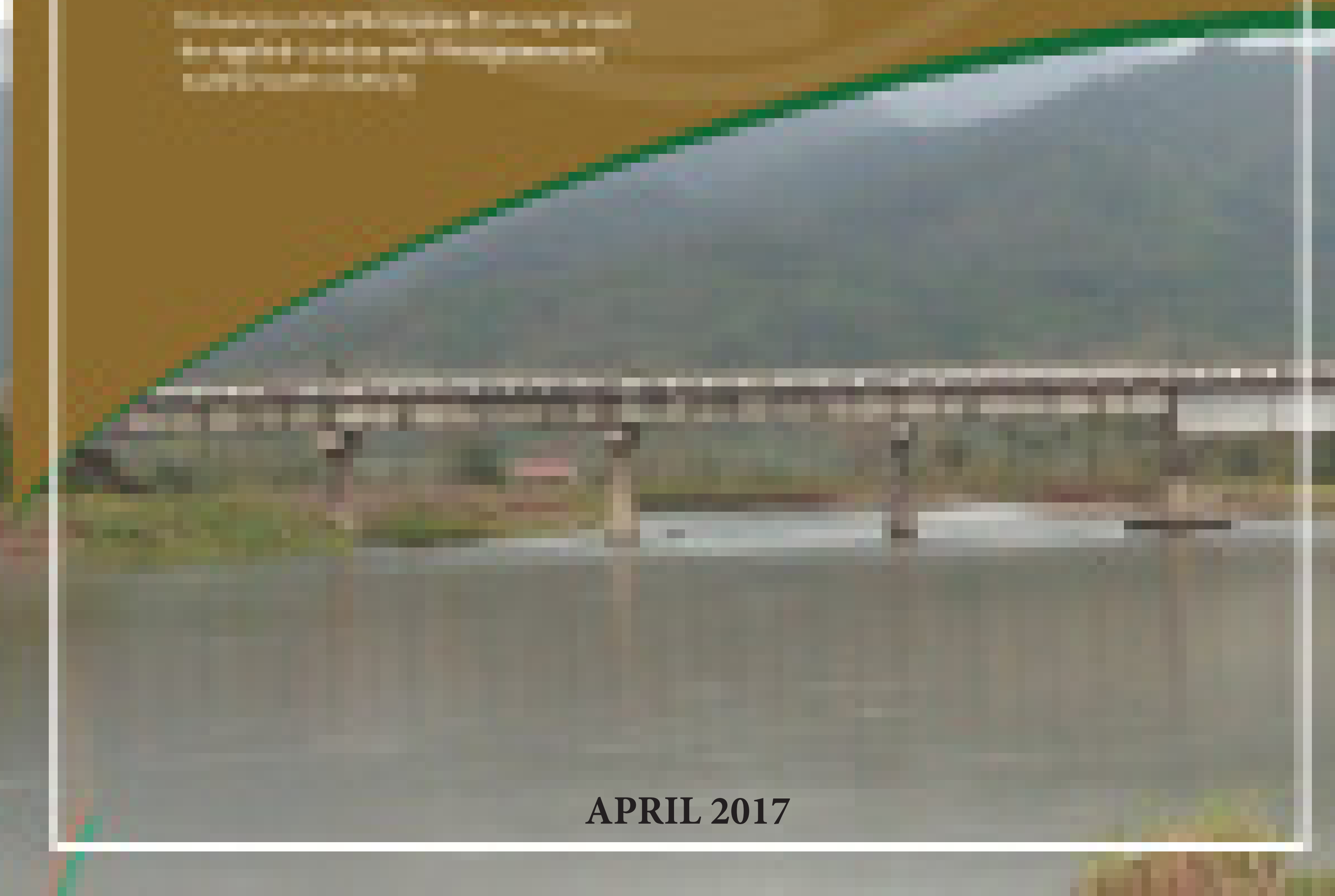
LiDAR Surveys and Flood Mapping of Casambalangan River



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CASAMBALANGAN RIVER

Enrico C. Paringit Dr. Eng., and Dr. Januel P. Floresca

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program primarily aimed to acquire 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.

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the Isabela State University (ISU). The ISU was 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 ten (10) river basins in the Cagayan Valley Region. The university is located at Ilagan City in the Province of Isabela.

1.2. Overview of the Casambalangan River Basin

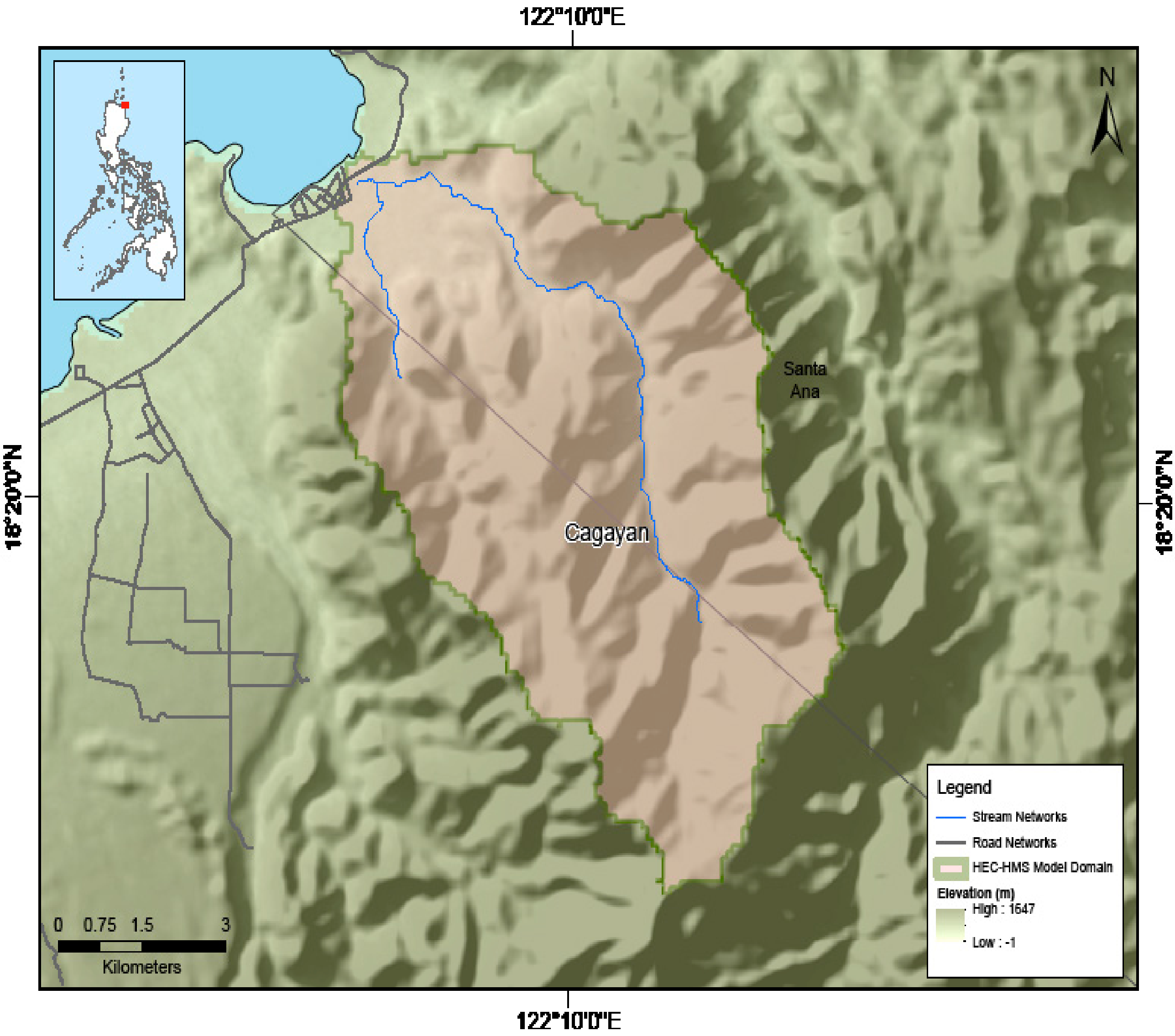


Figure 1. Map of Casambalangan River Basin

Based on the modified coronas classification, the Municipality of Sta. Ana, a second-class municipality in the Province of Cagayan, Philippines, is under type IV climatic condition, with more or less even distribution of rainfall throughout the year.

The Casambalangan River Basin which covers an area of 64.3855 square kilometers is located in the said municipality. The watershed traverses six (6) barangays namely Rapuli, Casambalangan, Santa Clara, San Jose, Patunungan and Santa Maria with a total population of 9,805 people. The Casambalangan Basin Model is consists of twenty (20) sub basins, ten (10) reaches, and nine (9) junctions. The basins were identified based on soil and land cover characteristics of the area. Within the watershed is a mix of industrial, commercial and agricultural economy. Most of the commercial and industrial activities are conducted at Port Irene and the Cagayan Special Economic Zone (CEZA) in Barangay Casambalangan. Some of its agricultural and aquatic products are rice, corn, coconut, cassava, fish, and shells, etc.

The Casambalangan River Basin (Figure 1) drains at Babuyan Channel. Its boundaries are at the ridge of the Tapha Mountain with 779 meters elevation and Palawig Range with 601 meters elevation.

The Super Typhoon Angela, known in the Philippines as Typhoon Rubing, was an intense tropical cyclone that formed in late September 1989. The storm ultimately peaked in intensity as a super typhoon when it struck northern Luzon that caused severe damage in the Philippines. It was estimated that 119 people perished, and 192 more were injured. Additionally, 28 remained missing following the storm. In total, 219,178 people, or 39,095 families, were affected by the cyclone. About 33,309 homes sustained some degree of damage. The typhoon’s intense winds and heavy rainfall triggered flooding and damaged crops. The hardest-hit areas were in the Cagayan province. Overall, the storm left approximately $8 million (1989 USD) in damage across the region.

CHAPTER 2: LIDAR DATA ACQUISITION OF CASAMBALANGAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Jasmine T. Alviar, Mr. Darryl M. Austria

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

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).
In order to acquire LiDAR data, the Data Acquisition Component (DAC) created flight plans within the delineated priority area of the Casambalangan Floodplain in the Province of Cagayan. These missions were planned for twenty one (21) lines, and ran for, at most, four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Casambalangan Floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK3A	850	35	50	125	40	130	5
BLK3B	900	35	50	125	40	130	5

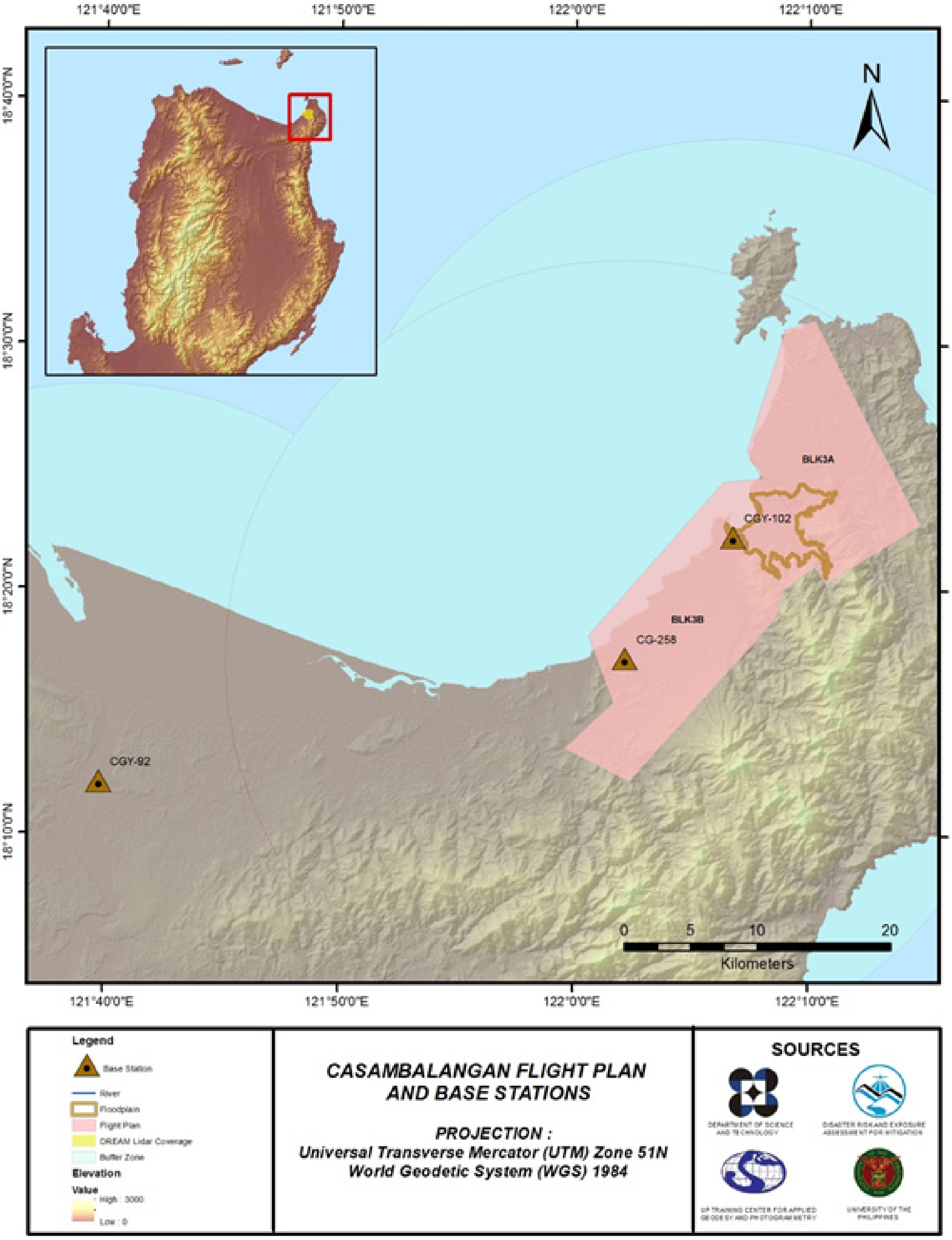


Figure 2. Flight plans and base stations used for Casambalangan Floodplain

2.2 Ground Base Stations

The Project Team was able to recover one (1) NAMRIA horizontal control point, CGY-102 which is of second (2nd) order accuracy. The field team also recovered one (1) NAMRIA benchmark, CG-258, which was reprocessed as a horizontal ground control point. The Certifications for the NAMRIA reference points are found in Annex 2 and the baseline processing report for CG-258 is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (April 28 to May 6, 2016). Base stations were observed using Dual Frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Casambalangan floodplain are shown in Figure 2.

Figure 3 to Figure 4 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations, while Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

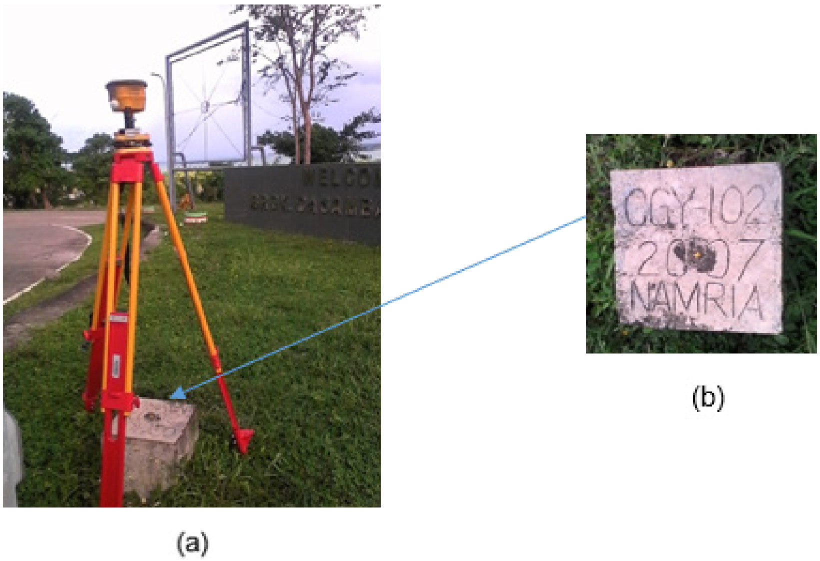
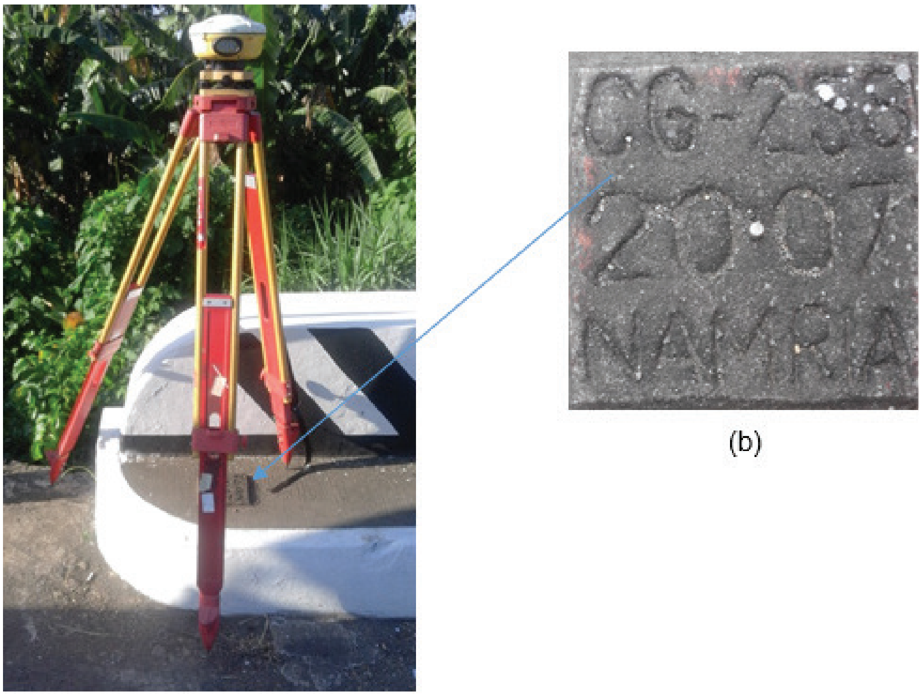


Figure 3. GPS set-up over CGY-102 located about two (2) meters from the south corner of the triangular island at the intersection of the national highway and the road to Port Irene in Santa Ana, Cagayan, and CGY-102 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point CGY-102 used as base station for the LiDAR acquisition

Station Name	CGY-102	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18°22’15.98573” North 122°6’41.74346” East 22.60800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	617476.569 meters 2032192.366 meters

Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84	Latitude Longitude Ellipsoidal Height	18°22’9.81367” North 122°6’46.31361” East 57.19500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	406145.45 meters 203135134 meters



(a) (b)

Figure 4. GPS set-up over CG-258 located along the national road and about 200 meters northeast of kilometer post no. 608 in Gonzaga, Cagayan (a) and NAMRIA benchmark CG-258 (b) as recovered by the field team

Table 3. Details of established ground control point CG-258 used as vertical reference point and established base station for the LiDAR acquisition

Station Name	CG-258	
Order of Accuracy	2nd	
Elevation	6.5266 +/- 0.0455 meters	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	18°17'21.328997" North
	Longitude	122°01'21.83970" East
	Ellipsoidal Height	12.774 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	18°17'15.16762" North
	Longitude	122°01'26.41723" East
	Ellipsoidal Height	47.419 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92	Easting	396708.418 meters
	Northing	2022343.154 meters

Table 4. Ground control used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
April 28, 2016	3971G	2BLK3CAG2MQR119A	CGY-102, CG-258
May 3, 2016	3989G	2BLK3CAG2QSR124A	CGY-102, CG-258
May 3, 2016	3991G	2BLK3CAG2MSQS124B	CGY-102, CG-258
May 6, 2016	4001G	2BLK3CAG2MRS127A	CGY-102, CG-258

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Casambalangan Floodplain, for a total of 14 hours and 38 minutes (14+38) of flying time for RP-C9022. All missions were acquired using the Gemini LiDAR System. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition in Casambalangan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Sur-veyed with-in the Floodplain (km2)	Area Sur-veyed out-side the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
April 28, 2016	3971G	401.86	162.97	9.07	153.90	-	4	15
May 3, 2016	3991G	229.33	161.30	14.14	147.16		3	57
May 3, 2016	3991G	229.33	121.82	14.46	107.36	-	2	26
May 6, 2016	4001G	401.86	127.08	7.11	119.97	-	4	00
TOTAL		631.19	471.66	23.35	448.31	-	14	38

Table 6. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3971G	850	30	50	125	50	130	5
3989G	800	30	50	125	50	130	5
3991G	800	30	50	125	50	130	5

2.4 Survey Coverage

Casambalangan Floodplain is located in the Province of Cagayan. The survey covered the Municipalities of Santa Ana and Gonzaga. The details of the survey coverage in these municipalities are shown in Table 7. The actual coverage of the LiDAR acquisition for Casambalangan Floodplain is presented in Figure 5.

Table 7. List of municipalities and cities surveyed during Casambalangan Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Cagayan	Santa Ana	437.13	175.18	35.20%
	Gonzaga	497.62	223.41	51.11%

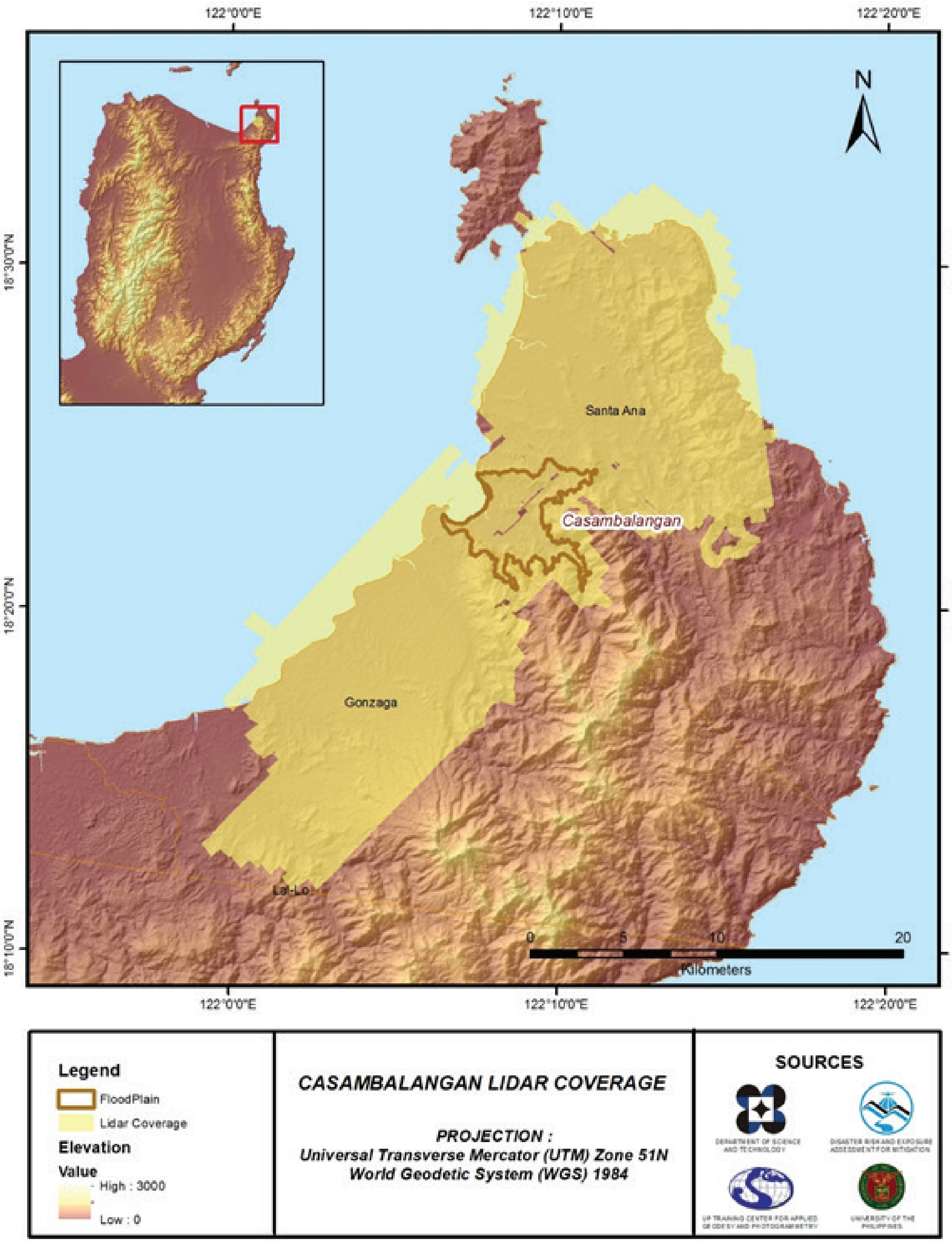


Figure 5. Actual LiDAR survey coverage for Casambalangan Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE CASAMBALANGAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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).
The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality 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 were then classified into various

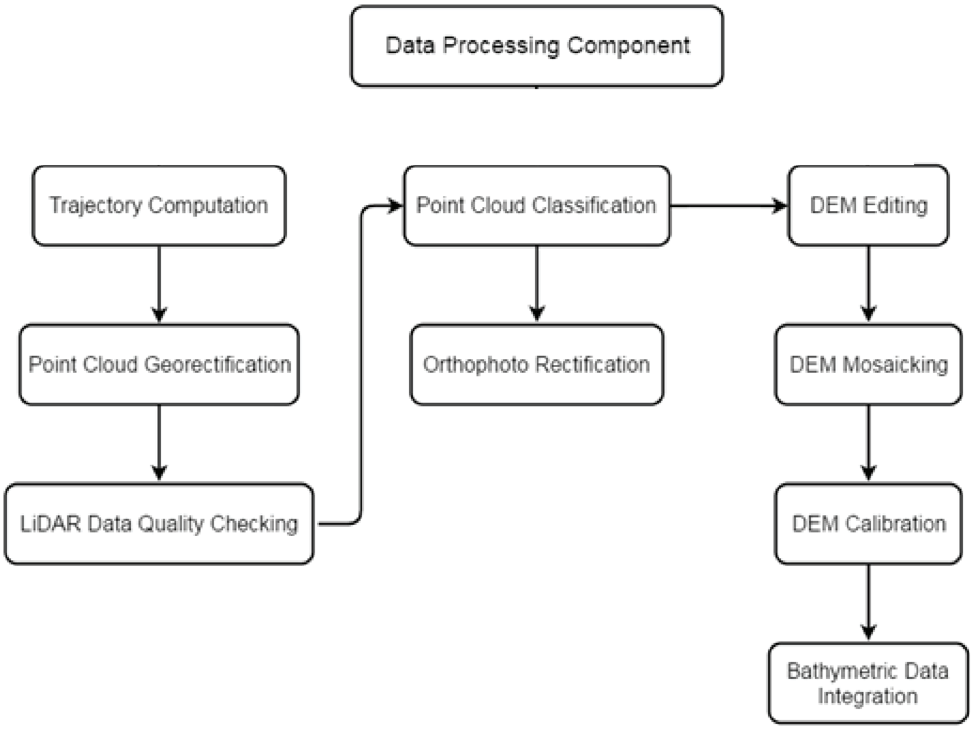

Figure 6. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of the Acquired LiDAR Data

Data Transfer Sheets for all the LiDAR missions for Casambalangan Floodplain can be found in Annex 5. Missions flown during all the surveys conducted in April and May 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System over Tuguegarao. The Data Acquisition Component (DAC) transferred a total of 62.85 Gigabytes of Range data, 0.88 Gigabytes of POS data, 48.33 Megabytes of GPS base station data, and 0 Gigabytes of raw image data to the data server on April 28, 2016 for the first survey and May 6, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Casambalangan was fully transferred on June 21, 2016, as indicated on the Data Transfer Sheets.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 4001G, one of the Casambalangan flights, which is the North, East, and Down position RMSE values are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 6, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

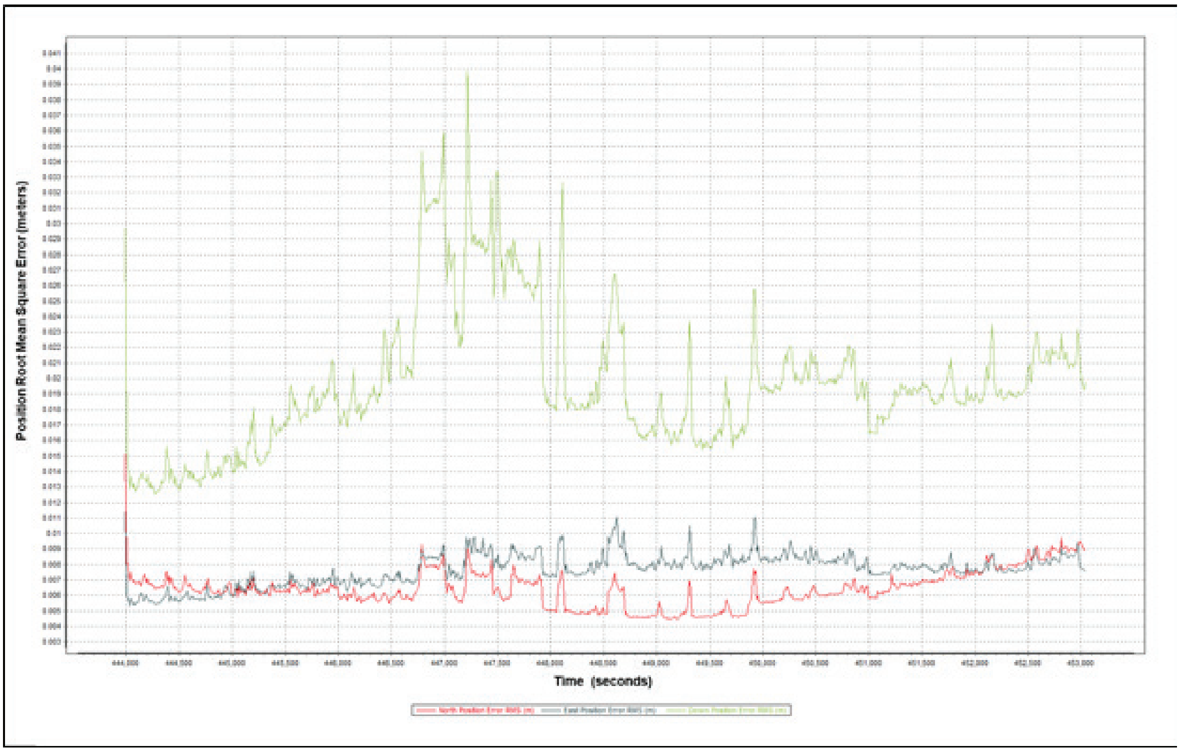

Figure 7. Smoothed Performance Metric Parameters of Casambalangan Flight 4001G

The time of flight was from 444000 seconds to 453000 seconds, which corresponds to morning of May 6, 2016. The initial spike seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and when the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaks at 1.00 centimeters, the East position RMSE peaks at 1.10 centimeters, and the Down position RMSE peaks at 4.00 centimeters, which are within the prescribed accuracies described in the methodology.

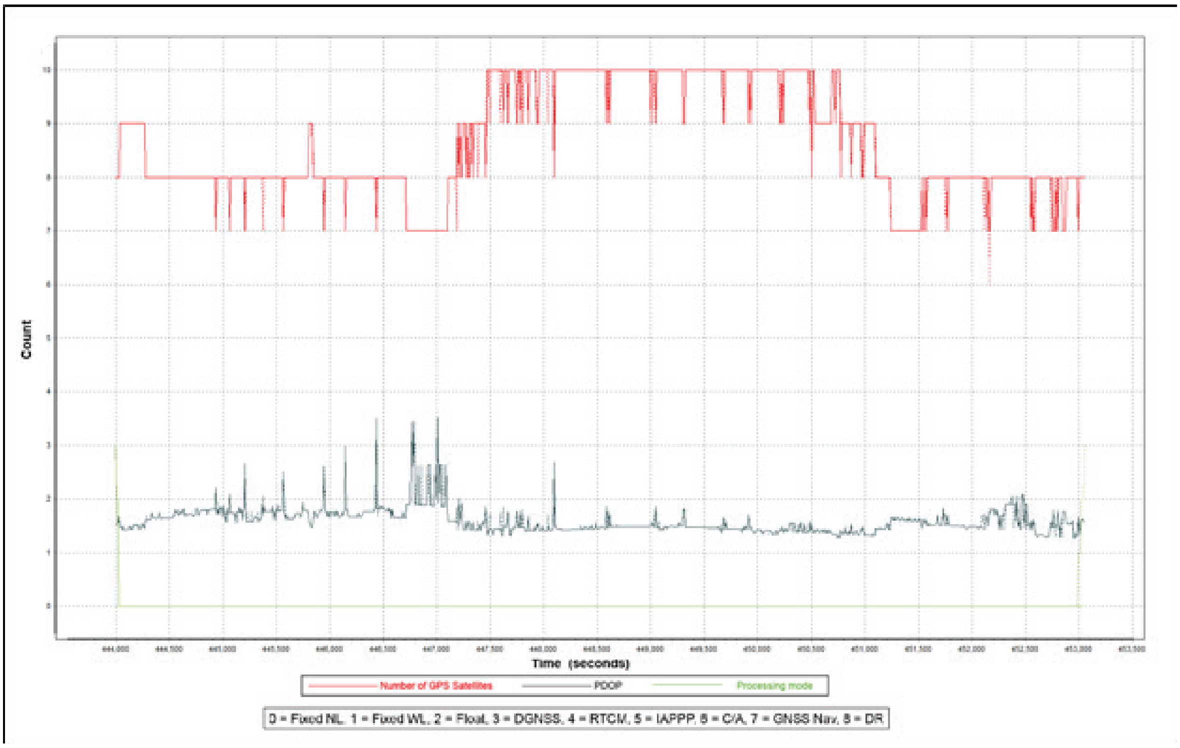

Figure 8. Solution Status Parameters of Casambalangan Flight 4001G

The Solution Status parameters of flight 4001G, one of the Casambalangan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. 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 Casambalangan flights is shown in Figure 9.

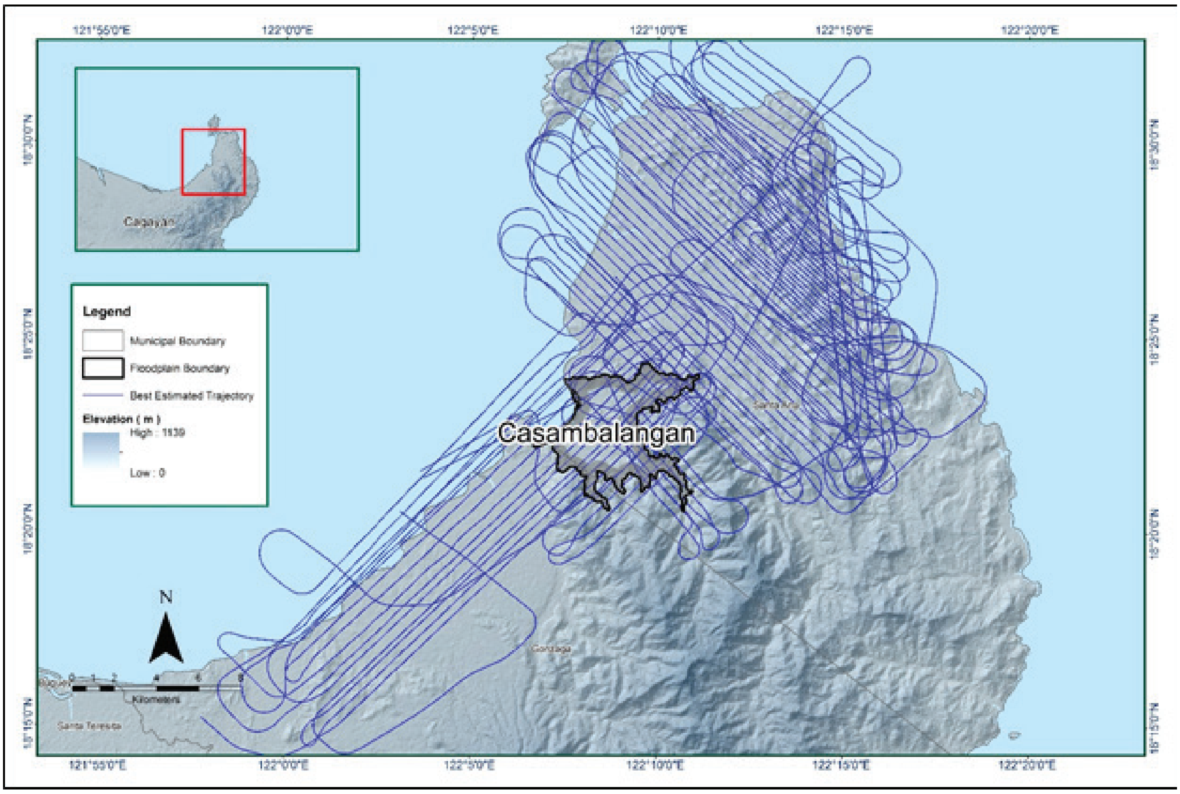

Figure 9. Best Estimated Trajectory over the Casambalangan Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 71 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Casambalangan floodplain are given in Table 8.

