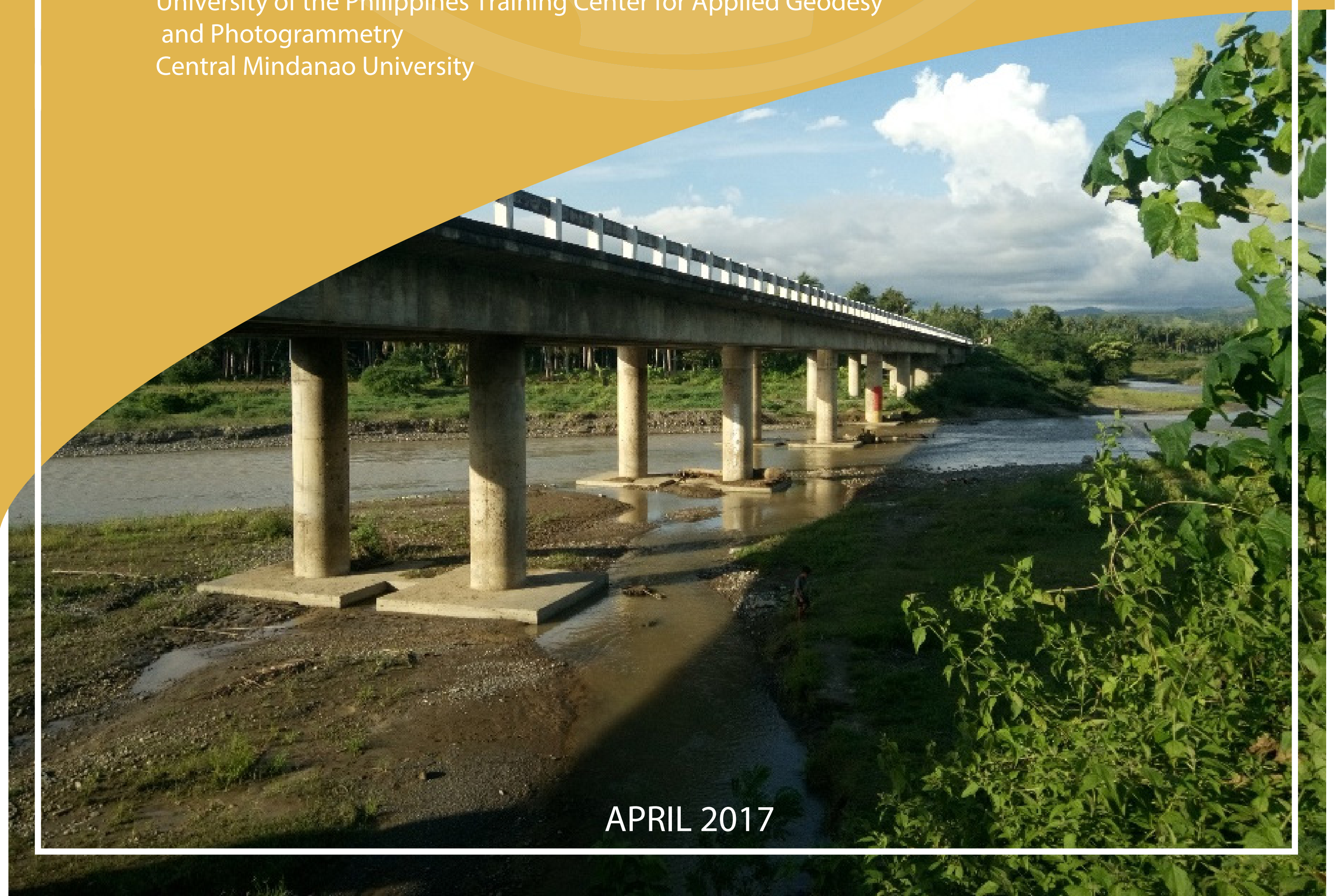
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Lun Masla River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
Central Mindanao 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, Philippines 1101

E.C. Paringit, and G.R. Puno, (Eds.). (2017), LiDAR Surveys and Flood Mapping of Lun Masla River. Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-167pp

For questions/queries regarding this report, contact:

Dr. George R. Puno
Project Leader, Phil-LIDAR 1 Program
Central Mindanao University
Maramag, Bukidnon 8714
geopuno@yahoo.com

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

National Library of the Philippines
ISBN: 978-621-430-014-3

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
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
CMU	Central Mindanao 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
MCM	
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
RCBO	River Basin Control Office
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
MSU-IIT	Mindanao State University - Iligan Institute of Technology
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 LUN MASLA RIVER

Enrico C. Paringit, Dr. Eng., Dr. George R. Puno, and Mr. Eric Bruno

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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, 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 implementing partner university for the Phil-LiDAR 1 Program is the Central Mindanao University (CMU). CMU 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 Central Mindanao Region. The university is located in Maramag in the province of Bukidnon.

1.2 Overview of the Lun Masla River Basin

The Lun Masla River Basin has a total area of 31,535 hectares and is located in the province of Sarangani and Davao Occidental. Four (4) municipalities lies within the basin namely Malapatan, Alabel, Glan in Sarangani and Don Marcilino in Davao Occidental. Specifically, 77% area of the river basin is within the Municipality of Malapatan, Sarangani. The DENR River Basin Control Office (RBCO) states that the Lun Masla River Basin has a drainage are of 234 km^2 and an estimated 468 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Lun Masla River or Big Lun River, is part of the twelve (12) river systems under the PHIL-LIDAR 1 Program partner State University and College (SUC), Central Mindanao University. Lun Masla river was among the assigned rivers to Central Mindanao University (CMU) generated with flood hazard maps using Light Detection and Ranging (LiDAR) technology under the Phil-LiDAR Program. The activity involved the development of Hydrologic Engineering Center's - Hydrologic Model System (HEC-HMS) and River Analysis System (HEC-RAS) models for precipitation-runoff and flood depth simulations, respectively.

The basin model generated for the Lun Masla River Basin used Synthetic Aperture Radar (SAR) 10m Digital Elevation Model (DEM) and digitized river centerline extracted from Google Earth, consisting of eighty seven (87) subbasins, forty-four (44) reaches and forty-five (45) junctions. The model was calibrated using the actual data during an event on October 9, 2016. Subsequent statistical tests employed revealed a good model performance. Using the calibrated model, hypothetical discharge scenarios were simulated using the Rainfall Intensity Duration Frequency (RIDF) data of Philippines Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) taken at a 31-year historical data of General Santos Airport rain gauge. Hydraulic simulations were conducted in HEC-RAS software using LiDAR Digital Terrain Model (DTM). Simulation results showing flood extent and depth information were used for the flood hazard map generation for the different flood scenarios in 5-, 25-, and 100-year return periods.

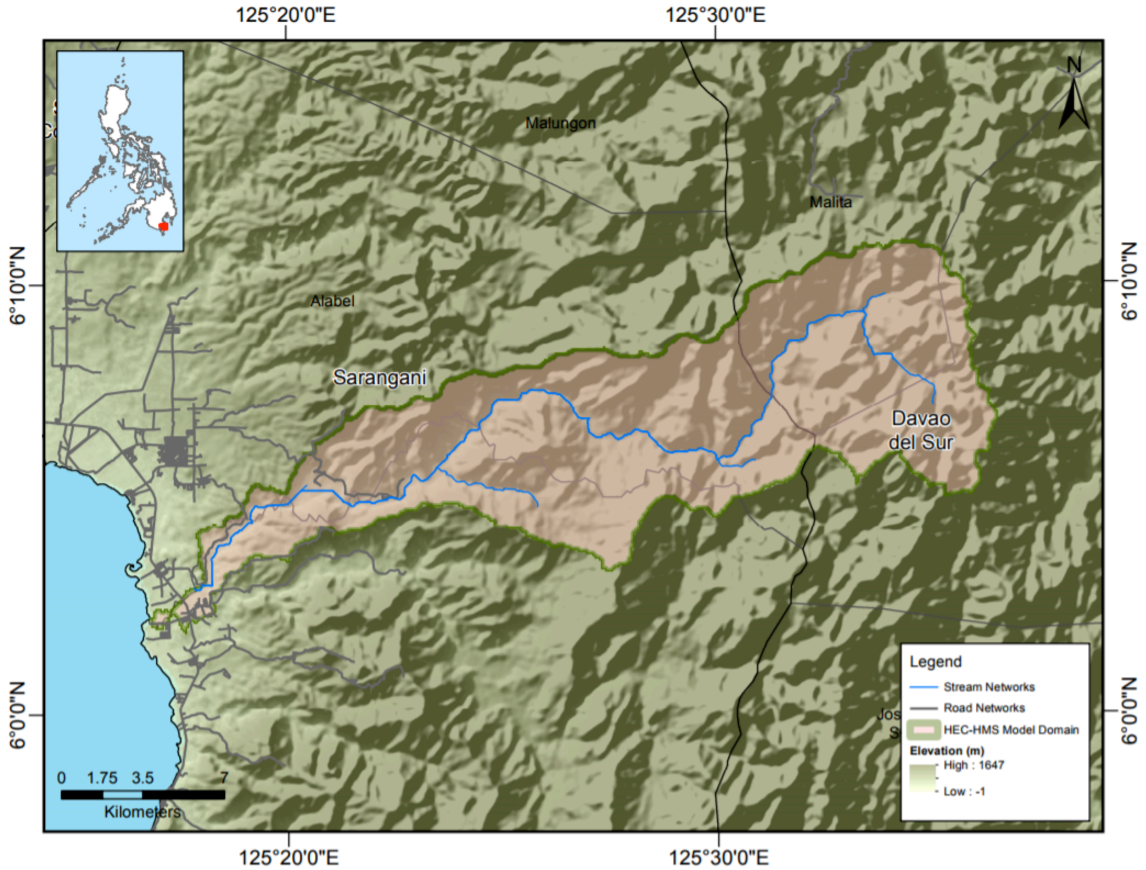


Figure 1. Map of Lun Masla River Basin

According to the 2015 national census of PSA, a total of 37,438 persons are residing within the immediate vicinity of the river, which is distributed among barangays Lun Masla, Lun Padidu, Daan Suyan, Patag, Upper Suyan, and Kinam in the Municipality of Malapatan.

Inhabitants in the river basin are a mixture of indigenous people called B'laan, Muslim Maguindanao and Christians mostly coming from the Visayas. While much of the Blaan are in the hinterlands, the migrant settlers on the other hand mostly occupies the rather urbane municipal and barangay centers in the lowland areas. Dominating crops were coconuts intercropped with corn, banana, fruit trees and other perennials planted on lowland plains and hill slopes. Specifically, coconut, corn, rice, banana, mango, durian, rubber, and sugarcane are the major crops of the province (Department of Health Regional Office XII, n.d.). Moreover, coasts in the basin are utilized for commercial fish production. In fact, the major industries in Sarangani are aquaculture, fisheries, agriculture plantations and tourism (Provincial Government of Sarangani, n.d.).

With regards to flooding, the earliest accounted flood incident was around 1970 during Typhoon Titang when Lun Masla river overflowed. Flooding has been a serious concern in the recent years, primarily in Barangay Patag and Lun Padidu. Specifically, recent flooding occurrences were on 2013 to 2016. Continuous heavy rainfall which started on February 12, 2016 affected 275 families in Alabel and 758 families in Malapatan and Glan in Sarangani Province as of February 24, 2012 according to a CDRC report (Citizens' Disaster Response Center, 2012).
News, 2016).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LUN MASLA FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Julie Pearl S. Mars, Jeriel Paul A. Alamban, Geol.

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 Lun Masla Floodplain in Sarangani. These missions were planned for 16 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Lun Masla Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK90A	600	30	36	70	50	120	5
BLK90B	600	30	36	70	50	120	5
BLK90C	600	30	36	70	50	120	5
BLK90D	600	30	36	70	50	120	5
BLK90E	600	30	36	70	50	120	5
BLK2D	600	30	36	70	50	120	5
BLK70C	850	30	50	200	30	130	5

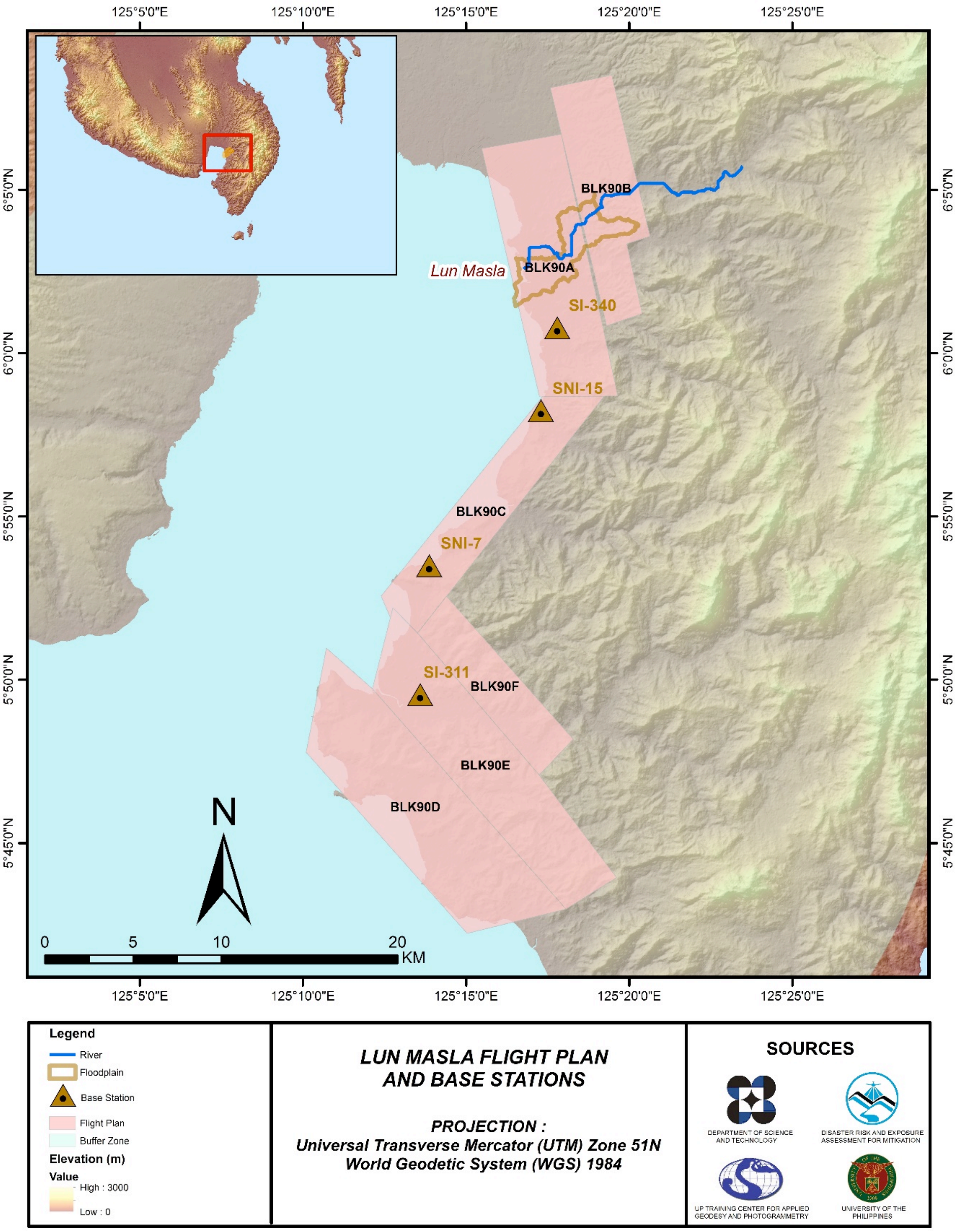


Figure 2. Flight plans and base stations used for Lun Masla Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: SNI-7 and SNI-15 which are of second (2nd) order accuracy. Two (2) NAMRIA benchmarks were also recovered: SI-311 and SI-340 which are of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control point is found in Annex 3. These were used as base stations during flight operations on October 23 - November 7, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Lun Masla floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 4 show the recovered NAMRIA control station within the area, in addition Table 2 to Table 5 show the details about the following NAMRIA control stations and established points, while Table 6 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

Figure 3. NAMRIA reference point SNI-7 as recovered by the field team within the premises of Lago Elementary School, Municipality of Glan, Sarangani.

Table 2. Details of the recovered NAMRIA horizontal control point SNI-7 used as base station for the LiDAR Acquisition.

Station Name	SNI-7	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 30’ 40.65974”North 122° 18’ 14.44217”East 6.715 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	533471.036 meters 941106.14 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	5° 55’ 21.90465’’ North 125° 16’ 28.13353’’ East 73.73600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	751,645.13 meters 655,226.36 meters

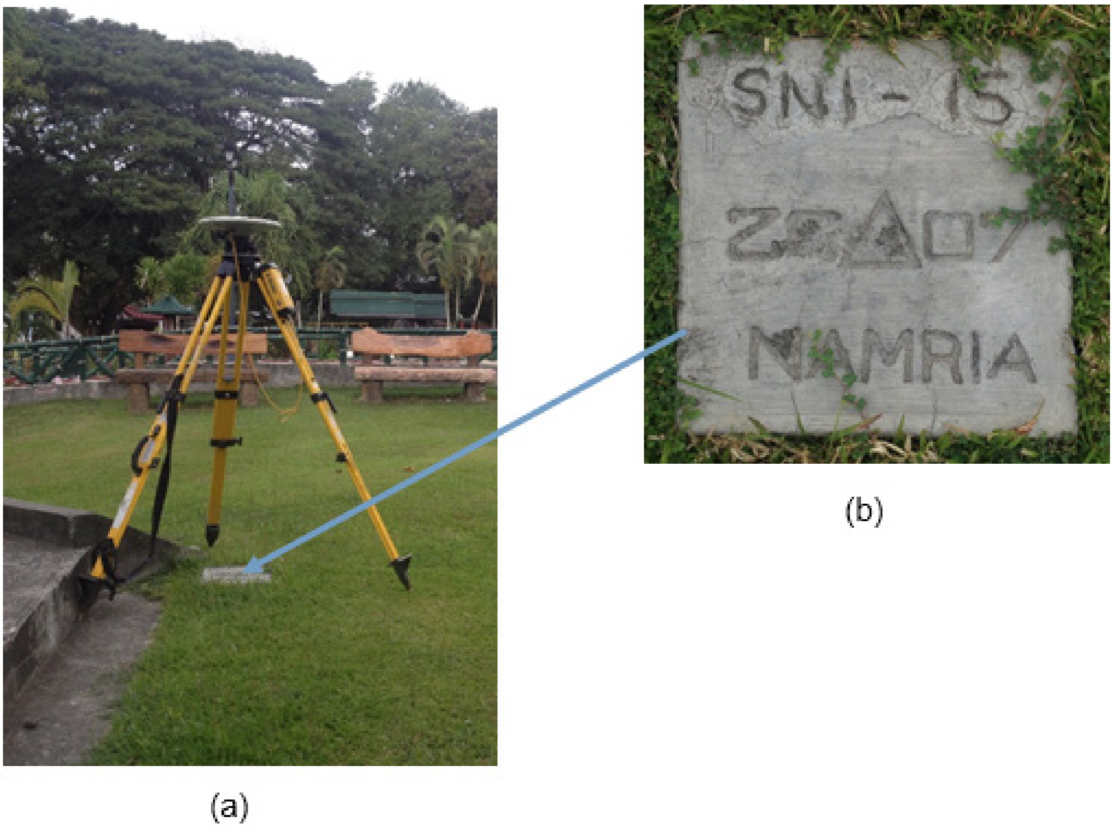


Figure 4. GPS set-up over SNI-15 outside the municipal hall of Malapatan, Sarangani (a) and NAMRIA reference point SNI-15 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA vertical control point SNI-15 used as base station for the LiDAR Acquisition with established coordinates.

Station Name	SNI-15	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	5° 58’ 16.93809’’ 125° 17’ 11.94043’’ 1.09600 m
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	531,736.654 meters 660,237.374 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	5° 58’ 14.08407’’ North 125° 17’ 17.56874’’ East 75.01600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	753,144.51 meters 660,523.74 meters

Table 4. Details of the recovered NAMRIA vertical control point SI-311 used as base station for the LiDAR Acquisition with established coordinates.

Station Name	SI-311	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	5° 49' 35.35336" 125° 13' 29.90925" 6.557 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	5° 49' 32.53295" North 125° 13' 35.55159" East 80.569 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	746,377.279 m 644,469.041 m

Table 5. Details of the recovered NAMRIA vertical control point SI-340 used as base station for the LiDAR Acquisition with established coordinates.

Station Name	SI-340	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,00110	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6° 00' 49.33497" 125° 17' 41.96935" 11.130 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 00' 46.47026" North 125° 17' 47.59361" East 84.998 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	754,048.831 m 665,210.517 m

Table 6. Ground Control Points used during LiDAR Data Acquisiton.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
October 26, 2014	2114A	3BLK90B299A	SNI-15 and SI-340
October 26, 2014	2116A	3BLK90A299B	SNI-15 and SI-340
October 27, 2014	2118A	3BLK90C300A	SNI-15 and SI-340
October 27, 2014	2120A	3BLK90D300B	SNI-7 and SI-311
October 28, 2014	2122A	3BLK90DSES301A	SNI-7 and SI-311
November 4, 2014	2150A	3BLK90S08A	SNI-15 and SI-340
November 7, 2014	2164A	3BLK90BATHY311B	SNI-15 and SI-340

2.3 Flight Missions

Three (3) missions were conducted to complete the LiDAR Data Acquisition in Lun Masla Floodplain, for a total of ten hours and forty-five minutes (10+45) of flying time for RP-C9122. The mission was acquired using the Aquarius LiDAR system. Majority of the floodplain was already surveyed during DREAM Program. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 shows the actual parameters used during the LiDAR data acquisition.

Table 7. Flight Missions for LiDAR Data Acquisition in Lun Masla 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 26, 2014	2114A	42.69	58.43	4.36	54.07	45	3	53
October 26, 2014	2116A	65.68	72.68	9.32	63.36	605	2	59
October 27, 2014	2118A	115.51	182.80	NA	182.80	NA	3	53
October 27, 2014	2120A	86.86	72.37	NA	72.37	NA	3	11
October 28, 2014	2122A	69.34	101.99	NA	101.99	NA	4	5
November 4, 2014	2150A	65.68	32.87	1.71	31.16	NA	3	29
November 7, 2014	2164A	65.68	26.66	3.07	23.59	NA	1	47
TOTAL		511.44	547.80	18.46	529.34	650	23	17

Table 8. Flight Missions for LiDAR Data Acquisition in Lun Masla Floodplain.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2114A	600	45	36	50	45	130	5
2116A	600	45	36	50	50	130	5
2118A	600	45	36	50	50	130	5
2120A	600	45	36	50	45	130	5
2122A	600	45	36	50	50	130	5
2150A	600	45	36	50	50	130	5
2164A	600	45	36	50	50	130	5

2.4. Survey Coverage

Lun Masla floodplain is located in the province of Sarangani with majority of the floodplain situated within the municipalities of Kiamba and Maitum. The list of cities and municipalities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Lun Masla floodplain is presented in Figure 5.

Table 9. Area of Coverage of the LiDAR Data Acquisition in Lun Masla Floodplain.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Sarangani	Glan	722.62	190.95	26%
	Malapatan	507.6	75.02	15%
	Alabel	479.67	64.39	13%
South Cotabato	Polomolok	287.02	8.06	3%
	General Santos City	474.73	10.33	2%
Total		2471.64	348.75	14.11%

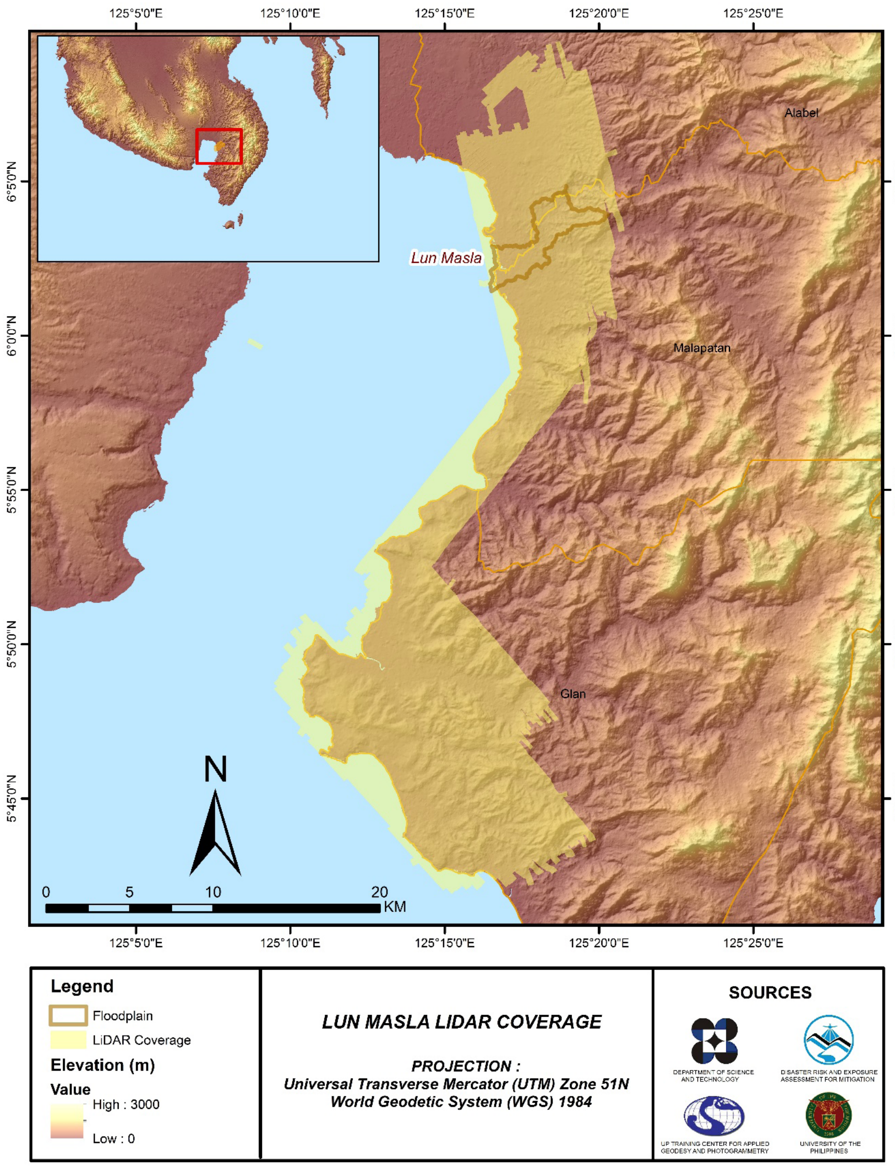


Figure 5. Actual LiDAR survey coverage for Lun Masla Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LUN MASLA FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Alex John B. Escobido , Engr. Ma Ailyn L. Olanda, Engr. Jovelle Anjeanette S. Canlas, Engr. Christy T. Lubiano , Engr. Jommer M. Medina, Esmael L. Guardian

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 6.

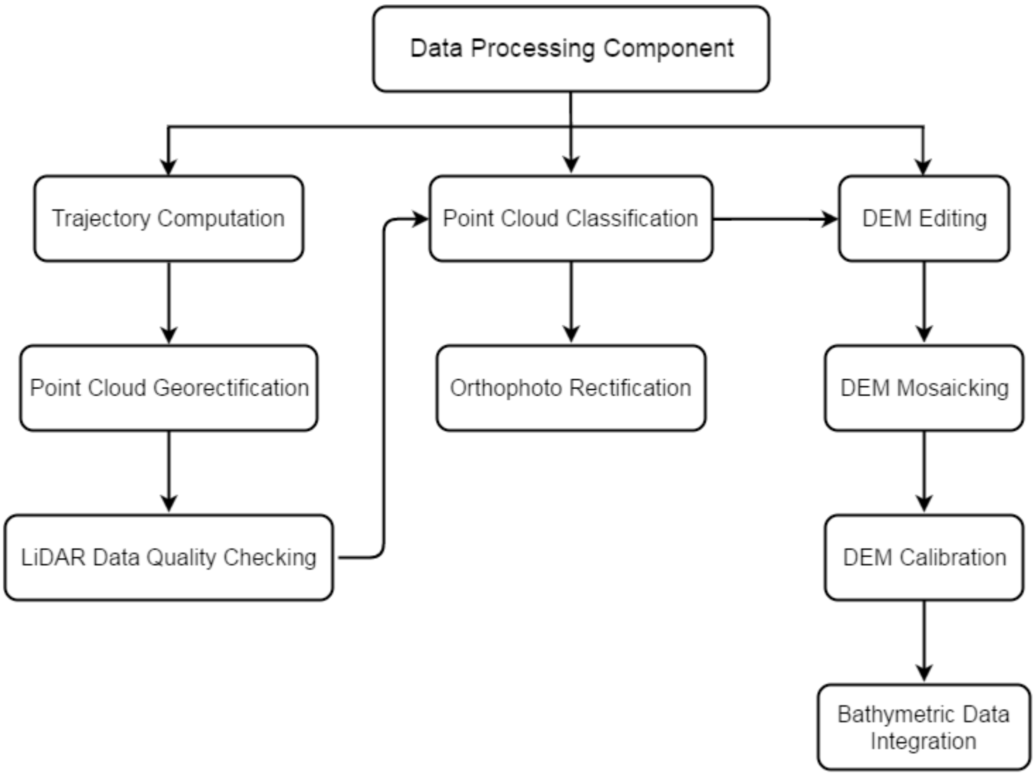


Figure 6. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Lun Masla floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the survey conducted on November 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Malapatan, Saranggani.

The Data Acquisition Component (DAC) transferred a total of 63.22 Gigabytes of Range data, 1.45 Gigabytes of POS data, and 85.21 Megabytes of GPS base station data to the data server on November 19, 2014 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Lun Masla was fully transferred on March 25, 2015, as indicated on the Data Transfer Sheets for Lun Masla floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2164A, one of the Lun Masla flights, which is the North, East, and Down position RMSE values are shown in Figure 7. 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 November 7, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

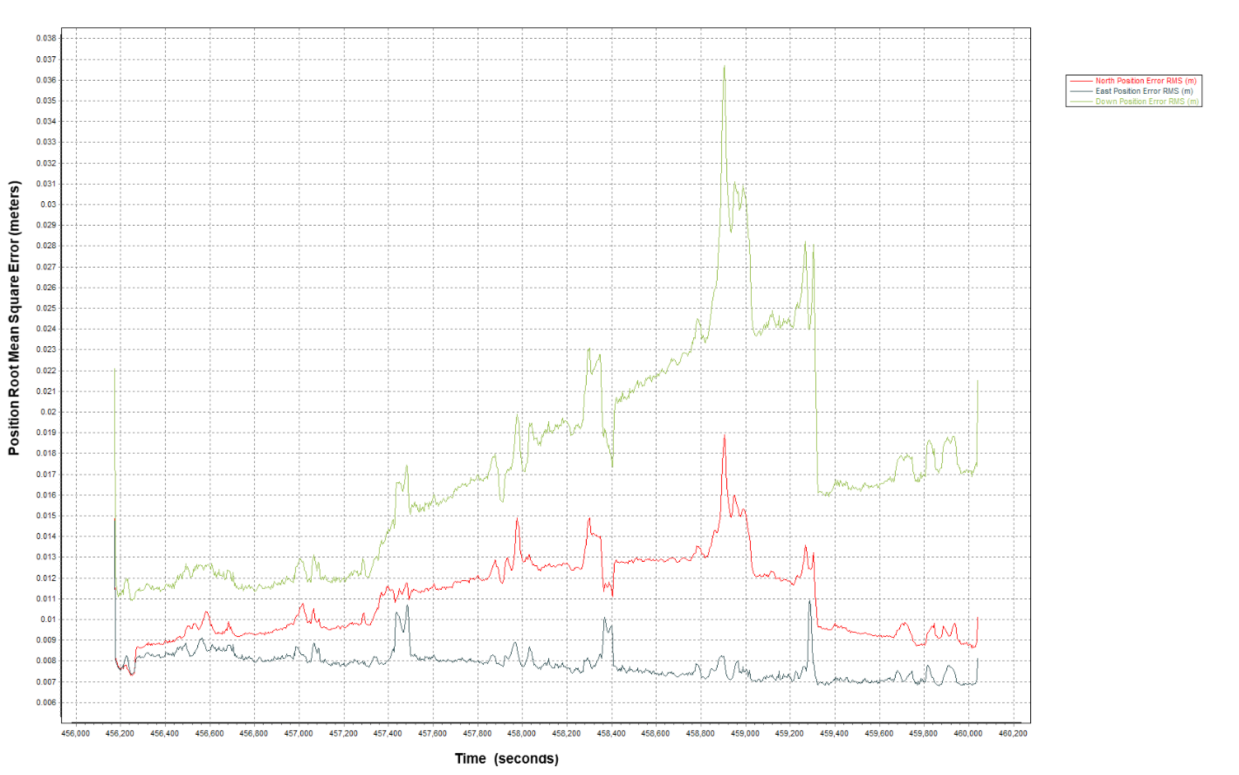


Figure 7. Smoothed Performance Metric Parameters of Lun Masla Flight 2164A.

The time of flight was from 456000 seconds to 460000 seconds, which corresponds to afternoon of November 7, 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 minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaks at 1.90 centimeters, the East position RMSE peaks at 1.10 centimeters, and the Down position RMSE peaks at 3.70 centimeters, which are within the prescribed accuracies described in the methodology.

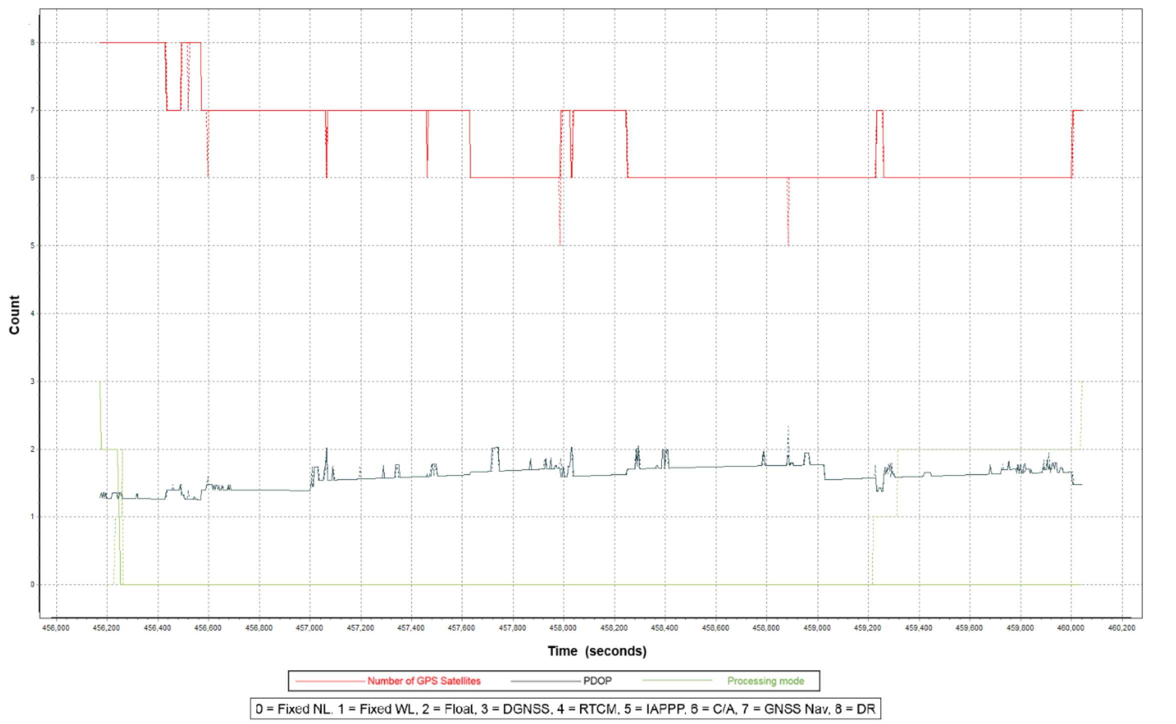


Figure 8. Solution Status Parameters of Lun Masla Flight 2164A.

The Solution Status parameters of flight 2164A, one of the Lun Masla flights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used are shown in Figure 8. The graphs indicate that majority of the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Lun Masla flights is shown in Figure 9.

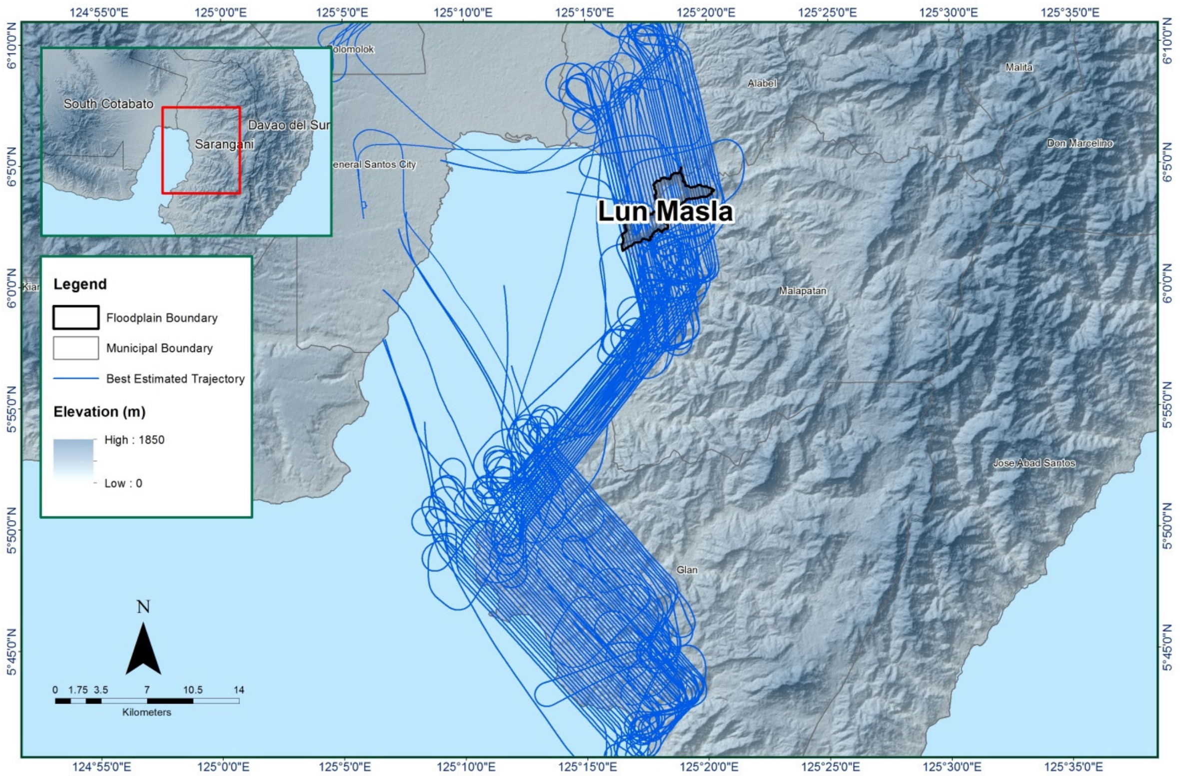


Figure 9. Best Estimated Trajectory for Lun Masla Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 175 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Lun Masla floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Lun Masla flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.00303
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000981
GPS Position Z-correction stdev (<0.01meters)	0.0075

The optimum accuracy is obtained for all Lun Masla 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 Lun Masla Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

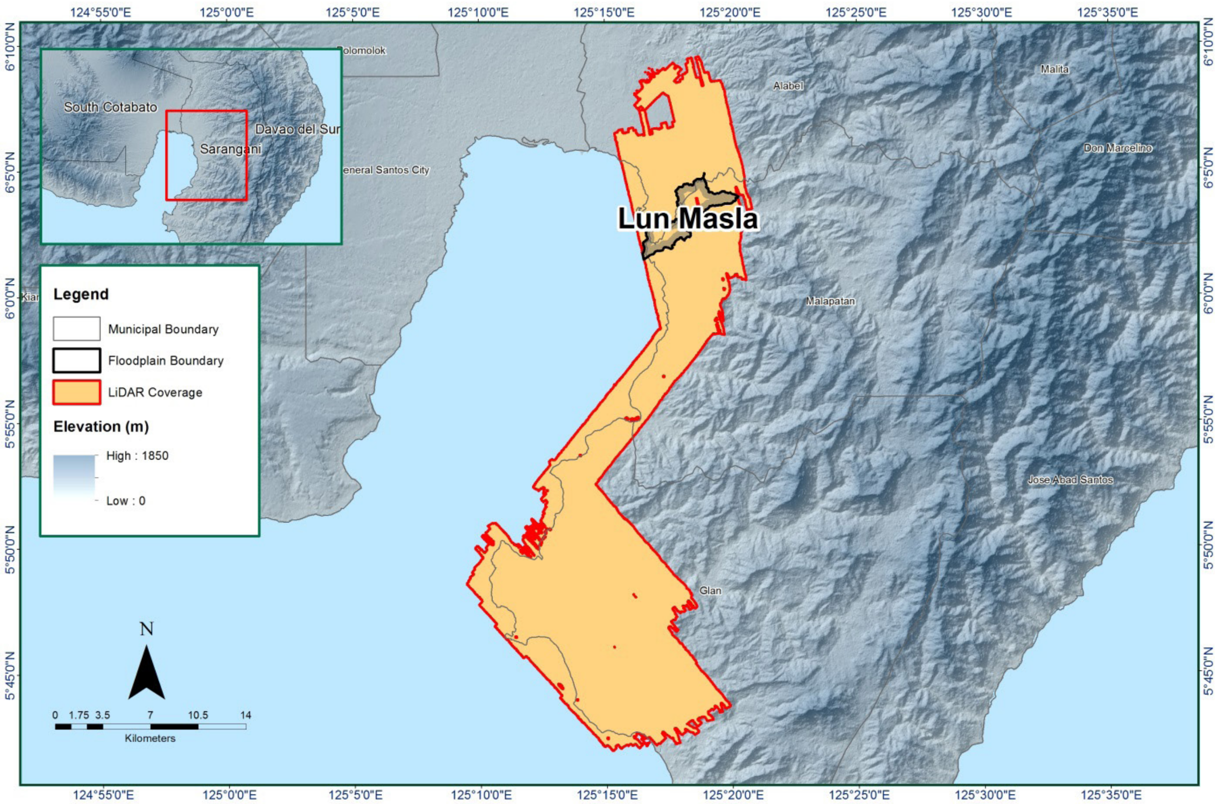


Figure 10. Boundary of the processed LiDAR data over Lun Masla Floodplain

The total area covered by the Lun Masla missions is 442.97 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Lun Masla Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
SouthCotabato_Sarangani_Blk90A	2116A	72.03
	2164A	
SouthCotabato_Sarangani_Blk90B	2114A	56.32
SouthCotabato_Sarangani_Blk90C	2118A	87.24
	2152A	
SouthCotabato_Sarangani_Blk90F	2126A	38.93
GeneralSantos_Blk90D	2122A	90.83
	2120A	
GeneralSantos_Blk90E	2122A	70.28
Buayan_Blk 2C_Additional	2150A	13.76
Buayan_Blk 2D_Additional	2150A	13.58
TOTAL		442.97 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 11. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

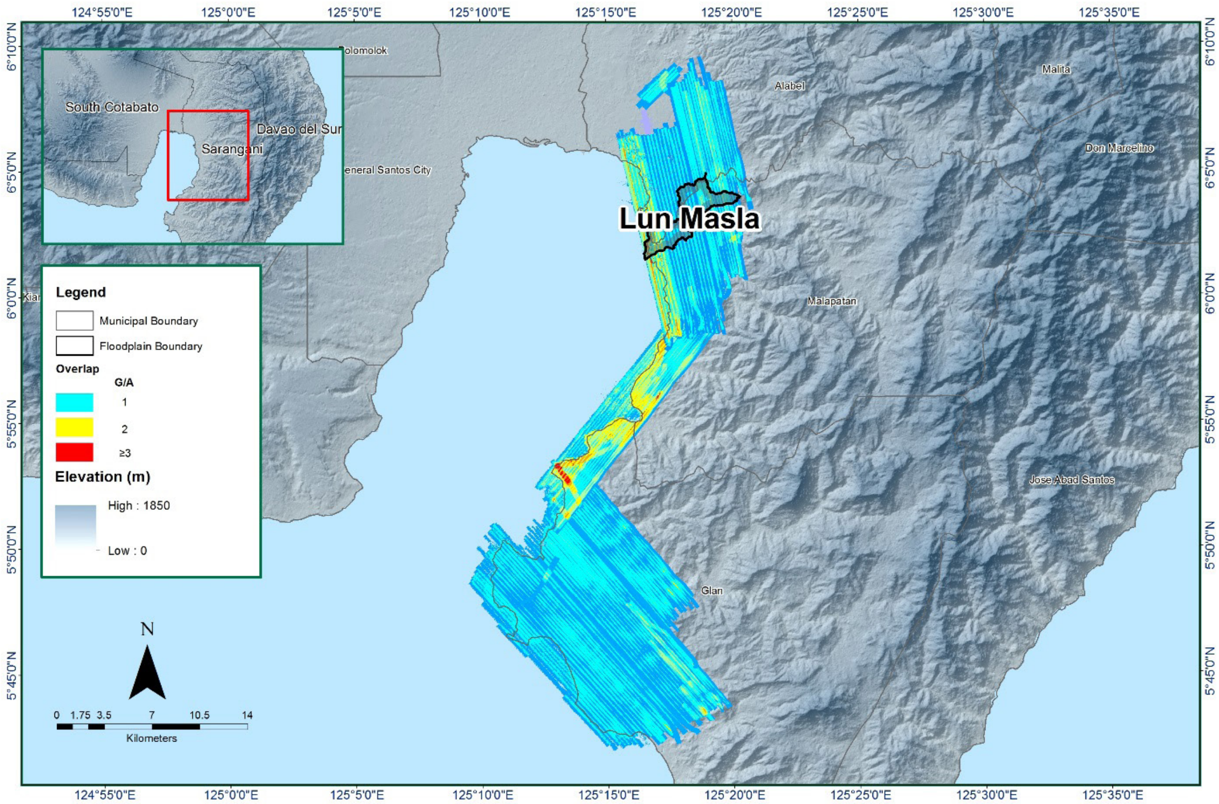


Figure 11. Image of data overlap for Lun Masla Floodplain.n

The overlap statistics per block for the Lun Masla floodplain can be found in Annex B-1. 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 45.19% and 61.64% 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 12. It was determined that all LiDAR data for Lun Masla floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.58 points per square meter.

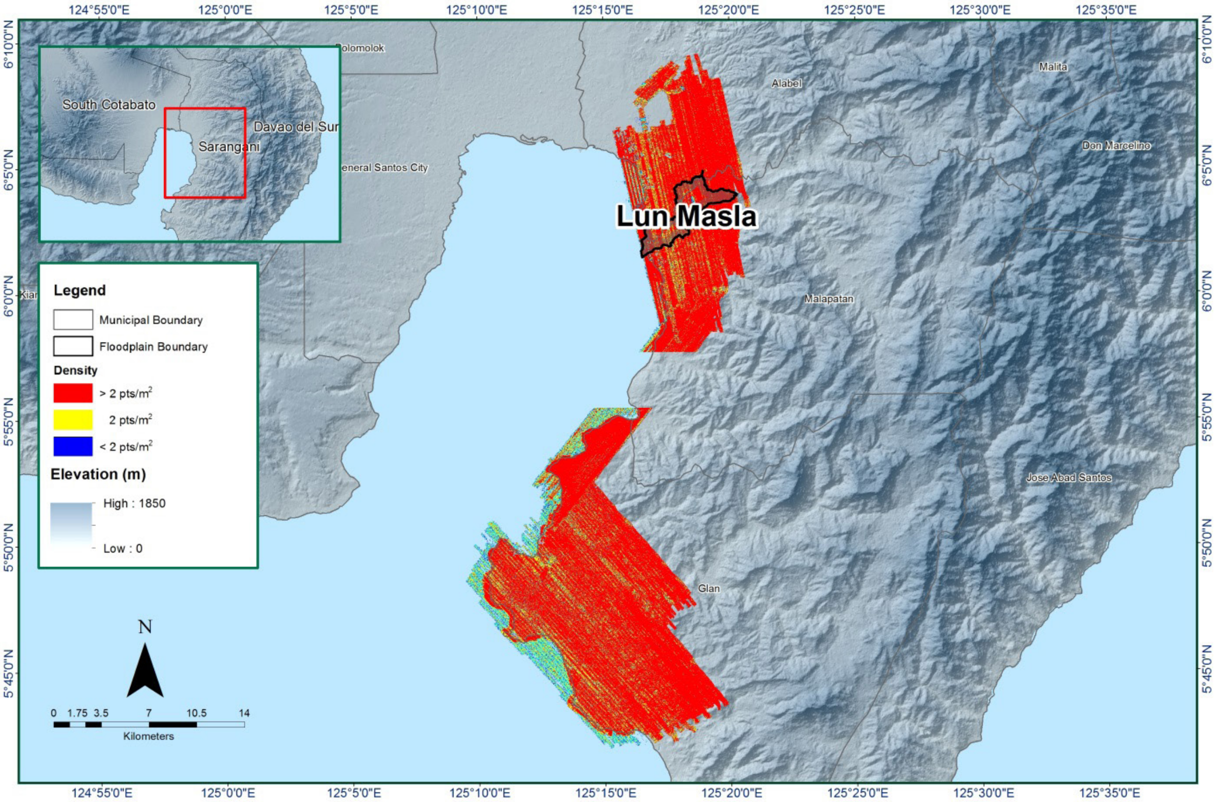


Figure 12. Pulse density map of merged LiDAR data for Lun Masla Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. 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.

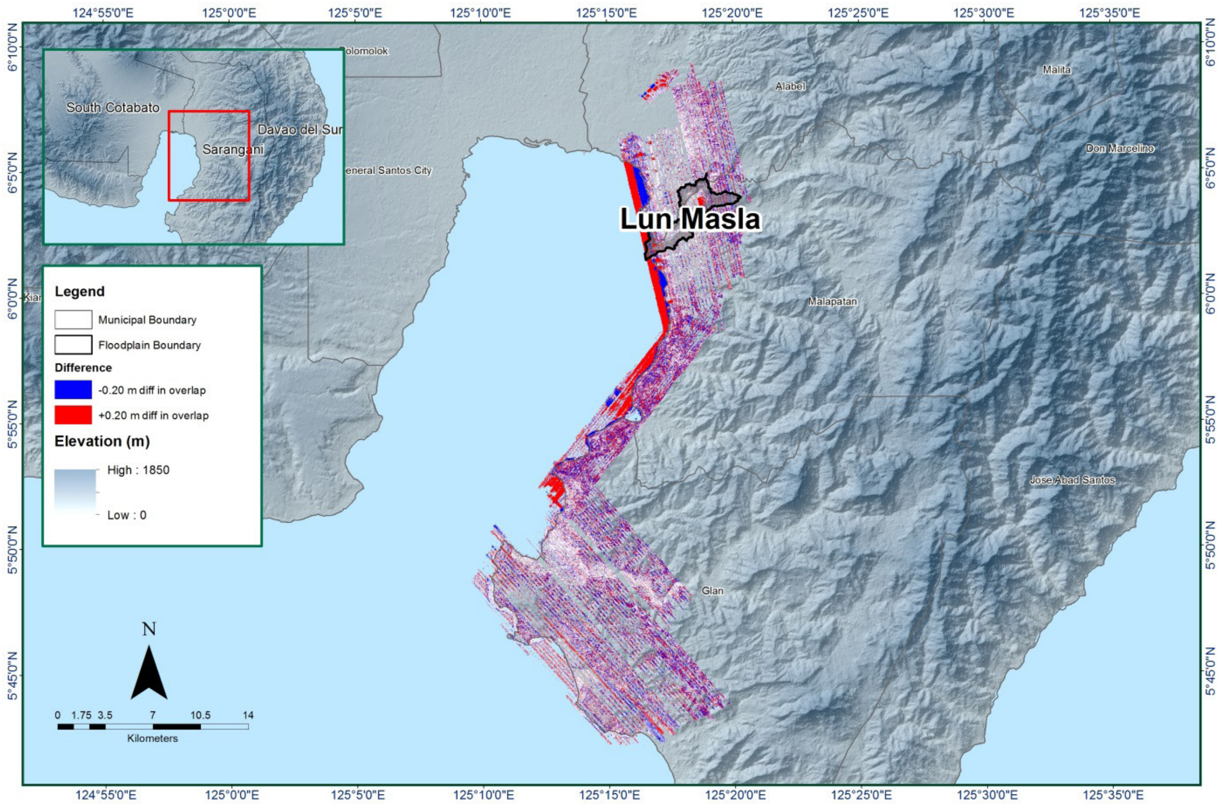


Figure 13. Elevation difference map between flight lines for Lun Masla Floodplain.

A screen capture of the processed LAS data from a Lun Masla flight 2164A loaded in QT Modeler is shown in Figure 14. 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.

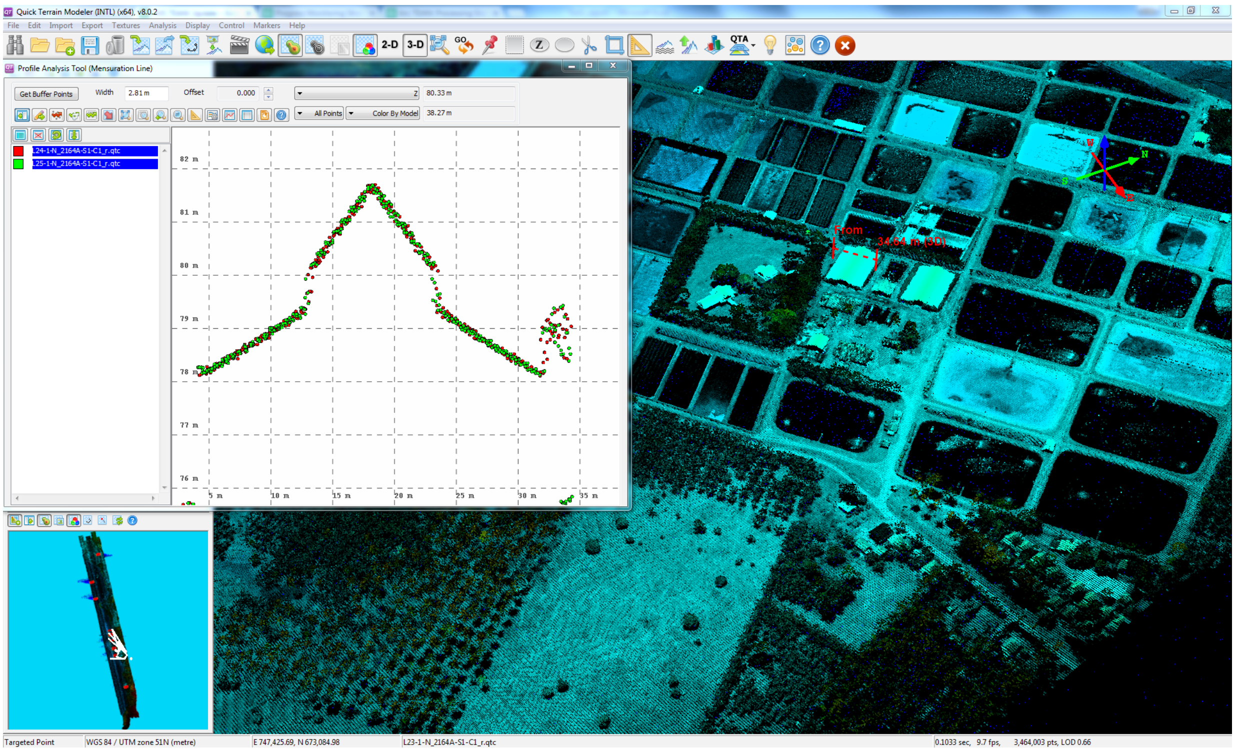


Figure 14. Quality checking for Lun Masla flight 2164 using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Lun Masla classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	273,929,652
Low Vegetation	280,850,551
Medium Vegetation	397,879,000
High Vegetation	420,842,083
Building	14,873,227

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Lun Masla floodplain is shown in Figure 16. A total of 660 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 576.89 meters and 20.91 meters respectively.

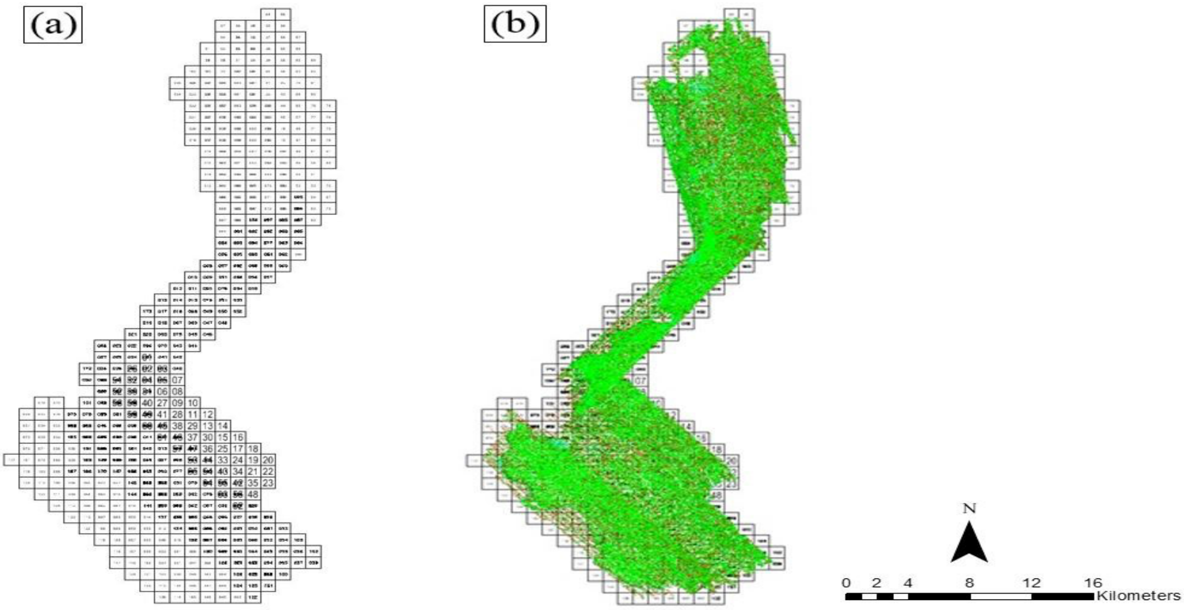


Figure 15.Tiles for Lun Masla Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 16. 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.

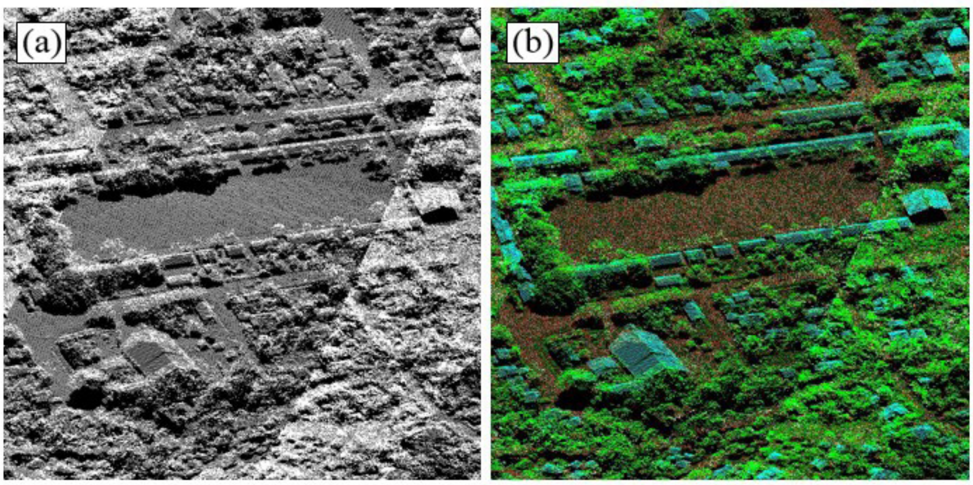


Figure 15. Point cloud before (a) and after (b) classification.

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

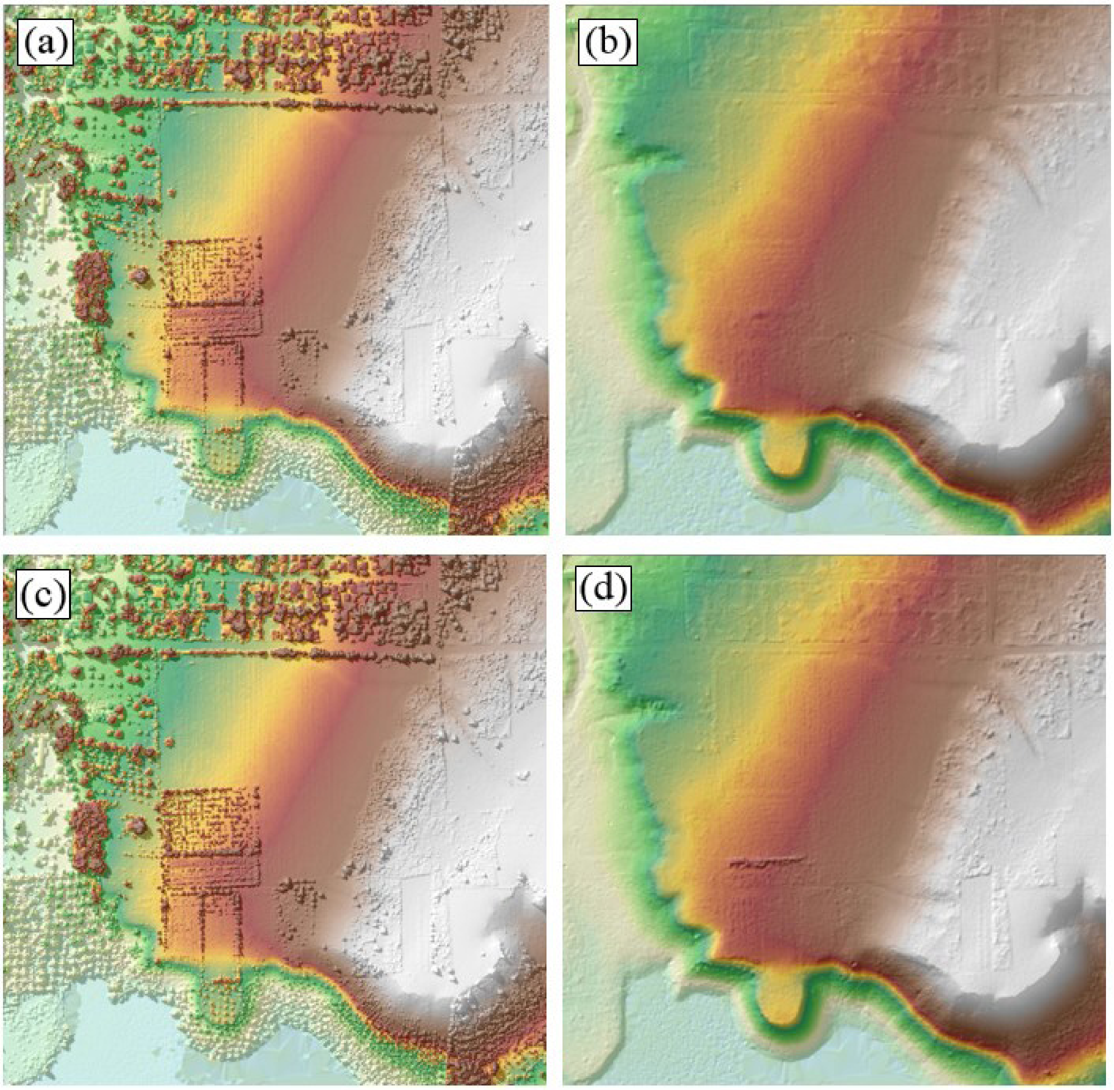


Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Lun Masla Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for Lun Masla floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Lun Masla floodplain. The a total area of 415.63 square kilometers Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
SouthCotabato_Sarangani_Blk90A	72.03
SouthCotabato_Sarangani_Blk90B	56.32
SouthCotabato_Sarangani_Blk90C	87.24
SouthCotabato_Sarangani_Blk90F	38.93
GeneralSantos_Blk90D	90.83
GeneralSantos_Blk90E	70.28
Buayan_Blk2C_additional	13.76
Buayan_Blk2D_additional	13.58
TOTAL	442.97 sq.km

Portions of DTM before and after manual editing are shown in Figure 18. The bridge (Figure 18a) is considered to be impedance to the flow of water along the river/stream and has to be removed (Figure 18b) in order to hydrologically correct the water flow.

On the other hand, object retrieval were done in areas such as paddies and ridges (Figure 18c and 18e) which have been removed during classification process and have to be retrieved to complete the surface (Figure 18d and 18f). Object retrieval uses the secondary DTM (t_layer) to fill in these areas.

