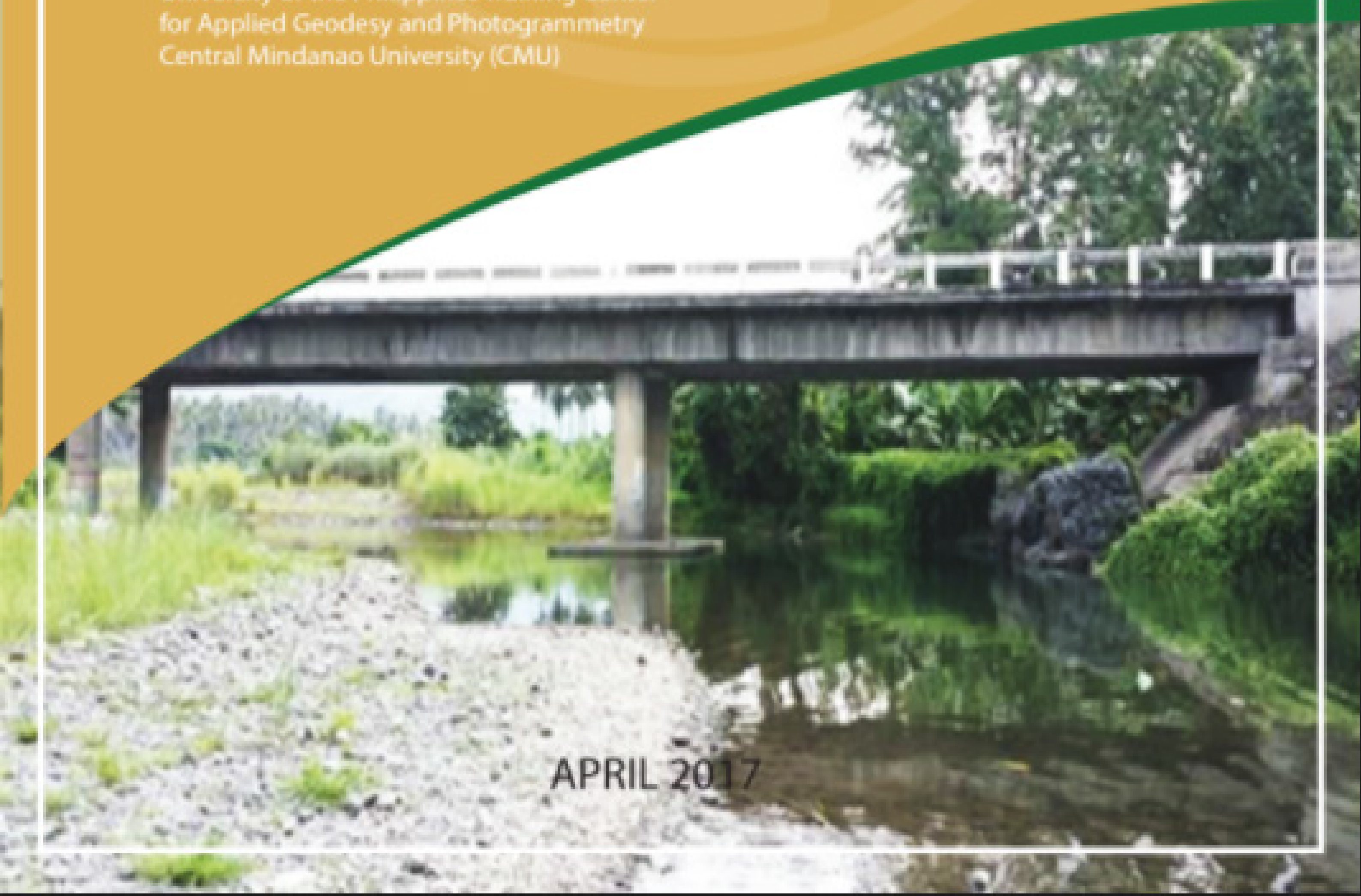
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Saub River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Central Mindanao University (CMU)



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For questions/queries regarding this report, contact:

Dr. George Puno
Project Leader, PHIL-LiDAR 1 Program
Central Mindanao University
Maramag, Bukidnon, Philippines 8710
E-mail: 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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SAUB RIVER

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) 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 the Department of Science and Technology (DOST). The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the 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 twelve (12) river basins in the Southern Mindanao region. The university is located in Maramag in the province of Bukidnon.

1.2 Overview of the Saub River Basin

Sumlog is called as the majestic river in the Municipality of Lupon which is largely part of the town's rich history. Lupon is said to have derived its name from the native word "naluponan," which means a body of land accumulated at the mouth of a river resulting from years of continued accretion. The settlers shortened the word "naluponan" in to what is called now "Lupon". This "naluponan" area was then applied to the mouth of the Sumlog River in the Municipality of Lupon of today (NSCB, 2016).

Sumlog Rver is one of the most important water channels within the gulf town municipalities covering District II, Province of Davao Oriental. It is invaluable because of its water service in the irrigable rice land of the Municipalities of Banaybanay and Lupon estimated to have about 3,100 hectares for the two (2) municipalities or 1,955.00 hectares for Banaybanay and 1,145.00 hectares for Lupon. Historically, the plain areas of Lupon in its creation as a municipality in 1949 were mostly developed with coconut plantation and only small areas were cultivated into rice land (ISRWMDP, 2016).

The Sumlog Watershed area is pre-occupied by the Mandaya, Mansaka and native Kalagan. The indigenous people had long engaged in farming activities, cleaning-up some parcel of forest land for agricultural purposes and wandering in other places starting anew for their planting activities. The natives have the common notion that all lands of public domain are alienable, disposable and can cultivate for such purposes. The coming of logging industries became the critical issues and problems that were identified in the Sumlog Watershed (ISRWMDP, 2016).

Today, Sumlog River is invaluable and essential to the lives of many people of Lupon and Banaybanay being the main source of water for irrigation. Domestic use has a huge contribution to the economic and socio cultural functions of the people, thus, the Sumlog River greatly affects the lives of many people (ISRWMDP, 2016).

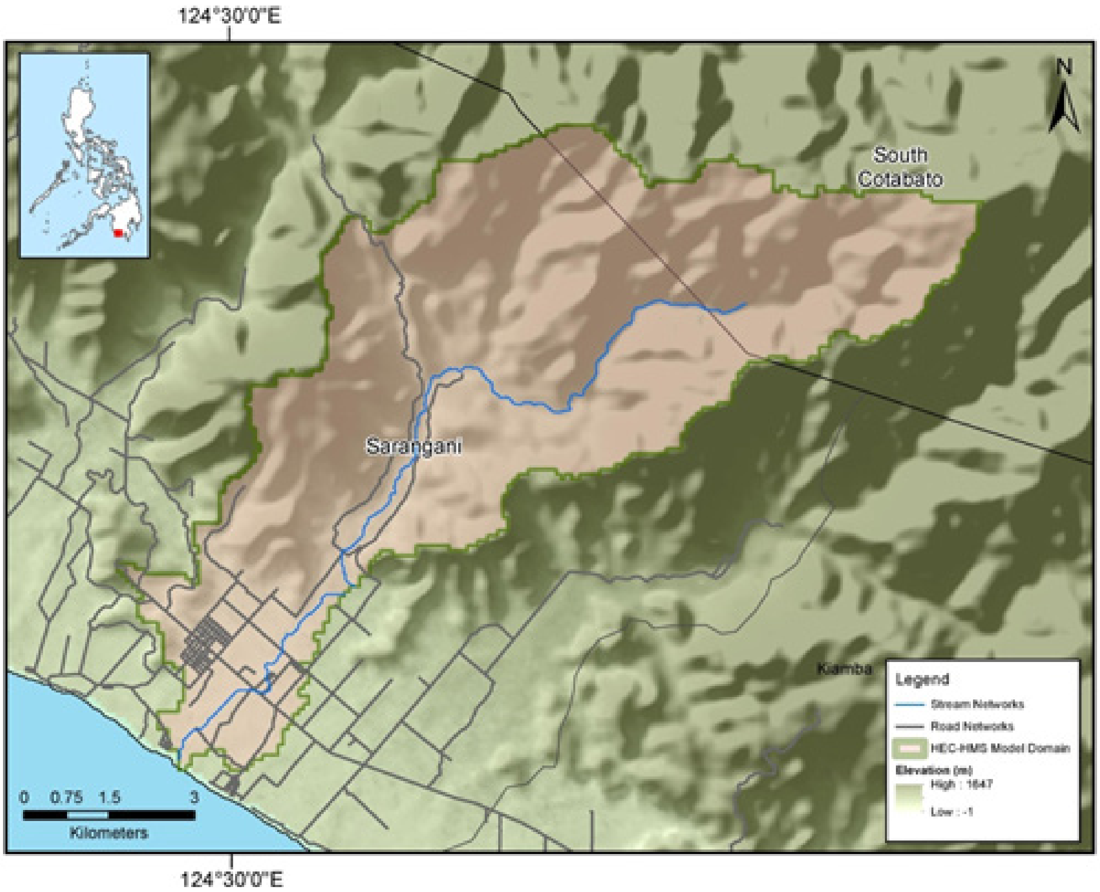


Figure 1. Location map of the Saub River Basin (in brown).

According to the 2015 national census of the Philippine Statistics Authority (PSA), the total population within the immediate vicinity of the river is 2,538 persons, which are all residents of Barangay Kalaong in the Municipality of Maitum.

The river was named after saubs, or giant bats in the local dialect, as the river was once a home to these creatures.

The major industries in the province of Sarangani are aquaculture, fisheries, agricultural plantations, and tourism (Provincial Government of Sarangani, n.d.). Coconuts, corn, rice, bananas, mangoes, durian, rubber, and sugarcane are the major crops of the province (Department of Health Regional Office XII, n.d.). The Municipality of Maitum serves as an agricultural center of the province, cultivating rice, bananas, and coconuts in its lowlands.

The flood history of the municipality reveals a recurrence of flooding in the recent years, particularly in 2013, until 2015. The barangays most vulnerable to flooding are Mabay, Malalag, Sison, and Kiayap.

On January 25, 2017, the National Disaster Risk Reduction Management Council (NDRRMC) released the 14th General Flood Advisory for Region XII, with the Kalaong, Buayan-Malungon, Little Lun, Big Lun, and Glan Rivers in the Sarangani province to be likely affected by light to occasionally moderate rains (National Disaster Risk Reduction and Management Council, 2017).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SAUB FLOODPLAIN

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

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).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Saub floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Sarangani. These missions were planned for sixteen (16) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Aquarius LiDAR system was used for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 illustrates the flight plans for the Saub floodplain.

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK90G	600	30	36	70	50	120	5
BLK90H	600	30	36	70	50	120	5
BLK90I	600	30	36	70	50	120	5

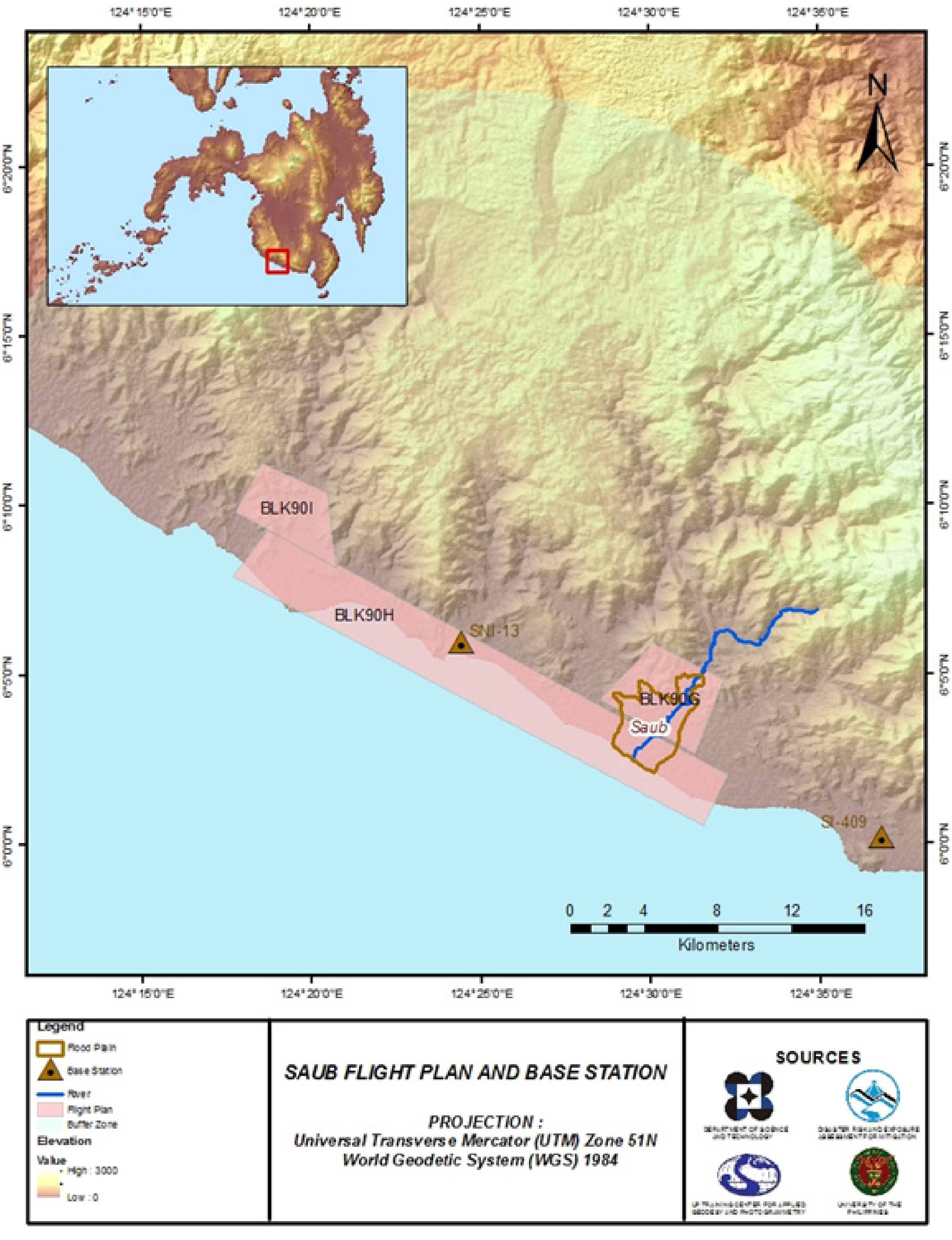


Figure 2. Flight plans and base stations used to cover the Saub floodplain.

2.2 Ground Base Stations

control point: SNI-13, which is of second (2nd) order accuracy. One (1) NAMRIA benchmark was also recovered: SI-409, which is of first (1st) order accuracy. This benchmark was used as a vertical reference point, and was also established as a ground control point. The certifications for the NAMRIA reference point and benchmark are found in Annex 2, while the baseline processing report for the established control points is in Annex 3. These were used as base stations during the flight operations held on November 4, 2014. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. The flight plans and locations of the base stations used during the aerial LiDAR acquisition in the Saub floodplain are presented in Figure 2. The composition of the project team is shown in Annex 4.

Figure 3 to Figure 4 exhibit the recovered NAMRIA control stations within the area. Table 2 to Table 3 provide the details about the NAMRIA control stations and established points, and Table 4 lists all the ground control points occupied during the acquisition with the corresponding dates of utilization.

(a)

(b)

Figure 3. (a) GPS set-up over SNI-13 within the premises of Maguling Elementary School in the Municipality of Maitum, Sarangani, and (b) NAMRIA reference point SNI-13, as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point SNI-15, used as base station for the LiDAR acquisition.

Station Name	SNI-13	
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	6° 6′ 1.73023″ 124° 24′ 20.42136″ 4.40200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	434,213.336 meters 674,541.48 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 5′ 58.75940″ North 124° 24′ 26.04611″ East 75.91000 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	655,553.39 meters 674,471.94 meters

(a) (b)

Figure 4. (a) GPS set-up over SI-409 on top of a box culvert near KM post 1747 in Barangay Badtasan, Kiamba, Sarangani along the General Santos City-Maitum National Highway, and (b) NAMRIA reference point SI-409, as recovered by the field team.

Table 3. Details of the recovered NAMRIA vertical control point SI-409, used as base station for the LiDAR acquisition, with established coordinates.

Station Name	SI-409	
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	6° 00’ 12.37199” 124° 36’ 20.42140” 9.552 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 00’ 9.44669” North 124° 36’ 53.92618” East 81.742 m
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	678,579.878 m 663,805.356 m

Table 4. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
October 30, 2014	2130A	3BLK90H303A	SNI-13 and SI-409
November 6, 2014	2158A	3BLK90GI310A	SNI-13 and SI-409
November 7, 2014	2162A	3BLK90I311A	SNI-13 and SI-409

2.3 Flight Missions

A total of three (3) flight missions were conducted to complete the LiDAR data acquisition in the Saub 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 by the DREAM Program. Annex 6 provides the flight logs of the missions. Table 5 indicates the total area of actual coverage and the corresponding flying hours for each mission, and Table 6 shows the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for the LiDAR data acquisition in the Saub 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 30, 2014	2130A	91.66	117.75	7.21	110.54	NA	4	23
November 6, 2014	2158A	37.61	42.92	8.96	33.96	NA	3	41
November 7, 2014	2162A	16.12	17.39	NA	17.39	NA	2	41
TOTAL		145.39	178.06	16.17	161.89	NA	10	45

Table 6. Actual parameters used during the LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2130A	600	45	36	50	45	130	5
2158A	750	45	36	50	50	130	5
2162A	800	45	36	50	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Saub floodplain, 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 outlined in Table 7. The actual coverage of the LiDAR acquisition for the Saub floodplain is presented in Figure 5. See Annex 7 for the flight status reports.

Table 7. Area of coverage for the LiDAR data acquisition in the Saub floodplain.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Sarangani	Kiamba	368.56	4.06	1.10%
	Maitum	298.13	71.56	24.00%
Sultan Kudarat	Palimbang	633.63	42.21	6.66%
Total		**1300.32**	**117.83**	**9.06%**

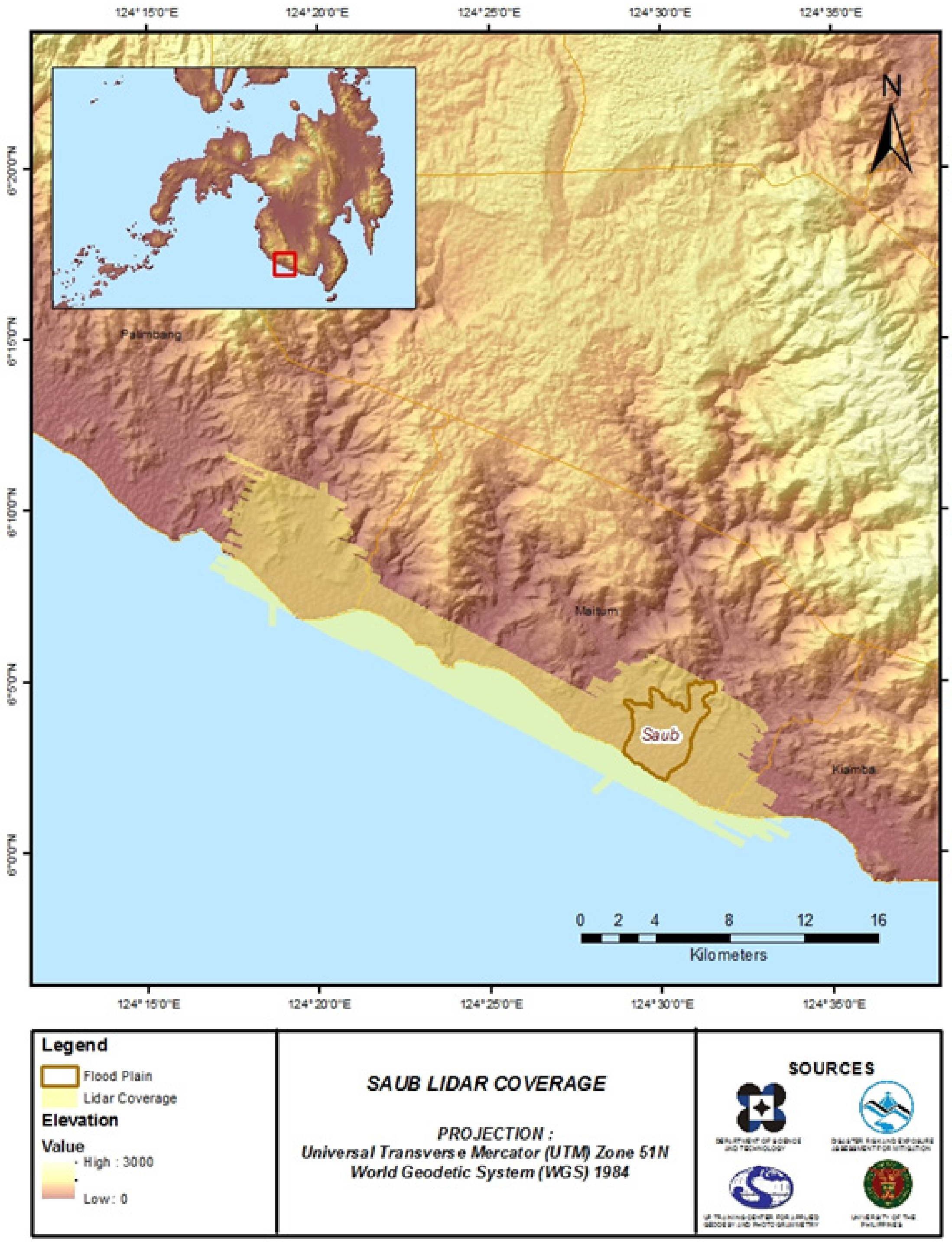


Figure 5. Actual LiDAR survey coverage of the Saub floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SAUB 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. Melanie C. Hingpit, Engr. Christy T. Lubiano, Engr. Jommer M. Medina, and 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 DAC were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and Digital Surface Model (DSM).

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

These processes are summarized in the diagram shown in Figure 6.

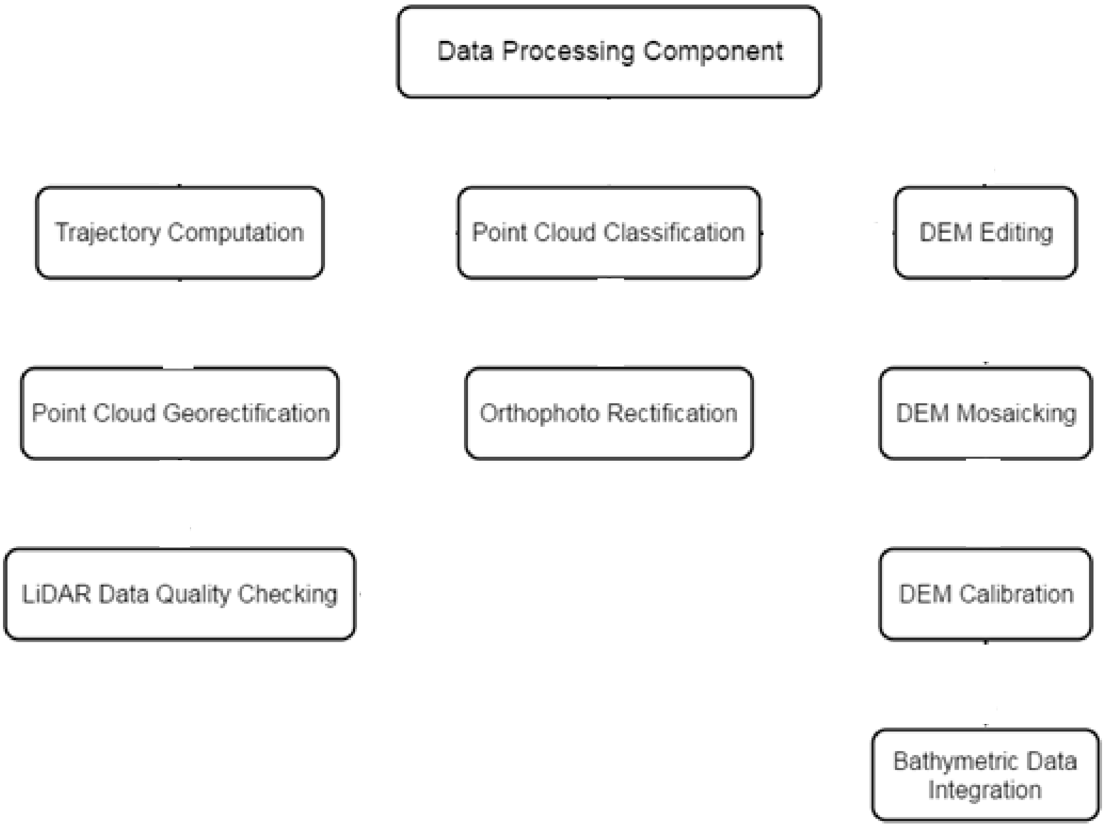


Figure 6. Schematic diagram for the Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Saub floodplain can be found in Annex 5. Missions flown during the survey conducted in October 2014 over Maitum, Sarangani used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system. The DAC transferred a total of 23.75 Gigabytes of Range data, 600 Megabytes of POS data, 24.67 Megabytes of GPS base station data, and no raw image data to the data server on November 17, 2014 for the entire survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Saub River Basin survey was fully transferred on November 19, 2014, as indicated on the data transfer sheets for the Saub floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 2130A, one of the Saub flights, which are the North, East, and Down position RMSE values, are depicted 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 fell on October 30, 2014 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

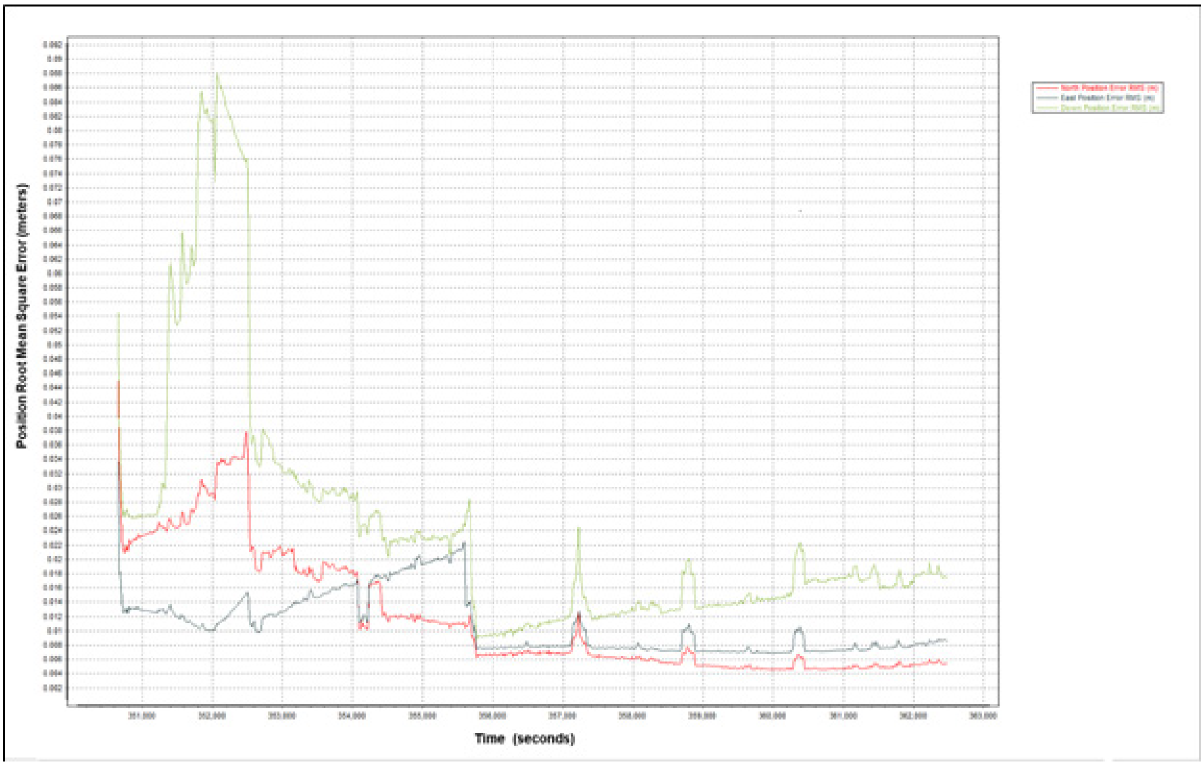


Figure 7. Smoothed Performance Metric parameters of a Saub Flight 2130A.

The time of flight was from 350500 seconds to 362500 seconds, which corresponds to the morning of October 20, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values corresponds 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 peaked at 1.22 centimeters, the East position RMSE peaked at 2.24 centimeters, and the Down position RMSE peaked at 2.84 centimeters, which are all within the prescribed accuracies described in the methodology.

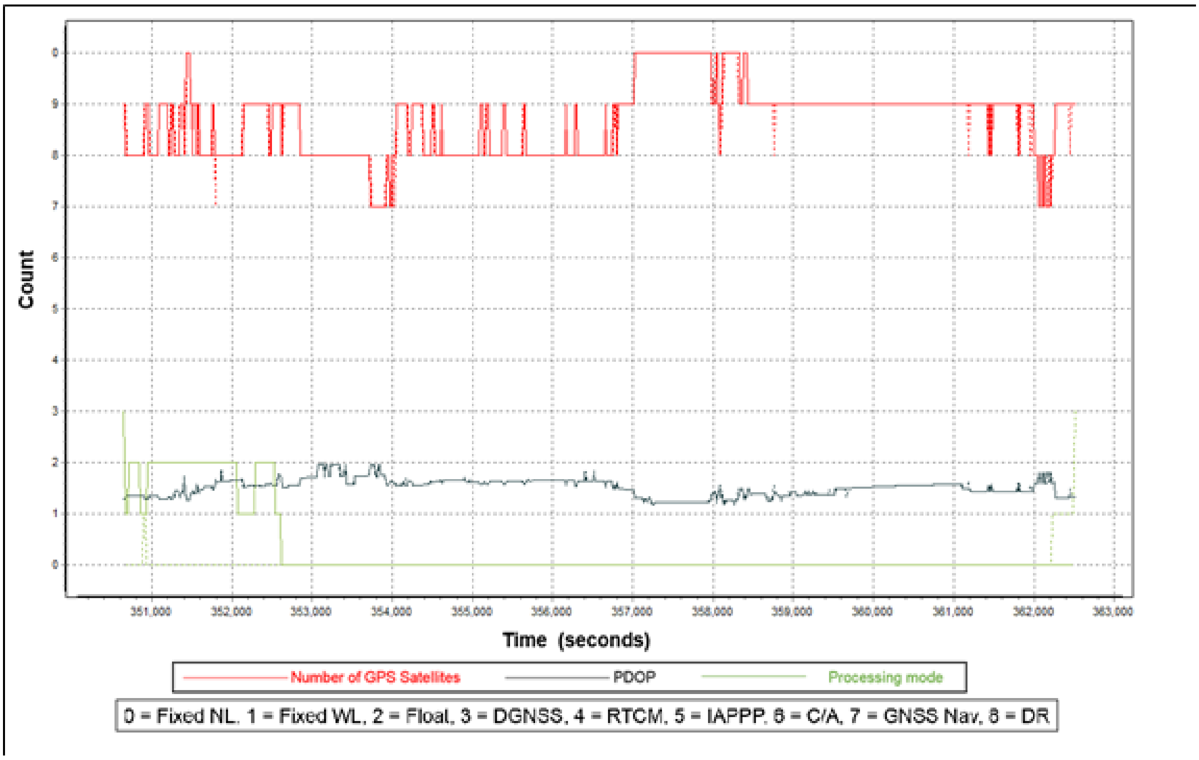


Figure 8. Solution Status parameters of a Saub Flight 2130A.

The Solution Status parameters of Flight 2130A, one of the Saub flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are exhibited in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to six (6). Majority of the time, the number of satellites tracked was between six (6) and ten (10). The PDOP value did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remained at the value of zero (0) for majority of the survey, with some peaks to up to one (1), attributed to the turns performed by the aircraft. The value of zero (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 satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Saub flights is presented in Figure 9.

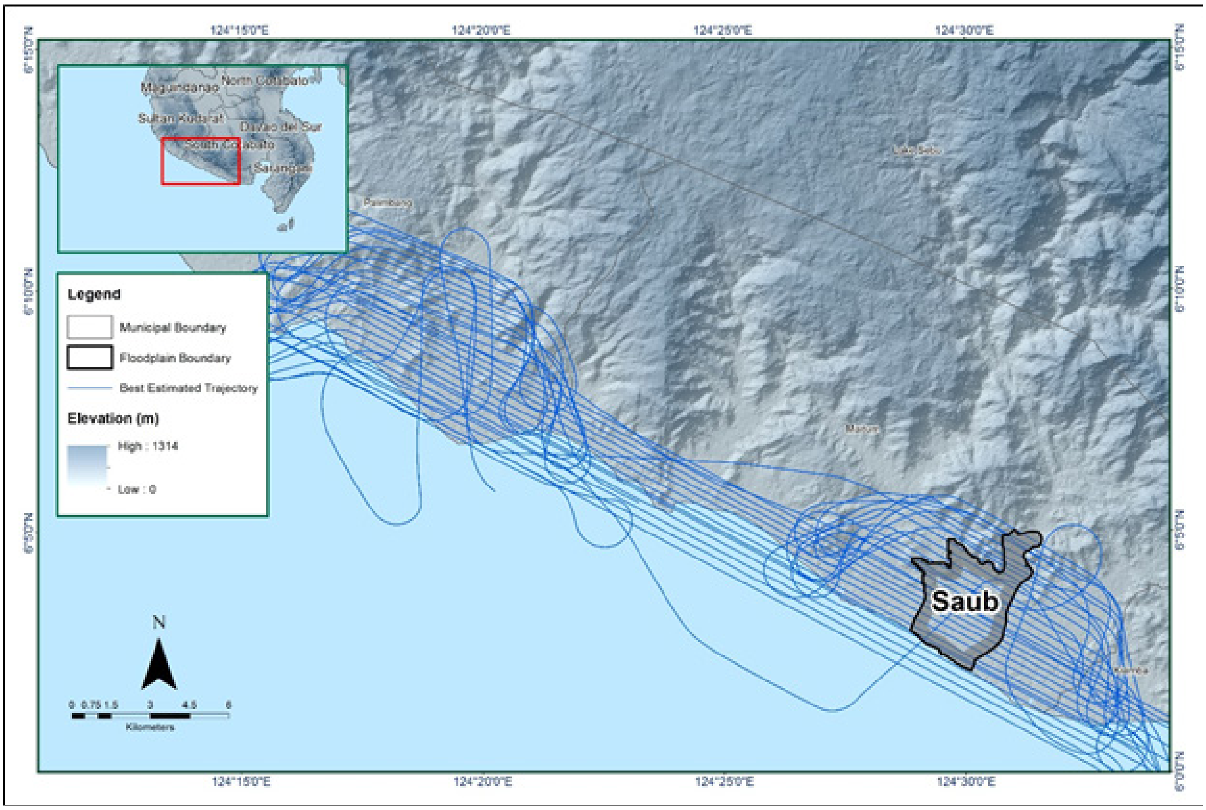


Figure 9. The best estimated trajectory conducted over the Saub floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains forty-three (43) flight lines, with each flight line containing one (1) channel, since the Aquarius system contains only one (1) channel. The summary of the self-calibration results of all flights over the Saub floodplain obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software is given in Table 8.

Table 8. Values of the self-calibration results for the Saub flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000541
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000929
GPS Position Z-correction stdev (<0.01meters)	0.0037

Optimum accuracy was obtained for all Saub flights, based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for the individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Saub floodplain are represented in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

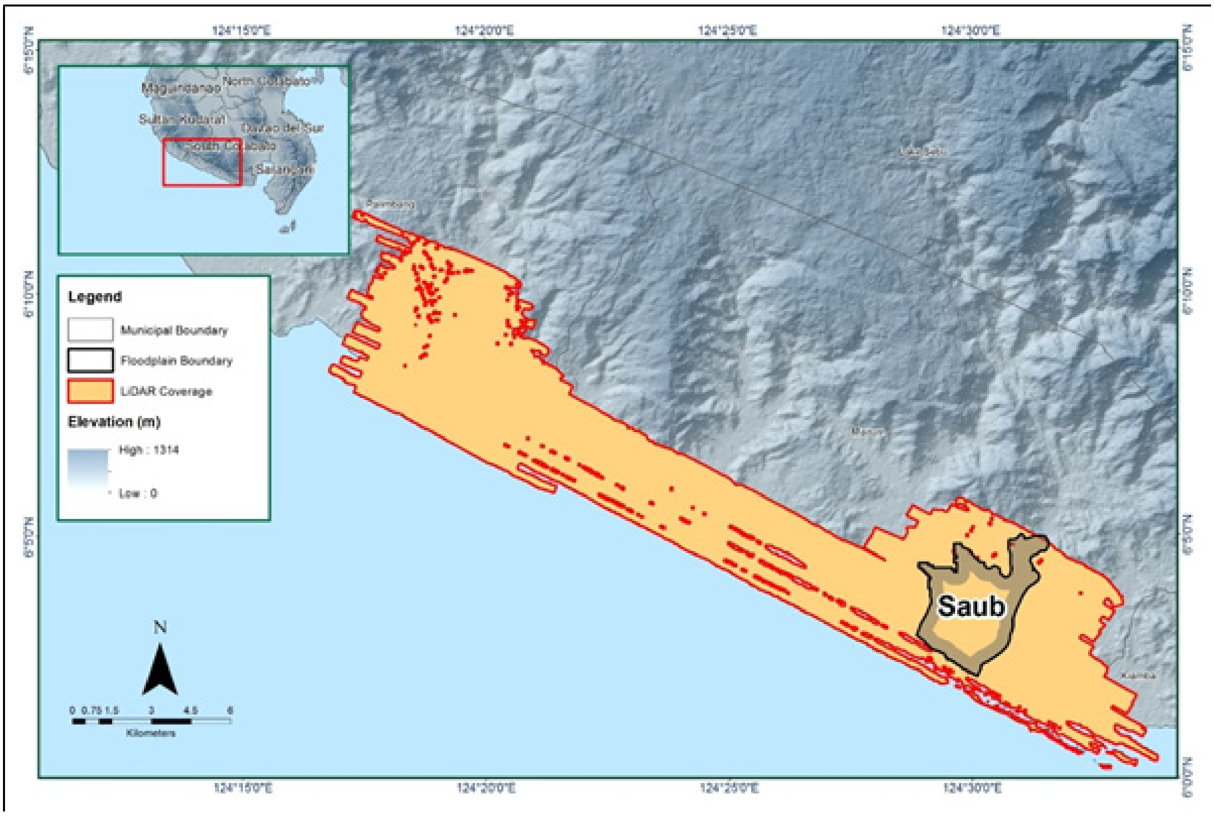


Figure 10. Boundaries of the processed LiDAR data over the Saub floodplain.

The total area covered by the Saub missions is 162.71 sq. km., comprised of three (3) flight acquisitions grouped and merged into three (3) blocks, as indicated in Table 9.

Table 9. List of LiDAR blocks for the Saub floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
SouthCotabato_Sarangani_Blk90G	2158A	32.81
SouthCotabato_Sarangani_Blk90H	2130A	107.68
SouthCotabato_Sarangani_Blk90I	2158A	22.22
	2162A	
TOTAL		**162.71 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 11. Since the Aquarius system employs one (1) channel, it is expected to have 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 (3) or more overlapping flight lines.

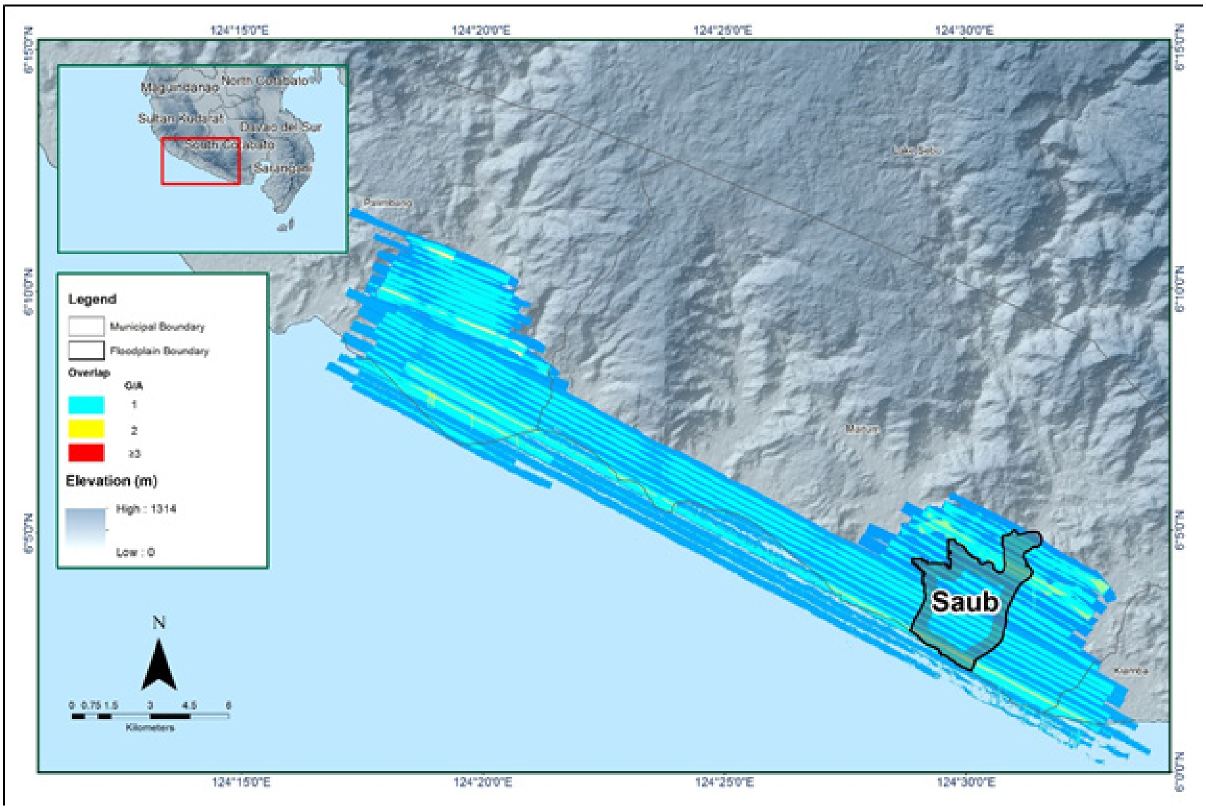


Figure 11. Image of data overlap for the Saub floodplain.

The overlap statistics per block for the Saub floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 41.00% and 48.48%, respectively, which satisfied 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 two (2) points per square meter criterion, is illustrated in Figure 12. It was determined that all LiDAR data for the Saub floodplain satisfy the point density requirement, and that the average density for the entire survey area is 2.79 points per square meter.