Table 8. Self-Calibration Results values for Casambalangan flights

Acceptable Value	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000342
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000718
GPS Position Z-correction stdev (<0.01meters)	0.0014

The optimum accuracy is obtained for all Casambalangan flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 7. Mission Summary Reports.

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Casambalangan Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

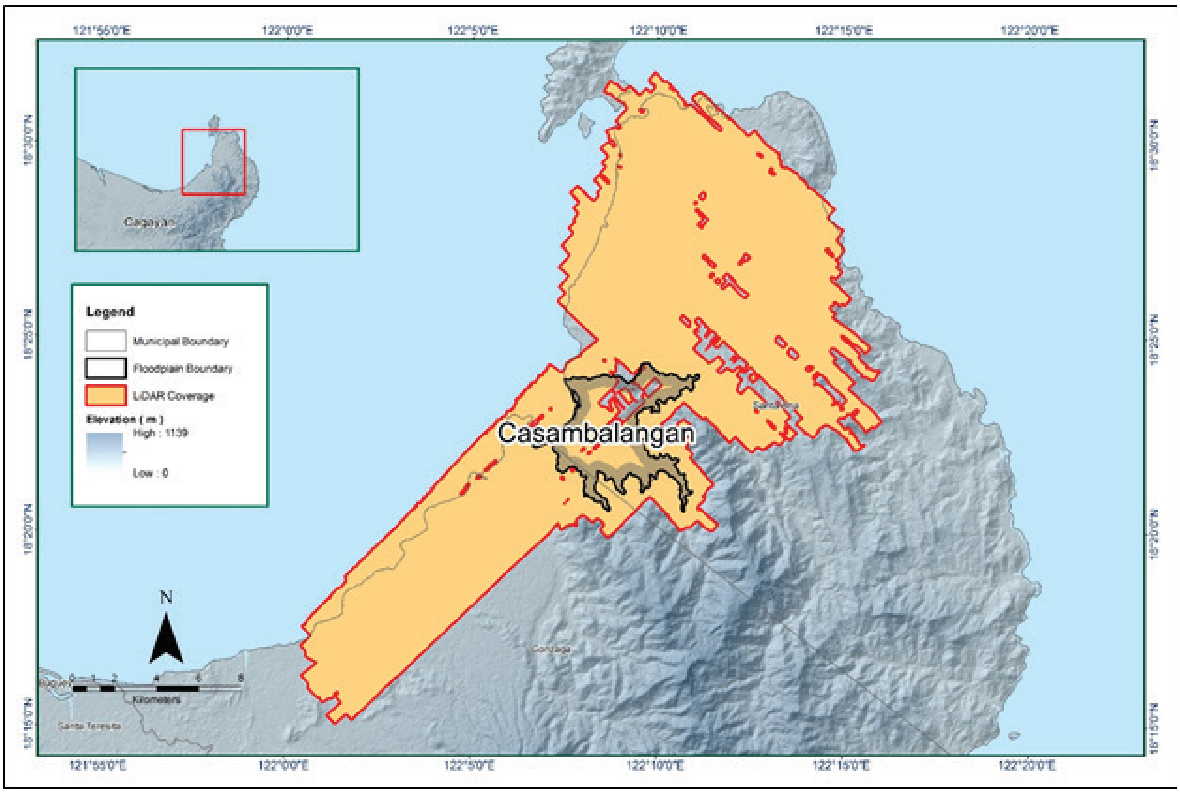

Figure 10. Boundary of the processed LiDAR data over Casambalangan Floodplain

The total area covered by the Casambalangan missions is 296.79 sq.km that is comprised of four (4) flight acquisitions grouped and merged into four (4) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Casambalangan Floodplain

LiDAR Blocks	Flight Num-bers	Area (sq. km)
Cagayan_reflights_Blk3B	4001G	17.72
Cagayan_reflights_Blk3B_ supplement	4001G	15.98
Cagayan_reflights_Blk3A	3971G	108.73
	3991G	
	4001G	
Cagayan_reflights_Blk3C	3991G	154.36
	3971G	
	3989G	
TOTAL		296.79 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 11. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

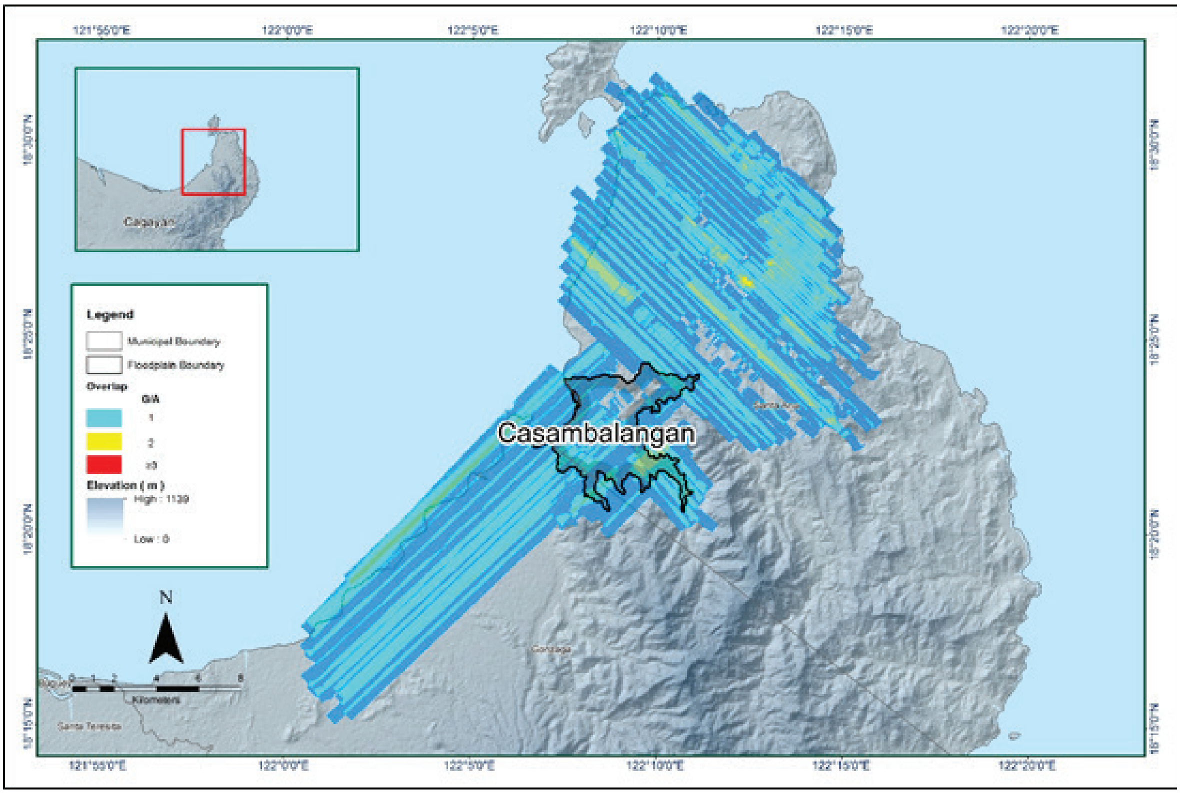

Figure 11. Image of data overlap for Casambalangan Floodplain

The overlap statistics per block for the Casambalangan floodplain can be found in Annex 7. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 33.01% and 42.36% respectively, which passed the 25% requirement.
The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 12. It was determined that all LiDAR data for Casambalangan floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.51 points per square meter.

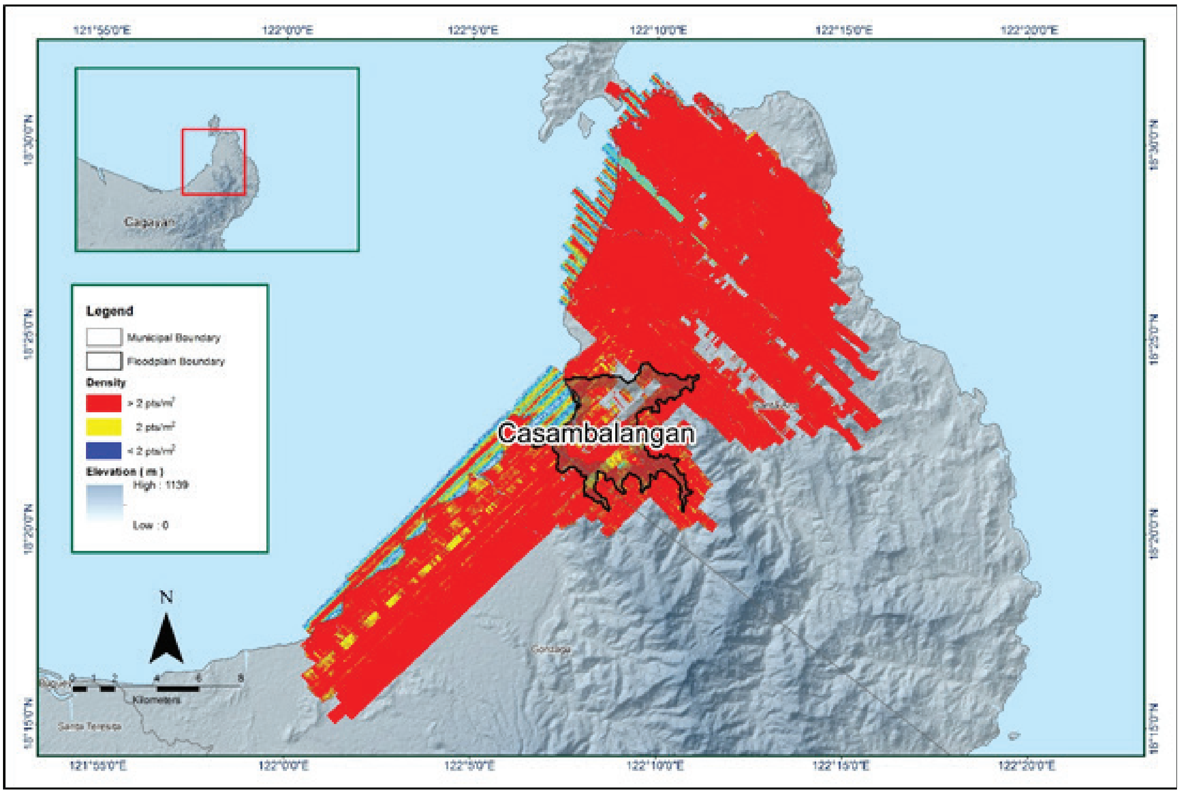

Figure 12. Density map of merged LiDAR data for Casambalangan Floodplain

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

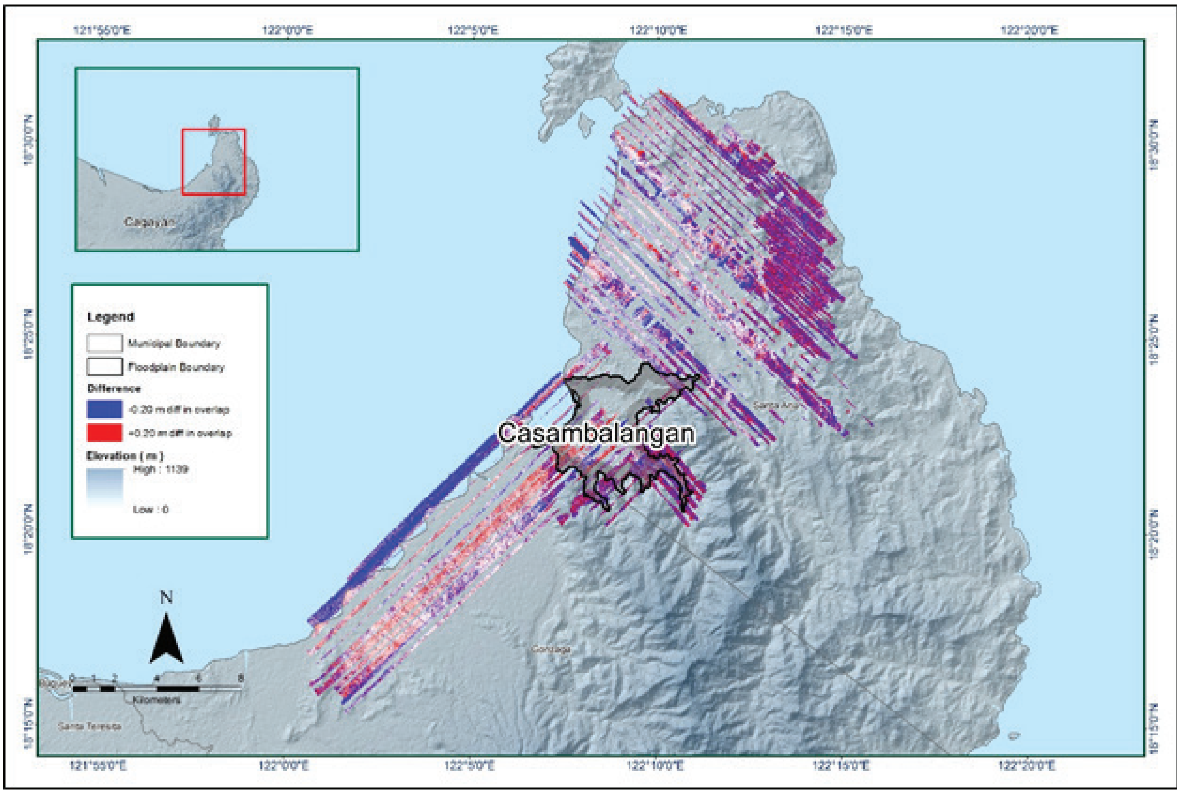

Figure 13. Elevation difference map between flight lines for Casambalangan Floodplain

A screen capture of the processed LAS data from Casambalangan flight 4001G loaded in QT Modeler is shown in Figure 14. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

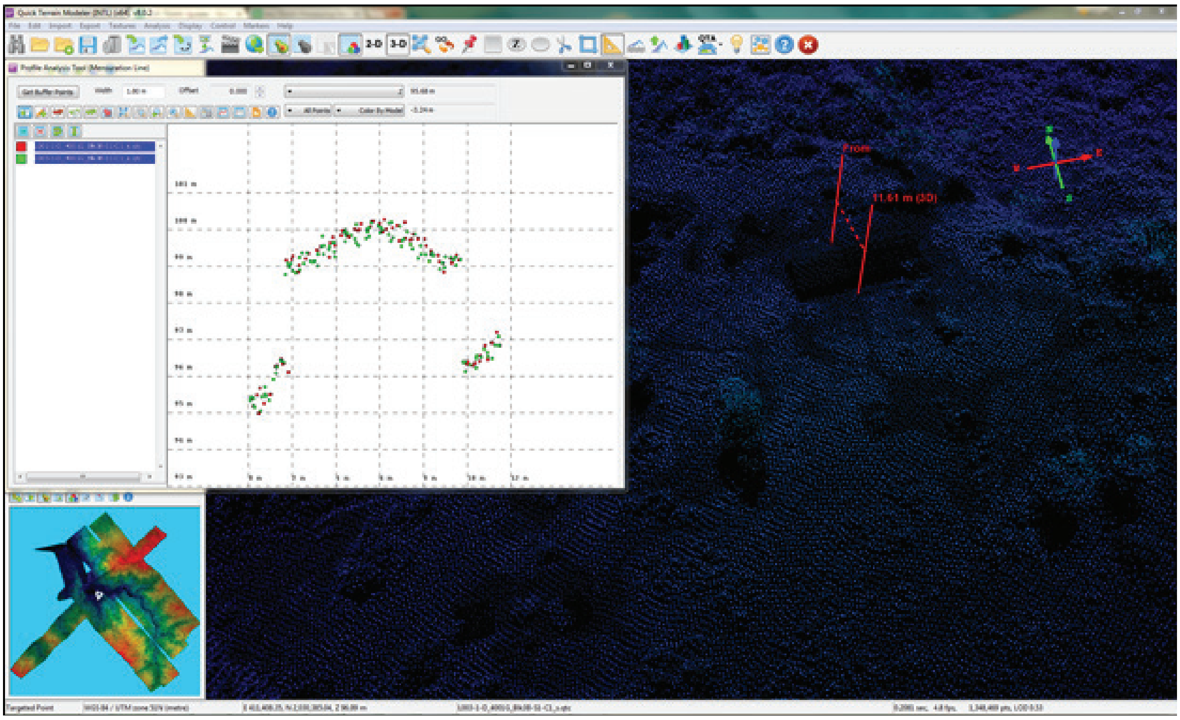

Figure 14. Quality checking for Casambalangan flight 4001G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Casambalangan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	142,535,546
Low Vegetation	144,411,072
Medium Vegetation	397,937,224
High Vegetation	740,606,078
Building	13,964,757

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Casambalangan floodplain is shown in Figure 15. A total of 436 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 801.02 meters and 22.03 meters respectively.

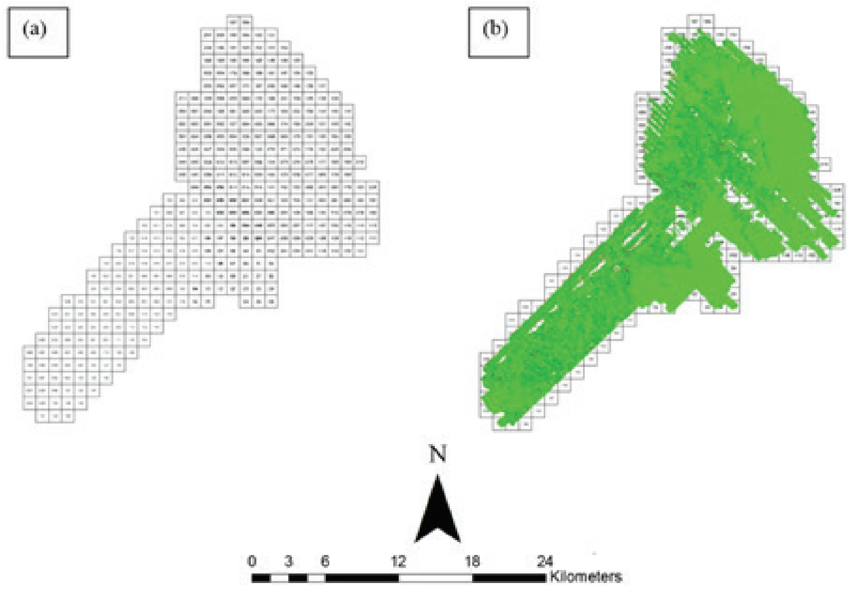

Figure 15. Tiles for Casambalangan Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 16. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

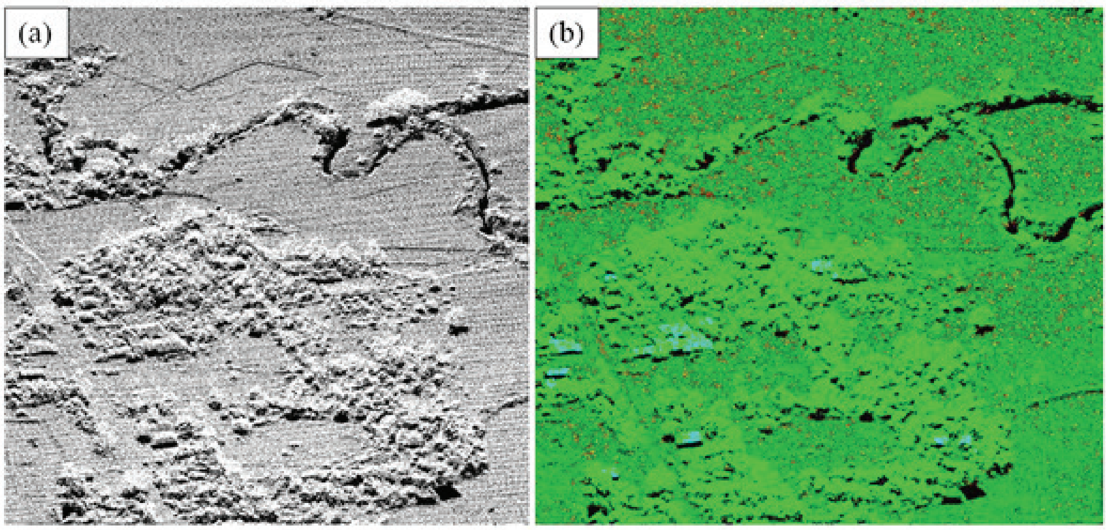

Figure 16. Point cloud before (a) and after (b) classification

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

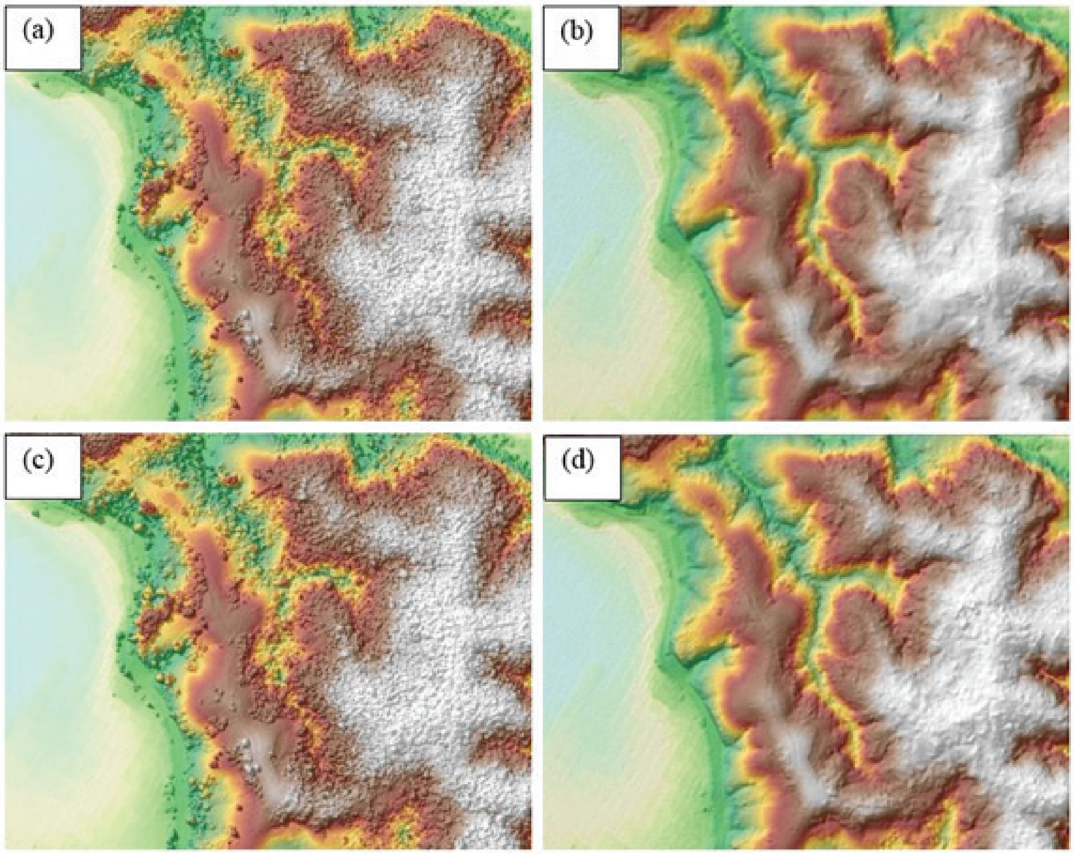

Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Casambalangan Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Casambalangan Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Casambalangan Floodplain. These blocks are composed of Cagayan reflights blocks with a total area of 296.79 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Cagayan_reflights_Blk3A	108.73
Cagayan_reflights _Blk3B	17.72
Cagayan_reflights_ Blk3B_supplement	15.98
Cagayan_reflights _Blk3C	154.36
TOTAL	296.79 sq.km

Portions of DTM before and after manual editing are shown in Figure 18. An interpolated ridge (Figure 18a) has been retrieved using object retrieval to achieve actual surface (Figure 18b). A river surface with filled data gaps, producing high elevation areas that formed triangles on the river surface (Figure 18c) was interpolated (Figure 18d) in order to correct the river system. Another example is a bridge (Figure 18e) has to be interpolated (Figure 18f) in order to correct the flow of water. Another example is a ridge (Figure 18g) has to be retrieved in order to get the actual surface (Figure 18h).

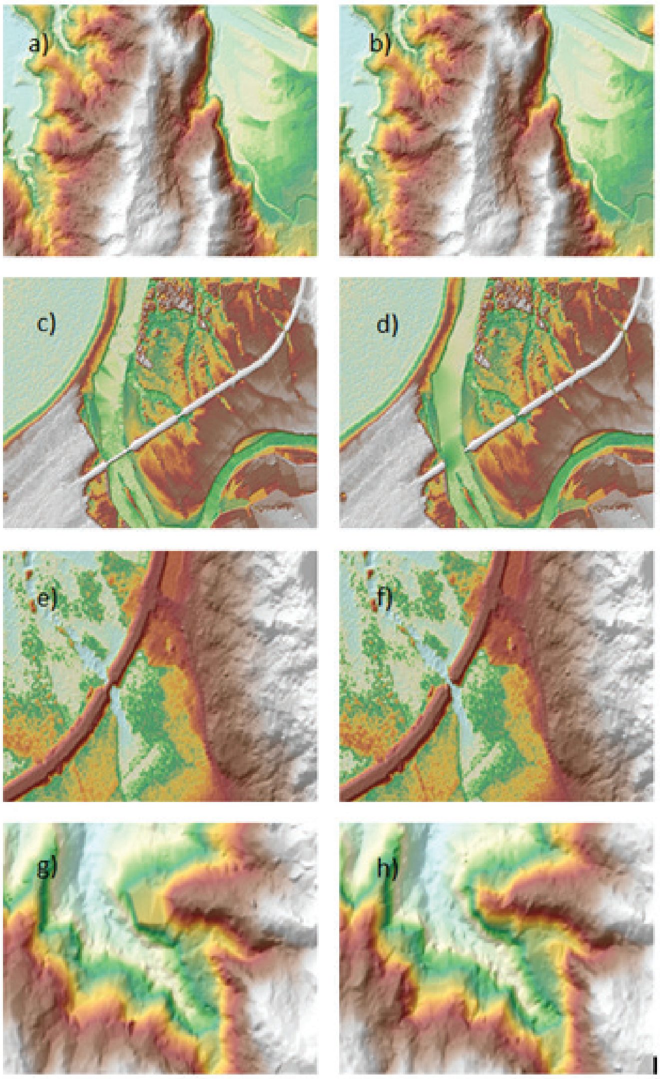

Figure 18. Portions in the DTM of Casambalangan floodplain – a ridge before (a) and after (b) retrieval; an interpolated river surface before (c) and after (d) manual editing; a bridge before (e) and after (f) interpolation; and a ridge before (g) and after (h) retrieval

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing Aunugay DEM which was calibrated using Cagayan DEM overlapping with the blocks to be mosaicked. Table 11 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Casambalangan floodplain is shown in Figure 19. It can be seen that the entire Casambalangan floodplain is 86.93% covered by LiDAR and 13.07% IFSAR data.

Table 11. Shift Values of each LiDAR Block of Casambalangan Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Cagayan_reflights_Blk3A	6.32	1.18	-4.72
Cagayan_reflights_Blk3B	5.89	1.91	-4.85
Cagayan_reflights_Blk3B_supplement	6.35	2.18	-4.89
Cagayan_reflights_Blk3C	5.99	2.06	-4.51

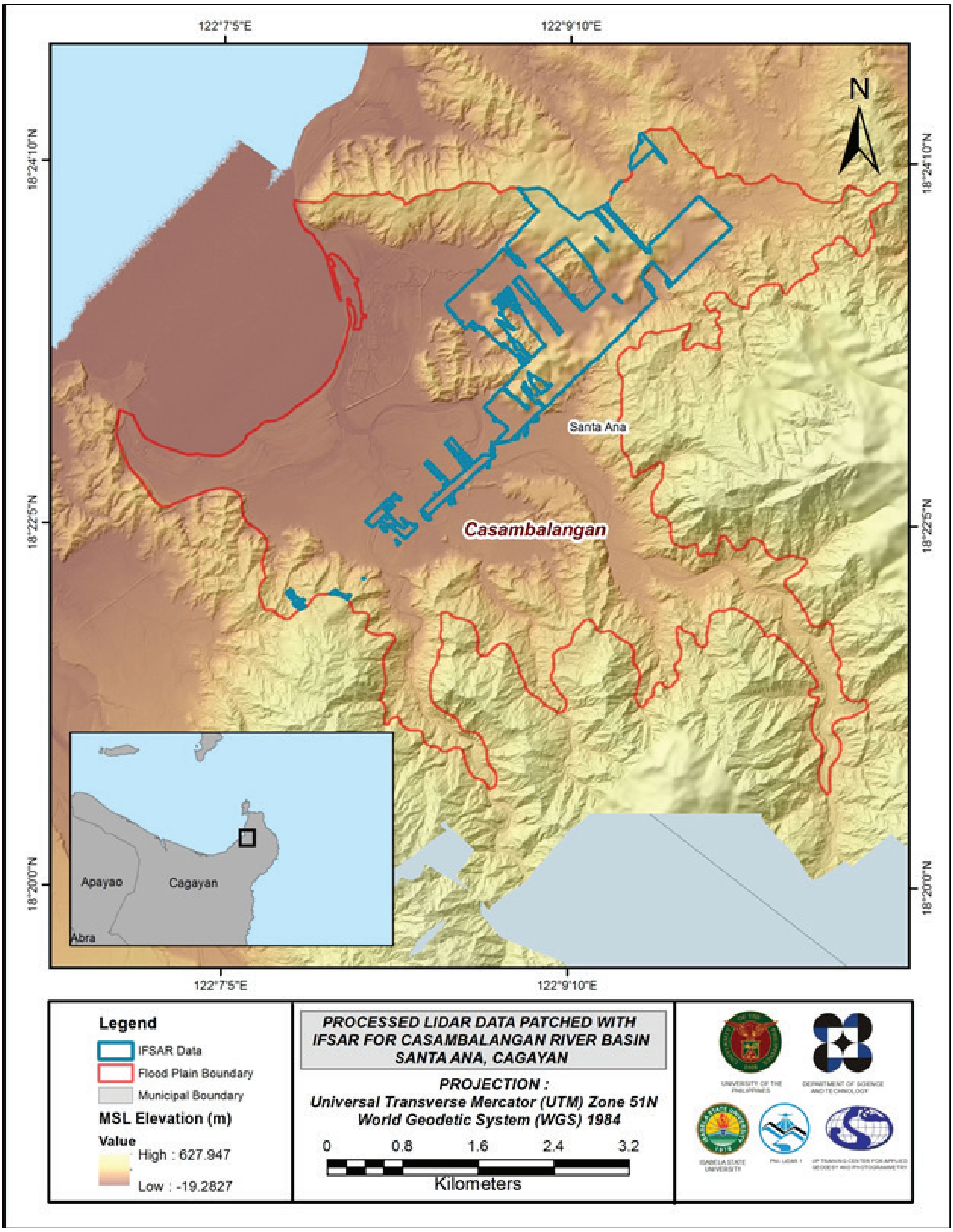

Figure 19. Map of Processed LiDAR Data for Casambalangan Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEMs

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Cagayan to collect points with which the LiDAR dataset was validated is shown in Figure 20. A total of 6,209 survey points were gathered for all the floodplains within Gonzaga and Santa Ana, Cagayan wherein the Casambalangan is located. However, the point dataset was not used for the calibration of the LiDAR data for Casambalangan because during the mosaicking process, each LiDAR block was referred to the calibrated Cagayan DEM. Therefore, the mosaicked DEM of Casambalangan can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Cagayan LiDAR DTM and ground survey elevation values is shown in Figure 21. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 4.07 meters with a standard deviation of 0.14 meters. Calibration of Cagayan LiDAR data was done by subtracting the height difference value, 4.07 meters, to Cagayan mosaicked LiDAR data. Table 12 shows the statistical values of the compared elevation values between Cagayan LiDAR data and calibration data. These values were also applicable to the Casambalangan DEM.

