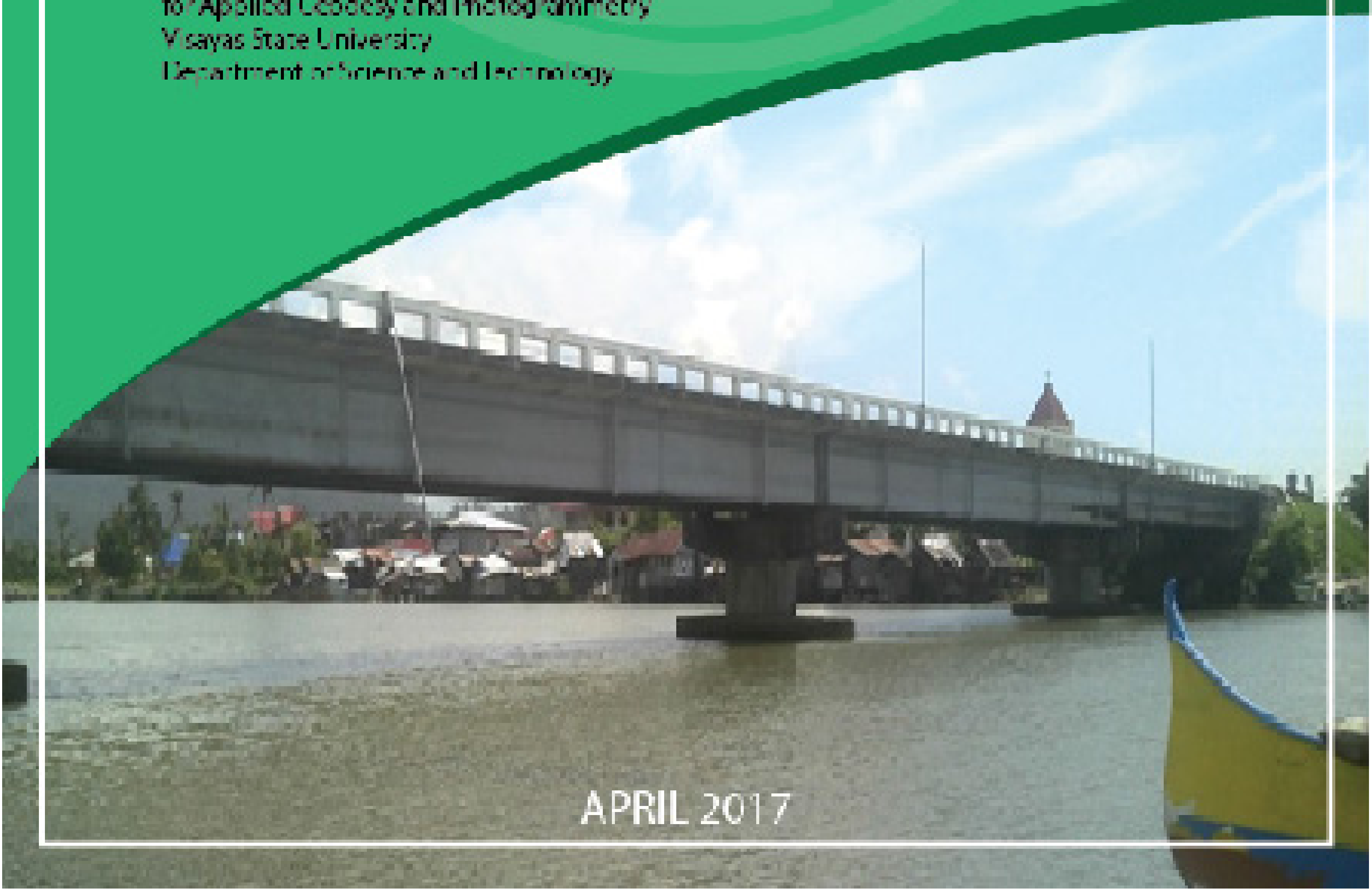
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Balangiga River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Visayas State University
Department of Science and Technology



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BALANGIGA RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU 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 twenty-eight (28) river basins in the Eastern Visayas region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Balangiga River Basin

The Balangiga River Basin is located in Eastern Visayas, at the Southern portion of Samar. It traverses through the Municipalities of Lawaan and Balangiga in the province of Eastern Samar. It covers an area of 129 square kilometers, and travels for approximately 24 kilometers from its source to its mouth in Balangiga. Based on the Department of Environment and Natural Resource (DENR) River Basin Control Office (RBCO), it has a drainage area of 169 km2 and an estimated 321 million cubic meter (MCM) annual run-off.

The river basin's main stem, the Balangiga River, is among the twenty-eight (28) river systems in Eastern Visayas under the PHIL-LiDAR 1 partner university, VSU. The river is named after the Municipality of Balangiga, where it is situated. Its waters are categorized as Class C, based on its beneficial use. This water type is generally used for fishery, recreation or boating, and supply for manufacturing processes after treatment.

The Municipality of Balangiga has a total population of 12,756 persons, according to the 2010 census of the National Statistics Office (NSO). It was one of the areas devastated by Super Typhoon Haiyan (local name, Yolanda) on November 8, 2013.

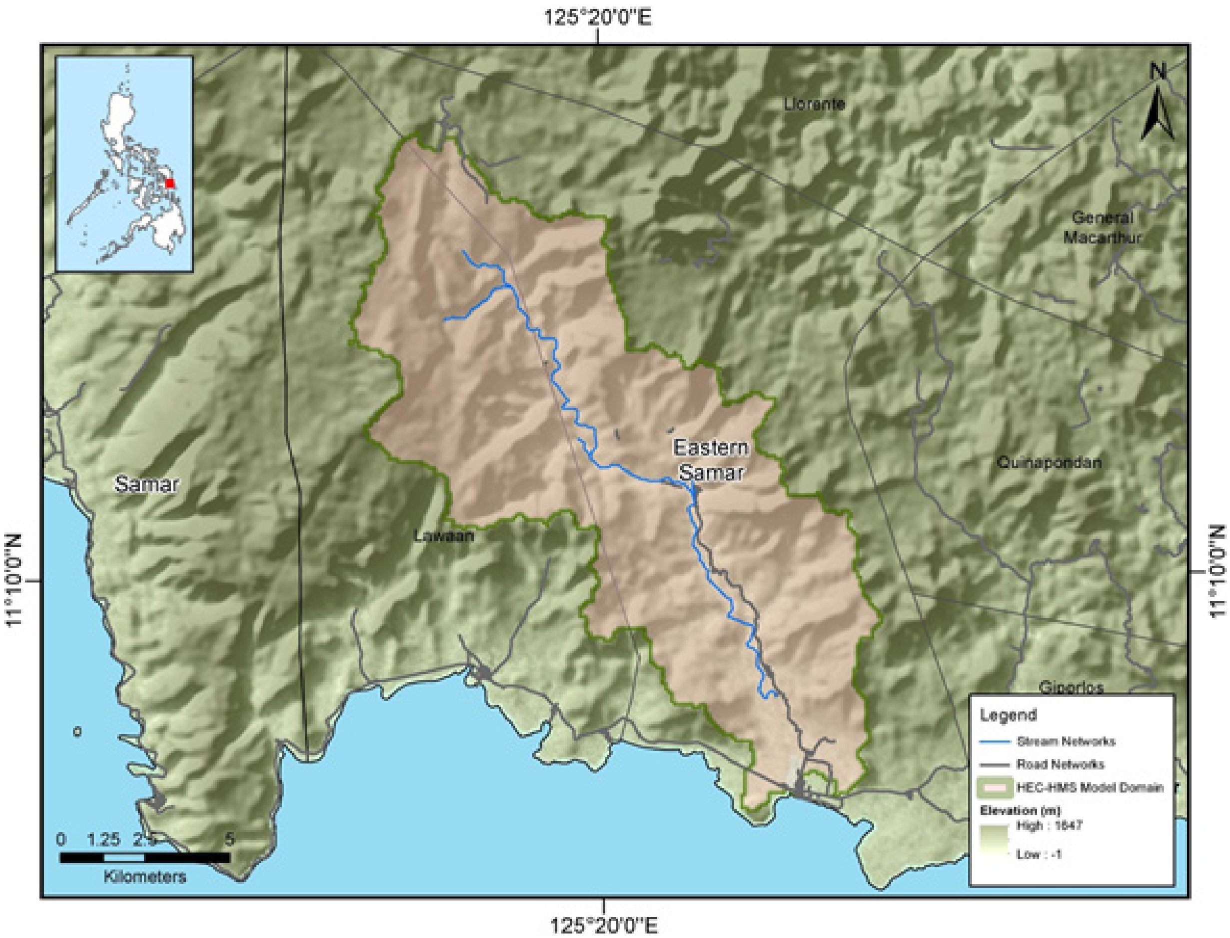

Figure 1. Location map of the Balangiga River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BALANGIGA FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the Balangiga floodplain in Eastern Samar. These missions were planned for sixteen (16) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. Two (2) sensors were used for the missions – Aquarius and Gemini (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR systems are found in Table 1 and Table 2. Figure 2 and Figure 3 illustrate the flight plans for the Balangiga floodplain using the Aquarius and Gemini LiDAR systems, respectively.

Table 1. Flight planning parameters for the Aquarius 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)
BLK33Q	500, 700	30	50, 36	70/50	40, 50	130	5
BLK33R	500, 600	30	50, 36	70/50	40, 50	130	5
BLK33S	600	30	36	50	50	130	5
BLK33T	700	30	36	50	50	130	5
BLK33U	600, 700	30	36	50	50	130	5
BLK33V	600	30	36	50	50	130	5

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK33A	850	30	40	125	50	130	5
BLK34K	850	30	40	125	50	130	5
BLK34L	850	30	40	125	50	130	5

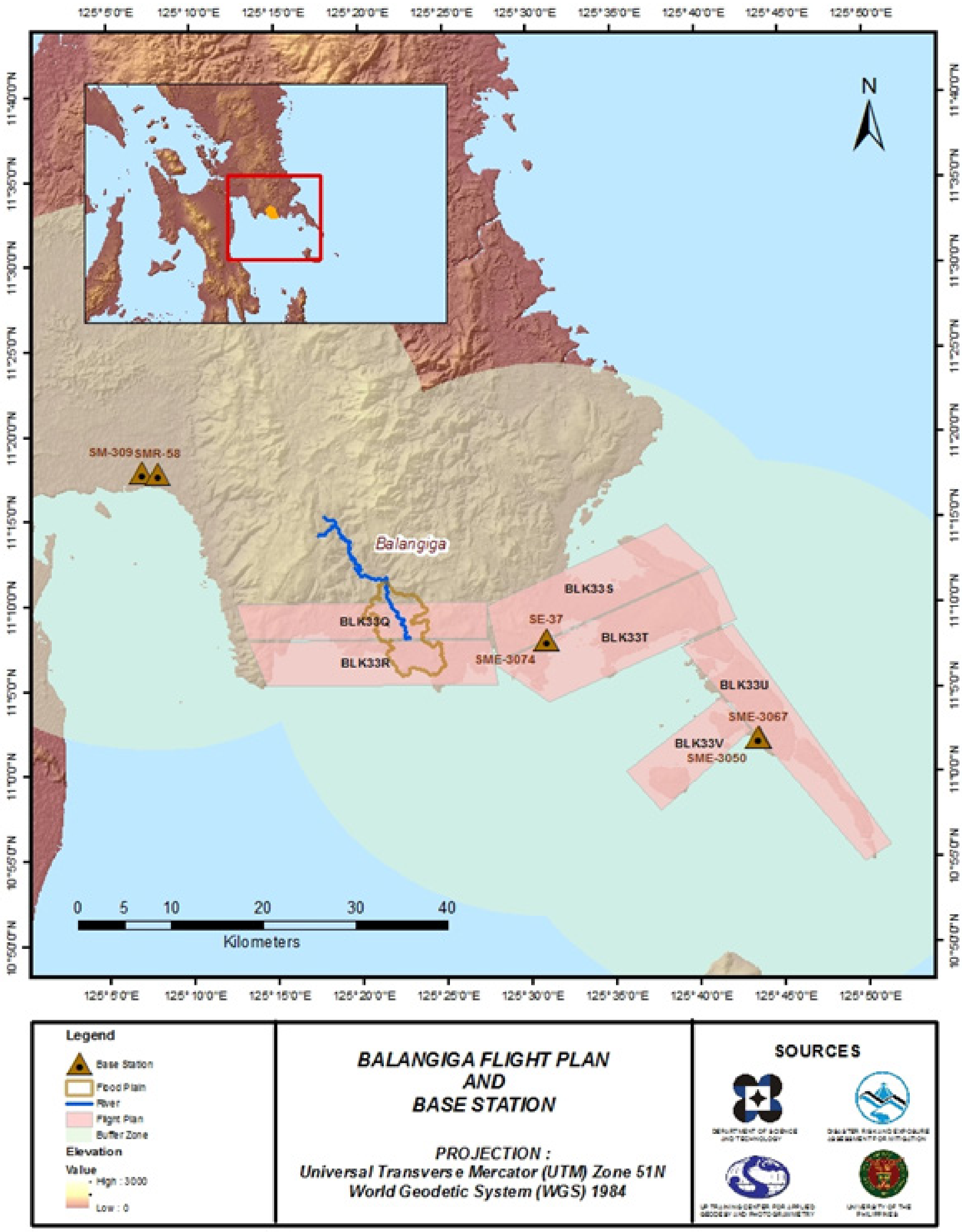

Figure 2. Flight Plan and base stations used for the Balangiga Floodplain survey using Aquarius sensor.

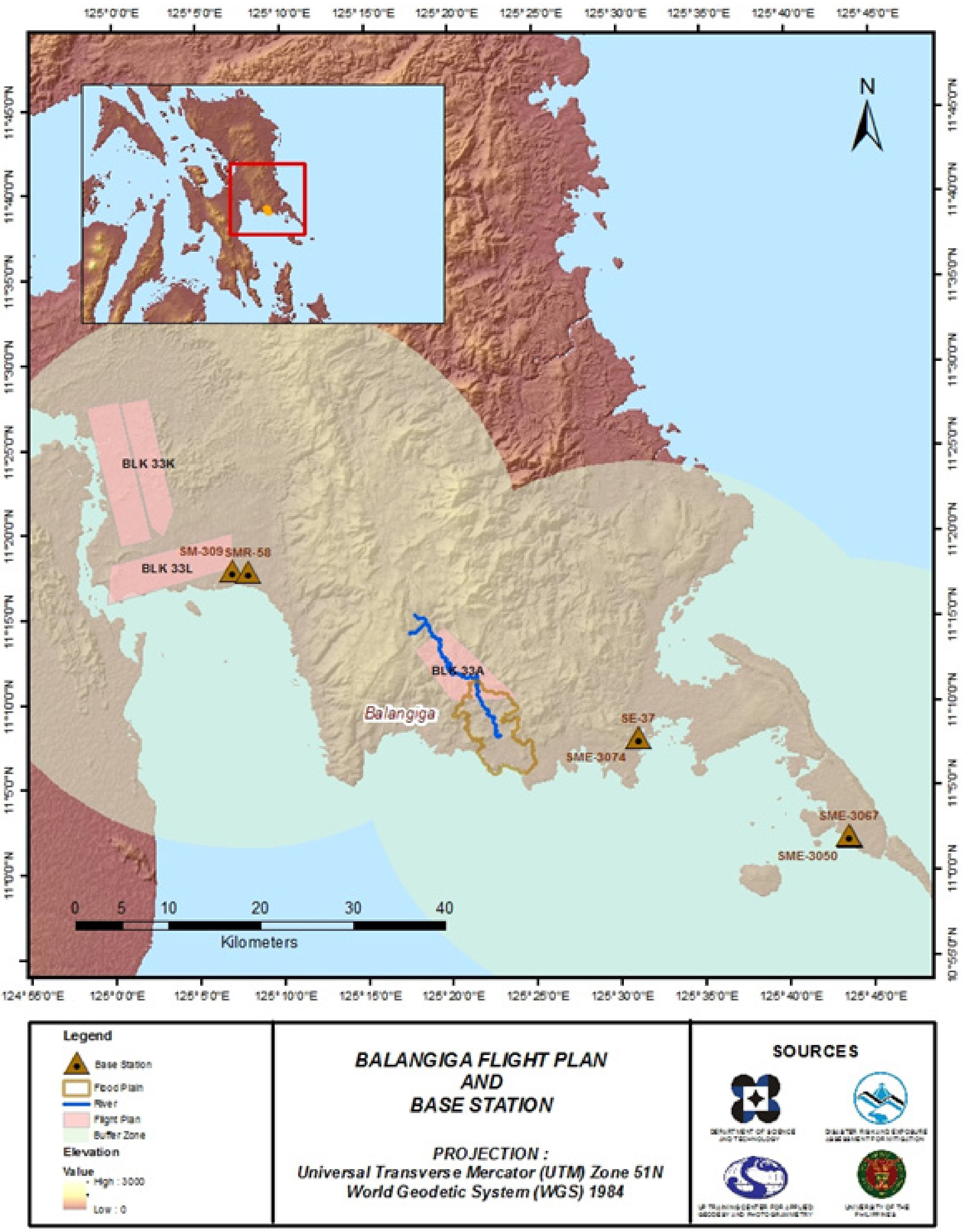

Figure 3. Flight plans and base stations used to cover the Balangiga Floodplain using the Gemini LiDAR system

2.2 Ground Base Stations

The field team for this undertaking was able to recover three (3) NAMRIA ground control points: (i.) SMR-58, which is of second (2nd) order accuracy; (ii.) SME-3050, which is of fourth (4th) order accuracy; and (iii.) SME-3067, which is also of fourth (4th) order accuracy. Two (2) NAMRIA benchmarks were also recovered: (i.) SM-309 and (ii.) SE-37; both are of first (1st) order accuracy. These benchmarks were used as vertical reference points, and were also established as ground control points. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2, while the baseline processing reports for the established control points are found in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on May 27-June 3, 2014, on January 31, 2016, and on February 5, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852, and SPS 985. The flight plans and the locations of the base stations used during the aerial LiDAR acquisition in the Balangiga floodplain are presented in Figure 2 and Figure 3. The composition of the project team is shown in Annex 4.
`

Figure 4 to Figure 9 depict the recovered NAMRIA control stations within the area. Table 3 to Table 8 provide the details on the NAMRIA control stations and established points, and Table 9 lists all ground control points occupied during the acquisition together with the dates of utilization.

(a) (b)

Figure 4. (a) GPS set-up over SMR-58 located inside Serum Elementary School, Barangay Serum, Basey, and (b) NAMRIA reference point SMR-58, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point SMR-58, used as base station for the LiDAR acquisition

Station Name	**SMR-58**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 17’ 55.05617” North 125o 7’ 51.16145” East 6.30062 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	514288.239 meters 1249361.531 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 17’ 50.78580” North 125o 7’ 56.31100” East 68.72300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	732600.57 meters 1249768.75 meters

Figure 5. (a) GPS set-up over SME-3074 near KM Post No. 988 in Quinapondan, Eastern Samar court, and (b) NAMRIA reference point SME-3074, as recovered by the field team

Table 4. Details of the reprocessed NAMRIA horizontal control point SME-3074, used as base station for the LiDAR acquisition

Station Name	**SME-3074**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 7’ 59.28388” North 125° 30’ 54.00697” East 5.502 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 7’ 55.08848” North 125° 30’ 59.16728” East 69.272 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	774,710.018 m 1,231,788.037 m

Figure 6. (a) GPS set-up over SME-3050 inside the premises of Central Elementary School, Barangay Poblacion, Guiuan, Eastern Samar, and (b) NAMRIA reference point SME-3050, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point SME-3050, used as base station for the LiDAR acquisition

Station Name	**SME-3050**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1 in 10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 2' 6.48019" 125° 43' 25.69474" -8.00900 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Latitude Longitude Ellipsoidal Height	579,092.375 m 1,220,310.599 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 2' 2.32770" North 125° 43' 30.86158" East 56.51100 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	797,631.78 m 1,221,142.79 m

Figure 7. (a) GPS set-up over SME-3067 inside the premises of Central Elementary School, Barangay Poblacion, Guiuan, Eastern Samar, and (b) NAMRIA reference point SME-3067, as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point SME-3067, used as base station for the LiDAR acquisition

Station Name	**SME-3067**	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1 in 10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 11' 16.35419" 124° 33' 36.47427" 38.29100 m
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Easting Northing	451,959.944 m 1,237,144.619 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 11' 12.06307" North 124° 33' 41.63876" East 350.938 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	670,347.64 m 1,237,125.91 m

Figure 8. (a) GPS set-up over SM-309 located at the Dalid Bridge along the national highway in Barangay San Pascual, Sta. Rita, Samar, and (b) NAMRIA reference point SM-309, as recovered by the field team

Table 7. Details of the recovered NAMRIA vertical control point SM-309, used as base station for the LiDAR acquisition with established coordinates

Station Name	**SM-309**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 17’ 59.30748” North 125o 06’ 56.29744” East 9.743 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 17’ 55.03553” North 125o 07’ 01.44700” East 72.125 meters

Figure 9. (a) GPS set-up over SE-37 along the National Highway in Barangay Santo Niño, Quinapondan, Eastern Samar, and (b) NAMRIA reference point SE-37, as recovered by the field team

Table 8. Details of the recovered NAMRIA horizontal control point SE-37, used as base station for the LiDAR acquisition

Station Name	**SE-37**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 07' 59.95" 125° 30' 54.91" 5.49 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 07' 55.05187" North 125° 30' 59.16996" East 69.239 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	774,864.486 m 1,231,736.179 m

Table 9. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 27, 2014	1506A	3BLK33U147A	SME-3050 and SME-3067
May 27, 2014	1508A	3BLK33UST147B	SME-3050 and SME-3067
May 28, 2014	1510A	3BLK33TSV148A	SME-3050 and SME-3067
May 30, 2014	1520A	3BLK33VSS150A	SME-3050 and SME-3067
May 31, 2014	1522A	3BLK33SS151A	SME-3074 and SE-37
June 1, 2014	1526A	3BLK33SSR152A	SME-3074 and SE-37
June 2, 2014	1530A	3BLK33RQ153A	SME-3074 and SE-37
June 3, 2014	1534A	3BLK33QS154A	SME-3074 and SE-37
January 31, 2016	3733G	2BLK33ABLK34L031A	SMR-58 and SM-309
February 5, 2016	3753G	2BLK34K33AB036A	SMR-58 and SM-309

2.3 Flight Missions

A total of ten (10) flight missions were conducted to complete the LiDAR data acquisition in the Balangiga floodplain, for a total of forty hours and eighty minutes (40+80) of flying time for RP-C9022. All missions were acquired using the Aquarius and Gemini LiDAR systems. Annex 6 presents the flight logs of the missions. Table 10 indicates the total area of actual coverage and the corresponding flying hours for each mission, and Table 11 shows the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for the LiDAR data acquisition in Balangiga Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 27, 2014	1506A	137.14	128.85	NA	128.85	1454	4	35
May 27, 2014	1508A	285.16	97.40	NA	97.40	121	3	59
May 28, 2014	1510A	215.89	107.00	NA	107.00	1768	4	35
May 30, 2014	1520A	207.31	139.46	NA	139.46	1476	4	5
May 31, 2014	1522A	139.44	42.13	NA	42.13	153	2	5
June 1, 2014	1526A	262.30	152.40	11.21	141.19	1633	4	41
June 2, 2014	1530A	226.60	130.16	12.94	117.22	483	4	35
June 3, 2014	1534A	103.74	89.48	15.42	74.06	787	4	17
January 31, 2016	3733G	97.04	248.73	7.98	240.75	NA	2	59
February 5, 2016	3753G	139.76	93.64	27.60	66.04	NA	4	17
TOTAL		**1814.38**	**1229.25**	**75.15**	**1154.10**	**7875**	**40**	**80**

Table 11. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1506A	600	25	44	50	45	130	5
1508A	700	30	36	50	50	130	5
1510A	500	30	50	70	40	130	5
1520A	600	30	44	50	40	130	5
1522A	600	30	44	50	45	130	5
1526A	600	30	44	50	45	130	5
1530A	600	35	44	50	45	130	5
1534A	700	30	36	50	50	130	5
3733G	850	30	40	100	50	130	5
3753G	850	30	40	100	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Balangiga floodplain located in the province of Eastern Samar, with majority of the floodplain situated within the municipality of Balangiga (See Annex 7 for the flight status report). The Municipality of Giporlos was fully covered by the survey. The list of cities and municipalities surveyed, with at least one (1) square kilometer coverage, is provided in Table 12. The actual coverage of the LiDAR acquisition for the Balangiga floodplain is presented in Figure 10.

Table 12. List of municipalities and cities surveyed during the Balangiga Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Eastern Samar	Balangiga	206.52	105.87	51.26%
	Giporlos	53.17	53.17	100%
	Guiuan	179.24	67.94	37.90%
	Lawaan	141.75	49.35	34.81%
	Mercedes	22.83	22.48	98.47%
	Quinapondan	136.47	48.86	35.80%
	Salcedo	121.35	120.22	99.07%
Samar	Basey	627.97	206.94	32.95%
	Marabut	148.82	42.16	28.33%
		250.37	31.48	12.57%
Total		1888.49	748.47	39.63%

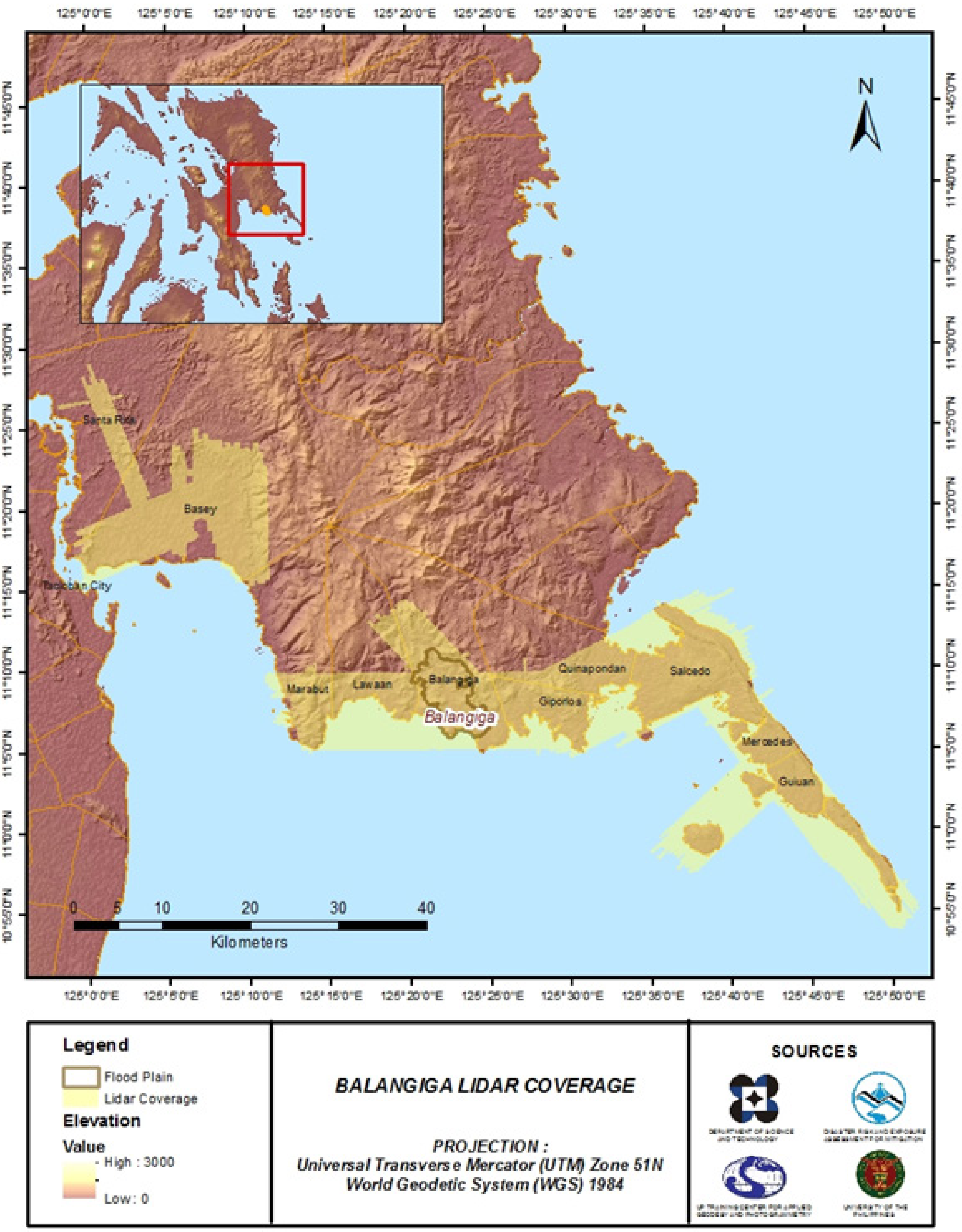

Figure 10. Actual LiDAR survey coverage of the Balangiga Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BALANGIGA FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the diagram in Figure 11.

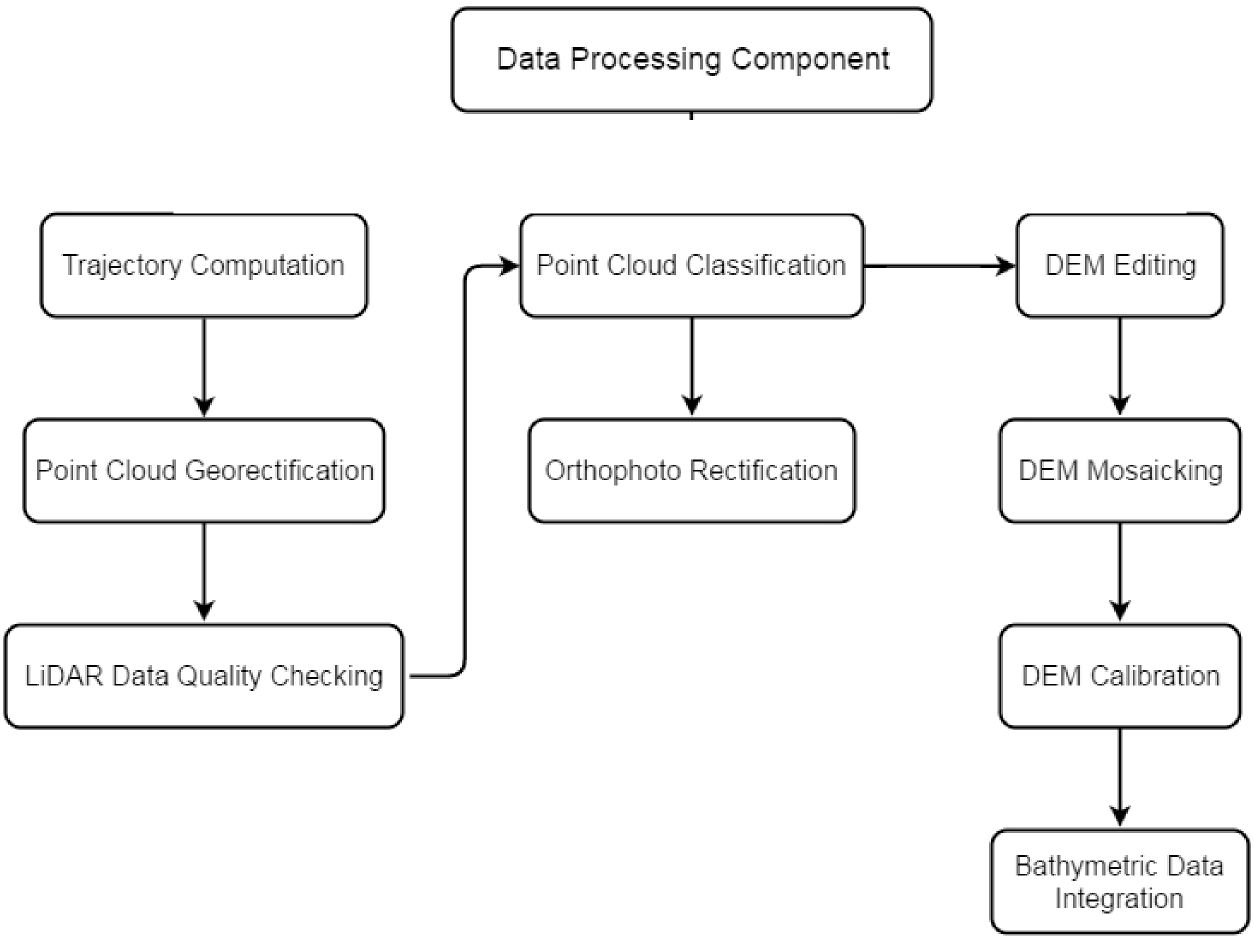


Figure 11. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for the Balangiga floodplain can be found in Annex 5. Missions flown during the first survey conducted in May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system, while missions acquired during the second survey in January 2016 were flown using the Gemini system over Balangiga, Eastern Samar. The DAC transferred a total of 136.47 Gigabytes of Range data, 2.358 Gigabytes of POS data, 82.66 Megabytes of GPS base station data, and 524.38 Gigabytes of raw image data to the data server on June 19, 2014 for the first survey, and on February 26, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Balangiga was fully transferred on February 26, 2016, as indicated on the data transfer sheets for the Balangiga floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1508A, one of the Balangiga flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on May 27, 2014 at 00:00 hrs. on that week. The y-axis is the RMSE value for that particular position.

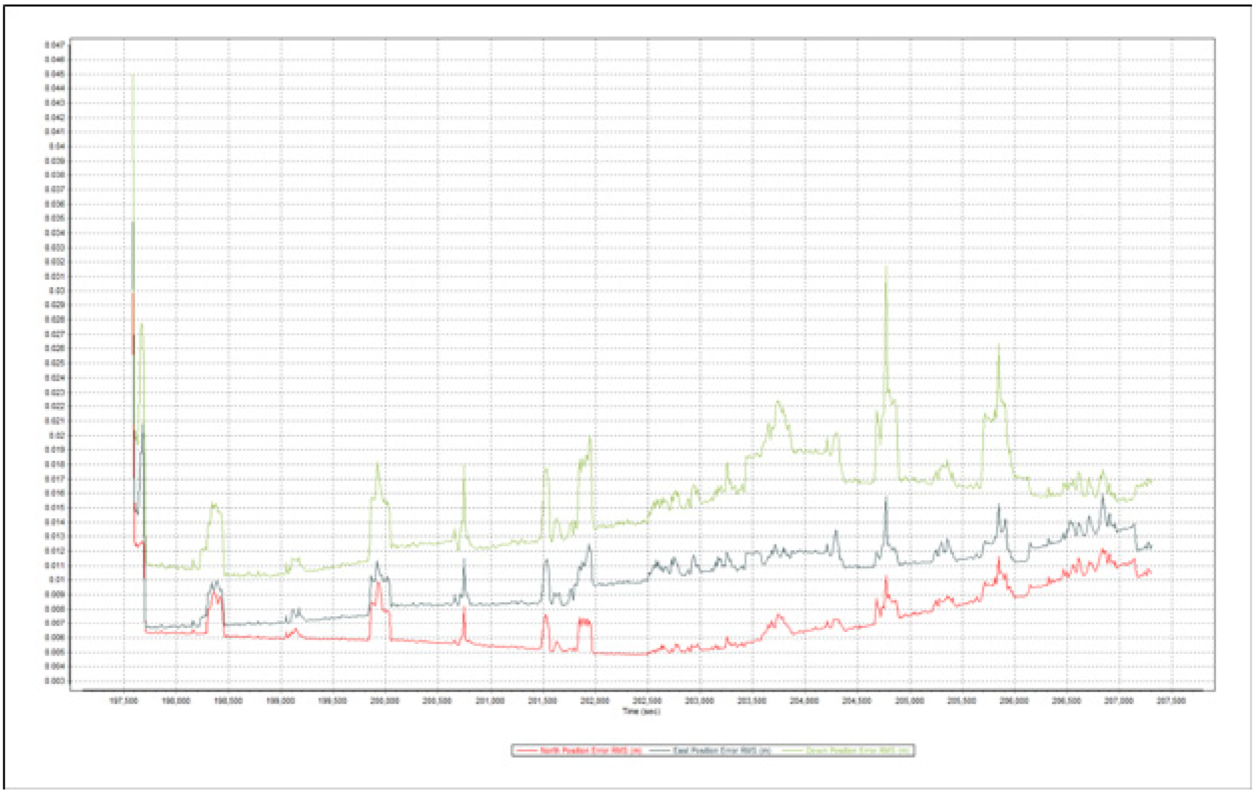


Figure 12. Smoothed Performance Metrics of Balangiga Flight 1508A

The time of flight was from 197500 seconds to 207500 seconds, which corresponds to afternoon of May 27, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaked at 1.22 centimeters, the East position RMSE peaked at 1.60 centimeters, and the Down position RMSE peaked at 3.18 centimeters, which are within the prescribed accuracies described in the methodology.

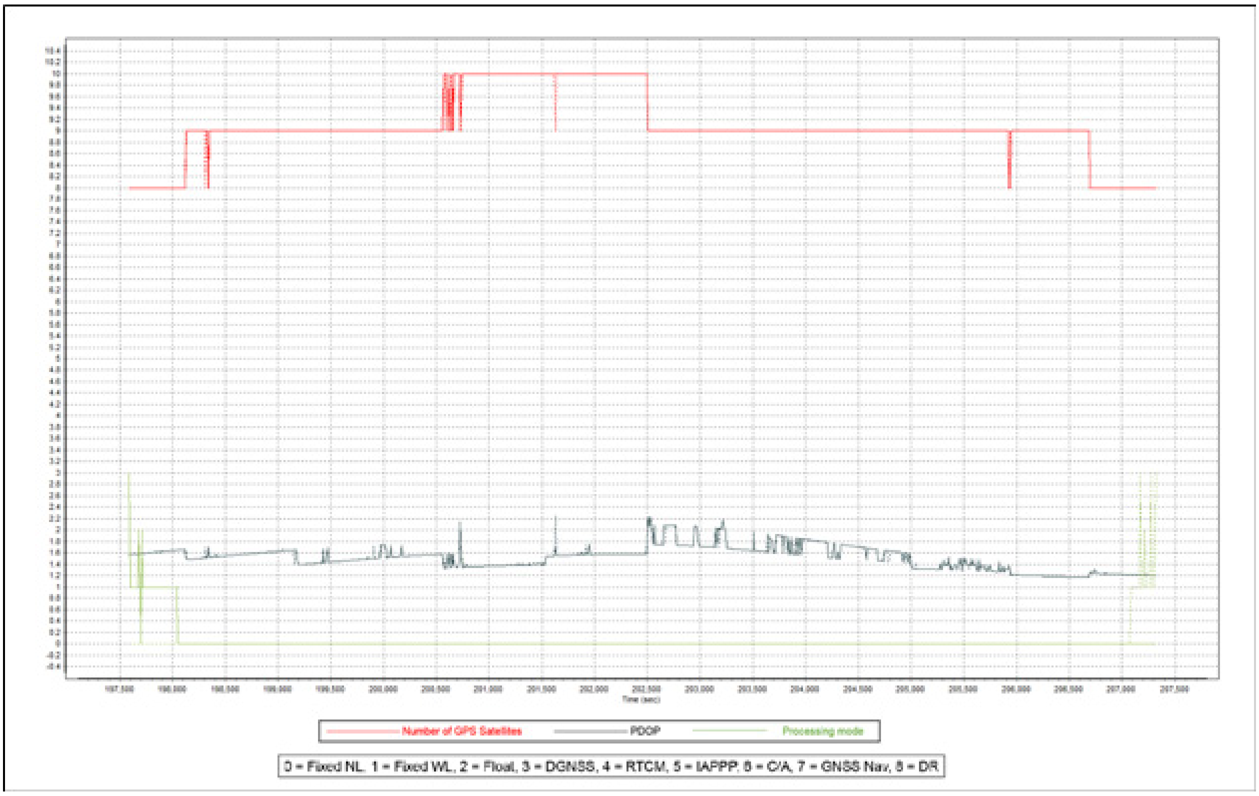


Figure 13. Solution Status Parameters of Balangiga Flight 1508A

The Solution Status parameters of flight 1508A, one of the Balangiga flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are exhibited in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to eight (8). Most of the time, the number of satellites tracked was between eight (8) and ten (10). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remained at zero (0) for majority of the survey. The value of zero (0) corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Balangiga flights is depicted in Figure 14.

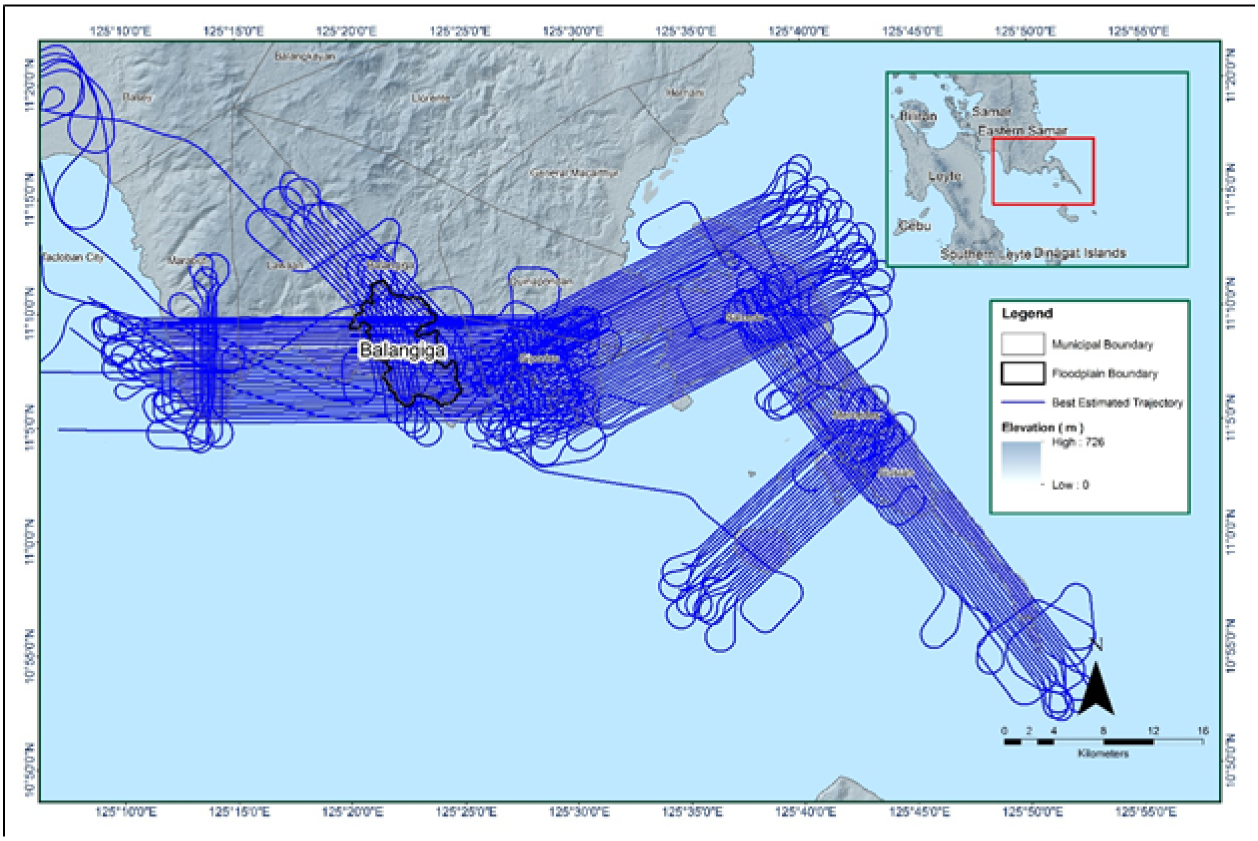


Figure 14. The best estimated trajectory conducted over the Balangiga floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains one hundred and sixty-three (163) flight lines, with each flight line containing one (1) channel, since the Gemini and Aquarius systems both contain only one (1) channel. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Balangiga floodplain is given in Table 13.

Table 13. Self-calibration results values for the Balangiga flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000589
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000983
GPS Position Z-correction stdev)	<0.01meters	0.0098

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data are represented in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

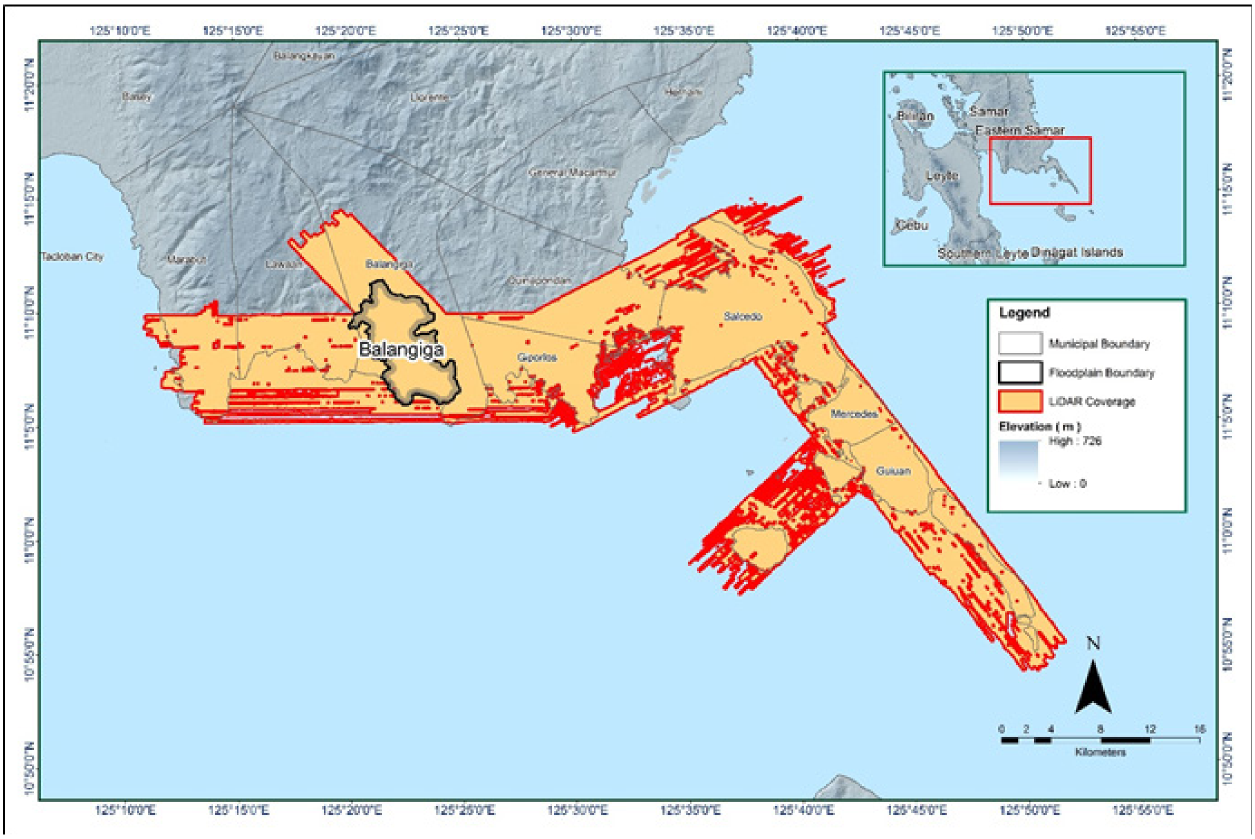


Figure 15. Boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Balangiga Floodplain.

The total area covered by the Balangiga missions is 782.07 sq. km., comprised of ten (10) flight acquisitions grouped and merged into nine (9) blocks, as indicated in Table 14.

Table 14. List of LiDAR blocks for the Balangiga Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk33Q	1530A	127.44
	1534A	
Samar_Leyte_Blk33R	1526A	114.66
	1530A	
Samar_Leyte_Blk33S	1520A	82.68
	1522A	
	1526A	
Samar_Leyte_Blk33S_ supplement	1520A	56.23
Samar_Leyte_Blk33T	1508A	101.19
	1510A	
Samar_Leyte_Blk33U	1506A	175.34
	1508A	
Samar_Leyte_Blk33V	1510A	46.78
	1520A	
Leyte_Blk33A	3733G	54.57
	3753G	
Leyte_Blk33A_supplement	3753G	23.18
TOTAL		**980.39**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 16. Since the Gemini and Aquarius systems both employ only one (1) channel, it is expected to have an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three (3) or more overlapping flight lines.

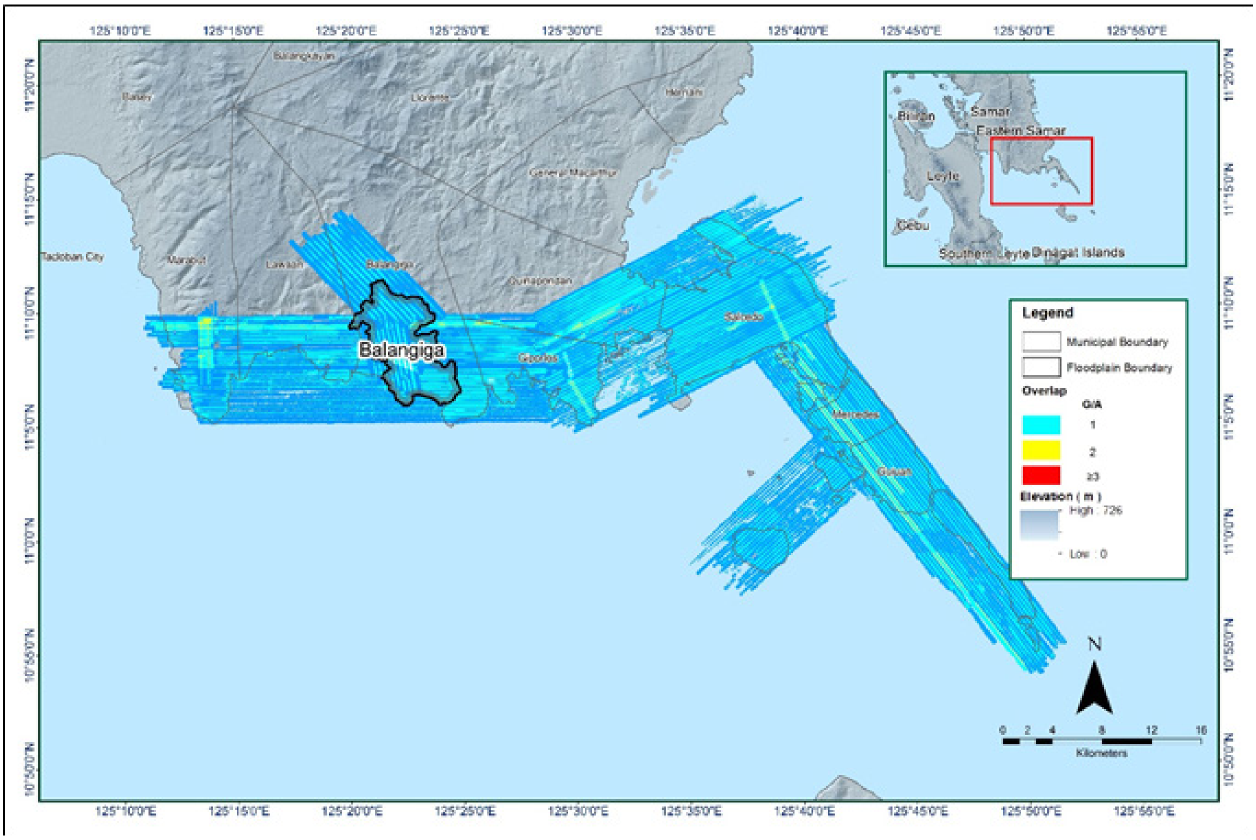


Figure 16. Image of data overlap for Balangiga Floodplain

The overlap statistics per block for the Balangiga floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 19.23% and 44.05%, respectively.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is illustrated in Figure 17. It was determined that all LiDAR data for the Balangiga floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.34 points per square meter.

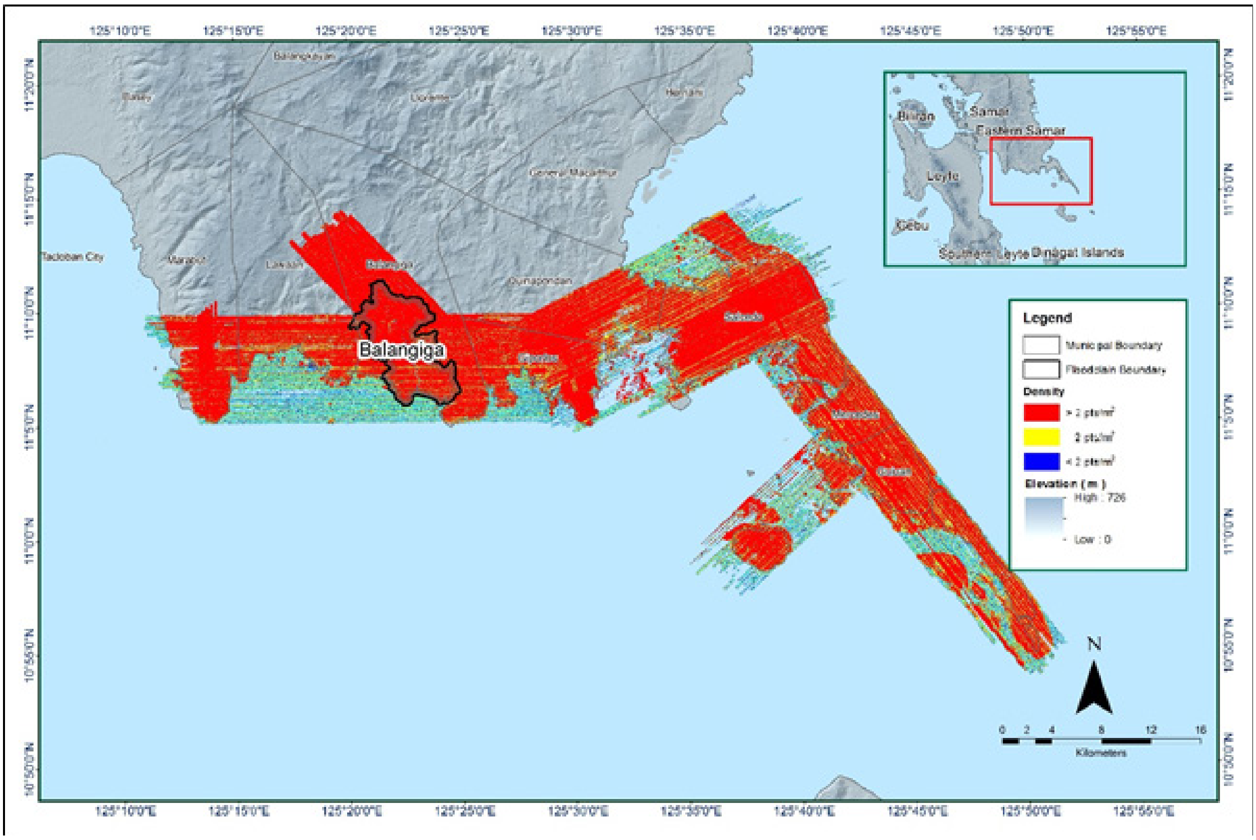


Figure 17. Pulse density map of merged LiDAR data for the Balangiga Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to the 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 were investigated further using the Quick Terrain (QT) Modeler software.

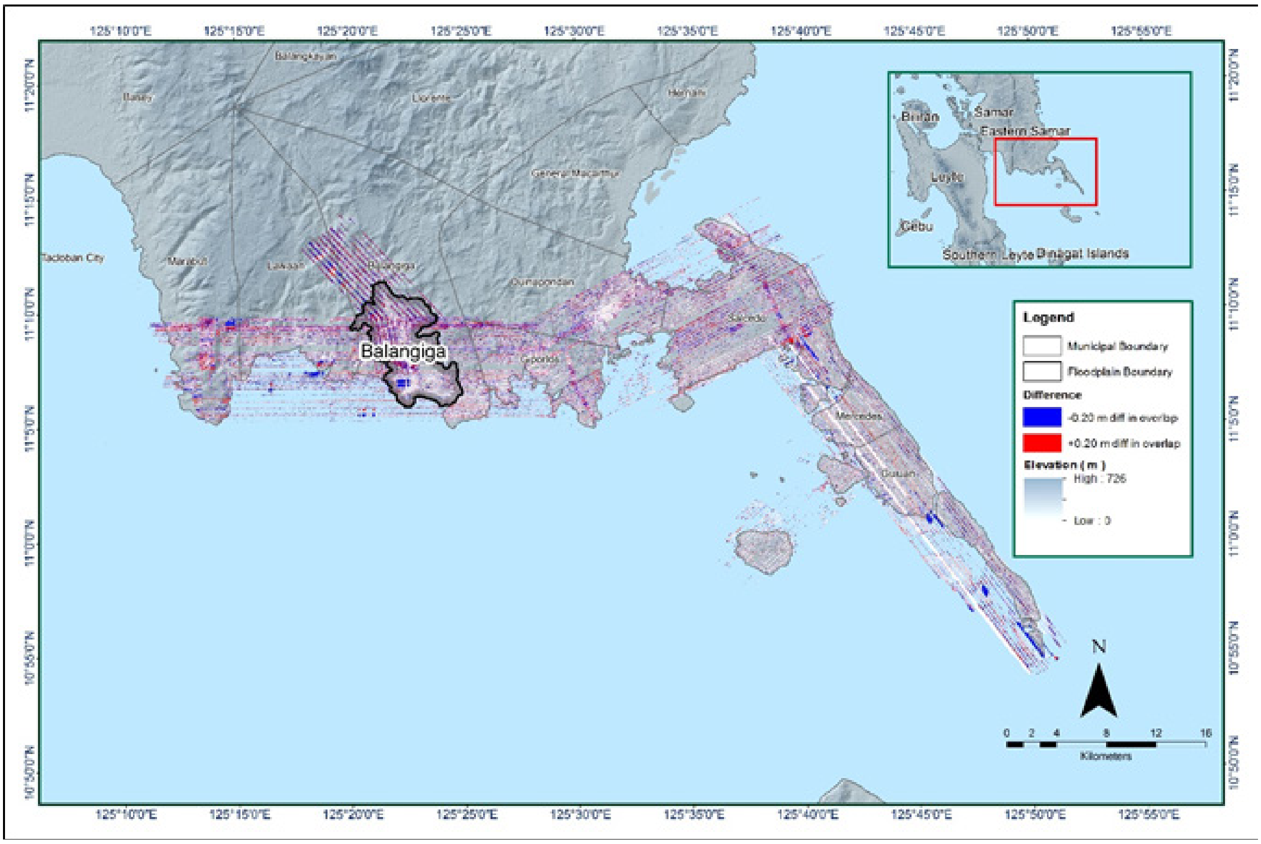


Figure 18. Elevation difference map between flight lines for the Balangiga Floodplain

A screen capture of the processed LAS data from Balangiga flight 1508A loaded in the QT Modeler is exhibited in Figure 19. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed green line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

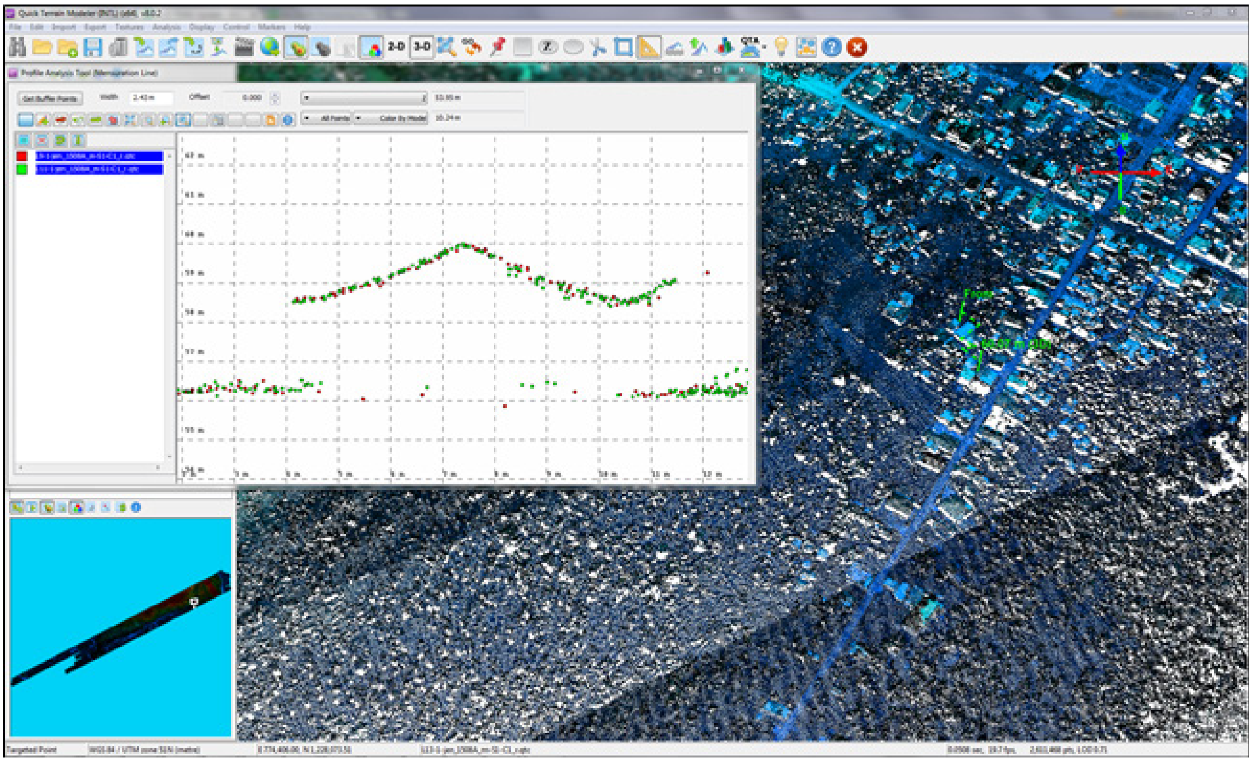


Figure 19. Quality checking for Balangiga flight 1508A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Summary of point cloud classification results in TerraScan for Balangiga River Floodplain.

Pertinent Class	Total Number of Points
Ground	415,219,505
Low Vegetation	356,235,224
Medium Vegetation	948,141,242
High Vegetation	459,571,915
Building	10,097,405

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Balangiga floodplain, are presented in Figure 20. A total of 1,275 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 15. The point cloud had a maximum and minimum height of 462.96 meters and 27.73 meters, respectively.

