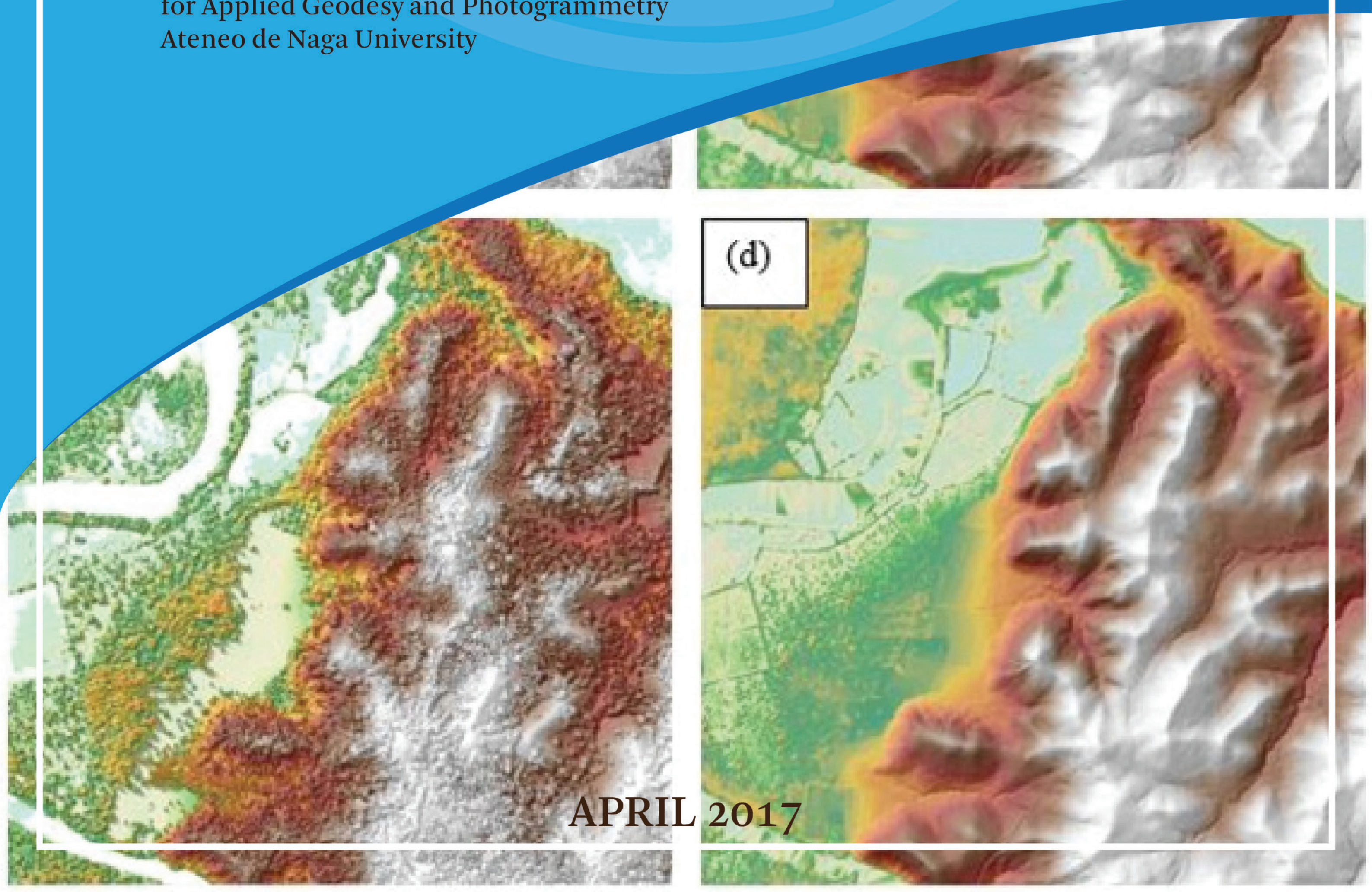
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Baleno River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Naga University



APRIL 2017

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

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

E.C. Paringit and J.C. Plopenio (eds.) (2017), LiDAR Surveys and Flood Mapping of Baleno River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-136pp.

For questions/queries regarding this report, contact:

Ms. Joanaviva C. Plopenio
Project Leader, Phil-LiDAR 1 Program
Ateneo de Naga University
Naga City, Philippines 4400
inecar@gbox.adnu.edu.ph

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

National Library of the Philippines
ISBN: 978-971-9695-59-2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva C. Plopenio, and Engr. Ferdinand Bien

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga University (ADNU). ADNU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 24 river basins in the Bicol region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Baleno River Basin

Baleno river basin is under the jurisdiction of a fourth-class municipality, Baleno town, and Masbate City which is a component city. Masbate City has a population of 95,359 while Baleno has 26,096 as of the 2015 census.

The major stream draining this basin is approximately 16.7 km long and is named the Baleno River. This empties out to Masbate Pass, the stretch of ocean between Ticao Island and mainland Masbate. It is bound to the west east and the west by very low hills. Down south, near where the headwaters are, the area is used for agricultural purposes.

The river basin experiences Type II climate where seasons are not pronounced except for having relatively dry months during November to April and wet during the rest of the year. Most agricultural produce includes corn, coconut, rice, and root crops. The area is also into producing cattle. In fact, the whole Masbate Province is second to Bukidnon in cattle-raising. Coastal barangays are into fisheries.

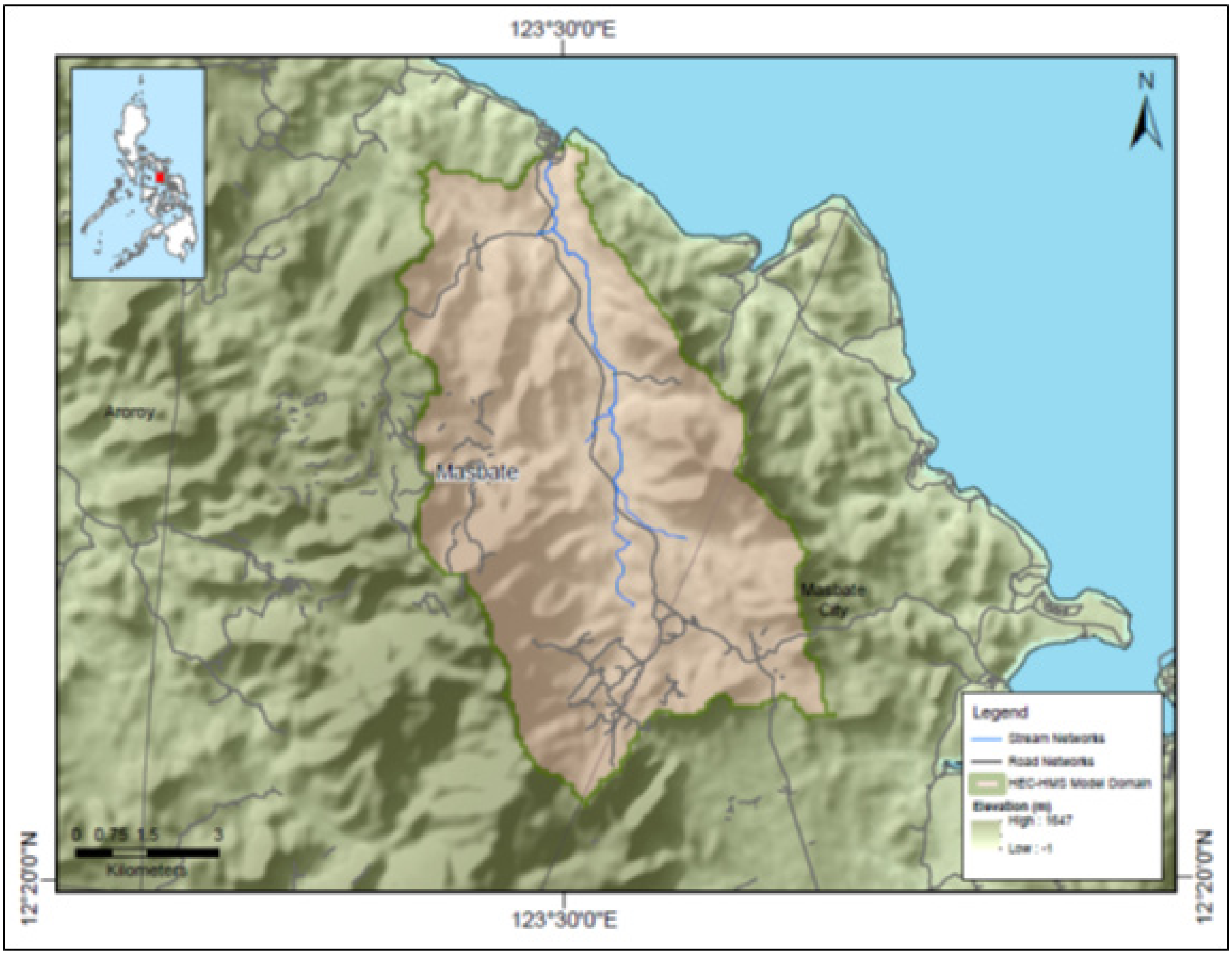


Figure 1. Location Map of the Baleno River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BALENO FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, and Engr. Grace Sinadjan

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Baleno floodplain in Masbate. These missions were planned for 14 lines that run for at most four (4) hours including take-off, landing, and turning time. The flight planning parameters used for the Pegasus LiDAR system is found in Table 1. Figure 2 shows the flight plan for Baleno floodplain survey.

Table 1. Flight planning parameters for Pegasus 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)
BLK32A	1000, 1200	30	50	200	30	130	5
BLK32B	1000, 1200	30	50	200	30	130	5
BLK32C	1000, 1200	30	50	200	30	130	5
BLK32D	1000, 1200	25, 30, 35, 40	50	200	30	130	5
BLK32G	1000, 1200	30	50	200	30	130	5

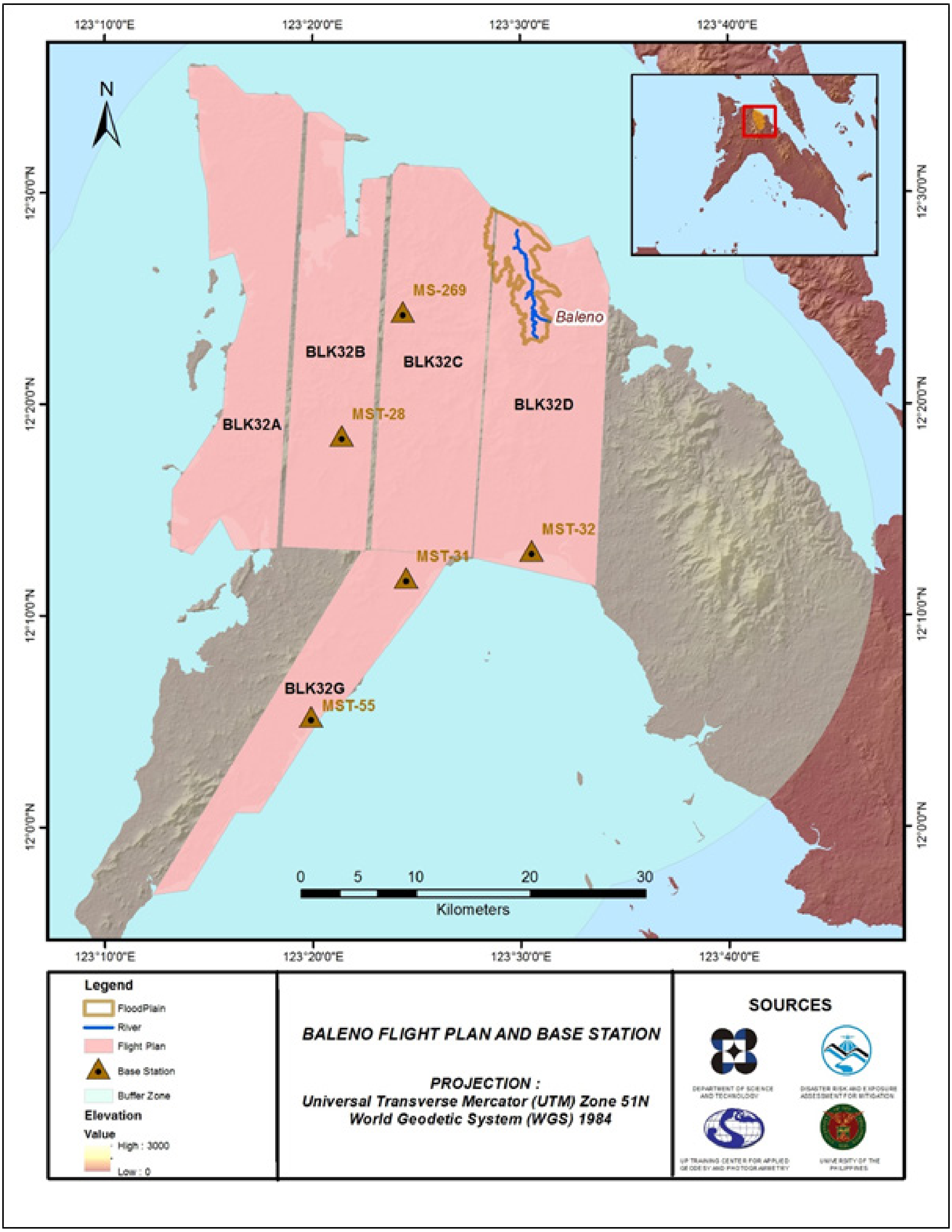


Figure 2. Flight plans and base stations used to cover Baleno floodplain.

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: MST-28, MST-31, MST-32, and MST-55 which are all of second (2nd) order accuracy and one (1) NAMRIA benchmark: MS-269 which is of first (1st) order accuracy. The benchmark was used as vertical reference point and was established as ground control point. The certifications for the NAMRIA reference points and benchmark are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (April 4 – 10, 2014). 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 Baleno floodplain are shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 6 show the details about the following NAMRIA control stations, while Table 7 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

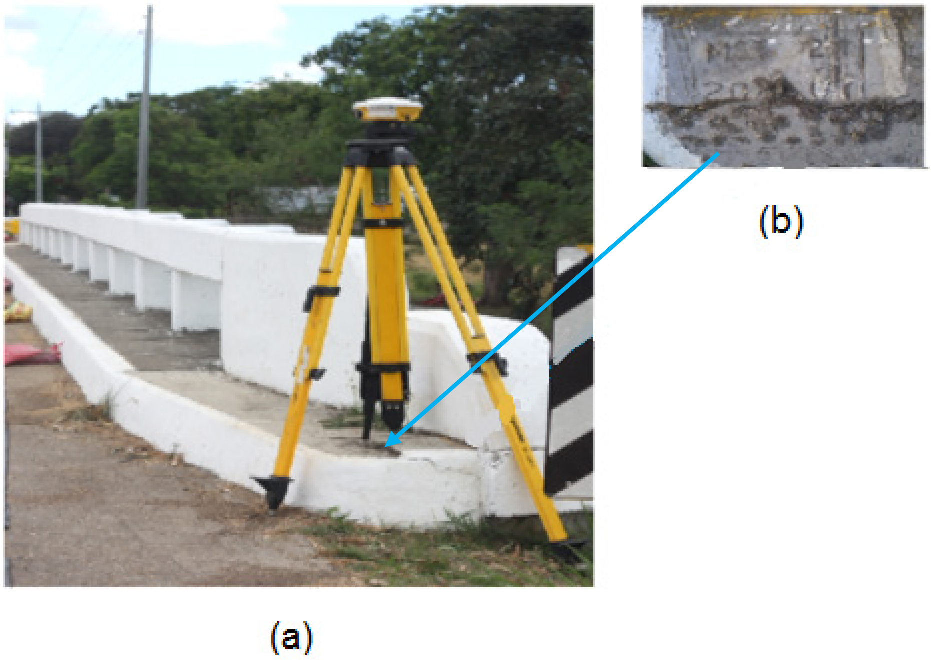


Figure 3. GPS set-up over MST-28 in Mambog Bridge, Barangay Bat-ongan, municipality of Mandaon, Masbate (a) and NAMRIA reference point MST-28 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MST-28 used as base station for the LiDAR acquisition.

Station Name	MST-28	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 18' 35.15371" North 123° 21' 19.21293" East 49.12800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	538651.166 meters 1361224.57 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 18' 30.47973" North 123° 21' 24.28923" East 104.64900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	538637.64 meters 1360748.12 meters

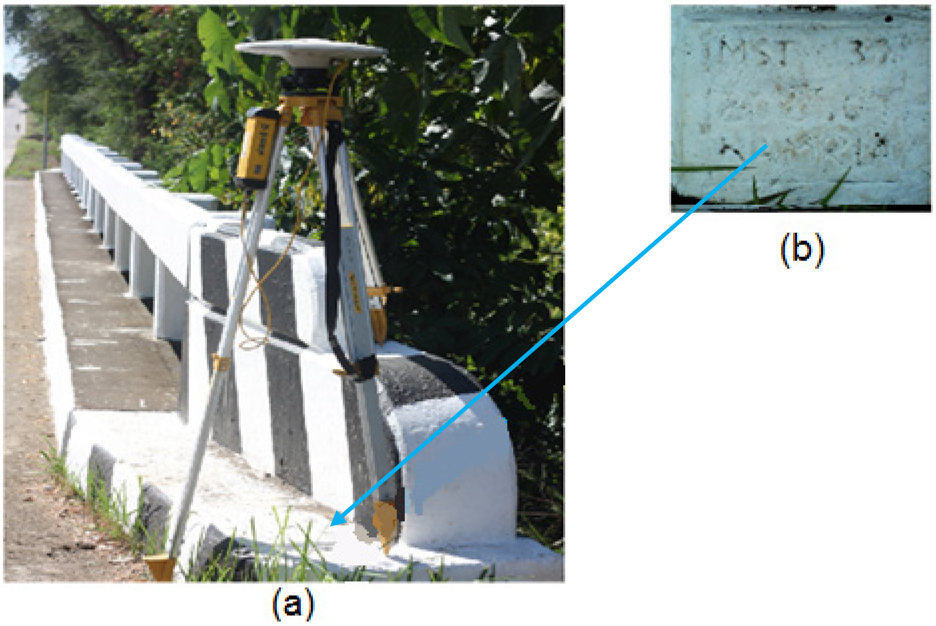


Figure 4. GPS set-up over MST-31 in Boracay Bridge, Barangay Bangad, municipality of Milagros, Masbate (a) and NAMRIA reference point MST-31 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MST-31 used as base station for the LiDAR Acquisition.

Station Name	MST-31	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 11’ 50.29728” North 123° 24’ 24.05419” East 18.45000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	544254.929 meters 1384892.732 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 11’ 45.65539” North 123° 24’ 29.13992” East 74.38600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	544239.44 meters 1348320.63 meters

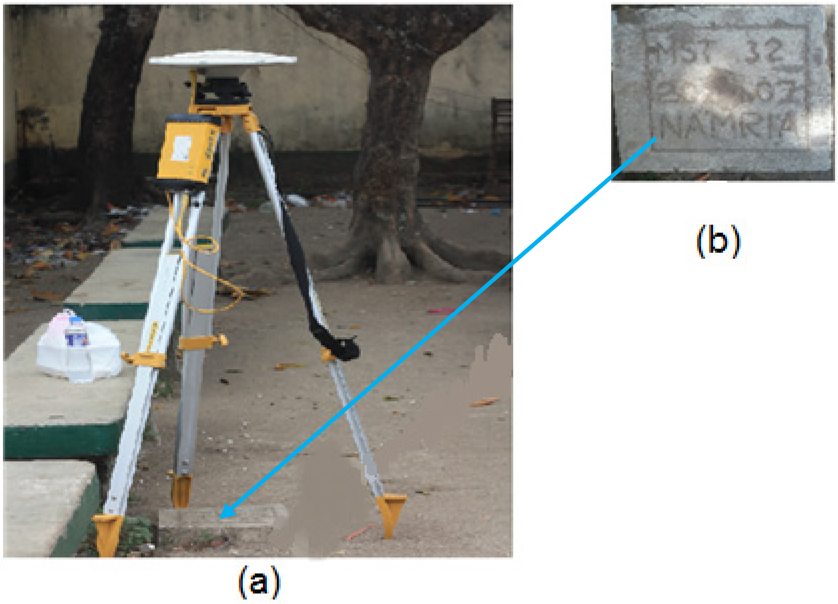


Figure 5. GPS set-up over MST-32 inside the compound of the Milagros Municipal Hall, Masbate (a) and NAMRIA reference point MST-32 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MST-32 used as base station for the LiDAR acquisition.

Station Name	MST-32	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 13' 7.66936" North 123° 30' 26.72479" East 3.78300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	555213.396 meters 1351188.593 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 13' 3.03064" North 123° 30' 31.80788" East 59.91100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1984)	Easting Northing	555194.07 meters 1350715.65 meters

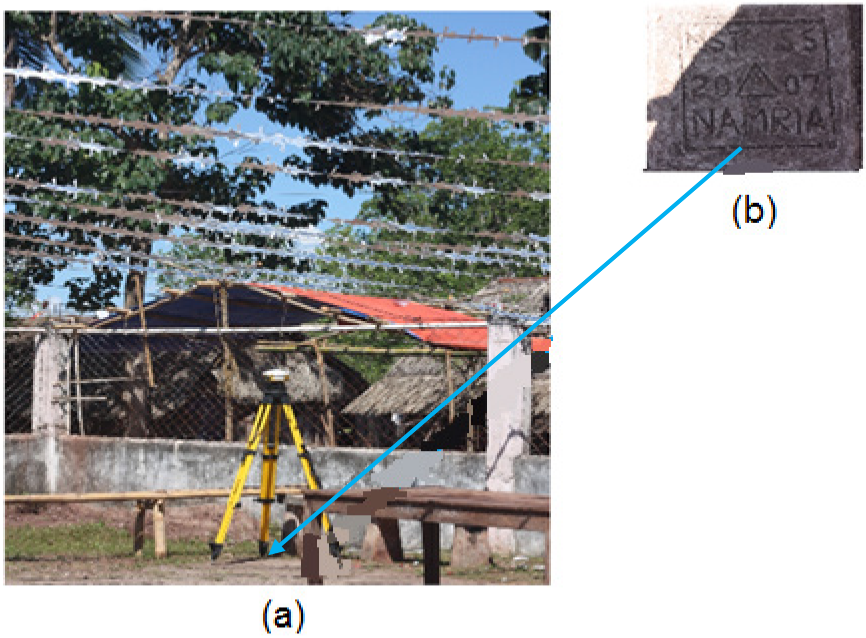


Figure 6. GPS set-up over MST-55 inside the compound of Casamongan Brgy. Hall, municipality of Balud, Masbate (a) and NAMRIA reference point MST-55 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MST-55 used as base station for the LiDAR acquisition.

Station Name	MST-55	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 05’ 16.28892” North 123° 19’ 50.73333” East 3.33300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	536007.686 meters 1336676.257 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 5’ 11.66770” North 123° 19’ 55.82918” East 59.36300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1984)	Easting Northing	535995.08 meters 1336207.40 meters

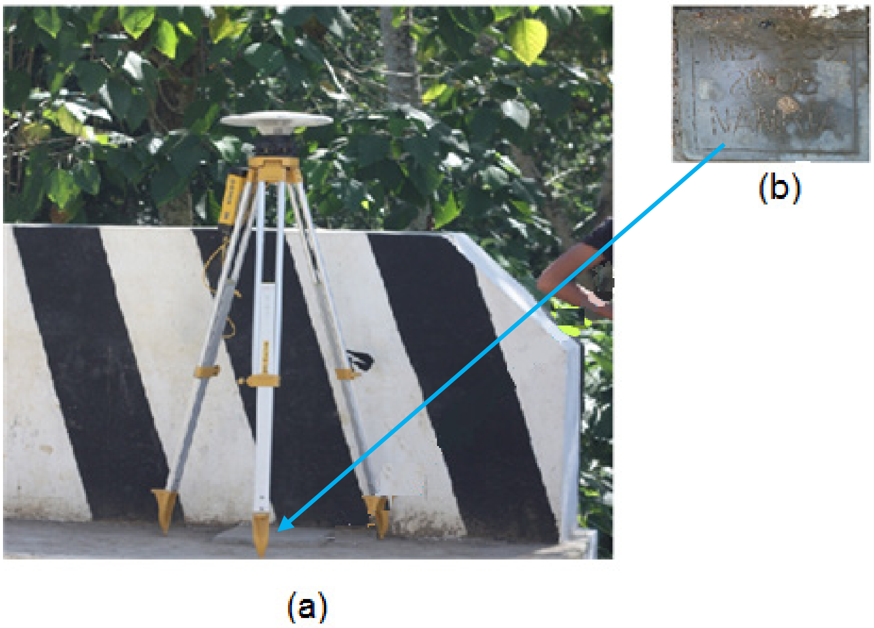


Figure 7. GPS set-up over MS-269 in Luy-a Bridge in Aroroy, Masbate (a) and NAMRIA benchmark MS-269 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA vertical control point MS-269 used as base station for the LiDAR acquisition with established coordinates.

Station Name	**MS-269**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 :50,000**	
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 24’ 21.62786” North 123° 24’ 21.40082” East 83.308 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 84)	Easting Northing	544123.868 meters 1,902,971.42 meters
Elevation (mean sea level)	27.4076 meters	

Table 7. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
April 4, 2014	1303P	1BLK32A094A	MS-269 & MST-28
April 5, 2014	1307P	1BLK32DG095A	MST 31 & MST 55
April 10, 2014	1327P	1BLK32D100A	MST 28 & MST 32

2.3 Flight Missions

Three (3) missions were conducted to complete LiDAR data acquisition in Baleno floodplain, for a total of eleven hours and fifty one minutes (11+51) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR systems. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Baleno floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
April 4, 2014	1303P	277.3	301.884	5.834	296.05	800	3	41
April 5, 2014	1307P	509.4	344.804	3.75	341.054	326	4	29
April 10, 2014	1327P	315.5	202.254	32.991	169.263	326	3	41
TOTAL		1102.2	848.942	42.575	806.367	1452	11	51

Table 9. 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)
1303P	1000, 1200	30	50	200	30	130	5
1307P	1000	25, 30	50	200	30	130	5
1327P	1000, 1200	30, 35, 40	50	200	30	130	5

2.4 Survey Coverage

Baleno floodplain is located in the province of Masbate, with majority of the floodplain situated within the municipality of Baleno. Municipalities of Masbate City and Baleno are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Baleno floodplain is presented in Figure 8.

Table 10. List of municipalities and cities surveyed during Baleno floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Masbate	Masbate City	192.96	120.50	62%
	Baleno	200.24	110.60	55%
	Milagros	530.43	198.58	37%
	Aroroy	403.62	121.30	30%
	Mandaon	267.43	63.42	24%
	Balud	217.54	46.34	21%
TOTAL		1812.22	660.74	38.17%

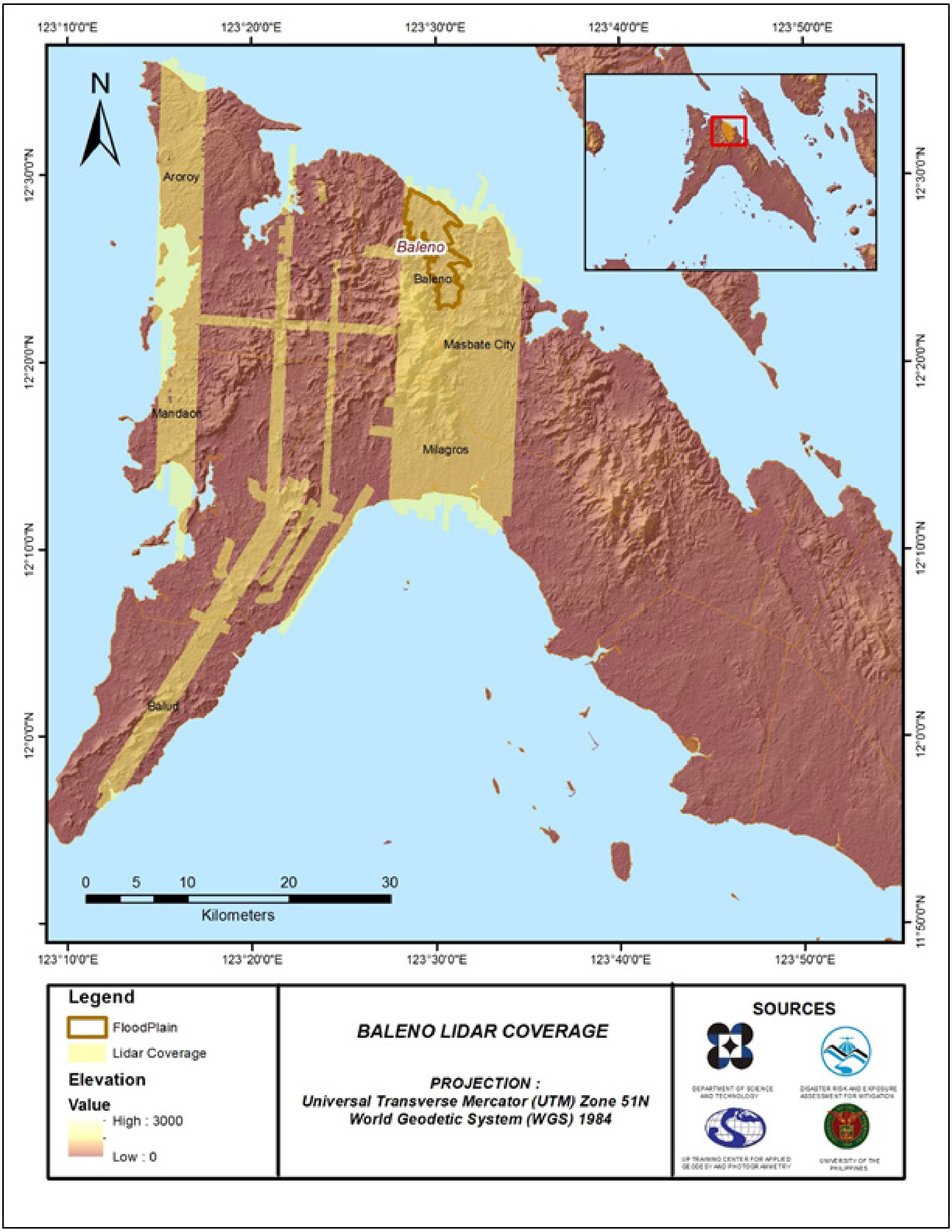


Figure 8. Actual LiDAR survey coverage for Baleno floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BALENO FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Gladys Mae Apat, Engr. Harmond F. Santos, Engr. Ma. Ailyn L. Olanda, Engr. Christy T. Lubiano, Aljon Rie V. Araneta, Jerry P. Ballori, Jaylyn L. Paterno, Ma. Jemelita Adbalagao, Daniel Baer, Francis Patray P. Bolaños, Engr. Mary Ruth A. Bongon. Carlota M. Davocol, Mark D. Delloro, Sarah Mae F. Fulleros, Berlin Phil V. Garciano, Jan Karl T. Ilarde, Julius Hector S. Manchete, Ernesto Razal Jr., Richmund P. Saldo, Aaron P. San Andres, Jayrik T. San Buenaventura, Jess Andre S. Soller, Engr. Herminio Magpantay and Engr. Ferdinand E. Bien

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 9.

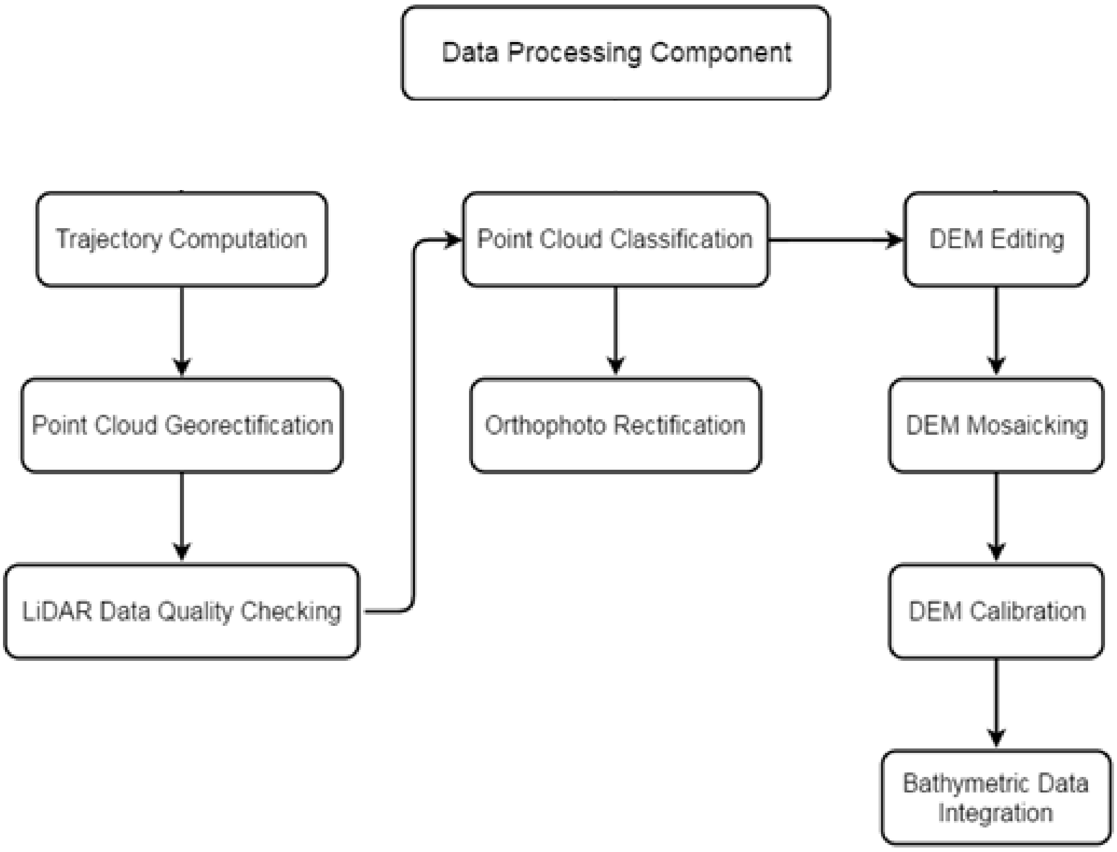


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Baleno floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on April 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Municipality of Baleno, Masbate.

The Data Acquisition Component (DAC) transferred a total of 88.80 Gigabytes of Range data, 664 Megabytes of POS data, 18.43 Megabytes of GPS base station data, and 156.70 Gigabytes of raw image data to the data server on April 22, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Baleno was fully transferred on April 23, 2014 as indicated on the Data Transfer Sheets for Baleno floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1307P, one of the Baleno flights, which is the North, East, and Down position RMSE values are shown in Figure 10. 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 April 05, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

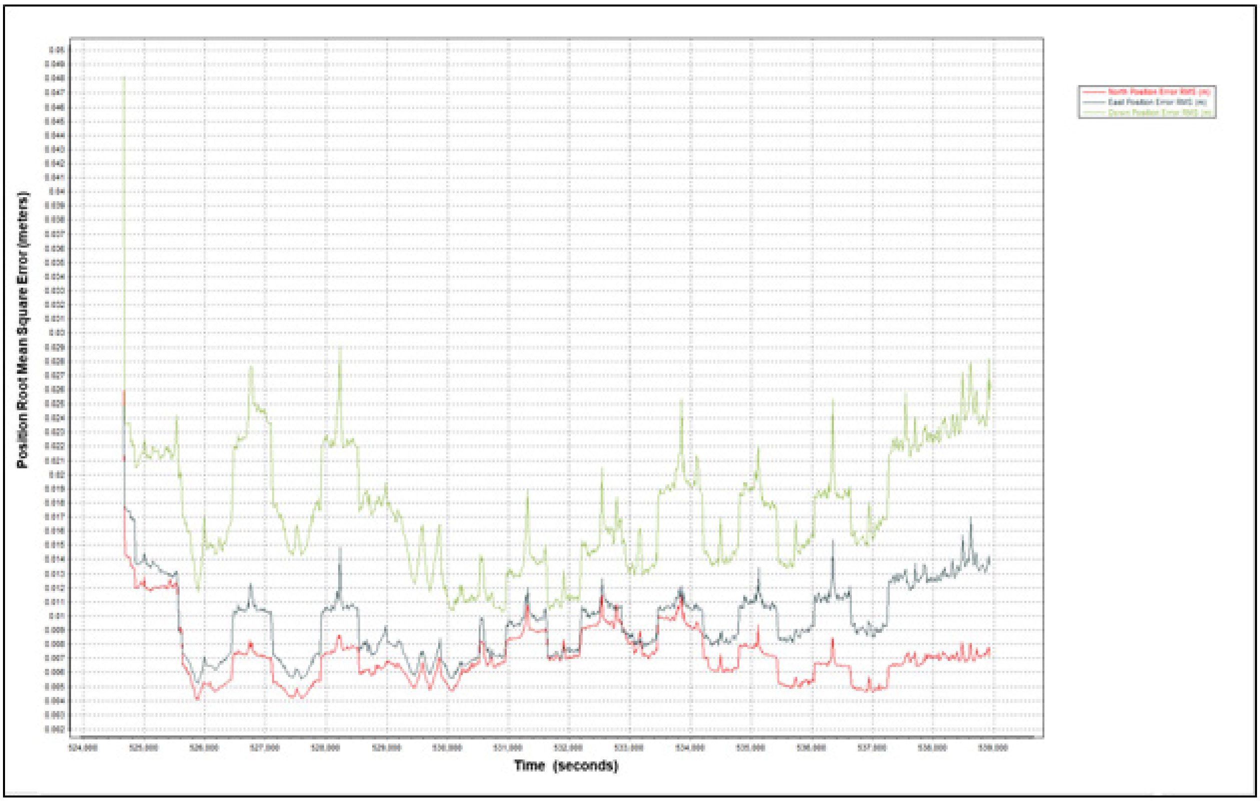


Figure 10. Smoothed Performance Metrics of a Baleno Flight 1307P.

The time of flight was from 524,000 seconds to 539,000 seconds, which corresponds to morning of April 05, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.28 centimeters, the East position RMSE peaks at 1.70 centimeters, and the Down position RMSE peaks at 2.90 centimeters, which are within the prescribed accuracies described in the methodology.

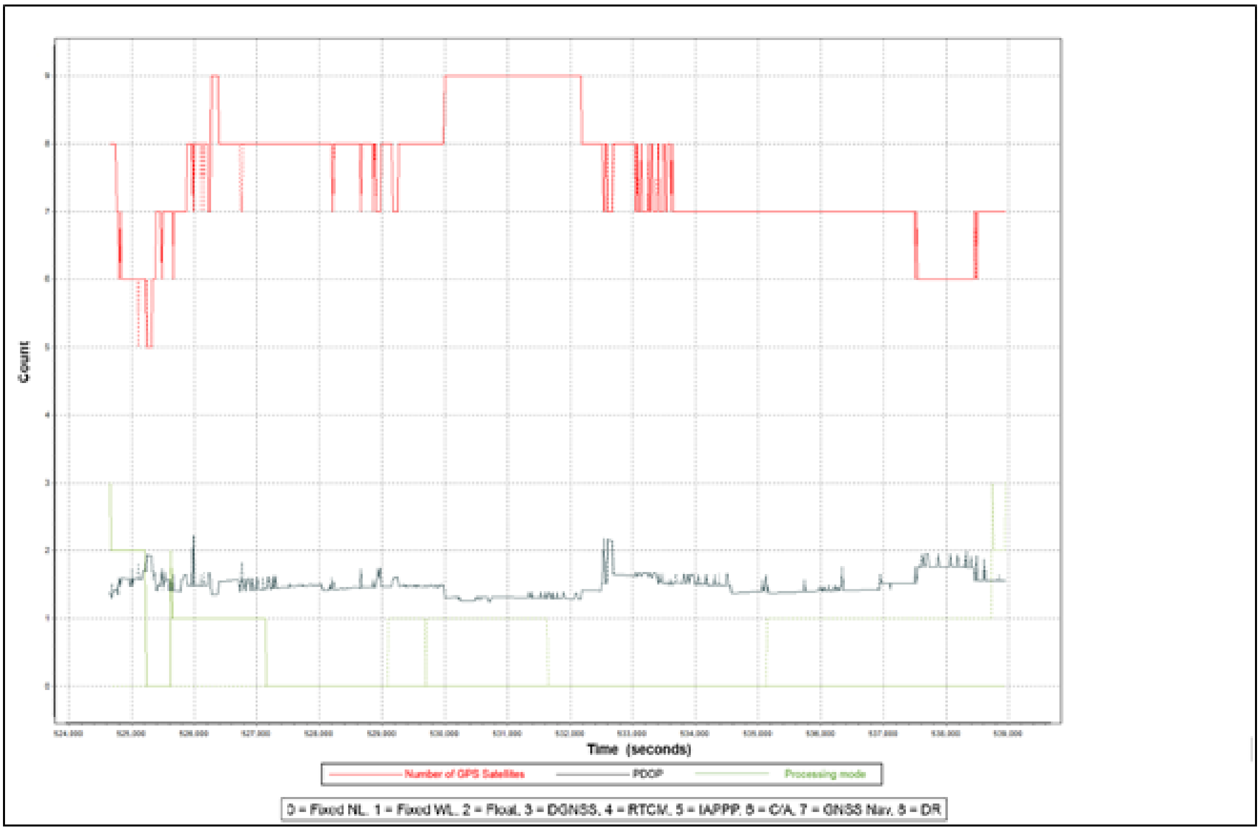


Figure 11. Solution Status Parameters of Baleno Flight 1307P.

The Solution Status parameters of flight 1307P, one of the Baleno flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Baleno flights is shown in Figure 12.

