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

LiDAR Surveys and Flood Mapping of Cabadbaran River

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

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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
CSU	CARAGA State University
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CABADBARAN RIVER

Enrico C. Paringit, Dr. Eng. and Engr. Meriam M. Santillan, Joy C. Casinginan, Jojene R. Santillan, and Arthur A. Amora

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The 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 Caraga State University (CSU). CSU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 11 river basins in the Northern Mindanao Region. The university is located in Butuan City, Agusan del Norte, Philippines.

1.2 Overview of the Cabadbaran River Basin

Cabadbaran River Basin is located in the western portion of the Island of Mindanao, Philippines. It lies generally between 125032’ to 125042’ east longitude and 907’ to 9013’ north latitude. It covers majority of Cabadbaran City and some portions of Municipality of Santiago in Agusan Del Norte. According to DENR-RCBO it has a drainage area of 215 km2 with an estimated annual run-off of 549 million cubic meters (MCM). The basin covers an area of approximately 240 square kilometers, and is about 21 kilometers long and averages about 26 kilometers in width.

Its main stem, Cabadbaran River, is one of the eleven (11) river systems under the PHIL-LiDAR partner HEI, CARAGA State University. The Cabadbaran River is the principal drainageway of the basin. It originates in the eastern, mountainous portion of Cabadbaran City, Agusan del Norte and traverses the entire length of the basin in a westerly direction and discharges into Butuan Bay. The northwestern tributary which is the Maraput River meets the Cabadbaran River at a junction near Barangay Comagascas, City of Cabadbaran, Agusan Del Norte. From this junction, Cabadbaran River flows towards Butuan Bay at a distance of approximately 7 kilometers. At this portion, the river is navigable by motor boats.

Cabadbaran River is situated in the City of Cabadbaran which has an estimated total population of 73,639 as recorded by the local government in 2015 (cabadbaranadn.gov.pv, 2017). It was politically subdivided into 31 Barangays 4 of which comprises the entire City of Cabadbaran namely, Jose Rizal, Sampaguita, Señora Candelaria and Sunflower. The economic activities in Cabadbaran are agriculture, fishery, and mining. Cabadbaran River is crucial to the economic growth of the city since it supports the Cabadbaran Regional Irrigation System which services a total of 3,213 ha of agricultural land. In Cabadbaran, copra, abaca, rice and corn remain as staple crops. The people’s main sources of living are fishing, corn cropping, logging, tourism and a small-scale gold mining. But new sources of wealth were now derived from the forests and mountains of Agusan.

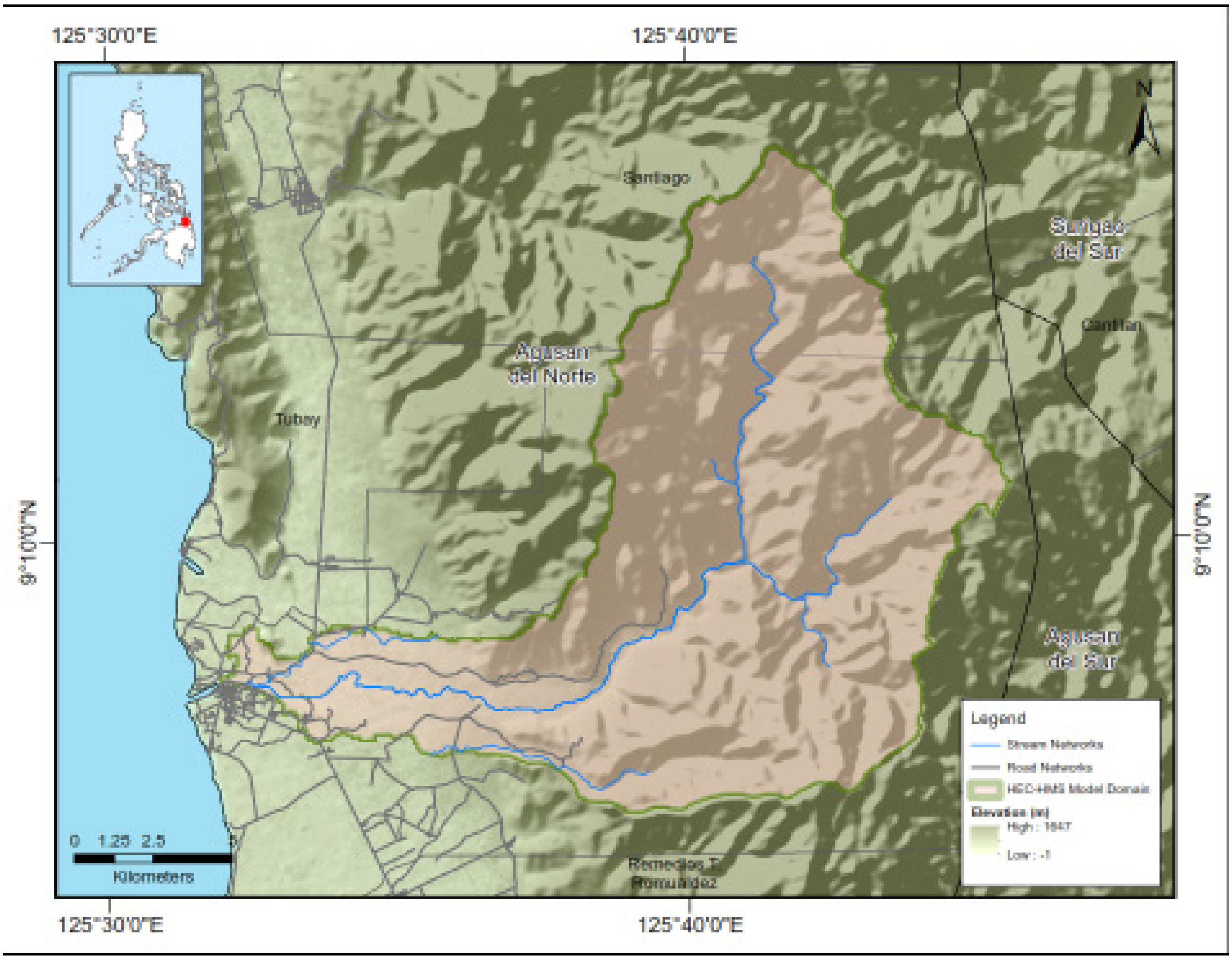

Figure 1. Map of Cabadbaran River Basin

The climate of the basin is Type II, characterized by no dry season but with a very pronounced precipitation period generally during November to January. The seasonal precipitation distribution, which is similar to that of the nearby Agusan River Basin, is caused primarily by the three main seasonal winds that pass through it. The northeast monsoon passes during the period from October to January, the trade wind with an east to southeast direction from February to April, and the southwest monsoon for the rest of the year . During Tropical Depression "Agaton" on January 2014, the city was declared to be in the 'state of calamity' and PDRRMC has recorded that a total of 1,099 families were displaced from the area because of flooding. Coastal barangays in Cabadbaran City are also prone to storm surge because of the swelling of Butuan Bay during typhoons. In addition, the river basin area is also prone to other environmental hazards like earthquakes and storm surges. The Eastern Mindanao Fault lies on the eastern part of Mindanao, cutting the provinces of Agusan del Norte, Agusan del Sur and Compostela Valley.
Region_X_issued_10FEB2014.pdf, 2017).

The basin's highest point is at 2,012 meters above mean sea level situated along the mountain ridges of Barangay Mahaba, City of Cabadbaran, Agusan del Norte . The most abundant soil type in the basin based on maps published by the Department of Agriculture was silt-loam which accounts for 92% of the basin's land area. The basin is mostly covered by open canopy forests and brush land leaving the built-up areas only covering less than 1% of the basin. Built-up areas and communities in the basin are concentrated in Cabadbaran City, particularly in Barangay Caasinan, where one of the tourist spots is located, commonly known as Caasinan Beach. Cabadbaran may be a small city located in the province of Agusan Norte in northeastern Mindanao, but it boasts of a rich culture and heritage, as well as scenic spots, making it a promising tourist destination in the Caraga Region.

The local language of the city is Cebuano. As for the sources of water both rural and urban areas, Cabadbaran City Water District is continuously providing the people with clean water sources from the basin's upstream watersheds. Folks who were living in rural areas could certainly enjoy the unlimited flowing of fresh clean water from the basin's tropical forest. Covered by a diverse ecosystem, the city is preserving and nurturing their natural resources such as the mangrove areas, tropical rain forest and aquatic resources.

CHAPTER 2: LIDAR ACQUISITION IN CABADBARAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Cabadbaran floodplain in Agusan del Norte. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Cabadbaran floodplain survey.

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

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK63A	600	30	18	50	45	130	5
BLK63B	600	30	18	50	45	130	5
BLK63C	600	30	18	50	45	130	5
BLK63D	600	30	18	50	45	130	5

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

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK59A	1000	30	40	100	20	130	5
BLK59B	1000	30	40	100	20	130	5

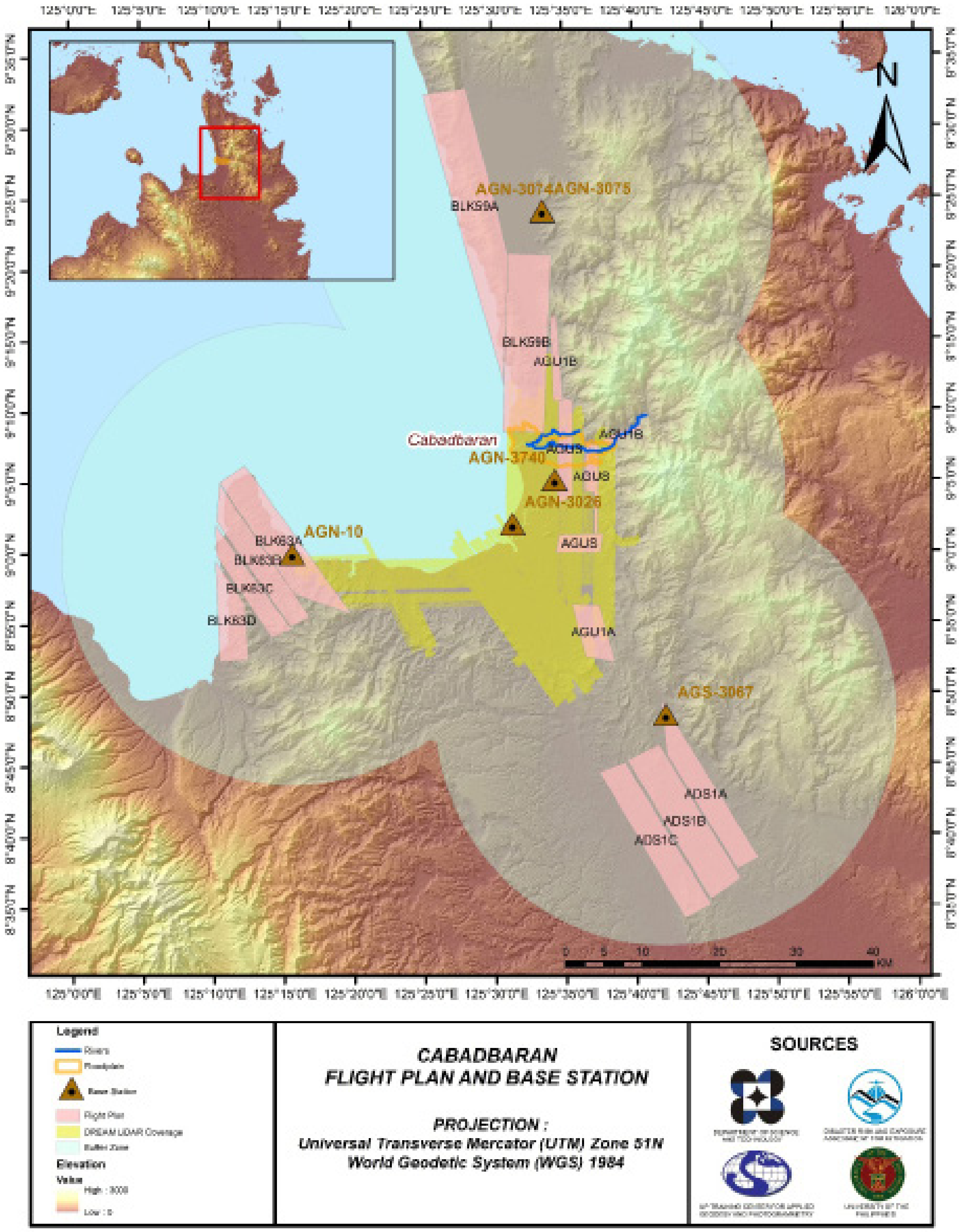

Figure 2. Flight plans and base stations used for Cabadbaran Floodplain

2.2 Ground Base Station

The project team/s was able to recover seven (7) NAMRIA ground control points: SRN-119, which is of second (2nd) order accuracy, AGN-10, which is of third (3rd) order accuracy, and AGN-3026, AGN-3067, AGN-3074, AGN-3075, AGN-3074, which are of fourth (4th) order accuracy. The baseline processing reports for established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 6 – July 3, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS852, and SPS985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Cabadbaran floodplain are shown in Figure 2.

Figure 3 to Figure 9 shows the sets of reference points, control stations and established points, and the ground control points for the entire Cabadbaran Floodplain LiDAR Survey. Table 3 to Table 9 show the details about the NAMRIA reference point and established points, and Table 10 shows the list of all ground control points occupied during the acquisition together with the dates they were utilized during the survey

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

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

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

Figure 4. GPS set-up over AGN-3074 near the entrance gate of Jaliobong National High School at Kitcharao, Agusan Del Norte (a) and NAMRIA reference point AGN-3074 (b) as recovered by the field team.

Table 4. Details of the established control point AGN-3074 used as base station for the LiDAR acquisition.

Station Name	**AGN-3074**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1:10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 24’ 4.13108” North 125° 33’ 31.76634” East 39.759 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	561376.548 meters 1039549.784 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°24 ’0.38679” North 125°33’37.07966” East 107.652 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	781185.928 meters 1040114.043 meters

Figure 5. GPS set-up over AGN-3075 near the flagpole of Jaliobong Elementary School at Kitcharao, Agusan Del Norte (a) and NAMRIA reference point AGN-3075 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point AGN-3075 used as base station for the LiDAR Acquisition.

Station Name	**AGN-3075**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1:10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 24’ 7.19957” North 125° 33’ 29.91739” East 38.994 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	561319.987 meters 1039643.962 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°24 ’3.45501” North 125° 33’ 35.23064” East 106.884 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	781128.795 meters 1040207.949 meters

Figure 6. GPS set-up over AGN-3026 infront of Buhang National High School, Municipality of Magallanes, Agusan del Norte (a) and NAMRIA reference point AGN-3026 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point AGN-3026 used as base station for the LiDAR Acquisition.

Station Name	**AGN-3026**	
Order of Accuracy	**4TH**	
Relative Error (horizontal positioning)	**1 in 10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°02'02.05467" North 125°31'15.59370" East 0.915 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting Northing	557280.19 meters 998929.182 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°01'58.40327" North 125°31'20.94031" East 69.513 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 (UTM 51N PRS 92)	Easting Northing	777,155.999 meters 999,495.498 meters

Figure 7. GPS set-up over AGN-3740 on the bridge at Barangay Sanghan, Cabadbaran, Agusan del Norte (a) and NAMRIA reference point AGN-3740 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point AGN-3740 used as base station for the LiDAR Acquisition.

Station Name	**AGN-3740**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1 in 10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°05’07.75605” North 125°34’15.27340” East 10.495 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	544797.009 meters 1436124.562 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°05’04.09554” North 125°34’20.61487” East 79.105 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	782606.301 meters 1005241.953 meters

Figure 8. GPS set-up over AGS-3067 near the flag pole of San Vicente Elementary School in the Municipality of Sibagat, Agusan del Sur (a) and NAMRIA reference point AGS-3067 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point AGS-3067 used as base station for the LiDAR Acquisition.

Station Name	AGN-3074	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1:10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°48'31.43541" North 125°42'01.74627" East 60.82800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	577062.844 meters 974057.922 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°48'27.85927" North 125°42'7.11122" East 130.34800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	797084.39 meters 974717.59 meters

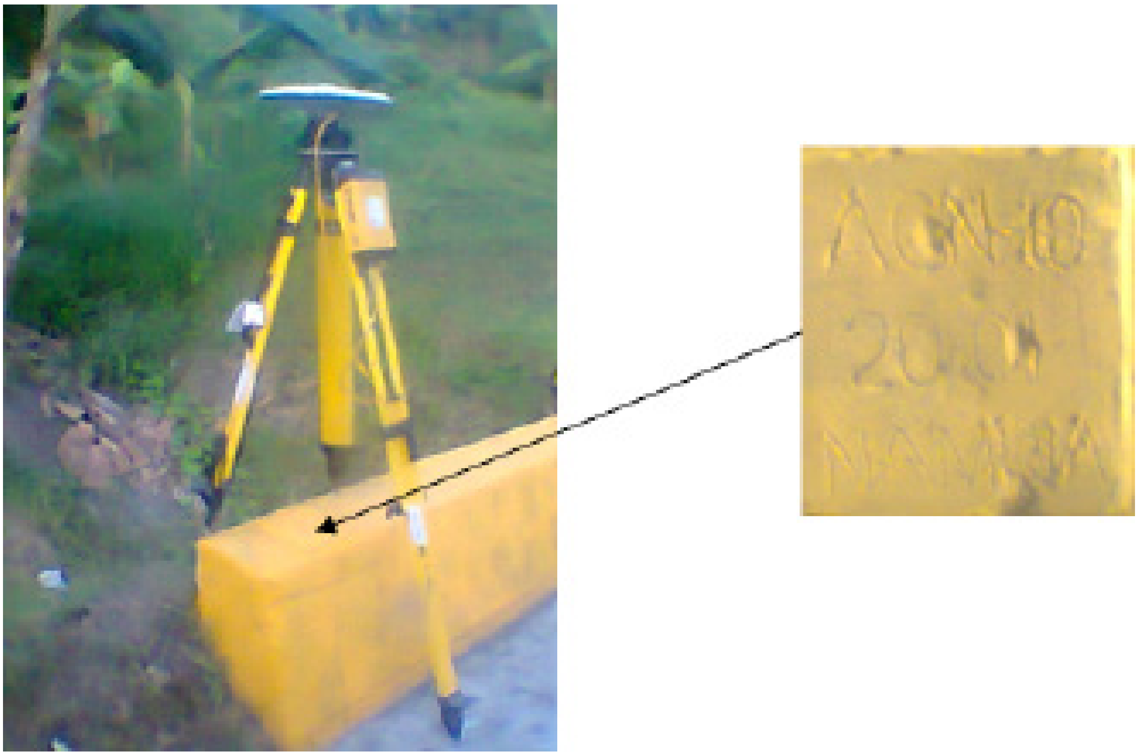

Figure 9. GPS set-up over AGN-10 on top of the concrete gutter of a culvert in Brgy. Tagcatong, Municipality of Carmen, Agusan del Norte (a) and NAMRIA reference point AGN-10 (b) as recovered by the field team.

Table 9. Details of the recovered NAMRIA horizontal control point AGN-10 used as base station for the LiDAR Acquisition.

Station Name	**AGN-3074**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1:10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 24' 4.13108" North 125° 33' 31.76634" East 39.759 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	561376.548 meters 1039549.784 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°24 '0.38679" North 125°33'37.07966" East 107.652 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	781185.928 meters 1040114.043 meters

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
June 20, 2014	1604A	3AGUS171A	AGN-3026, AGN-3740
June 22, 2014	1612A	3AGU1AB173A	AGN-3026
July 1, 2014	1648A	3BLK63DS182A	AGN-10, AGS-3067
July 2, 2014	1652A	3ADS1AS183A	AGS-3067
July 3, 2014	1654A	3ADS1ASB184A	AGS-3067
June 6, 2014	7294GC	2BLK59AB157A	AGN-3074, AGN-3075, SRN-119

2.3 Flight Missions

Three (3) missions under DREAM program covered around fifty (50) square kilometers (Table 11) within Cabadbaran floodplain. Six (6) missions were conducted to Cabadbaran floodplain, for a total of twenty one hour and forty eight minutes (21+48) of flying time for RP-C9122 and RP-C9322. All missions are acquired using the Aquarius and Gemini LiDAR system. Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions under DREAM program which covers Cabadbaran Floodplain.

Flight Number	Mission Name	Area Surveyed within the Floodplain (km2)
207P	1ASNC121A	16.54
209P	1ASD122A	17.72
211P	1ASN1S123A	15.67
TOTAL		49.93

Table 12. Flight missions for the LiDAR data acquisition of the Cabadbaran 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
June 20, 2014	1604A	52.34	84.02	14.35	57.41	909	4	17
June 22, 2014	1612A	41.03	58.23	0.81	69.66	641	4	23
July 1, 2014	1648A	102.06	100.99	-	100.99	NA	2	29
July 2, 2014	1652A	65.10	61.66	-	61.66	NA	2	47
July 3, 2014	1654A	96.76	35.37	-	35.37	NA	3	23
June 6, 2014	7294GC	289.61	231.06	3.87	227.19	NA	4	29
TOTAL		646.90	571.33	19.02	552.61	1550	21	48

Table 13. Actual parameters used during the LiDAR data acquisition of the Gandara Floodplain.

Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (kHz)	Scan Frequency (Hz)	Average Speed (Kts)	Average Turn Time (Minutes)
1604A	600	30	18	50	45	130	5
1612A	600	40, 50	18	50	45	130	5
1648A	600	60	18	50	45	130	5
1652A	600	30, 40	18	50	45	130	5
1654A	600	30	18	50	45	130	5
7294GC	1100	30	40	100	20	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Cabadbaran floodplain (See Annex 7). It is located in the province of Agusan del Norte with majority of the floodplain situated within the city of Cabadbaran City. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 14. Figure 10, on the other hand, shows the actual coverage of the LiDAR acquisition for the Cabadbaran floodplain.

Table 14. The list of municipalities and cities surveyed of the Cabadbaran Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Agusan del Norte	Tubay	107.14	76.51	71%
	Jabonga	269.89	57.63	21%
	Santiago	218.28	42.29	19%
	Remedios T. Romualdez	56.92	9.44	17%
	Cabadbaran City	343.91	54.84	16%
	Butuan City	670.79	58.68	9%
	Mainit Lake	69.28	3.48	5%
	Carmen	122.64	1.32	1%
Agusan del Sur	Bayugan City	328.06	49.79	15%
	Esperanza	851.27	27.92	3%
	Sibagat	640.31	6.37	1%
	Prosperidad	604.35	2.91	0%
Misamis Oriental	Magsaysay	118.05	16.36	14%
Surigao del Norte	Malimono	107.68	19.47	18%
Total		4508.57	427.01	9.47%

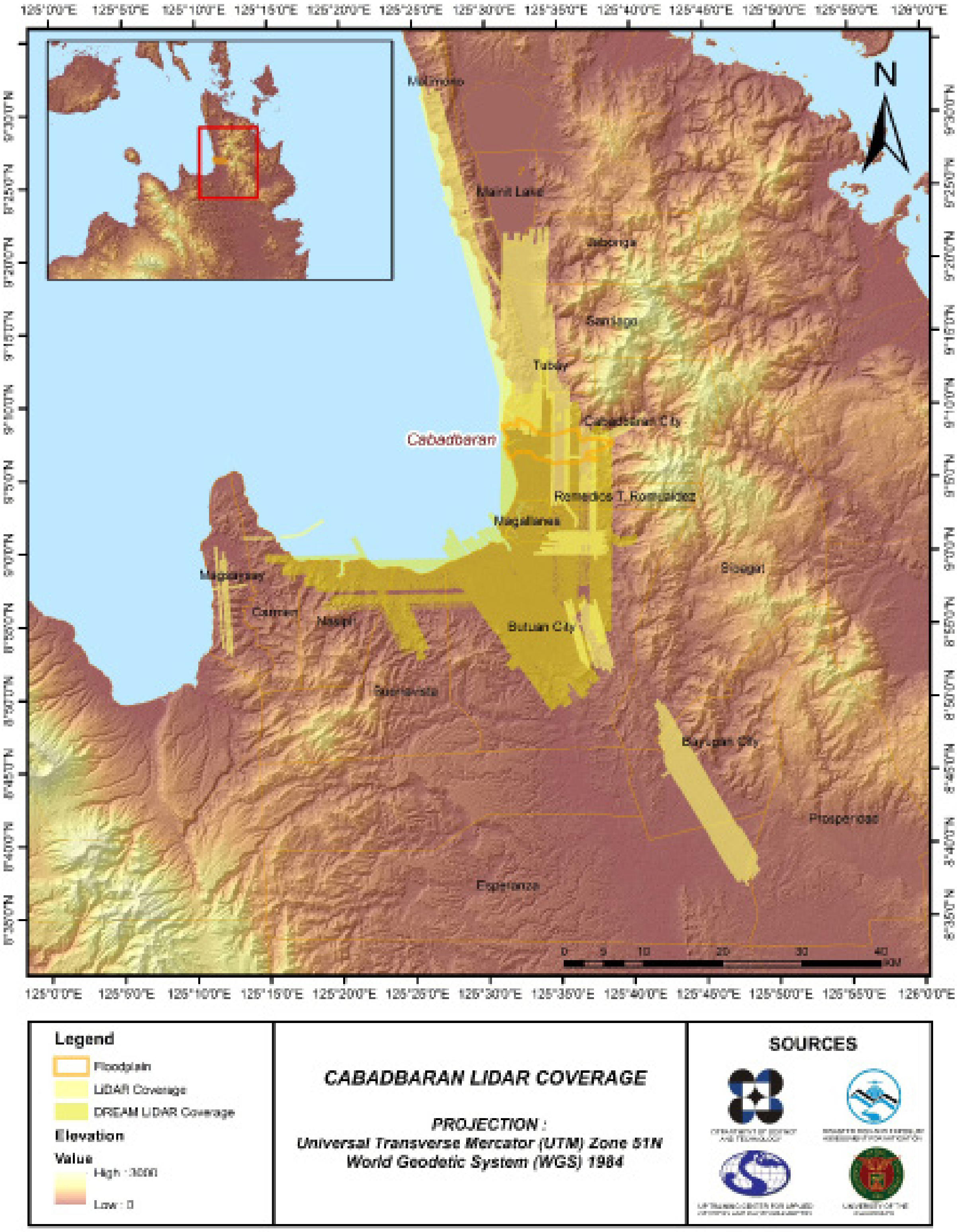

Figure 10. Actual LiDAR data acquisition for Cabadbaran floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR CABADBARAN FLOODPLAIN

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

3.1 Overview of LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 11.

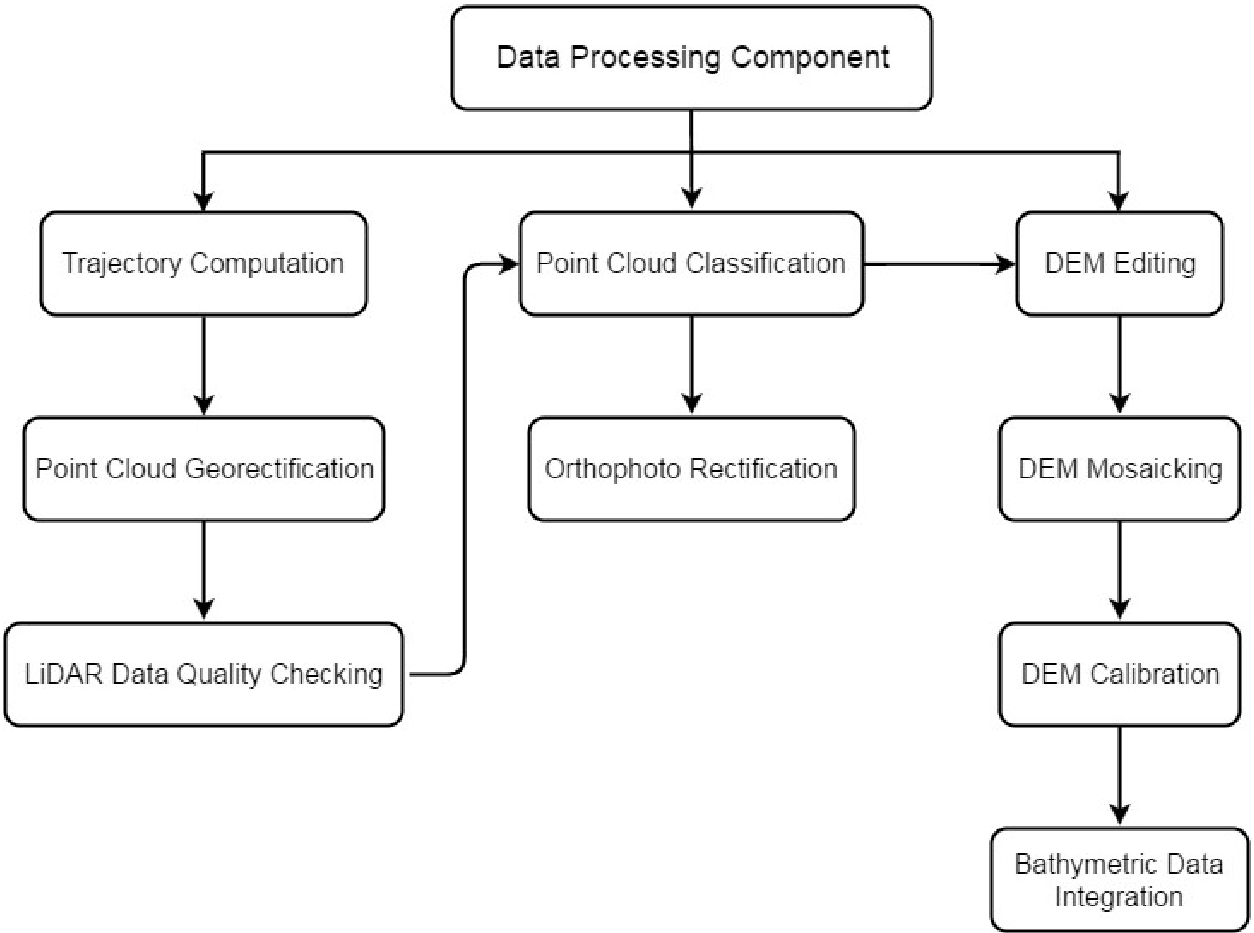


Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Cabadbaran floodplain can be found in Annex 5. Missions flown during the first survey conducted on April and May 2013 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on June and July 2014 were flown using the Aquarius and Gemini system.

The Data Acquisition Component (DAC) transferred a total of 141.90 Gigabytes of Range data, 2.29 Gigabytes of POS data, 165.47 Megabytes of GPS base station data, and 346.50 Gigabytes of raw image data to the data server on May 15, 2013 for the first survey and July 22, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Cabadbaran was fully transferred on July 23, 2016, as indicated on the Data Transfer Sheets for Cabadbaran floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1612A, one of the Cabadbaran flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The sum of these standard deviation values are indicated in the plot as the Trace values. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 22, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

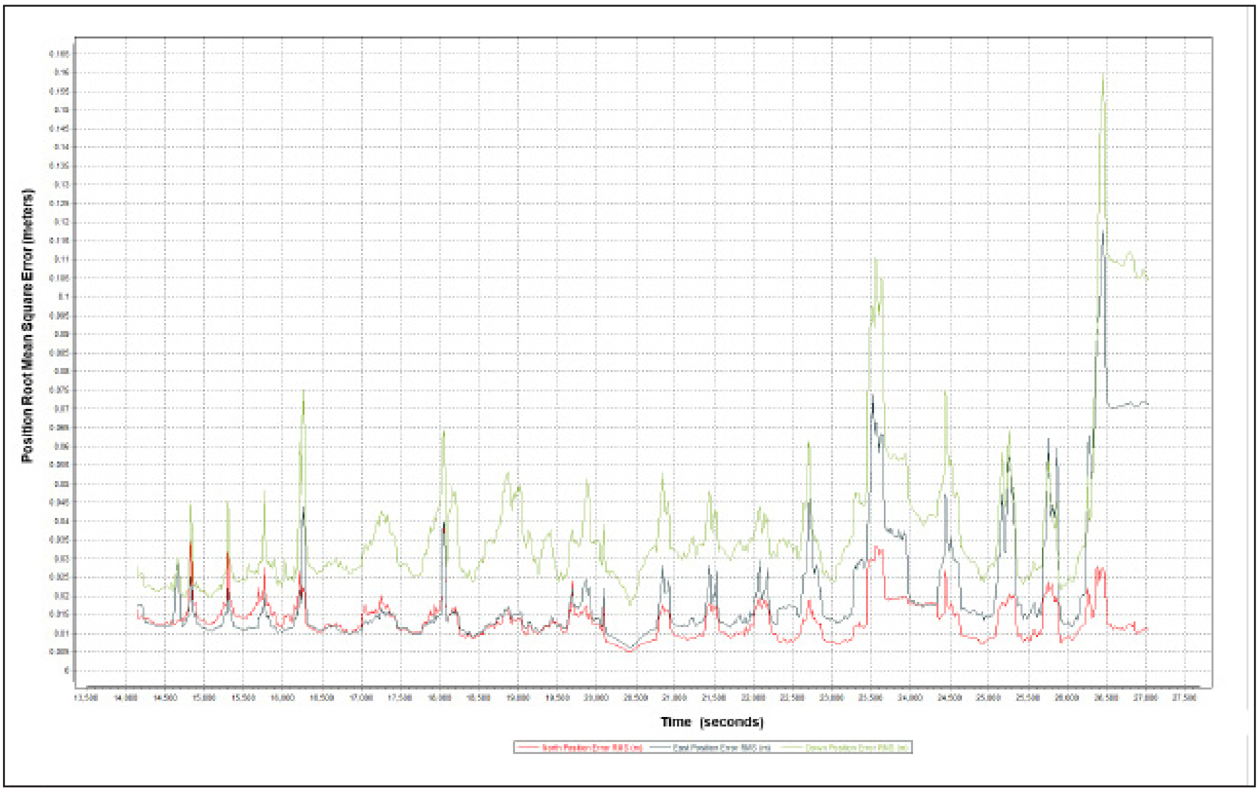


Figure 12. Smoothed Performance Metrics of Cabadbaran Flight 1612A.

The time of flight was from 14000 seconds to 27000 seconds, which corresponds to morning of June 22, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaks at 3.30 centimeters, the East position RMSE peaks at 7.40 centimeters, and the Down position RMSE peaks at 10.50 centimeters, which are within the prescribed accuracies described in the methodology.

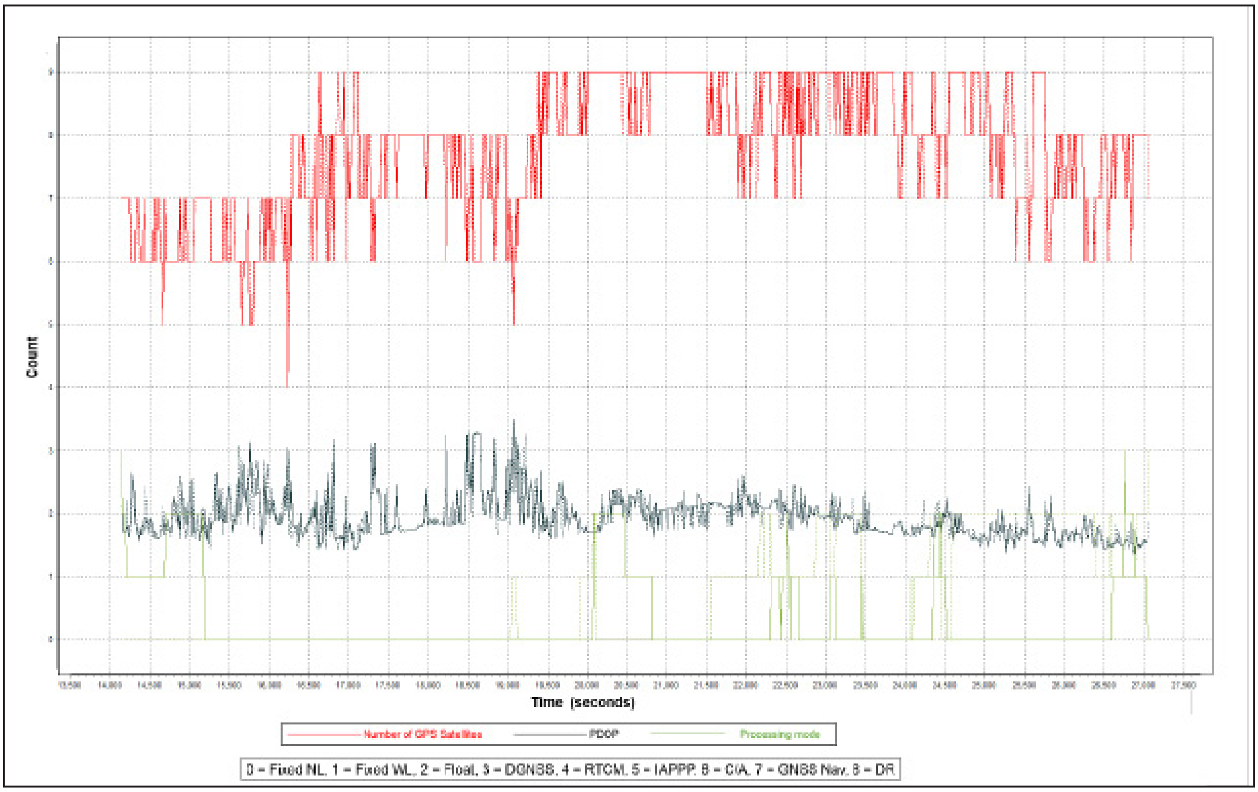


Figure 13. Solution Status Parameters of Cabadbaran Flight 1612A.

The Solution Status parameters of flight 1612A, one of the Cabadbaran flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, is shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 4. Most of the time, the number of satellites tracked was between 5 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 3 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Cabadbaran flights is shown in Figure 14.

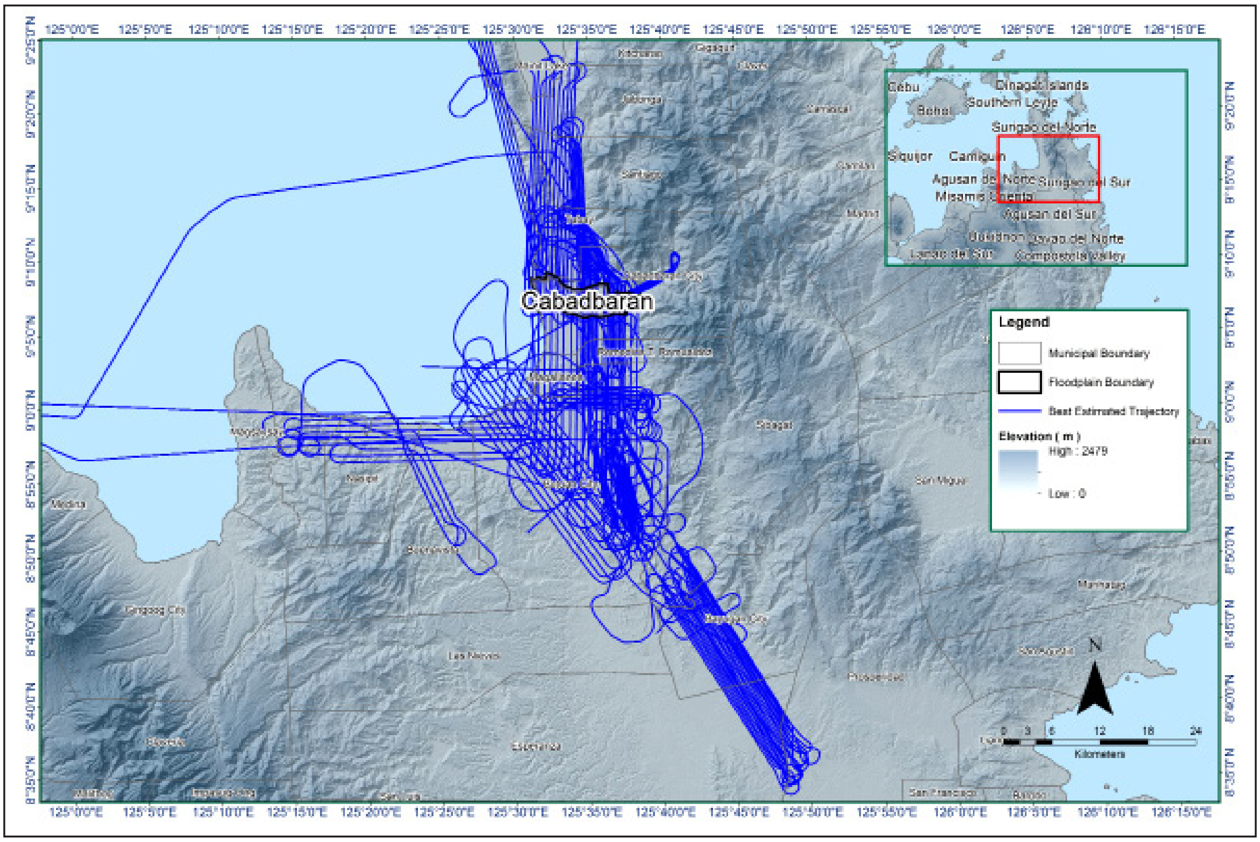


Figure 14. Best estimated trajectory of the LiDAR missions conducted over the Cabadbaran Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 135 flight lines, with each flight line containing one channel for the Gemini and Aquarius systems and two channels for each flight line in the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Cabadbaran floodplain are given in Table 15.

Table 15. Self-calibration Results values for Cabadbaran flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000498
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000523
GPS Position Z-correction stdev	(<0.01meters)	0.0088

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

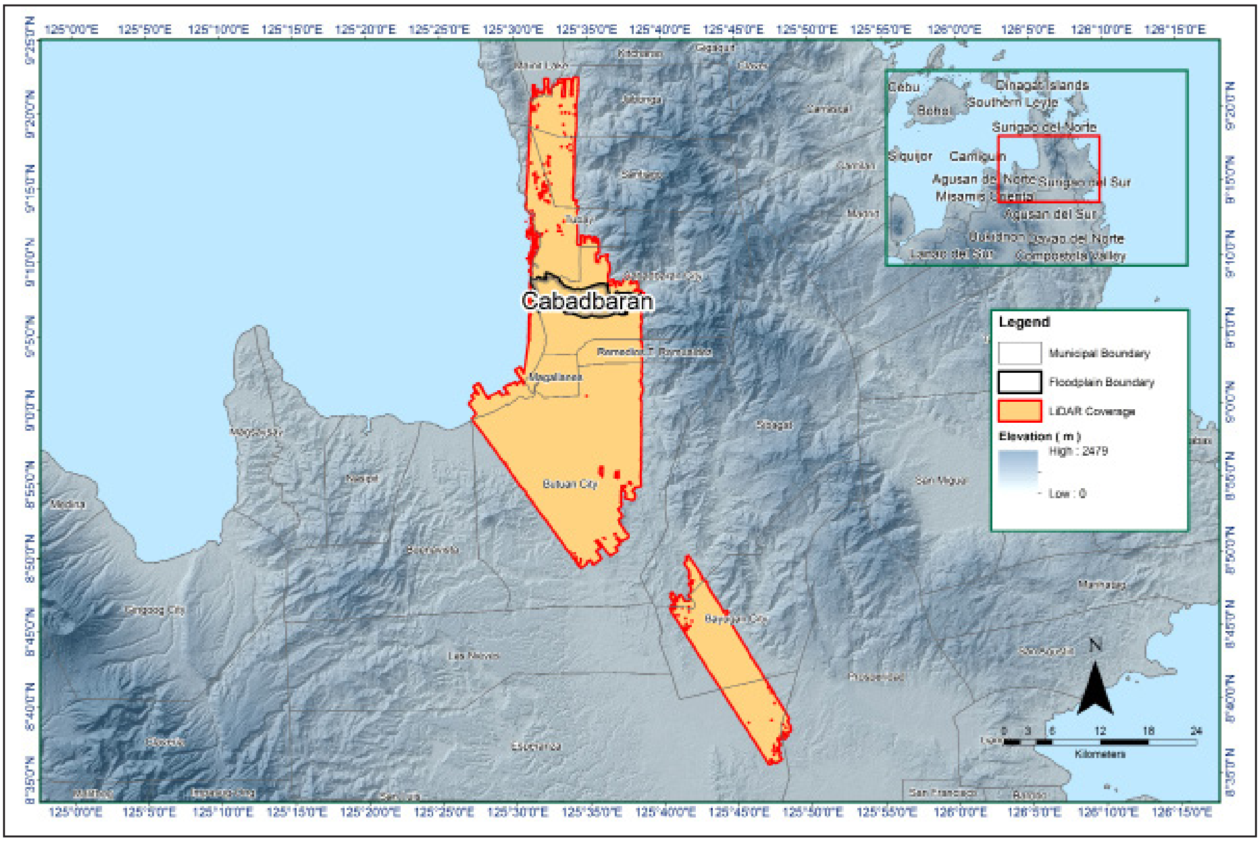


Figure 15. Boundaries of the processed LiDAR data on top of the SAR Elevation Data over the Cabadbaran Floodplain.

The total area covered by the Cabadbaran missions is 1027.68 sq.km that is comprised of ten (10) flight acquisitions grouped and merged into six (6) blocks as shown in in Table 16.

Table 16. List of LiDAR blocks for the Cabadbaran floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Butuan_Agus	1604A	77.79
Butuan_AgusAB	1612A	55.05
Butuan_ASD1A	1648A	124.12
	1652A	
	1654A	
Butuan_Agusan_right	207P	509.96
	209P	
	211P	
Butuan_Agusan_203P	203P	131.31
SurigaoDelNorte_Blk59B	7294GC	128.27
TOTAL		1026.50 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 16. Since the Gemini and Aquarius systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

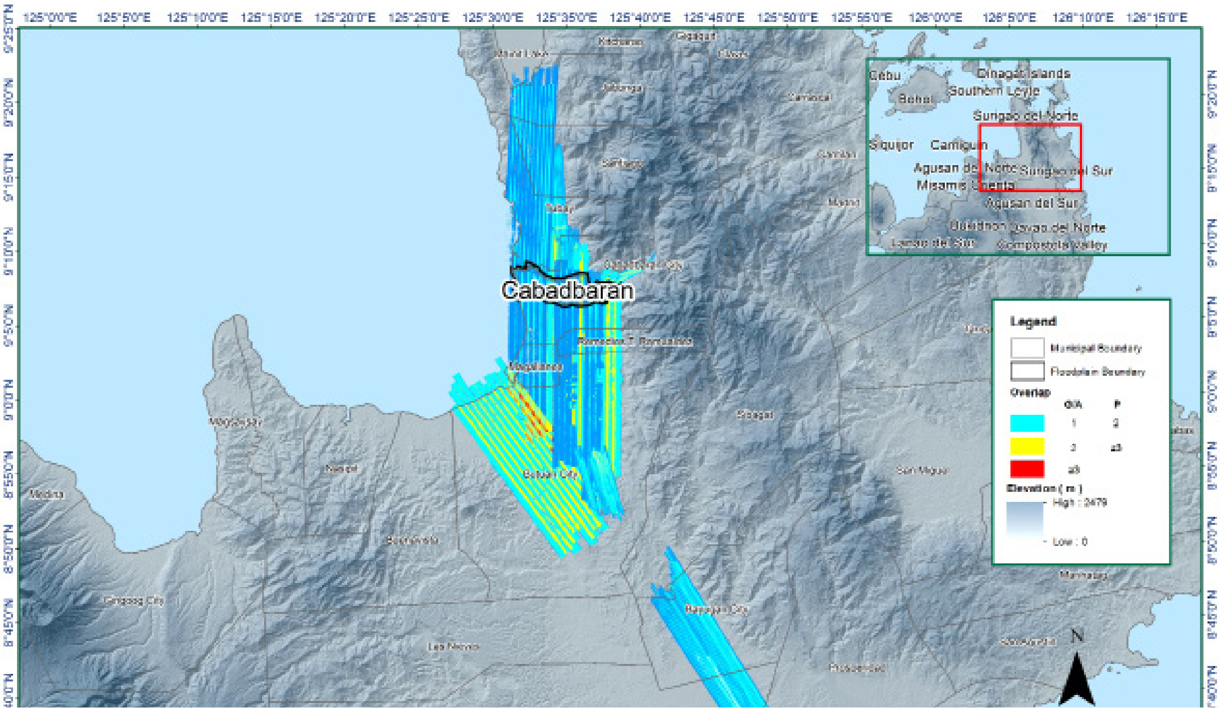


Figure 16. Image of data overlap for Cabadbaran Floodplain.

The overlap statistics per block for the Cabadbaran floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.83% and 54.54% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 17. As seen in the figure below, it was determined that all LiDAR data for the Cabadbaran Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.36 points per square meter.