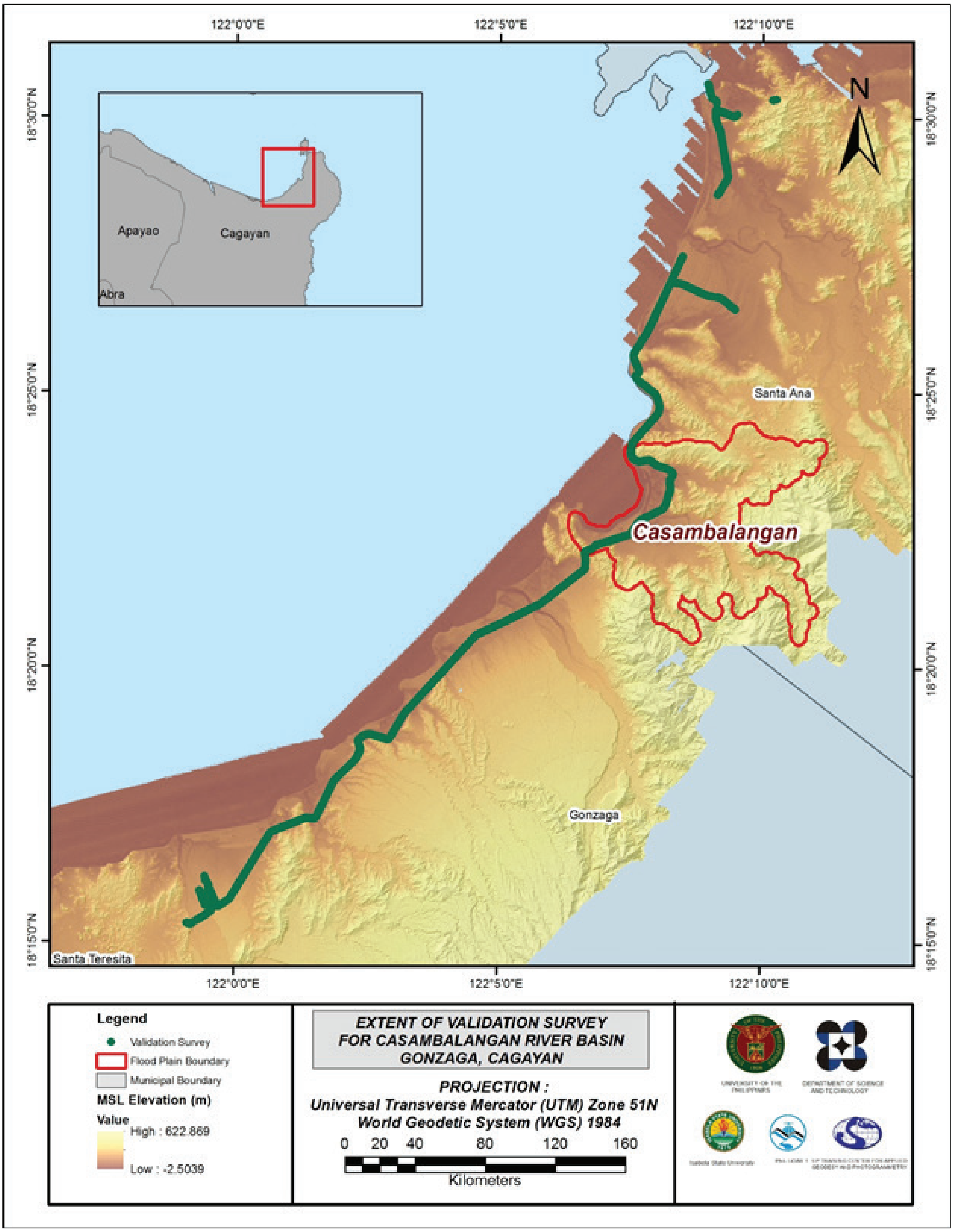

Figure 20. Map of Casambalangan Floodplain with validation survey points in green

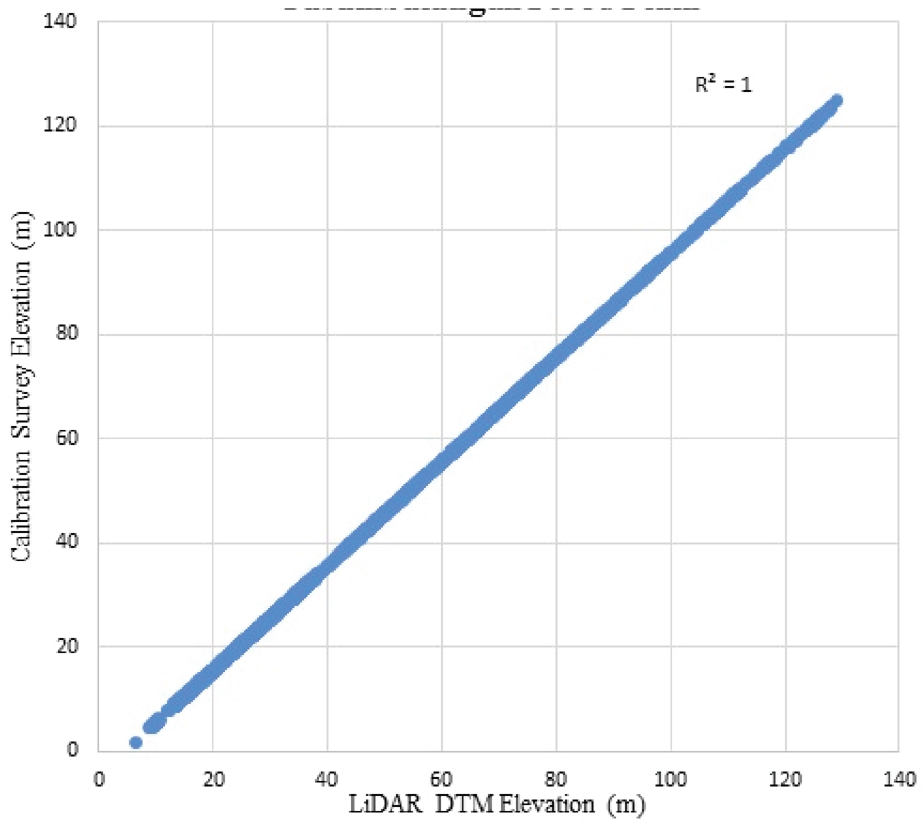

Figure 21. Correlation plot between calibration survey points and LiDAR data

Table 12. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.07
Standard Deviation	0.14
Average	-4.07
Minimum	-4.50
Maximum	-3.77

A total of 1,375 survey points lie within Casambalangan flood plain and were used for the validation of the calibrated Casambalangan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 22. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.06 meters, as shown in Table 13.

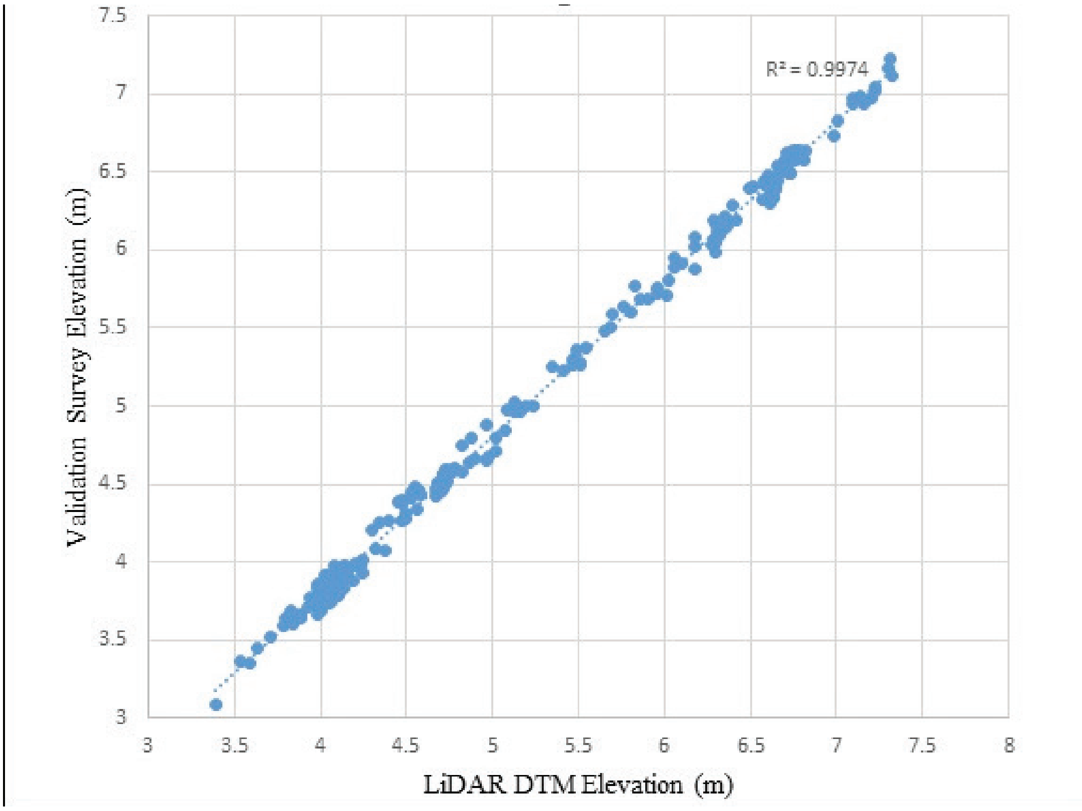

Figure 22. Correlation plot between validation survey points and LiDAR data

Table 13. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.06
Average	0.19
Minimum	0.06
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Casambalangan with 3732 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 0.25 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Casambalangan integrated with the processed LiDAR DEM is shown in Figure 23.

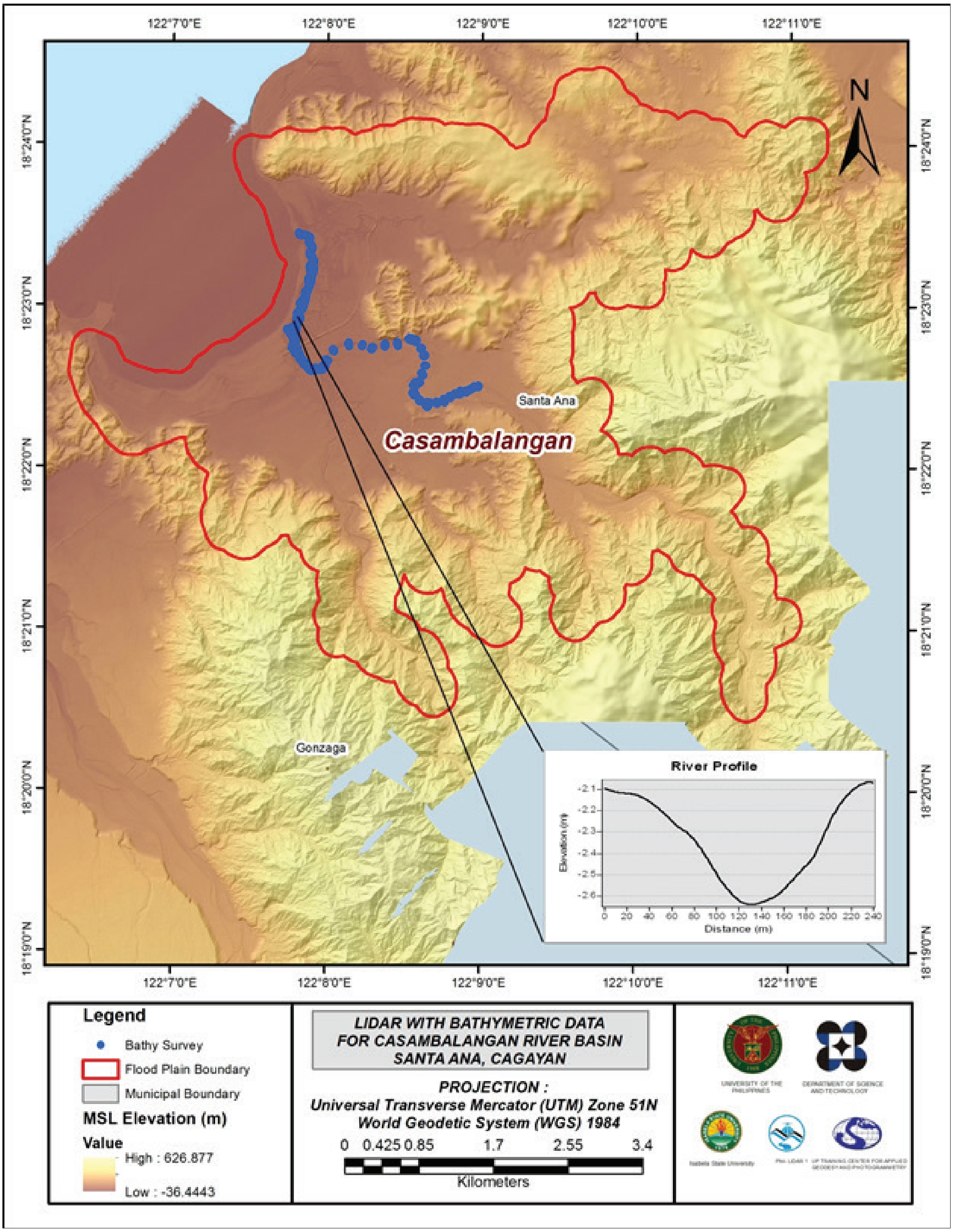

Figure 23. Map of Casambalangan Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

The Casambalangan Floodplain, including its 200 m buffer, has a total area of 33.04 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 343 building features, were considered for QC. Figure 24 shows the QC blocks for Casambalangan Floodplain.

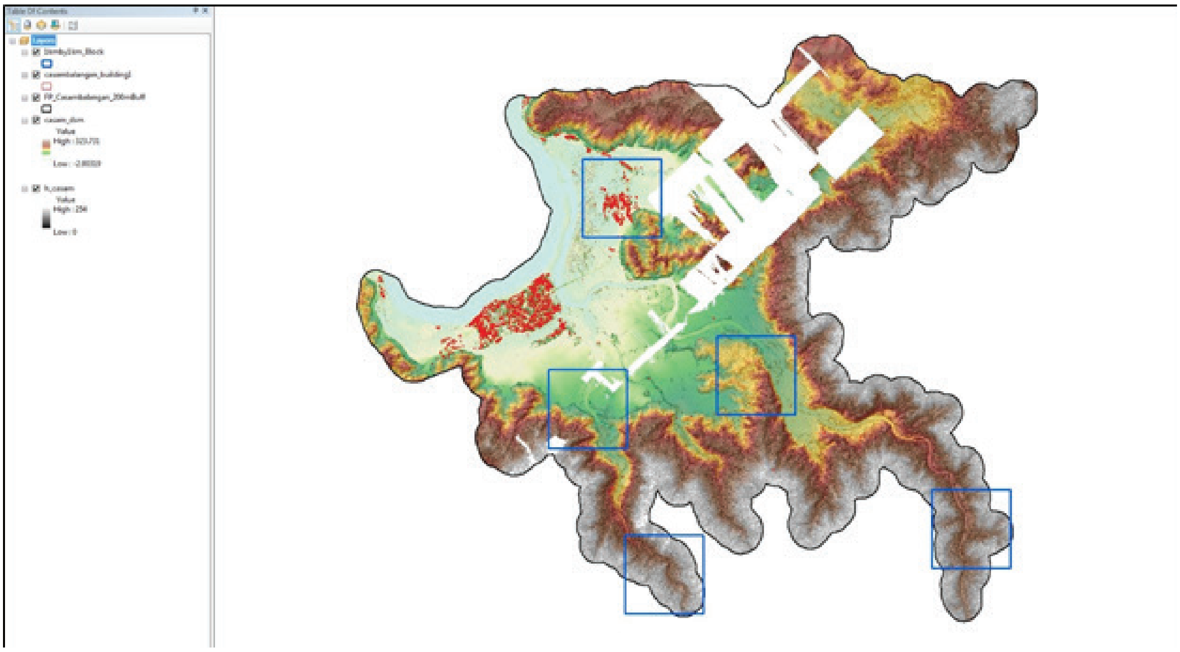

Figure 24. QC blocks for Casambalangan building features

Quality checking of Casambalangan building features resulted in the ratings shown in Table 14.

Table 14. Quality Checking Ratings for Casambalangan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Casambalangan	99.71	100.00	99.42	PASSED

3.12.2 Height Extraction

Height extraction was done for 1,691 building features in Casambalangan Floodplain. Of these building features, 108 were filtered out after height extraction, resulting to 1,592 buildings with height attributes. The lowest building height is at 2.01 m, while the highest building is at 10.51 m.

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table. Table 15 summarizes the number of building features per type. On the other hand, Table 16 shows the total length of each road type, while Table 17 shows the number of water features extracted per type.

Table 15. Building Features Extracted for Casambalangan Floodplain

Facility Type	No. of Features
Residential	1,534
School	34
Market	7
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	1
Barangay Hall	2
Military Institution	0
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	4
Power Plant/Substation	1
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0

Religious Institutions	7
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	0
Other Commercial Establishments	0
Total	1,592

Table 16. Total Length of Extracted Roads for Casambalangan Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Casambalangan	14.28	0.00	1.51	6.34	0.00	22.13

Table 17. Number of Extracted Water Bodies for Casambalangan Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Casambalangan	5	0	0	0	0	5

A total of 5 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 25 shows the Digital Surface Model (DSM) of Casambalangan Floodplain overlaid with its ground features.

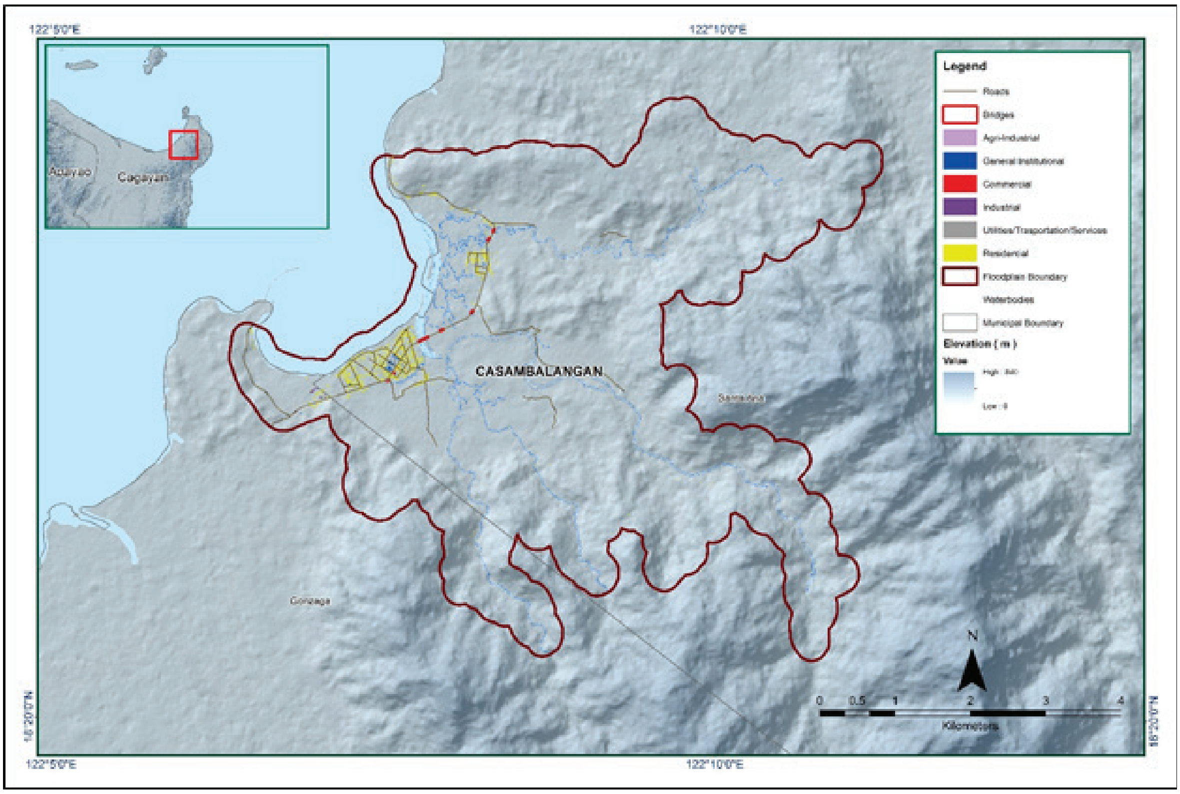

Figure 25. Extracted features for Casambalangan Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE CASAMBALANGAN RIVER BASIN

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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 Data Validation and Bathymetry Component conducted a field survey in Casambalanga River on October 11 – 21, 2016 and December 2, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Casambalangan Bridge in Brgy. Casambalangan, Santa Ana, Cagayan; validation points acquisition of about 41 km covering the municipalities of Santa Ana and Gonzaga, Cagayan; and bathymetric survey from its upstream in Brgy. Rapuli to the mouth of the river located in Brgy. Casambalangan, Santa Ana, with an approximate length of 4.356 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique.

4.2 Control Survey

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).

The GNSS network used for Casambalangan River Basin is composed of five (5) loops established on October 12, 2016 occupying the reference point PAT-2 from a previous PHIL-LiDAR survey on November 2014 for Himogaan River in Brgy. Pateng, Municipality of Gonzaga, Cagayan.

A control point, namely UP-BAU1, was also established along the approach of Baua Steel bridge in Brgy. Baua, Municipality of Gonzaga. NAMRIA established control points namely: CGY-101, in Brgy. Ipil, Municipality of Gonzaga; CGY-102, in Brgy. Casambalangan, Municipality of Sta. Ana; CG-234, in Brgy. Zinungan, Municipality of Sta. Ana; and CG-258, in Brgy. Tapel, Municipality of Gonzaga were also occupied to use as marker for the survey.

The summary of reference and control points and its location is summarized in Table while the GNSS network established is illustrated in Table 18

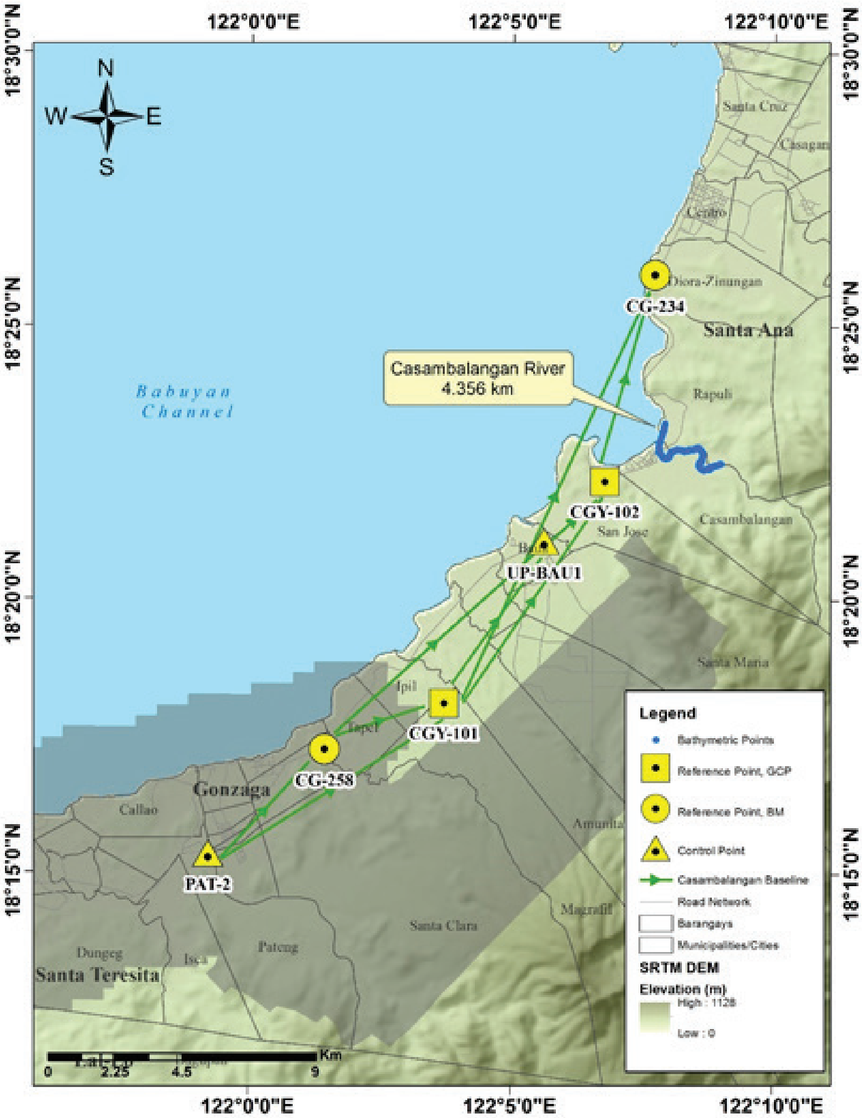


Figure 26. Casambalangan River Basin Control Survey Extent

Table 18. List of Reference and Control Points occupied for Casambalangan River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey on October 18, 2016						
PAT-2	fixed	18°15'20.41664"	121°59'13.60140"	59.538	21.505	10-12-2016
CGY-101	Used as marker	-	-		-	10-12-2016
CGY-102	Used as marker	-	-		-	10-13-2016
CG-234	Used as marker	-	-		-	10-13-2016
CG-258	Used as marker	-	-		-	10-12-2016
UP-BAU1	UP established	-	-		-	10-12-2016

The GNSS set-ups on recovered reference points and established control points in Casambalangan River are shown in Figure C-3 to Figure C-8.

Figure 27. GNSS receiver setup, Trimble® SPS 985, at PAT-2, located at the approach of Pateng Bridge in Brgy. Pateng, Municipality of Gonzaga, Cagayan

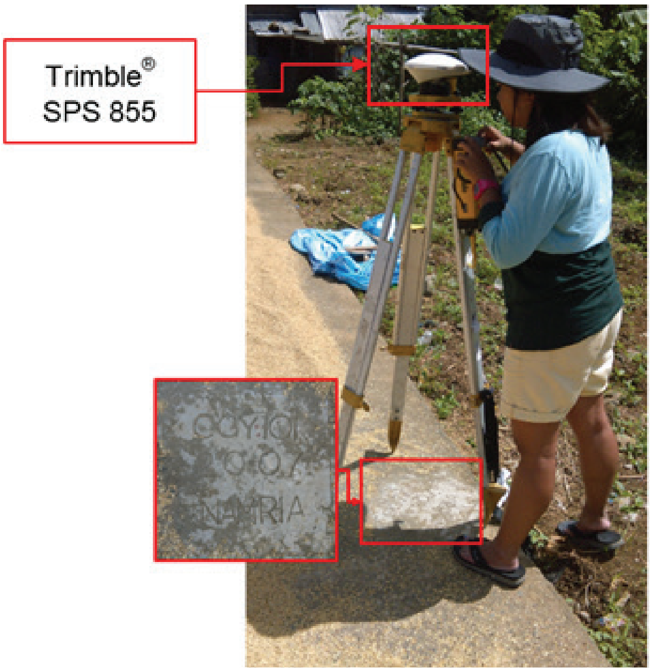


Figure 28. GNSS base set up, Trimble® SPS 855, at CGY-101, located inside a basketball court near San Francisco Elementary School, Brgy. Ipil, Municipality of Gonzaga, Cagayan

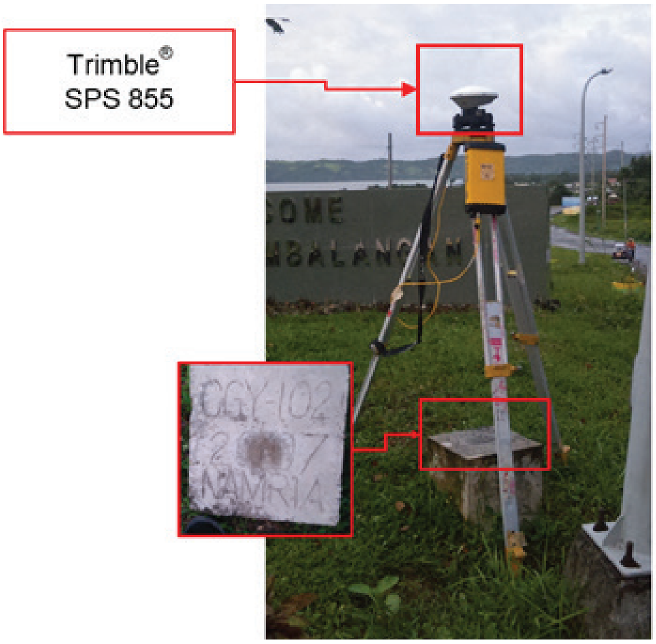


Figure 29. GNSS receiver setup, Trimble® SPS 855 at CGY-102, located inside a triangular island (near Port Irene) along Dug-San Vicente Rd, Brgy. Casambalangan, Municipality of Sta. Ana, Cagayan

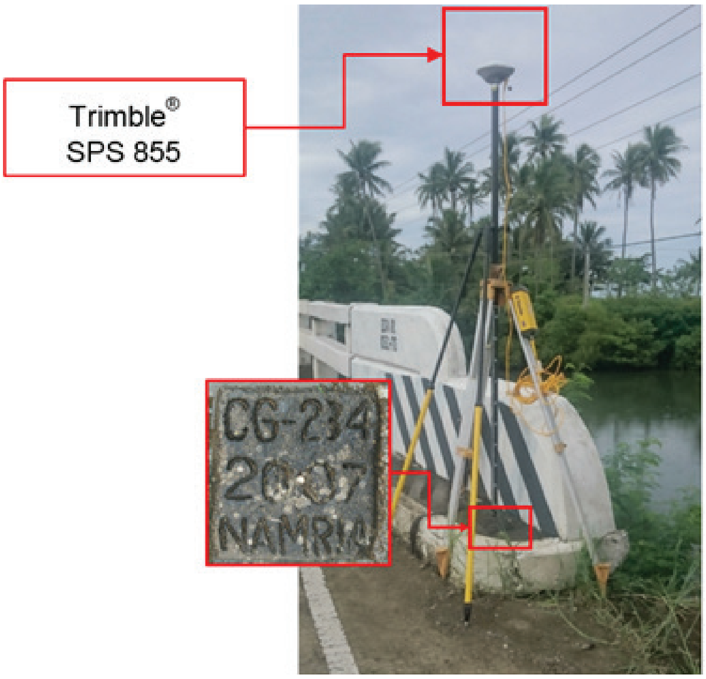


Figure 30. GNSS receiver setup, Trimble® SPS 885, at CG-234, located at the approach of Diora Bridge in Brgy. Zinungan, Municipality of Sta. Ana, Cagayan

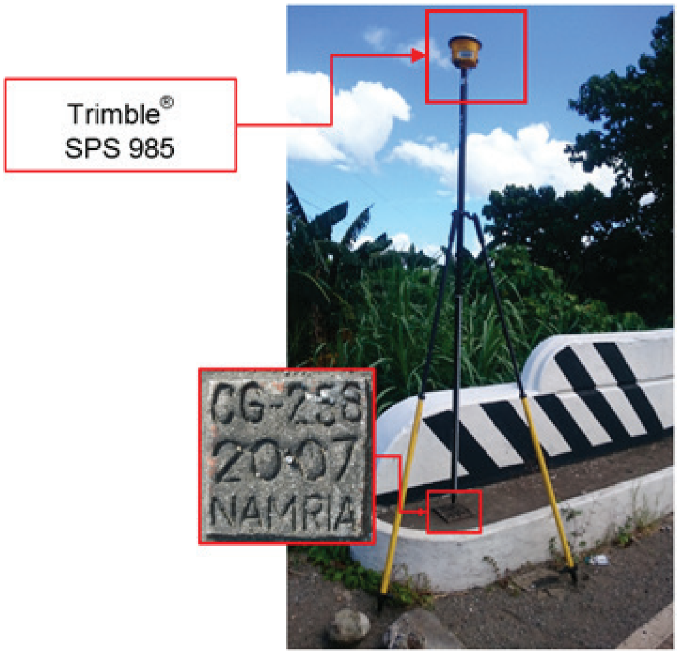


Figure 31. GNSS receiver setup, Trimble® SPS 985, at CG-258, located at the approach of a bridge near the welcome sign of Brgy. Tapel, Municipality of Gonzaga, Cagayan

Figure 32. GNSS receiver setup, Trimble® SPS 885, at UP-BAU1, located at the approach of Baua Steel bridge in Brgy. Baua, Municipality of Gonzaga, Cagayan

4.2.1 BASELINE PRO-

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

Table19. Baseline Processing Summary Report for Casambalangan River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist (Meter)	Height (Meter)
CGY-101 --- PAT-2	10-12-16	Fixed	0.004	0.036	57°12'53"	9404.155	23.252
UP-BAU1 --- CGY-101	10-12-16	Fixed	0.006	0.034	31°30'32"	6423.433	-36.919
UP-BAU1 --- CGY-101	10-12-16	Fixed	0.003	0.015	31°30'31"	6423.441	-36.889
UP-BAU1 --- CGY-101	10-12-16	Fixed	0.003	0.017	68°41'13"	4298.952	39.432
CG-258 --- PAT-2	10-12-16	Fixed	0.004	0.020	47°52'13"	5260.711	-16.180
UP-BAU1 --- CG-258	10-12-16	Fixed	0.004	0.028	226°18'00"	10185.210	-2.561
CG-234 --- UP-BAu1	10-13-16	Fixed	0.005	0.029	22°17'57"	9723.343	-5.507
CGY-102 --- CGY-101	10-13-16	Fixed	0.005	0.033	35°41'58"	9232.606	-29.695
CG-234 --- CGY-102	10-13-16	Fixed	0.003	0.017	13°22'55"	7169.699	-12.718
CGY-102 --- UP-BAU1	10-13-16	Fixed	0.003	0.021	45°08'22"	2865.049	7.194
UP-BAU1 --- CGY-101	10-13-16	Fixed	0.006	0.035	211°31'07"	6423.432	36.915
UP-BAU1 --- CGY101	10-13-16	Fixed	0.003	0.015	211°31'07"	6423.441	36.890

As shown in Table 19, a total of twelve (12) baselines were processed with coordinate and elevation values of PAT-2 fixed from Aunugay Survey. 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:

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 20 to 23 for complete details.

The six (6) control points, PAT-2, CGY-101, CGY-102, CG-234, CG-258, and UP-BAU1 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of PAT-2 were held fixed during the processing of the control points as presented in Table . Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 20. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PAT-2	Grid				Fixed
PAT-2	Global	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 21. All fixed control points have no values for grid and elevation errors.

Table 21. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PAT-2	392924.044	?	2018768.902	?	21.505	?	LLe
CGY-101	400856.162	0.009	2023815.895	0.007	45.099	0.081	
CG-258	396844.016	0.009	2022275.238	0.007	5.558	0.070	
UP-BAU1	404240.430	0.011	2029273.374	0.009	8.626	0.090	
CG-234	407973.653	0.011	2038248.421	0.009	3.769	0.051	
CGY-102	406280.704	0.007	2031283.618	0.005	15.970	0.043	

With the mentioned equation, $\sqrt{((x\_e)^2+(y\_e)^2)}<20\text{cm}$ for horizontal and $z\_e<10$ cm for the vertical; the computation for the accuracy are as follows:

PAT-2
horizontal accuracy = Fixed
vertical accuracy = Fixed

CGY-101
horizontal accuracy = $\sqrt{((0.7)^2 + (0.9)^2}$
= $\sqrt{(0.49 + 0.81)}$
= 1.14 < 20 cm
vertical accuracy = 8.1 < 10 cm

CGY-102
horizontal accuracy = $\sqrt{((0.5)^2 + (0.7)^2}$
= $\sqrt{(0.25 + 0.49)}$
= 0.86 < 20 cm
vertical accuracy = 4.3 < 10 cm

CG-234
horizontal accuracy = $\sqrt{((0.9)^2 + (1.1)^2}$
= $\sqrt{(0.81 + 1.21)}$
= 1.42 < 20 cm
vertical accuracy = 5.1 < 10 cm

CG-258
horizontal accuracy = $\sqrt{((0.7)^2 + (0.9)^2}$
= $\sqrt{(0.49 + 0.81)}$
= 1.14 < 20 cm
vertical accuracy = 7.0 < 10 cm

UP-BAU1
horizontal accuracy = $\sqrt{((0.9)^2 + (1.1)^2}$
= $\sqrt{(0.81 + 1.21)}$
= 1.42 < 20 cm
vertical accuracy = 9.0 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the two occupied control points are within the required precision.

Table 22. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
CG-258	N18°17'15.18320"	E122°01'26.44115"	43.357	0.070	
CGY-101	N18°18'05.99072"	E122°03'42.81396"	82.793	0.081	
PAT-2	N18°15'20.41664"	E121°59'13.60140"	59.538	?	LLe
UP-BAU1	N18°21'04.10030"	E122°05'37.15852"	45.903	0.090	
CG-234	N18°25'56.68760"	E122°07'42.88310"	40.384	0.051	
CGY-102	N18°22'09.82860"	E122°06'46.33709"	53.100	0.043	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 22. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table C-6.

Table 23. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
PAT-2	Fixed	18°15'20.41664"N	121°59'13.60140"E	59.538	2018768.902	392924.044	21.505
CGY-101	Used as marker	18°18'05.99072"N	122°03'42.81396"E	82.793	2023815.895	400856.162	45.099
CGY-102	Used as marker	18°22'09.82860"N	122°06'46.33709"E	53.100	2031283.618	406280.704	15.970
CG-234	Used as marker	18°25'56.68760"N	122°07'42.88310"E	40.384	2038248.421	407973.653	3.769
CG-258	Used as marker	18°17'15.18320"N	122°01'26.44115"E	43.357	2022275.238	396844.016	5.558
BAU1	UP established	18°21'04.10030"N	122°05'37.15852"E	45.903	2029273.374	404240.430	8.626

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

Cross-section and as-built surveys were conducted on October 17 and 19, 2016 at the downstream side of Casambalangan bridge in Brgy. Casambalangan, Municipality of Santa Ana as shown in Figure 32. A survey grade GNSS receiver Trimble® SPS 985 in PPK survey technique was utilized for this survey as shown in Figure 34.