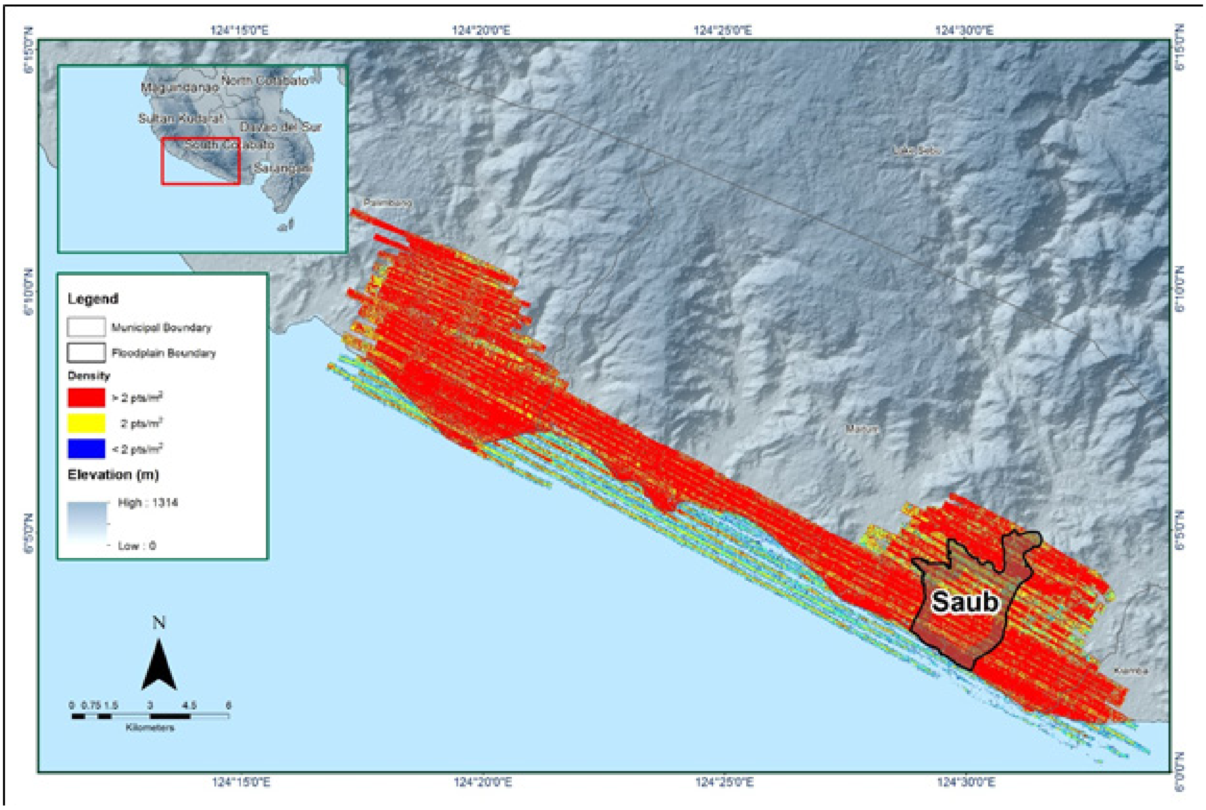


Figure 12. Pulse density map of merged LiDAR data for the Saub floodplain.

The elevation difference between overlaps of adjacent flight lines is depicted in Figure 13. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to elevations of its adjacent flight line. Areas with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

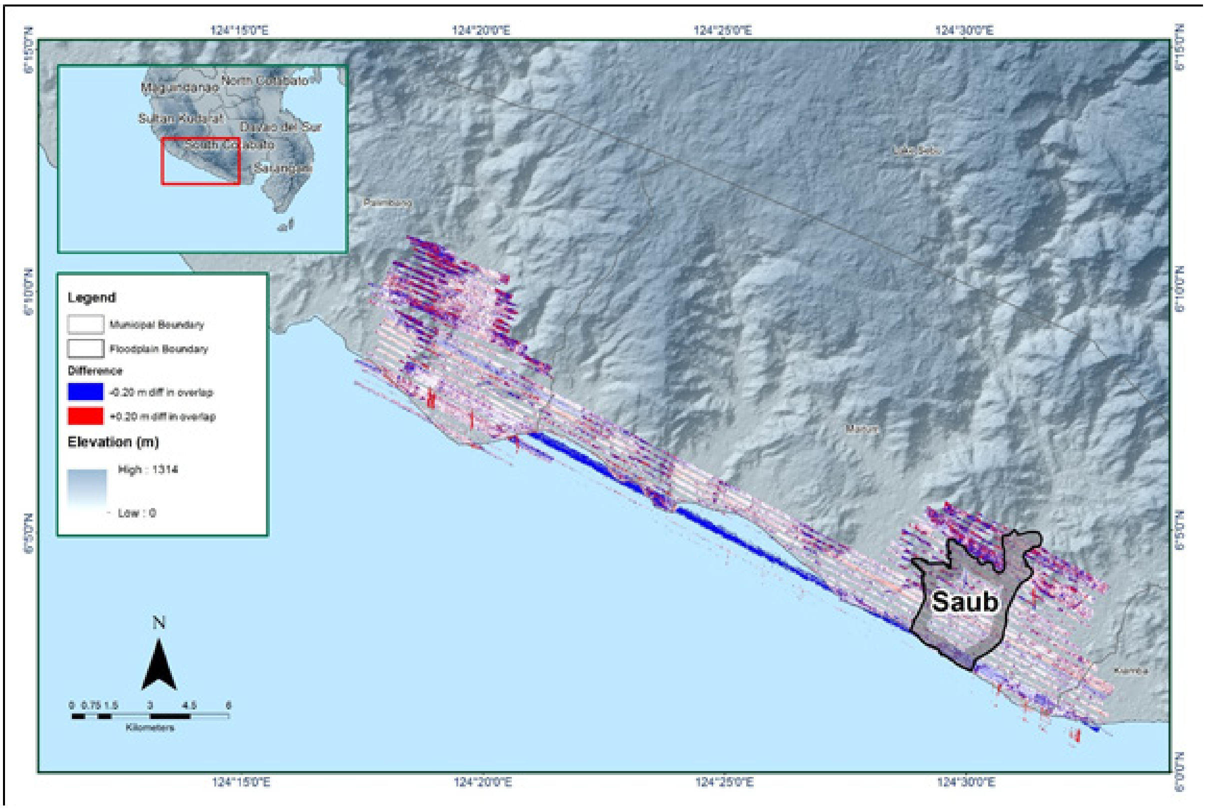


Figure 13. Elevation difference map between flight lines for the Saub floodplain.

A screen capture of the processed LAS data from a Saub Flight 2130A loaded in the QT Modeler is provided in Figure 14. The upper left image shows the elevations of the points from two (2) 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 were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

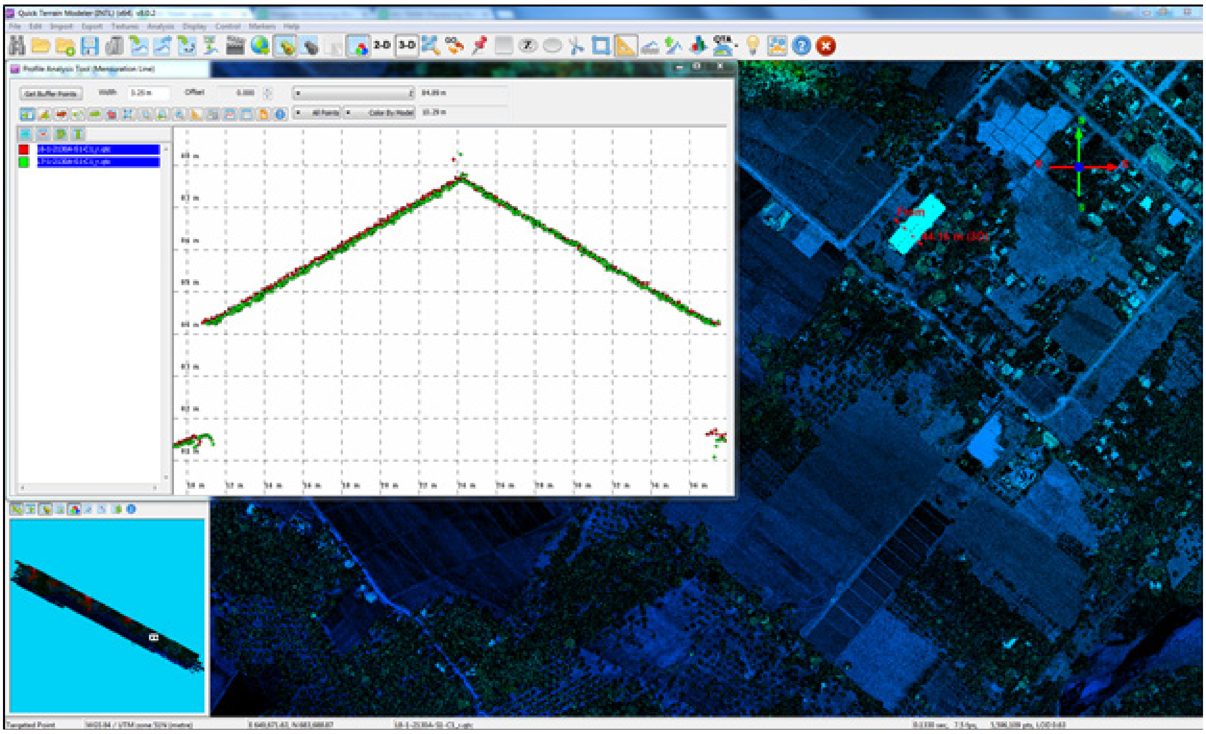


Figure 14. Quality checking for a Saub Flight 2130A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Saub classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	79,027,102
Low Vegetation	92,108,467
Medium Vegetation	97,023,170
High Vegetation	103,130,395
Building	2,828,795

The tile system that the TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Saub floodplain, are presented in Figure 15. A total of 251 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 10. The point cloud had a maximum and minimum height of 577.12 meters and 58.49 meters, respectively.

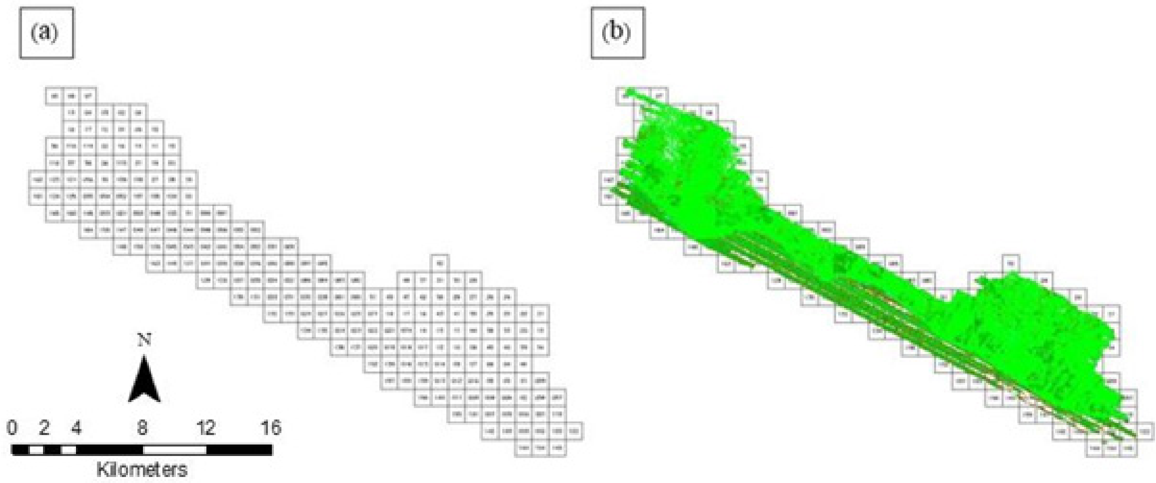


Figure 15. (a) Tiles for Saub floodplain, and (b) classification results in TerraScan.

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 is evident that residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

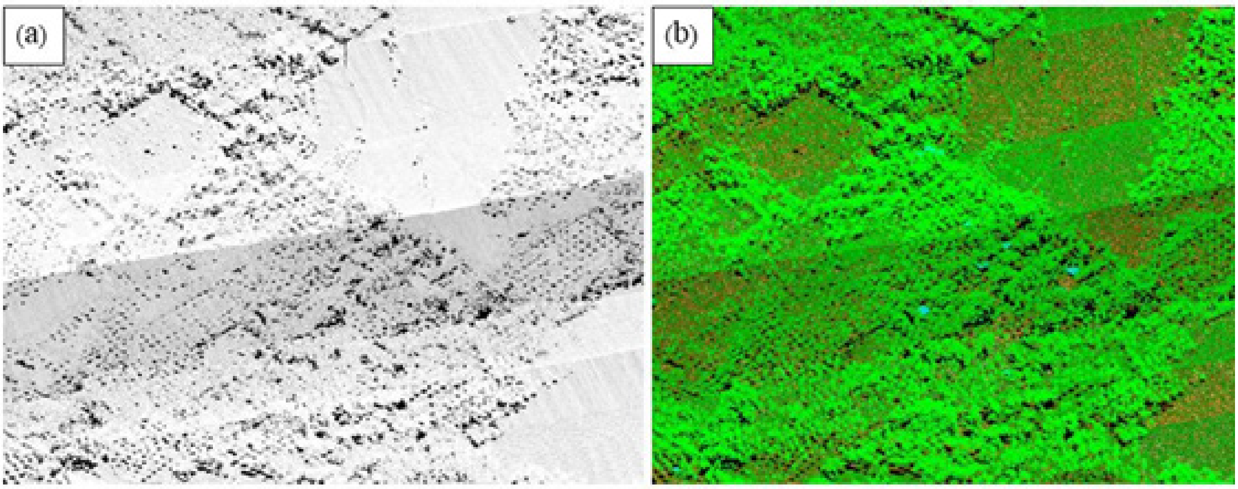


Figure 16. Point cloud (a) before and (b) after classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 17, in top view display. The figures depict that DTMs are a representation of the bare earth, while the DSMs reflect all features that are present, such as buildings and vegetation.

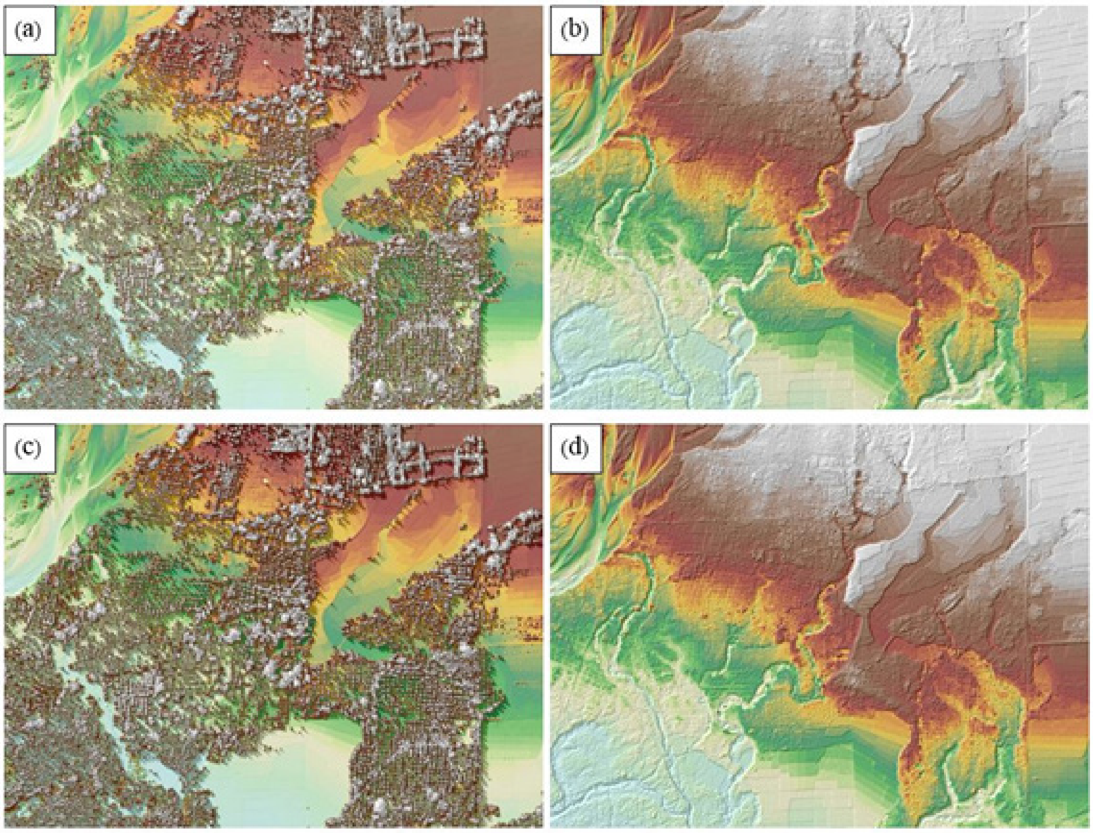


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of the Saub floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Saub floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Saub floodplain. These blocks are composed of SouthCotabato_Sarangani blocks, with a total area of 162.71 square kilometers. Table 11 indicates the name and corresponding area of each block, in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
SouthCotabato_Sarangani_Blk90G	32.81
SouthCotabato_Sarangani_Blk90H	107.68
SouthCotabato_Sarangani_Blk90I	22.22
TOTAL	**162.71 sq.km**

Portions of the DTM before and after manual editing are presented in Figure 18. The bridge (Figure 18a) and misclassified portions of a tributary (Figure 18c) were considered to be obstructions to the flow of water along the river and had to be removed (Figure 18b and Figure 18d, respectively), in order to hydrologically correct the water flow. This was executed through an interpolation process wherein a specific polygon determined the upstream and downstream elevation values to generate an interpolated portion of the river, and eventually remove the bridge and the misclassified footprints. On the other hand, object retrieval was performed in areas, such as the ridge (Figure 18e), which was removed during the classification process and had to be retrieved to complete the surface (Figure 18f). The object retrieval process utilized the secondary DTM (t_layer) to fill in these areas.

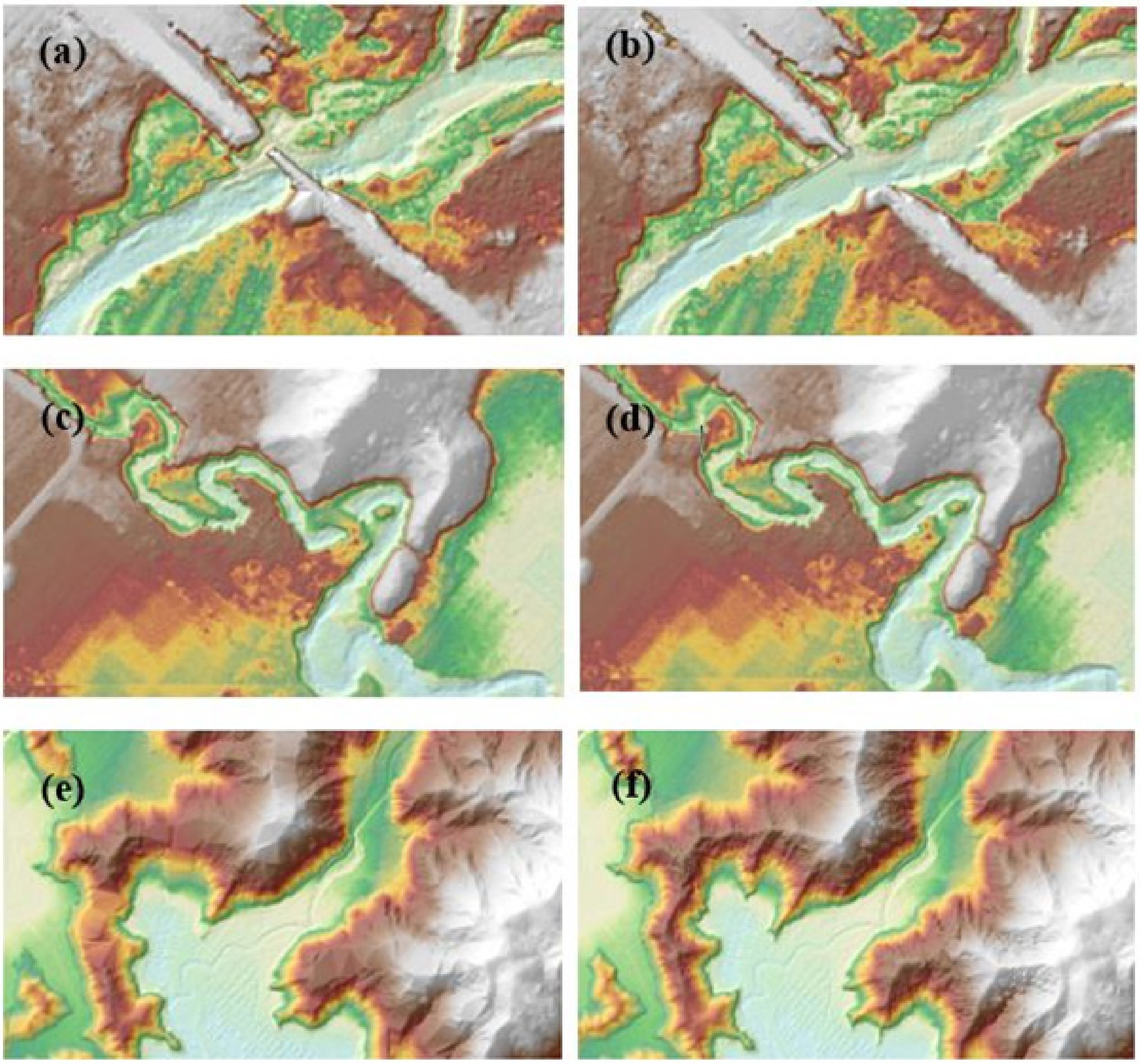


Figure 18. Portions in the DTM of the Saub floodplain –a bridge (a) before and (b) after interpolation; a misclassified portion of a tributary (c) before and, (d) after interpolation; and a misclassified ridge (e) before and (f) after data retrieval.

3.9 Mosaicking of Blocks

The SouthCotabato_Sarangani_Blk90H block was used as the reference block at the start of the mosaicking process, due to the availability of validation points that were used to calibrate such block. Table 12 lists the area of each LiDAR block and the shift values applied during mosaicking. Shifting values were derived from the height difference of the calibrated block and the overlapping adjacent block.

The mosaicked LiDAR DTM for the Saub floodplain is illustrated in Figure 19. It exhibits that the entire Saub floodplain is 100% covered by LiDAR data.

Table 12. Shift values of each LiDAR block of the Saub floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
SouthCotabato_Sarangani_Blk90G	0.00	0.00	0.15
SouthCotabato_Sarangani_Blk90H	0.00	0.00	0.00
SouthCotabato_Sarangani_Blk90I	0.00	0.00	0.10

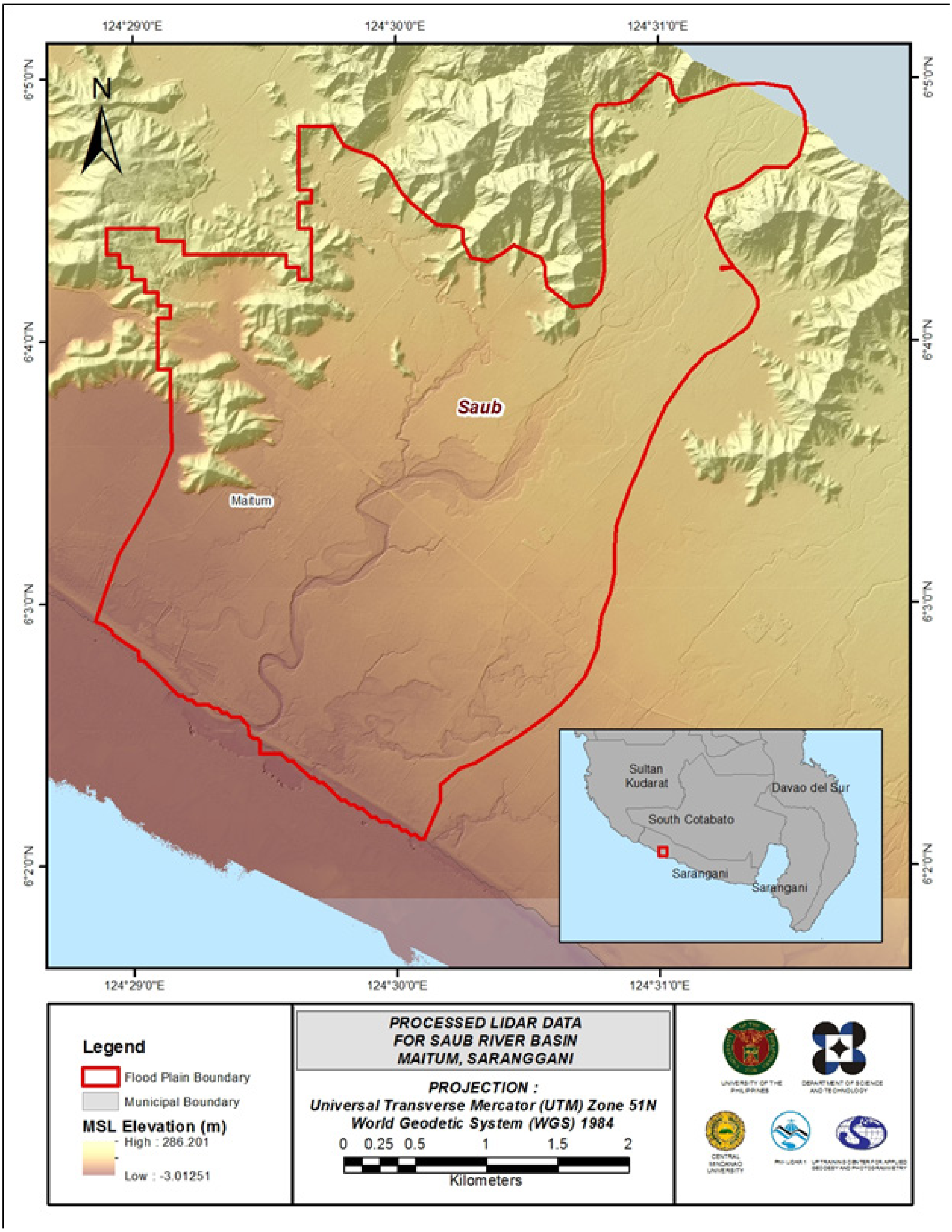


Figure 19. Map of processed LiDAR data for the Saub floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Saub floodplain. The extent of the validation survey done in the Saub River to collect points with which the LiDAR dataset was validated is shown in Figure 20, with the validation survey points highlighted in green.

A total of 3,479 survey points were used for the calibration and validation of the Saub LiDAR data. Random selection of 80% of the survey points resulted in 2,785 points that were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 21. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of the data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 2.31 meters, with a standard deviation of 0.15 meters. Calibration of the Saub LiDAR data was done by adding the height difference value, 2.31 meters, to the Saub mosaicked LiDAR data. Table 13 summarizes the statistical values of the compared elevation values between the LiDAR data and the calibration data.

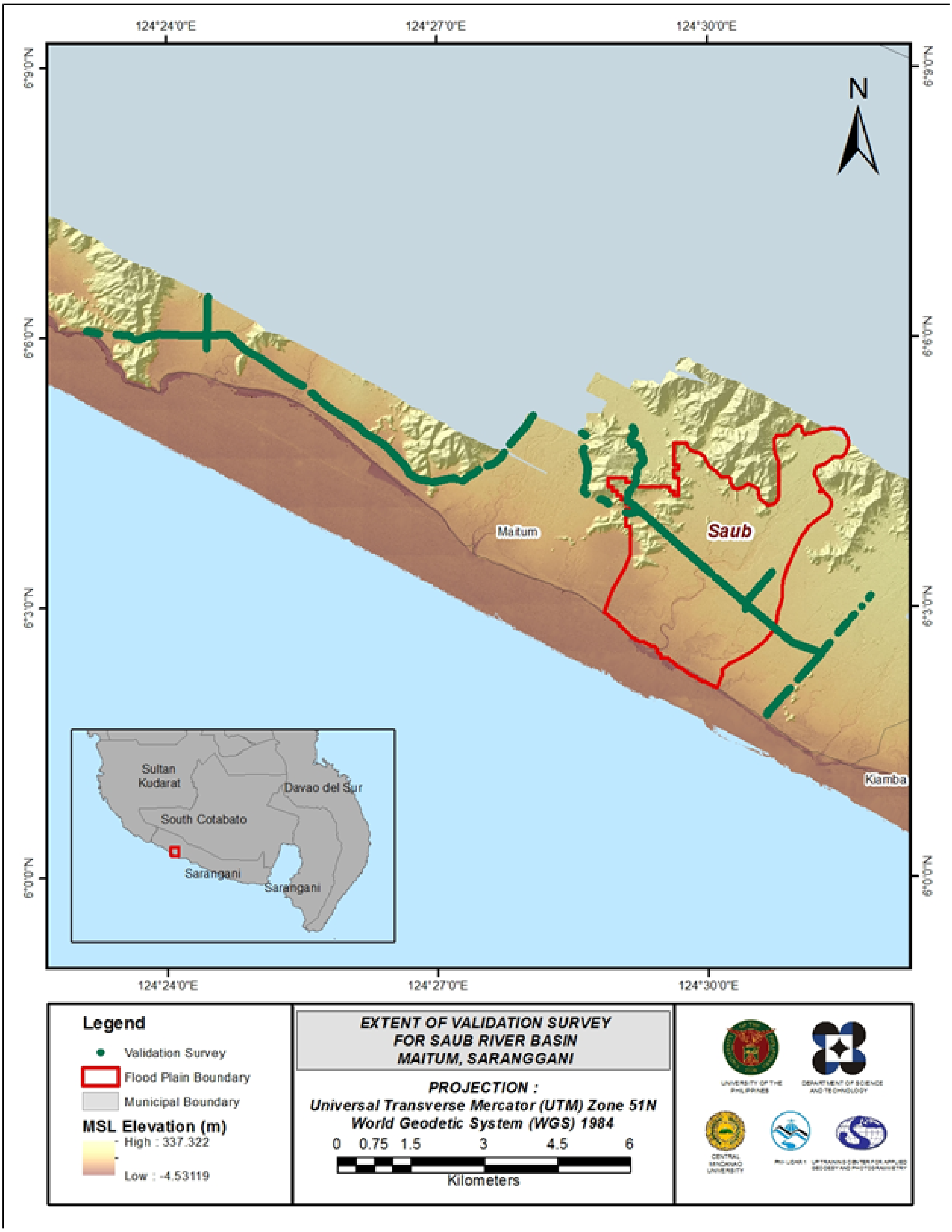


Figure 20. Map of the Saub floodplain, with the validation survey points in green.

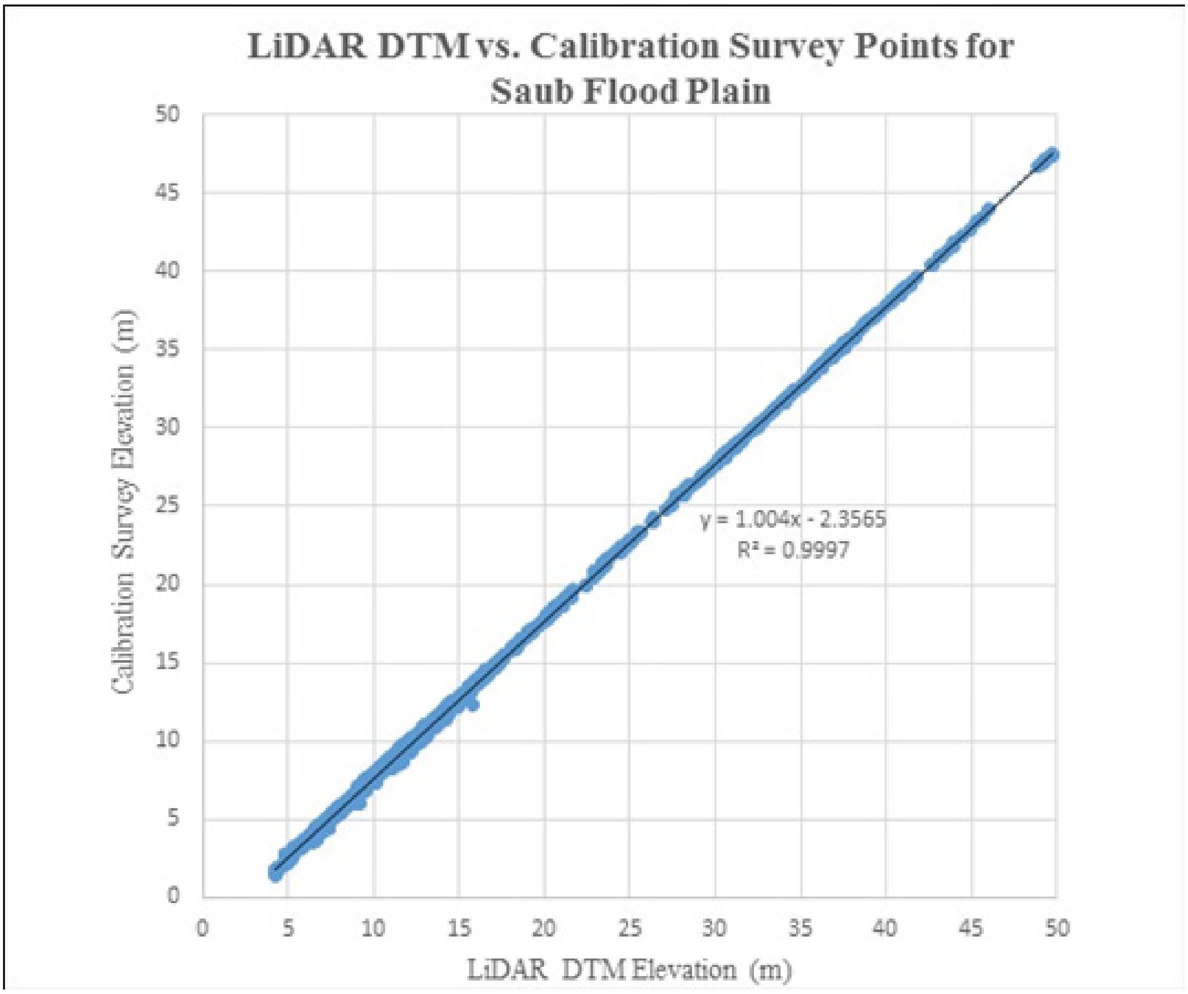


Figure 21. Correlation plot between the calibration survey points and the LiDAR data.

Table 13. Calibration statistical measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.31
Standard Deviation	0.15
Average	2.31
Minimum	1.96
Maximum	3.47

The remaining 20% of the total survey points, resulting in 696 points, were used for the validation of the calibrated Saub 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 demonstrated in Figure 22. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.19 meters, with a standard deviation of 0.18 meters, as given in Table 14.

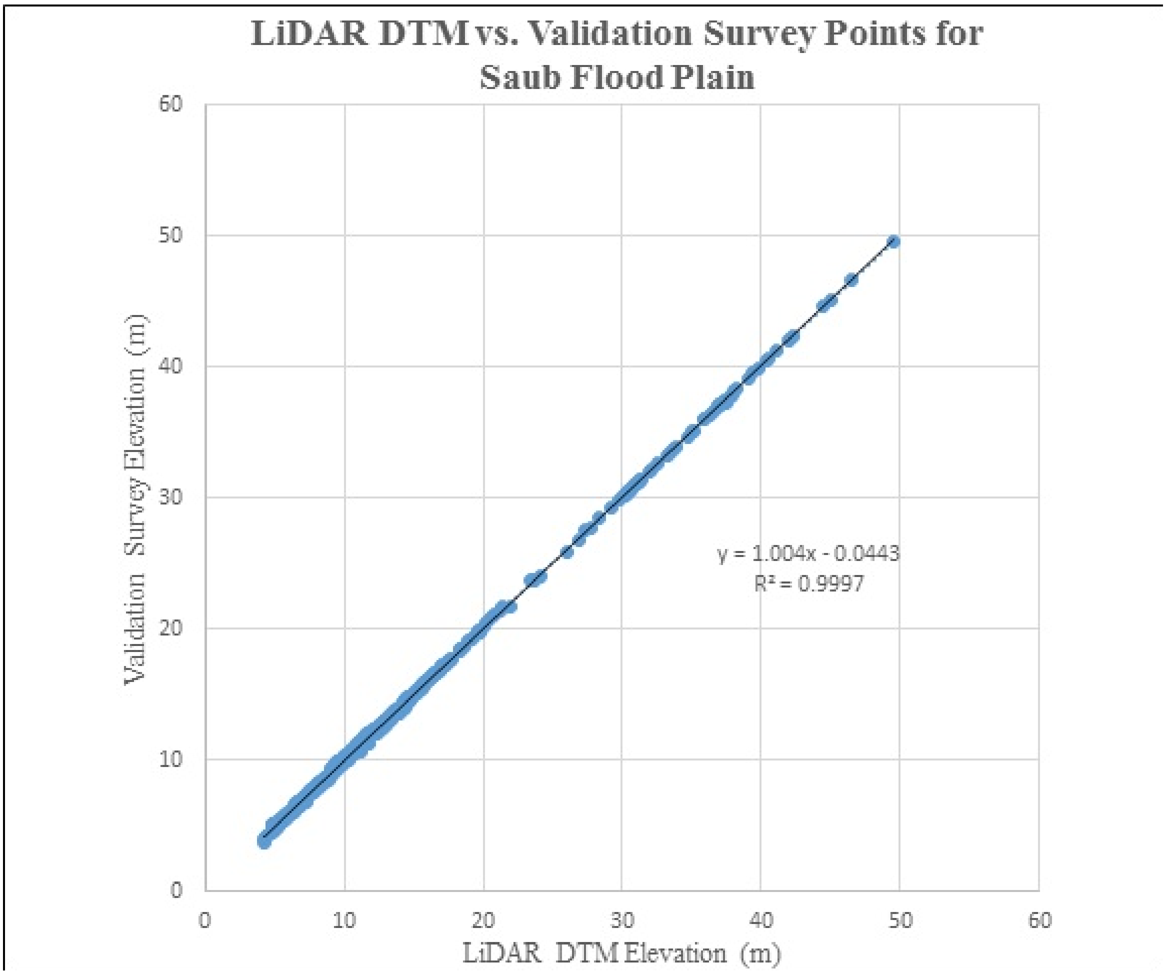


Figure 22. Correlation plot between the validation survey points and the LiDAR data.

Table 14. Validation statistical measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.18
Average	-0.08
Minimum	-0.38
Maximum	0.30

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross-section data were available for the Saub floodplain, with 1,132 bathymetric survey points. The resulting raster surface produced was obtained by applying the 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 0.22 meters. The extent of the bathymetric survey done by the DVBC in the Saub River Basin, integrated with the processed LiDAR DEM, is illustrated in Figure 23.

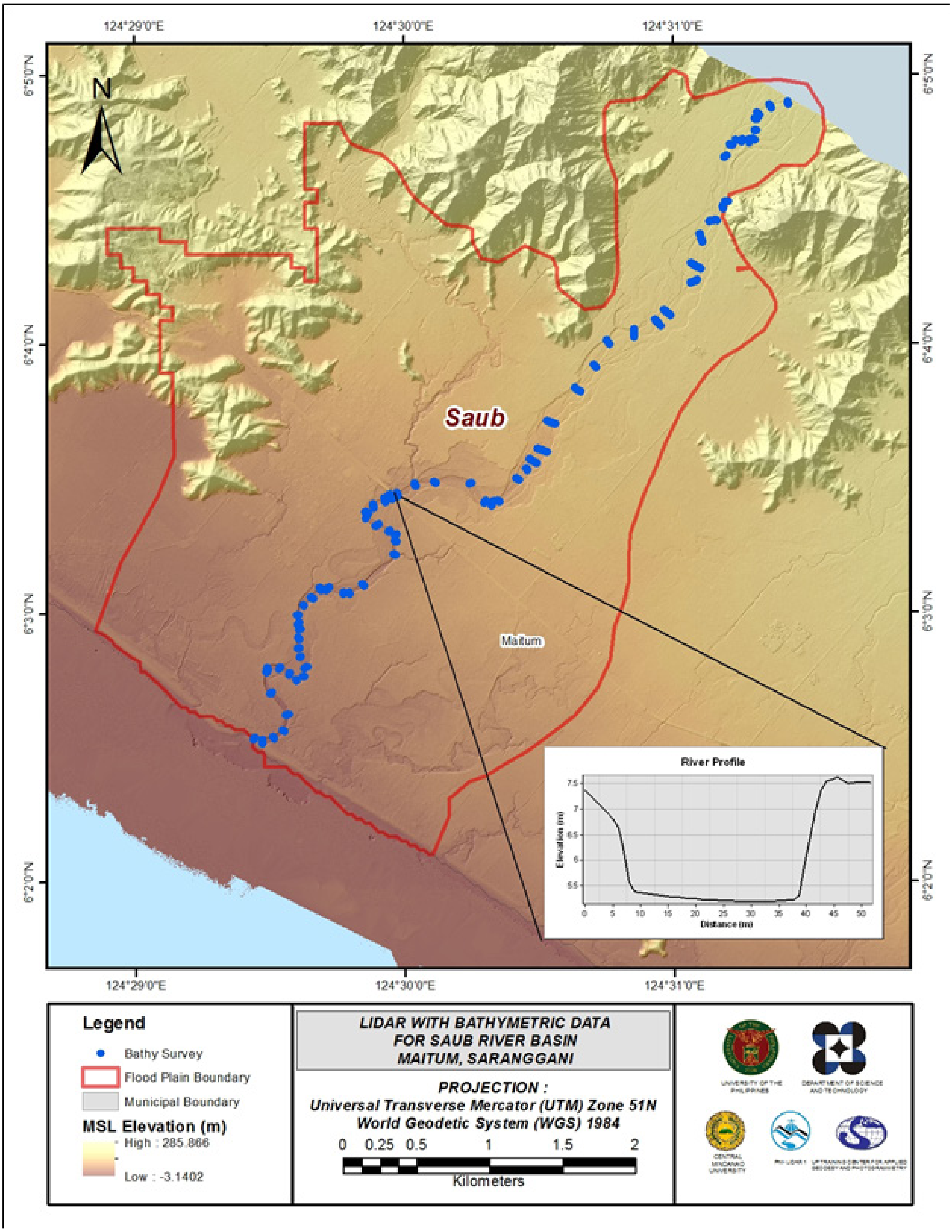


Figure 23. Map of the Saub floodplain, with bathymetric survey points shown in blue.

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 a 200-meter buffer zone. Mosaicked LiDAR DEM with a 1-meter 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 – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

The Saub floodplain, including its 200-meter buffer zone, has a total area of 18.59 sq. km. Of this area, a total of 5.0 sq. km., corresponding to a total of 548 building features, was considered for quality checking (QC). Figure 24 exhibits the QC blocks for the Saub floodplain.

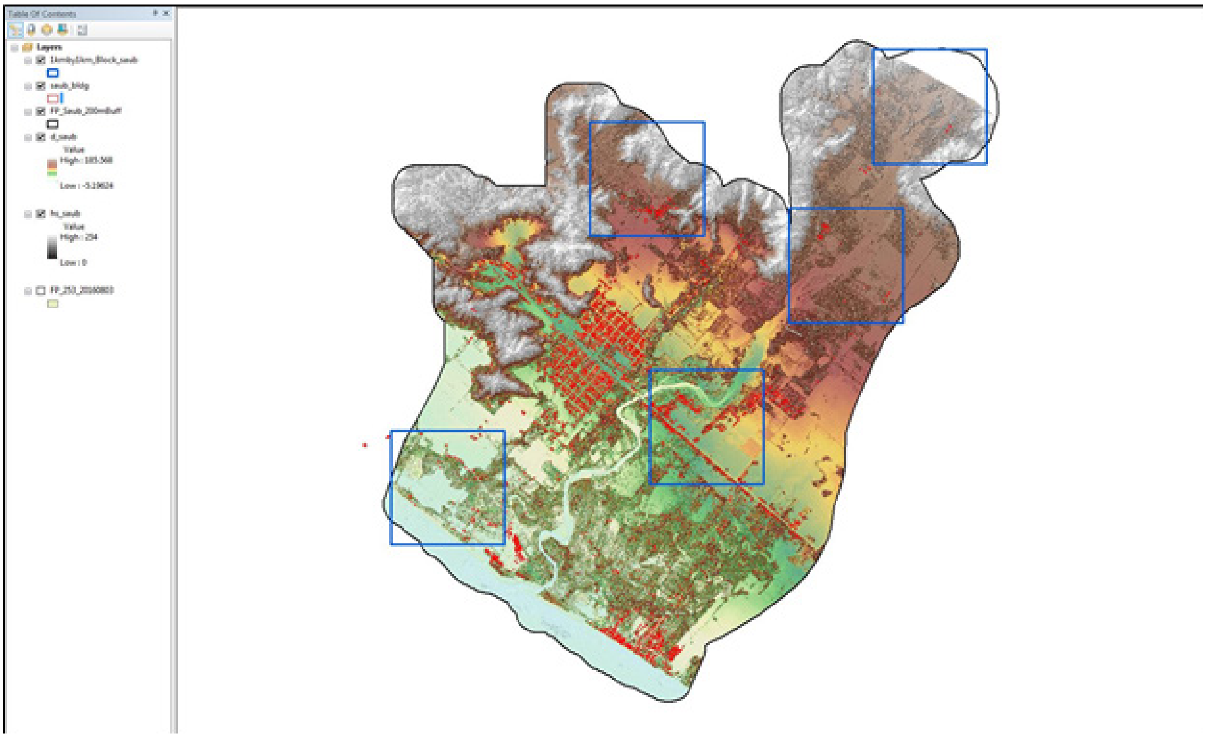


Figure 24. Blocks (in blue) of Saub building features that were subjected to QC.