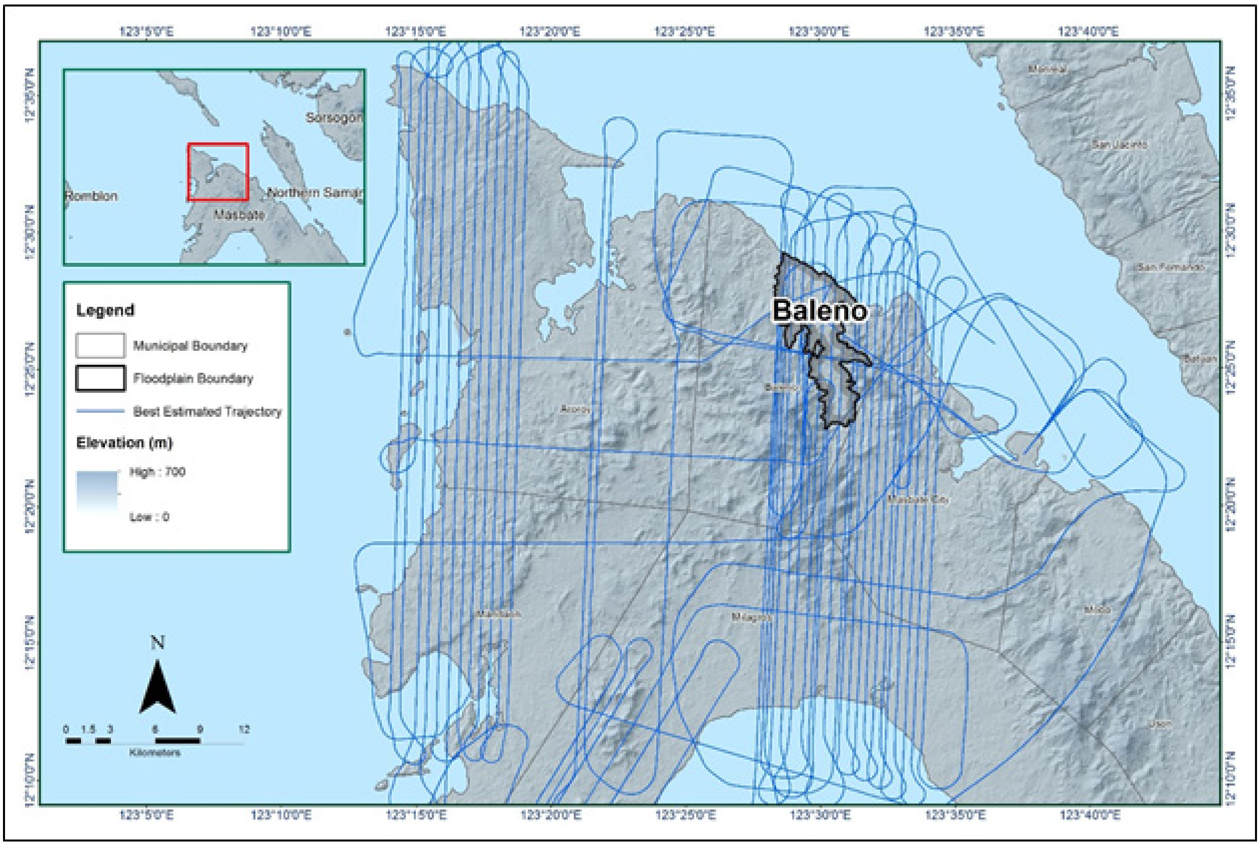


Figure 12. Best Estimated Trajectory for Baleno floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 62 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Baleno floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Baleno flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000387
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000085
GPS Position Z-correction stdev)	<0.01meters	0.0061

The optimum accuracy is obtained for all Baleno 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 8. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Baleno Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

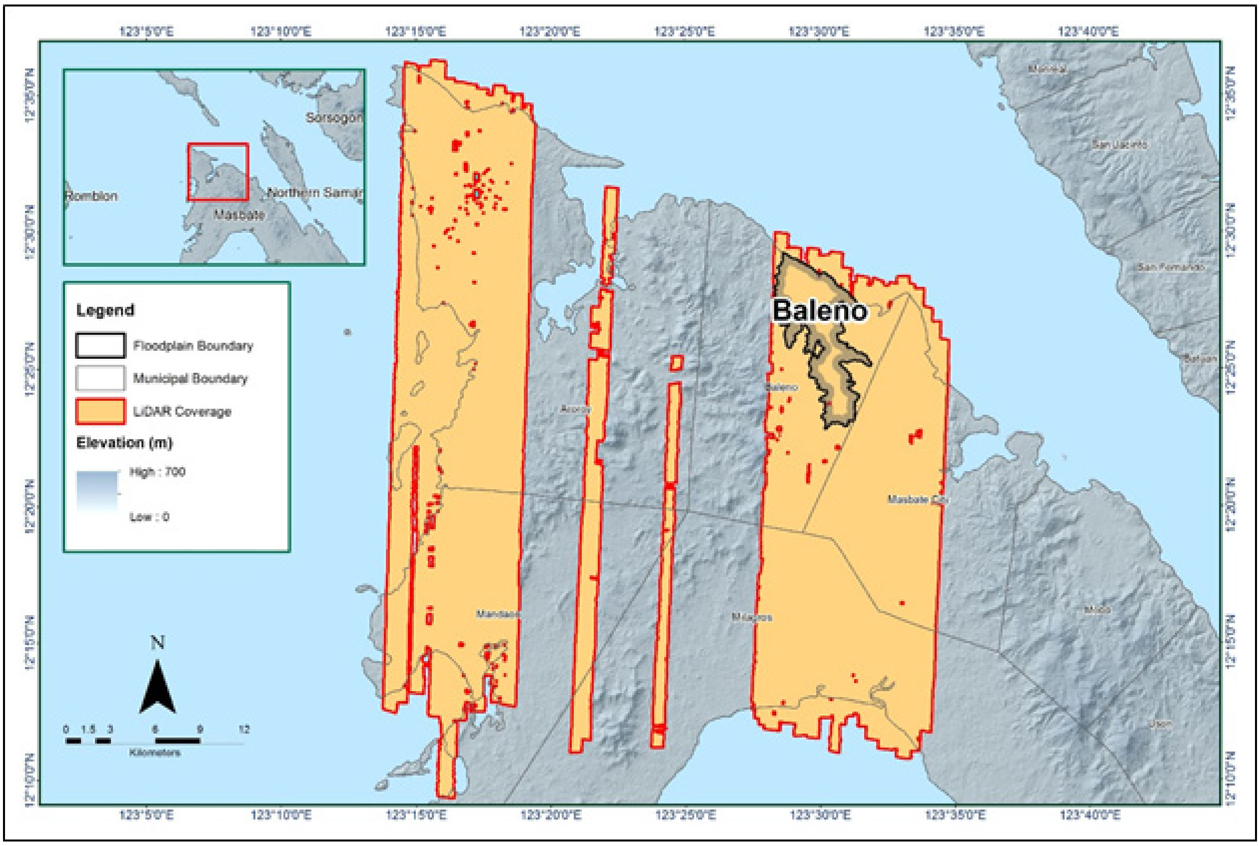


Figure 13. Boundary of the processed LiDAR data over Baleno Floodplain

The total area covered by the Baleno missions is 830.71 sq.km that is comprised of three (3) flight acquisitions grouped and merged into two (2) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Baleno floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Masbate_Blk32D	1307P	364.68
	1327P	
Masbate_Blk32A	1303P	466.03
TOTAL		830.71 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 14. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

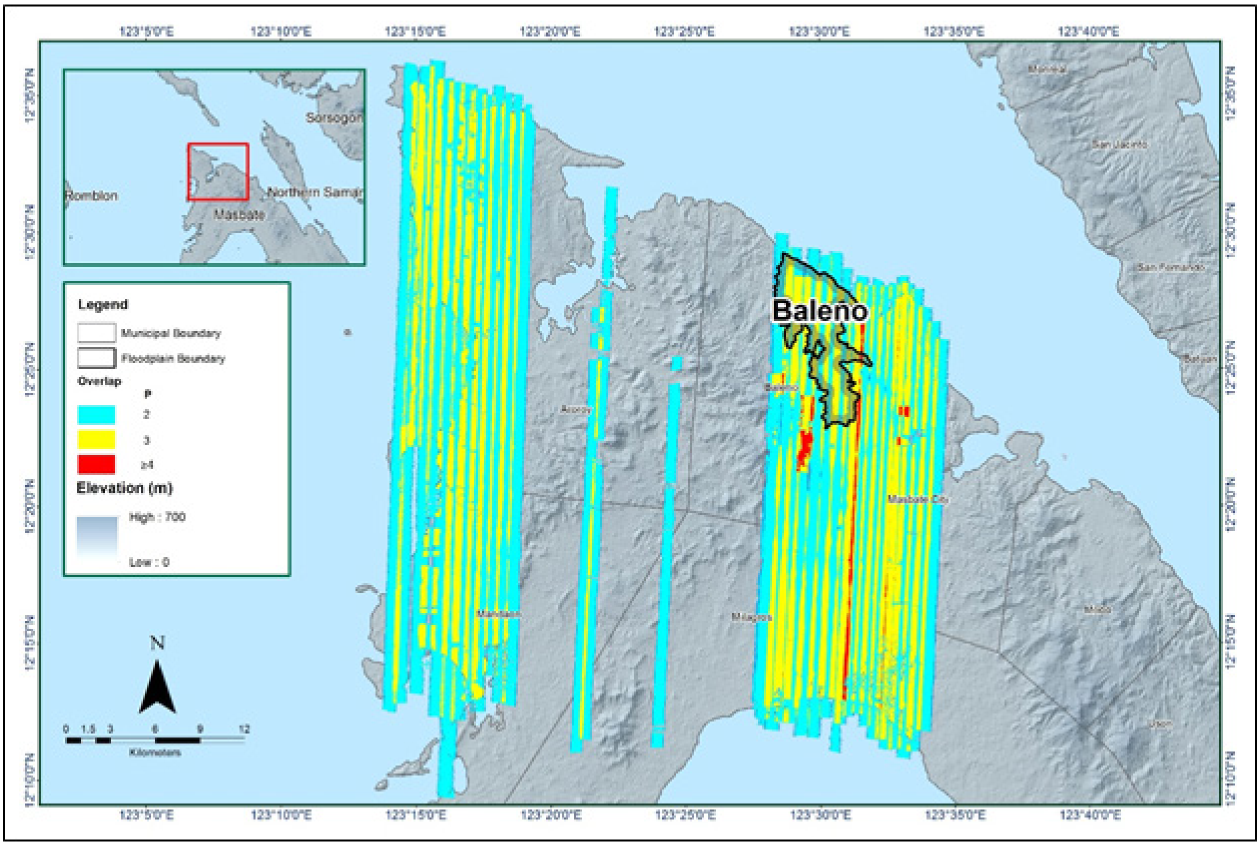


Figure 14. Image of data overlap for Baleno floodplain.

The overlap statistics per block for the Baleno floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 35.60% and 53.97% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Baleno floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.1575 points per square meter.

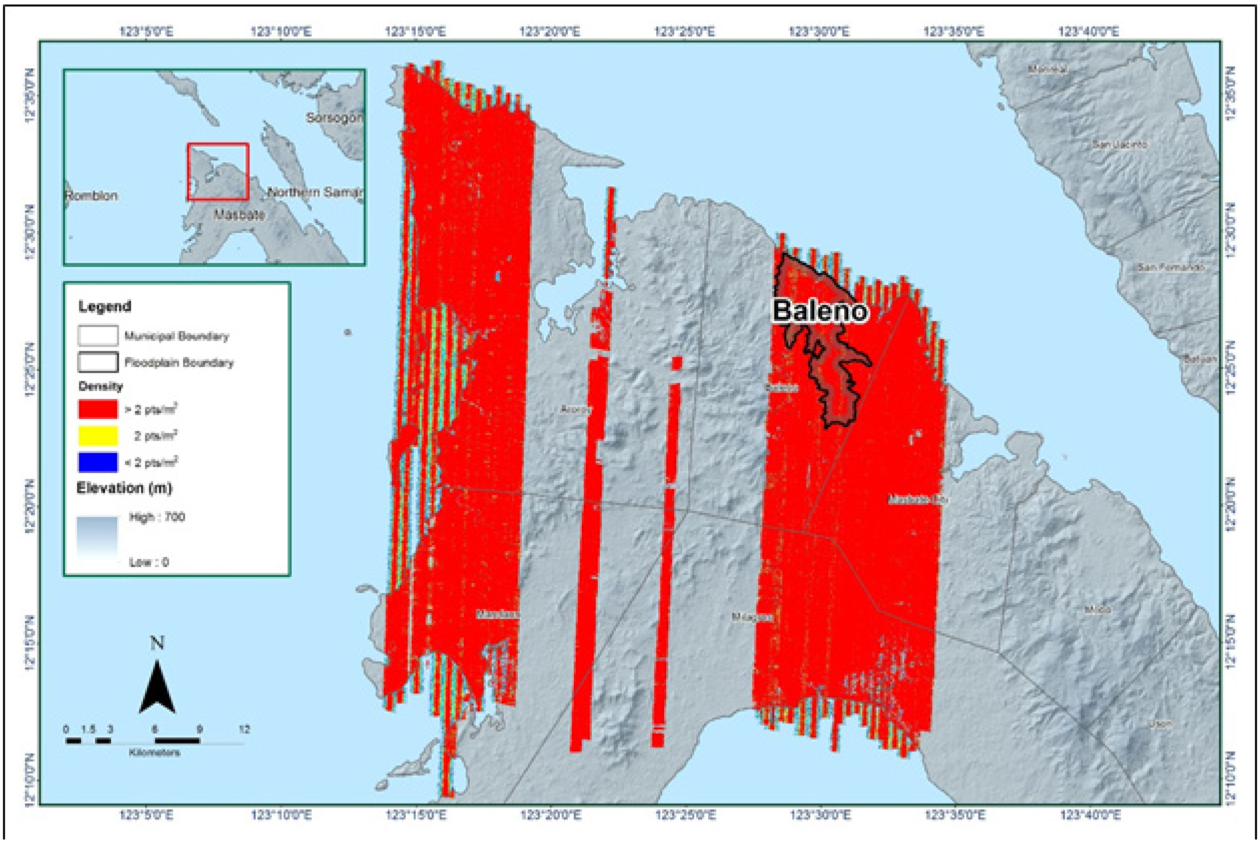


Figure 15. Pulse density map of merged LiDAR data for Baleno floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

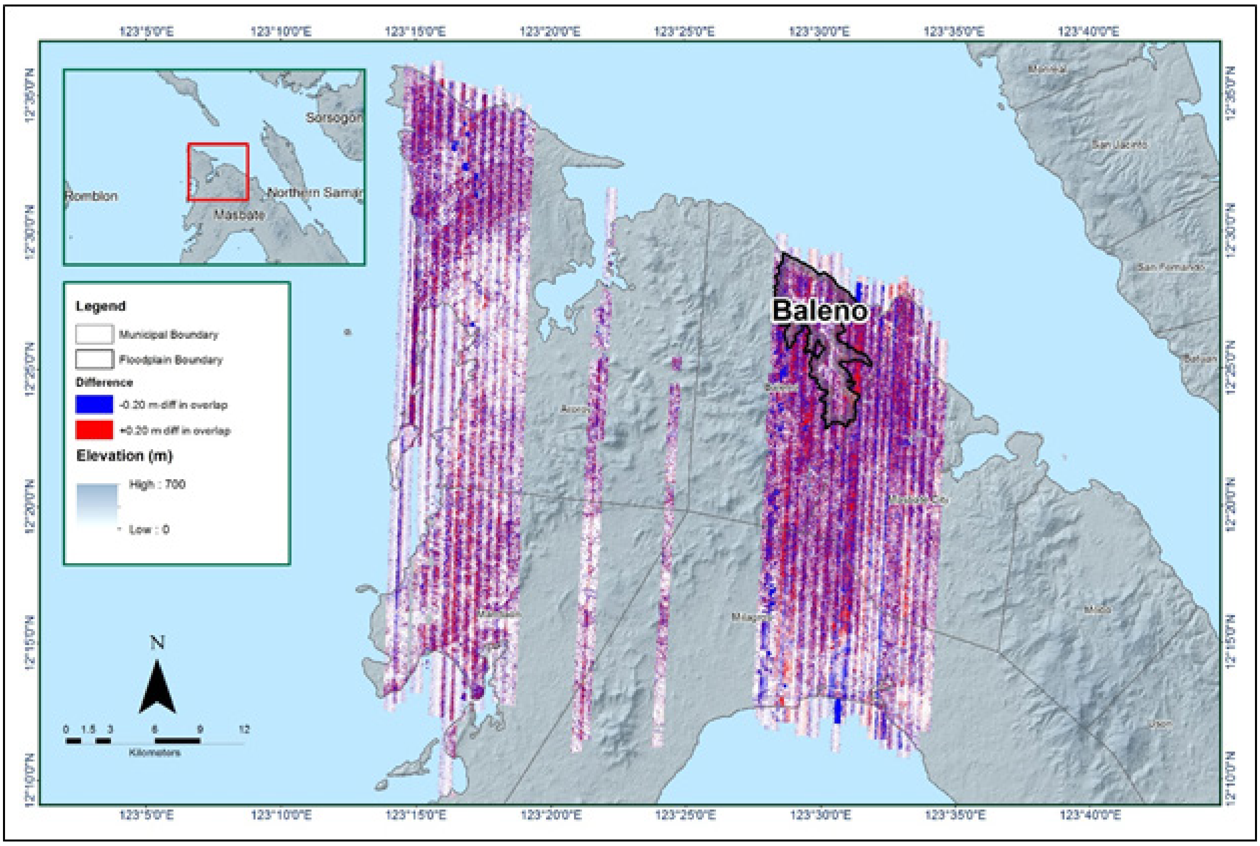


Figure 16. Elevation difference map between flight lines for Baleno floodplain.

A screen capture of the processed LAS data from a Baleno flight 1307P loaded in QT Modeler is shown in Figure 17. 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.

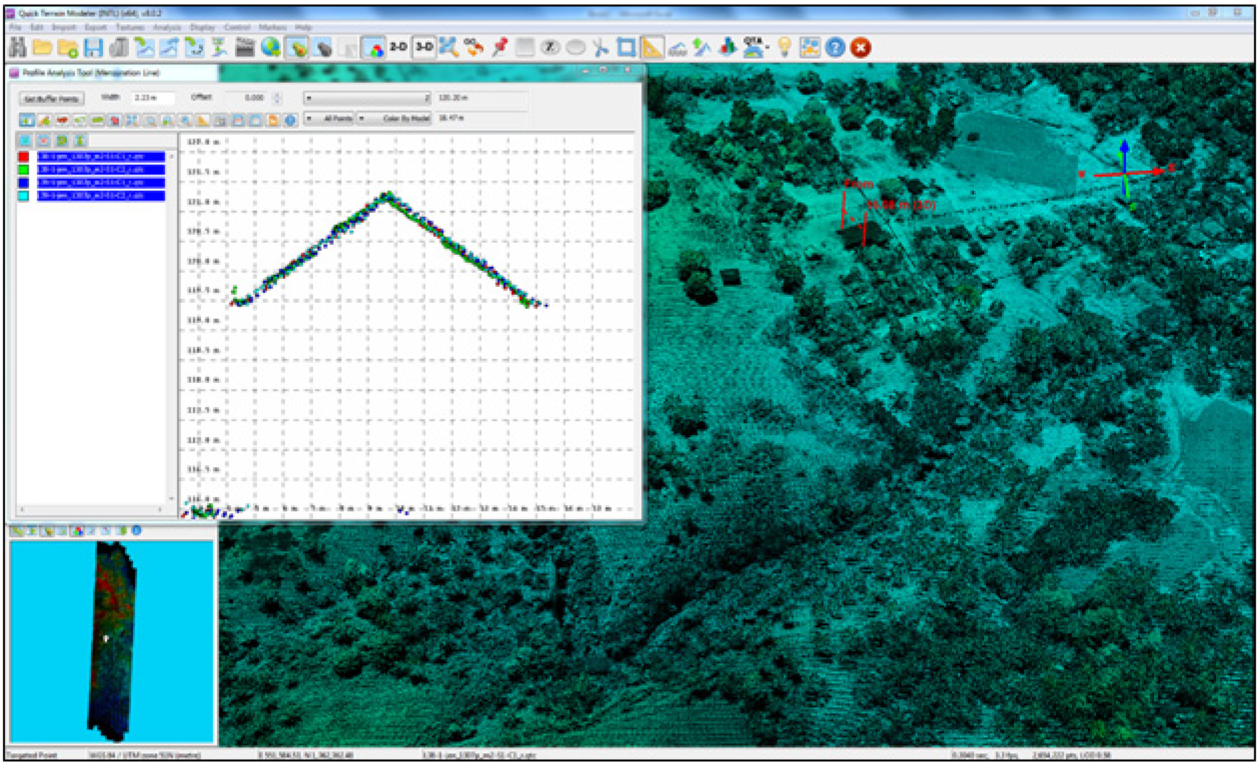


Figure 17. Quality checking for a Baleno flight 1307P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Baleno classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	964,755,037
Low Vegetation	754,888,085
Medium Vegetation	943,193,867
High Vegetation	627,358,511
Building	10,483,026

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Baleno floodplain is shown in Figure 18. A total of 1,092 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 847.76 meters and 47.46 meters respectively.

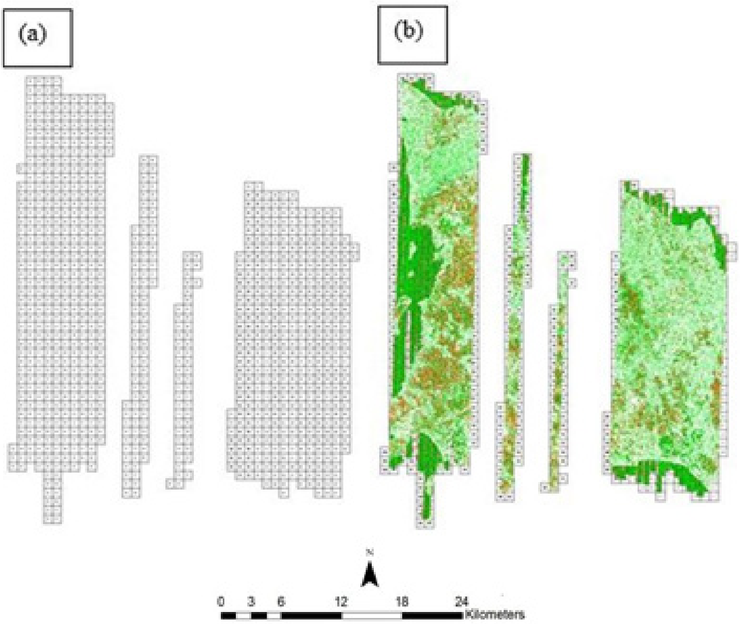


Figure 18. Tiles for Baleno floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

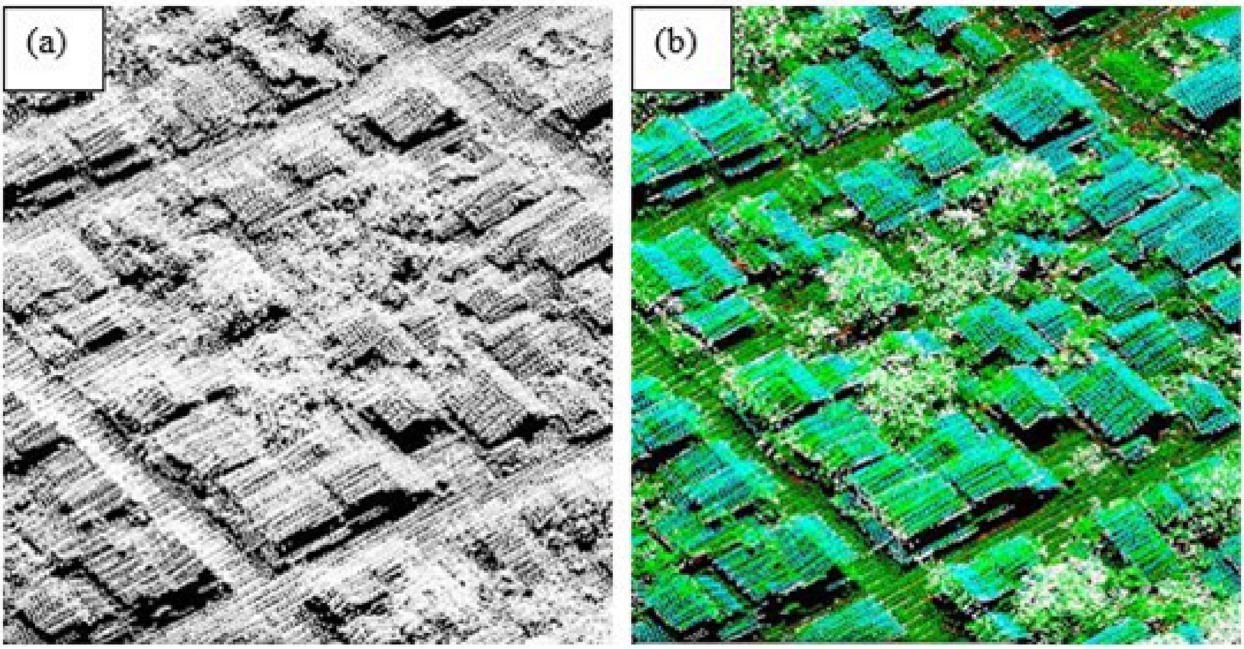


Figure 19. Point cloud before (a) and after (b) classification.

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

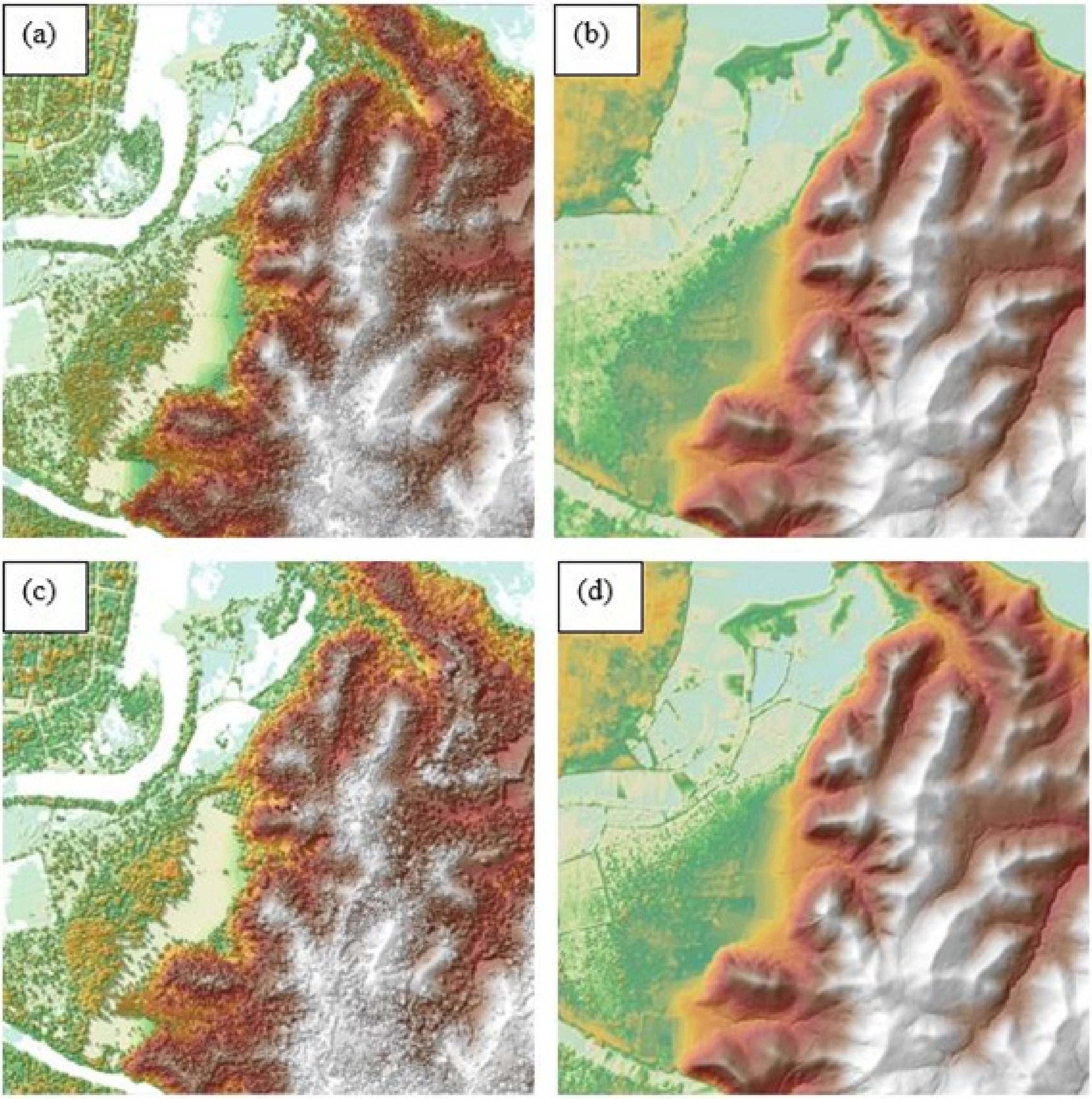


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Baleno floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,032 1km by 1km tiles area covered by Baleno floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Baleno floodplain has a total of 780.10 sq.km orthophotogaph coverage comprised of 2,552 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

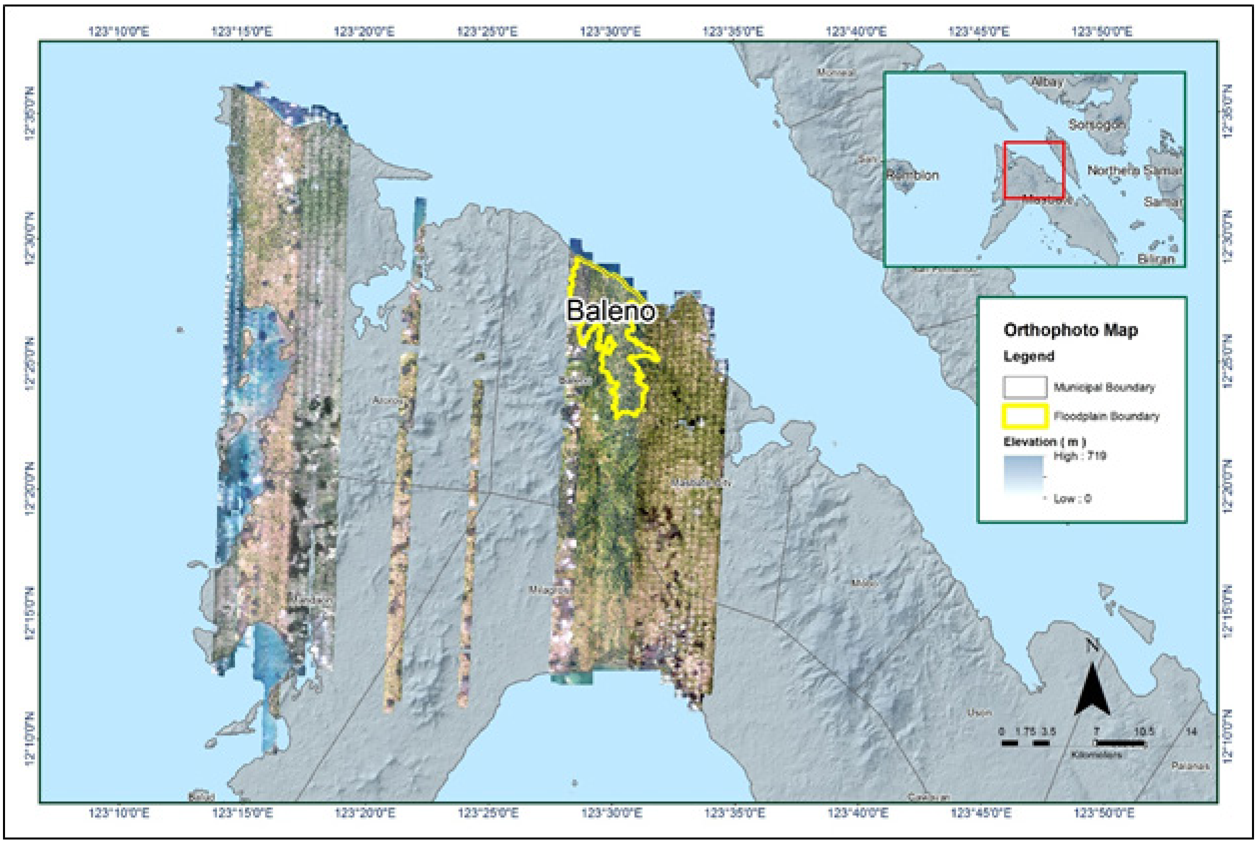


Figure 21. Baleno floodplain with available orthophotographs.

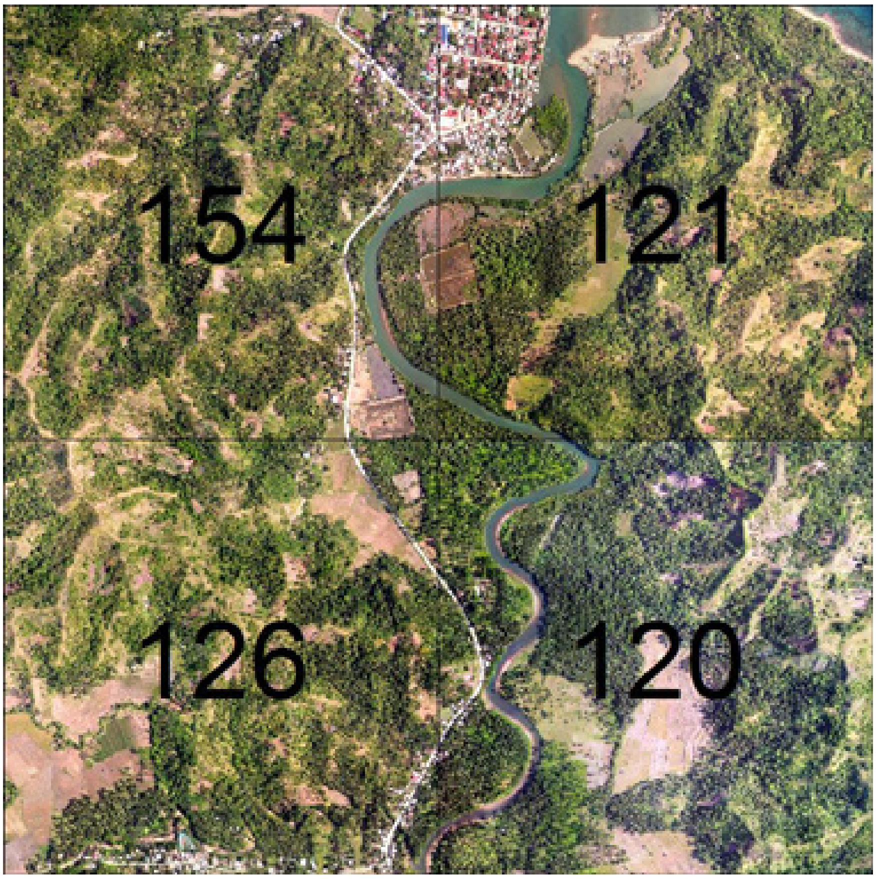


Figure 22. Sample orthophotograph tiles for Baleno floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Baleno flood plain. These blocks are composed of Masbate blocks with a total area of 830.71 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Masbate_Blk32A	466.03
Masbate_Blk32D	364.68
TOTAL	830.71 sq. km

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. Portion of the hills (Figure 23c) has also been misclassified that needs to be retrieved to retain the correct terrain (Figure 23d). Object retrieval uses the secondary DTM to fill in these areas.

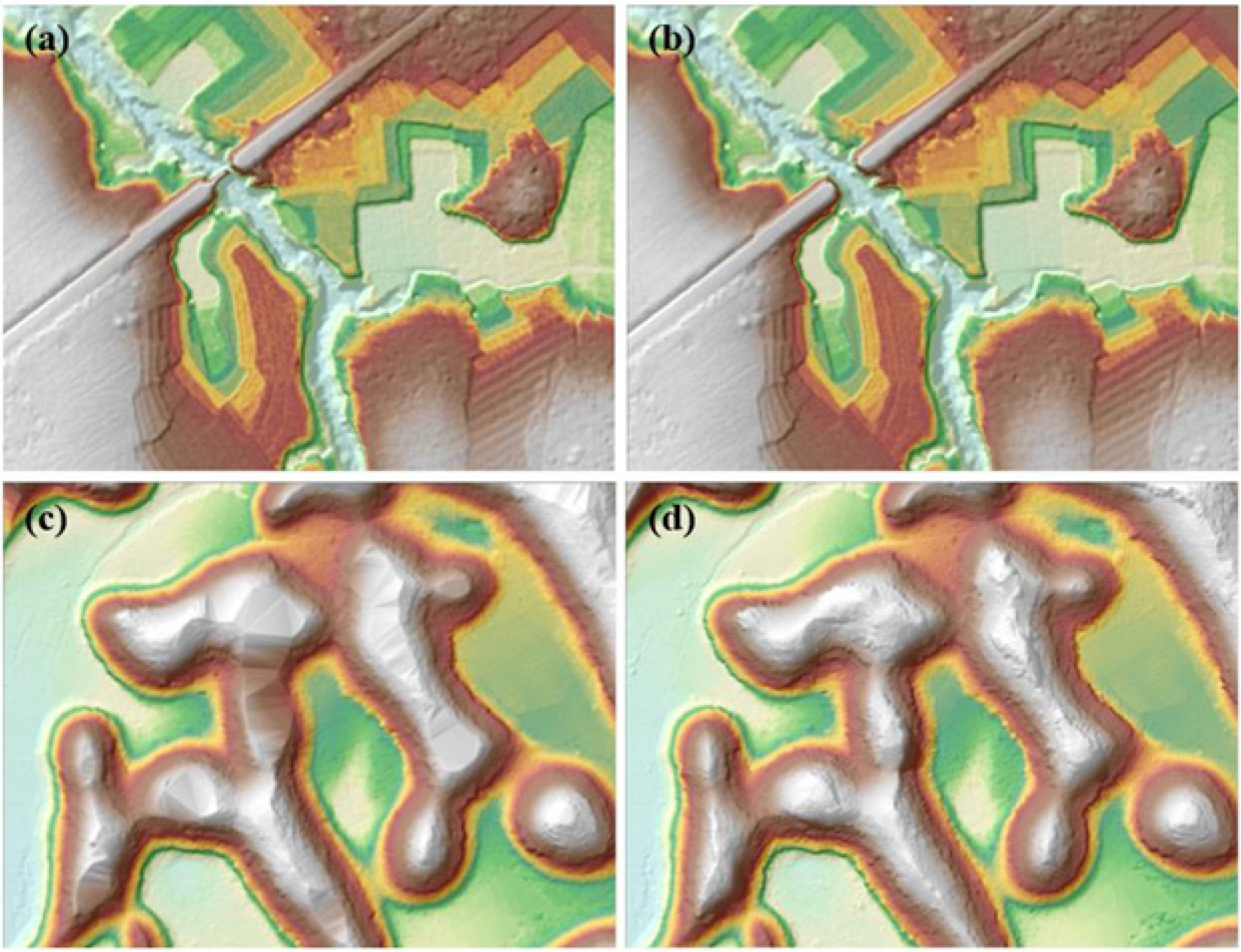


Figure 23. Portions in the DTM of Baleno floodplain – a bridge before (a) and after (b) manual editing; a misclassified hill before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Masbate_Blk32D was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Baleno floodplain is shown in Figure 24. It can be seen that the entire Baleno floodplain is 99.88% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Baleno floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Masbate_Blk32A	0.00	0.00	0.00
Masbate_Blk32D	0.00	0.00	0.00

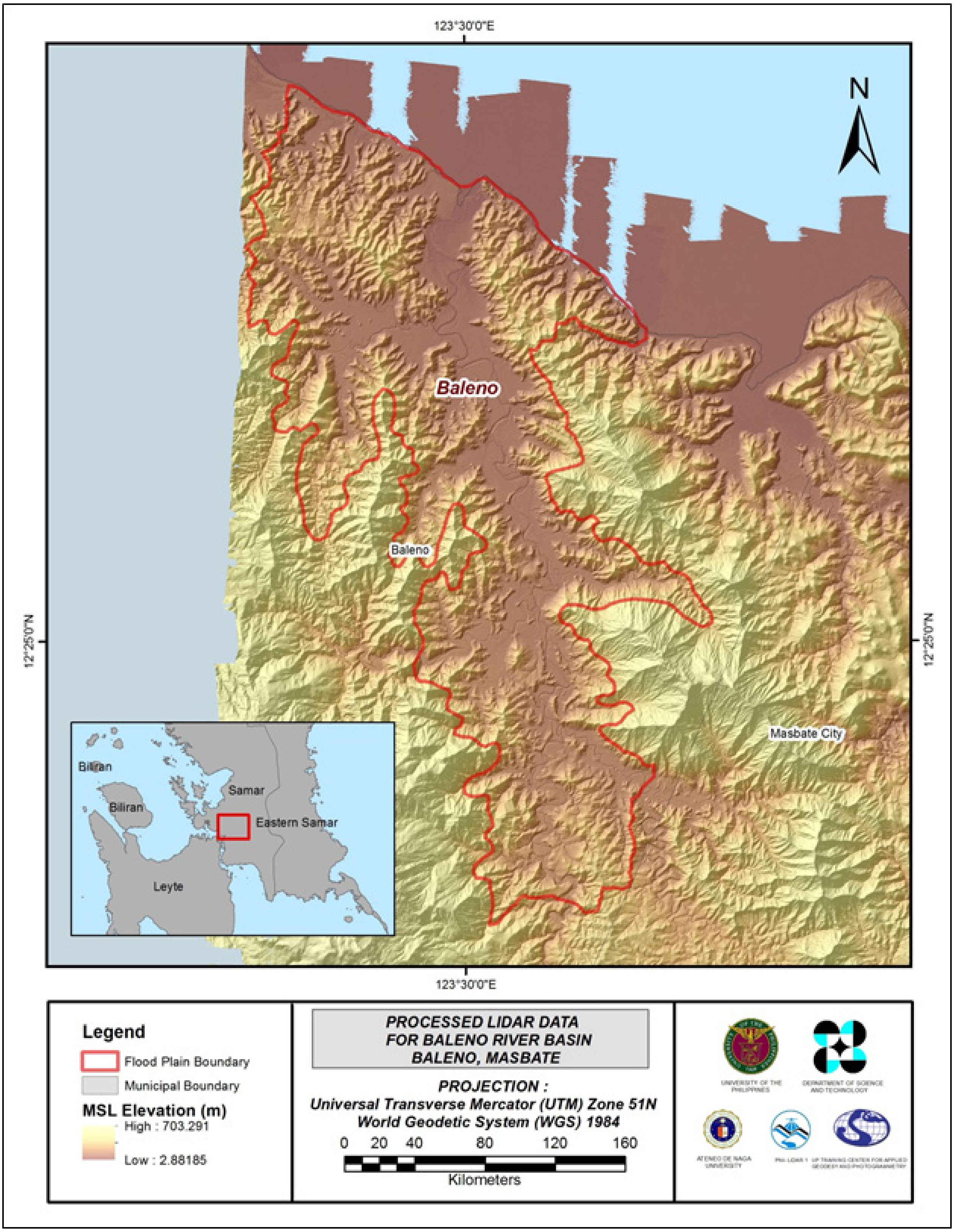


Figure 24. Map of Processed LiDAR Data for Baleno Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Baleno to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 2,639 survey points were used for calibration and validation of Baleno LiDAR data. Random selection of 80% of the survey points, resulting to 2,591 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26 Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 3.22 meters with a standard deviation of 0.16 meters. Calibration of Baleno LiDAR data was done by subtracting the height difference value, 3.22 meters, to Baleno mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

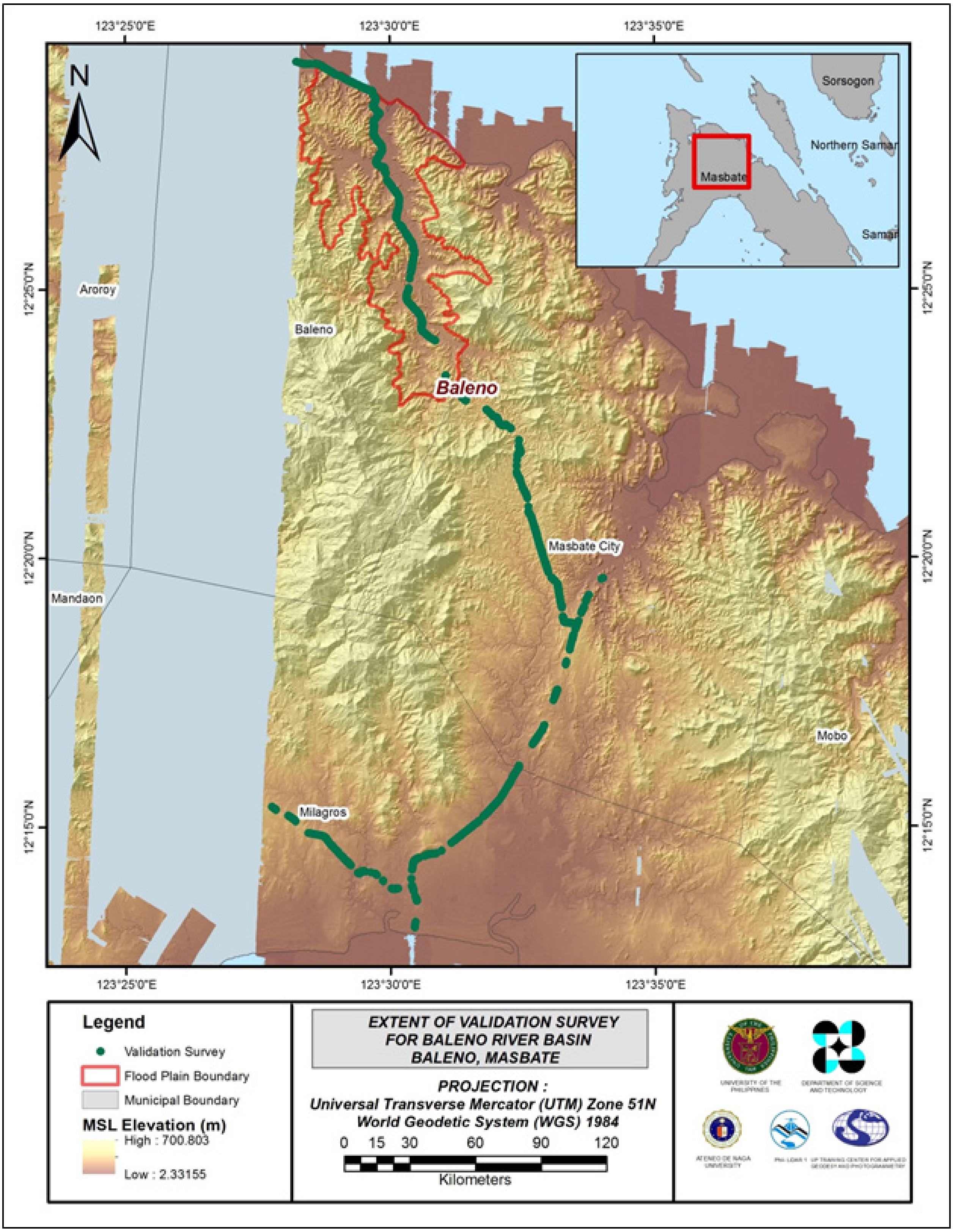


Figure 25. Map of Baleno Flood Plain with validation survey points in green.

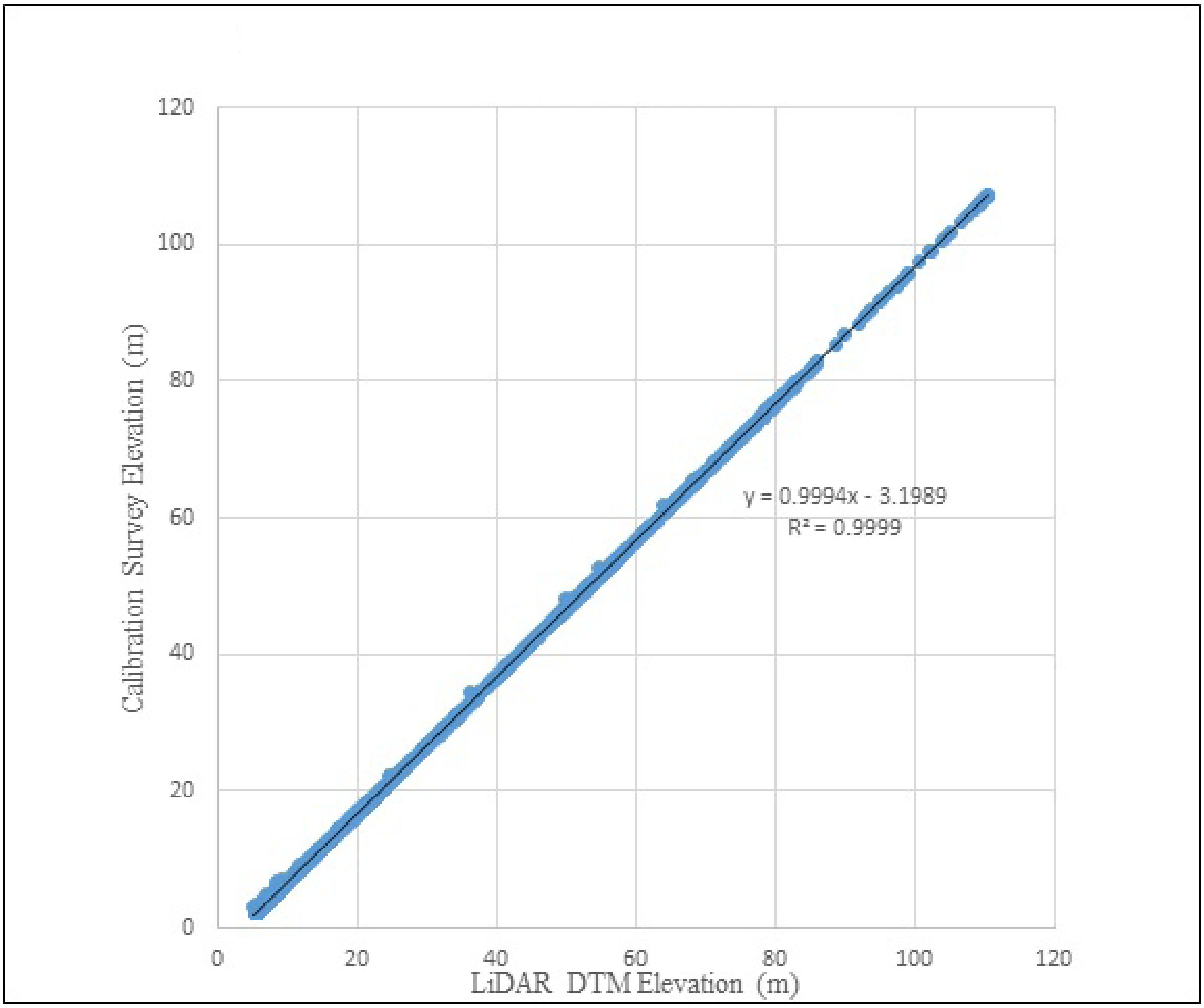


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.22
Standard Deviation	0.16
Average	-3.22
Minimum	-3.53
Maximum	-1.66

The remaining 20% of the total survey points, resulting to 217 points, were used for the validation of calibrated Baleno 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.10 meters with a standard deviation of 0.07 meters, as shown in Table 17.