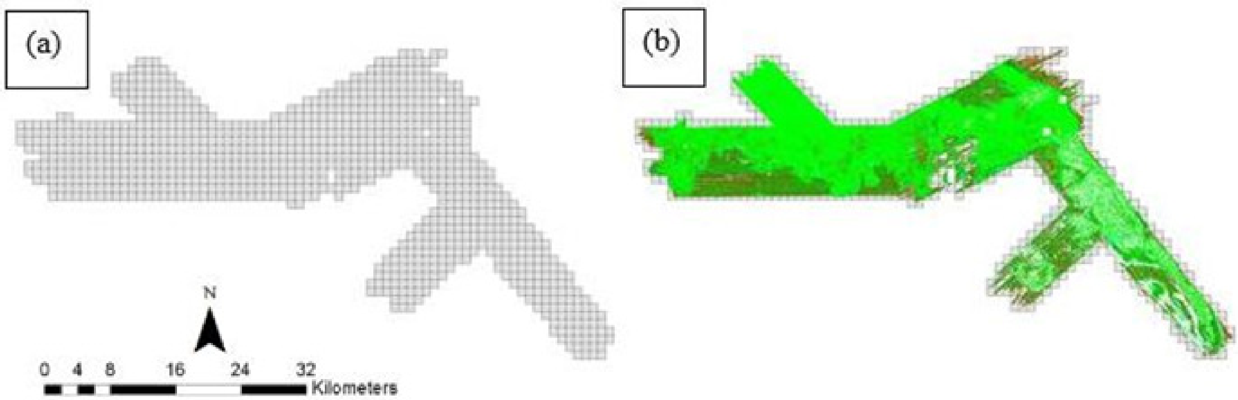


Figure 20. The coverage of the Balangiga Floodplain Survey (a) the tile system (b) depicts the classification results in TerraScan.

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

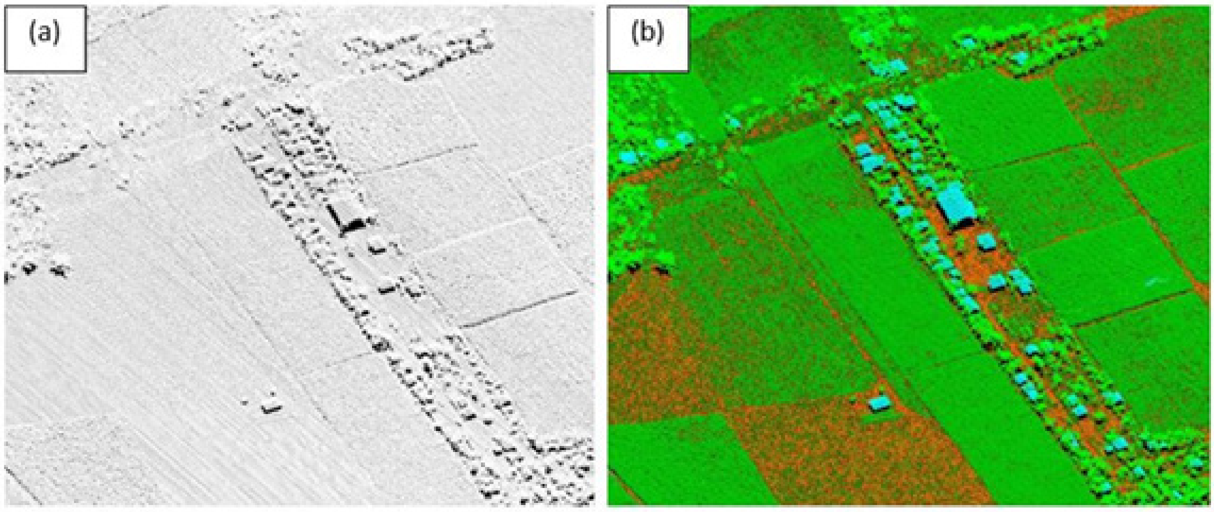


Figure 21. Point cloud (a) before and (b) after classification

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

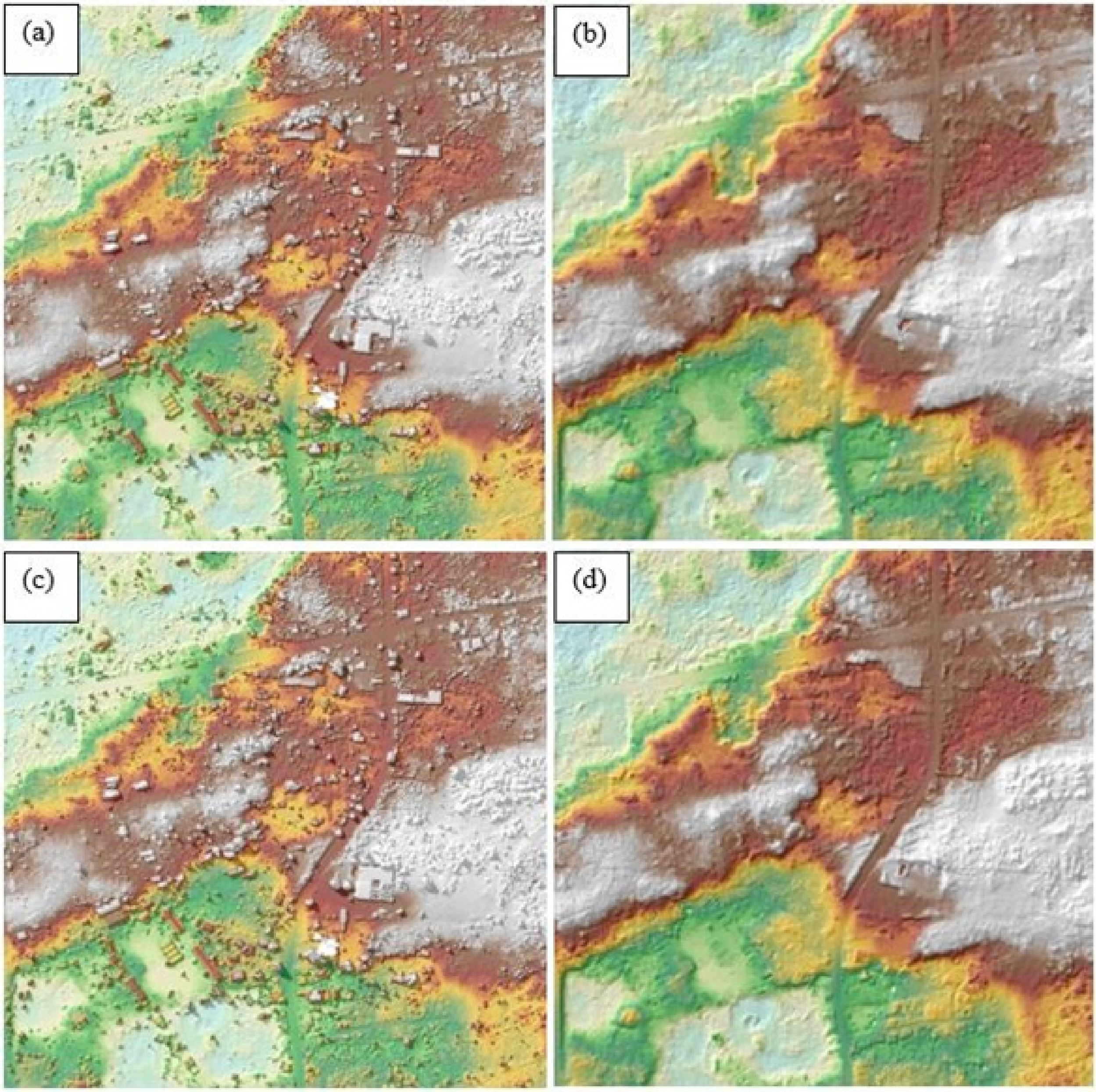


Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of the Balangiga Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,152 1km by 1km tiles area covered by the Balangiga floodplain is presented in Figure 23. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Balangiga floodplain survey attained a total of 685.95 sq. km. in orthophotographic coverage, comprised of 9,566 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 24.

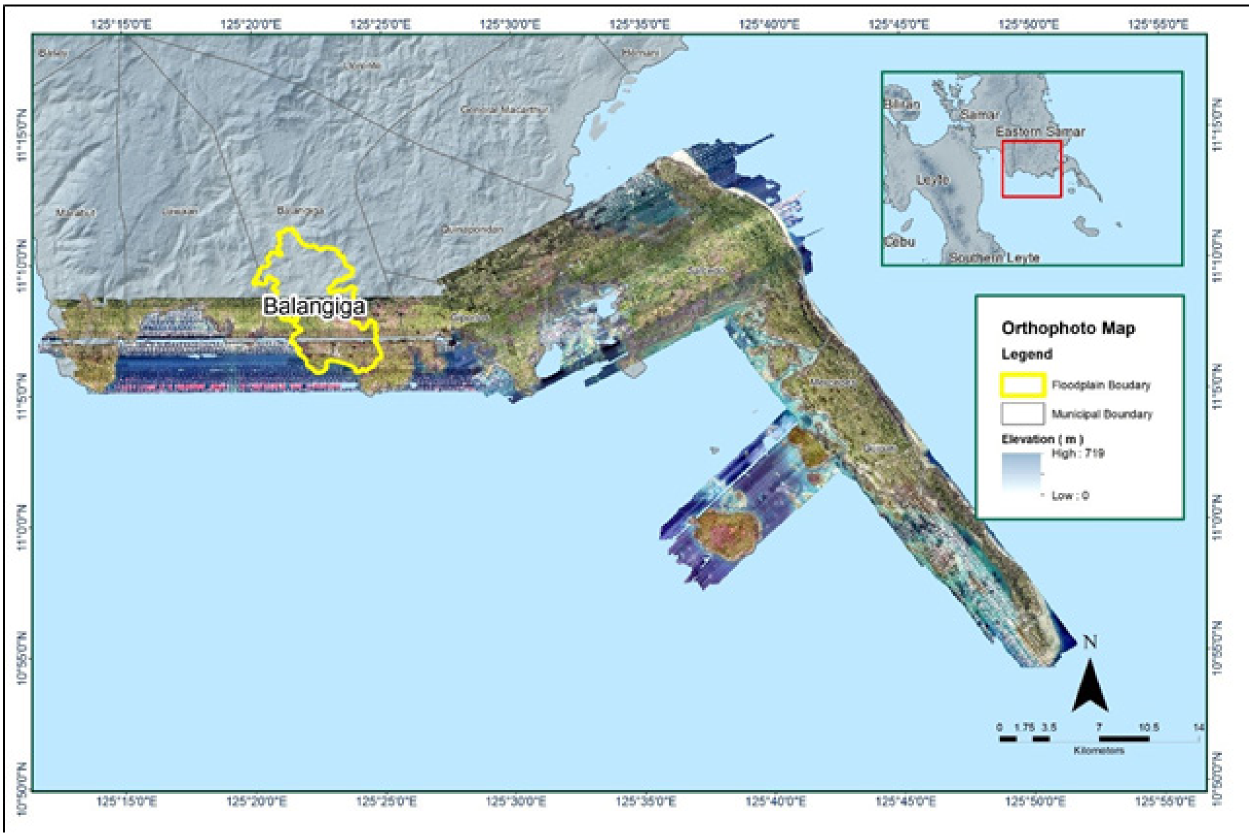


Figure 23. Balangiga Floodplain with available orthophotographs

Figure 24. Sample orthophotograph tiles for the Balangiga Floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for the Balangiga floodplain. These blocks are composed of SamarLeyte and Leyte blocks, with a total area of 755.88 square kilometers. Table 16 indicates the name and corresponding area of each block, in square kilometers.

Table 16. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
SamarLeyte_Blk33Q	127.44
SamarLeyte_Blk33R	114.66
SamarLeyte_Blk33S	82.68
SamarLeyte_Blk33S_supplement	56.23
SamarLeyte_Blk33T	101.19
Leyte_Blk33A	54.57
Leyte_Blk33A_supplement	23.18
SamarLeyte_Blk33V	149.15
SamarLeyte_Blk33U	46.78
TOTAL	755.88 sq. km

Portions of the DTM before and after manual editing are shown in Figure 25. The river embankment (Figure 25a) had been misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 25b) to allow for the correct flow of water. The bridge (Figure 25c) was considered to be an impedance to the flow of water along the river, and had to be removed (Figure 25d) in order to hydrologically correct the river. Areas with no data that are on flat terrains, like paddy fields (Figure 25e), had to be filled through manual editing (Figure 25f).

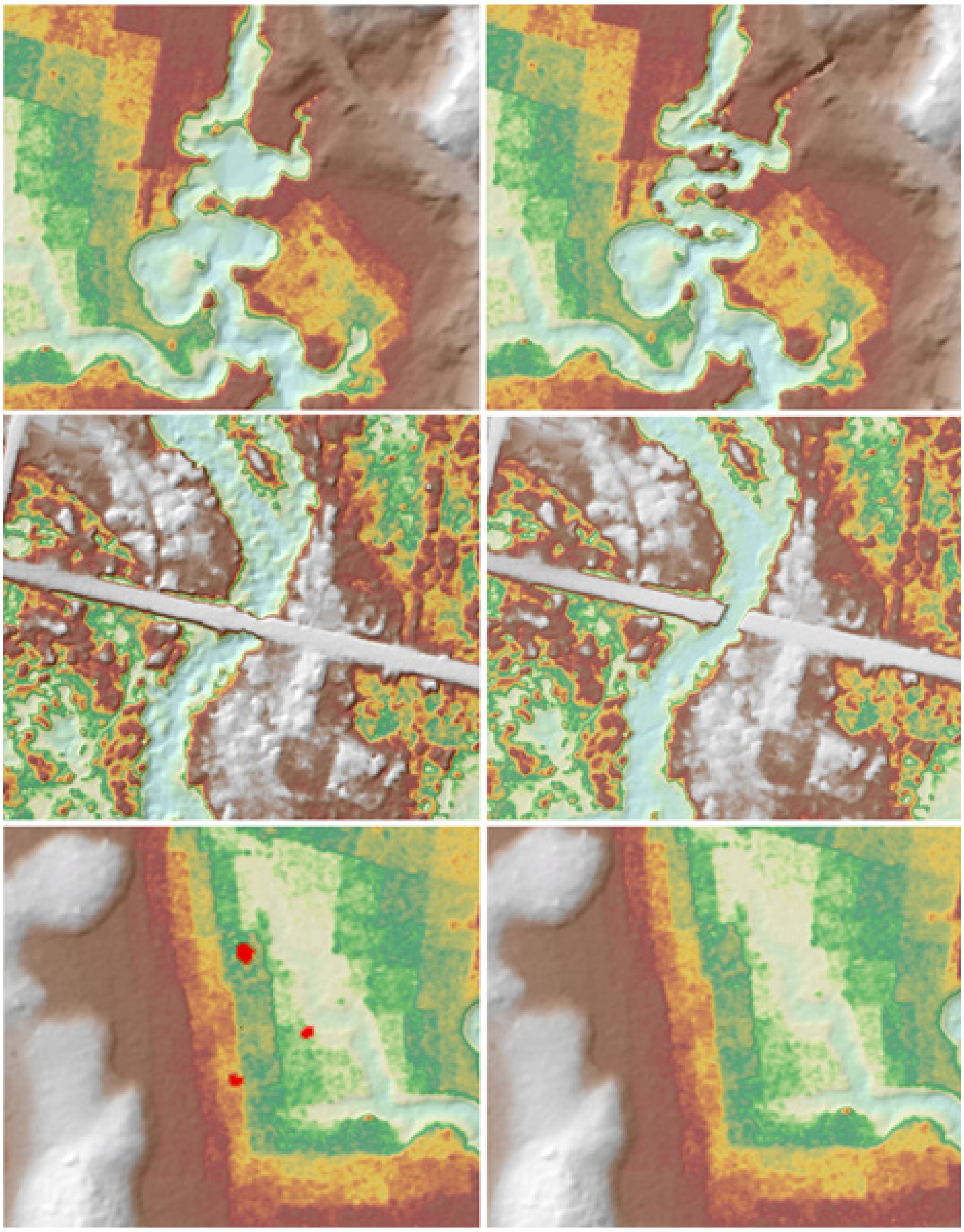


Figure 25. Portions in the DTM of Balangiga Floodplain – a river embankment (a) before and (b) after data retrieval; a bridge (c) before and (d) after manual editing; and data gaps in a paddy field (e) before and (f) after manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Tacloban DEM, overlapping with the blocks to be mosaicked for this floodplain. Table 17 outlines the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for the Balangiga floodplain is illustrated in Figure 26. It is visible that the entire Balangiga floodplain is 99% covered by LiDAR data.

Table 17. Shift values of each LiDAR block of the Balangiga Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
SamarLeyte_Blk33Q	-2.00	4.00	-4.20
SamarLeyte_Blk33R	-2.00	5.00	-4.20
SamarLeyte_Blk33S	-2.00	4.00	-4.20
SamarLeyte_Blk33S_supplement	17.00	-187.00	6.69
SamarLeyte_Blk33T	17.00	-187.00	6.66
Leyte_Blk33A	-2.00	4.00	-4.55
Leyte_Blk33A_supplement	-2.00	4.00	-4.54
SamarLeyte_Blk33U	17.00	-188	6.89
SamarLeyte_Blk33V	16.00	-188	6.83

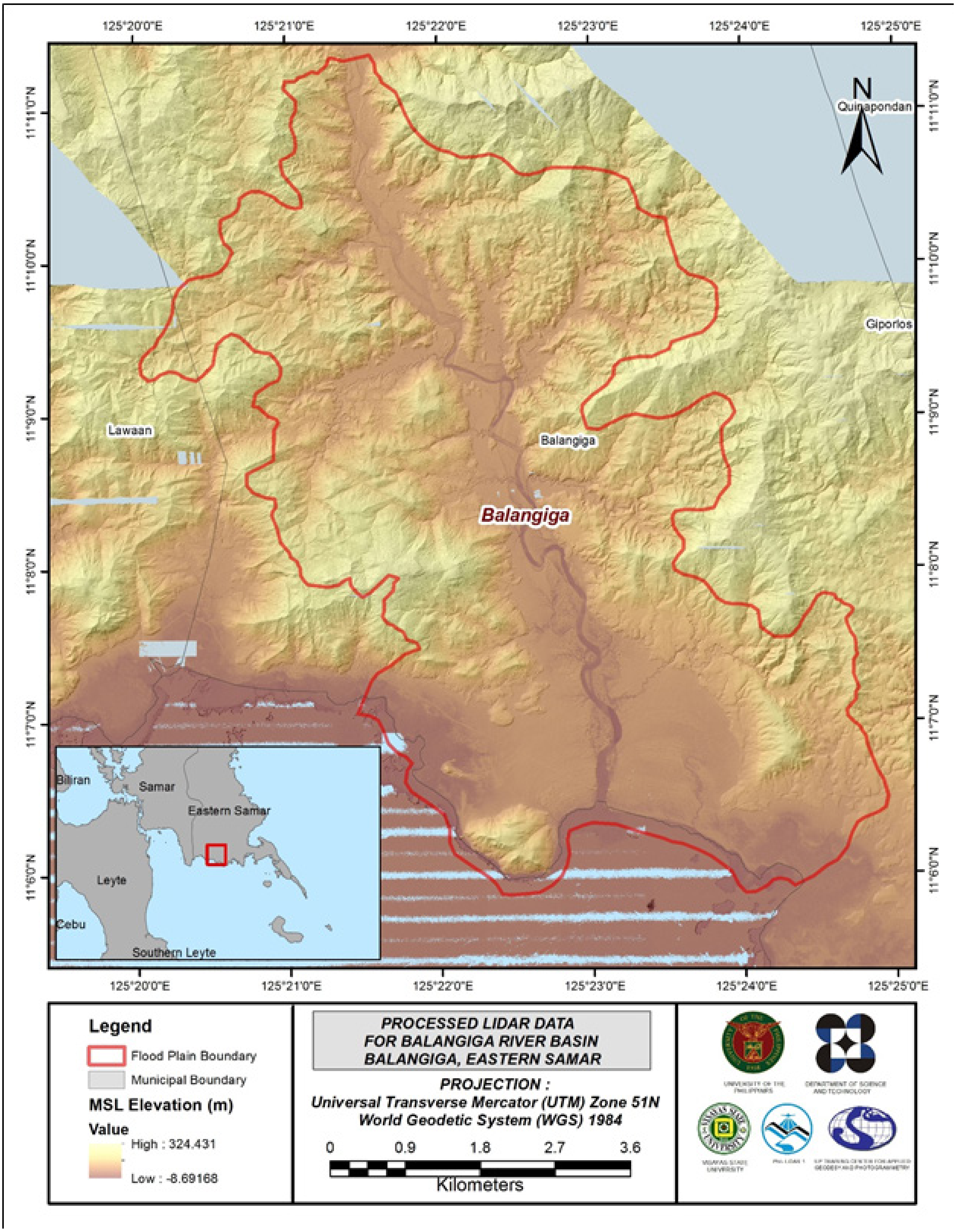


Figure 26. Map of processed LiDAR data for the Balangiga Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Balangiga floodplain. The extent of the validation survey done in Samar to collect points with which the LiDAR dataset was validated is illustrated in Figure 27, with the validation survey points highlighted in green. A total of 28,096 survey points were gathered for all the floodplains within Eastern and Western Samar, wherein the Balangiga floodplain is situated. However, the point dataset was not used for the calibration of the LiDAR data for Balangiga because during the mosaicking process, each LiDAR block referred to the already-calibrated Tacloban DEM. Therefore, the mosaicked DEM of Balangiga can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and the ground survey elevation values is reflected in Figure 28. Statistical values were computed from extracted LiDAR values using the selected points, to assess the quality of the data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration points is 0.14 meters, with a standard deviation of 0.13 meters. Calibration of the Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, from the Tacloban mosaicked LiDAR data. Table 18 summarizes the statistical values of the compared elevation values between the Tacloban LiDAR data and the calibration data. These values are also applicable to the Balangiga DEM.

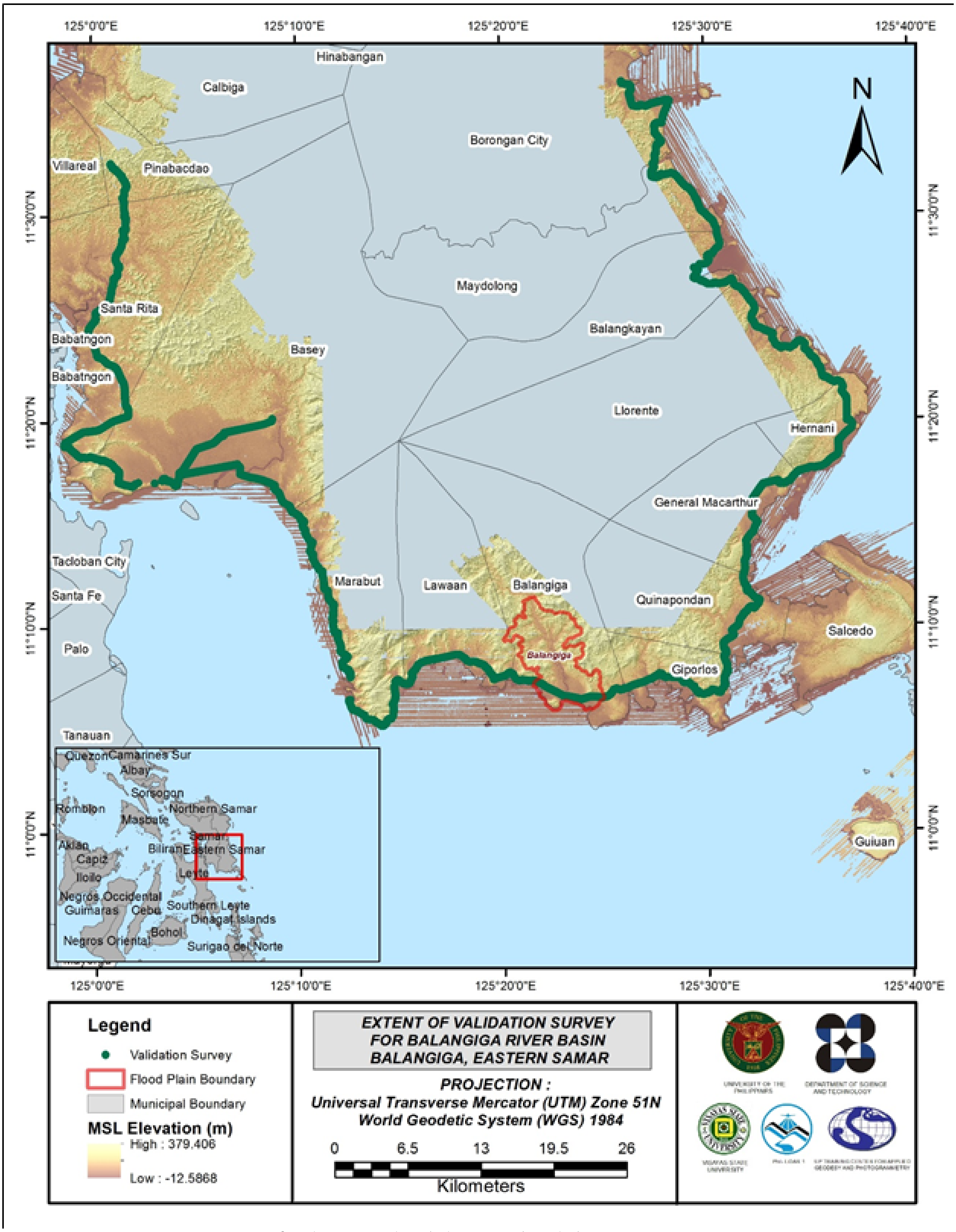


Figure 27. Map of Balangiga Floodplain, with validation survey points in green

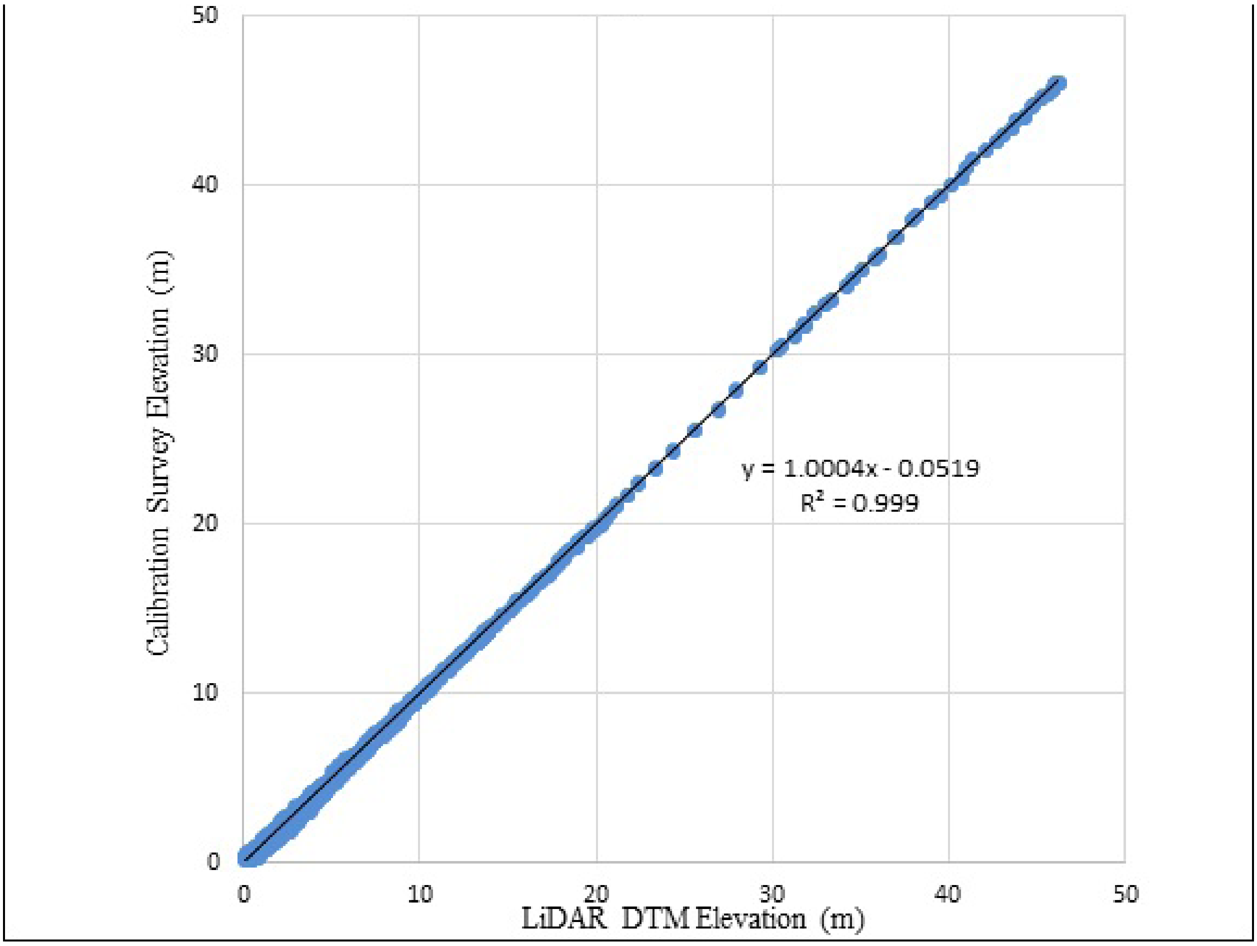


Figure 28. Correlation plot between the calibration survey points and the LiDAR data

Table 18. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.65
Maximum	0.50

A total of 945 survey points lie within the Balangiga floodplain and were used for the validation of the calibrated Balangiga DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is demonstrated in Figure 29. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.12 meters, with a standard deviation of 0.07 meters, as given in Table 19.

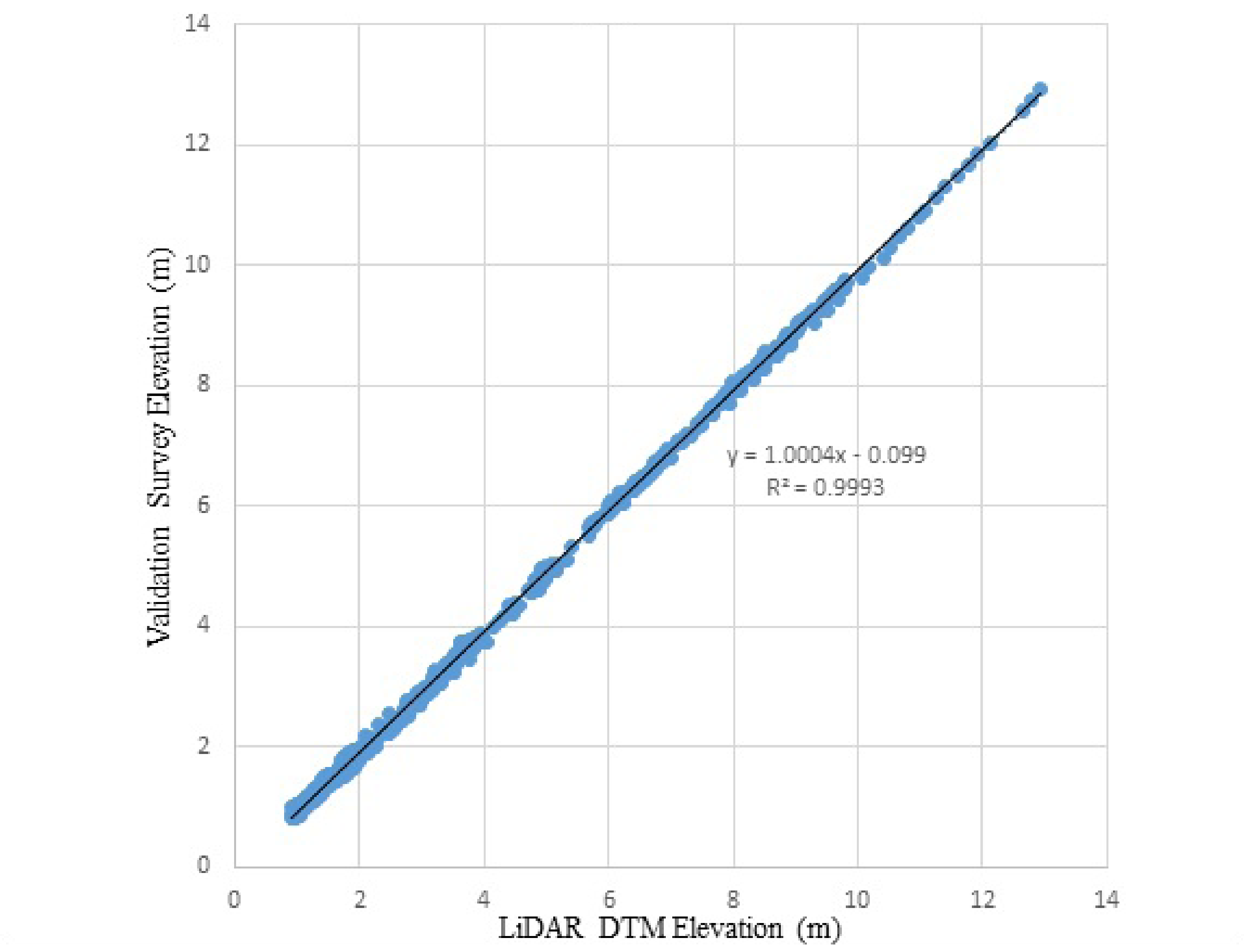


Figure 29. Correlation plot between the validation survey points and the LiDAR data

Table 19. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.07
Average	-0.10
Minimum	-0.29
Maximum	0.10

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for the Balangiga floodplain, with 570 bathymetric survey points. The resulting raster surface produced was done by applying the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.026 meters. The extent of the bathymetric survey done by the DVBC in Balangiga, integrated with the processed LiDAR DEM, is presented in Figure 30.

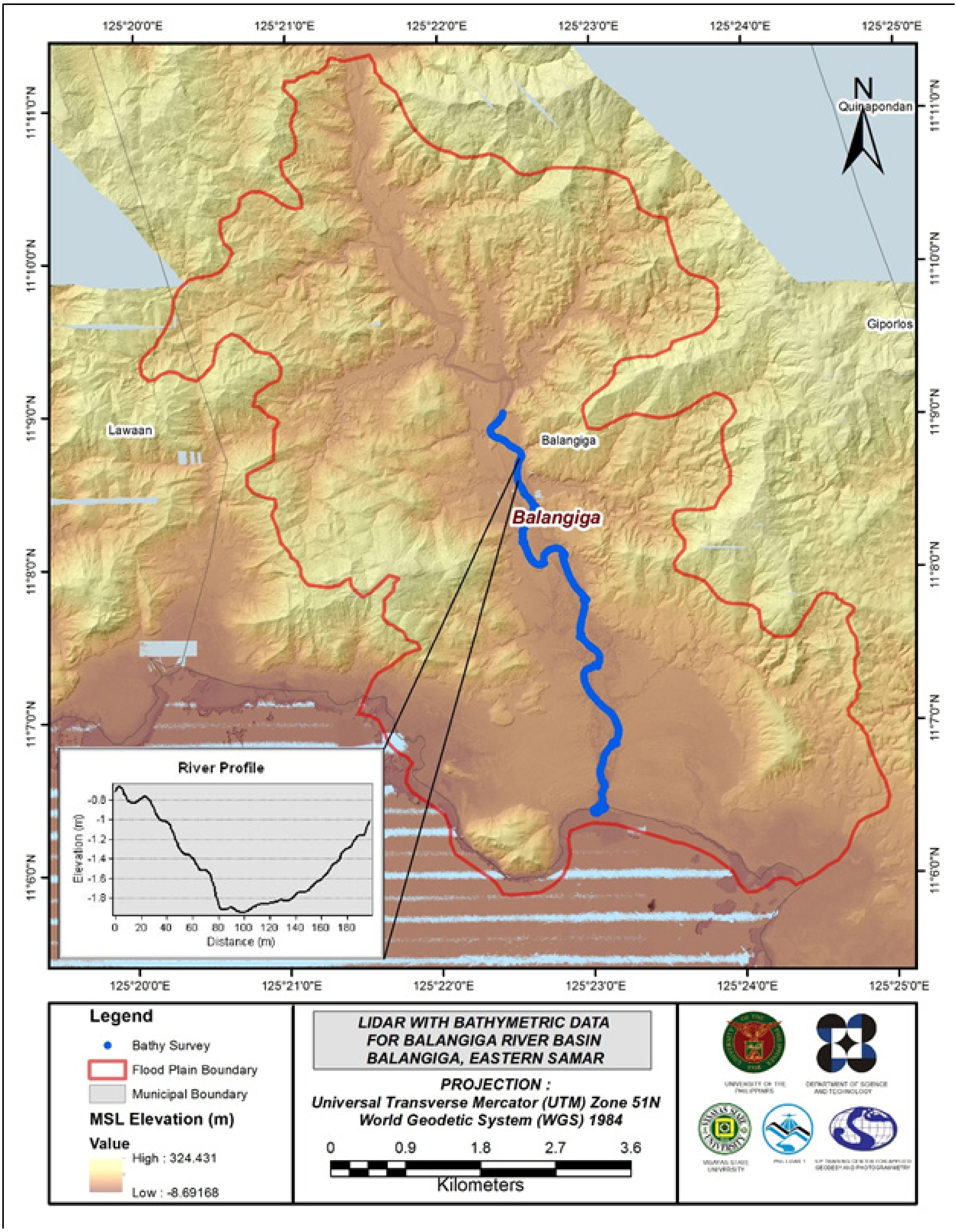


Figure 30. Map of the Balangiga Floodplain, with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Balangiga floodplain, including its 200-meter buffer zone, has a total area of 54.45 sq. km. Of this area, a total of 5.0 sq. km, corresponding to a total of 2,961 building features, were considered for quality checking (QC). Figure 31 illustrates the QC blocks for the Balangiga floodplain.

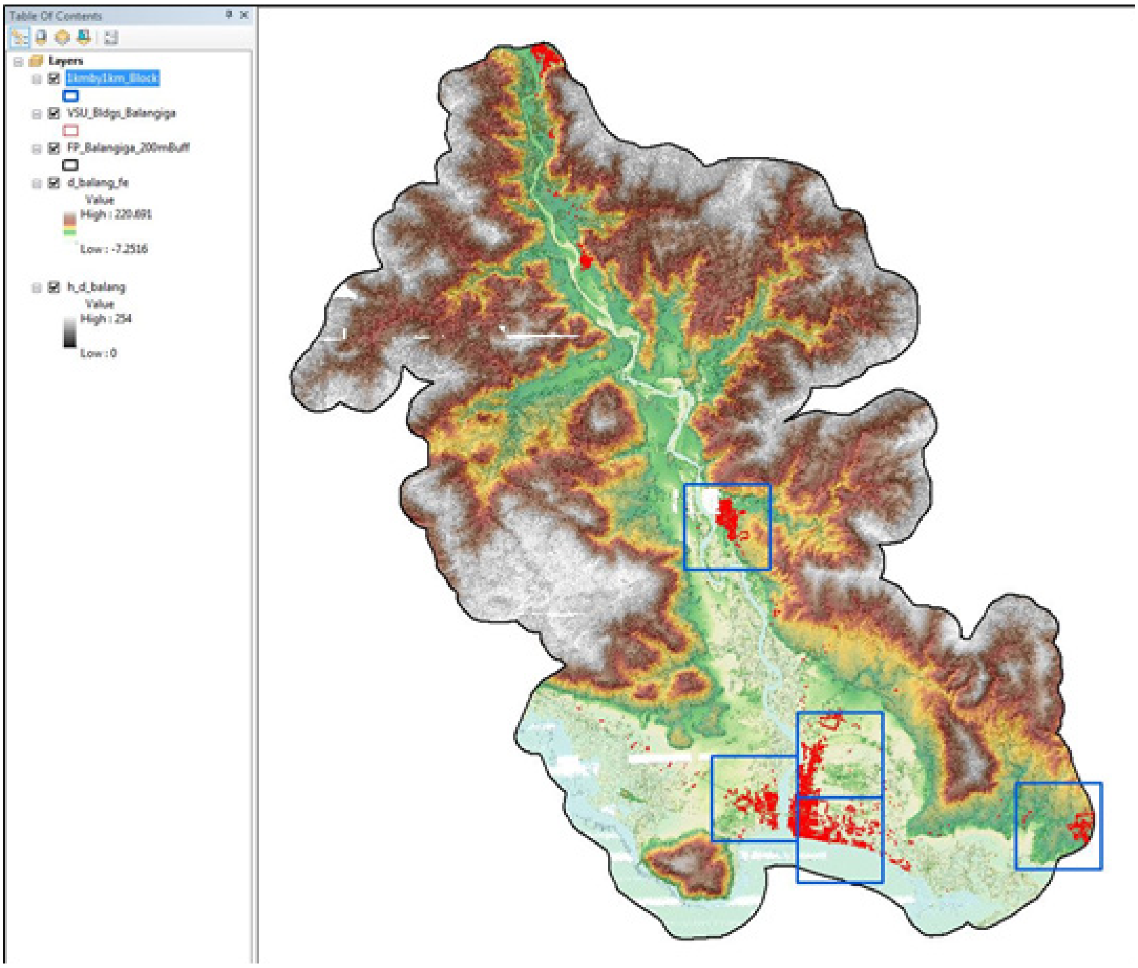


Figure 31. Blocks (in blue) of Balangiga building features that were subjected to QC

Quality checking of the Balangiga building features resulted in the ratings outlined in Table 20.

Table 20. Quality checking ratings for the Balangiga building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Balangiga	99.61	100.00	98.56	PASSED

3.12.2 Height Extraction

Height extraction was done for 3,696 building features in the Balangiga floodplain. Of these building features, 116 were filtered out after height extraction, resulting in 3,580 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 5.53 meters.

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; and then all other buildings were coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of the LiDAR acquisition were noted as new buildings in the attribute table.

Table 21 summarizes the number of building features per type. Table 22 lists the total length of each road type, and Table 23 lists the number of water features extracted per type.

Table 21. Building features extracted for the Balangiga Floodplain

Facility Type	No. of Features
Residential	3,360
School	85
Market	2
Agricultural/Agro-Industrial Facilities	7
Medical Institutions	13
Barangay Hall	10
Military Institution	3
Sports Center/Gymnasium/Covered Court	3
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	19
Water Supply/Sewerage	0
Religious Institutions	18
Bank	1
Factory	0
Gas Station	0
Fire Station	1
Other Government Offices	7
Other Commercial Establishments	51
Total	3,580

Table 22. Total length of extracted roads for the Balangiga Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Balangiga	32.39	0.96	0.00	7.52	0.00	40.87

Table 23. Number of extracted water bodies for the Balangiga Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Balangiga	27	0	0	0	0	27

A total of eighteen (18) 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 32 represents the Digital Surface Model (DSM) of the Balangiga floodplain, overlaid with its ground features.

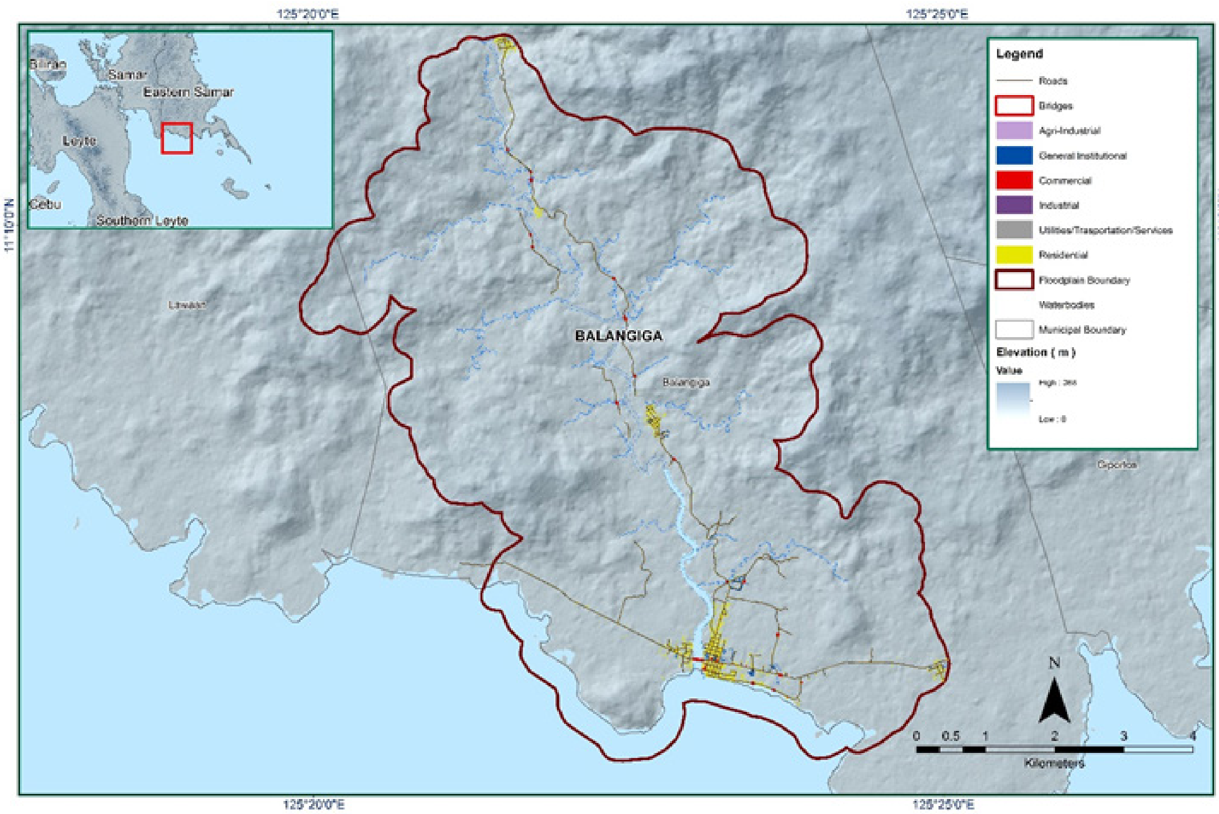


Figure 32. Extracted features for the Balangiga Floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto, Cybil Claire Atacador, and 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 DVBC conducted surveys in the Silaga, Basey, Balangiga, and Llorente Rivers on September 10-24, 2014, and on December 4-18, 2014. The scope of work for the first phase of the survey, covering the said rivers in Samar, were: (i.) initial reconnaissance; (ii.) establishment of a control points; and (iii.) cross-section and bridge as-built surveys and water level marking in MSL. The bathymetric survey was performed and completed during the second phase of the survey. The Balangiga River bathymetric survey started at the upstream in Barangay Santa Rosa, down to Barangay Poblacion V, with an estimated length of 6.70 km. Figure 33 illustrates the extent of the Balangiga River bathymetric survey.

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

4.2 Control Survey

The GNSS network used for the Balangiga River Basin is composed of three (3) loops and a baseline established on September 12, 12, 17, and 19 in 2014, occupying the following reference points: (i.) SME-18, a second-order GCP in Barangay Canciledes, Municipality of Hernani; and (ii.) SE-85, a first-order BM in Barangay 11 Poblacion, Municipality of Llorente. Both reference points are located in the province of Eastern Samar.

Two (2) control points were established along the approach of bridges namely: (i.) UP-CNG, located at the Can-Obing Bridge in Barangay Can-Abong, Borongan City, Eastern Samar; and (ii.) UP-BAL, located at the Balangiga Bridge in Barangay Poblacion V, Municipality of Balangiga, Eastern Samar. NAMRIA-established control points were also used as markers during the survey, namely: (i.) SME-12 in Barangay San Miguel, Municipality of Balangiga, Eastern Samar; (ii.) SE-49 in Barangay Aguinaldo, Municipality of General Macarthur, Eastern Samar; (iii.) SMR-3322 in Barangay Binongtu-an, Municipality of Basey, Samar; and (iv.) SM-335 in Pinalanga, Municipality of Marabut, Samar;.

The summary of reference and control points and their corresponding locations is provided in Table 24, while the GNSS network established is illustrated in Figure 34.

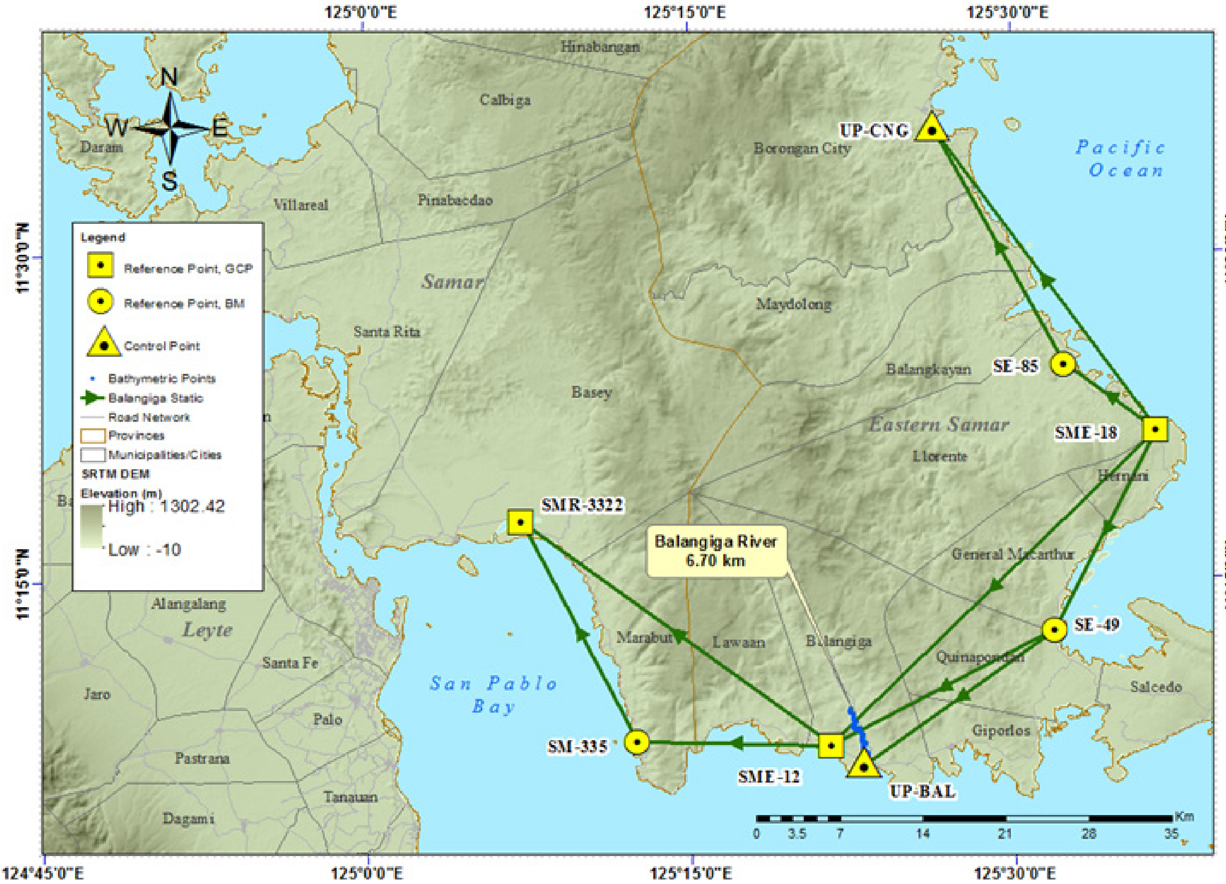


Figure 34. GNSS network of the Balangiga River field survey

Table 24. List of references and control points used in the Balangiga River survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
SME-18	2nd Order GCP	11°21'43.08127"	125°36'37.41862"	78.217	-	Sep 12, 2014
SE-85	1st Order BM	-	-	67.52	6.31	Sep 12, 2014
SME-12	Used as Marker	-	-	-	-	Sep 13, 2014
SMR-3322	Used as Marker	-	-	-	-	Sep 17, 016
SE-49	Used as Marker	-	-	-	-	Sep 13, 2014
SM-33S	Used as Marker	-	-	-	-	Sep 17, 2014
UP-						
CNG	UP Established	-	-	-	-	Sep 12, 2014

The GNSS set-ups on the recovered reference points and established control points in the Balangiga River are depicted in Figure 35 to Figure 42.

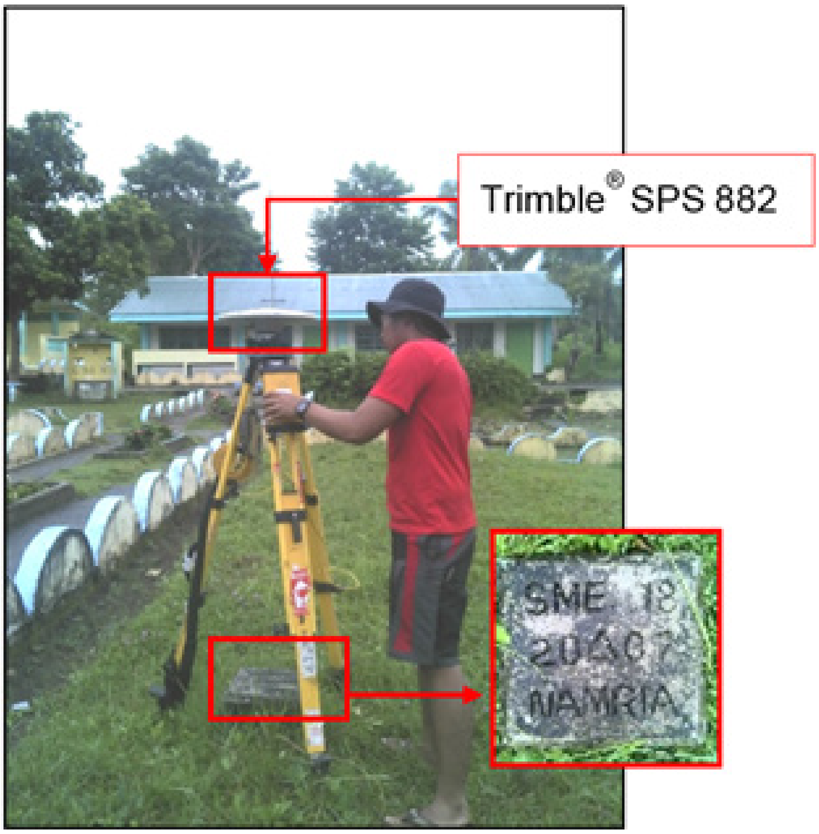


Figure 35. GNSS base receiver set-up, Trimble® SPS 852 at SME-18,located inside San Jose Elementary School, Barangay Cancildes, Municipality. of Hernani, Eastern Samar

Figure 36. GNSS receiver, Trimble® SPS 882, at SE-85, located at the approach of the Llorente Bridge in Barangay 11, Municipality of Llorente, Eastern Samar

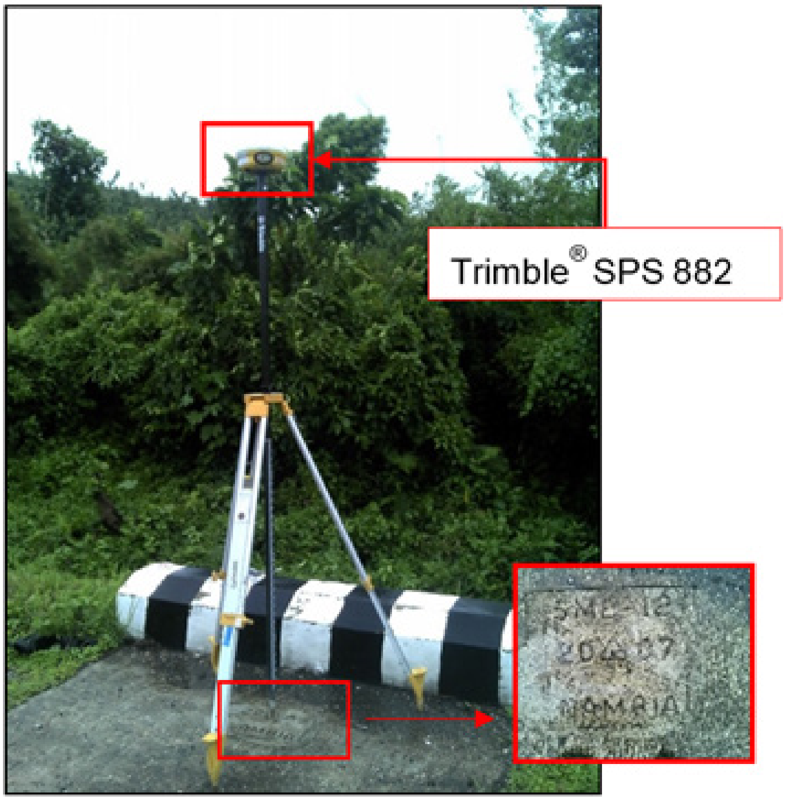


Figure 37. GNSS receiver occupation, Trimble® SPS 882, at SME-12 in Barangay San Miguel, Municipality of Balangiga, Eastern Samar

Figure 38. GNSS base occupation, Trimble® SPS 852, at SMR-3322, located at the approach of the Golden Bridge in Barangay Binongtu-an, Municipality of Basey, Samar

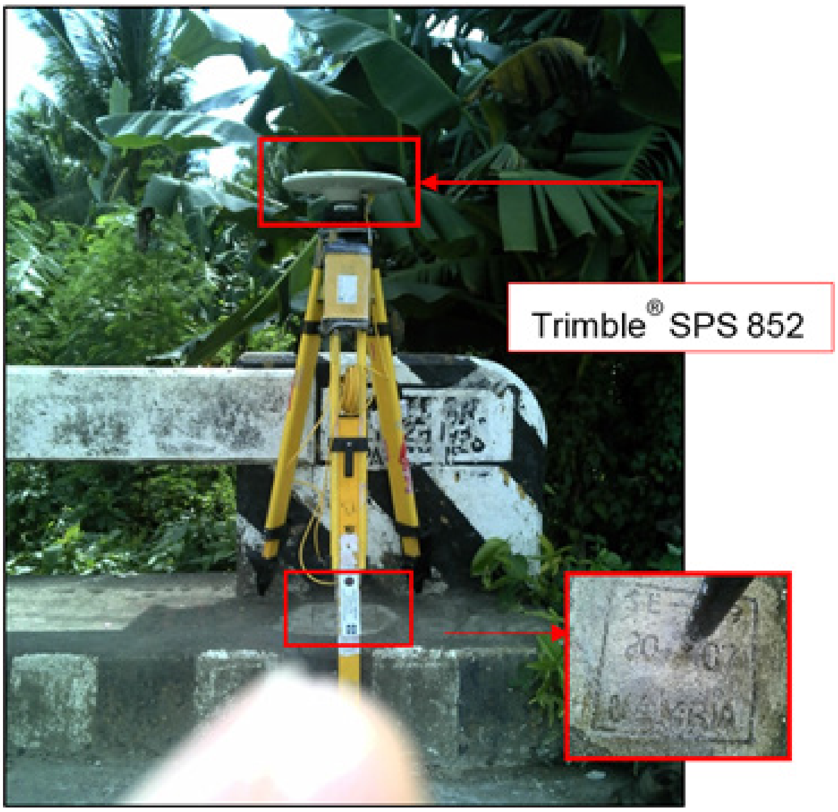


Figure 39. GNSS base occupation, Trimble® SPS 852, at SE-49, in Barangay Aguinaldo, Municipality of General Macarthur, Eastern Samar

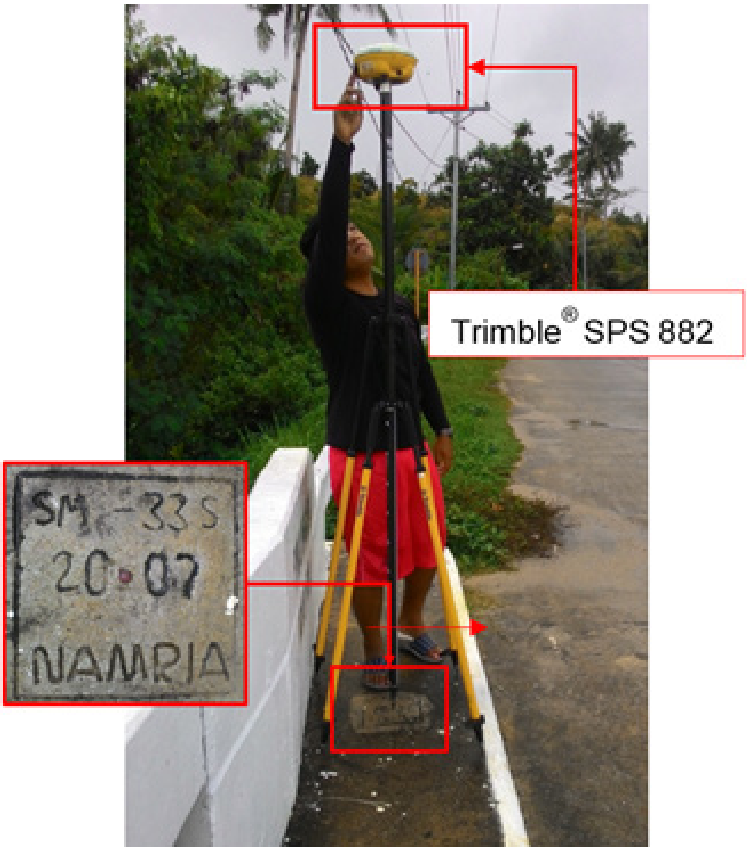


Figure 40. GNSS base occupation, Trimble® SPS 882, at SM-335, in Barangay Pinalanga, Municipality of Maravut, Samar

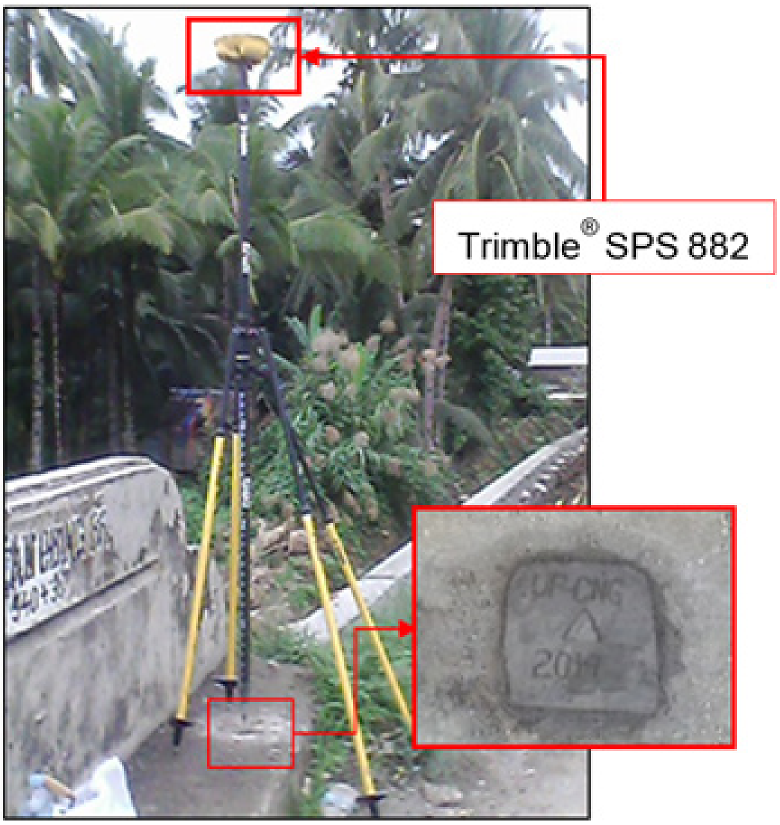


Figure 41. GNSS receiver occupation, Trimble® SPS 882, at UP-CNG, located at the approach of the Can-Obing Bridge in Barangay Can-Abong, Borongan City, Eastern Samar

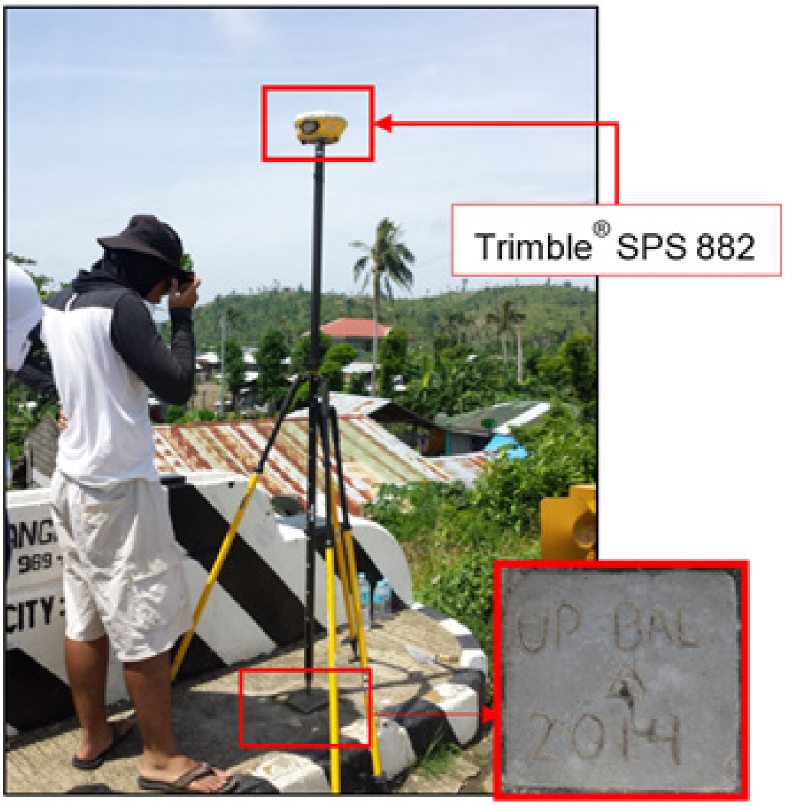


Figure 42. GNSS receiver occupation, Trimble® SPS 882, at control point UP-BAL, at the approach of the Balangiga Bridge in Barangay Poblacion V, Balangiga, Eastern Samar

4.3 Baseline Processing

GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of control points in the Balangiga River Basin generated by the TBC software is summarized in Table 25.

