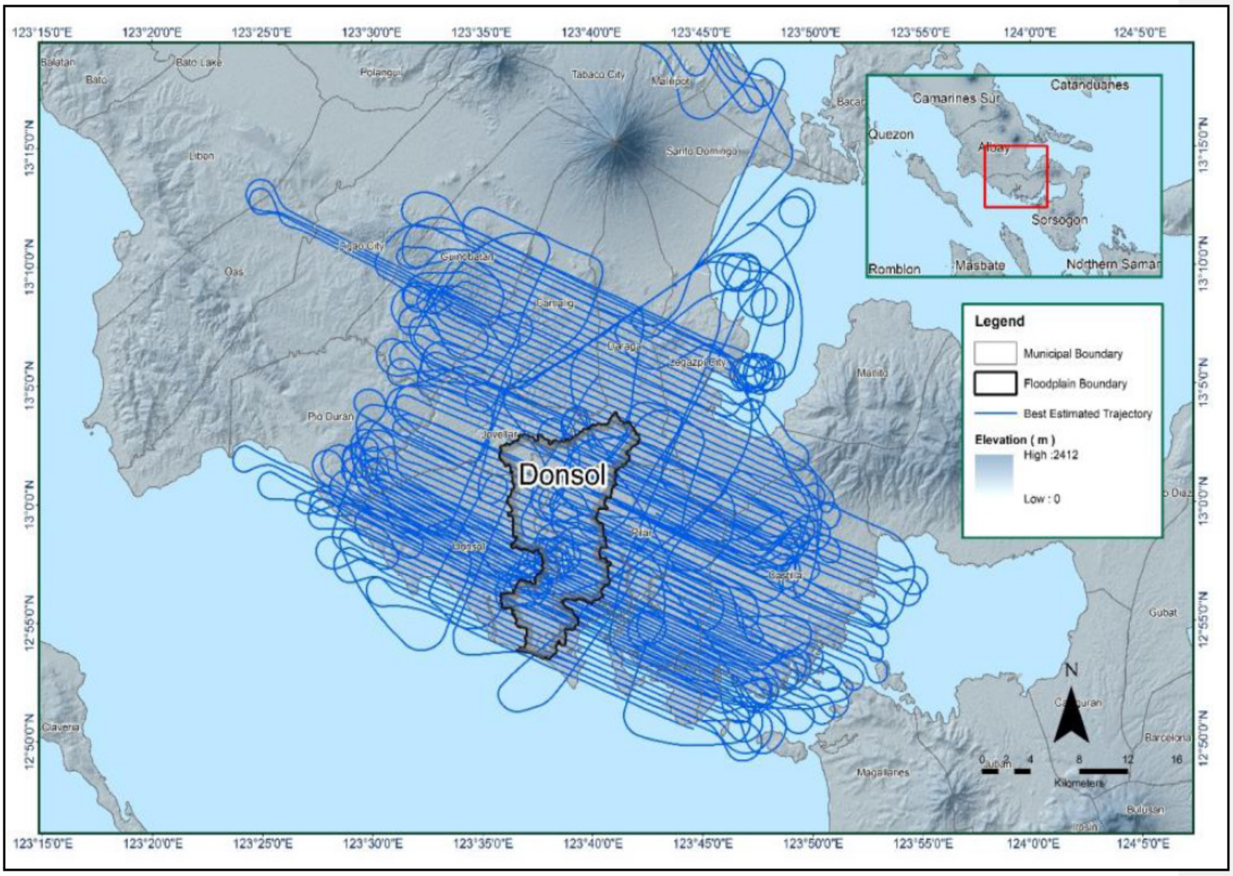


Figure 11. Best estimated trajectory for Donsol Floodplain

3.4 LiDAR Point Cloud Computation

The LAS data produced contain 135 flight lines, with each flight line containing one channel, since the Gemini and Gemini-CASI systems 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 Donsol Floodplain are given in in Table 10.

Table 10. Self-Calibration Results values for Donsol flights.

Acceptable Value	Value
Boresight Correction stdev (<0.001degrees)	0.000626
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000906
GPS Position Z-correction stdev (<0.01meters)	0.0098

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

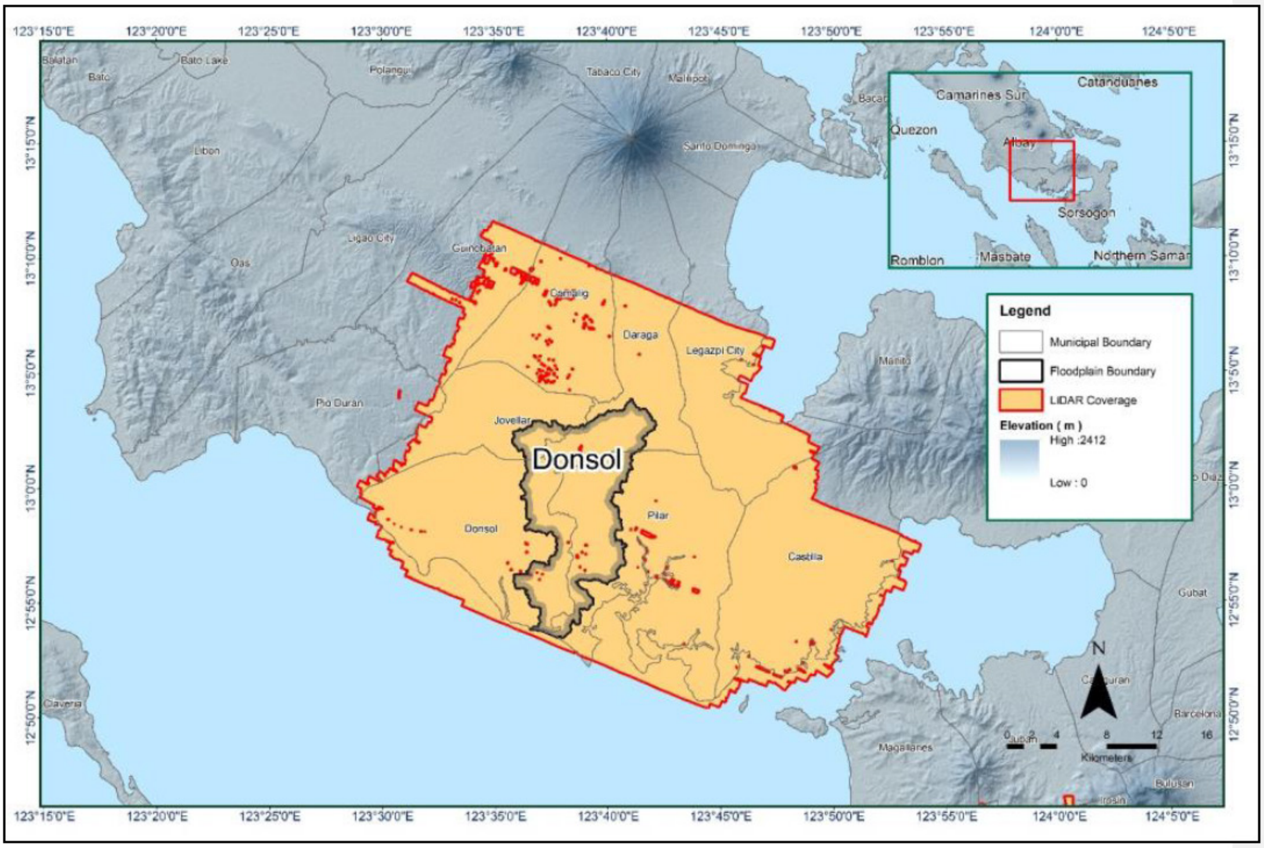


Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Donsol Floodplain.

The total area covered by the Donsol missions is 1,586.35 sq.km that is comprised of eleven (11) flight acquisitions grouped and merged into ten (10) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Donsol Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Albay_Sorgoson_Blk19I	7160GC	407.11
	7161GC	
Albay_Sorgoson_Blk19EG	7156GC	301.83
	7158GC	
	7216GC	
Albay_Sorgoson_Blk19M	7171GC	114.68
Albay_Sorgoson_Blk19M_additional	7171GC	48.22
Albay_Sorgoson_Blk19L	7168GC	192.24
Albay_Sorgoson_Blk19K	7167GC	238.9
Albay_Sorsogon_reflights_Blk19Q	3825G	62.34
Albay_Sorsogon_reflights_Blk19L	3815G	71.19
Albay_Sorsogon_reflights_Blk19I	3813G	74.76
Albay_Sorsogon_reflights_Blk19I_ additional	3813G	75.08
TOTAL		1,586.35 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 13. Since the Gemini and Gemini-CASI 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.

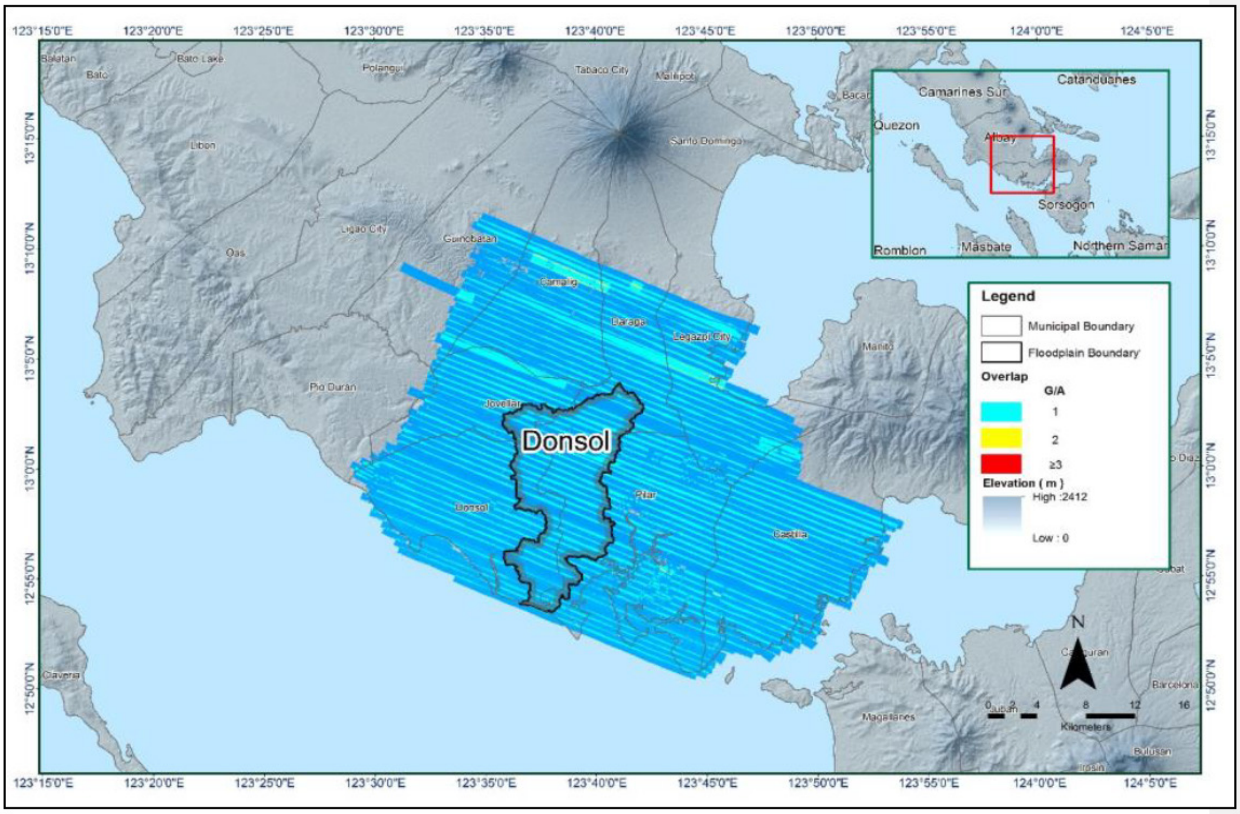


Figure 13. Image of data overlap for Donsol Floodplain

The overlap statistics per block for the Donsol floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 13.70% and 47.44% 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 14. It was determined that all LiDAR data for Donsol floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.02 points per square meter.

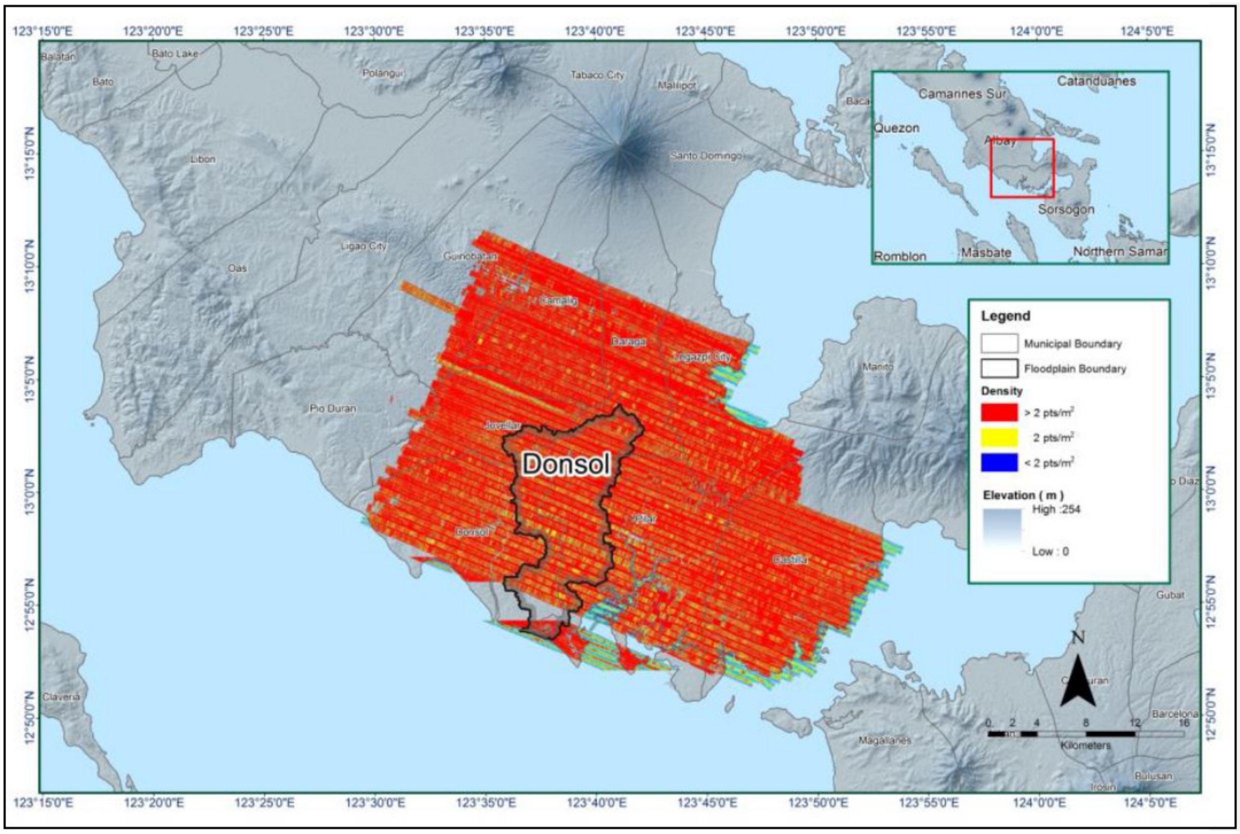


Figure 14. Pulse Density map of merged LiDAR data for Donsol Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

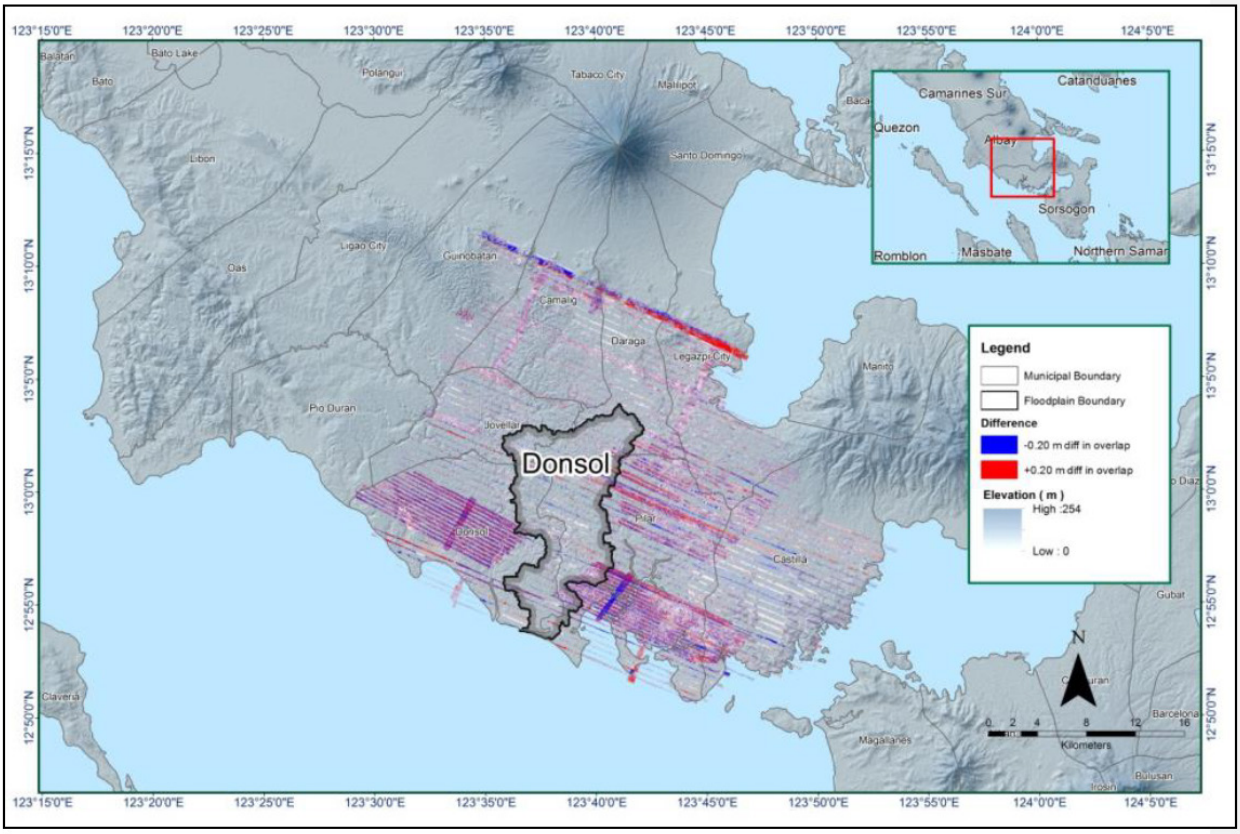


Figure 15. Elevation difference map between flight lines for Donsol Floodplain

A screen capture of the processed LAS data from a Donsol Flight 3815G loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

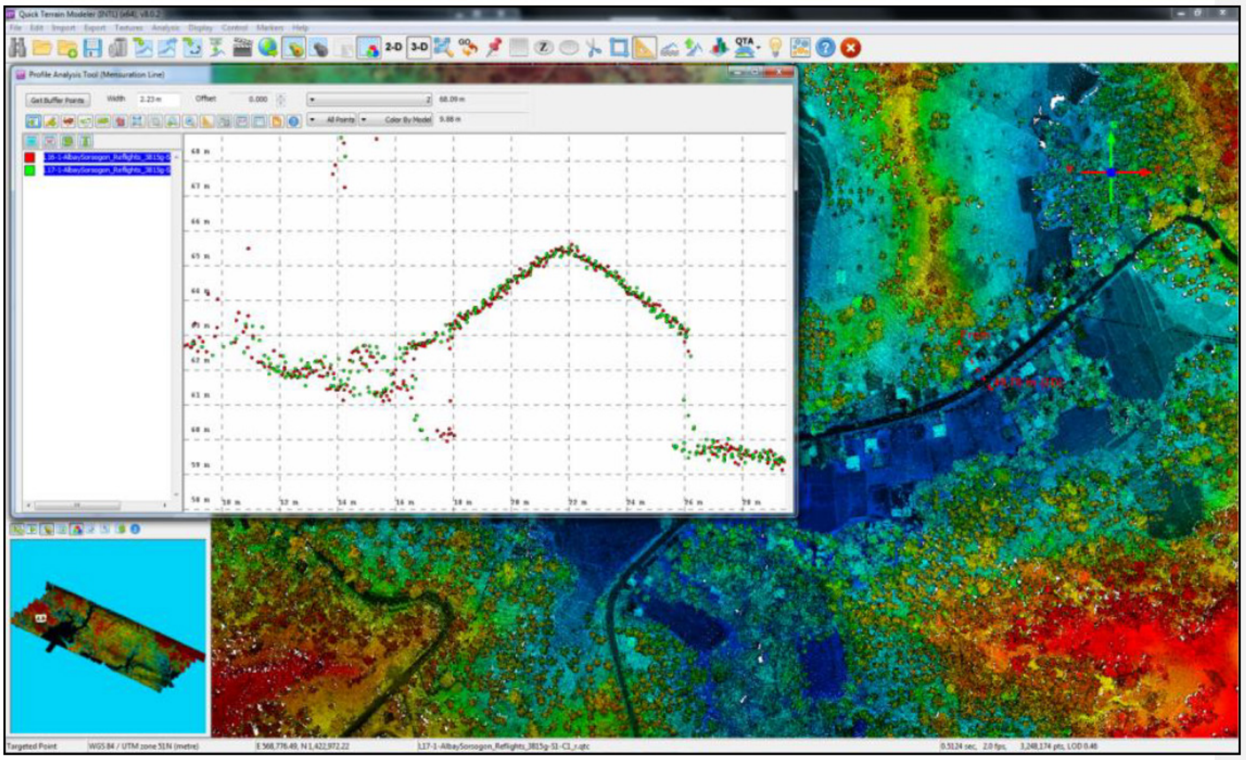


Figure 16. Quality checking for a Donsol flight 3815G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Donsol classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	667,007,734
Low Vegetation	620,432,220
Medium Vegetation	1,360,165,052
High Vegetation	2,544,475,538
Building	26,944,971

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Donsol floodplain is shown in Figure 17. A total of 2,157 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 447.71 meters and 52.66 meters respectively.

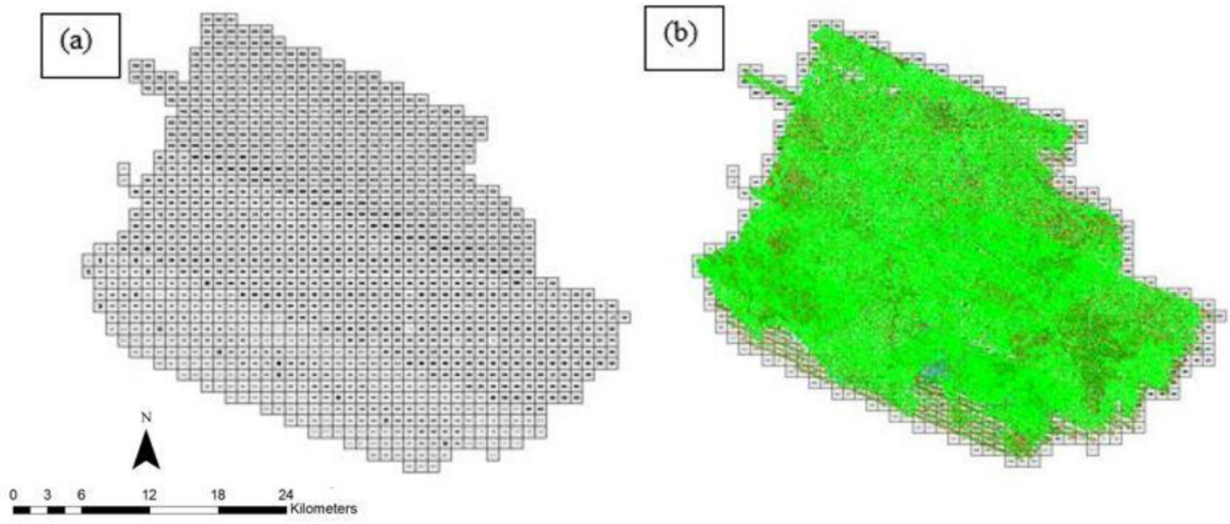


Figure 17. Tiles for Donsol Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

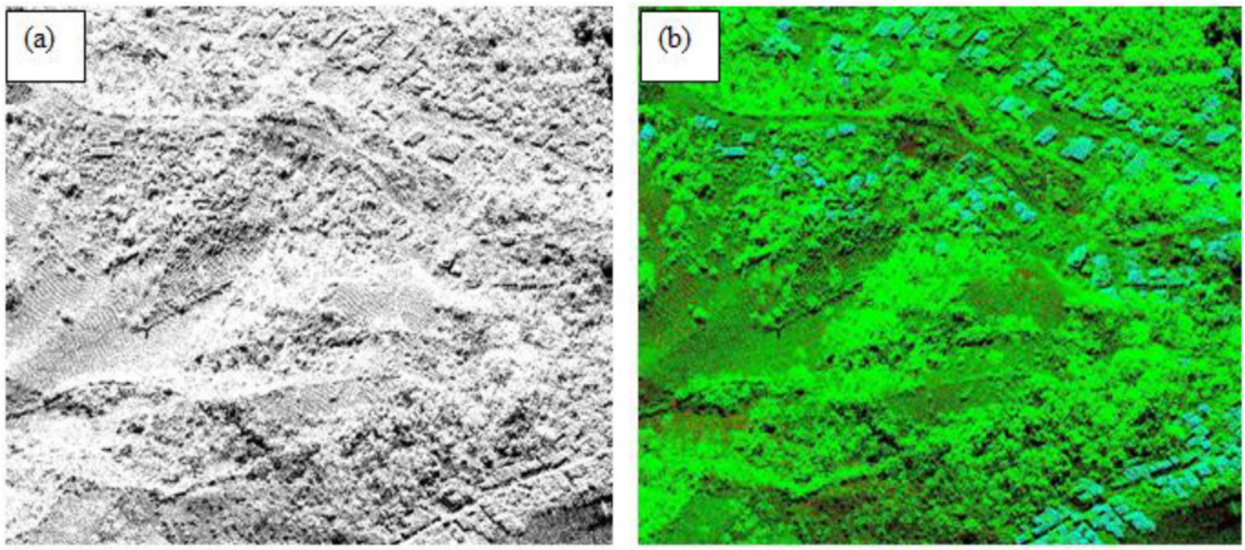


Figure 18. Point cloud before (a) and after (b) classification

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

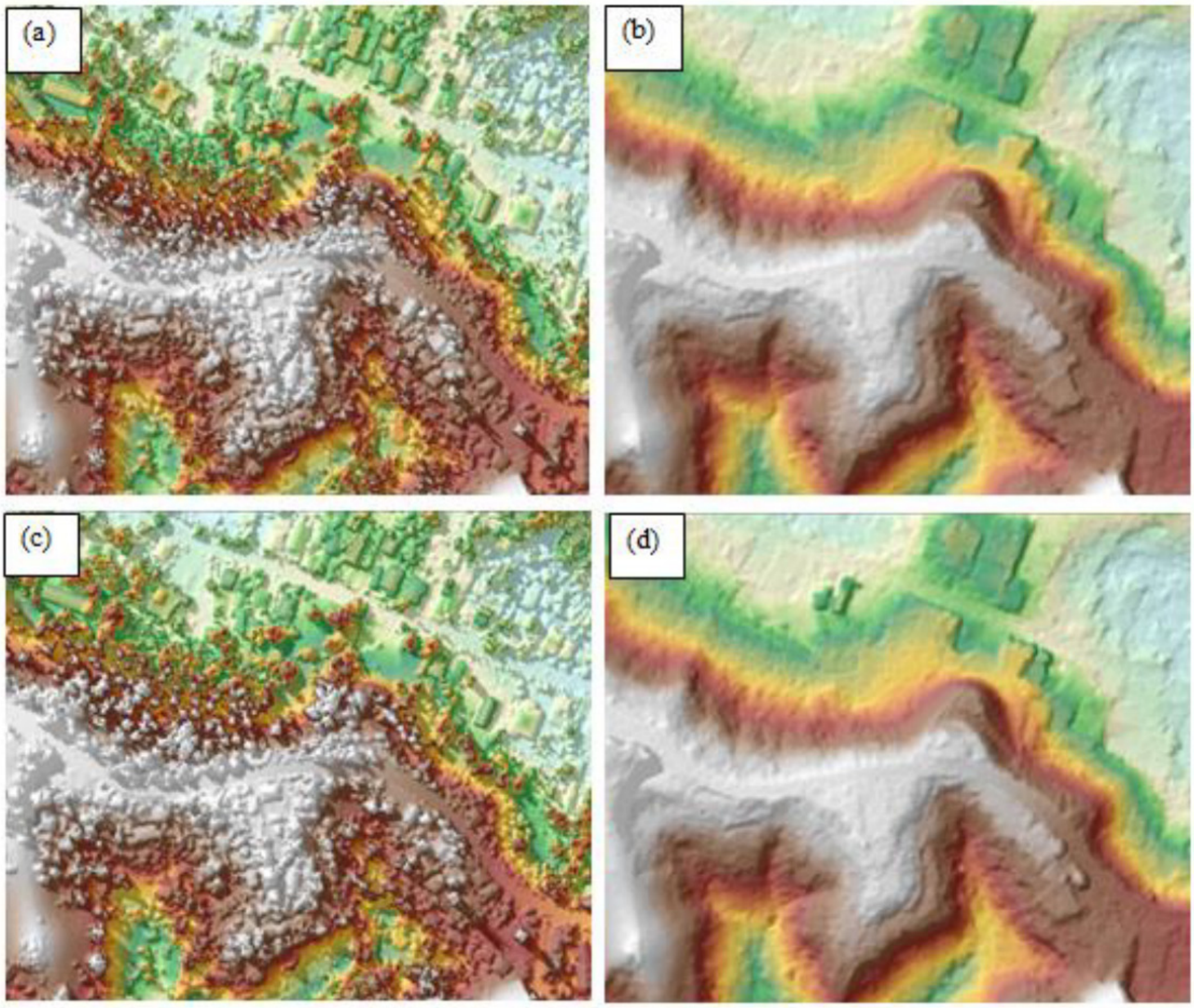


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Donsol Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 412 1km by 1km tiles area covered by Donsol Floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Donsol Floodplain has a total of 194.72 sq.km orthophotogaph coverage comprised of 2,167 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

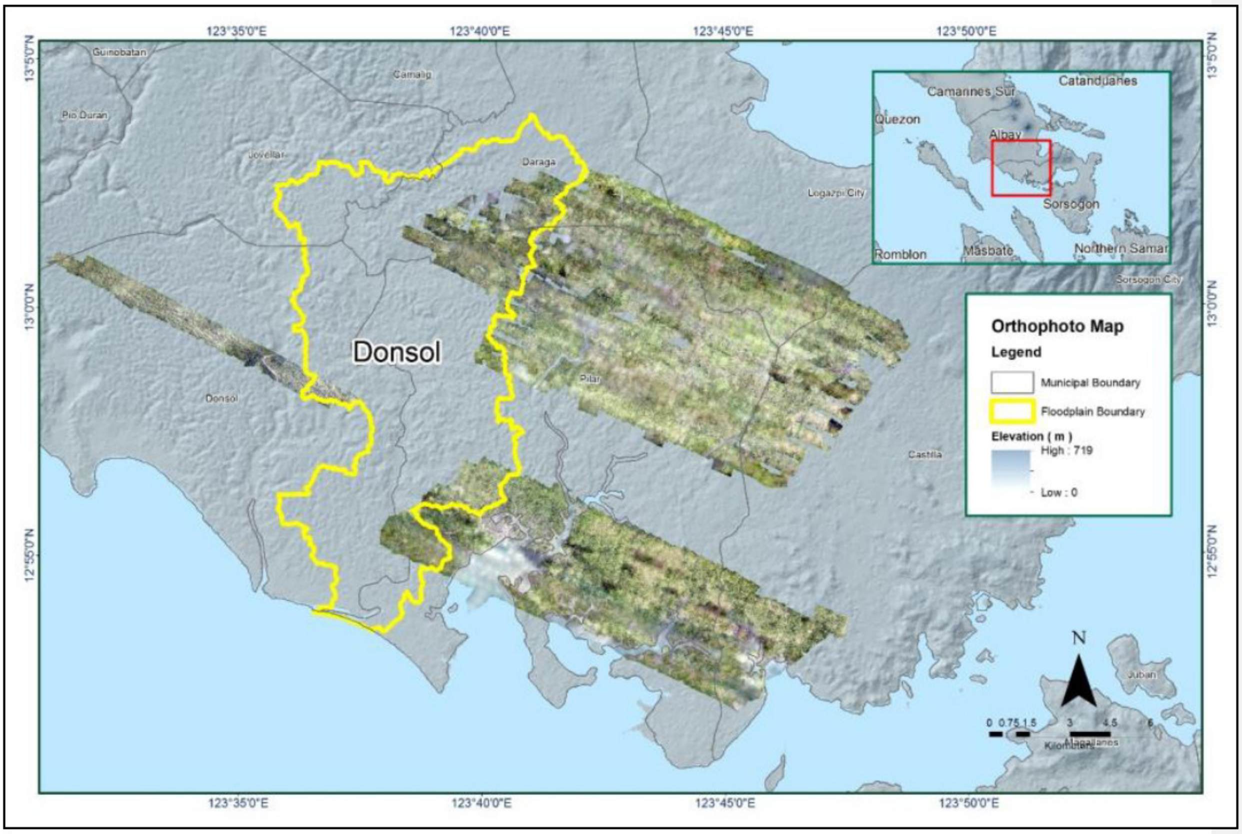


Figure 20. Donsol Floodplain with available orthophotographs

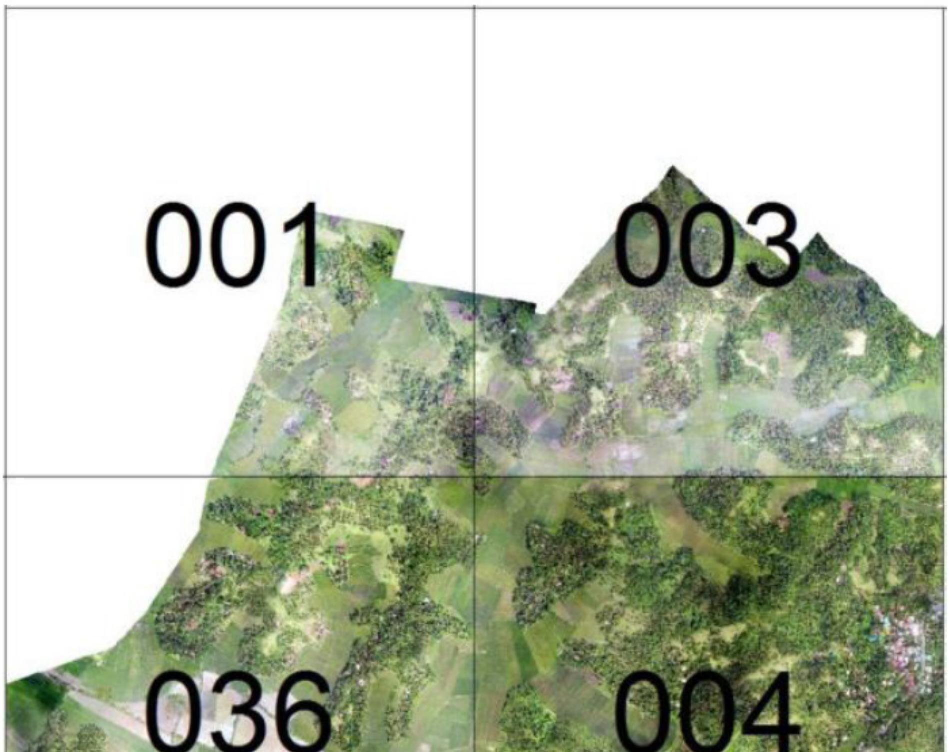


Figure 21. Sample orthophotograph tiles for Donsol Floodplain.

3.8 DEM Editing and Hydro-Correction

Ten (10) mission blocks were processed for Donsol Floodplain. These blocks are composed of Albay_ Sorsogon and Albay_Sorsogon_reflights blocks with a total area of 1,586.35 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Albay_Sorgoson_Blk19I	407.11
Albay_Sorgoson_Blk19EG	301.83
Albay_Sorgoson_Blk19M	114.68
Albay_Sorgoson_Blk19M_additional	48.22
Albay_Sorgoson_Blk19L	192.24
Albay_Sorgoson_Blk19K	238.90
Albay_Sorsogon_reflights_Blk19Q	62.34
Albay_Sorsogon_reflights_Blk19L	71.19
Albay_Sorsogon_reflights_Blk19I	74.76
Albay_Sorsogon_reflights_Blk19I_additional	75.08
TOTAL	1,586.35 sq. km

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

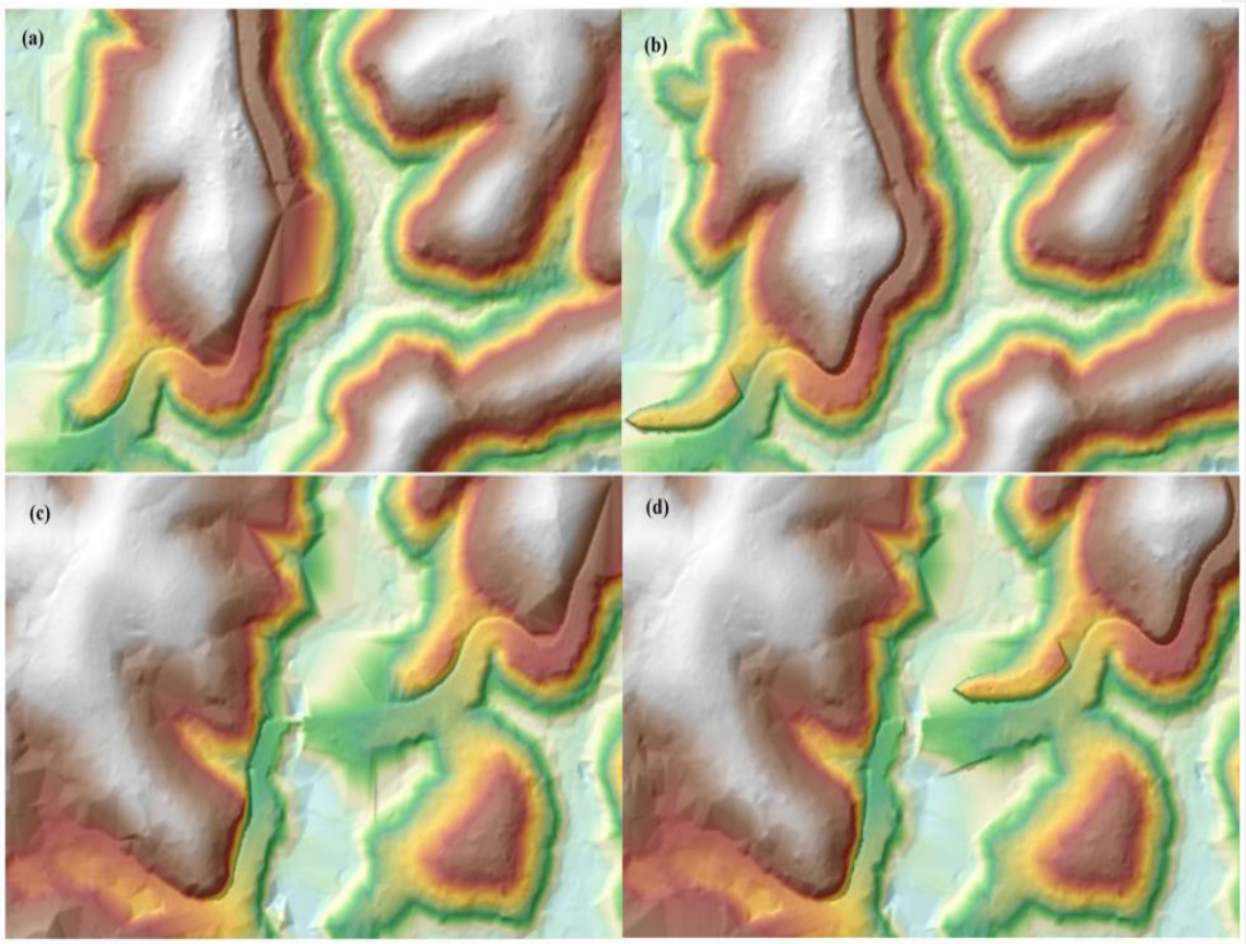


Figure 22. Portions in the DTM of Donsol Floodplain – a mountain ridge and road before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

Albay_Sorsogon Blk19M was used as the reference block at the start of mosaicking because it is the located in the estuary of the river.

Mosaicked LiDAR DTM for Donsol Floodplain is shown in Figure 23. It can be seen that the entire Donsol Floodplain is 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Donsol Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Albay_Sorsogon_Blk19I	0.26	1	-1.36
Albay_Sorsogon_Blk19EG	1	1.25	-1.34
Albay_Sorsogon_Blk19M	-2	2	-2.22
Albay_Sorsogon_Blk19M_additional	-2	2	-2.22
Albay_Sorsogon_Blk19L	0	2	-2.16
Albay_Sorsogon_Blk19K	-1	1	1.17
Albay_Sorsogon_reflights_Blk19Q	-1	2	-1.90
Albay_Sorsogon_reflights_Blk19L	0	0	-2.18
Albay_Sorsogon_reflights_Blk19I	1	1	-1.67
Albay_Sorsogon_reflights_Blk19I_additional	1	2	-1.72

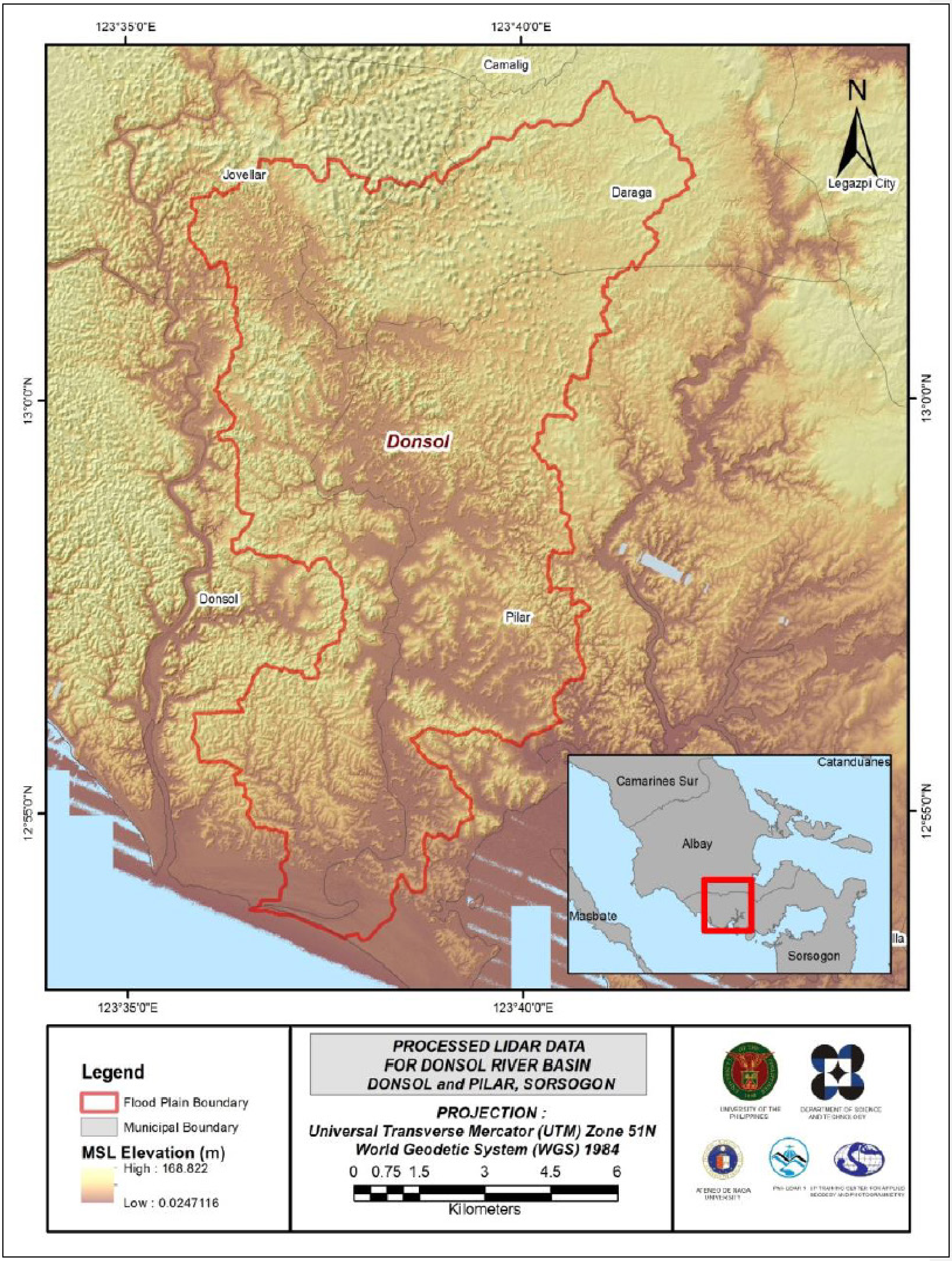


Figure 23. Map of Processed LiDAR Data for Donsol Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

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

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.41 meters with a standard deviation of 0.17 meters. Calibration of Donsol LiDAR data was done by adding the height difference value, 0.41 meters, to Donsol mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

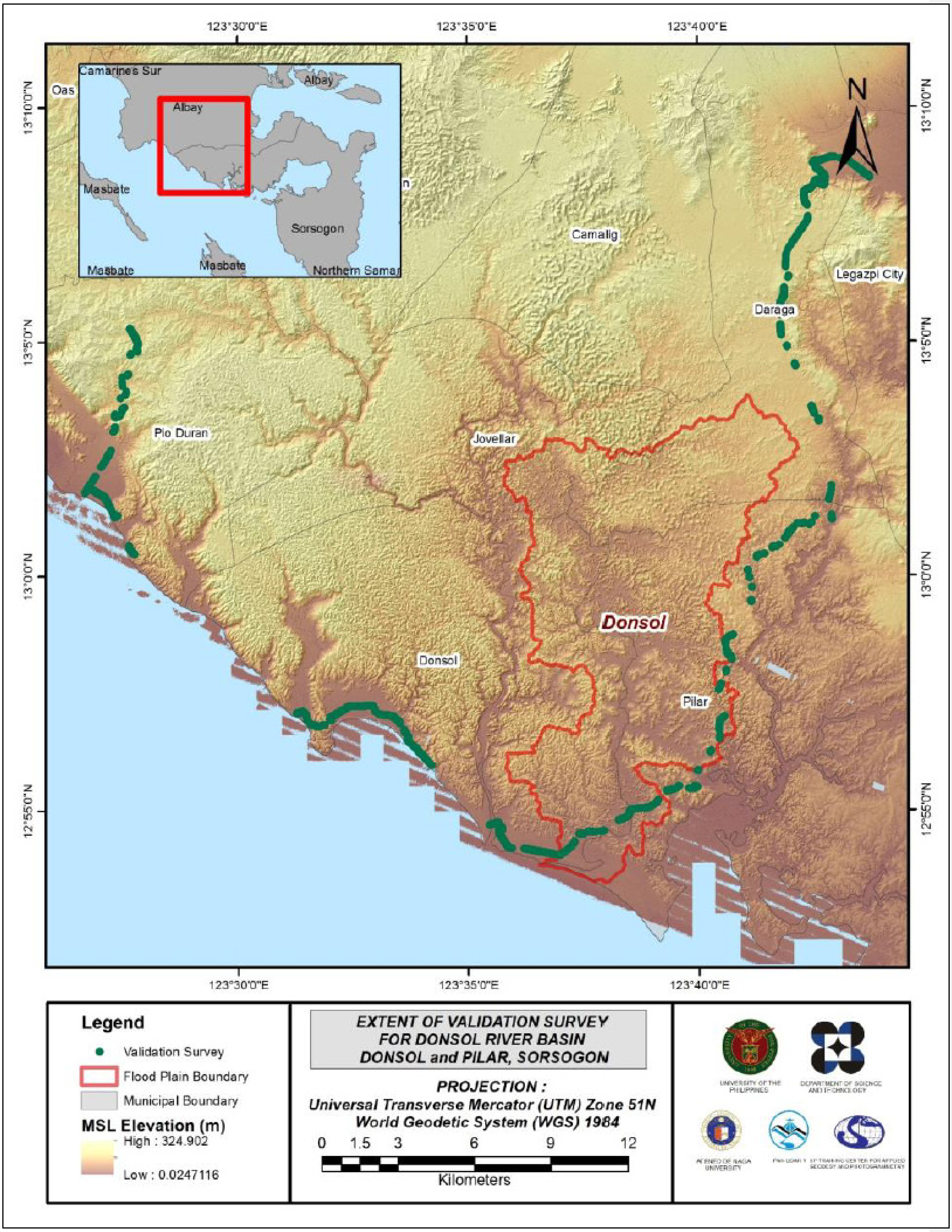


Figure 24. Map of Donsol Floodplain with validation survey points in green

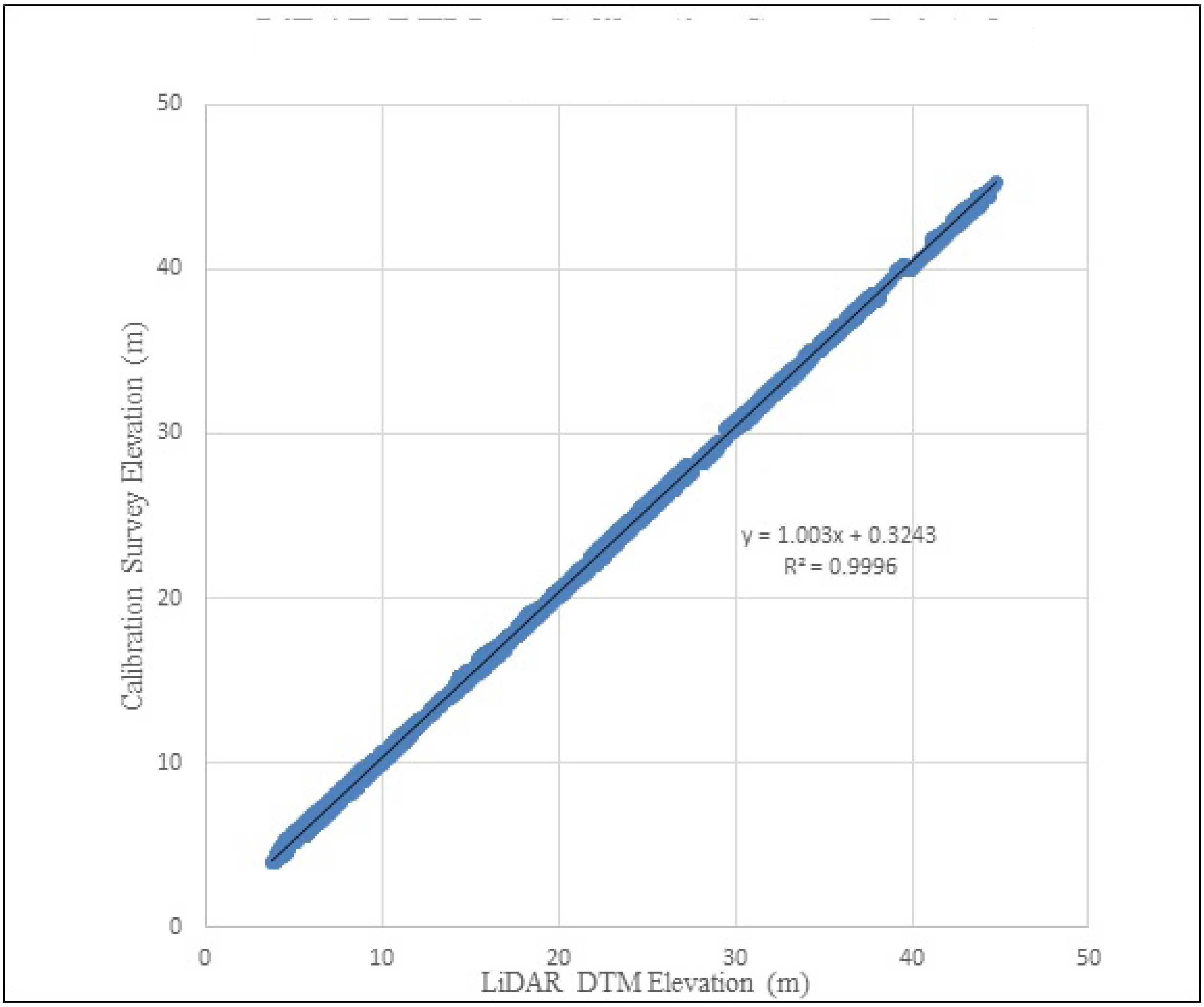


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 15. 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 4,270 points were collected by DVBC for the Donsol river basin. Random selection of points within the floodplain boundary, resulting to 248 points, were used for the validation of calibrated Donsol 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.12 meters, as shown in Table 16.

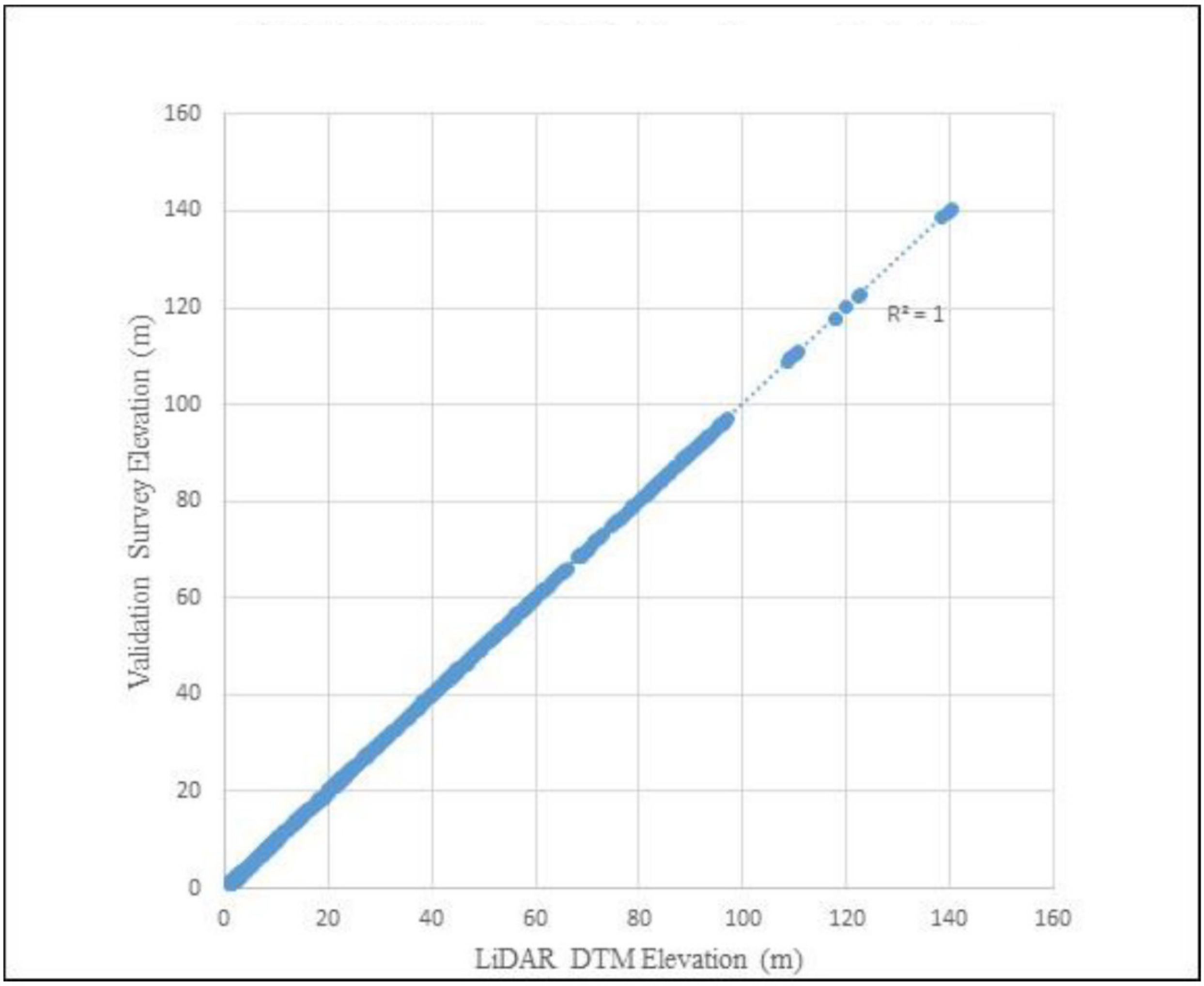


Figure 26. Correlation plot between validation survey points and LiDAR data

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.12
Average	0.16
Minimum	-0.06
Maximum	0.39

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Donsol with 3488 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.55 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Donsol integrated with the processed LiDAR DEM is shown in Figure 26.

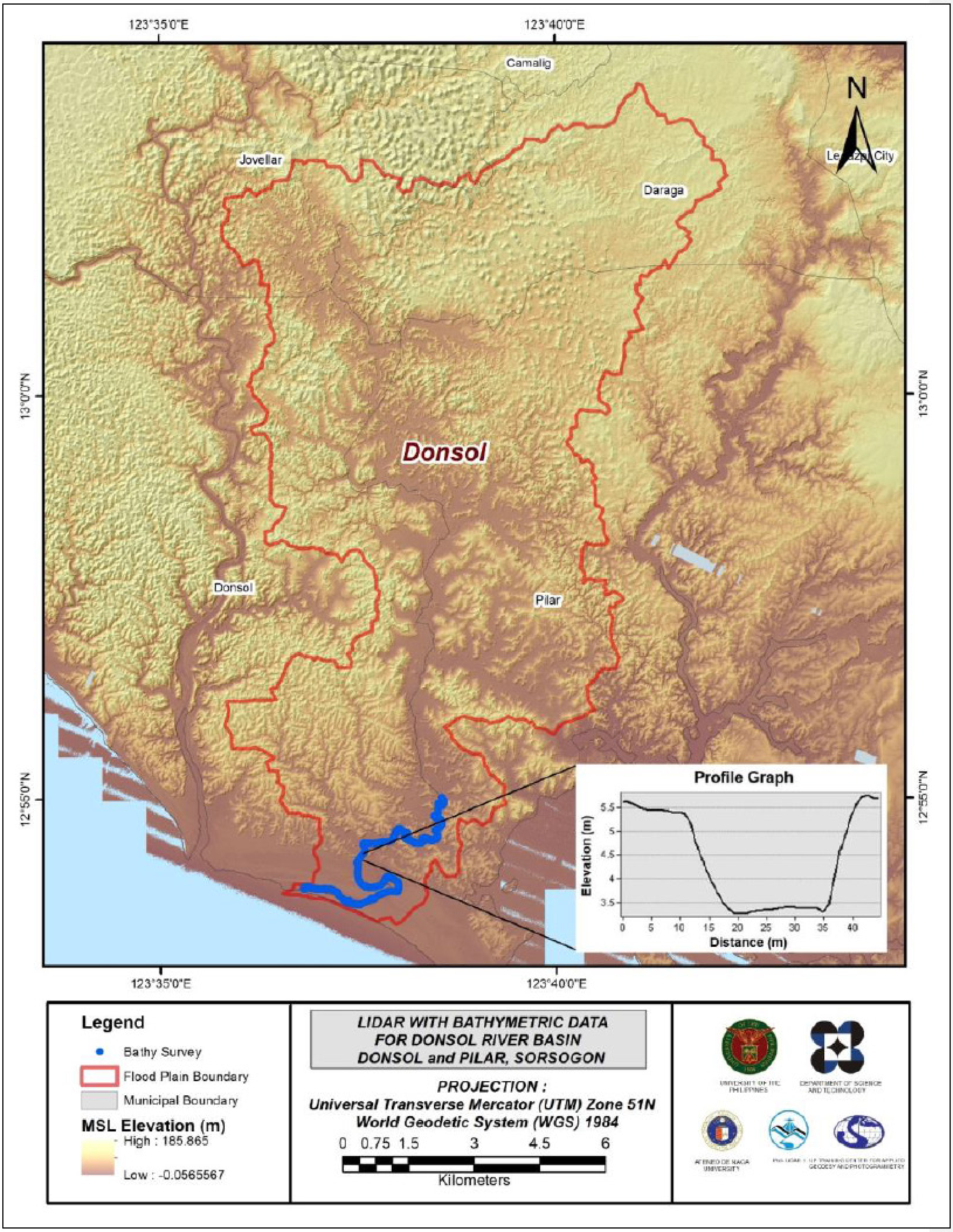


Figure 27. Map of Donsol Floodplain with bathymetric survey points shown in blue

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, consists of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks comprised of main thoroughfares such as highways and municipal and barangay roads 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

Donsol floodplain, including its 200 m buffer, has a total area of 208.01 sq km. For this area, a total of 6.0 sq. km., corresponding to a total of 1031 building features, are considered for QC. Figure 30 shows the QC blocks for Donsol floodplain.

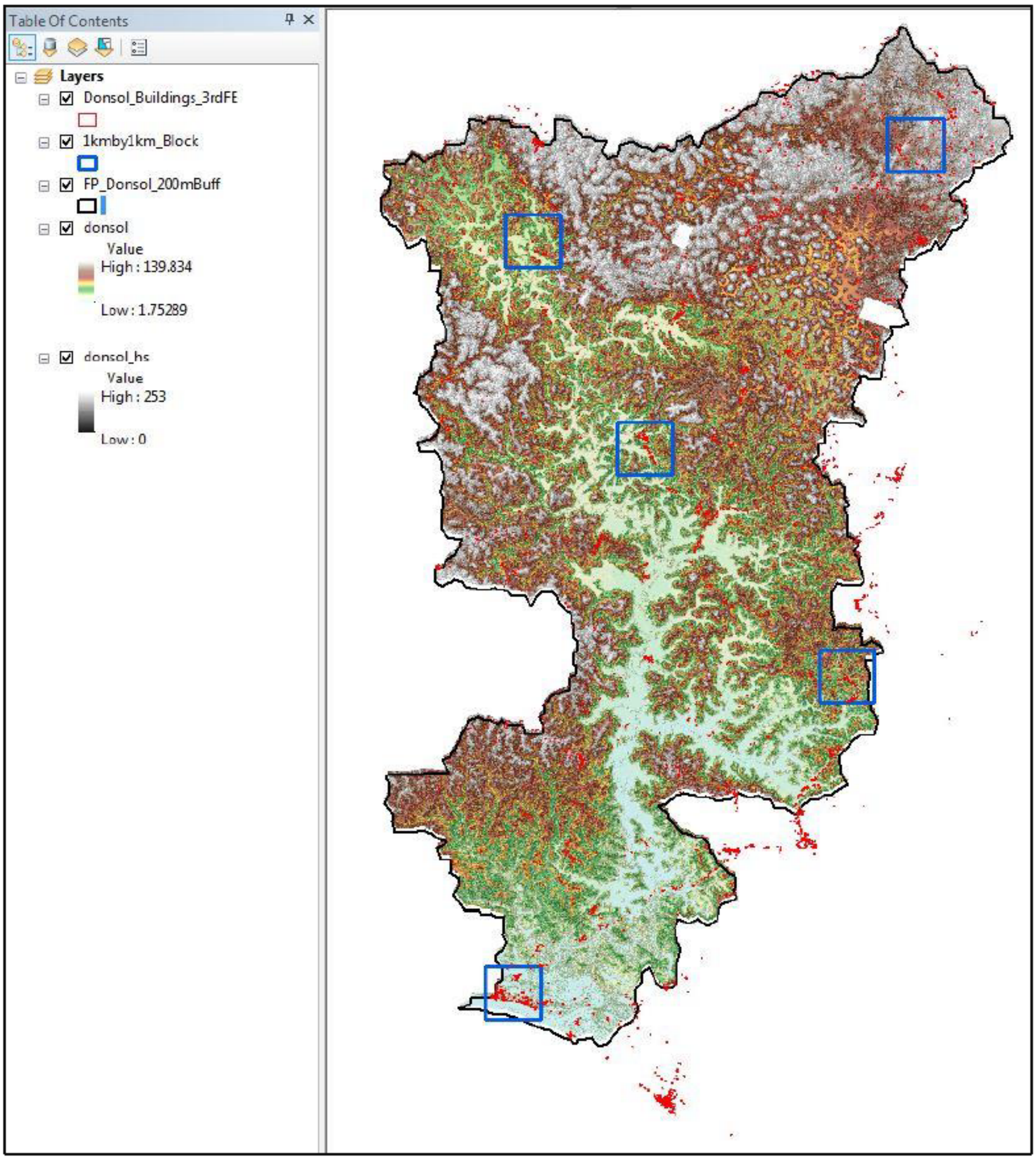


Figure 28. QC blocks for Donsol building features

Quality checking of Donsol building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Donsol Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Donsol	99.42	98.93	95.11	PASSED

3.12.2 Height Extraction

Height extraction was done for 6,321 building features in Donsol Floodplain. Of these building features, 97 were filtered out after height extraction, resulting to 6,224 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 19.36 m.