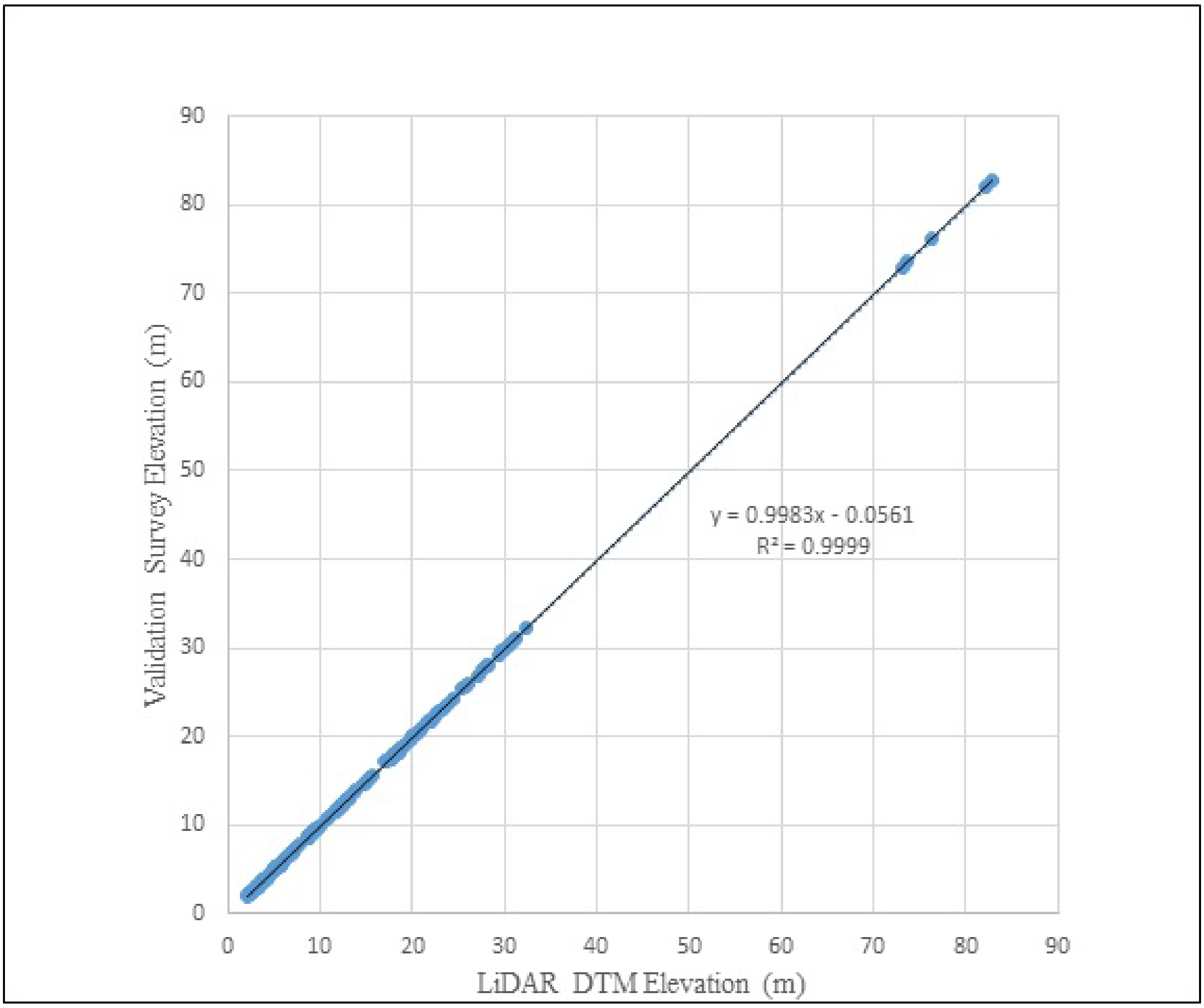


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.10
Standard Deviation	0.07
Average	-0.08
Minimum	-0.22
Maximum	0.06

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Baleno with 2,501 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 0.093 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Baleno integrated with the processed LiDAR DEM is shown in Figure 28.

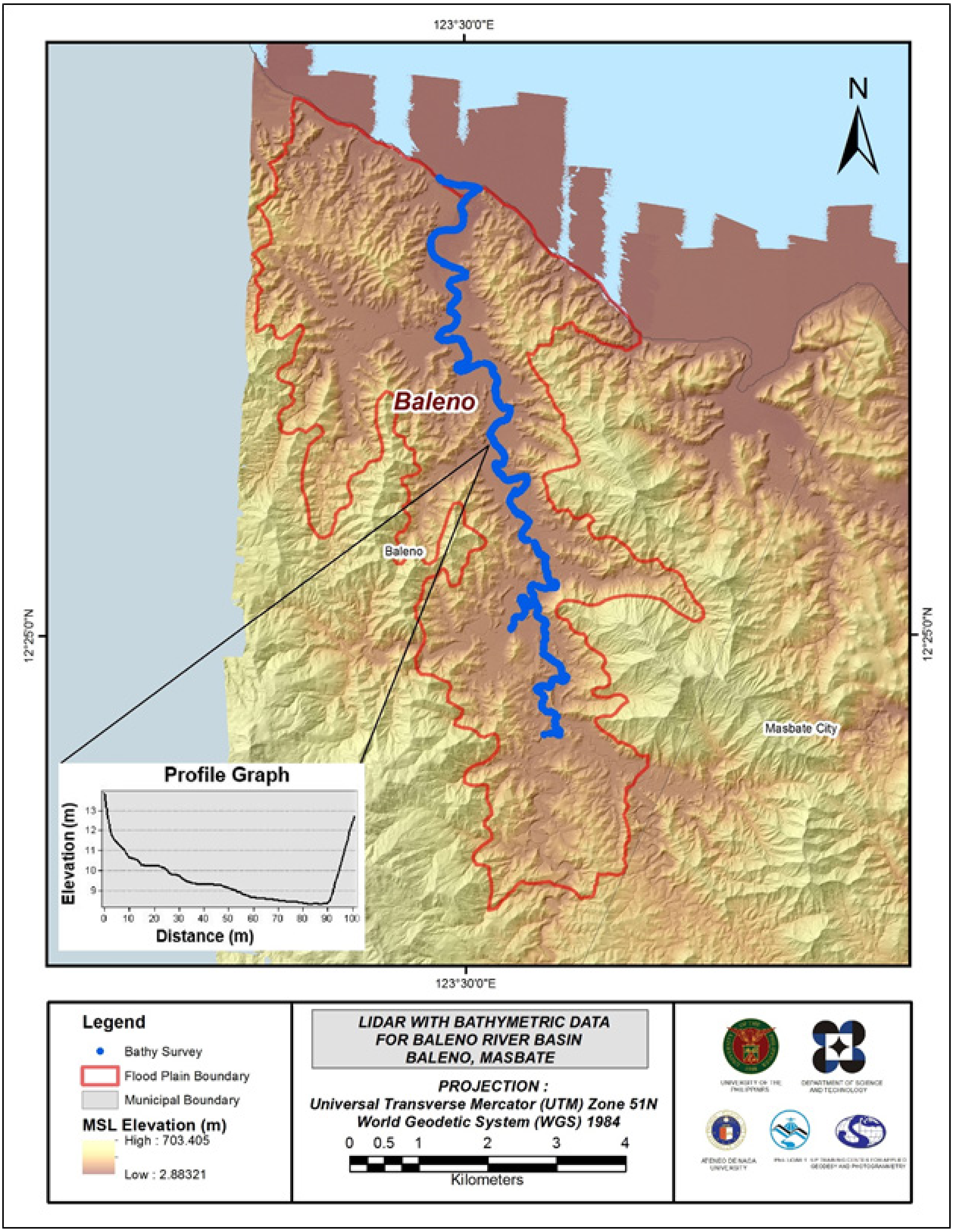


Figure 28. Map of Baleno Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Baleno floodplain, including its 200 m buffer, has a total area of 42.86 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 919 building features, are considered for QC. Figure 29 shows the QC blocks for Baleno floodplain.

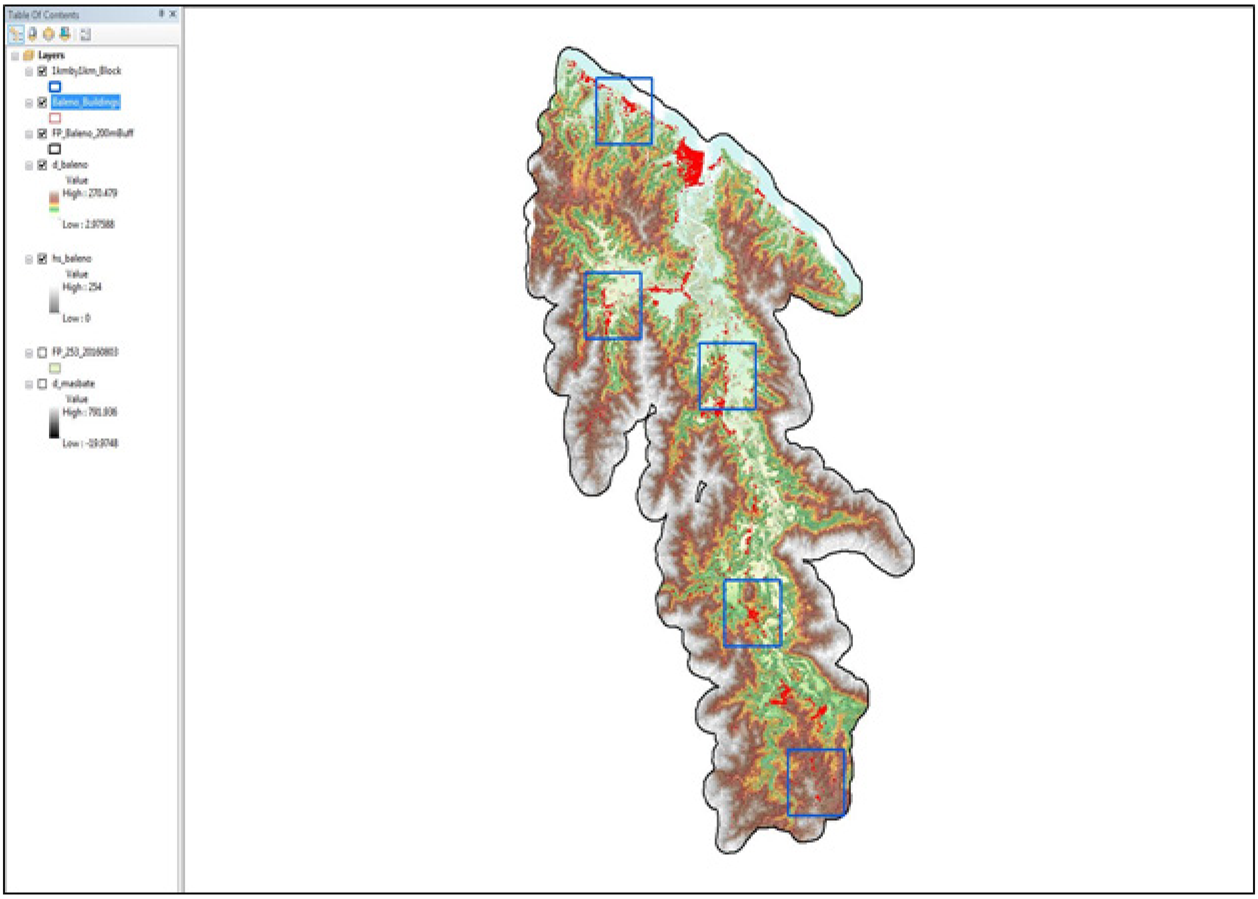


Figure 29. QC blocks for Baleno building features.

Quality checking of Baleno building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Baleno Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Baleno	100.00	99.89	99.46	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,220 building features in Baleno floodplain. Of these building features, 58 was filtered out after height extraction, resulting to 4,162 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.24 m.

3.12.3 Feature Attribution

Feature Attribution was done for 4,162 building features in Baleno Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

[1]Resource Extraction for Geographic Information System (reGIS), March 17,2015.

Table 19. Building Features Extracted for Baleno Floodplain.

Facility Type	No. of Features
Residential	3,976
School	89
Market	9
Agricultural/Agro-Industrial Facilities	8
Medical Institutions	7
Barangay Hall	12
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	1
Religious Institutions	22
Bank	0
Factory	0
Gas Station	2
Fire Station	0
Other Government Offices	8
Other Commercial Establishments	23
Total	4,162

Table 20. Total Length of Extracted Roads for Baleno Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Baleno	14.57	3.97	0	14.57	0.00	33.10

Table 21. Number of Extracted Water Bodies for Baleno Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Basud	1	17	0	0	0	18

A total of 3 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of Baleno floodplain overlaid with its ground features.

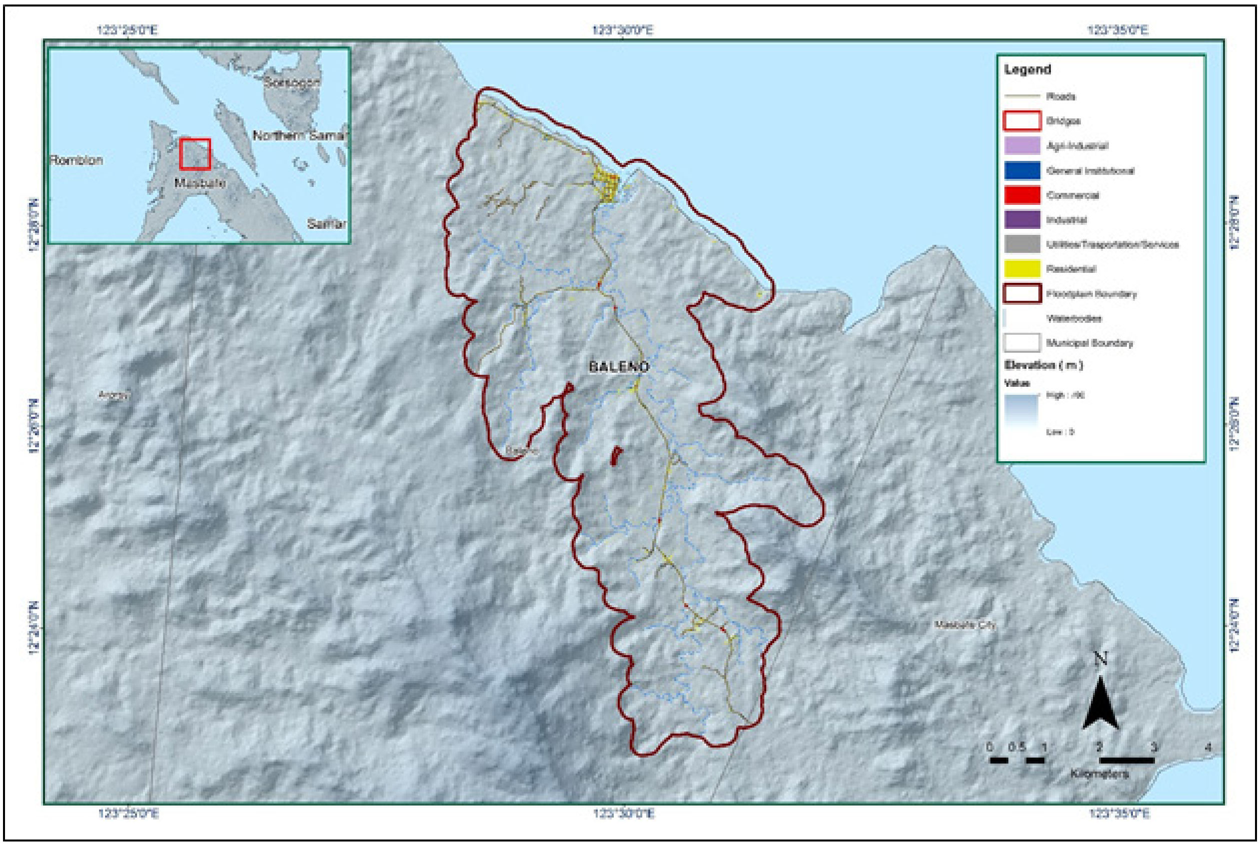


Figure 30. Extracted features for Baleno floodplain.

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

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

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 (DVBC) conducted a field survey for Baleno River on December 3 - 17, 2015 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for the bathymetric survey; courtesy call to the LGU of Masbate City and Municipality of Baleno; control survey for the establishment of control point UP-GAN at the approach of Gangao Bridge occupied as base station for GNSS surveys; cross-section, bridge-as-built and MSL water-level marking; validation data points acquisition for LiDAR data covering an approximate length of 112 km; and bathymetric survey of Baleno River starting from the upstream at Cancahorao Bridge in Brgy. Cancahorao down to the its mouth a Brgy. Lipata with an approximate length of 13.34 km using GNSS PPK survey technique.

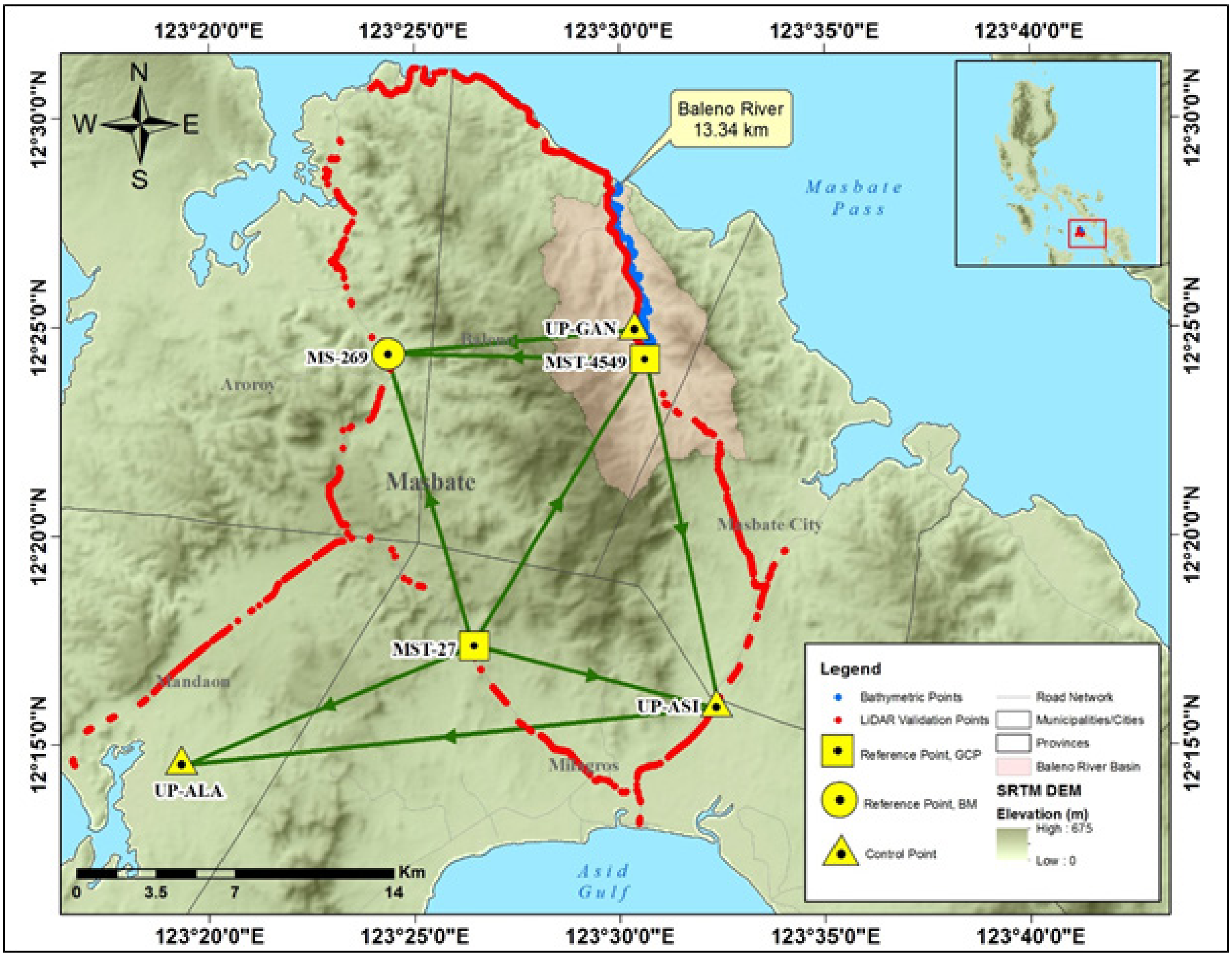


Figure 31. General survey area for Baleno River Basin

4.2 Control Survey

The GNSS network used for Baleno River Basin is composed of four (4) loops established on December 4, 5, 6 and 13, 2015 occupying the following reference points: MST-27, a second order GCP in Brgy. Matiporon, Municipality of Milagros; and MS-269, a first order benchmark in Brgy. Luy-A, Municipality of Aroroy.

Three (3) control points were established along the approach of bridges, namely: UP-ALA at Alas Bridge in Brgy. Alas, Municipality of Mandaon; UP-ASI at Asid Bridge in Brgy. Asid, Masbate City; and UP-GAN near Gangao Bridge, in Brgy. Gangao, Municipality of Baleno. The control point established by DENR, MST-4945, in Brgy. Gangao, also in Baleno was occupied to use as a marker for the network.

The summary of reference and control points and its location is summarized in Table 22. List of reference and control points occupied for Mandaon River Survey.while GNSS network established is illustrated in Figure 32.

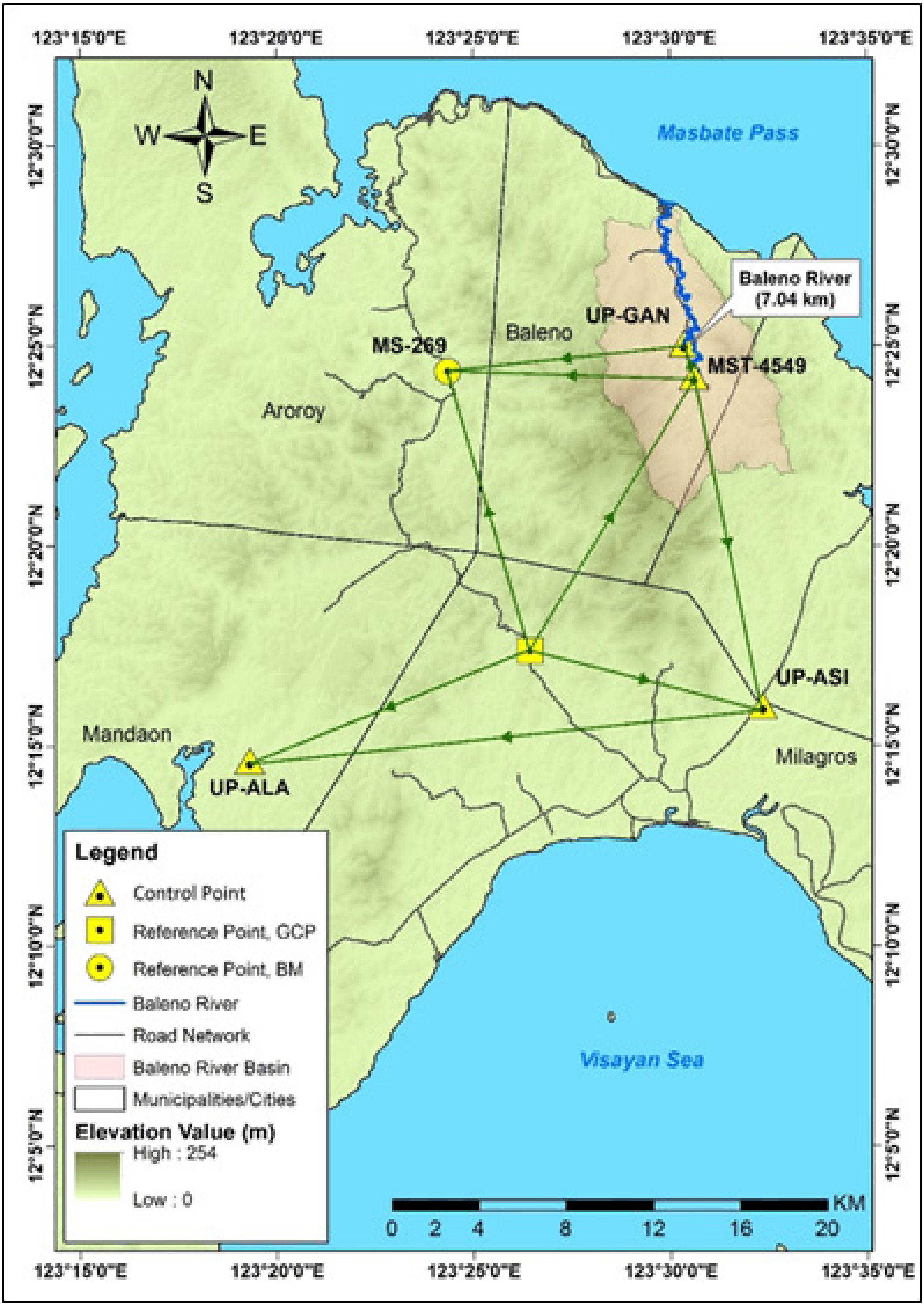


Figure 32. GNSS Network occupied in Baleno River Basin field survey

Table 22. List of reference and control points occupied for Baleno River Survey.
(Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
MST-27	2nd order, GCP	12°17'22.32360"N	123°26'26.50548"E	109.123	-	2007
MS-269	1st order, BM	-	-	82.132	27.408	2008
MST-4549	Used as Marker	-	-	-	-	2013
UP-ALA	UP Established	-	-	-	-	Dec. 12, 2015
UP-ASI	UP Established	-	-	-	-	Dec. 5, 2015
UP-GAN	UP Established	-	-	-	-	Dec. 4, 2015

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 33 to Figure 38:

Figure 33. GNSS receiver set up, Trimble® SPS 852 at MST-27, located at Mabuaya Bridge along Central Nautical Highway in Brgy. Matiporon, Milagros, Masbate

Figure 34. GNSS base set up, Trimble® SPS 852 at MS-269 located at Lanang Bridge, along Central Nautical Highway in Brgy. Luy-A, Aroroy, Masbate

Figure 35. Trimble® SPS 882 base setup at MST-4945, a DENR-established control point located at the approach of Cancahorao Bridge along Central Nautical Highway in Brgy. Gangao, Baleno, Masbate

Figure 36. Trimble® SPS 882 setup at UP-ALA, located at Alas Bridge in Brgy. Alas, Mandaon, Masbate

Figure 37. GNSS receiver setup, Trimble® SPS 882, at UP-ASI, at Asid Bridge, along Central Nautical Highway, Brgy. Asid, Masbate City

Figure 38. GNSS receiver setup, Trimble® SPS 882, at UP-GAN, located on the top of a riprap near Gangao Bridge, along Central Nautical Highway, Brgy. Gangao, Baleno, Masbate

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/-20cm and +/-10cm 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 Baleno River Basin is summarized in Table 23 generated TBC software.

Table 23. Baseline Processing Report for Baleno River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-GAN --- MS-269	12-04-2015	Fixed	0.064	0.077	263°25'15"	10958.94	8.902
UP-ASI --- UP-ALA	12-05-2015	Fixed	0.007	0.04	263°57'41"	23763.75	-9.332
MST-4549 --- UP-ASI	12-05-2015	Fixed	0.007	0.034	168°18'59"	15487.62	-10.509
MST-4549 --- MS-269	12-05-2015	Fixed	0.013	0.019	271°18'18"	11347.5	5.154
MST-4549 --- UP-GAN	12-04-2015	Fixed	0.003	0.005	343°10'30"	1581.606	-3.725
MST-27 --- UP-ALA	12-12-2015	Fixed	0.006	0.046	248°40'43"	13874.51	-52.04
MST-27 --- UP-ASI	12-05-2015	Fixed	0.005	0.019	103°19'39"	11002.41	-42.67
MST-27 --- MS-269	12-05-2015	Fixed	0.015	0.076	343°39'18"	13427.81	-26.942
MST-4549 ---MST-27	12-05-2015	Fixed	0.006	0.023	30°55'25"	14722.42	-32.154

As shown in Table 23, the accuracies of the processed baselines are within the precision requirement of the program.

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 20cm and z less than 10cm in equation from:

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

where:

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

The six (6) control points, MST-27, MST-4549, MS-269. UP-ALA, UP-ASI, UP-GAN were occupied and observed simultaneously to form a GNSS loop. Coordinates of MST-27 and elevation values of MS-269 were held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 24. Control Point Constraints

Point ID	**Type**	**East σ (Meter)**	**North σ (Meter)**	**Height σ (Meter)**	**Elevation σ (Meter)**
MST-27	Global	Fixed	Fixed	Fixed	
MS-269	Grid				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 25. All fixed control points have no values for grid and elevation errors.

Table 25. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MS-269	544123.788	0.018	1371483.424	0.013	27.408	?	e
MST-27	547922.386	?	1358609.337	?	53.606	0.063	LL
MST-4549	555464.635	0.009	1371246.784	0.006	21.829	0.043	
UP-ALA	535010.665	0.009	1353545.355	0.008	1.754	0.100	
UP-ASI	558628.712	0.007	1356091.508	0.006	10.476	0.069	
UP-GAN	555004.108	0.011	1372759.259	0.008	18.209	0.045	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 26. Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10\ cm$ for the vertical; below is the computation for accuracy that passed the required precision:

a. MST-27
Horizontal Accuracy = Fixed
Vertical Accuracy = 6.3 < 10 cm

b. MS-269
Horizontal Accuracy = √((1.8)² + (1.3)²
= √ (3.24 +1.69)
= 2.2 < 20 cm
Vertical Accuracy = Fixed

c. MST-4549
Horizontal Accuracy = √((0.9)² + (0.6)²
= √ (0.81 + 0.36)
= 1.08 < 20 cm
Vertical Accuracy = 4.30 < 10 cm

d. UP-ALA
Horizontal Accuracy = √((0.9)² + (0.8)²
= √ (0.81 + 0.64)
= 1.20 < 20 cm
Vertical Accuracy = 10 < 10 cm

e. UP-ASI
Horizontal Accuracy = √((0.7)² + (0.6)²
= √ (0.49 + 0.36)
= 0.92 < 20 cm
Vertical Accuracy = 6.90 < 10 cm

f. UP-GAN

Horizontal Accuracy	=	$\sqrt{((1.1)^2 + (0.8)^2}$
	=	$\sqrt{(1.21 + 0.64)}$
	=	1.36 < 20 cm
Vertical Accuracy	=	4.5 < 10 cm

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

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
MS-269	N12°24'21.62817"	E123°24'21.39816"	82.132	?	e
MST-27	N12°17'22.32360"	E123°26'26.50548"	109.123	0.063	LL
MST-4549	N12°24'13.29041"	E123°30'36.98735"	76.970	0.043	
UP-ALA	N12°14'38.06086"	E123°19'18.85903"	57.103	0.100	
UP-ASI	N12°15'59.72358"	E123°32'20.76940"	66.451	0.069	
UP-GAN	N12°25'02.55601"	E123°30'21.83023"	73.244	0.045	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 27. Reference and Control points 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)
MS-269	2nd order, GCP	12°17'22.32360"	123°26'26.50548"	109.123	1358609.337	547922.386	53.606
MST-27	1st order, BM	12°24'21.62817"	123°24'21.39816"	82.132	1371483.424	544123.788	27.408
MST-4549	Used as Marker	12°24'13.29041"	123°30'36.98735"	76.970	1371246.784	555464.635	21.829
UP-ALA	UP Established	12°d14'38.06086"	123°19'18.85903"	57.103	1353545.355	535010.665	1.754
UP-ASI	UP Established	12°15'59.72358"	123°32'20.76940"	66.451	1356091.508	558628.712	10.476
UP-GAN	UP Established	12°25'02.55601"	123°30'21.83023"	73.244	1372759.259	555004.108	18.209

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

Cross-section and as-built surveys was done on December 7, 2015 along the upstream side of Cancahorao and Gangao Bridge located in Brgy. Cancahorao and Brgy. Gangao, respectively. A GNSS receiver Trimble® SPS 882 in PPK survey technique was implemented to acquire the cross-sectional profile of the rivers using MST-4549 as the base station. Gathering of data points on bridge as-built features was also performed to get the distance of the abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high chord and meter tape to get the low chord elevation.

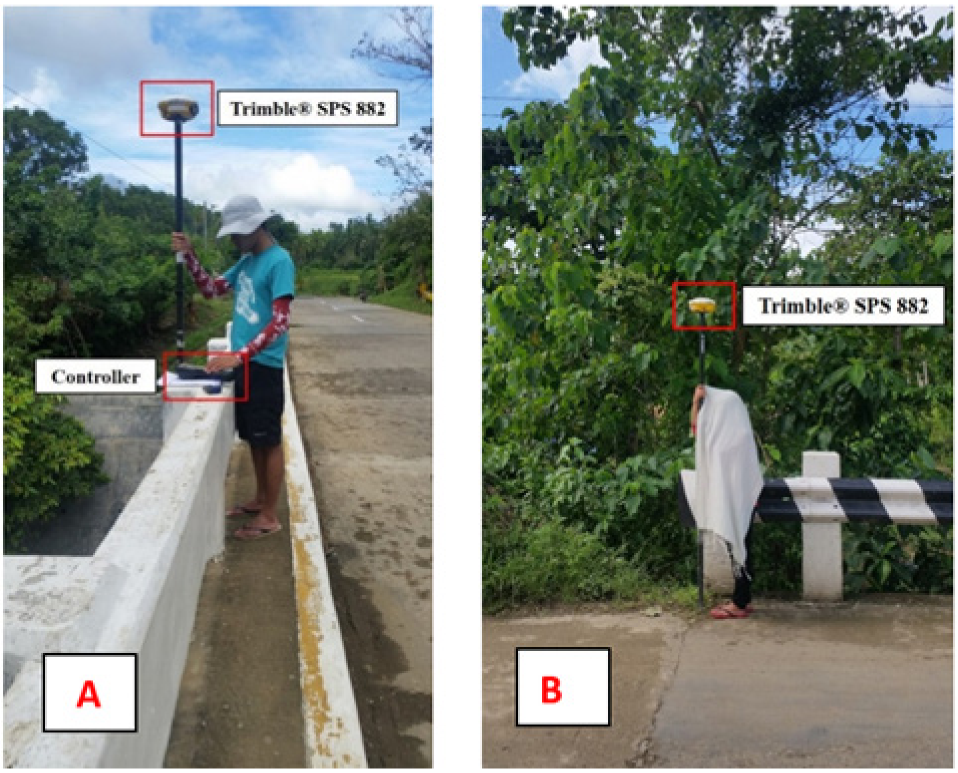


Figure 39. Setup during the Bridge As-built measurement in A) Cancahorao and B) Gangao Bridge

The cross-sectional line length of Cancahorao Bridge is 31 m with 10 cross-sectional points; while of Gangao Bridge is 48.50 m with 14 cross-sectional points. Bridge diagrams and location maps of the two bridges are illustrated in Figure 40 to Figure 43, while the bridge as-built forms are shown in Figure 44, and Figure 45 respectively.

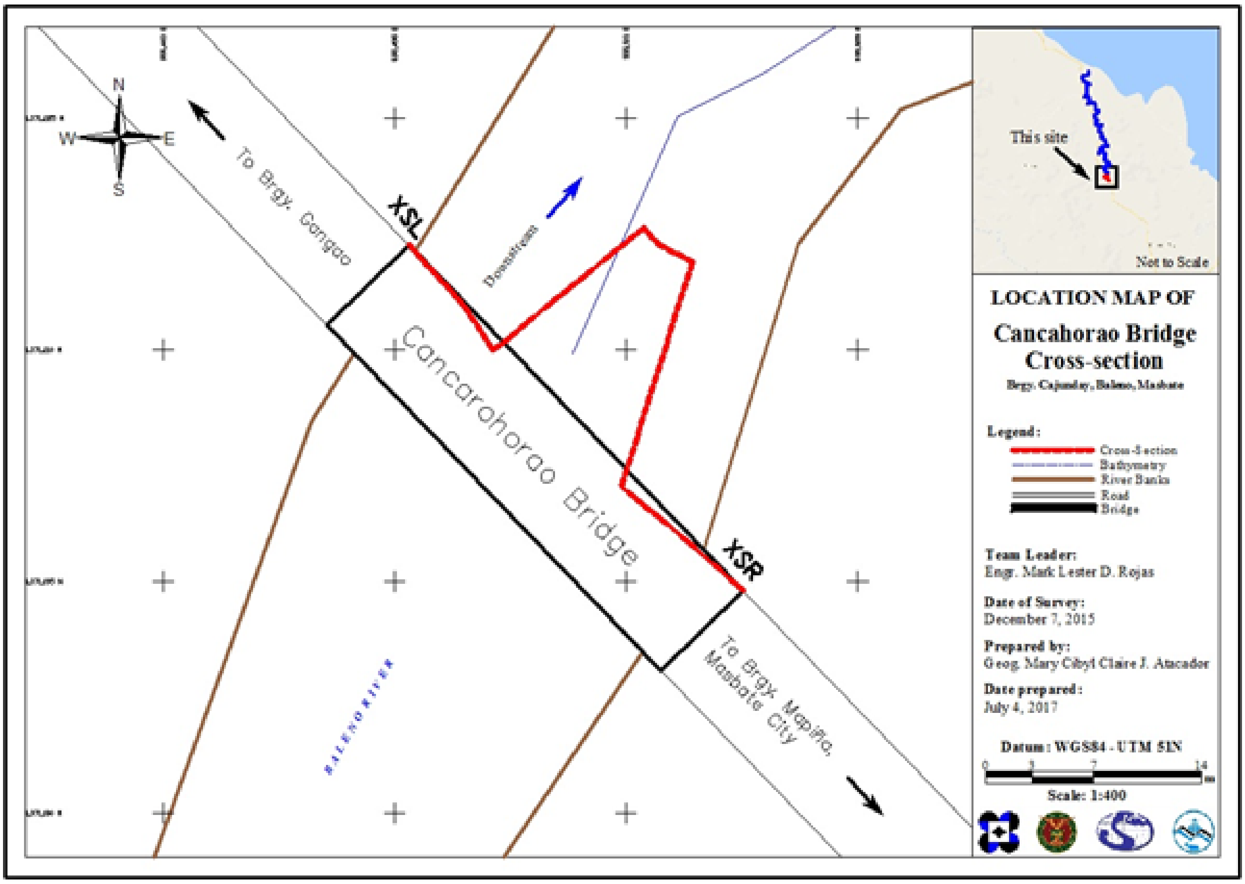


Figure 40. Cancahorao bridge cross-section location map

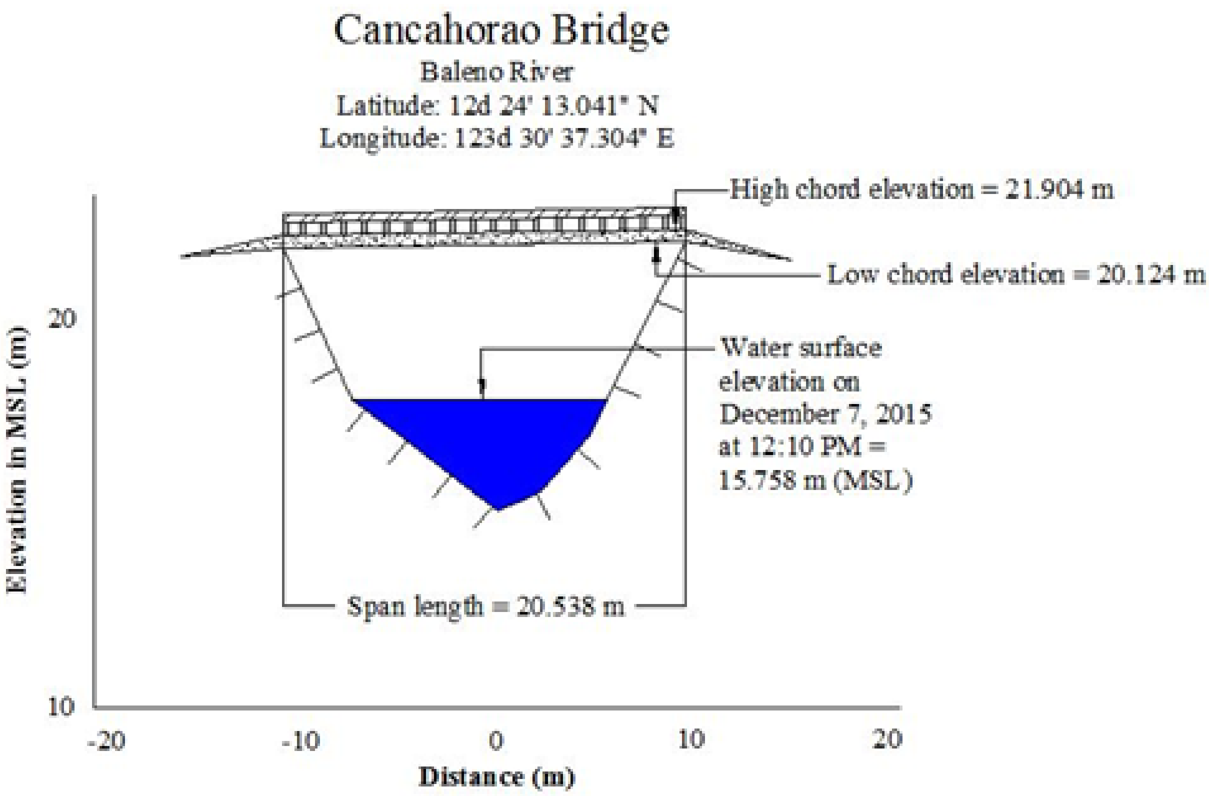


Figure 41. Cancahorao Bridge cross-section diagram

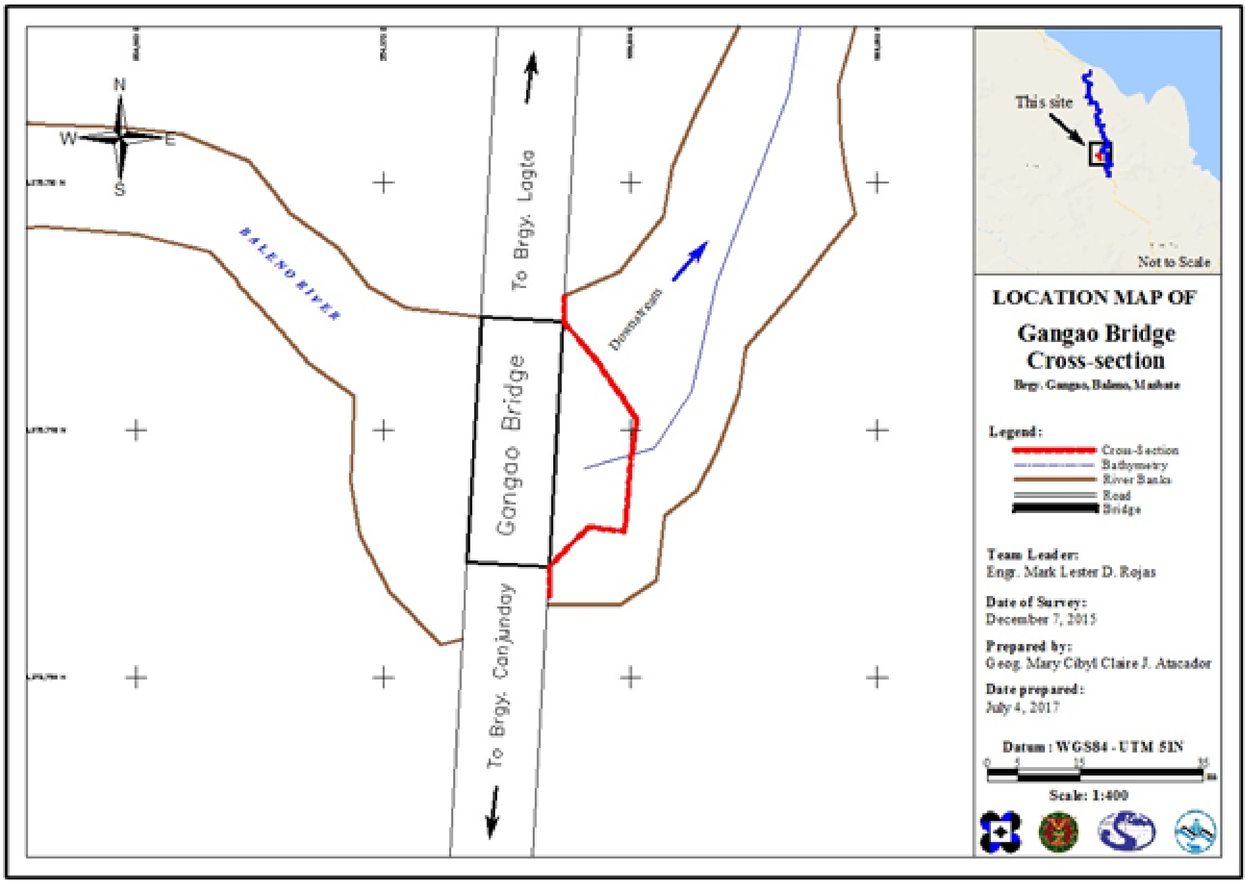


Figure 42. Gangao bridge cross-section location map

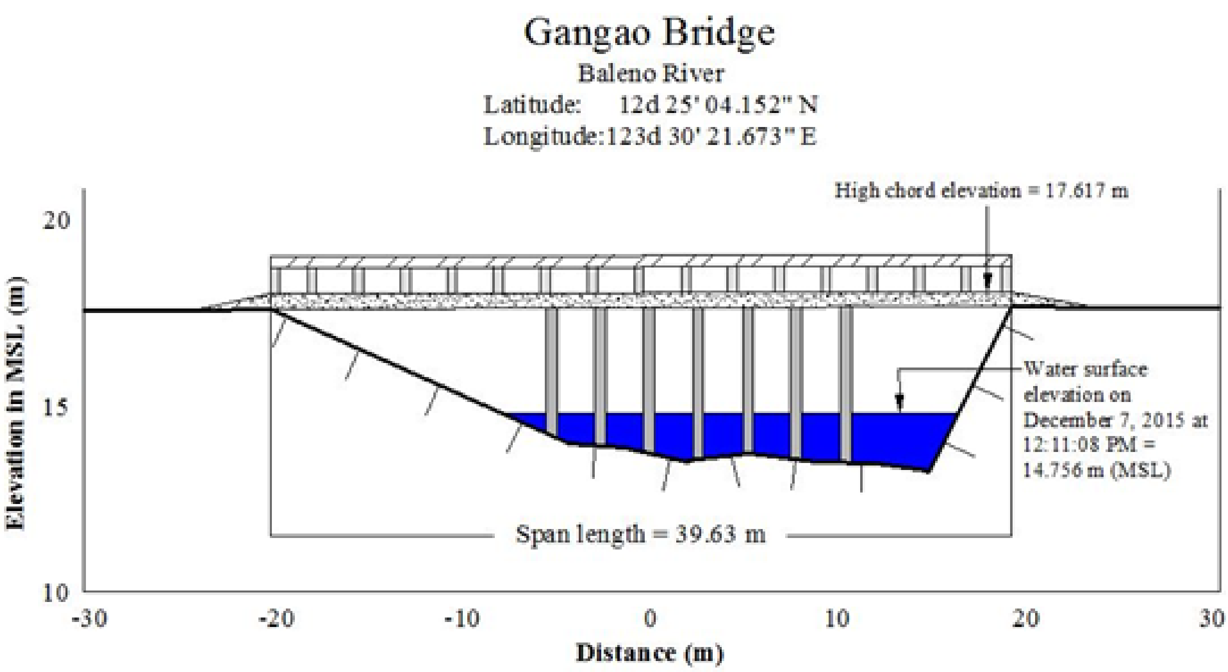


Figure 43. Bridge as-built and cross-sectional diagram of Baleno River at Gangao Bridge, Brgy. Gangao, Municipality of Baleno, Masbate