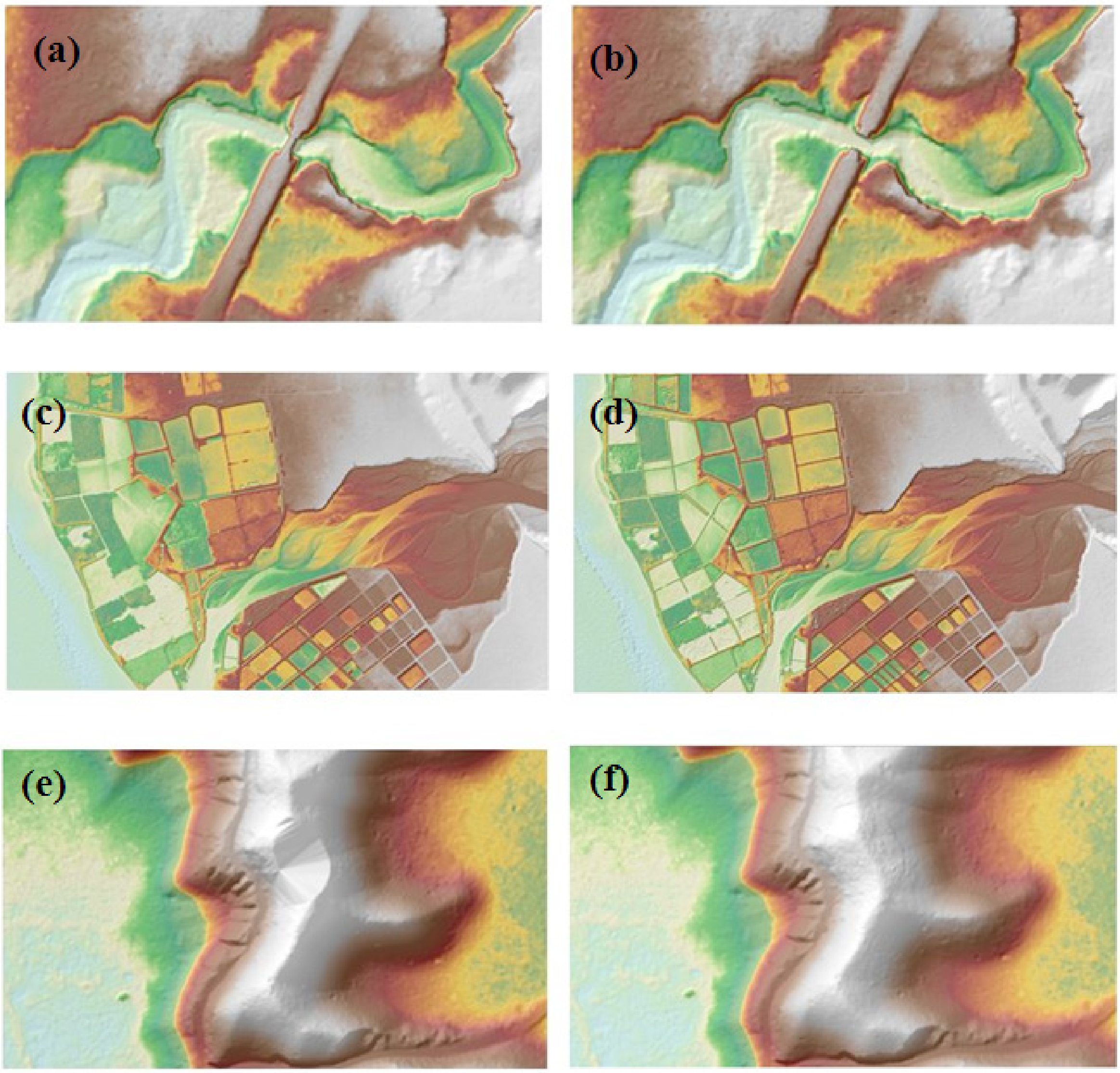


Figure 17. Figure 18. Portions in the DTM of Lun Masla Floodplain - -bridge, misclassified paddies and terrain before (a), (c), (e), and after (b), (d), (f) interpolation and data retrieval, respectively.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Buayan DEM overlapping with the blocks to be mosaicked. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Lun Masla floodplain is shown in Figure 19. It can be seen that the entire Lun Masla floodplain is almost 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Lun Masla Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
SouthCotabato_Sarangani_Blk90A	0.00	0.00	3.31
SouthCotabato_Sarangani_Blk90B	0.00	0.00	3.49
SouthCotabato_Sarangani_Blk90C	-0.36	0.00	3.15
GeneralSantos_Blk90D	-0.36	0.00	3.07
GeneralSantos_Blk90E	-0.36	0.00	3.87
SouthCotabato_Sarangani_Blk90F	-0.36	0.00	3.02
Buayan_Blk2C_additional	0.00	0.00	0.00
Buayan_Blk2D_additional	0.00	0.00	0.00

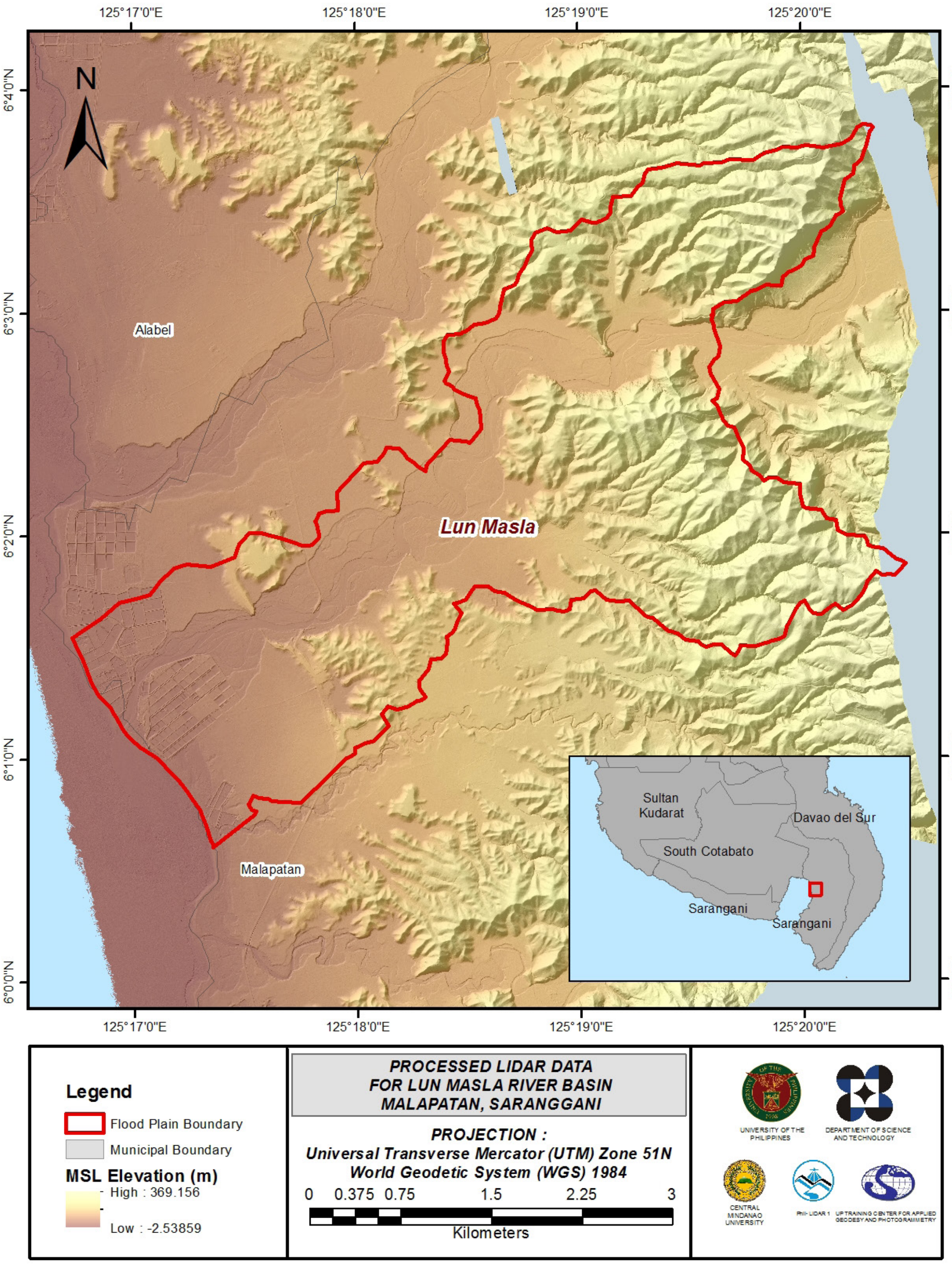


Figure 18. Map of Processed LiDAR Data for Lun Masla Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Lun Masla to collect points with which the LiDAR dataset is validated is shown in Figure 20. A total of 9568 survey points were gathered for calibration and validation of Lun Masla LiDAR data. However, the point dataset was not used for the calibration of the LiDAR data for Lun Masla because during the mosaicking process, each LiDAR block was referred to the calibrated Buayan DEM.

A good correlation between the uncalibrated Buayan LiDAR DTM and ground survey elevation values is shown in Figure 21. 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 points is 2.13 meters with a standard deviation of 0.07 meters. Calibration of Buayan LiDAR data was done by adding the height difference value, 2.13 meters, to Buayan mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between Buayan LiDAR data and calibration data. These values were also applicable to the Lun Masla DEM.

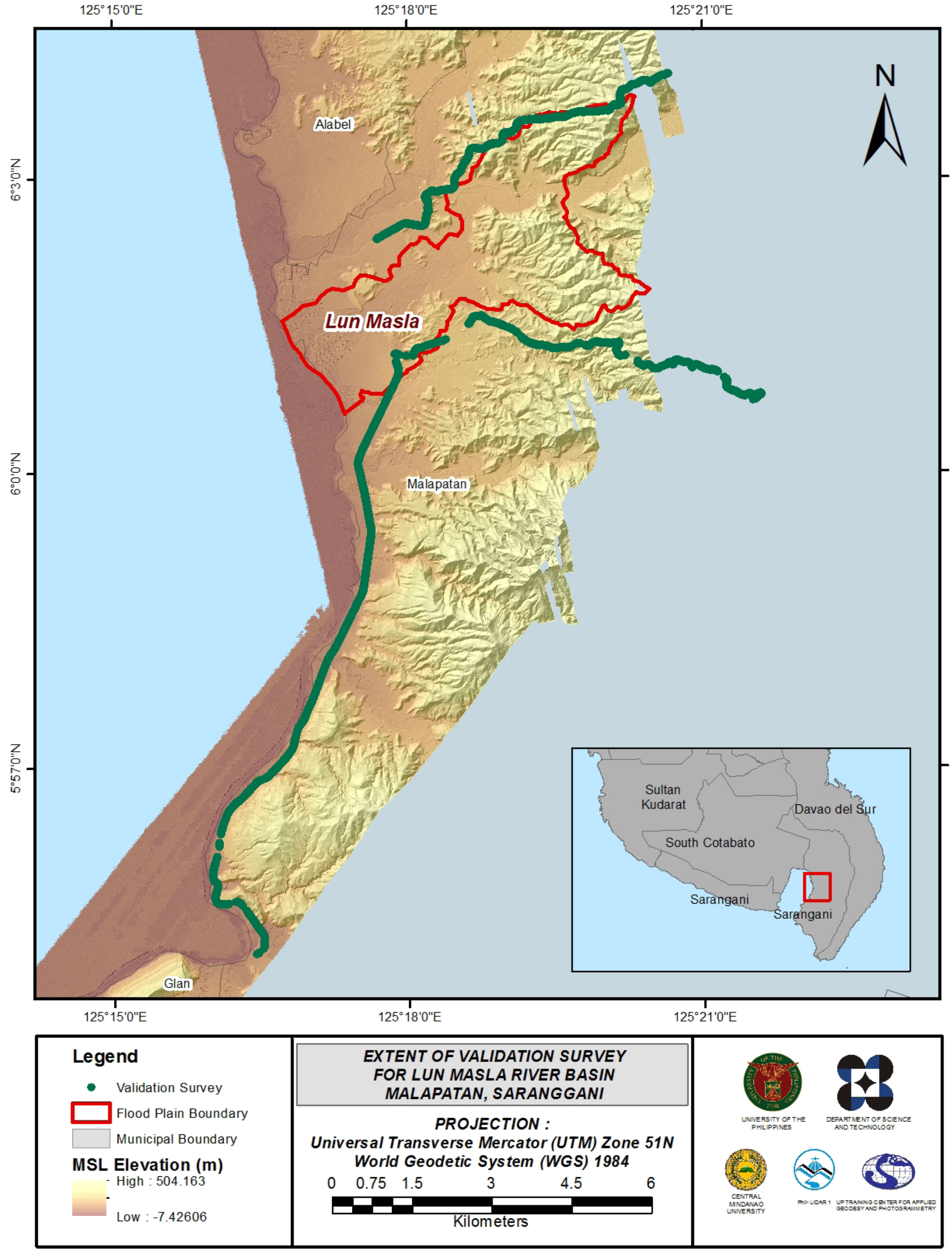


Figure 19. Map of Lun Masla Floodplain with validation survey points in green.

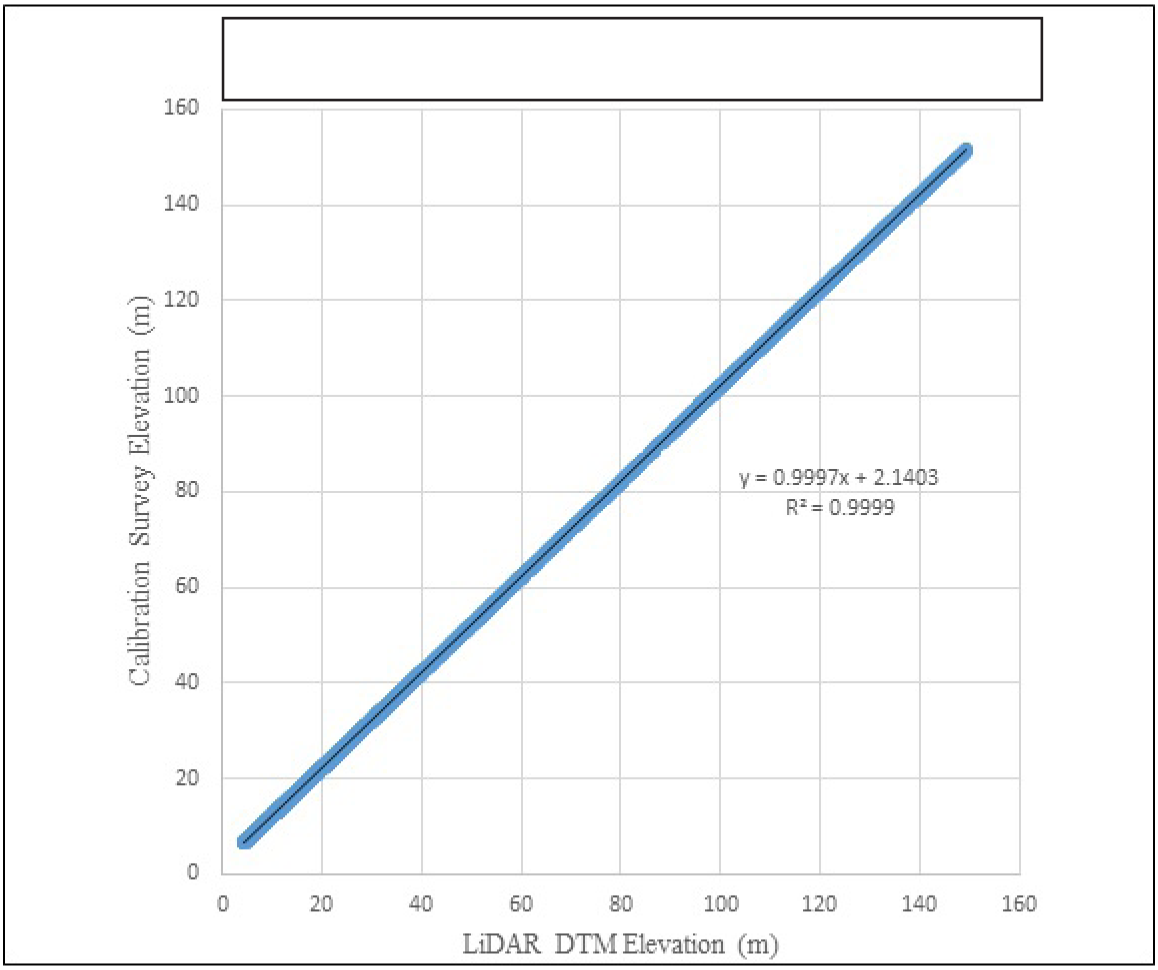


Figure 20. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.13
Standard Deviation	0.07
Average	2.13
Minimum	1.98
Maximum	2.27

Only 678 points that lie near the Lun Masla floodplain, derived from the 20% of the total survey points, were used for the validation of calibrated Lun Masla 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 22. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.11 meters, as shown in Table 16.

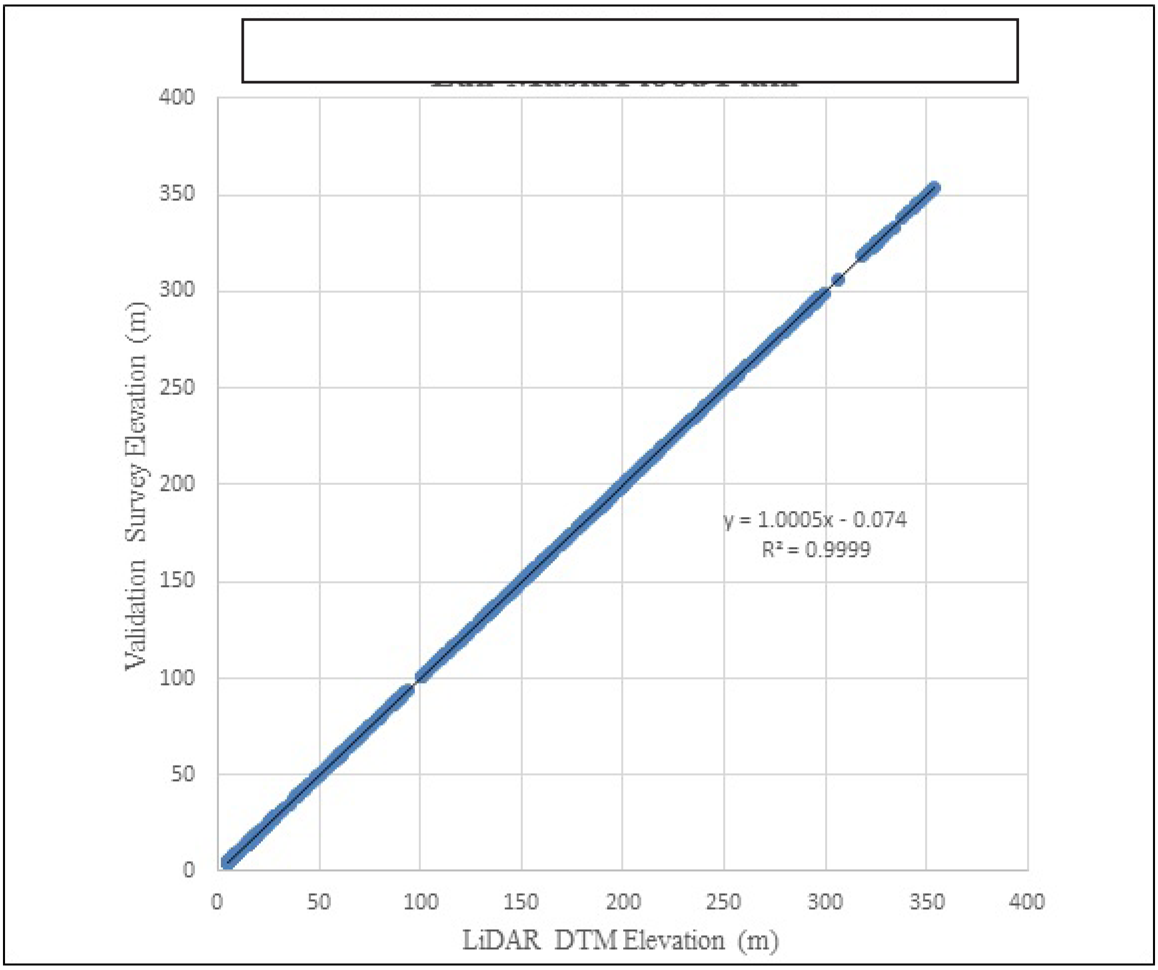


Figure 21. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.11
Average	-0.02
Minimum	-0.23
Maximum	0.20

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross section data were available for Lun Masla with 5, 945 total bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.35 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Lun Masla integrated with the processed LiDAR DEM is shown in Figure 23.

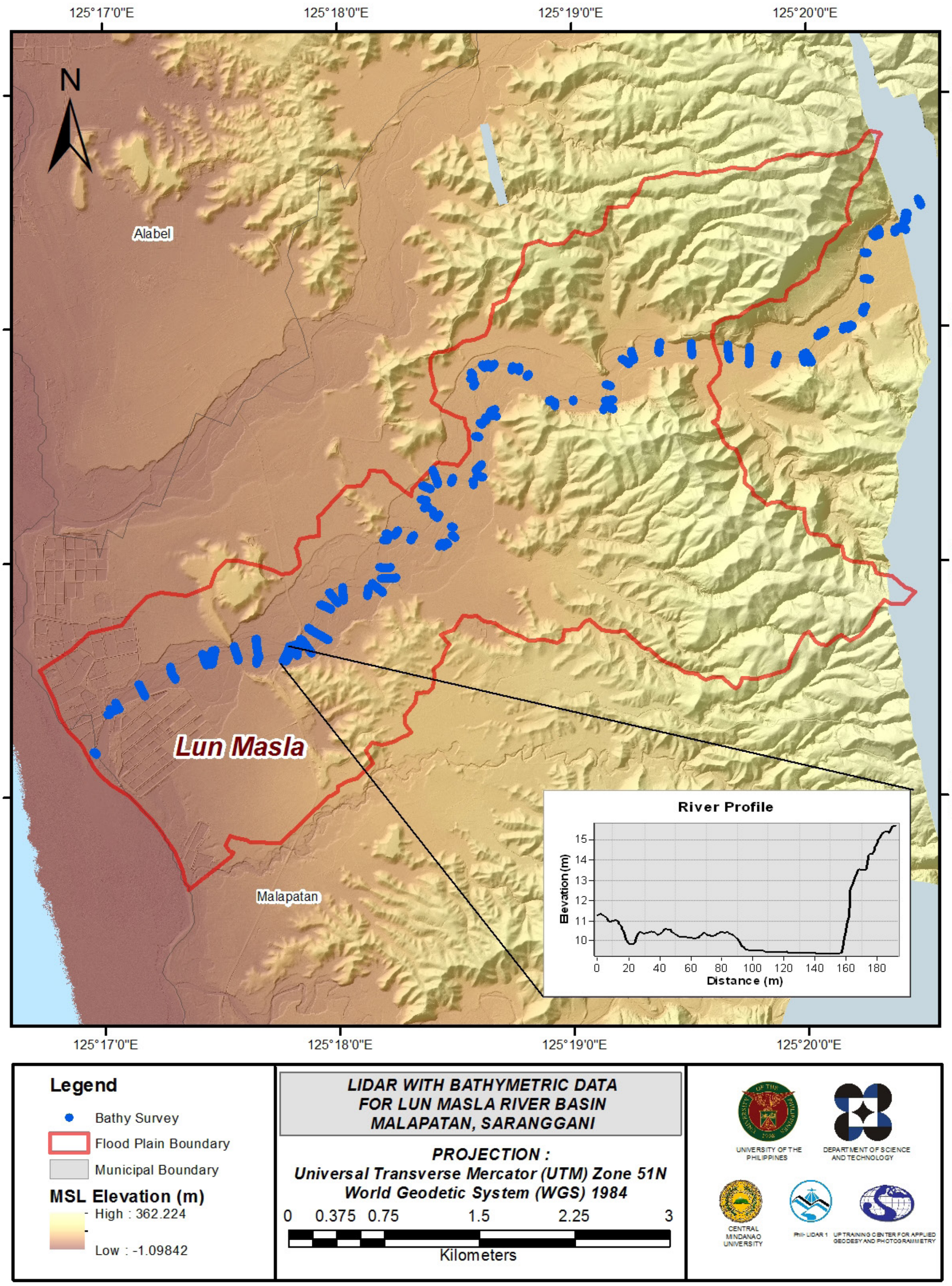


Figure 22. Map of Lun Masla Floodplain with bathymetric survey points shown in blue.

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

Lun Masla floodplain, including its 200 m buffer, has a total area of 18.36 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1144 building features, are considered for QC. Figure 24 shows the QC blocks for Lun Masla floodplain.

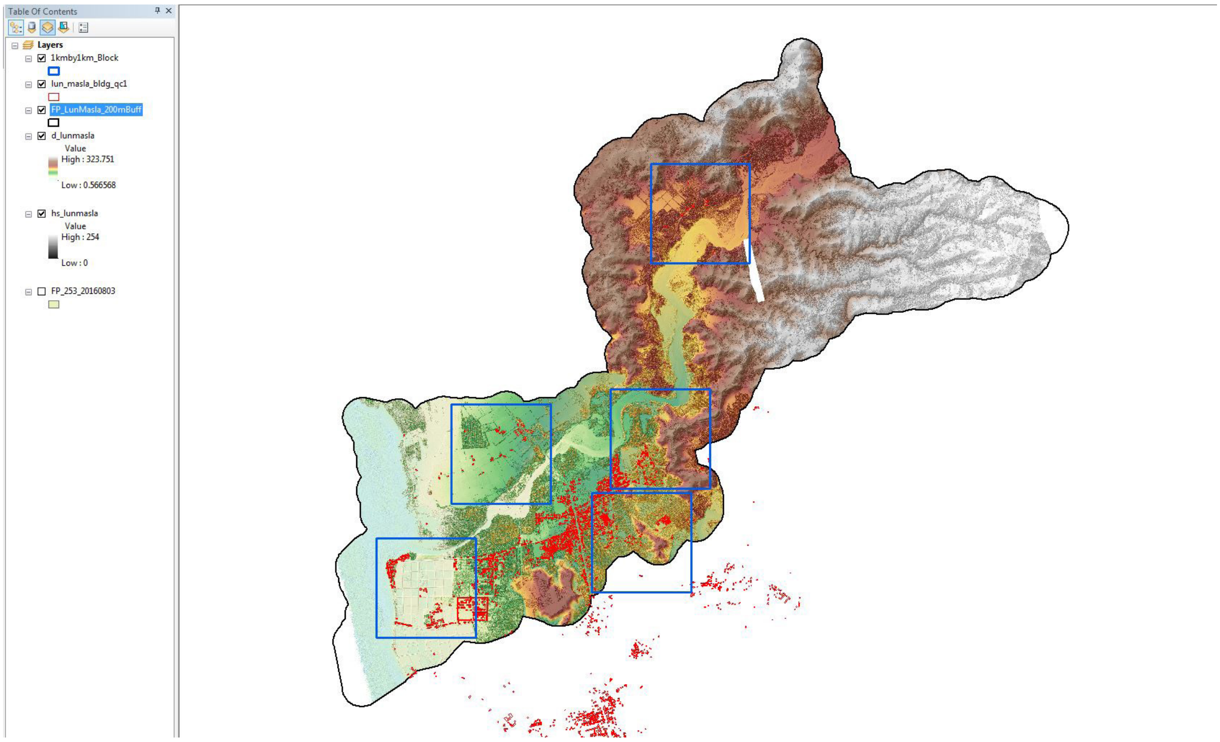


Figure 23. QC blocks for Lun Masla building features.

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

Table 17. Validation Statistical Measures.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Lun Masla	99.92	100.00	99.68	PASSED

3.12.2 Height Extraction

Height extraction was done for 1,548 building features in Lun Masla floodplain. Of these building features, none was filtered out after height extraction, resulting to 1,548 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 4.5 m.

3.12.3 Feature Attribution

Field data collection for the attribution process was done through Geotagging (point to a specific feature and shoot method) using a handheld GPS with a built-in camera. The x,y,z and the viewing direction of the GPS in 0-359 degrees during the photo capture were the essential information in the process. Using Arcmap's tool "Geotagged Photos to Points", the symbology of the imported point shapefile was set as "Airfield" and the viewing angle was set as "Direction". The "Path" is automatically created in the points' attribute table wherein the photo's directory is linked every after the "Identify" button is clicked to a specific point.

Table 18 summarizes the number of building features per type. Lun Masla buildings within the flood plain are mostly residential. For instance, commercial establishments are usually present in the poblacion area of the municipality proper. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Number of Building Features Extracted for Lun Masla Floodplain.

Facility Type	No. of Features
Residential	1,523
School	3
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	0
Barangay Hall	0
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	21
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	0
Other Commercial Establishments	1
Total	1, 548

Table 19. Total Length of Extracted Roads for Lun Masla Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Lun Masla	39.07	3.99	2.89	0	45.94	557.57

Table 20. Number of Extracted Water Bodies for Lun Masla Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Lun Masla	1	0	0	0	136	137

A total of 3 bridges that are part of the river networks were also extracted for the floodplain.

3.12.4Final 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 25 shows the Digital Surface Model (DSM) of Lun Masla floodplain overlaid with its ground features.

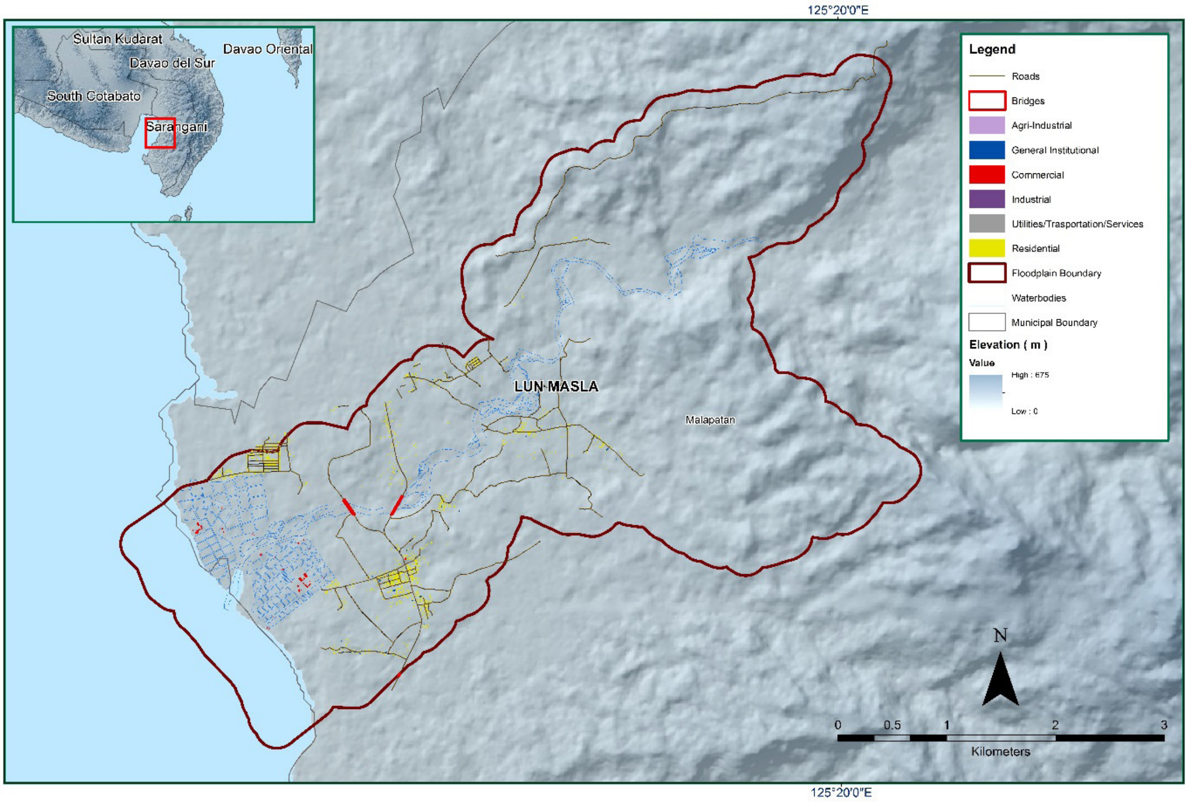


Figure 24. Extracted features for Lun Masla Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF LUN MASLA RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. 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 Lun Masla River on March 31, 2016, April 1-2, 2016, and April 4-6, 2016 with the following scope: reconnaissance; control survey; cross-section and as-built survey at Lun Masla Bridge in Brgy. Lun Masla, Malapatan, Sarangani; and bathymetric survey from its upstream in Brgy. Kinam to the mouth of the river located in Brgy. Lun Padidu, Malapatan, with an approximate length of 20.2 km using a Horizon® Total Station. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on October 20-28, 2016 using a survey grade GNSS receiver Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Lun Masla River Basin area. The entire survey extent is illustrated in Figure 26.

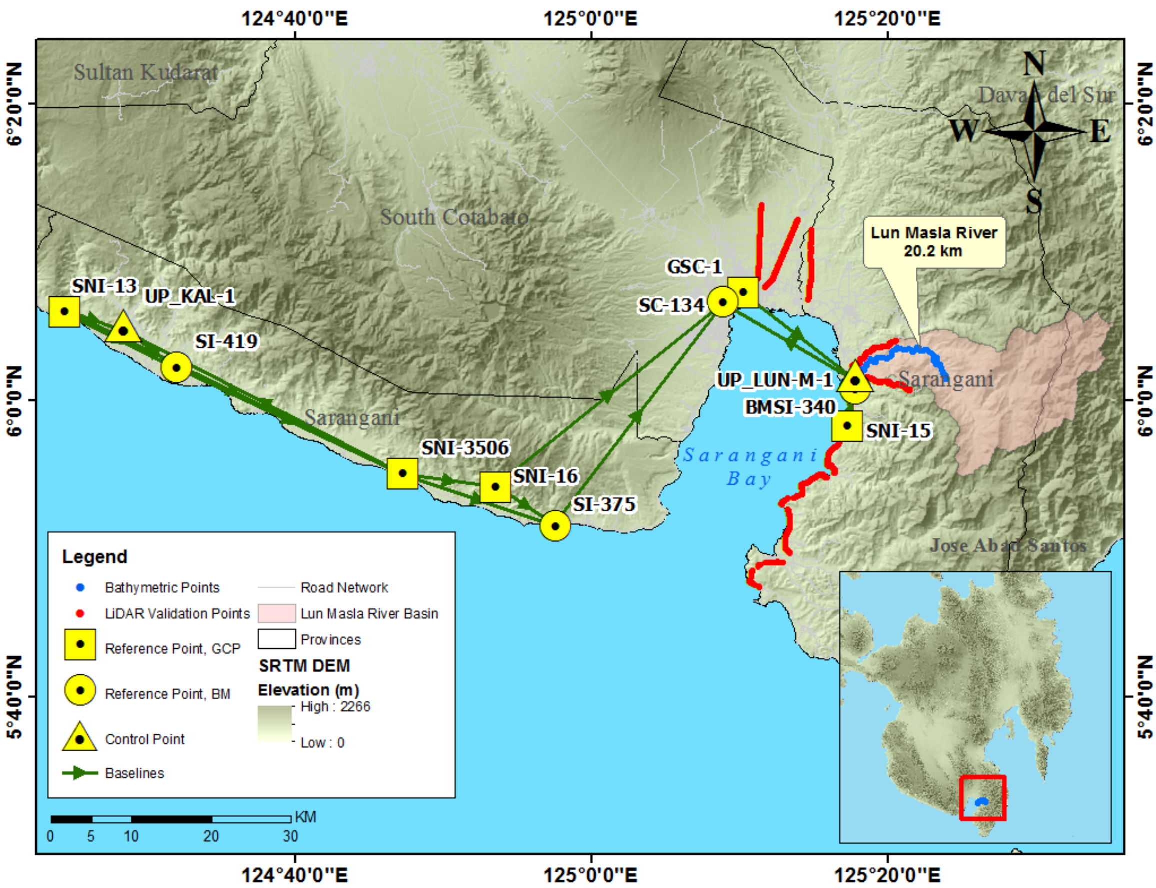


Figure 25. Lun Masla River Survey Extent

4.2 Control Survey

The GNSS network used for Lun Masla River is composed of eight (8) loops established on October 21-22, 2016 and October 25-27, 2016 occupying the following reference points: GSC-1, an established control point by DREAM Program last 2013, in Brgy. City Heights, General Santos City, South Cotabato; SC-134, a second-order BM, in Brgy. Labangal, General Santos City, South Cotabato; and SNI-3506, a third-order GCP, in Brgy. Lomuyon, Kiamba, Sarangani.

Six (6) other control points were used as markers; namely, BMSI-340, a first-order BM, in Brgy. Lun Masla, Malapatan, Sarangani; SI-375, a NAMRIA established BM, in Brgy. Kabatiol, Maasim, Sarangani; SI-419, a NAMRIA established BM, in Brgy. Pangi, Maitum, Sarangani; SNI-13, a second-order GCP, in Brgy. Maguling, Maitum, Sarangani; SNI-15, a second-order GCP in Brgy. Poblacion, Malapatan, Sarangani; and SNI-16, a second-order GCP, in Brgy. Malbang, Maasim, Sarangani.

Two (2) control points established in the area by ABSD were also occupied: UP_KAL-1 beside the approach of Kalaong Bridge in Brgy. Kalaong, Maitum, Sarangani, and UP_LUN-M-1 located at the approach of Lun Masla Bridge in Brgy. Lun Masla, Malapatan, Sarangani.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 27.

Table 21. List of reference and control points used during the survey in Lun Masla River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
GSC-1	2nd order, GCP	6°07'16.67814"N	125°10'14.17232"E	100.968	30.481	2013
SC-134	2nd order, BM	6°06'39.95883"N	125°08'54.60317"E	104.08	33.383	2012
SNI-3056	3rd order, GCP	5°55'02.04285"N	124°47'15.15313"E	78.611	7.291	2007
BMSI-340	Used as marker	6°00'46.46885"N	125°17'47.59214"E	87.143	18.105	2008
SI-375	Used as marker	5°51'34.23264"N	124°57'33.92737"E	85.438	15.691	2012
SI-419	Used as marker	6°02'12.83596"N	124°32'00.17889"E	90.879	19.231	2012
SNI-13	Used as marker	6°05'58.76635"N	124°24'26.04895"E	78.139	6.276	2007
SNI-15	Used as marker	5°58'14.08257"N	125d17'17.56678"E	77.391	8.356	2007
SNI-16	Used as marker	5°54'08.25615"N	124°53'30.98642"E	213.336	142.26	2007
UP_KAL-1	Established	6°05'04.17790"N	124°28'25.52392"E	94.629	22.502	4-9-2016
UP_LUN-M-1	Established	6°01'39.88031"N	125°17'48.95130"E	85.275	16.216	3-31-2016

Figure 26. GNSS Network covering Lun Masla River

The GNSS set-ups on recovered reference points and established control points in Lun Masla River are shown from Figure 28 to Figure 38.

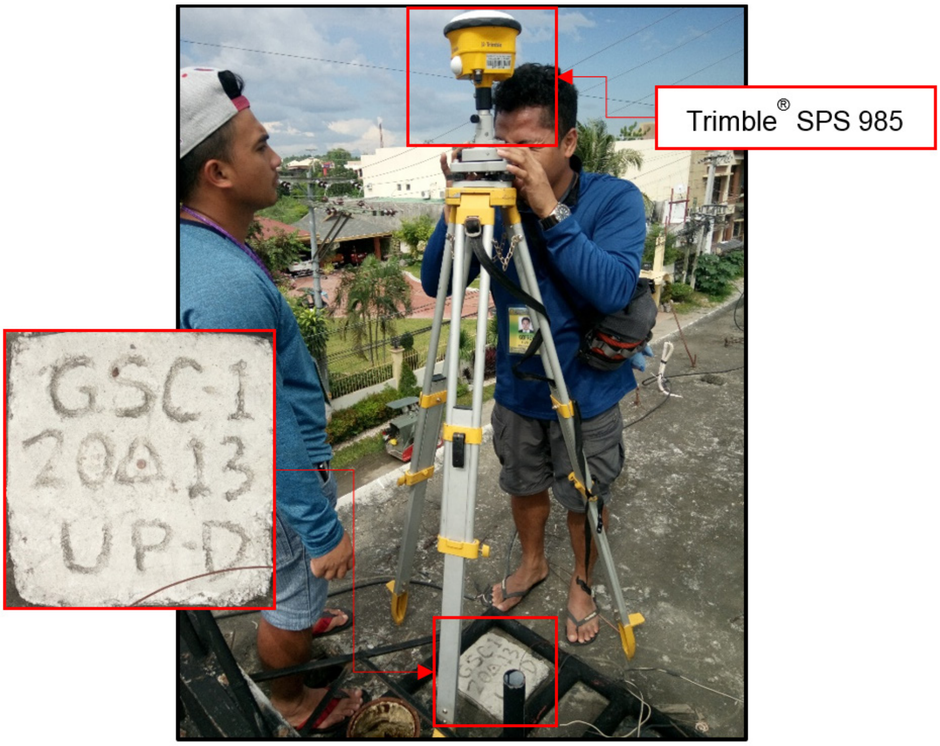


Figure 27. GNSS base set up, Trimble® SPS 985, at GSC-1, located on the rooftop of Ice Castle Experience Hotel in Ambassador Provido Village, Brgy. City Heights, General Santos City, South Cotabato

Figure 28. GNSS receiver set up, Trimble® SPS 985, at SC-134, located at the approach of Sinawal Bridge in Brgy. Labangal, General Santos City, South Cotabato

Figure 29. SNI-3506, a third-order GCP, located beside a flag pole inside Lomuyon Elementary School in Brgy. Brgy. Lomuyon, Kiamba, Sarangani

Figure 30. GNSS receiver set up, Hi-Target™ V30, at BMSI-340, located at the approach of Molo Bridge in Brgy. Lun Masla, Malapatan, Sarangani

Figure 31. SI-375, a NAMRIA established BM, located along the national highway in Brgy. Kabatiol, Maasim, Sarangani

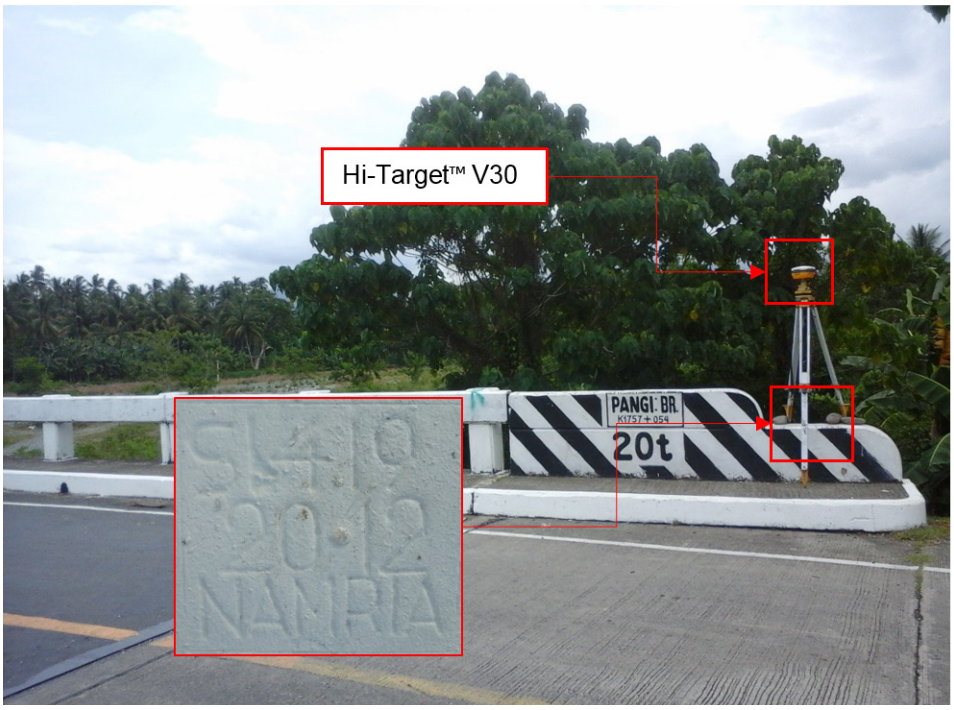


Figure 32. GNSS receiver set up, Hi-Target™ V30, at SI-419, a NAMRIA established BM, located on the barrier of Pangi Bridge in Brgy. Pangi, Maitum, Sarangani

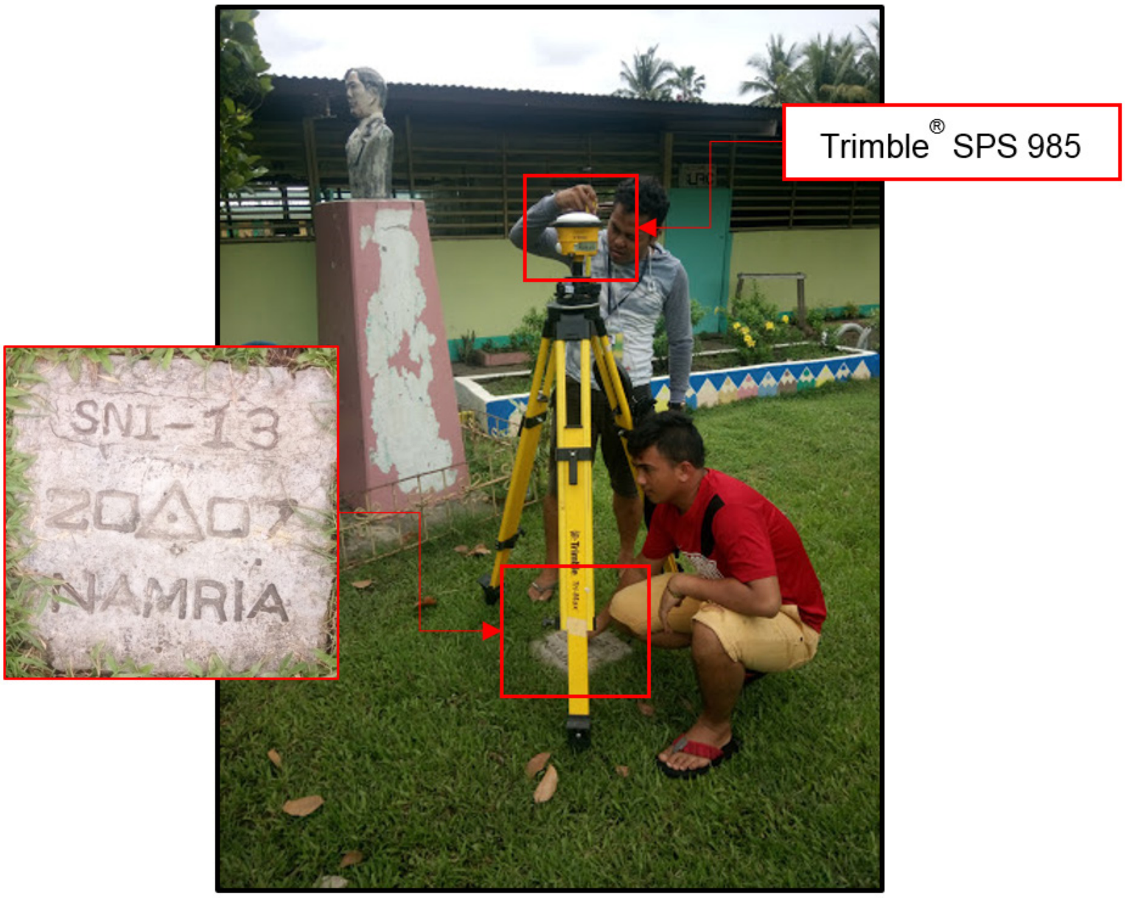


Figure 33. GNSS base set up, Trimble® SPS 985, at SNI-13, a second-order GCP, located beside a Jose Rizal bust inside Maguling Elementary School in Brgy. Maguling, Maitum, Sarangani

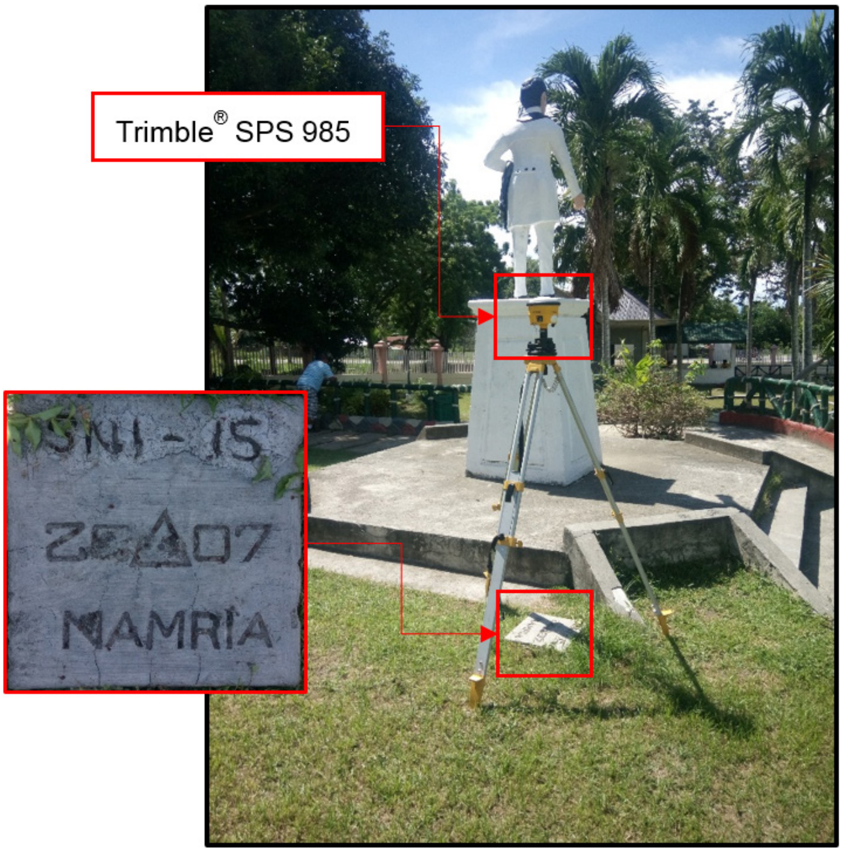


Figure 34. GNSS receiver set up, Trimble® SPS 985, at SNI-15, located behind a Jose Rizal monument inside the premises of Malapatan Municipal Hall in Brgy. Poblacion, Malapatan, Sarangani

Figure 35. SNI-16, a second-order GCP, located beside a flag pole inside the premises of Malbang Barangay Hall in Brgy. Malbang, Maasim, Sarangani

Figure 36. GNSS receiver set up, Hi-Target™ V30, at UP_KAL-1, an established control point, located beside the approach of Kalaong Bridge in Brgy. Kalaong, Maitum, Sarangani

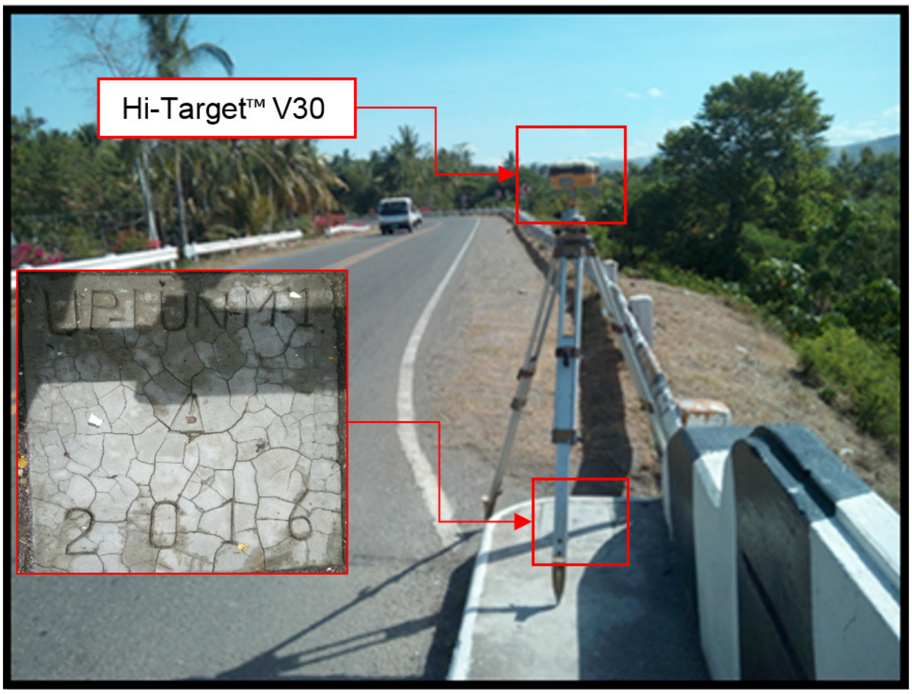


Figure 37. GNSS receiver set up, Hi-Target™ V30, at UP_LUN-M-1, located at the approach of Lun Masla Bridge in Brgy. Lun Masla, Malapatan, Sarangani

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Lun Masla River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Report for Lun Masla River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
SNI-15 --- BMSI-340	10-21-2016	Fixed	0.002	0.014	11°09'30"	4771.281	9.758
GSC-1 --- UP_LUN-M-1	10-22-2016	Fixed	0.003	0.013	126°29'17"	17395.366	-15.710
UP_LUN-M-1 --- BMSI-340	10-21-2016	Fixed	0.001	0.003	181°27'33"	1641.252	1.867
UP_LUN-M-1 --- SNI-15	10-21-2016	Fixed	0.002	0.012	188°40'51"	6395.051	-7.880
SNI-3506 --- UP_KAL-1	10-27-2016	Fixed	0.003	0.013	298°02'53"	39357.597	15.996
SNI-13 --- UP_KAL-1	10-27-2016	Fixed	0.005	0.020	102°49'31"	7552.049	16.523
SNI-13 --- SNI-3506	10-22-2016	Fixed	0.006	0.022	115°34'49"	46687.957	0.444
GSC-1 --- SC-134	10-22-2016	Fixed	0.002	0.007	65°14'48"	2694.035	-3.079
UP_LUN-M-1 --- SC-134	10-21-2016	Fixed	0.002	0.009	119°17'04"	18840.233	-18.797
SI-419 --- UP_KAL-1	10-22-2016	Fixed	0.009	0.030	308°34'18"	8442.306	3.779
SNI-13 --- SI-419	10-27-2016	Fixed	0.007	0.027	296°26'01"	15594.049	-12.728
SI-375 --- SC-134	10-27-2016	Fixed	0.002	0.016	216°58'04"	34818.418	-18.620
SNI-16 --- SI-375	10-25-2016	Fixed	0.005	0.025	122°20'07"	8844.822	-127.892
SNI-16 --- SI-375	10-26-2016	Fixed	0.004	0.028	122°20'07"	8844.830	-127.939
SNI-16 --- SC-134	10-25-2016	Fixed	0.003	0.018	230°54'15"	36606.170	109.221
SI-419 --- SNI-3506	10-26-2016	Fixed	0.005	0.017	295°11'56"	31096.425	12.287
SNI-3506 --- SI-375	10-25-2016	Fixed	0.004	0.020	108°31'54"	20075.492	6.805
SNI-3506 --- SNI-16	10-26-2016	Fixed	0.004	0.018	98°07'42"	11677.673	134.737
SNI-16 --- SC-134	10-25-2016	Fixed	0.003	0.018	230°54'15"	36606.170	109.221
SI-419 --- SNI-3506	10-27-2016	Fixed	0.005	0.017	295°11'56"	31096.425	12.287
SNI-3506 --- SI-375	10-26-2016	Fixed	0.004	0.020	108°31'54"	20075.492	6.805
SNI-3506 --- SNI-16	10-26-2016	Fixed	0.004	0.018	98°07'42"	11677.673	134.737

As shown Table 22 a total of eighteen (18) baselines were processed with the coordinates and elevation of GSC-1 and SC-134 and the coordinates of SNI-3506 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for complete details.

The eleven (11) control points, GSC-1, SNI-13, SNI-15, SNI-16, SNI-3506, SC-134, BMSI-340, SI-375, SI-419, UP_KAL-1, and UP-LUN-M-1 were occupied and observed simultaneously to form a GNSS loop. The coordinate and elevation values of GSC-1 and SC-134 and the coordinates of SNI-3506 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
GSC-1	Grid				Fixed
GSC-1	Global	Fixed	Fixed		
SC-134	Grid				Fixed
SC-134	Global	Fixed	Fixed		
SNI-3506	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. All fixed control points have no values for grid errors and elevation error.

Table 24. Adjusted Grid Coordinates

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BMSI-340	754219.347	0.008	665165.384	0.008	18.105	0.035	
GSC-1	740222.360	?	677098.698	?	30.481	?	LLe
SC-134	737779.631	?	675960.563	?	33.383	?	LLe
SI-375	716944.970	0.008	648053.192	0.007	15.689	0.055	
SI-419	669707.093	0.015	667522.186	0.011	19.228	0.097	
SNI-13	655724.820	0.016	674424.001	0.014	6.271	0.098	
SNI-15	753315.157	0.009	660478.632	0.009	8.357	0.052	
SNI-16	709454.516	0.008	652759.518	0.007	142.258	0.060	
SNI-3506	697887.596	?	654373.678	?	7.286	0.077	LL
UP_KAL-1	663092.171	0.011	672766.934	0.011	22.498	0.091	
UP_LUN-M-1	754254.254	0.007	666806.922	0.007	16.217	0.032	

With the mentioned equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for the horizontal and $z_e < 10\ cm$ for the vertical; the computation for the accuracy for:

a.	**BMSI-340**			
	horizontal accuracy	=	$\sqrt{((0.8)^2 + (0.8)^2}$	
		=	$\sqrt{(0.64 + 0.64)}$	
		=	1.13 < 20 cm	
	vertical accuracy	=	3.5 < 10 cM	
b.	**GSC-1**			
	horizontal accuracy	=	Fixed	
	vertical accuracy	=	FixeD	
c.	**SC-134**			
	horizontal accuracy	=	Fixed	
	vertical accuracy	=	Fixed	
d.	**SI-375**			
	horizontal accuracy	=	$\sqrt{((0.8)^2 + (0.7)^2}$	
		=	$\sqrt{(0.64+ 0.49)}$	
		=	1.06 < 20 cm	
	vertical accuracy	=	5.5 < 10 cm	
e.	**SI-419**			
	horizontal accuracy	=	$\sqrt{((1.5)^2 + (1.1)^2}$	
		=	$\sqrt{(2.25 + 1.21)}$	
		=	1.86 < 20 cm	
	vertical accuracy	=	9.7 < 10 cm	
f.	**SNI-13**			
	horizontal accuracy	=	$\sqrt{((1.6)^2 + (1.4)^2}$	
		=	$\sqrt{(2.56 + 1.96)}$	
		=	2.13 < 20 cm	
	vertical accuracy	=	9.8 < 10 cm	
g.	**SNI-15**			
	horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.9)^2}$	
		=	$\sqrt{(0.81 + 0.81)}$	
		=	1.27 < 20 cm	
	vertical accuracy	=	5.2 < 10 cm	
h.	**SNI-16**			
	horizontal accuracy	=	$\sqrt{((0.8)^2 + (0.7)^2}$	
		=	$\sqrt{(0.64 + 0.49)}$	
		=	1.06 < 20 cm	
	vertical accuracy	=	6.0 < 10 cm	
i.	**SNI-3506**			
	horizontal accuracy	=	Fixed	
	vertical accuracy	=	7.7 < 10 cm	
j.	**UP_KAL-1**			
	horizontal accuracy	=	$\sqrt{((1.1)^2 + (1.1)^2}$	
		=	$\sqrt{(1.21 + 1.21)}$	
		=	1.56 < 20 cm	
	vertical accuracy	=	9.1 < 10 cm	
k.	**UP_LUN-M-1**			
	horizontal accuracy	=	$\sqrt{((0.7)^2 + (0.7)^2}$	
		=	$\sqrt{(0.49 + 0.49)}$	
		=	0.99 < 20 cm	
	vertical accuracy	=	3.2 < 10 cm	

Following the given formula, the horizontal and vertical accuracy result of the nine (9) occupied control points are within the required precision.

Table 25. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height	Height σ (Meter)	Elevation σ (Meter)
BMSI-340	N6°00’46.46952”	E125°17'47.59324"	87.143	0.035	
GSC-1	N6°07'16.67814"	E125°10'14.17232"	100.968	?	LLe
SC-134	N6°06’39.95883”	E125°08’54.60317”	104.080	?	LLe
SI-375	N5°51'34.23058"	E124°57'33.92856"	85.436	0.055	
SI-419	N6°02'12.83147"	E124°32'00.17761"	90.876	0.097	
SNI-13	N6°05'58.76117"	E124°24'26.04688"	78.134	0.098	
SNI-15	N5°58'14.08305"	E125°17'17.56815"	77.391	0.052	
SNI-16	N5°54'08.25376"	E124°53'30.98712"	213.333	0.060	
SNI-3506	N5°55'02.03975"	E124°47'15.15342"	78.606	0.077	LL
UP_KAL-1	N6°05'04.17314"	E124°28'25.52215"	94.625	0.091	
UP_LUN-M-1	N6°01'39.88102"	E125°17'48.95230"	85.276	0.032	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 26.

Table 26. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)					
		Latitude	Longitude	Ellipsoidal Height (meter)	Northing (m)	Easting (m)	BM Ortho (m)
GSC-1	2nd order, GCP	6°07'16.67814"N	125°10'14.17232"E	100.968	677098.698	740222.36	30.481
SC-134	2nd order, BM	6°06'39.95883"N	125°08'54.60317"E	104.08	675960.563	737779.631	33.383
SNI-3056	3rd order, GCP	5°55'02.04285"N	124°47'15.15313"E	78.611	654373.773	697887.587	7.291
BMSI-340	Used as marker	6°00'46.46885"N	125°17'47.59214"E	87.143	665165.364	754219.313	18.105
SI-375	Used as marker	5°51'34.23264"N	124°57'33.92737"E	85.438	648053.255	716944.933	15.691
SI-419	Used as marker	6°02'12.83596"N	124°32'00.17889"E	90.879	667522.324	669707.132	19.231
SNI-13	Used as marker	6°05'58.76635"N	124°24'26.04895"E	78.139	674424.16	655724.883	6.276
SNI-15	Used as marker	5°58'14.08257"N	125d17'17.56678"E	77.391	660478.617	753315.115	8.356
SNI-16	Used as marker	5°54'08.25615"N	124°53'30.98642"E	213.336	652759.592	709454.494	142.26
UP_KAL-1	Established	6°05'04.17790"N	124°28'25.52392"E	94.629	672767.081	663092.225	22.502
UP_LUN-M-1	Established	6°01'39.88179 N	125°17'48.95259"E	85.284	666806.9	754254.223	16.216

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

Cross-section and as-built surveys were conducted on March 31, 2016 at the upstream side of Lun Masla Bridge in Brgy. Lun Masla, Malapatan as shown in Figure 39. A Horizon® Total Station was utilized for this survey as shown in Figure 40.

