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

LiDAR Surveys and Flood Mapping of Magallanes River

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

APRIL 2017

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

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

E.C. Paringit, and M.M. Santillan, (Eds.). (2017), LiDAR Surveys and Flood Mapping Report of Magallanes River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-187pp

For questions/queries regarding this report, contact:

Engr. Meriam Makinano-Santillan
Project Leader, Phil-LiDAR 1 Program
CARAGA State University
Butuan City, Agusan del Norte, 8600
E-mail: mmsantillan@carsu.edu.ph

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

National Library of the Philippines
ISBN: 987-621-430-026-6

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ABSD	AB Surveying and Development
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
CSU	CARAGA State University
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 MAGALLANES RIVER

Enrico C. Paringit, Dr. Eng., Engr. Meriam Makinano-Santillan, Jojene R. Santillan, Almer Cris N. Estorque, and Arthur A. Amora

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) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the Caraga State University (CSU). CSU 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 13 river basins in the Eastern Mindanao Region. The university is located in Butuan City in the province of Agusan del Norte..

1.2 Overview of the Magallanes River Basin

The Magallanes River Basin is located in the northeastern portion of the Island of Mindanao, Philippines. It lies generally between 125°35' to 125°49' east longitude and 9°21' to 9°36' north latitude. It got its name from a barangay named Magallanes, which is located in the mouth of one of the major rivers in the basin. The basin includes a major part of the municipalities of Bacuag, Gigacuit, and Claver, Surigao del Norte. The basin covers an area of approximately 384 square kilometers, and is about 28 kilometers long and averages about 23 kilometers in width.

The Magallanes River Basin is composed of three major rivers namely, Bacuag River in the municipality of Bacuag, Alambique River in the municipality of Gigaquit, and Baoy River in the municipality of Claver. All these rivers drain into the Philippine Sea. The river channels are wide and navigable by motor boat from downstream to upstream at an approximate distance of 3.8 kilometers from Barangay Campo, Bacuag, Surigao del Norte for Bacuag River, 6.7 kilometers from Barangay Anibongan, Gigacuit, Surigao del Norte for Alambique River, and 7.6 kilometers from Barangay Magallanes, Claver, Surigao del Norte for Baoy River.

The climate of the basin is Type II, which is characterized by no dry season but with a very pronounced precipitation period generally during November to January. The seasonal precipitation distribution, which is similar to that of the nearby Agusan River Basin, is caused primarily by the three main seasonal winds that pass through it. The northeast monsoon passes during the period from October to January, the trade wind with an east to southeast direction from February to April, and the southwest monsoon for the rest of the year.

The basin's highest point is at 1,175 meters above mean sea level situated at the mountain ridges along Barangay Baleguian, Municipality of Jabonga, Agusan del Norte. The most abundant soil type in the basin based on maps published by the Department of Agriculture was clay-loam, which accounts for 25% of the basin's land area. The basin is mostly covered by open canopy forests and brush land leaving the built-up areas only covering less than 1 % of the basin.

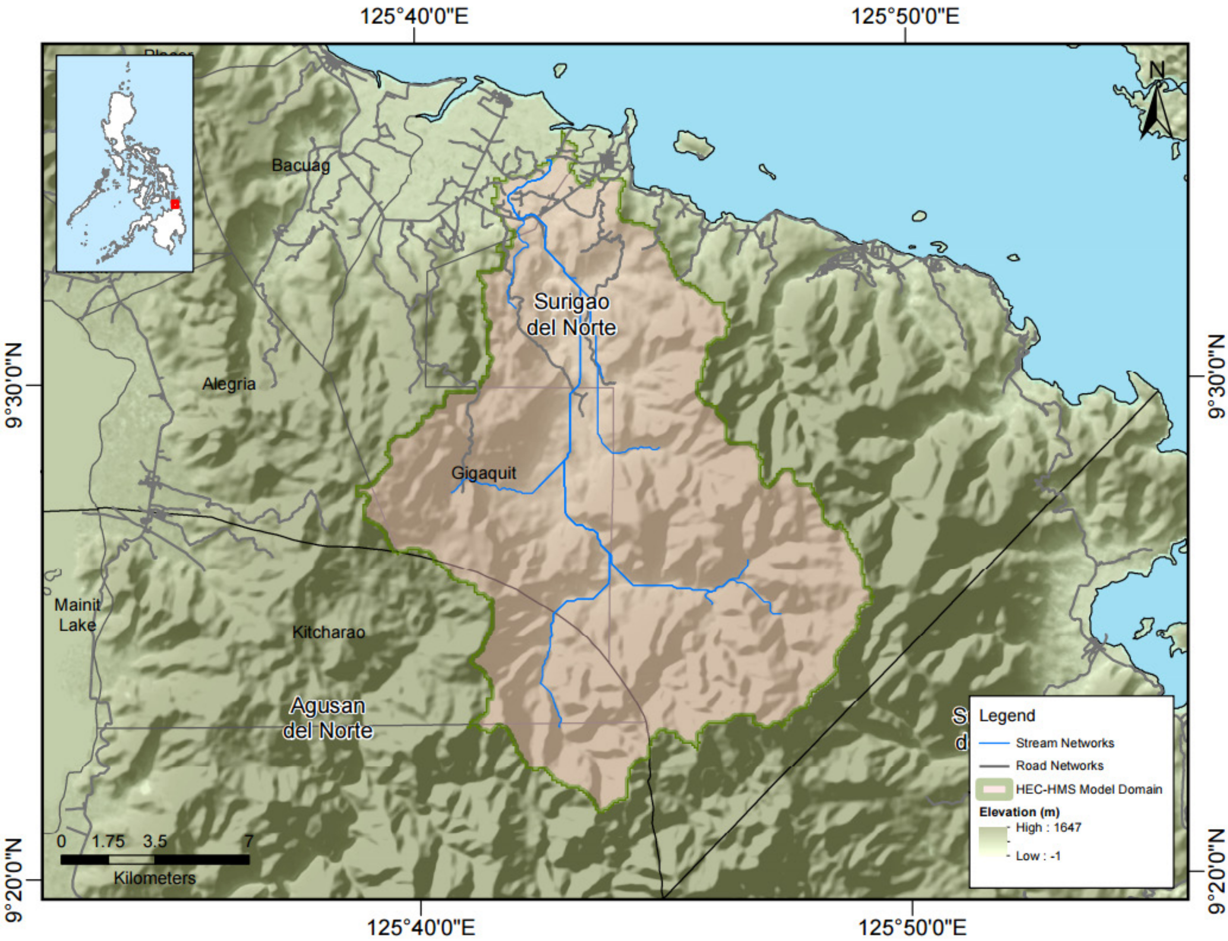


Figure 1. Map of Magallanes River Basin (in brown)

Built-up areas and communities in the basin are concentrated in each respective poblacion or the business district area of the municipalities. Out of the three municipalities in the basin, the Municipality of Claver, is considered a first class municipality and the largest one in the province of Surigao del Norte. According to the 2015 census, it has a population of 32,773 people. The Campo-Bacuag Bridge in the municipality of Bacuag and Daywan Bridge in the municipality of Claver plies the Surigao-Davao Coastal Road and connects the municipalities and other localities in the northwest to Carrascal, Surigao Del Sur in the southeast.

The local language of residents in the river basin is Surigaonon although some people used the Cebuano language. The municipality of Claver became the most progressive municipality within the river basin. Claver primarily became a mining town. Ion, nickel, copper, and silver deposits are abundant on its Pulang Lupa mountains, and are mainly exploited by the mining companies. Mining, trading, and traditional farming and fishing are the main sources of livelihood among residents. Fishing has become increasingly difficult due to water pollution because of mining activities. Bacuag Water District and Claver Water District provides the people, particularly in the urban areas, with clean water sourced from the basin's upstream watersheds.

The municipalities of Bacuag, Gigacuit, and Claver are some of localities that were affected during the onslaught of Tropical Storm "Agaton" in January 2014. It can be recalled that "Agaton" was the first Tropical Storm that affected the country. It was a low pressure area and developed into a Tropical Depression 130 kilometers northeast of Guiian, Eastern Samar in the morning of 17 January 2014, and it moved westward slowly at 5 kilometers per hour closer to the provinces of Surigao del Norte and Surigao del Sur. The slow movement of "Agaton" and the continuous rain and strong winds that it brought along has caused flooding and landslides not only in the Municipality of Magallanes but also in other localities in Mindanao.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MAGALLANES FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuna, Engr. Gerome Hipolito, Ms. Pauline Joanne G. Arceo, Engr. Gef F. Soriano

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Magallanes floodplain in Surigao del Norte. Each flight mission has an average of 12 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 are found in Table 1 and Table 2. Figure 2 shows the flight plan for Magallanes floodplain.

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK59s	600	30	18	50	45	130	5

Table 2. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK59C	800	30	50	125	50	130	5
BLK59D	800	30	50	125	50	130	5
BLK59F	800	30	50	125	50	130	5
BLK59G	800	30	50	125	50	130	5
BLK60C	800	30	50	125	50	130	5
BLK60D	800	30	50	125	50	130	5

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

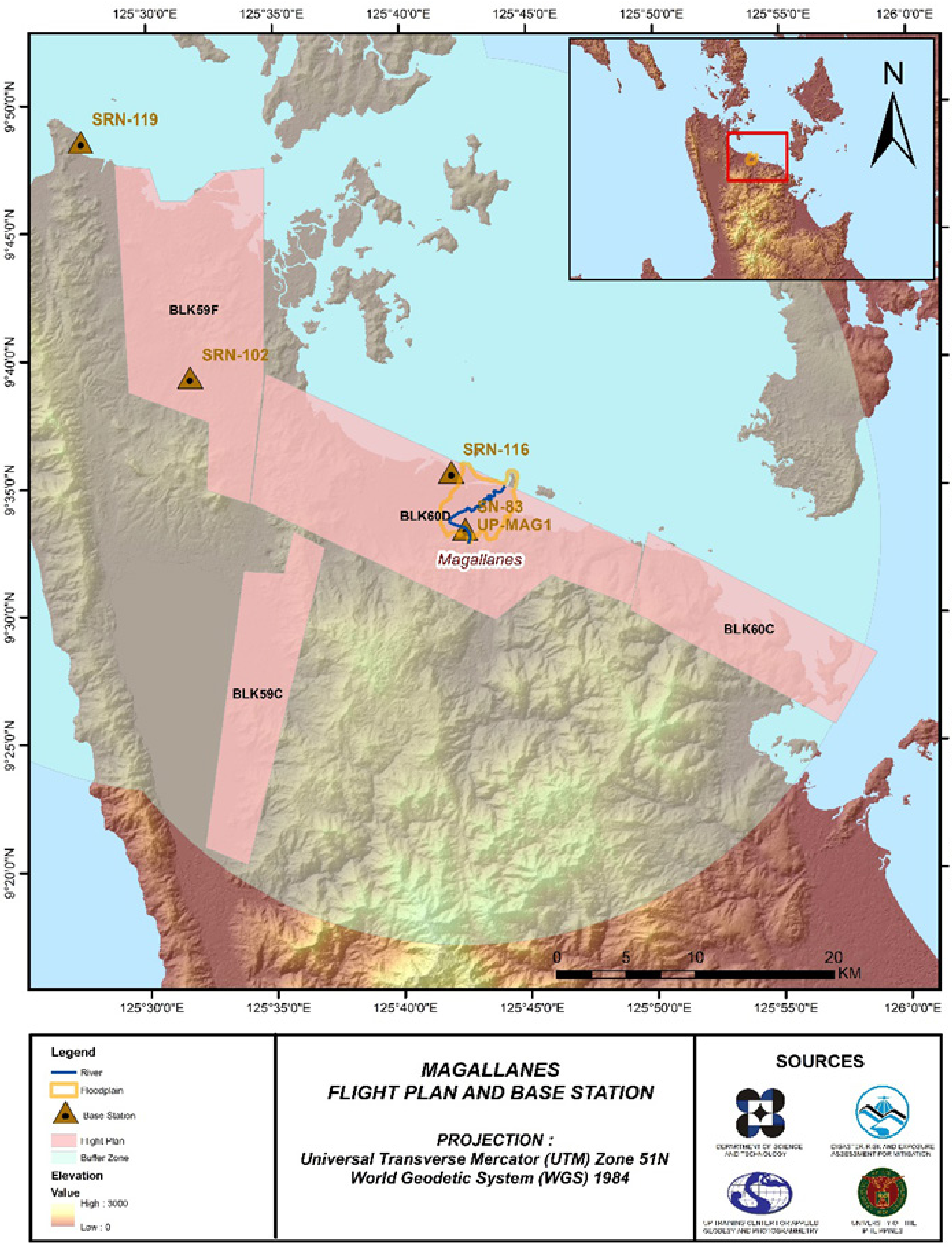


Figure 2. Flight Plans and base stations used for Magallanes Floodplain.

2.2 Ground Base Stations

The project team/s was able to recover three (3) NAMRIA ground control points: SRN-116, SRN-102, SRN-119, which are of second (2nd) order accuracy, and one (1) NAMRIA benchmark, SN-83. The project team also established one (1) ground control point, UP-MAG1. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the established points are found in Annex D. These were used as base stations during flight operations for the entire duration of the survey (July 31, 2014, September 9-10, 2014, and May 11-12, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS852, SPS985, and Topcon GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Magallanes floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 7 shows the details about the following NAMRIA control stations while Table 8 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a) (b)

Figure 3. GPS set-up over SRN-119 Kilometer Post 1114 along the National Highway at Surigao City, Surigao Del Norte (a) and NAMRIA reference point SRN-119 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point SRN-119 used as base station for the LiDAR Acquisition.

Station Name	**SRN-119**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1: 50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 48' 39.52825" North 125° 27' 19.47825" East 26.179 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	549958.116 meters 1084859.315 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 48' 35.66803" North 125° 27' 24.75607" East 92.905 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	769495.998 meters 1085380.264 meters

(a)

(b)

Figure 4. GPS set-up over SRN-102 at the first approach of Patag Bridge (right side) located at the Municipality of Sison, Surigao Del Norte (a) and NAMRIA reference point SRN-102 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point SRN-102 used as base station for the LiDAR Acquisition.

Station Name	SRN-102	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 39' 24.81730" North 125° 31' 40.71501" East 35.047 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	557783.962 meters 1067892.026 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 39' 21.00341" North 125° 31' 40.71501" East 102.294 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	777426.956 meters 1068387.750 meters

Figure 5. GPS set-up over SRN-116 in front of Ipil Primary School, near the concrete fence located at Gigaquit, Surigao Del Norte (a) and NAMRIA reference point SRN-116 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point SRN-116 used as base station for the LiDAR Acquisition.

Station Name	SRN-116	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference Of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 35' 38.35819" North 125° 41' 52.08650" East 2.650 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	576598.493 meters 1060905.34 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 35' 34.57572" North 125° 41' 57.38121" East 70.459 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	796293.133 meters 1061570.526 meters

Table 6. Details of the recovered NAMRIA vertical control point SN-83 used as base station for the LiDAR Acquisition.

Station Name	SN-83	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 33’ 23.94445” North 125° 42’ 24.18740” East 12.853 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 33’ 20.17252” North 125° 42’ 29.48535” East 80.767 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	797146.192 meters 1057494.439 meters

Table 7. Details of the recovered ground control point UP-MAG1 used as base station for the LiDAR Acquisition.

Station Name	SN-83	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 33’ 23.85603” North 125° 42’ 23.93365” East 12.425 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 33’ 20.08411” North 125° 42’ 29.23160” East 80.339 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	797138.469 meters 1057491.660 meters

Table 8. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
October 22, 2014	2098A	3BLK59S295A	SRN-119
June 3, 2014	7288GC	2BLK59C + BLK60D154A	SRN-102
June 5, 2014	7292GC	2BLK60DS156A	SRN-102
June 7, 2014	7296GC	2BLK60CDS158A	SRN-116
June 9, 2014	7300GC	2BLK5960V160A	SRN-116
May 11, 2016	8487AC	3BLK60AB132A	UP-MAG1, SN-83
May 18, 2016	8501AC	3BLK60AS139A	UP-MAG1, SN-83

2.3 Flight Missions

Seven (7) missions were conducted to complete the LiDAR data acquisition in Magallanes floodplain, for a total twenty five hours and twelve minutes (25+12) of flying time for RP-C9022 and RP-C9322. All missions are acquired using the Aquarius and Gemini LiDAR systems. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for the LiDAR data acquisition of the Magallanes Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
October 22, 2014	2098A	6.29	18.30	-	18.30	380	2	0
June 3, 2014	7288GC	328.25	209.13	8.06	201.07	NA	4	23
June 5, 2014	7292GC	231.82	167.60	12.09	155.51	NA	3	59
June 7, 2014	7296GC	102.86	188.31	-	188.31	NA	4	29
June 9, 2014	7300GC	24.15	136.23	2.00	134.24	NA	3	41
May 11, 2016	8487AC	102.86	70.11	9.44	60.67	NA	4	35
May 18, 2016	8501AC	231.82	19.29	4.08	15.22	NA	2	5
TOTAL		**1028.05**	**808.95**	**35.66**	**566.70**	**380**	**25**	**12**

Table 10. Actual parameters used during the LiDAR data acquisition of the Magallanes Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2098A	600	30	36	50	45	130	5
7288GC	800	30	50	125	50	130	5
7292GC	800	30	50	125	50	130	5
7296GC	800	30	50	125	50	130	5
7300GC	800	30	50	125	50	130	5
8487AC	500	30	36	50	45	130	5
8501AC	500	30	36	50	45	130	5

2.4 Survey Coverage

Magallanes floodplain is located in the province of Surigao del Norte. Municipalities of Alegria and Bacuag are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Magallanes floodplain is presented in Figure 6.

Table 11. List of municipalities and cities surveyed of the Magallanes Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Surigao del Norte	Alegria	63.68	57.67	91%
	Bacuag	88.79	70.14	79%
	Claver	37.53	23.34	62%
	Gigaquit	337.34	150.06	44%
	Mainit Lake	79.04	33.71	43%
	Mainit	119.02	41.17	35%
	Placer	68.78	15.88	23%
	Sison	81.99	9.76	12%
	Surigao City	240.67	19.39	8%
	Tagana-An	114.07	8.99	8%
Surigao del Sur	Carrascal	317.34	26.65	8%
Agusan del Norte	Jabonga	122.41	25.80	21%
	Kitcharao	69.28	6.56	9%
	Mainit Lake	269.89	18.19	7%
Total		**2009.83**	**507.31**	**25.24%**

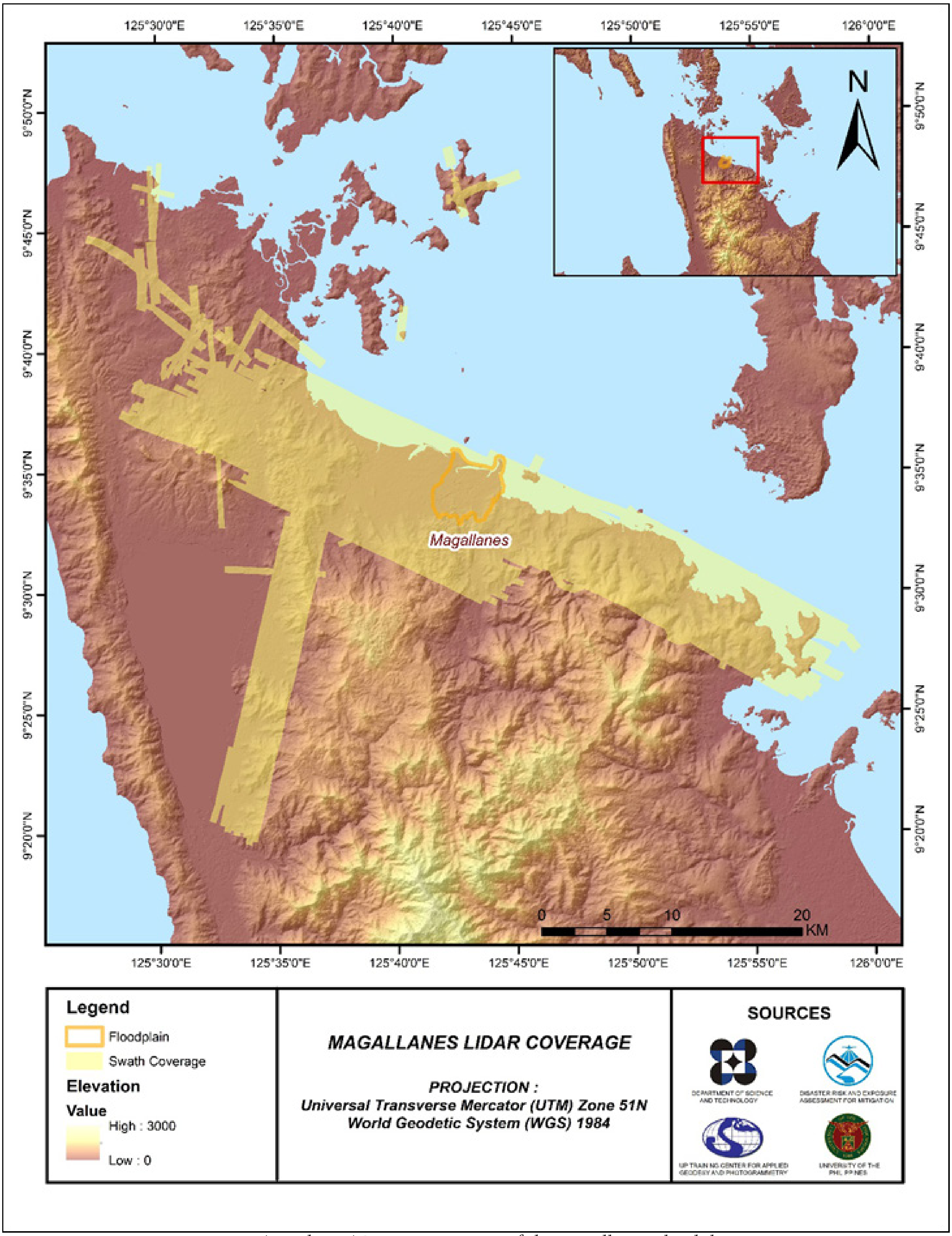


Figure 6. Actual LiDAR survey coverage of the Magallanes Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MAGALLANES FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Engr. Elainne R. Lopez , Engr. Ma. Ailyn L. Olanda, Aljon Rie V. Araneta, Engr. Irish R. Cortez, Engr. Christy T. Lubiano, Myra Laika C. Estur

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

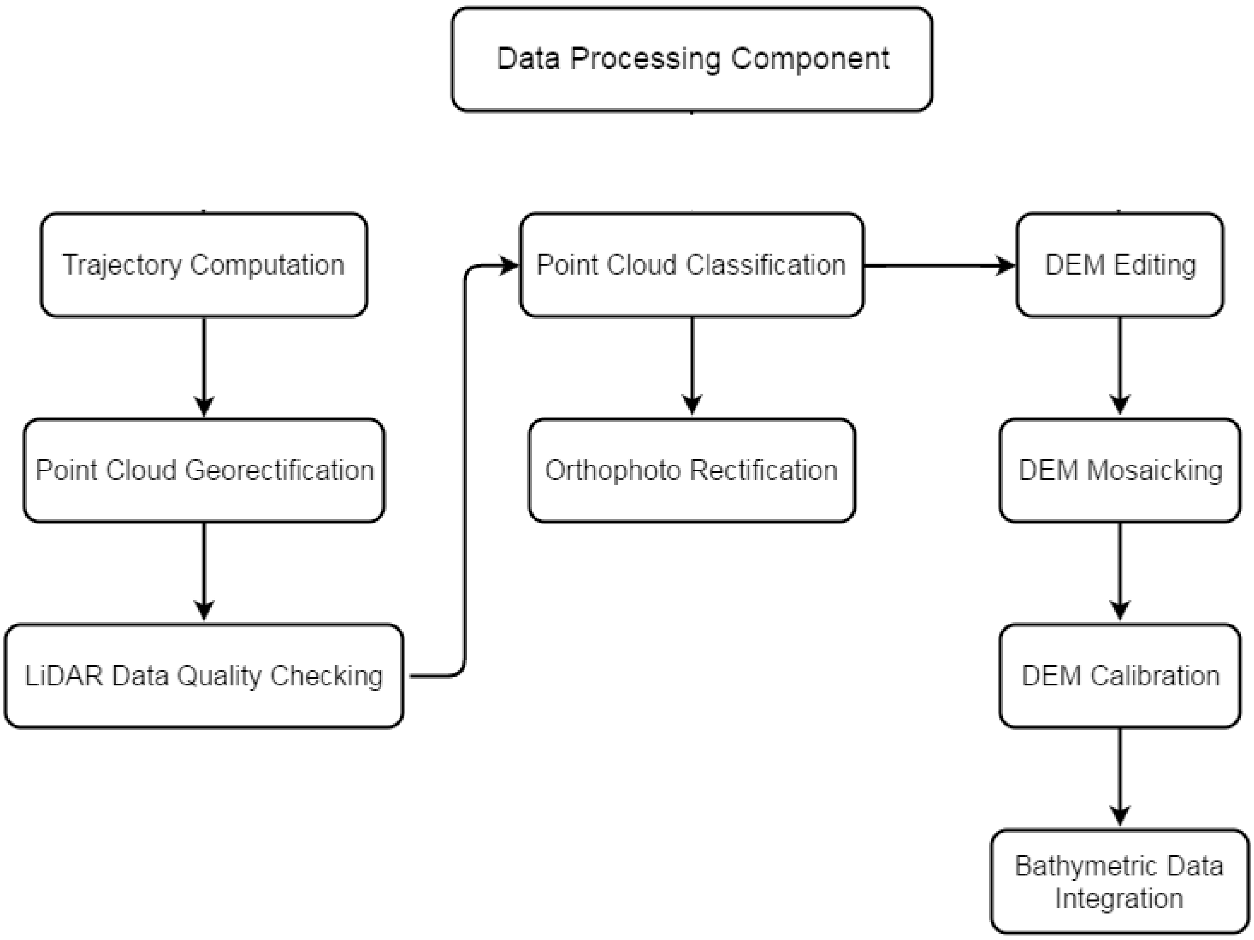


Figure 7. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Magallanes floodplain can be found in Annex 5: Data Transfer Sheets. Missions flown during the first survey conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius and Gemini systems over Surigao del Norte.

The Data Acquisition Component (DAC) transferred a total of 96.67 Gigabytes of Range data, 1.45 Gigabytes of POS data, 200.40 Megabytes of GPS base station data, and 88.2 Gigabytes of raw image data to the data server on June 16, 2014 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Magallanes was fully transferred on October 31, 2014, as indicated on the Data Transfer Sheets for Magallanes floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 8487A, one of the Magallanes flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 16, 2014 00:00 AM. The y-axis is the RMSE value for that particular position.

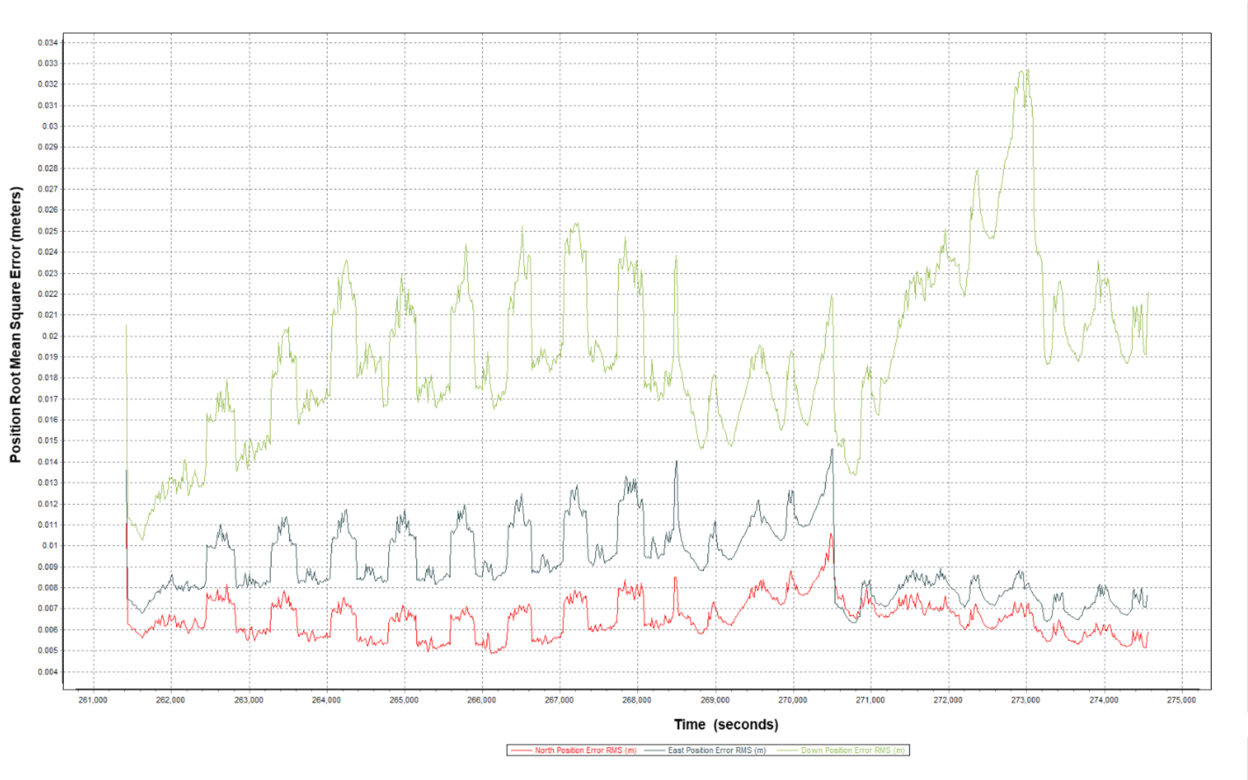


Figure 8. Smoothed Performance Metric Parameters of Magallanes Flight 8487A.

The time of flight was from 261,400 seconds to 274,600 seconds, which corresponds to morning of June 16, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 2.40 centimeters, the East position RMSE peaks at 2.80 centimeters, and the Down position RMSE peaks at 4.60 centimeters, which are within the prescribed accuracies described in the methodology.

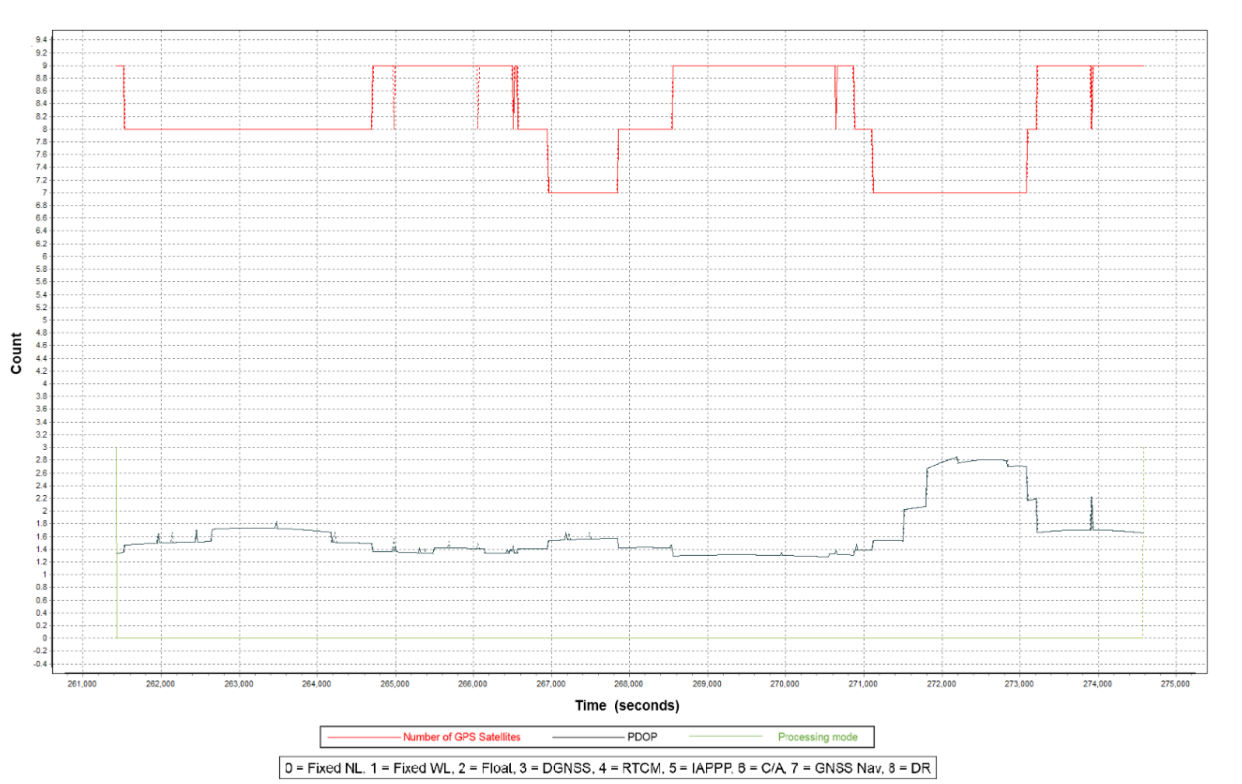


Figure 9. Solution Status Parameters of Magallanes Flight 8487A.

The Solution Status parameters of flight 8487A, one of the Magallanes flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. 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 Magallanes flights is shown in Figure 10.

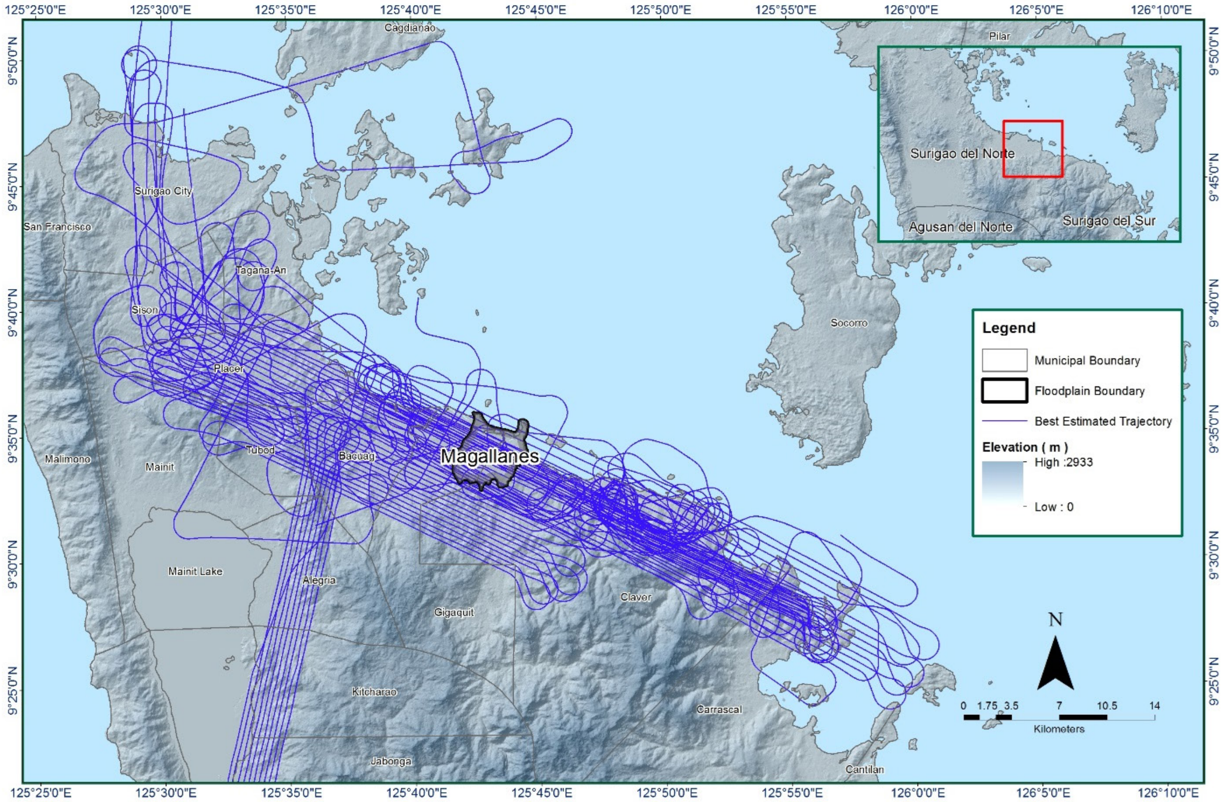


Figure 10. Best Estimated Trajectory of the LiDAR missions conducted over the Magallanes Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 129 flight lines, with each flight line containing one channel, since the Gemini and Aquarius 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 Magallanes floodplain are given in Table 12.

Table 12. Self-calibration Results values for Magallanes flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000167
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000941
GPS Position Z-correction stdev	<0.01meters	0.0027

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

3.5 LiDAR Data Quality Checking

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

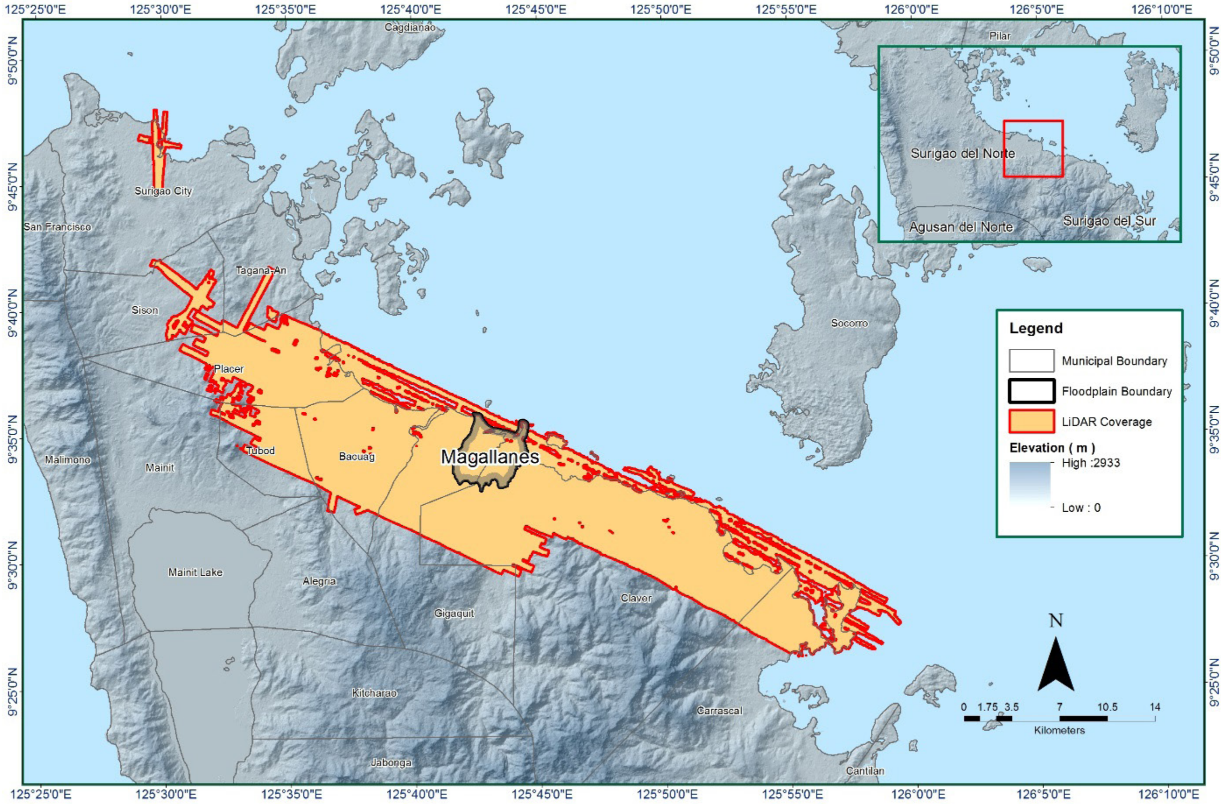


Figure 11. Boundary of the processed LiDAR data over Magallanes Floodplain

The total area covered by the Magallanes missions is 610.45 sq.km that is comprised of eleven (11) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Magallanes Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Siargao_Blk59S	2098A	16.23
Surigao_reflights_Blk60C	8487A	67.23
Surigao_reflights_Blk60D_supplement	8501A	31.68
SurigaoDelNorte_Blk60C	7296G	107.39
SurigaoDelNorte_Blk60D	7288G	255.31
	7292G	
	7296G	
SurigaoDelNorte_Blk60D_supplement	7292G	61.44
	7288G	
SurigaoDelNorte_Blk60D_additional	7300G	39.08
SurigaoDelNorte_Blk60C_additional	7300G	32.09
TOTAL		**610.45 sq.km**

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

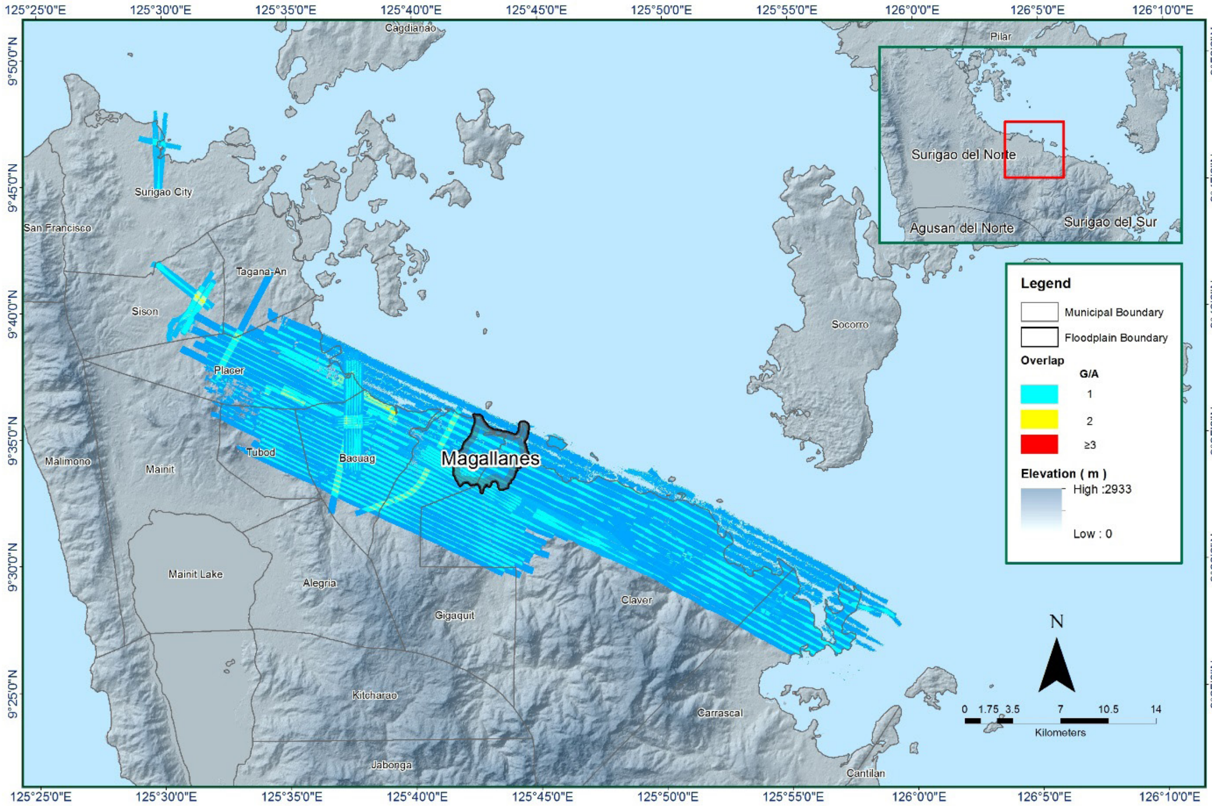


Figure 12. Image of data overlap for Magallanes Floodplain.

The overlap statistics per block for the Magallanes floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.16% and 62.60% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Magallanes floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.70 points per square meter.

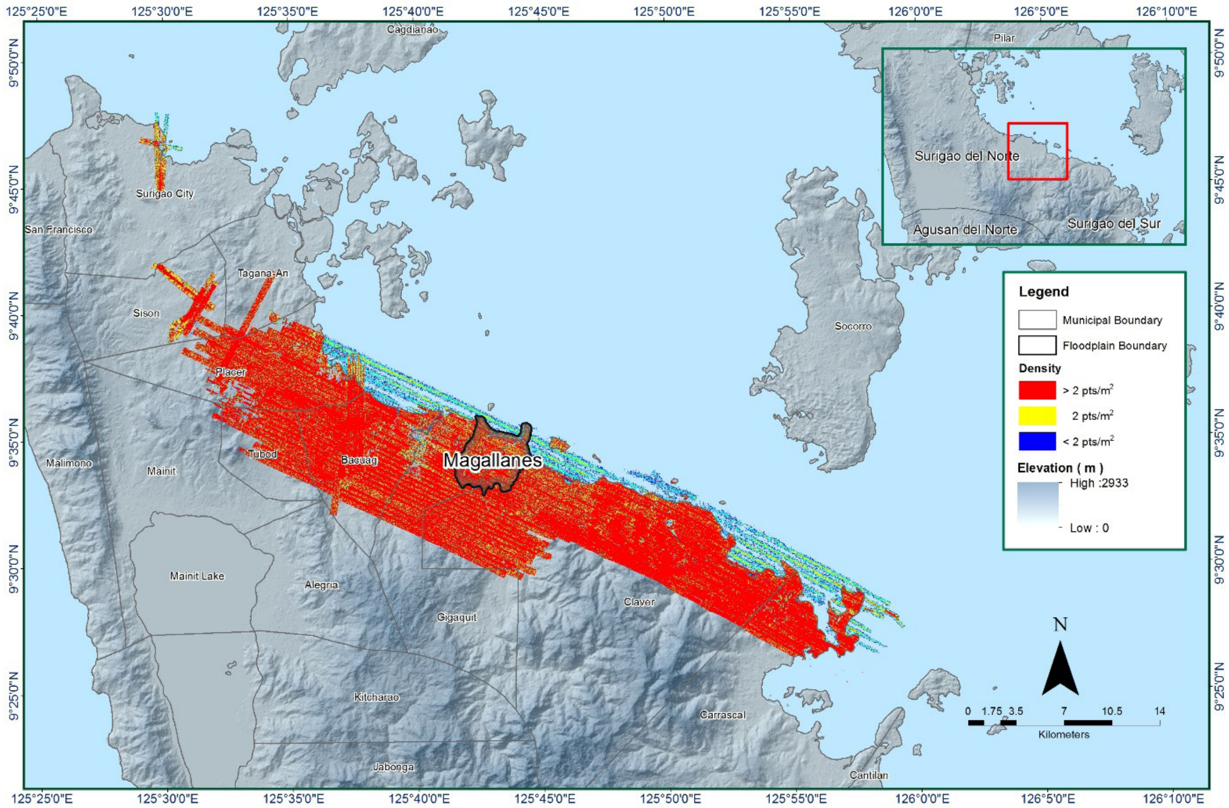


Figure 13. Pulse density map of merged LiDAR data for Magallanes Floodplain.

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

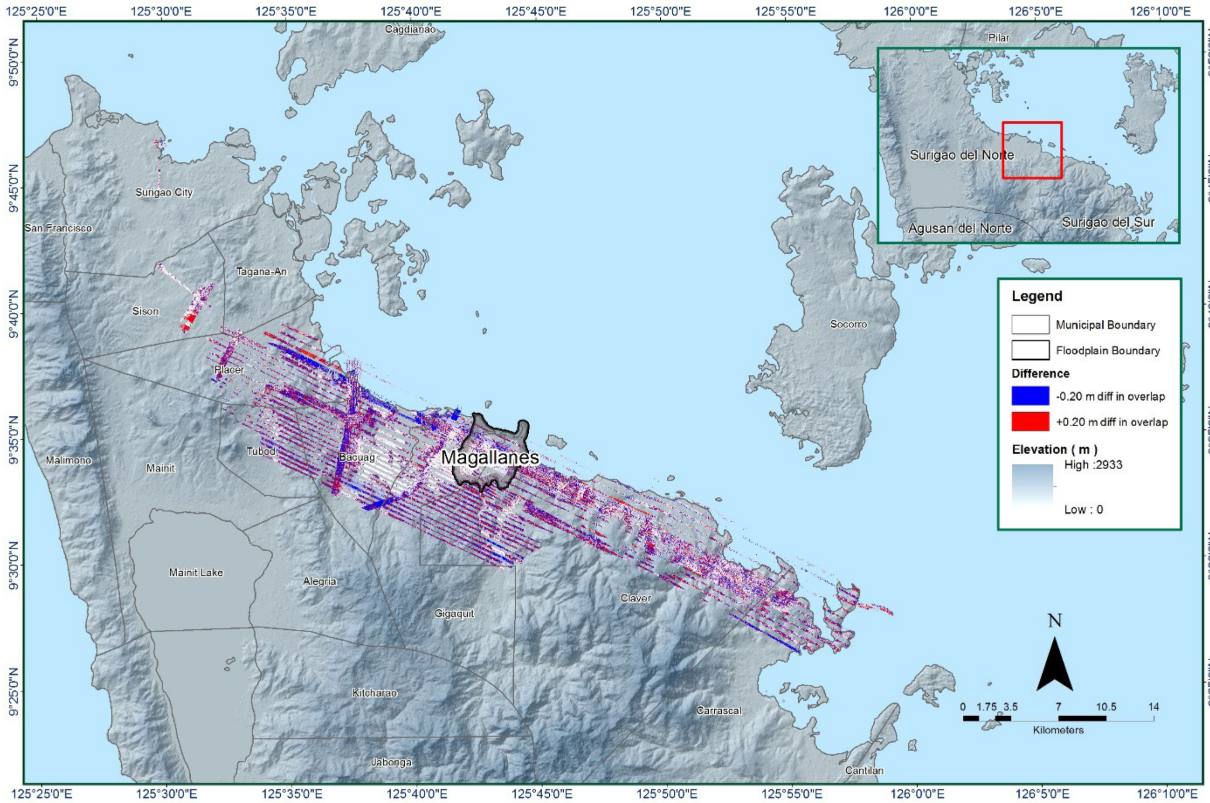


Figure 14. Elevation Difference Map between flight lines for Magallanes Floodplain Survey.

A screen capture of the processed LAS data from a Magallanes flight 8487A loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed 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.

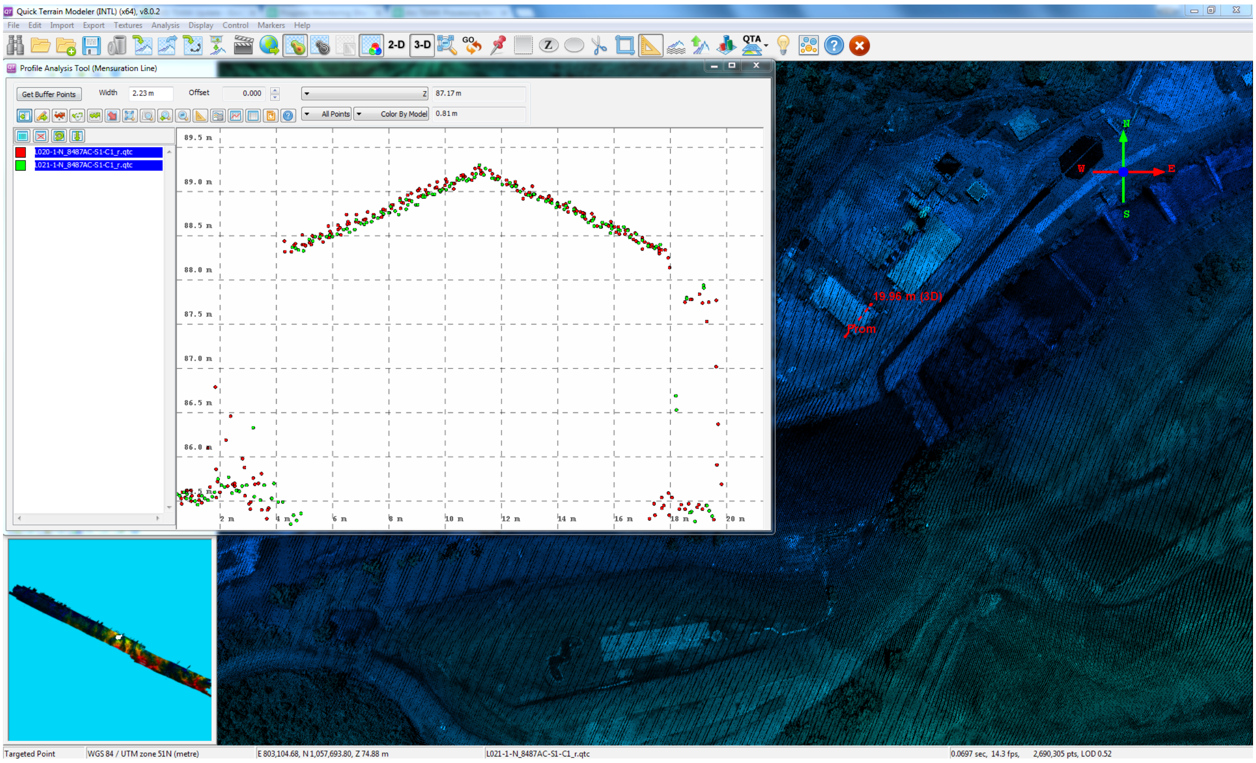


Figure 15. Quality checking for Magallanes flight 8487A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Magallanes classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	296,539,011
Low Vegetation	214,889,047
Medium Vegetation	376,783,680
High Vegetation	965,987,972
Building	1,9065,946

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Magallanes floodplain is shown in Table 16. A total of 1,186 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 962.45 meters and 60.00 meters respectively.

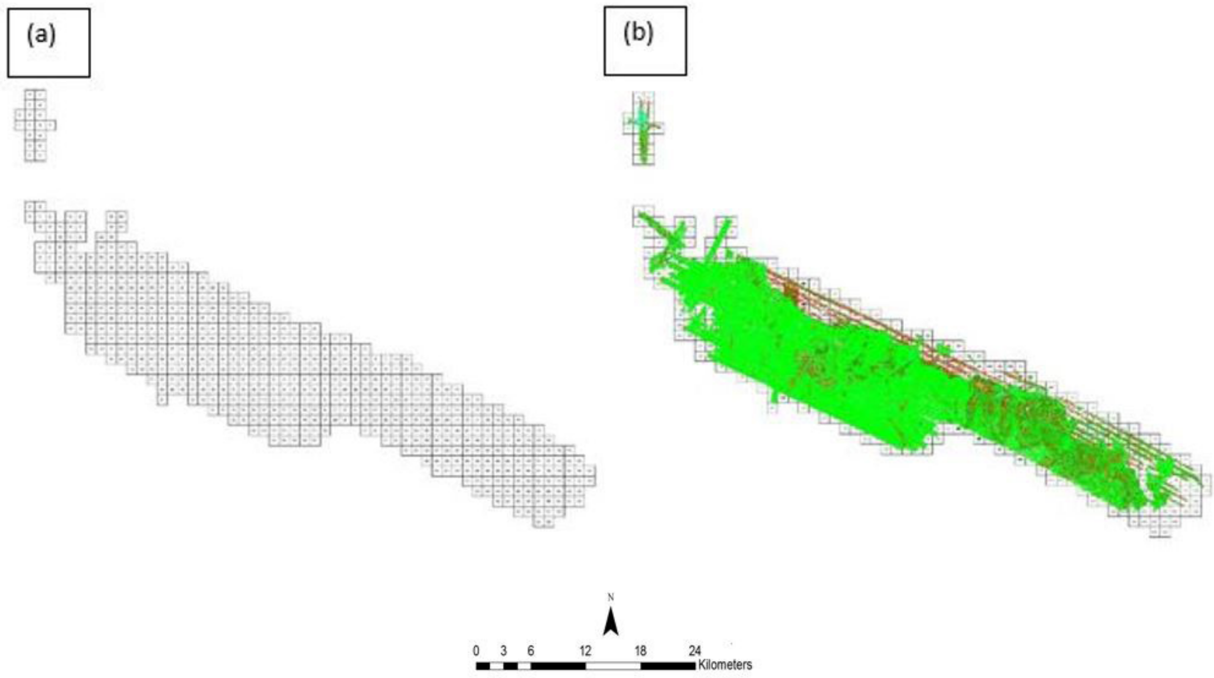


Figure 16. Tiles for Magallanes Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

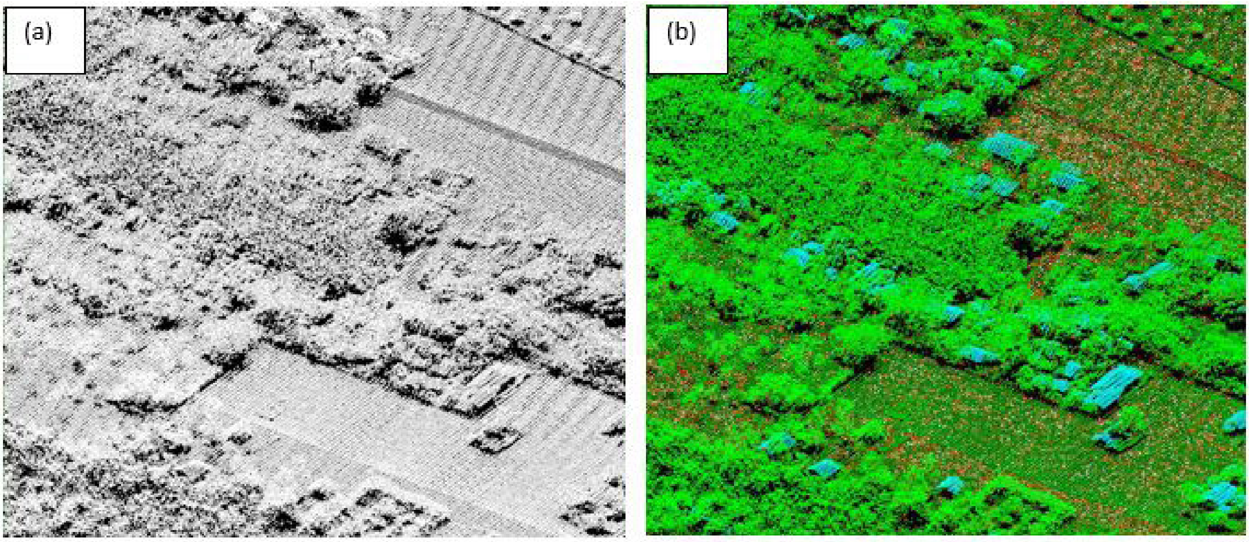


Figure 17. Point cloud before (a) and after (b) classification

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

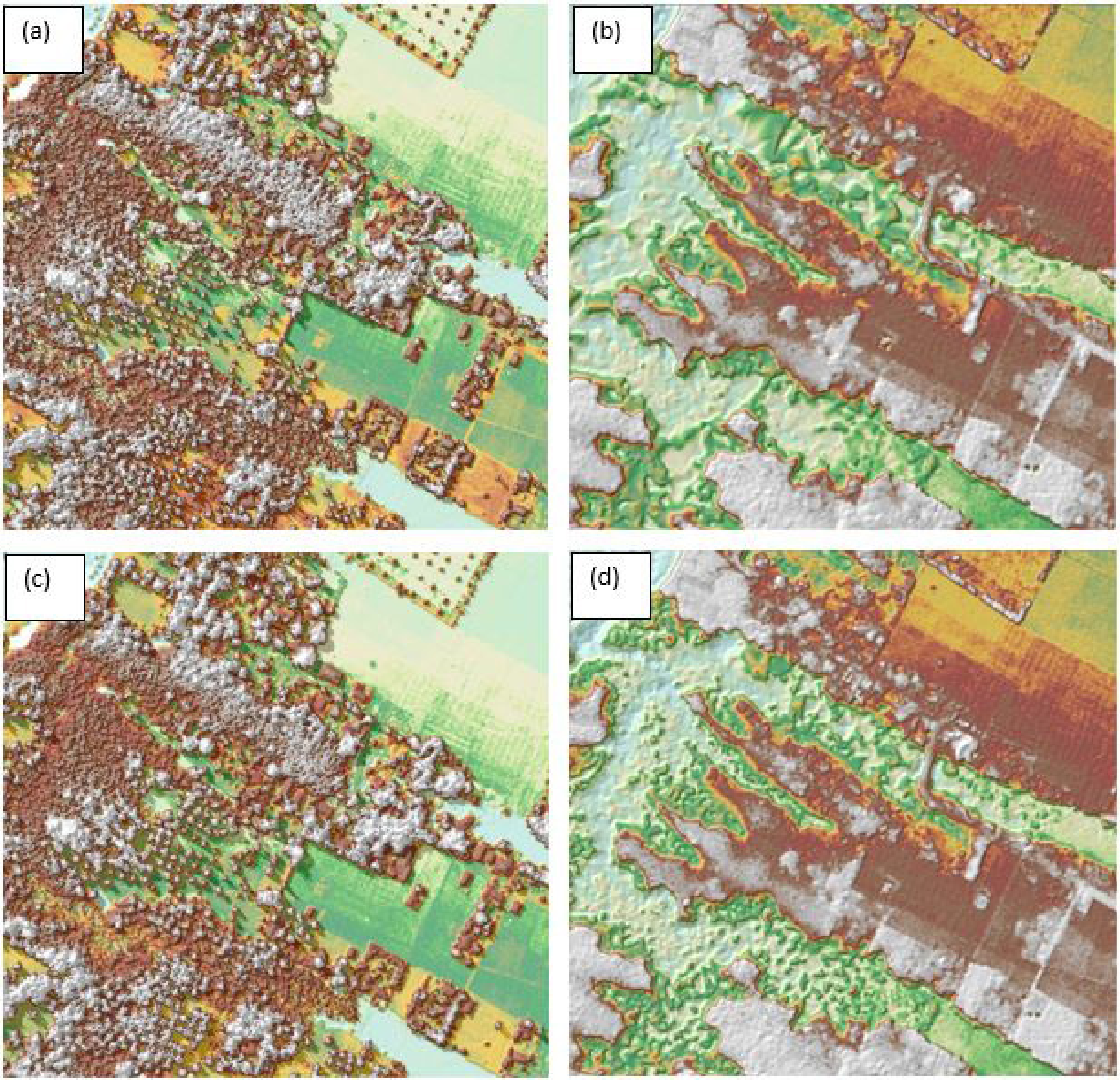


Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Magallanes Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Magallanes floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Magallanes flood plain. These are composed of SurigaodelNorte, Siargao and Surigao_reflights blocks with a total area of 610.45 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Siargao_Blk59S	16.23
Surigao_reflights_Blk60C	67.23
Surigao_reflights_Blk60D_supplement	31.68
SurigaoDelNorte_Blk60C	107.39
SurigaoDelNorte_Blk60D	255.31
SurigaoDelNorte_Blk60D_supplement	61.44
SurigaoDelNorte_Blk60D_additional	39.08
SurigaoDelNorte_Blk60C_additional	32.09
TOTAL	**610.45 sq.km**

Portions of DTM before and after manual editing are shown in Figure 19. Hilly portions (Figure 19a) have been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19b) to allow the correct flow of water. The bridge (Figure 19c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 19d) in order to hydrologically correct the river. Another example is a building that is still present in the DTM after classification (Figure 19e) and has to be removed through manual editing (Figure 19f).

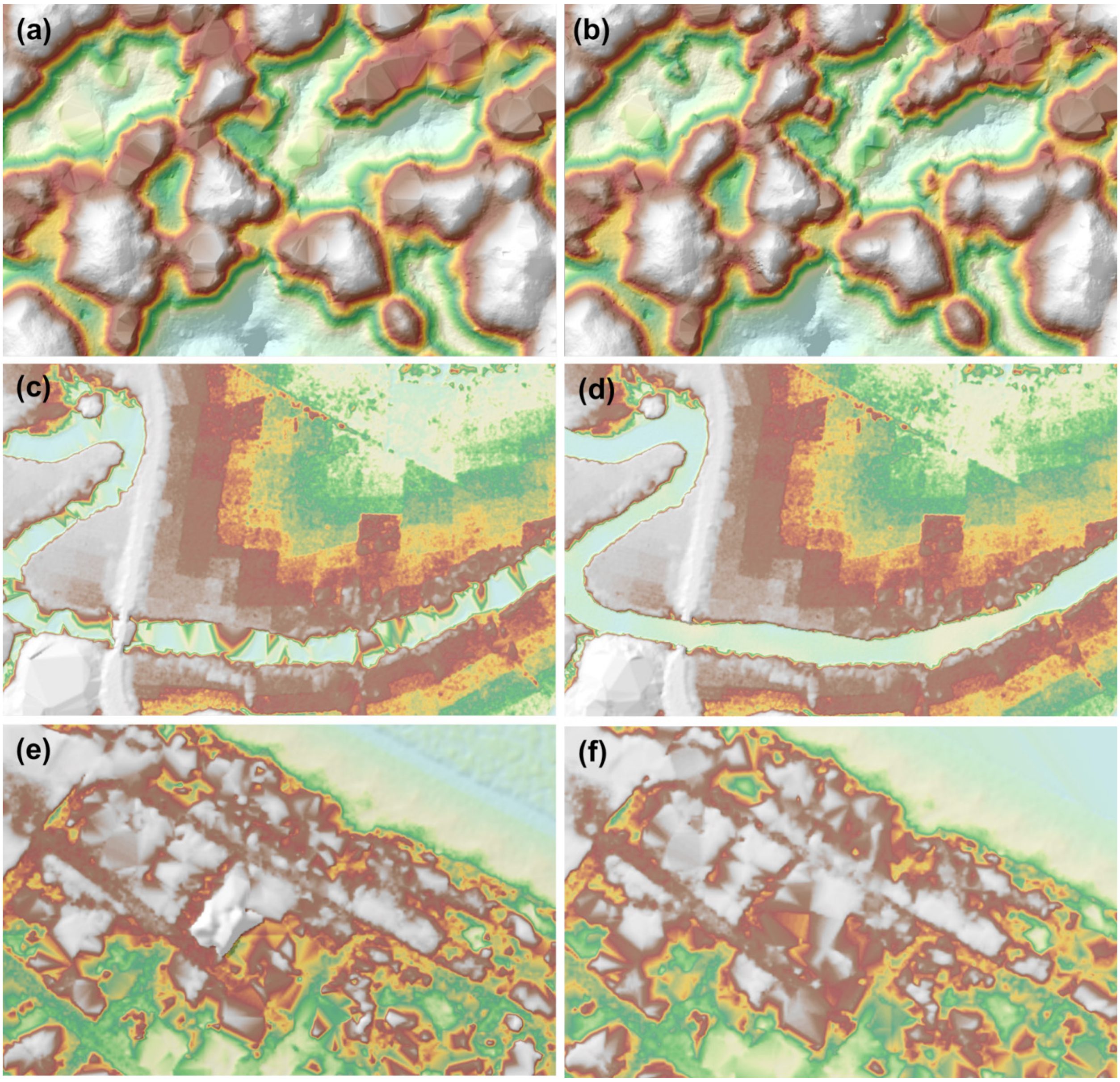


Figure 19. Portions in the DTM of Magallanes Floodplain – hilly portions before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

SurigaodelNorte_Blk59F was used as the reference block at the start of mosaicking because this block contained national highway in which the validation surveys passed through this road. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Magallanes floodplain is shown in Figure 20. It can be seen that the entire Magallanes floodplain is 97.80% covered by LiDAR data.