Quality checking of Saub building features resulted in the ratings presented in Table 15.

Table 15. Quality checking ratings for the Saub building features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Saub	99.90	99.97	99.39	PASSED

3.12.2 Height Extraction

Height extraction was done for 3,224 building features in the Saub floodplain. Of these building features, none was filtered out after height extraction, resulting in 3,209 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 8.06 meters.

3.12.3 Feature Attribution

Field data collection for the attribution process was done through Geotagging (i.e., "point to a specific feature and shoot" method) using a handheld GPS device with a built-in camera. The xyz-position and the viewing direction of the GPS in a range of 0 to 359 degrees during the photo capture were the essential information gathered 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" was automatically created in the points' attribute table, wherein the photo's directory was immediately linked everytime the "Identify" button was snapped to a specific point.

Table 16 summarizes the number of building features per type. Table 17 indicates the total length of each road type, and Table 18 provides the number of water features extracted per type.

Table 16. Building features extracted for the Saub floodplain.

Facility Type	No. of Features
Residential	2,986
School	82
Market	25
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	4
Barangay Hall	3
Military Institution	0
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	2
Transport Terminal	2
Warehouse	10
Power Plant/Substation	0
NGO/CSO Offices	4
Police Station	2
Water Supply/Sewerage	0
Religious Institutions	29
Bank	0
Factory	0
Gas Station	4
Fire Station	0
Other Government Offices	9
Other Commercial Establishments	45
Municipal Hall	1
Purok Hall	0
Total	3,209

Table 17. Total length of extracted roads for the Saub floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Saub	49.59		0.00	4.43	0.00	54.02

Table 18. Number of extracted water bodies for the Saub floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Saub	2	0	0	0	0	2

A total of two (2) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 25 presents the Digital Surface Model (DSM) of the Saub floodplain, overlaid with its ground features.

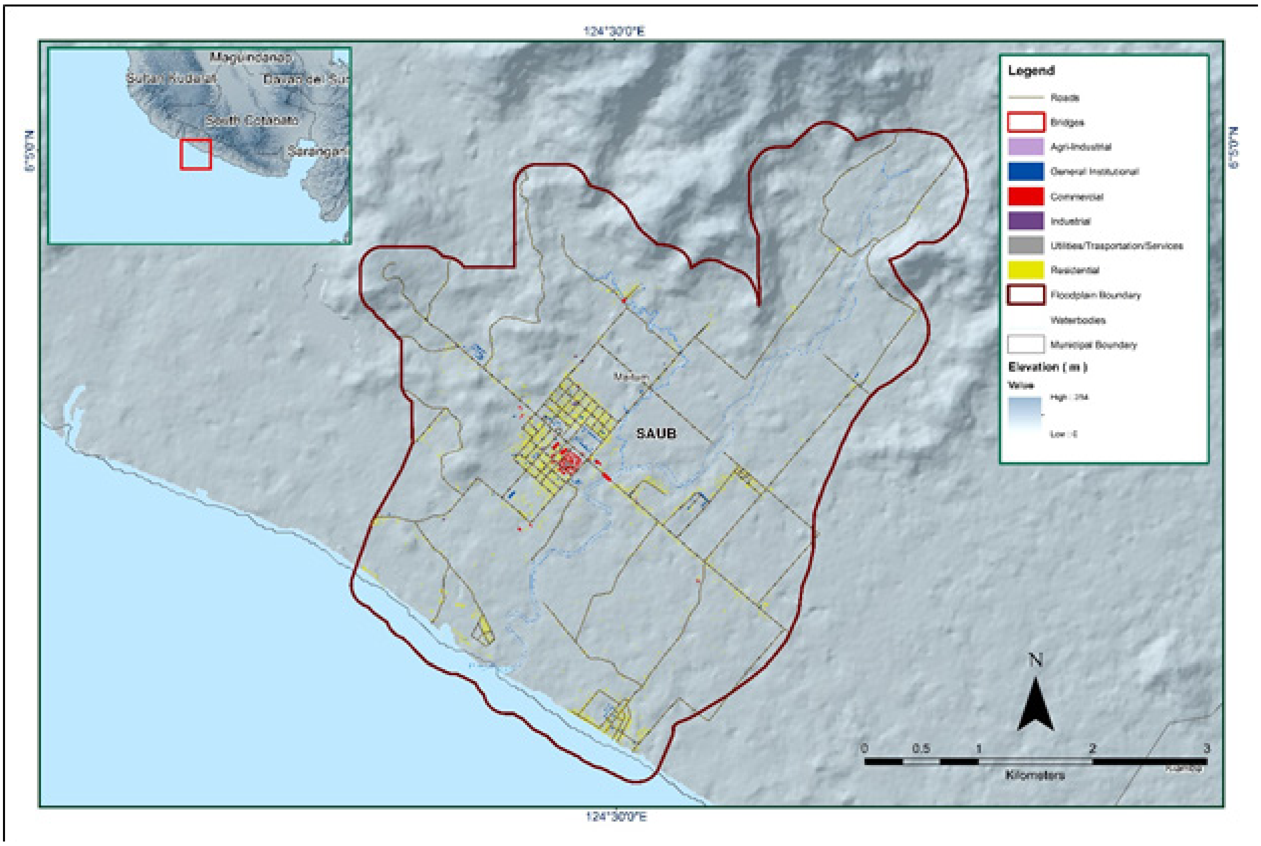


Figure 25. Extracted features for the Saub floodplain.

CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE SAUB RIVER BASIN

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

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).

4.1 Summary of Activities

The AB Surveying and Development (ABSD) Team conducted field surveys in the Saub River on April 9-11, 2016, with the following scope of work: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built surveys at the Kalaong Bridge in Barangay Kalaong, Maitum, Sarangani; and (iv.) bathymetric survey from the upstream side of the river down to its mouth in Barangay Kalaong, Maitum, with an approximate length of 3.37 km., using a Nikon® Total Station. In addition to this, validation points acquisition survey was conducted by the DVBC, covering the Saub River area. The extent of the survey is illustrated in Figure 26.

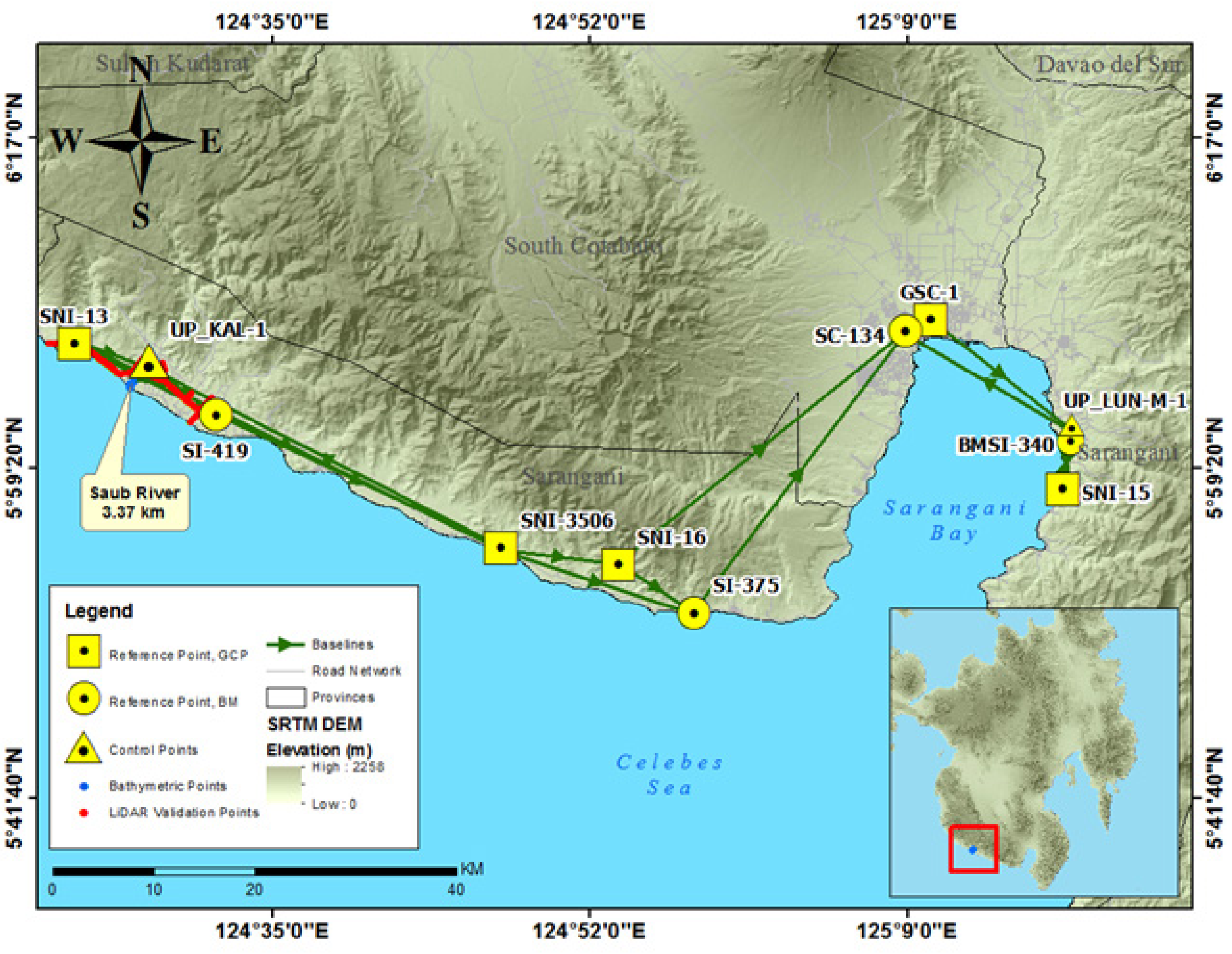


Figure 26. Extent of the bathymetric survey (in blue line) in the Saub River Survey and the LiDAR data validation survey (in red).

4.2 Control Survey

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

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

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

The list of the reference and control points and their corresponding locations is summarized in Table 19, while GNSS network established is illustrated in Figure 27.

Table 19. List of reference and control points used during the survey in Saub River (Source: NAMRIA; UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
Control Survey on December 10, 2016						
GSC-1	2nd order, GCP	6°07'16.67814"N	125°10'14.17232"E	-	30.481	2013
SC-134	2nd order, BM	6°06'39.95883"N	125°08'54.60317"E	-	33.383	2012
SNI-3056	3rd order, GCP	5°55'02.04285"N	124°47'15.15313"E	-	-	2007
BMSI-340	Used as marker	-	-	-	-	2008
SI-375	Used as marker	-	-	-	-	2012
SI-419	Used as marker	-	-	-	-	2012
SNI-13	Used as marker	-	-	-	-	2007
SNI-15	Used as marker	-	-	-	-	2007
SNI-16	Used as marker	-	-	-	-	2007
UP_KAL-1	Established	-	-	-	-	4-9-2016
UP_LUN-M-1	Established	-	-	-	-	3-31-2016

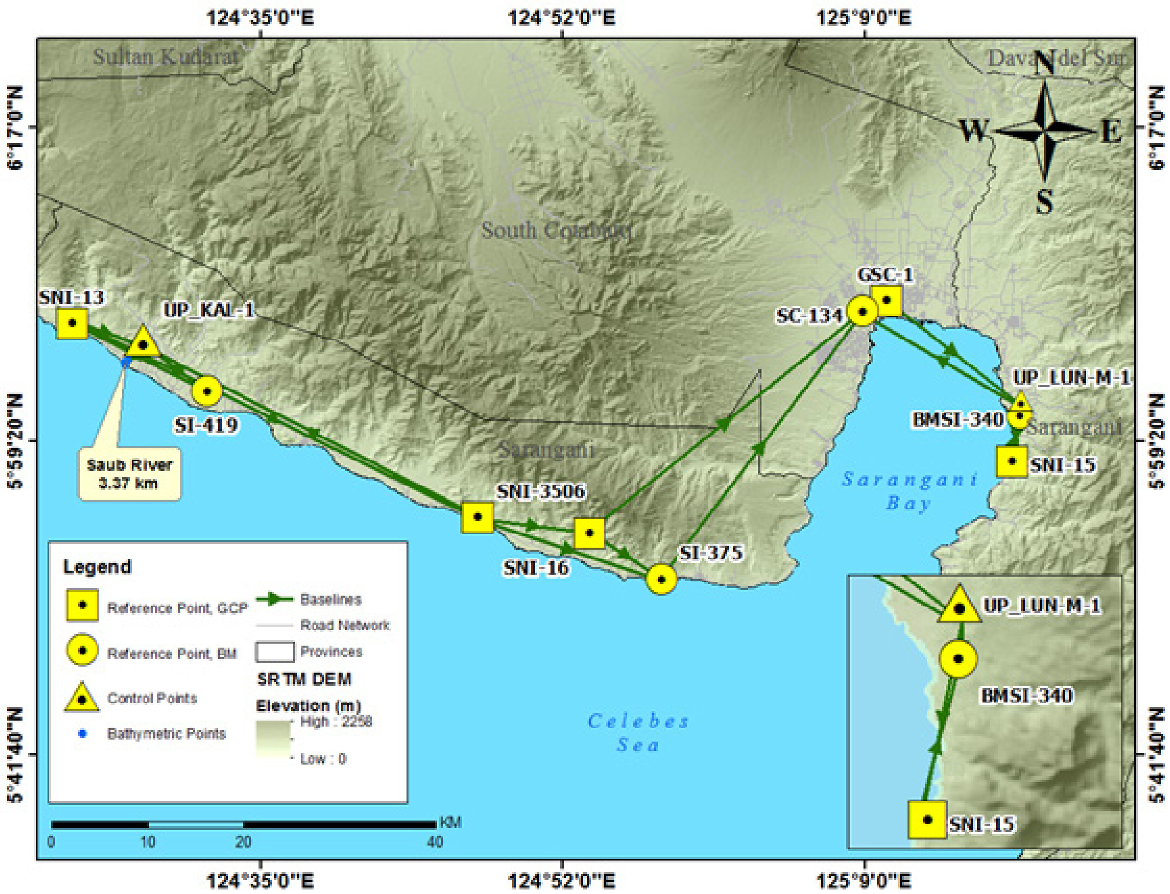


Figure 27. Extent of the Saub River Basin control survey.

The GNSS set-ups on recovered reference points and established control points in the Saub River are exhibited in Figure 28 to Figure 38.

Figure 28. GNSS base set-up, Trimble® SPS 985, at GSC-1, located on the rooftop of the Ice Castle Experience Hotel in Ambassador Provido Village, Barangay City Heights, General Santos City, South Cotabato.

Figure 29. GNSS receiver set-up, Trimble® SPS 985, at SC-134, located at the approach of the Sinawal Bridge in Barangay Labangal, General Santos City, South Cotabato.

Figure 30. SNI-3506, a third-order GCP, located beside a flag pole inside Lomuyon Elementary School in Barangay Lomuyon, Kiamba, Sarangani.

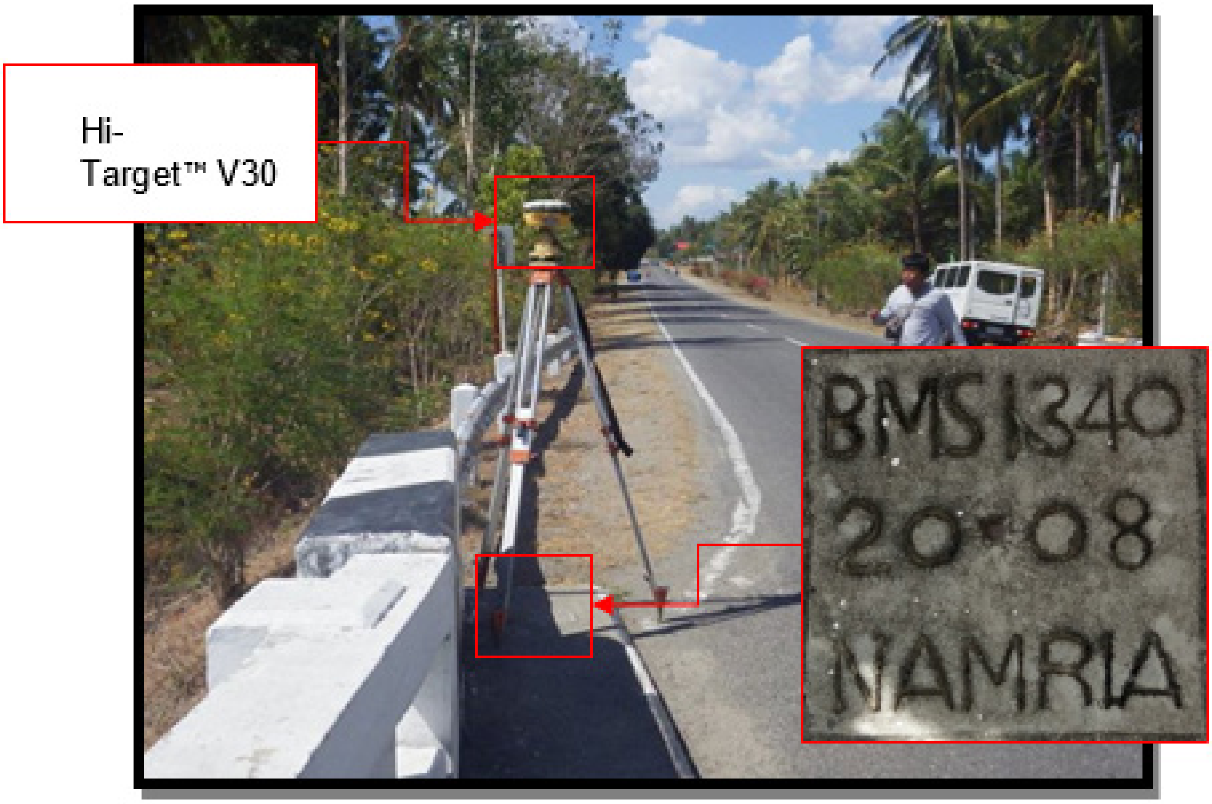


Figure 31. GNSS receiver set-up, Hi-Target™ V30, at BMSI-340, located at the approach of the Molo Bridge in Barangay Lun Masla, Malapatan, Sarangani.

Figure 32. SI-375, a NAMRIA established BM, located along the national highway in Barangay Kabatiol, Maasim, Sarangani.

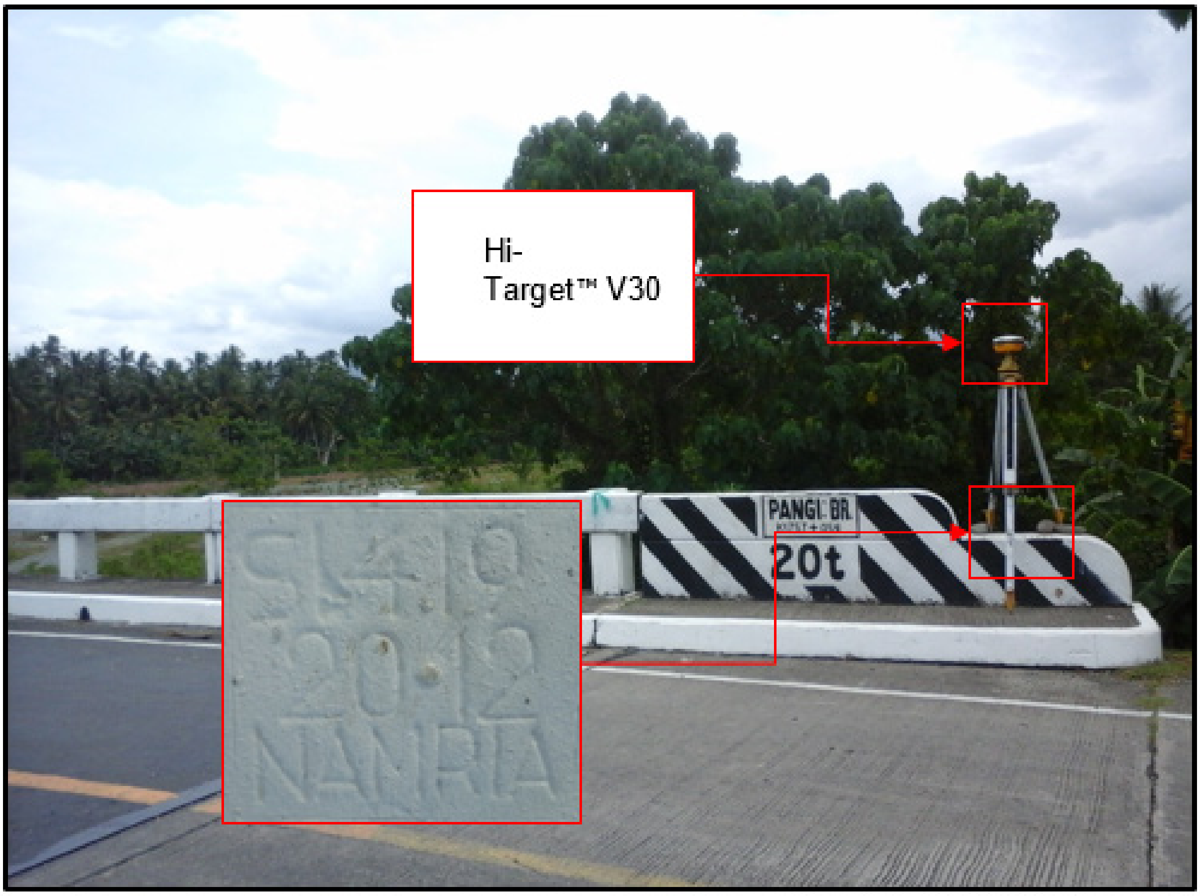


Figure 33. GNSS receiver set-up, Hi-Target™ V30, at SI-419, a NAMRIA established BM, located at the barrier of the Pangi Bridge in Barangay Pangi, Maitum, Sarangani.

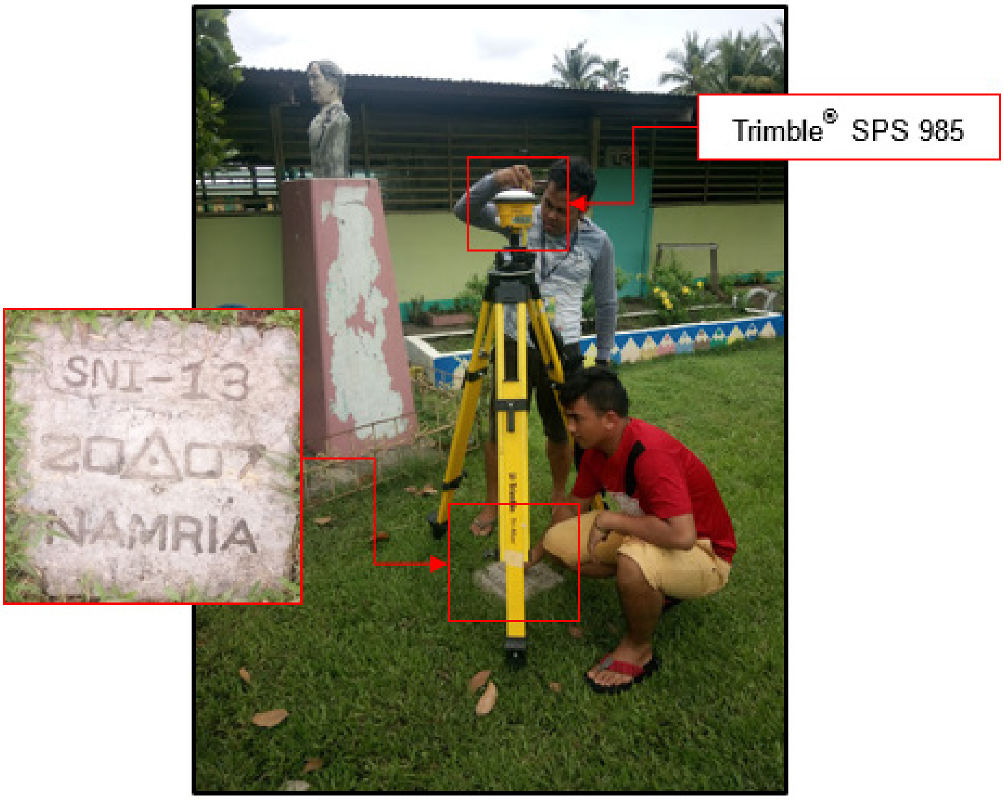


Figure 34. GNSS base set-up, Trimble® SPS 985, at SNI-13, a second-order GCP, located beside a Jose Rizal bust inside Maguling Elementary School in Barangay Maguling, Maitum, Sarangani.

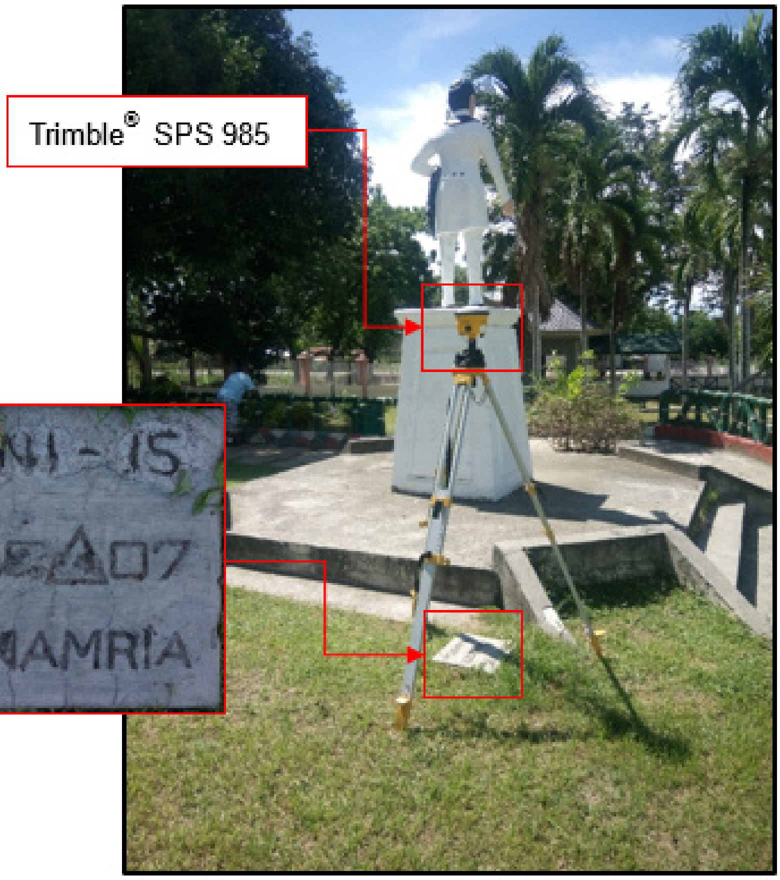


Figure 35. GNSS receiver set-up, Trimble® SPS 985, at SNI-15, located behind a Jose Rizal monument inside the premises of the Malapatan Municipal Hall in Barangay Poblacion, Malapatan, Sarangani

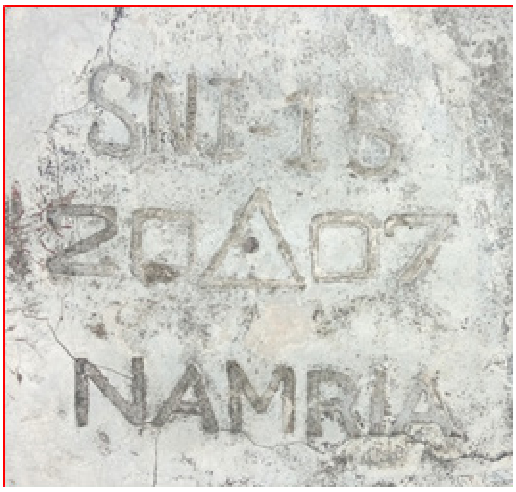


Figure 36. SNI-16, a second-order GCP, located beside a flag pole inside the premises of the Malbang Barangay Hall in Barangay Malbang, Maasim, Sarangani.

Figure 37. GNSS receiver set-up, Hi-Target™ V30, at UP_KAL-1, an established control point, located beside the approach of the Kalaong Bridge in Barangay Kalaong, Maitum, Sarangani.

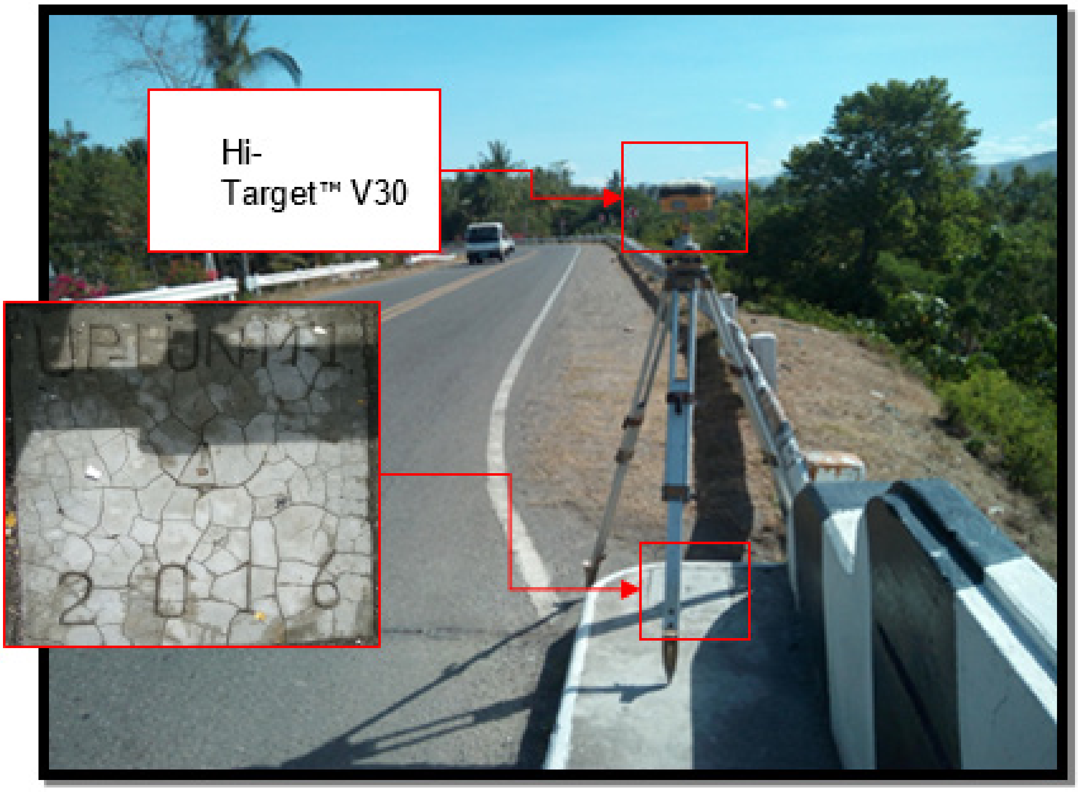


Figure 38. GNSS receiver set-up, Hi-Target™ V30, at UP_LUN-M-1, located at the approach of the Lun Masla Bridge in Barangay Lun Masla, Malapatan, Sarangani.

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm, and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of baseline data using the same processing software. It was repeatedly processed until all baseline requirements were met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of the control points in the Saub River Basin generated by the TBC software is summarized in Table 20.

Table 20. Baseline Processing Report for Saub River Static Survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
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						
10-22-2016	Fixed	0.002	0.009	119°17'04"	18840.233	-18.797	
SI-419 --- UP_KAL-1	10-27-2016	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	10-25-2016						
10-26-2016	Fixed	0.002	0.016	216°58'04"	34818.418	-18.620	
SNI-16 --- SI-375	10-25-2016						

As shown in Table 20, a total of eighteen (18) baselines were processed, with the coordinates and elevation values of GSC-1 and SC-134, and the coordinates of SNI-3506, held fixed. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was 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 squares of x and y must be less than 20 cm and z less than 10 cm, or in equation form:

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

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 from Table 21 to Table 24 for the 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 coordinates 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 demonstrated in Table 21. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 21. Constraints applied to the adjustments of the control points.

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 22. All fixed control points have no values for grid errors and elevation errors.

Table 22. Adjusted grid coordinates for the control points used in the Saub floodplain survey.

Point ID	Easting (Meter)	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 horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

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 results of the nine (9) occupied control points are within the required precision.

Table 23. Adjusted geodetic coordinates for control points used in the Saub River floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
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 reflected in Table 23. Based on the results of the computations, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Saub River GNSS Static Survey are indicated in Table 24.

Table 24. Reference and control points used in the Saub River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
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

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

The cross-section and bridge as-built surveys were conducted on April 9, 2016 at the downstream side of the Kalaong Bridge in Barangay Kalaong, Maitum, as presented in Figure 39. A Nikon® Total Station was utilized for this survey, as depicted in Figure 40.

Figure 39. The Kalaong Bridge facing upstream.

Figure 40. Bridge as-built survey of the Kalaong Bridge.

The length of the cross-sectional line surveyed in the Kalaong Bridge is about 134 meters with twenty-nine (29) cross-sectional points, using the control points UP_KAL-1 and UP_KAL-2 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 41 to Figure 43.

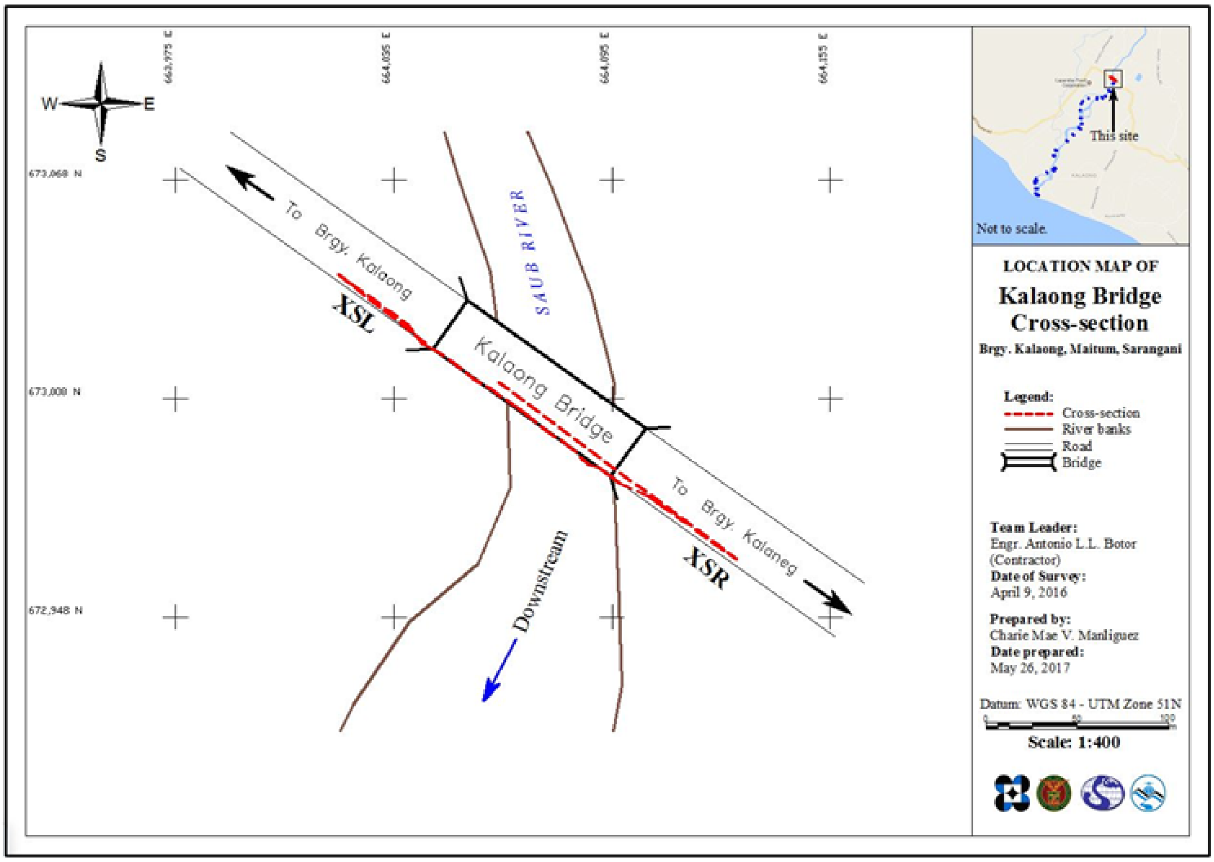


Figure 41. Location map of the Kalaong Bridge cross-section.

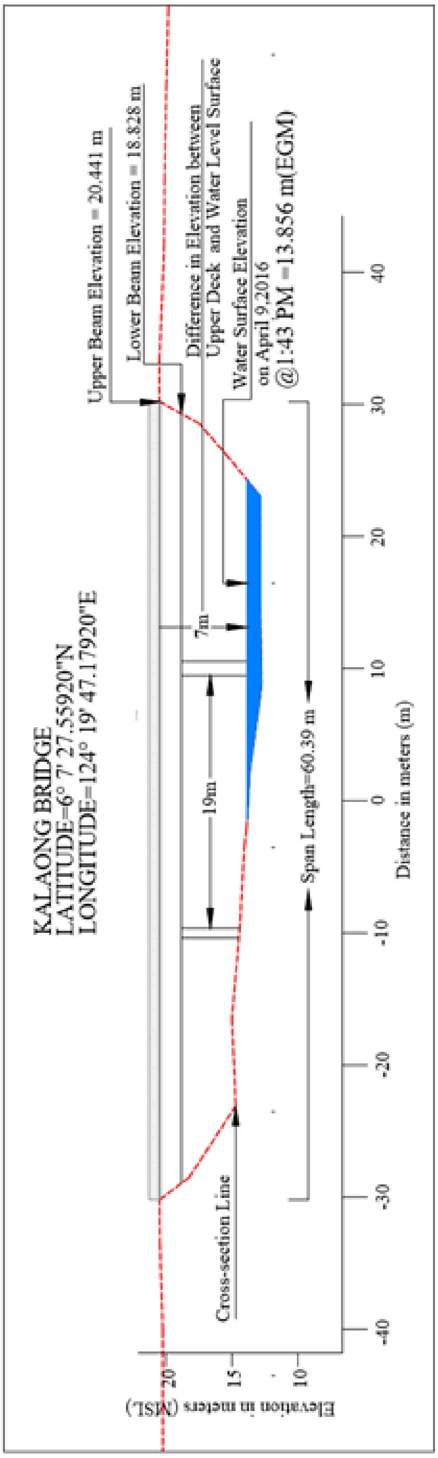


Figure 42. Kalaong Bridge cross-section diagram.

Bridge Data Form

Bridge Name: Kalaong Bridge

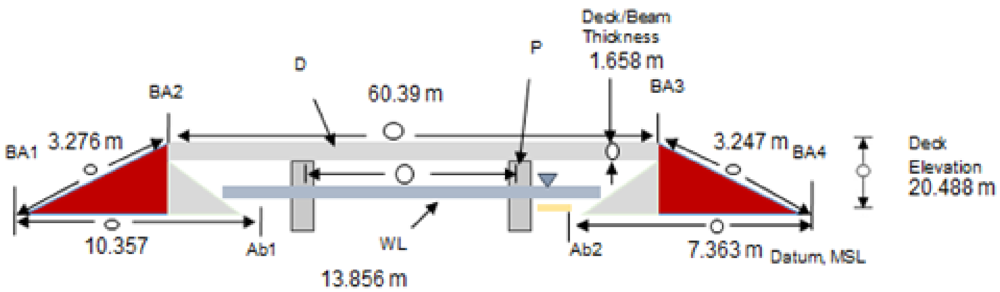
River Name: Saub River
Location (Brgy, City, Region): Brgy. Kalaong, Maitum, Sarangani

Survey Team: Alvin Solano, Ryan Nogas
Date and Time: April 9, 2016, 1:43 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	3.276 m	
2. BA2-BA3	60.39 m	
3. BA3-BA4	3.247 m	
4. BA1-Ab1	10.357 m	
5. Ab2-BA4	7.363 m	
6. Deck/beam thickness	1.658 m	
7. Deck elevation	20.488 m	

Note: Observer should be facing downstream

Figure 43. Kalaong Bridge Data Form.

The water surface elevation of the Saub River was determined by a Nikon® Total Station on April 9, 2016 at 13:43 hrs. at the Kalaong Bridge area, with a value of 13.856 meters in EGM08, as reflected in Figure 42. This was translated into markings on the bridge's pier, as demonstrated in Figure 44.

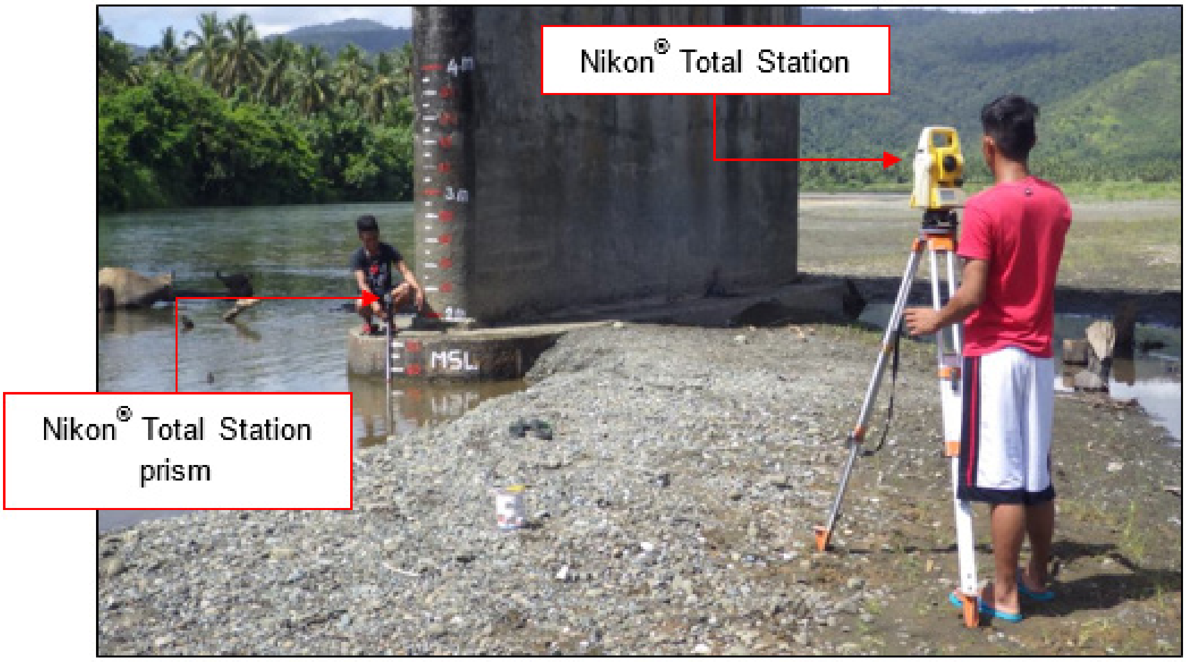


Figure 44. Water-level markings on Kalaong Bridge's pier.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by the DVBC on December 13, 2016, using a survey-grade GNSS Rover receiver, Trimble® SPS 985. The receiver was mounted on a range pole attached at the back of a vehicle as, depicted in Figure 45. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.398 meters, 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_KAL-1 occupied as the GNSS base station throughout the conduct of the survey.

Figure 45. Validation points acquisition survey set-up for the Saub River.

The survey began in Barangay Sison in the Municipality of Maitum, Sarangani, and headed northwest along the national highway, traversing seven (7) barangays in the Municipality of Maitum. The survey ended in Barangay Pinol in the Municipality of Maitum, Sarangani. The survey gathered a total of 3,459 points, with an approximate length of 27.2 km., using UP_KAL-1 as the GNSS base station for the entire extent of the validation points acquisition survey. This is represented by the map in Figure 46.

Figure 46. Extent of the LiDAR ground validation survey of the Saub River Basin area.

4.7 River Bathymetric Survey

A manual bathymetric survey was executed on April 9-10, 2016 using a Nikon® Total Station, as seen in Figure 47. The survey started in Barangay Kalaong, Maitum, Sarangani, with coordinates 6° 5' 1.07490"N, 124° 28' 24.18531"E; and ended at the mouth of the river in Barangay Kalaong, Maitum, Sarangani, with coordinates 6° 3' 38.55039"N, 124° 27' 23.58101"E. The control points UP_KAL-1 and UP_KAL-2 served as the GNSS base stations all throughout the survey.