Figure 38. Lun Masla Bridge facing downstream

Figure 39. As-built survey of Lun Masla Bridge

The cross-sectional line of Lun Masla Bridge is about 379 m with one hundred fifty-seven (157) cross-sectional points using the control points UP_LUN-M-1 and UP_LUN-M-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure 41 to Figure 43. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on October 22, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.887 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square Correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.020 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

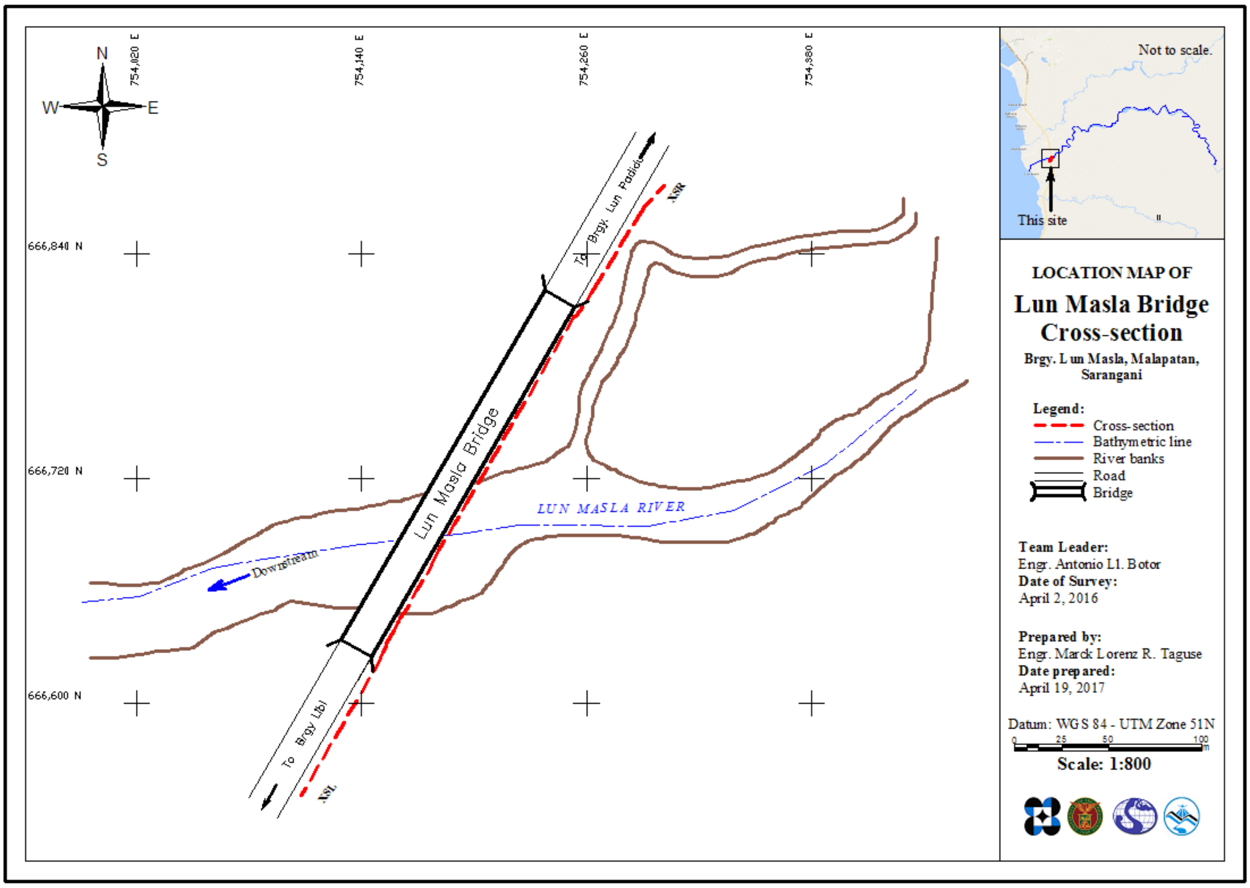


Figure 40. Location Map of Lun Masla Bridge River Cross-Section survey

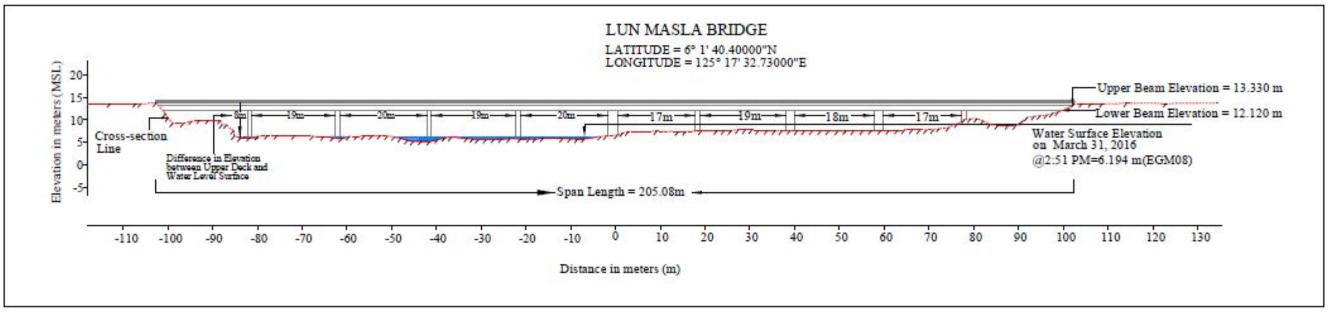


Figure 41. Lun Masla Bridge cross-section diagram

Bridge Data Form

Bridge Name: Lun Masla Bridge

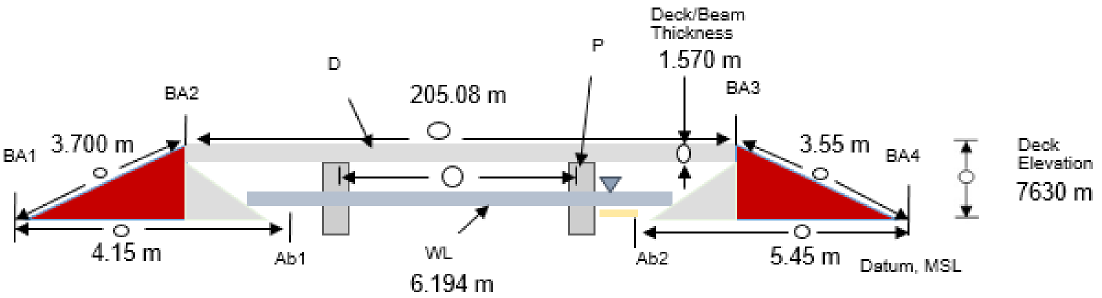
River Name: Lun Masla River
Location (Brgy, City, Region): Brgy. Lun Masla, Malapatan, Sarangani

Survey Team: A. Balber
Date and Time: March 31, 2016, 2:51 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	3.700 m	
2. BA2-BA3	205.08 m	
3. BA3-BA4	3.55 m	
4. BA1-Ab1	4.15 m	
5. Ab2-BA4	5.45 m	
6. Deck/beam thickness	1.570 m	
7. Deck elevation	7.630 m	

Note: Observer should be facing downstream

Figure 42. Bridge as-built form of Lun Masla Bridge

Water surface elevation of Lun Masla River was determined by a Horizon® Total Station on March 31, 2016 at 2:51 PM at Lun Masla Bridge area with a value of 6.194 m in EGM08 as shown in Figure 42. This was translated into marking on the bridge's pier as shown in Figure 44. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Lun Masla River, Central Mindanao University.

Figure 43. Water-level markings on Lun Masla Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on October 25-26, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached at the back of the vehicle as shown in Figure 45. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.4 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP_LUN-M-1 and LUN-M-2 occupied as the GNSS base stations in the conduct of the survey.

Figure 44. Validation points acquisition survey set-up for Lun Masla River

The survey started from Brgy. Olympong, General Santos City, Sarangani going southeast along the national highway, traversing five (5) barangays in General Santos City and two (2) barangays in Alabel before ending in Brgy. Baluntay, Alabel, Sarangani. The survey continued from Brgy. Lun Padidu, Malapatan going southwest along the national highway traversing (8) barangays in Alabel and five (5) barangays in Glan before ending in Brgy. Gumasa, Municipality of Glan, Sarangani. The survey gathered a total of 11,977 points with approximate length of 82.7 km using UP_LUN-M-1 and LUN-M-2 as GNSS base stations for the entire extent of validation points acquisition survey as illustrated in the map in Figure 46.

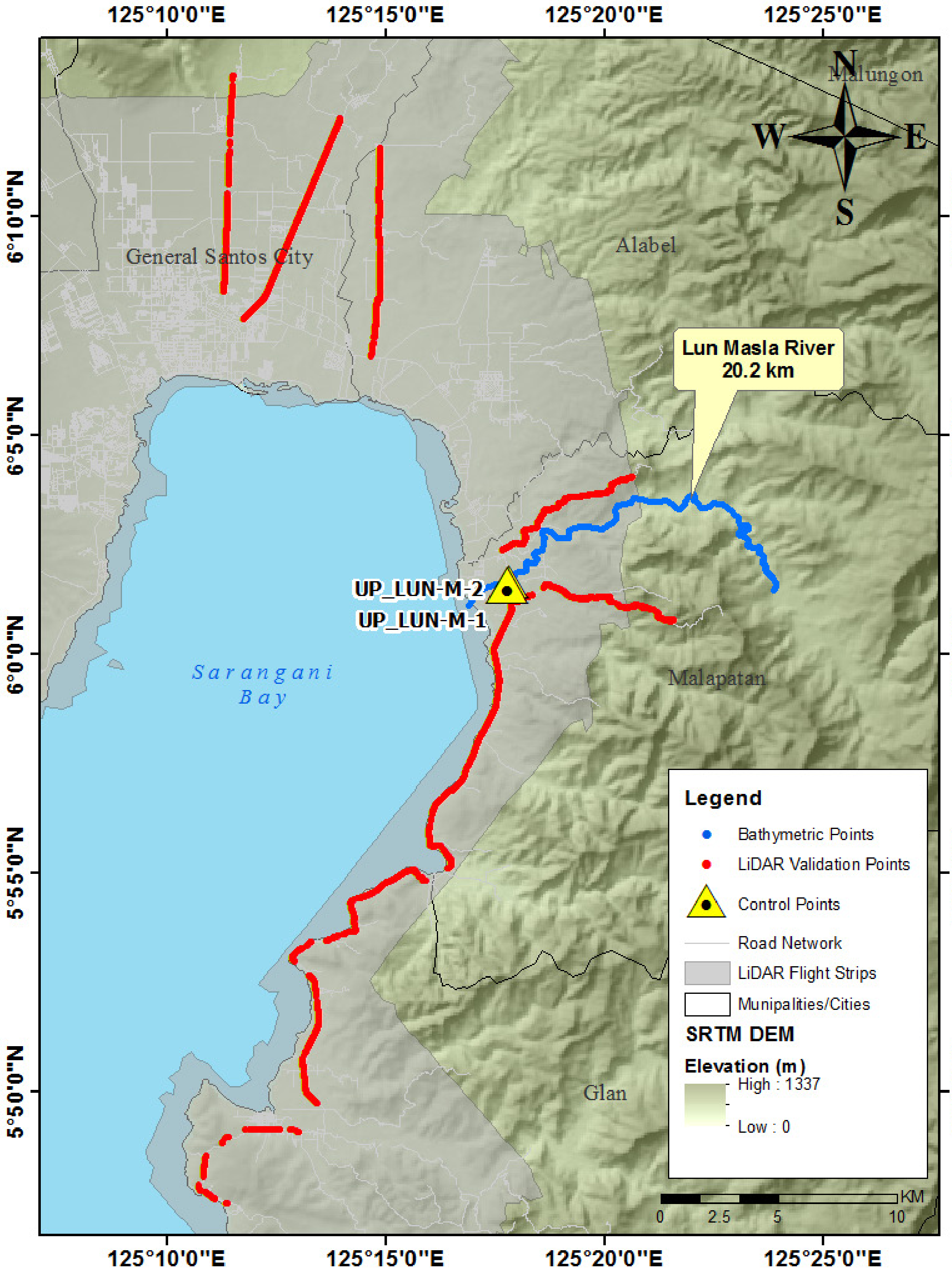


Figure C- 21 Validation points acquisition covering the Lun Masla River Basin Area

Figure 45. Validation point acquisition survey of Lun Masla River Basin

4.7 Bathymetric Survey

Bathymetric survey was executed manually on April 2, 4-6, 2016 using a Hi-Target™ Total Station as seen in Figure 47. The survey started in Brgy. Kinam, Malapatan, Sarangani with coordinates 6° 1' 27.42364"N, 125° 23' 51.50884"E and ended at the mouth of the river in Brgy. Lun Padidu, Malapatan, Sarangani with coordinates 6° 1' 11.29258"N, 125° 16' 57.25260"E. The control points UP_LUN-M-1 and UP_LUN-M-2 served as the GNSS base stations all throughout the survey.

Figure 46. Manual bathymetric survey of ABSD at Lun Masla River using Hi-Target™ Total Station

The bathymetric survey for Lun Masla River gathered a total of 6,933 points covering 20.2 km of the river traversing Barangays Kinam, Upper Suyan, Daan Suyan,Lun Padidu, Patag, and Lun Masla in the Malapatan as illustrated in Figure 48.

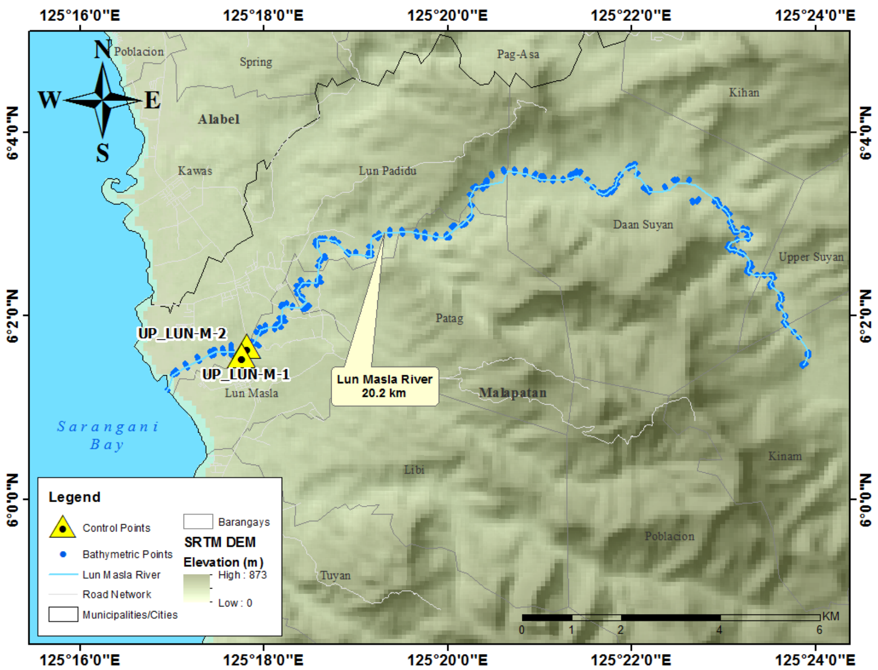


Figure 47. Bathymetric survey of Lun Masla River

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on October 22, 2016 using a GNSS Rover receiver, Trimble® SPS 882 attached to a 2-m pole. A map showing the DVBC bathymetric checking points is shown in Figure 49.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 value of 0.992 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.197 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

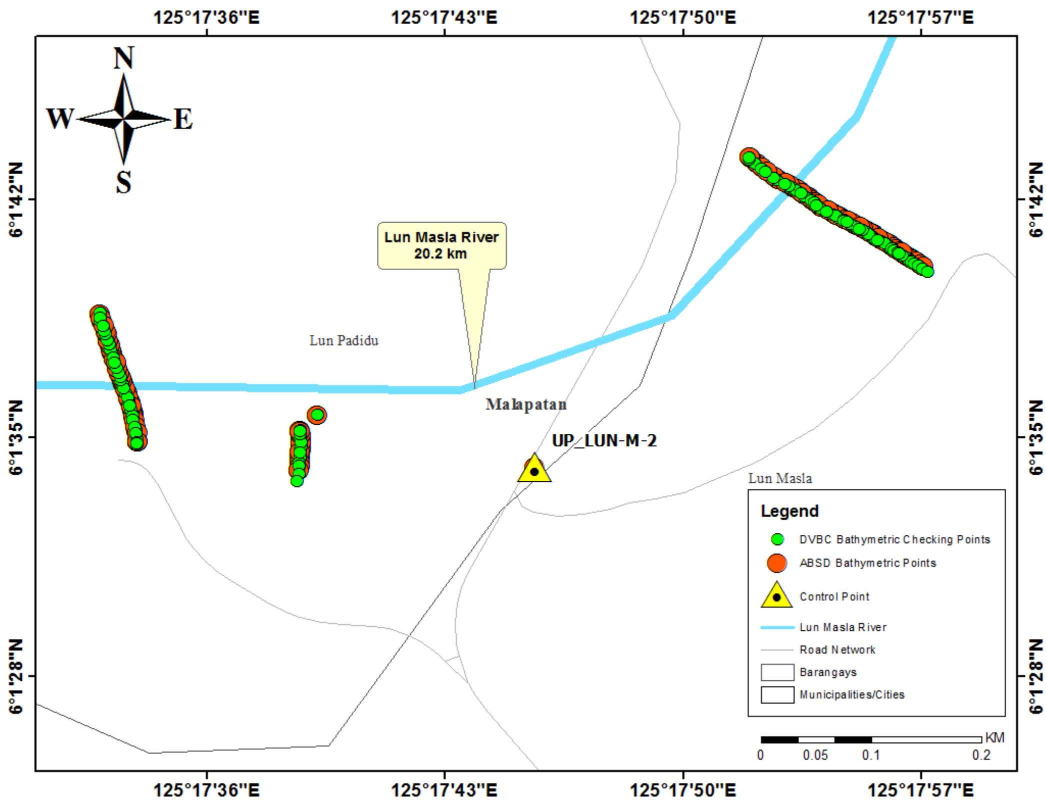


Figure 48. Quality checking points gathered along Lun Masla River by DVBC

A CAD drawing was also produced to illustrate the riverbed profile of Lun Masla River. As shown in Figure 50 and Figure 51, the highest and lowest elevation has a 110-m difference. The highest elevation observed was 110.724 m above MSL located in Brgy. Kinam, Malapatan while the lowest was 0.987 m above MSL located in Brgy. Lun Padidu, Malapatan.

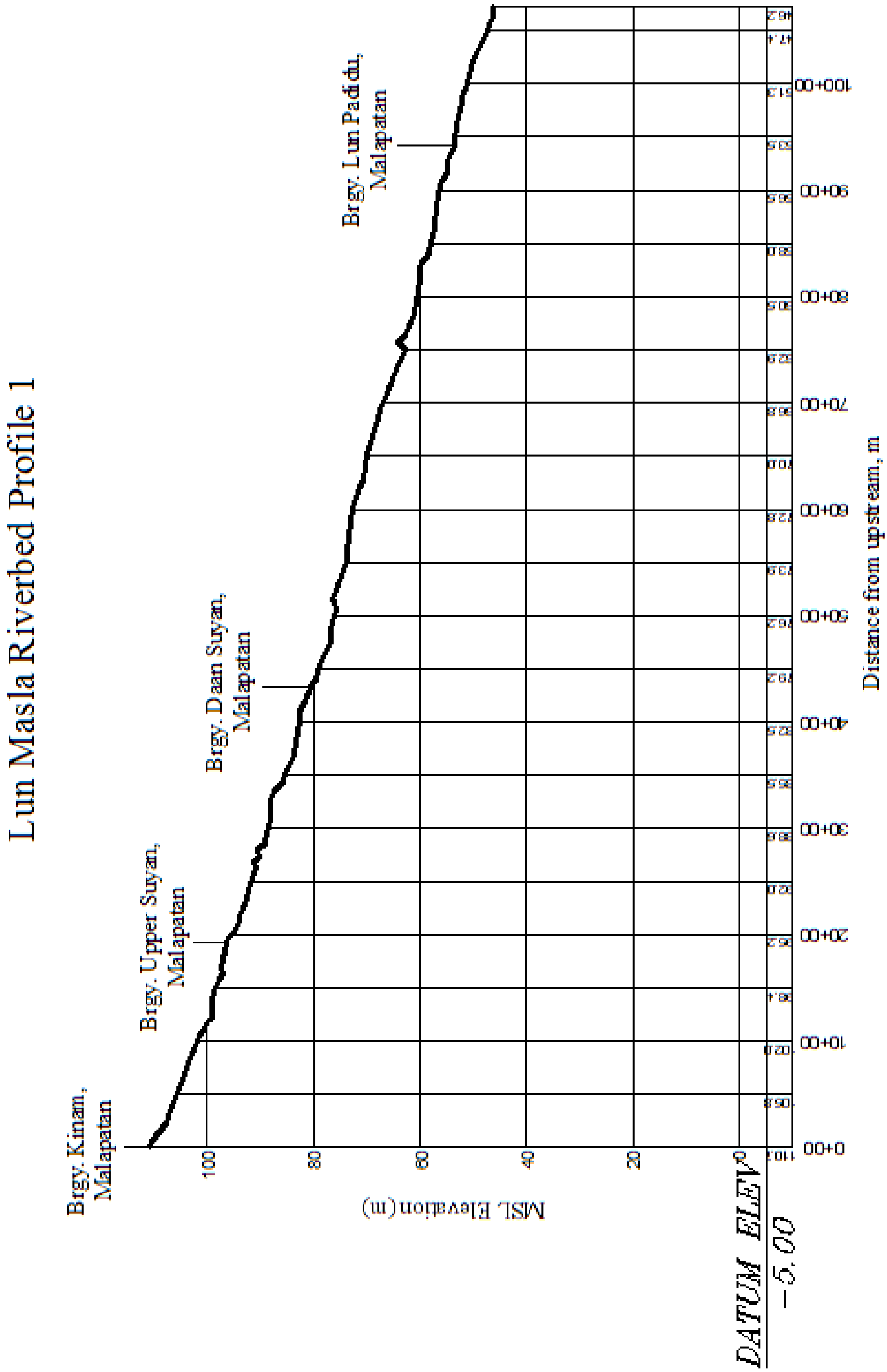


Figure 49. Lun Masla Riverbed Profile 1

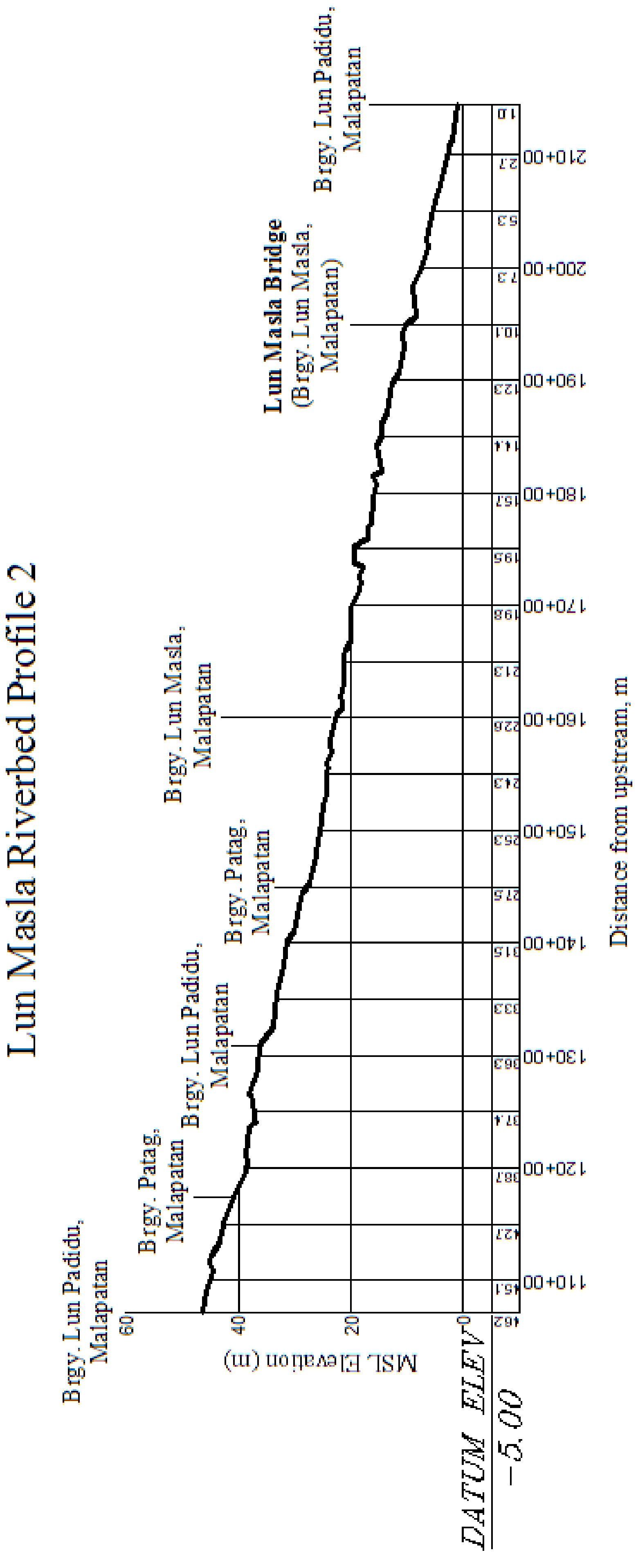


Figure 50. Lun Masla Riverbed Profile 2

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Mariel Monteclaro

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 in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

The Lun Masla River Basin has no existing automated rain gauges (ARGs) for the collection of rainfall data during events. However, the CMU – Phil-LiDAR 1 initializes to install rain gauges for the operation of the project. The two rain gauges were installed in the barangays of Daan Suyan (6° 3’17”N, 125° 22’46”E) and Kinam (6° 0’55”N, 125° 24’47”E). The two ARG are within the Lun Masla River Basin that is shown in Figure 52. An event occured in Lun Masla River last 09 October 2016 that the hydrologic data collection covered 09 hrs 20 minutes from 1310 hrs to 2230 hrs on 09 October 2016. Hydrologic data includes the river velocity, water depth and rainfall data. These were collected from data logging sensors (mechanical velocity meter, depth gauge and rain gauges) in specific time period of the event. Rainfall data can be downloaded from the web portal of Philippine E-Science Grid-ASTI (http://repo.pscigrid.gov.ph) for the ARGs of the DOST-ASTI.

The total precipitation for this event in Daan Suyan rain gauge is 0.2 mm. It peaked to 0.2mm on 09 October 2016, 14:15. For Kinam, total precipitation for this event is 5.2 mm. Peak rain of 2.8 mm was recorded on 09 October 2016, 13:45. The lag times between the peak rainfall and discharge of Daan Suyan and Kinam are 4 hours and 5 minutes and 3 hours and 25 minutes, respectively, illustrated in Figure 54.

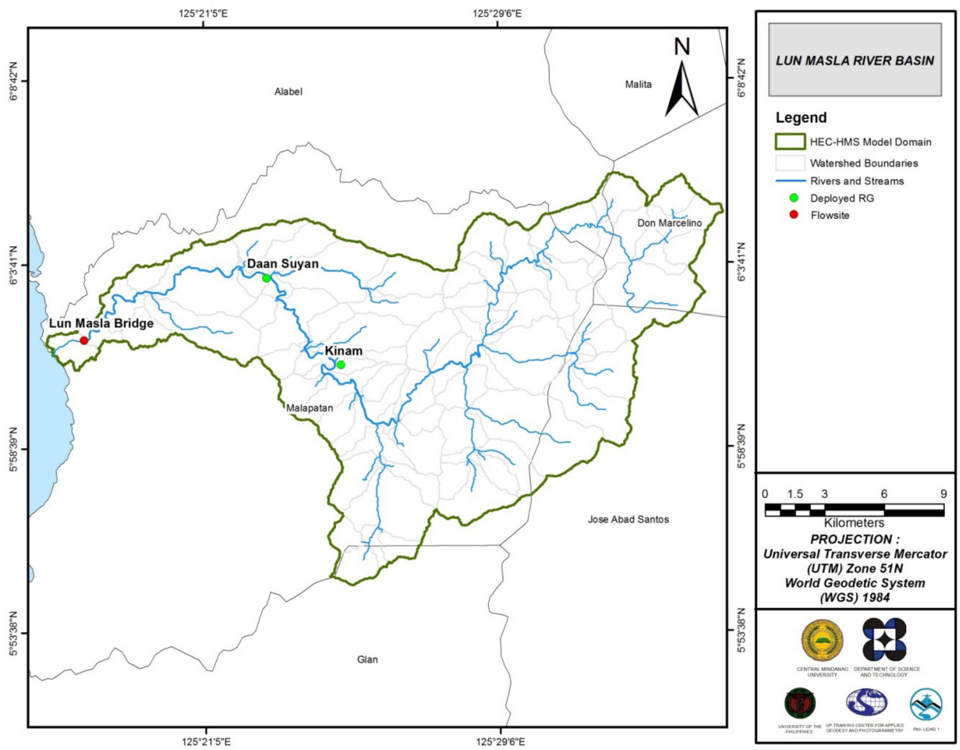


Figure 51. The location map of Lun Masla HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

Hydrologic data collected last 09 October 2016 were entered in HEC-HMS basin model of Lun Masla River Basin for the calibration. The event contributes to a 0.30 meter water level rise with a peak discharge of 4.095 m3/s recorded at 1750 hrs on 09 October 2016 with accumulated rainfall 5.4 mm (Figure 55). It is significant enough to calibrate the basin model of Lun Masla River Basin. Hydrologic measurements were taken from Lun Masla Bridge, Brgy Lun Masla, Malapatan, Sarangani.

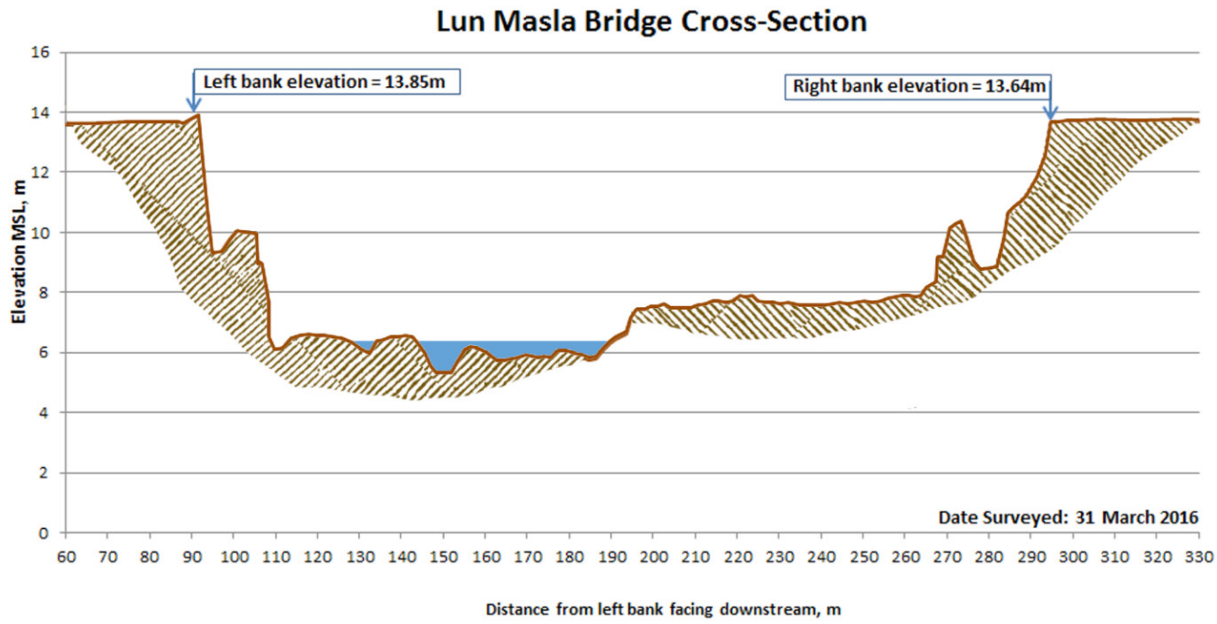


Figure 52. Cross-Section Plot of Lun Masla Bridge

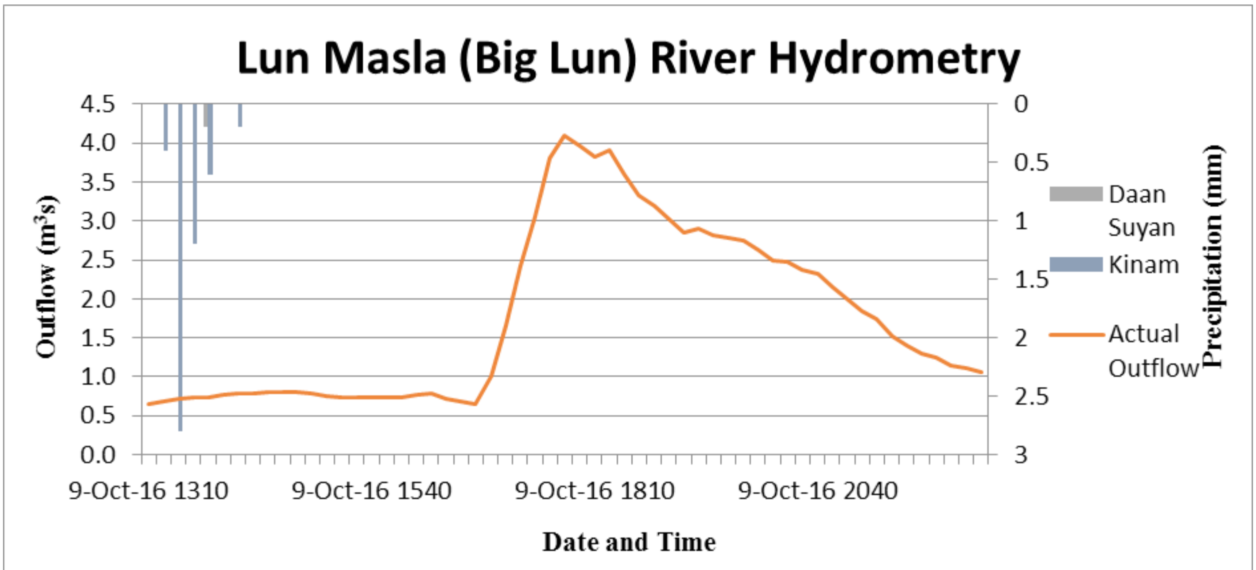


Figure 53. Rainfall and outflow data used for modeling

A rating curve was generated for the observed flow and water level. It shows the relationship of the two hydrologic data. It is expressed in the form of the following equation:

Q=anh

where, Q : Discharge (m3/s),
h : Gauge height (reading from Lun Masla Bridge depth gauge sensor), and
a and n : Constants.

The Lun Masla River Rating Curve measured at Lun Masla Bridge is expressed as Q = 3E-19e5.1272h (Figure 55).

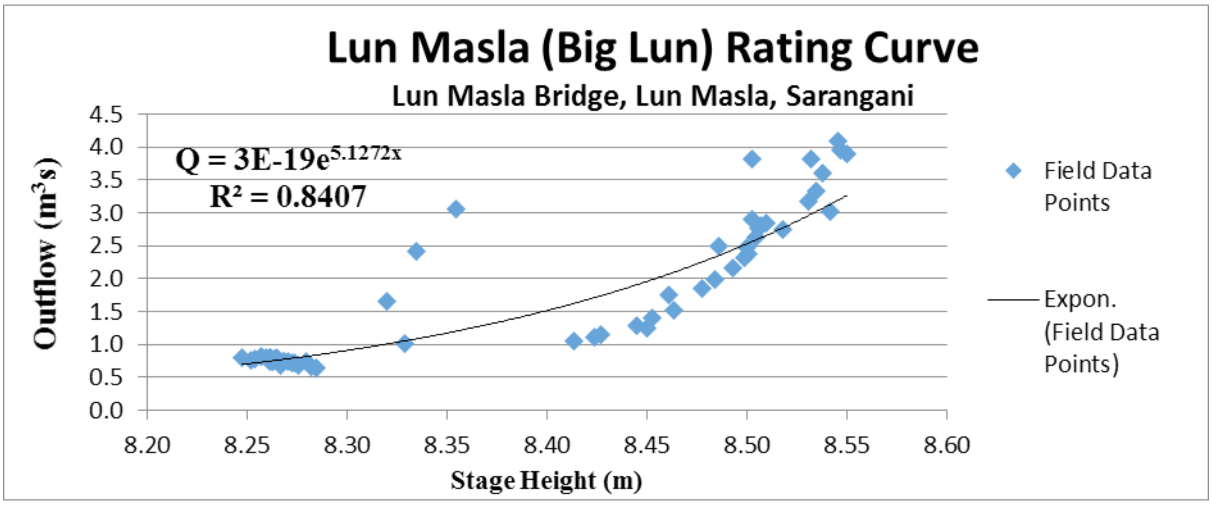


Figure 54. HQ Curve of HEC-HMS model

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the General Santos City 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 is chosen based on its proximity to the Lun Masla watershed. The extreme values for this watershed were computed based on a 31-year record, with the computed extreme values shown in Table 27.

Table 27. RIDF values for General Santos City Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	8.9	13.5	16.9	22.5	32.4	38.7	50.1	60.9	68.9
5	12.7	19.5	24.3	32.5	47.1	56.6	74	90.4	102.7
10	15.3	23.4	29.3	39.1	56.8	68.4	89.8	109.9	125.1
15	16.7	25.6	32.1	42.8	62.3	75.1	98.8	120.9	137.7
20	17.7	27.2	34	45.4	66.1	79.8	105	128.6	146.5
25	18.5	28.4	35.5	47.4	69.1	83.4	109.8	134.5	153.4
50	20.9	32.1	40.2	53.6	78.2	94.5	124.7	152.8	174.3
100	23.3	35.8	44.8	59.8	87.2	105.5	139.4	170.9	195.2

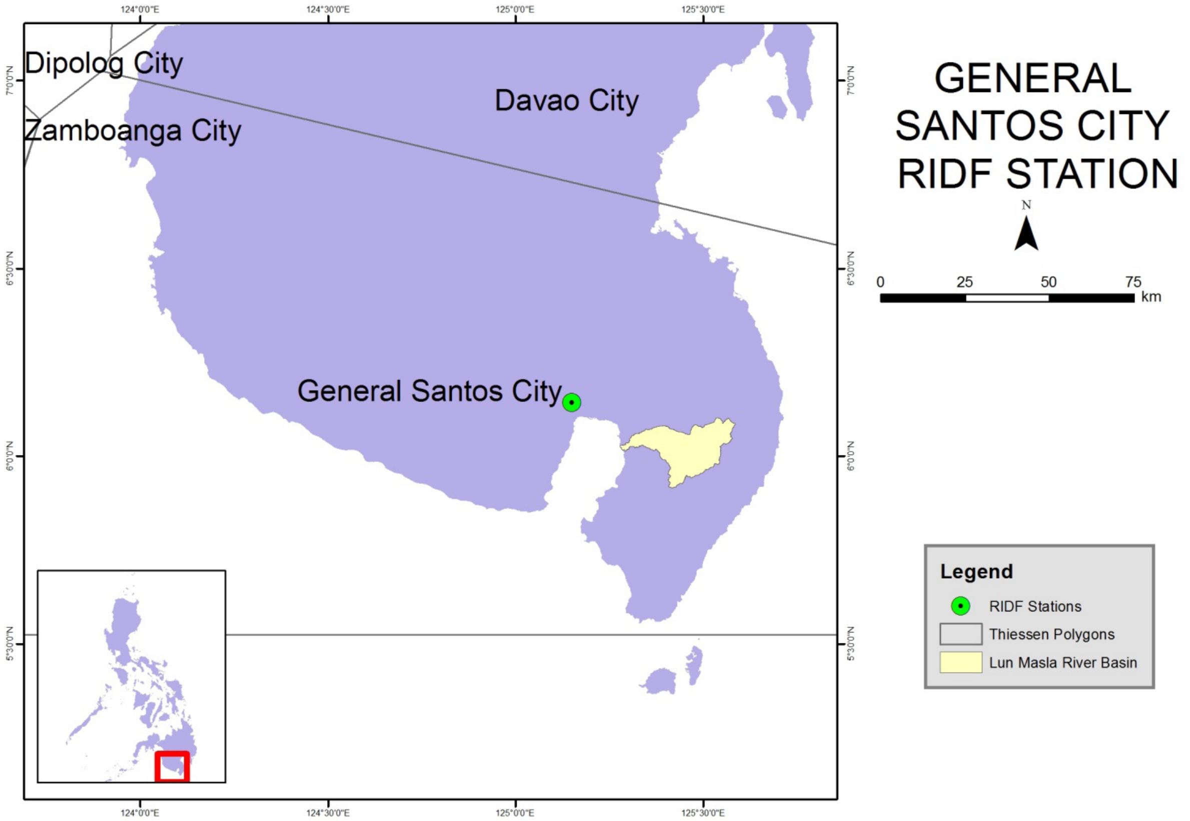


Figure 55. Location of General Santos City RIDF relative to Lun Masla River Basin

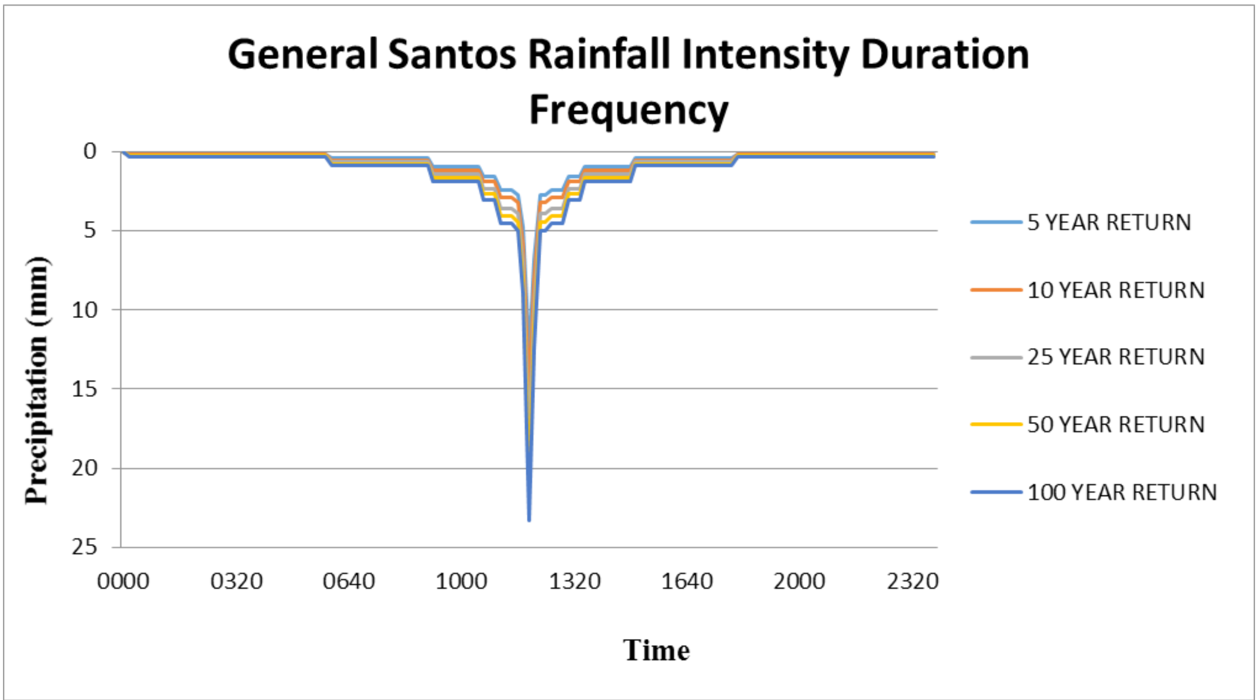


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management 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 Lun Masla River Basin are shown in Figure 58 and Figure 59, respectively.

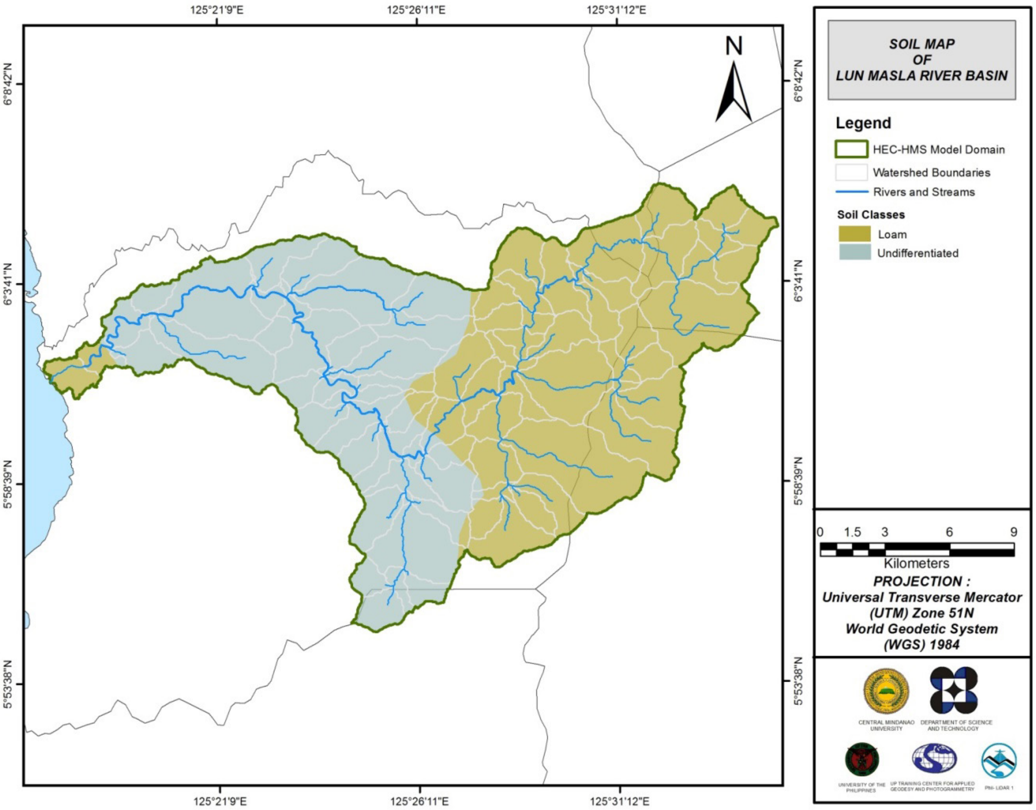


Figure 57. Soil map of Lun Masla River Basin used for the estimation of the CN parameter. (Source: DA)

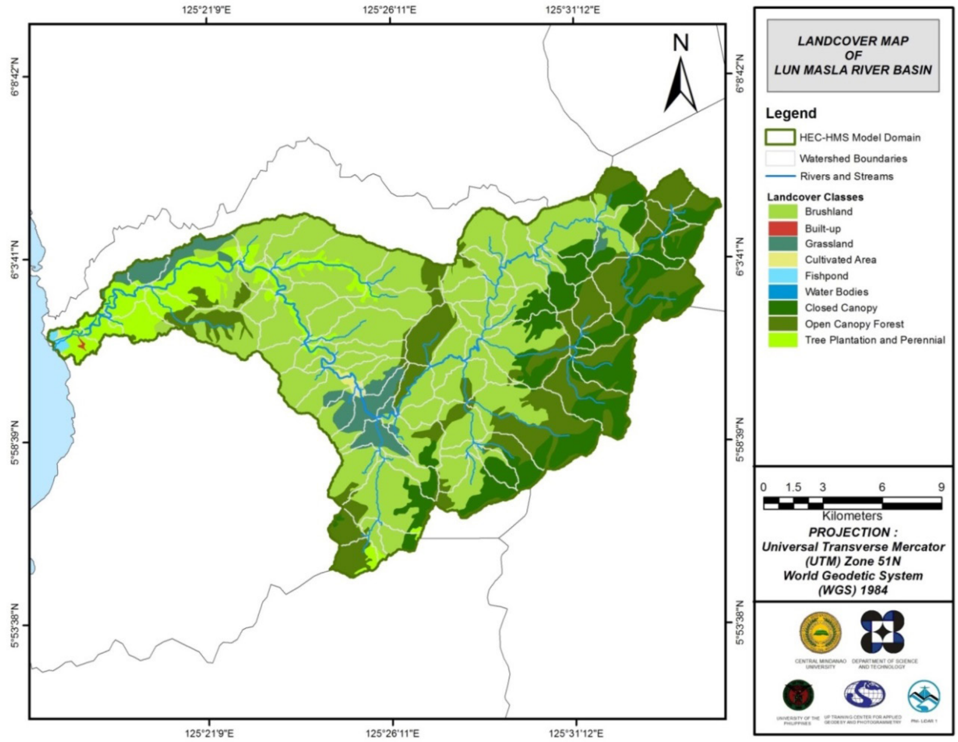


Figure 58. Land cover map of Lun Masla River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Lun Masla, two (2) soil classes were identified. These are loam and undifferentiated soil. Moreover, nine (9) land cover classes were identified. These are brushland, built-up, grassland, cultivated area, fishpond, water bodies, closed canopy, open canopy forest, and tree plantation and perennial.

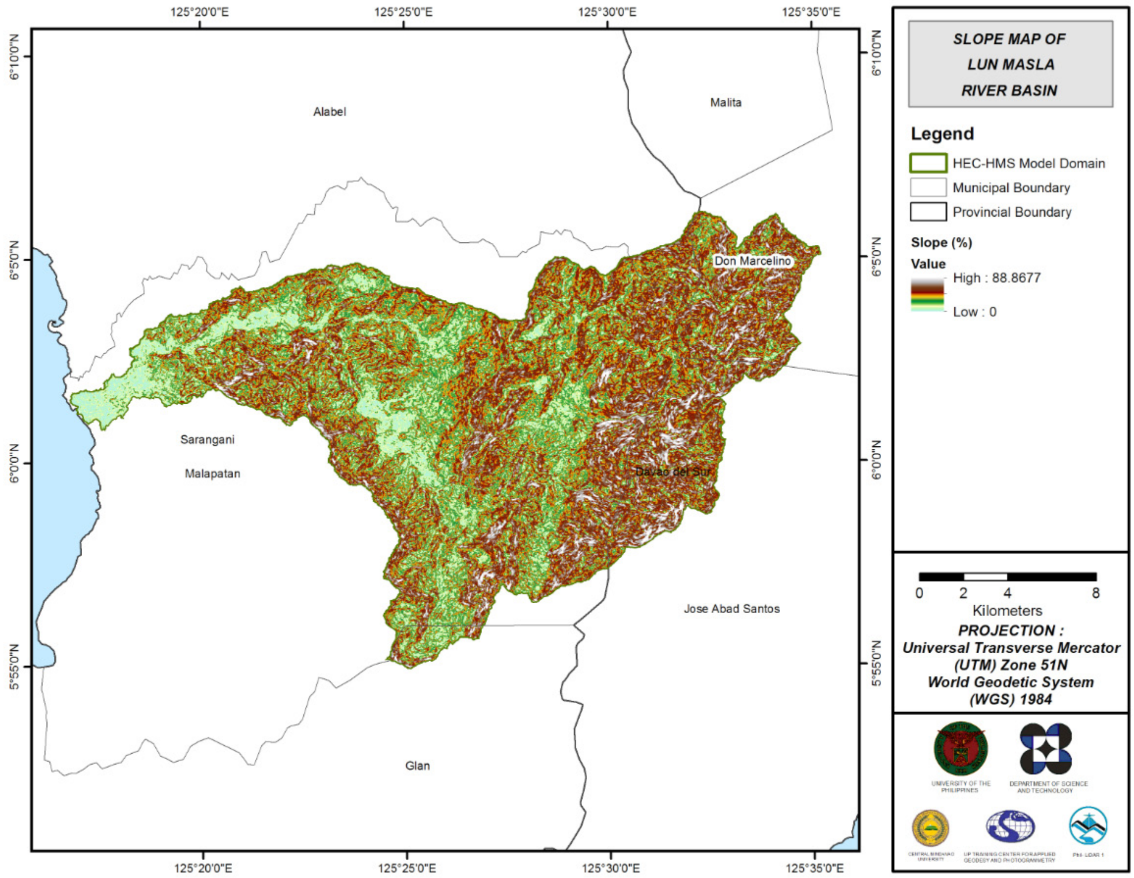


Figure 59. Slope map of Lun Masla River Basin

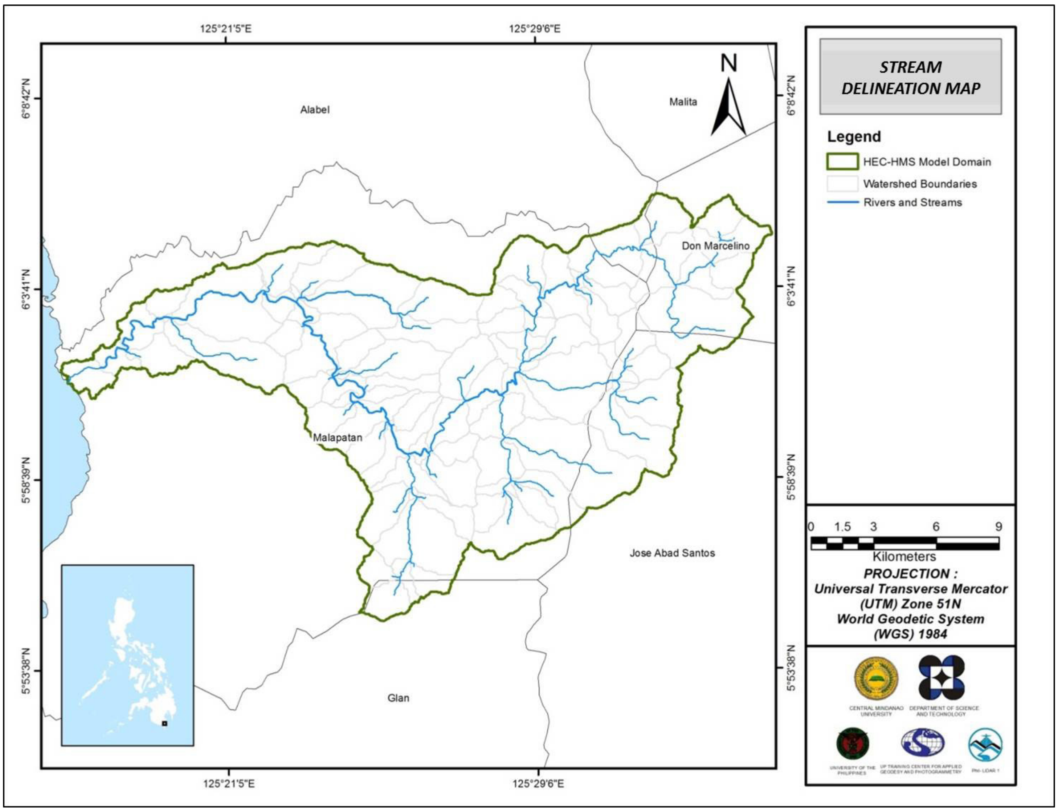


Figure 60. Stream delineation map of Lun Masla River Basin

Two main datasets for the delineation of the drainage system of Lun Masla River Basin are the SAR-DEM 10 meter resolution and river centreline. A drainage system includes the basin boundary, subbasin and the stream networks of the basin. The river centreline was digitized starting from upstream towards downstream in Google Earth (2014).

Using the SAR-based DEM, the Lun Masla basin was delineated and further subdivided into subbasins. Lun Masla River Basin generated eighty seven (87) subbasins, forty-four (44) reaches and forty-five (45) junctions including the main outlet consuming the SAR-DEM. Lun Masla drainage system is illustrated in Figure 62.

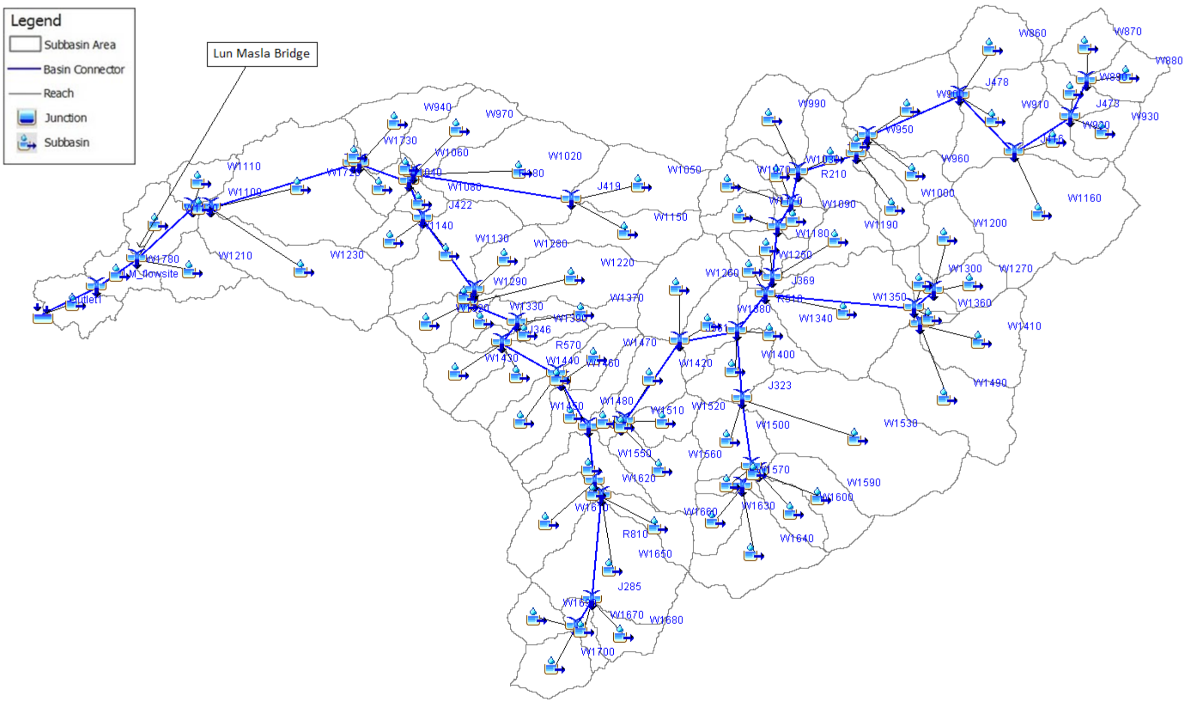


Figure 61. HEC-HMS generated Lun Masla River Basin Model.

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.

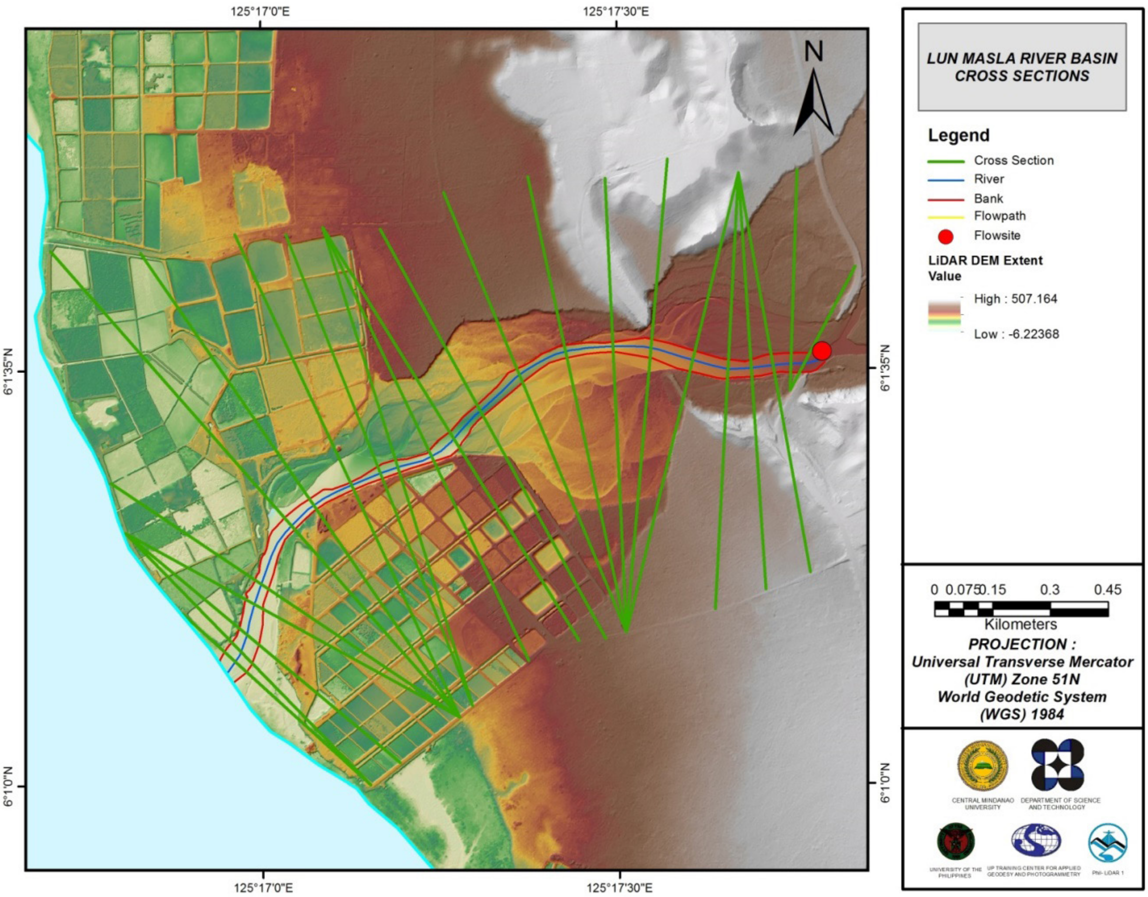


Figure 62. River cross-section of Lun Masla River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

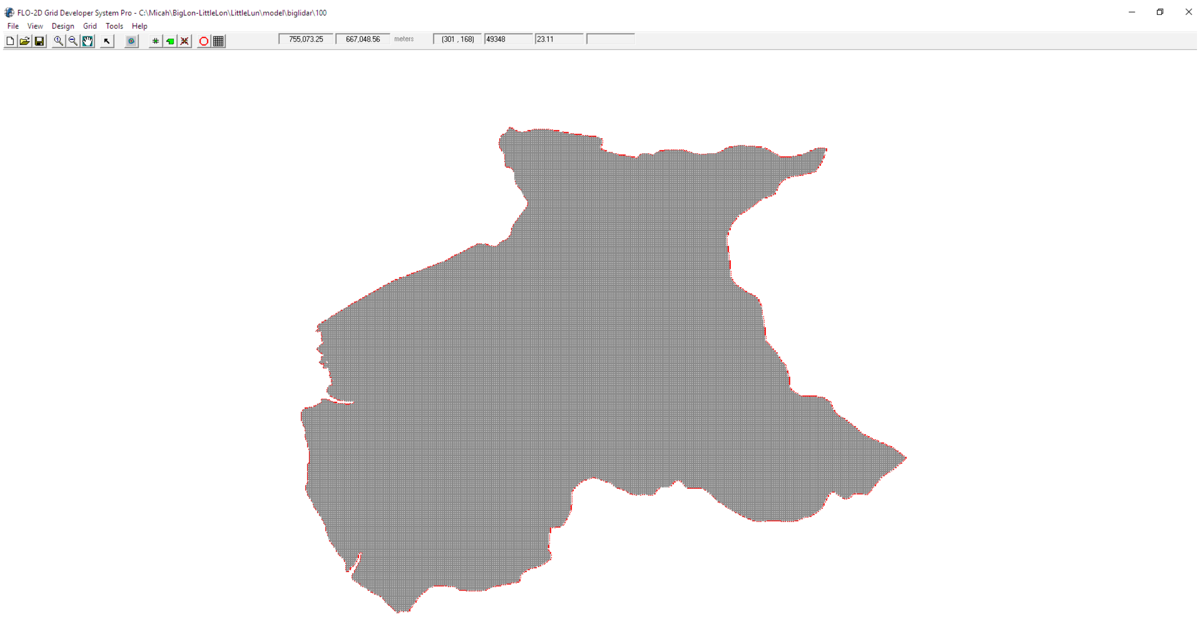


Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 39.55225 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 39 385 900.00 m2.

There is a total of 18 419 757.72 m3 of water entering the model. Of this amount, 10 725 727.85 m3 is due to rainfall while 7 694 029.87 m3 is inflow from other areas outside the model. 3 960 626.75 m3 of this water is lost to infiltration and interception, while 12 447 417.07 m3 is stored by the flood plain. The rest, amounting up to 2 011 714.06 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Lun Masla HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 65 shows the comparison between the two discharge data.

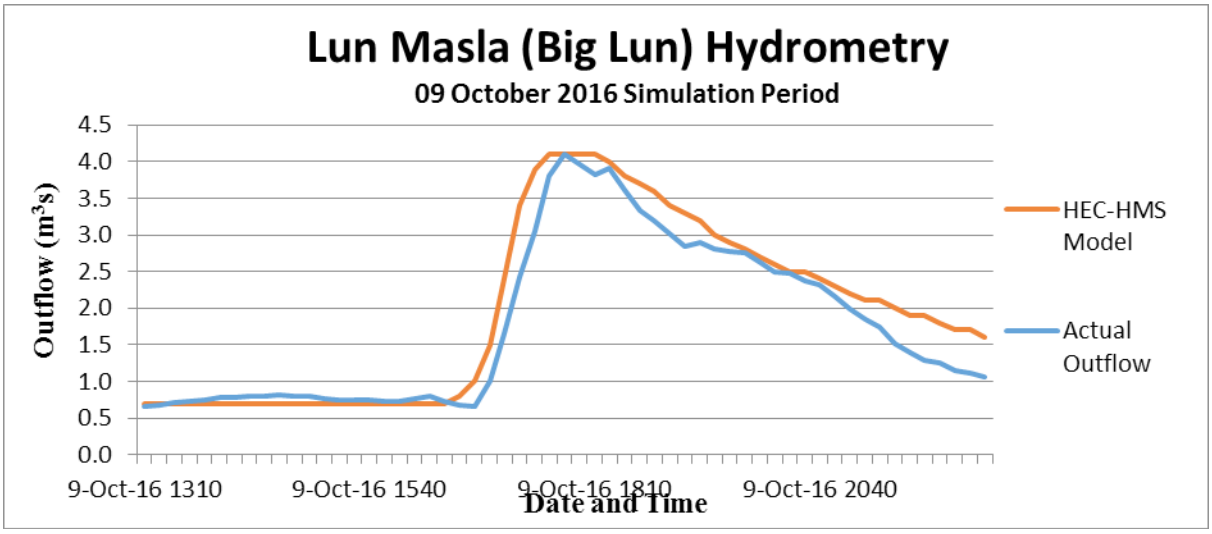


Figure 64. Outflow Hydrograph of Lun Masla produced by the HEC-HMS model compared with observed outflow.

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

Table 28. RIDF values for General Santos City Rain Gauge computed by PAGASA

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	85 - 170
			Curve Number	40 - 56
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.016 – 0.57
			Storage Coefficient (hr)	0.061 – 5.19
	Baseflow	Recession	Recession Constant	0.00001 – 0.009
			Ratio to Peak	0.4
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.001 – 0.02

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 85mm to 170mm signifies that there is average to high infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 40 to 65 for curve number is lower than the advisable range for Philippine watersheds (70 – 80) depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Lun Masla, the basin mostly consists of brushland and the soil consists of clay and undifferentiated soil.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.016 hours to 5 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.00001 – 0.009 indicates that the basin will quickly go back to its original discharge. Ratio to peak of 0.4 indicates a less steep receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.001 to 0.02 is less than the roughness coefficient of 0.1 corresponding to the value for the land cover of Lun Masla which is determined to be brushland (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Lun Masla HMS Model

Accuracy measure	Value
RMSE	0.3
r2	0.75
NSE	0.91
PBIAS	13.12
RSR	0.30

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.3 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 0.75.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.91.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 13.12.