Figure 33. Casambalangan Bridge facing upstream

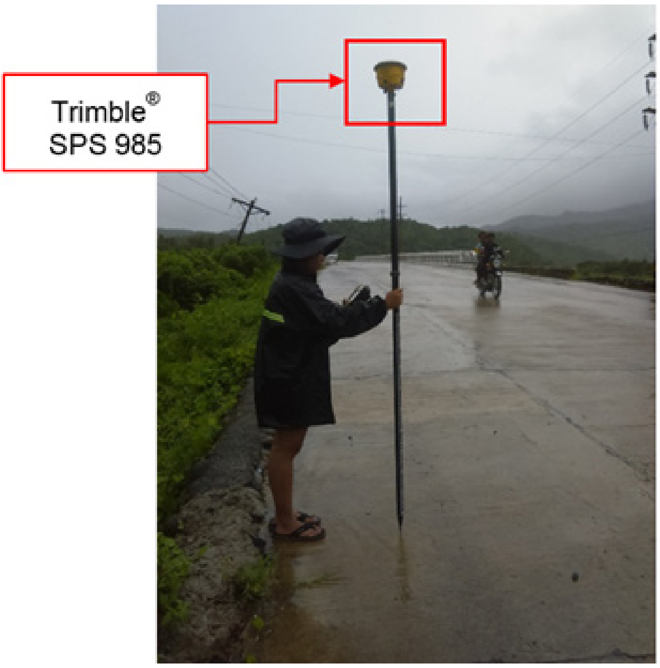


Figure 34. Casambalangan Bridge cross-section diagram

The cross-sectional line of Casambalangan Bridge is about 160 m with one hundred and ninety-five cross-sectional points using the control point CGY-102 as the GNSS base station The cross-section diagram, planimetric map, and the bridge data form are shown in Figure C-11 to Figure 35.

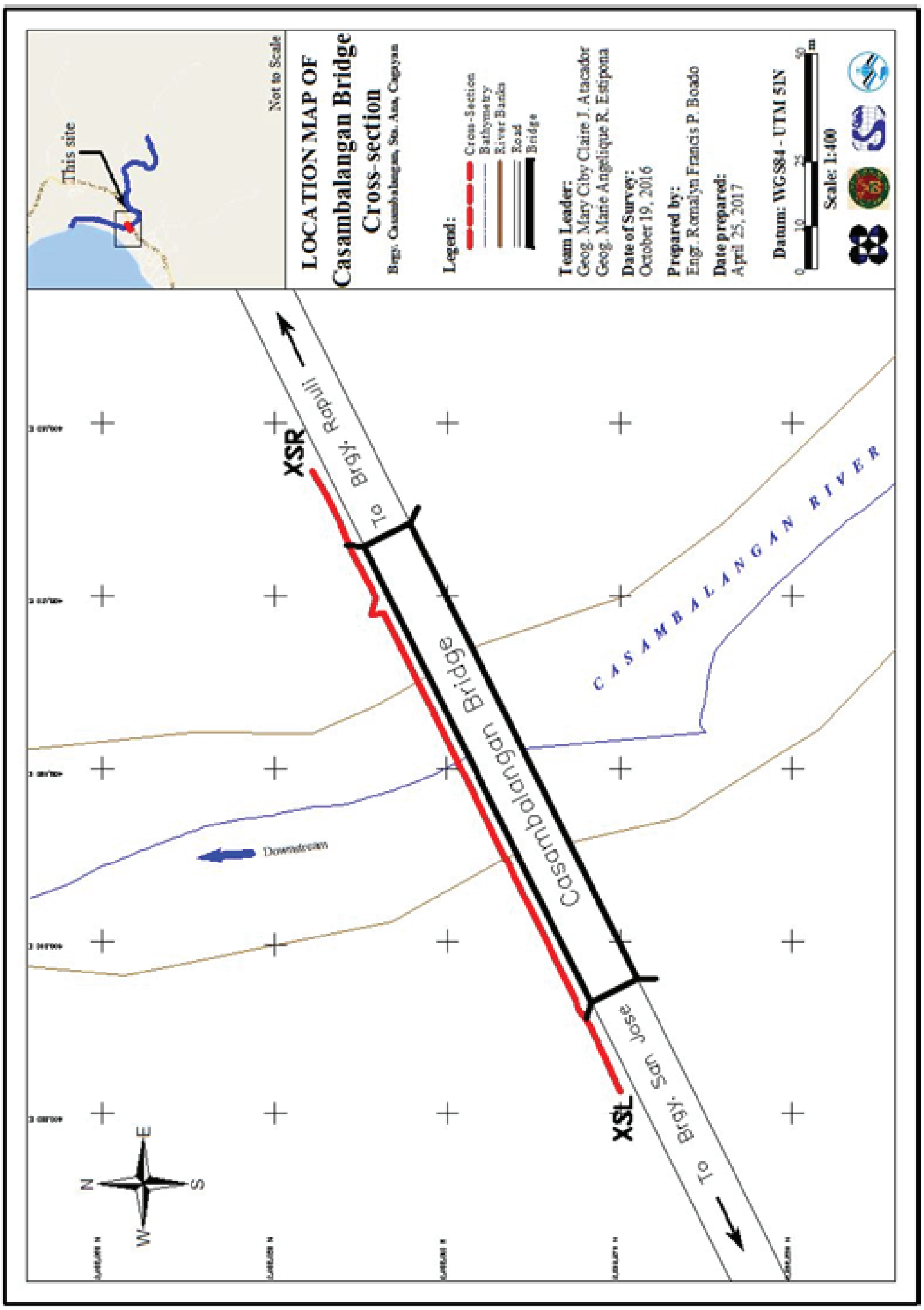


Figure 36. Location map of Casamblangan Bridge Cross Section survey

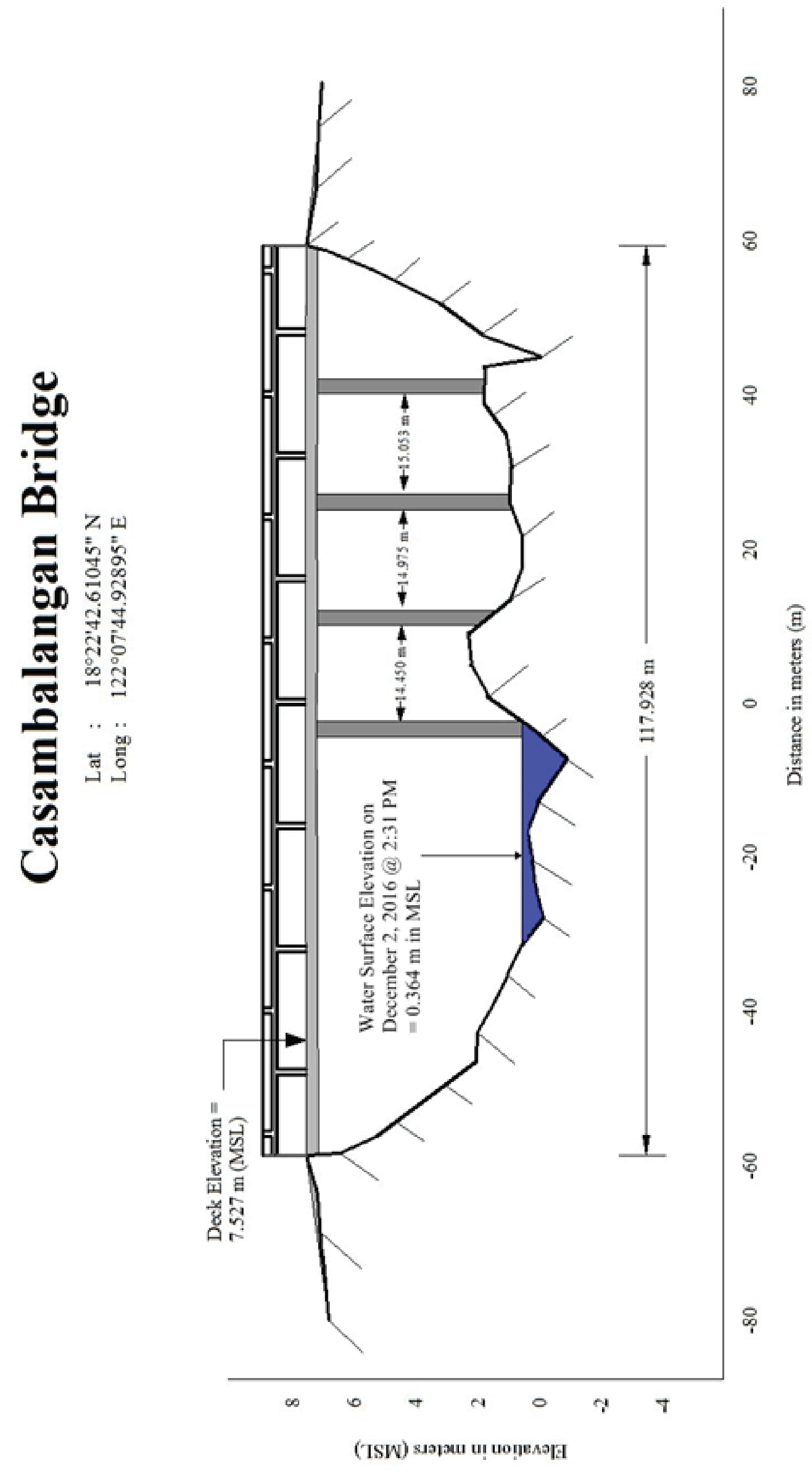


Figure 35. Casambalangan bridge cross-section plaimetric map

Bridge Data Form

Bridge Name: Casambalangan Bridge | **Date:** October 17 and 19, 2016

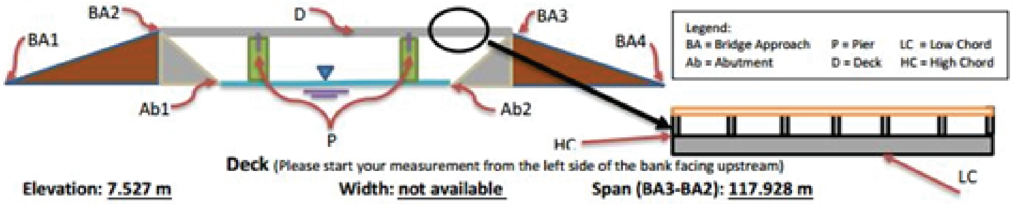
River Name: Casambalangan River | **Time:** 12:14 PM

Location (Brgy, City,Region): Brgy. Casambalangan, Santa Ana, Cagayan

Survey Team: Cibyl Atacador, Marie Angelique Estipona

Flow condition: average | **Weather Condition:** fair

Latitude: 18°22'42.61045"N | **Longitude:** 122°07'44.92895" E



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

Elevation: 7.527 m **Width:** not available **Span (BA3-BA2):** 117.928 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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	6.809 m	BA3	139.258 m	7.545 m
BA2	21.331 m	7.527 m	BA4	160.460 m	7.036 m

Abutment: Is the abutment sloping? ; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: round Number of Piers: 4 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	76.575 m	7.575 m	
Pier 2	91.026 m	7.555 m	
Pier 3	106.001 m	7.571 m	
Pier 4	121.054 m	7.557 m	

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

Figure 37. Bridge as-built form of Casambalangan Bridge

Water surface elevation of Casambalangan River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on December 2, 2016 at 2:31 PM at Casambalangan Bridge area with a value of 0.364 m in MSL as shown in Figure 35. This was translated into marking on the bridge's pier as shown in Figure 38. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Casambalangan River, the University of the Philippines Baguio.

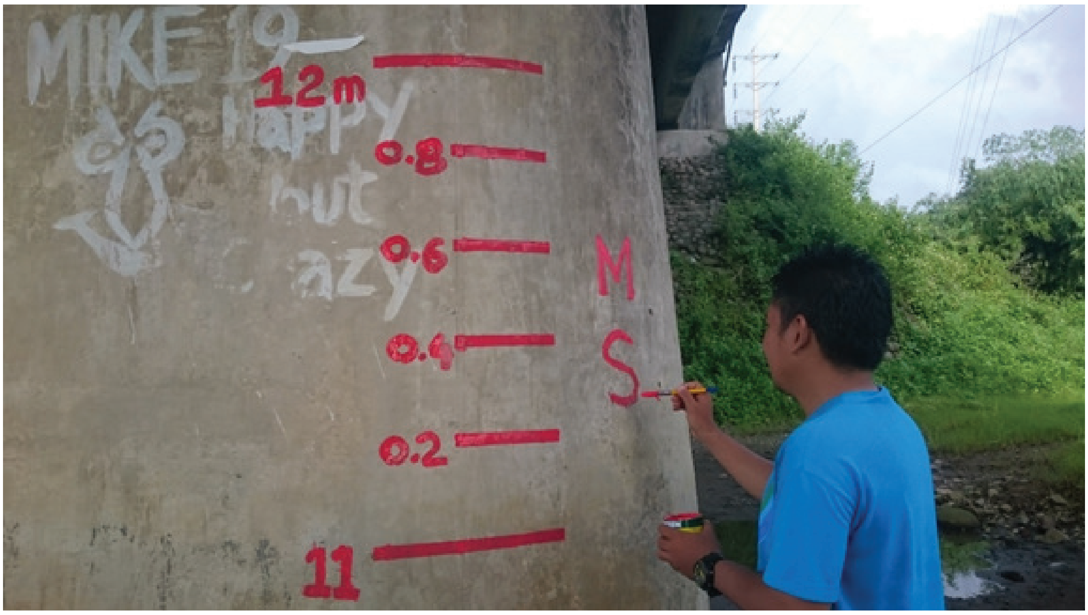


Figure 38. Water-level markings on Casambalangan Bridge

Validation Points Acquisition survey was conducted on October 13 and 16, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 985, mounted at the side of a vehicle as shown in Figure 38. Water-level markings on Casambalangan Bridge. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.15 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with PAT-2 occupied as the GNSS base station in the conduct of the survey.

4.3.4 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 13 and 16, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 985, mounted at the side of a vehicle as shown in Figure 39. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.15 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with PAT-2 occupied as the GNSS base station in the conduct of the survey.

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

The survey started in Brgy. San Vicente, Municipality of Santa Ana, Cagayan going south west along national high way covering thirteen (13) barangays in Municipality of Gonzaga, and eight (8) barangays of Santa Ana, and ended in Brgy. Pateng, Municipality of Gonzaga, Cagayan. The survey gathered a total of 7,706 points with approximate length of 42.761 km using PAT-2 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 40.

Figure 40. Validation point acquisition survey of Casambalangan River Basin

4.7 River Bathymetric Survey

Bathymetric Survey was executed on December 2, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 41. The survey started in Brgy. Casambalangan, Municipality of Santa Ana, Cagayan with coordinates 18°22'36.13371"N, 122°07'57.46966"E, and ended at the mouth of the river in Brgy. Rapuli, also in Municipality of Santa Ana, with coordinates 18°23'26.74808"N, 122°07'48.19089"E.

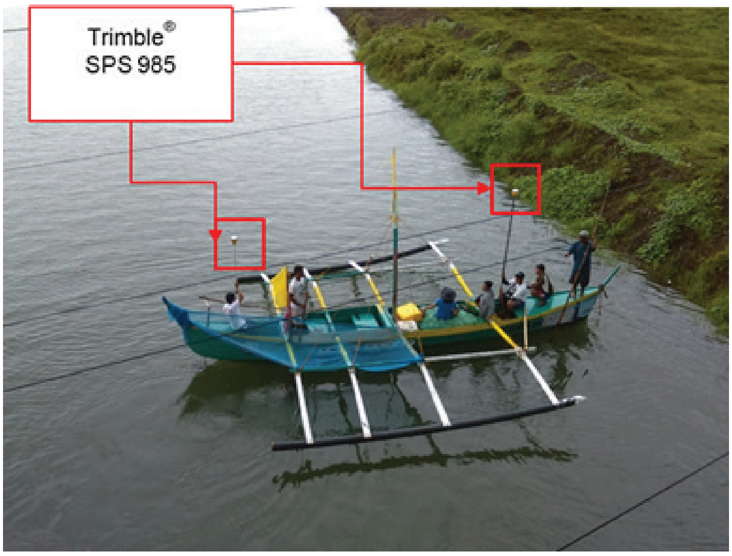


Figure 41. Bathymetric survey using a Trimble® SPS 985 in GNSS PPK survey technique in Casambalangan River

Manual Bathymetric survey on the other hand was executed on October 14 and 15, 2016 using Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 41. The survey started in Brgy. Rapuli, Municipality of Santa Ana with coordinates 18°22’30.11789”N, 122°08’58.96488”E, traversing down the river and ended at the starting point of bathymetric survey using boat in Brgy. Casambalangan, Municipality of Santa Ana. The control point CGY-102 was used as GNSS base station all throughout the entire survey.

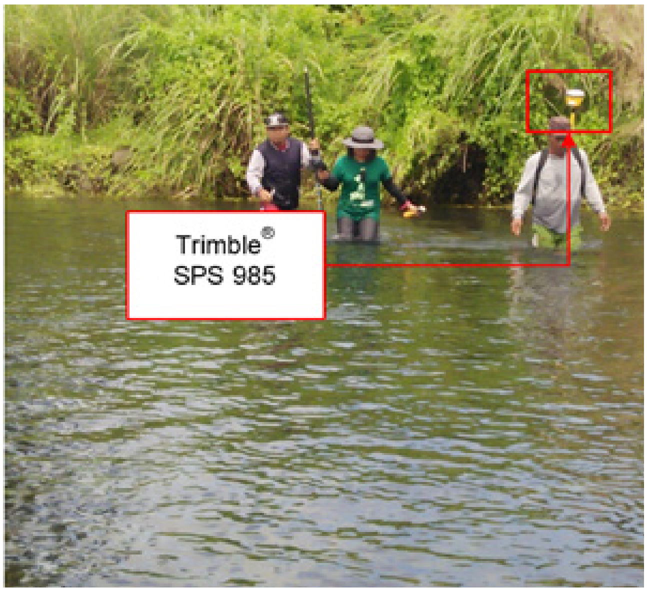


Figure 42. Manual bathymetric survey using a Trimble® SPS 985 in GNSS PPK survey technique in Casambalangan River

The bathymetric survey for Casambalangan River gathered a total of 11,358 points covering 4.356 km of the river traversing Barangays Rapuli and Casambalangan, in Municipality of Sta. Ana. A CAD drawing was also produced to illustrate the riverbed profile of Binalbagan River. As shown in Figure 44 and, the highest and lowest elevation has a 17-m difference. The highest elevation observed was 8.119 m above MSL located in Brgy. Rapuli, Municipality of Santa Ana; while the lowest was -4.236 m below MSL located in Brgy. Casambalangan, also in Municipality of Santa Ana.

Figure 43. Bathymetric survey of Casambalangan River

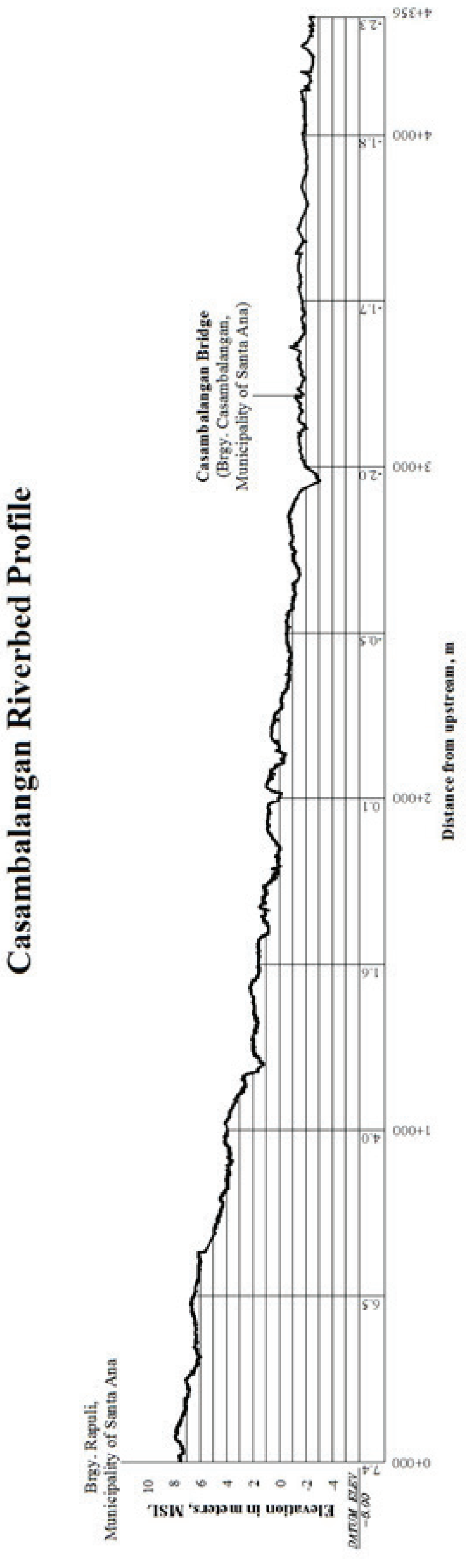


Figure 44. Casambalangan Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Cagayan, including the Casambalangan River Basin, often experiences heavy and long term rain such as Monsoon Rain during the months of January to February. The hydrologic data collection covered the period of 01 February 2017. Hydrologic data include the river velocity, water depth and rain collected from data logging sensors (mechanical velocity meter, depth gauge and rain gauges) in specific time period.

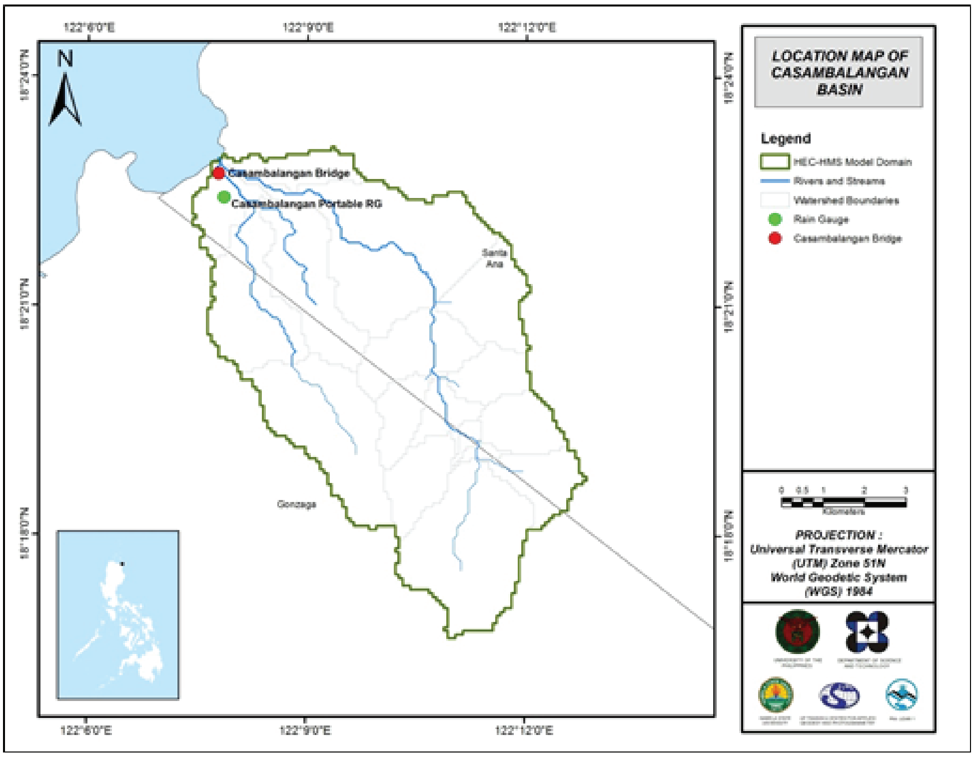


Figure 45. The location map of Casambalangan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

Monsoon rain that occurred on 01 February 2017 contributed to a 2.88 meter water level rise with peak discharge of 21.3 m3/s recorded at 9:00 AM on 01 February 2017 with accumulated rainfall 52.8 mm. These hydrologic data is the actual event of Casambalangan River and inputted to hydrologic modeling. Hydrologic measurements were taken from Casambalangan Bridge, Sta. Ana, Cagayan.

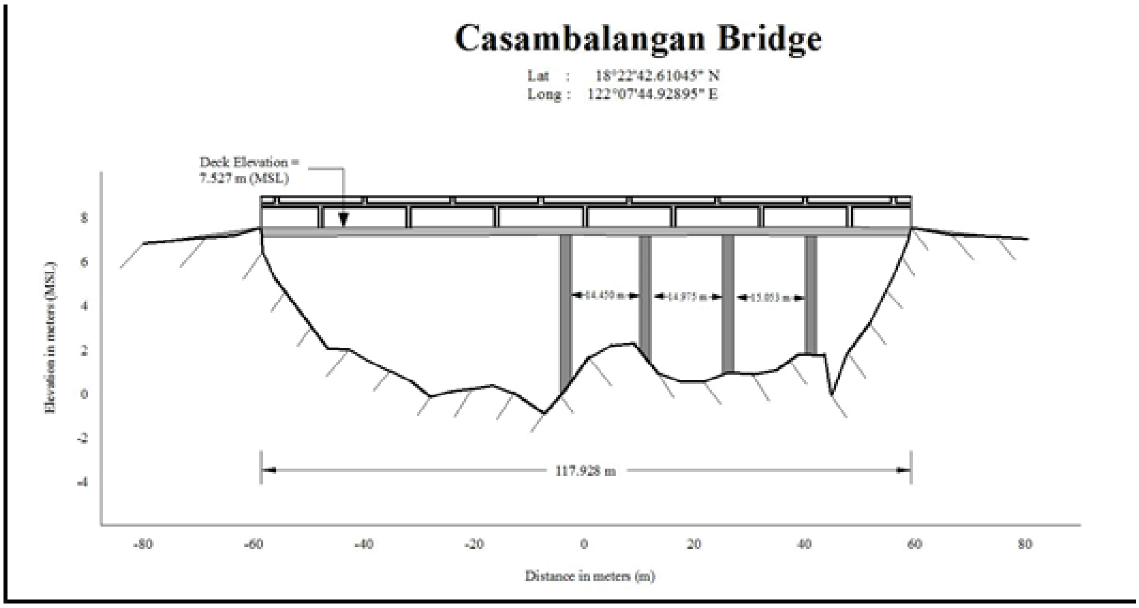


Figure 46. Cross-Section Plot of Casambalangan Bridge

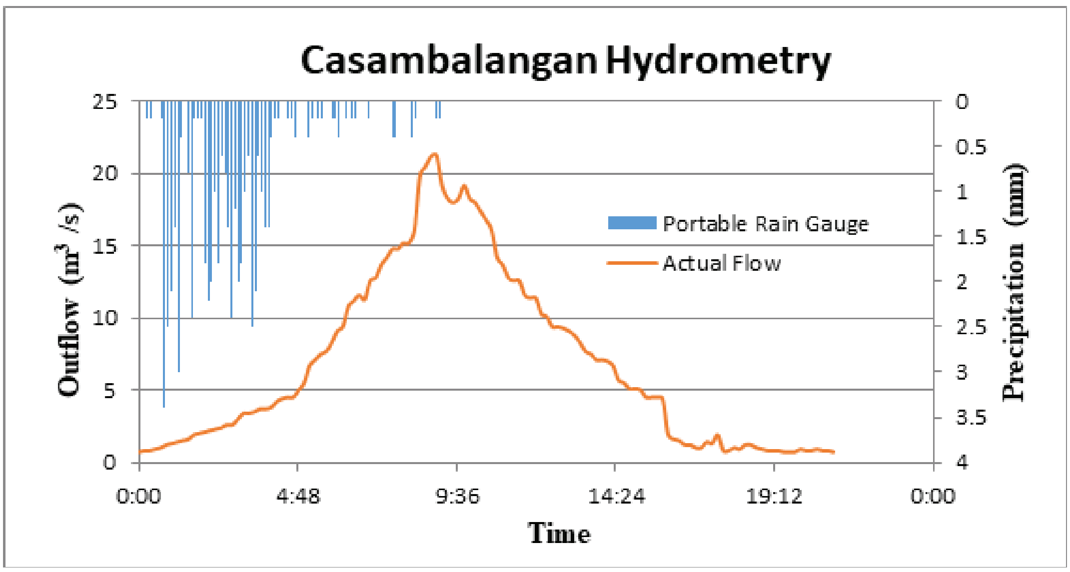


Figure 47. Rainfall and outflow data used for modeling

5.1.3 Rating Curves and River Outflow

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

$$Q=anh$$

where, Q : Discharge (m3/s),

h : Gauge height (reading from Casambalangan Bridge depth gauge sensor), and

a and n : Constants.

The Casambalangan River Rating Curve measured at Casambalangan Bridge is expressed as Q = 0.5765e1.2524x (Figure 48).

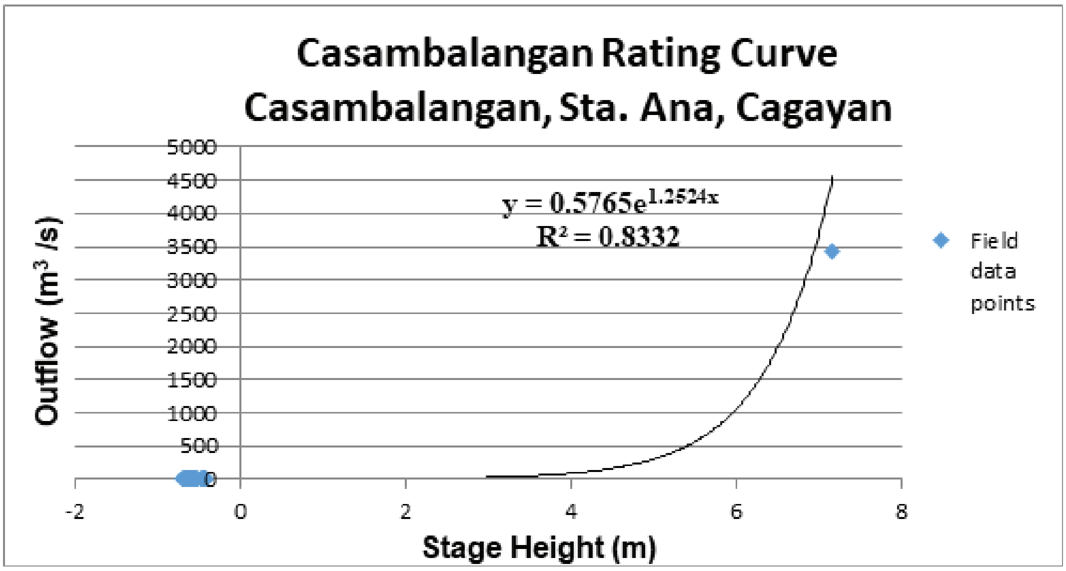


Figure 48. HQ Curve of HEC-HMS model

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Aparri Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station is chosen based on its proximity to the Casambalangan watershed. The extreme values for this watershed were computed based on a 47-year record.

Table 24. RIDF values for Aparri Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	20.1	31.4	39.4	53.3	75.6	92.2	119.4	147.7	167.9
5	28.5	44.9	55.8	78.7	110.4	137	173.6	221.2	252.5
10	34.1	53.8	66.6	95.6	133.4	166.6	209.5	269.9	308.5
15	37.2	58.8	72.7	105.1	146.5	183.4	229.7	297.4	340.2
20	39.4	62.3	77	111.8	155.6	195.1	243.9	316.6	362.3
25	41.1	65	80.3	116.9	162.6	204.1	254.8	331.4	379.3
50	46.3	73.4	90.5	132.7	184.2	231.9	288.4	377.1	431.9
100	51.4	81.7	100.6	148.4	205.6	259.5	321.7	422.4	484

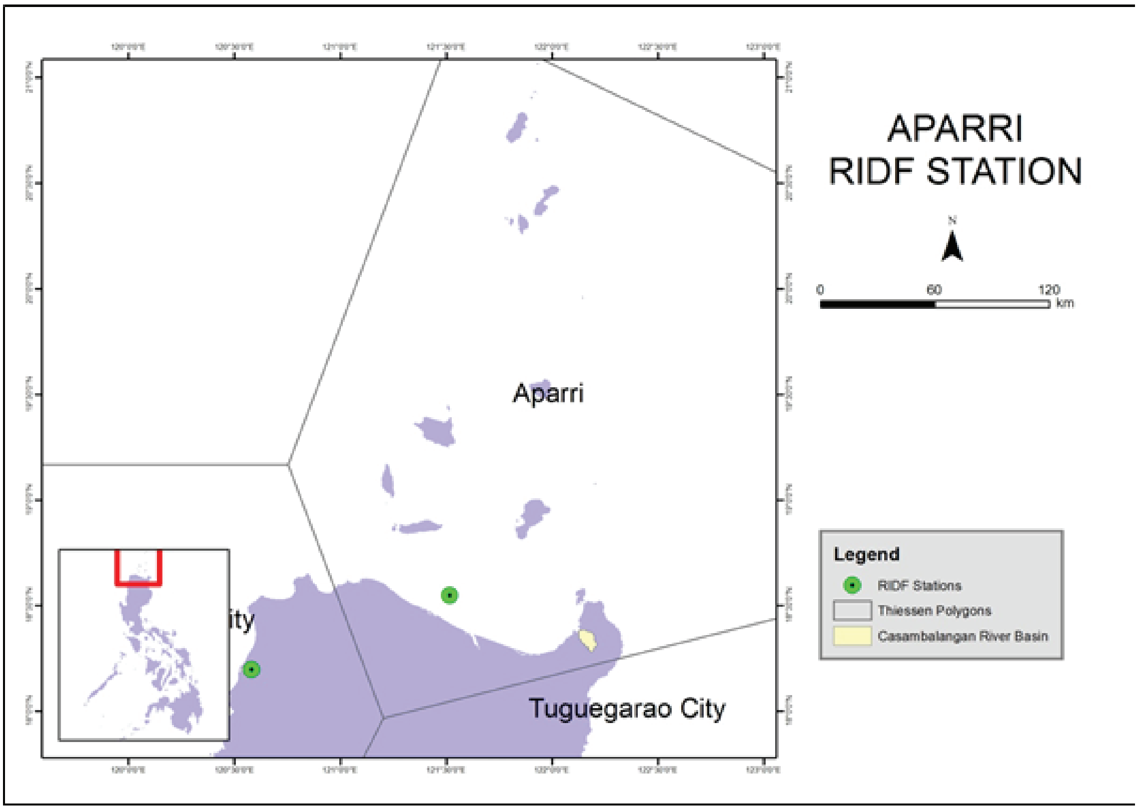


Figure 49. Location of Aparri RIDF Station relative to Casambalangan River Basin

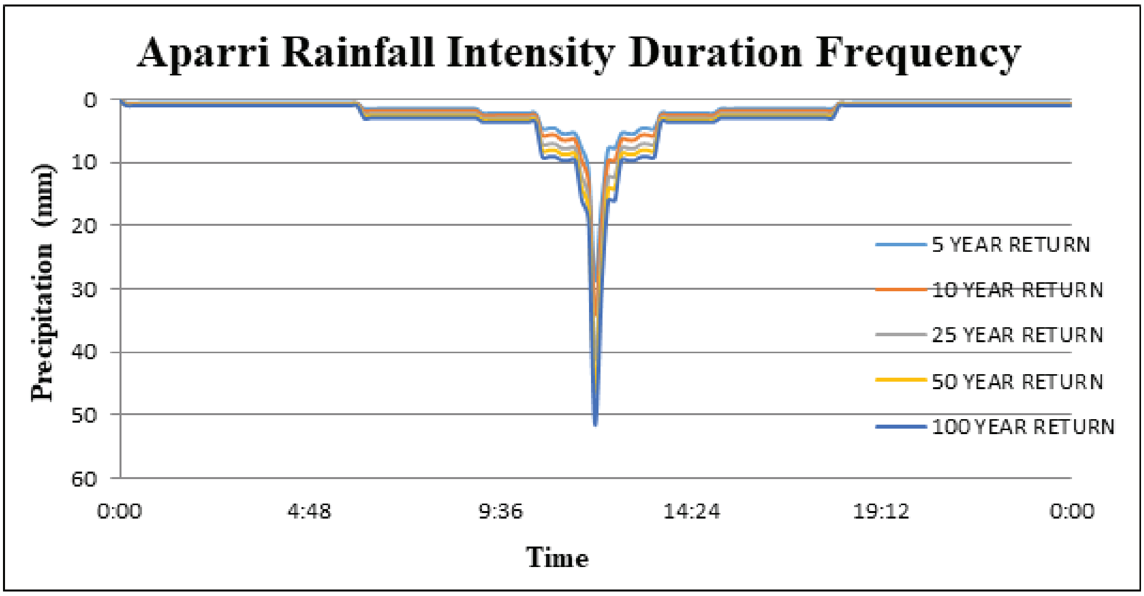


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

A drainage system includes the basin boundary, subbasin and the stream networks of the basin. Using ArcMap 10.2 with HEC-GeoHMS version 10.2 extension, the Casambalangan River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the Casambalangan river basin. The river centerline was digitized starting from upstream towards downstream in Google Earth (2014). Default threshold area used is 140 hectares.