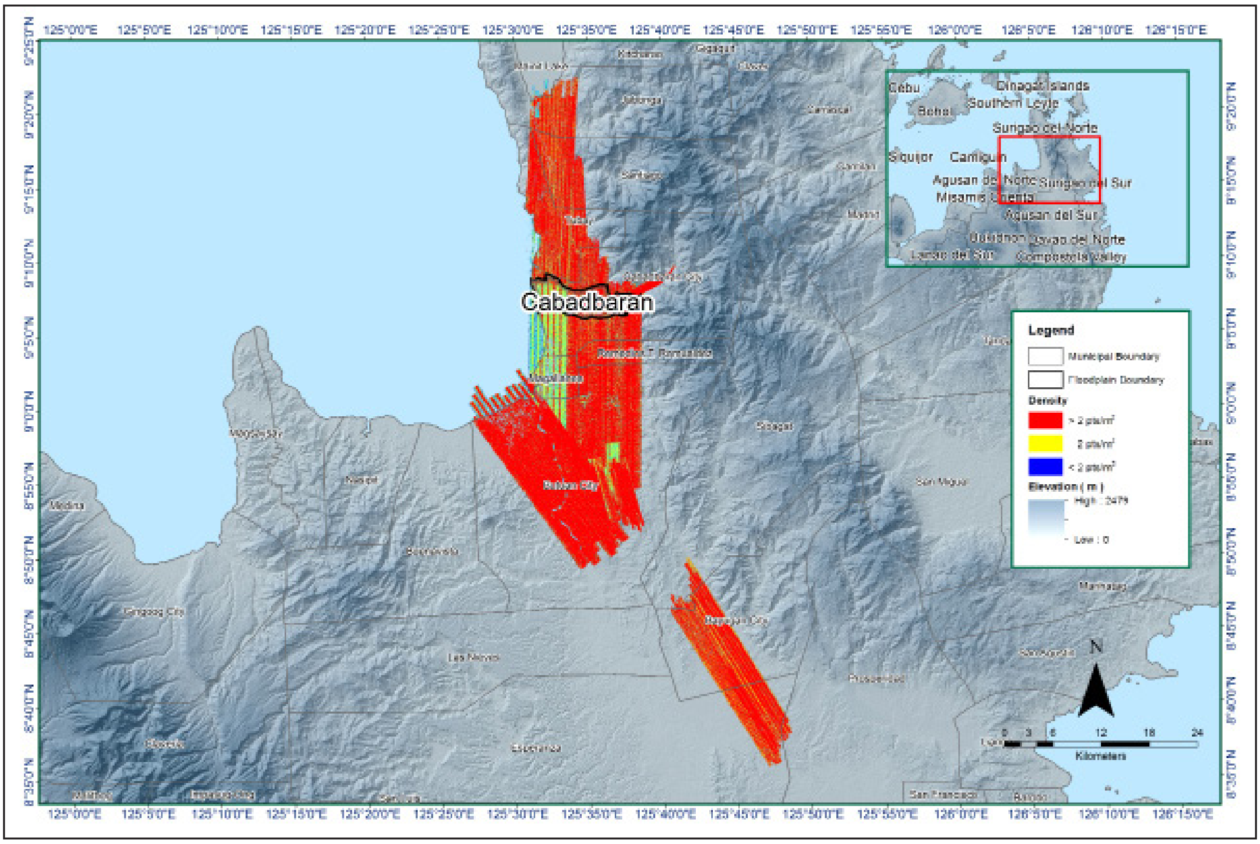


Figure 17. Pulse density map of merged LiDAR data for Cabadbaran Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20 m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

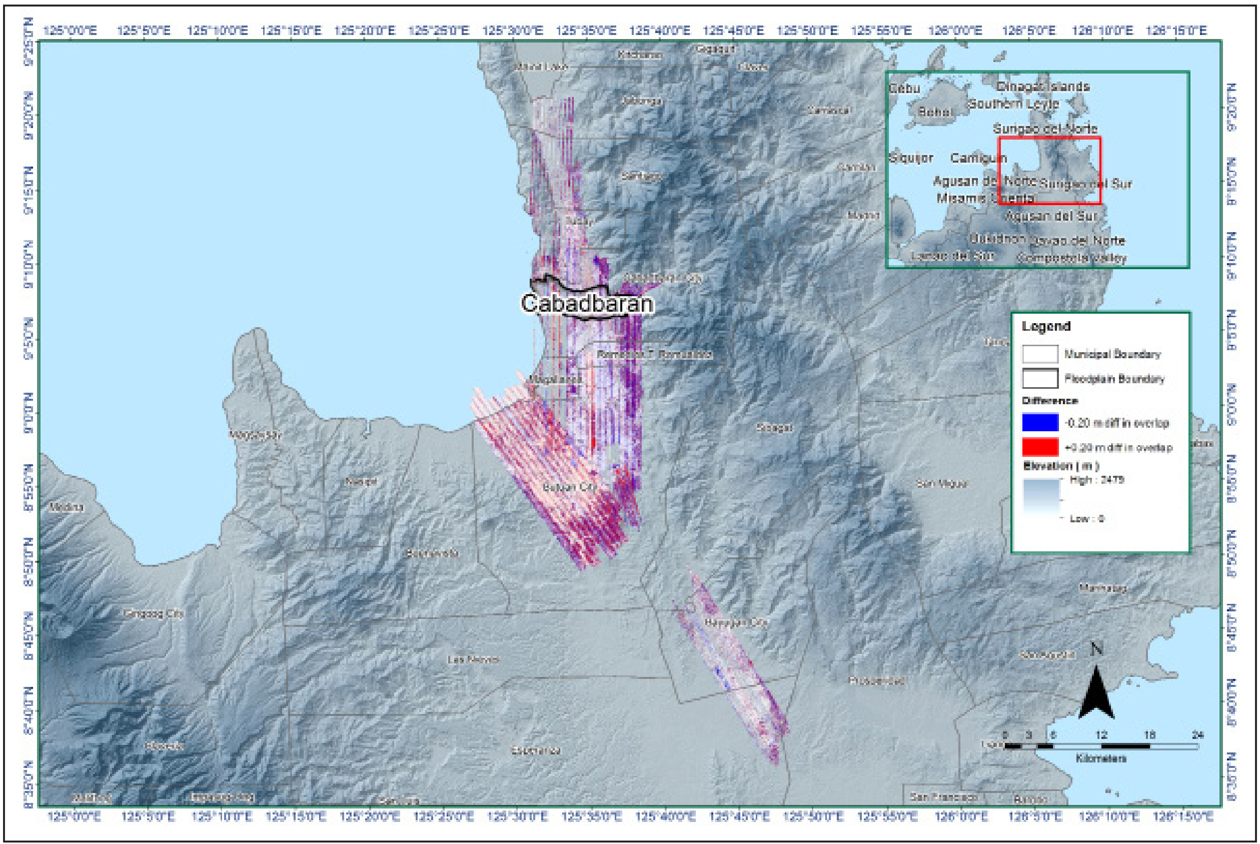


Figure 18. Elevation difference Map between flight lines for the Gandara Floodplain Survey.

A screen-capture of the processed LAS data from Cabadbaran flight 1612A loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

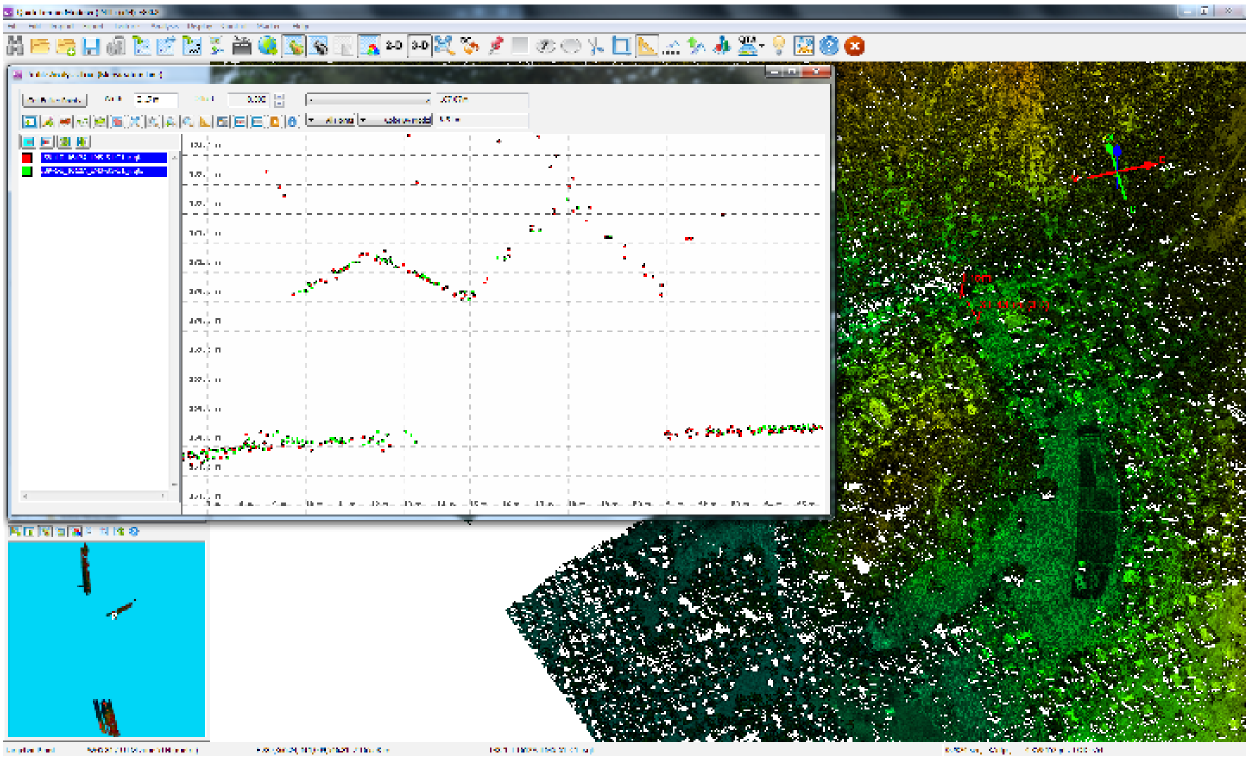


Figure 19. Quality checking for Cabadbaran flight 1612A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Cabadbaran classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	587,405,356
Low Vegetation	542,970,013
Medium Vegetation	629,210,700
High Vegetation	777,216,394
Building	36,817,904

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Gandara floodplain is shown in Figure 20. A total of 1,431 with 1 km. X 1 km tiles (one kilometer by one kilometer) size were produced. Correspondingly, Table 17 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 683.82 meters and 53.91 meters respectively.

Figure 20. Tiles for Cabadbaran Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. The ground points are highlighted in orange, while the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

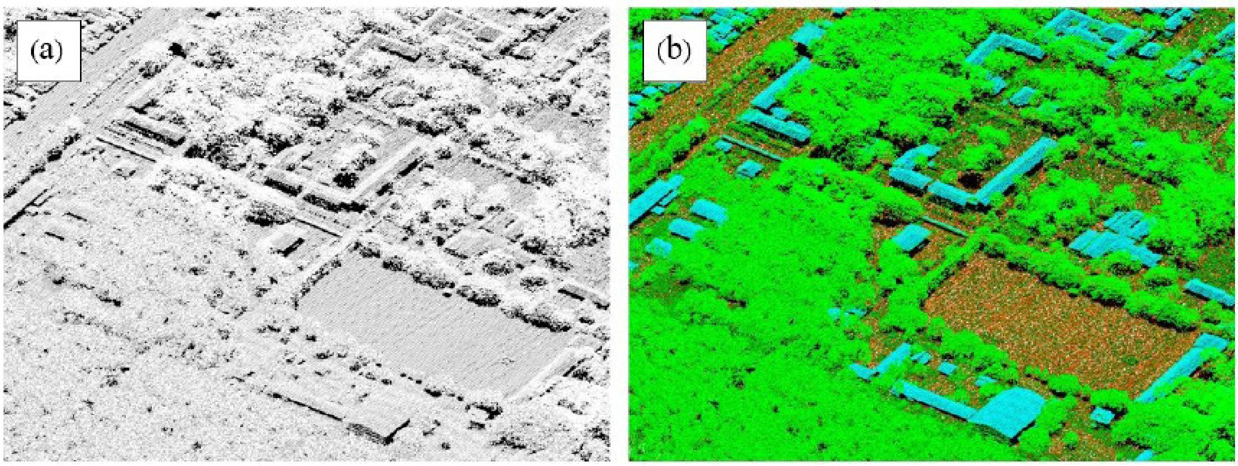


Figure 21. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show in Figure 22. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

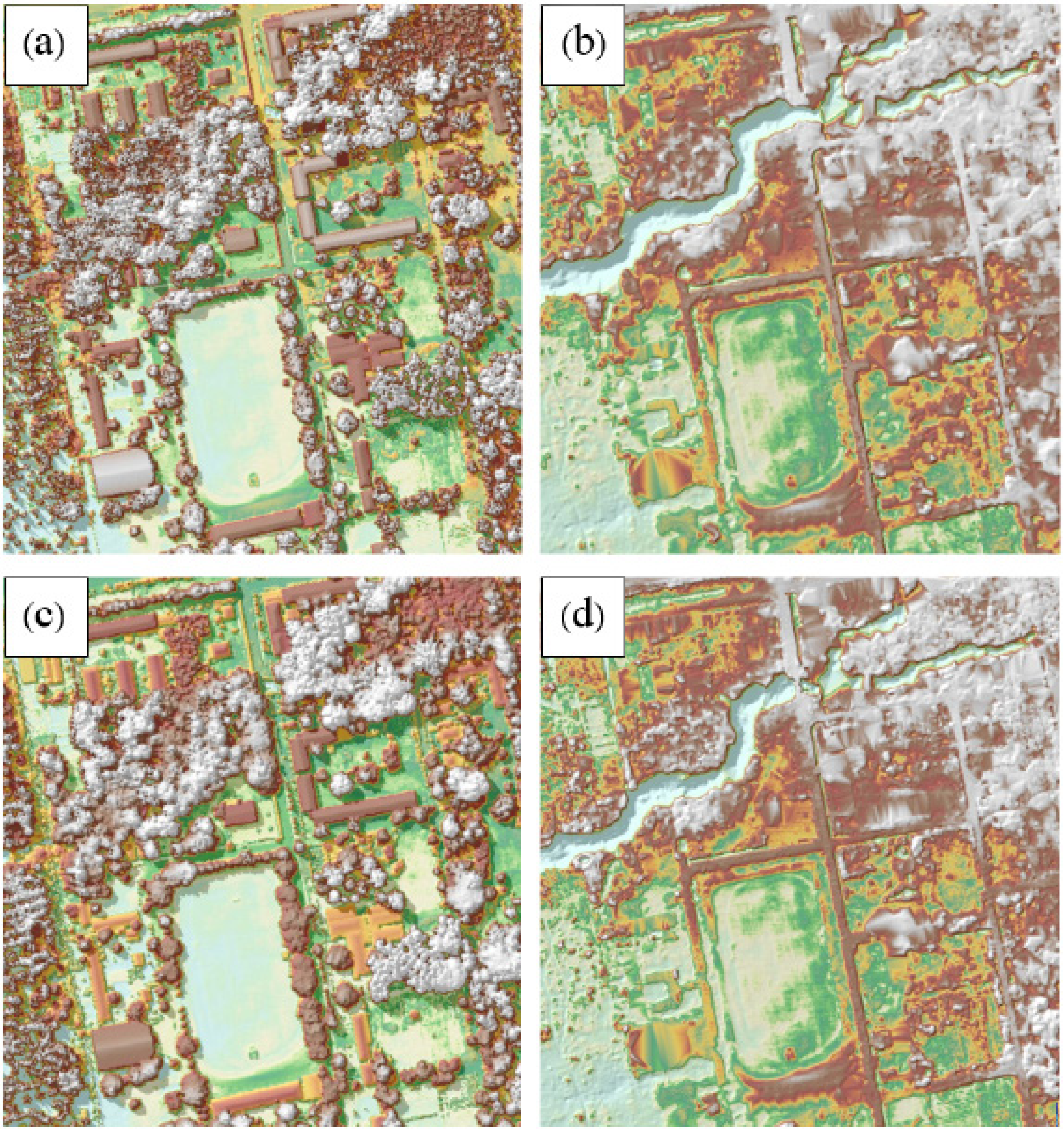


Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Cabadbaran floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,641 with 1km by 1km tiles area covered by the Cabadbaran floodplain is shown in Figure 23. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Cabadbaran floodplain attained a total of 702.36 sq.km orthophotogaph coverage comprised of 4,396 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

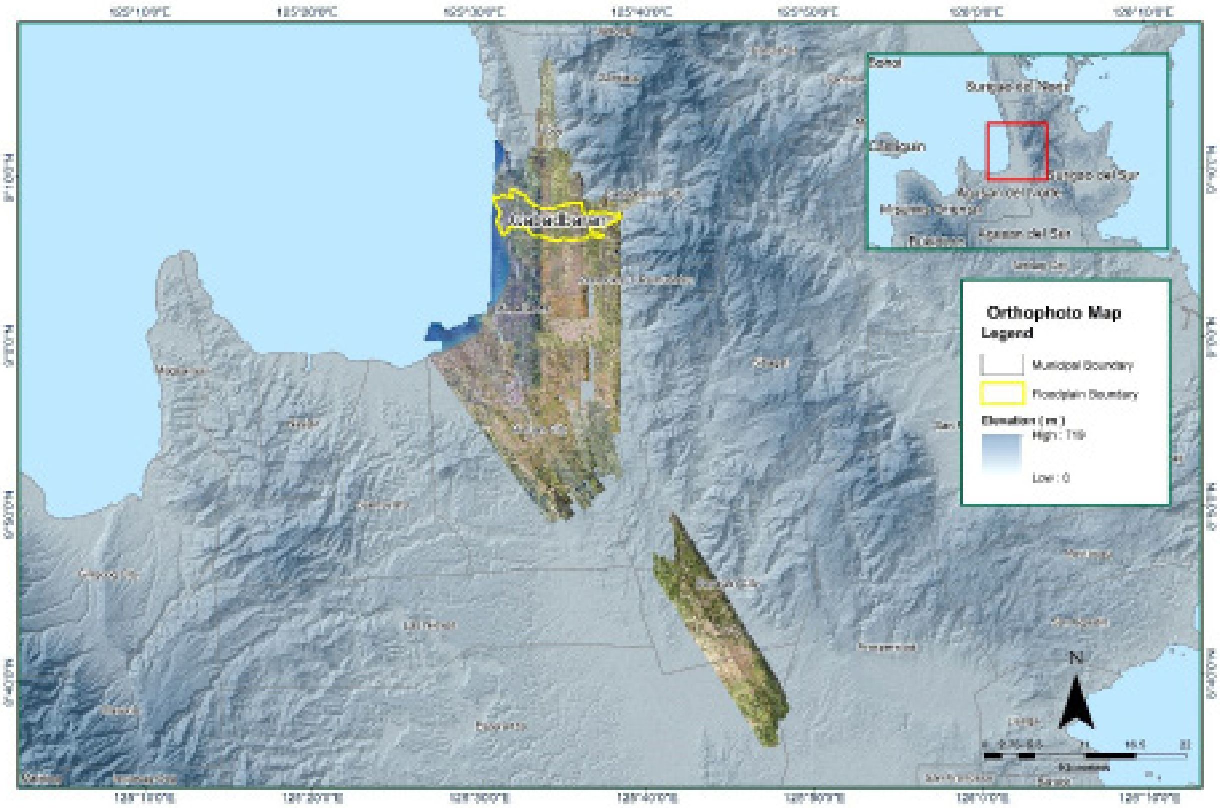


Figure 23. Cabadbaran Floodplain with available orthophotographs.

Figure 24. Sample orthophotograph tiles for Cabadbaran Floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Cabadbaran floodplain. These blocks are composed of Butuan-Agus and Surigao blocks with a total area of 338.95 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Butuan_AgusAB	55.05
Butuan_Agus	77.79
Butuan_ASD1A	124.12
Butuan_Agusan_right	509.96
Butuan_Agusan_203P	131.31
SurigaoDelNorte_Blk59B	128.27
TOTAL	1,026.50 sq.km

Figure 25 shows portions of a DTM before and after manual editing. As evident in the figure, the river embankment (Figure 25a) was misclassified and removed during the classification process and was retrieved and reclassified (Figure 25b) through manual editing to allow the correct water flow. Likewise, the bridge (Figure 25c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 25d).

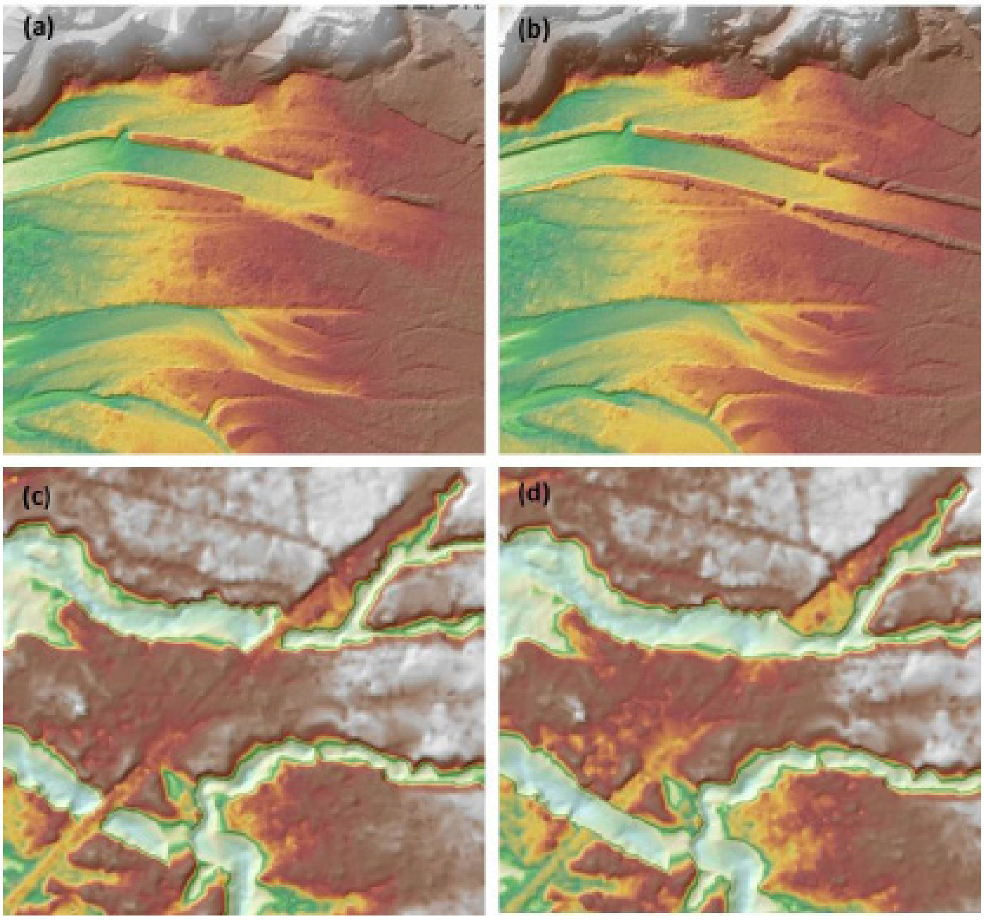


Figure 25. Portions in the DTM of the Cabadbaran Floodplain – mountainous portion (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated asn_csu DEM overlapping with the blocks to be mosaicked. Table 19 shows the shift values applied to the LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Cabadbaran Floodplain is shown in Figure 26. The entire Cabadbaran floodplain is 99.98% covered by LiDAR data while portions with LiDAR data.

Table 19. Shift Values of each LiDAR Block of Cabadbaran floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Butuan_AgusAB	28.00	0.09	1.93
Butuan_Agus	27.00	0.09	-2.21
Butuan_ASD1A	0.00	0.00	0.00
Butuan_Agusan_right	29.40	-0.50	0.00
Butuan_Agusan_203P	28.20	-0.67	0.00
SurigaoDelNorte_Blk59B	27.00	0.09	5.78

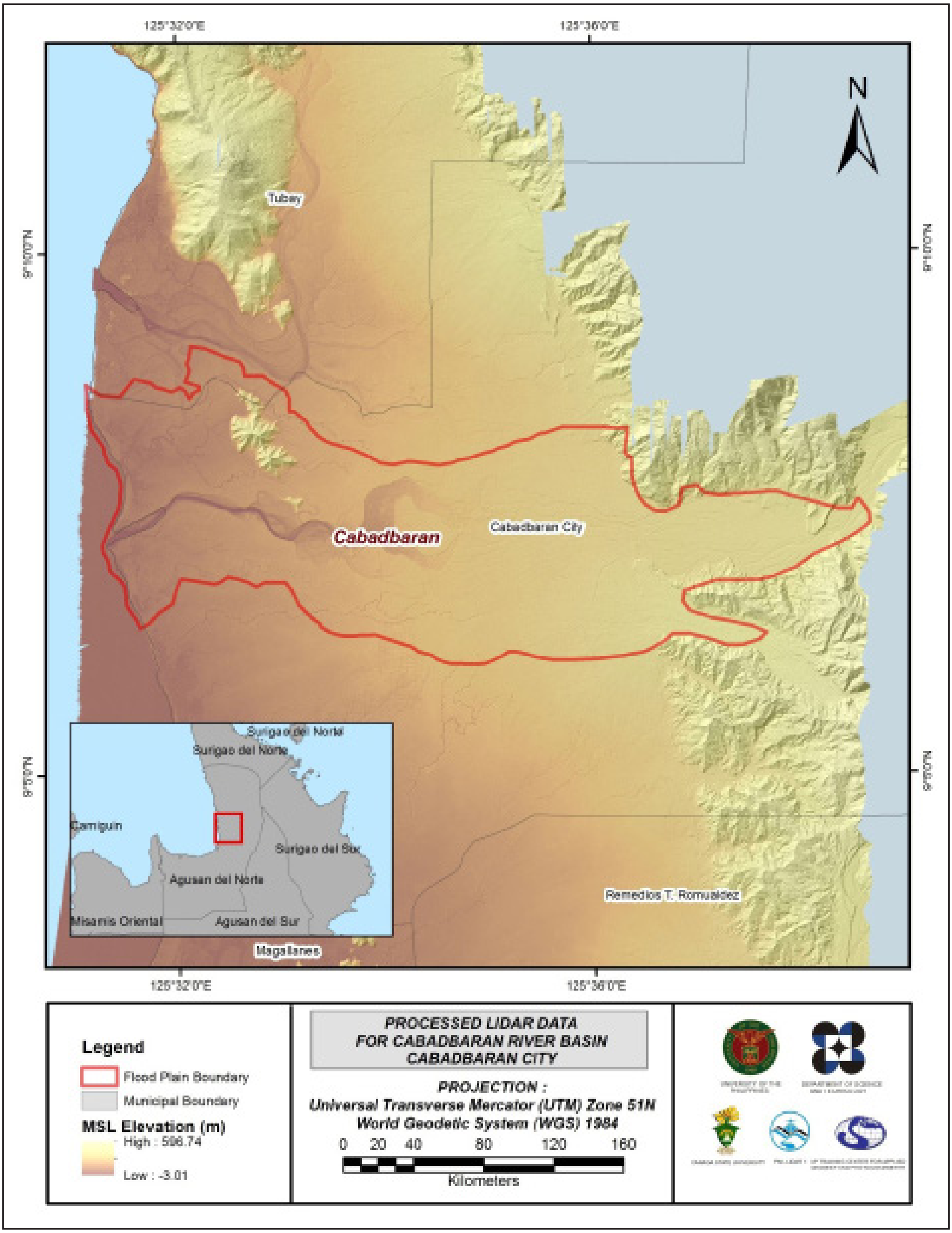


Figure 26. Map of Processed LiDAR Data for Cabadbaran Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Cabadbaran to collect points with which the LiDAR dataset is validated is shown in Figure 27, with the validation survey points highlighted in green. A total of 1,530 survey points were used for calibration and validation of Cabadbaran LiDAR data. However, the point dataset was not utilized because during the mosaicking process, each LiDAR block was already referred to the calibrated Agusan DEM.

A good correlation between the uncalibrated Agusan LiDAR DTM and calibration elevation values is shown in Figure 28. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.12 meters with a standard deviation of 0.10 meters. Calibration of Cabadbaran LiDAR data was done by adding the height difference value, 0.12 meters, to Cabadbaran mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between the Agusan LiDAR data and the calibration data.

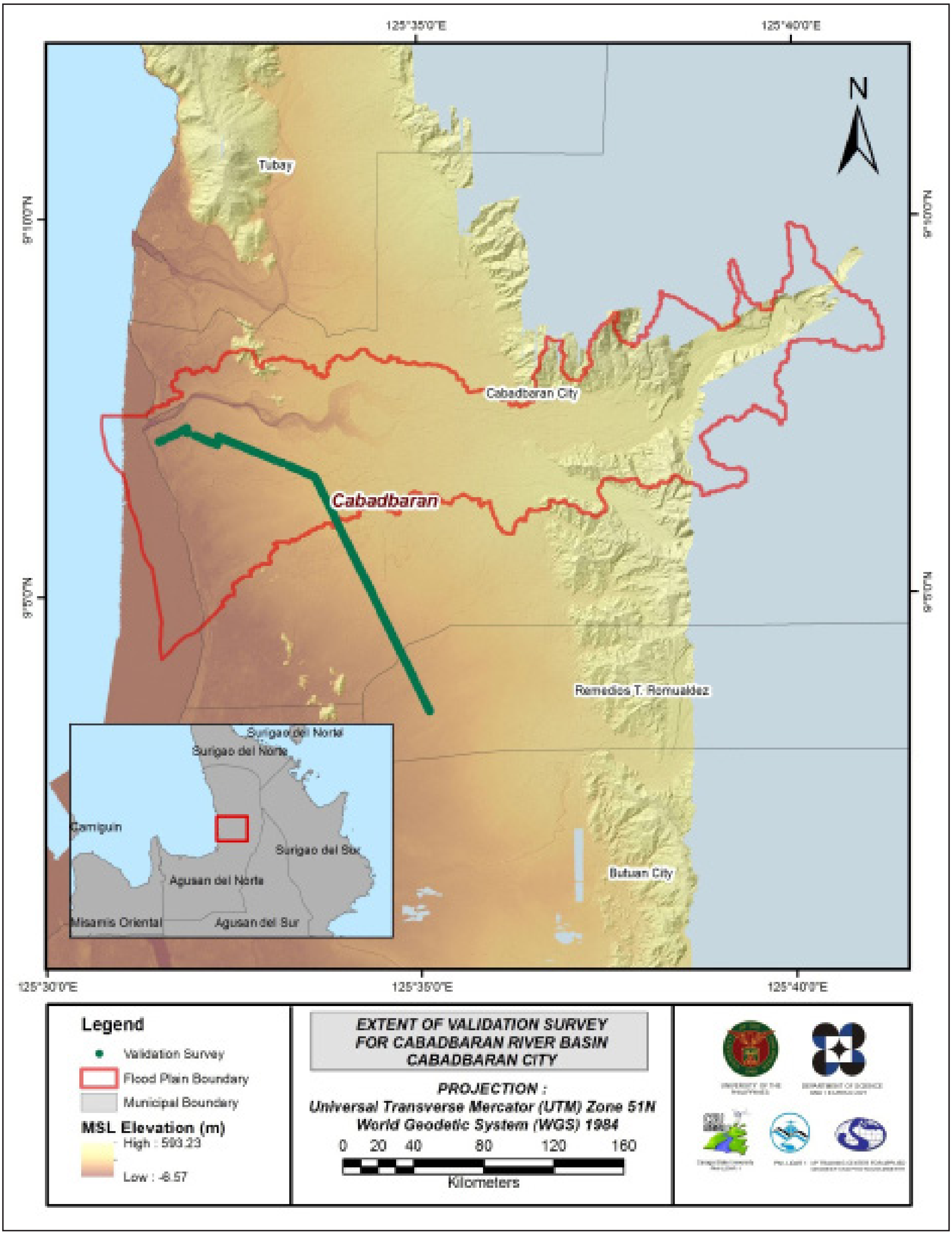


Figure 27. Map of Cabadbaran Floodplain with validation survey points in green.

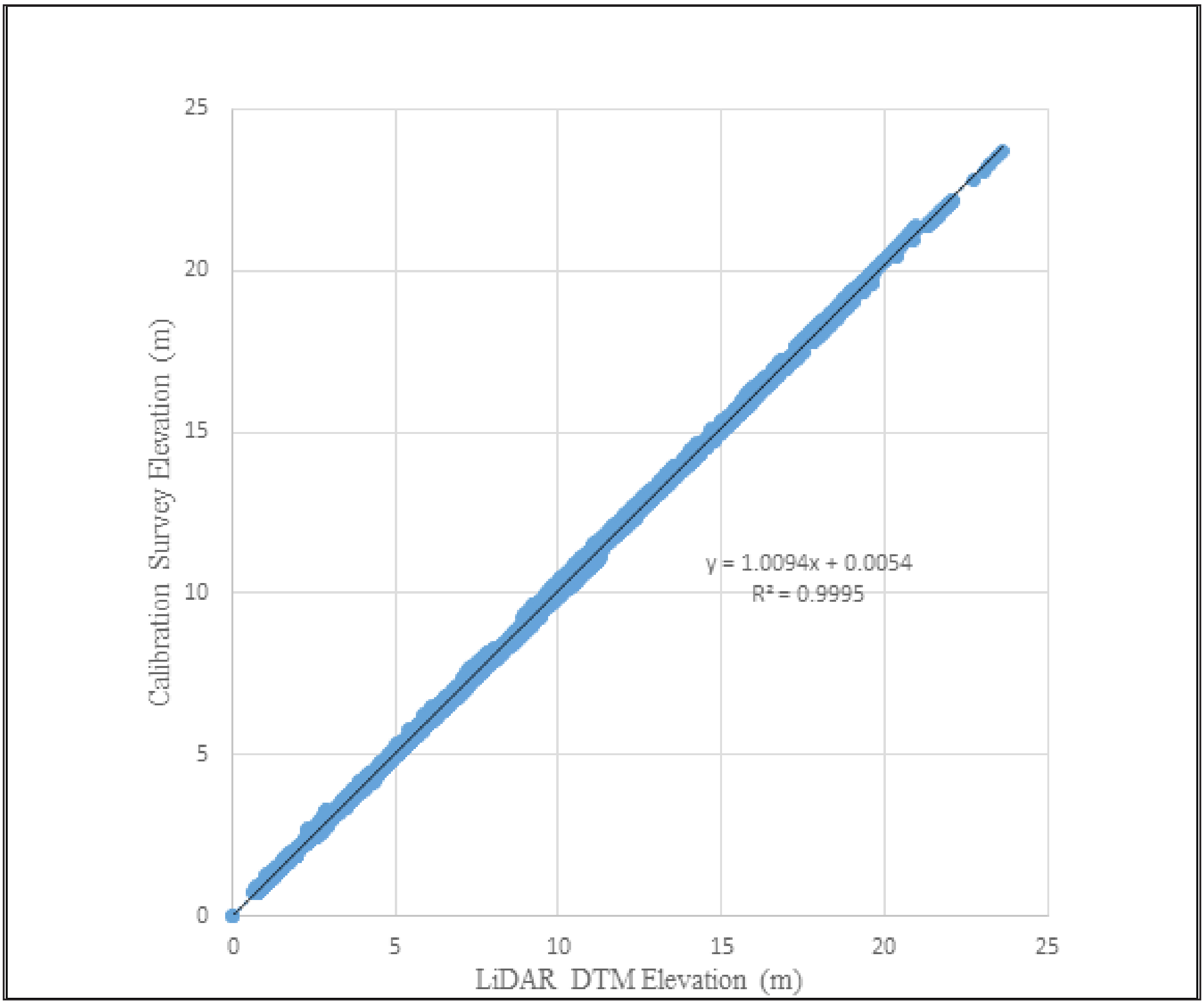


Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 20. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.12
Standard Deviation	0.11
Average	0.07
Minimum	-0.19
Maximum	0.41

The remaining 20% of the total survey points, resulting to 300 points, were used for the validation of calibrated Cabadbaran DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 29. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 1.57 meters with a standard deviation of 0.18 meters, as shown in Table 21.

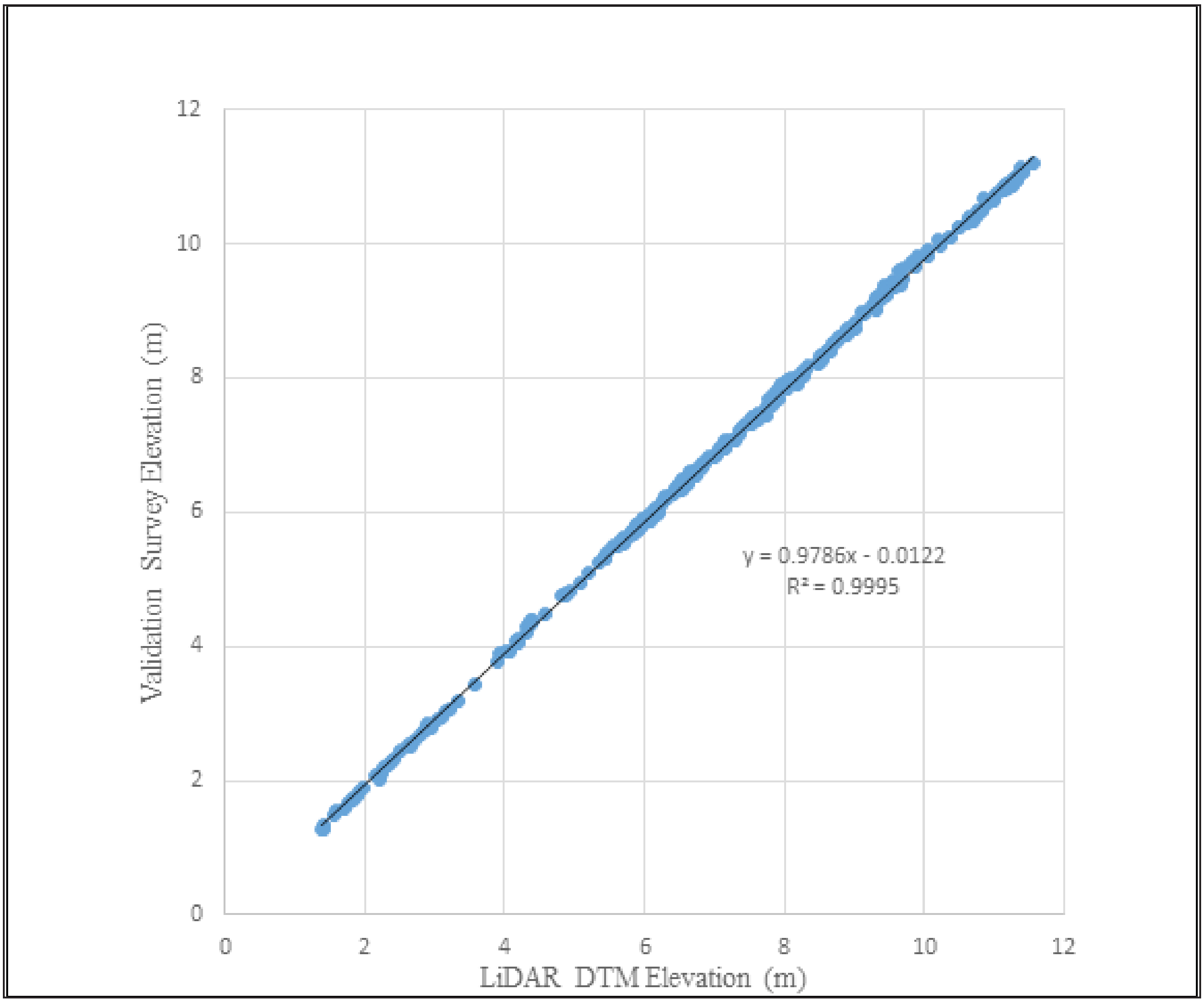


Figure 29. Correlation plot between the validation survey points and the LiDAR data.

Table 21. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	1.57
Standard Deviation	1.54
Average	-0.33
Minimum	-4.93
Maximum	2.99

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Cabadbaran with 3,792 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.14 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Cabadbaran integrated with the processed LiDAR DEM is shown in Figure 30.

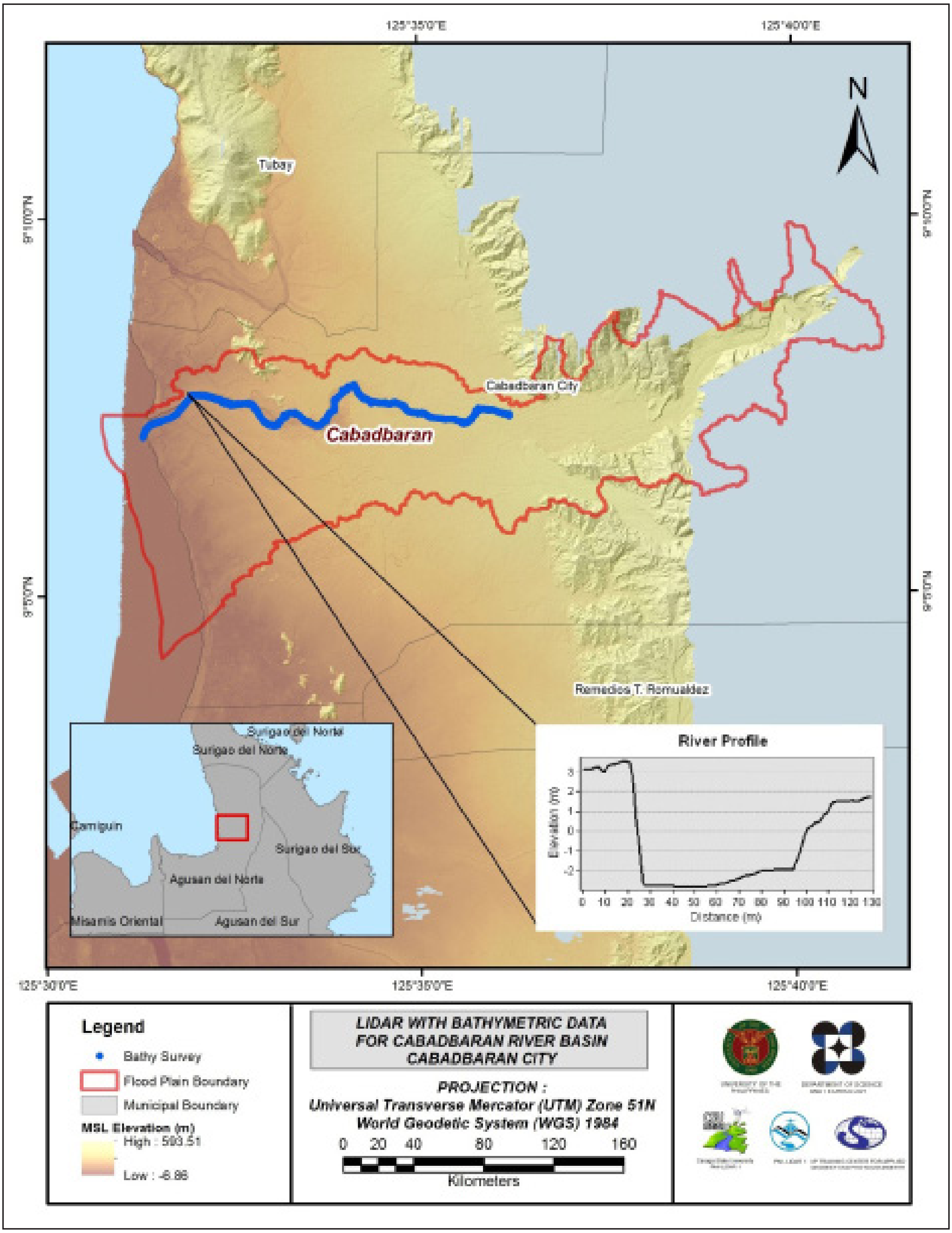


Figure 30. Map of Cabadbaran Flood Plain with bathymetric survey points shown in blue.

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 DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks comprise of main thoroughfares such as highways and municipal and barangay roads essential for the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Cabadbaran floodplain, including its 200 m buffer, has a total area of 48.96 sq. km. For this area, a total of 5.0 sq. km, corresponding to a total of 2,113 building features, are considered for QC. Figure 31 shows the QC blocks for the Cabadbaran floodplain.

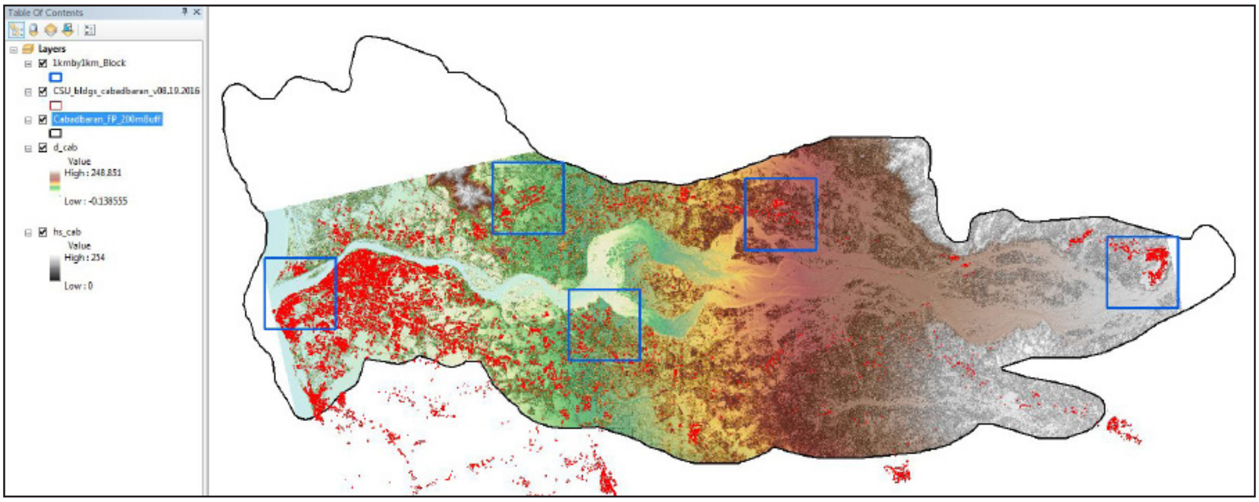


Figure 31. Blocks (in blue) of Cabadbaran building features that were subjected to QC.

Quality checking of Cabadbaran building features resulted in the ratings shown in Table 22.

Table 22. Details of the quality checking ratings for the building features extracted for the Cabadbaran River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Cabadbaran	96.17	100.00	87.63	PASSED

3.12.2 Height Extraction

Height extraction was done 11,387 building features in Cabadbaran floodplain. Of these building features, 405 buildings were filtered out after height extraction, resulting to 10,982 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 5.78 m.

3.12.3 Feature Attribution

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

Table 23 summarizes the number of building features per type, while Table 24 shows the total length of each road type. Table 25, on the other hand, shows the number of water features extracted per type.

Table 23. Building Features Extracted for Inagauan Floodplain.

Facility Type	No. of Features
Residential	10,528
School	166
Market	4
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	12
Barangay Hall	4
Military Institution	0
Sports Center/Gymnasium/Covered Court	16
Telecommunication Facilities	4
Transport Terminal	7
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	0
Religious Institutions	10
Bank	3
Factory	21
Gas Station	14
Fire Station	1
Other Government Offices	24
Other Commercial Establishments	166
Total	**10,982**

Table 24. Total Length of Extracted Roads for Inagauan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Cabadbaran	90.56	18.02	27.35	10.64	0.00	146.57

Table 25. Number of Extracted Water Bodies for Inagauan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cabadbaran	2	0	0	0	21	19

A total of 35 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 given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 32 shows the completed Digital Surface Model (DSM) of the Cabadbaran floodplain overlaid with its ground features.

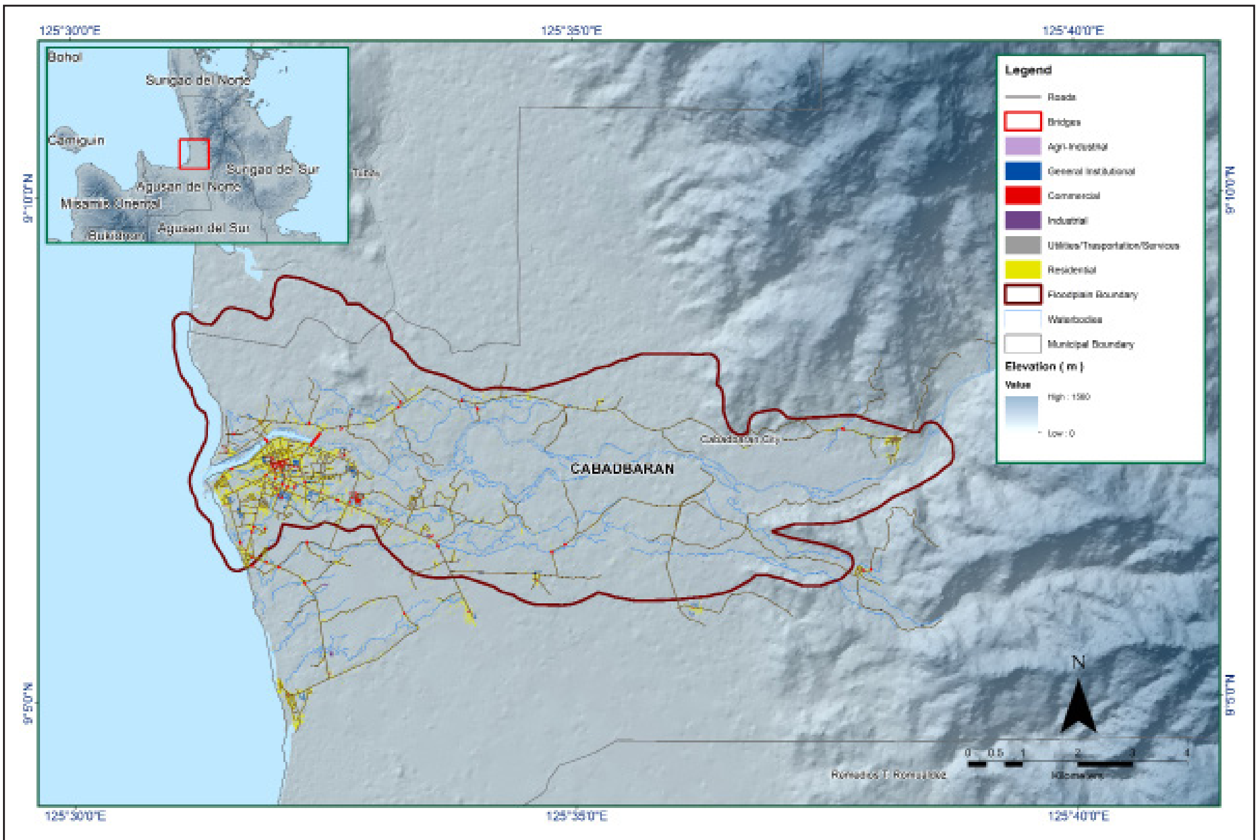


Figure 32. Extracted features for Inagauan Floodplain.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE CABADBARAN RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto

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

4.1 Summary of Activities

The DVBC team conducted a field survey in Cabadbaran Rivers from February 15 to 26, 2015 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section and bridge as-built survey of Cabadbaran Bridge in Brgy. Kauswagan, Cabadbaran City; ground validation data acquisition of about 19.4 km; and bathymetric survey covering Cabadbaran River Basin with an estimated length of 11 km using Ohmex™ Single Beam Echo Sounder and GNSS PPK survey technique as shown in Figure 33.

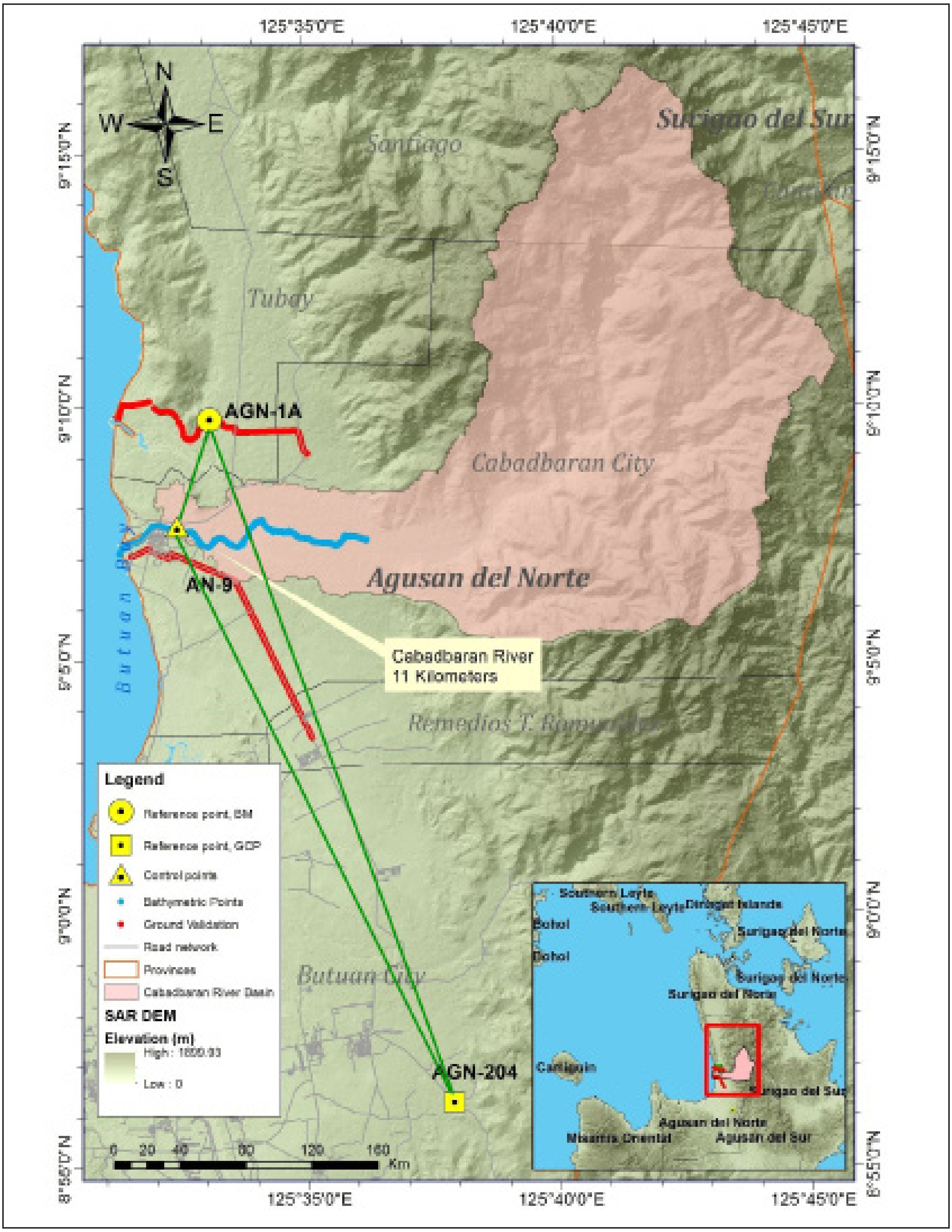


Figure 33. Extent of the bathymetric survey (in blue line) in Cabadbaran River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Cabadbaran River Basin is composed of a single loop established on February 19, 2015 occupying the following reference points: AGN-204, a second order GCP located in Brgy. Basag, Butuan City; and AGN-1A, a fixed control point from partner HEI, CSU levelling survey located in Brgy. Doña Rosario, Municipality of Tubay; both in Agusan Del Norte.