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 0.30.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 66) shows the Lun Masla River outflow using the General SAntos 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.

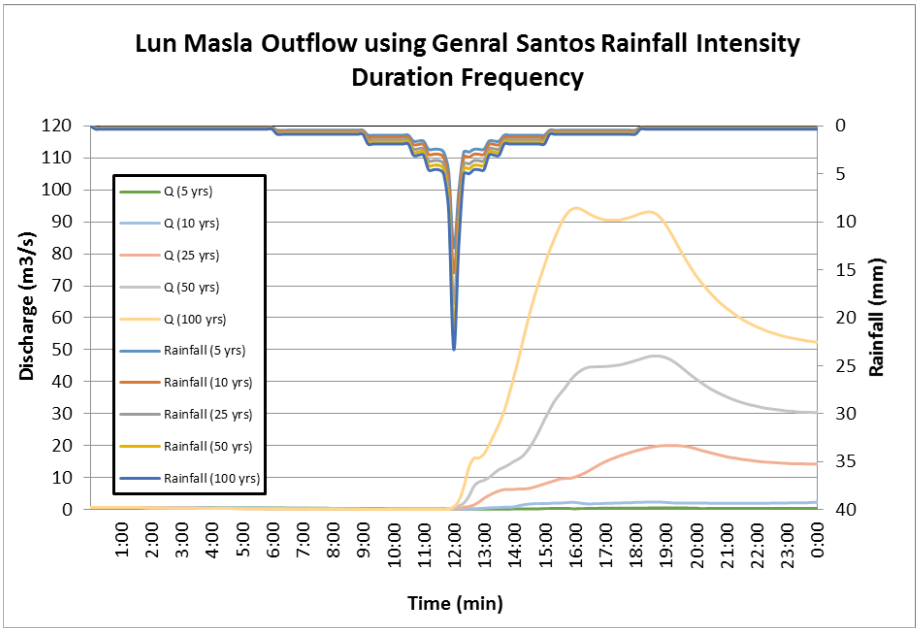


Figure 65. Outflow hydrograph at Lun Masla Station generated using General Santos City RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Lun Masla HECHMS Model outflow using the General Santos City RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	102.7	12.7	0.6	6 hours and 30 minutes
10-Year	125.1	15.3	2.4	6 hours and 20 minutes
25-Year	153.4	18.5	20.1	7 hours
50-Year	174.3	20.9	48.1	6 hours and 40 minutes
100-Year	195.2	23.3	94.3	4 hours

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

The river discharge values for the nine rivers entering the floodplain are shown in Figure 67 to Figure 68 and the peak values are summarized in Table 31 to Table 32.

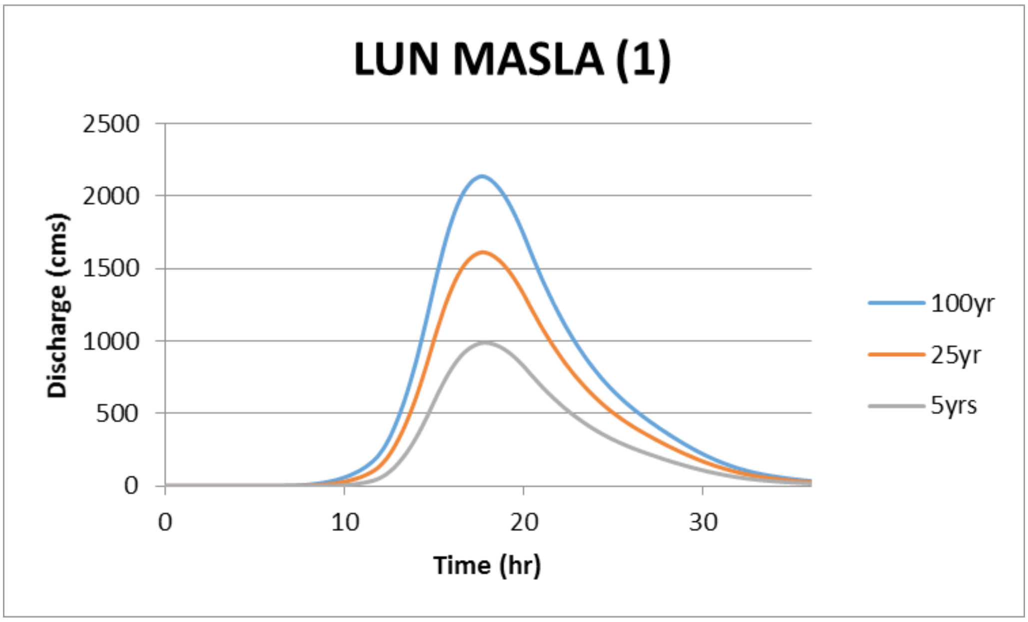


Figure 66. Lun Masla river (1) generated discharge using 5-, 25-, and 100-year General Santos City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

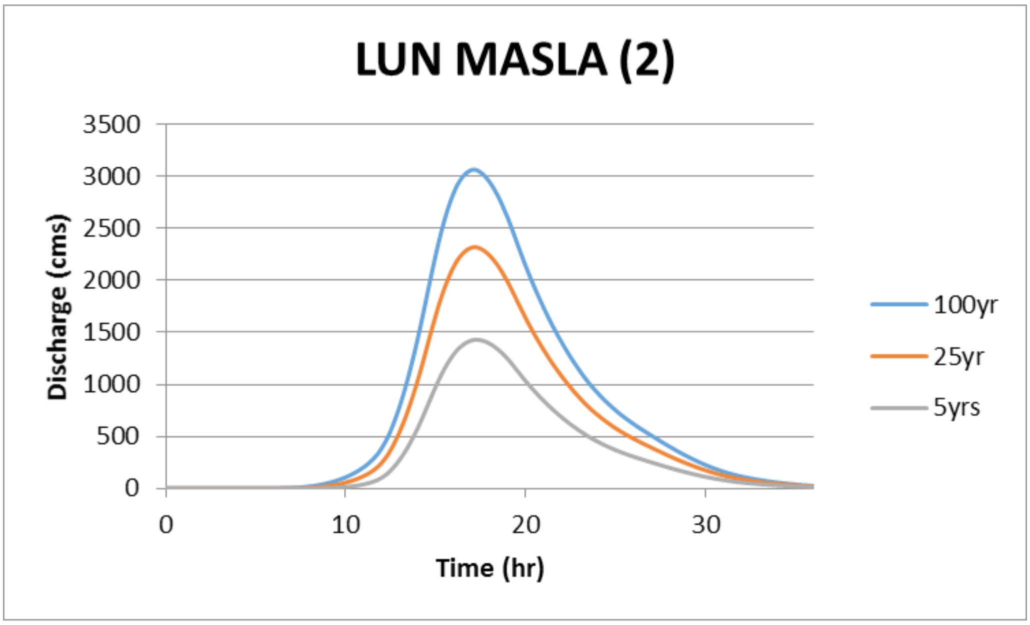


Figure 67. Lun Masla river (2) generated discharge using 5-, 25-, and 100-year General Santos City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Lun Masla river (1) discharge generated in HEC-HMSs

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2138.7	17 hours, 40 minutes
25-Year	1614.1	17 hours, 40 minutes
5-Year	989.5	17 hours, 40 minutes

Table 32. Summary of Lun Masla river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	3066.5	17 hours, 10 minutes
25-Year	2321.4	17 hours, 10 minutes
5-Year	1429.9	17 hours, 10 minutes

Table 33. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Lun Masla (1)	870.760	1236.683	615.503	Pass	Pass
Lun Masla (2)	1258.312	1171.098	526.717	Pass	Fail

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

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Lun Masla River using the calibrated HMS base flow is shown in Figure 69.

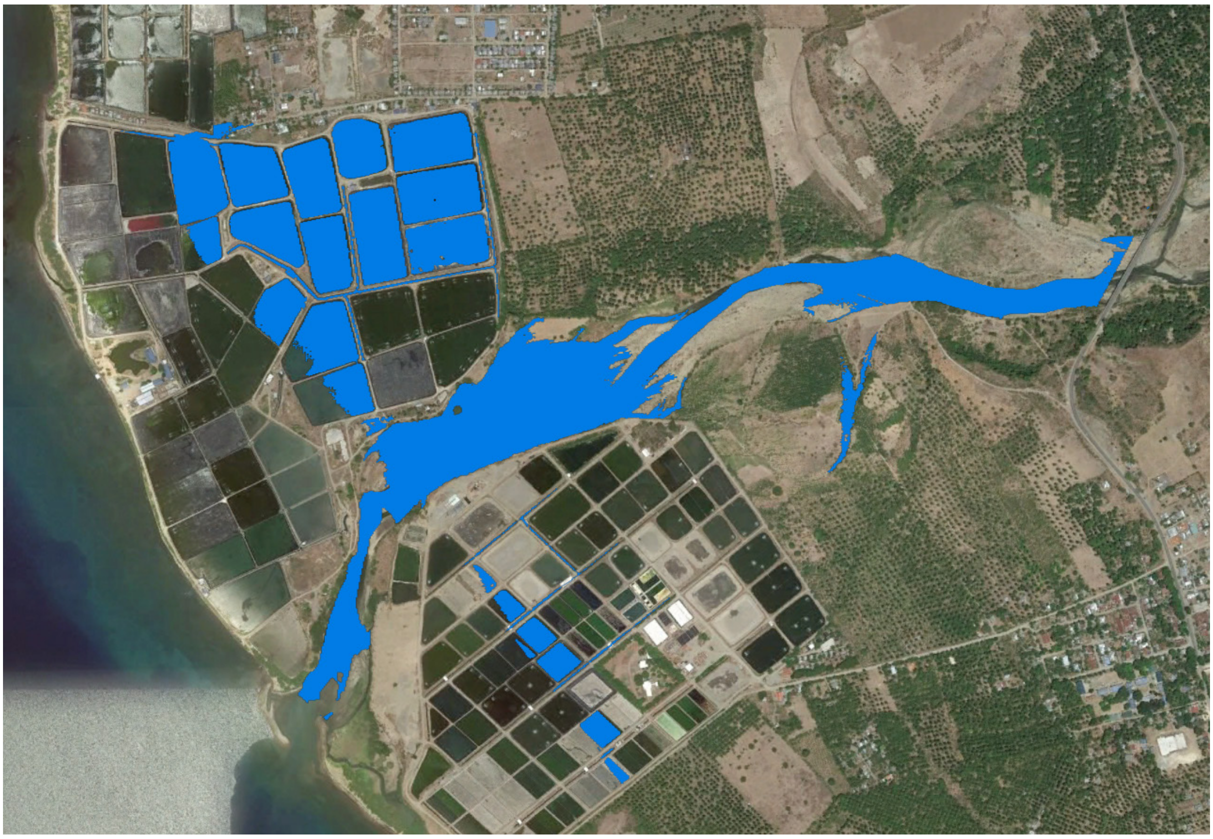


Figure 68. Sample output of Lun Masla RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 70 to Figure 75 shows the 5-, 25-, and 100-year rain return scenarios of the Lun Masla floodplain. The floodplain, with an area of 19.84 sq. km., covers two municipalites namely Alabel and Malapatan. Table 34 shows the percentage of area affected by flooding per municipality.

Table 34. Validation of river discharge estimates

City / Municipality	Total Area	Area Flooded	% Flooded
Alabel	494.45	2.78	0.56%
Malapatan	568.625	17.06	3.00%

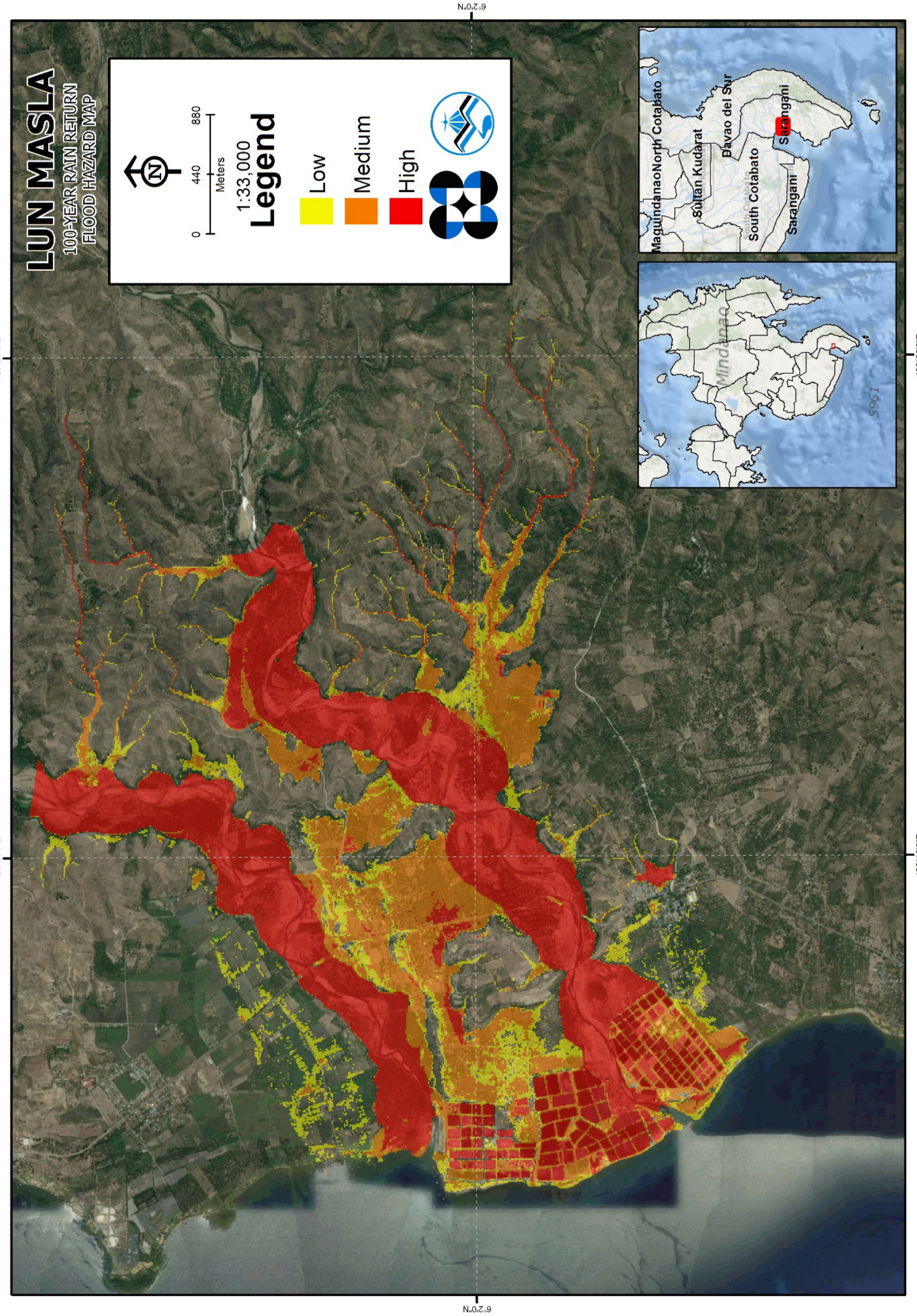


Figure 69. 100-year Flood Hazard Map for Lun Masla Floodplain overlaid on Google Earth imagery

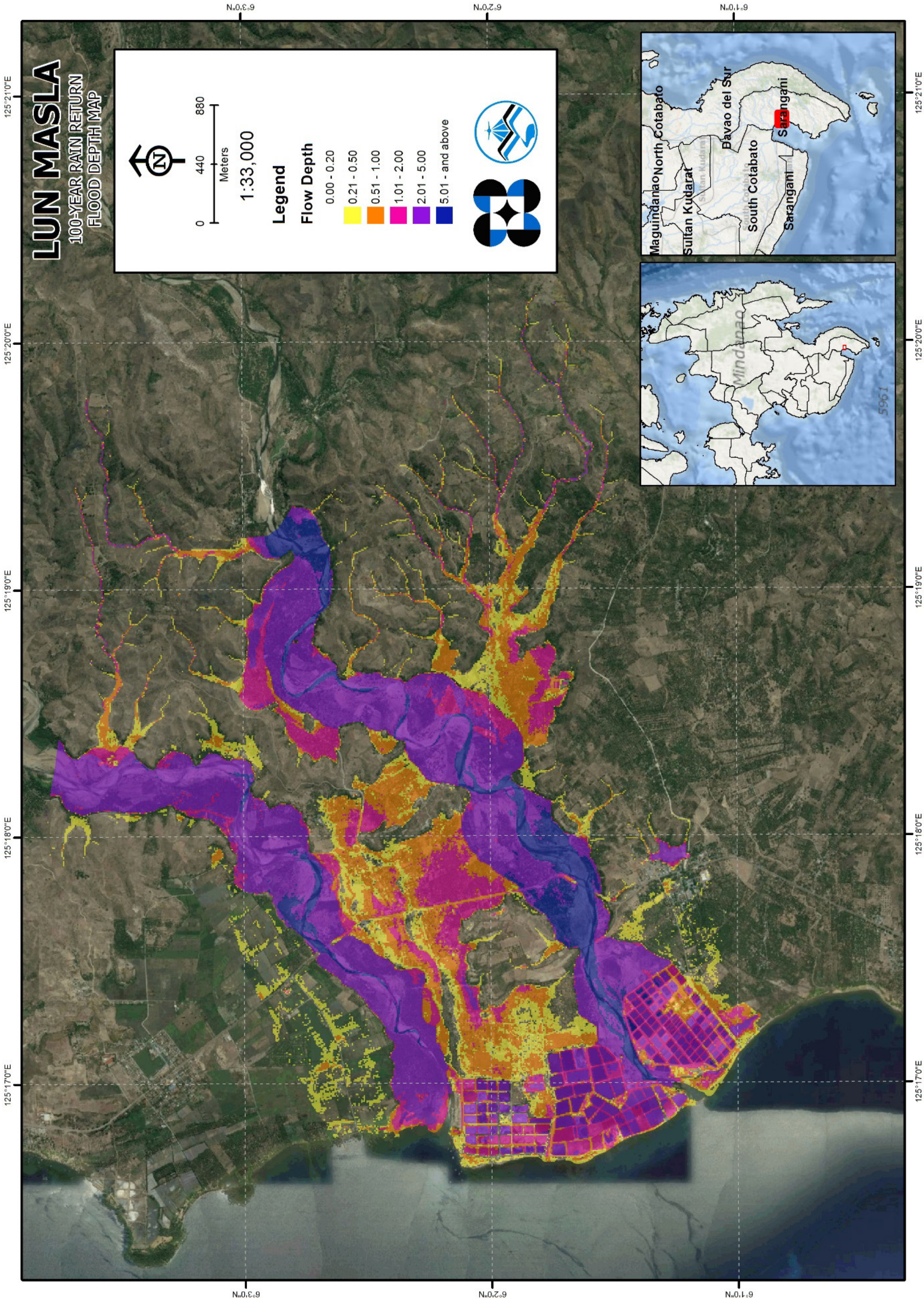


Figure 70. 100-year Flow Depth Map for Lun Masla Floodplain overlaid on Google Earth imagery

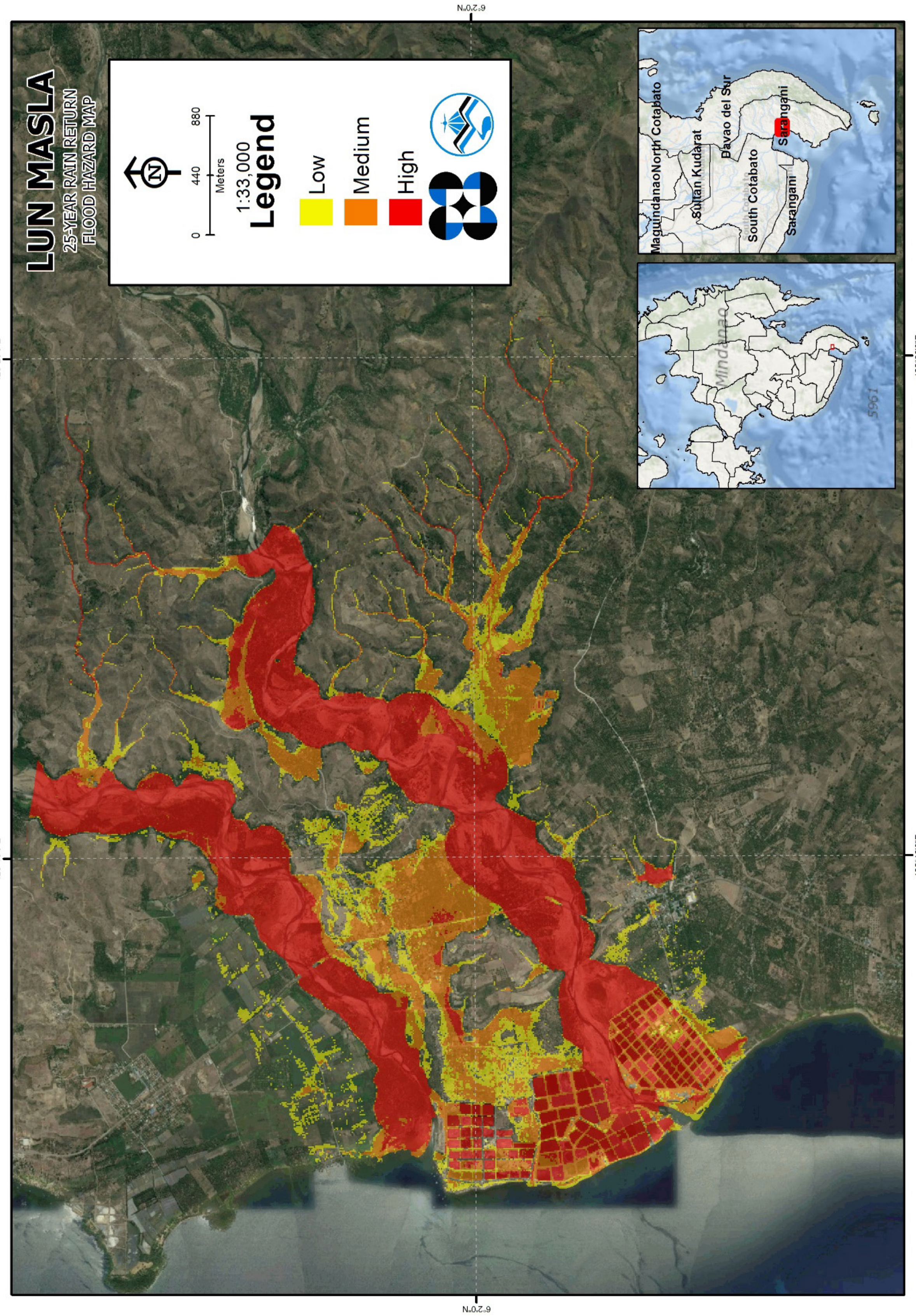


Figure 71. 25-year Flood Hazard Map for Lun Masla Floodplain overlaid on Google Earth imagery

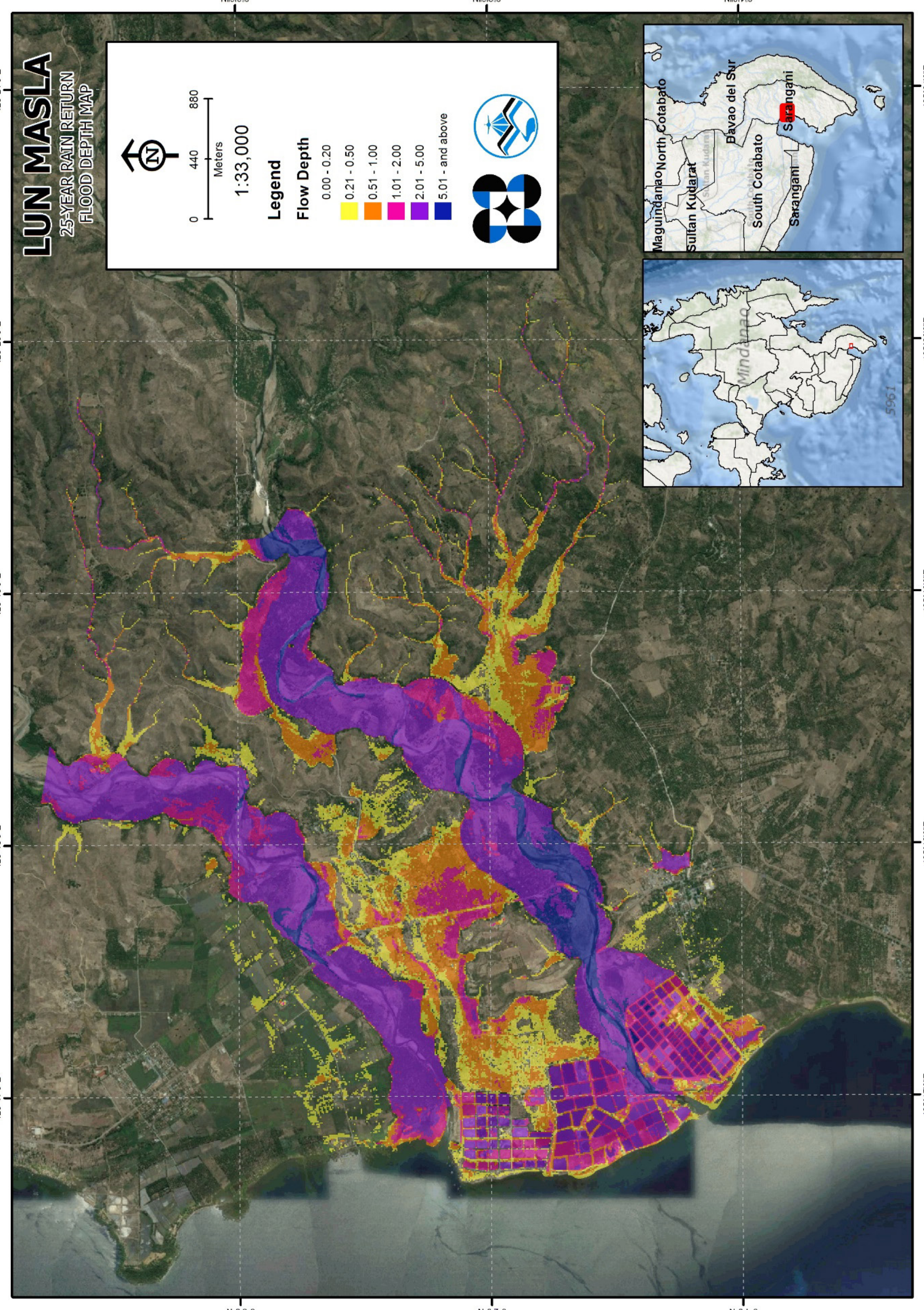


Figure 72. 25-year Flow Depth Map for Lun Masla Floodplain overlaid on Google Earth imagery

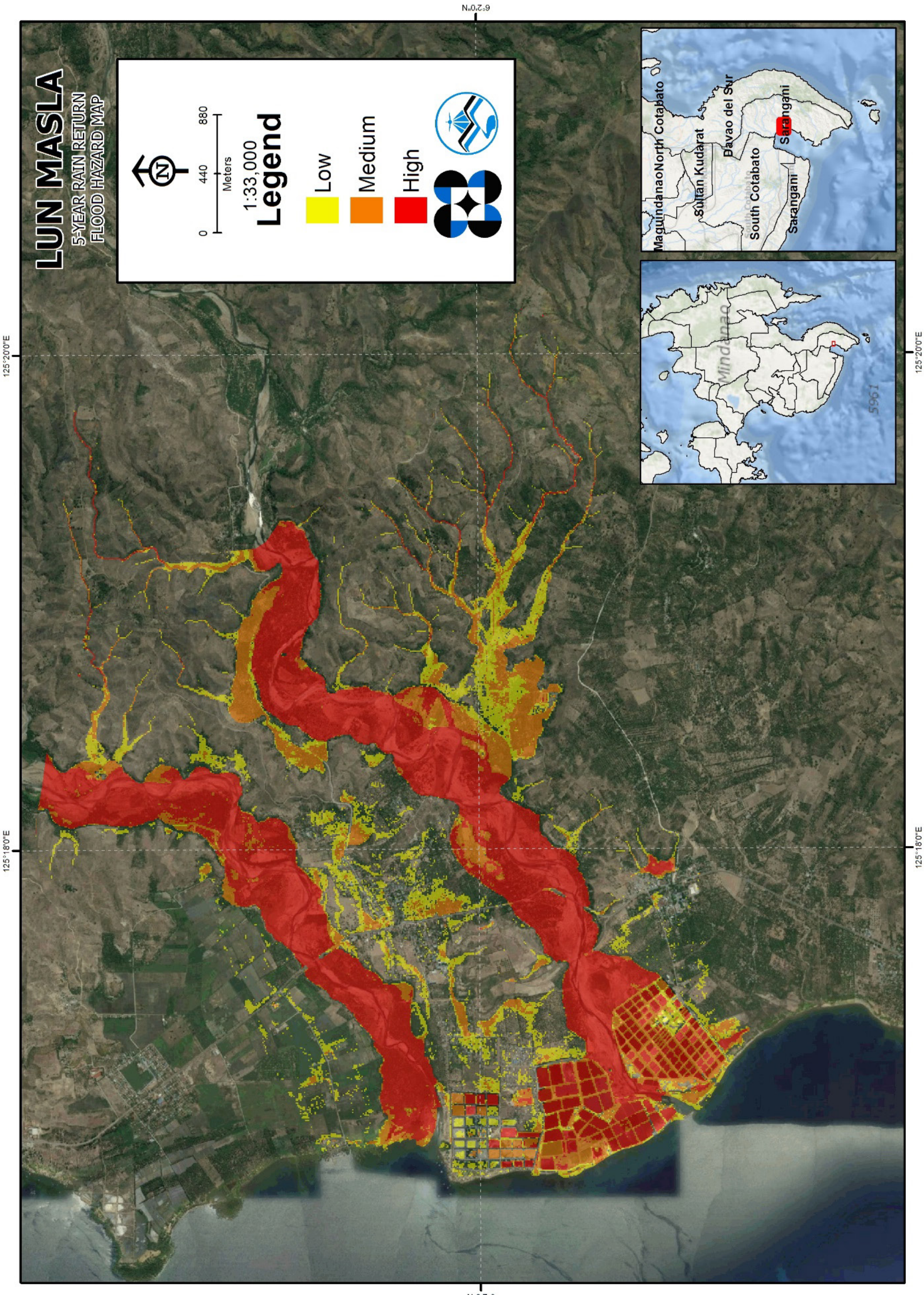


Figure 73. 5-year Flood Hazard Map for Lun Masla Floodplain overlaid on Google Earth imagery

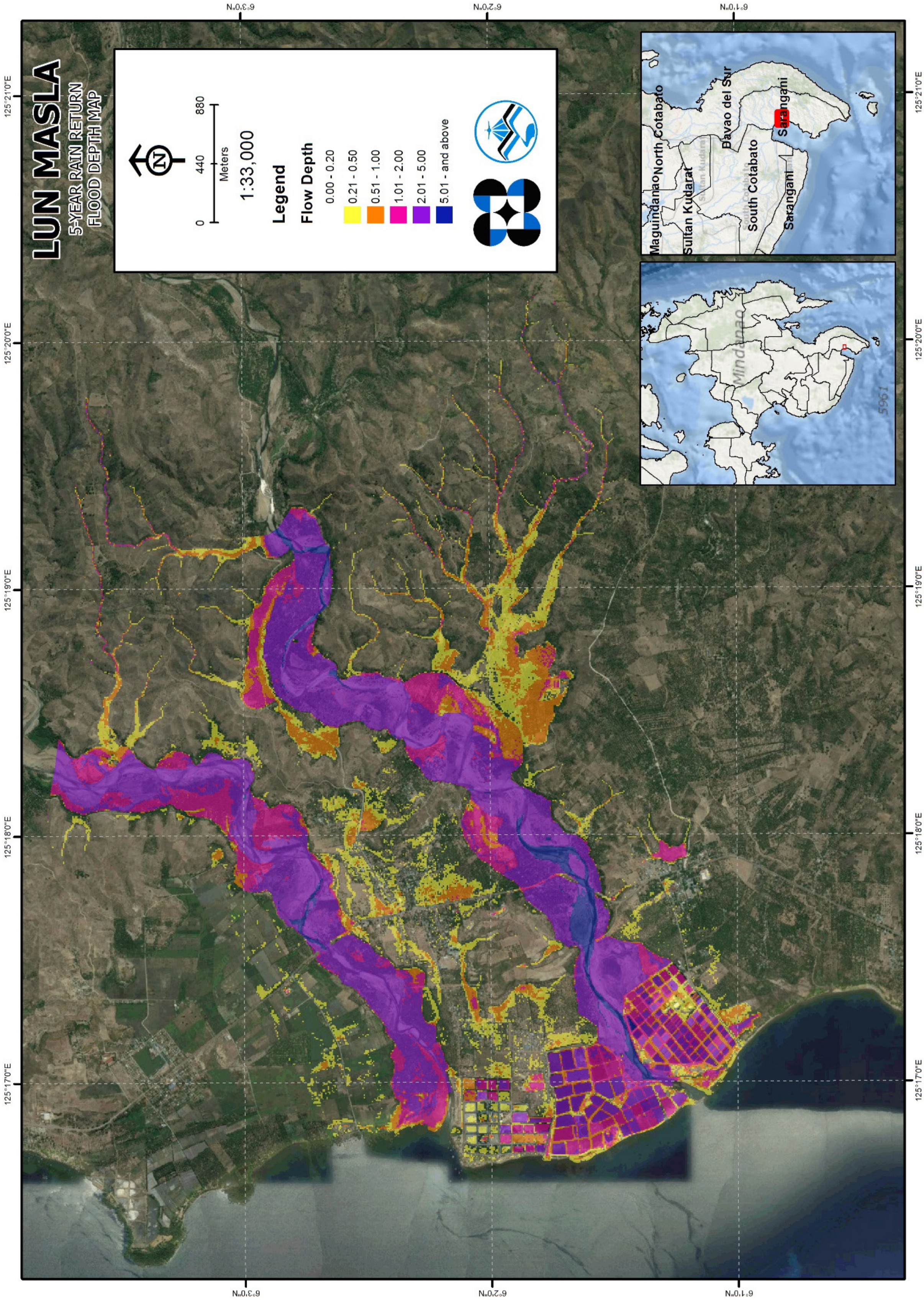


Figure 74. 5-year Flood Depth Map for Lun Masla Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Lun Masla river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 4 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 0.26% of the municipality of Alabel with an area of 479.67 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.03%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed Table 35 and shown in Figure 76 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Alabel, Sarangani during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Alabel (in sq. km)
	Kawas
0.03-0.20	1.26
0.21-0.50	0.12
0.51-1.00	0.046
1.01-2.00	0.12
2.01-5.00	0.33
> 5.00	0.013

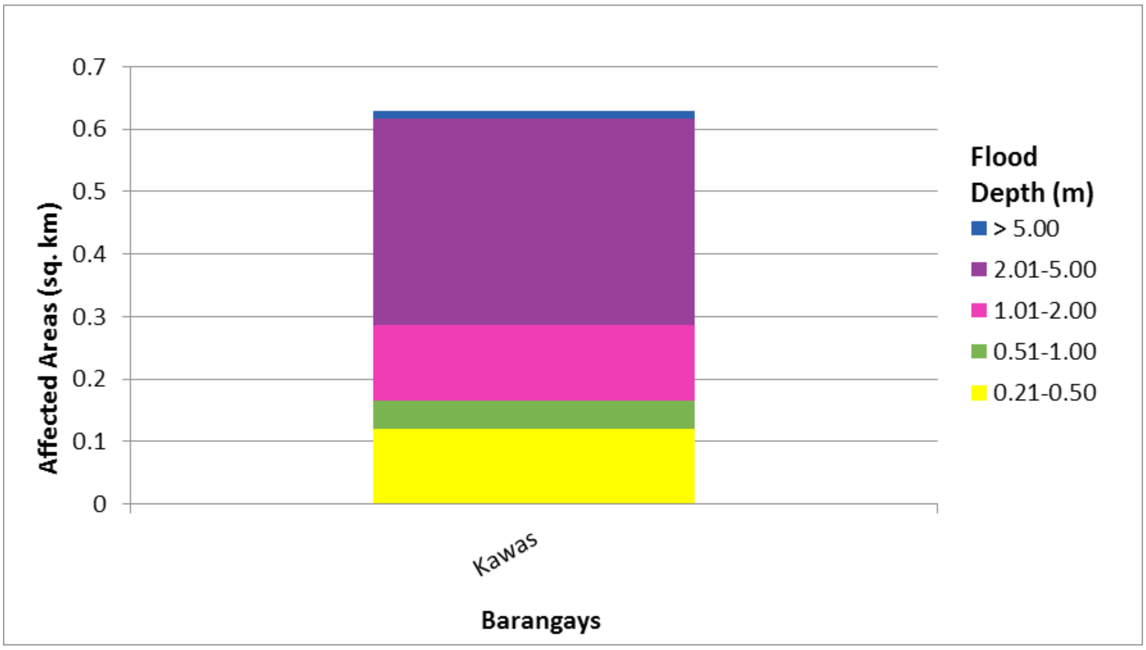


Figure 75. Affected Areas in Alabel, Sarangani during 5-Year Rainfall Return Period

For the 5-year return period, 2.13% of the municipality of Malapatan with an area of 507.60 sq. km. will experience flood levels of less than 0.20 meters. 0.28% of the area will experience flood levels of 0.21 to 0.50 meters while 0.21%, 0.25%, 0.61%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 and shown in Figure 77 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Alabel, Sarangani during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Malapatan (in sq. km)		
	Lun Masla	Lun Padidu	Patag
0.03-0.20	1.62	5.59	3.58
0.21-0.50	0.29	0.86	0.29
0.51-1.00	0.35	0.54	0.17
1.01-2.00	0.23	0.9	0.16
2.01-5.00	0.6	2.22	0.26
> 5.00	0.055	0.18	0.0012

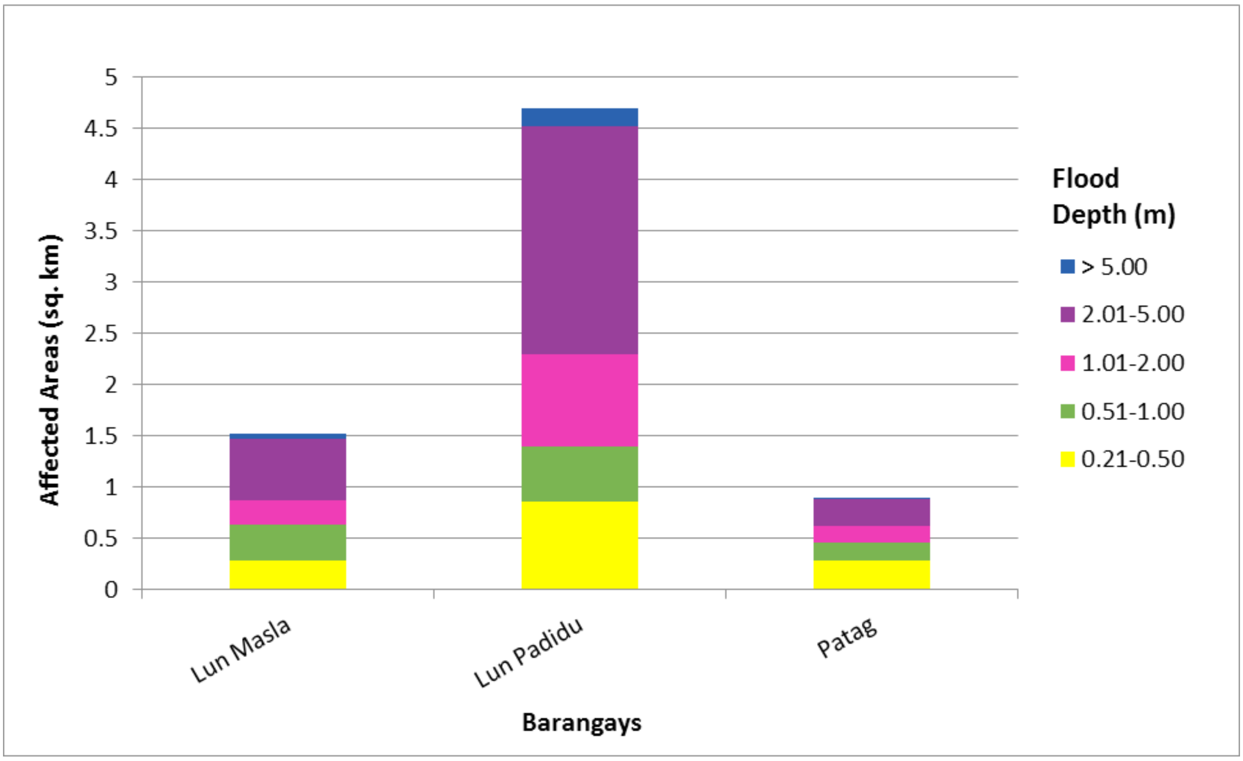


Figure 76. Affected Areas in Malapatan, Sarangani during 5-Year Rainfall Return Period

For the 25-year return period, 0.25% of the municipality of Alabel with an area of 479.67 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.02%, 0.08%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and shown in Figure 78 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Alabel, Sarangani during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Alabel (in sq. km)
	Kawas
0.03-0.20	1.18
0.21-0.50	0.17
0.51-1.00	0.046
1.01-2.00	0.076
2.01-5.00	0.39
> 5.00	0.031

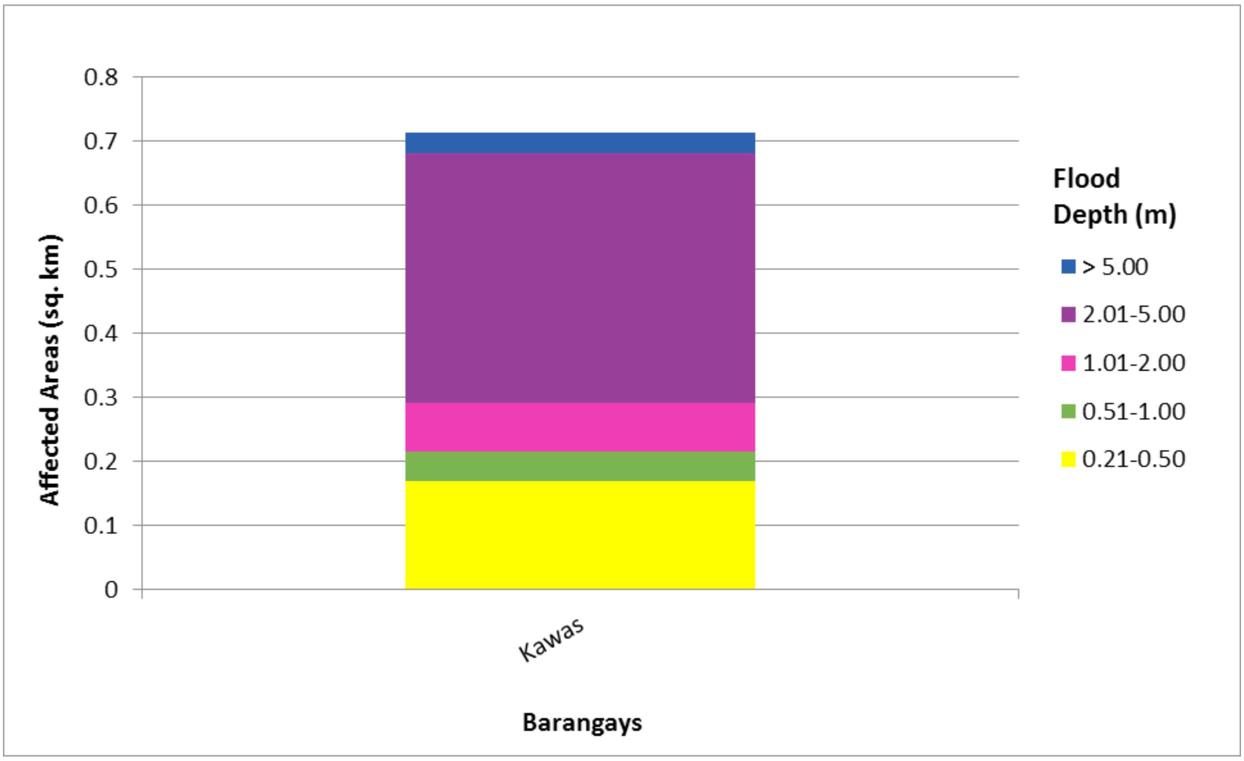


Figure 77. Affected Areas in Alabel, Sarangani during 25-Year Rainfall Return Period

For the 25-year return period, 1.86% of the municipality of Malapatan with an area of 507.60 sq. km. will experience flood levels of less than 0.20 meters. 0.29% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.28%, 0.68%, and 0.11% 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 79 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Malapatan, Sarangani during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Alabel (in sq. km)
	Kawas
0.03-0.20	1.18
0.21-0.50	0.17
0.51-1.00	0.046
1.01-2.00	0.076
2.01-5.00	0.39
> 5.00	0.031

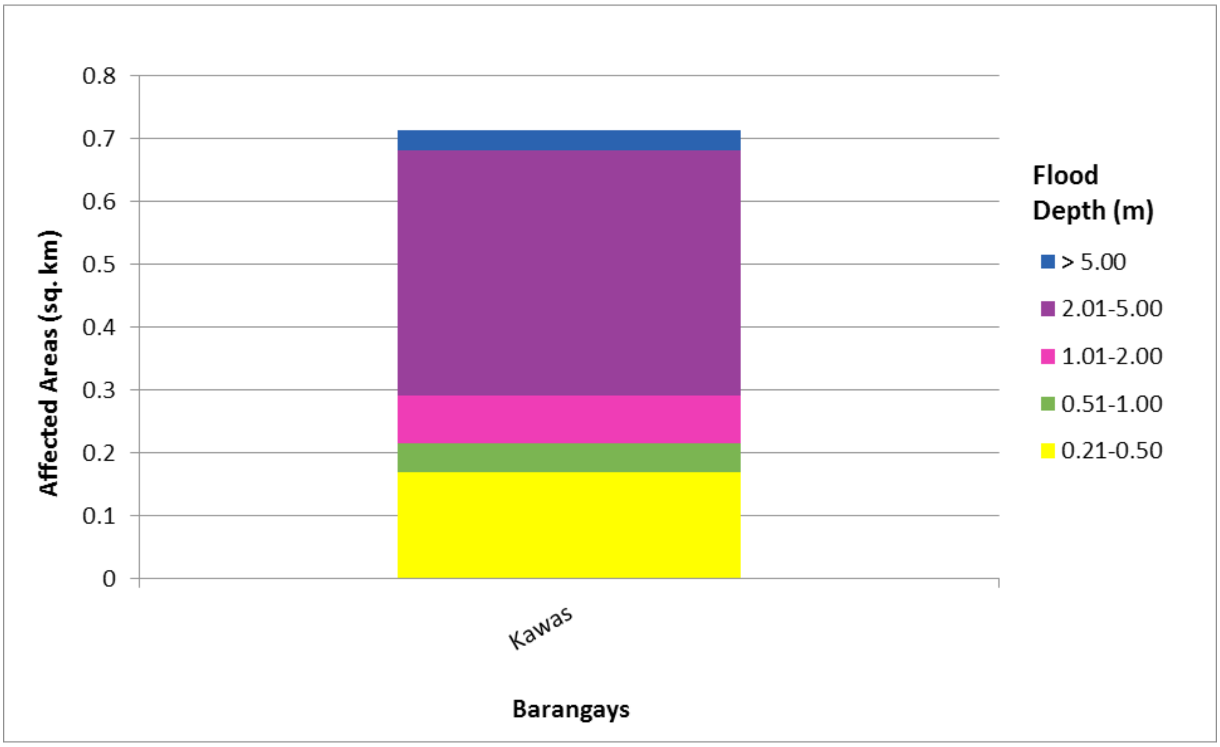


Figure 78. Affected Areas in Malapatan, Sarangani during 25-Year Rainfall Return Period

For the 100-year return period, 0.23% of the municipality of Alabel with an area of 479.67 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.01%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 39 and shown in Figure 80 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Alabel, Sarangani during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Alabel (in sq. km)
	Kawas
0.03-0.20	1.11
0.21-0.50	0.23
0.51-1.00	0.043
1.01-2.00	0.068
2.01-5.00	0.39
> 5.00	0

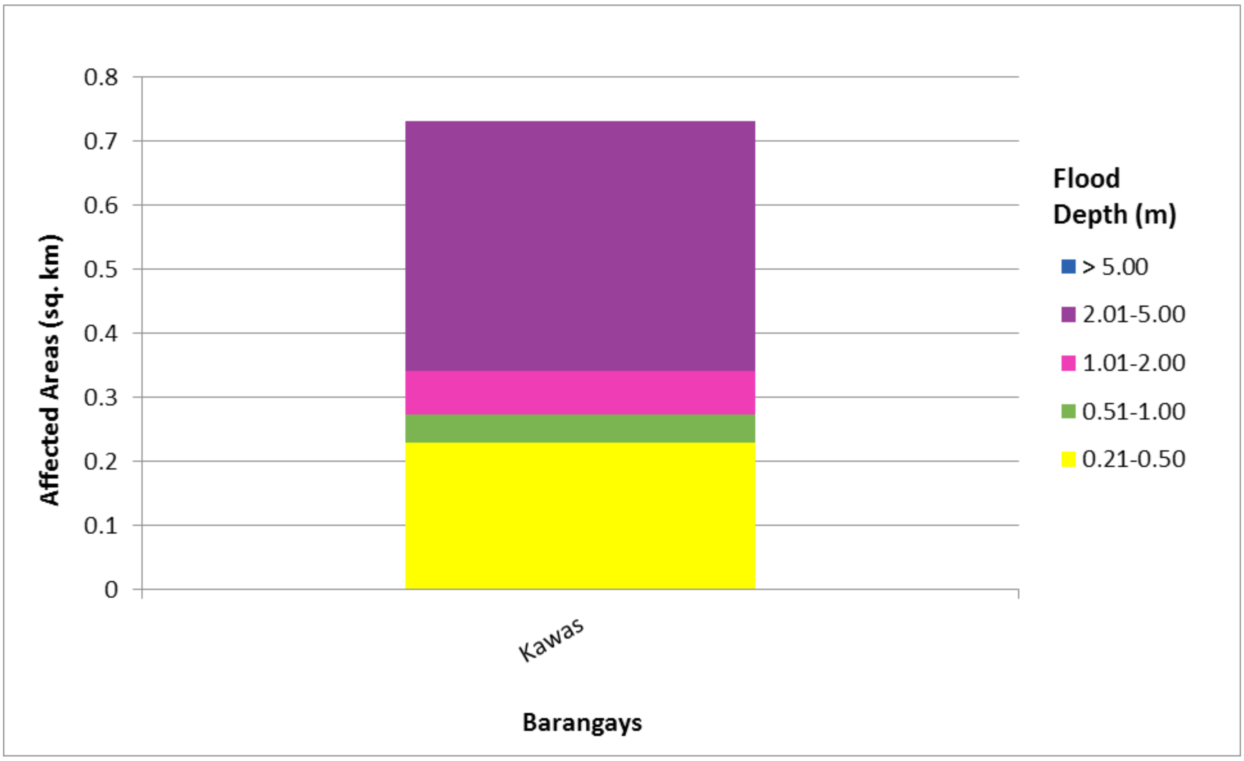


Figure 79. Affected Areas in Alabel, Sarangani during 100-Year Rainfall Return Period

For the 100-year return period, 1.77% of the municipality of Malapatan with an area of 507.60 sq. km. will experience flood levels of less than 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.31%, and 0.71% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 40 and shown in Figure 81 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Alabel, Sarangani during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Malapatan (in sq. km)		
	Lun Masla	Lun Padidu	Patag
0.03-0.20	1.41	4.1	3.45
0.21-0.50	0.26	0.76	0.24
0.51-1.00	0.33	1.19	0.27
1.01-2.00	0.32	1.12	0.12
2.01-5.00	0.61	2.6	0.37
> 5.00	0	0	0

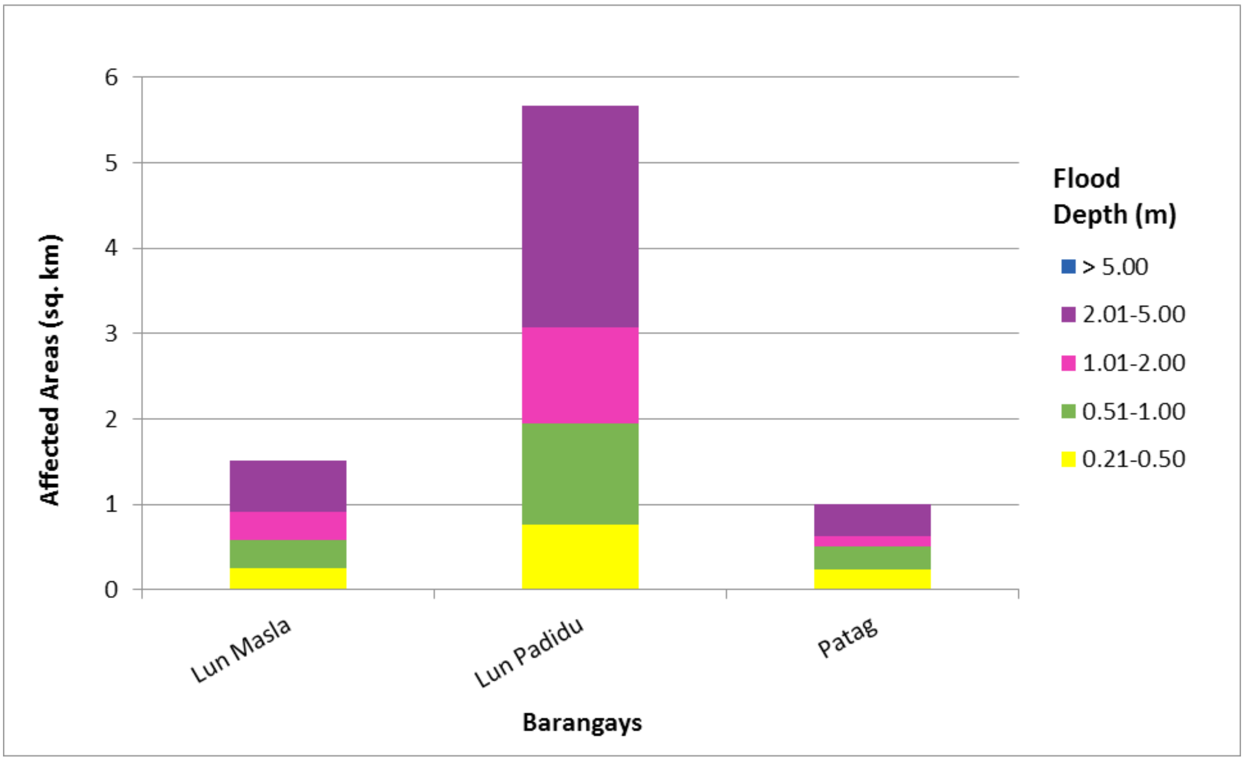


Figure 80. Affected Areas in Malapatan, Sarangani during 100-Year Rainfall Return Period

Brgy. Kawas is the only barangay affected in the municipality of Alabel in Sarangani. The barangay is projected to experience flood in 0.38% of the municipality.

Among the barangays in the municipality of Malapatan in Sarangani, Lun Padidu is projected to have the highest percentage of area that will experience flood levels at 2.04%. Meanwhile, Patag posted the second highest percentage of area that may be affected by flood depths at 0.93%.

Moreover, the generated flood hazard maps for the Lun Masla 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 10-year).

Table 41. 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	1.56	1.66	1.48
Medium	1.73	2.44	2.84
High	4.49	5.11	5.45
TOTAL	**7.78**	**9.21**	**9.77**

Of the three identified education institutions in Lun Masla floodplain, only one was assessed to be exposed to low-level flooding for both the 5- and 25- year scenario and to medium-level flooding for the 100-year scenario. It is Francisco A. Cagang Sr. School in Patag, Malapatan. The educational institutions affected by flooding in Lun Masla floodplain are enumerated in Annex 12.

Meanwhile, there are no health institutions affected by flooding in the Lun Masla floodplain.

5.11 Flood Validation

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

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

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

After which, 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 83.

The flood validation consisted of 153 points randomly selected all over the Lun Masla floodplain. It has an RMSE value of 1.32. Table 42 shows a contingency matrix of the comparison.

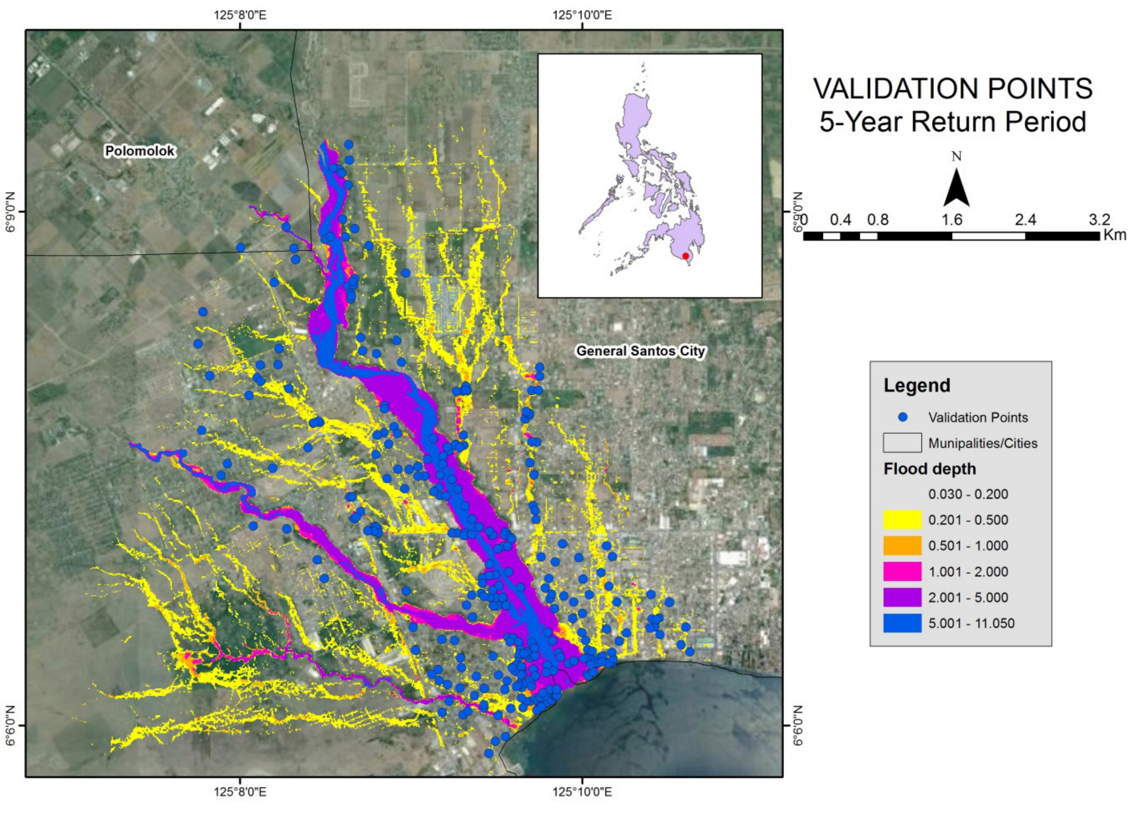


Figure 81. Affected Areas in Malapatan, Sarangani during 100-Year Rainfall Return Period

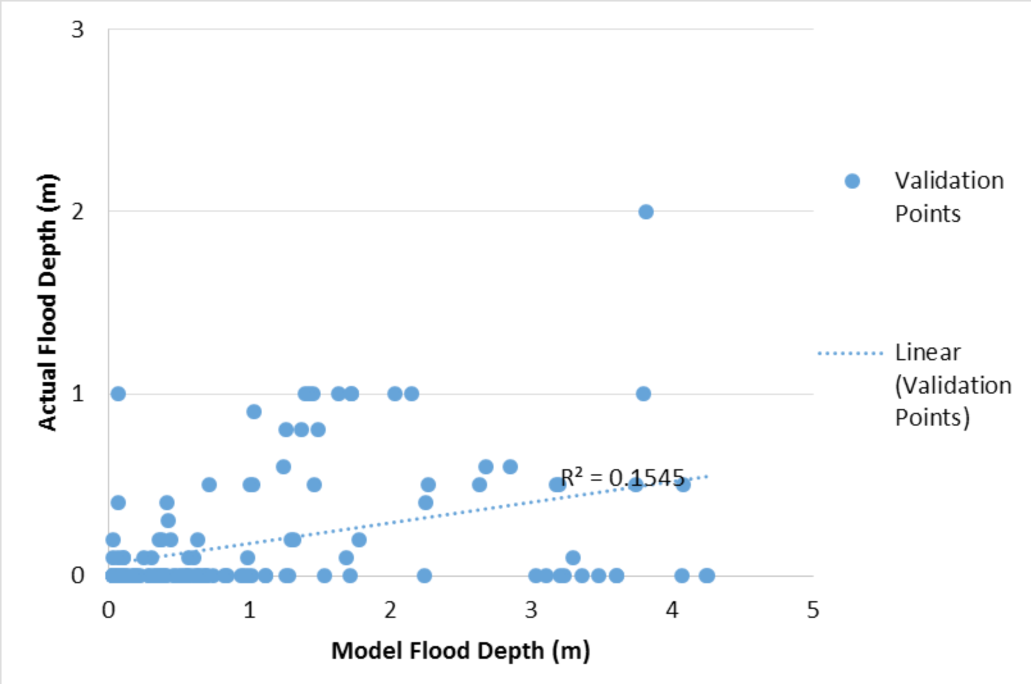


Figure 82. Flood map depth vs. actual flood depth

Table 42. Actual flood vs simulated flood depth at different levels in the Lun Masla 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	52	20	25	11	13	0	121
0.21-0.50	1	2	2	2	7	0	14
0.51-1.00	1	0	0	11	5	0	17
1.01-2.00	0	0	0	0	1	0	1
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	54	22	27	24	26	0	153

The overall accuracy generated by the flood model is estimated at 35.29% with 54 points correctly matching the actual flood depths. In addition, there were 35 points estimated one level above and below the correct flood depths while there were 33 points and 31 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 2 points were underestimated in the modelled flood depths of Lun Masla. Table 43 depicts the summary of the Accuracy Assessment in the Lun Masla River Basin Survey.

Table 43. Actual flood vs simulated flood depth at different levels in the Lun Masla River Basin.

	No. of Points	%
Correct	54	**35.29**
Overestimated	97	63.40
Underestimated	2	1.31
Total	153	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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Aquarius Sensor

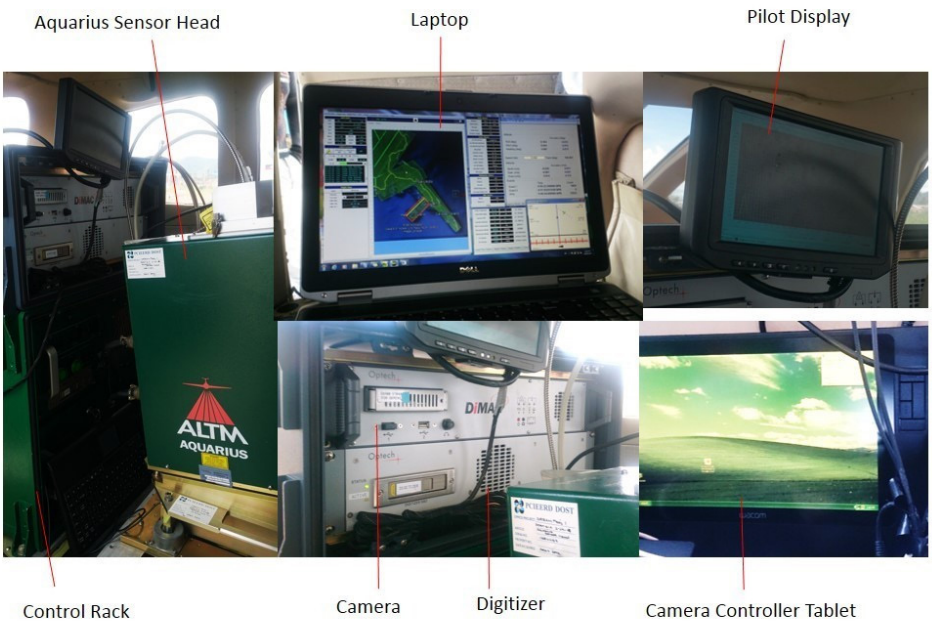


Figure A-1:1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the 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	
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

1. SNI-7

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-22**
Order: **2nd**

Island: **LUZON**
Municipality: **CALINTAAN**
Barangay: **TANYAG**

		PRS92 Coordinates			
Latitude:	12° 31' 36.76881"	Longitude:	120° 59' 13.46492"	Ellipsoidal Hgt:	35.12700 m.
		WGS84 Coordinates			
Latitude:	12° 31' 31.84278"	Longitude:	120° 59' 18.53734"	Ellipsoidal Hgt:	84.27100 m.
		PTM Coordinates			
Northing:	1385214.96 m.	Easting:	498595.125 m.	Zone:	3
		UTM Coordinates			
Northing:	1,385,563.72	Easting:	281,265.62	Zone:	51

Location Description

MRW-22

From Abra de Ilog to San Jose, along Nat'l Road, approx. 9 Km. from Calintaan Town Proper, located Lumintao Bridge at Brgy. Tanyag, Sitio Marilao, Calintaan, Occ. Mindoro. Station is located at the N end of the catwalk of Lumintao Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-22, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-446**

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

9 9 0 3 0 4 2 0 1 4 1 6 0 1 5 0

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/814

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

Figure A-2.1. SNI-7

2. SNI-15

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

November 05, 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: **SARANGANI**	
	Station Name: **SNI-15**	
	Order: **2nd**	
Island: **MINDANAO**	Barangay: **POBLACION (MALAPATAN)**	
Municipality: **MALAPATAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **5° 58' 16.93809"**	Longitude: **125° 17' 11.94043"**	Ellipsoidal Hgt: **1.09600 m.**
	WGS84 Coordinates	
Latitude: **5° 58' 14.08407"**	Longitude: **125° 17' 17.56874"**	Ellipsoidal Hgt: **75.01600 m.**
	PTM / PRS92 Coordinates	
Northing: **660237.374 m.**	Easting: **531736.654 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **660,523.74**	Easting: **753,144.51**	Zone: **51**

Location Description

SNI-15
Station is in Brgy. Poblacion, Malapatan, Sarangani. To reach the station travel for about 45 km from General Santos City towards Malapatan municipality taking the national highway until reaching the municipal hall of Malapatan. Mark is the head of a 4" copper nail embedded in a 0.30 x 0.30 x 1 m concrete monument with inscription SNI-15 2007 NAMRIA.