Table 16. Shift values of each LiDAR block of Magallanes Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Siargao_Blk59S	0.00	0.00	0.53
SurigaodelNorte_Blk60C	0.00	0.00	0.06
SurigaodelNorte_Blk60D	0.00	0.00	-0.70
SurigaodelNorte_Blk60D_Supplement	0.00	0.00	0.01
SurigaodelNorte_Blk60D_Additional	0.00	0.00	0.01
SurigaodelNorte_Blk60C_Additional	0.00	0.00	0.01
Surigao_reflights_Blk60C	0.00	0.00	0.62
Surigao_reflights_Blk60D_Supplement	0.00	0.00	0.66

Figure 20. Map of Processed LiDAR Data for Magallanes Floodplain

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

CSU's Field Survey Team (FST) in coordination with the Data Validation and Bathymetry Component (DVBC) in Magallanes conducted surveys to collect points for the Lidar validation (Figure 21). A total of 7,463 survey points were used for calibration and validation of Magallanes LiDAR data. Random selection of 80% of the survey points, resulting to 5,970 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. 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 0.22 meters with a standard deviation of 0.19 meters. Calibration of Magallanes LiDAR data was done by subtracting the height difference value, 0.22 meters, to Magallanes mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

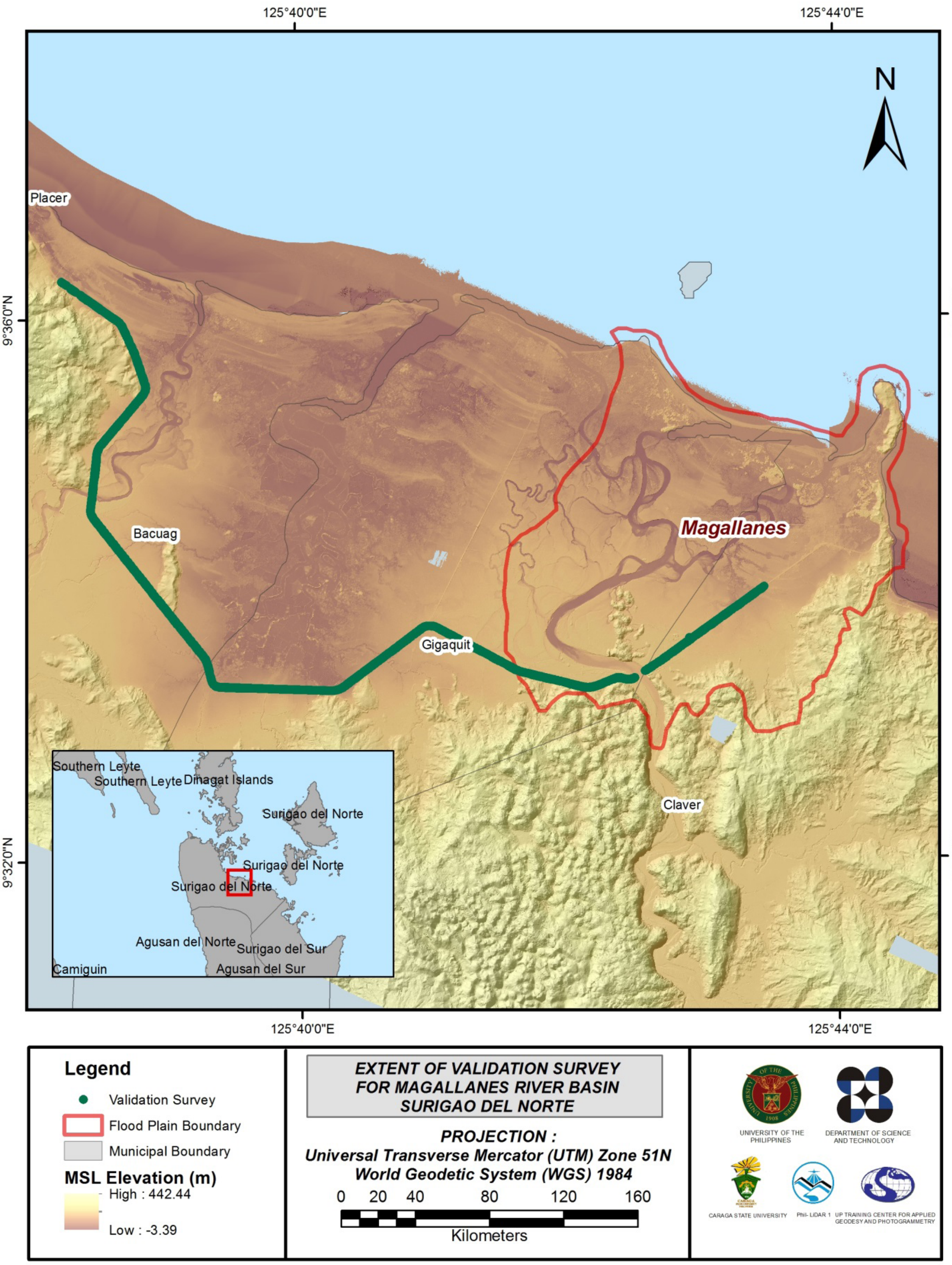


Figure 21. Map of Magallanes Floodplain with validation survey points in green.

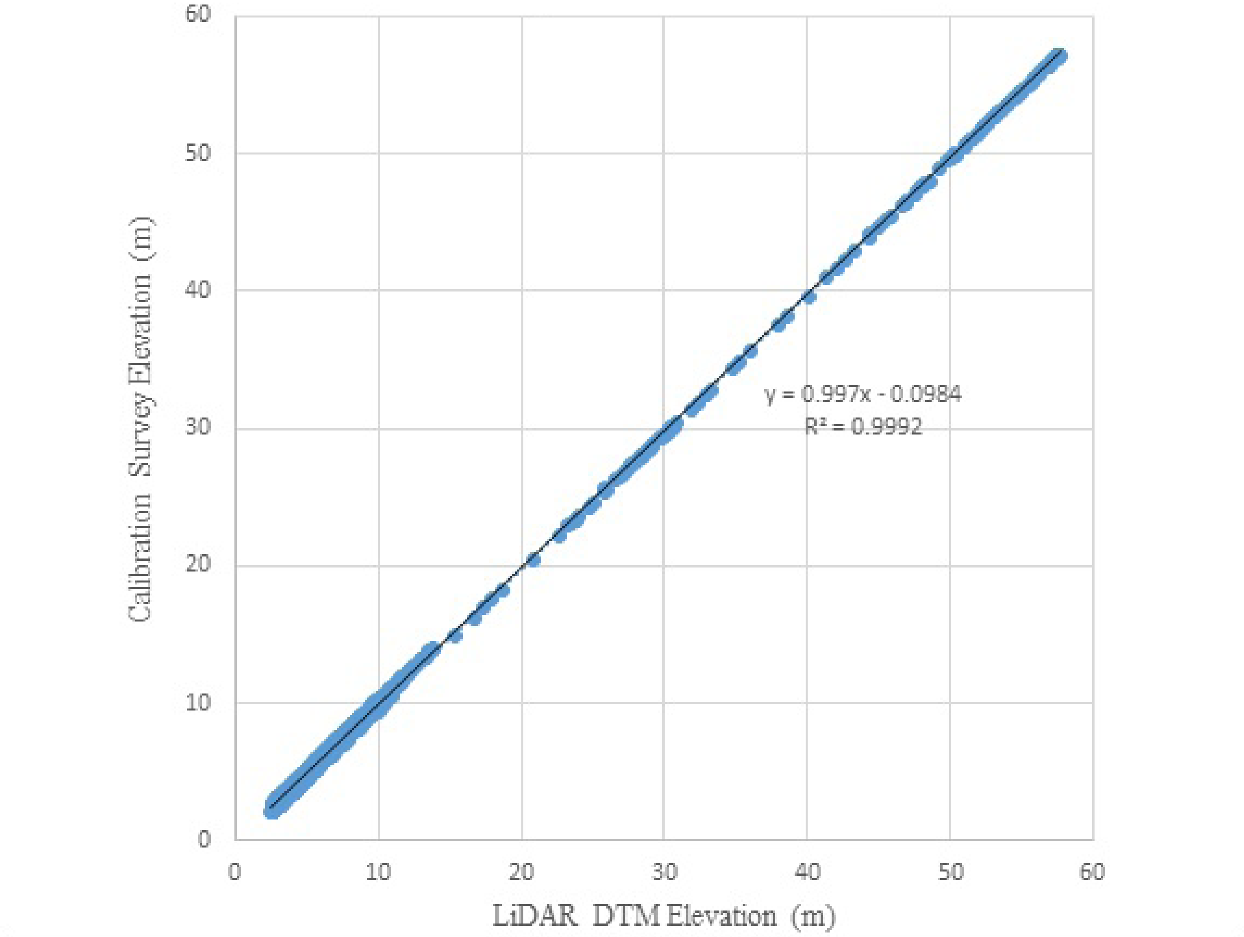


Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.22
Standard Deviation	0.19
Average	-0.12
Minimum	-0.50
Maximum	0.27

The remaining 20% of the total survey points, resulting to 1,493 points, 889 points were located within the Magallanes River Basin. These points were used for the validation of calibrated Magallanes DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.21 meters with a standard deviation of 0.16 meters, as shown in Table 18.

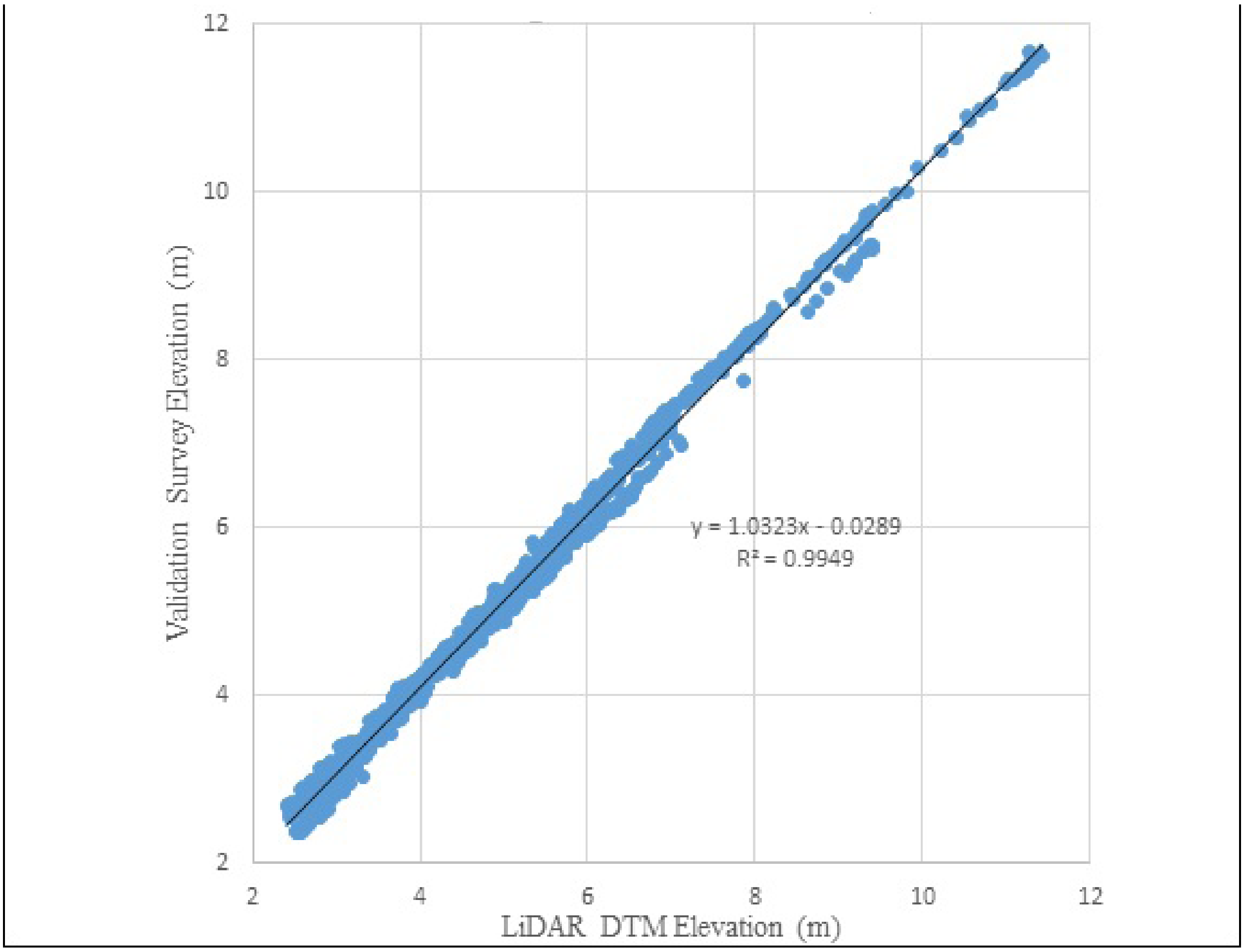


Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.21
Standard Deviation	0.16
Average	0.13
Minimum	-0.20
Maximum	0.45

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Magallanes with 9,645 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.23 meters. The extent of the bathymetric survey done by AB Surveying in coordination with the Data Validation and Bathymetry Component (DVBC) in Magallanes integrated with the processed LiDAR DEM is shown in Figure 24.

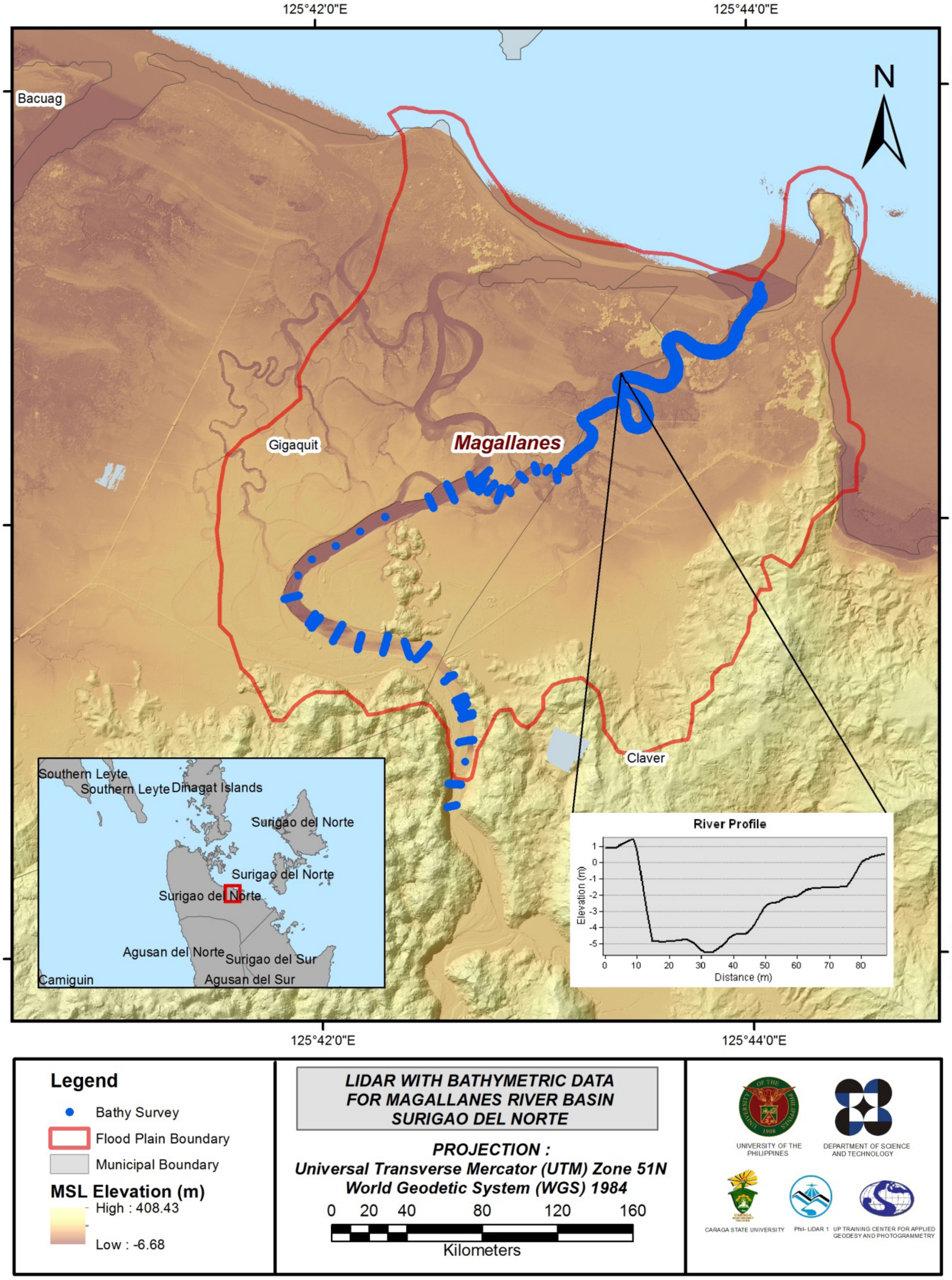


Figure 24. Map of Magallanes Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Magallanes floodplain, including its 200 m buffer, has a total area of 24.20 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,380 building features, are considered for QC. Figure 25 shows the QC blocks for Magallanes floodplain.

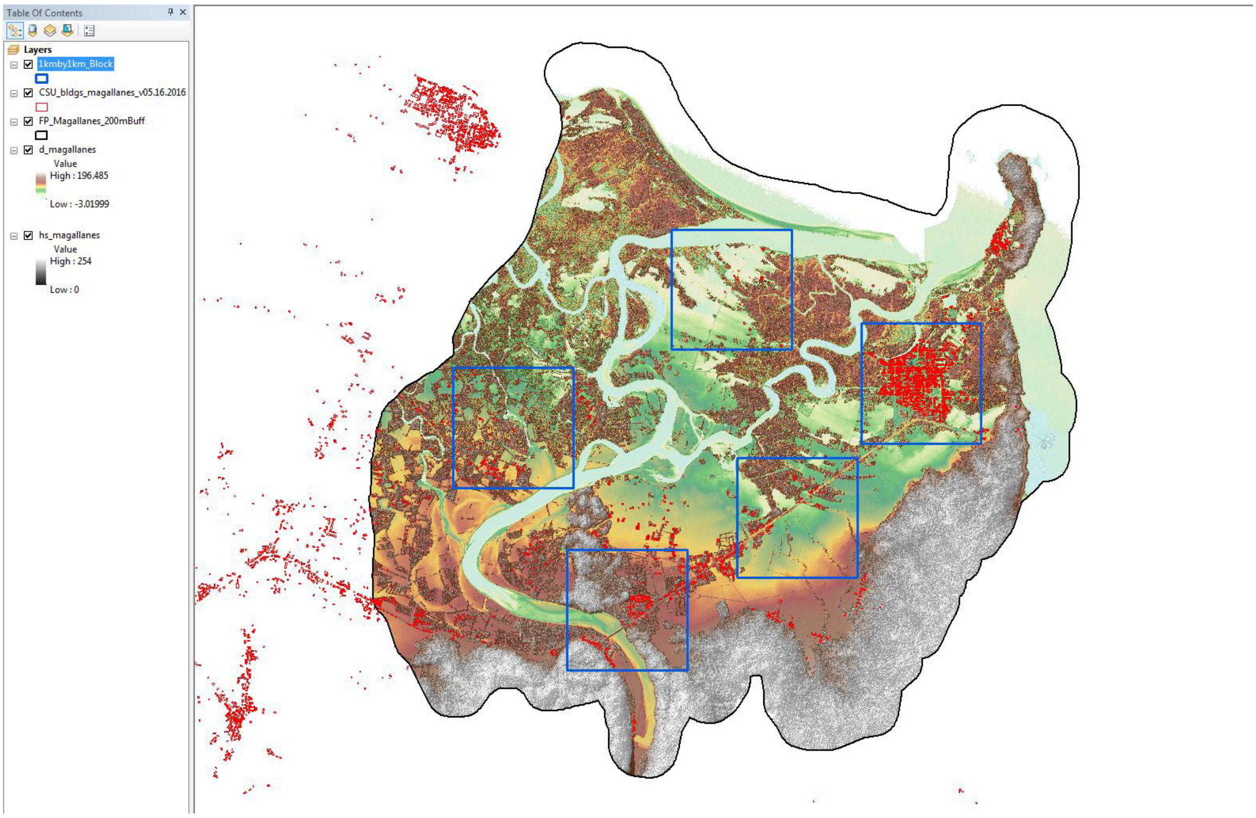


Figure 25. Blocks (in blue) of Magallanes building features that were subjected to QC

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

Table 19. Quality Checking Ratings for Magallanes Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Magallanes	100.00	100.00	98.86	PASSED

3.12.2 Height Extraction

Height extraction was done for 12,696 building features in Magallanes floodplain. Of these building features, 281 buildings were filtered out after height extraction, resulting to 12,415 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 5.47m.

3.12.3 Feature Attribution

Field surveys, familiarity with the area, and free online web maps such as Wikimapia (http://wikimapia.org/) and Google Map (https://www.google.com/maps) were used to gather information such as name and type of the features within the river basin.

Table 20 summarizes the number of building features per type. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Building Features Extracted for Magallanes Floodplain.

Facility Type	No. of Features
Residential	12,046
School	141
Market	2
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	0
Barangay Hall	2
Military Institution	0
Sports Center/Gymnasium/Covered Court	23
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	160
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	0
Religious Institutions	12
Bank	1
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	15
Other Commercial Establishments	10
Total	**12,415**

Table 21. Number of Extracted Roads for Magallanes Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Magallanes	42.83	26.05	61.91	19.01	0.00	149.80

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

Floodplain	Water Body Type						Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Magallanes	24	0	0	1	0	25	267

A total of 36 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 26 shows the Digital Surface Model (DSM) of Magallanes floodplain overlaid with its ground features.

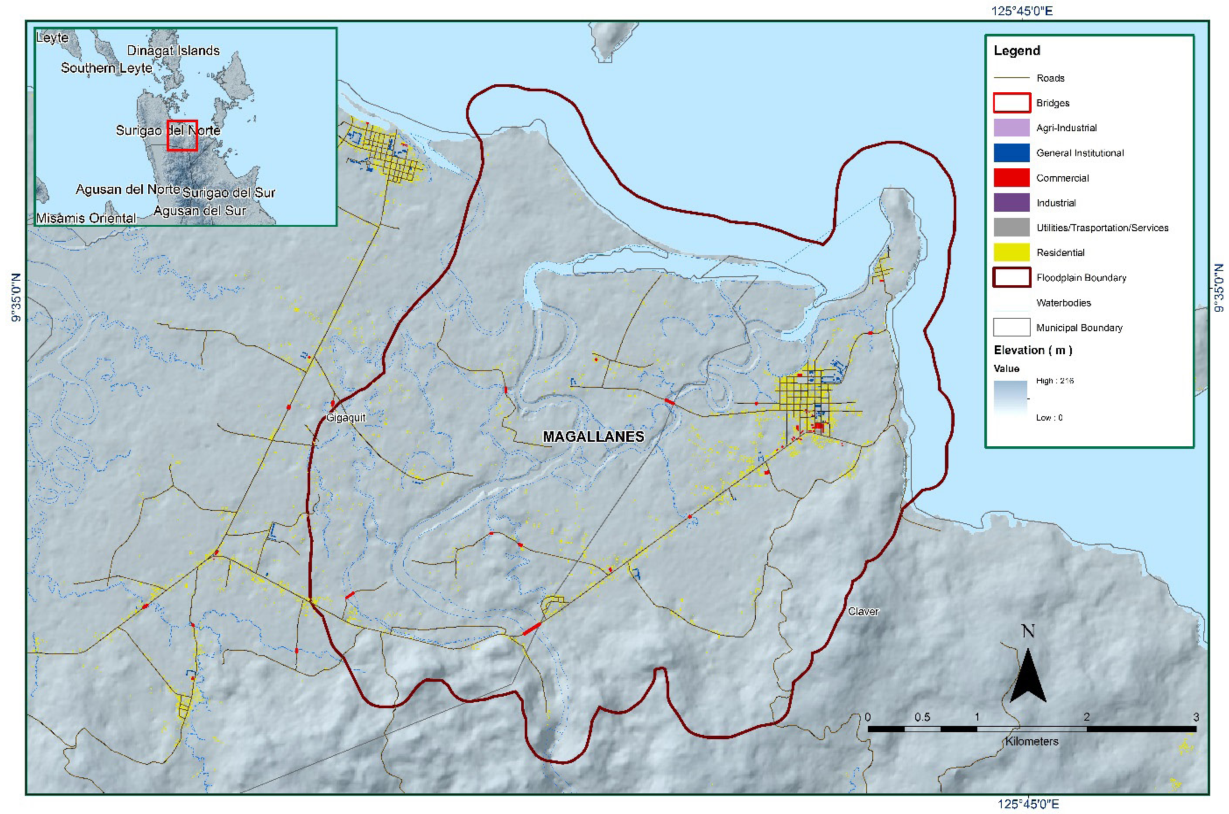


Figure 26. Extracted features for Magallanes Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie Caballero, Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, Vie Marie Paola M. Rivera

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

4.1 Summary of Activities

AB Surveying and Development (ABSD) conducted a field survey in Magallanes River on April 6-9, 2016, April 25, 2016, May 4, 5 and 10-12, 2016, and May 18, 2016 with the following scope: control survey, cross-section, bridge as-built and water level marking in MSL of Magallanes Bridge, bathymetric survey from the mouth of the river in Brgy. Daywan to the upstream in Brgy. San Isidro and manual bathymetric survey from downstream in Brgy. San Isidro to the upstream in Brgy. Sapa in the Municipality of Claver and Gigaquit using GNSS survey technique and Hi-Target™ echo sounder. Bathymetric survey and validation points acquisition survey covering the Magallanes River Basin area were executed by CSU on June 20-24, 2016, June 27-July 1, 2016, and July 11-15, 2016 using a South Single Beam Echo Sounder and South S86T GNSS RTK survey technique. The entire survey extent is illustrated in Figure 27.

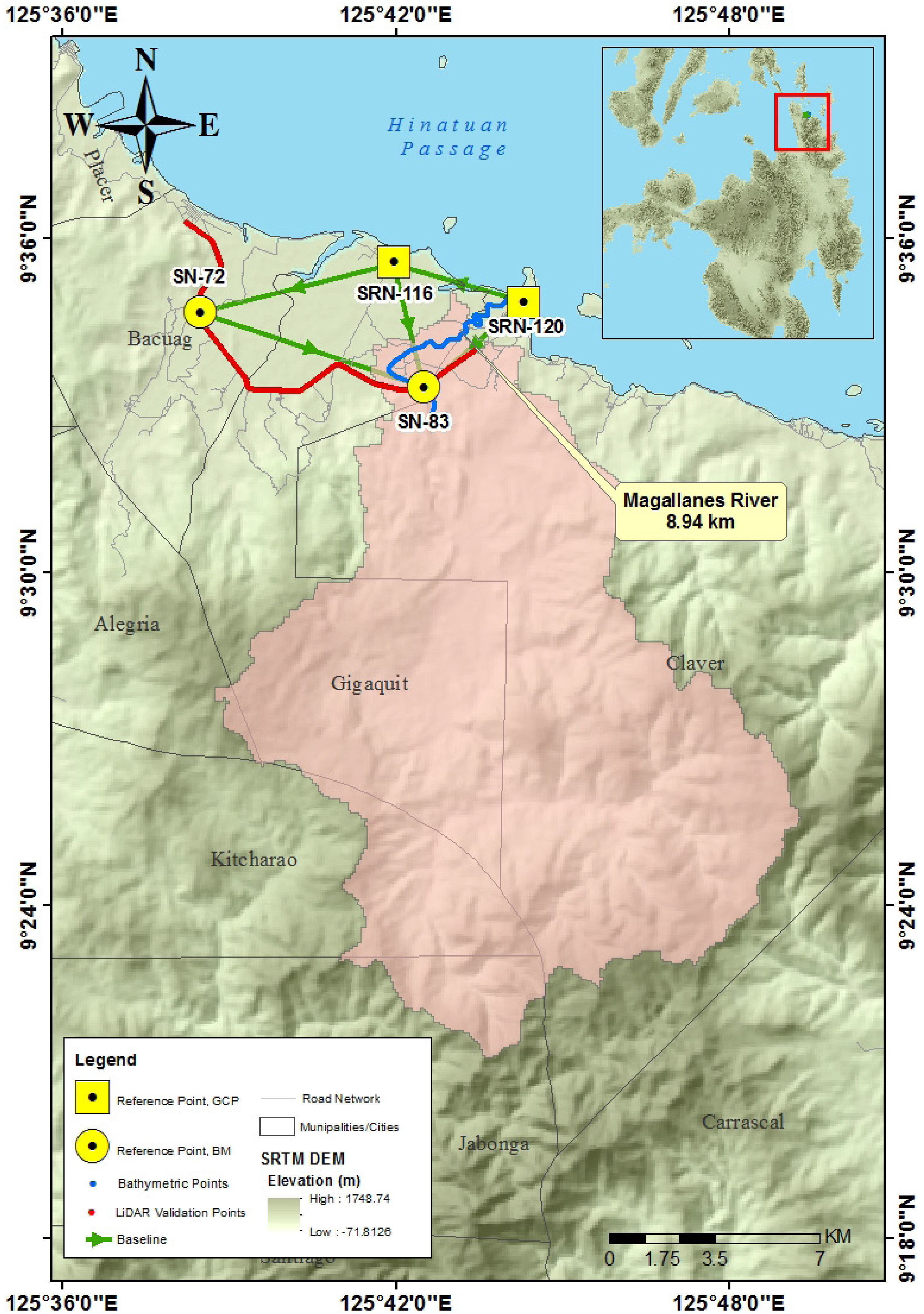


Figure 27. Extent of the bathymetric survey (in blue line) in Magallanes River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Magallanes River is composed of two (2) loops established on April 11-16, 2016 and April 25-27, 2016 occupying the following reference point: SRN-116, a second-order GCP, in Brgy. Ipil, Gigaquit, Surigao del Norte, SRN-120, a second-order GCP, in Brgy. Tayaga, Municipality of Claver, Surigao del Norte, SN-72, a BM, in Brgy. Campo, Bacuag, Surigao del Norte, and SN-83, a BM, in Brgy. San Isidro, Gigaquit, Surigao del Norte.

The summary of reference and control points and its location is summarized in Table 23 and Table 24 while GNSS network established is illustrated in Figure 28.

Table 23. List of Reference and Control Points occupied for Magallanes River Survey (First Network)

(Source: NAMRIA; UP-TCAGP)

Base Station	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
SRN-116	2nd order, GCP	9°33'20.17195"N	125°42'29.48533"E	80.6477	1.4885	2009
SRN-120	2nd order, GCP	9°34’51.71200”N	125°44’18.45049”E	71.1790	2.2169	2007
SN-83	BM	9°33'20.17195"N	125°42'29.48533"E	80.6477	11.4206	2008

Table 24. List of Reference and Control Points occupied for Magallanes River Survey (Second Network)

(Source: NAMRIA; UP-TCAGP)

Base Station	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
SRN-116	2nd order, GCP	9°35'34.57572"N	125°41'57.38121"E	70.4590	1.5296	2007
SN-72	BM	9°34'41.24832"N	125°38'27.85416"E	78.3304	9.4225	2006
SN-83	BM	9°33'20.17263"N	125°42'29.48541"E	80.6066	11.4206	2008

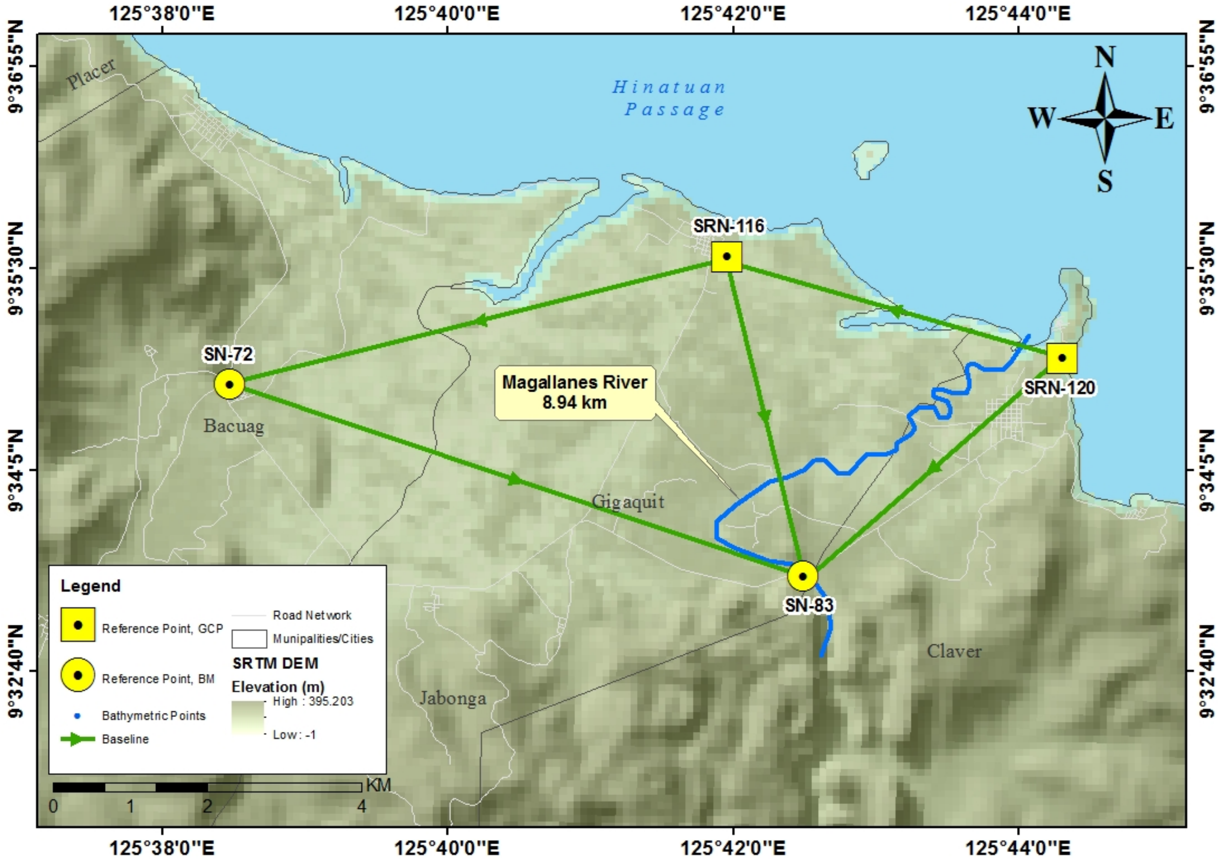


Figure 28. Magallanes River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Magallanes River by ABSD are shown from Figure 29 to Figure 32.

Figure 29. SRN-116, a second-order GCP, located in front of Ipil Primary School, Brgy. Ipil, Gigaquit, Province of Surigao del Norte

Figure 30. SRN-120, a second-order GCP, located in Brgy. Tayaga, Claver, Province of Surigao del Norte

Figure 31. SN-72, a BM, located in Brgy. Campo, Bacuag, Province of Surigao del Norte

Figure 32. SN-72, a BM, located in Brgy. San Isidro, Gigaquit, Province of Surigao del Norte

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in South Processing and TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Magallanes River Basin is summarized in Table 25 and Table 26 generated by TBC software.

Table 25. Baseline Processing Summary Report for Magallanes River Survey (First Network)
(Source: NAMRIA, UP TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SRN-116 --- SN-83	4-11-2016	Fixed	0.004	0.010	166°39'42"	4243.812	10.160
SRN-120--- SN-83	4-11-2016	Fixed	0.005	0.011	229°45'29"	4353.280	9.502
SRN-116--- SRN-120	4-11-2016	Fixed	0.005	0.011	287°01'30"	4498.687	-0.666

Table 26. Baseline Processing Summary Report for Magallanes River Survey (Second Network)
(Source: NAMRIA, UP TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SRN-116 --- SN-83	4-11-2016	Fixed	0.005	0.010	166°39’42”	4243.812	10.147
SRN-116 --- SN-72	4-11-2016	Fixed	0.006	0.012	255°37’19”	6595.874	7.873
SN-72 --- SN-83	4-11-2016	Fixed	0.008	0.014	108°40’20”	7778.157	2.279

As shown in Table 25 and Table 26 a total of six (6) baselines were processed with coordinate and ellipsoidal height values of SRN-116 and SN-83 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

is the Easting Error,

is the Northing Error, and

is the Elevation Error

for each control point. See the Network Adjustment Report shown from Table 27 to Table 32 for the complete details.

The four (4) control points, SRN-116, SRN-120, SN-72 and SN-83 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal heights of SRN-116 and SN-83 were held fixed during the processing of the control points. Through these reference points, the coordinates and ellipsoidal height of the unknown control points were computed.

Table 27. Adjusted grid coordinates

Coordinate System Name: UTM Datum: WGS 1984 Zone: 51 North Geoid: EGM08			
Point List			
Point ID	Easting (Meter)	Northing (Meter)	Elevation (Meter)
0083	797305.2285	1057446.1294	11.5181
0116	796293.1376	1061570.5264	1.5860
S120	800608.0800	1060286.7583	2.2169

Table 28. Adjusted grid coordinates

Coordinate System Name: UTM Datum: WGS 1984 Zone: 51 North Geoid: EGM08			
Point List			
Point ID	Easting (Meter)	Northing (Meter)	Elevation (Meter)
0083	797305.2306	1057446.1294	11.4770
A116	796293.1376	1061570.5264	1.5860
SN72	789912.6785	1060286.7583	9.4789

Table 29. Adjusted grid coordinates

Coordinate System Name: UTM Datum: WGS 1984 Zone: 51 North Geoid: EGM08			
Point List			
Point ID	Easting (Meter)	Northing (Meter)	Elevation (Meter)
0083	N9º33'20.17195"	E125º42'29.48533"	80.6477
0116	N9º35'34.57572"	E125º42'29.48533"	70.4590
S120	N9º34'51.71200"	E125º42'29.48533"	71.1790

Table 30. Adjusted grid coordinates

Coordinate System Name: UTM Datum: WGS 1984 Zone: 51 North Geoid: EGM08			
Point List			
Point ID	Easting (Meter)	Northing (Meter)	Elevation (Meter)
0083	N9º33'20.17263"	E125º42'29.48541"	80.6066
0116	N9º35'34.57572"	E125º41'57.38121"	70.4590
S120	N9º34'41.24832"	E125º38'27.85416"	78.3304

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29 and Table 30.

The summary of reference control points used is indicated in Table 31 and Table 32.

Table 31. Reference and control points used and its location – First Network (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)
SRN-116	2nd order, GCP	9°33'20.17195"N	125°42'29.48533"E	80.6477	797305.2285	1057446.1294	1.4885
SRN-120	2nd order, GCP	9°34'51.71200"N	125°44'18.45049"E	71.1790	796293.1376	1061570.5264	2.2169
SN-83	BM	9°33'20.17195"N	125°42'29.48533"E	80.6477	800608.0800	1060286.7583	11.4206

Table 32. Reference and control points used and its location – Second Network (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)
SRN-116	2nd order, GCP	9°35'34.57572"N	125°41'57.38121"E	70.4590	797305.2285	1057446.1503	1.5296
SN-72	BM	9°34'41.24832"N	125°38'27.85416"E	78.3304	796293.1376	1061570.5264	9.4225
SN-83	BM	9°33'20.17263"N	125°42'29.48541"E	80.6066	800608.0800	1059881.4274	11.4206

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

Cross-section and as-built surveys were conducted on April 7, 2016 at the downstream side of Magallanes Bridge in Brgy. Mahanub, Gigaquit, Province of Surigao del Norte as shown in Figure 33. A Horizon® Total Station was utilized for this survey as shown in Figure 34.

Figure 33. Downstream side of Magallanes Bridge

Figure 34. As-built survey of Magallanes Bridge

The cross-sectional line of Magallanes Bridge is about 345.958 m with ninety-seven (97) cross-sectional points using the control points UP_MAG-1 and UP_MAG-2 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown from Figure 35 to Figure 37.

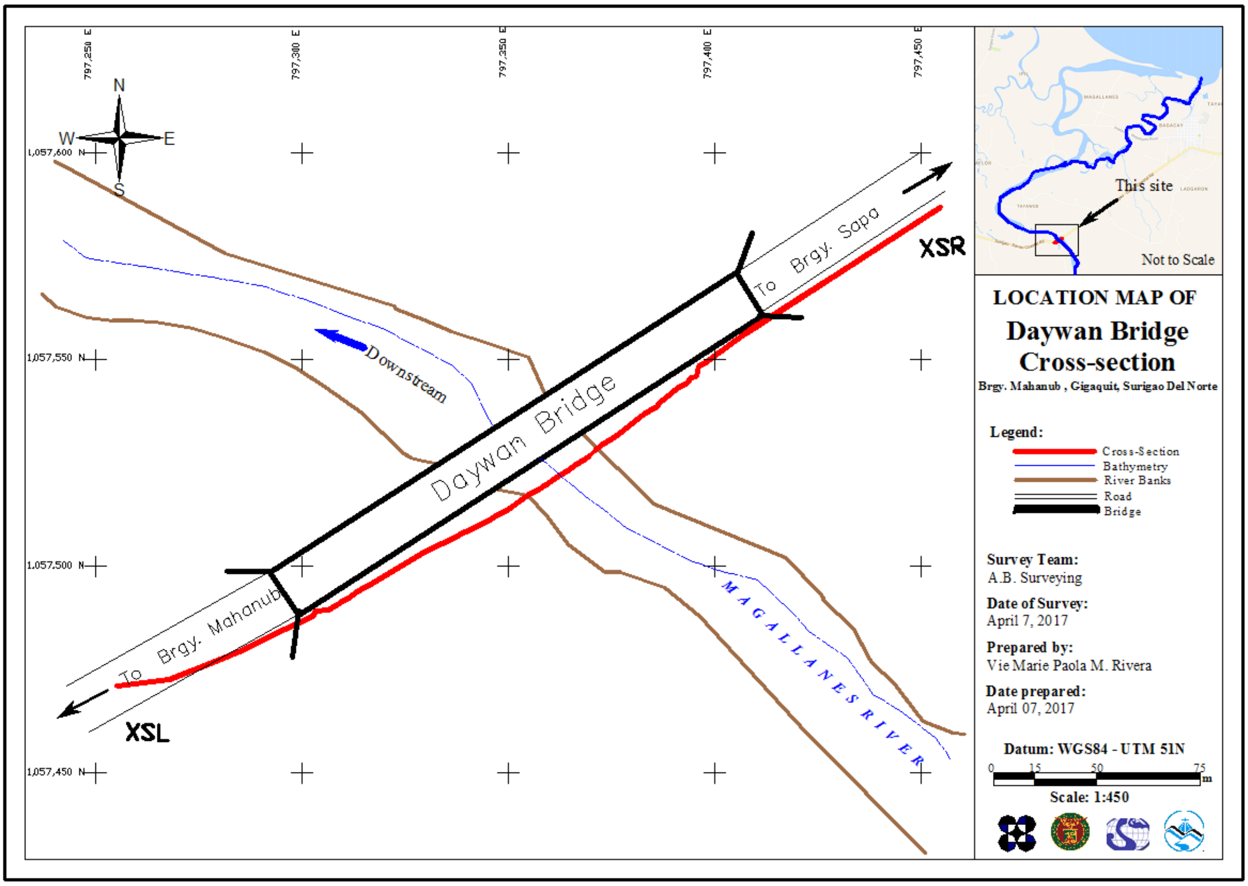


Figure 35. Location map of Daywan Bridge cross-section survey

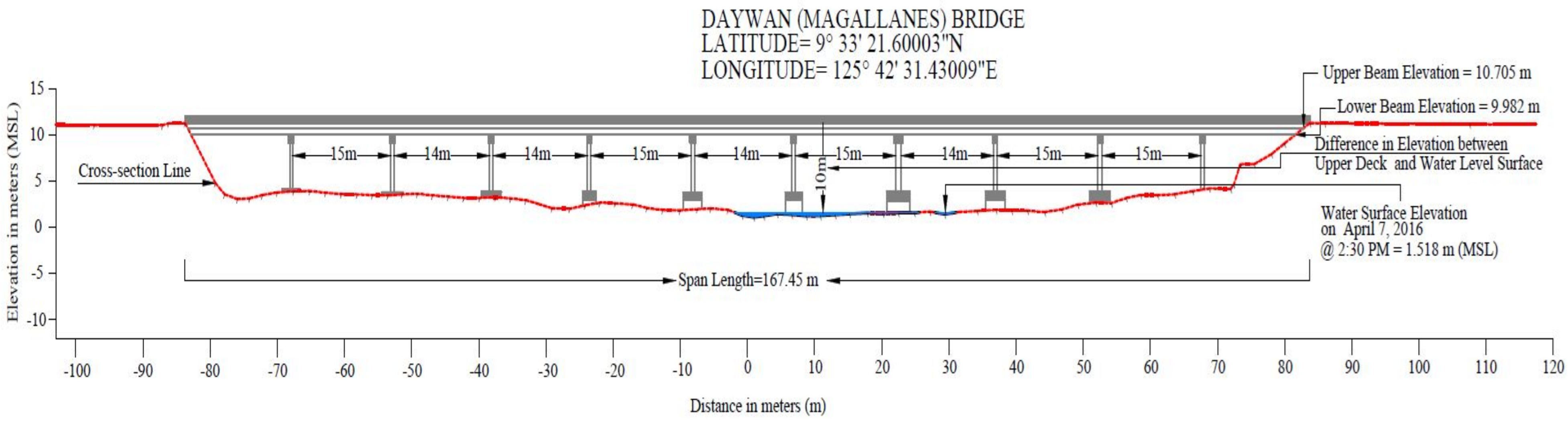


Figure 36. Daywan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Magallanes Bridge

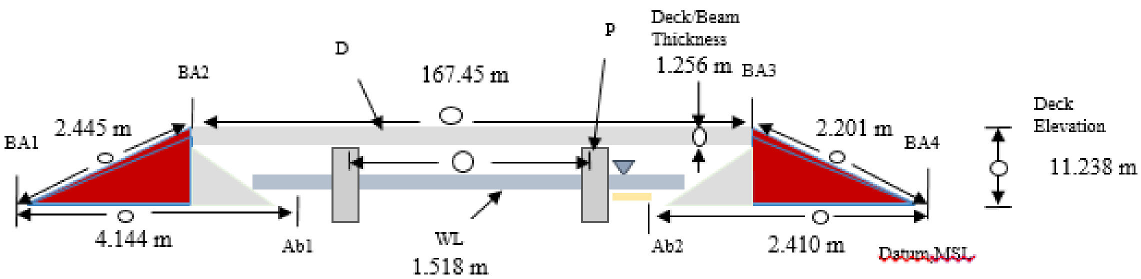
River Name: Magallanes River
Location (Brgy.City.Region): Brgy. Mahanub, Gigaquit, Surigao del Norte

Survey Team: Sherwin Sobia, Bonifacio Atienza
Date and Time: April 7, 2016, 2:30 P.M.

Flow Condition: low normal ✔ high

Weather Condition: ✔ fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	2.445 m	
2. BA2-BA3	167.45 m	
3. BA3-BA4	2.201 m	
4. BA1-Ab1	4.144 m	
5. Ab2-BA4	2.410 m	
6. Deck/beam thickness	1.256 m	
7. Deck elevation	11.238 m	

Note: Observer should be facing downstream

Figure 37. Magallanes Bridge data sheet.

Water surface elevation of Magallanes River was determined by a Horizon® Total Station on April 7, 2016 at 2:30 PM at Magallanes Bridge area with a value of 1.518 m in MSL as shown in Figure 36. This was translated into marking on the bridge's pier as shown in Figure 38. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Magallanes River, the Caraga State University.

Figure 38. Water-level markings on Magallanes Bridge

The survey started from Brgy. Campo, Municipality of Bacuag, Surigao del Norte going southeast along the national highway, covering four (4) barangays in the Municipality of Bacuag, three (3) barangays in the Municipality of Gigaquit, and three (3) barangays in the Municipality of Claver, and ended in Brgy. Tayaga, Municipality of Claver, Surigao del Norte. The survey gathered a total of 4,111 points with approximate length of 15.12 km using SN-72 as GNSS base station for the entire extent of validation points acquisition

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by CSU on July 11-15, 2016 using a survey grade GNSS Rover receiver, South S86T, mounted on a range pole which was attached in front of the vehicle as shown in Figure 39. It was secured with a bipod and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.950 m and measured from the ground up to the antenna face center of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode

Figure 39. Validation points acquisition survey set up along Magallanes River Basin.

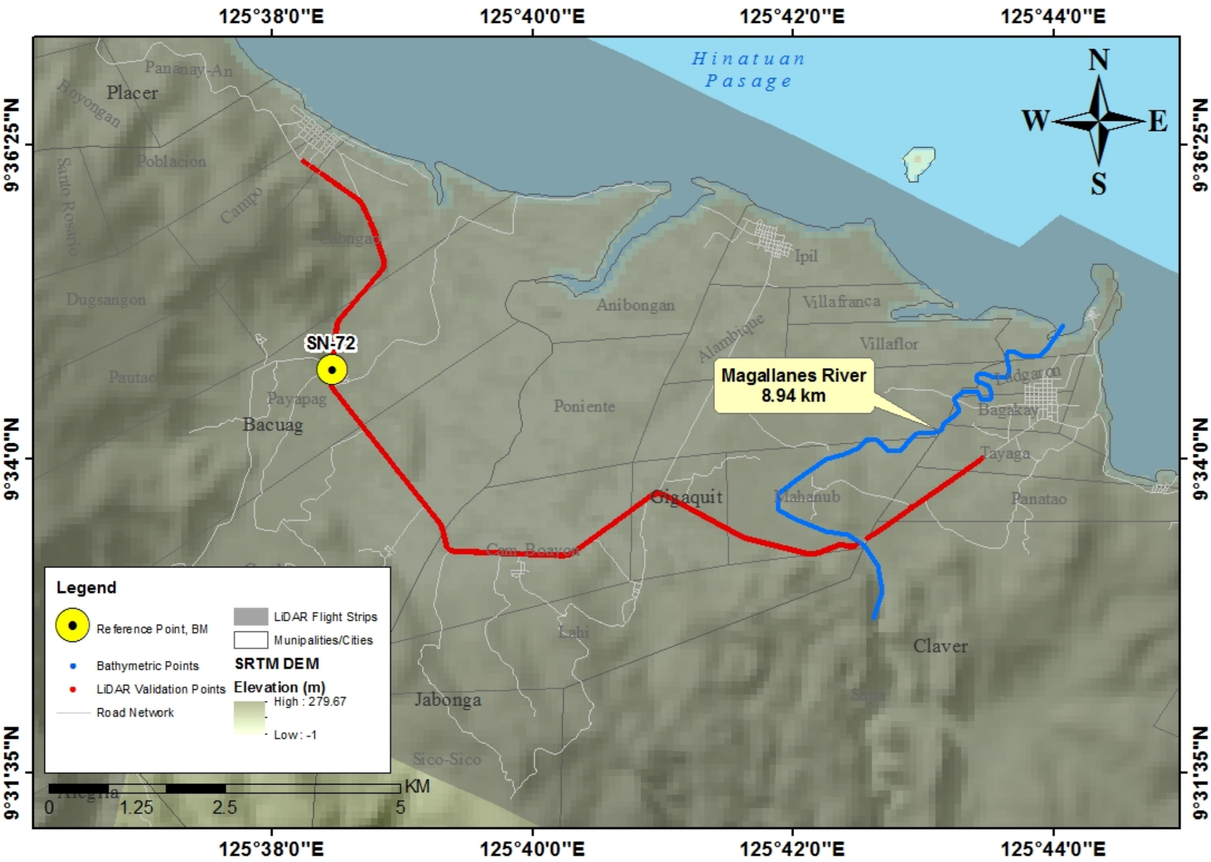


Figure 40. Extent of the LiDAR ground validation survey (in red) for Magallanes River Basin.

4.7 River Bathymetric Survey

Bathymetric survey was both executed by ABSD and CSU. Bathymetric survey executed by CSU was done on May 4, 2016 using a Hi-Target™ V30 echo sounder as illustrated in Figure 41 and Figure 42. The survey for the delineated bathymetric line started in Brgy. Mahanub, Municipality of Gigaquit, Surigao del Norte with coordinates 9°32'50.961"N, 119°10'21.262"E and ended at the mouth of the river in Brgy. Dayawan, Municipality of Gigaquit, Surigao del Norte, with coordinates 9°35'1.715"N, 125°44'1.877"E. The reference point SN-83 was used as GNSS base station all throughout the entire survey.

Figure 41. Bathymetric survey of CSU at Magallanes River using Hi-Target V30

The bathymetric survey for Magallanes River surveyed by CSU gathered a total of 65,535 points covering 5.13 km of the delineated bathymetric line of the river traversing barangay of Mahanub in the Municipality of Gigaquit and barangays Dayawan, Ladgaron, Bagakay, Tayaga, and Panatao in the Municicpality of Claver. A CAD drawing was also produced to illustrate the riverbed profile of Magallanes River. As shown in Figure 43, the highest and lowest elevation has a 10-m difference. The highest elevation observed was 6.40 m above MSL located in Brgy. Sapa, Municipality of Gigaquit while the lowest was -4.70 m below MSL located in Brgy. Ladgaron, Municipality of Claver.

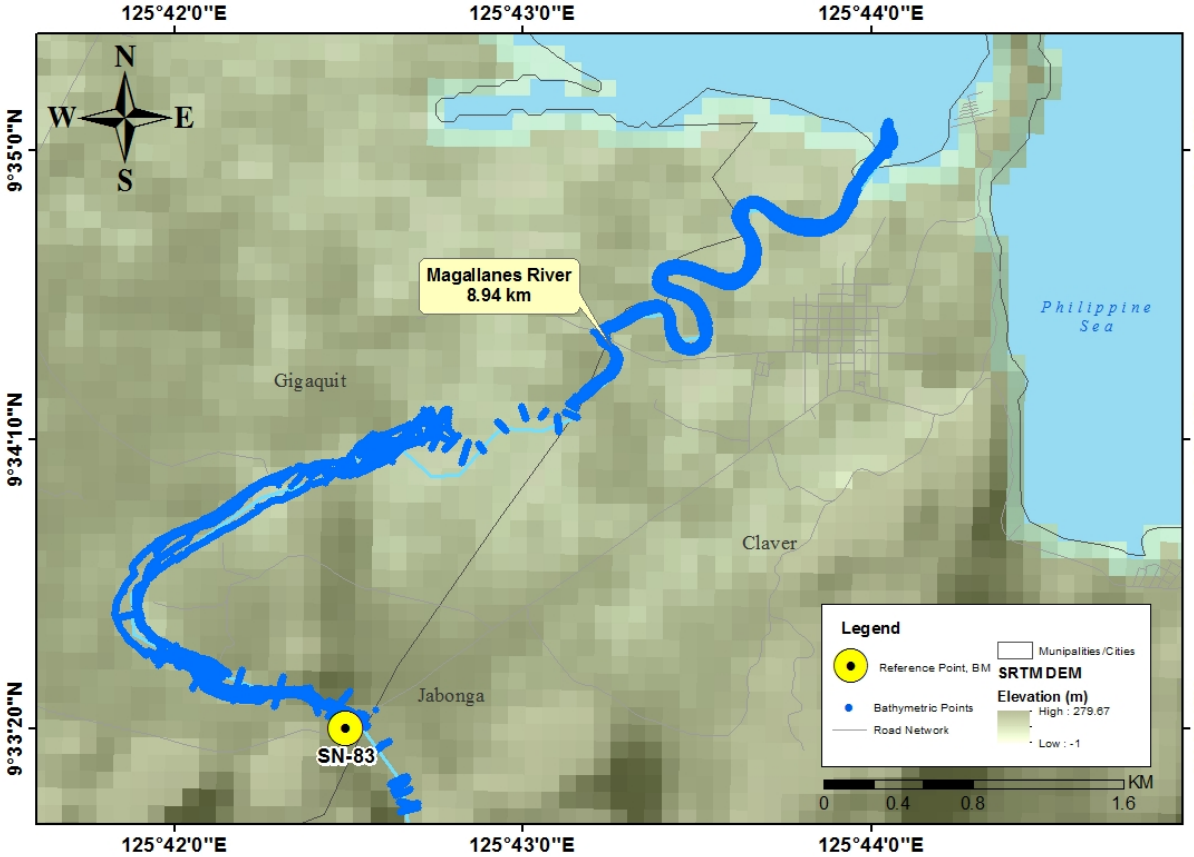


Figure 42. Extent of the Magallanes River Bathymetry Survey and the LiDAR bathymetric data validation points.

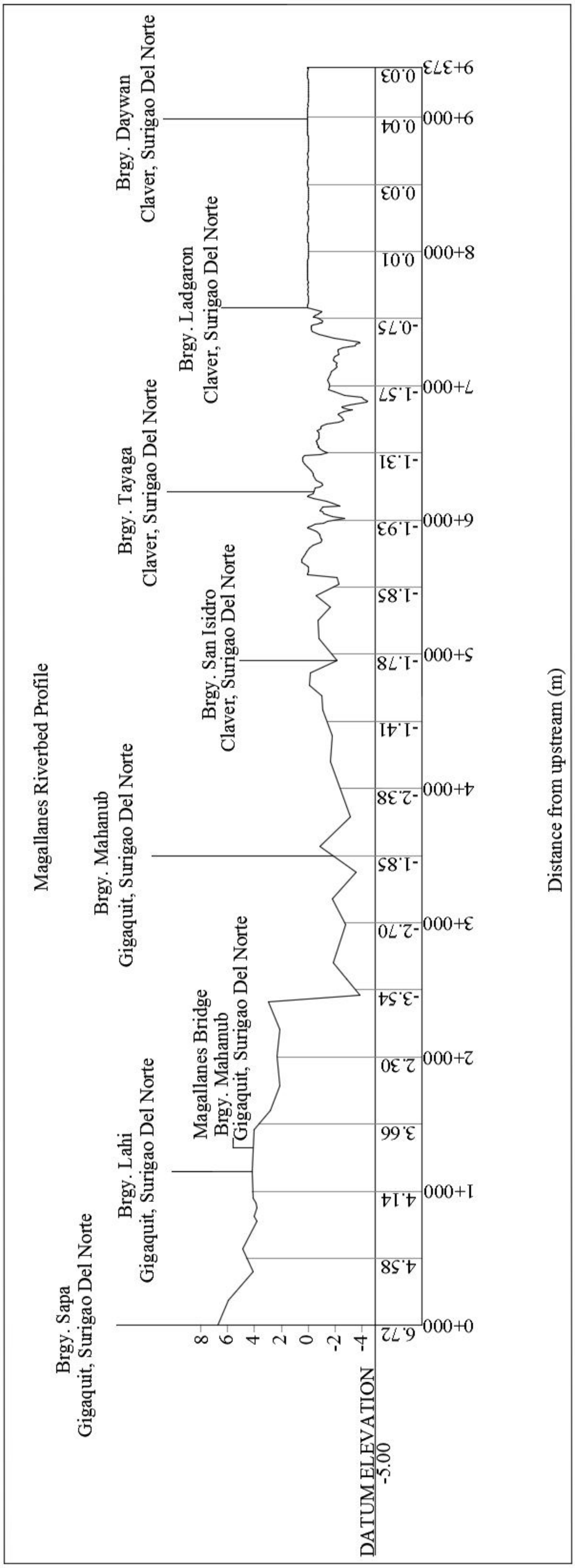


Figure 43. Magallanes riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Alfredo Mahar Francisco A. Lagmay, Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, and Neil R. Tingin

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from two rain gauges installed by CSU Phil-LiDAR 1. These rain gauges were temporarily installed at Brgy. Payapag in the Municipality of Bacuag and at Baoy Dam at Brgy. Daywani in the Municipality of Claver. The location of the rain gauge is shown in Figure 44.

Total rain recorded at Brgy. Payapag and Baoy Dam from 18 September 2016 13:00 to 19 September 2016 6:00 were 2.2 mm and 4.6 mm, respectively. At Brgy. Payapag, the rain peaked to 0.4 mm on 18 September 2016 14:40 while at Baoy Dam, the rain peaked to 0.6 mm on 18 September 2016 17:40. The lag time between the peak rainfall and its corresponding peak discharge at Campo Bridge is 2 hours, as seen in Figure 47.

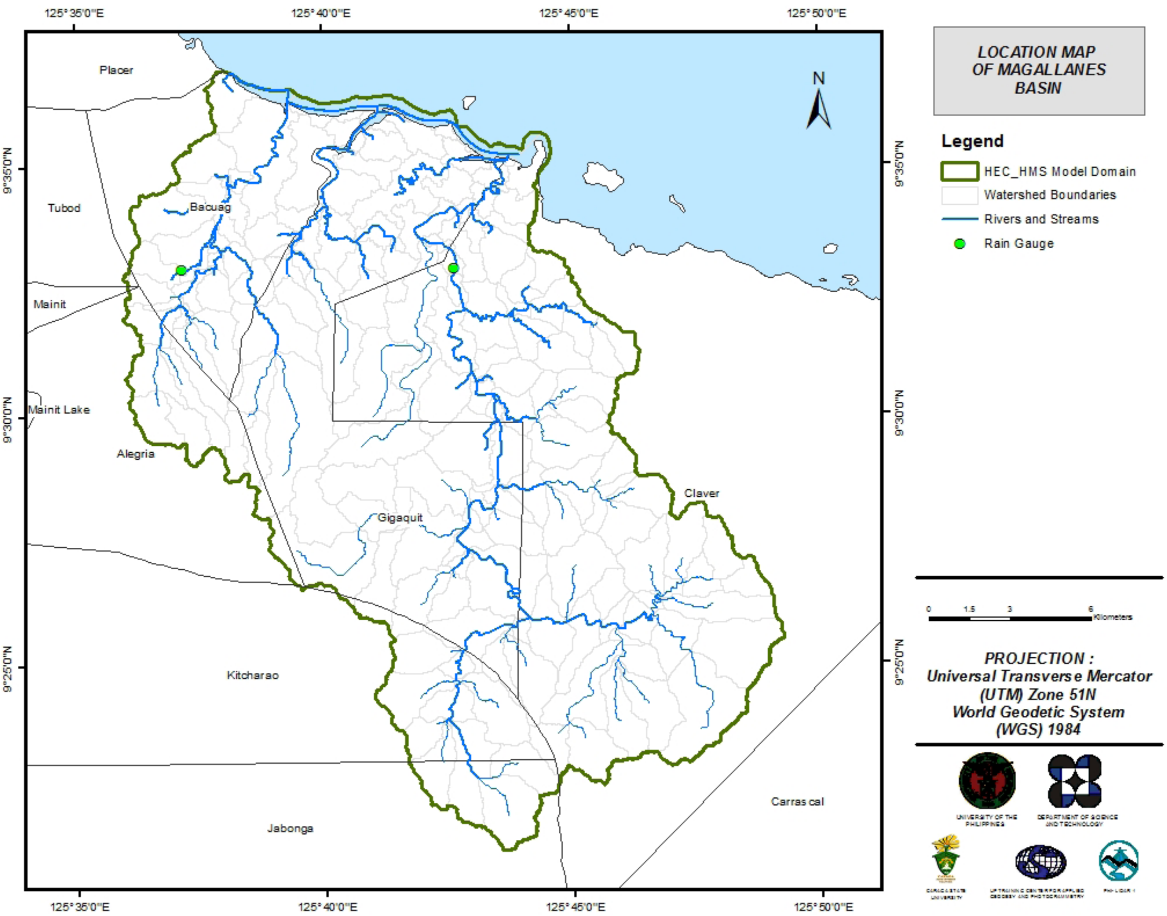


Figure 44. Location map of the Magallanes HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Campo Bridge, Bacuag, Surigao del Norte (9°34'41.89"N, 125°38'28.62"E). It gives the relationship between the observed water levels from Campo Bridge and outflow of the watershed at this location.

For Campo Bridge, the rating curve is expressed as Q = (5.6918) H1.7256 as shown in Figure 46.