Table 25. Baseline Processing Report for the Balangiga River control point survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SME-12 --- SM-335	09-17-14	Fixed	0.004	0.017	271°35'44"	16305.472	1.501
SME-18 --- UP-CNG	09-12-14	Fixed	0.003	0.013	324°17'44"	31862.046	-11.107
SE-49 --- UP-BAL	9-15-14	Fixed	0.004	0.016	235°25'12"	19579.859	3.935
SE-49 --- SME-12	09-13-14	Fixed	0.004	0.019	242°52'57"	21244.542	0.227
SE-85 --- UP-CNG	09-12-14	Fixed	0.007	0.019	331°52'51"	22970.857	-0.437
UP-CNG --- SE-85	09-12-14	Fixed	0.005	0.041	331°52'51"	22970.859	-0.416
SME-18 --- SE-49	09-13-14	Fixed	0.003	0.016	207°09'17"	18943.356	-11.212
SME-18 --- SE-85	09-12-14	Fixed	0.005	0.033	305°49'17"	9586.977	-10.719
SME-18 --- SE-85	09-12-14	Fixed	0.004	0.015	305°49'17"	9586.978	-10.699
SME-12 --- SM-335	09-17-14	Fixed	0.019	0.033	271°35'44"	16305.477	1.450
SME-18 --- SME-12	09-13-14	Fixed	0.004	0.018	226°05'03"	38255.209	-11.019
SME-12 --- SMR-3322	09-17-14	Fixed	0.003	0.014	306°16'15"	32291.859	3.461
SMR-3322 --- SM-335	09-17-14	Fixed	0.004	0.014	332°24'22"	21038.056	-1.964
SMR-3322 --- SM-335	09-17-14	Fixed	0.006	0.038	332°24'22"	21038.062	-1.976

As shown in Table 25, a total of fourteen (14) baselines were processed, with coordinates of SME-18 and elevation values of reference point SE-85 held fixed. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report provided in Table 26 to Table 29 for the complete details.

The eight (8) control points – SME-18, SE-85, SME-12, SMR-3322, SE-49, SM-33S, UP-CNG, and UP-CLG – were occupied and observed simultaneously to form a GNSS loop. Coordinates of SME-18 and elevation values of SE-85 were held fixed during the processing of the control points, as presented in Table 26 . Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 26. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SE-85	Grid				Fixed
SME-18	Local	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 27. All fixed control points have no values for grid and elevation errors.

Table 27. Adjusted grid coordinates for the control points used in the Balangiga Floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SE-49	776407.626	0.007	1240340.446	0.005	3.779	0.050	
SE-85	777079.164	0.006	1262825.941	0.004	6.310	?	e
SM-33S	741264.593	0.010	1230815.204	0.007	3.951	0.061	
SME-12	757572.894	0.007	1230490.556	0.005	2.721	0.051	
SME-18	784907.431	?	1257282.043	?	17.660	0.032	LL
SMR-3322	731377.313	0.009	1249392.087	0.007	6.636	0.060	
UP-CNG	766068.484	0.005	1282999.389	0.004	6.035	0.036	

The results of the computation for accuracy are as follows:

a. SME-18

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	3.2 < 10 cm

b. SE-85

Horizontal Accuracy	=	$\surd((0.6)^2 + (0.4)^2$
	=	$\surd\ (0.36 + 0.16)$
	=	0.72 < 20 cm
Vertical Accuracy	=	Fixed

c. SME-12

Horizontal Accuracy	=	$\surd((0.7)^2 + (0.5)^2$
	=	$\surd\ (0.49 + 0.25)$
	=	0.86 < 20 cm
Vertical Accuracy	=	5.1 < 10 cm

d. SMR-3322

Horizontal Accuracy	=	$\surd((0.9)^2 + (0.7)^2$
	=	$\surd\ (0.81 + 0.49)$
	=	1.14 < 20 cm
Vertical Accuracy	=	6.0 < 10 cm

e. SE-49

Horizontal Accuracy	=	$\surd((0.7)^2 + (0.5)^2$
	=	$\surd\ (0.49 + 0.25)$
	=	0.86 < 20 cm
Vertical Accuracy	=	5.0 < 10 cm

f. SM-33S

Horizontal Accuracy	=	$\surd((1.0)^2 + (0.7)^2$
	=	$\surd\ (1.0 + 0.49)$
	=	1.22 < 20 cm
Vertical Accuracy	=	6.1 < 10 cm

g. UP-CNG

Horizontal Accuracy	=	$\surd((0.5)^2 + (0.4)^2$
	=	$\surd\ (0.25 + 0.16)$
	=	0.65 < 20 cm
Vertical Accuracy	=	3.6 < 10 cm

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

Table 28. Adjusted geodetic coordinates for control points used in the Balangiga River Floodplain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
SE-49	N11°12'34.48802"	E125°31'52.42238	66.981	0.050	
SE-85	N11°24'45.65441"	E125°32'20.98934	67.520	?	e
SM-33S	N11°07'33.79721"	E125°12'32.14831	68.705	0.061	
SME-12	N11°07'19.15395"	E125°21'29.28283	67.212	0.051	
SME-18	N11°21'43.08127"	E125°36'37.41862	78.217	0.032	LL
SMR-3322	N11°17'40.55190"	E125°07'10.82309	70.666	0.060	
UP-CNG	N11°35'44.92939"	E125°26'23.62776	67.094	0.036	

The corresponding geodetic coordinates of the observed points are within the required accuracies, as shown in Table 28. Based on the results of the computations, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points used in the Balangiga River GNSS Static Survey are indicated in Table 29.

Table 29. Reference and control points used in the Balangiga River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SME-18	2nd Order, GCP	11d21'43.08127"	125d36'37.41862"	78.217	1257282.043	784907.431	17.66
SE-85	1st Order, BM	11d24'45.65441"	125d32'20.98934"	67.52	1262825.941	777079.164	6.31
SME-12	Used as Marker	11d07'19.15395"	125d21'29.28283"	67.212	1230490.556	757572.894	2.721
SMR-3322	Used as Marker	11d17'40.55190"	125d07'10.82309"	70.666	1249392.087	731377.313	6.636
SE-49	Used as Marker	11d12'34.48802"	125d31'52.42238"	66.981	1240340.446	776407.626	3.779
SM-33S	Used as Marker	11d07'33.79721"	125d12'32.14831"	68.705	1230815.204	741264.593	3.951
UP-CNG	UP Established	11d35'44.92939"	125d26'23.62776"	67.094	1282999.389	766068.484	6.035
UP-BAL	UP Established	11d06'32.69356"	125d23'01.19762"	70.922	1229084.693	760374.629	6.453

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

The cross-section and bridge as-built surveys were conducted on September 15, 2014 at the upstream side of the Balangiga Bridge in Barangay Poblacion V, Municipality of Balangiga, Eastern Samar, using Trimble® SPS 882 GNSS PPK survey technique (Figure 43).

Figure 43. The Balangiga Bridge facing upstream

The length of the cross-sectional line surveyed in the Balangiga Bridge is 387.66 meters, with a total of fifty-seven (57) points gathered using the control point UP-BAL as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 44, Figure 45, and Figure 46, respectively.

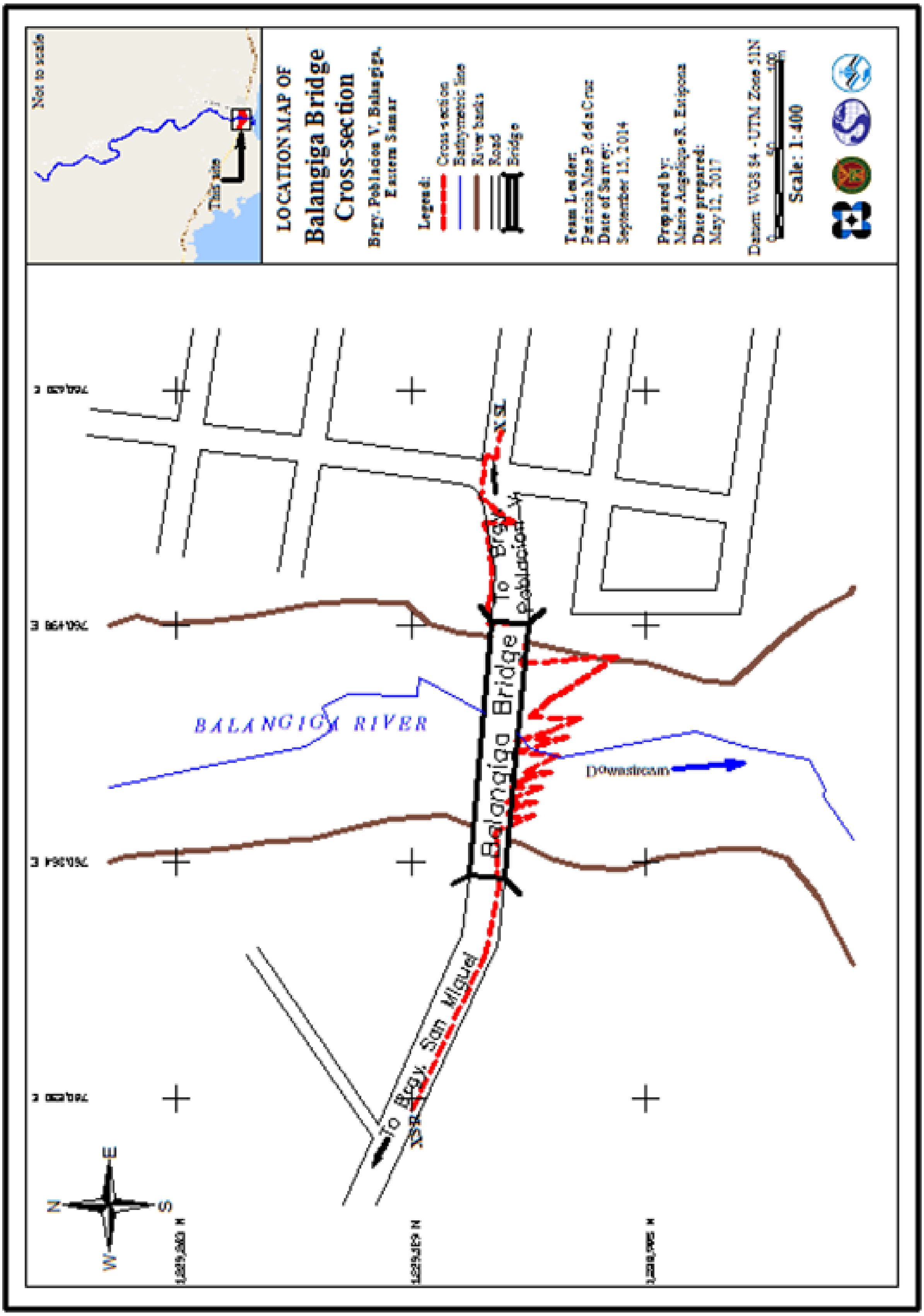


Figure 44. Balangiga Bridge location map

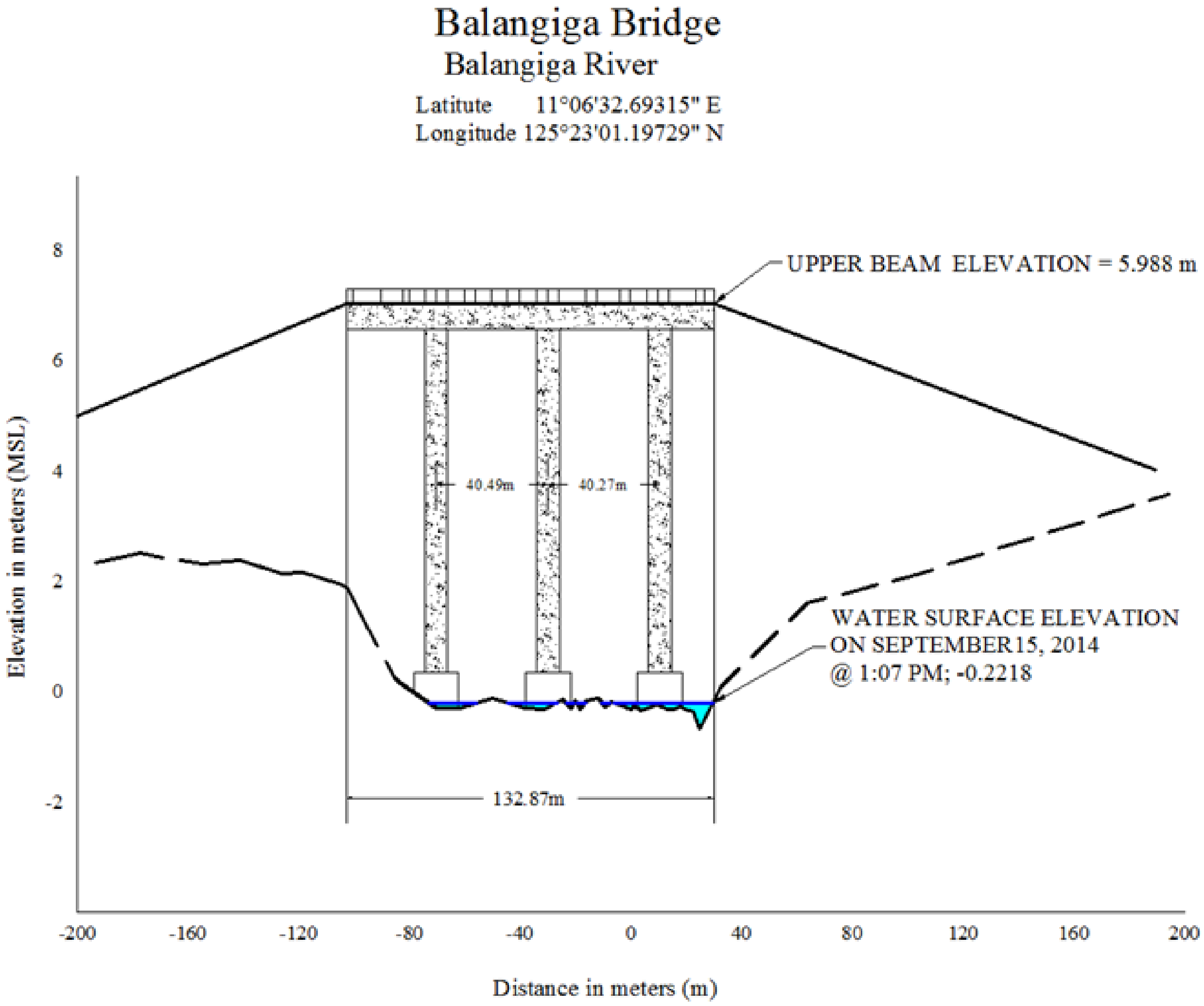


Figure 45. Balangiga Bridge cross-section diagram

Bridge Data Form

Bridge Name: Balangiga Bridge **Date:** 15-Sep-14

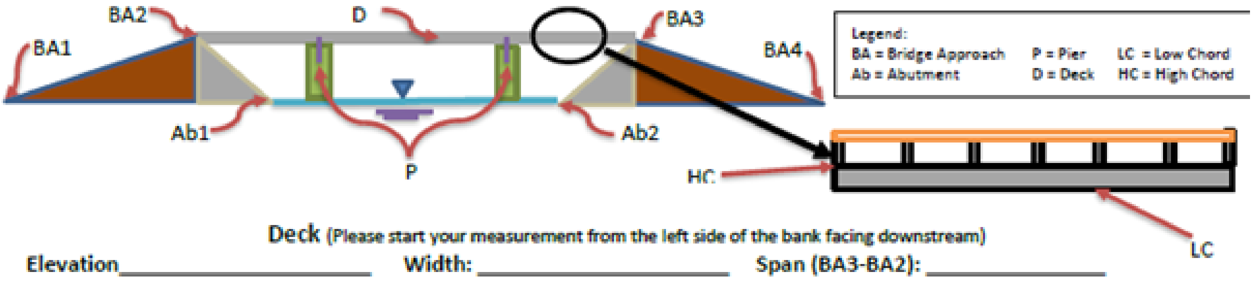
River Name: Balangiga River **Time:** 10:45 PM

Location (Brgy, City, Region): Barangay Poblacion V , Balangiga, Eastern Samar

Survey Team: ______

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

Latitude: 11d24'45.65448" **Longitude:** 125d32'20.98938"



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

Elevation ______ **Width:** ______ **Span (BA3-BA2):** ______

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			
5			

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	2.2892	BA3	234.36 m	6.0322
BA2	101.49 m	6.2012	BA4	386.38 m	3.6082

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

	Station (Distance from BA1)	Elevation
Ab1	109.19 m	-0.281
Ab2	227.82 m	0.185

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

Shape: ______ **Number of Piers:** 3 **Height of column footing:** ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	135.89 m		
Pier 2	176.01 m		
Pier 3	216.39 m		
Pier 4			
Pier 5			

Figure 46. Balangiga Bridge data form

The water surface elevation of the Balangiga River was acquired using PPK survey technique on September 15, 2014 at 13:07 hrs. The resulting water surface elevation data was -0.2218 meters above MSL. This was translated into markings on the bridge's pier using the same technique, as depicted in Figure 47. The markings on the bridge's pier served as a reference for flow data gathering and depth gauge deployment of the VSU PHIL-LiDAR 1 Team.

Figure 47. (A) Actual and (B) finished MSL water level markings on the Balangiga Bridge's pier

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 14, 15, 17, 18, 19, and 20 of 2014, using a survey-grade GNSS rover receiver, Trimble® SPS 882. The receiver was mounted on a pole attached to the front of a vehicle, as exhibited in Figure 48. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced.`

Figure 48. Validation points acquisition survey set-up along the Balangiga River Basin

The survey started at Barangay Purok D1 in Borongan City, and headed south through the National Highway, traversing Borongan City; nine (9) Municipalities of Eastern Samar – Maydolong, Balangkayan, Llorente, Hernani, General Macarthur, Quinapondan, Giporlos, Balangiga, and Lawaan; and four (4) Municipalities of Samar – Marabut, Basey, Santa Rita, and Pinabacdao. The survey ended in Barangay Laygayon in the Municipality of Pinabacdao, Samar. A total of 30,114 points were gathered with an approximate length of 296.68 km., using UP-CNG, SE-49, SM-33S, SMR-3322, and SE-85 as the GNSS base stations for the entire extent of the validation points acquisition survey. This is represented by the map in Figure 49.

Figure 49. Extent of the LiDAR ground validation survey along Samar and Eastern Samar Region

4.7 River Bathymetric Survey

Manual bathymetry was performed all throughout the survey due to the malfunctioning echo sounder. Two (2) types of manual bathymetry were executed. The first method was performed by carrying a range pole with an installed Trimble® SPS 882 receiver on the upstream and shallow section of the river, as depicted in Figure 50.

Figure 50. Actual execution of manual bathymetric survey in the Balangiga River

The second type of manual bathymetric survey was carried out by using a portable depth sounder to acquire depth data, as shown in Figure 51. A boat was installed with a range pole mounted with a Trimble® SPS 882 GPS in its gunwale while a portable depth sounder was being used to measure the depth of the waters in the deeper downstream portion of the river. Bamboo poles and paddles were used to fix the position of the boat while encoding depth readings into the Trimble Controller. The team also deployed a stadia rod every 100 meters to check if the portable depth sounder was accurate and functioning properly.

Figure 51. Manual bathymetric survey using a portable depth sounder and stadia deployment for depth-checking in the Balangiga River

The survey started in Barangay Sta. Rosa in the Municipality of Balangiga, with coordinates 11°09'00.61957"N, 125°22'24.83231"E; and traversed down to the mouth of the river in Barangay Poblacion V, also in Balangiga, with coordinates 11°06'23.61968"N, 125°23'00.84270"E. This is illustrated in Figure 52. The established control point, UP-BAL, was occupied as the base station throughout the bathymetric survey.

The bathymetric survey for the Balangiga River gathered a total of 475 points covering 6.70 km. of the river, traversing five (5) barangays in Municipality of Balangiga. A CAD drawing was also produced to illustrate the riverbed profile of the Balangiga River (Figure 53). The profile reflects that the highest and lowest elevations had a 9-meter difference. The highest elevation observed was 0.394 meters in MSL, located at Barangay Sta. Rosa, Balangiga; while the lowest was -6.797 meters below MSL, located at the downstream portion of the river in Barangay Poblacion V, also in the Municipality of Balangiga.

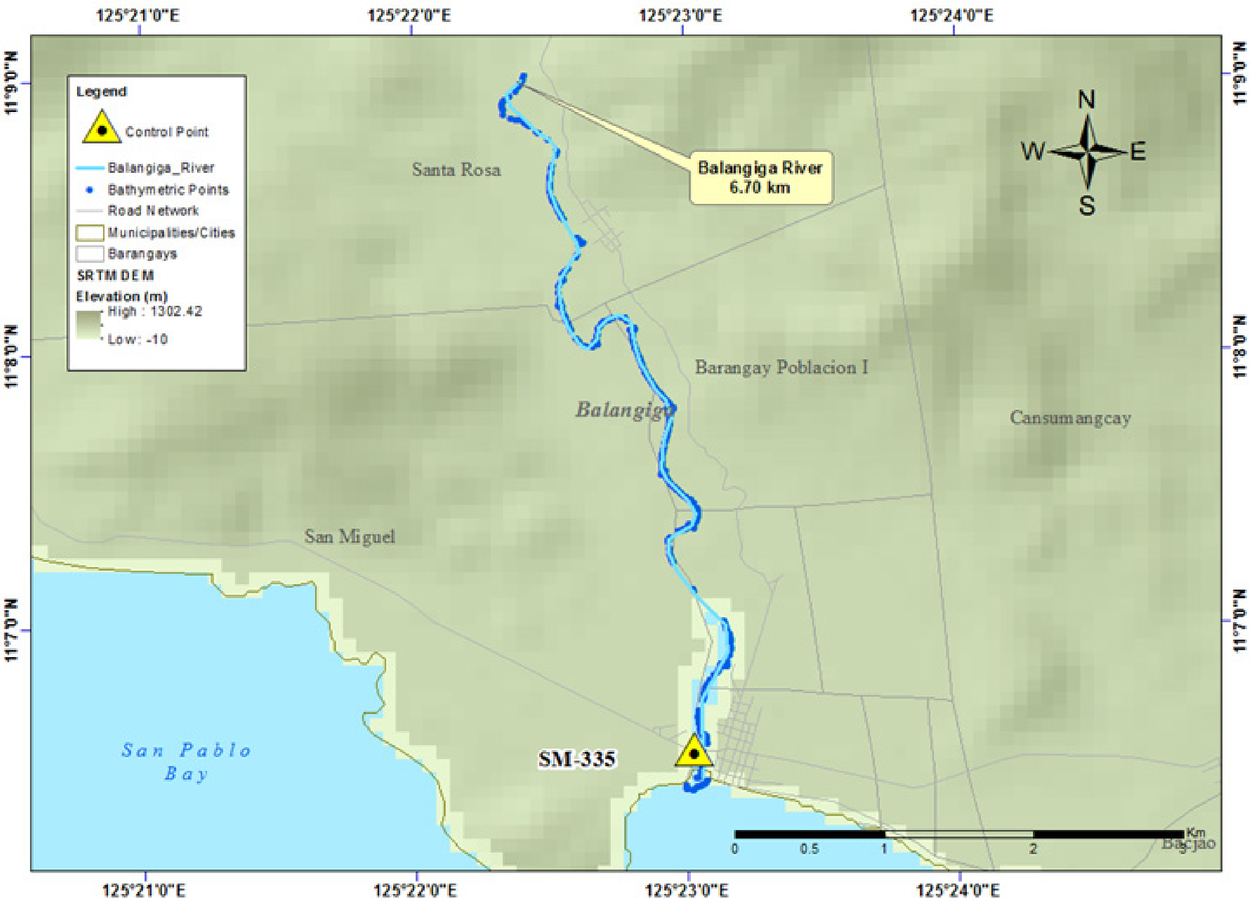


Figure 52. Extent of the bathymetric survey of the Balangiga River

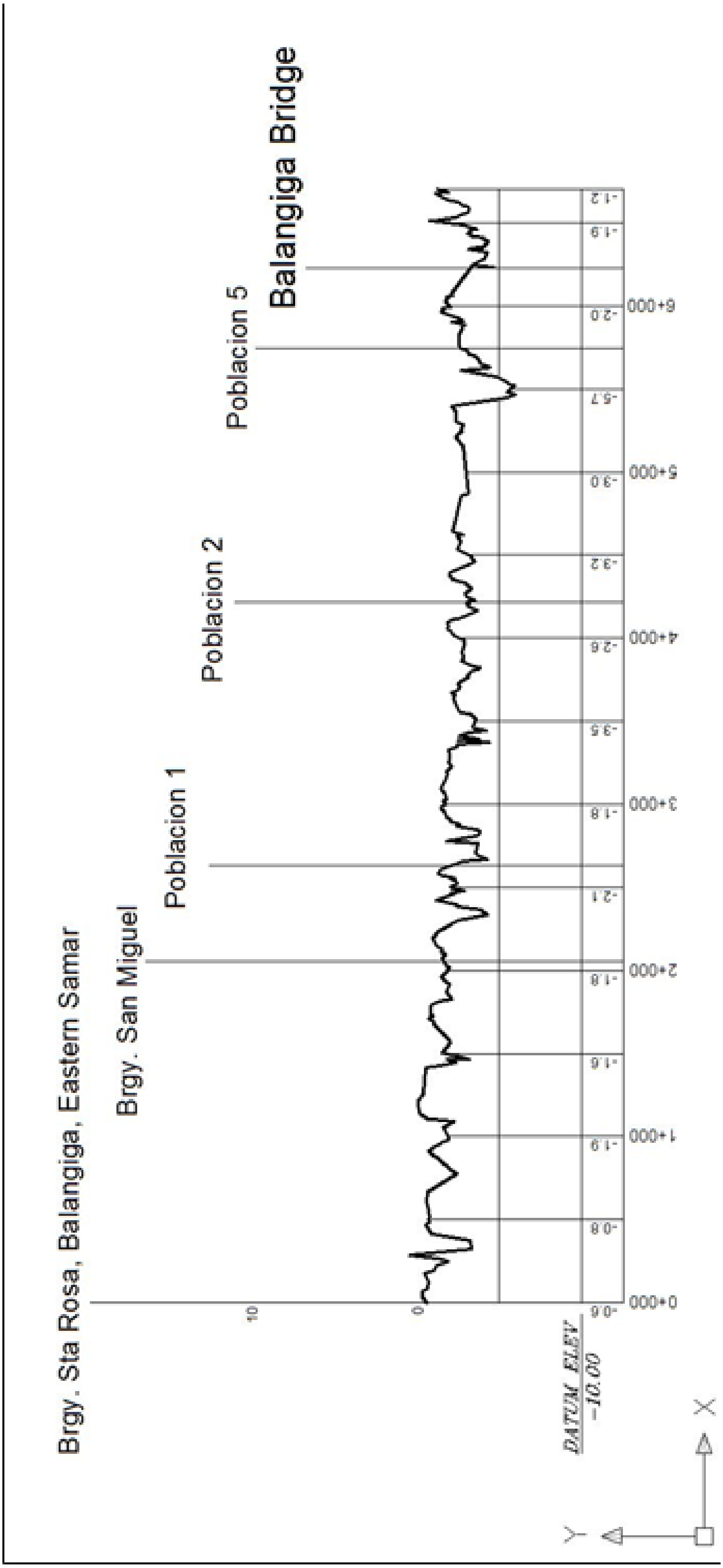


Figure 53. Balangiga riverbed centerline profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed by the Flood Modeling Component (FMC) at Barangay Sta. Rosa in the Municipality of Balangiga, Eastern Samar. The location of the rain gauge is seen in Figure 54.

Total rain from the National Irrigation Administration (NIA) Dam rain gauge was 214.5 mm. It peaked at 14 mm on January 16, 2017 at 01:15 hrs. The lag time between the peak rainfall and discharge was one hour and thirty five minutes (1+35).

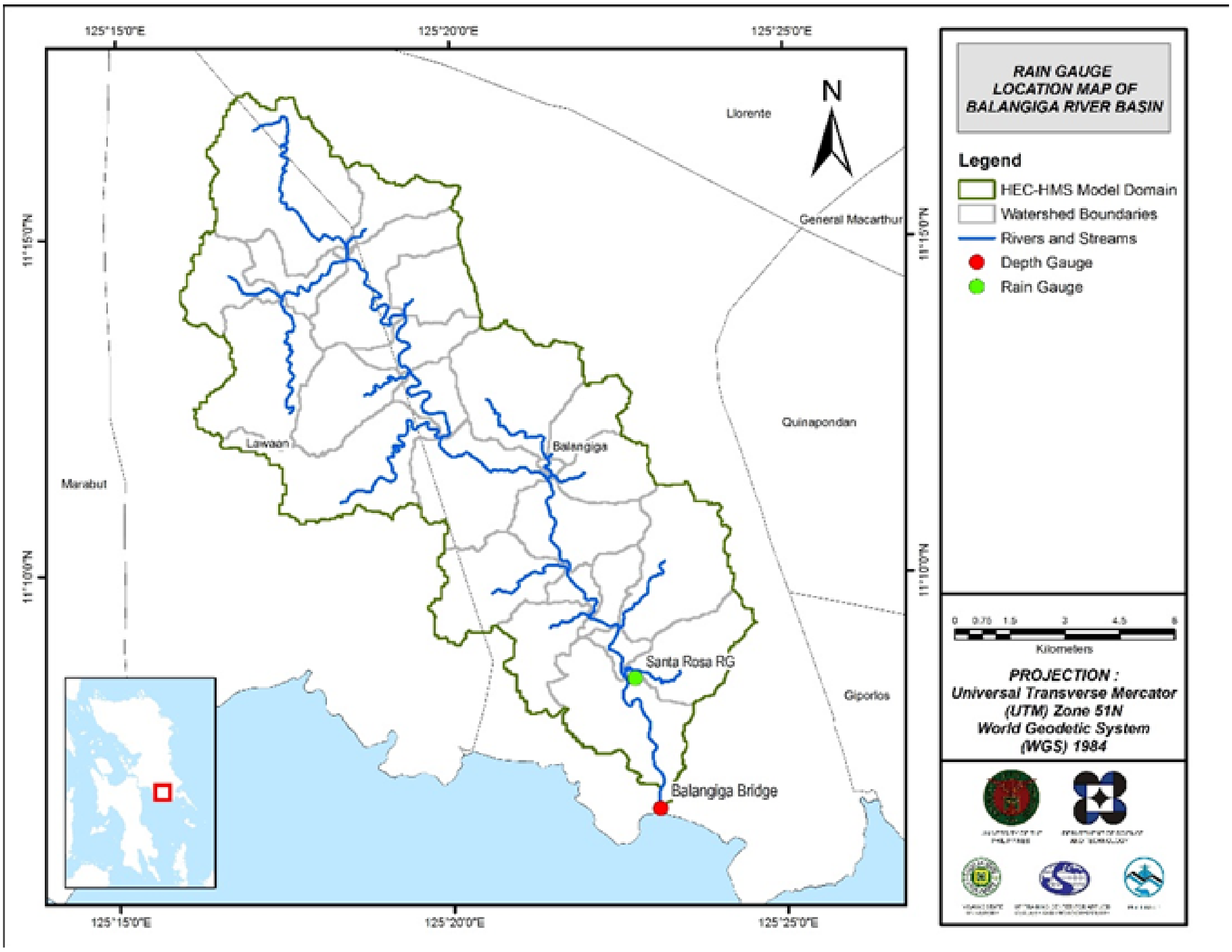


Figure 54. Location map of the Balangiga HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed at the prevailing cross-section (Figure 55) at the Balangiga Bridge, Barangay Poblacion V, Balangiga, Eastern Samar, to establish the relationship between the observed water levels (H) at the bridge and the outflow (Q) of the watershed at this location.

For the Balangiga Bridge, the rating curve is expressed as Q = 18.74e6.9429h, as shown in Figure 56.

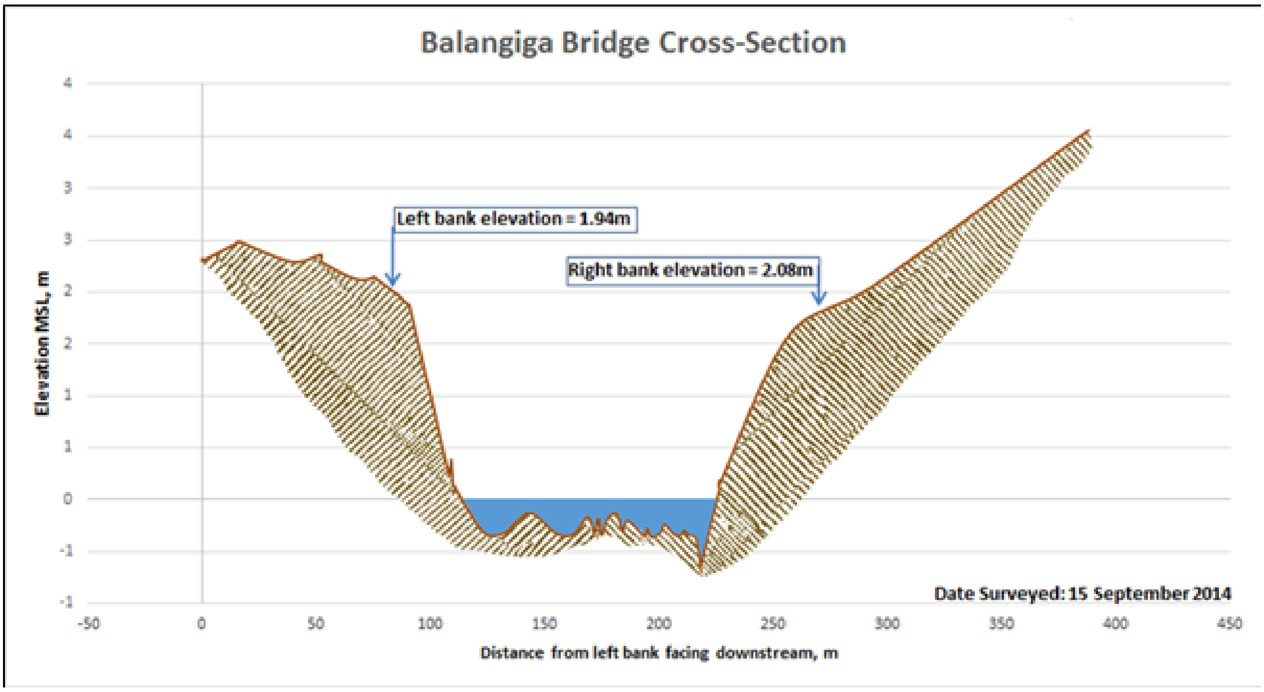


Figure 55. Cross-section plot of the Balangiga Bridge

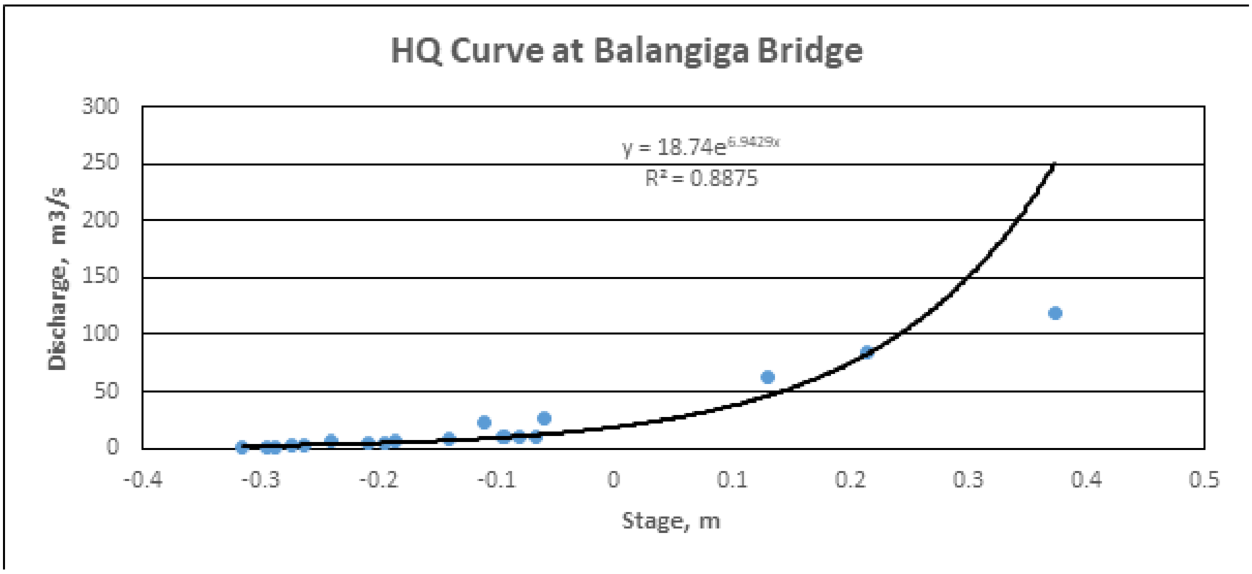


Figure 56. Rating curve at the Balangiga Bridge

The resulting rating curve equation was used to compute for the river outflow at the Balangiga Bridge, for the calibration of the HEC-HMS model presented in Figure 57. Peak discharge was 341.3 m3/s on January 16, 2017 at 14:40 hrs.

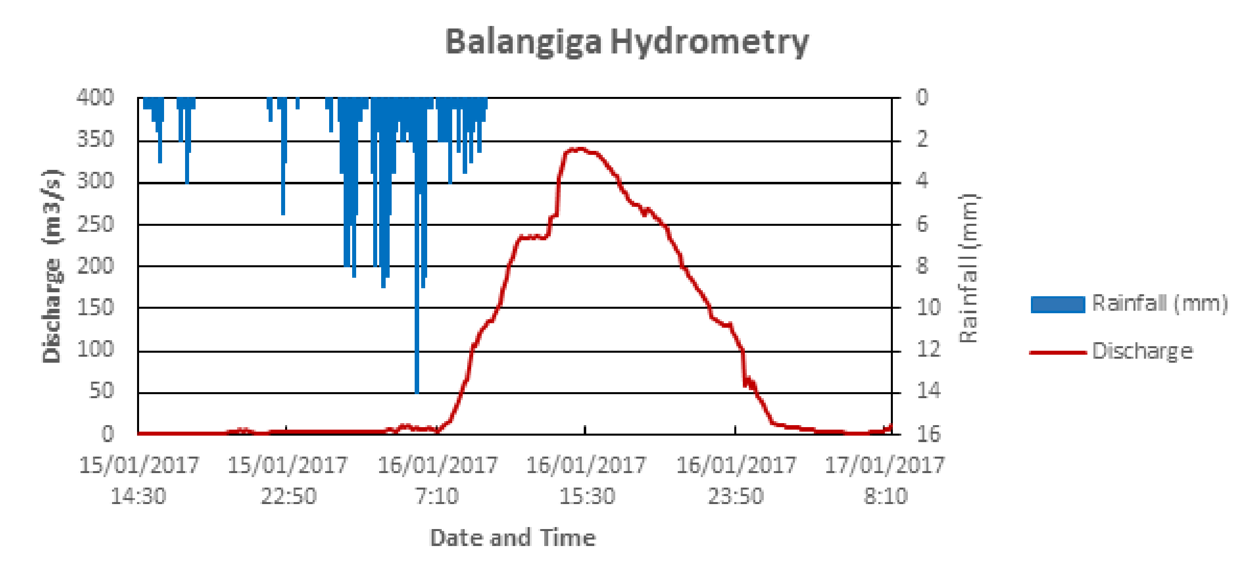


Figure 57. Rainfall and outflow data at the Balangiga Bridge used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Tacloban Rain Gauge (Table 30). This station was selected based on its proximity to the Balangiga watershed (Figure 58). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time (Figure 59). The extreme values for this watershed were computed based on a 59-year record.

Table 30. RIDF values for the Tacloban Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	17.8	26.9	33.6	42.8	59.7	70.5	87.2	104	120.6
5	24.3	36.7	45.7	57.4	80.7	95.2	117.9	140.6	161.4
10	28.5	43.2	53.7	67.1	94.6	111.5	138.2	164.9	188.4
15	30.9	46.8	58.3	72.5	102.5	120.7	149.6	178.6	203.7
20	32.6	49.4	61.4	76.3	108	127.1	157.7	188.1	214.3
25	33.9	51.4	63.9	79.3	112.2	132.1	163.8	195.5	222.6
50	37.9	57.5	71.4	88.3	125.2	147.4	182.9	218.2	247.9
100	41.8	63.5	78.9	97.3	138.2	162.5	201.8	240.8	273

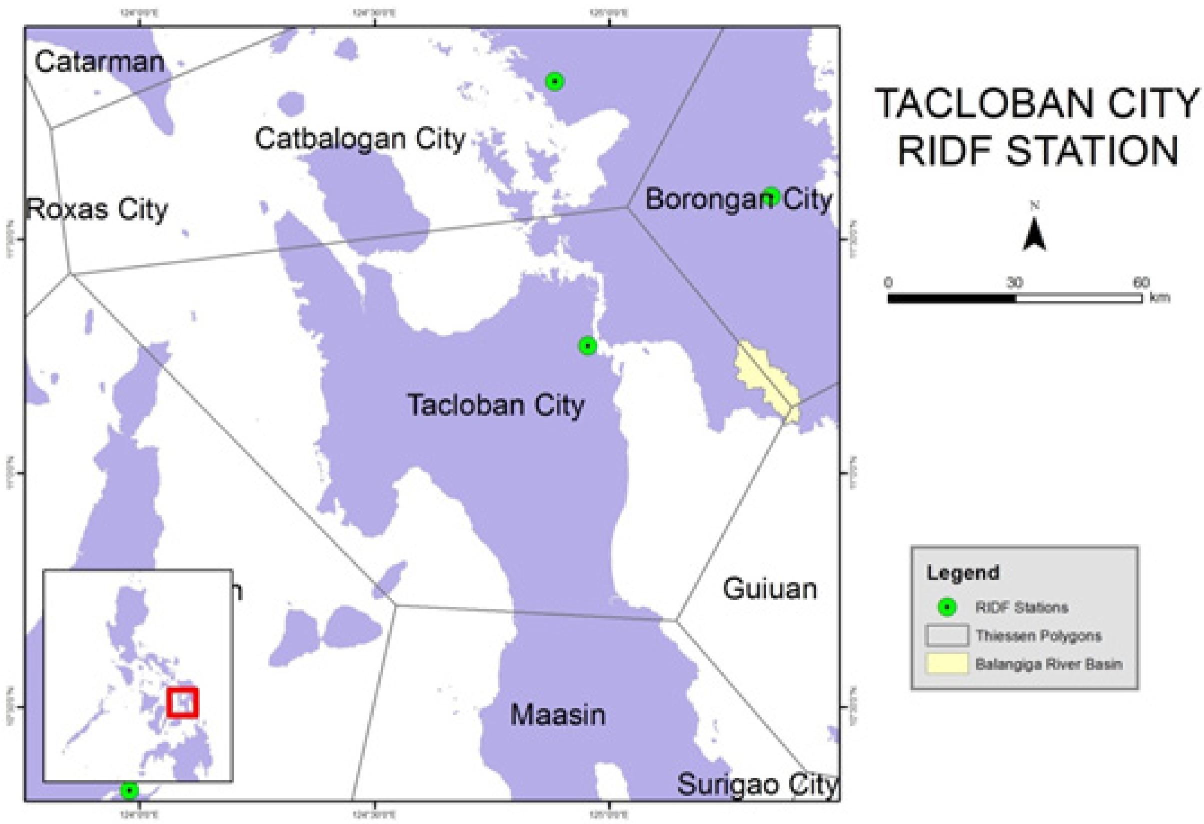


Figure 58. Location of the Tacloban RIDF station relative to the Balangiga River Basin

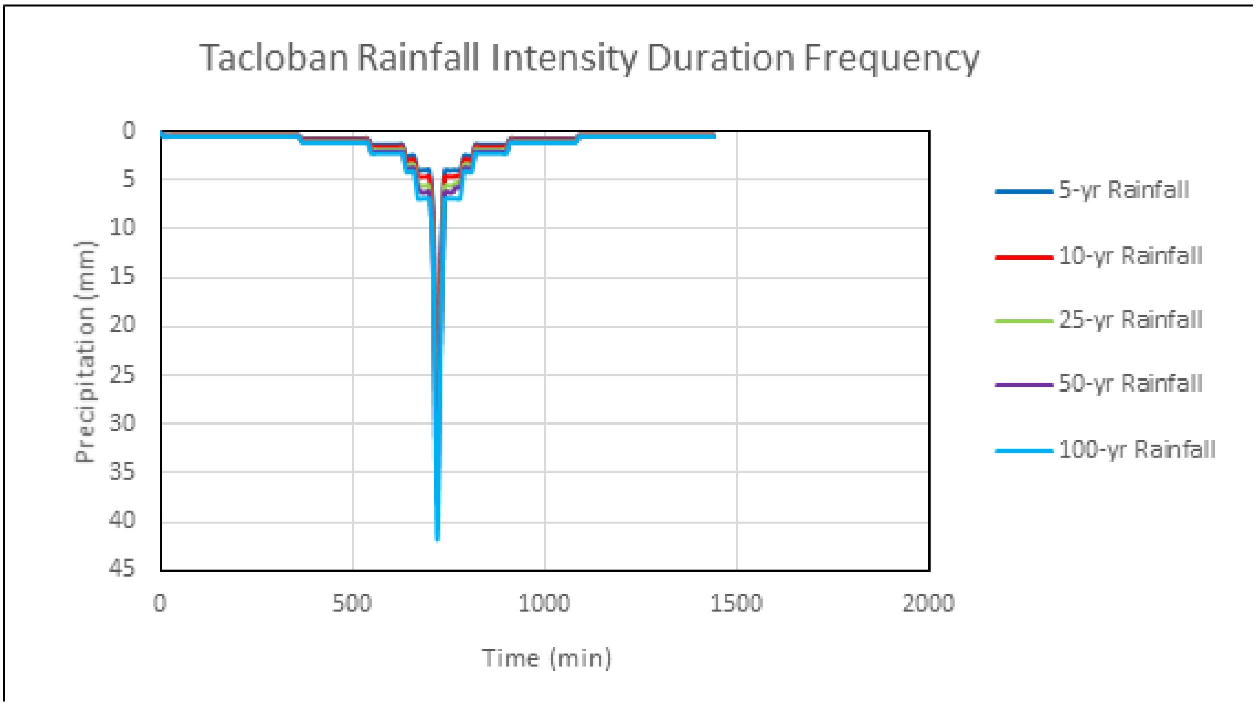


Figure 59. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were generated before 2004. The soil and land cover maps of the Balangiga River Basin are presented in Figures 60 and 61, respectively.

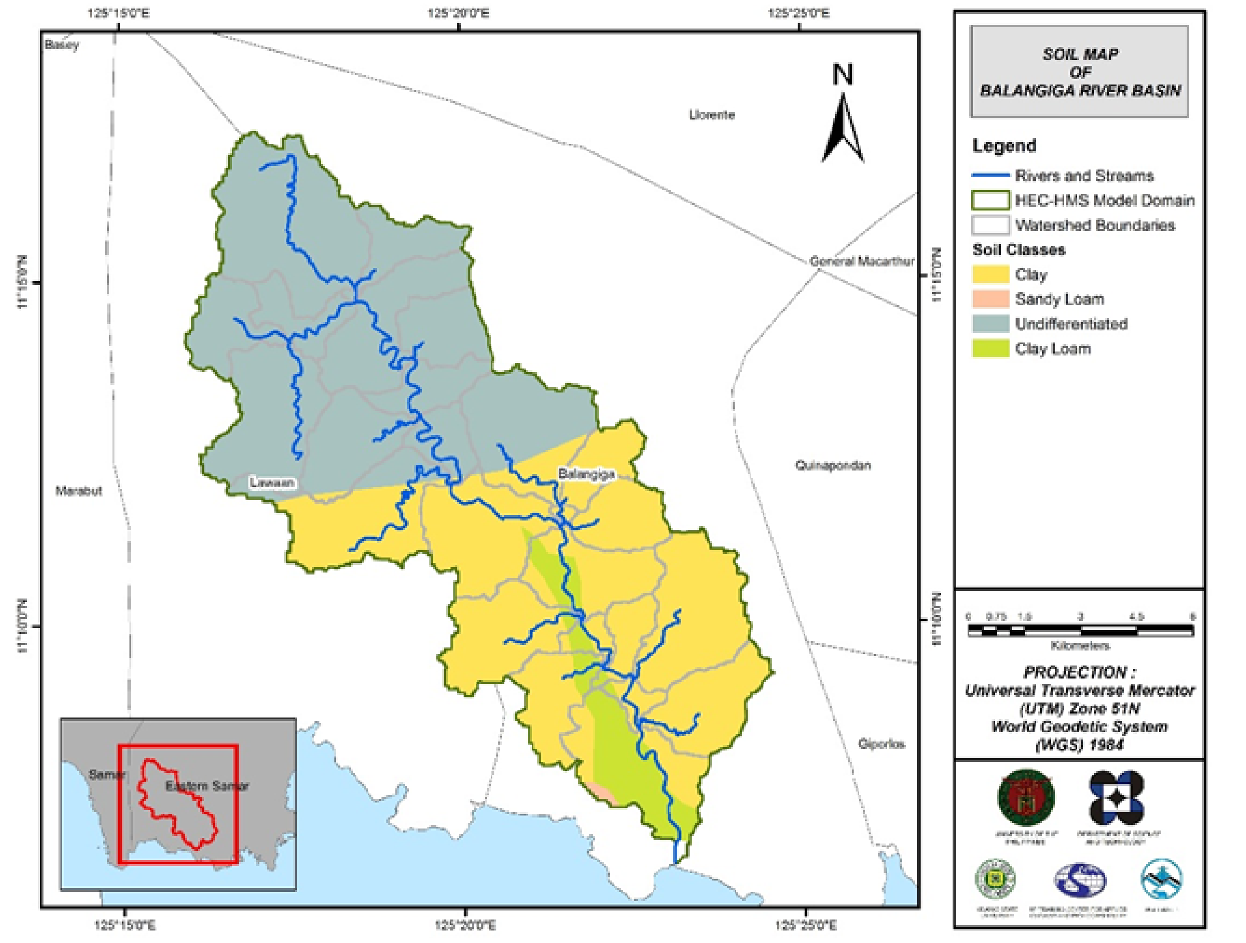


Figure 60. Soil map of the Balangiga River Basin (Source: DA)

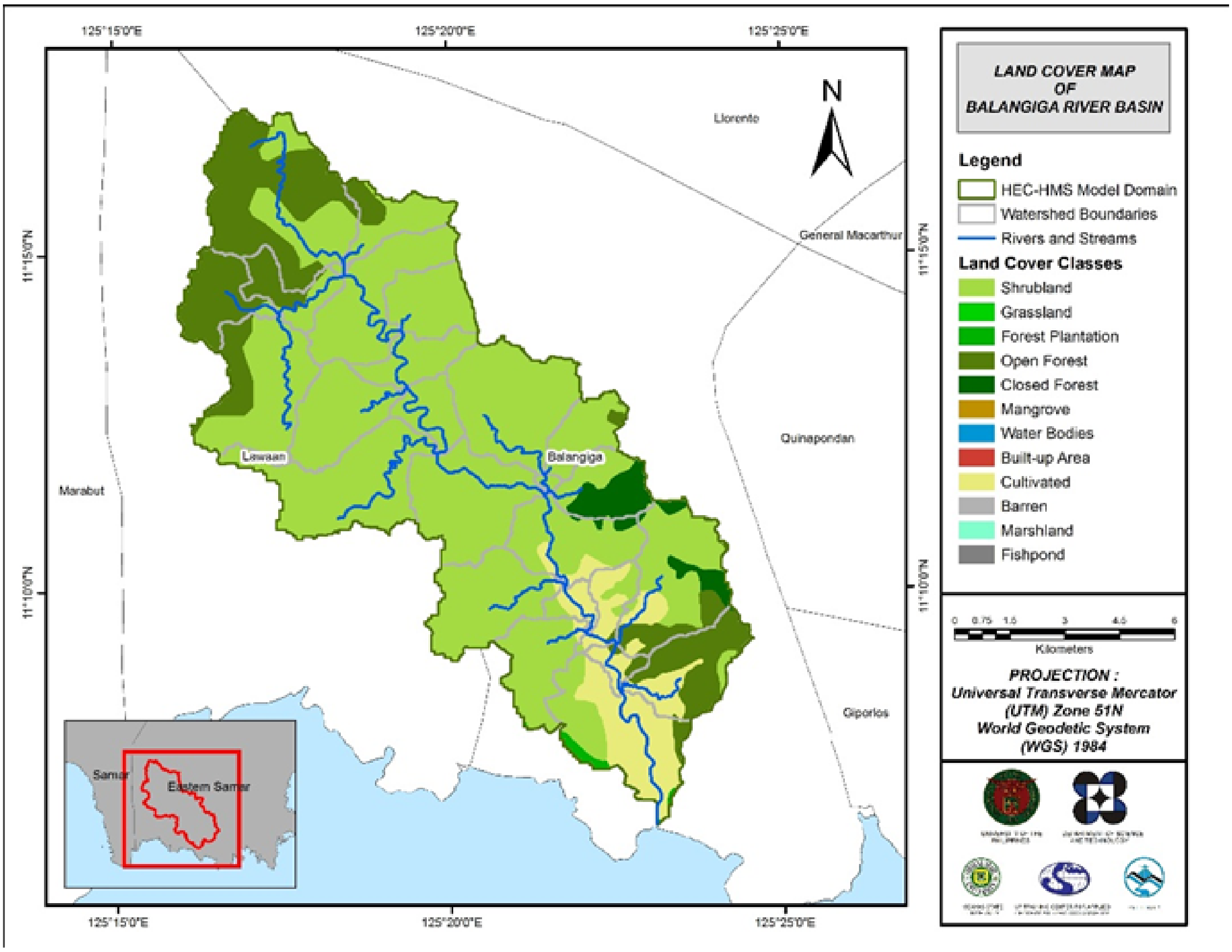


Figure 61. Land cover map of the Balangiga River Basin (Source: NAMRIA)

For Balangiga, the soil classes identified were clay, undifferentiated soil, and clay loam. The land cover types identified were shrub lands, forest plantations, open forests, closed forests, and cultivated land.

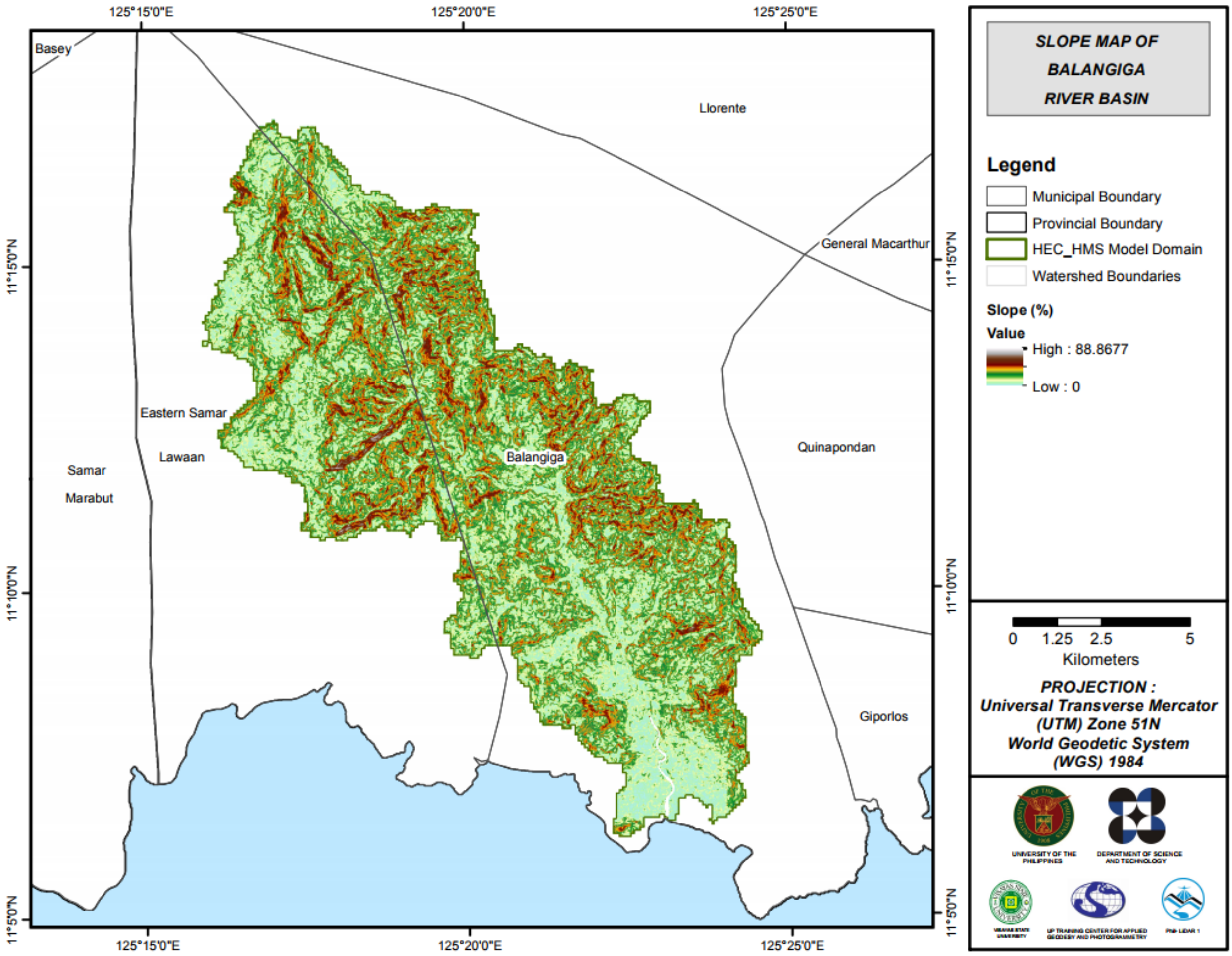


Figure 62. Slope map of the Balangiga River Basin

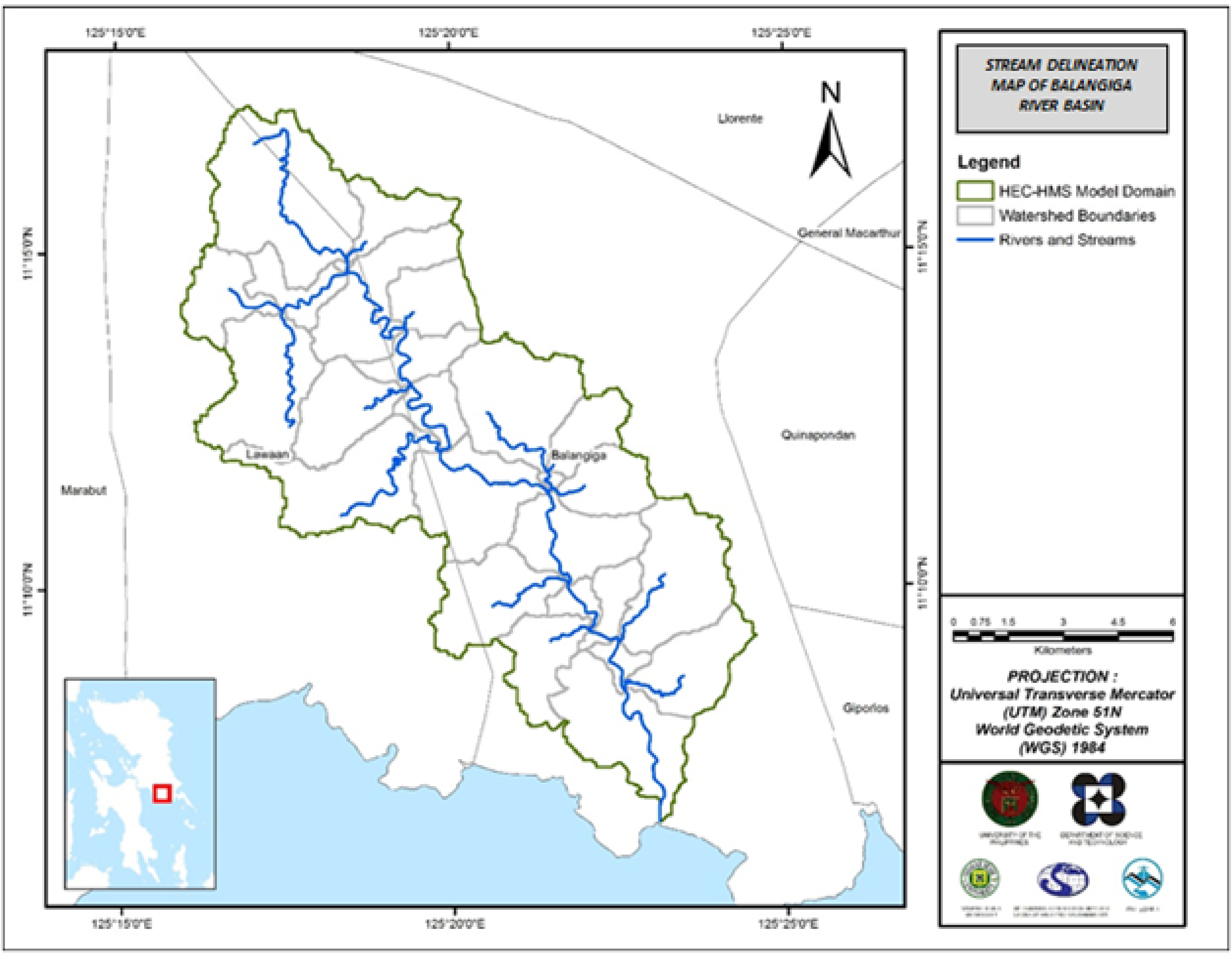


Figure 63. Stream delineation map of the Balangiga River Basin

Using the SAR-based DEM, the Balangiga basin was delineated and further subdivided into sub basins. The model consists of twenty-seven (27) sub basins, twenty-one (21) reaches, and thirteen (13) junctions, as exhibited in Figure 64. The main outlet is at the Balangiga Bridge. See Annex 10 for the Balangiga Model Reach Parameters.