Bridge Data Form

Bridge Name: CANCAHORAO BRIDGE **Date:** December 7, 2015

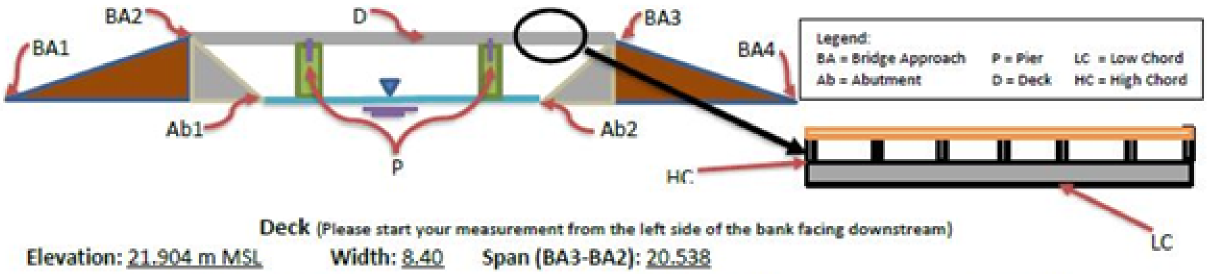
River Name: BALENO RIVER **Time:** 10:30 AM

Location (Brgy, City, Region): Brgy. Cancahorao, Baleno, Masbate

Survey Team: Mark Lester Rojas, Anthony Felix Abogado, Jessica Emil Compuesto, Mary Cibyl Claire Atacador

Flow condition: low (normal) high **Weather Condition:** (fair) rainy

Latitude: 12°24'12.91441" **Longitude:** 123°30'37.42249"



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

Elevation: 21.904 m MSL **Width:** 8.40 **Span (BA3-BA2):** 20.538

	Station	High Chord Elevation	Low Chord Elevation
1	5.282693	21.736	19.956
2	20.82436	16.881	15.101
3			
4			
5			
6			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	21.498	BA3	25.82033	21.904
BA2	5.282693	21.736	BA4	31.15621	21.422

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

	Station (Distance from BA1)	Elevation
Ab1	8.732493	17.886
Ab2	20.82436	16.881

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

Shape: ____________ **Number of Piers:** 0 **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			

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

Figure 44. Bridge Data Form of Cancahorao Bridge

Bridge Data Form

Bridge Name: GANGAO BRIDGE Date: December 7, 2015

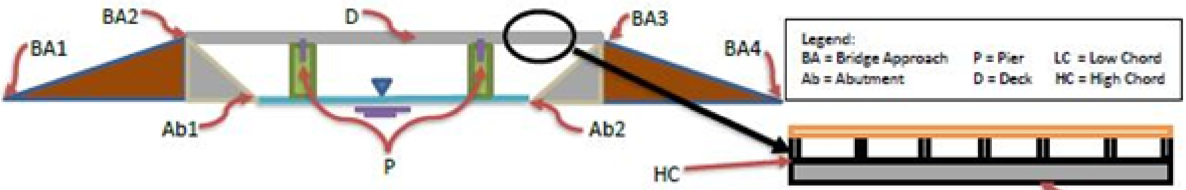
River Name: BALENO RIVER Time: 12:11 pm

Location (Brgy, City, Region): Brgy. Gangao, Baleno, Masbate

Survey Team: Mark Lester Rojas, Anthony Felix Abogado, Jessica Emil Compuesto, Mary Cibyl Claire Atacador

Flow condition: low (normal) high Weather Condition: (fair) rainy

Latitude: 12°25'04.15166" Longitude: 123°30'21.67259"



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

Elevation: 10.598 m MSL Width: n/a Span (BA3-BA2): 39.63 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 7	17.625	
2	Pier 6	17.624	
3	Pier 5	17.640	
4	Pier 4	17.644	
5	Pier 3	17.627	
6	Pier 2	17.636	
7	Pier 1	17.632	

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	17.533	BA3	43.77134	17.617
BA2	4.149448	17.562	BA4	48.49967	17.607

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

	Station (Distance from BA1)	Elevation
Ab1	11.96771	14.700
Ab2	37.49496	14.725

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

Shape: ____________ Number of Piers: 7 Height of column footing: n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	19.23950	17.632	
Pier 2	21.84147	17.636	
Pier 3	24.41719	17.627	
Pier 4	27.04572	17.644	
Pier 5	29.72036	17.640	

Figure 45. Gangao Bridge Data Form

Water surface elevation in MSL of Baleno River was determined using Trimble® SPS 882 in PPK mode survey on December 7, 2015 at 12:10 AM. This was translated onto marking on Cancahorao bridge's abutment using a digital level. The resulting water surface elevation data is 15.758 meters above MSL. The marking on the bridge's abutment with an elevation of 19.956 meters is shown in Figure 46. The water-level marker with an elevation of 16.208 meters in Gangao Bridge on the other hand was done in the first pier from the right side of the bridge when facing downstream. This shall serve as a reference for flow data gathering and depth gauge deployment of ADNU PHIL-LIDAR 1.

Figure 46. Water-level marking on an abutment of Cancahorao Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 5 to 6, 2015. A Trimble® SPS 882 was attached in front of a vehicle, as shown in Figure 47, to measure points utilizing continuous topo method in a PPK survey technique. The height of instrument was measured and noted a 1.902-meter distance from the ground up to the bottom of notch. Points were gathered along major concrete roads with the aid of a vehicle which moved at a speed of 20-40 kph, cutting across the flight strips of the DAC with the aid of available topographic maps and Google EarthTM images.

On December 5, validation points acquisition survey ran from Mabuaya Bridge in Brgy. Matiporon, Milagros to Brgy. Poblacion, Aroroy via Baleno in an almost semi-circumferential route. The reference point MST-4549 was utilized during this survey. The second day of this survey also started in Mabuayan Bridge going to Brgy. Poblacion in Aroroy via Mandaon, the other half of the circumferential road. This survey also covered Mandaon Road which started from Brgy. Mabatobato going southwest towards Brgy. Nailaban, both in the Municipality of Mandaon. The reference point MST-27 was used as base station for the last route.

Figure 47. Validation points acquisition survey setup: A Trimble® SPS 882, mounted on top of the vehicle

The map in Figure 48 shows the extent of the ground validation survey which acquired a total of 4,709 ground validation points with an approximate length of 112 km.

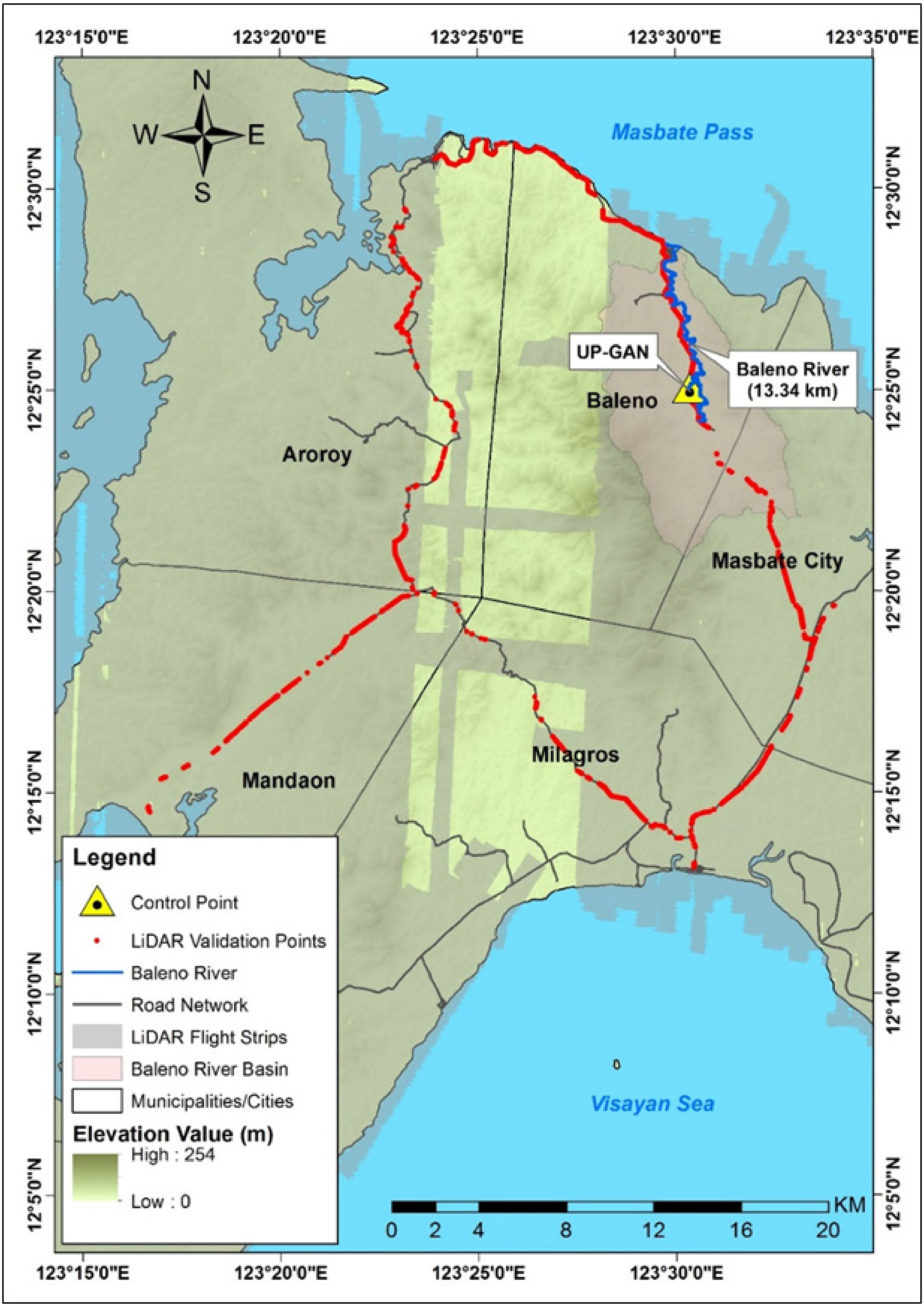


Figure 48. Points gathered during the LiDAR Ground Validation Survey for Baleno River Basin

4.7 River Bathymetric Survey

Bathymetric survey for Baleno River was conducted on December 8, 12, 13 and 14, 2015 using MST-4549 as the base station during the survey. A boat installed with an Ohmex™ single-beam echo sounder and a mounted Trimble® SPS 882 GNSS receiver was used in the deep portions of the river from Brgy. Lipata up to Brgy. Sog-Ong as shown in Figure 50.

Manual bathymetric survey, in which the river was traversed on foot while the Trimble® SPS 882 GNSS receiver attached to a range pole was carried manually and pointed upright during the collection of data points, was also conducted on shallow portions of the river as exhibited in Figure 49.

Figure 49. Setup of Trimble® SPS 882 receiver on a range pole for the manual bathymetric survey in Baleno River

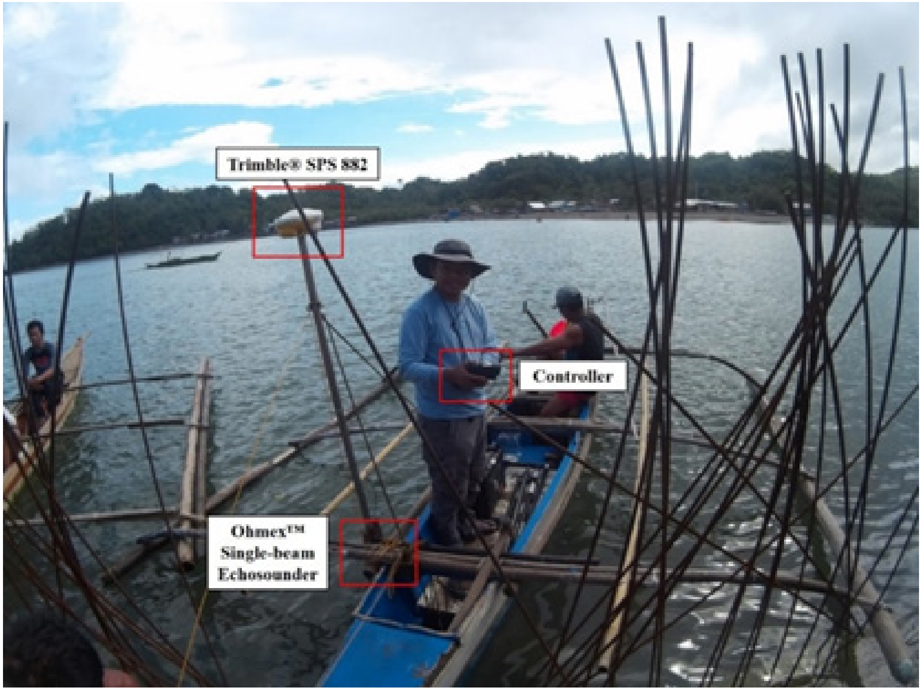


Figure 50. Setup of Trimble® SPS 882 receiver and Ohmex™ single-beam echosounder in a boat for the bathymetric survey in Baleno River

The bathymetric line surveyed has an estimated length of 13.34 km with 2,438 bathymetric points covering eight barangays in Municipality of Baleno namely: Batuila, Cagara, Canjunday, Gangao, Lagta, Lipata, Poblacion, and Song-ong. The survey started upstream in Brgy. Canjunday in the Municipality of Baleno with coordinates 12°24’13.29005” 123°30’36.98723” down to the mouth of the river in Brgy. Lipata, also in the Municipality of Baleno. A CAD drawing illustrating the centerline bathymetric profile of Baleno was generated and shown in Figure 52 and Figure 53. An elevation drop of 5.52 -meters was observed between the upstream end and the downstream end of the riverbed profile. The highest elevation observed was 15.558 m in MSL located at the upstream part of the river in Brgy. Canjunday, while the highest elevation observed was -6.818 m below MSL located near the mouth of the river in Brgy. Poblacion, both in Municipality of Baleno.

The planned bathymetric profile length is 7.04 km, it was extended because the bridges namely, Cancahorao and Gangao bridges are located in the upstream portion of the river. The extension for the main river is around 5.57 km and the tributary from Gangao Bridge to the main river runs approximately 0.700 km.

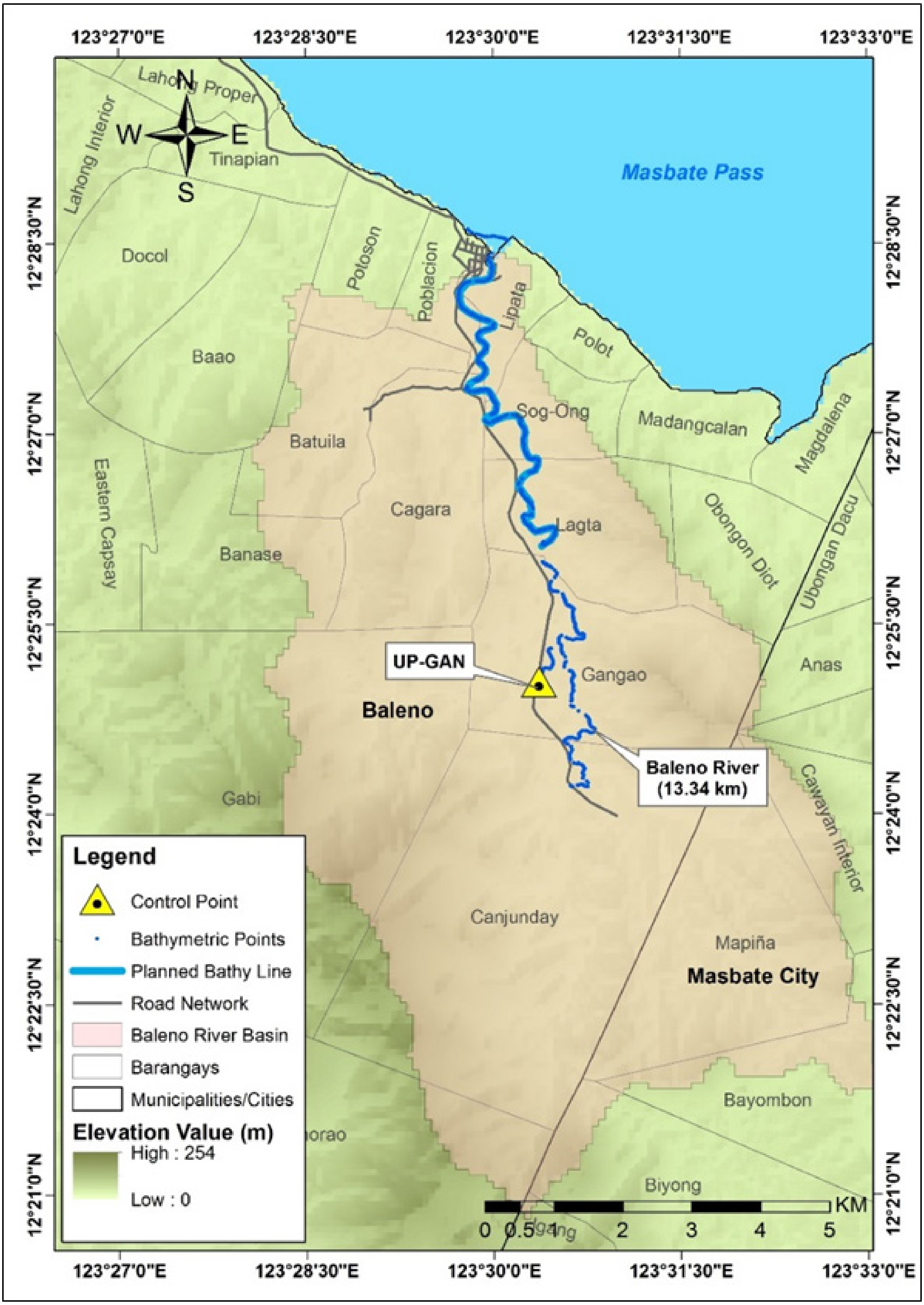


Figure 51. Acquired bathymetric points for Baleno River

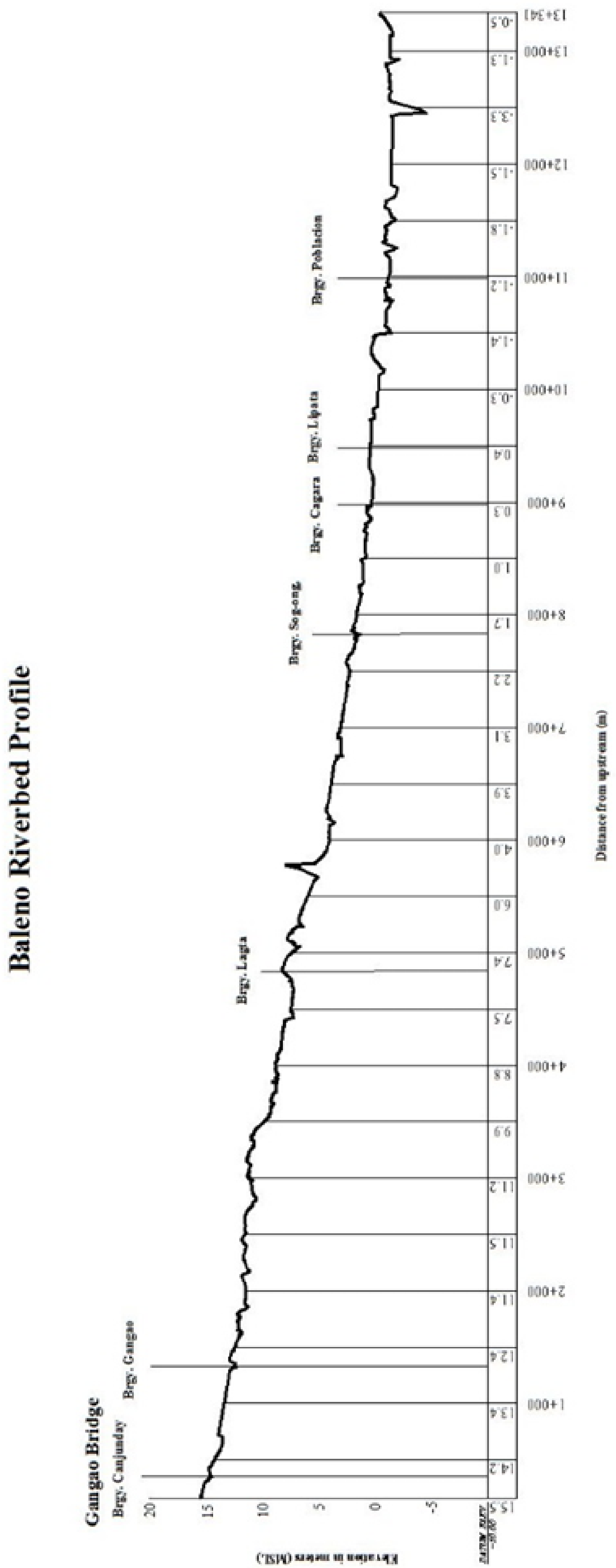


Figure 52. Segment 1 of 2 of Baleno centerline riverbed profile

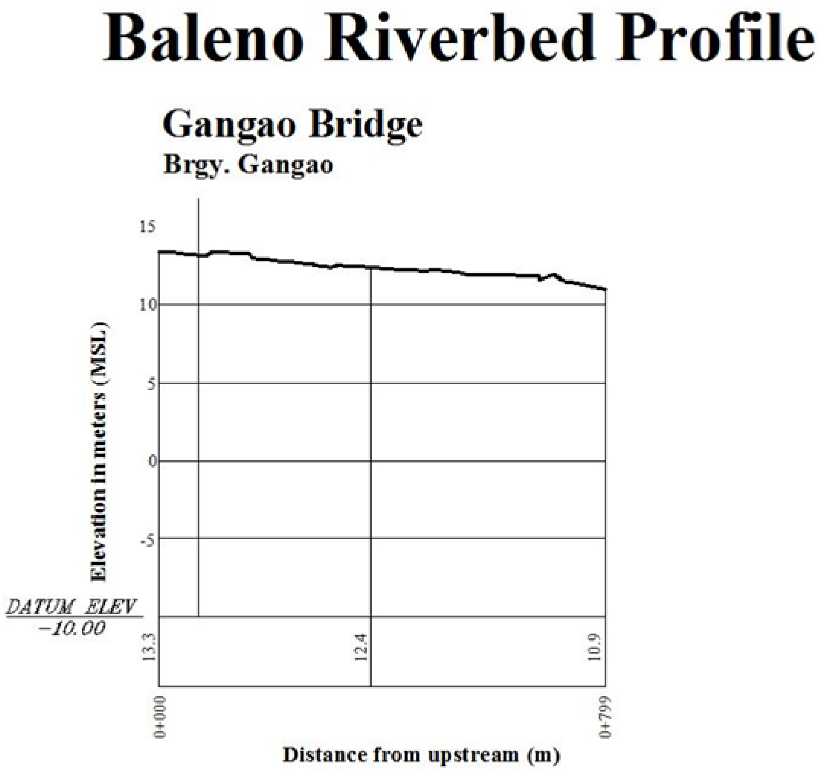


Figure 53. Segment 2 of 2 of Baleno centerline riverbed profile

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, Gianni Sumajit, Daniel S. Baer Jr., Sarah Mae F. Fulleros, Berlin Phil V. Garciano, Julius Hector S. Manchete, Ernesto F. Razal Jr., and Engr. Herminio Magpantay and Engr. Ferdinand E. Bien

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARGs) deployed by the ADNU-FMC team. The rain gauge is located at Masbate City (Figure 54). The precipitation data collection started from January 14, 2017 at 12:00 AM to January 17, 2017 at 12:00 AM with a 10-minute recording interval.

The total precipitation for this event in the deployed ARG is 52.2mm. It has a peak rainfall of 5.8mm on January 14, 2017 at 4:10 AM. The lag time between the peak rainfall and discharge is 43 hours and 20 minutes.

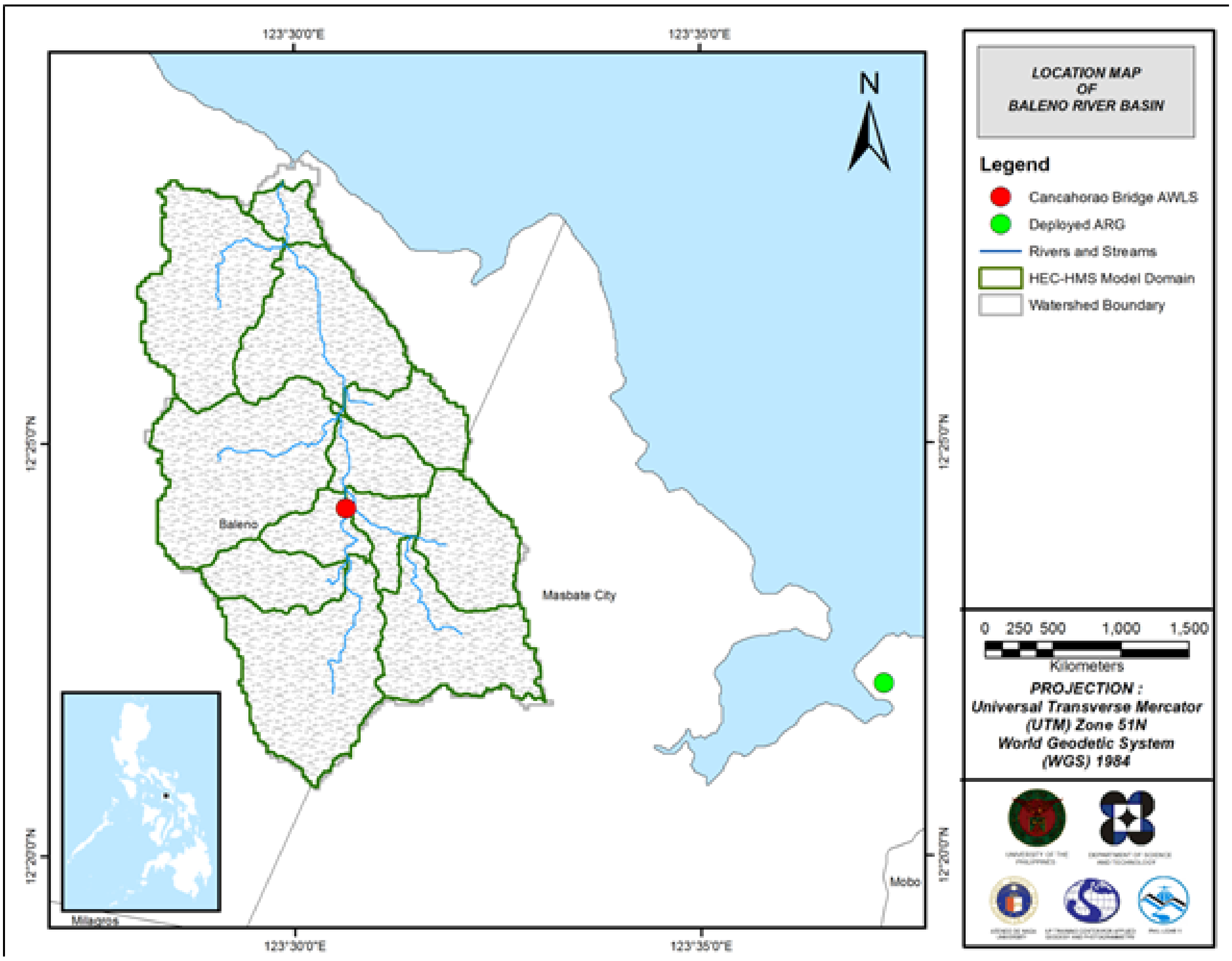


Figure 54. The location map of Baleno HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Cancahorao Bridge, Baleno, Masbate (12°24'13"N, 123°30'37.8"E). It gives the relationship between the observed water levels at Cancahorao Bridge and outflow of the watershed at this location.

For Cancahorao Bridge, the rating curve is expressed as Q = 0.00003e.0.7283h as shown in Figure 56.

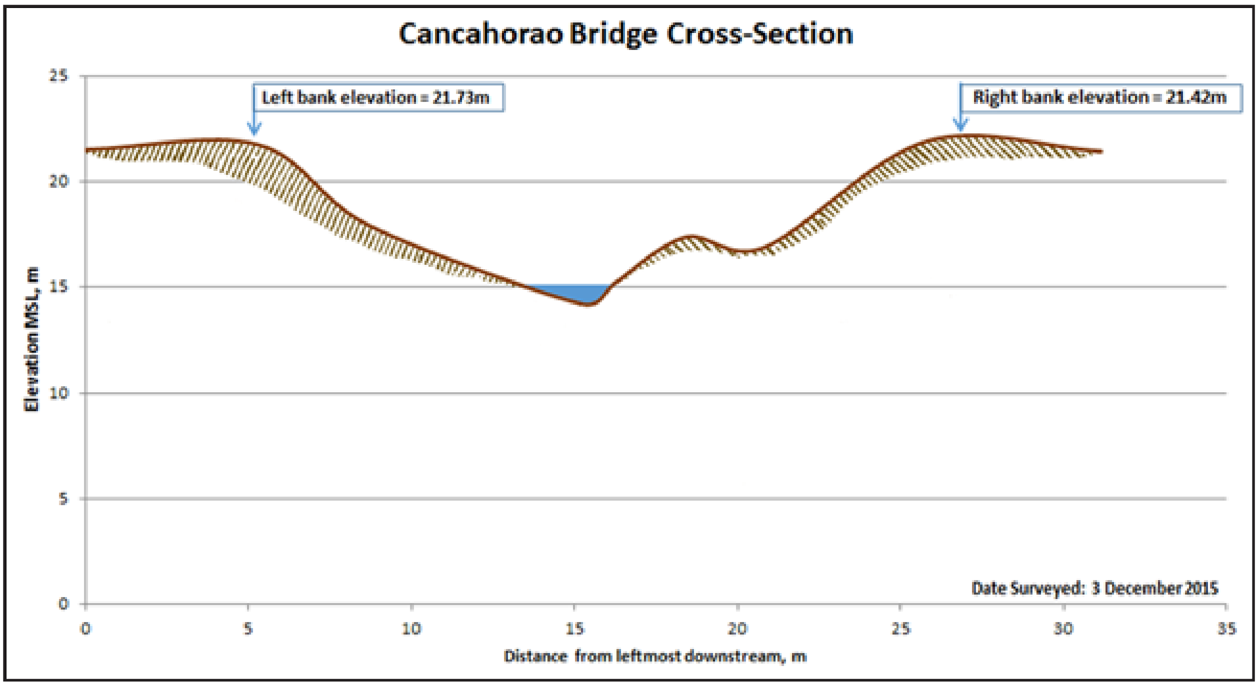


Figure 55. The cross-section plot of Cancahorao Bridge

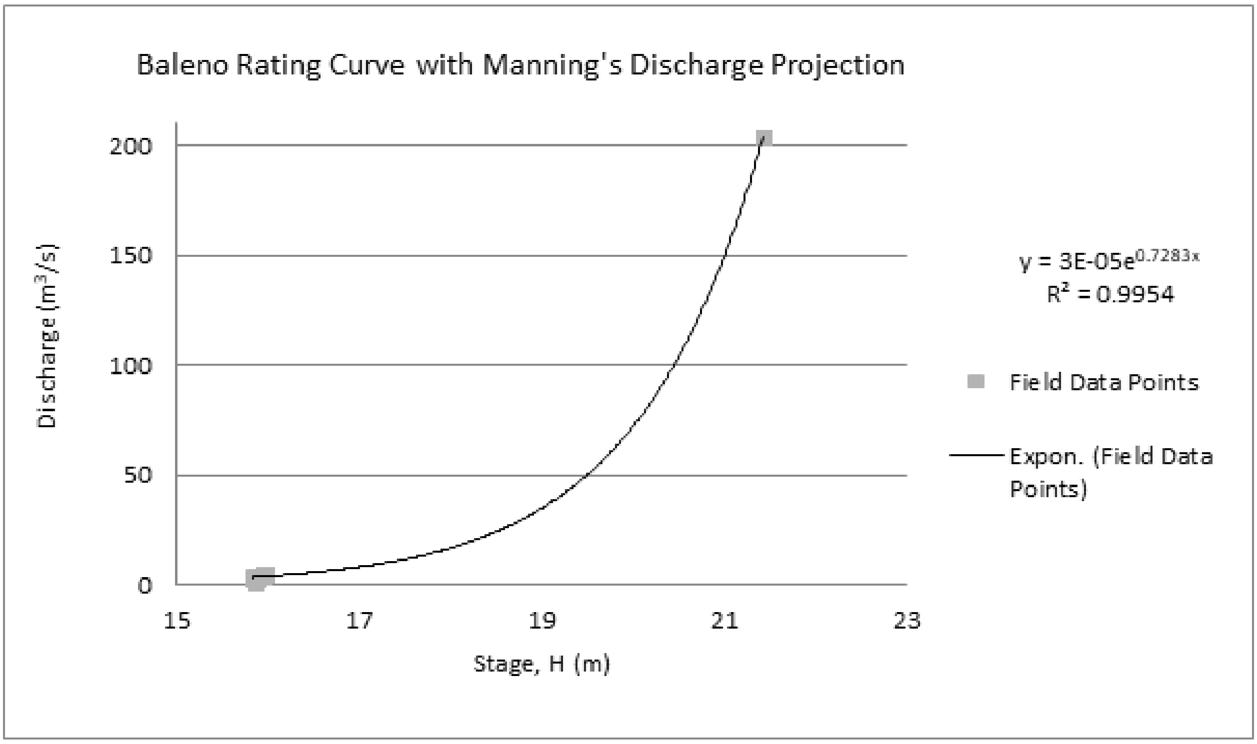


Figure 56. The rating curve of Cancahorao Bridge in Baleno, Masbate

This rating curve equation was used to compute the river outflow at Cancahorao Bridge for the calibration of the HEC-HMS model shown in Figure 57. The total rainfall for this event is 52.2mm and the peak discharge is 3.5m3/s at 11:30 PM, January 15, 2017.

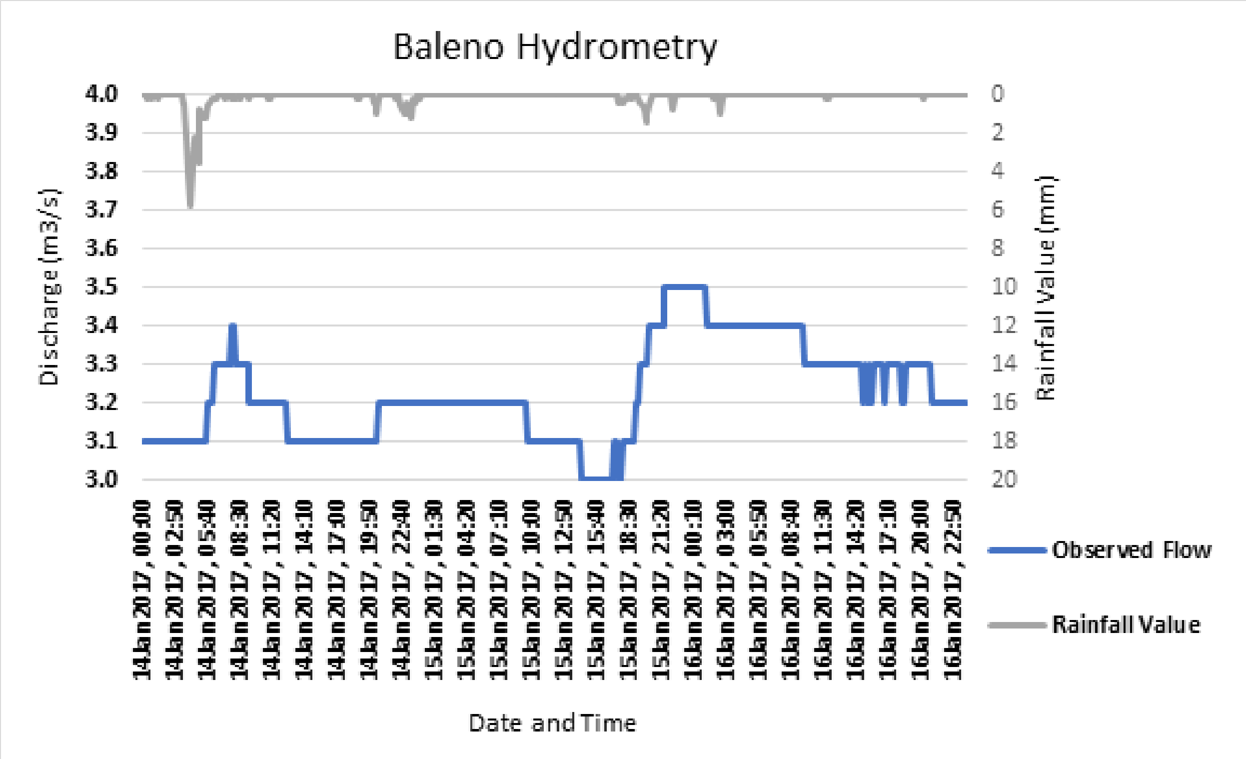


Figure 57. Rainfall and outflow data of the Baleno River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Legazpi RIDF. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Baleno watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 28. RIDF values for Baleno Rain Gauge computed by PAG-ASA

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	21	31.9	39.6	53.4	74.5	89.3	119.2	145.5	176.4
5	29.1	43.8	54.5	76.7	113.4	138.5	189.8	228.7	260.5
10	34.5	51.6	64.3	92.2	139.1	171.1	236.6	283.8	316.1
15	37.5	56	69.8	100.9	153.6	189.4	263	314.8	347.5
20	39.6	59.1	73.7	107	163.7	202.3	281.5	336.6	369.5
25	41.3	61.5	76.7	111.7	171.6	212.2	295.7	353.4	386.4
50	46.3	68.9	85.9	126.2	195.7	242.7	339.6	405	438.6
100	51.3	76.2	95.1	140.5	219.6	273.1	383.1	456.2	490.3

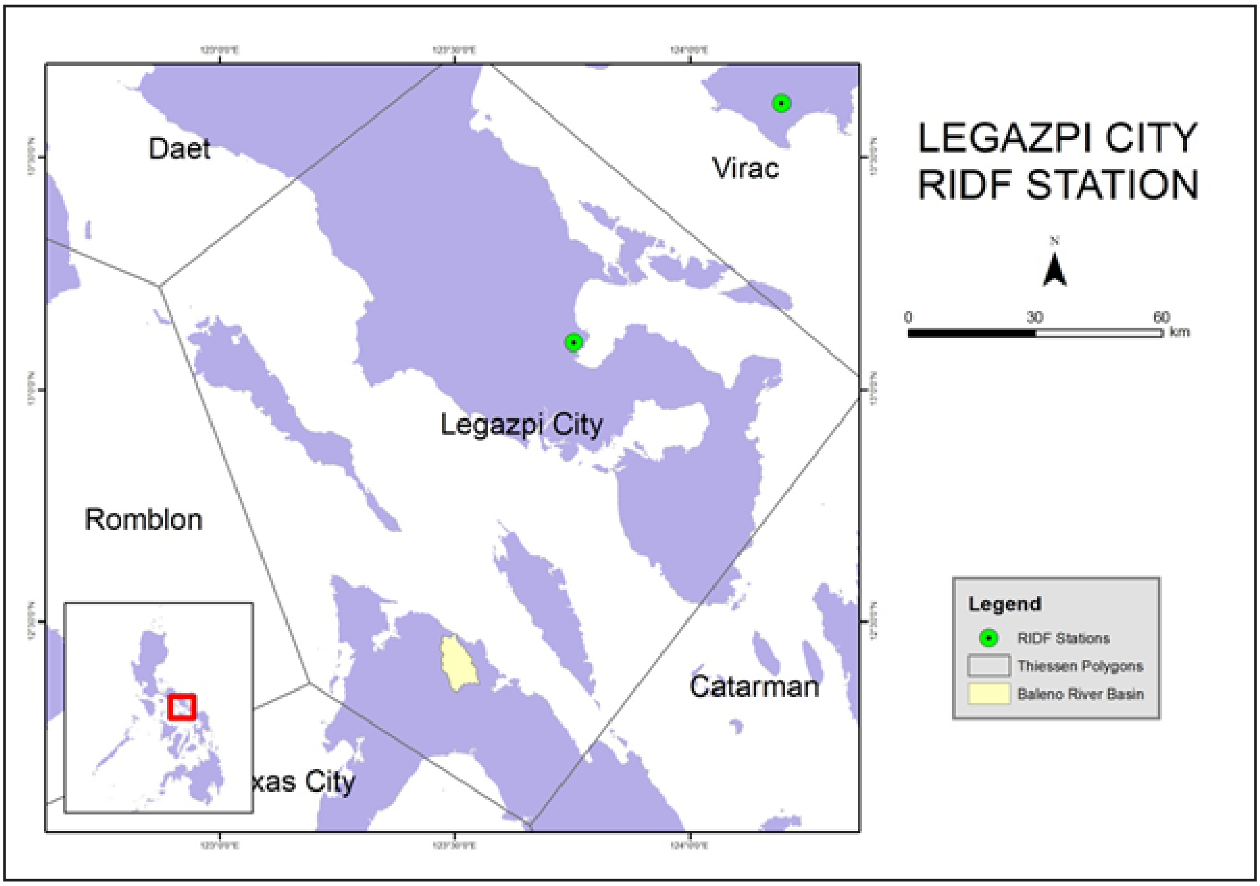


Figure 58. The location of the Legazpi City RIDF station relative to the Baleno River Basin

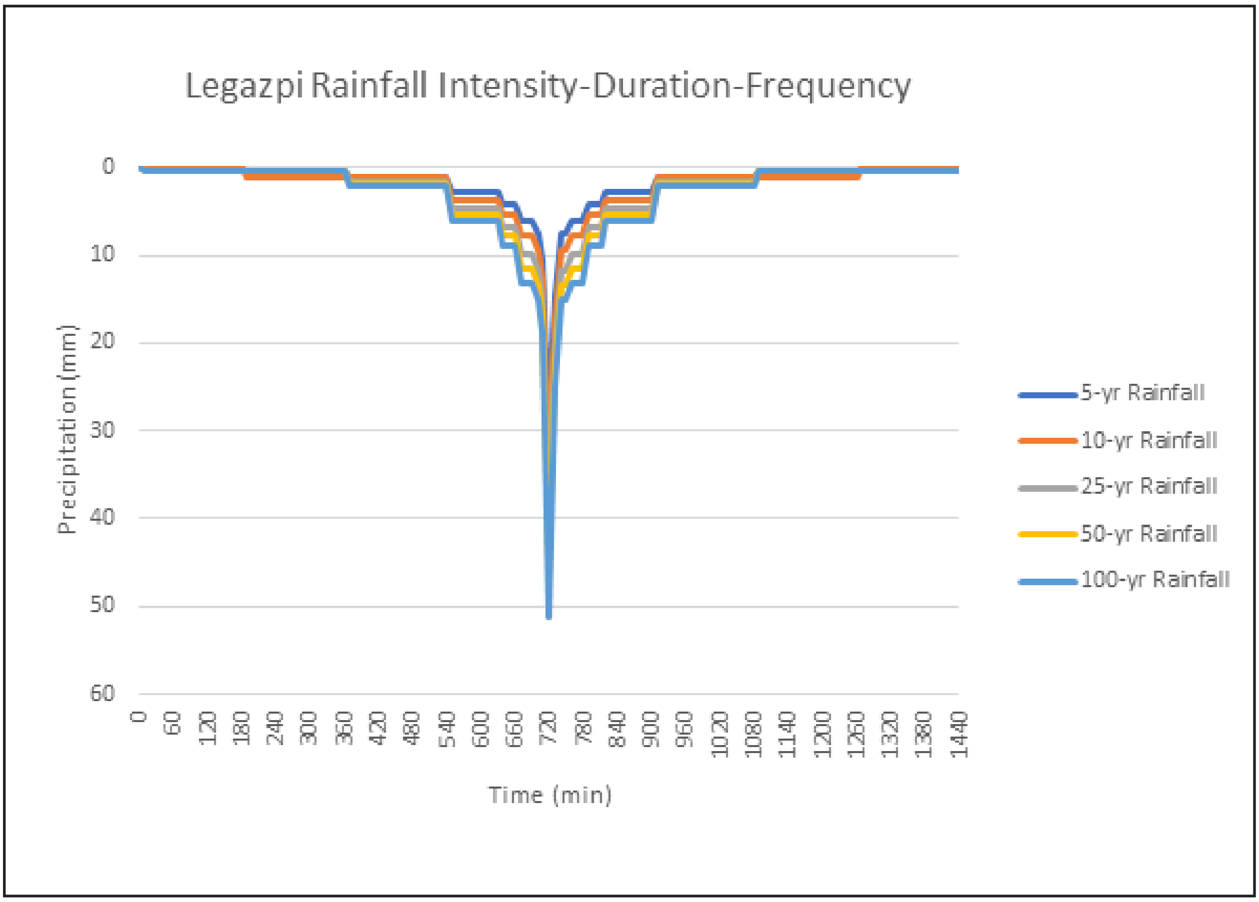


Figure 59. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover shape file is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Baleno River Basin are shown in Figures 60 and 61, respectively.