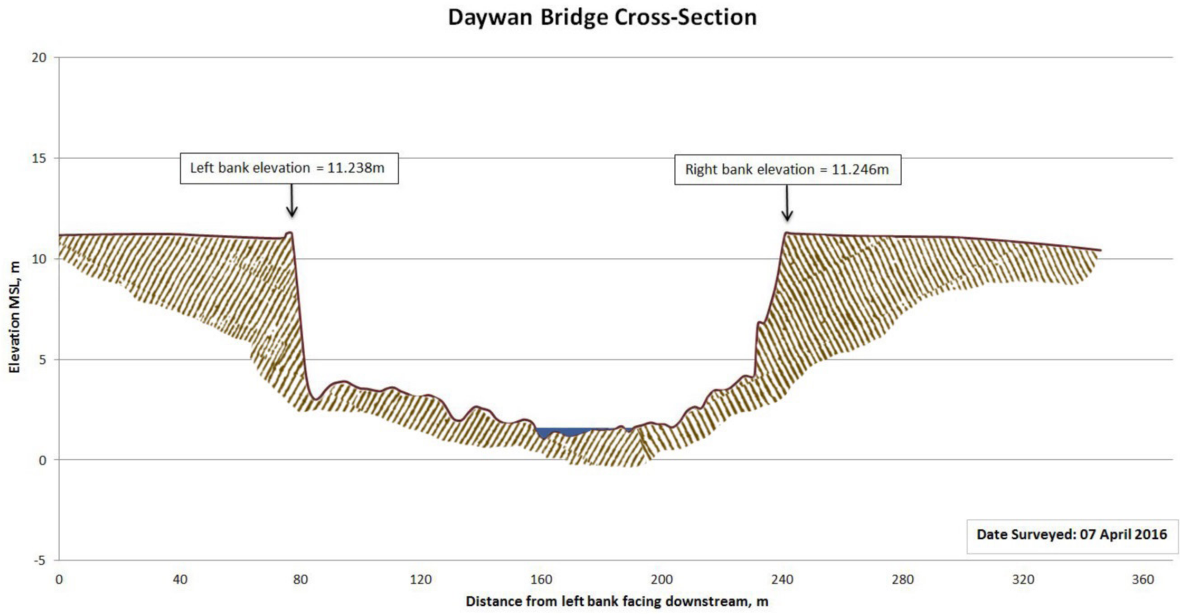


Figure 45. Cross-section plot of Campo Bridge

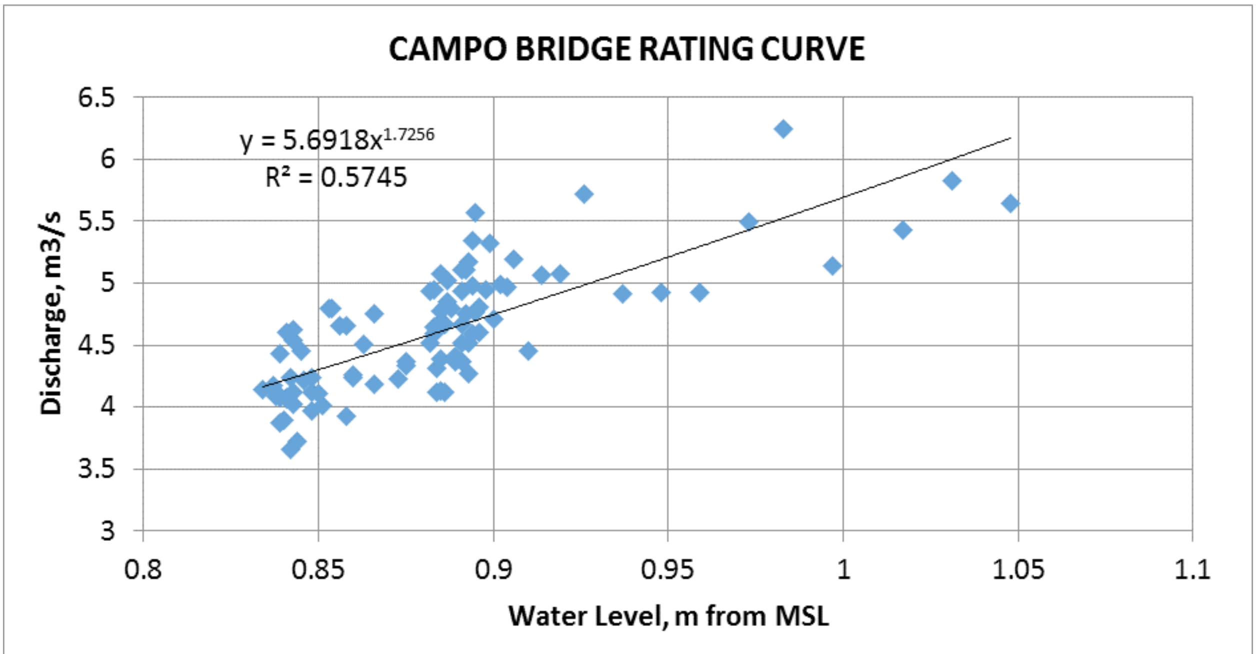


Figure 46. Rating curve at Campo Bridge, Bacuag, Surigao del Sur.

The river outflow measured at Campo Bridge (Figure 47) was utilized for the calibration of the HEC-HMS model. Peak discharge is 6.53 cubic meter per second (cms) at 7:40 PM, September 18, 2016.

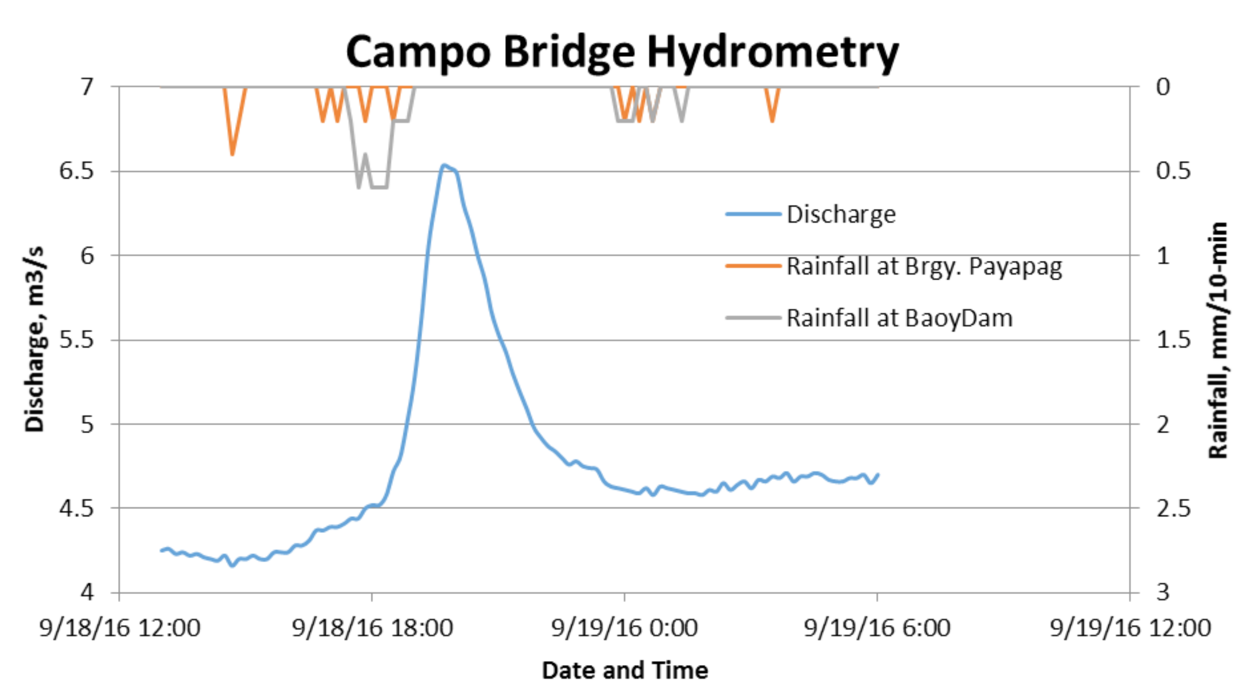


Figure 47. Rainfall at Brgy. Payapag and Baoy Dam, and outflow data at Campo Bridge used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Surigao Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Magallanes watershed. The extreme values (Table 33) for this watershed were computed based on a 46-year record.

Table 33. Computed extreme values (in mm) of precipitation at Magallanes river basin based on average RIDF data of Surigao station.

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**
5	17.2	34.34	39.7	88.3	125.8	150.9	199.2	246.3	286.5
10	21.1	42.3	48.6	107.7	155	186.5	245.8	305.1	351.2
25	26.1	52.2	59.7	132.2	191.8	231.4	304.7	379.5	433
50	29.8	59.6	68	150.3	219.1	264.8	348.4	434.6	493.7
100	33.5	66.9	76.2	168.3	246.2	297.9	391.8	489.4	553.9

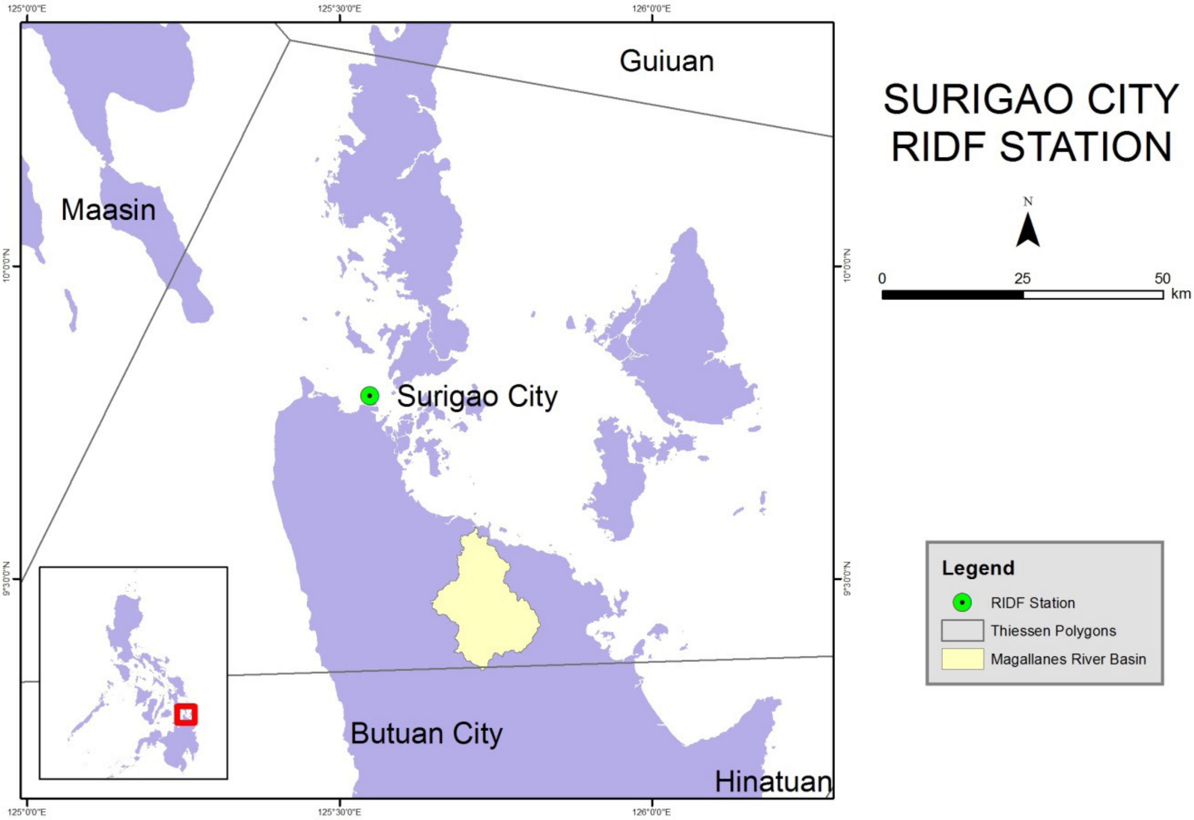


Figure 48. Location of Surigao RIDF station relative to the Magallanes River Basin.

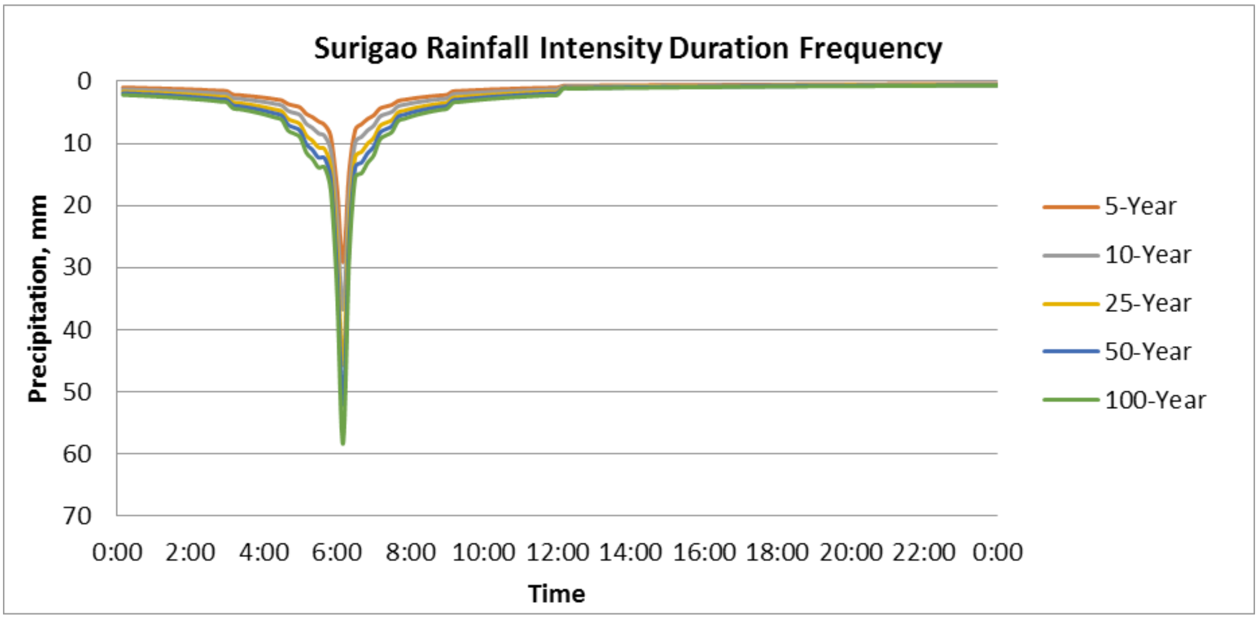


Figure 49. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was taken before 2004 from the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Magallanes River Basin are shown in Figure 50 and Figure 51, respectively.

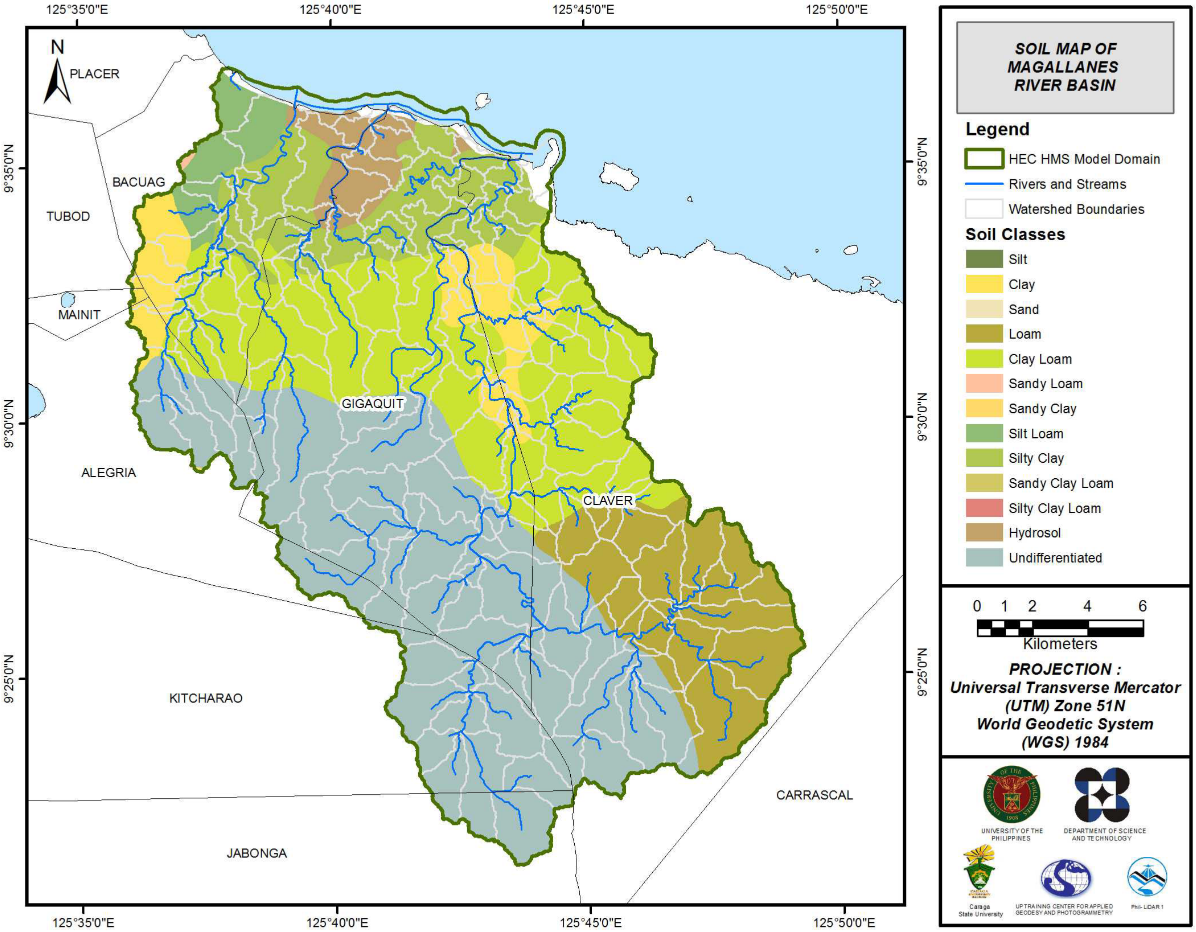


Figure 50. Soil map of the Magallanes River Basin used for the estimation of the CN parameter

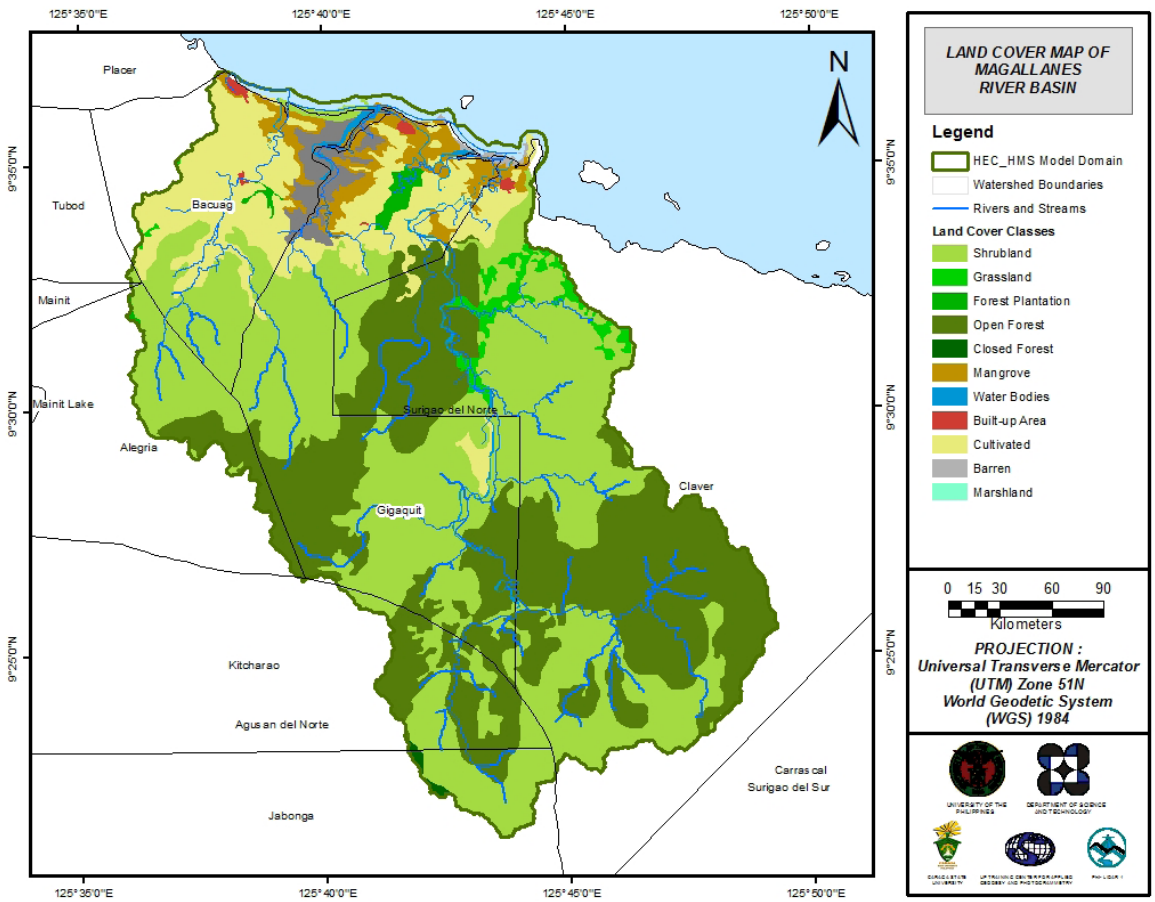


Figure 51. Land cover map of Magallanes River Basin used for the estimation of the Curve Number (CN) and the watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Magallanes, at least six (6) soil classes were identified. These are silt, clay, loam, clay loam, silt loam, and hydrosol, while the rest are undifferentiated. Moreover, at least six (6) land cover classes were identified. These are shrubland, grassland, forest plantation, open forest, closed forest, and mangrove, while the rest are cultivated and built-up area.

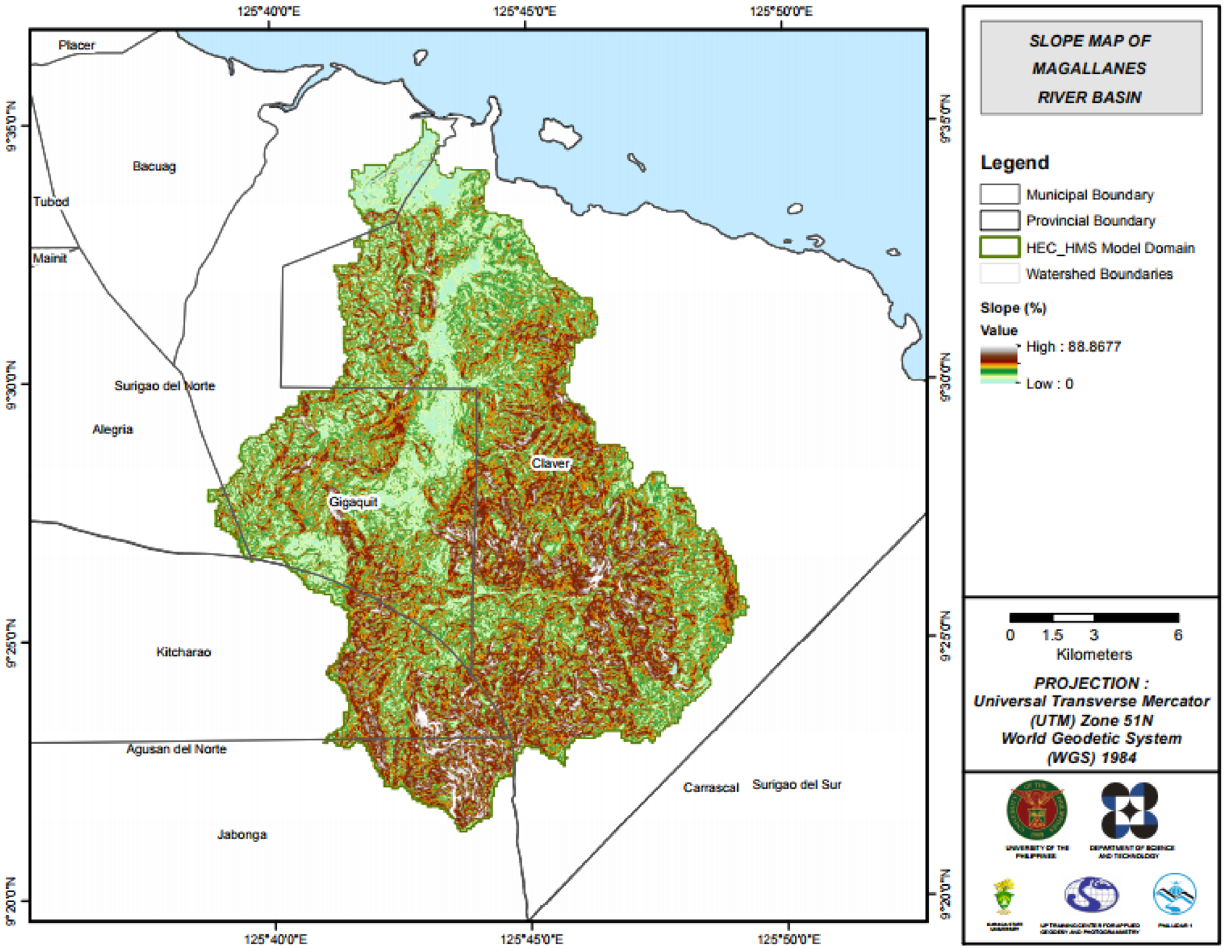


Figure 52. Slope Map of Magallanes River Basin

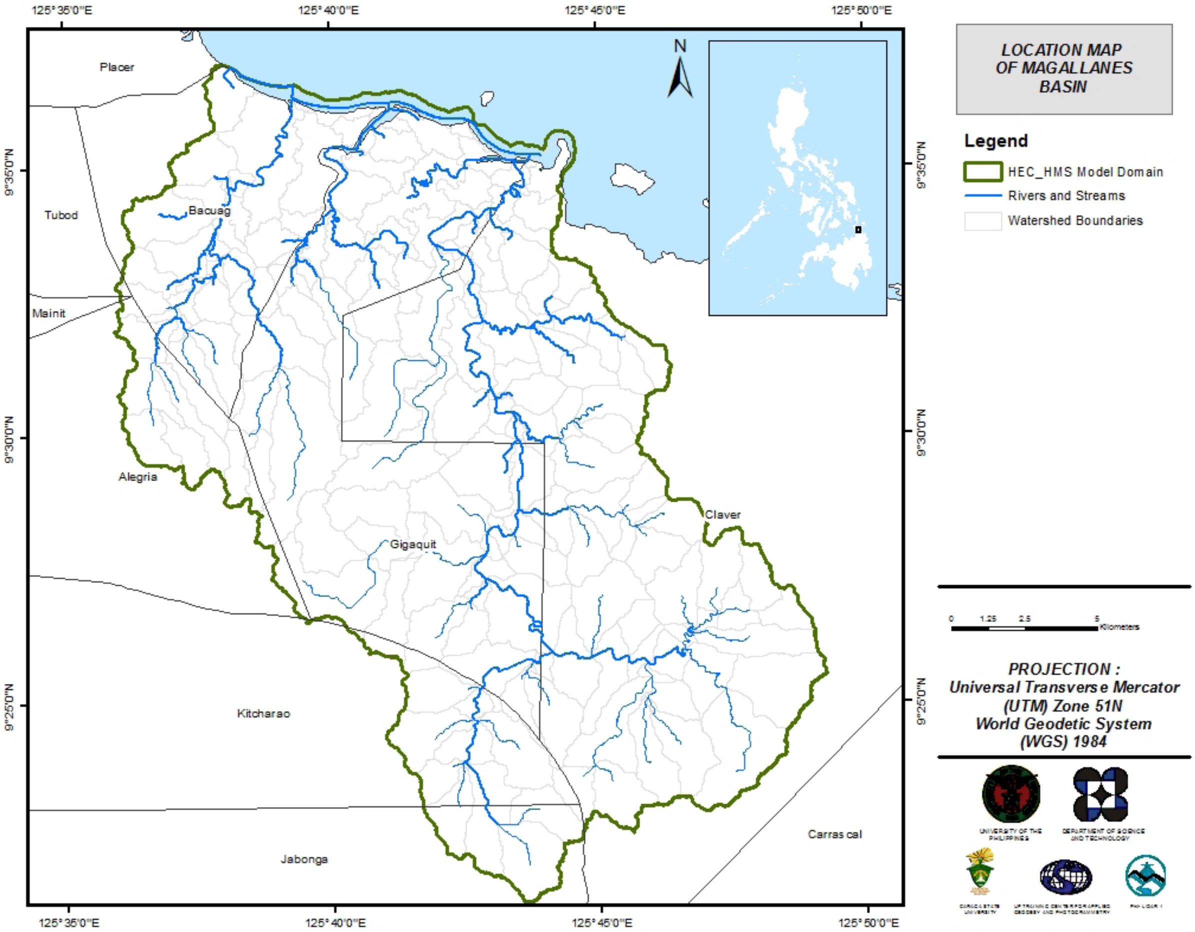


Figure 53. Stream Delineation Map of Magallanes River Basin

The Magallanes basin model consists of 161 sub basins, 87 reaches and 88 junctions. This basin model is illustrated in Figure 54. The basins were identified based on the delineation using the 10 meter SAR DEM. Precipitation was taken from DOST rain gauges. Finally, it was calibrated using data gathered through hydrological measurement at Campo Bridge station.

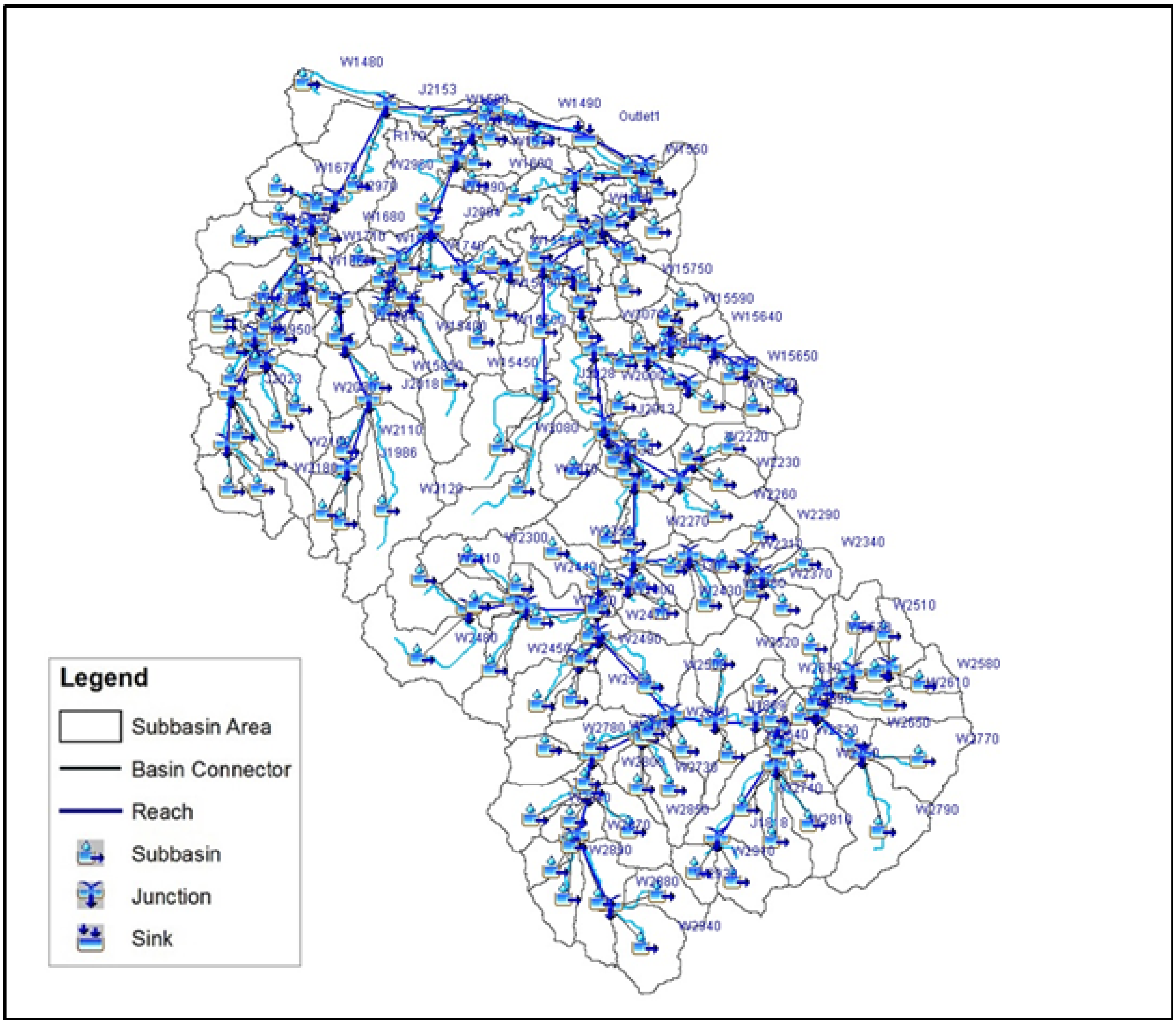


Figure 54. Magallanes River Basin model generated in HEC-HMS

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.

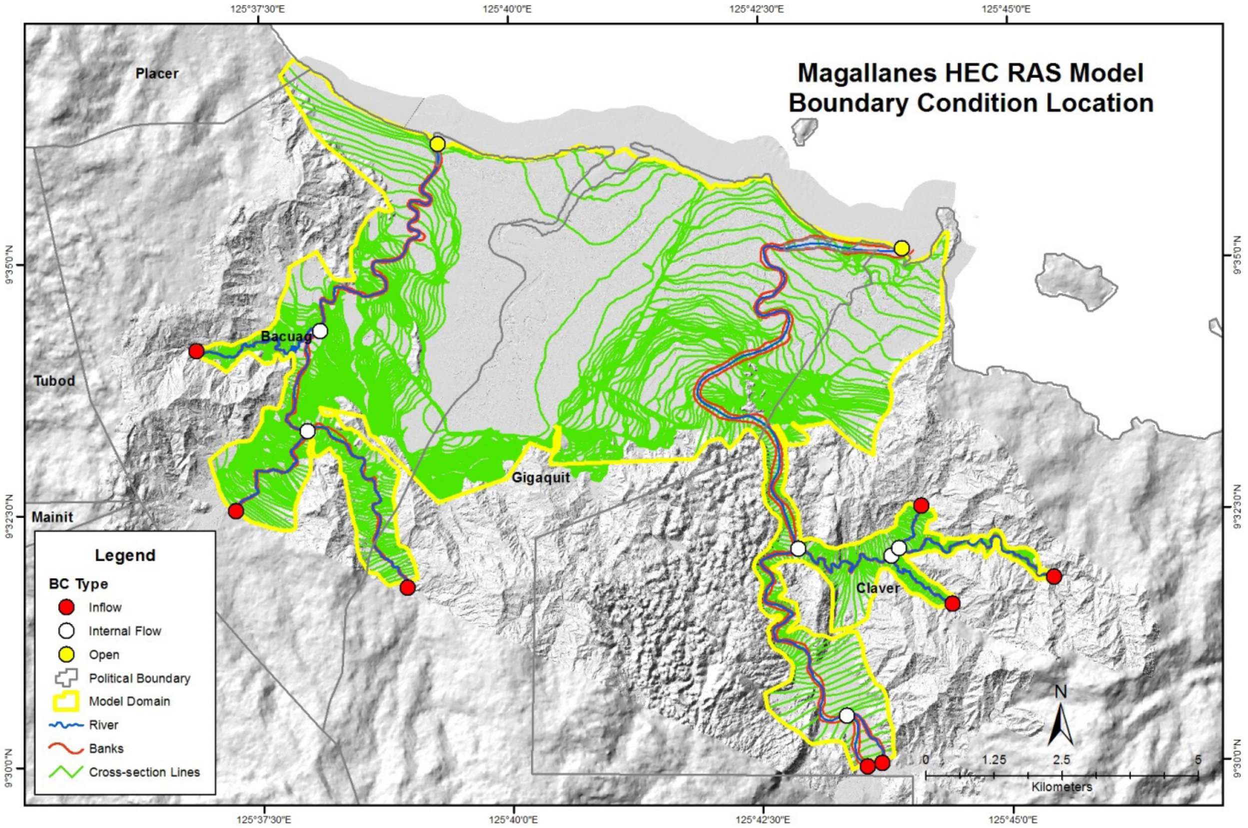


Figure 55. Map of boundary condition locations of the Magallanes HEC RAS model.

5.5 Flo 2D Model

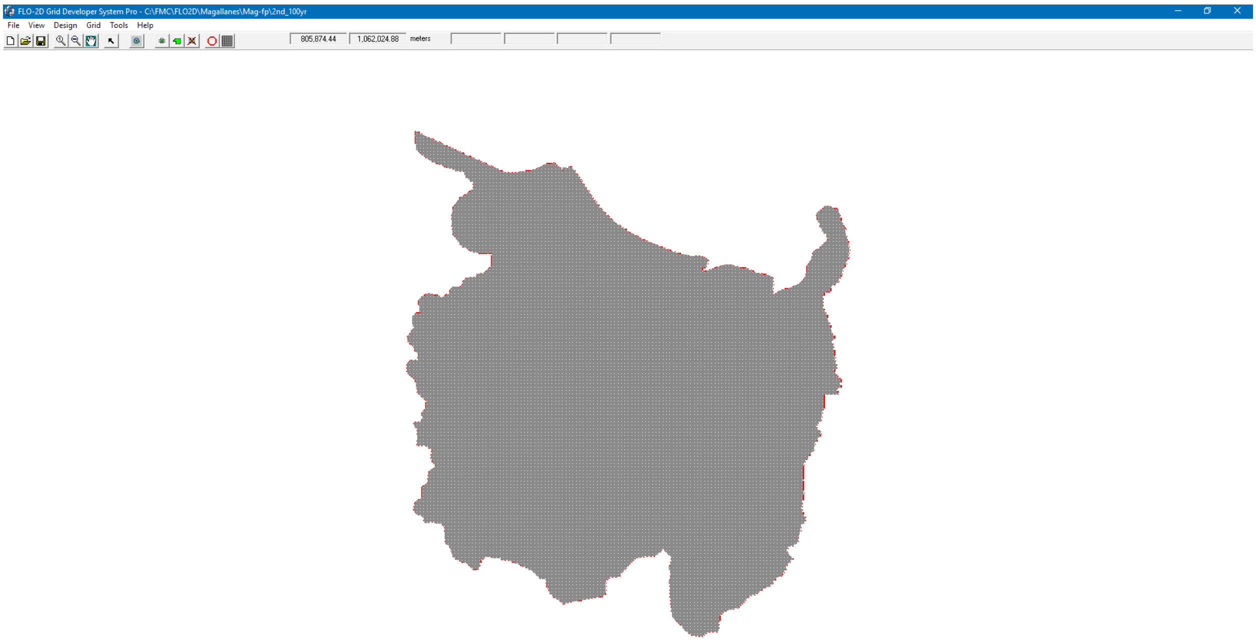


Figure 56. Screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

5.6 Results of HMS Calibration

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

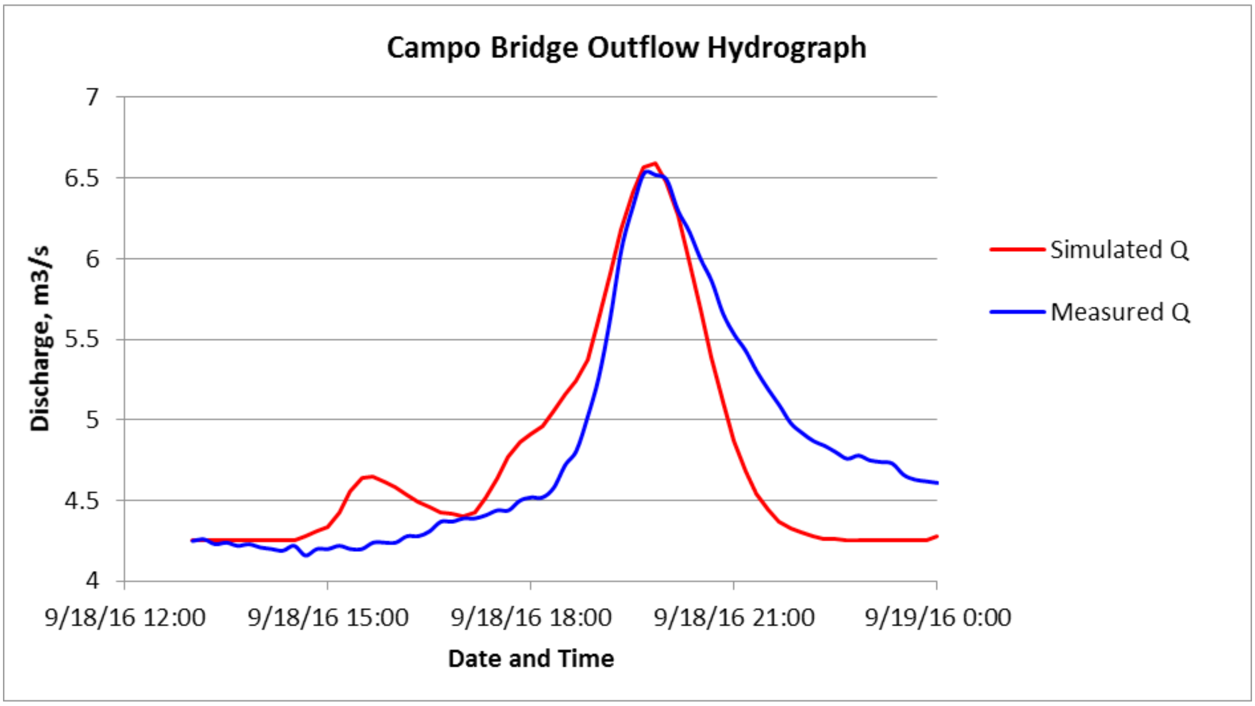


Figure 57. Outflow hydrograph of Campo Bridge produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 34 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 34. Range of calibrated values for Surigao Watershed.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.00
			Curve Number	50.62-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0-17
			Storage Coefficient (hr)	0.06-1.29
	Baseflow	Recession	Recession Constant	0.03-0.65
			Ratio to Peak	1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.05

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. A value of 0 means that the amount of infiltration or rainfall interception by vegetation is very minimal.

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 55 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 Magallanes, the basin mostly consists of brushlands and the soil consists of clay loam, hydrosols, and undifferentiated soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from0.06 to 1.29 hours determines the reaction time of the model with respect to the rainfall.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.05 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.01 corresponds to the common roughness in the Magallanes watershed, which is determined to be mostly shrub lands and open forest (Brunner, 2010).

Table 35. Summary of the Efficiency Test of the Magallanes HMS Model

Accuracy measure	Value
RMSE	0.4
r2	0.7237
NSE	0.7
PBIAS	1.29
RSR	0.55

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified to be 0.4 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 0.7237.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model, with E = 1 being the optimal value. The model attained an efficiency coefficient of 0.70.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is 1.29.

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 0.55.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The historical rainfall records at the ARGs of DOST-ASTI within the proximity of Magallanes River Basin were gathered. These data were then utilized to capture the extreme rainfall events that occurred to the river basin and caused severe flooding. Based on the records, there were two (2) extreme events that were recorded. These were during typhoon “Agaton” that happened last January 10-23, 2014 and typhoon “Seniang” that happened last December 18, 2014-January 3, 2015.

The summary graph (Figure 58) shows the Magallanes outflow using the Surigao Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

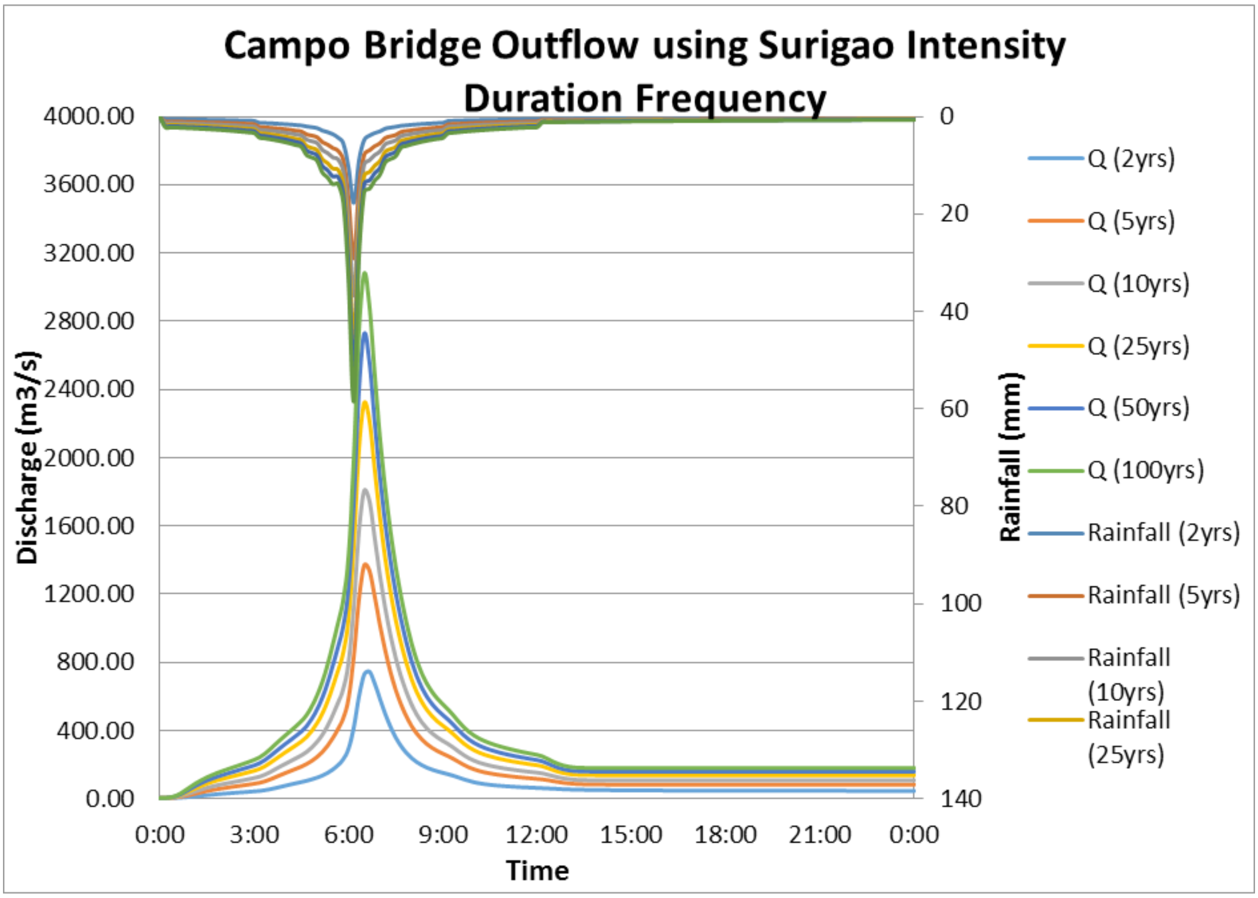


Figure 58. Outflow hydrograph at Surigao Station, generated using the Surigao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Magallanes discharge using the Surigao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 36.

Table 36. Peak values of the Magallanes HEC-HMS Model outflow using the Surigao RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
2-Year	165.93	17.71	745.69	40 minutes
5-Year	274.83	29.14	1,369.36	30 minutes
10-Year	347.43	36.80	1,806.65	30 minutes
25-Year	432.67	45.74	2,322.09	30 minutes
50-Year	493.33	52.13	2,726.64	30 minutes
100-Year	553.48	58.46	3,080.46	30 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. The sample generated map of Magallanes River using the calibrated HMS TS Agaton flow is shown in Figure 59.

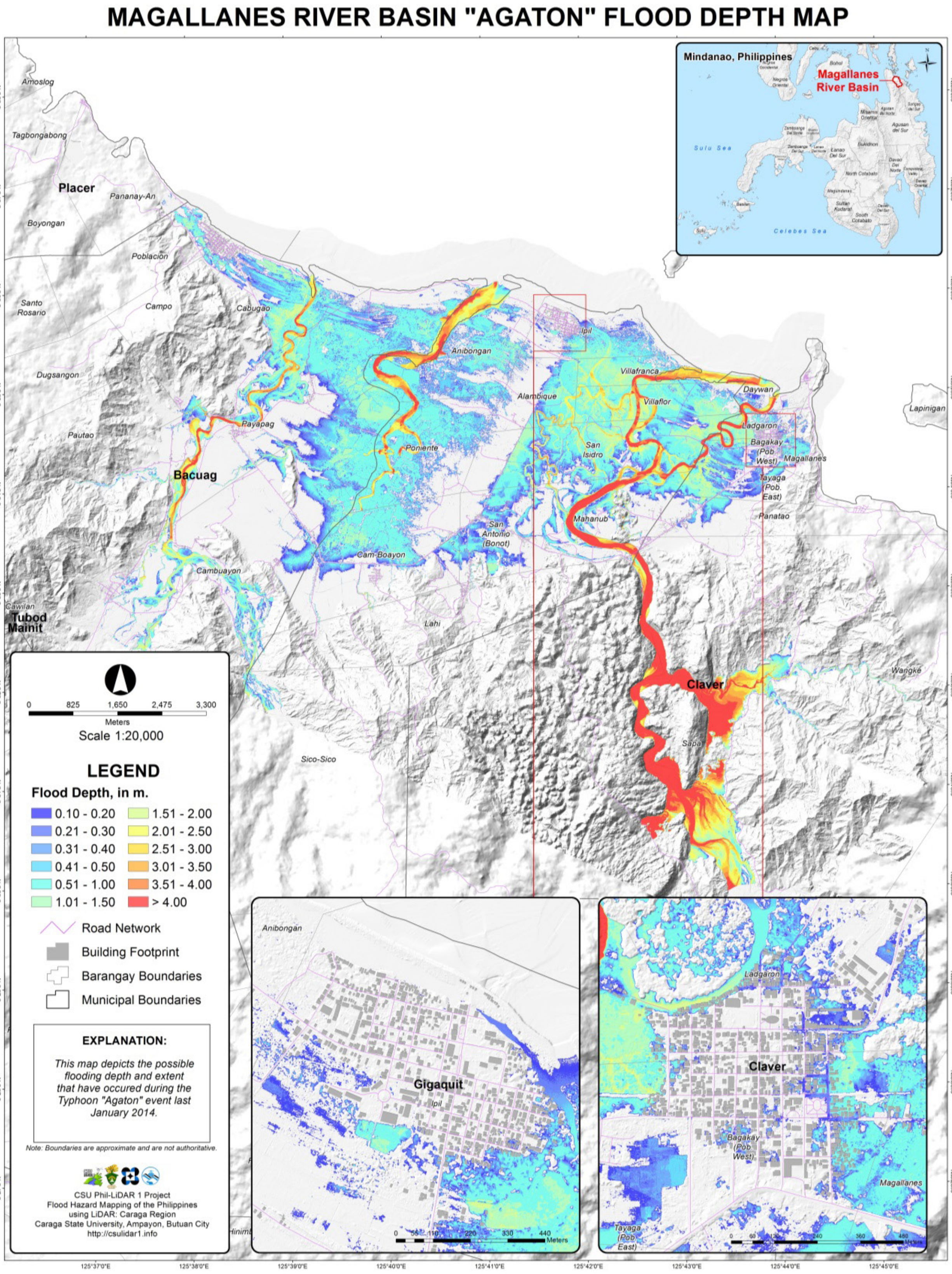


Figure 59. Flood depth and extent at Magallanes River basin during typhoon "Agaton".

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Magallanes floodplain are shown in Figure 60 to Figure 65.

The generated flood hazard maps for the Magallanes Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA 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). Figure 60 to Figure 65 shows the 5-, 25-, and 100-year rain return scenarios of the Magallanes floodplain. The floodplain, with an area of 456.35 sq. km., covers two municipalites namely Claver and Gigaguit. Table 37 shows the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in Magallanes Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Claver	337.34	9.47	2.81%
Gigaquit	119.02	11.91	10.01%

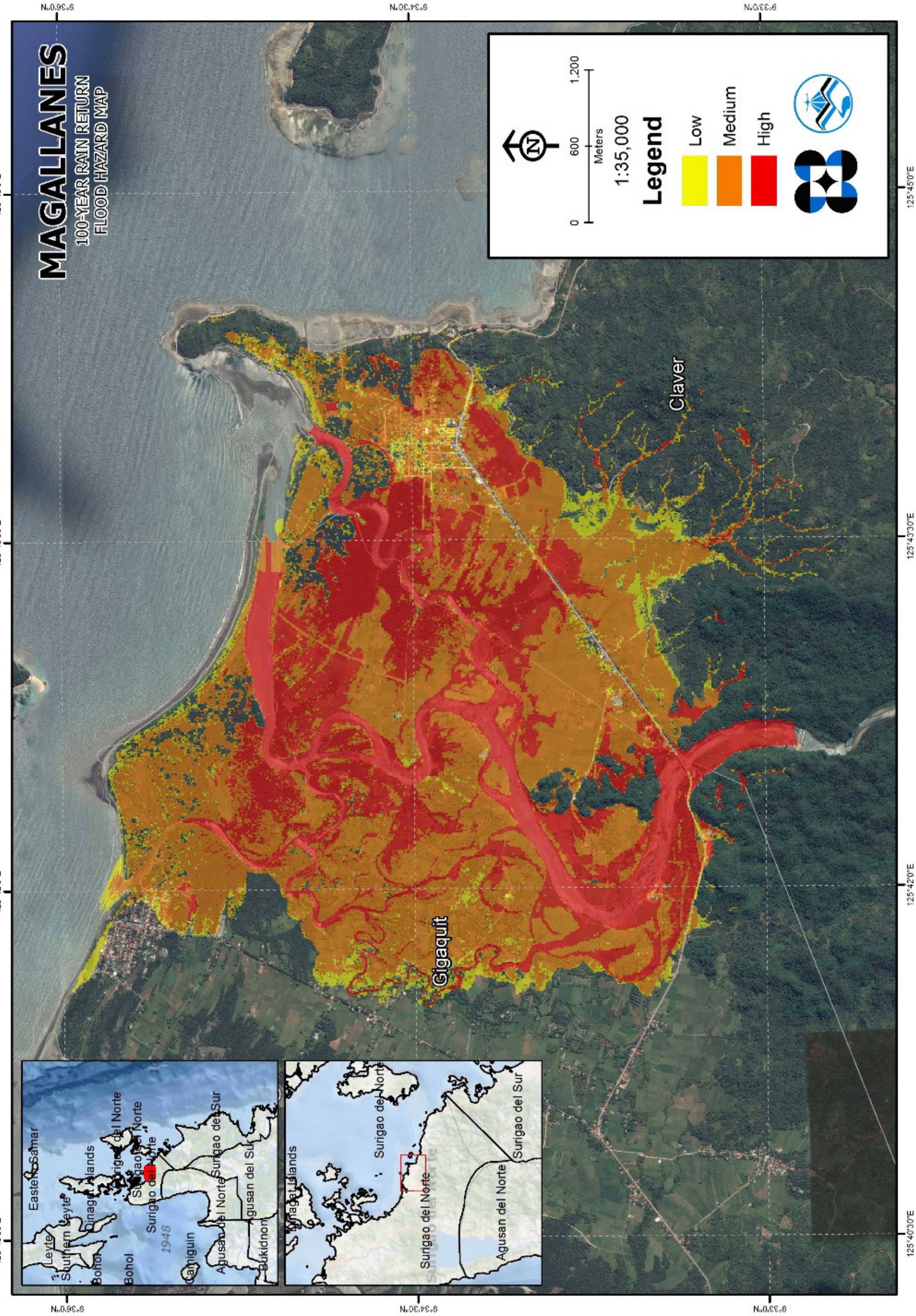


Figure 60. 100-year Flood Hazard Map for Magallanes Floodplain overlaid on Google Earth imagery

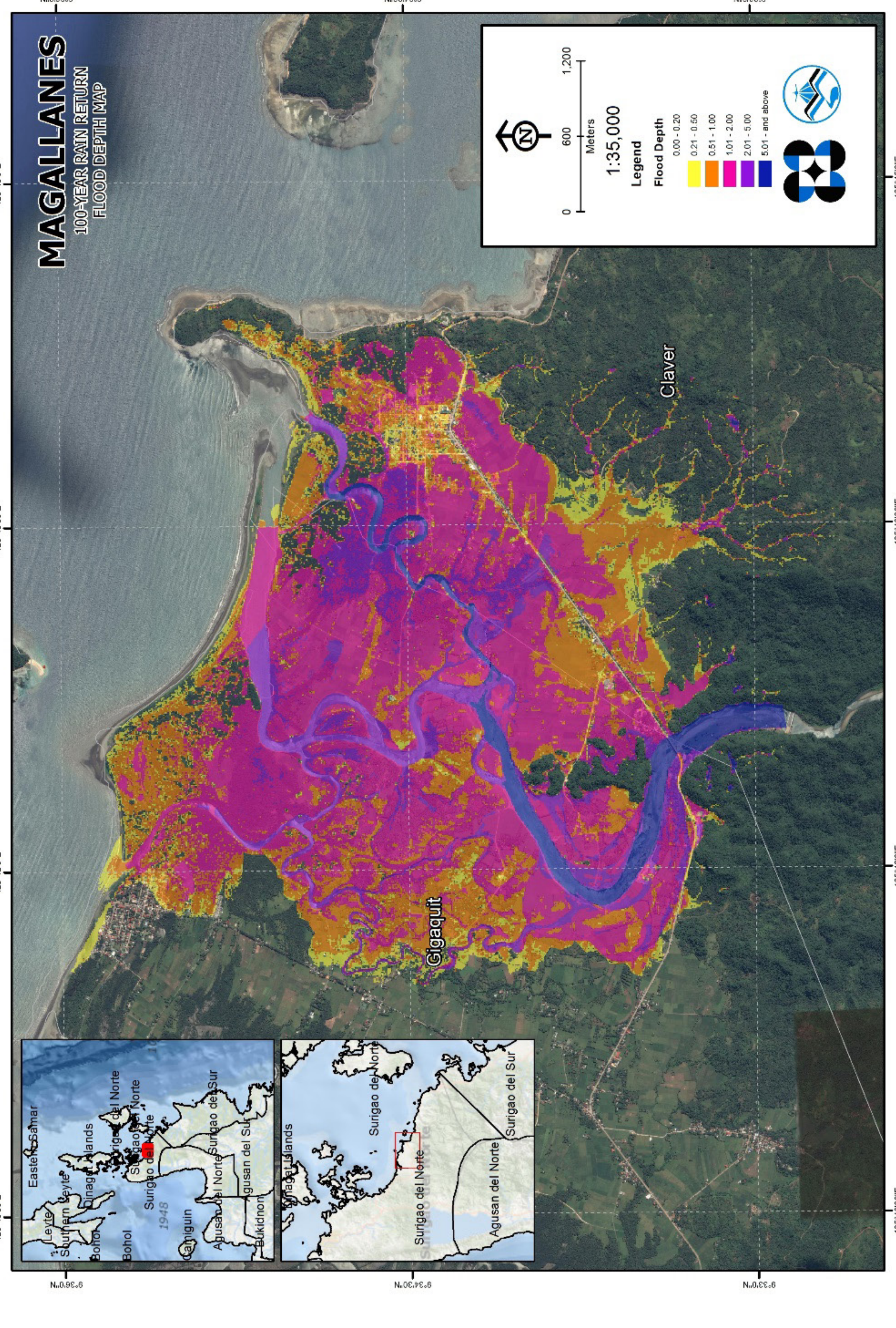


Figure 61. 100-year Flow Depth Map for Magallanes Floodplain overlaid on Google Earth imagery

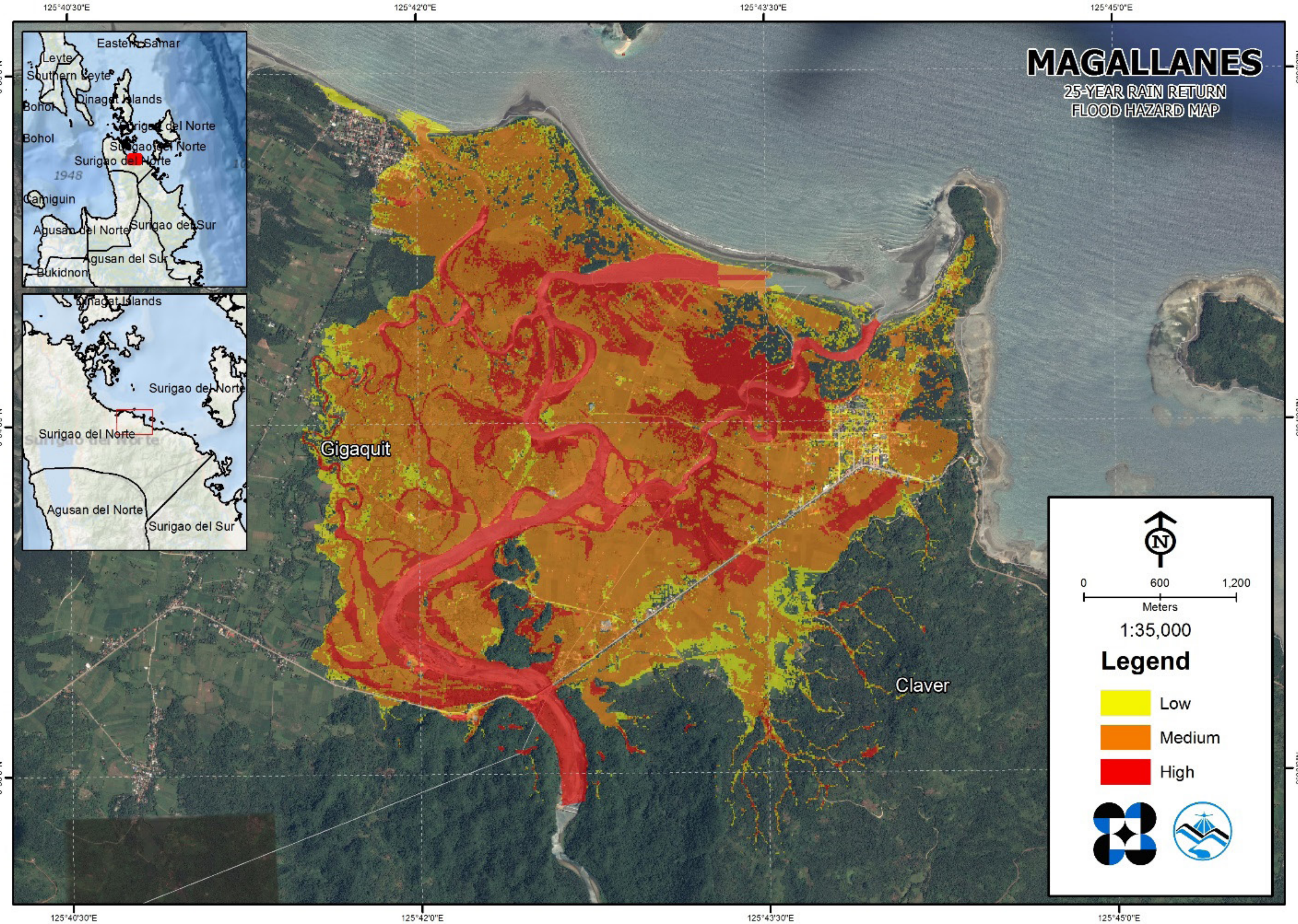


Figure 62. 25-year Flood Hazard Map for Magallanes Floodplain overlaid on Google Earth imagery

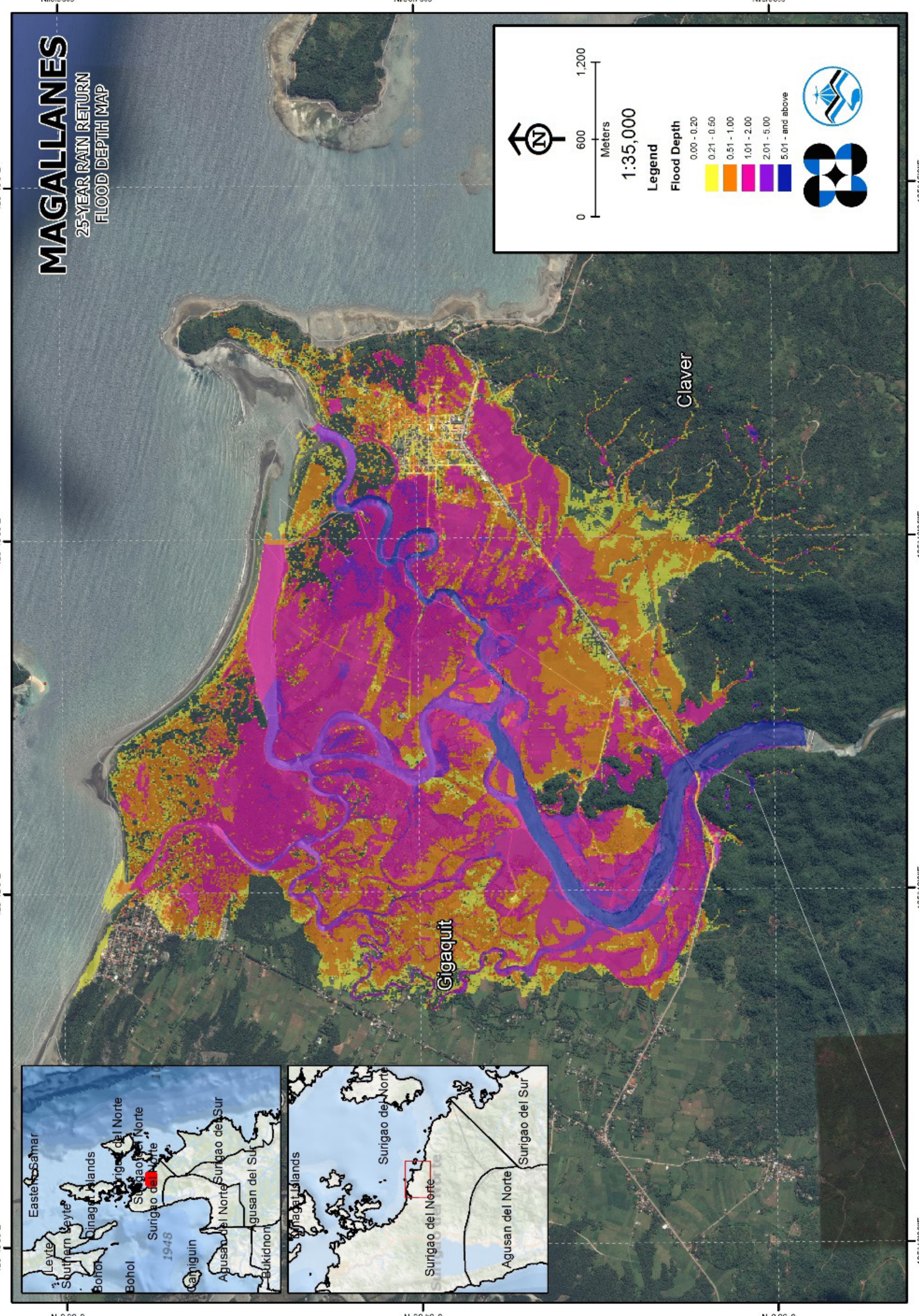


Figure 63. 25-year Flow Depth Map for Magallanes Floodplain overlaid on Google Earth imagery

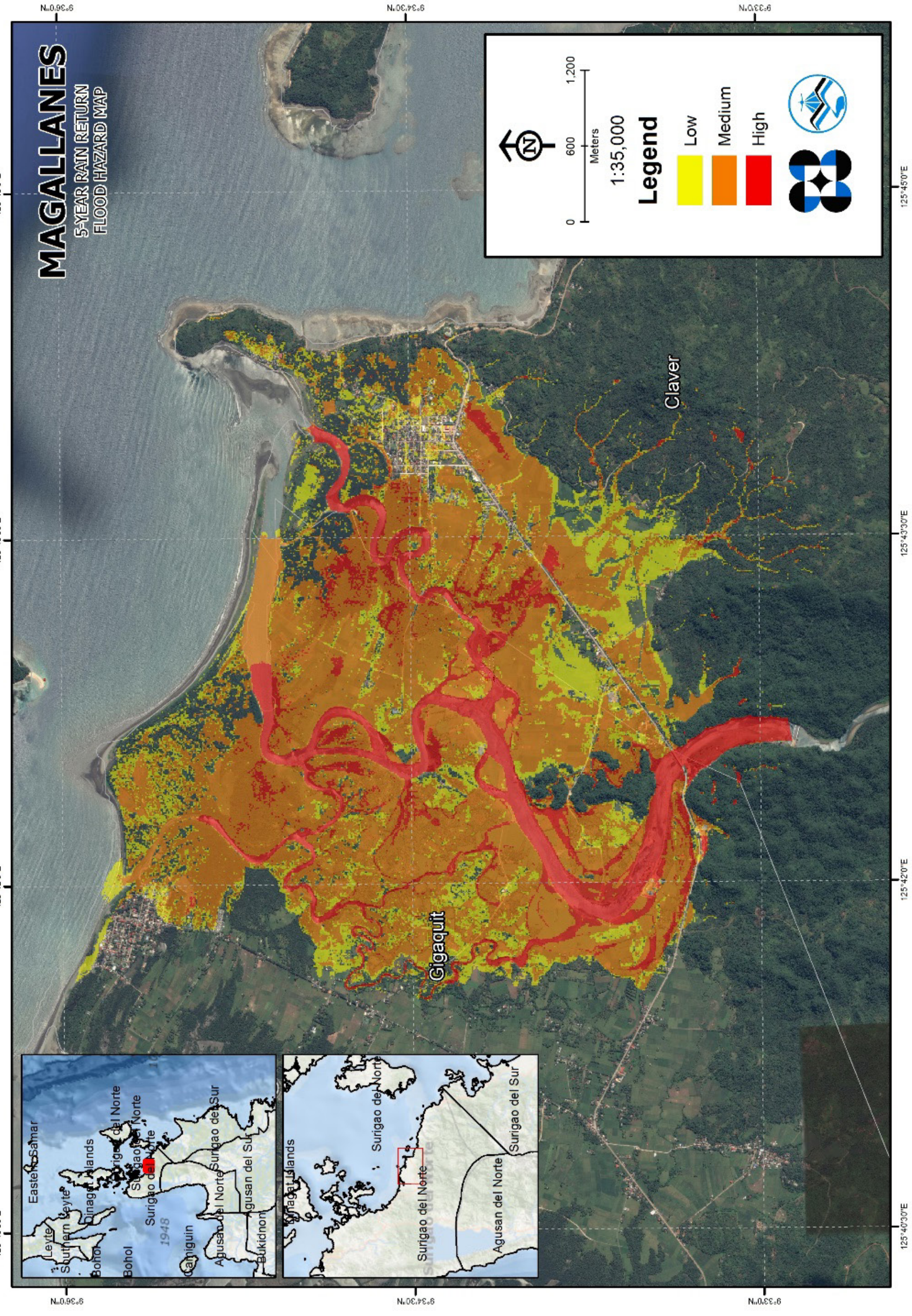


Figure 64. 5-year Flood Hazard Map for Magallanes Floodplain overlaid on Google Earth imagery

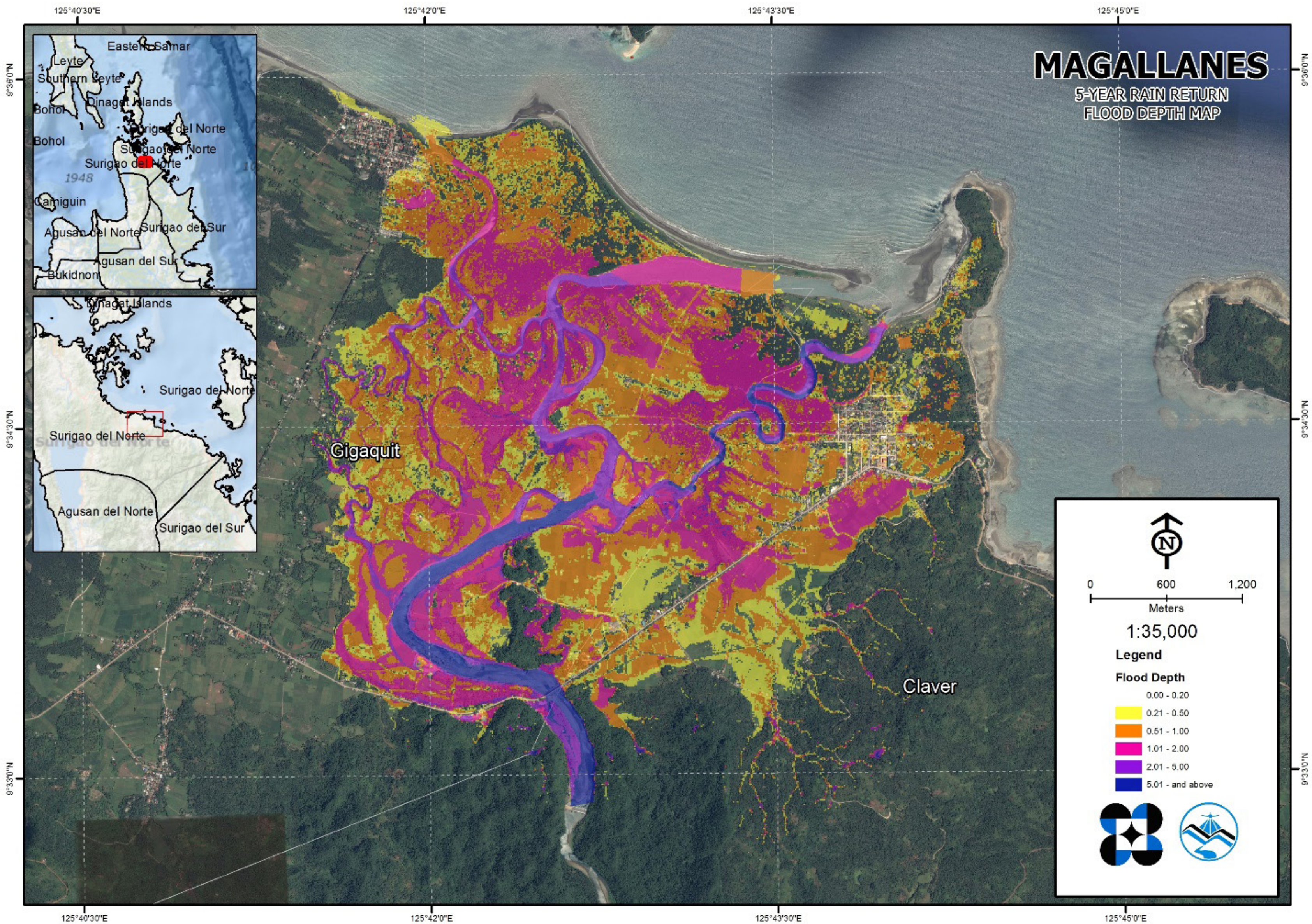


Figure 65. 5-year Flood Depth Map for Manicahan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Magallanes River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 15 barangays are expected to experience flooding.