Figure 47. Manual bathymetric survey by the ABSD at the Saub River using a Nikon® Total Station.

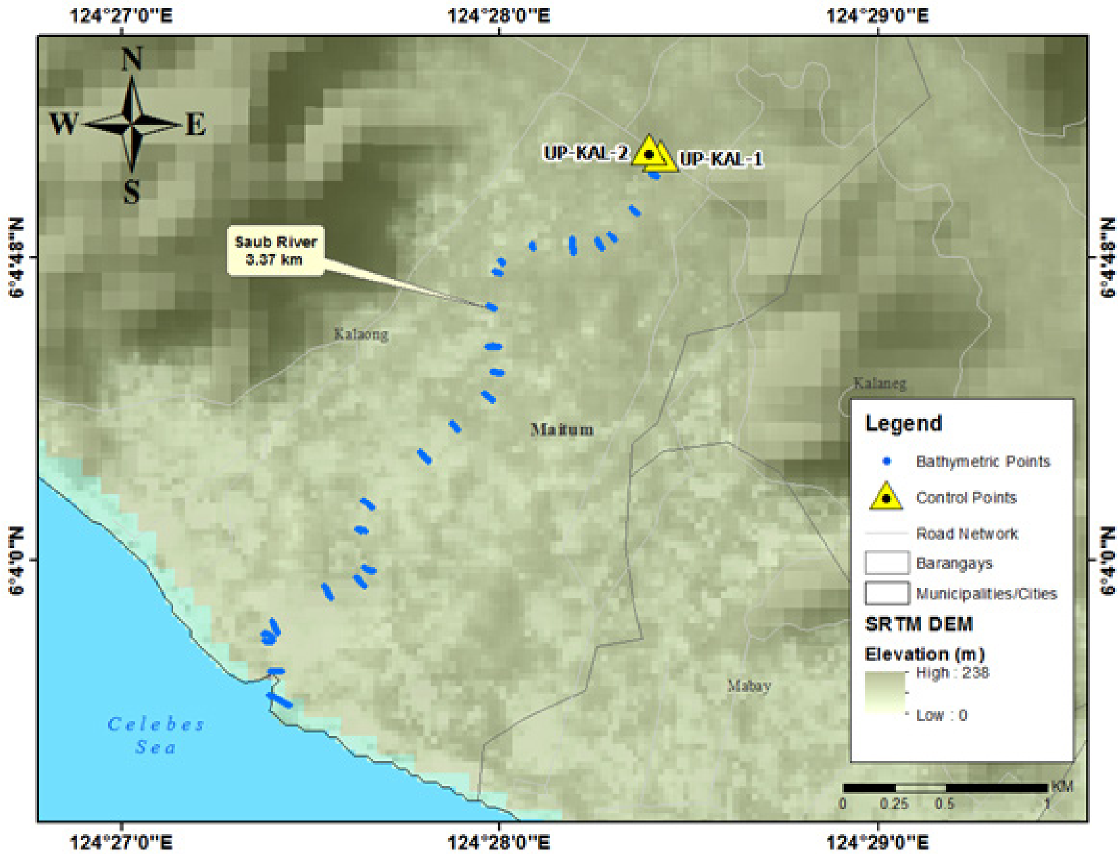


Figure 48. Extent of the bathymetric survey of the Saub River.

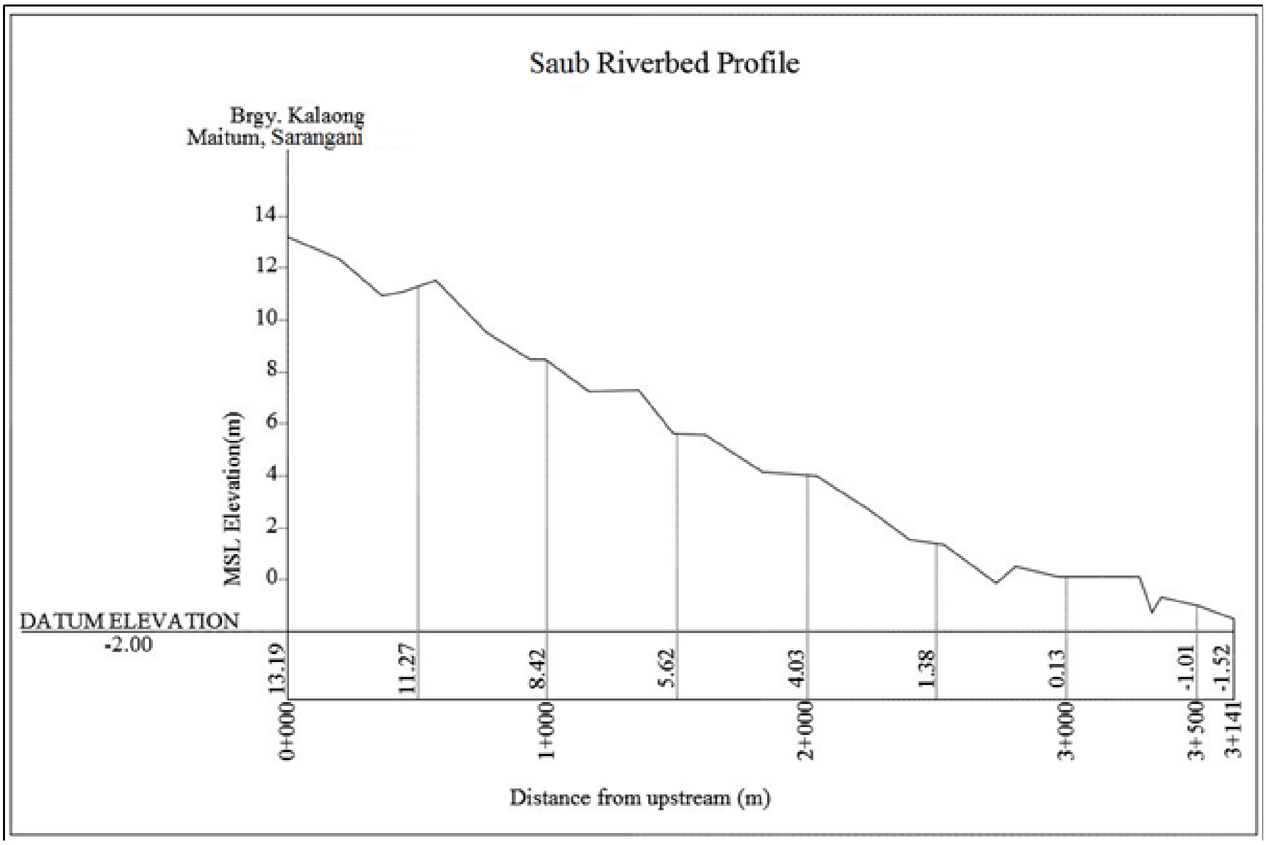


Figure 49. Saub riverbed profile

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, Narvin Clyd Tan, Hannah Aventurado

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which are all components and data that affect the hydrologic cycle of the Saub River Basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation is one of the hydrologic data required for basin model calibration. It is used to simulate the relationship of a rainfall event to the discharge and water level changes at the point of observation. The precipitation data was taken from the digital rain gauge installed by CMU at Barangay Zion in Maitum, Sarangani (see Figure 50). The localized rainfall event on July 12-13, 2016 served as input data. The total rainfall volume for the event was 68 mm, which peaked at 17.8 mm on July 12, 2016 at 1400 hrs. The lag time between the peak rainfall and discharge was two (2) hours and fifty (50) minutes.

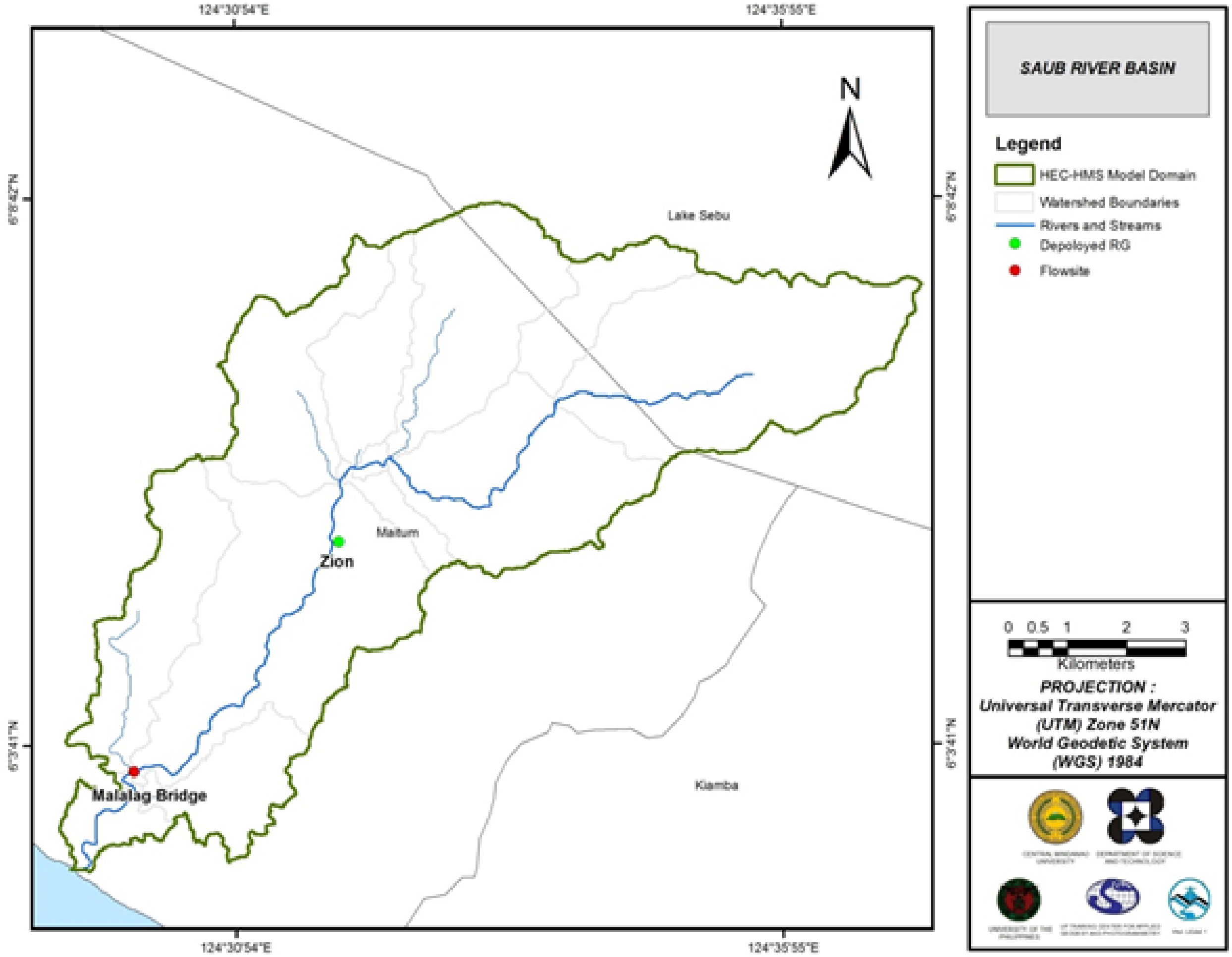


Figure 50. Location map of the Saub HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

The measurement of the water level and velocity at the flow site was conducted simultaneously with the rainfall event. Flow measurements were specifically conducted at the Malalag Bridge on the National Highway along Barangay Malalag, Maitum, Sarangani (6°3'26.13"N, 124°29'57.80"E). The flow data were necessary in the calculation of the river discharge. During the rainfall event, the peak discharge was at 17.97 m3/s on July 12, 2016 at 16:50 hrs. Figure 52 depicts the river discharge as affected by the rainfall. The localized rainfall event resulted in a 0.2-meter water level rise.

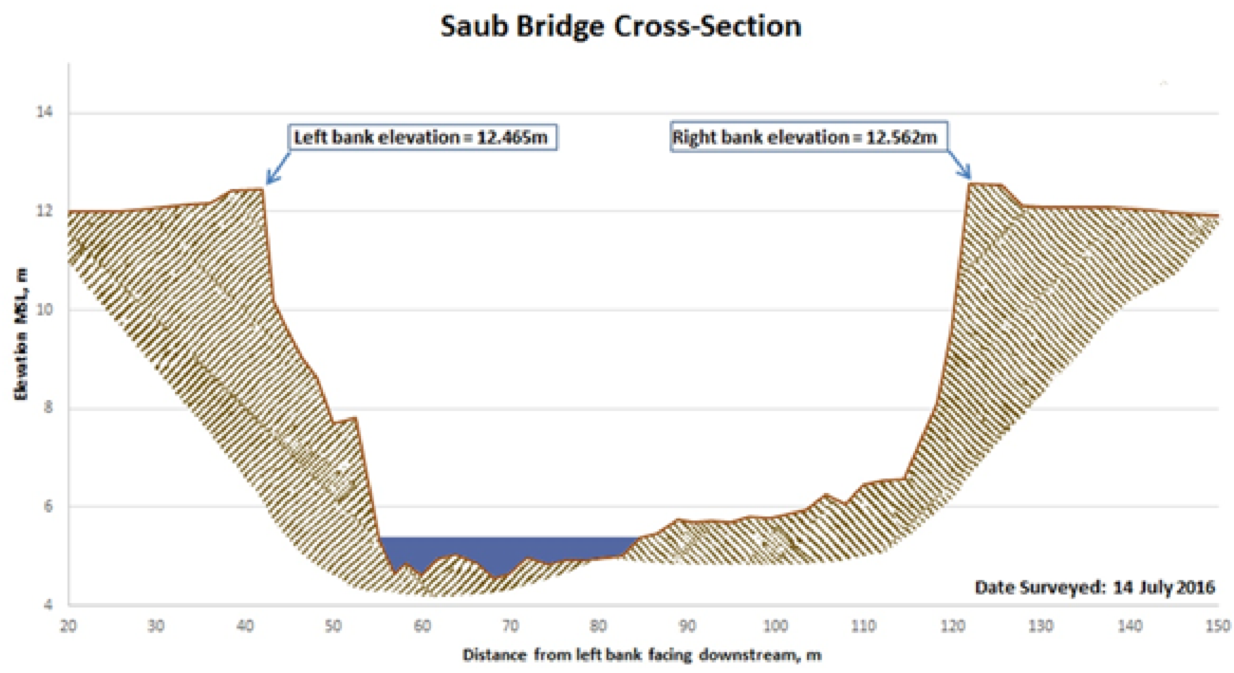


Figure 51. Cross-section plot of the Saub Bridge.

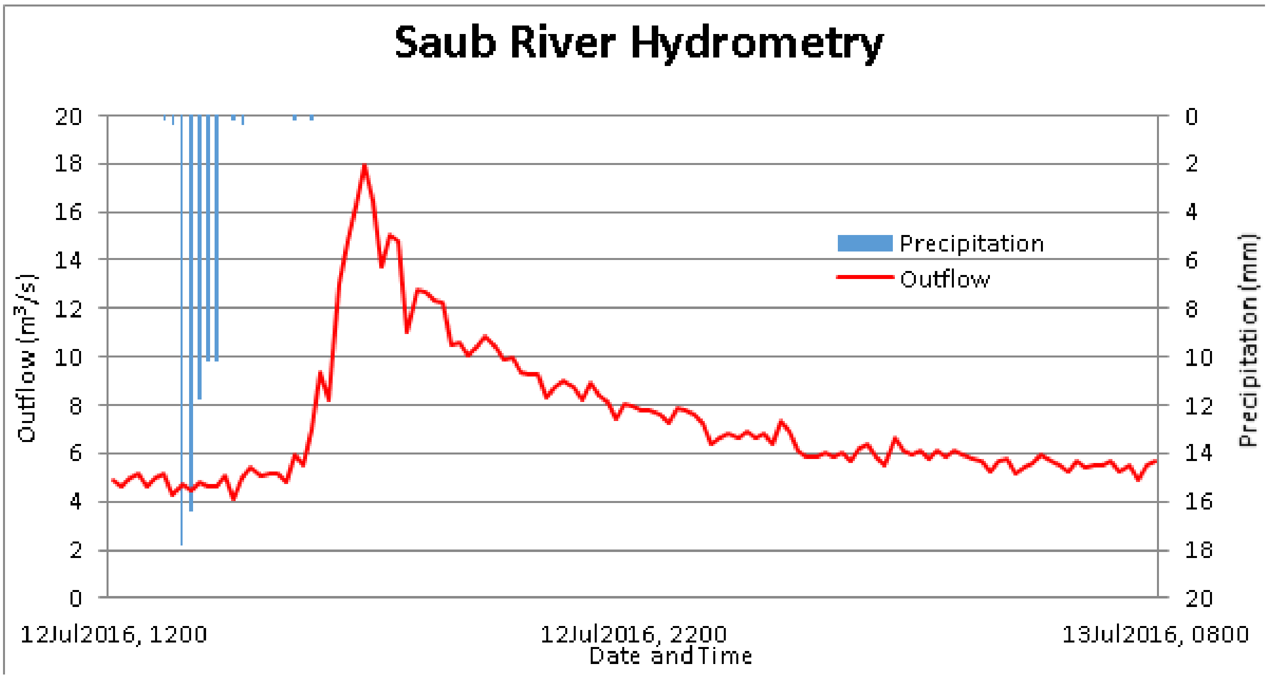


Figure 52. Rainfall and outflow data used for modeling.

The river outflow data were then used to generate the rating curve. The computed curve at the prevailing cross-section (Figure 51) establishes the relationship between the observed water levels and the river outflow of the watershed at the flow site location. It is expressed in the form of the following equation: Q=anh

where, Q : Discharge (m3/s);
h : Gauge height (reading from Riverside staff gauge); and
a and n : Constants.

The rating curve for the data collected at the Saub flow site is expressed as Q=2.0812e0.1136x, as illustrated in Figure 53. This equation is significant in calculating the discharge using water level data.

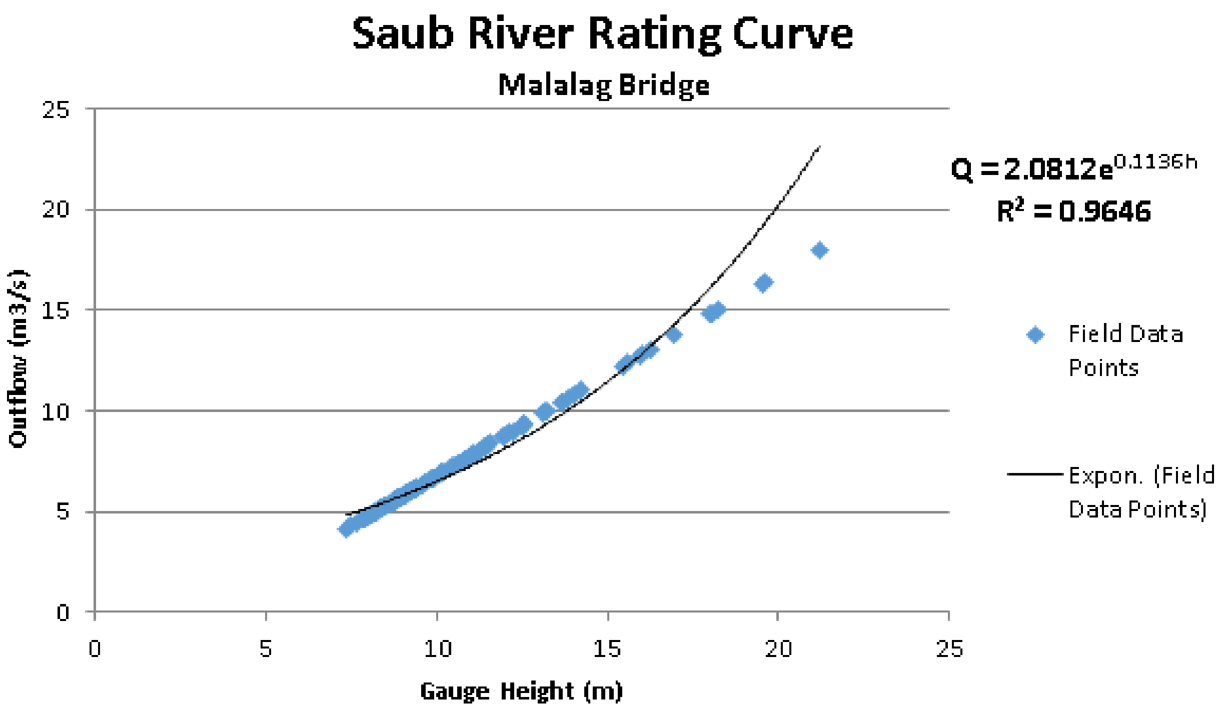


Figure 53. Rating curve of the HEC-HMS model.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the General Santos City Rain Gauge (Table 25). This station was selected based on its proximity to the Saub watershed (Figure 54). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that a certain peak value was attained at a certain time. The extreme values for this watershed were computed based on a 31-year record.

Table 25. RIDF values for the 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

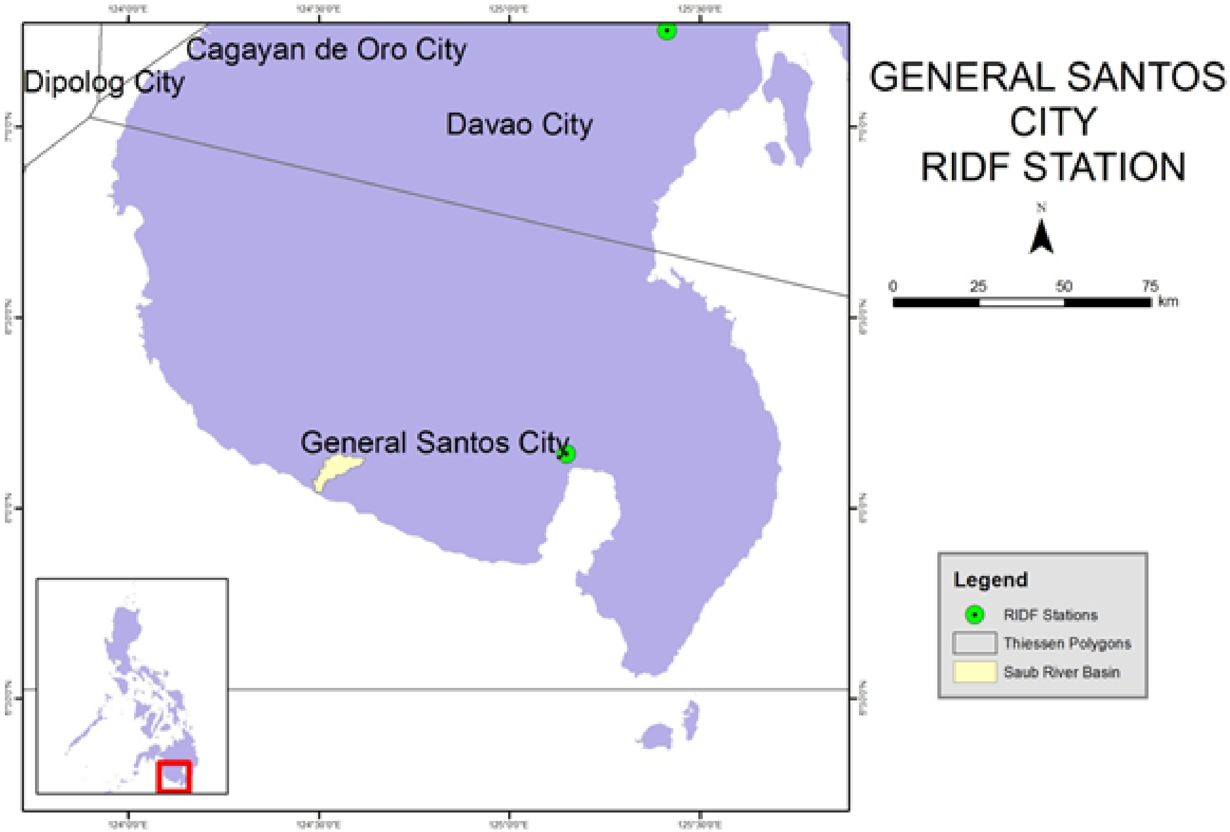


Figure 54. Location of the General Santos City RIDF Station relative to the Saub River Basin.

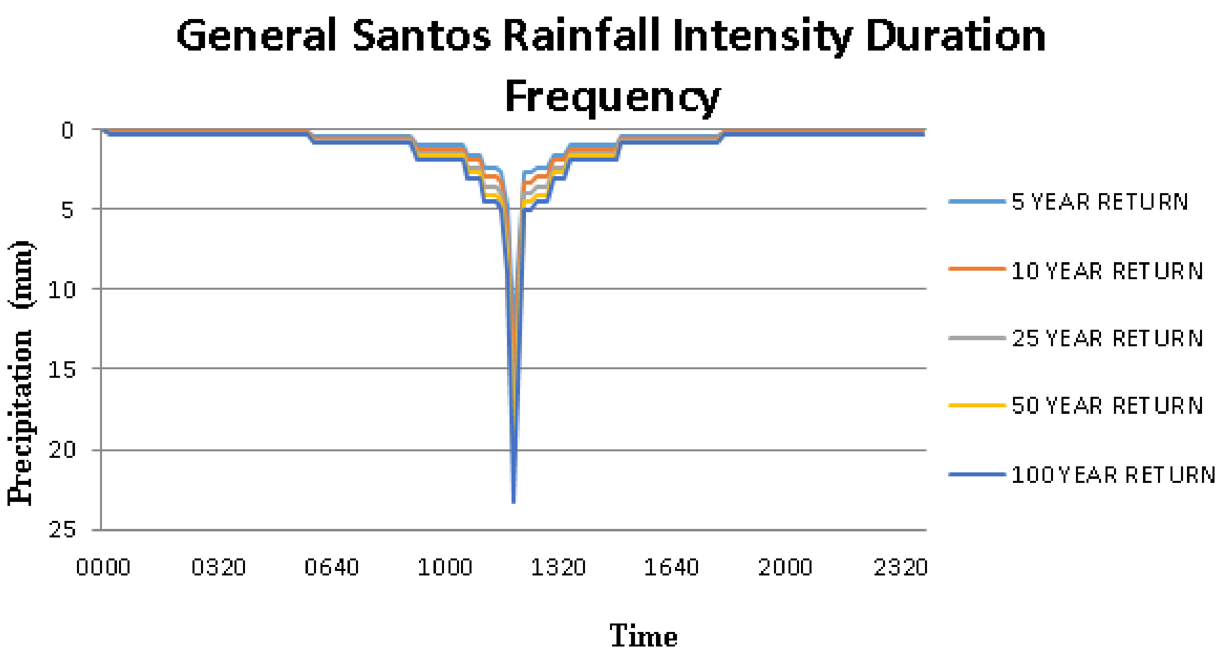


Figure 55. Synthetic storm generated from a 24-hr period rainfall, for various rainfall return periods.

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Saub River Basin are presented in Figures 56 and 57, respectively.

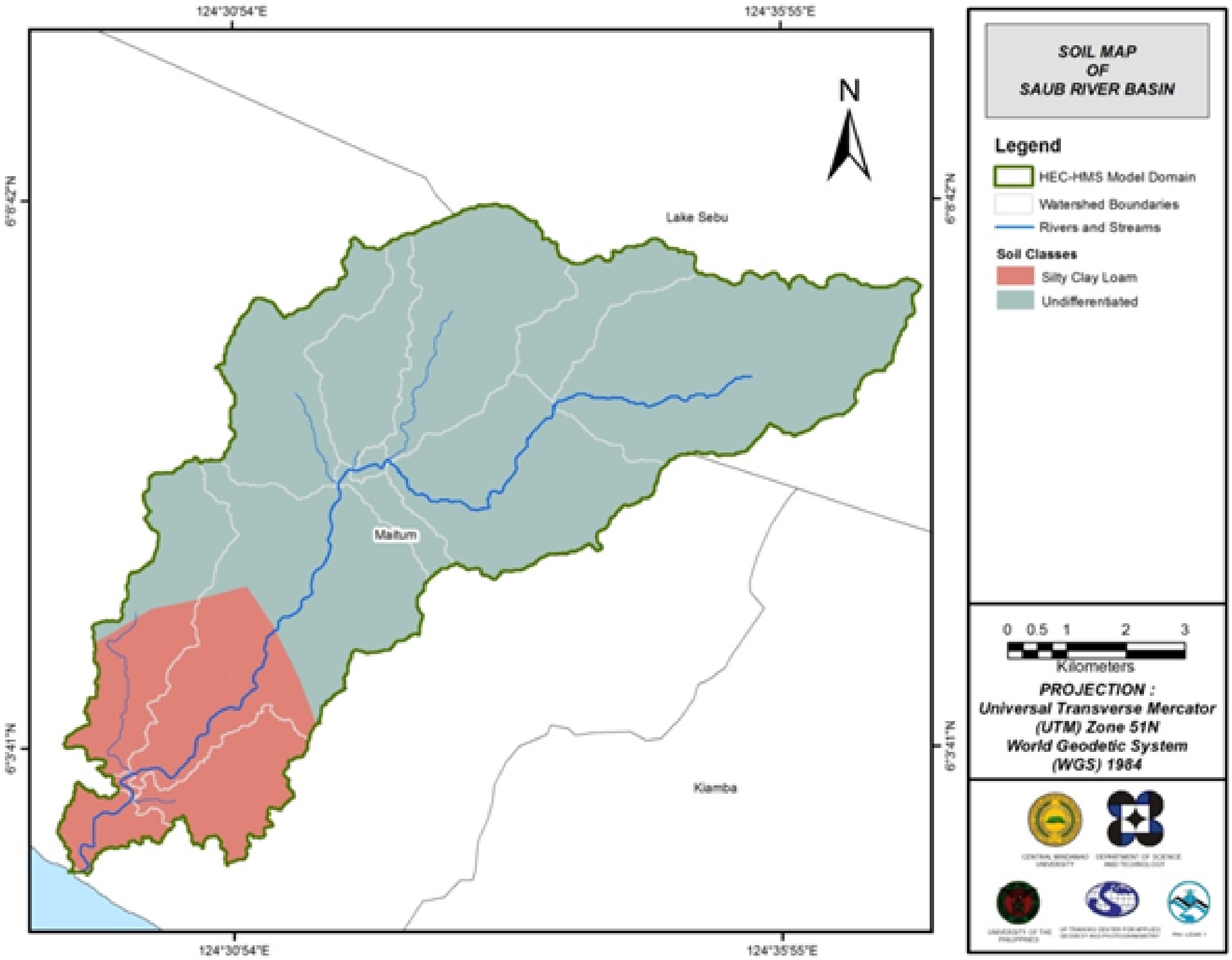


Figure 56. Soil map of the Saub River Basin (Source: DA).

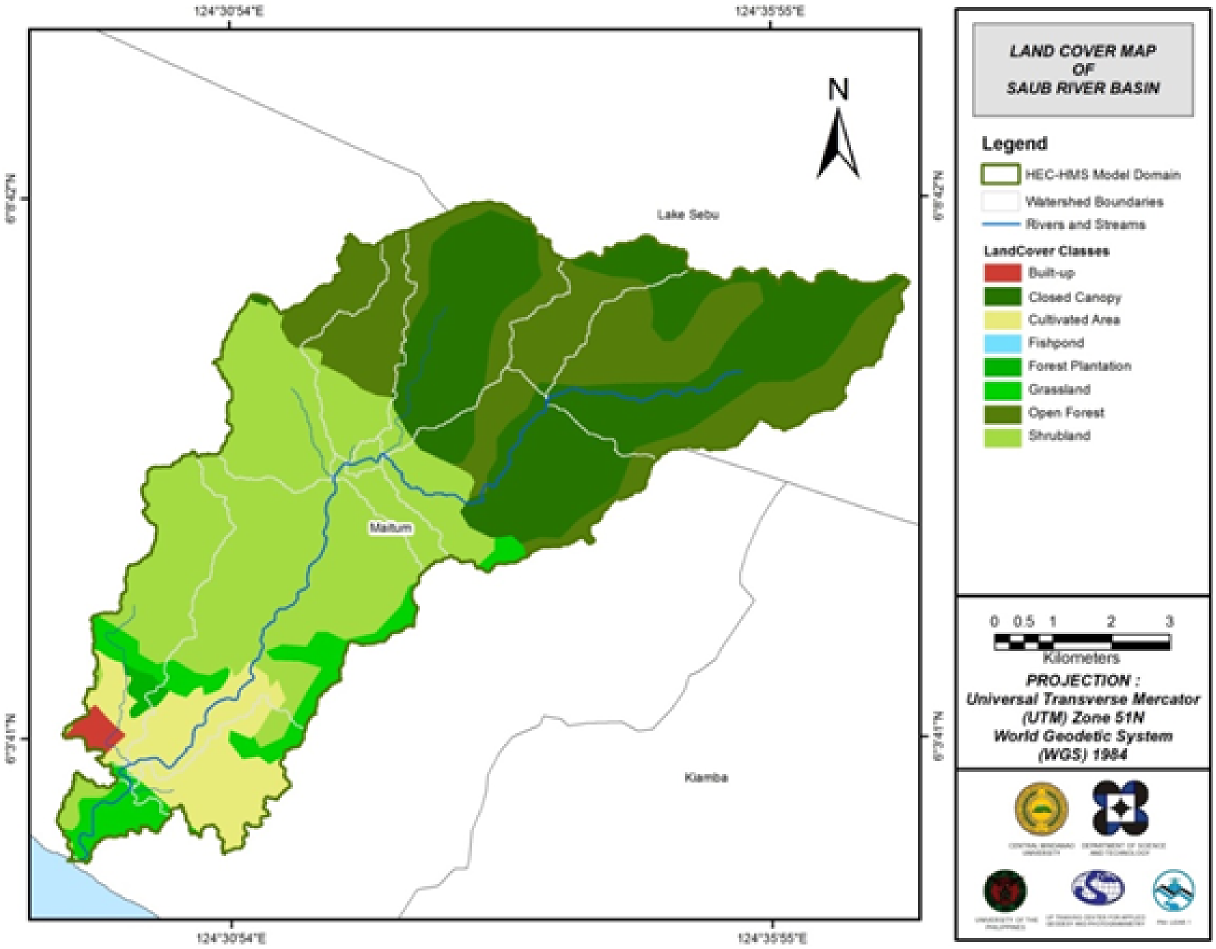


Figure 57. Land cover map of the Saub River Basin (Source: NAMRIA).

For Saub, two (2) soil classes were identified. These are silty clay loam and undifferentiated soil. Moreover, eight (8) land cover classes were identified. These are built-up land, closed canopies, cultivated areas, fishponds, forest plantations, grasslands, open forests, and shrub lands.

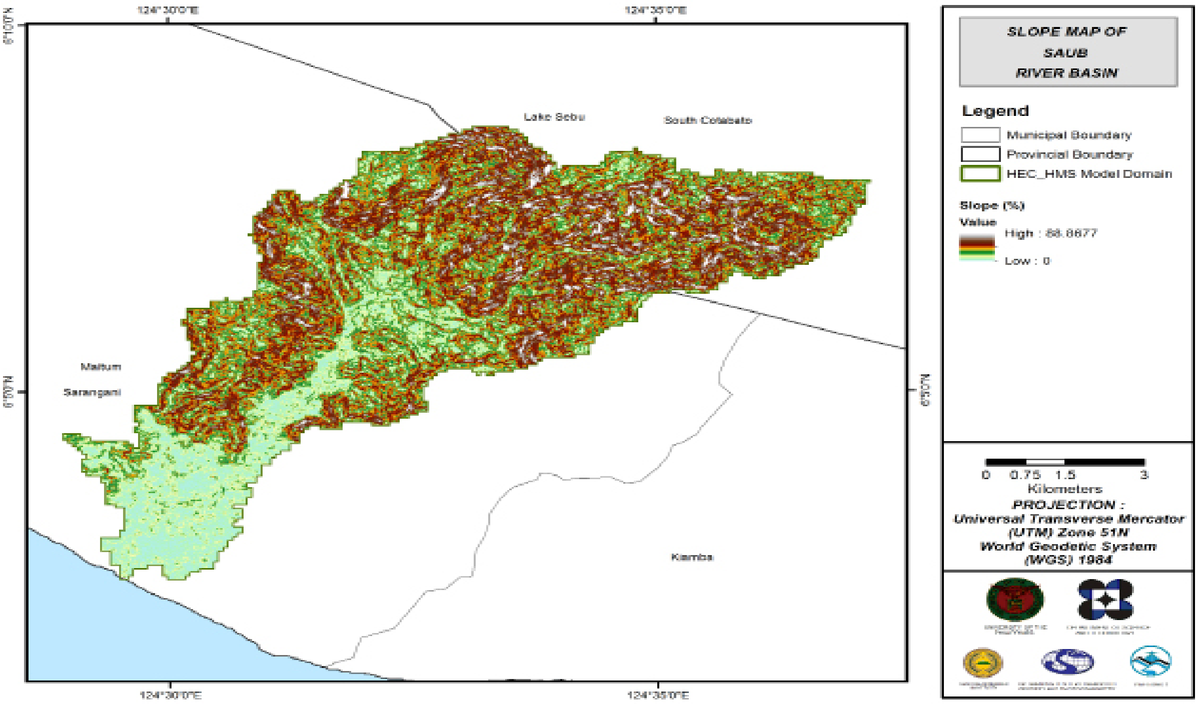


Figure 58. Slope map of the Saub River Basin.

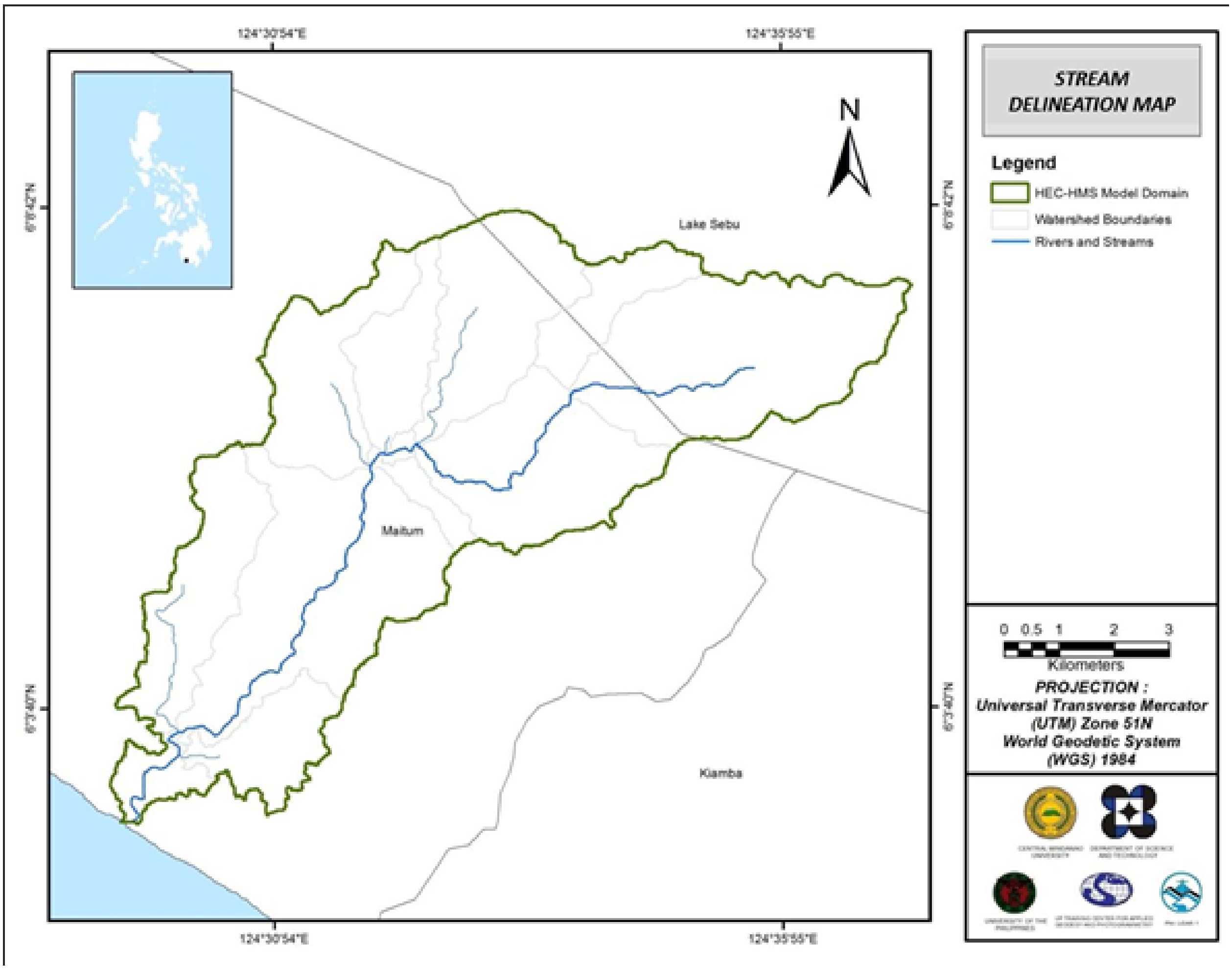


Figure 59. Stream delineation map of Saub River Basin.

Using ArcMap 10.1 with the HEC-GeoHMS version 10.1 extension, the drainage system of the Saub River was delineated using the river's centerline and the SAR-DEM with a 10-meter resolution as the primary input data. The delineated drainage system includes the basin boundaries, sub-basins, and stream networks. The river's centerline was digitized starting from the upstream towards the downstream on Google Earth (version 2014).

Using the 10-meter SAR-DEM with a default threshold area of 500 hectares, the delineated drainage system of the Saub River Basin generated seventy-three (73) sub-basins, thirty-seven (37) reaches, and thirty-eight (38) junctions, including the main outlet (Figure 60). See Annex 10 for the Saub Model Reach Parameters.

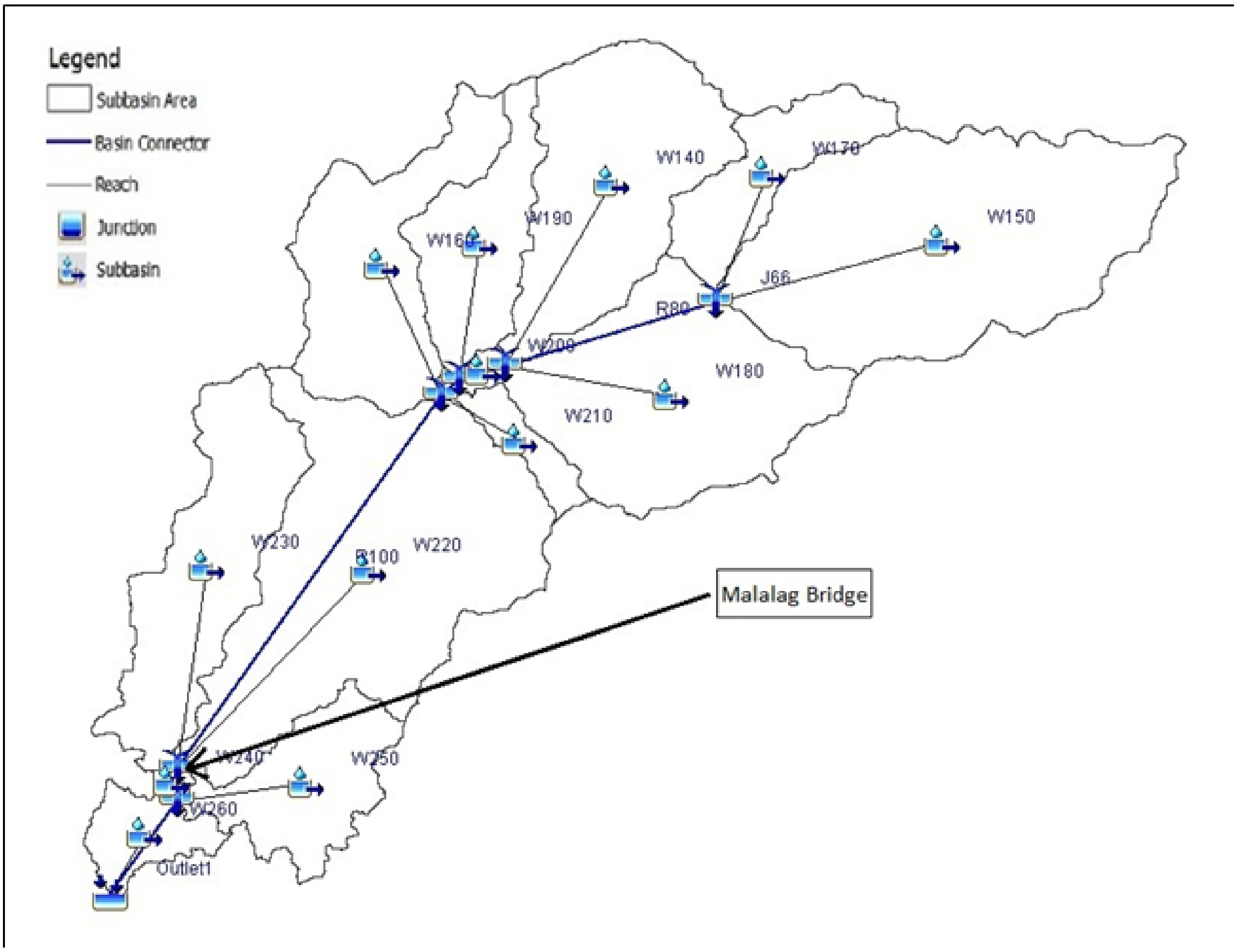


Figure 60. The Saub River Basin Model generated through HEC-HMS.