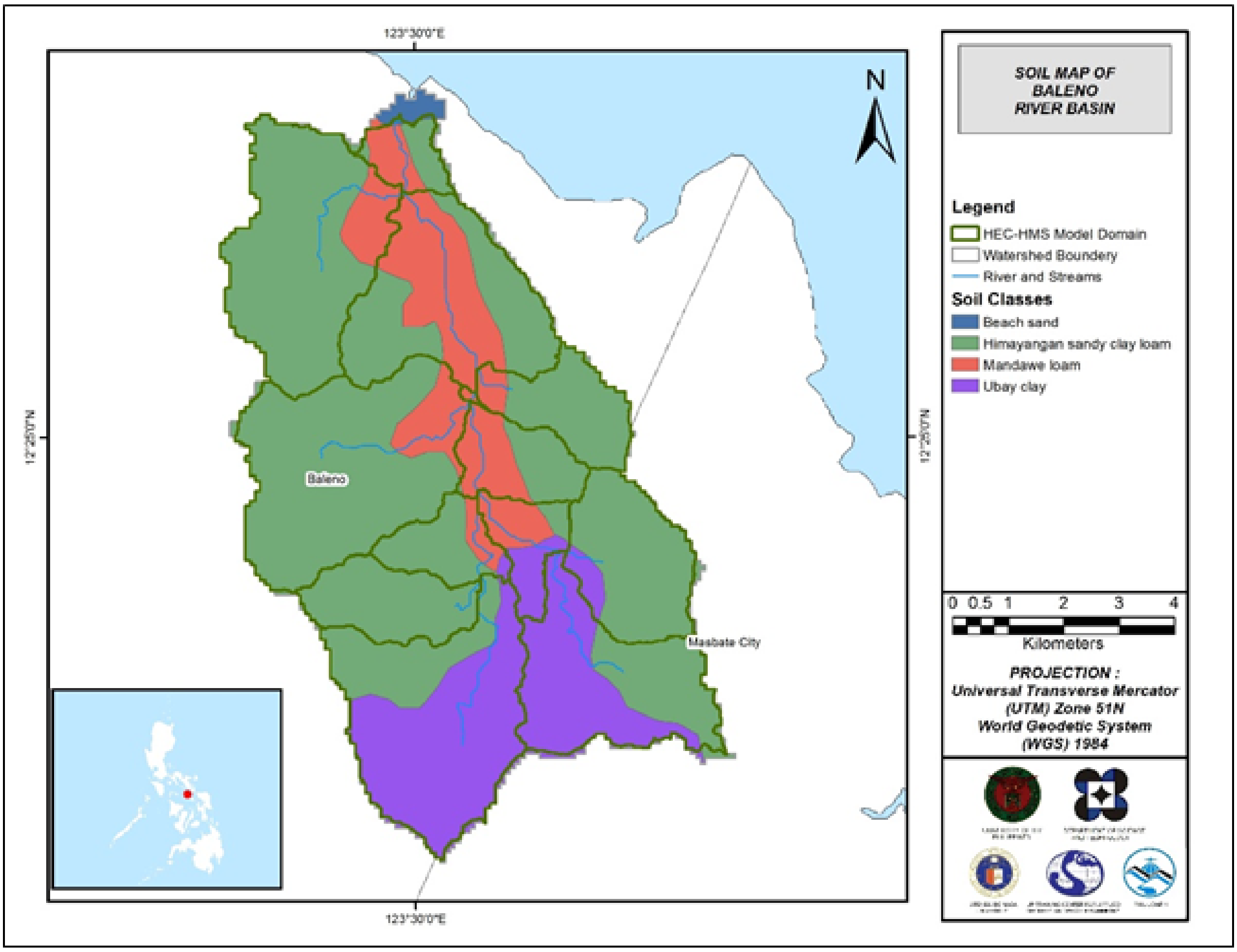


Figure 60. Soil map of Baleno River Basin

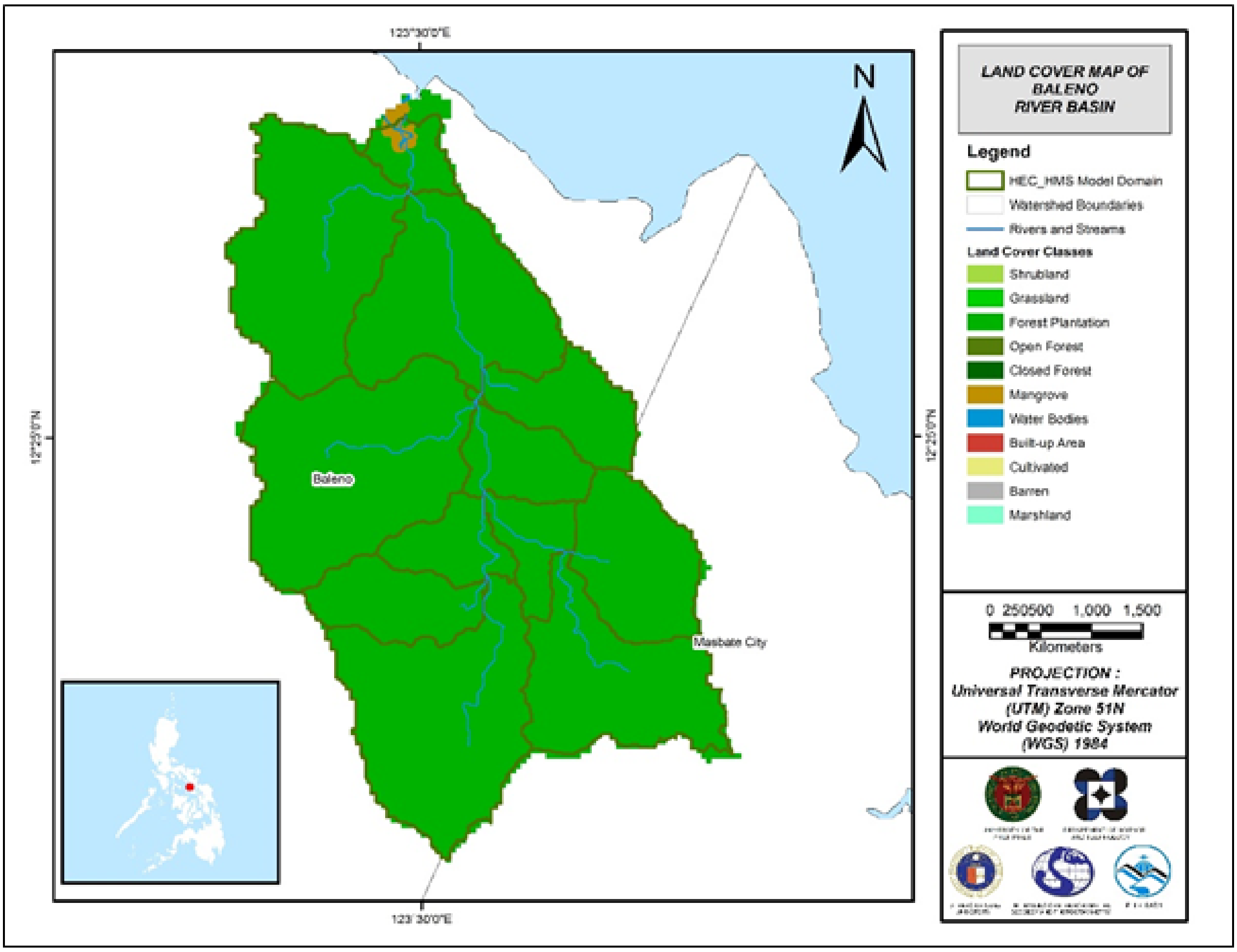


Figure 61. Land cover map of Baleno River Basin

For Baleno, four soil classes were identified: Himayangan sandy clay loam, Mandawe loam, Ubay clay, and beach sand. Moreover, two land cover classes were identified: forest plantation and mangrove.

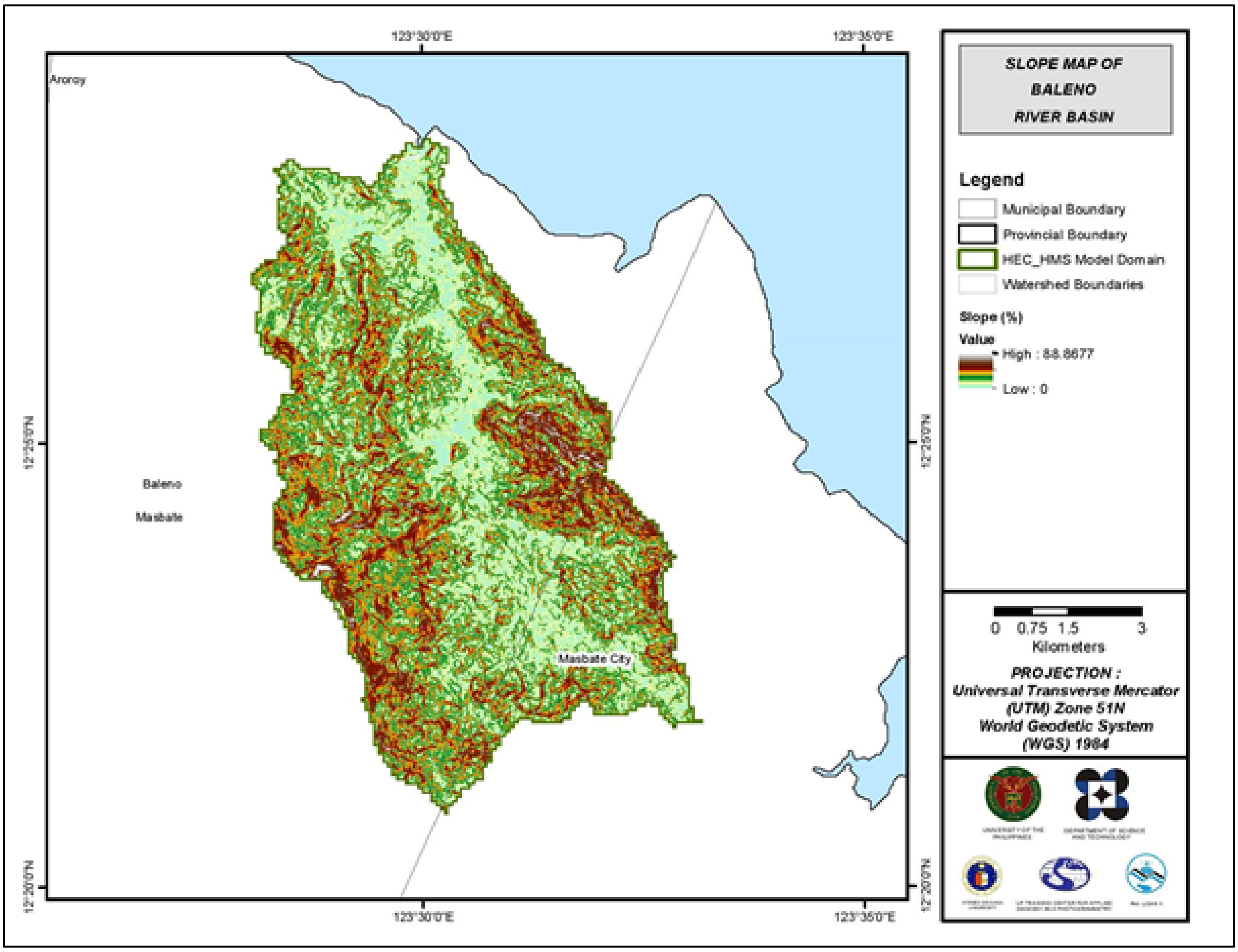


Figure 62. Slope map of Baleno River Basin

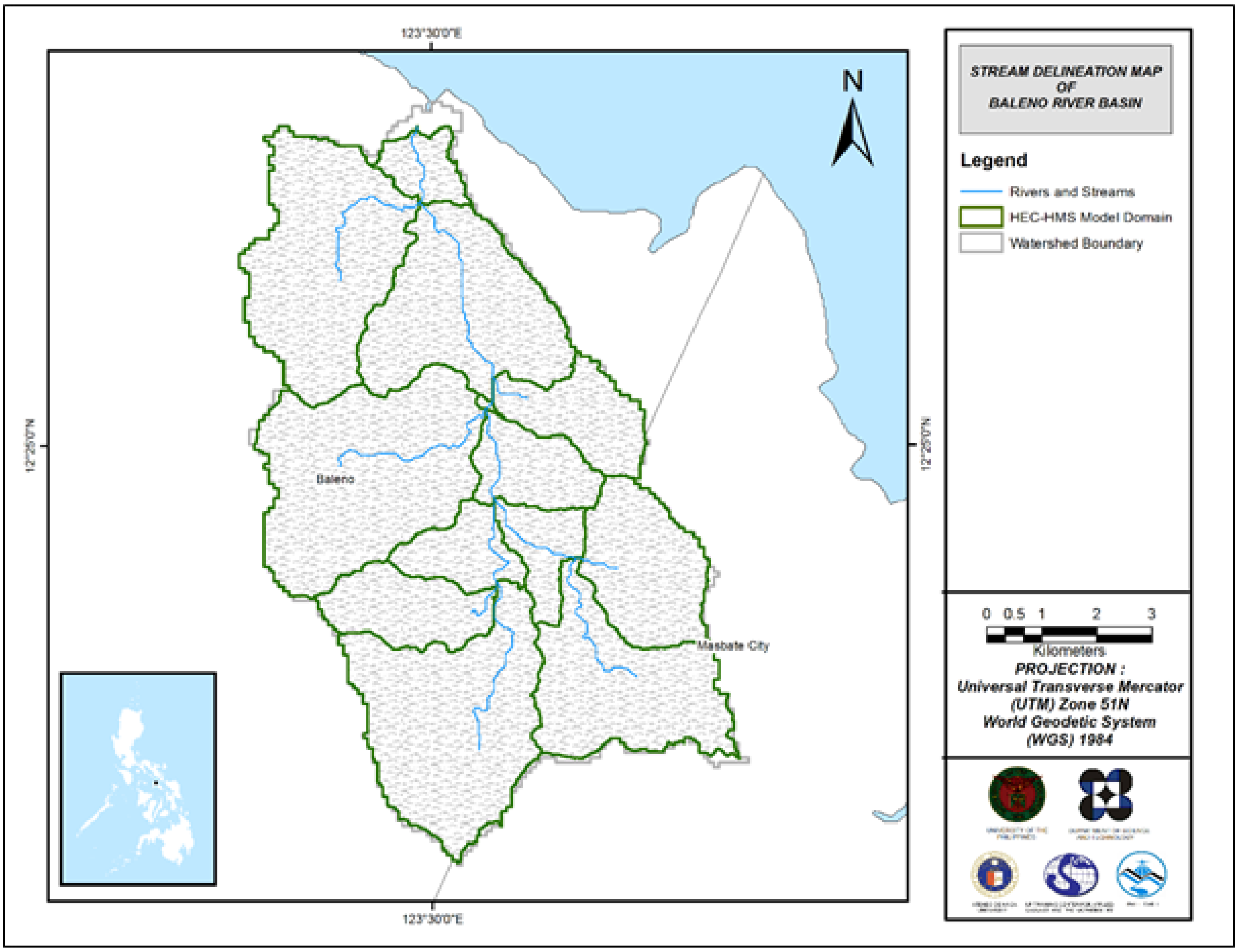


Figure 63. Stream delineation map of Baleno River Basin

Using the SAR-based DEM, the Baleno basin was delineated and further divided into subbasins. The model consists of 23 sub basins, 11 reaches, and 11 junctions as shown in Figure 64. The main outlet is Cancahorao Bridge.

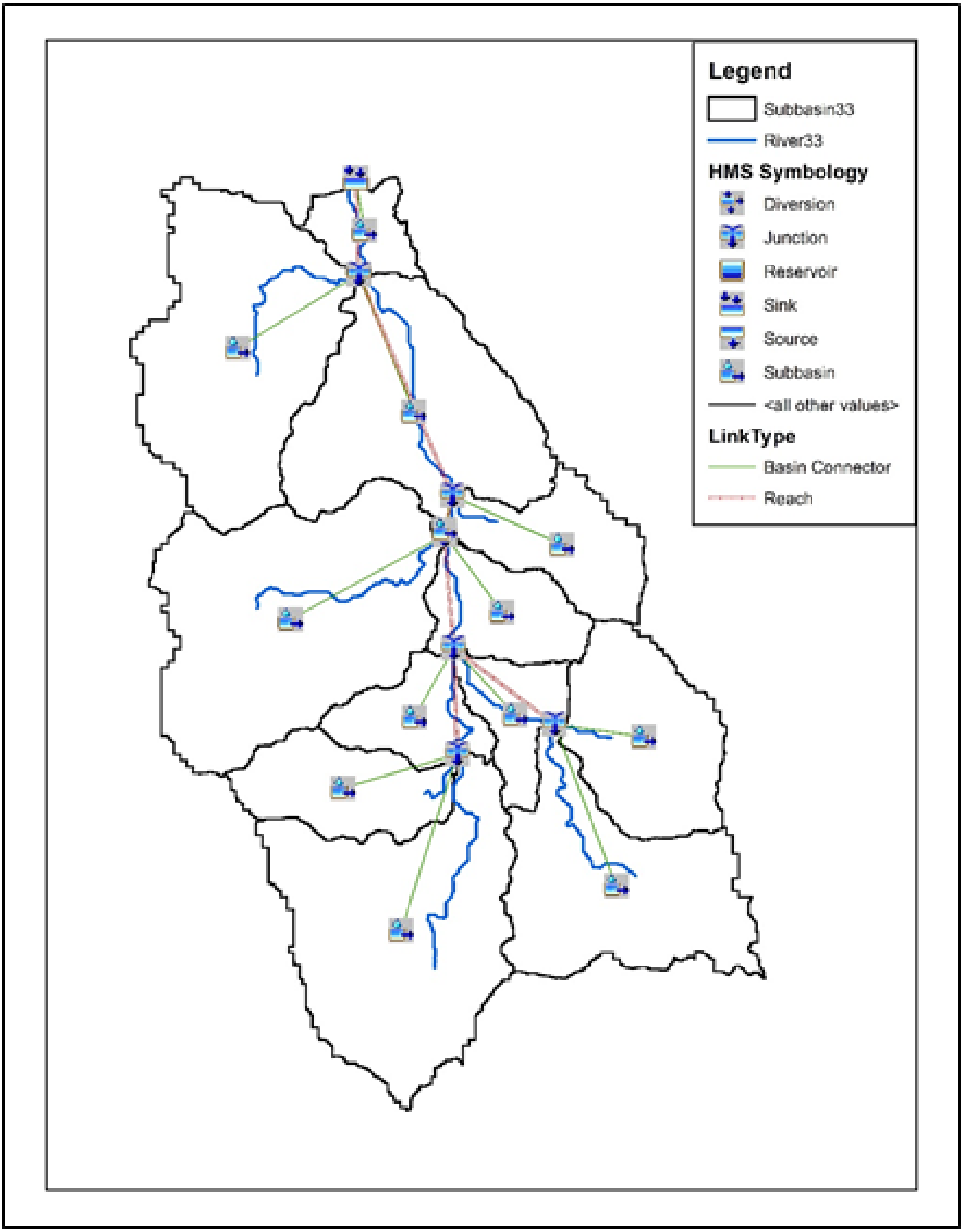


Figure 64. The Baleno river basin model generated using HEC-HMS

5.4 Cross-section Data

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

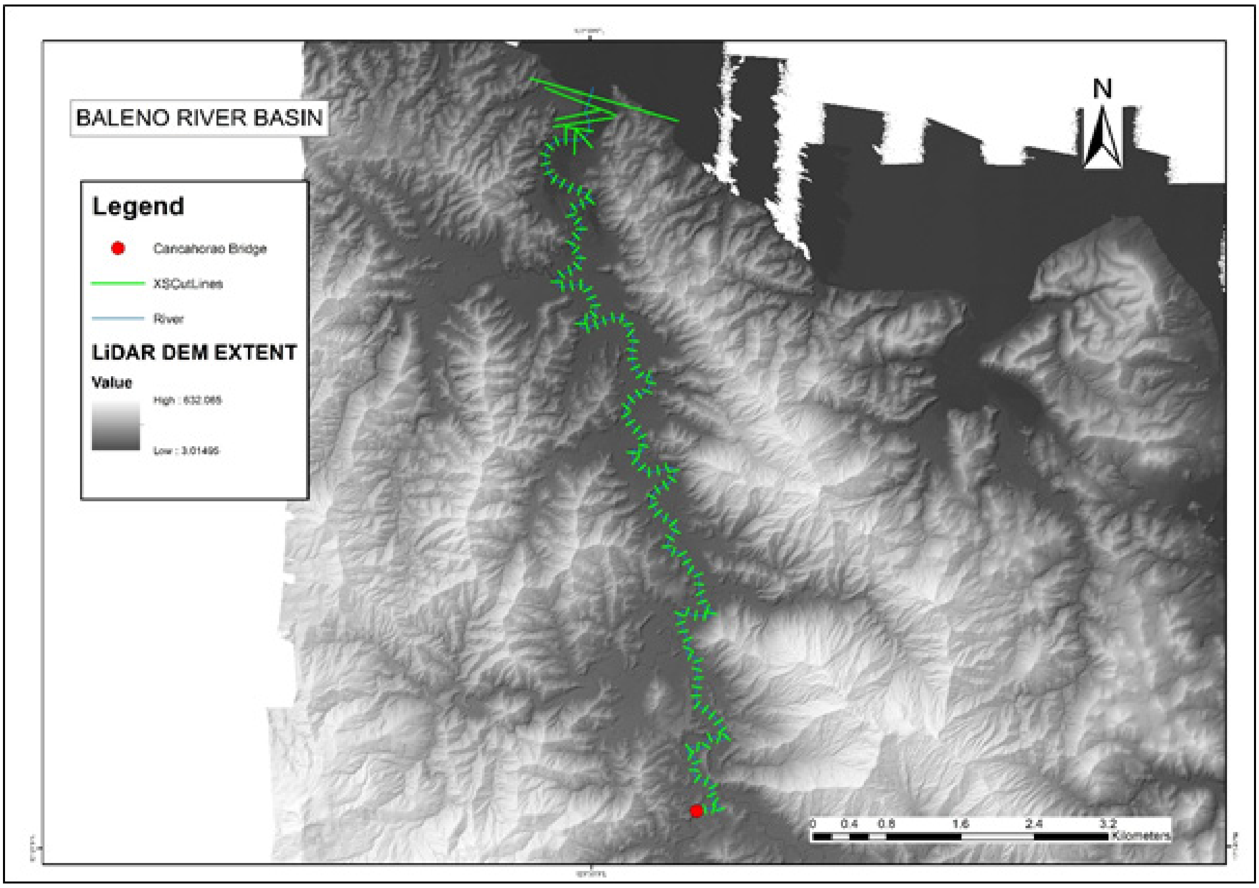


Figure 65. River cross-section of Baleno River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 66. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 33.61829 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Baleno are in Figure 70, Figure 72, and Figure 74.

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 46 961 000.00 m2. The generated flood depth maps for Baleno are in Figure 71, Figure 73, and Figure 75.

There is a total of 16,218,008.26 m3 of water entering the model. Of this amount, 10,661,313.81 m3 is due to rainfall while 5,556,694.45 m3 is inflow from other areas outside the model. 2,883,062.75 m3 of this water is lost to infiltration and interception, while 2,856,480.05 m3 is stored by the flood plain. The rest, amounting up to 10,475,738.96 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Baleno HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 67 shows the comparison between the two discharge data.

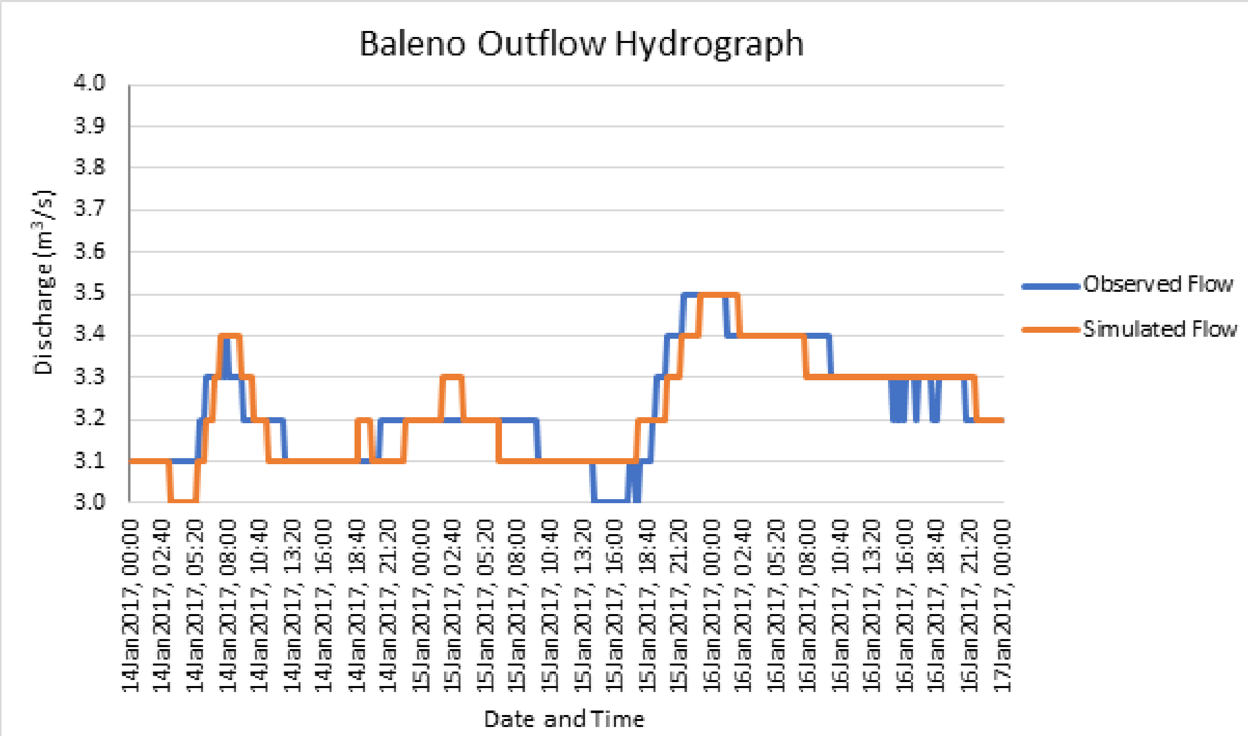


Figure 67. Outflow hydrograph of Baleno River Basin produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for the Baleno River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.002-490
			Curve Number	40-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-86
			Storage Coefficient (hr)	0.06-473
	Baseflow	Recession	Recession Constant	0.00001
			Ratio to Peak	0.0001-0.2
Reach	Routing	Muskingum-Cunge	Slope	0.001-0.01
			Manning's n	0.0001-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.002mm to 490mm means that there is minimal to high 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 40 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Baleno, the basin mostly consists of forest plantation and the soil consists of Himayangan sandy clay loam, Mandawe loam, and Ubay clay.

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 0.02 hours to 86 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. For Baleno, it will take at least 25 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.99 corresponds to the common roughness in Baleno watershed, which is determined to be shrubland with medium to dense brush (Brunner, 2010).

Table 30. Summary of the Efficiency Test of the Baleno HMS Model

Accuracy measure	Value
RMSE	0.06
r2	0.77
NSE	0.56
PBIAS	0.11
RSR	0.49

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.06 (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 0.77.

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 0.56.

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 0.11.

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 0.49.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 68) shows the Baleno outflow using the synthetic storm events using the Legazpi 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 from 46m3/s in a 5-year return period to 113.6m3/s in a 100-year return period.

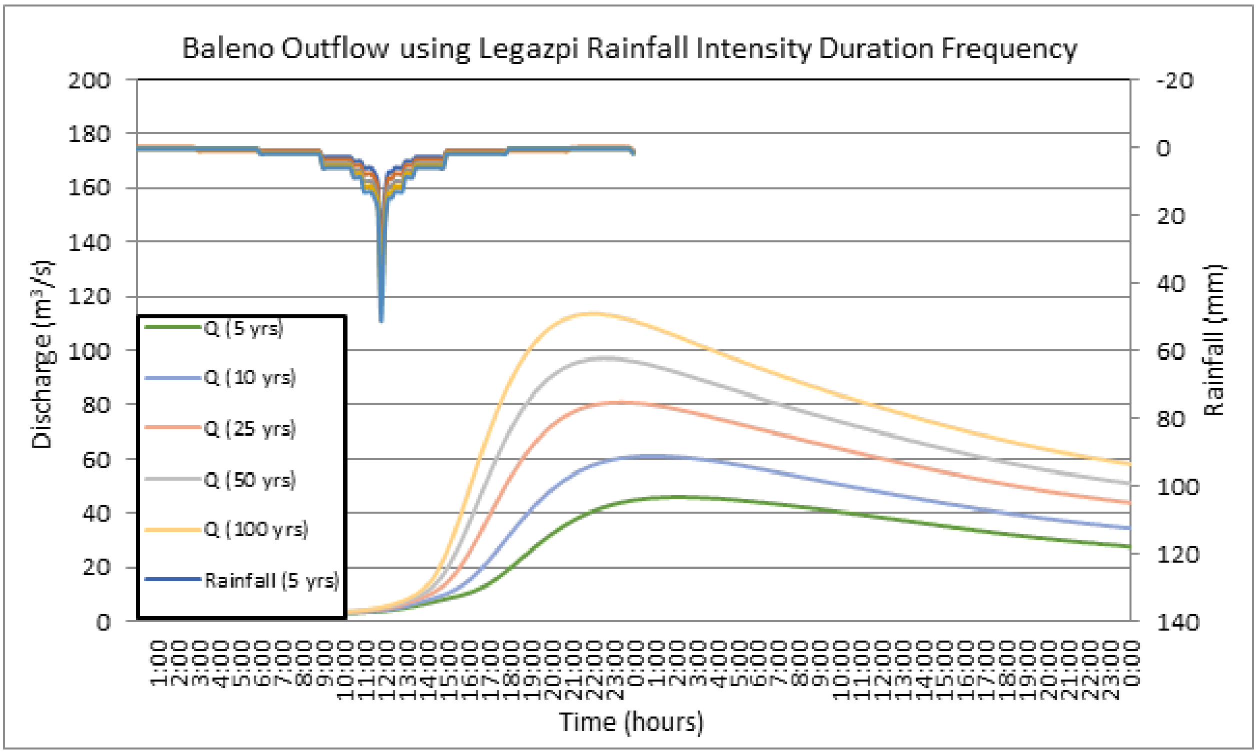


Figure 68. The outflow hydrograph at the Baleno River Basin, generated using the simulated events for 24-hour period for Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Baleno discharge using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Outlines the peak values of the Baleno HEC-HMS Model outflow using the Legazpi RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	260.50	29.1	46	13 hours, 50 minutes
10-Year	316.10	34.5	61.2	12 hours, 40 minutes
25-Year	386.40	41.3	81	11 hours, 20 minutes
50-Year	438.40	46.3	97.2	10 hours, 30 minutes
100-Year	490.30	51.3	113.6	10 hours

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, since only the ADNU-DVC base flow was calibrated. The sample generated map of Baleno River using the calibrated HMS base flow is shown in Figure 69.

Figure 69. The sample output map of the Baleno RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 17 to 22 show the 5-, 25-, and 100-year rain return scenarios of the Baleno flood plain. The flood plain, with an area of 66.74km2, covers two (2) municipalities, namely Baleno and Masbate City. Table 32 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Baleno flood plain

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Baleno	200.24	46.76	23.35
Masbate City	192.96	0.19	0.1

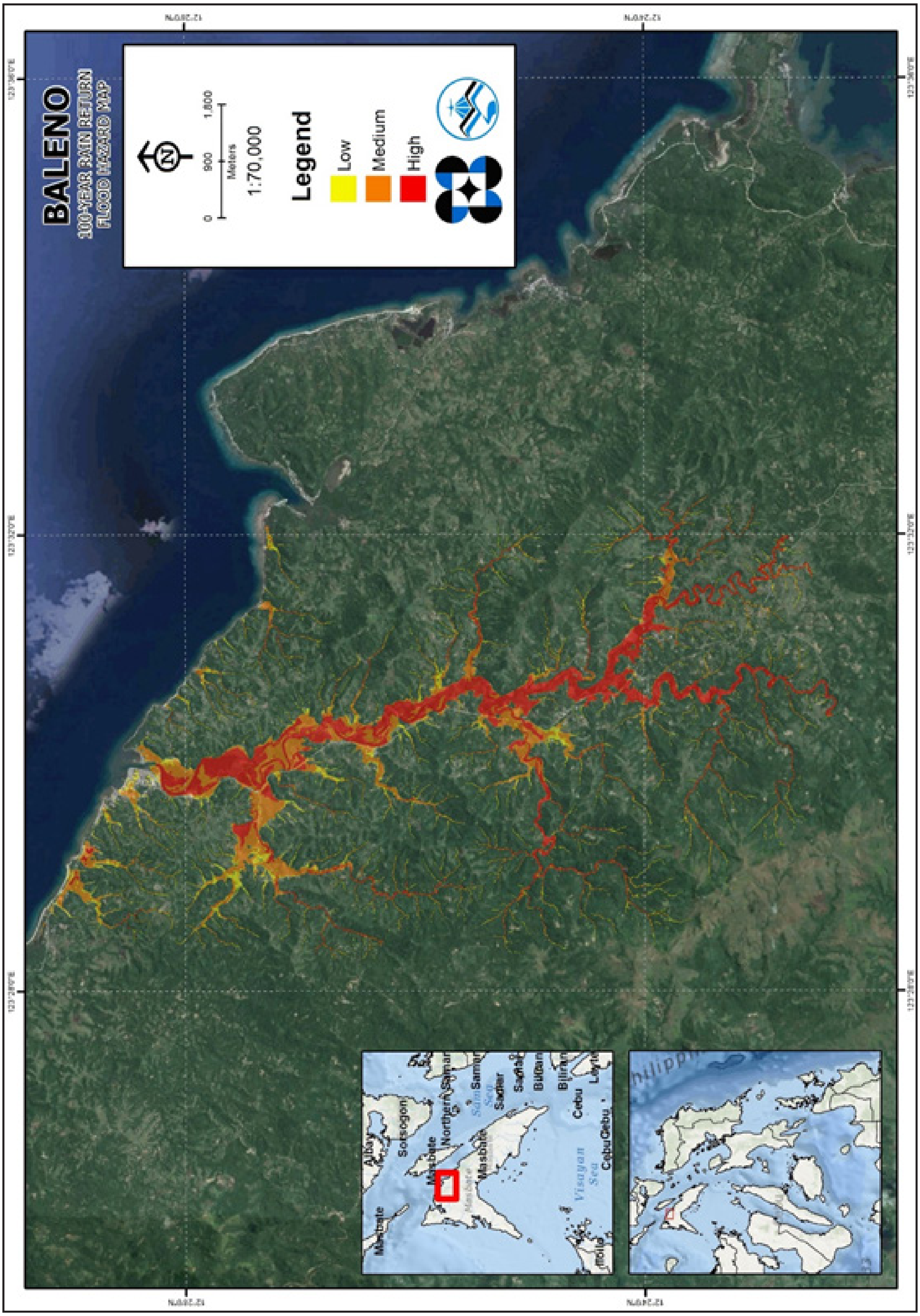


Figure 70. 100-year flood hazard map for the Baleno flood plain overlaid on Google Earth imagery

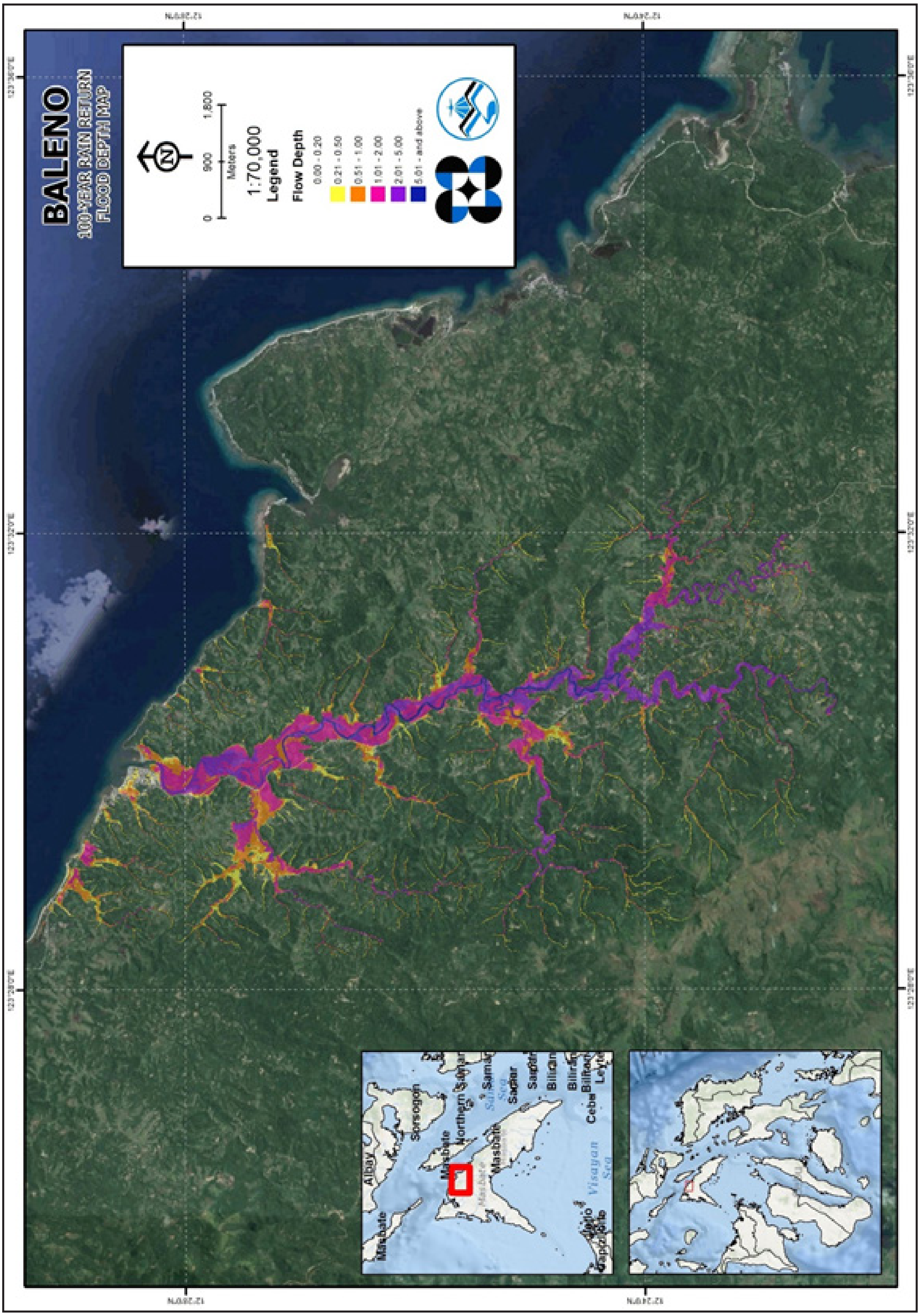


Figure 71. 100-year flow depth map for the Baleno flood plain overlaid on Google Earth imagery

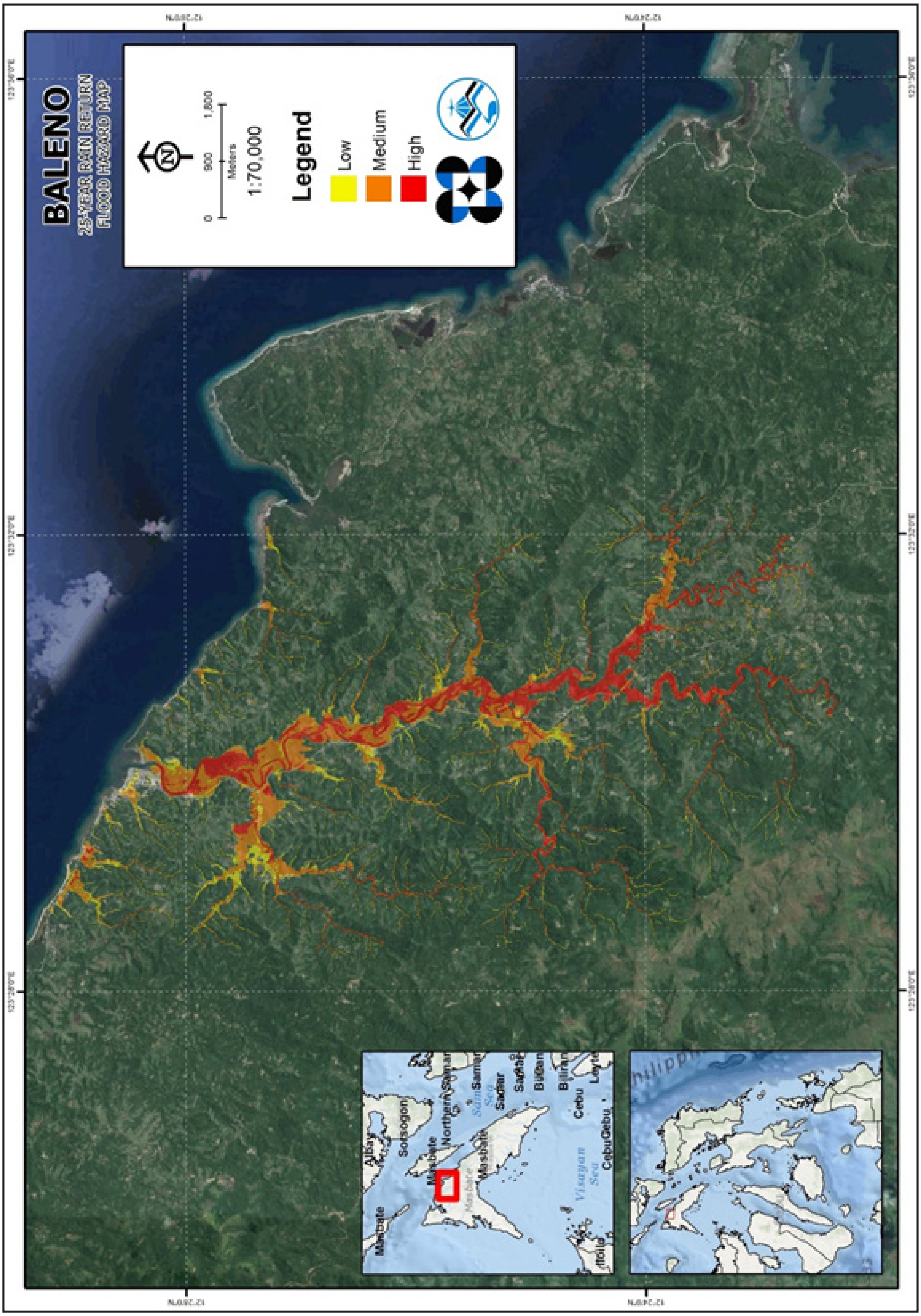


Figure 72. 25-year flood hazard map for the Baleno flood plain overlaid on Google Earth imagery

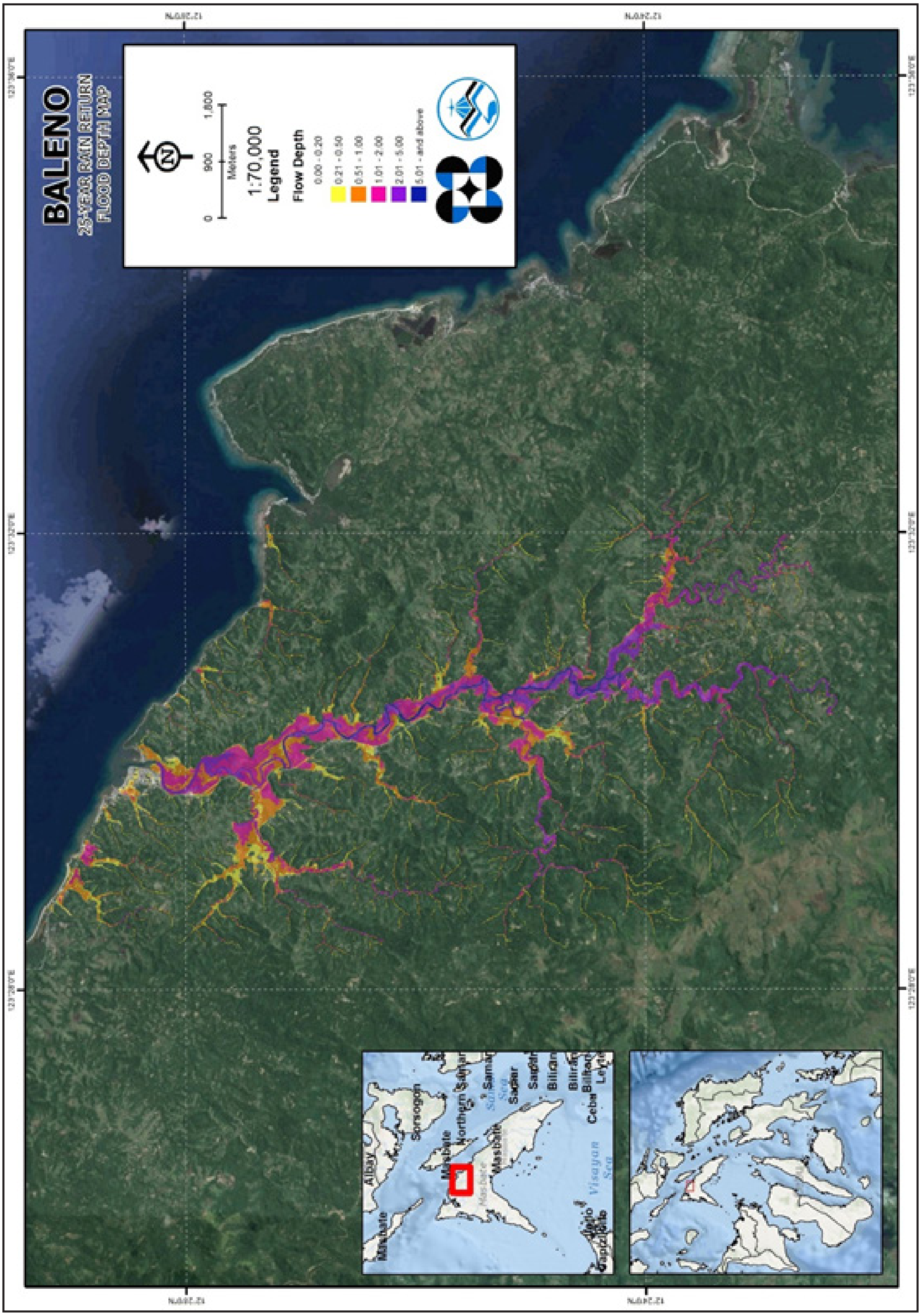


Figure 73. 25-year flow depth map for the Baleno flood plain overlaid on Google Earth imagery