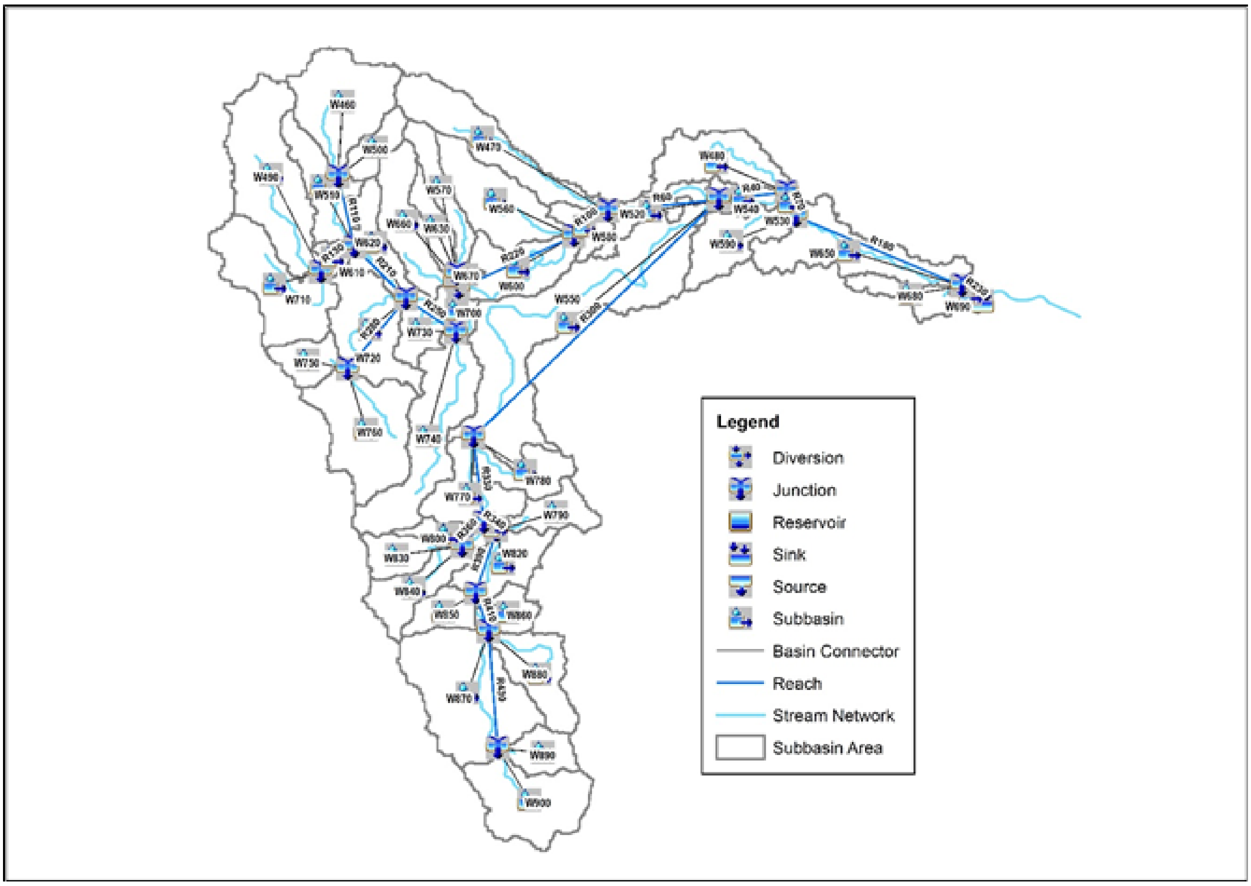


Figure 64. The Balangiga River Basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 65).

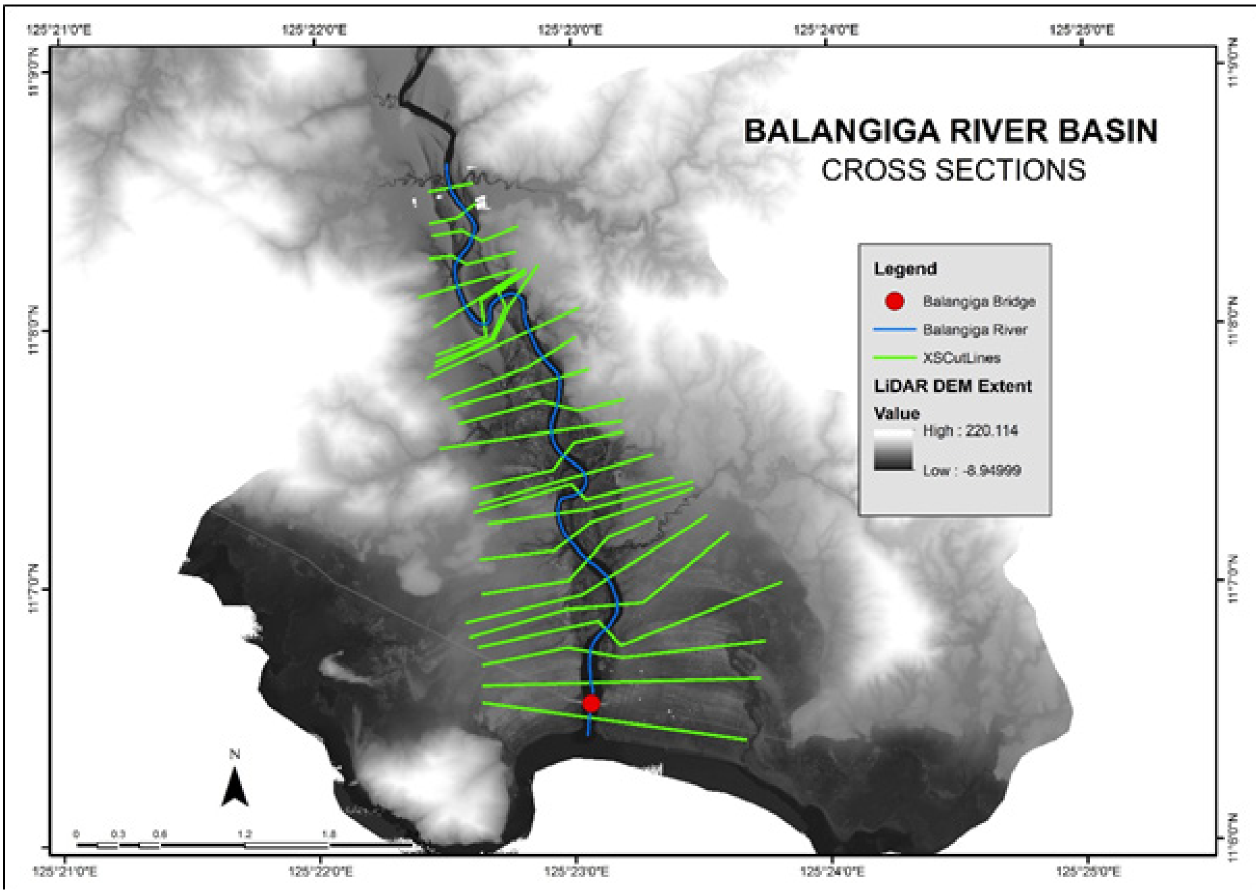


Figure 65. Cross-section of the Balangiga River generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. Each element was then attributed with the parameters required for modeling, such as x-and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation value. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements, in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

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

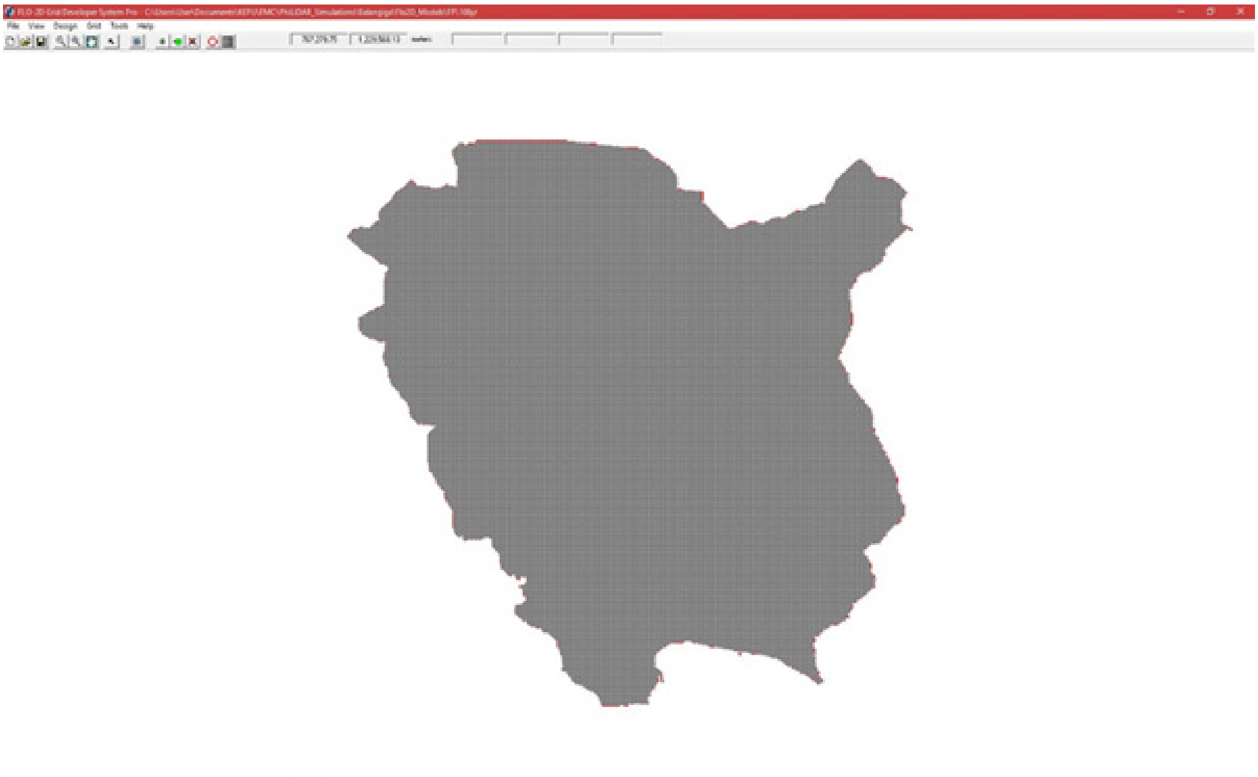


Figure 66. Screenshot of a sub-catchment with the computational area to be modeled in the FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 45.96643 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 34437700.00 m2.

There is a total of 54699408.21 m3 of water entering the model. Of this amount, 14061062.80 m3 is due to rainfall while 40638345.41 m3 is inflow from other areas outside the model. 4131393.75 m3 of this water is lost to infiltration and interception, while 9950596.90 m3 is stored by the flood plain. The rest, amounting up to 40617448.12 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Balangiga HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 67 depicts the comparison between the two (2) discharge data. The Balangiga Model Basin Parameters are found in Annex 9.

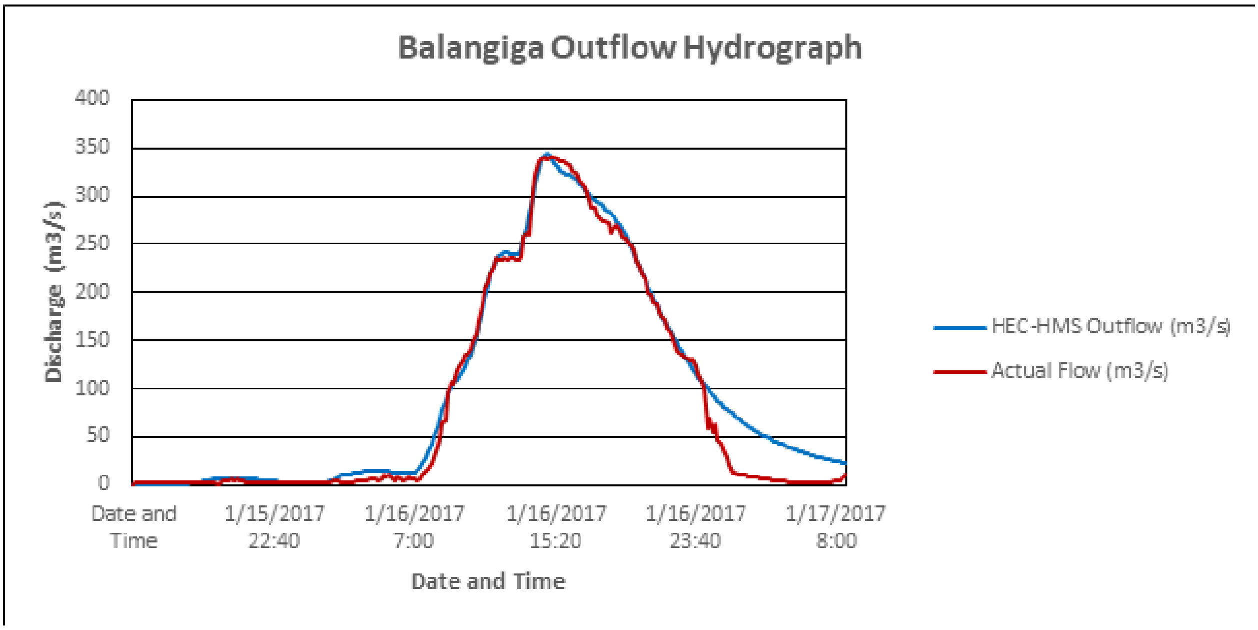


Figure 67. Outflow Hydrograph of the Balangiga Bridge generated in the HEC-HMS model, compared with observed outflow

Table 31. Range of calibrated values for the Balangiga River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3 – 45
			Curve Number	52 - 93
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1 - 93
			Storage Coefficient (hr)	0.32 – 7
	Baseflow	Recession	Recession Constant	0.5
			Ratio to Peak	0.01
Reach	Routing	Muskingum-Cunge	Slope	0.0005 - 0.045
			Manning's Coefficient	0.04

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 3mm to 45mm means that there is a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 70 to 90 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area. For Balangiga, the basin mostly consists of shrub lands, and the soil consists of clay and clay loam. The curve number range of the model is 52 to 93.

The time of concentration and the storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.1 hours to 7 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.

The recession constant is the rate at which baseflow recedes between storm events; and the ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.5 indicates that the basin is unlikely to quickly return to its original discharge, and will be higher instead. A ratio to peak of 0.1 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.04 corresponds to the common roughness of Philippine watersheds. The Balangiga River Basin is determined to be cultivated with mature field crops (Brunner, 2010).

Table 32. Summary of the Efficiency Test of Balangiga HMS Model

Accuracy measure	Value
RMSE	18.60
r2	0.98
NSE	0.97
PBIAS	-10.56
RSR	0.162

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 18.60 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.98.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. The optimal value is 1. The model attained an efficiency coefficient of 0.97.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -10.56.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model has an RSR value of 0.162.

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) demonstrates the Balangiga outflow using the Tacloban RIDF curves in five (5) different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the PAGASA data. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

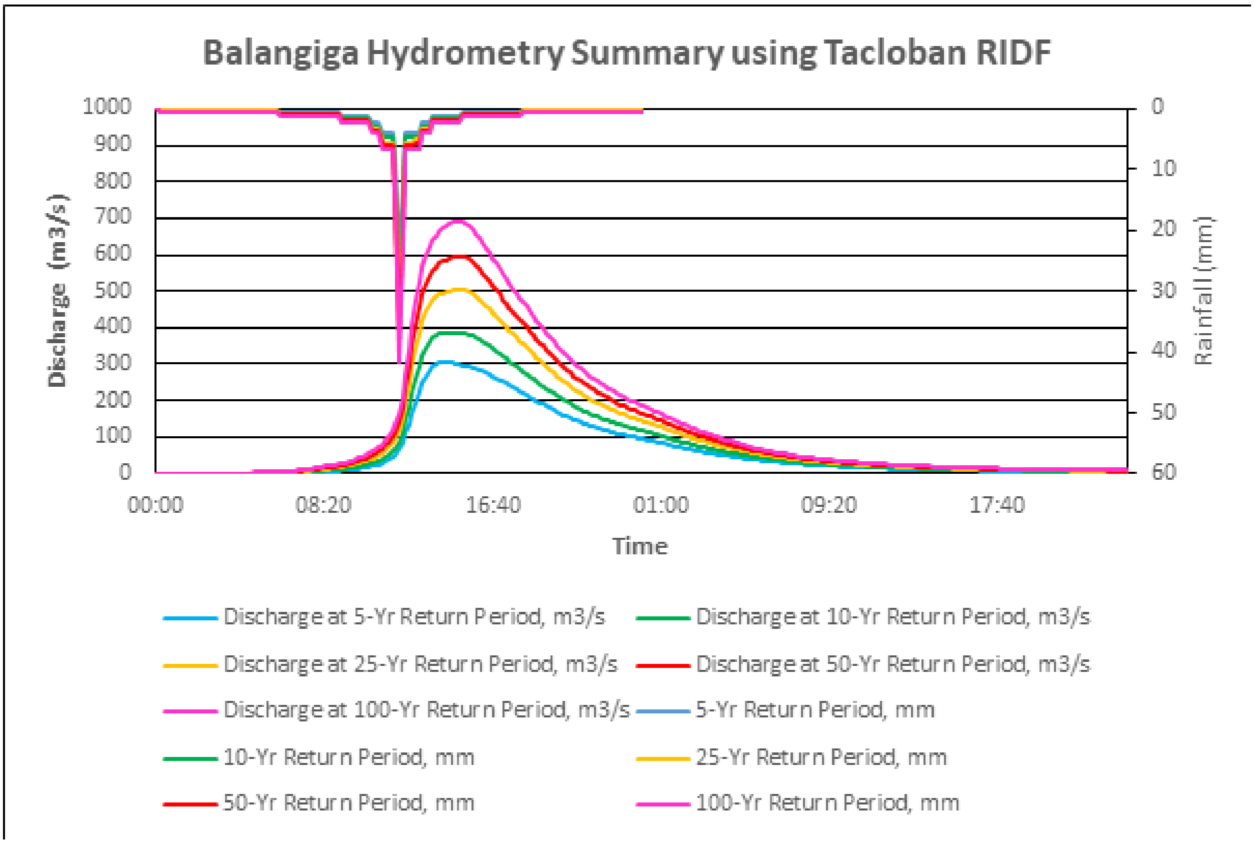


Figure 68. Outflow hydrograph at the Balangiga Station, generated using the Tacloban RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Balangiga discharge using the Tacloban RIDF curves in five (5) different return periods is outlined in Table 33.

Table 33. Peak values of the Balangiga HEC-HMS Model outflow using the Tacloban RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	161.4	24.3	308.1	2 hours, 10 minutes
10-Year	188.4	28.5	386.9	2 hours, 20 minutes
25-Year	222.6	33.9	503.7	3 hours, 00 minutes
50-Year	247.9	37.9	595.4	3 hours, 00 minutes
100-Year	273.0	41.8	690.4	3 hours, 00 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model was used in determining the flooded areas within the model. The simulated model will be an integral part in determining 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 is presented, since only the VSU-FMC base flow was calibrated. The sample generated map of the Balangiga River using the calibrated HMS base flow is provided in Figure 69.

Figure 69. Sample output map of the Balangiga RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Balangiga floodplain are shown in Figures 70 to 75. The floodplain, with an area of 34.44 sq. km., covers one (1) municipality, which is Balangiga. Table 34 indicates the percentage of area affected by flooding in the Municipality of Balangiga.

Table 34. Municipalities affected in the Balangiga Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Balangiga	206.52	34.35667	16.64%

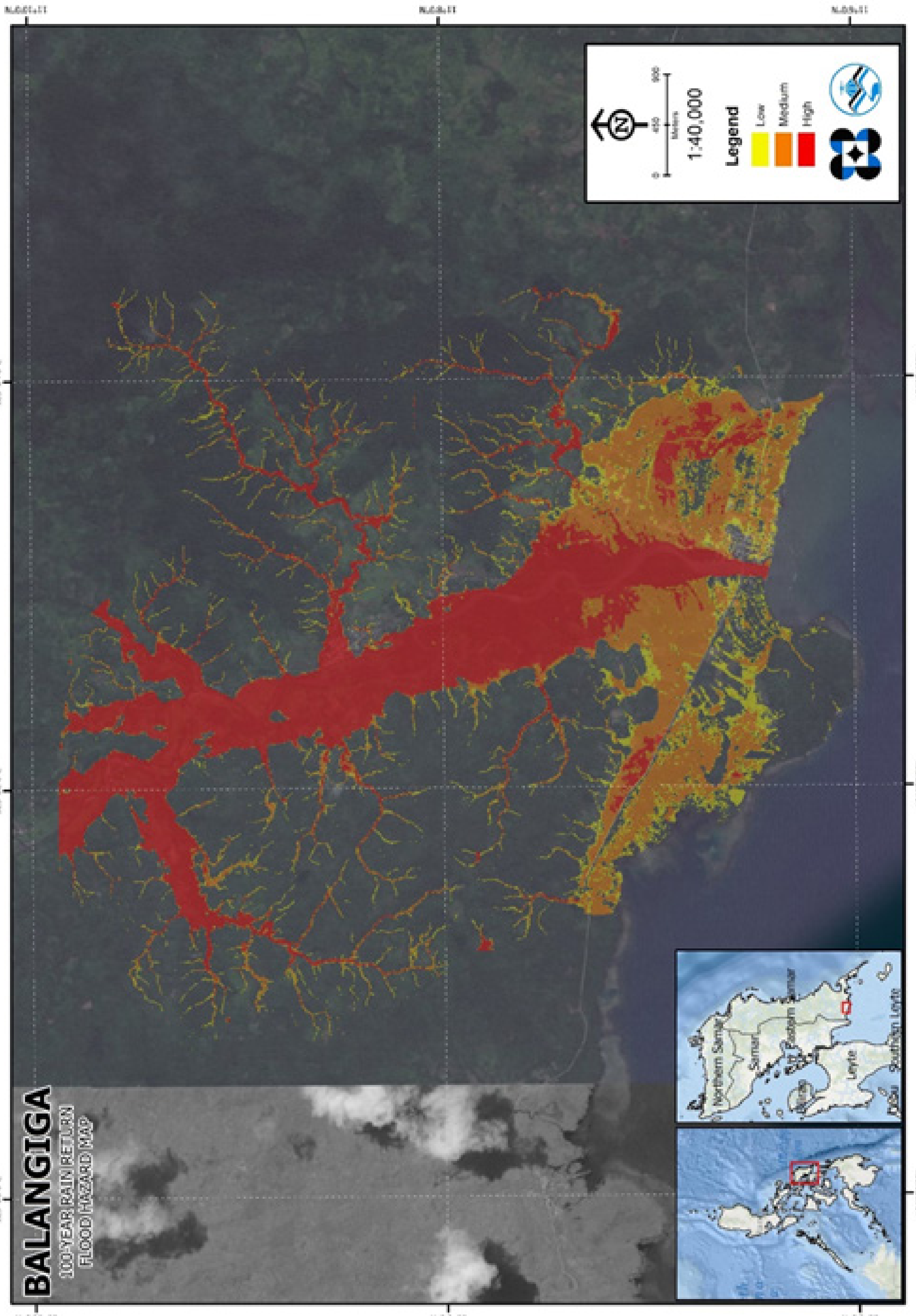


Figure 70. 100-year flood hazard map for the Balangiga Floodplain

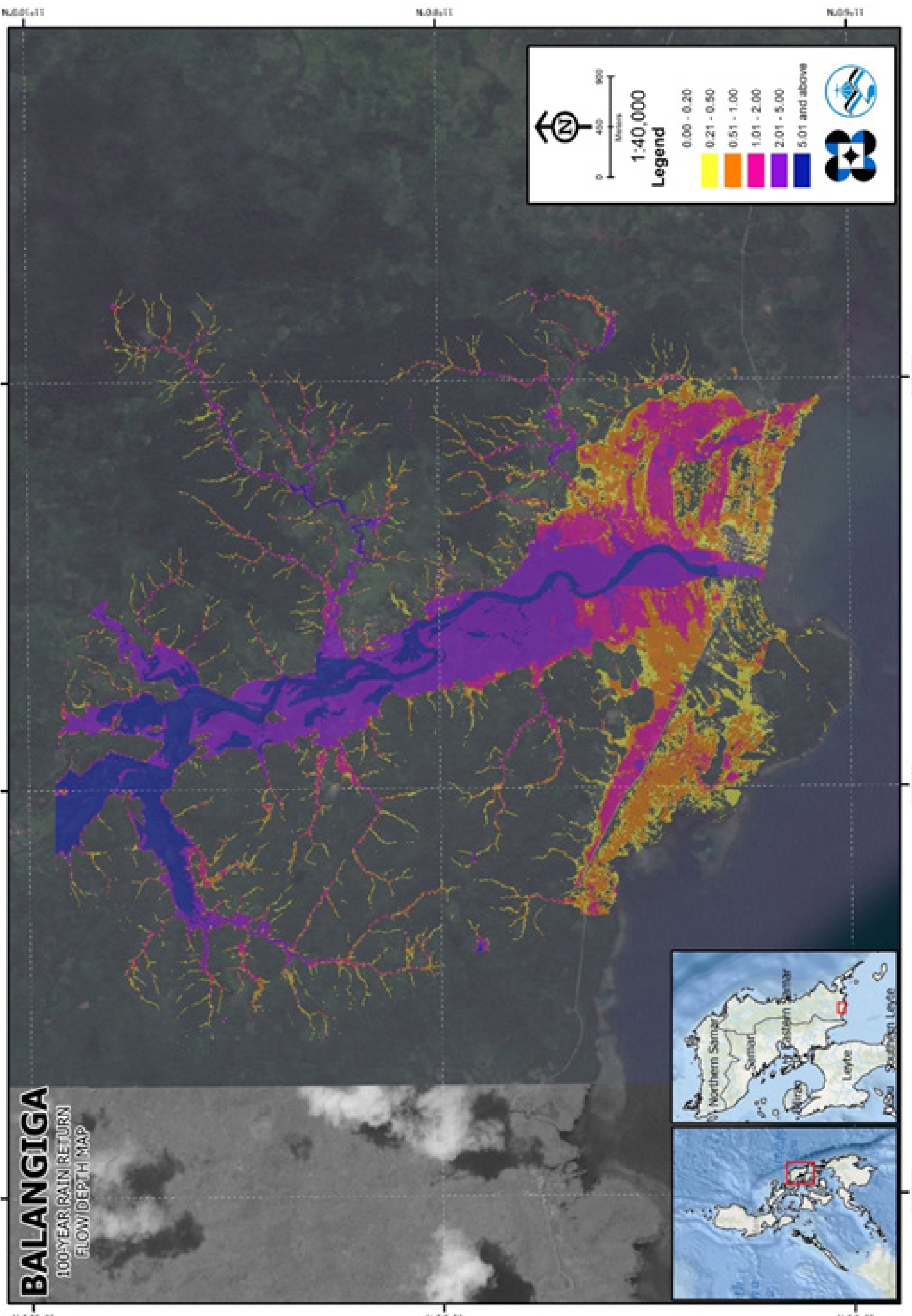


Figure 71. 100-year flow depth map for the Balangiga Floodplain

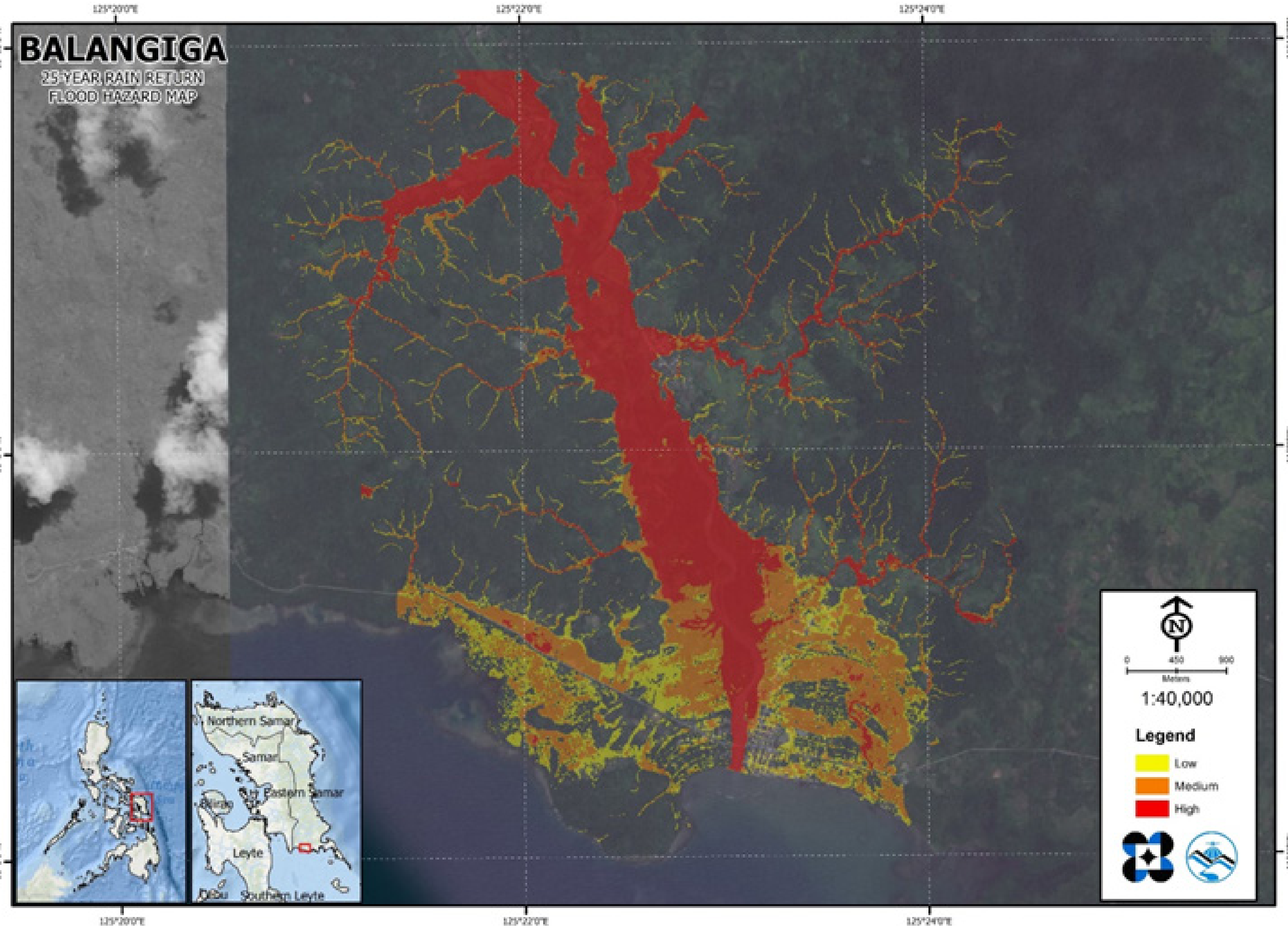


Figure 72. 25-year flood hazard map for the Balangiga Floodplain

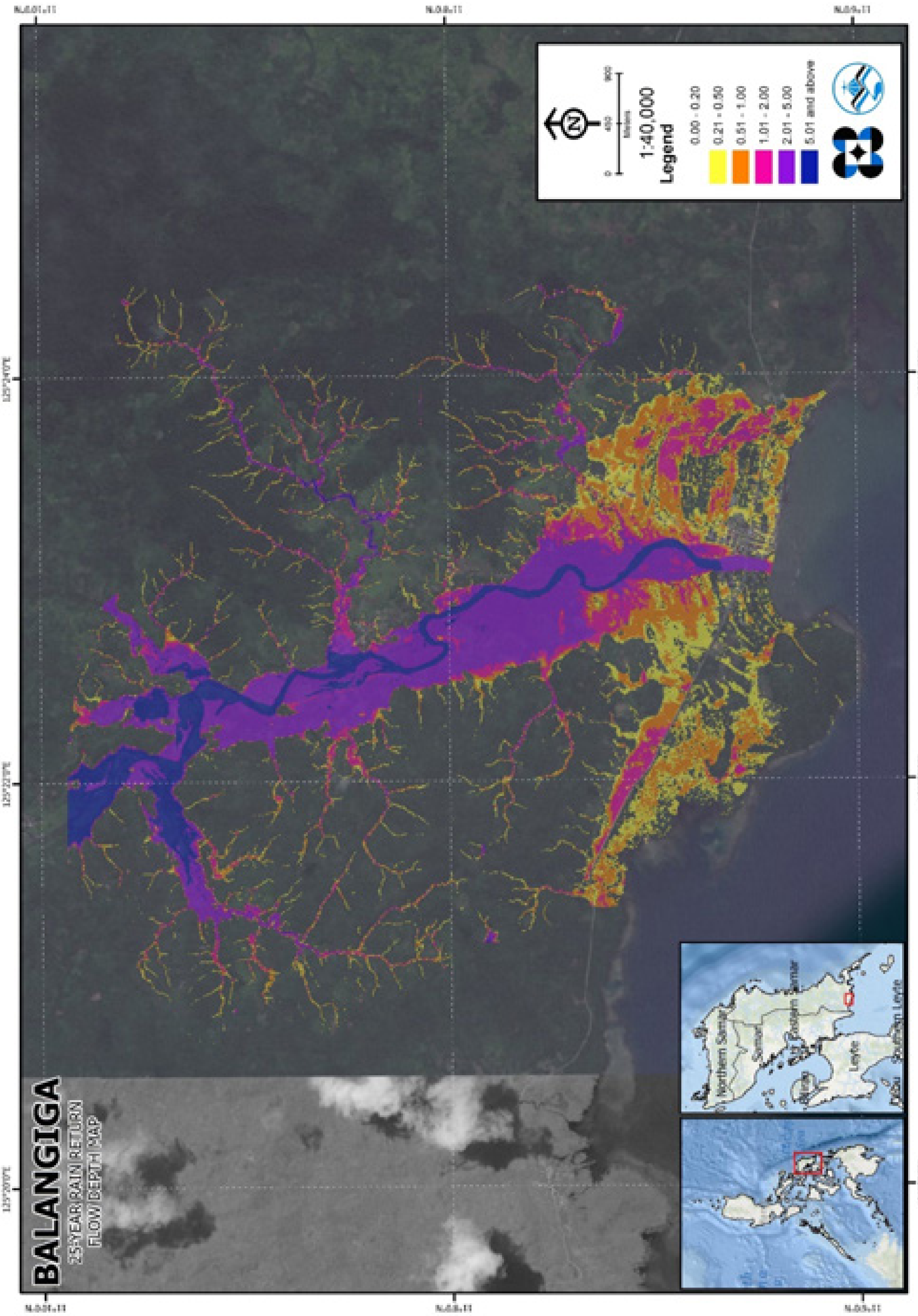


Figure 73. 25-year flow depth map for the Balangiga Floodplain

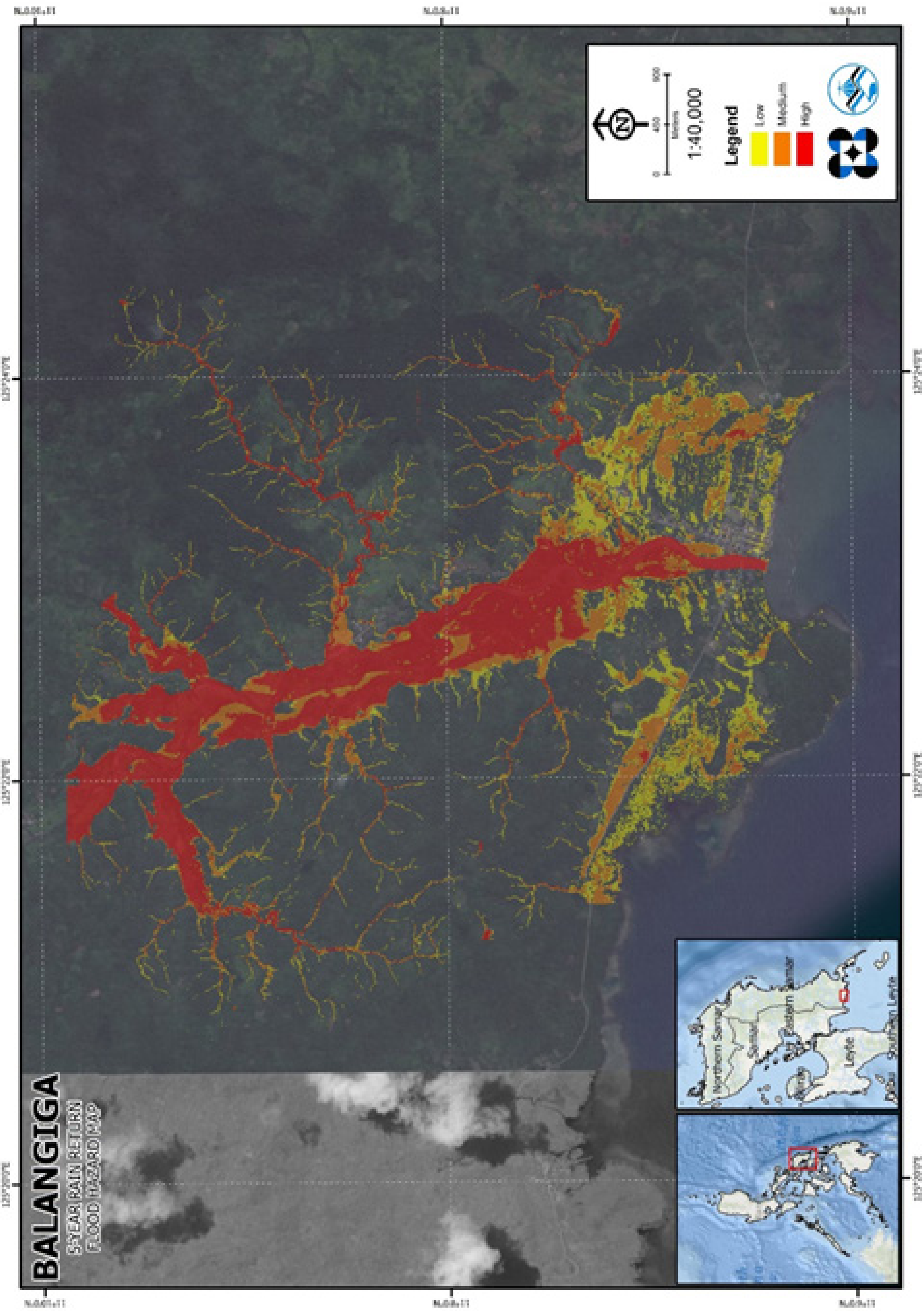


Figure 74. 5-year flood hazard map for the Balangiga Floodplain

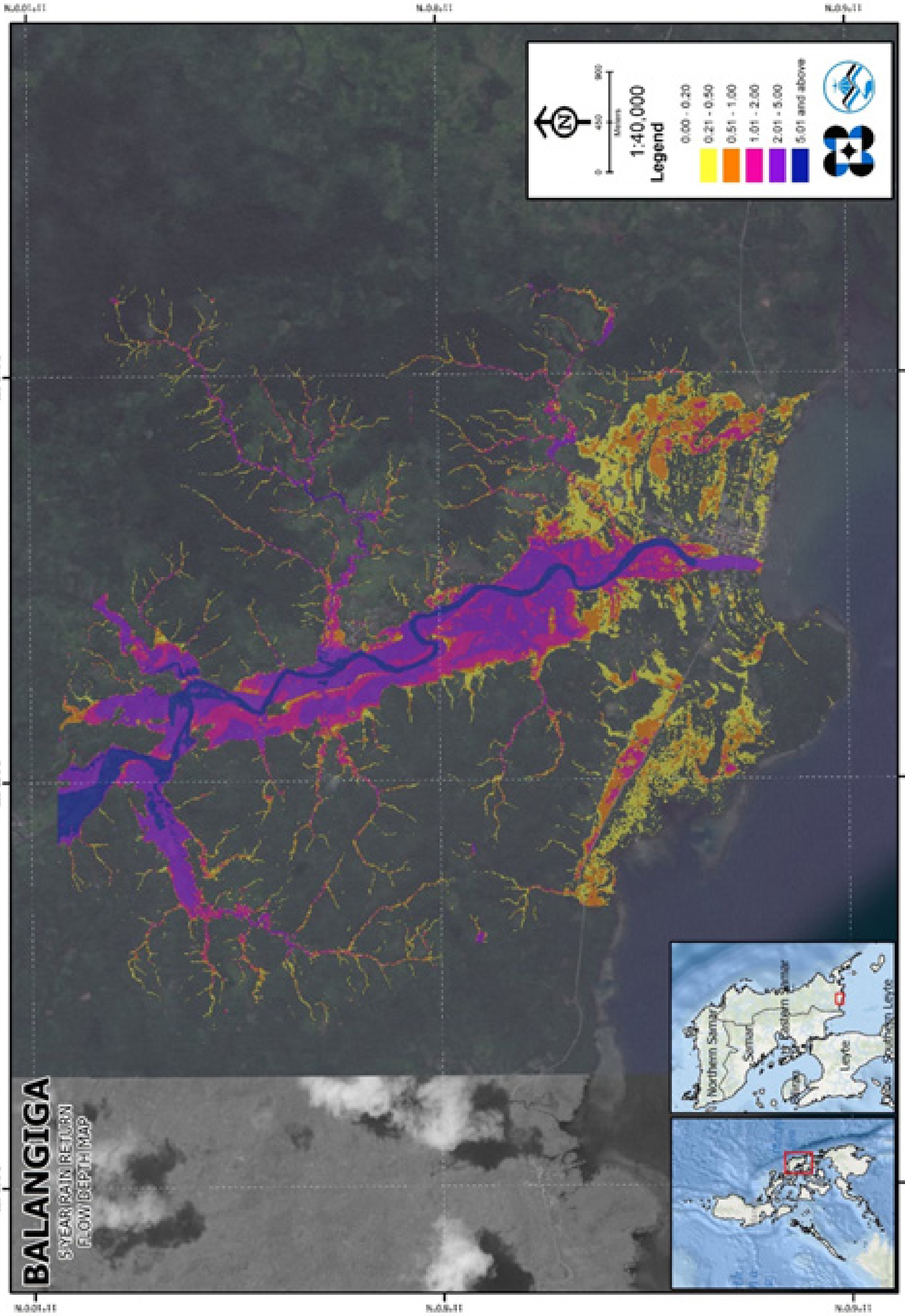


Figure 75. 5-year flow depth map for the Balangiga Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Balangiga River Basin are listed below. Only the Municipality of Balangiga, consisting of nine (9) barangays, is expected to experience flooding when subjected to the available rainfall return period scenarios (i.e., 5-year, 25-year, and 100-year).

For the 5-year return period, 4.12% of the Municipality of Balangiga, with an area of 627.97 sq. km., will experience flood levels of less 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.25%, 0.26%, 0.36%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 and Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected Areas in Balangiga, Eastern Samar during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Balangiga (in sq. km.)				
	Barangay Poblacion I	Barangay Poblacion II	Barangay Poblacion III	Barangay Poblacion IV	Barangay Poblacion V
0.03-0.20	2.68	0.34	0.57	0.16	0.54
0.21-0.50	0.12	0.21	0.28	0.067	0.17
0.51-1.00	0.095	0.083	0.25	0.093	0.072
1.01-2.00	0.11	0.14	0.044	0.039	0.019
2.01-5.00	0.2	0.12	0.026	0	0.051
> 5.00	0.083	0.064	0.0002	0	0.0036

Table 36. Affected Areas in Balangiga, Eastern Samar during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Balangiga (in sq. km.)			
	Barangay Poblacion VI	Cansumangcay	San Miguel	Santa Rosa
0.03-0.20	0.064	4.42	6.7	10.4
0.21-0.50	0.0074	0.12	0.95	0.35
0.51-1.00	0.0002	0.068	0.55	0.36
1.01-2.00	0.000041	0.049	0.5	0.75
2.01-5.00	0	0.044	0.48	1.35
> 5.00	0	0.0013	0.054	0.53

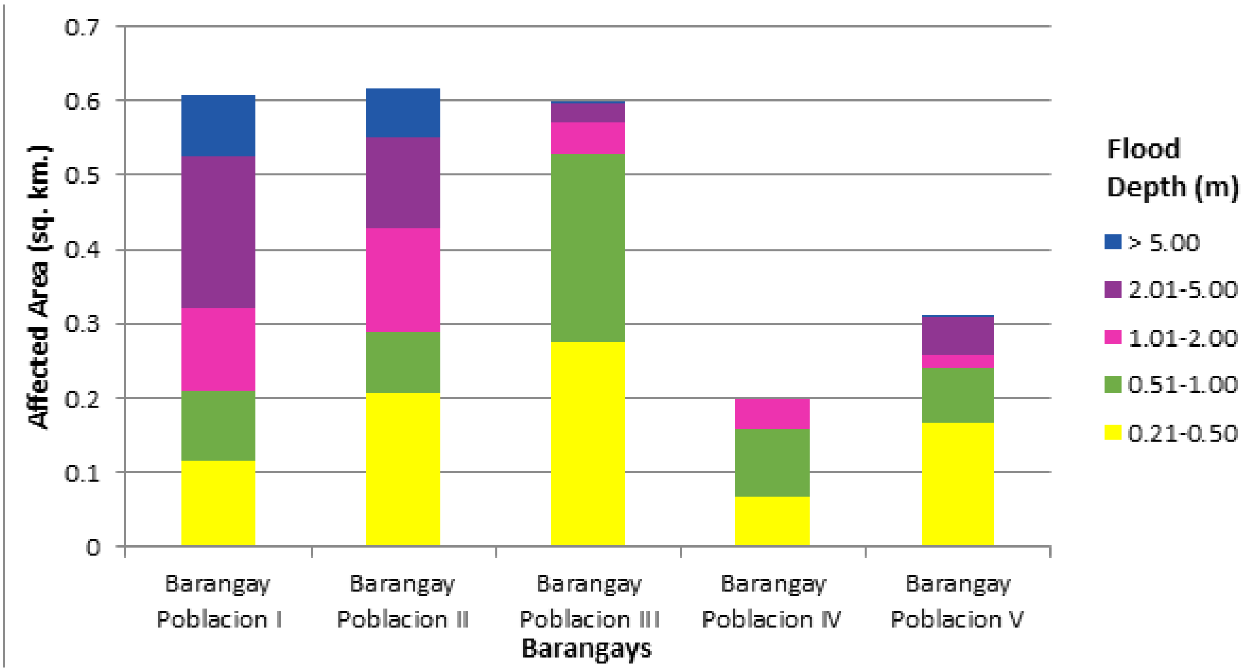


Figure 76. Affected Areas in Balangiga, Eastern Samar during a 5-Year Rainfall Return Period

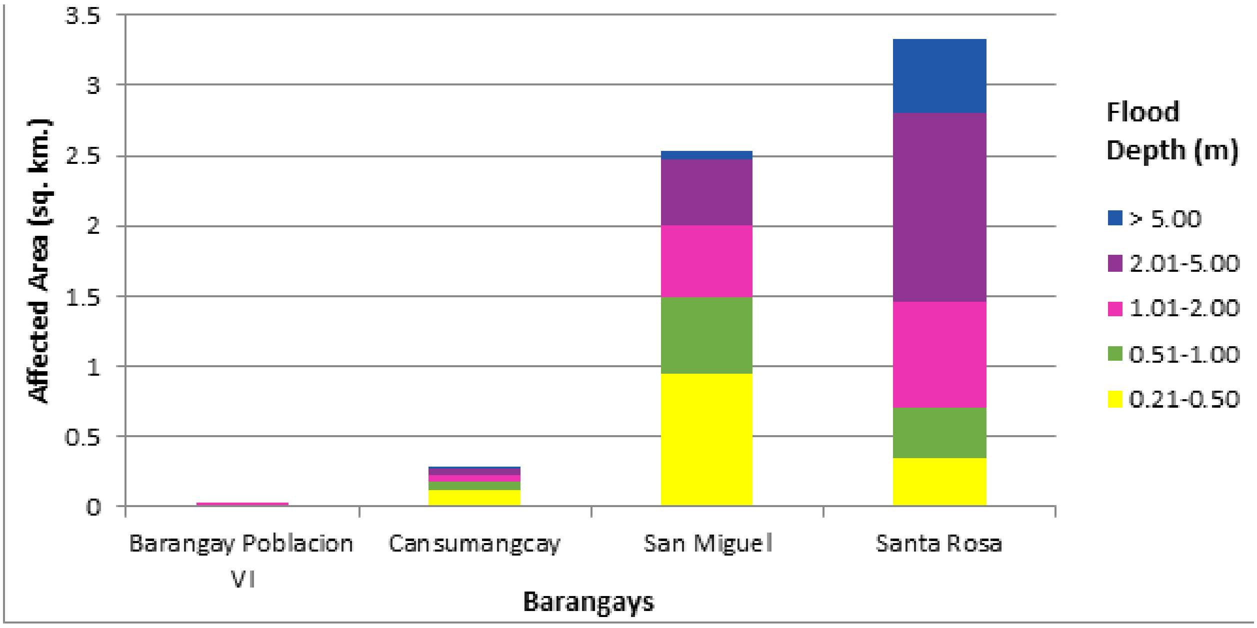


Figure 77. Affected Areas in Balangiga, Eastern Samar during a 5-Year Rainfall Return Period

For the 25-year return period, 3.84% of the Municipality of Balangiga, with an area of 627.97 sq. km., will experience flood levels of less 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.34%, 0.24%, 0.49%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected Areas in Balangiga, Eastern Samar during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Balangiga (in sq. km.)				
	Barangay Poblacion I	Barangay Poblacion II	Barangay Poblacion III	Barangay Poblacion IV	Barangay Poblacion V
0.03-0.20	2.61	0.11	0.46	0.095	0.38
0.21-0.50	0.13	0.13	0.2	0.051	0.2
0.51-1.00	0.083	0.26	0.31	0.11	0.15
1.01-2.00	0.11	0.15	0.16	0.097	0.057
2.01-5.00	0.27	0.24	0.033	0.0042	0.047
> 5.00	0.091	0.068	0.0006	0	0.015

Table 38. Affected Areas in Balangiga, Eastern Samar during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Balangiga (in sq. km.)			
	Barangay Poblacion VI	Cansumangcay	San Miguel	Santa Rosa
0.03-0.20	0.052	4.36	5.91	10.14
0.21-0.50	0.017	0.14	1.06	0.35
0.51-1.00	0.0027	0.076	0.86	0.28
1.01-2.00	0.000041	0.063	0.47	0.42
2.01-5.00	0	0.057	0.87	1.58
> 5.00	0	0.0025	0.066	0.97

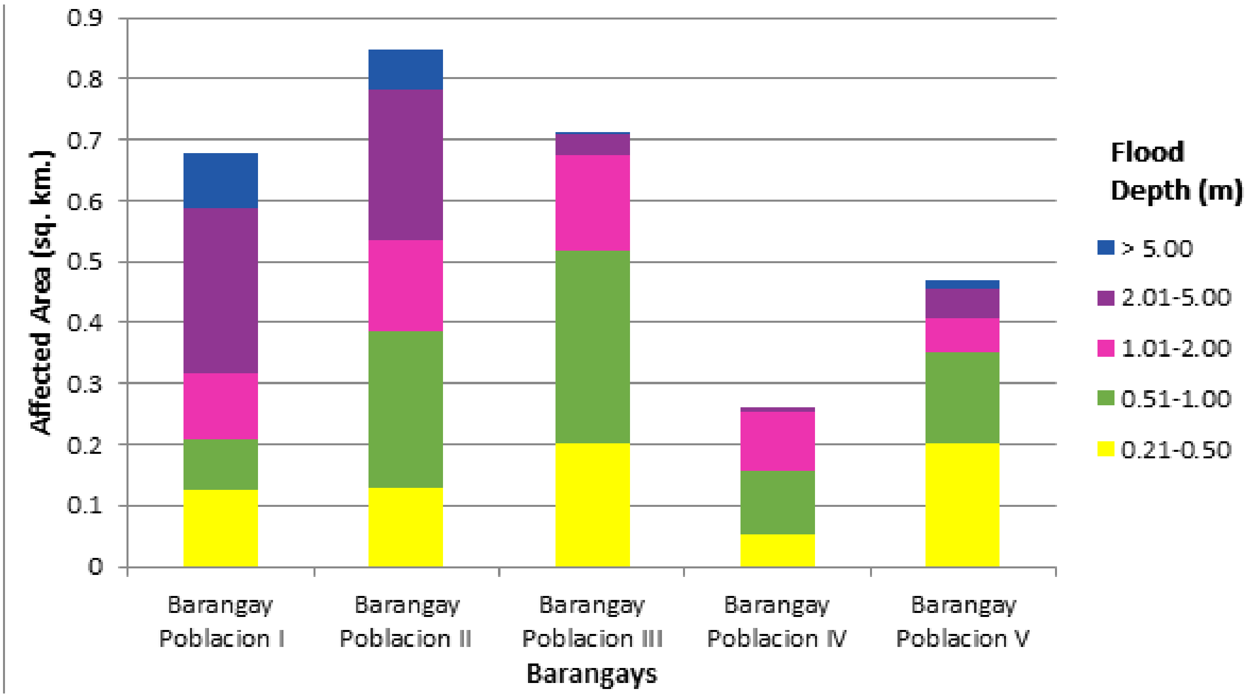


Figure 78. Affected Areas in Balangiga, Eastern Samar during a 25-Year Rainfall Return Period

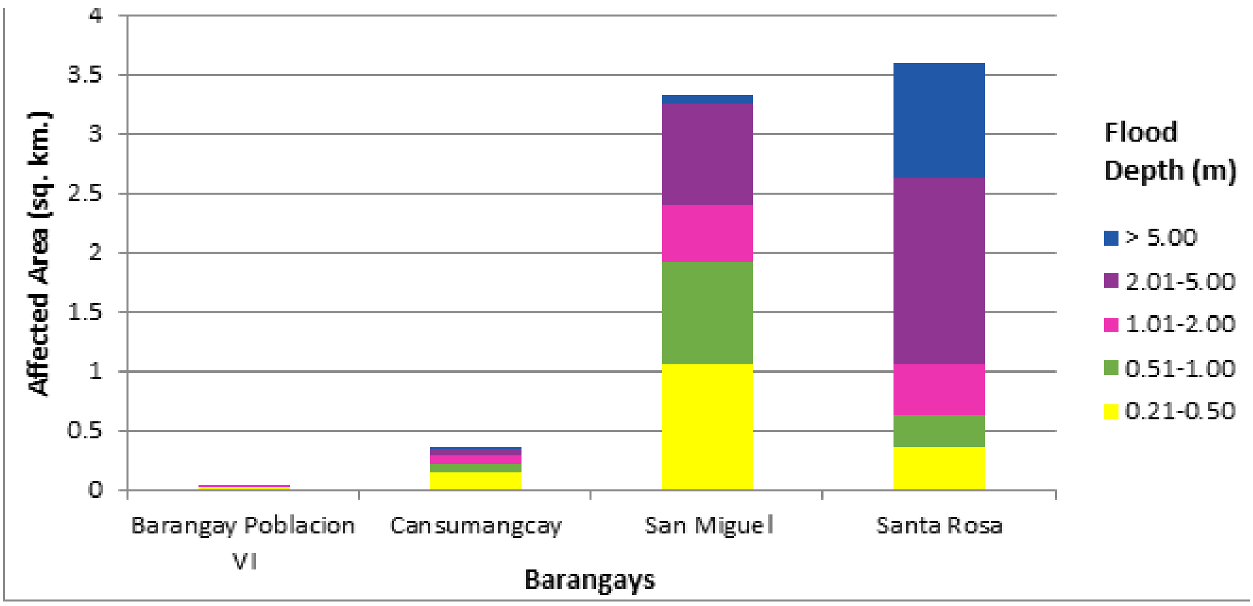


Figure 79. Affected Areas in Balangiga, Eastern Samar during a 25-Year Rainfall Return Period

For the 100-year return period, 3.84% of the Municipality of Balangiga, with an area of 627.97 sq. km., will experience flood levels of less 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.34%, 0.24%, 0.49%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 39-40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected Areas in Balangiga, Eastern Samar during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Balangiga (in sq. km.)				
	Barangay Poblacion I	Barangay Poblacion II	Barangay Poblacion III	Barangay Poblacion IV	Barangay Poblacion V
0.03-0.20	2.57	0.045	0.39	0.047	0.2
0.21-0.50	0.14	0.049	0.14	0.041	0.18
0.51-1.00	0.082	0.17	0.29	0.079	0.27
1.01-2.00	0.091	0.34	0.3	0.17	0.12
2.01-5.00	0.3	0.28	0.06	0.02	0.063
> 5.00	0.11	0.072	0.001	0	0.019

Table 40. Affected Areas in Balangiga, Eastern Samar during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Balangiga (in sq. km.)			
	Barangay Poblacion VI	Cansumangcay	San Miguel	Santa Rosa
0.03-0.20	0.043	4.31	5.53	9.93
0.21-0.50	0.017	0.16	0.82	0.37
0.51-1.00	0.012	0.082	1.12	0.27
1.01-2.00	0.0013	0.069	0.71	0.35
2.01-5.00	0	0.066	0.95	1.35
> 5.00	0	0.0043	0.11	1.46

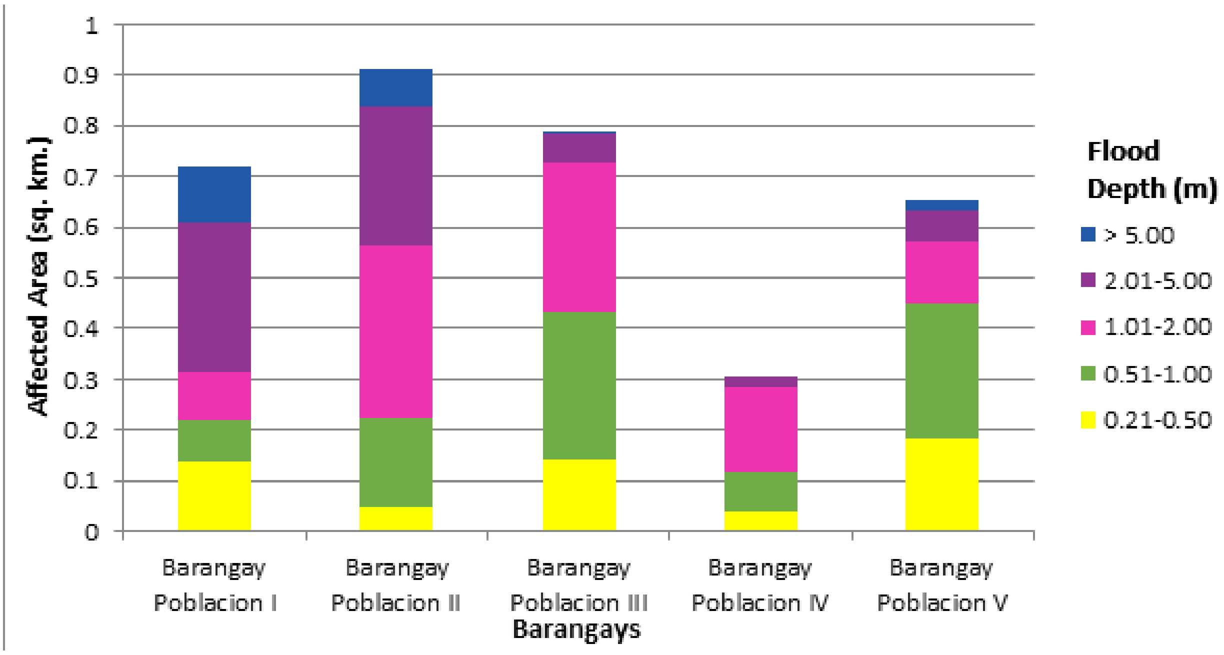


Figure 80. Affected Areas in Balangiga, Eastern Samar during a 100-Year Rainfall Return Period

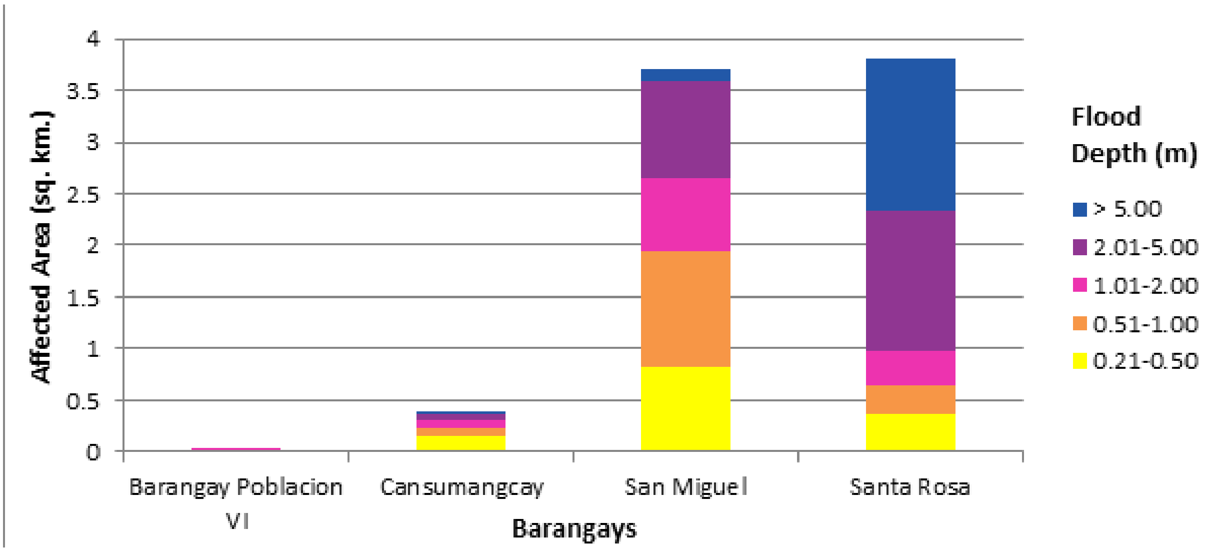


Figure 81. Affected Areas in Balangiga, Eastern Samar during a 100-Year Rainfall Return Period

Among the barangays in the Municipality of Balangiga, Sta. Rosa is projected to have the highest percentage of area that will experience flood levels, at 2.19%. Meanwhile, San Miguel posted the second highest percentage of area that may be affected by flood depths, at 1.47%.