Using the SAR-based DEM, the Casambalangan basin was delineated and further subdivided into subbasins. The Casambalangan basin model consists of 20 subbasins, 10 reaches, and 9 junctions. The main outlet is at Outlet 1. This basin model is illustrated in Figure 56. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 1 February 2017 (Monsoon Rain) was taken from the portable rain gauge installed. Finally, it was calibrated using data from the Casambalangan depth gauge sensor.

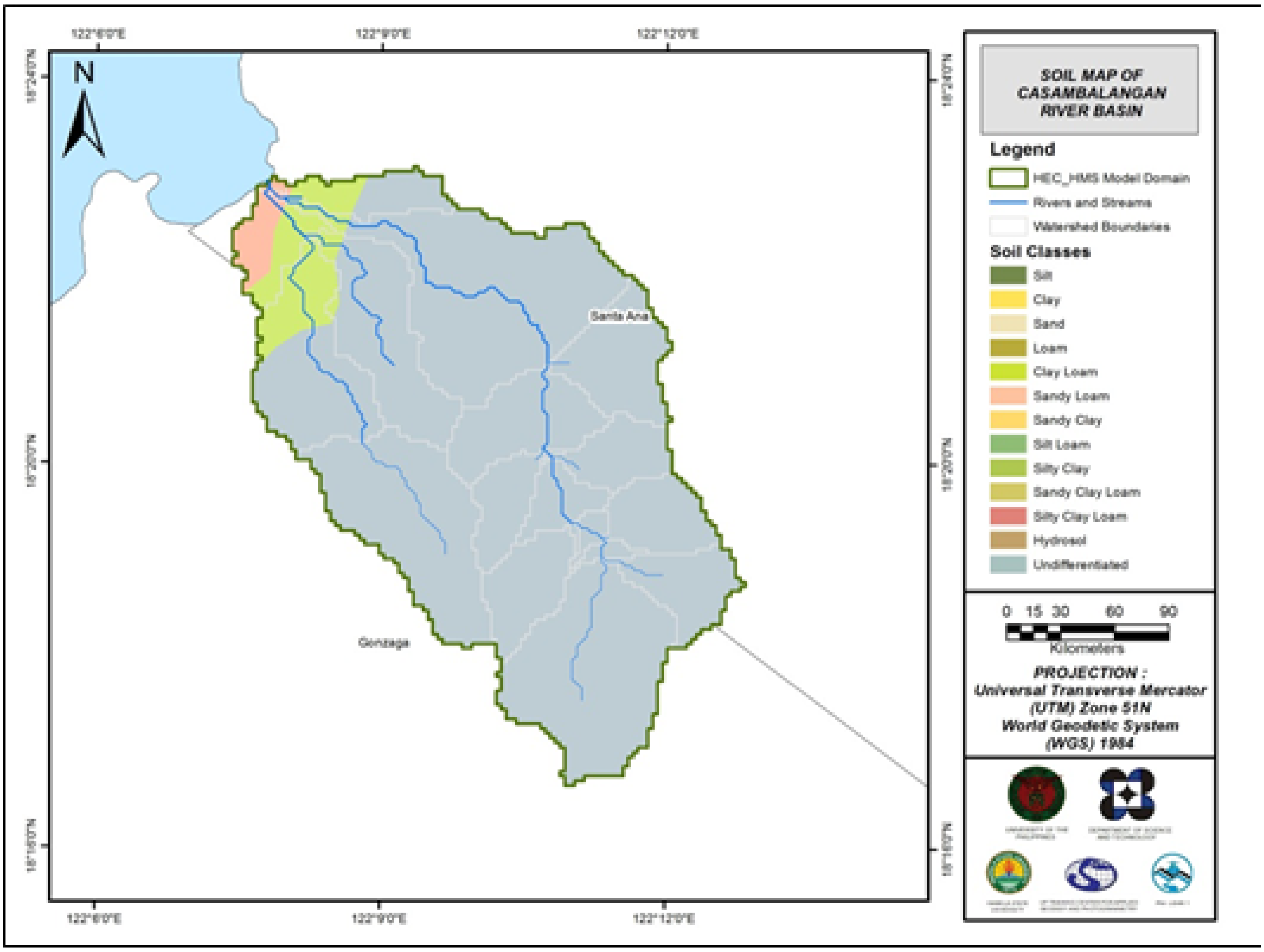


Figure 51. The soil map of the Casambalangan River Basin

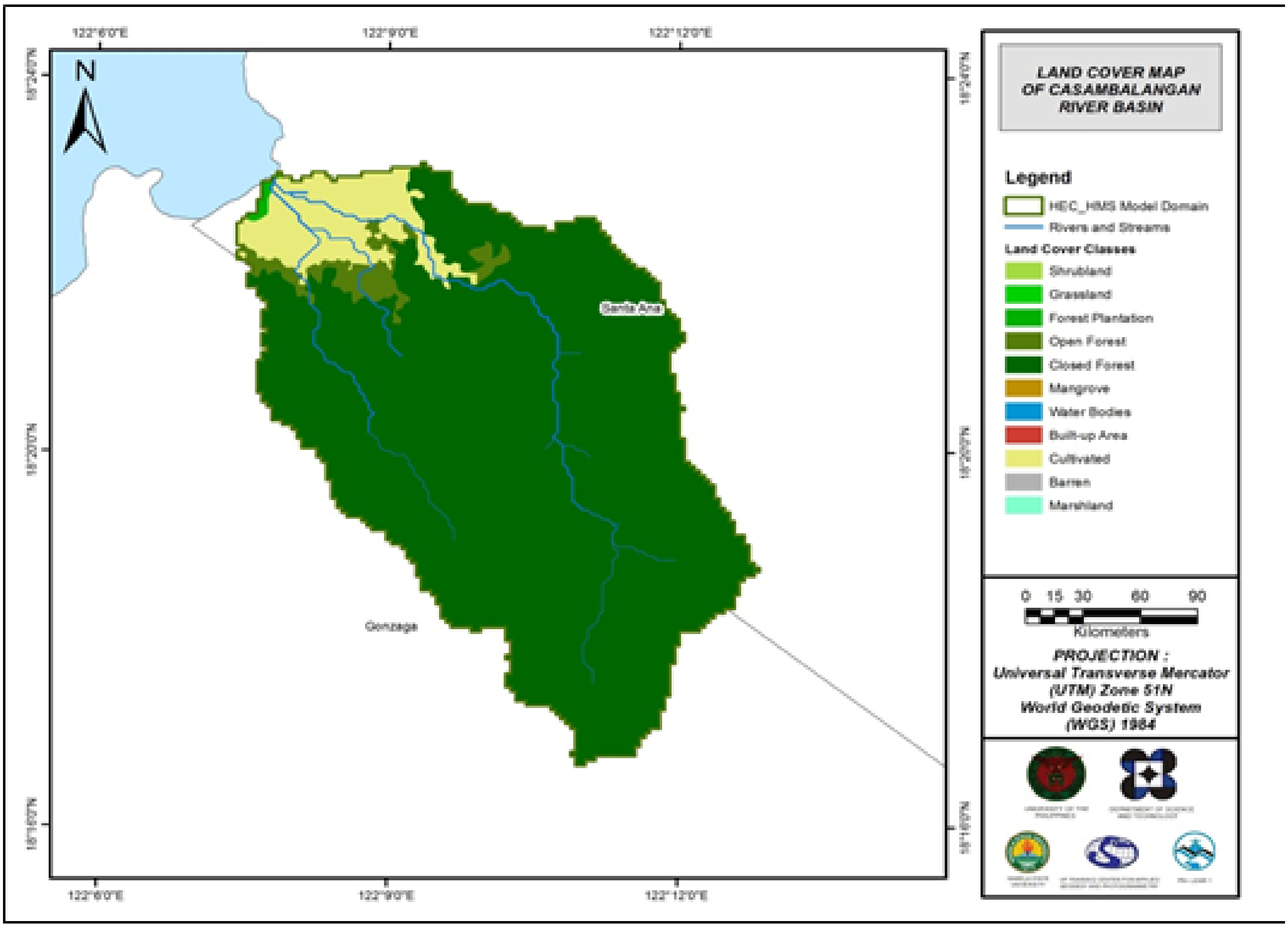


Figure 52. The land cover map of the Casambalangan River Basin

For Casambalangan, three soil classes were identified. These are clay loam, sandy loam, and undifferentiated soil. Moreover, four land cover classes were identified. These are open forest, closed forest, grassland, and cultivated land.

A drainage system includes the basin boundary, subbasin and the stream networks of the basin. Using ArcMap 10.2 with HEC-GeoHMS version 10.2 extension, the Casambalangan River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the Casambalangan river basin. The river centerline was digitized starting from upstream towards downstream in Google Earth (2014). Default threshold area used is 140 hectares.
Using the SAR-based DEM, the Casambalangan basin was delineated and further subdivided into subbasins. The Casambalangan basin model consists of 20 subbasins, 10 reaches, and 9 junctions. The main outlet is at Outlet 1. This basin model is illustrated in Figure 12. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 1 February 2017 (Monsoon Rain) was taken from the portable rain gauge installed. Finally, it was calibrated using data from the Casambalangan depth gauge sensor.

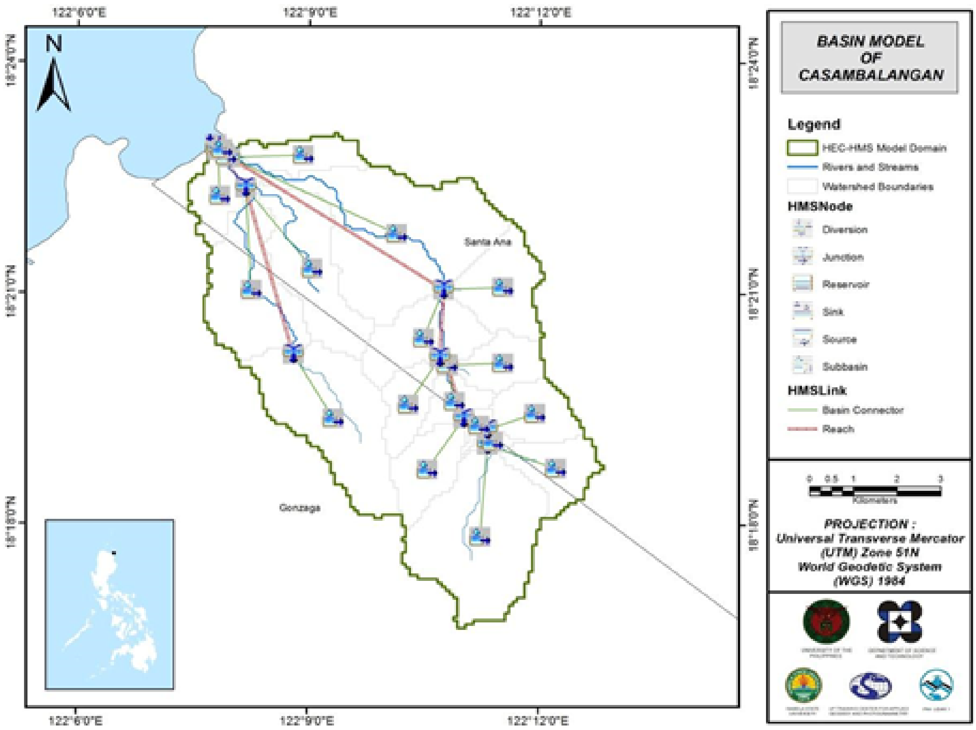


Figure 53. HEC-HMS generated Casambalangan River Basin Model.

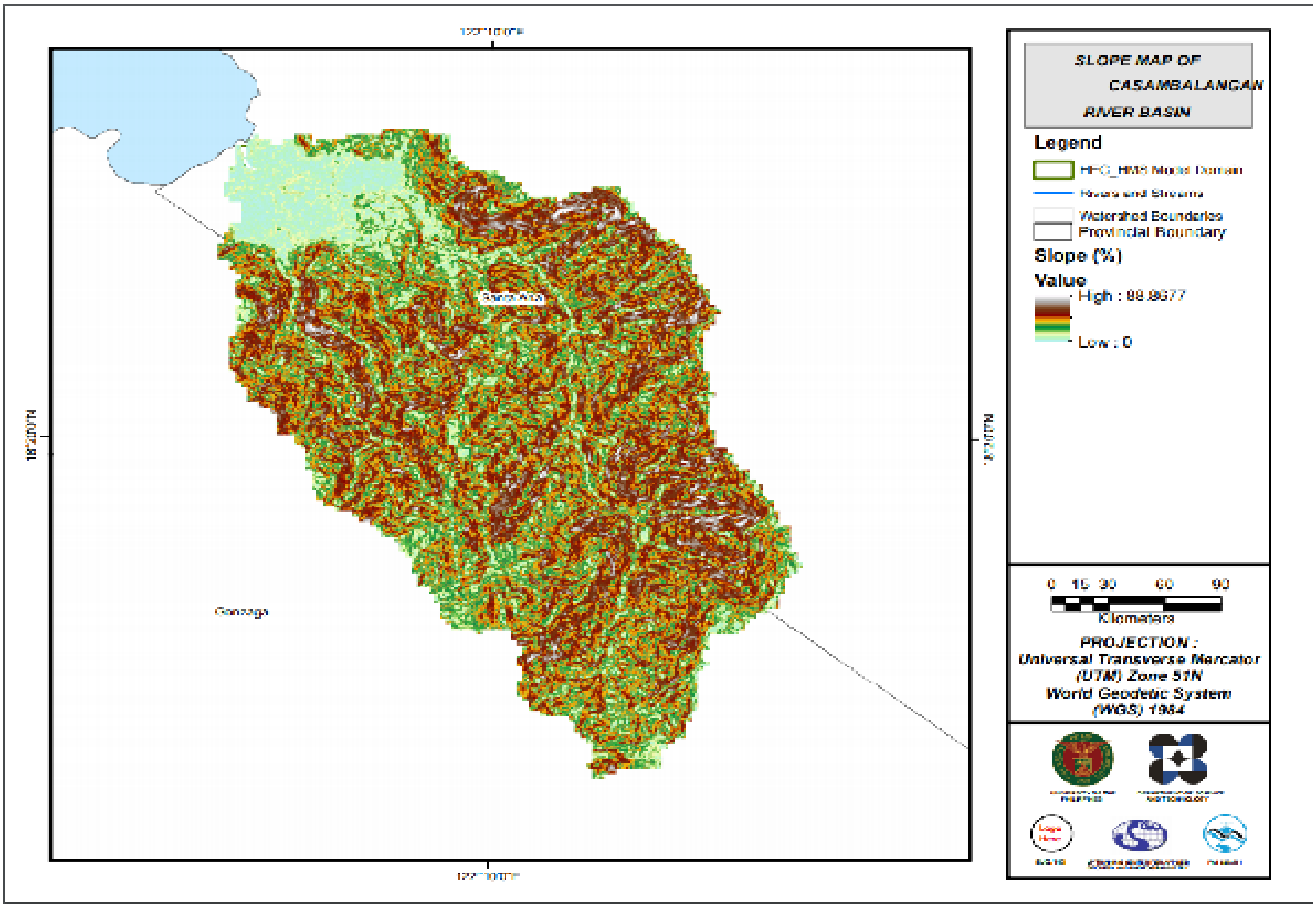


Figure 54. The Soil Map of the Casamba;angan River Basin

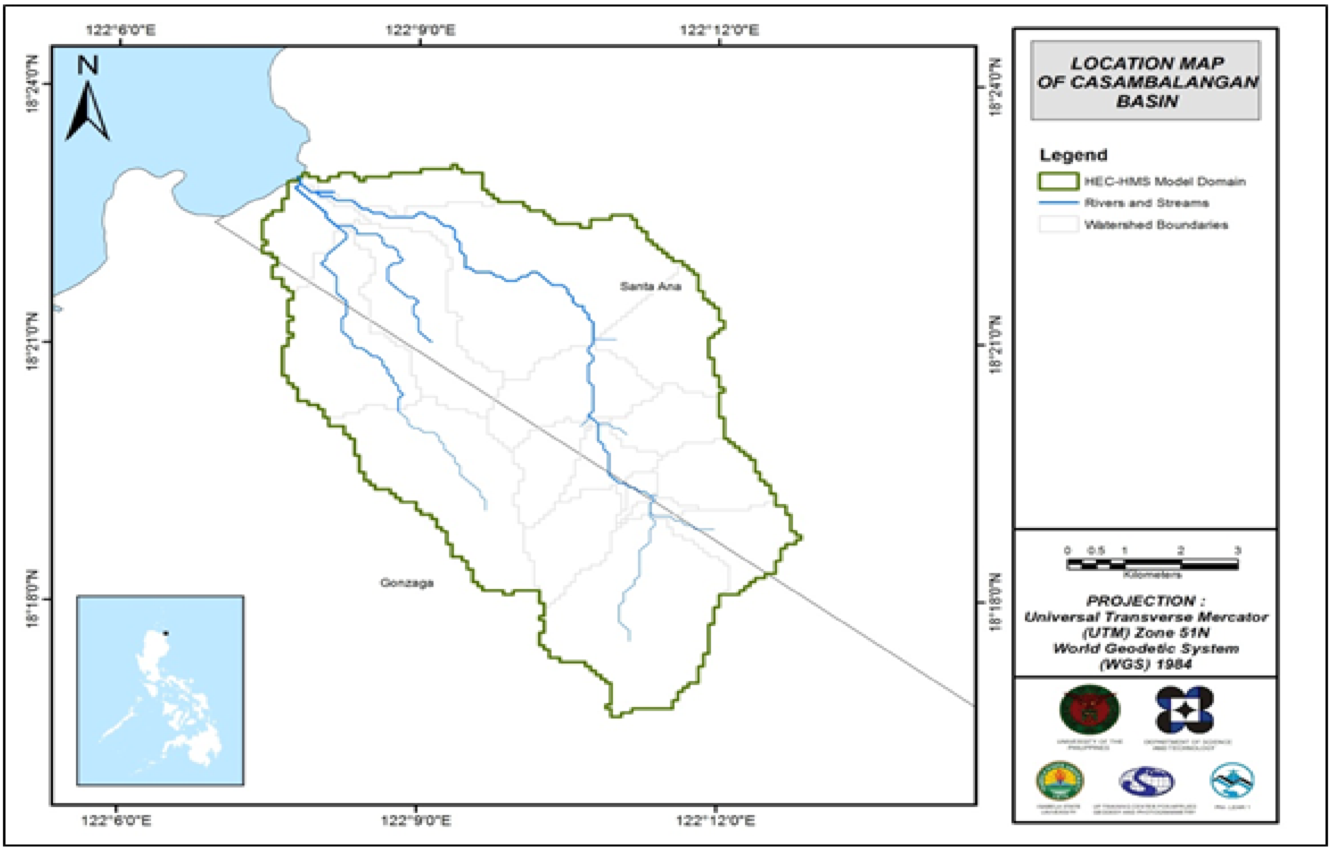


Figure 55. Stream delineation map of Casambalangan river basin

5.4 Cross-section Data

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

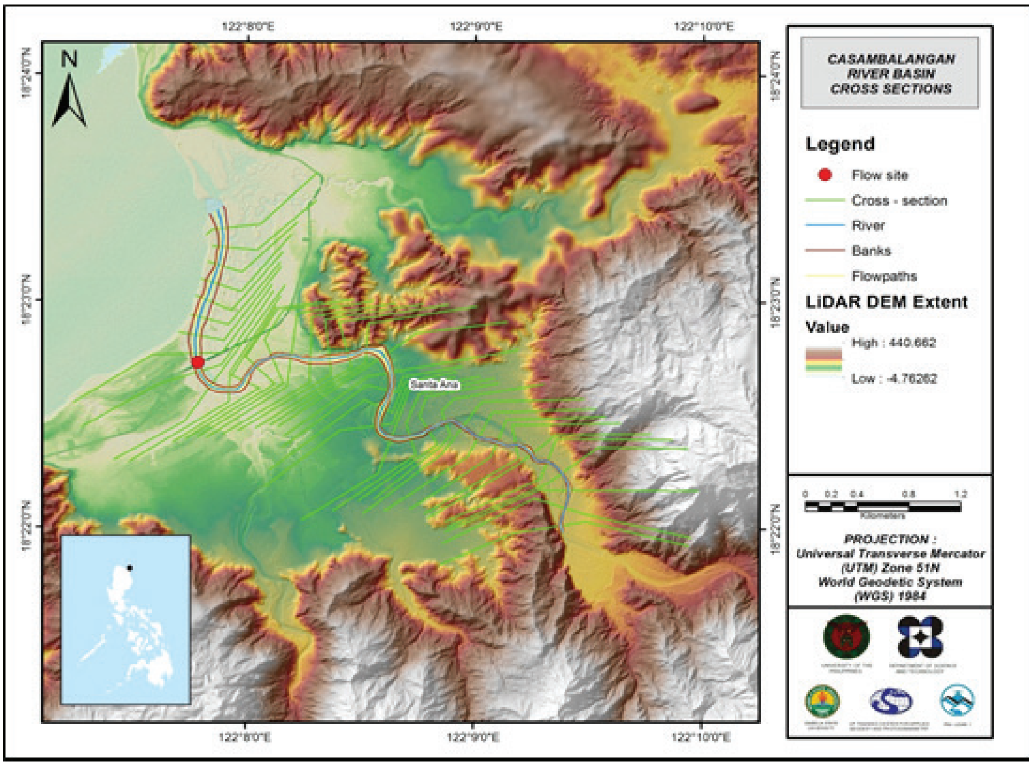


Figure 56. Casambalangan River Cross-section generated using HEC GeoRAS tool

5.5 Flo 2D Model

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

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

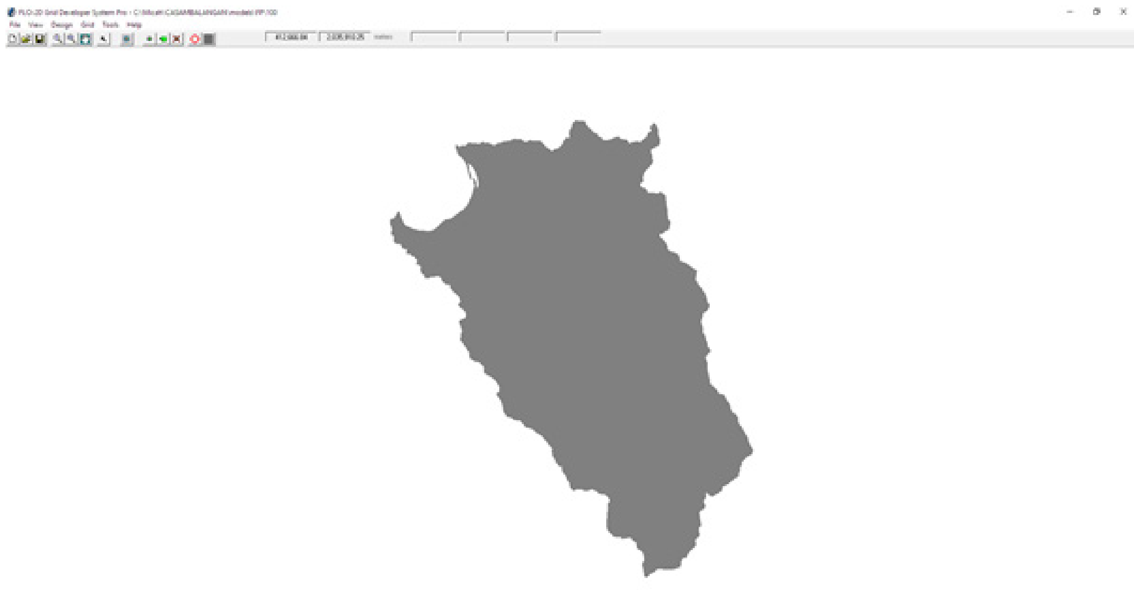


Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

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

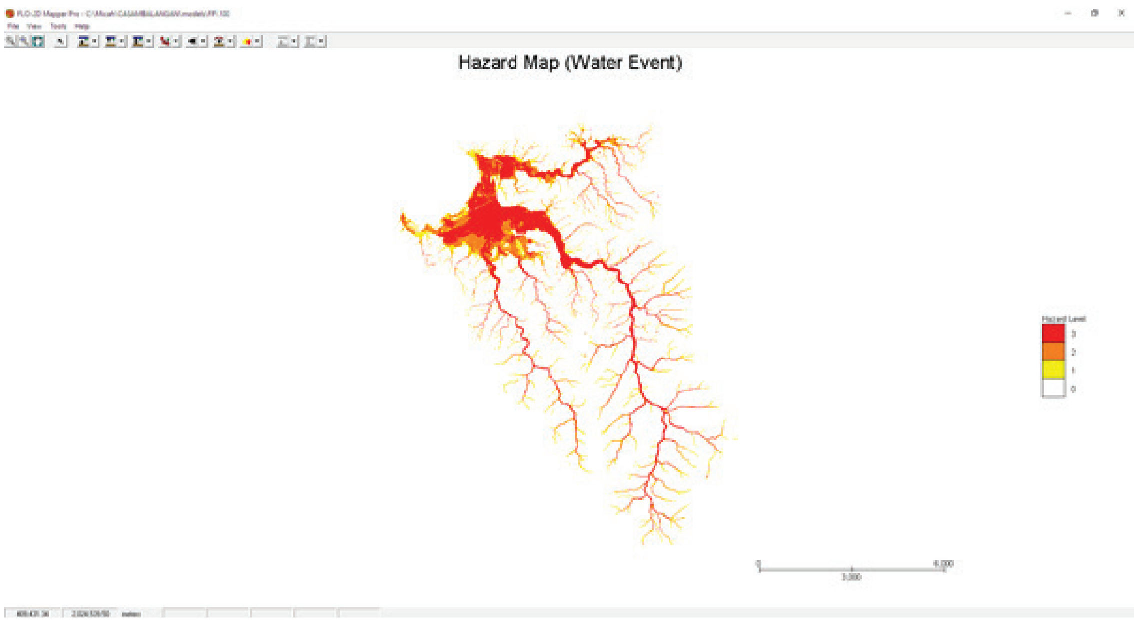


Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper

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

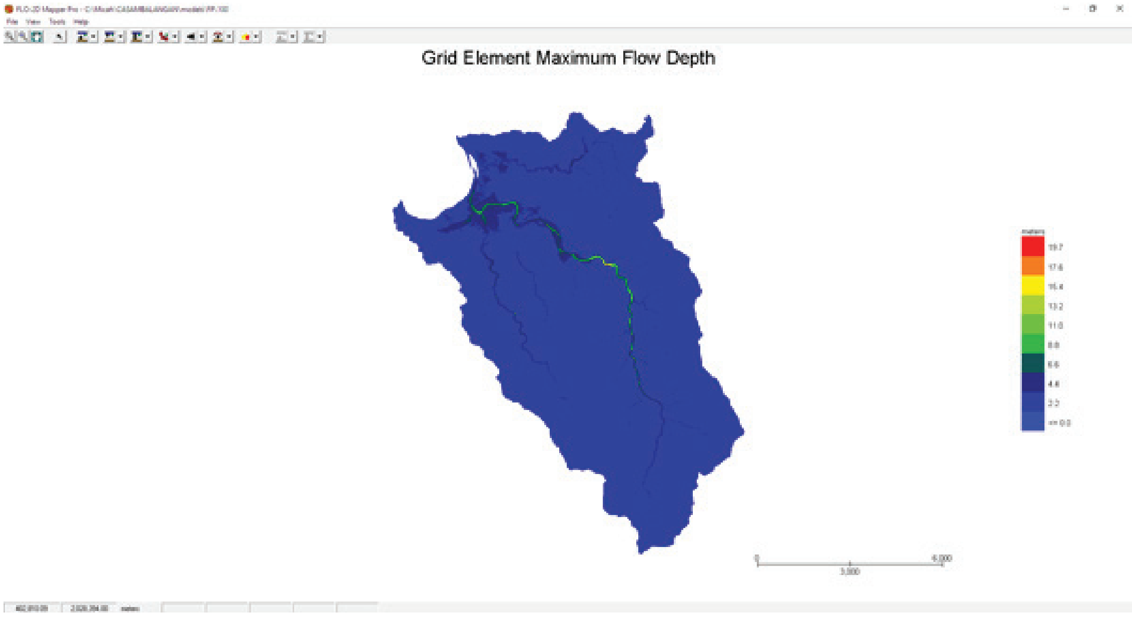


Figure 59. Generated 100-year rain return flow depth map from FLO-2D Mapper

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

5.6 Results of HMS Calibration

After calibrating the Casambalangan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 56 shows the comparison between the two discharge data. See Annex 9.

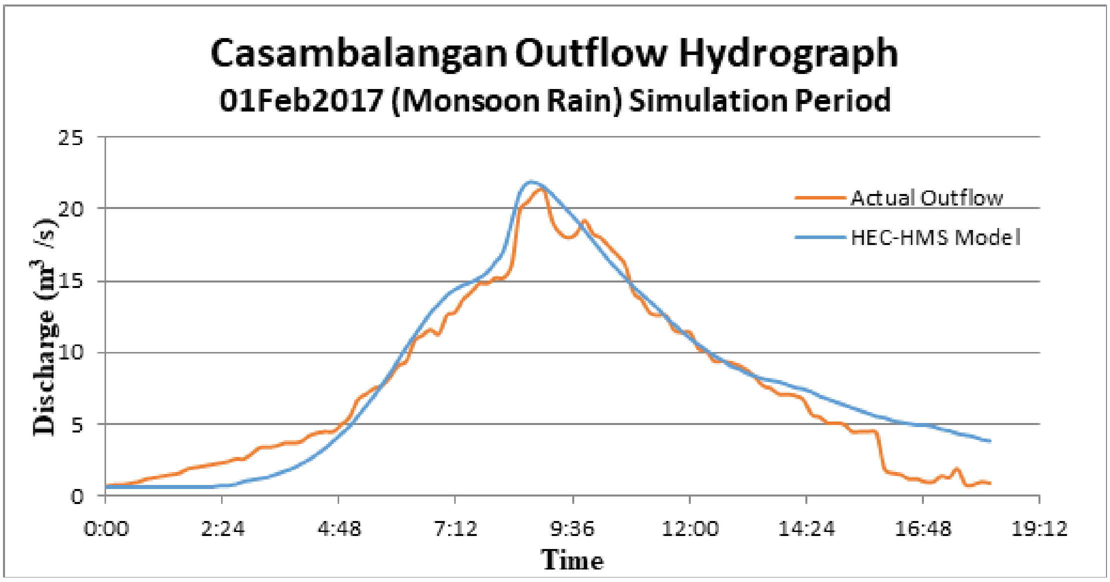


Figure 60. Outflow Hydrograph of Casambalangan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 25 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 25. Range of Calibrated Values for Silaga

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	7 - 31
			Curve Number	37 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 5
			Storage Coefficient (hr)	0.4 - 6
	Baseflow	Recession	Recession Constant	0.09 - 0.5
			Ratio to Peak	0.02
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.007 - 0.07

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 7mm to 31mm 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 37 to 99 for curve number is wider than the advisable range for Philippine watersheds (70-80) which depends on the soil and land cover of the area. For Casambalangan, the basin mostly consists of closed forest and the soil consists of undifferentiated soil, clay loam and sandy loam soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 hours to 6 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.09-0.5 indicates that the basin will quickly go back to its original discharge. Ratio to peak of 0.02 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.007-0.07 is lower than the common roughness of Philippine watersheds which is 0.04.

Table 26. Summary of the Efficiency Test of Casambalangan HMS Model

r2	0.9365
NSE	0.92
PBIAS	-8.94
RSR	0.28

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.7 (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 0.9365.

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 0.92.

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 -8.94.

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 0.28.

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

The summary graph (Figure 57) shows the Casambalangan River outflow using the Cagayan de Oro 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.

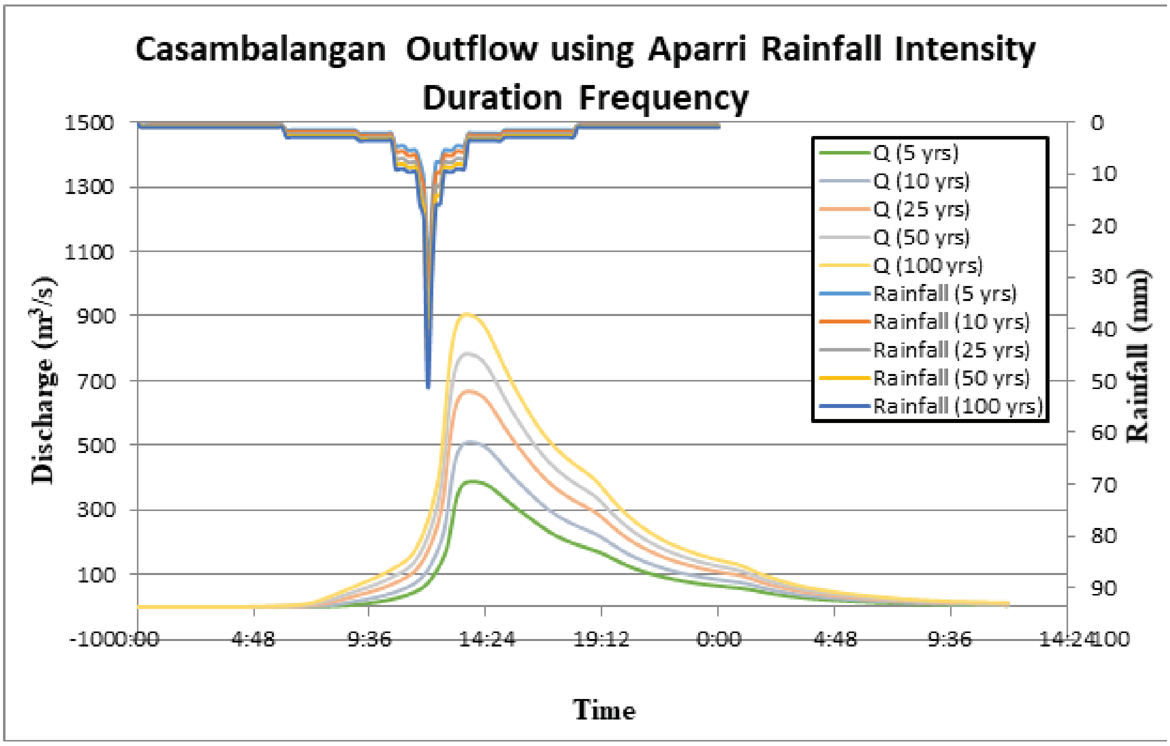


Figure 61. Outflow hydrograph at Casambalangan Station generated using Aparri RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Casambalangan discharge using the Aparri Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 27.