A NAMRIA established control point namely AN-9, located along the approach of Cabadbaran Bridge, in Brgy. Kauswagan, Cabadbaran City, Agusan Del Norte; was also occupied to use as marker for the survey.

Table 26 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 34 shows the GNSS network established in the Cabadbaran River Survey.

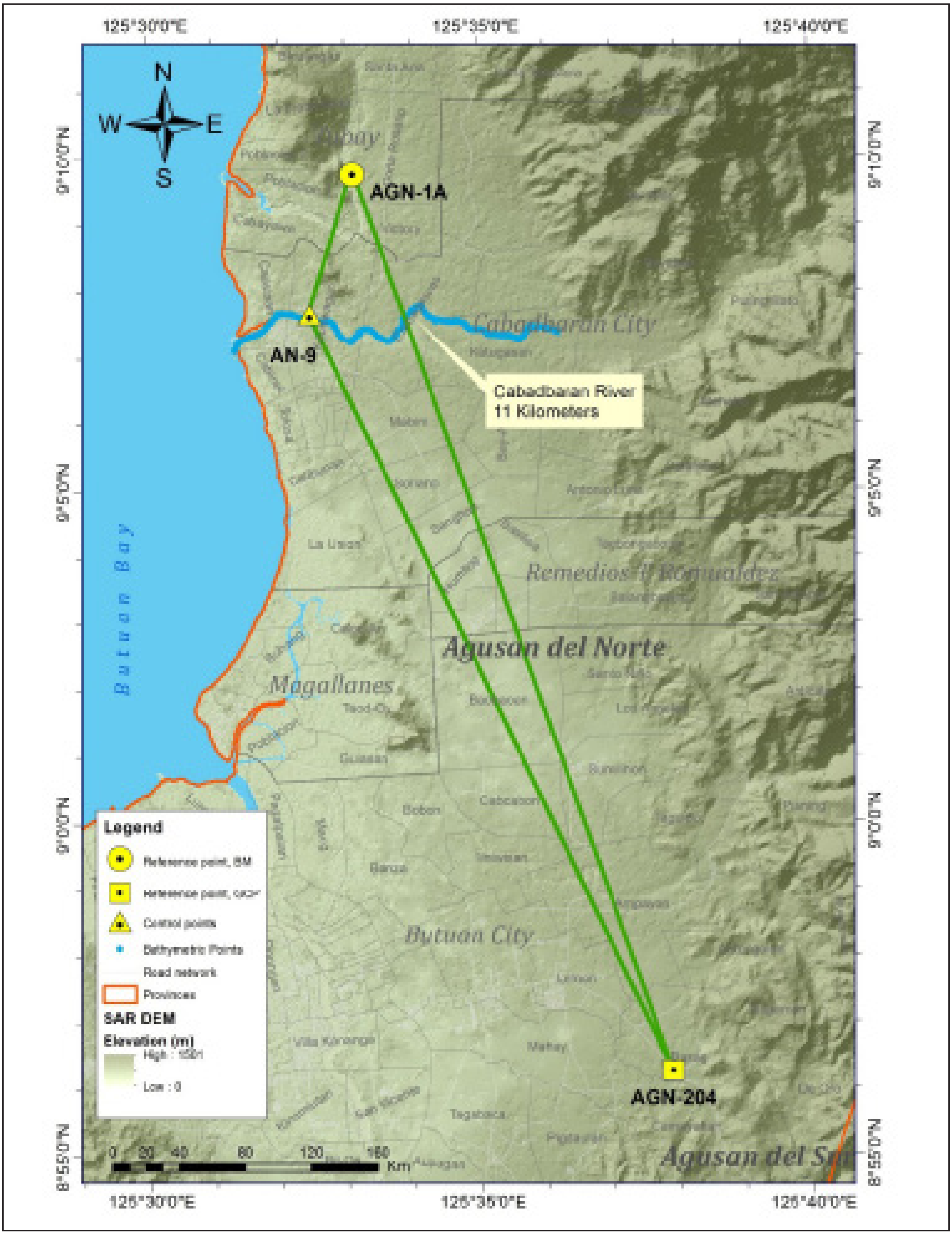


Figure 34. The GNSS Network established in the Cabadbaran River Survey.

Table 26. List of reference and control points used in Cabadbaran River Basin survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
AGN-204	2nd Order, GCP	8°56'16.03323"	125°37'53.34384"	96.791	-	2007
AGN-1A	Fixed, CSU Established	-	-	78.994	10.568	2010
AN-9	Used as marker	-	-	76.54	-	2007

Figure 35 to Figure 37 depict the setup of the GNSS on recovered reference points and established control points in the Cabadbaran River.

Figure 35. Trimble® SPS 852 set-up at AGN-204 located near the concrete fence of Taligaman Elementary School, in Brgy. Basag, Butuan City, Agusan Del Norte.

Figure 36. Trimble® SPS 882 at AGN-1A located along the approach of Tubay Bridge in Brgy. Doña Rosario, Municipality of Tubay, Agusan del Norte

Figure 37. Trimble SPS® 882 set-up at AN-9 located at the approach of Cabadbaran Bridge, Brgy. Kauswagan, Cabadbaran City, Agusan Del Norte

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Table 27 presents the baseline processing results of control points in the Cabadbaran River Basin, as generated by the TBC software.

Table 27. The Baseline processing report for the Cabadbaran River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
AGN-1A – AGN-204	02-19-15	Fixed	0.005	0.023	340°36'12"	26343.613	-17.798
AGN-1A – AN-9	02-19-15	Fixed	0.003	0.012	17°17'35"	4050.187	2.450
AN-9-- AGN-204	02-19-15	Fixed	0.004	0.025	334°37'12"	23222.966	-20.253

As shown in Table 27 Three (3) control points were occupied at the same time. The point AGN-204 was held fixed and was used as a control for the network. Baseline AGN-1A to AGN-204 has a fixed solution type with horizontal and vertical accuracies of 0.4 cm and 2.3 cm, respectively. Baseline AN-9 to AGN-204 has horizontal and vertical accuracies of 0.4 cm and 1.9 cm, respectively, and AGN-1A to AN-9 has a horizontal precision of 0.3 cm and a vertical precision of 1 cm. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

For complete details, see the Network Adjustment Report shown in Table 28 to Table 31.

The three (3) control points, AGN-204, AGN-1A and AN-9 were occupied and observed simultaneously to form a GNSS loop. Elevation value of AGN-1A and coordinates of point AGN-204 were held fixed during the processing of the control points as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 28. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
AGN-204	Local	Fixed	Fixed		
AGN-1A	Grid				Fixed
Fixed = 0.000001(Meter)					

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 29. All fixed control points have no values for grid and elevation errors.

Table 29. Adjusted grid coordinates for the control points used in the Cabadbaran River Floodplain survey.

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
AGN-1A	780449.982	0.016	1013806.588	0.012	10.568	?	e
AGN-204	789383.684	?	989007.083	?	28.115	0.100	LL
AN-9	779272.654	0.015	1009928.879	0.012	8.302	0.063	

The network is fixed at reference point AGN-204 and AGN-1A with known elevation, and with known coordinates. As shown in Table 29, the standard errors (xe and ye) of AGN-1A are 0.016 m and 0.012 m; AN-9
with 0.015 m and 0.012 m, respectively. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$ for the horizontal and vertical, respectively. The results of the computation for accuracy are as follows:

a. AGN-204
Horizontal accuracy = fixed
Vertical accuracy = 10 cm

b. AGN-1A
horizontal accuracy = √((1.6)² + (1.2)²
= √(2.56 + 1.44)
= 2 cm < 20 cm
vertical accuracy = fixed

c. AN-9
horizontal accuracy = √((1.5)² + (1.2)²
= √(2.25 + 1.44)
= 1.92 cm < 20 cm
vertical accuracy = 6.3 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the three (3) occupied control points are within the required precision.

Table 30. Adjusted geodetic coordinates for control points used in the Cabadbaran River Floodplain validation.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
AGN-1A	N9°09'44.79823"	E125°33'06.77787"	78.994	?	E
AGN-204	N8°56'16.03323"	E125°37'53.34384"	96.791	0.100	LLh
AN-9	N9°07'38.92818"	E125°32'27.34268"	76.540	0.063	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 30. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Cabadbaran River GNSS Static Survey are seen in Table 31.

Table 31. The reference and control points utilized in the Cabadbaran 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	Easting	MSL Elevation (m)
AGN-204	2nd order GCP	8°56' 16.03323"	125°37' 53.34384"	96.791	989007.083	789383.684	28.115
AGN-1A	Fixed, CSU established	9°09' 44.79823"	125°33' 06.77787"	78.994	1013806.588	780449.982	10.568
AN-9	Used as marker	9°07' 38.92818"	125°32' 27.34268"	76.54	1009928.879	779272.654	8.302

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

Cross-section and as-built survey were conducted on February 23, 2015 along the downstream side of Cabadbaran Bridge located in Brgy. Kauswagan, Cabadbaran City, Agusan del Norte using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 38.

Figure 38. Cross-section and bridge as-built survey at the downstream side of Cabadbaran Bridge in Brgy. Kauswagan, Cabadbaran City, Agusan del Norte

The cross-sectional line length in Cabadbaran Bridge is about 289 m with 73 cross-sectional points acquired using the control point AN-9 as the GNSS base station. The cross-section diagram, planimetric map, and the bridge data form are shown in Figure 39 to Figure 41, respectively.

Caraga State University acquired water surface elevation of Cabadbaran River. The water surface elevation in MSL was marked along the piers of Cabadbaran Bridge to serve as a reference for their flow data gathering and depth gauge deployment activities.

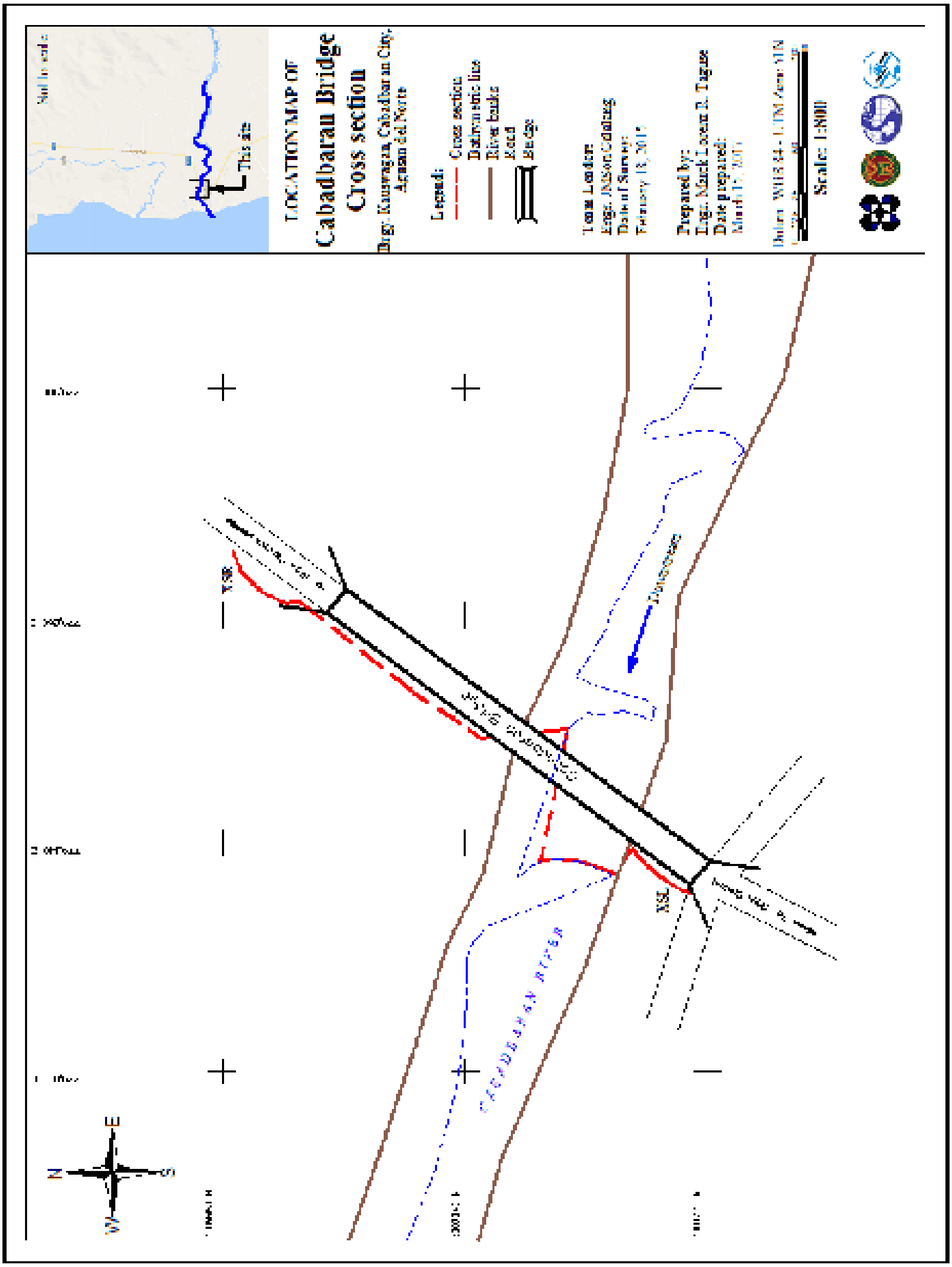


Figure 39. Location map of the Cabadbaran cross-section survey in Cabadbaran Bridge.

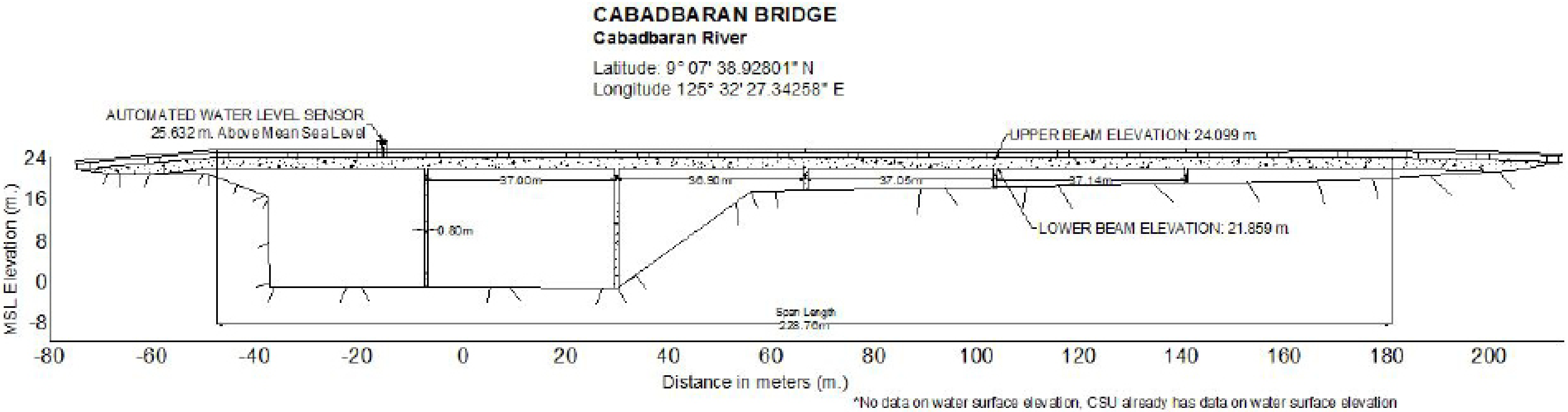
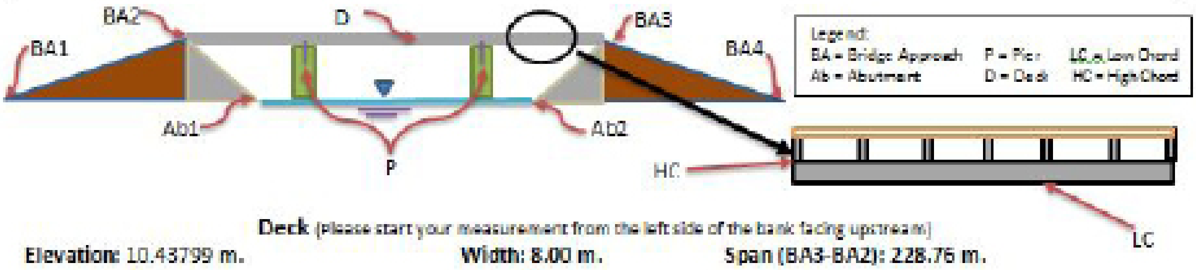


Figure 40. The Cabadbaran cross-section survey in Cabadbaran Bridge drawn to scale.

Bridge Data Form

Bridge Name: Cabadbaran Bridge	Date: February 23, 2015
River Name: Cabadbaran River	Time: 3:30 PM
Location (Brgy, City,Region): Bgy. Kauswagan, Cabadbaran City, Agusan del Norte	
Survey Team: Mark Lester D. Rojas, Bernard Paul Maramot, Dona Rina Patricia Tajora, Edjie Abalos	
Flow condition: low ✓normal high	Weather Condition: ✓fair rainy
Latitude: 9°7'38.92801" N	Longitude: 125°32'27.34258" E



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

Elevation: 10.43799 m. Width: 8.00 m. Span (BA3-BA2): 228.76 m.

	Station	High Chord Elevation	Low Chord Elevation
1	68.3128	24.08799	21.84799
2	105.3174	24.07399	21.83399
3	142.2197	24.09699	21.85699
4	179.2671	24.09999	21.85999
5	216.4024	24.11899	21.87899

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	23.14199	BA3	256.3541	24.10699
BA2	27.59814	24.06799	BA4	289.7952	23.17599

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

	Station (Distance from BA1)	Elevation
Ab1	37.45257	16.19699
Ab2	248.2616	19.49899

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

Shape: Cylindrical Number of Piers: 5 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	68.3128	24.08799	approx. 0.8 m.
Pier 2	105.3174	24.07399	approx. 0.8 m.
Pier 3	142.2197	24.09699	approx. 0.8 m.
Pier 4	179.2671	24.09999	approx. 0.8 m.
Pier 5	216.4024	24.11899	approx. 0.8 m.

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

Figure 41. Bridge As-built form of Cabadbaran Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on February 20, 2015 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 1.522 m was measured from the ground up to the bottom of notch of the GNSS Rover receiver.

Figure 42. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The validation points acquisition survey for the Cabadbaran River Basin traversed the municipalities of Tubay and Remedios T. Romualdez and Cabadbaran City, Agusan del Norte. The route of the survey aims to perpendicularly traverse LiDAR flight strips for the basin. A total of 3,120 points with an approximate length of 20 km using AGN-1A as the GNSS base station was acquired for the validation points acquisition survey as shown in the map in Figure 43. The team experienced difficulty in initialization due to the presence of obstructions such as canopy of trees; hence, there are gaps in the validation line with a maximum length of 250 m.

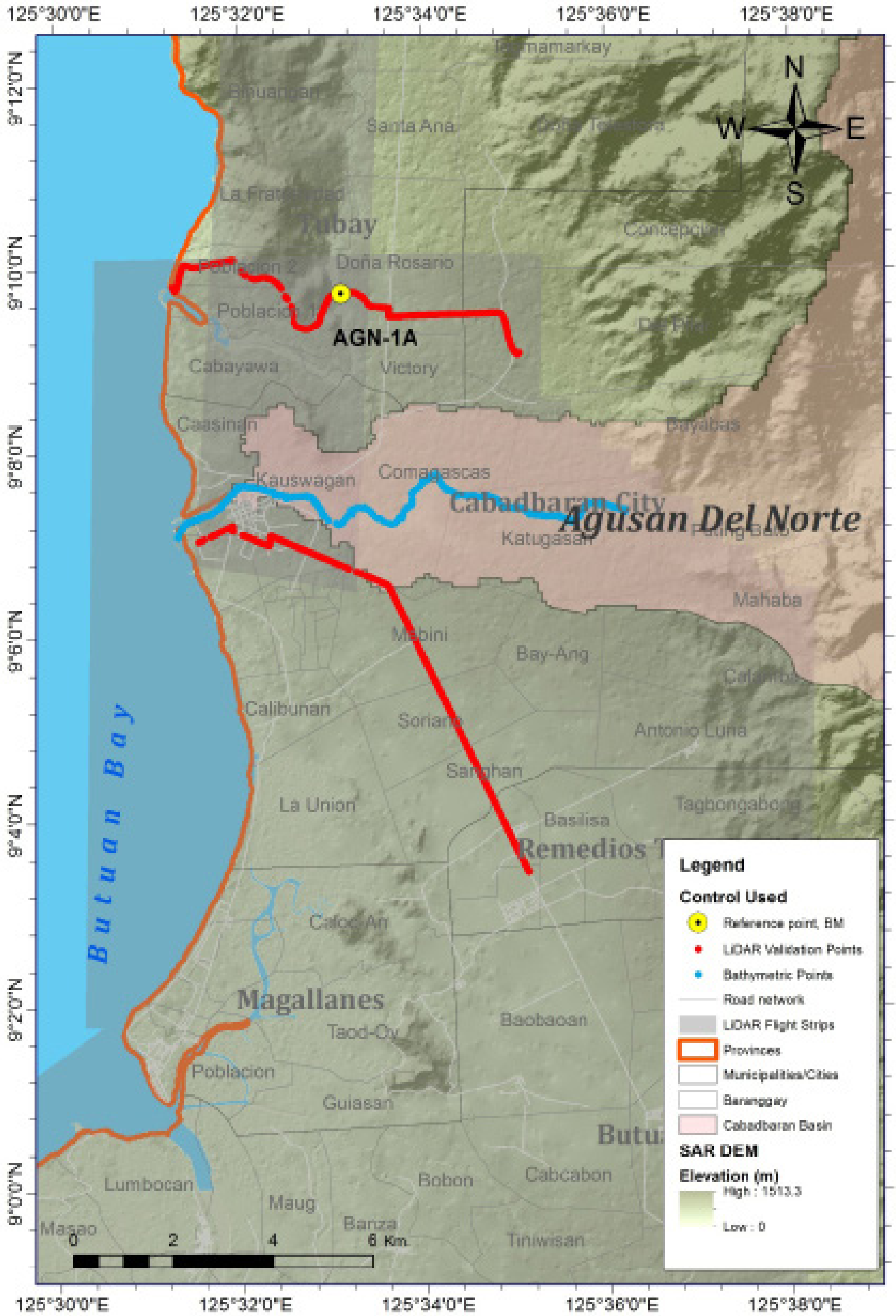


Figure 43. The extent of the LiDAR ground validation survey (in red) for Cabadbaran River Basin.

4.7 Bathymetric Survey

Bathymetric survey of Cabadbaran River was conducted on February 18, 2015 using OHMEXTM and a Trimble® SPS 882 GNSS rover receiver attached to a pole on the side of the boat as shown in Figure 42.

The survey began at the middle portion of the river in Brgy. Kauswagan, Cabadbaran City with coordinates 09°07'20.53155"N, 125°32'54.26889"E, down to the mouth of the river in Brgy. Caasinan, also in Cabadbaran City with coordinates 09°07'07.06466"N, 125°31'19.10209"E.

Manual bathymetric survey was also done on the same day using Trimble®.SPS 882 in GNSS PPK survey technique as shown in Figure 44. The survey started from the uppermost part of the river in Brgy. Katugasan, Cabadbaran City with coordinates 09°07'22.92008"N, 125°36'12.287969"E, walk down the river by foot, and ended at the starting point of the bathymetric survey using boat. The control point AGN-9 was used as the GNSS base all throughout the bathymetric survey.

Figure 44. Set up of the bathymetric survey in Cabadbaran River.

The bathymetric survey gathered a total of 3,740 points covering an estimated length of 11 km of the river traversing four barangays of Cabadbaran City namely: Caasinan, Comagasgas, Katugasan, and Kauswagan as shown in Figure 45. A CAD drawing was also produced to illustrate the riverbed profile of Cabadbaran River. In Figure 46, the highest and lowest elevation has a 38-m difference. The highest elevation observed was 35.10 m in MSL located at the upstream part of the river in Brgy. Katugasan, while the lowest elevation value observed was -3.62 m below MSL located just few meters above the Cabadbaran bridge area in Brgy. Kauswagan.

Figure 45. The extent of the Cabadbaran River Bathymetry Survey and the LiDAR bathymetric data validation points.

A CAD drawing was also produced to illustrate the Cabadbaran riverbed profile. As shown in Figure 44, the change in elevation is gradual from Brgy. Kauswagan to its downstream in Brgy. Caasinan, Cabadbaran City, Agusan del Norte. The difference between the elevation is about 36.1 m from the first point upstream to the last point downstream with total of 3,740 points gathered. The average change of slope per 1 km station is approximately 3.3 km.

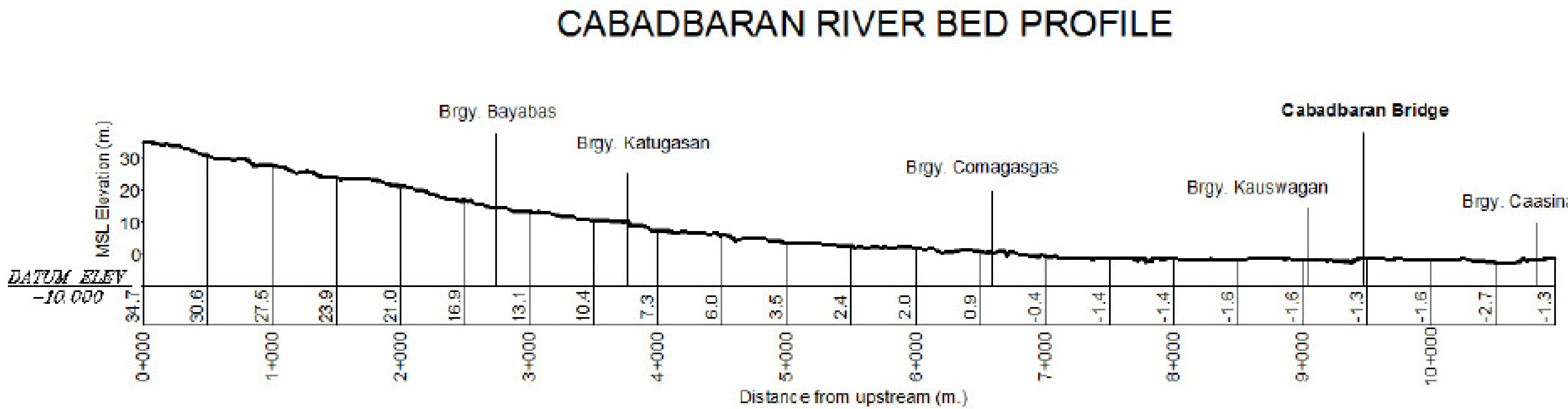


Figure 46. The Cabadbaran River Bed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data used in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute as illustrated in Figure 47. Total rain recorded from Cabadbaran rain gauge from 09 January 2014 00:00 to 14 January 2014 00:00 is 190 mm. It peaked to 4.3 mm on 10 January 2014 15:45. The lag time between the peak rainfall and its corresponding peak discharge at Cabadbaran Bridge is 2 hours and 55 minutes.

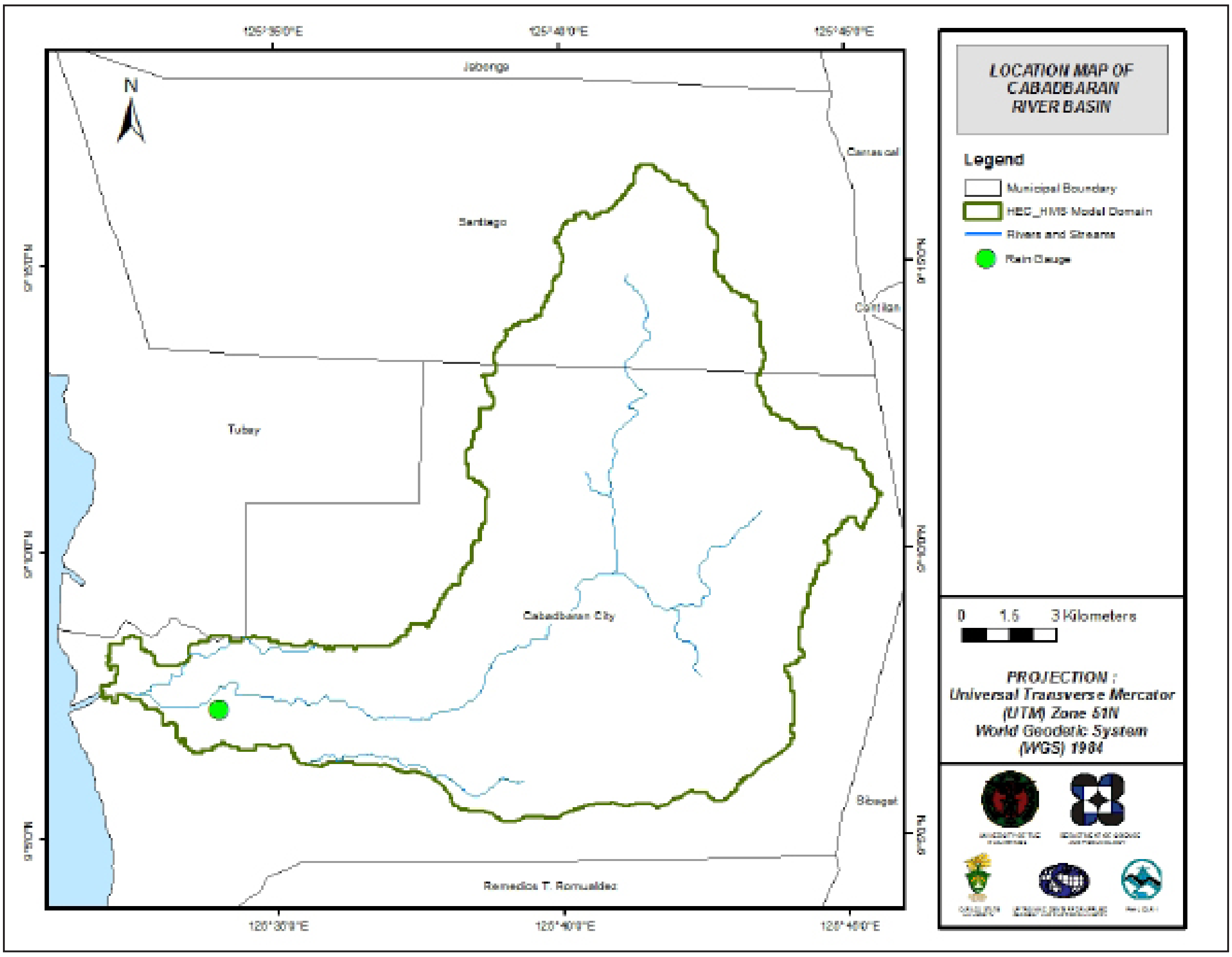


Figure 47. Location Map of the Cabadbaran HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Cabadbaran Bridge, Cabadbaran City, Agusan del Norte (9°07'34.93"N, 125°32'24.15"E). It gives the relationship between the observed water levels from Cabadbaran Bridge Automated Water Level Station (AWLS) and outflow of the watershed at this location.

For Cabadbaran Bridge, the rating curve is expressed as Q = 33.264H2 + 25.136H + 13.155 as shown in Figure 49.

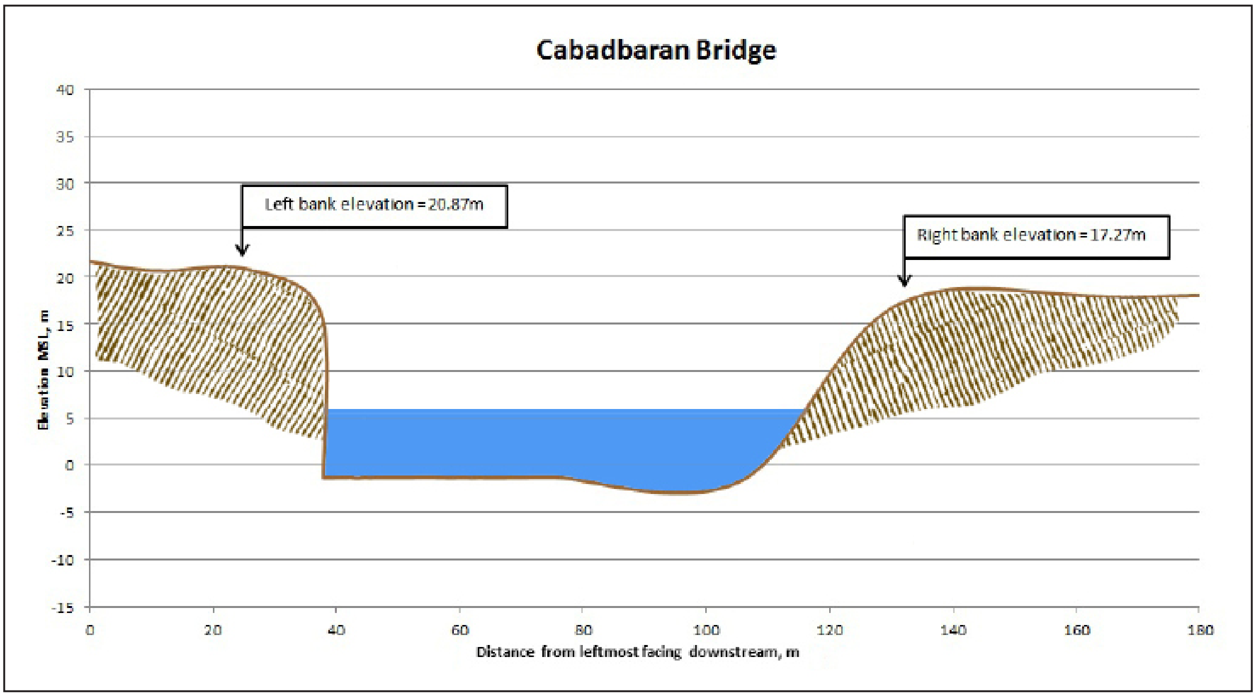


Figure 48. The Cross-section plot of Cabadbaran Bridge

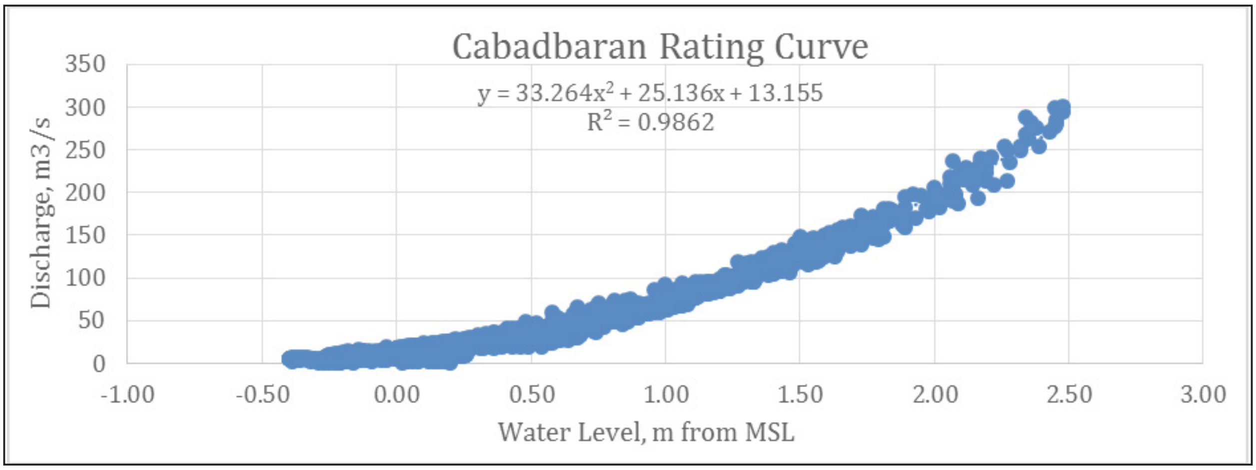


Figure 49. The rating curve at Cabadbaran Bridge, Cabadbaran City, Agusan del Norte.

This rating curve equation was used to compute the river outflow at Cabadbaran Bridge for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 287.44 cubic meter per second (cms) at 01:40 PM, January 12, 2014.

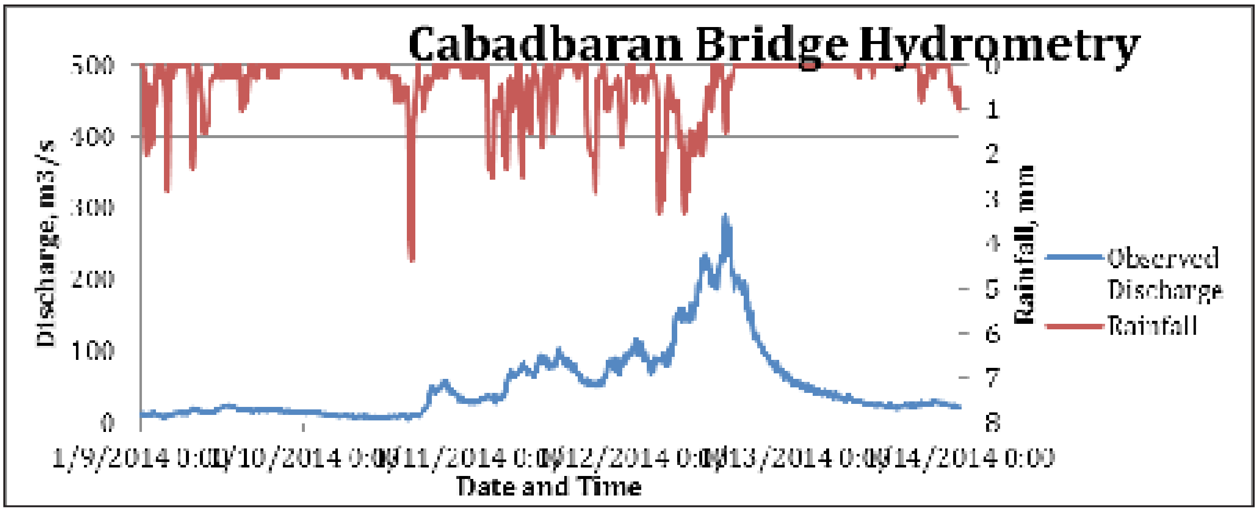


Figure 50. Rainfall at Cabadbaran ARG and outflow data which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Butuan City Rain Gauge (Table 32). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 52). This station was selected based on its proximity to the Cabadbaran watershed. The extreme values for this watershed were computed based on a 21-year record.

Table 32. RIDF values for the Cabadbaran River Basin based on average RIDF data of Butuan station, as 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
5	23.9	36.6	41.7	52.9	71.2	81.3	104.6	142.6	175.2
10	27.6	42.1	47.9	60.8	81.5	93	119.7	170.8	207.5
25	32.3	49.1	55.7	70.9	94.6	107.7	138.8	206.5	248.3
50	35.8	54.3	61.5	78.4	104.3	118.7	153	232.9	278.6
100	39.2	59.5	67.3	85.8	114	129.5	167.1	259.1	308.6

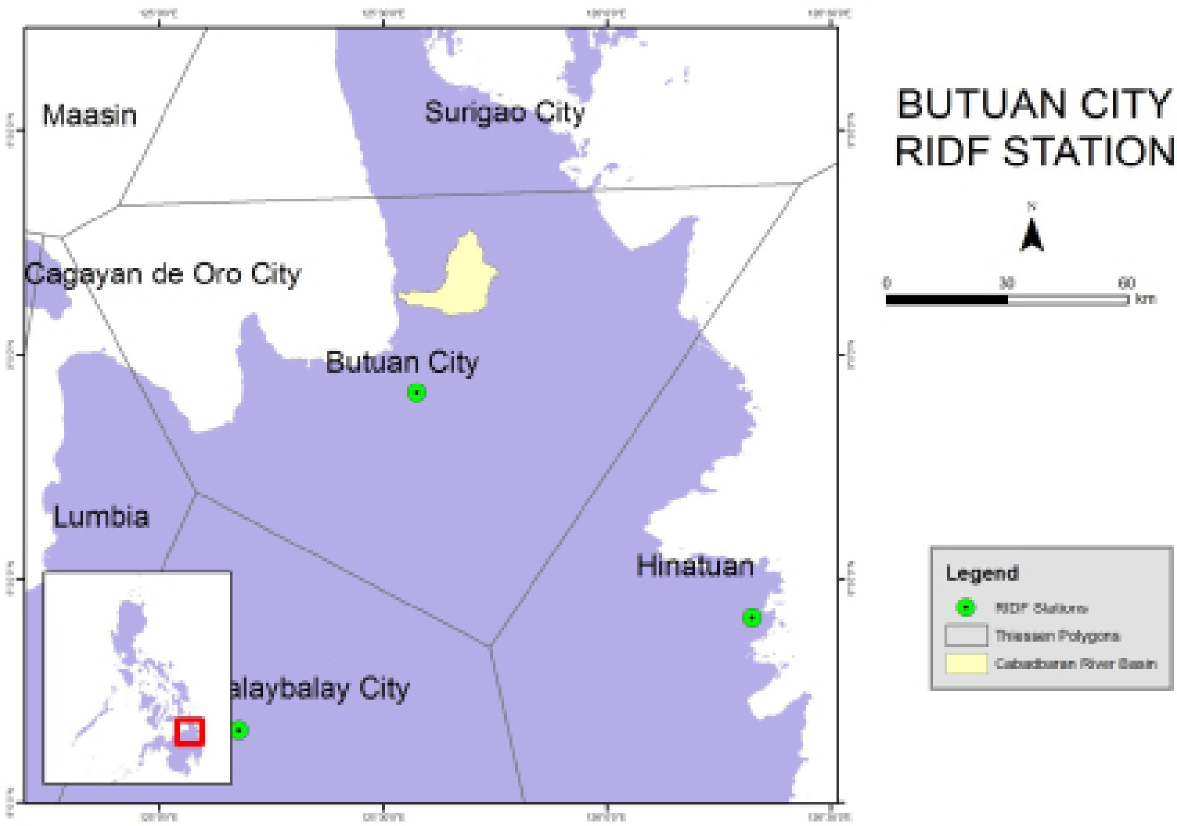


Figure 51. The location of the Butuan RIDF station relative to the Cabadbaran River Basin.

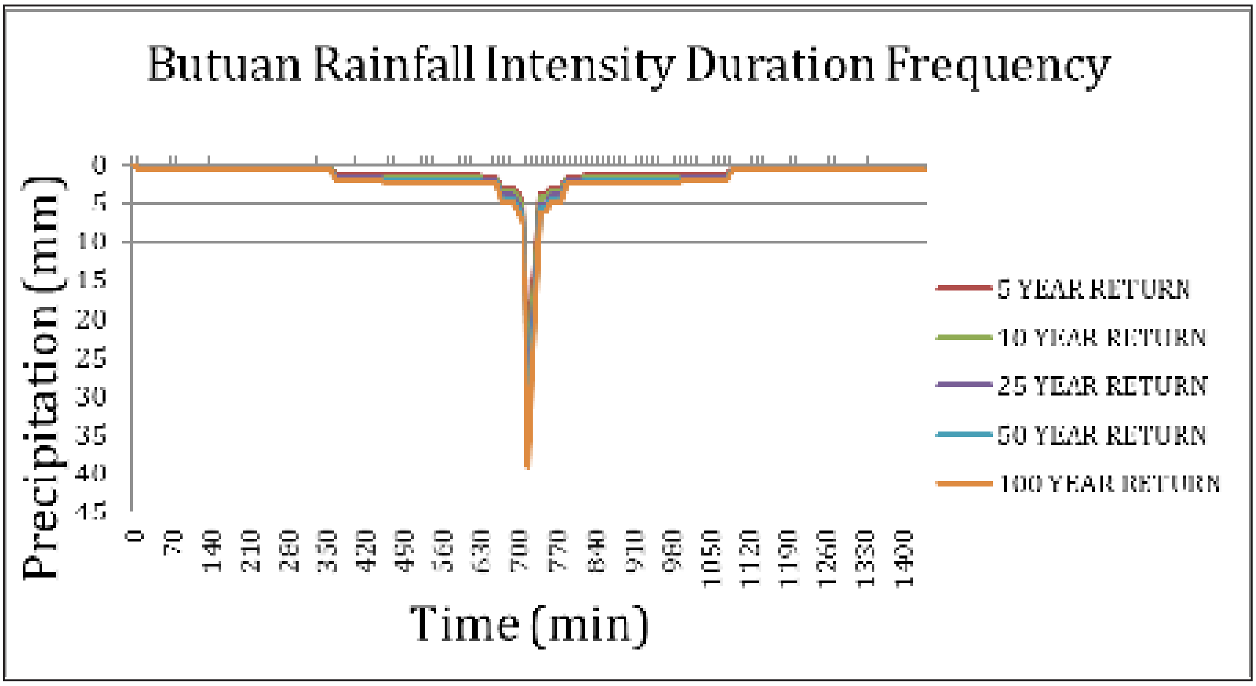


Figure 52. The synthetic storm generated for a 24-hour period rainfall for various return periods.

5.3 HMS Model

These soil dataset was generated before 2004 by the Bureau of Soils and Water Management (BSWM). It is under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Cabadbaran River Basin are shown in Figure 53 and Figure 54 respectively.

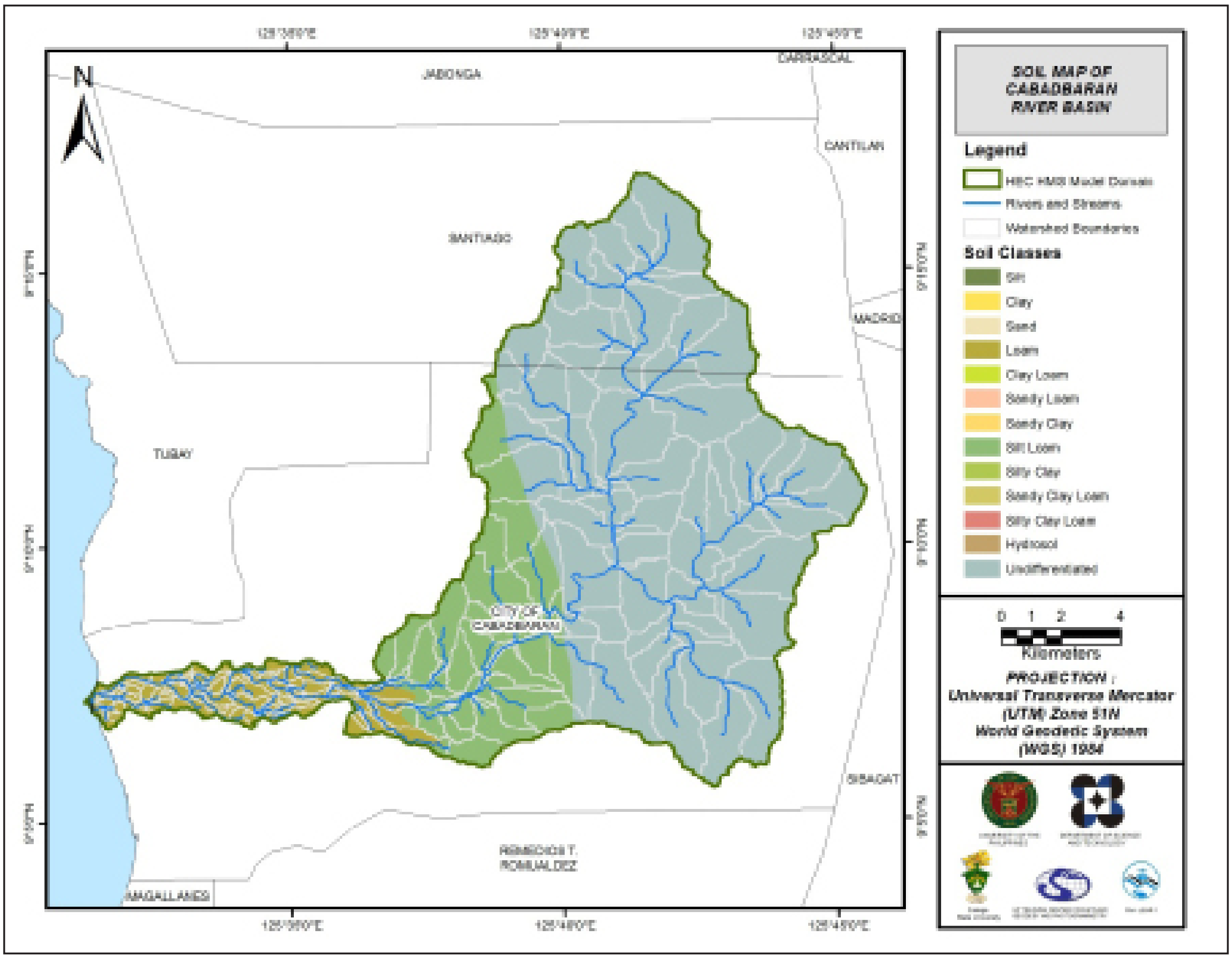


Figure 53. Soil Map of Cabadbaran River Basin.

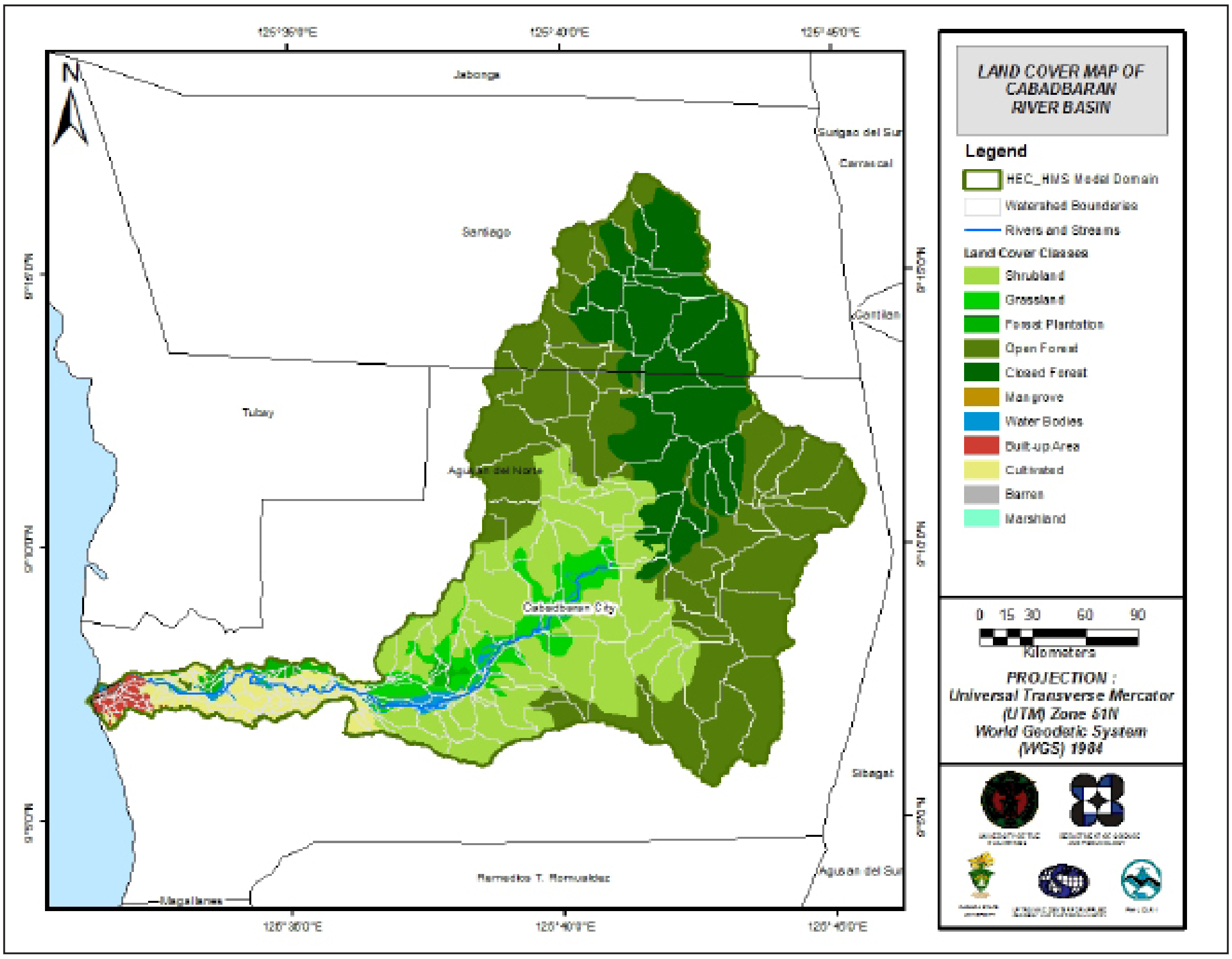


Figure 54. Land Cover Map of Cabadbaran River Basin.