3.12.3 Feature Attribution

Feature Attribution was done for 6,224 building features in Donsol Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

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

Table 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

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

Table 18. Building Features Extracted for Donsol Floodplain.

Facility Type	No. of Features
Residential	5957
School	176
Market	0
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	13
Barangay Hall	30
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	2
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	0
Water Supply/Sewerage	1
Religious Institutions	33
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	5
Other Commercial Establishments	3
Total	6,224

Table 19. Total Length of Extracted Roads for Donsol Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Donsol	95.76	0	0.89	13.21	0.00	109.86

Table 20. Number of extracted water bodies for Donsol floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Donsol	1	33	1	0	0	35

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

3.12.4 Final Quality Checking of Extracted Features

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

Figure 28 shows the Digital Surface Model (DSM) of Donsol floodplain overlaid with its ground features.

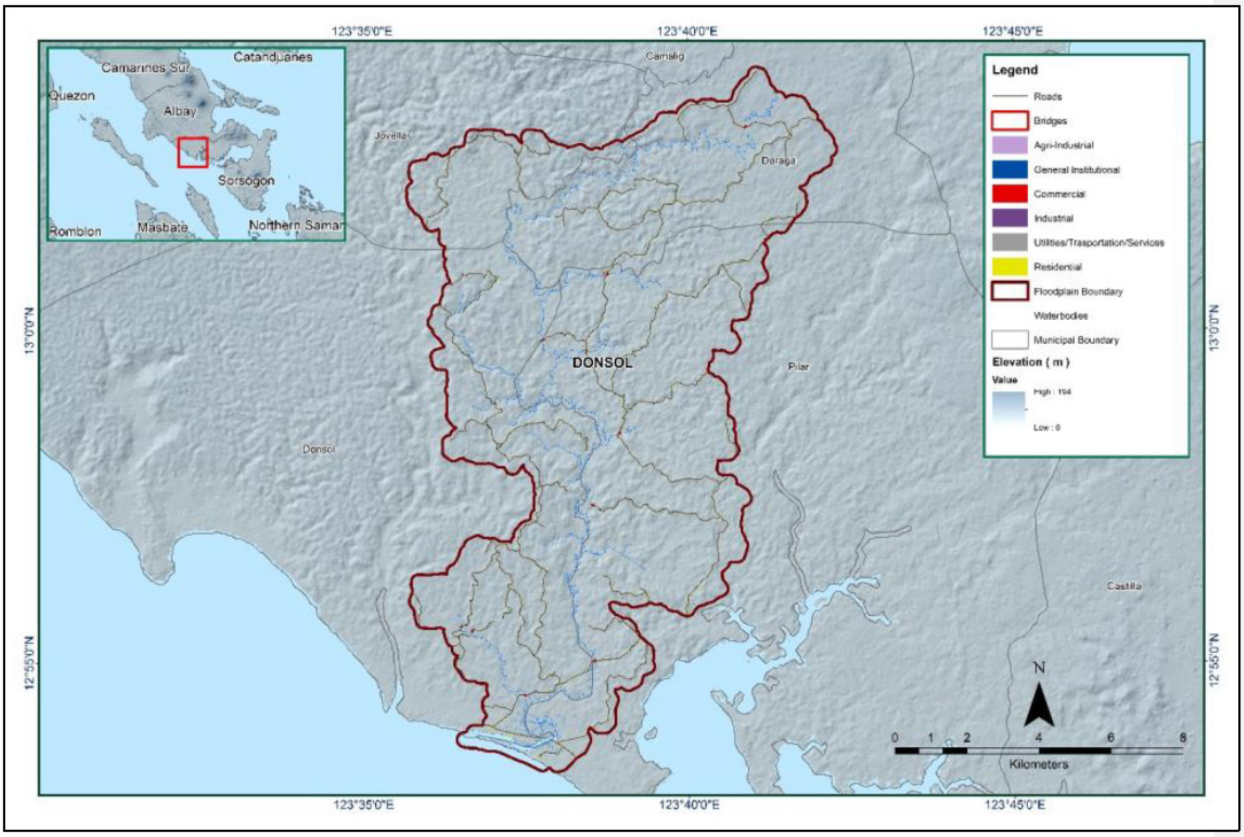


Figure 29. Extracted features for Donsol Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE DONSOL 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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Donsol River on October 15 to 24, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built of Dancalan Bridge in Brgy. Dancalan, Municipality of Donsol; ground validation data acquisition of about 58 km; and bathymetric survey with an estimated length of 8 km using Ohmex™ Single Beam Echo Sounder and GNSS PPK survey technique.

Figure 30. Survey extent for Donsol River Basin

4.2 Control Survey

The GNSS network used for Donsol River Basin is composed of a single loop established on October 17 and a baseline on October 19, 2014 occupying the control points SRG-46, a second-order GCP, in Brgy. Pangpang, Municipality of Donsol, Sorsogon; and AL-298, a first-order BM, in Brgy. Sagpon, Legazpi City. Albay Province.

Two (2) control points were established along the approach of bridges namely: UP-DON, located at Dancalan Bridge in Brgy. Dancalan, Municipality of Donsol; and UP-ILG, at Ilog Bridge, in Brgy. Gura, also in Municipality of Donsol.

The summary of reference and control points and its location is summarized in Table C-1 while the GNSS network established is illustrated in Figure 31.

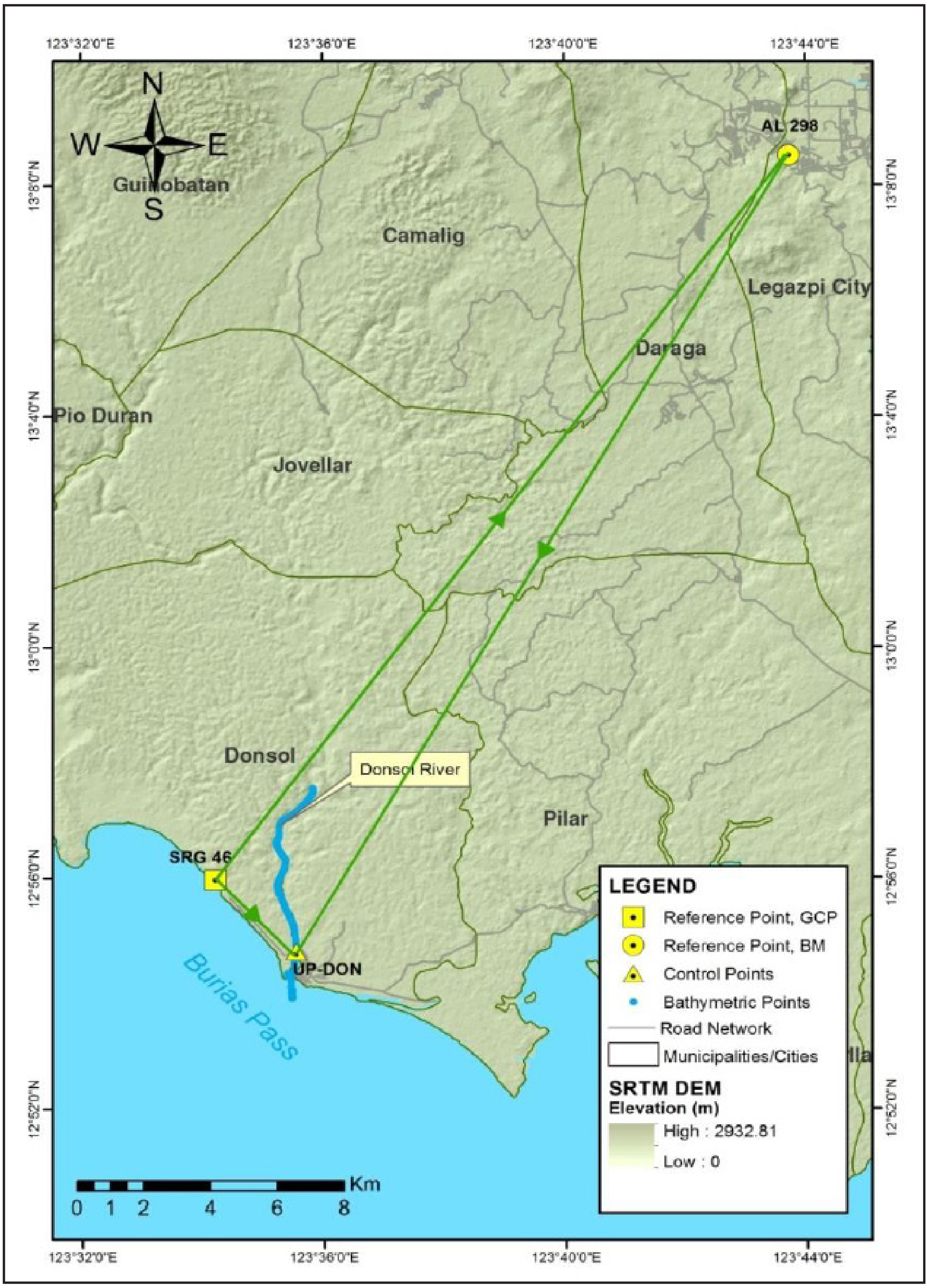


Figure 31. GNSS Network of Donsol River field survey

Table 21. References used and control points established in the Donsol River Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
SRG-46	2nd order GCP	12°55'58.28467"N	123°34'12.66564"E	56.687	-	2009
AL-298	1st order BM	-	-	65.015	11.6955	2007
UP-DON	UP Estab-lished	-	-	-	-	10-17-2014
UP-ILG 01	UP Estab-lished	-	-	-	-	10-17-2014

The GNSS set-ups on recovered points and established control points in Donsol River are shown in Figure 32 to Figure 34.

Figure 32. Trimble® SPS 852 at AL-298, located at Sagpon Bridge, in Brgy. Sagpon, Legazpi City, Albay

Figure 33. Trimble® SPS 882 at SRG-46 in Pangpang Elementary School, Donsol, Sorsogon

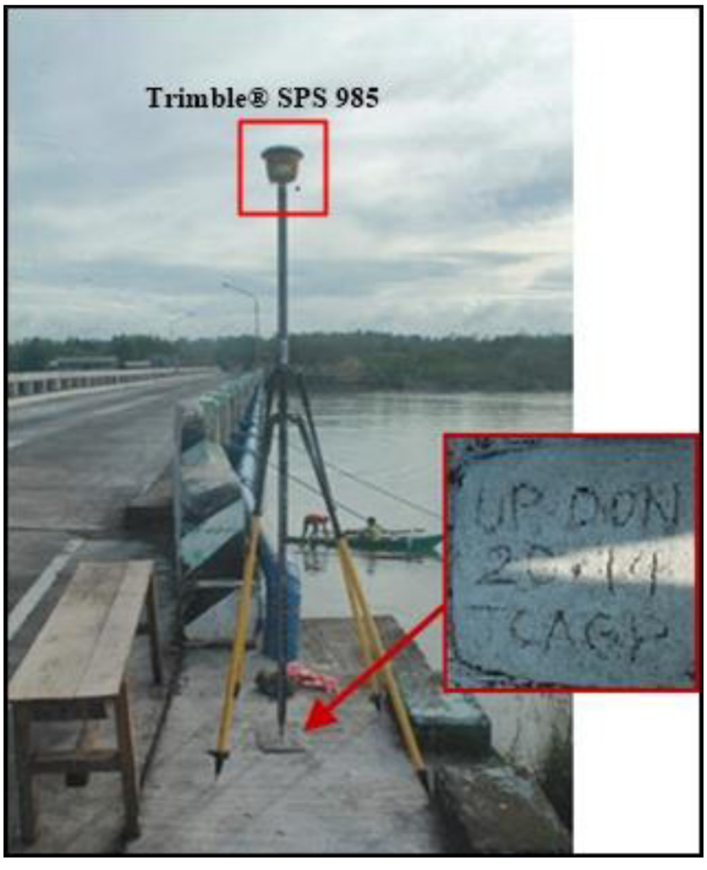


Figure 34. Trimble® SPS 985 at UP-DON at the approach of Dancalan Bridge in Donsol, Sorsogon

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 where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Donsol River Basin is summarized in Table 22 generated by TBC software.

Table 22. The Baseline processing report for the Donsol River GNSS static observation survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
AL-298 --- SRG-46	10-17-2014	Fixed	0.004	0.024	216°40’29”	28826.526	-8.314
AL-298 --- UP-DON	10-17-2014	Fixed	0.004	0.019	210°20’38”	29503.778	-7.692
AL-298 --- UP-DON	10-17-2014	Fixed	0.003	0.023	210°20’37”	29502.776	-7.727
UP-ILG --- UP-DON	10-17-2014	Fixed	0.004	0.014	263°59’54”	5550.558	-5.457
UP-DON --- SRG-46	10-17-2014	Fixed	0.002	0.008	135°18’48”	3290.945	0.642
UP-ILG --- SRG-46	10-17-2014	Fixed	0.005	0.017	102°38’48”	8029.084	6.145

Four (4) control points were occupied in the fieldwork. SRG-46 was held fixed and used as control for the network. Formed baselines acquired fixed solutions and passed the required ±20 cm and ±10 cm for horizontal and vertical precision, respectively, as shown in Table 22.

4.4 Network Adjustment

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

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

where:

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

for each control point. Table C-3 to Table C-5 show the results of GNSS network adjustment.

Table 23. Constraints applied to the adjustment of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SRG-46	Local	Fixed	Fixed		
AL-298	Grid				Fixed
Fixed = 0.000001 (Meter)					

Coordinates of SRG-46, and elevation of AL-298 were fixed during the processing of the network for Donsol River survey, as shown in Table .

Table 24. Adjusted grid coordinates for the control points used in the Donsol River flood plain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SRG-46	776407.626	0.007	1240340.446	0.005	3.779	0.050	
561849.132	?	1429779.512	?	2.948	0.080	LL	e
AL-298	741264.593	0.010	1230815.204	0.007	3.951	0.061	
578994.142	0.012	1452941.041	0.009	11.696	?	e	
UP-DON	784907.431	?	1257282.043	?	17.660	0.032	LL
564167.815	0.008	1427445.746	0.007	3.659	0.074		
UP-ILG	766068.484	0.005	1282999.389	0.004	6.035	0.036	
569684.587	0.014	1428039.705	0.011	9.210	0.098		

Table 24 shows the adjusted grid coordinates of the network. The network is fixed at reference point SRG-46 with fixed coordinates and AL-298 with fixed elevation. With the mentioned equation, the computation for the horizontal and vertical accuracy requirements are as follows:

a. SRG-46
horizontal accuracy = Fixed
vertical accuracy = 8.0 cm < 10 cm

b. AL-298
horizontal accuracy = $\sqrt{((1.2)^2 + (0.9)^2}$
= $\sqrt{(1.44 + 0.81)}$
= 1.5 cm < 20 cm
vertical accuracy = Fixed

c. UP-DON
horizontal accuracy = $\sqrt{((0.8)^2 + (0.7)^2}$
= $\sqrt{(0.64 + 0.49)}$
= 1.06 cm < 20 cm
vertical accuracy = 7.4 cm < 10 cm

d. UP-ILG
horizontal accuracy = $\sqrt{((1.4)^2 + (1.1)^2}$
= $\sqrt{(1.96 + 1.21)}$
= 1.78 cm < 20 cm
vertical accuracy = 9.8 cm < 10 cm

Table 25. Adjusted geodetic coordinates for control points used in the Donsol River Flood Plain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
AL-298	N13°08'30.80115"	E123°43'43.85582"	65.015	?	e
SRG-46	N12°55'58.28467"	E123°34'12.66564"	56.687	0.080	LL
UP-DON	N12°54'42.14411"	E123°35'29.43706"	57.332	0.074	
UP-ILG	N12°55'01.04655"	E123°38'32.55519"	62.804	0.098	

The adjusted geodetic coordinates in Table illustrates that all points complied with the vertical accuracy requirement. The errors of the coordinates and elevation passed the required accuracy. Therefore, the result of the control survey for Donsol River Basin has met the required data accuracy for GNSS surveys.

The summary of references and control points used is indicated in

Table 26. The reference and control points utilized in the Donsol River Static Survey with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SRG-46	2nd Order, GCP	12°55'58.28467"	123°34'12.66564"	56.687	1429779.512	561849.132	2.948
AL-298	1st Order, BM	13°08'30.80115"	123°43'43.85582"	65.015	1452941.041	578994.142	11.696
UP-DON	UP Estab-lished	12°54'42.14411"	123°35'29.43706"	57.332	1427445.746	564167.815	3.659
UP-ILG	UP Estab-lished	12°55'01.04655"	123°38'32.55519"	62.804	1428039.705	569684.587	9.210

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

Cross-section and bridge as-built survey were conducted on October 17, 2014 at the downstream part of Dancalan Bridge in Brgy. Dancalan, Municipality of Donsol, Sorsogon as shown in Figure 35. The survey was done using a Trimble® SPS 882 in PPK survey technique with UP-DON as a base station.

Figure 35. Dancalan Bridge facing upstream

The cross-sectional line of Dancalan Bridge is about 337 m with seventy-five (75) cross-sectional points using the control point UP-DON as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 36 to Figure 38 respectively.

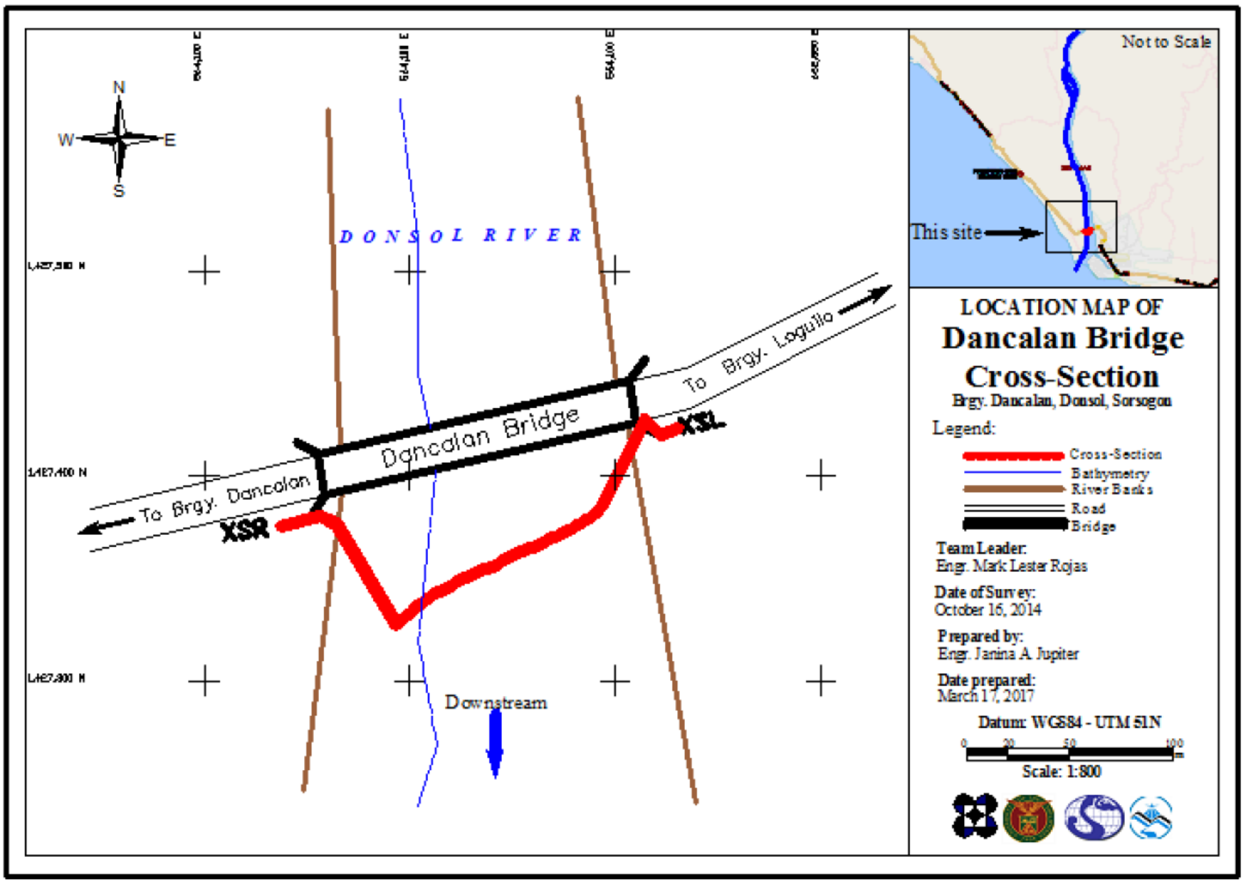


Figure 36. Dancalan bridge cross-section location map

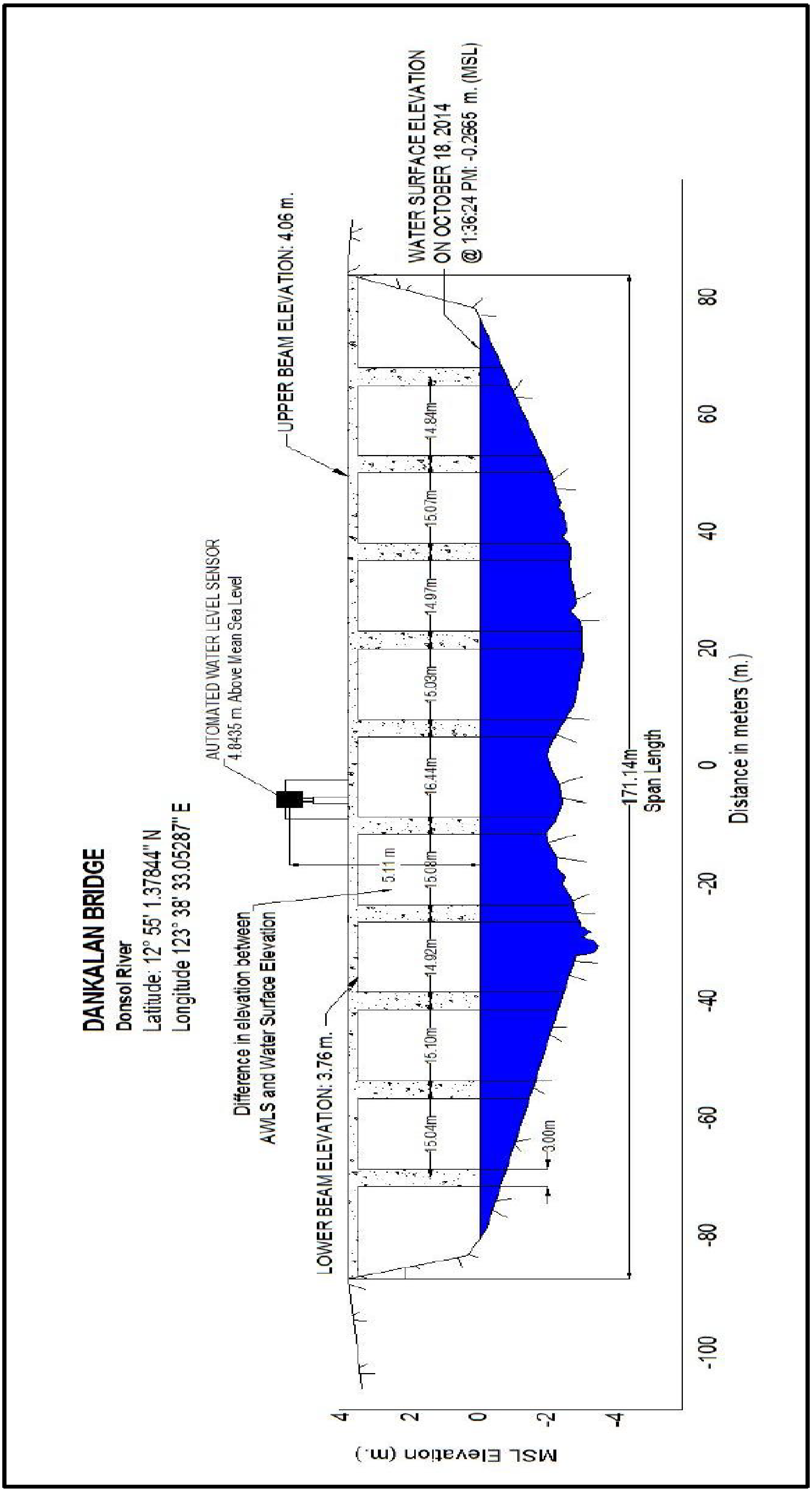
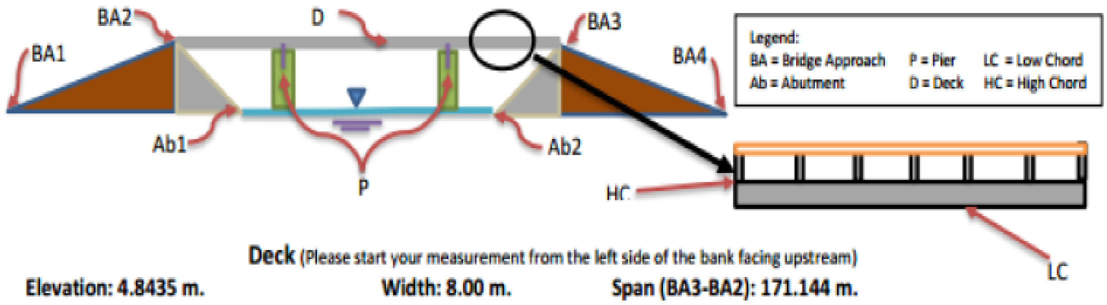


Figure 37. Dancalan Bridge cross-section diagram

Bridge Data Form

Bridge Name: DANCALAN Bridge	**Date: October 1, 2014**
River Name: DONSOL River	**Time: 10:00 AM**
Location (Brgy, City,Region): Dancalan, Donsol, Sorsogon	
Survey Team: Mark Lester D. Rojas, John Louis Gacad, Dona Rina Patricia Tajora, Nancy Dimayacyac	
Flow condition: low ✓ normal high	**Weather Condition:** ✓ fair rainy
Latitude: 12°54'43.03553" N	**Longitude: 123°35'32.03943" E**



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

Elevation: 4.8435 m. **Width: 8.00 m.** **Span (BA3-BA2): 171.144 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	100.465	4.0555	3.7555

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	4.948	BA3	294.160	5.4793
BA2	39.537	5.273	BA4	327.185	4.2043

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

	Station (Distance from BA1)	Elevation
Ab1	22.838	0.296
Ab2	184.323	0.070

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

Shape:Rectangle Number of Piers: 10 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	36.05844	3.8215	2.99
Pier 2	51.09472	3.8185	2.99
Pier 3	66.19595	3.8405	2.99
Pier 4	81.11564	3.7605	2.99
Pier 5	96.19823	3.8375	2.99
Pier 6	112.6446	3.8825	2.99
Pier 7	127.6676	3.8785	2.99
Pier 8	142.6422	3.8785	2.99
Pier 9	157.7065	3.8755	2.99
Pier 10	172.5533	3.8715	2.99

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

Figure 38. Dancalan Bridge Data Form

Water surface elevation of Donsol River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on October 18, 2014 at 1:36 PM with a value of --0.266 m in MSL as shown in Figure C-7. This was translated into marking on the bridge's abutment using the same technique as shown in Figure C-10. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HE responsible for Donsol River, the Ateneo De Naga University.

Figure 39. Water level marking on Dancalan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 17 to 19, 2014 using a survey grade GNSS rover receiver, Trimble® SPS 882, attached to a pole and installed on a van utilizing post process kinematic in topography mode as shown in Figure C-11. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.57 m measured from the ground to the bottom of the notch of the GNSS rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with AL-298 SRG-46 and UP-ILG occupied as the GNSS base stations in the conduct of the survey

Figure 40. Validation Points Acquisition survey setup

The first part of the survey started at Ilog Bridge in Pilar, Sorsogon and ended in Brgy. Sagpon, Legazpi City, Albay. The second part of the survey covered Brgy. Pio Duran going to Ligao City, Albay The survey gathered a total of 4,266 points with an approximate length of 58.12 km using AL-298 SRG-46 and UP-ILG as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure C-12.

Figure 41. Validation Points Acquisition survey extent in Donsol River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on October 16, 2014 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode. The survey started in the upstream in Brgy. San Isidro with coordinates 12°57'33.25899"N, 123°35'49.25959"E, and ended at the mouth of the river in Brgy. Dancalan, with coordinates 12°53'55.17114"N, 123°35'28.48256"E, both in Municipality of Donsol, Sorsogon as shown in Figure C-13 The control point UP-DON was used as the GNSS base station all throughout the entire survey.

The bathymetric survey for Donsol River gathered a total of 3,519 points covering 8 km of the river traversing barangays Dancalan, Girawan, Juan Adre, San Isidro, San Ramon, Suguian, and Tupas in Municipality of Donsol A CAD drawing was also produced to illustrate the riverbed profile of Ogod River. As shown in Figure C-14.the highest and lowest elevation has a 2m difference. The highest elevation observed was -0.880 m above MSL located in Brgy. Suguian, while the lowest was -3.084 m below MSL located in Brgy. Tupas, both in Municipality of Donsol.

Figure 42. Bathymetric Survey of Donsol River

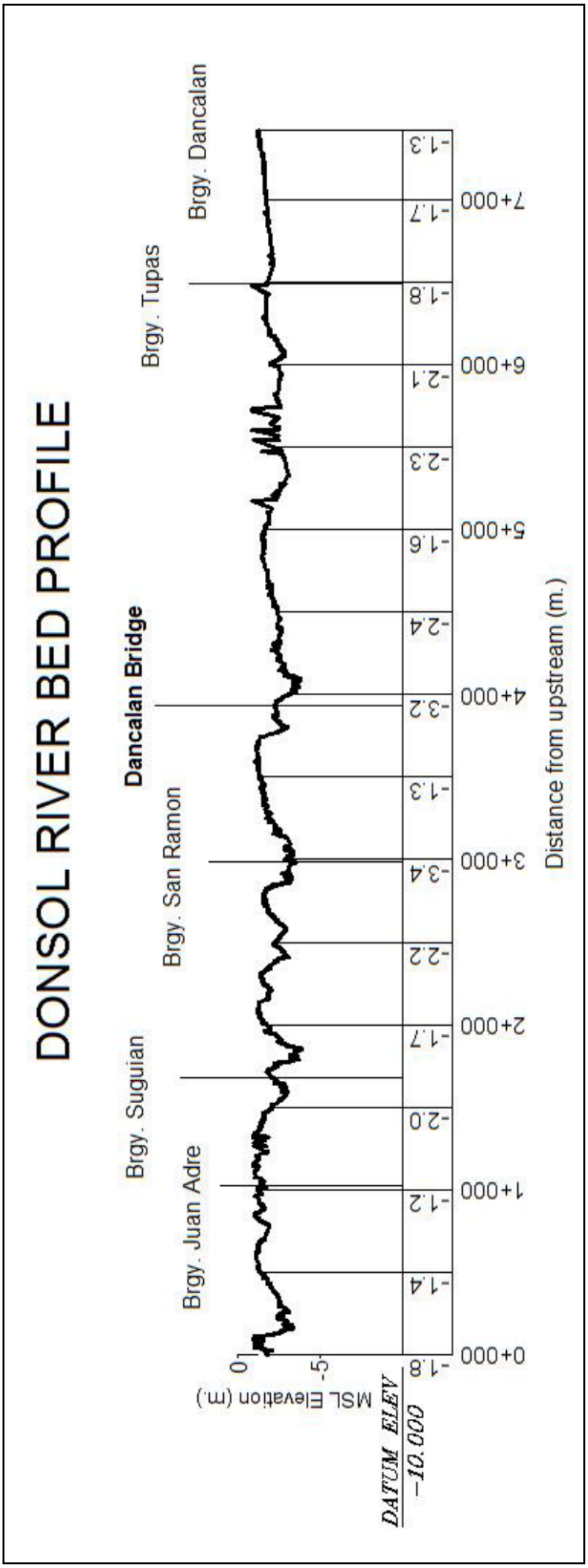


Figure 43. Riverbed Profile of Donsol River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Donsol 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 Donsol 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 Tagaytay Bridge ARG (Figure 1). The precipitation data collection started from December 06, 2014 at 12:00 AM to December 09, 2014 at 4:00 PM with a 10-minute recording interval.

The total precipitation for this event in Tagaytay Bridge ARG is 26.6mm. It has a peak rainfall of 5mm on December 08, 2014 at 11:30 AM. The lag time between the peak rainfall and discharge is 14 hours.

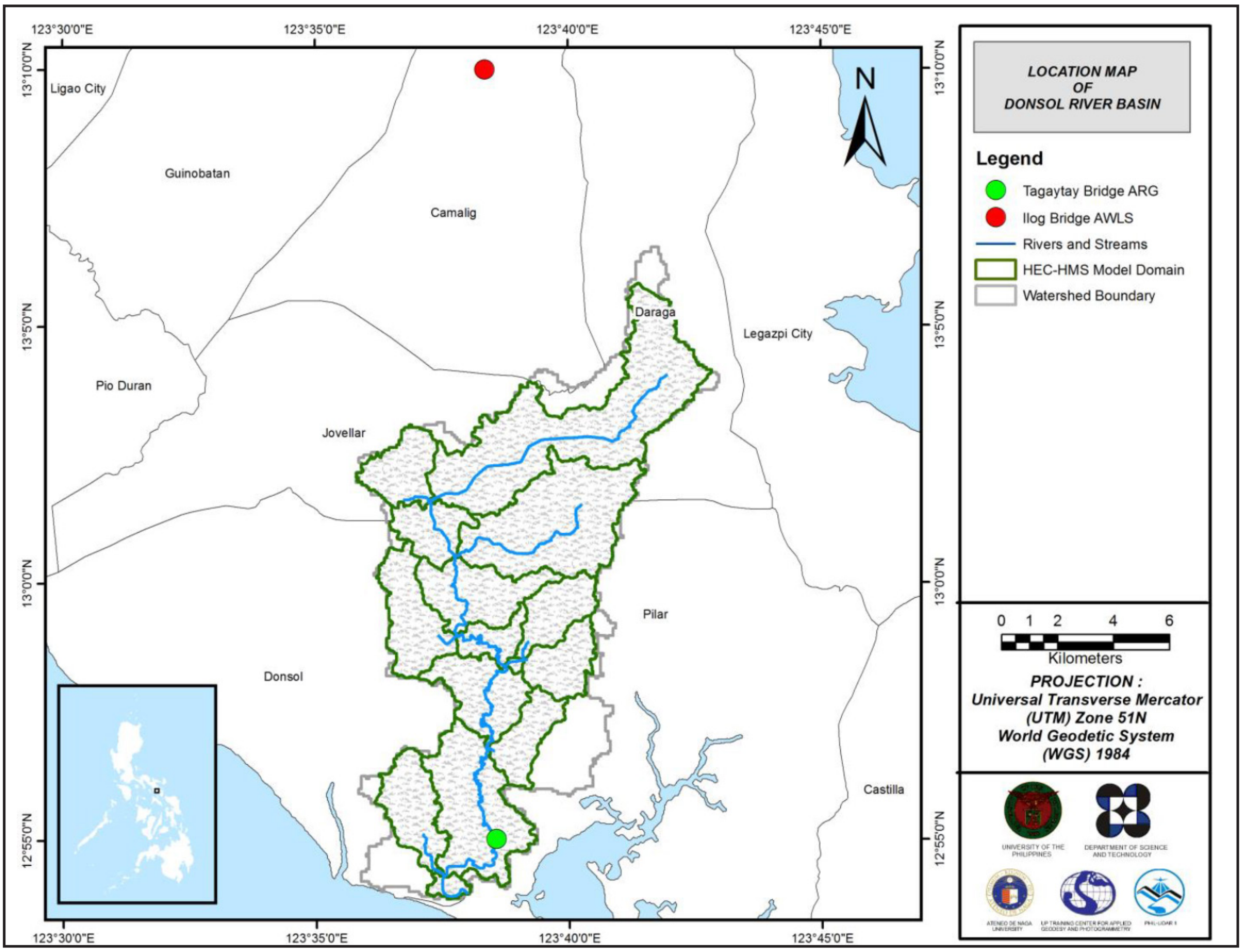


Figure 44. Location map of the Donsol HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Ilog Bridge, Brgy. Sta. Fe, Pilar, Sorsogon (12°55’1.31”N, 123°38’33.21”E). It gives the relationship between the observed water levels at Ilog Bridge and outflow of the watershed at this location.

For Ilog Bridge, the rating curve is expressed as Q = 17.933e0.6765h as shown in Figure 3.

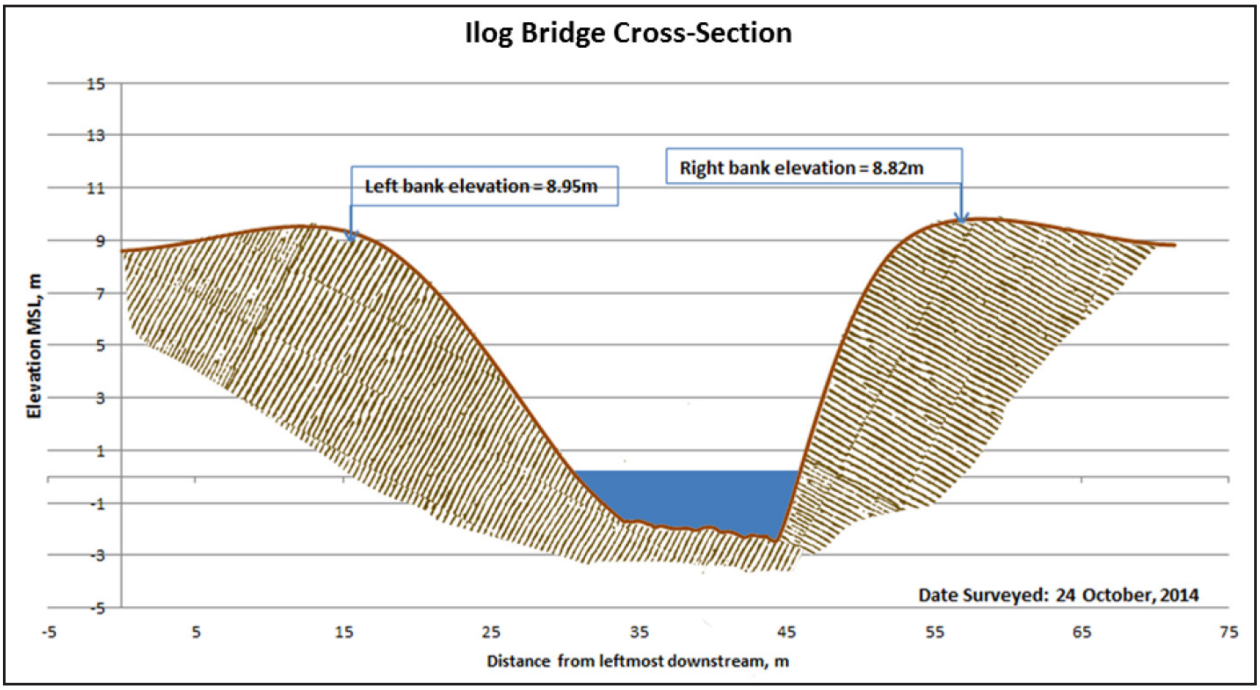


Figure 45. The cross-section plot of Ilog Bridge

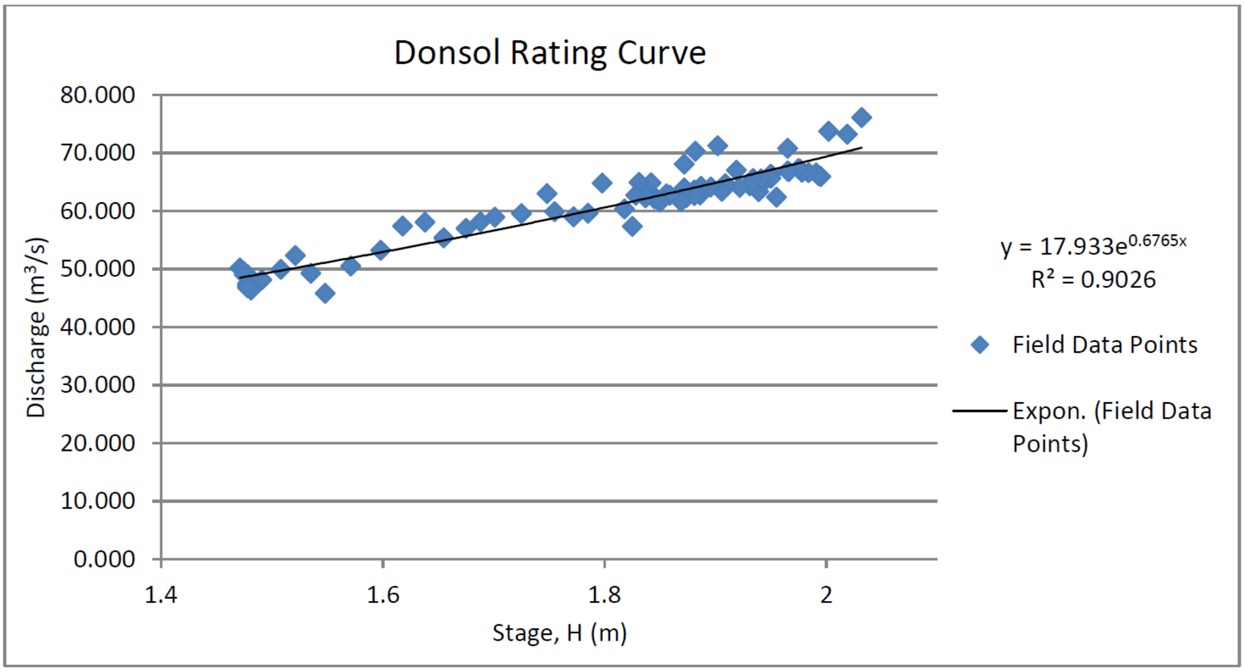


Figure 46. The rating curve of Ilog Bridge in Pilar, Sorsogon

This rating curve equation was used to compute the river outflow at Ilog Bridge for the calibration of the HEC-HMS model shown in Figure 47. The total rainfall for this event is 26.6mm and the peak discharge is 82.843m3/s at 1:30 AM, December 09, 2014.

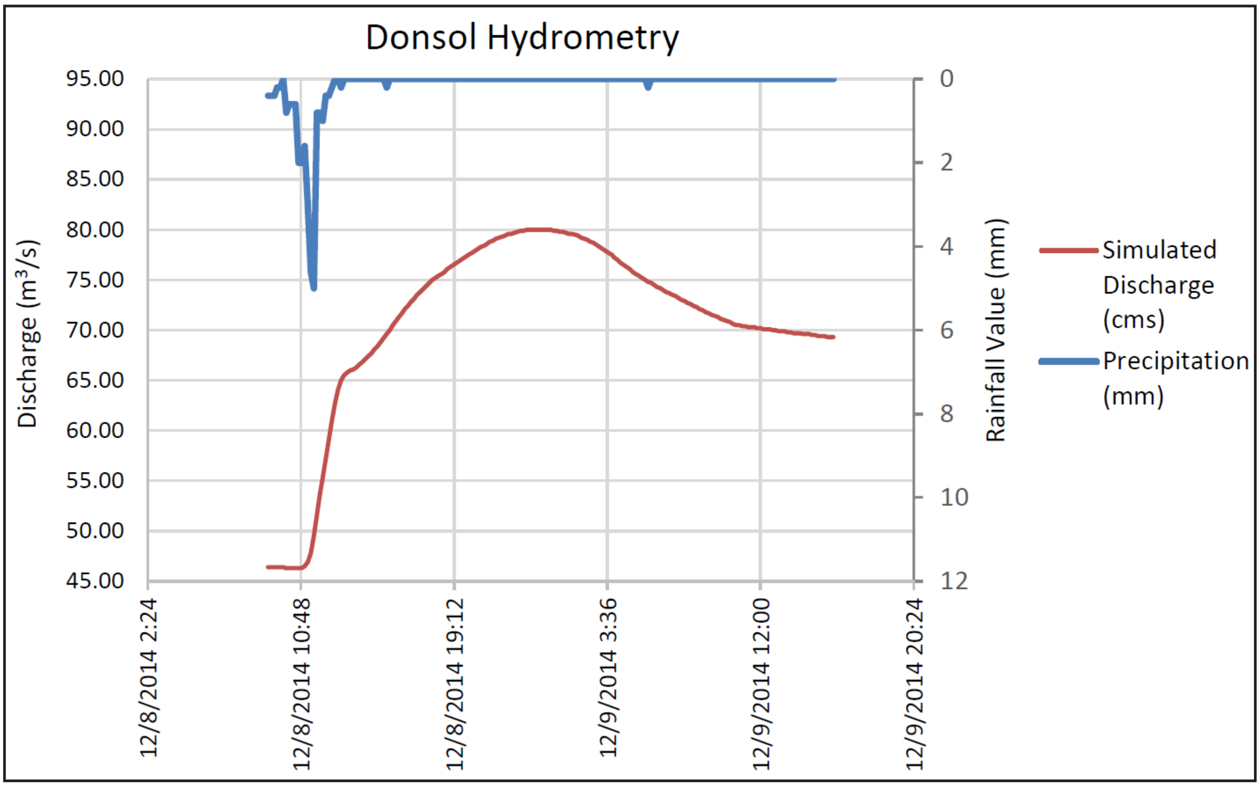


Figure 47. Rainfall and outflow data of the Donsol River Basin, which was used for modeling

5.2 RIDF Station

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

Table 27. RIDF values for Donsol Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	21	31.9	39.6	53.4	74.5	89.3	119.2	145.5	176.4
5	29.1	43.8	54.5	76.7	113.4	138.5	189.8	228.7	260.5
10	34.5	51.6	64.3	92.2	139.1	171.1	236.6	283.8	316.1
15	37.5	56	69.8	100.9	153.6	189.4	263	314.8	347.5
20	39.6	59.1	73.7	107	163.7	202.3	281.5	336.6	369.5
25	41.3	61.5	76.7	111.7	171.6	212.2	295.7	353.4	386.4
50	46.3	68.9	85.9	126.2	195.7	242.7	339.6	405	438.6
100	51.3	76.2	95.1	140.5	219.6	273.1	383.1	456.2	490.3

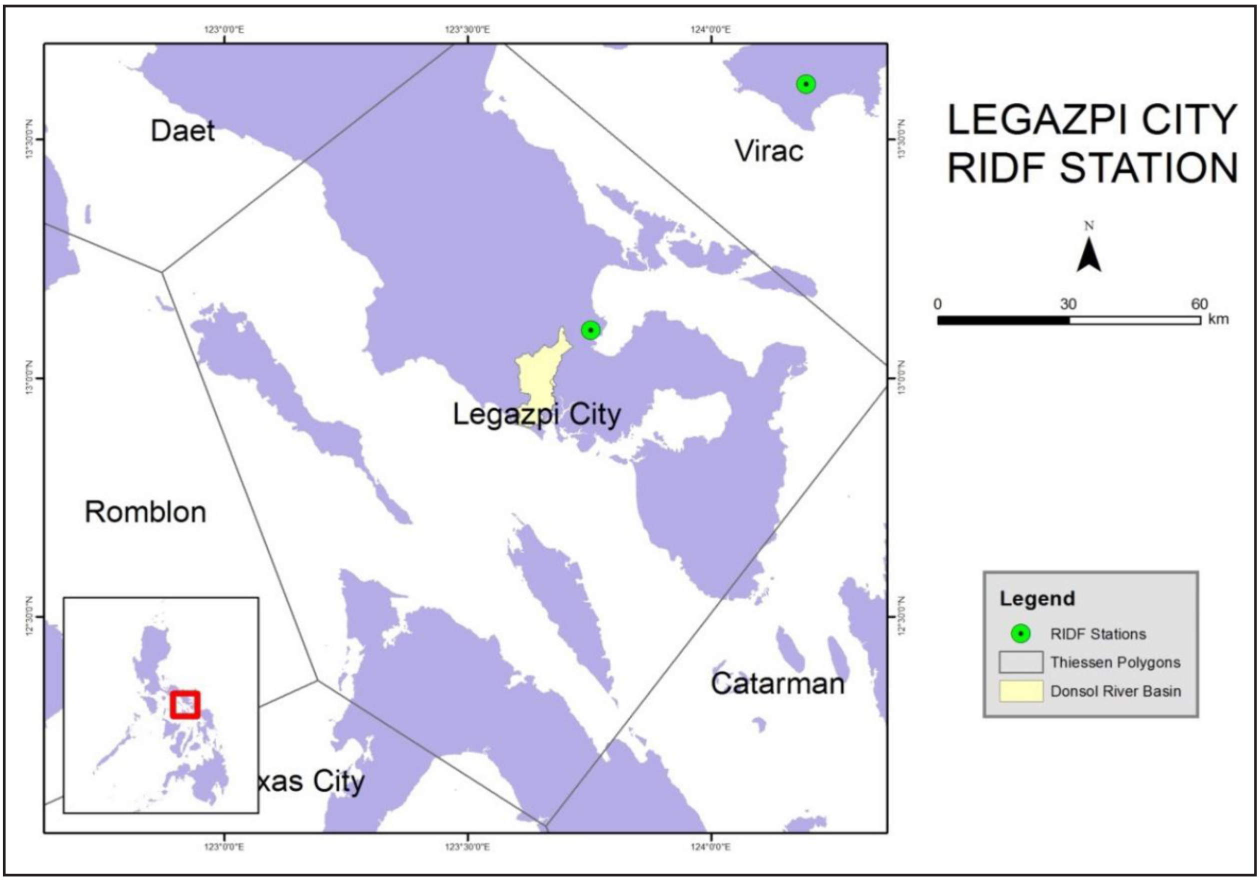


Figure 48. The location of the Legazpi City RIDF station relative to the Donsol River Basin

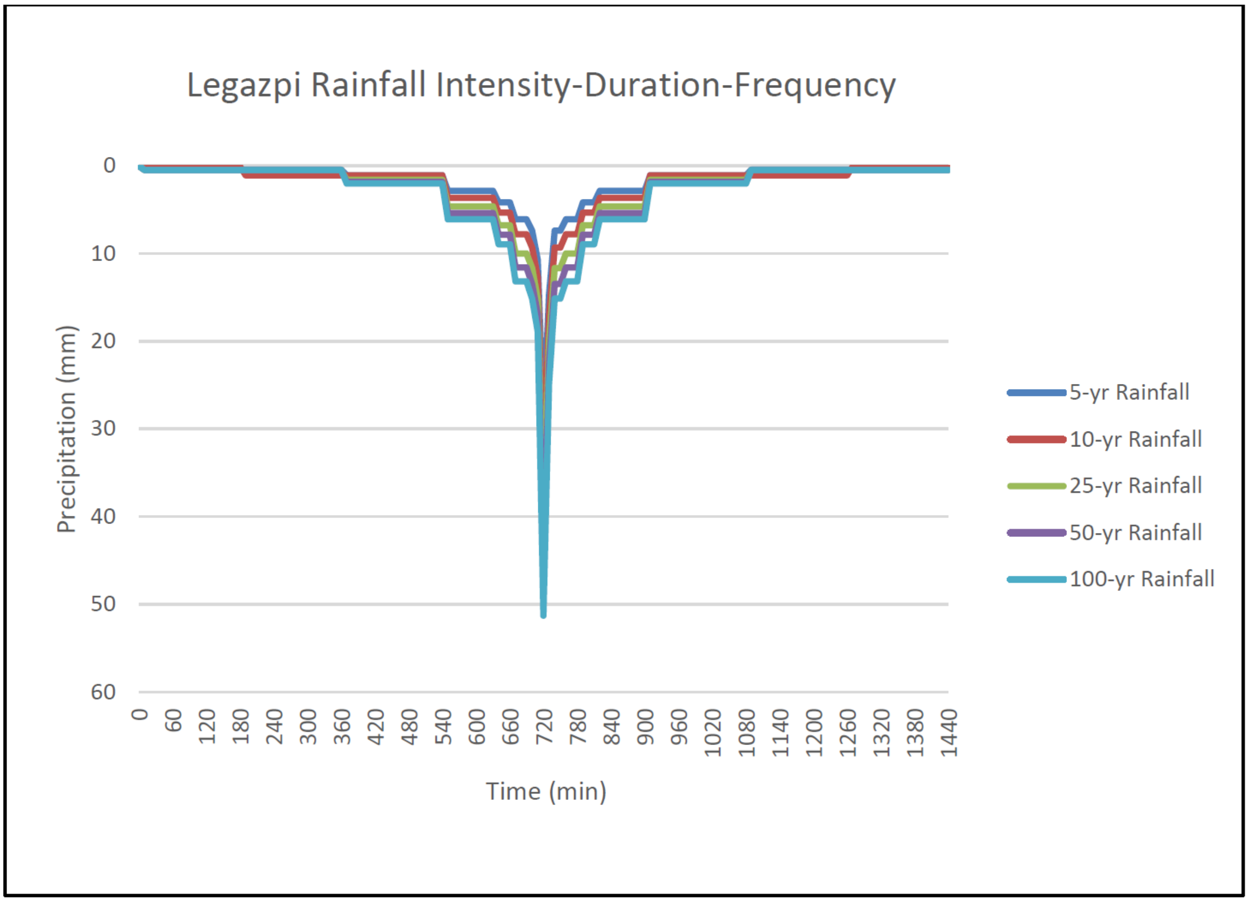


Figure 49. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Donsol River Basin are shown in Figures 50 and 51, respectively.

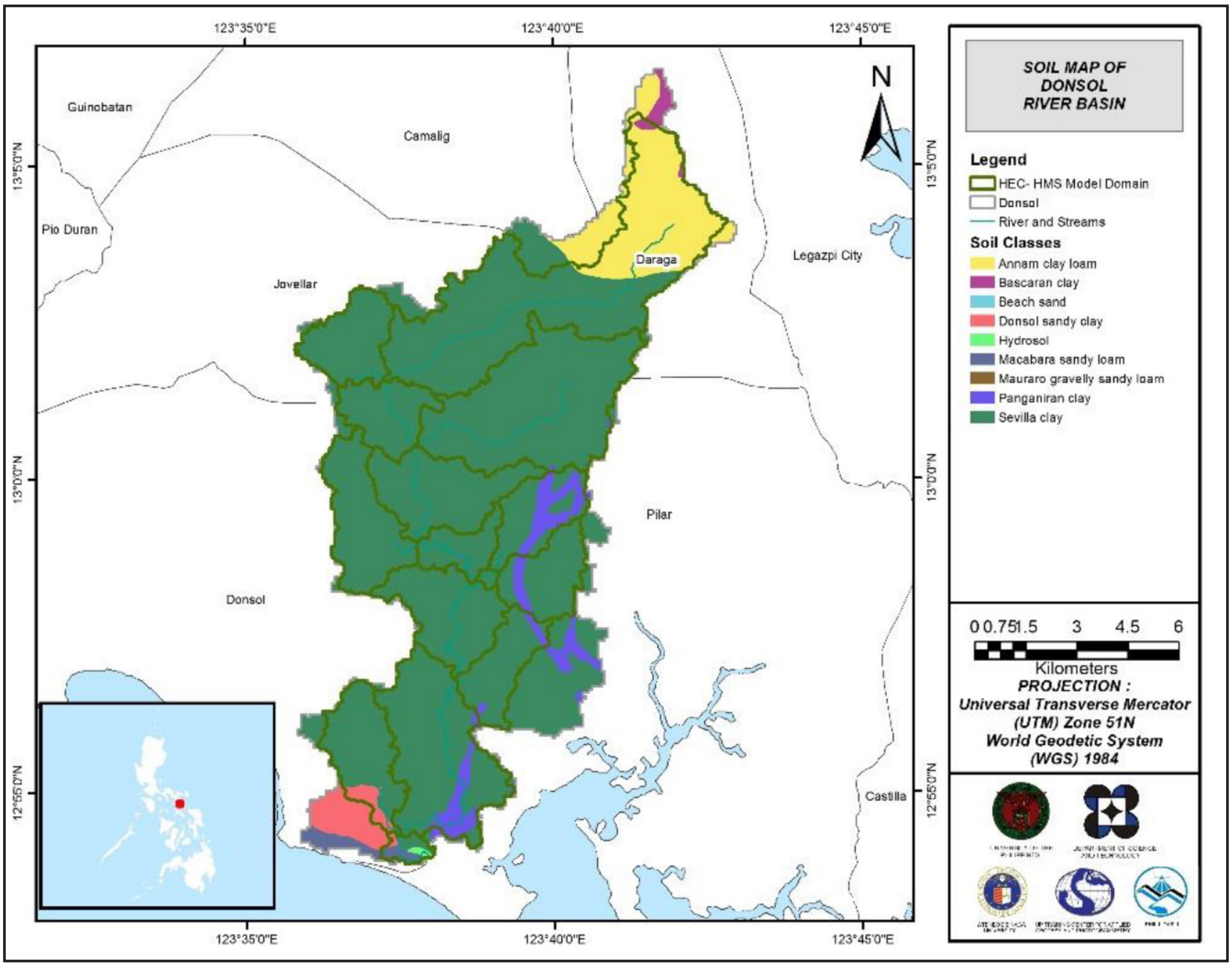


Figure 50. Soil map of Donsol River Basin

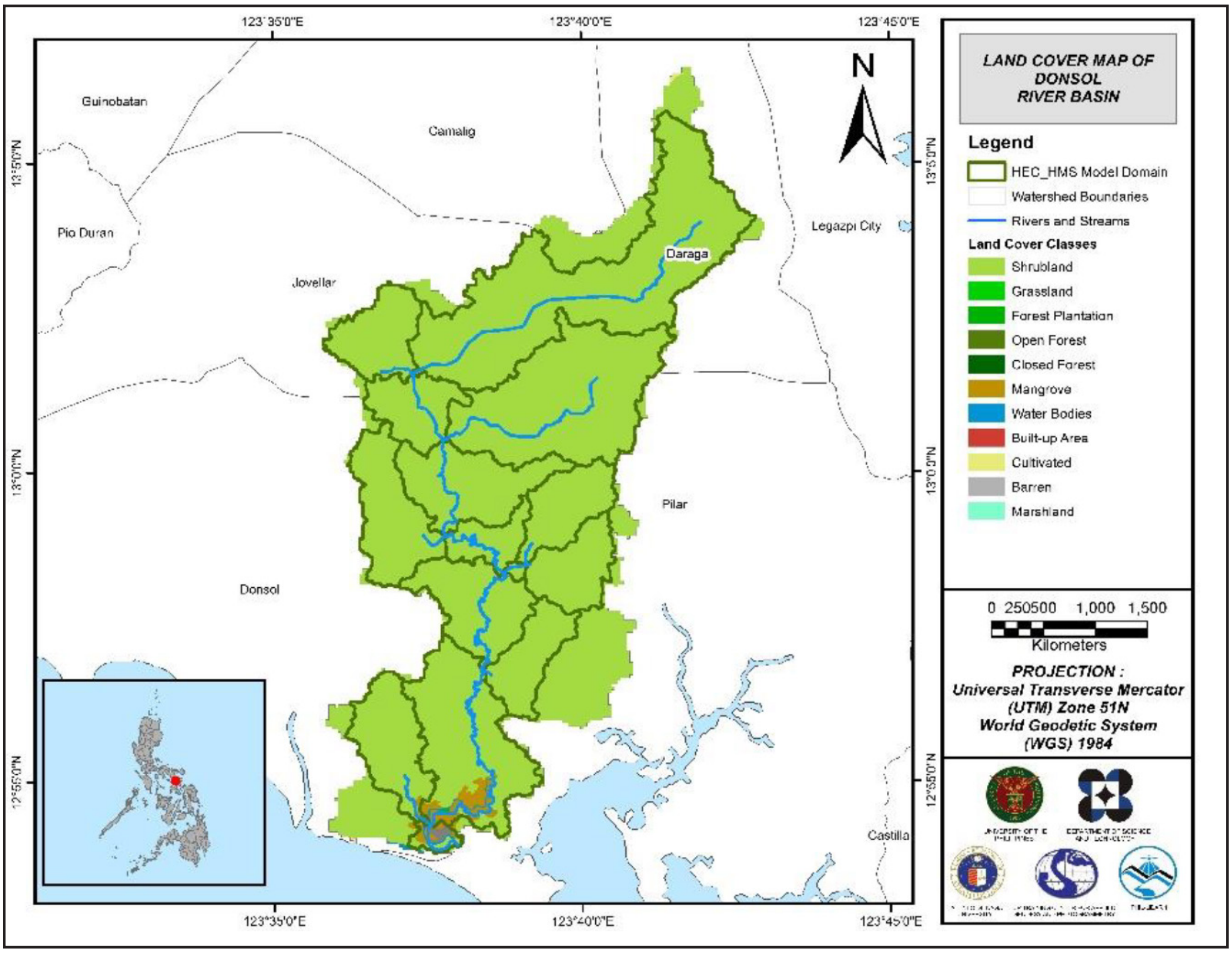


Figure 51. Land cover map of Donsol River Basin

For Donsol, six soil classes were identified. These are Sevilla clay, Annam clay loam, Panganiran clay, and Donsol sandy clay. Moreover, three land cover classes were identified. These are shrubland, mangrove, and barren areas.