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model were derived from the LiDAR DEM data. These were defined using the Arc GeoRAS tool and post-processed in ArcGIS (Figure 61).

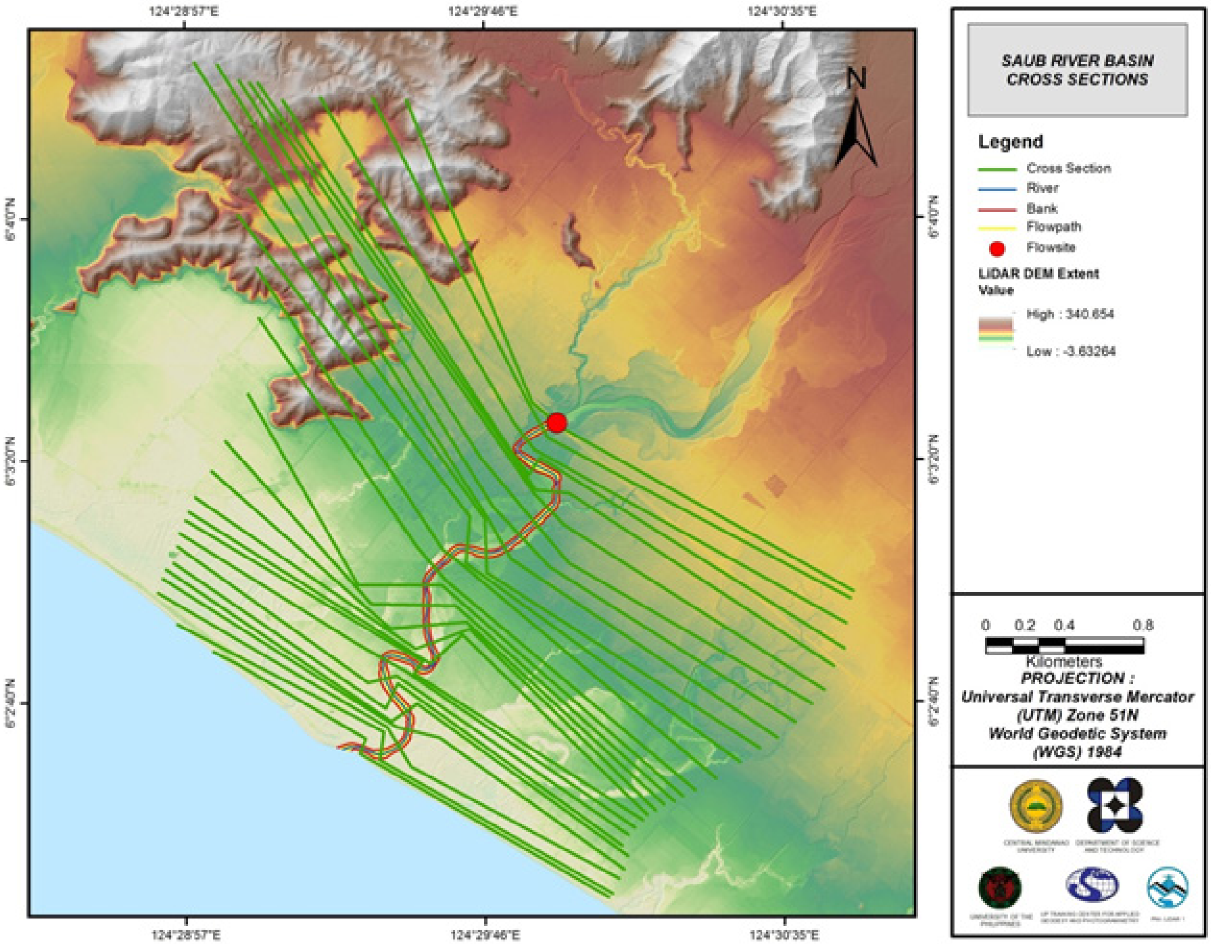


Figure 61. Saub River cross-section generated using the HEC GeoRAS tool.

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. And then each element was attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

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

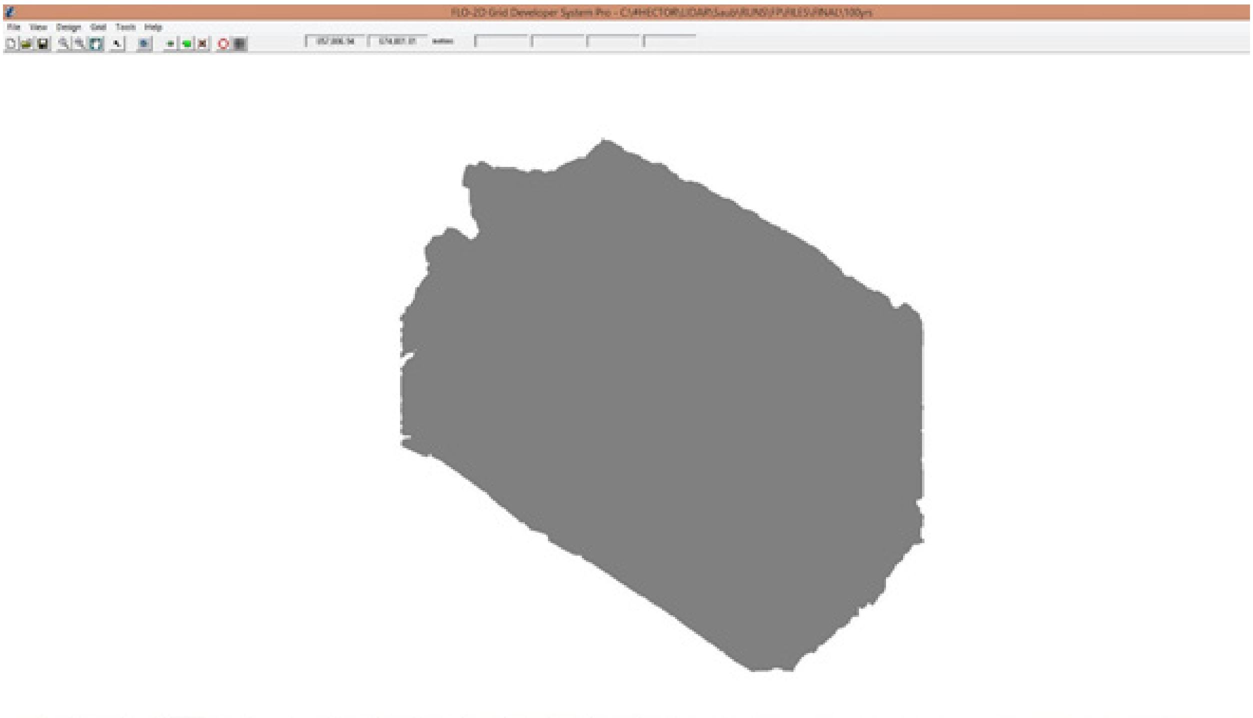


Figure 62. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 27.07799 hours. After the simulation, the FLO-2D Mapper Pro was 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 depths and velocity values for Low, Medium, and High created following food hazard maps. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 meters, while the minimum vh (product of maximum velocity (v) and maximum depth (h)) was set at 0 m2/s.

The creation of flood hazard maps from the model also automatically created flow depth maps, depicting the maximum amount of inundation for every grid element. The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 41,211,700.00 m2.

There was a total of 30,329,915.58 m3 of water that entered the model. Of this amount, 14,264,441.76 m3 was due to rainfall, while 16,065,473.83 m3 was inflow from other areas outside the model. 4,647,596.50 m3 of this water was lost to infiltration and interception, while 2,437,983.07 m3 was stored by the floodplain. The rest, amounting to up to 23,244,334.78 m3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Saub HEC-HMS River Basin model, its accuracy was measured against the observed values. Figure 63 illustrates the comparison between the two (2) discharge data. The Saub Model Basin Parameters are found in Annex 9.

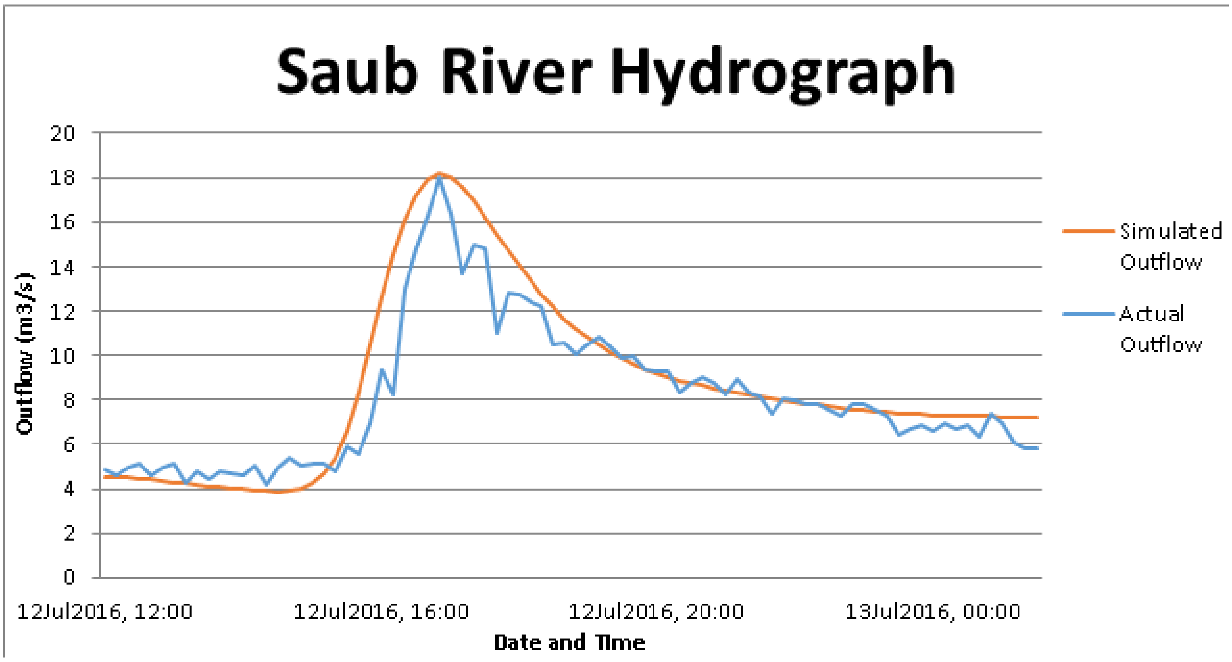


Figure 63. Outflow hydrograph of the Saub produced by the HEC-HMS model, compared with observed outflow.

Table 26 enumerates the adjusted ranges of values of the parameters used in calibrating the model.

Table 26. Range of calibrated values for the Saub River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	32.03 – 34.66
			Curve Number	38.56 – 51.62
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1.05 – 3.21
			Storage Coefficient (hr)	0.41 – 3.93
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values from 32.03mm to 34.66mm for the initial abstraction signifies that there is an average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 38.56 to 51.62 for the curve number is lower than the advisable range for Philippine watersheds (i.e., 70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Saub, the basin mostly consists of shrub lands, and the soil consists of undifferentiated soil.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.41 hours to 3.93 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; while ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 1 indicates that the basin is unlikely to quickly return to its original discharge, and will be higher instead. A ratio to peak of 0.5 indicates a less steep receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.0001 is the lowest possible value for the said parameter.

Table 27. Summary the Efficiency Test of the Saub HMS Model.

Accuracy measure	Value
RMSE	1.33
r2	0.79
NSE	0.78
PBIAS	12.44
RSR	0.46

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.33 (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 was measured at 0.79.

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 0.78.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is 12.44.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model has an RSR value of 0.46.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 64) shows the Saub River outflow using the General Santos RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

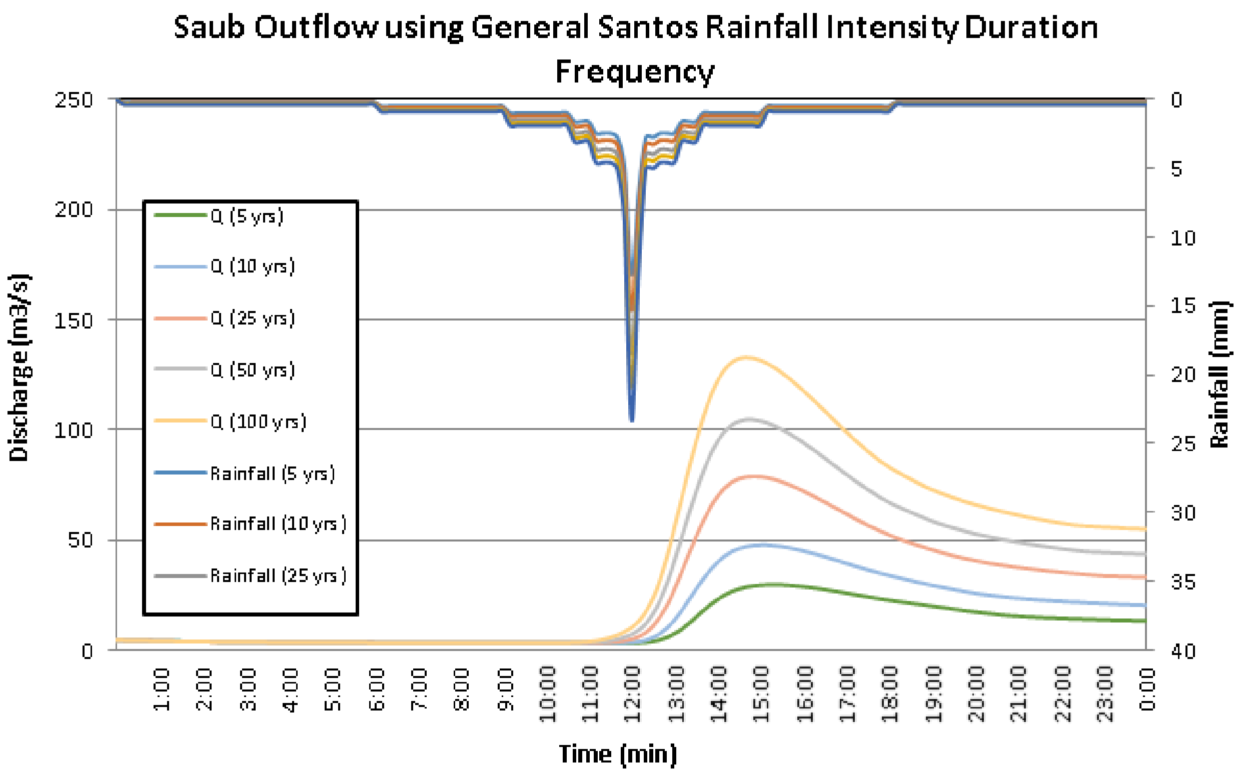


Figure 64. Outflow hydrograph at the Saub Station, generated using the General Santos RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Saub discharge using the General Santos RIDF curves in five (5) different return periods is provided in Table 28.

Table 28. Peak values of the Saub HEC-HMS Model outflow, using the General Santos RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	102.7	12.7	29.74	3 hours, 20 minutes
10-Year	125.1	15.3	47.74	3 hours
25-Year	153.4	18.5	78.99	2 hours, 50 minutes
50-Year	174.3	20.9	104.66	2 hours, 50 minutes
100-Year	195.2	23.3	132.88	2 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

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

Figure 65. Sample output map of the Saub RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10-meter resolution. Figure 66 to Figure 71 shows the 5-, 25-, and 100-year rain return scenarios of the Saub floodplain. The floodplain, with an area of 41.03 sq. km., covers two (2) municipalities, namely Kiamba and Maitum. Table 29 indicates the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in the Saub floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Kiamba	428.85	0.64	0.15%	23.71 %
Maitum	286.35	40.39	14.11%	5.65%

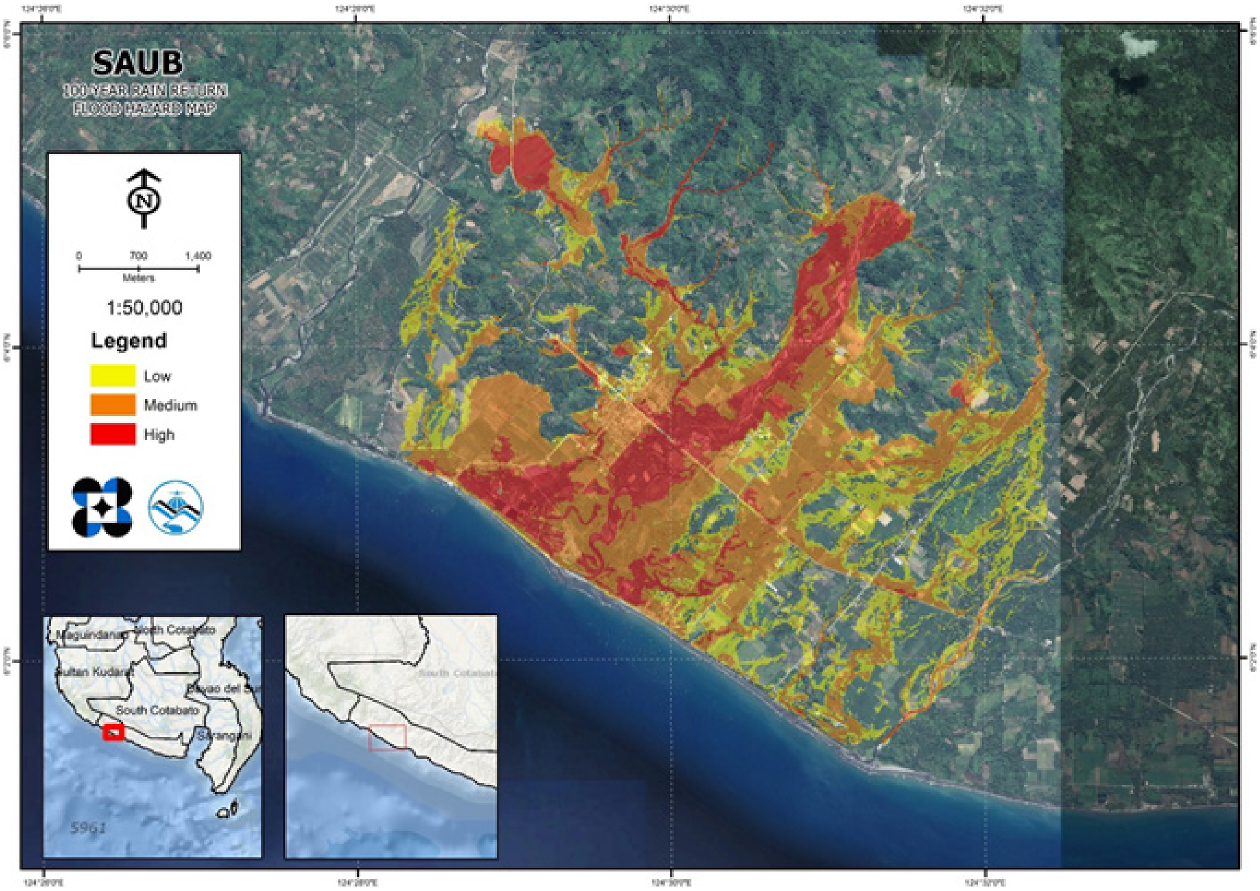


Figure 66. 100-year flood hazard map for the Saub floodplain.

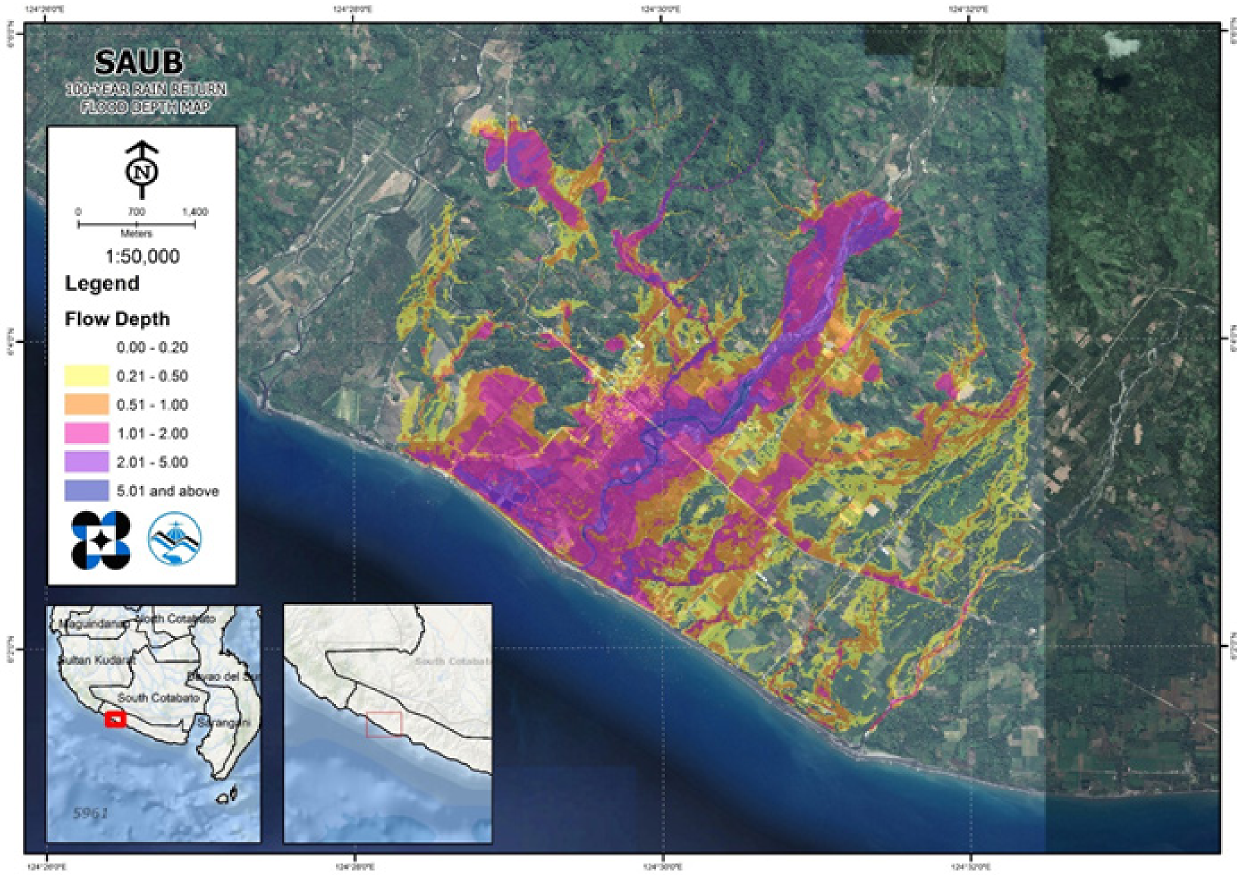


Figure 67. 100-year flow depth map for the Saub floodplain.

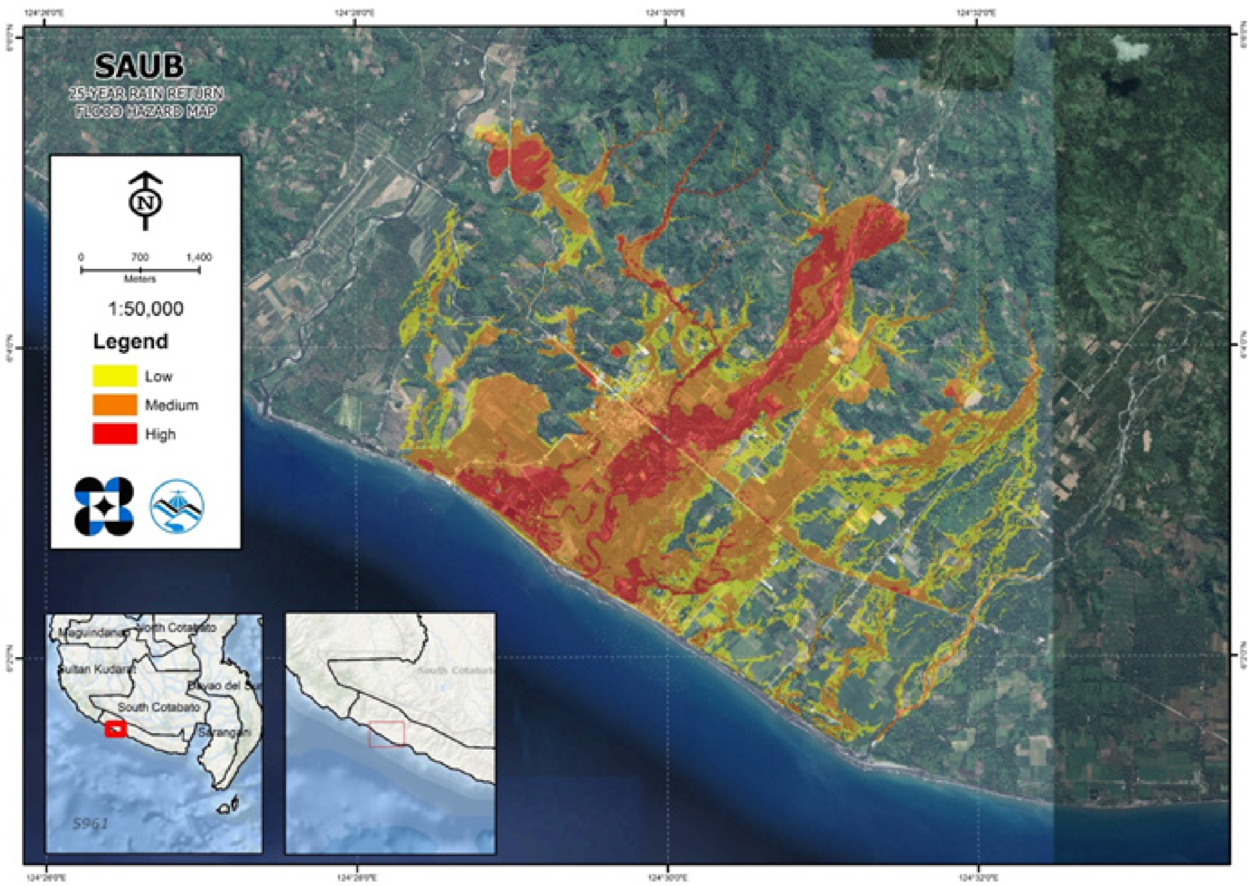


Figure 68. 25-year flood hazard map for the Saub floodplain.

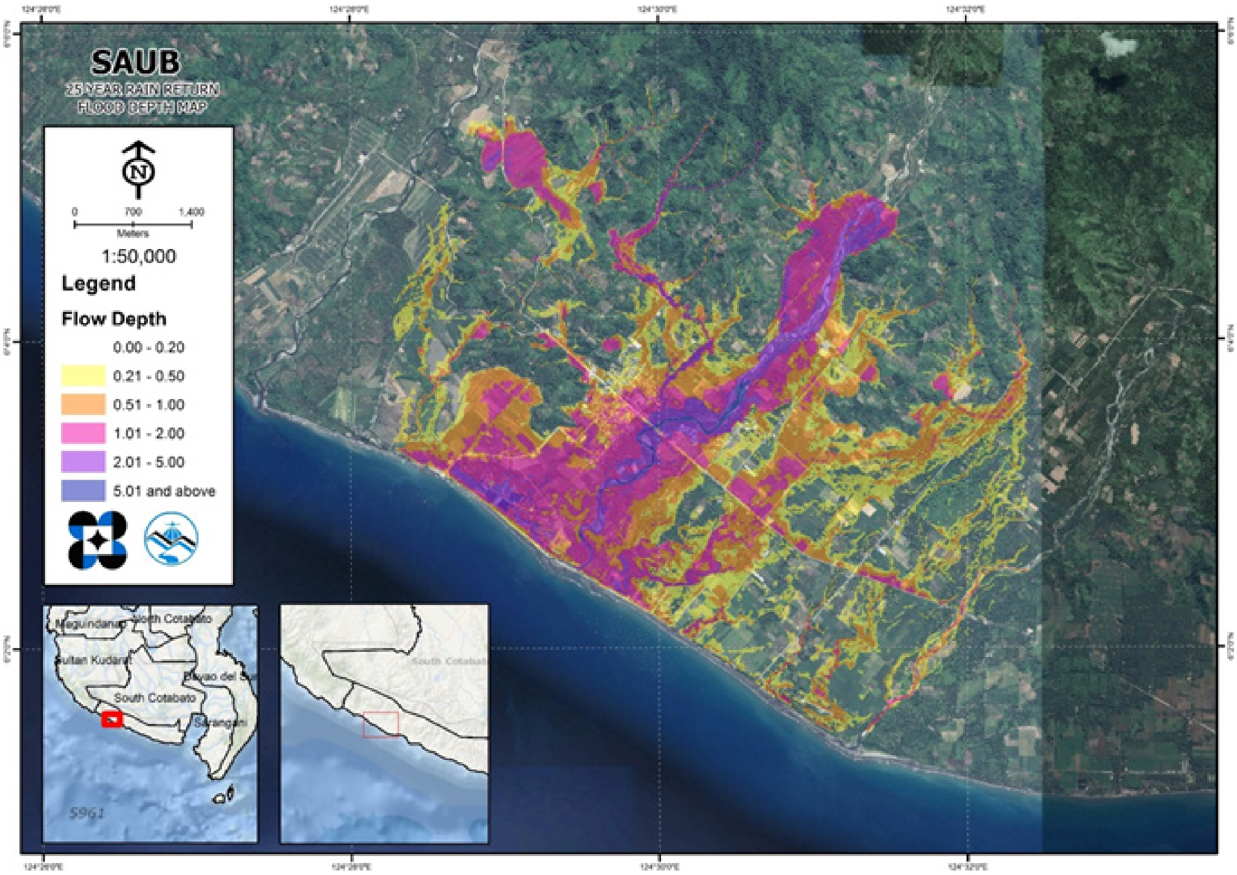


Figure 69. 25-year flow depth map for the Saub floodplain.

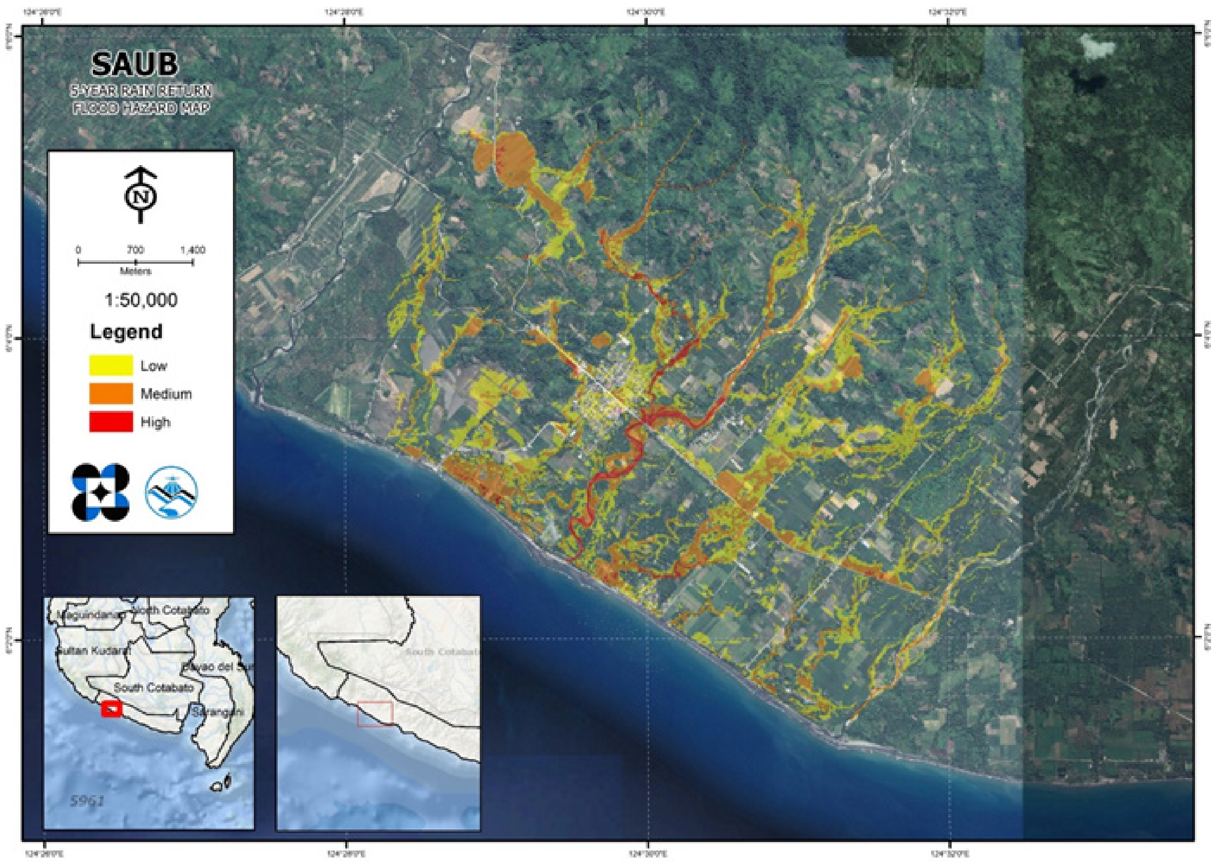


Figure 70. 5-year flood hazard map for the Saub floodplain.

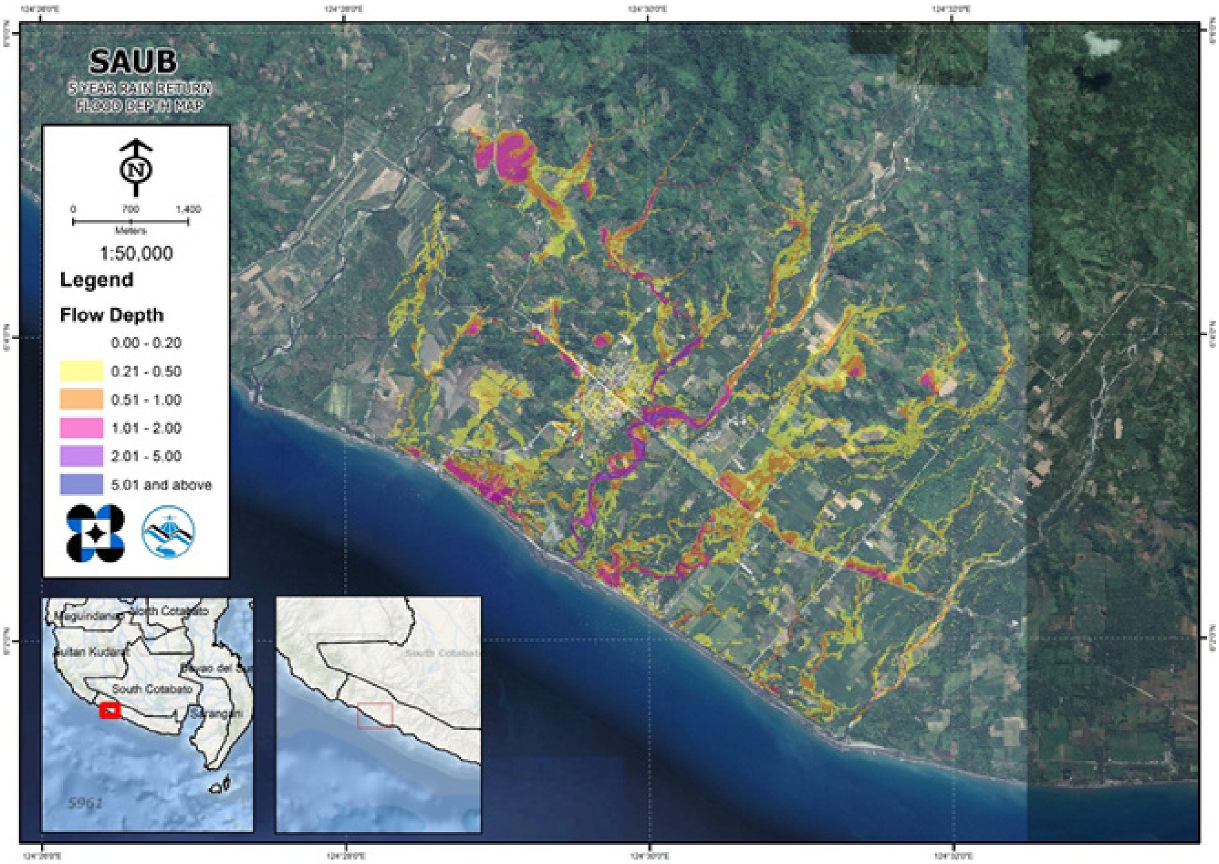


Figure 71. 5-year flood depth map for the Saub floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Saub River Basin are listed below. For the said basin, only the Municipality of Maitum, consisting of ten (10) barangays, is expected to experience flooding when subjected to the 5-year, 25-year, and 100-year rainfall return periods.
For the 5-year return period, 10.53% of the municipality of Maitum, with an area of 298.128522 sq. km., will experience flood levels of less than 0.20 meters. 1.99% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile 0.83%, 0.36%, and 0.06% 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 30 are the affected areas, in square kilometers, by flood depth per barangay.

Table 30. Affected Areas in Maitum, Sarangani during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maitum (in sq. km)					
	Kalaneg	Kalaong	Kiambing	Kiayap	Mabay	Malalag
0.03-0.20	7.09	0.68	1.87	6.29	3.19	1.66
0.21-0.50	0.7	0.1	0.38	1.06	1.14	0.44
0.51-1.00	0.46	0.055	0.16	0.42	0.45	0.15
1.01-2.00	0.27	0.1	0.019	0.15	0.26	0.12
2.01-5.00	0.0066	0	0	0.061	0.032	0.075
> 5.00	0	0	0	0	0.0008	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maitum (in sq. km)					
	Old Poblacion	Pangi	Sison	Upo		
0.03-0.20	2.72	3.53	4.35	0.00084		
0.21-0.50	0.62	0.48	1	0		
0.51-1.00	0.34	0.14	0.31	0		
1.01-2.00	0.095	0.03	0.034	0		
2.01-5.00	0.003	0.0003	0.0001	0		
> 5.00	0	0	0	0		

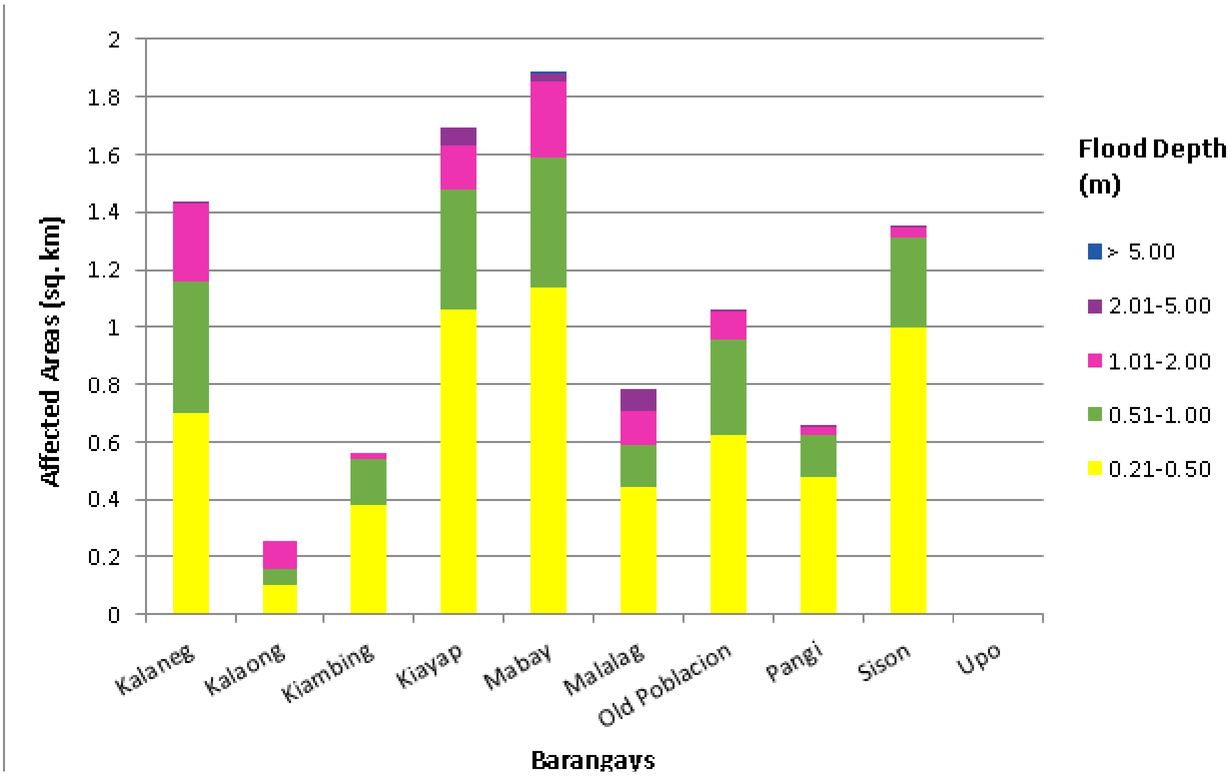


Figure 72. Affected Areas in Maitum, Sarangani during a 5-Year Rainfall Return Period.

For the 25-year return period, 7.30% of the municipality of Maitum, with an area of 298.128522 sq. km., will experience flood levels of less than 0.20 meters. 2.02% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.04%, 1.82%, 0.54%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 31 are the affected areas, in square kilometers, by flood depth per barangay.