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

Table 41. 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	2.29	2.29	1.92
Medium	2.45	3.12	3.77
High	3.87	4.95	5.72

Of the fourteen (14) identified educational institutions in the Balangiga floodplain, six (6) were assessed to be exposed to Low-level flooding during a 5-year scenario; while only one (1) school was assessed to be exposed to Medium-level flooding in the same scenario. In a 25-year scenario, three (3) schools were assessed to be exposed to Low-level flooding, six (6) were assessed to be exposed to Medium-level flooding, and two (2) were assessed to be exposed to High-level flooding. In a 100-year scenario, five (5) institutions were assessed to be subjected to Low-level flooding and six (6) schools to Medium-level flooding. In the same scenario, one (1) school was assessed to be exposed to High-level flooding. See Annex 12 for a detailed enumeration and assessment of the educational institutions in the Balangiga floodplain.

Only one (1) medical institution was identified in the Balangiga floodplain. In the 25-year scenario, it was assessed to be exposed to Low-level flooding. And in the 100-year scenario, it was assessed to be subjected to Medium-level flooding. See Annex 13 for the assessment of this medical institution in the Balangiga floodplain.

5.11 Flood Validation

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

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

The validation personnel then went to the specified points identified in the river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area. The flood validation data were obtained on April 27-29, 2016.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 84.

The flood validation consists of two hundred and thirty-eight (238) points, randomly selected all over the Balangiga floodplain. It has an RMSE value of 1.77 and 1.108, for the 5-year and 100-year return periods, respectively. Table 42 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

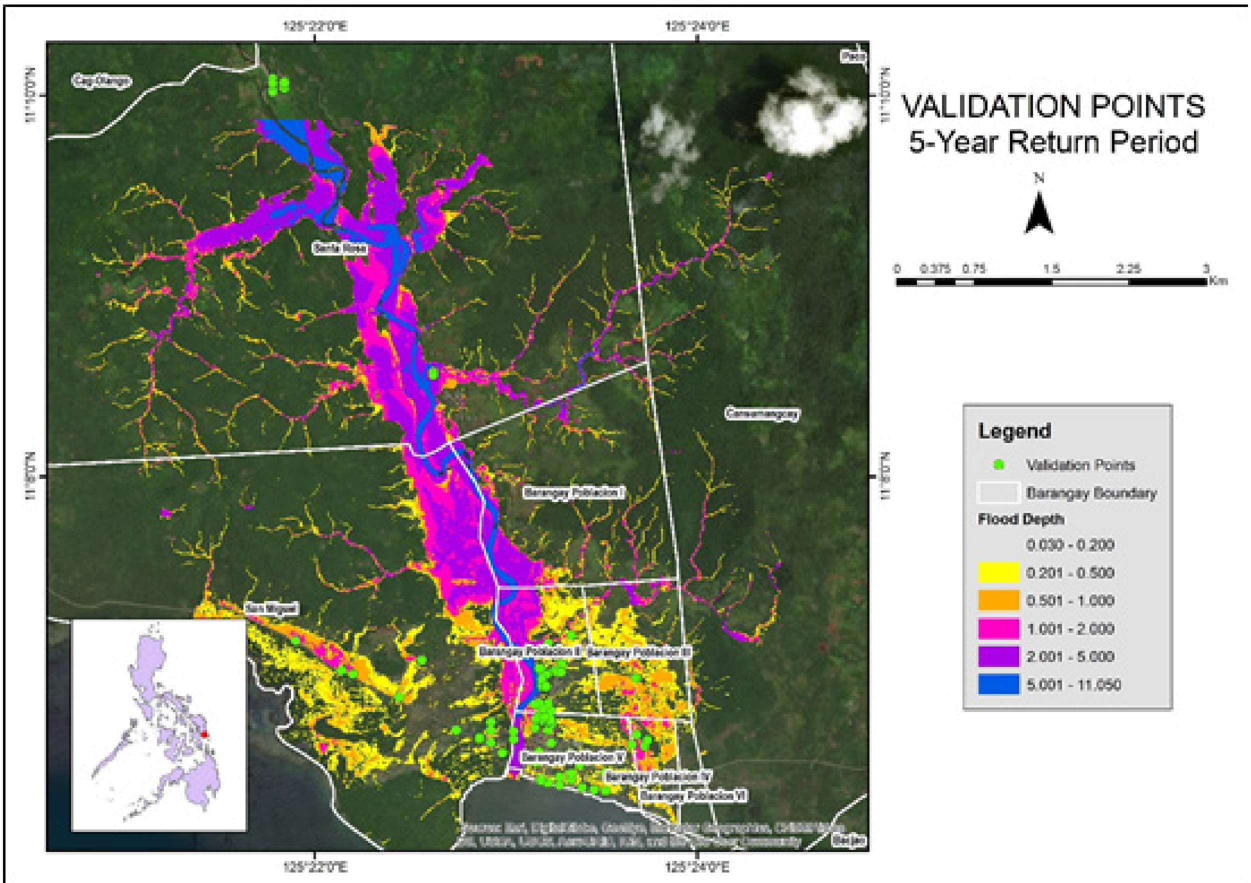


Figure 82. Validation points for 5-year flood depth map of the Balangiga Floodplain

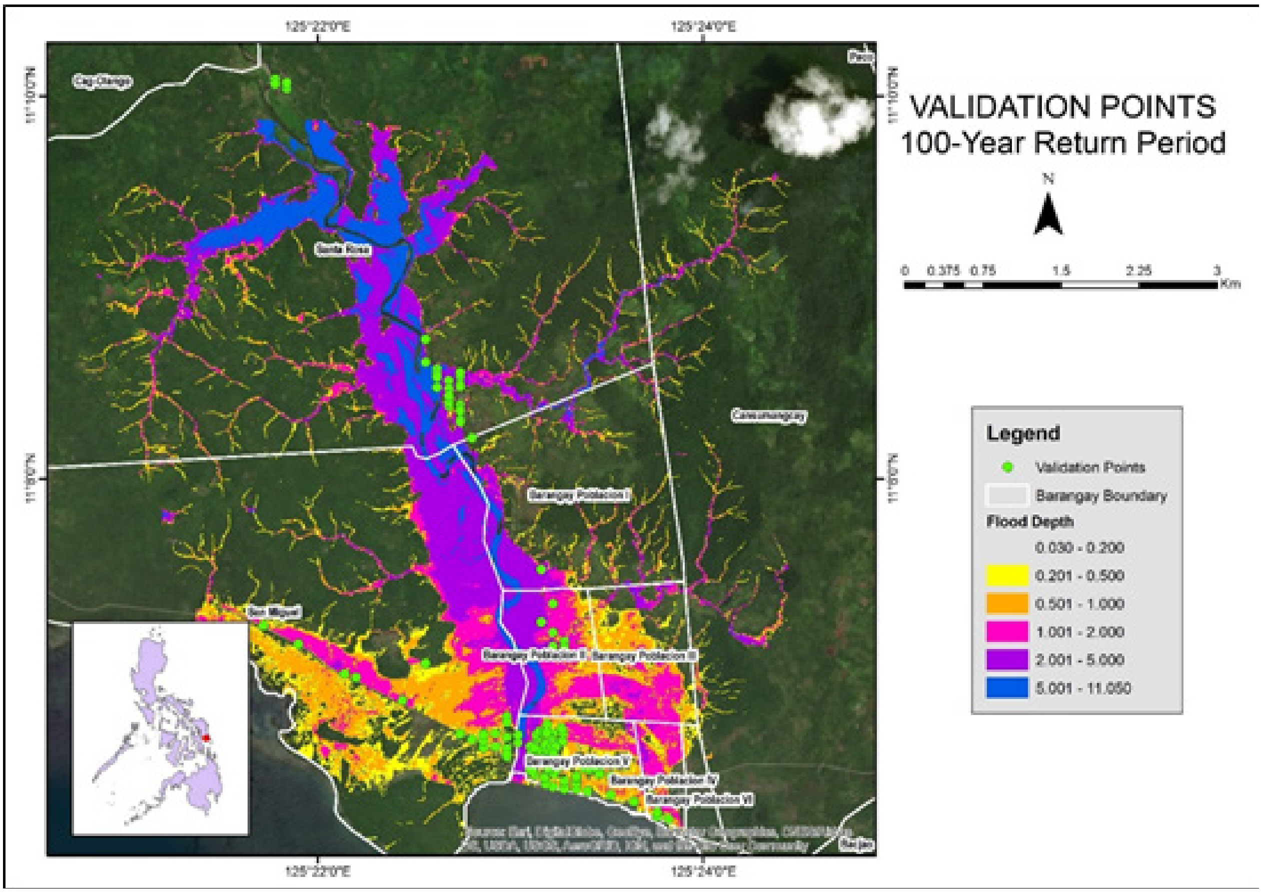


Figure 83. Validation points for a 100-year flood depth map of the Balangiga Floodplain

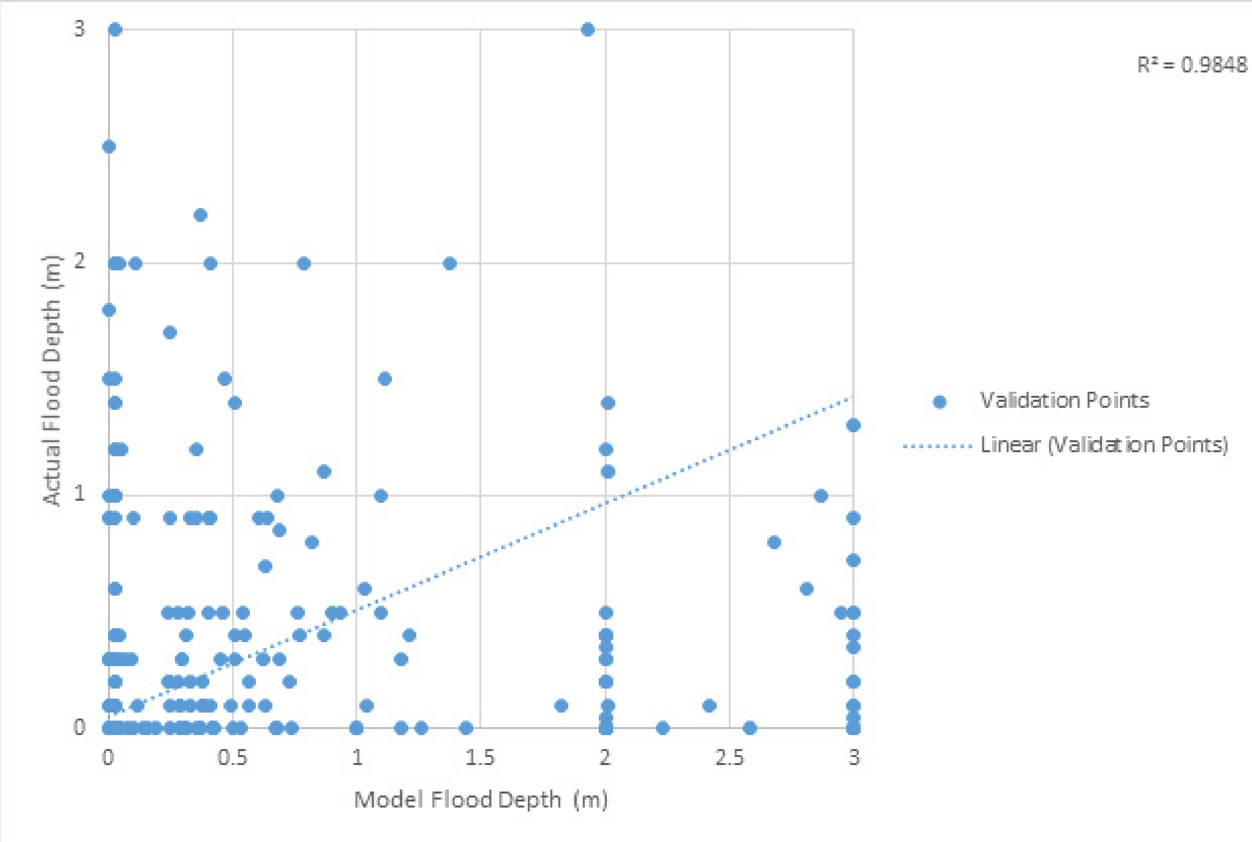


Figure 84. Flood map depth vs. actual flood depth

Table 42. Actual flood depth vs. simulated flood depth in Balangiga

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	36	26	12	20	18	1	113
0.21-0.50	16	9	11	11	6	0	53
0.51-1.00	11	5	6	2	6	3	33
1.01-2.00	14	4	3	3	5	1	30
2.01-5.00	3	2	0	1	0	2	8
> 5.00	0	0	0	0	0	1	1
Total	80	46	32	37	35	8	238

The overall accuracy generated by the flood model is estimated at 23.11%, with fifty-five (55) points correctly matching the actual flood depths. There were seventy-one (71) points estimated one (1) level above and below the correct flood depths, and forty-five (45) points and sixty-seven (67) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of one hundred and twenty-four (124) points were overestimated, while a total of fifty-nine (59) points were underestimated in the modeled flood depths of the Balangiga River Basin. Table 43 presents the summary of the Accuracy Assessment in the Balangiga River Basin flood depth map.

Table 43. Summary of Accuracy Assessment in Balangiga River Basin survey

	No. of Points	**%**
Correct	55	23.11
Overestimated	124	52.10
Underestimated	59	24.79
Total	238	100

REFERENCES

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Balangiga Floodplain Survey

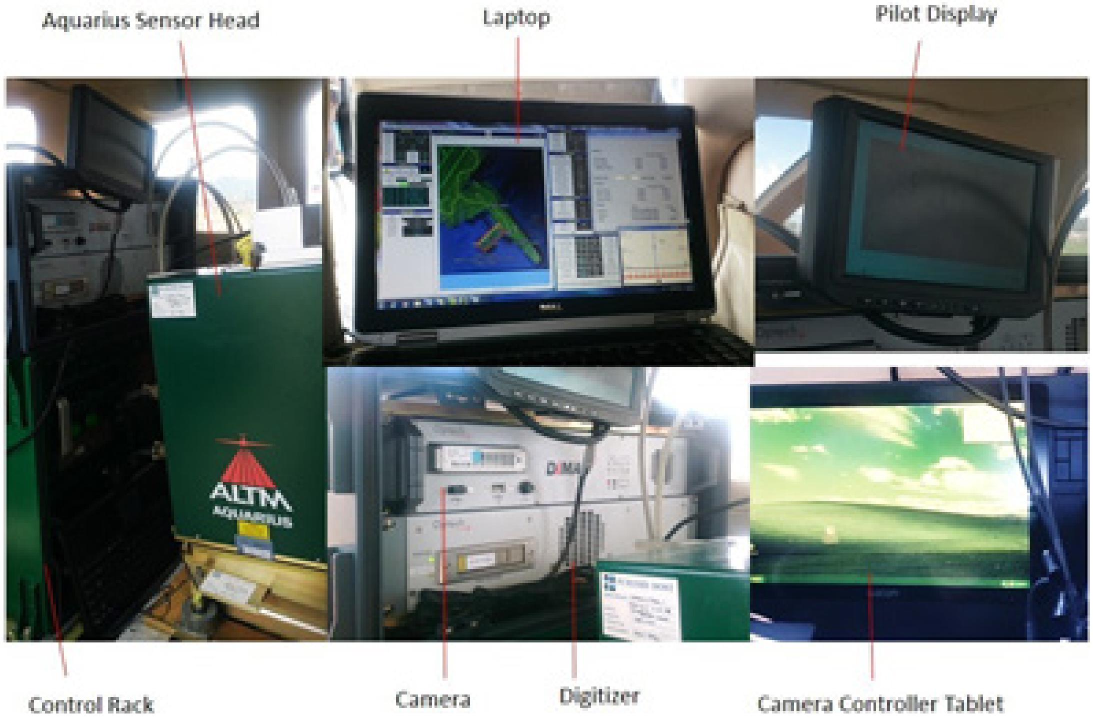


Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

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

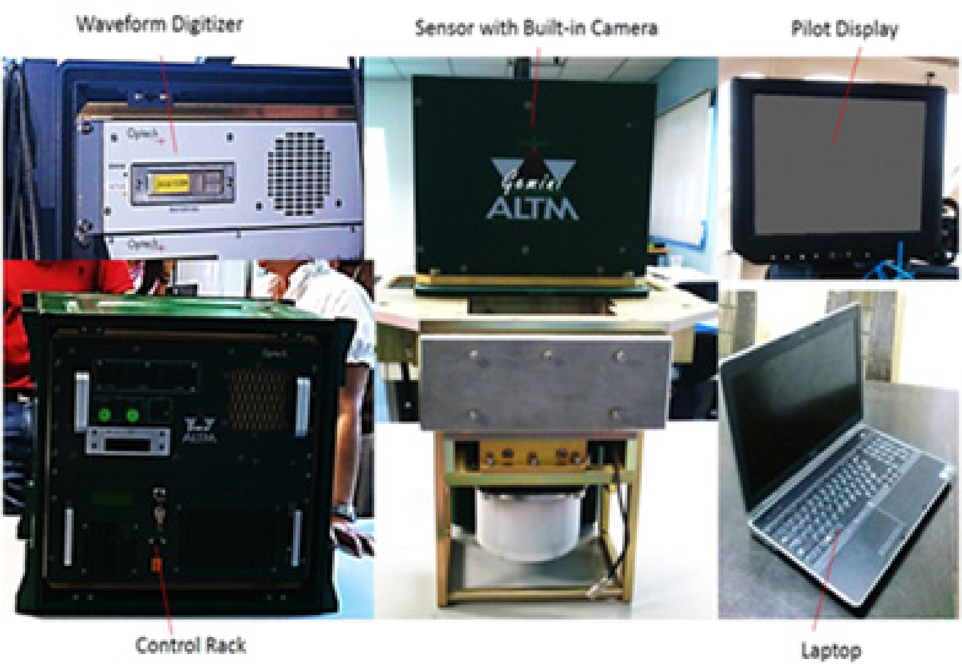


Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the Gemini Sensor

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

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

1. SMR-58

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

		Province: **SAMAR (WESTERN SAMAR)**			
		Station Name: **SMR-58**			
		Order: **2nd**			
Island:	**VISAYAS**	Barangay:	**SERUM**		
Municipality:	**BASEY**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**11° 17' 55.05617"**	Longitude:	**125° 7' 51.16145"**	Ellipsoidal Hgt:	**6.30062 m.**
		WGS84 Coordinates			
Latitude:	**11° 17' 50.78580"**	Longitude:	**125° 7' 56.31100"**	Ellipsoidal Hgt:	**68.72300 m.**
		PTM / PRS92 Coordinates			
Northing:	**1249361.531 m.**	Easting:	**514288.239 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**1,249,768.75**	Easting:	**732,600.57**	Zone:	**51**

Location Description

SMR-58
From Basey proper, travel about 20 km. north going to Brgy. Serum. From National Road, travel another 1 km. north going to Brgy. Serum. The NAMRIA was established inside the Serum Elementary School, 10 m. east from the school gate, and 15 m. north from the school building. The School site was near the River about 30 m. north. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-58; 2007; NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0327**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 SMR-58

2. SME-3050

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **EASTERN SAMAR**	
	Station Name: **SME-3050**	
	Order: **4th**	
Island: **VISAYAS** Municipality: **GUIUAN**		Barangay: **POBLACION**
	PRS92 Coordinates	
Latitude: **11° 2' 6.48019"**	Longitude: **125° 43' 25.69474"**	Ellipsoidal Hgt: **-8.00900 m.**
	WGS84 Coordinates	
Latitude: **11° 2' 2.32770"**	Longitude: **125° 43' 30.86158"**	Ellipsoidal Hgt: **56.51100 m.**
	PTM Coordinates	
Northing: **1220310.599 m.**	Easting: **579092.375 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,221,142.79**	Easting: **797,631.78**	Zone: **51**

Location Description

SME-3050

Station is located 15 m W of the NE corner of Central Elem. School of Poblacion, Guiuan. Mark is the head of a 4 in. copper nail set flushed on a 0.20 m x 0.20 m x 1.00 m cement putty with inscriptions, "SME-3050, 2008, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1295**

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

9906062014164227

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 SME-3050

3. SME-3067

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **EASTERN SAMAR**
Station Name: **SME-3067**
Order: **4th**

Island: **VISAYAS**		Barangay: **POBLACION WARD 8**
Municipality: **GUIUAN**		
	PRS92 Coordinates	
Latitude: **11° 2' 8.60288"**	Longitude: **125° 43' 22.71877"**	Ellipsoidal Hgt: **-7.96600 m.**
	WGS84 Coordinates	
Latitude: **11° 2' 4.45017"**	Longitude: **125° 43' 27.88556"**	Ellipsoidal Hgt: **56.55000 m.**
	PTM Coordinates	
Northing: **1220375.601 m.**	Easting: **579001.882 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,221,207.23**	Easting: **797,540.79**	Zone: **51**

Location Description

SME-3067

Station is located about 165 m SW of the NE corner of Central Elem. School of Guiuan and about 150 m SW of SME-3050. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument embedded in the ground with inscriptions, "SME-3067, 2008, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1296**

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

9906062014164253

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 SME-3067

4. SE-37

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

May 02, 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: **EASTERN SAMAR** Station Name: **SE-37**	
Island: **VISAYAS**	Municipality: **QUINAPONDAN**	Barangay: **SANTO NIÑO**
Elevation: **1.3583 m.**	Order: **1st Order**	Datum:

Location Description

SE-37 is in the Province of Eastern Samar, town of Quinapondan, Brgy. Sto Nino along right side of the National highway. It is located beside Km 995, positioned approximately 1.00m S and 4.90m from the centerline of the national highway. Station mark is the head of 4" copper nail centered on a 0.30m x 0.30m concrete block and mark with "SE-37, 2007, NAMRIA."

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8796083 A**
T.N.:	**2014-1028**

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

9905022014154806

CIP/4701/12/09/614

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 SE-37

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

1. SME-3074

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Satellite Available
SME3074 — SE37 (B5)	SME3074	SE37	6/2/2014 7:47:33 AM	6/2/2014 12:39:00 PM	Fixed	0.007	0.003	-0.288	0.266	-1.054	175°52'59"	1.112	-0.063	GPS: 15 GLONASS: 11 Galileo: 0 QZSS: 0
SE37 — PTAC (B4)	PTAC	SE37	6/2/2014 7:59:44 AM	6/2/2014 11:59:43 AM	Fixed	0.008	0.020	-47131.604	-30238.524	-12795.297	103°04'25"	57441.188	-16.490	GPS: 12 GLONASS: 10 Galileo: 0 QZSS: 0
SME3074 — PTAC (B6)	PTAC	SME3074	6/2/2014 7:59:44 AM	6/2/2014 11:59:43 AM	Fixed	0.008	0.020	-47131.323	-30238.778	-12794.238	103°04'21"	57440.856	-16.413	GPS: 14 GLONASS: 10 Galileo: 0 QZSS: 0

Vector Components (Mark to Mark)

From:	SME3074				
Grid		Local		Global	
Easting	774710.019 m	Latitude	N11°07'59.28294"	Latitude	N11°07'55.08754"
Northing	1231788.008 m	Longitude	E125°30'54.00701"	Longitude	E125°30'59.16732"
Elevation	5.508 m	Height	5.541 m	Height	69.310 m

To:	SE37				
Grid		Local		Global	
Easting	774710.109 m	Latitude	N11°07'59.24685"	Latitude	N11°07'55.05146"
Northing	1231786.899 m	Longitude	E125°30'54.00964"	Longitude	E125°30'59.16995"
Elevation	5.446 m	Height	5.478 m	Height	69.247 m

Vector					
ΔEasting	0.089 m	NS Fwd Azimuth	175°52'59"	ΔX	-0.154 m
ΔNorthing	-1.109 m	Ellipsoid Dist.	1.112 m	ΔY	0.078 m
ΔElevation	-0.063 m	ΔHeight	-0.063 m	ΔZ	-1.100 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°08'25"	σ ΔX	0.003 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

Figure A-3.1 Baseline Processing Report - A

2. SE-37

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Satellite Available
SME3074 — SE37 (B5)	SME3074	SE37	6/2/2014 7:47:33 AM	6/2/2014 12:39:00 PM	Fixed	0.007	0.003	-0.288	0.266	-1.054	175°52'59"	1.112	-0.063	GPS: 15 GLONASS: 11 Galileo: 0 QZSS: 0
SE37 — PTAC (B4)	PTAC	SE37	6/2/2014 7:59:44 AM	6/2/2014 11:59:43 AM	Fixed	0.008	0.020	-47131.604	-30238.524	-12796.297	103°04'25"	57441.188	-16.490	GPS: 12 GLONASS: 10 Galileo: 0 QZSS: 0
SME3074 — PTAC (B6)	PTAC	SME3074	6/2/2014 7:59:44 AM	6/2/2014 11:59:43 AM	Fixed	0.008	0.020	-47131.323	-30238.778	-12794.238	103°04'21"	57440.856	-16.413	GPS: 14 GLONASS: 10 Galileo: 0 QZSS: 0

Vector Components (Mark to Mark)

From:	SME3074				
Grid		Local		Global	
Easting	774710.019 m	Latitude	N11°07'59.28294"	Latitude	N11°07'55.08754"
Northing	1231788.008 m	Longitude	E125°30'54.00701"	Longitude	E125°30'59.16732"
Elevation	5.509 m	Height	5.541 m	Height	69.310 m

To:	SE37				
Grid		Local		Global	
Easting	774710.109 m	Latitude	N11°07'59.24685"	Latitude	N11°07'55.05146"
Northing	1231786.899 m	Longitude	E125°30'54.00964"	Longitude	E125°30'59.16995"
Elevation	5.446 m	Height	5.478 m	Height	69.247 m

Vector					
ΔEasting	0.089 m	NS Fwd Azimuth	175°52'59"	ΔX	-0.154 m
ΔNorthing	-1.109 m	Ellipsoid Dist.	1.112 m	ΔY	0.078 m
ΔElevation	-0.063 m	ΔHeight	-0.063 m	ΔZ	-1.100 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°08'25"	σ ΔX	0.003 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

Figure A-3.2 Baseline Processing Report - B

Annex 4. The LIDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Supervising SRS	LOVELY GRACIA ACUÑA	UP-TCAGP
	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
		ENGR. GEROME HIPOLITO	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	FAITH JOY SABLE	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
		GRACE SINADJAN	UP-TCAGP
		JONATHAN ALMALVEZ	UP-TCAGP
LiDAR Operation	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RANDY SISON	PHILIPPINE AIR FORCE (PAF)
		SSG. RAYMUND DOMINE	PAF
	Pilot	CAPT. JACKSON JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. ALBERT PAUL LIM	AAC
			AAC

Annex 5. Data Transfer Sheet for Balangiga Floodplain

DATA TRANSFER SHEET
06/10/2014(Samar on-going)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5/15/2014	1458A	3BLK35B135A	AQUARIUS	na	730	2.24	277	81.7	593	13.3	NA	14.6	1KB	1KB	6	13	Z:\Airborne_Raw\1458A
5/17/2014	1466A	3BLK35F137A	AQUARIUS	na	883	1.29	284	94.7	136/563	16	181	7.95	1KB	1KB	4	NA	Z:\Airborne_Raw\1466A
5/19/2014	1474A	3BLK35G139A	AQUARIUS	na	1484	1.61	291	80.2	599	14	218	9.7	1KB	1KB	6	NA	Z:\Airborne_Raw\1474A
5/24/2014	1494A	3BLK35GSH144A	AQUARIUS	na	812/599	1.25	282	89.2	656	14.7	162	7.64	1KB	1KB	5	NA	Z:\Airborne_Raw\1494A
5/25/2014	1498A	3BLK35HSI145A	AQUARIUS	na	1622	1.7	282	88.7	654	3.23	9.47	8.04	1KB	1KB	5	NA	Z:\Airborne_Raw\1498A
5/26/2014	1502A	3BLK35ISI46A	AQUARIUS	na	766	1.2	278	86.7	404	13.9	107	15.7	1KB	1KB	5	NA	Z:\Airborne_Raw\1502A
5/26/2014	1504A	3BLK35AIS146B	AQUARIUS	na	513/850	1.37	265	61.3	480	11.4	20.9	15.7	1KB	1KB	5	NA	Z:\Airborne_Raw\1504A
5/27/2014	1506A	3BLK33U147A	AQUARIUS	na	864	1.34	276	97.2	737	14.4	56.2/32.5	15	1KB	1KB	4	NA	Z:\Airborne_Raw\1506A
5/27/2014	1508A	3BLK33UST147B	AQUARIUS	na	249/1243	2	232	8.1/53.6	63/409	11.5	NA	15	1KB	1KB	5	NA	Z:\Airborne_Raw\1508A
5/28/2014	1510A	3BLK33TSV148A	AQUARIUS	na	815/172	1.61	269	114	534	18.5	155	6.85	1KB	1KB	5	NA	Z:\Airborne_Raw\1510A

Received from

Name C. JOAQUIN
Position
Signature

Received by

Name JOIDA F. PRIETO 6/10/14
Position SSRS
Signature

Figure A-5.1 Data Transfer Sheet for Balangiga Floodplain - A

DATA TRANSFER SHEET
6/19/2014 (Samar - Leyte)

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	
30-May-14	1520A	3BLK33VSS150A	Aquarius	NA	424/602	1.48	289	88.5	748	14	164	10.5	1KB	1KB	4	NA	X:\Airborne_Raw\1520A
31-May-14	1522A	3BLK33SS151A	Aquarius	NA	288	469KB	112	9.78/21	164/69	4.87	59.1	4.53	1KB	1KB	5	NA	X:\Airborne_Raw\1522A
1-Jun-14	1526A	3BLK33SSR152A	Aquarius	NA	456/784	1.68	277	119	403	15.5	204	8.36	1KB	1KB	6	NA	X:\Airborne_Raw\1526A
2-Jun-14	1530A	3BLK33RSQ153A	Aquarius	NA	353/605	1.48	254	30.9/80.2	555/246	15.6	165	7.88	1KB	1KB	3	NA	X:\Airborne_Raw\1530A
3-Jun-14	1534A	3BLK33QS154A	Aquarius	NA	1175	1.49	250	56.9/35.1	399/154	14.5	114/95.5	6.6	1KB	1KB	7	NA	X:\Airborne_Raw\1534A
7-Jun-14	1550A	3BLK33P158A	Aquarius	NA	657	1.03	199	52.9	na	10.8	149	7	1KB	1KB	3	NA	X:\Airborne_Raw\1550A
8-Jun-14	1554A	3BLK33PSM159A	Aquarius	NA	533/1012	1.78	257	99.8	695	14.5	27.2/59/32.2	16.4	1KB	1KB	3	NA	X:\Airborne_Raw\1554A
8-Jun-14	1556A	3BLK33MS159B	Aquarius	NA	982	1.52	291	97.2	477	15.9	216	16.4	1KB	1KB	5	NA	X:\Airborne_Raw\1556A
9-Jun-14	1558A	3BLK33J160A	Aquarius	NA	833	1.27	277	95.7	452	14.2	95.6/80.5	16.1	1KB	1KB	4	NA	X:\Airborne_Raw\1558A
9-Jun-14	1560A	3BLK33J	Aquarius	NA	1583	1.67	223	72.2	357	12.1	123	16.1	1KB	1KB	5	NA	X:\Airborne_Raw\1560A

Received from

Name O. Joaquin
Position
Signature

Received by

Name JOIDA PRIETO
Position
Signature 6/19/14

Figure A-5.2 Data Transfer Sheet for Balangiga Floodplain - B

DATA TRANSFER SHEET
Tacloban,Leyte 2/23/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
29-Jan	3727G	2BLK34U029B	GEMINI	NA	322	691	243	NA	NA	22.8	NA	4.2	1KB	1KB	206	NA	Z:\DAC\RAW DATA
30-Jan	3729G	2BLK34HJ030A	GEMINI	NA	592	0.97	243	NA	NA	20.3	NA	608	1KB	1KB	209	NA	Z:\DAC\RAW DATA
30-Jan	3731G	2BLK34LM030B	GEMINI	NA	29	NA	208	NA	NA	24.2	NA	3.19	1KB	1KB	206/209/194	NA	Z:\DAC\RAW DATA
31-Jan	3733G	2BLK33ABLK34L031A	GEMINI	NA	646	1.03	172	NA	NA	11.4	NA	3.84	1KB	1KB	239/293/293	NA	Z:\DAC\RAW DATA
5-Feb	3753G	2BLK34K33AB036A	GEMINI	NA	853	712	227	NA	NA	16.2	NA	4.1	1KB	1KB	293/431/293	NA	Z:\DAC\RAW DATA
6-Feb	3757G	2BLK34K037A	GEMINI	NA	772	483	177	NA	NA	10.2	NA	4.61	1KB	1KB	378	NA	Z:\DAC\RAW DATA

Received from

Name: REDRAN P UNSTO
Position:
Signature:

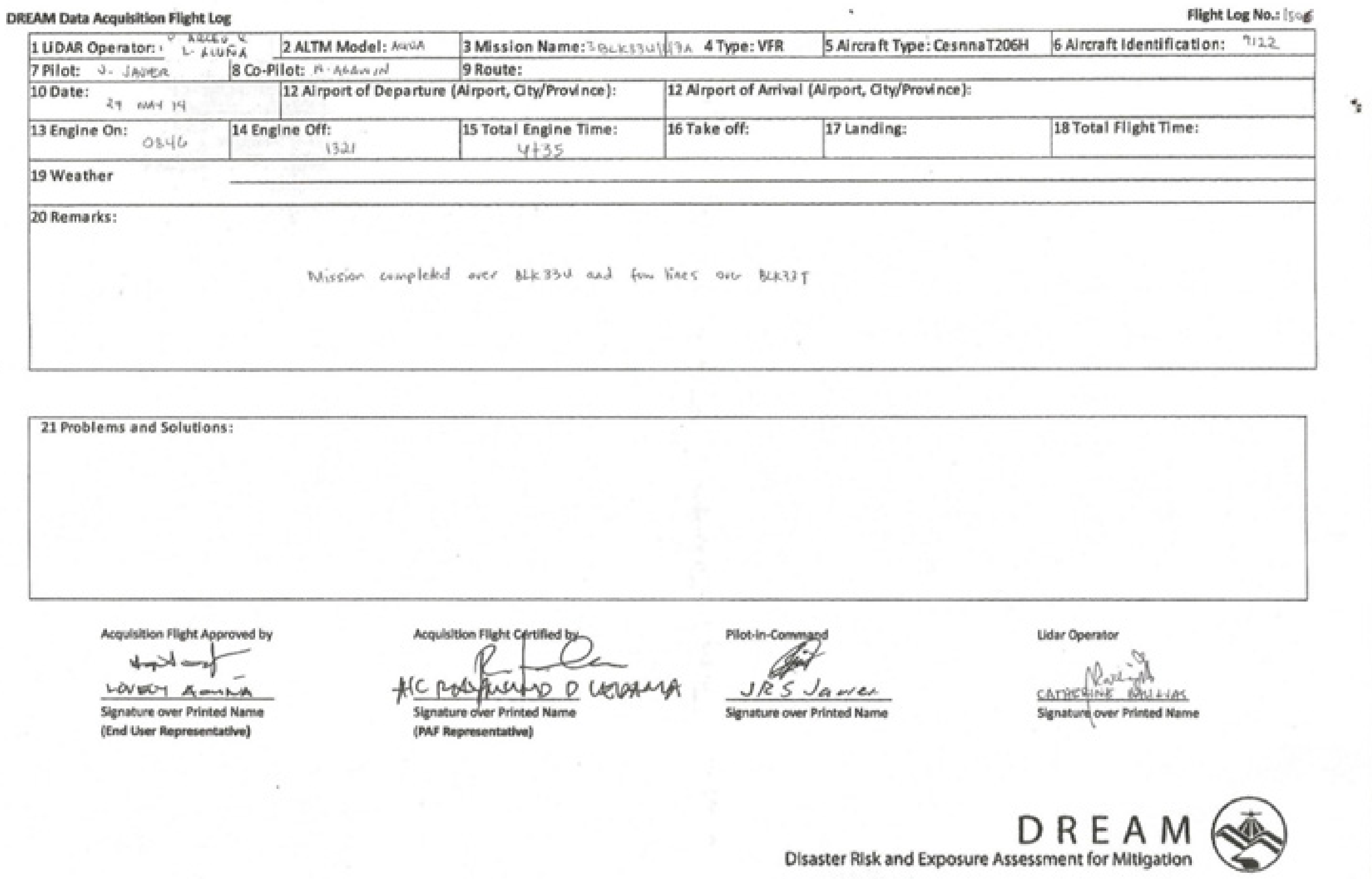
Received by

Name: AC Bongat
Position: SSRS
Signature: 2/26/16

Figure A-5.3 Data Transfer Sheet for Balangiga Floodplain - C

Annex 6. Flight logs for the flight missions

1. Flight Log for 1506A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1506

1 LiDAR Operator: L. Aluña	2 ALTM Model: AQUA	3 Mission Name: 3BLK33U149A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Javier	8 Co-Pilot: R. Abawin	9 Route:			
10 Date: 29 MAY 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0846	14 Engine Off: 1321	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed over BLK33U and few lines over BLK33T

21 Problems and Solutions:

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

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

Pilot-in-Command
J R S Javier
Signature over Printed Name

Lidar Operator
Catherine Balicas
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1 Flight Log for Mission 1506A

2. Flight Log for 1508A Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1508

1 LIDAR Operator: MCE BALICUAS	2 ALTM Model: AQUA	3 Mission Name: 1BLK33USTN178	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: 27 NOV 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1406	14 Engine Off: 1805	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed over BLK33U and few lines over BLK33T					

21 Problems and Solutions:

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

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

Pilot-in-Command: JRS Javier — Signature over Printed Name

Lidar Operator: CAM BALICUAS — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2 Flight Log for Mission 1508A

3. Flight Log for 1510A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1510

1 LiDAR Operator: NICE BALUGAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK33TSV149A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ASANIN	9 Route:			
10 Date: 28 MAY 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0837	14 Engine Off: 1312	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed over BLK33T and 4 lines over BLK33V

21 Problems and Solutions:

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

Acquisition Flight Certified by: A1C RAYMUND D CEDAMA — Signature over Printed Name (PAF Representative)

Pilot-in-Command: JRS Javier — Signature over Printed Name

Lidar Operator: CATH BALUGAS — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3 Flight Log for Mission 1510A

4. Flight Log for 1520A Missionv

DREAM Data Acquisition Flight Log — Flight Log No.: 1520

1 LiDAR Operator: NICE BALILONG	2 ALTM Model: AQUA	3 Mission Name: 3BLK33VS150A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALAWIN	9 Route:			
10 Date: 30 MAY 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1229	14 Engine Off: 1722	15 Total Engine Time: 4+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed over BLK33V and 8 lines over BLK33S					

21 Problems and Solutions:

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

Acquisition Flight Certified by
A1C RAYMUND D LEDAMA
Signature over Printed Name
(PAF Representative)

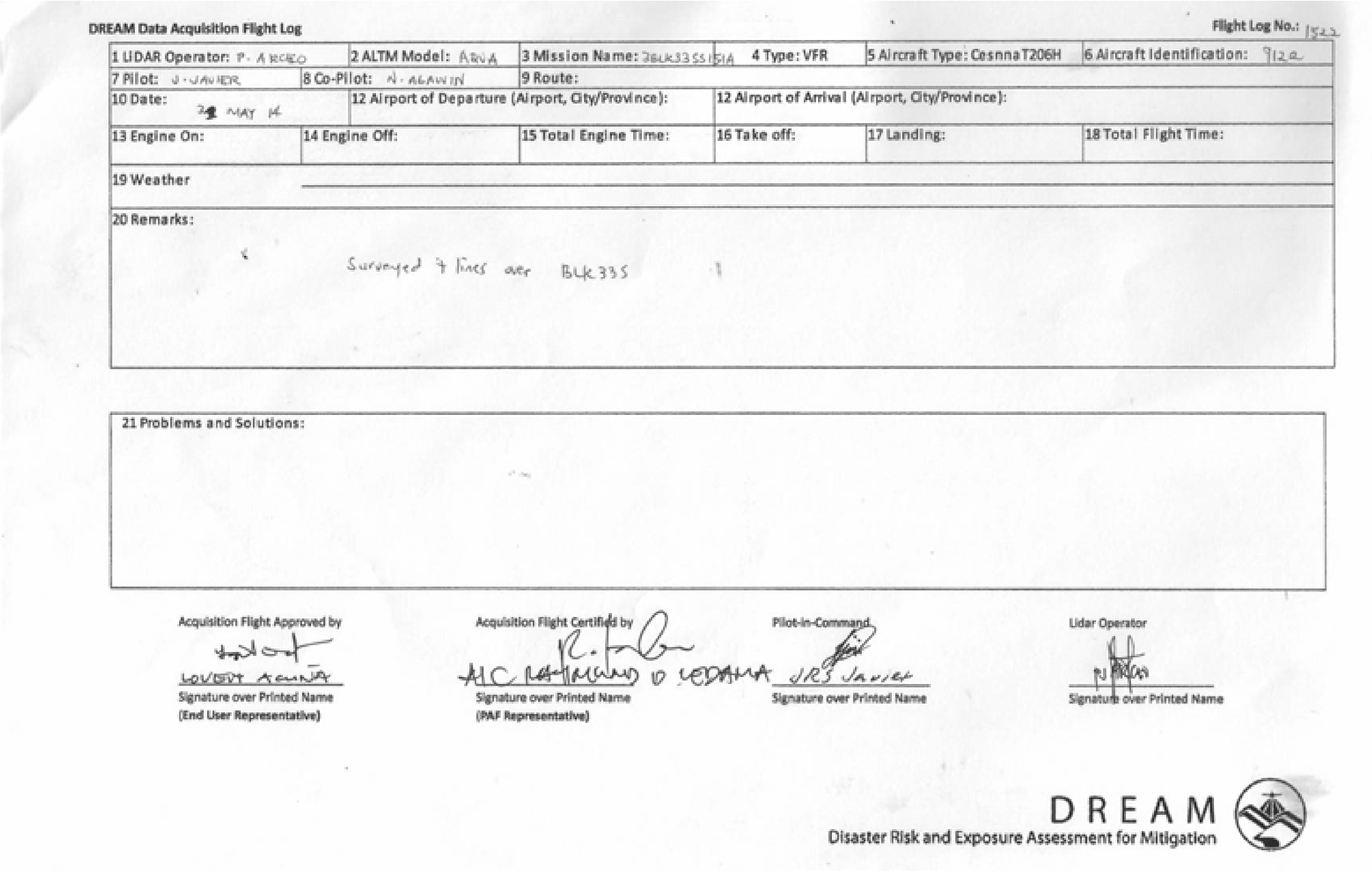
Pilot-in-Command
JRS JAVIER
Signature over Printed Name

Lidar Operator
CATH BALILONG
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4 Flight Log for Mission 1520A

5. Flight Log for 1522A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1522

1 LiDAR Operator: P. ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK33SS151A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: 31 MAY 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 7 lines over BLK33S					

21 Problems and Solutions:

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

Acquisition Flight Certified by — A1C RAHAMAN D LEDAMA — Signature over Printed Name (PAF Representative)

Pilot-in-Command — JRS JAVIER — Signature over Printed Name

Lidar Operator — PJ ARCEO — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.5 Flight Log for Mission 1522A

6. Flight Log for 1526A Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1526

1 LIDAR Operator: MCE BALICAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK33S&R152A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ACAYAN	9 Route:			
10 Date: 01 JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK33S and surveyed 7 lines over BLK33R					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	A1C RAYMUND D LEDAMA	J.R.S. JAVIER	CATH BALICAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.6 Flight Log for Mission 1526A

7. Flight Log for 1530A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1530

1 LiDAR Operator: P. AREVALO	2 ALTM Model: AQUA	3 Mission Name: 3BLK33RSQ153A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ACABAN	9 Route:			
10 Date: 02 JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0804	14 Engine Off: 1239	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK33R and surveyed 7 lines over BLK33 Q					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	A1C RAYMUND D LEDAMA	J. JAVIER	P. AREVALO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.7 Flight Log for Mission 1530A

8. Flight Log for 1534A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1534

1 LIDAR Operator: MCE BALUGAS	2 ALTM Model: AQUA	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ACAIWIN	9 Route:			
10 Date: 08 JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0808	14 Engine Off: 1208	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission over BLK33Q and covered voids over BLK33R

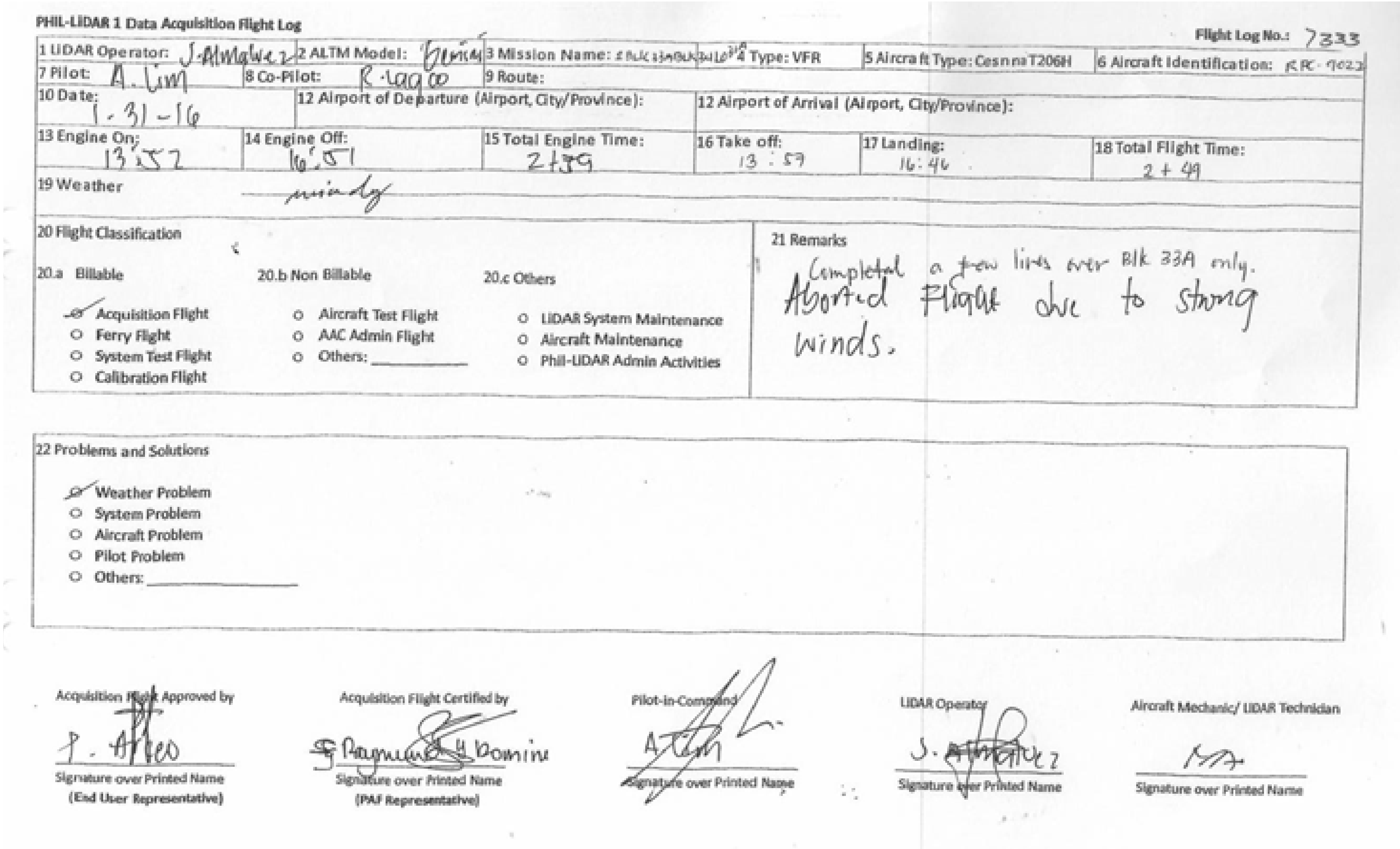
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	A1C RAYMUND P CEDANA	J. JAVIER	CMS BALUGAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.8 Flight Log for Mission 1534A

9. Flight Log for 3733G Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7333

1 LIDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: A. Lim	8 Co-Pilot: R. Iagao	9 Route:			
10 Date: 1-31-16	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 13:52	14 Engine Off: 16:51	15 Total Engine Time: 2+59	16 Take off: 13:57	17 Landing: 16:46	18 Total Flight Time: 2+49
19 Weather: windy					

20 Flight Classification

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

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

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

21 Remarks

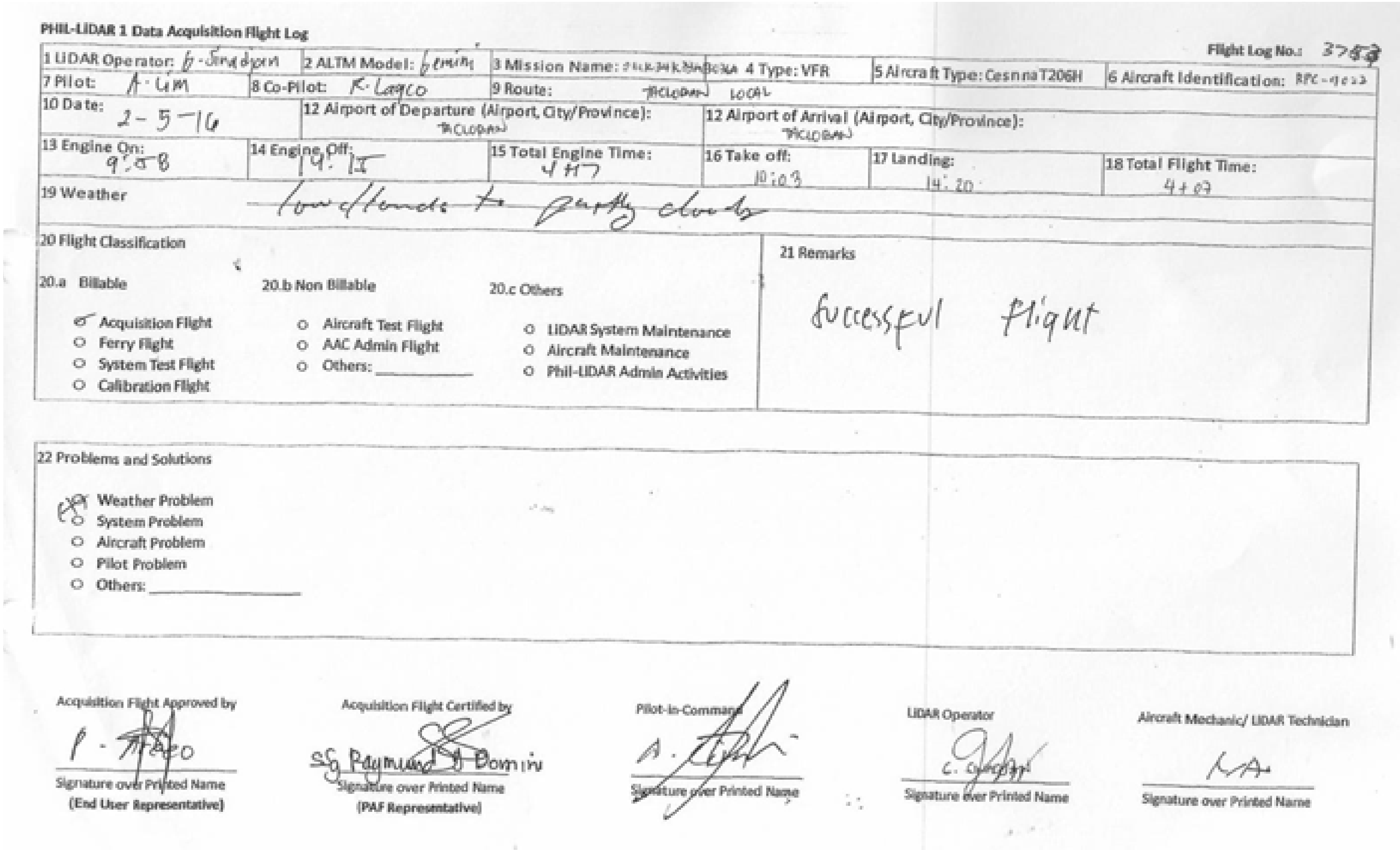
Completed a few lines over Blk 33A only. Aborted Flight due to strong winds.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
P. Alreo	[illegible] Dominic	A. Lim	J. Almalvez	[illegible]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.9 Flight Log for Mission 3733G

10. Flight Log for 3753G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3753G

1 LIDAR Operator: G. Sinadjan	2 ALTM Model: Gemini	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route: Tacloban Local			
10 Date: 2-5-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 9:58	14 Engine Off: 14:15	15 Total Engine Time: 4+17	16 Take off: 10:03	17 Landing: 14:20	18 Total Flight Time: 4+07
19 Weather: few clouds to partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
P. [illegible]	SG Raymund [illegible] Domin	A. [illegible]	G. [illegible]	[illegible]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.10 Flight Log for Mission 3753G

Annex 7. Flight status reports

EASTERN SAMAR
(May 27-June 3, 2014, and January 31 and February 5, 2016)

Table A-7.1 Flight Status Reports

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1506A	BLK33U	3BLK33U147A	P.J. Arceo, L.G. Acuna	May 27, 2014	Completed 15 lines over BLK33U.
1508A	BLK33U, BLK33T	3BLK33UST147B	M.C.E. Baliguas	May 27, 2014	Mission completed over BLK33U and few lines over BLK33T.
1510A	BLK33T, BLK33V	3BLK33TSV148A	M.C.E. Baliguas	May 28, 2014	Mission completed over BLK33T and four lines over BLK33V.
1520A	BLK33S, BLK33V	3BLK33VSS150A	M.C.E. Baliguas	May 30, 2014	Mission completed over BLK33V and eight lines over BLK33S.
1522A	BLK33S	3BLK33SS151A	P.J. Arceo	May 31, 2014	Surveyed 7 lines over BLK33S.
1526A	BLK33S, BLK33R	3BLK33SSR152A	M.C.E. Baliguas	June 1, 2014	Completed mission over BLK33S and surveyed 7 lines over BLK33R.
1530A	BLK33R, BLK33Q	3BLK33RSQ153A	P.J. Arceo	June 2, 2014	Completed mission over BLK33R and surveyed 7 lines over BLK33Q.
1534A	BLK33Q BLK33R	3BLK33QS154A	M.C.E. Baliguas	June 3, 2014	Completed mission over BLK33Q and covered voids over BLK33R.
3733G	BLK34L	2BLK33ABLK34L031A	J. Almalvez	January 31, 2016	Completed BLK34L and surveyed 7 lines at BLK33A.
3753G	BLK34K	2BLK34K33AB036A	G. Sinadjan	February 5, 2016	Surveyed BLK34K and completed BLK33A & 33B.