Table 27.Peak values of the Casambalangan HECHMS Model outflow using the Aparri RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3s)	Time to Peak
5-Year	252.5	28.5	389.3	1 hour, 50 minutes
10-Year	308.5	34.1	511.3	1 hour, 50 minutes
25-Year	379.3	41.1	668.4	1 hour, 40 minutes
50-Year	431.9	46.3	785.0	1 hour, 40 minutes
100-Year	484	51.4	902.2	1 hour, 40 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Casambalangan River using the calibrated HMS base flow is shown in Figure 58.

Figure 62. Sample output of Casambalangan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Casambalangan floodplain are shown in Figures 59 to 64.

Table 28 . Municipalities affected in Casambalangan floodplain

Municipality	Total Area	Area Flooded	% Flooded
Gonzaga	527.15	3.87	0.73%
Sta Ana	434.50	40.39	9.30%

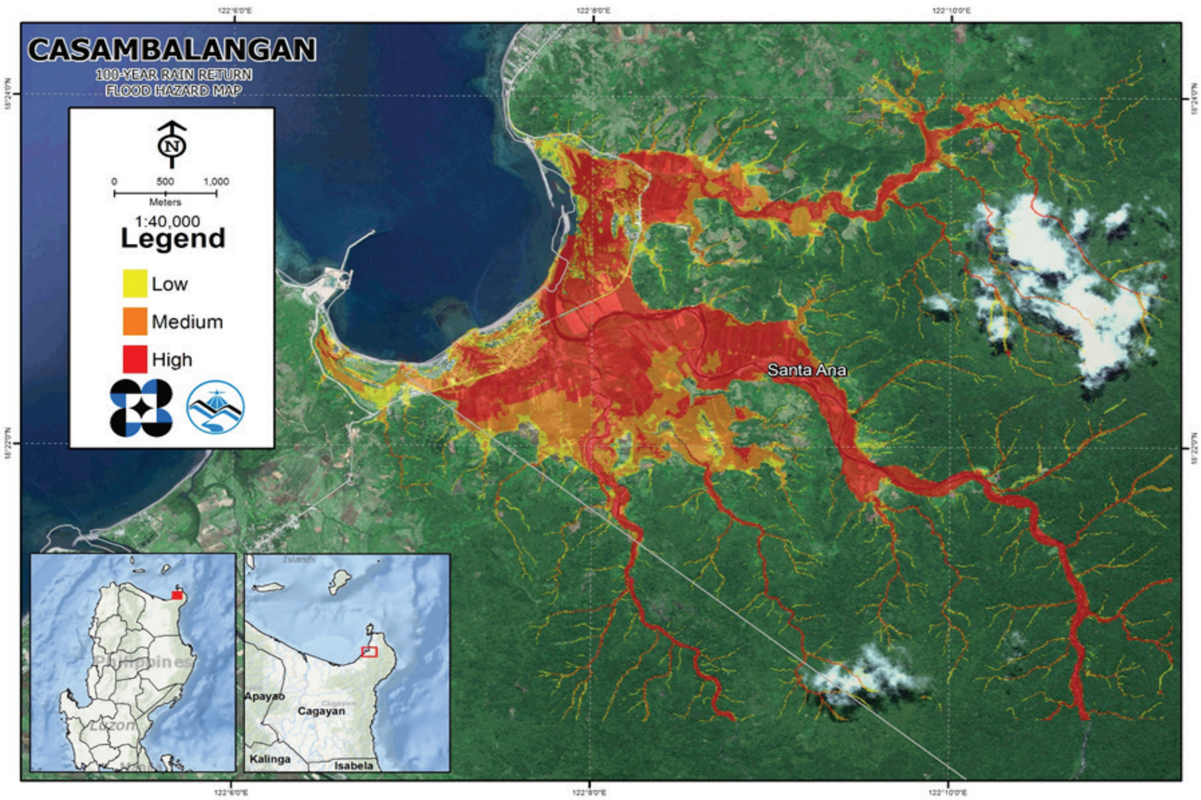


Figure 63. 100-year Flood Hazard Map for Casambalangan Floodplain

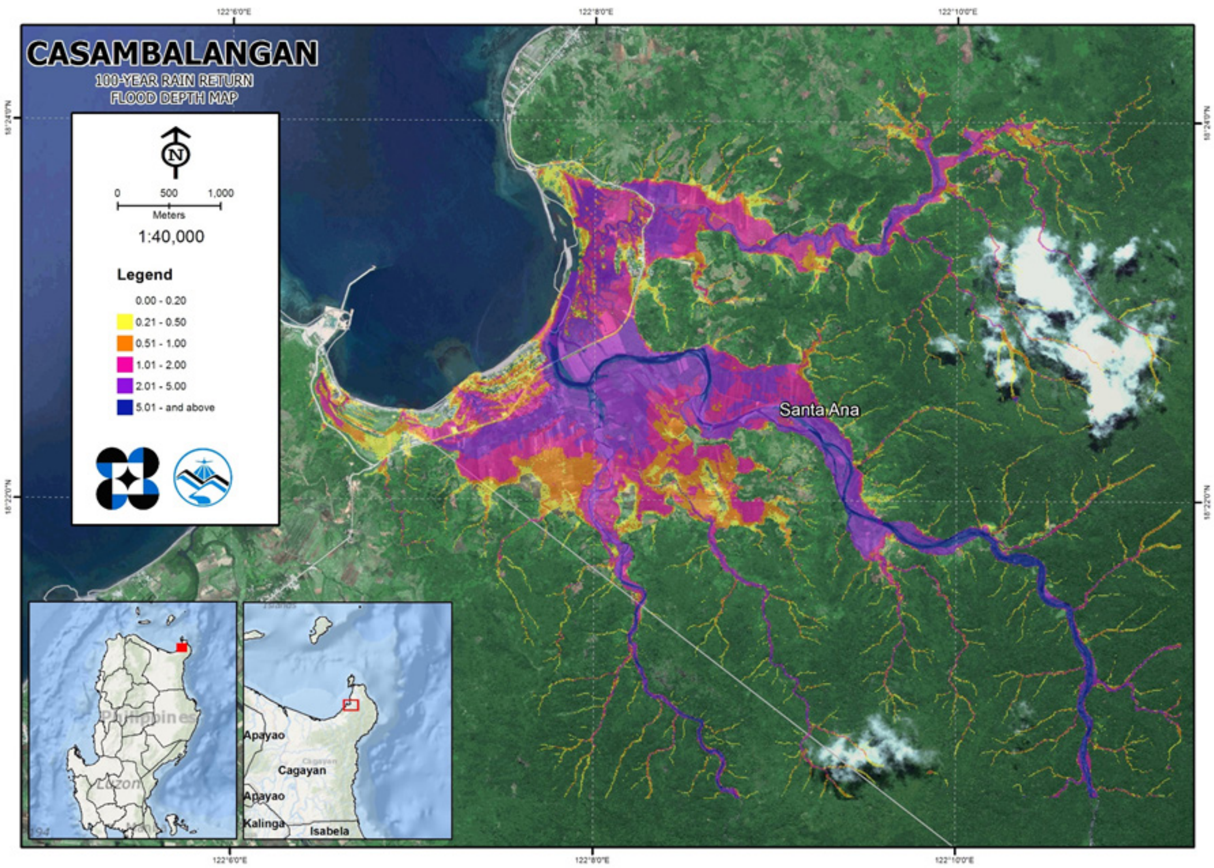


Figure 64. 100-year Flow Depth Map for Casambalangan Floodplain

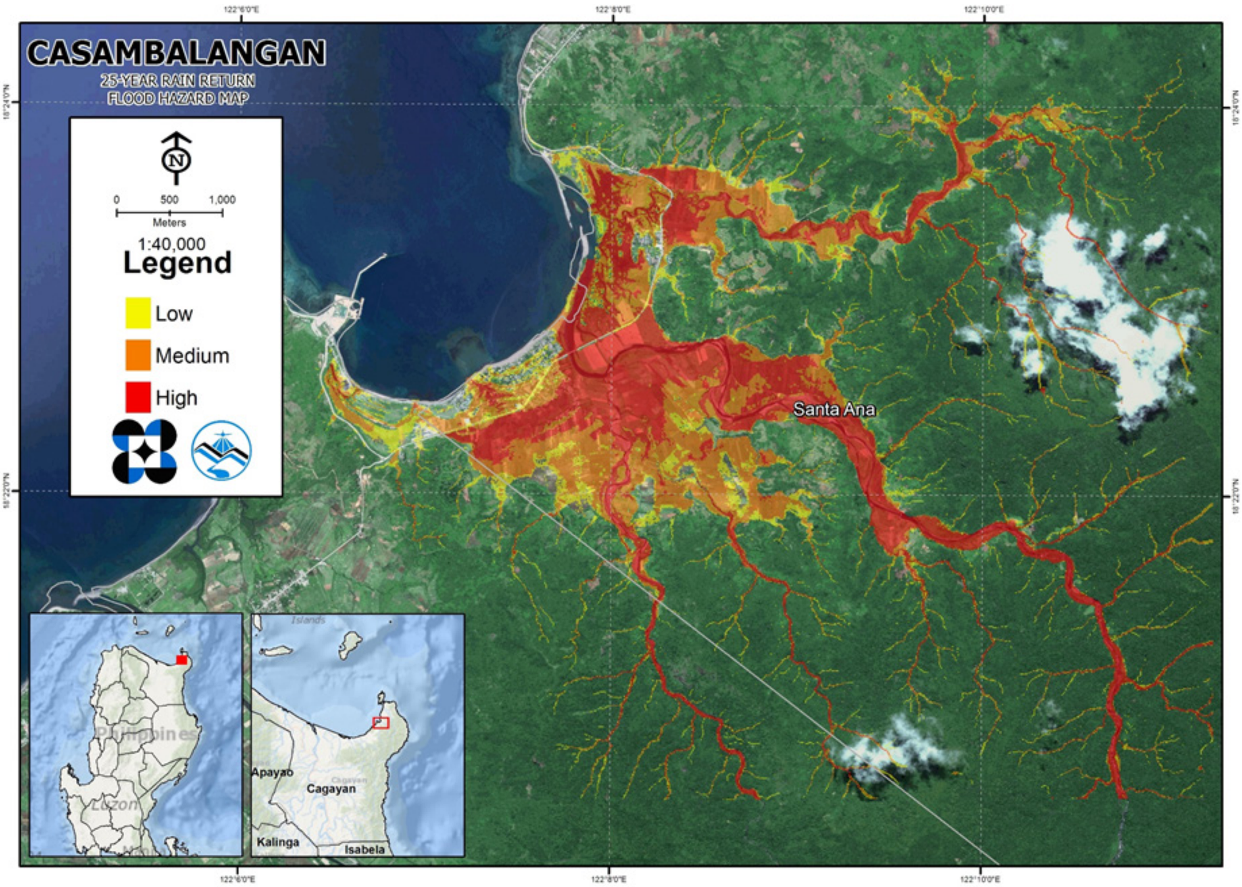


Figure 65. 25-year Flood Hazard Map for Casambalangan Floodplain

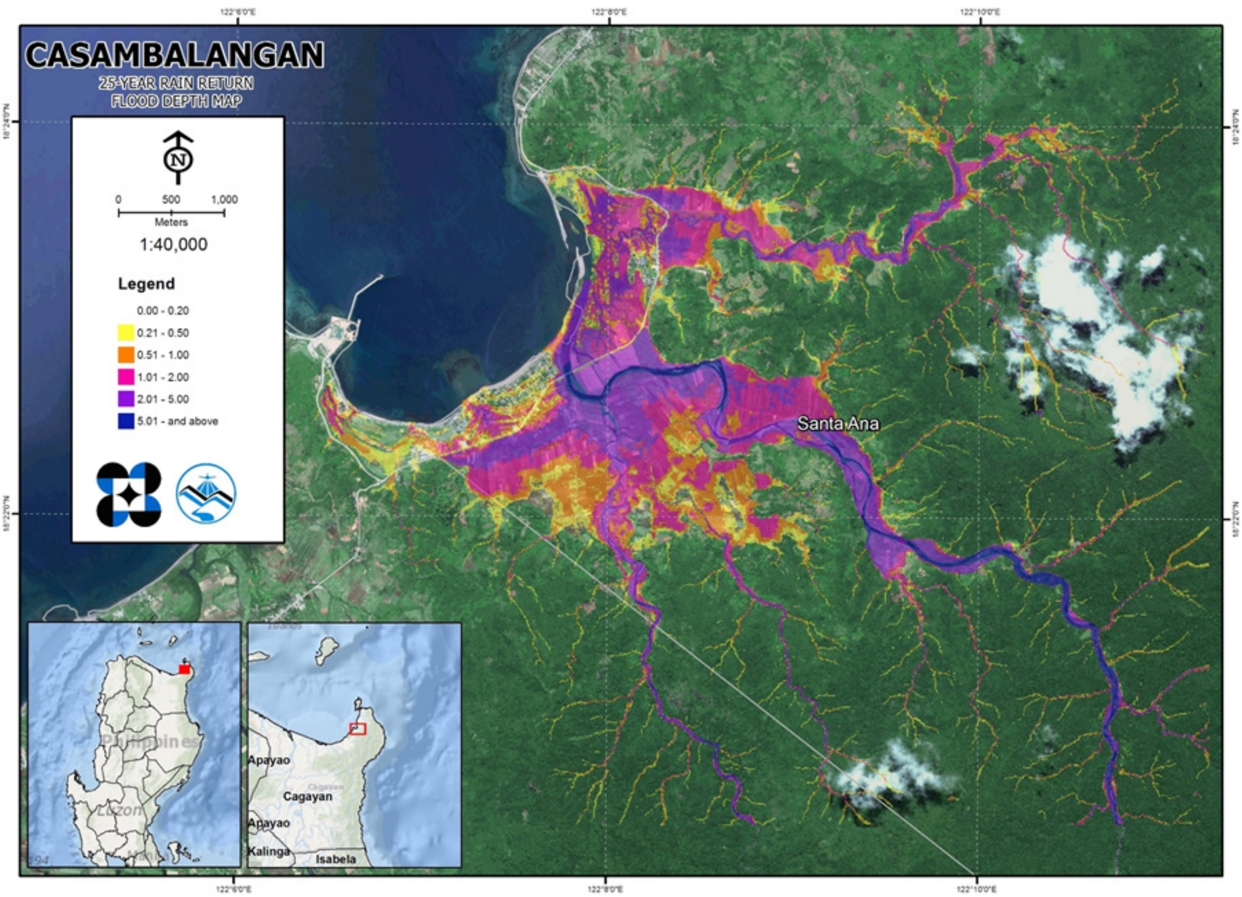


Figure 66. 25-year Flow Depth Map for Casambalangan Floodplain

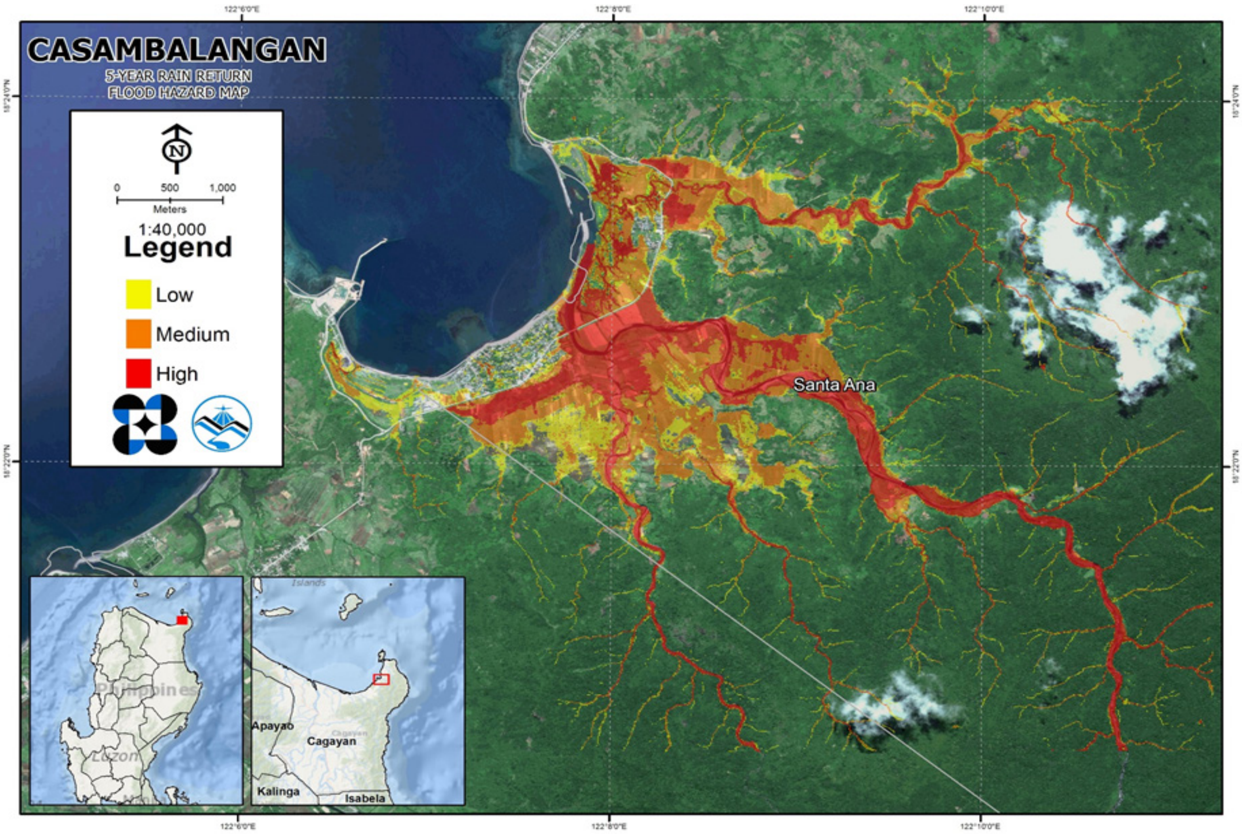


Figure 67. 5-year Flood Hazard Map for Casambalangan Floodplain

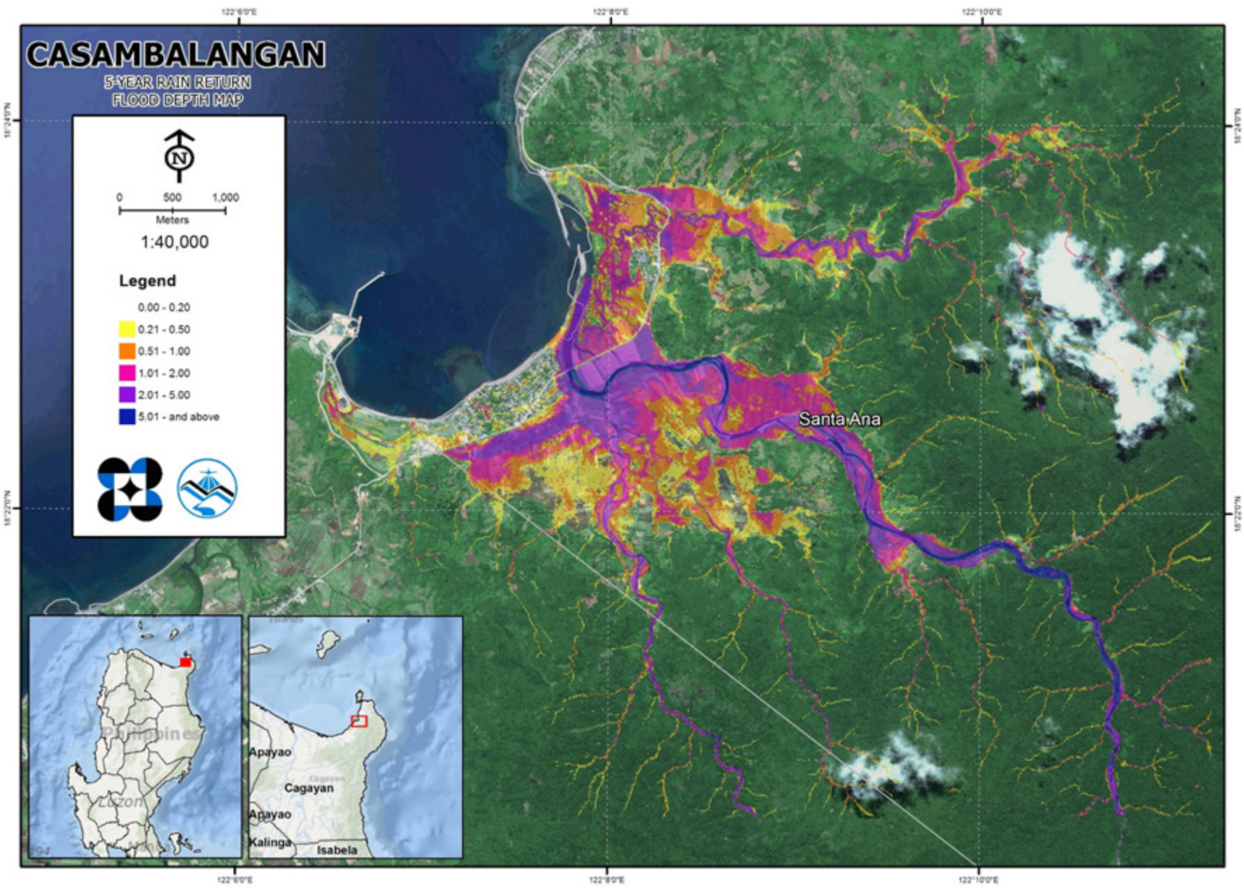


Figure 68. 5-year Flood Depth Map for Casambalangan Floodplain

5.10 Inventory of Exposed to Flooding Areas

Affected barangays in Casambalangan river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 6 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 6.56% of the municipality of Santa Ana with an area of 437.13 sq. km. will experience flood levels of less 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters while 0.49%, 0.53%, 0.41%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay.

Table 29. Affected Areas in Santa Ana, Cagayan during 5-Year Rainfall Return Period

CASAMBALANGAN BASIN		Affected Barangays in Santa Ana			
		Casambalangan	Patunungan	Rapuli	Santa Clara
Af-fect-ed Area (sq. km.)	0.03-0.20	10.17	10.17	10.17	10.17
	0.21-0.50	1.03	0.083	0.62	0.22
	0.51-1.00	1.08	0.055	0.85	0.15
	1.01-2.00	1.1	0.039	1.07	0.1
	2.01-5.00	1.3	0.016	0.46	0.019
	> 5.00	0.29	0.0002	0.02	0.0011

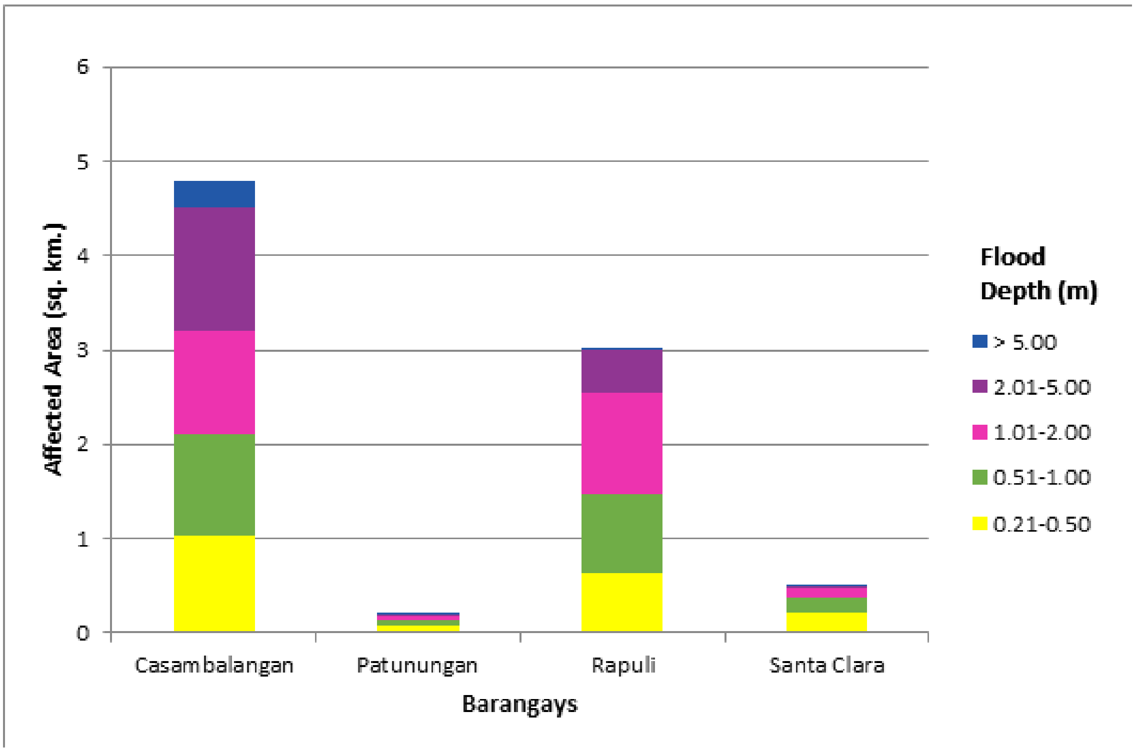


Figure 69. Affected Areas in Santa Ana, Cagayan during 5-Year Rainfall Return Period

For the municipality of Gonzaga, with an area of 497.62 sq. km., 1.28% will experience flood levels of less 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.01%, 0.01, and 0.0008% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, and more than 2 meters respectively.

Table 30. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

CASAMBALANGAN BASIN		Affected Barangays in Gonzaga	
		San Jose	Santa Maria
Affected Area (sq. km.)	0.03-0.20	6.14	0.25
	0.21-0.50	0.3	0.0064
	0.51-1.00	0.15	0.00083
	1.01-2.00	0.073	0
	2.01-5.00	0.064	0
	> 5.00	0.0042	0

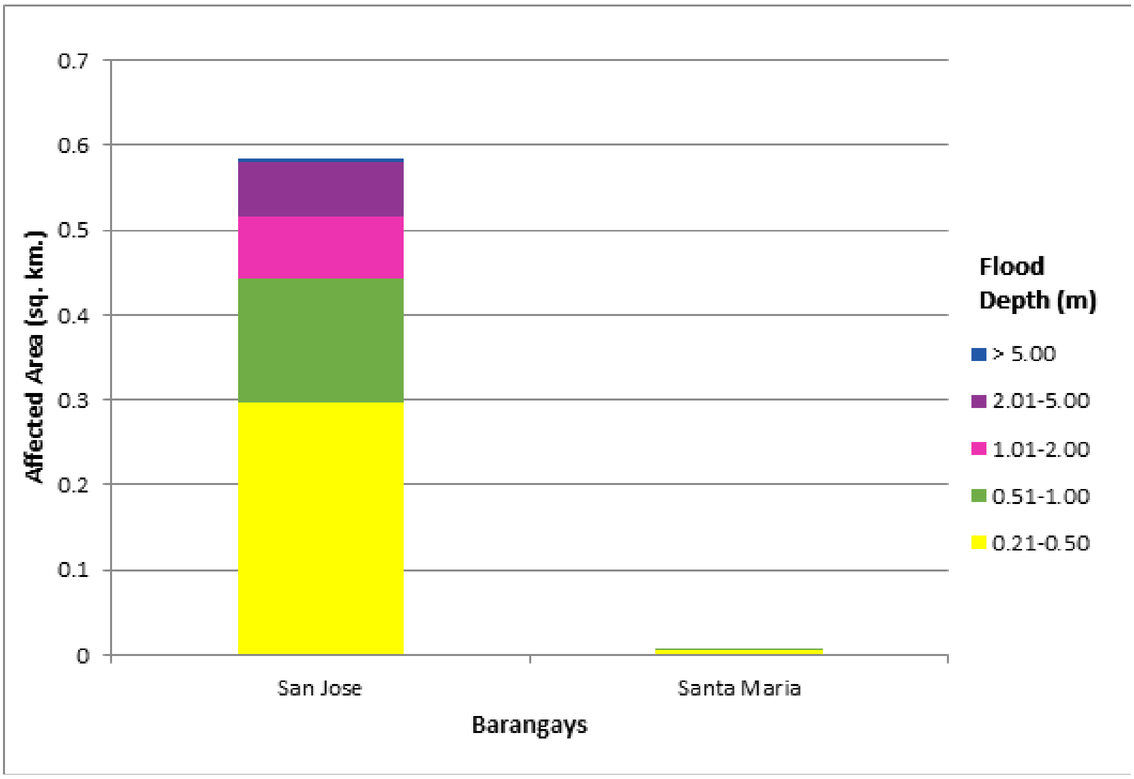


Figure 70. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

For the 25-year return period, 6.31% of the municipality of Santa Ana with an area of 437.13 sq. km. will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.45%, 0.67%, 0.58%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay.

Table 31. Affected Areas in Santa Ana, Cagayan during 25-Year Rainfall Return Period

CASAMBALANGAN BASIN		Affected Barangays in Santa Ana			
		Casambalangan	Patunungan	Rapuli	Santa Clara
Affect-ed Area	0.03-0.20	9.51	3.02	8.48	6.56
	0.21-0.50	0.8	0.098	0.57	0.25
	0.51-1.00	1.16	0.057	0.6	0.18
	1.01-2.00	1.4	0.048	1.34	0.13
	2.01-5.00	1.69	0.029	0.8	0.045
	> 5.00	0.41	0.0012	0.032	0.0014

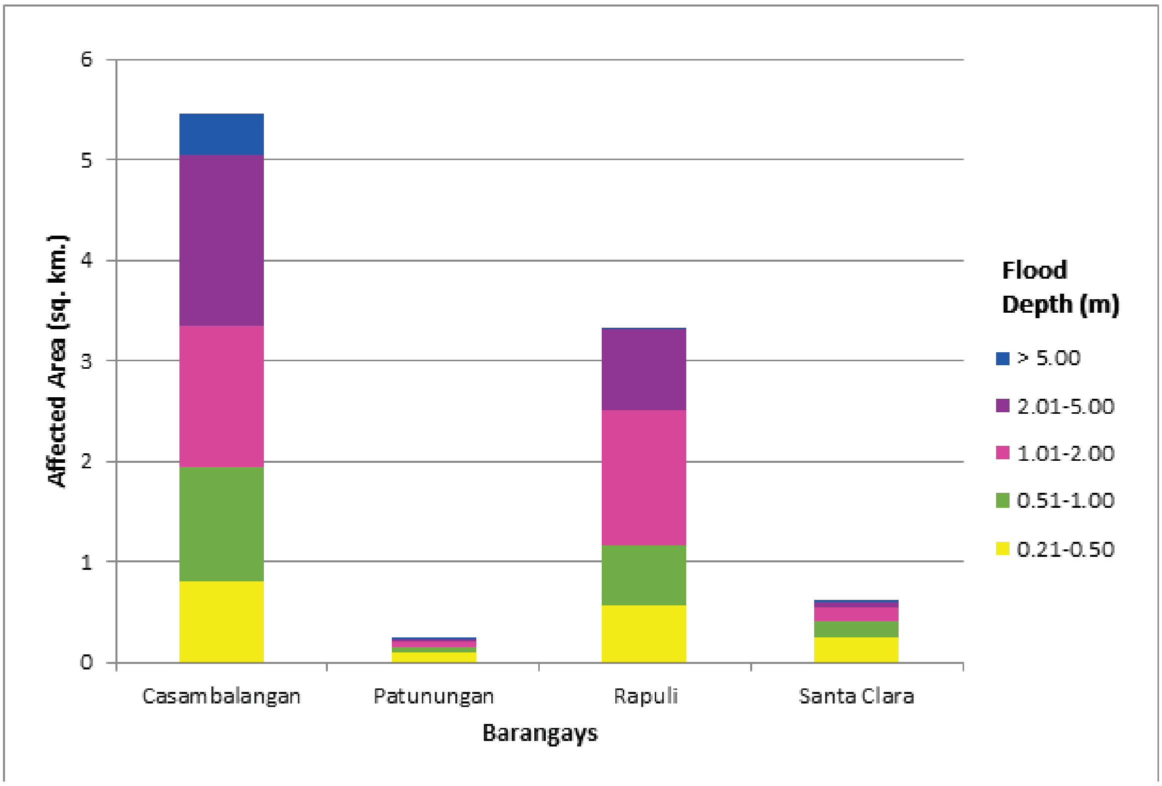


Figure 71. Affected Areas in Santa Ana, Cagayan during 5-Year Rainfall Return Period

For the municipality of Gonzaga, with an area of 497.62 sq. km., 1.26% will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.02%, 0.01%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, and more than 2 meters respectively.