Table 31. Affected Areas in Maitum, Sarangani during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maitum (in sq. km)					
	Kalaneg	Kalaong	Kiambing	Kiayap	Mabay	Malalag
0.03-0.20	6.7	0.57	1.58	3.54	1.2	0.26
0.21-0.50	0.65	0.14	0.5	1	0.58	0.19
0.51-1.00	0.56	0.07	0.28	1.19	1.25	0.58
1.01-2.00	0.55	0.13	0.057	1.3	1.69	1.07
2.01-5.00	0.057	0.035	0.0007	0.87	0.33	0.3
> 5.00	0.0005	0	0	0.064	0.0038	0.031

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maitum (in sq. km)					
	Old Poblacion	Pangi	Sison	Upo		
0.03-0.20	1.78	2.79	3.34	0.00084		
0.21-0.50	0.92	0.9	1.14	0		
0.51-1.00	0.72	0.41	1.01	0		
1.01-2.00	0.33	0.086	0.21	0		
2.01-5.00	0.021	0.0008	0.0007	0		
> 5.00	0	0	0	0		

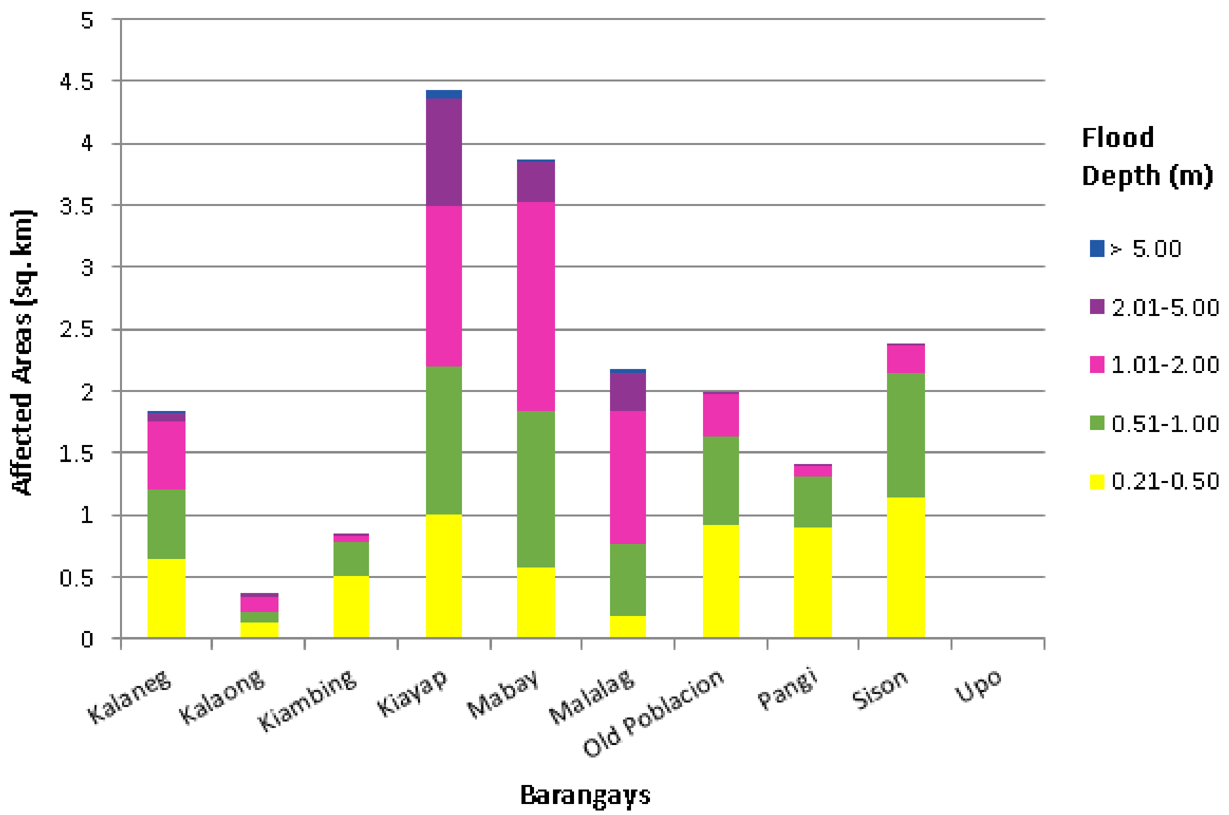


Figure 73. Affected Areas in Maitum, Sarangani during a 25-Year Rainfall Return Period.

For the 100-year return period, 6.72% of the municipality of Maitum, with an area of 298.128522 sq. km., will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.12%, 2.13%, 0.70%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 are the affected areas, in square kilometers, by flood depth per barangay.

Table 32. Affected Areas in Maitum, Sarangani during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maitum (in sq. km)					
	Kalaneg	Kalaong	Kiambing	Kiayap	Mabay	Malalag
0.03-0.20	6.53	0.53	1.39	3.29	1.01	0.18
0.21-0.50	0.65	0.15	0.59	0.89	0.57	0.17
0.51-1.00	0.57	0.079	0.36	1.33	0.93	0.52
1.01-2.00	0.64	0.1	0.089	1.39	2.06	1.19
2.01-5.00	0.13	0.08	0.0018	0.99	0.49	0.35

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maitum (in sq. km)					
	Old Poblacion	Pangi	Sison	Upo		
0.03-0.20	1.47	2.52	3.11	0.00084		
0.21-0.50	0.93	1.06	1.1	0		
0.51-1.00	0.9	0.47	1.16	0		
1.01-2.00	0.44	0.13	0.32	0		
2.01-5.00	0.029	0.0019	0.0026	0		

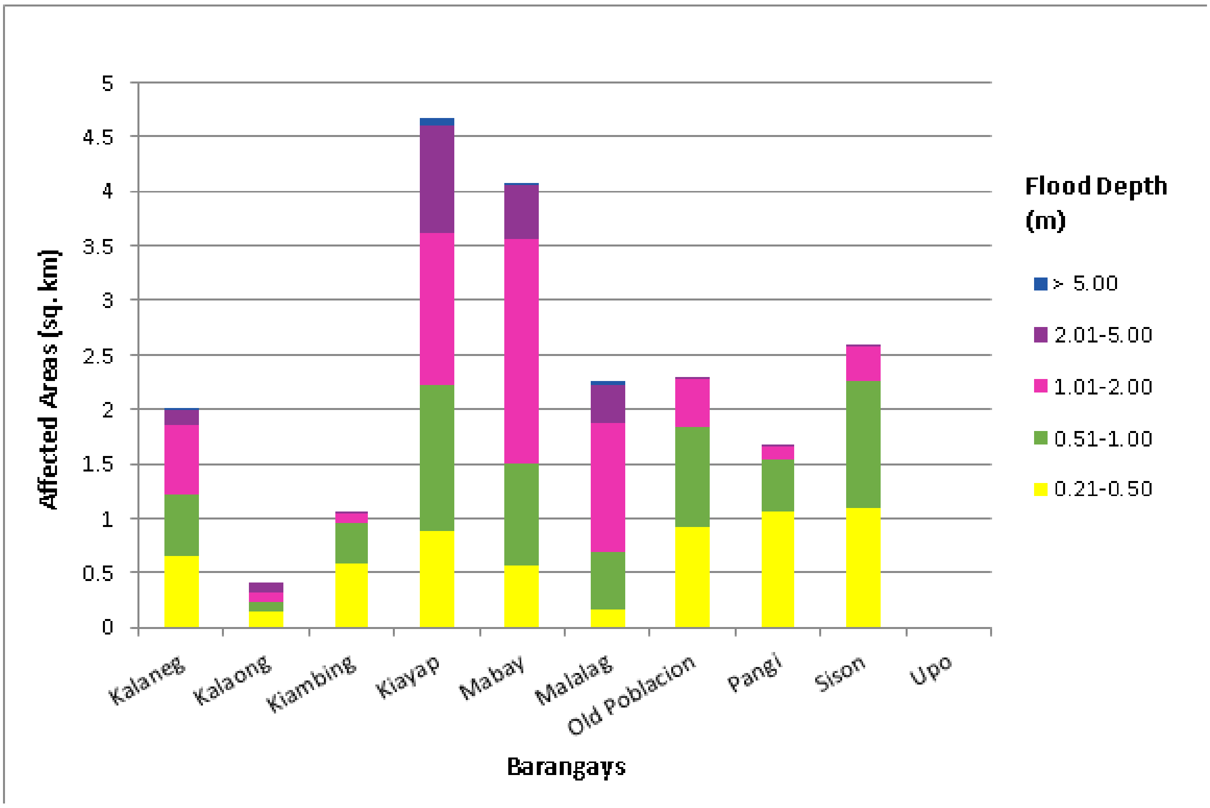


Figure 74. Affected Areas in Maitum, Sarangani during a 100-Year Rainfall Return Period.

Among the barangays in the Municipality of Maitum in the province of Sarangani, Kalaneg is projected to have the highest percentage of area that will experience flood levels, at 2.64%. Meanwhile, Kiayap posted the second highest percentage of area that may be affected by flood depths, at 2.37%.

The generated flood hazard maps for the Saub floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the hazard maps – Low, Medium, and High – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year).

Table 33. 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	6.12	6.13	6.22
Medium	3.45	9.68	10.47
High	0.41	3.73	4.58

Of the nineteen (19) identified educational institutions in the Saub floodplain, six (6) were assessed to be exposed to Low-level flooding during a 5-year scenario, while one (1) school was found to be exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, five (5) schools were found to be exposed to Low-level flooding, while eleven (11) were discovered to be exposed to Medium-level flooding. In the same scenario, one (1) school was assessed to be exposed to High-level flooding.

For the 100-year scenario, three (3) schools were discovered to be exposed to Low-level flooding, eleven (11) to Medium-level flooding, and three (3) to High-level flooding. See Annex 12 for a detailed enumeration of the educational institutions exposed to flooding in the Saub floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in the different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in the river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in the particular area.

After the above, the actual data from the field were compared against the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 76.

The flood validation consists of three hundred and four (304) points, randomly selected all over the Saub floodplain. It has an RMSE value of 0.47. Table 34 shows a contingency matrix of the comparison. The validation points are available in Annex 11.

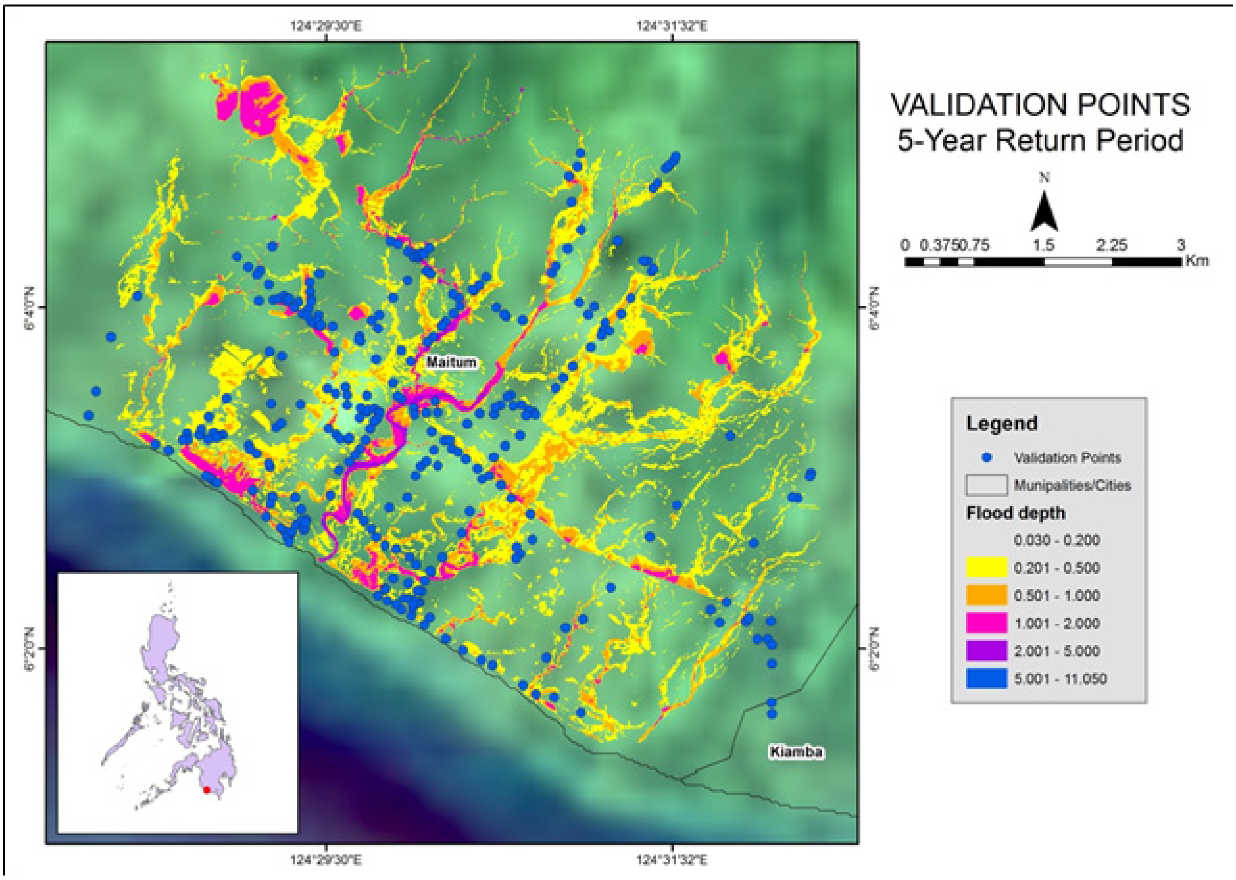


Figure 75. Saub flood validation points.

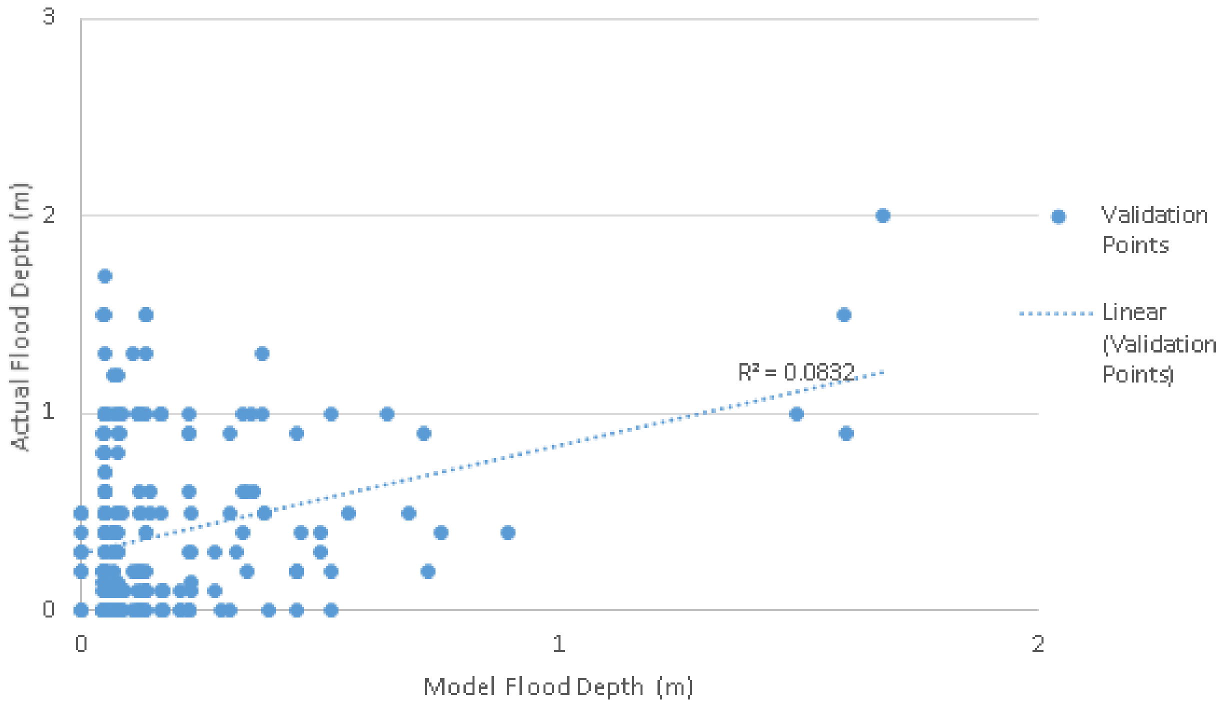


Figure 76. Flood map depth vs. actual flood depth.

Table 34. Actual flood vs. simulated flood depth at different levels in the Saub River Basin.

SAUB BASIN		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
Actual Flood Depth (m)	0-0.20	63	7	5	0	0	0	75
	0.21-0.50	39	4	9	1	0	0	53
	0.51-1.00	34	7	6	3	0	0	50
	1.01-2.00	40	5	3	0	0	0	48
	2.01-5.00	6	2	1	0	0	0	9
	> 5.00	0	0	0	0	0	0	0
	Total	182	25	24	4	0	0	235

The overall accuracy generated by the flood model is estimated at 50.33%, with one hundred and fifty-three (153) points correctly matching the actual flood depths. There were seventy-eight (78) points estimated one (1) level above and below the correct flood depths, and there were fifty (50) points and eleven (11) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of one hundred and twenty-two (122) points were underestimated in the modeled flood depths of the Saub floodplain. Table 35 depicts the summary of the Accuracy Assessment in the Saub River Basin Survey.

Table 35. Summary of the Accuracy Assessment in the Saub River Basin Survey.

	No. of Points	%
Correct	153	50.33
Overestimated	29	9.54
Underestimated	122	40.13
Total	304	100.00

REFERENCES

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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.

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

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

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

ANNEXES

Annex 1. Technical Specifications of the Aquarius LiDAR Sensor used in the Saub Floodplain Survey

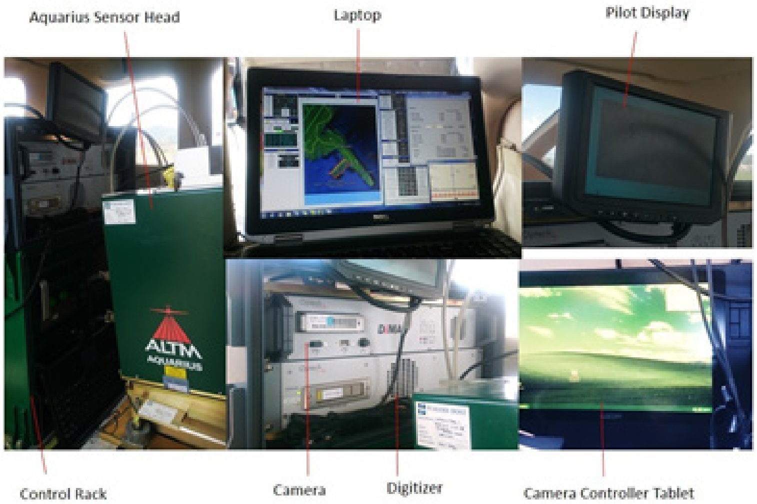


Table A-1.1. Specifications of the Aquarius LiDAR sensor

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 Certificate of Reference Points Used in the LiDAR Survey

1. SNI-13

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-13**
Order: **2nd**

Island: **MINDANAO**	Barangay: **MAGULING**		
Municipality: **MAITUM**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **6° 6' 1.73023"**	Longitude: **124° 24' 20.42136"**	Ellipsoidal Hgt:	**4.40200 m.**
	WGS84 Coordinates		
Latitude: **6° 5' 58.75940"**	Longitude: **124° 24' 26.04611"**	Ellipsoidal Hgt:	**75.91000 m.**
	PTM / PRS92 Coordinates		
Northing: **674541.48 m.**	Easting: **434213.336 m.**	Zone:	**5**
	UTM / PRS92 Coordinates		
Northing: **674,471.94**	Easting: **655,553.39**	Zone:	**51**

Location Description

SNI-13
Station is in Brgy. Maguling, Maitum, Sarangani. From Gen. San. travel for about 104 km towards Maitum municipality, upon reaching the town proper travel for about 20.3 km towards Brgy. Maguling Elementary School. Station is located at the east part of the Rizal monument. 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-13 2007 NAMRIA.

Requesting Party:	**Christopher Cruz / PHIL-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075142 I**
T.N.:	**2014-2624**

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

9 9 1 1 0 5 2 0 1 4 1 4 0 7 5 6

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-2.1. SNI-13

2. SI-409

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-409**

Island: **Mindanao**	Municipality: **KIAMBA**	Barangay: **BADTASAN**
Elevation: **10.2789 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

SI-409 is in the Brgy. Badtasan, Kiamba, Sarangani, along Gensa-Maitum Highway. Station mark is located at the top of Box culvert and about 60 m from KM post 1747 rightside going to Municipality of Maitum.

Mark is the head of concrete nail set on a drilled hole and cemented on top of a 15X15 cm cement putty with the inscription "SI-409, 2012, NAMRIA".

Requesting Party:	**Christopher Cruz / PHIL-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075142 I**
T.N.:	**2014-2627**

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

99110520141164201

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-2.1. SI-409

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

1. SI-409

Table A-3.1. SI-409

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SNI-13 --- SI-409 (B1)	SNI-13	SI-409	Fixed	0.005	0.017	115°00'12"	25378.435	5.149
SNI-13 --- SI-409 (B2)	SNI-13	SI-409	Fixed	0.003	0.019	115°00'12"	25378.435	5.032

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SNI-13				
Grid		Local		Global	
Easting	655553.385 m	Latitude	N6°06'01.73022"	Latitude	N6°05'58.75940"
Northing	674471.943 m	Longitude	E124°24'20.42140"	Longitude	E124°24'26.04611"
Elevation	4.047 m	Height	4.403 m	Height	75.910 m

To:	SI-409				
Grid		Local		Global	
Easting	678579.878 m	Latitude	N6°00'12.37199"	Latitude	N6°00'09.44669"
Northing	663805.356 m	Longitude	E124°36'48.29437"	Longitude	E124°36'53.92618"
Elevation	9.970 m	Height	9.552 m	Height	81.742 m

Vector					
ΔEasting	23026.492 m	NS Fwd Azimuth	115°00'12"	ΔX	-19595.120 m
ΔNorthing	-10666.588 m	Ellipsoid Dist.	25378.435 m	ΔY	-12093.162 m
ΔElevation	5.923 m	ΔHeight	5.149 m	ΔZ	-10670.093 m

Standard Errors

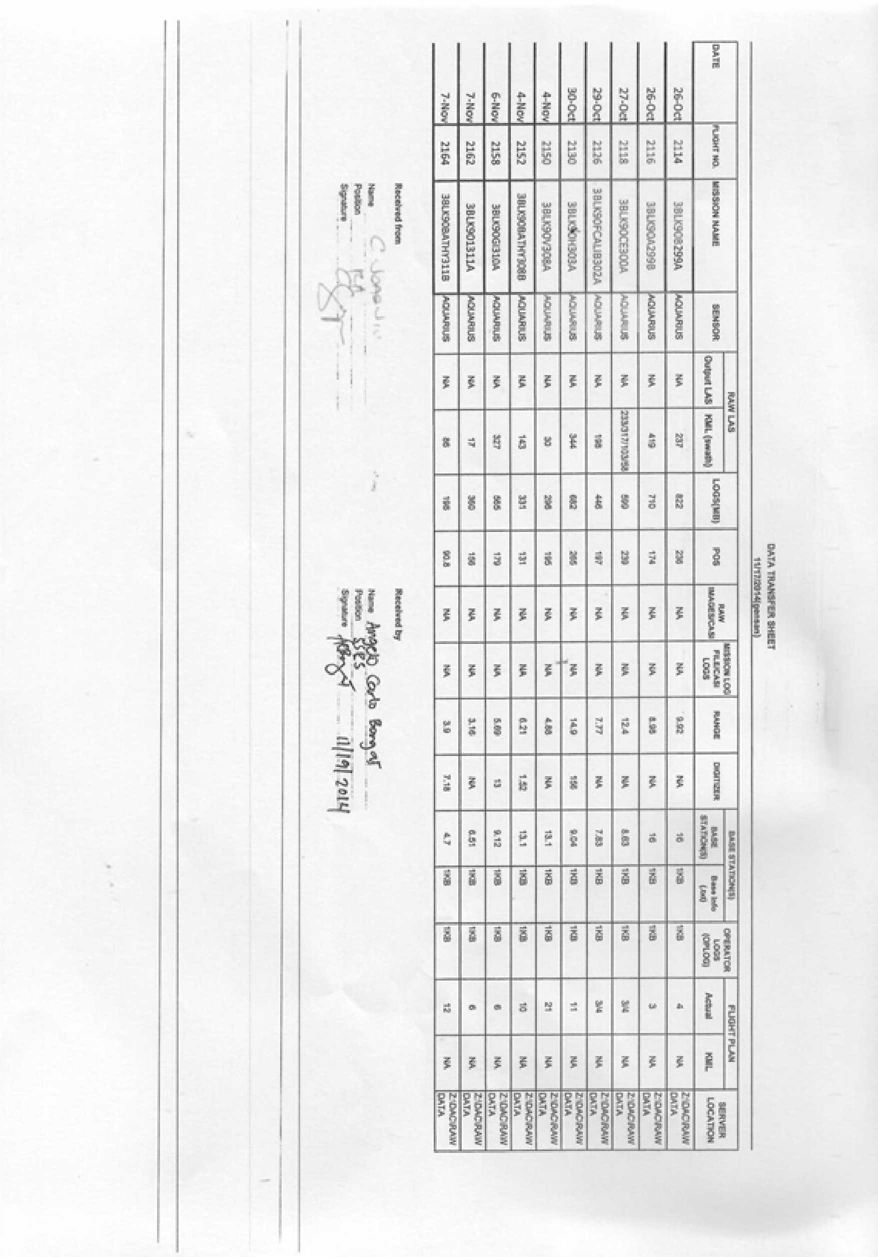
Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
Survey Supervisor	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
	RA	GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	PILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. MARK GARCHITORENA	AAC

ANNEX 5. Data Transfer Sheet for Sumlog Floodplain



DATA TRANSFER SHEET
11/17/2014(pensan)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS Output LAS	RAW LAS KML (swath)	LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S) BASE STATION(S)	BASE STATION(S) Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN Actual	FLIGHT PLAN KML	SERVER LOCATION
26-Oct	2114	3BLK90B299A	AQUARIUS	NA	237	822	226	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	233/317/103/98	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	285	NA	NA	14.9	156	9.04	1KB	1KB	11	NA	Z:\DAC\RAW DATA
4-Nov	2150	3BLK90V308A	AQUARIUS	NA	30	298	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	3BLK90G310A	AQUARIUS	NA	327	565	179	NA	NA	5.69	13	9.12	1KB	1KB	6	NA	Z:\DAC\RAW DATA
7-Nov	2162	3BLK90I311A	AQUARIUS	NA	17	360	198	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

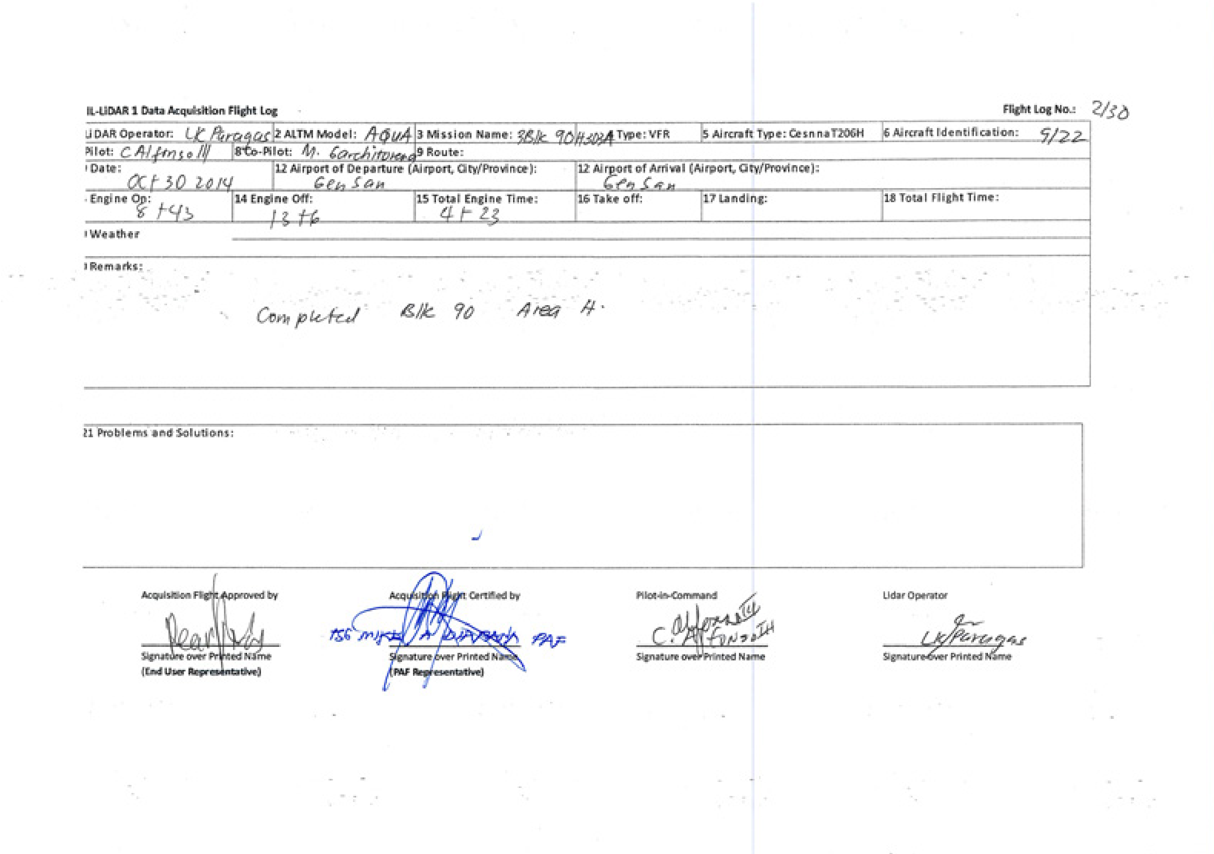
Received from
Name C. Joson Jr.
Position EA
Signature

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

Figure A-5.1. Data Transfer Sheet for the Saub Floodplain

Annex 6. Flight logs for the flight missions

1. Flight Log for 2130A Mission


IL-LiDAR 1 Data Acquisition Flight Log — Flight Log No.: 2130

LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3Blk 90H303A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
Pilot: C Alfonso III	8 Co-Pilot: M. Garchitorena	9 Route:			
Date: Oct 30 2014	12 Airport of Departure (Airport, City/Province): Gen San		12 Airport of Arrival (Airport, City/Province): Gen San		
Engine On: 8+43	14 Engine Off: 13+16	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
Weather					

Remarks: Completed Blk 90 Area 4.

21 Problems and Solutions:

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

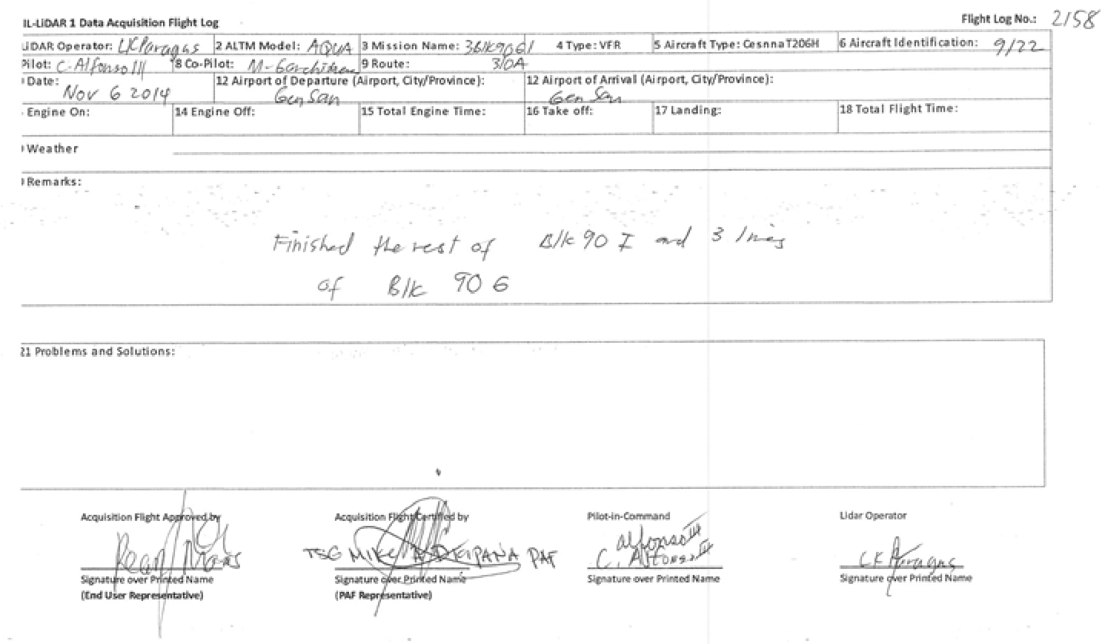
Acquisition Flight Certified by — TSG Mike A Dayandayan PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator — LK Paragas — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2130A

2. Flight Log for 2158A Mission



IL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2158

LIDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK90GI	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
Pilot: C. Alfonso III	8 Co-Pilot: M. Garchitorena	9 Route: 310A			
Date: Nov 6 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:

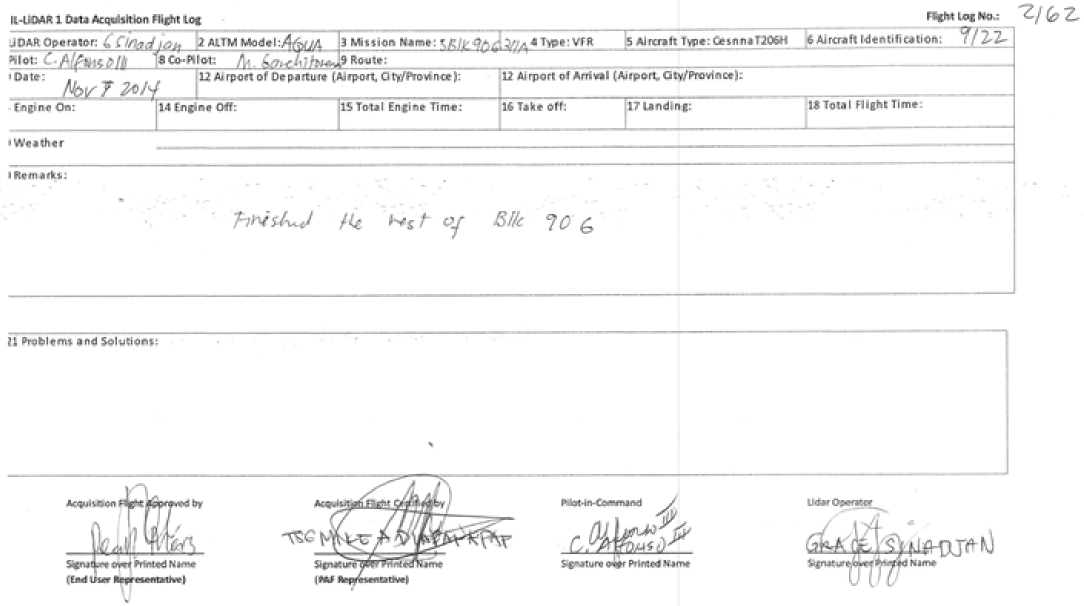
Finished the rest of Blk 90 I and 3 lines of Blk 90 G

21 Problems and Solutions:

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

Figure A-6.2. Flight Log for Mission 2158A

3. Flight Log for 2162A Mission


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2162

1 LiDAR Operator: G Sinadjan	2 ALTM Model: AQUA	3 Mission Name: 3BLK906311A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: M. Gonchitorena	9 Route:			
10 Date: Nov 7 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Finished the rest of Blk 906

21 Problems and Solutions:

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

Acquisition Flight Certified by — TSG Mike A Dimapakpak — 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-6.3. Flight Log for Mission 2162A

Annex 7. Flight status reports

Table A-7-1. Flight Status Report

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

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2130A	BLK90H	3BLK90H303A	L.K. Paragas	30-OCT	Mission Completed; Blk90H
2158A	BLK90GI	3BLK90GI310A	L.K. Paragas	6-NOV	Mission Completed; Blk90I and 3 lines of Blk90G
2162A	BLK90I	3BLK901311A	G. Sinadjan	7-NOV	Mission Completed; Blk90G

LAS BOUNDARIES PER FLIGHT

Flight No. : 2130
Area: BLK90H
Mission Name: BLK90H303A
Parameters: Altitude: 500m; Scan Frequency: 45; Scan Angle: 20;
Overlap: 30%
Area surveyed: 104.48

SWATH

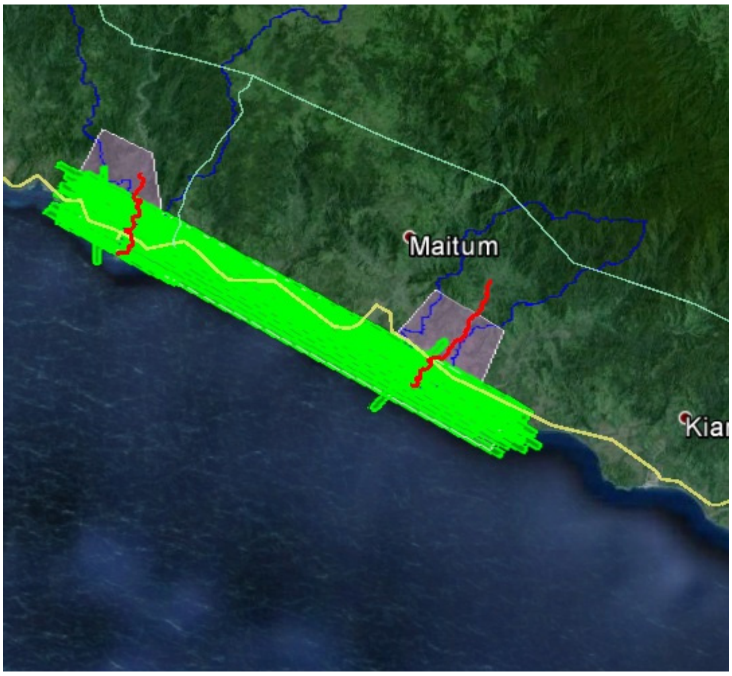
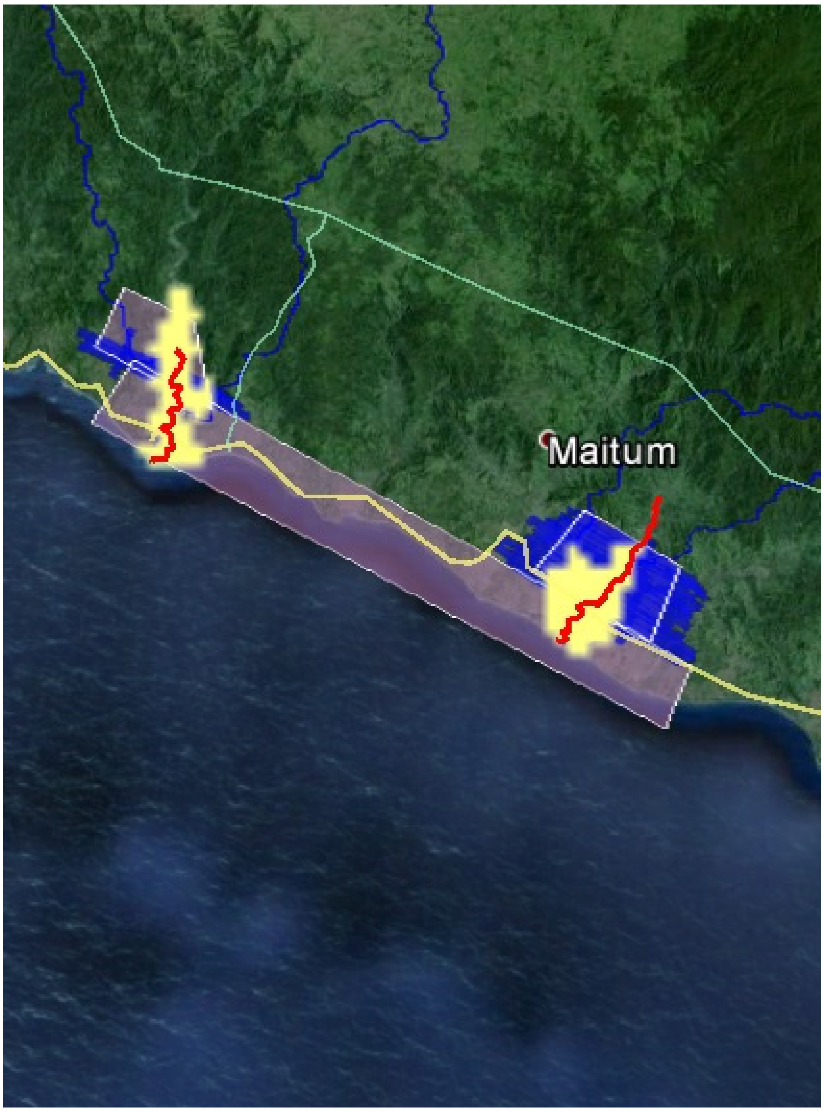


Figure A-7.1. Swath for Flight No. 2130

FFlight No. : 2158
Area: BLK90GI
Mission Name: 3BLK90GI310A
Parameters: Altitude: 600m; Scan Frequency: 45; Scan Angle: 18;
Overlap: 45%
Area surveyed: 33.133

SWATH



FFlight No. : 2162
Area: BLK90I
Mission Name: 3BLK901311A
Parameters: Altitude: 600m; Scan Frequency: 45; Scan Angle: 18;
Overlap: 40%
Area surveyed: 11.764

SWATH

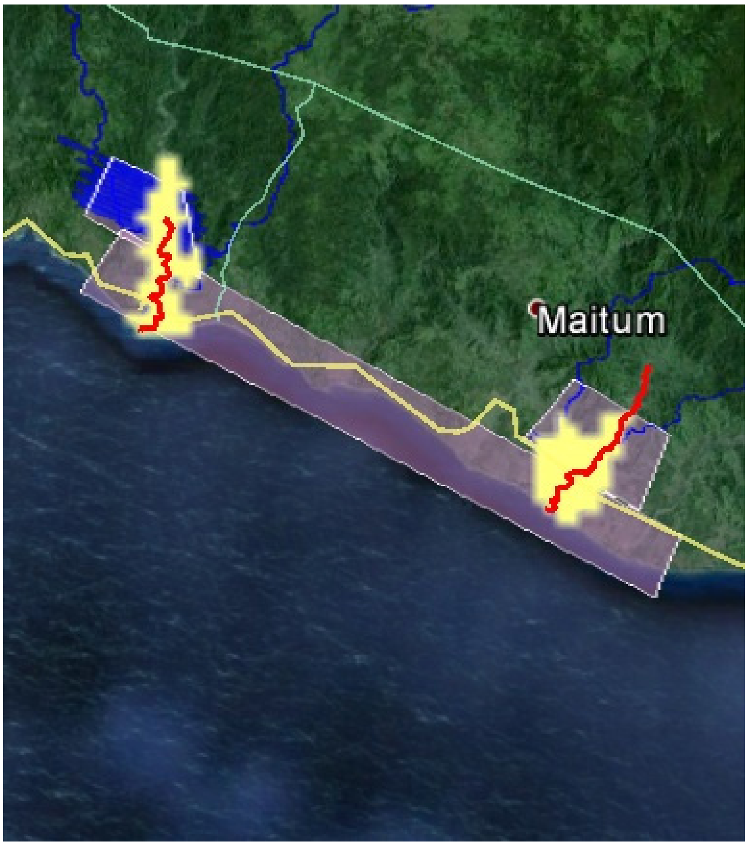


Figure A-7.3. Swath for Flight No. 2162

ANNEX 8. Mission Summary Reports

Flight Area	South Cotabato_Sarangani
Mission Name	Blk90I
Inclusive Flights	2162A
Range data size	3.16 GB
Base data size	6.51 MB
POS	156 MB
Image	
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)	1.15
RMSE for East Position (<4.0 cm)	0.82
RMSE for Down Position (<8.0 cm)	2.90
Boresight correction stdev (<0.001deg)	0.000944
IMU attitude correction stdev (<0.001deg)	0.000709
GPS position stdev (<0.01m)	0.0081
Minimum % overlap (>25)	48.48
Ave point cloud density per sq.m. (>2.0)	2.84
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	39
Maximum Height	577.12 m
Minimum Height	74.76 m
Classification (# of points)	
Ground	9026539
Low vegetation	8787635
Medium vegetation	13031537
High vegetation	28591971
Building	316814
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. Melissa Fernandez