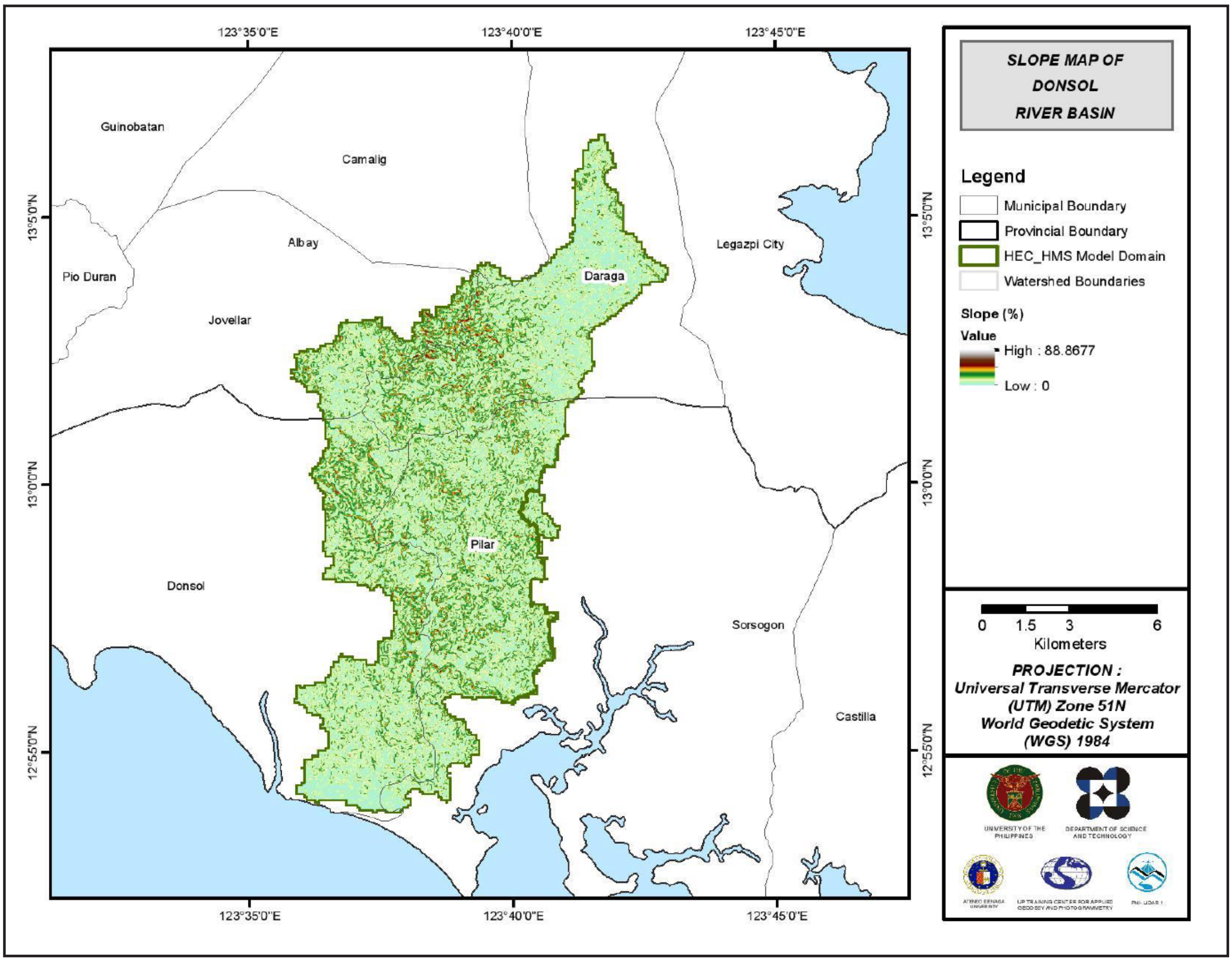


Figure 52. Slope map of Donsol River Basin

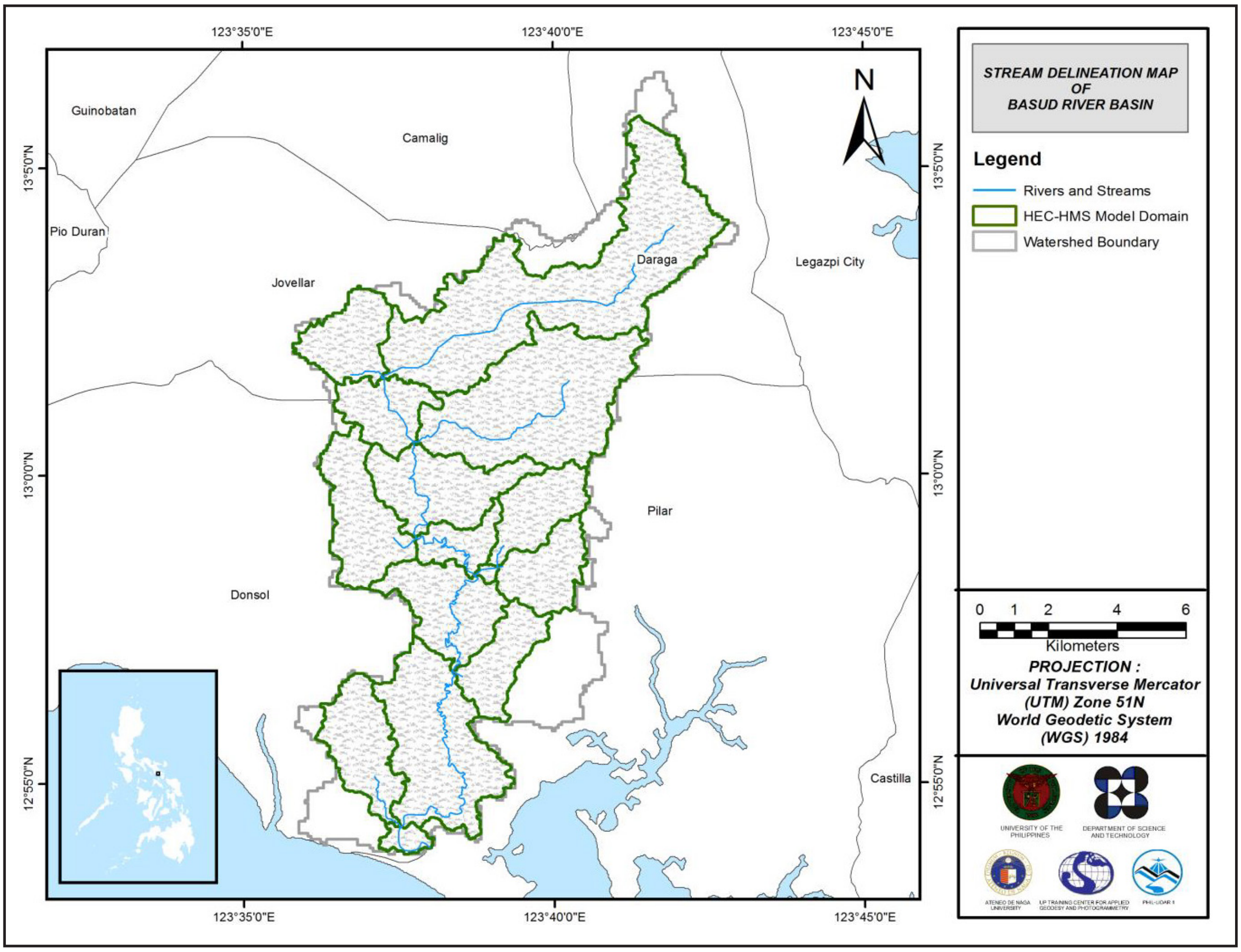


Figure 53. Stream delineation map of Donsol River Basin

Using the SAR-based DEM, the Donsol basin was delineated and further divided into subbasins. The model consists of 19 sub basins, 9 reaches, and 9 junctions, as shown in Figure 54. The main outlet is Ilog Bridge.

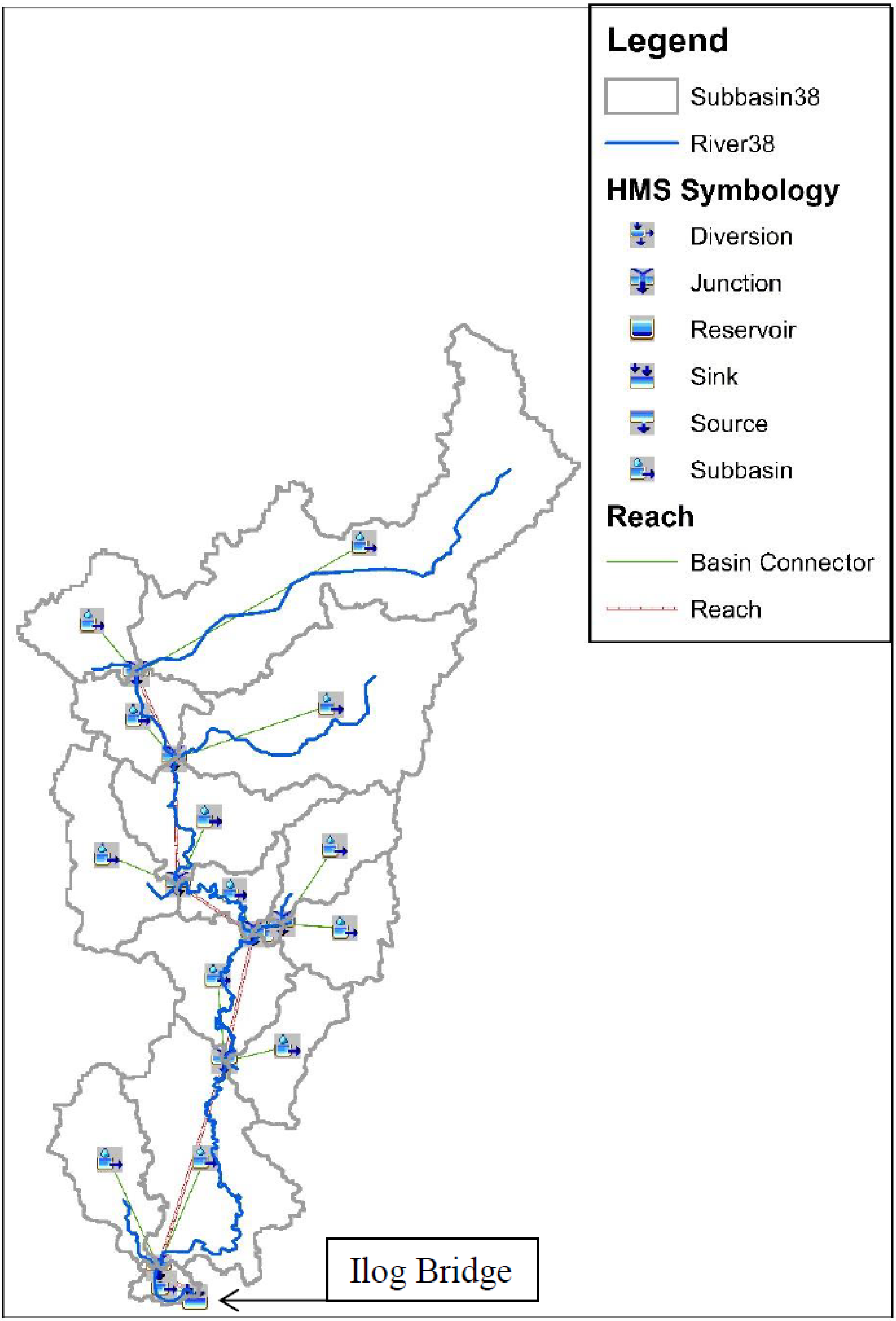


Figure 54. The Donsol River Basin model generated in HEC-HMS

5.4 Cross-section Data

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

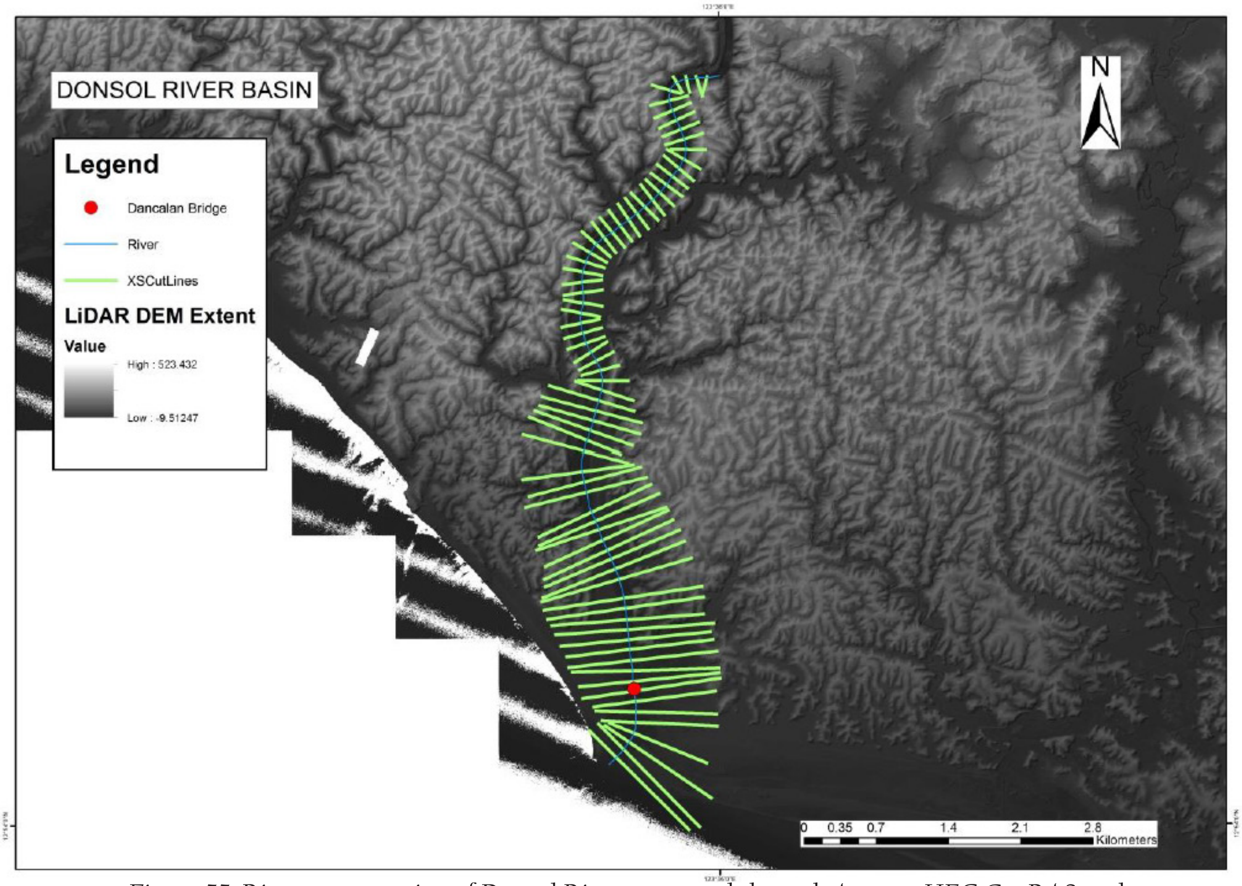


Figure 55. River cross-section of Donsol River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

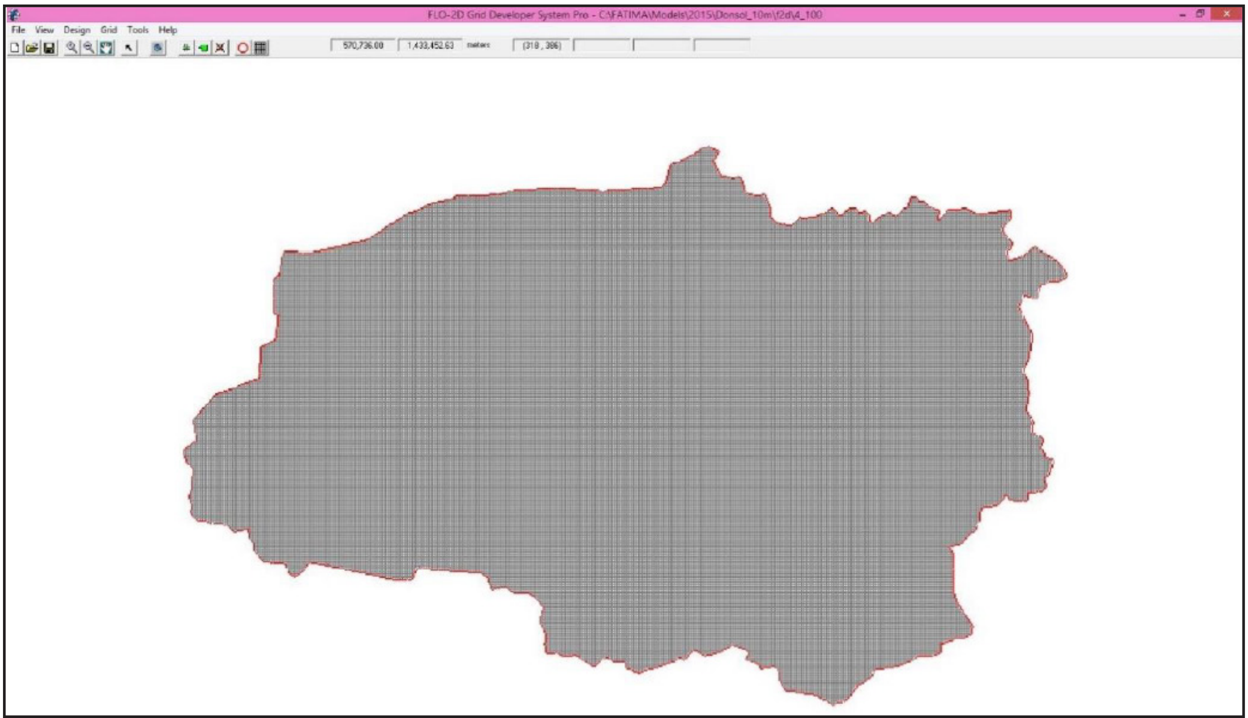


Figure 56. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 16.46484 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 0.2m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0m2/s. The generated hazard maps for Donsol are in Figures 17, 19, and 21.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 16,319,900.00m2. The generated flood depth maps for Donsol are in Figures 16, 18, and 20.

There is a total of 19,430,200.63m3 of water entering the model. Of this amount, 7,994,434.58m3 is due to rainfall while 11,435,766.05m3 is inflow from other areas outside the model. 1,658,242.75m3 of this water is lost to infiltration and interception, while 4,173,463.01m3 is stored by the flood plain. The rest, amounting up to 13,598,497.30m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Donsol HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

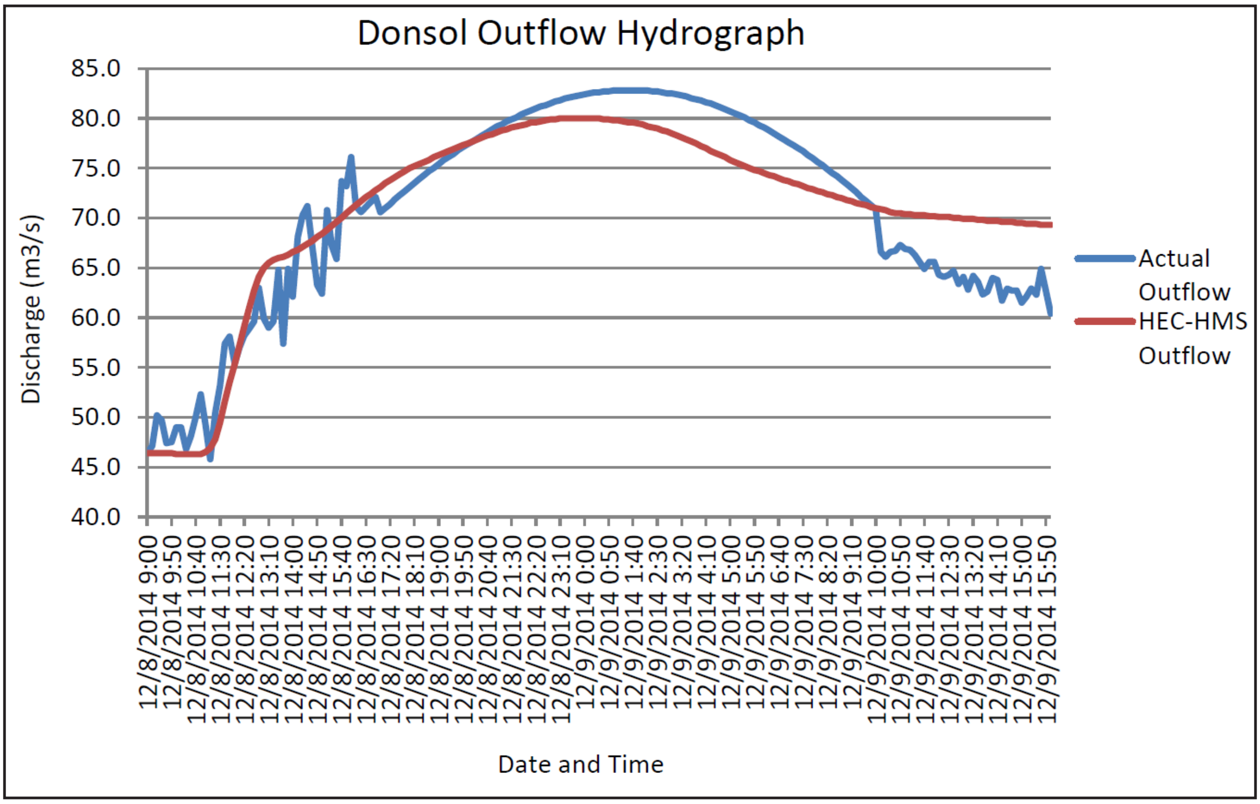


Figure 57. Outflow hydrograph of Donsol River Basin produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of calibrated values for the Donsol River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 - 20
			Curve Number	65 - 90
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	4 - 12
			Storage Coefficient (hr)	2 - 7
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

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 1 mm to 6 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 64 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 Donsol, the basin mostly consists of grassland and the soil consists of Sevilla clay, Annam clay loam, and Panganiran clay.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 17 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. For Donsol, it will take at least 17 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 1 corresponds to the common roughness in Donsol watershed, which is determined to be a mangrove forest with trees with heavy stand that flow into branches (Brunner, 2010).

Table 29. Summary of the Efficiency Test of the Donsol HMS Model

Accuracy measure	Value
RMSE	3.812
r2	0.8607
NSE	0.8593
PBIAS	0.0377
RSR	0.3752

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 3.812 (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 0.8607.

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 0.8593.

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 0.0377.

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 0.3752.

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 58) shows the Donsol outflow using the synthetic storm events using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 554m3/s in a 5-year return period to 1111.8m3/s in a 100-year return period.

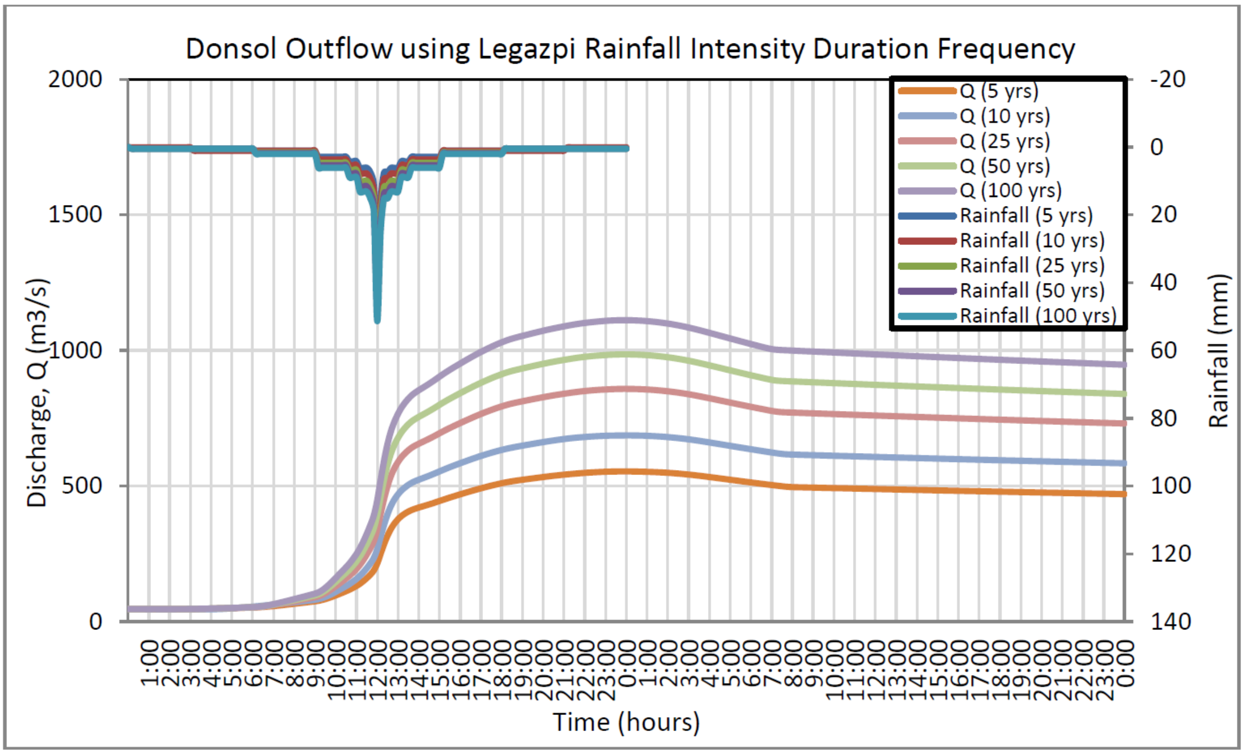


Figure 58. The Outflow hydrograph at the Donsol Station, generated using the simulated rain events for 24-hour period for Tacloban station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Donsol discharge using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Outlines the peak values of the Donsol HEC-HMS Model outflow using the Legazpi RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	260.5	29.1	554	11 hours, 40 minutes
10-Year	316.1	34.5	686.8	12 hours
25-Year	386.4	41.3	858.4	11 hours, 50 minutes
50-Year	438.4	46.3	985.7	11 hours, 50 minutes
100-Year	490.3	51.3	1111.8	11 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 59 shows a generated sample map of the Donsol River using the calibrated HMS base flow.

Figure 59. Sample output map of the Donsol RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 60 to 65 show the 5-, 25-, and 100-year rain return scenarios of the Donsol flood plain. The flood plain, with an area of 118,670km2, covers four (4) municipalities, namely Daraga, Jovellar, Donsol, and Pilar. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Donsol Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Daraga	135.66	26.13	19.26
Jovellar	82.35	8.91	10.82
Donsol	153	35	22.88
Pilar	196.62	42.6	21.66

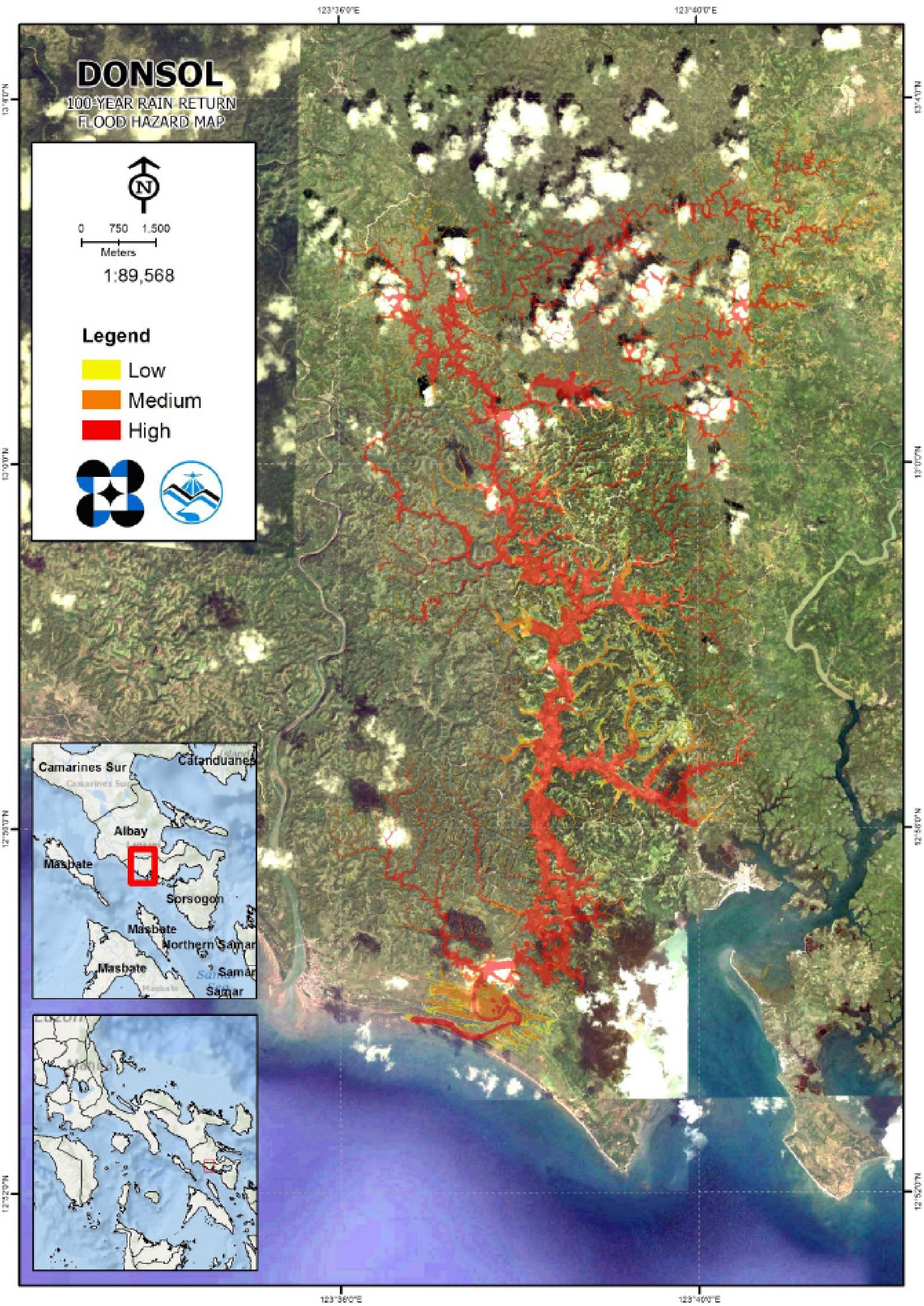


Figure 60. 100-year flood hazard map for the Donsol flood plain overlaid on Google Earth imagery

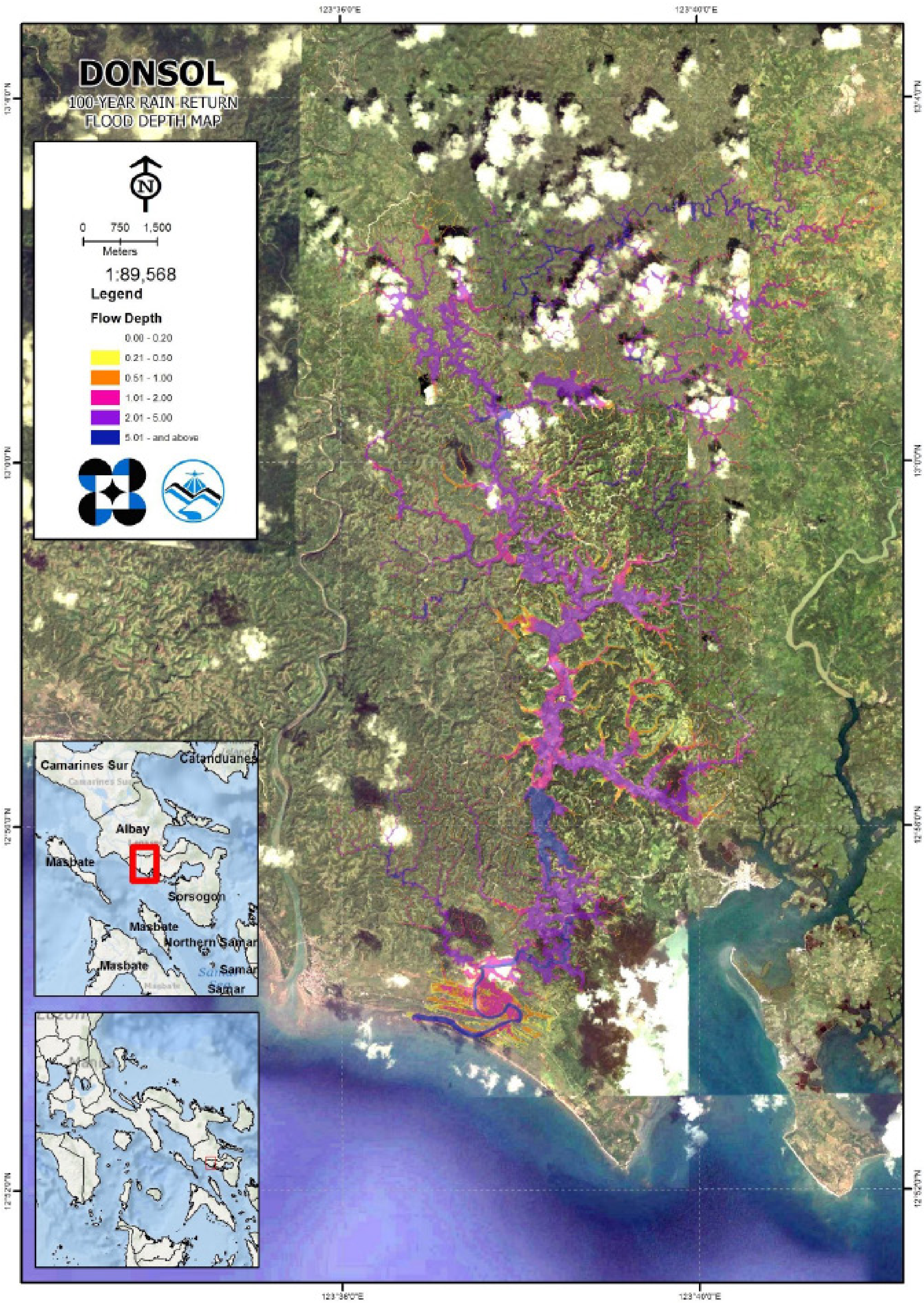


Figure 61. 100-year flow depth map for the Donsol flood plain overlaid on Google Earth imagery

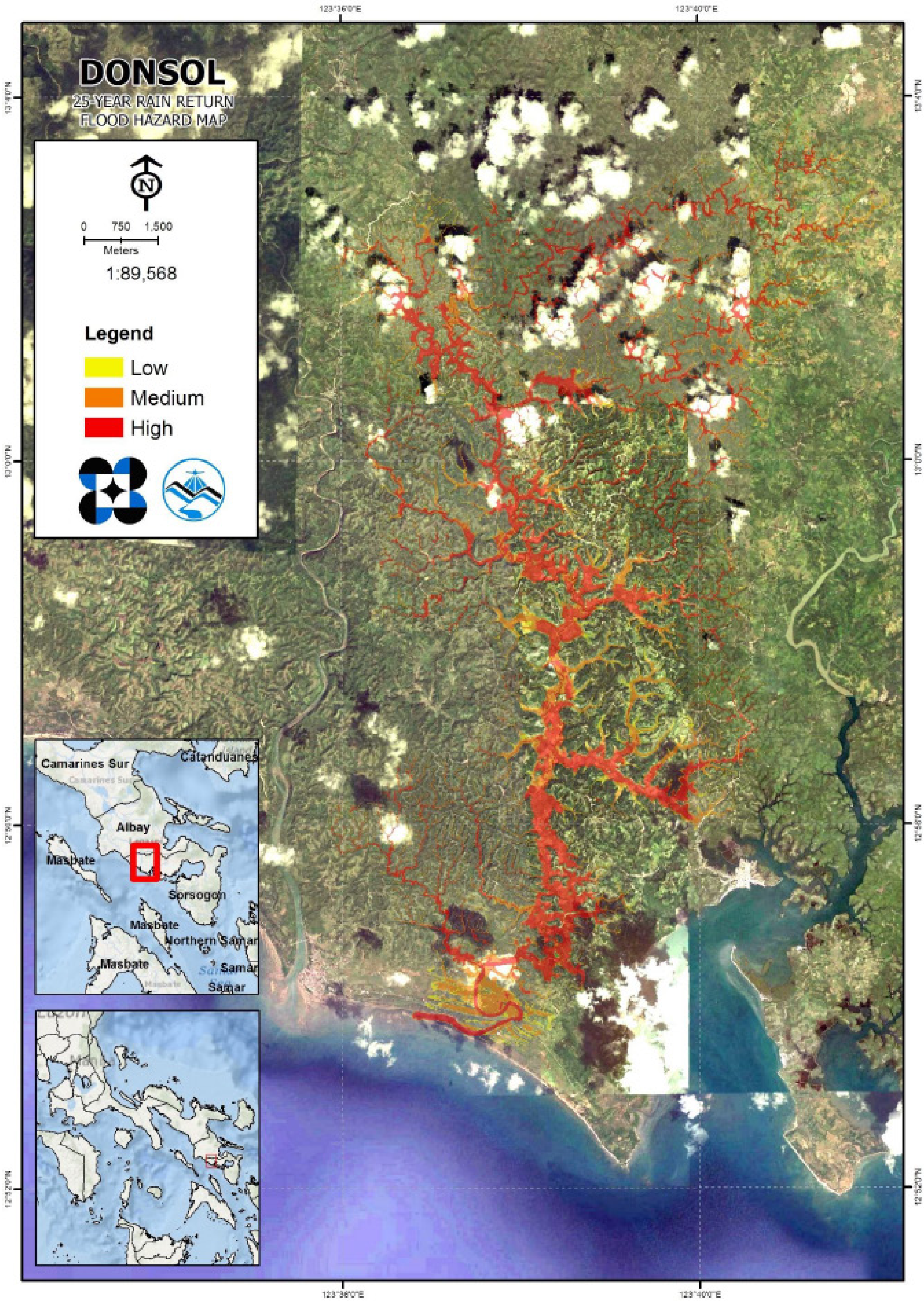


Figure 62. 25-year flood hazard map for the Donsol flood plain overlaid on Google Earth imagery

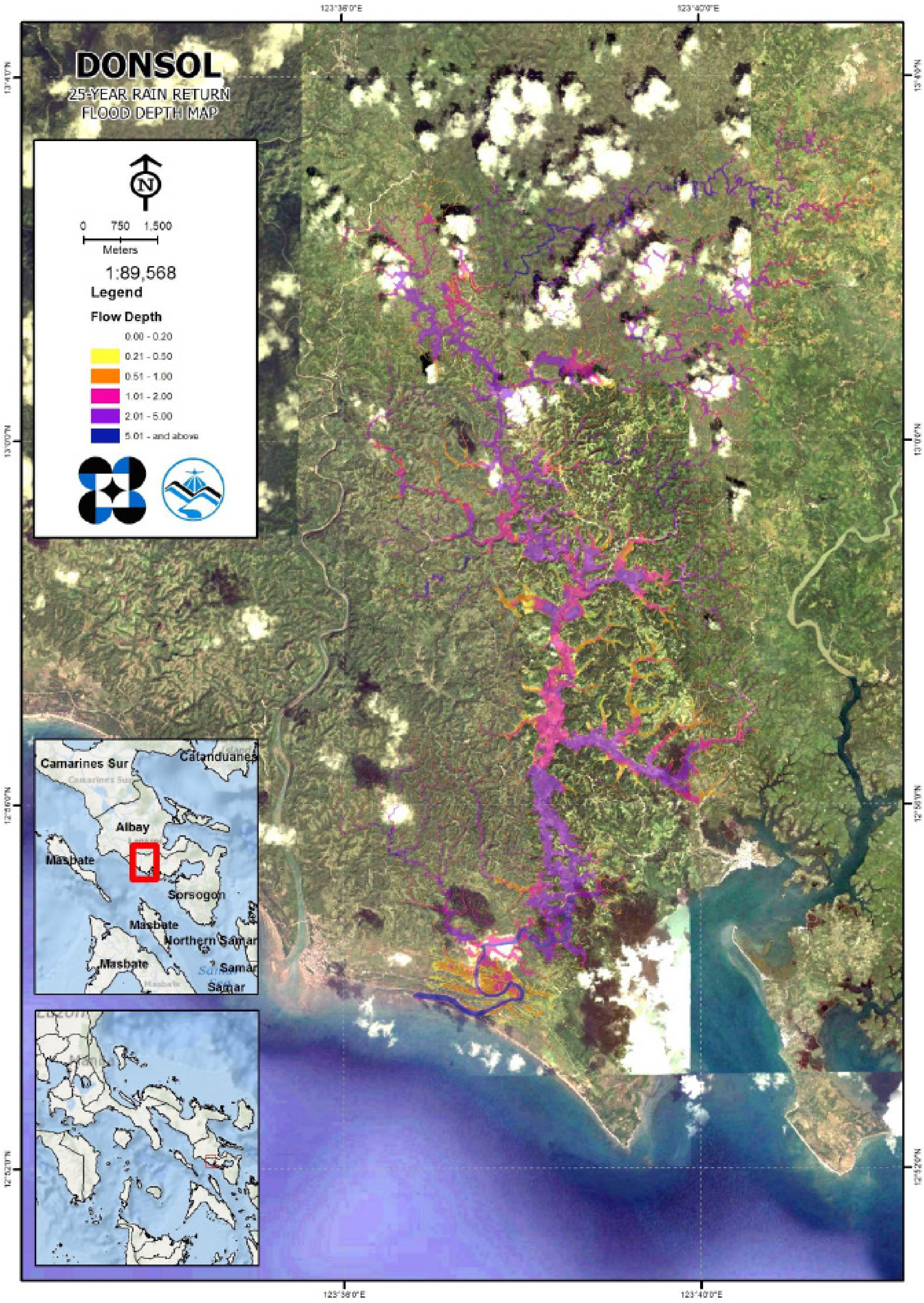


Figure 63. 25-year flow depth map for the Donsol flood plain overlaid on Google Earth imagery

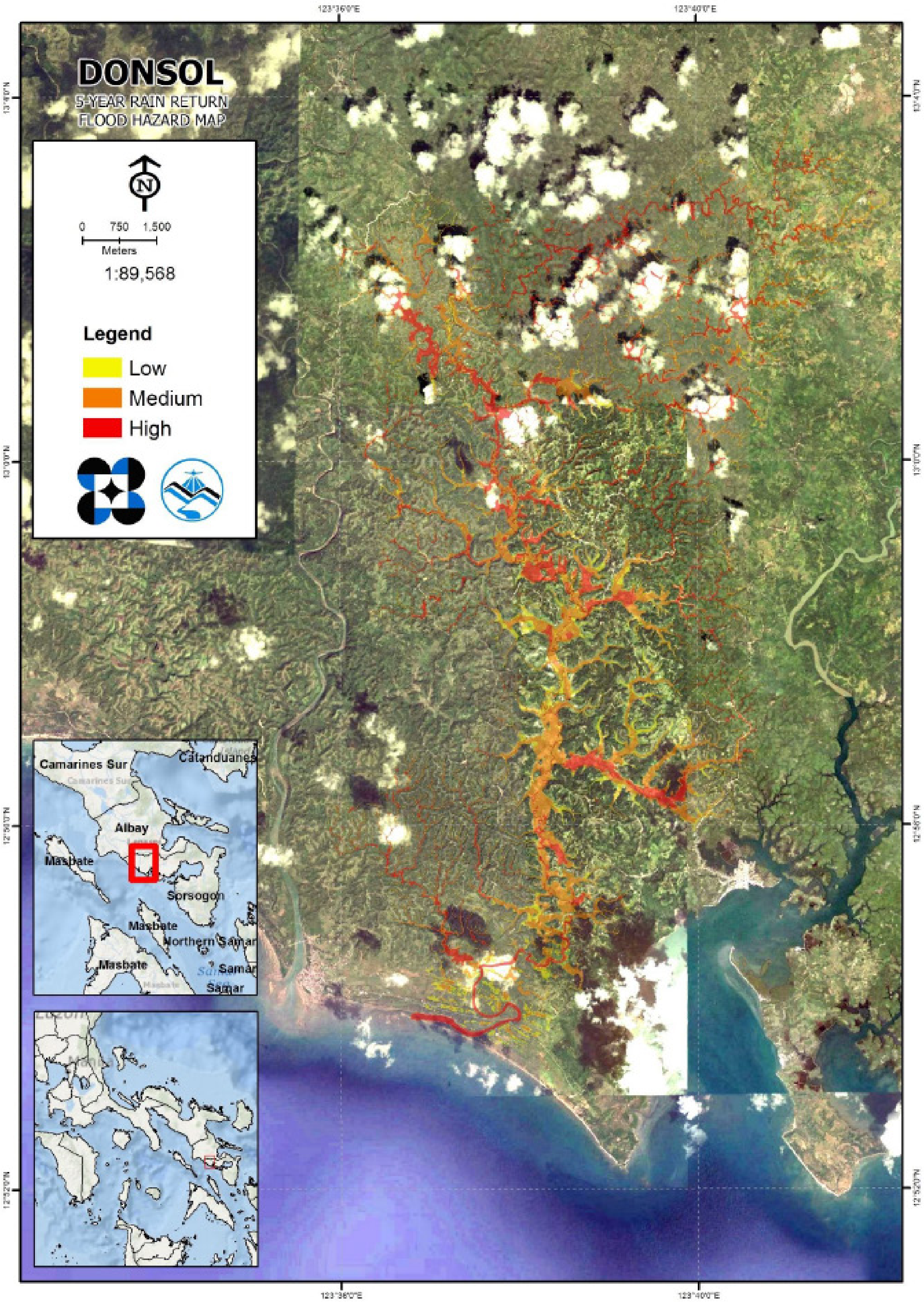


Figure 64. 25-year flood hazard map for the Donsol flood plain overlaid on Google Earth imagery

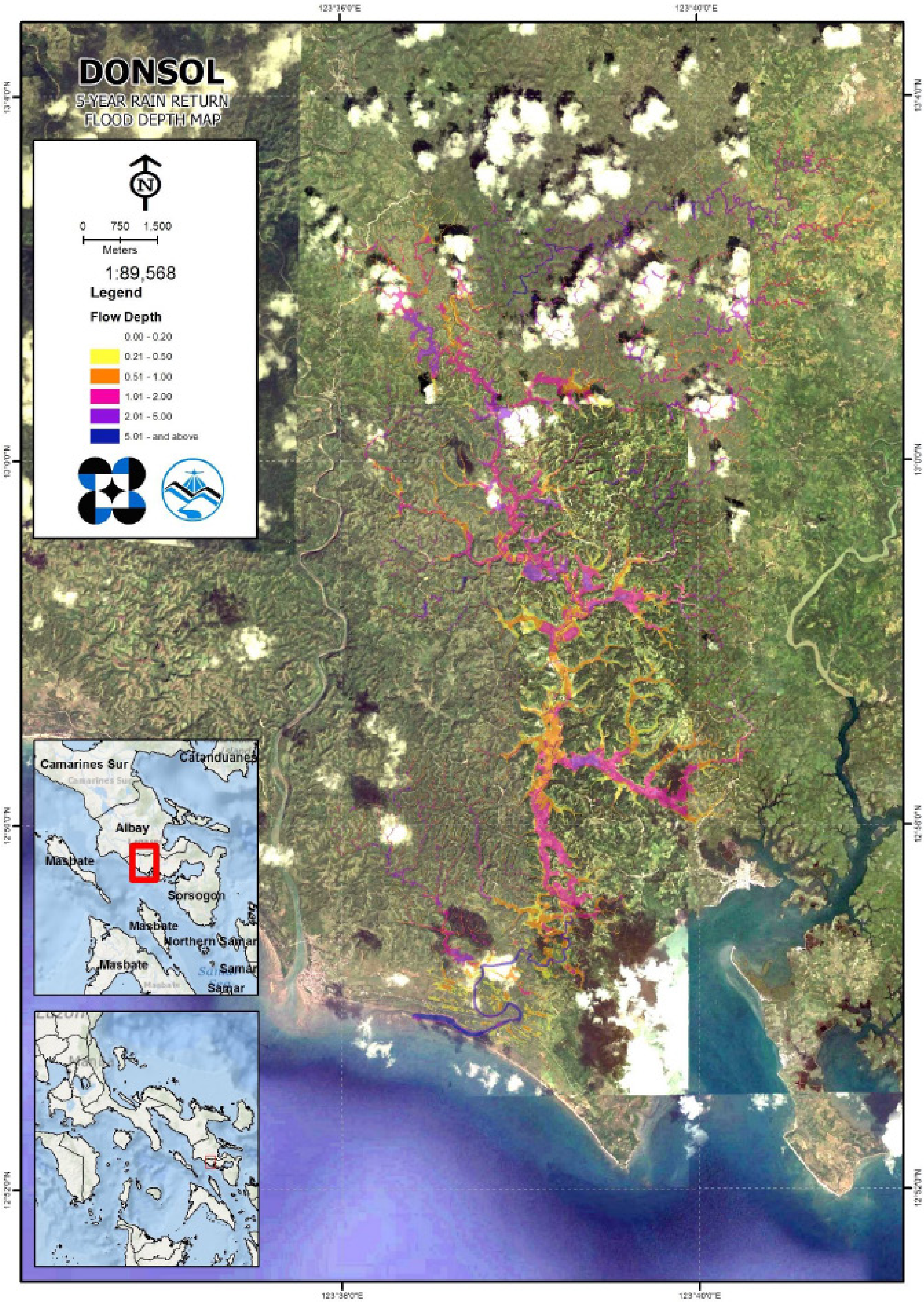


Figure 65. 25-year flood hazard map for the Donsol flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Donsol River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of 50 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 16.45% of the municipality of Daraga with an area of 135.66 sq. km. will experience flood levels of less than 0.20 meters. 0.64% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.67%, 0.8%, 0.59%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 32 depicts the areas affected in Daraga in square kilometers by flood depth per barangay.

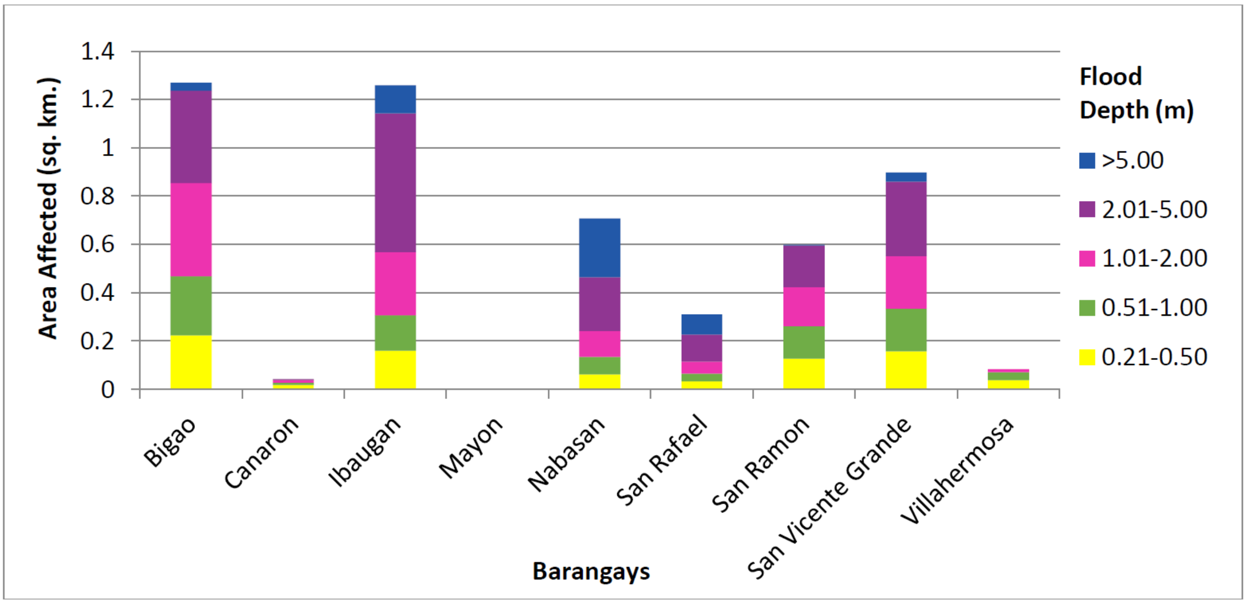


Figure 66. Affected areas in Daraga, Albay during the 5-Year Rainfall Return Period

Table 32. Affected Areas in Daraga, Albay during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daraga (in sq. km.)								
	Bigao	Canaron	Ibaugan	Mayon	Nabasan	San Rafael	San Ramon	San Vicente Grande	Villahermosa
0.03-0.20	4.61	0.47	5.15	0.021	2.72	1.03	3.06	4.71	0.54
0.21-0.50	0.22	0.015	0.23	0.0012	0.064	0.029	0.12	0.16	0.037
0.51-1.00	0.25	0.0096	0.26	0.0005	0.067	0.034	0.12	0.15	0.022
1.01-2.00	0.31	0.0066	0.28	0.0004	0.1	0.044	0.15	0.18	0.0043
2.01-5.00	0.16	0.0017	0.15	0	0.19	0.093	0.062	0.14	0
> 5.00	0.002	0	0.048	0	0.078	0.0051	0	0.0017	0

For the Municipality of Jovellar with an area of 82.35 sq. km., 9.25% will experience flood levels of less than 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.42%, 0.5%, 0.28%, and 0.007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 33 depicts the areas affected in Jovellar in square kilometers by flood depth per barangay.

Table 33. Affected areas in Jovellar, Albay during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jovellar (in sq. km.)			
	Del Rosario	Florista	San Isidro	San Roque
0.03-0.20	5.77	0.33	0.77	0.75
0.21-0.50	0.23	0.0052	0.034	0.03
0.51-1.00	0.3	0.0055	0.016	0.023
1.01-2.00	0.37	0.011	0.0074	0.024
2.01-5.00	0.21	0.016	0	0.0048
> 5.00	0.0051	0.0004	0	0

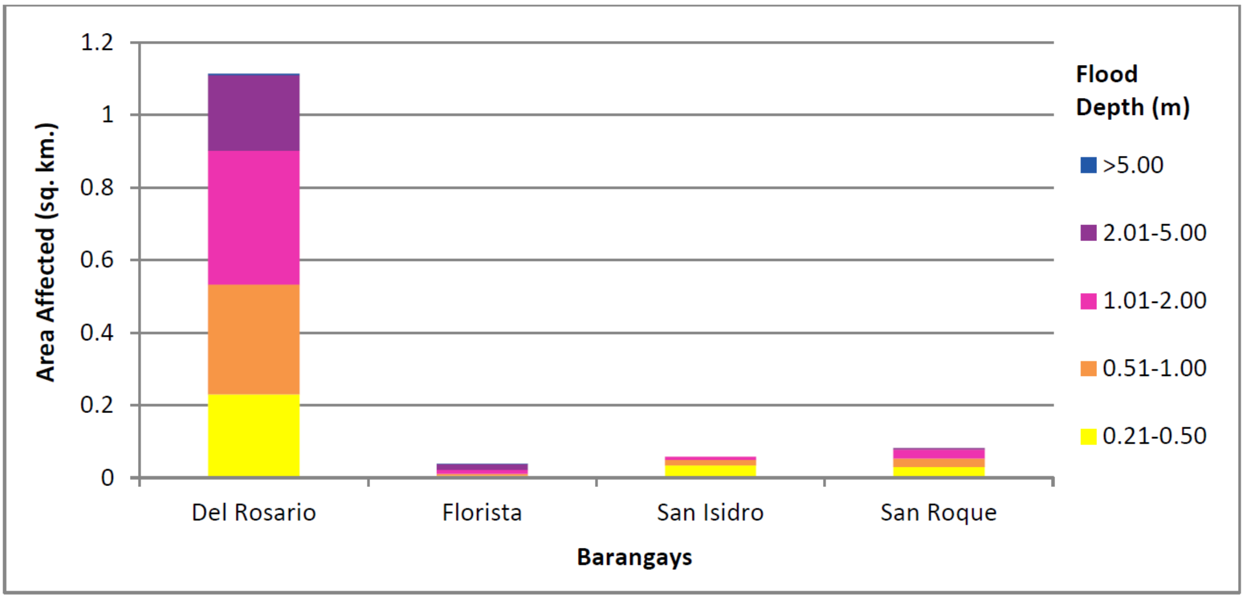


Figure 67. Affected areas in Jovellar, Albay during the 5-Year Rainfall Return Period

For the municipality of Donsol with an area of 153 sq. km., 18.77% will experience flood levels of less than 0.20 meters. 1.03% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.32%, 1.01%, 0.6%, and 0.15% 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 34 and 35 depict the areas affected in Donsol in square kilometers by flood depth per barangay.

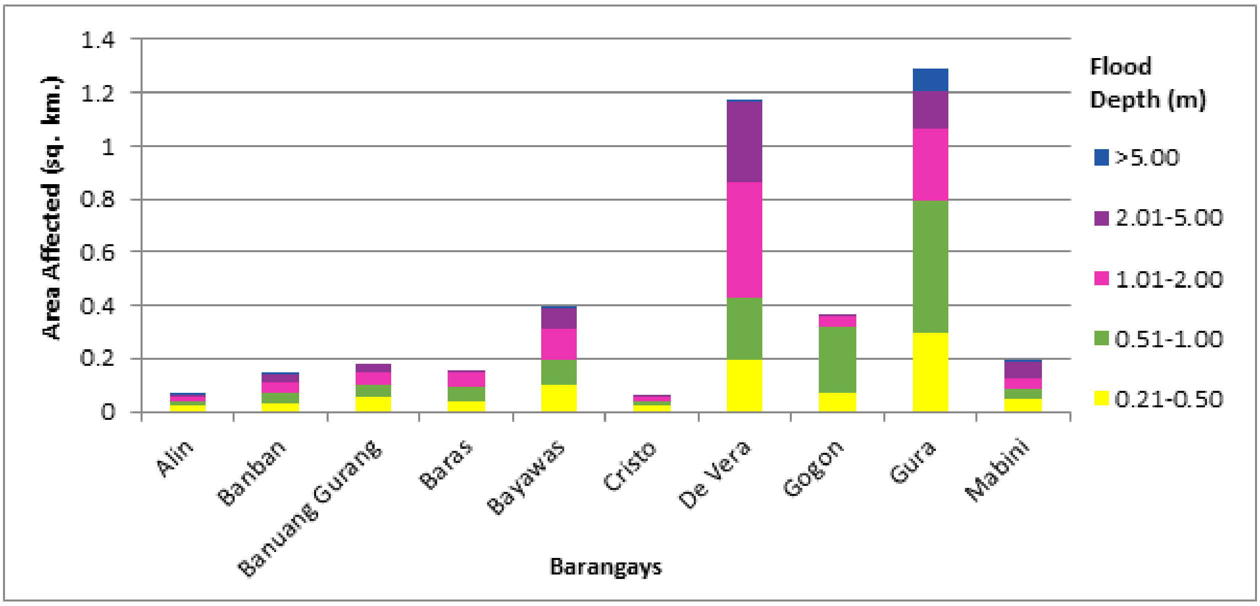


Figure 68. Affected areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period

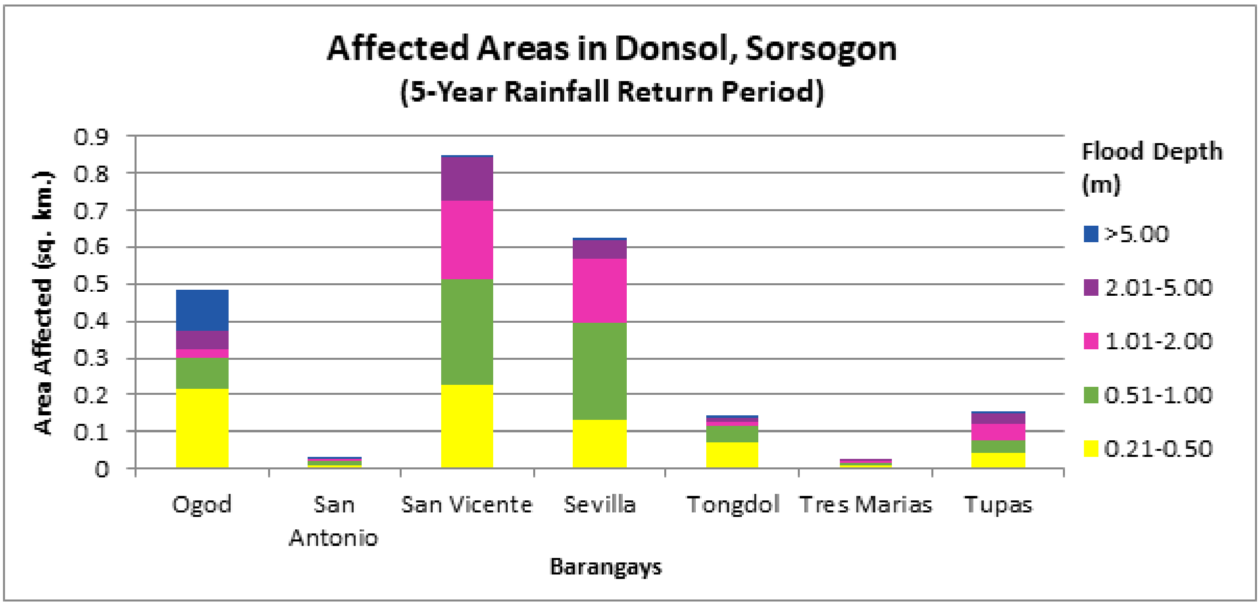


Figure 69. Affected areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period

Table 34. Affected areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol (in sq. km.)									
	Alin	Banban	Banuang Gurang	Baras	Bayawas	Cristo	De Vera	Gogon	Gura	Mabini
0.03-0.20	0.57	1.39	1.7	0.83	2.64	0.66	4.63	0.77	3.54	1.73
0.21-0.50	0.022	0.034	0.052	0.038	0.1	0.021	0.2	0.068	0.3	0.048
0.51-1.00	0.016	0.035	0.047	0.054	0.09	0.018	0.24	0.25	0.5	0.039
1.01-2.00	0.013	0.039	0.048	0.056	0.12	0.016	0.43	0.036	0.27	0.036
2.01-5.00	0.011	0.03	0.033	0.01	0.078	0.00011	0.3	0.004	0.15	0.06
> 5.00	0.0007	0.003	0	0	0.004	0	0.002	0	0.084	0.012

Table 35. Affected areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol (in sq. km.)						
	Ogod	San Antonio	San Vicente	Sevilla	Tongdol	Tres Marias	Tupas
0.03-0.20	1.09	0.43	2.76	3.51	0.99	0.18	1.32
0.21-0.50	0.22	0.011	0.23	0.13	0.071	0.009	0.041
0.51-1.00	0.086	0.008	0.29	0.26	0.043	0.007	0.037
1.01-2.00	0.019	0.007	0.21	0.18	0.015	0.006	0.042
2.01-5.00	0.055	0.003	0.12	0.047	0.007	0.0008	0.027
> 5.00	0.11	0.0002	0.002	0.003	0.0003	0	0.001

For the municipality of Pilar with an area of 196.62 sq. km., 16.82% will experience flood levels of less than 0.20 meters. 1.1% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.37%, 1.85%, 0.46%, and 0.07% 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 36 and 37 depict the areas affected in Pilar in square kilometers by flood depth per barangay.

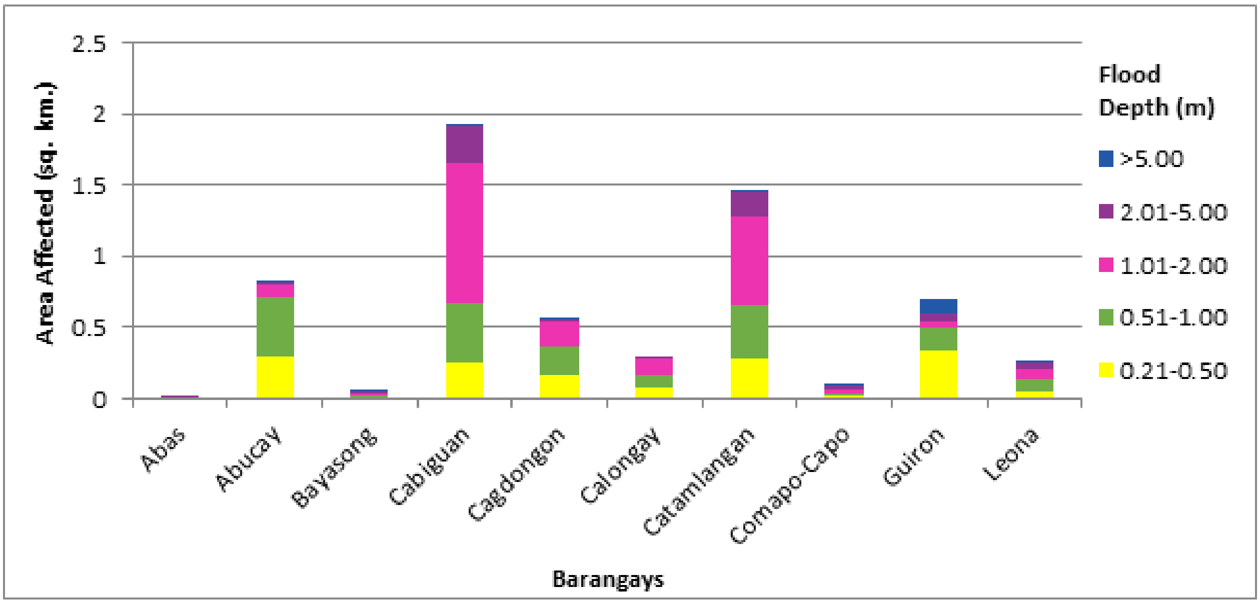


Figure 70. Affected areas in Pilar, Sorsogon during the 5-Year Rainfall Return Period

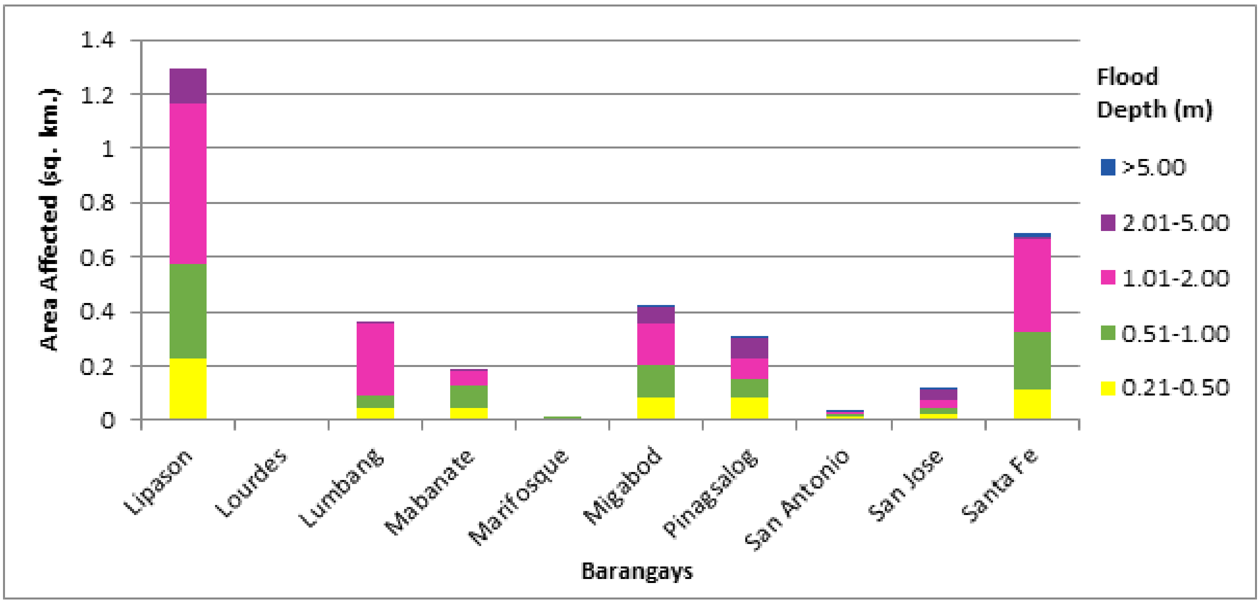


Figure 71. Affected areas in Pilar, Sorsogon during the 5-Year Rainfall Return Period

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Abas	Abucay	Bayasong	Cabiguan	Cagdongon	Calongay	Catamlangan	Comapo-Capo	Guiron	Leona
0.03-0.20	0.052	3.16	0.55	3.28	3.02	0.92	6.05	0.69	1.9	1.5
0.21-0.50	0.0009	0.3	0.013	0.25	0.16	0.08	0.29	0.023	0.35	0.056
0.51-1.00	0.00051	0.42	0.0095	0.43	0.21	0.084	0.37	0.018	0.16	0.086
1.01-2.00	0.0024	0.088	0.014	0.98	0.17	0.12	0.62	0.025	0.035	0.062
2.01-5.00	0.0024	0.013	0.014	0.25	0.009	0.0001	0.18	0.022	0.055	0.042
> 5.00	0	0.0022	0.0004	0.0015	0.0001	0	0.0093	0.0001	0.11	0.0035

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Lipason	Lourdes	Lumbang	Mabanate	Marifosque	Migabod	Pinagsalog	San Antonio	San Jose	Santa Fe
0.03-0.20	2.67	0.032	0.95	0.83	0.18	1.5	2.72	5.47	1.08	1.56
0.21-0.50	0.23	0.00052	0.047	0.046	0.0097	0.083	0.079	0.24	0.024	0.11
0.51-1.00	0.34	0	0.044	0.081	0.0037	0.12	0.069	0.27	0.02	0.21
1.01-2.00	0.59	0	0.26	0.058	0	0.15	0.076	0.35	0.029	0.34
2.01-5.00	0.12	0	0.0064	0.0023	0	0.054	0.075	0.2	0.039	0.011
> 5.00	0	0	0	0	0	0.0001	0.00086	0.0013	0.0029	0.013

For the 25-year rainfall return period, 15.84% of the municipality of Daraga with an area of 135.66 sq. km. will experience flood levels of less than 0.20 meters. 0.62% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.67%, 0.92%, 0.97%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Daraga in square kilometers by flood depth per barangay.