Requesting Party: **Christopher Cruz / PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075142 I**
T.N.: **2014-2625**

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. SNI-15

3. SI-311

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

November 07, 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: **SARANGANI** Station Name: **SI-311**	
Island: **Mindanao**	Municipality: **GLAN**	Barangay: **GLAN PADIDU**
Elevation: **16.3484 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

BM SI-311 is located at the end wing of Glan Bridge at Brgy. Glan Municipality of Saranggani along Saranggani-Davao Del Sur Coastal Rd.

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a bridge with inscription "BMSI-311,NAMRIA,2008".

Requesting Party: **Christopher Cruz / PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075142 I**
T.N.: **2014-2634**

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

9 9 1 1 0 7 2 0 1 4 1 0 2 7 0 3

CP/4701/12/99914

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. SI-311

4. SI-340

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

November 05, 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: **SARANGANI** Station Name: **SI-340**		
Island: **Luzon**	Municipality: **MALAPATAN**	Barangay:
Elevation: **18.7180 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

The station is located at Molo Bridge about 290 m from KM post 1668, along Malapatan-Gensan National Highway.

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a bridge with inscription ""SI-340,NAMRIA,2008".

Requesting Party: **Christopher Cruz / PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075142 I**
T.N.: **2014-2626**

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-2.4. SI-340

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

1. SI-311

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SNI-07 --- SI-311 (B1)	SNI-07	SI-311	Fixed	0.005	0.017	184°00'42"	7294.092	-20.341
SNI-07 --- SI-311 (B2)	SNI-07	SI-311	Fixed	0.007	0.019	184°00'42"	7294.070	-20.338

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SNI-07				
Grid		Local		Global	
Easting	746858.814 m	Latitude	N5°53'32.23760"	Latitude	N5°53'29.39976"
Northing	651749.801 m	Longitude	E125°13'46.49661"	Longitude	E125°13'52.13278"
Elevation	31.750 m	Height	26.898 m	Height	100.810 m

To:	SI-311				
Grid		Local		Global	
Easting	746377.279 m	Latitude	N5°49'35.35336"	Latitude	N5°49'32.53295"
Northing	644469.041 m	Longitude	E125°13'29.90925"	Longitude	E125°13'35.55159"
Elevation	12.065 m	Height	6.557 m	Height	80.569 m

Vector					
ΔEasting	-481.535 m	NS Fwd Azimuth	184°00'42"	ΔX	-0.160 m
ΔNorthing	-7280.760 m	Ellipsoid Dist.	7294.092 m	ΔY	884.473 m
ΔElevation	-19.684 m	ΔHeight	-20.341 m	ΔZ	-7240.308 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Figure A-3.1. Baseline Processing Report – A

2. SI-340

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SNI-15 --- SI-340 (B1)	SNI-15	SI-340	Fixed	0.005	0.021	11°09'36"	4771.332	10.033
SNI-15 --- SI-340 (B2)	SNI-15	SI-340	Fixed	0.005	0.016	11°09'36"	4771.328	9.932

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SNI-15				
Grid		Local		Global	
Easting	753144.505 m	Latitude	N5°58'16.93808"	Latitude	N5°58'14.08407"
Northing	660523.744 m	Longitude	E125°17'11.94046"	Longitude	E125°17'17.56874"
Elevation	5.982 m	Height	1.096 m	Height	75.016 m

To:	SI-340				
Grid		Local		Global	
Easting	754048.831 m	Latitude	N6°00'49.33497"	Latitude	N6°00'46.47026"
Northing	665210.517 m	Longitude	E125°17'41.96935"	Longitude	E125°17'47.59361"
Elevation	15.960 m	Height	11.130 m	Height	84.998 m

Vector					
ΔEasting	904.326 m	NS Fwd Azimuth	11°09'36"	ΔX	-477.120 m
ΔNorthing	4686.773 m	Ellipsoid Dist.	4771.332 m	ΔY	-924.228 m
ΔElevation	9.979 m	ΔHeight	10.033 m	ΔZ	4656.593 m

Standard Errors

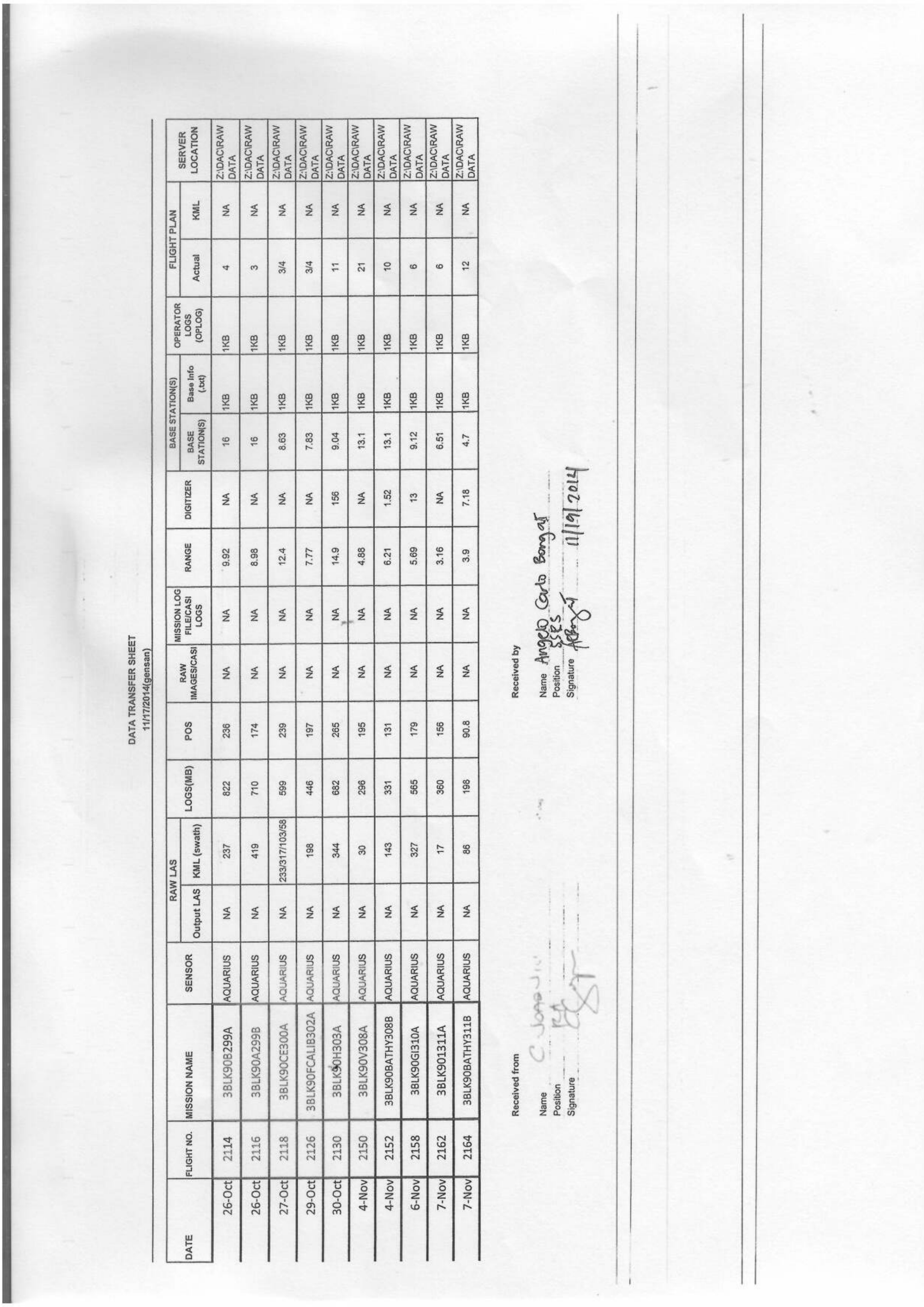
Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.002 m

Figure A-3.2. Baseline Processing Report - B

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
		GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. MARK GARCHITORENA	AAC

Annex 5. Data Transfer Sheets



DATA TRANSFER SHEET
11/17/2014(gensan)

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	
26-Oct	2114	3BLK90B299A	AQUARIUS	NA	237	822	236	NA	NA	9.92	NA	16	1KB	1KB	4	NA	Z:\DAC\RAW DATA
26-Oct	2116	3BLK90A299B	AQUARIUS	NA	419	710	174	NA	NA	8.98	NA	16	1KB	1KB	3	NA	Z:\DAC\RAW DATA
27-Oct	2118	3BLK90CE300A	AQUARIUS	NA	233/317/103/58	599	239	NA	NA	12.4	NA	8.63	1KB	1KB	3/4	NA	Z:\DAC\RAW DATA
29-Oct	2126	3BLK90FCALIB302A	AQUARIUS	NA	198	446	197	NA	NA	7.77	NA	7.83	1KB	1KB	3/4	NA	Z:\DAC\RAW DATA
30-Oct	2130	3BLK90H303A	AQUARIUS	NA	344	682	265	NA	NA	14.9	156	9.04	1KB	1KB	11	NA	Z:\DAC\RAW DATA
4-Nov	2150	3BLK90V308A	AQUARIUS	NA	30	296	195	NA	NA	4.88	NA	13.1	1KB	1KB	21	NA	Z:\DAC\RAW DATA
4-Nov	2152	3BLK90BATHY308B	AQUARIUS	NA	143	331	131	NA	NA	6.21	1.52	13.1	1KB	1KB	10	NA	Z:\DAC\RAW DATA
6-Nov	2158	3BLK90GI310A	AQUARIUS	NA	327	565	179	NA	NA	5.69	13	9.12	1KB	1KB	6	NA	Z:\DAC\RAW DATA
7-Nov	2162	3BLK901311A	AQUARIUS	NA	17	360	156	NA	NA	3.16	NA	6.51	1KB	1KB	6	NA	Z:\DAC\RAW DATA
7-Nov	2164	3BLK90BATHY311B	AQUARIUS	NA	86	198	90.8	NA	NA	3.9	7.18	4.7	1KB	1KB	12	NA	Z:\DAC\RAW DATA

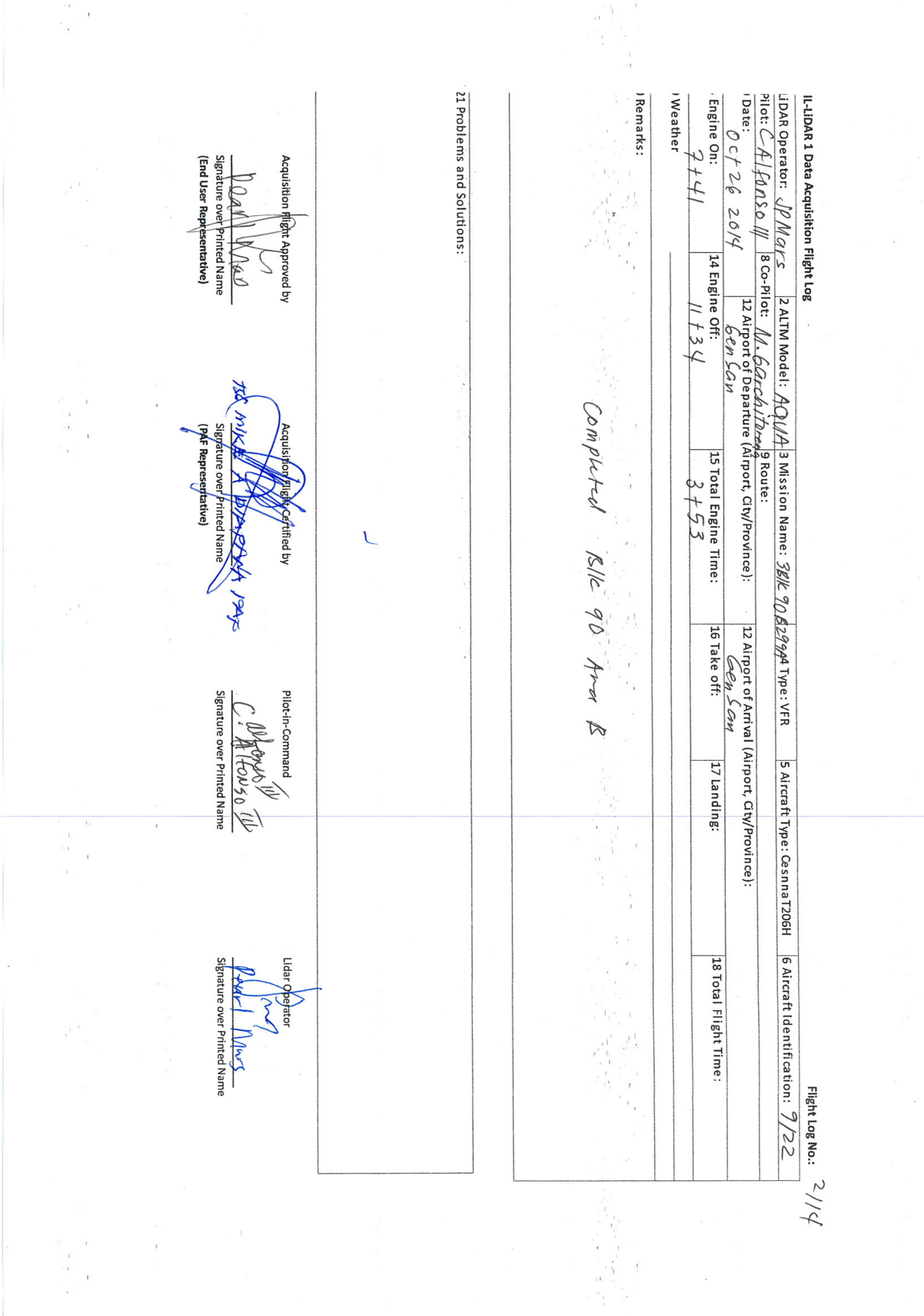
Received from
Name C. JOAQUIN
Position RA
Signature

Received by
Name Angelo Carlo Bongat
Position SSRS
Signature 11/19/2014

Figure A-5.1. Data Transfer Sheet for Lun Masla Floodplain - A

Annex 6. Flight Logs

1. Flight Log for 2114A Mission


IL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2114

LIDAR Operator: JP Mars	2 ALTM Model: AQUA	3 Mission Name: 3BLK90B299A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
Pilot: C. Alfonso III	8 Co-Pilot: M. Garchitorena	9 Route:			
Date: Oct 26 2014	12 Airport of Departure (Airport, City/Province): Gen San		12 Airport of Arrival (Airport, City/Province): Gen San		
Engine On: 7+41	14 Engine Off: 11+34	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:

Weather

Remarks:

Completed BLK 90 Area B

21 Problems and Solutions:

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

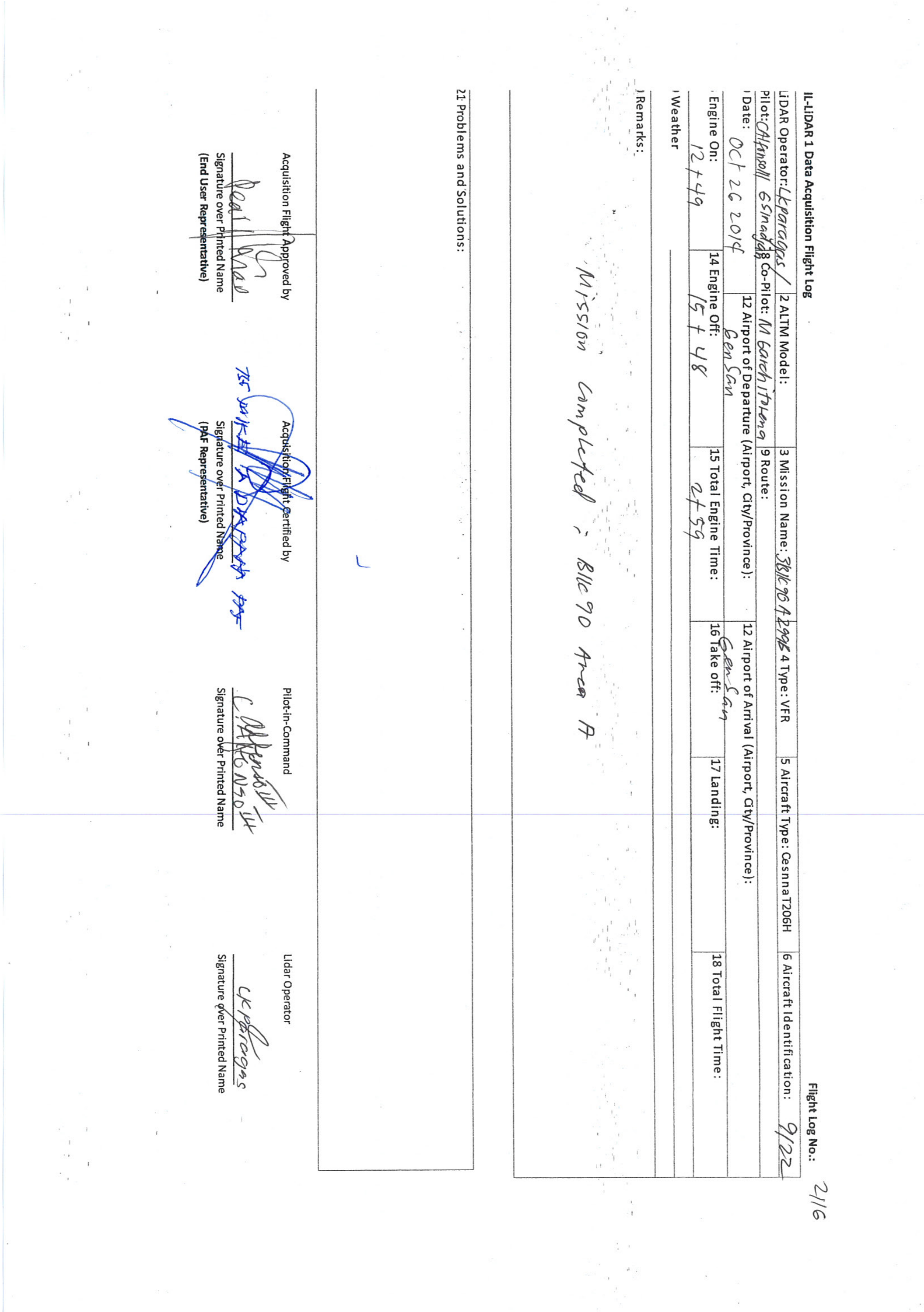
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — C. Alfonso III — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.1. Flight Log for 2114A Mission

2. Flight Log for 2116A Mission


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 9/22 — 2116

1 LiDAR Operator: C.K. Paragas	2 ALTM Model:	3 Mission Name: 3BLK90A299B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: C. Alfonso / G. Sinadjan	8 Co-Pilot: M. Gaoch / Toleng	9 Route:			
10 Date: Oct 26 2014	12 Airport of Departure (Airport, City/Province): Gen San		12 Airport of Arrival (Airport, City/Province): Gen San		
13 Engine On: 12+49	14 Engine Off: 15+48	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed ; BLK 90 Area A					
21 Problems and Solutions:					

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

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

Pilot-in-Command — C. Alfonso III — Signature over Printed Name

Lidar Operator — C.K. Paragas — Signature over Printed Name

Figure A-6.2. Flight Log for 2116A Mission

3. Flight Log for 2118A Mission

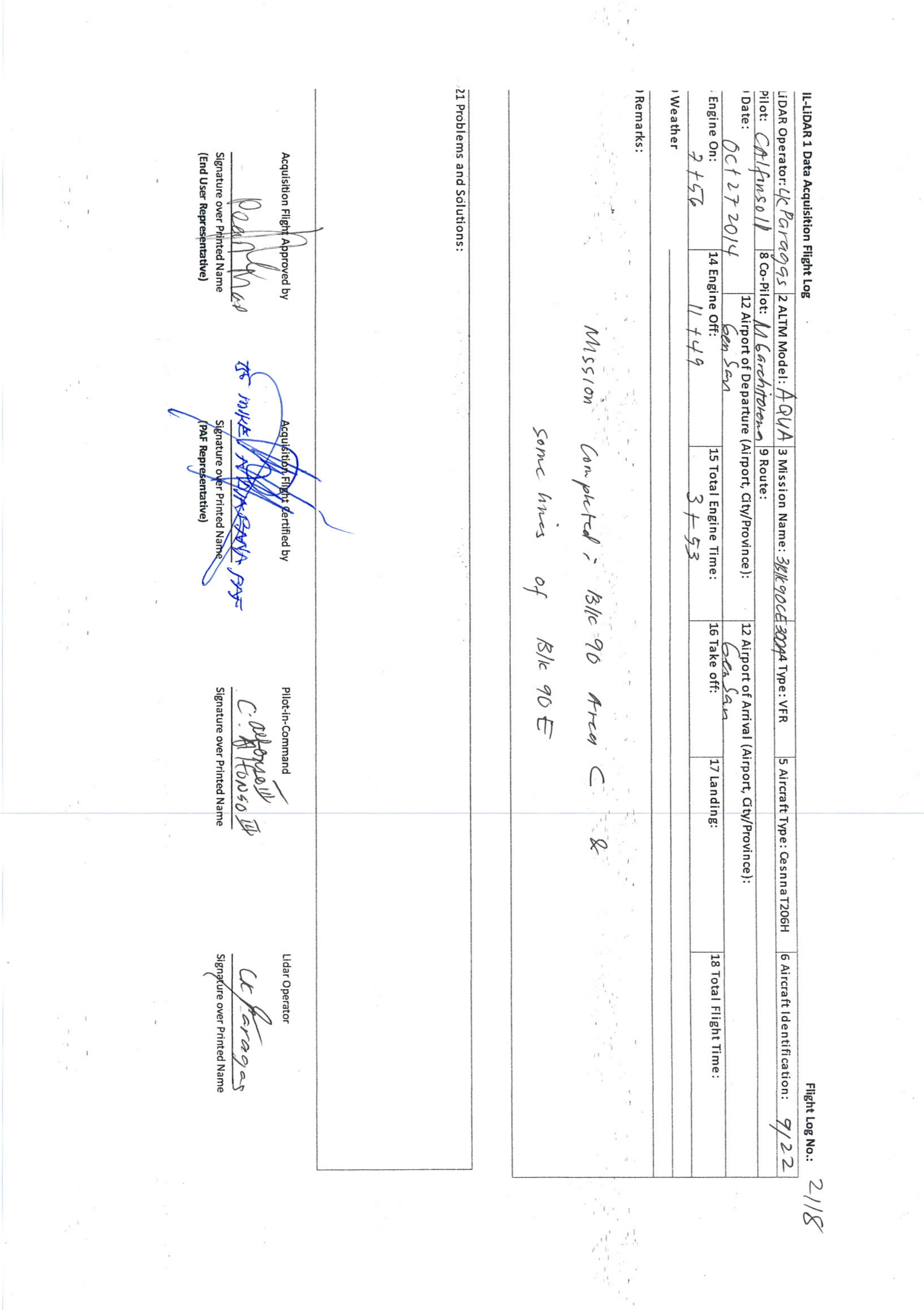
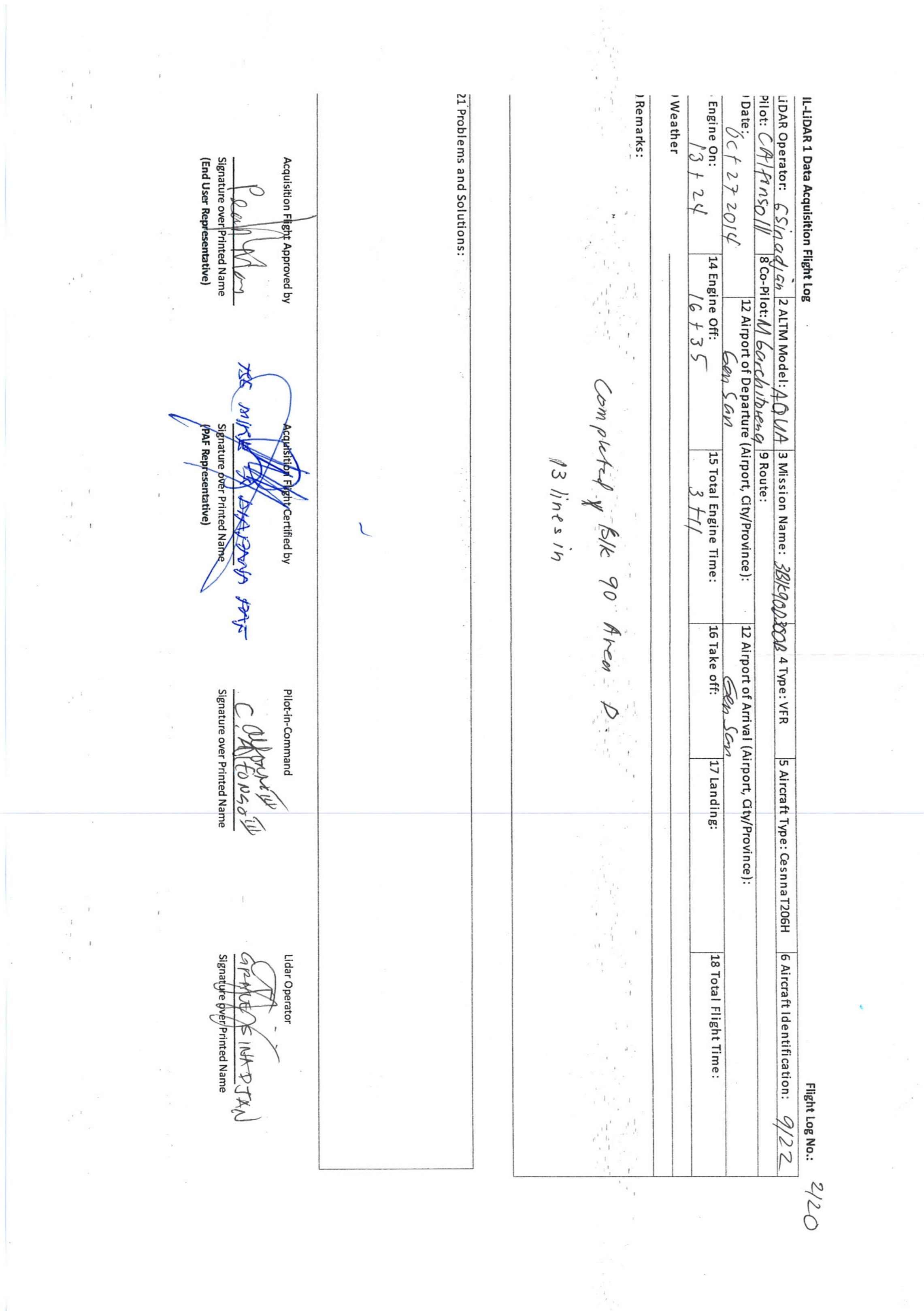


Figure A-6.3. Flight Log for 2118A Mission

4. Flight Log for 2120A Mission


IL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 9122 2120

LiDAR Operator: G Sinadjan	2 ALTM Model: AQUA	3 Mission Name: 3BLK90D300B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
Pilot: C Alfonso III	8 Co-Pilot: M Bachiteng	9 Route:			
Date: Oct 27 2014	12 Airport of Departure (Airport, City/Province): Gen San		12 Airport of Arrival (Airport, City/Province): Gen San		
Engine On: 13+24	14 Engine Off: 16+35	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:

Weather

Remarks: Completed Blk 90 Area D. 13 lines in

21 Problems and Solutions:

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

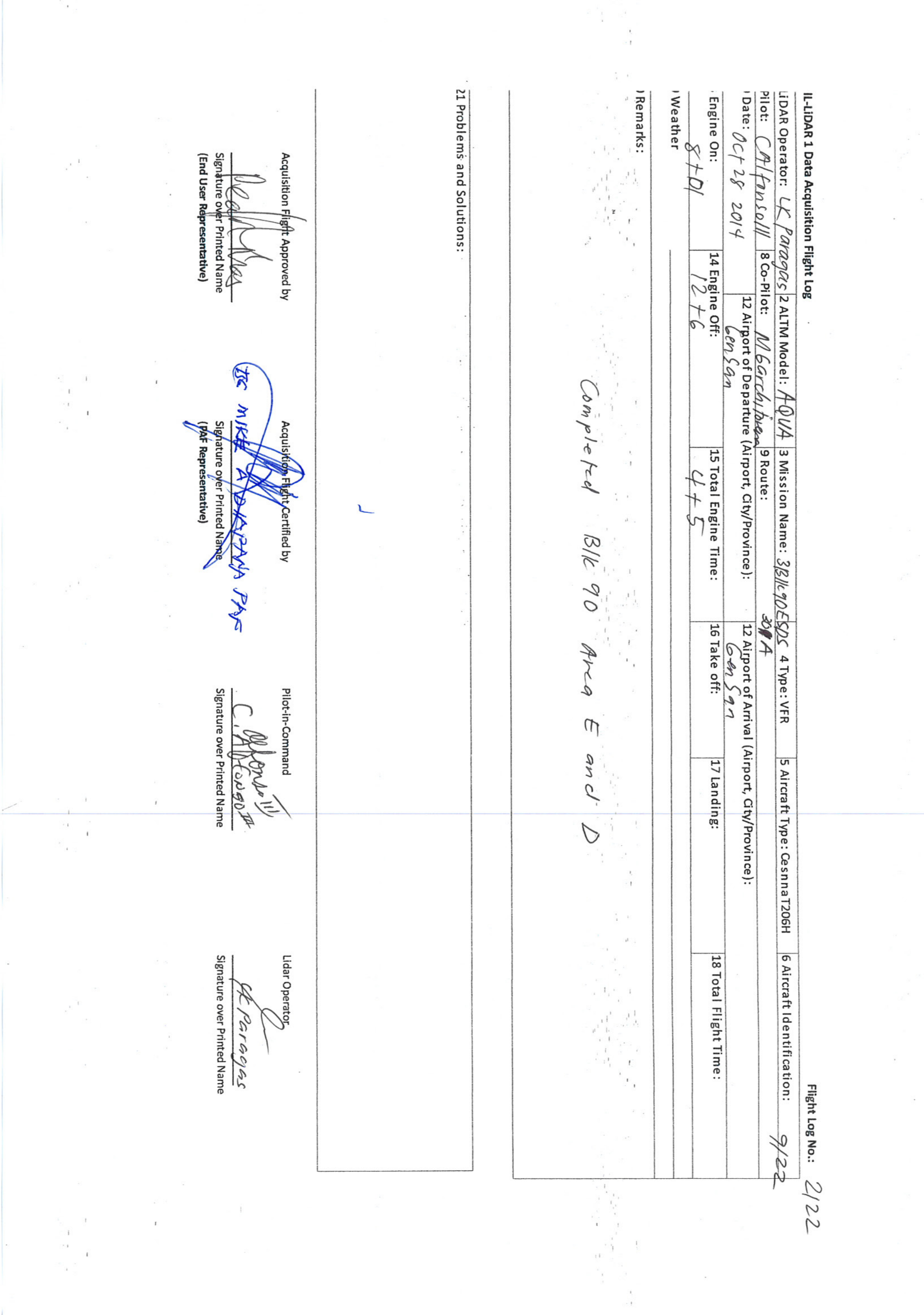
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — C Alfonso III — Signature over Printed Name

Lidar Operator — G Sinadjan — Signature over Printed Name

Figure A-6.4. Flight Log for 2120A Mission

5. Flight Log for 2122A Mission


Flight Log No.: 2122

IL-LIDAR 1 Data Acquisition Flight Log

LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK90ESDS 30?A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
Pilot: C. Alfonso III	8 Co-Pilot: M. Garchitorena	9 Route:			
Date: Oct 28 2014	12 Airport of Departure (Airport, City/Province): Gen San		12 Airport of Arrival (Airport, City/Province): Gen San		
Engine On: 8+01	14 Engine Off: 12+6	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:

Weather

Remarks:

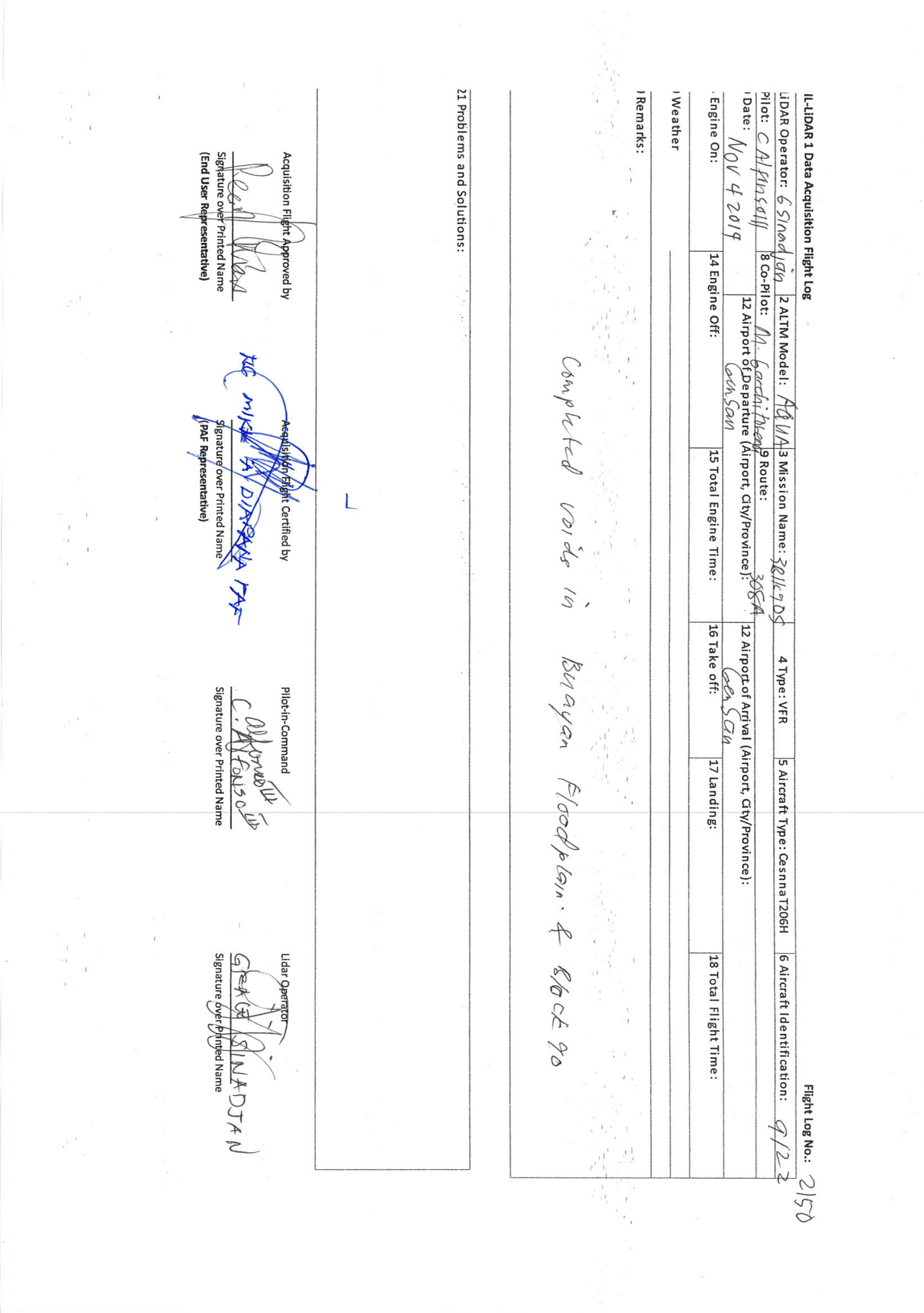
Completed Blk 90 Area E and D

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	JSG Mike A. Dakipana PAF Signature over Printed Name (PAF Representative)	C. Alfonso III Signature over Printed Name	LK Paragas Signature over Printed Name

Figure A-6.5. Flight Log for 2122A Mission

6. Flight Log for 2150A Mission



IL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2150

LiDAR Operator: G Sinadjan	2 ALTM Model: AQUA	3 Mission Name: 3BLK90S	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
Pilot: C Alfonso III	8 Co-Pilot: M. Garchitorena	9 Route: 308A			
Date: Nov 4 2019	12 Airport of Departure (Airport, City/Province): GenSan		12 Airport of Arrival (Airport, City/Province): GenSan		
Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

Weather

Remarks:

Completed voids in Buayan Floodplain & Block 90

21 Problems and Solutions:

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

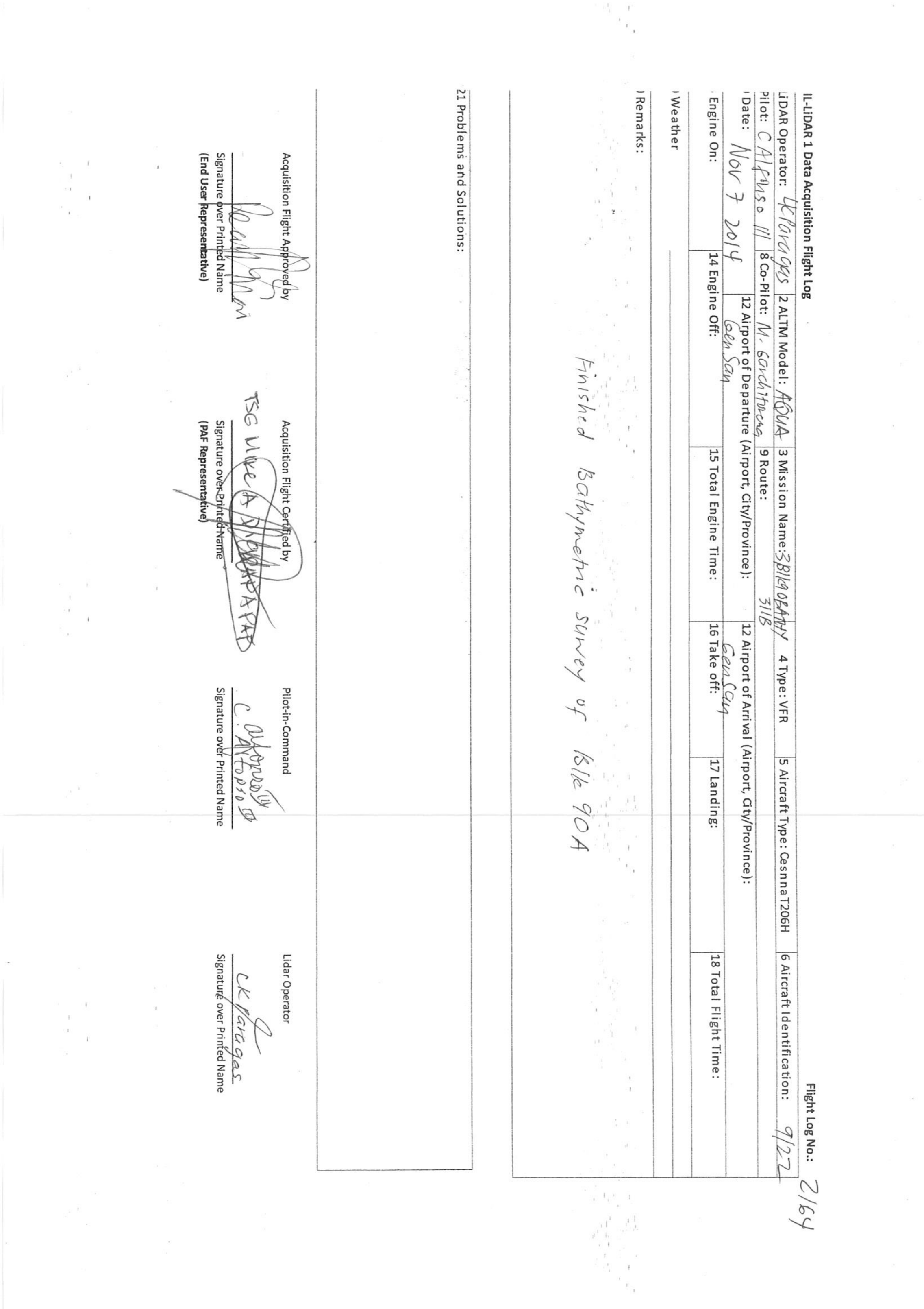
Acquisition Flight Certified by — 1LT MIKE A DIAPANA PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command — C. ALFONSO III — Signature over Printed Name

Lidar Operator — GRACE SINADJAN — Signature over Printed Name

Figure A-6.6. Flight Log for 2150A Mission

7. Flight Log for 2164A Mission


IL-LIDAR 1 Data Acquisition Flight Log | Flight Log No.: 2164

LIDAR Operator: CK Paragas | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK90BATHY | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9122

Pilot: C Alfonso III | 8 Co-Pilot: M. Gandhinava | 9 Route: 311B

Date: Nov 7 2014 | 12 Airport of Departure (Airport, City/Province): Gen San | 12 Airport of Arrival (Airport, City/Province): Gen San

Engine On: | 14 Engine Off: | 15 Total Engine Time: | 16 Take off: | 17 Landing: | 18 Total Flight Time:

Weather

Remarks:

Finished bathymetric survey of Blk 90A

21 Problems and Solutions:

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

Acquisition Flight Certified by — TSG Mike A [illegible] PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command — C. Alfonso III — Signature over Printed Name

Lidar Operator — CK Paragas — Signature over Printed Name

Figure A-6.7. Flight Log for 2164A Mission

Annex 7. Flight Status Report

SOUTH COTABATO AND SARANGANI
(October 30, November 6-7, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2114	BLK90B	3BLK90B299A	P MARS	26-OCT	Mission Completed; Blk90B. Some lines cut due to terrain
2116	BLK90A	3BLK90A299B	LK PARAGAS/ G SINADJAN	26-OCT	Mission Completed; Blk90A
2118	BLK90C	3BLK90CE300A	LK PARAGAS	27-OCT	Mission Completed; Blk90C, Finished 4 lines in Blk90E
2120	BLK90D	3BLK90D300B	G SINADJAN	27-OCT	Finished lines in Blk90D
2122	BLK90DE	3BLK90DSES301A	LK PARAGAS	28-OCT	Mission Completed; Supplementary flight for Blk90D and E
2150	VOIDS OVER BUAYAN FP	3BLK90V308A	G SINADJAN	4-NOV	Mission Completed; voids in Blk 90 and Buayan floodplain
2164	BLK90AS	3BLK90BATHY311B	LK PARAGAS	7-NOV	Mission Completed; Bathymetric Survey in Blk90A

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	2114A
Area:	BLK90B
Mission Name:	3BLK90B299A
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 40%
Area surveyed:	51.949

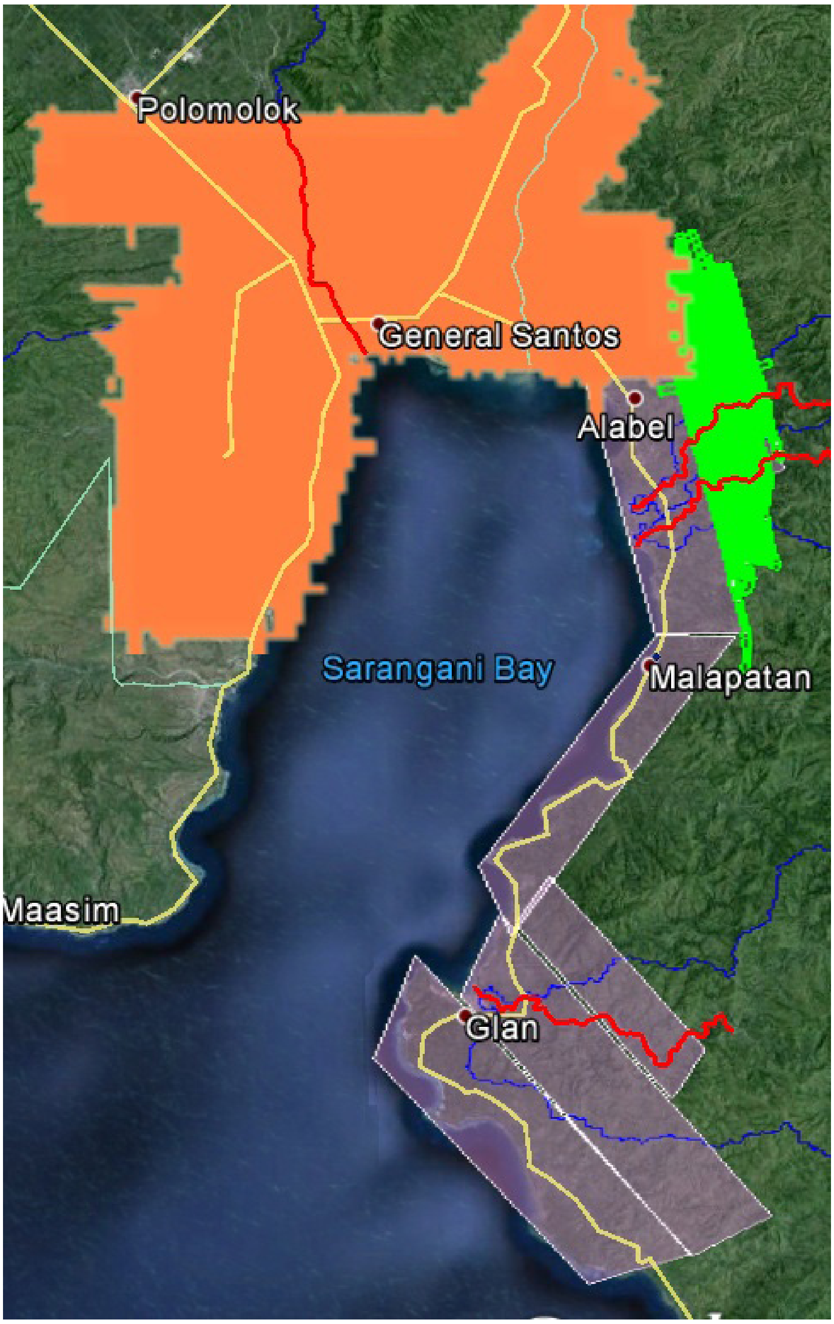


Figure A-7.1. Swath for Flight No. 2114A

Flight No. :	2116
Area:	BLK90A
Mission Name:	3BLK90A299B
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 30%
Area surveyed:	67.406

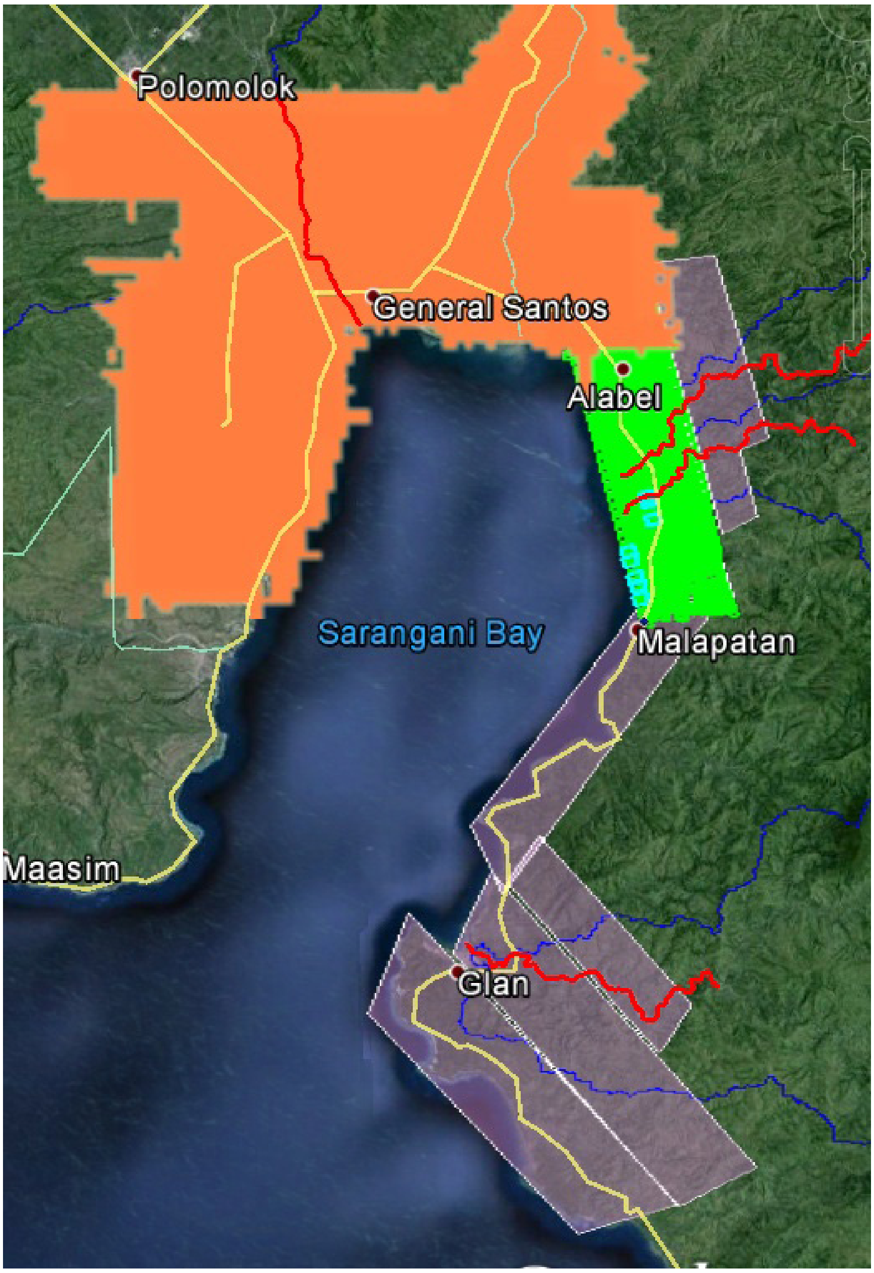


Figure A-7.2. Swath for Flight No. 2116A

Flight No. :	2118A
Area:	BLK90CE
Mission Name:	3BLK90CE300A
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 30%
Area surveyed:	54.808

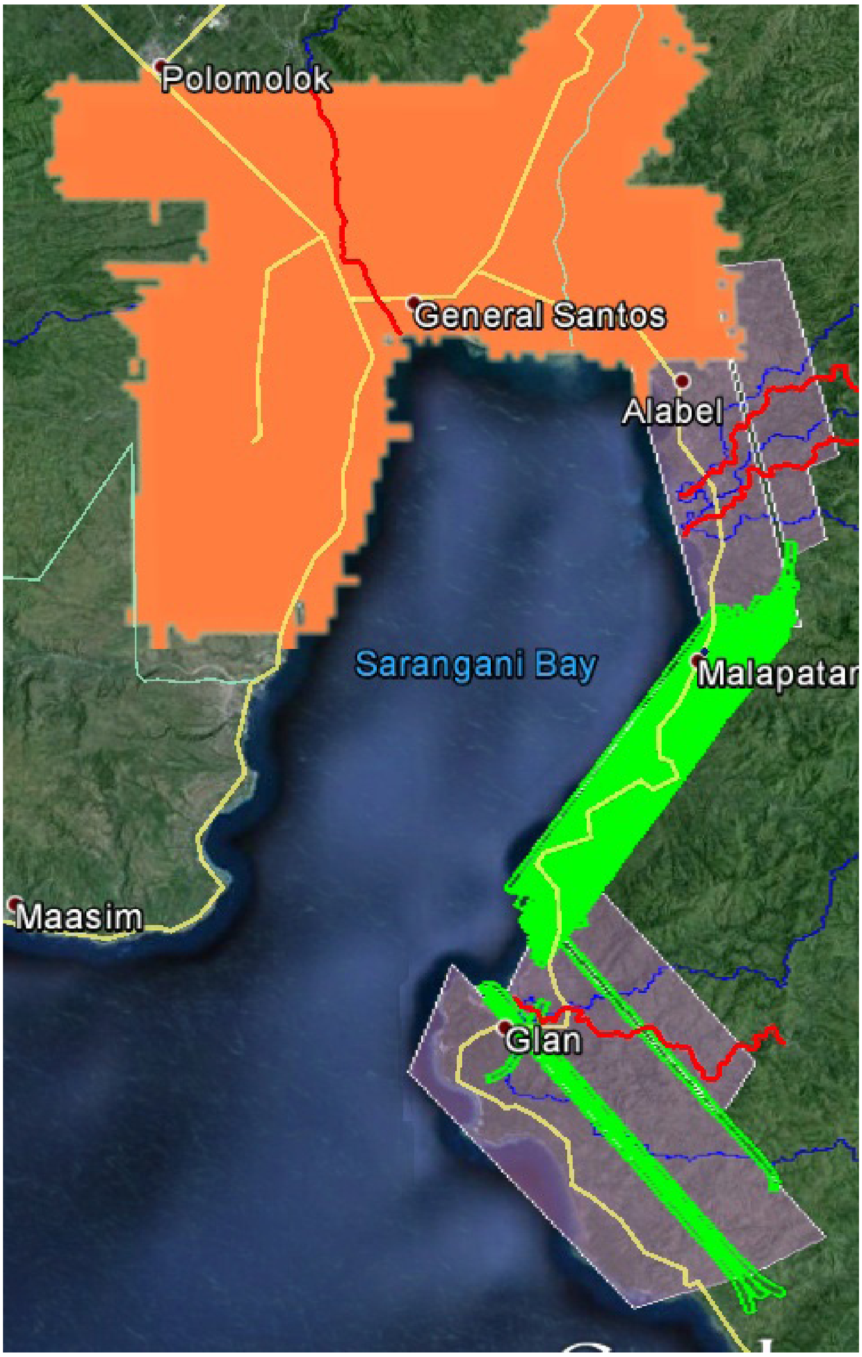


Figure A-7.4. Swath for Flight No. 2118A

Flight No. :	2120A
Area:	BLK90D
Mission Name:	3BLK90D300B
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 30%
Area surveyed:	63.974

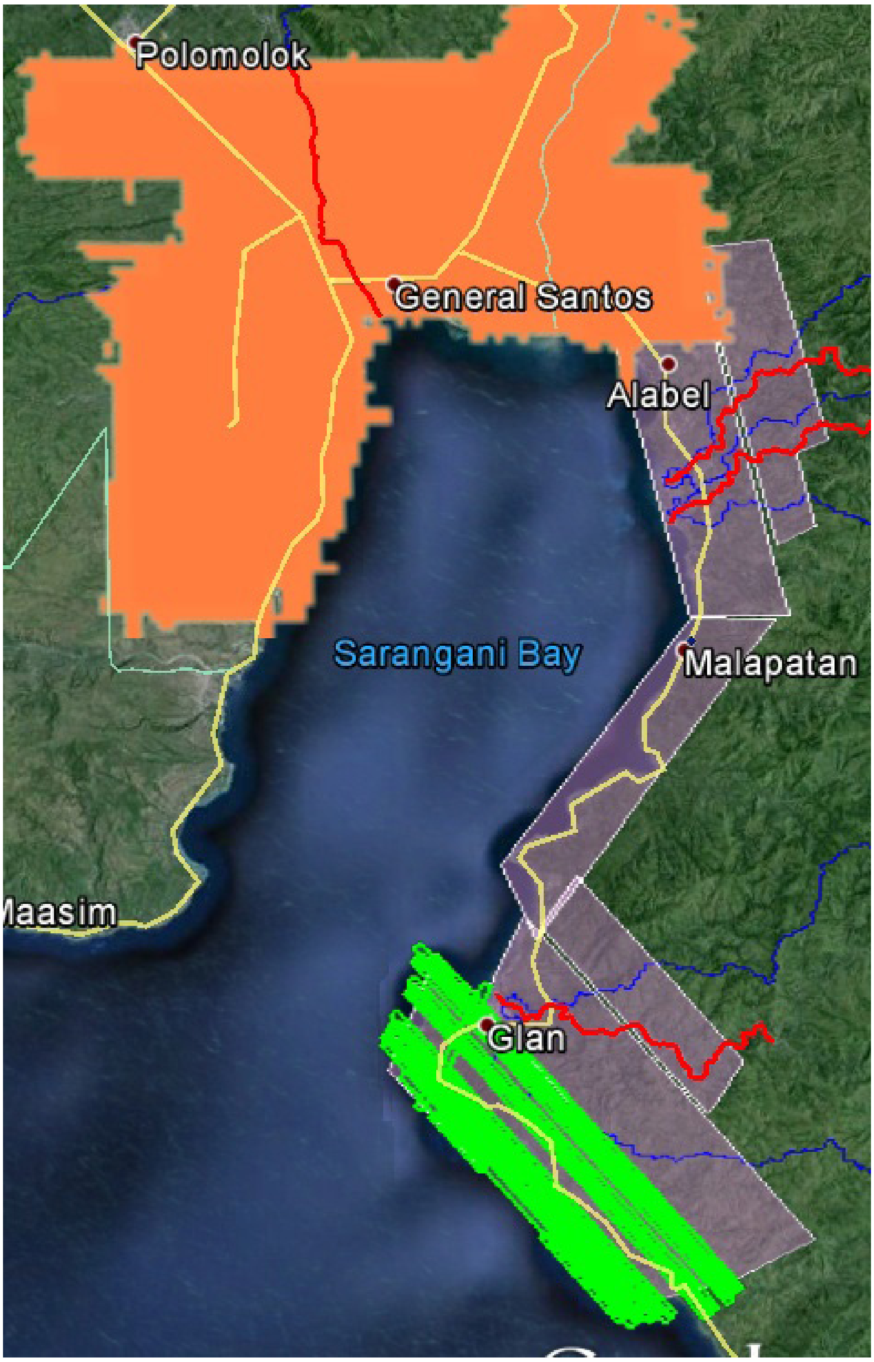


Figure A-7.5. Swath for Flight No. 2120A

Flight No. :	2122A
Area:	BLK90DE
Mission Name:	3BLK90DES301A
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 30%
Area surveyed:	95.367

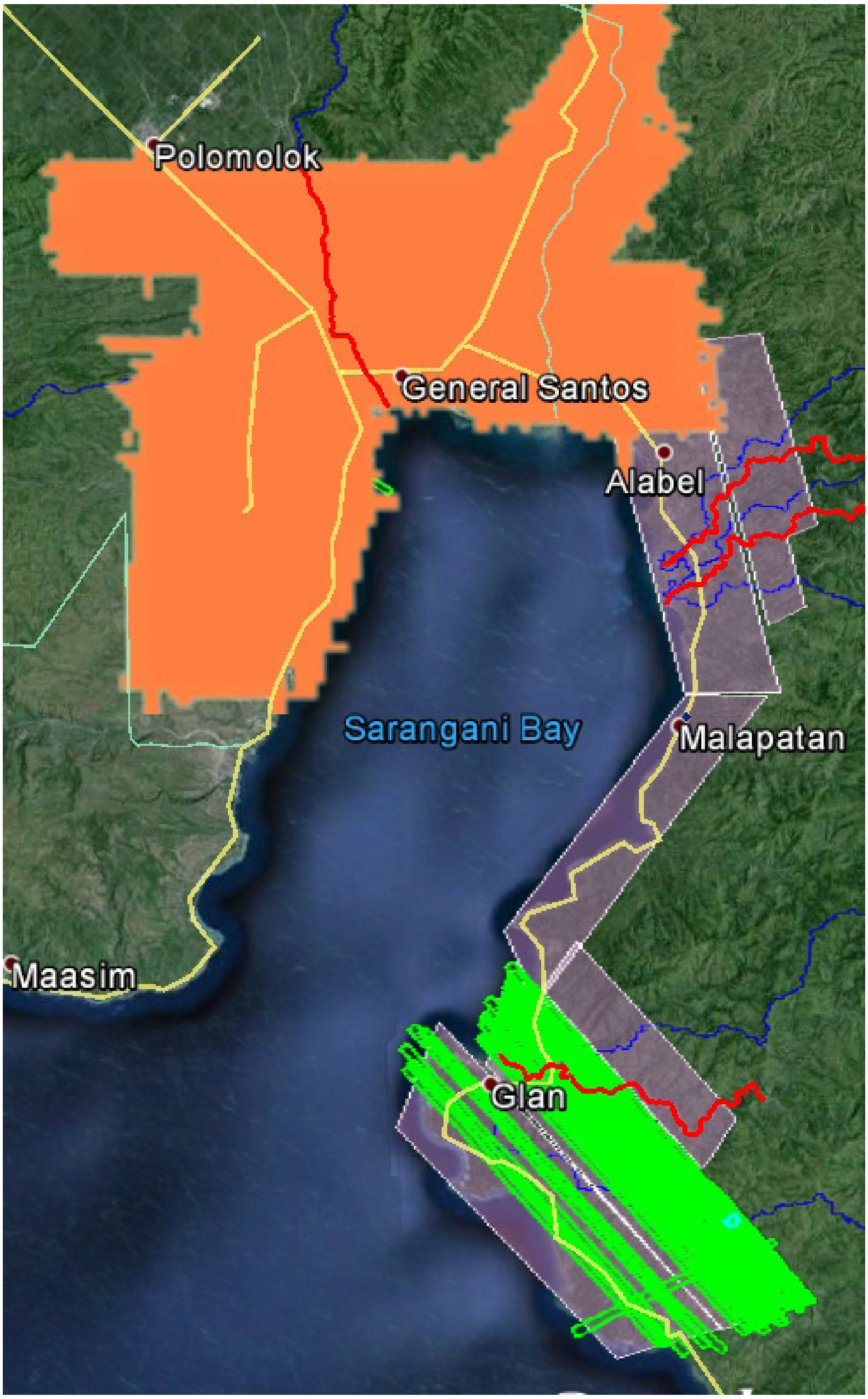


Figure A-7.6. Swath for Flight No. 2122A

Flight No. :	2150A
Area:	voids over Buayan FP and BLKD
Mission Name:	3BLK90V308A
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 45%
Area surveyed:	33.133

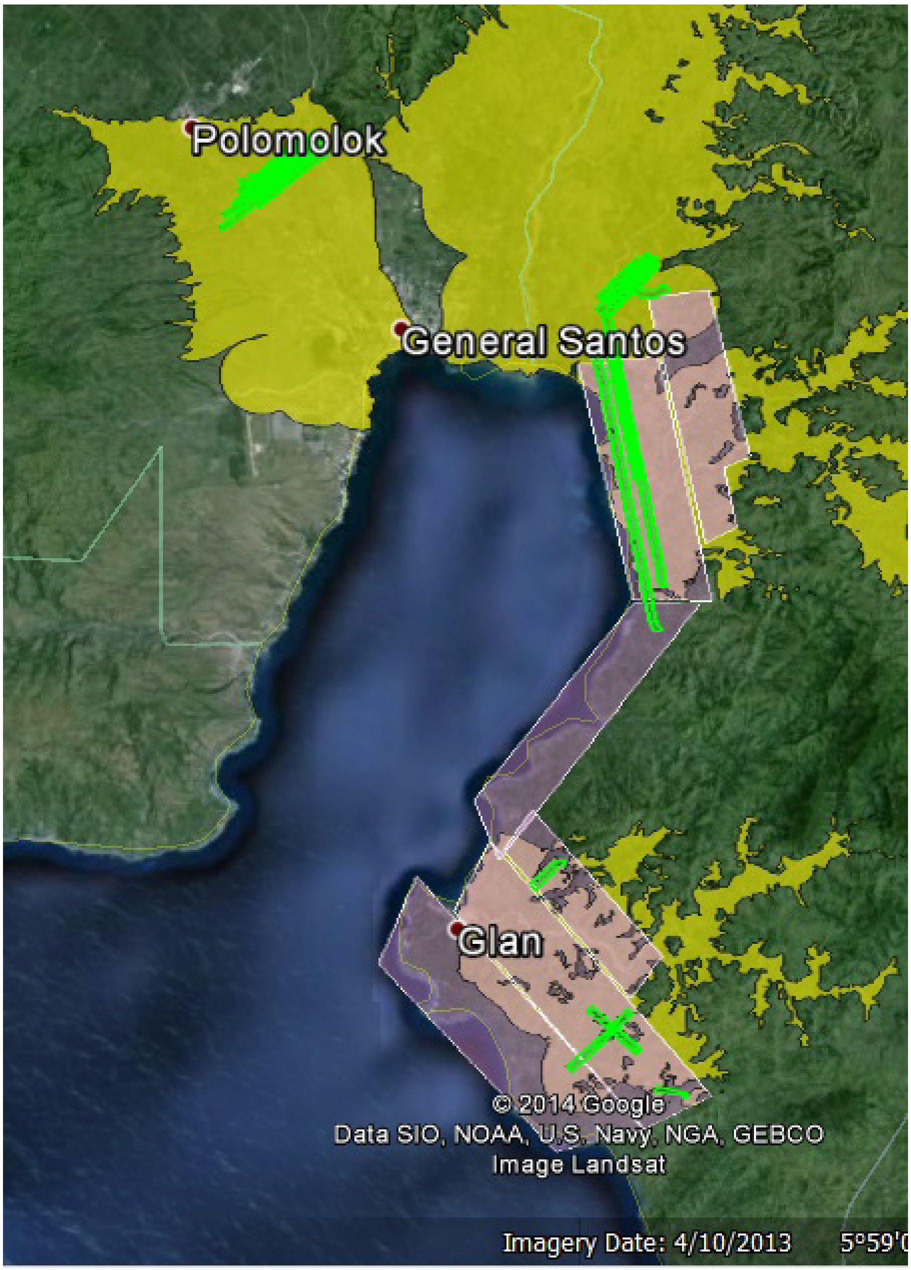


Figure A-7.7. Swath for Flight No. 2150A

Flight No. :	2164A
Area:	BLK90AS
Mission Name:	3BLK90BATHY311B
Parameters:	Alt: 600m; Scan Fz: 45; Scan angle: 18; Overlap: 30%
Area surveyed:	23.108