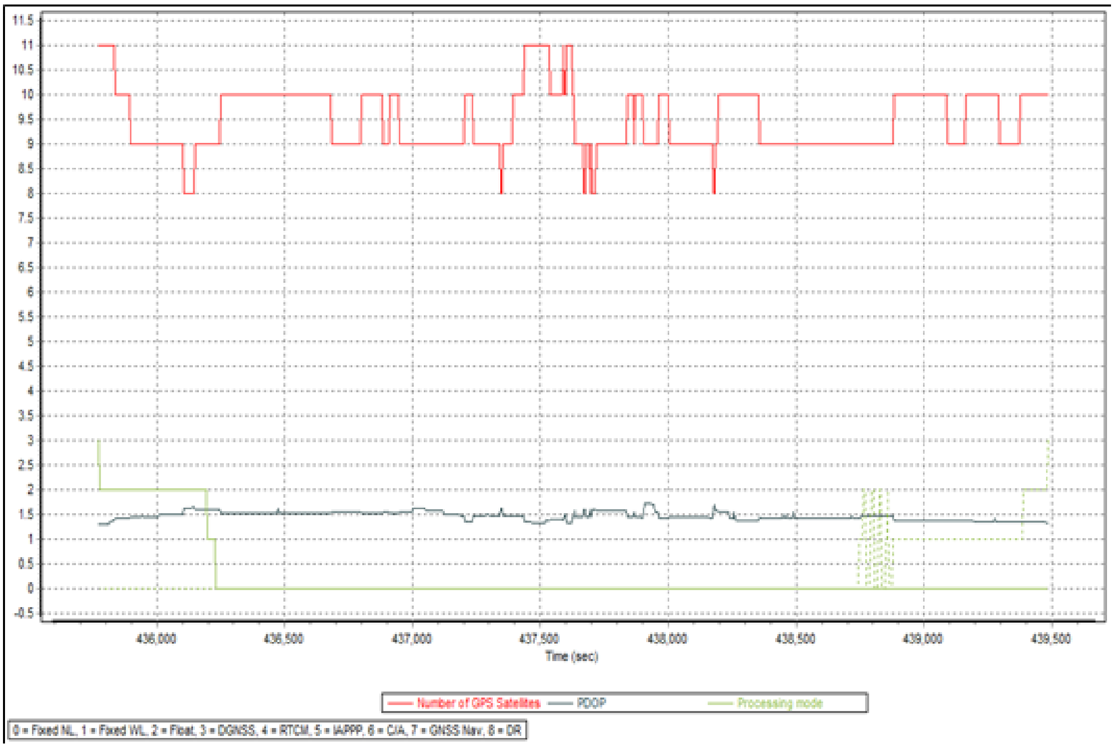


Figure A-8.1. Solution Status

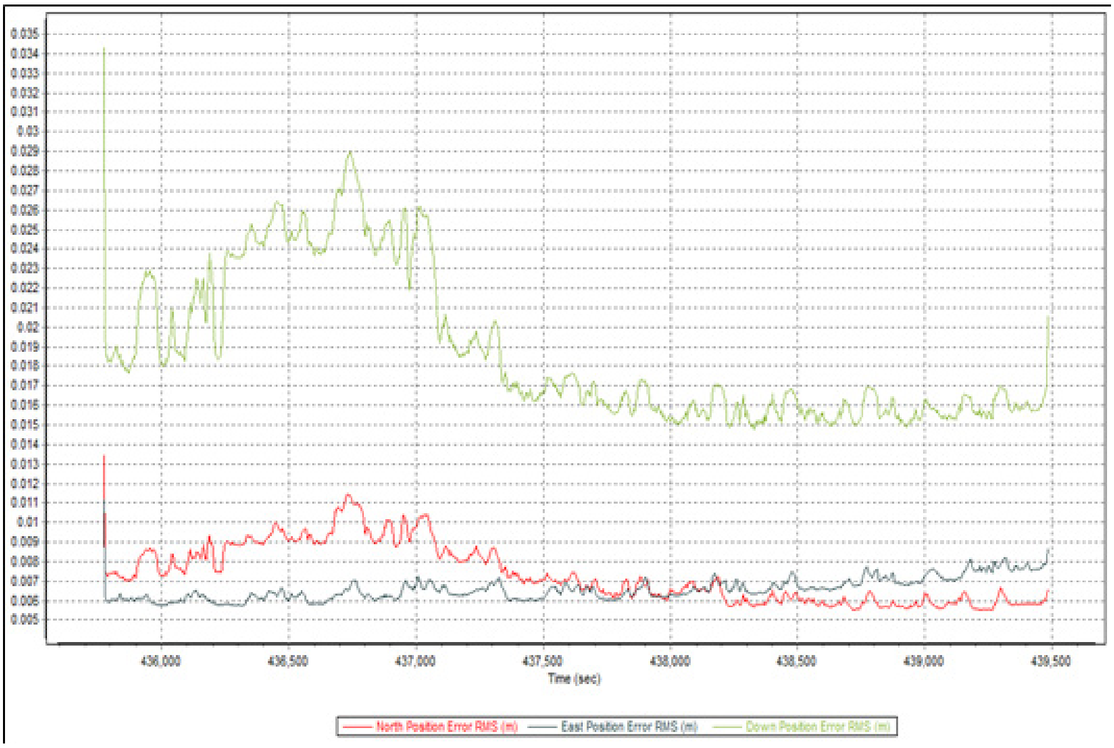


Figure A-8.2. Smoothed Performance Metric Parameters

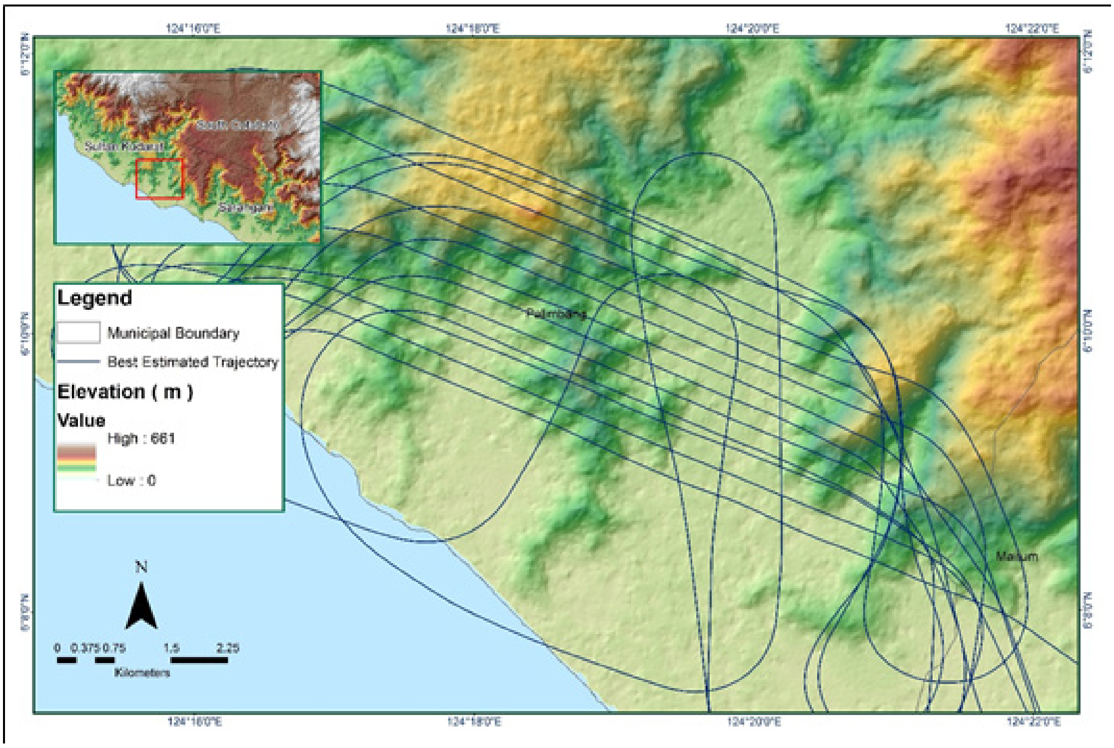


Figure A-8.3. Best Estimated Trajectory

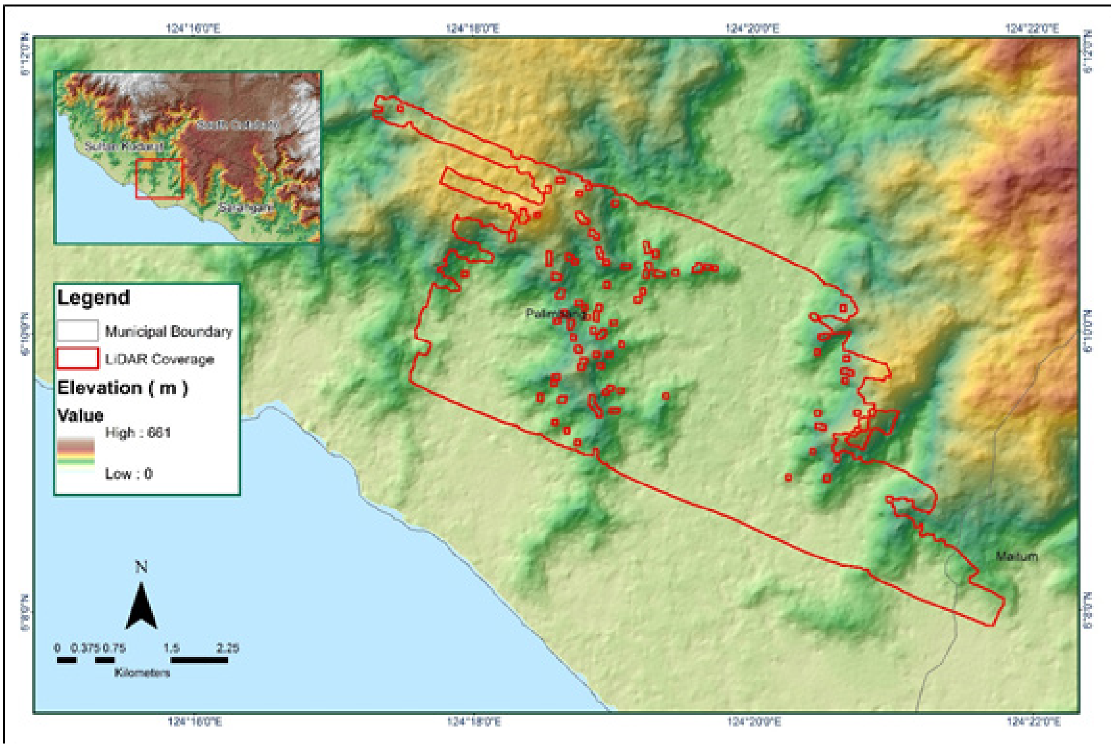


Figure A-8.4. Coverage of LiDAR data

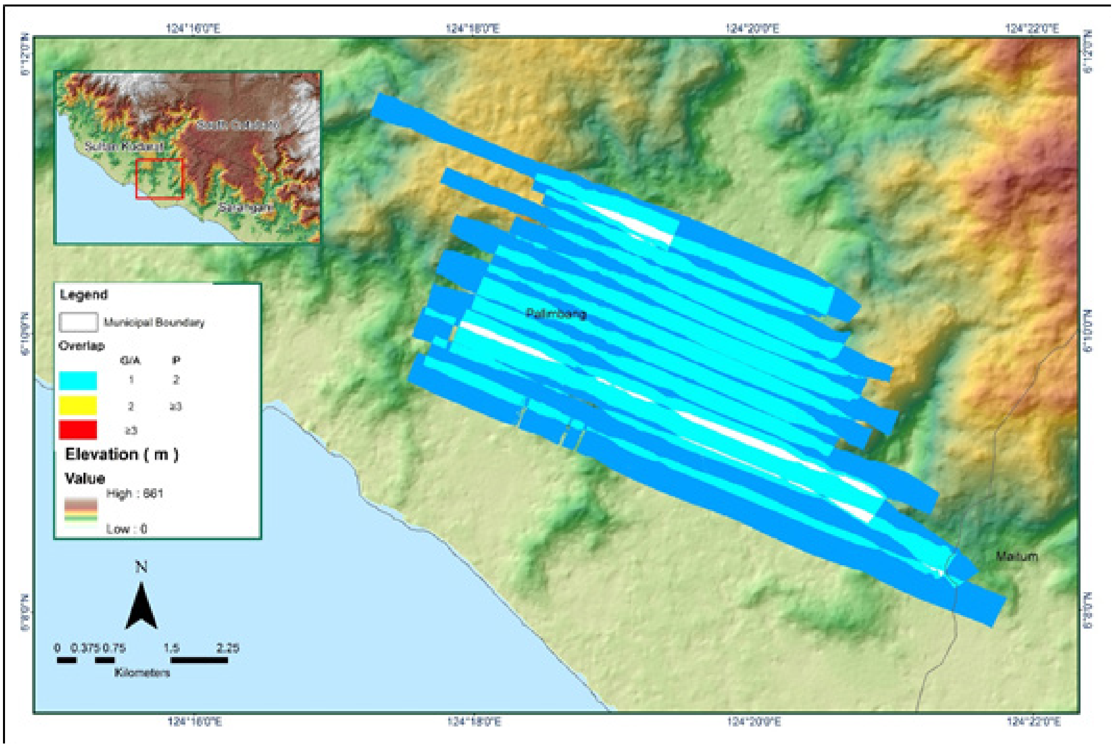


Figure A-8.5. Image of data overlap

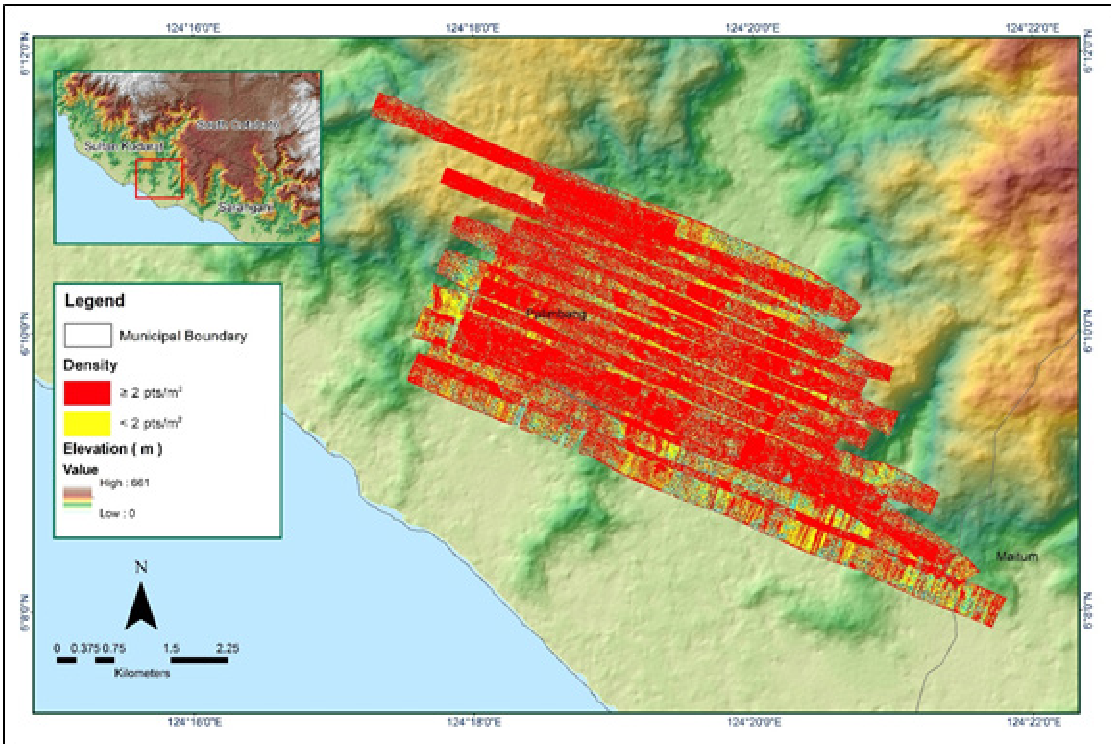


Figure A-8.6. Density map of merged LiDAR data

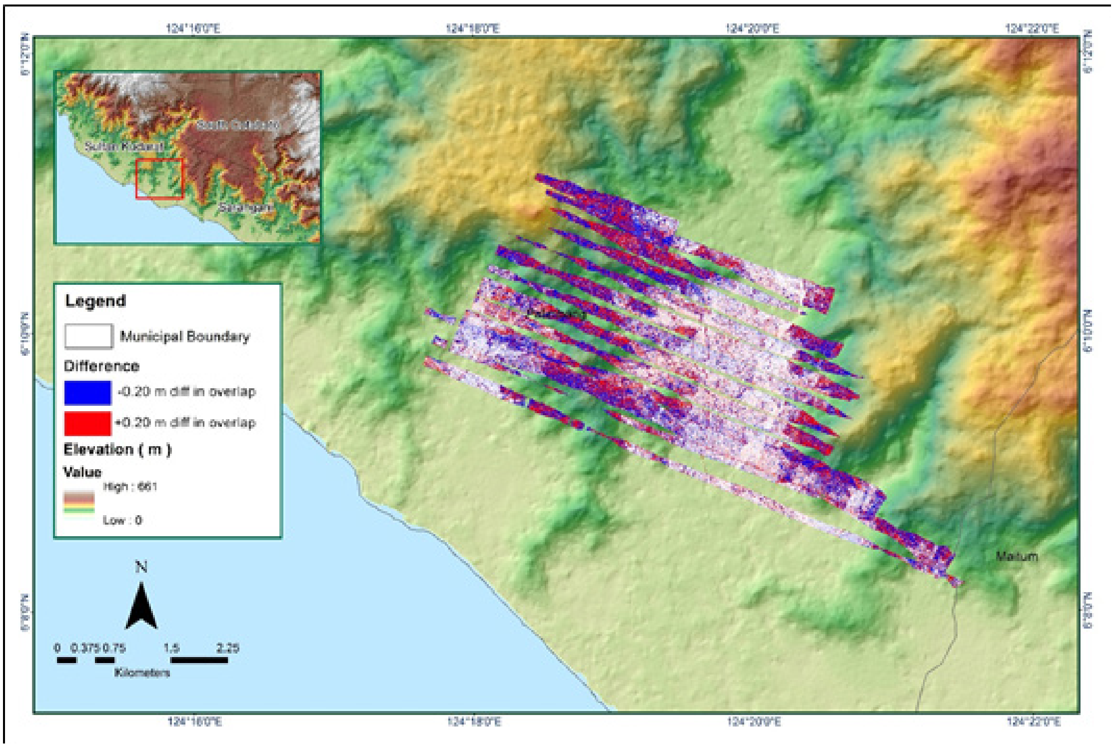


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk90H

Flight Area	South Cotabato_Sarangani
Mission Name	Blk90H
Inclusive Flights	2130A
Range data size	14.9 GB
Base data size	9.04 MB
POS	265 MB
Image	
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)	3.78
RMSE for East Position (<4.0 cm)	2.25
RMSE for Down Position (<8.0 cm)	8.80
Boresight correction stdev (<0.001deg)	0.000541
IMU attitude correction stdev (<0.001deg)	0.000452
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	41.00
Ave point cloud density per sq.m. (>2.0)	2.66
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	161
Maximum Height	346.97 m
Minimum Height	58.49 m
Classification (# of points)	
Ground	53285925
Low vegetation	65328211
Medium vegetation	60745634
High vegetation	53418806
Building	1883244
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Chelou Prado, Engr. Melissa Fernandez

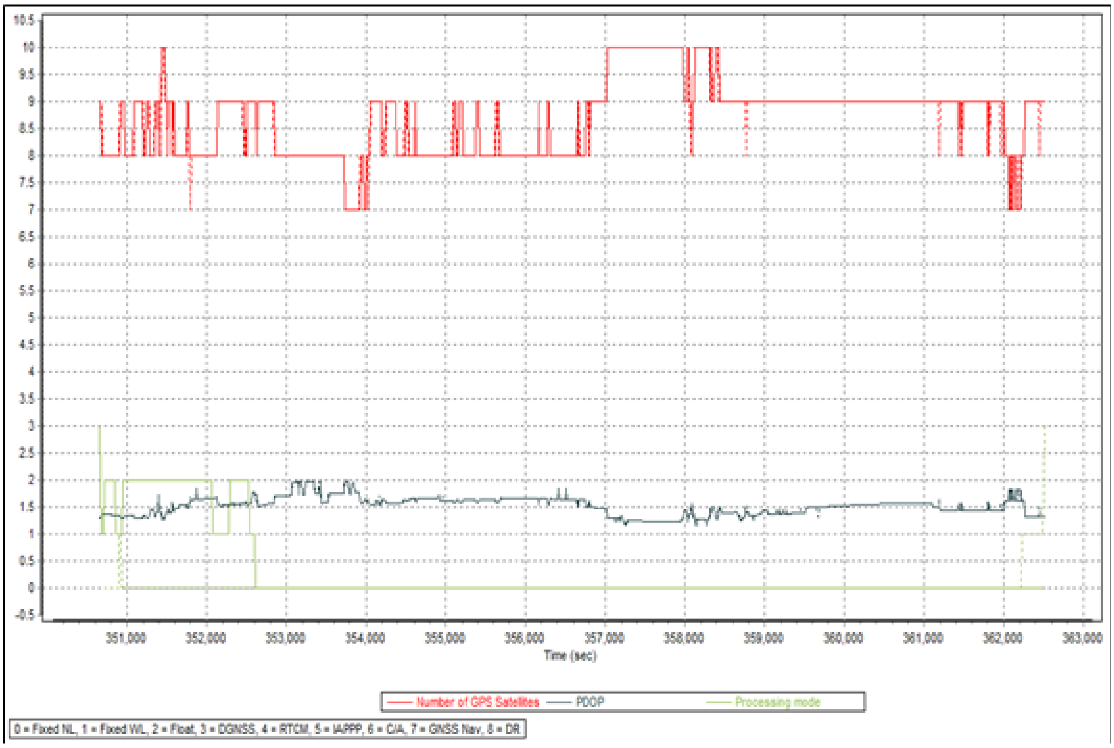


Figure A-8.8. Solution Status

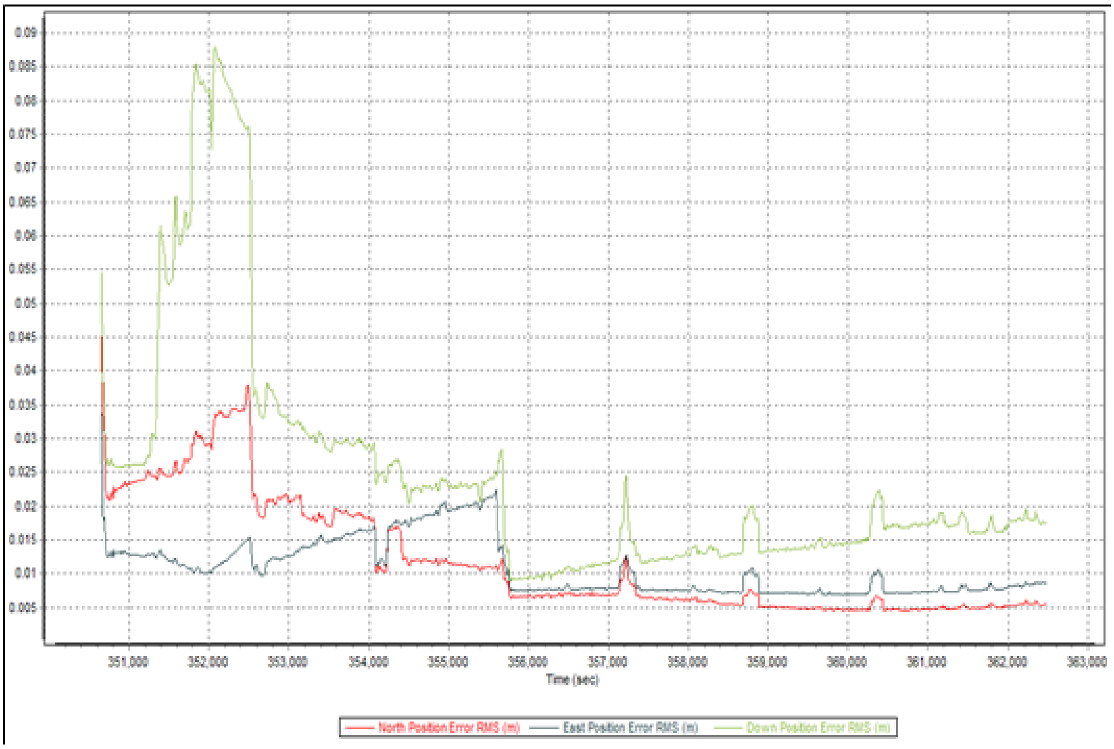


Figure A-8.9. Smoothed Performance Metric Parameters

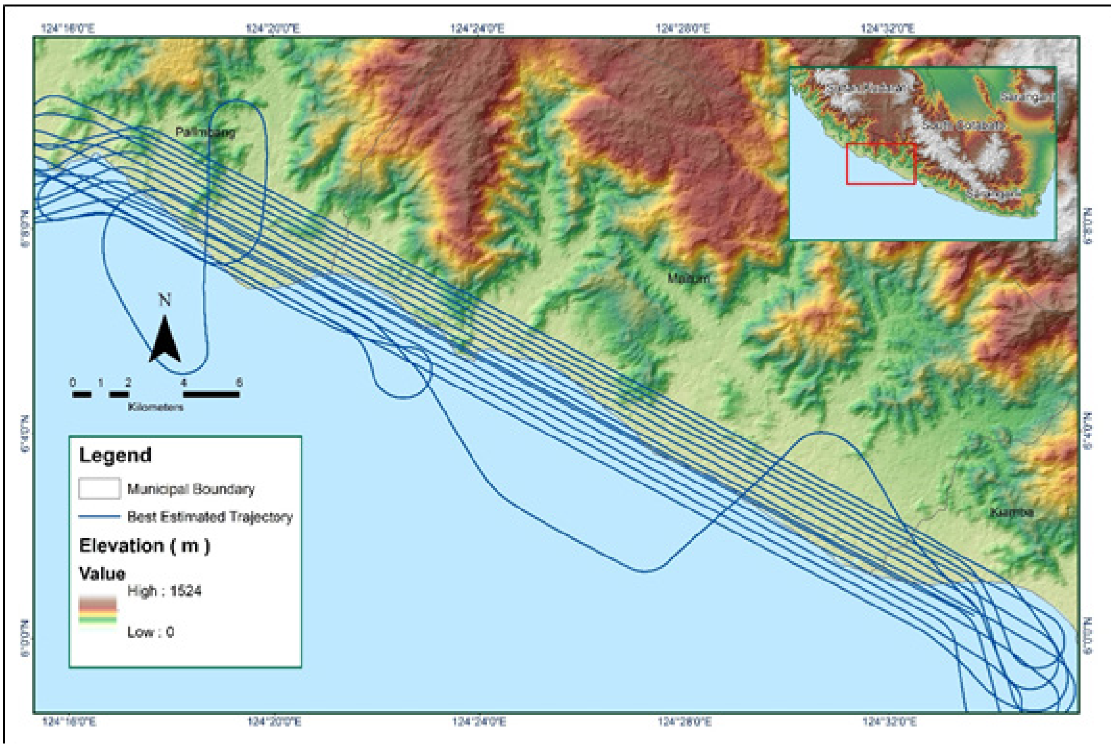


Figure A-8.10. Best Estimated Trajectory

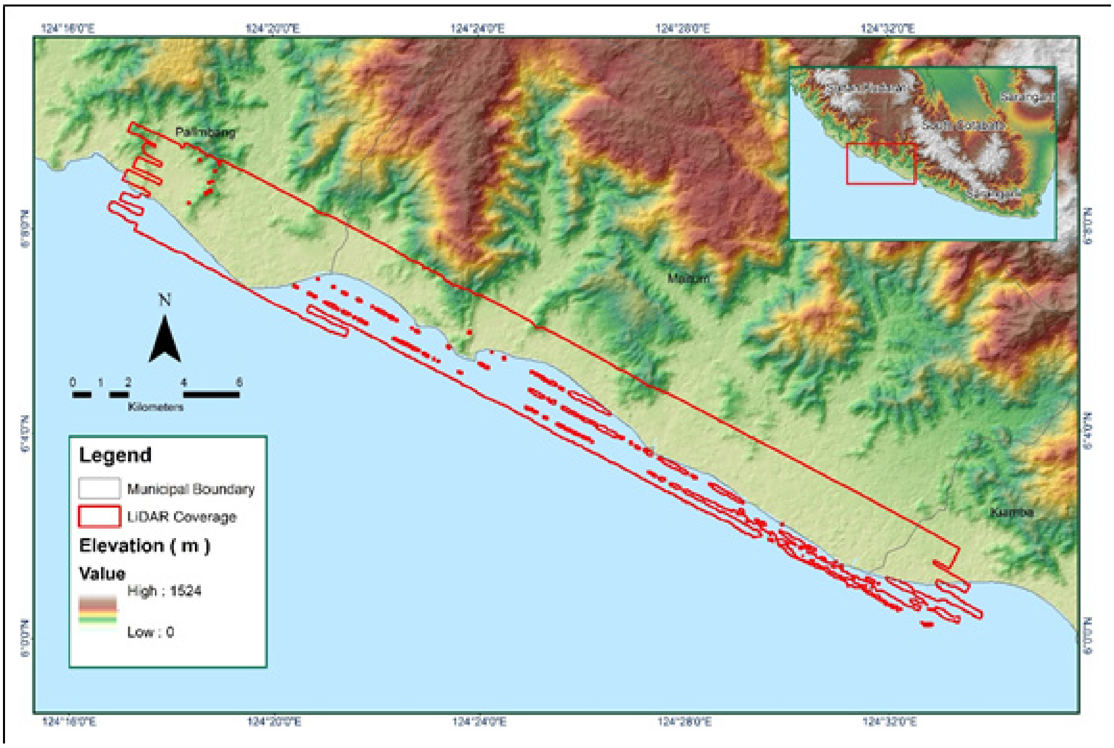


Figure A-8.11. Coverage of LiDAR data

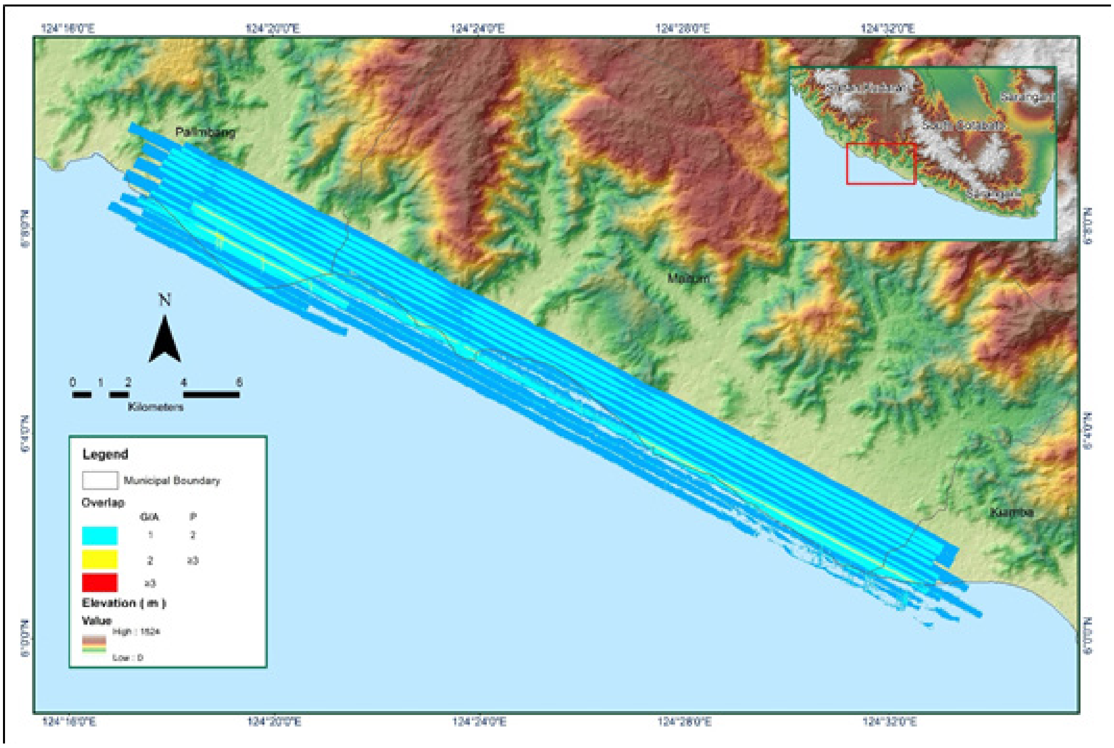


Figure A-8.12. Image of data overlap

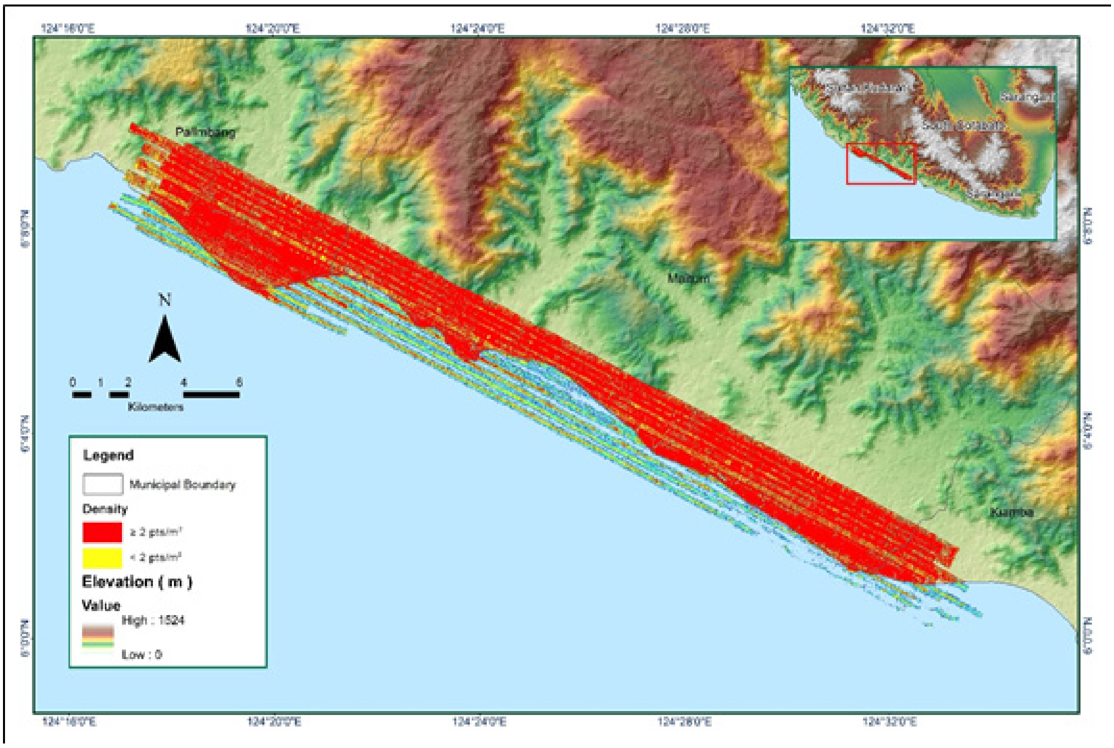


Figure A-8.13. Density map of merged LiDAR data

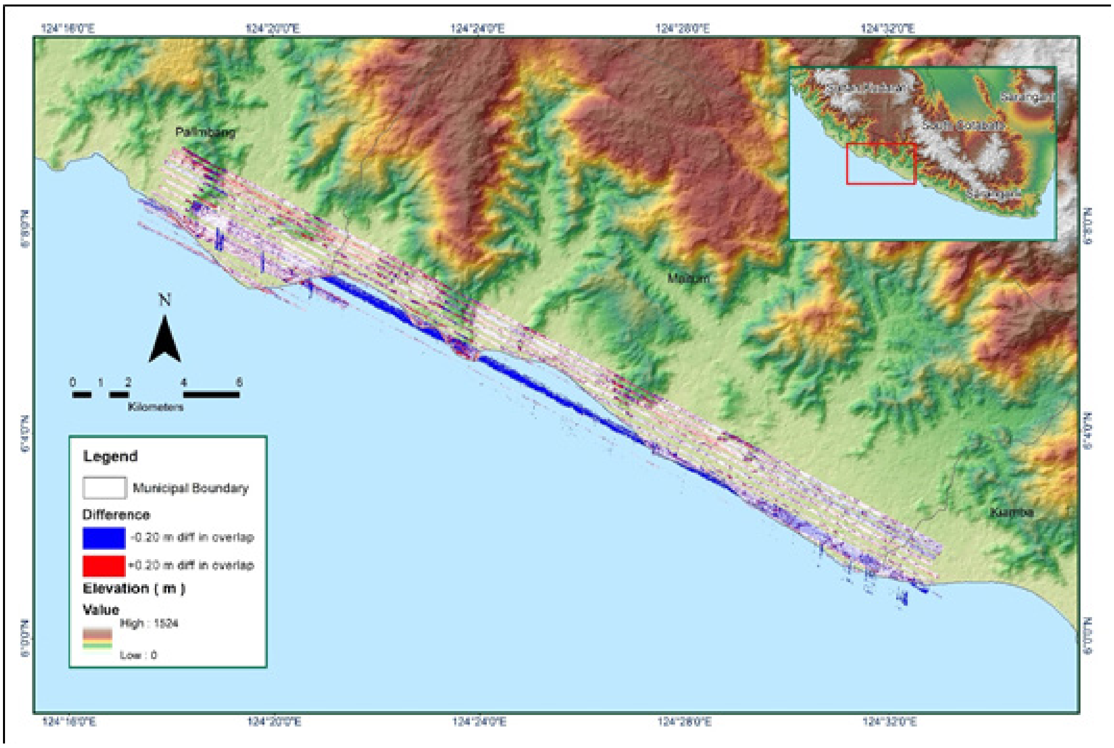


Figure A-8.14. Elevation difference between flight lines

Flight Area	South Cotabato_Sarangani
Mission Name	Blk90G
Inclusive Flights	2158A
Range data size	5.69 GB
Base data size	9.12 MB
POS	179 MB
Image	November 19, 2014
Transfer date	
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)	1.32
RMSE for East Position (<4.0 cm)	1.20
RMSE for Down Position (<8.0 cm)	2.80
Boresight correction stdev (<0.001deg)	0.000290
IMU attitude correction stdev (<0.001deg)	0.000362
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	44.26
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	51
Maximum Height	431.28 m
Minimum Height	72.06 m
Classification (# of points)	
Ground	16,714,638
Low vegetation	17,992,621
Medium vegetation	23,245,999
High vegetation	21,119,618
Building	628,737
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Melissa Fernandez

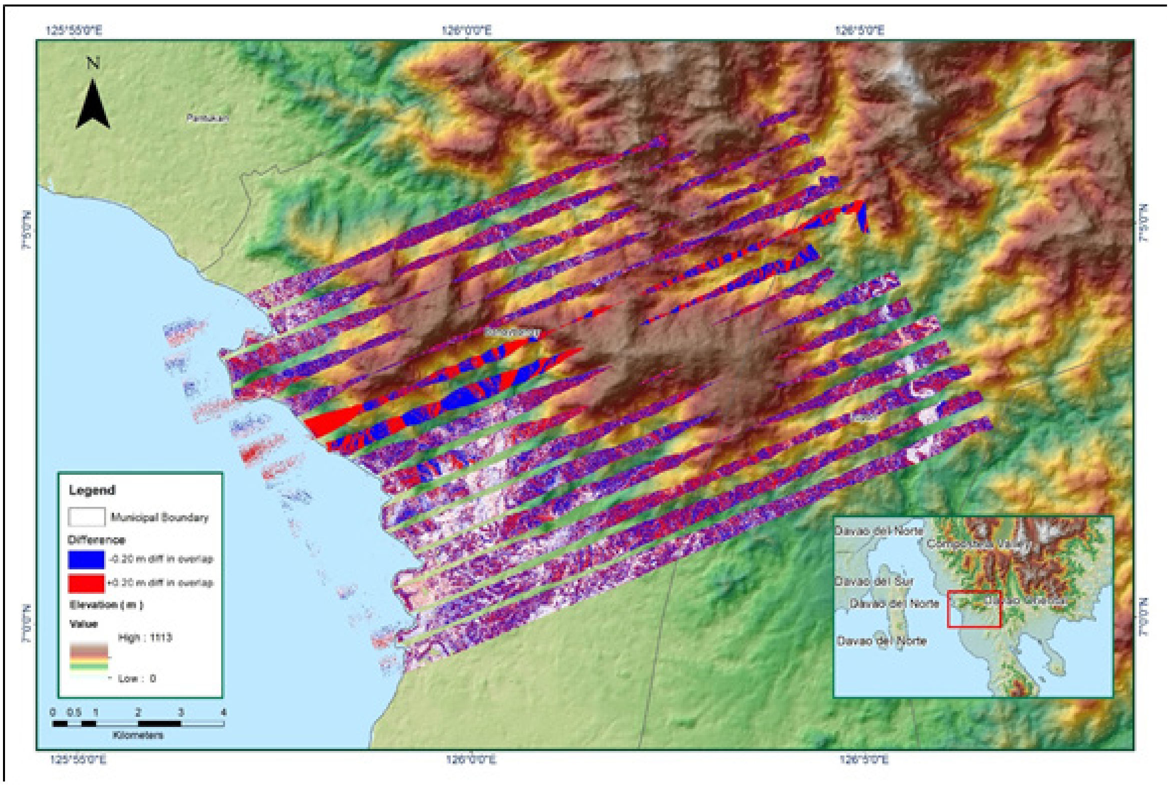


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk86B
Inclusive Flights	7322G
Range data size	23.0 GB
POS	242 MB
Image	na
Transfer date	July 2, 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)	1.1
RMSE for East Position (<4.0 cm)	1.46
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000188
IMU attitude correction stdev (<0.001deg)	0.001441
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	33.62%
Ave point cloud density per sq.m. (>2.0)	3.30
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	16
Maximum Height	374.79 m
Minimum Height	88.63 m
Classification (# of points)	
Ground	5850713
Low vegetation	5128592
Medium vegetation	8580789
High vegetation	23883495
Building	100524
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Analyn Naldo, Engr. Gladys Mae Apat