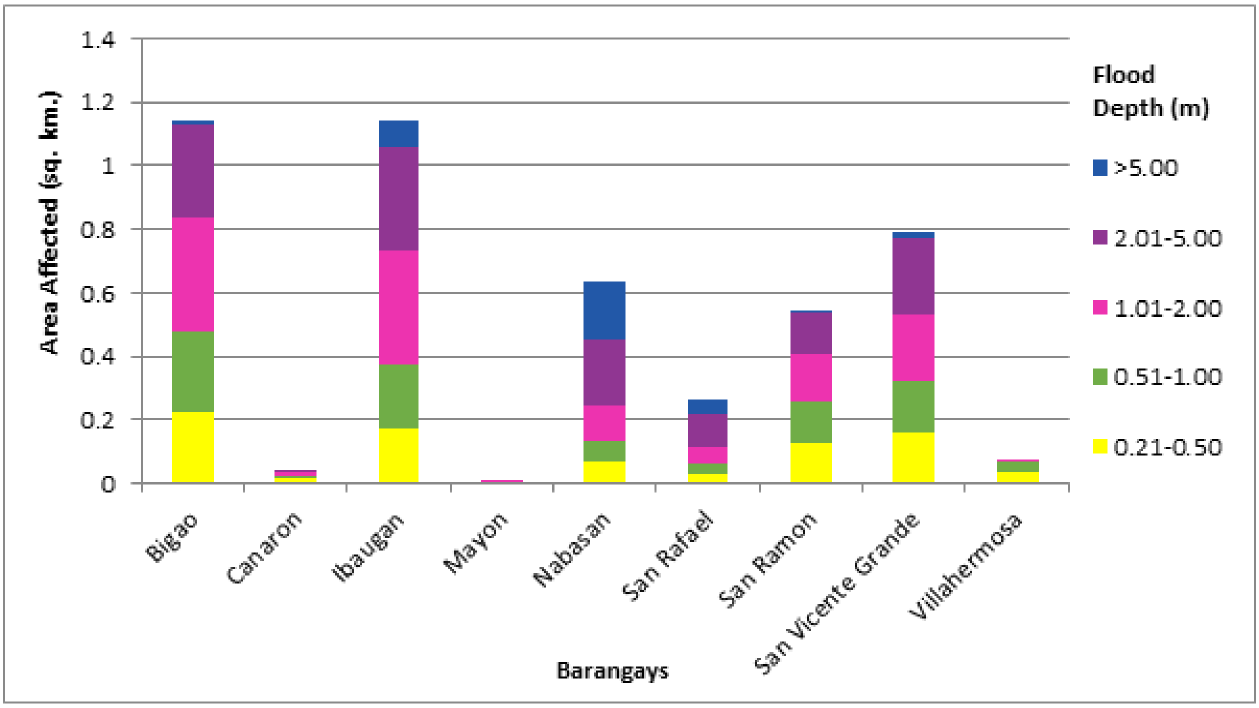


Figure 72. Affected areas in Daraga, Albay during the 25-Year Rainfall Return Period

Table 38. Affected areas in Daraga, Albay during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daraga (in sq. km.)								
	Bigao	Canaron	Ibaugan	Mayon	Nabasan	San Rafael	San Ramon	San Vicente Grande	Villahermosa
0.03-0.20	4.42	0.47	4.97	0.02	2.59	0.97	2.98	4.55	0.53
0.21-0.50	0.23	0.016	0.17	0.0013	0.067	0.033	0.13	0.16	0.039
0.51-1.00	0.25	0.011	0.2	0.00064	0.069	0.033	0.13	0.17	0.027
1.01-2.00	0.36	0.0085	0.36	0.0008	0.11	0.047	0.15	0.2	0.0085
2.01-5.00	0.29	0.0024	0.33	0	0.21	0.11	0.13	0.24	0
> 5.00	0.016	0	0.086	0	0.18	0.049	0.0006	0.017	0

For the Municipality of Jovellar with an area of 82.35 sq. km., 9% will experience flood levels of less than 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.32%, 0.59%, 0.56%, 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. Table 39 depicts the areas affected in Jovellar in square kilometers by flood depth per barangay.

Table 39. Affected areas in Jovellar, Albay during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basey (in sq. km.)			
	Del Rosario	Florista	San Isidro	San Roque
0.03-0.20	5.58	0.32	0.76	0.74
0.21-0.50	0.2	0.004	0.037	0.028
0.51-1.00	0.21	0.0055	0.02	0.024
1.01-2.00	0.43	0.011	0.012	0.029
2.01-5.00	0.43	0.022	0.0001	0.01
> 5.00	0.024	0.0066	0	0

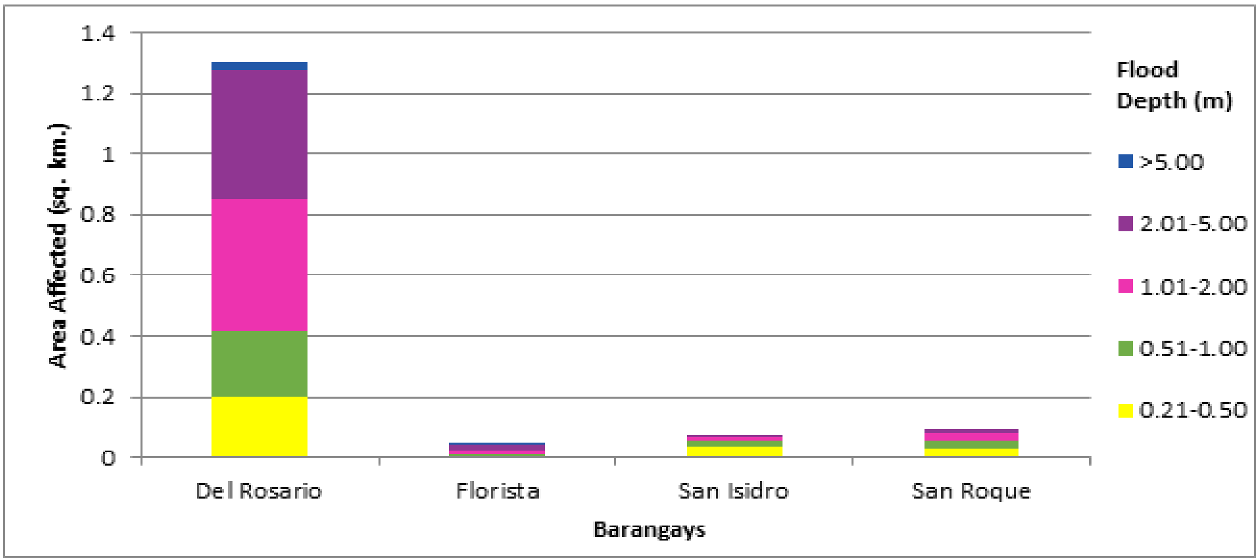


Figure 73. Affected areas in Jovellar, Albay during the 25-Year Rainfall Return Period

For the Municipality of Donsol with an area of 153 sq. km., 17.95% will experience flood levels of less than 0.20 meters. 0.8% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.96%, 1.37%, 1.59%, and 0.21% 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 40 and 41 depict the areas affected in Donsol in square kilometers by flood depth per barangay.

Table 40. Affected areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol (in sq. km.)								
	Alin	Banban	Banuang Gurang	Baras	Bayawas	Cristo	De Vera	Gogon	Gura
0.03-0.20	0.55	1.36	1.67	0.8	2.56	0.65	4.49	0.74	3.2
0.21-0.50	0.023	0.035	0.051	0.027	0.092	0.022	0.16	0.046	0.12
0.51-1.00	0.018	0.028	0.049	0.037	0.083	0.018	0.2	0.062	0.2
1.01-2.00	0.017	0.044	0.056	0.075	0.094	0.021	0.25	0.26	0.45
2.01-5.00	0.016	0.051	0.054	0.044	0.19	0.0031	0.68	0.019	0.73
> 5.00	0.0014	0.0056	0.0008	0	0.019	0	0.0048	0	0.11

Table 41. Affected areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol (in sq. km.)							
	Mabini	Ogod	San Antonio	San Vicente	Sevilla	Tongdol	Tres Marias	Tupas
0.03-0.20	1.69	0.81	0.43	2.66	3.43	0.94	0.17	1.3
0.21-0.50	0.054	0.22	0.012	0.16	0.12	0.037	0.0066	0.039
0.51-1.00	0.041	0.28	0.0087	0.23	0.13	0.044	0.0096	0.041
1.01-2.00	0.042	0.079	0.0088	0.28	0.28	0.086	0.0061	0.046
2.01-5.00	0.067	0.049	0.0039	0.28	0.18	0.015	0.0026	0.04
> 5.00	0.027	0.13	0.0002	0.0018	0.012	0.0011	0	0.0034

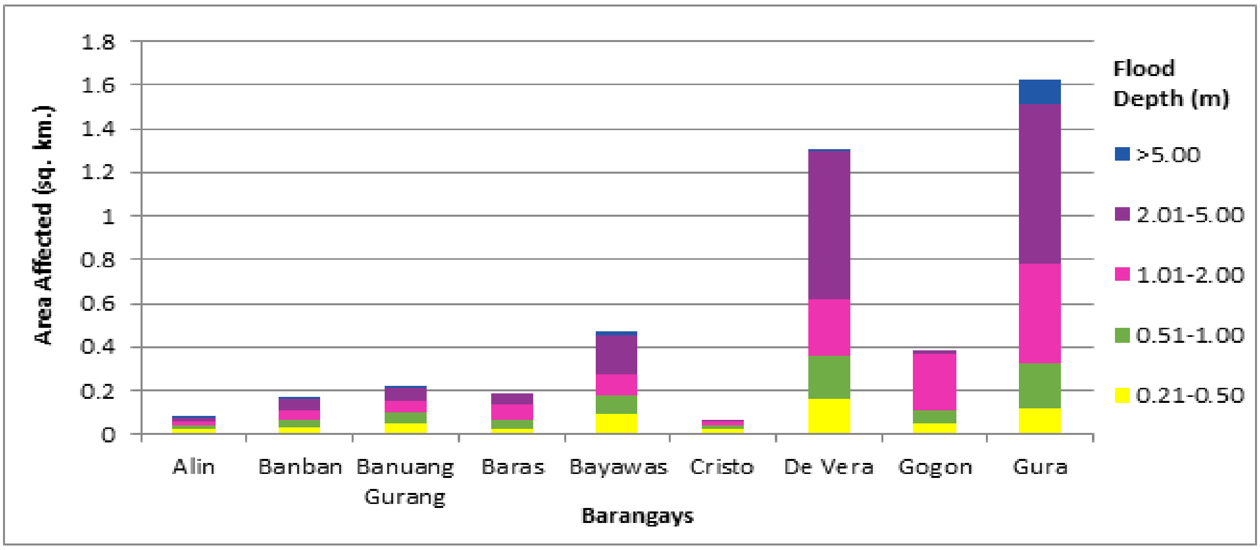


Figure 74. Affected areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period

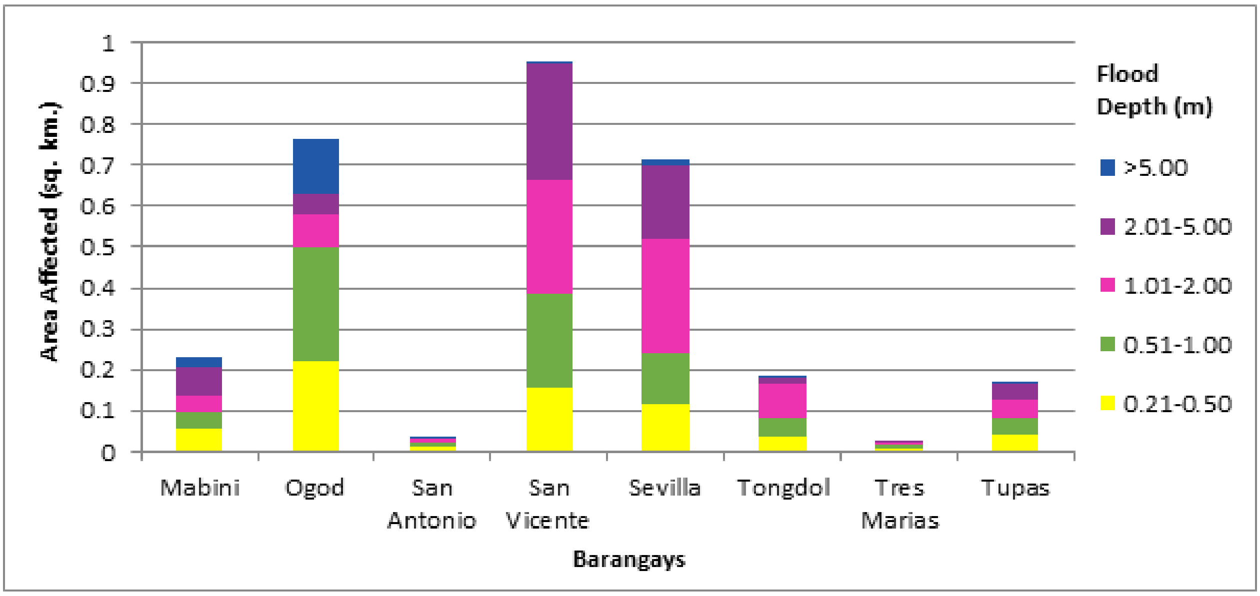


Figure 75. Affected areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period

For the Municipality of Pilar with an area of 196.62 sq. km., 18.35% will experience flood levels of less than 0.20 meters. 0.92% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.15%, 1.88%, 2.33%, and 0.12% 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 42 and 43 depict the areas affected in Pilar in square kilometers by flood depth per barangay.

Table 42 Affected areas in Pilar, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Abas	Abucay	Bayasong	Cabiguan	Cagdongon	Calongay	Catamlangan	Comapo-Capo	Guiron	Leona
0.03-0.20	0.052	3.03	0.54	3.08	2.94	0.87	5.85	0.67	1.43	1.46
0.21-0.50	0.001	0.2	0.013	0.16	0.15	0.052	0.23	0.027	0.26	0.053
0.51-1.00	0.0008	0.29	0.011	0.2	0.2	0.077	0.26	0.021	0.36	0.066
1.01-2.00	0.0015	0.39	0.015	0.73	0.12	0.096	0.54	0.026	0.3	0.11
2.01-5.00	0.0039	0.07	0.019	1.01	0.15	0.1	0.62	0.029	0.12	0.055
> 5.00	0	0.0023	0.0013	0.0015	0.0002	0	0.02	0.0015	0.14	0.0074

Table 43 . Affected areas in Pilar, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Lipason	Lourdes	Lumbang	Mabanate	Marifosque	Migabod	Pinagsalog	San Antonio	San Jose	Santa Fe
0.03-0.20	2.52	0.032	0.87	0.8	0.18	1.43	2.67	5.2	1.06	1.4
0.21-0.50	0.16	0.00062	0.03	0.032	0.0061	0.052	0.081	0.22	0.025	0.066
0.51-1.00	0.17	0	0.023	0.051	0.0063	0.086	0.074	0.27	0.021	0.067
1.01-2.00	0.39	0	0.036	0.11	0.0094	0.19	0.085	0.41	0.029	0.11
2.01-5.00	0.72	0	0.34	0.013	0	0.15	0.1	0.43	0.049	0.58
> 5.00	0.0056	0	0.0042	0	0	0.00047	0.011	0.0059	0.0071	0.02

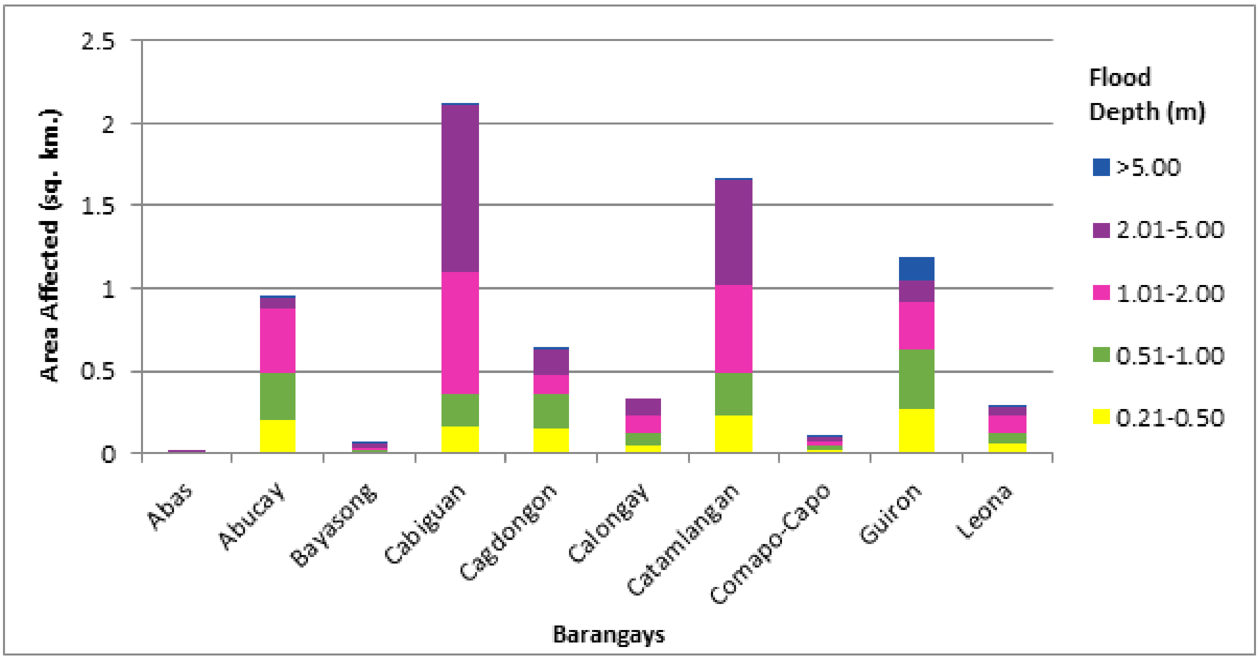


Figure 76. Affected areas in Pilar, Sorsogon during the 25-Year Rainfall Return Period

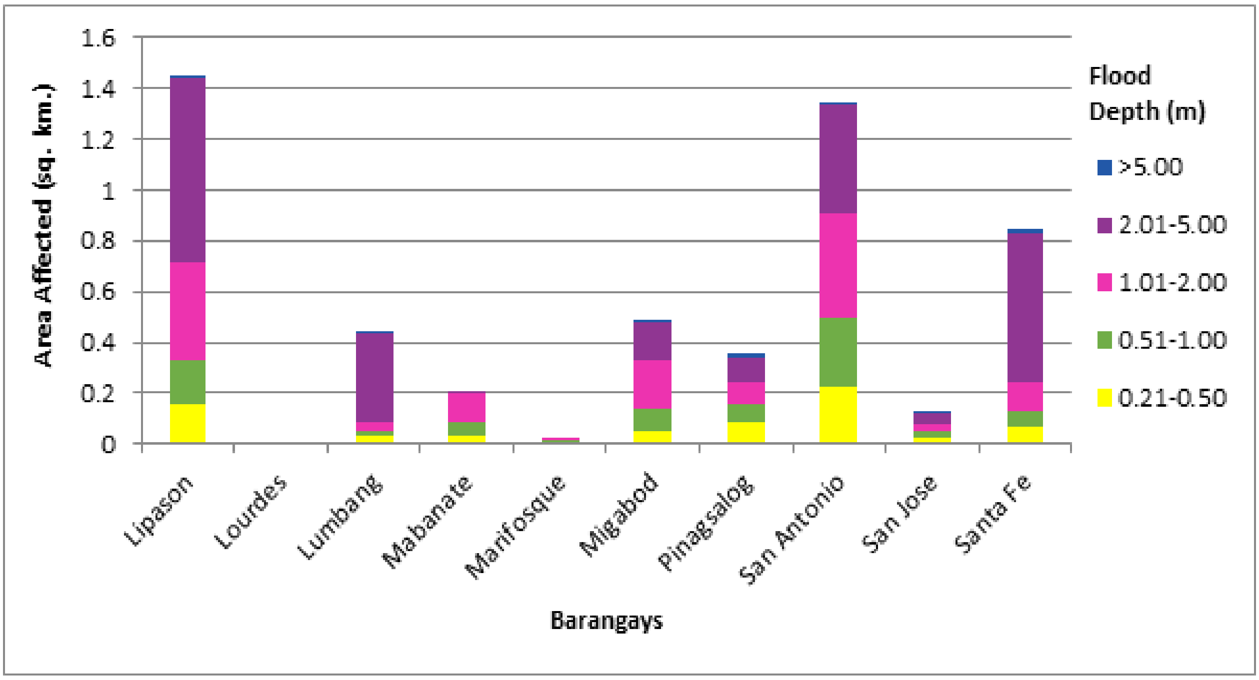


Figure 77. Affected areas in Pilar, Sorsogon during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 15.45% of the Municipality of Daraga with an area of 135.66 sq. km. will experience flood levels of less than 0.20 meters. 0.61% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.63%, 0.89%, 1.31%, and 0.38% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, and greater than 5 meters, respectively. Table 44 depicts 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.)	Area of affected barangays in Daraga (in sq. km.)								
	Bigao	Canaron	Ibaugan	Mayon	Nabasan	San Rafael	San Ramon	San Vicente Grande	Villahermosa
0.03-0.20	4.29	0.46	4.85	0.02	2.52	0.93	2.92	4.44	0.52
0.21-0.50	0.22	0.018	0.16	0.0019	0.062	0.032	0.13	0.16	0.039
0.51-1.00	0.24	0.011	0.15	0.00044	0.071	0.033	0.13	0.18	0.031
1.01-2.00	0.39	0.0097	0.26	0.0012	0.11	0.05	0.16	0.22	0.013
2.01-5.00	0.38	0.0033	0.58	0	0.22	0.11	0.17	0.31	0
> 5.00	0.032	0	0.12	0	0.24	0.083	0.0032	0.039	0

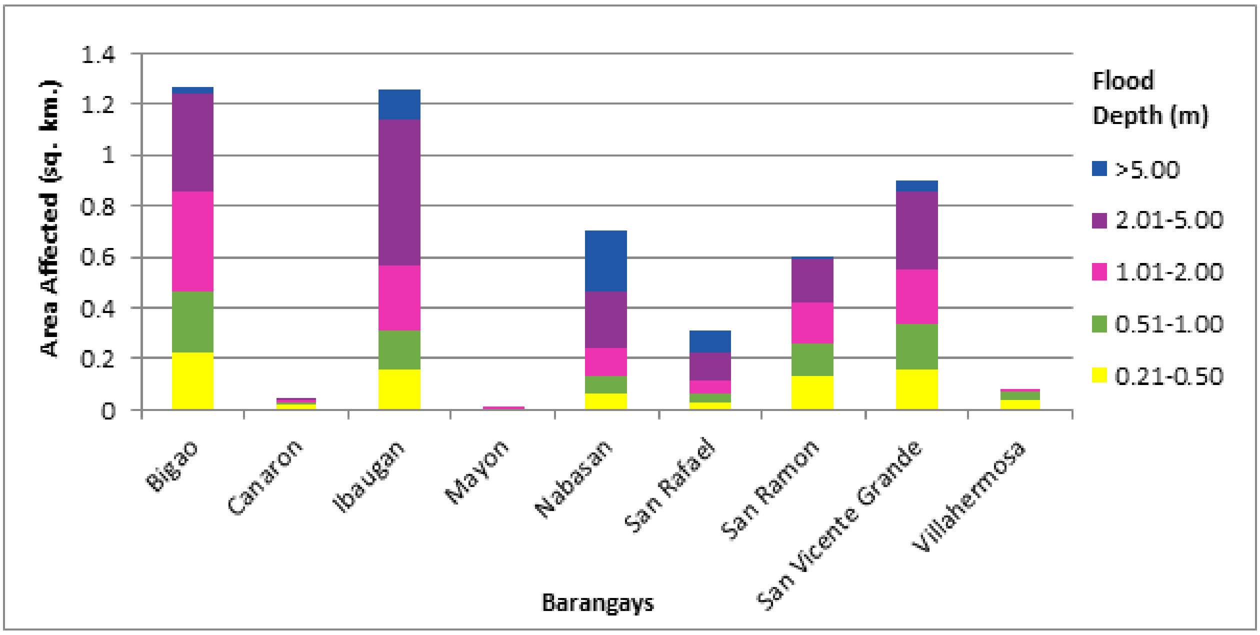


Figure 78. Affected Areas in Daraga, Albay during the 100-Year Rainfall Return Period

For the Municipality of Jovellar with an area of 82.35 sq. km., 8.81% will experience flood levels of less than 0.20 meters. 0.32% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.3%, 0.47%, 0.85%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 45 depicts the areas affected in Jovellar in square kilometers by flood depth per barangay.

Table 45. Affected areas in Jovellar, Albay during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basey (in sq. km.)			
	Del Rosario	Florista	San Isidro	San Roque
0.03-0.20	5.46	0.31	0.75	0.73
0.21-0.50	0.19	0.0042	0.039	0.029
0.51-1.00	0.19	0.0048	0.022	0.025
1.01-2.00	0.33	0.0092	0.015	0.032
2.01-5.00	0.66	0.026	0.001	0.015
> 5.00	0.042	0.013	0	0

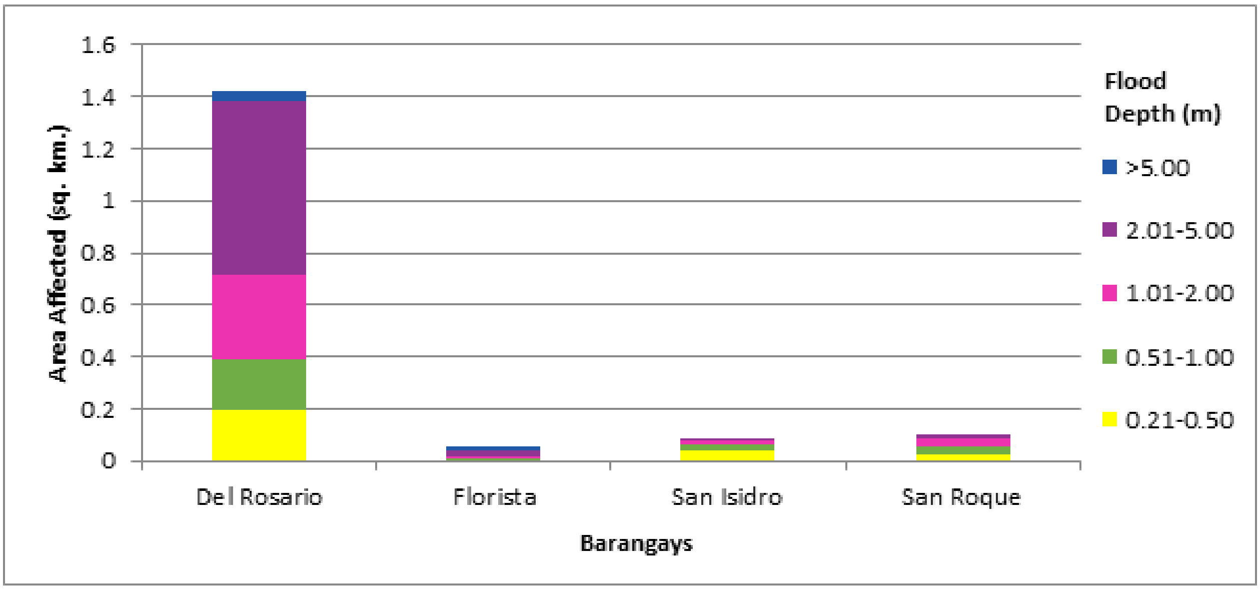


Figure 79. Affected areas in Jovellar, Albay during the 100-Year Rainfall Return Period

For the Municipality of Donsol with an area of 153 sq. km., 17.54% will experience flood levels of less than 0.20 meters. 0.77% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.9%, 1.16%, 2.13%, and 0.39% 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 46 and 47 depict the areas affected in Donsol in square kilometers by flood depth per barangay.

Table 46. Affected areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol (in sq. km.)								
	Alin	Banban	Banuang Gurang	Baras	Bayawas	Cristo	De Vera	Gogon	Gura
0.03-0.20	0.55	1.35	1.65	0.78	2.51	0.64	4.4	0.73	3.11
0.21-0.50	0.022	0.038	0.053	0.023	0.089	0.023	0.16	0.044	0.11
0.51-1.00	0.018	0.027	0.048	0.022	0.088	0.018	0.18	0.049	0.14
1.01-2.00	0.018	0.035	0.056	0.065	0.094	0.021	0.23	0.11	0.35
2.01-5.00	0.023	0.07	0.07	0.088	0.17	0.0083	0.76	0.2	0.98
> 5.00	0.0018	0.0065	0.0012	0	0.08	0	0.075	0	0.14

Table 47. Affected areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol (in sq. km.)							
	Mabini	Ogod	San Antonio	San Vicente	Sevilla	Tongdol	Tres Marias	Tupas
0.03-0.20	1.67	0.66	0.43	2.6	3.38	0.93	0.17	1.29
0.21-0.50	0.055	0.21	0.012	0.13	0.12	0.034	0.0066	0.04
0.51-1.00	0.045	0.31	0.01	0.22	0.11	0.036	0.011	0.041
1.01-2.00	0.046	0.21	0.0098	0.18	0.23	0.069	0.0061	0.05
2.01-5.00	0.071	0.05	0.0045	0.47	0.19	0.056	0.0035	0.048
> 5.00	0.035	0.14	0.0003	0.0018	0.11	0.0021	0	0.005

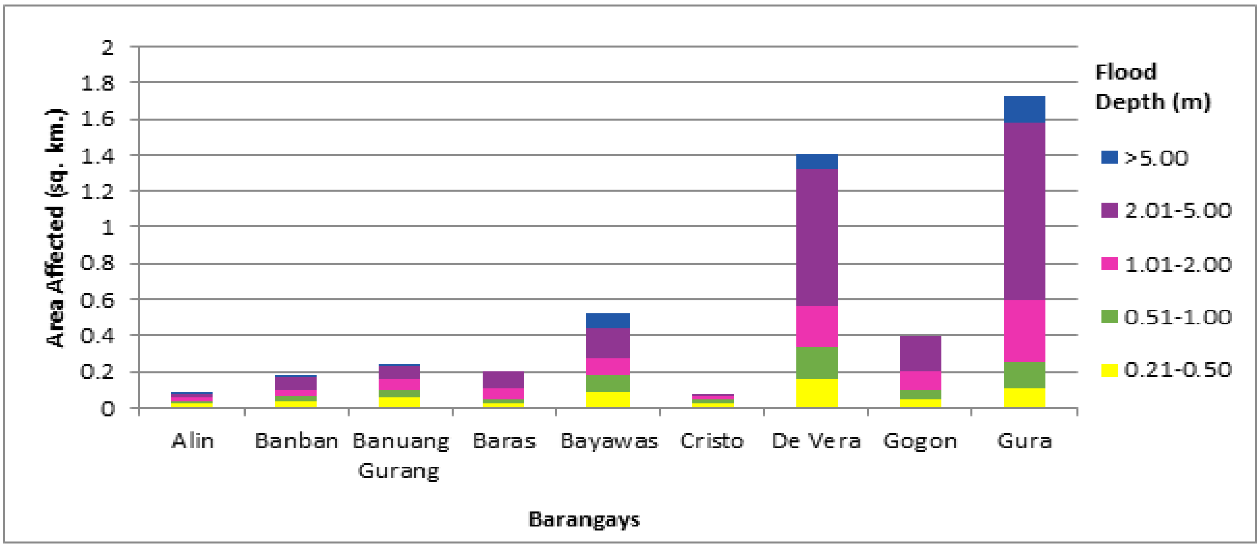


Figure 80. Affected areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period

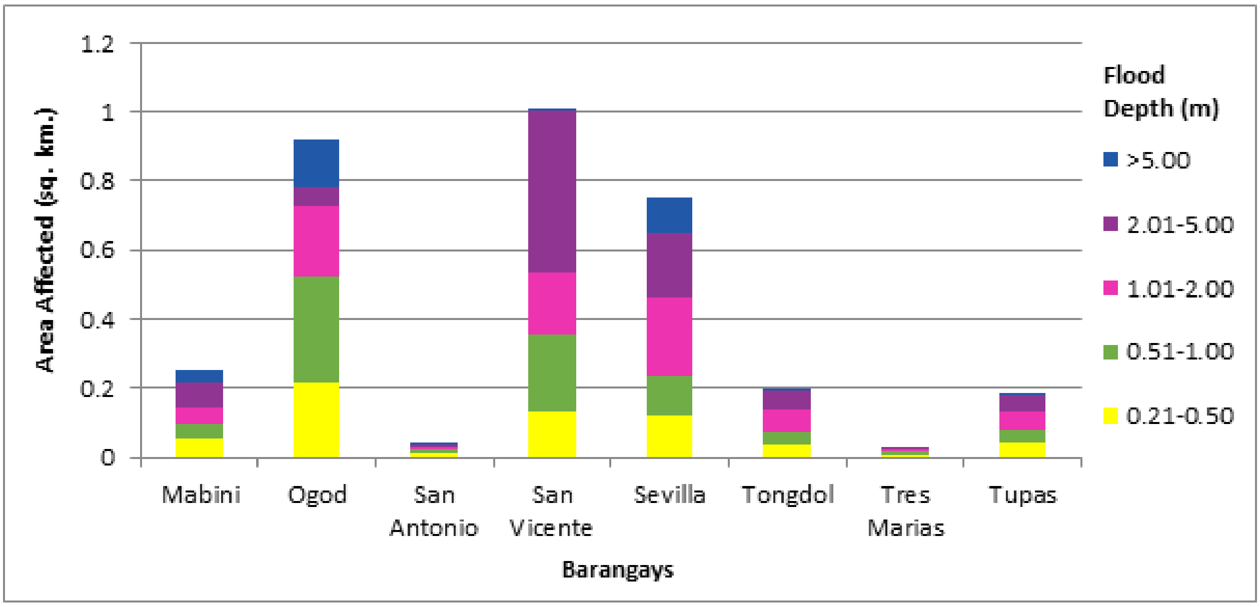


Figure 81. Affected areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period

For the Municipality of Pilar with an area of 196.62 sq. km., 17.85% will experience flood levels of less than 0.20 meters. 0.85% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.98%, 1.61%, 3.08%, and 0.38% 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 48 and 49 depict the areas affected in Pilar in square kilometers by flood depth per barangay.

Table 48. Affected areas in Pilar, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Abas	Abucay	Bayasong	Cabiguan	Cagdongon	Calongay	Catamlangan	Comapo-Capo	Guiron	Leona
0.03-0.20	0.051	2.98	0.53	2.96	2.89	0.84	5.71	0.66	1.29	1.44
0.21-0.50	0.00043	0.17	0.014	0.14	0.14	0.043	0.21	0.03	0.25	0.053
0.51-1.00	0.0014	0.24	0.012	0.16	0.19	0.073	0.23	0.021	0.27	0.056
1.01-2.00	0.0012	0.32	0.016	0.42	0.17	0.076	0.37	0.027	0.45	0.13
2.01-5.00	0.0045	0.28	0.021	1.49	0.19	0.16	0.97	0.034	0.2	0.066
> 5.00	0	0.003	0.0025	0.0027	0.0003	0	0.028	0.0032	0.15	0.013

Table 49. Affected areas in Pilar, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Lipason	Lourdes	Lumbang	Mabanate	Marifosque	Migabod	Pinagsalog	San Antonio	San Jose	Santa Fe
0.03-0.20	2.45	0.032	0.84	0.79	0.17	1.4	2.63	5.04	1.05	1.34
0.21-0.50	0.13	0.0006	0.027	0.025	0.0056	0.045	0.087	0.22	0.024	0.058
0.51-1.00	0.15	0.000015	0.022	0.044	0.0044	0.055	0.076	0.26	0.021	0.048
1.01-2.00	0.27	0	0.028	0.076	0.014	0.16	0.09	0.44	0.03	0.092
2.01-5.00	0.8	0	0.12	0.078	0.0018	0.25	0.11	0.57	0.051	0.66
> 5.00	0.17	0	0.28	0	0	0.0017	0.023	0.019	0.014	0.054

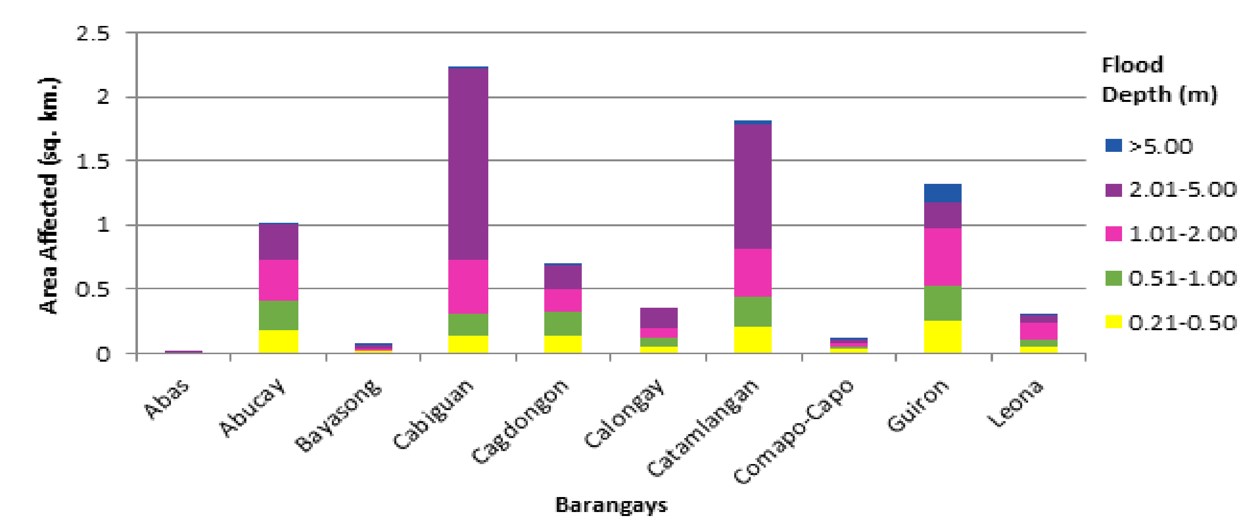


Figure 82. Affected areas in Pilar, Sorsogon during the 100-Year Rainfall Return Period

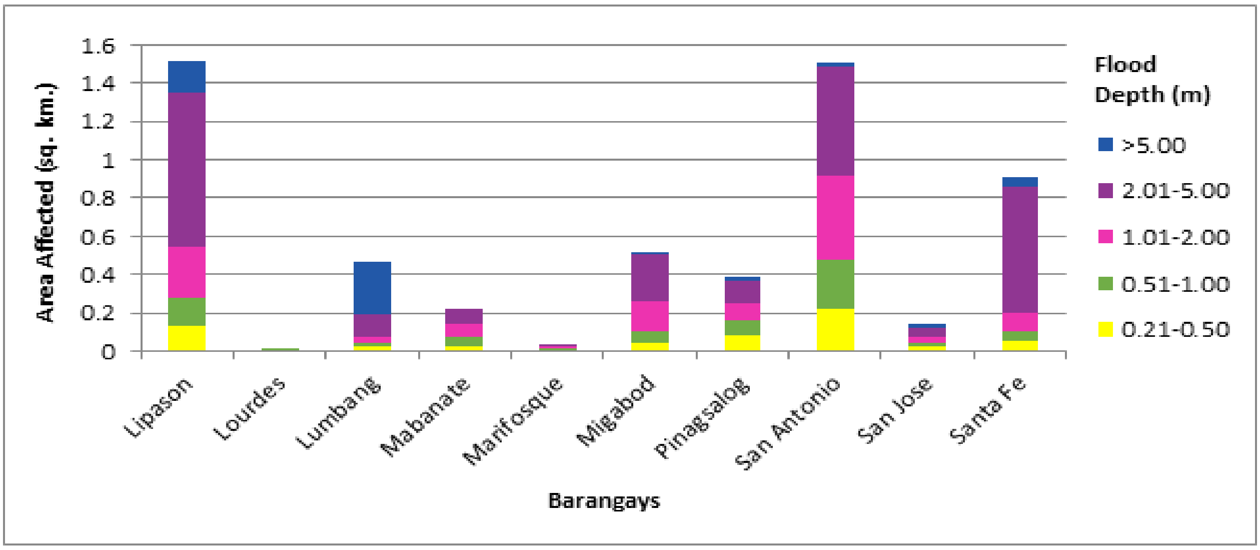


Figure 83. Affected areas in Pilar, Sorsogon during the 100-Year Rainfall Return Period

Among the barangays in the Municipality of Daraga, Ibaugan is projected to have the highest percentage of area that will experience flood levels at 4.5%. Meanwhile, Bigao posted the second highest percentage of area that may be affected by flood depths at 4.1%.

Among the barangays in the Municipality of Jovellar, Del Rosario is projected to have the highest percentage of area that will experience flood levels at 8.35%. Meanwhile, San Roque posted the second highest percentage of area that may be affected by flood depths at 1.01%.

Among the barangays in the Municipality of Donsol, De Vera is projected to have the highest percentage of area that will experience flood levels of at 3.79%. Meanwhile, Gura posted the second highest percentage of area that may be affected by flood depths of at 3.15%.

Among the barangays in the Municipality of Pilar, Catamlangan is projected to have the highest percentage of area that will experience flood levels of at 3.82%. Meanwhile, San Antonio posted the second highest percentage of area that may be affected by flood depths of at 3.33%.

Moreover, the generated flood hazard maps for the Donsol 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 50. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5-year	25-year	100-year
Low	5.18	4.21	3.99
Medium	10.37	8.6	7.74
High	6.62	13.68	17.03
TOTAL	**22.17**	**26.49**	**28.76**

Of the forty five (45) identified Educational Institutions in Donsol Floodplain, two (2) were assessed to be exposed to low, seven (7) to medium, and one (1) to high level flooding during the 5-year scenario. In the 25-year scenario, two (2) were assessed to be exposed to low, six (6) to medium, and three (3) to high level flooding. In the 100-year scenario, two (2) were assessed to be exposed to low, six (6) to medium, and five (5) to high level flooding.

Of the twelve (12) identified Medical Institutions in Donsol Floodplain, none was assessed to be exposed to low and high, while three (3) were assessed to be exposed to medium level flooding in the 5-year scenario. In the 25-year scenario, none was assessed to be exposed to low, one (1) was assessed to be exposed to medium, and three (3) were assessed to be exposed to high level flooding. In the 100-year scenario, none was assessed to be exposed to low, one (1) was assessed to be exposed to medium, and three (3) were assessed to be exposed to high level flooding.

5.11 Flood Validation

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

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

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

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

The flood validation data were obtained on November 13-15, 2015. The flood validation consists of 196 points randomly selected all over the Donsol Floodplain. It has an RMSE value of 1.38464553.

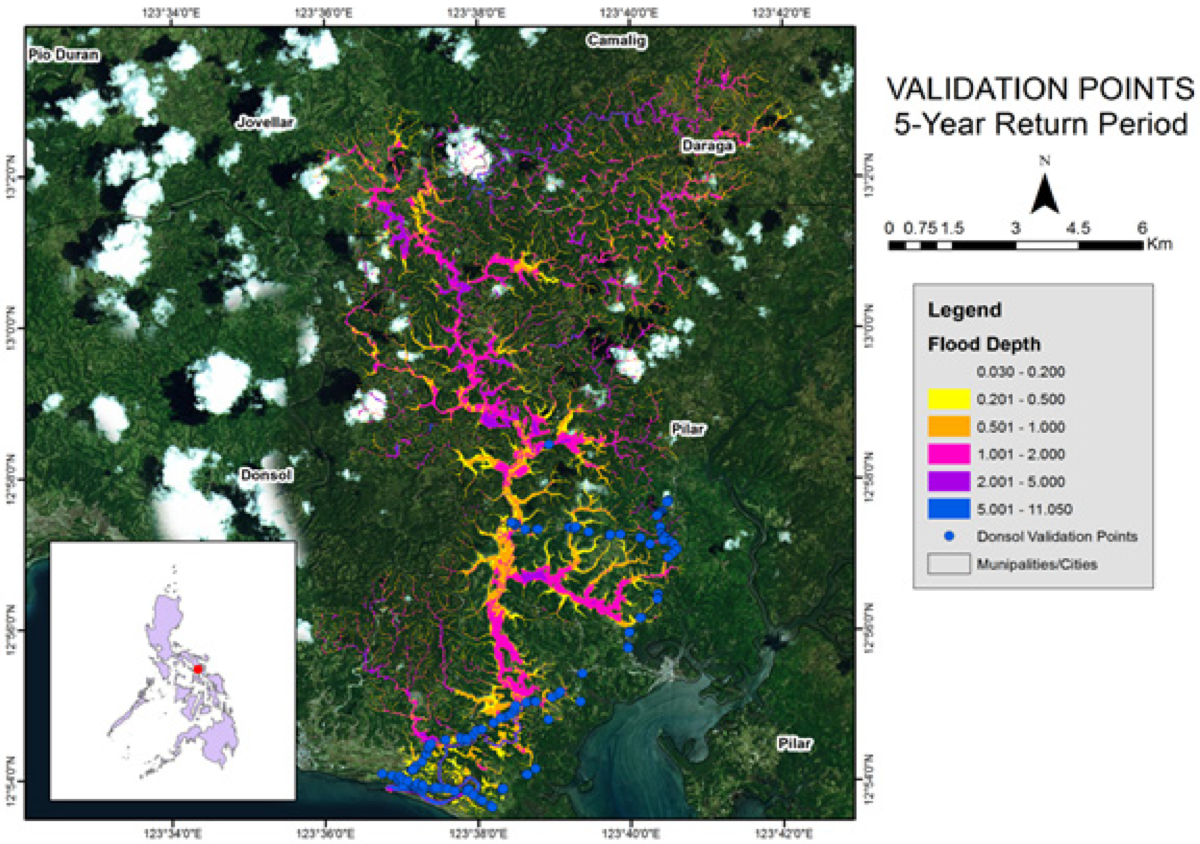


Figure 84. The validation points for the 5-Year flood depth map of the Donsol Floodplain

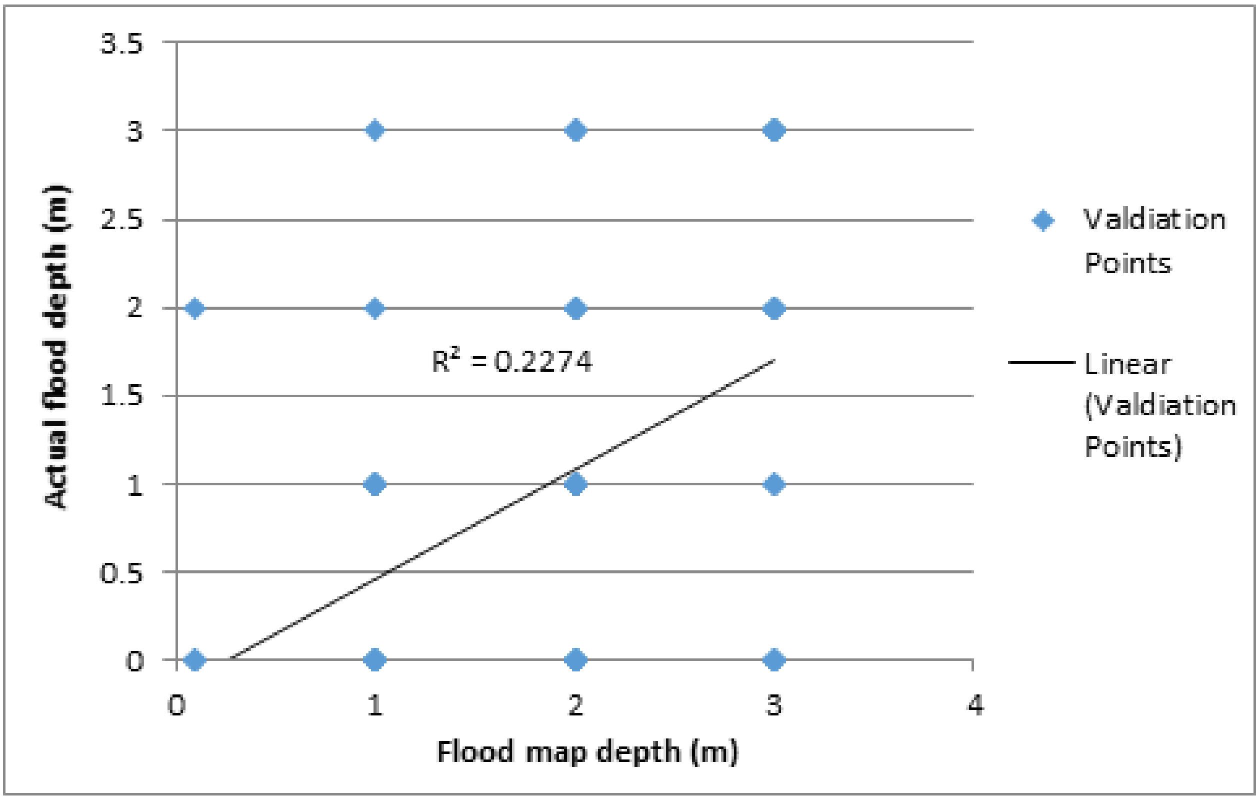


Figure 85. Flood map depth vs. Actual flood depth

Table 51. Actual flood vs simulated flood depth at differnent levels in the Donsol 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	8	0	0	1	0	0	9
0.21-0.50	0	0	0	0	0	0	0
0.51-1.00	33	0	17	1	1	0	52
1.01-2.00	28	0	20	10	9	0	67
2.01-5.00	15	0	6	13	23	0	57
> 5.00	0	0	0	0	0	0	0
Total	84	0	43	25	33	0	185

On the whole, the overall accuracy generated by the flood model is estimated at 31.35%, with 58 points correctly matching the actual flood depths. In addition, there were 43 points estimated one level above and below the correct flood depths, 40 points estimated two levels above and below, and 44 points estimated three or more levels above and below the correct flood depths. A total of 12 points were overestimated while a total of 115 points were underestimated in the modelled flood depths of Donsol. Table 52 depicts the summary of the accuracy assessment in the Donsol River Basin survey.

Table 52. Summary of the Accuracy Assessment in the Donsol River Basin Survey

DONSOL	No. of Points	%
Correct	58	31.35
Overestimated	12	6.49
Underestimated	115	62.16
Total	185	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Gemini Sensor

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

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

1. ABY-82

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

Location Description

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

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. ABY-92

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

February 24, 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: **ABY-82**

Order: **2nd**

Island: **LUZON**	Barangay:		
Municipality: **JOVELLAR**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **13° 4' 16.27314"**	Longitude: **123° 35' 53.17428"**	Ellipsoidal Hgt:	**39.77600 m.**
	WGS84 Coordinates		
Latitude: **13° 4' 11.43271"**	Longitude: **123° 35' 58.18268"**	Ellipsoidal Hgt:	**93.89000 m.**
	PTM / PRS92 Coordinates		
Northing: **1445500.97 m.**	Easting: **564865.27 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **1,444,995.02**	Easting: **564,842.57**	Zone:	**51**

Location Description

ABY-82
From Guinobatan Town Proper, travel S for about 16 km. to reach Jovellar Town Proper. Station is located at the right corner (about 12 m.) of the Rizal monument in front of Jovellar Catholic Church and 12 m. from the road centerline. 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-82 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0415**

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

9 9 0 2 2 4 2 0 1 6 1 4 0 5 2 1

CP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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**		Barangay:
Municipality: **LEGASPI CITY**		

	PRS92 Coordinates	
Latitude: **13° 9' 11.38733"**	Longitude: **123° 43' 45.95874"**	Ellipsoidal Hgt: **14.54010 m.**
	WGS84 Coordinates	
Latitude: **13° 9' 6.53800"**	Longitude: **123° 43' 50.95900"**	Ellipsoidal Hgt: **68.75400 m.**
	PTM Coordinates	
Northing: **1454607.115 m.**	Easting: **579082.538 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,454,097.98**	Easting: **579,054.86**	Zone: **51**

Location Description

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

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

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

99041020141415 48

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

1. LPH – 01

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

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

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

2

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. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP TCAGP

FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA-PAGADOR	UP-TCAGP
		CHRISTOPHER JOAQUIN	UP-TCAGP
	Research Associate (RA)	LARAH KRISELLE PARAGAS	UP-TCAGP
		MA. VERLINA E. TONGA	
		MILLIE SHANE REYES	
		IRO NIEL ROXAS	
		KRISTINE ANDAYA	
		JERIEL PAUL ALAMBAN	
Ground Survey, Data Download and Transfer	Research Associate (RA)	KENNETH QUISADO	UP-TCAGP
		JASMIN DOMINGO	
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJIE CARBOLLEDO	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION
		CAPT. CESAR ALFONSO III	
		CAPT. RAUL CZ SAMAR II	

Annex 5. Data Transfer Sheet for Donsol Floodplain

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

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS (KB)	POS (MB)	RAW IMAGES/ CASI (GB)	MISSION LOG FILE (KB)	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath in KB)							BASE STATIONS (MB)	Base Info (.txt)		Actual (KB)	KML	
Mar 29, 2014	7156GC	2BLK19E088A	GEMINI	NA	60	107	96.4	12.2	25/46KB	4.55	NA	7.33	1KB	1KB	41	7	Z:\Airborne_Raw\7156GC
Mar 30, 2014	7158GC	2BLK19ES089A & 2BLK19G089A	GEMINI	NA	400	666	266	20.2	49.7	30.1	NA	10.1	1KB	1KB	275	11	Z:\Airborne_Raw\7158GC
Mar 31, 2014	7160GC	2BLK19I90A	GEMINI	NA	9.18	58.5	71.4	NA	NA	2.89	NA	7.45	1KB	NA	3	NA	Z:\Airborne_Raw\7160GC
Mar 31, 2014	7161GC	2BLK19IS090B	GEMINI	NA	187	312	136	51.2	71.63/28.7	14.2	NA	4.18	1KB	1KB	129	7	Z:\Airborne_Raw\7161GC
Apr 2, 2014	7165GC 7164GC	2BLK19CS092A	GEMINI	NA	149	280	120	40.1	70.4	11.3	NA	5.89	1KB	1KB	102	7	Z:\Airborne_Raw\7164GC
Apr 3, 2014	7167 7166GC	2BLK19K093A & 2BLK10IS093A	GEMINI	NA	677	550	222	93.5	106	25.5	NA	7.6	1KB	1KB	233	13	Z:\Airborne_Raw\7166GC
Apr 4, 2014	7168GC	2BLK19L094A	GEMINI	NA	90.5	485	193	54.6	142	22.4	NA	10.9	1KB	1KB	204	NA	Z:\Airborne_Raw\7168GC
Apr 4, 2014	7169GC	2BLK19B094B	GEMINI	NA	59.2	398	172	73.4	104	17.9	NA	11.1	1KB	1KB	137	10	Z:\Airborne_Raw\7169GC
Apr 5, 2014	7171GC	2BLK19M095A	GEMINI	NA	62.1	340	166	30.3	88.5	14.5	NA	11.6	1KB	1KB	257	NA	Z:\Airborne_Raw\7171GC
Apr 6, 2014	7172GC	2BLK19CS & 2BLKD096A	GEMINI	NA	560	674	263	NA	NA	30.9	NA	12.2	1KB	1KB	384	13	Z:\Airborne_Raw\7172GC

Received from

Name CHRIS V DADULANT

Position RA

Signature

Received by

Name JENNIFER B. SAGUKAN

Position RA

Signature 04/21/2014

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

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/20/2013	7200GC	2BLK19JS110A & 2BLK19N110A	GEMINI	NA	221KB	402KB	237MB	60.5	133	17.3	NA	7.61	1KB	1KB	151	24	Z:\Airborne_Raw\7200GC
4/22/2014	7204GC	2BLK19A112A	GEMINI	NA	130/20MB	359	206	NA	NA	15.1	N/A	1.14	1KB	1KB	384	7	Z:\Airborne_Raw\7204GC
4/26/2014	7212GC	2BLK19P116A & 2BLK19O116A	GEMINI	NA	125	431	126	N/A	N/A	17.7	N/A	1.68	1KB	1KB	244	11	Z:\Airborne_Raw\7212GC
4/26/2014	7213GC	2BLK19OS116B & VOIDS	GEMINI	NA	33.6	263	141	N/A	N/A	8.77	N/A	1.68	1KB	1KB	311	3	Z:\Airborne_Raw\7213GC
4/28/2014	7216GC	2BLK19AS118A & VOIDS	GEMINI	NA	46.2	311	184	41.5	N/A	12.1	N/A	7.36	1KB	1KB	191	5kb/2kb	Z:\Airborne_Raw\7216P

Received from

Name Chris Sajonia
Position RA
Signature [signature]

Received by

Name Benjamin Magallon
Position SSRS
Signature [signature]
5/5/2014

DATA TRANSFER SHEET
ALBAY/SORSOGON 3/2/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
25-Feb-16	3813G	2BLK19BS 56B	GEMINI	NA	665	1.12	202	66.8	538	26.6	NA	5.61	1KB	2KB	34/33/40/36/ 12/11/12/12	NA	Z:\DAC\RAW DATA
26-Feb-16	3815G	2BLK19KS LS57A	GEMINI	NA	537	11.3	209	51.6	323	22.1	NA	7.02	1KB	1KB	12/9/9/9	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature] 3/4/2016

DATA TRANSFER SHEET
ALBAY/SORSOGON 3/18/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
28-Feb-16	3825G	2BLK19JFS 059B	GEMINI	NA	233	13.3	176	4.37	37	19.1	NA	6.33	1KB	2KB	15/11	233	Z:\DAC\RAW DATA
29-Feb-16	3827G	2BLK19AB S060A	GEMINI	NA	NA	2.03	265	2.2	1	33.6	NA	11.7	1KB	3KB	38/29/30	376	Z:\DAC\RAW DATA
29-Feb-16	3829G	2BLK19FS 060B	GEMINI	NA	686	1.98	130	26.9	252	14	NA	11.7	1KB	1KB	36/32/29/30/30	NA	Z:\DAC\RAW DATA
4-Mar-16	3843G	2BLK19DS 064A	GEMINI	NA	942	5.18	274	88.1	735	39.2	NA	9.29	1KB	1KB	32/29	NA	Z:\DAC\RAW DATA
6-Mar-16	3851G	2BLK19aA B066A	GEMINI	NA	331	587	183	28.7	227	16	NA	4.19	1KB	1KB	30/28/27	331	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/21/16

Annex 6. Flight logs for the flight missions

1. Flight Log for 7156GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7156

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

20 Remarks:

Surveyed 3 lines (with CASI)

21 Problems and Solutions:

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

2. Flight Log for 7158GC Mission

DREAM Data Acquisition Flight Log Flight Log No.: 7158

1 LiDAR Operator: MVE TONGA	2 ALTM Model: Gemini & CAS1	3 Mission Name: 2BLK19E5089A & 2BLK19G089A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: R. SAMAR	8 Co-Pilot: CE ALFONSO	9 Route: RPLP - RPLP			
10 Date: 3-30-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 8+59	14 Engine Off: 13+28	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed

21 Problems and Solutions:

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

3. Flight Log for 7160GC Mission

DREAM Data Acquisition Flight Log Gemini 9r

Flight Log No.: 7160

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK19IDE090A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR	8 Co-Pilot: CS ALFONSO	9 Route: RPLP – RPLP			
10 Date: 3-31-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 7+57	14 Engine Off: 9+32	15 Total Engine Time: 1+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Surveyed 1 line (without CASI)					

21 Problems and Solutions:

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

4. Flight Log for 7161GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7161

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

21 Problems and Solutions:

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

5. Flight Log for 7167GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7167

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini CAS	3 Mission Name: 2BLK19K093A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: CS Alfonso III	9 Route:			
10 Date: 4-3-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 13+31	14 Engine Off: 17+24	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

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

6. Flight Log for 7168GC Mission

DREAM Data Acquisition Flight Log **Flight Log No.:** 7168

1 LIDAR Operator: LK Paragas	2 ALTM Model: Gemini CASI	3 Mission Name: 2BLK19L0944	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route:			
10 Date: 4-4-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 7+58	14 Engine Off: 11+27	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

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

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

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

Lidar Operator: L. Paragas — Signature over Printed Name

7. Flight Log for 7171GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7171

1 LiDAR Operator: LK Paragas	2 ALTM Model: CASI (Gemini 2)	3 Mission Name: 2BLK19M095A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: GS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-5-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 14:41	14 Engine Off: 17:40	15 Total Engine Time: 2:59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
AL Matira	[signature]	R. Samar	L. Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

8. Flight Log for 7216GC Mission

DREAM Data Acquisition Flight Log Gemini 2 **Flight Log No.:** 7216

1 LiDAR Operator: MV Tonga	2 ALTM Model: CASI	3 Mission Name: 2BLK19A5118A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: OS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-28-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0633H	14 Engine Off: 0944H	15 Total Engine Time: 3+11	16 Take off: 0638H	17 Landing: 0949 H	18 Total Flight Time: 3+03
19 Weather					
20 Remarks: Mission completed including voids (with CASI) BLK19A					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Matira	B. Sartalledo	R. Samar	Mye Tong
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

9. Flight Log for 3813G Mission

DREAM | Data Acquisition Flight Log

Flight Log No.: 3813

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

20 Flight Classification

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

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

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

21 Remarks

Surveyed blk 19IS & BLK 19KS

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
CHRIS SOORIAN	BONGIE CARBALLEDO	J Mooney	MS REYES	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

10. Flight Log for 3815G Mission

DREAM | Data Acquisition Flight Log

Flight Log No.: 3815

1 LIDAR Operator: J ALAMBAN	2 ALTM Model: Gemini	3 Mission Name: 2BLK19KS L57A	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 26, 2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 0903	14 Engine Off: 1238	15 Total Engine Time: 3+35	16 Take off: 0908	17 Landing: 1233	18 Total Flight Time: 3+25
19 Weather	Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed Blk 19 K and 19L

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
CHRIS S. OPOSIN	FARLIE CARBOLLEDO	J. MOONEY	JP ALAMBAN	JJM
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

11. Flight Log for 3825G Mission

DREAM | Data Acquisition Flight Log

Flight Log No.: 3825

1 LiDAR Operator: MS REYES	2 ALTM Model: Gemini	3 Mission Name: 2BLK19JS FS 59B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: J MOONEY	8 Co-Pilot: D CABUDOL	9 Route:			
10 Date: Feb 28,2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 1430	14 Engine Off: 1741	15 Total Engine Time: 3+11	16 Take off: 1435	17 Landing: 1736	18 Total Flight Time: 3+01
19 Weather	Cloudy on some areas				

20 Flight Classification

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

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

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

21 Remarks

Surveyed Blk 19JS & some parts of Blk 19FS

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	BERNIS CARBOLLEDO	Jerome Mooney	MS REYES	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight status reports