SWATH PER FLIGHT MISSION

Flight No. :	1506A			
Area:	BLK33U			
Mission Name:	3BLK33U147A			
Parameters:	Altitude:	500m;	Scan Frequency:	45Hz;
	Scan Angle:	22deg;	Overlap:	25%

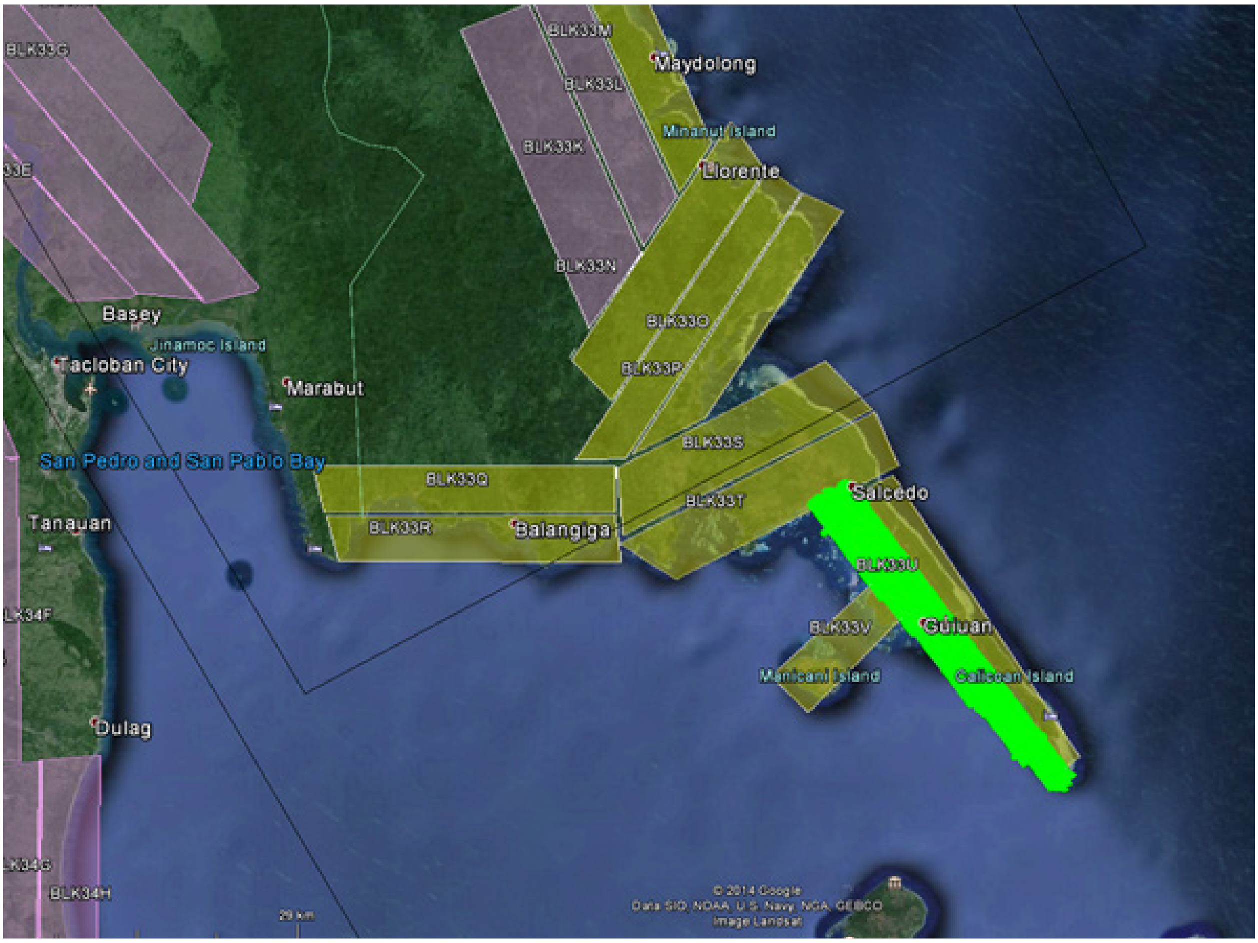


Figure A-7.1 Swath for Flight No. 1506A

Flight No. :	1508A			
Area:	BLK33U			
Mission Name:	3BLK33UST147B			
Parameters:	Altitude:	600m;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

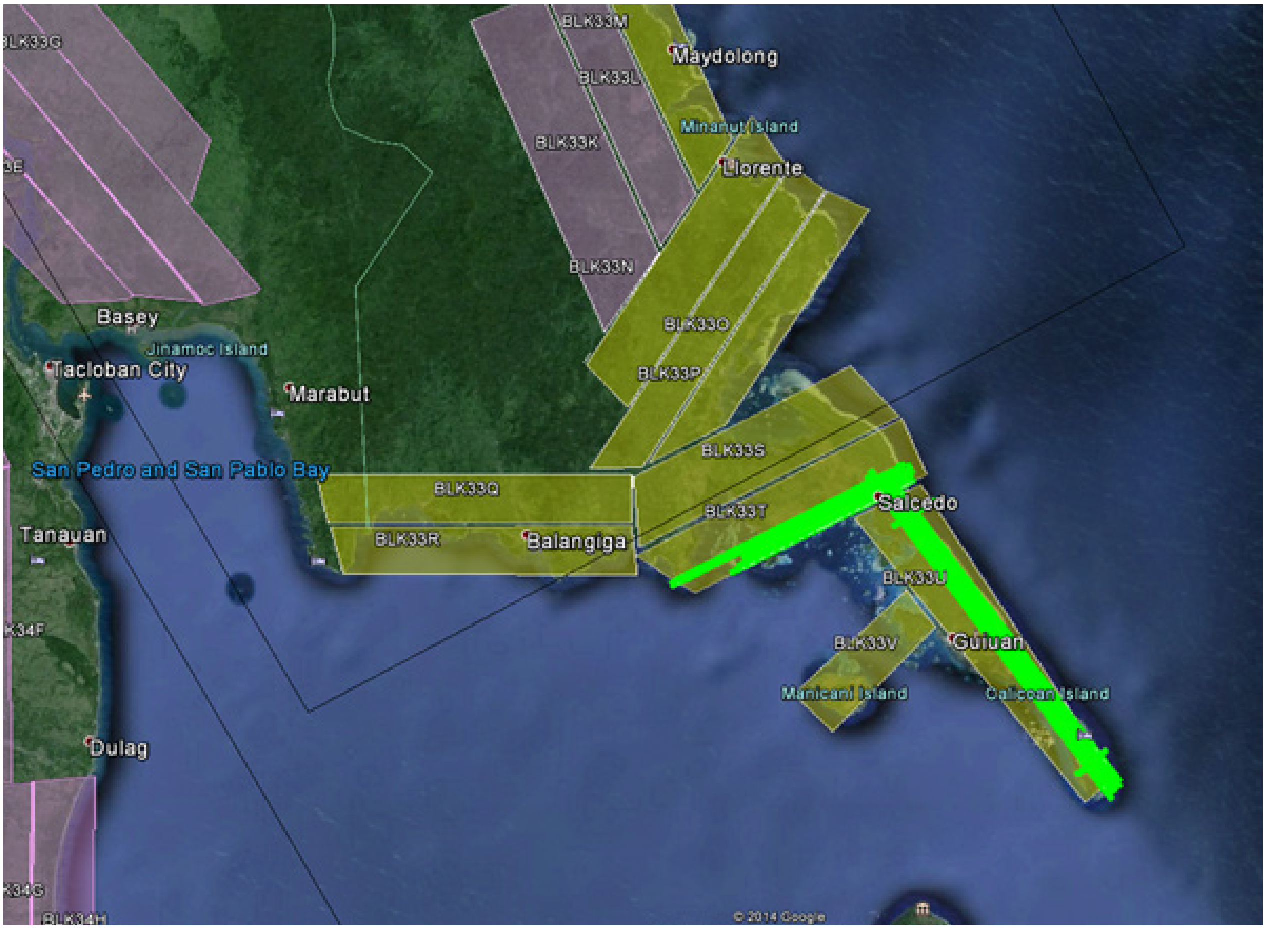


Figure A-7.2 Swath for Flight No. 1508A

Flight No. :	1510A			
Area:	BLK33T, BLK33V			
Mission Name:	3BLK33TSV148A			
Parameters:	Altitude:	600m;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

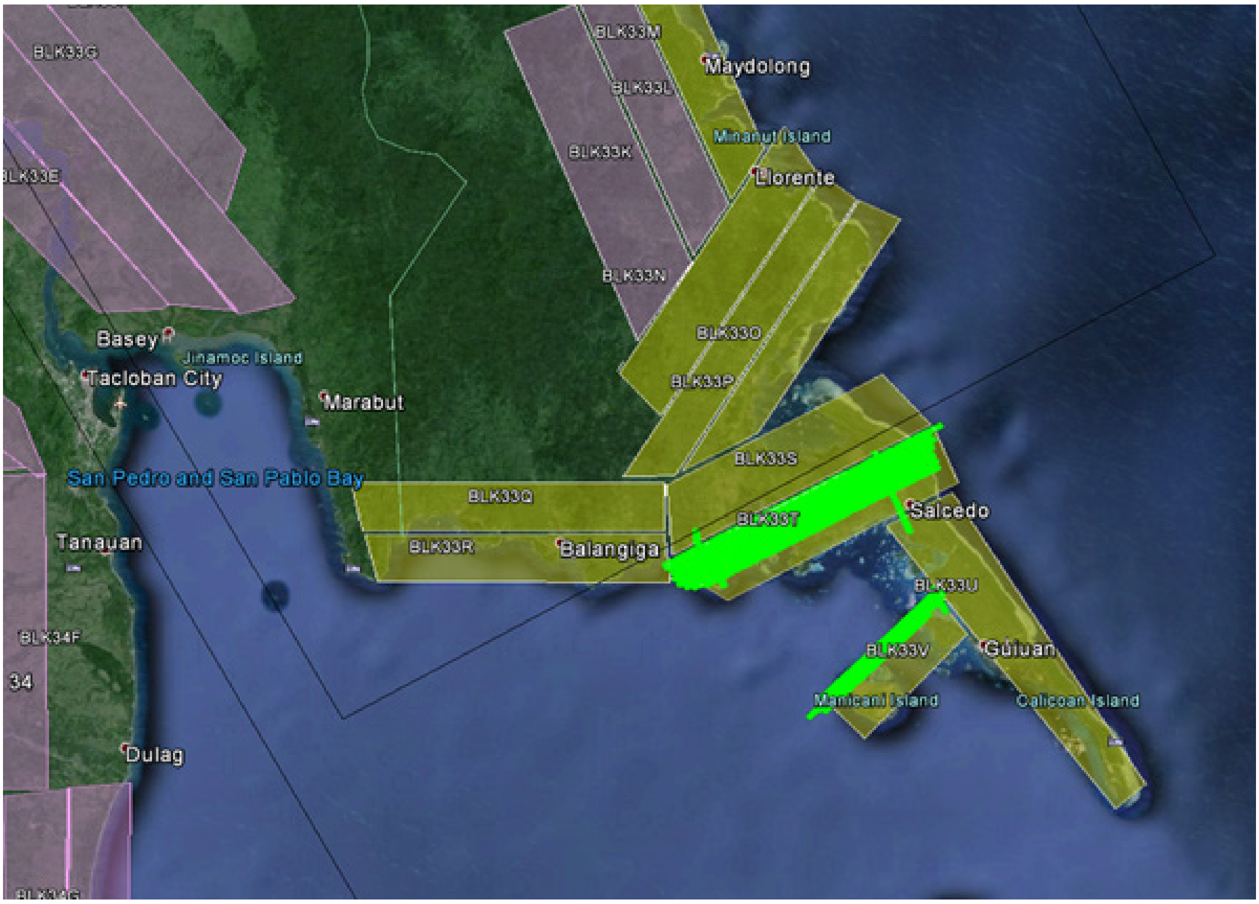


Figure A-7.3 Swath for Flight No. 1510A

Flight No. :	1520A			
Area:	BLK33S, BLK33V			
Mission Name:	3BLK33VSS150A			
Parameters:	Altitude:	500m;	Scan Frequency:	45Hz;
	Scan Angle:	22deg;	Overlap:	30%

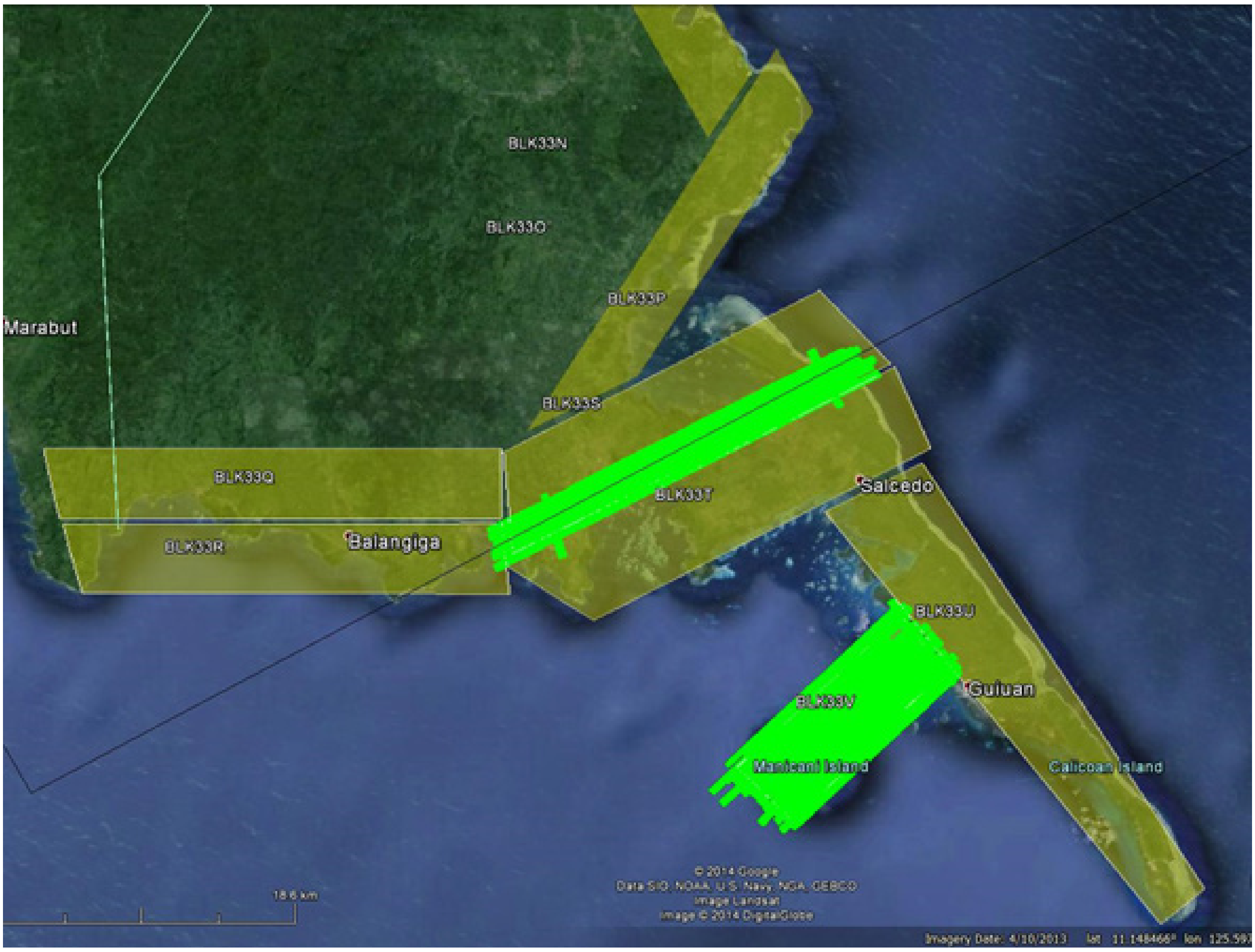


Figure A-7.4 Swath for Flight No. 1520A

Flight No. :	1522A			
Area:	BLK33S			
Mission Name:	3BLK33SS151A			
Parameters:	Altitude:	1200m;	Scan Frequency:	45Hz;
	Scan Angle:	22deg;	Overlap:	30%

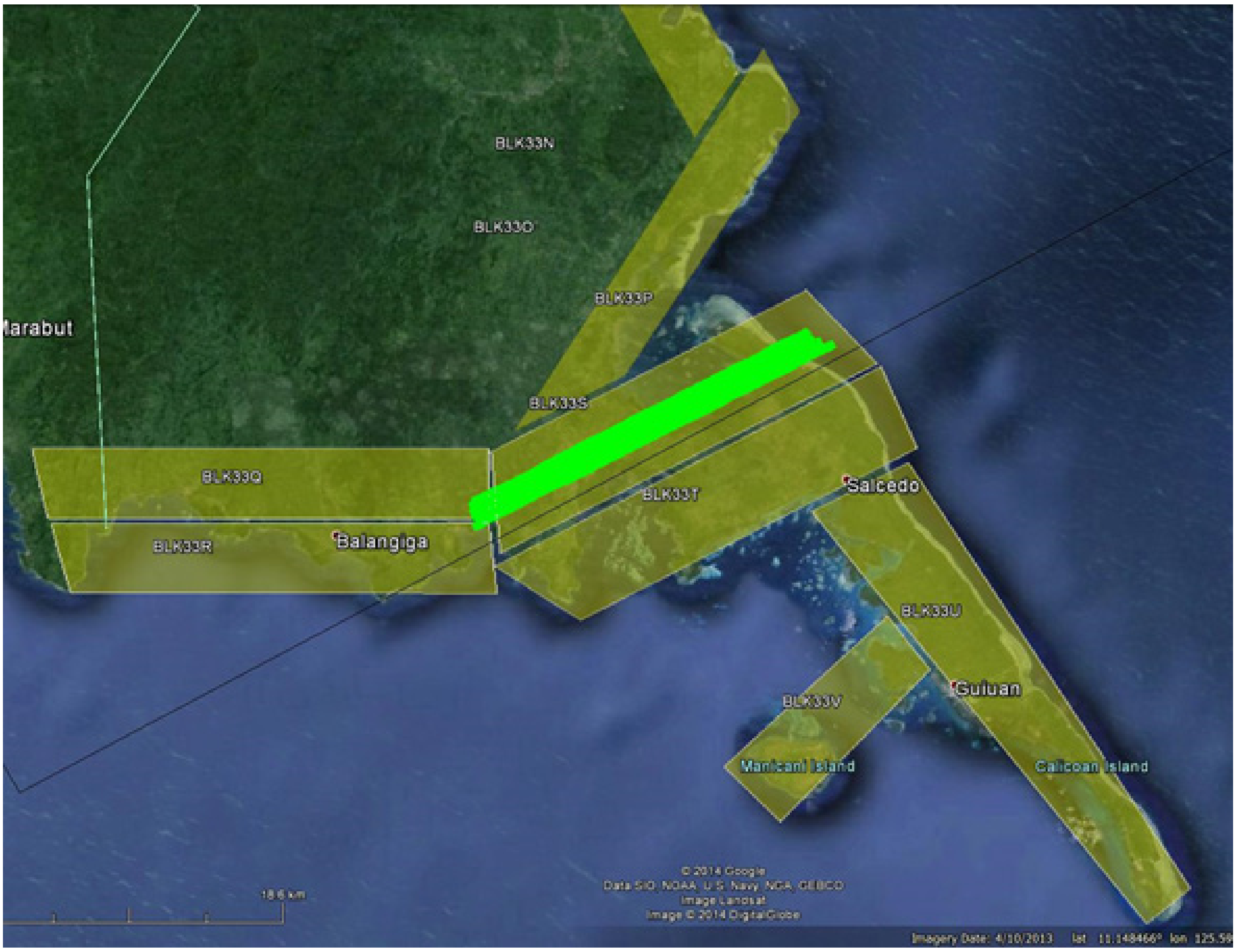


Figure A-7.5 Swath for Flight No. 1522A

Flight No. :	1526A			
Area:	BLK33R, BLK33S			
Mission Name:	3BLK33SSR152A			
Parameters:	Altitude:	500m;	Scan Frequency:	45Hz;
	Scan Angle:	22deg;	Overlap:	30%

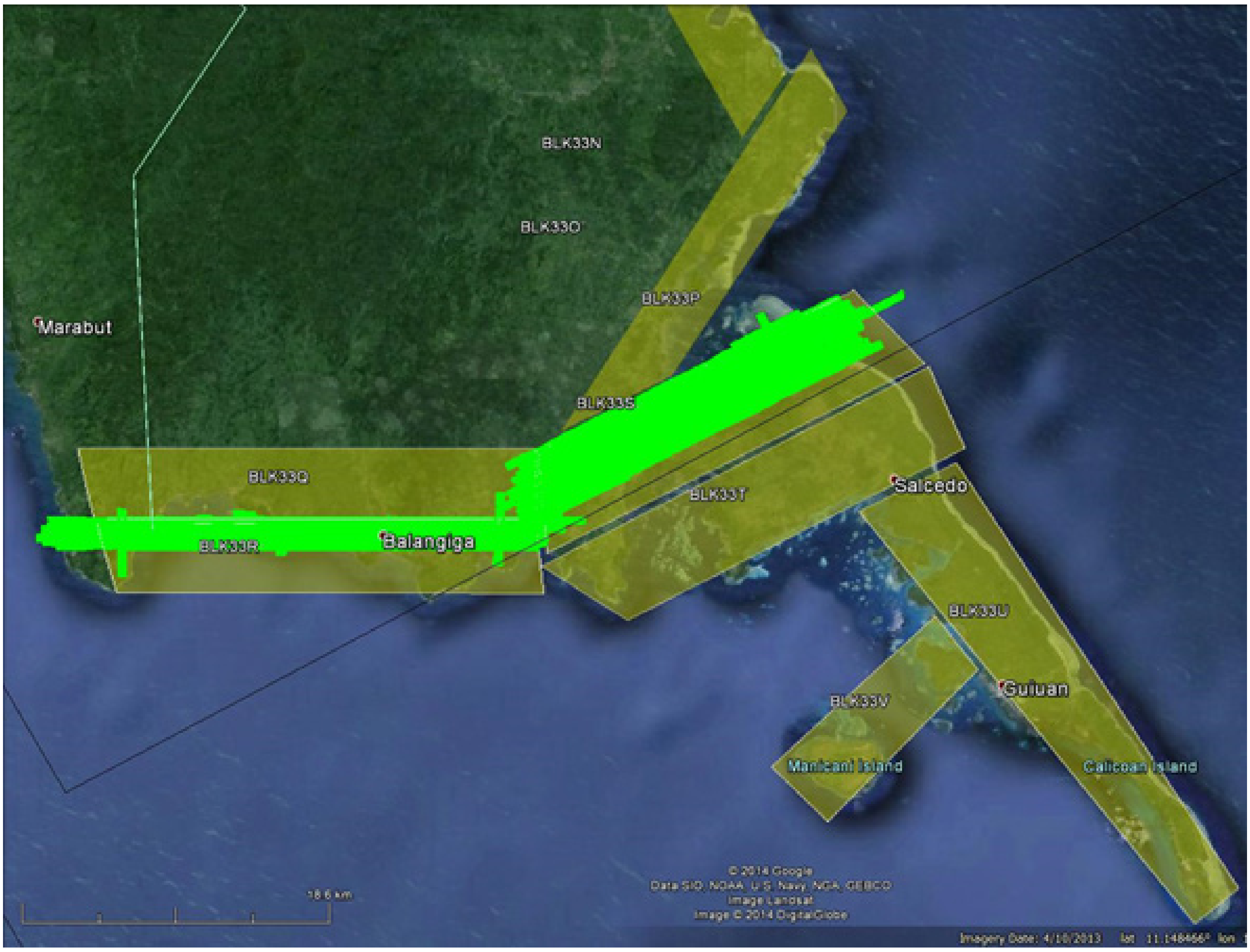


Figure A-7.6 Swath for Flight No. 1526A

Flight No. :	1530A			
Area:	BLK33Q, BLK33R			
Mission Name:	3BLK33RSQ153A			
Parameters:	Altitude:	500m;	Scan Frequency:	45Hz;
	Scan Angle:	22deg;	Overlap:	35%

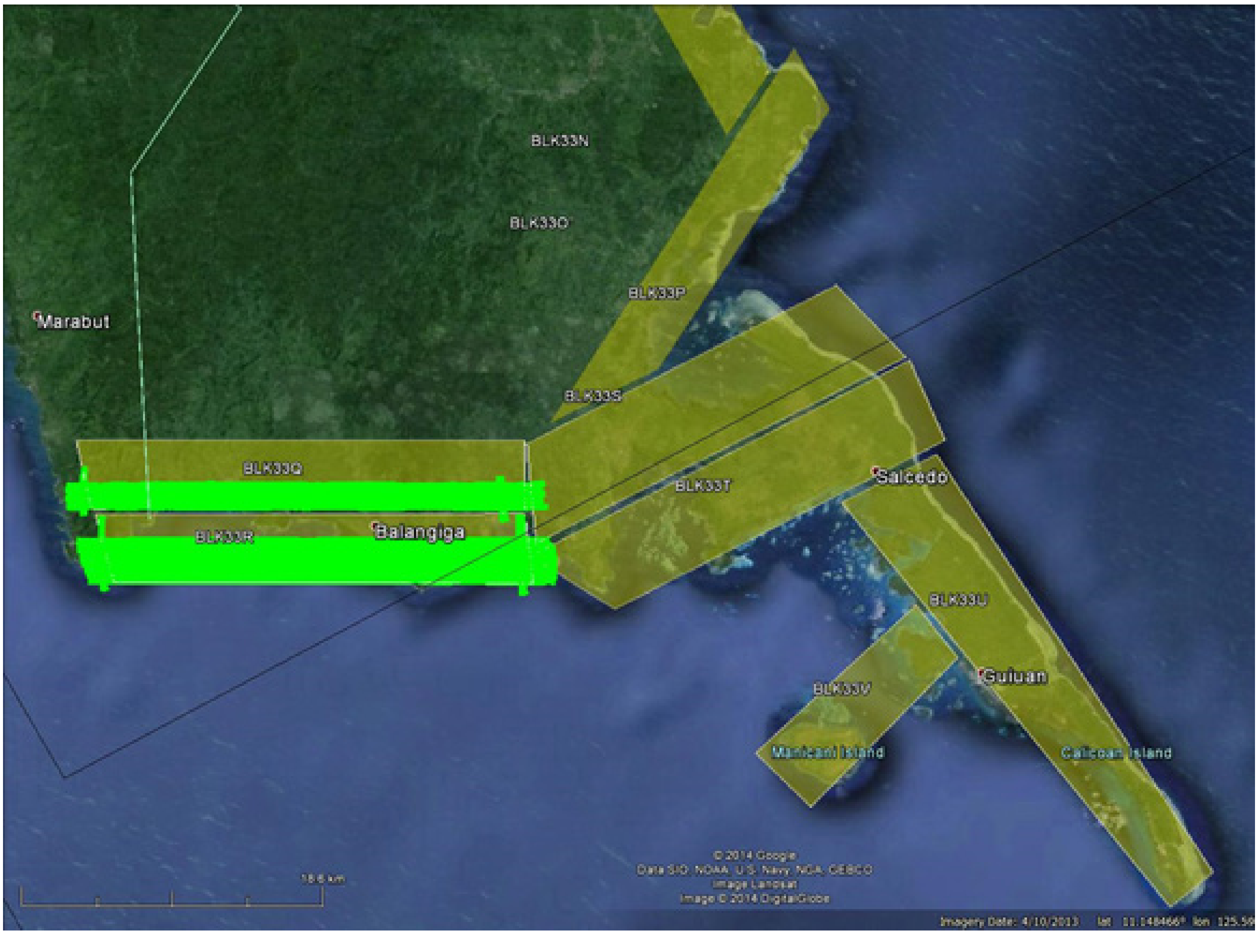


Figure A-7.7 Swath for Flight No. 1530A

Flight No. :	1534A			
Area:	BLK33Q, BLK33R			
Mission Name:	3BLK33QS154A			
Parameters:	Altitude:	600m;	Scan Frequency:	50Hz;
	Scan Angle:	18deg;	Overlap:	30%

Figure A-7.8 Swath for Flight No. 1534A

Flight No. :	3733G			
Area:	BLK34L			
Mission Name:	2BLK33ABLK34L031A			
Parameters:	Altitude:	850m;	Scan Frequency:	50Hz;
	Scan Angle:	20deg;	Overlap:	35%

Figure A-7.9 Swath for Flight No. 3733G

Flight No. :	3753G			
Area:	BLK34K			
Mission Name:	2BLK34K33AB036A			
Parameters:	Altitude:	850m;	Scan Frequency:	50Hz;
	Scan Angle:	20deg;	Overlap:	35%

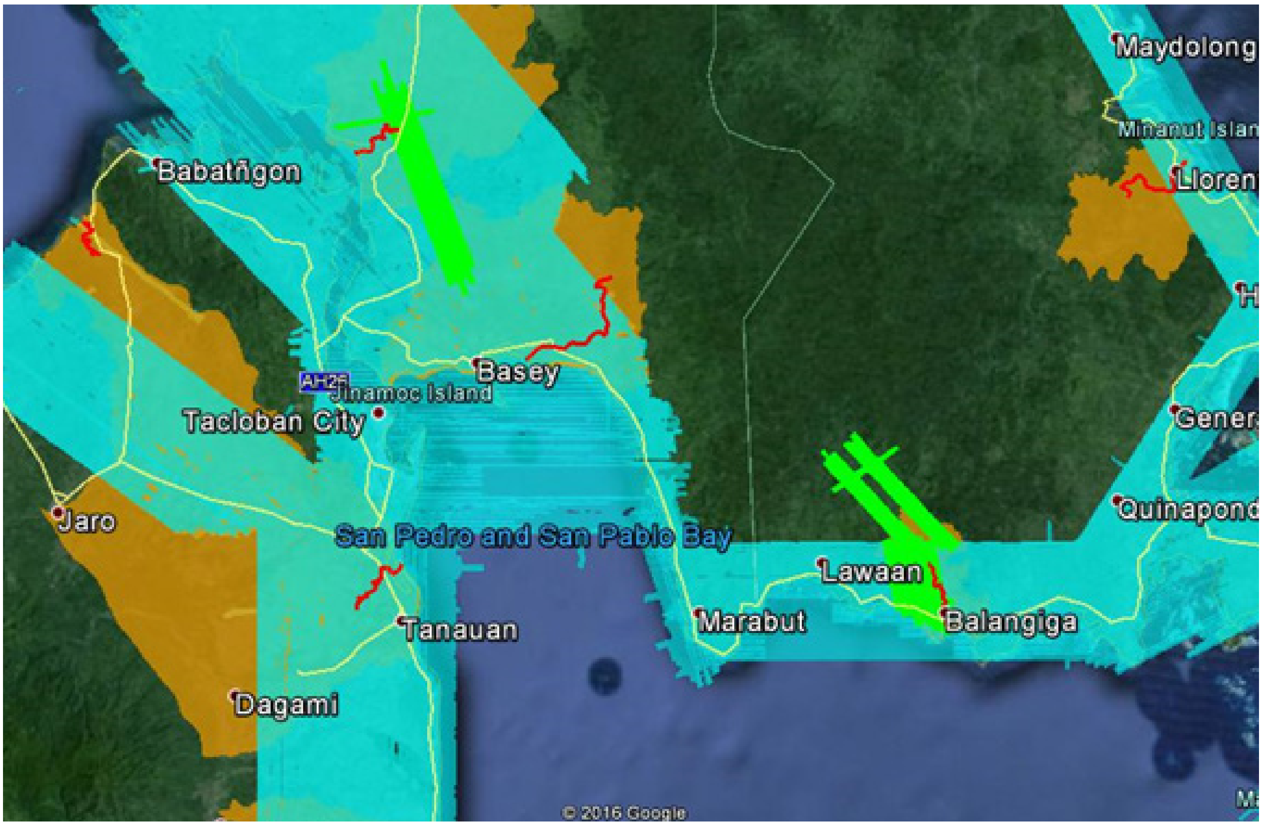


Figure A-7.10 Swath for Flight No. 3753G

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk33Q

Flight Area	Samar-Leyte
Mission Name	Blk33Q
Inclusive Flights	1534A, 1530A
Range data size	30.1 GB
POS	504 MB
Base data size	14.48 MB
Image	203.1 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.6
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	1.1
Boresight correction stdev (<0.001deg)	0.000504
IMU attitude correction stdev (<0.001deg)	0.013905
GPS position stdev (<0.01m)	0.0294
Minimum % overlap (>25)	44.05%
Ave point cloud density per sq.m. (>2.0)	3.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	196
Maximum Height	462.96 m
Minimum Height	52.49 m
Classification (# of points)	
Ground	77,920,392
Low vegetation	63,820,050
Medium vegetation	219,098,054
High vegetation	97,216,382
Building	733,313
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Velina Angela Bemida, Engr. Gladys Mae Apat

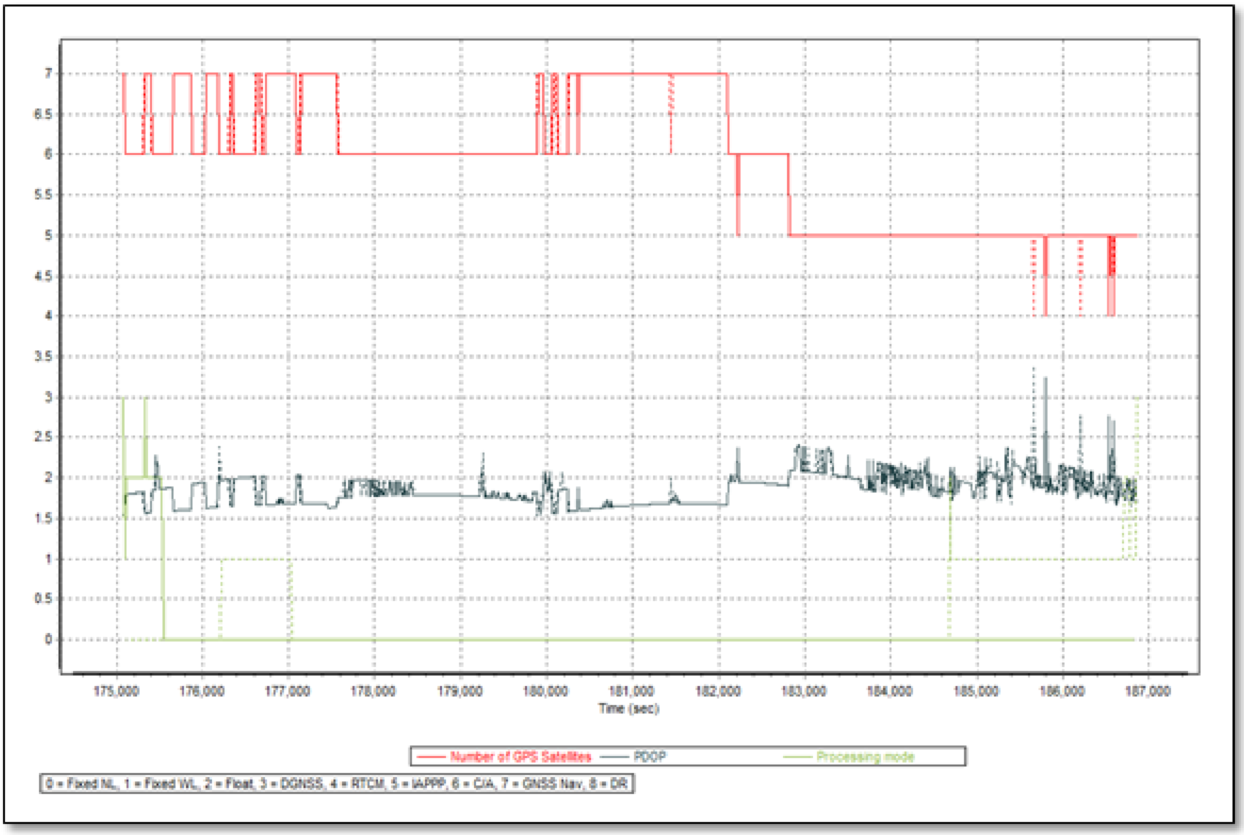


Figure A-8.1 Solution Status

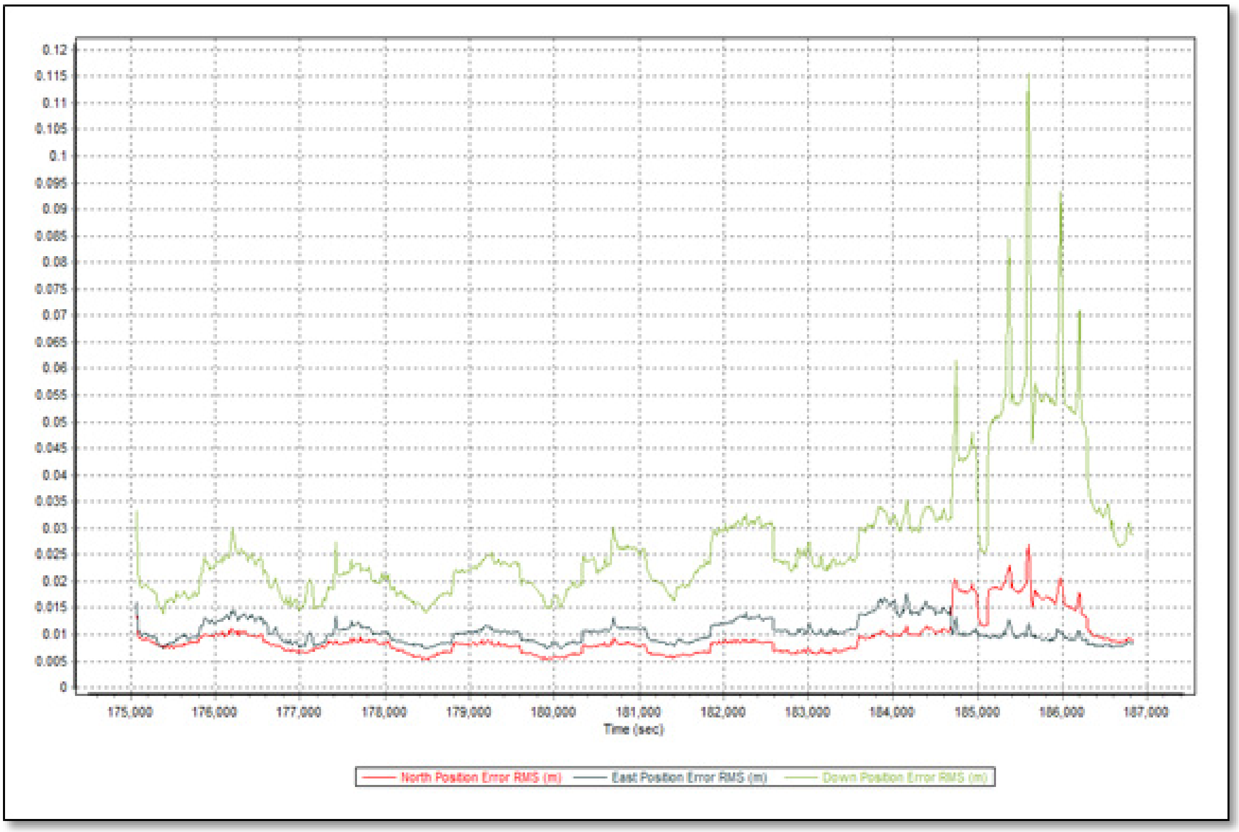


Figure A-8.2 Smoothed Performance Metric Parameters

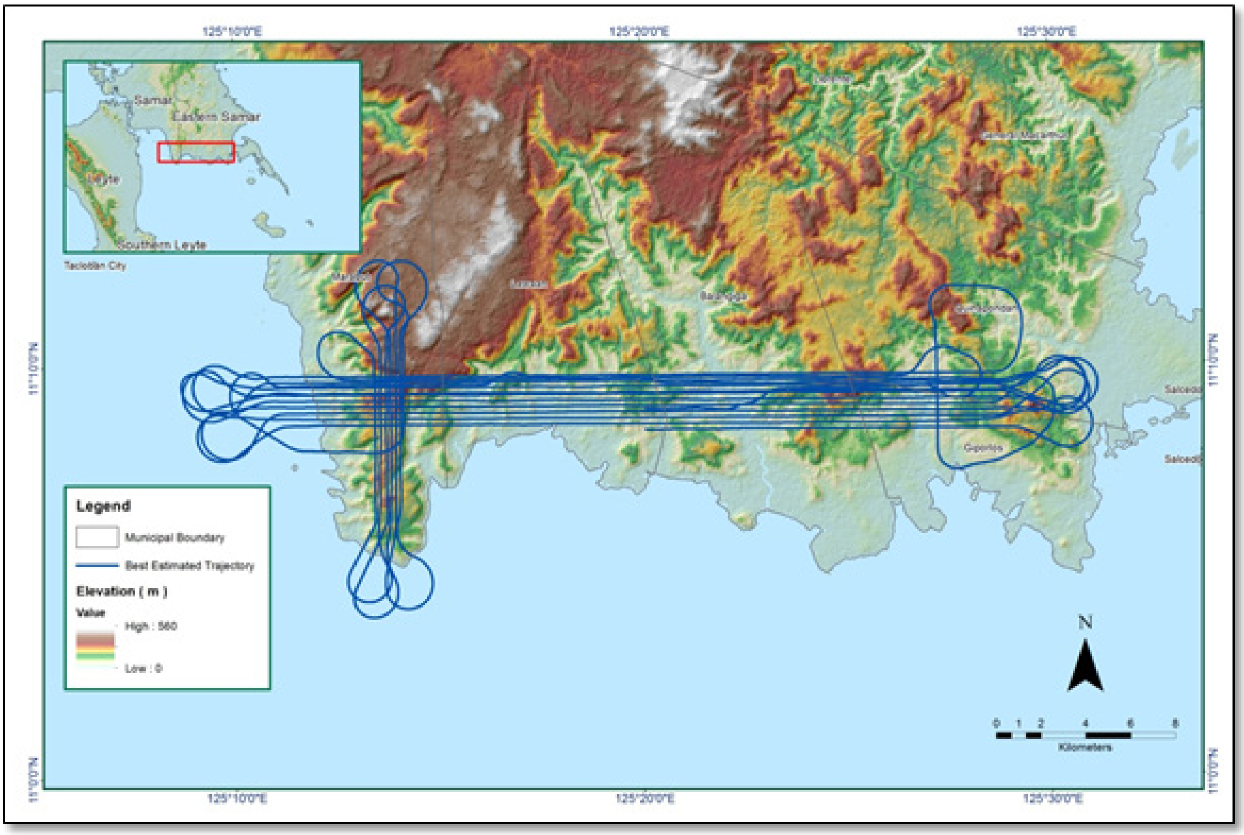


Figure A-8.3 Best Estimated Trajectory

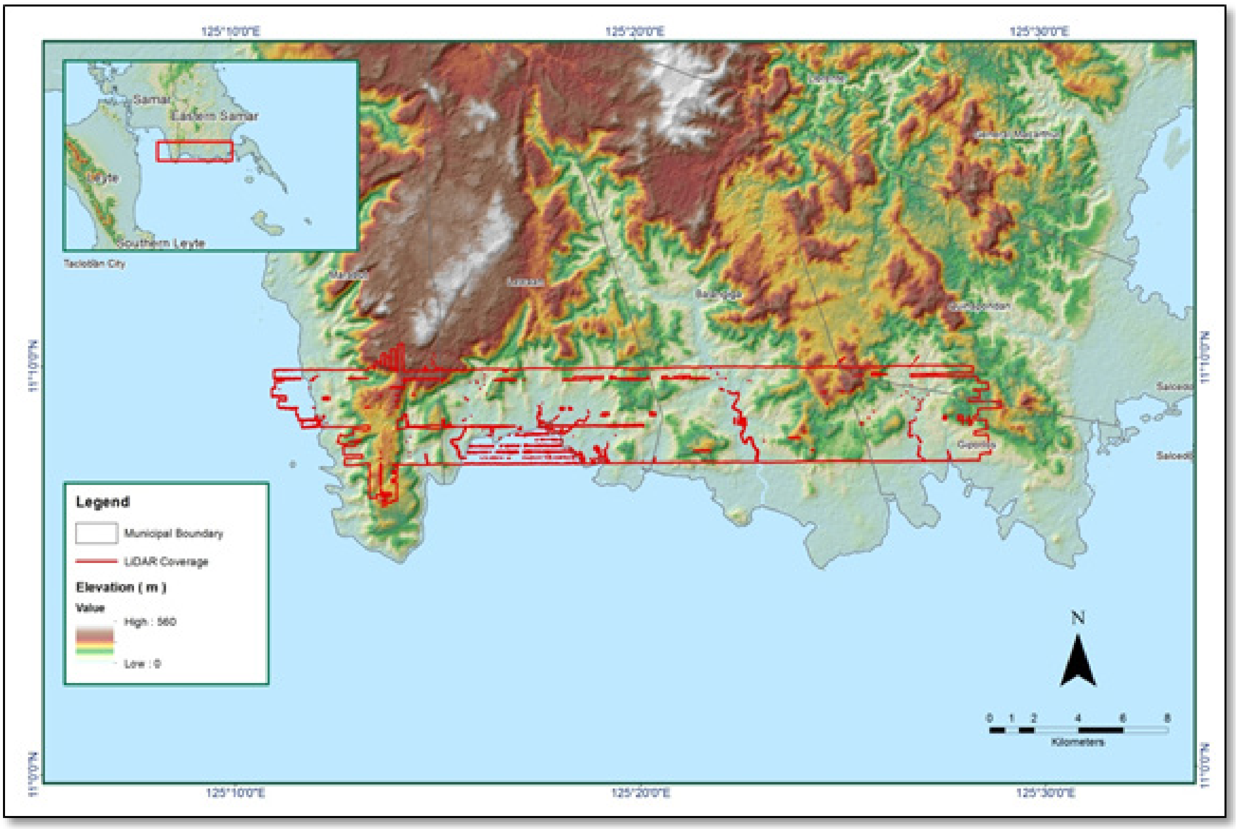


Figure A-8.4 Coverage of LiDAR data

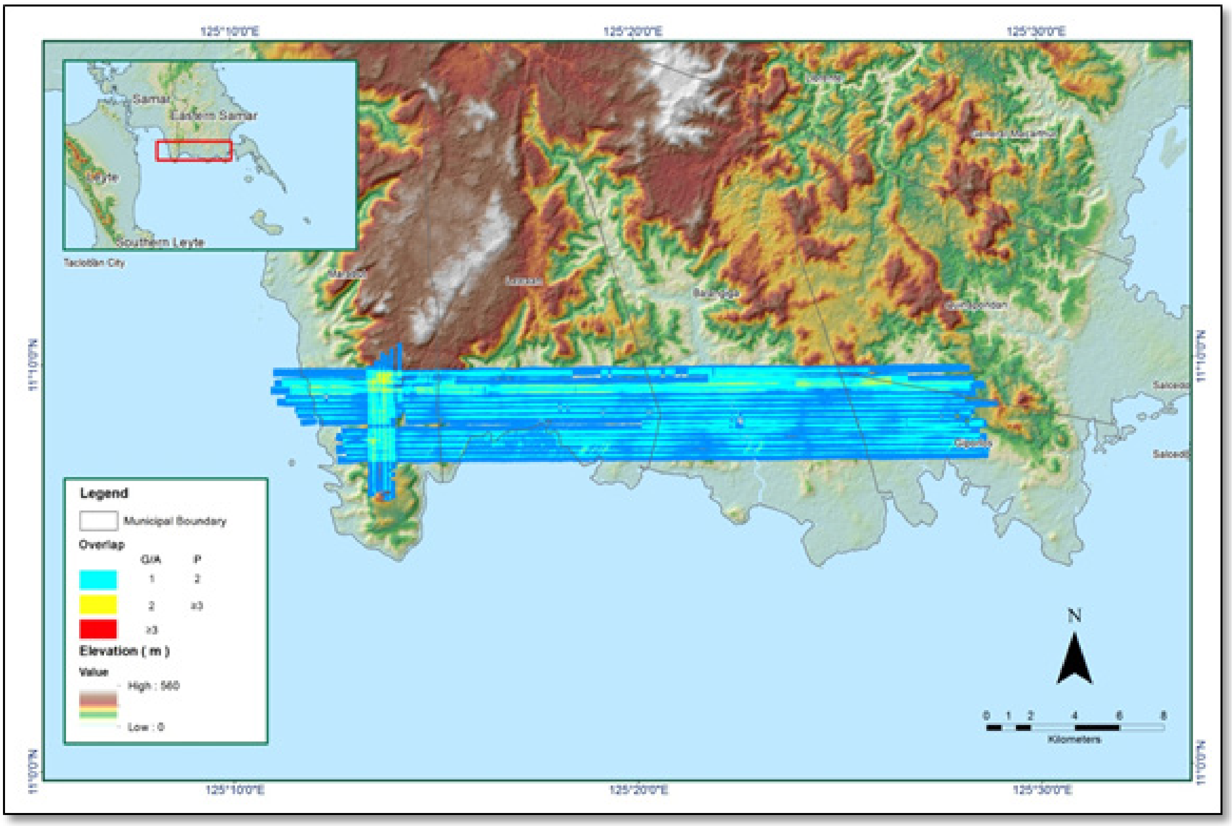


Figure A-8.5 Image of Data Overlap

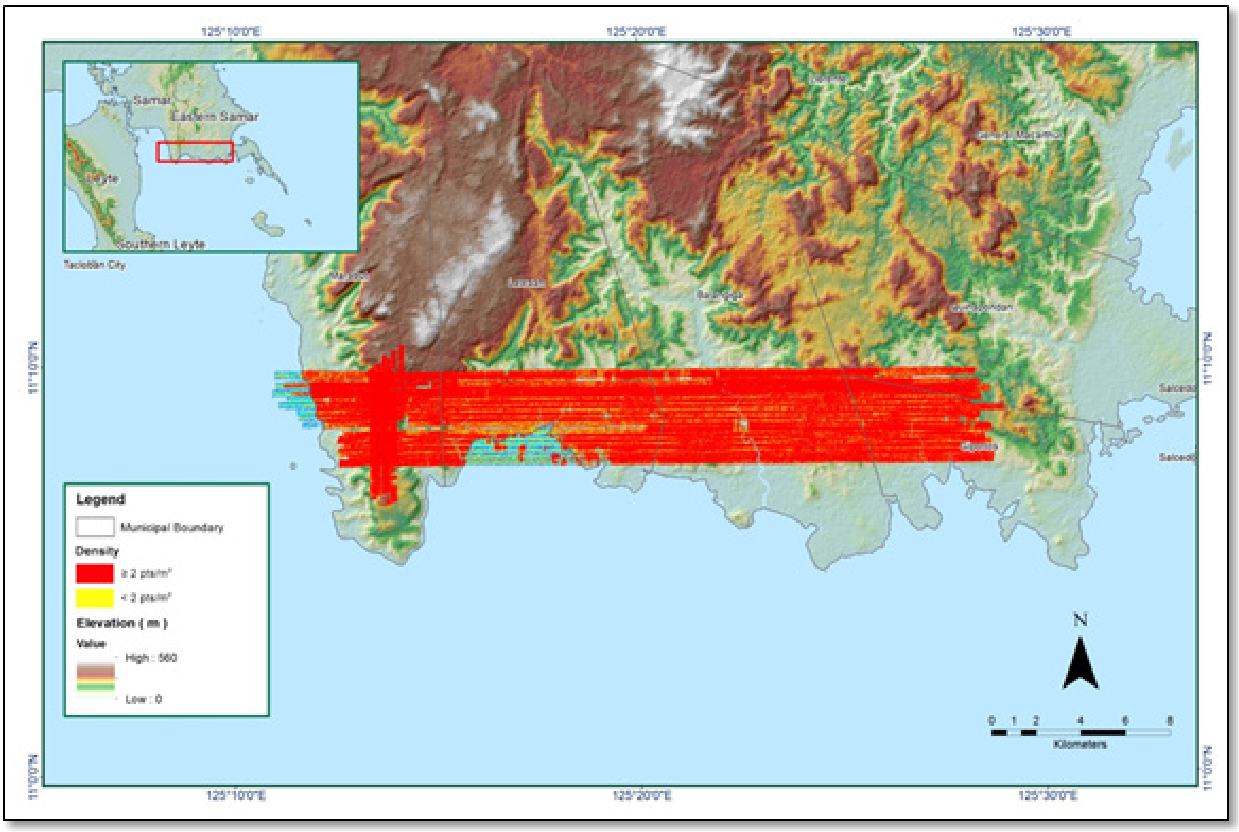


Figure A-8.6 Density map of merged LiDAR data

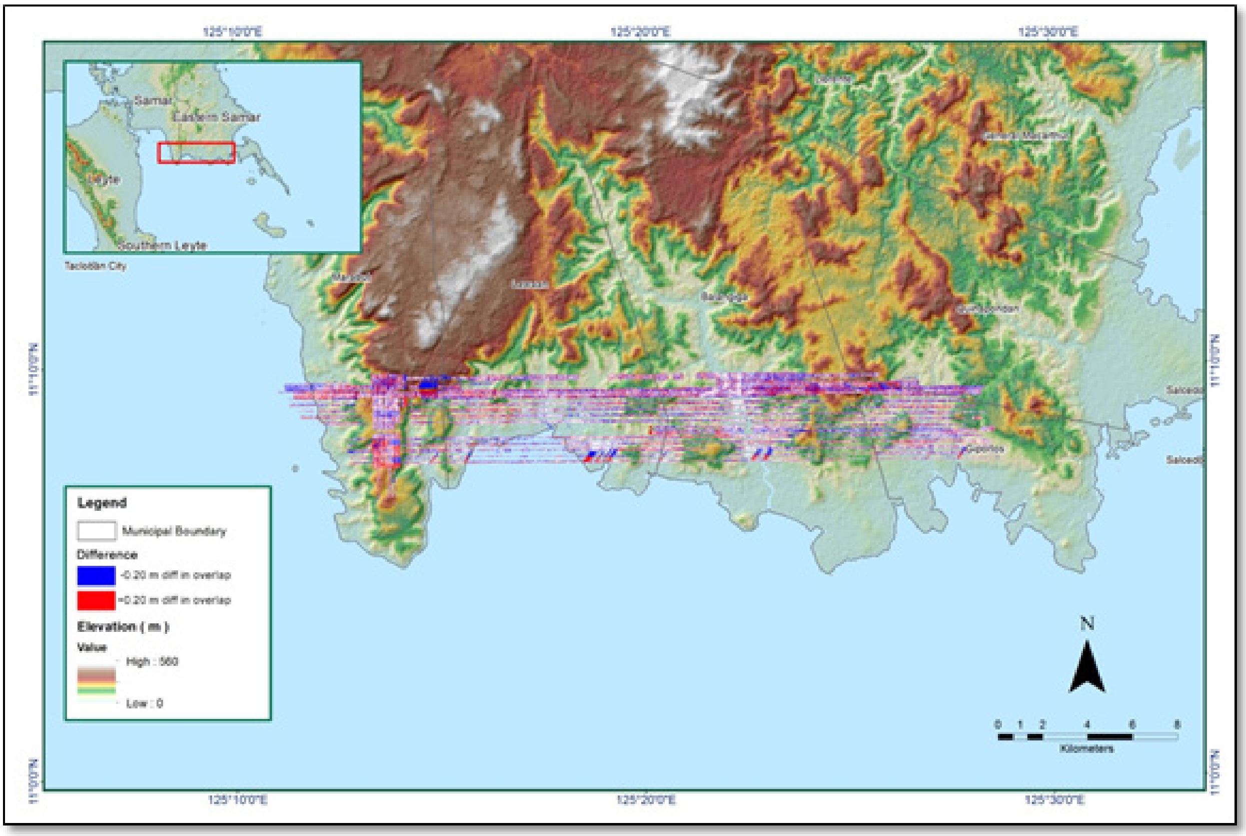


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk33S

Flight Area	Samar-Leyte
Mission Name	Blk33S
Inclusive Flights	1522A,1526A
Range data size	20.37 GB
POS	389 MB
Base data size	12.89 MB
Image	149.78 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000290
IMU attitude correction stdev (<0.001deg)	0.002644
GPS position stdev (<0.01m)	0.0125
Minimum % overlap (>25)	38.17%
Ave point cloud density per sq.m. (>2.0)	2.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	138
Maximum Height	405.46 m
Minimum Height	54.73 m
Classification (# of points)	
Ground	46,953,977
Low vegetation	41,436,786
Medium vegetation	95,425,090
High vegetation	45,588,763
Building	527,403
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Engr. Gladys Mae Apat