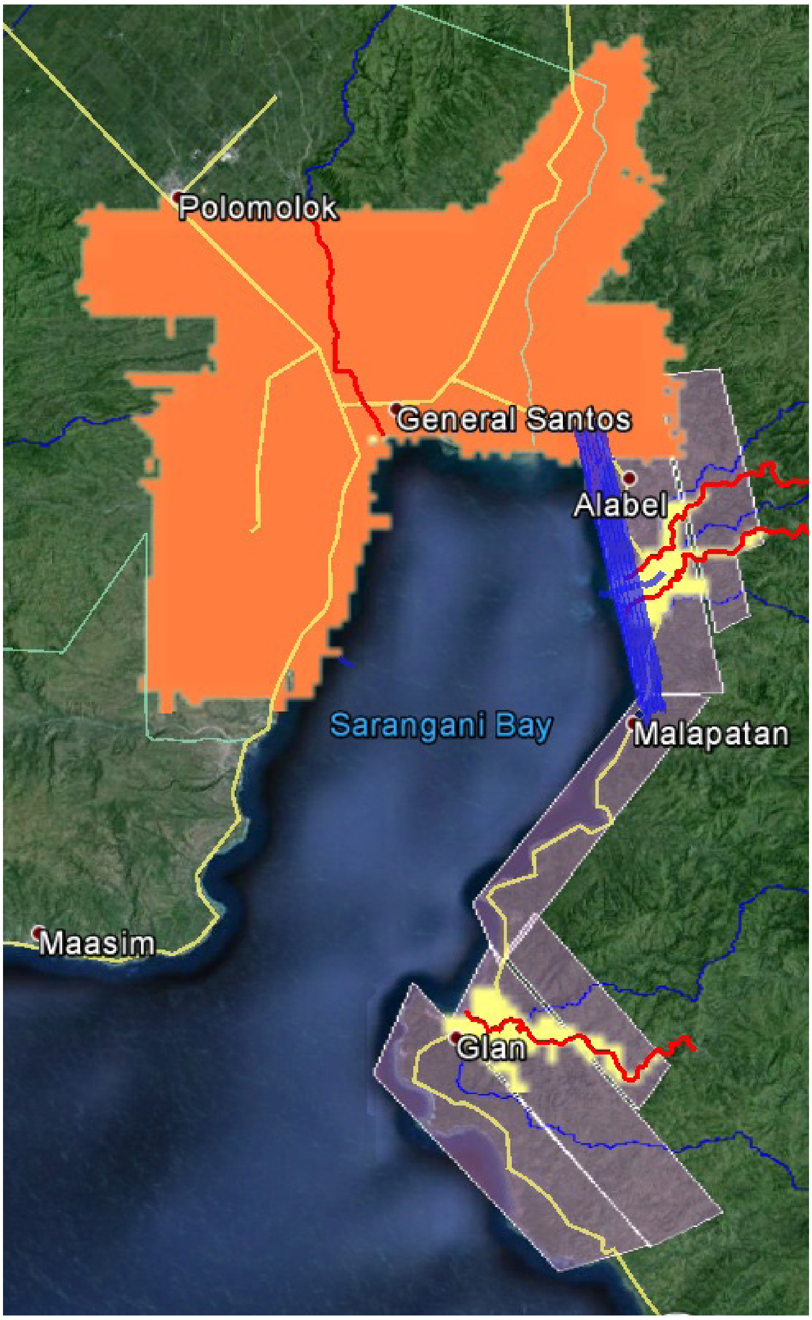


Figure A-7.8. Swath for Flight No. 2164A

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk 90A

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90A
Inclusive Flights	2116A, 2164A
Range data size	12.88 GB
POS	264.8 MB
Image	n/a
Base Station Data	20.7 MB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.892
RMSE for East Position (<4.0 cm)	1.244
RMSE for Down Position (<8.0 cm)	3.67
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.002288
GPS position stdev (<0.01m)	0.0075
Minimum % overlap (>25)	61.29
Ave point cloud density per sq.m. (>2.0)	3.77
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	99
Maximum Height	576.89
Minimum Height	62.87

Classification (# of points)	
Ground	48,831,977
Low vegetation	58,075,952
Medium vegetation	82,035,068
High vegetation	50,206,904
Building	3,063,181
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Melissa Fernandez

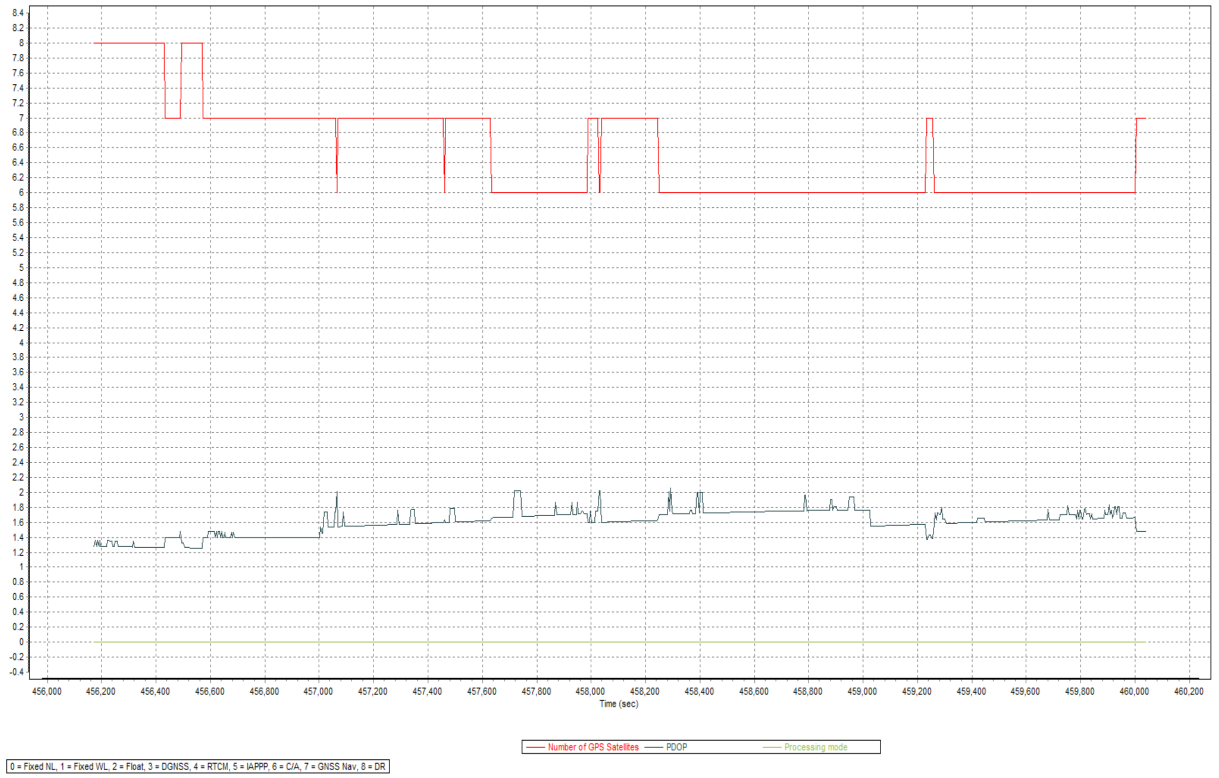


Figure A-8.1 Solution Status

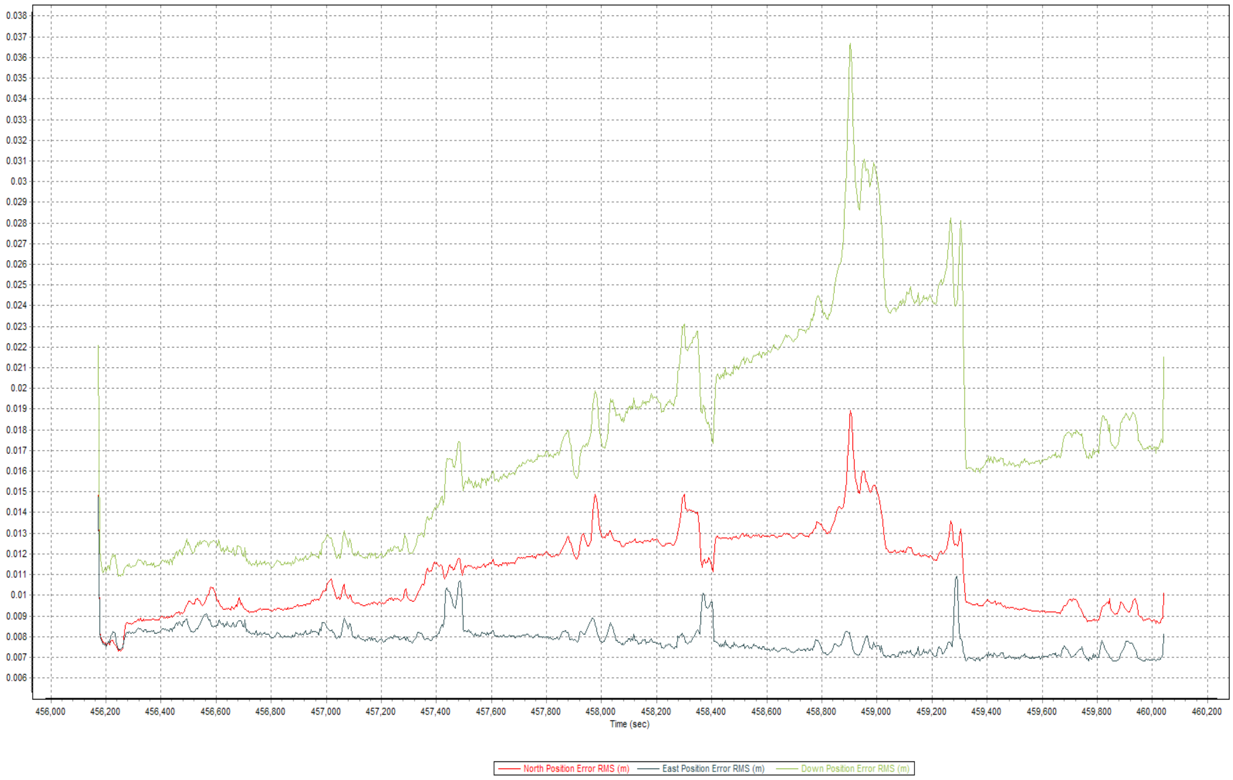


Figure A-8.2 Smoothed Performance Metrics Parameters

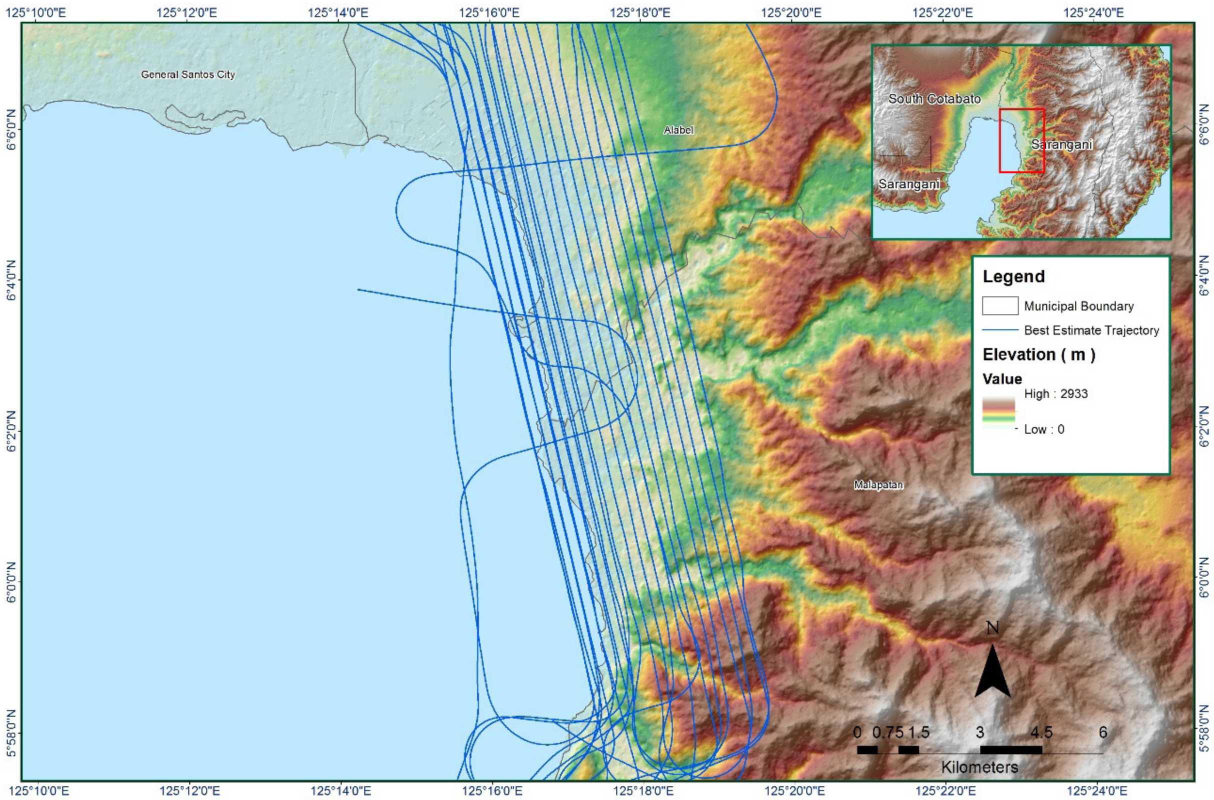


Figure A-8.3 Best Estimated Trajectory

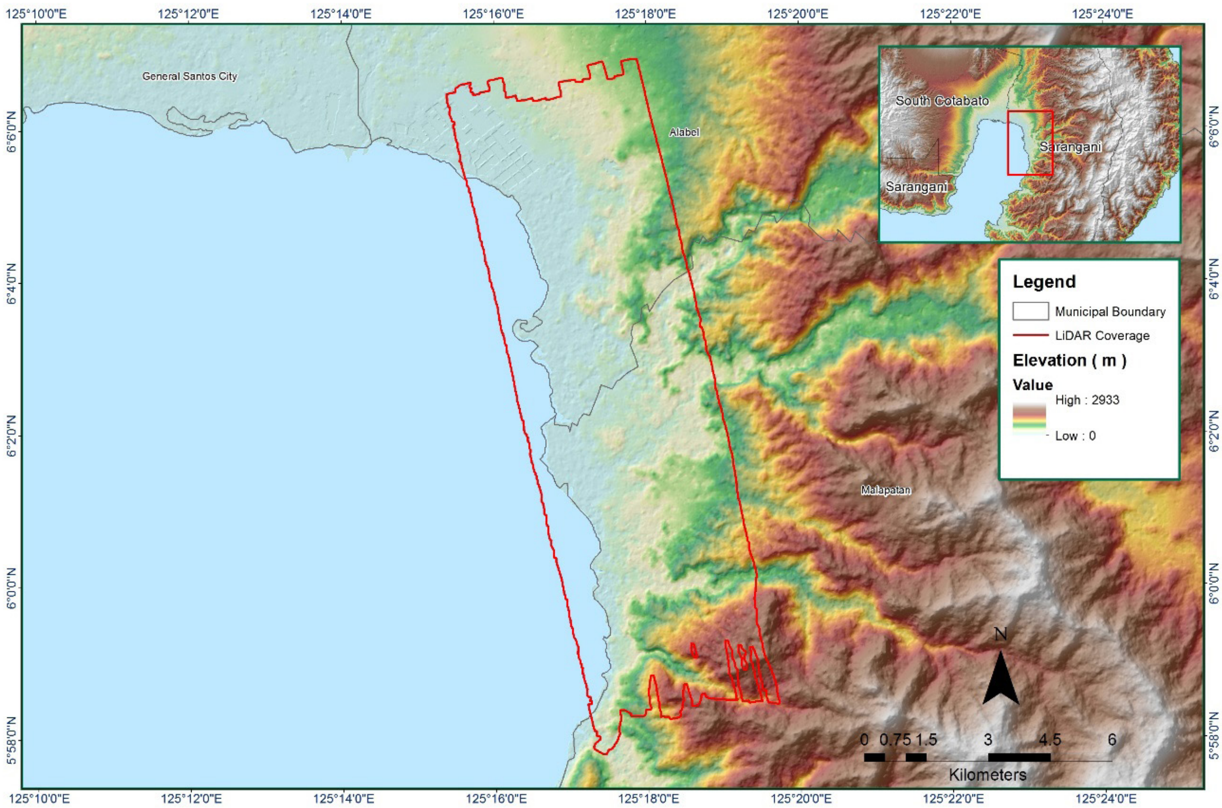


Figure A-8.4. Coverage of LiDAR data

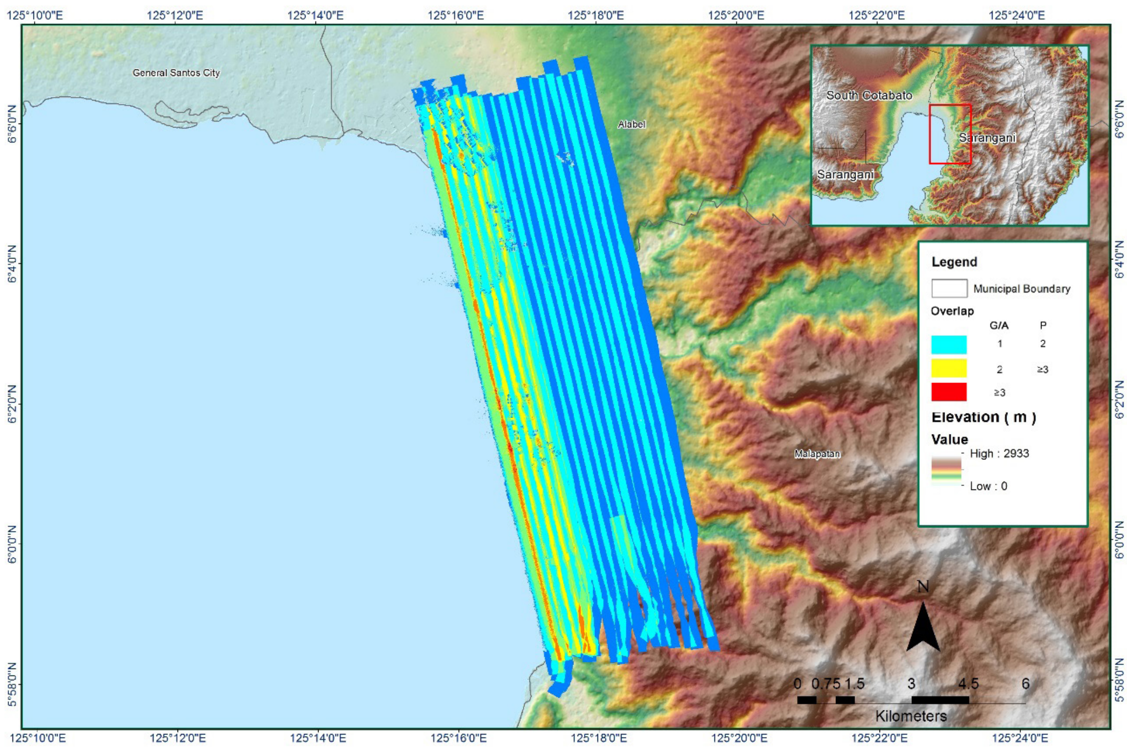


Figure A-8.5. Image of data overlap

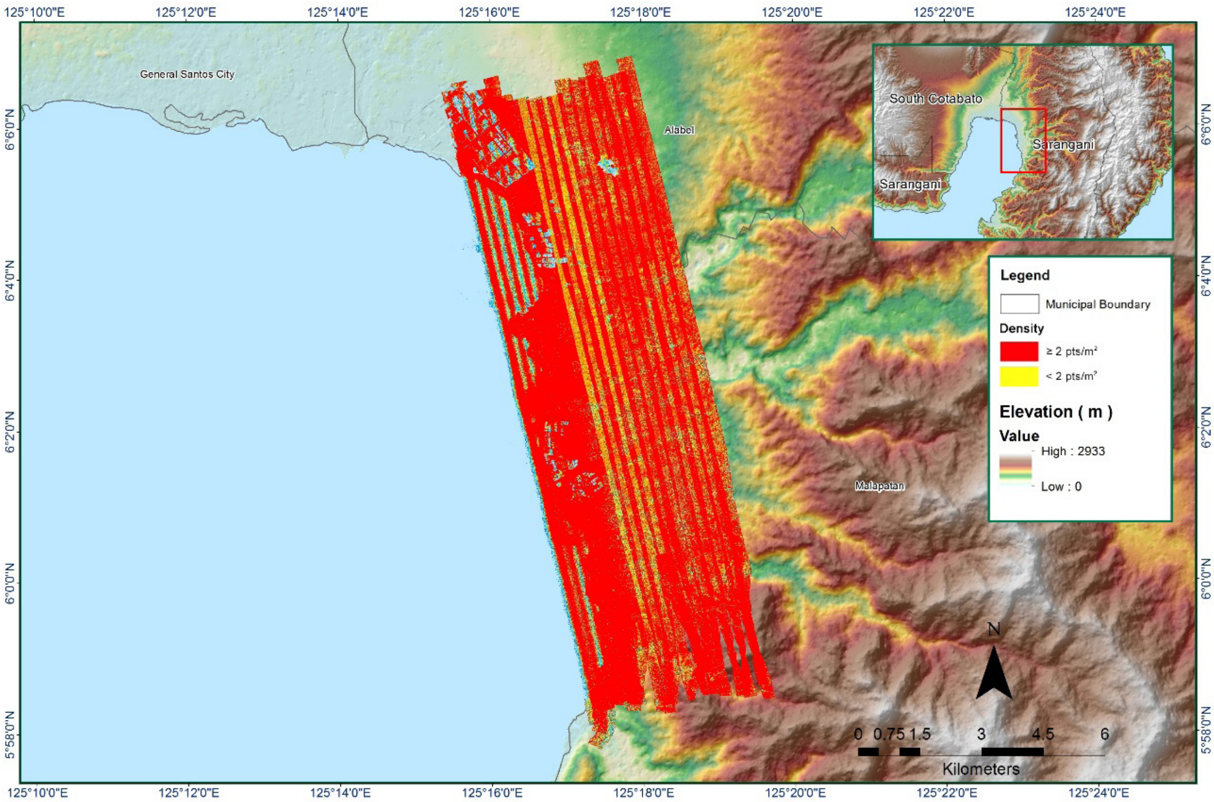


Figure A-8.6 Density of merged LiDAR data

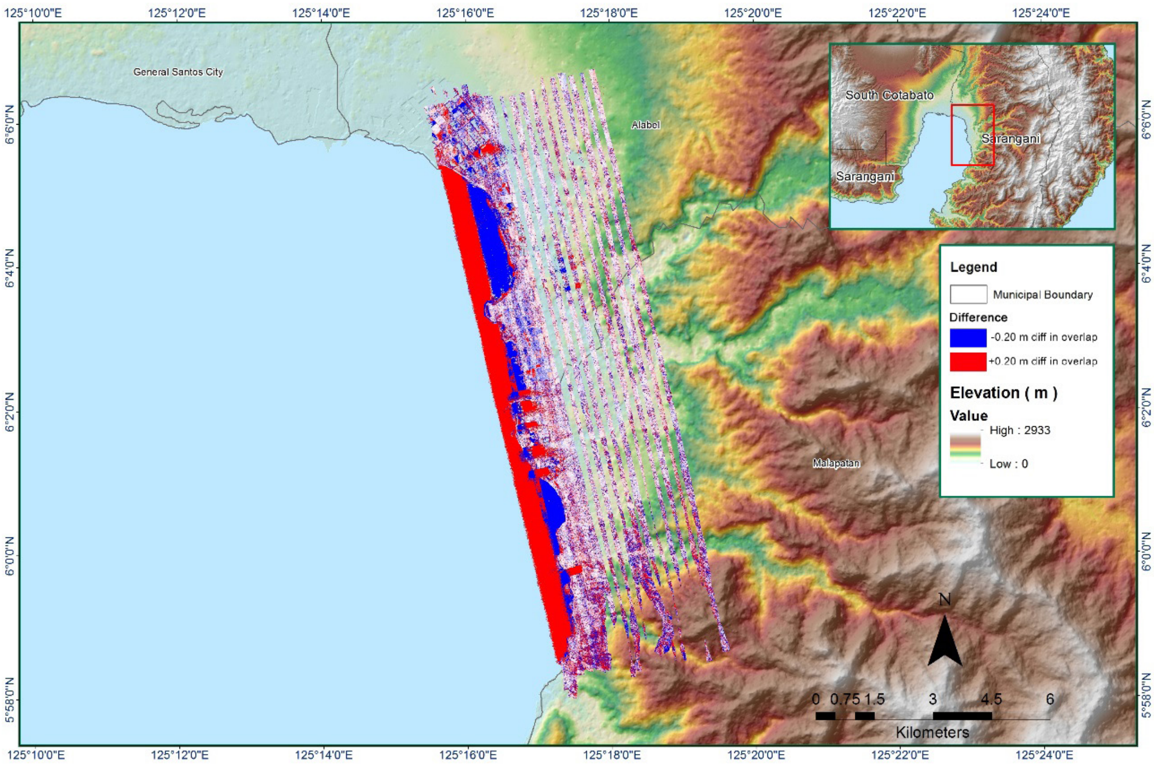


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk 90B

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90B
Inclusive Flights	2114A
Range data size	9.92 GB
POS	236 MB
Image	na
Base Station Data	16 MB
Transfer date	November 19, 2014
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)	2.137
RMSE for East Position (<4.0 cm)	1.942
RMSE for Down Position (<8.0 cm)	5.126
Boresight correction stdev (<0.001deg)	0.000164
IMU attitude correction stdev (<0.001deg)	0.000550
GPS position stdev (<0.01m)	0.0063
Minimum % overlap (>25)	61.64
Ave point cloud density per sq.m. (>2.0)	4.46
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	89
Maximum Height	560.43 m
Minimum Height	90.94 m

Classification (# of points)	
Ground	47,028,761
Low vegetation	47,012,132
Medium vegetation	70,024,925
High vegetation	50,937,946
Building	848,463
Orthophoto	No
Processed by	Engr. Benjamin Jonah Magallon, Engr. Melanie Hingpit, Engr. Elainne Lopez

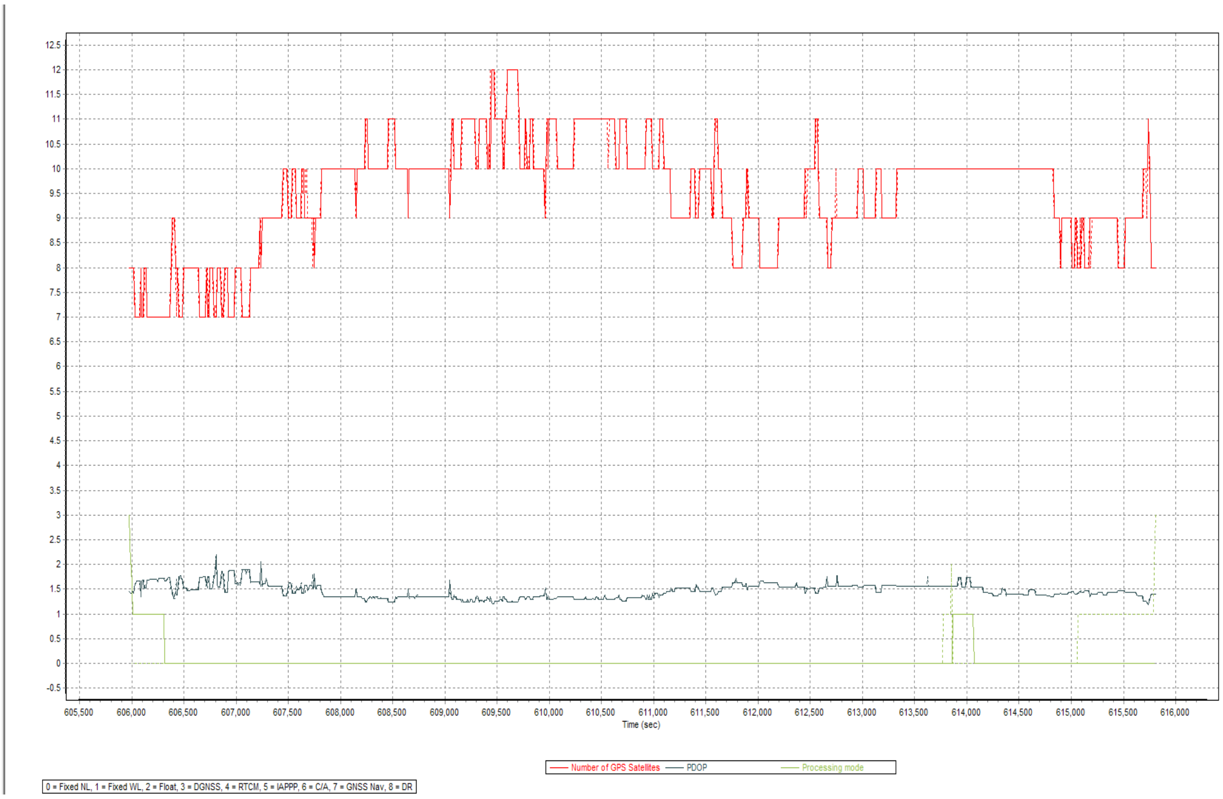


Figure A-8.8. Solution Status

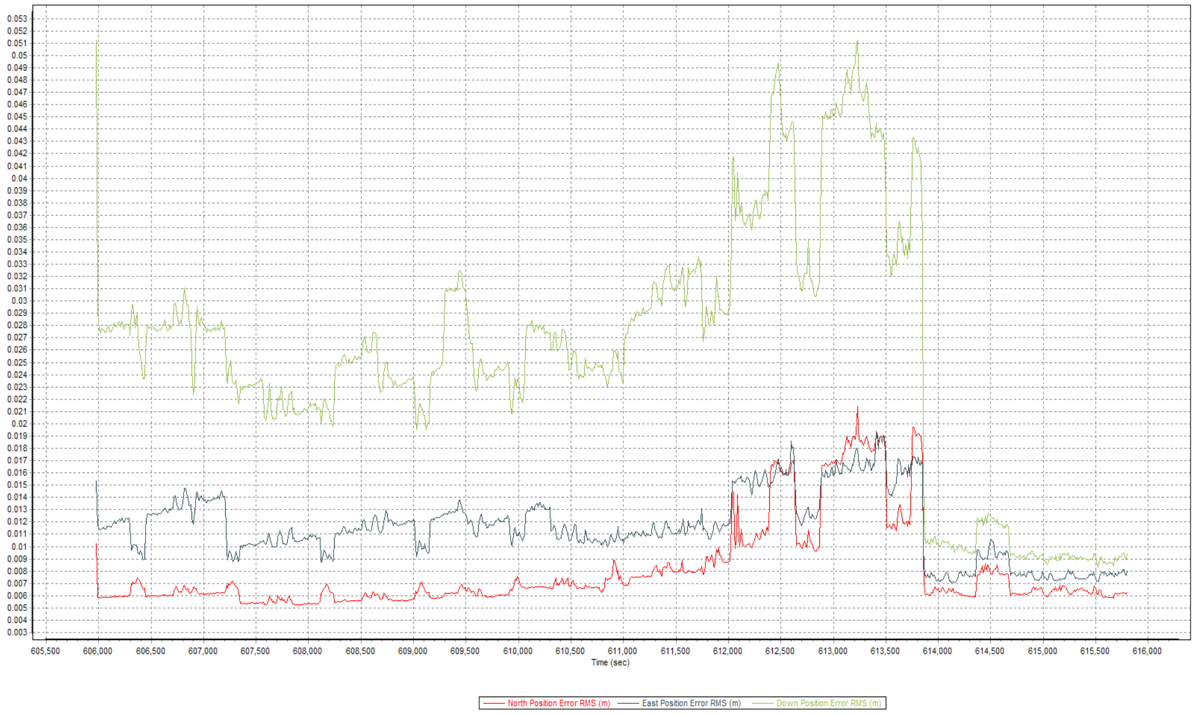


Figure A-8.9. Smoothed Performance Metrics Parameters

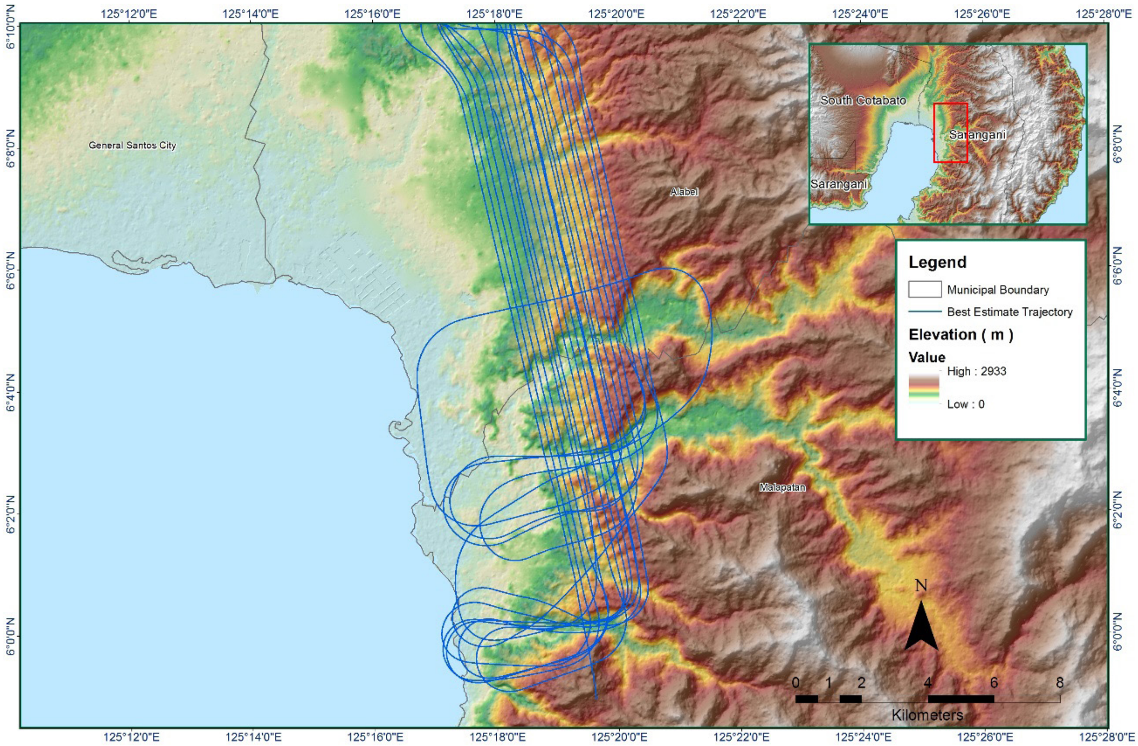


Figure A-8.10. Best Estimated Trajectory

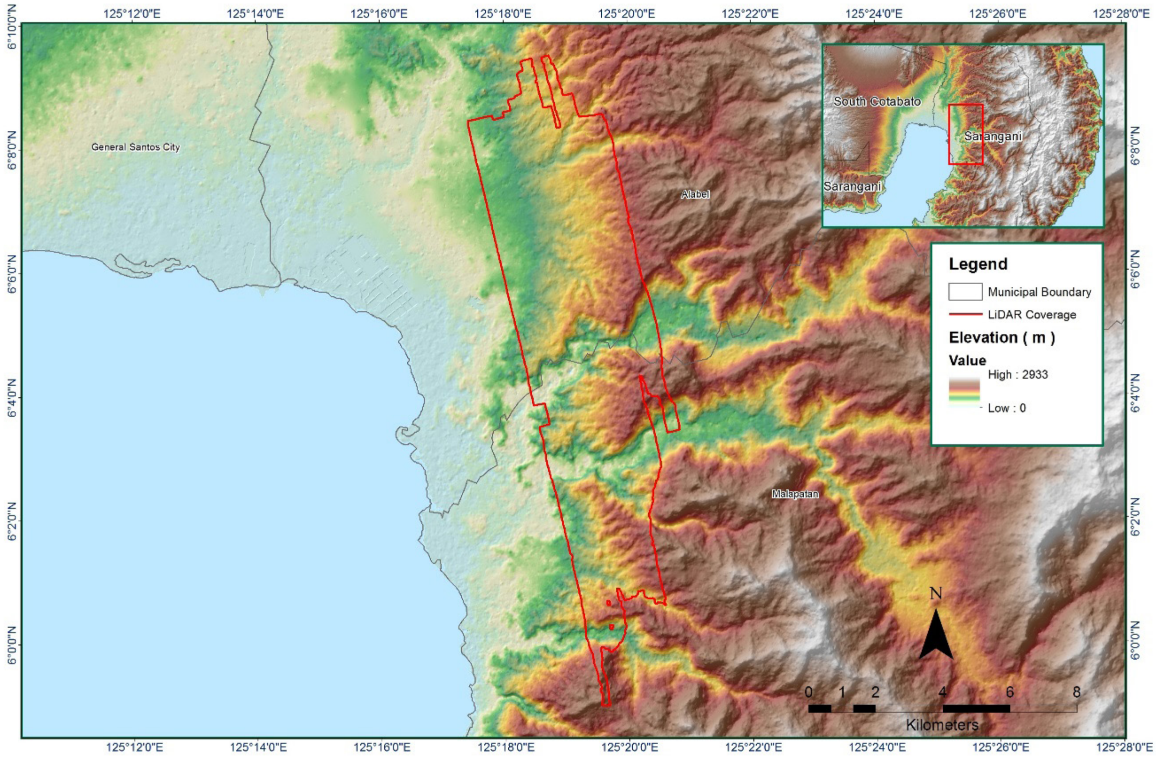


Figure A-8.11. Coverage of LiDAR data

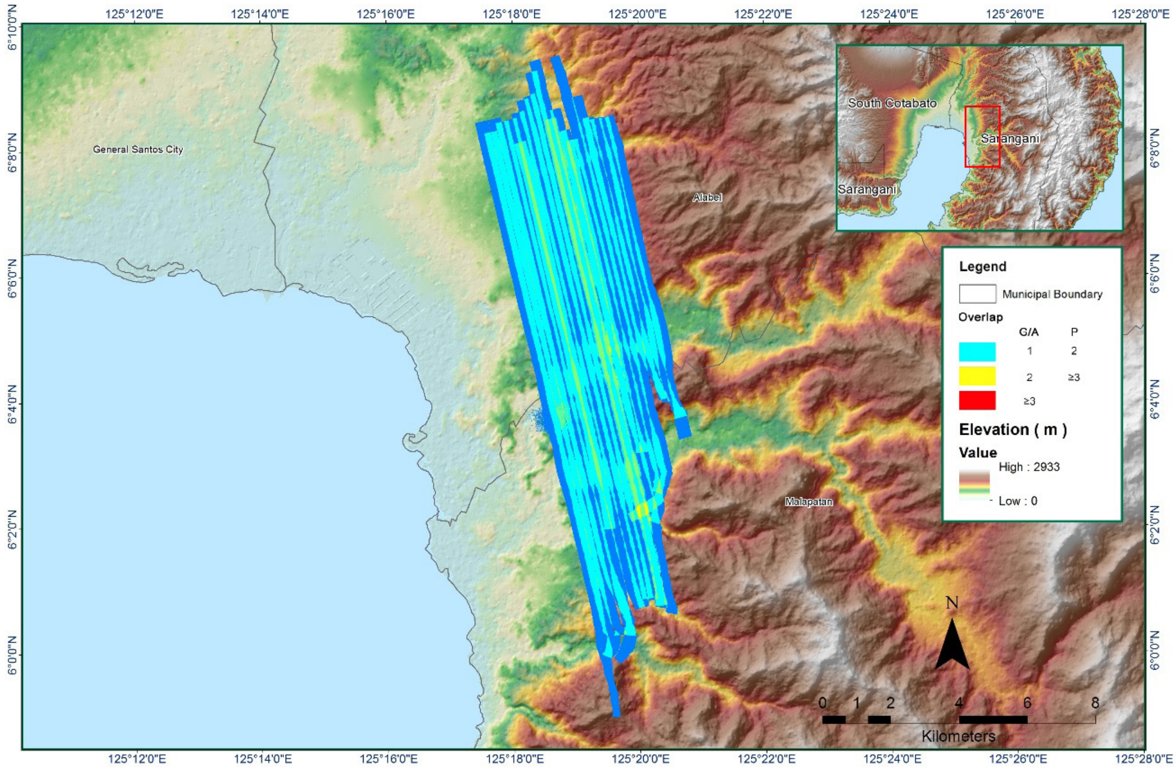


Figure A-8.12. Image of data overlap

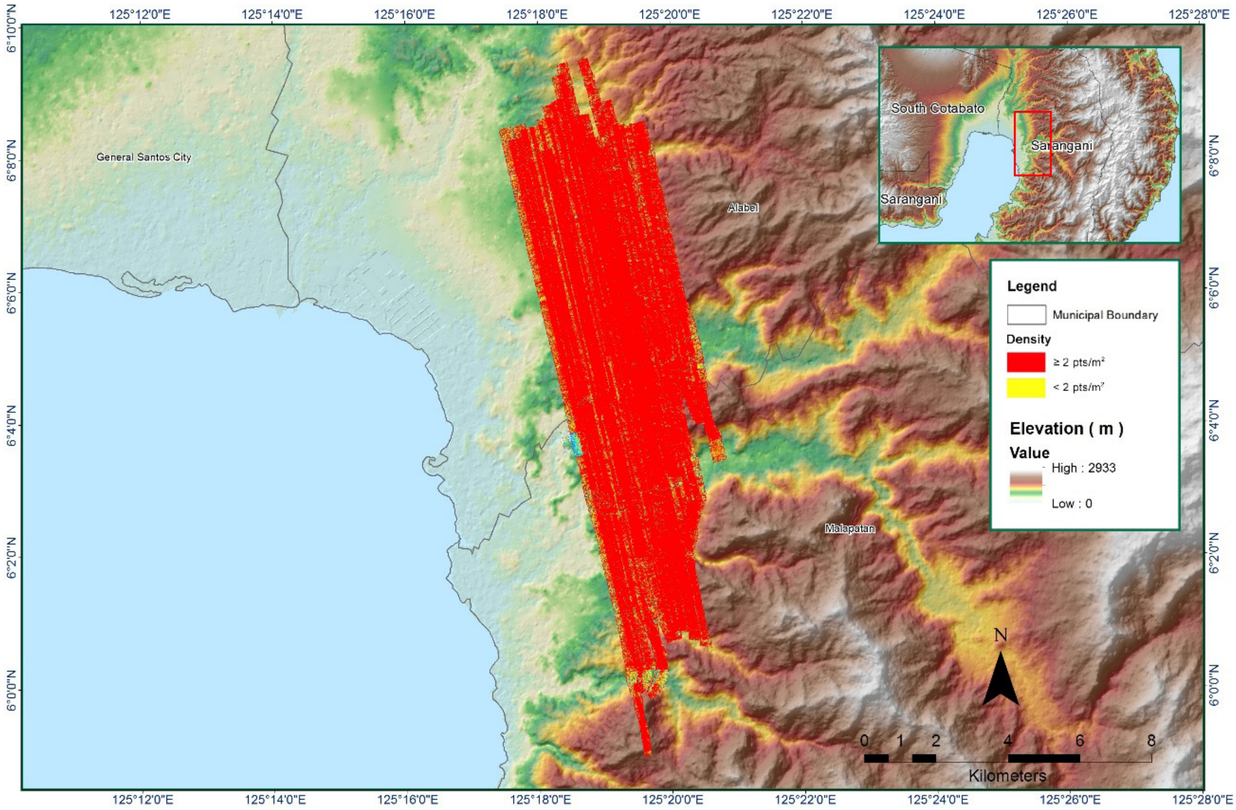


Figure A-8.13. Density of merged LiDAR data

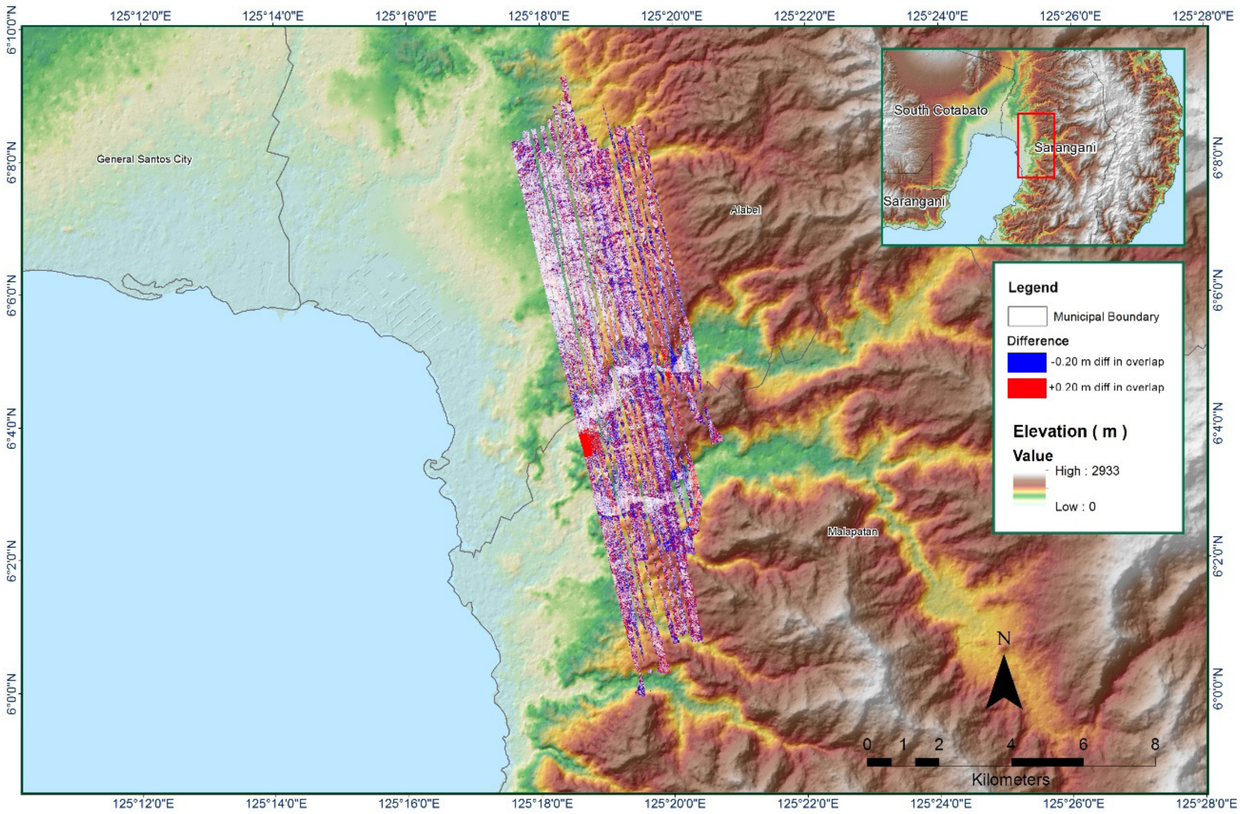


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk 90C

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90C
Inclusive Flights	2118A, 2152A
Range data size	18.61 GB
POS	370 MB
Image	na
Base Station Data	21.73 MB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.322
RMSE for East Position (<4.0 cm)	1.471
RMSE for Down Position (<8.0 cm)	2.890
Boresight correction stdev (<0.001deg)	0.000215
IMU attitude correction stdev (<0.001deg)	0.001399
GPS position stdev (<0.01m)	0.0218
Minimum % overlap (>25)	60.95
Ave point cloud density per sq.m. (>2.0)	4.53
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	174
Maximum Height	576.49 m
Minimum Height	51.04 m

Classification (# of points)	
Ground	54948631
Low vegetation	63669401
Medium vegetation	95656635
High vegetation	120677828
Building	4641693
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Engr. Jeffrey Delica

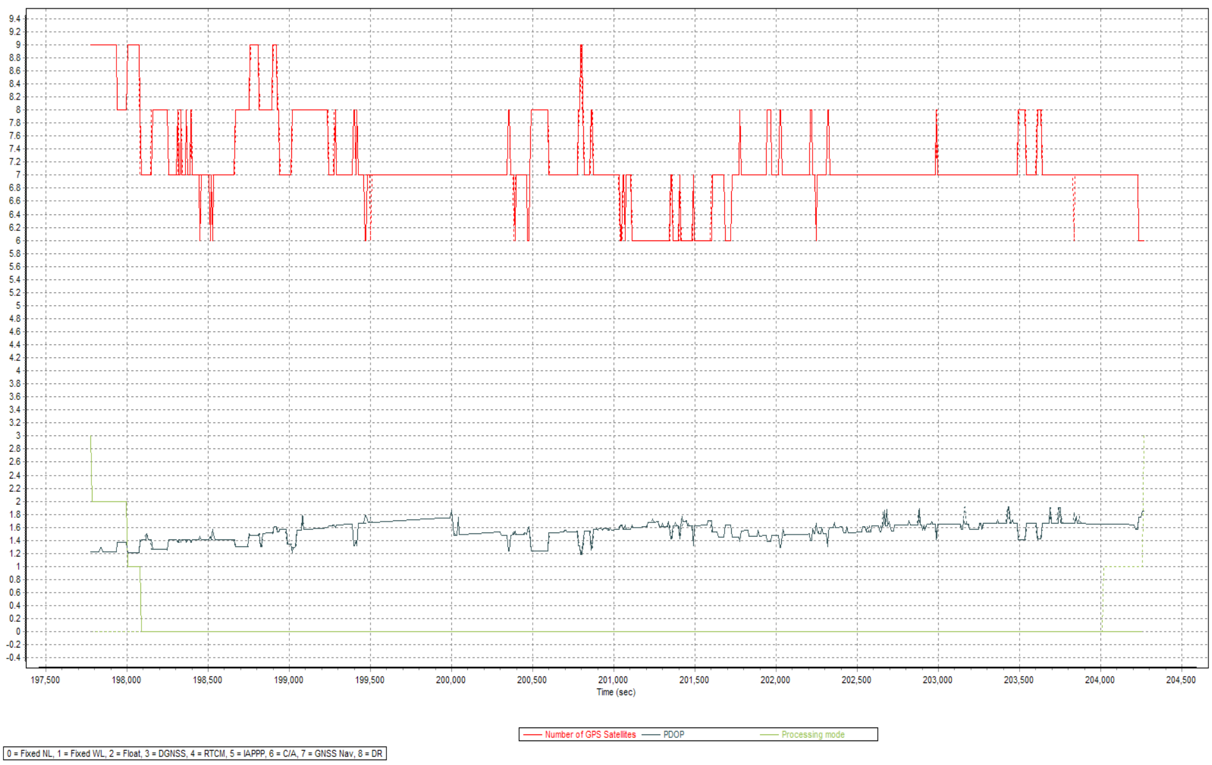


Figure A-8.15. Solution Status

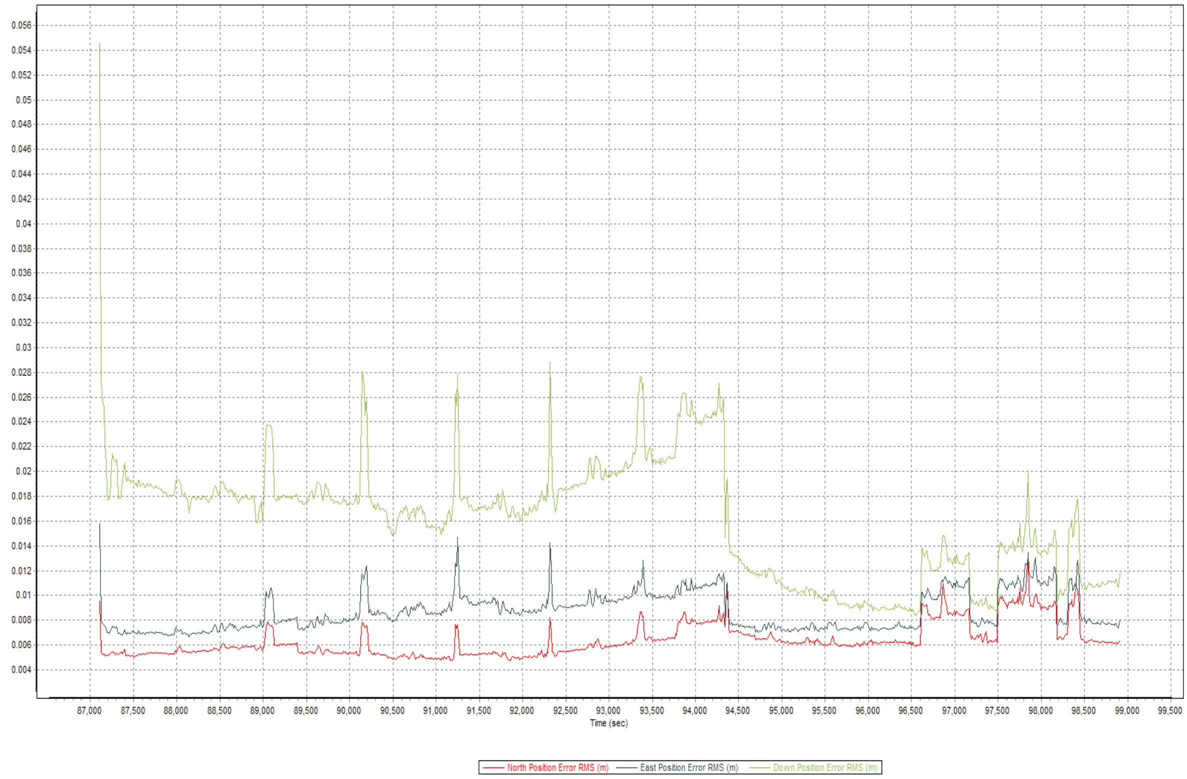


Figure A-8.16. Smoothed Performance Metrics Parameters

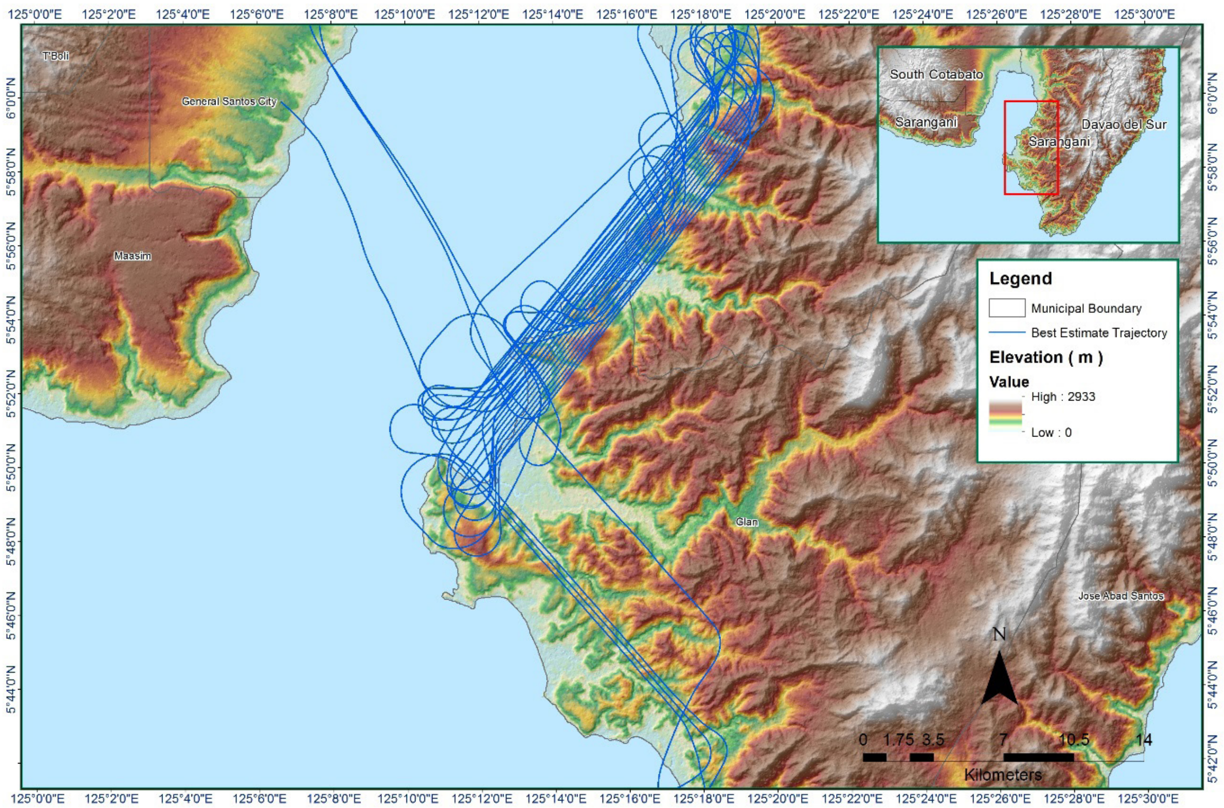


Figure A-8.17. Best Estimated Trajectory

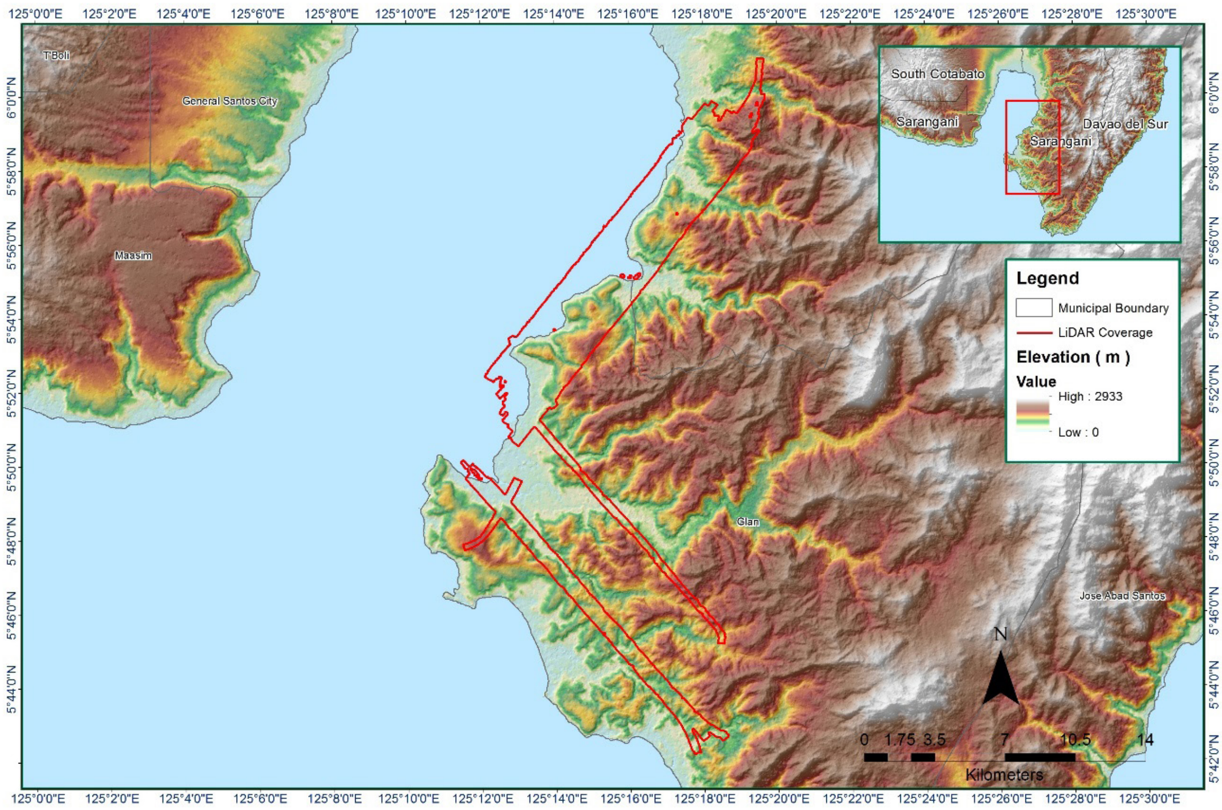


Figure A-8.18. Coverage of LiDAR data

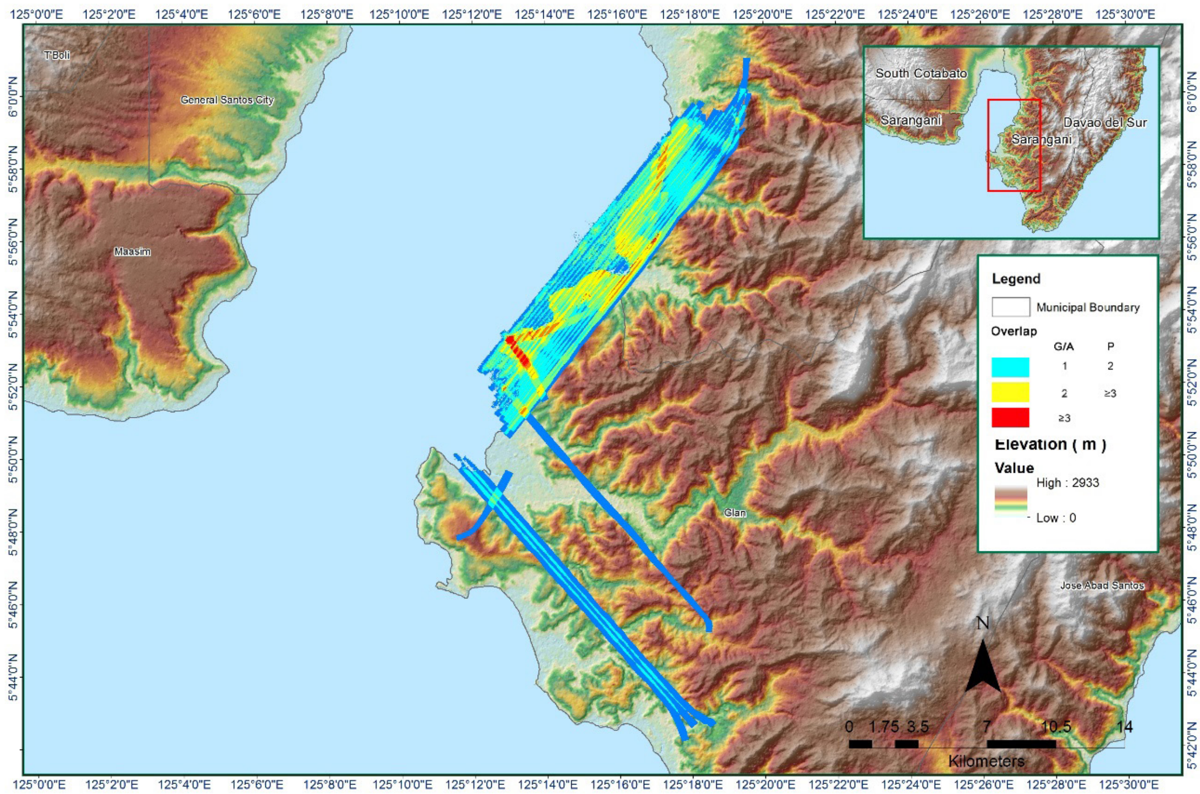


Figure A-8.19. Image of data overlap

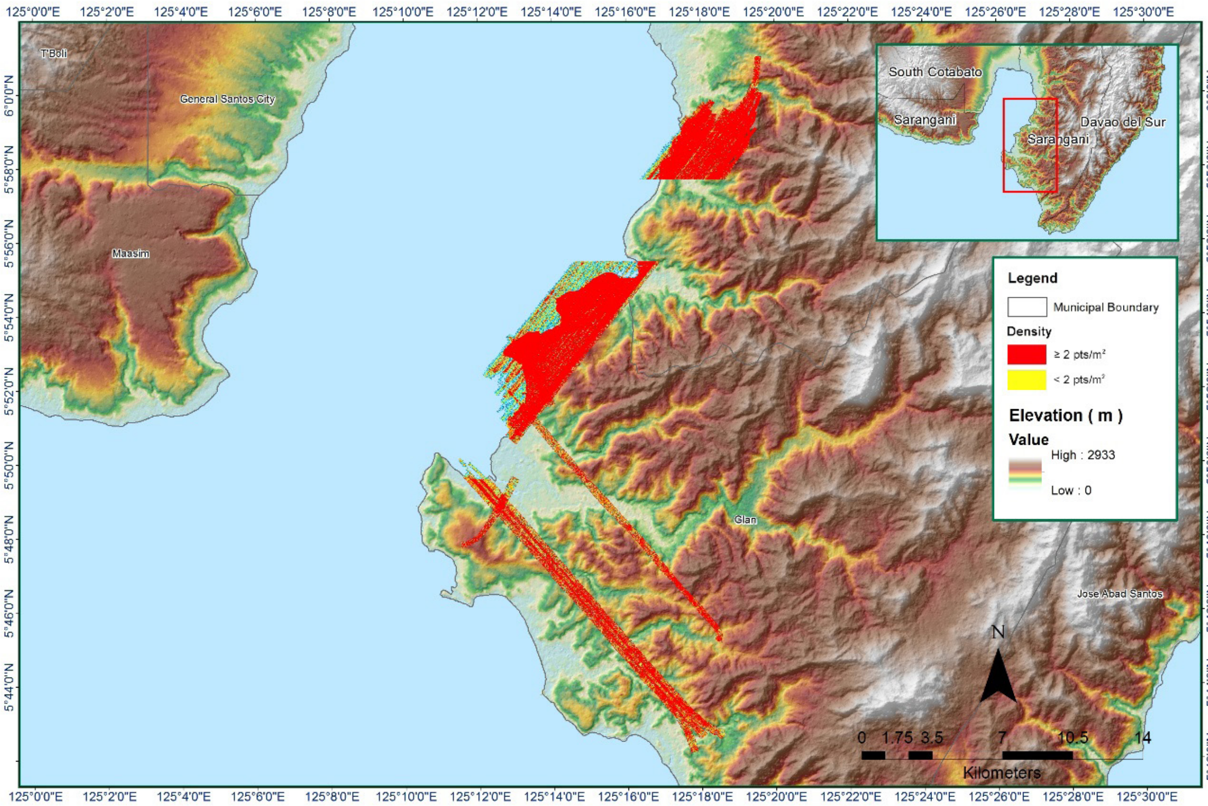


Figure A-8.20. Density of merged LiDAR data

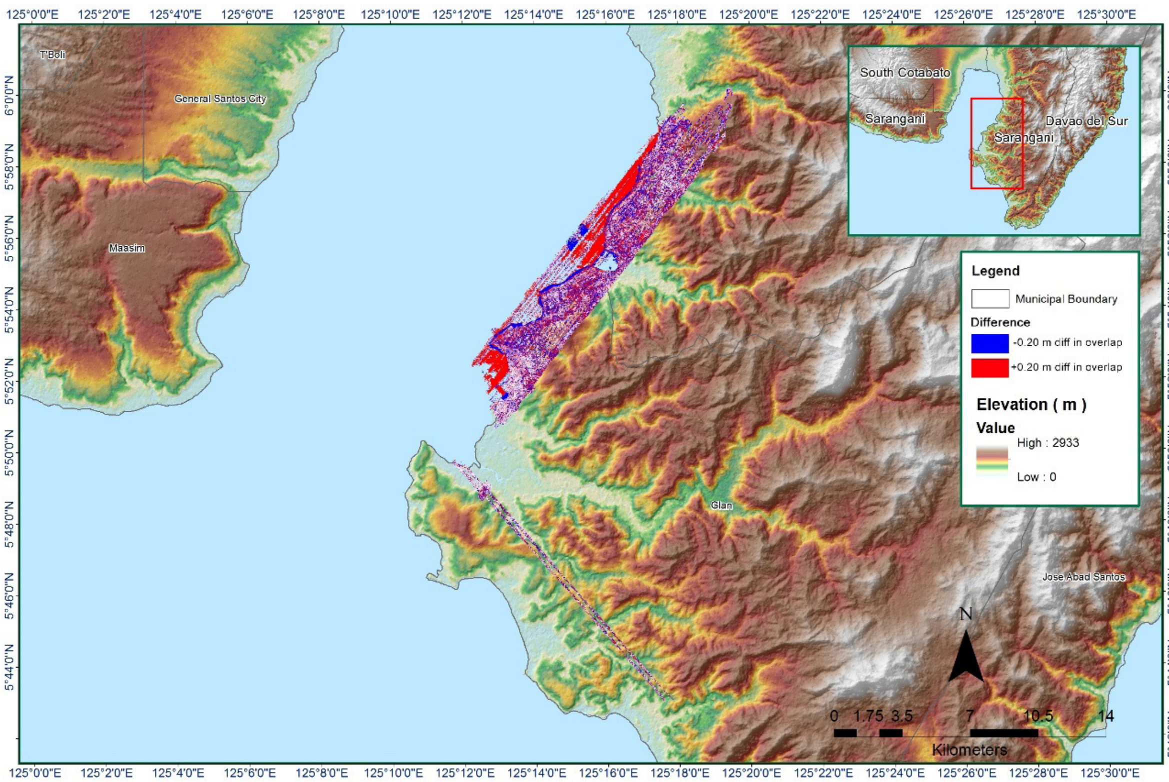


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk 90F

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90F
Inclusive Flights	2126A
Range data size	7.77 GB
POS	197 MB
Image	na
Base Station Data	7.83 MB
Transfer date	November 19, 2014
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)	0.947
RMSE for East Position (<4.0 cm)	1.361
RMSE for Down Position (<8.0 cm)	3.265
Boresight correction stdev (<0.001deg)	0.000257
IMU attitude correction stdev (<0.001deg)	0.000739
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	50.80
Ave point cloud density per sq.m. (>2.0)	3.65
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	65
Maximum Height	532.85 m
Minimum Height	63.16 m