For the 5-year return period, 1.89% of the municipality of Claver with an area of 337.34 sq. km. will experience flood levels of less than 0.20 meters. 0.99% of the area will experience flood levels of 0.21 to 0.50 meters while 1.33%, 1.44%, 1.55%, and 1.83% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 and shown in Figure 66 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Claver, Surigao del Norte during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claver (in sq. km.)						
	Bagakay	Daywan	Ladgaron	Magallanes	Panatao	Sapa	Tayaga
0.03-0.20	0.23	0.58	0.29	0.45	0.81	2.6	0.43
0.21-0.50	0.13	0.14	0.11	0.062	0.5	0.28	0.13
0.51-1.00	0.29	0.059	0.088	0.12	0.34	0.19	0.39
1.01-2.00	0.1	0.017	0.14	0.017	0.11	0.052	0.42
2.01-5.00	0.025	0.038	0.053	0.00038	0.0021	0.083	0.019
> 5.00	0.021	0.0095	0.035	0	0	0.12	0.0019

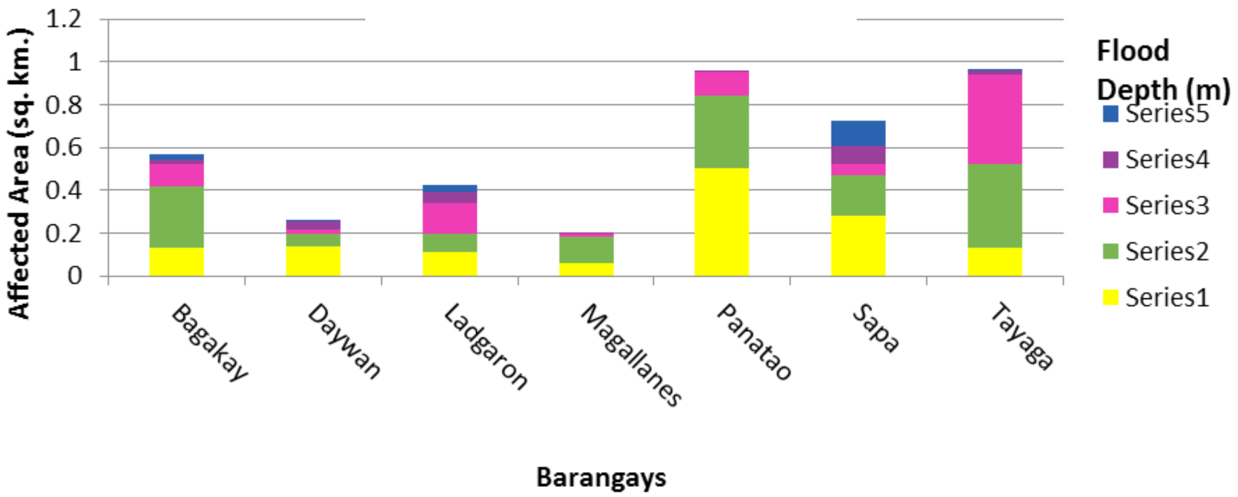


Figure 66. Affected Areas in Claver, Surigao del Norte during 5-Year Rainfall Return Period

For the 5-year return period, 1.73% of the municipality of Gigaquit with an area of 119.02 sq. km. will experience flood levels of less than 0.20 meters. 1.43% of the area will experience flood levels of 0.21 to 0.50 meters while 3.22%, 2.61%, 0.67%, and 0.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 and shown in Figure 67 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Gigaquit, Surigao del Norte during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gigaquit (in sq. km.)							
	Alambique	Anibongan	Ipil	Lahi	Mahanub	San Isidro	Villaflor	Villafranca
0.03-0.20	0.11	0.034	0.52	0.3	0.49	0.23	0.23	0.15
0.21-0.50	0.13	0.0026	0.39	0.009	0.38	0.56	0.15	0.079
0.51-1.00	0.13	0	0.52	0.0067	0.93	1.28	0.68	0.28
1.01-2.00	0.028	0	0.12	0.016	0.9	0.92	0.7	0.42
2.01-5.00	0.042	0	0	0.014	0.22	0.32	0.15	0.056
> 5.00	0	0	0	0.0025	0.38	0.043	0.00077	0

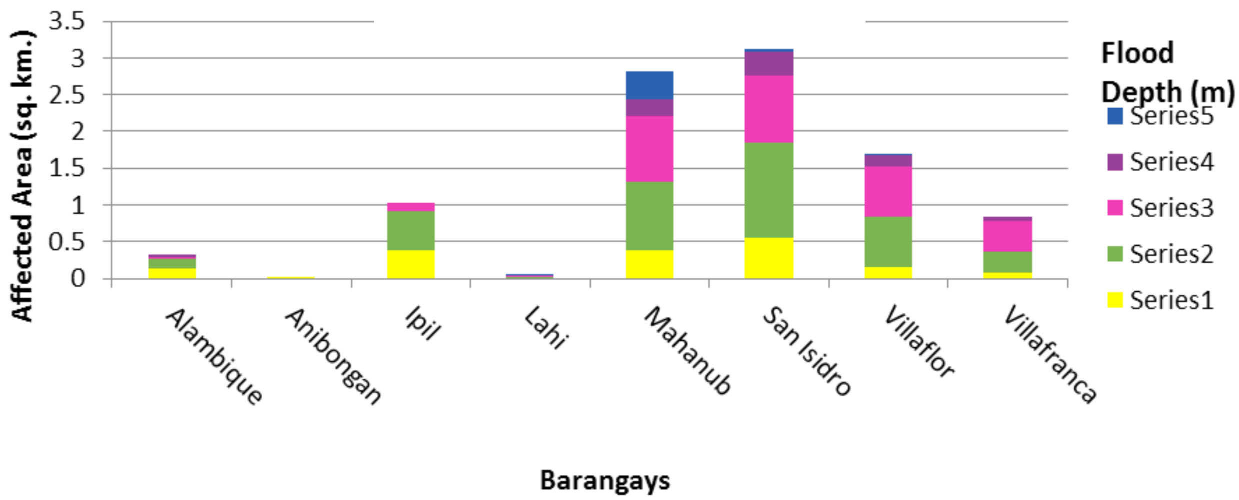


Figure 67. Affected Areas in Gigaquit, Surigao del Norte during 5-Year Rainfall Return Period

For the 25-year return period, 1.68% of the municipality of Claver with an area of 337.34 sq. km. will experience flood levels of less than 0.20 meters. 0.88% of the area will experience flood levels of 0.21 to 0.50 meters while 1.37%, 1.56%, 1.57%, and 1.86% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 and shown in Figure 68 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Claver, Surigao del Norte during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claver (in sq. km.)						
	Bagakay	Daywan	Ladgaron	Magallanes	Panatao	Sapa	Tayaga
0.03-0.20	0.11	0.47	0.17	0.41	0.65	2.49	0.37
0.21-0.50	0.1	0.14	0.087	0.04	0.28	0.25	0.061
0.51-1.00	0.18	0.14	0.15	0.079	0.58	0.26	0.22
1.01-2.00	0.35	0.032	0.18	0.12	0.24	0.24	0.11
2.01-5.00	0.033	0.048	0.075	0.00068	0.01	0.039	0.077
> 5.00	0.027	0.014	0.05	0	0	0.18	0.0021

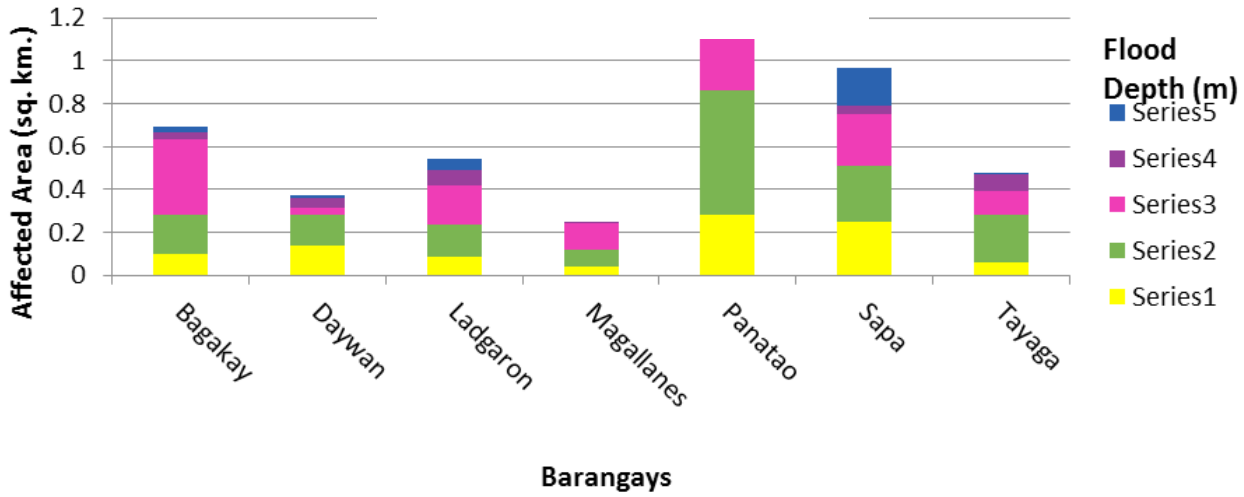


Figure 68. Affected Areas in Claver, Surigao del Norte during 25-Year Rainfall Return Period

For the 25-year return period, 1.28% of the municipality of Gigaquit with an area of 119.02 sq. km. will experience flood levels of less than 0.20 meters. 0.80% of the area will experience flood levels of 0.21 to 0.50 meters while 2.61%, 4.55%, 0.96%, 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 more than 5 meters, respectively. Listed in the Table 41 and shown in Figure 69 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Gigaquit, Surigao del Norte during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gigaquit (in sq. km.)							
	Alambique	Anibongan	Ipil	Lahi	Mahanub	San Isidro	Villaflor	Villafranca
0.03-0.20	0.076	0.032	0.37	0.29	0.39	0.11	0.16	0.1
0.21-0.50	0.093	0.0043	0.3	0.012	0.14	0.28	0.068	0.049
0.51-1.00	0.18	0	0.59	0.0069	0.75	1.08	0.34	0.16
1.01-2.00	0.046	0	0.29	0.014	1.27	1.27	1.42	1.11
2.01-5.00	0.046	0	0.0011	0.018	0.34	0.41	0.25	0.083
> 5.00	0	0	0	0.005	0.39	0.057	0.0012	0

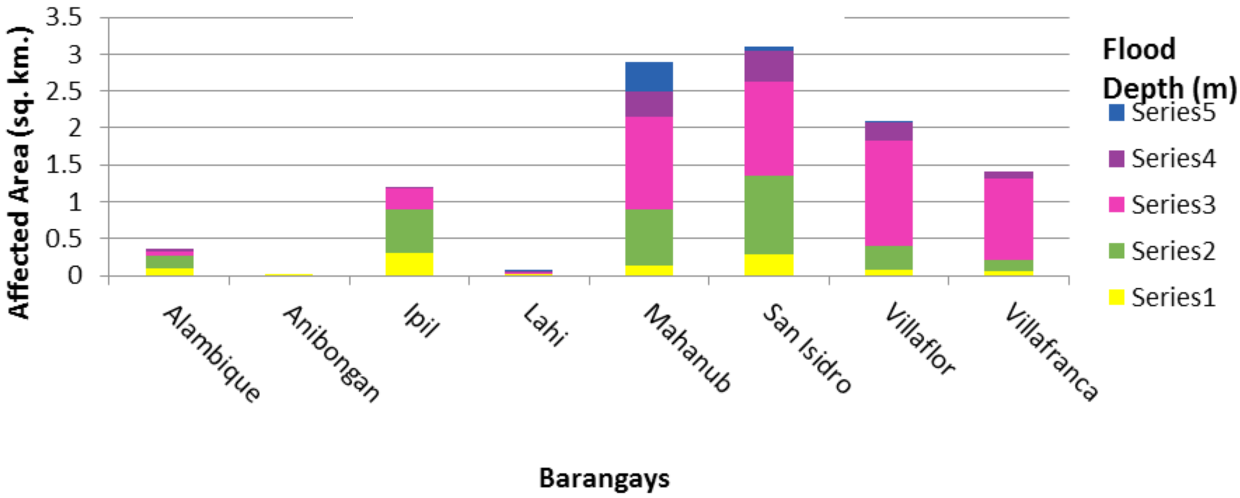


Figure 69. Affected Areas in Gigaquit, Surigao del Norte during 25-Year Rainfall Return Period

For the 100-year return period, 1.59% of the municipality of Claver with an area of 337.34 sq. km. will experience flood levels of less than 0.20 meters. 0.83% of the area will experience flood levels of 0.21 to 0.50 meters while 1.34%, 1.79%, 1.62%, and 1.87% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 and shown in Figure 70 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Claver, Surigao del Norte during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claver (in sq. km.)						
	Bagakay	Daywan	Ladgaron	Magallanes	Panatao	Sapa	Tayaga
0.03-0.20	0.059	0.42	0.12	0.4	0.59	2.42	0.35
0.21-0.50	0.069	0.14	0.06	0.035	0.21	0.23	0.049
0.51-1.00	0.16	0.17	0.16	0.054	0.58	0.29	0.12
1.01-2.00	0.42	0.054	0.18	0.16	0.36	0.16	0.7
2.01-5.00	0.055	0.047	0.12	0.00081	0.025	0.036	0.17
> 5.00	0.029	0.016	0.056	0	0	0.19	0.0021

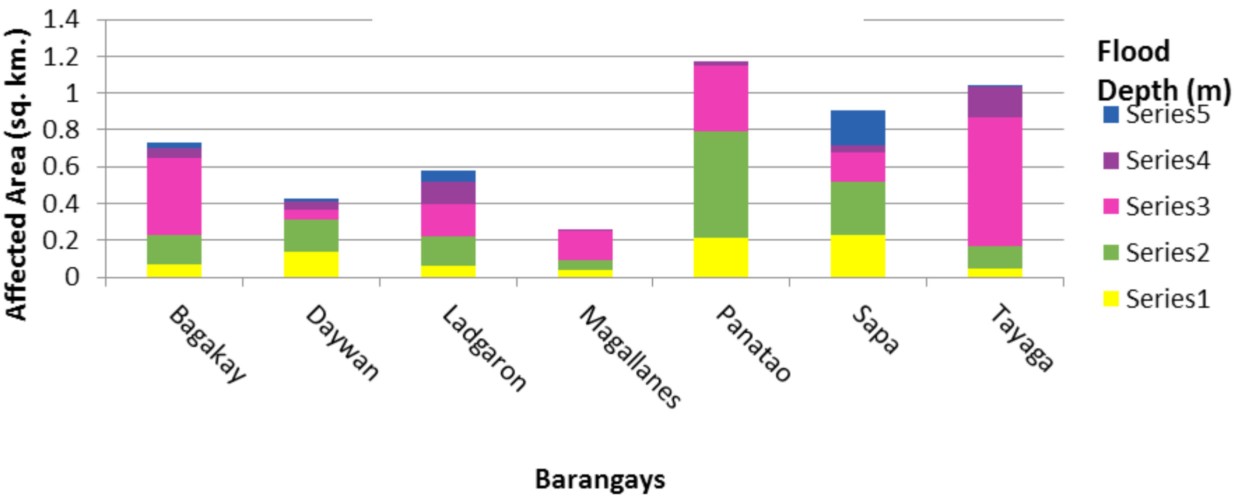


Figure 70. Affected Areas in Claver, Surigao del Norte during 100-Year Rainfall Return Period

For the 100-year return period, 1.15% of the municipality of Gigaquit with an area of 119.02 sq. km. will experience flood levels of less than 0.20 meters. 0.60% of the area will experience flood levels of 0.21 to 0.50 meters while 2.02%, 4.56%, 1.28%, and 0.40% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 and shown in Figure 71 are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Gigaquit, Surigao del Norte during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gigaquit (in sq. km.)							
	Alambique	Anibongan	Ipil	Lahi	Mahanub	San Isidro	Villaflor	Villafranca
0.03-0.20	0.055	0.032	0.32	0.28	0.37	0.078	0.14	0.093
0.21-0.50	0.084	0.005	0.26	0.012	0.094	0.18	0.048	0.035
0.51-1.00	0.19	0.000099	0.58	0.0085	0.47	0.8	0.23	0.13
1.01-2.00	0.069	0	0.38	0.015	1.5	1.69	1.16	0.61
2.01-5.00	0.048	0	0.0047	0.018	0.46	0.53	0.35	0.11
> 5.00	0	0	0	0.0075	0.4	0.064	0.0013	0

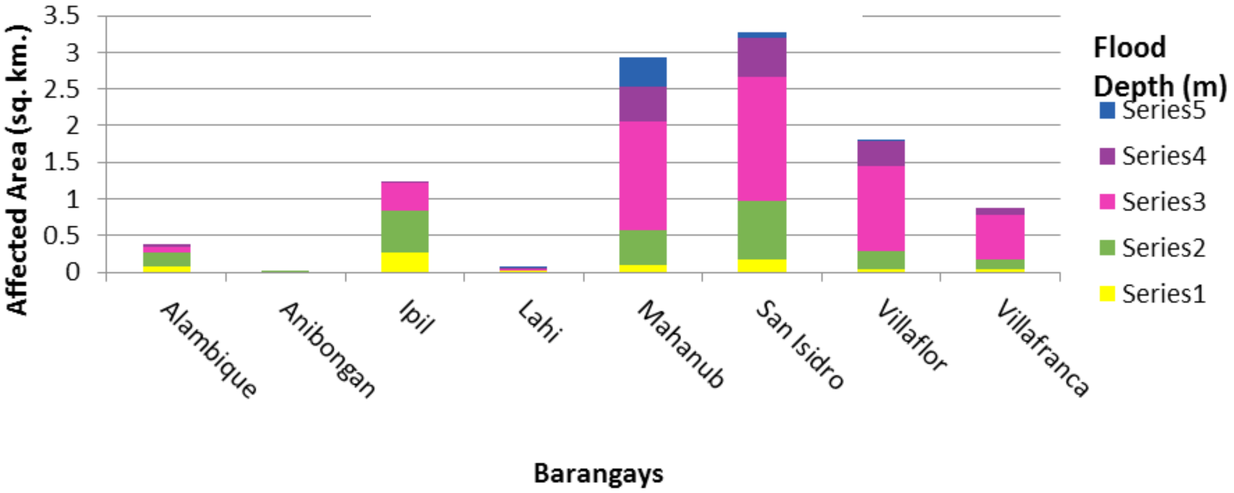


Figure 71. Affected Areas in Gigaquit, Surigao del Norte during 25-Year Rainfall Return Period

Among the barangays in the municipality of Claver, Sapa is projected to have the highest percentage of area that will experience flood levels at 0.99%. Meanwhile, Panatao posted the second highest percentage of area that may be affected by flood depths at 0.52%.

Among the barangays in the municipality of Gigaquit, San Isidrois projected to have the highest percentage of area that will experience flood levels at 2.81%. Meanwhile, Mahanubposted the second highest percentage of area that may be affected by flood depths at 2.77%.

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

Table 44. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.02	1.87	1.50
Medium	8.55	9.08	8.43
High	2.66	4.52	6.01
TOTAL	**14.23**	**15.47**	**15.94**

Of the 8 identified Education Institute in the Magallanes Flood plain, three (3) schools were discovered exposed to Low-level flooding during a 5-year scenario, while two (2) schools were found exposed to Medium-level flooding in the same scenario. In the 25-year scenario, two (2) schools were found exposed to Low-level flooding, while five (5) schools were discovered exposed to Medium-level flooding. In the 100-year scenario, six (6) schools were found exposed to high-level flooding. The educational institutions exposed to flooding are shown in Annex 12

Meanwhile, there were no health or medical institutions exposed to flooding in the Magallanes floodplain.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about past flooding events or interview with some residents with knowledge of or had experienced flooding in a particular area. The flood validation points were obtained on August 1-3, 2017.

The actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 73.

The flood validation consists of 354 points randomly selected all over the Magallanes floodplain (Figure 36). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 4.77m. Table 45 shows a contingency matrix of the comparison.

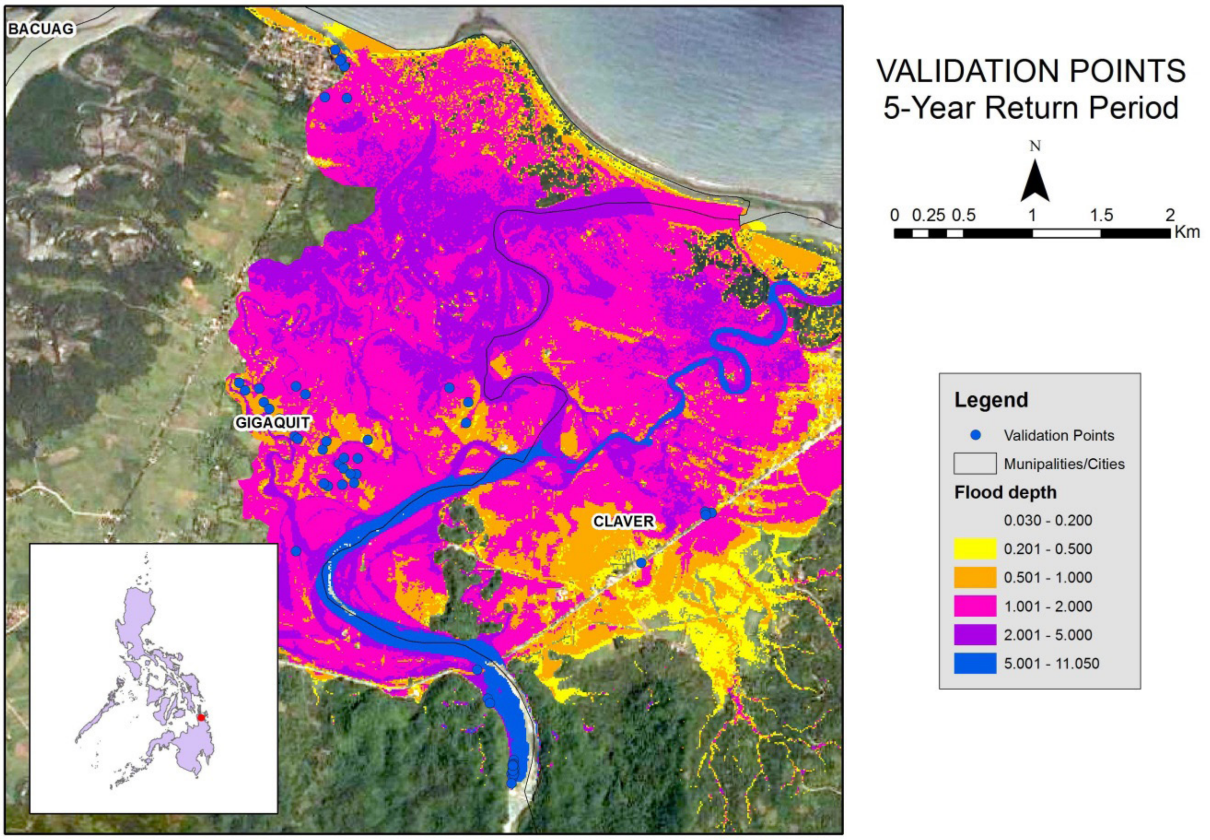


Figure 72. Magallanes River Basin Flood Validation Points

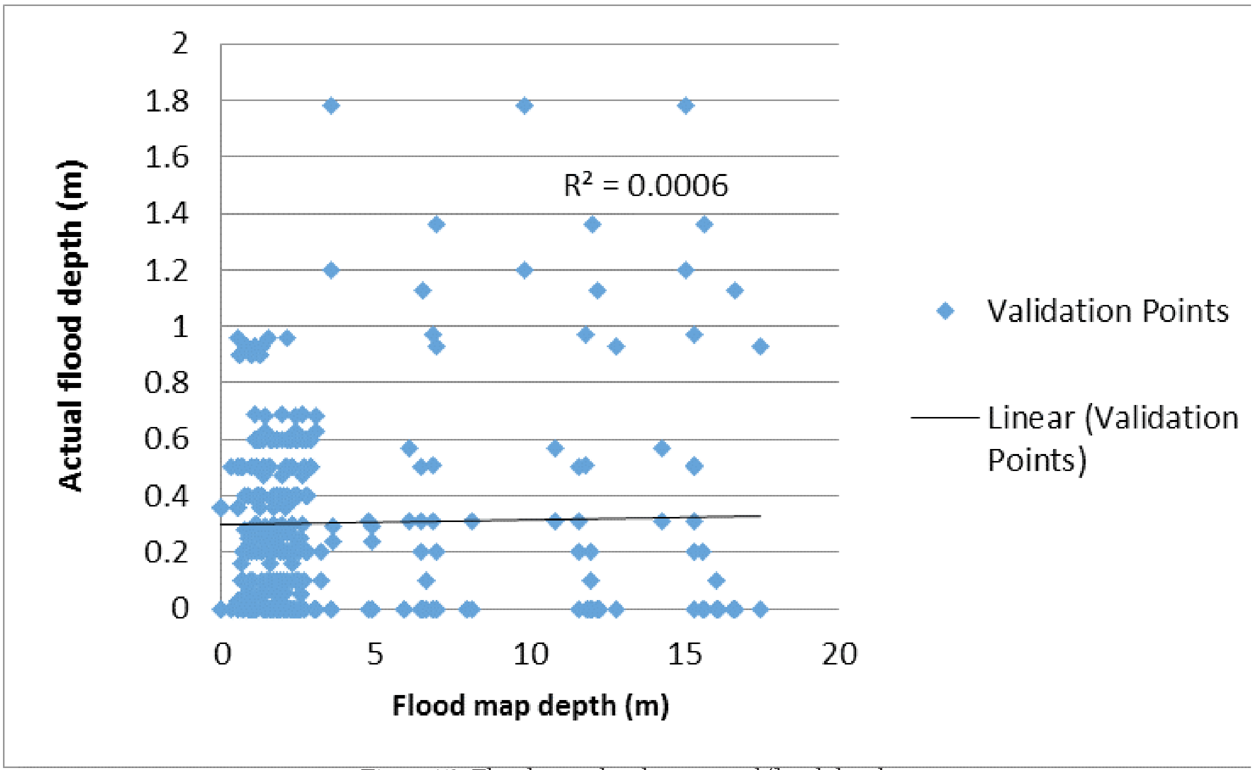


Figure 73. Flood map depth vs. actual flood depth

Table 45. Actual flood vs simulated flood depth at different levels in Magallanes 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	2	1	24	49	47	57	180
0.21-0.50	4	1	15	38	30	11	99
0.51-1.00	0	0	7	25	19	12	63
1.01-2.00	0	0	0	0	2	10	12
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	6	2	46	112	98	90	354

The overall accuracy generated by the flood model is estimated at 2.82% with 10 points correctly matching the actual flood depths. In addition, there were 47 points estimated one level above and below the correct flood depths while there were 91 points and 206 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 4 points were underestimated in the modelled flood depths of Magallanes. The summary of the accuracy assessment is presented in Table 46.

Table 46. Summary of the Accuracy Assessment in the Magallanes River Basin Survey

	No. of Points	%
Correct	10	2.82
Overestimated	340	96.05
Underestimated	4	1.13
Total	**354**	**100.00**

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

National Mapping and Resource Information Authority (NAMRIA). (n.d.). Retrieved from http://www.namria.gov.ph/4120-IIClaver.html

National Disaster Risk Reduction and Management Council (NDRRMC) 2014. Final Report, re: Effects of Tropical Depression "AGATON" (Rep.). (2014, January). Retrieved http://ndrrmc.gov.ph/attachments/article/2783/FINAL_REPORT_re_Effects_of_Tropical_Depression_AGATON_17_-_20JAN2014.pdf

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

US Department of Interior, 1966. A Report on the Agusan River Basin, Mindanao, Philippines. Bureau of Reclamation, US Department of Interior.

ANNEXES

Annex 1. Optech Technical Specification of the Sensors Used in the Magallanes LiDAR Data Acquisition Surveys

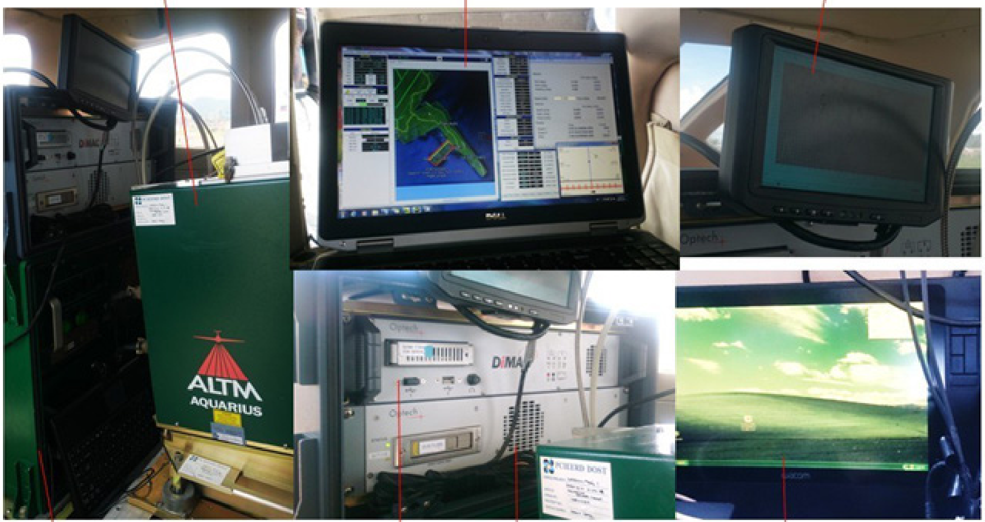


Figure A-1.1. Parameters and Specification of Aquarius Sensor

Table A-1.1. Parameters and Specification of Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg;
Control rack: 591 x 485 x 578 mm; 53 kg	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing
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

Figure A-1.1. Parameters and Specification of Gemini Sensor

Table A-1.1. Parameters and Specification of 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	Programmable, 0-75 ˚
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	-10˚C to +35˚C (with insulating jacket)
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. SRN-119

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

June 06, 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: **SURIGAO DEL NORTE**
Station Name: **SRN-119**
Order: **2nd**

Island: **MINDANAO**
Municipality: **SURIGAO CITY (CAPITAL)**
Barangay: **LIPATA**

PRS92 Coordinates

Latitude:	9° 48' 39.52825"	Longitude:	125° 27' 19.47825"	Ellipsoidal Hgt:	26.17900 m.

WGS84 Coordinates

Latitude:	9° 48' 35.66803"	Longitude:	125° 27' 24.75607"	Ellipsoidal Hgt:	92.90500 m.

PTM Coordinates

Northing:	1084859.315 m.	Easting:	549958.116 m.	Zone:	5

UTM Coordinates

Northing:		Easting:		Zone:	

Location Description

SRN-119
From Surigao City plaza travel NW distance of 10 km passing Surigao/ Butuan/ Lipata junction road. Upon reaching km post 114, SRN-119 is located beside km post 1114 along the national highway. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground inscribe with SRN-119 2007 NAMRIA.

Requesting Party:	UP-TCAGP
Pupose:	Reference
OR Number:	8796290 A
T.N.:	2014-1297

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

9906062014164321

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

CP/4701/12/01/814

Figure A-2.1. SRN-119

2. SRN-102

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

June 06, 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: **SURIGAO DEL NORTE**
Station Name: **SRN-102**
Order: **2nd**

Island: **MINDANAO**
Municipality: **SISON**
Barangay: **POBLACION (SAN PEDRO)**

PRS92 Coordinates

Latitude: **9° 39' 24.81730"** Longitude: **125° 31' 35.42419"** Ellipsoidal Hgt: **35.04700 m.**

WGS84 Coordinates

Latitude: **9° 39' 21.00341"** Longitude: **125° 31' 40.71501"** Ellipsoidal Hgt: **102.29400 m.**

PTM Coordinates

Northing: **1067829.026 m.** Easting: **557783.962 m.** Zone: **5**

UTM Coordinates

Northing: Easting: Zone:

Location Description

SRN-102
From Brgy. Bad-as junction landmark travel towards municipality of Sison for 7.1 km NE, turn left in the first municipality of Sison for 50 m to the barangay hall landmark then turn left by 300 m up to Patag bridge where SRN-102 monument is located. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground inscribe with SRN-102 2007 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1299**

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

9 9 0 6 0 6 2 0 1 4 1 6 4 4 1 8

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. SRN-102

3. SRN-116

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

June 06, 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: **SURIGAO DEL NORTE**
Station Name: **SRN-116**
Order: **2nd**

Island: **MINDANAO** Municipality: **GIGAQUIT**		Barangay: **POBLACION**
	PRS92 Coordinates	
Latitude: **9° 35' 38.35819"**	Longitude: **125° 41' 52.08650"**	Ellipsoidal Hgt: **2.65000 m.**
	WGS84 Coordinates	
Latitude: **9° 35' 34.57572"**	Longitude: **125° 41' 57.38121"**	Ellipsoidal Hgt: **70.45900 m.**
	PTM Coordinates	
Northing: **1060905.34 m.**	Easting: **576598.493 m.**	Zone: **5**
	UTM Coordinates	
Northing:	Easting:	Zone:

Location Description

SRN-116
From Barangay Bad-as landmark travel towards the municipality of Gigaquit for 27 km to the junction forward to municipality of Gigaquit for 3 km, turn right on Gijal Street about 200 m, then turn left for 30 m. The station is located in front of Ipil Primary School near the concrete fence, 7 m south side from the residence of Jerry Pipino. Mark is the head of a 3" copper nail set at the center of cement block embedded on the ground inscribe with SRN-116 2007 NAMRIA.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1300**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. SRN-116

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

1. SN-83

Table A-3.1. SN-83

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SRN-91 --- SRN-91A (B3)	SRN-91	SRN-91A	Fixed	0.001	0.002	98°42'29"	2.273	0.154
SRN-91 --- SRN-91A (B2)	SRN-91	SRN-91A	Fixed	0.001	0.003	98°42'35"	2.275	0.150
BMSN-106 --- SRN-106 (B5)	SRN-106	BMSN-106	Fixed	0.002	0.002	321°38'41"	659.752	1.558
SN-46 --- SRN-99 (B4)	SN-46	SRN-99	Fixed	0.026	0.137	149°46'09"	2796.818	5.434
SRN-116 --- BMSN-83 (B7)	SRN-116	BMSN-83	Fixed	0.003	0.016	166°39'47"	4243.865	10.203
BMSN-83 --- UPMAG-01 (B1)	BMSN-83	UPMAG-01	Fixed	0.001	0.002	250°39'29"	8.201	-0.428

Vector Components (Mark to Mark)

From:	SRN-116				
Grid		Local		Global	
Easting	796134.205 m	Latitude	N9°35'38.35818"	Latitude	N9°35'34.57572"
Northing	1061618.891 m	Longitude	E125°41'52.08650"	Longitude	E125°41'57.38121"
Elevation	1.587 m	Height	2.650 m	Height	70.459 m

To:	BMSN-83				
Grid		Local		Global	
Easting	797146.192 m	Latitude	N9°33'23.94445"	Latitude	N9°33'20.17252"
Northing	1057494.439 m	Longitude	E125°42'24.18740"	Longitude	E125°42'29.48535"
Elevation	11.642 m	Height	12.853 m	Height	80.767 m

Vector					
ΔEasting	1011.987 m	NS Fwd Azimuth	166°39'47"	ΔX	-1201.753 m
ΔNorthing	-4124.452 m	Ellipsoid Dist.	4243.865 m	ΔY	-5.351 m
ΔElevation	10.055 m	ΔHeight	10.203 m	ΔZ	-4070.167 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

2. UP-MAG1

Table A-3.2. UP-MAG1

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SRN-91 --- SRN-91A (B3)	SRN-91	SRN-91A	Fixed	0.001	0.002	98°42'29"	2.273	0.154
SRN-91 --- SRN-91A (B2)	SRN-91	SRN-91A	Fixed	0.001	0.003	98°42'35"	2.275	0.150
BMSN-106 --- SRN-106 (B5)	SRN-106	BMSN-106	Fixed	0.002	0.002	321°38'41"	659.752	1.558
SN-46 --- SRN-99 (B4)	SN-46	SRN-99	Fixed	0.026	0.137	149°46'09"	2796.818	5.434
SRN-116 --- BMSN-83 (B7)	SRN-116	BMSN-83	Fixed	0.003	0.016	166°39'47"	4243.865	10.203
BMSN-83 --- UPMAG-01 (B1)	BMSN-83	UPMAG-01	Fixed	0.001	0.002	250°39'29"	8.201	-0.428

Vector Components (Mark to Mark)

From:	BMSN-83				
Grid		Local		Global	
Easting	797146.192 m	Latitude	N9°33'23.94445"	Latitude	N9°33'20.17252"
Northing	1057494.439 m	Longitude	E125°42'24.18740"	Longitude	E125°42'29.48535"
Elevation	11.642 m	Height	12.853 m	Height	80.767 m

To:	UPMAG-01				
Grid		Local		Global	
Easting	797138.469 m	Latitude	N9°33'23.85603"	Latitude	N9°33'20.08411"
Northing	1057491.660 m	Longitude	E125°42'23.93365"	Longitude	E125°42'29.23160"
Elevation	11.213 m	Height	12.425 m	Height	80.339 m

Vector					
ΔEasting	-7.722 m	NS Fwd Azimuth	250°39'29"	ΔX	6.267 m
ΔNorthing	-2.779 m	Ellipsoid Dist.	8.201 m	ΔY	4.540 m
ΔElevation	-0.429 m	ΔHeight	-0.428 m	ΔZ	-2.750 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'08"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, DR.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. MILLIE SHANE REYES ENGR. RENAN PUNTO ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. GEF SORIANO KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA SSG. CHARISMA NAVARRO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC
		CAPT. RANDY LAGCO	AAC
		CAPT. JERICHO JECIEL	AAC

Annex 5. Data Transfer Sheet for Magallanes Floodplain

DATA TRANSFER SHEET
06/16/2014(Surigao)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5/30/2014	7280GC	2BLK59FG150A	Gemini	na	82.6	236	100	na	na	8.34	NA	3.96	1KB	1KB	8	9.91	Z:\Airborne_Raw\7280GC
5/30/2014	7281GC	2BLK59F150B	Gemini	na	143	259	139	na	na	10.4	NA	4.42	1KB	1KB	9.16	NA	Z:\Airborne_Raw\7281GC
5/31/2014	7282GC	2BLK59EFS151A	Gemini	na	557	560	245	na	na	20.3	NA	2.86	1KB	1KB	7.14	NA	Z:\Airborne_Raw\7282GC
5/31/2014	7283GC	2BLK59GS151B	Gemini	na	150	334	133	na	na	12.3	NA	4.36	1KB	1KB	9.54	25.9	Z:\Airborne_Raw\7283GC
6/1/2014	7284GC	2BLK59GS152A	Gemini	na	23.3	188	117	na	na	6.03	NA	4.98	1KB	1KB	3.99	NA	Z:\Airborne_Raw\7284GC
6/2/2014	7286GC	2BLK59CD153A	Gemini	na	235	375	214	na	na	13.8	NA	4.32	1KB	1KB	10	NA	Z:\Airborne_Raw\7286GC
6/3/2014	7288GC	2BLK59C+BLK60D154A	Gemini	na	417	540	261	na	na	22.2	NA	4.6	1KB	1KB	7.4	9.44	Z:\Airborne_Raw\7288GC

Received from

Name C. Sodoyeni
Position RA
Signature [signature]

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature [signature] 6/16/14

Figure A-5.1. Transfer Sheet for Magallanes Floodplain - A

DATA TRANSFER SHEET
06/20/2014(Surigao)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Jun-14	7292GC	2BLK60DS156A	Gemini	na	352	483	230	na	na	19.1	NA	1.09	1KB	1KB	16	29	Z:\Airborne_Raw\7292GC
5-Jun-14	7293GC	2BLK59GS156B	Gemini	na	312	291	122	na	na	12.4	NA	4.07	1KB	1KB	4	NA	Z:\Airborne_Raw\7293GC
6-Jun-14	7294GC	2BLK59AB157A	Gemini	na	345	595	260	na	na	6.18	NA	8.24	1KB	1KB	6	15	Z:\Airborne_Raw\7294GC
6-Jun-14	7295GC	2BLK59GS+FV157B	Gemini	na	32.7	275	123	na	na	9.98	NA	8.24	1KB	1KB	13	na	Z:\Airborne_Raw\7295GC
7-Jun-14	7296GC	2BLK60CDS158A	Gemini	na	95.8	557	257	na	na	20.9	NA	8.45	1KB	1KB	10	NA	Z:\Airborne_Raw\7296GC
7-Jun-14	7297GC	2BLK59ES158B	Gemini	na	61.2	149	99.9	na	na	5.1	NA	8.45	1KB	1KB	22	14	Z:\Airborne_Raw\7297GC
8-Jun-14	7298GC	2BLK59ASDS159A	Gemini	na	73.6	463	204	na	na	17.9	NA	8.52	1KB	1KB	10	17	Z:\Airborne_Raw\7298GC
9-Jun-14	7300GC	2BLK59FG+BLK60DCV160A	Gemini	na	258	468	216	na	na	15.4	NA	4.78	1KB	1KB	18	na	Z:\Airborne_Raw\7300GC

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name JOIDA F. PRIETO 6/20/2014
Position SSRS
Signature

Figure A-5.2. Transfer Sheet for Magallanes Floodplain - B

DATA TRANSFER SHEET
10/30/2014(Surigao-Dinagat)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
14-Sep	1946A	3BLK59BS257A	Aquarius	na	844	0.98	170	na	na	8.45	na	9.26	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
15-Sep	1950A	3BLK59D258A	Aquarius	na	286	577	209	na	na	11.2	na	9.14	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Sep	1966A	3BLK59C262A	Aquarius	na	1167	2.14	214	na	na	12	na	10.3	1KB	1KB	10	na	Z:\DAC\RAW DATA
19-Sep	1968A	3BLK59D262B	Aquarius	na	231	1.99	137	na	na	6.56	na	10.3	1KB	1KB	10/7	na	Z:\DAC\RAW DATA
20-Sep	1970A	3BLK59S263A	Aquarius	na	341	2.98	153	na	na	6.25	na	9.05	1KB	1KB	11	na	Z:\DAC\RAW DATA
21-Sep	1974A	3BLK59S264A	Aquarius	na	204	867	182	na	na	8.2	na	13.4	1KB	1KB	8	na	Z:\DAC\RAW DATA
23-Sep	1982A	3BLK59DS266A	Aquarius	na	149	324	142	na	na	6.44	na	8.44	1KB	1KB	10	na	Z:\DAC\RAW DATA
24-Sep	1986A	3BLK59E267A	Aquarius	na	332	643	220	na	na	13.5	na	22.7	1KB	1KB	14.8	na	Z:\DAC\RAW DATA
24-Sep	1988A	3BLK59ES267B	Aquarius	na	630	0.98	186	na	na	11.6	na	22.7	1KB	1KB	7	na	Z:\DAC\RAW DATA
27-Sep	1998A	3BLK59F270A	Aquarius	na	537/119	1.3	278	na	na	15.7	na	12.4	1KB	1KB	12/18	na	Z:\DAC\RAW DATA
28-Sep	2002A	3BLK59FDS271A	Aquarius	na	226	619	207	na	na	11.7	na	9.74	1KB	1KB	10/18	na	Z:\DAC\RAW DATA
11-Oct	2054A	3BLK59S284A	Aquarius	na	na	466	212	na	na	6.7	na	8.54	1KB	1KB	10/20/21	na	Z:\DAC\RAW DATA
12-Oct	2060A	3BLK59FS285B	Aquarius	na	40	1.33	120	na	na	2.36	na	13.7	1KB	1KB	21/24	na	Z:\DAC\RAW DATA
18-Oct	2082A	3BLK59S291A	Aquarius	na	431	724	152	na	na	4.73	na	6.1	1KB	1KB	na	na	Z:\DAC\RAW DATA
20-Oct	2090A	3BLK59DS293A	Aquarius	na	89	240	117	na	na	5.04	na	5.43	1KB	1KB	11	na	Z:\DAC\RAW DATA
21-Oct	2094A	3BLK63R294A	Aquarius	na	193	691	205	na	na	8.75	na	10.4	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
21-Oct	2096A	3BLK63R294B	Aquarius	na	405	875	190	na	na	8.84	na	9.64	1KB	1KB	5/6	na	Z:\DAC\RAW DATA
22-Oct	2098A	3BLK59S295A	Aquarius	na	na	329	106	na	na	2.48	na	8.9	1KB	1KB	15/23	na	Z:\DAC\RAW DATA

Received from
Name C. Joaquin
Position SA
Signature

Received by
Name JUDIDA F. PRIETO
Position SUPSRS
Signature
10/31/2014

Figure A-5.3. Transfer Sheet for Magallanes Floodplain - C

DATA TRANSFER SHEET

20/06/2016 SURIGAO DEL NORTE AND DINAGAT

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5/8/2016	8481AC	3BLK59AB129A	AQUARIUS	NA	268	683	253	42.9	31.8/6.19	11.7	163	76.5	1KB	1KB	17/187	NA	Z:\DAC\RAWDATA
5/10/2016	8485AC	3BLK59BC131A	AQUARIUS	NA	250	659	231	39.8	92.4/181/0	10.6	183	74.9	1KB	1KB	15.3/170	42.9	Z:\DAC\RAWDATA
5/11/2016	8487AC	3BLK60AB132A	AQUARIUS	NA	311	1.01	270	77.2	199/120	13.5	147	125	1KB	1KB	16.3/219	NA	Z:\DAC\RAWDATA
5/11/2016	8488AC	3BLK60D132B	AQUARIUS	NA	108	1.01	144	30.1	199/120	5.13	76.8	125	1KB	1KB	13/75.2	NA	Z:\DAC\RAWDATA
5/12/2016	8489AC	3BLK60EF133A	AQUARIUS	NA	210	585	256	75.5	164/172	9.49	152	91.3	1KB	1KB	13/75.2	NA	Z:\DAC\RAWDATA
5/12/2016	8490AC	3BLK60CEsG133B	AQUARIUS	NA	318	948	146	23.2	164/172	5.19	NA	91.3	1KB	1KB	13	NA	Z:\DAC\RAWDATA
5/13/2016	8491AC	3CALIB134A & 3BLK59C134A	AQUARIUS	NA	156	734	190	37.6	384/554	7.13	113	91.6	1KB	1KB	14.1/107	NA	Z:\DAC\RAWDATA
5/13/2016	8492AC	3BLK60CS134B	AQUARIUS	NA	306	268	146	NA	NA	4.79	74.7	91.6	1KB	1KB	13/143	NA	Z:\DAC\RAWDATA
5/14/2016	8493AC	3DNGB135A	AQUARIUS	NA	43.6	156	74.8	12.9	64.9	2.24	13.5	28.4	1KB	1KB	4.38/29.4	NA	Z:\DAC\RAWDATA
5/16/2016	8497AC	3DNGABSC137A	AQUARIUS	NA	216	604	240	51.4	183	9.66	NA	75.7	1KB	1KB	6.87/144	NA	Z:\DAC\RAWDATA
5/17/2016	8499AC	3DNGE138A	AQUARIUS	NA	210	611	236	NA	NA	9.44	NA	3	1KB	1KB	4.59/145	14.5	Z:\DAC\RAWDATA
5/18/2016	8501AC	3BLK60AS139A	AQUARIUS	NA	59.6	173	113	11	76.2	3.09	NA	47.6	1KB	1KB	40.6	NA	Z:\DAC\RAWDATA

Name DARRYL M. AUSTRIA
Position R.A.
Signature

Name AC Bongat
Position SSRS
Signature 6/23/16

Figure A-5.4. Transfer Sheet for Magallanes Floodplain - D

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 3BLK59S295A

PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No. 2

1 LIDAR Operator: L. PUNTO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK59S295A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. ALFONSO	8 Co-Pilot: M.A. GARCHITORENA	9 Route:			
10 Date: OCT. 22, 2014	12 Airport of Departure (Airport, City/Province): SURIGAO		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 10:19	14 Engine Off: 12:19	15 Total Engine Time: 2	16 Take off: 10:24	17 Landing: 12:14	18 Total Flight Time: 1+50
19 Weather					
20 Remarks: MISSION SUCCESSFUL.					
21 Problems and Solutions:					

CERTIFIED PHOTOCOPY
Signature
Name LEMUEL GARCIA
Date 11.24.14

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	JE CACANINDIN	Ceasar Alfonso III	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 3BLK59S295A

2. Flight Log for 2BLK59C + BLK60D154A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7288

1 LIDAR Operator: MV Tongo	2 ALTM Model: Gemini/CASI	3 Mission Name: 2BLK59C60D154A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R-Samar II	8 Co-Pilot: B-Donguines	9 Route:			
10 Date: 6-3-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5+13	14 Engine Off: 9+36	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 59C completed and surveyed lines in 60D without CASI

21 Problems and Solutions:

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

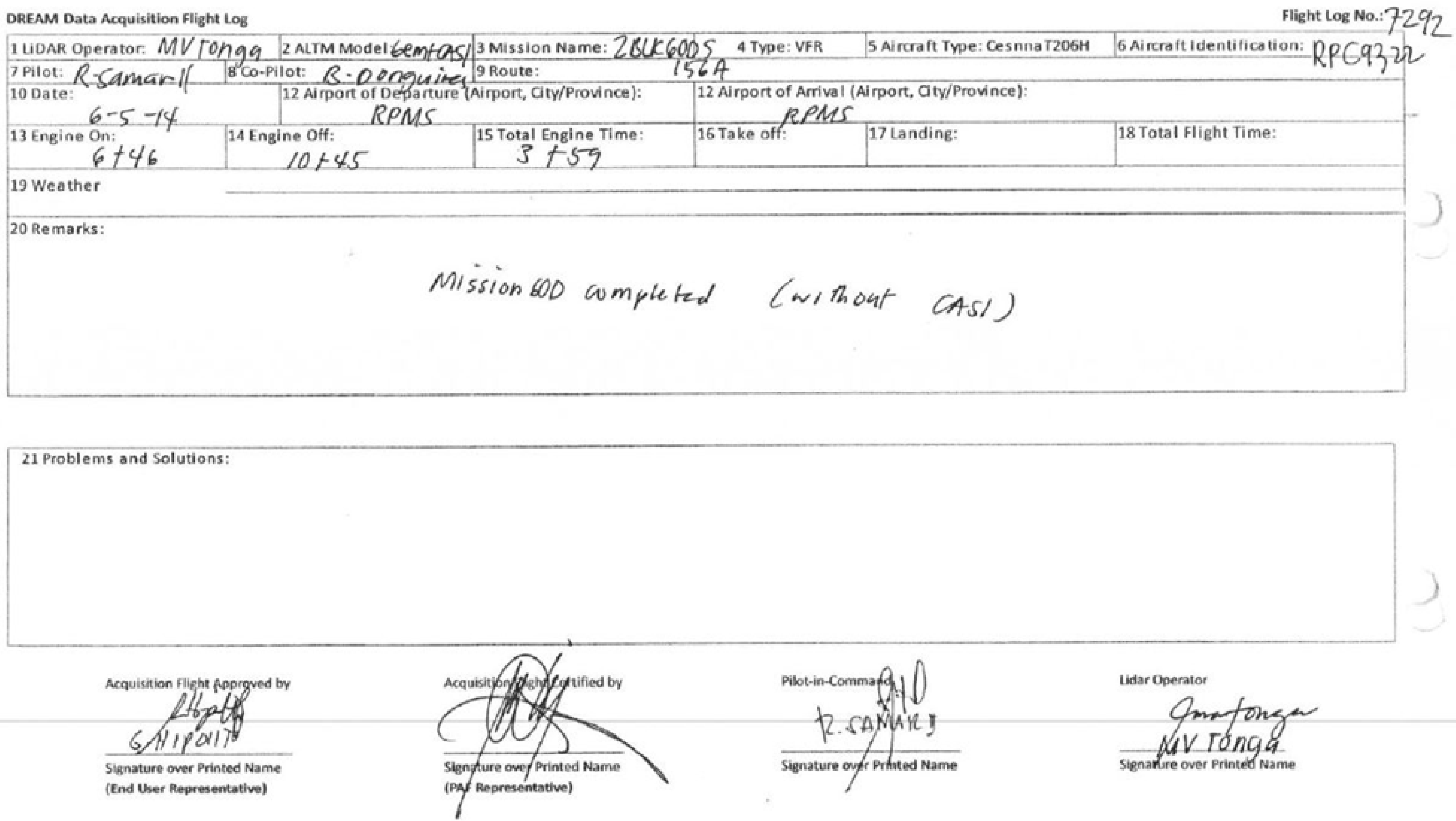
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
MV Tongo
Signature over Printed Name

Figure A-6.2. Flight Log for Mission 2BLK59C + BLK60D154A

3. Flight Log for 22BLK60DS156A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7292

1 LiDAR Operator: MV Tongga	2 ALTM Model: Gem+CASI	3 Mission Name: 2BLK60DS156A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9322
7 Pilot: R. Samaril	8 Co-Pilot: R. Dongguines	9 Route:			
10 Date: 6-5-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 6+46	14 Engine Off: 10+45	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission 60D completed (without CASI)					

21 Problems and Solutions:

Acquisition Flight Approved by: Signature over Printed Name (End User Representative) 6/11/2017

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

Pilot-in-Command: R. SAMARIL Signature over Printed Name

Lidar Operator: MV TONGA Signature over Printed Name

Figure A-6.3. Flight Log for Mission 22BLK60DS156A

4. Flight Log for 2BLK60CDS158A Mission

Flight Log No.: 7296

DREAM Data Acquisition Flight Log

1 LIDAR Operator: LK Paragas	2 ALTM Model: Gemini/CASI	3 Mission Name: 2BLK60CDS158A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R Santa-11	8 Co-Pilot: B. Donguines	9 Route:			
10 Date: 6-7-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5+39	14 Engine Off: 10+8	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 60C completed & surveyed voids in 60D (without CASI)

21 Problems and Solutions:

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

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

Pilot-in-Command — R. Santa — Signature over Printed Name

Lidar Operator — LK Paragas — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2BLK60CDS158A

5. Flight Log for 2BLK5960V160A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7306

1 LIDAR Operator: LK Paragas	2 ALTM Model: Gemini CASI	3 Mission Name: 2BLK5960V160A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R.Samaniego	8 Co-Pilot: B. Dongulaes	9 Route:			
10 Date: 6-9-14	12 Airport of Departure (Airport, City/Province): RPMS		12 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5+28	14 Engine Off: 9+9	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: Surveyed voids in Blk 59 & 60 (without CASI)					
21 Problems and Solutions:					

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

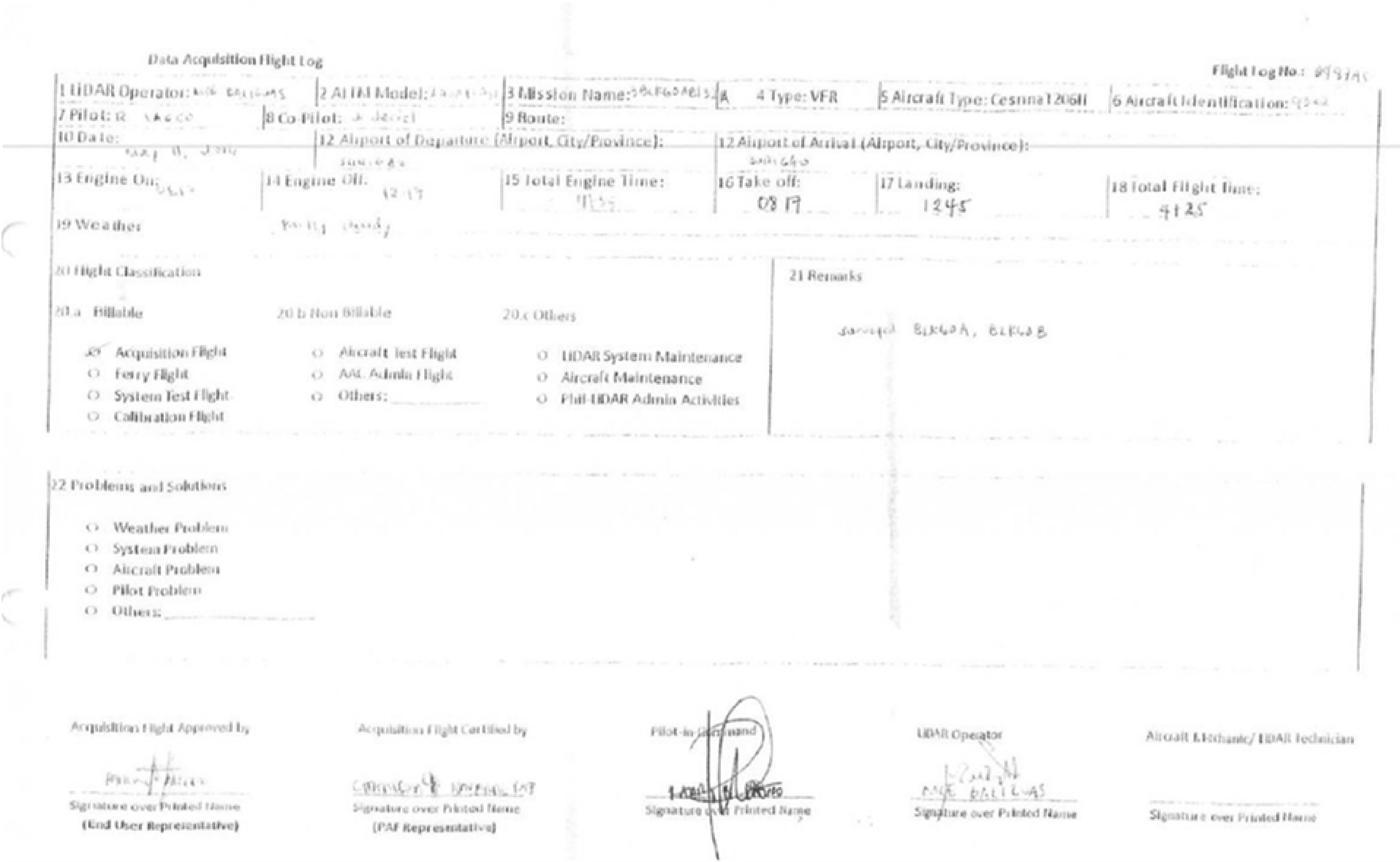
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
R. SAMANIEGO
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2BLK5960V160A

6. Flight Log for 23BLK60AB132A Mission



Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: | 2 ALTM Model: | 3 Mission Name: | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification:

7 Pilot: | 8 Co-Pilot: | 9 Route:

10 Date: | 12 Airport of Departure (Airport, City/Province): | 12 Airport of Arrival (Airport, City/Province):

13 Engine On: | 14 Engine Off: | 15 Total Engine Time: | 16 Take off: 0817 | 17 Landing: 1245 | 18 Total Flight Time: 4+25

19 Weather

20 Flight Classification

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

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

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

21 Remarks

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

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

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

Pilot-in-Command — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 3BLK60AB132A

7. Flight Log for 3BLK60AS139A Mission

Data Acquisition Flight Log

Flight Log No.: 8902AC

1 LIDAR Operator:	2 ALTM Model:	3 Mission Name: 3BLK60AS139A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. LAGCO	8 Co-Pilot: J. JERIEL	9 Route:			
10 Date:	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1255	14 Engine Off: 1500	15 Total Engine Time: 2+05	16 Take off: 1300	17 Landing: 1455	18 Total Flight Time: 1+55
19 Weather	Partly cloudy				

20 Flight Classification

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

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

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

21 Remarks

Covered voids over BLK60AS

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	RANDY E LAGCO Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 3BLK60AS139A