For Cabadbaran river basin, the three (3) major soil classes identified were loam, silty clay and undifferentiated soils. The six (6) landcover types identified were closed and open forest, shrubland, cultivated areas, grassland and built-up areas.

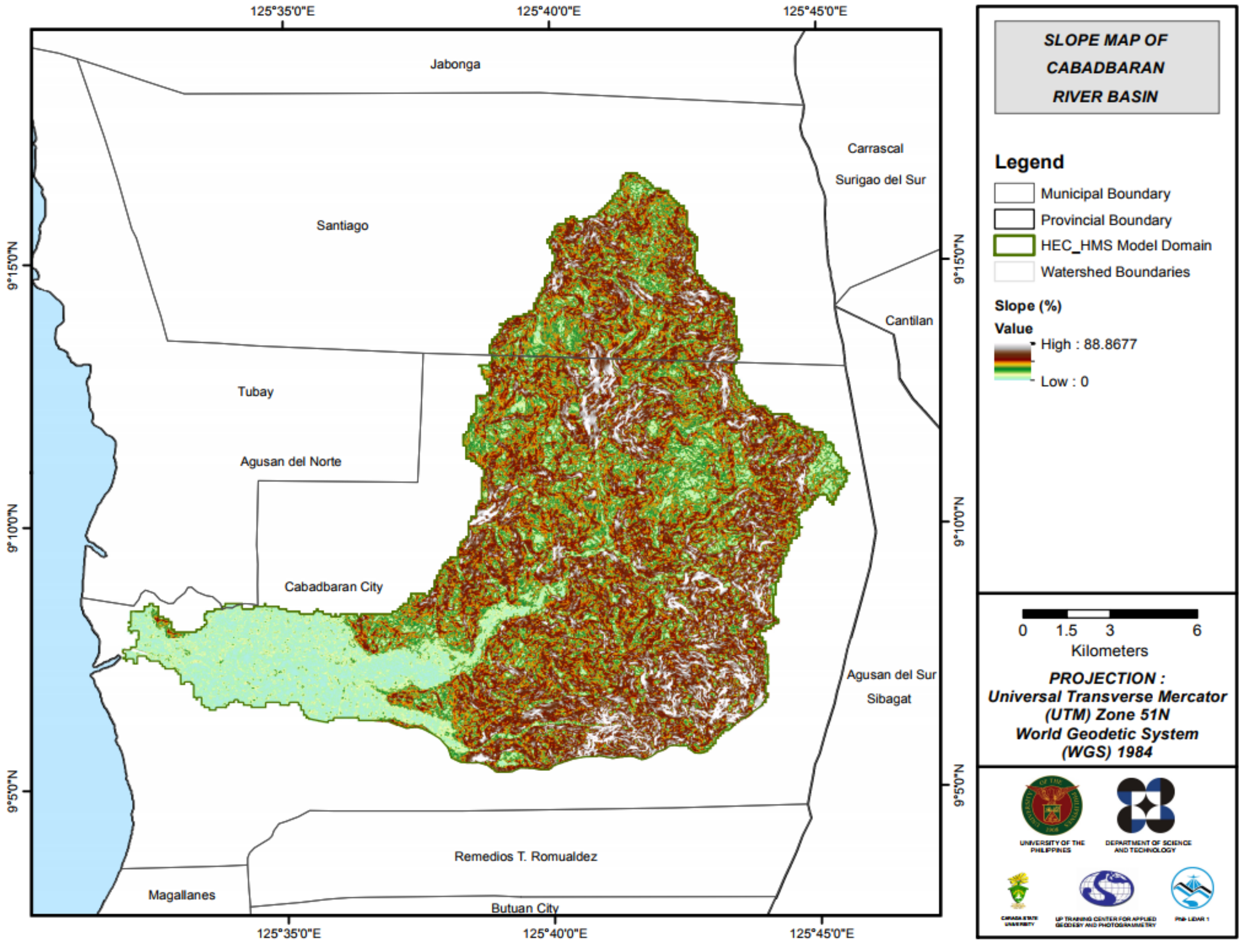


Figure 55. Slope map of Cabadbaran River Basin

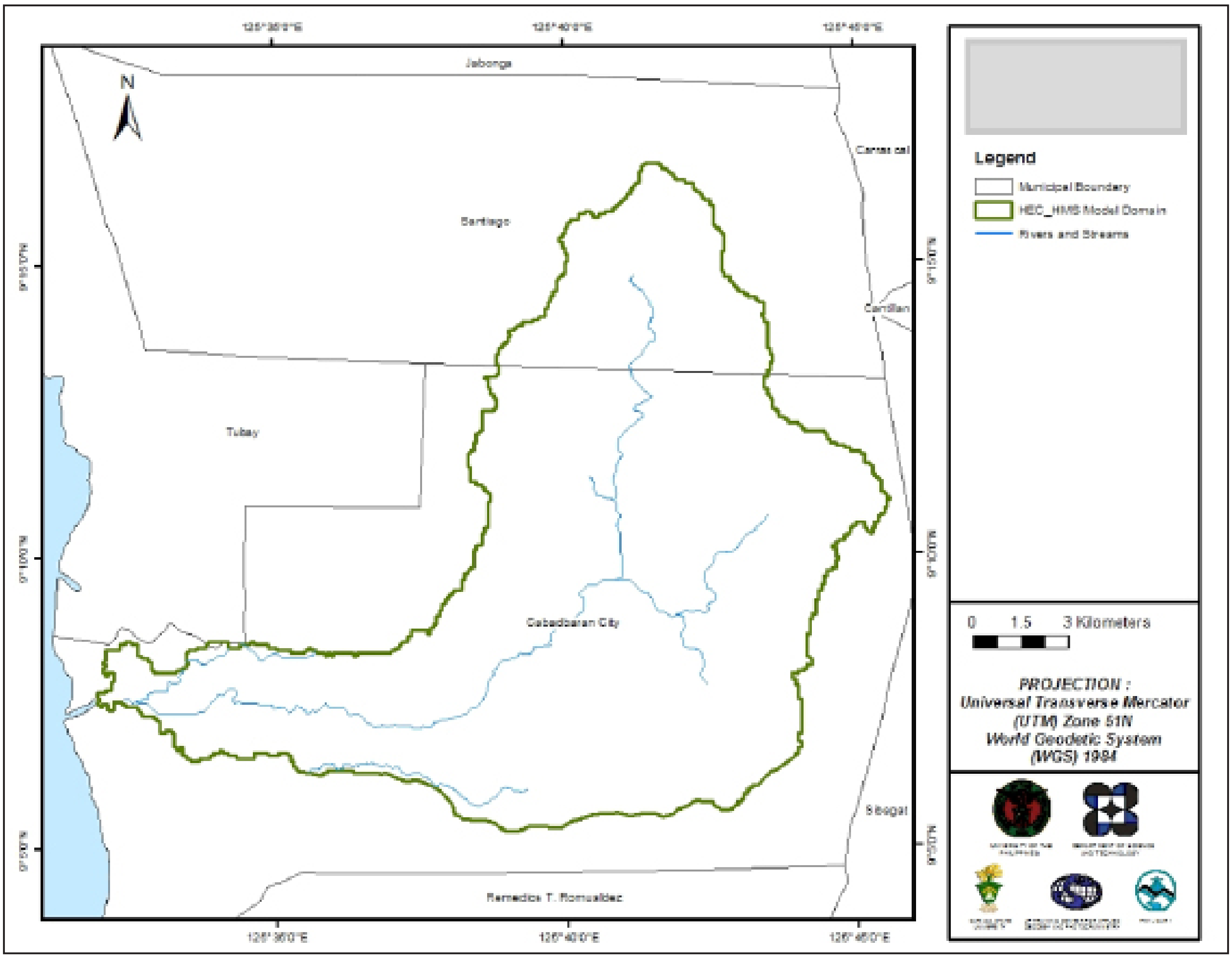


Figure 56. Stream Delineation Map of the Cabadbaran River Basin

Using the SAR-based DEM, the Cabadbaran river basin was delineated and further subdivided into subbasins. The model consists of 204 sub basins, 140 reaches, 130 junctions, and 6 diversions as shown in Figure 54. The main outlet is at Cabadbaran Bridge.

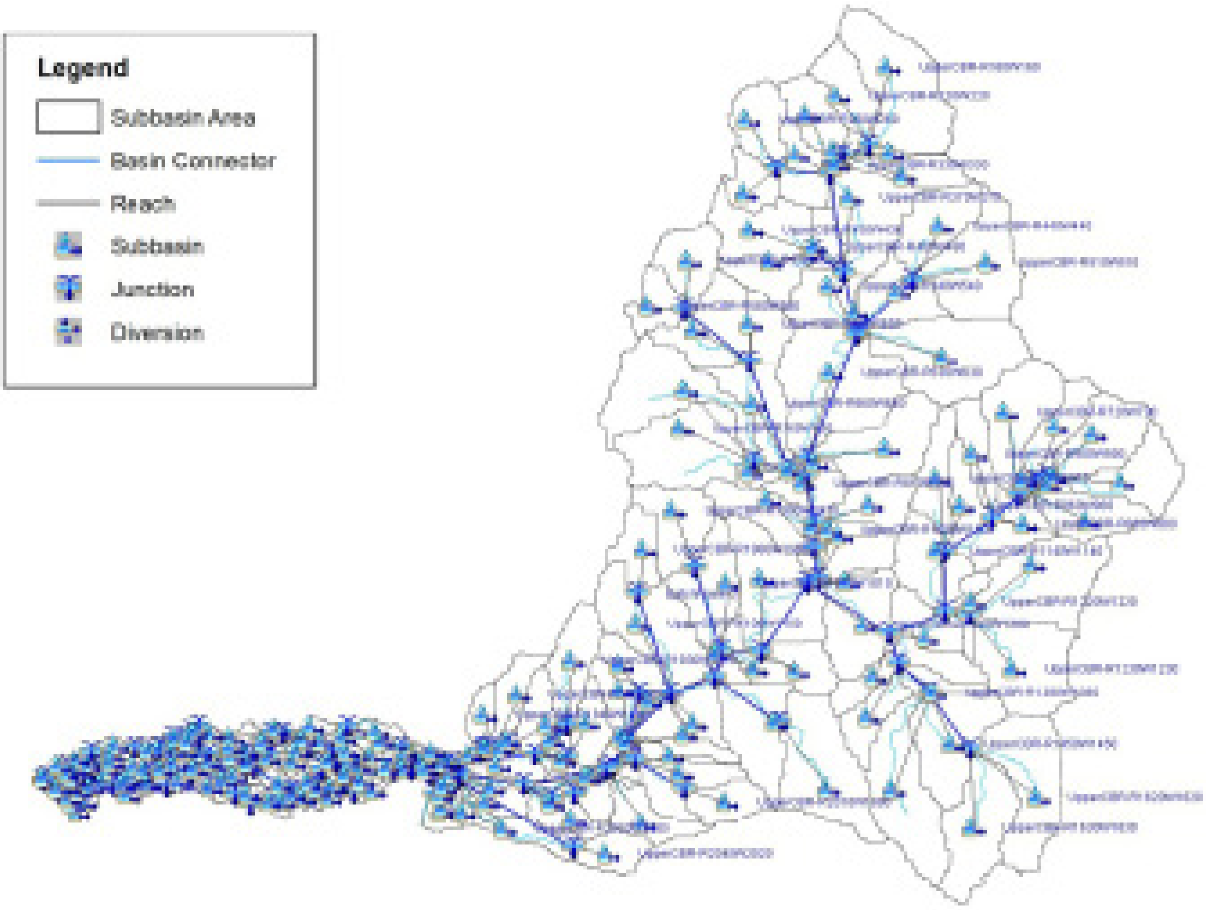


Figure 57. HEC-HMS generated Cabadbaran River Basin Model.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS. For Cabadbaran River basin, there were a total of 7 reaches and 97 cross-section lines as shown in Figure 55.

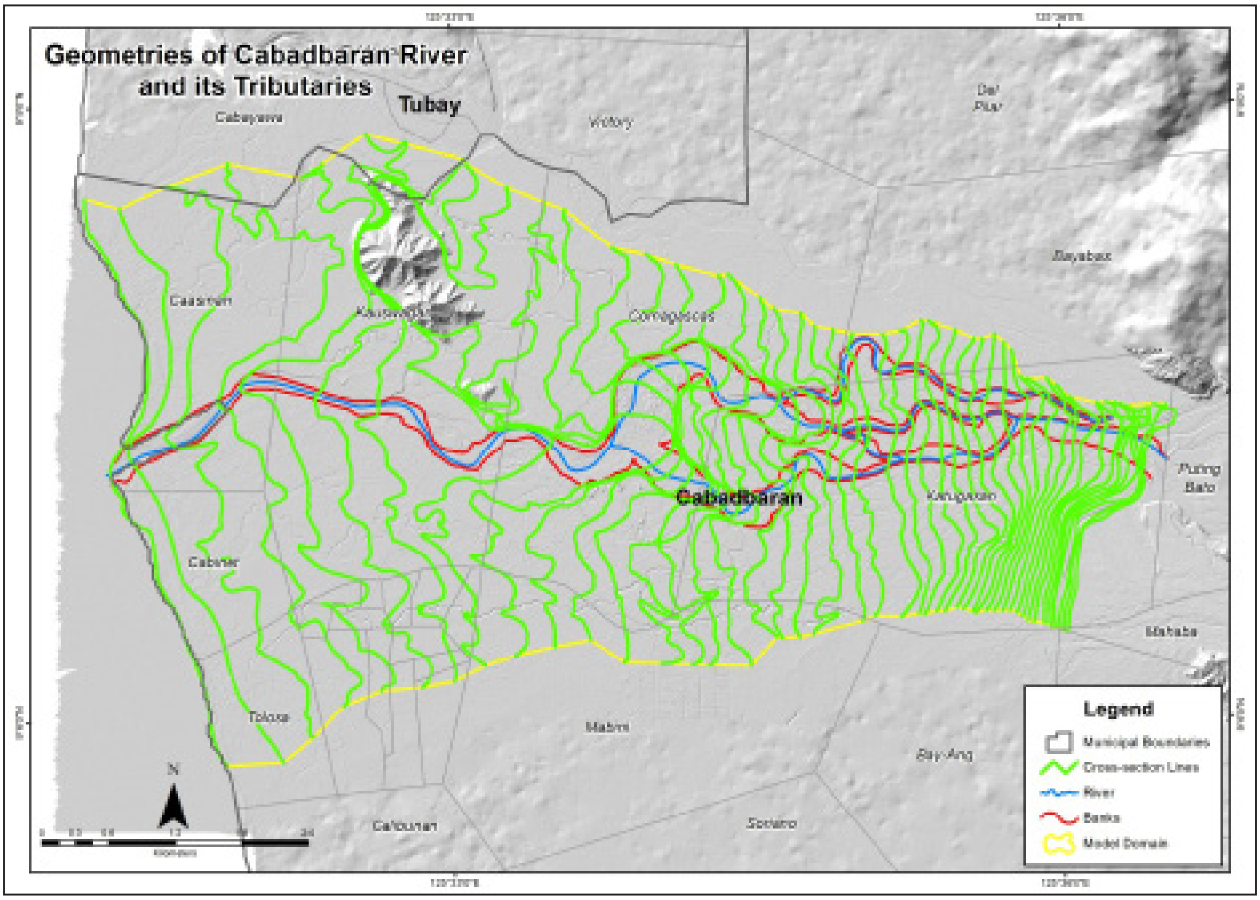


Figure 58. River cross-section of the Cabadbaran River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

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

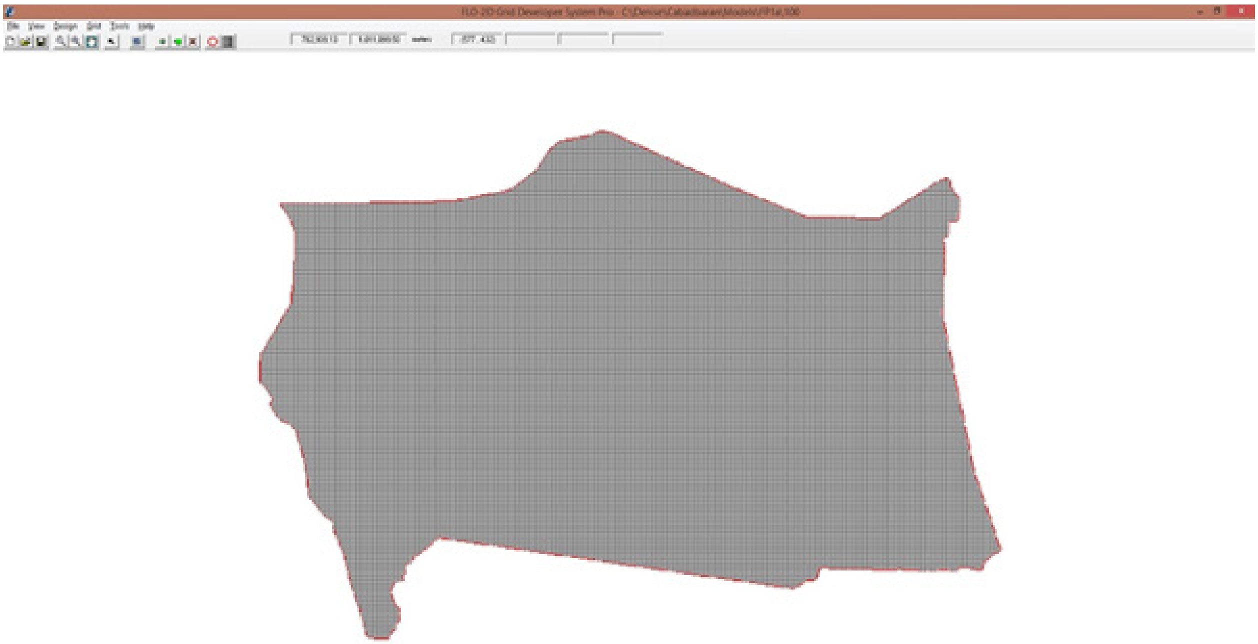


Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 33.31152 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 18823000.00 m2.

There is a total of 47158793.12 m3 of water entering the model. Of this amount, 5761528.71 m3 is due to rainfall while 1397264.40 m3 is inflow from other areas outside the model. 4190050.75 m3 of this water is lost to infiltration and interception, while 3765950.54 m3 is stored by the flood plain. The rest, amounting up to 39202789.16 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Cabadbaran HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 58 shows the comparison between the two discharge data.

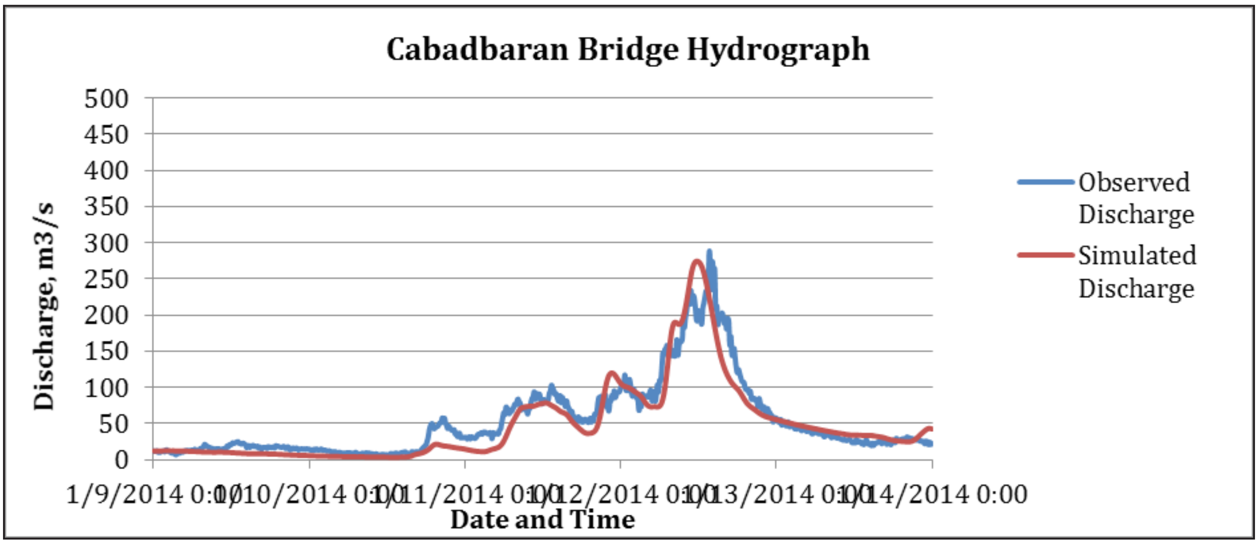


Figure 60. Outflow Hydrograph of Cabadbaran Bridge produced by the HEC-HMS model compared with observed outflow.

Table 33 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of calibrated values for the Cabadbaran River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.51-41.56
			Curve Number	55-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0-100
			Storage Coefficient (hr)	2.04-110.22
	Baseflow	Recession	Recession Constant	0.35
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.014-0.8

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.51-41.56mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 36 to 97 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area. For Cabadbaran, the basin mostly consists of grasslands and the soil consists of loam, silty clay and undifferentiated soils.

Lag time is the travel time of runoff in a watershed. The range of calibrated values from 2.04-110.22 minutes determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.35 indicates that the basin is unlikely to quickly return to its original discharge and instead, will be higher.

Manning's roughness coefficient of 0.014-0.8 corresponds to the landcover types in Cabadbaran riverbasin. These were identified as closed and open forest, shrubland, cultivated areas, grassland and built-up areas.

Table 34. Summary of the Efficiency Test of Cabadbaran HMS Model

Accuracy measure	Value
RMSE	19.8
r2	0.886
NSE	0.865
PBIAS	11.20
RSR	0.37

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed to be 19.8 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.886.

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 0.865.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 11.20.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.37.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Cabadbaran outflow using the Butuan Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

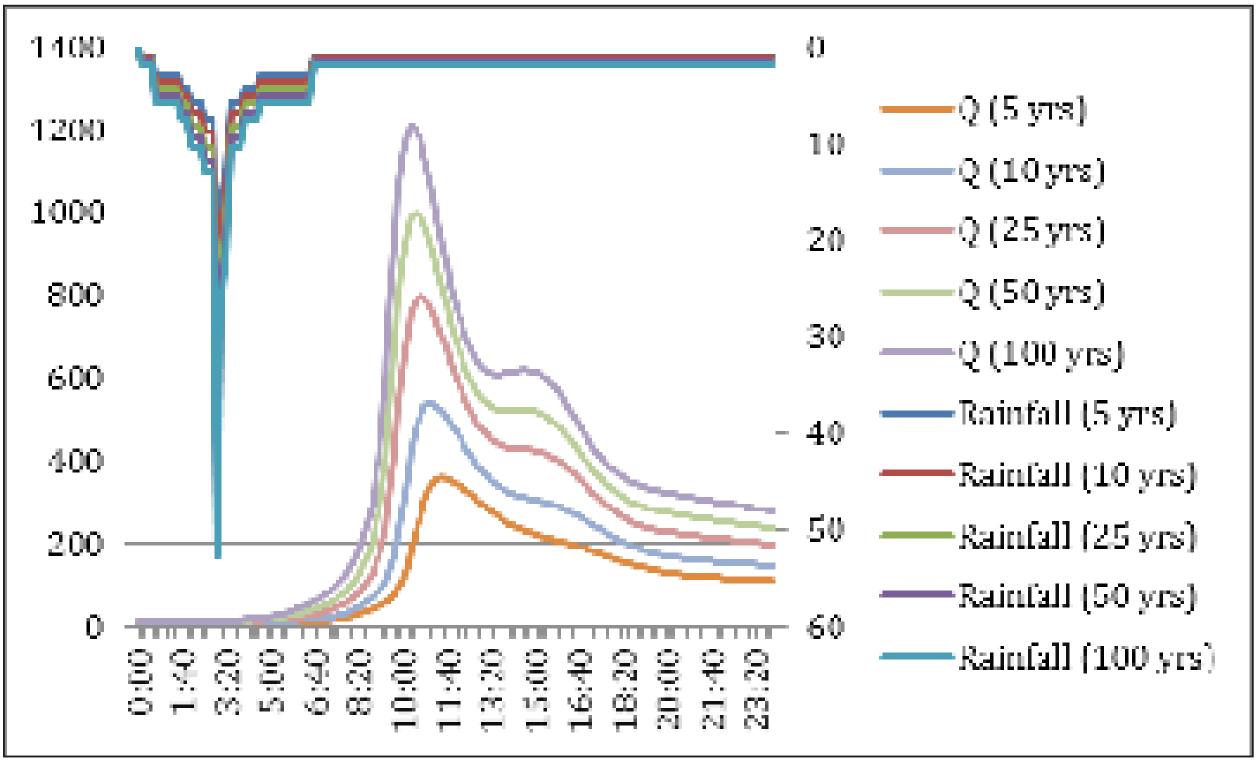


Figure 61. Outflow hydrograph at Brgy. Novallas, Cabadbaran City generated using Dumaguete Point RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Cabadbaran discharge using the Butuan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 35.

Table 35. The peak values of the Cabadbaran HEC-HMS Model outflow using the Butuan City RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	168.18	21.04	444.5	3 hours, 20 min
10-Year	207.48	24.29	676.5	3 hours
25-Year	248.28	28.36	1006.9	2 hours, 40 min
50-Year	278.58	31.4	1267.3	2 hours, 30 min
100-Year	308.58	34.34	1538.4	2 hours, 20 min

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

The river discharges for the three rivers entering the floodplain are shown in Figures 62 to 63, and the peak values are summarized in Tables 36 to 38.

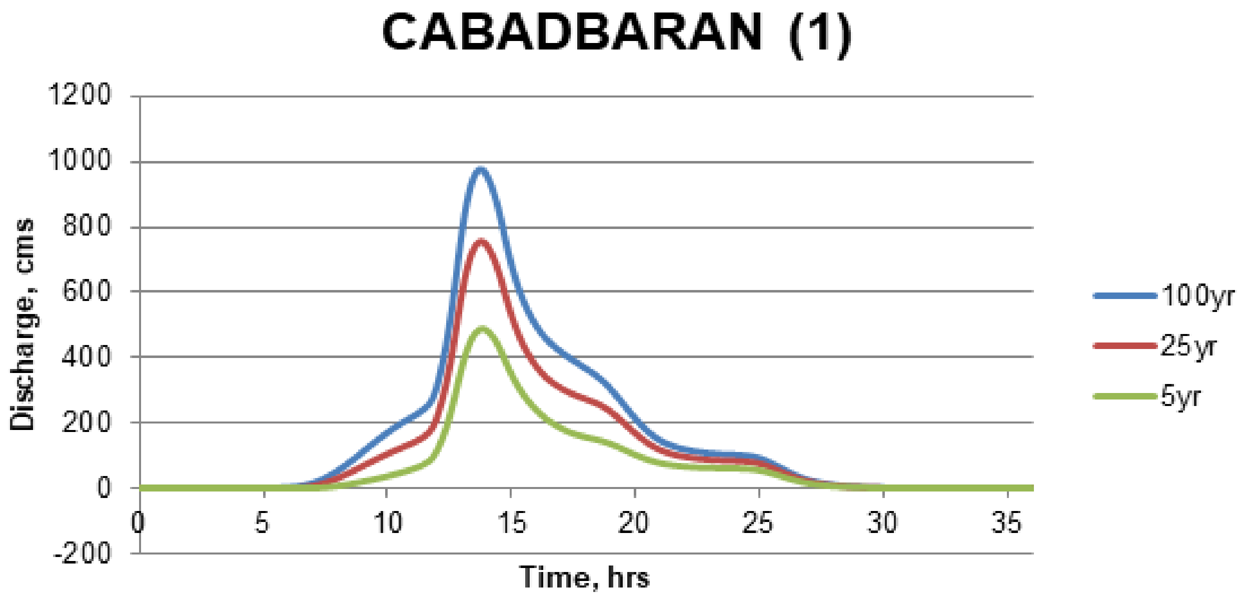


Figure 62. Cabadbaran river (1) generated discharge using 5-, 25-, and 100-year Butuan City RIDF in HEC-HMS

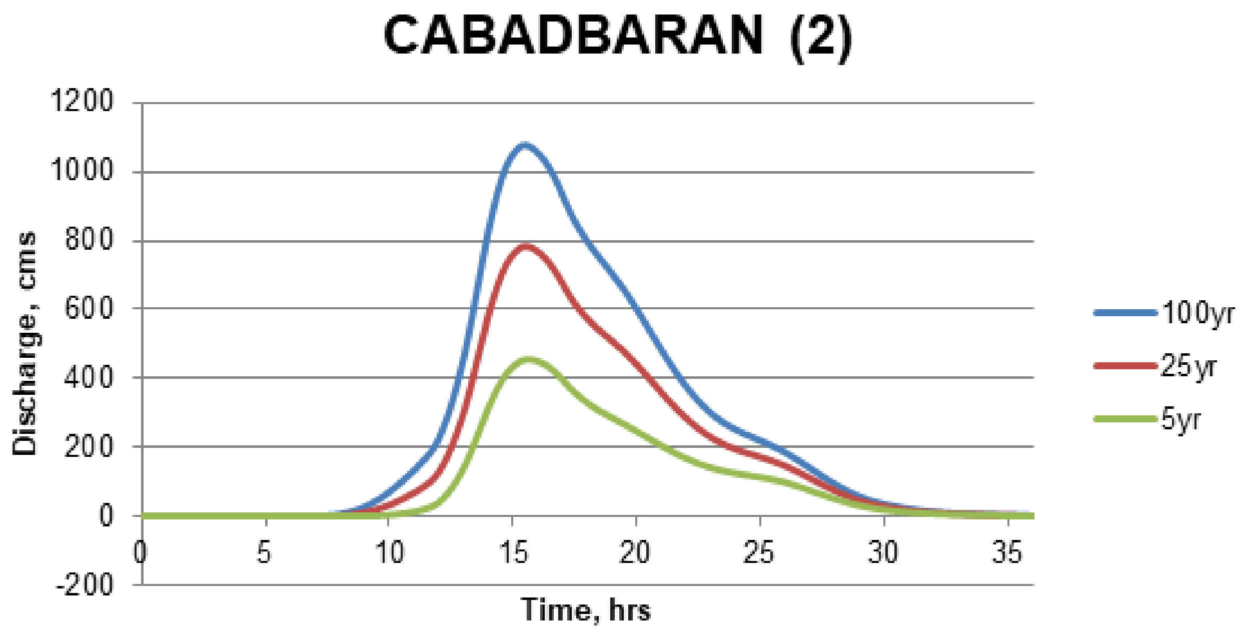


Figure 63. Cabadbaran river (2) generated discharge using 5-, 25-, and 100-year Butuan City RIDF in HEC-HMS

Table 36. Summary of Cabadbaran river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	973.7	13 hours, 40 minutes
25-Year	753.8	13 hours, 40 minutes
5-Year	489.6	13 hours, 40 minutes

Table 37. Summary of Cabadbaran river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1079.2	15 hours, 30 minutes
25-Year	786.5	15 hours, 30 minutes
5-Year	454.5	15 hours, 30 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 38.

Table 38. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Cabadbaran (1)	430.848	511.328	302.261	Pass	Pass
Cabadbaran (2)	399.960	582.878	445.789	Pass	Pass

The two values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis Model Simulation

Regarding the methodology, the HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 64 shows a generated sample map of the Cabadbaran River using the calibrated HMS base flow during typhoon "Seniang".

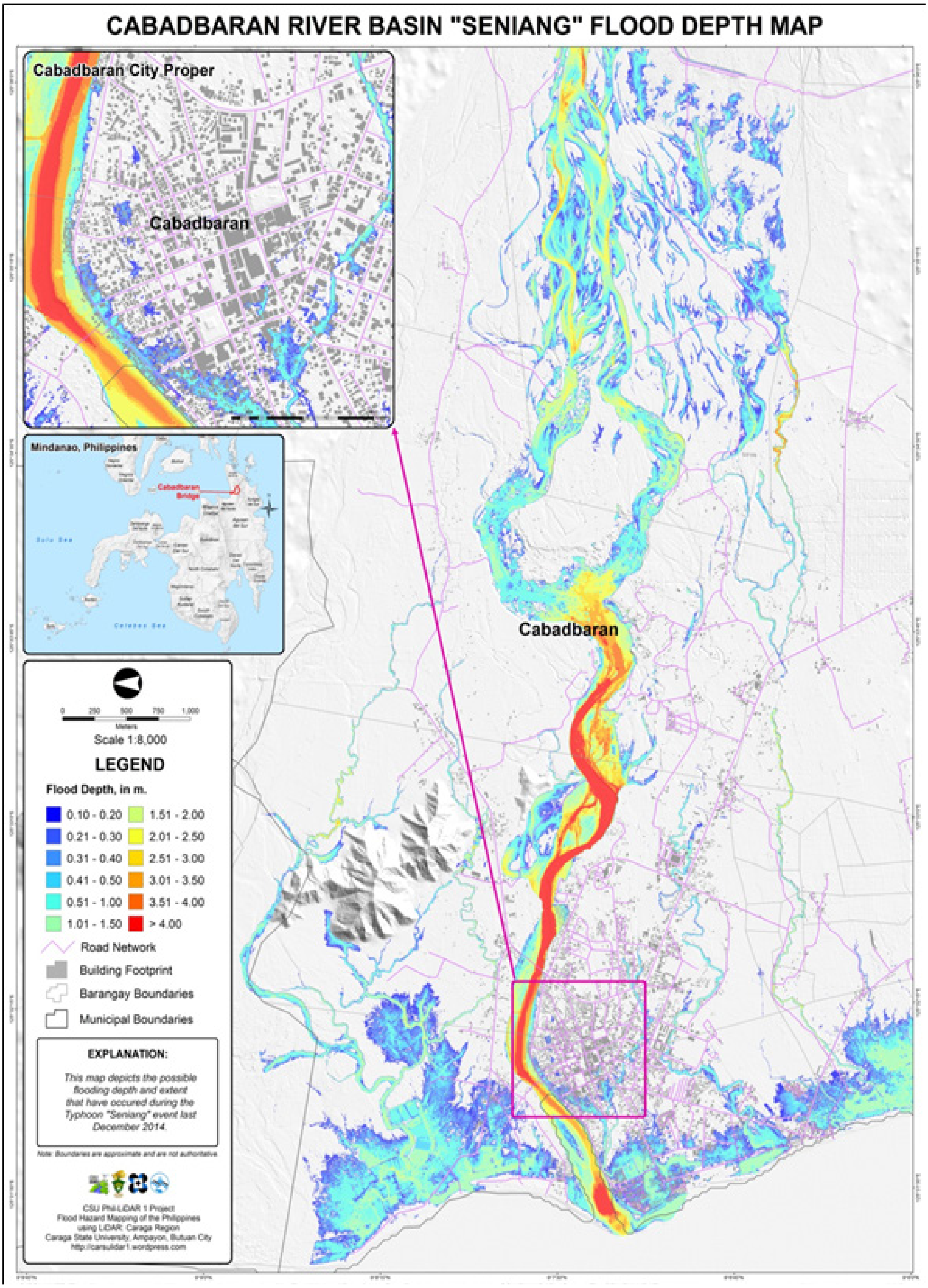


Figure 64. Flood depth and extent at Cabadbaran River basin during typhoon "Seniang".

5.9 Flood Hazard and Flow Depth Map

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

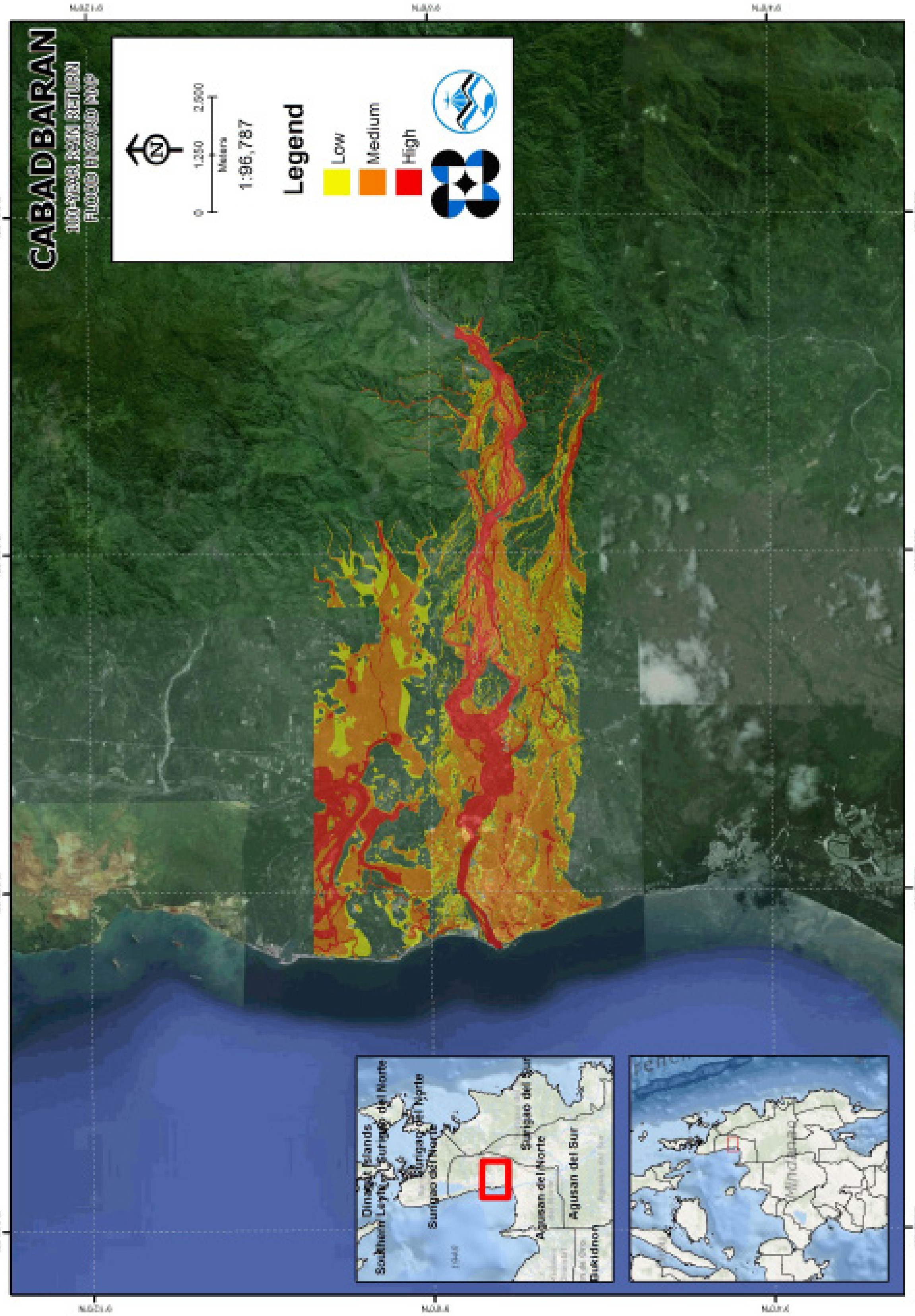


Figure 65. 100-year Flood Hazard Map for Cabadbaran Floodplain overlaid in Google Earth imagery

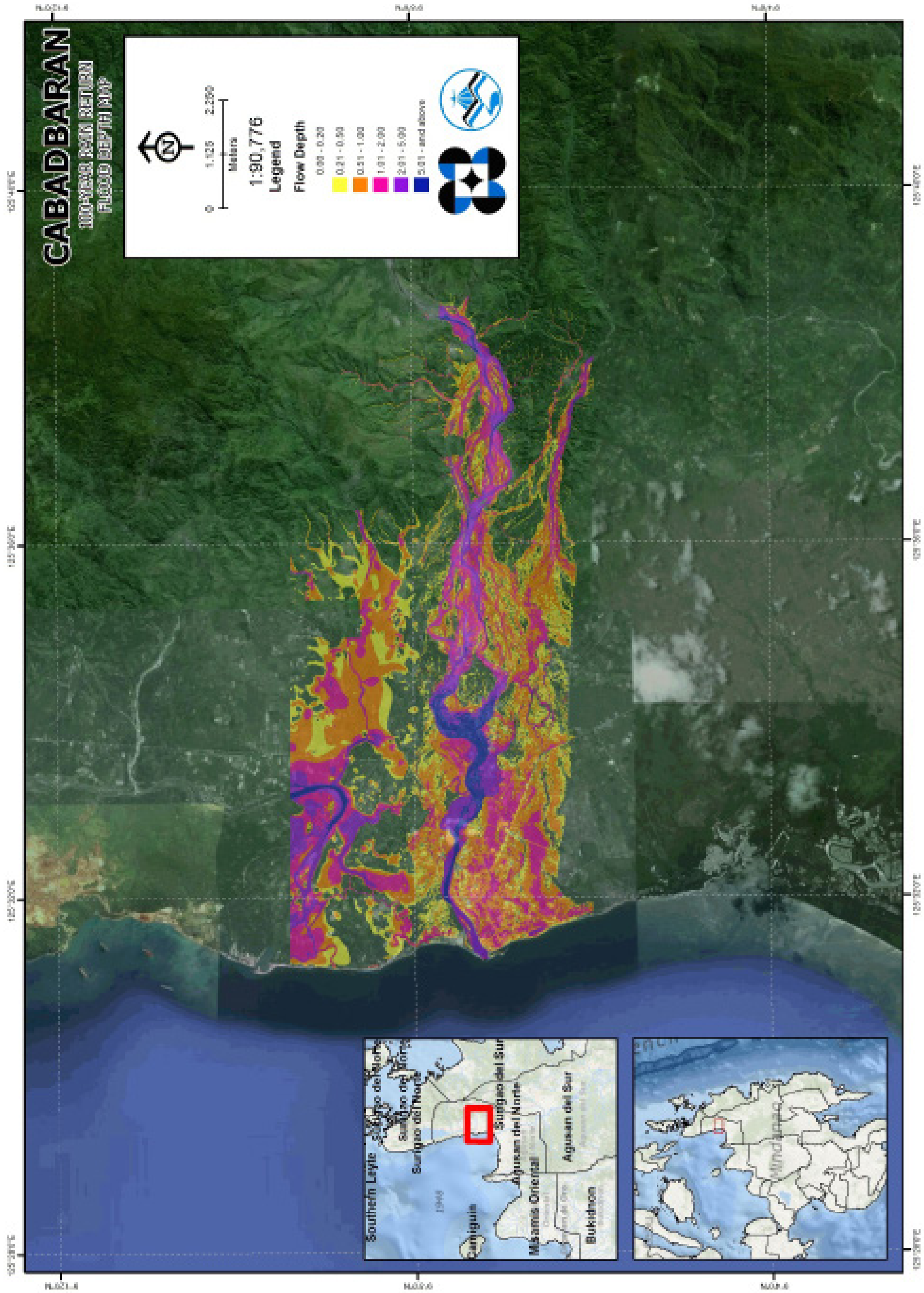


Figure 66. 100-year Flow Depth Map for Cabadbaran Floodplain overlaid in Google Earth imagery

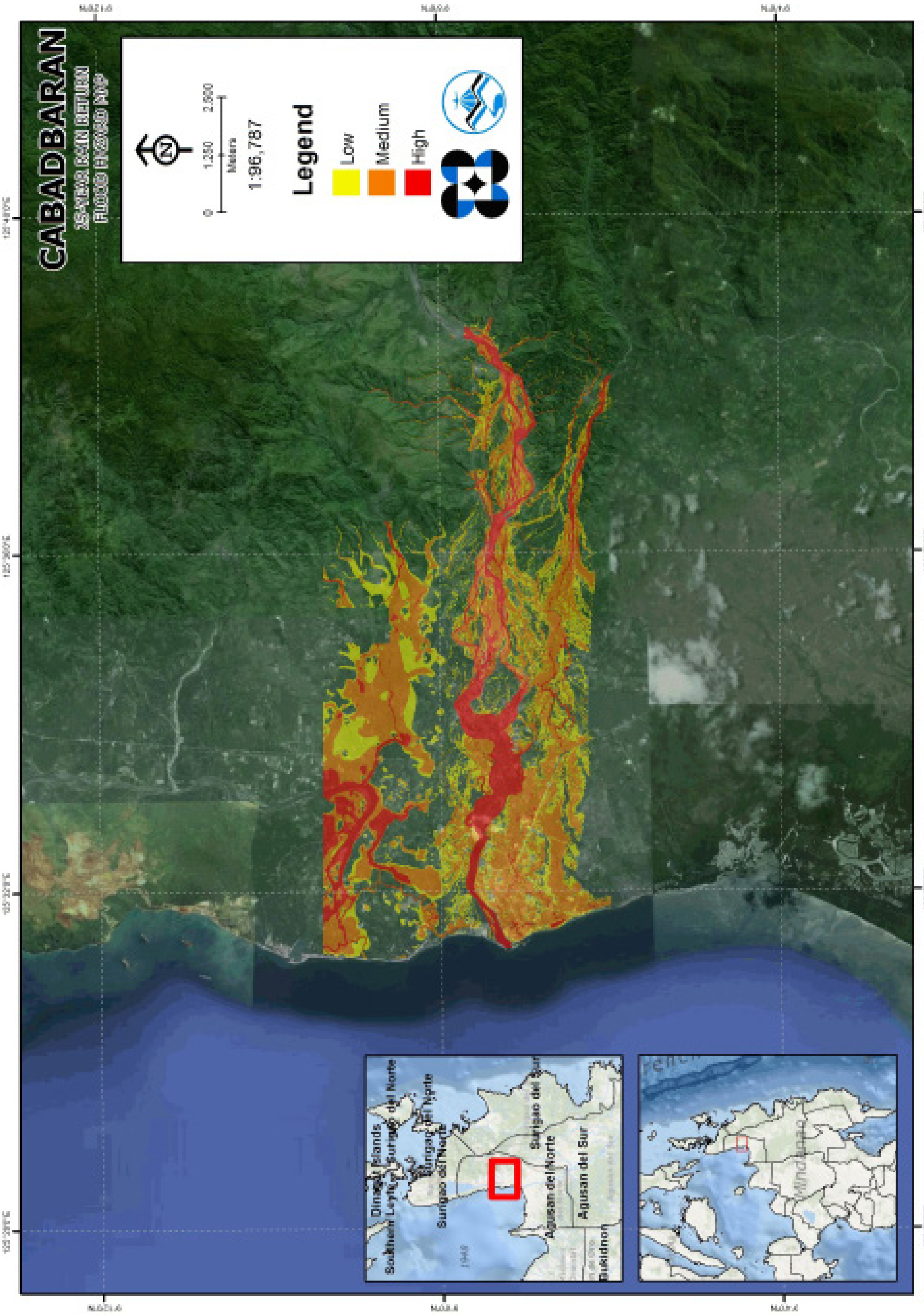


Figure 67. 25-year Flood Hazard Map for Cabadbaran Floodplain overlaid in Google Earth imagery

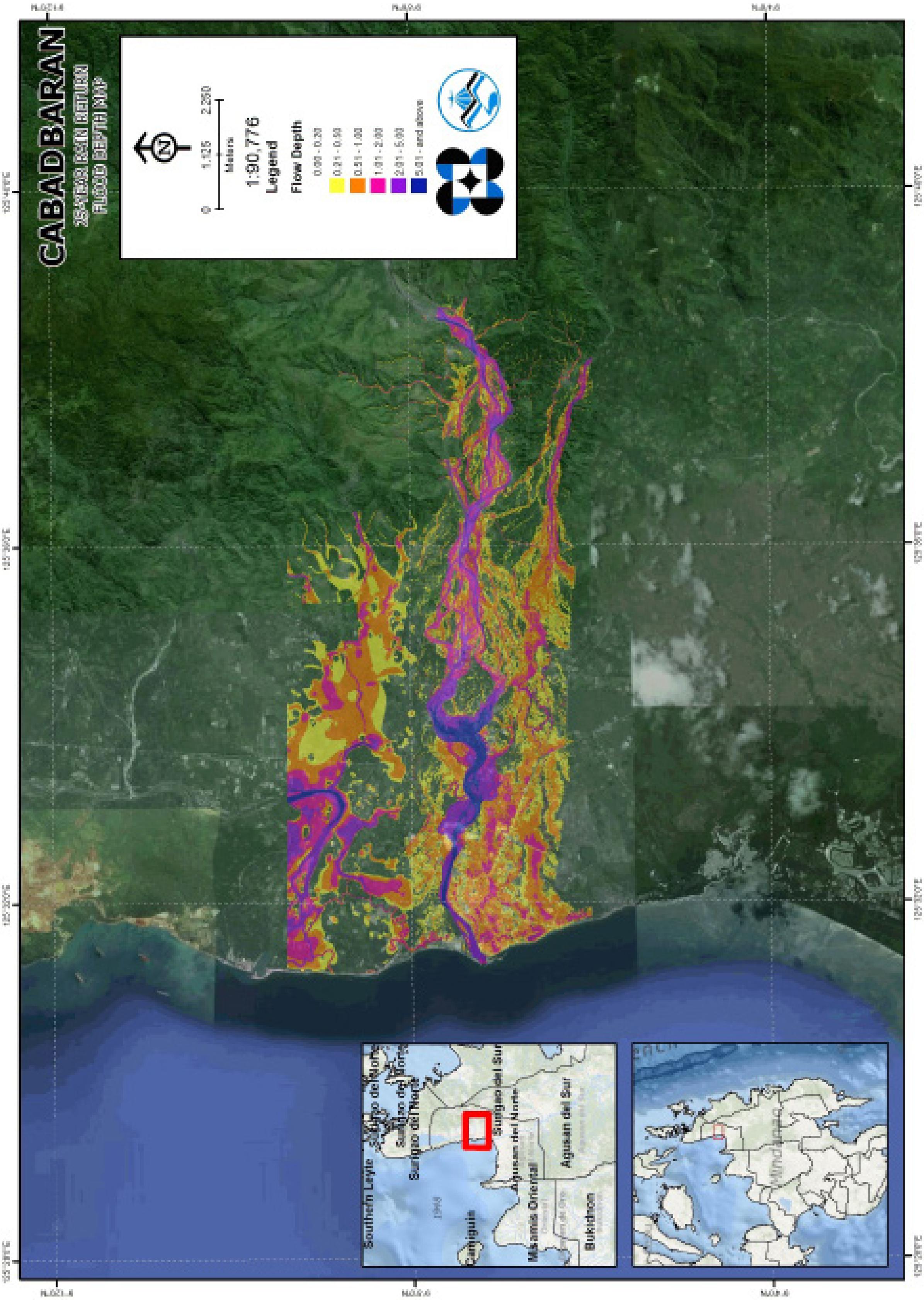


Figure 68. 25-year Flow Depth Map for Cabadbaran Floodplain overlaid in Google Earth imagery