Classification (# of points)	
Ground	25,453,075
Low vegetation	24,021,462
Medium vegetation	32,403,168
High vegetation	48,332,353
Building	1,081,345
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Engr. Elainne Lopez

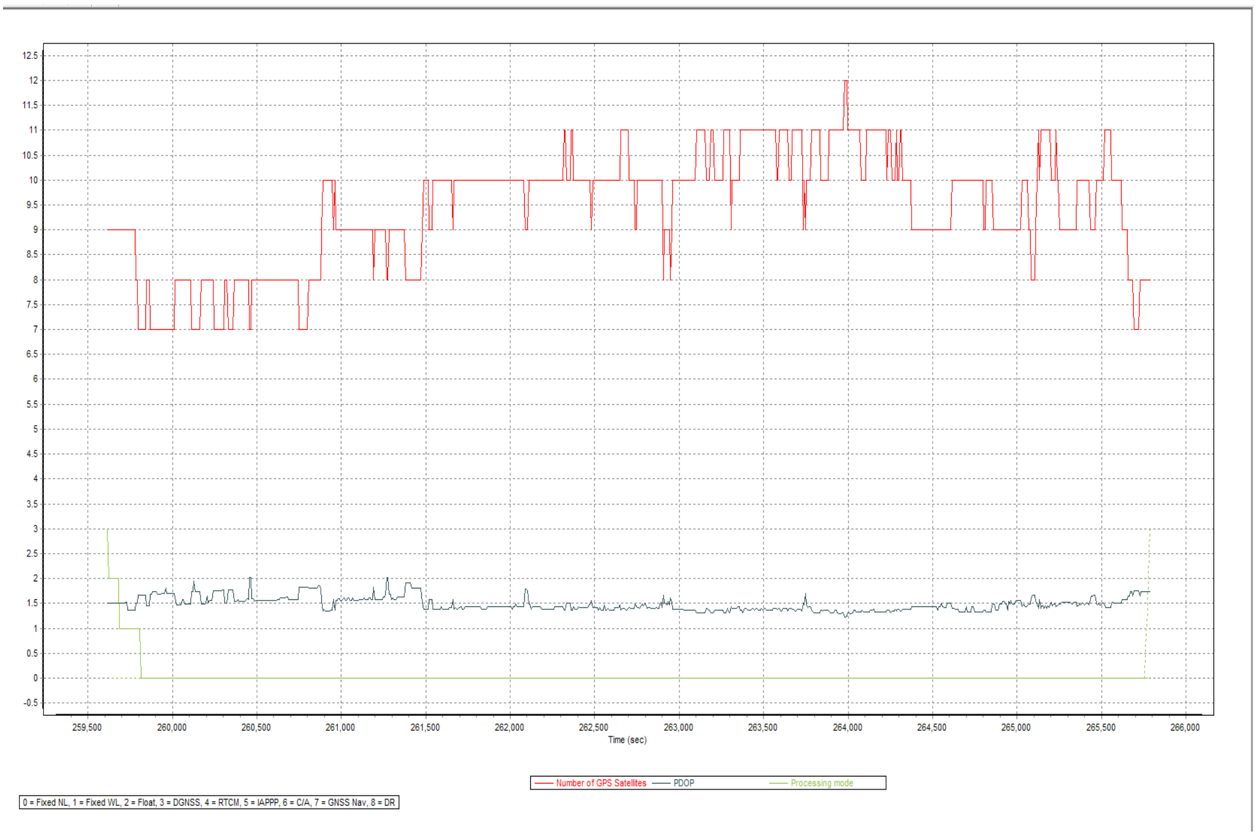


Figure A-8.22. Solution Status

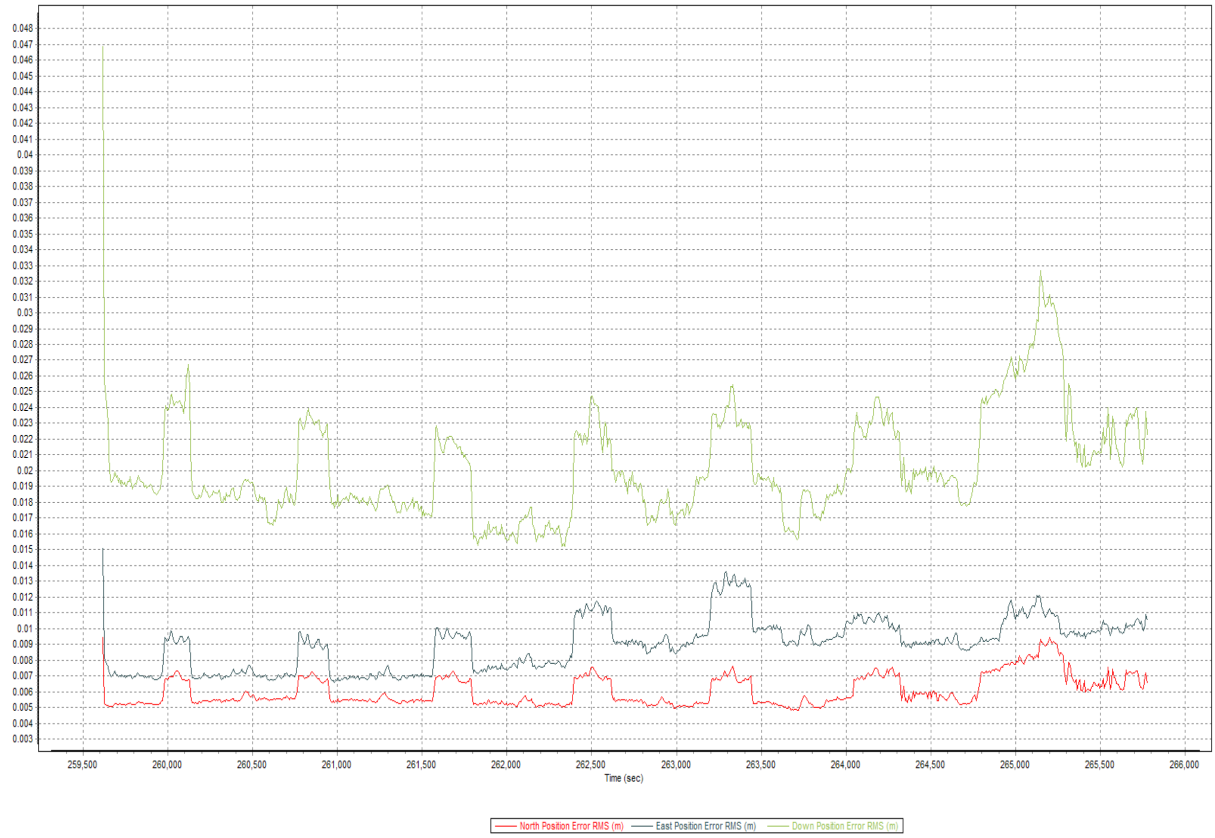


Figure A-8.23. Smoothed Performance Metrics Parameters

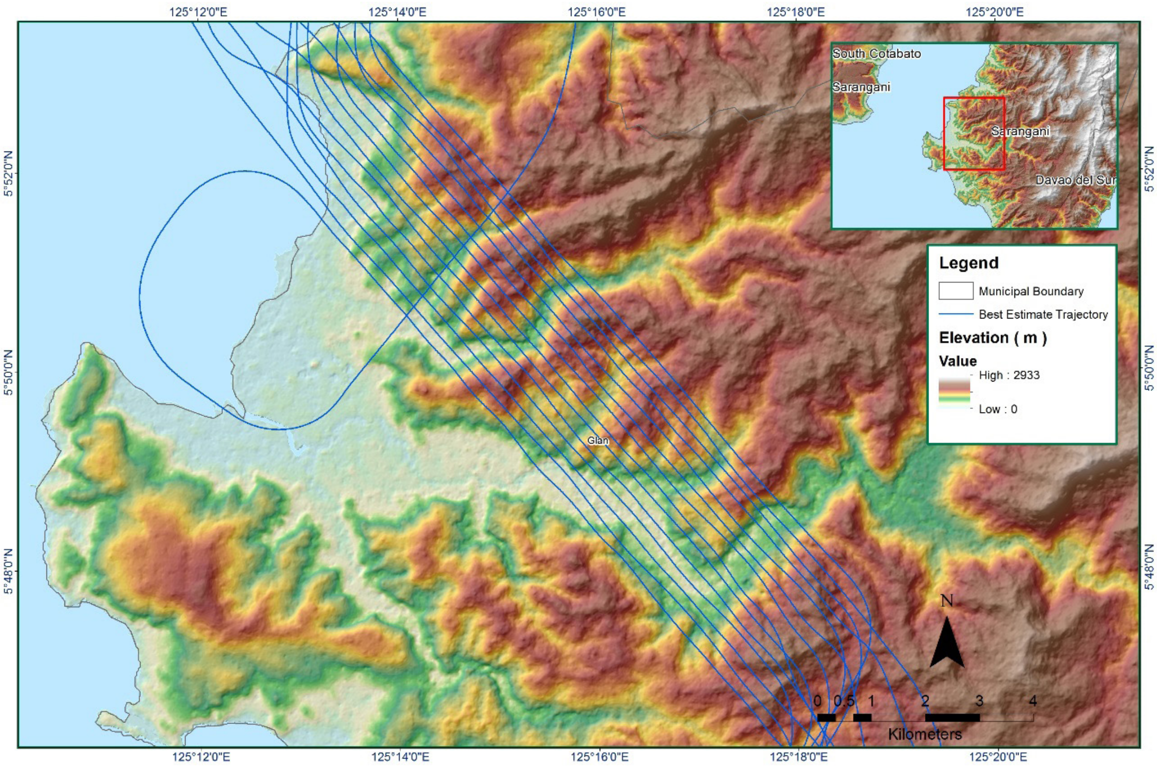


Figure A-8.24. Best Estimated Trajectory

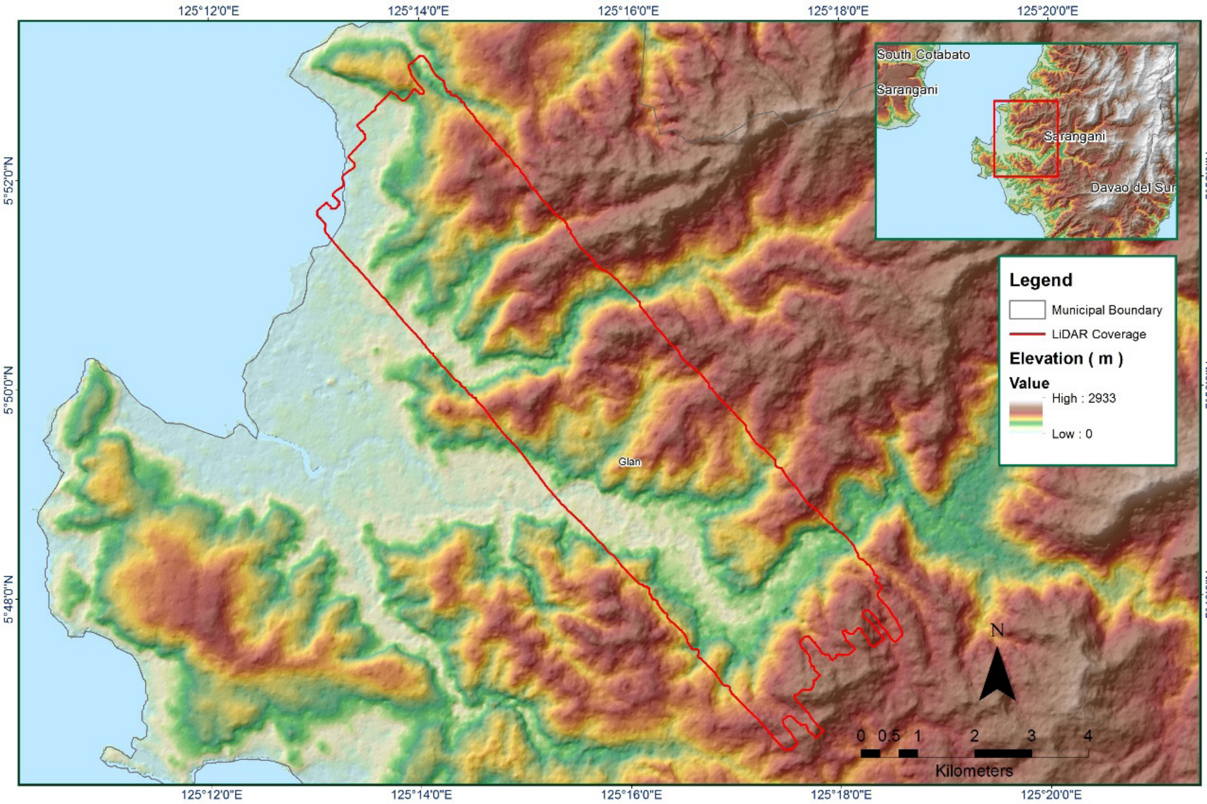


Figure A-8.25. Coverage of LiDAR data

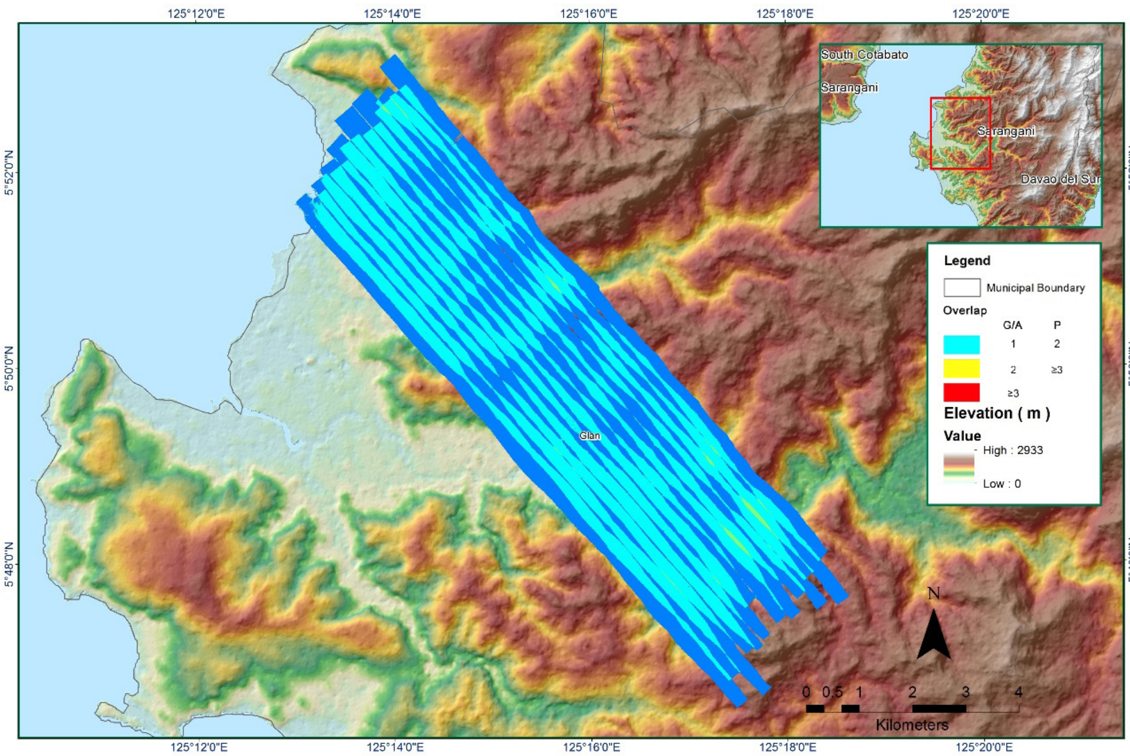


Figure A-8.26. Image of data overlap

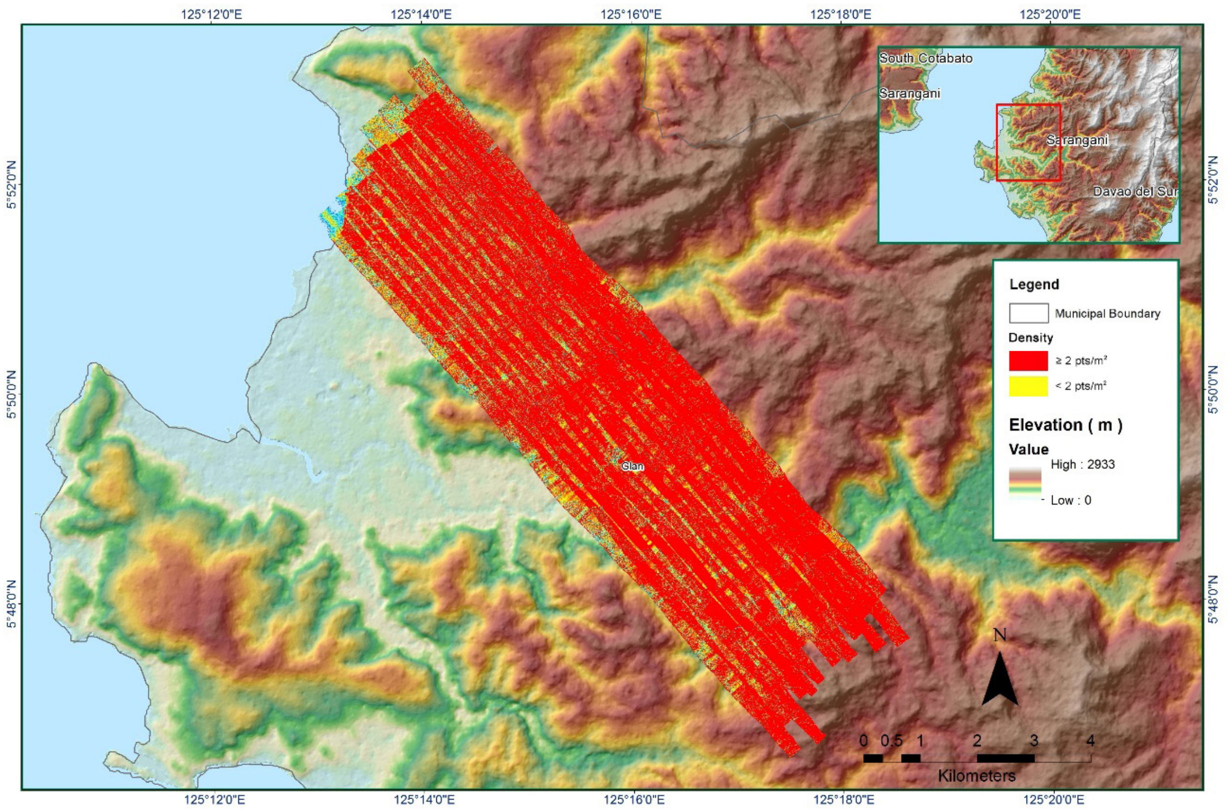


Figure A-8.27. Density of merged LiDAR data

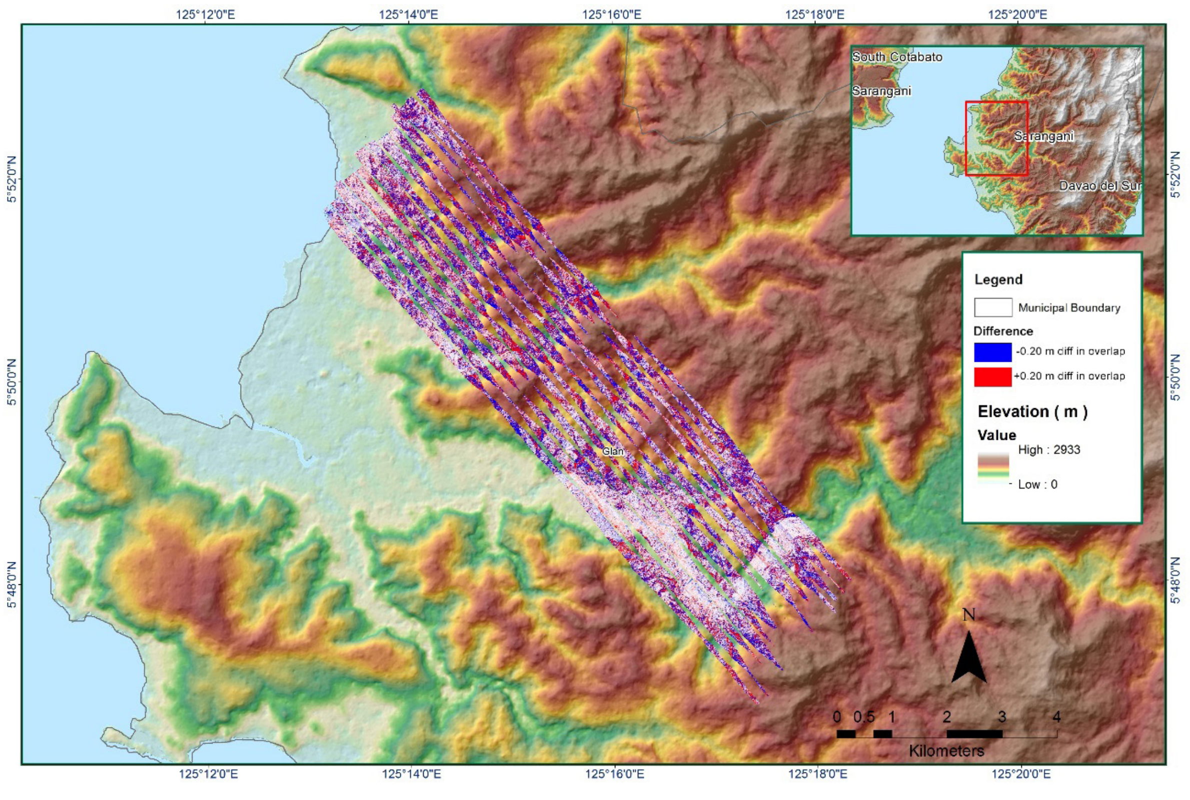


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk 90D

Flight Area	South Cotabato/Saranggani
Mission Name	Blk 90D
Inclusive Flights	2120A, 2122A
Range data size	22.5 GB
POS	423 MB
Image	n/a
Base Station Data	14.48 MB
Transfer date	March 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.001323
GPS position stdev (<0.01m)	0.0075
Minimum % overlap (>25)	49.63%
Ave point cloud density per sq.m. (>2.0)	2.98
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	130
Maximum Height	372.92 m
Minimum Height	50.45 m

Classification (# of points)	
Ground	53550595
Low vegetation	46662134
Medium vegetation	57119721
High vegetation	91014022
Building	1779534
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Elainne Lopez

Figure A-8.29. Solution Status

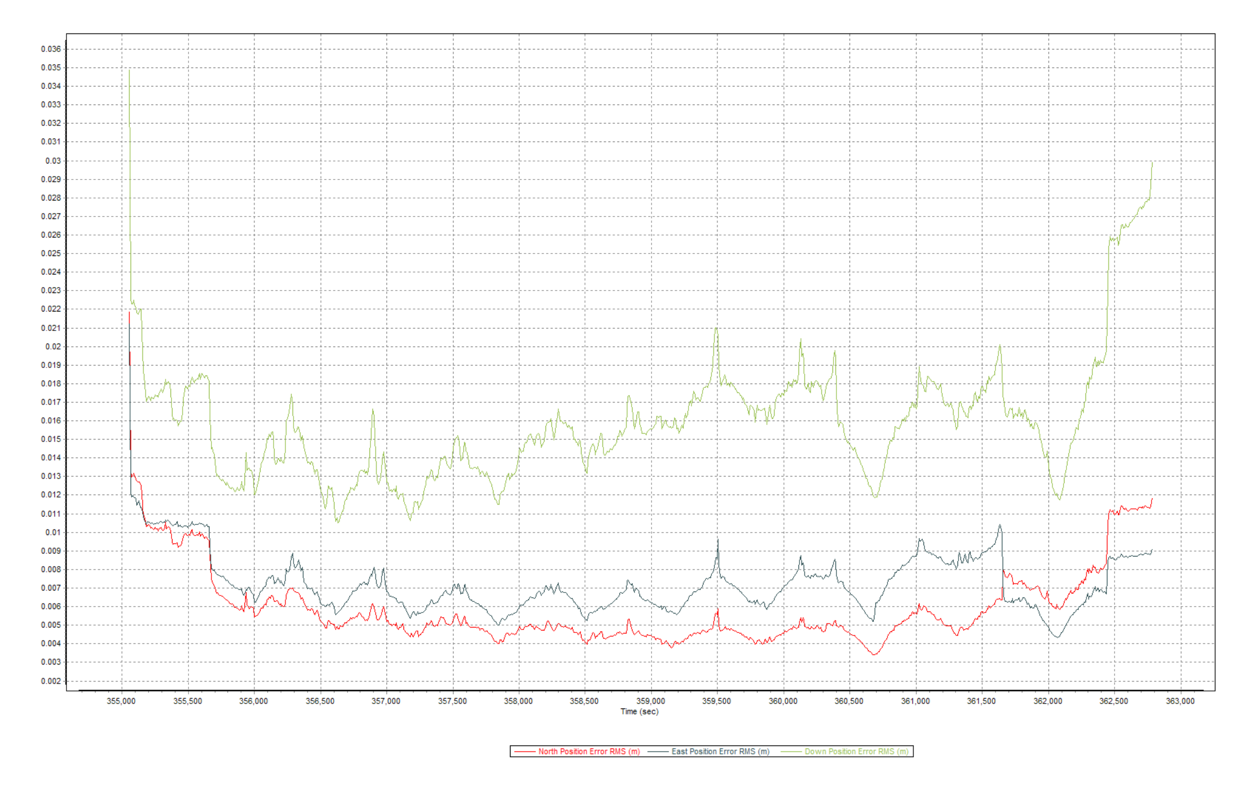


Figure A-8.30. Smoothed Performance Metrics Parameters

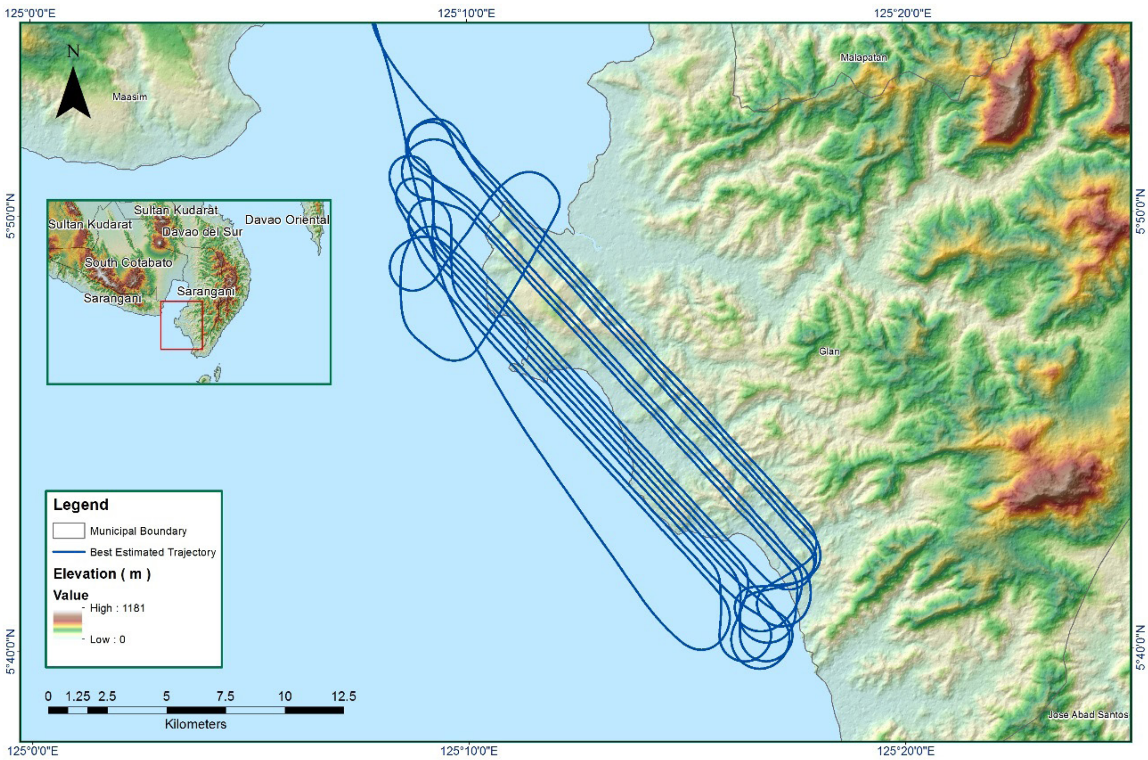


Figure A-8.31. Best Estimated Trajectory

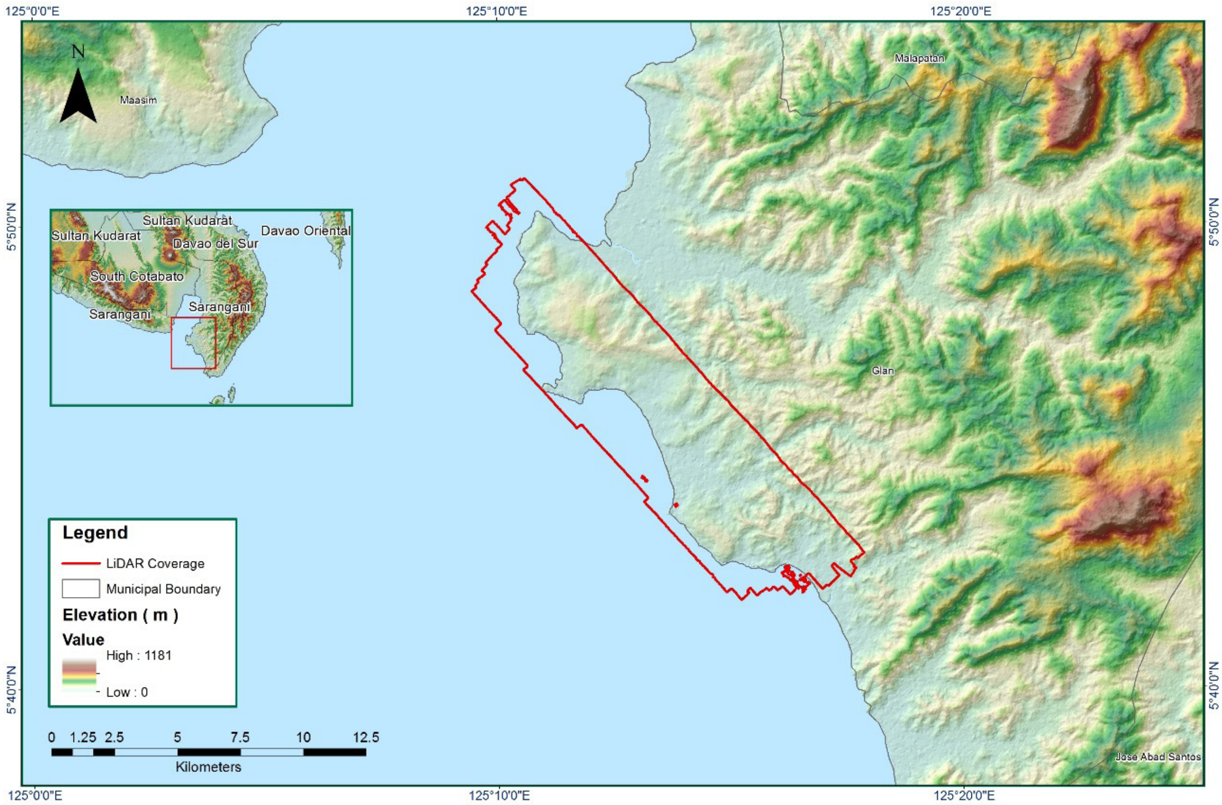


Figure A-8.32. Coverage of LiDAR data

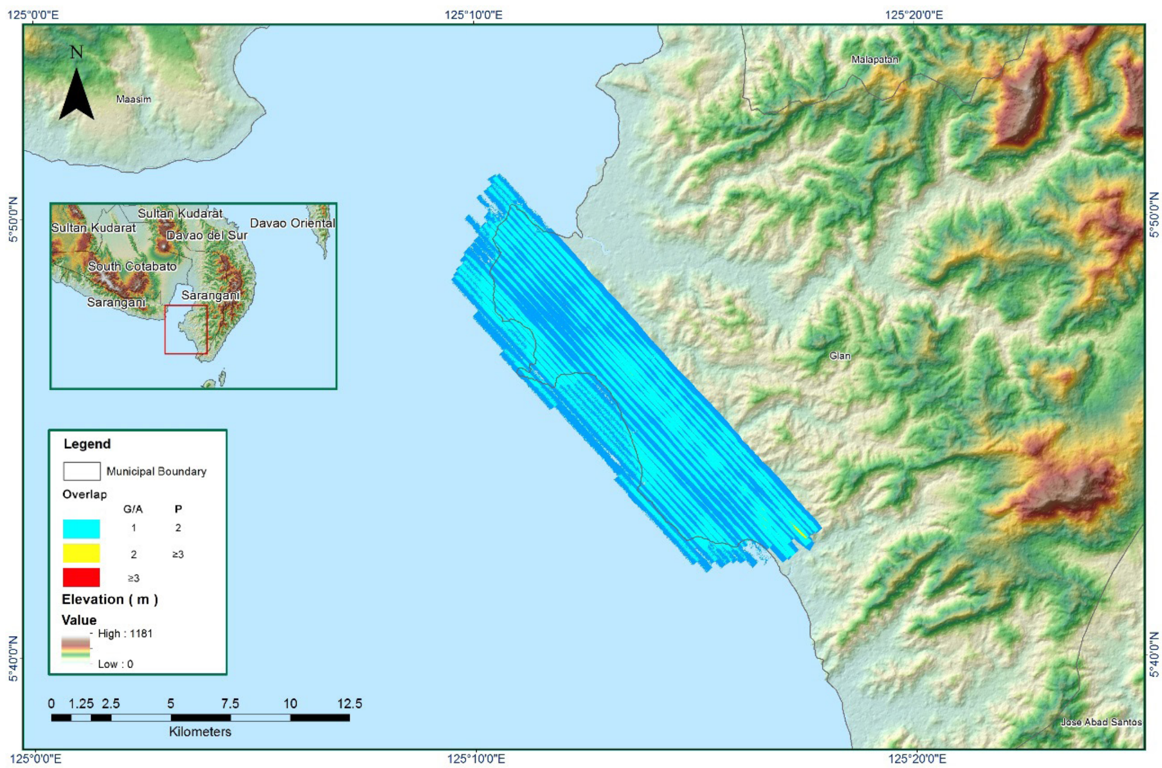


Figure A-8.33. Image of data overlap

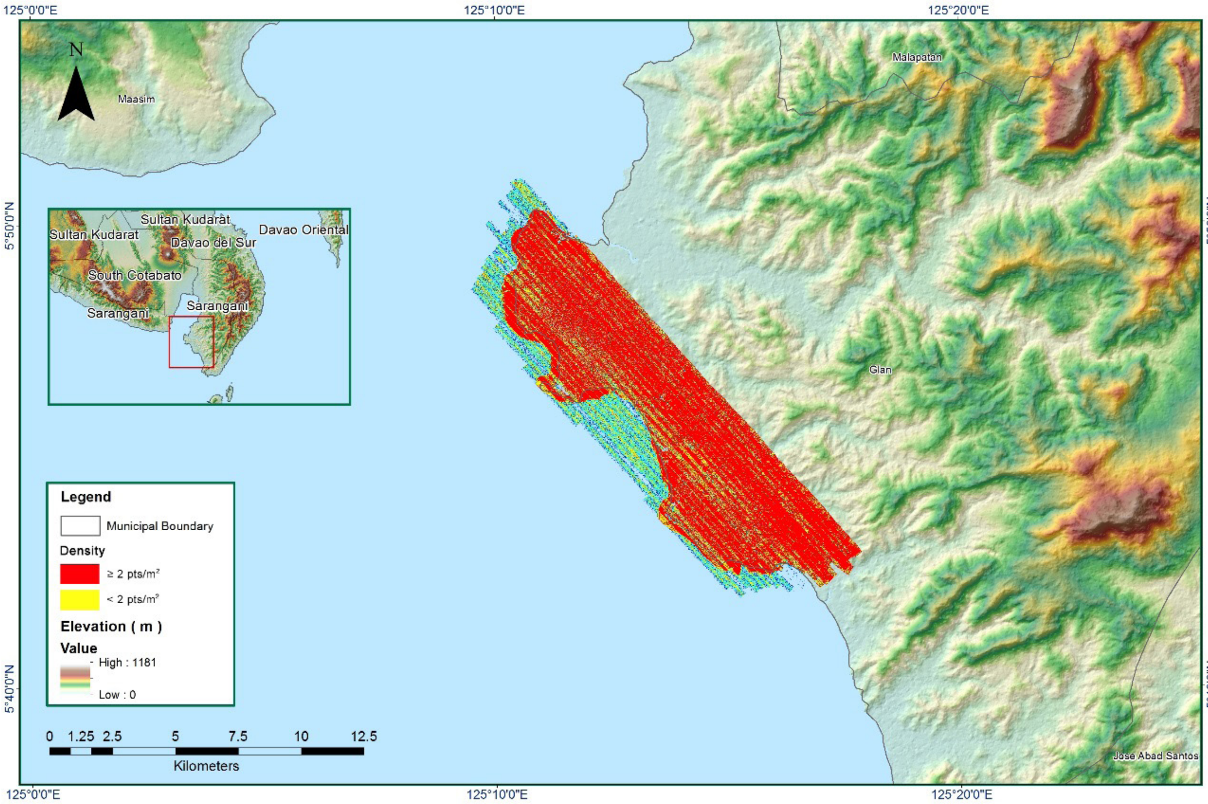


Figure A-8.34. Density of merged LiDAR data

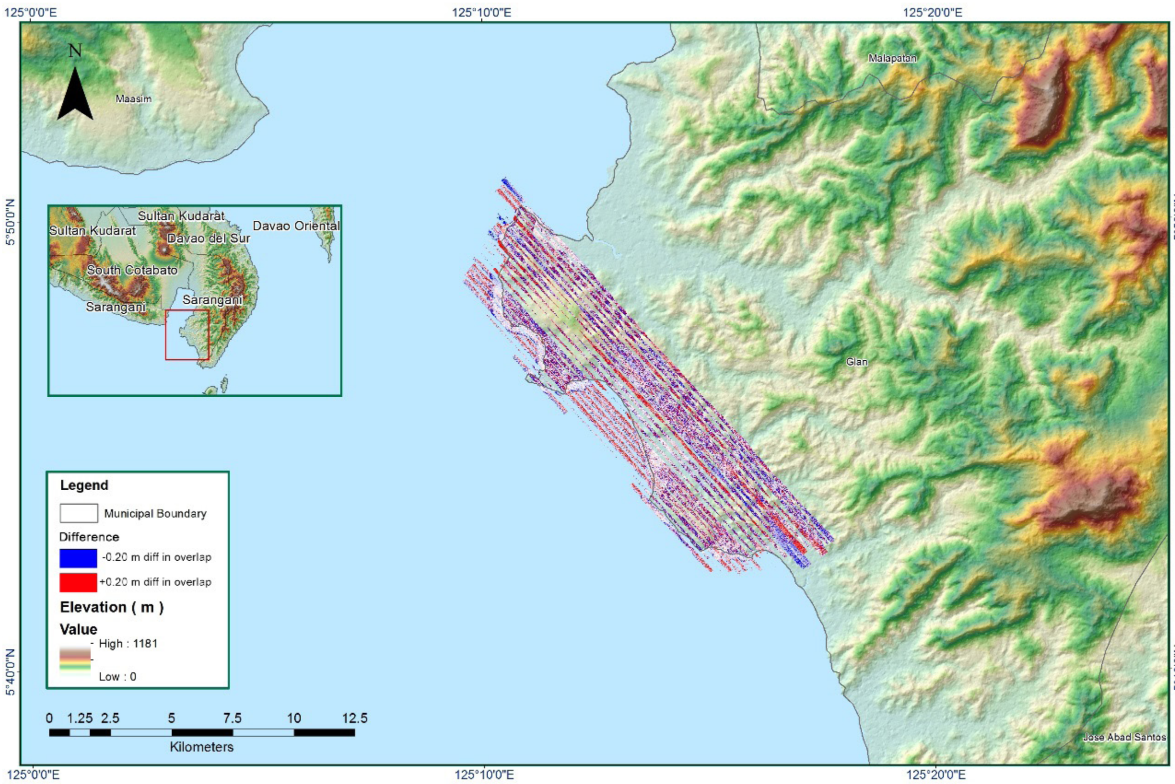


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk 90E

Flight Area	General Santos
Mission Name	BLK 90E
Inclusive Flights	2122A
Range data size	13.7 GB
POS	251 MB
Image	n/a
Base station data	8.7 MB
Transfer date	March 25,2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.44
RMSE for East Position (<4.0 cm)	1.62
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000221
IMU attitude correction stdev (<0.001deg)	0.001040
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	52.60
Ave point cloud density per sq.m. (>2.0)	4.03
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	539.61 m
Minimum Height	59.94 m

Classification (# of points)	
Ground	44116613
Low vegetation	41409470
Medium vegetation	60639483
High vegetation	59673030
Building	3459011
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Alex John Escobido

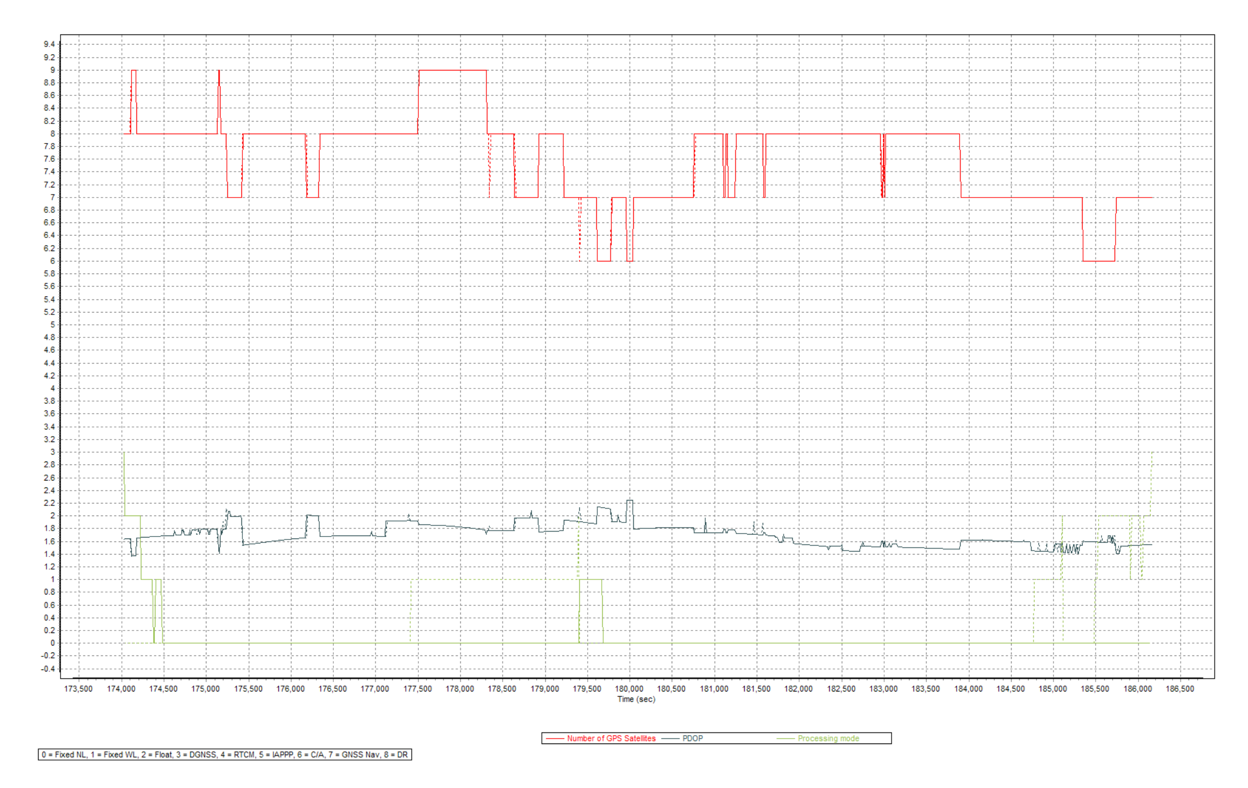


Figure A-8.36. Solution Status

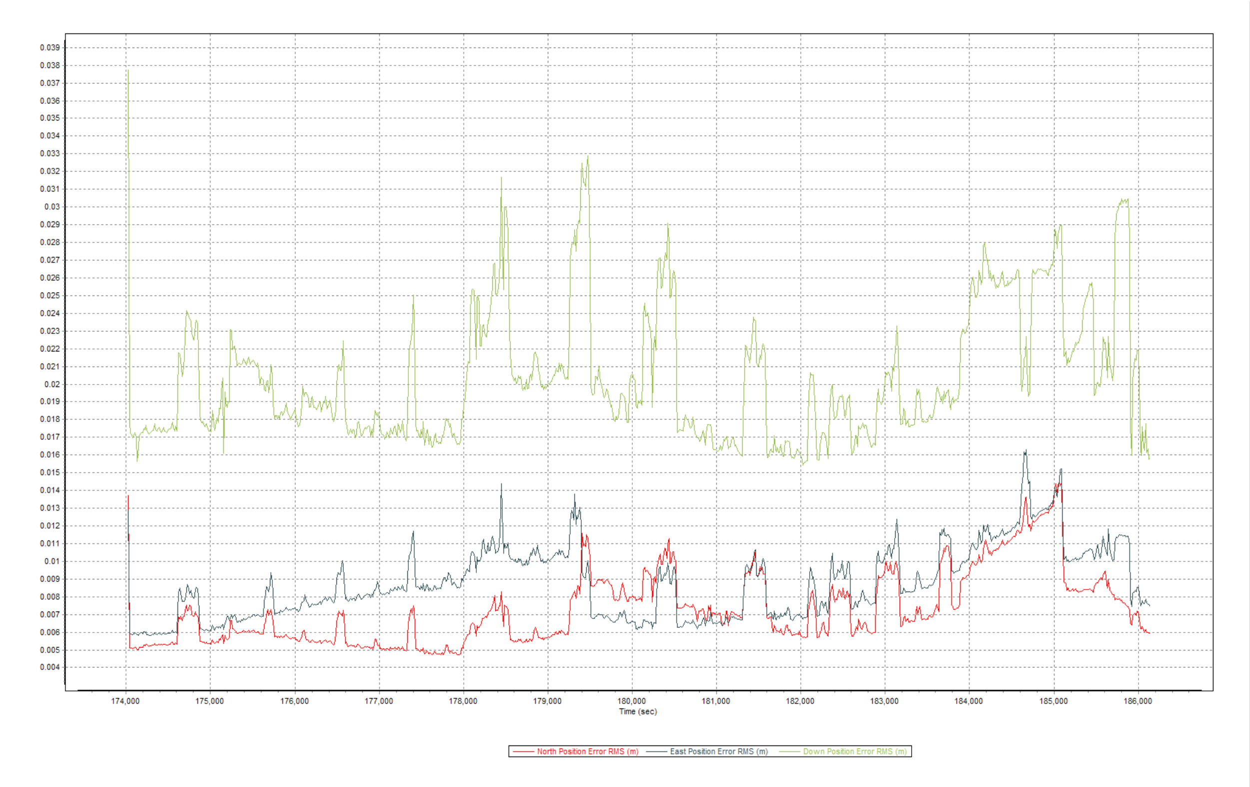


Figure A-8.37. Smoothed Performance Metric Parameters

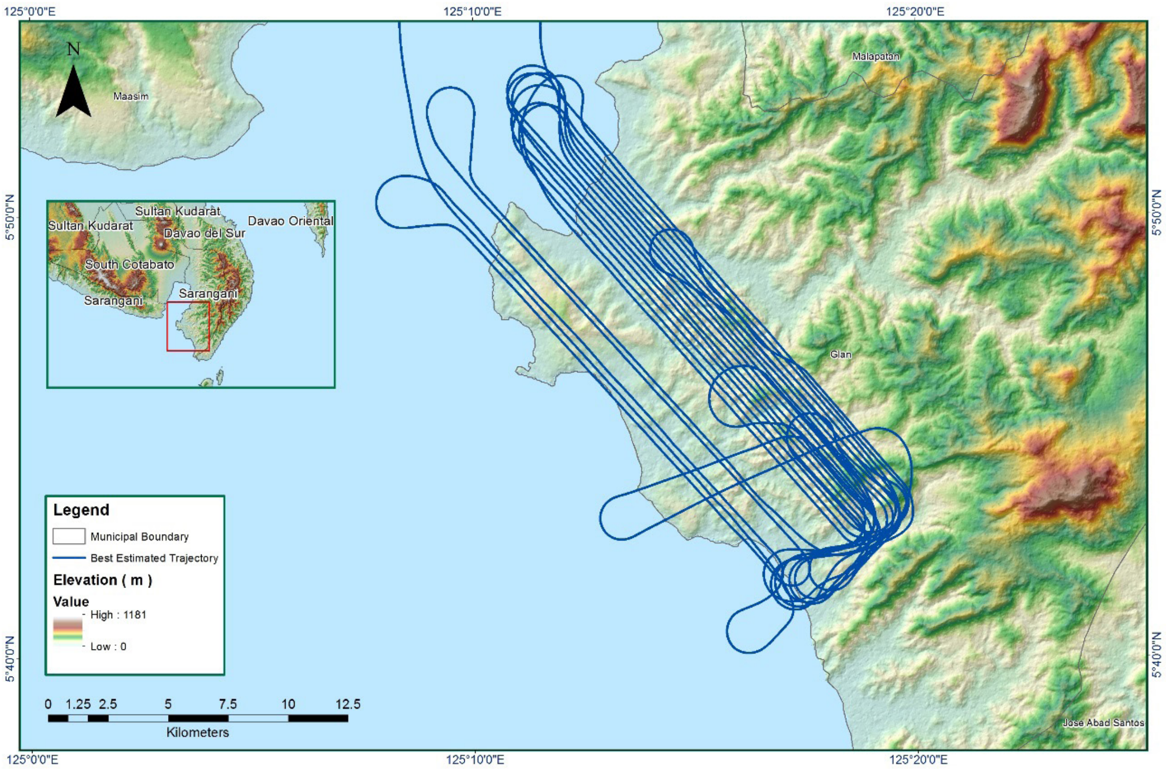


Figure A-8.38. Best Estimate Trajectory

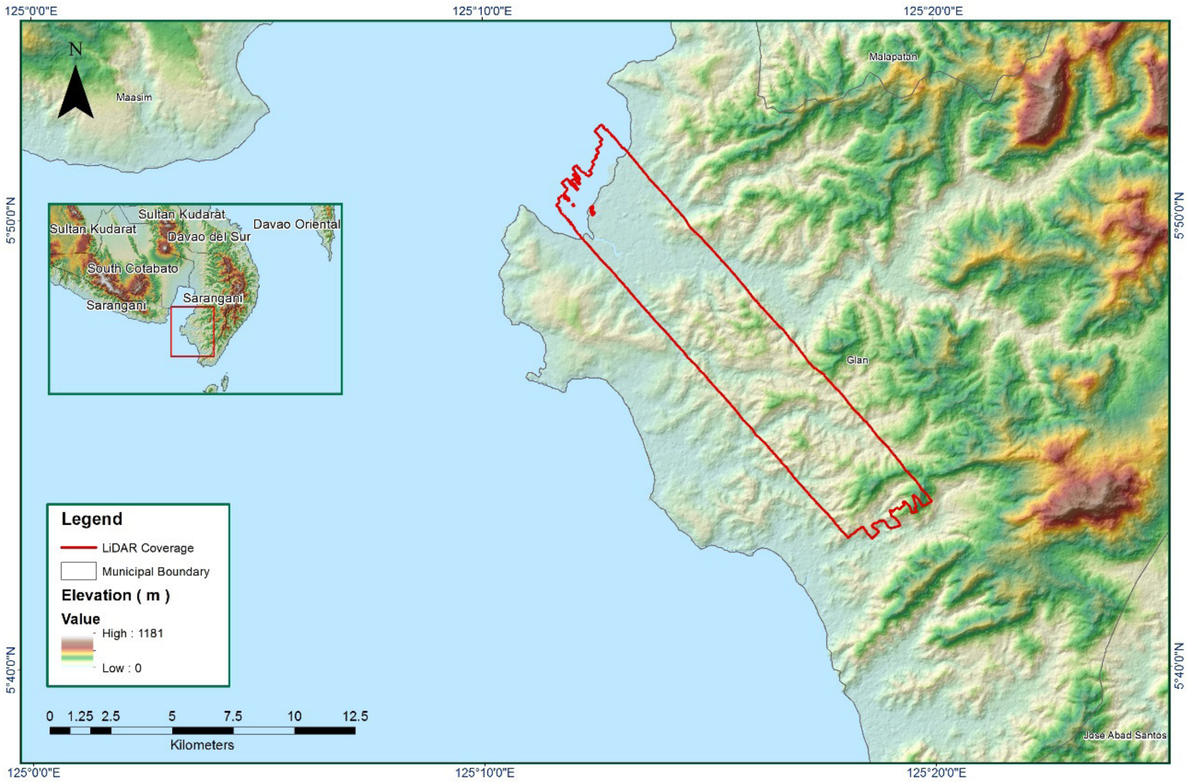


Figure A-8.39. Coverage of LiDAR data

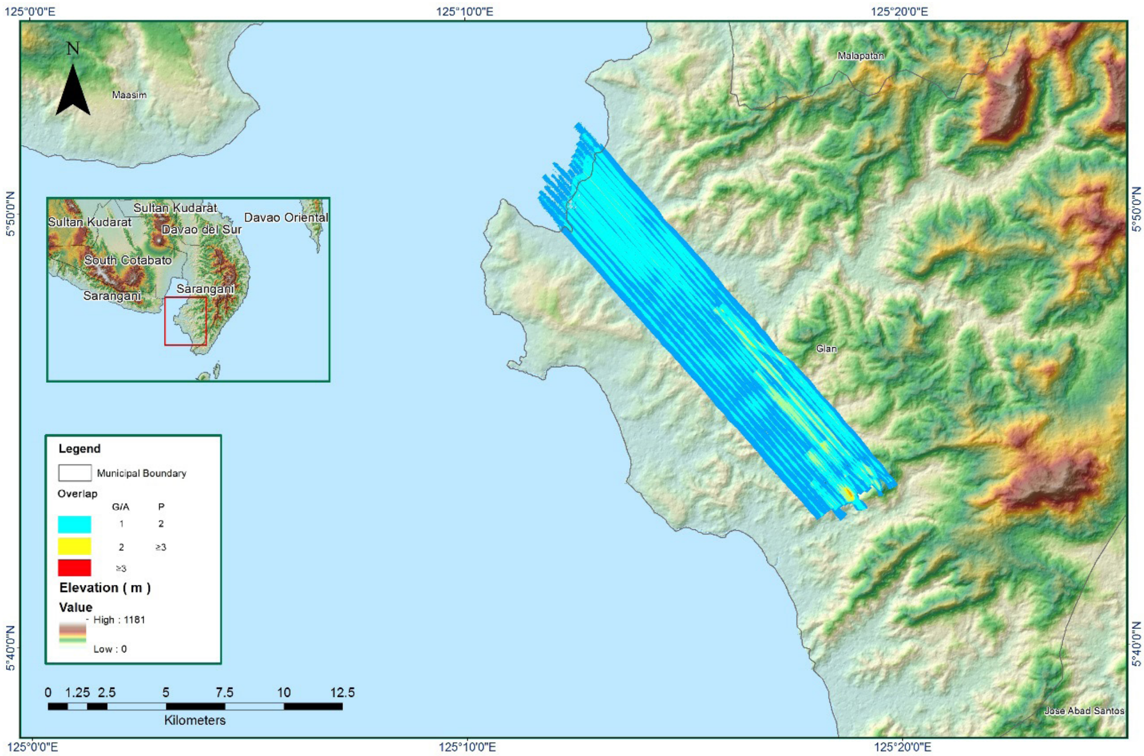


Figure A-8.40 Image of data overlap

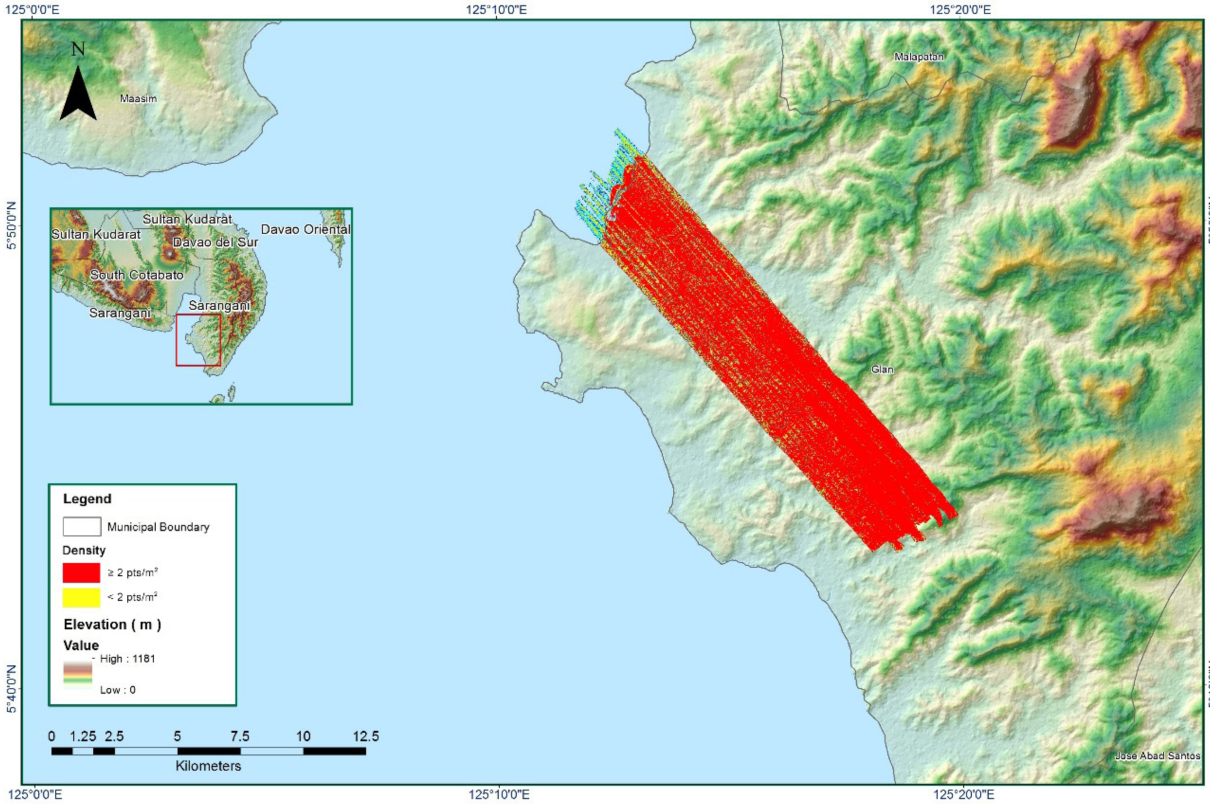


Figure A-8.41 Density Map of merged LiDAR data

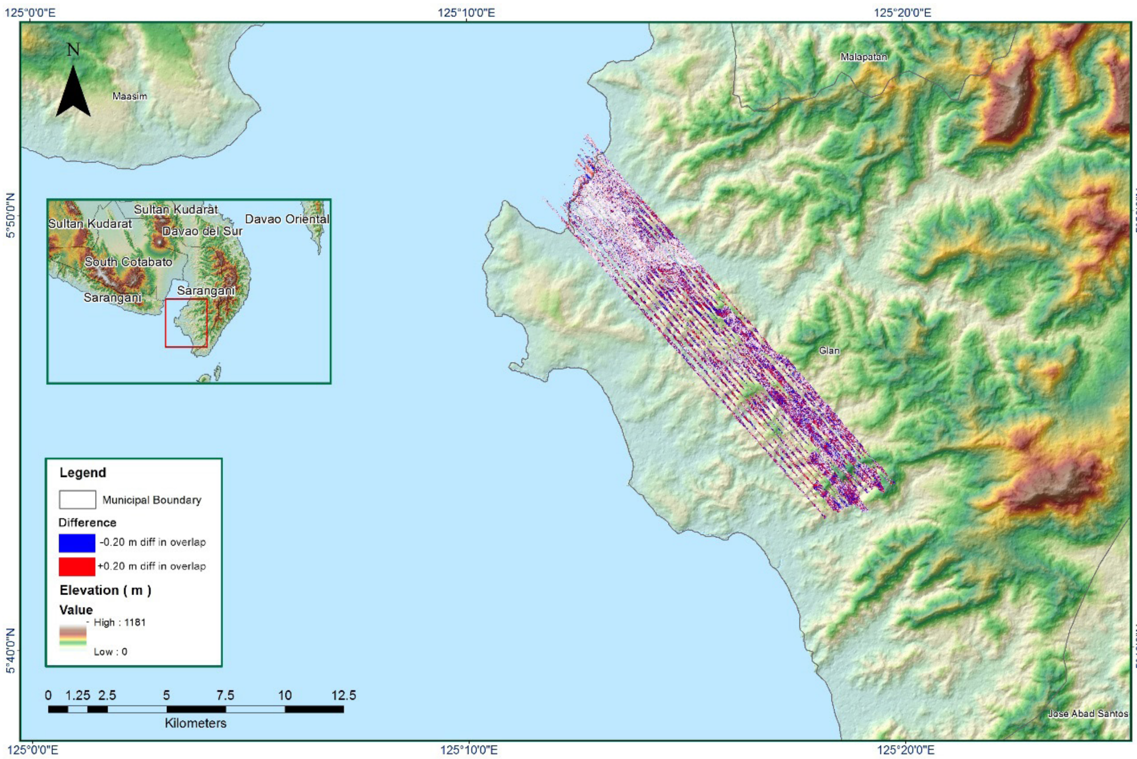


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7 Mission Summary Report for Mission Blk 2C_additional