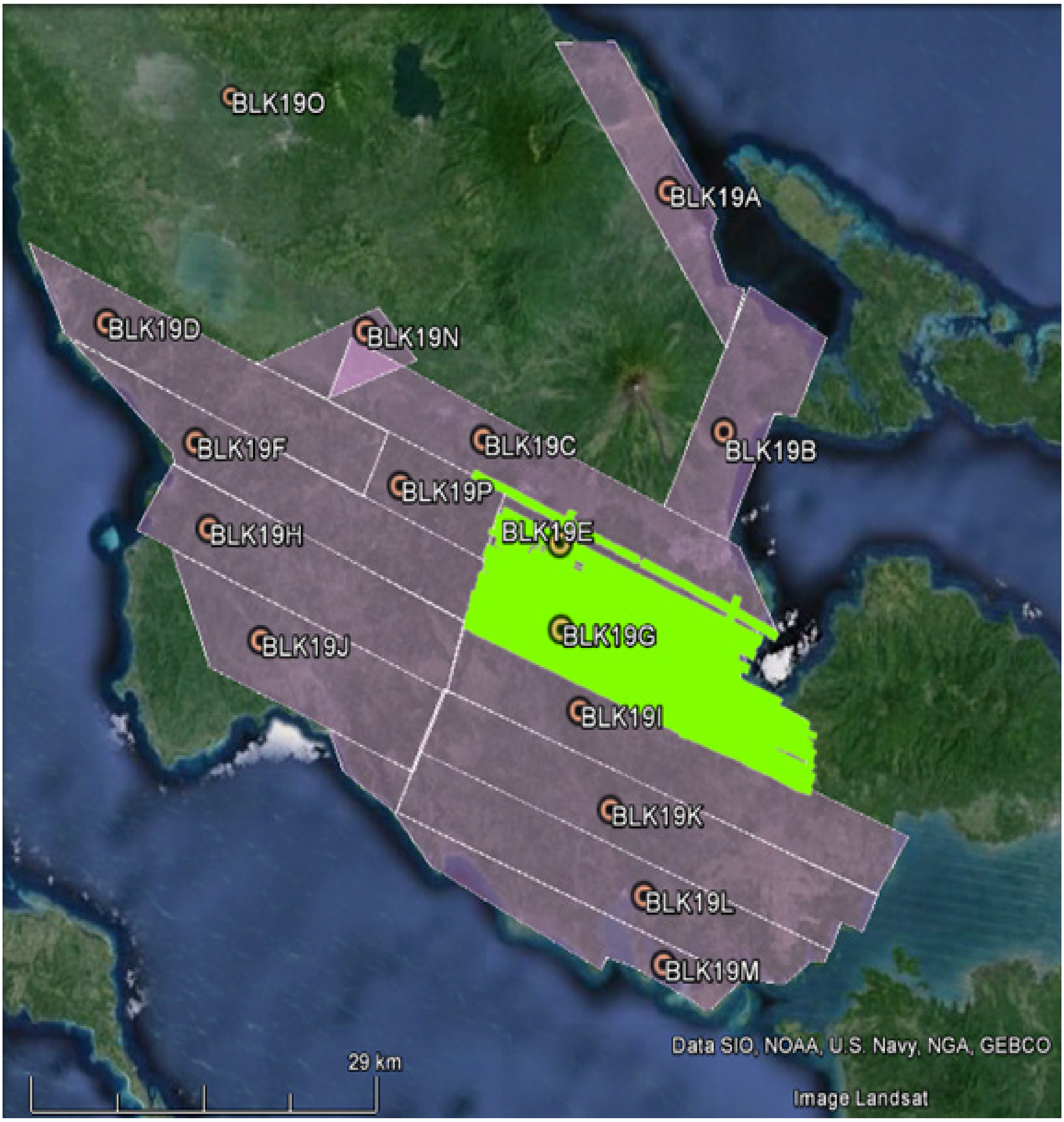
FLIGHT STATUS REPORT
ALBAY AND SORSOGON
(March 26 – April 30, 2014 and February 24 – March 20, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7156GC	BLK19E	2BLK19E088A	MVE TONGA	03-29-14	Surveyed 3 lines (with CASI)
7158GC	BLK19	2BLK19ES089A & 2BLK19G089A	MVE TONGA	03-30-14	Mission completed (with CASI)
7160GC	BLK19	2BLK19I90A	MVE TONGA	03-31-14	Surveyed 1 line (without CASI)
7161GC	BLK19	2BLK19IS090B	MVE TONGA	03-31-14	Surveyed 6 lines (with CASI)
7167GC	BLK19	2BLK19K093A & 2BLK10IS093A	MVE TONGA	04-03-14	Mission completed (with CASI)
7168GC	BLK19	2BLK19L094A	L. PARAGAS	04-04-14	Mission completed (with CASI)
7171GC	BLK19	2BLK19M095A	L. PARAGAS	04-05-14	Mission completed (with CASI)
7216GC	BLK19	2BLK19AS118A & VOIDS (BLK19Q)	MVE TONGA	04-28-14	Mission completed (with CASI)
3813G	BLK19IS & BLK19KS	2BLK19IS056B	M. REYES	02-25-16	SURVEYED BLK19IS AND HALF OF BLK19KS
3815G	BLK19KS & BLK19LS	2BLK19KLS057A	J. ALAMBAN	02-26-16	SURVEYED REST OF BLK19KS AND BLK19LS
3825G	BLK19JS & BLK19FS	2BLK19JFS059B	M. REYES	02-28-16	SURVEYED BLK19J AND SOME LINES OF BLK19FS

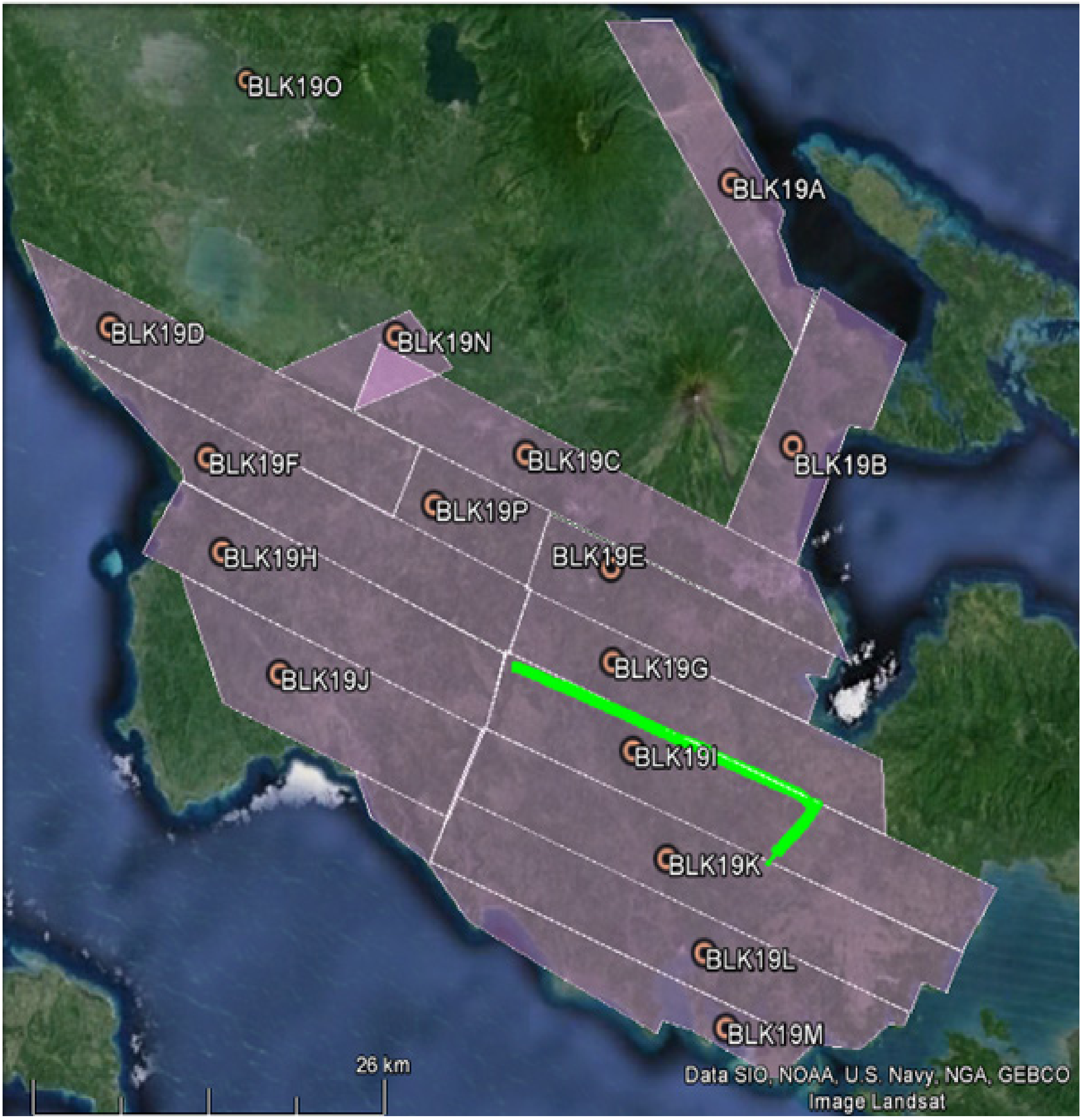
LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	7156 GC
Area:	BLK19E
Mission name:	2BLK19E088A
Parameters:	Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 35 %

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

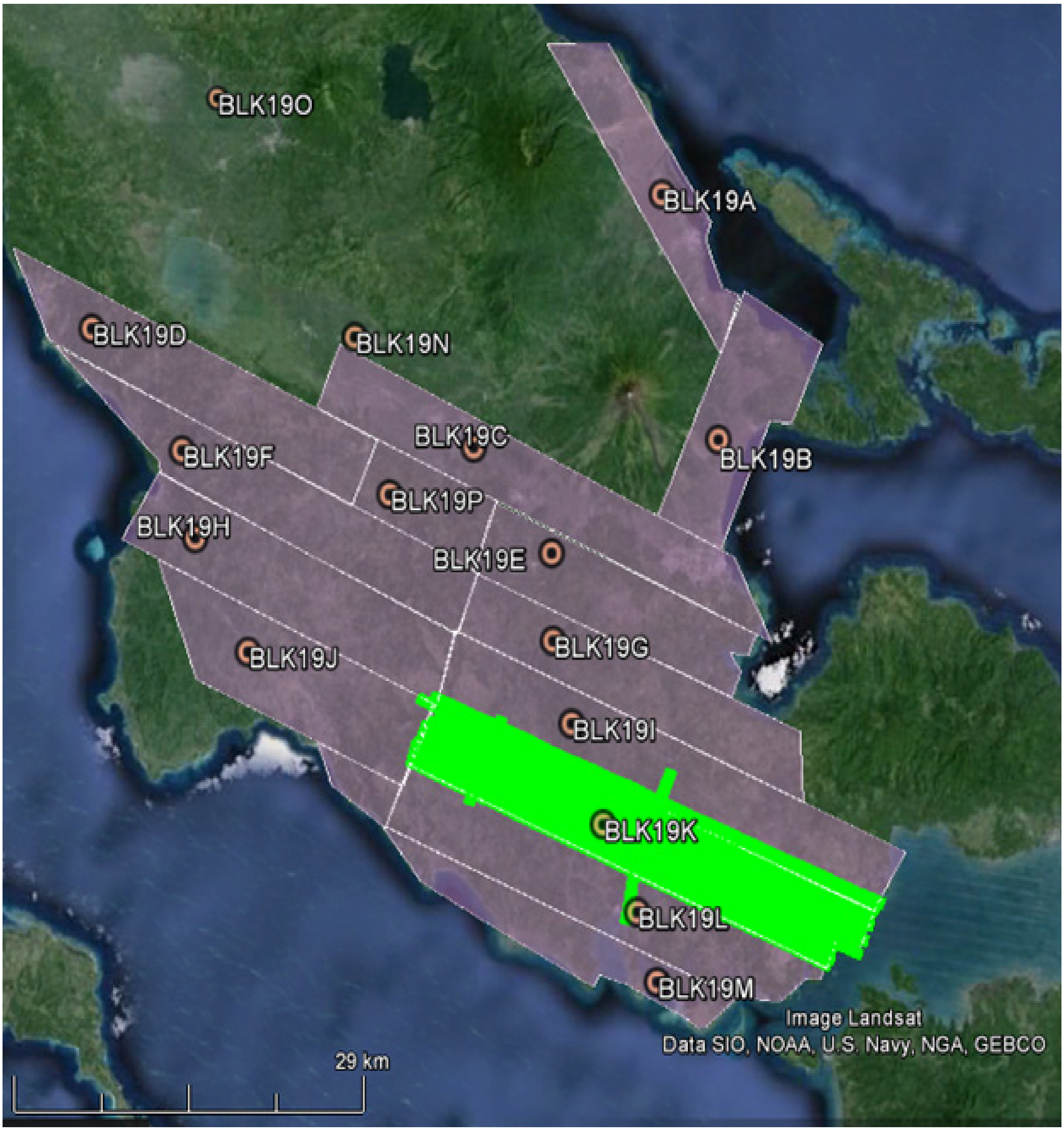


Flight No. : 7160 GC
Area: BLK19I
Mission name: 2BLK19IS090A
Parameters: Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 45 %

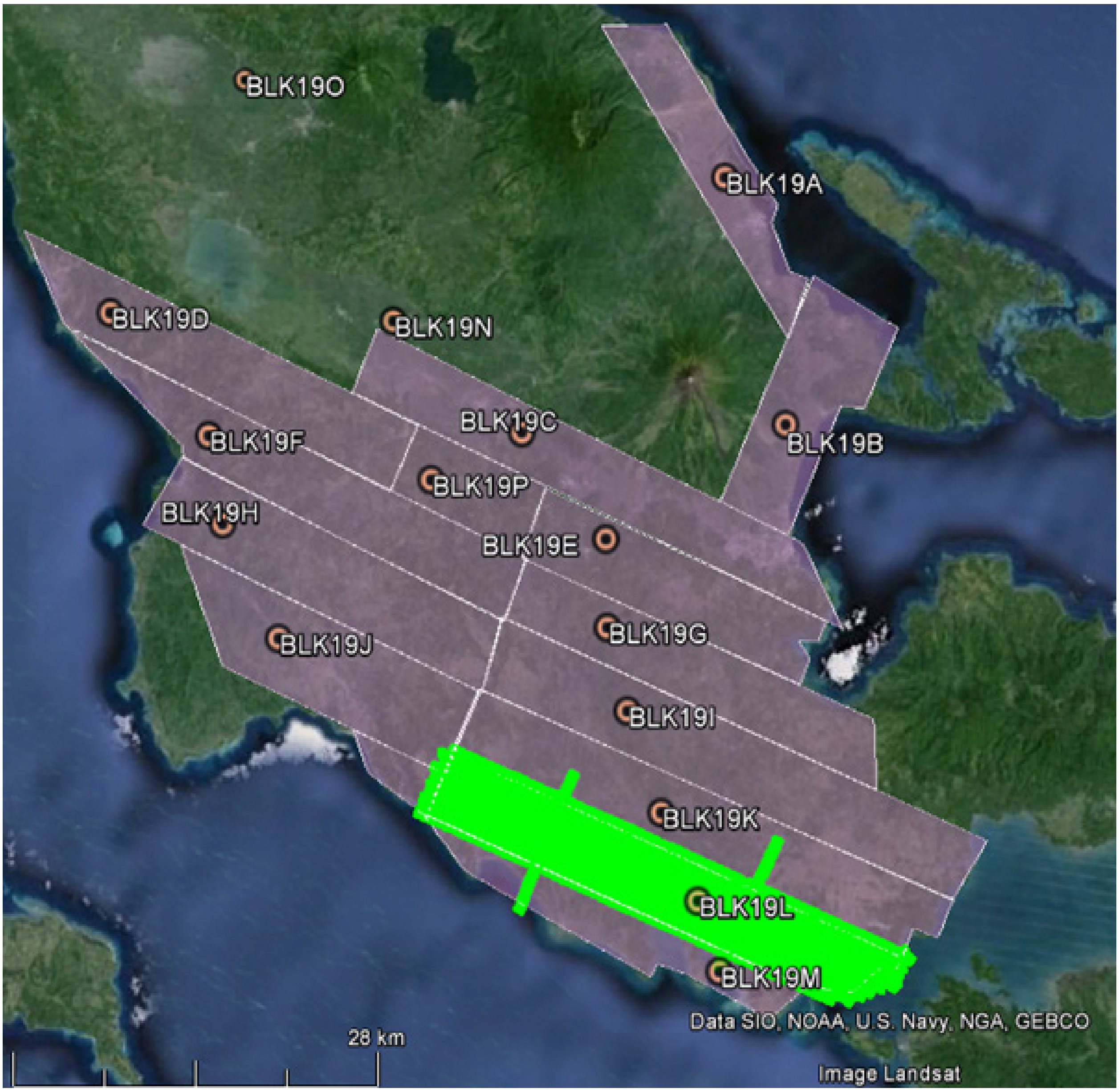


Flight No. :	7161 GC
Area:	BLK19I
Mission name:	2BLK19IS090B
Parameters:	Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 45 %

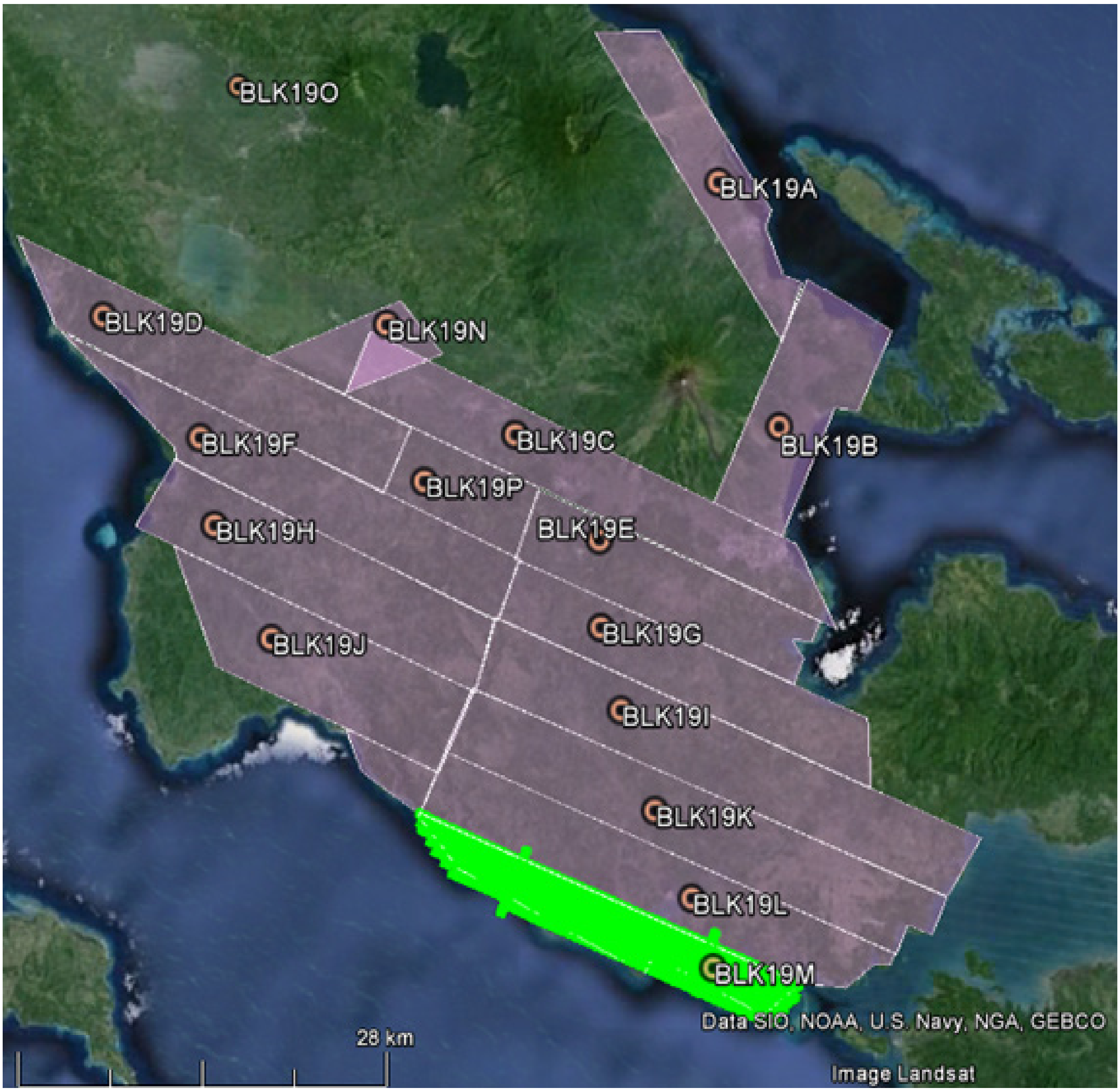
Flight No. :	7167 GC
Area:	BLK19K AND BLK19I
Mission name:	2BLK19K093A & 2BLK19IS093B
Parameters:	Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 40 %



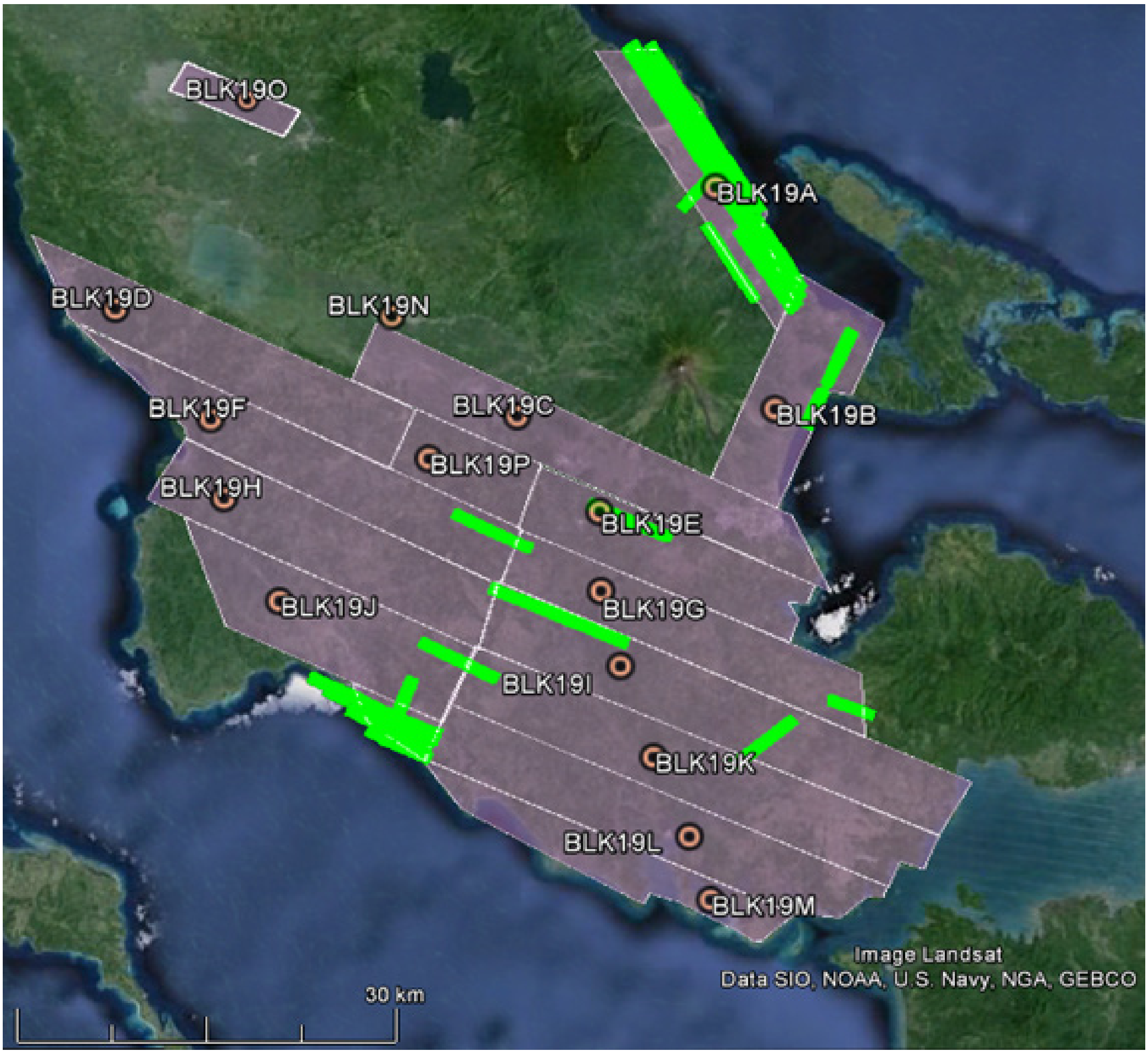
Flight No. :	7168 GC
Area:	BLK19L
Mission name:	BLK19L
Parameters:	Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 40 %



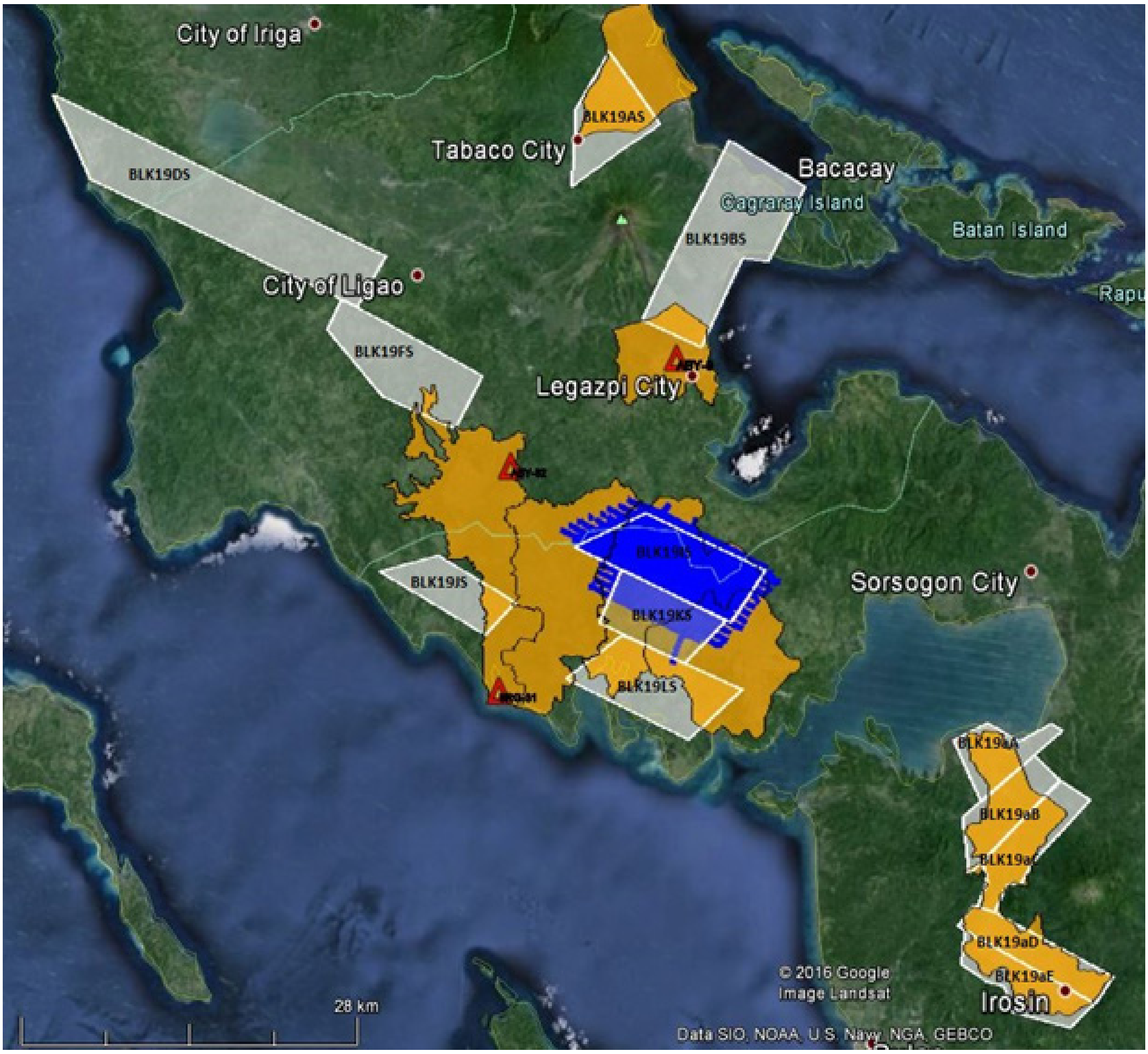
Flight No. : 7171 GC
Area: BLK19M
Mission name: 2BLK19M095A
Parameters: Altitude: 900; Scan Frequency: 50; FOV: 40; Overlap: 20 %



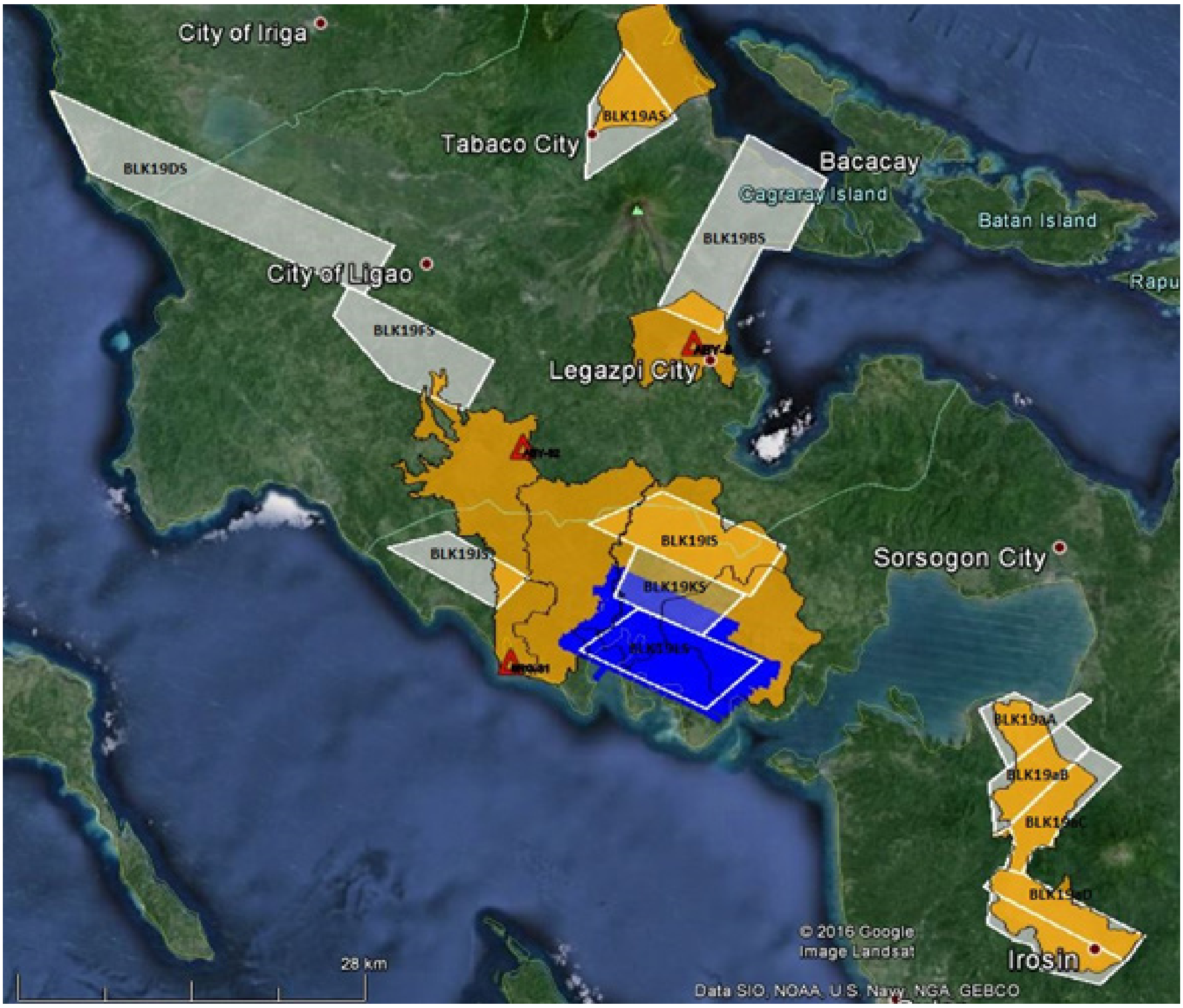
Flight No. : 7216 GC
Area: BLK19A
Mission name: 2BLK19AS118A & VOIDS (BLK19Q)
Parameters: Altitude: 1300; Scan Frequency: 50; FOV: 34 and 40; Overlap: 50 %



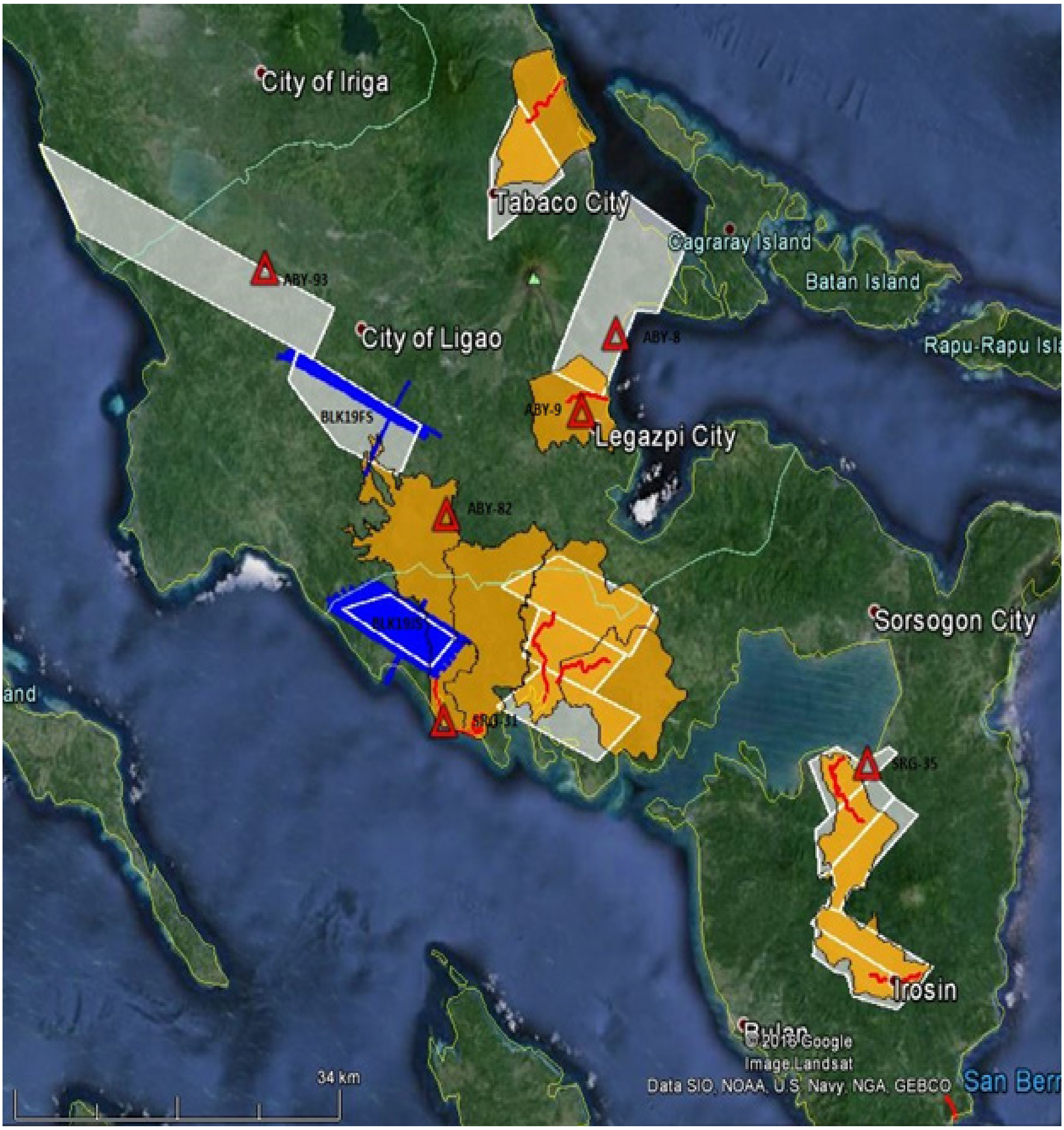
Flight No. : 3813G
Area: BLK19IS, BLK19KS
Mission Name: 2BLK19IS056B
Parameters: Altitude: 650; Scan Frequency: 40; FOV: 50; Overlap: 40 %



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



Flight No. : 3825G
Area: BLK19JS, BLK19FS
Mission Name: 2BLK19JFS059B
Parameters: Altitude: 650; Scan Frequency: 40; FOV: 50; Overlap: 40 %



Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report of Mission Blk19I

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

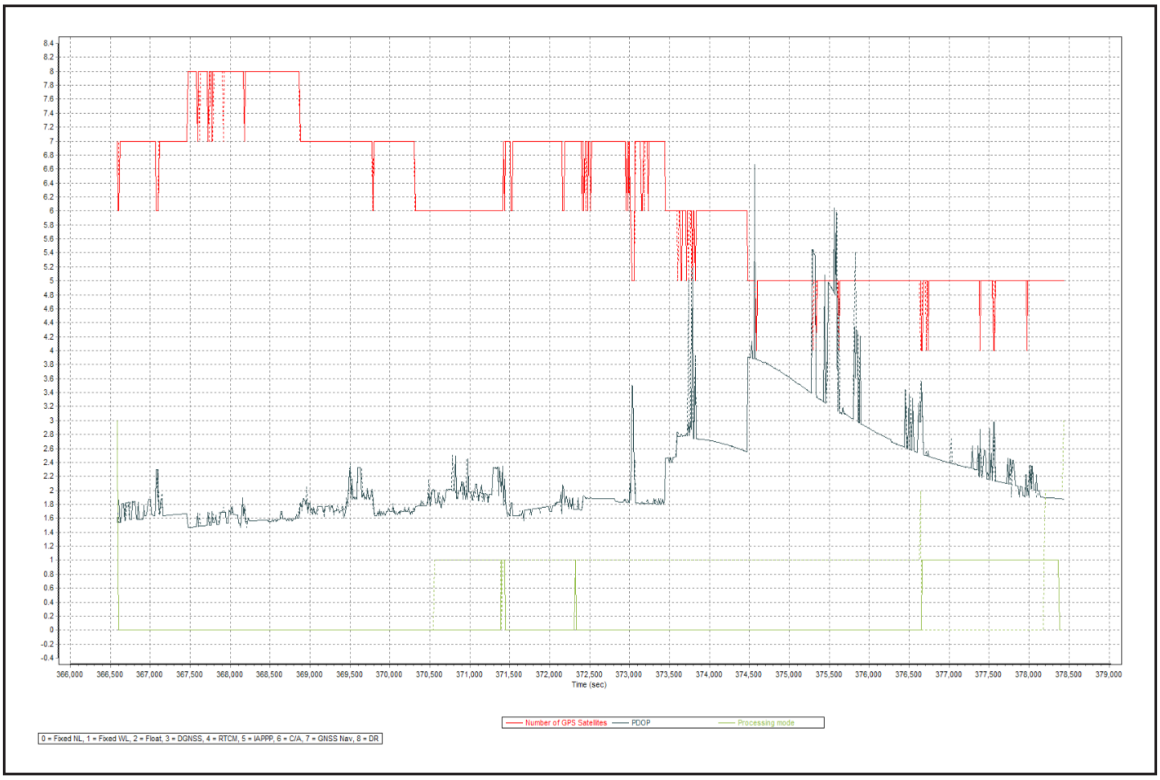


Figure 1.1.1 Solution Status

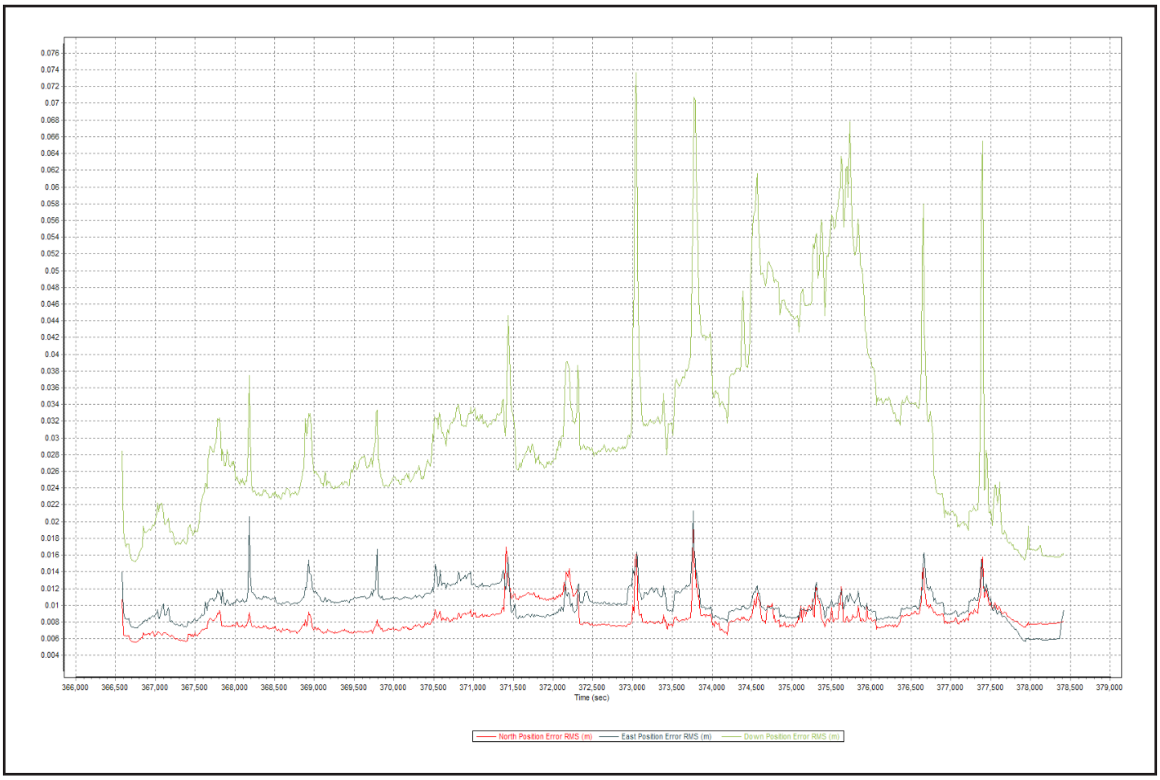


Figure 1.1.2 Smoothed Performance Metric Parameters

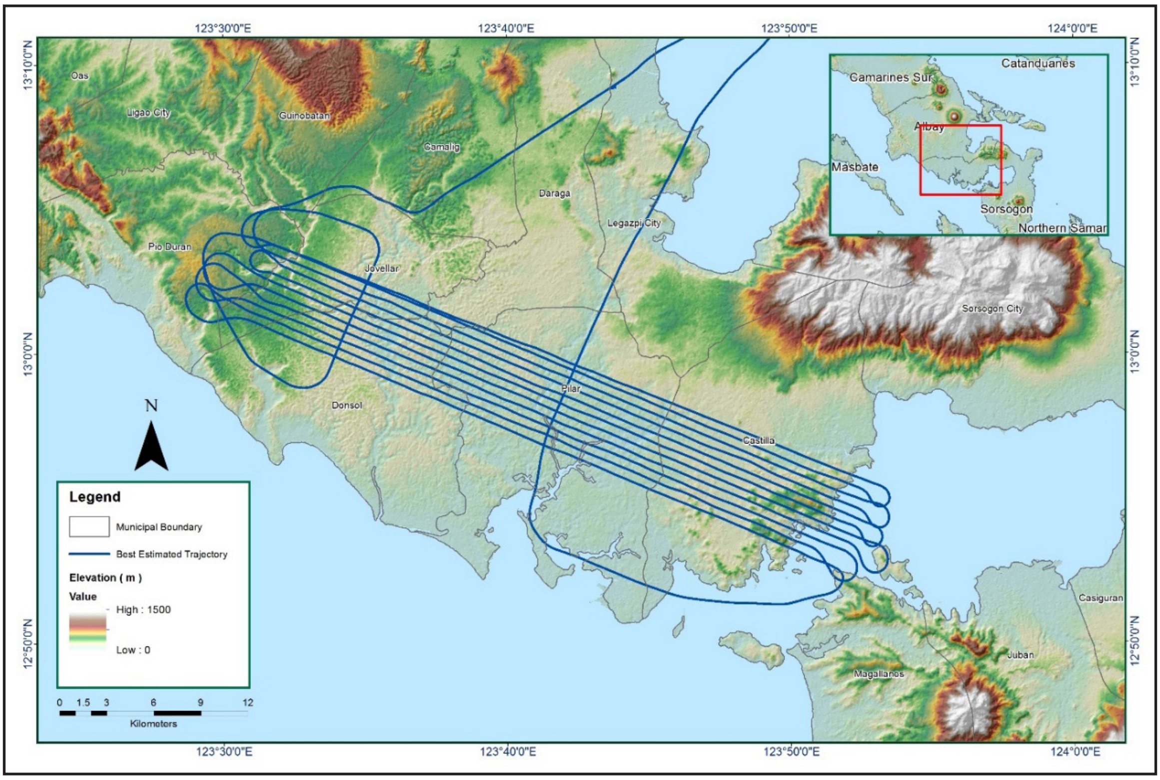


Figure 1.1.3 Best Estimated Trajectory

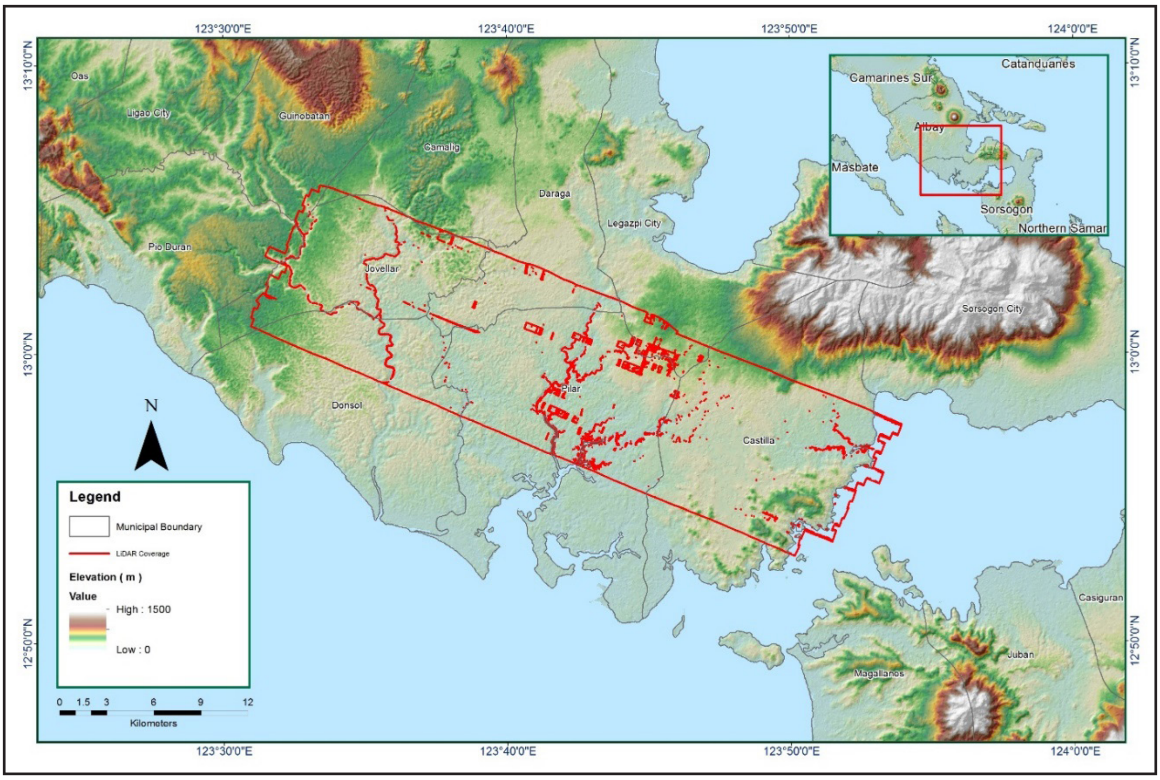


Figure 1.1.4 Coverage of LiDAR data

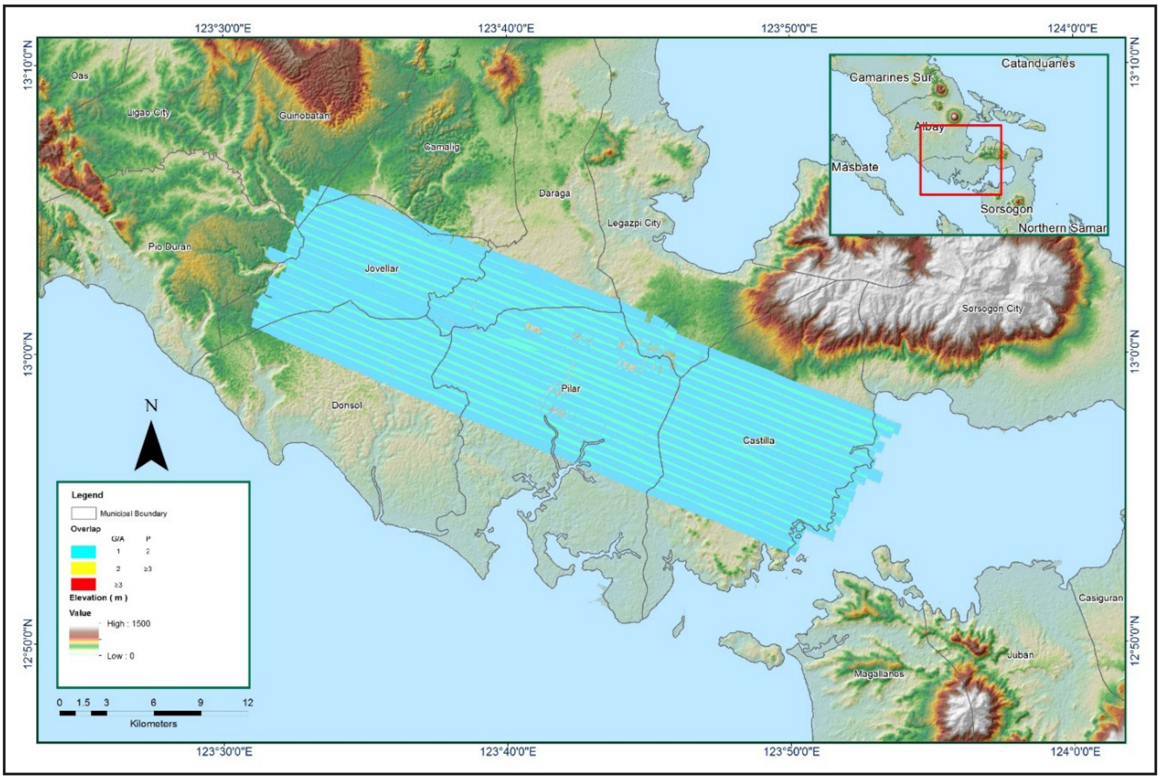


Figure 1.1.5 Image of Data Overlap

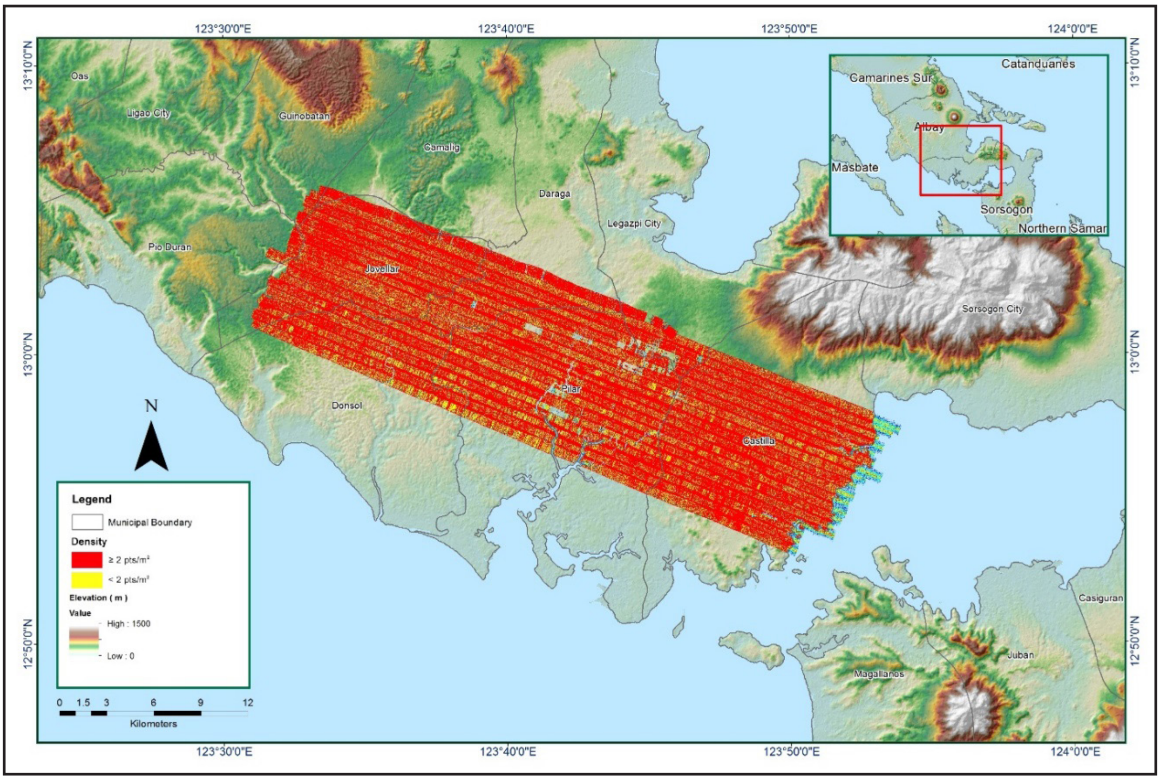


Figure 1.1.6 Density Map

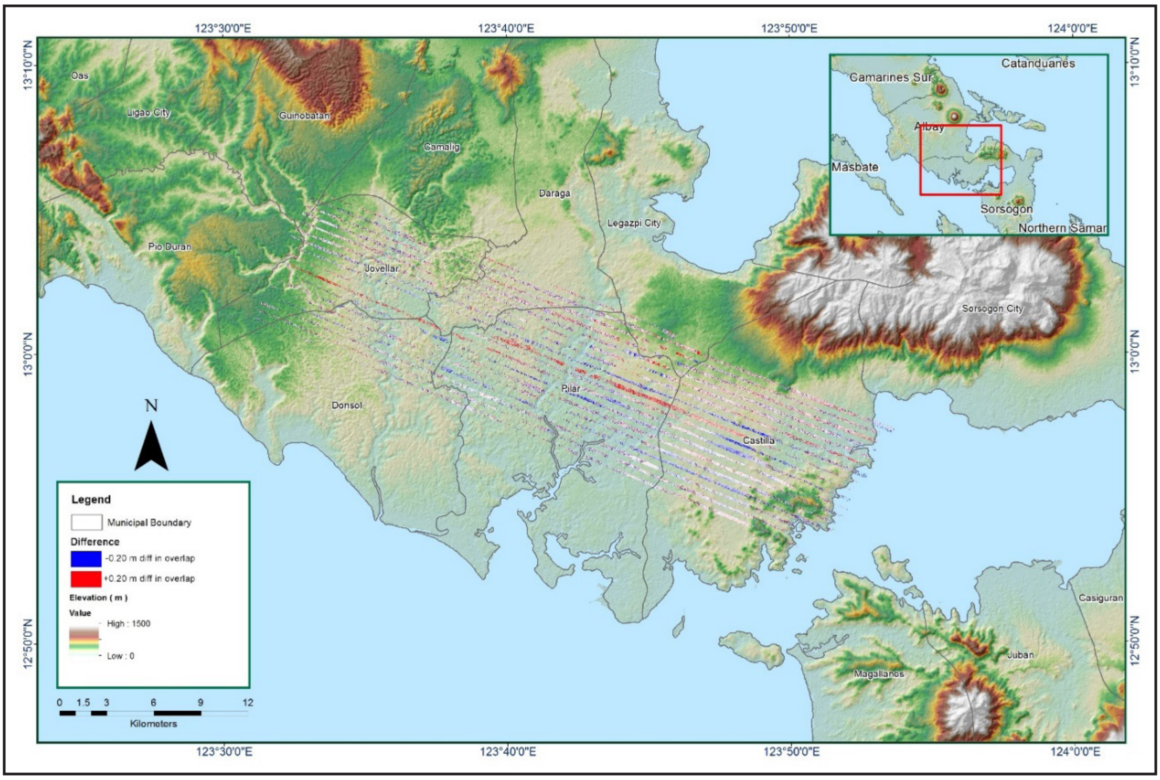


Figure 1.1.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report of Mission Blk19EG

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19EG**
Inclusive Flights	7156GC, 7158GC, 7216GC
Range data size	46.75 GB
POS	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