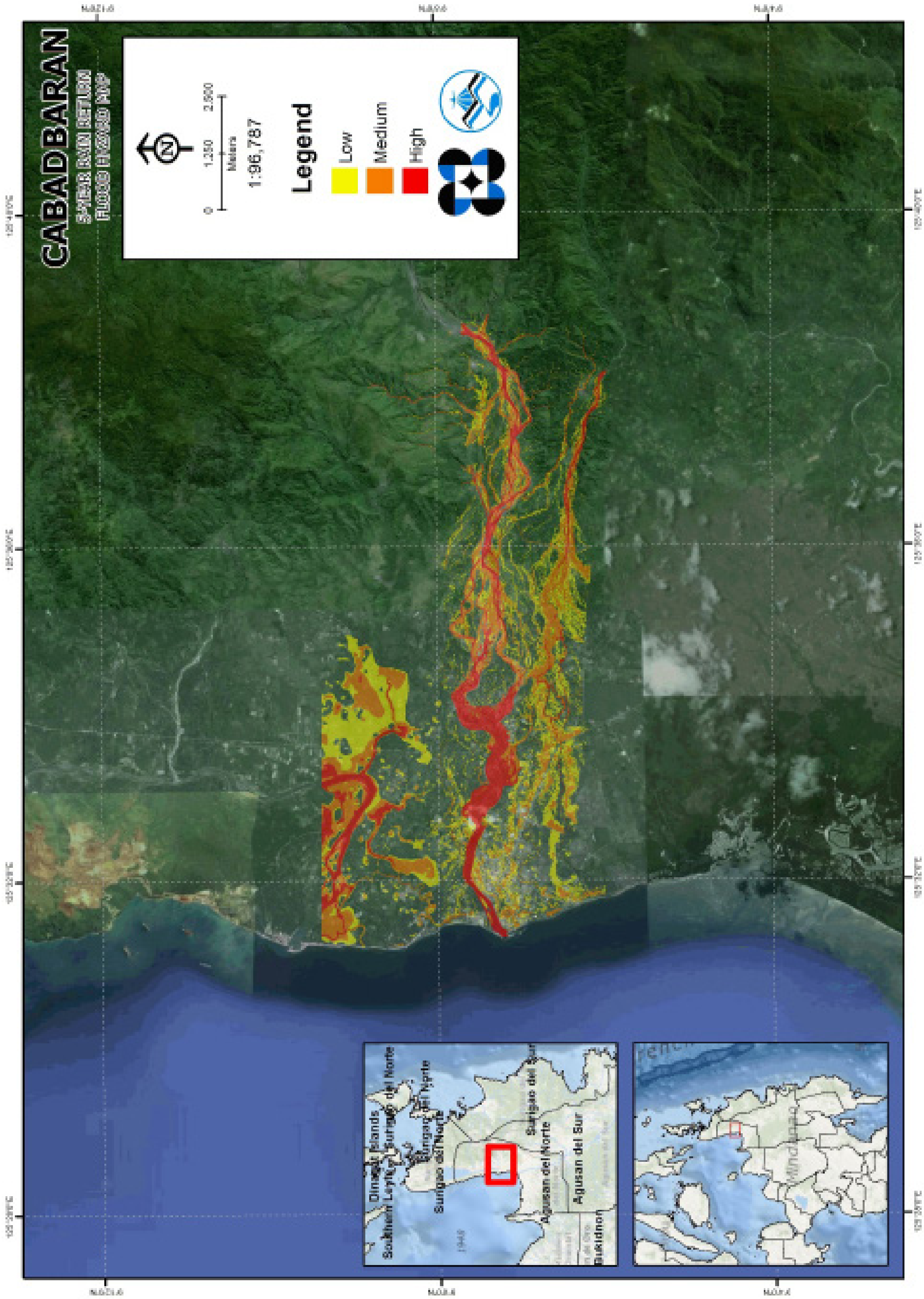


Figure 69. 5-year Flood Hazard Map for Cabadbaran Floodplain overlaid in Google Earth imagery

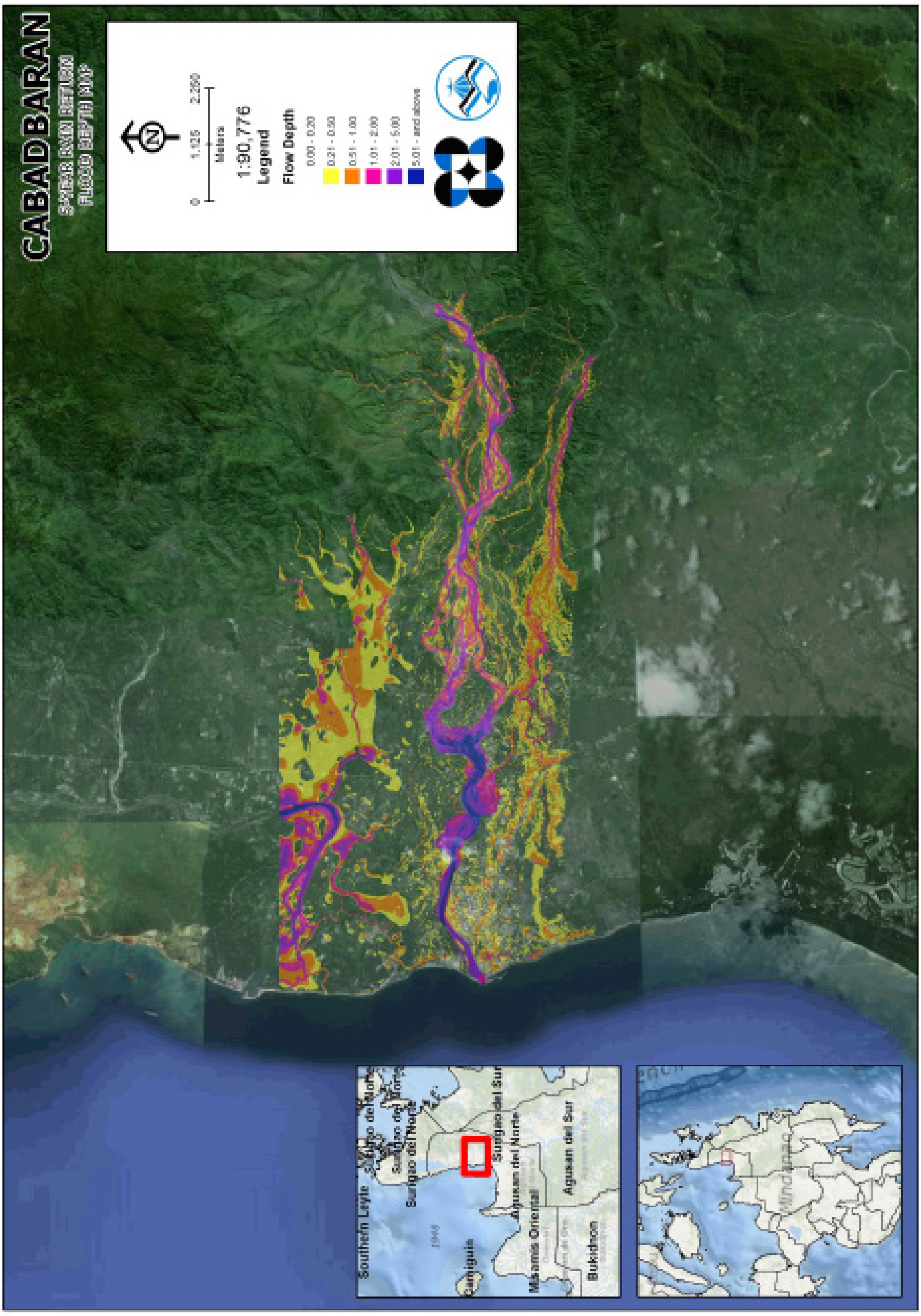


Figure 70. 5-year Flow Depth Map for Cabadbaran Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Cabadbaran River Basin, grouped accordingly by city/ municipality. For the said basin, two (2) municipalities consisting of 28 barangays are expected to experience flooding when subjected to a 5-year, 25-year and 100-year rainfall return period.

For the 5-year return period, 11.01% of the municipality of Cabadbaran City with an area of 343.91 sq. km. will experience flood levels of less than 0.20 meters. 2.74% of the area will experience flood levels of 0.21 to 0.50 meters while 1.72%, 0.88%, 0.62%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding, respectively.

Table 39. Affected Areas in Cabadbaran during 5-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Bay-Ang	Bayabas	Caasinan	Cabinet	Calamba	Comagascas	Del Pilar	Katugasan
0.03-0.20	0.36	5.35	2.55	0.99	0.25	4.8	2.54	4.52
0.21-0.50	0.24	0.86	0.57	0.36	0.027	1.79	0.51	1.7
0.51-1.00	0.12	0.61	0.4	0.14	0.024	0.89	0.18	1.61
1.01-2.00	0.018	0.2	0.11	0.025	0.0083	0.43	0.066	0.94
2.01-5.00	0.0004	0.026	0.045	0	0.0006	0.72	0.0061	0.42
> 5.00	0	0.000065	0.032	0	0	0.38	0	0.0013

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Kauswagan	Mabini	Mahaba	Poblacion 1	Poblacion 2	Poblacion 3	Poblacion 4	Poblacion 5
0.03-0.20	5.21	1.26	4.69	0.082	0.013	0.1	0.05	0.032
0.21-0.50	1.26	0.63	0.33	0.0075	0.017	0.054	0.0011	0.0082
0.51-1.00	0.45	0.21	0.33	0.01	0.023	0.0009	0	0.0019
1.01-2.00	0.26	0.043	0.25	0.0023	0.0027	0.0005	0	0.00027
2.01-5.00	0.45	0.032	0.086	0.000099	0	0	0	0
> 5.00	0.23	0	0.00076	0	0	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Poblacion 6	Poblacion 7	Poblacion 8	Poblacion 9	Poblacion 10	Poblacion 12	Puting Bato	Tolosa
0.03-0.20	0.05	0.094	0.056	0.063	0.02	0.00024	4.58	0.22
0.21-0.50	0.046	0.079	0.049	0.057	0.000011	0	0.77	0.064
0.51-1.00	0.019	0.028	0.025	0.029	0	0	0.77	0.036
1.01-2.00	0.0013	0.0027	0	0.0034	0	0	0.66	0.00054
2.01-5.00	0.0002	0.00083	0	0.00074	0	0	0.35	0
> 5.00	0	0	0	0	0	0	0.019	0

For the 5-year return period, 0.59% of the municipality of Tubay with an area of 515.17 sq. km. will experience flood levels of less than 0.20 meters. 0.38% of the area will experience flood levels of 0.21 to 0.50 meters while 0.29%, 0.22%, 0.15%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Tubay during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Tubay			
	Cabayawa	Doña Rosario	Poblacion 1	Victory
0.03-0.20	2.13	0.12	0.19	0.59
0.21-0.50	0.35	0.093	0.081	1.42
0.51-1.00	0.48	0.043	0.15	0.82
1.01-2.00	0.5	0.02	0.22	0.38
2.01-5.00	0.38	0.015	0.13	0.25
> 5.00	0.0094	0.0056	0	0.078

For the 25-year return period, 8.37% of the municipality of Cabadbaran City with an area of 343.91 sq. km. will experience flood levels of less than 0.20 meters. 2.92% of the area will experience flood levels of 0.21 to 0.50 meters while 3.15%, 1.57%, 0.87%, and 0.30% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Cabadbaran during 25-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Bay-Ang	Bayabas	Caasinan	Cabinet	Calamba	Comagascas	Del Pilar	Katugasan
0.03-0.20	0.28	4.97	1.76	0.11	0.23	3.37	2.38	3.15
0.21-0.50	0.27	0.87	0.66	0.33	0.034	1.74	0.56	1.8
0.51-1.00	0.14	0.85	0.71	0.78	0.031	1.93	0.24	2.12
1.01-2.00	0.039	0.31	0.47	0.27	0.016	0.55	0.11	1.39
2.01-5.00	0.0004	0.054	0.082	0.0095	0.0017	0.76	0.011	0.73
> 5.00	0	0.000065	0.034	0	0	0.67	0	0.0077

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Kauswagan	Mabini	Mahaba	Poblacion 1	Poblacion 2	Poblacion 3	Poblacion 4	Poblacion 5
0.03-0.20	2.83	0.93	4.49	0.033	0	0.041	0.026	0.026
0.21-0.50	1.53	0.74	0.35	0.04	0.003	0.038	0.025	0.013
0.51-1.00	1.94	0.42	0.35	0.021	0.015	0.035	0.000099	0.0026
1.01-2.00	0.72	0.057	0.35	0.0073	0.037	0.042	0	0.00067
2.01-5.00	0.56	0.038	0.14	0.001	0	0.0003	0	0.0003
> 5.00	0.28	0	0.0023	0	0	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Poblacion 6	Poblacion 7	Poblacion 8	Poblacion 9	Poblacion 10	Poblacion 12	Puting Bato	Tolosa
0.03-0.20	0.024	0.038	0.04	0.034	0.02	0.00024	3.91	0.097
0.21-0.50	0.013	0.06	0.042	0.055	0.00029	0	0.8	0.07
0.51-1.00	0.054	0.1	0.047	0.057	0	0	0.87	0.11
1.01-2.00	0.025	0.0045	0	0.0054	0	0	0.94	0.045
2.01-5.00	0.0003	0.00093	0	0.00094	0	0	0.59	0.000099
> 5.00	0	0	0	0	0	0	0.053	0

For the 25-year return period, 0.40% of the municipality of Tubay with an area of 515.17 sq. km. will experience flood levels of less than 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.40%, 0.34%, 0.24%, 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. Table 39 depicts the areas affected in square kilometers by flood depth per barangay.

Table 42. Affected areas in Tubay during a 25-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Tubay			
	Cabayawa	Doña Rosario	Poblacion 1	Victory
0.03-0.20	1.56	0.082	0.11	0.31
0.21-0.50	0.41	0.085	0.042	0.73
0.51-1.00	0.55	0.079	0.12	1.29
1.01-2.00	0.71	0.024	0.24	0.78
2.01-5.00	0.6	0.022	0.27	0.33
> 5.00	0.022	0.0077	0	0.1

For the 100-year return period, 7.26% of the municipality of Cabadbaran City with an area of 343.91 sq. km. will experience flood levels of less than 0.20 meters. 2.69% of the area will experience flood levels of 0.21 to 0.50 meters while 3.59%, 2.24%, 1.02%, and 0.37% 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. Table 40 depicts the areas affected in Cabadbaran in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Cabadbaran during 100-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Bay-Ang	Bayabas	Caasinan	Cabinet	Calamba	Comagascas	Del Pilar	Katugasan
0.03-0.20	0.24	4.73	1.41	0.043	0.22	2.48	2.27	2.44
0.21-0.50	0.28	0.93	0.78	0.17	0.031	1.68	0.59	1.56
0.51-1.00	0.16	0.94	0.74	0.75	0.037	2.37	0.29	2.44
1.01-2.00	0.054	0.37	0.63	0.52	0.023	0.94	0.14	1.8
2.01-5.00	0.0004	0.075	0.11	0.022	0.0024	0.72	0.012	0.94
> 5.00	0	0.000065	0.035	0	0	0.83	0	0.029

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Kauswagan	Mabini	Mahaba	Poblacion 1	Poblacion 2	Poblacion 3	Poblacion 4	Poblacion 5
0.03-0.20	2.3	0.77	4.37	0.0093	0	0.012	0.012	0.02
0.21-0.50	1.08	0.75	0.35	0.033	0	0.027	0.022	0.018
0.51-1.00	2.28	0.54	0.36	0.039	0.0056	0.052	0.018	0.0036
1.01-2.00	1.3	0.084	0.41	0.02	0.049	0.064	0	0.00074
2.01-5.00	0.61	0.04	0.18	0.0014	0	0.0006	0	0.0004
> 5.00	0.29	0	0.0033	0	0	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Cabadbaran City							
	Poblacion 6	Poblacion 7	Poblacion 8	Poblacion 9	Poblacion 10	Poblacion 12	Puting Bato	Tolosa
0.03-0.20	0.016	0.018	0.03	0.019	0.019	0.00024	3.48	0.064
0.21-0.50	0.011	0.032	0.042	0.04	0.0011	0	0.76	0.059
0.51-1.00	0.025	0.1	0.057	0.079	0	0	0.94	0.13
1.01-2.00	0.064	0.052	0.0004	0.013	0	0	1.11	0.065
2.01-5.00	0.0004	0.0012	0	0.0016	0	0	0.79	0.000099
> 5.00	0	0	0	0	0	0	0.083	0

For the 100-year return period, 0.31% of the municipality of Tubay with an area of 515.17 sq. km. will experience flood levels of less than 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.39%, 0.41%, 0.30%, 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 41 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in Tubay during a 100-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Tubay			
	Cabayawa	Doña Rosario	Poblacion 1	Victory
0.03-0.20	1.23	0.064	0.083	0.24
0.21-0.50	0.45	0.08	0.018	0.43
0.51-1.00	0.54	0.077	0.074	1.3
1.01-2.00	0.87	0.039	0.24	0.98
2.01-5.00	0.73	0.032	0.35	0.43
> 5.00	0.026	0.0093	0.0002	0.14

Moreover, the generated flood hazard maps for the cabadbaran Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr) as shown Table 42.

Table 45. 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	10.03	11.32	10.19
Medium	8.88	17.85	21.21
High	15.64	8.14	10.10
TOTAL	34.55	37.31	41.50

Of the 28 identified Education Institutions in the Cabadbaran Floodplain, four (4) schools were assessed to be exposed to the Low level flooding during a 5-year scenario while one (1) was assessed to be exposed to Medium level flooding in the same scenario and none on the High level flooding. In the 25 year scenario, five (5) schools were assessed to be exposed to the Low level flooding, eleven (11) schools were assessed to be exposed to Medium level flooding, and none were exposed to High level flooding. For the 100 year scenario, four (4) schools were assessed for Low level flooding and fourteen (14) schools for Medium level flooding. In the same scenario, none were assessed to be exposed to High level flooding. See Annex 12 for a detailed enumeration of schools inside Cabadbaran floodplain.

Of the 5 identified Medical Institutions in Gandara Flood plain, 1 was assessed to be exposed to the Low level flooding during a 5-year scenario. In the 25-year scenario, two (2) were exposed to Low level flooding while three (3) were exposed to Middle level flooding. However, in the 100 year scenario, all five (5) wer assessed to be exposed to the Medium level flooding. See Annex 13 for a detailed enumeration of medical institutions inside Cabadbaran floodplain.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 71.

The flood validation consists of 876 points randomly selected all over the Cabadbaran floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.73 m. Table 46 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

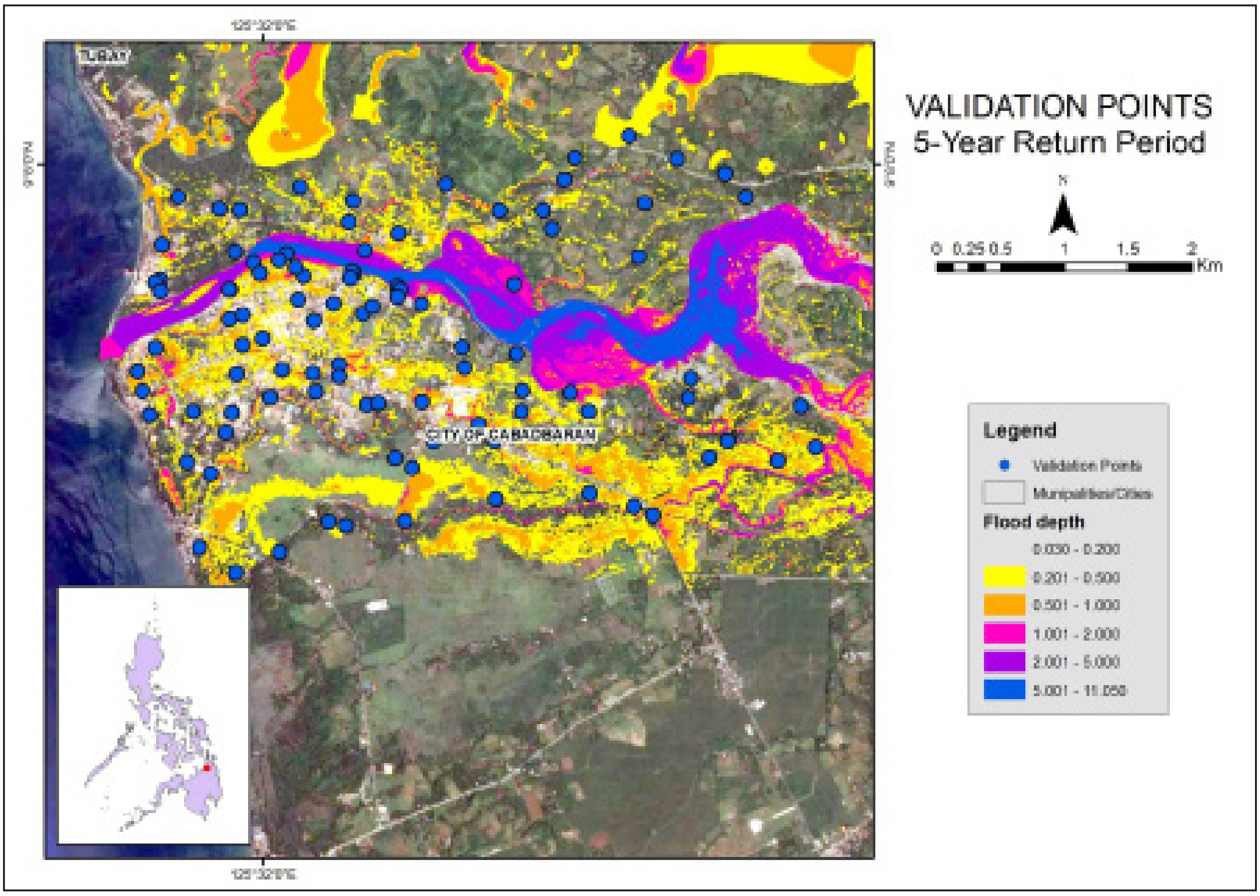


Figure 71. Validation Points for Flood Depth Map of the Cabadbaran Floodplain.

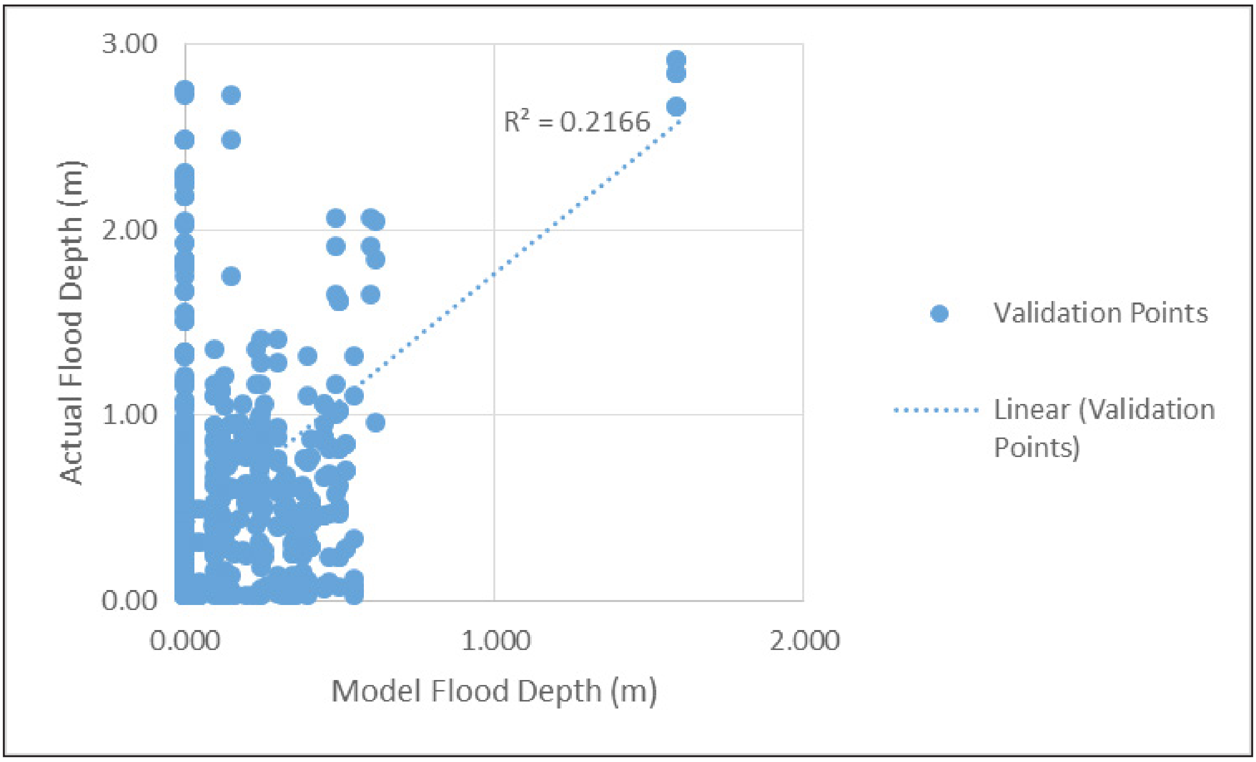


Figure 72. Flood map depth versus actual flood depth.

Table 46. Actual Flood Depth versus Simulated Flood Depth at different levels in the Cabadbaran River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
0-0.20	279	37	6	0	0	0	322
0.21-0.50	153	42	3	0	0	0	198
0.51-1.00	184	57	5	0	0	0	246
1.01-2.00	44	19	5	0	0	0	68
2.01-5.00	21	4	8	9	0	0	42
> 5.00	0	0	0	0	0	0	0
Total	681	159	27	9	0	0	876

The overall accuracy generated by the flood model is estimated at 37.21% with 326 points correctly matching the actual flood depths. In addition, there were 264 points estimated one level above and below the correct flood depths while there were 217 points estimated two levels above and below, and 69 points estimated three or more levels above and below the correct flood. A total of 46 points were overestimated while a total of 504 points were underestimated in the modelled flood depths of Bislig.

Table 44 depicts the summary of the Accuracy Assessment in the Cabadbaran River Basin Flood Depth Map.

Table 47. Summary of the Accuracy Assessment in the Cabadbaran River Basin Survey

	No. of Points	**%**
Correct	326	37.21
Overestimated	46	5.25
Underestimated	504	57.53
Total	876	100.00

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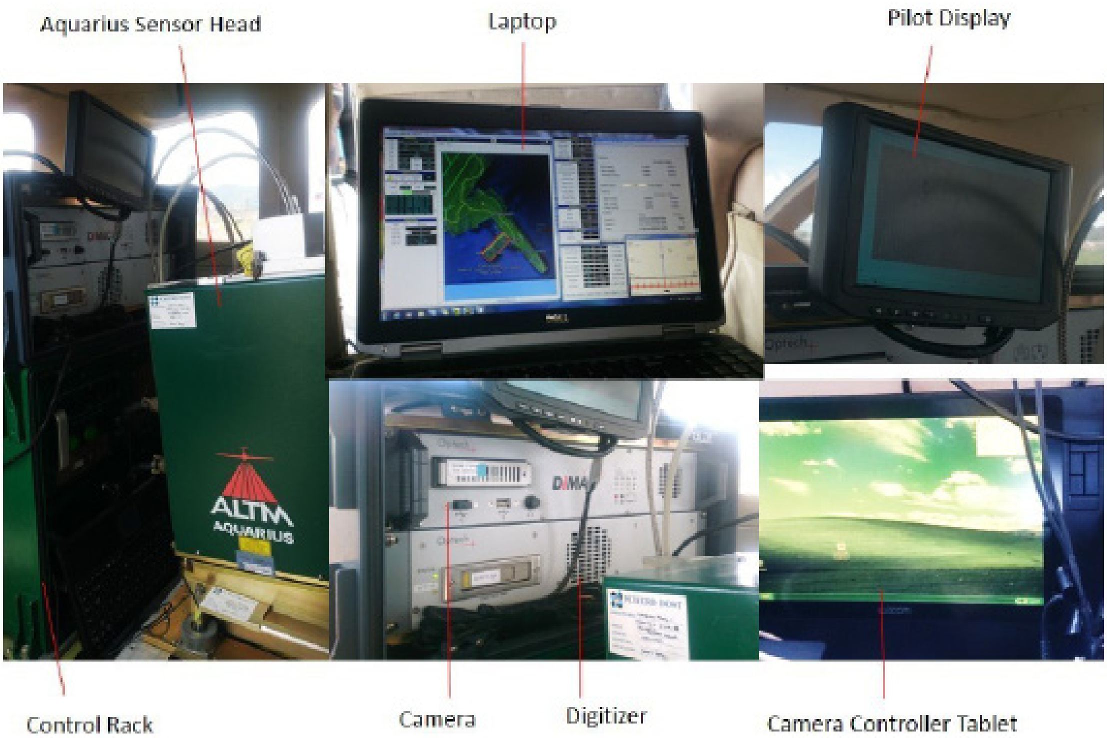
Annex 1. Optech Technical Specification of the Sensor

1. AQUARIUS SENSOR



2. PARAMETERS AND SPECIFICATIONS OF THE AQUARIUS SENSOR

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

3. GEMINI SENSOR

4. PARAMETERS AND SPECIFICATIONS OF THE GEMINI SENSOR

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. SRN-119

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **SURIGAO DEL NORTE**
Station Name: **SRN-119**
Order: **2nd**

Island: **MINDANAO**		Barangay: **LIPATA**
Municipality: **SURIGAO CITY (CAPITAL)**		
	PRS92 Coordinates	
Latitude: **9° 48' 39.62826"**	Longitude: **125° 27' 19.47825"**	Ellipsoidal Hgt: **26.17900 m.**
	WGS84 Coordinates	
Latitude: **9° 48' 35.65803"**	Longitude: **125° 27' 24.75607"**	Ellipsoidal Hgt: **92.90500 m.**
	PTM Coordinates	
Northing: **1084859.315 m.**	Easting: **549958.116 m.**	Zone: **5**
	UTM Coordinates	
Northing:	Easting:	Zone:

Location Description

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. AGN-3074

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **AGUSAN DEL NORTE**
Station Name: **AGN-3074**
Order: **4th**

Island: **MINDANAO** Municipality: **KITCHARAO**		Barangay: **JALIOBONG**
	PRS92 Coordinates	
Latitude: **9° 24' 4.13108"**	Longitude: **125° 33' 31.76634"**	Ellipsoidal Hgt: **39.75900 m.**
	WGS84 Coordinates	
Latitude: **9° 24' 0.38679"**	Longitude: **125° 33' 37.07966"**	Ellipsoidal Hgt: **107.05200 m.**
	PTM Coordinates	
Northing: **1039549.784 m.**	Easting: **561376.548 m.**	Zone: **5**
	UTM Coordinates	
Northing:	Easting:	Zone:

Location Description

AGN-3074

The station is located at the entrance gate of Jaliobong National High School.

30 x 30 x 100cm. concrete block with 80cm. set forth below the ground and 20cm. above the ground, marked with a 2" concrete nail in the center, embedded in the ground with inscriptions "AGN-3074; 2007; DENR/LMS XIII."

Requesting Party: UP-TCAGP
Purpose: Reference
OR Number: 0796299 A
T.N.: 2014-1302

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

NAMRIA OFFICES:
Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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3. AGN-3075

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: AGUSAN DEL NORTE
Station Name: AGN-3075
Order: 4th

Island: MINDANAO Municipality: KITCHARAO		Barangay: JALIOBONG
	PRS92 Coordinates	
Latitude: 9° 24' 7.19957"	Longitude: 125° 33' 29.91739"	Ellipsoidal Hgt: 38.99400 m.
	WGS84 Coordinates	
Latitude: 9° 24' 3.45501"	Longitude: 125° 33' 35.23064"	Ellipsoidal Hgt: 108.98400 m.
	PTM Coordinates	
Northing: 1039643.982 m.	Easting: 561319.987 m.	Zone: 5
	UTM Coordinates	
Northing:	Easting:	Zone:

Location Description

AGN-3075

The station is located beside Jaliobong Elementary School near the flagpole.

30 x 30 x 100cm. concrete block with 80cm. set forth below the ground and 20cm. above the ground, marked with a 2" concrete nail in the center, embedded in the ground with inscriptions "AGN-3075; 2007; DENR/LMS XIII."

Requesting Party: UP-TCAGP
Pupose: Reference
OR Number: 8795290 A
T.N.: 2014-1303

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

NAMRIA OFFICES
Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No. (632) 810-4831 to 41
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www.namria.gov.ph

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4. AGN-3026

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

June 26, 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: AGUSAN DEL NORTE
Station Name: AGN-3026
Order: 4th

Island: MINDANAO
Municipality: MAGALLANES
Barangay: BUHANG

PRS92 Coordinates

Latitude: 9° 2' 2.08829"	Longitude: 125° 31' 15.56287"	Ellipsoidal Hgt: 3.24800 m.

WGS84 Coordinates

Latitude: 9° 1' 58.43690"	Longitude: 125° 31' 20.90948"	Ellipsoidal Hgt: 71.84600 m.

PTM Coordinates

Northing: 998929.182 m.	Easting: 557280.19 m.	Zone: 5

UTM Coordinates

Northing: 999,496.52	Easting: 777,155.05	Zone: 51

Location Description

30 x 30 x 100 cm. concrete block with 80 cm. set forth below the ground and 20 cm. above the ground, marked with a 2" concrete nail in the center, embedded in the ground with inscriptions "AGN-3026; 2007; DENR/LMS." The station is located at the right side of the main gate or entrance of Buhang National Highway School in front of guard house.

23.5 km. north from Butuan City through national highway going to Surigao, passing Magallanes proper.

Requesting Party: UP-TCAGP
Pupose: Reference
OR Number: 8796391 A
T.N.: 2014-1474

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

NAMRIA OFFICES:
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5. AGN-10

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

June 26, 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: **AGUSAN DEL NORTE**
Station Name: **AGN-10**
Order: **3rd**

Island: **MINDANAO** Municipality: **CARMEN**		Barangay: **TAGCATONG**
	PRS92 Coordinates	
Latitude: **9° 0' 0.89032"**	Longitude: **125° 15' 35.40217"**	Ellipsoidal Hgt: **9.27600 m.**
	WGS84 Coordinates	
Latitude: **8° 59' 57.22480"**	Longitude: **125° 15' 40.75438"**	Ellipsoidal Hgt: **77.30100 m.**
	PTM Coordinates	
Northing: **995175.315 m.**	Easting: **528569.795 m.**	Zone: **5**
	UTM Coordinates	
Northing: **995,583.65**	Easting: **748,451.81**	Zone: **51**

Location Description

AGN-10
Is located on the SE side of the reinforced concrete pipe culvert. It is about 40 m. SE of Km. Post 1275 and is about 200 m. W of Tagcatong Elem. School. Station mark is the head of a 4" concrete nail set flush on a 0.10 m. x 0.10 m. cement putty set on top of the concrete gutter, 1 m. dia. reinforced concrete pipe culvert. It is inscribed with the station name "AGN-10 2001 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796391 A**
T.N.: **2014-1473**

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

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6. AGN-3740

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

June 26, 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: **AGUSAN DEL NORTE**
Station Name: **AGN-3740**
Order: **4th**

Island: **Mindanao**
Municipality: **CABADBARAN**
Barangay: **SANGHAN**

PRS92 Coordinates

Latitude:	**9° 5' 7.75869"**	Longitude:	**125° 34' 15.24993"**	Ellipsoidal Hgt:	**9.80800 m.**

WGS84 Coordinates

Latitude:	**9° 5' 4.09807"**	Longitude:	**125° 34' 20.59141"**	Ellipsoidal Hgt:	**78.41800 m.**

PTM Coordinates

Northing:	**1004641.328 m.**	Easting:	**562759.097 m.**	Zone:	**5**

UTM Coordinates

Northing:	**1,005,242.03**	Easting:	**782,605.58**	Zone:	**51**

Location Description

AGN-3740

STA. MARK: AGN 3740 is a quadrilateral concrete monument 20cm x 20 cm x 100 cm with variable depth set on the ground (80 cm-100 cm) inscribed name "AGN 3740, 2012, 4th order, DENR and Copper nail embedded at the center.

ACCESS: AGN 3740 is located at Barangay Sanghan, from Butuan City, this monument is on the right side of the road and near at the bridge with an approximate distance of 5 m.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796391 A**
T.N.: **2014-1472**

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

NAMRIA OFFICES:
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

7. AGN-3067

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

July 11, 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: **AGUSAN DEL SUR**
Station Name: **AGS-3067**
Order: **3rd**

Island:	**MINDANAO**			Barangay:	**SAN VICENTE**
Municipality:	**SIBAGAT**			MSL Elevation:	
		PRS92 Coordinates			
Latitude:	**8° 48' 31.43541"**	Longitude:	**125° 42' 1.74627"**	Ellipsoidal Hgt:	**60.82800 m.**
		WGS84 Coordinates			
Latitude:	**8° 48' 27.85927"**	Longitude:	**125° 42' 7.11122"**	Ellipsoidal Hgt:	**130.34800 m.**
		PTM / PRS92 Coordinates			
Northing:	**974057.922 m.**	Easting:	**577062.844 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**974,717.59**	Easting:	**797,084.39**	Zone:	**51**

Location Description

AGS-3067
From Butuan City plaza landmark travel to Ampayon junction for 7 km. From junction of Ampayon going to Municipality of Sibagat for about 29 km. AGS-3067 is located on the concrete foundation of the flagpole, inside San Vicente Elementary School compound Sibagat district; 1 km from the main gate Sibagat Municipality going to Davao National highway left side. It is a walking distance of 150 m from the national highway angd 32 m from the main gate of San Vicente Elementary School. Mark is the head of a 3" copper nail set at the center of a 0.30 cm x 0.30 cm cement putty type block embedded in the ground with inscriptions AGS-3067 2007 NAMRIA.

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796607 A**
T.N.: **2014-1591**

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

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Annex 3. Baseline Processing Report of Reference Points Used

There are no baseline processing reports for the Cabadbaran river basin.

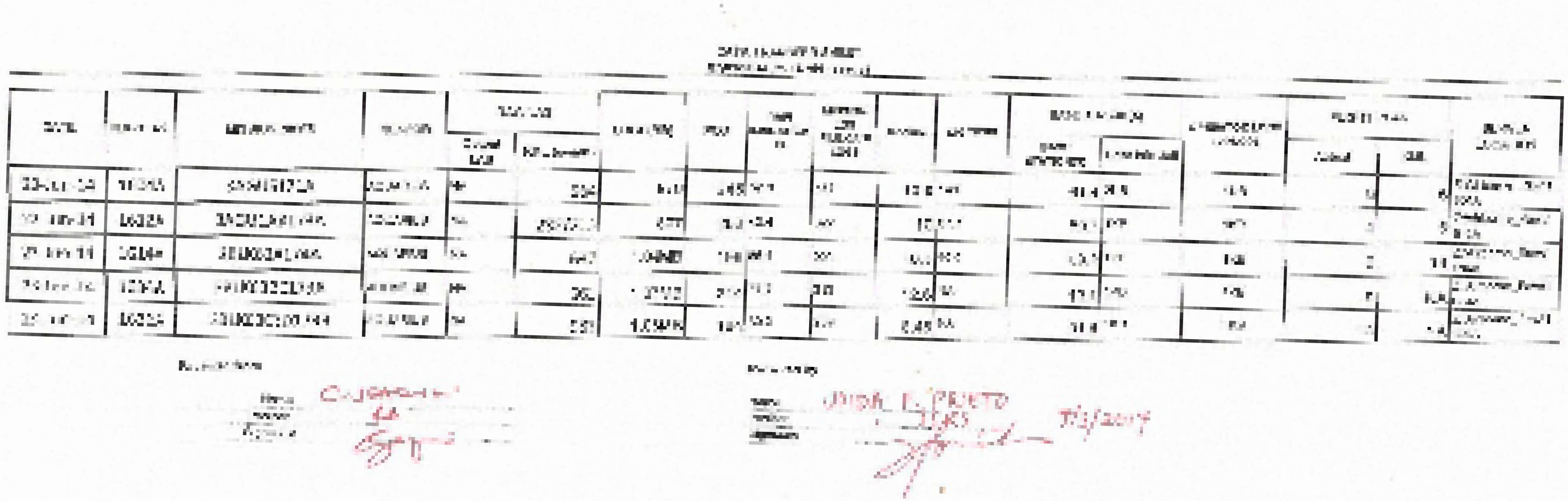
Annex 4. The LiDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME HIPOLITO	UP TCAGP
	Research Associate	MARY CATHERINE ELIZABETH BALIGUAS	UP TCAGP
	(RA)	MA VERLINA TONGA	UP TCAGP
		RA	UP TCAGP
		ENGR. LARAH KRISELLE PARAGAS	UP TCAGP
Ground Survey, Data download and transfer	RA	KRISTINE JOY ANDAYA	UP TCAGP
		KENNETH QUISADO	UP TCAGP
LiDAR Operation	Airborne Security	SSG. MICHAEL BERONILLA	PHILIPPINE AIR FORCE (PAF)
		SSG. MIKE DIAPANA	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RAUL CZ SAMAR II	AAC
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. JOHN BRYAN DONGUINES	AAC

Annex 5. Data Transfer Sheet For Cabadbaran Floodplain



DATA TRANSFER SHEET

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							Base Station(s)	Base Info (.txt)		Actual	KML	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Received from

Name [illegible]
Position [illegible]
Signature

Received by

Name [illegible]
Position [illegible]
Signature [illegible]

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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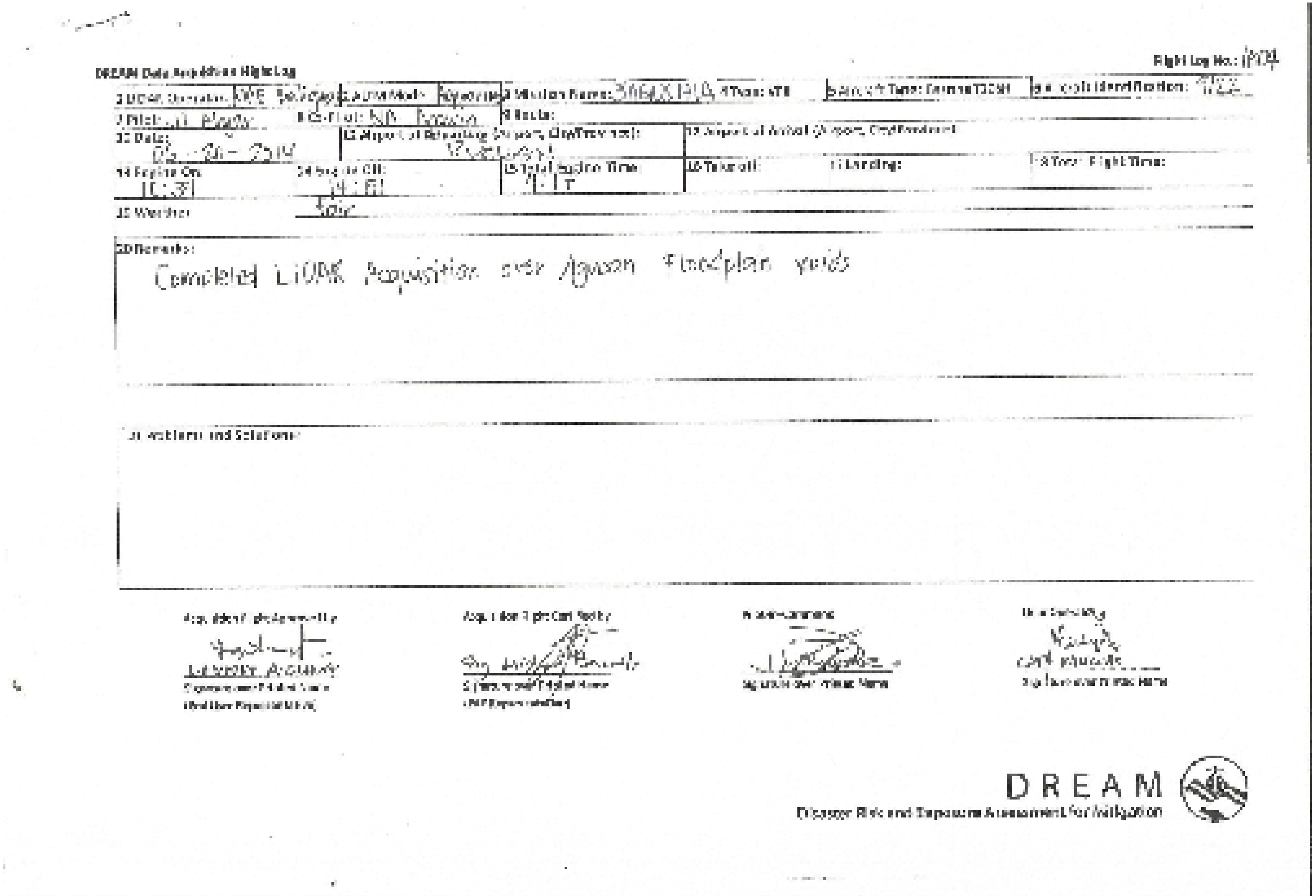
Annex 6. Flight Logs

1. Flight Log for 3AGUS171A Mission.



DREAM Data Acquisition Flight Log

20 Remarks:

Completed LiDAR Acquisition over Agusan Floodplain voids

21 Problems and Solutions:

DREAM

Disaster Risk and Exposure Assessment for Mitigation

2. Flight Log for 3AGU1AB173A Mission.

Flight Log No. 1612

DREAM Data Acquisition Flight Log

1 LIDAR Operator: MRS Bakawan	2 ALTM Model: Aquarius	3 Mission Name: 3AGU1AB173A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: JJ Nagor	8 Co-Pilot: MR Anyacon	9 Route:			
10 Date: Dec 22 - 2016	12 Airport of Departure (Airport, City/Province): Bukidnon		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1133	14 Engine Off: 1556	15 Total Engine Time: 423	16 Take off:	17 Landing:	18 Total Flight Time
19 Weather					

20 Remarks:

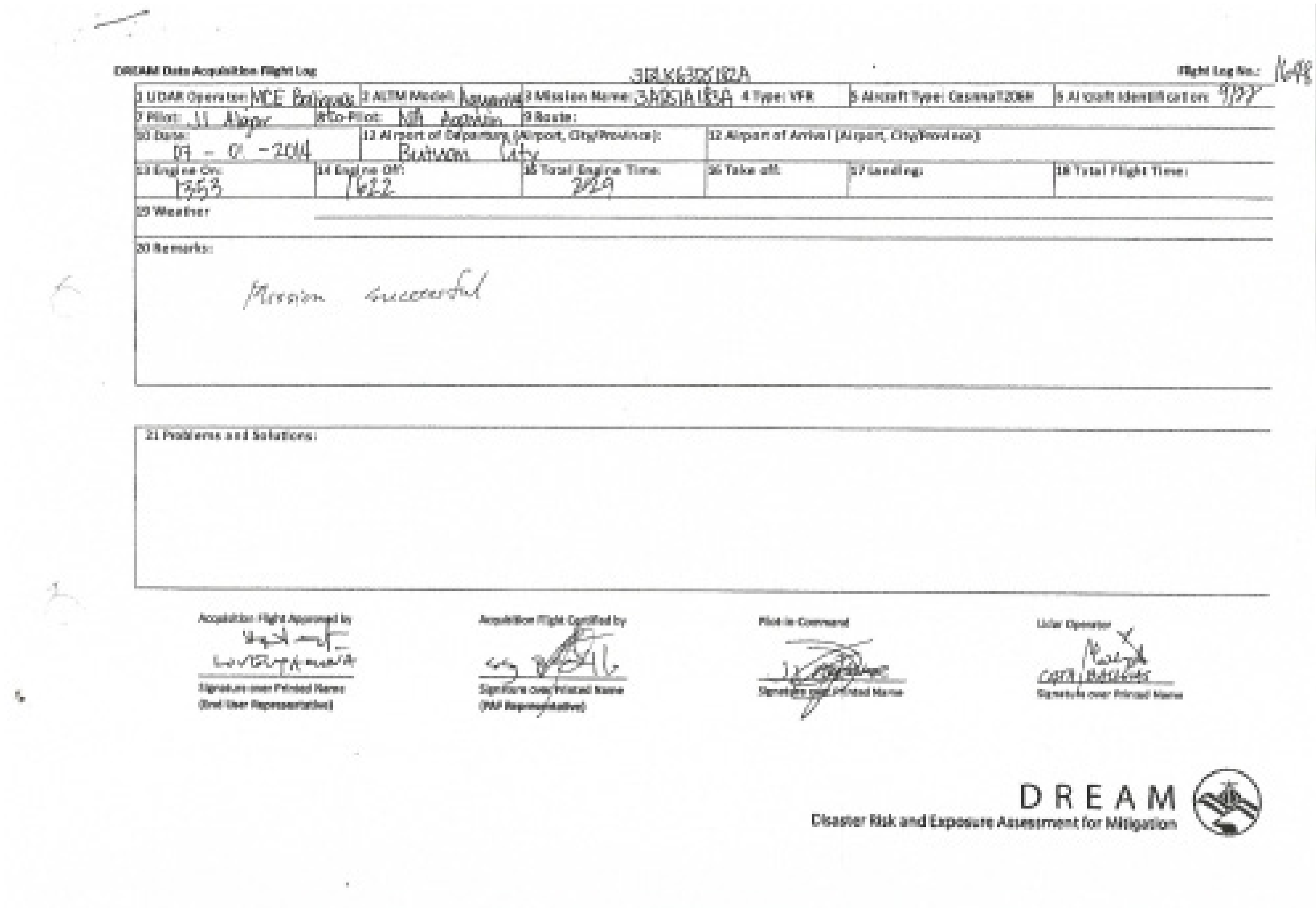
Mission Completed over AGU 1A and AGU 1B

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 3BLK63DS182A & 3ADS1A183A Mission.