Flight Area	Buayan
Mission Name	Blk 2C_additional
Inclusive Flights	2150A
Range data size	4.88 GB
POS	195 MB
Image	NA
Transfer date	November 19, 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)	1.19
RMSE for East Position (<4.0 cm)	1.13
RMSE for Down Position (<8.0 cm)	3.27
Boresight correction stdev (<0.001deg)	0.000720
IMU attitude correction stdev (<0.001deg)	0.002817
GPS position stdev (<0.01m)	0.0219
Minimum % overlap (>25)	11.14%
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	43
Maximum Height	246.7
Minimum Height	63.68

Classification (# of points)	
Ground	7753451
Low vegetation	7672693
Medium vegetation	6205668
High vegetation	5200343
Building	423068
Orthophoto	no
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Jeffrey Delica
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Alex John Escobido

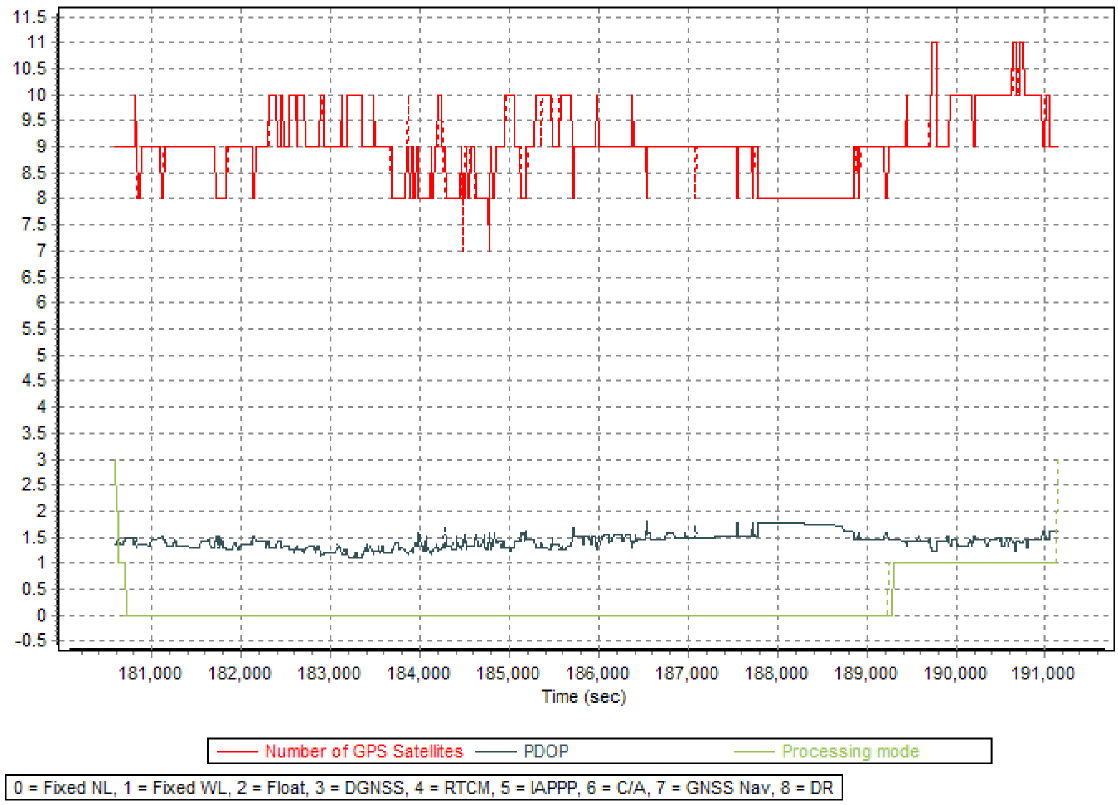


Figure A-8.43. Solution Status

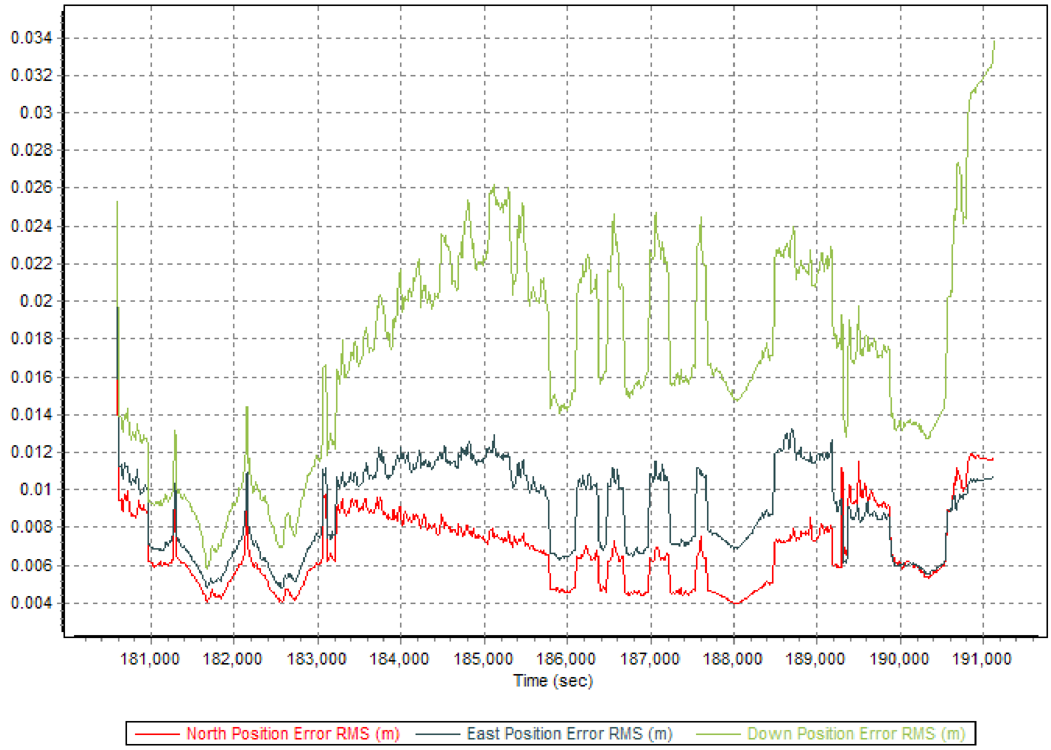


Figure A-8.44. Smoothed Performance Metric Parameters

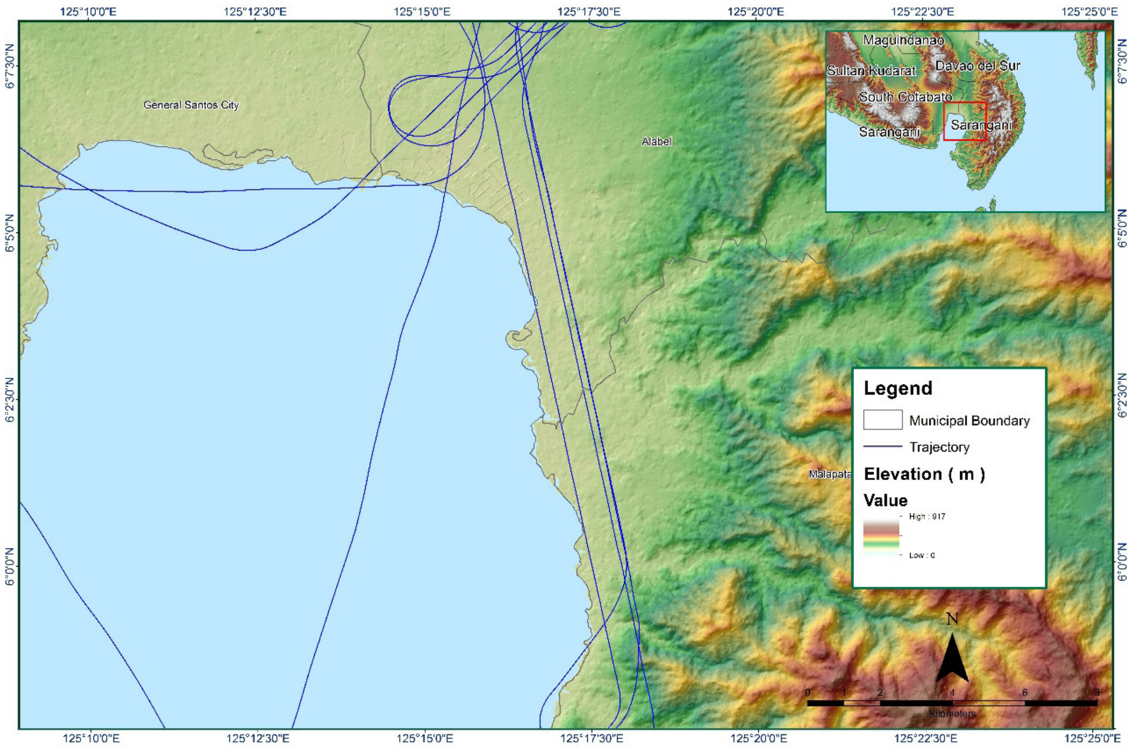


Figure A-8.45. Best Estimate Trajectory

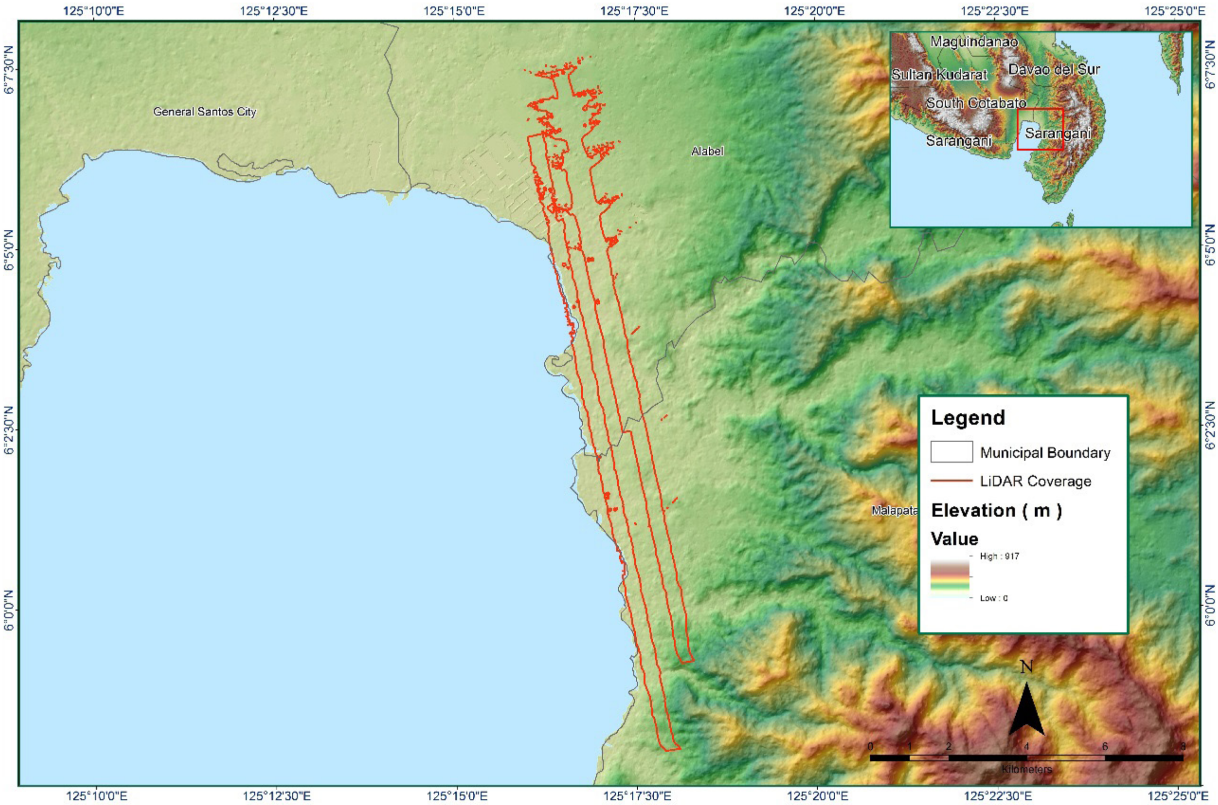


Figure A-8.46. Coverage of LiDAR data

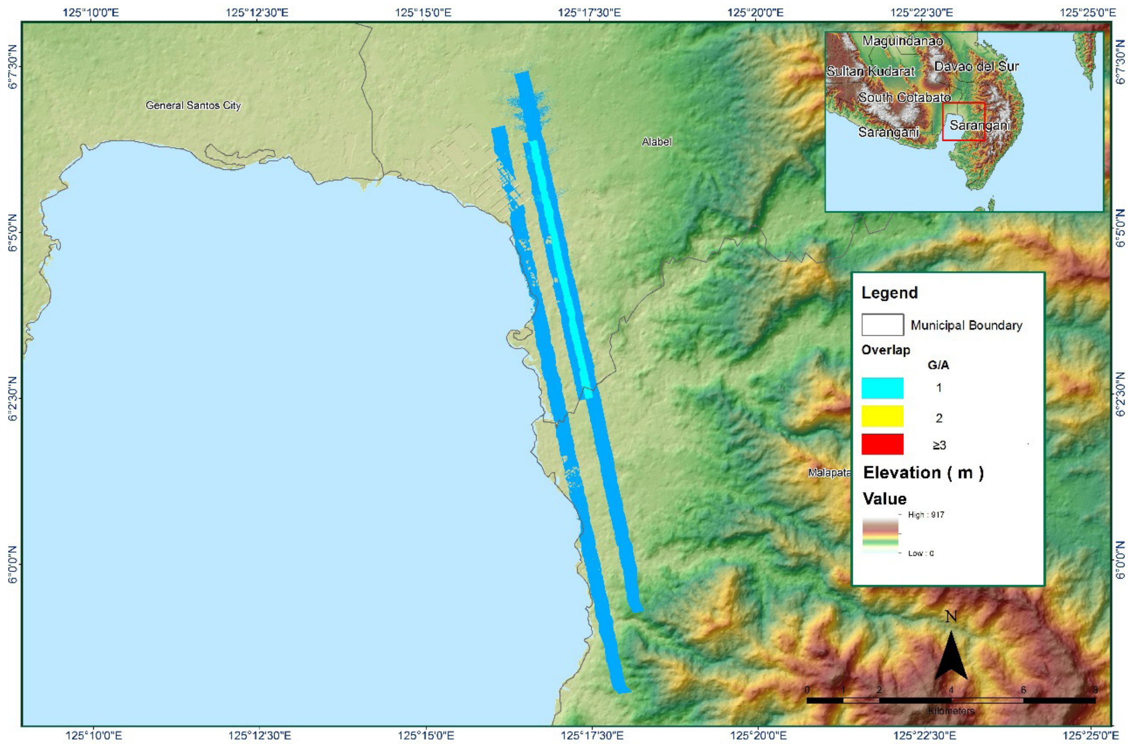


Figure A-8.47 Image of data overlap

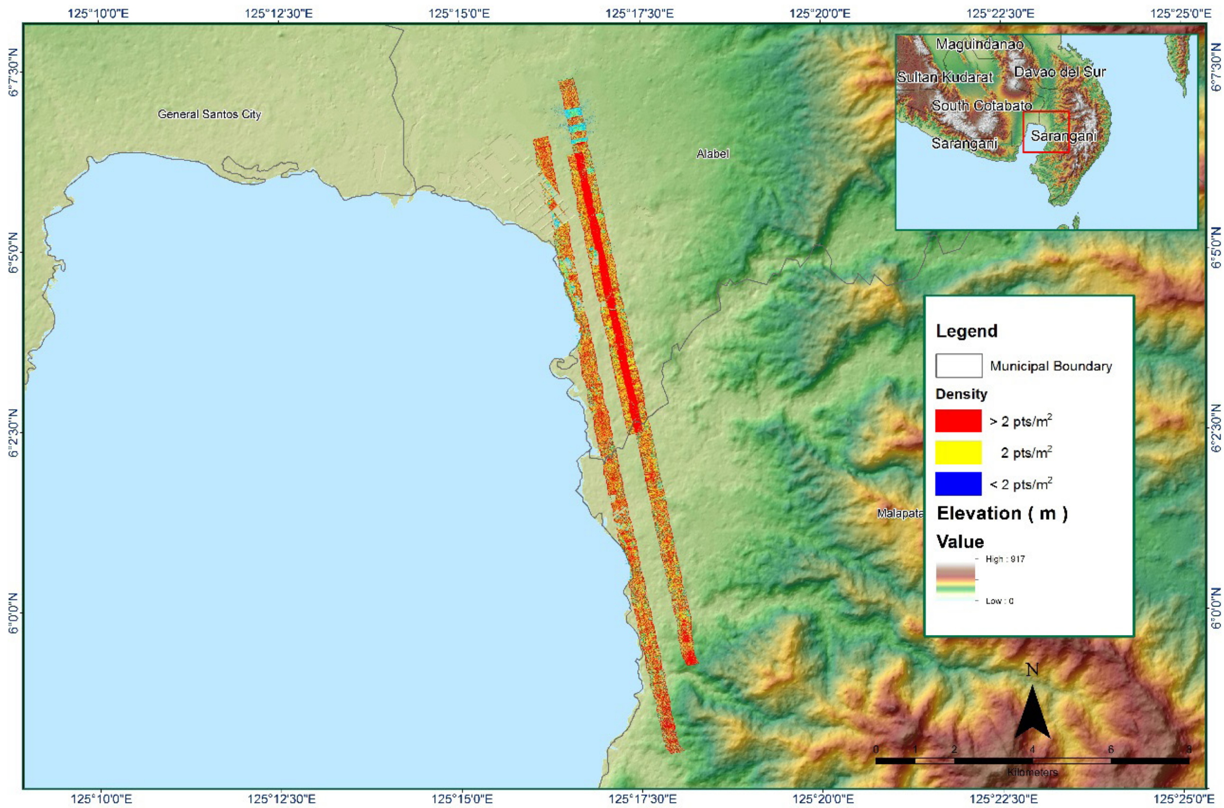


Figure A-8.48 Density Map of merged LiDAR data

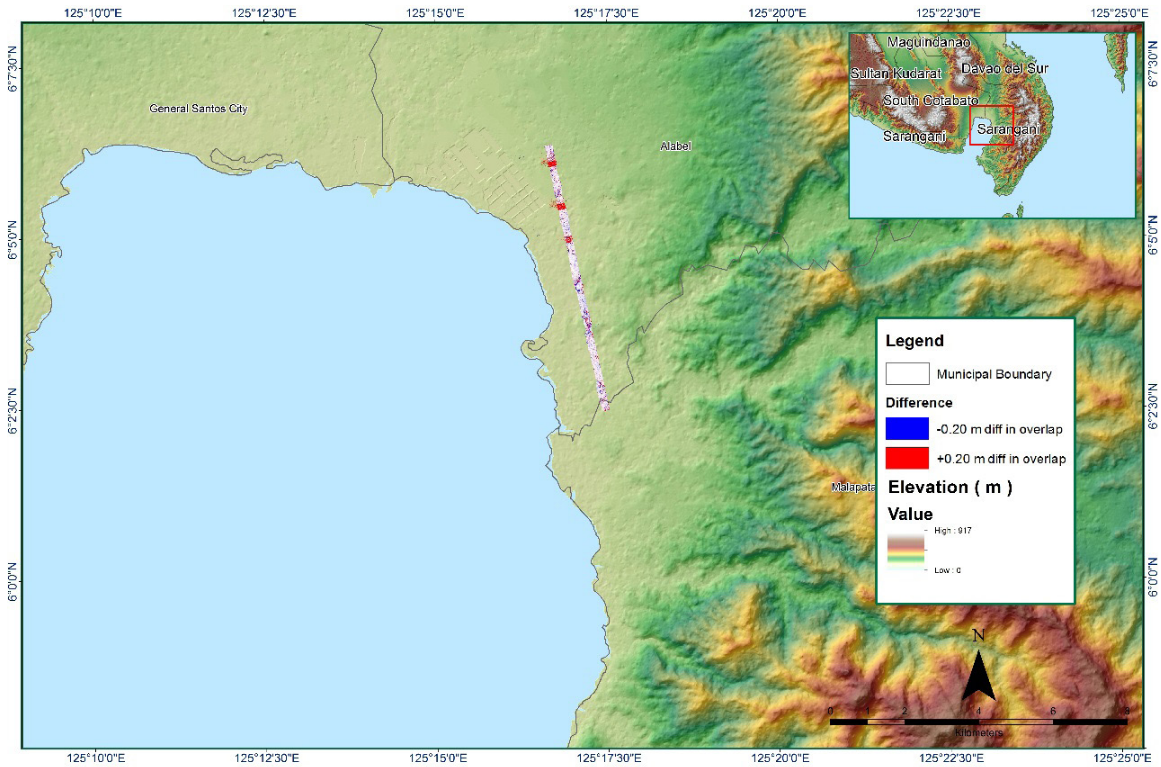


Figure A-8.49 Elevation Difference Between flight

Table A-8.8 Mission Summary Report for Mission

Flight Area	
Mission Name	
Inclusive Flights	
Range data size	
POS	
Image	
Transfer date	
Solution Status	
Number of Satellites (>6)	
PDOP (<3)	
Baseline Length (<30km)	
Processing Mode (<=1)	
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	
RMSE for East Position (<4.0 cm)	
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	
IMU attitude correction stdev (<0.001deg)	
GPS position stdev (<0.01m)	
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	
Maximum Height	
Minimum Height	

Classification (# of points)	
Ground	
Low vegetation	
Medium vegetation	
High vegetation	
Building	
Orthophoto	
Processed by	
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Alex John Escobido

Figure A-8.50. Solution Status

Figure A-8.51. Smoothed Performance Metric Parameters

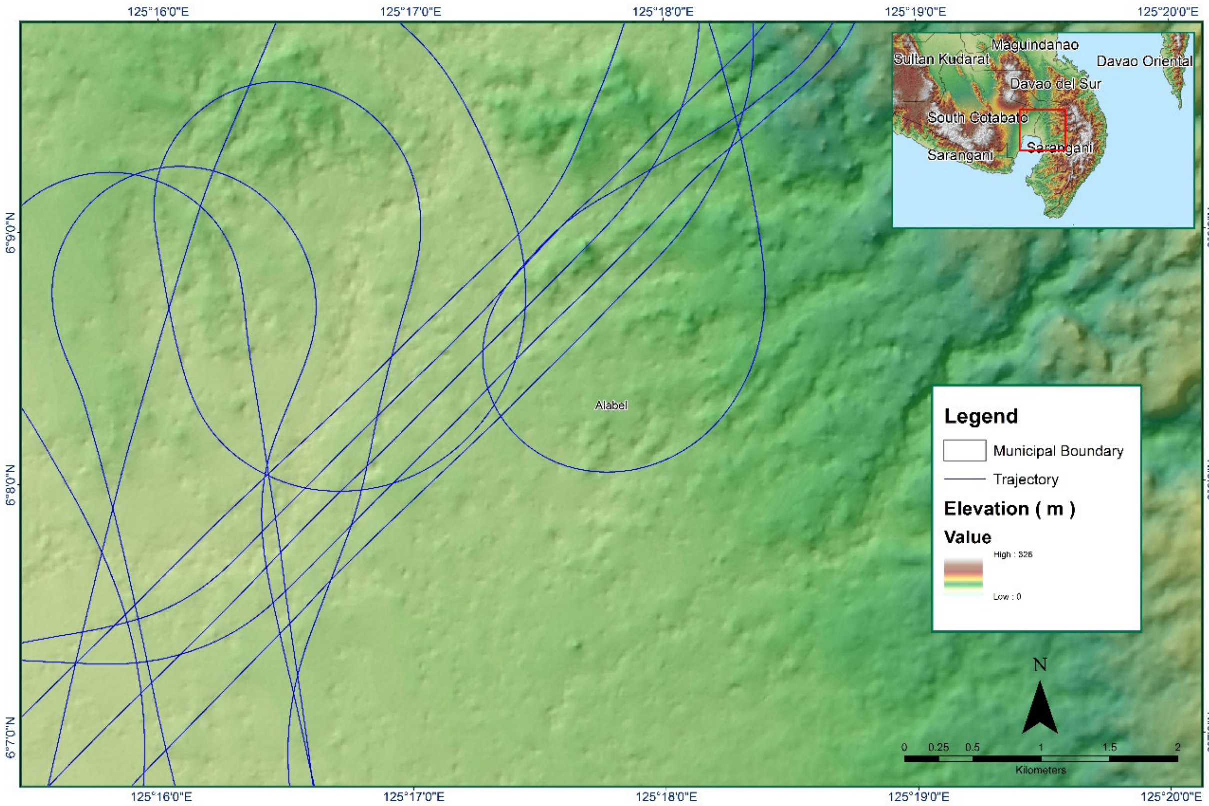


Figure A-8.52. Best Estimate Trajectory

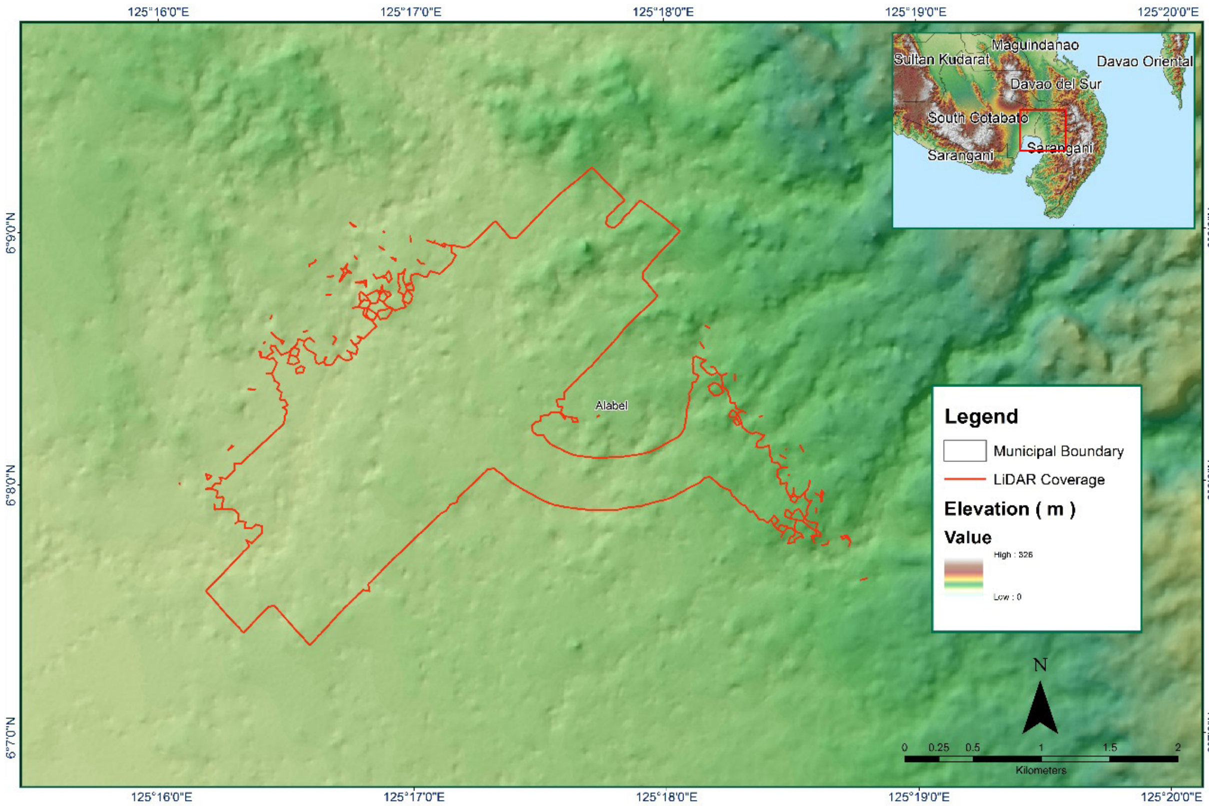


Figure A-8.53. Coverage of LiDAR data

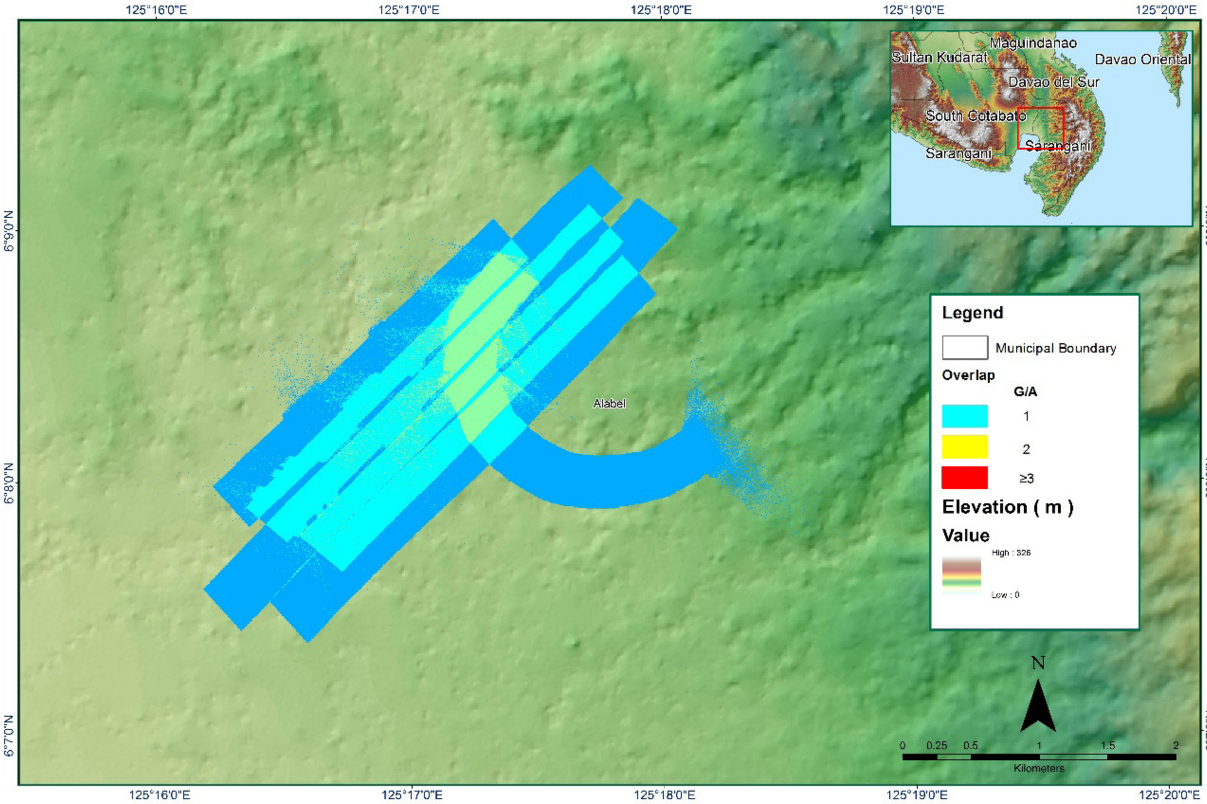


Figure A-8.54 Image of data overlap

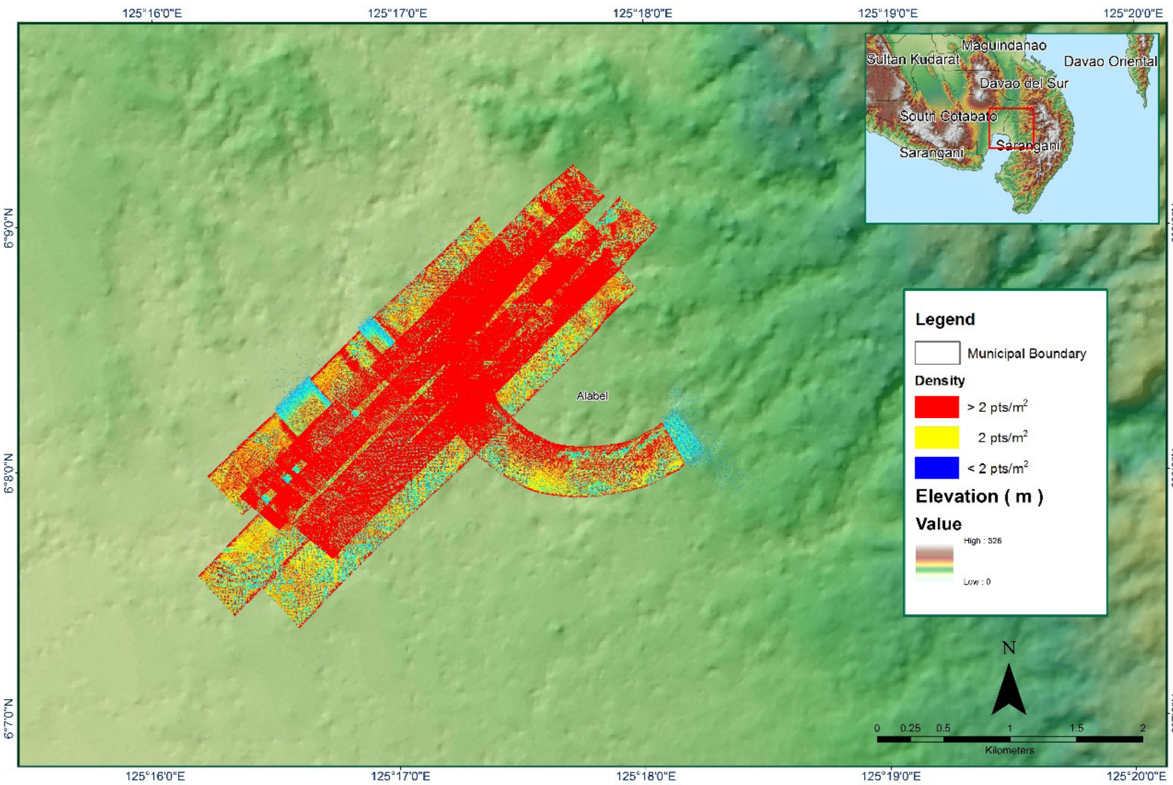


Figure A-8.55 Density Map of merged LiDAR data

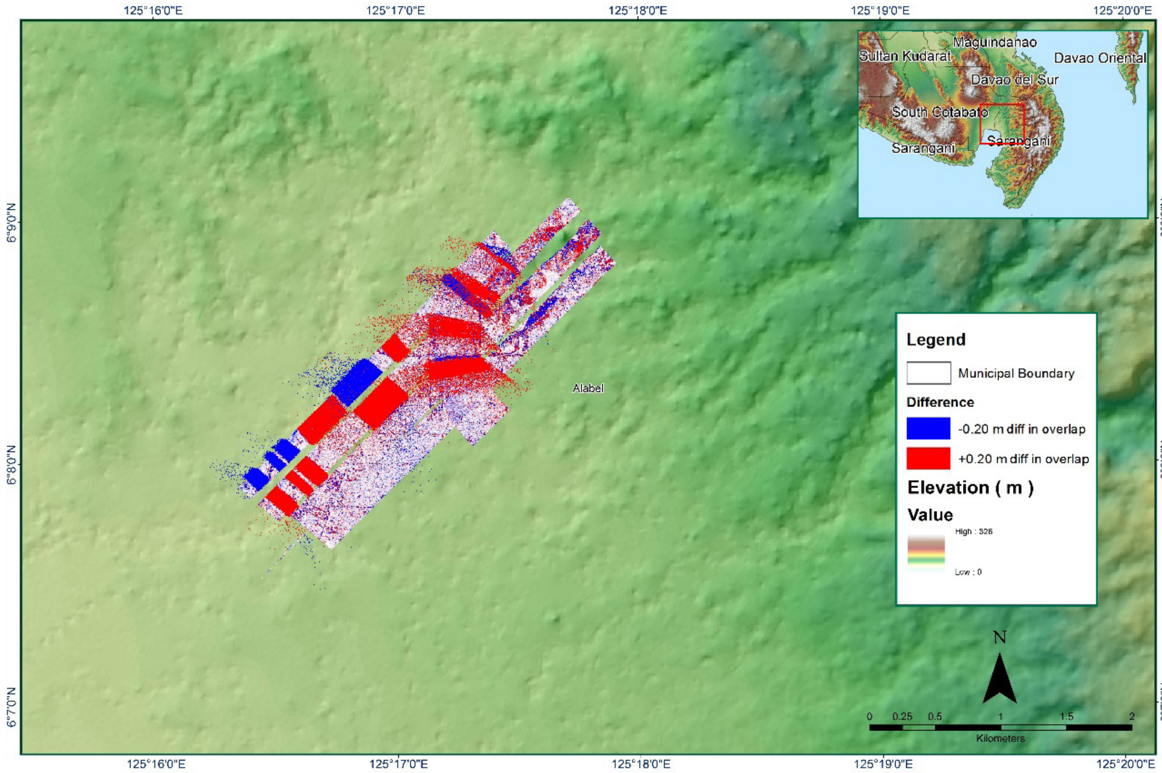


Figure A-8.56 Elevation Difference Between flight lines

Annex 9. Lun Masla Model Basin Parameters

Table A-9.1 Lun Masla Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Impervi-ousness (%)	Time of Concen-tration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W1780	73.810798	55.80264	0	0.18457	1.5061	Discharge	0.0047922	0.05
W1730	95.968522	50.91954	0	0.055106	0.44967	Discharge	0.000280178	0.0077073
W1700	104.32626	49.29266	0	0.21514	1.7555	Discharge	0.0072191	0.05
W1690	110.39246	48.175	0	0.21168	1.7273	Discharge	0.0047241	0.05
W1680	161.27426	40.47848	0	0.28014	2.286	Discharge	0.0046344	0.05
W1670	141.132	43.21154	0	0.3069	2.5043	Discharge	0.0030474	0.05
W1660	158.00594	40.89914	0	0.3047	2.4864	Discharge	0.0057329	0.05
W1650	153.85864	41.4428	0	0.52474	4.2819	Discharge	0.0226784	0.0113298
W1640	147.08678	42.36612	0	0.33958	2.771	Discharge	0.0132667	0.0077073
W1630	156.1737	41.13776	0	0.23382	1.908	Discharge	0.0050948	0.05
W1620	161.36092	40.467	0	0.10059	1.3555	Discharge	0.000413596	0.0166547
W1610	161.65804	40.43092	0	0.37992	0.40471	Discharge	0.0097483	0.05
W1600	141.09486	43.21646	0	0.24796	1.58	Discharge	0.0051398	0.05
W1590	124.65422	45.73714	0	0.30238	1.5546	Discharge	0.0089996	0.05
W1580	170.32404	39.36	0	0.103864	2.0574	Discharge	0.000194248	0.05
W1570	168.45466	39.58632	0	0.197168	2.2538	Discharge	0.0022303	0.05
W1560	147.0125	42.37596	0	0.25424	2.2377	Discharge	0.0101251	0.05
W1550	124.22092	45.80848	0	0.32162	3.8537	Discharge	0.0070049	0.05
W1540	117.95045	46.85152	0	0.110318	2.4939	Discharge	0.0019377	0.05
W1530	128.73962	45.08524	0	0.57202	1.7172	Discharge	0.0381759	0.05
W1520	166.83288	39.78394	0	0.26678	0.73874	Discharge	0.0046439	0.05
W1510	113.853908	47.56	0	0.016821	2.7902	Discharge	6.89704E-05	0.05
W1500	147.74292	42.2751	0	0.37796	1.821	Discharge	0.0095478	0.0113298
W1490	114.519952	47.44356	0	0.463	2.2207	Discharge	0.0191688	0.05
W1480	117.398302	46.94582	0	0.24018	0.76278	Discharge	0.0098295	0.05
W1470	155.85182	41.17958	0	0.30426	1.448	Discharge	0.004884	0.05
W1460	51.770684	61.68778	0	0.30426	1.8671	Discharge	0.000154222	0.05
W1450	139.94352	43.38374	0	0.31322	2.362	Discharge	0.0065081	0.05
W1440	153.6977	41.46494	0	0.33434	0.81017	Discharge	0.0106976	0.05
W1430	169.69266	39.43708	0	0.20622	4.2009	Discharge	0.0068177	0.05
W1420	122.52486	46.08564	0	0.25212	1.9593	Discharge	0.0079099	0.05
W1410	119.437288	46.59978	0	0.33424	0.12353	Discharge	0.0133018	0.0077073
W1400	162.83414	40.28086	0	0.3136	2.7757	Discharge	0.0084944	0.05

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Impervi-ousness (%)	Time of Concen-tration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W1390	167.47664	39.70522	0	0.18746	3.4002	Discharge	0.0042203	0.009
W1380	152.6454	41.60598	0	0.2149	1.7639	Discharge	0.0077502	0.009
W1370	170.32404	39.36	0	0.3988	2.2345	Discharge	0.0048858	0.009
W1360	114.729174	47.40666	0	0.108522	0.11691	Discharge	0.0010563	0.009
W1350	145.70022	42.55964	0	0.45388	2.3003	Discharge	0.0247287	0.009
W1340	169.55648	39.45266	0	0.30694	2.4553	Discharge	0.0054349	0.009
W1330	135.11532	44.10124	0	0.169916	1.5145	Discharge	0.0041561	0.009
W1320	170.32404	39.36	0	0.165796	1.8515	Discharge	0.004927	0.009
W1310	170.32404	39.36	0	0.165796	2.4547	Discharge	1.69599E-05	0.009
W1300	114.996582	47.36074	0	0.190312	2.3031	Discharge	0.0036787	0.009
W1290	153.59866	41.47806	0	0.045066	1.3767	Discharge	0.00035141	0.009
W1280	167.66234	39.68308	0	0.43278	1.5783	Discharge	0.0059446	0.009
W1270	114.2674	47.48784	0	0.184728	2.9287	Discharge	0.005315	0.009
W1260	115.015152	47.35746	0	0.3598	0.79698	Discharge	0.0115986	0.009
W1250	167.21666	39.7372	0	0.176586	3.3333	Discharge	0.0035216	0.009
W1770	39.617238	65.49668	0	0.3296	2.2542	Discharge	0.0066806	0.009
W1230	117.234886	46.9737	0	0.497	1.2479	Discharge	0.0217761	0.009
W1220	164.95112	40.01682	0	0.4433	1.2176	Discharge	0.0146312	0.009
W1210	84.791858	53.2713	0	0.36358	0.0614649	Discharge	0.0078974	0.009
W1200	110.632632	48.13154	0	0.24098	1.397655	Discharge	0.0073568	0.009
W1190	158.51352	40.8319	0	0.26392	0.33097	Discharge	0.008039	0.009
W1180	170.32404	39.36	0	0.18875	3.1783	Discharge	0.0041873	0.009
W1170	166.5729	39.81592	0	0.15295	1.3566	Discharge	0.0046411	0.009
W1160	114.616516	47.42634	0	0.70022	2.6424	Discharge	0.0313058	0.009
W1150	150.61508	41.87986	0	0.40986	1.2969	Discharge	0.0113498	0.009
W1140	151.92736	41.70274	0	0.153884	2.4206	Discharge	0.0046224	0.009
W1130	154.30432	41.38458	0	0.38152	3.6499798	Discharge	0.0161088	0.009
W1120	86.4124	52.91706	0	0.27962	3.2556	Discharge	0.0075983	0.009
W1110	113.67316	47.59198	0	0.3591	2.6701	Discharge	0.0045839	0.009
W1100	101.121078	49.90356	0	0.03738	1.7697	Discharge	0.000286058	0.009
W1090	170.32404	39.36	0	0.137772	1.9382	Discharge	0.0028583	0.009
W1080	105.565498	49.05978	0	0.161868	1.3862	Discharge	0.0027493	0.009
W1070	136.09334	43.95364	0	0.29088	1.1233	Discharge	0.0050109	0.009
W1060	158.90968	40.78188	0	0.147528	5.1425	Discharge	0.000502466	0.009
W1050	156.49558	41.09512	0	0.41118	3.01	Discharge	0.0132285	0.009

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Impervi-ousness (%)	Time of Concen-tration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W1040	112.846176	47.73712	0	0.192572	1.1301	Discharge	0.0038822	0.009
W1030	165.26062	39.97746	0	0.24616	2.8018	Discharge	0.005197	0.009
W1020	143.90512	42.81384	0	0.7064	2.0536	Discharge	0.0237208	0.009
W1720	102.89018	49.5649	0	0.4815	2.6373	Discharge	0.0294481	0.009
W1000	142.9271	42.95406	0	0.23124	0.27451	Discharge	0.0063516	0.009
W990	157.38694	40.97868	0	0.37226	1.0118	Discharge	0.0097981	0.009
W980	170.32404	39.36082	0	0.35382	1.1888	Discharge	0.011358	0.009
W970	168.78892	39.54532	0	0.46486	2.1362	Discharge	0.0103571	0.009
W960	142.6176	42.99834	0	0.17491	1.0835	Discharge	0.0051386	0.009
W950	170.32404	39.36	0	0.075924	3.0197	Discharge	0.000994983	0.009
W940	136.78662	43.85032	0	0.5113	1.4142	Discharge	0.0100964	0.009
W930	121.04545	46.33082	0	0.188842	1.8078	Discharge	0.0059907	0.009
W920	124.30758	45.79372	0	0.22798	5.187796	Discharge	0.0066827	0.009
W910	145.2793	42.61868	0	0.23064	3.5361	Discharge	0.0131822	0.009
W900	158.45162	40.8401	0	0.42028	1.6982	Discharge	0.0179199	0.009
W890	109.954208	48.25372	0	0.22474	2.7339	Discharge	0.0043623	0.009
W880	110.086674	48.22994	0	0.23938	2.5984	Discharge	0.0056524	0.009
W870	110.654916	48.12826	0	0.20834	3.414	Discharge	0.0061944	0.009
W860	122.87769	46.02742	0	0.27206	1.2845	Discharge	0.0101839	0.009

Annex 10. Lun Masla Model Reach Parameters

Table A-10.1 Bulalacao Model Reach Parameters

Reach	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R40	Automatic Fixed Interval	1402.9	0.069298	0.001	Trapezoid	79.68	1
R60	Automatic Fixed Interval	5379.2	0.0286286	0.001	Trapezoid	79.68	1
R70	Automatic Fixed Interval	3134.9	0.38676	0.001	Trapezoid	79.68	1
R80	Automatic Fixed Interval	2365	0.0670529	0.001	Trapezoid	79.68	1
R90	Automatic Fixed Interval	891.54	0.0213115	0.001	Trapezoid	79.68	1
R140	Automatic Fixed Interval	2906.9	0.0213285	0.001	Trapezoid	79.68	1
R150	Automatic Fixed Interval	2536.2	0.0023657	0.001	Trapezoid	79.68	1
R160	Automatic Fixed Interval	295.12	0.001	0.001	Trapezoid	79.68	1
R180	Automatic Fixed Interval	5751.3	0.0213533	0.001	Trapezoid	79.68	1
R210	Automatic Fixed Interval	1225.8	0.0171314	0.001	Trapezoid	79.68	1
R230	Automatic Fixed Interval	641.76	0.0140239	0.001	Trapezoid	79.68	1
R250	Automatic Fixed Interval	2493.9	0.0068167	0.001	Trapezoid	79.68	1
R290	Automatic Fixed Interval	1280.5	0.0288951	0.001	Trapezoid	79.68	1
R310	Automatic Fixed Interval	4757.4	0.0025224	0.001	Trapezoid	79.68	1
R340	Automatic Fixed Interval	1758.1	0.0369714	0.001	Trapezoid	79.68	1
R360	Automatic Fixed Interval	4032.2	0.004464	0.001	Trapezoid	79.68	1

Reach	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R400	Automatic Fixed Interval	676.47	0.0325218	0.001	Trapezoid	79.68	1
R410	Automatic Fixed Interval	610.92	0.0081844	0.001	Trapezoid	79.68	1
R420	Automatic Fixed Interval	30.13	0.001	0.001	Trapezoid	79.68	1
R450	Automatic Fixed Interval	927.26	0.0905064	0.001	Trapezoid	79.68	1
R470	Automatic Fixed Interval	2435.8	0.0057477	0.001	Trapezoid	79.68	1
R490	Automatic Fixed Interval	5268.9	0.25736	0.001	Trapezoid	79.68	1
R500	Automatic Fixed Interval	827.83	0.0613361	0.001	Trapezoid	79.68	1
R510	Automatic Fixed Interval	2354.8	0.0135891	0.001	Trapezoid	79.68	1
R530	Automatic Fixed Interval	2495.4	0.0008015	0.001	Trapezoid	79.68	1
R540	Automatic Fixed Interval	1851.5	0.0054009	0.001	Trapezoid	79.68	1
R570	Automatic Fixed Interval	3118	0.008018	0.001	Trapezoid	79.68	1
R580	Automatic Fixed Interval	331.43	0.001	0.001	Trapezoid	79.68	1
R600	Automatic Fixed Interval	2392.7	0.45958	0.001	Trapezoid	79.68	1
R630	Automatic Fixed Interval	3711.8	0.0231696	0.001	Trapezoid	79.68	1
R650	Automatic Fixed Interval	198.13	0.0504711	0.001	Trapezoid	79.68	1
R660	Automatic Fixed Interval	2219.6	0.0063075	0.001	Trapezoid	79.68	1

Reach	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R670	Automatic Fixed Interval	1626.4	0.0086079	0.001	Trapezoid	79.68	1
R700	Automatic Fixed Interval	2508.3	0.0382289	0.001	Trapezoid	79.68	1
R710	Automatic Fixed Interval	316.22	0.0470611	0.001	Trapezoid	79.68	1
R720	Automatic Fixed Interval	1961.8	0.54738	0.001	Trapezoid	79.68	1
R730	Automatic Fixed Interval	830.98	0.0707624	0.001	Trapezoid	79.68	1
R750	Automatic Fixed Interval	558.68	0.0430832	0.001		79.68	1
R810	Automatic Fixed Interval	3632.3	0.0513524	0.001		79.68	1
R830	Automatic Fixed Interval	1102.9	0.0618804	0.001		79.68	1
R1740	Automatic Fixed Interval	237.59	0.0462977	0.001		79.68	1
R240	Automatic Fixed Interval	6656	0.0024038	0.001		79.68	1
R460	Automatic Fixed Interval	2230.4	0.001	0.01		79.68	1
R1800	Automatic Fixed Interval	2371.8	0.0050595	0.02		79.68	1

Annex 11. Bulalacao Flood Validation Data

Table A-11.1 Bulalacao Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	6.049721	125.321382	0.03	0.1	0.07	2014	5YR
2	6.050201	125.321374	0.03	0.2	0.17	2014	5YR
3	6.047376	125.316437	0.982	0.1	-0.882	2014	5YR
4	6.046328	125.317445	2.2487	0.4	-1.8487	2014	5YR
5	6.046609	125.317192	1.688	0.1	-1.588	2014	5YR
6	6.037662	125.296819	0.37	0	-0.37	2014	5YR
7	6.037197	125.299234	0.0655	0	-0.0655	2014	5YR
8	6.037237	125.2996	0.2023	0	-0.2023	2014	5YR
9	6.036975	125.299715	0.0655	0	-0.0655	2014	5YR
10	6.0365	125.300565	0.0655	0	-0.0655	2014	5YR
11	6.037535	125.298069	0.0437	0	-0.0437	2014	5YR
12	6.030086	125.286551	0.1015	0.1	-0.0015	2014	5YR
13	6.029359	125.281497	0.6	0.1	-0.5	2014	5YR
14	6.029308	125.2819	0.3037	0.1	-0.2037	2014	5YR
15	6.029757	125.28445	0.0725	0	-0.0725	2014	5YR
16	6.031849	125.28535	0.081	0	-0.081	2014	5YR
17	6.031867	125.286133	0.1088	0	-0.1088	2014	5YR
18	6.031152	125.287355	0.0655	0	-0.0655	2014	5YR
19	6.031415	125.287361	0.0655	0	-0.0655	2014	5YR
20	6.030235	125.296225	3.291	0.1	-3.191	2014	5YR
21	6.031356	125.298412	3.2297	0	-3.2297	2014	5YR
22	6.031615	125.298342	1.5313	0	-1.5313	2014	5YR
23	6.031306	125.297657	3.0327	0	-3.0327	2014	5YR
24	6.033012	125.307826	0.5687	0.1	-0.4687	2014	5YR
25	6.034935	125.308485	1.4587	0.5	-0.9587	2014	5YR
26	6.03239	125.313127	0.3615	0.2	-0.1615	2014	5YR
27	6.030935	125.314846	0.1035	0.1	-0.0035	2014	5YR
28	6.034738	125.316221	0.034	0	-0.034	2014	5YR
29	6.035495	125.31736	0.35	0	-0.35	2014	5YR
30	6.033293	125.309398	0.085	0	-0.085	2014	5YR
31	6.031414	125.30845	0.3315	0	-0.3315	2014	5YR
32	6.028165	125.302342	0.034	0	-0.034	2014	5YR
33	6.027279	125.300298	0.4807	0	-0.4807	2014	5YR
34	6.020052	125.298556	0.52	0	-0.52	2014	5YR
35	6.019946	125.300864	0.139	0	-0.139	2014	5YR
36	6.019573	125.300801	0.03	0	-0.03	2014	5YR
37	6.018779	125.299009	0.0655	0	-0.0655	2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
38	6.019767	125.290177	0.124	0	-0.124	2014	5YR
39	6.019981	125.290739	0.0803	0	-0.0803	2014	5YR
40	6.020349	125.292564	0.0475	0	-0.0475	2014	5YR
41	6.021291	125.29507	0.048	0	-0.048	2014	5YR
42	6.021604	125.296239	0.0697	0	-0.0697	2014	5YR
43	6.02325	125.29638	0.0655	0	-0.0655	2014	5YR
44	6.022905	125.295844	0.031	0	-0.031	2014	5YR
45	6.023149	125.295707	0.0625	0	-0.0625	2014	5YR
46	6.023164	125.295811	0.0317	0	-0.0317	2014	5YR
47	6.023054	125.295526	0.0625	0	-0.0625	2014	5YR
48	6.022568	125.296004	0.062	0	-0.062	2014	5YR
49	6.022309	125.296159	0.0583	0	-0.0583	2014	5YR
50	6.022038	125.29633	0.0655	0	-0.0655	2014	5YR
51	6.020487	125.29685	0.048	0	-0.048	2014	5YR
52	6.030019	125.296068	3.2	0	-3.2	2014	5YR
53	6.029243	125.29584	3.6068	0	-3.6068	2014	5YR
54	6.0287	125.295924	3.6068	0	-3.6068	2014	5YR
55	6.040616	125.30449	0.0326	0	-0.0326	2014	5YR
56	6.040665	125.30431	0.0326	0	-0.0326	2014	5YR
57	6.038591	125.305035	1.0173	0.5	-0.5173	2014	5YR
58	6.038741	125.305364	1.4878	0.8	-0.6878	2014	5YR
59	6.038159	125.304912	2.1475	1	-1.1475	2014	5YR
60	6.037826	125.304698	2.0273	1	-1.0273	2014	5YR
61	6.037582	125.304258	2.237	0	-2.237	2014	5YR
62	6.039243	125.30377	0.064	0	-0.064	2014	5YR
63	6.035419	125.302198	0.034	0	-0.034	2014	5YR
64	6.036823	125.29799	0.0655	0	-0.0655	2014	5YR
65	6.036866	125.297906	0.0655	0.4	0.3345	2014	5YR
66	6.03659	125.29769	0.0852	0	-0.0852	2014	5YR
67	6.036527	125.296529	0.2822	0	-0.2822	2014	5YR
68	6.035679	125.296827	0.4613	0	-0.4613	2014	5YR
69	6.035041	125.296791	0.283	0	-0.283	2014	5YR
70	6.037048	125.295247	0.0655	0.1	0.0345	2014	5YR
71	6.030816	125.288251	0.046	0	-0.046	2014	5YR
72	6.031123	125.289487	0.9357	0	-0.9357	2014	5YR
73	6.031021	125.289648	1.0153	0	-1.0153	2014	5YR
74	6.027454	125.289884	2.8455	0.6	-2.2455	2014	5YR
75	6.027427	125.290476	2.6745	0.6	-2.0745	2014	5YR
76	6.028199	125.288807	0.038	0	-0.038	2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
77	6.029284	125.288292	0.0597	0	-0.0597	2014	5YR
78	6.029185	125.286065	0.19	0	-0.19	2014	5YR
79	6.028178	125.286083	0.4008	0	-0.4008	2014	5YR
80	6.029535	125.283716	0.0655	0	-0.0655	2014	5YR
81	6.025926	125.285882	3.1727	0.5	-2.6727	2014	5YR
82	6.027012	125.288362	3.7393	0.5	-3.2393	2014	5YR
83	6.026654	125.289067	3.195	0.5	-2.695	2014	5YR
84	6.026774	125.287999	4.0763	0.5	-3.5763	2014	5YR
85	6.027215	125.28757	0.218	0	-0.218	2014	5YR
86	6.027612	125.290999	1.2773	0	-1.2773	2014	5YR
87	6.028317	125.293008	4.0685	0	-4.0685	2014	5YR
88	6.028742	125.293277	4.2395	0	-4.2395	2014	5YR
89	6.02858	125.294859	4.2533	0	-4.2533	2014	5YR
90	6.02146	125.295538	0.0655	0	-0.0655	2014	5YR
91	6.023441	125.29424	0.176	0	-0.176	2014	5YR
92	6.023739	125.292266	3.101	0	-3.101	2014	5YR
93	6.024587	125.291234	3.817	2	-1.817	2014	5YR
94	6.02383	125.291297	3.7903	1	-2.7903	2014	5YR
95	6.019172	125.289738	0.1763	0	-0.1763	2014	5YR
96	6.018036	125.287822	0.6318	0	-0.6318	2014	5YR
97	6.019838	125.290204	0.077	0	-0.077	2014	5YR
98	6.031671	125.305989	0.9553	0	-0.9553	2014	5YR
99	6.032165	125.306328	0.8385	0	-0.8385	2014	5YR
100	6.031945	125.306955	0.6855	0	-0.6855	2014	5YR
101	6.031382	125.308731	0.5482	0	-0.5482	2014	5YR
102	6.031487	125.308928	0.5482	0	-0.5482	2014	5YR
103	6.031247	125.307952	0.5631	0	-0.5631	2014	5YR
104	6.030999	125.308078	0.604	0	-0.604	2014	5YR
105	6.030602	125.308289	0.6318	0.2	-0.4318	2014	5YR
106	6.03059	125.308311	0.6318	0	-0.6318	2014	5YR
107	6.031117	125.308597	0.364	0	-0.364	2014	5YR
108	6.030223	125.309511	0.692	0	-0.692	2014	5YR
109	6.030052	125.310009	0.6705	0	-0.6705	2014	5YR
110	6.029156	125.310543	0.3823	0	-0.3823	2014	5YR
111	6.028672	125.310724	0.034	0	-0.034	2014	5YR
112	6.028292	125.310882	1.317	0.2	-1.117	2014	5YR
113	6.028265	125.310684	1.2967	0.2	-1.0967	2014	5YR
114	6.030804	125.311178	0.3953	0	-0.3953	2014	5YR
115	6.031113	125.310461	0.3777	0.2	-0.1777	2014	5YR

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
116	6.031003	125.310171	0.4377	0.2	-0.2377	2014	5YR
117	6.032216	125.314055	0.4205	0.3	-0.1205	2014	5YR
118	6.031611	125.313354	1.0293	0.9	-0.1293	2014	5YR
119	6.031264	125.313557	1.3665	0.8	-0.5665	2014	5YR
120	6.031092	125.313535	1.2613	0.8	-0.4613	2014	5YR
121	6.031993	125.312888	0.7143	0.5	-0.2143	2014	5YR
122	6.031465	125.312441	1.238	0.6	-0.638	2014	5YR
123	6.032722	125.313352	0.2487	0.1	-0.1487	2014	5YR
124	6.032279	125.31341	0.416	0.4	-0.016	2014	5YR
125	6.032779	125.315715	0.1043	0	-0.1043	2014	5YR
126	6.033106	125.316688	0.1855	0	-0.1855	2014	5YR
127	6.033582	125.31571	0.5033	0	-0.5033	2014	5YR
128	6.033874	125.314183	0.5631	0	-0.5631	2014	5YR
129	6.036263	125.309998	1.7807	0.2	-1.5807	2014	5YR
130	6.037129	125.310553	1.4463	1	-0.4463	2014	5YR
131	6.037671	125.310056	1.2572	0	-1.2572	2014	5YR
132	6.038333	125.310073	1.42	1	-0.42	2014	5YR
133	6.037685	125.310293	1.3963	1	-0.3963	2014	5YR
134	6.03598	125.309847	1.116	0	-1.116	2014	5YR
135	6.034137	125.308628	0.8303	0	-0.8303	2014	5YR
136	6.034034	125.308387	0.8195	0	-0.8195	2014	5YR
137	6.034094	125.308053	0.9993	0.5	-0.4993	2014	5YR
138	6.034255	125.307189	0.6963	0	-0.6963	2014	5YR
139	6.033478	125.306347	2.6332	0.5	-2.1332	2014	5YR
140	6.033341	125.306615	0.7427	0	-0.7427	2014	5YR
141	6.03363	125.308101	1.112	0	-1.112	2014	5YR
142	6.032021	125.308431	0.3173	0	-0.3173	2014	5YR
143	6.031944	125.309059	0.402	0	-0.402	2014	5YR
144	6.030694	125.308187	0.6365	0	-0.6365	2014	5YR
145	6.031153	125.304911	0.989	0	-0.989	2014	5YR
146	6.029901	125.297324	3.4787	0	-3.4787	2014	5YR
147	6.029881	125.297414	3.357	0	-3.357	2014	5YR
148	6.024997	125.293965	0.0655	1	0.9345	2014	5YR
149	6.026218	125.292639	2.2687	0.5	-1.7687	2014	5YR
150	6.020851	125.298321	1.6303	1	-0.6303	2014	5YR
151	6.020824	125.298554	1.724	1	-0.724	2014	5YR
152	6.021128	125.298497	1.7227	1	-0.7227	2014	5YR
153	6.021581	125.298472	1.716	0	-1.716	2014	5YR

Annex 12. Bulalacao Flood Validation Data

Table A-11.1 Educational Institutions in Malapatan, Sarangani affected by flooding in Lun Masla Floodplain

SARANGANI				
MALAPATAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Lun Masla Malapatan (Day Care Center)	Lun Masla			
Policarpo H. Millona Center Intergrated School	Lun Masla			
Francisco A. Cagang SR. (School)	Patag	Low	Low	Medium

Annex 13. Health Institutions Affected in Lun Masla Floodplain

There are no health institutions affected by flooding in Lun Masla Floodplain.