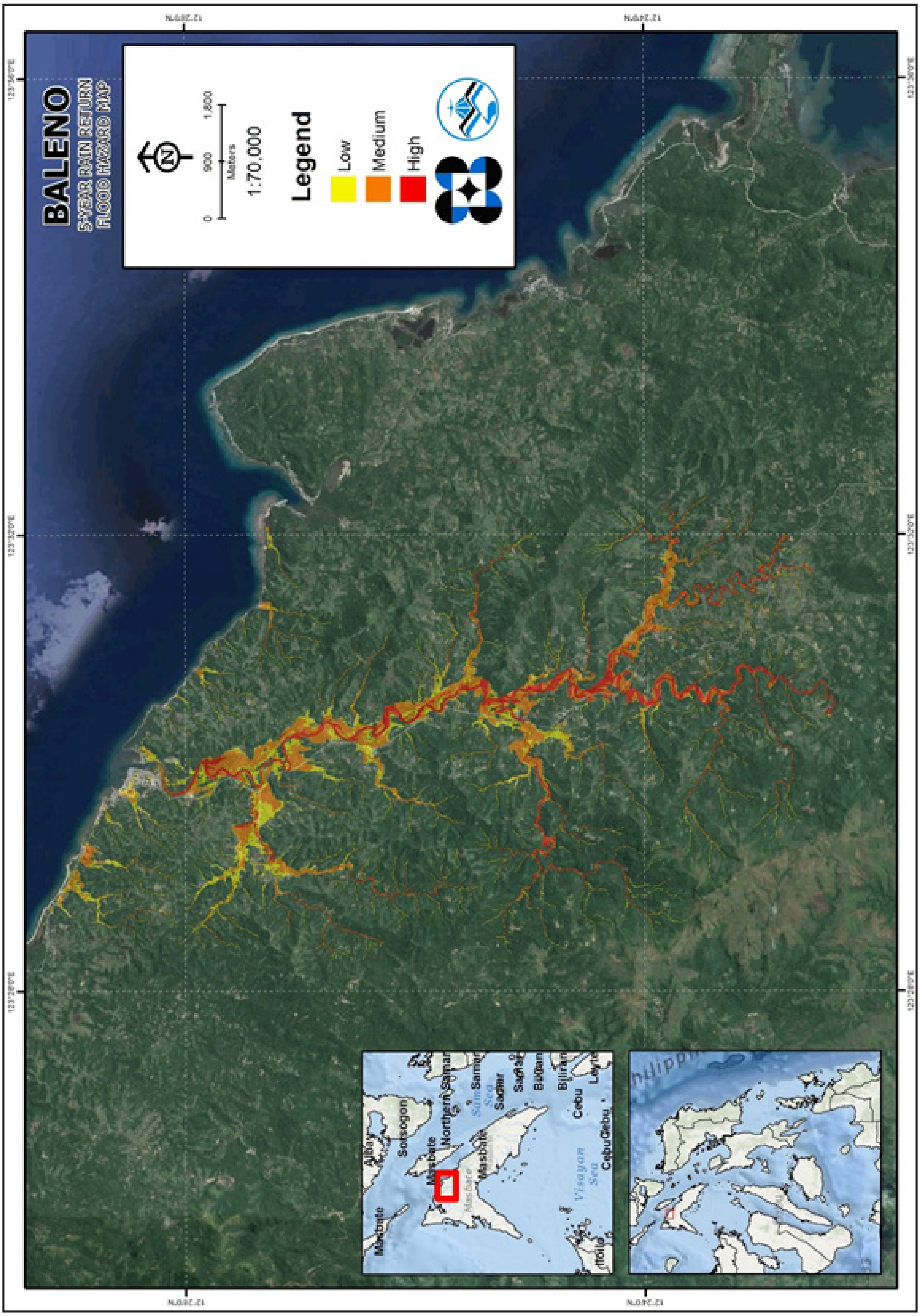


Figure 74. 5-year flood hazard map for the Baleno flood plain overlaid on Google Earth imagery

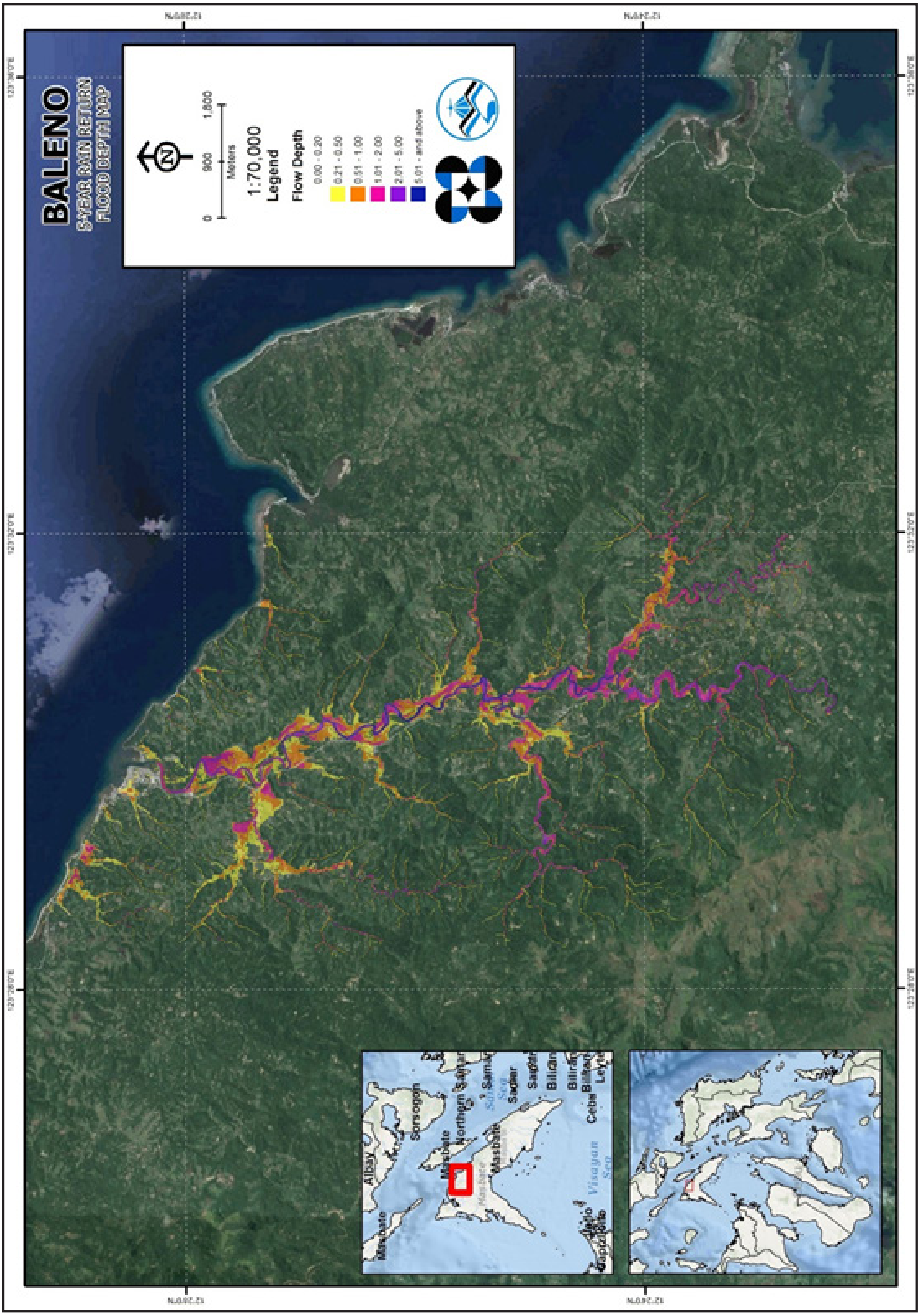


Figure 75. 5-year flow depth map for the Baleno flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Baleno River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 19 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 20.17% of the municipality of Baleno with an area of 200.24 sq. km. will experience flood levels of less than 0.20 meters. 1.07% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.05%, 0.72%, 0.24%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 76 depicts the areas affected in Baleno in square kilometers by flood depth per barangay.

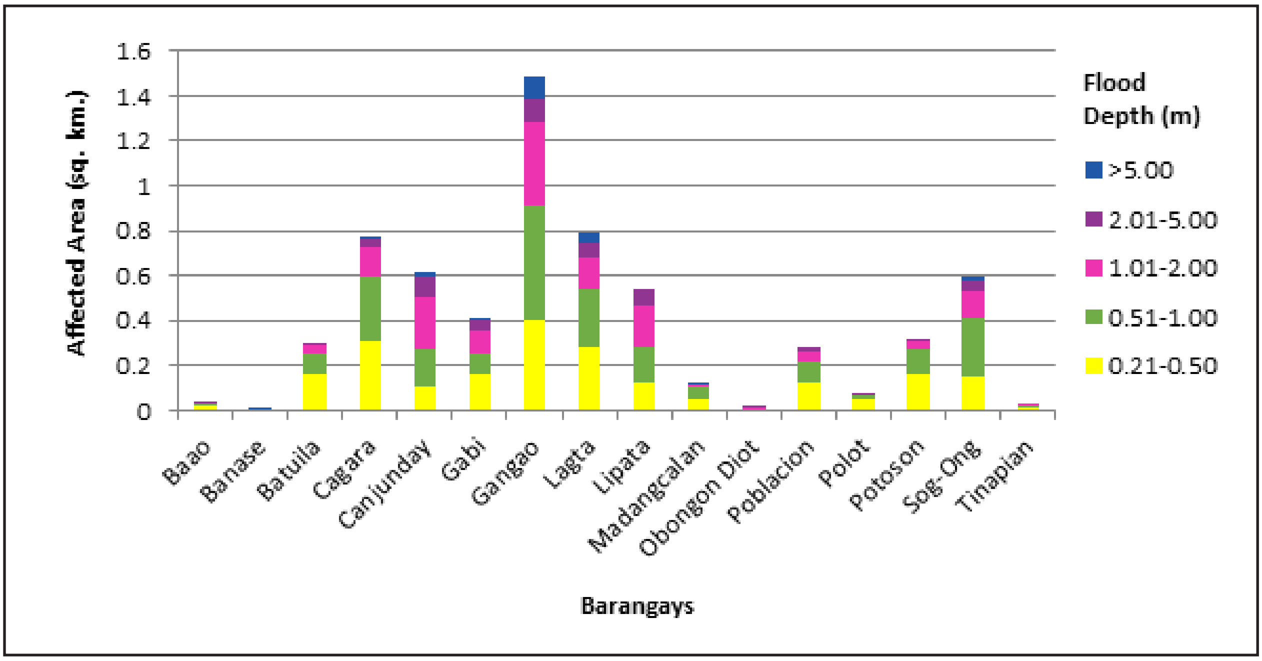


Figure 76. Affected Areas in Baleno, Masbate during the 5-Year Rainfall Return Period

For Masbate City with an area of 192.96 sq. km., 0.1% will experience flood levels of less than 0.20 meters. 0.0003% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.0004%, 0.0007%, 0.0005%, and 0.00005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 77 depicts the areas affected in Masbate City in square kilometers by flood depth per barangay.

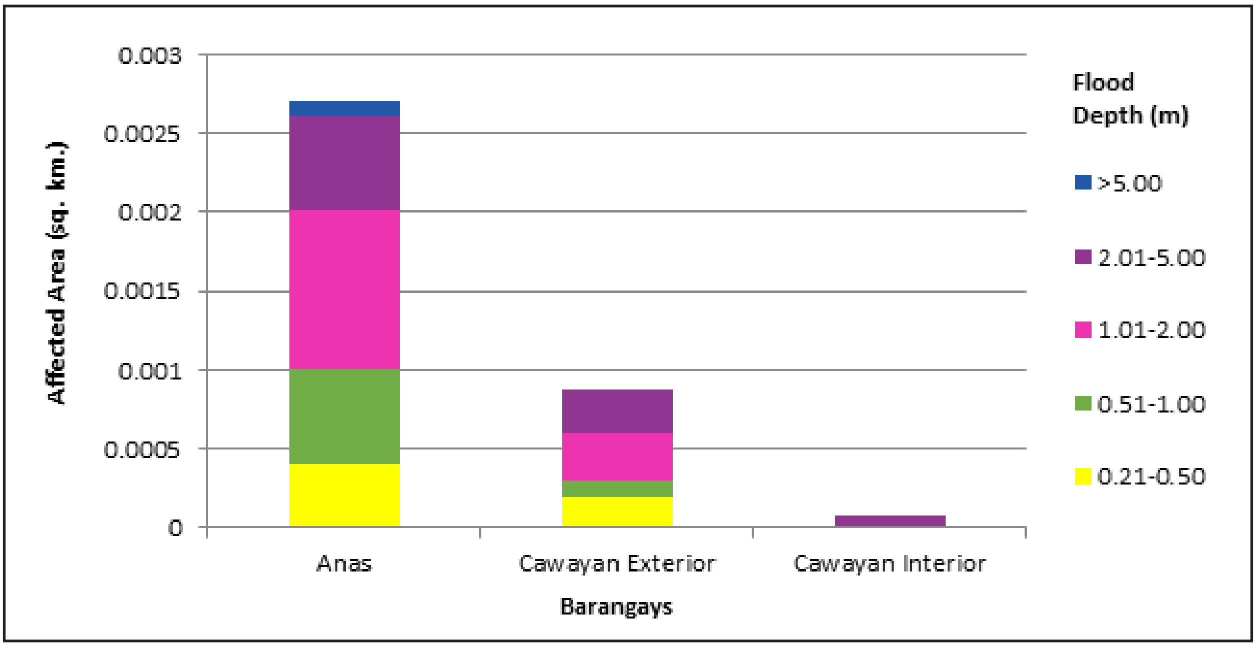


Figure 77. Affected Areas in Masbate City, Masbate during the 5-Year Rainfall Return Period

For the 25-year rainfall return period, 19.69% of the municipality of Baleno with an area of 200.24 sq. km. will experience flood levels of less than 0.20 meters. 0.81% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.95%, 1.15 %, 0.62%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 78 depicts the areas affected in Baleno in square kilometers by flood depth per barangay.

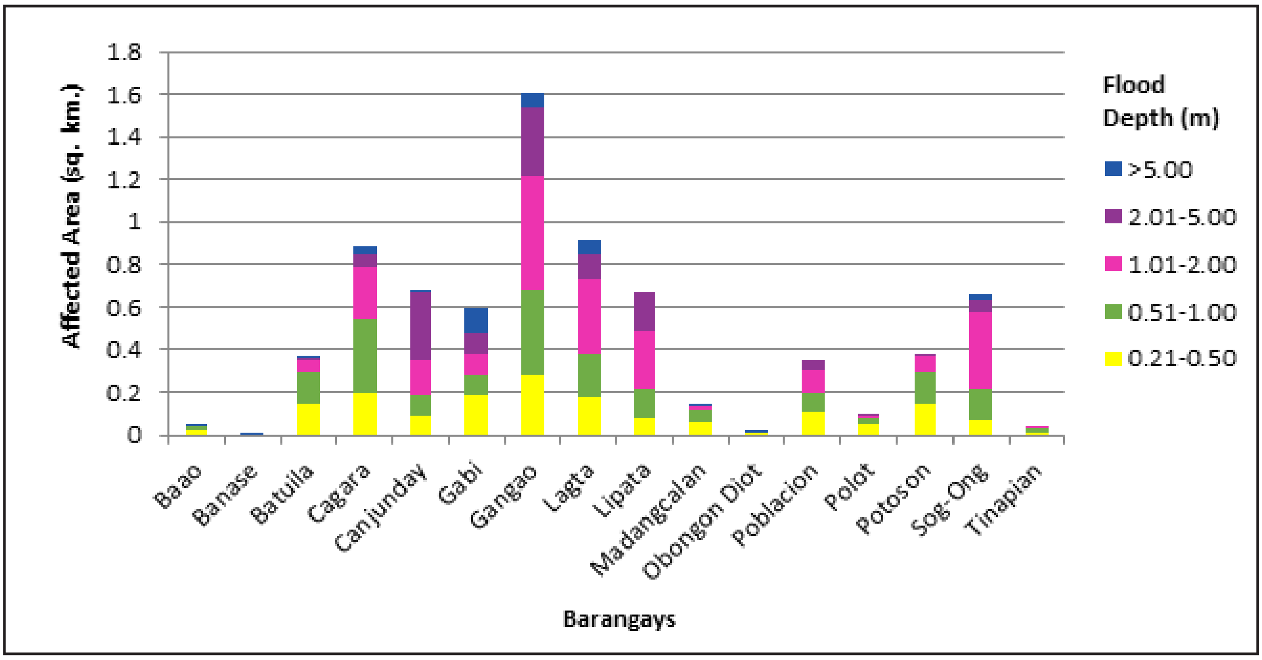


Figure 78. Affected Areas in Baleno, Masbate during the 25-Year Rainfall Return Period

For Masbate City with an area of 192.96 sq. km., 0.1% will experience flood levels of less than 0.20 meters. 0.0005% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.0003%, 0.0005%, 0.001%, and 0.0002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 79 depicts the areas affected in Masbate City in square kilometers by flood depth per barangay.

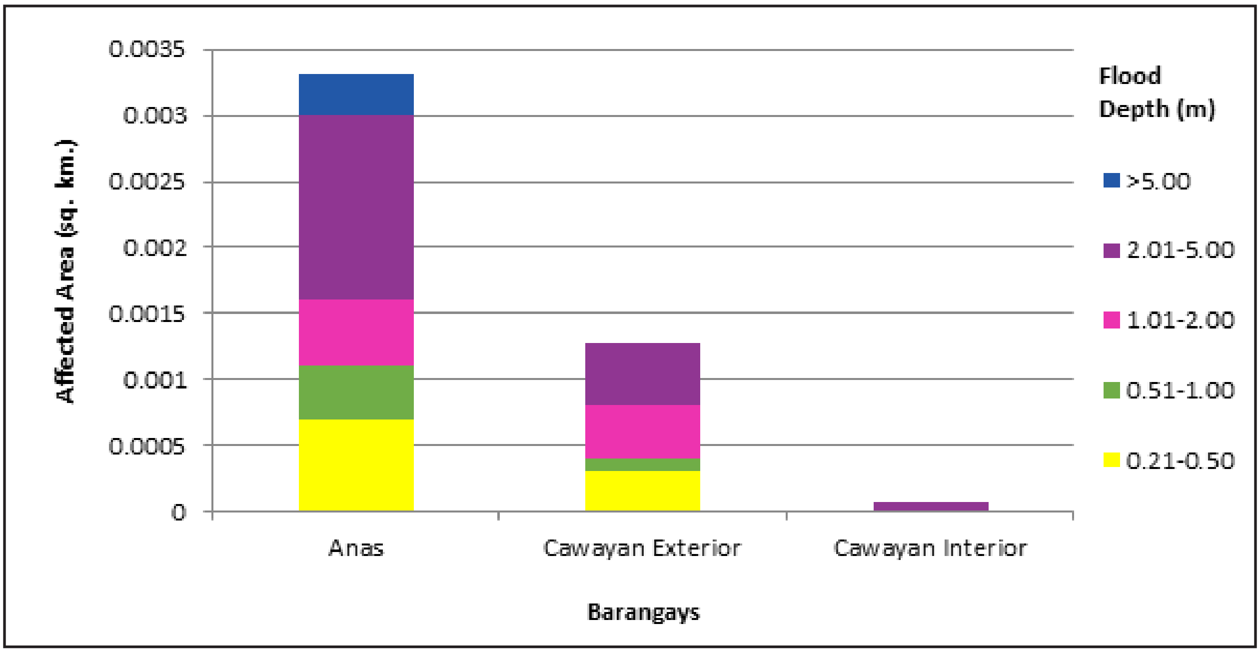


Figure 79. Affected Areas in Masbate City, Masbate during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 19.43% of the municipality of Baleno with an area of 200.24 sq. km. will experience flood levels of less than 0.20 meters. 0.76% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.83%, 1.17 %, 0.99%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 80 depicts the areas affected in Baleno in square kilometers by flood depth per barangay.

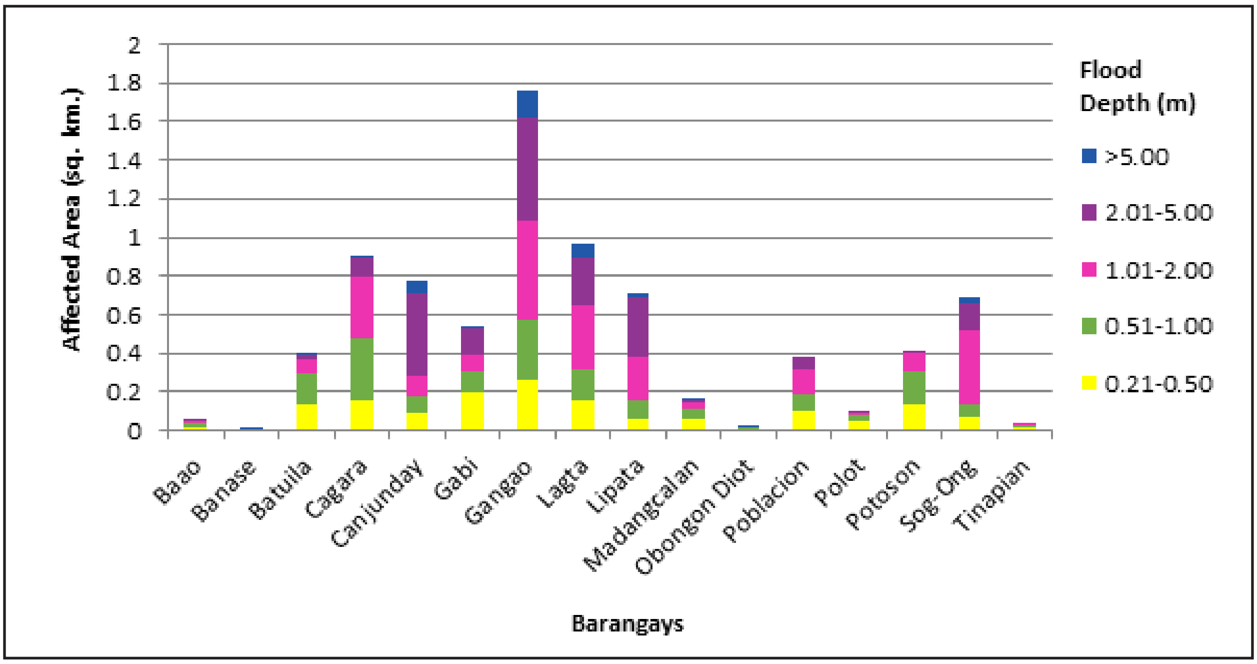


Figure 80. Affected Areas in Baleno, Masbate during the 100-Year Rainfall Return Period

For Masbate City with an area of 192.96 sq. km., 0.1% will experience flood levels of less than 0.20 meters. 0.0004% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.0004%, 0.0005%, 0.001%, and 0.0003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 81 depicts the areas affected in Masbate City in square kilometers by flood depth per barangay.

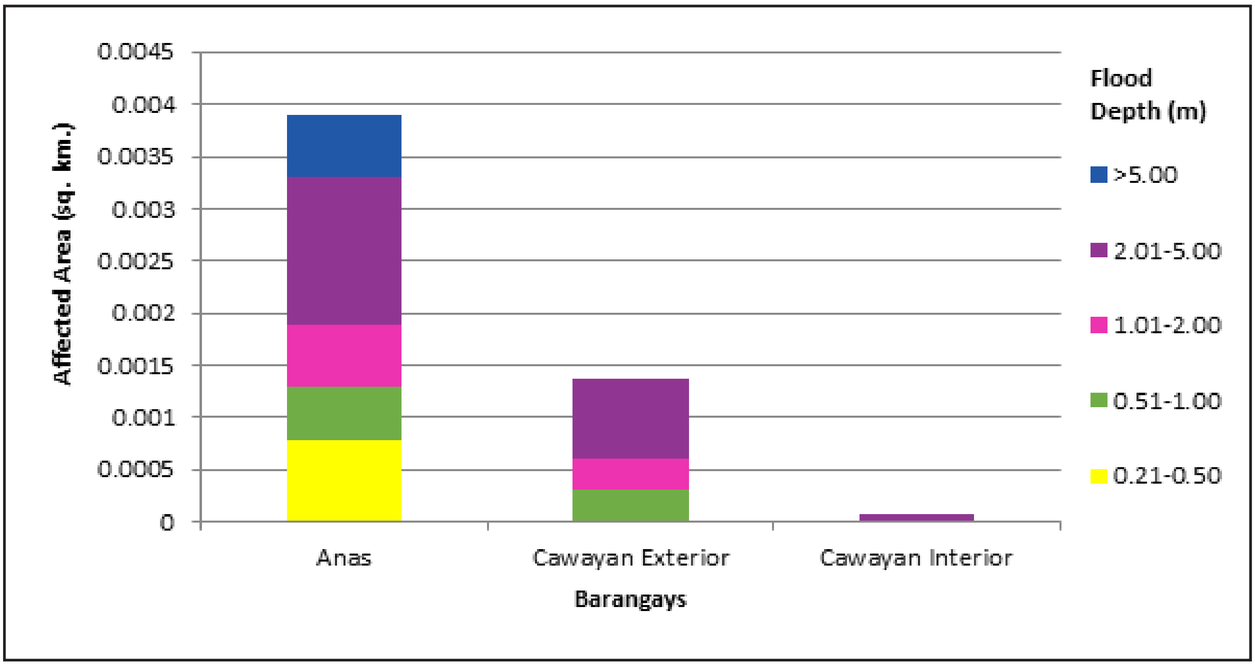


Figure 81. Affected Areas in Masbate City, Masbate during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Baleno, Gangao is projected to have the highest percentage of area that will experience flood levels of at 4.35%. Meanwhile, Gabi posted the second highest percentage of area that may be affected by flood depths at 4.18%.

Among the barangays in Masbate City, Anas is projected to have the highest percentage of area that will experience flood levels of at 0.08%. Meanwhile, Cawayan Exterior posted the second highest percentage of area that may be affected by flood depths at 0.02%.

Moreover, the generated flood hazard maps for the Baleno flood plain 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 33. 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	2.08	1.02	1.49
Medium	3.16	3.25	2.84
High	1.21	2.57	3.59

Of the 30 identified Educational Institutions in Baleno flood plain, 4 were assessed to be exposed to low, 3 to medium, and none to high level flooding during the 5-year scenario. In the 25-year scenario, 1 was assessed to be exposed to low, 5 to medium, and none to high level flooding. In the 100-year scenario, 4 were assessed to be exposed to low, 5 to medium, and 1 to high level flooding.

Of the 7 identified Medical Institutions in Baleno flood plain, 1 was assessed to be exposed to low, 1 to medium, and none to high level flooding in the 5-year scenario. In the 25-year scenario, none was assessed to be exposed to both low and high-level flooding, while 2 were assessed to be exposed to medium level flooding. In the 100-year scenario, 2 were assessed to be exposed to low, 2 to medium, and none to high level flooding.

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 188 points randomly selected all over the Baleno flood plain. It has an RMSE value of 0.585938509.

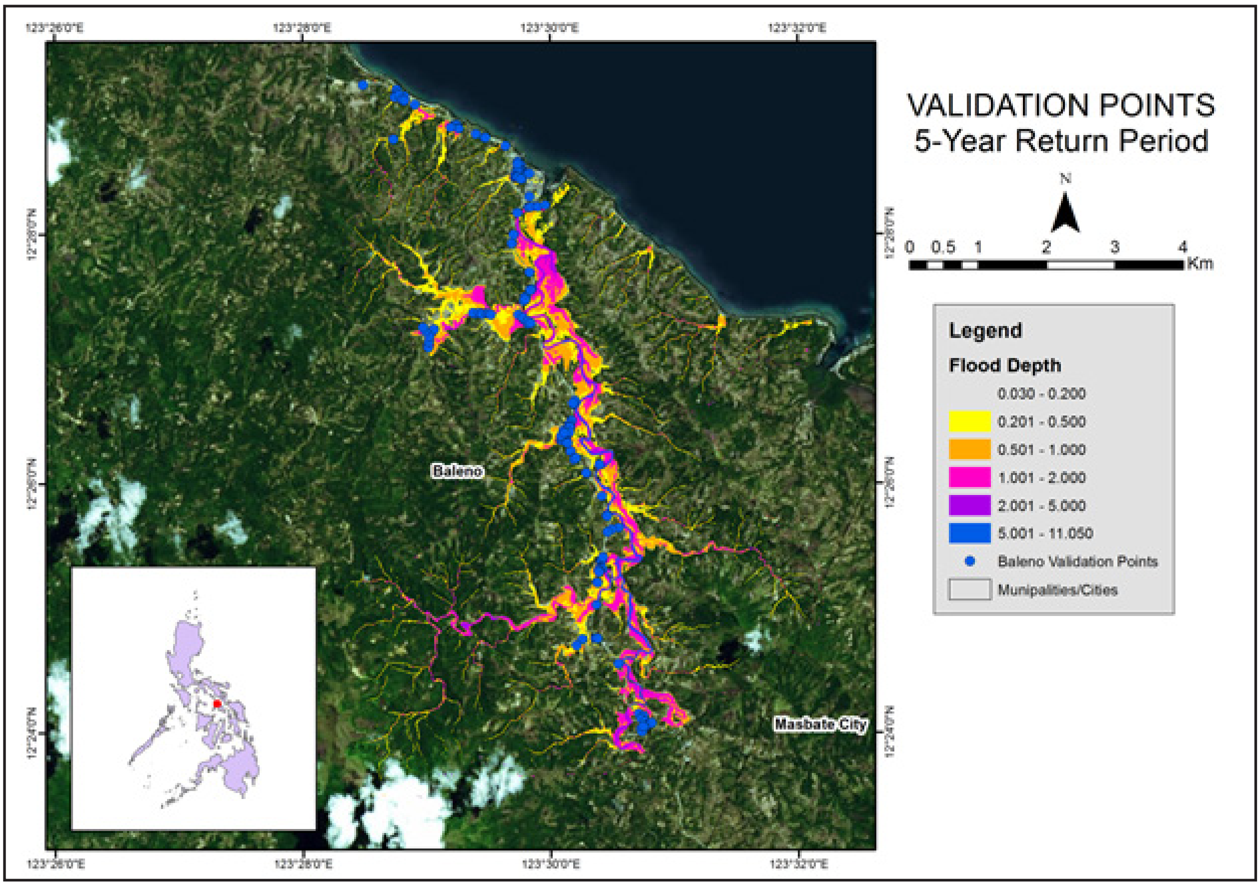


Figure 82. The validation points for the 5-Year flood depth map of the Baleno flood plain

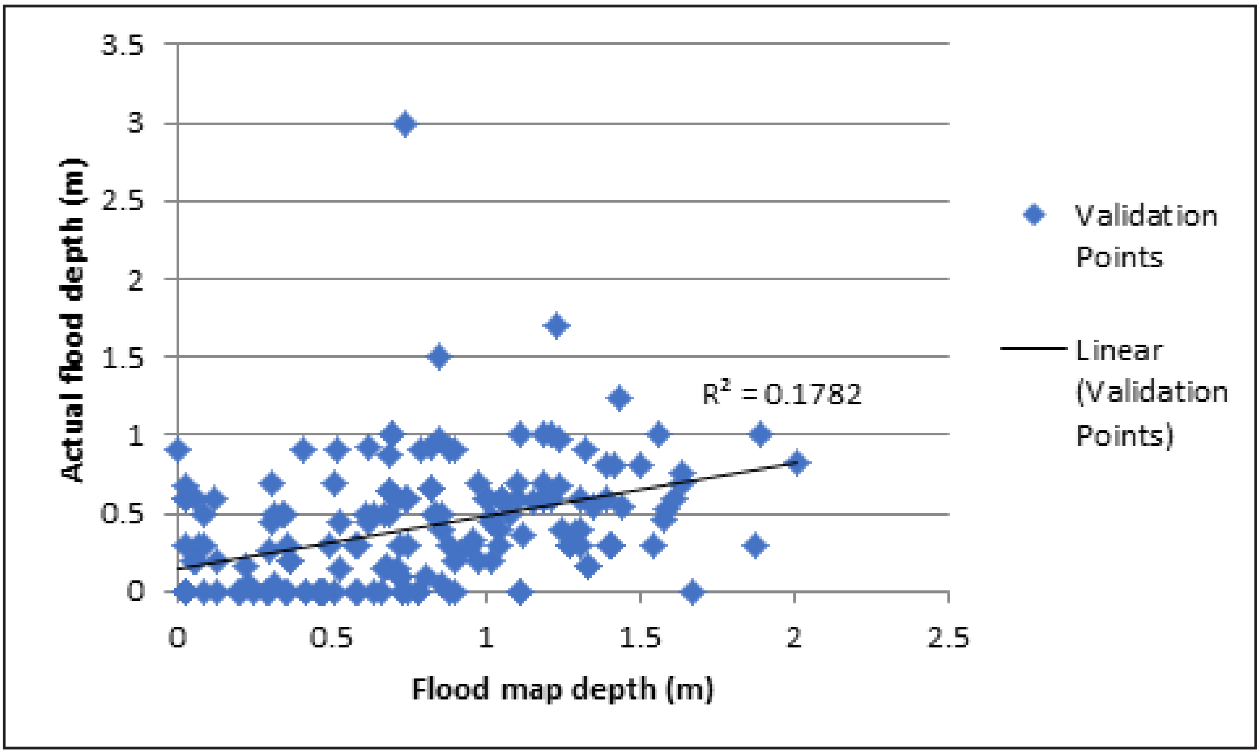


Figure 83. Flood map depth vs. Actual flood depth

Table 34. Actual flood vs. Simulated flood depth at different levels in the Baleno River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	31	19	22	6	0	0	78
0.21-0.50	4	7	18	18	0	0	47
0.51-1.00	6	2	20	30	1	0	59
1.01-2.00	0	0	1	2	0	0	3
2.01-5.00	0	0	1	0	0	0	1
> 5.00	0	0	0	0	0	0	0
Total	41	28	62	56	1	0	188

On the whole, the overall accuracy generated by the flood model is estimated at 31.91%, with 60 points correctly matching the actual flood depths. In addition, there were 38 points estimated one level above and below the correct flood depths, 18 points estimated two levels above and below, and 16 points estimated three or more levels above and below the correct flood depths. A total of 114 points were overestimated while a total of 14 points were underestimated in the modelled flood depths of Baleno. Table 35 depicts the summary of the accuracy assessment in the Baleno River Basin survey.

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

BALENO	No. of Points	%
Correct	60	31.91
Overestimated	114	60.64
Underestimated	14	7.45
Total	188	100

REFERENCES

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

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

Brunner, G. H. 2010a. HEC-RAS River Analysis System Hydraulic Reference Manual. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.

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

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

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

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

ANNEXES

ANNEX 1. Technical Specifications of the LIDAR Sensors used in the Baleno Floodplain Survey

Figure A-1.1. Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

ANNEX 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

1. MST-28

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-28**
Order: **2nd**

Island: **LUZON**		Barangay: **BAT-ONGAN**
Municipality: **MANDAON**		
	PRS92 Coordinates	
Latitude: **12° 18' 35.15371"**	Longitude: **123° 21' 19.21293"**	Ellipsoidal Hgt: **49.12800 m.**
	WGS84 Coordinates	
Latitude: **12° 18' 30.47973"**	Longitude: **123° 21' 24.28923"**	Ellipsoidal Hgt: **104.64900 m.**
	PTM Coordinates	
Northing: **1361224.57 m.**	Easting: **538651.166 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,360,748.12**	Easting: **538,637.64**	Zone: **51**

Location Description

MST-28
From Masbate City Proper, travel for about 50.6 km. along the Nat'l. Highway going to Mambog Bridge at Brgy. Bat-ongan, Mandaon Town. Station is located at the right side wing of the said bridge. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "MST-28 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-829**

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

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. MST-28

2. MST-31

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-31**
Order: **2nd**

Island: **LUZON**
Municipality: **MILAGROS**
Barangay: **BANGAD**

	PRS92 Coordinates	
Latitude: **12° 11' 50.29728"**	Longitude: **123° 24' 24.05419"**	Ellipsoidal Hgt: **18.45000 m.**
	WGS84 Coordinates	
Latitude: **12° 11' 45.65539"**	Longitude: **123° 24' 29.13992"**	Ellipsoidal Hgt: **74.38600 m.**
	PTM Coordinates	
Northing: **1348792.732 m.**	Easting: **544254.929 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,348,320.63**	Easting: **544,239.44**	Zone: **51**

Location Description

MST-31
From Masbate City Proper, travel for about 38 km. along the Nat'l. Highway going to Balud Town Proper until reaching Brgy. Bangad, Milagros Town. Station is located at the right side wing of Boracay Bridge. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-31 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-827**

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

9904102014140150

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. MST-31

3. MST-32

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-32**
Order: **2nd**

Island: **LUZON**
Municipality: **MILAGROS**
Barangay:

PRS92 Coordinates

Latitude: **12° 13' 7.66936"**	Longitude: **123° 30' 26.72479"**	Ellipsoidal Hgt: **3.78300 m.**

WGS84 Coordinates

Latitude: **12° 13' 3.03064"**	Longitude: **123° 30' 31.80788"**	Ellipsoidal Hgt: **59.91100 m.**

PTM Coordinates

Northing: **1351188.593 m.**	Easting: **555213.396 m.**	Zone: **4**

UTM Coordinates

Northing: **1,350,715.65**	Easting: **555,194.07**	Zone: **51**

Location Description

MST-32
From Masbate City Proper, travel for about 26 km. along the Nat'l. Highway going to Pob. Milagros. Station is located at the compound of the Milagros Mun. Hall, 30 m. NW, 2 m. E of the concrete fence, 5 m. SW of the basketball court and 10 m. W of the volleyball court. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete, with inscriptions "MST-32 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-838**

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

9904102014140542

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. MST-32

4. MST-55

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-55**
Order: **2nd**

Island: **LUZON**
Municipality: **BALUD**
Barangay: **CASAMONGAN**

	PRS92 Coordinates	
Latitude: **12° 5' 16.28892"**	Longitude: **123° 19' 50.73333"**	Ellipsoidal Hgt: **3.33300 m.**
	WGS84 Coordinates	
Latitude: **12° 5' 11.66770"**	Longitude: **123° 19' 55.82918"**	Ellipsoidal Hgt: **59.36300 m.**
	PTM Coordinates	
Northing: **1336675.257 m.**	Easting: **536007.686 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,336,207.40**	Easting: **535,995.08**	Zone: **51**

Location Description

MST-55
From Masbate City Proper, travel for about 56 km. along the Nat'l. Highway going to Balud Town Proper to reach the crossing going to Brgys. Casamongan and Villa Alvarez. From Brgy. Villa Alvarez, continue traveling for at least 8.5 km. to reach Brgy. Casamongan. Station is located at the compound of Casamongan Brgy. Hall, beside the basketball court, 10 m. NE of the stage, 30 m. E from the brgy. hall and 2 m. SW from the concrete fence. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "MST-55 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-830**

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

99041020141140251

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. MST-55

5. MS-269

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **MASBATE** Station Name: **MS-269**	
Island: **LUZON**	Municipality: **AROROY**	Barangay: **LUY-A**
Elevation: **27.4076 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

MS-269

Station is in the Island / Province of Masbate, Municipality of Aroroy, along the road linking Aroroy with the town of Milagros, Barangay Luy-a, at the top of a concrete bridge. A diesel station is located nearby. Mark is the head of a 3" copper nail embedded into the bridge walkway / pavement with cement putty and inscription "MS-269; 2008; NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-841**

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

9904102014140638

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.5. MS-269

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

1. MS-269

Table A-3.1. MS-269

MS-269 - MST-28 (6:36:44 AM-10:31:44 AM) (S1)

Baseline observation:	MS-269 --- MST-28 (B1)
Processed:	5/13/2014 3:15:01 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.009 m
Vertical precision:	0.024 m
RMS:	0.004 m
Maximum PDOP:	2.923
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/4/2014 6:37:04 AM (Local: UTC+8hr)
Processing stop time:	4/4/2014 10:31:44 AM (Local: UTC+8hr)
Processing duration:	03:54:40
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	MST-28				
Grid		Local		Global	
Easting	538790.668 m	Latitude	N12°18'30.47973"	Latitude	N12°18'30.47973"
Northing	1360689.389 m	Longitude	E123°21'24.28923"	Longitude	E123°21'24.28923"
Elevation	49.498 m	Height	104.649 m	Height	104.649 m

To:	MS-269				
Grid		Local		Global	
Easting	544123.868 m	Latitude	N12°24'21.62786"	Latitude	N12°24'21.62786"
Northing	1371483.415 m	Longitude	E123°24'21.40082"	Longitude	E123°24'21.40082"
Elevation	28.584 m	Height	83.308 m	Height	83.308 m

Vector					
ΔEasting	5333.200 m	NS Fwd Azimuth	26°22'11"	ΔX	-3185.907 m
ΔNorthing	10794.025 m	Ellipsoid Dist.	12044.246 m	ΔY	-4889.699 m
ΔElevation	-20.914 m	ΔHeight	-21.341 m	ΔZ	10536.100 m

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 ACUNA	UP TCAGP
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME B. HIPOLITO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG MARLON TORRE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	

ANNEX 5. Data Transfer Sheet for Baleno Floodplain

DATA TRANSFER SHEET
Apr 3, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Mar 19, 2014	1241P	1BLK32E078A	PEGASUS	703MB	2.80MB	8.99MB	281MB	33.3GB	297KB	6.0GB	N/A	5.78MB	121B	825B	82.6KB	N/A	Z:\Airborne_Raw\1241P
Mar 20, 2014	1243P	1BLK32E079A	PEGASUS	1.14GB	2.37MB	6.18MB	169MB	41GB	335KB	21.3GB	N/A	5.45MB	225B	688B	80.3KB	N/A	Z:\Airborne_Raw\1243P
Mar 20, 2014	1245P	1BLK32G079B	PEGASUS	2.33GB	2.22MB	6.76MB	189MB	49.2GB	363KB	22.7GB	N/A	5.45MB	225B	377B	115KB	N/A	Z:\Airborne_Raw\1245P
Mar 21, 2014	1247P	1BLK32U080A	PEGASUS	4.09GB	3.96MB	9.60MB	244MB	55.2GB	426KB	40.8GB	N/A	5.78MB	95B	527B	137KB	N/A	Z:\Airborne_Raw\1247P
Mar 25, 2014	1263P	1BLK32K084A	PEGASUS	2.21GB	2.98MB	8.71MB	217MB	48.9GB	366KB	26.6GB	N/A	4.54MB	92B	936B	136KB	N/A	Z:\Airborne_Raw\1263P
Mar 26, 2014	1267P	1BLK32M085A	PEGASUS	3.67GB	4.25MB	10.8MB	283MB	58.2GB	451KB	36.4GB	N/A	5.94MB	92B	758B	254KB	N/A	Z:\Airborne_Raw\1267P
Mar 27, 2014	1271P	1BLK32H086A	PEGASUS	3.43GB	3.99MB	11.1MB	259MB	74.8GB	585KB	33.8GB	N/A	5.24MB	92B	678B	156KB	N/A	Z:\Airborne_Raw\1271P
Mar 28, 2014	1275P	1BLK32H087A	PEGASUS	2.18GB	2.11MB	6.13MB	164MB	38.4GB	315KB	21.1GB	N/A	6.67MB	93B	350B	145KB	N/A	Z:\Airborne_Raw\1275P
Mar 29, 2014	1281P	1BLK32I088B	PEGASUS	1.45GB	1.58MB	3.74MB	102MB	N/A	N/A	13.8GB	N/A	7.37MB	93B	455B	26.5KB	N/A	Z:\Airborne_Raw\1281P
Mar 31, 2014	1289P	1BLK32K090A	PEGASUS	1.45GB	1.63MB	4.32MB	116MB	22.6GB	162KB	14.1GB	N/A	8.08MB	93B	253B	31.9KB	N/A	Z:\Airborne_Raw\1289P

Received from
Name: Faith Joy Sabile
Position:
Signature:

Received by
Name: JOIDA F. PRIETO
Position: SSRS
Signature:

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

DATA TRANSFER SHEET
4/22/2014(MASBATE)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS (mb)	POS (mb)	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/1/2014	1291P	1BLK32KL091A	PEGASUS	2.91	3.36	9.99	256	43.6	332	29.8	NA	7.81	1KB	602	376	NA	Z:\Airborne_Raw\1291P
4/1/2014	1293P	1BLK32H091B	PEGASUS	1.75	1.46	3.85	115	24.7	213	15.6	NA	7.81	1KB	221	68.5	NA	Z:\Airborne_Raw\1293P
4/2/2014	1295P	1BLK32I092A	PEGASUS	2.93	3.42	8.9	225	54.2	404	29.2	NA	867KB	1KB	512	137	NA	Z:\Airborne_Raw\1295P
4/3/2014	1299P	1BLK32FG093A	PEGASUS	2.68	3.23	8.65	232	33.4	267	26.8	NA	7.59	1KB	358	113	NA	Z:\Airborne_Raw\1299P
4/3/2014	1301P	1BLK32F093B	PEGASUS	1.95	2.42	5.95	149	44.6	352	19.6	NA	7.59	1KB	538	201	NA	Z:\Airborne_Raw\1301P
4/4/2014	1303P	1BLK32A094A	PEGASUS	2.77	3.48	2.99	218	52.5	404	29.4	NA	6.67	1KB	694	186	NA	Z:\Airborne_Raw\1303P
4/4/2014	1305P	1BLK32A094B	PEGASUS	2.41	2.85	6.88	161	44.3	324	23.3	NA	6.67	1KB	400	2.41	NA	Z:\Airborne_Raw\1305P
4/5/2014	1307P	1BLK32DG095A	PEGASUS	3.84	4.49	4.12	271	67.2	514	37.7	NA	6.49	1KB	623	270	NA	Z:\Airborne_Raw\1307P
4/8/2014	1319P	1BLK32B098A	PEGASUS	3.66	4.32	9.93	254	17.7	526	36.2	NA	4.95	1KB	731	382	NA	Z:\Airborne_Raw\1319P
4/10/2014	1327P	1BLK32D100A	PEGASUS	2.16	2.47	6.99	175	37	277	21.7	NA	5.27	1KB	747	243	NA	Z:\Airborne_Raw\1327P
4/11/2014	1331P	1BLK32B101A	PEGASUS	1.76	1.9	5.09	134	29.8	232	17.6	NA	4.09	1KB	574	316	NA	Z:\Airborne_Raw\1331P

Received from

Name CARLS JOAQUIN
Position RA
Signature 4/23/14

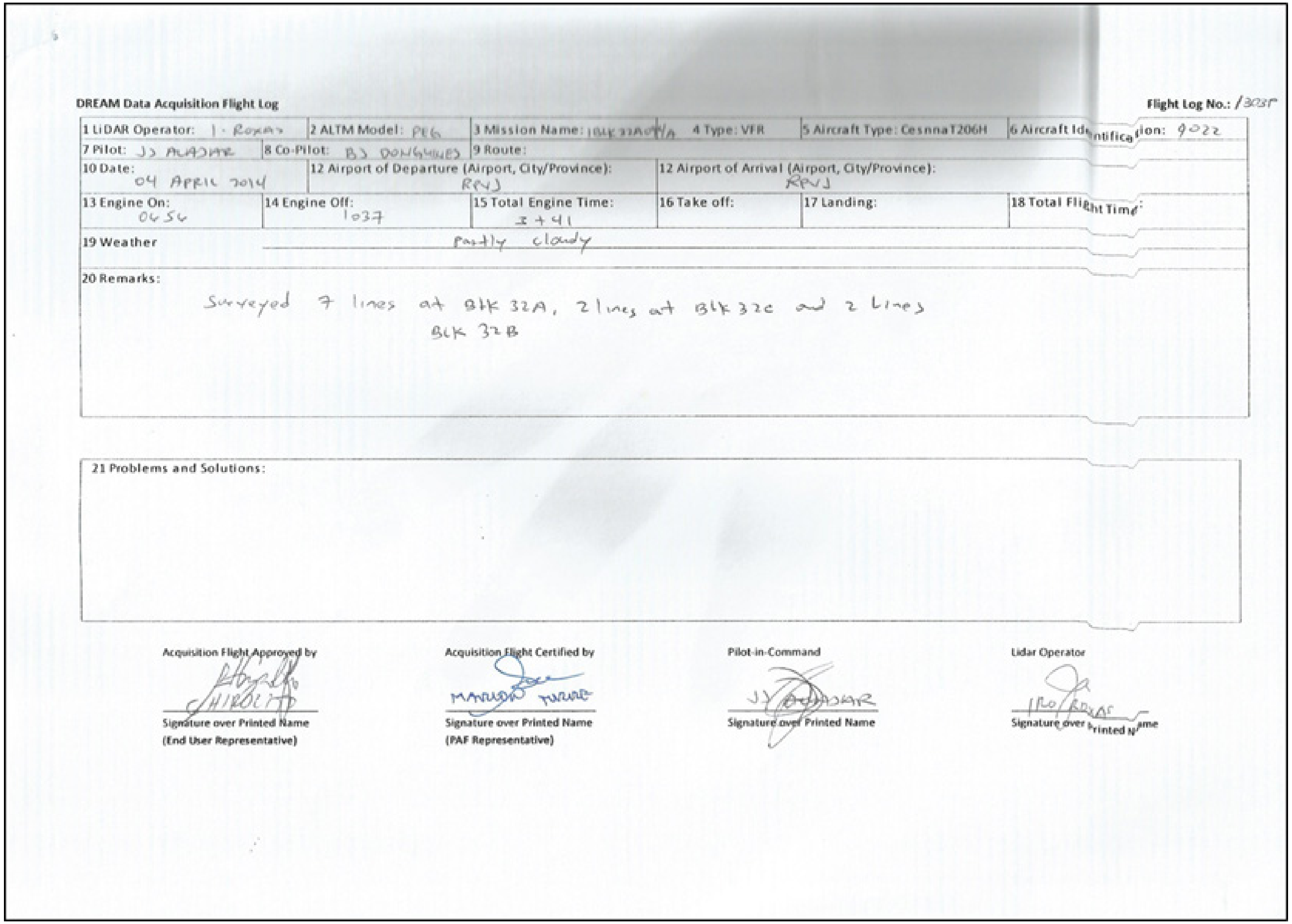
Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 4/23/14

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

ANNEX 6. Flight logs for the flight missions

1. Flight Log for Mission 1303P


DREAM Data Acquisition Flight Log

Flight Log No.: 1303P

1 LiDAR Operator: I. Roxas	2 ALTM Model: PEG	3 Mission Name: 1BLK32ACB	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 04 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0456	14 Engine Off: 1037	15 Total Engine Time: 5+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

Surveyed 7 lines at BLK 32A, 2 lines at BLK 32C and 2 lines BLK 32B

21 Problems and Solutions:

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

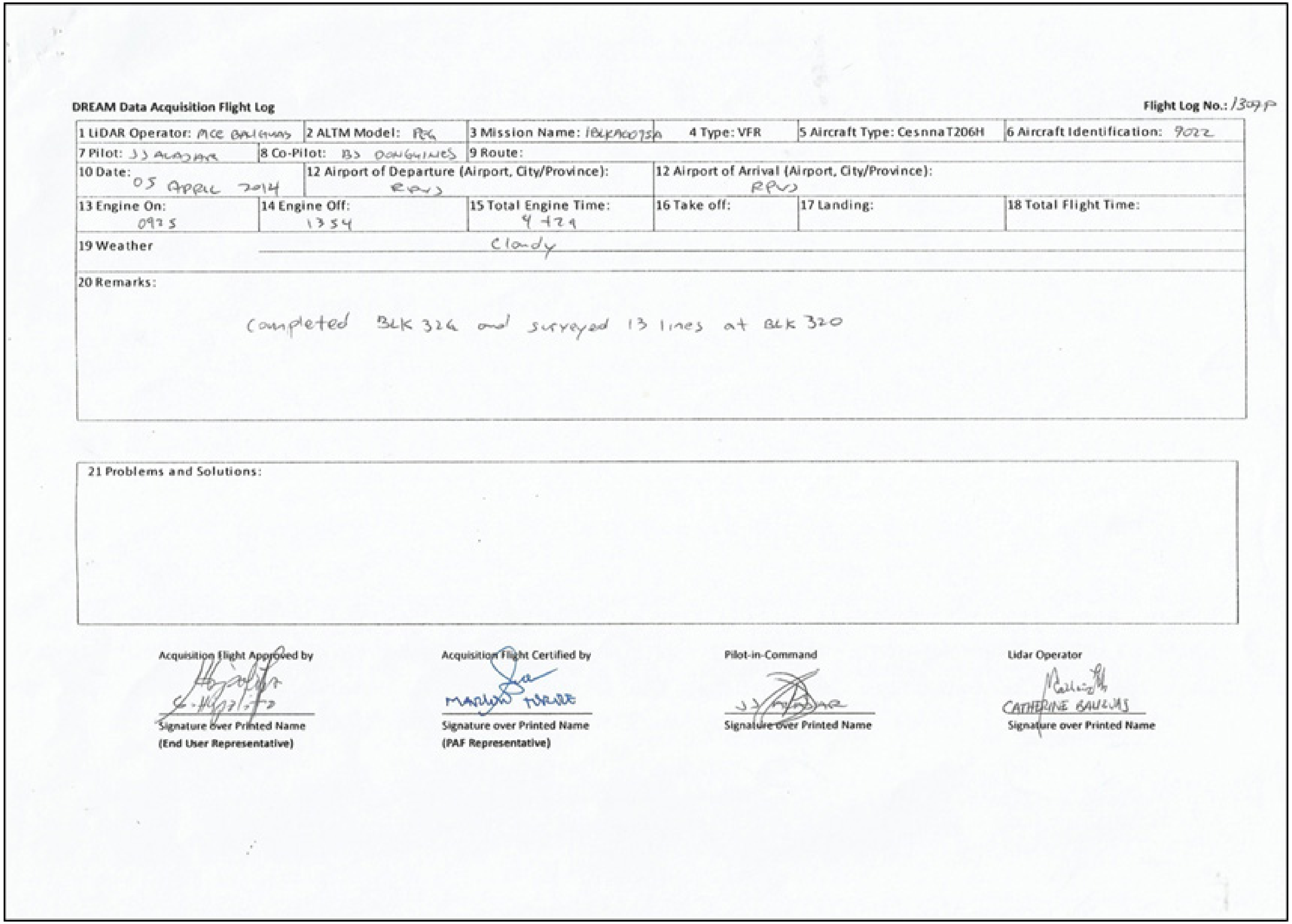
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

Pilot-in-Command: JJ ALAJAR — Signature over Printed Name

Lidar Operator: I. ROXAS — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1303P

2. Flight Log for Mission 1307P



DREAM Data Acquisition Flight Log — Flight Log No.: 1307P

1 LiDAR Operator: MCE Balguas	2 ALTM Model: Peg	3 Mission Name: 1BLKA0095A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alagar	8 Co-Pilot: BS Donguines	9 Route:			
10 Date: 05 April 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0925	14 Engine Off: 1354	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Completed BLK 32G and surveyed 13 lines at BLK 32D					
21 Problems and Solutions:					

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

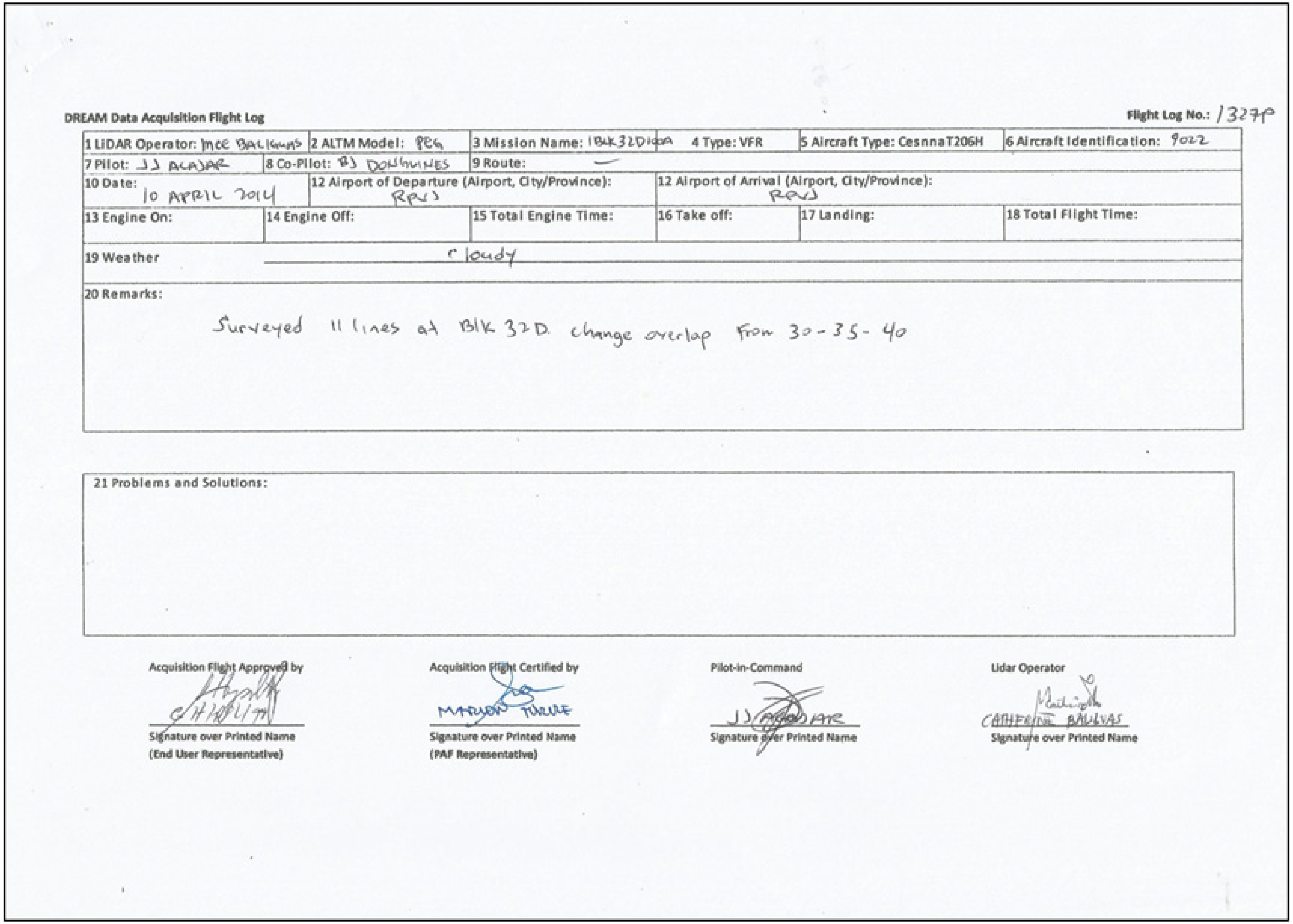
Acquisition Flight Certified by — Marilyn Torre — Signature over Printed Name (PAF Representative)

Pilot-in-Command — JJ Alagar — Signature over Printed Name

Lidar Operator — Catherine Balguas — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1307P

3. Flight Log for Mission 1327P



DREAM Data Acquisition Flight Log

Flight Log No.: 1327P

1 LiDAR Operator: MCE Balicuas	2 ALTM Model: PEG	3 Mission Name: 1BLK32D100A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alajar	8 Co-Pilot: RJ Donguines	9 Route: —			
10 Date: 10 April 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather: cloudy

20 Remarks:

Surveyed 11 lines at BLK 32D. change overlap from 30-35-40

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Marlon Tirante Signature over Printed Name (PAF Representative)	JJ Alajar Signature over Printed Name	Catherine Balicuas Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1307P

ANNEX 7. Flight status reports

MASBATE
March 18- April 14, 2014

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1303P	BLK 32A	1BLK32A094A	I. Roxas	April 4, 2014	Surveyed 7 lines at blk32a, 2 lines at blk32c and 2 lines blk32b
1307P	BLK 32D and BLK 32G	1BLK32DG095A	MCE. Baliguas	April 5, 2014	Completed blk32g and surveyed 13 lines at blk32d
1327P	BLK 32D	1BLK32D100A	MCE. Baliguas	April 10, 2014	Surveyed 11 lines at blk32d. changed overlap from 30-35-40

LAS BOUNDARIES PER FLIGHT

Flight No.:	1303P		
Area:	BLK 32A, 32B, 32C		
Mission Name:	1BLK32A094A		
Parameters:	Altitude:	1000m & 1200m;	Scan Frequency: 30Hz;
	Scan Angle:	50deg;	Overlap: 30%

LAS

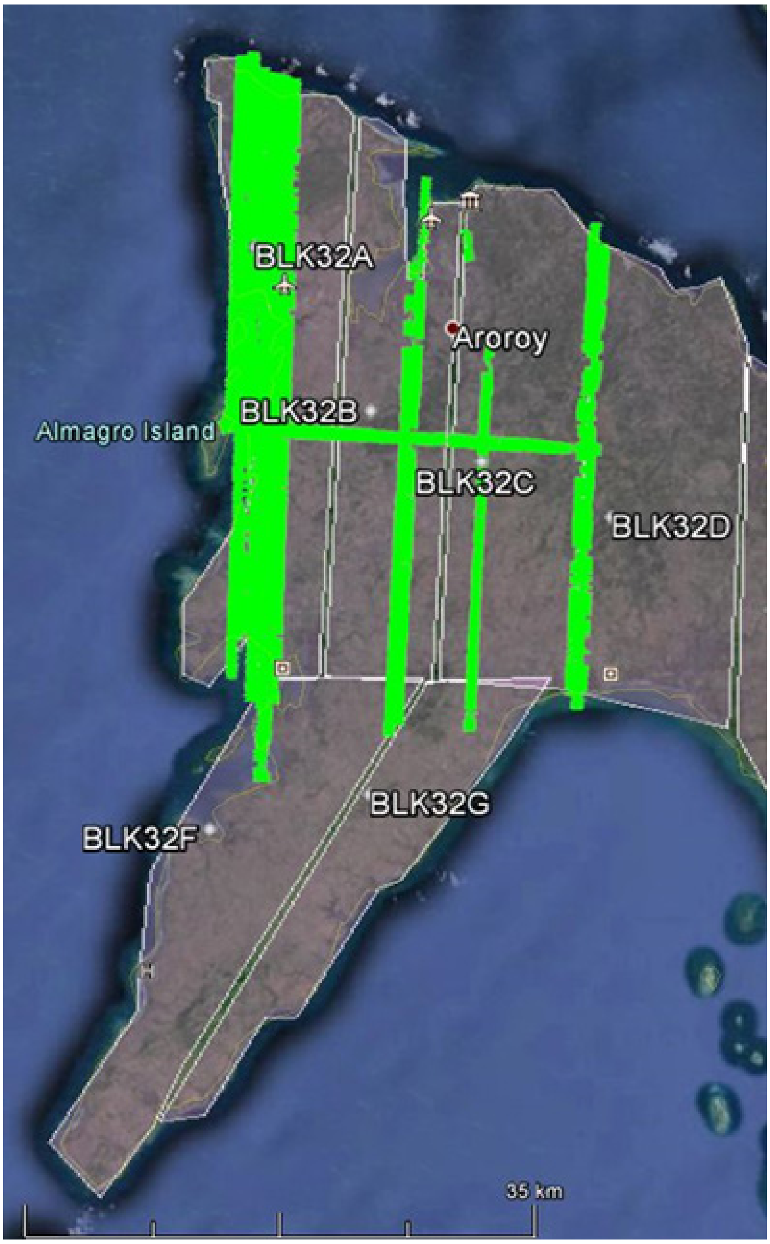


Figure A-7.1. Swath for Flight No. 1303P

Flight No.:	1307P		
Area:	BLK32D & BLK32G		
Mission Name:	1BLK32DG095A		
Parameters:	Altitude:	1000;	Scan Frequency: 30Hz;
	Scan Angle:	50deg;	Overlap: 25% & 30%

LAS

Figure A-7.2. Swath for Flight No. 1307P

Flight No. :	1327P		
Area:	BLK32D		
Mission Name:	1BLK32D100A		
Parameters:	Altitude:	1000m & 1200m;	Scan Frequency: 30Hz;
	Scan Angle:	50deg;	Overlap: 30%, 35% & 40%

LAS/SWATH

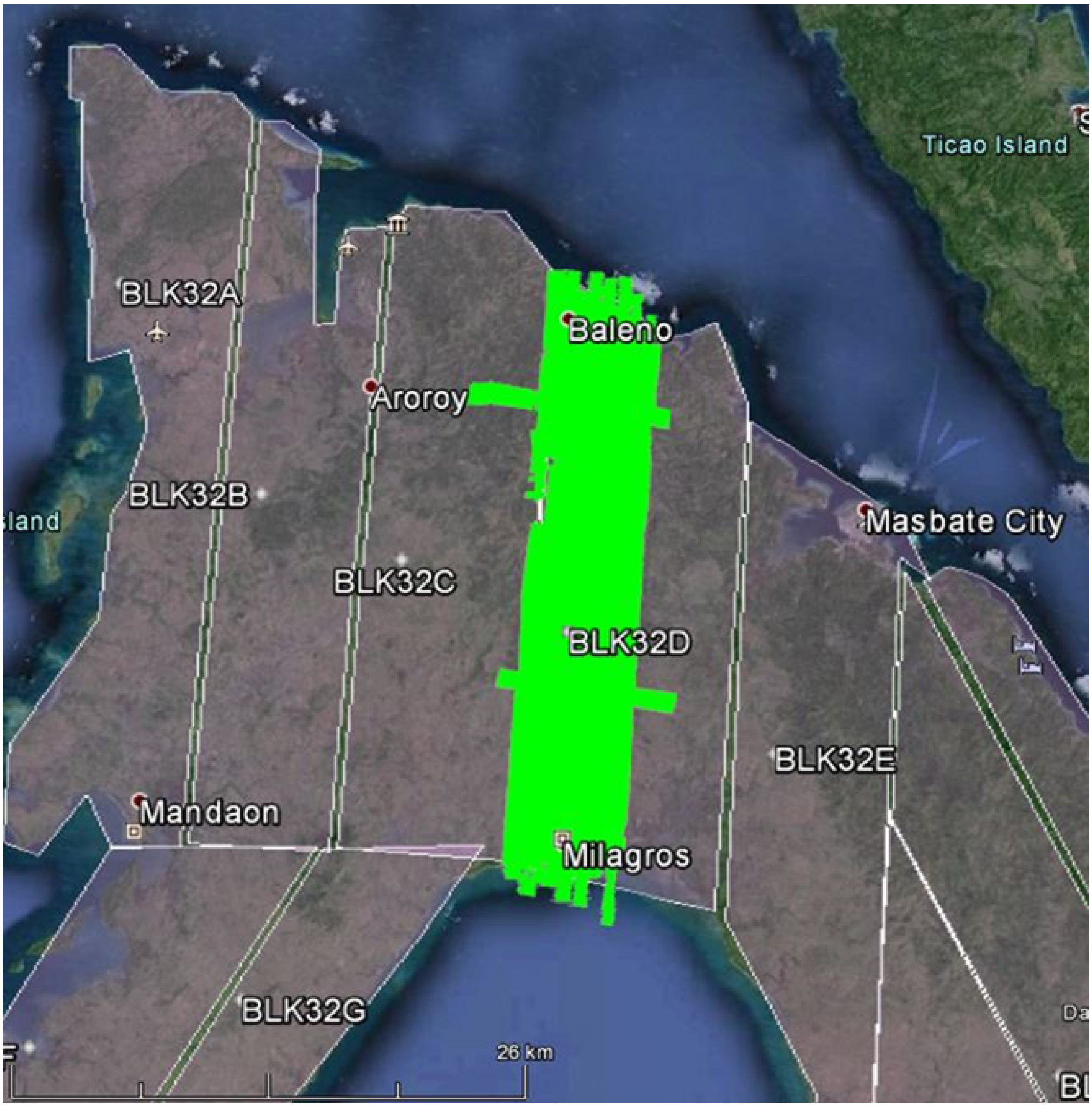


Figure A-7.3. Swath for Flight No. 1327P

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk32D

Flight Area	MASBATE
Mission Name	Blk 32D
Inclusive Flights	1307P, 1327P
Mission Name	1BLK32DG095A, 1BLK32D100A
Range data size	59.4 GB
Base data size	446 MB
POS	11. 76 MB
Image	63.9 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.07
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	3.22
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	53.97%
Ave point cloud density per sq.m. (>2.0)	3.54
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	421
Maximum Height	847.76
Minimum Height	47.46
Classification (# of points)	
Ground	408478727
Low vegetation	335594682
Medium vegetation	504152982
High vegetation	367118997
Building	5625146

Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Merven Matthew Natino, Engr. Gladys Mae Apat

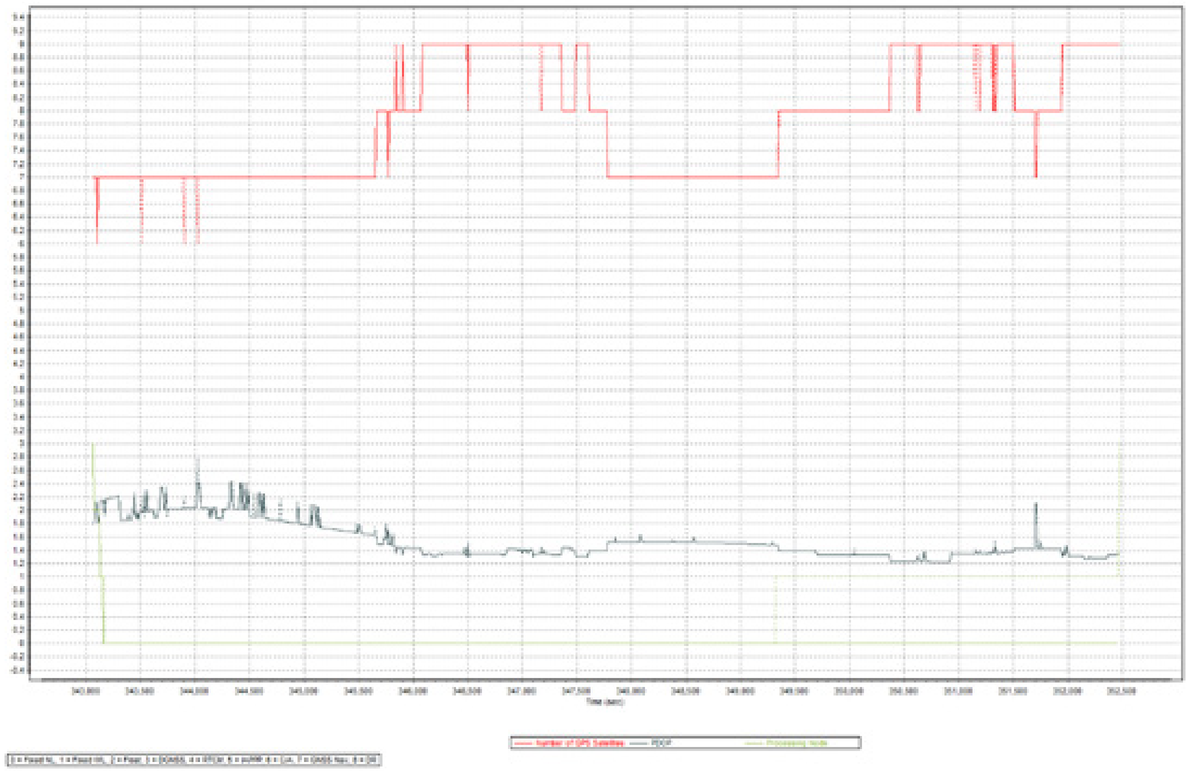


Figure A-8.1. Solution Status

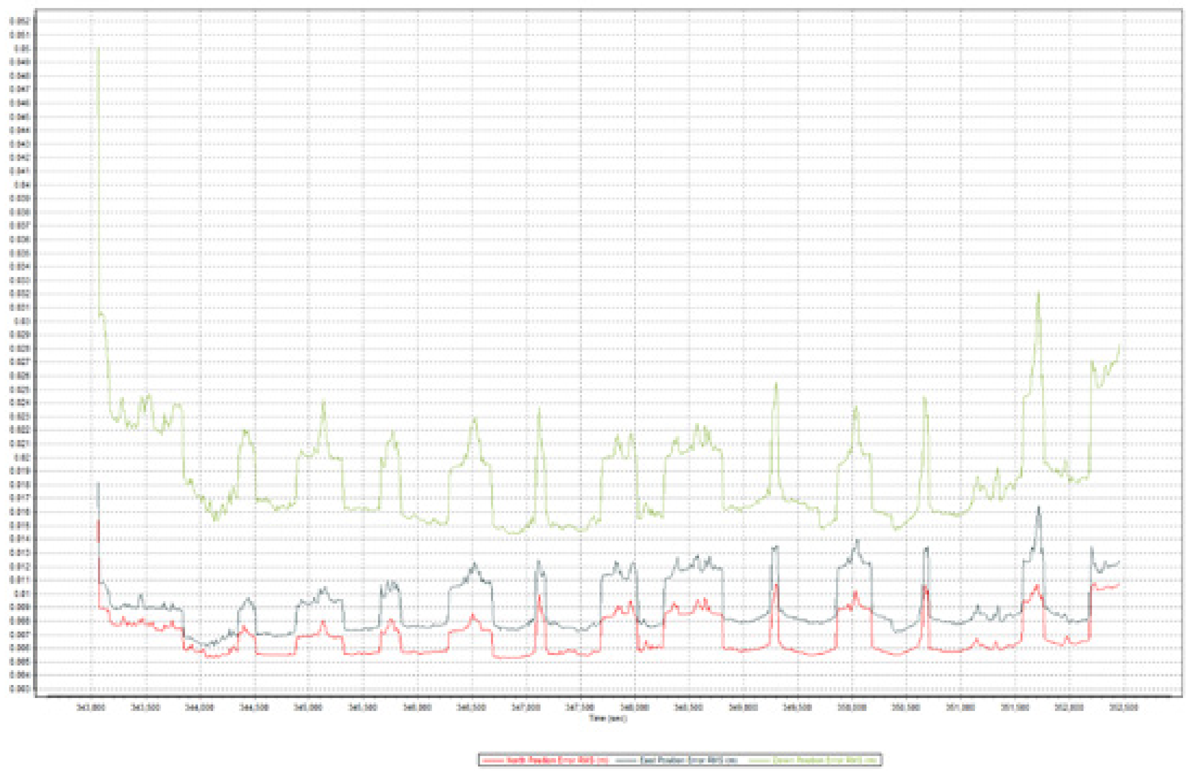


Figure A-8.2. Smoothed Performance Metric Parameters

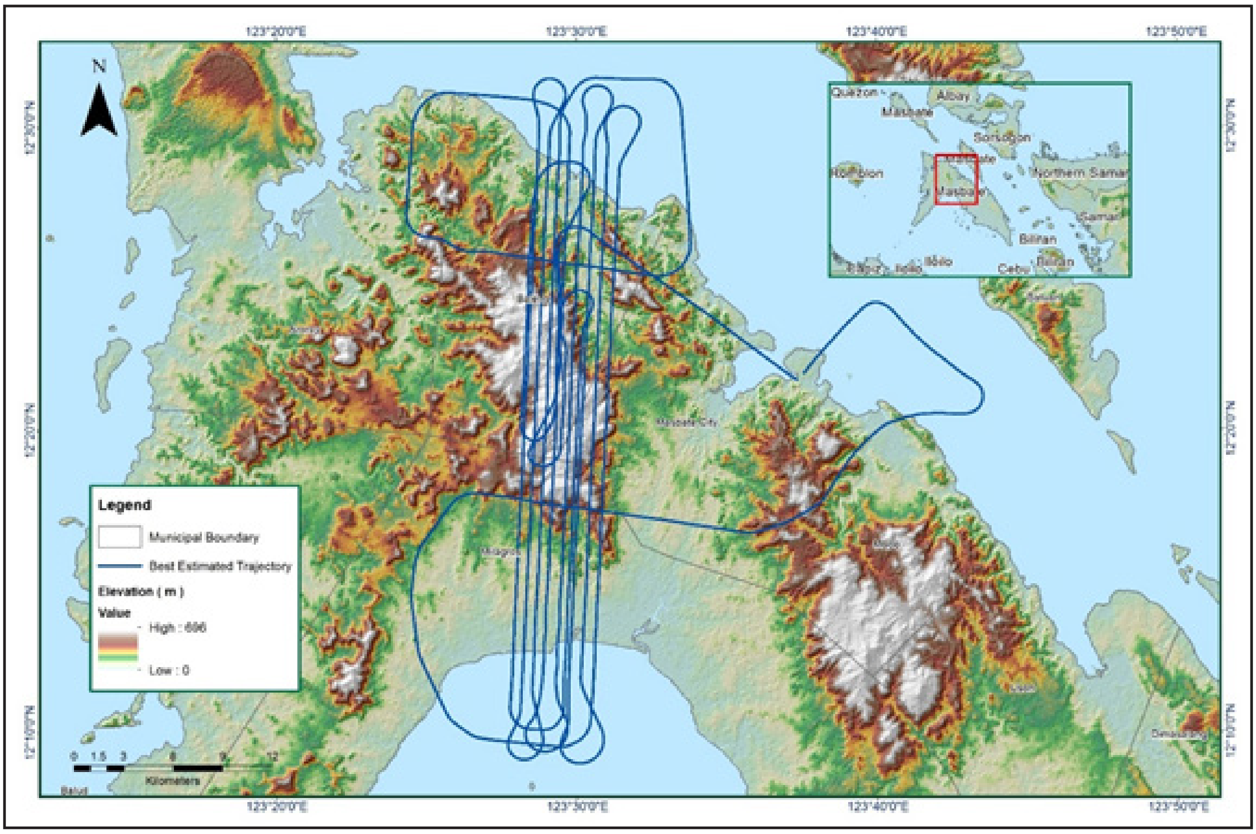


Figure A-8.3. Best Estimated Trajectory

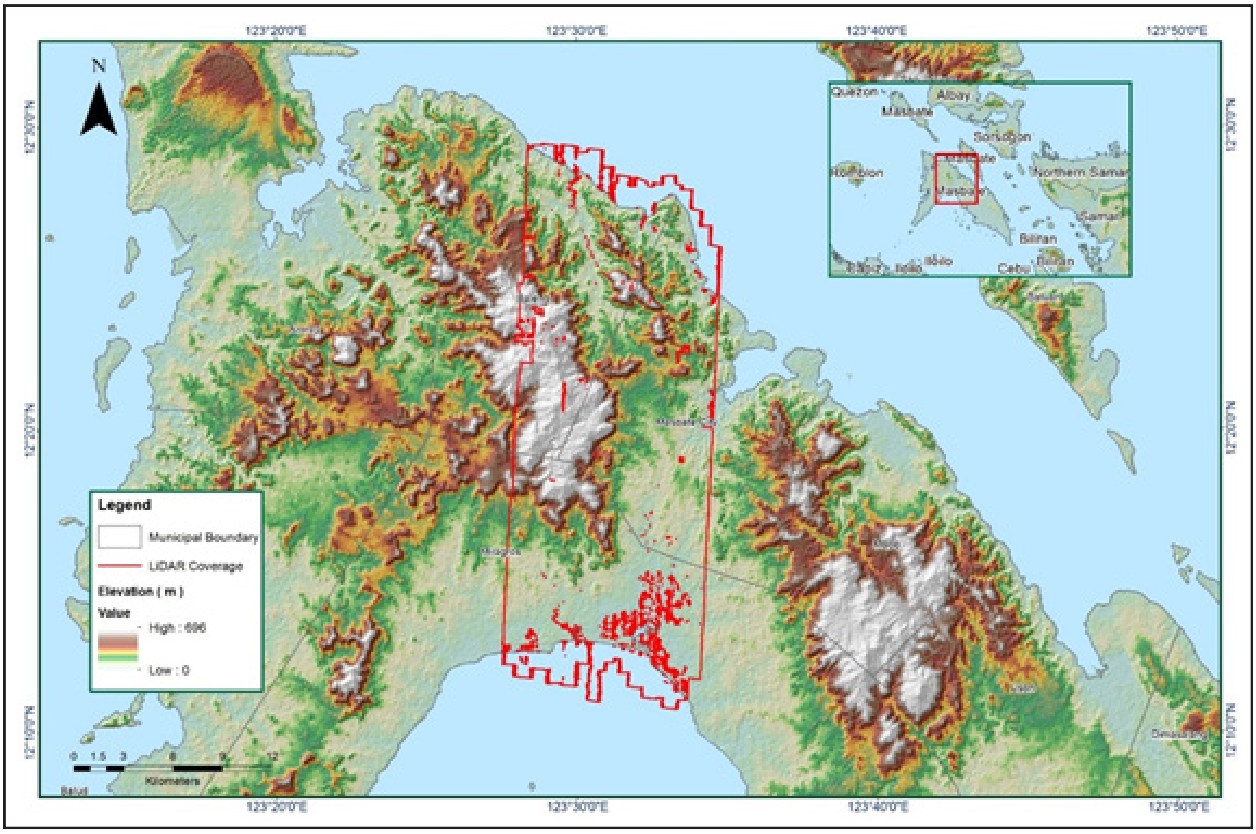


Figure A-8.4. Coverage of LiDAR data

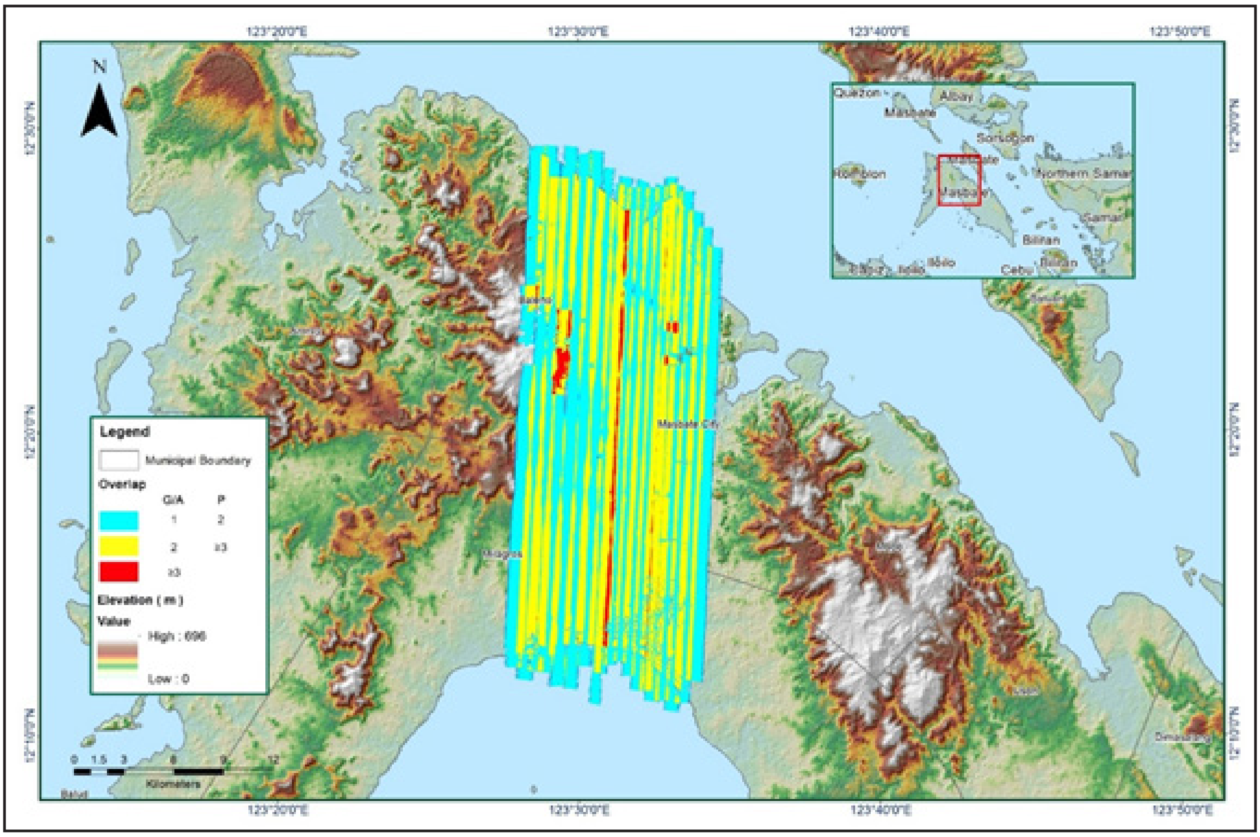


Figure A-8.5. Image of data overlap

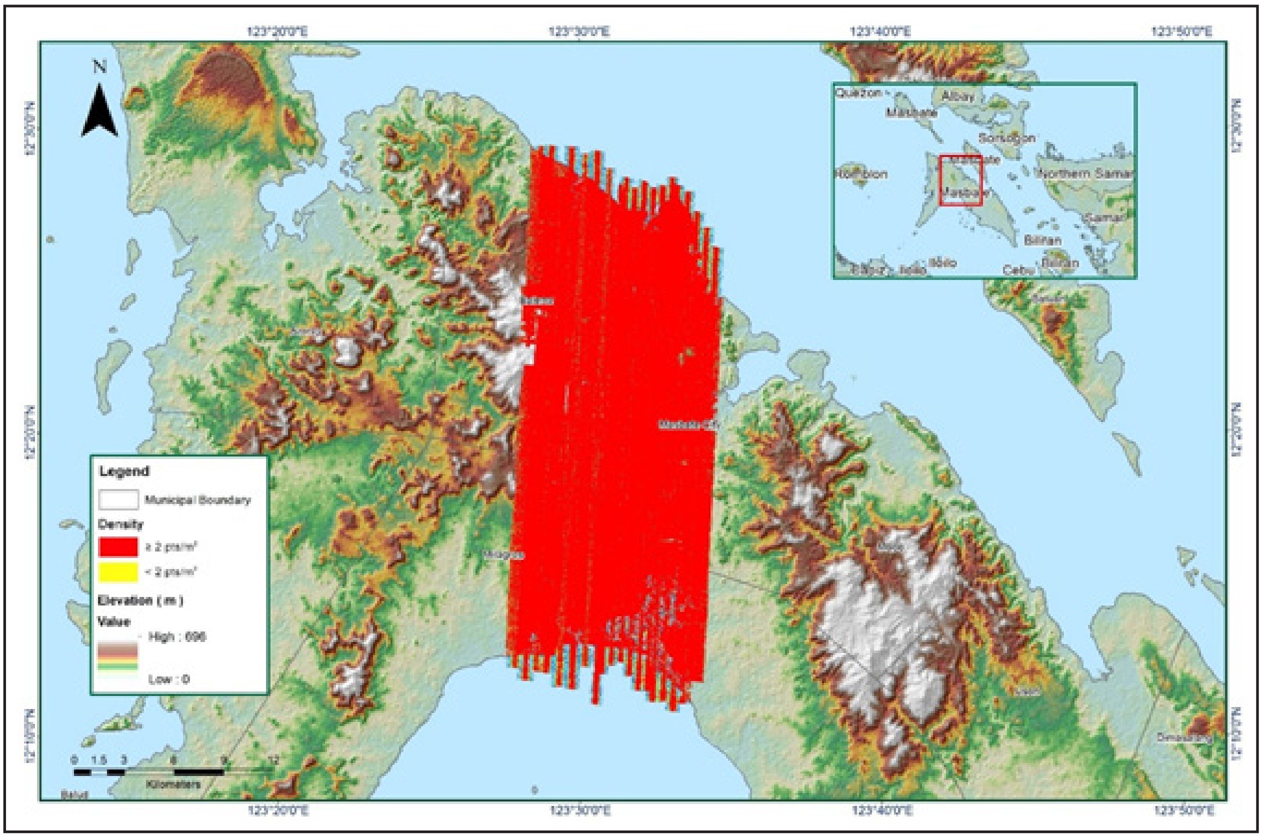


Figure A-8.6. Density map of merged LiDAR data

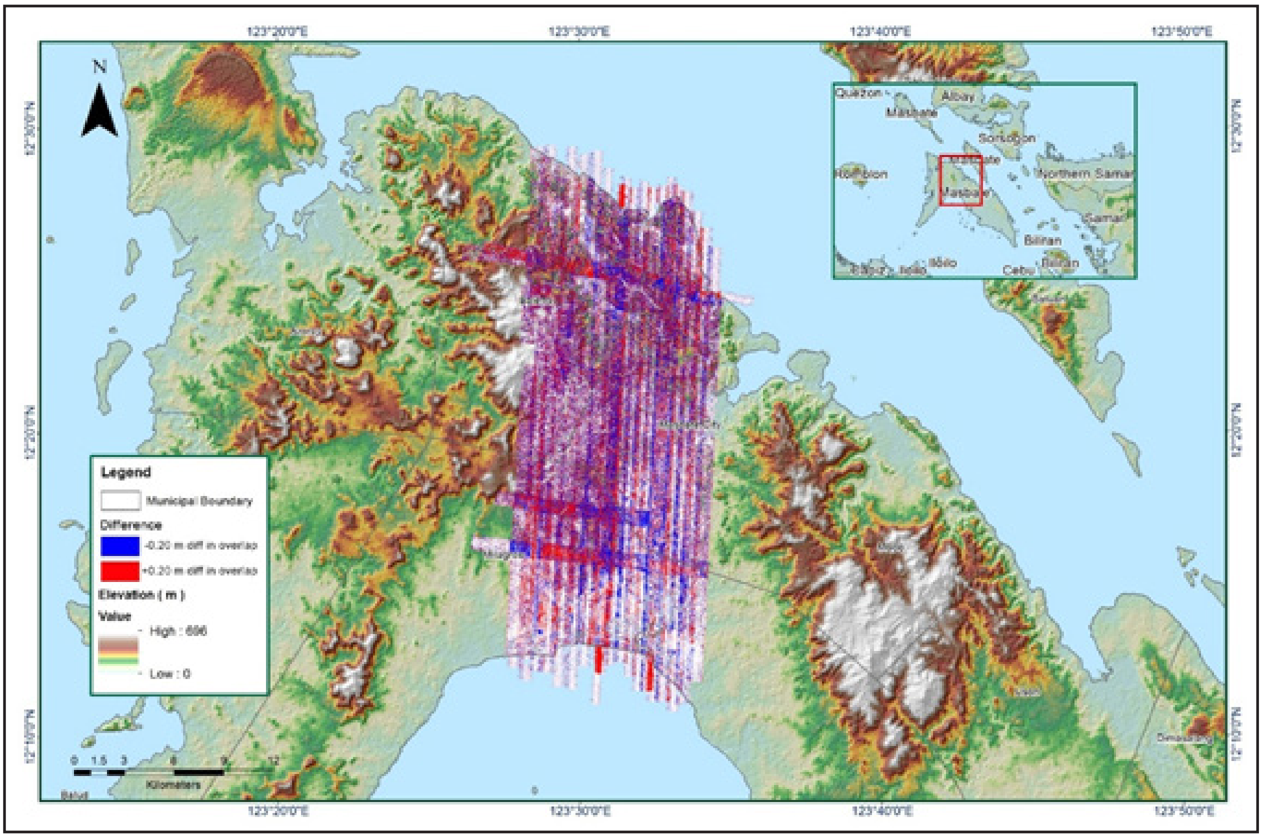


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk32A

Flight Area	**MASBATE**
Mission Name	Blk 32A
Inclusive Flights	1303P, 1305P
Mission Name	1BLK32A094A, 1BLK32A094B
Range data size	52.7 GB
Base data size	379 MB
POS	13.34 MB
Image	96.8 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	35.60%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	671
Maximum Height	710.95m
Minimum Height	55.95m
Classification (# of points)	
Ground	556,276,310
Low vegetation	419,293,403
Medium vegetation	439,040,885
High vegetation	260,239,514
Building	4,857,880
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