Annex 7. Flight Status Reports

Zamboanga City - Zamboanga Sibugay Flights
February 5 to 8, 2015

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2098A	BLK 60S	3BLK59S295A	R. Punto	Oct 22, 2015	Filled up some gaps in Surigao City/del Norte
7288GC	BLK59C & BLK60D	2BLK59C + BLK60D154A	MV. TONGA	03-Jun-14	Completed area C, but there are gaps due to high terrain, also covered 7 strips of area BLK60D.
7292GC	BLK60D	2BLK60DS156A	MV. TONGA	05-Jun-14	Covered 17 lines, some lines were shortened due to low cloud ceiling
7296GC	BLK60C & BLK60D	2BLK60CDS158A	L. PARAGAS	07-Jun-14	Completed area C, however there are some possible voids due to clouds and high terrain. Also covered gaps in area D.
7300GC	BLK59 F, BLK59G, BLK60C & BLK60D	2BLK59FG + BLK60DCV160A	L. PARAGAS	09-Jun-14	Covered all the voids and gaps in BLKS59 F, G, & BLKS60 C & D.
8487AC	BLK60A, BLK60B	3BLK60AB132A	MCE BALIGUAS	May 11, 2016	Surveyed BLK60AB132A
8501AC	BLK60A	3BLK60AS139A	MCE BALIGUAS	May 18, 2016	Completed voids over Gigaquit

LAS BOUNDARIES PER MISSION FLIGHT

Flight No. :	2098A		
Area:	BLK 59 mainland Surigao		
Mission Name:	3BLK59S295A		
Parameters:	PRF 50khz	SF 45hz	SCA 18deg

Figure A-7.1. Swath for Flight No. 2098A

Flight log no: 7288GC
Area: BLK59C & BLK60D
Mission Name: 2BLK59C+BLK60D154A

Figure A-7.2. Swath for Flight No. 7288GC

Flight Log No.: 7292GC
Area: BLK60D
Mission Name: 2BLK60DS156A

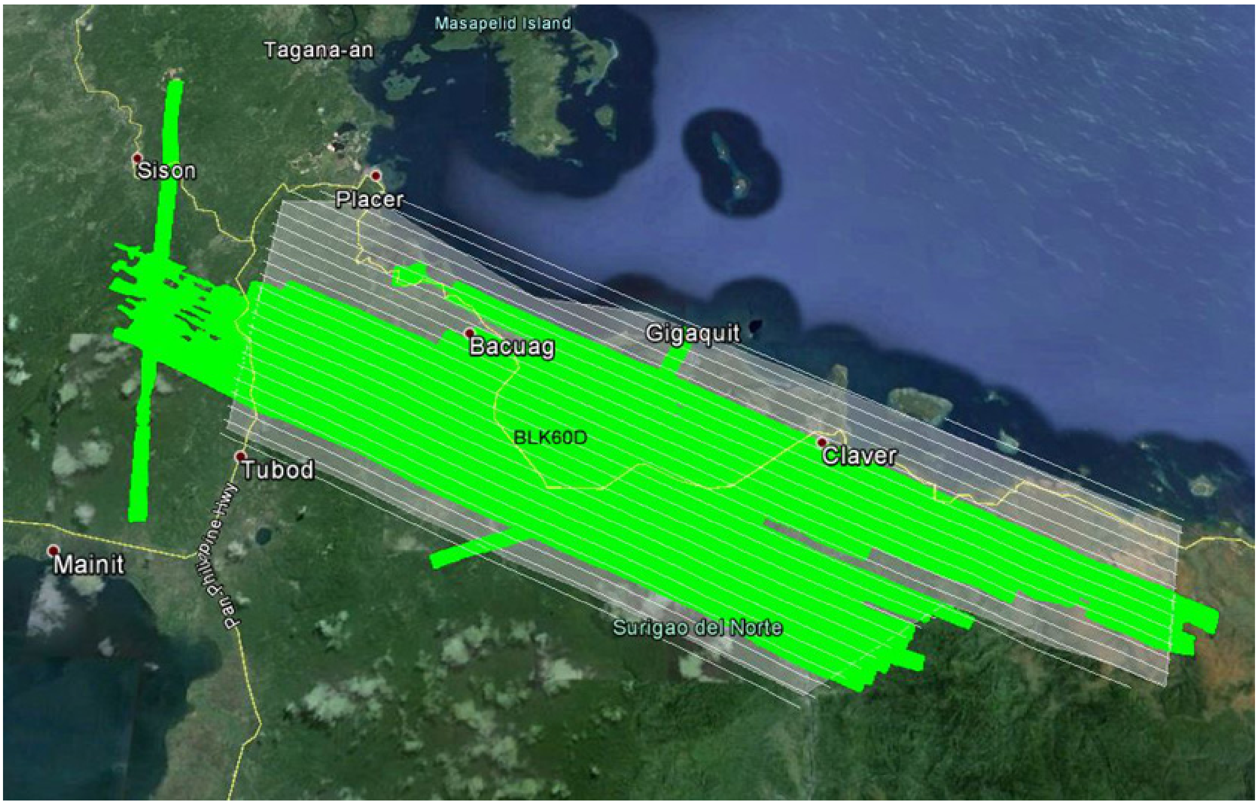


Figure A-7.3. Swath for Flight No. 7292GC

Flight Log No.: 7296GC
Area: BLK59C & BLK59D
Mission Name: 2BLK60CDS158A

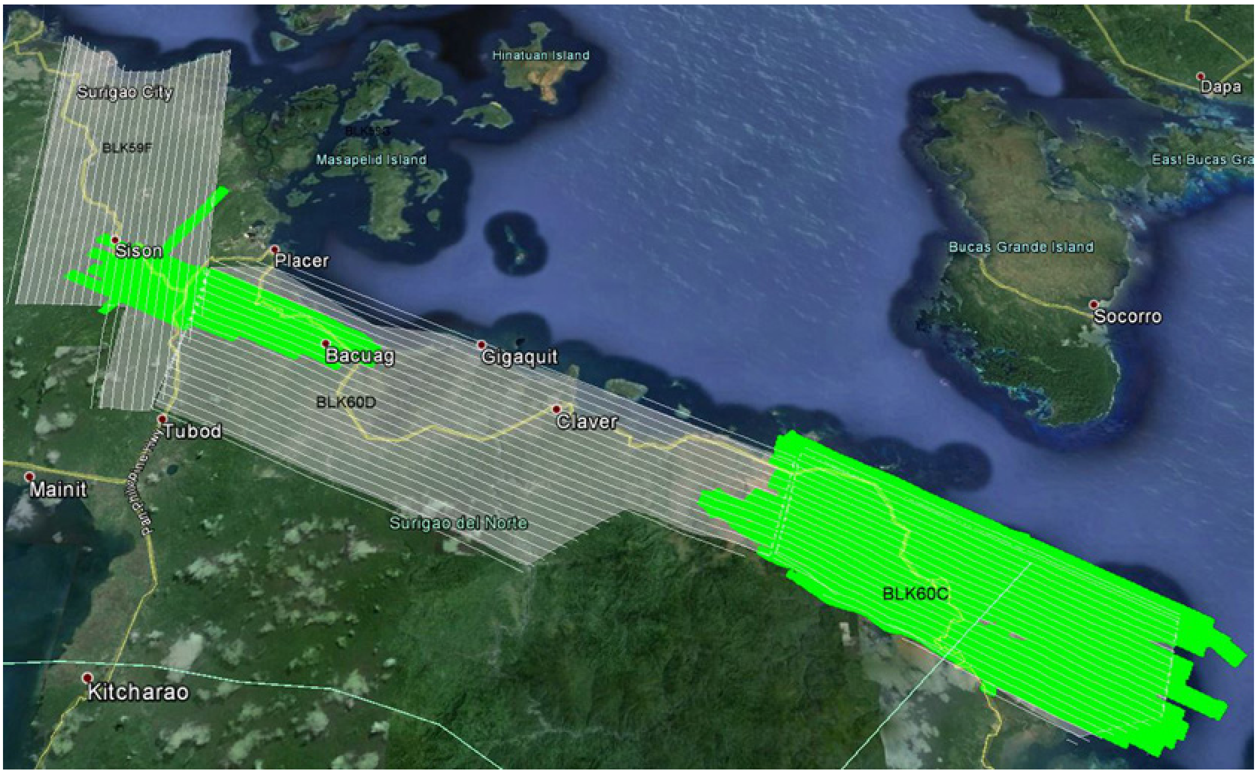


Figure A-7.4. Swath for Flight No. 7296GC

Flight Log No.: 7300GC
Area: BLK59F, BLK59G, BLK60C & BLK60D
Mission Name: 2BLK59FG+BLK60DCV160A

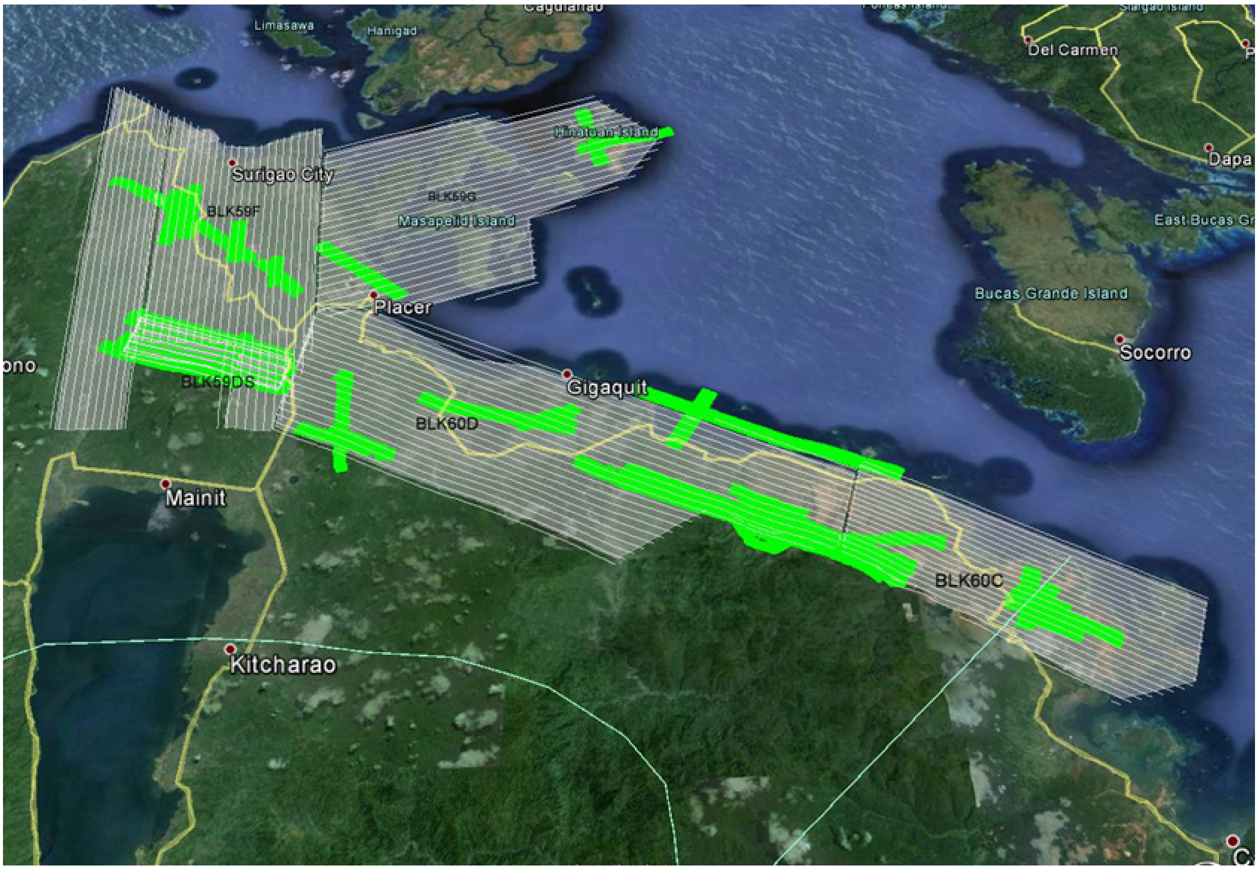


Figure A-7.5. Swath for Flight No. 7300GC

Flight No.: 8487
Area: SURIGAO DEL NORTE
Mission Name : 3BLK60AB132A
Alt: 500m Scan Freq: 45hz Scan Angle: 18 deg

Figure A-7.6. Swath for Flight No. 8487

Flight No. : 8501
Area: SURIGAO DEL NORTE
Mission Name: 3BLK60AS139A
Alt: 500m Scan Freq: 45hz Scan Angle: 18 deg

Figure A-7.7. Swath for Flight No. 8501

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk59S (Siargao)

Flight Area	Surigao City
Mission Name	Blk59S (Siargao)
Inclusive Flights	2098A
Range data size	2.48 GB
POS data size	106 MB
Base data size	8.9 MB
Image	NA
Transfer date	October 31, 2014
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)	1.55
RMSE for East Position (<4.0 cm)	1.50
RMSE for Down Position (<8.0 cm)	2.60
Boresight correction stdev (<0.001deg)	0.000419
IMU attitude correction stdev (<0.001deg)	0.079240
GPS position stdev (<0.01m)	0.0046
Minimum % overlap (>25)	25.16%
Ave point cloud density per sq.m. (>2.0)	2.64
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	395.70 m
Minimum Height	61.78 m
Classification (# of points)	
Ground	7,605,135
Low vegetation	6,863,127
Medium vegetation	8,127,697
High vegetation	11,046,719
Building	1,042,530
Orthophoto	No
Processed by	Engr. Irish Cortez, Eng. Chelou Prado, Engr. Melissa Fernandez

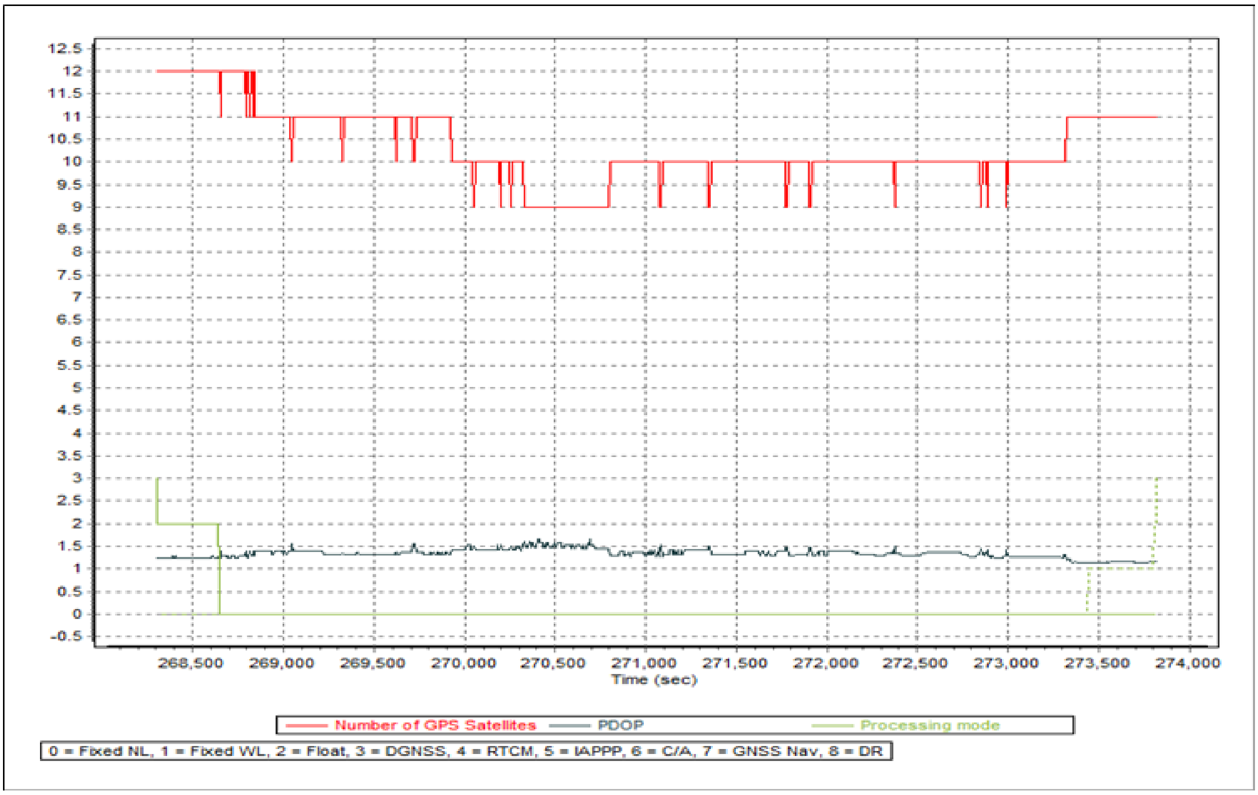


Figure A-8.1. Solution Status

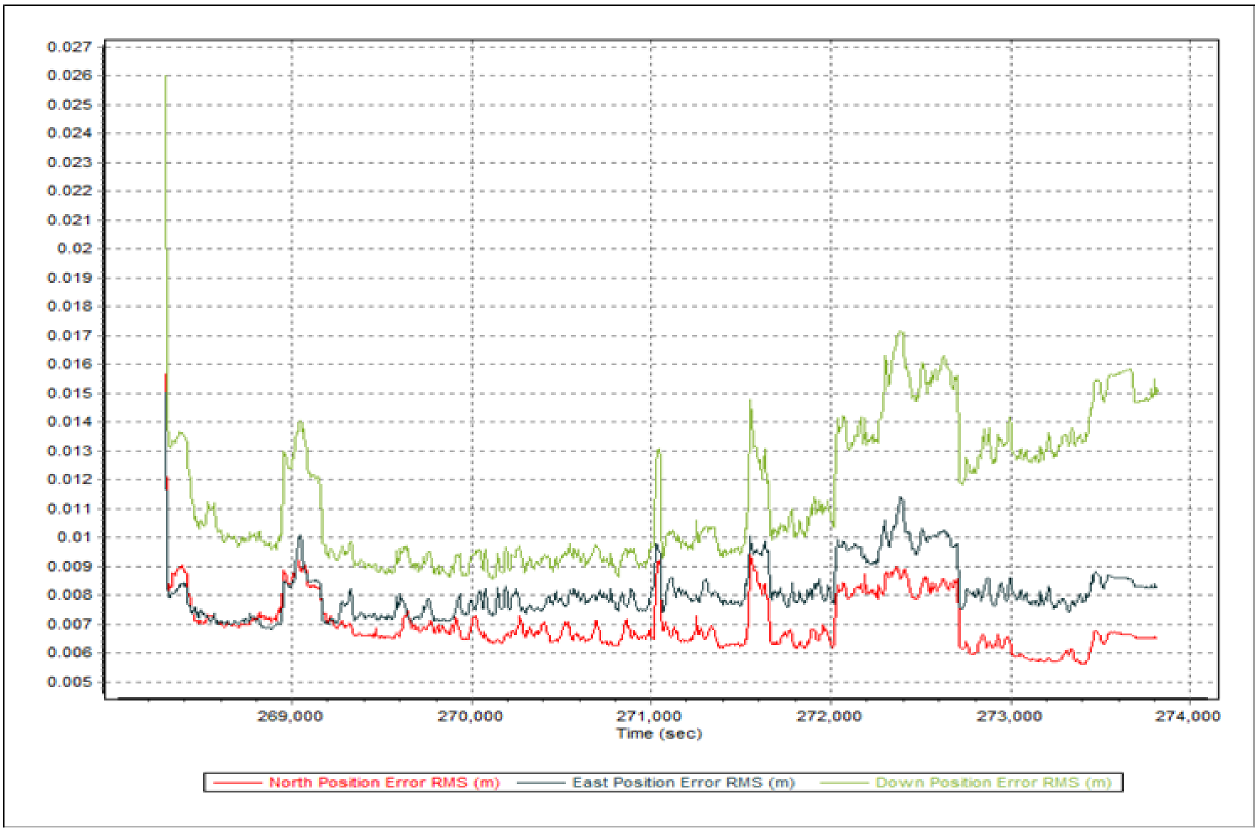


Figure A-8.2. Smoothed Performance Metrics Parameters

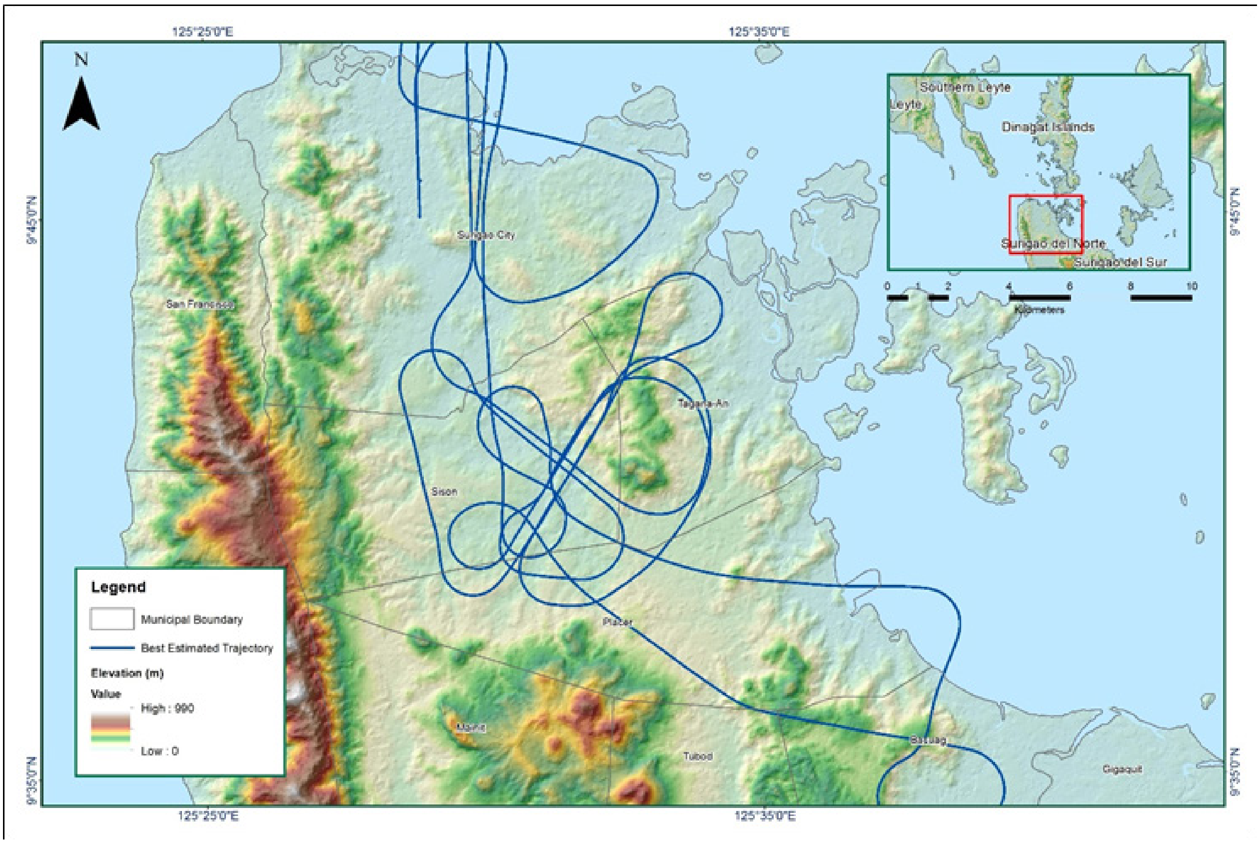


Figure A-8.3. Best Estimated Trajectory

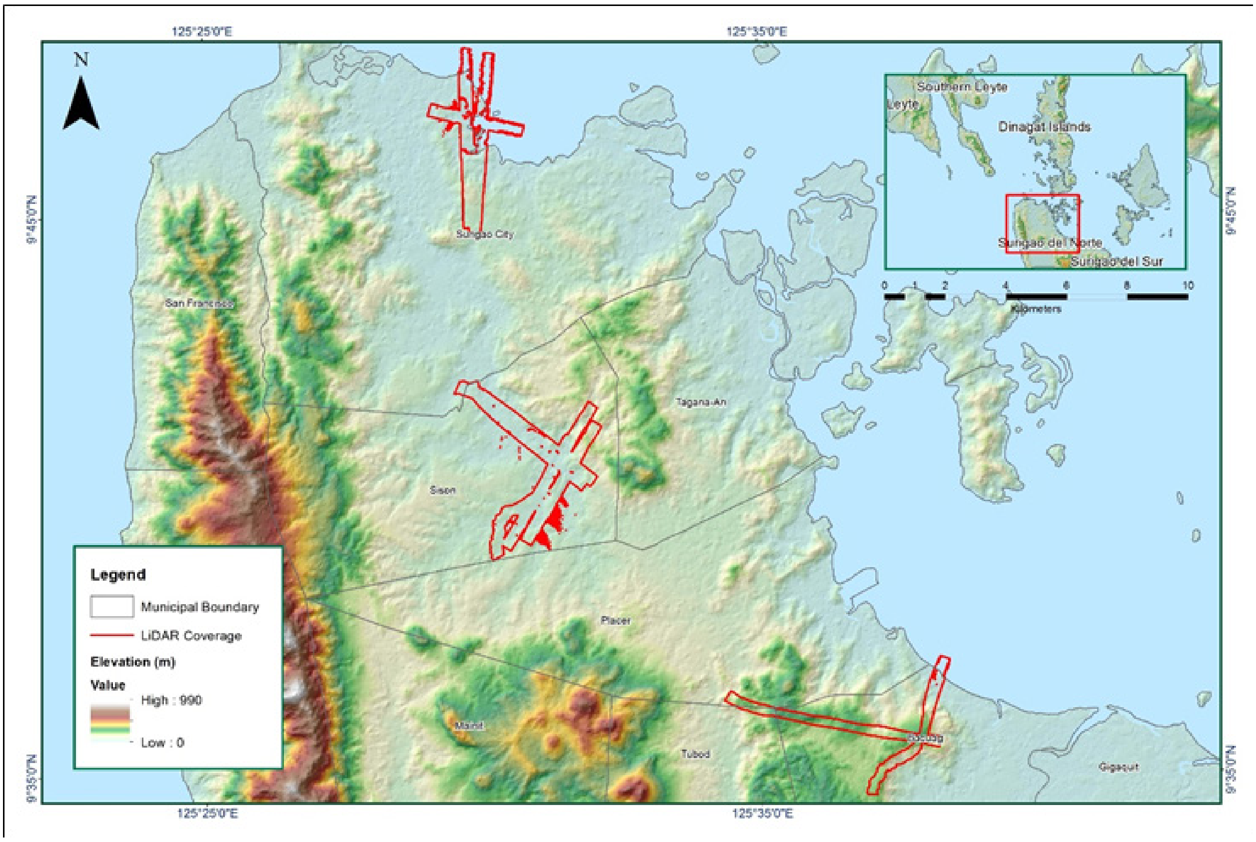


Figure A-8.4. Coverage of LiDAR data

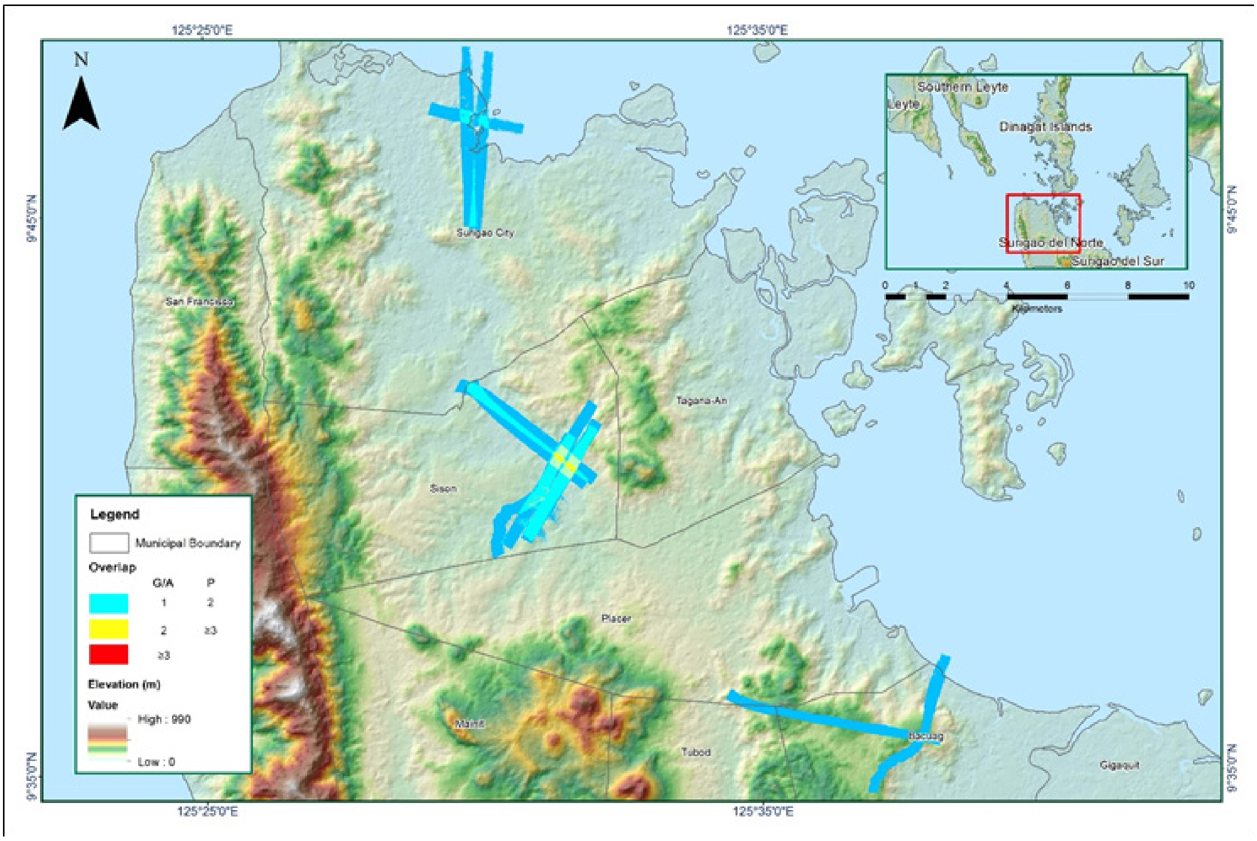


Figure A-8.5. Image of Data Overlap

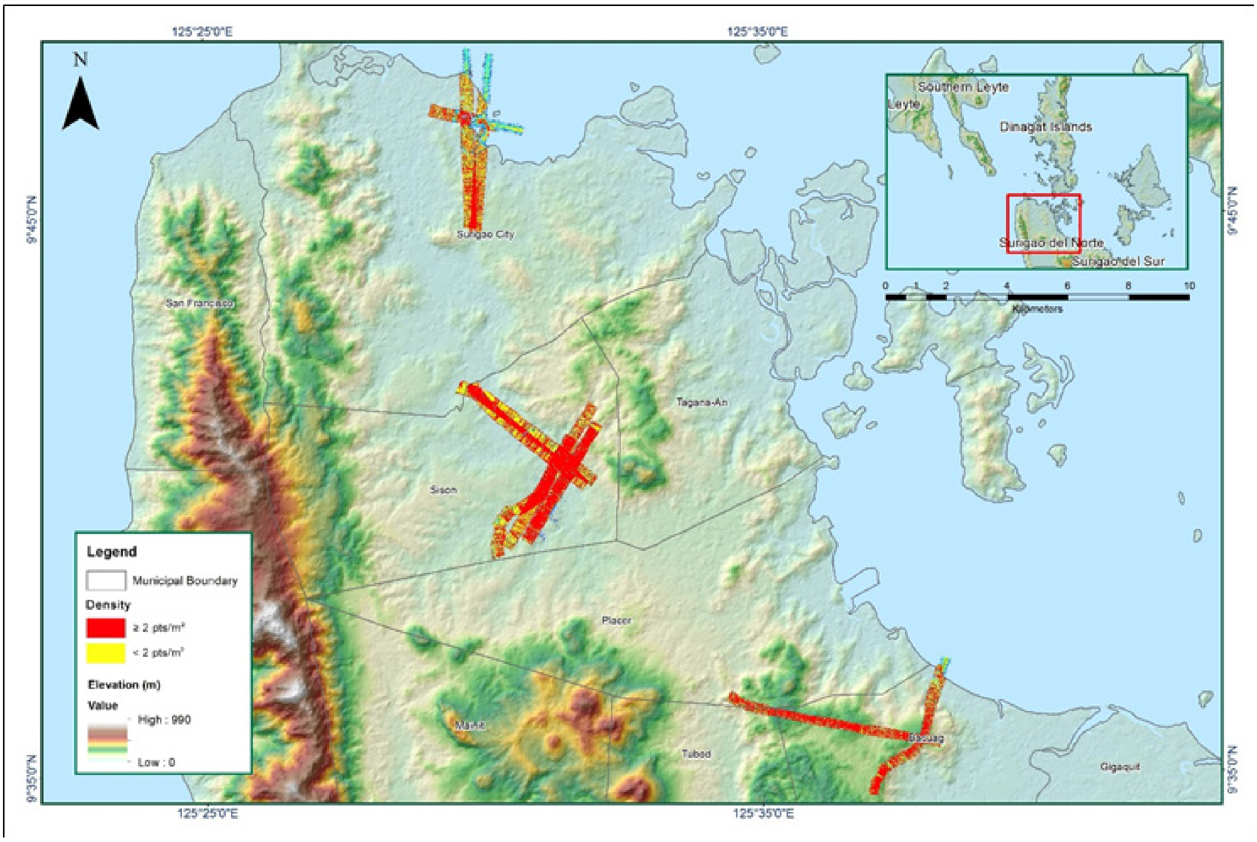


Figure A-8.6. Density map of merged LiDAR data

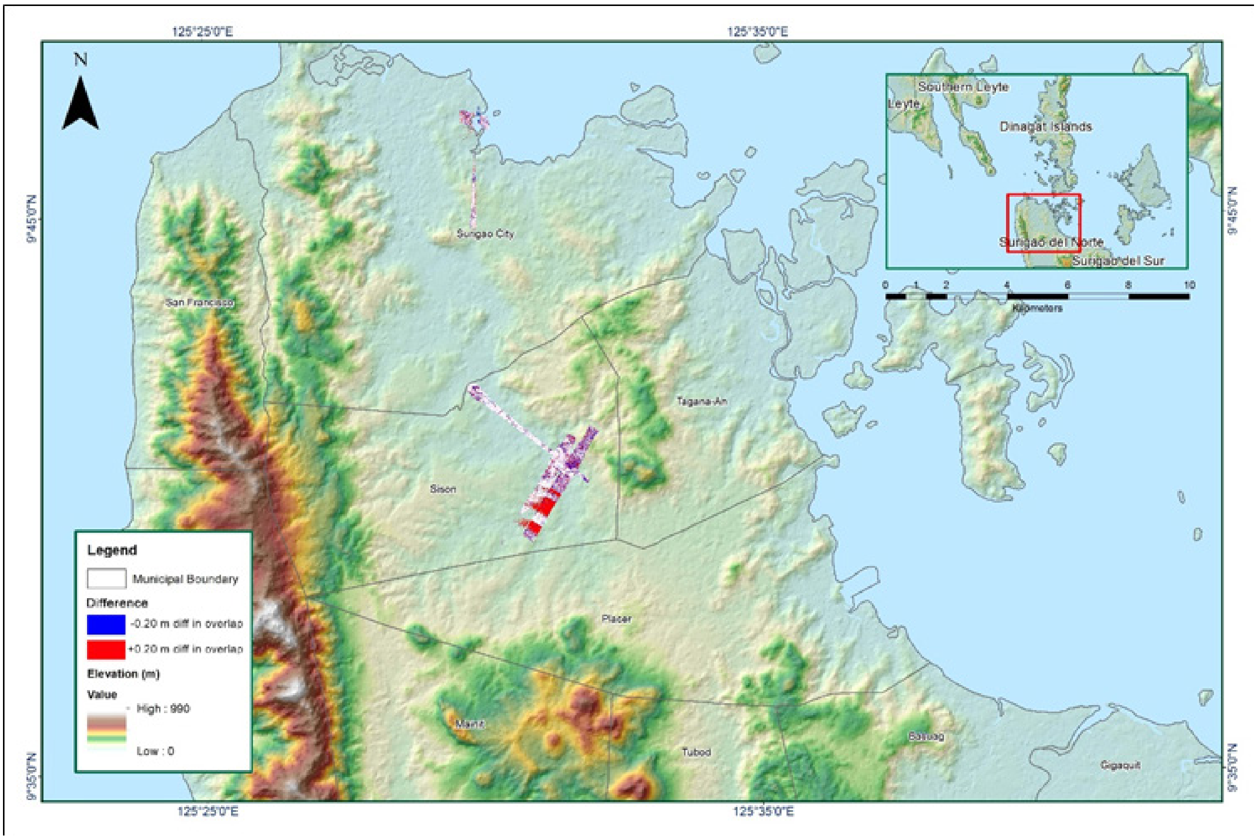


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Block 60C

Flight Area	Surigao Reflights
Mission Name	Block 60C
Inclusive Flights	8487AC
Range data size	13.5 GB
POS data size	270 MB
Base data size	125 MB
Image	77.2 GB
Transfer date	June 23, 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)	0.819
RMSE for East Position (<4.0 cm)	1.179
RMSE for Down Position (<8.0 cm)	2.362
Boresight correction stdev (<0.001deg)	0.000128
IMU attitude correction stdev (<0.001deg)	0.000043
GPS position stdev (<0.01m)	0.0338
Minimum % overlap (>25)	62.60
Ave point cloud density per sq.m. (>2.0)	5.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	126
Maximum Height	568.09 m
Minimum Height	63.42 m
Classification (# of points)	
Ground	81,286,560
Low vegetation	61,770,655
Medium vegetation	83,239,547
High vegetation	97,383,253
Building	3,852,190
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Engr. Czarina Jean Añonuevo

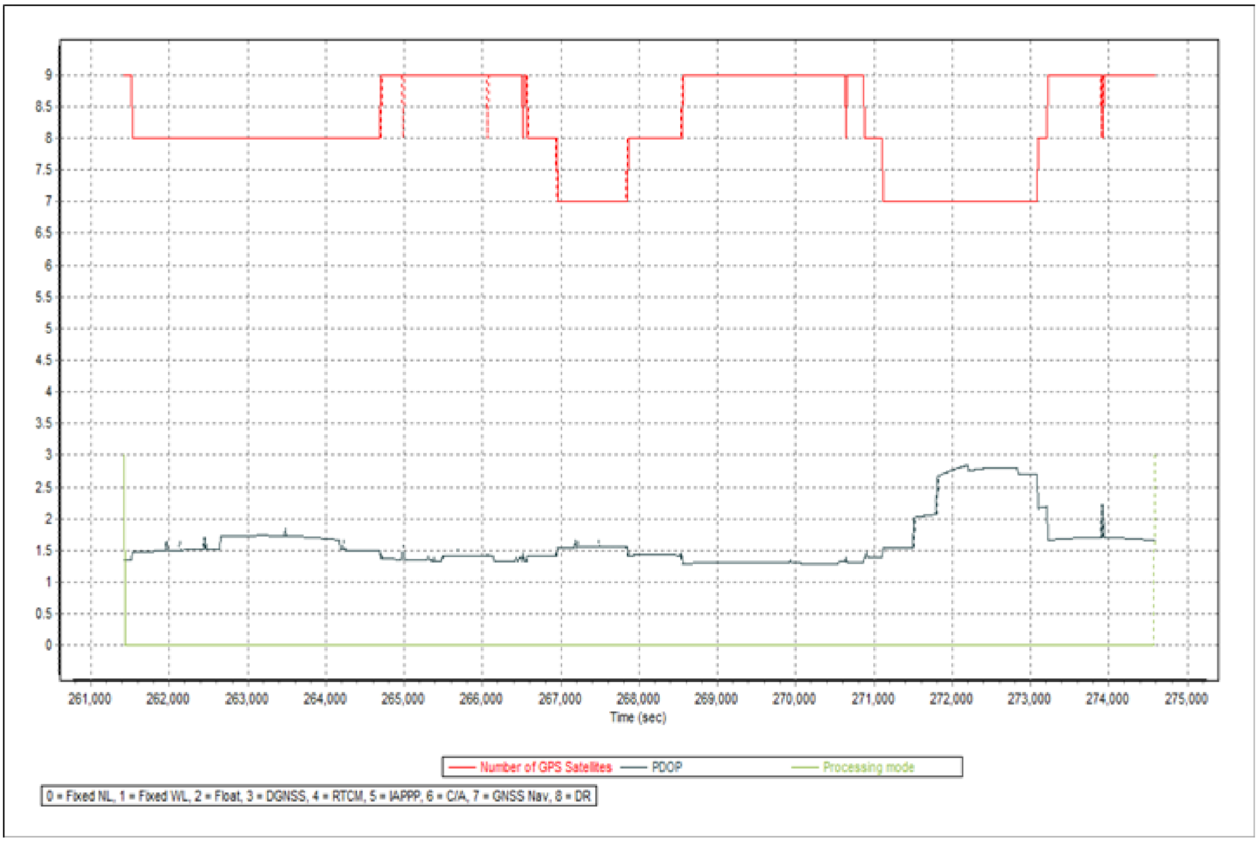


Figure A-8.8. Solution Status Parameters

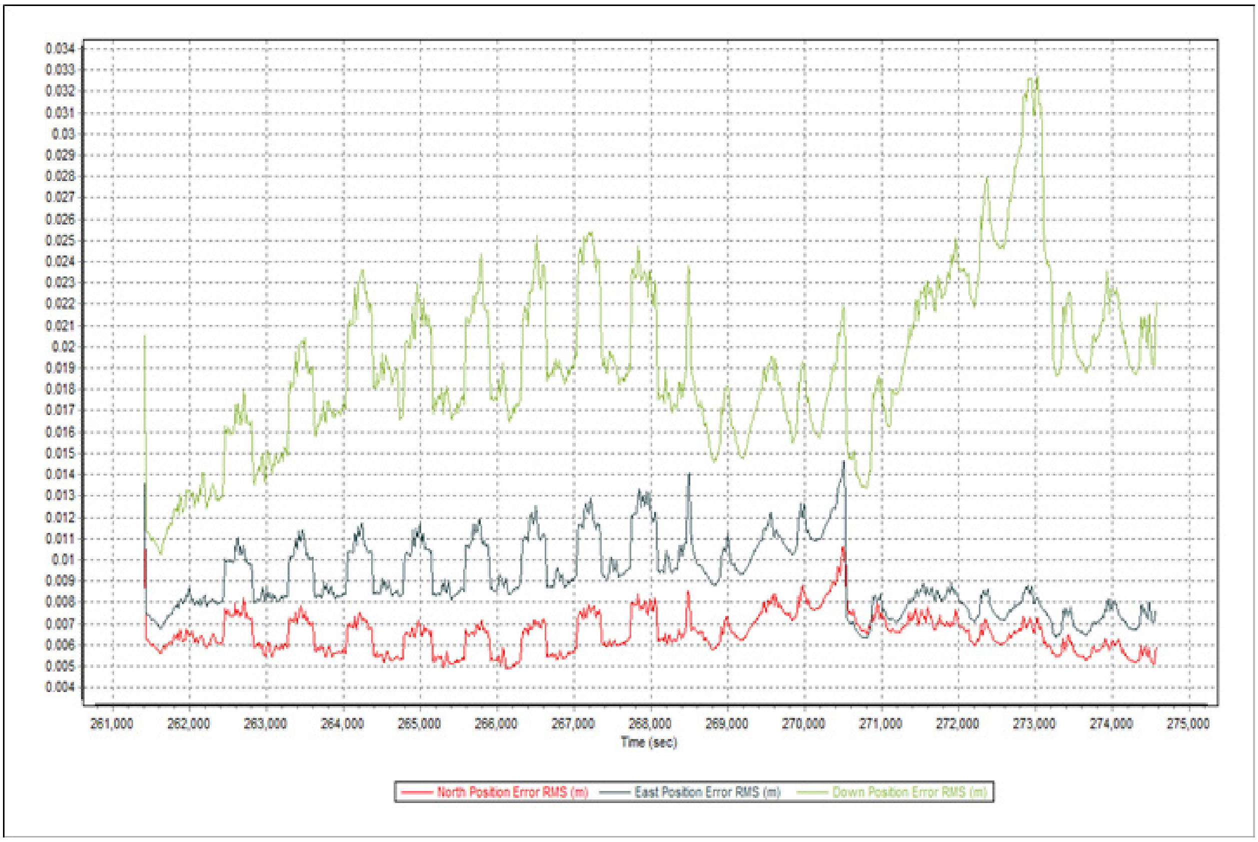


Figure A-8.9. Smoothed Performance Metrics Parameters

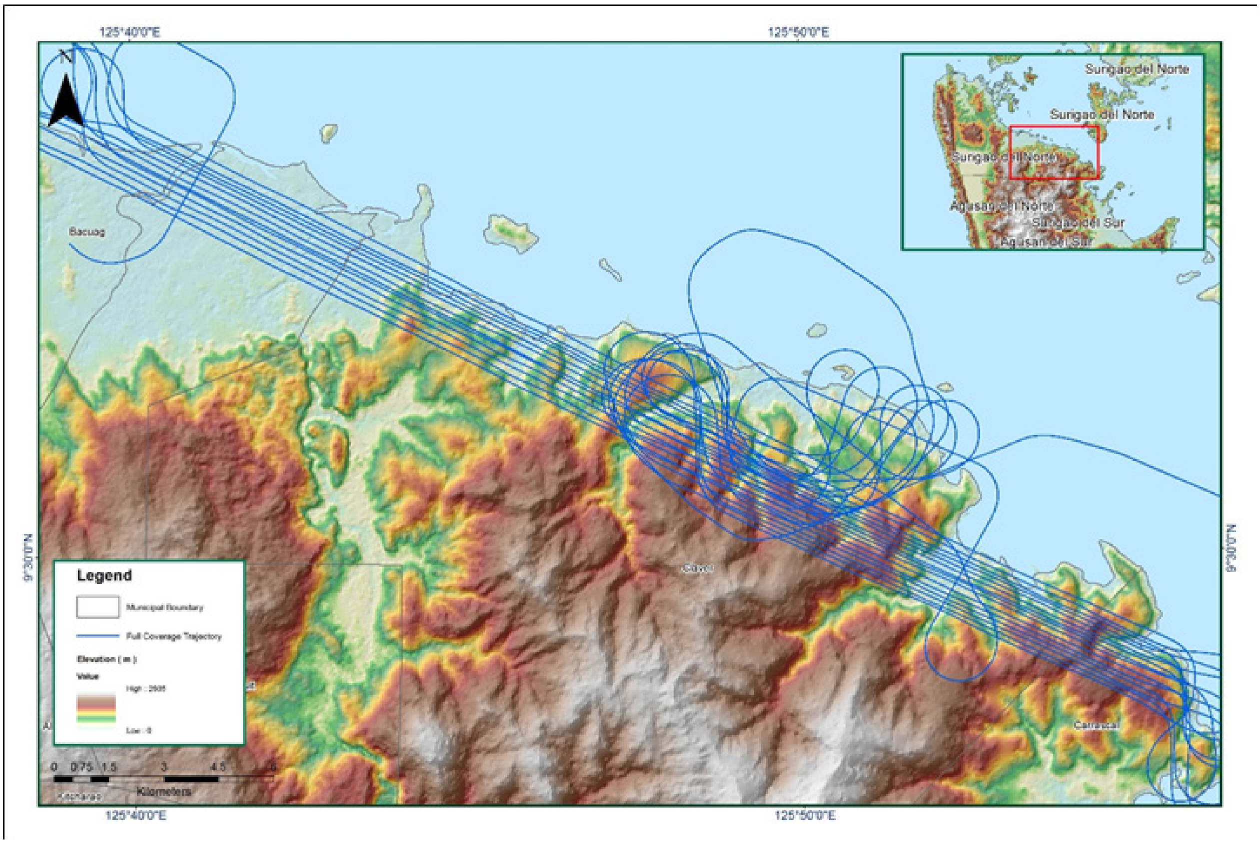


Figure A-8.10. Best Estimated Trajectory

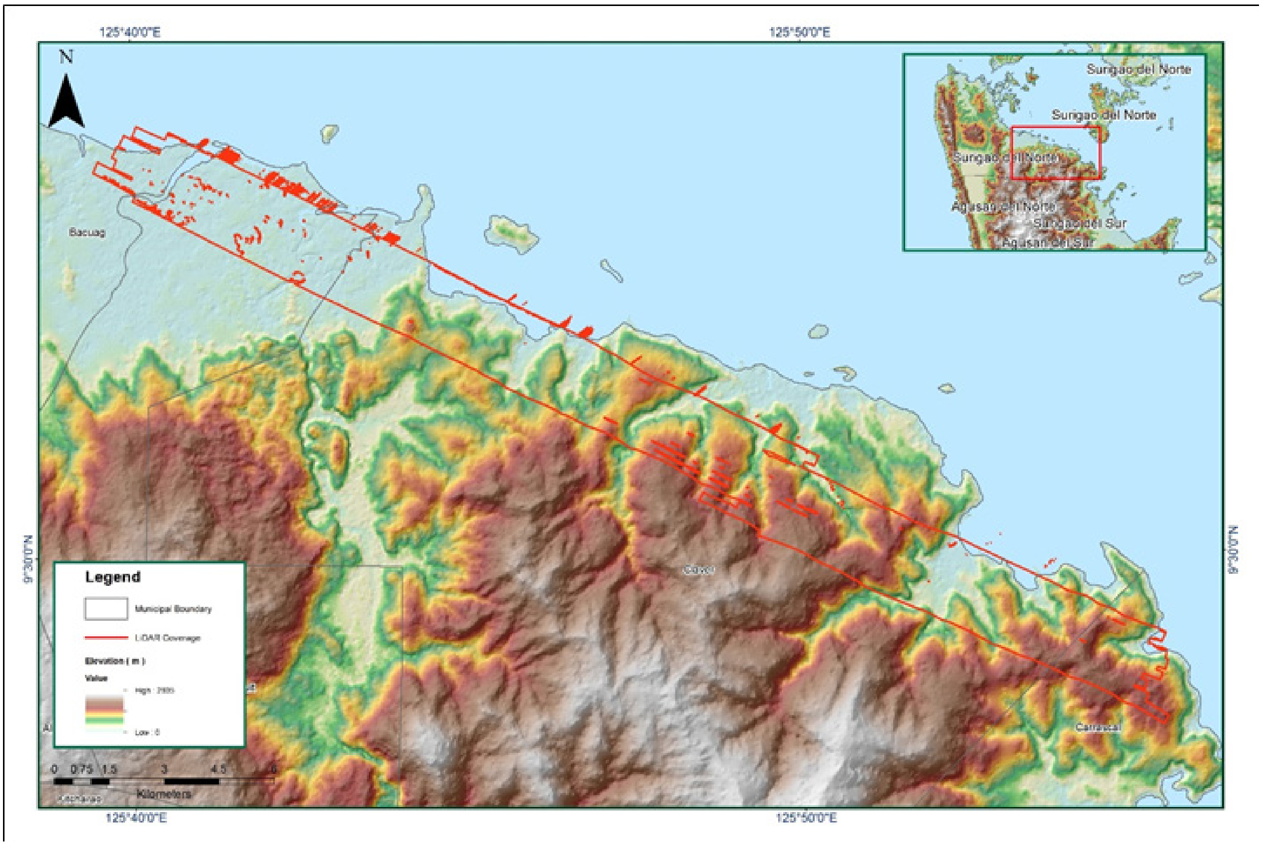


Figure A-8.11. Coverage of LiDAR data

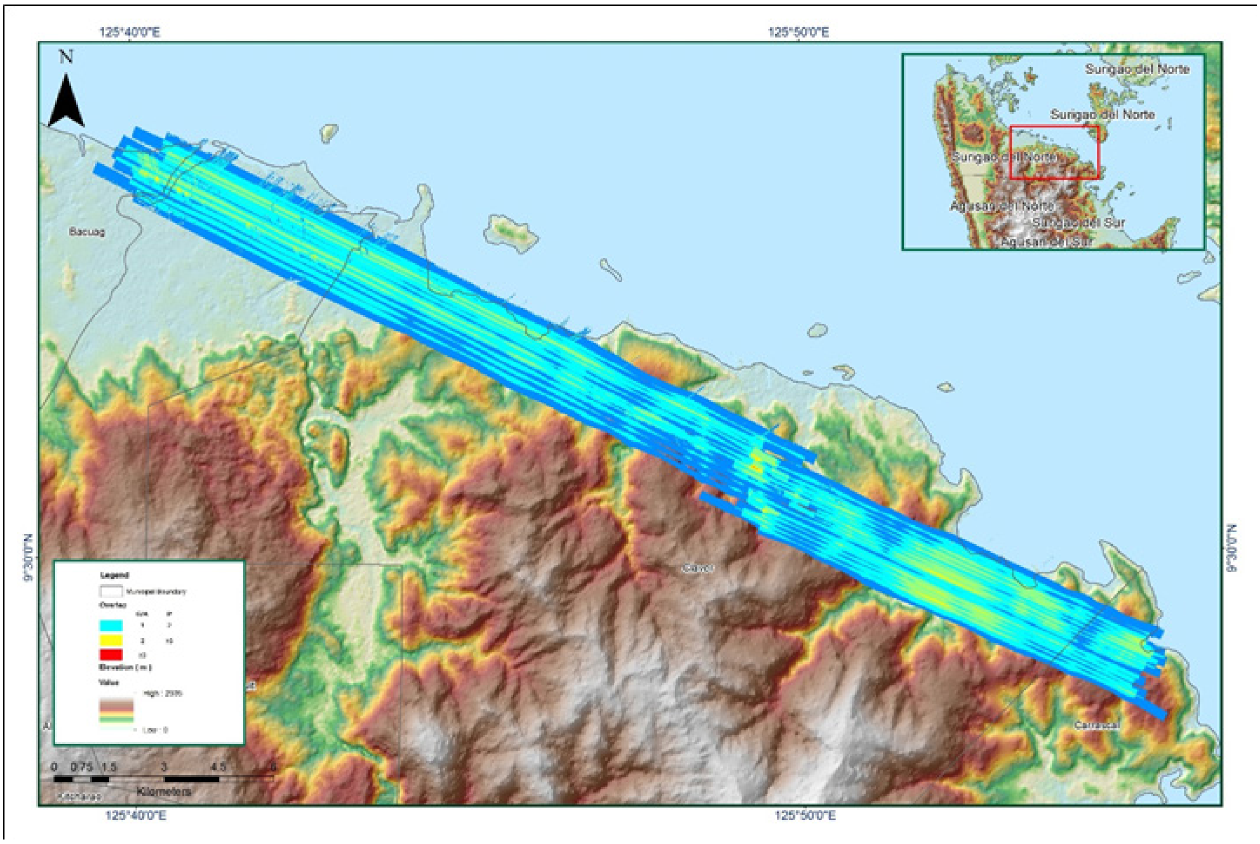


Figure A-8.12. Image of Data Overlap

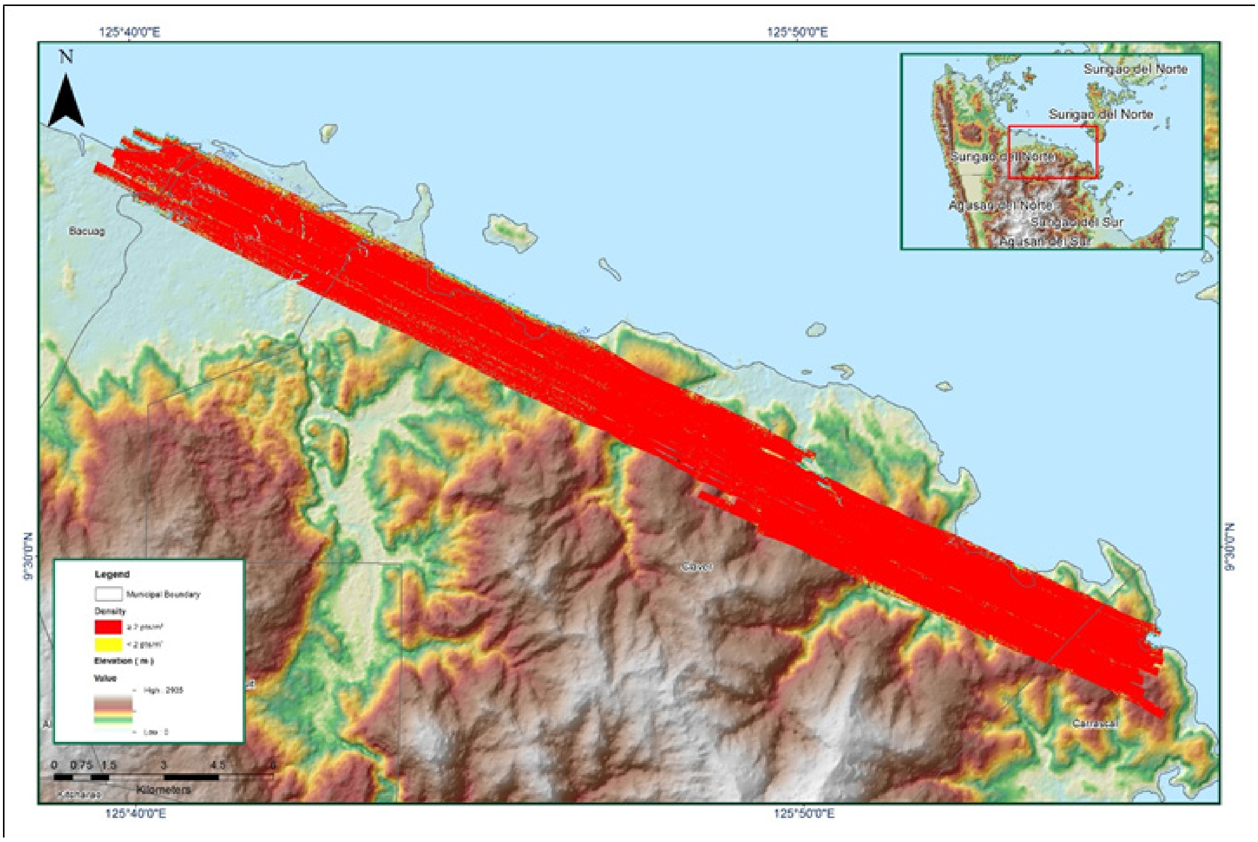


Figure A-8.13. Density map of merged LiDAR data

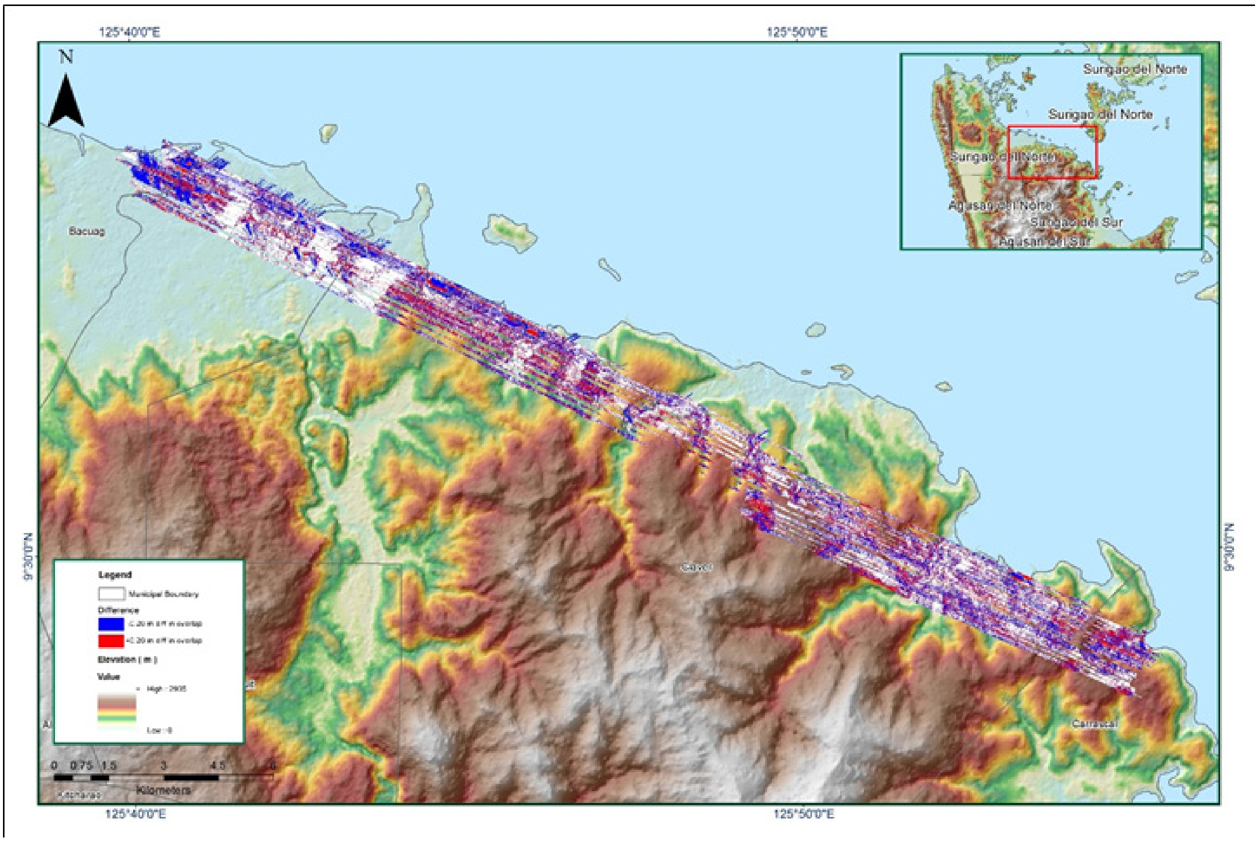


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Block 60D_supplement

Flight Area	Surigao Reflights
Mission Name	Block 60D_supplement
Inclusive Flights	8485AC
Range data size	10.6 GB
POS data size	231 MB
Base data size	74.9 MB
Image	39.8 GB
Transfer date	June 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.184
RMSE for East Position (<4.0 cm)	1.387
RMSE for Down Position (<8.0 cm)	4.314
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	39.65
Ave point cloud density per sq.m. (>2.0)	4.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	76
Maximum Height	520.53 m
Minimum Height	65.23 m
Classification (# of points)	
Ground	22,774,141
Low vegetation	11,541,808
Medium vegetation	17,115,654
High vegetation	67,517,444
Building	1,645,630
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