DREAM Data Acquisition Flight Log

3BLK63DS182A

Flight Log No.: 1648

1 LIDAR Operator: MCE Balicanta	2 ALTM Model: Aquarius	3 Mission Name: 3ADS1A183A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: JJ Alajar	8 Co-Pilot: NM Aguilar	9 Route:			
10 Date: 07 - 01 - 2014	12 Airport of Departure (Airport, City/Province): Butuan City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1353	14 Engine Off: 1622	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission successful

21 Problems and Solutions:

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
CAPA. BALICANTA
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

4. Flight Log for 3ADS1A183A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 1652

1 LIDAR Operator: MCE Baliguas	2 ALTM Model:	3 Mission Name: 3ADS1A183A 4 Type: VFR		5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9177
7 Pilot: JJ Alayar	8 Co-Pilot: NA Agonia	9 Route:			
10 Date: 07-02-2014	12 Airport of Departure (Airport, City/Province): Butuan City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1333	14 Engine Off: 1620	15 Total Engine Time: 247	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: No Digitizer					

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator: Cate Baliguas — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

5. Flight Log for 3ADS1AB184A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 1659

1 LiDAR Operator: MCE Balicanot	2 ALTM Model: Aquarius	3 Mission Name: 3ADS1AB184A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: JS Alajar	8 Co-Pilot: NB Aquino	9 Route:			
10 Date: 7/3/2014 A	12 Airport of Departure (Airport, City/Province): Butuan City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0855	14 Engine Off: 1218	15 Total Engine Time: 0323	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission over ADS1A and surveyed 2 lines over ADS1B.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuna		JS Alajar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

6. Flight Log for 2BLK59AB157A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7294

1 LIDAR Operator: M.V. Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK59AB	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samar	8 Co-Pilot: R. Dangayan	9 Route: 157A			
10 Date: 6-6-15	12 Airport of Departure (Airport, City/Province): RPMS		13 Airport of Arrival (Airport, City/Province): RPMS		
13 Engine On: 5:26	14 Engine Off: 9:55	15 Total Engine Time: 4:29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather:					

20 Remarks:

Mission 59B completed & surveyed lines in 59C (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

Signature over Printed Name (PAF Representative)

Pilot-in-Command

R. Samar

Signature over Printed Name

Lidar Operator

M.V. Tonga

Signature over Printed Name

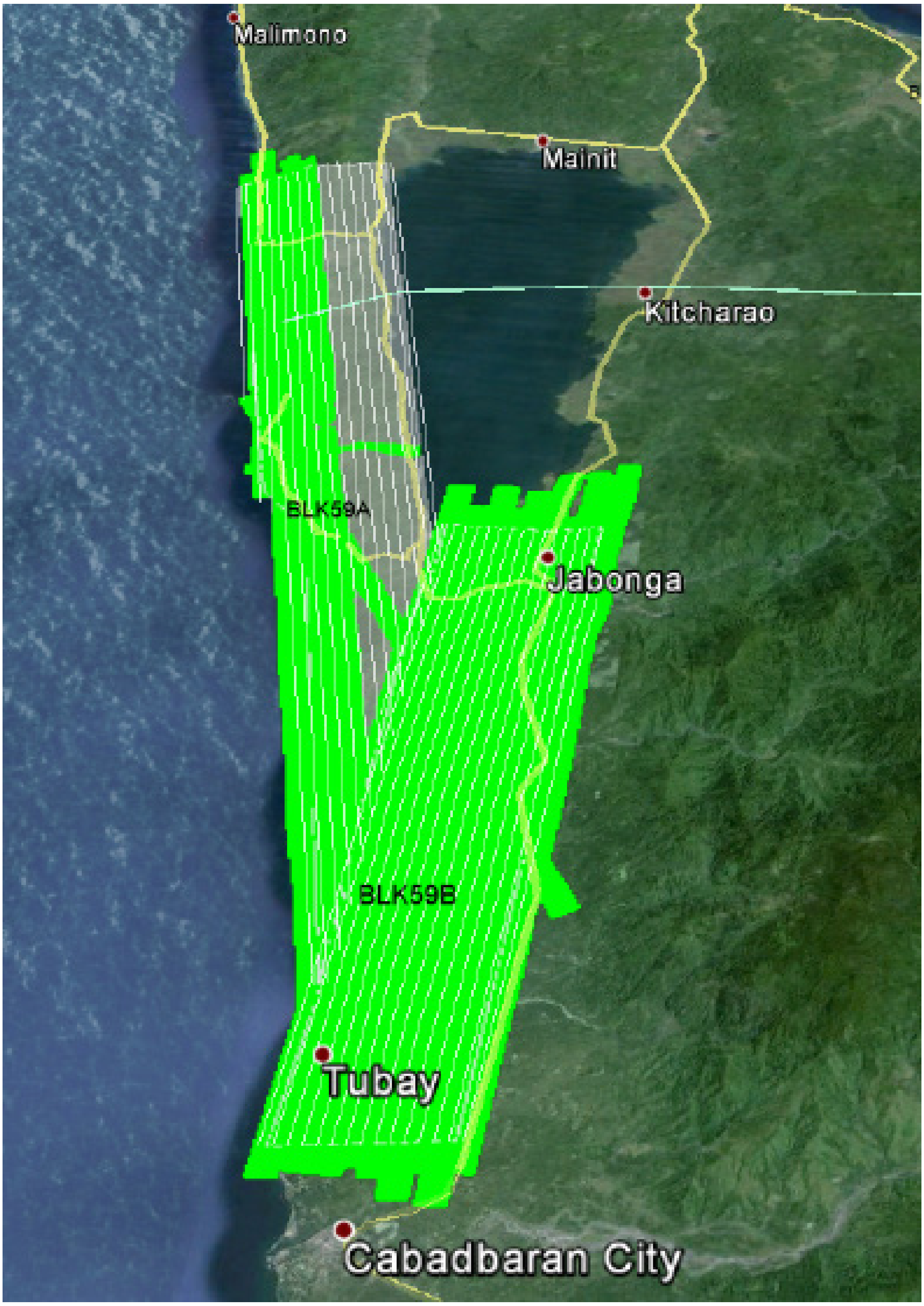
Annex 7. Flight Status

FLIGHT STATUS REPORT
CABADBARAN
June 6 – July 3, 2014

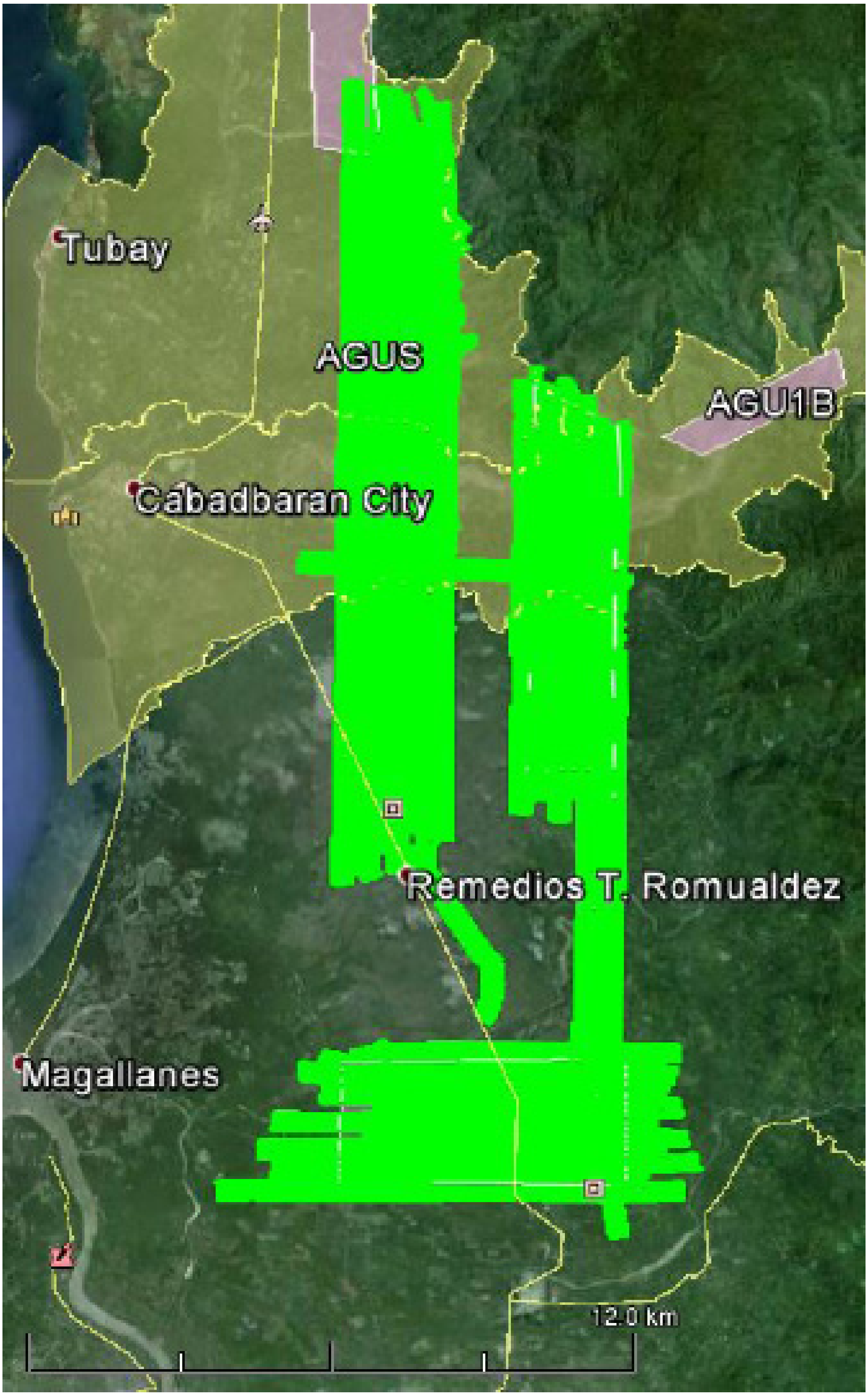
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7294	BLK59A & BLK59B	2BLK59AB157A	MV. TONGA	06 JUNE 14	Completed area B and covered 5 strips of area A
1604	AGU	3AGUS171A	MCE BALIGUAS	20 JUNE 14	Completed LiDAR Acquisition over Agusan Floodplain voids
1612	AGU1A & AGU1B	3AGU1AB173A	MCE BALIGUAS	22 JUNE 14	Mission completed over AGU 1A and AGU 1B
1648	BLK63D & ADS1A	3BLK63DS182A & 3ADS1A183A	MCE BALIGUAS	01 JUL 14	Completed mission over BLK63D and covered 2 lines over ADS1A
1652	ADS1A	3ADS1A183A	MCE BALIGUAS	02 JUL 14	Covered 9 lines over ADS1A. No digitizer.
1654	ADS1A	3ADS1AB184A	MCE BALIGUAS	03 JUL 14	Completed mission over ADS1A and surveyed 2 lines over ADS1B

SWATH PER FLIGHT MISSION

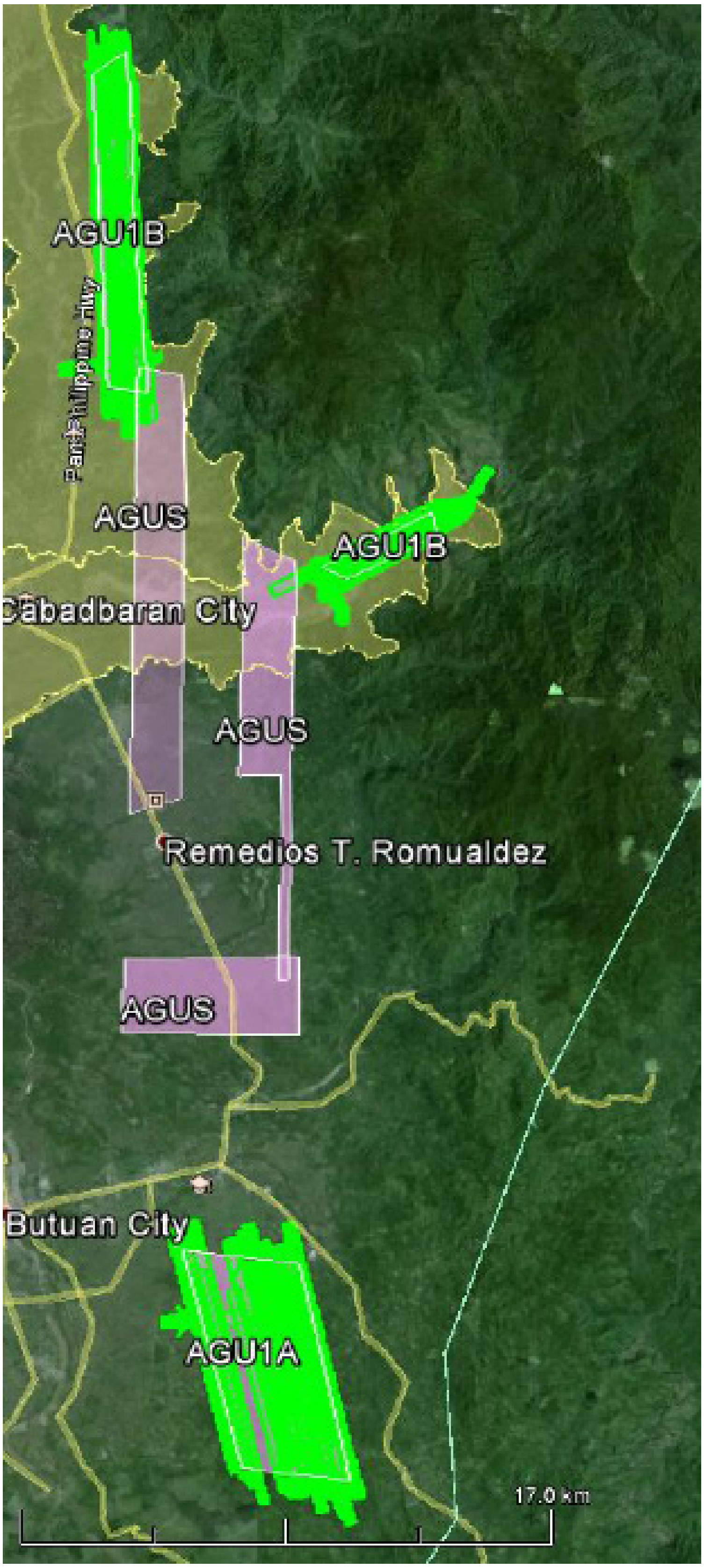
Flight No.:	7294GC
Area:	BLK59A & BLK59B
Mission Name:	2BLK59AB157A
Altitude:	1100m
PRF:	100 kHz SCF: 20Hz



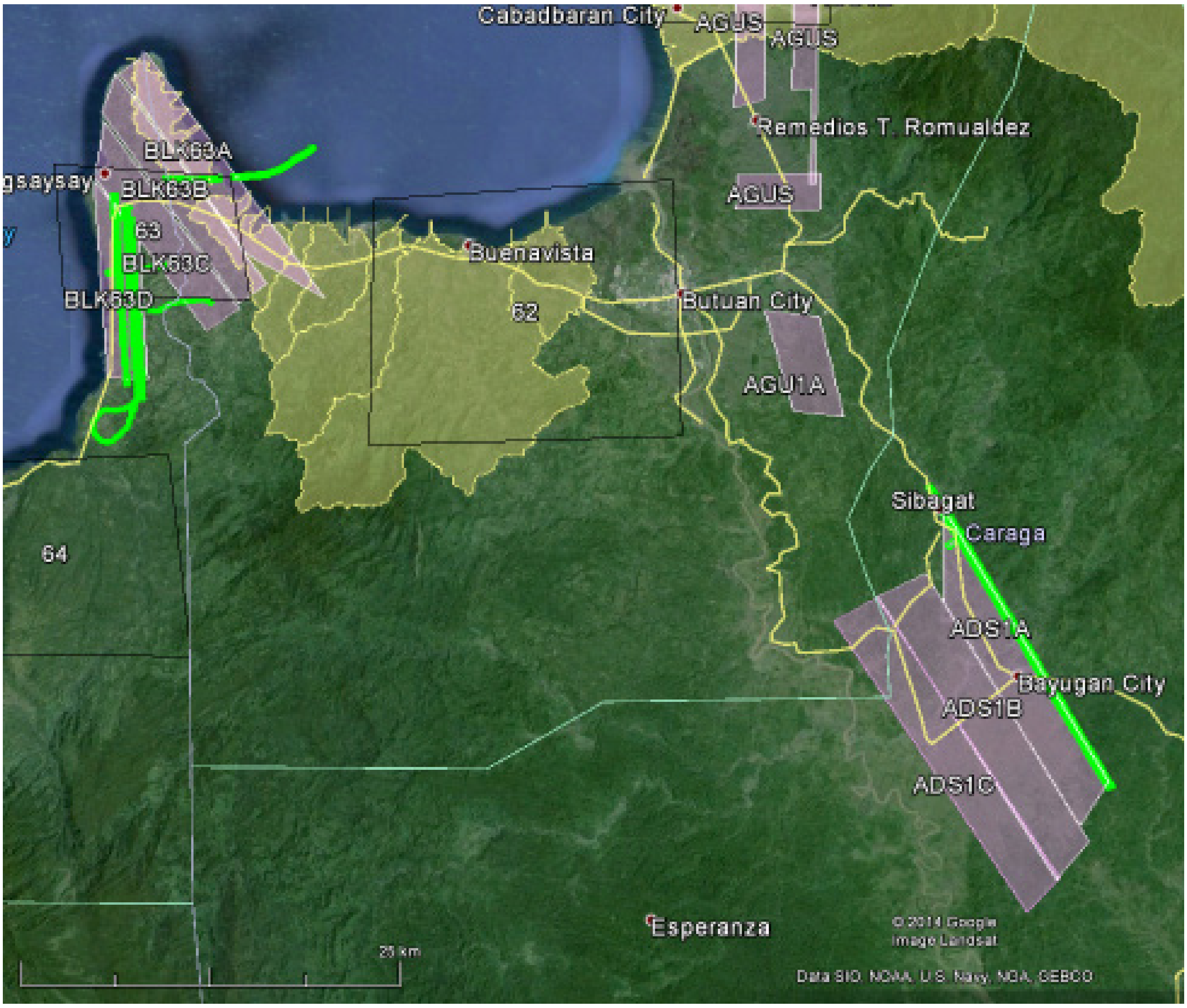
Flight No:	1604	
Area:	AGU	
Mission Name:	3AGUS171A	
Altitude:	600m	
PRF:	50 kHz	SCF: 45Hz
LiDAR FOV:	18 deg	Sidelap: 30%



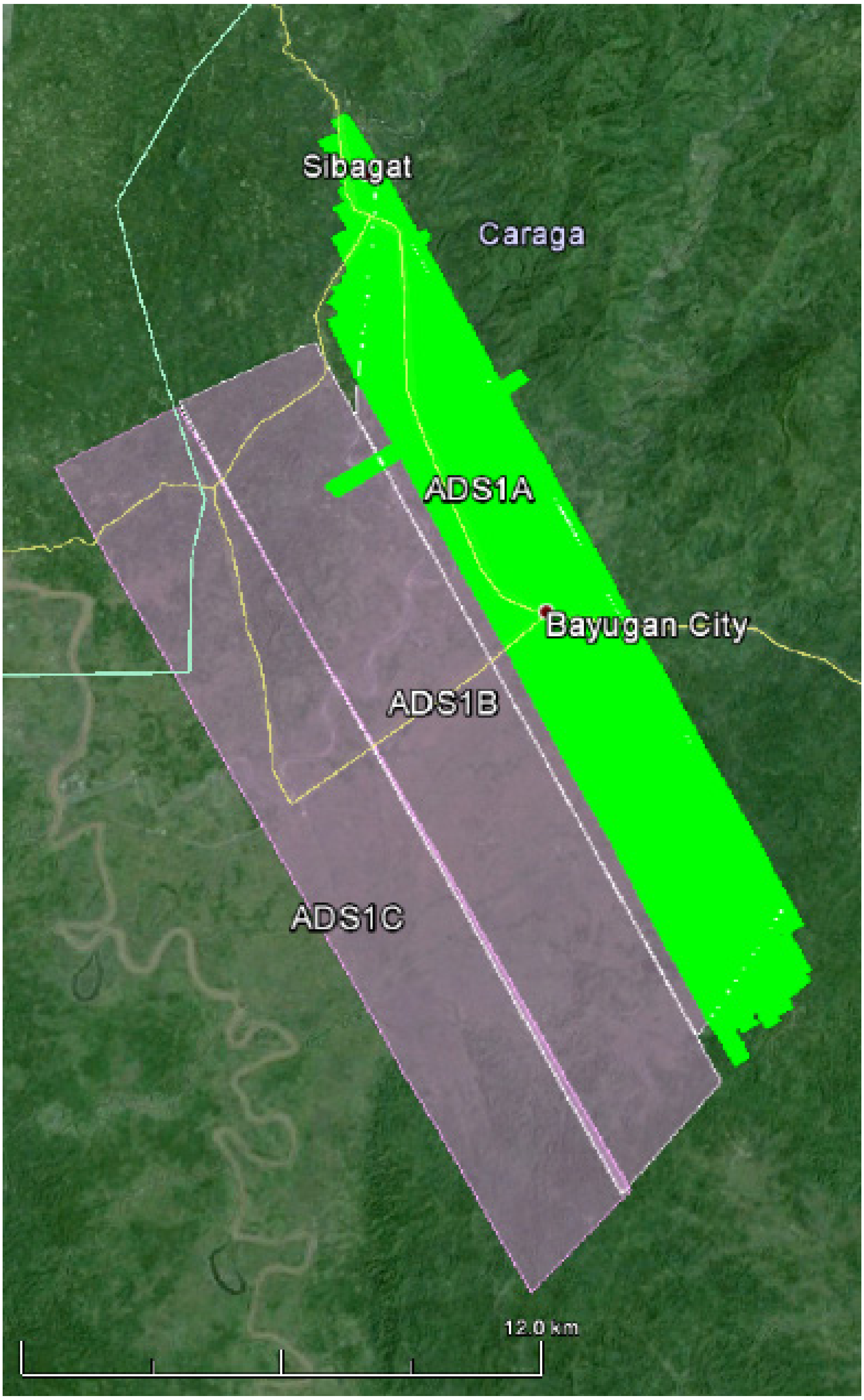
Flight No:	1612	
Area:	AGU1A & AGU1B	
Mission Name:	3AGU1AB173A	
Altitude:	600m	
PRF:	50 kHz	SCF: 45Hz
LiDAR FOV:	18 deg.	Sidelap: 40-50%



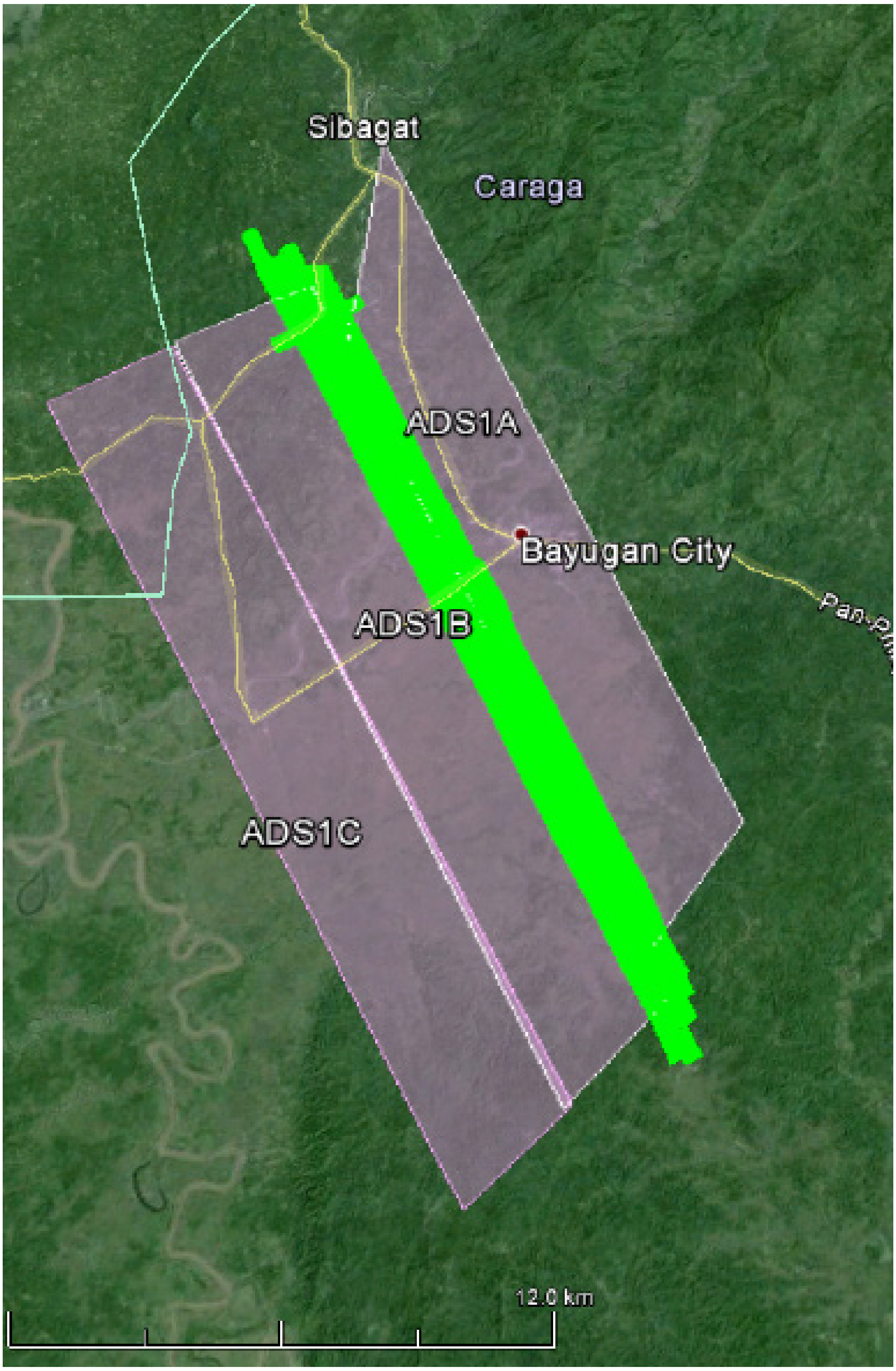
FLIGHT NO.:	1648	
AREA:	BLK63D & ADS1A	
MISSION NAME:	3BLK63DS182A & 3ADS1A182A	
ALTITUDE:	600M	
PRF:	50 KHZ	SCF: 45 HZ
LIDAR FOV:	18 DEG.	SIDELAP: 60%



FLIGHT NO.:	1652	
AREA:	ADS1A	
MISSION NAME:	3ADS1A183A	
ALTITUDE:	600M	
PRF:	50 KHZ	SCF: 45 HZ
LIDAR FOV:	18 DEG.	SIDELAP: 40-30%



FLIGHT NO.:	1654	
AREA:	ADS1A	
MISSION NAME:	3ADS1AB184A	
ALTITUDE:	600M	
PRF:	50 KHZ	SCF: 45 HZ
LIDAR FOV:	18 DEG.	SIDELAP: 30%



ANNEX 8. Mission Summary Reports

Flight Area	Surigao City
Mission Name	Blk59B (Surigao Del Norte)
Inclusive Flights	7294GC
Range data size	6.18 GB
POS	260 MB
Base Data	8.24 MB
Image	N/A
Transfer date	June 20, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.00
RMSE for East Position (<4.0 cm)	3.40
RMSE for Down Position (<8.0 cm)	7.00
Boresight correction stdev (<0.001deg)	0.000756
IMU attitude correction stdev (<0.001deg)	0.003861
GPS position stdev (<0.01m)	0.0166
Minimum % overlap (>25)	28.05%
Ave point cloud density per sq.m. (>2.0)	3.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	173
Maximum Height	576.57 m
Minimum Height	53.91 m
Classification (# of points)	
Ground	44,272,907
Low vegetation	51,399,009
Medium vegetation	91,433,498
High vegetation	188,352,003
Building	2,861,340
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Gladys Mae Apat

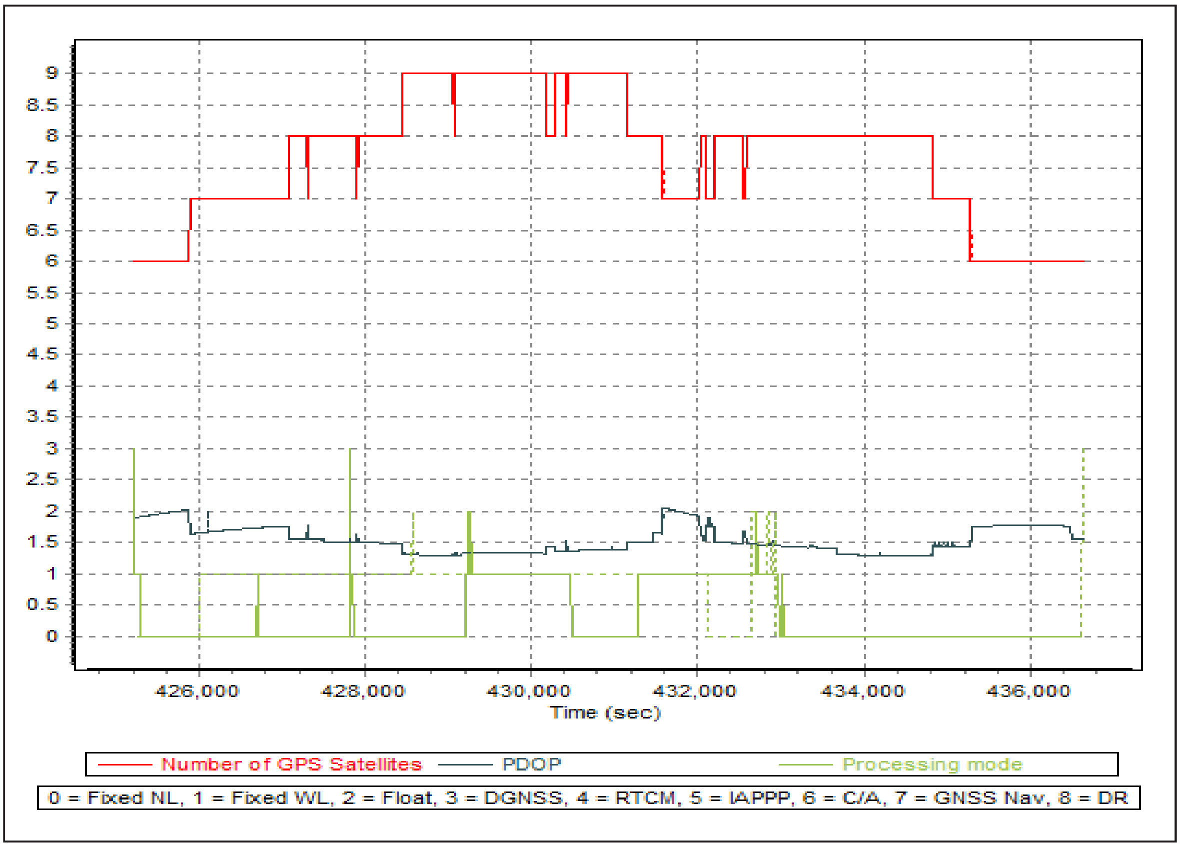


Figure A-8.1. Solution Status

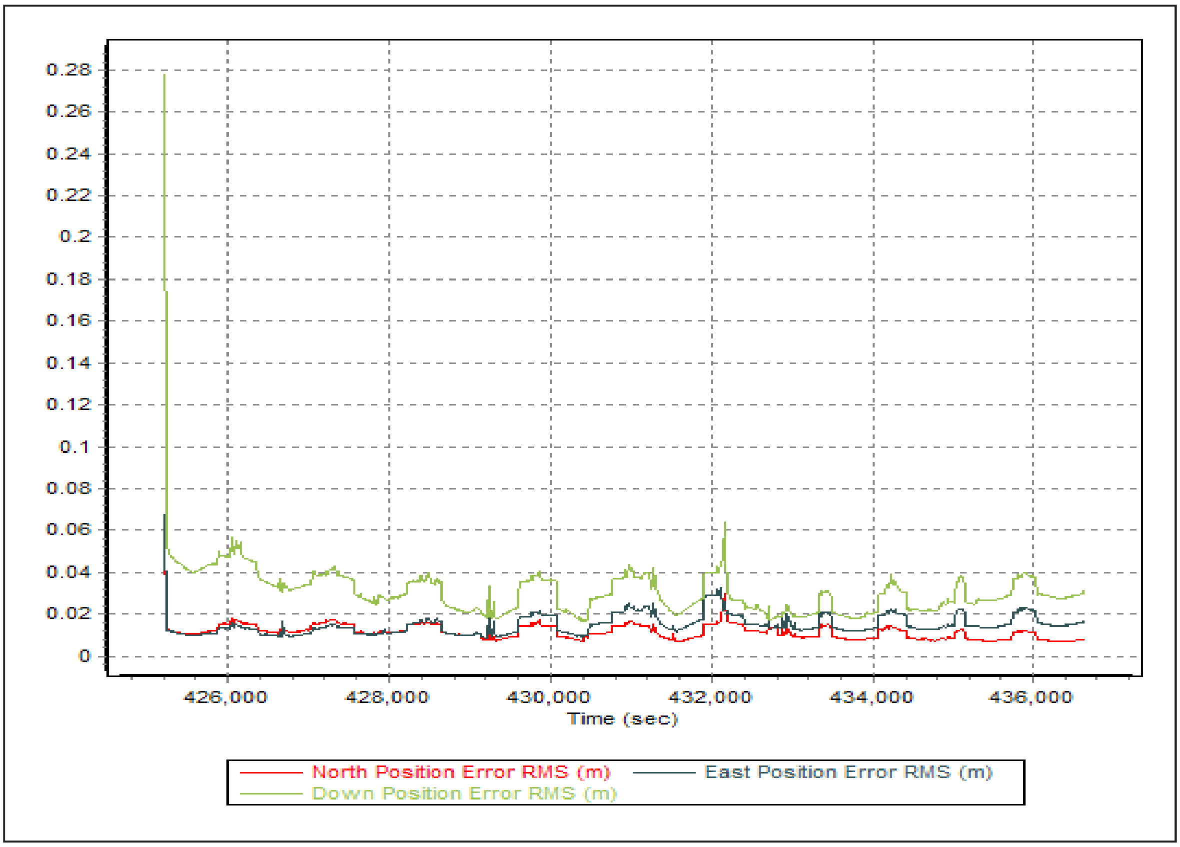


Figure A-8.2. Smoothed Performance Metric Parameters

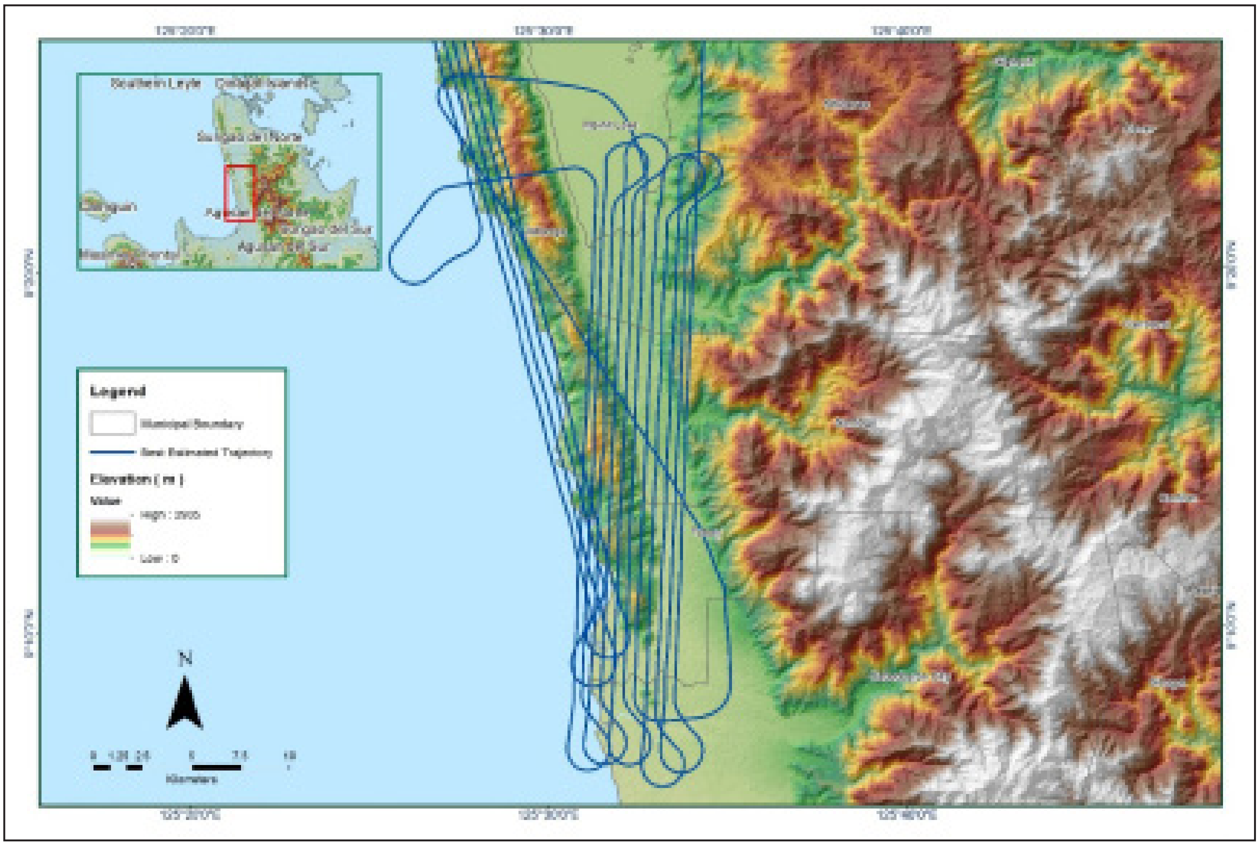


Figure A-8.3. Best Estimated Trajectory

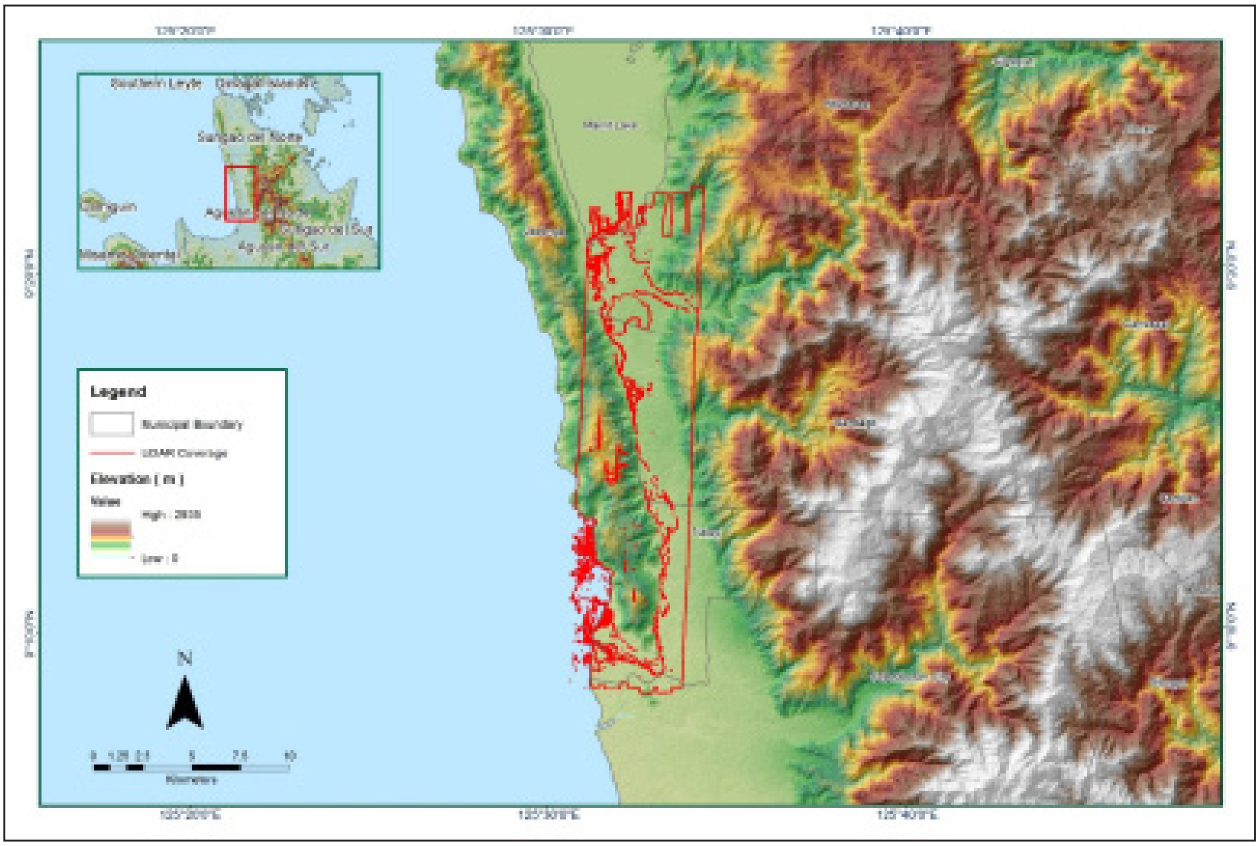


Figure A-8.4. Coverage of LiDAR data

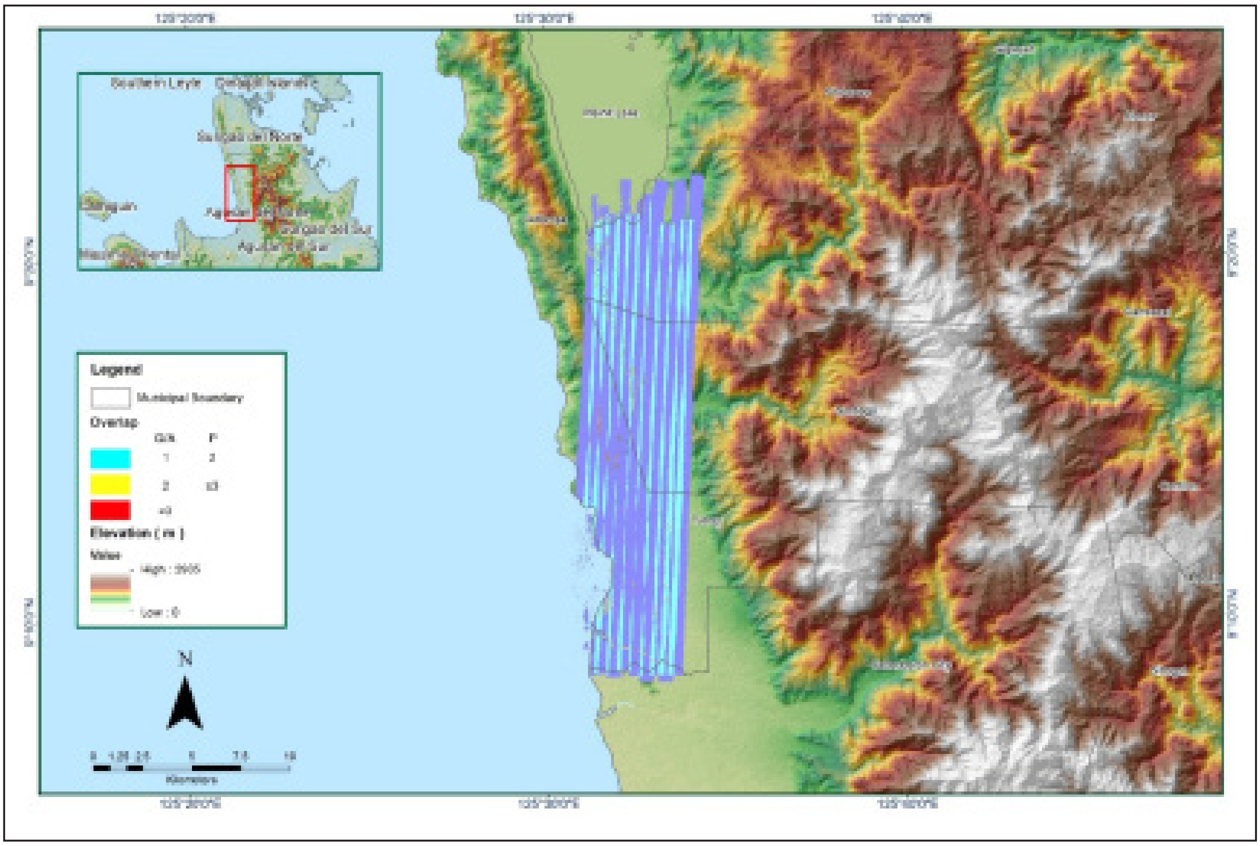


Figure A-8.5. Image of data overlap

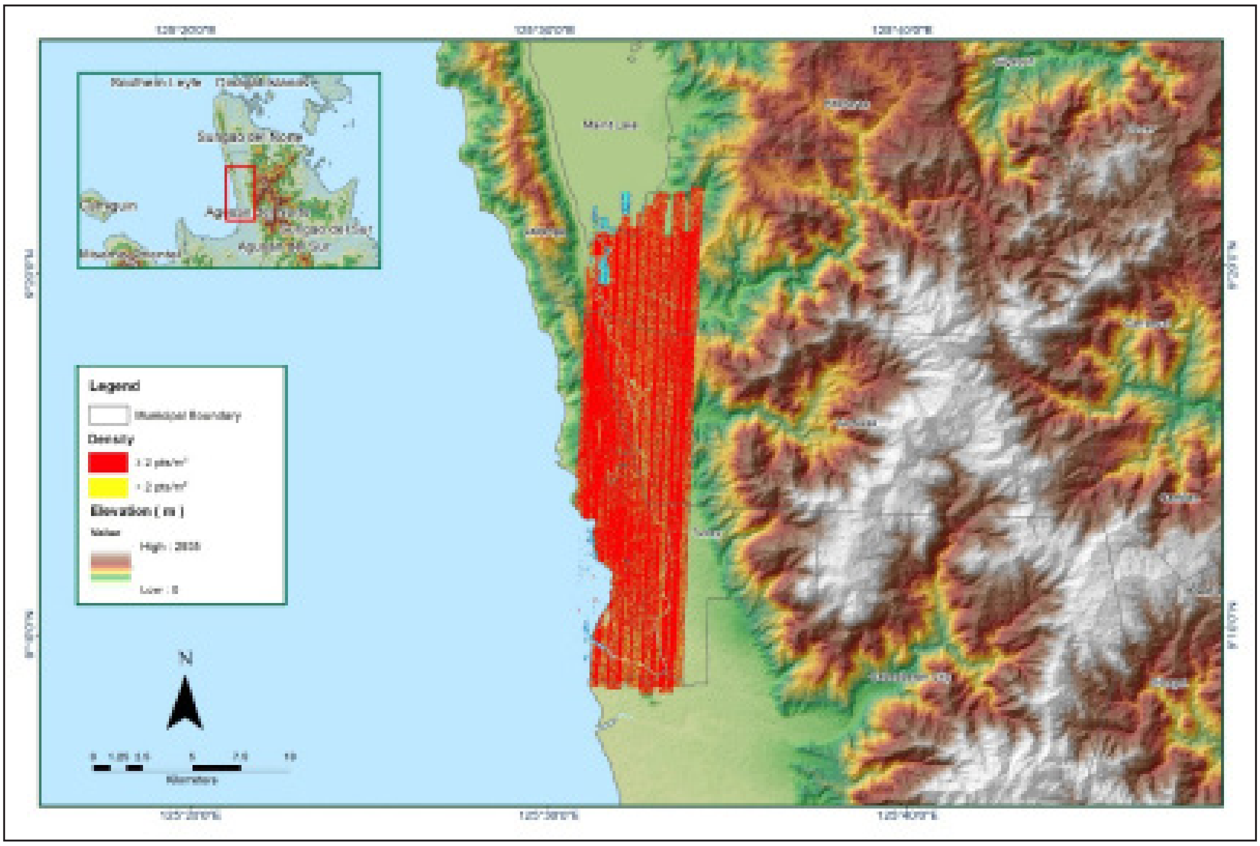


Figure A-8.6. Density map of merged LiDAR data

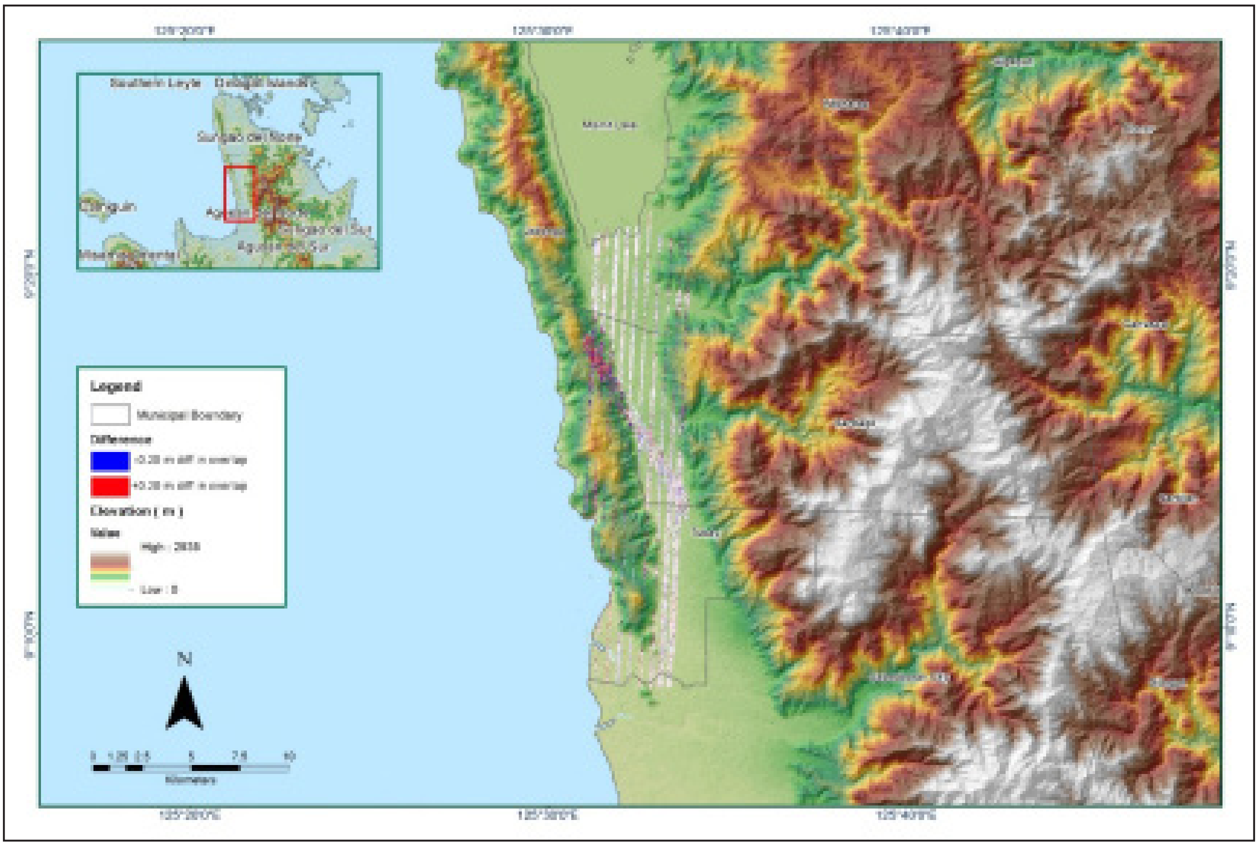


Figure A-8.7. Elevation difference between flight lines

Flight Area	Butuan
Mission Name	AGUS
Inclusive Flights	1604A
Range data size	10.8GB
POS	246 MB
Image	67.9 GB
Transfer date	July 23, 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)	1.46
RMSE for East Position (<4.0 cm)	2.95
RMSE for Down Position (<8.0 cm)	4.80
Boresight correction stdev (<0.001deg)	0.0025
IMU attitude correction stdev (<0.001deg)	0.001820
GPS position stdev (<0.01m)	0.000646
Minimum % overlap (>25)	40.39%
Ave point cloud density per sq.m. (>2.0)	3.08
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	140
Maximum Height	480.32m
Minimum Height	63.59m
Classification (# of points)	
Ground	39,939,925
Low vegetation	52,206,744
Medium vegetation	61,772,135
High vegetation	44,097,605
Building	1,264,124
Orthophoto	Yes