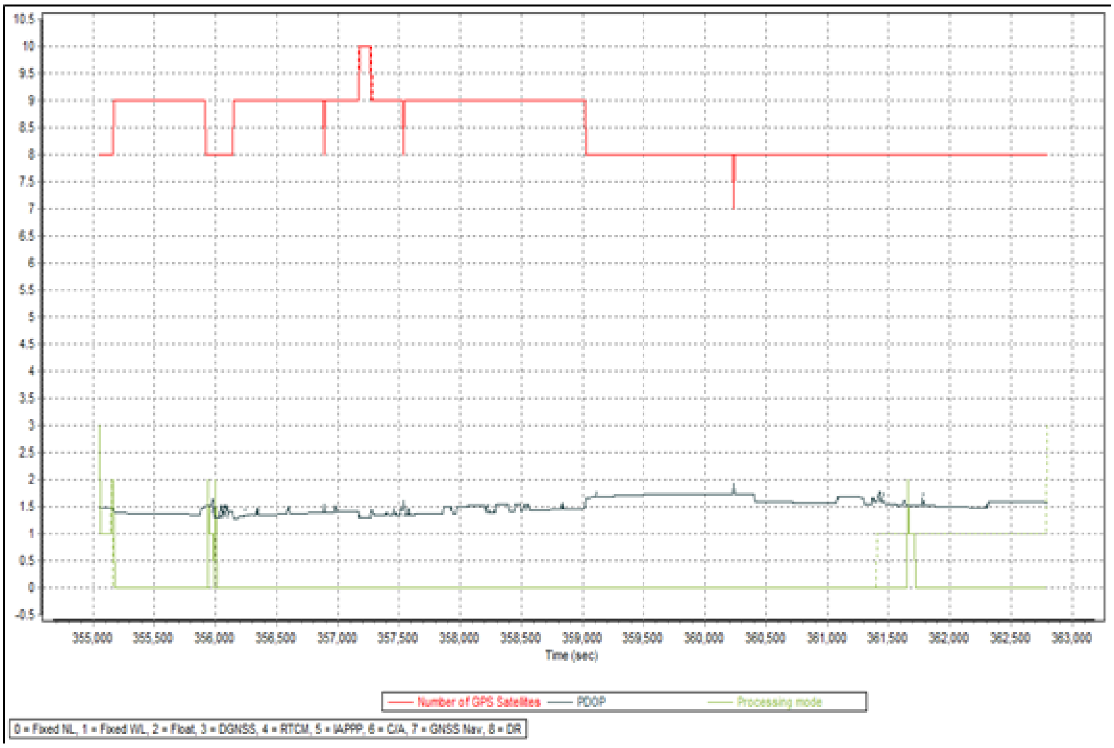


Figure A-8.15. Solution Status

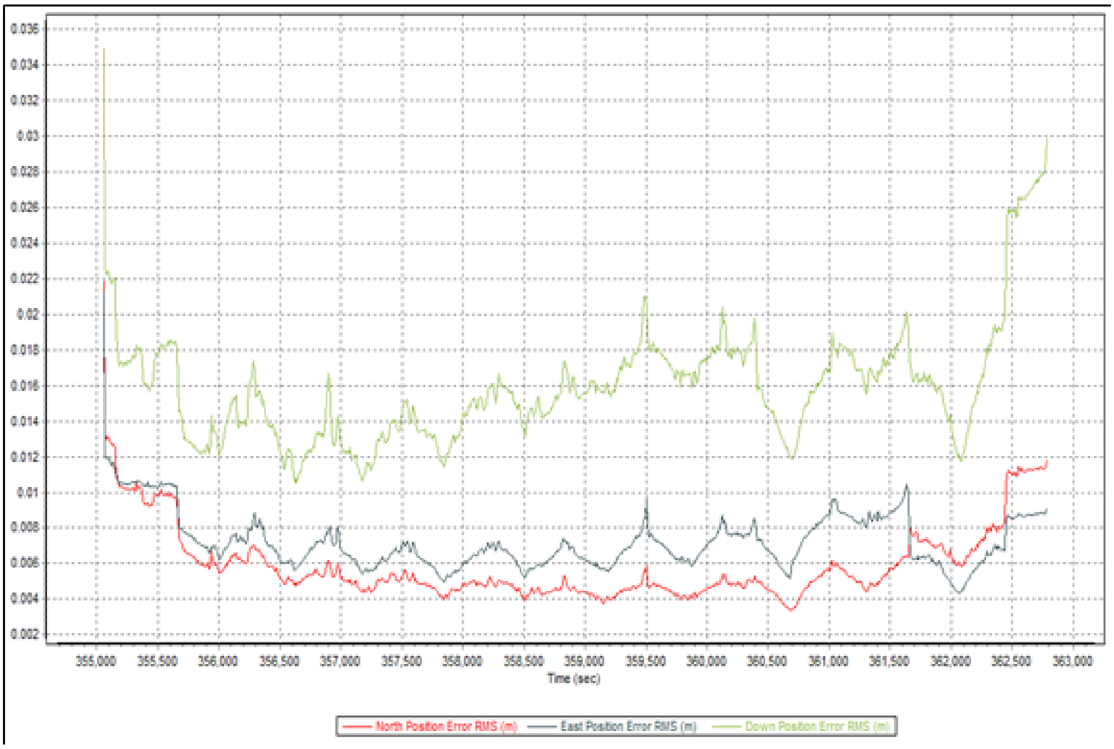


Figure A-8.16. Smoothed Performance Metric Parameters

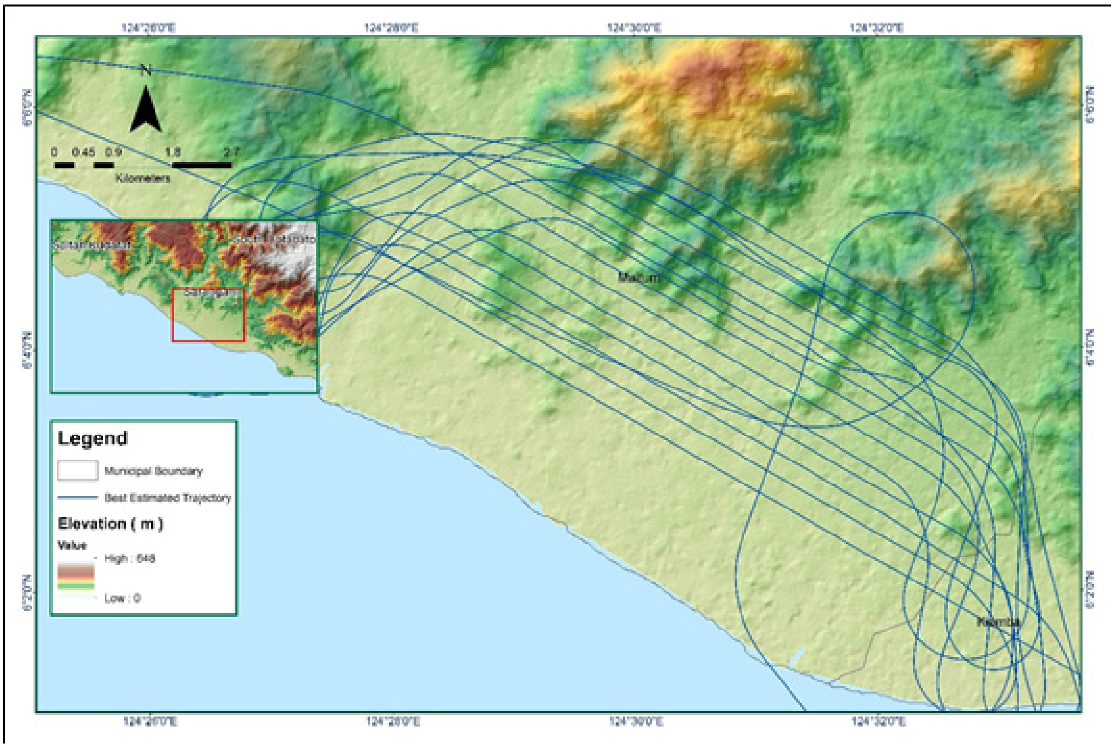


Figure A-8.17. Best Estimated Trajectory

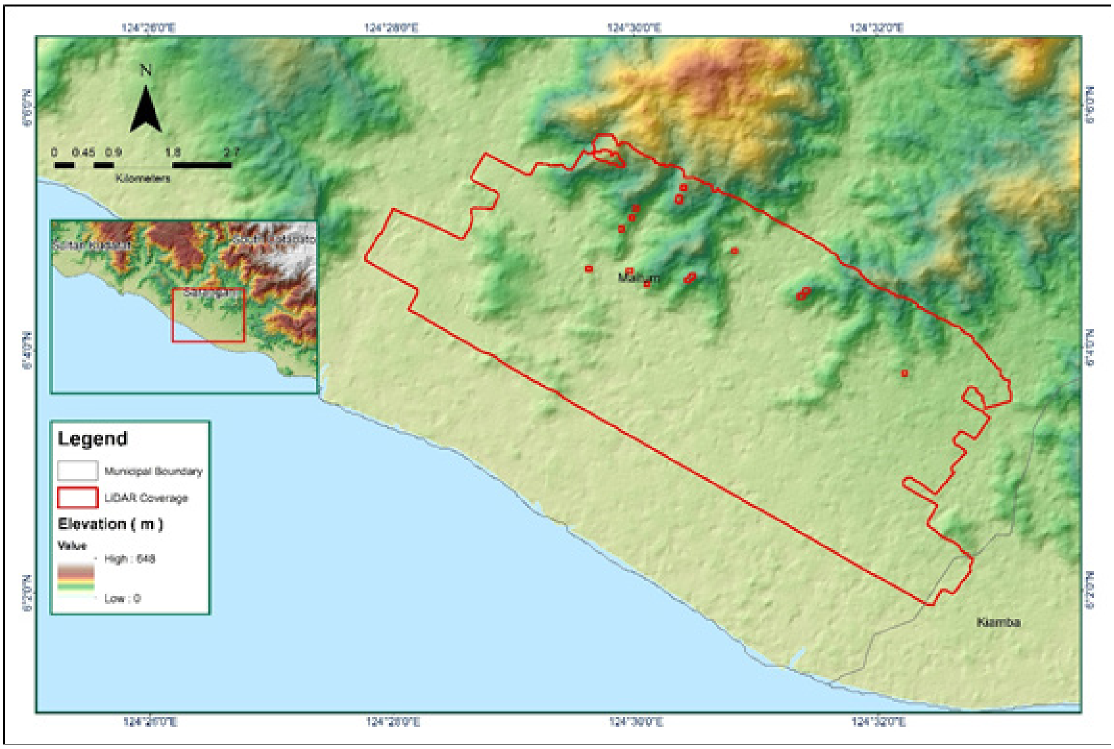


Figure A-8.18. Coverage of LiDAR data

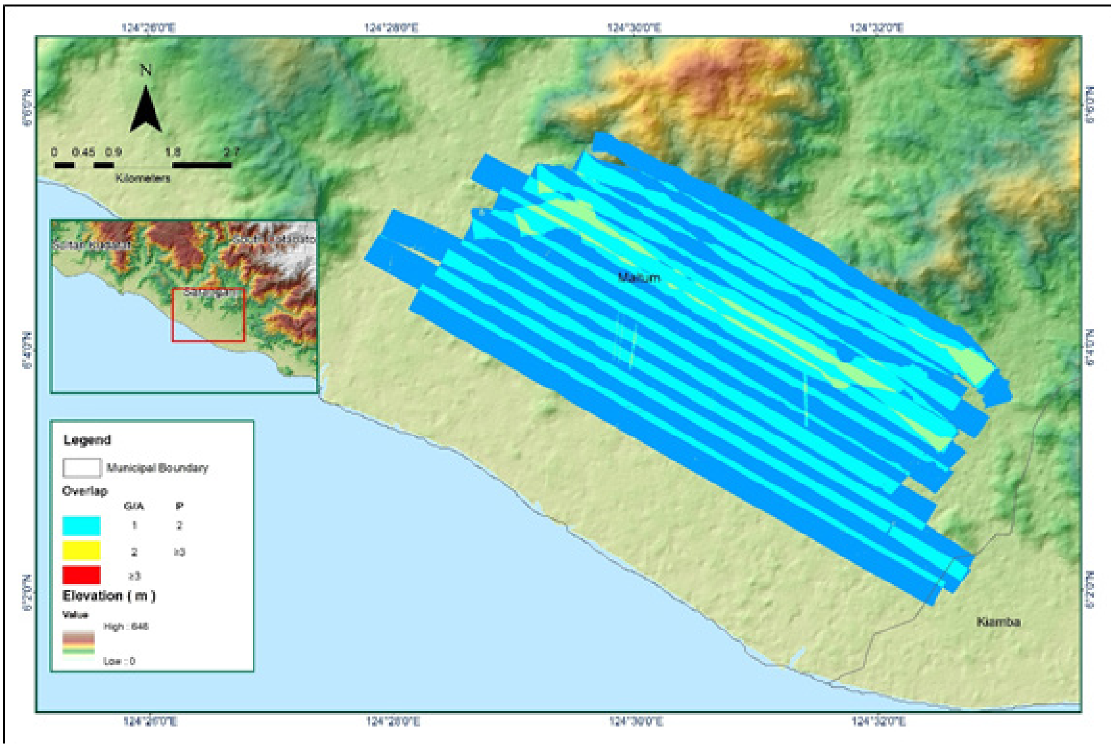


Figure A-8.20. Image of data overlap

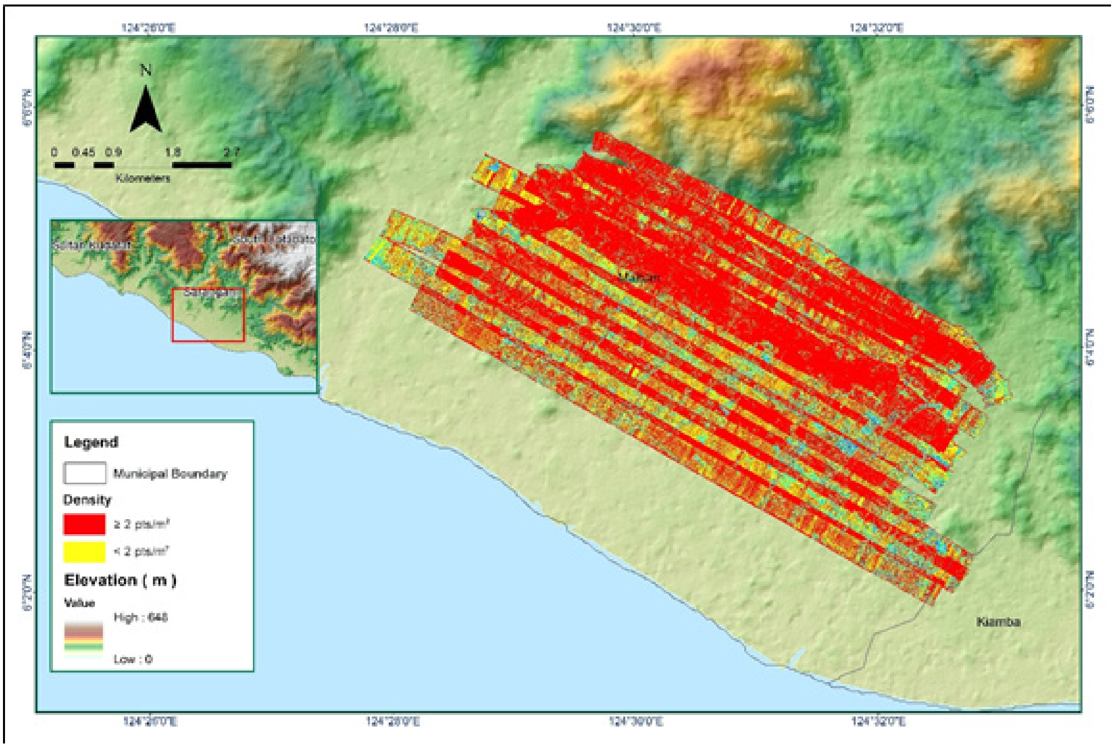


Figure A-8.21 Density map of merged LiDAR data

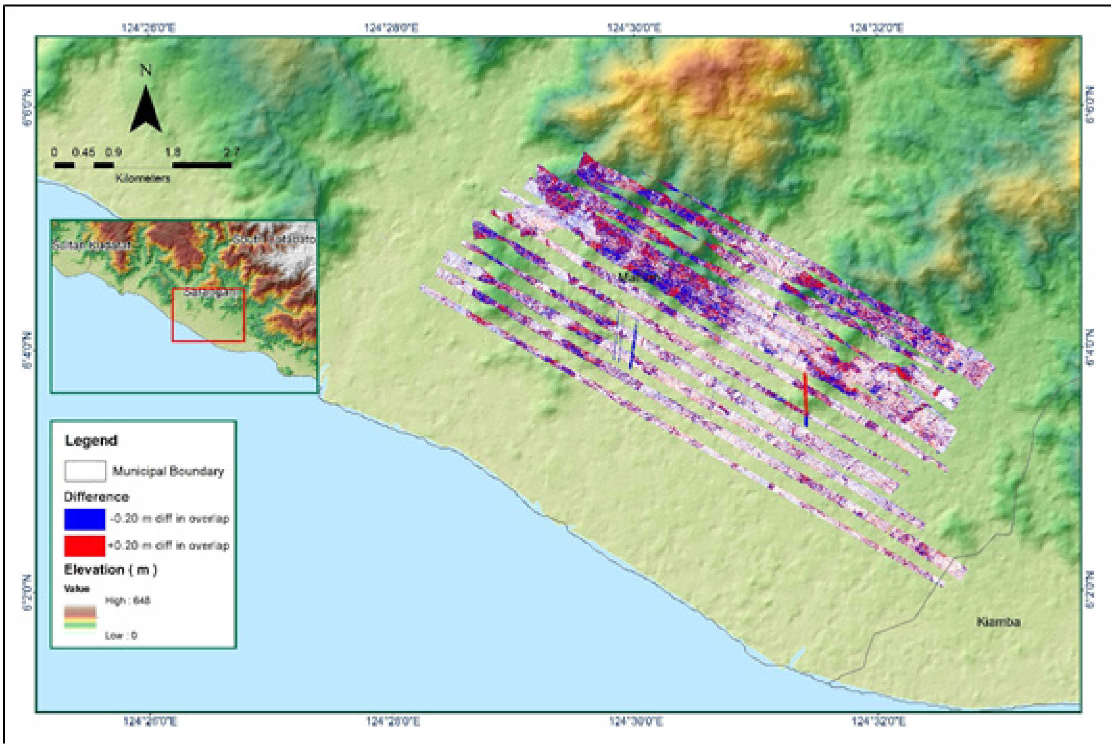


Figure A-8.21. Elevation difference between flight lines

Annex 9. Saub Model Basin Parameters

Table A-9.1. Saub Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base Flow				
	Initial Abstraction (mm)	Curve Number	Impervious %	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W140	33.69820	42.848	0	1.8341	1.6850524	Discharge	0.5409	1	Ratio to Peak	0.5
W150	33.59210	43.352	0	2.1075	2.1312599	Discharge	0.95567	1	Ratio to Peak	0.5
W160	34.29670	40.121	0	1.9815	1.9256613	Discharge	0.42017	0.0001	Ratio to Peak	0.5
W170	33.510	43.746	0	1.5412	1.2071411	Discharge	0.21524	0.0001	Ratio to Peak	0.5
W180	33.88410	41.979	0	2.0813	2.0884437	Discharge	0.62522	0.0001	Ratio to Peak	0.5
W190	33.744450	42.63	0	1.8801	1.7601793	Discharge	0.25969	1	Ratio to Peak	0.5
W200	33.0	44.146521	0	1.0508	0.4067095	Discharge	0.0183156	1	Ratio to Peak	0.5
W210	34.65860	38.563	0	1.7024	1.4700979	Discharge	0.0758596	1	Ratio to Peak	0.5
W220	33.748210	42.612029	0	3.2124	3.9344491	Discharge	0.97995	1	Ratio to Peak	0.5
W230	33.616760	43.234	0	2.425	2.6493987	Discharge	0.44271	1	Ratio to Peak	0.5
W240	33.13970	45.578	0	1.1182	0.516805	Discharge	0.0080538	1	Ratio to Peak	0.5
W250	32.03030	51.617	0	2.2249	2.3227955	Discharge	0.25276	1	Ratio to Peak	0.5
W260	33.32670	44.64263	0	2.9724	3.5427644	Discharge	0.10711	1	Ratio to Peak	0.5

Annex 10. Saub Model Reach Parameters

Table A-10.1. Saub Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's N	Shape	Width	Side Slope
R100	Automatic Fixed Interval	7679.5	0.008576	0.0001	Trapezoid	50	1
R110	Automatic Fixed Interval	668.86	0.001607	0.0001	Trapezoid	50	1
R130	Automatic Fixed Interval	2095.7	0.01667	0.0001	Trapezoid	50	1
R50	Automatic Fixed Interval	787.66	0.020769	0.0001	Trapezoid	50	1
R70	Automatic Fixed Interval	361.98	0.022414	0.9	Trapezoid	50	1
R80	Automatic Fixed Interval	4656.7	0.041126	0.0001	Trapezoid	50	1

Annex 11. Sumlog Field Validation Points

Table A-11.1. Saub Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	6.067625	**Long**	0.129999995	0	-0.129999995	2001	5YR
2	6.070216	124.521497	0.134827584	0.4	0.265172416	2001	5YR
3	6.070467	124.523553	0.085000001	0.1	0.014999999	2001	5YR
4	6.071196	124.523772	0.047463976	0.15	0.102536024	2001	5YR
5	6.07125	124.523133	0.06909091	0	-0.06909091	2001	5YR
6	6.073207	124.522738	0.047463976	0	-0.047463976	2001	5YR
7	6.078329	124.520246	0.725000024	0.2	-0.525000024	2001	5YR
8	6.078841	124.523709	0.047463976	0.5	0.452536024	2001	5YR
9	6.080271	124.524094	0.047463976	0.7	0.652536024	2001	5YR
10	6.080575	124.524967	0.047463976	0.7	0.652536024	2001	5YR
11	6.081041	124.525272	0.00	0.2	0.2	2001	5YR
12	6.081437	124.525715	0.00	0.3	0.3	2001	5YR
13	6.066039	124.5259	0.047463976	0	-0.047463976	2001	5YR
14	6.06518	124.520583	0.360000014	0.6	0.239999986	2001	5YR
15	6.065984	124.518998	0.047463976	0.2	0.152536024	2001	5YR
16	6.0668	124.517363	0.076379307	0.5	0.423620693	2001	5YR
17	6.067175	124.517934	0.047463976	1	0.952536024	2001	5YR
18	6.064467	124.516486	0.085000001	0.5	0.414999999	2001	5YR
19	6.062821	124.518778	0.127333328	0.2	0.072666672	2001	5YR
20	6.059803	124.517617	0.047463976	0	-0.047463976	2001	5YR
21	6.060928	124.514946	0.167999998	0	-0.167999998	2001	5YR
22	6.058781	124.515835	0.047463976	0	-0.047463976	2001	5YR
23	6.056506	124.514144	0.06909091	0.2	0.13090909	2001	5YR
24	6.056213	124.511992	0.047463976	0.2	0.152536024	2001	5YR
25	6.056654	124.512146	0.047463976	0.5	0.452536024	2001	5YR
26	6.057179	124.511468	0.047463976	0.3	0.252536024	2001	5YR
27	6.058122	124.510835	0.047463976	0	-0.047463976	2001	5YR
28	6.057958	124.509783	0.047463976	0	-0.047463976	2001	5YR
29	6.057083	124.509426	0.076379307	0	-0.076379307	2001	5YR
30	6.056157	124.509991	0.047463976	0	-0.047463976	2001	5YR
31	6.05417	124.511266	0.047463976	0	-0.047463976	2001	5YR
32	6.053159	124.510688	0.043809522	0.15	0.106190478	2001	5YR
33	6.052032	124.509208	0.047463976	0	-0.047463976	2001	5YR
34	6.068919	124.508107	0.06769231	0	-0.06769231	2001	5YR
35	6.070312	124.486093	0.047463976	0	-0.047463976	2001	5YR
36	6.072649	124.48525	0.047463976	0	-0.047463976	2001	5YR
37	6.071662	124.48644	0.047463976	0	-0.047463976	2001	5YR
38	6.070639	124.483007	0.047463976	0	-0.047463976	2001	5YR
39	6.06991	124.484084	0.043809522	0	-0.043809522	2001	5YR
40	6.067455	124.484928	0.06909091	0	-0.06909091	2001	5YR
41	6.067354	124.486569	0.047463976	0	-0.047463976	2001	5YR
42	6.067538	124.485129	0.076379307	0.3	0.223620693	2001	5YR
43	6.067837	124.487071	0.047463976	0	-0.047463976	2001	5YR
44	6.06747	124.487569	0.501428545	0.3	-0.201428545	2001	5YR
45	6.067247	124.487793	0.685000002	0.5	-0.185000002	2001	5YR
46	6.067536	124.487965	0.076379307	0.4	0.323620693	2001	5YR
47	6.067208	124.48808	0.047463976	0.4	0.352536024	2001	5YR

48	6.066701	124.489021	0.716666639	0.9	0.183333361	2001	5YR
49	6.066063	124.488592	0.308888882	0.9	0.591111118	2001	5YR
50	6.066581	124.489394	0.381999999	0.5	0.118000001	2001	5YR
51	6.070015	124.489966	0.047463976	0	-0.047463976	2001	5YR
52	6.069146	124.491067	0.047463976	0	-0.047463976	2001	5YR
53	6.068251	124.490131	0.06769231	0	-0.06769231	2001	5YR
54	6.067509	124.490154	0.047463976	0	-0.047463976	2001	5YR
55	6.06729	124.490264	0.076379307	0	-0.076379307	2001	5YR
56	6.06588	124.49023	0.639999986	1	0.360000014	2001	5YR
57	6.065322	124.489861	0.501428545	0.4	-0.101428545	2001	5YR
58	6.065119	124.490248	0.523750007	1	0.476249993	2001	5YR
59	6.065897	124.490495	0.222857147	0	-0.222857147	2001	5YR
60	6.065403	124.490978	0.047463976	0	-0.047463976	2001	5YR
61	6.064851	124.490915	0.460000008	0.4	-0.060000008	2001	5YR
62	6.06495	124.49109	0.344285697	0.2	-0.144285697	2001	5YR
63	6.064838	124.491212	0.06909091	0.4	0.33090909	2001	5YR
64	6.062321	124.492337	0.308888882	0	-0.308888882	2001	5YR
65	6.063859	124.492539	0.047463976	0	-0.047463976	2001	5YR
66	6.06341	124.494973	0.276666671	0.3	0.023333329	2001	5YR
67	6.063515	124.495076	0.230000004	0.5	0.269999996	2001	5YR
68	6.064634	124.494922	0.076379307	0.3	0.223620693	2001	5YR
69	6.065433	124.496741	0.134827584	0.2	0.065172416	2001	5YR
70	6.065957	124.496187	0.047463976	0	-0.047463976	2001	5YR
71	6.067647	124.496897	0.076379307	0	-0.076379307	2001	5YR
72	6.069322	124.498269	0.047463976	0	-0.047463976	2001	5YR
73	6.07318	124.49967	0.047463976	0	-0.047463976	2001	5YR
74	6.072888	124.498034	0.047463976	0	-0.047463976	2001	5YR
75	6.072175	124.498758	0.047463976	0	-0.047463976	2001	5YR
76	6.071966	124.499685	1.600000024	0.9	-0.700000024	2001	5YR
77	6.071586	124.500248	0.047463976	0.2	0.152536024	2001	5YR
78	6.071515	124.500254	1.595000029	1.5	-0.095000029	2001	5YR
79	6.071702	124.500731	1.495000005	1	-0.495000005	2001	5YR
80	6.071889	124.500644	0.230000004	0.3	0.069999996	2001	5YR
81	6.072074	124.500799	0.222857147	0	-0.222857147	2001	5YR
82	6.071905	124.501051	0.120000005	0	-0.120000005	2001	5YR
83	6.072518	124.50124	0.207777768	0	-0.207777768	2001	5YR
84	6.070264	124.501779	0.451000005	0.9	0.448999995	2001	5YR
85	6.069964	124.501519	0.560000002	0.5	-0.060000002	2001	5YR
86	6.068328	124.501941	0.451000005	0.2	-0.251000005	2001	5YR
87	6.06966	124.506182	0.047463976	0.2	0.152536024	2001	5YR
88	6.068856	124.50736	0.047463976	0.2	0.152536024	2001	5YR
89	6.065805	124.506686	0.047463976	0	-0.047463976	2001	5YR
90	6.06546	124.509336	0.047463976	0	-0.047463976	2001	5YR
91	6.066007	124.510913	0.047463976	0	-0.047463976	2001	5YR
92	6.066704	124.509117	0.076379307	0	-0.076379307	2001	5YR
93	6.066065	124.508352	0.076379307	0	-0.076379307	2001	5YR
94	6.065309	124.504156	0.07923077	0	-0.07923077	2001	5YR
95	6.064899	124.503413	0.116428569	0	-0.116428569	2001	5YR
96	6.063802	124.503062	0.223636359	0	-0.223636359	2001	5YR
97	6.063302	124.502158	0.047463976	0	-0.047463976	2001	5YR
98	6.061404	124.501602	0.223636359	0.3	0.076363641	2001	5YR
99	6.070074	124.499959	0.37833333	1.3	0.92166667	2001	5YR
100	6.070735	124.513767	0.134827584	1.3	1.165172416	2001	5YR

101	6.072442	124.51417	0.134827584	1.5	1.365172416	2001	5YR
102	6.074244	124.515337	0.133846149	1.5	1.366153851	2001	5YR
103	6.076993	124.516635	0.043809522	1.5	1.456190478	2001	5YR
104	6.079532	124.515731	0.222857147	1	0.777142853	2001	5YR
105	6.080422	124.515481	0.164444447	1	0.835555553	2001	5YR
106	6.081795	124.516285	0.355000019	1	0.644999981	2001	5YR
107	6.049902	124.516616	0.047463976	0.1	0.052536024	2001	5YR
108	6.046784	124.506969	0.167999998	0.1	-0.067999998	2001	5YR
109	6.0446	124.505759	0.047463976	0	-0.047463976	2001	5YR
110	6.042257	124.504967	0.047463976	0.1	0.052536024	2001	5YR
111	6.039998	124.5031	0.207777768	0.1	-0.107777768	2001	5YR
112	6.038947	124.501339	0.127333328	0.1	-0.027333328	2001	5YR
113	6.037866	124.501025	0.047463976	0	-0.047463976	2001	5YR
114	6.037787	124.500833	0.088	0.1	0.012	2001	5YR
115	6.036563	124.500729	0.116428569	0.1	-0.016428569	2001	5YR
116	6.037295	124.500056	0.171111122	0.1	-0.071111122	2001	5YR
117	6.035678	124.50014	0.043809522	0.2	0.156190478	2001	5YR
118	6.036409	124.501294	0.164444447	0.5	0.335555553	2001	5YR
119	6.037168	124.501816	0.047463976	0.1	0.052536024	2001	5YR
120	6.038258	124.499079	0.107000001	0.2	0.092999999	2001	5YR
121	6.037709	124.499313	0.523750007	0.2	-0.323750007	2001	5YR
122	6.038033	124.498536	0.116428569	0.2	0.083571431	2001	5YR
123	6.038559	124.497664	0.088	0.1	0.012	2001	5YR
124	6.0392	124.496791	0.451000005	0	-0.451000005	2001	5YR
125	6.039113	124.497469	0.451000005	0.2	-0.251000005	2001	5YR
126	6.039181	124.497466	0.451000005	0.2	-0.251000005	2001	5YR
127	6.040178	124.497551	0.06909091	0	-0.06909091	2001	5YR
128	6.039718	124.498311	0.06909091	0.1	0.03090909	2001	5YR
129	6.039013	124.499732	0.047463976	0.2	0.152536024	2001	5YR
130	6.038173	124.500646	0.047463976	0.3	0.252536024	2001	5YR
131	6.038037	124.499915	0.122500002	0.2	0.077499998	2001	5YR
132	6.037693	124.500357	0.070416667	0.1	0.029583333	2001	5YR
133	6.04081	124.500225	0.047463976	0.1	0.052536024	2001	5YR
134	6.040959	124.501964	0.047463976	0.1	0.052536024	2001	5YR
135	6.041544	124.501879	0.070416667	0.4	0.329583333	2001	5YR
136	6.042282	124.500506	0.134827584	0.4	0.265172416	2001	5YR
137	6.043099	124.499872	0.116428569	1	0.883571431	2001	5YR
138	6.04346	124.498558	0.335555553	0.6	0.264444447	2001	5YR
139	6.044246	124.49749	0.047463976	0.6	0.552536024	2001	5YR
140	6.045066	124.496626	0.043809522	0.9	0.856190478	2001	5YR
141	6.045847	124.496123	0.076379307	0.9	0.823620693	2001	5YR
142	6.046573	124.495384	0.07923077	0.5	0.42076923	2001	5YR
143	6.047109	124.494817	0.076379307	0.3	0.223620693	2001	5YR
144	6.048133	124.497901	0.047463976	0.3	0.252536024	2001	5YR
145	6.051144	124.499635	0.06909091	0.3	0.23090909	2001	5YR
146	6.051209	124.50098	0.06769231	0.1	0.03230769	2001	5YR
147	6.051616	124.502605	0.047463976	0.1	0.052536024	2001	5YR
148	6.052765	124.501498	0.171111122	0.1	-0.071111122	2001	5YR
149	6.05369	124.502281	0.047463976	0	-0.047463976	2001	5YR
150	6.052886	124.503285	0.122500002	0	-0.122500002	2001	5YR
151	6.052539	124.503997	0.047463976	0.1	0.052536024	2001	5YR
152	6.051886	124.504641	0.047463976	0.1	0.052536024	2001	5YR
153	6.050937	124.505369	0.047463976	0.2	0.152536024	2001	5YR

154	6.050216	124.506502	0.293333322	0	-0.293333322	2001	5YR
155	6.048044	124.507666	0.389999986	0	-0.389999986	2001	5YR
156	6.049333	124.509785	0.889999986	0.4	-0.489999986	2001	5YR
157	6.058875	124.5088	0.276666671	0.1	-0.176666671	2001	5YR
158	6.058271	124.493616	0.06909091	0.4	0.33090909	2001	5YR
159	6.058759	124.49265	0.047463976	0.4	0.352536024	2001	5YR
160	6.057204	124.491818	0.107000001	0	-0.107000001	2001	5YR
161	6.054942	124.489223	0.047463976	0	-0.047463976	2001	5YR
162	6.053248	124.486828	0.06909091	0.4	0.33090909	2001	5YR
163	6.052787	124.484157	0.223636359	0.6	0.376363641	2001	5YR
164	6.052392	124.484284	0.127333328	0.5	0.372666672	2001	5YR
165	6.051106	124.484909	0.381999999	0.5	0.118000001	2001	5YR
166	6.048154	124.486211	0.047463976	0.5	0.452536024	2001	5YR
167	6.04594	124.488678	0.107000001	1.3	1.192999999	2001	5YR
168	6.044361	124.489751	0.047463976	0.5	0.452536024	2001	5YR
169	6.044806	124.488175	0.047463976	0.5	0.452536024	2001	5YR
170	6.045117	124.487619	0.047463976	0.5	0.452536024	2001	5YR
171	6.044257	124.487229	0.122500002	1	0.877499998	2001	5YR
172	6.04374	124.487867	0.047463976	1	0.952536024	2001	5YR
173	6.044783	124.488084	0.047463976	1	0.952536024	2001	5YR
174	6.044929	124.488415	0.164444447	1	0.835555553	2001	5YR
175	6.045598	124.489483	0.120000005	1	0.879999995	2001	5YR
176	6.045458	124.48918	0.07923077	0.9	0.82076923	2001	5YR
177	6.045834	124.488811	0.06769231	1	0.93230769	2001	5YR
178	6.045174	124.489318	0.085000001	1	0.914999999	2001	5YR
179	6.045647	124.489641	0.120000005	1	0.879999995	2001	5YR
180	6.046934	124.48966	0.047463976	1	0.952536024	2001	5YR
181	6.046249	124.489266	0.047463976	0.4	0.352536024	2001	5YR
182	6.051422	124.485823	0.337500006	0.4	0.062499994	2001	5YR
183	6.054227	124.486123	0.122500002	0.5	0.377499998	2001	5YR
184	6.054856	124.481592	0.06909091	1.2	1.13090909	2001	5YR
185	6.054252	124.491913	0.144000009	0.5	0.355999991	2001	5YR
186	6.053871	124.492687	0.047463976	0.5	0.452536024	2001	5YR
187	6.053781	124.493072	0.335555553	1	0.664444447	2001	5YR
188	6.053914	124.493883	0.07923077	1	0.92076923	2001	5YR
189	6.055892	124.493992	0.133846149	0.1	-0.033846149	2001	5YR
190	6.05714	124.494979	0.133846149	0.1	-0.033846149	2001	5YR
191	6.056819	124.493775	0.164444447	1	0.835555553	2001	5YR
192	6.056451	124.495068	0.047463976	1.3	1.252536024	2001	5YR
193	6.056683	124.495684	0.076379307	1	0.923620693	2001	5YR
194	6.056751	124.495848	0.047463976	1	0.952536024	2001	5YR
195	6.056494	124.496424	0.047463976	1	0.952536024	2001	5YR
196	6.056279	124.496896	0.047463976	0.9	0.852536024	2001	5YR
197	6.055838	124.496908	0.047463976	1	0.952536024	2001	5YR
198	6.055583	124.4967	0.076379307	0.8	0.723620693	2001	5YR
199	6.054828	124.496416	0.047463976	0.7	0.652536024	2001	5YR
200	6.053712	124.496051	0.047463976	1	0.952536024	2001	5YR
201	6.052899	124.495554	0.37833333	1	0.62166667	2001	5YR
202	6.052231	124.495014	0.164444447	1	0.835555553	2001	5YR
203	6.050818	124.49454	0.047463976	0.8	0.752536024	2001	5YR
204	6.04833	124.492965	0.043809522	0.8	0.756190478	2001	5YR
205	6.051581	124.492121	0.222857147	0.9	0.677142853	2001	5YR
206	6.057791	124.49397	0.047463976	1.7	1.652536024	2001	5YR

207	6.057982	124.499034	0.047463976	0.8	0.752536024	2001	5YR
208	6.046482	124.498724	0.134827584	0.1	-0.034827584	2001	5YR
209	6.043979	124.51167	0.076379307	0	-0.076379307	2001	5YR
210	6.04261	124.511878	0.070416667	0	-0.070416667	2001	5YR
211	6.043281	124.510692	0.222857147	0	-0.222857147	2001	5YR
212	6.042135	124.510335	0.06769231	0	-0.06769231	2001	5YR
213	6.034337	124.510299	0.043809522	0.2	0.156190478	2001	5YR
214	6.033206	124.50342	0.171111122	0	-0.171111122	2001	5YR
215	6.032232	124.505094	0.523750007	0	-0.523750007	2001	5YR
216	6.031733	124.506893	0.323333323	0.3	-0.023333323	2001	5YR
217	6.029749	124.50797	0.047463976	1	0.952536024	2001	5YR
218	6.028913	124.510958	0.134827584	0.1	-0.034827584	2001	5YR
219	6.0286	124.51224	0.06909091	0	-0.06909091	2001	5YR
220	6.027127	124.514012	0.047463976	0	-0.047463976	2001	5YR
221	6.03246	124.516648	0.043809522	0	-0.043809522	2001	5YR
222	6.035377	124.513252	0.134827584	0	-0.134827584	2001	5YR
223	6.036237	124.515151	0.047463976	0	-0.047463976	2001	5YR
224	6.039302	124.516843	0.047463976	0	-0.047463976	2001	5YR
225	6.044282	124.519559	0.047463976	0	-0.047463976	2001	5YR
226	6.047365	124.523349	0.047463976	0	-0.047463976	2001	5YR
227	6.054121	124.526015	0.308888882	0.5	0.191111118	2001	5YR
228	6.061725	124.531231	0.00	0.4	0.4	2001	5YR
229	6.06428	124.544666	0.00	0.3	0.3	2001	5YR
230	6.053756	124.547566	0.00	0.5	0.5	2001	5YR
231	6.05313	124.545908	0.00	0.5	0.5	2001	5YR
232	6.050507	124.546502	0.047463976	0.4	0.352536024	2001	5YR
233	6.050174	124.539124	0.047463976	0.4	0.352536024	2001	5YR
234	6.048053	124.539035	0.06769231	0	-0.06769231	2001	5YR
235	6.048146	124.537839	0.06769231	0	-0.06769231	2001	5YR
236	6.043675	124.537337	0.047463976	0	-0.047463976	2001	5YR
237	6.036011	124.533535	0.047463976	0.2	0.152536024	2001	5YR
238	6.034283	124.535219	0.00	0.2	0.2	2001	5YR
239	6.034258	124.534897	0.06909091	0.3	0.23090909	2001	5YR
240	6.033723	124.533887	0.00	0.3	0.3	2001	5YR
241	6.031858	124.535306	0.00	0.3	0.3	2001	5YR
242	6.028091	124.535306	0.00	0.5	0.5	2001	5YR
243	6.026979	124.535282	0.00	0.5	0.5	2001	5YR
244	6.035968	124.53529	0.00	0	0	2001	5YR
245	6.03633	124.532723	0.00	0	0	2001	5YR
246	6.03789	124.53302	0.00	0	0	2001	5YR
247	6.037163	124.530877	0.043809522	0	-0.043809522	2001	5YR
248	6.035876	124.529345	0.043809522	0.1	0.056190478	2001	5YR
249	6.059306	124.530197	0.043809522	0	-0.043809522	2001	5YR
250	6.062513	124.49827	0.043809522	0	-0.043809522	2001	5YR
251	6.061614	124.499033	0.043809522	0	-0.043809522	2001	5YR
252	6.058115	124.496582	0.043809522	0	-0.043809522	2001	5YR
253	6.058129	124.495684	0.047463976	0.6	0.552536024	2001	5YR
254	6.057289	124.493766	0.047463976	0.6	0.552536024	2001	5YR
255	6.061944	124.486363	0.047463976	0	-0.047463976	2001	5YR
256	6.062394	124.487364	0.047463976	0	-0.047463976	2001	5YR
257	6.056834	124.486192	0.047463976	1.5	1.452536024	2001	5YR
258	6.056221	124.50028	0.047463976	0	-0.047463976	2001	5YR
259	6.056396	124.500362	0.047463976	0	-0.047463976	2001	5YR

260	6.057524	124.501491	0.047463976	0	-0.047463976	2001	5YR
261	6.056416	124.50237	0.047463976	0	-0.047463976	2001	5YR
262	6.054562	124.502613	0.047463976	0	-0.047463976	2001	5YR
263	6.054542	124.50204	0.047463976	0.3	0.252536024	2001	5YR
264	6.050225	124.502033	0.047463976	0.1	0.052536024	2001	5YR
265	6.053726	124.500462	0.047463976	0.5	0.452536024	2001	5YR
266	6.055343	124.503821	0.047463976	0.5	0.452536024	2001	5YR
267	6.056303	124.505529	0.047463976	0.5	0.452536024	2001	5YR
268	6.056265	124.506731	0.047463976	0.5	0.452536024	2001	5YR
269	6.057129	124.508159	0.047463976	0	-0.047463976	2001	5YR
270	6.056949	124.508763	0.047463976	0.6	0.552536024	2001	5YR
271	6.063946	124.508281	0.047463976	0.6	0.552536024	2001	5YR
272	6.064404	124.51863	0.047463976	0.6	0.552536024	2001	5YR
273	6.068402	124.519407	0.047463976	1	0.952536024	2001	5YR
274	6.066832	124.506038	0.047463976	1	0.952536024	2001	5YR
275	6.067614	124.504792	0.047463976	1	0.952536024	2001	5YR
276	6.06799	124.504689	0.047463976	1	0.952536024	2001	5YR
277	6.055381	124.504114	0.047463976	0.4	0.352536024	2001	5YR
278	6.054148	124.48729	0.047463976	0.1	0.052536024	2001	5YR
279	6.054469	124.481129	0.06769231	0.3	0.23230769	2001	5YR
280	6.053966	124.480686	0.06909091	0	-0.06909091	2001	5YR
281	6.053782	124.48099	0.070416667	0	-0.070416667	2001	5YR
282	6.054375	124.480153	0.070416667	0.5	0.429583333	2001	5YR
283	6.05422	124.479404	0.070416667	0.15	0.079583333	2001	5YR
284	6.054355	124.47929	0.070416667	0	-0.070416667	2001	5YR
285	6.05376	124.478081	0.076379307	0.15	0.073620693	2001	5YR
286	6.053738	124.478183	0.076379307	0.5	0.423620693	2001	5YR
287	6.052681	124.477687	0.076379307	1.2	1.123620693	2001	5YR
288	6.052752	124.476361	0.085000001	0	-0.085000001	2001	5YR
289	6.05334	124.476249	0.085000001	0	-0.085000001	2001	5YR
290	6.048192	124.475028	0.120000005	0.6	0.479999995	2001	5YR
291	6.047475	124.486476	0.122500002	0	-0.122500002	2001	5YR
292	6.048837	124.486268	0.127333328	0	-0.127333328	2001	5YR
293	6.049649	124.484549	0.127333328	1	0.872666672	2001	5YR
294	6.049927	124.480811	0.133846149	1	0.866153851	2001	5YR
295	6.050079	124.480493	0.134827584	1.5	1.365172416	2001	5YR
296	6.050235	124.480278	0.144000009	0.6	0.455999991	2001	5YR
297	6.049538	124.479937	0.171111122	0	-0.171111122	2001	5YR
298	6.056131	124.481038	0.207777768	0	-0.207777768	2001	5YR
299	6.058482	124.468483	0.223636359	0.9	0.676363641	2001	5YR
300	6.063797	124.469186	0.230000004	0.1	-0.130000004	2001	5YR
301	6.067816	124.470666	0.230000004	0.15	-0.080000004	2001	5YR
302	6.054826	124.473241	0.344285697	0.6	0.255714303	2001	5YR
303	6.057823	124.479511	0.75	0.4	-0.35	2001	5YR
304	6.056022	124.48195	1.674999952	2	0.325000048	2001	5YR

Annex 12. Educational Institutions affected by flooding in Saub Flood Plain

Table A-12.1. Educational Institutions Affected by Flooding in the Saub Floodplain

Sarangani				
Maitum				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Malalag National High School	Kalaneg			
New Life Christian Academy	Kalaneg	Low	Low	Low
Patriarch Ambassador College of the Philippines	Kalaneg	Low	Medium	Medium
Day care center	Kiayap		Low	Low
Edenton Mission College, Inc.	Kiayap		Medium	Medium
Kiayap Day Care	Kiayap		Low	Medium
Kiayap Elementary School	Kiayap			
Sison Annex Day Care	Kiayap	Low	Medium	Medium
Sison Elementary School	Kiayap	Medium	Medium	Medium
Maitum Elementary School	Mabay	Low	Low	Medium
Malalag Day Care Center	Mabay		Low	Low
School	Mabay		Medium	Medium
School	Mabay		Medium	Medium
AUSAID	Malalag		High	High
Maitum Life Outreach Academy	Malalag		Medium	Medium
Malaglag Elementary School	Malalag	Low	Medium	High
Malalag Day Care	Malalag	Low	Medium	Medium
Notre Dame of Maitum	Malalag		Medium	High
School	Malalag		Medium	Medium

Annex 13. Medical Institutions affected by flooding in Saub Flood Plain

Table A-13.1. Medical Institutions Affected by Flooding in the Saub Floodplain

Sarangani				
Maitum				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Maitum Municipal Hospital	Kalaneg			
Health center	Kiayap		Low	Low
George Y. Yakes Maternity Home	Malalag			
Maitum Municipal Hospital	Malalag			
Rural health unit	Malalag			