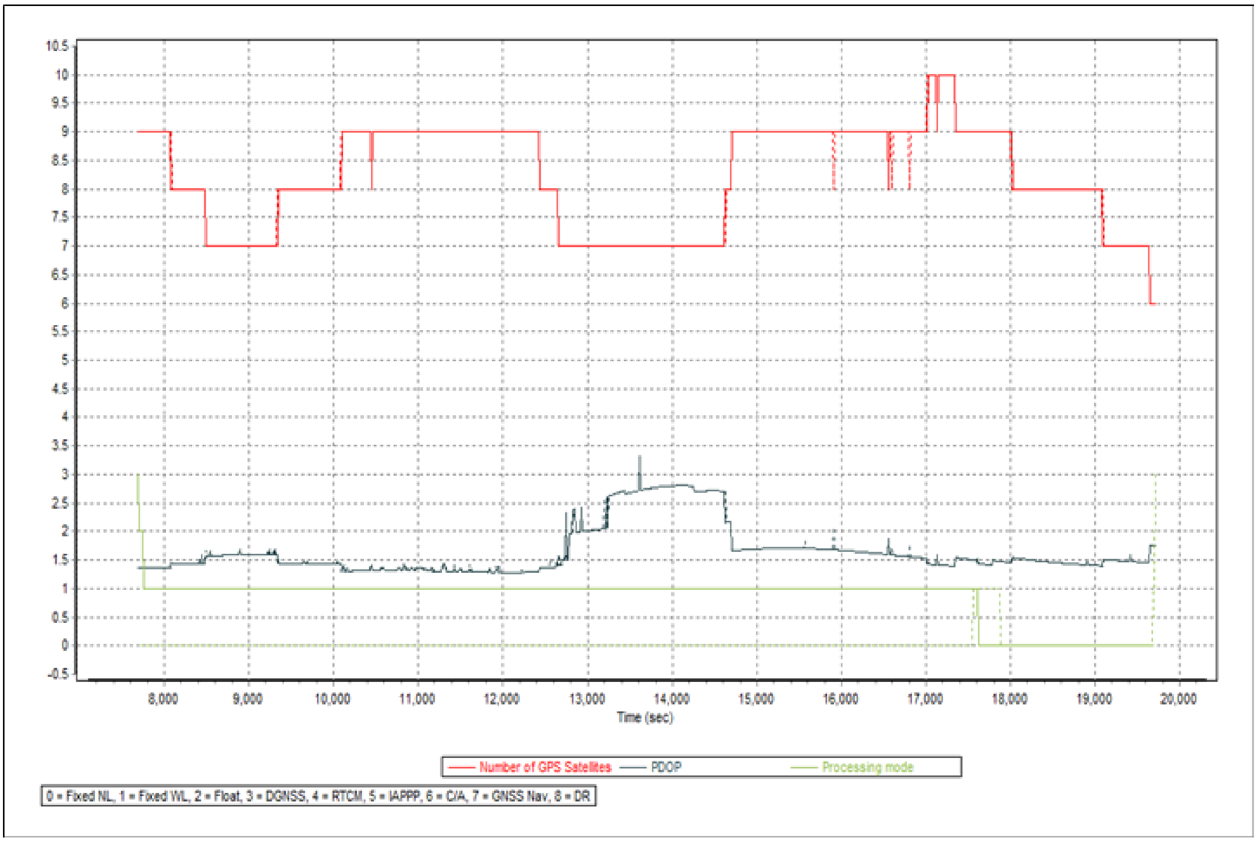


Figure A-8.15. Solution Status

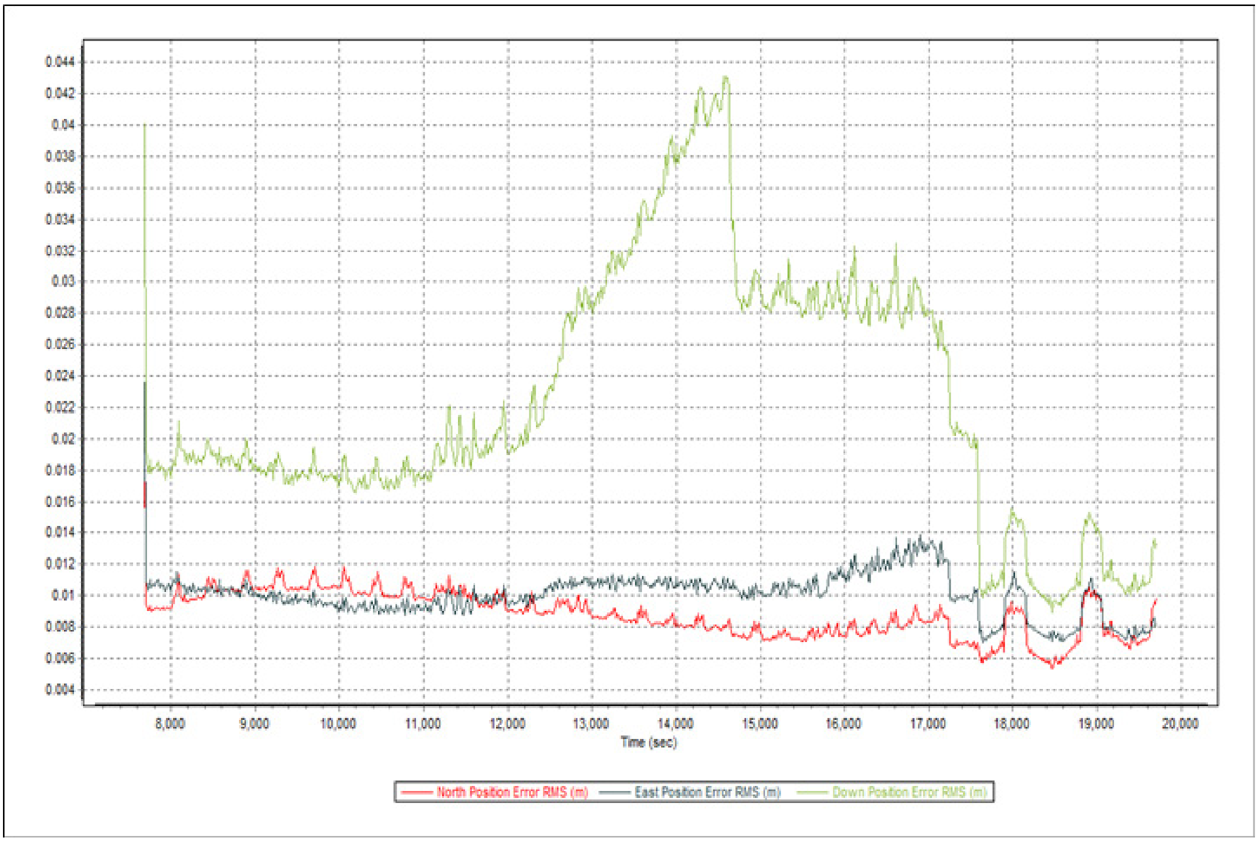


Figure A-8.16. Smoothed Performance Metric Parameters

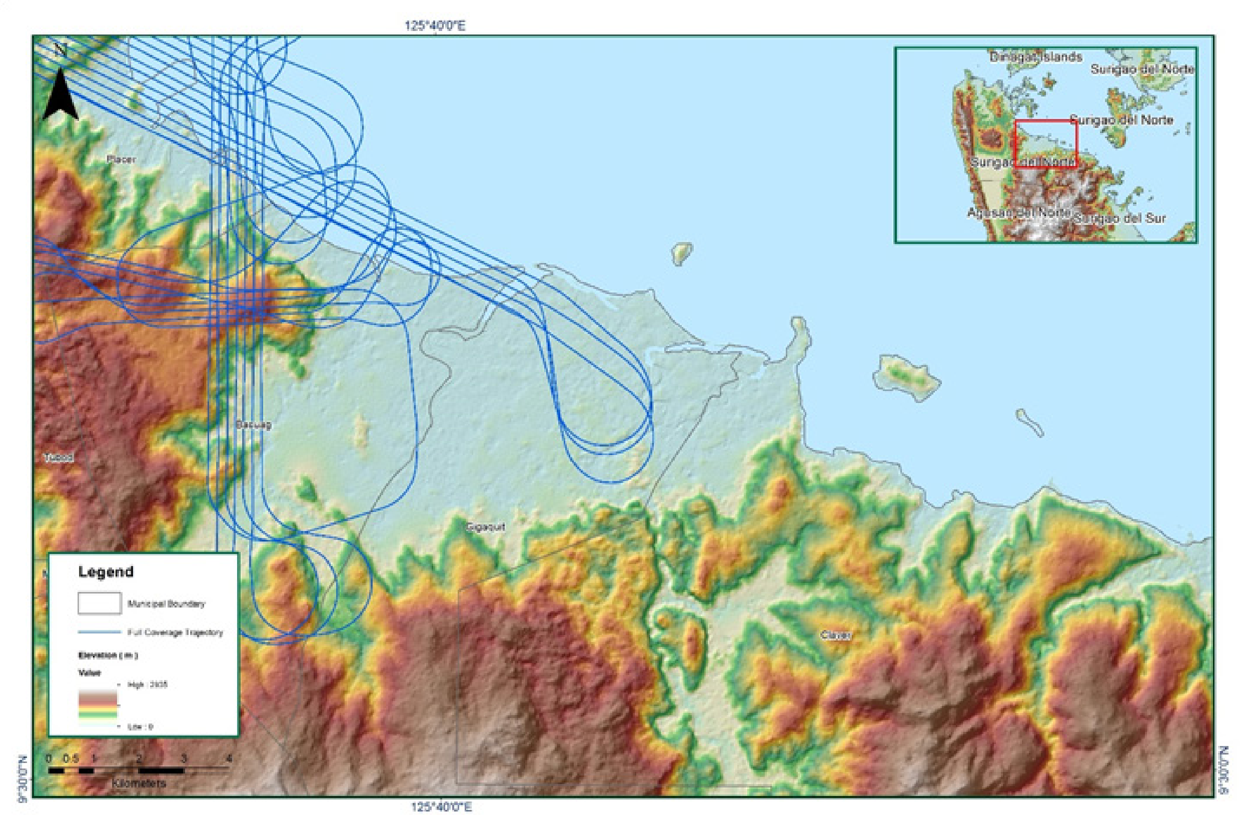


Figure A-8.17. Best Estimated Trajectory

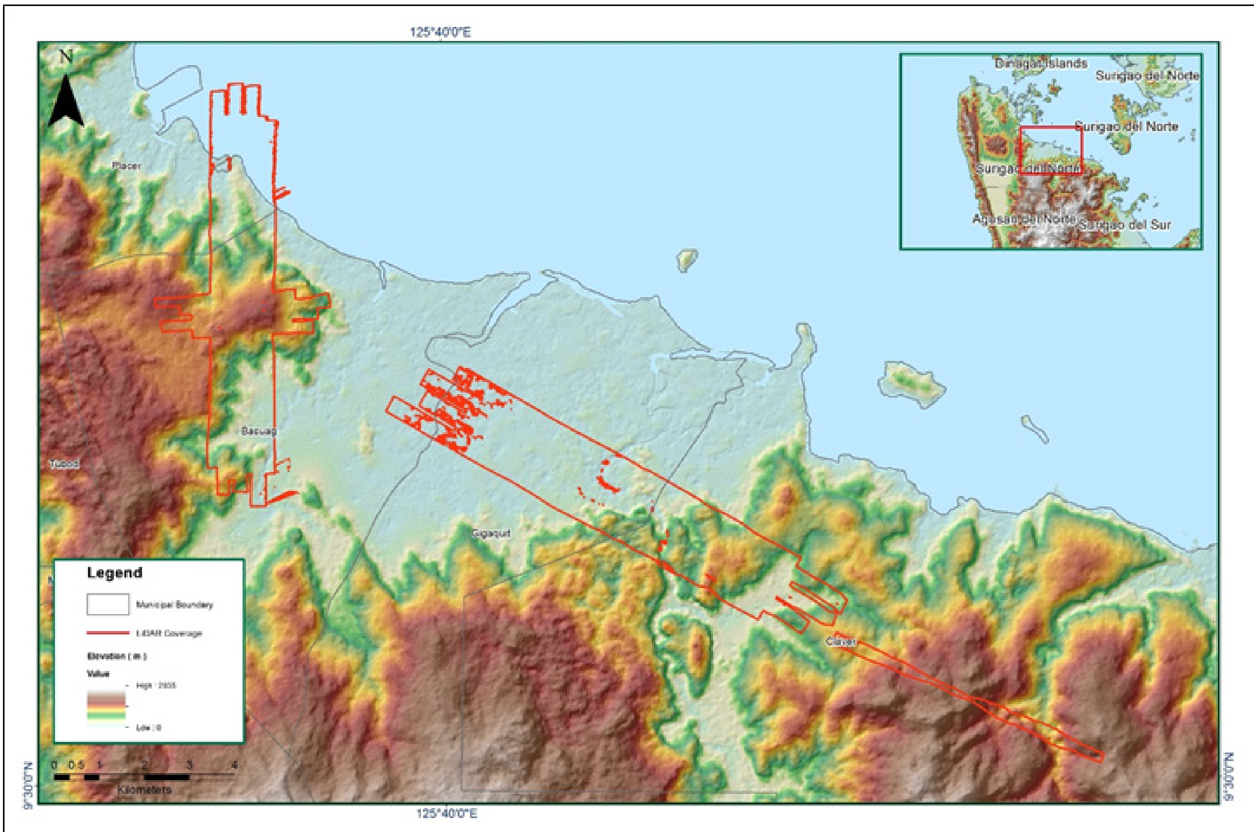


Figure A-8.18. Coverage of LiDAR data

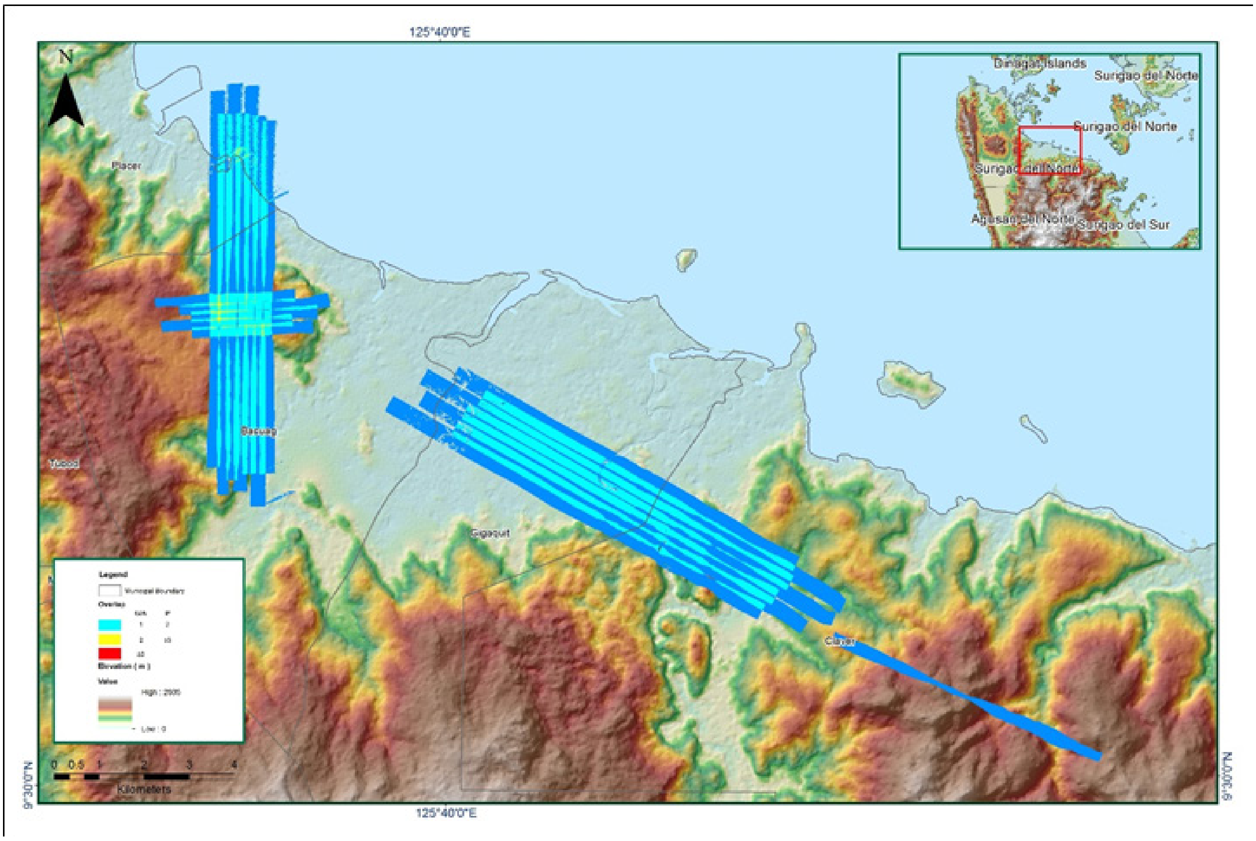


Figure A-8.19. Image of Data Overlap

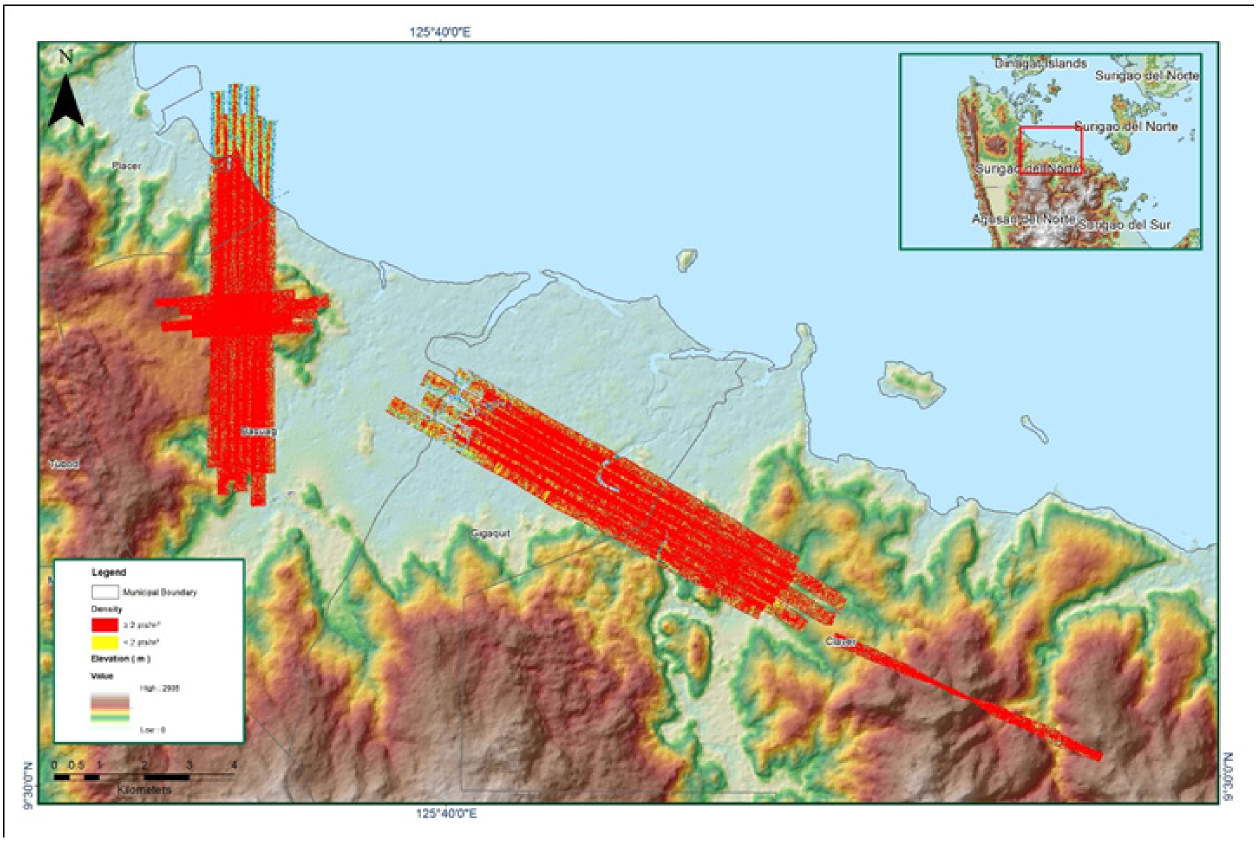


Figure A-8.20. Density map of merged LiDAR data

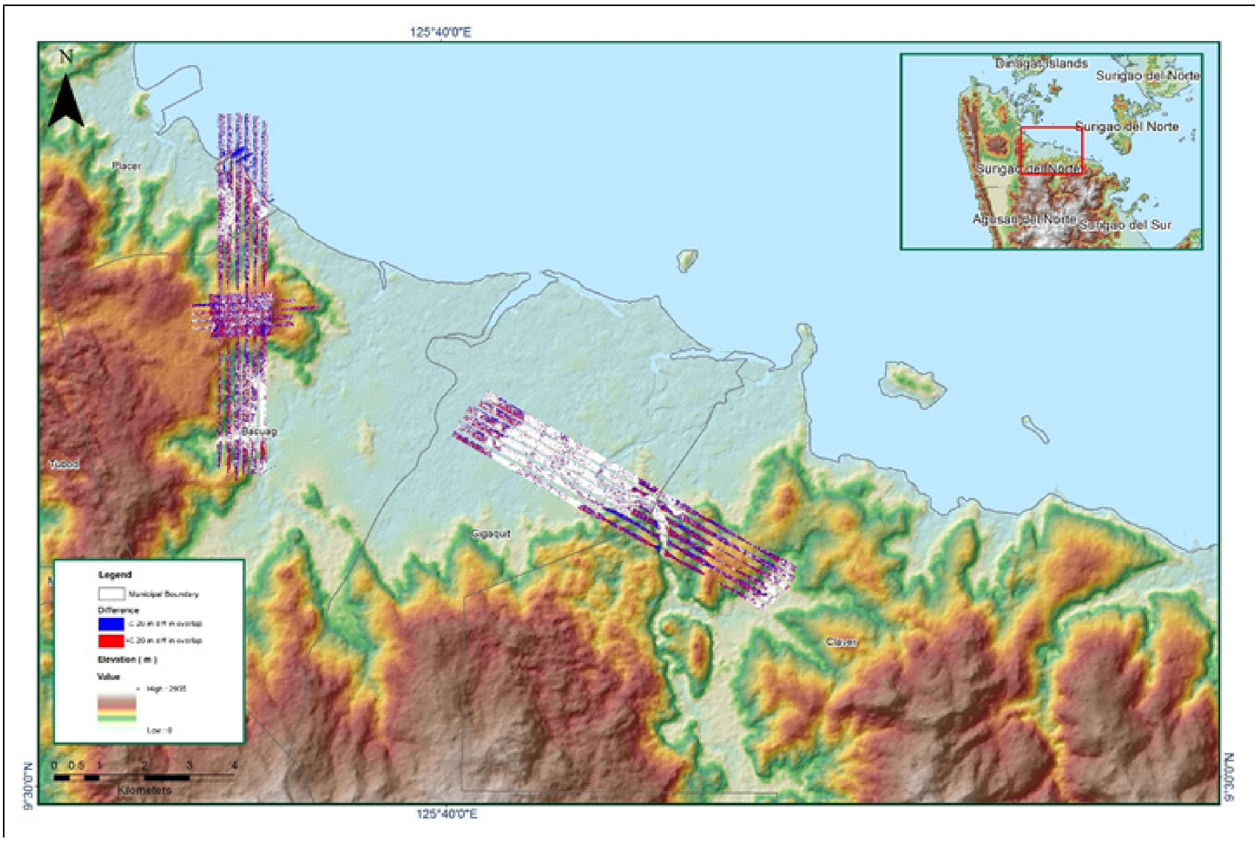


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk60C (Surigao Del Norte)

Flight Area	Surigao City
Mission Name	Blk60C (Surigao Del Norte)
Inclusive Flights	7296GC
Range data size	20.90 GB
POS	257 MB
Image	N/A
Transfer date	June 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.45
RMSE for East Position (<4.0 cm)	2.60
RMSE for Down Position (<8.0 cm)	5.80
Boresight correction stdev (<0.001deg)	--
IMU attitude correction stdev (<0.001deg)	--
GPS position stdev (<0.01m)	--
Minimum % overlap (>25)	19.57%
Ave point cloud density per sq.m. (>2.0)	2.94
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	179
Maximum Height	673.59 m
Minimum Height	60.00 m
Classification (# of points)	
Ground	47,700,403
Low vegetation	37,635,615
Medium vegetation	86,284,792
High vegetation	81,487,192
Building	1,213,244
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Charmaine Cruz, Engr. Gladys Apat

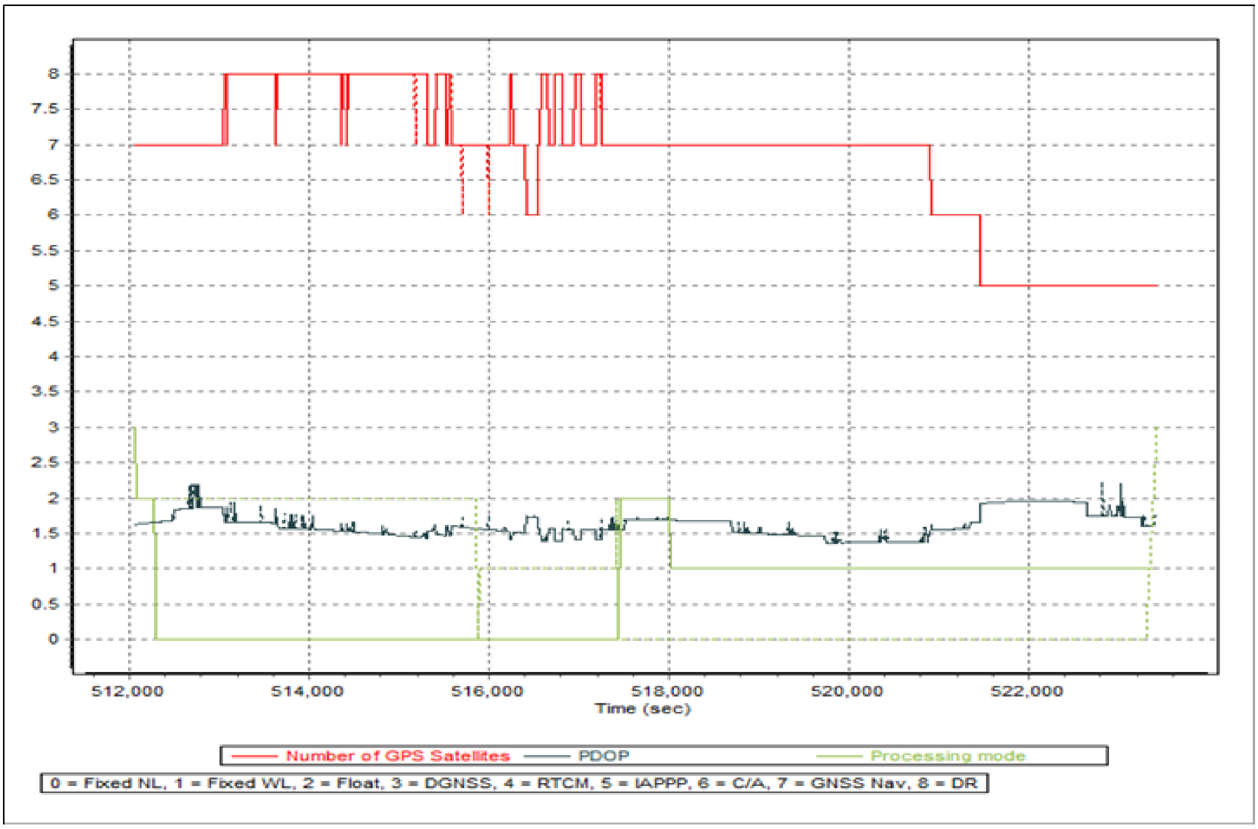


Figure A-8.22. Solution Status

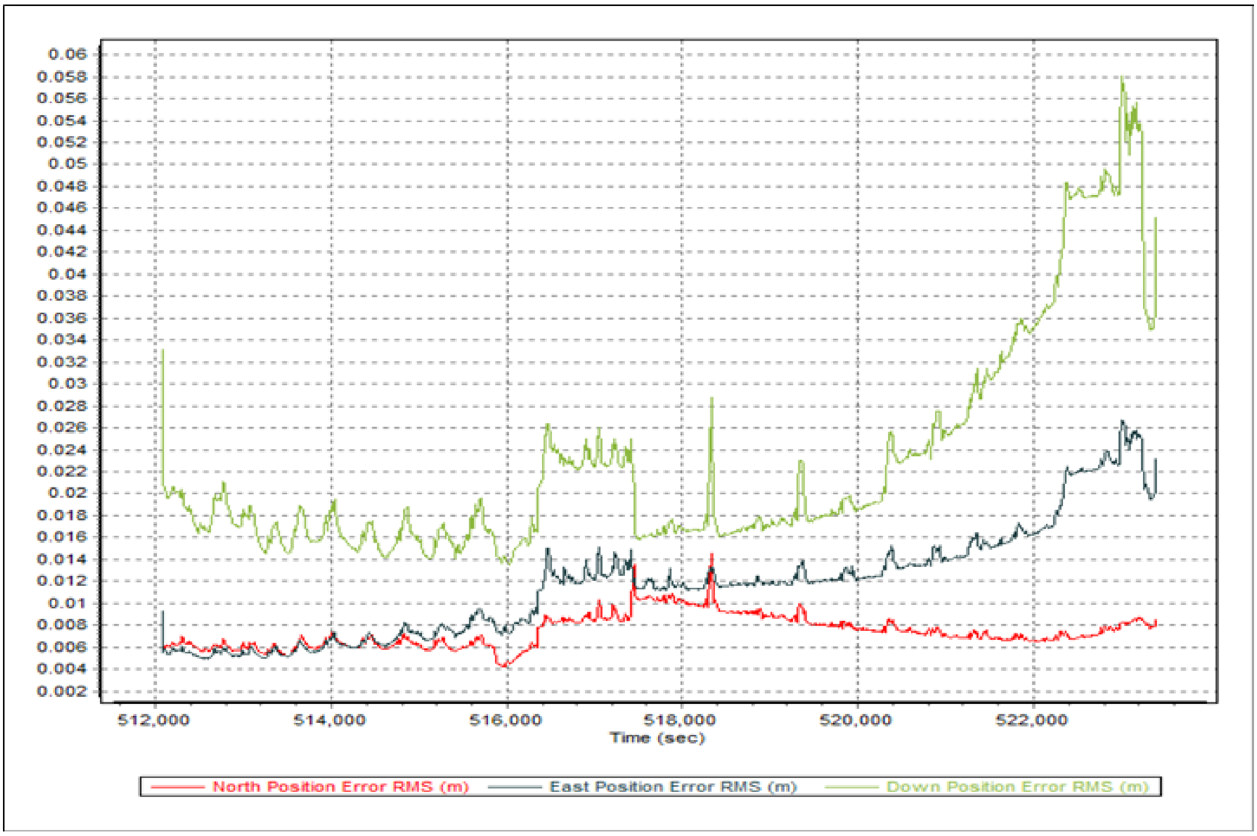


Figure A-8.23. Smoothed Performance Metric Parameters

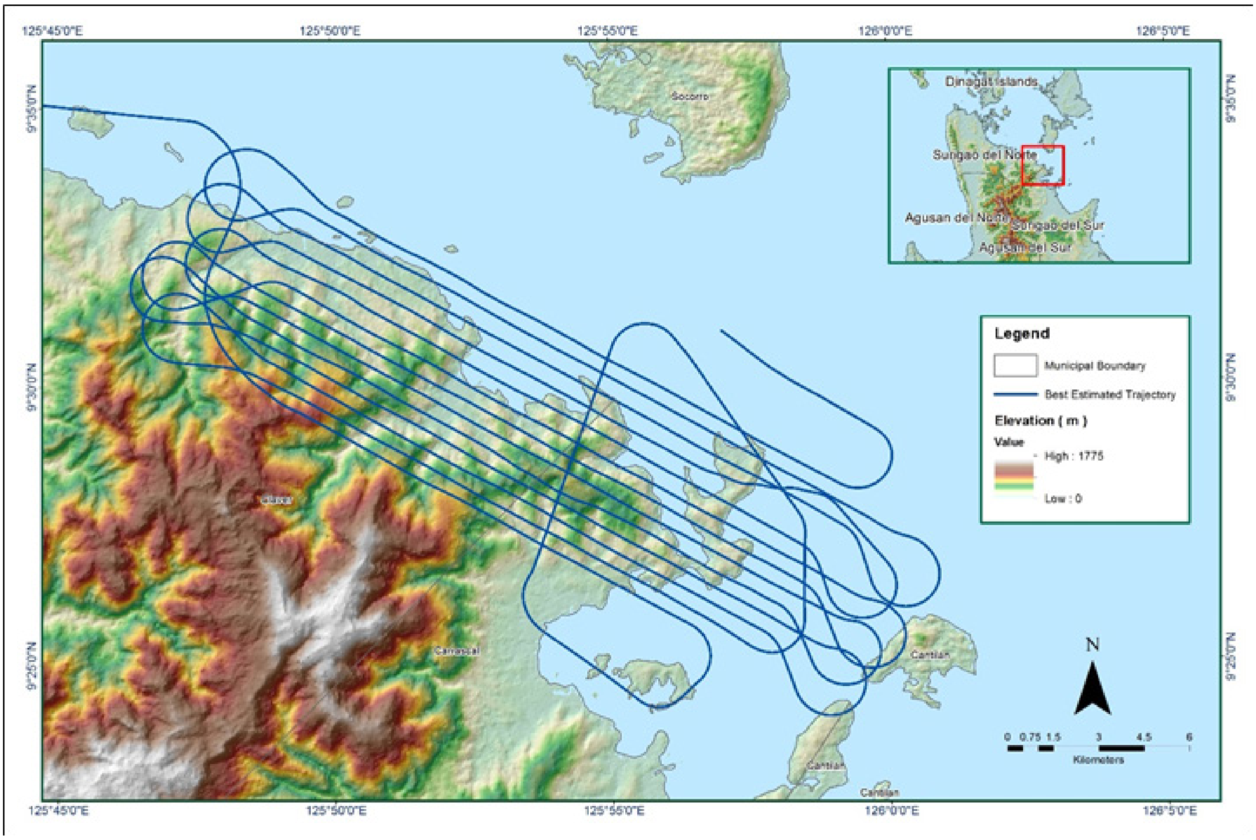


Figure A-8.24. Best Estimated Trajectory

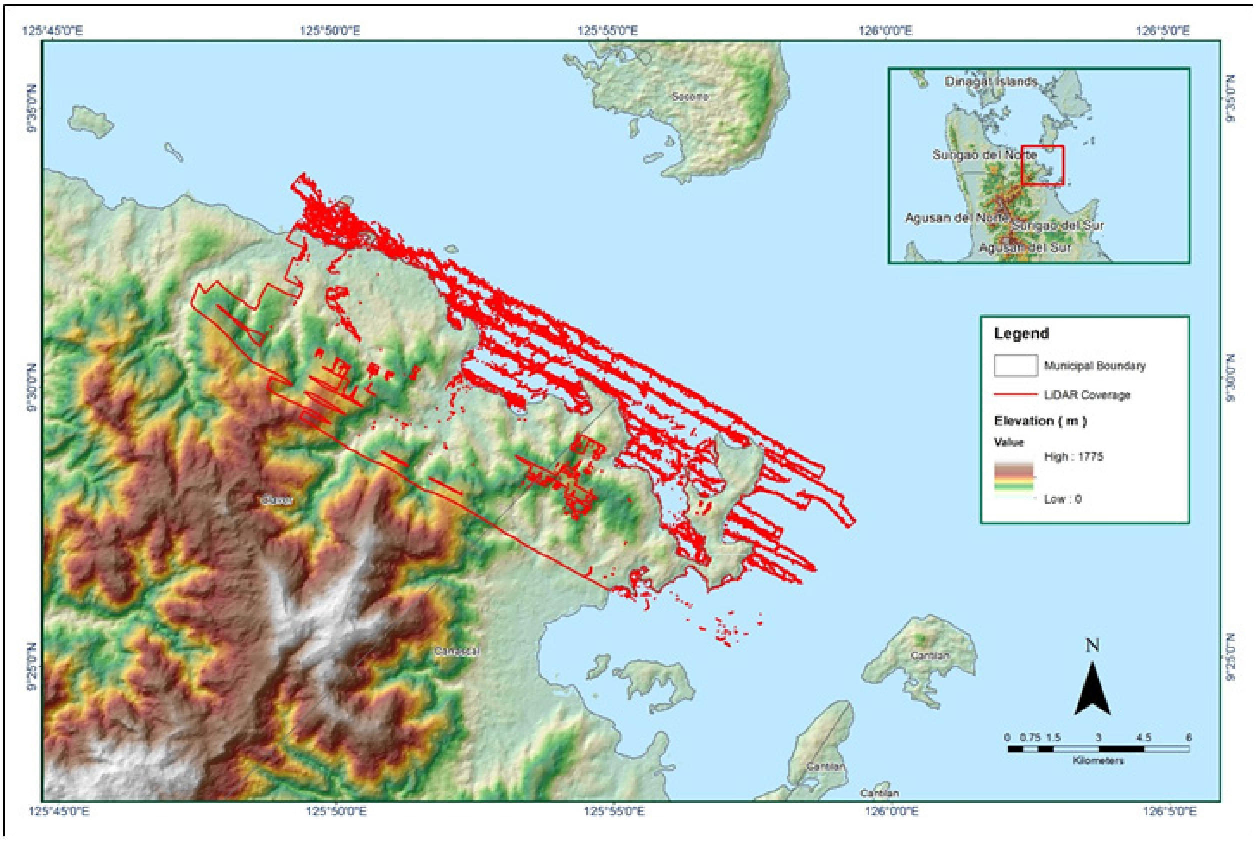


Figure A-8.25. Coverage of LiDAR data

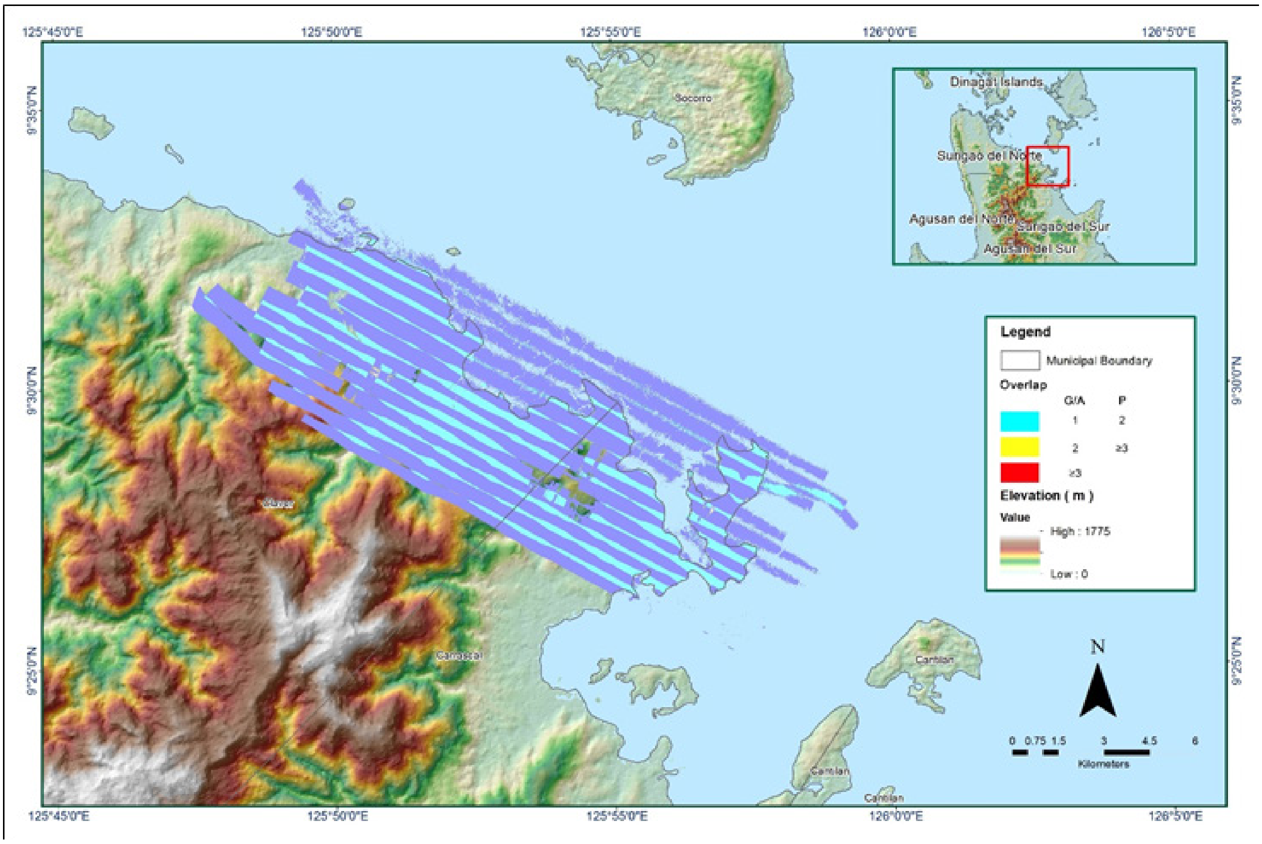


Figure A-8.26. Image of Data Overlap

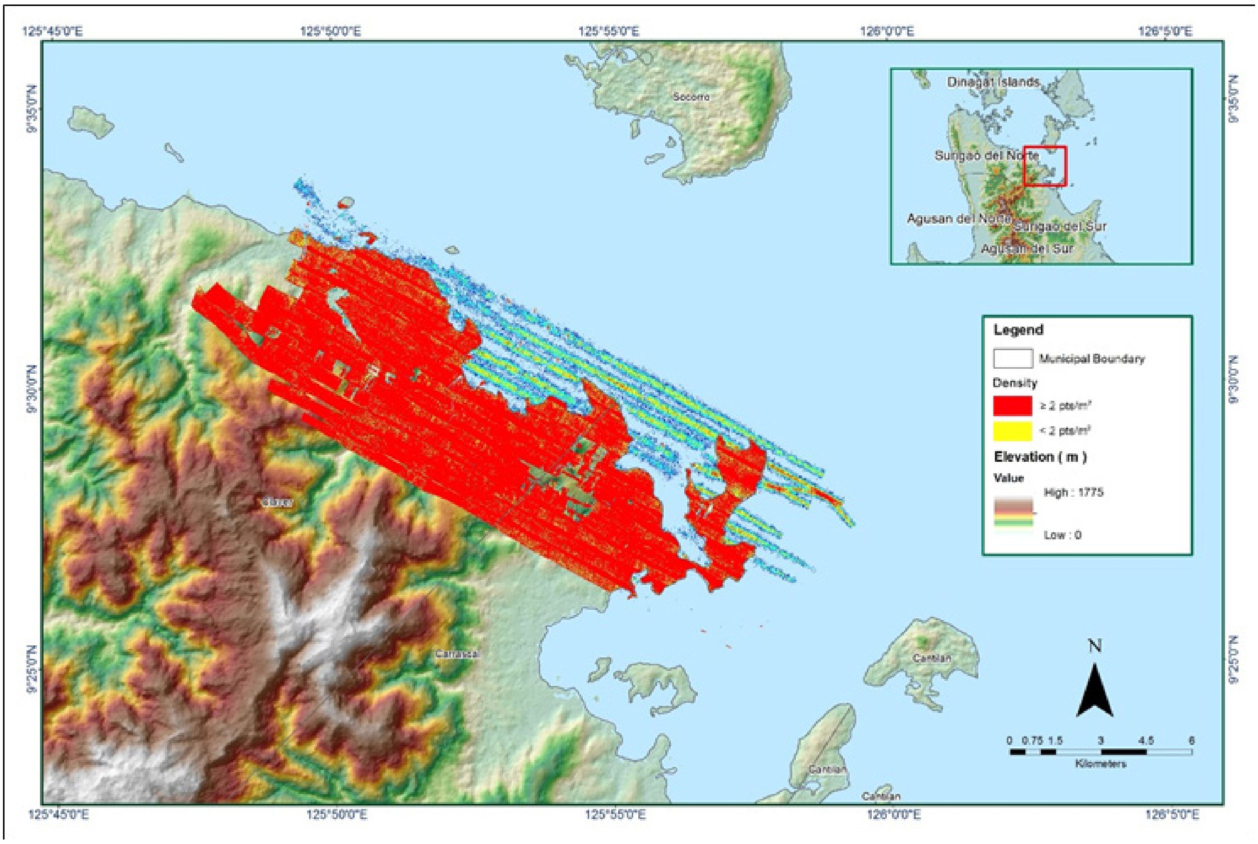


Figure A-8.27. Density map of merged LiDAR data

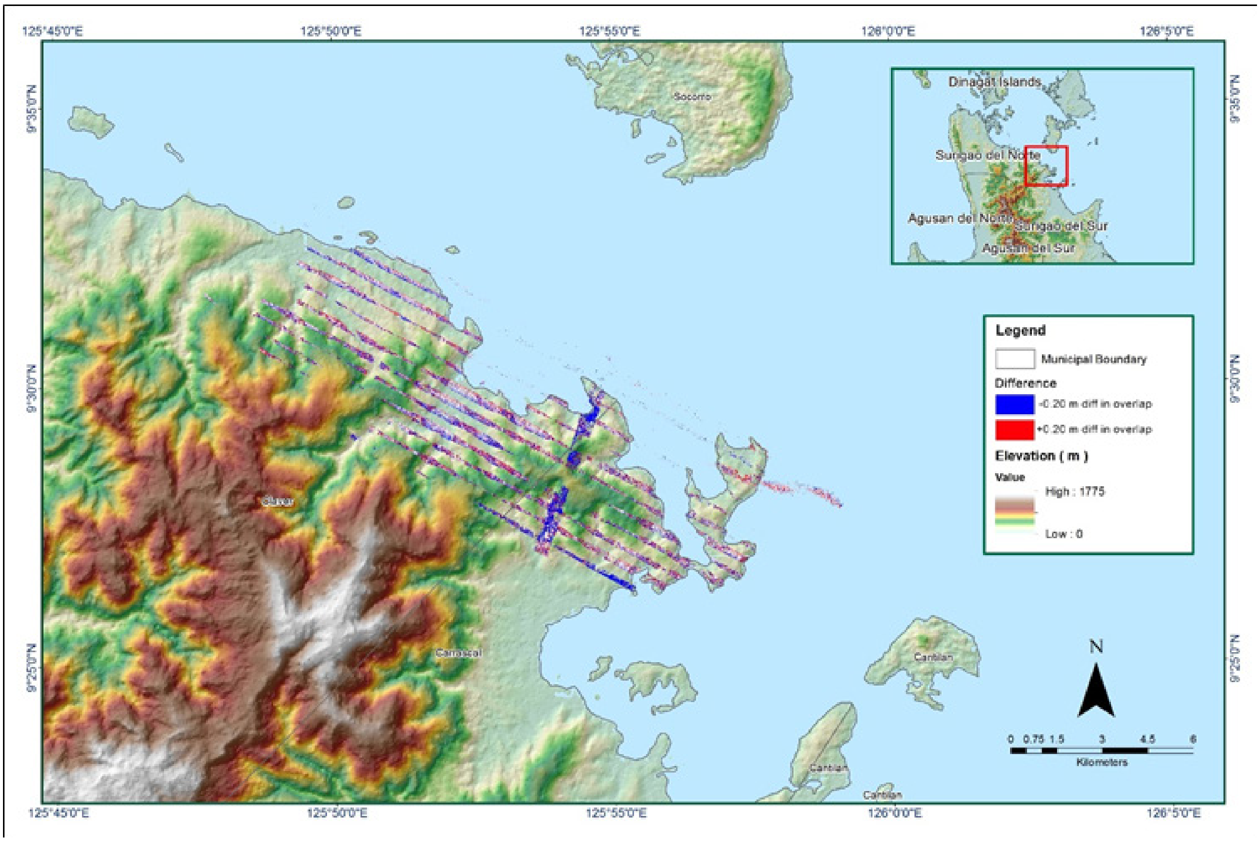


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk60D (Surigao Del Norte)

Flight Area	Surigao City
Mission Name	Blk60D (Surigao Del Norte)
Inclusive Flights	7288GC, 7292GC & 7296GC
Range data size	62.20 GB
POS data size	748 MB
Base data size	14.1 MB
Image	N/A
Transfer date	June 16 & 20, 2014
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)	1.10
RMSE for East Position (<4.0 cm)	1.50
RMSE for Down Position (<8.0 cm)	3.00
Boresight correction stdev (<0.001deg)	0.000262
IMU attitude correction stdev (<0.001deg)	0.001423
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	30.61%
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	387
Maximum Height	962.45 m
Minimum Height	68.11 m
Classification (# of points)	
Ground	77,824,017
Low vegetation	66,577,816
Medium vegetation	100,876,714
High vegetation	420,021,332
Building	9,261,425
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

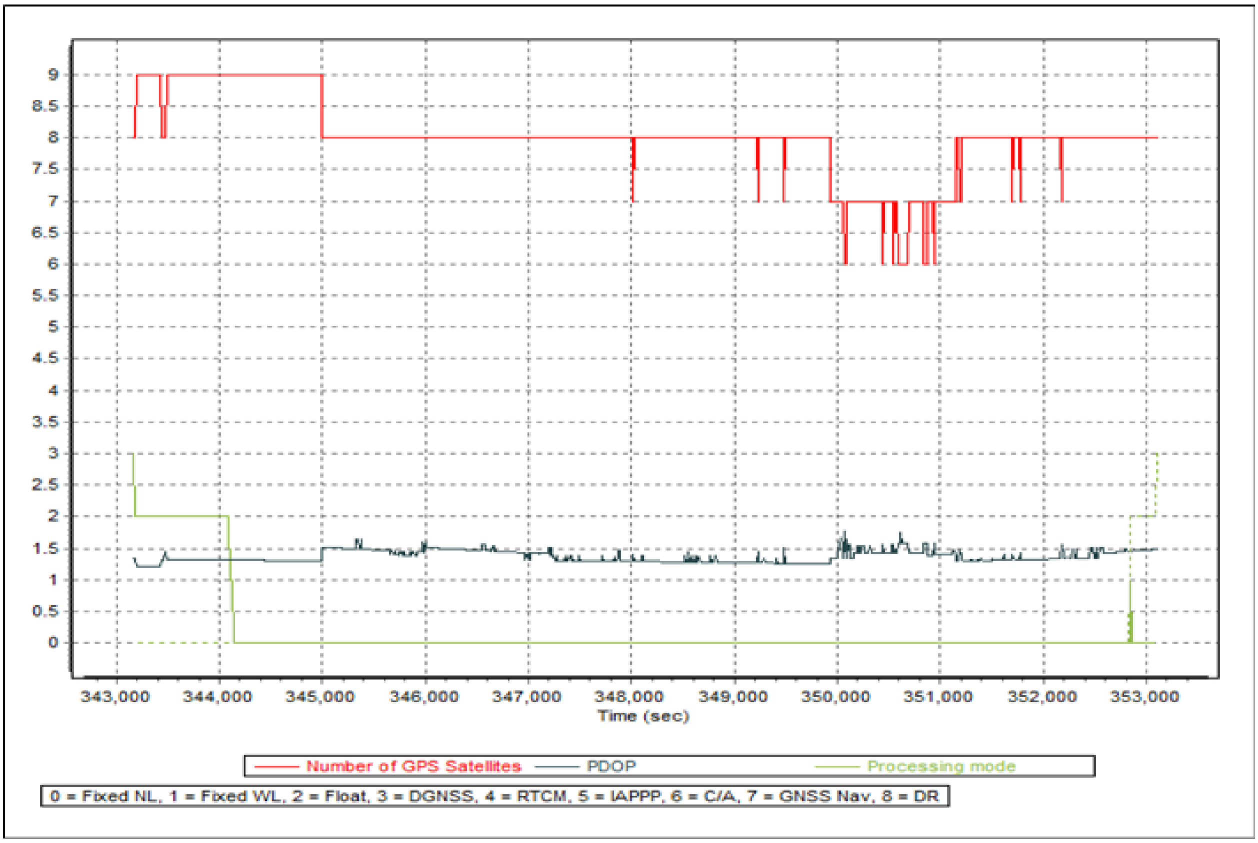


Figure A-8.29. Solution Status

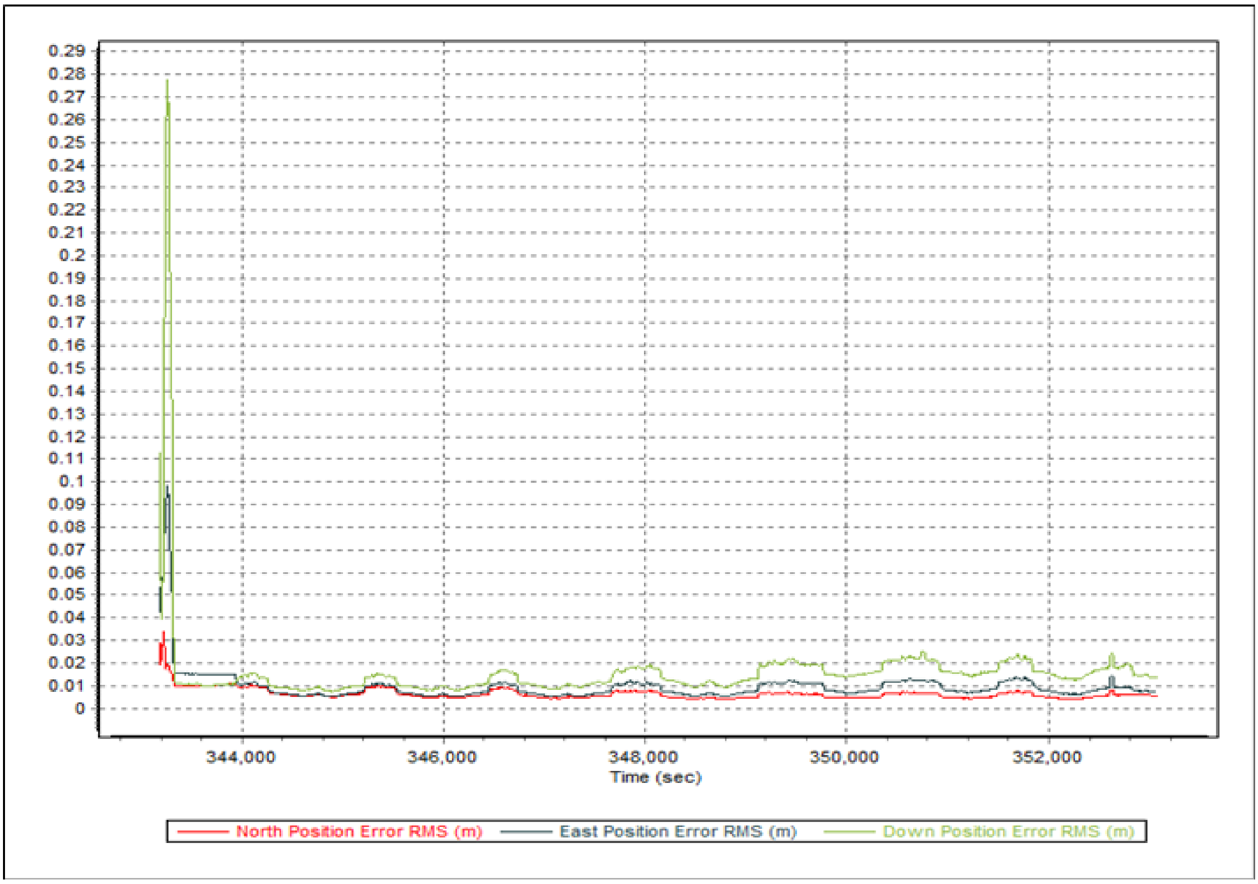


Figure A-8.30. Smoothed Performance Metric Parameters

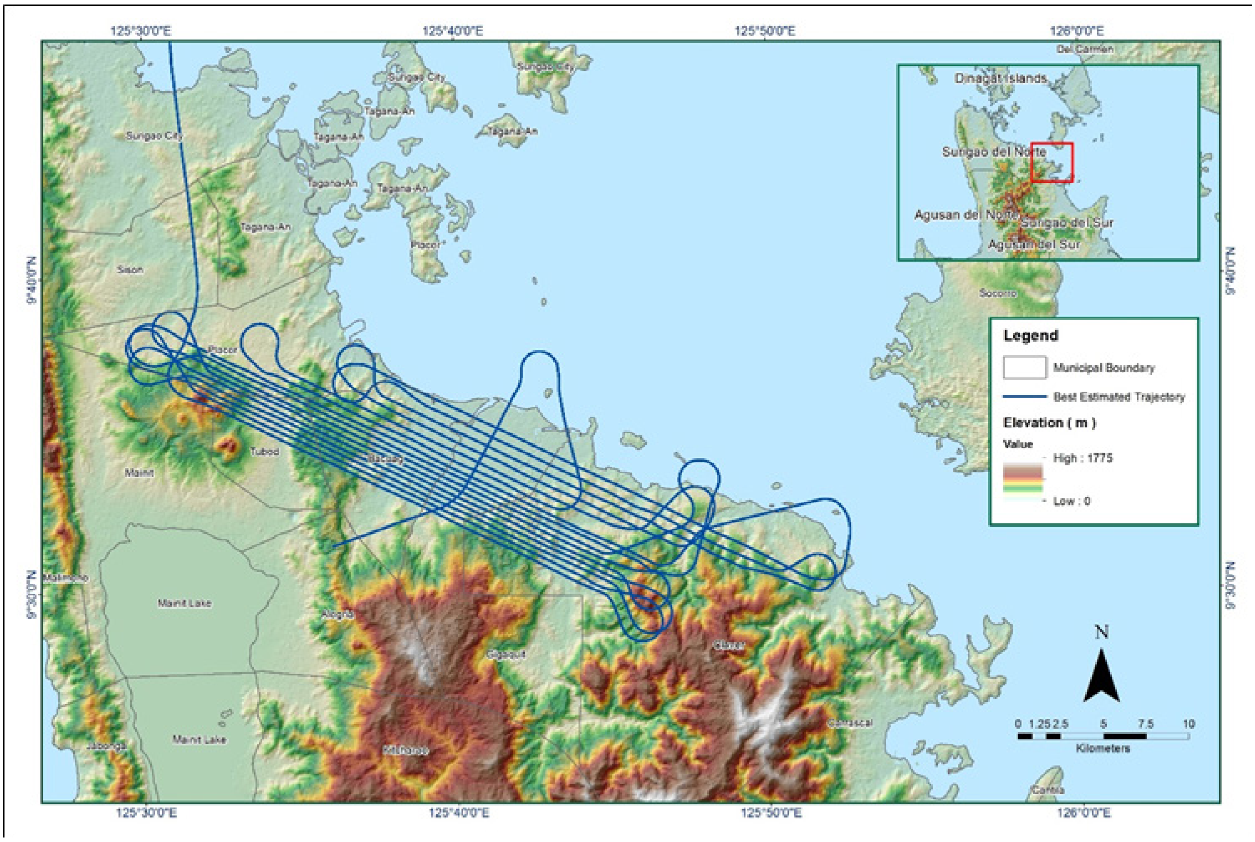


Figure A-8.31. Best Estimated Trajectory

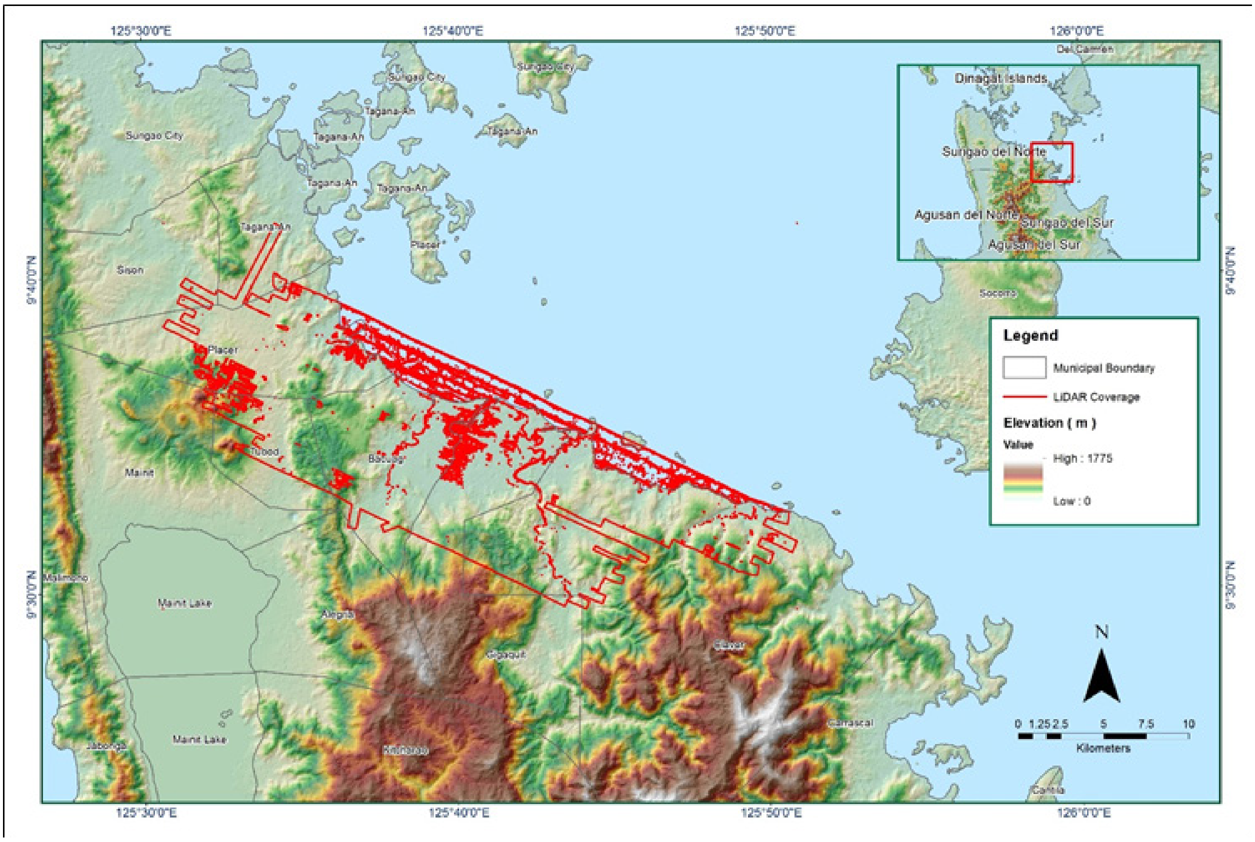


Figure A-8.32. Coverage of LiDAR data

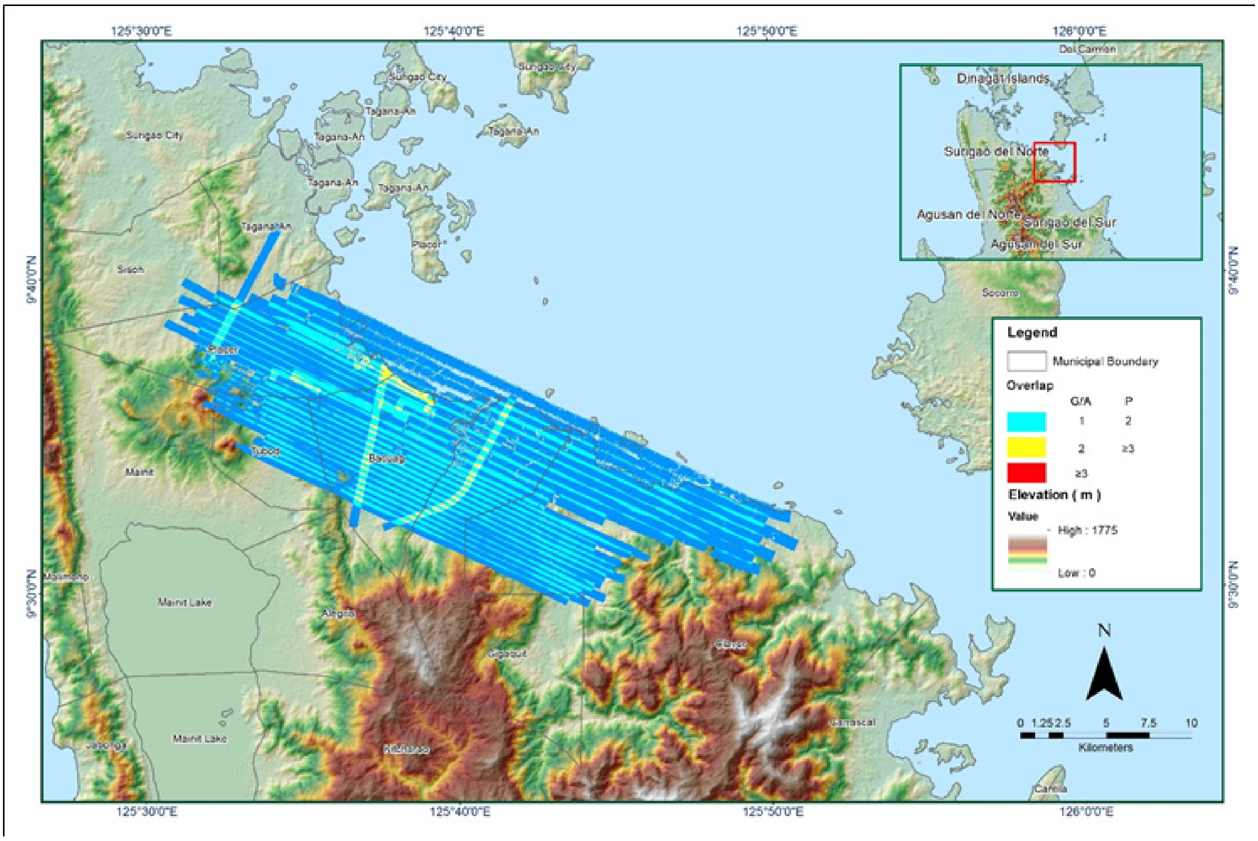


Figure A-8.33. Image of Data Overlap

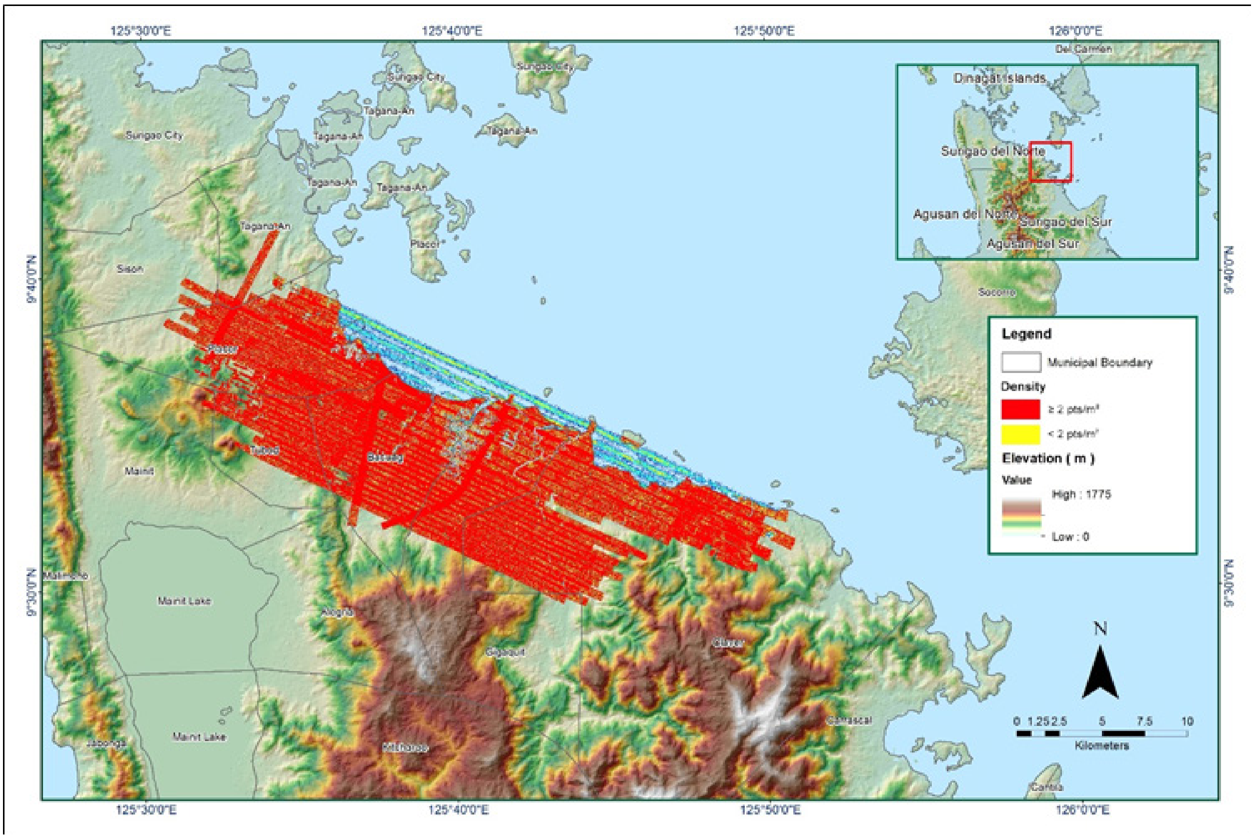


Figure A-8.34. Density map of merged LiDAR data

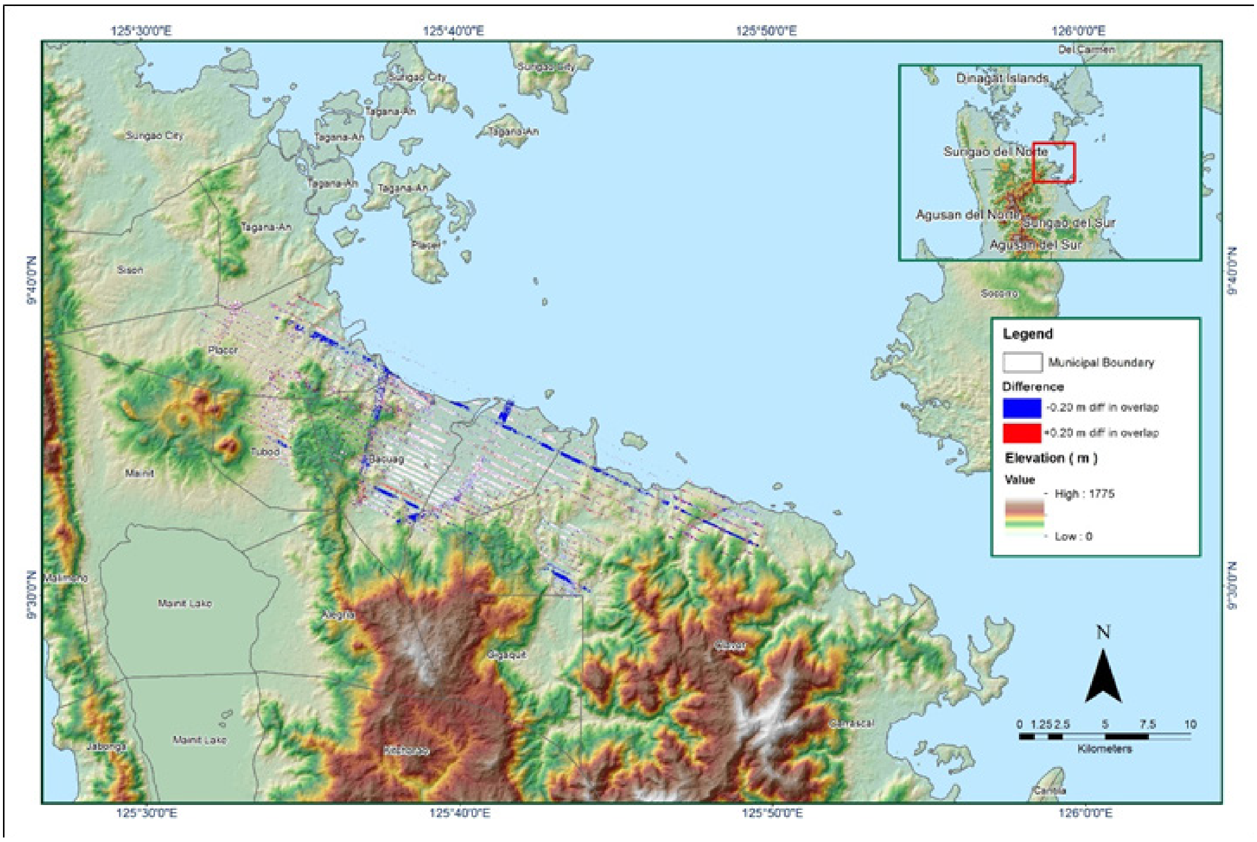


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Block 60D_supplement

Flight Area	Surigao Del Norte
Mission Name	Block 60D_supplement
Inclusive Flights	7292GC, 7288G
Range data size	41.3 GB
POS data size	491MB
Base data size	5.69 MB
Image	N/A
Transfer date	June 3 & 5, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.05
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	3.25
Boresight correction stdev (<0.001deg)	0.000167
IMU attitude correction stdev (<0.001deg)	0.000941
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	15.95
Ave point cloud density per sq.m. (>2.0)	4.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	154
Maximum Height	689.78 m
Minimum Height	69.05
Classification (# of points)	
Ground	34,286,798.0
Low vegetation	12,278,895.0
Medium vegetation	32,138502.0
High vegetation	161,981,282.0
Building	987,666.0
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Irish Cortez, Engr. Melanie Hingpit