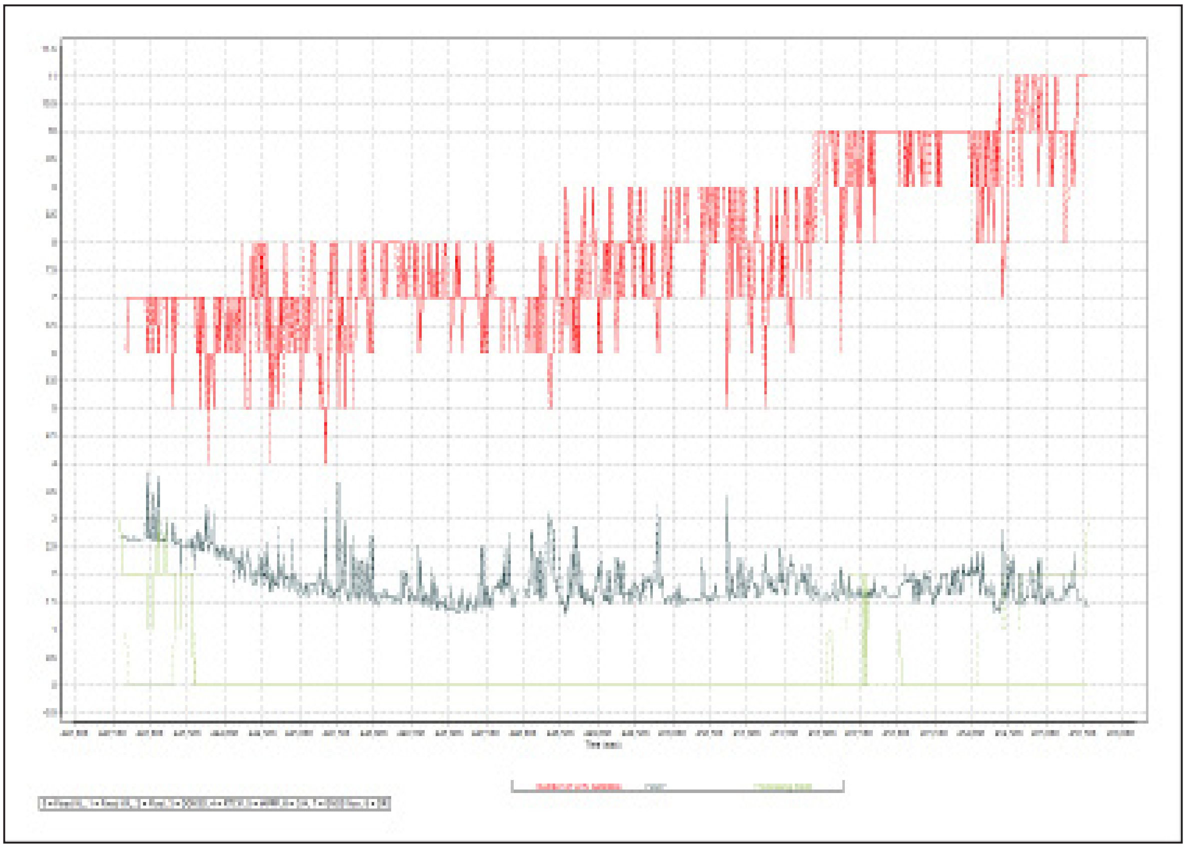


Figure A-8.8. Solution Status

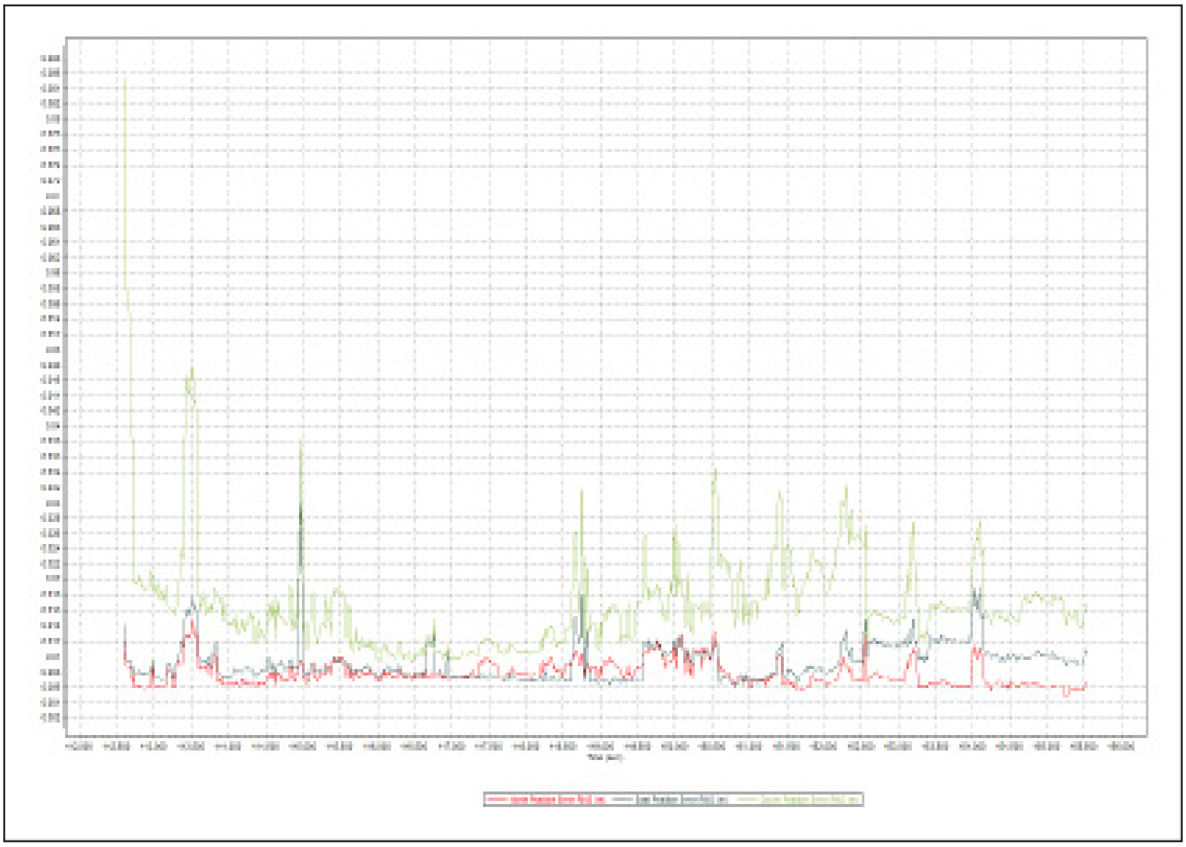


Figure A-8.9. Smoothed Performance Metric Parameters

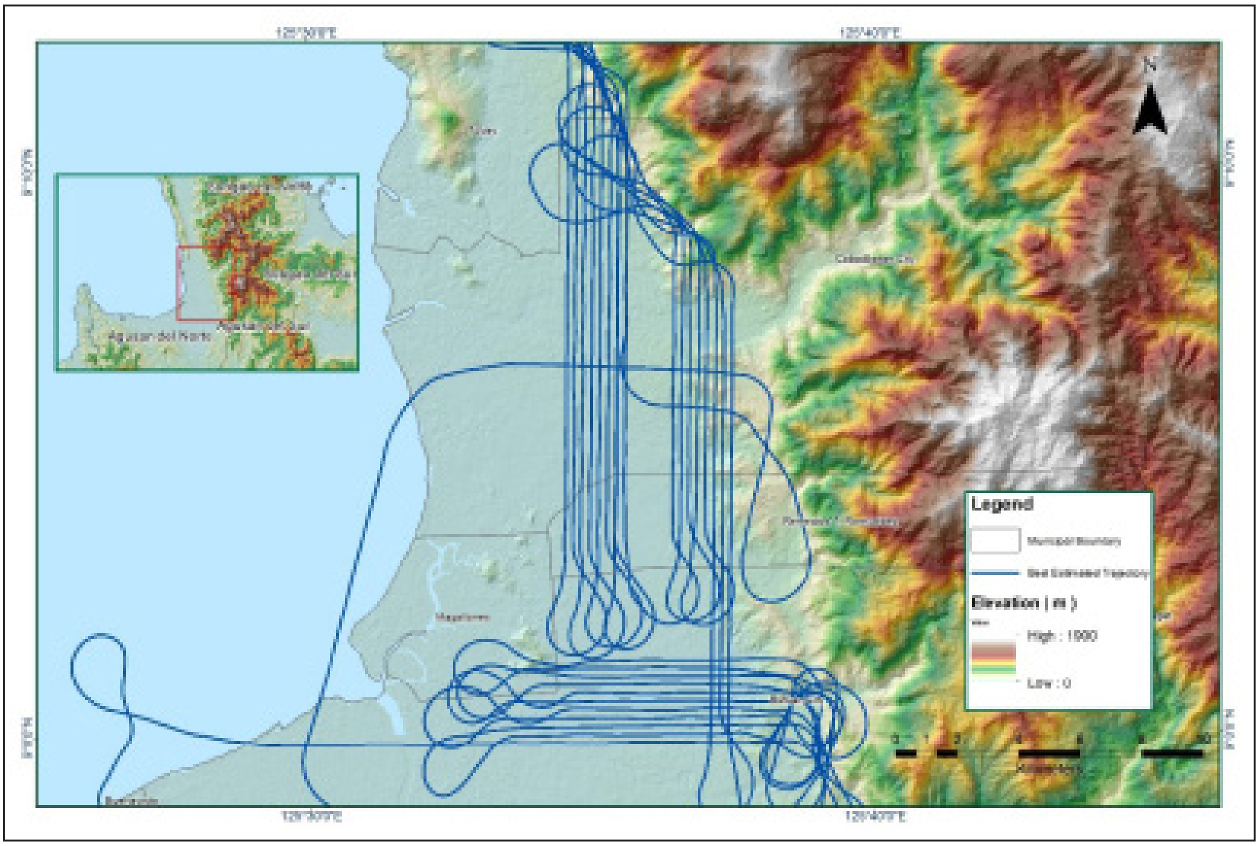


Figure A-8.10. Best Estimated Trajectory

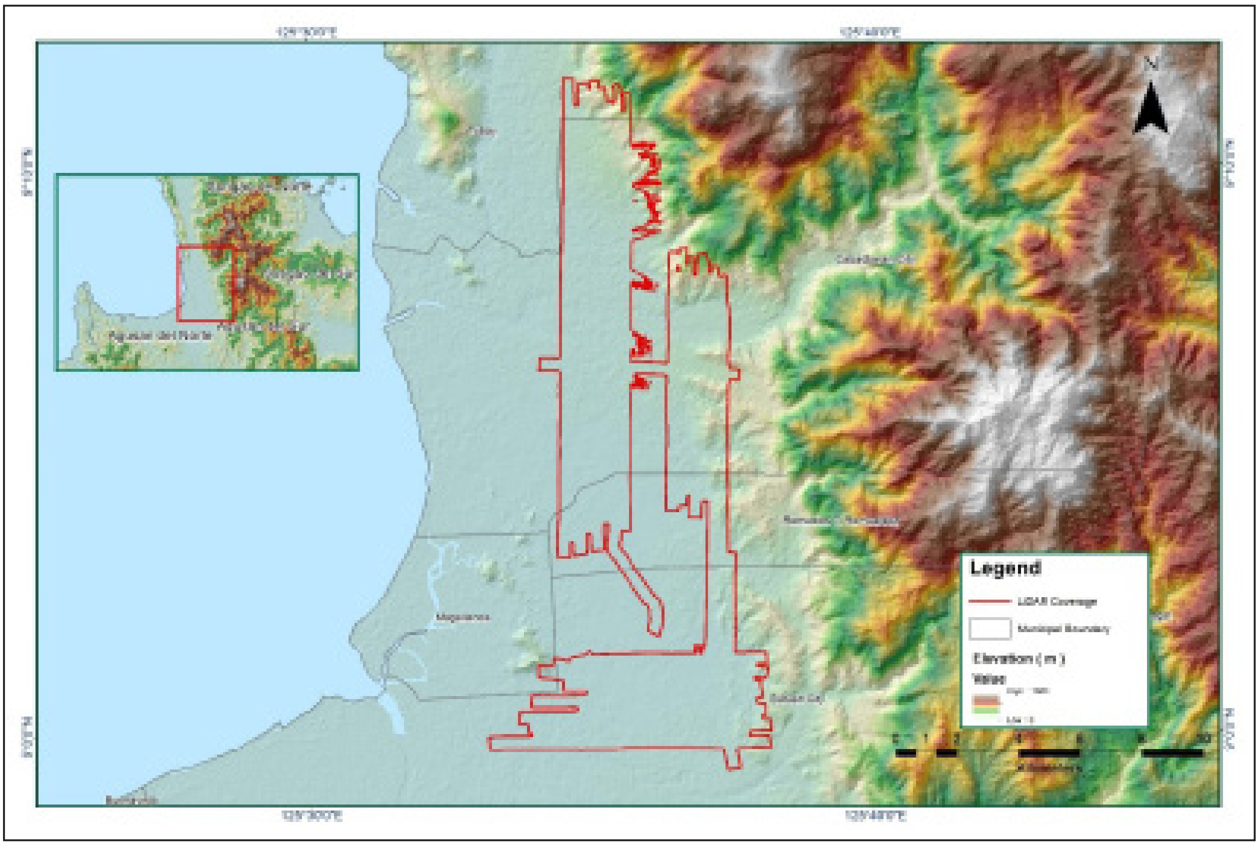


Figure A-8.11. Coverage of LiDAR data

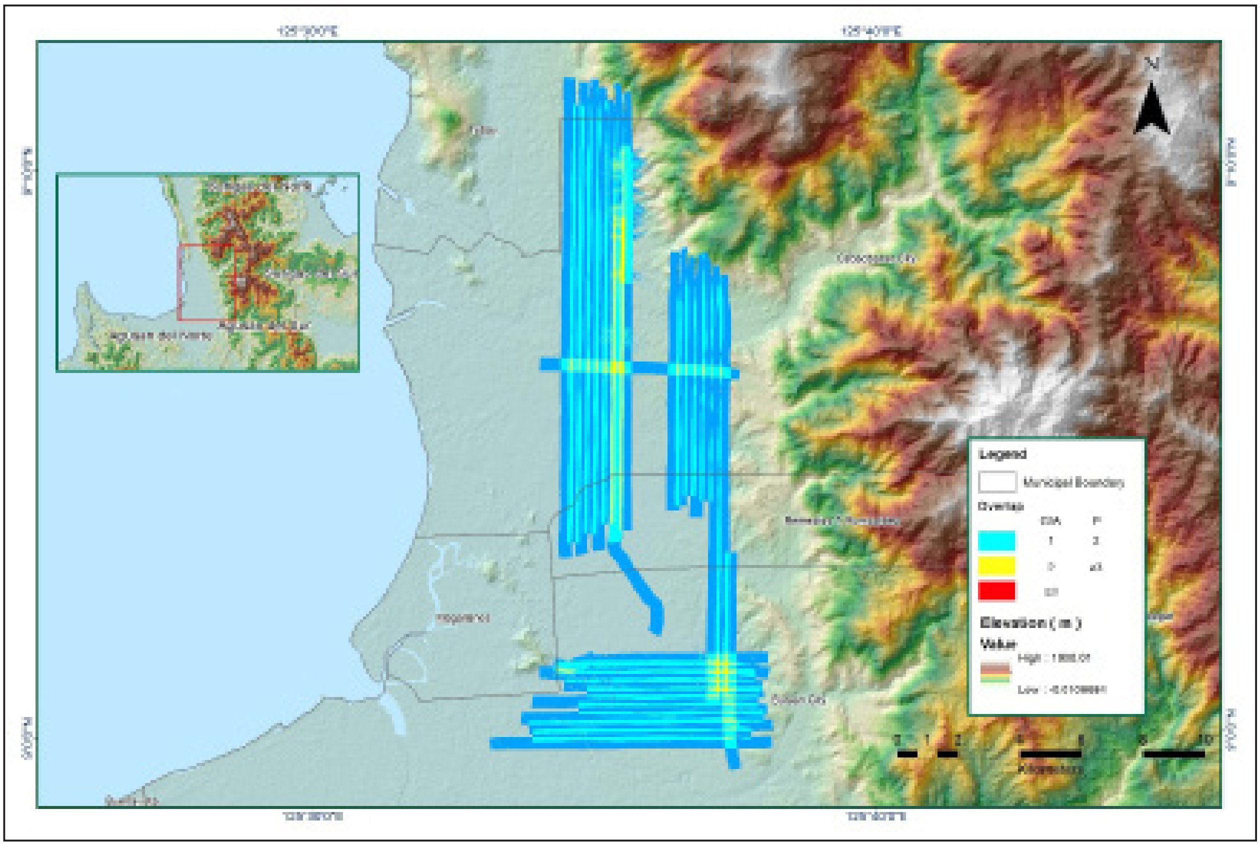


Figure A-8.12. Image of data overlap

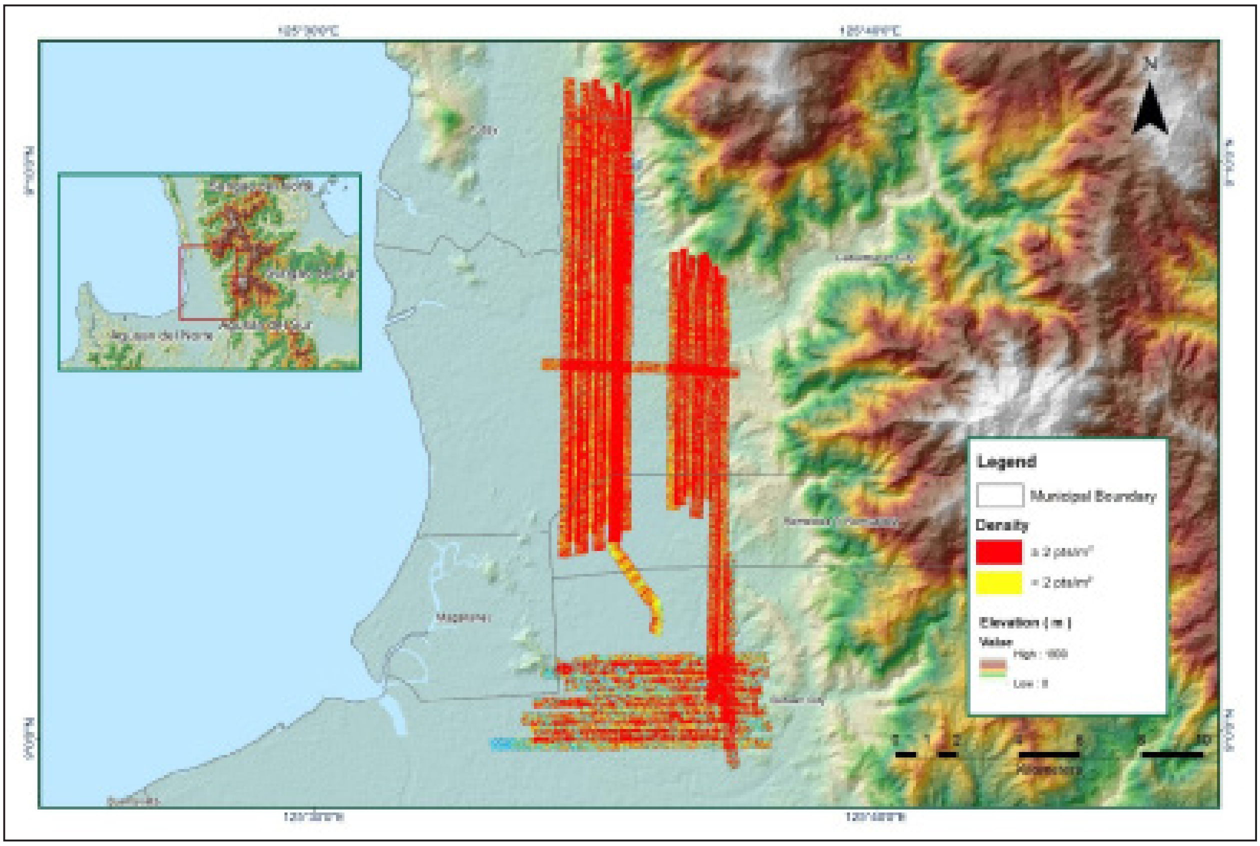


Figure A-8.13. Density map of merged LiDAR data

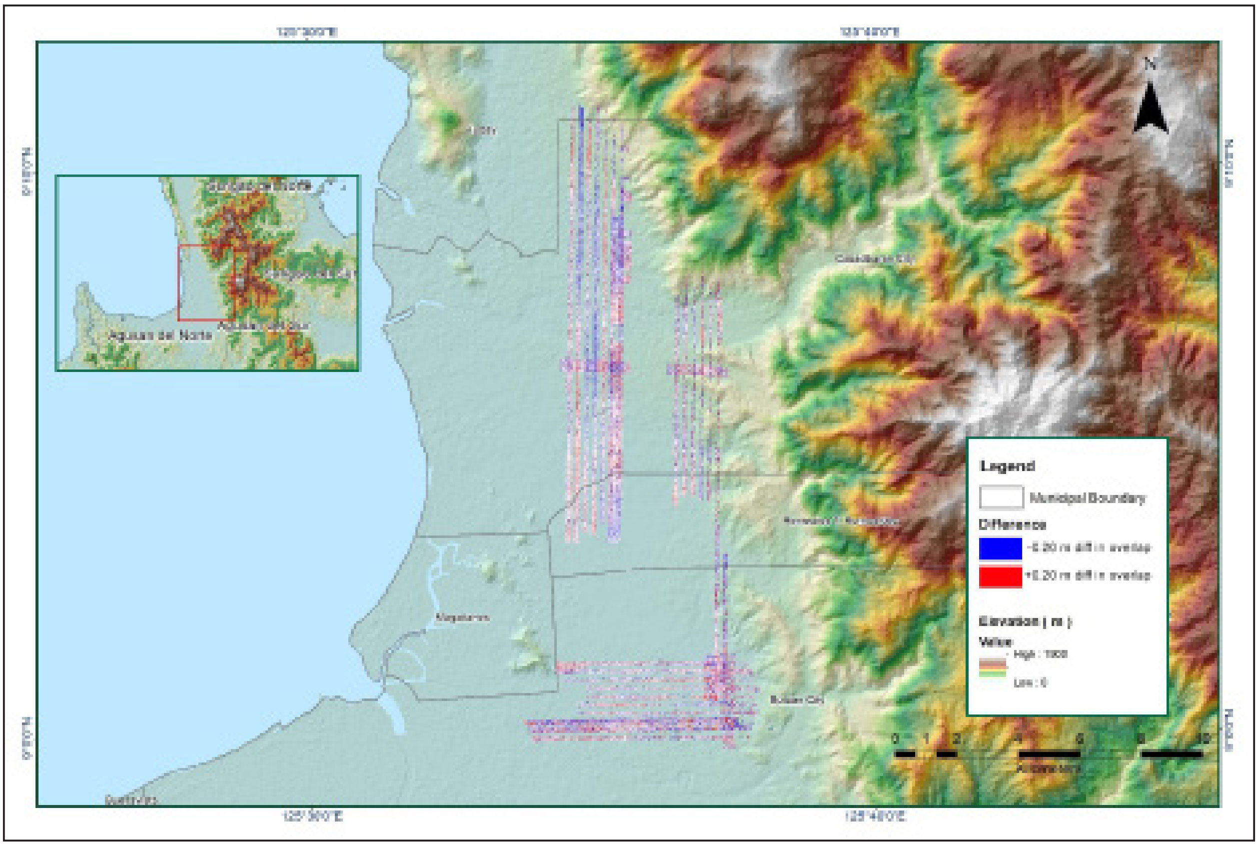


Figure A-8.14. Elevation difference between flight lines

Flight Area	Butuan
Mission Name	AGUSAB
Inclusive Flights	1612A
Range data size	10.0 GB
POS	262 MB
Image	43.4 GB
Transfer date	July 23, 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)	3.9
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	1.6
Boresight correction stdev (<0.001deg)	0.001118
IMU attitude correction stdev (<0.001deg)	0.000588
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	52.81%
Ave point cloud density per sq.m. (>2.0)	4.54
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	115
Maximum Height	566.80m
Minimum Height	75.78m
Classification (# of points)	
Ground	22,002,136
Low vegetation	22,729,223
Medium vegetation	58,533,229
High vegetation	97,963,913
Building	3,133,596
Orthophoto	Yes

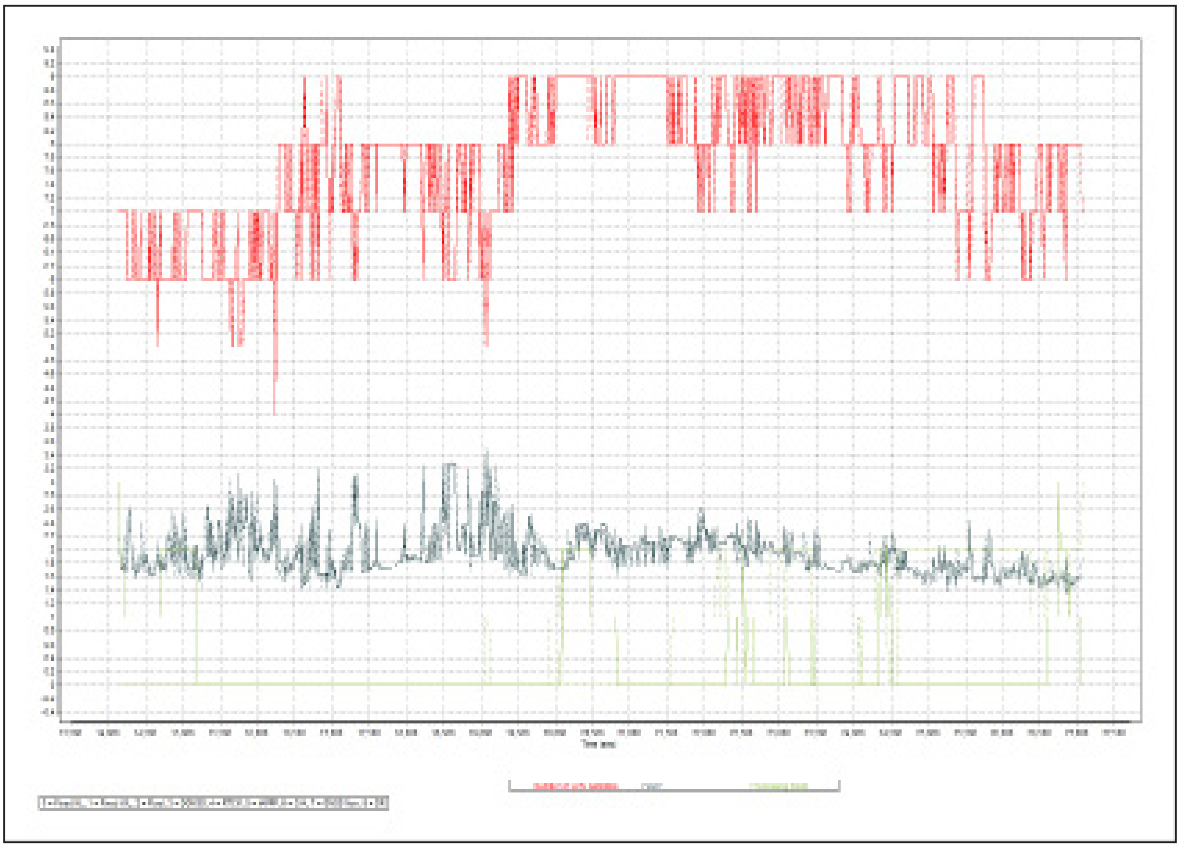


Figure A-8.15. Solution Status

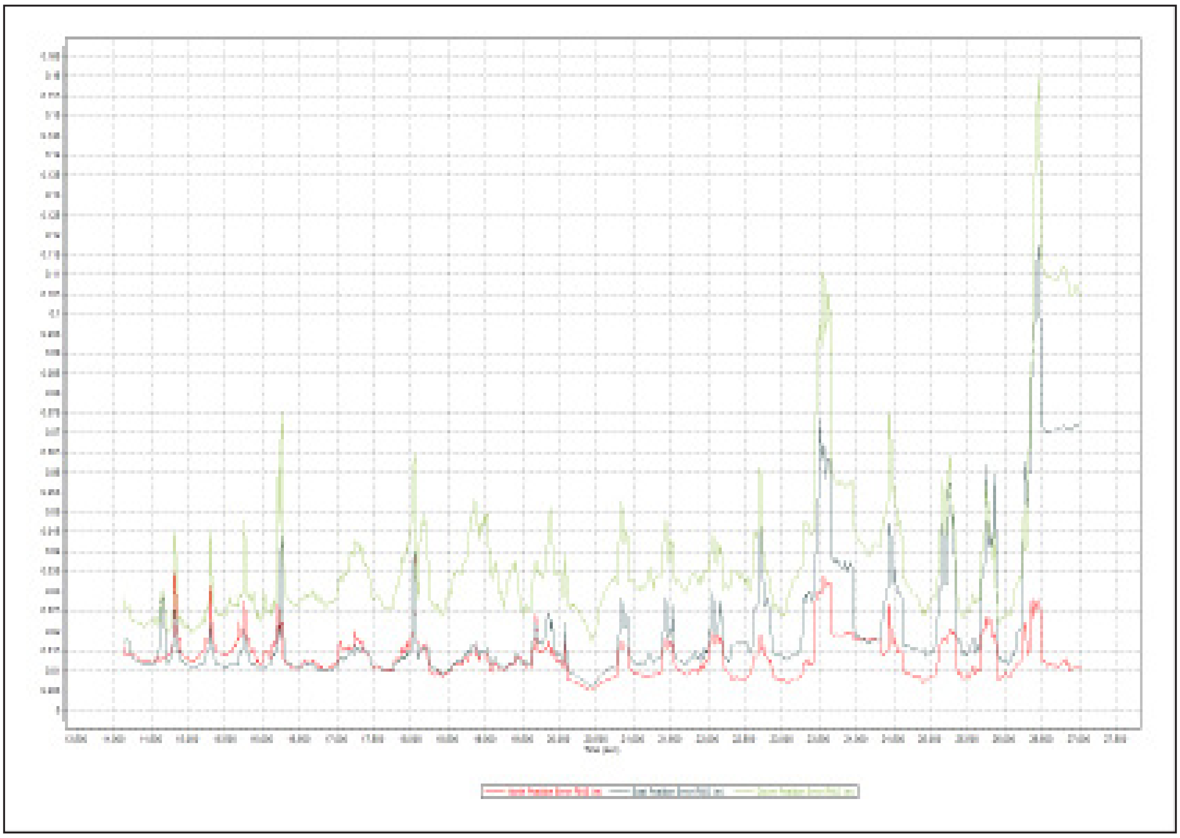


Figure A-8.16. Smoothed Performance Metric Parameters

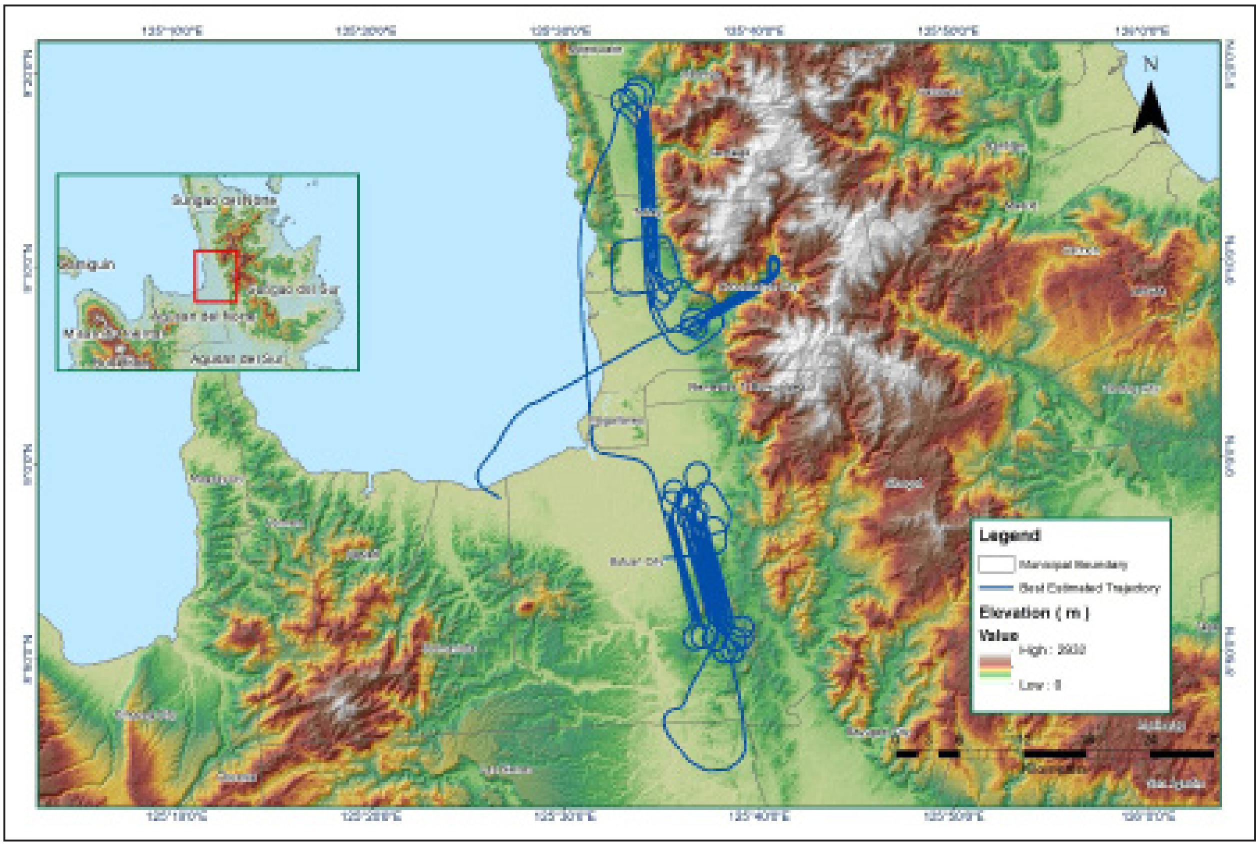


Figure A-8.17. Best Estimated Trajectory

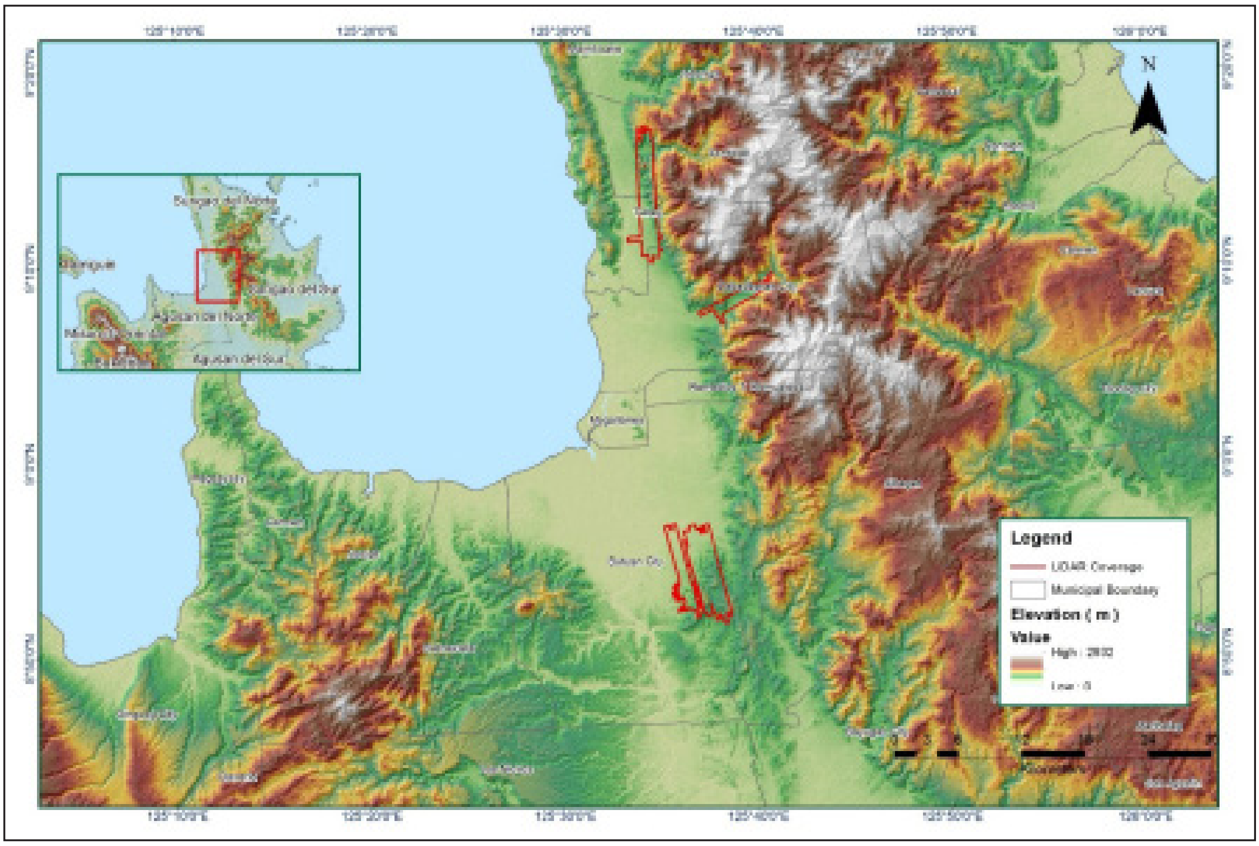


Figure A-8.18. Coverage of LiDAR data

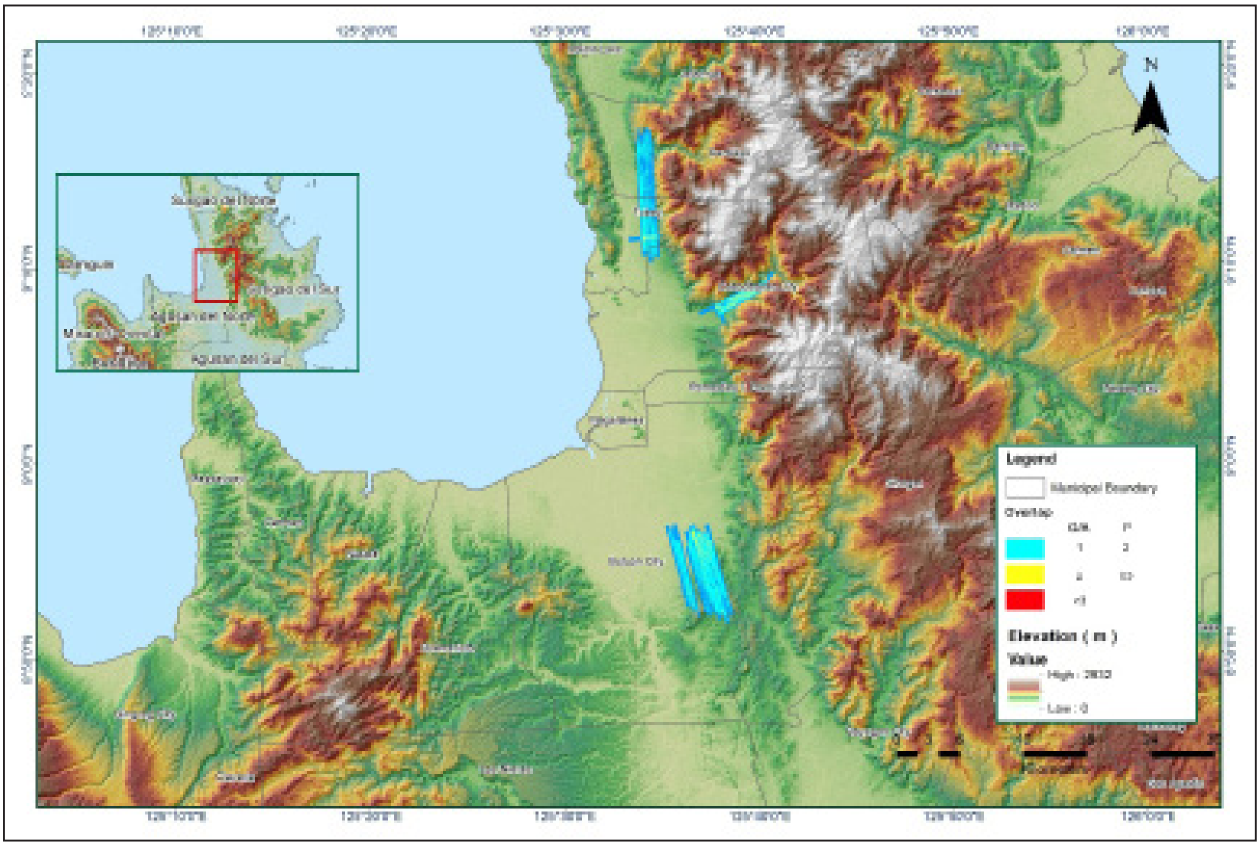


Figure A-8.19. Image of data overlap

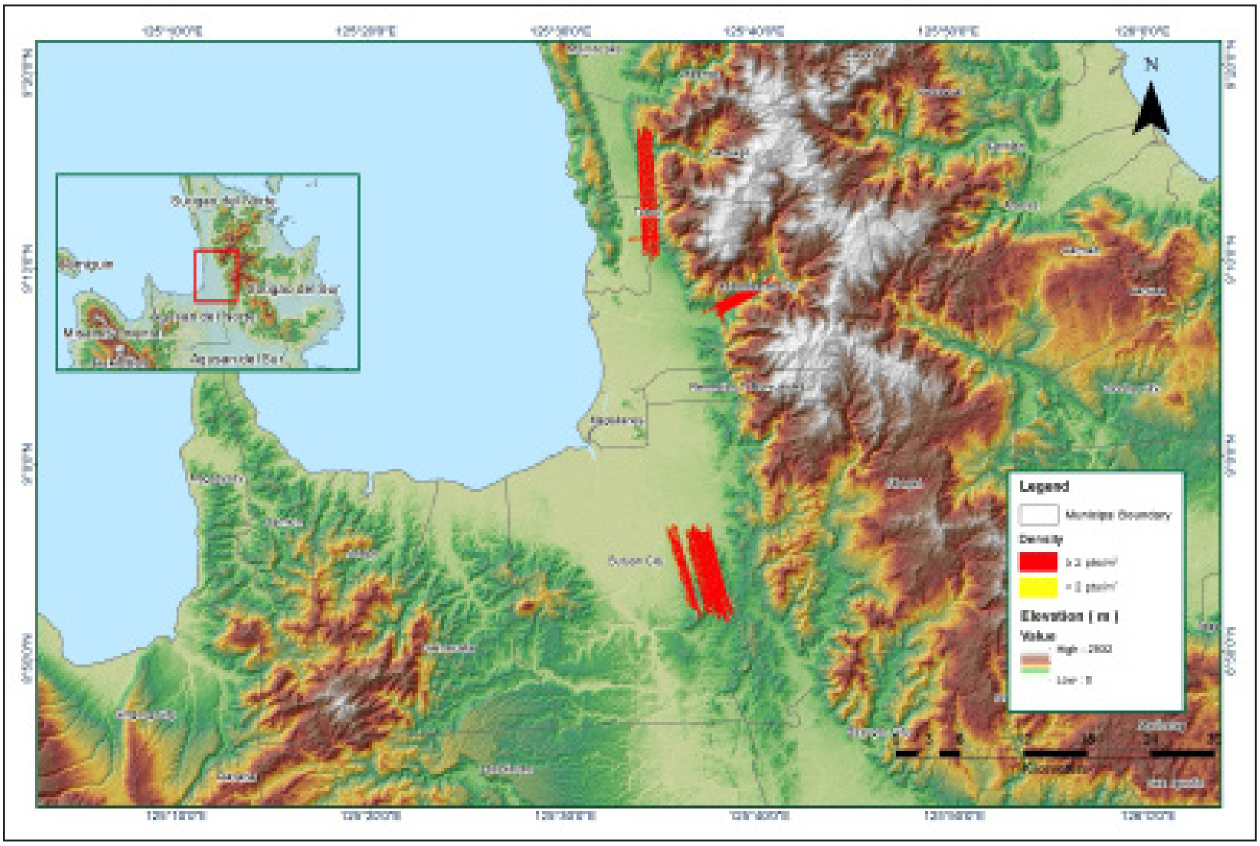


Figure A-8.20. Density map of merged LiDAR data

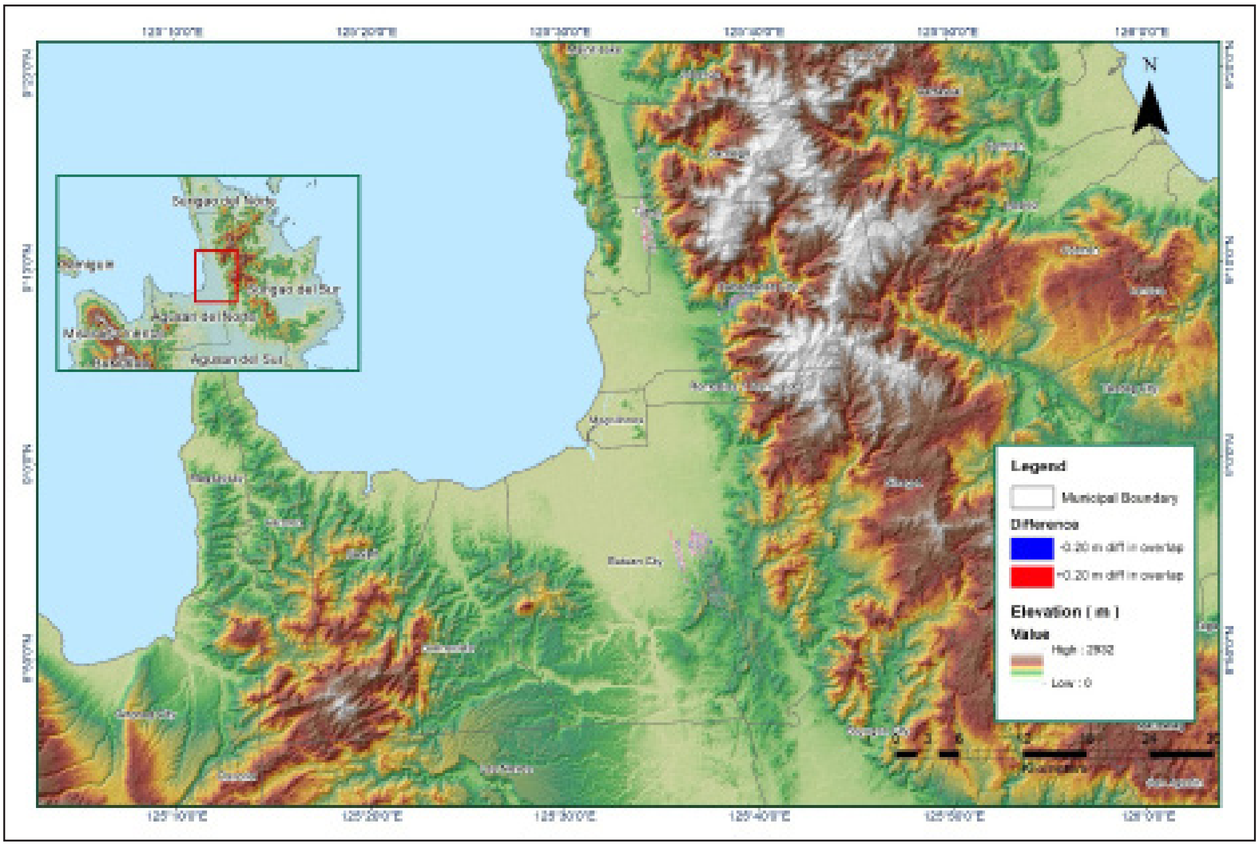


Figure A-8.21. Elevation difference between flight lines

Flight Area	Butuan
Mission Name	AGUS ADS1A
Inclusive Flights	1648A, 1652A, 1654A
Range data size	21.12 GB
POS	472 MB
Image	111.7 GB
Transfer date	July 23, 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)	1.08
RMSE for East Position (<4.0 cm)	1.28
RMSE for Down Position (<8.0 cm)	2.10
Boresight correction stdev (<0.001deg)	0.000386
IMU attitude correction stdev (<0.001deg)	0.001187
GPS position stdev (<0.01m)	0.007800
Minimum % overlap (>25)	54.54%
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	171
Maximum Height	303.69m
Minimum Height	79.72m
Classification (# of points)	
Ground	75,010,958
Low vegetation	114,307,767
Medium vegetation	75,612,820
High vegetation	91,965,481
Building	5,585,967
Orthophoto	Yes