Table 32. Affected Areas in Gonzaga, Cagayan during 25-Year Rainfall Return Period

CASAMBALANGAN BASIN		Affected Barangays in Gonzaga	
		San Jose	Santa Maria
Af-fect-ed Area (sq. km.)	0.03-0.20	6.01	0.25
	0.21-0.50	0.34	0.0074
	0.51-1.00	0.18	0.0015
	1.01-2.00	0.11	0.00013
	2.01-5.00	0.071	0
	> 5.00	0.018	0

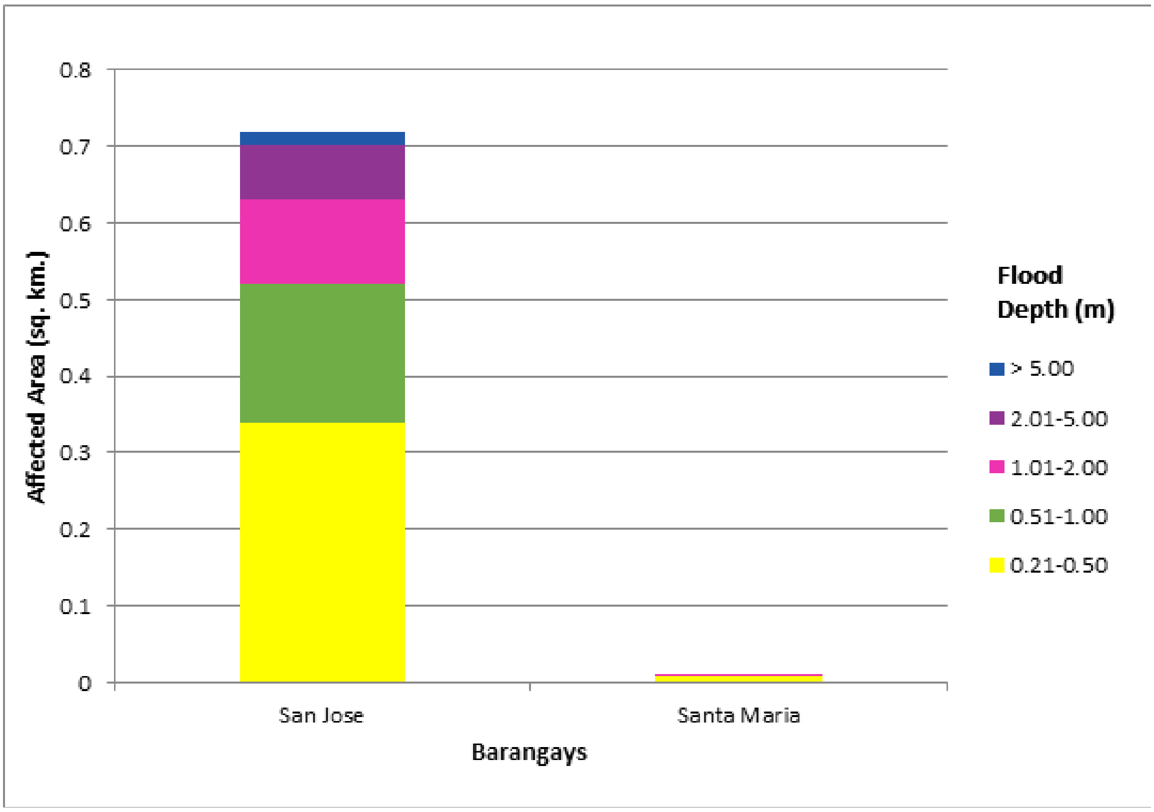


Figure 72. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

For the 100-year return period, 6.18% of the municipality of Santa Ana with an area of 437.13 sq. km. will experience flood levels of less 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters while 0.42%, 0.68%, 0.74%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Santa Ana, Cagayan during 100-Year Rainfall Return Period

CASAMBALANGAN BASIN		Affected Barangays in Santa Ana			
		Casambalangan	Patunungan	Rapuli	Santa Clara
Af-fect-ed Area (sq. km.)	0.03-0.20	9.25	2.99	8.29	6.49
	0.21-0.50	0.65	0.1	0.57	0.27
	0.51-1.00	1.08	0.064	0.5	0.19
	1.01-2.00	1.47	0.052	1.3	0.15
	2.01-5.00	2	0.038	1.13	0.068
	> 5.00	0.52	0.0026	0.038	0.0014

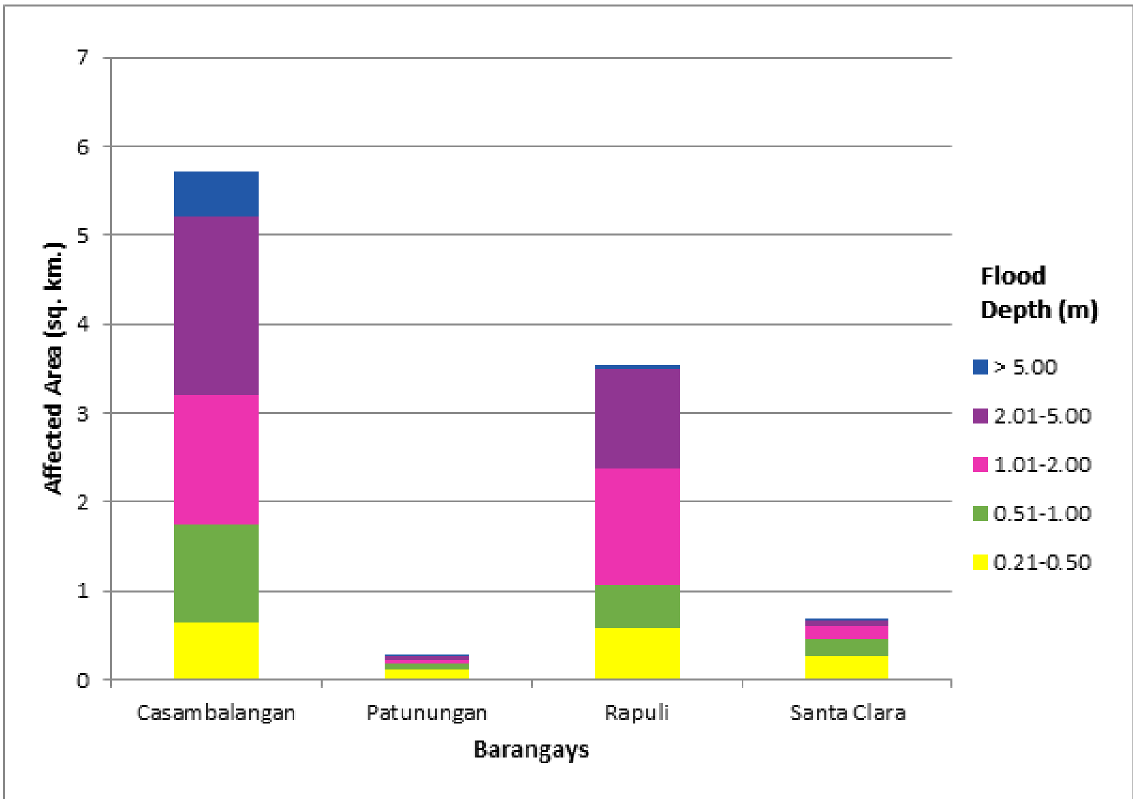


Figure 73. Affected Areas in Santa, Cagayan during 100-Year Rainfall Return Period

For the municipality of Gonzaga, with an area of 497.62 sq. km., 1.24% will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.03%, 0.01%, and 0.008% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, and more than 2 meters respectively.

Table 34. Affected Areas in Gonzaga, Cagayan during 100-Year Rainfall Return Period

CASAMBALANGAN BASIN		Affected Barangays in Gonzaga	
		San Jose	Santa Maria
Af-fected Area (sq. km.)	0.03-0.20	5.92	0.25
	0.21-0.50	0.35	0.0089
	0.51-1.00	0.21	0.0021
	1.01-2.00	0.13	0.00013
	2.01-5.00	0.07	0
	> 5.00	0.039	0

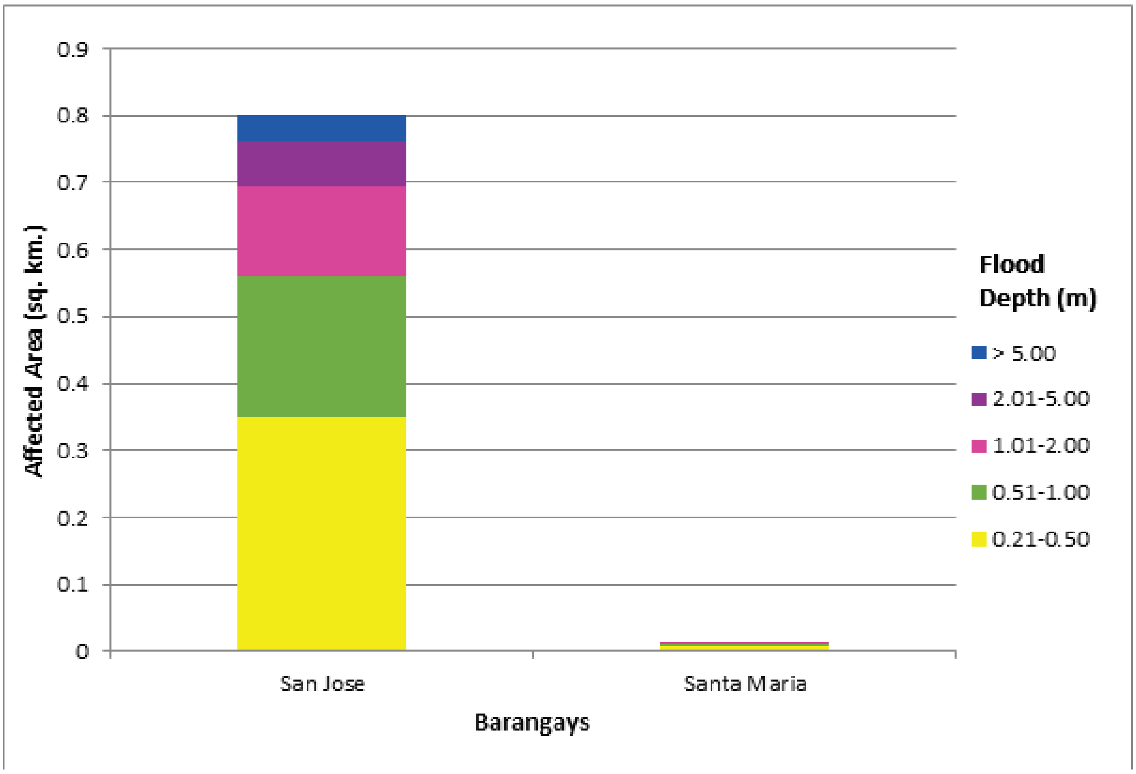


Figure 74. Affected Areas in Gonzaga, Cagayan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Sta. Ana, Casambalangan is projected to have the highest percentage of area that will experience flood levels at 0.07%. Meanwhile, Rapuli posted the second highest percentage of area that may be affected by flood depths at 0.005%.

Among the barangays in the municipality of Gonzaga, San Jose is projected to have the highest percentage of area that will experience flood levels of at 1.35%. Meanwhile, Santa Maria posted the percentage of area that may be affected by flood depths of at 0.05%.

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

Table 35. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	2.2104	1.9673	1.8448
Medium	3.6207	3.8214	3.5542
High	3.4076	4.7069	5.7457

Of the five (5) identified Education Institute in Casambalangan Flood plain, 3 schools were assessed to be exposed to the Low level flooding during a 5 year scenario. In the 25 year scenario, 4 schools were assessed to be exposed to the medium level flooding while 1 school were assessed to be exposed to high level flooding. For the 100 year scenario, 4 schools were assessed to be exposed to the medium level flooding while 1 school were assessed to be exposed to high level flooding. All the identified schools are located in Barangay Casambalangan and Barangay Rapuli.

One (1) Medical Institution was identified in Casambalangan Floodplain and is assessed to be exposed to medium level flooding in all the rainfall scenarios.

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 gather secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

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

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

The flood validation consists of 196 points randomly selected all over the Casambalangan flood plain. It has an RMSE value of 1.108.

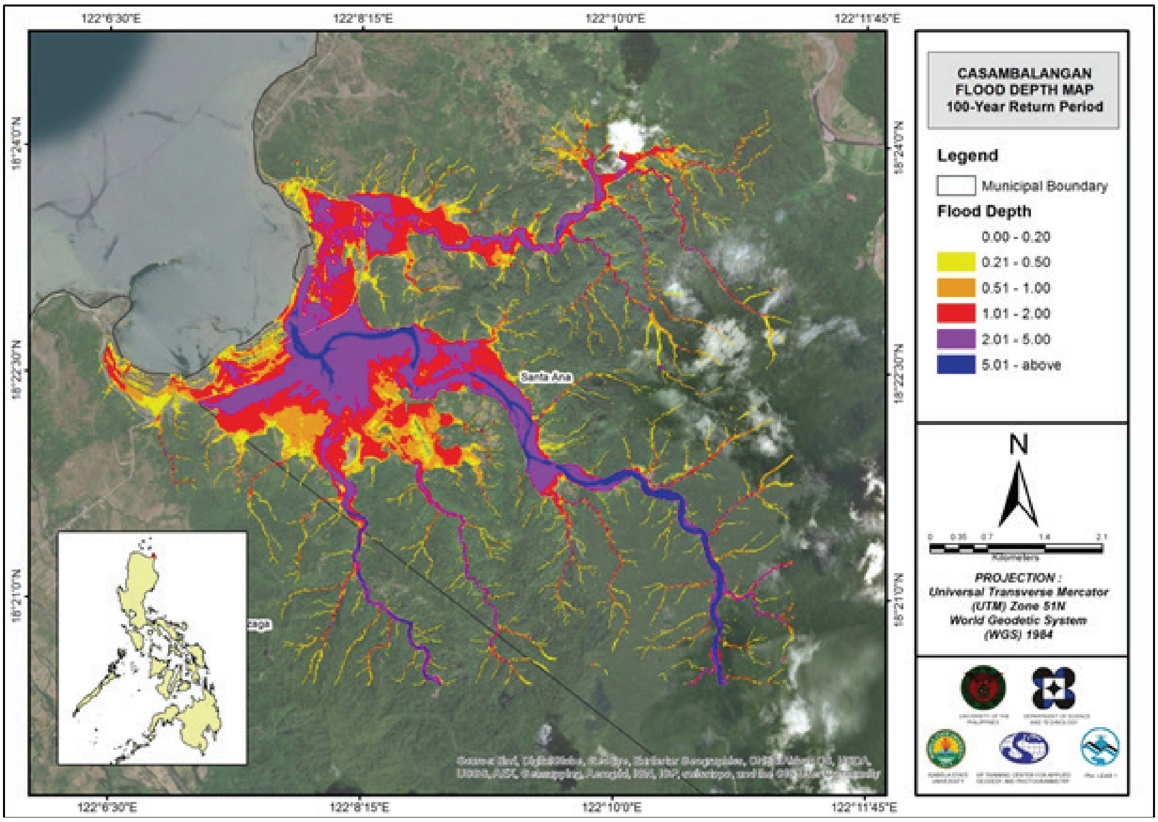


Figure 75. The Validation Points for a 5-year Flood Depth Map of the Casambalangan floodplain

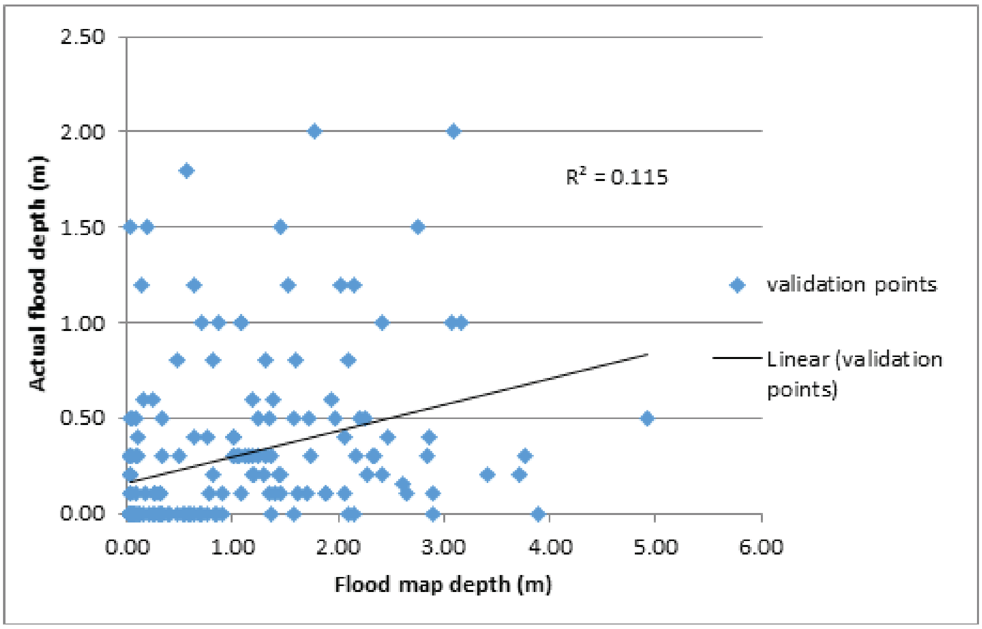


Figure 76 . Flood map depth vs actual flood depth

Table36. Actual Flood Depth vs Simulated Flood Depth in Casambalangan

CASAMBALANGAN BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	62	15	15	15	12	0	119
	0.21-0.50	14	3	2	18	11	0	48
	0.51-1.00	1	2	3	7	4	0	17
	1.01-2.00	3	0	2	3	4	0	12
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	80	20	22	43	31	0	196

The overall accuracy generated by the flood model is estimated at 36.22%, with 71 points correctly matching the actual flood depths. In addition, there were 46 points estimated one level above and below the correct flood depths while there were 38 points and 41 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 103 points were overestimated while a total of 22 points were underestimated in the modelled flood depths of Casambalangan.

Table 37. Summary of Accuracy Assessment in Casambalangan

	No. of Points	%
Correct	71	36.22
Overestimated	103	52.55
Underestimated	22	11.22
Total	196	100.00

REFERENCES:

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specification of the LiDAR Sensor used in the Casambalan-

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, in-cluding last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (op-tional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

1. CGY-102

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

December 02, 2015

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: CAGAYAN	
	Station Name: CGY-102	
	Order: 2nd	
Island: LUZON	Barangay: CASAMBALANGAN	
Municipality: SANTA ANA	MSL Elevation:	
	PRS92 Coordinates	
Latitude: 18° 22' 15.98573"	Longitude: 122° 6' 41.74346"	Ellipsoidal Hgt: 22.60800 m.
	WGS84 Coordinates	
Latitude: 18° 22' 9.81367"	Longitude: 122° 6' 46.31361"	Ellipsoidal Hgt: 57.19500 m.
	PTM / PRS92 Coordinates	
Northing: 2032192.366 m.	Easting: 617476.569 m.	Zone: 3
	UTM / PRS92 Coordinates	
Northing: 2,031,351.34	Easting: 406,145.45	Zone: 51

Location Description

CGY-102
From Gonzaga, travel along the nat'l. highway to Santa Ana. Station is located about 2 m. from the S corner of the triangular isalnd at the intersection of the nat'l. highway and the road to Port Irene. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-102 2007 NAMRIA".

Requesting Party: UP DREAM
Purpose: Reference
OR Number: 8088735 I
T.N.: 2015-3961

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. CG-258

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

May 17, 2016

CERTIFICATION

To whom it may concern:

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

Province: **CAGAYAN**
Station Name: **CG-258**

Island: **Luzon**	Municipality: **GONZAGA**	Barangay: **TAPEL**
Elevation: **6.5266 +/- 0.0455 m.**	Accuracy Class at 95% C.L: **4 cm**	Datum: **Mean Sea Level**
Latitude: **18° 17' 15.50000"**	Longitude: **122° 1' 26.40000"**	

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

BM CG-258 is in the Province of Cagayan, Municipality of Gonzaga, Brgy. of Tapel, along the national road and about 200 m NE of Kilometer post no. 608, It is embedded in a hole drilled on top of and near the West end of the North sidewalk of a concrete bridge. It is 0.22 m above the bridge floor, almost 4.33 m North of the centerline of the bridge. It is located at the right side of the national road going to Aparri, almost 37.7 m North post of the Tapel Brgy. marker.

Mark is a 1/2" x 2" brass rod embedded in a drilled hole, with an inscription on the cement putty placed around the mark as shown; CG-258; 2007; NAMRIA

Requesting Party:	**UP-DREAM**
Purpose:	**Reference**
OR Number:	**8090370 I**
T.N.:	**2016-1109**

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

9 9 0 5 1 7 2 0 1 6 0 9 5 8 0 7

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

Vector Components (Mark to Mark)

From:	CGY-102				
Grid		Local		Global	
Easting	406145.451 m	Latitude	N18°22'15.98572"	Latitude	N18°22'09.81367"
Northing	2031351.336 m	Longitude	E122°06'41.74346"	Longitude	E122°06'46.31361"
Elevation	20.066 m	Height	22.609 m	Height	57.195 m

To:	CG-258				
Grid		Local		Global	
Easting	396708.418 m	Latitude	N18°17'21.32897"	Latitude	N18°17'15.16762"
Northing	2022343.154 m	Longitude	E122°01'21.83970"	Longitude	E122°01'26.41723"
Elevation	9.620 m	Height	12.774 m	Height	47.419 m

Vector					
ΔEasting	-9437.033 m	NS Fwd Azimuth	226°03'09"	ΔX	6452.377 m
ΔNorthing	-9008.183 m	Ellipsoid Dist.	13049.913 m	ΔY	7393.391 m
ΔElevation	-10.445 m	ΔHeight	-9.835 m	ΔZ	-8602.642 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000235542		
Y	-0.0000335823	0.0000546286	
Z	-0.0000130276	0.0000212981	0.0000098327

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. GEROME HIPO-LITO	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Re-search Specialist (SSRS)	JONATHAN ALMALVEZ	UP-TCAGP
	Research Associate (RA)	SANDRA POBLETE	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	DARRYL AUSTRIA	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. JOHN ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JERICO JECIEL	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. Data Transfer Sheet for Casambalangan Floodplain Flights

15-41

DATA TRANSFER SHEET
cagayan2 12/2/15

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	
18-Nov	2866P	1BLK2G322A	pegasus	2.33	na	11.8	266	34.7	258	22.8	na	15.6	1KB	1KB	129	NA	Z:\DAC\RAW DATA
18-Nov	2868P	1BLK2H322B	pegasus	1.87	na	7.94	157	27.7	207	18	na	15.6	1KB	1KB	74	NA	Z:\DAC\RAW DATA
19-Nov	2870P	1BLK21AB323A	pegasus	2.11	na	11.6	255	23.2	211	22.8	na	10.3	1KB	1KB	46	NA	Z:\DAC\RAW DATA
20-Nov	2874P	1BLK21C324A	pegasus	1.22	na	8.12	195	7.3	80	12	na	10.8	1KB	1KB	57/90	NA	Z:\DAC\RAW DATA
21-Nov	2880P	1BLK2HS325A	pegasus	1.76	na	12.2	231	30	240/1	17.7	na	11.4	1KB	1KB	84/76/74	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat 12/4/15
Position
Signature

Annex 6. Flight logs for the flight missions

1. Flight Log for 3971G Mission

UP DREAM Data Acquisition Flight Log

Flight Log No.: 3971

1 LIDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2H119A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORTEZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: APRIL 28, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1009 H	14 Engine Off: 1424 H	15 Total Engine Time: 04 + 15	16 Take off: 1014 H	17 Landing: 1419 H	18 Total Flight Time: 04 + 05
19 Weather: FAIR					

20 Flight Classification

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

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

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

21 Remarks

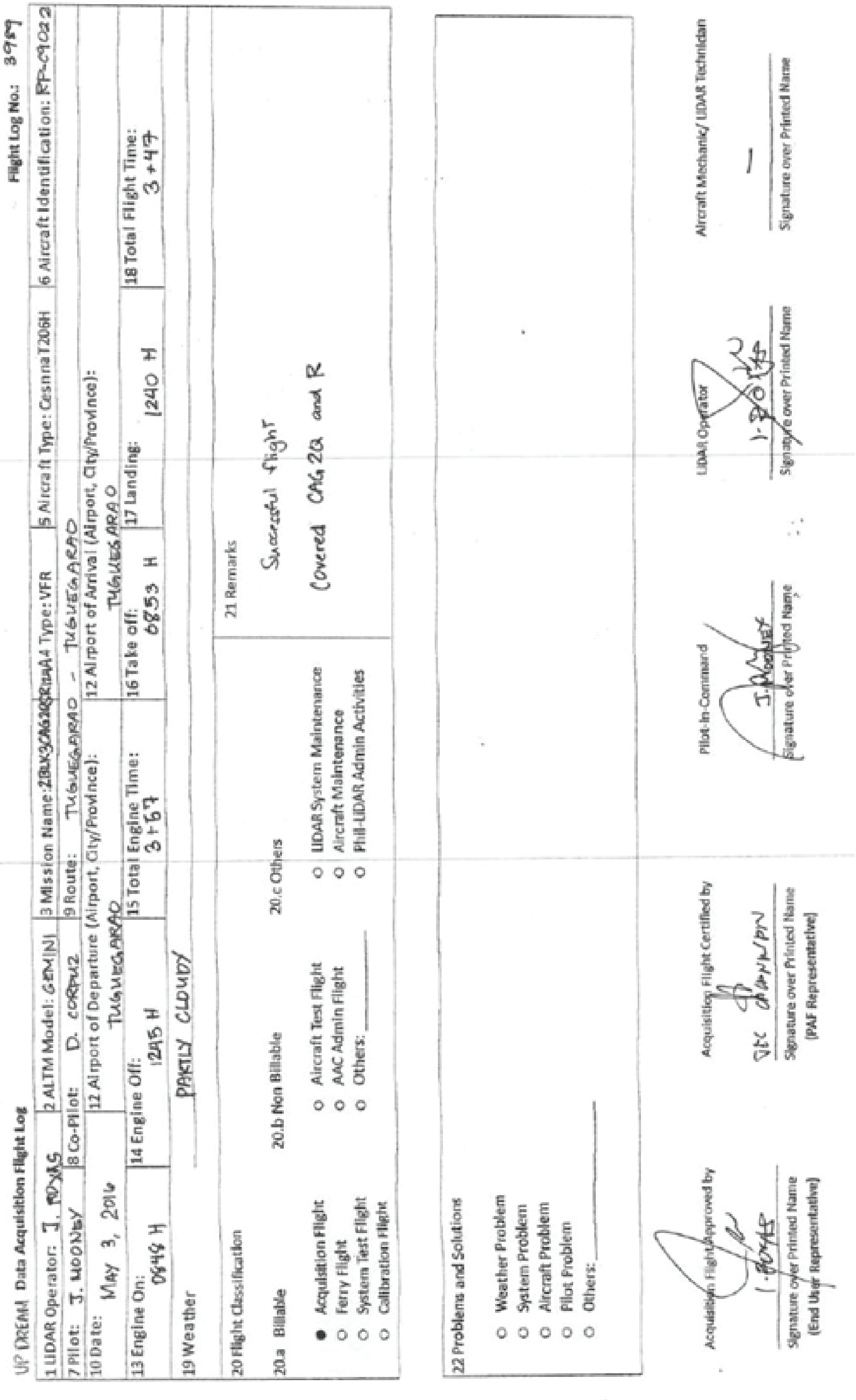
SUCCESSFUL FLIGHT

Covered Bova, Casambalangan & Palawig floodplains

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
I. ROXAS	SEC BACANNON	J. MOONEY	J. ALMALVEL	–
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 3989G Mission



UP DREAM Data Acquisition Flight Log

Flight Log No.: 3989

1 LIDAR Operator: I. ROXAS	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2QSR	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 3, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 0848 H	14 Engine Off: 1245 H	15 Total Engine Time: 3+57	16 Take off: 0853 H	17 Landing: 1240 H	18 Total Flight Time: 3+47
19 Weather	PARTLY CLOUDY				

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Covered CAG 2Q and R

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

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

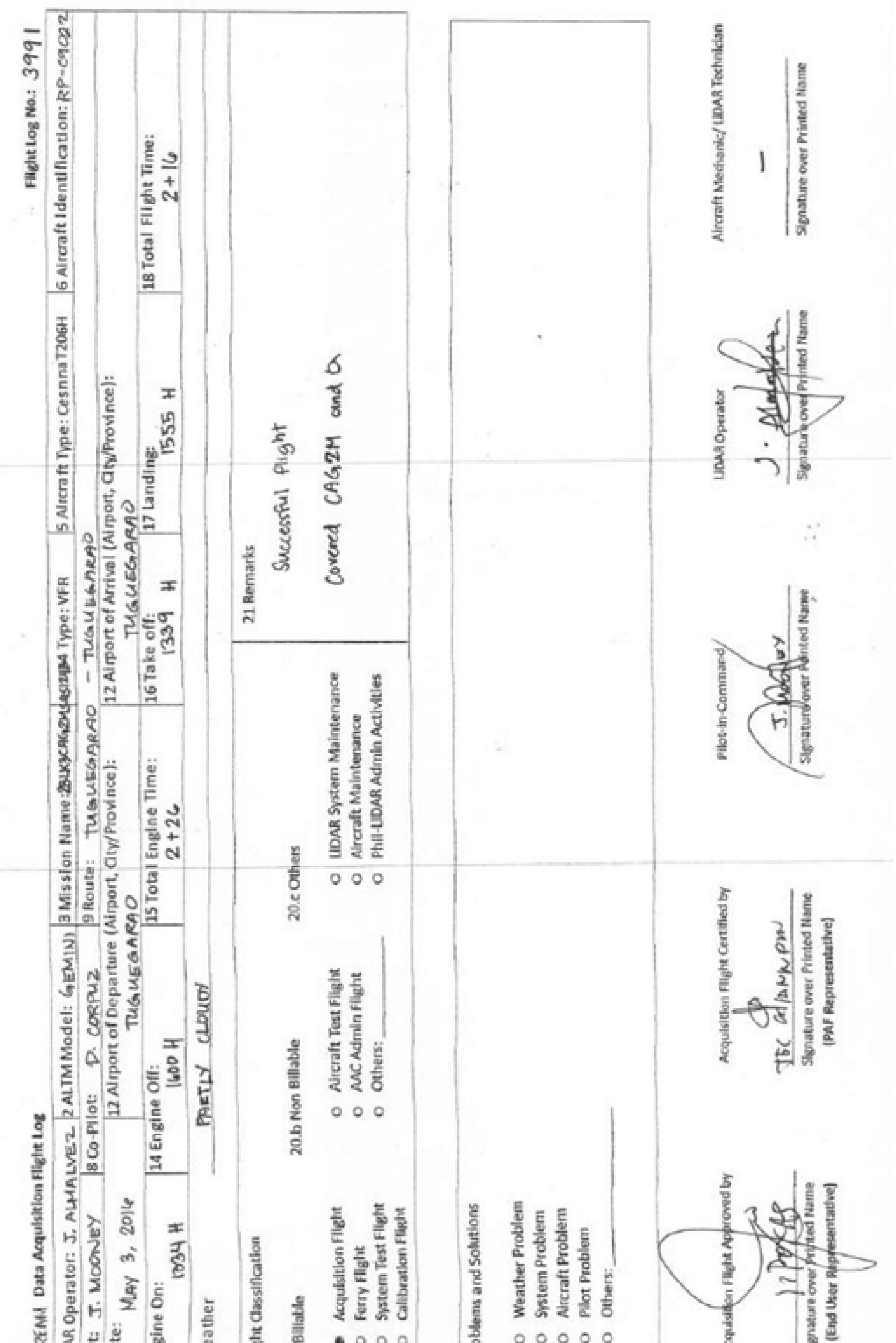
Acquisition Flight Certified by: SSC CHANNAPAN — Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. MOONEY — Signature over Printed Name

LIDAR Operator: I. ROXAS — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — — Signature over Printed Name

3. Flight Log for 3991G Mission



UP DREAM Data Acquisition Flight Log

Flight Log No.: 3991

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2M125A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO – TUGUEGARAO			
10 Date: MAY 3, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1334 H	14 Engine Off: 1600 H	15 Total Engine Time: 2+26	16 Take off: 1339 H	17 Landing: 1555 H	18 Total Flight Time: 2+16
19 Weather	PARTLY CLOUDY				

20 Flight Classification

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

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

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

21 Remarks

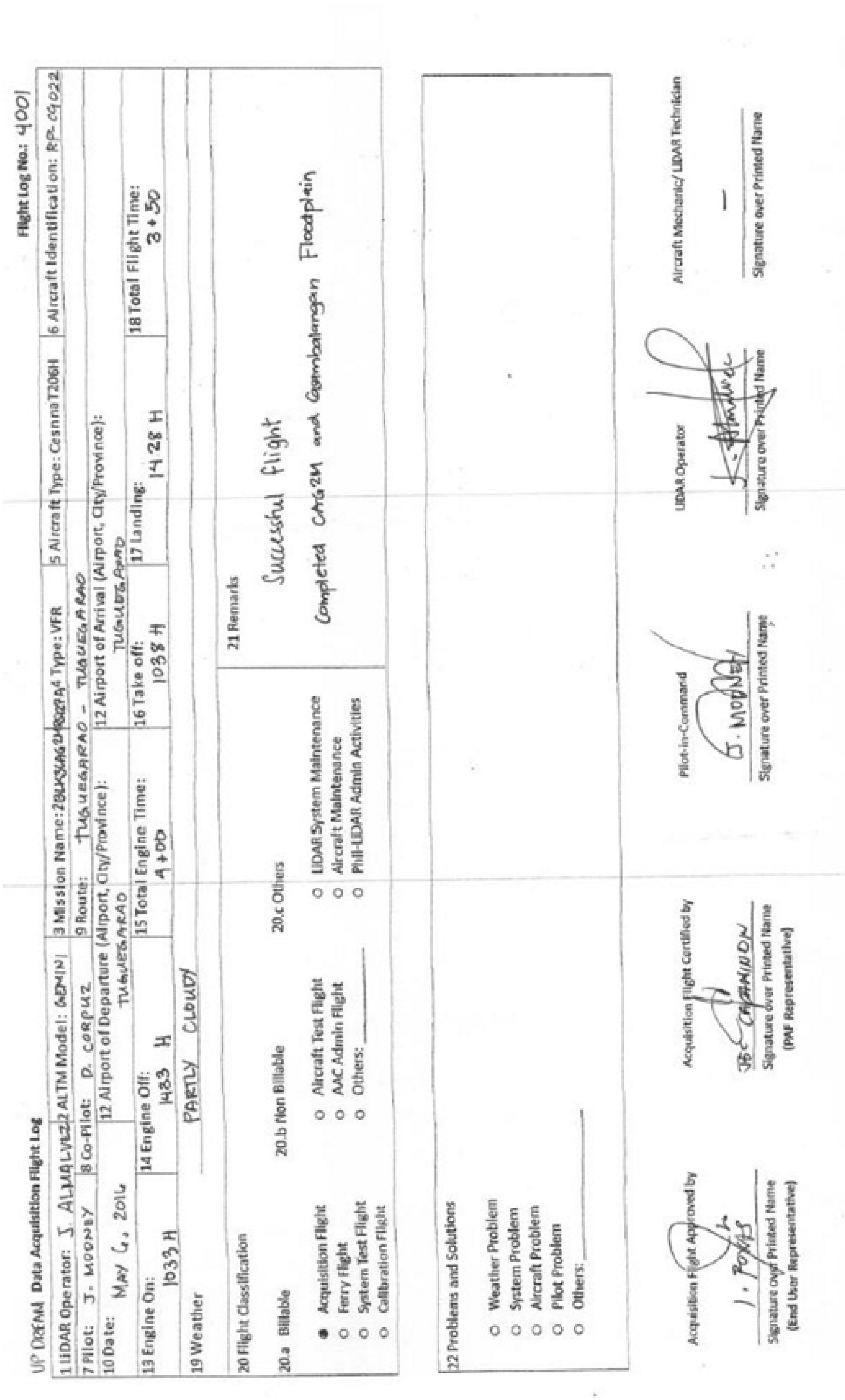
Successful flight

Covered CAG2M and C

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
1) POKAS	TSC ALIBANAPON	J. MOONEY	J. Almalvez	–
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 4001G Mission



Flight Log No.: 4001

UP DREAM Data Acquisition Flight Log

1 LIDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK39AG127A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 6, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO	12 Airport of Arrival (Airport, City/Province): TUGUEGARAO			
13 Engine On: 1033 H	14 Engine Off: 1433 H	15 Total Engine Time: 4+00	16 Take off: 1038 H	17 Landing: 1428 H	18 Total Flight Time: 3+50
19 Weather: PARTLY CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Completed CAG2M and Gambalangan Floodplain

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

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

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

Pilot-in-Command: J. Mooney — Signature over Printed Name

LIDAR Operator: J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

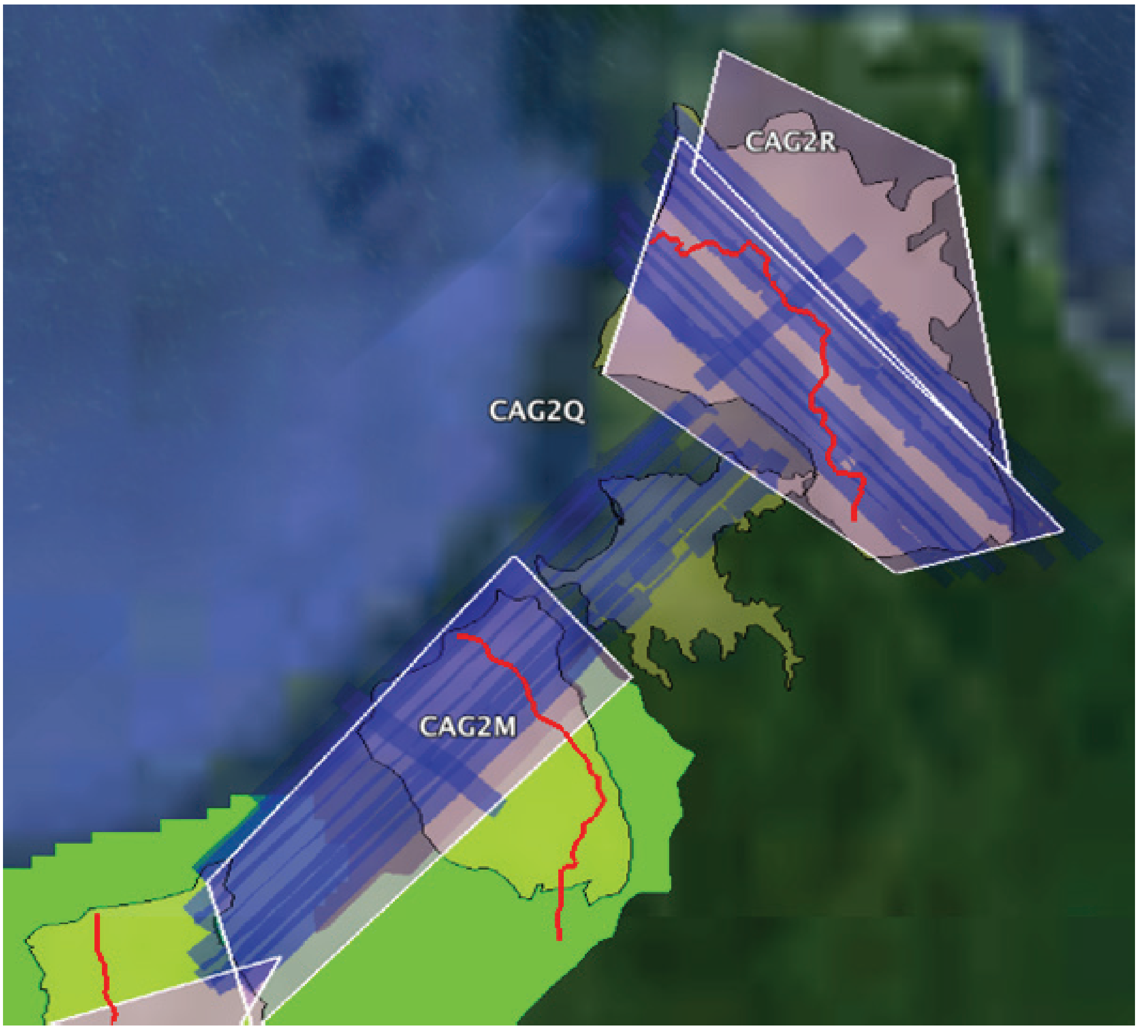
Annex 7. Flight Status Report

CAGAYAN REFLIGHTS
(APRIL 28 – MAY 6, 2016)