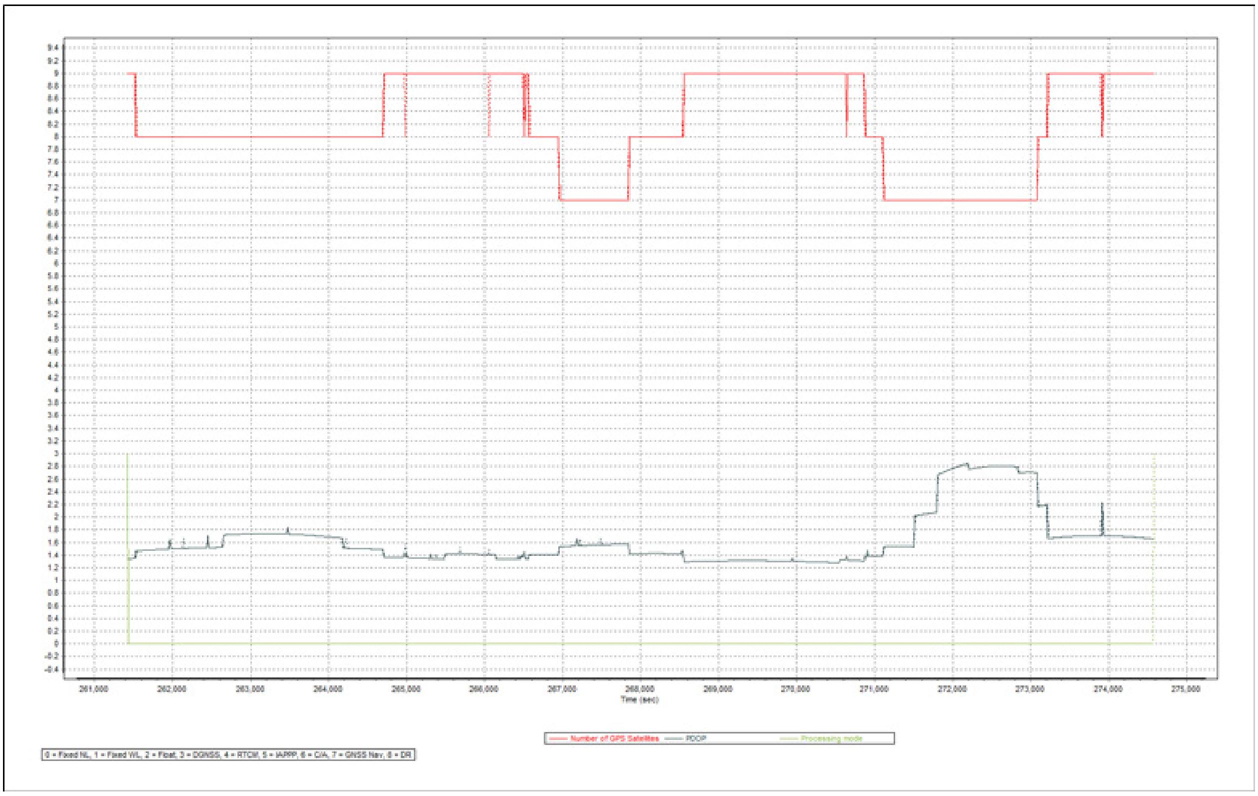


Figure A-8.36. Solution Status

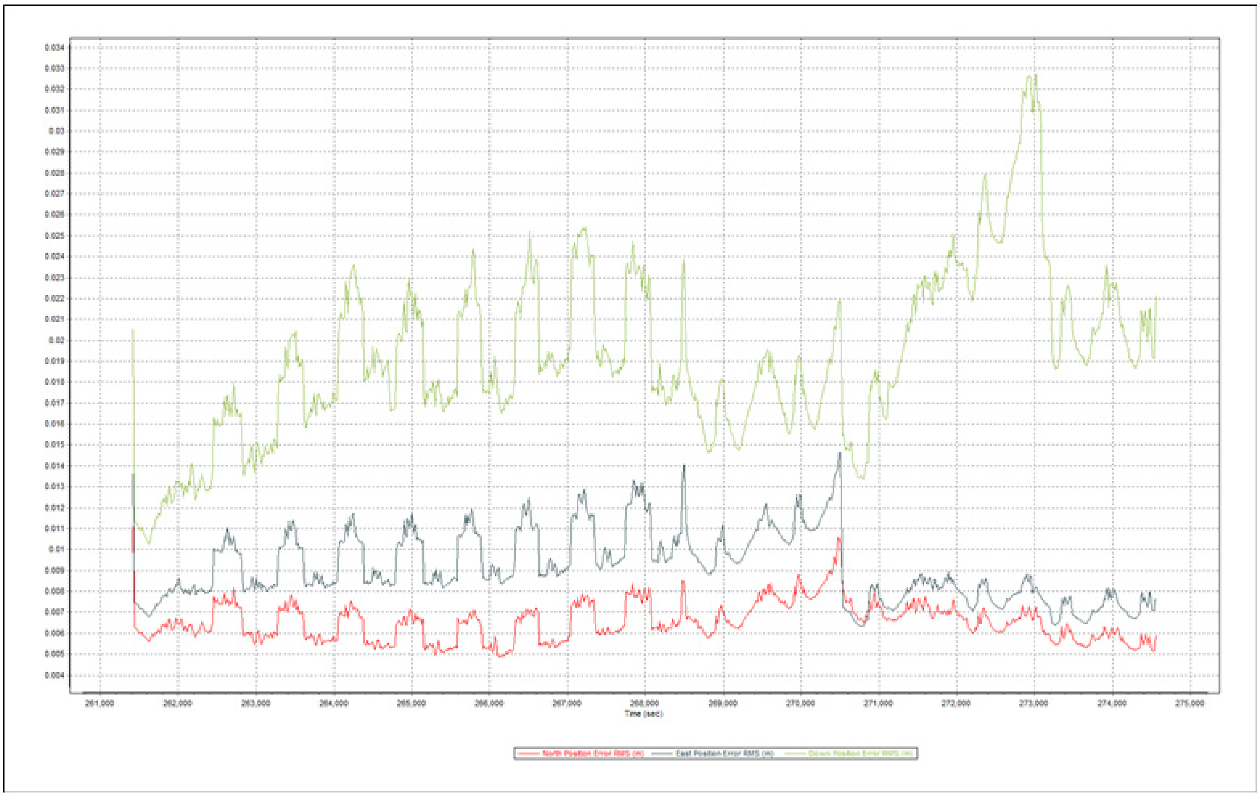


Figure A-8.37. Smoothed Performance Metric Parameters

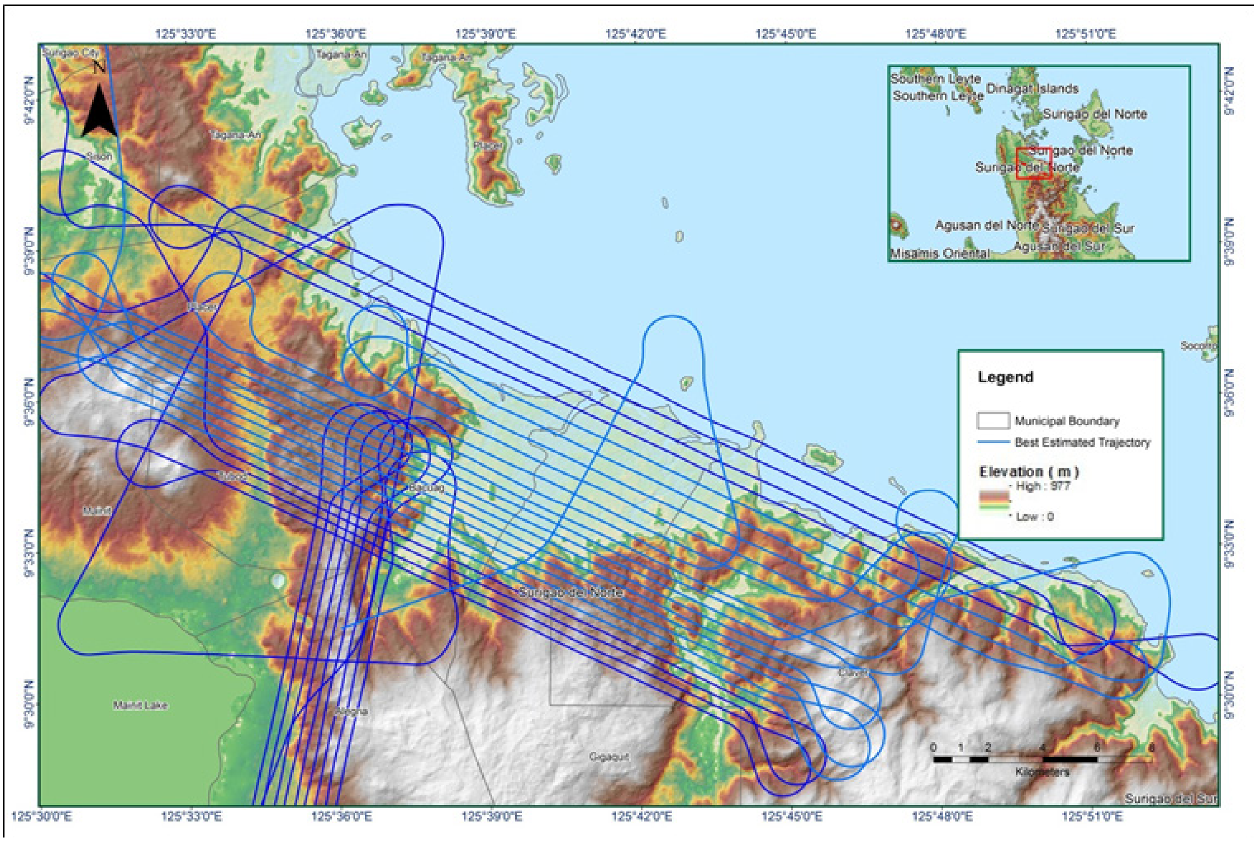


Figure A-8.38. Best Estimated Trajectory

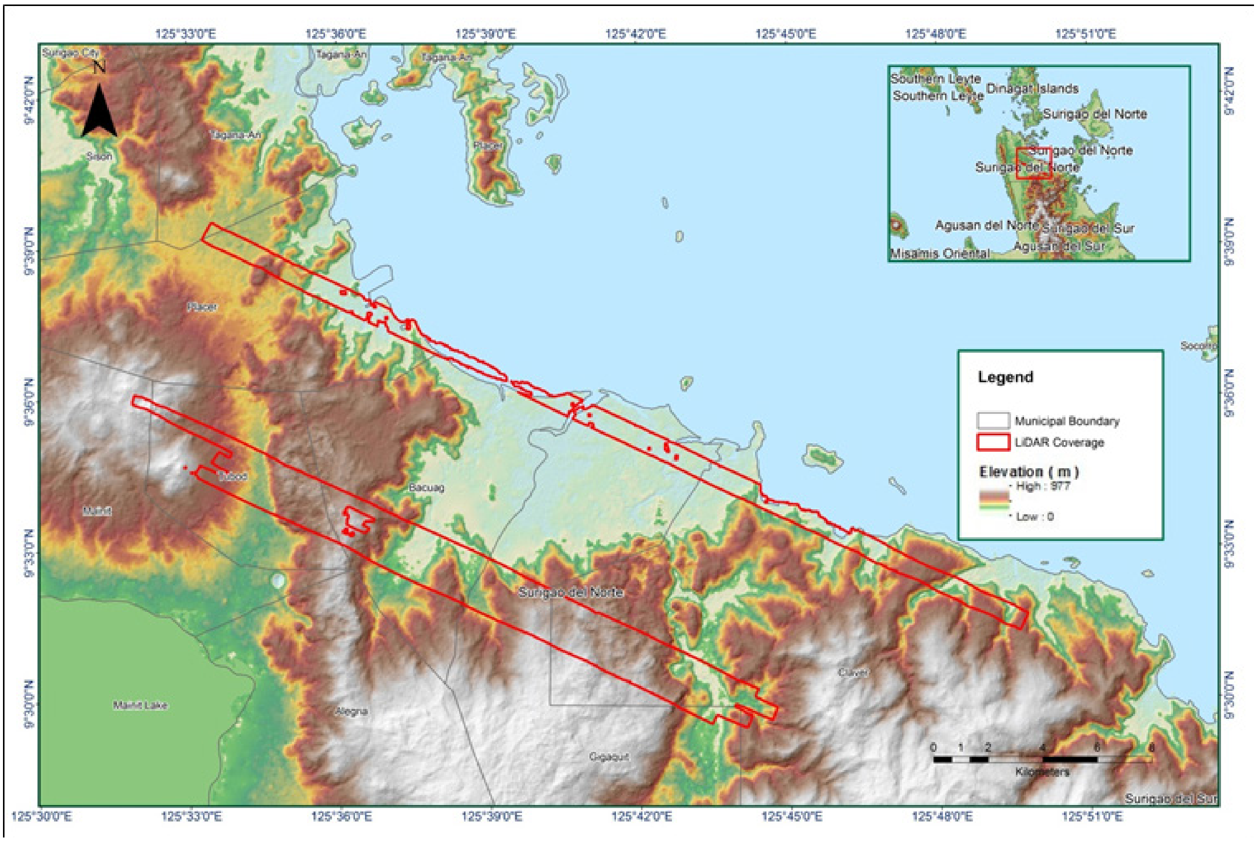


Figure A-8.39. Coverage of LiDAR data

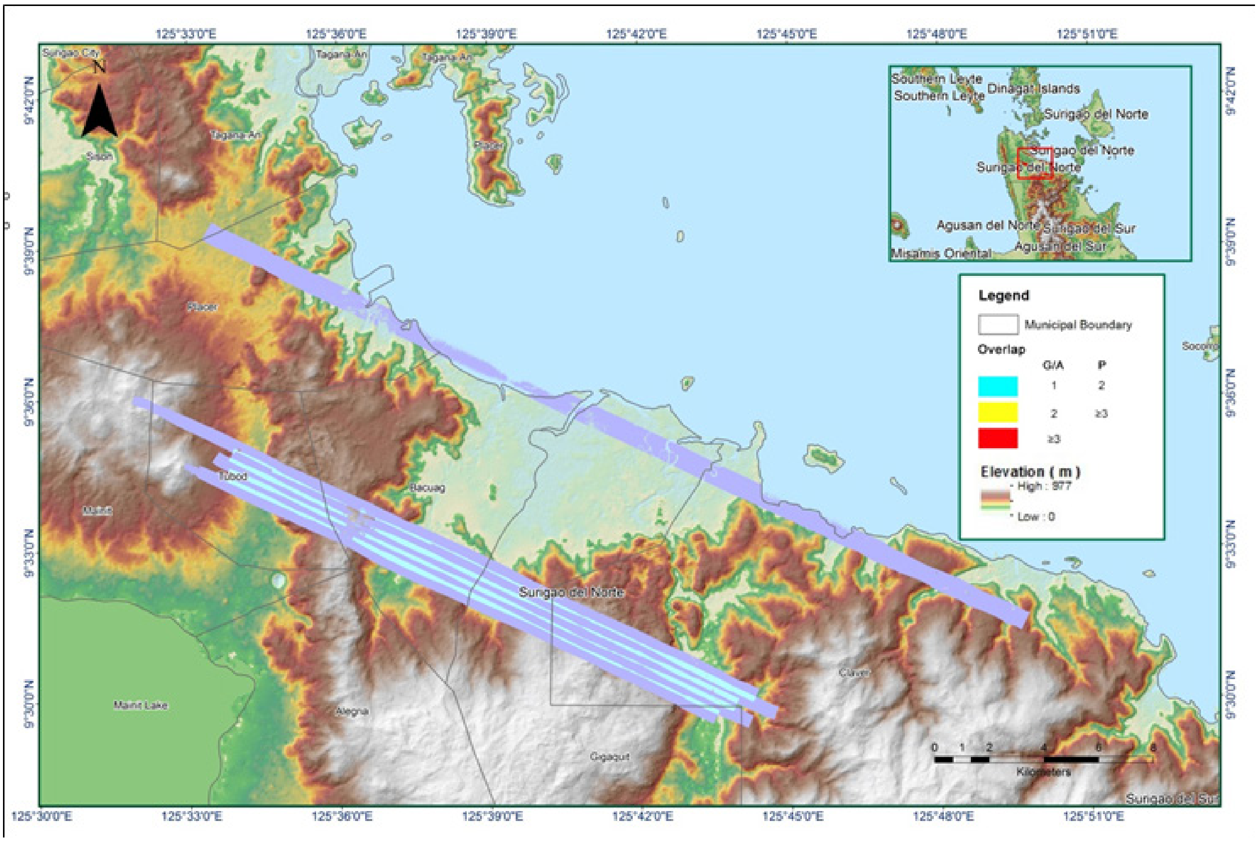


Figure A-8.40. Image of Data Overlap

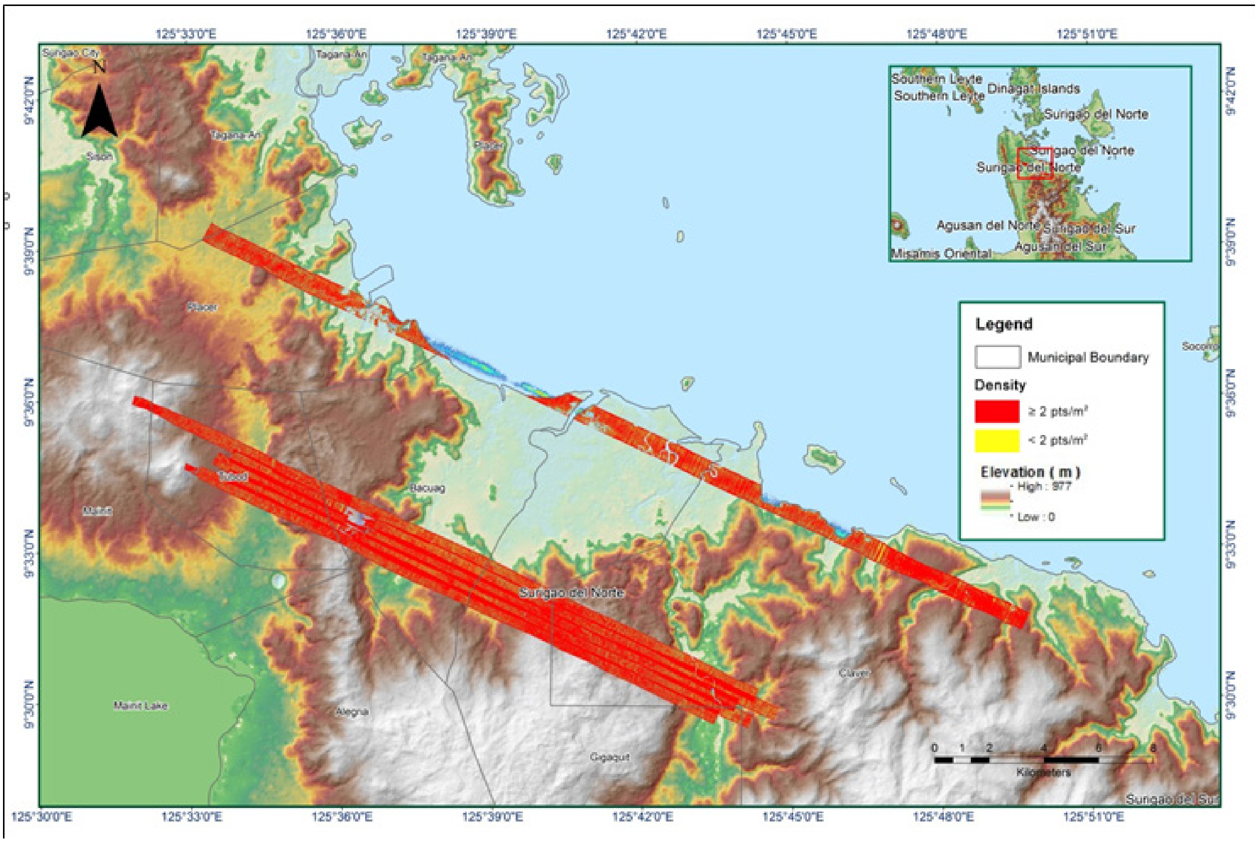


Figure A-8.41. Density map of merged LiDAR data

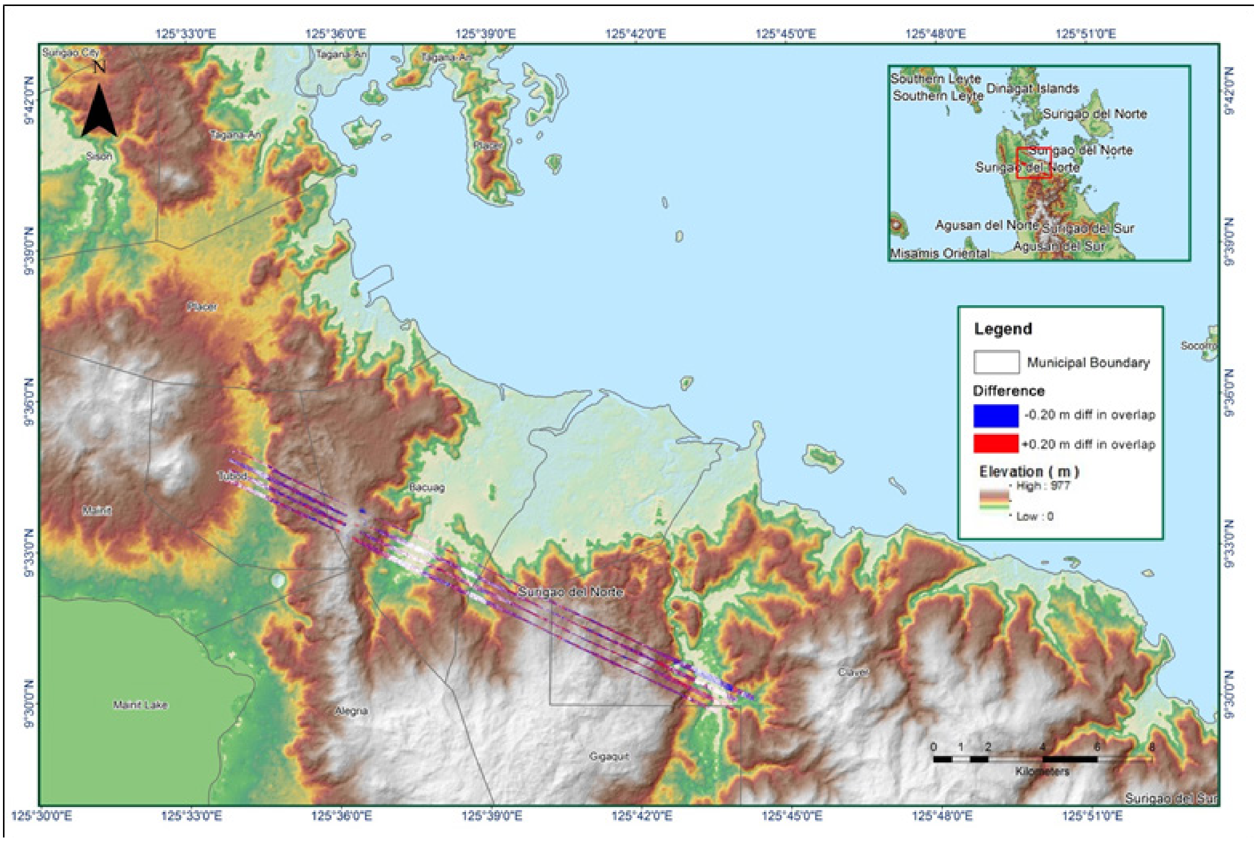


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk60D Additional

Flight Area	Surigao City
Mission Name	Blk60D Additional
(Surigao Del Norte)	2852P, 2848P
Inclusive Flights	7300GC
Range data size	15.40 GB
POS data size	216 MB
Base data size	4.78 MB
Image	N/A
Transfer date	June 20, 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)	1.55
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	14.31%
Ave point cloud density per sq.m. (>2.0)	3.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	112
Maximum Height	698.71 m
Minimum Height	68.19 m
Classification (# of points)	
Ground	12,827,029
Low vegetation	9,667,652
Medium vegetation	24,772,882
High vegetation	68,987,762
Building	559,269
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

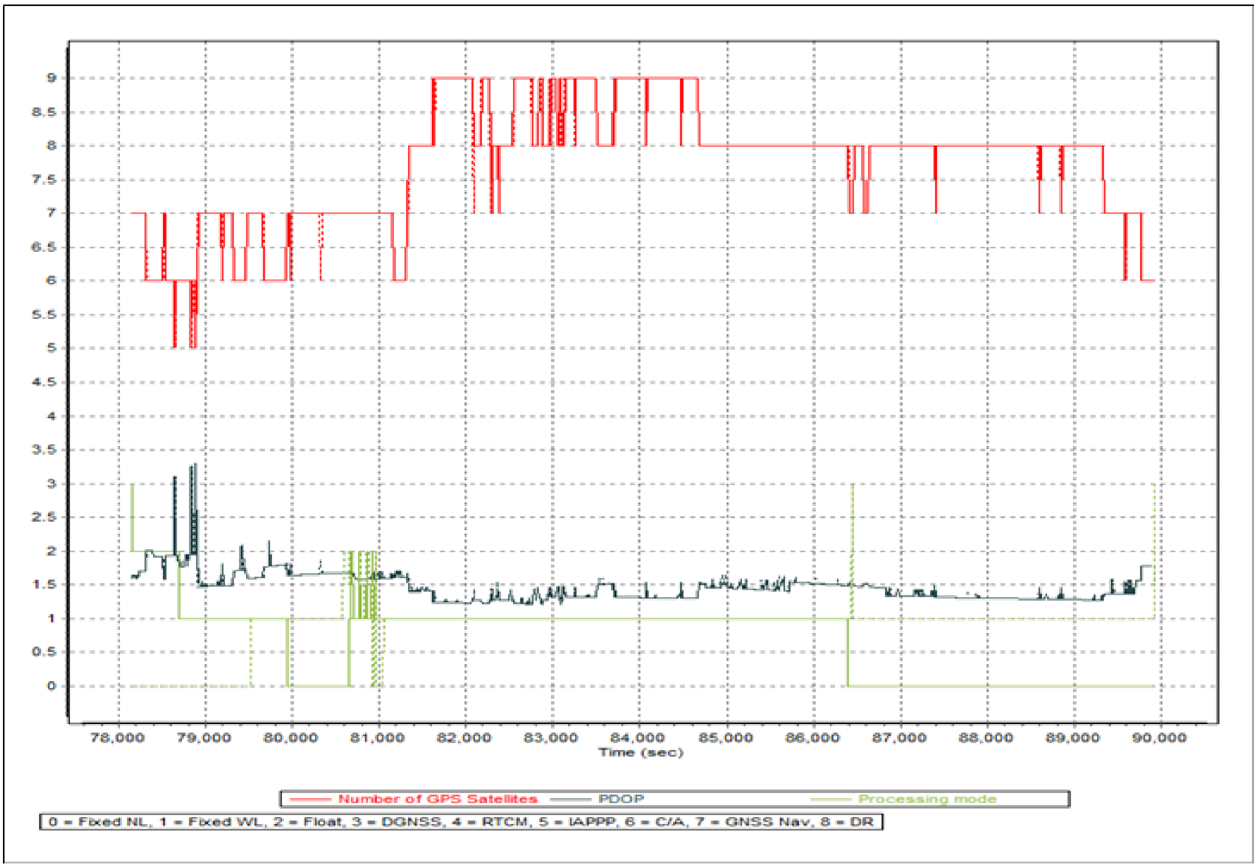


Figure A-8.43. Solution Status

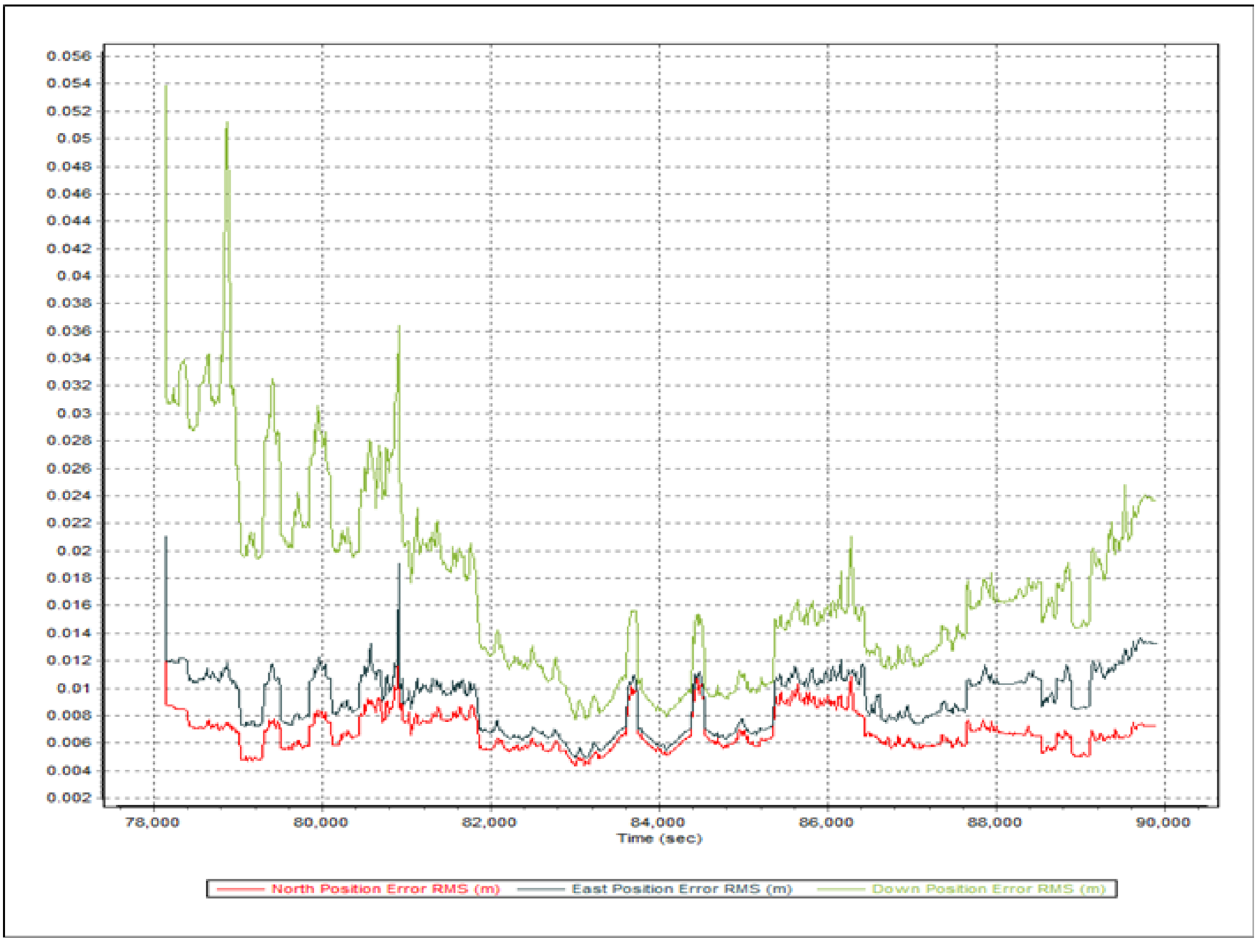


Figure A-8.44. Smoothed Performance Metric Parameters

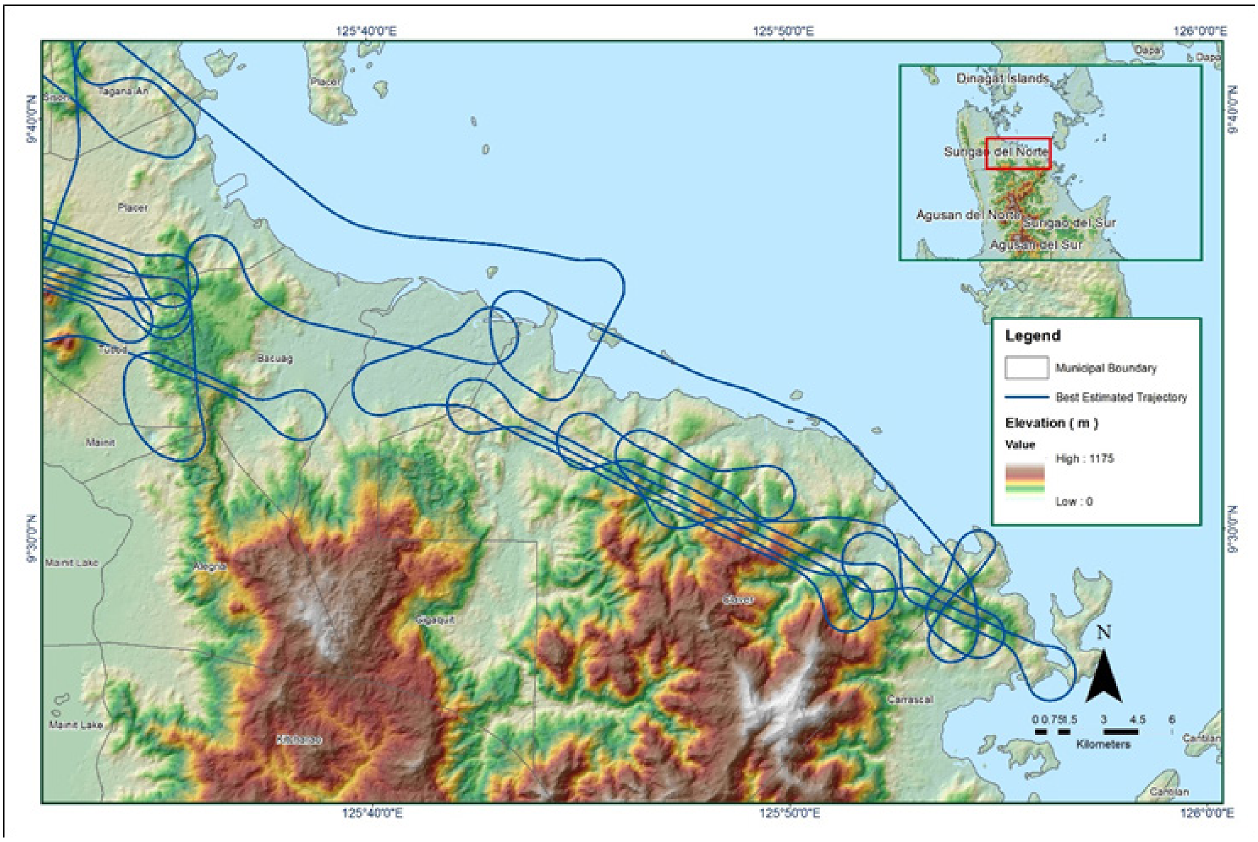


Figure A-8.45. Best Estimated Trajectory

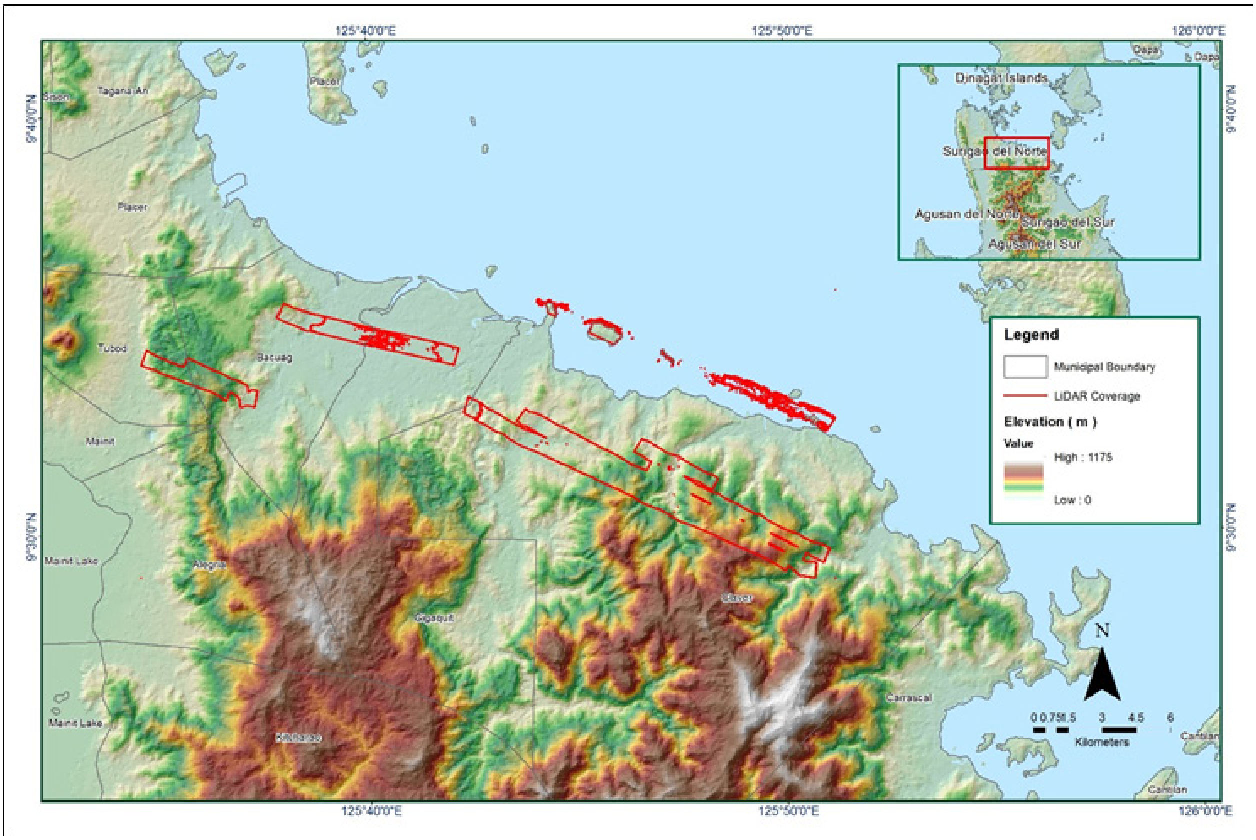


Figure A-8.46. Coverage of LiDAR data

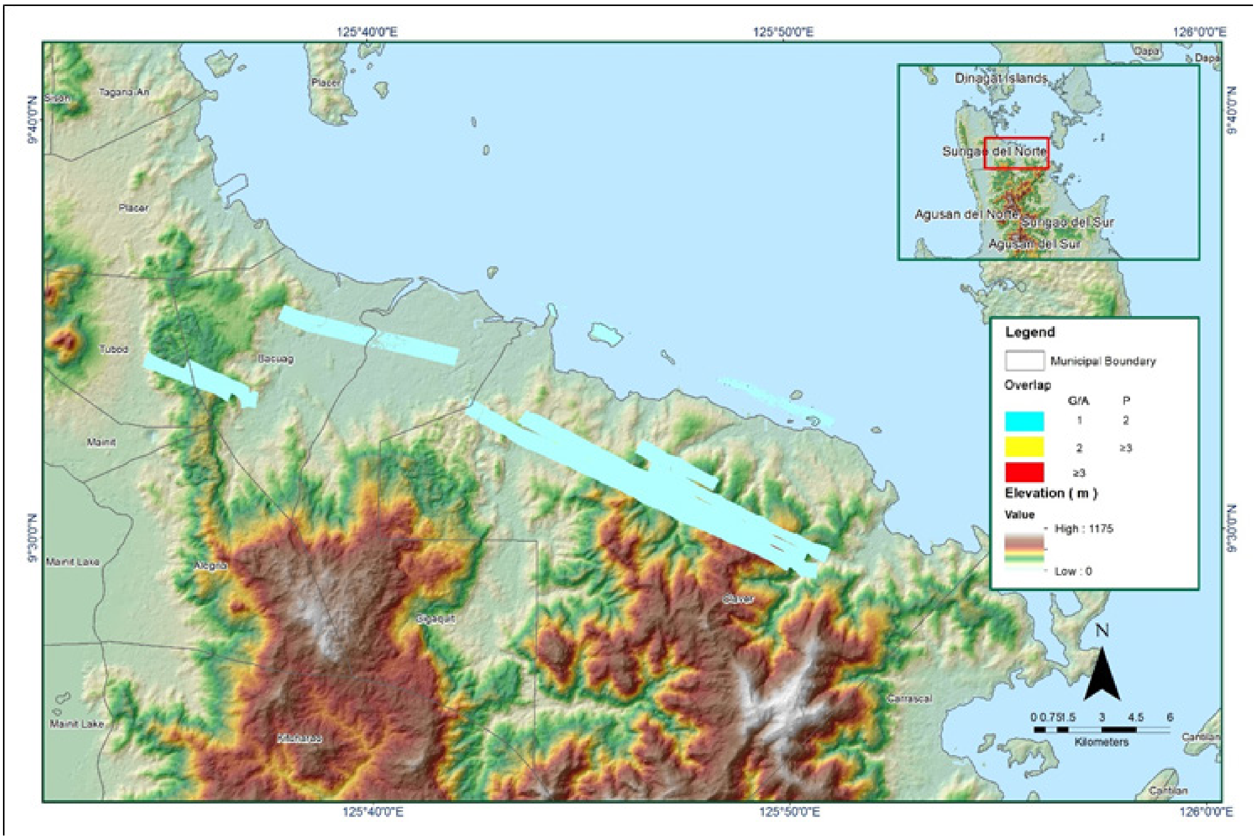


Figure A-8.47. Image of Data Overlap

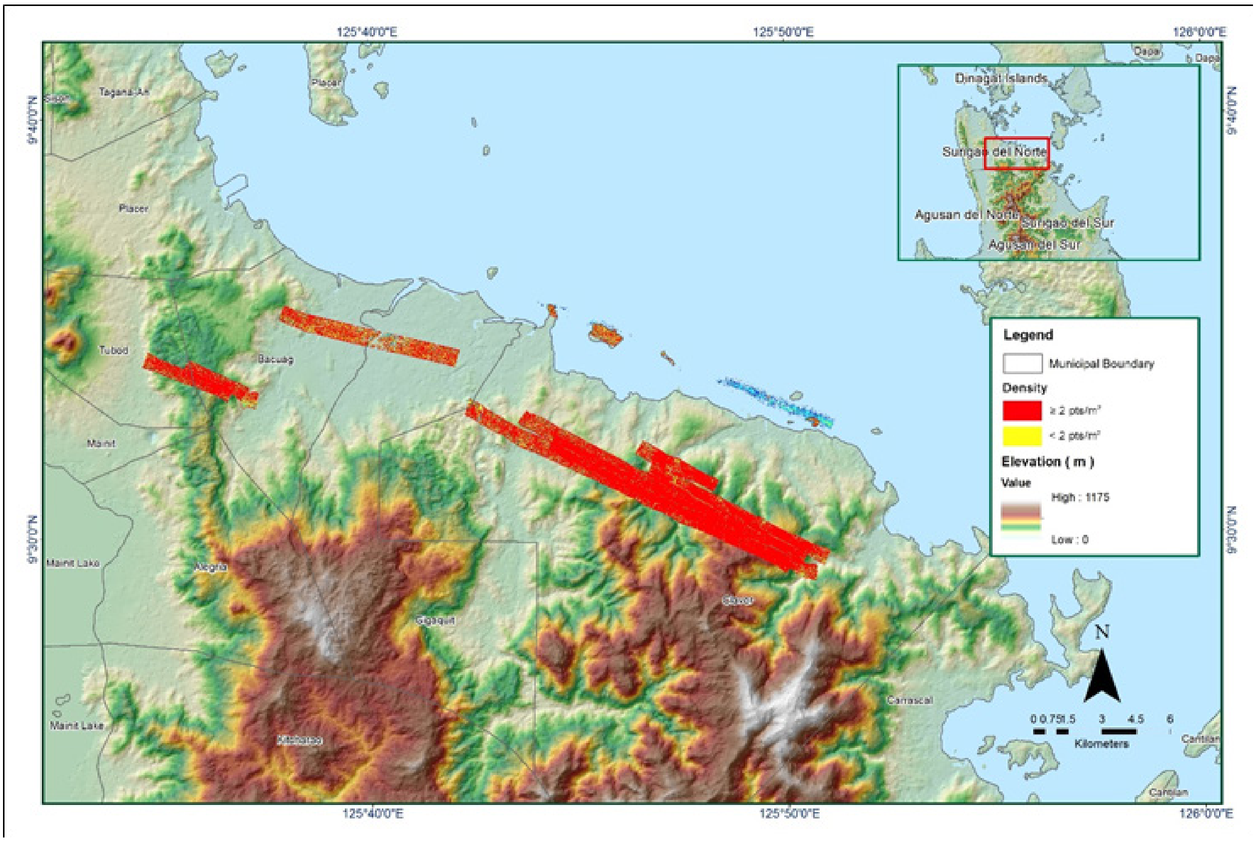


Figure A-8.48. Density map of merged LiDAR data

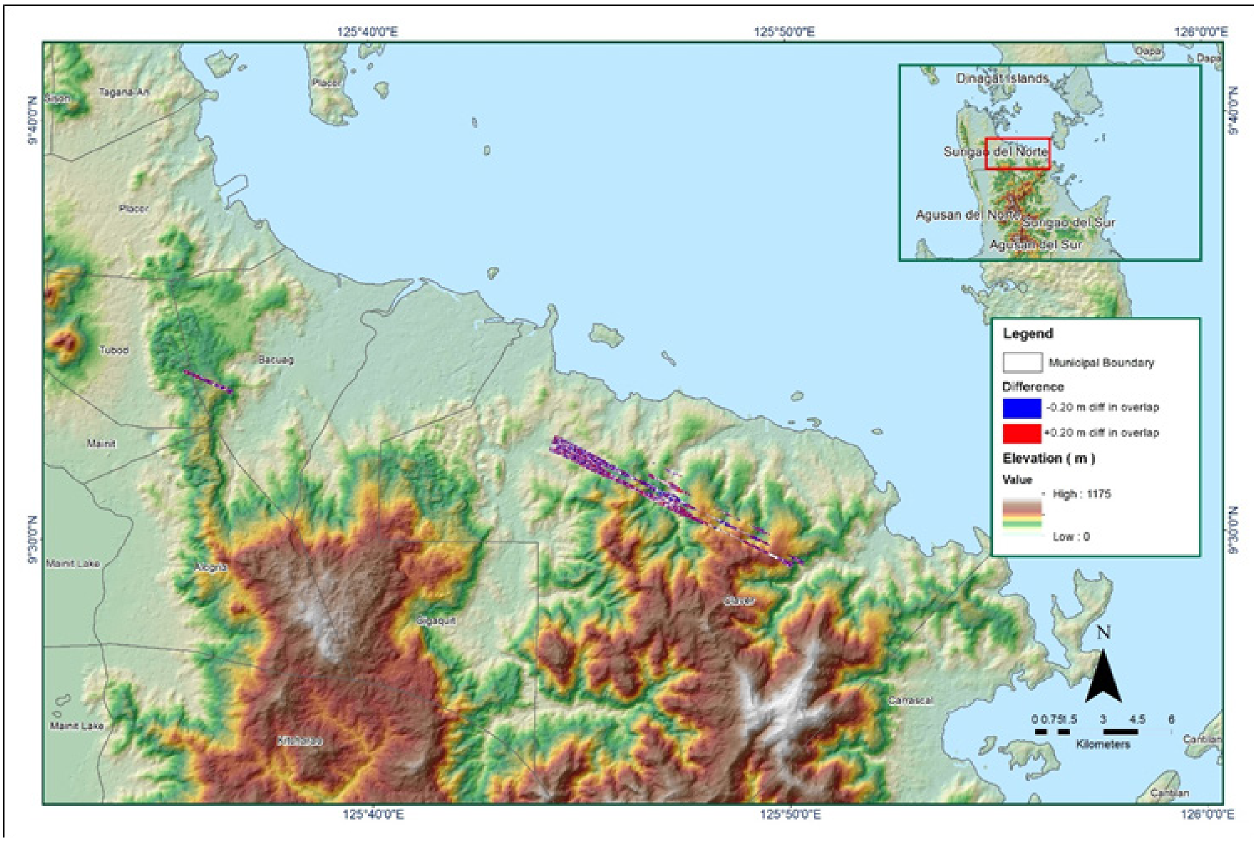


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk60C Additional

Flight Area	Surigao City
Mission Name	Blk60C Additional
(Surigao Del Norte)	2848P
Inclusive Flights	7300GC
Range data size	15.40 GB
POS data size	216 MB
Base data size	4.78 MB
Image	N/A
Transfer date	June 20, 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)	1.55
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	16.69%
Ave point cloud density per sq.m. (>2.0)	3.45
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	91
Maximum Height	698.71 m
Minimum Height	68.19 m
Classification (# of points)	
Ground	12,123,885
Low vegetation	8,589,635
Medium vegetation	24,273,212
High vegetation	57,365,665
Building	504,169
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