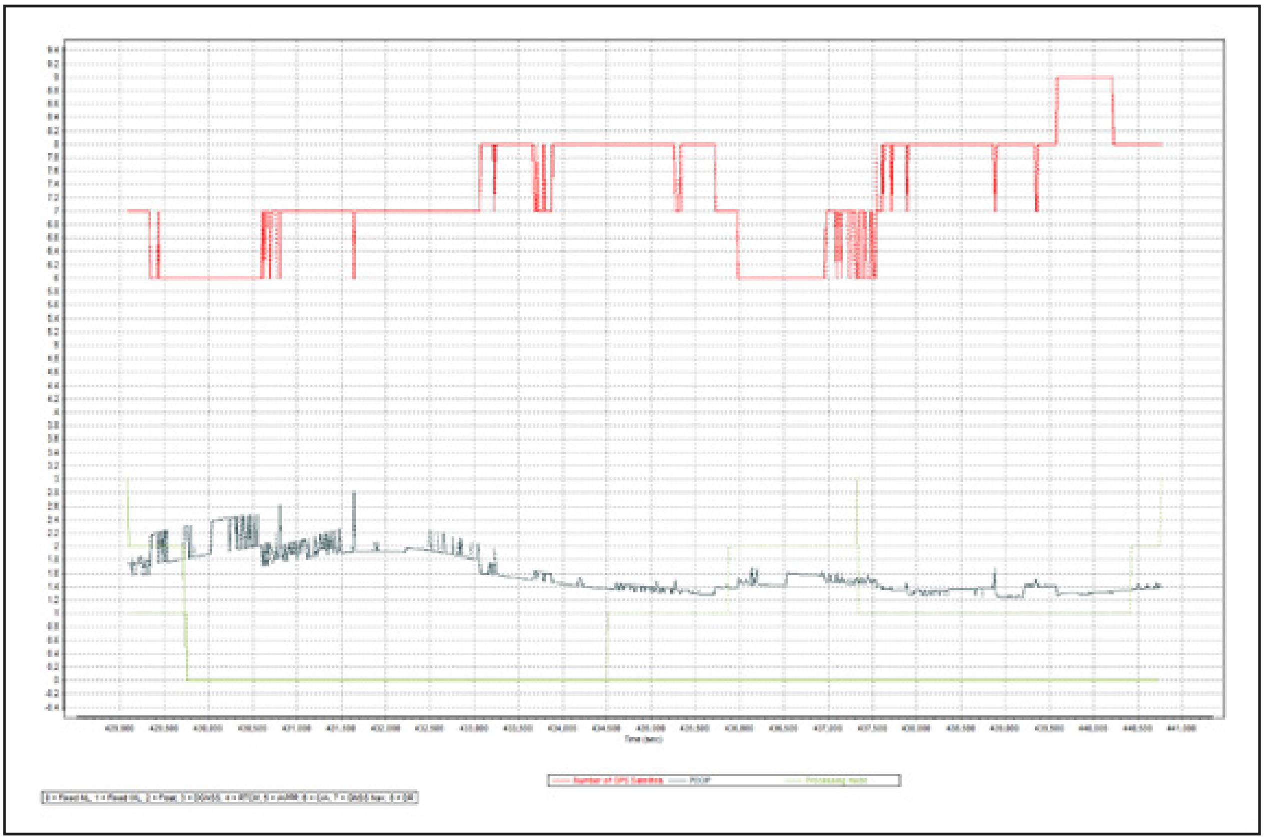


Figure A-8.8. Solution Status

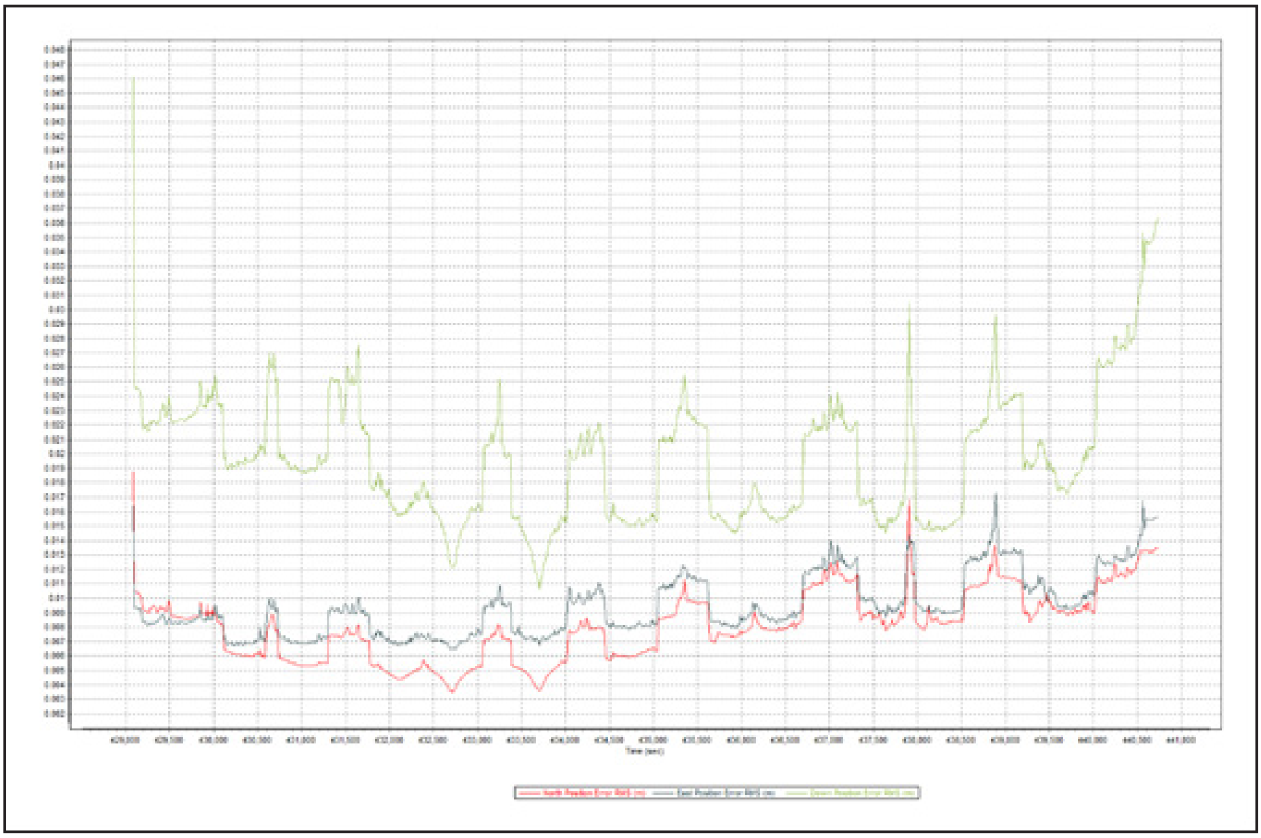


Figure A-8.9. Smoothed Performance Metric Parameters

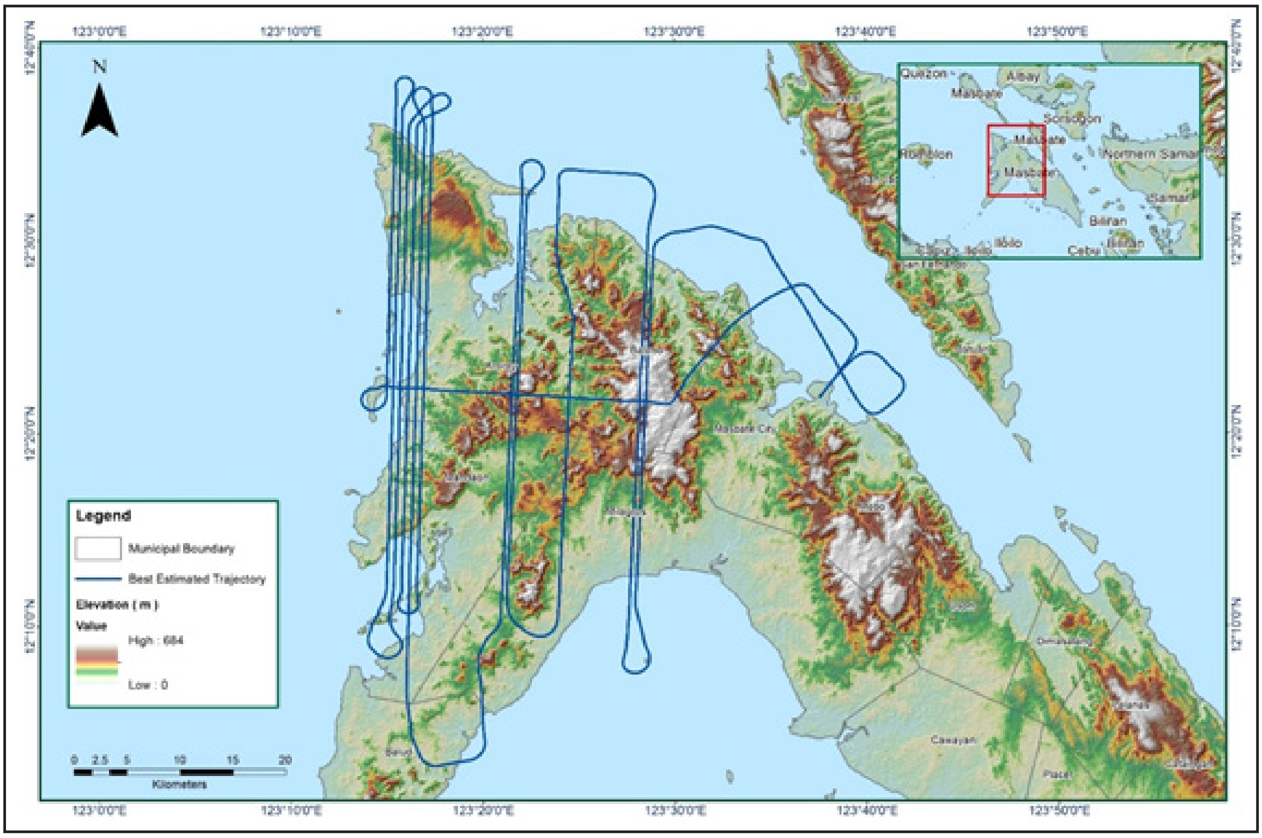


Figure A-8.10. Best Estimated Trajectory

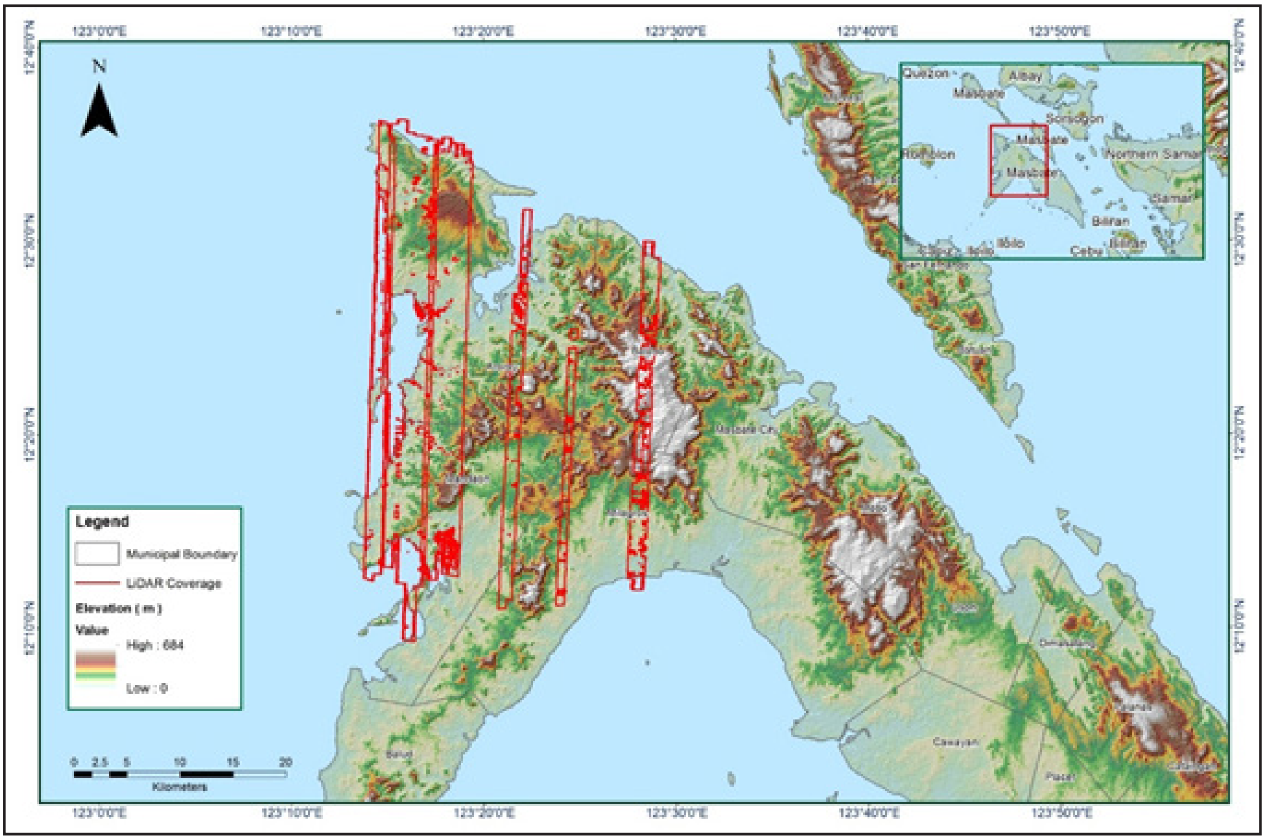


Figure A-8.11. Coverage of LiDAR data

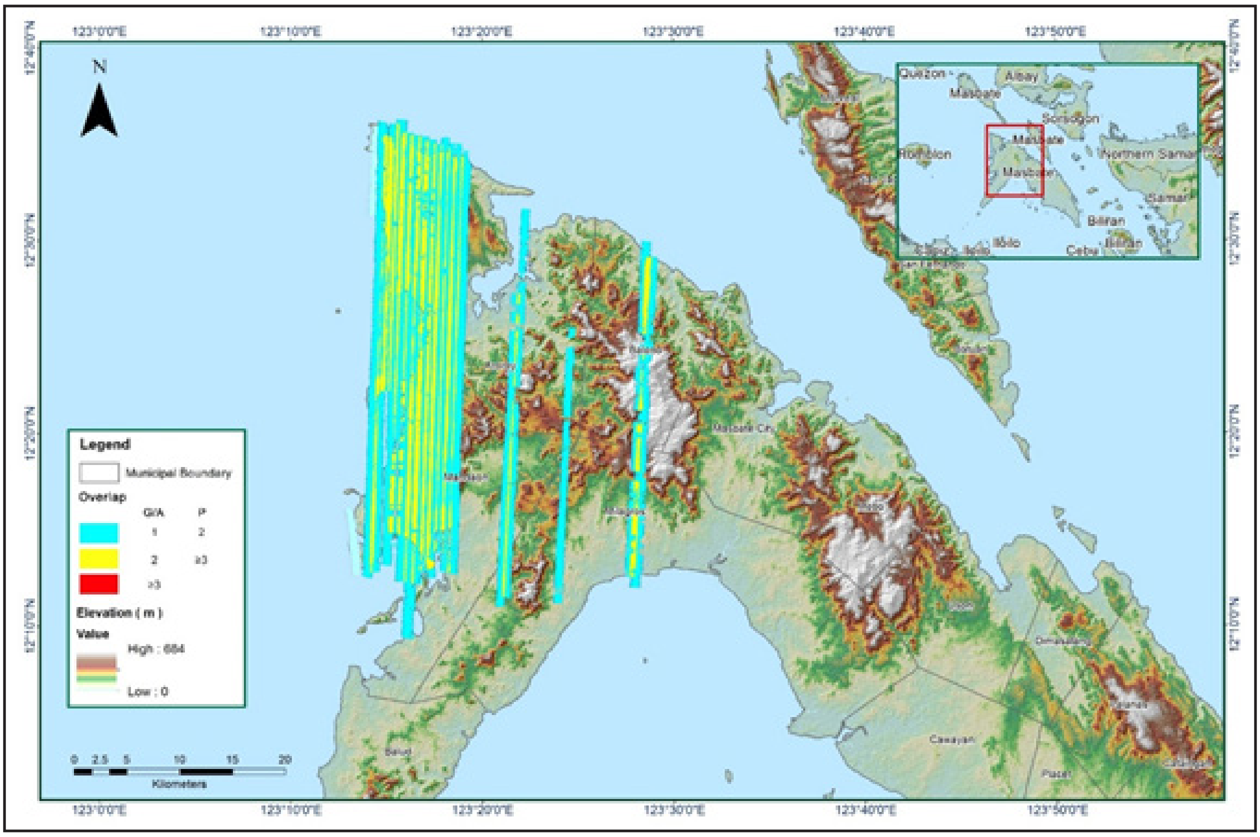


Figure A-8.12. Image of data overlap

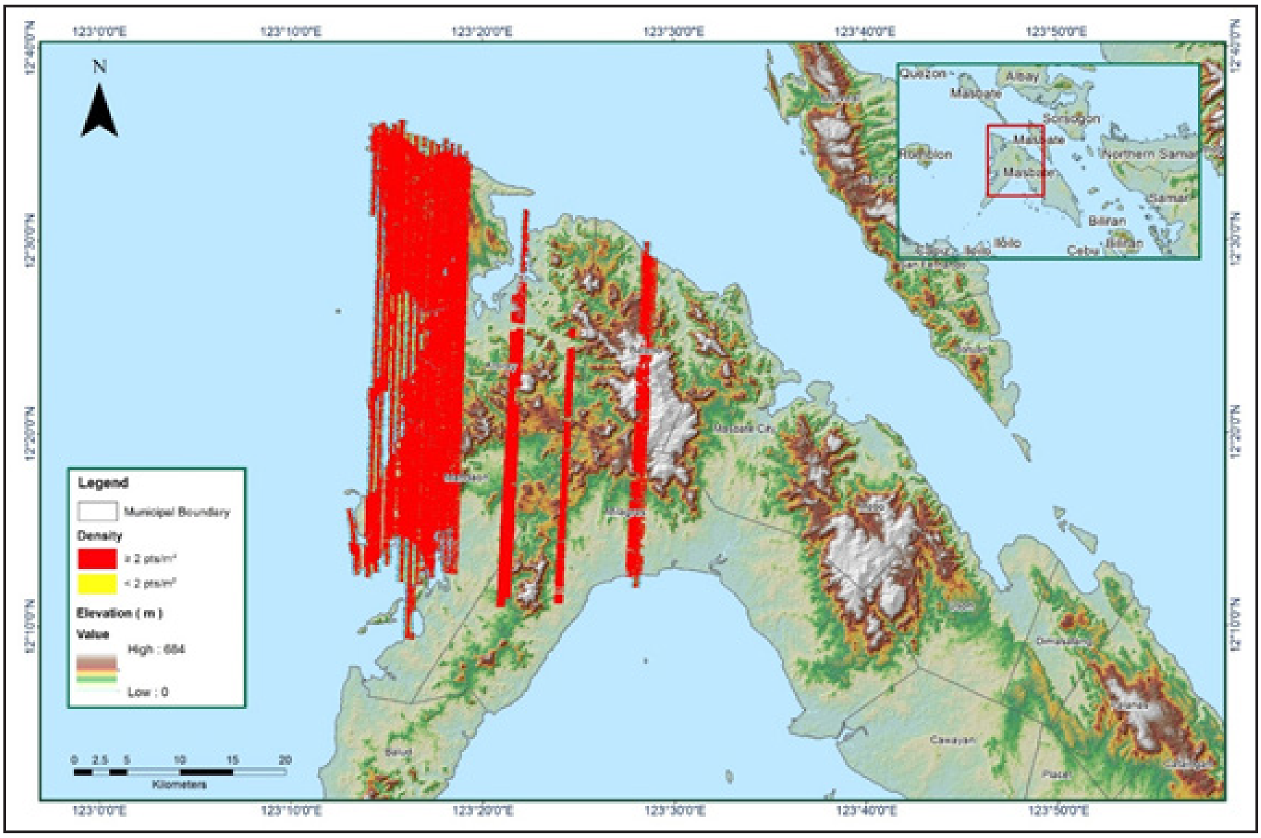


Figure A-8.13. Density map of merged LiDAR data

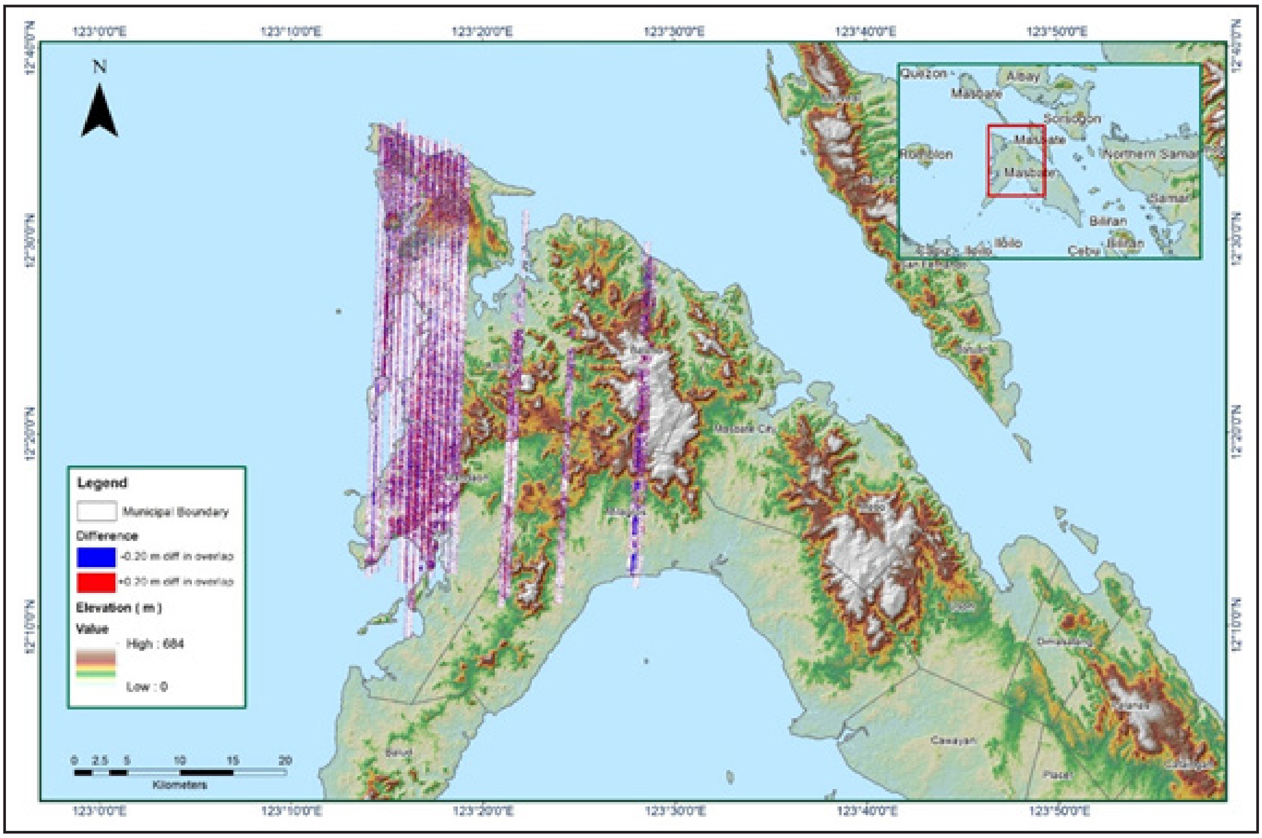


Figure A-8.14. Elevation difference between flight lines

ANNEX 9. Baleno Model Basin Parameters

Table A-9.1. Baleno Model Basin Parameters

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W240	4.62810	97.24000	0	4.11040	12.20900	Discharge	0.0805	0.07803	Ratio to Peak	0.89990
W250	301.23000	59.21300	0	200.00000	0.06164	Discharge	0.0904	0.00001	Ratio to Peak	0.00023
W260	307.45000	53.02000	0	2.00000	461.51000	Discharge	0.0118	0.00001	Ratio to Peak	0.00033
W270	137.12000	77.00500	0	0.25000	282.86000	Discharge	0.0668	0.00001	Ratio to Peak	0.08916
W280	0.21252	98.19000	0	69.22500	11.18300	Discharge	0.1062	0.00001	Ratio to Peak	0.06627
W290	2.92580	92.51700	0	23.92600	18.21000	Discharge	0.1706	0.00001	Ratio to Peak	0.00149
W300	0.00488	95.48600	0	73.43100	13.34800	Discharge	0.1600	0.00001	Ratio to Peak	0.04084
W310	0.03395	74.51300	0	36.74600	12.18600	Discharge	0.0981	0.00001	Ratio to Peak	0.00539
W320	490.02000	66.00000	0	5.64100	349.78000	Discharge	0.1332	0.00001	Ratio to Peak	0.00820
W330	310.59000	59.21300	0	0.13039	167.32000	Discharge	0.0026	0.00001	Ratio to Peak	0.00016
W340	479.97000	99.00000	0	0.14677	209.25000	Discharge	0.1450	0.00001	Ratio to Peak	0.01960
W350	92.86000	99.00000	0	85.50000	102.26000	Discharge	0.1273	0.00001	Ratio to Peak	0.18998

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W360	141.85000	53.52400	0	50.97300	66.58400	Discharge	0.5212	0.00001	Ratio to Peak	0.00014
W370	322.01000	39.56000	0	0.01667	190.20000	Discharge	0.0910	0.00001	Ratio to Peak	0.13457
W380	0.00154	97.90800	0	60.00900	8.44850	Discharge	0.1285	0.00001	Ratio to Peak	0.02109
W390	125.49000	56.70300	0	2.99700	473.31000	Discharge	0.0823	0.00001	Ratio to Peak	0.00243
W400	57.98300	58.22200	0	0.01667	5.48000	Discharge	0.2296	0.00001	Ratio to Peak	0.00023
W410	320.13000	49.11200	0	0.15657	45.70400	Discharge	0.1454	0.00001	Ratio to Peak	0.07030
W420	4.22990	74.08000	0	3.09240	0.06905	Discharge	0.0183	0.00001	Ratio to Peak	0.00043
W430	1.57580	92.14900	0	14.48300	9.37060	Discharge	0.0868	0.00001	Ratio to Peak	0.20185
W440	0.00399	53.93000	0	2.20840	0.06181	Discharge	0.3523	0.00001	Ratio to Peak	0.00049
W450	0.00841	98.20100	0	0.14776	0.06590	Discharge	0.0865	0.00001	Ratio to Peak	0.00011
W460	124.60000	52.92600	0	1.60650	13.47300	Discharge	0.1656	0.00001	Ratio to Peak	0.05629

Annex 10. Baleno Model Reach Parameters

Table A-10.1. Baleno Model Reach Parameters

Reach Number	Muskingum-Cunge Channel Routing						
	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side slope
R20	Automatic Fixed Interval	2129.1	0.00366	0.98562	Trapezoid	12.092	1
R30	Automatic Fixed Interval	1229.5	0.00226	0.04528	Trapezoid	12.092	1
R40	Automatic Fixed Interval	555.68	0.00134	0.34820	Trapezoid	12.092	1
R60	Automatic Fixed Interval	2262.4	0.00134	0.93439	Trapezoid	12.092	1
R90	Automatic Fixed Interval	2615.7	0.00174	0.66802	Trapezoid	12.092	1
R110	Automatic Fixed Interval	438.21	0.01070	0.01651	Trapezoid	12.092	1
R130	Automatic Fixed Interval	2157.4	0.00105	0.03328	Trapezoid	12.092	1
R140	Automatic Fixed Interval	2600.5	0.00289	0.00032	Trapezoid	12.092	1
R160	Automatic Fixed Interval	3086.3	0.00449	0.78517	Trapezoid	12.092	1
R180	Automatic Fixed Interval	867.38	0.01360	0.59851	Trapezoid	12.092	1
R200	Automatic Fixed Interval	2595.2	0.01211	0.00010	Trapezoid	12.092	1

Annex 11. Baleno Floodplain Field Validation Points

Table A-11.1. Baleno Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
187	12.40015209	123.5122623	0.03	0	0.03		5-Year
143	12.40044682	123.5121511	0.03	0	0.03		5-Year
186	12.40071901	123.5126003	0.03	0	0.03		5-Year
188	12.40080367	123.5124285	0.03	0	0.03		5-Year
184	12.40113234	123.5133089	0.03	0	0.03		5-Year
183	12.40115879	123.5132205	0.03	0	0.03		5-Year
185	12.40128017	123.5135896	0.03	0	0.03		5-Year
182	12.4015189	123.5126933	0.06	0.6	-0.54		5-Year
181	12.40183759	123.5121834	0.03	0	0.03		5-Year
179	12.40192087	123.5123884	0.03	0	0.03		5-Year
180	12.40217114	123.512446	0.03	0	0.03		5-Year
178	12.40251881	123.5118583	1.87	0.3	1.57		5-Year
177	12.40919443	123.509096	0.03	0	0.03		5-Year
174	12.41163456	123.5034545	0.35	0.5	-0.15	STY Ondoy 2009	5-Year
173	12.41247042	123.5041961	0.58	0.3	0.28	STY Ondoy 2009	5-Year
172	12.412578	123.5059276	0.03	0	0.03		5-Year
176	12.41258284	123.5062721	0.09	0.5	-0.41	STY Ondoy 2009	5-Year
175	12.41263562	123.5061619	0.03	0	0.03		5-Year
171	12.41704779	123.5061405	1.31	0.4	0.91	2014	5-Year
170	12.42002757	123.5062994	0.47	0	0.47		5-Year
169	12.42014473	123.5061917	0.83	0.5	0.33	STY Ondoy 2009	5-Year
167	12.42146822	123.5065473	1.04	0.4	0.64	STY Ondoy 2009	5-Year
168	12.42148062	123.5065053	1.42	0.8	0.62	2016	5-Year
166	12.42169922	123.506423	1.89	1	0.89	2015	5-Year
165	12.42180023	123.5065892	1.64	0.76	0.88	2015	5-Year
163	12.42187206	123.5067197	1.59	0.52	1.07	STY Yolanda 2013	5-Year
164	12.42196255	123.5069106	2.01	0.83	1.18	2015	5-Year
162	12.42202926	123.5066342	1.43	1.24	0.19	2015	5-Year
161	12.42207939	123.5066538	1.58	0.46	1.12	2015	5-Year
158	12.42288225	123.5067157	1.15	0.58	0.57	STY Ruby 2014	5-Year
159	12.42292061	123.5068174	1.12	0.36	0.76	STY Ondoy 2009	5-Year
157	12.42300165	123.5067438	1.27	0.3	0.97	STY Ruby 2014	5-Year
160	12.42342226	123.5070109	0.86	0.05	0.81	2015	5-Year
156	12.42679206	123.507682	0.03	0	0.03		5-Year
155	12.42712245	123.508217	0.03	0	0.03		5-Year
154	12.42738466	123.5091367	0.36	0	0.36		5-Year
153	12.42896637	123.507619	0.03	0	0.03		5-Year
151	12.42904709	123.5075176	0.03	0	0.03		5-Year
152	12.42909873	123.5076074	0.03	0.6	-0.57	2016	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
150	12.43163484	123.5068757	0.85	1.5	-0.65	1976	5-Year
147	12.43463661	123.5048189	0.25	0	0.25		5-Year
149	12.43469154	123.504779	0.36	0.3	0.06	2015	5-Year
148	12.43583683	123.5065659	0.58	0	0.58		5-Year
145	12.43650944	123.5031346	0.03	0.6	-0.57		5-Year
146	12.43666151	123.503403	0.07	0.3	-0.23	2014	5-Year
144	12.43668964	123.5032542	0.2	0	0.2		5-Year
63	12.43758036	123.5027189	0.35	0	0.35		5-Year
136	12.43873262	123.5022794	0.52	0.9	-0.38	1989	5-Year
132	12.43910986	123.5015329	0.06	0.2	-0.14	TY Glenda 2014	5-Year
133	12.43950833	123.5014484	0.42	0	0.42	STY Yolanda 2013	5-Year
62	12.4396203	123.502106	0.73	0	0.73		5-Year
125	12.43964376	123.5021024	0.73	0	0.73		5-Year
61	12.43970934	123.5021232	0.78	0	0.78		5-Year
134	12.43972495	123.5014692	0.31	0.7	-0.39		5-Year
54	12.43973787	123.5018594	0.64	0.5	0.14		5-Year
135	12.44009289	123.5019168	0.74	3	-2.26	1981	5-Year
130	12.4401417	123.502338	1.1	0.7	0.4		5-Year
131	12.44016397	123.5025351	1.56	1	0.56	STY Yolanda 2013	5-Year
60	12.44037957	123.501764	0.62	0.92	-0.3	STY Ondoy 2009	5-Year
59	12.44043099	123.5023393	1.23	1.7	-0.47	1980s	5-Year
126	12.44062481	123.5025319	1.31	0.3	1.01	heavy rains	5-Year
58	12.44072548	123.5024706	1.02	0.44	0.58	STY Yolanda 2013	5-Year
129	12.44082534	123.5025733	1.11	1	0.11	STY Yolanda 2013	5-Year
127	12.44084719	123.5025613	1.11	0	1.11		5-Year
128	12.44085808	123.5026399	1.32	0.9	0.42		5-Year
57	12.44092611	123.5024407	1.02	0.48	0.54	2014	5-Year
56	12.44129472	123.502564	0.96	0.33	0.63	TY Glenda 2014	5-Year
55	12.4417413	123.5028289	0.51	0	0.51		5-Year
53	12.44389577	123.5030626	0.03	0	0.03		5-Year
124	12.44407972	123.5030214	0.09	0	0.09		5-Year
123	12.44437732	123.5032826	0.98	0.7	0.28		5-Year
106	12.45156579	123.4836159	0.81	0.1	0.71		5-Year
41	12.45174643	123.4835771	0.32	0.05	0.27	2015	5-Year
42	12.45187531	123.4836051	0.64	0	0.64		5-Year
107	12.45232548	123.4836922	0.92	0.25	0.67	STY Ruby 2014	5-Year
108	12.45303609	123.4837619	0.72	0.3	0.42	STY Ruby 2014	5-Year
43	12.45358774	123.4838304	0.9	0.2	0.7	STY Ruby 2014	5-Year
44	12.45363207	123.4839514	1.11	0	1.11		5-Year
109	12.45374165	123.4832147	0.71	0.15	0.56		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
45	12.45376323	123.4842217	0.95	0.29	0.66	2013 or 14	5-Year
46	12.45397964	123.4843996	0.78	0	0.78		5-Year
110	12.45418956	123.482886	0.3	0.26	0.04	STY Yolanda 2013	5-Year
52	12.4546893	123.4969947	1.67	0	1.67	STY Ruby 2014	5-Year
122	12.45476998	123.4973599	0.61	0.5	0.11		5-Year
51	12.45497041	123.4968624	1.29	0.38	0.91		5-Year
121	12.45504734	123.4969695	1.4	0.3	1.1		5-Year
119	12.45528848	123.4964108	1.21	1	0.21	STY Ruby 2014	5-Year
120	12.45551993	123.4963253	1.64	0.7	0.94	2014	5-Year
118	12.4558775	123.495718	1.08	0.5	0.58	2014	5-Year
117	12.4558916	123.4920072	0.75	0.3	0.45	1985	5-Year
113	12.45598619	123.4907978	0.88	0.9	-0.02	1983	5-Year
114	12.45598619	123.4907978	0.88	0.3	0.58		5-Year
116	12.45603732	123.4918025	0.84	0.5	0.34	1983	5-Year
49	12.45605044	123.4907665	0.82	0.93	-0.11		5-Year
115	12.45604977	123.4915113	0.9	0	0.9		5-Year
48	12.45605592	123.4899312	0.03	0	0.03		5-Year
50	12.45605552	123.4914311	0.9	0.9	0	1998	5-Year
47	12.45608537	123.4898391	1.24	0.67	0.57	1996	5-Year
112	12.45611929	123.4904077	0.75	0	0.75		5-Year
111	12.45612967	123.4895846	1.54	0.3	1.24		5-Year
40	12.45772971	123.4964795	0.03	0	0.03	STY Ruby 2014	5-Year
105	12.4579252	123.4966718	1.05	0.6	0.45		5-Year
39	12.45820657	123.4965571	1.5	0.8	0.7	STY Ruby 2014	5-Year
38	12.45825454	123.4967428	1.61	0.6	1.01	2015	5-Year
103	12.45913005	123.4973918	1.19	0.69	0.5	STY Ondoy 2009	5-Year
104	12.45913005	123.4973918	1.19	1	0.19	STY Ruby 2014	5-Year
37	12.45917438	123.4973077	0.68	0.17	0.51	2015	5-Year
36	12.45931629	123.4974912	0.03	0	0.03		5-Year
35	12.46159091	123.4972507	0.41	0.9	-0.49	2014 Habagat	5-Year
34	12.46544448	123.4948366	0.03	0.68	-0.65	STY Yolanda 2013	5-Year
33	12.46546432	123.4948795	0.29	0	0.29		5-Year
102	12.46661423	123.4950801	0.13	0	0.13		5-Year
101	12.46948503	123.4956327	0.03	0	0.03		5-Year
29	12.47024202	123.4971212	1.33	0.16	1.17	STY Ruby 2014	5-Year
97	12.47024411	123.4971221	1.33	0.16	1.17	STY Ruby 2014	5-Year
98	12.47028284	123.4973851	0.82	0.66	0.16	STY Yolanda 2013, STY Ruby 2014	5-Year
30	12.47030372	123.497385	0.82	0.66	0.16	2015	5-Year
99	12.47032408	123.4983543	1.02	0.2	0.82		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
31	12.47032802	123.4983371	0.98	0.2	0.78		5-Year
28	12.47037954	123.4977727	0.69	0.88	-0.19	Sunod sa STY Yolanda 2013	5-Year
32	12.47055386	123.4993658	1.41	0.3	1.11	STY Ruby 2014	5-Year
100	12.47058816	123.4994	1.41	0.3	1.11	STY Ruby 2014	5-Year
137	12.47173161	123.4972727	0.03	0	0.03		5-Year
27	12.47401185	123.4961933	0.21	0	0.21		5-Year
96	12.4740933	123.4961196	0.49	0.3	0.19	STY Ruby 2014, STY Yolanda 2013	5-Year
25	12.47415831	123.4957544	0.69	0.65	0.04	2016	5-Year
26	12.47416063	123.4957212	0.69	0.65	0.04		5-Year
24	12.47426455	123.4952626	0.53	0.45	0.08		5-Year
93	12.47429339	123.4954963	0.79	0.9	-0.11		5-Year
94	12.47429495	123.4955546	0.88	0	0.88		5-Year
95	12.47429993	123.4956605	0.86	0.5	0.36		5-Year
92	12.47446945	123.4953174	0.51	0.7	-0.19	STY Yolanda 2013	5-Year
23	12.47474206	123.495389	0.62	0.45	0.17		5-Year
89	12.47478583	123.4972041	0.3	0	0.3		5-Year
88	12.47481063	123.4970561	0.46	0	0.46		5-Year
87	12.47483528	123.4970008	0.46	0	0.46		5-Year
21	12.47483934	123.497095	0.42	0	0.42		5-Year
85	12.47488747	123.4966825	0.47	0	0.47		5-Year
86	12.47489216	123.4967434	0.48	0	0.48		5-Year
20	12.47506553	123.4964927	0.23	0.05	0.18		5-Year
91	12.47512873	123.4956138	0.71	0.6	0.11	STY Yolanda 2013	5-Year
84	12.47517554	123.4961723	0.48	0	0.48		5-Year
22	12.4751968	123.4955199	0.74	0.6	0.14	2015	5-Year
83	12.47530205	123.4960032	0.66	0	0.66		5-Year
90	12.47534315	123.4956682	0.69	0.5	0.19	2013/2014	5-Year
82	12.47560043	123.4959043	0.59	0	0.59		5-Year
19	12.47562915	123.4959079	0.59	0.3	0.29	STY Reming 2006	5-Year
18	12.47578661	123.4958594	0.67	0.5	0.17		5-Year
81	12.47585204	123.4960803	0.22	0.16	0.06		5-Year
80	12.47599354	123.4957065	0.67	0.15	0.52		5-Year
142	12.47605399	123.4956595	0.53	0.15	0.38		5-Year
79	12.47634046	123.4956622	0.03	0	0.03		5-Year
17	12.4784601	123.4939914	0.05	0.2	-0.15	STY Yolanda 2013	5-Year
78	12.47934075	123.4789352	0.72	0.1	0.62		5-Year
15	12.47934511	123.4789055	0.72	0.1	0.62		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
141	12.47954481	123.4913368	0.13	0.2	-0.07		5-Year
140	12.47957215	123.4911629	0.12	0.6	-0.48		5-Year
16	12.48001995	123.4900088	0.31	0.45	-0.14		5-Year
77	12.48078217	123.4877325	1.19	0.6	0.59	STY Ondoy 2009	5-Year
14	12.48079253	123.487746	1.19	0.6	0.59	STY Ondoy 2009	5-Year
76	12.4808802	123.4876854	1.35	0.54	0.81		5-Year
138	12.48094678	123.4865855	1.39	0.6	0.79	STY Yolanda 2013	5-Year
13	12.48105476	123.4877308	1.44	0.54	0.9	TY Glenda 2014	5-Year
73	12.48117774	123.4869713	1.21	0.6	0.61	TY Glenda 2014	5-Year
10	12.48117854	123.4869524	1.31	0.6	0.71	STY Yolanda 2013	5-Year
72	12.48120907	123.4870838	1.04	0.3	0.74	TY Glenda 2014	5-Year
9	12.48121638	123.4871133	1.27	0.3	0.97	STY Yolanda 2013	5-Year
12	12.48129007	123.4874642	1.24	0.98	0.26		5-Year
11	12.48129223	123.487324	1.25	0.4	0.85	TY Nona 2015	5-Year
75	12.48133129	123.4874328	0.85	0.98	-0.13		5-Year
74	12.48136247	123.4873525	0.86	0.4	0.46	TY Nona 2015	5-Year
139	12.48401888	123.4818705	1.39	0.8	0.59		5-Year
7	12.48449119	123.4804047	1	0.6	0.4	STY Ruby 2014	5-Year
71	12.48457319	123.4804661	1.05	0.6	0.45	STY Ruby 2014	5-Year
8	12.48458827	123.4804535	1.05	0.6	0.45	STY Ruby 2014	5-Year
70	12.48475193	123.4801183	1.01	0.6	0.41	STY Ruby 2014	5-Year
6	12.48475919	123.4801234	1.1	0.6	0.5	STY Ruby 2014	5-Year
68	12.48500538	123.479177	0.34	0.5	-0.16		5-Year
4	12.48504843	123.4792197	0.32	0.5	-0.18		5-Year
64	12.48515131	123.4803987	0.75	0.6	0.15	STY Yolanda 2013	5-Year
3	12.4851606	123.4792852	0.37	0.2	0.17	STY Ruby 2014	5-Year
67	12.48516509	123.4792794	0.37	0.2	0.17	STY Ruby 2014	5-Year
5	12.48521754	123.4797126	0.7	1	-0.3	TY Amang 2015	5-Year
69	12.48529674	123.4797515	0.7	1	-0.3	TY Amang 2015	5-Year
2	12.48547605	123.4795006	0.09	0.3	-0.21	2015 STY Ruby 2014	5-Year
66	12.48553732	123.479409	0.03	0.3	-0.27		5-Year
65	12.48602311	123.4793952	0.03	0	0.03	TY Carina 2016	5-Year
1	12.48665833	123.4748285	0	0.9	-0.9	STY Ruby 2014	5-Year

ANNEX 12. Educational Institutions affected by flooding in Baleno Floodplain

Table A-12.1. Educational Institutions in Baleno, Masbate affected by flooding in Baleno Floodplain

Masbate				
Baleno				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Batuila Day Care Center	Batuila			Low
Batuila Elementary School	Batuila			
Masbate Polythecnic Devt College	Batuila			
Cagara Day Care Center	Cagara	Low	Medium	Medium
Cagara Elementary School	Cagara	Low	Medium	Medium
Brgy Gangao Amador Bello High School	Canjunday			
Cancahorao Elem School	Canjunday			
Canjonday Day Care	Canjunday			
Canjonday Elem.school	Canjunday			
Gangao Elem Sc	Canjunday			
Brgy Gangao Amador Bello High School	Gangao			
Gangao Day Care Center	Gangao			
Gangao Elem Sc	Gangao			
Esquilona Elementary School Lagta	Lagta	Low	Low	Low
Lagta Day Care	Lagta	Medium	Medium	High
Sogong Elementary School	Lagta			
Day Care Poblacion Baleno	Lipata			Medium
Lipata Daycare Center	Lipata			
Lipata Elem School	Lipata			
Masbate Polytechnic And Development College	Lipata			
Polot Daycare Center	Madangcalan	Medium	Medium	Medium
Polot Elem. School	Madangcalan			
Baleno Central School	Poblacion			
Baleno Elementary School	Poblacion	Medium	Medium	Medium
Baleno National high School	Poblacion			
Masbate Polytechnic And Development College	Poblacion			
St Bernard Of Clairvaux Mission school	Poblacion	Low		Low

Day Care Center Potoson Baleno	Potoson			Low
Potoson Elementary School Baleno	Potoson			
Sogong Elementary School	Sog-Ong			

ANNEX 13. Health Institutions affected by flooding in Baleno Floodplain

Table A-13.1. Health Institutions in Baleno, Masbate affected by flooding in Baleno Floodplain

Masbate				
Baleno				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Batuila Health Center	Batuila			Low
Cagara Health Center	Cagara	Low	Medium	Medium
Gangao Health Center	Gangao			
Sogong Health Center	Lagta			
Polot Health Center	Madangcalan	Medium	Medium	Medium
Rural Health Unit	Poblacion			Low
Potoson Health Center Baleno	Potoson			