Figure A-8.22. Solution Status

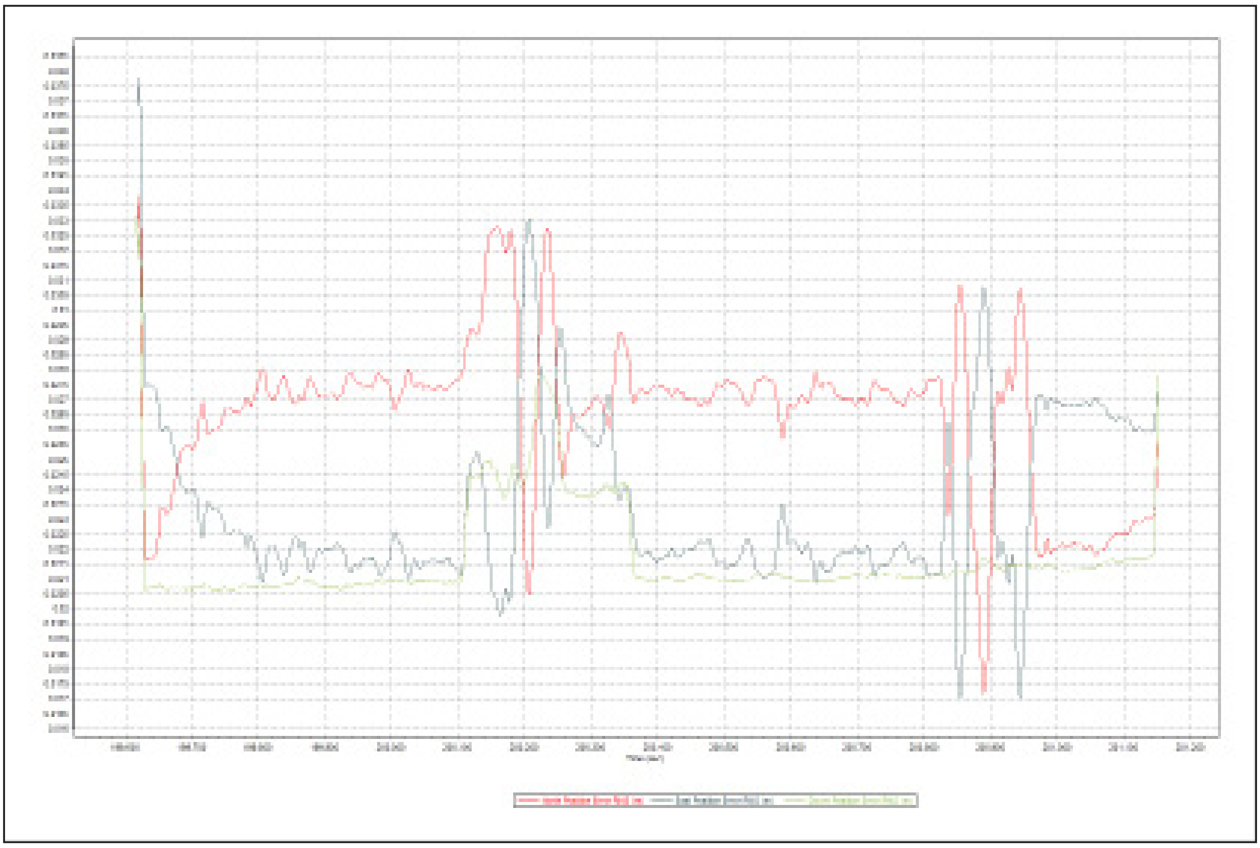


Figure A-8.23. Smoothed Performance Metric Parameters

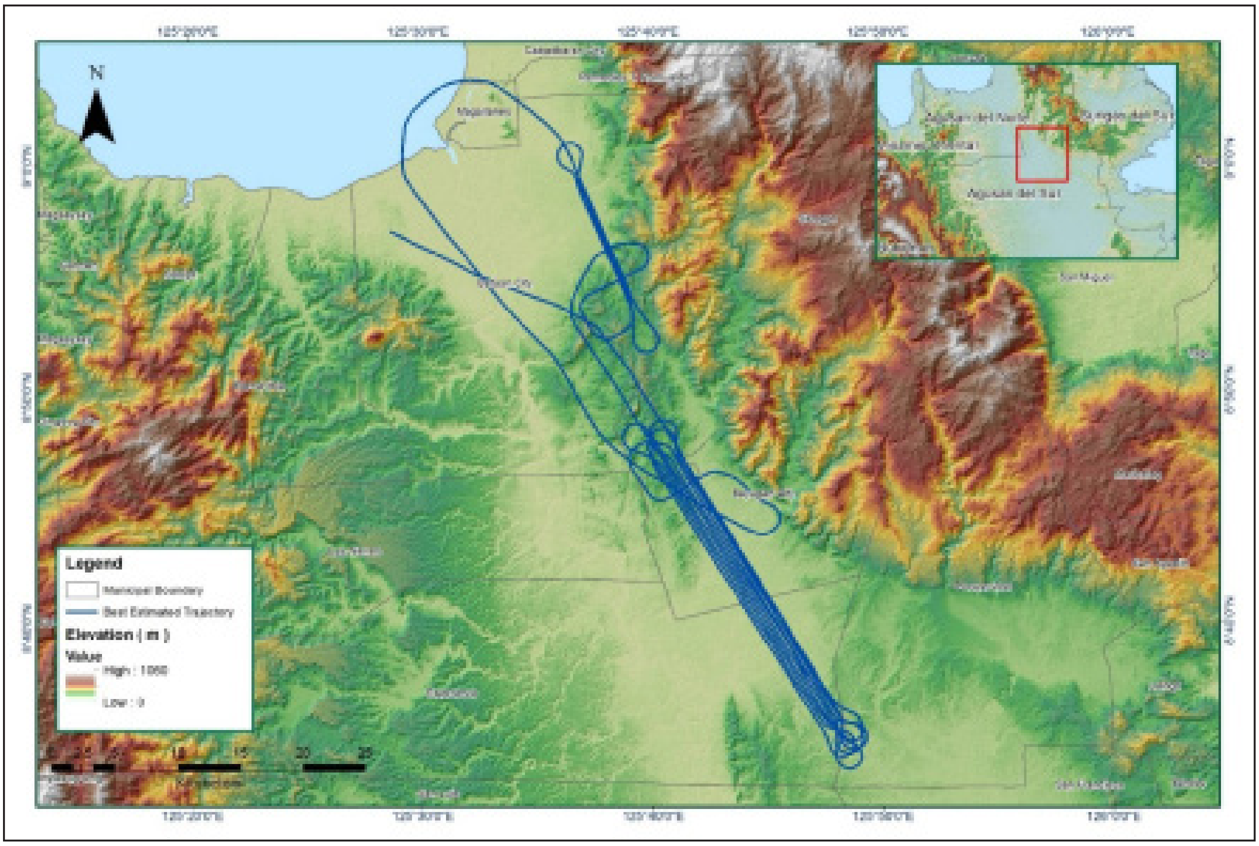


Figure A-8.24. Best Estimated Trajectory

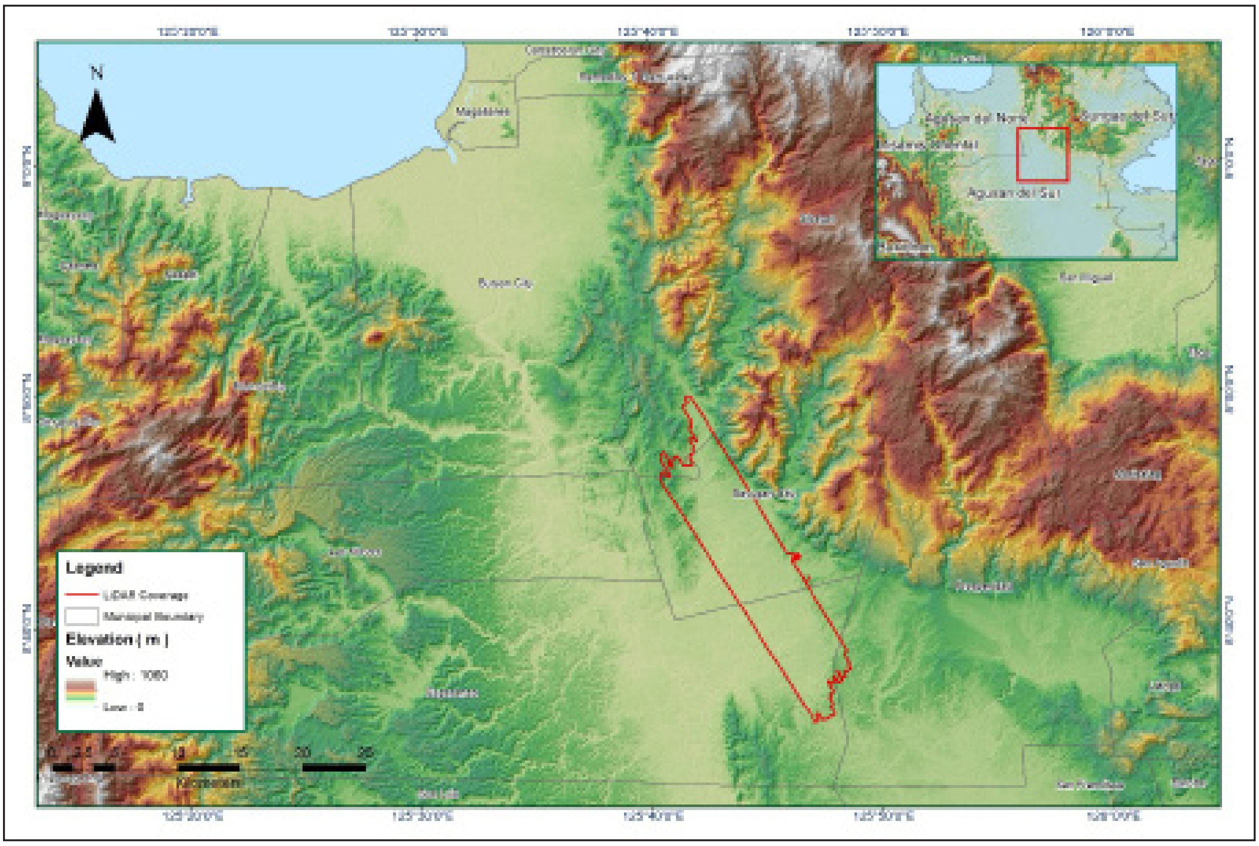


Figure A-8.25. Coverage of LiDAR data

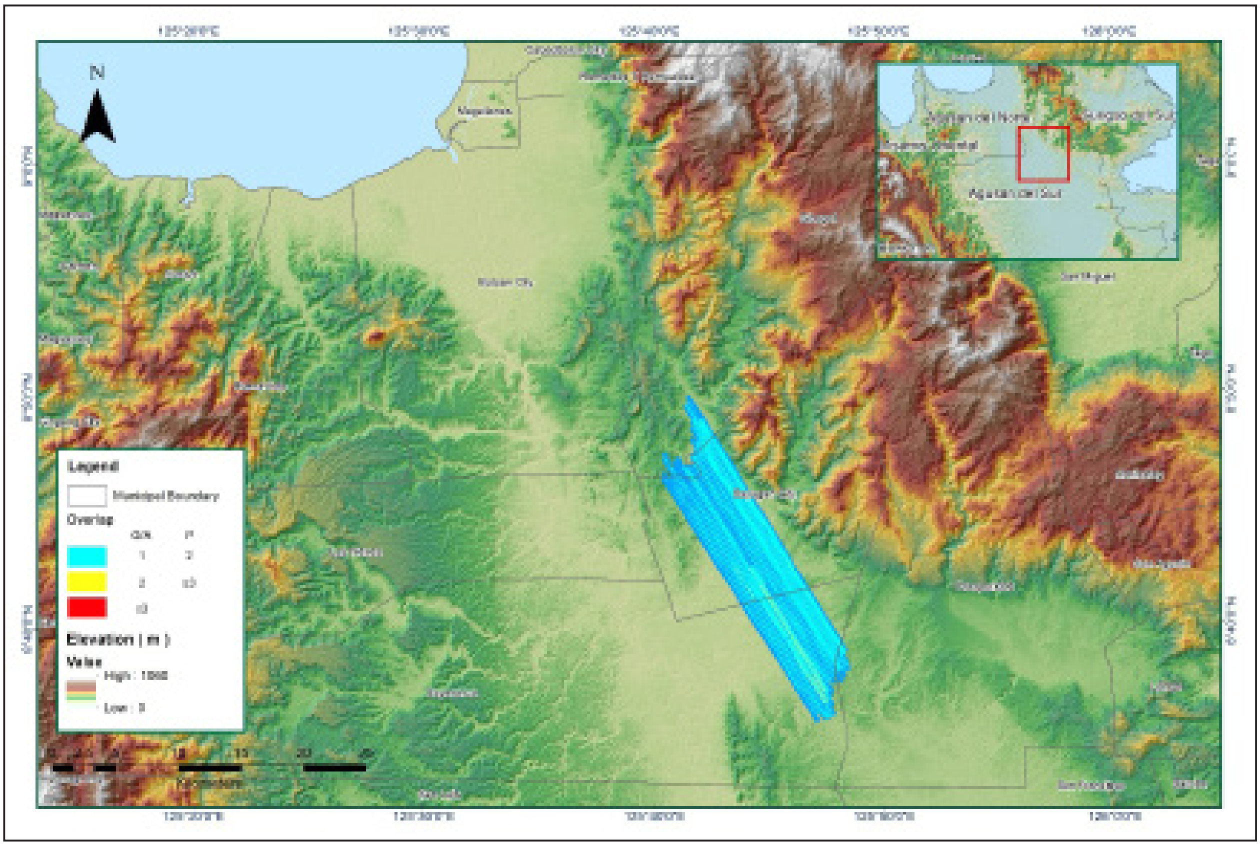


Figure A-8.26. Image of data overlap

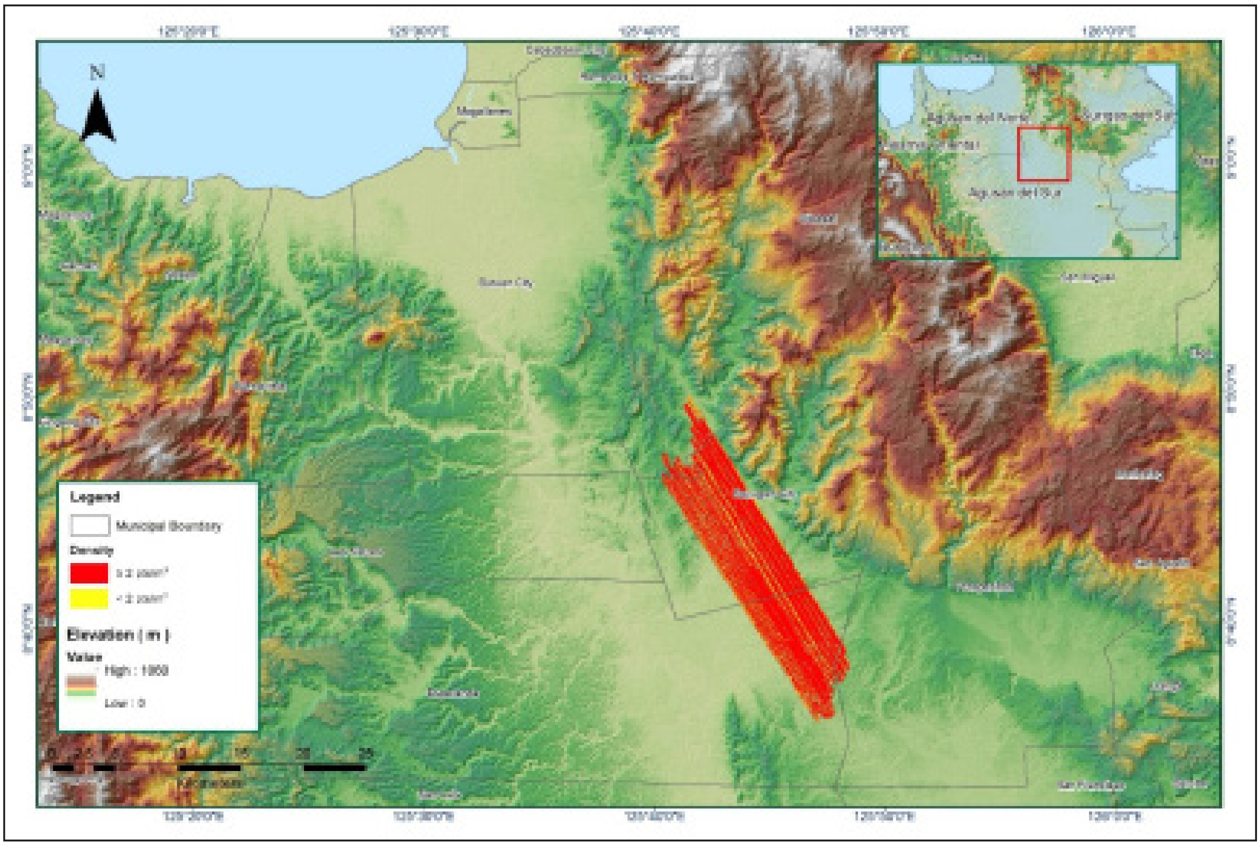


Figure A-8.27. Density map of merged LiDAR data

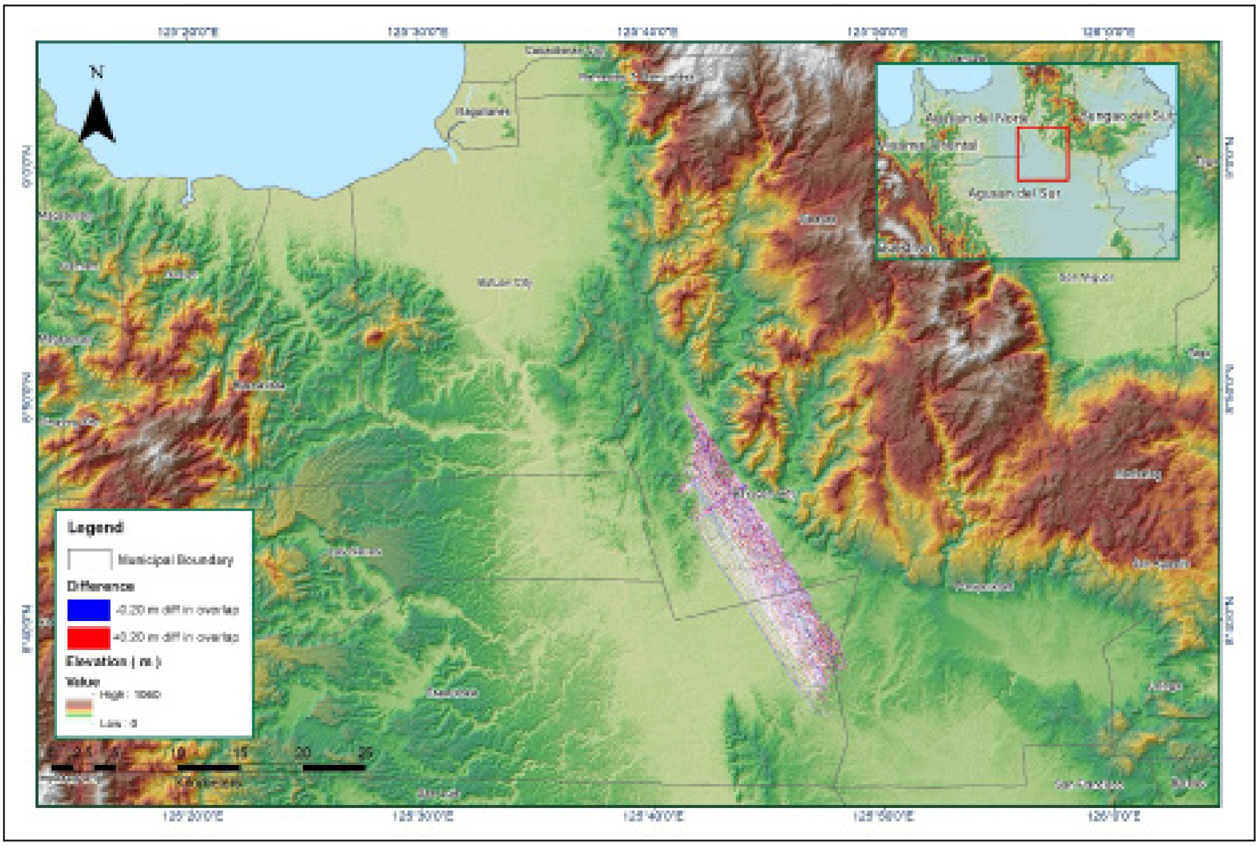


Figure A-8.28. Elevation difference between flight lines

Annex 9. Cabadbaran Model Basin Parameters

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
LowerCBR-R5890W5890	21.77	70.00	8.10	79.26	Discharge	0.03	0.35	Ratio to Peak	0.2
LowerCBR-R5930W5930	19.76	72.00	0.50	30.06	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R5980W5980	21.77	70.00	5.80	25.26	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6030W6030	26.17	66.00	1.60	71.40	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R6040W6040	11.92	81.00	0.00	12.48	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6080W6080	11.15	82.00	0.00	16.92	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6090W6090	17.85	74.00	0.00	40.74	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6230W6230	23.91	68.00	2.80	98.34	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R6260W6260	9.68	84.00	37.60	26.94	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6340W6340	13.50	79.00	0.00	23.58	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6350W6350	16.93	75.00	0.70	52.56	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R6360W6360	25.02	67.00	0.70	41.58	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6380W6380	9.68	84.00	0.00	7.02	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6390W6390	11.15	82.00	0.00	36.66	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R6470W6470	16.93	75.00	0.00	26.28	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6510W6510	6.93	88.00	21.10	21.00	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6550W6550	23.91	68.00	0.60	110.22	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6600W6600	16.04	76.00	0.00	36.18	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R6630W6630	6.93	88.00	97.90	35.70	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6700W6700	10.40	83.00	0.00	17.28	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6740W6740	12.70	80.00	1.40	16.08	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6750W6750	8.96	85.00	0.00	25.92	Discharge	0.01	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
LowerCBR-R6760W6760	14.33	78.00	0.00	19.38	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6830W6830	22.82	69.00	1.90	40.02	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6860W6860	7.59	87.00	96.50	29.94	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6870W6870	11.15	82.00	0.00	10.80	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6890W6890	6.93	88.00	36.80	30.36	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6900W6900	8.96	85.00	0.00	20.64	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R6910W6910	5.64	90.00	0.00	7.74	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6970W6970	14.33	78.00	1.30	16.14	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R6980W6980	10.40	83.00	0.00	27.96	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R6990W6990	8.96	85.00	0.00	18.78	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R7020W7020	1.04	98.00	17.60	6.54	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7030W7030	7.59	87.00	95.20	23.82	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7060W7060	11.15	82.00	67.70	36.66	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7070W7070	11.92	81.00	63.70	40.92	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7080W7080	15.17	77.00	11.00	26.88	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R7160W7160	0.51	99.00	0.00	14.76	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7170W7170	6.93	88.00	67.70	28.50	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7200W7200	6.93	88.00	99.60	2.04	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7210W7210	8.96	85.00	81.20	19.08	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7250W7250	13.50	79.00	0.00	37.68	Discharge	0.03	0.35	Ratio to Peak	0.2
LowerCBR-R7280W7280	13.50	79.00	53.90	46.50	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7310W7310	16.93	75.00	0.70	39.12	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R7330W7330	8.96	85.00	80.70	35.46	Discharge	0.00	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
LowerCBR-R7340W7340	19.76	72.00	17.70	53.46	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R7350W7350	6.93	88.00	100.00	4.44	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7360W7360	11.15	82.00	62.80	21.42	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7390W7390	26.17	66.00	0.40	61.74	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R7400W7400	29.83	63.00	0.00	17.46	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7440W7440	8.96	85.00	0.00	8.64	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7520W7520	11.92	81.00	0.00	7.08	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R7570W7570	27.35	65.00	0.20	51.60	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R7590W7590	27.35	65.00	0.00	38.82	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R7650W7650	17.85	74.00	6.90	45.18	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R7980W7980	21.77	70.00	0.00	67.02	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R8000W8000	8.96	85.00	82.10	11.28	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8010W8010	6.93	88.00	73.00	2.28	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8020W8020	6.93	88.00	100.00	13.26	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8040W7990	9.68	84.00	76.60	10.32	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8050W8030	6.93	88.00	100.00	22.92	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8060W8040	16.93	75.00	24.20	43.38	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8070W8050	12.70	80.00	55.30	35.34	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8100W8060	13.50	79.00	38.20	28.86	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R8110W8070	14.33	78.00	39.50	24.96	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8120W8080	11.15	82.00	67.00	21.84	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8130W8090	23.91	68.00	7.00	47.16	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R8140W8100	4.42	92.00	0.00	4.26	Discharge	0.00	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
LowerCBR-R8150W8110	17.85	74.00	0.10	37.32	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R8160W8120	12.70	80.00	0.60	37.86	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8170W8130	25.02	67.00	0.00	13.62	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8180W8140	20.75	71.00	1.00	51.00	Discharge	0.02	0.35	Ratio to Peak	0.2
LowerCBR-R8190W8150	9.68	84.00	0.00	17.82	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8200W8160	23.91	68.00	1.20	44.40	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8210W8170	19.76	72.00	2.20	46.20	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8220W8180	11.92	81.00	0.00	33.54	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8230W8190	21.77	70.00	0.60	60.24	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8240W8200	21.77	70.00	5.30	42.12	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8250W8210	11.92	81.00	72.00	16.98	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8260W8220	8.96	85.00	68.40	5.88	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8270W8230	9.68	84.00	78.30	24.66	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8290W8250	21.77	70.00	5.10	68.16	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8300W8260	18.79	73.00	24.90	26.52	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8310W8270	19.76	72.00	17.00	42.60	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8320W8280	12.70	80.00	61.30	19.44	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8330W8290	26.17	66.00	0.10	15.30	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8340W8300	8.96	85.00	0.00	9.84	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8350W8310	22.82	69.00	0.00	33.96	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8360W8320	23.91	68.00	0.40	33.90	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8370W8330	11.92	81.00	66.40	38.58	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8400W8340	15.17	77.00	46.50	39.12	Discharge	0.00	0.35	Ratio to Peak	0.2
LowerCBR-R8420W8240	6.93	88.00	96.90	4.68	Discharge	0.00	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
LowerCBR-R8430W8350	8.96	85.00	0.00	18.12	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8440W8360	23.91	68.00	2.10	39.42	Discharge	0.01	0.35	Ratio to Peak	0.2
LowerCBR-R8450W8370	19.76	72.00	11.70	38.28	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1000W1000	29.83	63.00	0.00	31.32	Discharge	0.04	0.35	Ratio to Peak	0.2
UpperCBR-R1010W1010	26.17	66.00	0.00	38.76	Discharge	0.17	0.35	Ratio to Peak	0.2
UpperCBR-R1070W1070	39.91	56.00	0.00	48.42	Discharge	0.28	0.35	Ratio to Peak	0.2
UpperCBR-R1080W1080	33.87	60.00	0.00	32.82	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R1090W1090	26.17	66.00	0.00	23.16	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1100W1100	27.35	65.00	0.00	40.44	Discharge	0.25	0.35	Ratio to Peak	0.2
UpperCBR-R1120W1120	23.91	68.00	0.00	38.82	Discharge	0.28	0.35	Ratio to Peak	0.2
UpperCBR-R1140W1140	35.30	59.00	0.00	40.50	Discharge	0.15	0.35	Ratio to Peak	0.2
UpperCBR-R1200W1200	35.30	59.00	0.00	25.98	Discharge	0.10	0.35	Ratio to Peak	0.2
UpperCBR-R1220W1220	38.32	57.00	0.00	26.04	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R1230W1230	39.91	56.00	0.00	41.94	Discharge	0.26	0.35	Ratio to Peak	0.2
UpperCBR-R1290W1290	32.48	61.00	0.00	35.70	Discharge	0.20	0.35	Ratio to Peak	0.2
UpperCBR-R1300W1300	36.79	58.00	0.00	38.34	Discharge	0.13	0.35	Ratio to Peak	0.2
UpperCBR-R1320W1320	18.79	73.00	0.00	18.84	Discharge	0.07	0.35	Ratio to Peak	0.2
UpperCBR-R1340W1340	33.87	60.00	0.00	28.80	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R1350W1350	17.85	74.00	0.00	12.60	Discharge	0.03	0.35	Ratio to Peak	0.2
UpperCBR-R1370W1370	39.91	56.00	0.00	40.68	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R1380W1380	38.32	57.00	0.00	26.94	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R1400W1400	25.02	67.00	0.00	23.70	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1410W1410	26.17	66.00	0.00	24.00	Discharge	0.08	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
UpperCBR-R1420W1420	26.17	66.00	0.00	39.00	Discharge	0.19	0.35	Ratio to Peak	0.2
UpperCBR-R1440W1440	39.91	56.00	0.00	54.78	Discharge	0.27	0.35	Ratio to Peak	0.2
UpperCBR-R1450W1450	39.91	56.00	0.00	33.06	Discharge	0.22	0.35	Ratio to Peak	0.2
UpperCBR-R1460W1460	23.91	68.00	0.00	29.40	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R1470W1470	15.17	77.00	0.00	25.14	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1540W1540	28.58	64.00	0.00	35.58	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R1550W1550	15.17	77.00	0.00	3.60	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R1570W1570	27.35	65.00	0.00	13.86	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1580W1580	15.17	77.00	0.00	20.46	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1600W1600	22.82	69.00	0.00	32.82	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R160W160	41.56	55.00	0.00	56.10	Discharge	0.32	0.35	Ratio to Peak	0.2
UpperCBR-R1610W1610	19.76	72.00	0.00	18.66	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1620W1620	38.32	57.00	0.00	42.42	Discharge	0.26	0.35	Ratio to Peak	0.2
UpperCBR-R1630W1630	38.32	57.00	0.00	39.60	Discharge	0.23	0.35	Ratio to Peak	0.2
UpperCBR-R1640W1640	23.91	68.00	0.00	46.14	Discharge	0.03	0.35	Ratio to Peak	0.2
UpperCBR-R1650W1650	23.91	68.00	0.00	77.70	Discharge	0.07	0.35	Ratio to Peak	0.2
UpperCBR-R1660W1660	25.02	67.00	0.00	32.70	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R1690W1690	13.50	79.00	0.00	6.90	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R1700W1700	8.96	85.00	0.00	5.52	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R1710W1710	16.93	75.00	0.00	38.04	Discharge	0.04	0.35	Ratio to Peak	0.2
UpperCBR-R1750W1750	27.35	65.00	0.00	21.66	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R1800W1800	8.27	86.00	0.00	9.54	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R1820W1820	20.75	71.00	0.00	31.68	Discharge	0.05	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
UpperCBR-R1830W1830	22.82	69.00	0.00	6.12	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R1840W1840	26.17	66.00	0.00	20.28	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R1870W1850	22.82	69.00	0.00	3.00	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R1890W1870	25.02	67.00	0.00	34.98	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R1900W1880	33.87	60.00	0.00	35.22	Discharge	0.10	0.35	Ratio to Peak	0.2
UpperCBR-R1910W1890	31.14	62.00	0.00	30.12	Discharge	0.12	0.35	Ratio to Peak	0.2
UpperCBR-R1920W1900	25.02	67.00	0.00	25.92	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R1930W1910	28.58	64.00	0.00	33.18	Discharge	0.13	0.35	Ratio to Peak	0.2
UpperCBR-R1940W1920	23.91	68.00	0.00	28.80	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R1950W1930	22.82	69.00	0.00	25.02	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R1960W1940	29.83	63.00	0.00	15.36	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R1970W1950	32.48	61.00	0.00	23.22	Discharge	0.04	0.35	Ratio to Peak	0.2
UpperCBR-R1980W1960	36.79	58.00	0.00	26.76	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R1990W1970	38.32	57.00	0.00	37.14	Discharge	0.16	0.35	Ratio to Peak	0.2
UpperCBR-R2000W1980	39.91	56.00	0.00	54.12	Discharge	0.30	0.35	Ratio to Peak	0.2
UpperCBR-R2010W1990	39.91	56.00	0.00	29.46	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R2020W2000	28.58	64.00	0.00	51.42	Discharge	0.07	0.35	Ratio to Peak	0.2
UpperCBR-R2030W2010	12.70	80.00	0.00	37.14	Discharge	0.02	0.35	Ratio to Peak	0.2
UpperCBR-R2040W2020	33.87	60.00	0.00	28.08	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R220W220	41.56	55.00	0.00	42.30	Discharge	0.11	0.35	Ratio to Peak	0.2
UpperCBR-R260W260	41.56	55.00	0.00	36.42	Discharge	0.12	0.35	Ratio to Peak	0.2
UpperCBR-R290W290	41.56	55.00	0.00	34.26	Discharge	0.11	0.35	Ratio to Peak	0.2
UpperCBR-R300W300	41.56	55.00	0.00	33.66	Discharge	0.03	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
UpperCBR-R310W310	39.91	56.00	0.00	11.76	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R320W320	41.56	55.00	0.00	42.72	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R330W330	39.91	56.00	0.00	13.44	Discharge	0.00	0.35	Ratio to Peak	0.2
UpperCBR-R350W350	41.56	55.00	0.00	27.84	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R360W360	41.56	55.00	0.00	30.36	Discharge	0.10	0.35	Ratio to Peak	0.2
UpperCBR-R370W370	39.91	56.00	0.00	52.92	Discharge	0.21	0.35	Ratio to Peak	0.2
UpperCBR-R430W430	39.91	56.00	0.00	47.22	Discharge	0.18	0.35	Ratio to Peak	0.2
UpperCBR-R440W440	41.56	55.00	0.00	39.66	Discharge	0.15	0.35	Ratio to Peak	0.2
UpperCBR-R470W470	41.56	55.00	0.00	38.58	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R480W480	39.91	56.00	0.00	29.34	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R510W510	41.56	55.00	0.00	47.52	Discharge	0.27	0.35	Ratio to Peak	0.2
UpperCBR-R520W520	41.56	55.00	0.00	34.92	Discharge	0.12	0.35	Ratio to Peak	0.2
UpperCBR-R540W540	39.91	56.00	0.00	31.14	Discharge	0.12	0.35	Ratio to Peak	0.2
UpperCBR-R560W560	39.91	56.00	0.00	40.26	Discharge	0.14	0.35	Ratio to Peak	0.2
UpperCBR-R580W580	38.32	57.00	0.00	27.72	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R610W610	41.56	55.00	0.00	52.38	Discharge	0.31	0.35	Ratio to Peak	0.2
UpperCBR-R620W620	38.32	57.00	0.00	18.30	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R630W630	39.91	56.00	0.00	46.08	Discharge	0.38	0.35	Ratio to Peak	0.2
UpperCBR-R640W640	41.56	55.00	0.00	49.98	Discharge	0.19	0.35	Ratio to Peak	0.2
UpperCBR-R650W650	41.56	55.00	0.00	28.08	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R660W660	39.91	56.00	0.00	50.82	Discharge	0.15	0.35	Ratio to Peak	0.2
UpperCBR-R680W680	39.91	56.00	0.00	74.40	Discharge	0.26	0.35	Ratio to Peak	0.2
UpperCBR-R720W720	41.56	55.00	0.00	50.52	Discharge	0.21	0.35	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			SCS Unit Hydrograph Transform	Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Lag Time (min)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
UpperCBR-R730W730	41.56	55.00	0.00	42.72	Discharge	0.17	0.35	Ratio to Peak	0.2
UpperCBR-R740W740	41.56	55.00	0.00	43.20	Discharge	0.10	0.35	Ratio to Peak	0.2
UpperCBR-R750W750	41.56	55.00	0.00	54.72	Discharge	0.21	0.35	Ratio to Peak	0.2
UpperCBR-R760W760	39.91	56.00	0.00	55.98	Discharge	0.26	0.35	Ratio to Peak	0.2
UpperCBR-R770W770	36.79	58.00	0.00	17.34	Discharge	0.02	0.35	Ratio to Peak	0.2
UpperCBR-R790W790	35.30	59.00	0.00	20.22	Discharge	0.03	0.35	Ratio to Peak	0.2
UpperCBR-R800W800	38.32	57.00	0.00	14.46	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R810W810	35.30	59.00	0.00	29.70	Discharge	0.09	0.35	Ratio to Peak	0.2
UpperCBR-R820W820	38.32	57.00	0.00	14.22	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R830W830	41.56	55.00	0.00	61.74	Discharge	0.16	0.35	Ratio to Peak	0.2
UpperCBR-R840W840	36.79	58.00	0.00	21.36	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R860W860	38.32	57.00	0.00	16.98	Discharge	0.01	0.35	Ratio to Peak	0.2
UpperCBR-R870W870	39.91	56.00	0.00	44.10	Discharge	0.13	0.35	Ratio to Peak	0.2
UpperCBR-R880W880	39.91	56.00	0.00	24.78	Discharge	0.05	0.35	Ratio to Peak	0.2
UpperCBR-R900W900	36.79	58.00	0.00	51.78	Discharge	0.08	0.35	Ratio to Peak	0.2
UpperCBR-R910W910	41.56	55.00	0.00	65.76	Discharge	0.11	0.35	Ratio to Peak	0.2
UpperCBR-R920W920	39.91	56.00	0.00	41.16	Discharge	0.11	0.35	Ratio to Peak	0.2
UpperCBR-R930W930	29.83	63.00	0.00	40.68	Discharge	0.13	0.35	Ratio to Peak	0.2
UpperCBR-R960W960	39.91	56.00	0.00	52.68	Discharge	0.17	0.35	Ratio to Peak	0.2
UpperCBR-R970W970	25.02	67.00	0.00	13.56	Discharge	0.00	0.35	Ratio to Peak	0.2

Annex 10. Cabadbaran Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
LowerCBR-R5930	Automatic Fixed Interval	808.60	0.0036	0.0465	Trapezoid	185.35	1
LowerCBR-R5980	Automatic Fixed Interval	463.80	0.0087	0.0668	Trapezoid	36.11	1
LowerCBR-R6040	Automatic Fixed Interval	373.80	0.0043	0.0400	Trapezoid	30.18	1
LowerCBR-R6080	Automatic Fixed Interval	389.20	0.0043	0.0400	Trapezoid	533.45	1
LowerCBR-R6260	Automatic Fixed Interval	1153.30	0.0013	0.0339	Trapezoid	93.62	1
LowerCBR-R6340	Automatic Fixed Interval	589.81	0.0053	0.0440	Trapezoid	152.47	1
LowerCBR-R6350	Automatic Fixed Interval	1710.20	0.0056	0.0383	Trapezoid	100.74	1
LowerCBR-R6360	Automatic Fixed Interval	447.50	0.0038	0.2574	Trapezoid	16.89	1
LowerCBR-R6380	Automatic Fixed Interval	183.50	0.0136	0.0549	Trapezoid	36.11	1
LowerCBR-R6390	Automatic Fixed Interval	1325.70	0.0035	0.0398	Trapezoid	355.63	1
LowerCBR-R6510	Automatic Fixed Interval	787.90	0.0013	0.0393	Trapezoid	199.78	1
LowerCBR-R6600	Automatic Fixed Interval	813.10	0.0084	0.0573	Trapezoid	23.87	1
LowerCBR-R6700	Automatic Fixed Interval	541.65	0.0074	0.0400	Trapezoid	82.19	1
LowerCBR-R6740	Automatic Fixed Interval	693.10	0.0013	0.0397	Trapezoid	103.40	1
LowerCBR-R6750	Automatic Fixed Interval	842.90	0.0045	0.0392	Trapezoid	223.53	1
LowerCBR-R6760	Automatic Fixed Interval	454.10	0.0075	0.0400	Trapezoid	36.40	1
LowerCBR-R6860	Automatic Fixed Interval	334.20	0.0031	0.0208	Trapezoid	7.41	1
LowerCBR-R6870	Automatic Fixed Interval	294.60	0.0029	0.0400	Trapezoid	118.14	1
LowerCBR-R6890	Automatic Fixed Interval	535.80	0.0013	0.0394	Trapezoid	179.10	1
LowerCBR-R6900	Automatic Fixed Interval	730.80	0.0017	0.0400	Trapezoid	268.07	1
LowerCBR-R6910	Automatic Fixed Interval	200.40	0.0021	0.0400	Trapezoid	289.47	1
LowerCBR-R6970	Automatic Fixed Interval	394.57	0.0094	0.0400	Trapezoid	44.81	1
LowerCBR-R6980	Automatic Fixed Interval	1143.80	0.0055	0.0400	Trapezoid	188.10	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
LowerCBR-R6990	Automatic Fixed Interval	703.22	0.0093	0.0400	Trapezoid	49.74	1
LowerCBR-R7030	Automatic Fixed Interval	616.00	0.0013	0.0164	Trapezoid	13.45	1
LowerCBR-R7070	Automatic Fixed Interval	341.80	0.0050	0.0151	Trapezoid	17.94	1
LowerCBR-R7080	Automatic Fixed Interval	1044.30	0.0013	0.0336	Trapezoid	88.05	1
LowerCBR-R7160	Automatic Fixed Interval	164.80	0.0013	0.0400	Trapezoid	179.10	1
LowerCBR-R7170	Automatic Fixed Interval	386.01	0.0013	0.0459	Trapezoid	30.75	1
LowerCBR-R7200	Automatic Fixed Interval	24.10	0.0013	0.0140	Trapezoid	17.94	1
LowerCBR-R7210	Automatic Fixed Interval	420.60	0.0018	0.0821	Trapezoid	13.45	1
LowerCBR-R7250	Automatic Fixed Interval	1321.80	0.0046	0.0400	Trapezoid	289.47	1
LowerCBR-R7280	Automatic Fixed Interval	981.60	0.0036	0.1107	Trapezoid	14.22	1
LowerCBR-R7310	Automatic Fixed Interval	465.40	0.0067	0.0394	Trapezoid	15.86	1
LowerCBR-R7350	Automatic Fixed Interval	108.30	0.0021	0.0140	Trapezoid	7.00	1
LowerCBR-R7360	Automatic Fixed Interval	193.60	0.0027	0.0786	Trapezoid	22.18	1
LowerCBR-R7400	Automatic Fixed Interval	305.10	0.0013	0.4000	Trapezoid	5.00	1
LowerCBR-R7440	Automatic Fixed Interval	390.90	0.0041	0.0400	Trapezoid	18.95	1
LowerCBR-R7520	Automatic Fixed Interval	202.30	0.0179	0.0400	Trapezoid	12.67	1
LowerCBR-R7650	Automatic Fixed Interval	1368.70	0.0048	0.1120	Trapezoid	17.08	1
LowerCBR-R7990	Automatic Fixed Interval	95.00	0.0013	0.2596	Trapezoid	13.10	1
LowerCBR-R8000	Automatic Fixed Interval	315.40	0.0025	0.0878	Trapezoid	13.10	1
LowerCBR-R8010	Automatic Fixed Interval	29.10	0.0013	0.0140	Trapezoid	13.10	1
LowerCBR-R8030	Automatic Fixed Interval	14.10	0.0013	0.0140	Trapezoid	13.10	1
LowerCBR-R8040	Automatic Fixed Interval	172.40	0.0021	0.1587	Trapezoid	13.10	1
LowerCBR-R8090	Automatic Fixed Interval	172.80	0.0033	0.1318	Trapezoid	17.94	1
LowerCBR-R8100	Automatic Fixed Interval	525.20	0.0013	0.0335	Trapezoid	84.20	1
LowerCBR-R8110	Automatic Fixed Interval	367.80	0.0013	0.1245	Trapezoid	45.36	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
LowerCBR-R8120	Automatic Fixed Interval	304.40	0.0014	0.0757	Trapezoid	22.18	1
LowerCBR-R8130	Automatic Fixed Interval	641.30	0.0047	0.4000	Trapezoid	17.08	1
LowerCBR-R8140	Automatic Fixed Interval	97.53	0.0013	0.0391	Trapezoid	121.33	1
LowerCBR-R8160	Automatic Fixed Interval	975.30	0.0052	0.0395	Trapezoid	98.25	1
LowerCBR-R8170	Automatic Fixed Interval	447.50	0.0038	0.2574	Trapezoid	16.89	1
LowerCBR-R8190	Automatic Fixed Interval	404.26	0.0075	0.0400	Trapezoid	170.08	1
LowerCBR-R8230	Automatic Fixed Interval	1316.90	0.0044	0.1085	Trapezoid	12.67	1
LowerCBR-R8240	Automatic Fixed Interval	907.80	0.0058	0.0855	Trapezoid	15.86	1
LowerCBR-R8250	Automatic Fixed Interval	185.40	0.0018	0.3357	Trapezoid	13.10	1
LowerCBR-R8280	Automatic Fixed Interval	5.00	0.0013	0.0230	Trapezoid	45.36	1
LowerCBR-R8300	Automatic Fixed Interval	241.40	0.0014	0.0645	Trapezoid	14.53	1
LowerCBR-R8310	Automatic Fixed Interval	347.60	0.0014	0.0626	Trapezoid	14.53	1
LowerCBR-R8320	Automatic Fixed Interval	252.30	0.0013	0.1791	Trapezoid	14.53	1
LowerCBR-R8350	Automatic Fixed Interval	562.80	0.0083	0.1794	Trapezoid	15.28	1
LowerCBR-R8360	Automatic Fixed Interval	581.80	0.0097	0.2387	Trapezoid	15.28	1
LowerCBR-R8390	Automatic Fixed Interval	78.30	0.0061	0.0140	Trapezoid	45.36	1
LowerCBR-R8420	Automatic Fixed Interval	22.10	0.0022	0.0140	Trapezoid	45.36	1
LowerCBR-R8430	Automatic Fixed Interval	782.30	0.0030	0.0386	Trapezoid	533.45	1
LowerCBR-R8450	Automatic Fixed Interval	467.80	0.0026	0.2533	Trapezoid	17.08	1
Reach-1	Automatic Fixed Interval	320.70	0.0023	0.0400	Trapezoid	36.40	1
Reach-2	Automatic Fixed Interval	1261.43	0.0077	0.0400	Trapezoid	42.40	1
Reach-3	Automatic Fixed Interval	673.48	0.0078	0.0400	Trapezoid	39.09	1
Reach-4	Automatic Fixed Interval	701.33	0.0055	0.0400	Trapezoid	188.10	1
Reach-5	Automatic Fixed Interval	186.80	0.0018	0.0400	Trapezoid	12.06	1
Reach-6	Automatic Fixed Interval	335.99	0.0018	0.0400	Trapezoid	12.06	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
Reach-7	Automatic Fixed Interval	288.43	0.0056	0.0400	Trapezoid	89.41	1
Reach-8	Automatic Fixed Interval	314.69	0.0056	0.0400	Trapezoid	101.87	1
Reach-9	Automatic Fixed Interval	244.91	0.0075	0.0400	Trapezoid	20.84	1
UpperCBR-R1000	Automatic Fixed Interval	739.40	0.0013	0.0320	Trapezoid	46.04	1
UpperCBR-R1010	Automatic Fixed Interval	2278.80	0.1436	0.8000	Trapezoid	12.08	1
UpperCBR-R1090	Automatic Fixed Interval	289.70	0.0013	0.0320	Trapezoid	59.02	1
UpperCBR-R1100	Automatic Fixed Interval	3073.20	0.1249	0.0300	Trapezoid	10.61	1
UpperCBR-R1120	Automatic Fixed Interval	3527.10	0.0268	0.0300	Trapezoid	83.00	1
UpperCBR-R1140	Automatic Fixed Interval	1793.00	0.0764	0.8000	Trapezoid	37.85	1
UpperCBR-R1200	Automatic Fixed Interval	1745.00	0.0523	0.0320	Trapezoid	34.22	1
UpperCBR-R1220	Automatic Fixed Interval	697.30	0.0990	0.8000	Trapezoid	31.83	1
UpperCBR-R1290	Automatic Fixed Interval	2565.90	0.0156	0.0320	Trapezoid	47.36	1
UpperCBR-R1300	Automatic Fixed Interval	1123.40	0.0735	0.0300	Trapezoid	20.81	1
UpperCBR-R1320	Automatic Fixed Interval	1519.10	0.0107	0.0300	Trapezoid	61.35	1
UpperCBR-R1350	Automatic Fixed Interval	742.30	0.0116	0.0300	Trapezoid	59.37	1
UpperCBR-R1380	Automatic Fixed Interval	1207.70	0.0631	0.4000	Trapezoid	20.81	1
UpperCBR-R1400	Automatic Fixed Interval	1311.40	0.0357	0.4000	Trapezoid	10.03	1
UpperCBR-R1410	Automatic Fixed Interval	1273.80	0.0104	0.0300	Trapezoid	73.54	1
UpperCBR-R1420	Automatic Fixed Interval	2400.60	0.1244	0.0320	Trapezoid	14.14	1
UpperCBR-R1450	Automatic Fixed Interval	2123.20	0.0854	0.0320	Trapezoid	31.83	1
UpperCBR-R1460	Automatic Fixed Interval	1374.50	0.0104	0.4000	Trapezoid	16.66	1
UpperCBR-R1470	Automatic Fixed Interval	1885.20	0.0075	0.0400	Trapezoid	68.43	1
UpperCBR-R1550	Automatic Fixed Interval	147.40	0.0246	0.0400	Trapezoid	57.35	1
UpperCBR-R1570	Automatic Fixed Interval	393.50	0.0094	0.0320	Trapezoid	51.10	1
UpperCBR-R1580	Automatic Fixed Interval	739.30	0.0074	0.0400	Trapezoid	78.60	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
UpperCBR-R1610	Automatic Fixed Interval	898.80	0.0107	0.0140	Trapezoid	52.15	1
UpperCBR-R1640	Automatic Fixed Interval	1101.00	0.0084	0.0320	Trapezoid	14.50	1
UpperCBR-R1650	Automatic Fixed Interval	2415.70	0.0096	0.0400	Trapezoid	42.02	1
UpperCBR-R1660	Automatic Fixed Interval	893.60	0.0268	0.0320	Trapezoid	30.57	1
UpperCBR-R1690	Automatic Fixed Interval	196.60	0.0093	0.0320	Trapezoid	40.12	1
UpperCBR-R1700	Automatic Fixed Interval	68.30	0.0013	0.0400	Trapezoid	22.86	1
UpperCBR-R1710	Automatic Fixed Interval	2549.50	0.0092	0.0400	Trapezoid	52.16	1
UpperCBR-R1750	Automatic Fixed Interval	999.00	0.0088	0.0400	Trapezoid	51.25	1
UpperCBR-R1800	Automatic Fixed Interval	566.10	0.0131	0.0400	Trapezoid	39.81	1
UpperCBR-R1820	Automatic Fixed Interval	522.00	0.0117	0.0400	Trapezoid	53.64	1
UpperCBR-R1830	Automatic Fixed Interval	167.40	0.0084	0.0320	Trapezoid	51.14	1
UpperCBR-R1840	Automatic Fixed Interval	7.10	0.0013	0.0320	Trapezoid	63.59	1
UpperCBR-R1870	Automatic Fixed Interval	41.20	0.0013	0.0320	Trapezoid	48.65	1
UpperCBR-R1880	Automatic Fixed Interval	5.00	0.0040	0.0320	Trapezoid	63.59	1
UpperCBR-R1890	Automatic Fixed Interval	77.40	0.0105	0.0320	Trapezoid	49.42	1
UpperCBR-R1910	Automatic Fixed Interval	1556.00	0.1581	0.8000	Trapezoid	19.57	1
UpperCBR-R1960	Automatic Fixed Interval	1110.20	0.0093	0.4000	Trapezoid	29.74	1
UpperCBR-R1970	Automatic Fixed Interval	606.60	0.0068	0.0400	Trapezoid	36.87	1
UpperCBR-R2020	Automatic Fixed Interval	4475.50	0.0239	0.3800	Trapezoid	19.37	1
UpperCBR-R2030	Automatic Fixed Interval	1839.90	0.0081	0.0400	Trapezoid	60.15	1
UpperCBR-R300	Automatic Fixed Interval	755.10	0.1273	0.8000	Trapezoid	31.83	1
UpperCBR-R310	Automatic Fixed Interval	363.80	0.1144	0.0320	Trapezoid	31.83	1
UpperCBR-R330	Automatic Fixed Interval	311.60	0.1470	0.8000	Trapezoid	31.83	1
UpperCBR-R360	Automatic Fixed Interval	1447.50	0.1015	0.8000	Trapezoid	31.83	1
UpperCBR-R370	Automatic Fixed Interval	3285.10	0.0612	0.0320	Trapezoid	33.81	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
UpperCBR-R480	Automatic Fixed Interval	1062.00	0.1167	0.0300	Trapezoid	29.93	1
UpperCBR-R540	Automatic Fixed Interval	1958.90	0.0592	0.0320	Trapezoid	29.93	1
UpperCBR-R560	Automatic Fixed Interval	2041.00	0.0807	0.0300	Trapezoid	29.92	1
UpperCBR-R620	Automatic Fixed Interval	113.10	0.0013	0.0320	Trapezoid	29.92	1
UpperCBR-R630	Automatic Fixed Interval	4222.40	0.0477	0.0300	Trapezoid	32.71	1
UpperCBR-R640	Automatic Fixed Interval	2585.40	0.1071	0.0320	Trapezoid	31.83	1
UpperCBR-R660	Automatic Fixed Interval	3379.80	0.1338	0.8000	Trapezoid	31.83	1
UpperCBR-R770	Automatic Fixed Interval	421.10	0.0576	0.8000	Trapezoid	37.03	1
UpperCBR-R790	Automatic Fixed Interval	983.60	0.1217	0.0300	Trapezoid	31.83	1
UpperCBR-R800	Automatic Fixed Interval	543.10	0.0953	0.8000	Trapezoid	31.83	1
UpperCBR-R810	Automatic Fixed Interval	1318.10	0.0628	0.0320	Trapezoid	44.48	1
UpperCBR-R820	Automatic Fixed Interval	306.40	0.0772	0.8000	Trapezoid	32.27	1
UpperCBR-R840	Automatic Fixed Interval	395.20	0.1015	0.0320	Trapezoid	32.27	1
UpperCBR-R860	Automatic Fixed Interval	259.40	0.0766	0.0320	Trapezoid	32.27	1
UpperCBR-R880	Automatic Fixed Interval	978.40	0.0810	0.0320	Trapezoid	32.27	1
UpperCBR-R960	Automatic Fixed Interval	1536.10	0.0541	0.8000	Trapezoid	37.85	1
UpperCBR-R970	Automatic Fixed Interval	579.10	0.0449	0.0300	Trapezoid	46.04	1

Annex 11. Cabadbaran Field Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						

Annex 12. Educational Institutions Affected in Cabadbaran Floodplain

AGUSAN DEL SUR				
Cabadbaran City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Katugasan Elementary School	Bayabas	0	0	0
Cabinet Elementary School	Caasinan	0	0	1
Candelaria Institute	Caasinan	0	1	1
Candelaria Institute Pre-School	Caasinan	0	0	1
Kauswagan Elementary School	Caasinan	0	0	0
Northern Mindanao College	Caasinan	1	2	2
Calibunan Elementary School	Cabinet	0	2	2
CSU Cabadbaran Campus	Cabinet	0	2	2
Tolosa Elementary School	Cabinet	1	2	2
A. Dagani Elementary School	Comagascas	2	2	2
Katugasan Elementary School	Comagascas	0	0	0
A. Dagani Elementary School	Kauswagan	0	1	2
Bishop Haden College Inc.	Kauswagan	0	1	2
Cabadbaran National High School	Kauswagan	0	2	2
Cabadbaran South Central Elementary School	Kauswagan	0	2	2
CSU Cabadbaran Campus	Kauswagan	0	2	2
Mindanao Institute	Kauswagan	1	2	2
North Cabadbaran Central Elementary School	Kauswagan	1	2	2
Northern Mindanao College	Kauswagan	0	1	2
Bay-ang Elementary School	Mabini	0	0	0
Mahaba Elementary School	Mahaba	0	1	1
Puting Bato Elementary School	Puting Bato	0	0	0
Calibunan Elementary School	Tolosa	0	2	2

Annex 13. Health Institutions Affected in Cabadbaran Floodplain

AGUSAN DEL SUR				
Cabadbaran City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Dr. Jongko's Clinic	Caasinan	0	1	2
Cabadbaran City District Hospital	Cabinet	0	2	2
Duay Hospital	Cabinet	0	1	2
Cabadbaran Puriculture	Kauswagan	0	2	2
Mabini Health Center	Kauswagan	1	2	2