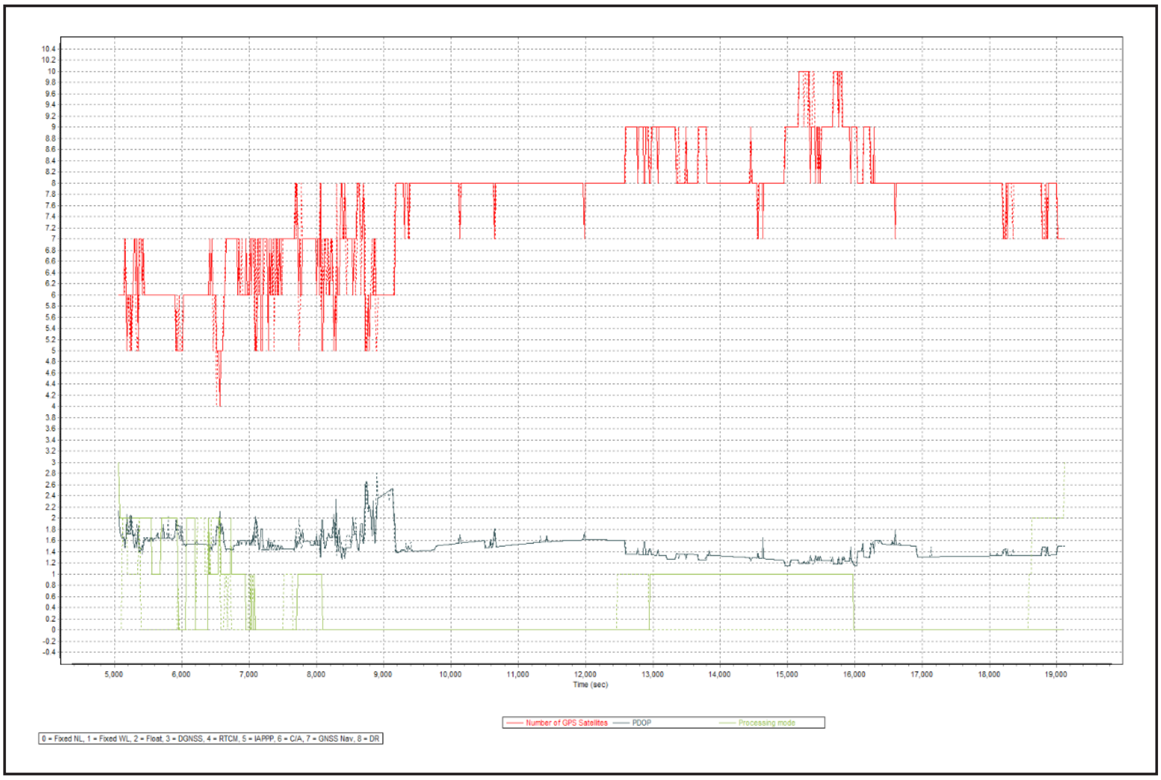


Figure 1.2.1 Solution Status

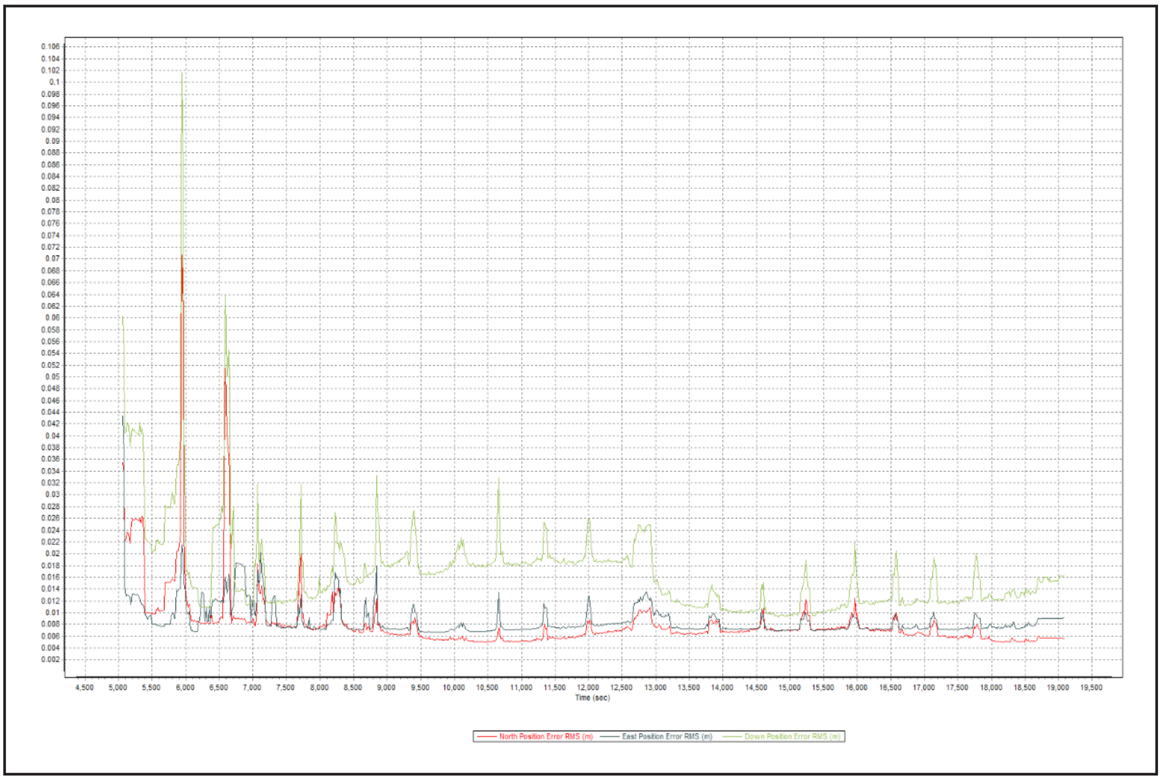


Figure 1.2.2 Smoothed Performance Metric Parameters

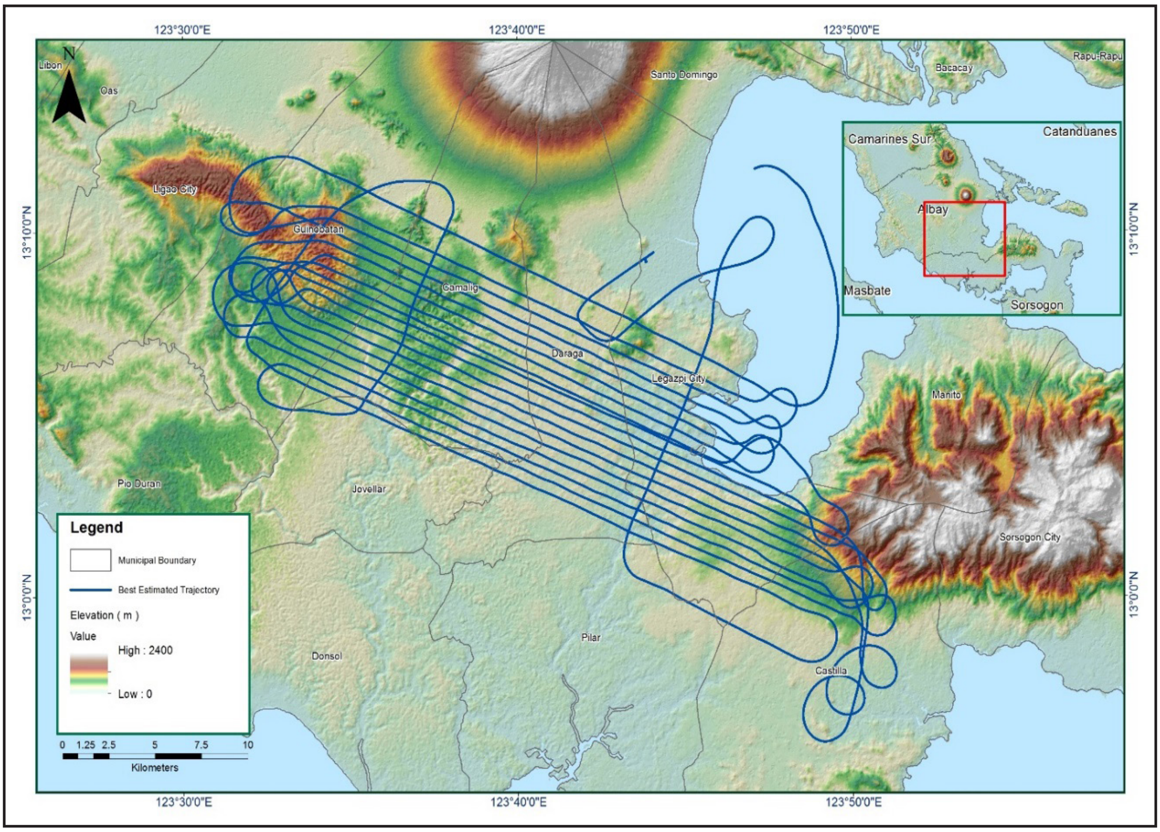


Figure 1.2.3 Best Estimated Trajectory

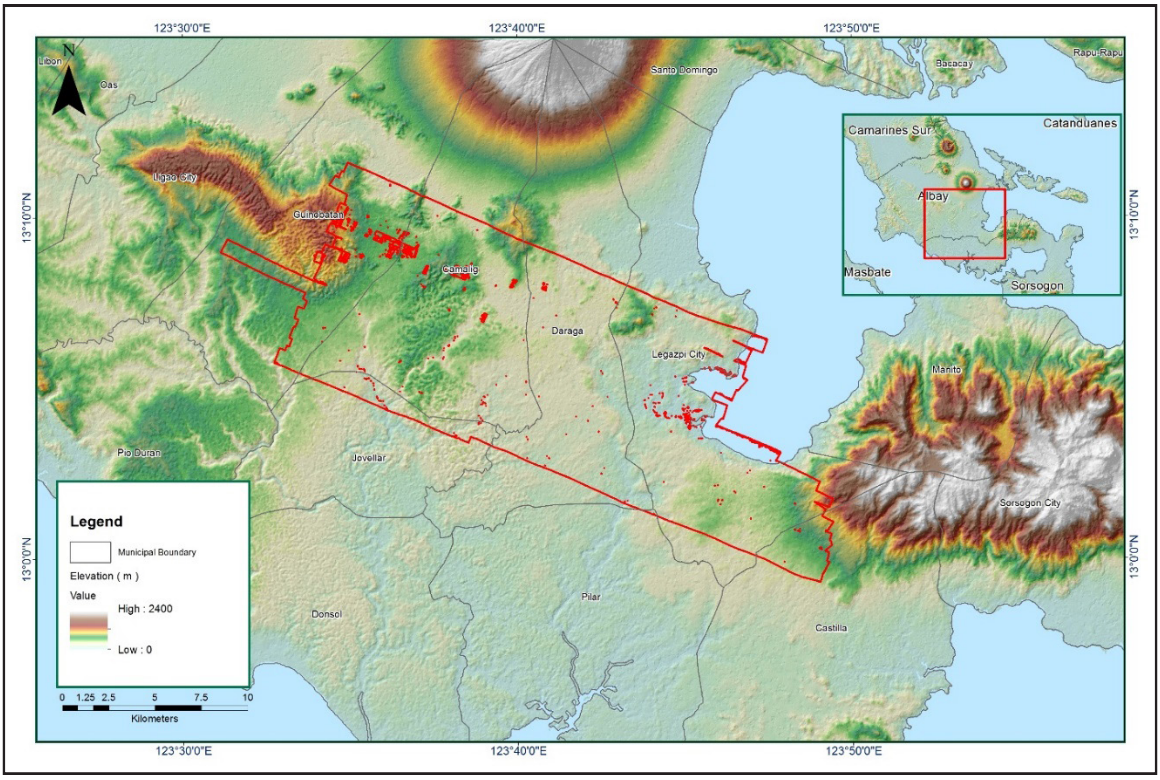


Figure 1.2.4 Coverage of LiDAR data

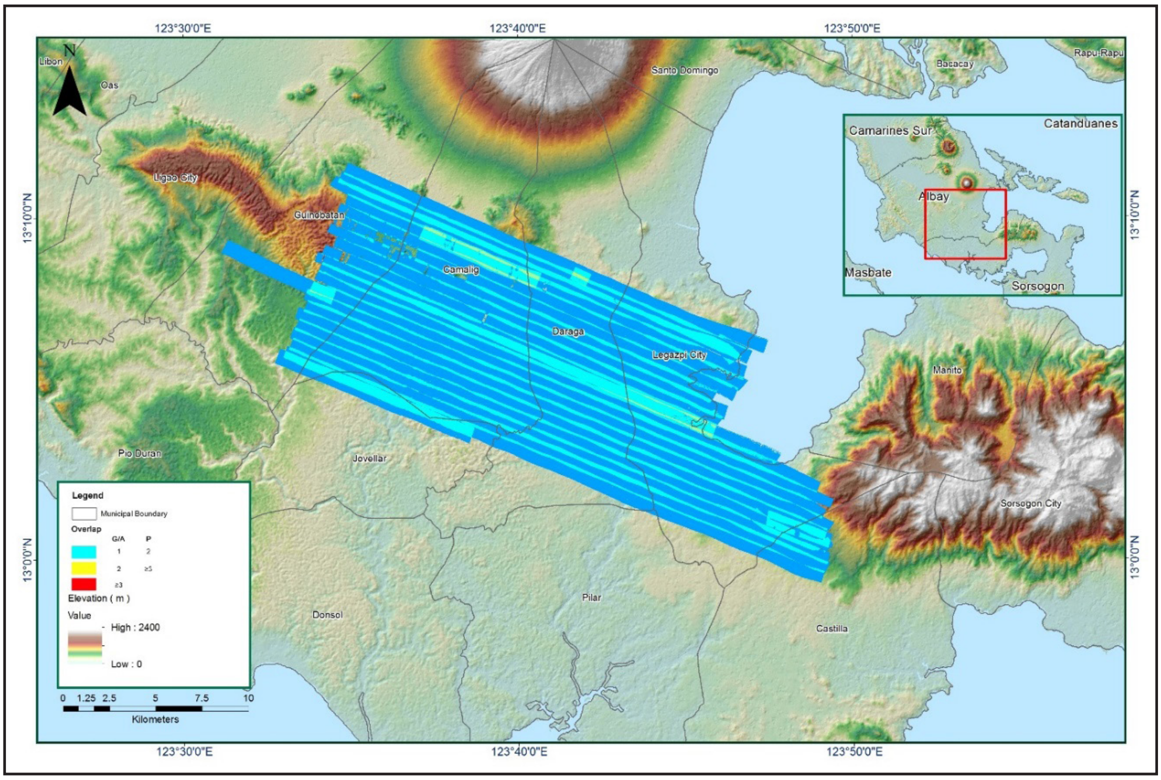


Figure 1.2.5 Image of Data Overlap

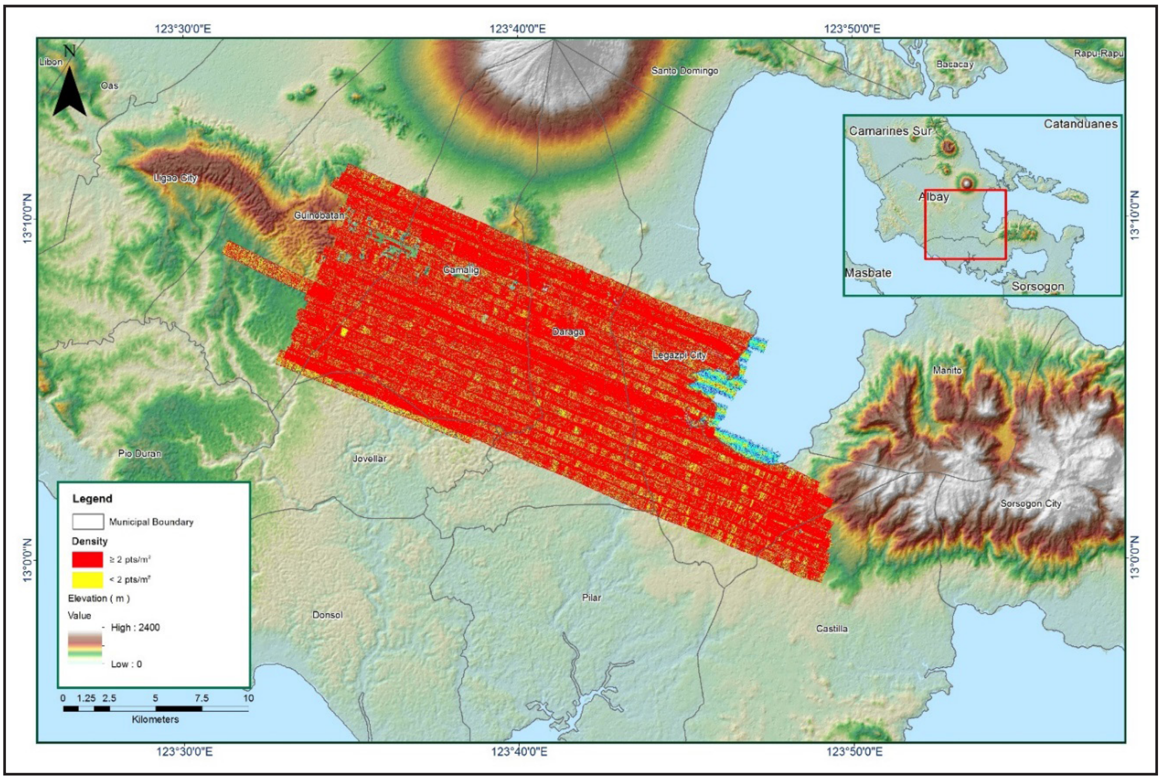


Figure 1.2.6 Density Map

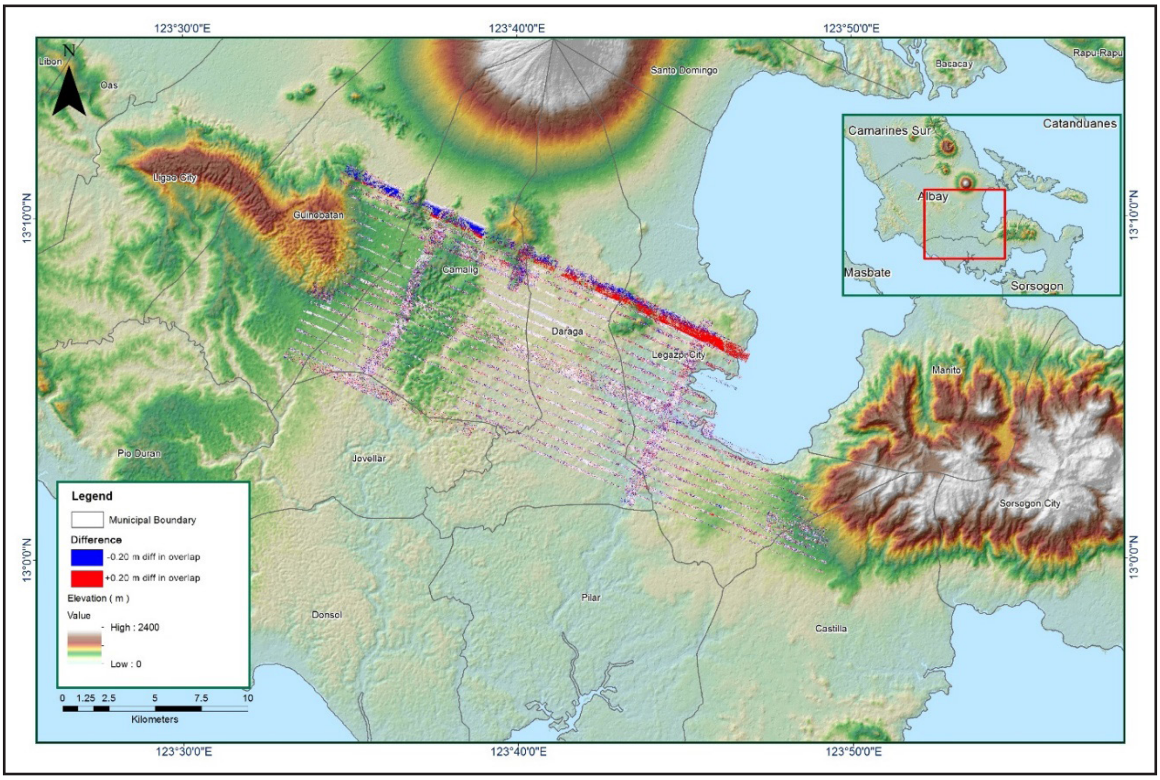


Figure 1.2.7 Elevation difference between flight lines

Table A-8.3 Mission Summary Report of Mission Blk19M

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19M**
Inclusive Flights	7171GC
Range data size	14.5 GB
POS	166 MB
Base data size	11.6 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)	5.2
RMSE for East Position (<4.0 cm)	4.4
RMSE for Down Position (<8.0 cm)	22.5
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000456
GPS position stdev (<0.01m)	0.0067
Minimum % overlap (>25)	15.07 %
Ave point cloud density per sq.m. (>2.0)	2.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	165
Maximum Height	179.86
Minimum Height	52.66
Classification (# of points)	
Ground	40578668
Low vegetation	35563429
Medium vegetation	48648596
High vegetation	105602789
Building	2349495
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. Krisha Marie Bautista

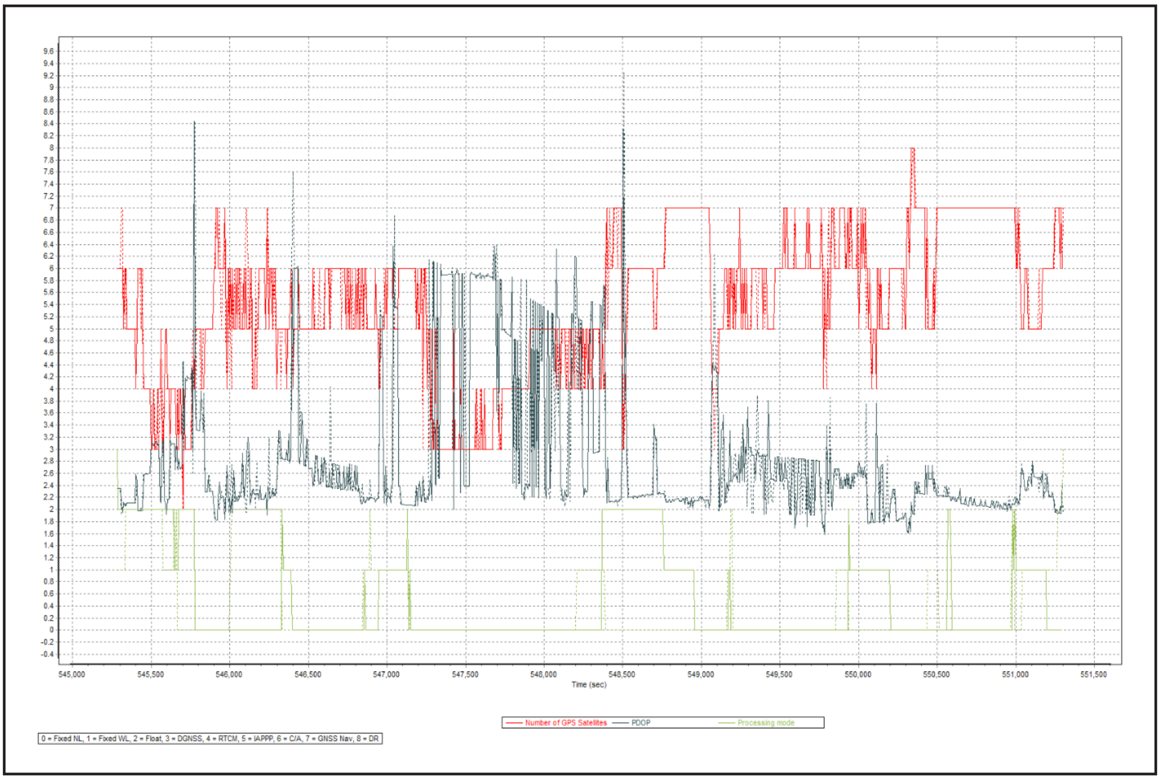


Figure 1.3.1 Solution Status

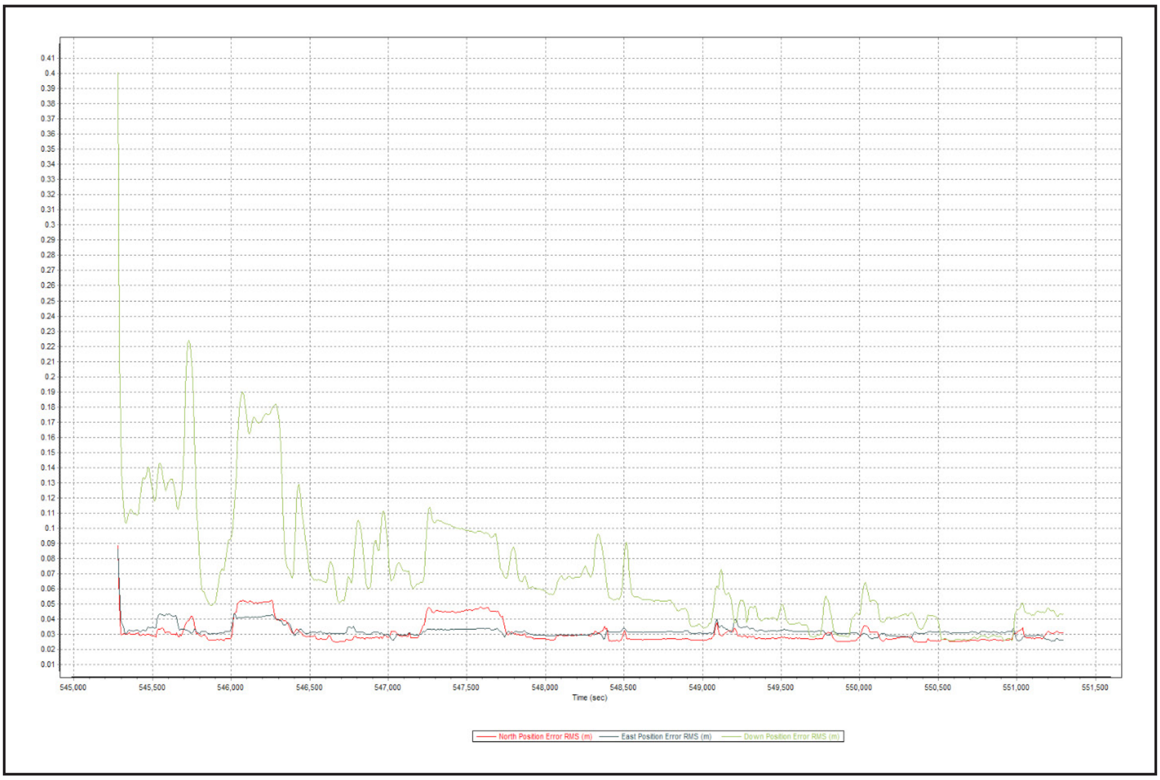


Figure 1.3.2 Smoothed Performance Metric Parameters

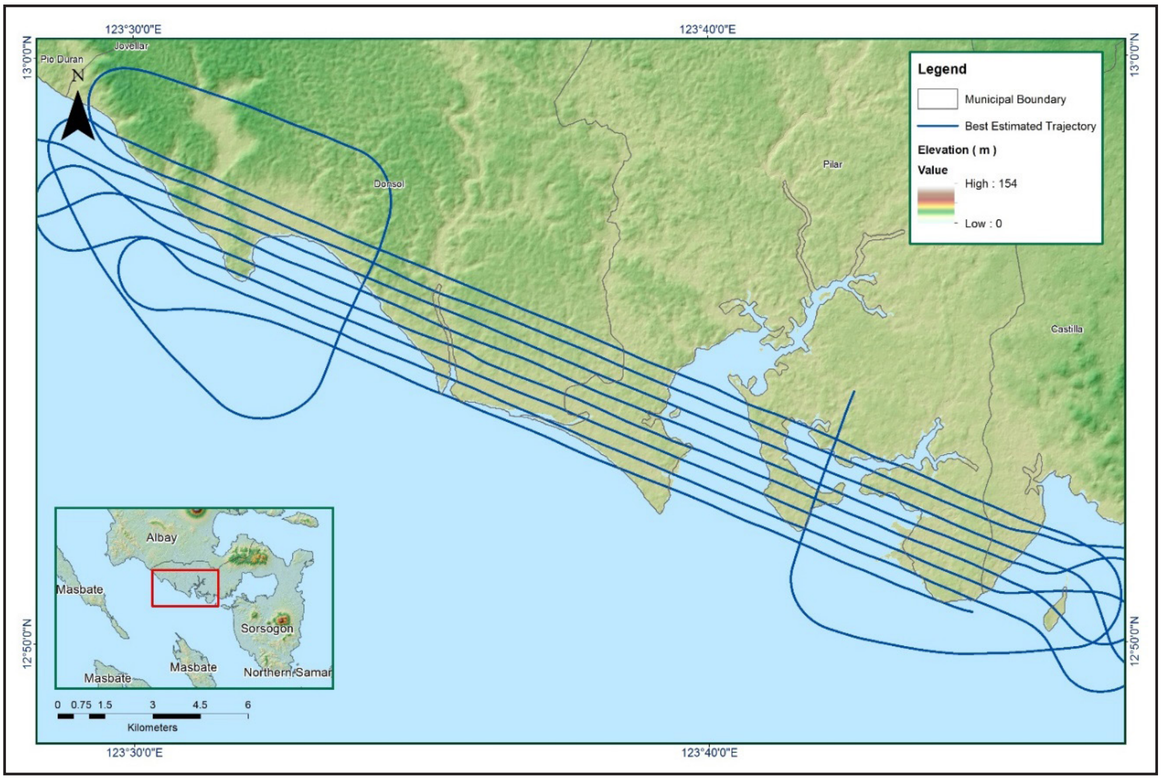


Figure 1.3.3 Best Estimated Trajectory

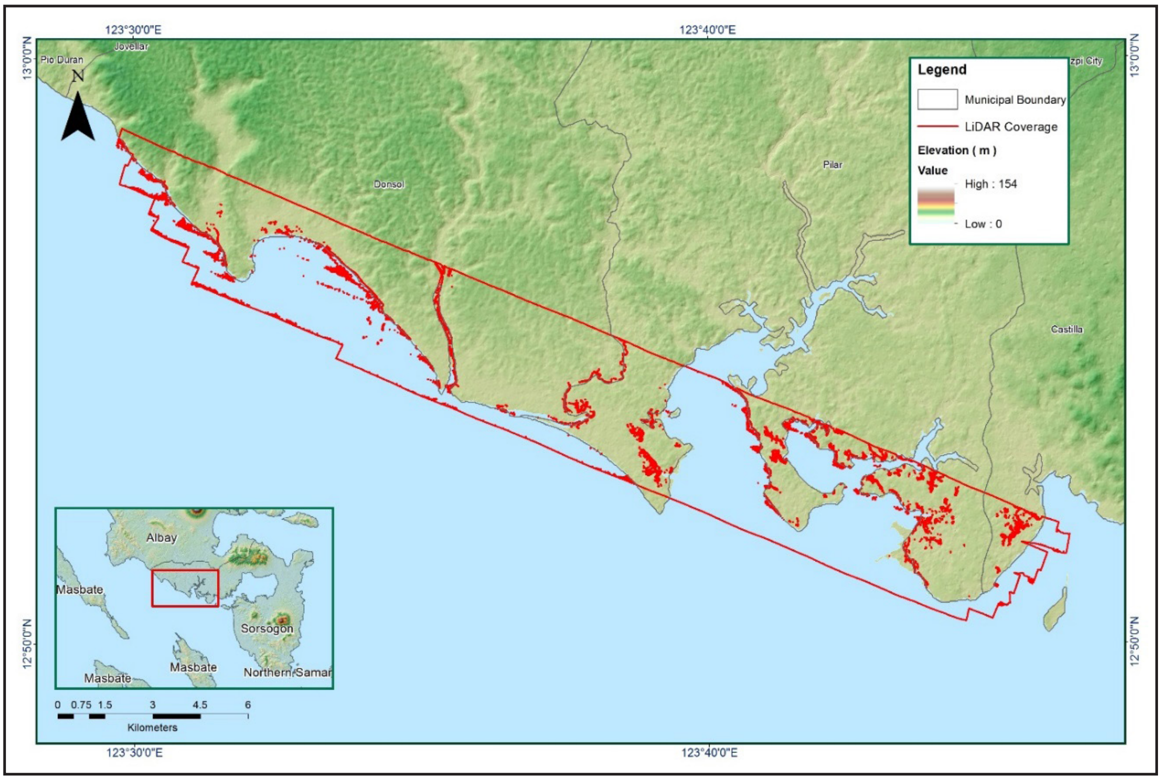


Figure 1.3.4 Coverage of LiDAR data

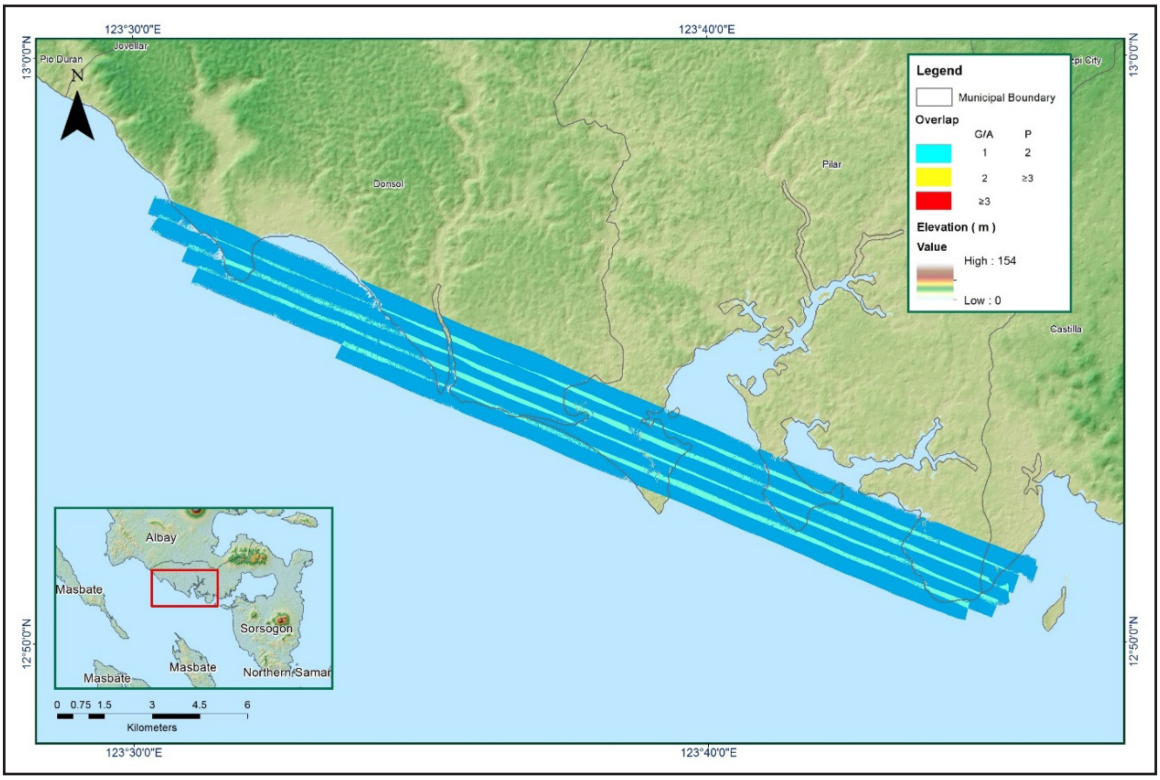


Figure 1.3.5 Image of Data Overlap

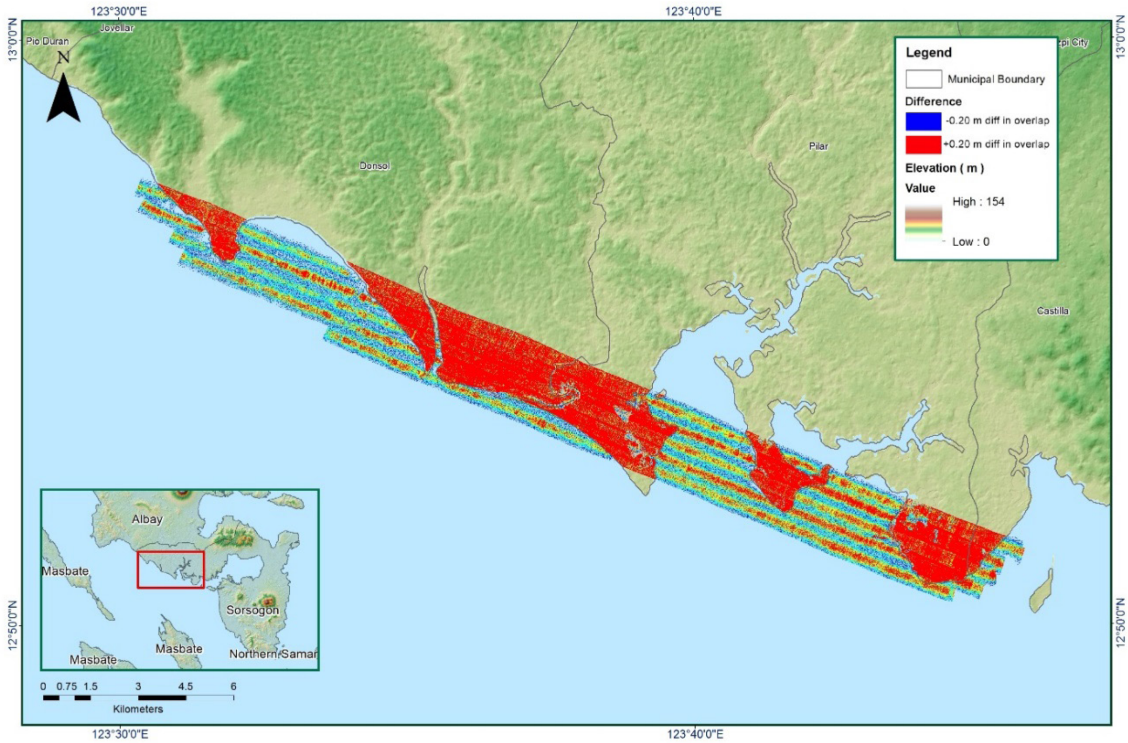


Figure 1.3.6 Density Map

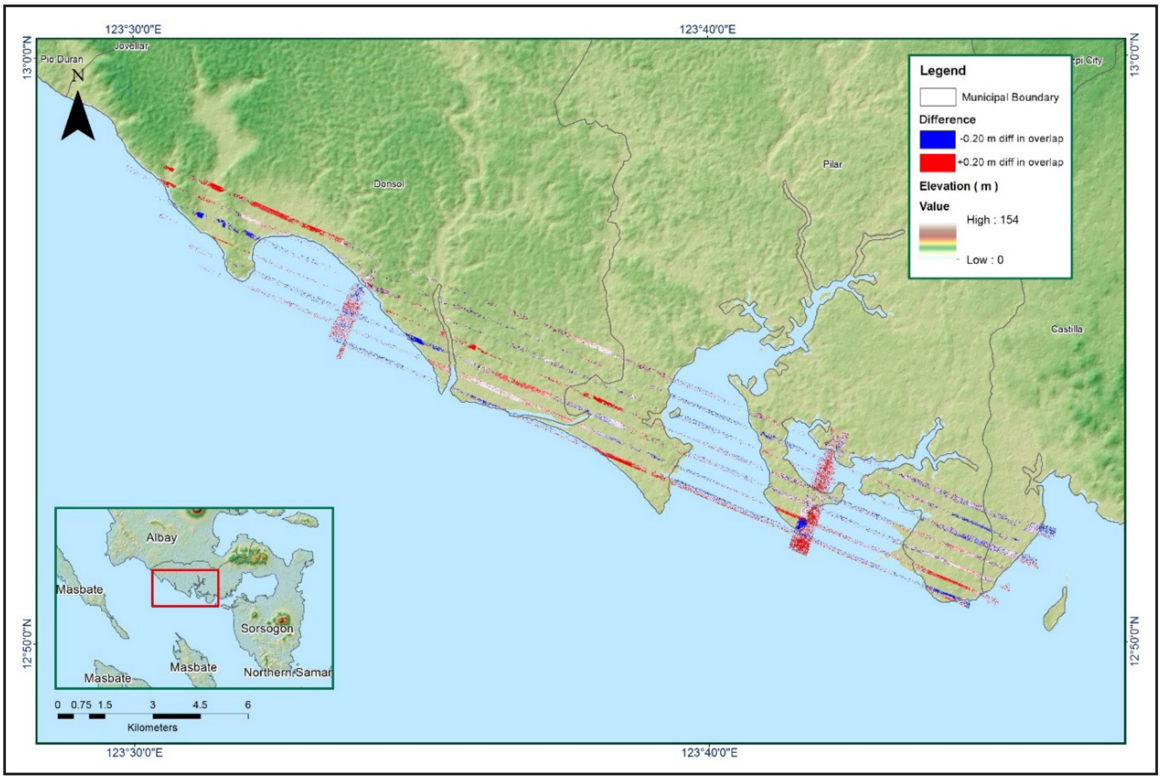


Figure 1.3.7 Elevation difference between flight lines

Table A-8.4 Mission Summary Report of Mission Blk19M_Additional

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19M_Additional**
Inclusive Flights	7171GC
Range data size	14.5 GB
POS	166 MB
Base data size	11.6 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)	5.2
RMSE for East Position (<4.0 cm)	4.4
RMSE for Down Position (<8.0 cm)	22.5
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000456
GPS position stdev (<0.01m)	0.0067
Minimum % overlap (>25)	13.70 %
Ave point cloud density per sq.m. (>2.0)	2.93
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	95
Maximum Height	179.81
Minimum Height	54.08
Classification (# of points)	
Ground	15934374
Low vegetation	13968667
Medium vegetation	20218656
High vegetation	68566425
Building	1117461
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Alex John Escobido

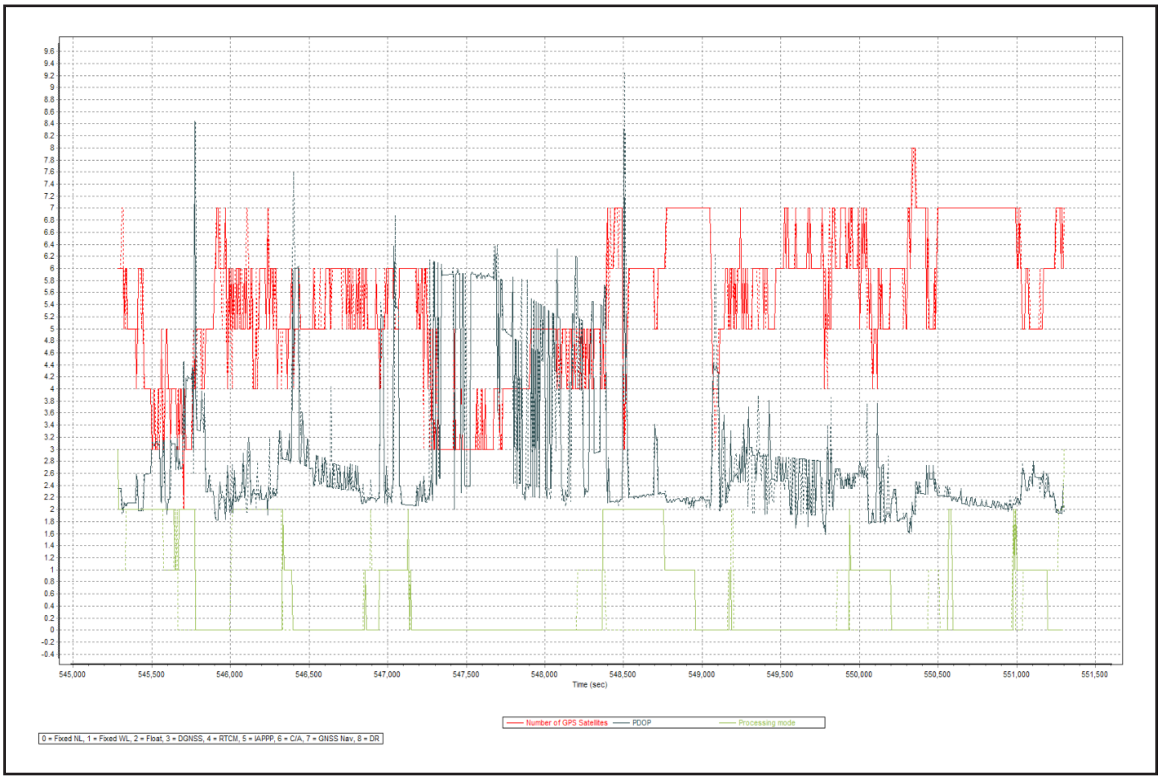


Figure 1.4.1 Solution Status

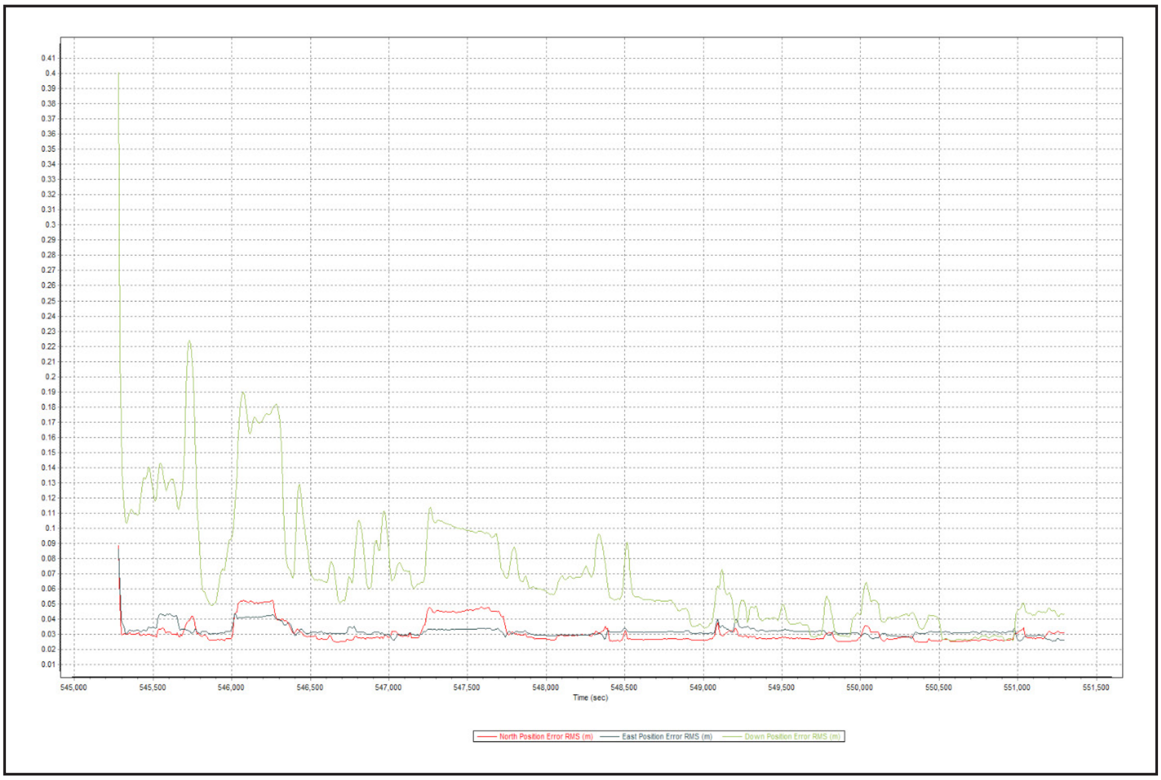


Figure 1.4.2 Smoothed Performance Metric Parameters

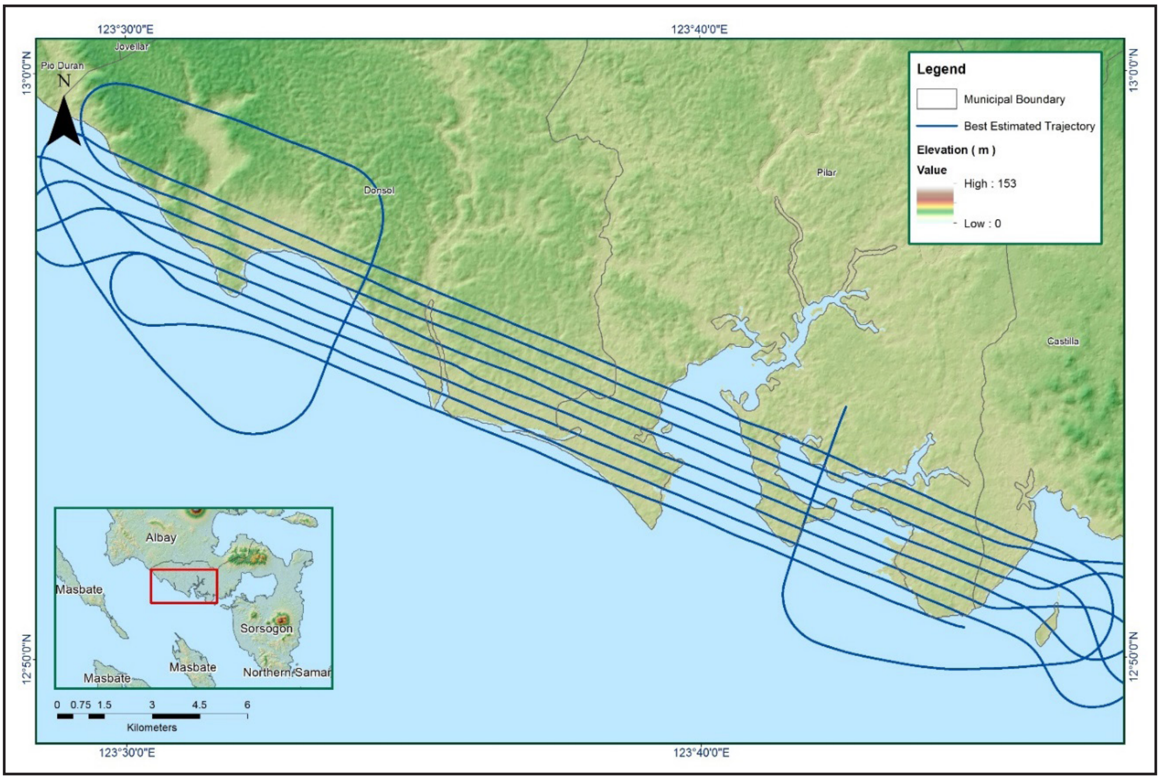


Figure 1.4.3 Best Estimated Trajectory

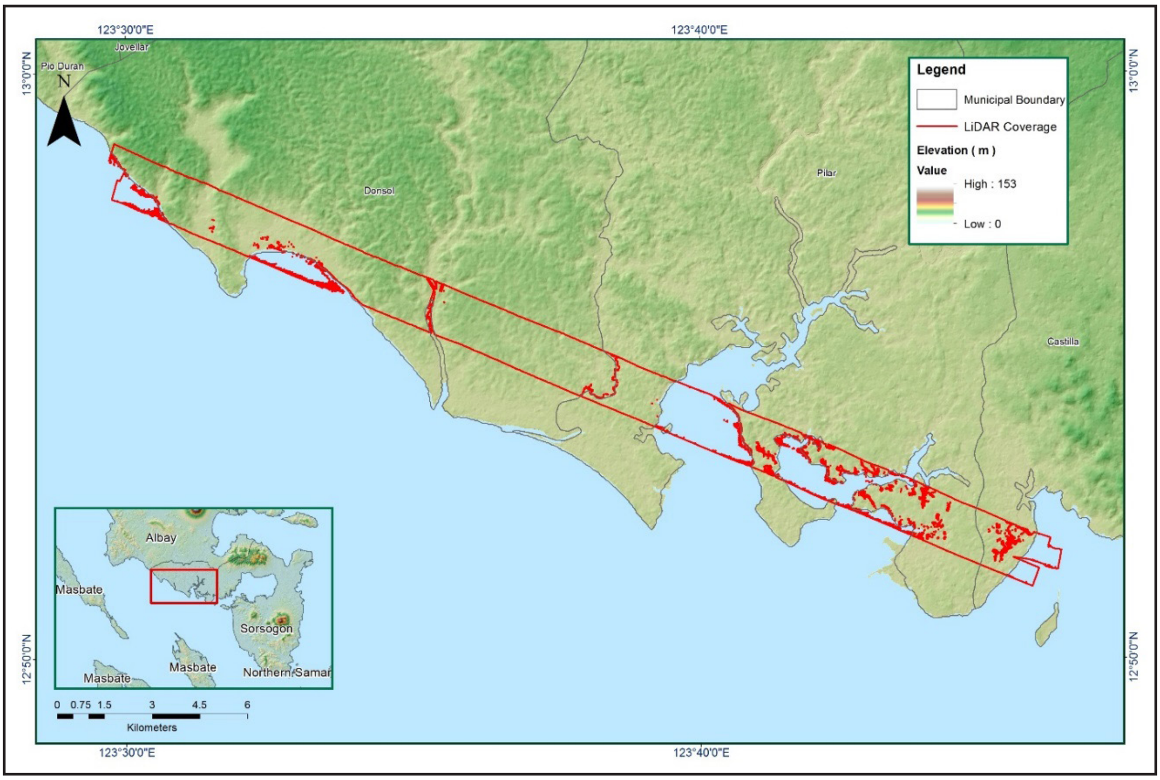


Figure 1.4.4 Coverage of LiDAR data

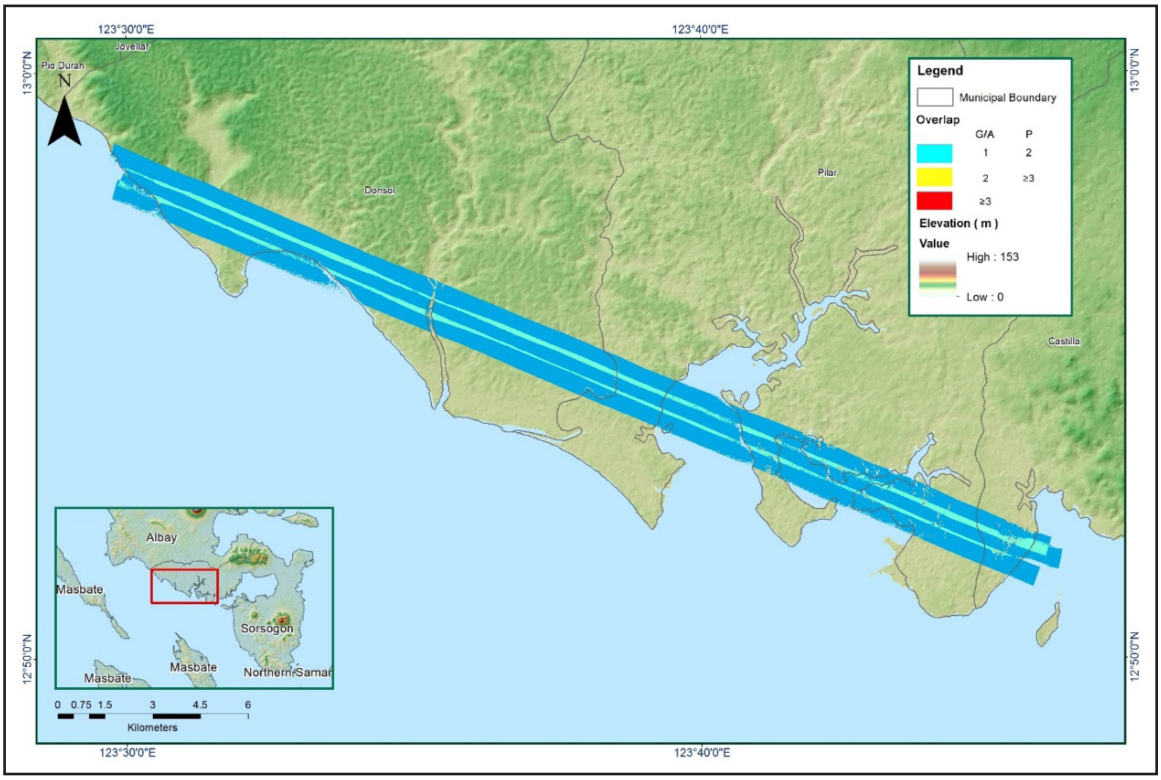


Figure 1.4.5 Image of Data Overlap

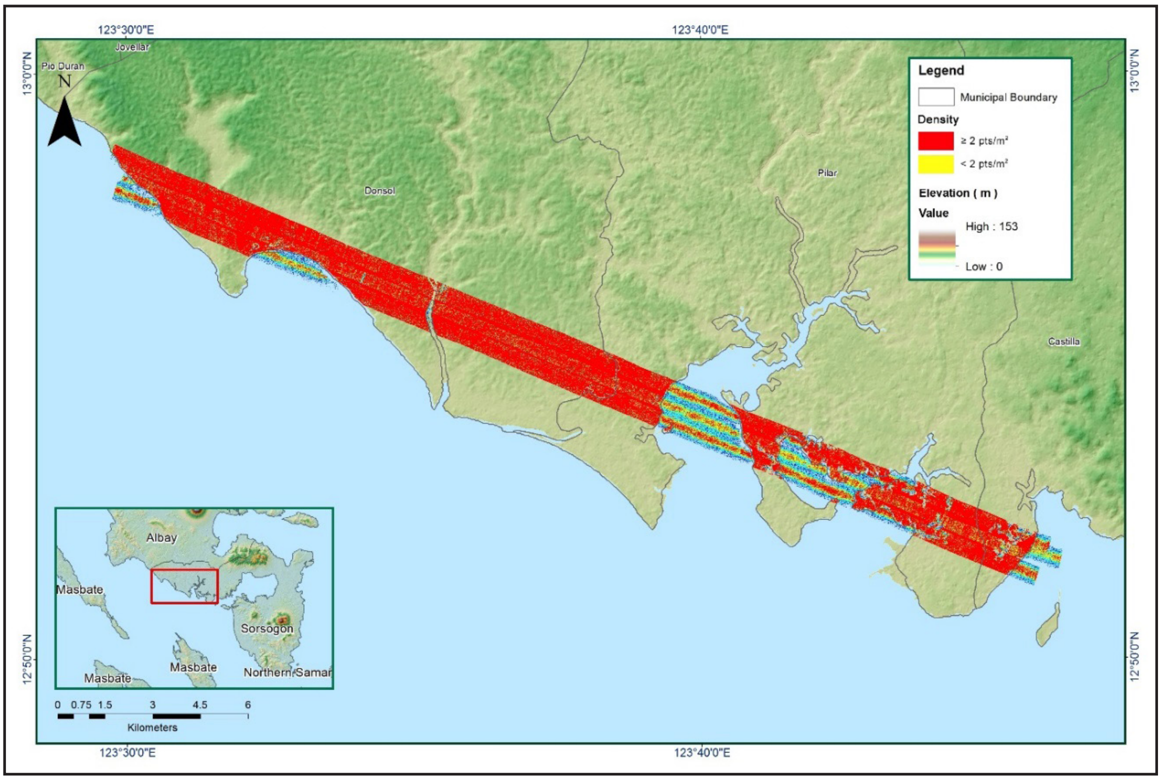


Figure 1.4.6 Density Map

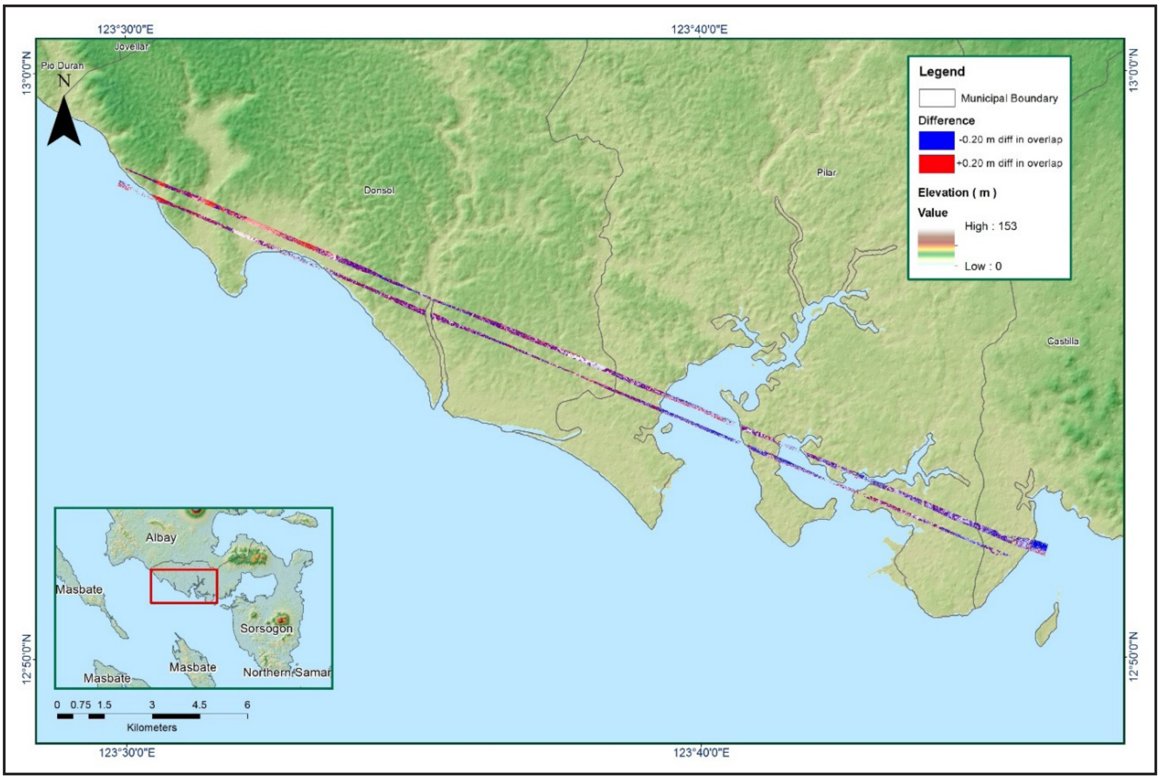


Figure 1.4.7 Elevation difference between flight lines

Table A-8.5 Mission Summary Report of Mission Blk19L

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19L**
Inclusive Flights	7168GC
Range data size	22.4 GB
POS	193 MB
Base data size	10.9 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)	7.7
RMSE for East Position (<4.0 cm)	10.6
RMSE for Down Position (<8.0 cm)	17.5
Boresight correction stdev (<0.001deg)	0.000200
IMU attitude correction stdev (<0.001deg)	0.001959
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	21.81 %
Ave point cloud density per sq.m. (>2.0)	2.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	265
Maximum Height	238.97
Minimum Height	52.76
Classification (# of points)	
Ground	58020284
Low vegetation	46865776
Medium vegetation	84917293
High vegetation	266182218
Building	2788874
`Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Antonio Chua, Jr., Ailyn Biñas