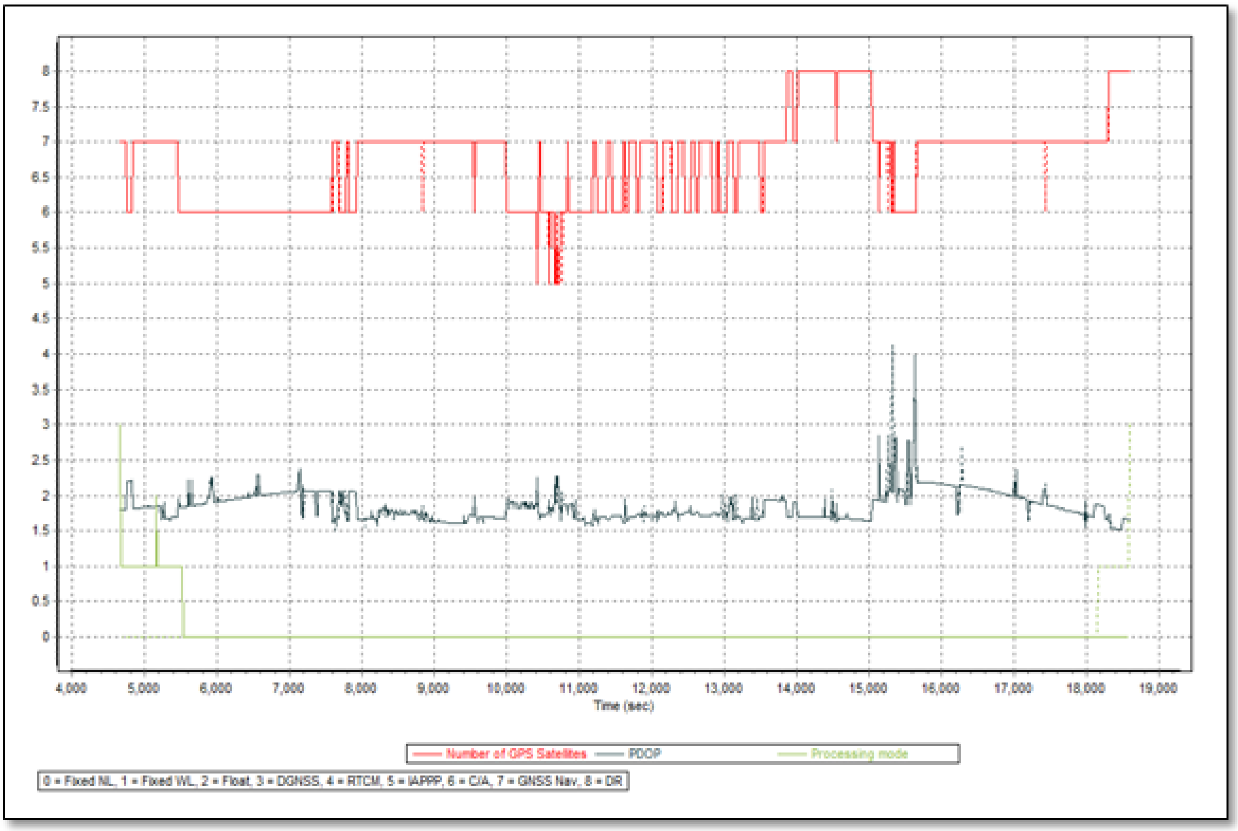


Figure A-8.8 Solution Status Parameters

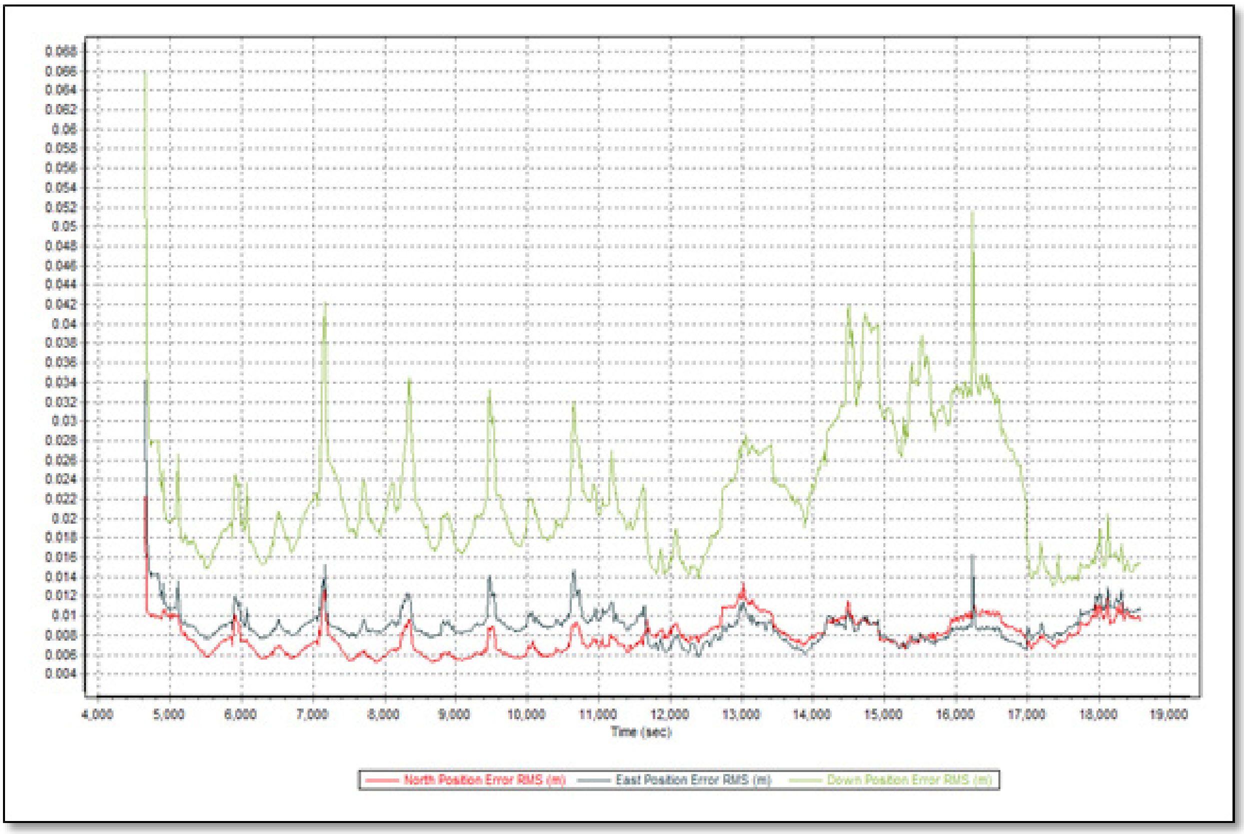


Figure A-8.9 Smoothed Performance Metrics Parameters

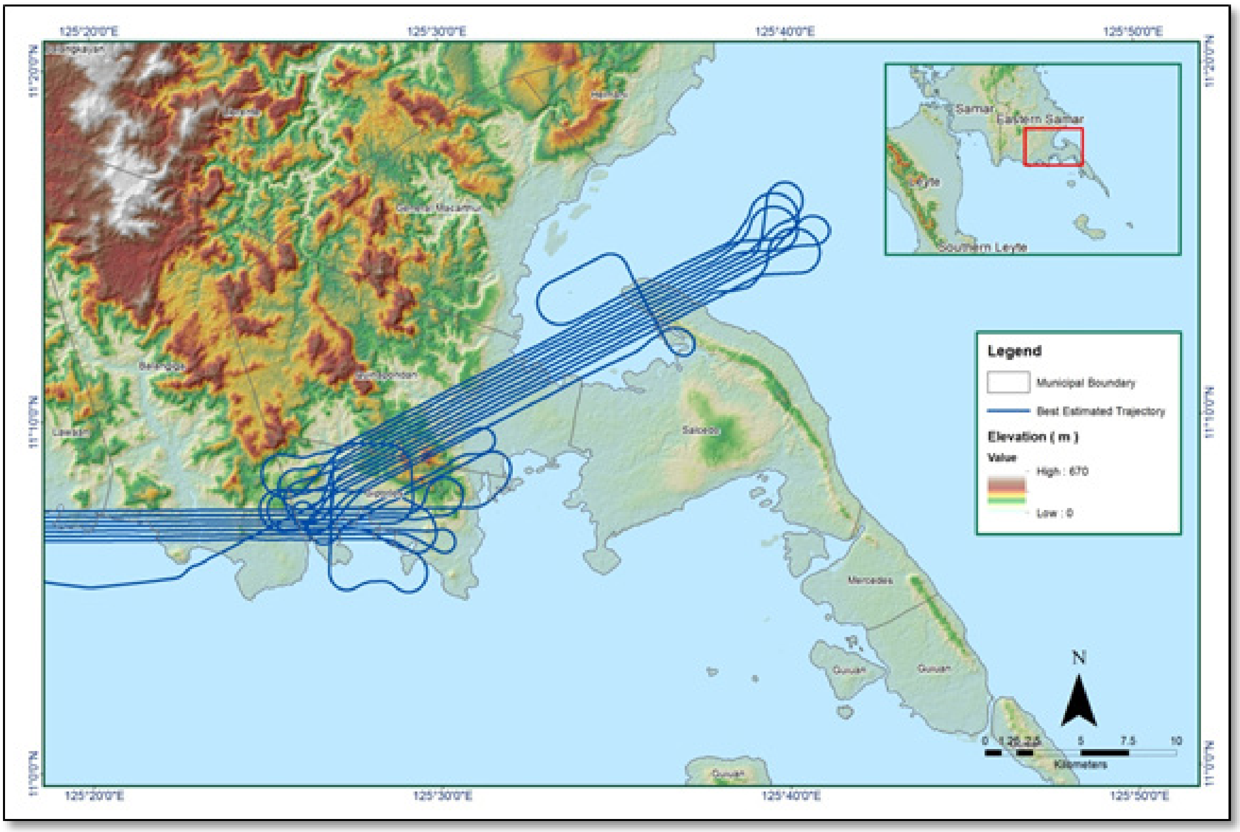


Figure A-8.10 Best Estimated Trajectory

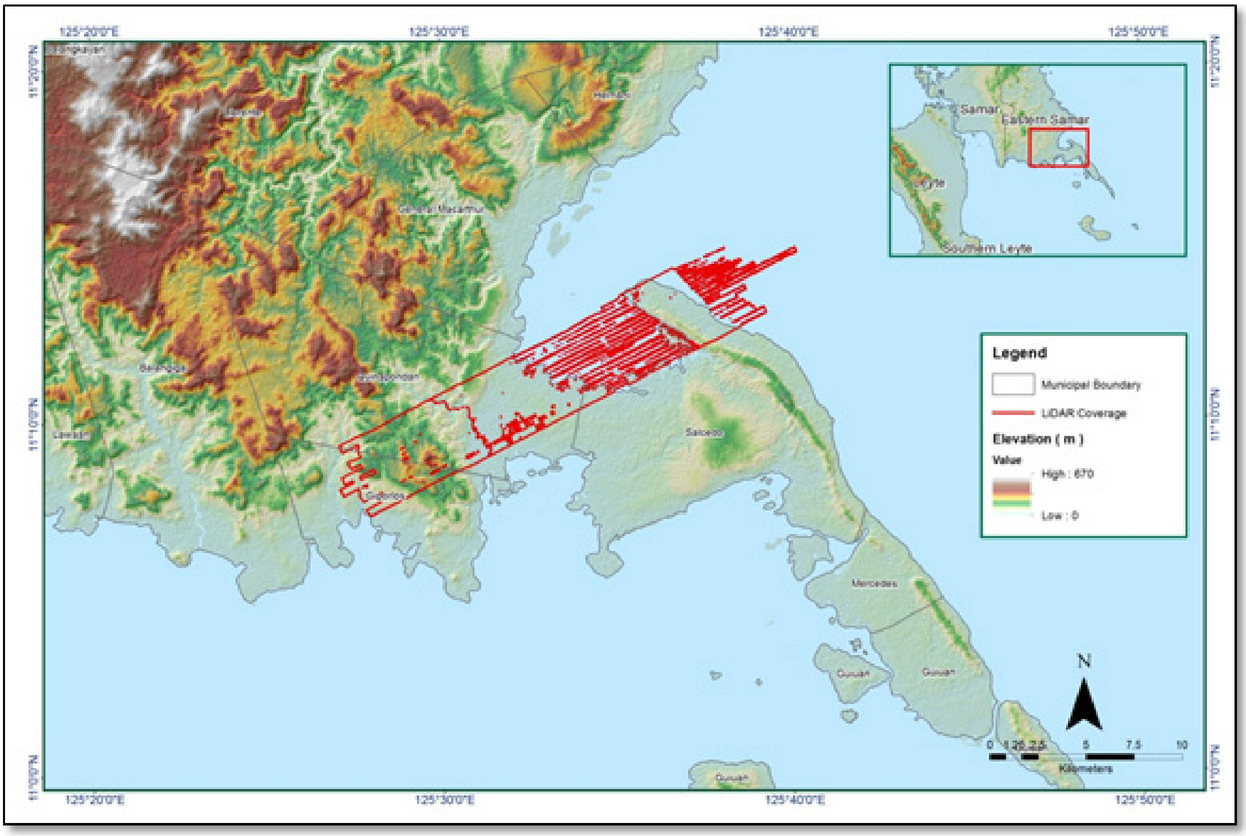


Figure A-8.11 Coverage of LiDAR data

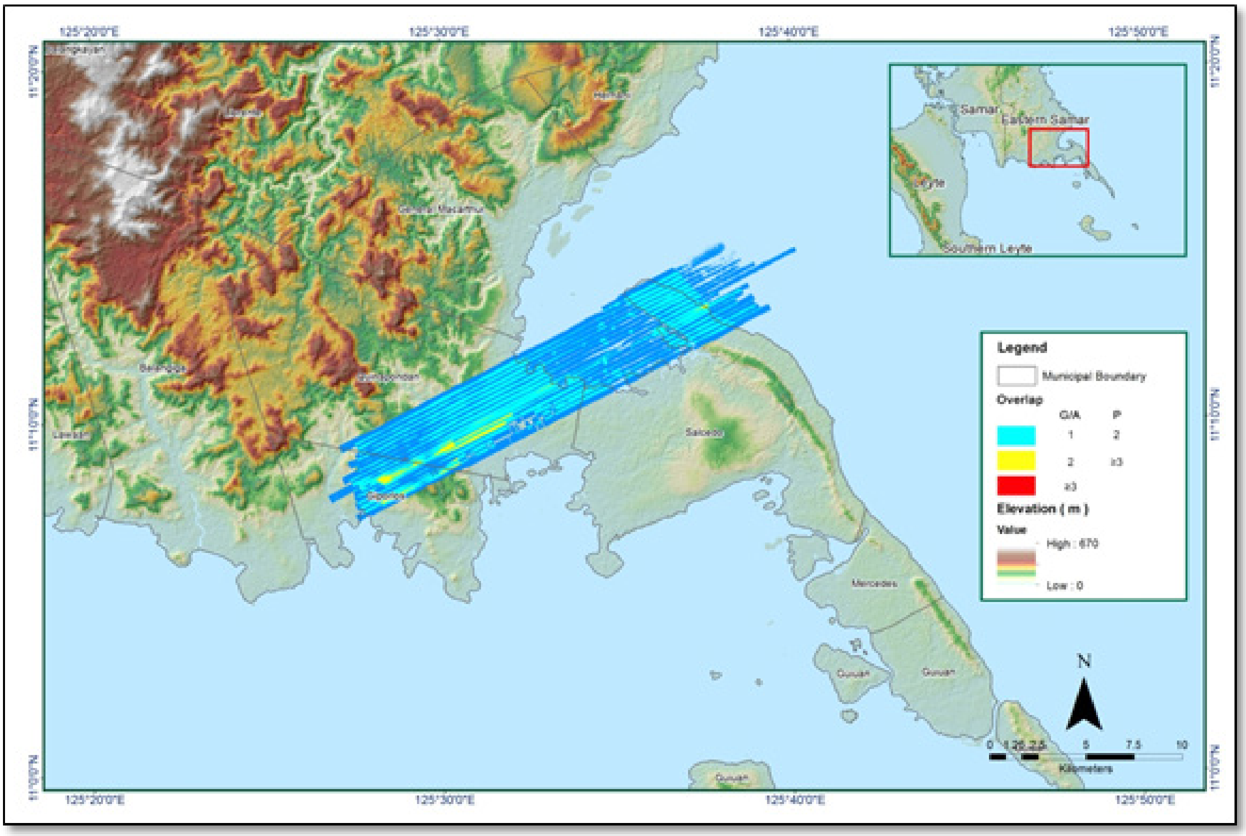


Figure A-8.12 Image of Data Overlap

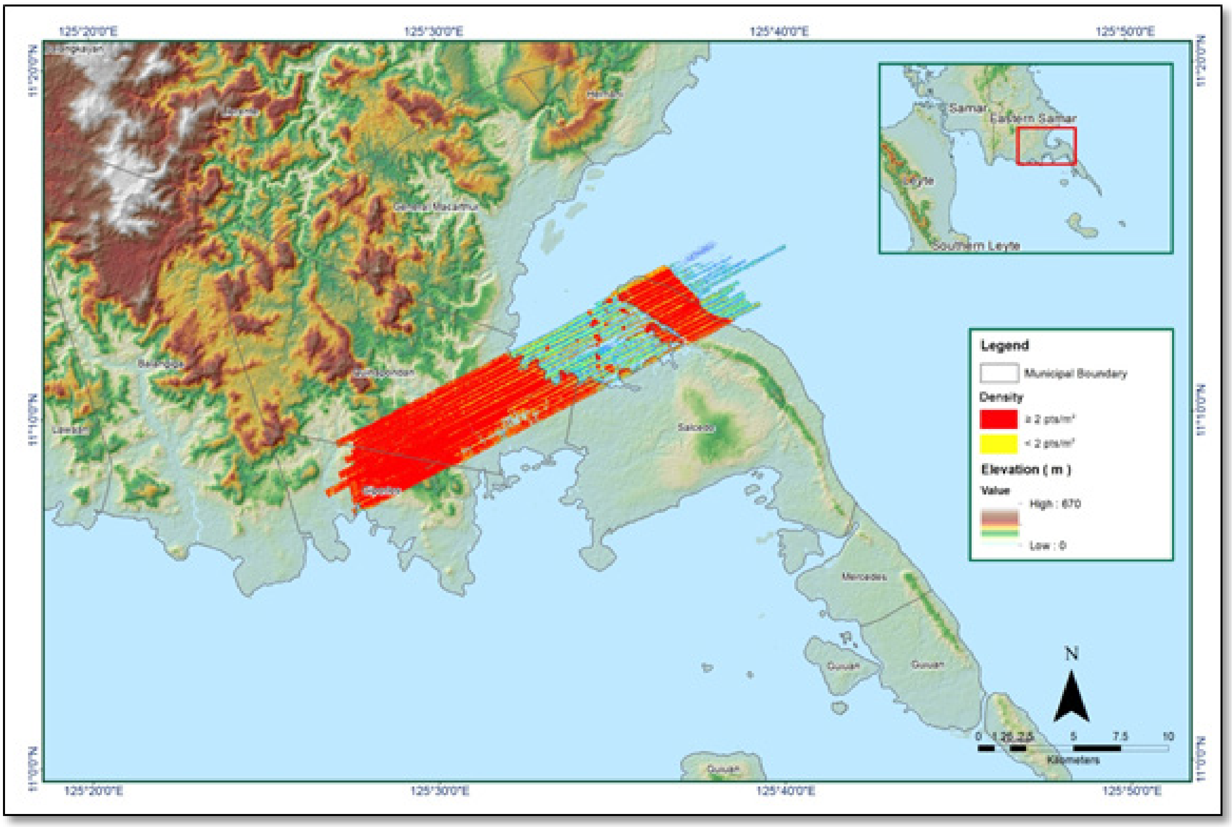


Figure A-8.13 Density map of merged LiDAR data

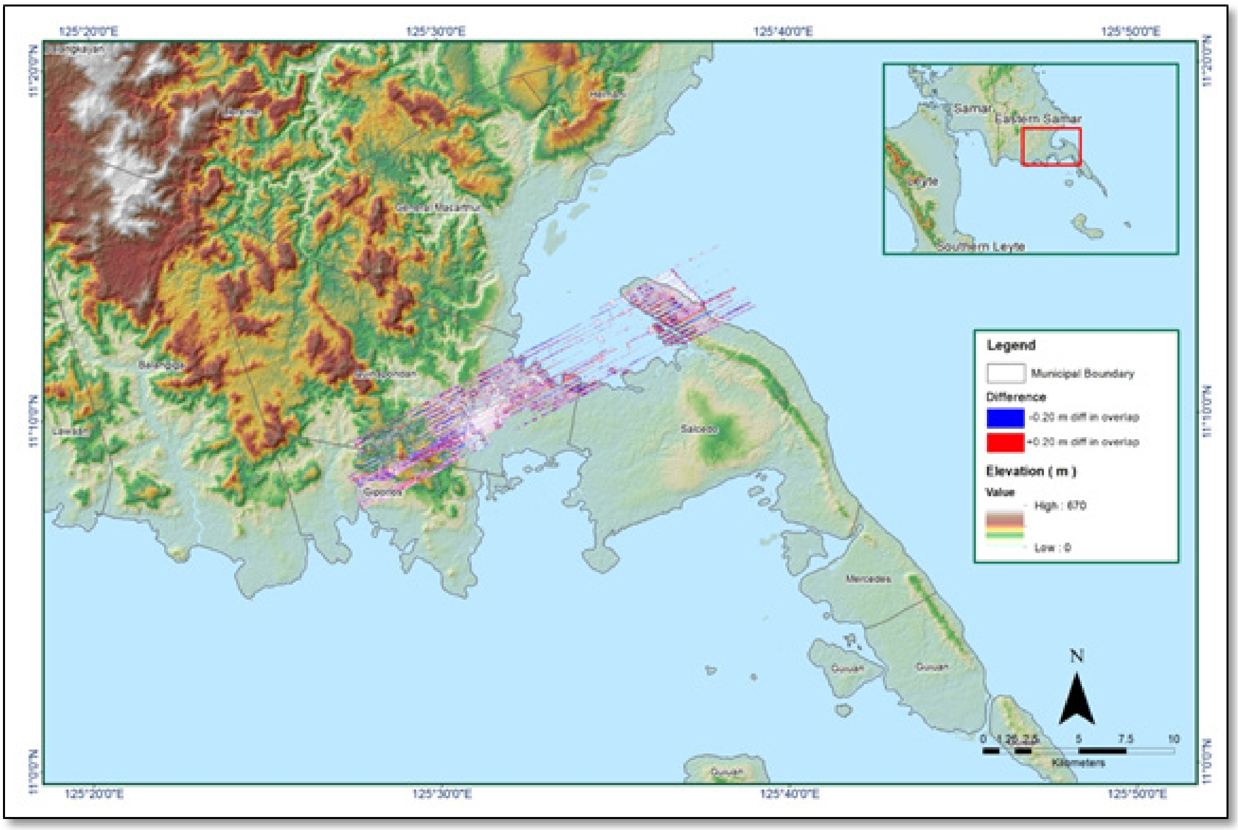


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk33S_supplement

Flight Area	Samar-Leyte
Mission Name	Blk 33S_supplement
Inclusive Flights	1520A
Range data size	20.37 GB
POS	289 MB
Base data size	10.5 MB
Image	88.5 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000313
IMU attitude correction stdev (<0.001deg)	0.001811
GPS position stdev (<0.01m)	0.0116
Minimum % overlap (>25)	29.45%
Ave point cloud density per sq.m. (>2.0)	2.62
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	104
Maximum Height	317.07 m
Minimum Height	40.58 m
Classification (# of points)	
Ground	32,417,680
Low vegetation	19,545,232
Medium vegetation	53,769,619
High vegetation	24,723,198
Building	275,825
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Engr. Gladys Mae Apat

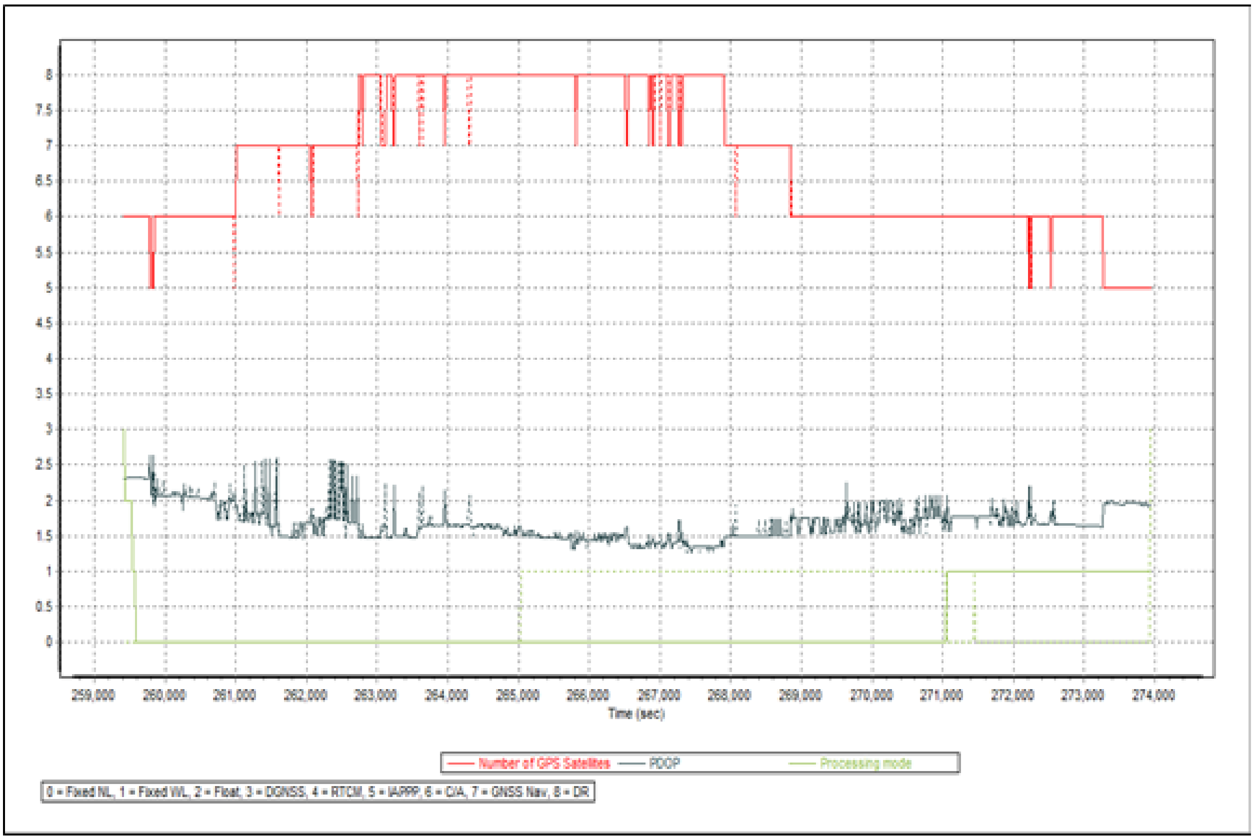


Figure A-8.15 Solution Status

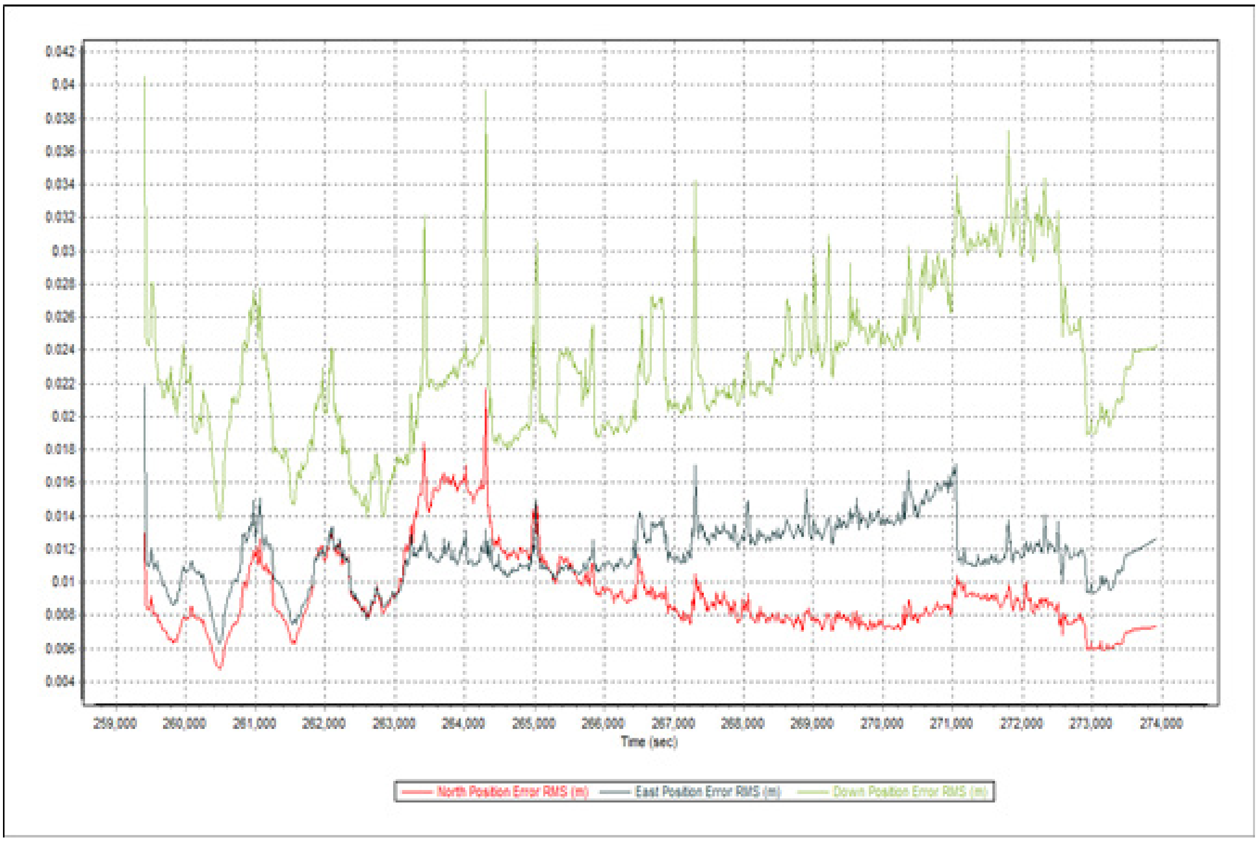


Figure A-8.16 Smoothed Performance Metric Parameters

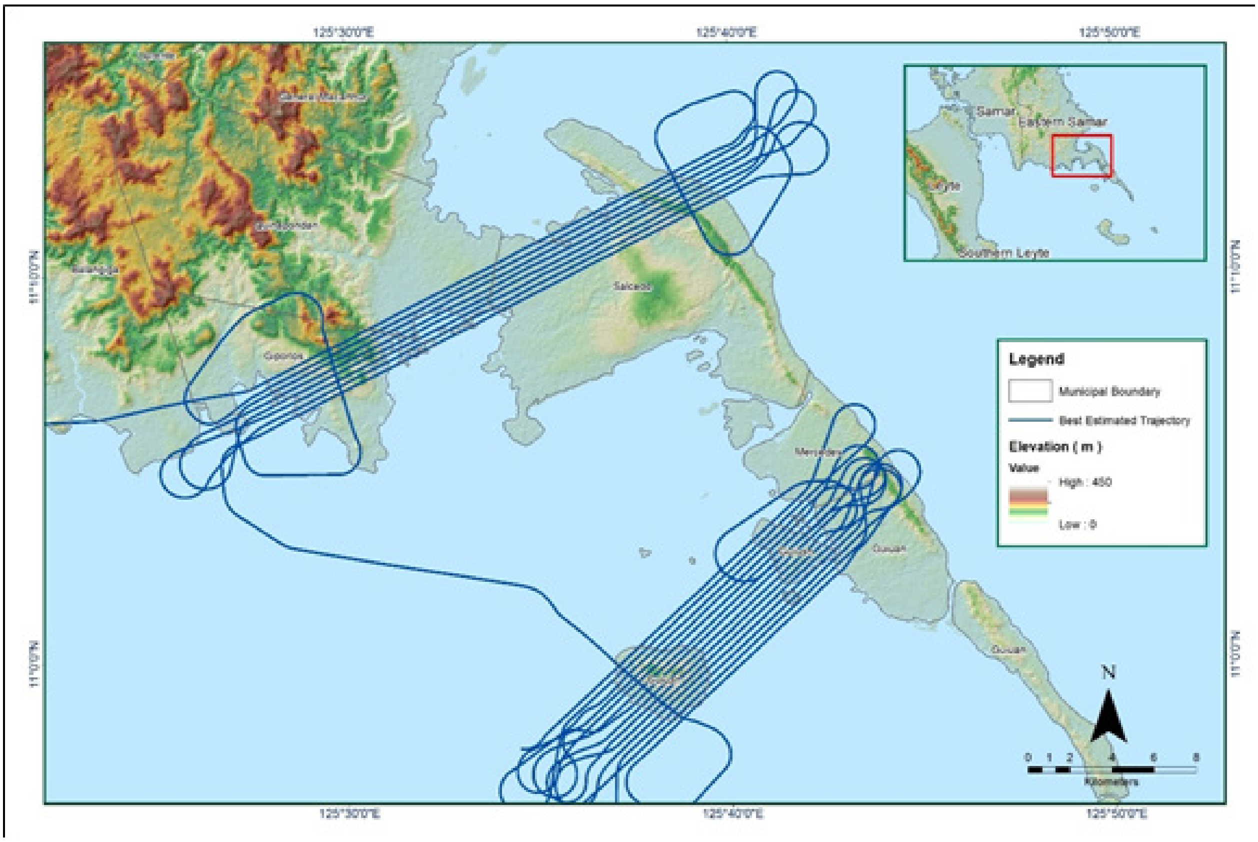


Figure A-8.17 Best Estimated Trajectory

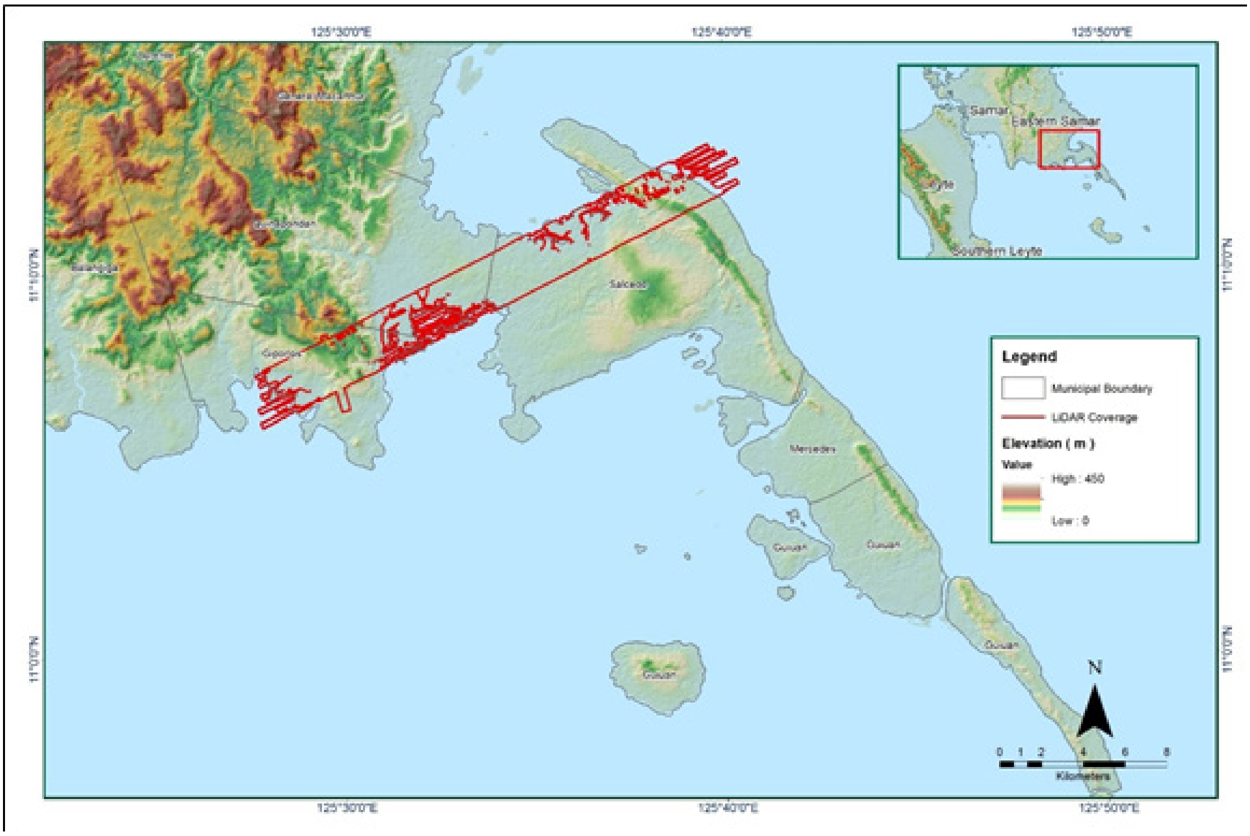


Figure A-8.18 Coverage of LiDAR data

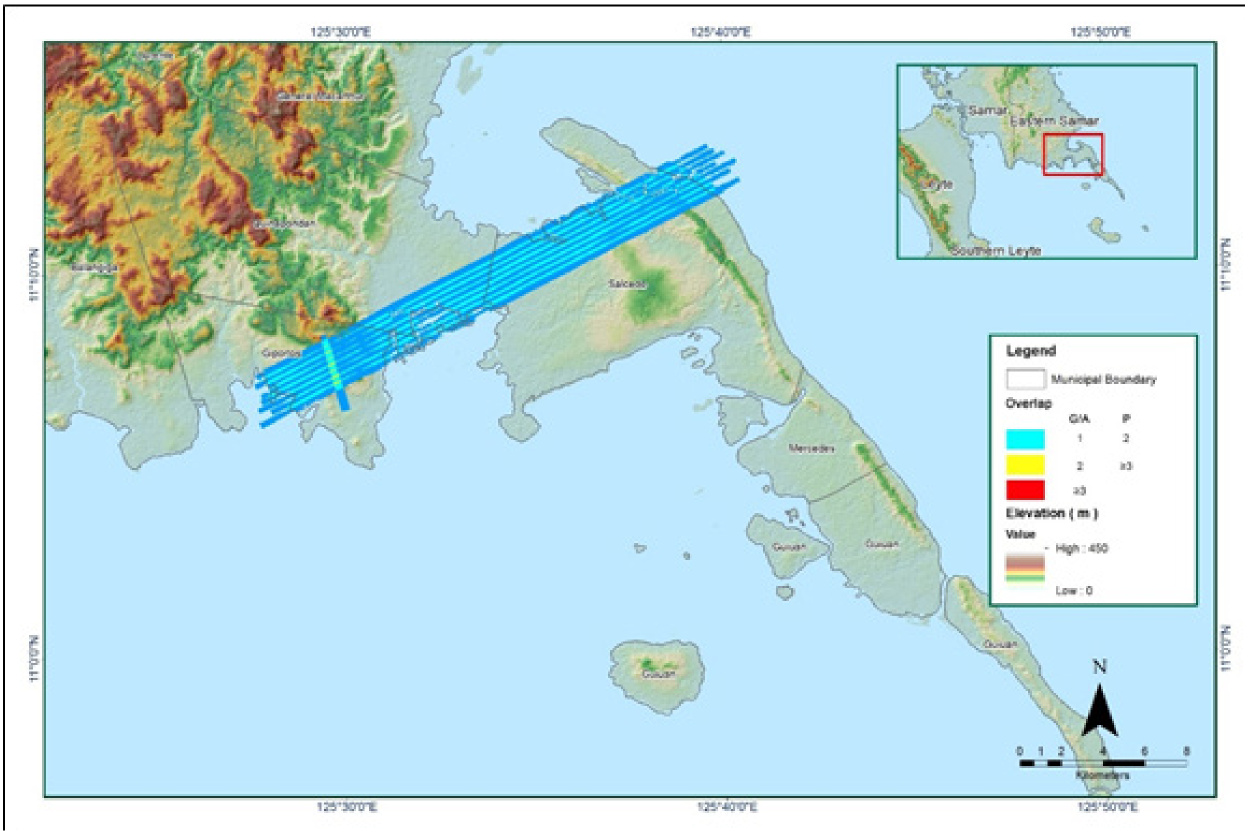


Figure A-8.19 Image of Data Overlap

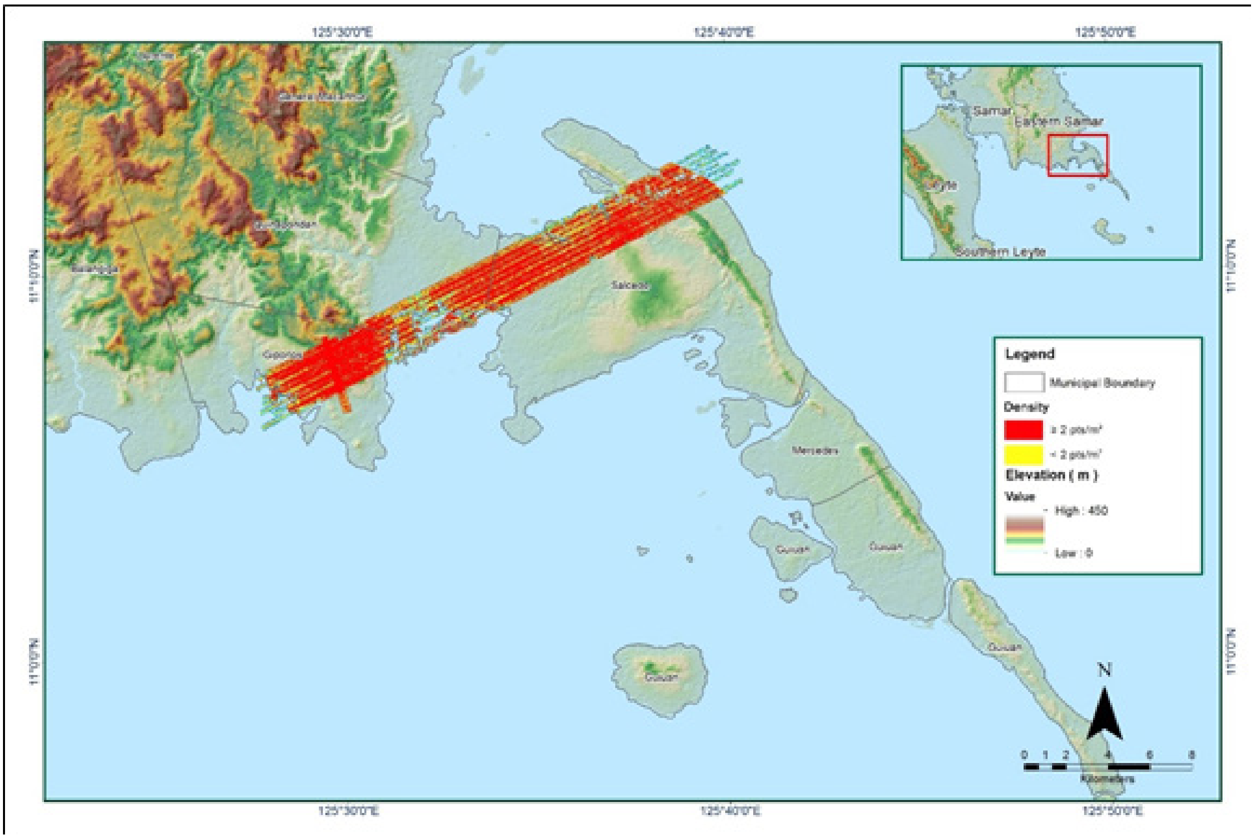


Figure A-8.20 Density map of merged LiDAR data

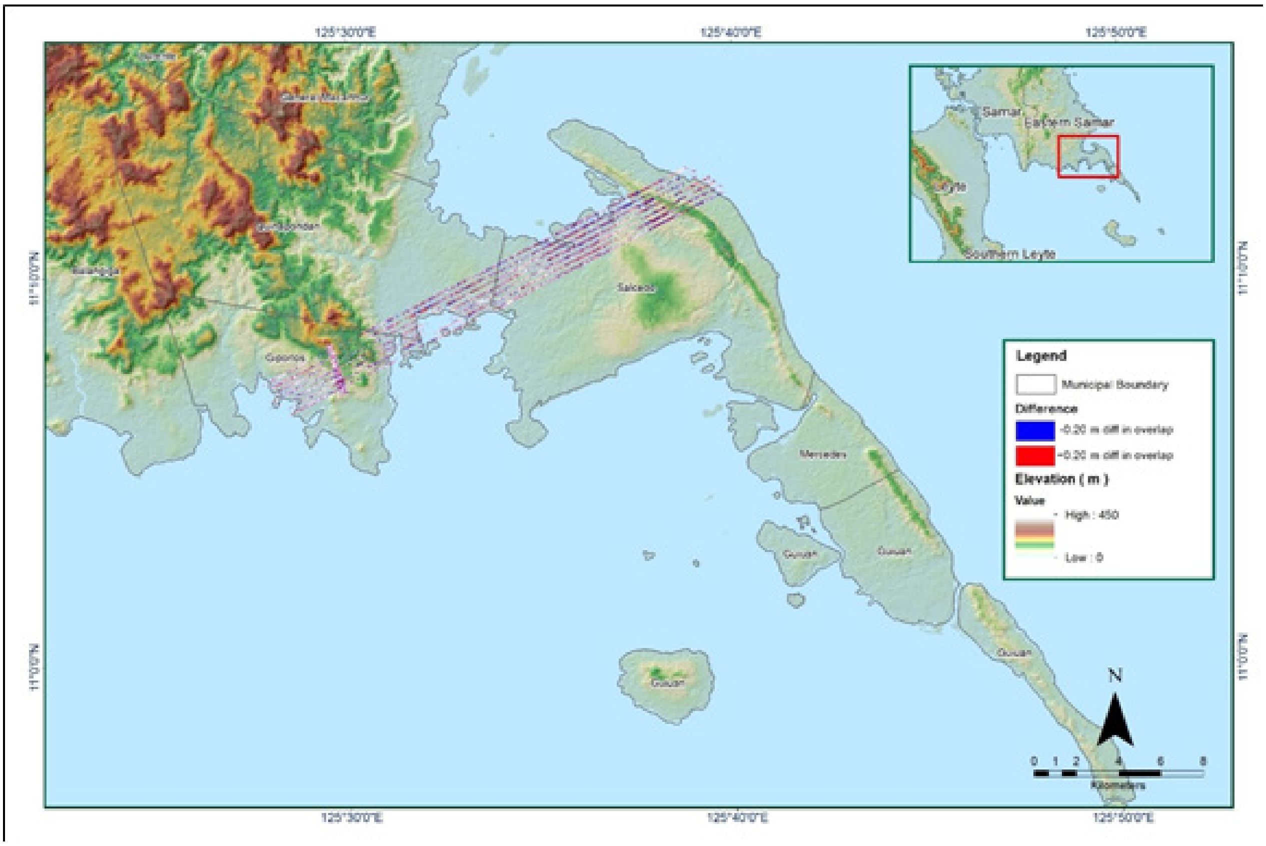


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk33T

Flight Area	Samar-Leyte
Mission Name	Blk 33T
Inclusive Flights	1508A, 1510A
Range data size	30 GB
POS	501 MB
Base data size	21.85 MB
Image	175.7 GB
Transfer date	June 10, 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)	1.3
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000589
IMU attitude correction stdev (<0.001deg)	0.007224
GPS position stdev (<0.01m)	0.0137
Minimum % overlap (>25)	35.21%
Ave point cloud density per sq.m. (>2.0)	3.61
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	176
Maximum Height	269.90 m
Minimum Height	39.35 m
Classification (# of points)	
Ground	47,454,400
Low vegetation	47,186,524
Medium vegetation	180,813,041
High vegetation	51,144,244
Building	814,789
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Engr. Gladys Mae Apat

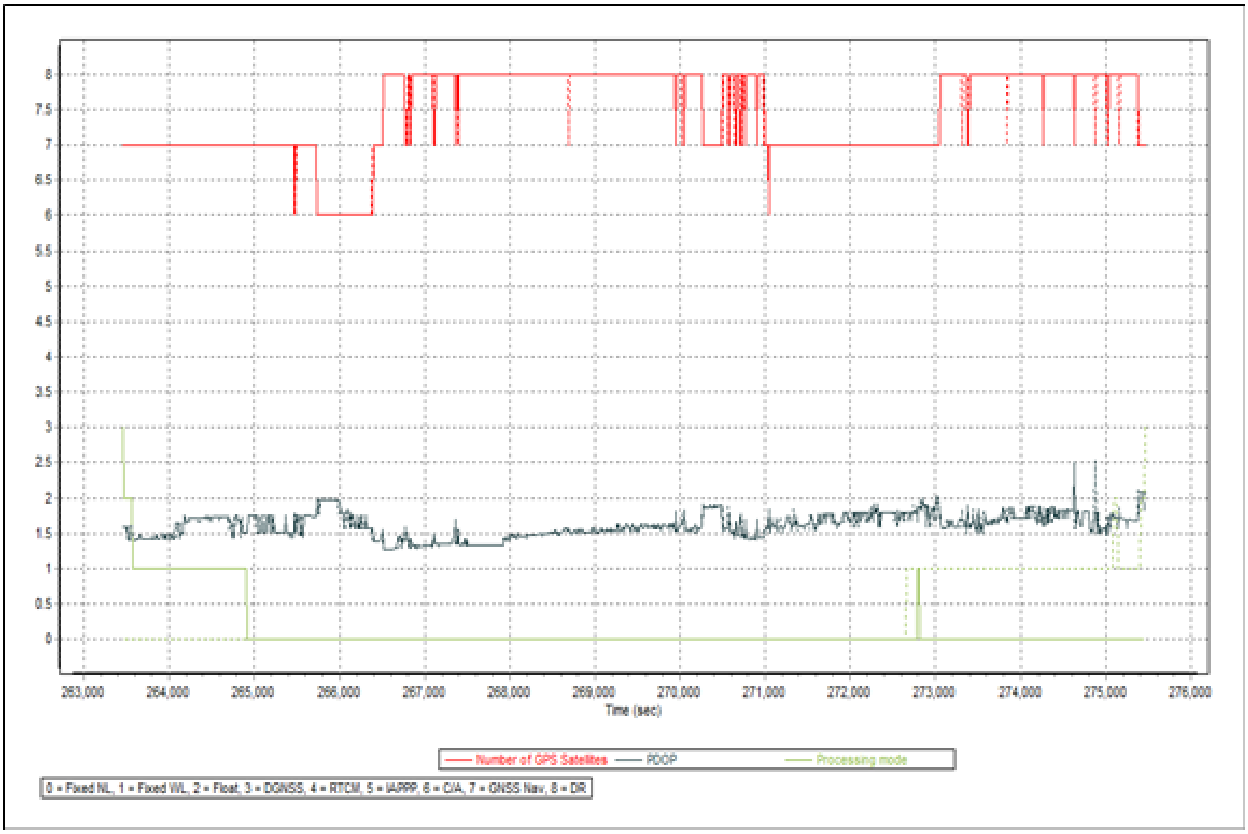


Figure A-8.22 Solution Status

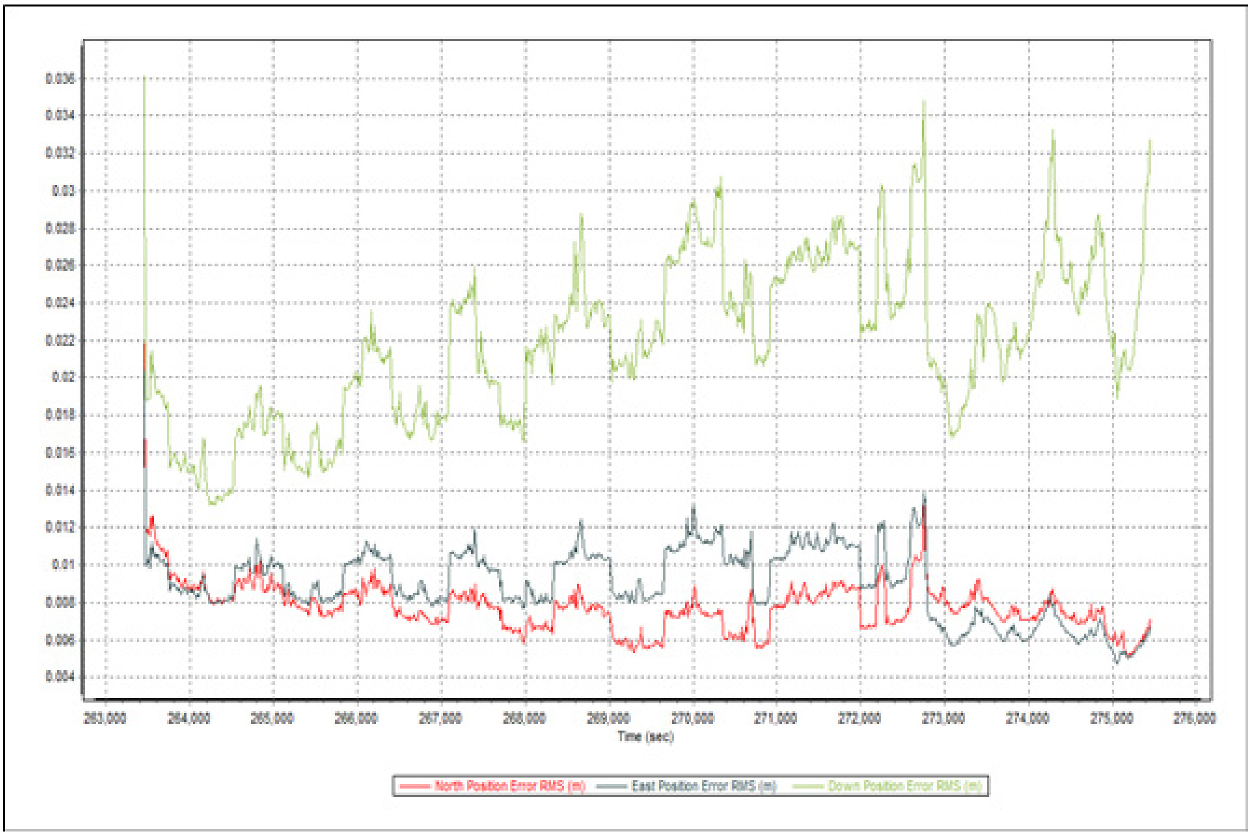


Figure A-8.23 Smoothed Performance Metric Parameters

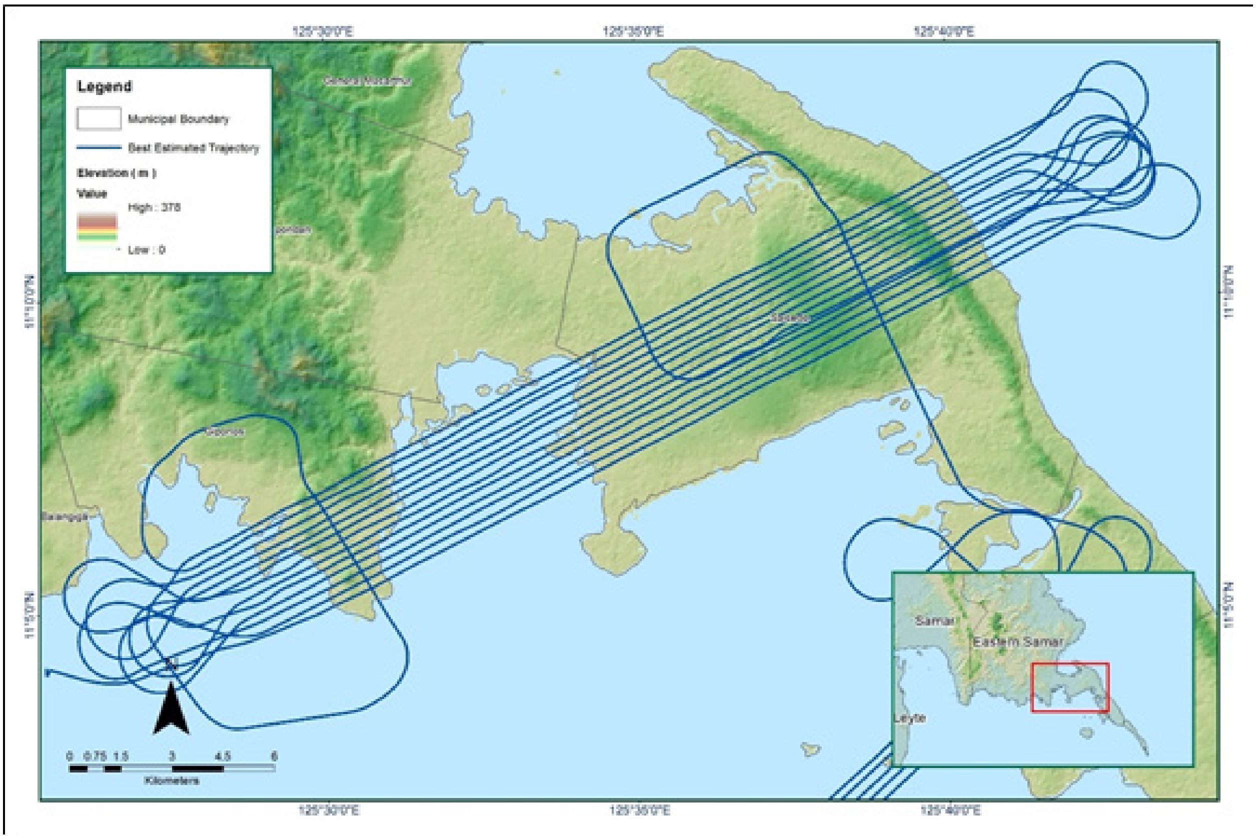


Figure A-8.24 Best Estimated Trajectory

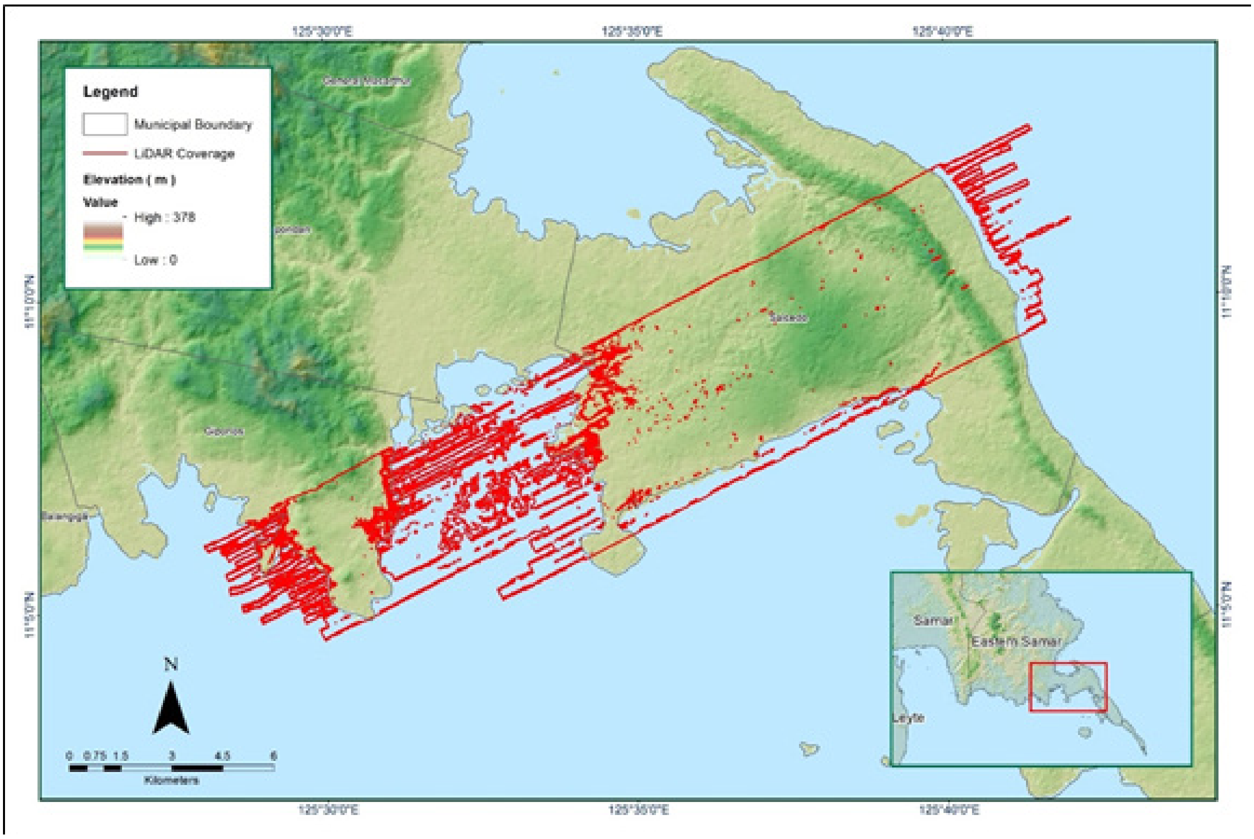


Figure A-8.25 Coverage of LiDAR data

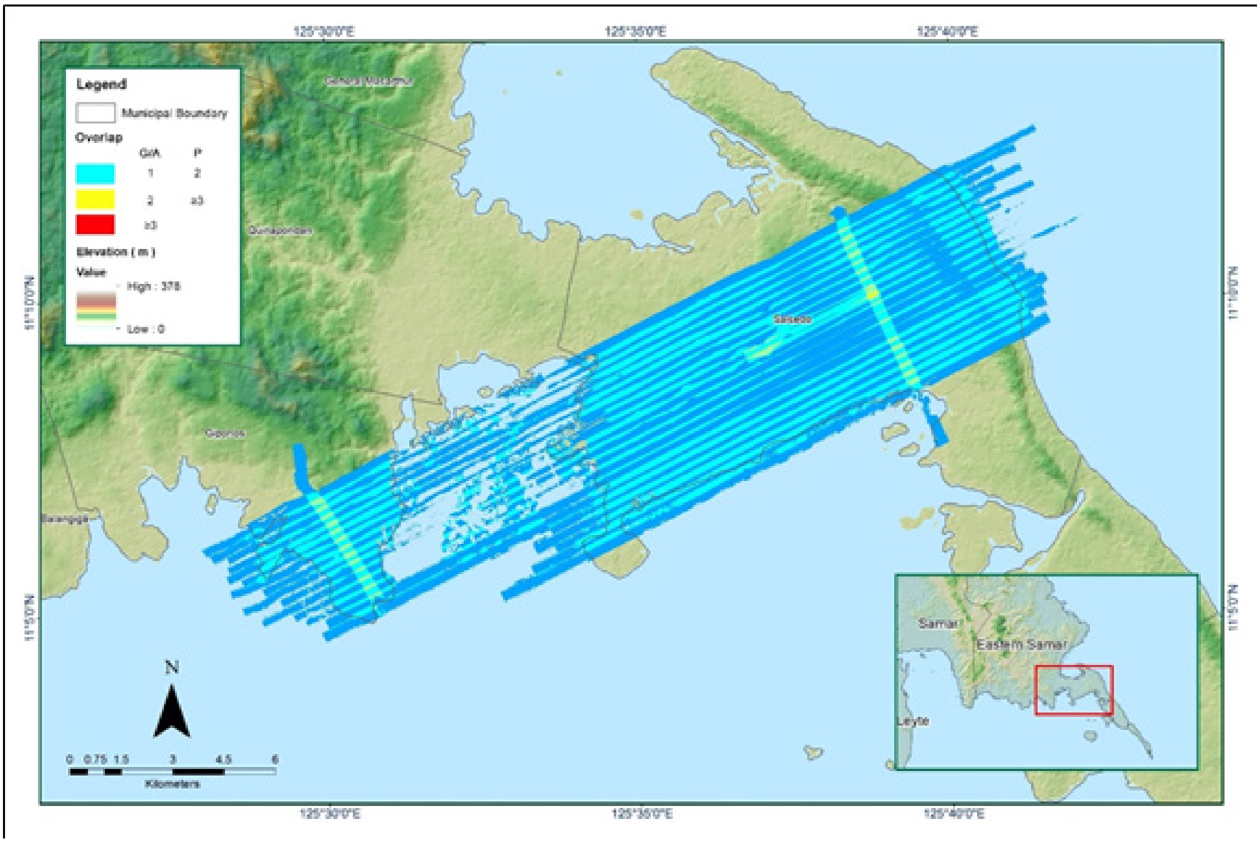


Figure A-8.26 Image of Data Overlap

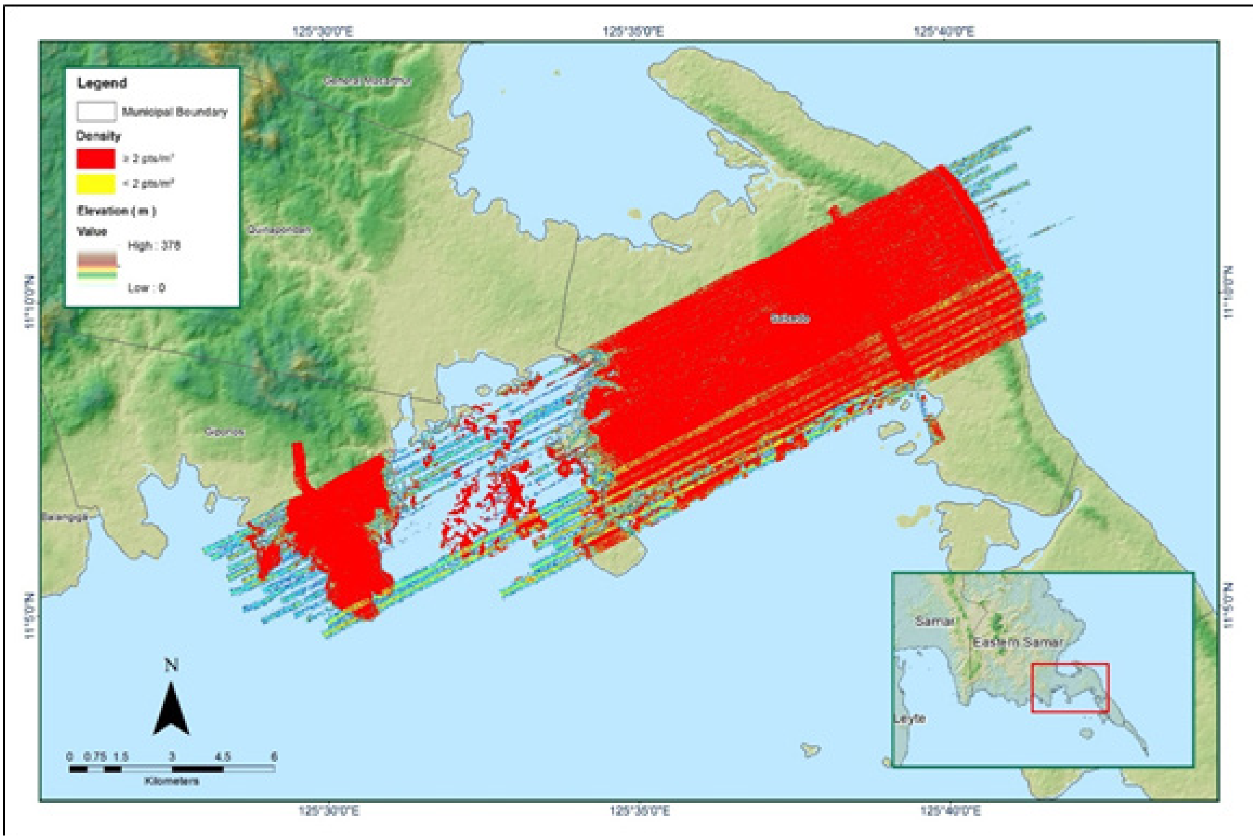


Figure A-8.27 Density map of merged LiDAR data

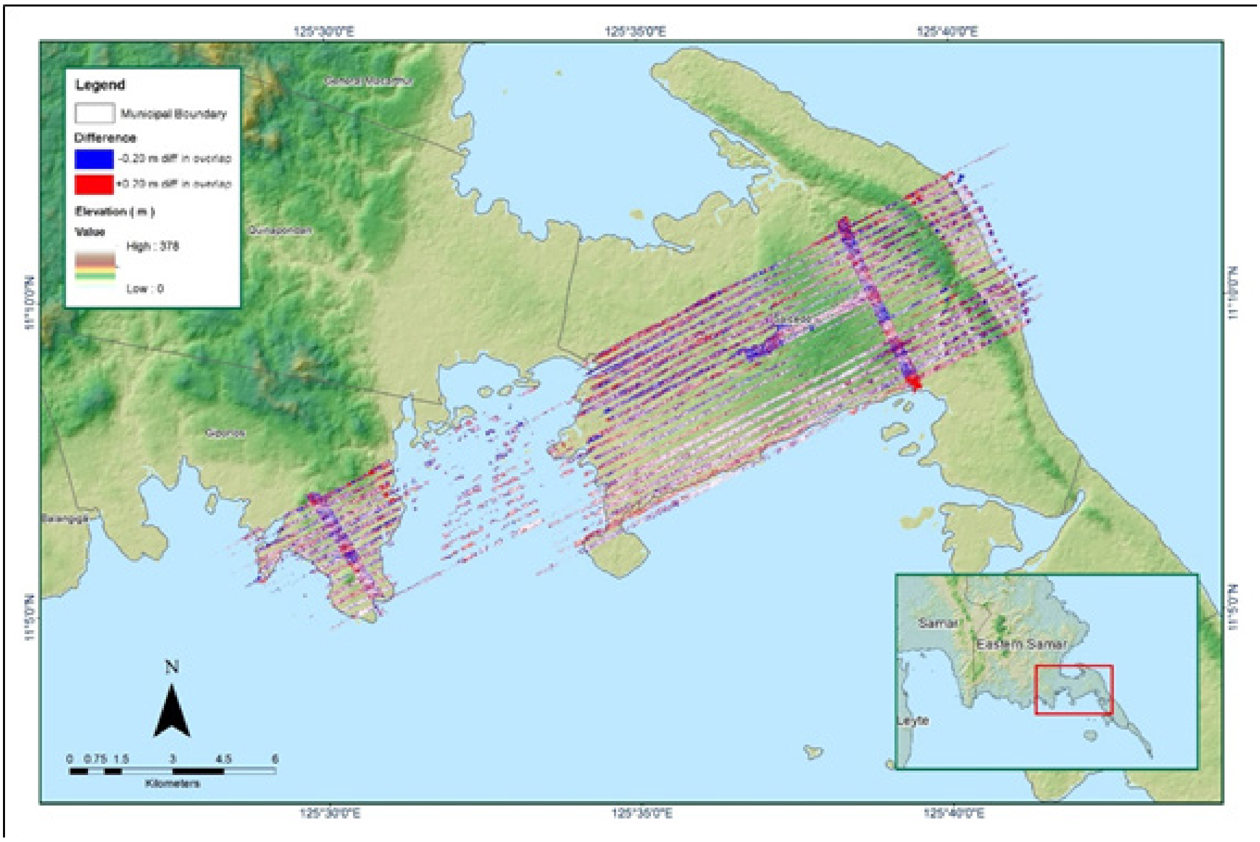


Figure A-8.28 Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk33U

Flight Area	Samar-Leyte
Mission Name	Blk 33U
Inclusive Flights	1508A, 1506A
Range data size	25.9 GB
POS	508 MB
Base data size	30 MB
Image	158.9 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.001105
IMU attitude correction stdev (<0.001deg)	0.006236
GPS position stdev (<0.01m)	0.0350
Minimum % overlap (>25)	39.26%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	245
Maximum Height	200.93 m
Minimum Height	27.73 m
Classification (# of points)	
Ground	81,446,909
Low vegetation	86,186,281
Medium vegetation	170,533,364
High vegetation	42,831,377
Building	4,036,669
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Mark Joshua Salvacion, Engr. Gladys Mae Apat