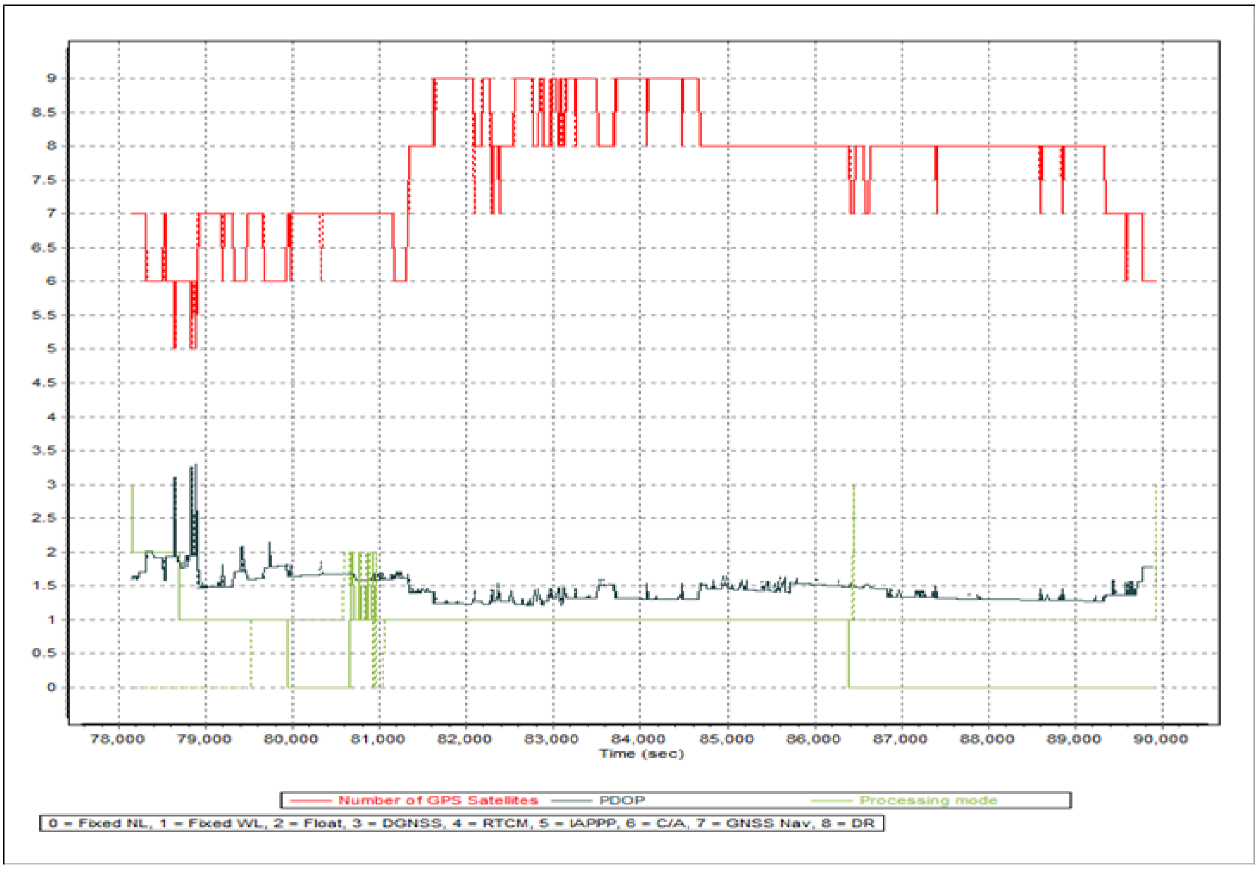


Figure A-8.50. Solution Status

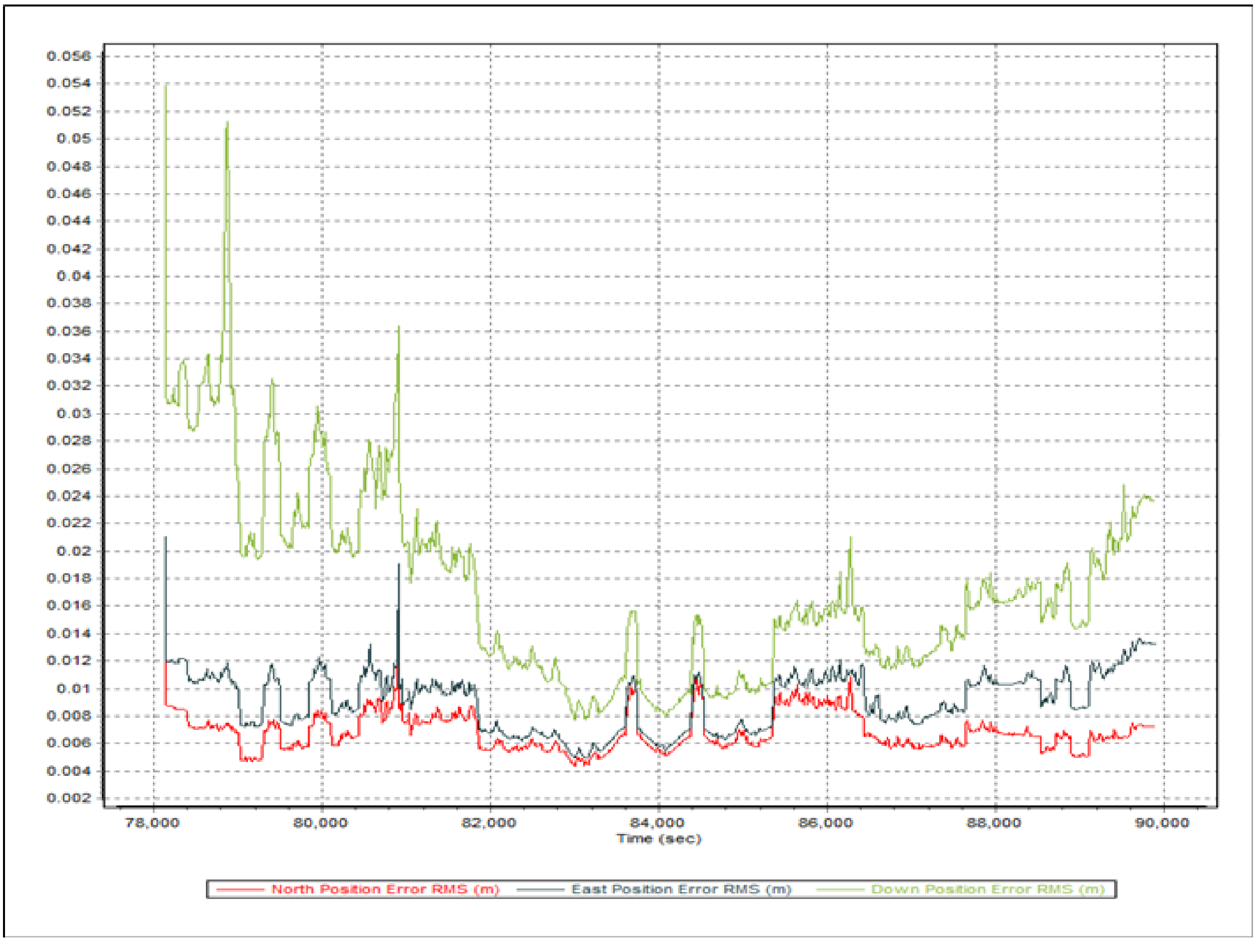


Figure A-8.51. Smoothed Performance Metric Parameters

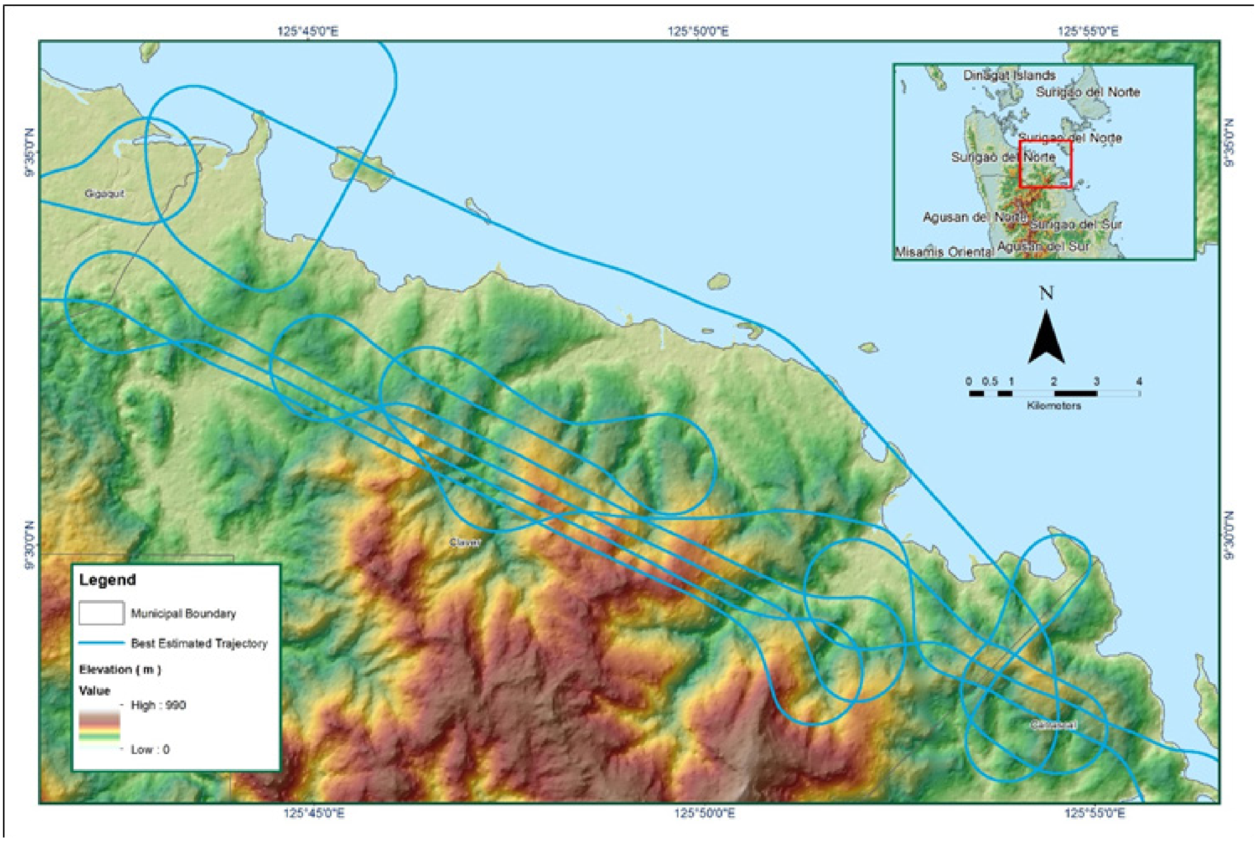


Figure A-8.52. Best Estimated Trajectory

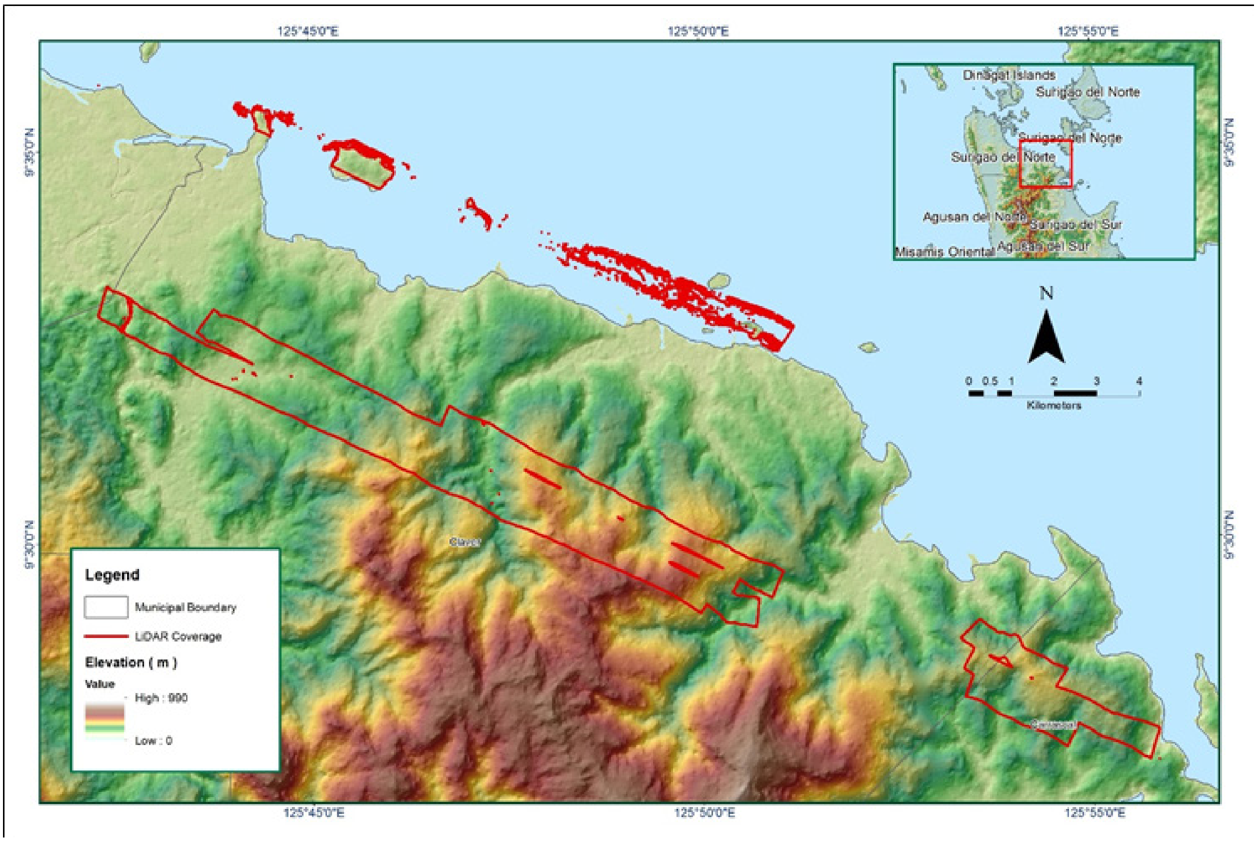


Figure A-8.53. Coverage of LiDAR data

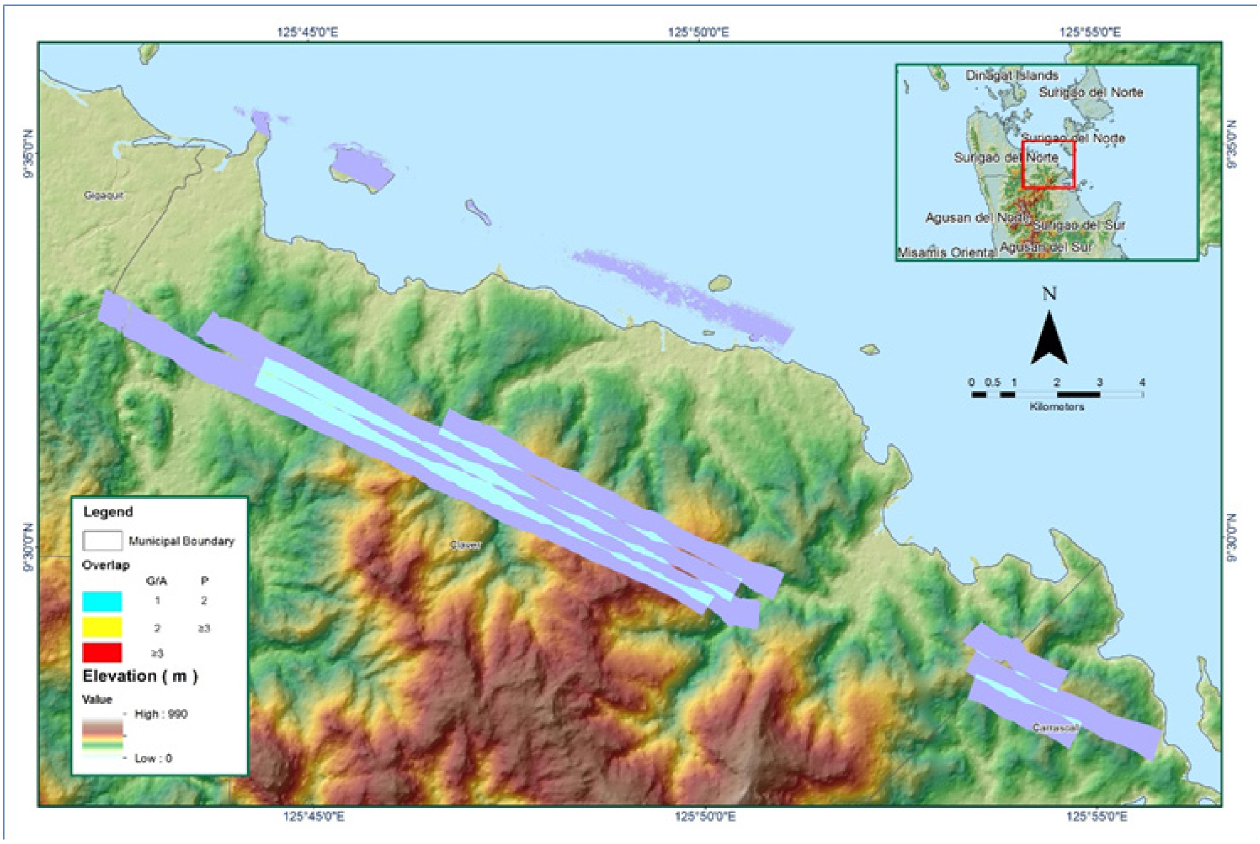


Figure A-8.54. Image of Data Overlap

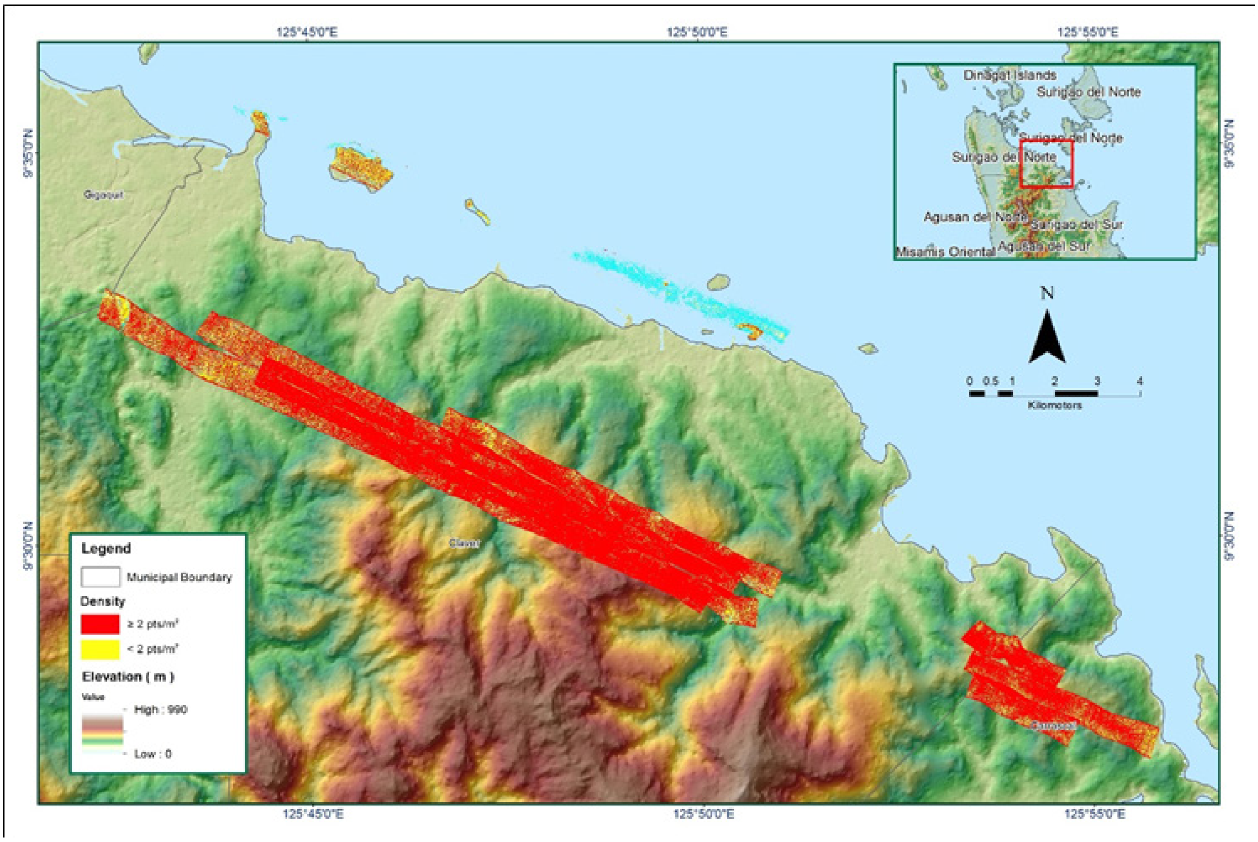


Figure A-8.55. Density map of merged LiDAR data

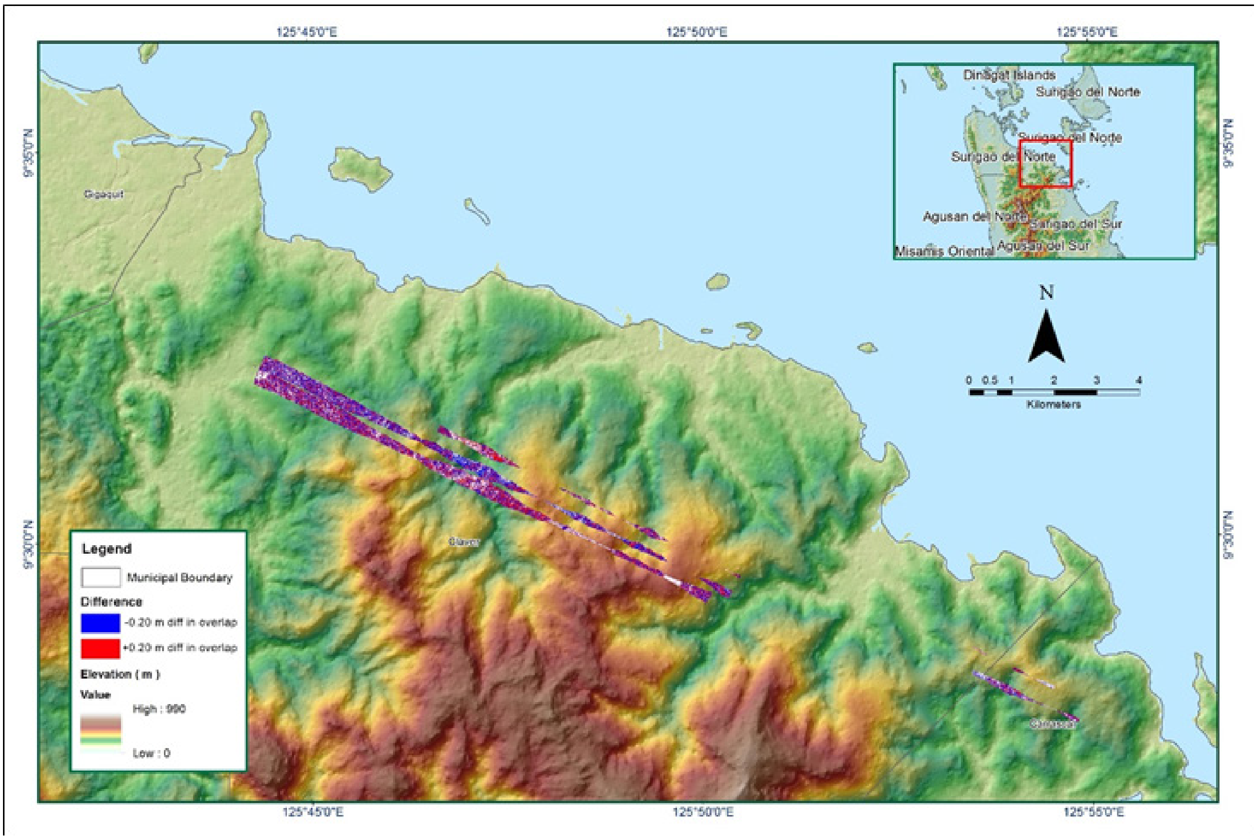


Figure A-8.56. Elevation difference between flight lines

Annex 9. Magallanes Model Basin Parameters

Table A-9.1. Magallanes Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1480	0.00	80.42	11.02	0.7993	0.3997	Discharge	0.211130	1	Ratio to Peak	0.05
W1490	0.00	87.98	0.00	0.9347	0.4673	Discharge	0.133400	1	Ratio to Peak	0.05
W1500	0.00	85.12	0.00	0.8024	0.4012	Discharge	0.130470	1	Ratio to Peak	0.05
W1510	0.00	87.05	0.00	0.0628	0.0314	Discharge	0.001367	1	Ratio to Peak	0.05
W1520	0.00	85.12	0.00	0.3347	0.1673	Discharge	0.046236	1	Ratio to Peak	0.05
W15290	0.00	99.00	0.00	0.5164	0.2582	Discharge	0.181050	1	Ratio to Peak	0.05
W1530	0.00	81.51	13.32	0.7458	0.3729	Discharge	0.124800	1	Ratio to Peak	0.05
W15300	0.00	99.00	0.00	0.3091	0.1545	Discharge	0.126360	1	Ratio to Peak	0.05
W15340	0.00	99.00	0.00	0.3152	0.1576	Discharge	0.078605	1	Ratio to Peak	0.05
W15390	0.00	82.57	0.00	0.3261	0.1630	Discharge	0.067705	1	Ratio to Peak	0.05
W15400	0.00	78.73	0.00	0.3602	0.1801	Discharge	0.128040	1	Ratio to Peak	0.05
W15440	0.00	84.12	0.00	0.3731	0.1866	Discharge	0.029621	1	Ratio to Peak	0.05
W15450	0.00	78.73	0.00	0.6995	0.3497	Discharge	0.380920	1	Ratio to Peak	0.05
W15490	0.00	81.51	0.00	0.3479	0.1739	Discharge	0.118790	1	Ratio to Peak	0.05
W1550	0.00	89.22	0.00	0.6263	0.3131	Discharge	0.093963	1	Ratio to Peak	0.05
W15500	0.00	79.30	0.00	0.3564	0.1782	Discharge	0.184230	1	Ratio to Peak	0.05
W15540	0.00	84.12	0.72	0.5514	0.2757	Discharge	0.096393	1	Ratio to Peak	0.05
W15550	0.00	80.97	0.00	0.3495	0.1748	Discharge	0.114880	1	Ratio to Peak	0.05
W15590	0.00	80.42	0.00	0.3646	0.1823	Discharge	0.103550	1	Ratio to Peak	0.05
W1560	0.00	86.10	0.00	0.4120	0.2060	Discharge	0.081041	1	Ratio to Peak	0.05
W15600	0.00	80.42	0.00	0.3409	0.1705	Discharge	0.098240	1	Ratio to Peak	0.05
W15640	0.00	79.86	0.00	0.3943	0.1972	Discharge	0.135080	1	Ratio to Peak	0.05

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W15650	0.00	79.30	0.00	0.3948	0.1974	Discharge	0.109750	1	Ratio to Peak	0.05
W15690	0.00	78.73	0.00	0.3977	0.1988	Discharge	0.116500	1	Ratio to Peak	0.05
W1570	0.00	84.12	0.00	0.5944	0.2972	Discharge	0.113490	1	Ratio to Peak	0.05
W15700	0.00	78.73	0.00	0.3073	0.1537	Discharge	0.133250	1	Ratio to Peak	0.05
W15740	0.00	82.04	0.00	0.5224	0.2612	Discharge	0.112100	1	Ratio to Peak	0.05
W15750	0.00	80.42	0.00	0.4027	0.2014	Discharge	0.159190	1	Ratio to Peak	0.05
W15790	0.00	99.00	0.00	0.3867	0.1933	Discharge	0.081249	1	Ratio to Peak	0.05
W15800	0.00	99.00	0.00	0.4478	0.2239	Discharge	0.270410	1	Ratio to Peak	0.05
W15840	0.00	99.00	0.00	0.3316	0.1658	Discharge	0.129280	1	Ratio to Peak	0.05
W15850	0.00	50.62	0.00	0.5069	0.2535	Discharge	0.350080	1	Ratio to Peak	0.05
W1590	0.00	86.10	0.00	0.8999	0.4499	Discharge	0.476240	1	Ratio to Peak	0.05
W1600	0.00	83.09	0.00	0.8157	0.4078	Discharge	0.104990	1	Ratio to Peak	0.05
W1610	0.00	85.61	6.05	0.5672	0.2836	Discharge	0.142990	1	Ratio to Peak	0.05
W1620	0.00	87.52	0.00	0.1304	0.0652	Discharge	0.008334	1	Ratio to Peak	0.05
W1630	0.00	83.09	0.00	0.5710	0.2855	Discharge	0.095764	1	Ratio to Peak	0.05
W1640	0.00	80.97	4.50	0.5103	0.2552	Discharge	0.066396	1	Ratio to Peak	0.05
W1650	0.00	83.09	0.33	1.2947	0.6473	Discharge	0.309550	1	Ratio to Peak	0.05
W1660	0.00	84.62	0.00	0.4331	0.2165	Discharge	0.098570	1	Ratio to Peak	0.05
W1670	0.00	74.81	0.00	0.4107	0.2053	Discharge	0.193870	1	Ratio to Peak	0.05
W1680	0.00	80.31	0.00	0.5871	0.2936	Discharge	0.056864	1	Ratio to Peak	0.05
W1690	0.00	82.57	0.00	0.4384	0.2192	Discharge	0.057350	1	Ratio to Peak	0.05
W1700	0.00	82.04	3.21	0.4046	0.2023	Discharge	0.105040	1	Ratio to Peak	0.05
W1710	0.00	79.01	0.00	0.3976	0.1988	Discharge	0.054285	1	Ratio to Peak	0.05
W1730	0.00	85.12	0.00	0.2292	0.1146	Discharge	0.023413	1	Ratio to Peak	0.05
W1740	0.00	87.05	0.00	0.5270	0.2635	Discharge	0.133210	1	Ratio to Peak	0.05

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1750	0.00	84.12	0.00	0.4953	0.2477	Discharge	0.156430	1	Ratio to Peak	0.05
W1760	0.00	80.97	0.00	0.4404	0.2202	Discharge	0.118610	1	Ratio to Peak	0.05
W1800	0.00	84.62	0.00	0.4578	0.2289	Discharge	0.129241	1	Ratio to Peak	0.05
W1810	0.00	86.10	0.00	0.4446	0.2223	Discharge	0.026673	1	Ratio to Peak	0.05
W1820	0.00	82.57	0.00	0.6927	0.3463	Discharge	0.172030	1	Ratio to Peak	0.05
W1830	0.00	80.42	0.00	0.5455	0.2727	Discharge	0.312130	1	Ratio to Peak	0.05
W1860	0.00	79.89	0.00	0.3182	0.1591	Discharge	0.026776	1	Ratio to Peak	0.05
W1900	0.00	78.57	0.00	0.2576	0.1288	Discharge	0.022784	1	Ratio to Peak	0.05
W1910	0.00	78.12	0.00	0.5224	0.2612	Discharge	0.065003	1	Ratio to Peak	0.05
W1920	0.00	75.79	0.00	0.3722	0.1861	Discharge	0.102190	1	Ratio to Peak	0.05
W1940	0.00	75.79	0.00	0.2831	0.1416	Discharge	0.099977	1	Ratio to Peak	0.05
W1950	0.00	75.79	0.00	0.3375	0.1688	Discharge	0.025065	1	Ratio to Peak	0.05
W1960	0.00	79.86	0.00	0.2925	0.1463	Discharge	0.041882	1	Ratio to Peak	0.05
W1980	0.00	51.23	0.00	0.3381	0.1691	Discharge	0.141420	1	Ratio to Peak	0.05
W1990	0.00	75.30	0.00	0.2992	0.1496	Discharge	0.023167	1	Ratio to Peak	0.05
W2000	0.00	80.97	0.00	0.4205	0.2103	Discharge	0.225530	1	Ratio to Peak	0.05
W2010	0.00	80.42	0.00	0.3909	0.1955	Discharge	0.230820	1	Ratio to Peak	0.05
W2020	0.00	61.87	0.00	0.5180	0.2590	Discharge	0.233620	1	Ratio to Peak	0.05
W2030	0.00	92.46	0.00	0.5530	0.2765	Discharge	0.215230	1	Ratio to Peak	0.05
W2040	0.00	80.42	0.00	0.3343	0.1671	Discharge	0.101910	1	Ratio to Peak	0.05
W2050	0.00	79.30	0.00	0.2692	0.1346	Discharge	0.099121	1	Ratio to Peak	0.05
W2070	0.00	79.86	0.00	0.7793	0.3896	Discharge	0.472980	1	Ratio to Peak	0.05
W2080	0.00	79.86	0.00	0.6492	0.3246	Discharge	0.438360	1	Ratio to Peak	0.05
W2090	0.00	79.57	0.00	0.3330	0.1665	Discharge	0.166960	1	Ratio to Peak	0.05
W2100	0.00	98.85	0.00	0.5672	0.2836	Discharge	0.157320	1	Ratio to Peak	0.05

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2110	0.00	59.51	0.00	0.4221	0.2111	Discharge	0.157980	1	Ratio to Peak	0.05
W2120	0.00	98.61	0.00	0.7614	0.3807	Discharge	0.694220	1	Ratio to Peak	0.05
W2130	0.00	79.86	0.00	0.3710	0.1855	Discharge	0.240400	1	Ratio to Peak	0.05
W2140	0.00	79.86	0.00	0.3675	0.1838	Discharge	0.074736	1	Ratio to Peak	0.05
W2150	0.00	78.73	0.00	0.4034	0.2017	Discharge	0.130140	1	Ratio to Peak	0.05
W2160	0.00	78.73	0.00	0.3970	0.1985	Discharge	0.165760	1	Ratio to Peak	0.05
W2170	0.00	75.30	0.00	0.3224	0.1612	Discharge	0.161750	1	Ratio to Peak	0.05
W2180	0.00	77.43	0.00	0.3895	0.1948	Discharge	0.143480	1	Ratio to Peak	0.05
W2190	0.00	81.51	0.00	0.2506	0.1253	Discharge	0.058944	1	Ratio to Peak	0.05
W2200	0.00	78.73	0.00	0.4564	0.2282	Discharge	0.111110	1	Ratio to Peak	0.05
W2210	0.00	80.97	0.00	0.2419	0.1210	Discharge	0.026426	1	Ratio to Peak	0.05
W2220	0.00	78.73	0.00	0.3205	0.1603	Discharge	0.084372	1	Ratio to Peak	0.05
W2230	0.00	78.73	0.00	0.3088	0.1544	Discharge	0.112760	1	Ratio to Peak	0.05
W2240	0.00	77.58	0.00	0.3508	0.1754	Discharge	0.126860	1	Ratio to Peak	0.05
W2250	0.00	58.02	0.00	0.3752	0.1876	Discharge	0.128950	1	Ratio to Peak	0.05
W2260	0.00	78.73	0.00	0.4148	0.2074	Discharge	0.284320	1	Ratio to Peak	0.05
W2270	0.00	79.86	0.00	0.5248	0.2624	Discharge	0.185390	1	Ratio to Peak	0.05
W2280	0.00	80.42	0.00	0.5056	0.2528	Discharge	0.310300	1	Ratio to Peak	0.05
W2290	0.00	79.30	0.00	0.2432	0.1216	Discharge	0.106530	1	Ratio to Peak	0.05
W2300	0.00	79.30	0.00	0.4828	0.2414	Discharge	0.242070	1	Ratio to Peak	0.05
W2310	0.00	75.76	0.00	0.3831	0.1916	Discharge	0.176470	1	Ratio to Peak	0.05
W2320	0.00	78.15	0.00	0.3568	0.1784	Discharge	0.139560	1	Ratio to Peak	0.05
W2330	0.00	79.86	0.00	0.3007	0.1503	Discharge	0.077847	1	Ratio to Peak	0.05
W2340	0.00	73.88	0.00	0.4478	0.2239	Discharge	0.149620	1	Ratio to Peak	0.05
W2350	0.00	78.73	0.00	0.4642	0.2321	Discharge	0.260890	1	Ratio to Peak	0.05

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2360	0.00	68.47	0.00	0.5011	0.2506	Discharge	0.165620	1	Ratio to Peak	0.05
W2370	0.00	70.57	0.00	0.3253	0.1627	Discharge	0.090580	1	Ratio to Peak	0.05
W2380	0.00	67.75	0.00	0.4063	0.2032	Discharge	0.172660	1	Ratio to Peak	0.05
W2390	0.00	79.86	0.00	0.2626	0.1313	Discharge	0.044947	1	Ratio to Peak	0.05
W2400	0.00	79.30	0.00	0.2192	0.1096	Discharge	0.028843	1	Ratio to Peak	0.05
W2410	0.00	79.86	0.00	0.4585	0.2293	Discharge	0.259970	1	Ratio to Peak	0.05
W2420	0.00	78.73	0.00	0.3236	0.1618	Discharge	0.144340	1	Ratio to Peak	0.05
W2430	0.00	76.97	0.00	0.3540	0.1770	Discharge	0.151020	1	Ratio to Peak	0.05
W2440	0.00	78.73	0.00	0.2427	0.1213	Discharge	0.052645	1	Ratio to Peak	0.05
W2450	0.00	78.73	0.00	0.5339	0.2669	Discharge	0.210170	1	Ratio to Peak	0.05
W2460	0.00	78.73	0.00	0.5489	0.2744	Discharge	0.322990	1	Ratio to Peak	0.05
W2470	0.00	79.30	0.00	0.3664	0.1832	Discharge	0.075844	1	Ratio to Peak	0.05
W2480	0.00	79.86	0.00	0.7021	0.3510	Discharge	0.482920	1	Ratio to Peak	0.05
W2490	0.00	79.30	0.00	0.2634	0.1317	Discharge	0.035000	1	Ratio to Peak	0.05
W2500	0.00	80.42	0.00	0.5129	0.2564	Discharge	0.408210	1	Ratio to Peak	0.05
W2510	0.00	67.75	0.00	0.6049	0.3025	Discharge	0.202600	1	Ratio to Peak	0.05
W2520	0.00	71.25	0.00	0.5404	0.2702	Discharge	0.297950	1	Ratio to Peak	0.05
W2530	0.00	67.75	0.00	0.5198	0.2599	Discharge	0.226890	1	Ratio to Peak	0.05
W2540	0.00	67.75	0.00	0.5726	0.2863	Discharge	0.142790	1	Ratio to Peak	0.05
W2550	0.00	78.73	0.00	0.2810	0.1405	Discharge	0.109670	1	Ratio to Peak	0.05
W2560	0.00	79.30	0.00	0.3780	0.1890	Discharge	0.230730	1	Ratio to Peak	0.05
W2570	0.00	67.75	0.00	0.3046	0.1523	Discharge	0.098279	1	Ratio to Peak	0.05
W2580	0.00	67.75	0.00	0.4644	0.2322	Discharge	0.105870	1	Ratio to Peak	0.05
W2590	0.00	67.75	0.00	0.2640	0.1320	Discharge	0.030476	1	Ratio to Peak	0.05
W2600	0.00	67.75	0.00	0.1365	0.0682	Discharge	0.005042	1	Ratio to Peak	0.05

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2610	0.00	67.75	0.00	0.7812	0.3906	Discharge	0.229040	1	Ratio to Peak	0.05
W2620	0.00	67.75	0.00	0.2418	0.1209	Discharge	0.031358	1	Ratio to Peak	0.05
W2630	0.00	67.75	0.00	0.3493	0.1747	Discharge	0.099581	1	Ratio to Peak	0.05
W2640	0.00	77.56	0.00	0.4494	0.2247	Discharge	0.189040	1	Ratio to Peak	0.05
W2650	0.00	67.75	0.00	0.5548	0.2774	Discharge	0.188540	1	Ratio to Peak	0.05
W2660	0.00	79.30	0.00	0.2479	0.1240	Discharge	0.032595	1	Ratio to Peak	0.05
W2670	0.00	67.75	0.00	0.3985	0.1993	Discharge	0.103040	1	Ratio to Peak	0.05
W2680	0.00	79.30	0.00	0.3351	0.1676	Discharge	0.222990	1	Ratio to Peak	0.05
W2690	0.00	69.88	0.00	0.3414	0.1707	Discharge	0.060123	1	Ratio to Peak	0.05
W2700	0.00	79.30	0.00	0.4549	0.2275	Discharge	0.241540	1	Ratio to Peak	0.05
W2710	0.00	79.30	0.00	0.1205	0.0602	Discharge	0.005379	1	Ratio to Peak	0.05
W2720	0.00	71.25	0.00	0.2461	0.1230	Discharge	0.024761	1	Ratio to Peak	0.05
W2730	0.00	79.86	0.00	0.3726	0.1863	Discharge	0.104640	1	Ratio to Peak	0.05
W2740	0.00	79.30	0.00	0.4488	0.2244	Discharge	0.302420	1	Ratio to Peak	0.05
W2750	0.00	75.14	0.00	0.3026	0.1513	Discharge	0.108440	1	Ratio to Peak	0.05
W2760	0.00	79.30	0.00	0.3863	0.1932	Discharge	0.241260	1	Ratio to Peak	0.05
W2770	0.00	67.02	0.00	0.7378	0.3689	Discharge	0.376190	1	Ratio to Peak	0.05
W2780	0.00	79.30	0.00	0.2913	0.1457	Discharge	0.180830	1	Ratio to Peak	0.05
W2790	0.00	67.75	0.00	0.9209	0.4605	Discharge	0.501880	1	Ratio to Peak	0.05
W2800	0.00	79.30	0.00	0.2416	0.1208	Discharge	0.055296	1	Ratio to Peak	0.05
W2810	0.00	79.30	0.00	0.4068	0.2034	Discharge	0.214600	1	Ratio to Peak	0.05
W2820	0.00	76.97	0.00	0.4234	0.2117	Discharge	0.251080	1	Ratio to Peak	0.05
W2830	0.00	79.86	0.00	0.0934	0.0467	Discharge	0.003311	1	Ratio to Peak	0.05
W2840	0.00	79.86	0.00	0.3361	0.1680	Discharge	0.231570	1	Ratio to Peak	0.05
W2850	0.00	79.30	0.00	0.3910	0.1955	Discharge	0.257110	1	Ratio to Peak	0.05

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2860	0.00	79.30	0.00	0.2944	0.1472	Discharge	0.131650	1	Ratio to Peak	0.05
W2870	0.00	78.73	0.00	0.0899	0.0450	Discharge	0.002288	1	Ratio to Peak	0.05
W2880	0.00	79.30	0.00	0.3611	0.1806	Discharge	0.307660	1	Ratio to Peak	0.05
W2890	0.00	78.73	0.00	0.2388	0.1194	Discharge	0.104540	1	Ratio to Peak	0.05
W2900	0.00	78.73	0.00	0.3436	0.1718	Discharge	0.180558	1	Ratio to Peak	0.05
W2910	0.00	78.73	0.00	0.2311	0.1155	Discharge	0.133000	1	Ratio to Peak	0.05
W2920	0.00	78.73	0.00	0.2932	0.1466	Discharge	0.212660	1	Ratio to Peak	0.05
W2930	0.00	79.30	0.00	0.2994	0.1497	Discharge	0.193730	1	Ratio to Peak	0.05
W2940	0.00	78.73	0.00	0.2740	0.1370	Discharge	0.303680	1	Ratio to Peak	0.05
W2960	0.00	80.42	0.16	1.0380	0.5190	Discharge	0.512320	1	Ratio to Peak	0.05
W2970	0.00	80.74	17.70	0.1777	0.0888	Discharge	0.035188	1	Ratio to Peak	0.05
W3010	0.00	83.09	0.00	0.2034	0.1017	Discharge	0.026595	1	Ratio to Peak	0.05
W3060	0.00	81.51	0.00	0.1775	0.0887	Discharge	0.045634	1	Ratio to Peak	0.05
W3070	0.00	80.97	0.00	0.1757	0.0878	Discharge	0.045323	1	Ratio to Peak	0.05

Annex 10. Magallanes Model Reach Parameters

Table A-10.1. Magallanes Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R100	Automatic Fixed Interval	2425.20	0.000400	0.01	Rectangle	4.72
R1000	Automatic Fixed Interval	1243.00	0.025704	0.01	Rectangle	4.72
R1070	Automatic Fixed Interval	1293.30	0.134520	0.01	Rectangle	4.72
R1090	Automatic Fixed Interval	1422.50	0.039614	0.01	Rectangle	4.72
R1100	Automatic Fixed Interval	351.42	0.000831	0.01	Rectangle	4.72
R1130	Automatic Fixed Interval	1471.50	0.055286	0.01	Rectangle	4.72
R1140	Automatic Fixed Interval	6237.70	0.004526	0.01	Rectangle	30.57
R1170	Automatic Fixed Interval	1866.30	0.011107	0.01	Rectangle	33.42
R1180	Automatic Fixed Interval	1849.10	0.013071	0.01	Rectangle	31.29
R1190	Automatic Fixed Interval	1103.80	0.012749	0.01	Rectangle	28.85
R1200	Automatic Fixed Interval	1041.40	0.004148	0.01	Rectangle	19.52
R1210	Automatic Fixed Interval	2313.70	0.024619	0.01	Rectangle	32.90
R1220	Automatic Fixed Interval	453.55	0.043269	0.01	Rectangle	4.72
R1230	Automatic Fixed Interval	696.69	0.052453	0.01	Rectangle	4.72
R1250	Automatic Fixed Interval	3277.30	0.028254	0.01	Rectangle	38.35
R1270	Automatic Fixed Interval	3137.00	0.011339	0.01	Rectangle	32.83
R1290	Automatic Fixed Interval	1005.30	0.049390	0.01	Rectangle	4.72
R130	Automatic Fixed Interval	275.56	0.000400	0.01	Rectangle	4.72
R1310	Automatic Fixed Interval	1732.40	0.017771	0.01	Rectangle	29.74
R1320	Automatic Fixed Interval	250.00	0.061333	0.01	Rectangle	25.92
R1360	Automatic Fixed Interval	2054.90	0.026813	0.01	Rectangle	22.50
R1380	Automatic Fixed Interval	197.28	0.025413	0.01	Rectangle	4.72

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R1390	Automatic Fixed Interval	4522.40	0.066742	0.01	Rectangle	74.13
R140	Automatic Fixed Interval	2369.40	0.000400	0.01	Rectangle	120.88
R1450	Automatic Fixed Interval	2719.50	0.022003	0.01	Rectangle	4.72
R15370	Automatic Fixed Interval	1679.20	0.013947	0.01	Rectangle	18.05
R15660	Automatic Fixed Interval	1651.40	0.023124	0.01	Rectangle	11.75
R15870	Automatic Fixed Interval	2645.30	0.018399	0.01	Rectangle	18.05
R170	Automatic Fixed Interval	5194.60	0.002141	0.01	Rectangle	47.31
R180	Automatic Fixed Interval	2244.10	0.000465	0.01	Rectangle	39.81
R20	Automatic Fixed Interval	118.28	0.000400	0.01	Rectangle	4.72
R210	Automatic Fixed Interval	654.56	0.001594	0.01	Rectangle	18.76
R220	Automatic Fixed Interval	1687.50	0.000400	0.01	Rectangle	51.34
R230	Automatic Fixed Interval	4231.70	0.001353	0.01	Rectangle	83.26
R240	Automatic Fixed Interval	692.55	0.000400	0.01	Rectangle	66.64
R250	Automatic Fixed Interval	984.68	0.010030	0.01	Rectangle	4.72
R260	Automatic Fixed Interval	1137.40	0.003474	0.01	Rectangle	33.25
R280	Automatic Fixed Interval	1796.10	0.000400	0.01	Rectangle	27.22
R290	Automatic Fixed Interval	1344.00	0.009629	0.01	Rectangle	4.72
R2980	Automatic Fixed Interval	1006.70	0.000400	0.01	Rectangle	27.68
R30	Automatic Fixed Interval	3450.50	0.000400	0.01	Rectangle	4.72
R3040	Automatic Fixed Interval	1139.80	0.020852	0.01	Rectangle	72.35
R3090	Automatic Fixed Interval	1579.50	0.000400	0.01	Rectangle	72.08
R310	Automatic Fixed Interval	2510.50	0.000972	0.01	Rectangle	74.37
R320	Automatic Fixed Interval	3272.90	0.002163	0.01	Rectangle	24.80
R330	Automatic Fixed Interval	1272.00	0.005677	0.01	Rectangle	11.16
R340	Automatic Fixed Interval	2242.10	0.001660	0.01	Rectangle	4.72

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R350	Automatic Fixed Interval	1352.30	0.000400	0.01	Rectangle	21.50
R360	Automatic Fixed Interval	869.12	0.004707	0.01	Rectangle	17.91
R380	Automatic Fixed Interval	973.55	0.002174	0.01	Rectangle	4.72
R390	Automatic Fixed Interval	966.69	0.004512	0.01	Rectangle	4.72
R400	Automatic Fixed Interval	2958.10	0.006171	0.01	Rectangle	8.87
R410	Automatic Fixed Interval	2353.80	0.006468	0.01	Rectangle	37.06
R430	Automatic Fixed Interval	977.40	0.012076	0.01	Rectangle	4.72
R440	Automatic Fixed Interval	367.99	0.029035	0.01	Rectangle	4.72
R450	Automatic Fixed Interval	1115.00	0.006794	0.01	Rectangle	71.57
R460	Automatic Fixed Interval	1166.40	0.000400	0.01	Rectangle	11.26
R470	Automatic Fixed Interval	677.70	0.012824	0.01	Rectangle	4.72
R480	Automatic Fixed Interval	3001.20	0.000400	0.01	Rectangle	14.08
R490	Automatic Fixed Interval	2201.40	0.014744	0.01	Rectangle	11.75
R50	Automatic Fixed Interval	3274.80	0.000400	0.01	Rectangle	4.72
R520	Automatic Fixed Interval	5069.00	0.036542	0.01	Rectangle	4.72
R530	Automatic Fixed Interval	2331.10	0.023925	0.01	Rectangle	11.86
R540	Automatic Fixed Interval	1977.90	0.016914	0.01	Rectangle	9.34
R560	Automatic Fixed Interval	1618.90	0.008551	0.01	Rectangle	18.05
R570	Automatic Fixed Interval	1201.20	0.007957	0.01	Rectangle	4.72
R590	Automatic Fixed Interval	4291.00	0.000400	0.01	Rectangle	33.95
R600	Automatic Fixed Interval	406.27	0.004566	0.01	Rectangle	60.41
R630	Automatic Fixed Interval	1767.10	0.050875	0.01	Rectangle	4.72
R650	Automatic Fixed Interval	1094.60	0.005477	0.01	Rectangle	50.91
R70	Automatic Fixed Interval	891.25	0.000400	0.01	Rectangle	376.24
R700	Automatic Fixed Interval	2623.10	0.100320	0.01	Rectangle	4.72

Reach Number	Muskingum Cunge Channel Routing					
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width
R730	Automatic Fixed Interval	1116.70	0.029380	0.01	Rectangle	16.67
R740	Automatic Fixed Interval	1329.00	0.003857	0.01	Rectangle	68.32
R750	Automatic Fixed Interval	3122.80	0.003998	0.01	Rectangle	19.31
R810	Automatic Fixed Interval	2888.30	0.000400	0.01	Rectangle	66.12
R830	Automatic Fixed Interval	2249.10	0.023464	0.01	Rectangle	17.46
R840	Automatic Fixed Interval	2680.80	0.032795	0.01	Rectangle	4.72
R860	Automatic Fixed Interval	787.70	0.078504	0.01	Rectangle	4.72
R880	Automatic Fixed Interval	1096.60	0.005823	0.01	Rectangle	43.23
R90	Automatic Fixed Interval	1031.20	0.000400	0.01	Rectangle	220.91
R900	Automatic Fixed Interval	1431.10	0.003789	0.01	Rectangle	91.00
R940	Automatic Fixed Interval	505.56	0.045539	0.01	Rectangle	19.28
R950	Automatic Fixed Interval	886.57	0.000400	0.01	Rectangle	58.45
R960	Automatic Fixed Interval	2003.10	0.125410	0.01	Rectangle	17.06
R980	Automatic Fixed Interval	3063.70	0.028888	0.01	Rectangle	15.69
R990	Automatic Fixed Interval	1586.60	0.006428	0.01	Rectangle	51.03

Annex 11. Magallanes Field Validation Points

Table A-11.1. Magallanes Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	9.565722	125.723111	0.55	0.5	-0.550	Seniang	5-year
2	9.565806	125.722694	1.35	0	-0.670	Seniang	5-year
3	9.565583	125.72275	1.42	0.68	-1.060	Seniang	5-year
4	9.562472	125.718528	0	0.36	0.000	Seniang	5-year
5	9.5555	125.707806	3.07	0	-3.070	Seniang	5-year
6	9.553611	125.7085	4.78	0	-4.540	Seniang	5-year
7	9.553333	125.708639	1.4	0.24	-1.400	Seniang	5-year
8	9.54875	125.710222	6.51	0	-6.510	Seniang	5-year
9	9.548694	125.710056	0	0	0.000	Seniang	5-year
10	9.5485	125.710111	6.97	0	-6.970	Seniang	5-year
11	9.548667	125.710194	6.51	0	-5.310	Seniang	5-year
12	9.548083	125.710056	3.55	1.2	-3.550	Seniang	5-year
13	9.549	125.710167	6.84	0	-6.740	Seniang	5-year
14	9.549083	125.710222	6.61	0.1	-6.300	Seniang	5-year
15	9.549222	125.710139	6.45	0.31	-6.450	Seniang	5-year
16	9.548917	125.710111	6.46	0	-6.460	Seniang	5-year
17	9.548917	125.710139	6.46	0	-5.490	Seniang	5-year
18	9.549472	125.710167	6.84	0.97	-6.270	Seniang	5-year
19	9.549583	125.710194	6.08	0.57	-4.720	Seniang	5-year
20	9.549361	125.710194	6.95	1.36	-6.950	Seniang	5-year
21	9.549306	125.710111	6.97	0	-6.970	Seniang	5-year
22	9.54925	125.710139	6.45	0	-6.450	Seniang	5-year
23	9.592861	125.697861	1.39	0	-1.390	Seniang	5-year
24	9.573722	125.692639	0.88	0	-0.880	Seniang	5-year
25	9.574222	125.692278	0.68	0	-0.680	Seniang	5-year
26	9.573833	125.693556	1.04	0	-1.040	Seniang	5-year
27	9.572944	125.693861	0.7	0	-0.600	Seniang	5-year
28	9.572528	125.694222	0.62	0.1	-0.620	Seniang	5-year
29	9.571361	125.695444	1.08	0	-0.880	Seniang	5-year
30	9.571889	125.694889	0.84	0.2	-0.640	Seniang	5-year
31	9.57175	125.695139	1.28	0.2	-1.280	Seniang	5-year
32	9.570694	125.695889	1.16	0	-1.060	Seniang	5-year
33	9.571833	125.696278	0.91	0.1	-0.710	Seniang	5-year
34	9.571833	125.695833	1.16	0.2	-1.060	Seniang	5-year
35	9.573472	125.696583	1.53	0.1	-0.930	Seniang	5-year
36	9.573972	125.695972	1.22	0.6	-0.820	Seniang	5-year
37	9.570556	125.696083	1.18	0.4	-1.080	Seniang	5-year
38	9.569861	125.697722	0.71	0.1	-0.680	Seniang	5-year
39	9.5705	125.700667	0.51	0.03	0.090	Seniang	5-year
40	9.568944	125.698806	1.08	0.6	-0.780	Seniang	5-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	9.569306	125.699111	1.16	0.3	-0.560	Seniang	5-year
42	9.569278	125.7	1.56	0.6	-1.160	Seniang	5-year
43	9.56825	125.699917	1.17	0.4	-0.890	Seniang	5-year
44	9.567694	125.699778	0.74	0.28	-0.740	Seniang	5-year
45	9.568639	125.699083	0.95	0	-0.900	Seniang	5-year
46	9.568278	125.699528	0.78	0.05	-0.780	Seniang	5-year
47	9.567556	125.699	1.55	0	-1.350	Seniang	5-year
48	9.567472	125.698056	0.99	0.2	-0.730	Seniang	5-year
49	9.567639	125.697778	1.14	0.26	-0.670	Seniang	5-year
50	9.563222	125.695972	1.35	0.47	-1.050	Seniang	5-year
51	9.571611	125.707083	1.1	0.3	-1.050	Seniang	5-year
52	9.572944	125.707222	0.99	0.05	-0.490	Seniang	5-year
53	9.573889	125.706	1.36	0.5	-1.360	Seniang	5-year
54	9.570389	125.697944	0.9	0	0.000	Seniang	5-year
55	9.594858	125.699133	0.58	0.9	0.350	Seniang	5-year
56	9.595378	125.698958	0.8	0.93	-0.300	Seniang	5-year
57	9.595222	125.698839	0.64	0.5	-0.580	Seniang	5-year
58	9.592789	125.699297	1.23	0.06	-1.230	Seniang	5-year
59	9.595939	125.698531	0.29	0	-0.290	Seniang	5-year
60	9.565722	125.723111	1.51	0.5	-0.550	Seniang	25-year
61	9.565806	125.722694	2.35	0	-0.670	Seniang	25-year
62	9.565583	125.72275	2.42	0.68	-1.060	Seniang	25-year
63	9.562472	125.718528	0	0.36	0.000	Seniang	25-year
64	9.5555	125.707806	4.85	0	-3.070	Seniang	25-year
65	9.553611	125.7085	6.88	0	-4.540	Seniang	25-year
66	9.553333	125.708639	3.62	0.24	-1.400	Seniang	25-year
67	9.54875	125.710222	12.22	0	-6.510	Seniang	25-year
68	9.548694	125.710056	3.56	0	0.000	Seniang	25-year
69	9.5485	125.710111	12.81	0	-6.970	Seniang	25-year
70	9.548667	125.710194	12.22	0	-5.310	Seniang	25-year
71	9.548083	125.710056	9.82	1.2	-3.550	Seniang	25-year
72	9.549	125.710167	12.23	0	-6.740	Seniang	25-year
73	9.549083	125.710222	11.98	0.1	-6.300	Seniang	25-year
74	9.549222	125.710139	11.57	0.31	-6.450	Seniang	25-year
75	9.548917	125.710111	11.84	0	-6.460	Seniang	25-year
76	9.548917	125.710139	11.84	0	-5.490	Seniang	25-year
77	9.549472	125.710167	11.8	0.97	-6.270	Seniang	25-year
78	9.549583	125.710194	10.81	0.57	-4.720	Seniang	25-year
79	9.549361	125.710194	12.05	1.36	-6.950	Seniang	25-year
80	9.549306	125.710111	11.97	0	-6.970	Seniang	25-year
81	9.54925	125.710139	11.57	0	-6.450	Seniang	25-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	9.592861	125.697861	1.88	0	-1.390	Seniang	25-year
83	9.573722	125.692639	1.86	0	-0.880	Seniang	25-year
84	9.574222	125.692278	1.63	0	-0.680	Seniang	25-year
85	9.573833	125.693556	2.03	0	-1.040	Seniang	25-year
86	9.572944	125.693861	1.71	0	-0.600	Seniang	25-year
87	9.572528	125.694222	1.58	0.1	-0.620	Seniang	25-year
88	9.571361	125.695444	1.81	0	-0.880	Seniang	25-year
89	9.571889	125.694889	1.67	0.2	-0.640	Seniang	25-year
90	9.57175	125.695139	2.11	0.2	-1.280	Seniang	25-year
91	9.570694	125.695889	1.78	0	-1.060	Seniang	25-year
92	9.571833	125.696278	1.77	0.1	-0.710	Seniang	25-year
93	9.571833	125.695833	2.02	0.2	-1.060	Seniang	25-year
94	9.573472	125.696583	2.52	0.1	-0.930	Seniang	25-year
95	9.573972	125.695972	2.21	0.6	-0.820	Seniang	25-year
96	9.570556	125.696083	1.78	0.4	-1.080	Seniang	25-year
97	9.569861	125.697722	1.28	0.1	-0.680	Seniang	25-year
98	9.5705	125.700667	1.25	0.03	0.090	Seniang	25-year
99	9.568944	125.698806	1.61	0.6	-0.780	Seniang	25-year
100	9.569306	125.699111	1.7	0.3	-0.560	Seniang	25-year
101	9.569278	125.7	2.13	0.6	-1.160	Seniang	25-year
102	9.56825	125.699917	1.78	0.4	-0.890	Seniang	25-year
103	9.567694	125.699778	1.3	0.28	-0.740	Seniang	25-year
104	9.568639	125.699083	1.49	0	-0.900	Seniang	25-year
105	9.568278	125.699528	1.36	0.05	-0.780	Seniang	25-year
106	9.567556	125.699	2.08	0	-1.350	Seniang	25-year
107	9.567472	125.698056	1.54	0.2	-0.730	Seniang	25-year
108	9.567639	125.697778	1.68	0.26	-0.670	Seniang	25-year
109	9.563222	125.695972	1.97	0.47	-1.050	Seniang	25-year
110	9.571611	125.707083	1.98	0.3	-1.050	Seniang	25-year
111	9.572944	125.707222	1.94	0.05	-0.490	Seniang	25-year
112	9.573889	125.706	2.28	0.5	-1.360	Seniang	25-year
113	9.570389	125.697944	1.56	0	0.000	Seniang	25-year
114	9.594858	125.699133	0.95	0.9	0.350	Seniang	25-year
115	9.595378	125.698958	1.1	0.93	-0.300	Seniang	25-year
116	9.595222	125.698839	0.95	0.5	-0.580	Seniang	25-year
117	9.592789	125.699297	1.71	0.06	-1.230	Seniang	25-year
118	9.595939	125.698531	0.54	0	-0.290	Seniang	25-year
119	9.565722	125.723111	2.12	0.5	-0.550	Seniang	100-year
120	9.565806	125.722694	2.98	0	-0.670	Seniang	100-year
121	9.565583	125.72275	3.05	0.68	-1.060	Seniang	100-year
122	9.562472	125.718528	0.54	0.36	0.000	Seniang	100-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
123	9.5555	125.707806	5.94	0	-3.070	Seniang	100-year
124	9.553611	125.7085	8.1	0	-4.540	Seniang	100-year
125	9.553333	125.708639	4.88	0.24	-1.400	Seniang	100-year
126	9.54875	125.710222	16.65	0	-6.510	Seniang	100-year
127	9.548694	125.710056	7.93	0	0.000	Seniang	100-year
128	9.5485	125.710111	17.45	0	-6.970	Seniang	100-year
129	9.548667	125.710194	16.65	0	-5.310	Seniang	100-year
130	9.548083	125.710056	15.04	1.2	-3.550	Seniang	100-year
131	9.549	125.710167	16.62	0	-6.740	Seniang	100-year
132	9.549083	125.710222	16.04	0.1	-6.300	Seniang	100-year
133	9.549222	125.710139	15.31	0.31	-6.450	Seniang	100-year
134	9.548917	125.710111	16.08	0	-6.460	Seniang	100-year
135	9.548917	125.710139	16.08	0	-5.490	Seniang	100-year
136	9.549472	125.710167	15.32	0.97	-6.270	Seniang	100-year
137	9.549583	125.710194	14.29	0.57	-4.720	Seniang	100-year
138	9.549361	125.710194	15.64	1.36	-6.950	Seniang	100-year
139	9.549306	125.710111	15.59	0	-6.970	Seniang	100-year
140	9.54925	125.710139	15.31	0	-6.450	Seniang	100-year
141	9.592861	125.697861	2.25	0	-1.390	Seniang	100-year
142	9.573722	125.692639	2.54	0	-0.880	Seniang	100-year
143	9.574222	125.692278	2.3	0	-0.680	Seniang	100-year
144	9.573833	125.693556	2.7	0	-1.040	Seniang	100-year
145	9.572944	125.693861	2.39	0	-0.600	Seniang	100-year
146	9.572528	125.694222	2.28	0.1	-0.620	Seniang	100-year
147	9.571361	125.695444	2.49	0	-0.880	Seniang	100-year
148	9.571889	125.694889	2.36	0.2	-0.640	Seniang	100-year
149	9.57175	125.695139	2.81	0.2	-1.280	Seniang	100-year
150	9.570694	125.695889	2.43	0	-1.060	Seniang	100-year
151	9.571833	125.696278	2.47	0.1	-0.710	Seniang	100-year
152	9.571833	125.695833	2.73	0.2	-1.060	Seniang	100-year
153	9.573472	125.696583	3.2	0.1	-0.930	Seniang	100-year
154	9.573972	125.695972	2.88	0.6	-0.820	Seniang	100-year
155	9.570556	125.696083	2.43	0.4	-1.080	Seniang	100-year
156	9.569861	125.697722	1.91	0.1	-0.680	Seniang	100-year
157	9.5705	125.700667	1.91	0.03	0.090	Seniang	100-year
158	9.568944	125.698806	2.22	0.6	-0.780	Seniang	100-year
159	9.569306	125.699111	2.31	0.3	-0.560	Seniang	100-year
160	9.569278	125.7	2.74	0.6	-1.160	Seniang	100-year
161	9.56825	125.699917	2.41	0.4	-0.890	Seniang	100-year
162	9.567694	125.699778	1.91	0.28	-0.740	Seniang	100-year
163	9.568639	125.699083	2.1	0	-0.900	Seniang	100-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
164	9.568278	125.699528	1.98	0.05	-0.780	Seniang	100-year
165	9.567556	125.699	2.68	0	-1.350	Seniang	100-year
166	9.567472	125.698056	2.15	0.2	-0.730	Seniang	100-year
167	9.567639	125.697778	2.29	0.26	-0.670	Seniang	100-year
168	9.563222	125.695972	2.63	0.47	-1.050	Seniang	100-year
169	9.571611	125.707083	2.62	0.3	-1.050	Seniang	100-year
170	9.572944	125.707222	2.57	0.05	-0.490	Seniang	100-year
171	9.573889	125.706	2.9	0.5	-1.360	Seniang	100-year
172	9.570389	125.697944	2.22	0	0.000	Seniang	100-year
173	9.594858	125.699133	1.23	0.9	0.350	Seniang	100-year
174	9.595378	125.698958	1.31	0.93	-0.300	Seniang	100-year
175	9.595222	125.698839	1.16	0.5	-0.580	Seniang	100-year
176	9.592789	125.699297	2.08	0.06	-1.230	Seniang	100-year
177	9.595939	125.698531	0.71	0	-0.290	Seniang	100-year
178	9.565722	125.723111	0.55	0.96	0.41	Agaton	5-year
179	9.565806	125.722694	1.35	0	-1.35	Agaton	5-year
180	9.565583	125.72275	1.42	0.63	-0.79	Agaton	5-year
181	9.562472	125.718528	0	0.36	0.36	Agaton	5-year
182	9.5555	125.707806	3.07	0	-3.07	Agaton	5-year
183	9.553611	125.7085	4.78	0.31	-4.47	Agaton	5-year
184	9.553333	125.708639	1.4	0.29	-1.11	Agaton	5-year
185	9.54875	125.710222	6.51	0	-6.51	Agaton	5-year
186	9.548694	125.710056	0	0	0	Agaton	5-year
187	9.5485	125.710111	6.97	0.93	-6.04	Agaton	5-year
188	9.548667	125.710194	6.51	1.13	-5.38	Agaton	5-year
189	9.548083	125.710056	3.55	1.78	-1.77	Agaton	5-year
190	9.549	125.710167	6.84	0	-6.84	Agaton	5-year
191	9.549083	125.710222	6.61	0	-6.61	Agaton	5-year
192	9.549222	125.710139	6.45	0.5	-5.95	Agaton	5-year
193	9.548917	125.710111	6.46	0	-6.46	Agaton	5-year
194	9.548917	125.710139	6.46	0	-6.46	Agaton	5-year
195	9.549472	125.710167	6.84	0.51	-6.33	Agaton	5-year
196	9.549583	125.710194	6.08	0.31	-5.77	Agaton	5-year
197	9.549361	125.710194	6.95	0	-6.95	Agaton	5-year
198	9.549306	125.710111	6.97	0.2	-6.77	Agaton	5-year
199	9.54925	125.710139	6.45	0.2	-6.25	Agaton	5-year
200	9.592861	125.697861	1.39	0	-1.39	Agaton	5-year
201	9.573722	125.692639	0.88	0.25	-0.63	Agaton	5-year
202	9.574222	125.692278	0.68	0.2	-0.48	Agaton	5-year
203	9.573833	125.693556	1.04	0.1	-0.94	Agaton	5-year
204	9.572944	125.693861	0.7	0.1	-0.6	Agaton	5-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
205	9.572528	125.694222	0.62	0.16	-0.46	Agaton	5-year
206	9.571361	125.695444	1.08	0	-1.08	Agaton	5-year
207	9.571889	125.694889	0.84	0.4	-0.44	Agaton	5-year
208	9.57175	125.695139	1.28	0.4	-0.88	Agaton	5-year
209	9.570694	125.695889	1.16	0.6	-0.56	Agaton	5-year
210	9.571833	125.696278	0.91	0.23	-0.68	Agaton	5-year
211	9.571833	125.695833	1.16	0.4	-0.76	Agaton	5-year
212	9.573472	125.696583	1.53	0.2	-1.33	Agaton	5-year
213	9.573972	125.695972	1.22	0.6	-0.62	Agaton	5-year
214	9.570556	125.696083	1.18	0.4	-0.78	Agaton	5-year
215	9.569861	125.697722	0.71	0.2	-0.51	Agaton	5-year
216	9.5705	125.700667	0.51	0.03	-0.48	Agaton	5-year
217	9.568944	125.698806	1.08	0.6	-0.48	Agaton	5-year
218	9.569306	125.699111	1.16	0.3	-0.86	Agaton	5-year
219	9.569278	125.7	1.56	0.6	-0.96	Agaton	5-year
220	9.56825	125.699917	1.17	0.6	-0.57	Agaton	5-year
221	9.567694	125.699778	0.74	0.4	-0.34	Agaton	5-year
222	9.568639	125.699083	0.95	0.1	-0.85	Agaton	5-year
223	9.568278	125.699528	0.78	0.05	-0.73	Agaton	5-year
224	9.567556	125.699	1.55	0.5	-1.05	Agaton	5-year
225	9.567472	125.698056	0.99	0.27	-0.72	Agaton	5-year
226	9.567639	125.697778	1.14	0.38	-0.76	Agaton	5-year
227	9.563222	125.695972	1.35	0.6	-0.75	Agaton	5-year
228	9.571611	125.707083	1.1	0.69	-0.41	Agaton	5-year
229	9.572944	125.707222	0.99	0.05	-0.94	Agaton	5-year
230	9.573889	125.706	1.36	0.5	-0.86	Agaton	5-year
231	9.570389	125.697944	0.9	0	-0.9	Agaton	5-year
232	9.594858	125.699133	0.58	0.9	0.32	Agaton	5-year
233	9.595378	125.698958	0.8	0.93	0.13	Agaton	5-year
234	9.595222	125.698839	0.64	0.5	-0.14	Agaton	5-year
235	9.592789	125.699297	1.23	0.36	-0.87	Agaton	5-year
236	9.595939	125.698531	0.29	0.5	0.21	Agaton	5-year
237	9.565722	125.723111	1.51	0.96	-0.55	Agaton	25-year
238	9.565806	125.722694	2.35	0	-2.35	Agaton	25-year
239	9.565583	125.72275	2.42	0.63	-1.79	Agaton	25-year
240	9.562472	125.718528	0	0.36	0.36	Agaton	25-year
241	9.5555	125.707806	4.85	0	-4.85	Agaton	25-year
242	9.553611	125.7085	6.88	0.31	-6.57	Agaton	25-year
243	9.553333	125.708639	3.62	0.29	-3.33	Agaton	25-year
244	9.54875	125.710222	12.22	0	-12.22	Agaton	25-year
245	9.548694	125.710056	3.56	0	-3.56	Agaton	25-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
246	9.5485	125.710111	12.81	0.93	-11.88	Agaton	25-year
247	9.548667	125.710194	12.22	1.13	-11.09	Agaton	25-year
248	9.548083	125.710056	9.82	1.78	-8.04	Agaton	25-year
249	9.549	125.710167	12.23	0	-12.23	Agaton	25-year
250	9.549083	125.710222	11.98	0	-11.98	Agaton	25-year
251	9.549222	125.710139	11.57	0.5	-11.07	Agaton	25-year
252	9.548917	125.710111	11.84	0	-11.84	Agaton	25-year
253	9.548917	125.710139	11.84	0	-11.84	Agaton	25-year
254	9.549472	125.710167	11.8	0.51	-11.29	Agaton	25-year
255	9.549583	125.710194	10.81	0.31	-10.5	Agaton	25-year
256	9.549361	125.710194	12.05	0	-12.05	Agaton	25-year
257	9.549306	125.710111	11.97	0.2	-11.77	Agaton	25-year
258	9.54925	125.710139	11.57	0.2	-11.37	Agaton	25-year
259	9.592861	125.697861	1.88	0	-1.88	Agaton	25-year
260	9.573722	125.692639	1.86	0.25	-1.61	Agaton	25-year
261	9.574222	125.692278	1.63	0.2	-1.43	Agaton	25-year
262	9.573833	125.693556	2.03	0.1	-1.93	Agaton	25-year
263	9.572944	125.693861	1.71	0.1	-1.61	Agaton	25-year
264	9.572528	125.694222	1.58	0.16	-1.42	Agaton	25-year
265	9.571361	125.695444	1.81	0	-1.81	Agaton	25-year
266	9.571889	125.694889	1.67	0.4	-1.27	Agaton	25-year
267	9.57175	125.695139	2.11	0.4	-1.71	Agaton	25-year
268	9.570694	125.695889	1.78	0.6	-1.18	Agaton	25-year
269	9.571833	125.696278	1.77	0.23	-1.54	Agaton	25-year
270	9.571833	125.695833	2.02	0.4	-1.62	Agaton	25-year
271	9.573472	125.696583	2.52	0.2	-2.32	Agaton	25-year
272	9.573972	125.695972	2.21	0.6	-1.61	Agaton	25-year
273	9.570556	125.696083	1.78	0.4	-1.38	Agaton	25-year
274	9.569861	125.697722	1.28	0.2	-1.08	Agaton	25-year
275	9.5705	125.700667	1.25	0.03	-1.22	Agaton	25-year
276	9.568944	125.698806	1.61	0.6	-1.01	Agaton	25-year
277	9.569306	125.699111	1.7	0.3	-1.4	Agaton	25-year
278	9.569278	125.7	2.13	0.6	-1.53	Agaton	25-year
279	9.56825	125.699917	1.78	0.6	-1.18	Agaton	25-year
280	9.567694	125.699778	1.3	0.4	-0.9	Agaton	25-year
281	9.568639	125.699083	1.49	0.1	-1.39	Agaton	25-year
282	9.568278	125.699528	1.36	0.05	-1.31	Agaton	25-year
283	9.567556	125.699	2.08	0.5	-1.58	Agaton	25-year
284	9.567472	125.698056	1.54	0.27	-1.27	Agaton	25-year
285	9.567639	125.697778	1.68	0.38	-1.3	Agaton	25-year
286	9.563222	125.695972	1.97	0.6	-1.37	Agaton	25-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
287	9.571611	125.707083	1.98	0.69	-1.29	Agaton	25-year
288	9.572944	125.707222	1.94	0.05	-1.89	Agaton	25-year
289	9.573889	125.706	2.28	0.5	-1.78	Agaton	25-year
290	9.570389	125.697944	1.56	0	-1.56	Agaton	25-year
291	9.594858	125.699133	0.95	0.9	-0.05	Agaton	25-year
292	9.595378	125.698958	1.1	0.93	-0.17	Agaton	25-year
293	9.595222	125.698839	0.95	0.5	-0.45	Agaton	25-year
294	9.592789	125.699297	1.71	0.36	-1.35	Agaton	25-year
295	9.595939	125.698531	0.54	0.5	-0.04	Agaton	25-year
296	9.565722	125.723111	2.12	0.96	-1.16	Agaton	100-year
297	9.565806	125.722694	2.98	0	-2.98	Agaton	100-year
298	9.565583	125.72275	3.05	0.63	-2.42	Agaton	100-year
299	9.562472	125.718528	0.54	0.36	-0.18	Agaton	100-year
300	9.5555	125.707806	5.94	0	-5.94	Agaton	100-year
301	9.553611	125.7085	8.1	0.31	-7.79	Agaton	100-year
302	9.553333	125.708639	4.88	0.29	-4.59	Agaton	100-year
303	9.54875	125.710222	16.65	0	-16.65	Agaton	100-year
304	9.548694	125.710056	7.93	0	-7.93	Agaton	100-year
305	9.5485	125.710111	17.45	0.93	-16.52	Agaton	100-year
306	9.548667	125.710194	16.65	1.13	-15.52	Agaton	100-year
307	9.548083	125.710056	15.04	1.78	-13.26	Agaton	100-year
308	9.549	125.710167	16.62	0	-16.62	Agaton	100-year
309	9.549083	125.710222	16.04	0	-16.04	Agaton	100-year
310	9.549222	125.710139	15.31	0.5	-14.81	Agaton	100-year
311	9.548917	125.710111	16.08	0	-16.08	Agaton	100-year
312	9.548917	125.710139	16.08	0	-16.08	Agaton	100-year
313	9.549472	125.710167	15.32	0.51	-14.81	Agaton	100-year
314	9.549583	125.710194	14.29	0.31	-13.98	Agaton	100-year
315	9.549361	125.710194	15.64	0	-15.64	Agaton	100-year
316	9.549306	125.710111	15.59	0.2	-15.39	Agaton	100-year
317	9.54925	125.710139	15.31	0.2	-15.11	Agaton	100-year
318	9.592861	125.697861	2.25	0	-2.25	Agaton	100-year
319	9.573722	125.692639	2.54	0.25	-2.29	Agaton	100-year
320	9.574222	125.692278	2.3	0.2	-2.1	Agaton	100-year
321	9.573833	125.693556	2.7	0.1	-2.6	Agaton	100-year
322	9.572944	125.693861	2.39	0.1	-2.29	Agaton	100-year
323	9.572528	125.694222	2.28	0.16	-2.12	Agaton	100-year
324	9.571361	125.695444	2.49	0	-2.49	Agaton	100-year
325	9.571889	125.694889	2.36	0.4	-1.96	Agaton	100-year
326	9.57175	125.695139	2.81	0.4	-2.41	Agaton	100-year
327	9.570694	125.695889	2.43	0.6	-1.83	Agaton	100-year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
328	9.571833	125.696278	2.47	0.23	-2.24	Agaton	100-year
329	9.571833	125.695833	2.73	0.4	-2.33	Agaton	100-year
330	9.573472	125.696583	3.2	0.2	-3	Agaton	100-year
331	9.573972	125.695972	2.88	0.6	-2.28	Agaton	100-year
332	9.570556	125.696083	2.43	0.4	-2.03	Agaton	100-year
333	9.569861	125.697722	1.91	0.2	-1.71	Agaton	100-year
334	9.5705	125.700667	1.91	0.03	-1.88	Agaton	100-year
335	9.568944	125.698806	2.22	0.6	-1.62	Agaton	100-year
336	9.569306	125.699111	2.31	0.3	-2.01	Agaton	100-year
337	9.569278	125.7	2.74	0.6	-2.14	Agaton	100-year
338	9.56825	125.699917	2.41	0.6	-1.81	Agaton	100-year
339	9.567694	125.699778	1.91	0.4	-1.51	Agaton	100-year
340	9.568639	125.699083	2.1	0.1	-2	Agaton	100-year
341	9.568278	125.699528	1.98	0.05	-1.93	Agaton	100-year
342	9.567556	125.699	2.68	0.5	-2.18	Agaton	100-year
343	9.567472	125.698056	2.15	0.27	-1.88	Agaton	100-year
344	9.567639	125.697778	2.29	0.38	-1.91	Agaton	100-year
345	9.563222	125.695972	2.63	0.6	-2.03	Agaton	100-year
346	9.571611	125.707083	2.62	0.69	-1.93	Agaton	100-year
347	9.572944	125.707222	2.57	0.05	-2.52	Agaton	100-year
348	9.573889	125.706	2.9	0.5	-2.4	Agaton	100-year
349	9.570389	125.697944	2.22	0	-2.22	Agaton	100-year
350	9.594858	125.699133	1.23	0.9	-0.33	Agaton	100-year
351	9.595378	125.698958	1.31	0.93	-0.38	Agaton	100-year
352	9.595222	125.698839	1.16	0.5	-0.66	Agaton	100-year
353	9.592789	125.699297	2.08	0.36	-1.72	Agaton	100-year
354	9.595939	125.698531	0.71	0.5	-0.21	Agaton	100-year

Annex 12. Educational Institutions affected by flooding in Magallanes Floodplain

Table A-12.1. Educational Institutions in Claver, Surigao del Norte affected by flooding in Magallanes Floodplain

Surigao del Norte				
Claver				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sabang Elementary School	Daywan	0	0	0
Claver Central Elementary School	Ladgaron	0	1	2
Claver National High School	Ladgaron	2	2	2
Daywan Elementary School	Panatao	1	1	2
Ladragon Elementary School	Tayaga	1	2	2
LAPAKAN SCHOOL	Tolosa	None	None	None

Table A-12.2. Educational Institutions in Gigaquit, Surigao del Norte affected by flooding in Magallanes Floodplain

Surigao del Norte				
Gigaquit				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Villaflor Elementary School	Mahanub	1	2	2
Magallanes Elementary School	San Isidro	0	0	0
Villaflor Elementary School	San Isidro	2	2	2
Daywan Elementary School	Panatao	1	1	2
Ladragon Elementary School	Tayaga	1	2	2
LAPAKAN SCHOOL	Tolosa	None	None	None

Annex 13. Health Institutions affected by flooding in Magallanes Floodplain

There are no health institutions affected by flooding in Magallanes floodplain.