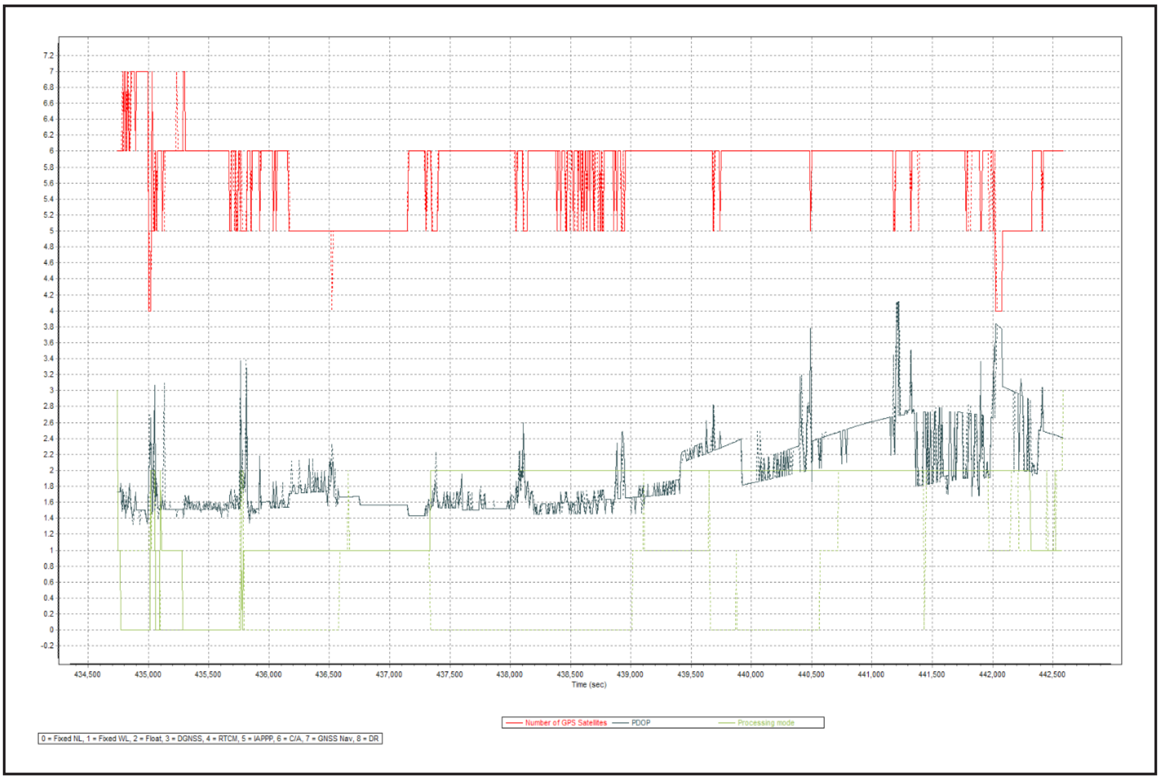


Figure 1.5.1 Solution Status

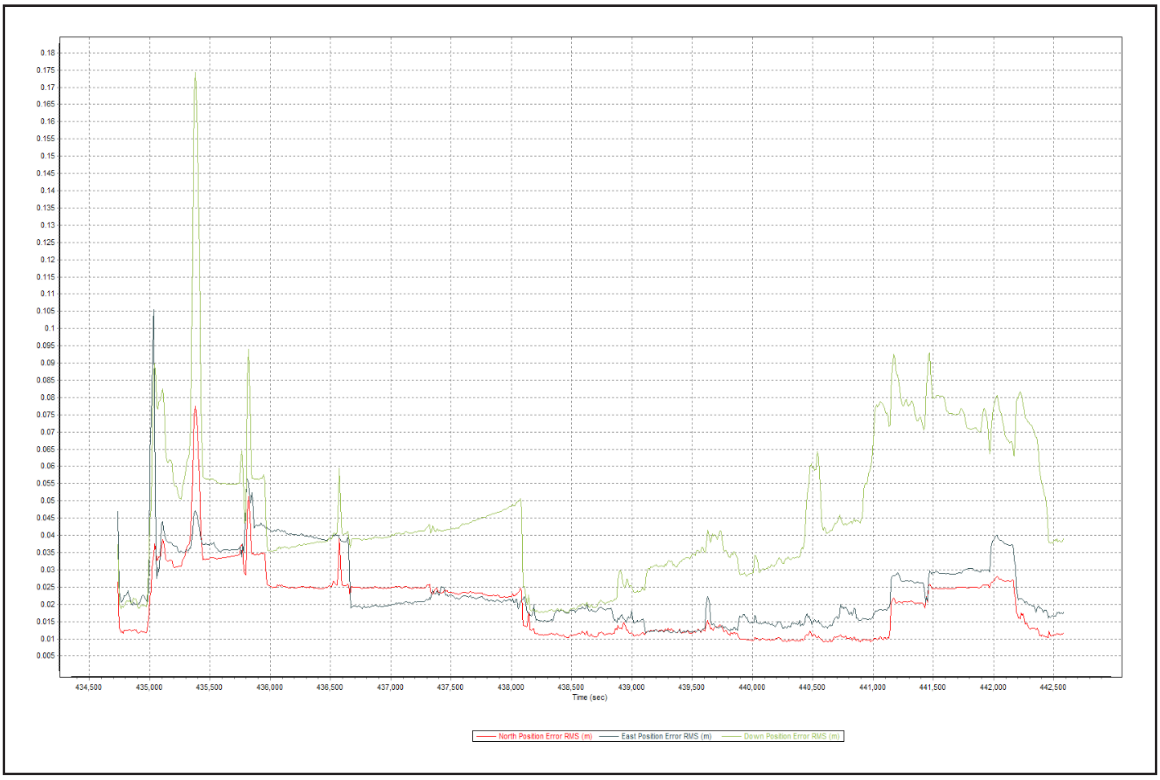


Figure 1.5.2 Smoothed Performance Metric Parameters

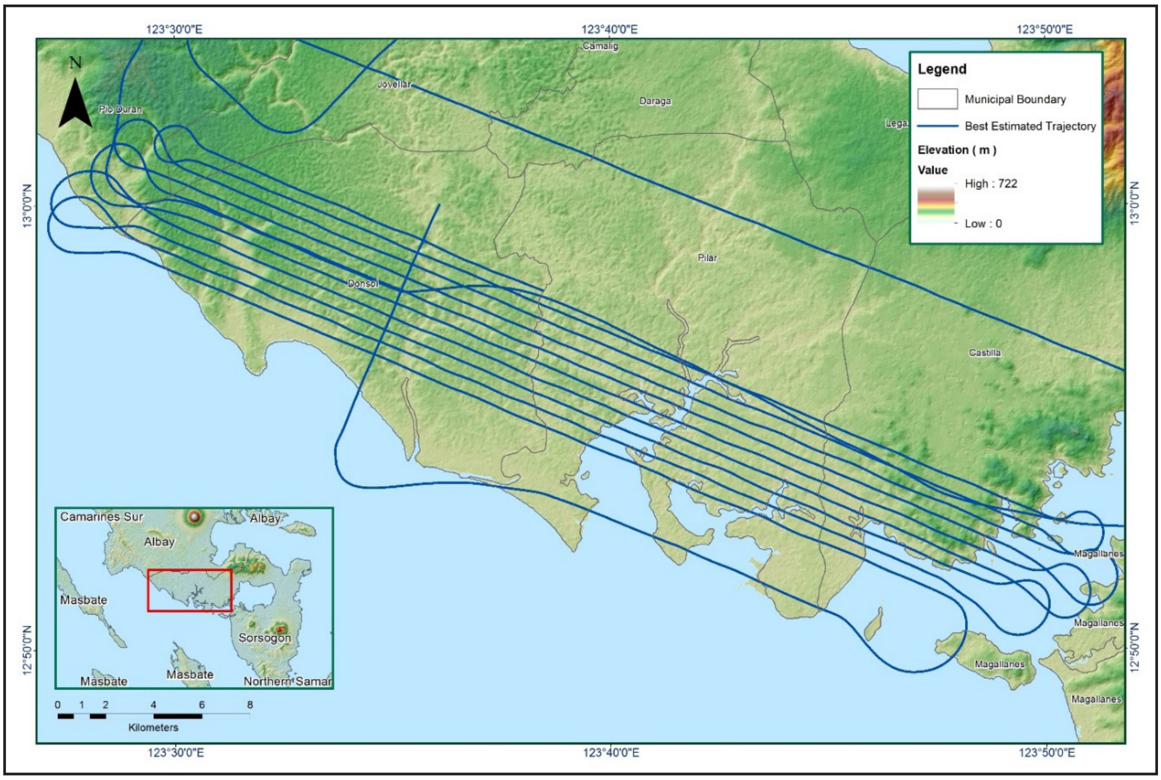


Figure 1.5.3 Best Estimated Trajectory

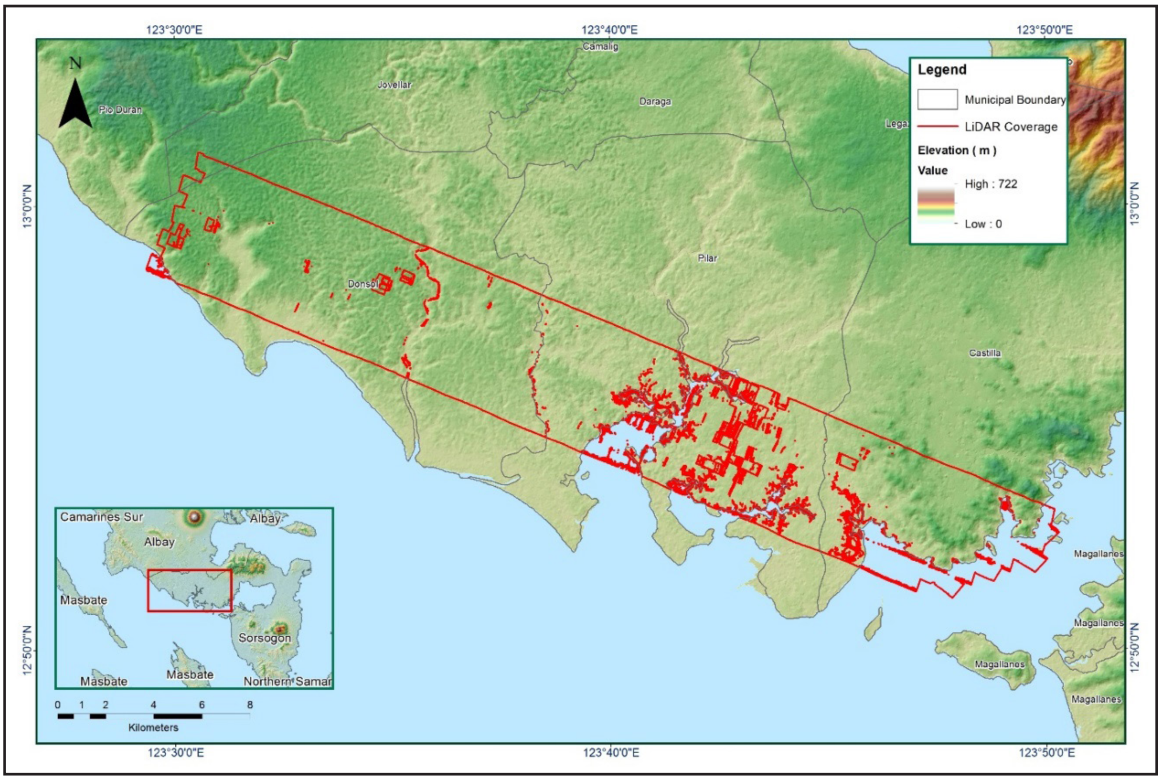


Figure 1.5.4 Coverage of LiDAR data

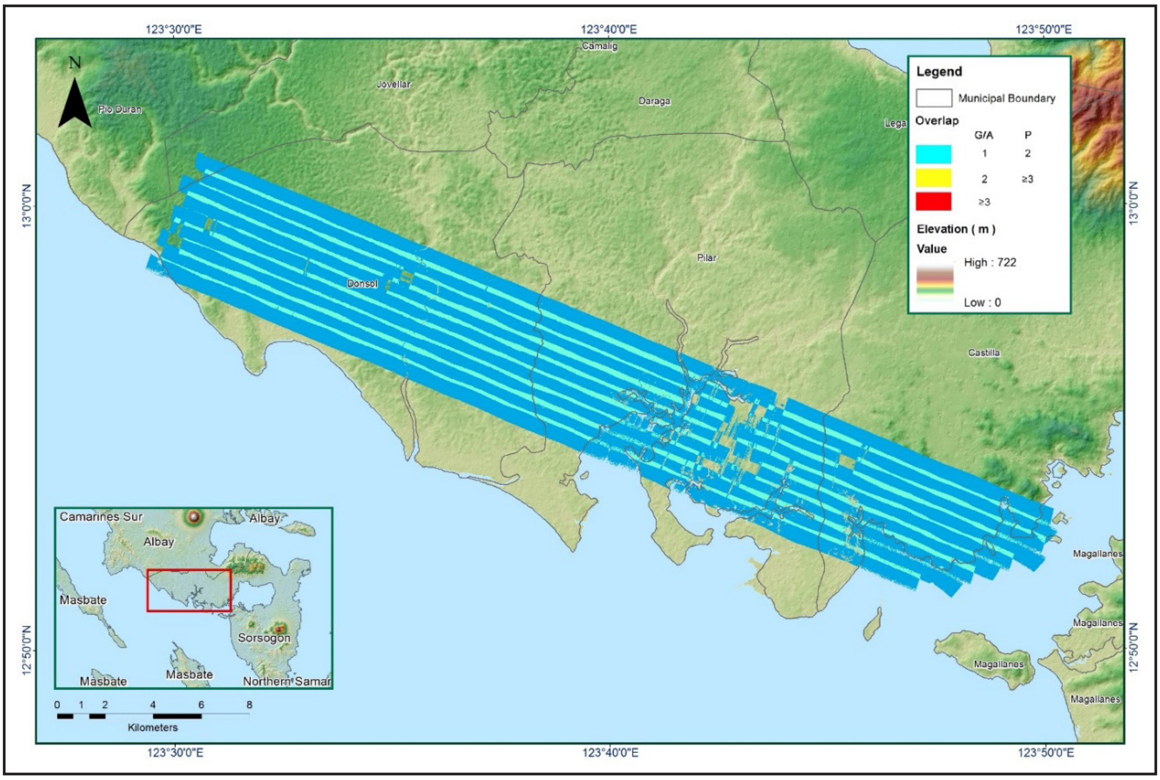


Figure 1.5.5 Image of Data Overlap

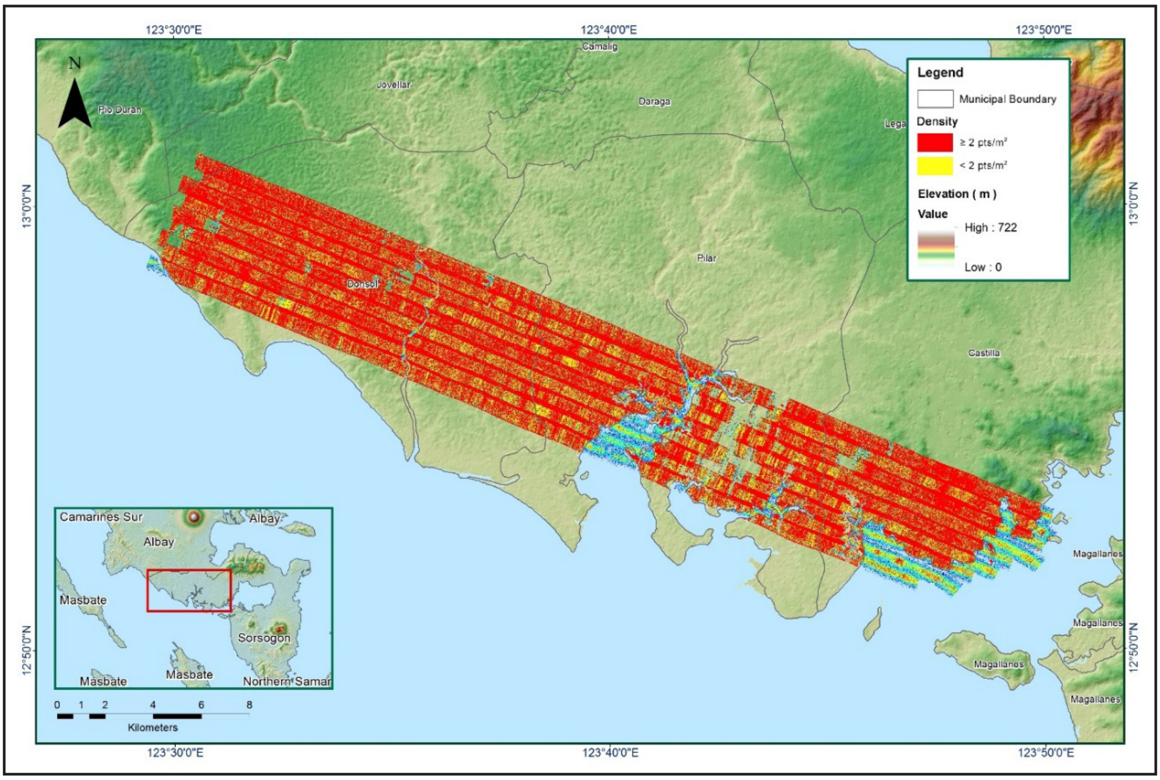


Figure 1.5.6 Density Map

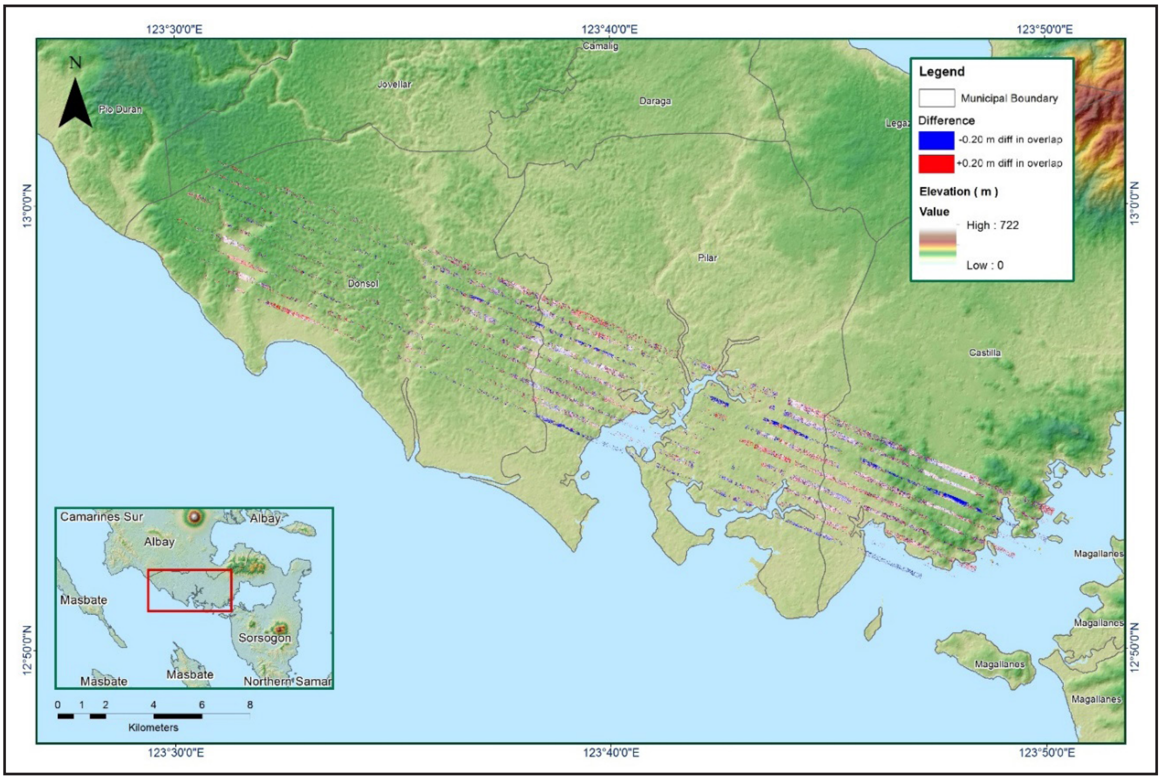


Figure 1.5.7 Elevation difference between flight lines

Table A-8.6 Mission Summary Report of Mission Blk19K

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

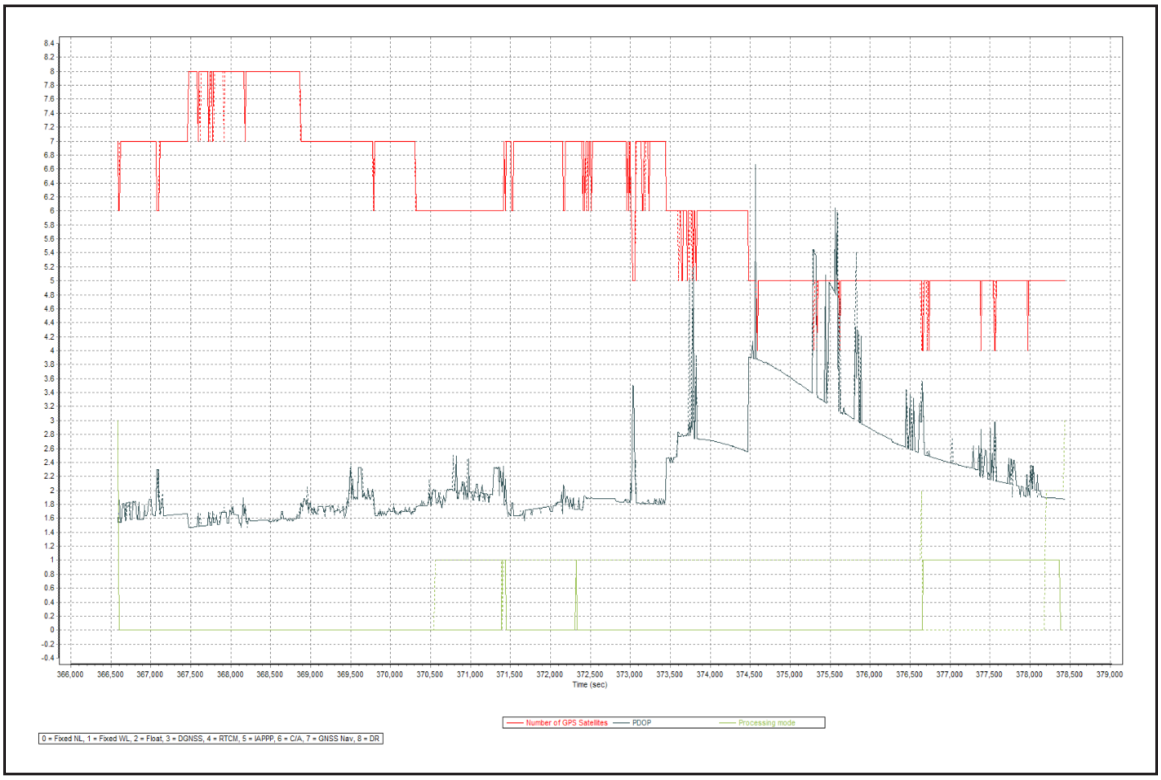


Figure 1.6.1 Solution Status

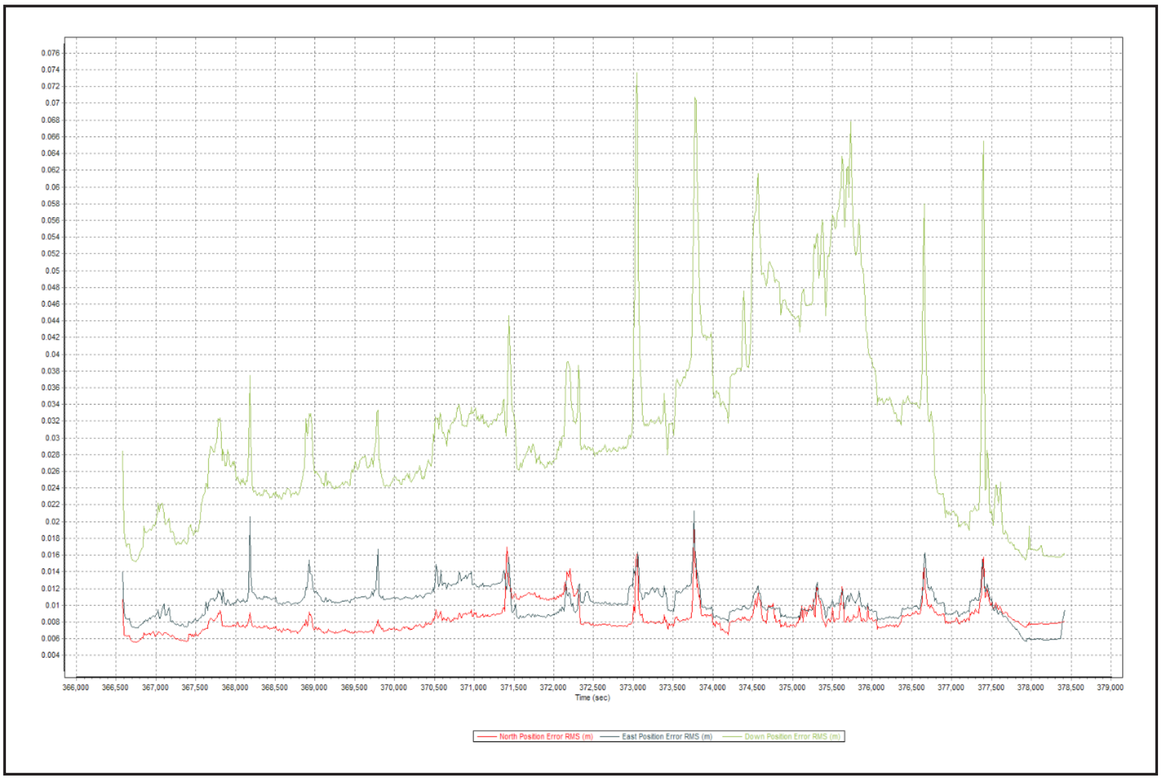


Figure 1.6.2 Smoothed Performance Metric Parameters

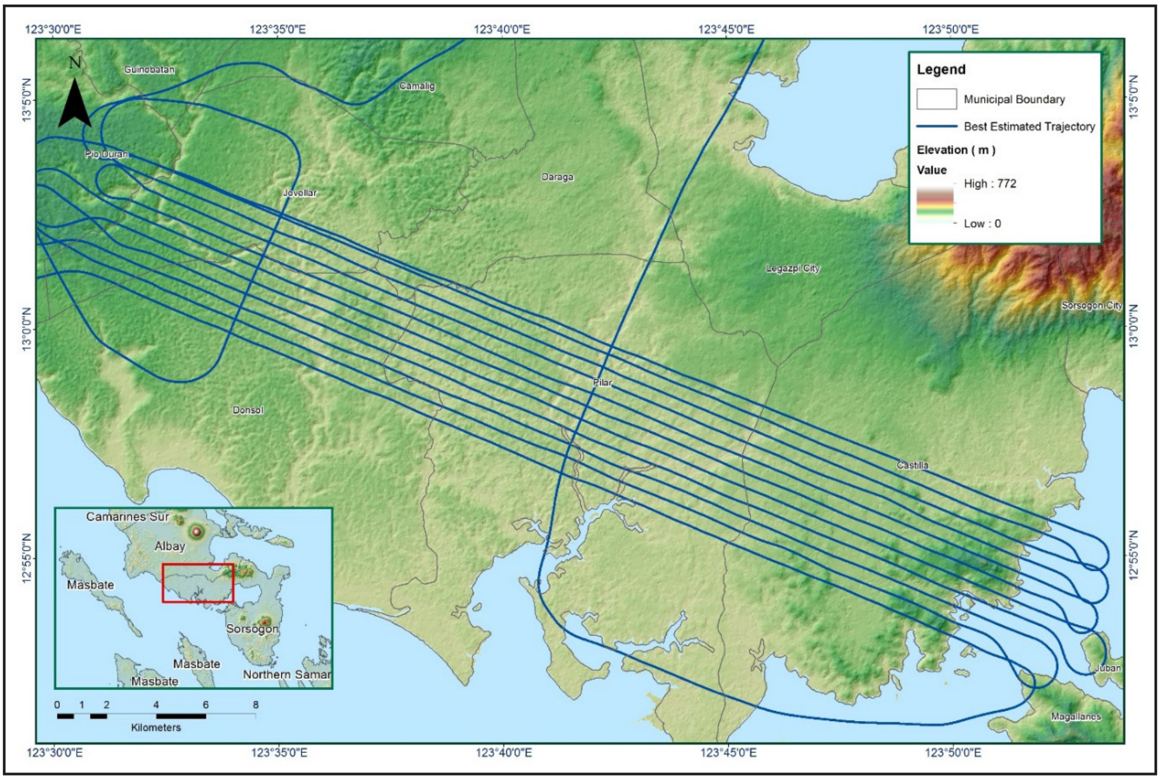


Figure 1.6.3 Best Estimated Trajectory

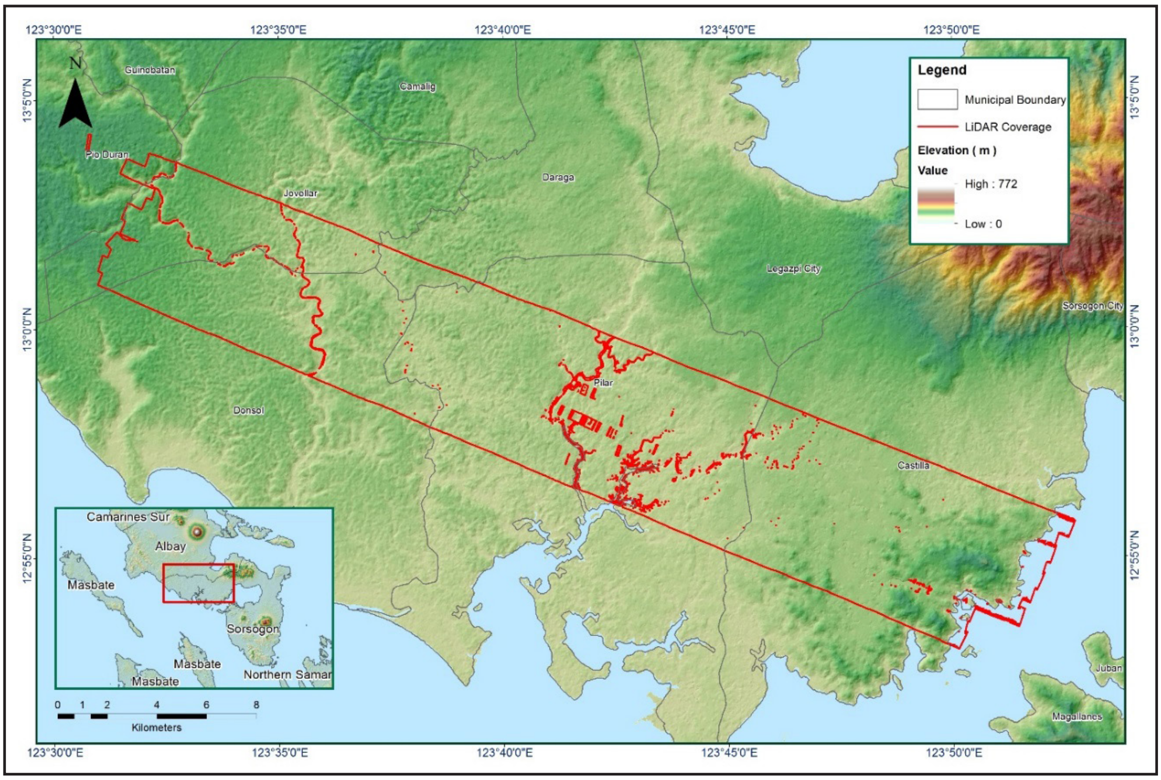


Figure 1.6.4 Coverage of LiDAR data

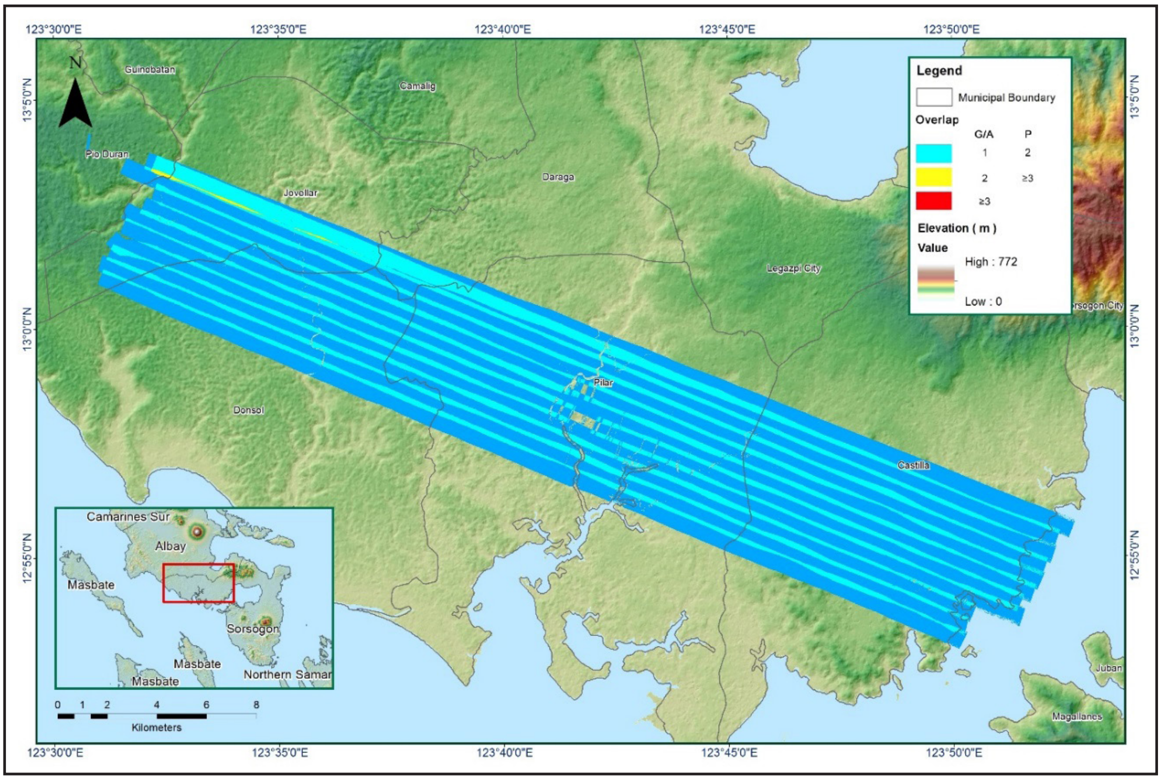


Figure 1.6.5 Image of Data Overlap

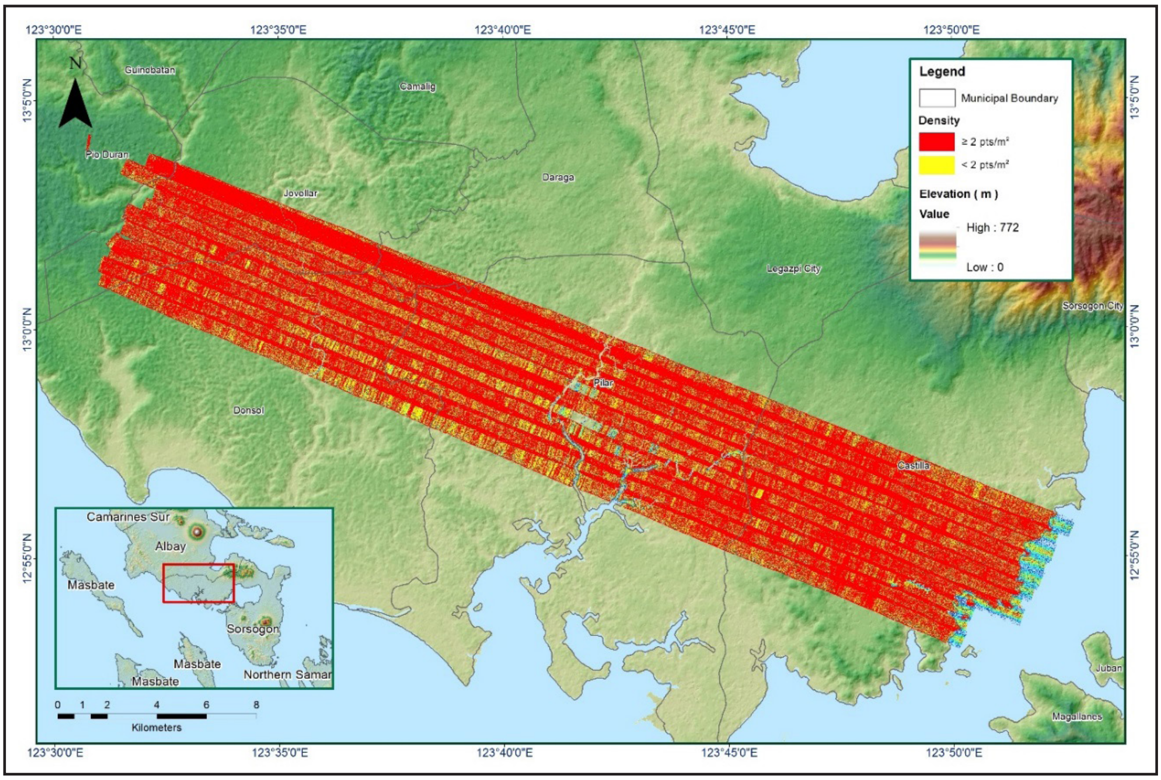


Figure 1.6.6 Density Map

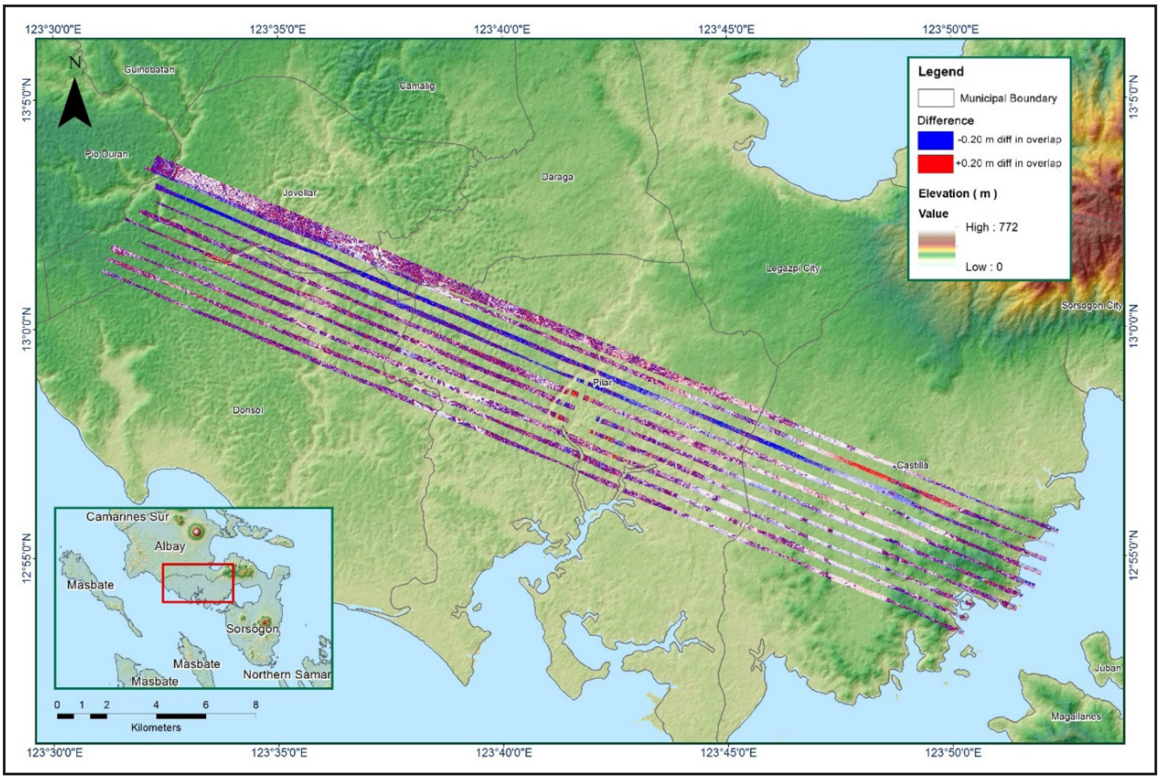


Figure 1.6.7 Elevation difference between flight lines

Table A-8.7 Mission Summary Report of Mission Blk19Q

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19Q
Inclusive Flights	3825G
Range data size	19.1 GB
POS data size	176 MB
Base data size	6.33 MB
Image	4.37 MB
Transfer date	March 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.925
RMSE for East Position (<4.0 cm)	1.005
RMSE for Down Position (<8.0 cm)	4.500
Boresight correction stdev (<0.001deg)	0.000491
IMU attitude correction stdev (<0.001deg)	0.002958
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	47.44 %
Ave point cloud density per sq.m. (>2.0)	7.42
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	89
Maximum Height	224.93 m
Minimum Height	53.78 m
Classification (# of points)	
Ground	44,126,598
Low vegetation	26,703,296
Medium vegetation	147,927,046
High vegetation	2377,320,296
Building	320,912
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. Krisha Marie Bautista

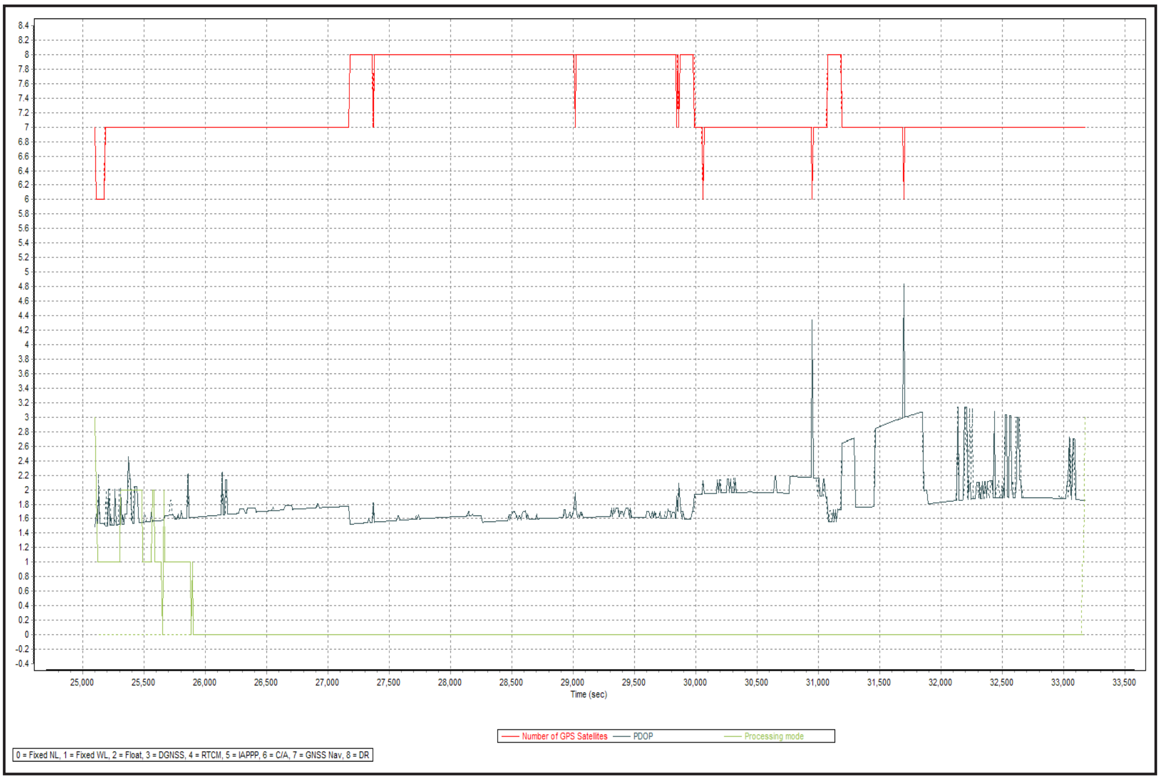


Figure 1.7.1. Solution Status

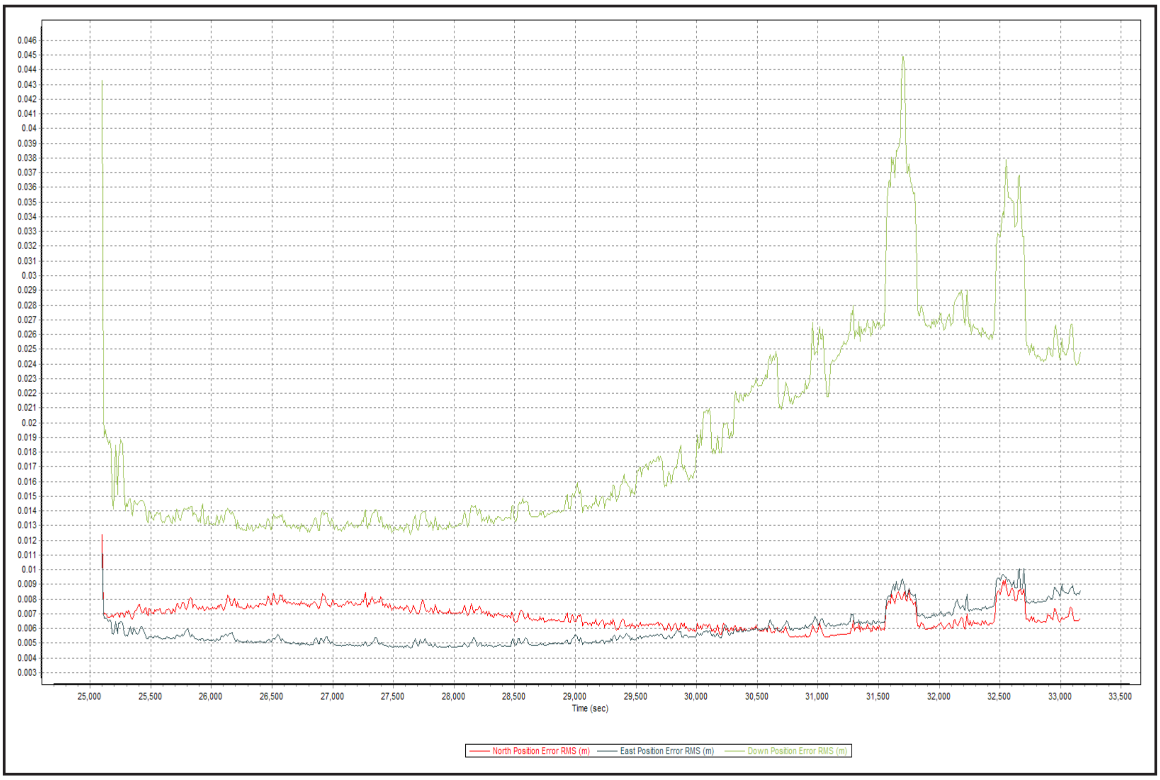


Figure 1.7.2. Smoothed Performance Metric Parameters

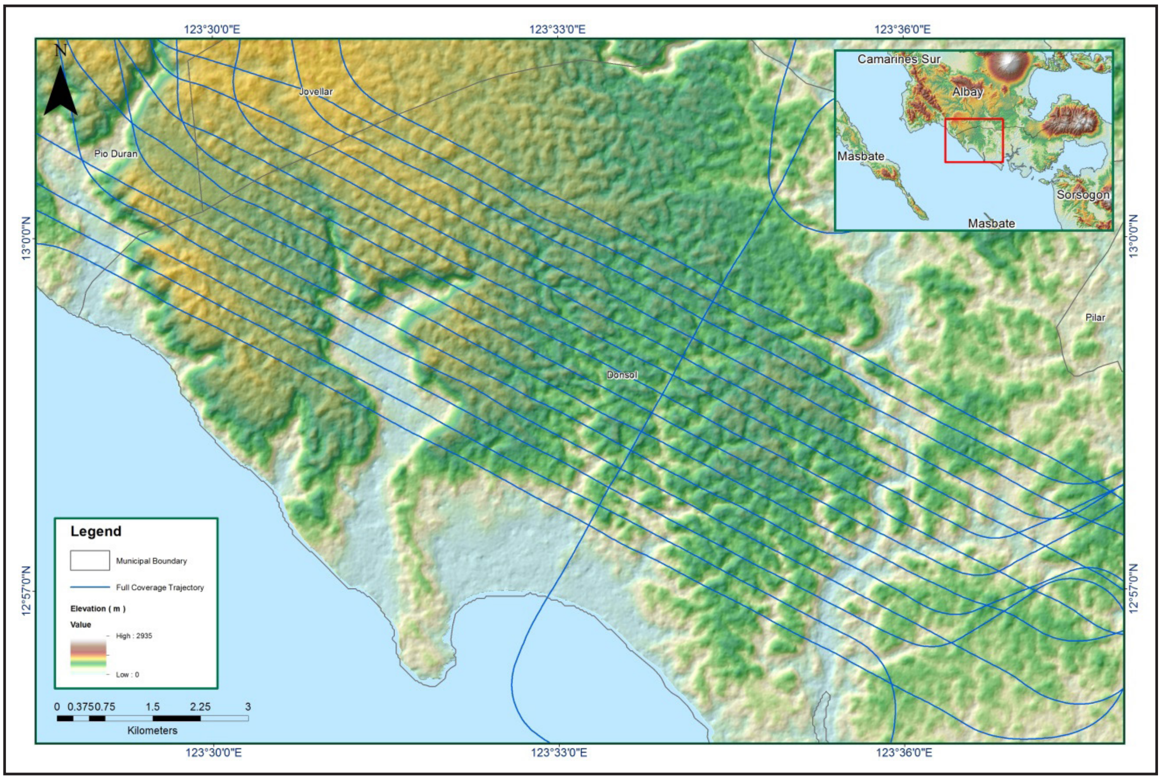


Figure 1.7.3. Best Estimated Trajectory

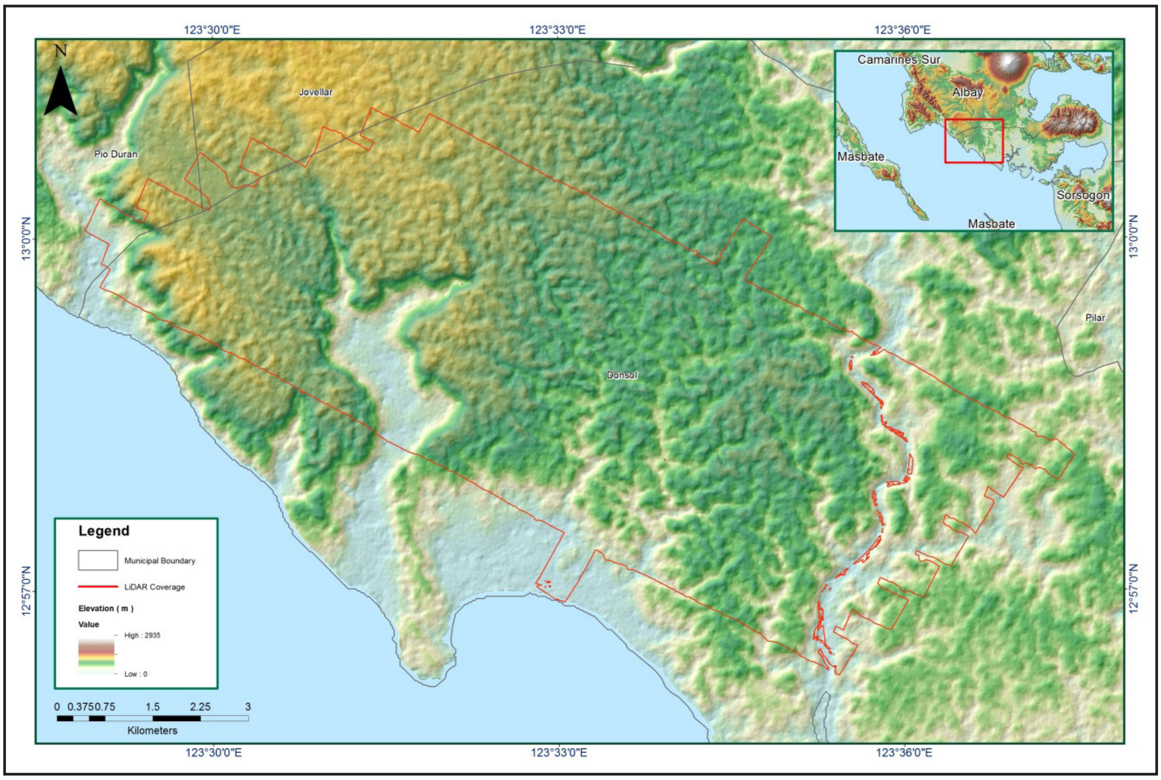


Figure 1.7.4. Coverage of LiDAR Data

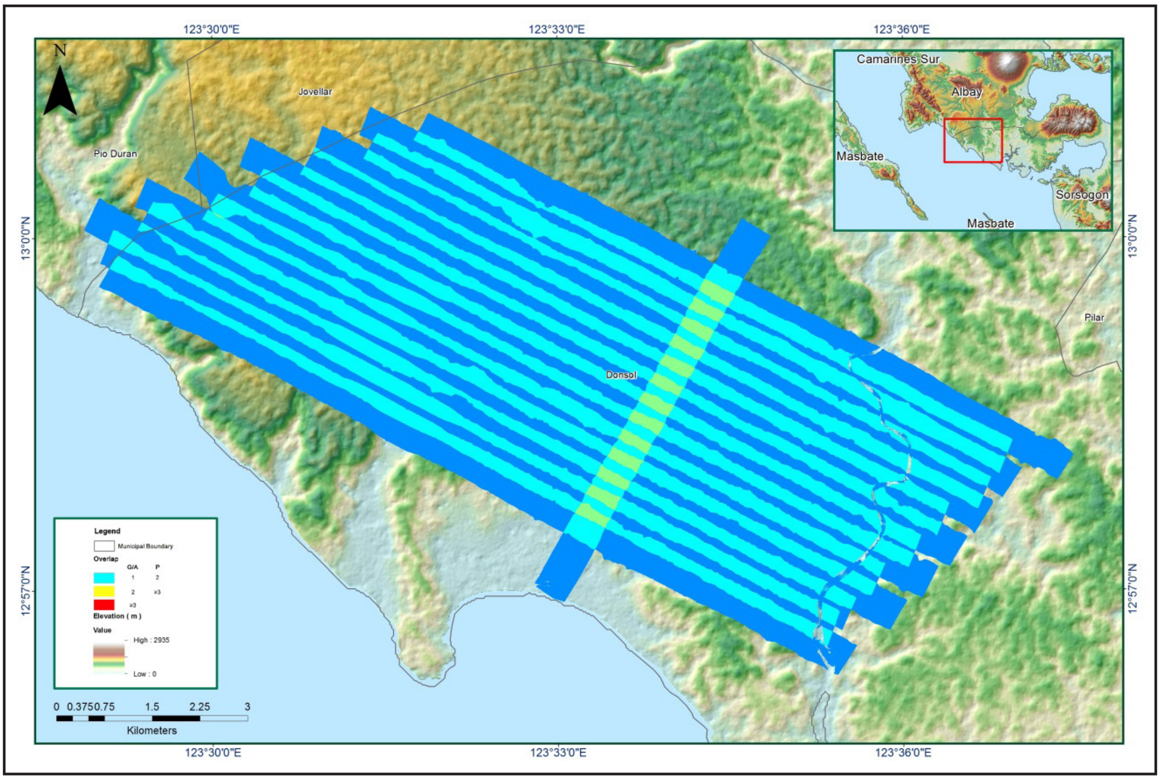


Figure 1.7.5. Image of data overlap

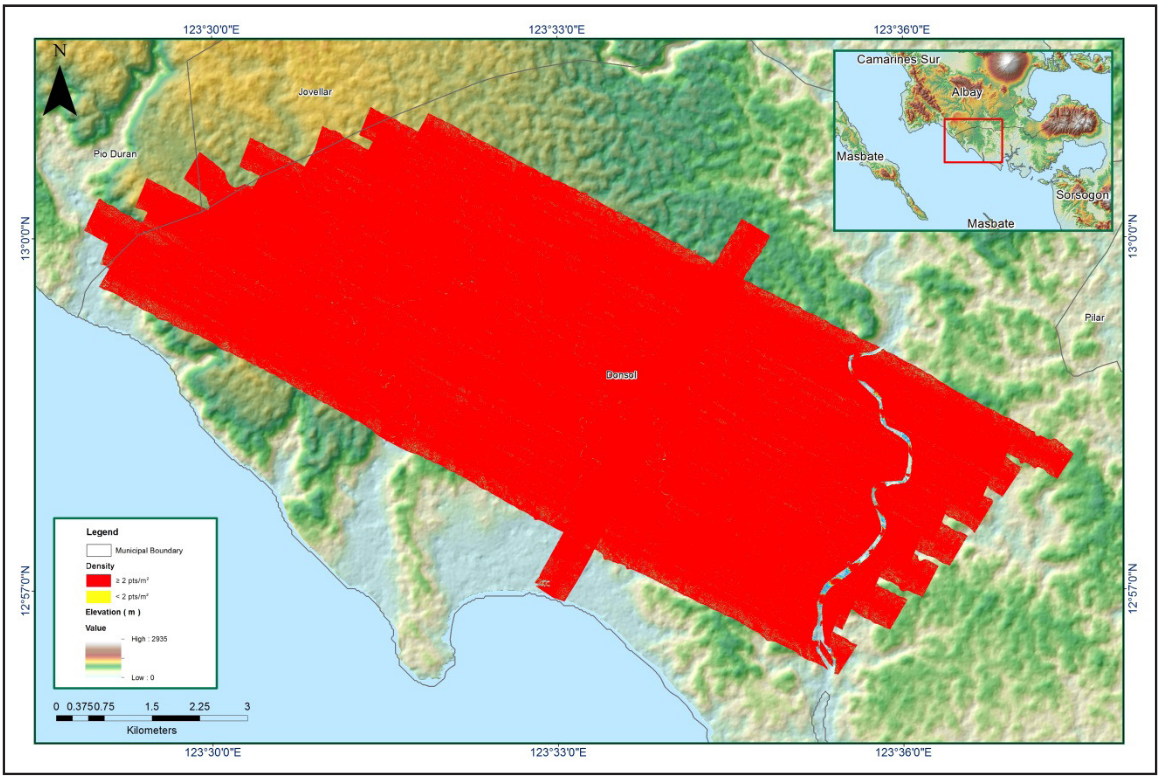


Figure 1.7.6. Density map of merged LiDAR data

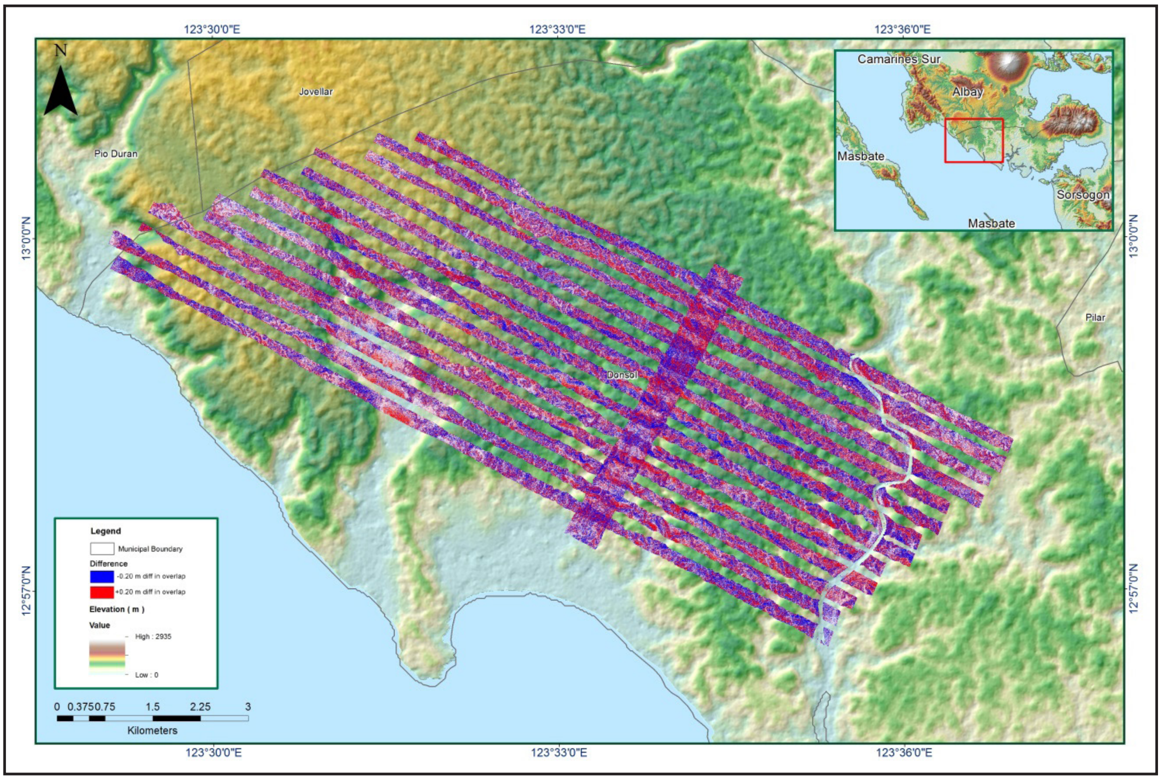


Figure 1.7.7. Elevation difference between flight lines

Table A-8.8 Mission Summary Report of Mission Blk19L

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19L
Inclusive Flights	3815G
Range data size	22.1 GB
POS data size	209 MB
Base data size	7.02 MB
Image	51.6 MB
Transfer date	March 4, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.402
RMSE for East Position (<4.0 cm)	1.710
RMSE for Down Position (<8.0 cm)	3.345
Boresight correction stdev (<0.001deg)	0.000626
IMU attitude correction stdev (<0.001deg)	0.004092
GPS position stdev (<0.01m)	0.0161
Minimum % overlap (>25)	34.93 %
Ave point cloud density per sq.m. (>2.0)	6.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	200.52 m
Minimum Height	53.21 m
Classification (# of points)	
Ground	33,363,169
Low vegetation	35,353,120
Medium vegetation	199,279,746
High vegetation	167,904,428
Building	1,115,853
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan, Ryan James Nicholai Dizon

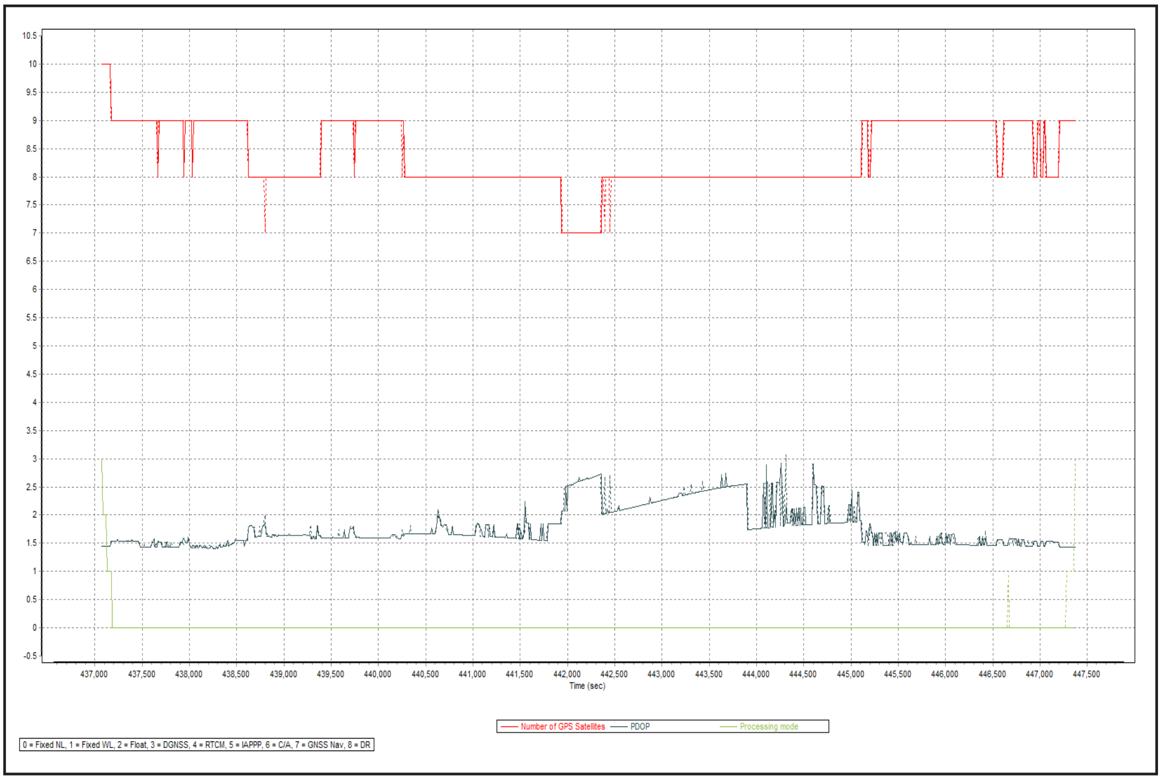


Figure 1.8.1. Solution Status

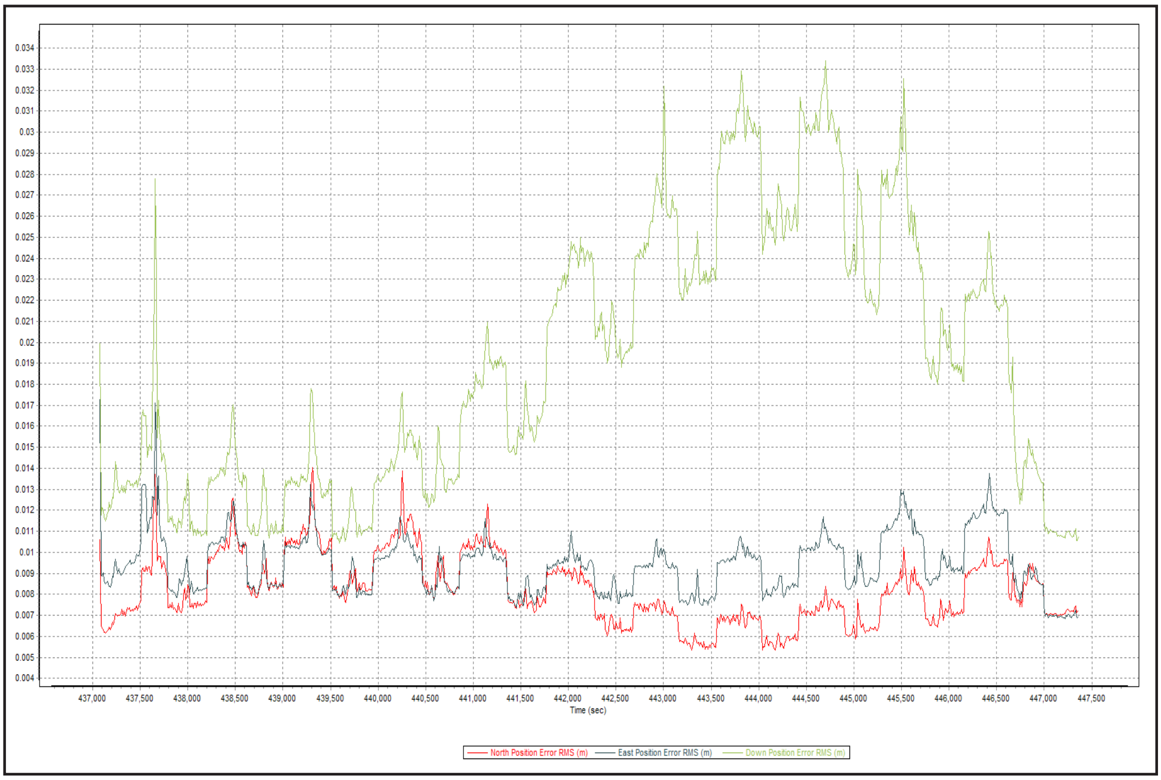


Figure 1.8.2. Smoothed Performance Metric Parameters

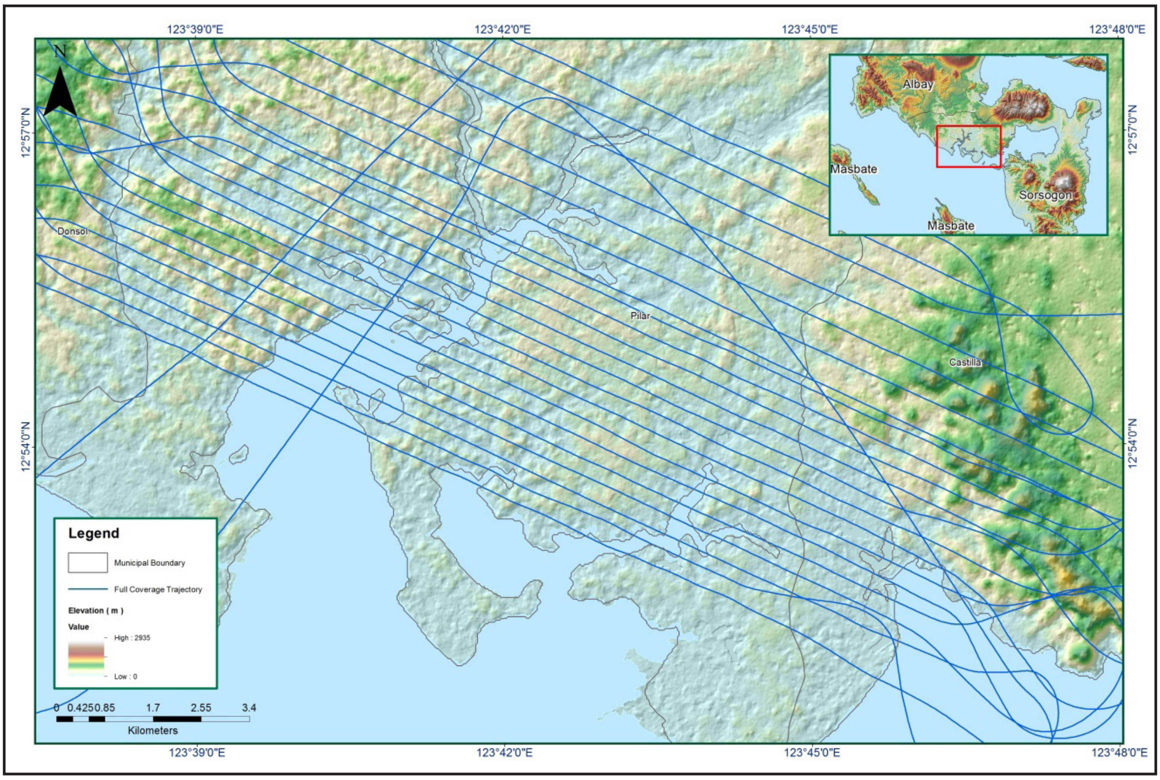


Figure 1.8.3. Best Estimated Trajectory

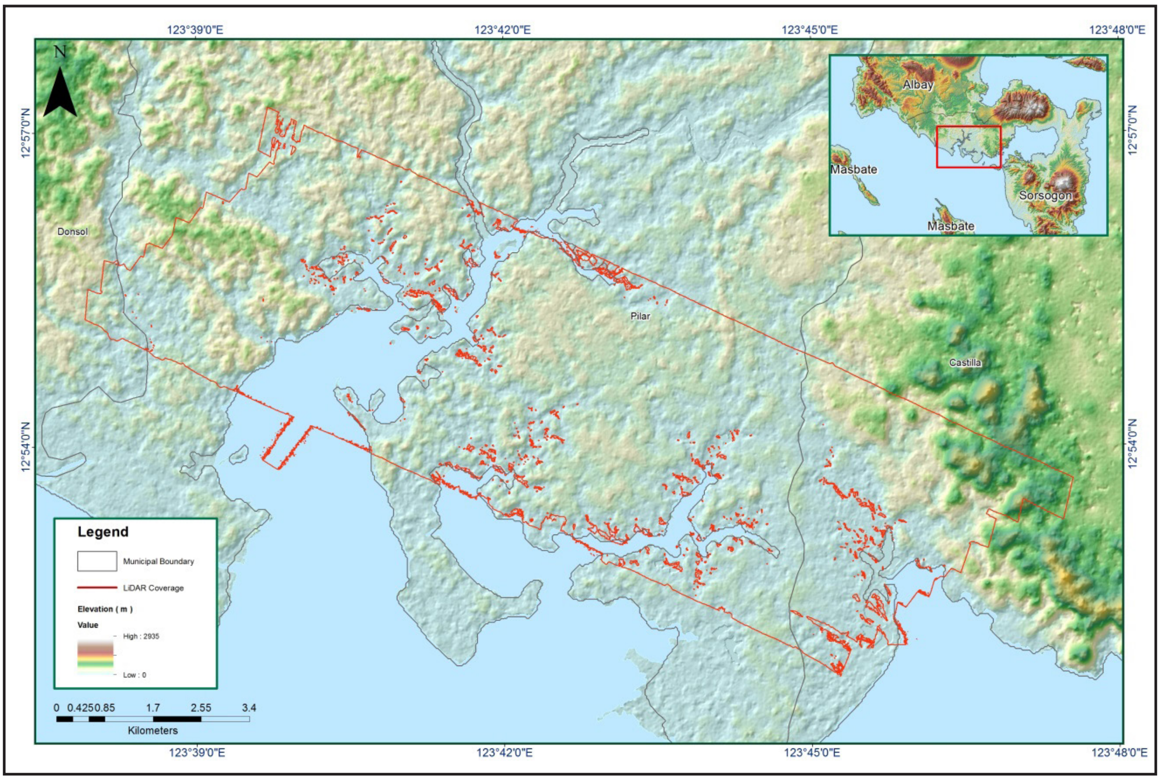


Figure 1.8.4. Coverage of LiDAR Data

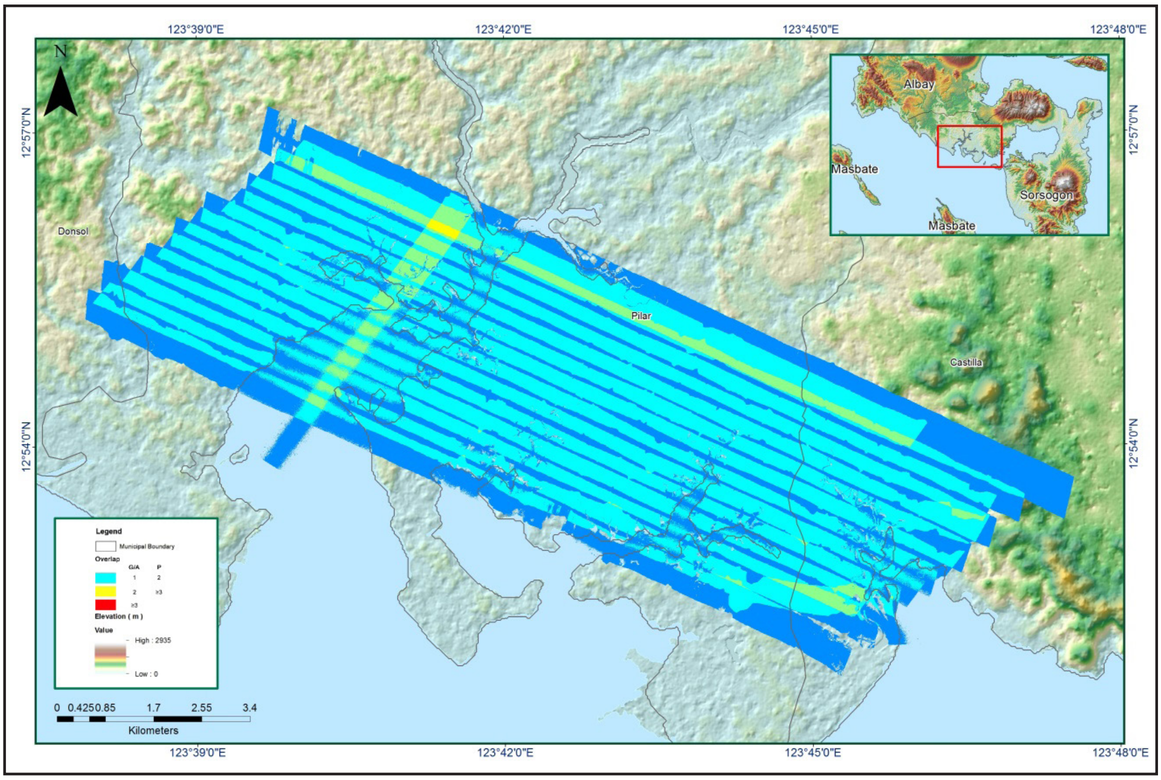


Figure 1.8.5. Image of data overlap

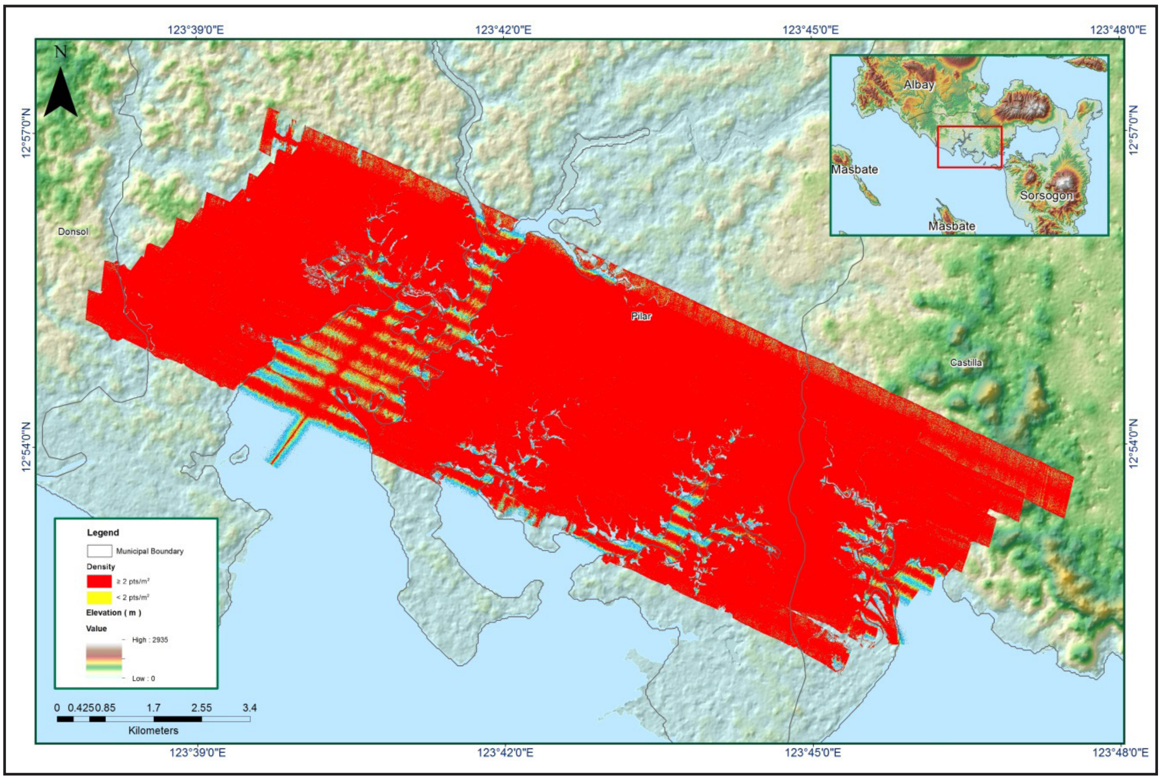


Figure 1.8.6. Density map of merged LiDAR data

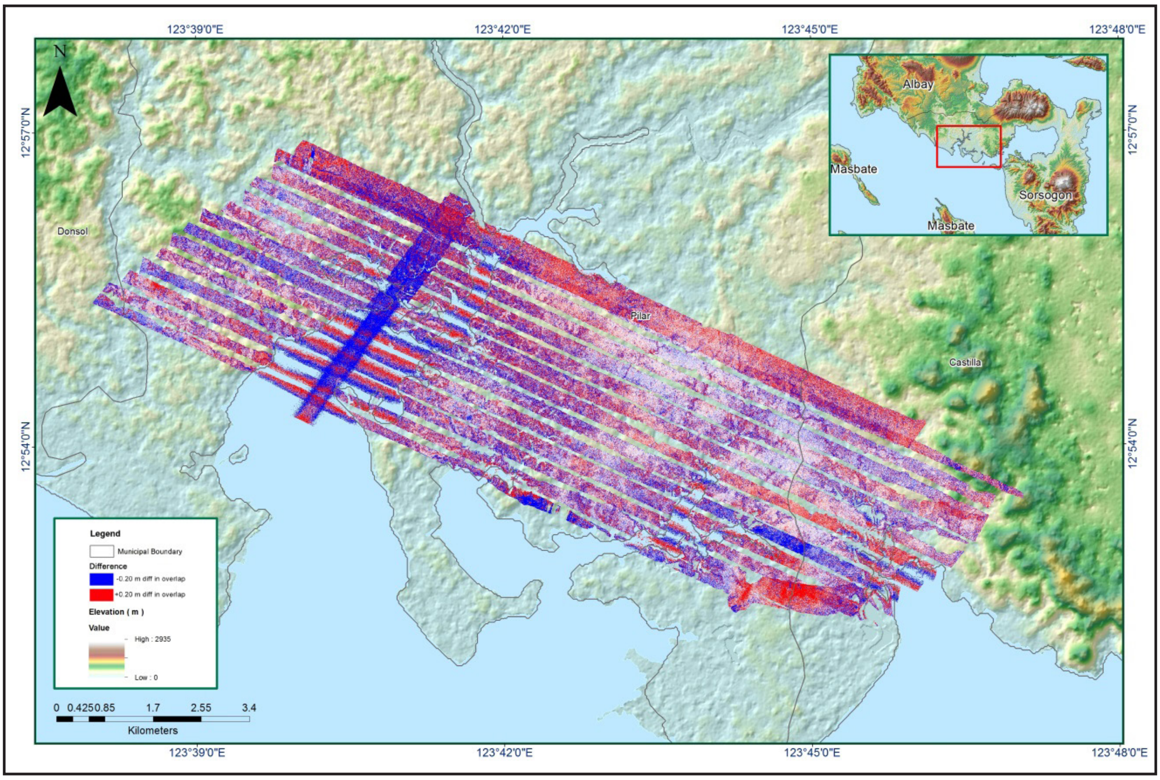


Figure 1.8.7. Elevation difference between flight lines

Table A-8.8 Mission Summary Report of Mission Blk19I

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19I
Inclusive Flights	3813G
Range data size	26.8 GB
POS data size	202 MB
Base data size	5.61 MB
Image	66.8 MB
Transfer date	March 4, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.001
RMSE for East Position (<4.0 cm)	1.070
RMSE for Down Position (<8.0 cm)	2.090
Boresight correction stdev (<0.001deg)	0.002121
IMU attitude correction stdev (<0.001deg)	0.005422
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	28.49 %
Ave point cloud density per sq.m. (>2.0)	6.18
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	154
Maximum Height	222.00 m
Minimum Height	53.88 m
Classification (# of points)	
Ground	37,487,618
Low vegetation	42,720,599
Medium vegetation	181,607,838
High vegetation	162,838,123
Building	825,908
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan