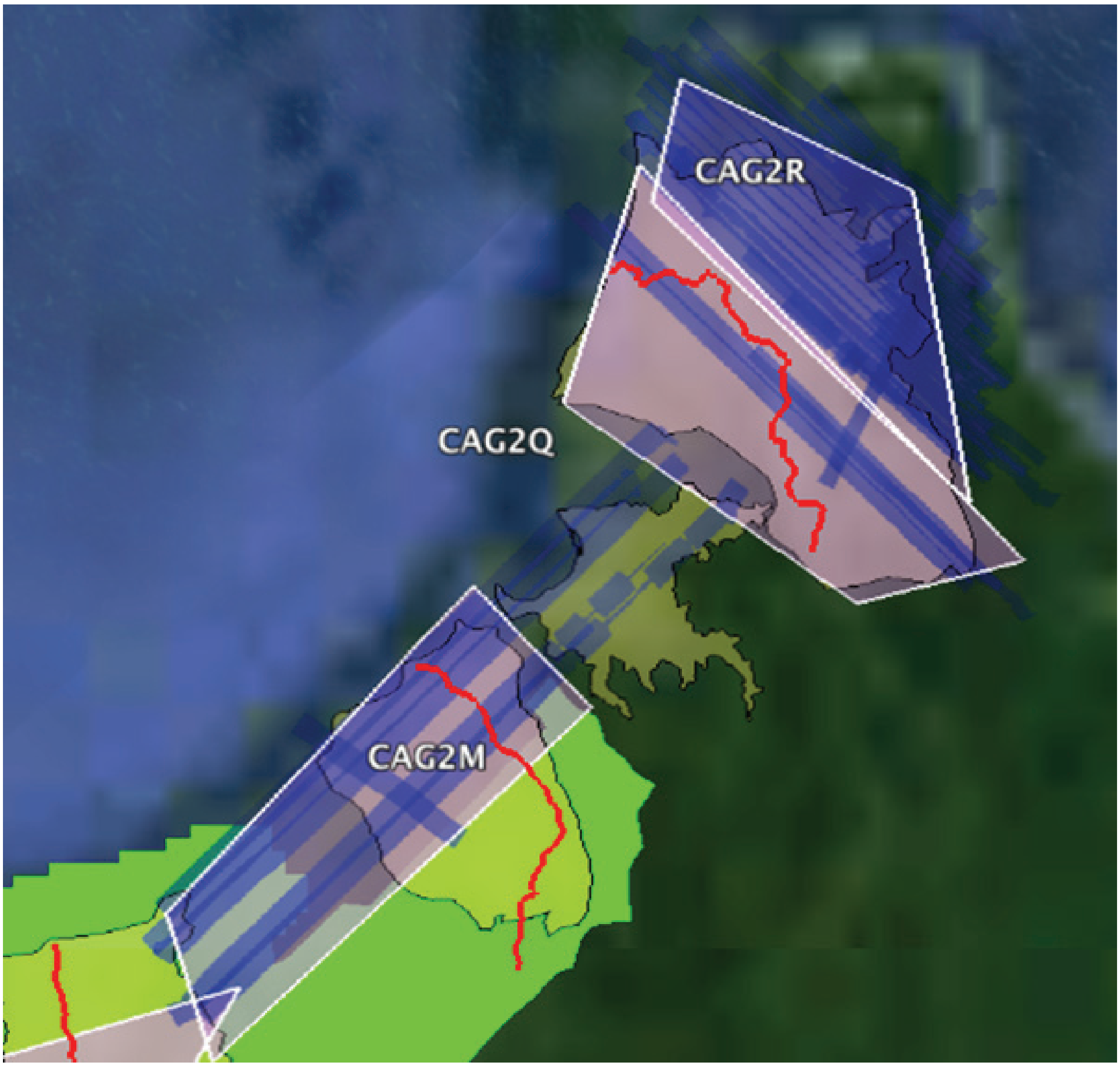
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3971G	CAG2M, CAG2Q, CAG2R	2BLK3CAG2MQR119A	J. ALMALVEZ	APRIL 28, 2016	COVERED CASAMBA-LANGAN, CASAMBA-LANGAN AND PALAWIG FLOODPLAINS
3989G	CAG2C, CAG2J	2CAG2CJ122B	I. ROXAS	May 3, 2016	Covered CAG2J and part of CAG2C
3991G	CAG2M, CAG2Q, CAG2R	2BLK3CAG2MSQS124B	J. ALMALVEZ	May 3, 2016	COVERED CAG2Q AND R
4001G	CAG2M, CAG2R	2BLK3CAG2MRS127A	J. ALMALVEZ	May 6, 2016	COMPLETED CAG2M AND

LAS BOUNDARIES PER FLIGHT

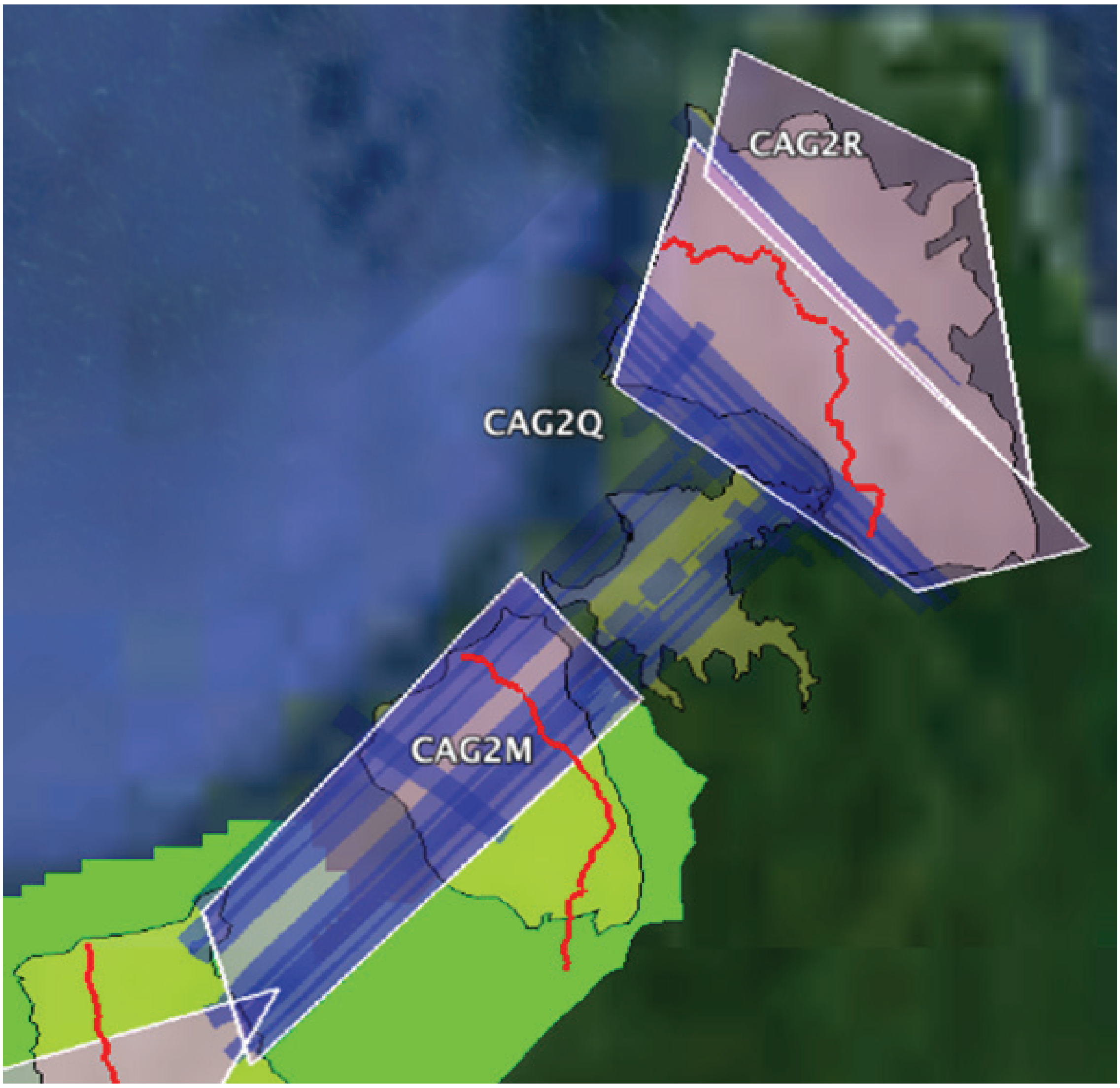
FLIGHT NO.: 3971G
AREA: CAG2M, CAG2Q, CAG2R
MISSION NAME: 2BLK3CAG2MQR119A



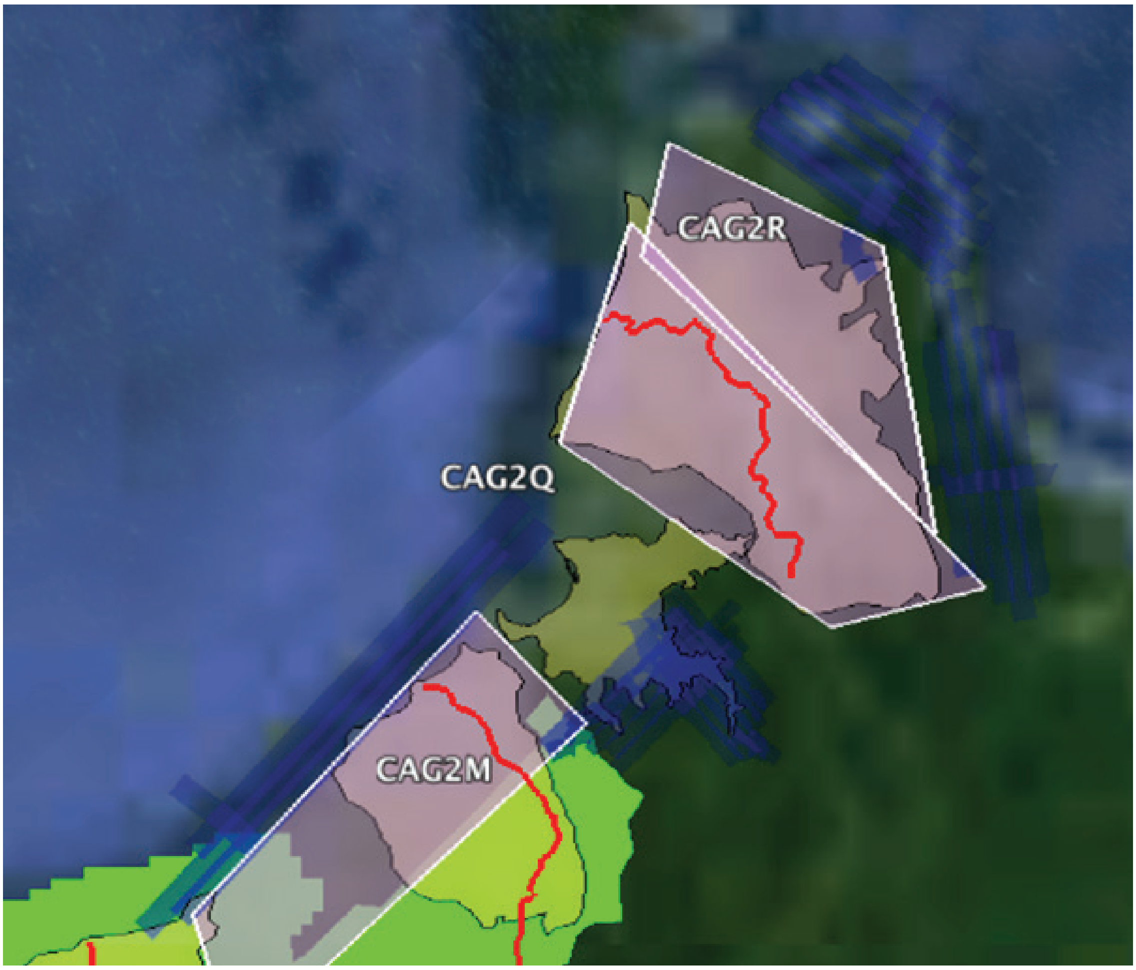
FLIGHT:	**3989G**
AREA:	**CAG2Q, CAG2R**
MISSION NAME:	**2BLK3CAG2QSR124A**



FLIGHT NO.:	3991G
AREA:	CAG2M, CAG2Q, CAG2R
MISSION NAME:	2BLK3CAG2MSQS124B



FLIGHT NO.: 4001G
AREA: CAG2M, CAG2R
MISSION NAME: 2BLK3CAG2MRS127A



Annex 8. Mission Summary Report

Annex 9. Casambalangan Basin Parameters

Basin No.	SCS Curve Number Loss			Clark Unit Hydro-graph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W200	9.5312	85.076	0.0	0.51404	0.62141
W210	9.9978	87.34872	0.0	1.6449	1.9885
W220	31.044	99	0.0	1.4255	1.7233
W230	7.3227	94.21842	0.0	1.5750	1.9041
W240	16.177	68.80716	0.0	3.0787	3.7218
W260	14.703	73.10748	0.0	2.7911	3.3741
W270	17.973	64.46094	0.0	4.8182	5.8246
W280	20.782	64.52622	0.0	1.3281	1.6055
W290	20.782	42.1821	0.0	1.8883	2.2828
W300	20.782	99	0.0	1.4883	1.7992
W310	20.782	65.46258	0.0	0.37340	0.45140
W320	20.782	66.4377	0.0	1.2737	1.5397
W330	20.782	96.47466	0.0	1.3079	1.5811
W340	20.782	63.39096	0.0	0.53044	0.64124
W350	20.782	61.92114	0.0	1.5331	1.8533
W360	20.782	83.01066	0.0	1.1152	1.3481
W370	20.782	64.75674	0.0	0.56328	0.68095
W380	20.782	37.82262	0.0	2.6221	3.1698
W400	20.782	75.98388	0.0	1.5721	1.9005
W410	20.782	61.67532	0.0	2.8717	3.4716

Recession Baseflow				
Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
Dis-charge	0.0011171	0.5	Ratio to Peak	0.02
Dis-charge	0.0220834	0.0967901	Ratio to Peak	0.02
Dis-charge	.000343711	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0204508	0.14519	Ratio to Peak	0.02
Dis-charge	0.0559389	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0610086	0.0987654	Ratio to Peak	0.02
Dis-charge	0.11944	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0375504	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0390112	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0199352	0.14519	Ratio to Peak	0.02
Dis-charge	.000601494	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0212241	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0152951	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0041245	0.0987654	Ratio to Peak	0.02
Dis-charge	0.027325	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0250050	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0034371	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0930597	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0259502	0.0987654	Ratio to Peak	0.02
Dis-charge	0.0818891	0.33178	Ratio to Peak	0.02

Annex 10. Casambalangan Model Reach Parameters

Reach No.	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	154.57	0.0064694	0.04	Trapezoid	96.4344	0.0207
R100	Automatic Fixed Interval	256.11	0.0429508	0.0693883	Trapezoid	96.4344	0.0207
R120	Automatic Fixed Interval	1417.7	0.0550191	0.060163	Trapezoid	96.4344	0.0207
R130	Automatic Fixed Interval	655.80	0.0747176	0.068217	Trapezoid	96.4344	0.0207
R160	Automatic Fixed Interval	5065.3	0.0361280	0.060858	Trapezoid	96.4344	0.0207
R170	Automatic Fixed Interval	437.20	0.0754800	0.0689893	Trapezoid	96.4344	0.0207
R20	Automatic Fixed Interval	346.65	0.0144236	0.0577479	Trapezoid	96.4344	0.0207
R40	Automatic Fixed Interval	1243.0	0.0056314	0.0079012	Trapezoid	96.4344	0.0207
R60	Automatic Fixed Interval	7222.9	0.0132910	0.04508	Trapezoid	96.4344	0.0207
R80	Automatic Fixed Interval	1817.4	0.0390671	0.0461919	Trapezoid	96.4344	0.0207

Annex 11. Casambalangan Field Validation Points

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	18.36518	122.15948	3.09	2.00	-1.09	TS Tasing/ October 1989	5 Yr
2	18.36569	122.15880	1.08	0.10	-0.98	TS Tasing/ October 1989	5 Yr
3	18.36786	122.15804	0.09	0.30	0.21	TS Tasing/ October 1989	5 Yr
4	18.36919	122.13445	1.52	1.20	-0.32	TS Tasing/ October 1989	5 Yr
5	18.36927	122.13758	0.03	1.50	1.47	TS Tasing/ October 1989	5 Yr
6	18.36939	122.13715	0.71	1.00	0.29	TS Tasing/ October 1989	5 Yr
7	18.36958	122.13602	0.87	1.00	0.13	TS Tasing/ October 1989	5 Yr
8	18.36977	122.15723	0.16	0.60	0.44	TS Tasing/ October 1989	5 Yr
9	18.36982	122.13501	1.09	1.00	-0.09	TS Tasing/ October 1989	5 Yr
10	18.36998	122.13452	1.09	1.00	-0.09	TS Tasing/ October 1989	5 Yr
11	18.37078	122.15669	1.97	0.50	-1.47	TS Tasing/ October 1989	5 Yr
12	18.37083	122.13439	1.46	1.50	0.04	TS Tasing/ October 1989	5 Yr
13	18.37132	122.13414	2.03	1.20	-0.83	TS Tasing/ October 1989	5 Yr
14	18.37152	122.15631	1.06	0.30	-0.76	TS Tasing/ October 1989	5 Yr
15	18.37168	122.12637	2.32	0.30	-2.02	TS Tasing/ October 1989	5 Yr
16	18.37232	122.13393	2.15	1.20	-0.95	TS Tasing/ October 1989	5 Yr
17	18.37242	122.12728	1.45	0.20	-1.25	TS Tasing/ October 1989	5 Yr
18	18.37258	122.12608	1.89	0.10	-1.79	TS Tasing/ October 1989	5 Yr
19	18.37269	122.12102	0.39	0.00	-0.39		5 Yr
20	18.37273	122.12610	2.06	0.10	-1.96	TS Tasing/ October 1989	5 Yr
21	18.37275	122.12721	2.89	0.10	-2.79	TS Tasing/ October 1989	5 Yr
22	18.37281	122.13213	0.64	0.40	-0.24	TS Tasing/ October 1989	5 Yr
23	18.37300	122.15476	1.94	0.60	-1.34	TS Tasing/ October 1989	5 Yr
24	18.37291	122.12777	2.64	0.10	-2.54	TS Tasing/ October 1989	5 Yr
25	18.37314	122.13195	1.32	0.30	-1.02	TS Tasing/ October 1989	5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
26	18.37316	122.11983	0.47	0.00	-0.47		5 Yr
27	18.37320	122.12597	1.88	0.10	-1.78	TS Tasing/ October 1989	5 Yr
28	18.37325	122.13171	1.60	0.80	-0.80	TS Tasing/ October 1989	5 Yr
29	18.37322	122.12196	0.03	0.00	-0.03		5 Yr
30	18.37327	122.12060	0.15	0.00	-0.15		5 Yr
31	18.37335	122.13357	2.42	1.00	-1.42	TS Tasing/ October 1989	5 Yr
32	18.37339	122.13151	0.47	0.80	0.33	TS Tasing/ October 1989	5 Yr
33	18.37336	122.12158	0.26	0.00	-0.26		5 Yr
34	18.37347	122.12876	2.62	0.15	-2.47	TS Tasing/ October 1989	5 Yr
35	18.37351	122.12368	0.07	0.00	-0.07		5 Yr
36	18.37367	122.12952	1.41	0.10	-1.31	TS Tasing/ October 1989	5 Yr
37	18.37368	122.12548	0.90	0.10	-0.80		5 Yr
38	18.37384	122.13010	1.01	0.40	-0.61	TS Tasing/ October 1989	5 Yr
39	18.37386	122.13125	1.59	0.50	-1.09	TS Tasing/ October 1989	5 Yr
40	18.37386	122.12568	0.84	0.00	-0.84		5 Yr
41	18.37391	122.13330	2.09	0.80	-1.29	TS Tasing/ October 1989	5 Yr
42	18.37405	122.15355	1.72	0.50	-1.22	TS Tasing/ October 1989	5 Yr
43	18.37395	122.13060	0.82	0.20	-0.62	TS Tasing/ October 1989	5 Yr
44	18.37390	122.11948	0.04	0.00	-0.04		5 Yr
45	18.37392	122.12430	0.08	0.10	0.02	TS Tasing/ October 1989	5 Yr
46	18.37396	122.12965	2.27	0.20	-2.07	TS Tasing/ October 1989	5 Yr
47	18.37406	122.13114	2.17	0.30	-1.87	TS Tasing/ October 1989	5 Yr
48	18.37409	122.13022	1.71	0.10	-1.61	TS Tasing/ October 1989	5 Yr
49	18.37410	122.13135	2.47	0.40	-2.07	TS Tasing/ October 1989	5 Yr
50	18.37415	122.12960	3.41	0.20	-3.21	TS Tasing/ October 1989	5 Yr
51	18.37414	122.12529	0.03	0.00	-0.03		5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
52	18.37417	122.13229	2.21	0.50	-1.71	TS Tasing/ October 1989	5 Yr
53	18.37427	122.12649	0.60	0.00	-0.60		5 Yr
54	18.37437	122.11925	0.03	0.00	-0.03		5 Yr
55	18.37444	122.13014	2.35	0.30	-2.05	TS Tasing/ October 1989	5 Yr
56	18.37454	122.12127	0.10	0.00	-0.10		5 Yr
57	18.37462	122.12613	0.03	0.00	-0.03		5 Yr
58	18.37462	122.12613	0.03	0.00	-0.03		5 Yr
59	18.37467	122.13010	2.85	0.30	-2.55	TS Tasing/ October 1989	5 Yr
60	18.37467	122.12332	0.03	0.00	-0.03		5 Yr
61	18.37474	122.12691	0.30	0.00	-0.30		5 Yr
62	18.37476	122.12767	0.70	0.00	-0.70		5 Yr
63	18.37487	122.11957	0.03	0.00	-0.03		5 Yr
64	18.37497	122.12606	0.03	0.00	-0.03		5 Yr
65	18.37499	122.12795	0.58	0.00	-0.58		5 Yr
66	18.37503	122.13001	2.87	0.40	-2.47	TS Tasing/ October 1989	5 Yr
67	18.37504	122.12716	0.32	0.00	-0.32		5 Yr
68	18.37515	122.14915	1.24	0.50	-0.74	TS Tasing/ October 1989	5 Yr
69	18.37531	122.14990	1.39	0.60	-0.79	TS Tasing/ October 1989	5 Yr
70	18.37522	122.12959	3.71	0.20	-3.51	TS Tasing/ October 1989	5 Yr
71	18.37524	122.12994	3.77	0.30	-3.47	TS Tasing/ October 1989	5 Yr
72	18.37535	122.15105	1.35	0.50	-0.85	TS Tasing/ October 1989	5 Yr
73	18.37524	122.12260	0.24	0.00	-0.24		5 Yr
74	18.37528	122.12820	0.70	0.00	-0.70		5 Yr
75	18.37539	122.14803	1.29	0.20	-1.09	TS Tasing/ October 1989	5 Yr
76	18.37532	122.12935	2.15	0.00	-2.15		5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
77	18.37530	122.12087	0.03	0.00	-0.03		5 Yr
78	18.37536	122.12925	2.06	0.40	-1.66	TS Tasing/ October 1989	5 Yr
79	18.37538	122.12865	1.37	0.00	-1.37		5 Yr
80	18.37547	122.12818	0.55	0.00	-0.55		5 Yr
81	18.37573	122.14601	1.16	0.30	-0.86	TS Tasing/ October 1989	5 Yr
82	18.37565	122.12036	0.03	0.00	-0.03		5 Yr
83	18.37575	122.12610	0.33	0.00	-0.33		5 Yr
84	18.37575	122.12419	0.22	0.00	-0.22		5 Yr
85	18.37576	122.12189	0.85	0.00	-0.85		5 Yr
86	18.37586	122.12929	2.42	0.20	-2.22	TS Tasing/ October 1989	5 Yr
87	18.37591	122.12664	0.03	0.00	-0.03		5 Yr
88	18.37614	122.14476	1.02	0.30	-0.72	TS Tasing/ October 1989	5 Yr
89	18.37611	122.12795	0.05	0.00	-0.05		5 Yr
90	18.37615	122.12899	1.45	0.10	-1.35	TS Tasing/ October 1989	5 Yr
91	18.37623	122.12687	0.03	0.00	-0.03		5 Yr
92	18.37628	122.12106	0.03	0.00	-0.03		5 Yr
93	18.37649	122.12503	0.03	0.00	-0.03		5 Yr
94	18.37670	122.12153	0.03	0.30	0.27	TS Tasing/ October 1989	5 Yr
95	18.37679	122.12877	0.03	0.00	-0.03		5 Yr
96	18.37680	122.12774	0.33	0.00	-0.33		5 Yr
97	18.37684	122.12648	0.03	0.00	-0.03		5 Yr
98	18.37702	122.12417	0.27	0.10	-0.17	TS Tasing/ October 1989	5 Yr
99	18.37702	122.12360	0.03	0.20	0.17	TS Lawin/ October 2016	5 Yr
100	18.37723	122.12862	0.78	0.10	-0.68	TS Tasing/ October 1989	5 Yr
101	18.37723	122.12248	0.11	0.30	0.19	TS Tasing/ October 1989	5 Yr
102	18.37730	122.12330	0.03	0.30	0.27	TS Tasing/ October 1989	5 Yr
103	18.37739	122.12874	1.21	0.20	-1.01	TS Tasing/ October 1989	5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
104	18.37740	122.12344	0.03	0.30	0.27	TS Tasing/ October 1989	5 Yr
105	18.37743	122.12570	0.27	0.10	-0.17	TS Tasing/ October 1989	5 Yr
106	18.37758	122.14417	4.92	0.50	-4.42	TS Tasing/ October 1989	5 Yr
107	18.37765	122.12591	0.63	0.00	-0.63		5 Yr
108	18.37769	122.12743	0.03	0.00	-0.03		5 Yr
109	18.37784	122.12508	0.03	0.00	-0.03		5 Yr
110	18.37806	122.12825	0.03	0.00	-0.03		5 Yr
111	18.37816	122.12629	0.03	0.00	-0.03		5 Yr
112	18.37819	122.12887	0.03	0.30	0.27	TS Tasing/ October 1989	5 Yr
113	18.37848	122.14402	3.07	1.00	-2.07	TS Tasing/ October 1989	5 Yr
114	18.37862	122.12713	0.03	0.00	-0.03		5 Yr
115	18.37867	122.12948	3.90	0.00	-3.90		5 Yr
116	18.37873	122.12485	0.03	0.20	0.17	TS Lawin/ October 2016	5 Yr
117	18.37886	122.12676	0.03	0.00	-0.03		5 Yr
118	18.37906	122.14391	2.75	1.50	-1.25	TS Tasing/ October 1989	5 Yr
119	18.37942	122.14376	3.16	1.00	-2.16	TS Tasing/ October 1989	5 Yr
120	18.37942	122.12630	0.03	0.30	0.27	TS Lawin/ October 2016	5 Yr
121	18.37950	122.13930	2.26	0.50	-1.76	TS Tasing/ October 1989	5 Yr
122	18.37974	122.14408	1.32	0.80	-0.52	TS Tasing/ October 1989	5 Yr
123	18.37968	122.13153	0.03	0.00	-0.03		5 Yr
124	18.37974	122.12700	0.03	0.30	0.27	TS Lawin/ October 2016	5 Yr
125	18.37982	122.14106	0.07	0.00	-0.07		5 Yr
126	18.37978	122.12743	0.05	0.50	0.45	TS Tasing/ October 1989	5 Yr
127	18.37988	122.12745	0.03	0.30	0.27	TS Lawin/ October 2016	5 Yr
128	18.37995	122.13207	2.89	0.00	-2.89		5 Yr
129	18.38001	122.13812	1.02	0.30	-0.72	TS Tasing/ October 1989	5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
130	18.38006	122.14410	0.33	0.50	0.17	TS Tasing/ October 1989	5 Yr
131	18.38010	122.12774	0.03	0.50	0.47	TS Tasing/ October 1989	5 Yr
132	18.38013	122.12785	0.09	0.50	0.41	TS Tasing/ October 1989	5 Yr
133	18.38028	122.12808	0.03	0.30	0.27	TS Tasing/ October 1989	5 Yr
134	18.38039	122.14352	0.03	0.10	0.07	TS Tasing/ October 1989	5 Yr
135	18.38053	122.12878	1.77	2.00	0.23	TS Lawin/ October 2016	5 Yr
136	18.38061	122.12829	0.24	0.60	0.36	TS Tasing/ October 1989	5 Yr
137	18.38098	122.13422	0.07	0.00	-0.07		5 Yr
138	18.38110	122.13743	1.44	0.20	-1.24	TS Tasing/ October 1989	5 Yr
139	18.38108	122.12870	0.81	0.80	-0.01	TS Tasing/ October 1989	5 Yr
140	18.38183	122.12921	0.63	1.20	0.57	TS Tasing/ October 1989	5 Yr
141	18.38193	122.13714	1.62	0.10	-1.52	TS Tasing/ October 1989	5 Yr
142	18.38219	122.13594	0.54	0.00	-0.54		5 Yr
143	18.38247	122.12950	0.14	1.20	1.06	TS Tasing/ October 1989	5 Yr
144	18.38288	122.13677	0.71	0.00	-0.71		5 Yr
145	18.38353	122.13662	0.13	0.00	-0.13		5 Yr
146	18.38351	122.12983	0.19	1.50	1.31	TS Tasing/ October 1989	5 Yr
147	18.38377	122.12995	0.56	1.80	1.24	TS Tasing/ October 1989	5yr
148	18.38672	122.13754	0.03	0.00	-0.03		5yr
149	18.38688	122.13673	0.03	0.00	-0.03		5yr
150	18.38720	122.13775	0.03	0.00	-0.03		5yr
151	18.38721	122.13635	0.03	0.00	-0.03		5yr
152	18.38784	122.13781	0.03	0.00	-0.03		5yr
153	18.38819	122.13645	0.03	0.00	-0.03		5yr
154	18.38910	122.13655	0.03	0.00	-0.03		5yr
155	18.38913	122.13764	0.03	0.00	-0.03		5yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
156	18.38917	122.13682	0.76	0.00	-0.76		5yr
157	18.38929	122.14740	0.50	0.30	-0.20	TS Tasing/ October 1989	5yr
158	18.38926	122.13554	0.03	0.00	-0.03		5yr
159	18.38945	122.14861	0.03	0.20	0.17	TS Tasing/ October 1989	5yr
160	18.38987	122.14973	1.35	0.10	-1.25	TS Tasing/ October 1989	5yr
161	18.39025	122.15029	0.03	0.00	-0.03		5yr
162	18.39033	122.14645	1.19	0.20	-0.99	TS Tasing/ October 1989	5yr
163	18.39037	122.15044	0.03	0.00	-0.03		5yr
164	18.39038	122.13767	0.41	0.00	-0.41		5yr
165	18.39048	122.14638	1.25	0.30	-0.95	TS Tasing/ October 1989	5yr
166	18.39086	122.15132	0.03	0.00	-0.03		5yr
167	18.39081	122.13791	2.09	0.00	-2.09		5yr
168	18.39087	122.13793	1.58	0.00	-1.58		5yr
169	18.39113	122.15186	0.03	0.00	-0.03		5yr
170	18.39116	122.14568	1.04	0.30	-0.74	TS Tasing/ October 1989	5yr
171	18.39133	122.14535	0.10	0.40	0.30	TS Tasing/ October 1989	5yr
172	18.39148	122.15288	0.04	0.00	-0.04		5yr
173	18.39177	122.13855	0.90	0.00	-0.90		5yr
174	18.39188	122.14428	0.34	0.30	-0.04	TS Tasing/ October 1989	5yr
175	18.39205	122.13133	0.32	0.10	-0.22	TS Tasing/ October 1989	5yr
176	18.39236	122.14381	1.19	0.60	-0.59	TS Tasing/ October 1989	5yr
177	18.39241	122.14379	1.19	0.30	-0.89	TS Tasing/ October 1989	5yr
178	18.39264	122.14320	1.01	0.40	-0.61	TS Tasing/ October 1989	5yr
179	18.39268	122.14196	0.76	0.40	-0.36	TS Tasing/ October 1989	5yr
180	18.39265	122.13113	0.03	0.10	0.07	TS Tasing/ October 1989	5yr
181	18.39271	122.14005	1.37	0.30	-1.07	TS Tasing/ October 1989	5yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
182	18.39271	122.14109	1.12	0.30	-0.82	TS Tasing/ October 1989	5yr
183	18.39277	122.13864	1.75	0.30	-1.45	TS Tasing/ October 1989	5yr
184	18.39350	122.13746	0.03	0.00	-0.03		5yr
185	18.39348	122.13072	0.31	0.10	-0.21	TS Tasing/ October 1989	5yr
186	18.39372	122.12976	0.17	0.10	-0.07	TS Tasing/ October 1989	5yr
187	18.39399	122.12913	0.03	0.00	-0.03		5yr
188	18.39421	122.13567	0.04	0.00	-0.04		5yr
189	18.39497	122.12856	0.07	0.00	-0.07		5yr
190	18.39523	122.13305	0.03	0.00	-0.03		5yr
191	18.39572	122.12921	0.06	0.00	-0.06		5yr
192	18.39613	122.12865	0.09	0.00	-0.09		5yr
193	18.39625	122.12730	0.13	0.00	-0.13		5yr
194	18.39643	122.13080	0.03	0.00	-0.03		5yr
195	18.39721	122.12584	0.32	0.00	-0.32		5yr
196	18.39882	122.12543	0.03	0.00	-0.03		5yr

Annex 12. Educational Institutions Affected by flooding in Casambalangan

Cagayan				
Sta. Ana				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Casambalangan Day Care Center	Casambalangan		High	High
Casambalangan Elementary School	Casambalangan		Medi-um	Medi-um
Casambalangan National High School	Casambalangan	Low	Medi-um	Medi-um
Punti Day Care Center	Rapuli	Low	Medi-um	Medi-um
Punti Elementary School	Rapuli	Low	Medi-um	Medi-um

Annex 13. Health Institutions affected by flooding in Casambalangan Flood-

Cagayan				
Sta. Ana				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Rapuli Barangay Hall	Rapuli	Medium	Medium	Medium