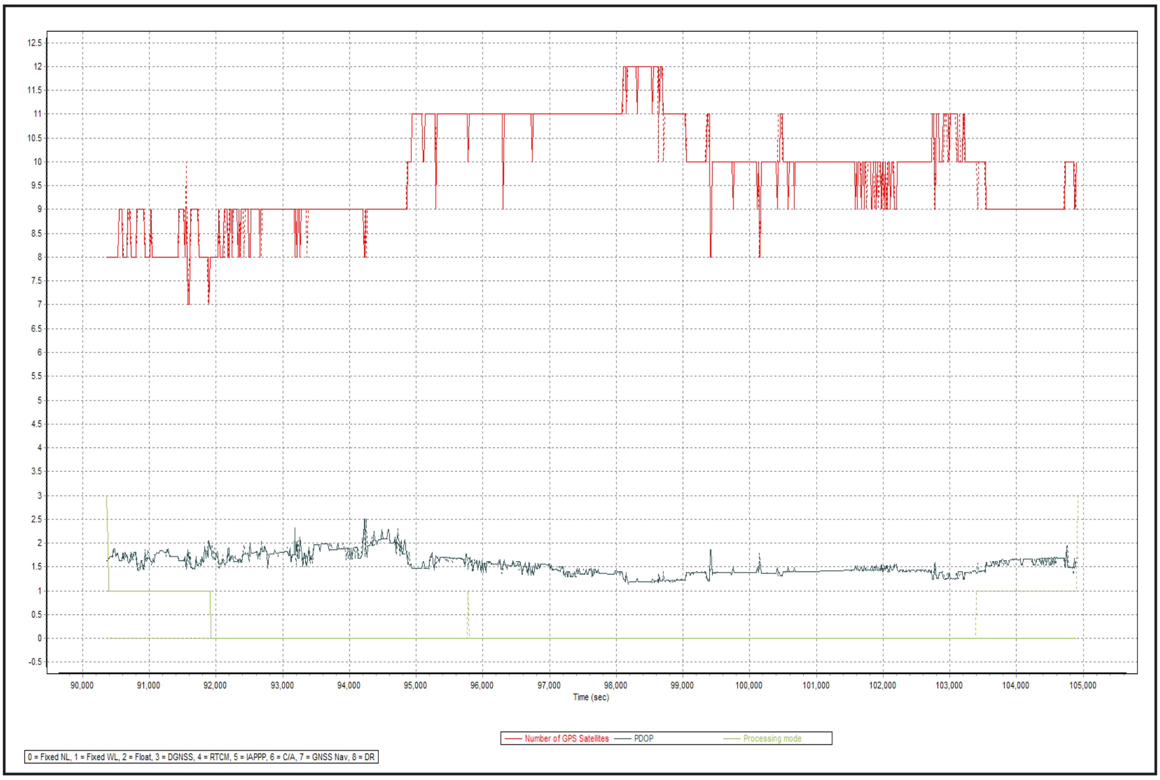


Figure 1.9.1. Solution Status

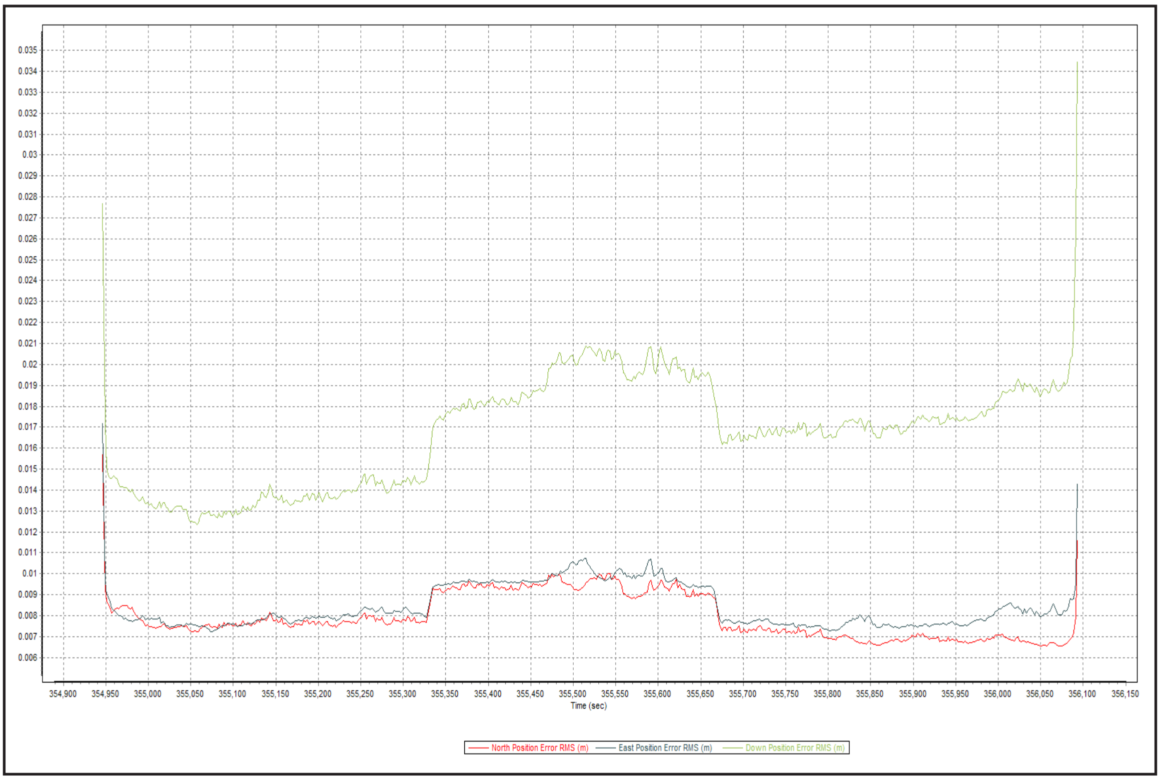


Figure 1.9.2. Smoothed Performance Metric Parameters

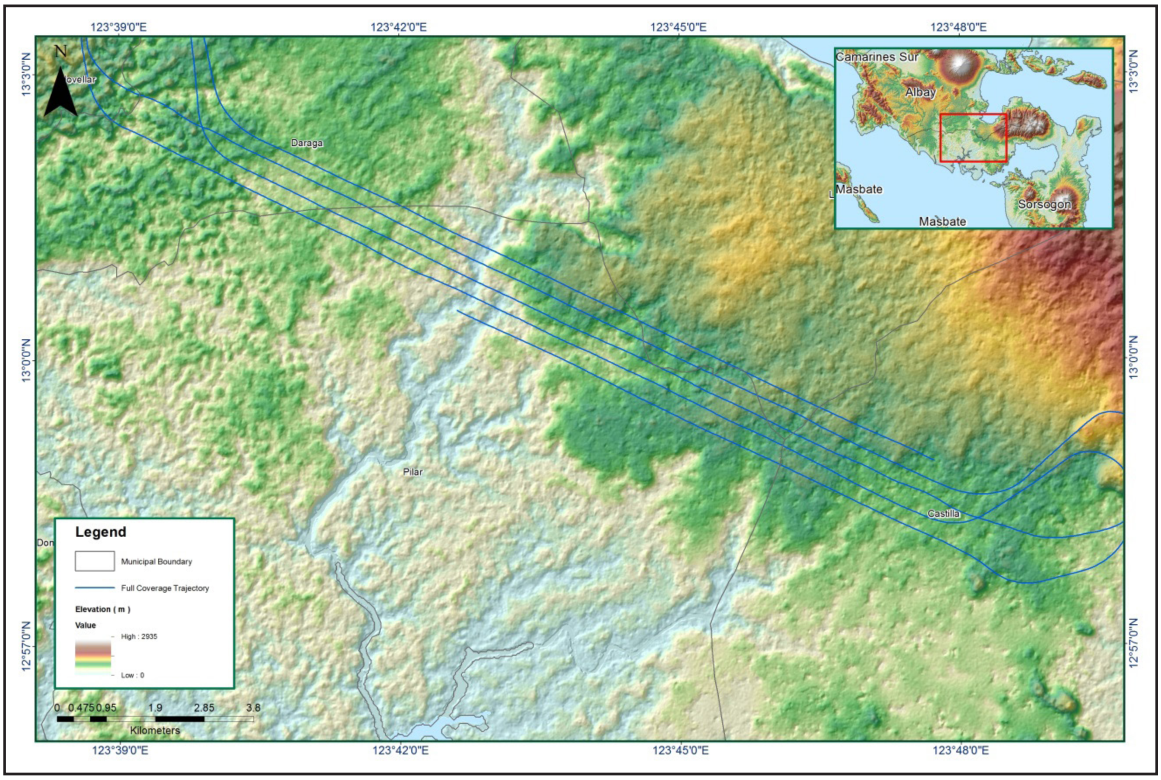


Figure 1.9.3. Best Estimated Trajectory

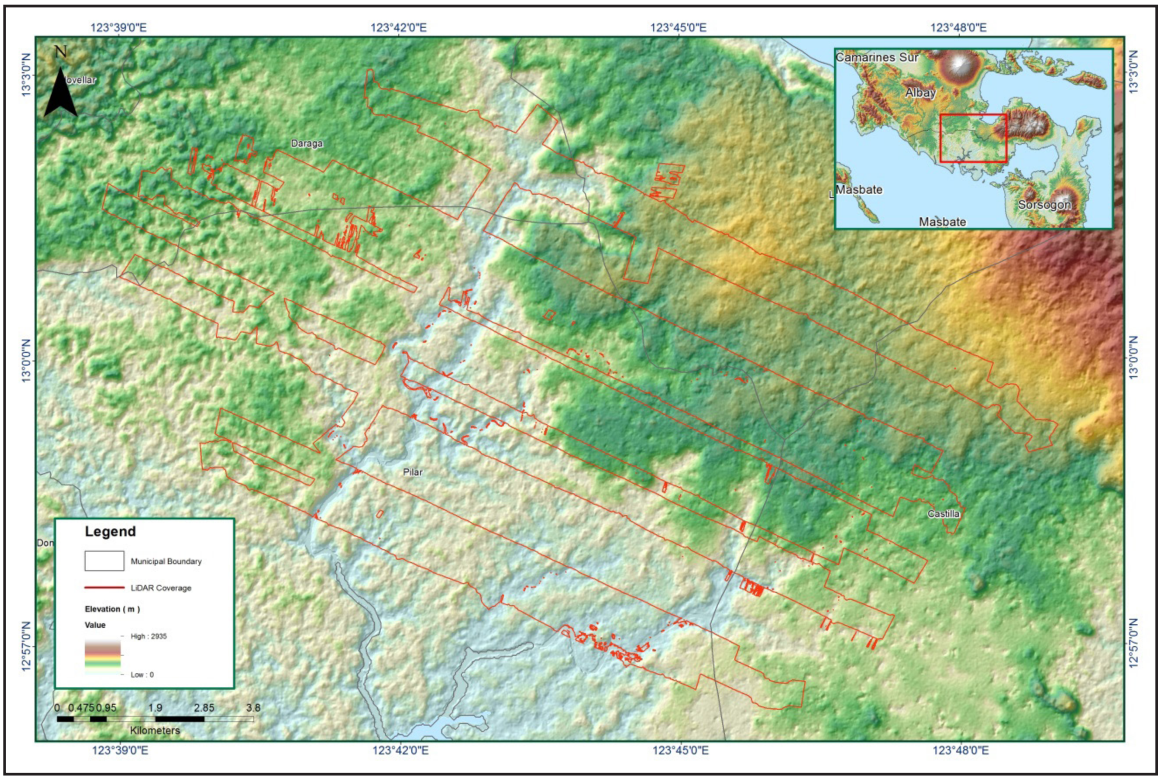


Figure 1.9.4. Coverage of LiDAR Data

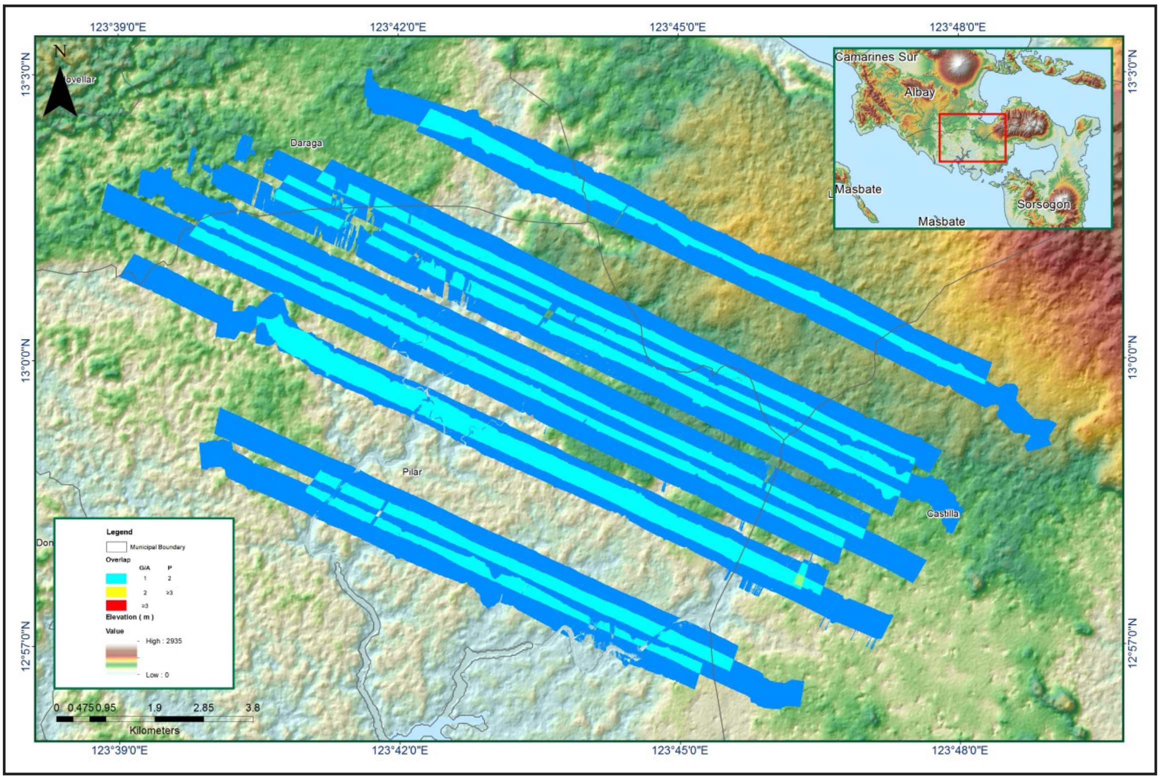


Figure 1.9.5. Image of data overlap

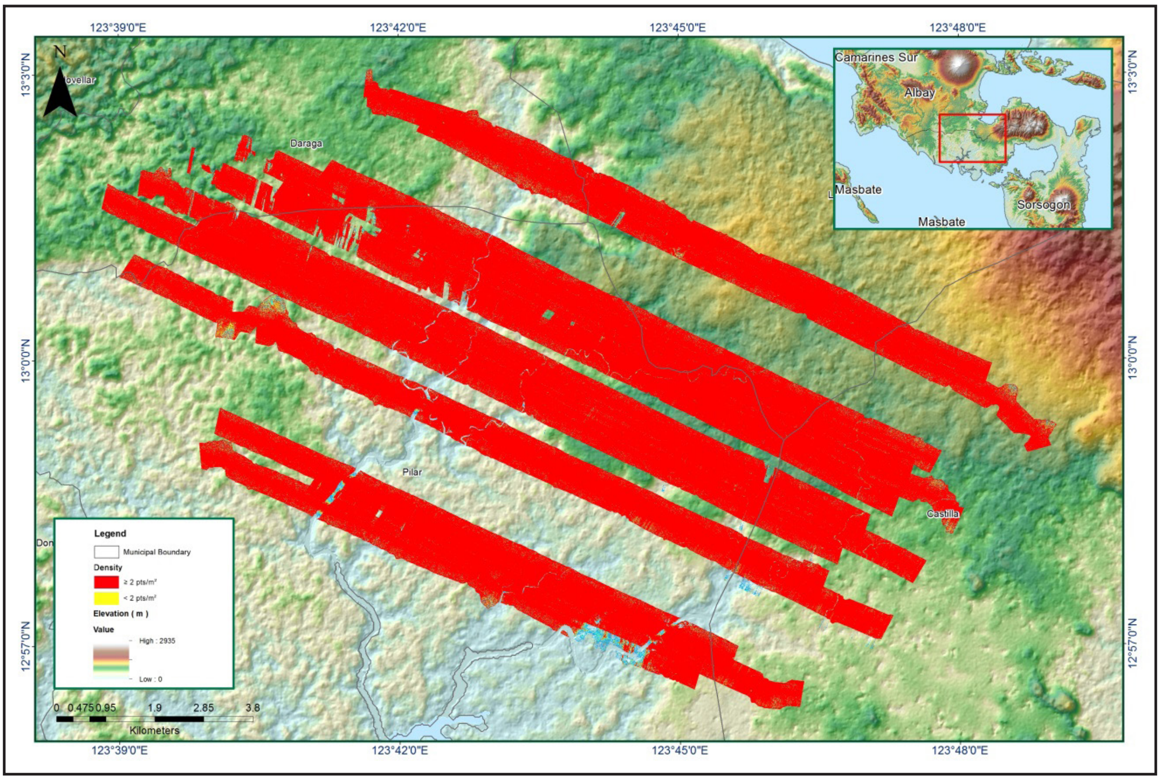


Figure 1.9.6. Density map of merged LiDAR data

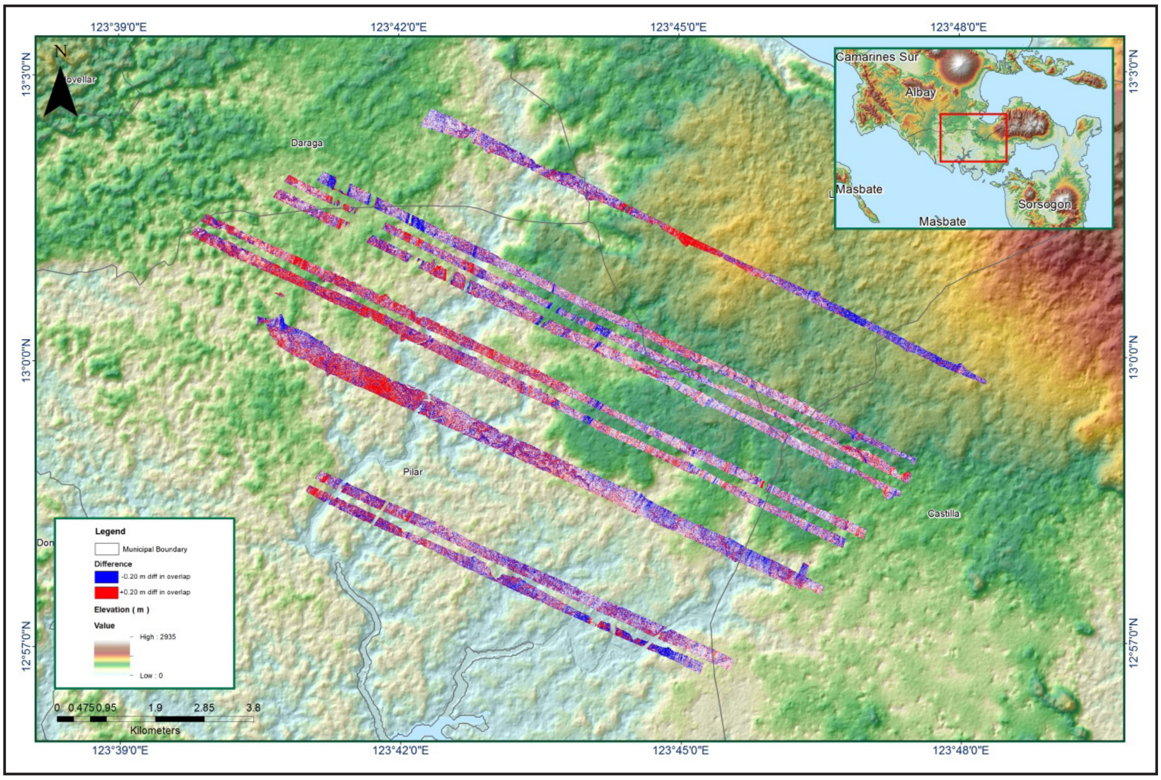


Figure 1.9.7. Elevation difference between flight lines

Table A-8.10 Mission Summary Report of Mission Blk19I_additional

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19I_additional
Inclusive Flights	3813G
Range data size	26.8 GB
POS data size	202 MB
Base data size	5.61 MB
Image	66.8 MB
Transfer date	March 4, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.275
RMSE for East Position (<4.0 cm)	1.524
RMSE for Down Position (<8.0 cm)	3.333
Boresight correction stdev (<0.001deg)	0.000343
IMU attitude correction stdev (<0.001deg)	0.001725
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	26.86 %
Ave point cloud density per sq.m. (>2.0)	6.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	134
Maximum Height	198.30 m
Minimum Height	53.71 m
Classification (# of points)	
Ground	35,301,737
Low vegetation	47,816,552
Medium vegetation	180,246,768
High vegetation	152,332,905
Building	761,702
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Jovelle Anjeanette Canlas, Engr. Elainne Lopez

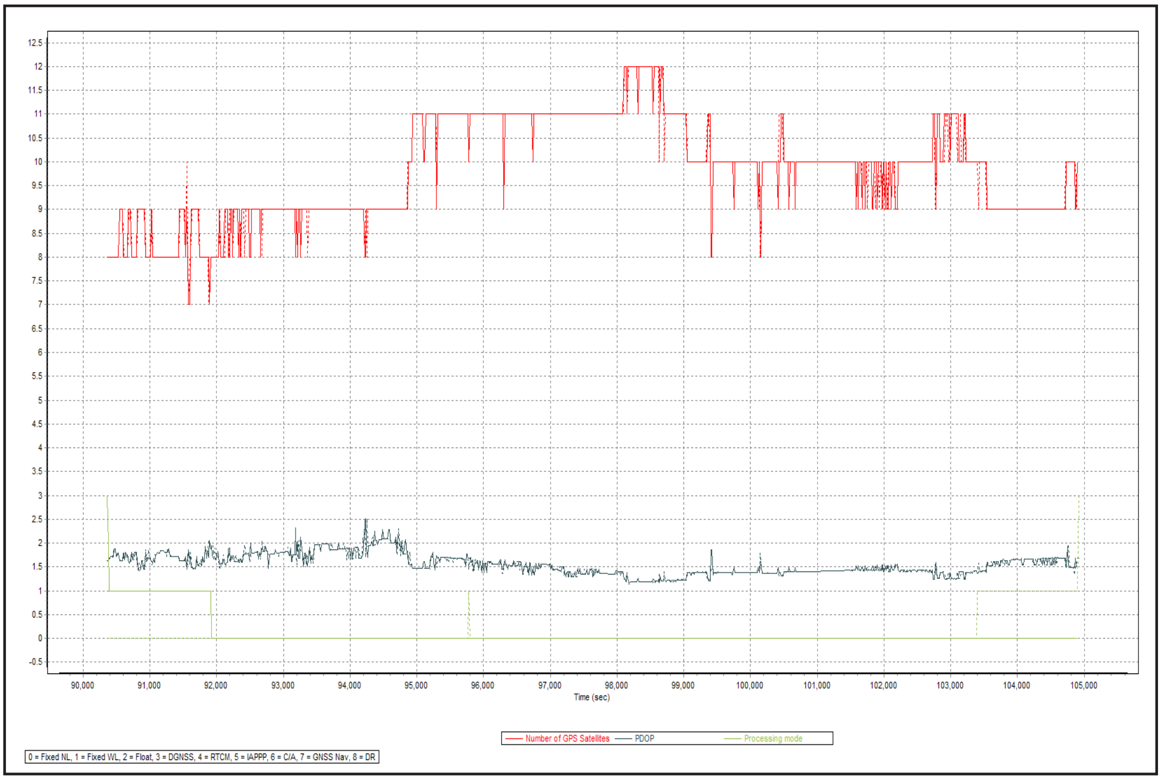


Figure 1.10.1. Solution Status

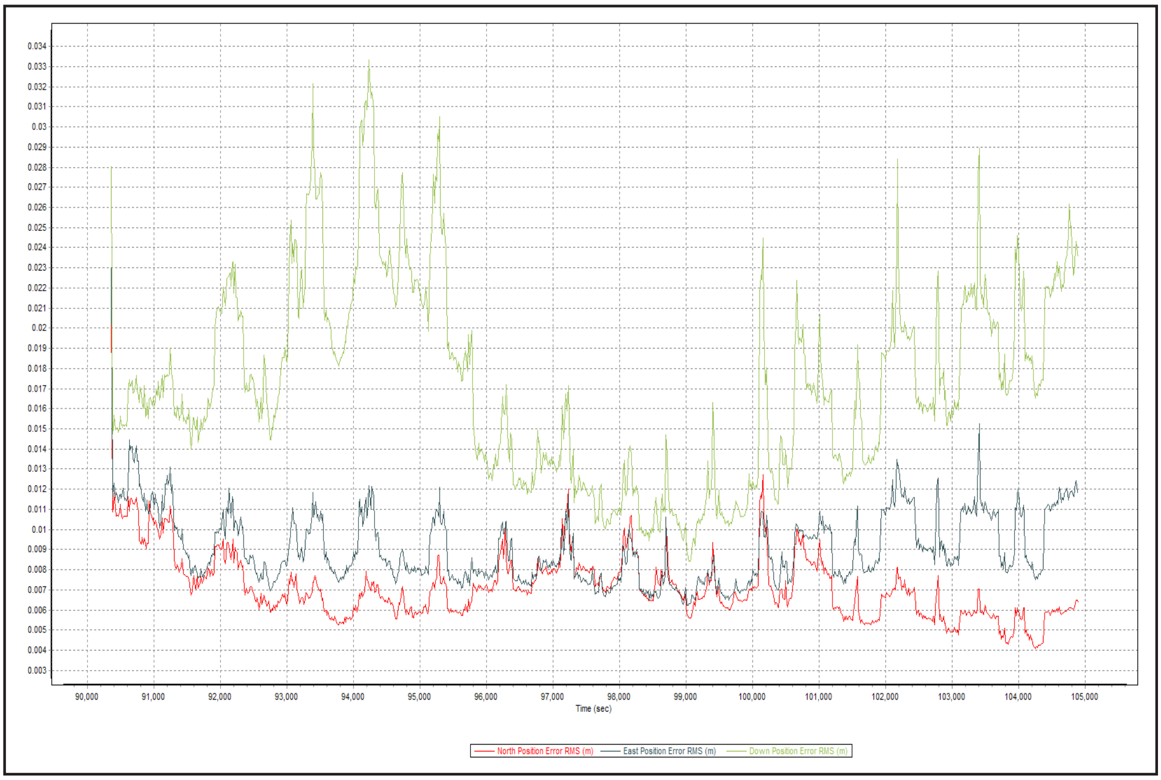


Figure 1.10.2. Smoothed Performance Metric Parameters

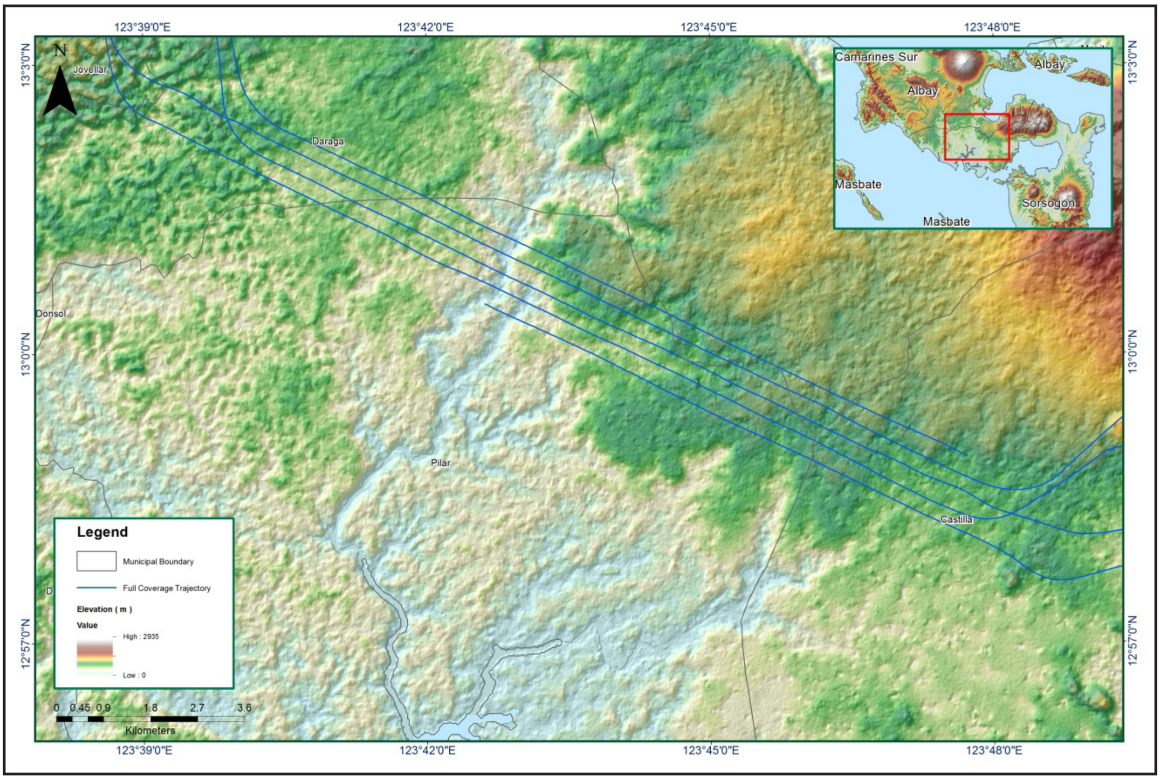


Figure 1.10.3. Best Estimated Trajectory

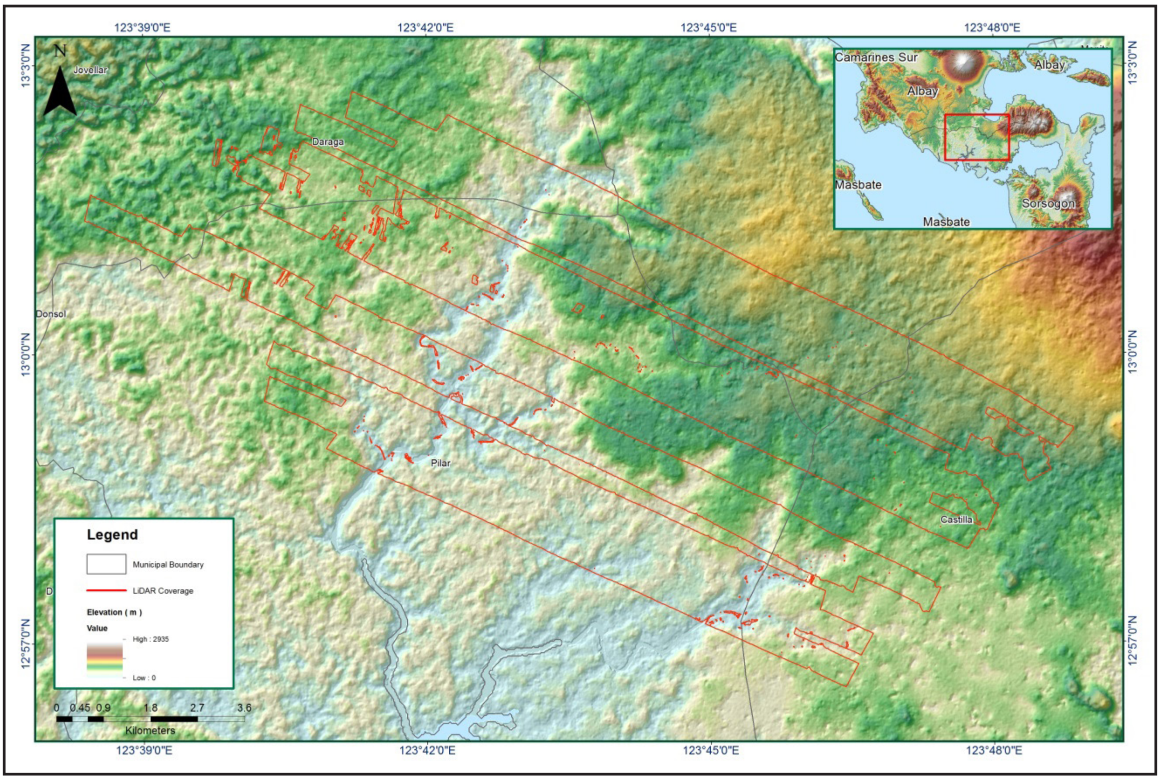


Figure 1.10.4. Coverage of LiDAR Data

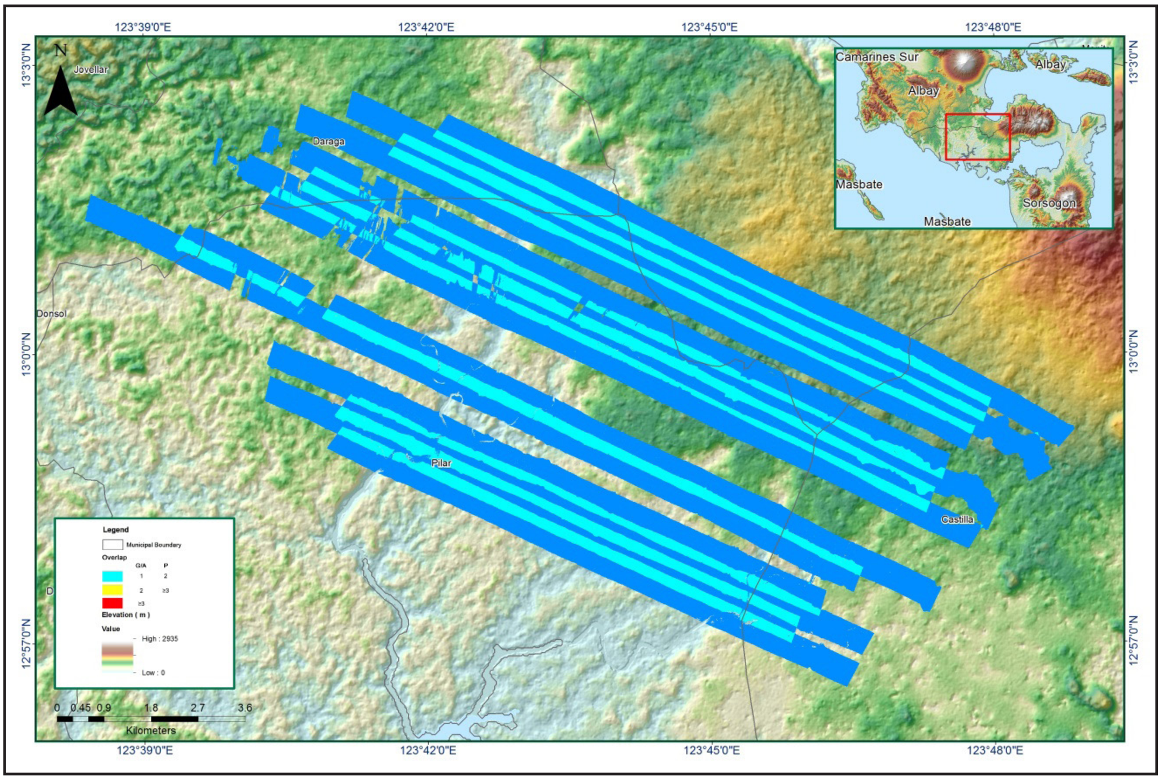


Figure 1.10.5. Image of data overlap

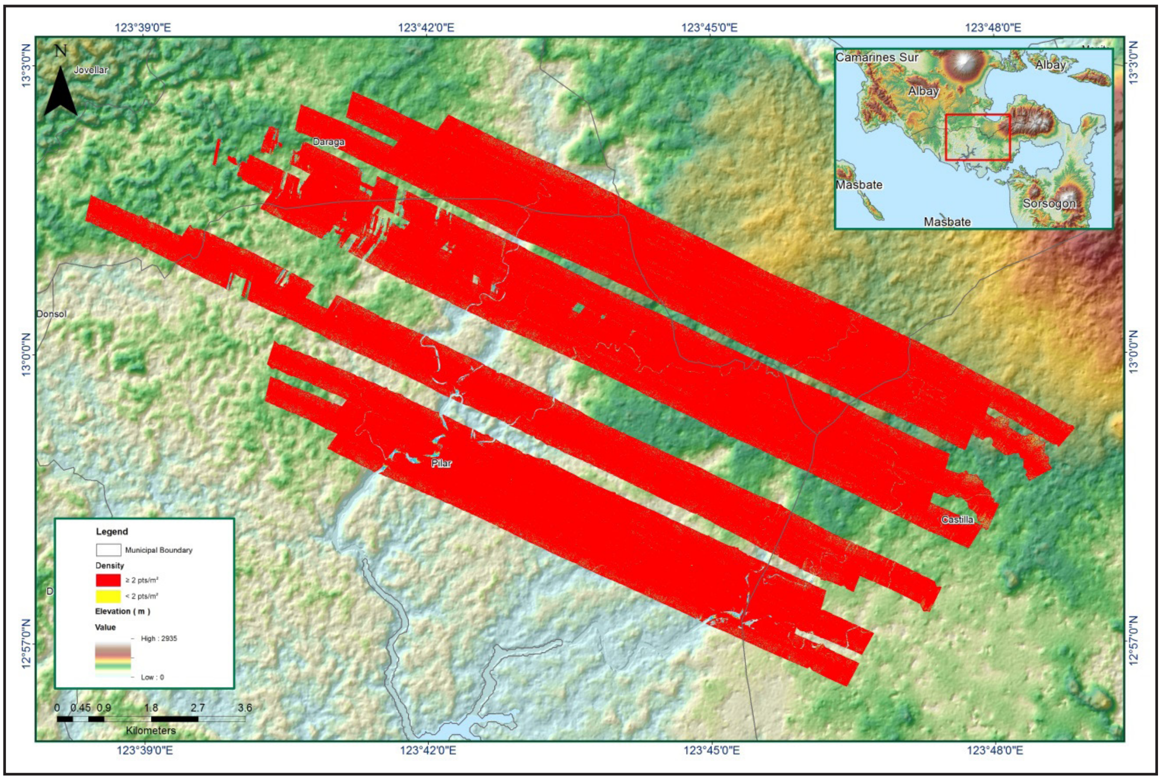


Figure 1.10.6. Density map of merged LiDAR data

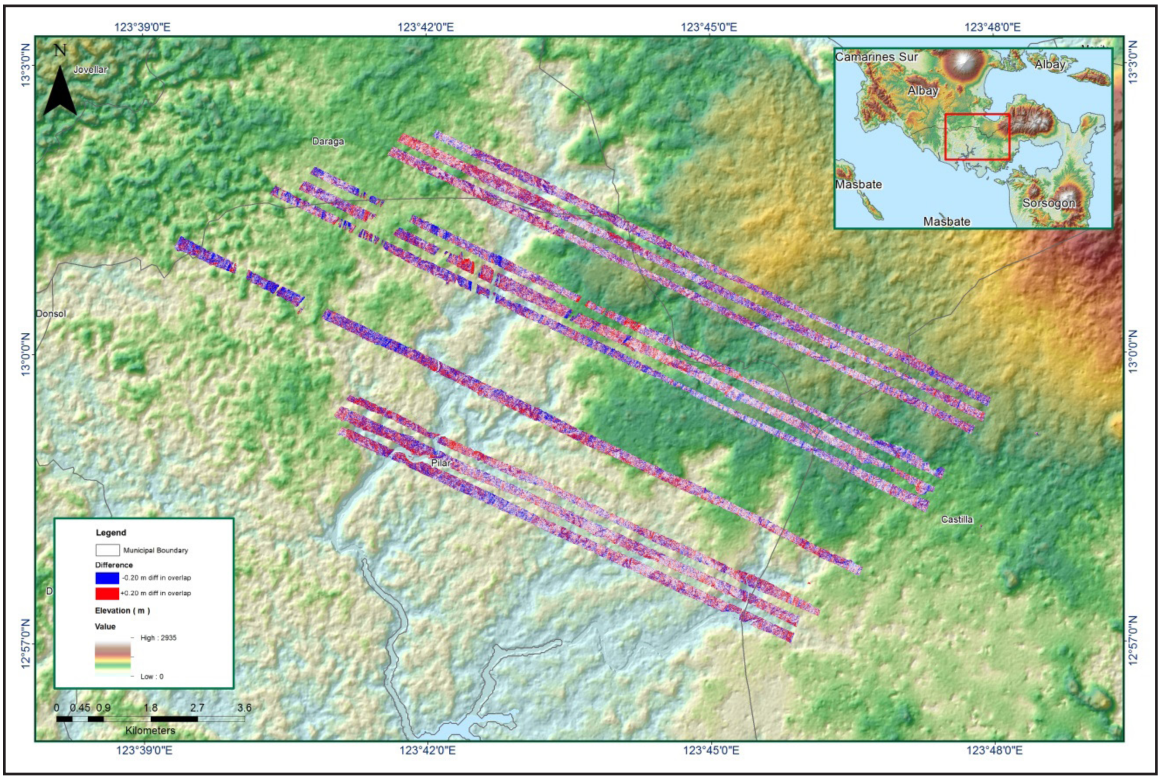


Figure 1.10.7. Elevation difference between flight lines

ANNEX 9. Donsol 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	2.035	99.000	0	14.391	7.07470	Discharge	11.2800	0.83080	Ratio to Peak	0.61468
W210	3.830	99.000	0	16.993	3.40960	Discharge	2.0475	1.00000	Ratio to Peak	1.00000
W220	4.397	96.634	0	6.011	10.18100	Discharge	7.2599	1.00000	Ratio to Peak	1.00000
W230	4.424	93.625	0	0.167	3.19730	Discharge	1.8025	1.00000	Ratio to Peak	1.00000
W240	4.143	98.887	0	0.143	3.40000	Discharge	0.9872	1.00000	Ratio to Peak	1.00000
W250	4.411	98.940	0	0.017	8.52310	Discharge	1.6786	1.00000	Ratio to Peak	1.00000
W260	35.312	99.000	0	0.126	0.22431	Discharge	0.0018	0.66051	Ratio to Peak	1.00000
W270	3.951	92.808	0	0.165	2.32820	Discharge	0.4412	0.65398	Ratio to Peak	1.00000
W280	4.458	69.169	0	0.146	6.51440	Discharge	1.6715	1.00000	Ratio to Peak	0.46488
W290	3.949	76.424	0	0.146	5.70260	Discharge	1.9126	0.66643	Ratio to Peak	0.96600
W300	4.048	94.064	0	0.147	9.57070	Discharge	1.7442	0.64027	Ratio to Peak	0.66667

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
W310	2.756	86.762	0	0.017	3.97860	Discharge	0.4529	0.65863	Ratio to Peak	1.00000
W320	4.324	64.251	0	0.017	7.40240	Discharge	2.0103	1.00000	Ratio to Peak	1.00000
W330	1.322	99.000	0	0.155	5.71030	Discharge	0.1502	1.00000	Ratio to Peak	0.32014
W340	4.108	72.742	0	0.149	4.78960	Discharge	2.6756	1.00000	Ratio to Peak	1.00000
W350	5.988	71.903	0	0.017	4.49550	Discharge	1.9141	0.67898	Ratio to Peak	0.96504
W360	4.022	75.111	0	0.165	5.70840	Discharge	2.5278	0.95976	Ratio to Peak	1.00000
W370	3.622	76.628	0	0.166	7.80920	Discharge	5.6395	1.00000	Ratio to Peak	1.00000
W380	4.784	92.138	0	0.888	0.06637	Discharge	0.2029	0.68042	Ratio to Peak	0.43045

Annex 10. Donsol Model Reach Parameters

Reach	Muskingum-Cunge Channel Routing						
Number	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side slope
R30	Automatic Fixed Interval	2335.6	0.43297	1.00000	Trapezoid	35.961	1
R60	Automatic Fixed Interval	1910.5	0.21088	0.48358	Trapezoid	35.961	1
R70	Automatic Fixed Interval	38.3	0.05785	0.04033	Trapezoid	35.961	1
R100	Automatic Fixed Interval	2067.2	0.10355	0.25088	Trapezoid	35.961	1
R120	Automatic Fixed Interval	747.7	0.30433	0.47604	Trapezoid	35.961	1
R130	Automatic Fixed Interval	1044.0	0.00010	0.00010	Trapezoid	35.961	1
R150	Automatic Fixed Interval	3946.9	0.050017	0.0793342	Trapezoid	35.961	1
R180	Automatic Fixed Interval	6420.7	0.0015498	0.0023624	Trapezoid	35.961	1
R190	Automatic Fixed Interval	560.62	0.10352	0.24468	Trapezoid	35.961	1

Annex 11. Donsol Floodplain Field Validation Points

DONSOL			
ID	Latitude	Longitude	Depth
1	12.90223	123.6187	0.5
2	12.90235	123.6189	0.6
3	12.9023	123.6191	0.7
4	12.90274	123.6194	0.9
5	12.90318	123.6196	0.5
6	12.9059	123.622	0
7	12.90714	123.6225	1
8	12.9072	123.6225	0.6
9	12.90742	123.6225	1.1
10	12.90779	123.6227	1.3
11	12.90884	123.6261	1.7
12	12.90896	123.6262	0
13	12.90948	123.6294	1.65
14	12.90931	123.6306	1.6
15	12.90923	123.6304	1.3
16	12.91006	123.6323	1.35
17	12.9111	123.6333	2.9
18	12.91399	123.6392	3.07
19	12.9146	123.6405	3
20	12.91569	123.6414	2.967
21	12.91565	123.6413	3.36
22	12.91751	123.6455	1
23	12.91739	123.6454	2.2
24	12.91827	123.6495	0.4
25	12.90096	123.6162	0.8
26	12.90081	123.6157	0.1
27	12.90105	123.6146	0.1
28	12.90148	123.6124	0.23
29	12.90018	123.6159	0.92
30	12.89782	123.6308	0
31	12.89795	123.631	0.25
32	12.90043	123.6158	0.58
33	12.90009	123.6158	0.75
34	12.89979	123.6162	1.17
35	12.89931	123.6167	0.36
36	12.89916	123.617	0
37	12.90043	123.6166	0.8
38	12.89893	123.617	0
39	12.89871	123.617	1.15
40	12.89872	123.619	0.78
41	12.89865	123.6189	0.54

DONSOL			
ID	Latitude	Longitude	Depth
42	12.89873	123.6192	0.49
43	12.89878	123.6191	1.27
44	12.89865	123.6194	0.2
45	12.89846	123.6197	0.15
46	12.89845	123.6199	1.07
47	12.89835	123.6204	0.7
48	12.89811	123.6208	1.35
49	12.8979	123.6212	0.8
50	12.8985	123.6215	0.6
51	12.89813	123.6236	0
52	12.89839	123.6238	0.4
53	12.89839	123.6246	0.98
54	12.89831	123.6249	0.98
55	12.89812	123.6267	0.54
56	12.89758	123.6282	0.8
57	12.89749	123.631	0
58	12.89581	123.6339	0.57
59	12.89546	123.6343	0.56
60	12.89443	123.6362	0.48
61	12.8941	123.6364	0.45
62	12.89798	123.6385	0.25
63	12.89814	123.6387	0.32
64	12.89812	123.6388	0.4
65	12.90126	123.6438	0
65	12.90123	123.6438	0
66	12.90127	123.6441	0
67	12.90255	123.6459	0
68	12.91337	123.6487	0
69	12.92347	123.6561	0.5
70	12.92359	123.6561	0.95
71	12.91726	123.6557	0
72	12.90092	123.6162	0.5
73	12.90025	123.617	0.8
74	12.90025	123.6168	1.2
75	12.89988	123.6179	0.5
76	12.89929	123.6201	0.5
77	12.899	123.6211	0.6
78	12.89893	123.6213	0.6
79	12.89838	123.6241	0.8
80	12.89799	123.6312	2
81	12.90249	123.619	0.8
82	12.90235	123.619	0.5
83	12.90408	123.6211	1.5

DONSOL			
ID	Latitude	Longitude	Depth
84	12.90416	123.621	0.5
85	12.90709	123.6225	0.1
86	12.90708	123.6226	0.8
87	12.90739	123.6227	0.5
88	12.90743	123.6225	1
89	12.90806	123.623	0.5
90	12.90896	123.6296	2
91	12.90899	123.6296	0.5
92	12.90919	123.6308	1
93	12.91108	123.633	2
94	12.91101	123.633	2
95	12.9113	123.6341	2.5
96	12.91261	123.6367	1
97	12.91277	123.6368	1
98	12.91372	123.6383	5
99	12.91372	123.6383	3
100	12.9137	123.6382	2
101	12.91637	123.6415	2.5
102	12.91714	123.6438	2
103	12.91742	123.6456	0.8
104	12.91734	123.6458	3
105	12.91735	123.6459	5
106	12.91899	123.6509	0.5
107	12.91949	123.6513	0.5
108	12.96173	123.6749	0.5
109	12.96146	123.6748	0.5
110	12.95935	123.6737	2
111	12.9594	123.6736	2
112	12.95922	123.6733	2
113	12.95921	123.6733	2
114	12.95856	123.6726	3
115	12.95846	123.6726	3
116	12.95845	123.6726	4
117	12.95843	123.6726	3
118	12.95843	123.6726	4
119	12.95585	123.6731	1.5
120	12.95582	123.6732	1.7
121	12.95579	123.6732	1.7
122	12.95454	123.6735	2.5
123	12.95439	123.6736	2.3
124	12.95384	123.6741	2
125	12.95376	123.6742	2
126	12.95375	123.6742	2

DONSOL			
ID	Latitude	Longitude	Depth
127	12.95365	123.6742	1.5
128	12.9528	123.675	2
129	12.95278	123.675	1.5
130	12.95286	123.6751	2
131	12.95273	123.6752	3
132	12.95203	123.6761	2
133	12.95204	123.6762	2
134	12.95105	123.6768	1.3
135	12.95078	123.6766	1.3
136	12.94986	123.6757	1.5
137	12.94992	123.6758	1.5
138	12.94918	123.6748	1.2
139	12.9492	123.6748	2
140	12.94917	123.6749	1
141	12.93584	123.669	0.5
142	12.93584	123.669	1
143	12.93574	123.6688	1
144	12.97412	123.6489	2.5
145	12.96141	123.6747	1
146	12.95923	123.6732	1.5
147	12.95915	123.6731	2
148	12.95895	123.6729	2
149	12.95884	123.6728	2
150	12.9586	123.6727	2.2
151	12.95845	123.6725	1.8
152	12.95666	123.6413	2
153	12.95649	123.6414	2
154	12.95636	123.6414	1.5
155	12.95626	123.6414	0.5
156	12.95658	123.6414	2
157	12.95655	123.6415	3
158	12.95687	123.6411	0.5
159	12.95685	123.6409	3
160	12.95687	123.6408	2
161	12.95523	123.6437	0.5
162	12.95542	123.6436	0.5
163	12.95544	123.6462	0.5
164	12.95545	123.6465	0.2
165	12.95587	123.6533	1
166	12.9558	123.6534	0.8
167	12.95539	123.6543	1
168	12.95547	123.6545	0.2
169	12.95572	123.6546	0.1

DONSOL			
ID	Latitude	Longitude	Depth
170	12.95596	123.6547	0.1
171	12.9548	123.6576	0.1
172	12.95391	123.6622	0.1
173	12.95417	123.6623	0.1
174	12.95427	123.6645	0.1
175	12.95424	123.6646	0.5
176	12.95344	123.6689	0.2
177	12.95201	123.6709	0.1
178	12.95205	123.671	0.1
179	12.95287	123.6738	0.5
180	12.94108	123.6728	0.1
181	12.94102	123.6728	0.1
182	12.94106	123.6727	0.1
183	12.94018	123.6726	1
184	12.94006	123.6726	1
185	12.94	123.6726	1
186	12.93288	123.6665	1
187	12.93276	123.6665	1.2
188	12.93267	123.6663	1.2
189	12.92947	123.666	0.5
190	12.92927	123.6661	0.8
191	12.92914	123.6661	0.9
192	12.89674	123.6322	3
193	12.89673	123.6323	3
194	12.8957	123.6339	0.5
195	12.89576	123.6338	0.5
196	12.89554	123.6342	0.5

Annex 12. Educational Institutions Affected in Donsol Floodplain

ALBAY				
Daraga				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Bigay Elementary School	Bigao			
Lourdes Elementary School	Bigao			
Nabasan Elementary School	Nabasan			
San Ramon Elementary School	San Ramon			
San Ramon Multipurpose Day Care	San Ramon			
San Vicente Grande High School	San Vicente Grande			
Jovellar				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Del Rosario Elementary School	Del Rosario			
San isidro Elementary School	Del Rosario			
San Isidro National High School	Del Rosario			

SORSOGON				
Donsol				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Banuang Gurang Day Care Center	Banuang Gurang	High	High	High
Baras Elementary School	Banuang Gurang			Medium
Alin Day Care Center	Baras	Low	Low	Medium
Alin Elementary School	Baras	Medium	High	High
Cristo Elementary School	Bayawas			
Bamban Elementary school	De Vera	Medium	Medium	Medium
Bamban Elementary School	De Vera	Medium	Medium	Medium
Daycare Brgy Bamban	De Vera	Medium	Medium	Medium
Bayawas Elementary School	Gura			
Gura Elementary School	Gura			
Mabini Day Care Center	Mabini		Low	Low
Mabini Elementary School	Mabini			
Nagalon Elementary School San Vicente	Mabini			
Ogod Daycare Center	Ogod			Low
San Antoio Elementary School	San Antonio			
San Vicente Elementary School	San Vicente			
Tongdol Daycare Center	San Vicente			
Tungdol Elementary School	San Vicente			
DSWD Sevilla Day Care Center	Sevilla			
Sevilla Elementary School	Sevilla			

SORSOGON				
Pilar				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Cogdongon Elementary School	Abucay			
Day Care Center Cagdongon	Abucay			
Lipason Elementary School	Abucay			
Abucay Elementary School	Cabiguan	Low	Medium	Medium
Abucay National High School	Cabiguan			
Calongay Elementary School	Calongay			
Cabiguan Elementary School	Catamlangan	Medium	Medium	High
Catamlangan Elementary School	Catamlangan	Medium	Medium	High
Leona Elementary School	Catamlangan			
Migabod Elementary School	Catamlangan			
Abucay National High School	Leona			
Mabanate Elementary School	Mabanate	Medium	High	High
MM2P Learning Center and SMMG(closed)(clinic)	Marifosque			
Leona Elementary School	San Antonio			
Pinagsalog Elementary School	San Antonio			
San Antonio or Millabas	San Antonio			

Annex 13. Medical Institutions Affected in Donsol Floodplain

ALBAY				
Daraga				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Barangay Health Station	San Vicente Grande			
Jovellar				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Brgy Del Rosario Health Center	Del Rosario			

SORSOGON				
Donsol				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Baras Barangay Health Center	Banuang Gurang		High	High
Brgy Alin Health Center	Baras	Medium	High	High
Barangay Cristo Health Center	Bayawas			
Healthcare Center	De Vera	Medium	Medium	Medium
Mabini Health Center	Mabini			
Brgy Health Center	Sevilla			
Jovellar				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Lipason Health Center	Abucay			
Intergrated Health Center	Cabiguan			
Intervida Health Facility	Cabiguan			
Health Center Mabanate	San Jose	Medium	High	High