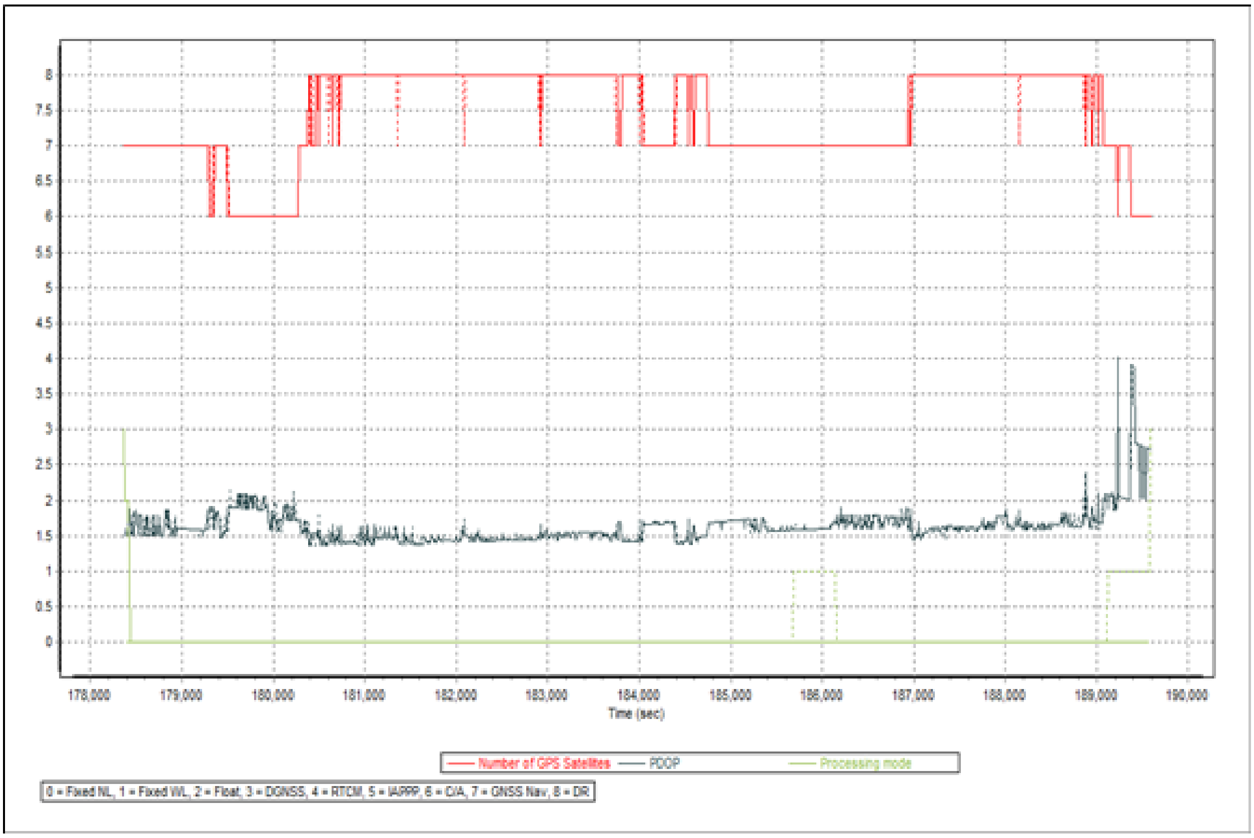


Figure A-8.29 Solution Status

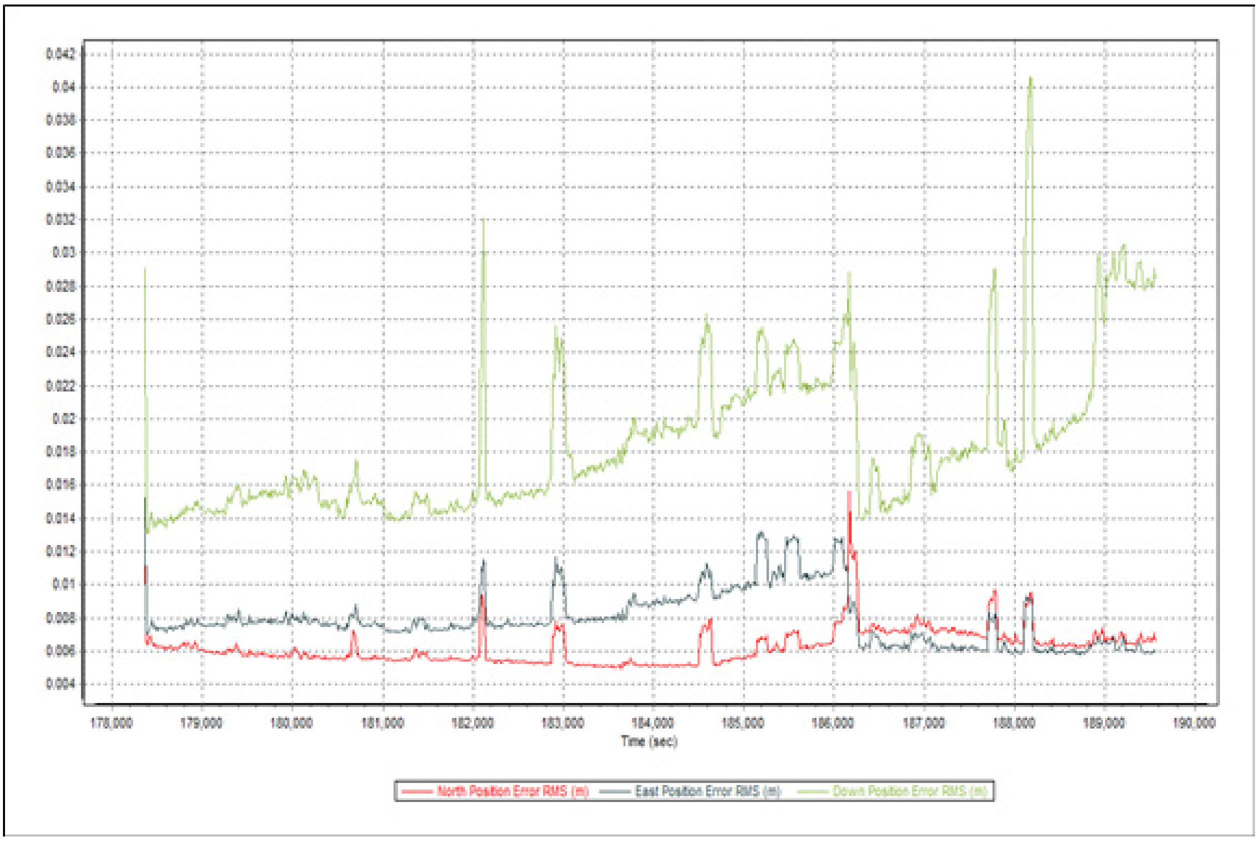


Figure A-8.30 Smoothed Performance Metric Parameters

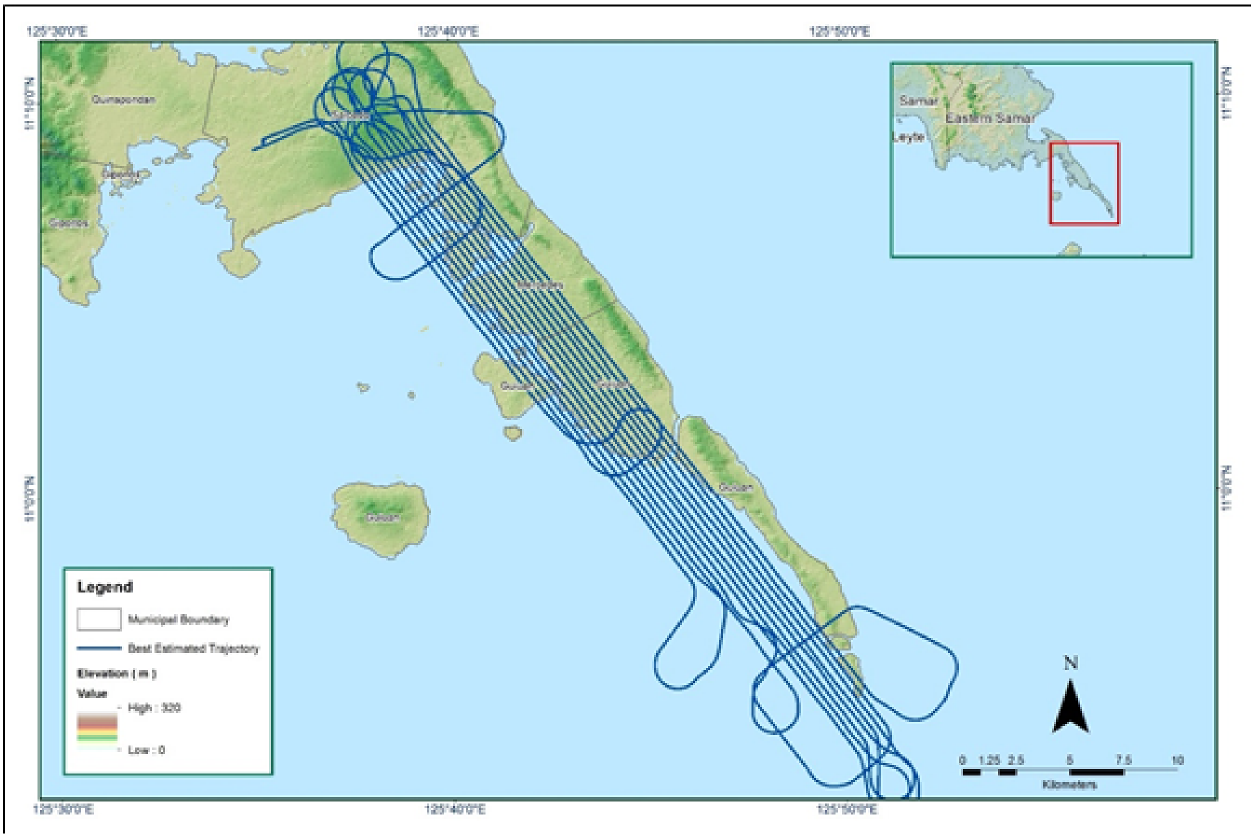


Figure A-8.31 Best Estimated Trajectory

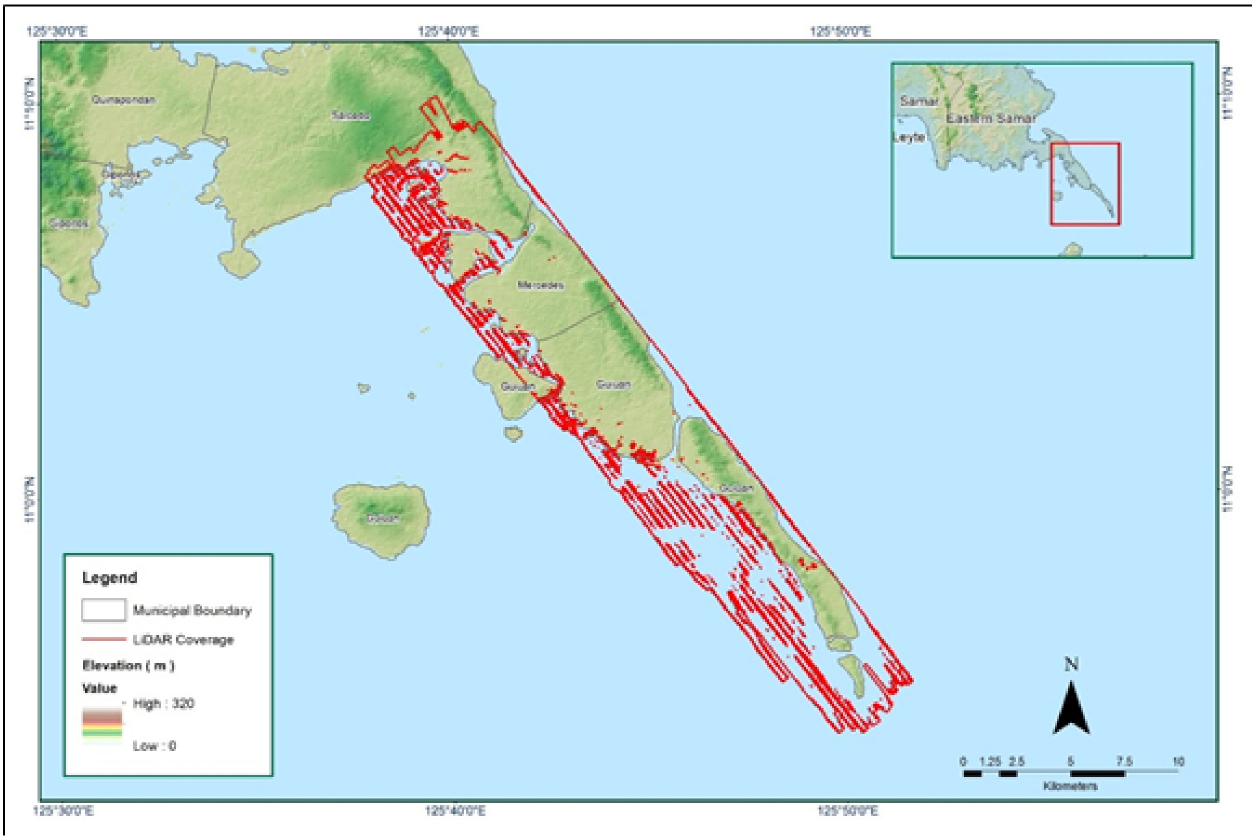


Figure A-8.32 Coverage of LiDAR data

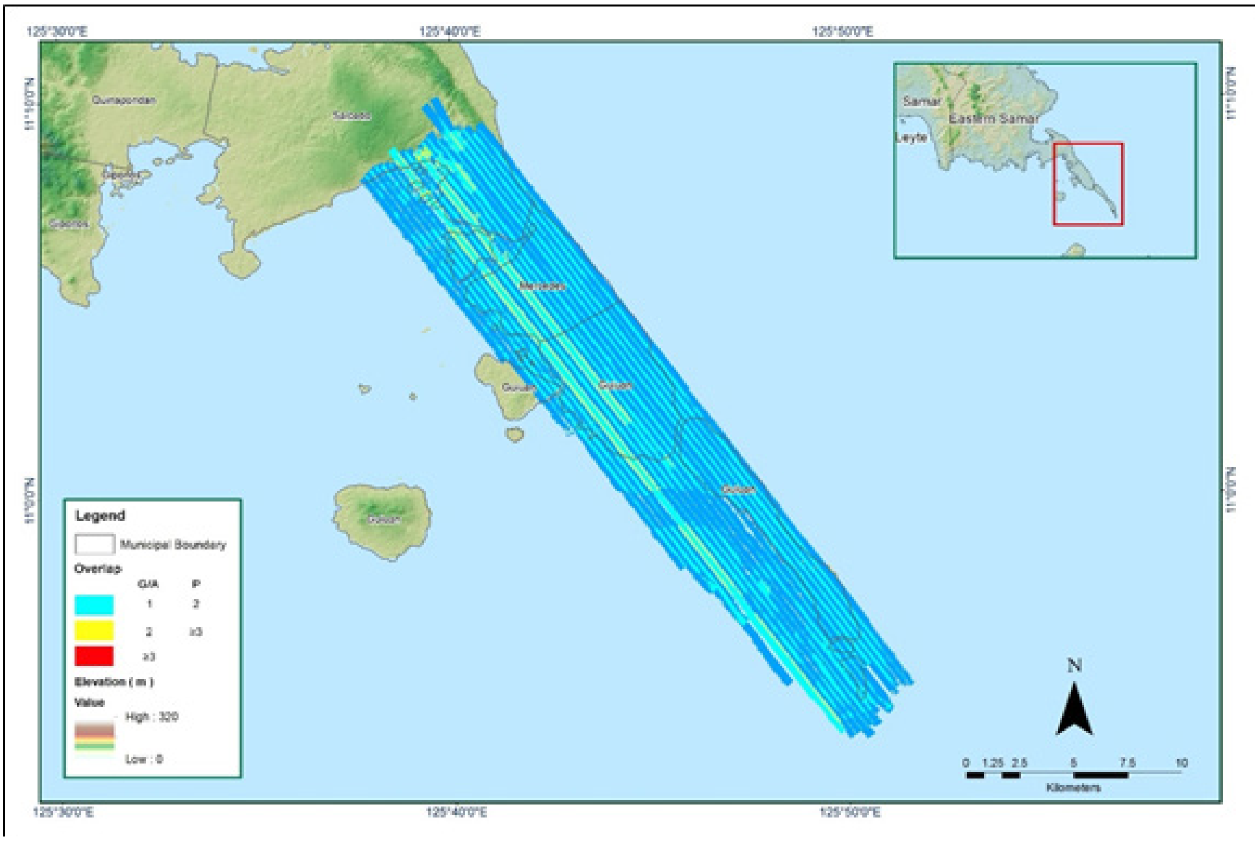


Figure A-8.33 Image of Data Overlap

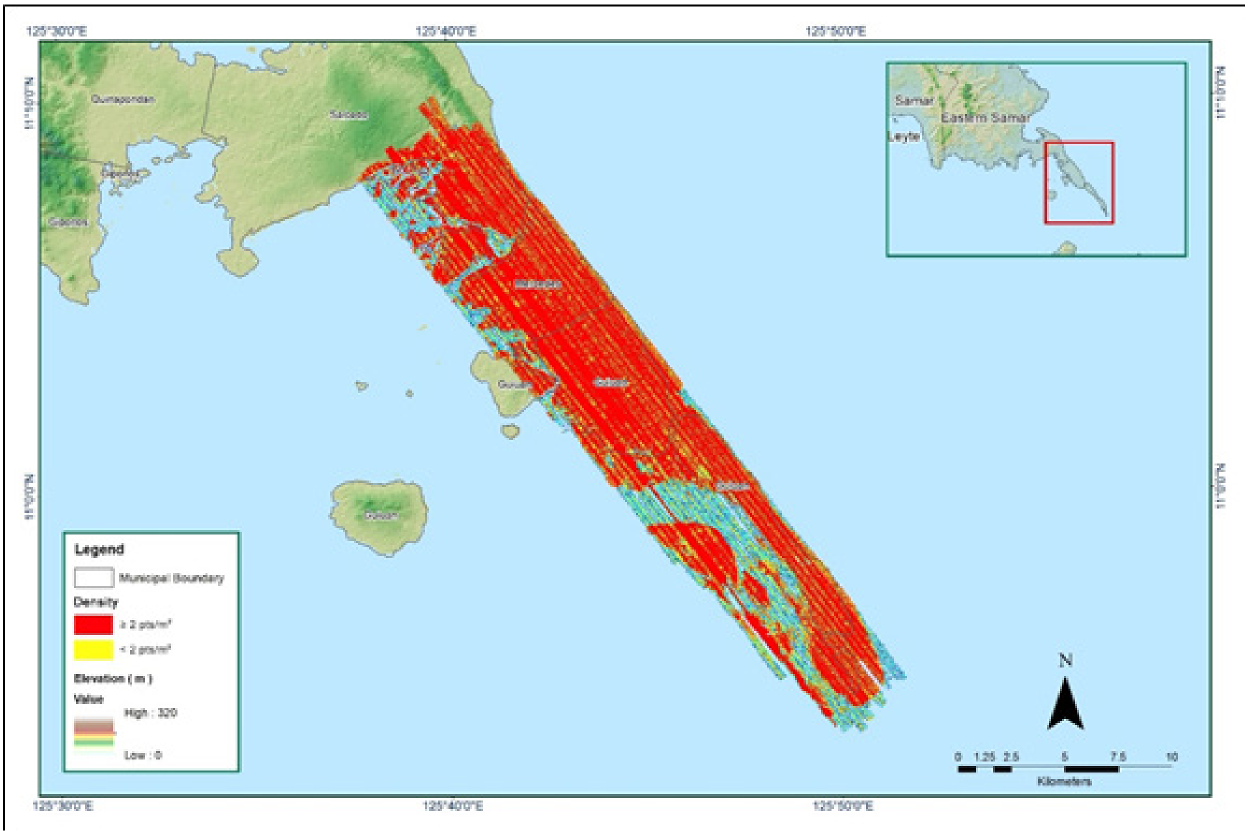


Figure A-8.34 Density map of merged LiDAR data

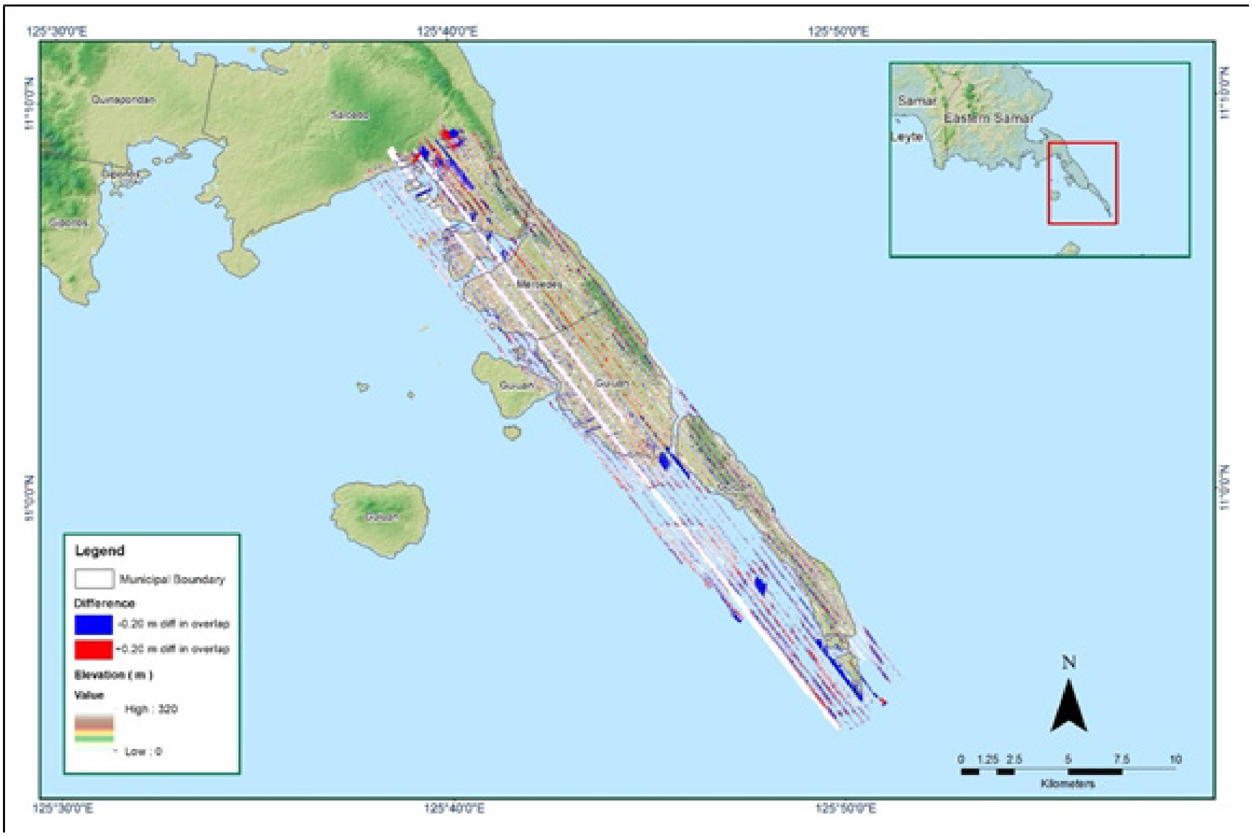


Figure A-8.35 Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk33V

Flight Area	Samar-Leyte
Mission Name	Blk 33V
Inclusive Flights	1510A, 1520A
Range data size	32.5 GB
POS	558 MB
Base data size	17.35 MB
Image	202.5 GB
Transfer date	June 10, 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)	1.4
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000383
IMU attitude correction stdev (<0.001deg)	0.002751
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	19.23%
Ave point cloud density per sq.m. (>2.0)	2.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	118
Maximum Height	203.06 m
Minimum Height	35.33 m
Classification (# of points)	
Ground	30,771,860
Low vegetation	30,935,760
Medium vegetation	34,869,813
High vegetation	3,419,758
Building	669,969
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Mark Joshua Salvacion, Engr. Gladys Mae Apat

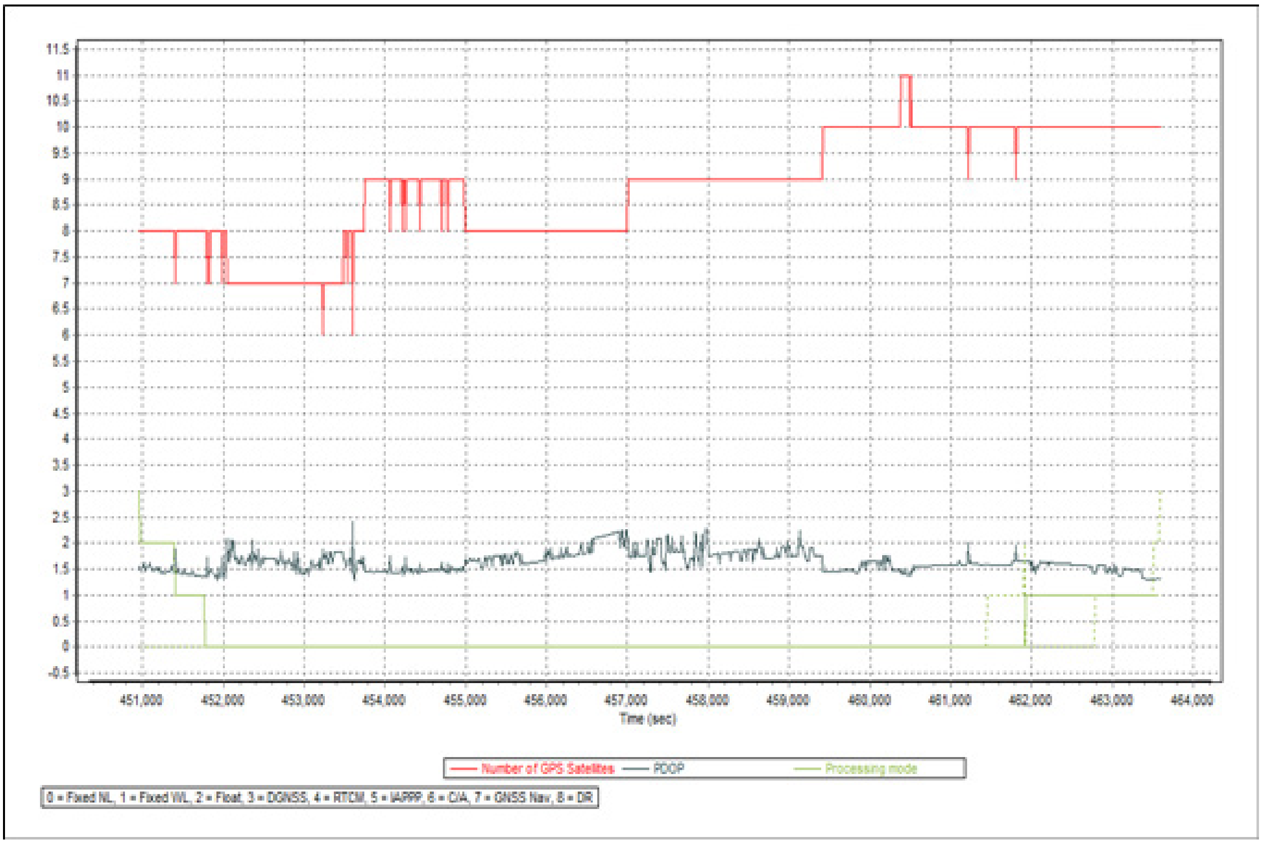


Figure A-8.36 Solution Status

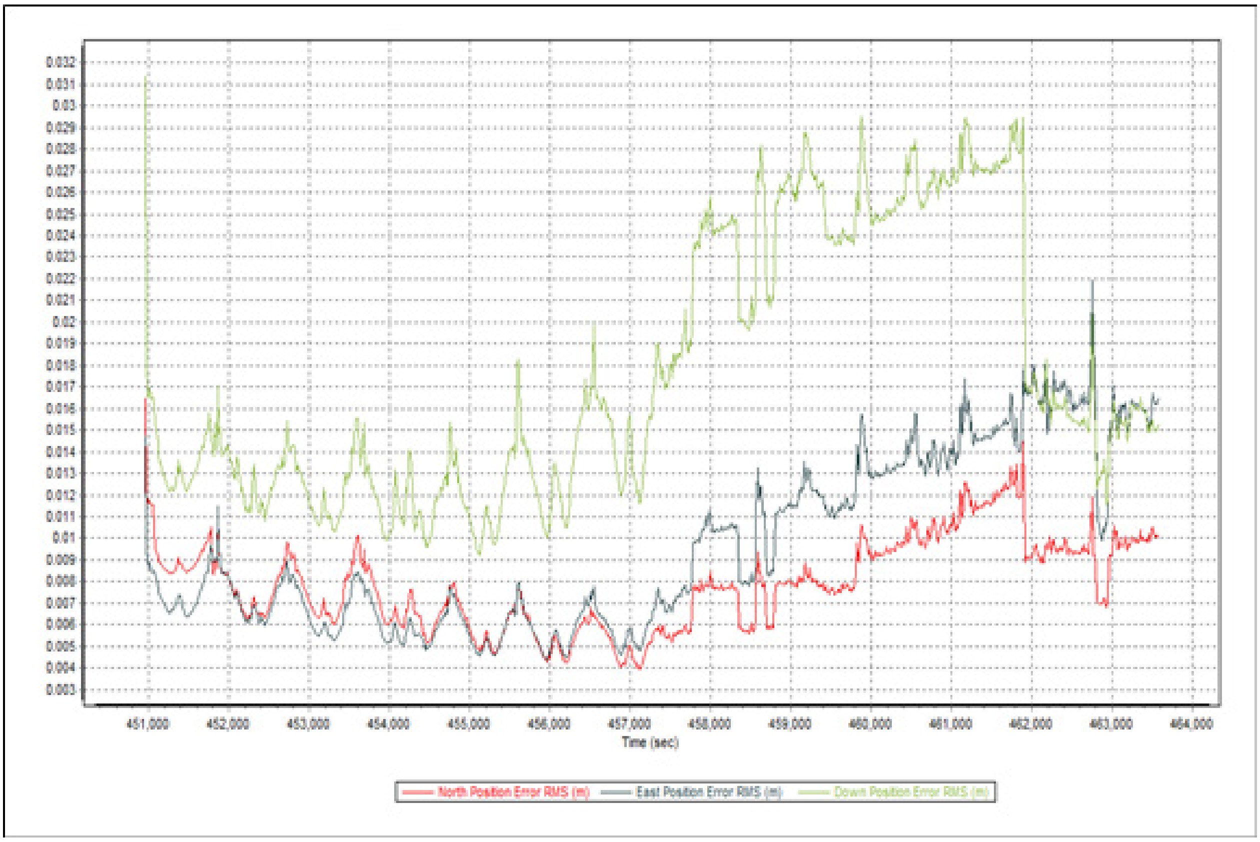


Figure A-8.37 Smoothed Performance Metric Parameters

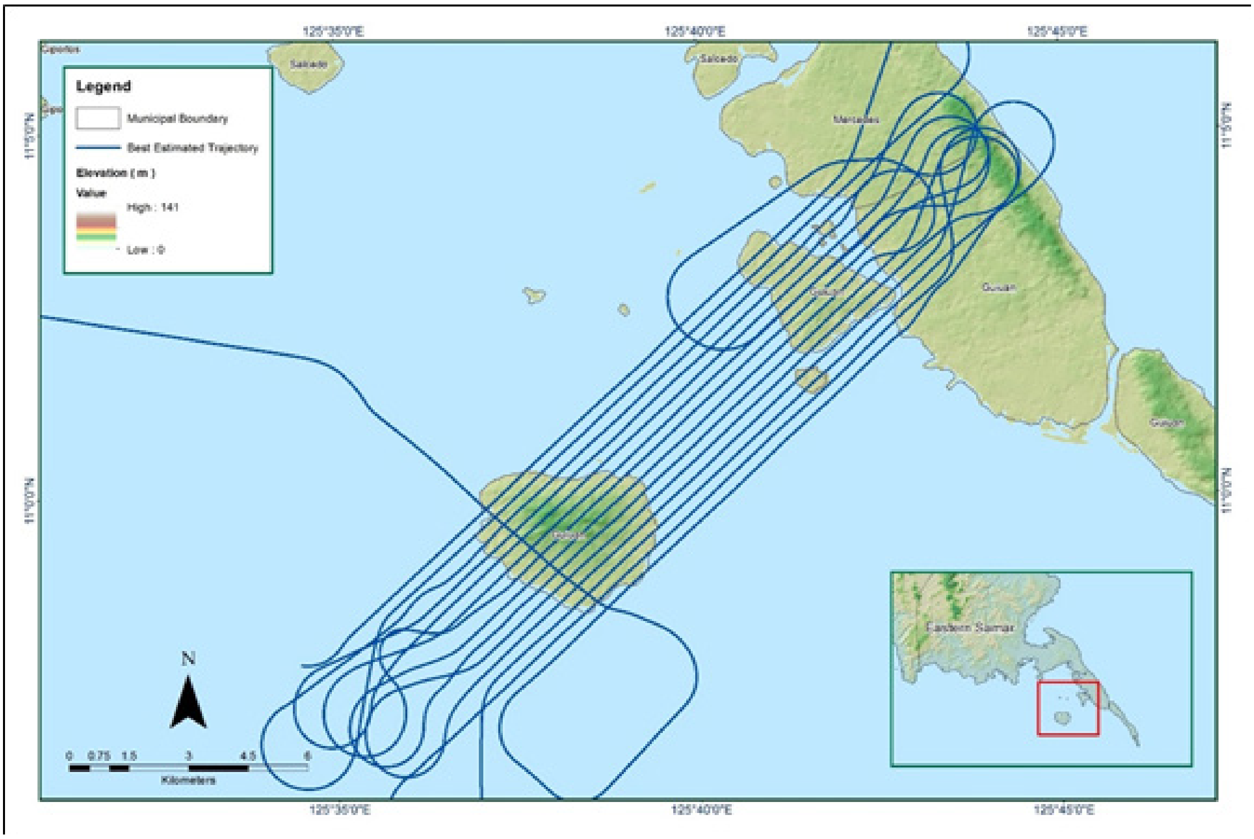


Figure A-8.38 Best Estimated Trajectory

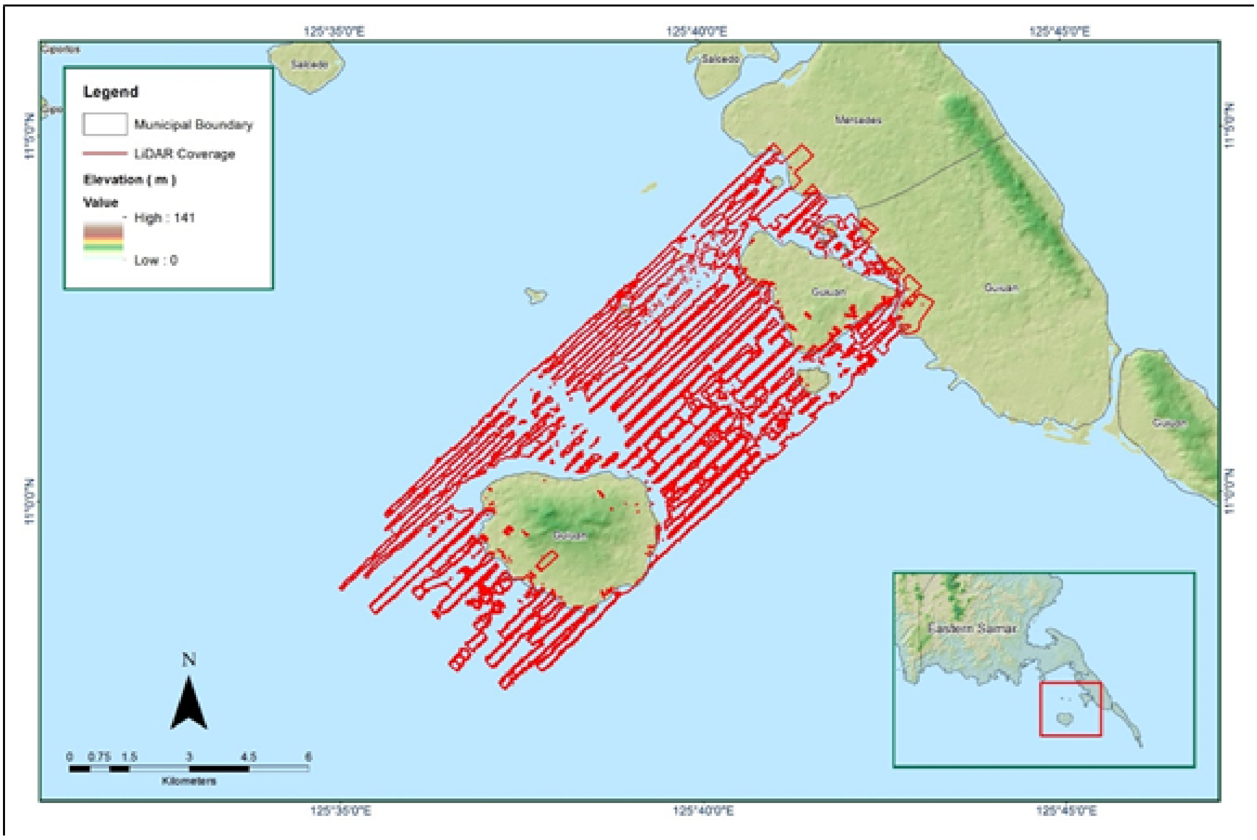


Figure A-8.39 Coverage of LiDAR data

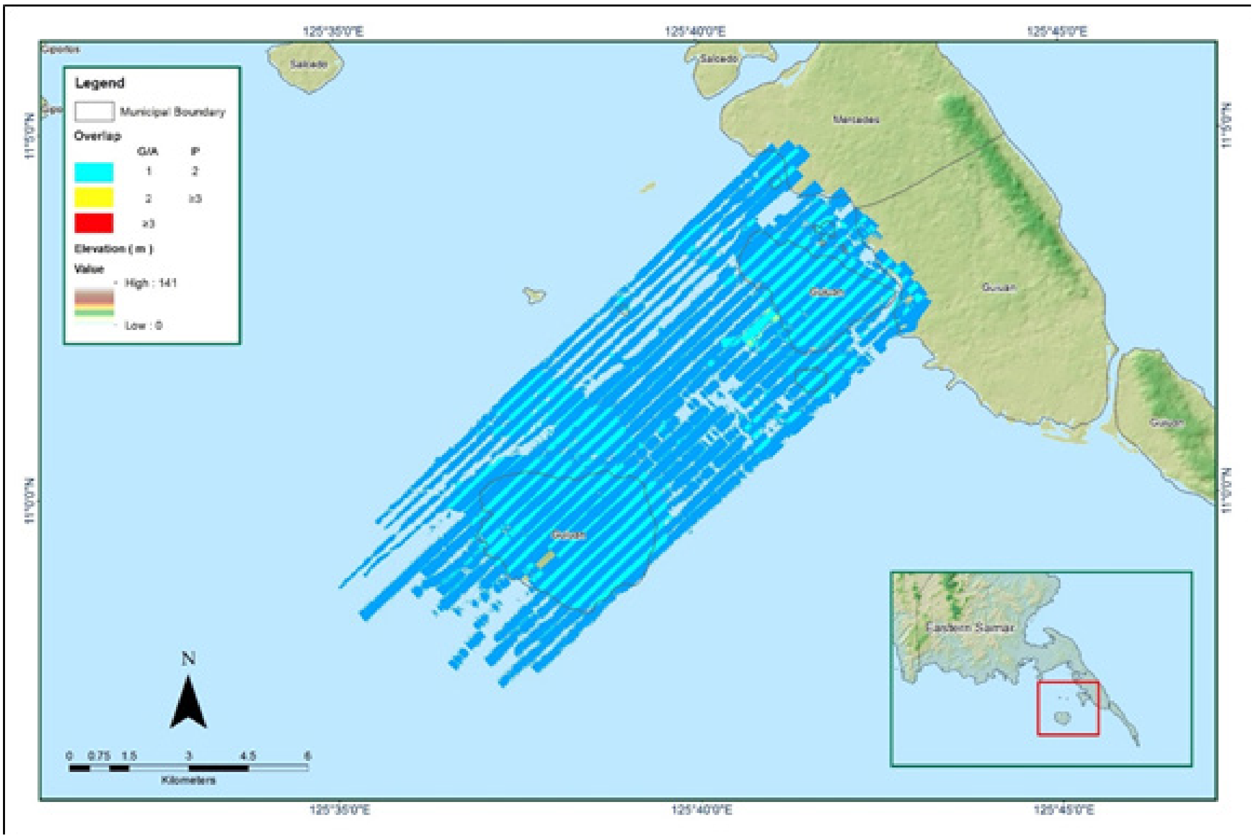


Figure A-8.40 Image of Data Overlap

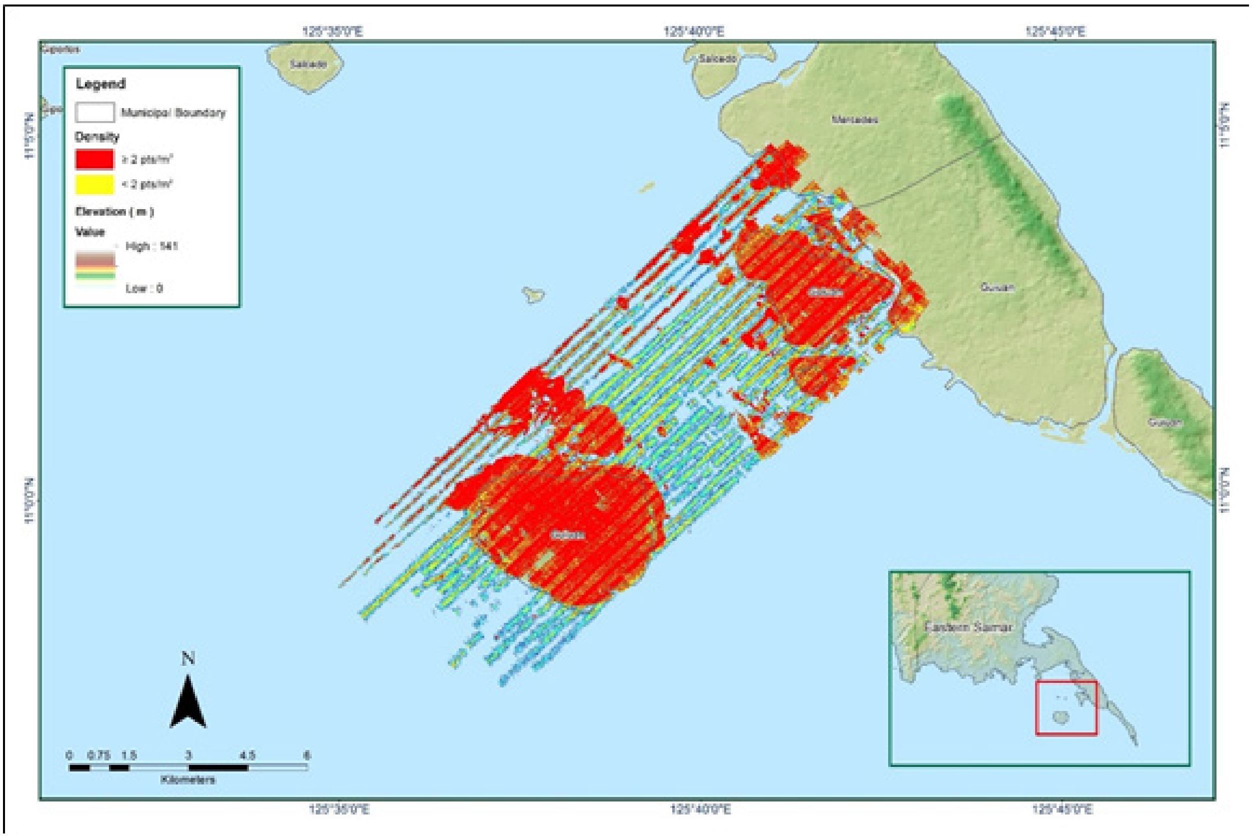


Figure A-8.41 Density map of merged LiDAR data

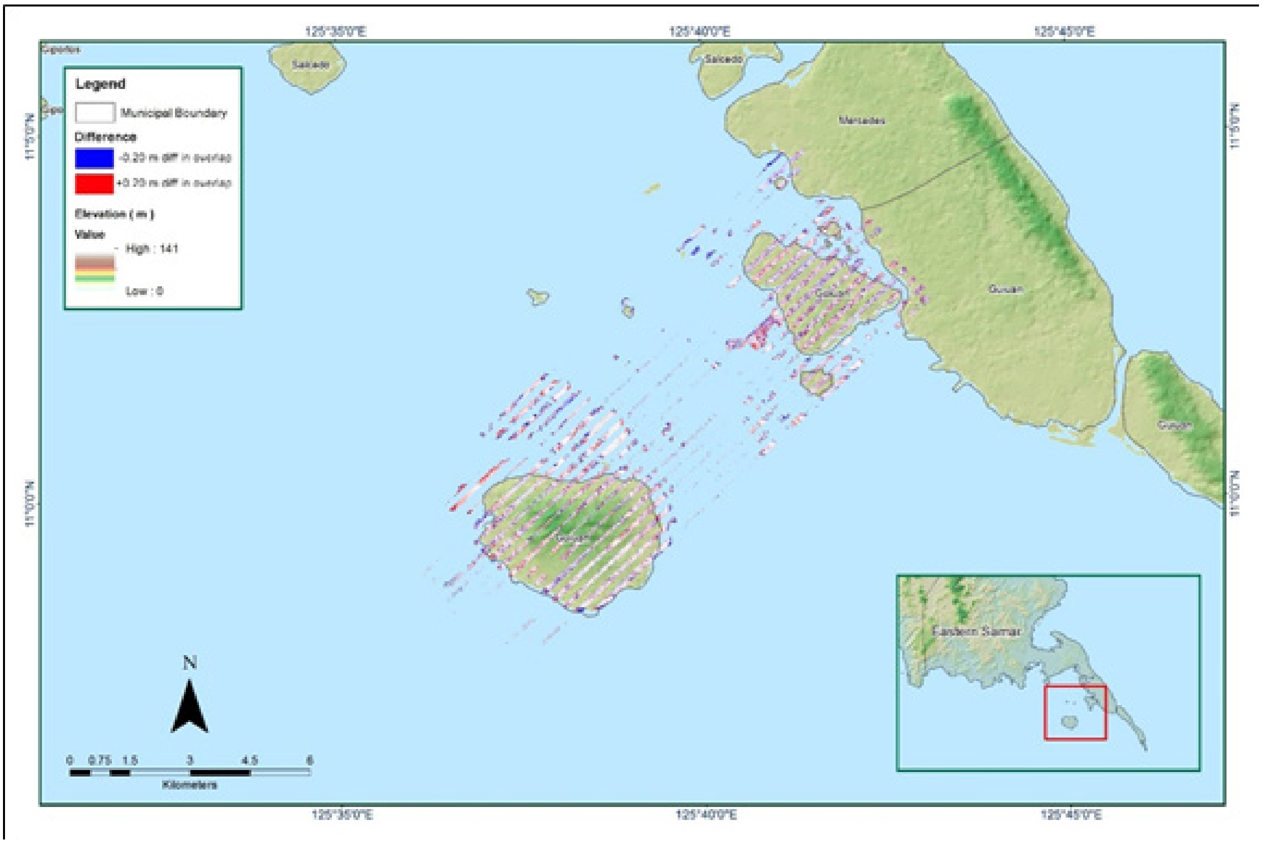


Figure A-8.42 Elevation difference between flight lines

Table A-8.7 Mission Summary Report for Mission Blk33R

Flight Area	Samar-Leyte
Mission Name	Blk33R
Inclusive Flights	1526A, 1530A
Range data size	31.1 GB
POS	531 MB
Base data size	16.24 MB
Image	230.1 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.9
Boresight correction stdev (<0.001deg)	0.000361
IMU attitude correction stdev (<0.001deg)	0.333120
GPS position stdev (<0.01m)	0.0306
Minimum % overlap (>25)	32.40%
Ave point cloud density per sq.m. (>2.0)	2.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	175
Maximum Height	363.63 m
Minimum Height	52.83 m
Classification (# of points)	
Ground	83,197,472
Low vegetation	62,581,524
Medium vegetation	113,281,399
High vegetation	23,663,109
Building	1,886,248
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. Gladys Mae Apat

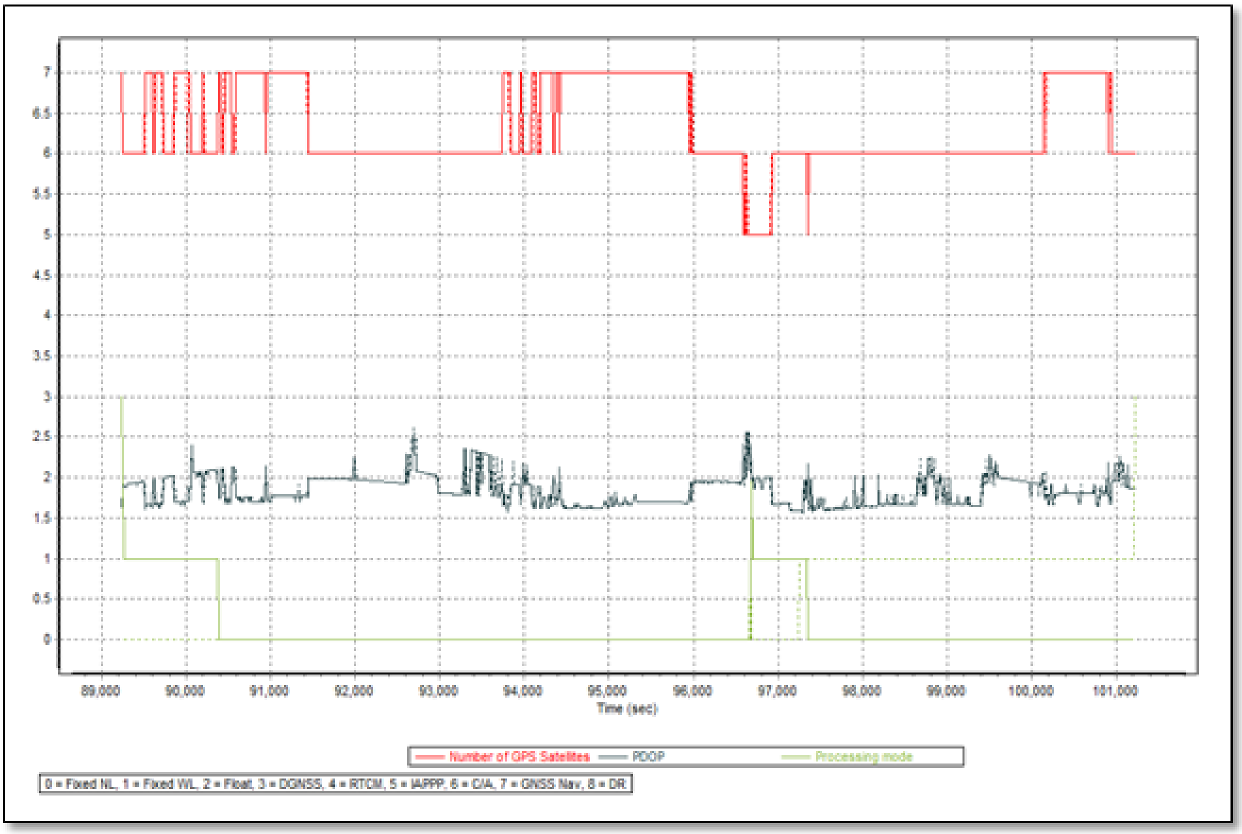


Figure A-8.43 Solution Status

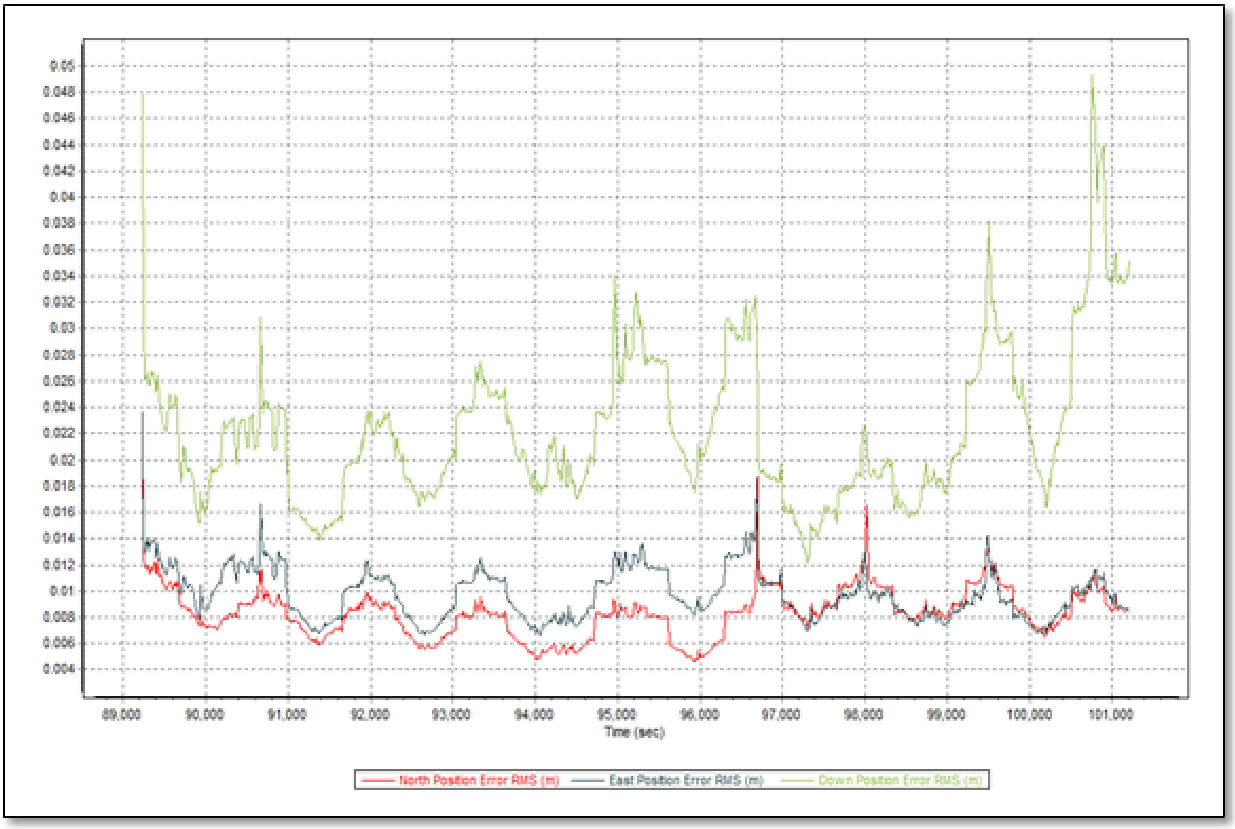


Figure A-8.44 Smoothed Performance Metric Parameters

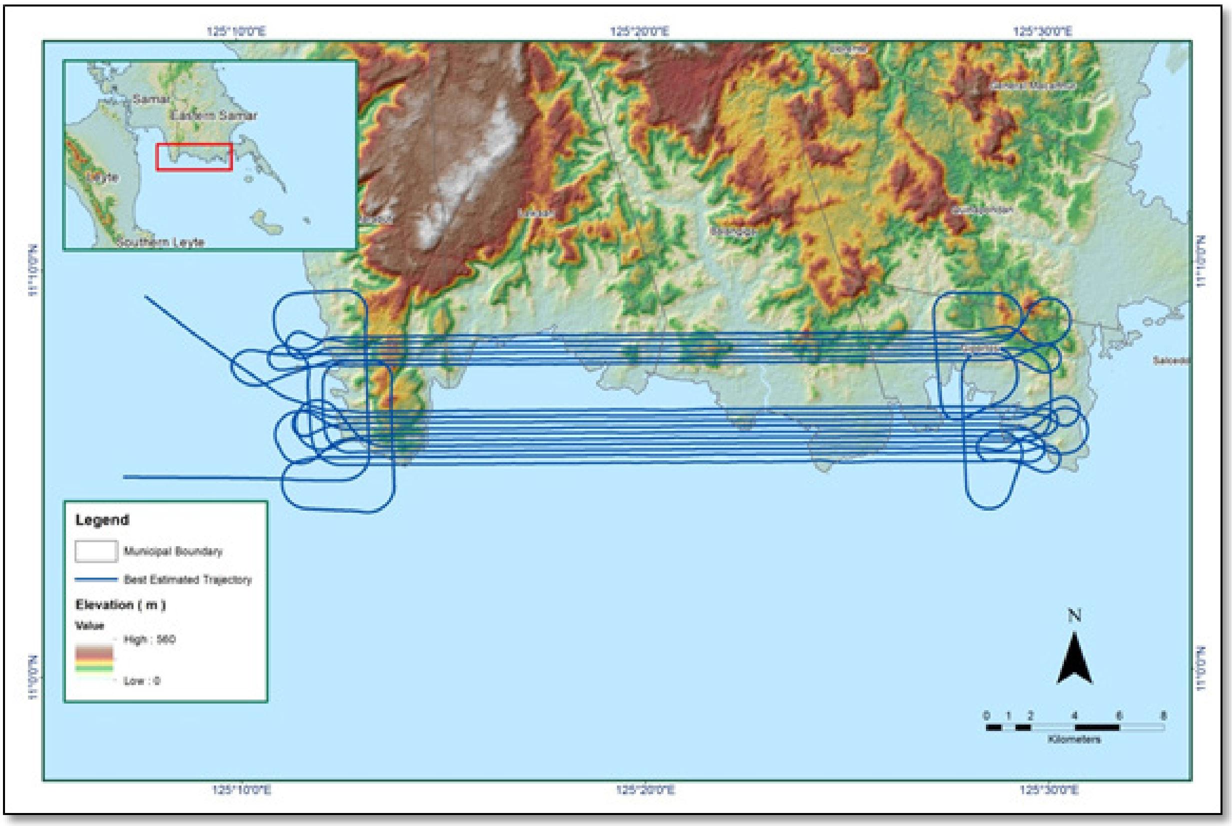


Figure A-8.45 Best Estimated Trajectory

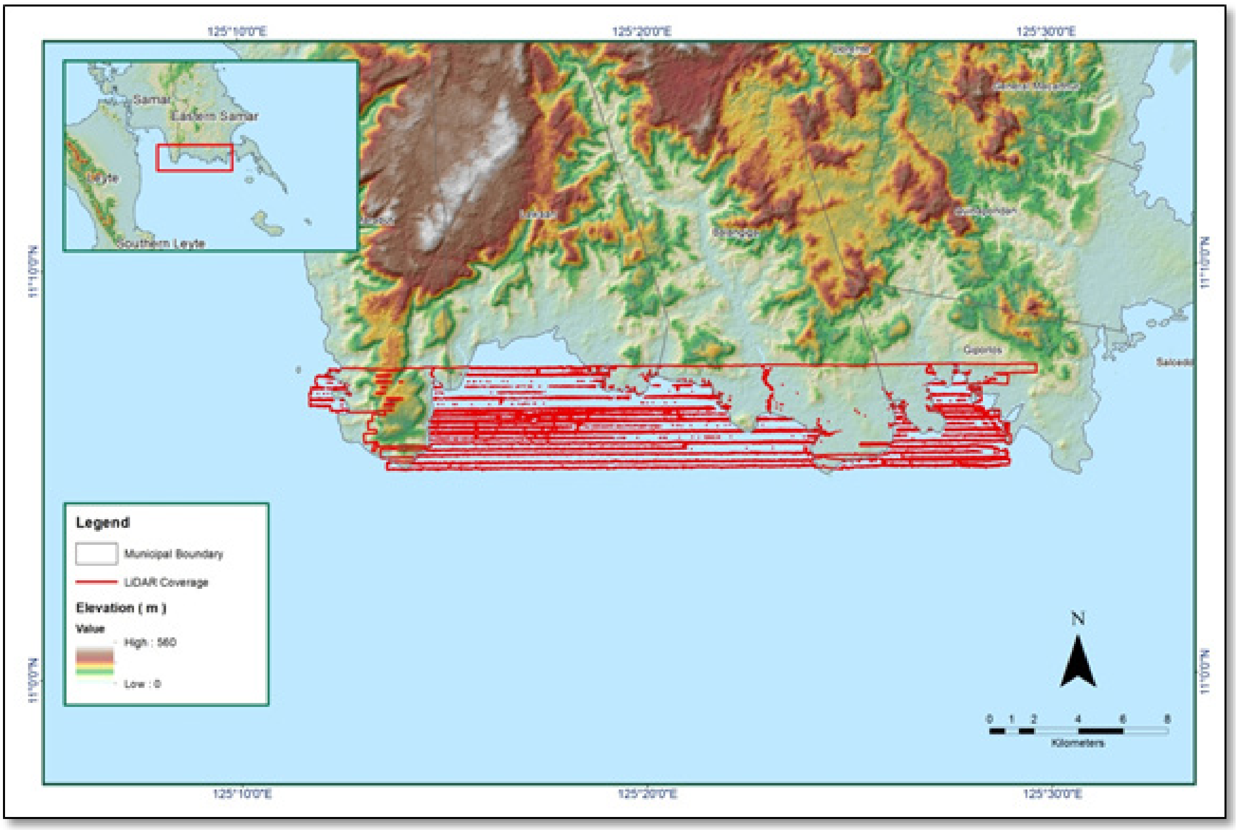


Figure A-8.46 Coverage of LiDAR data

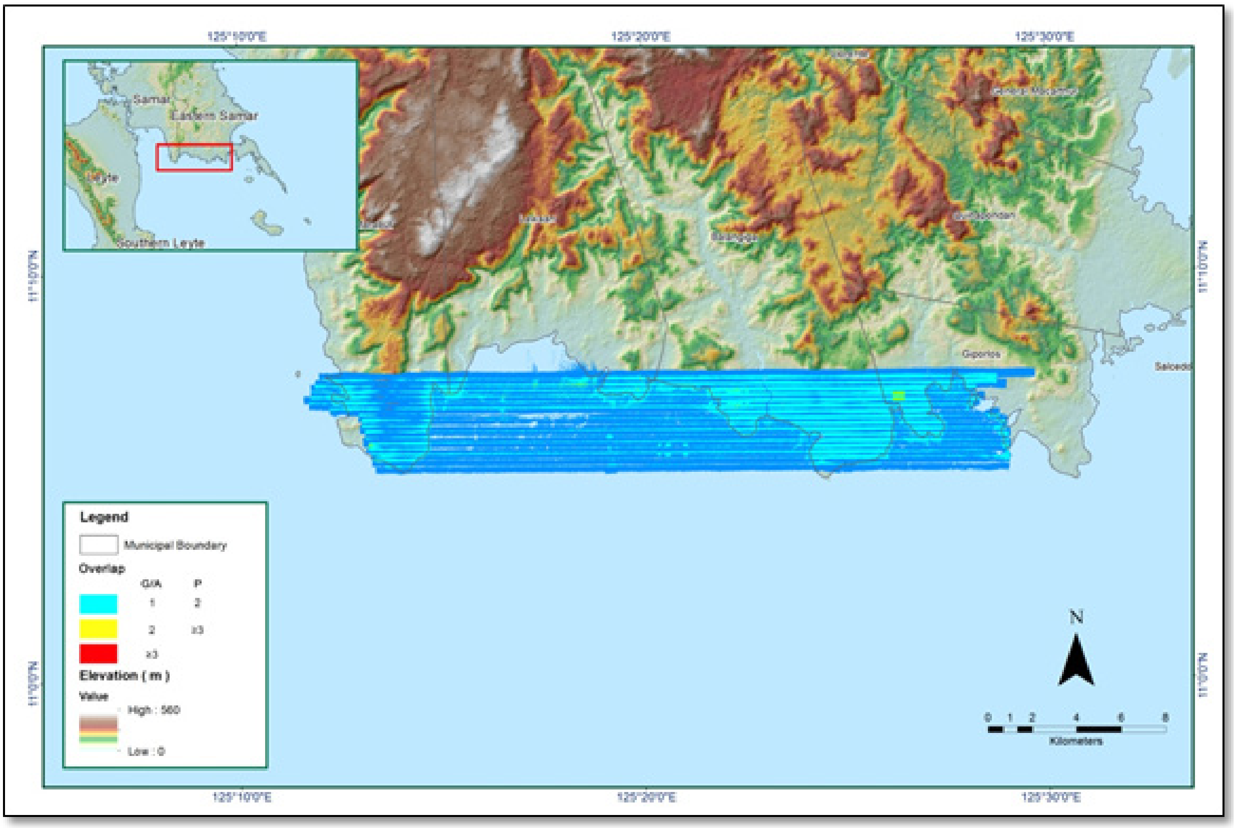


Figure A-8.47 Image of Data Overlap

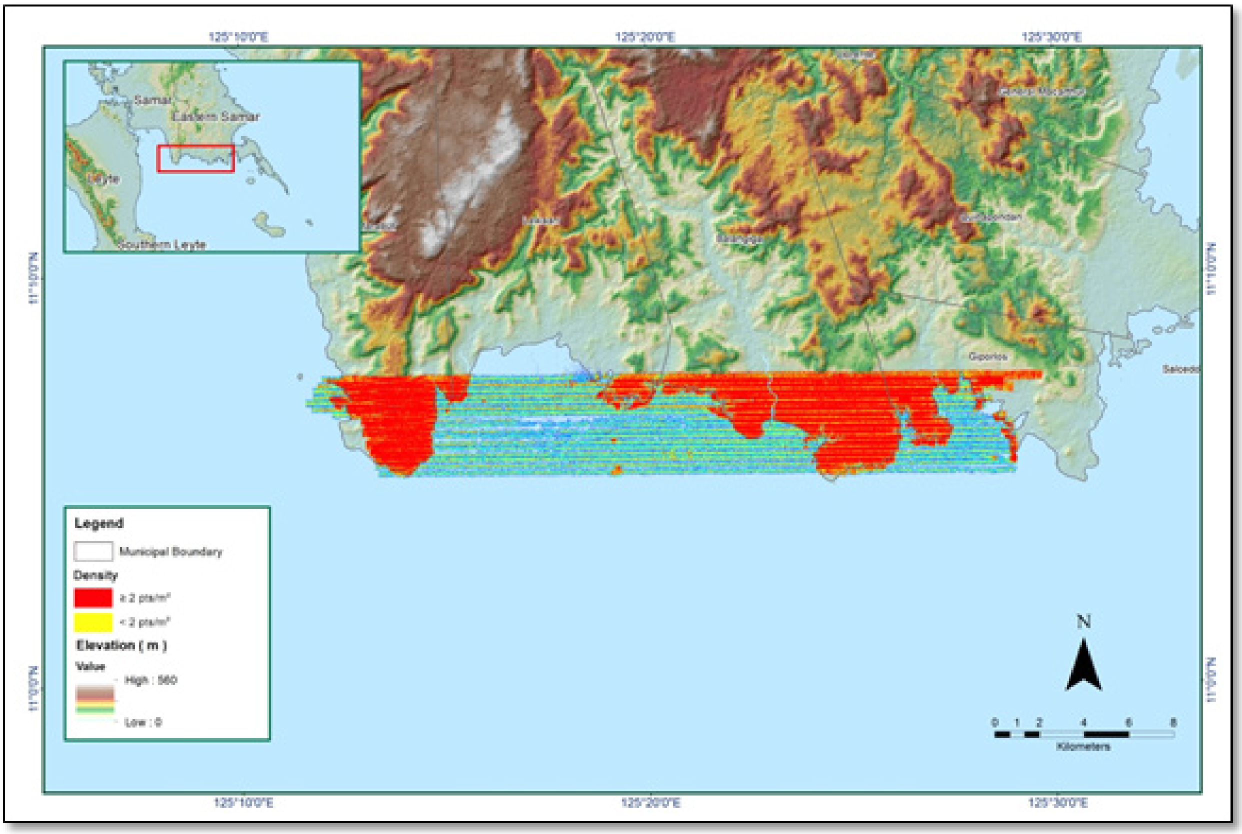


Figure A-8.48 Density map of merged LiDAR data

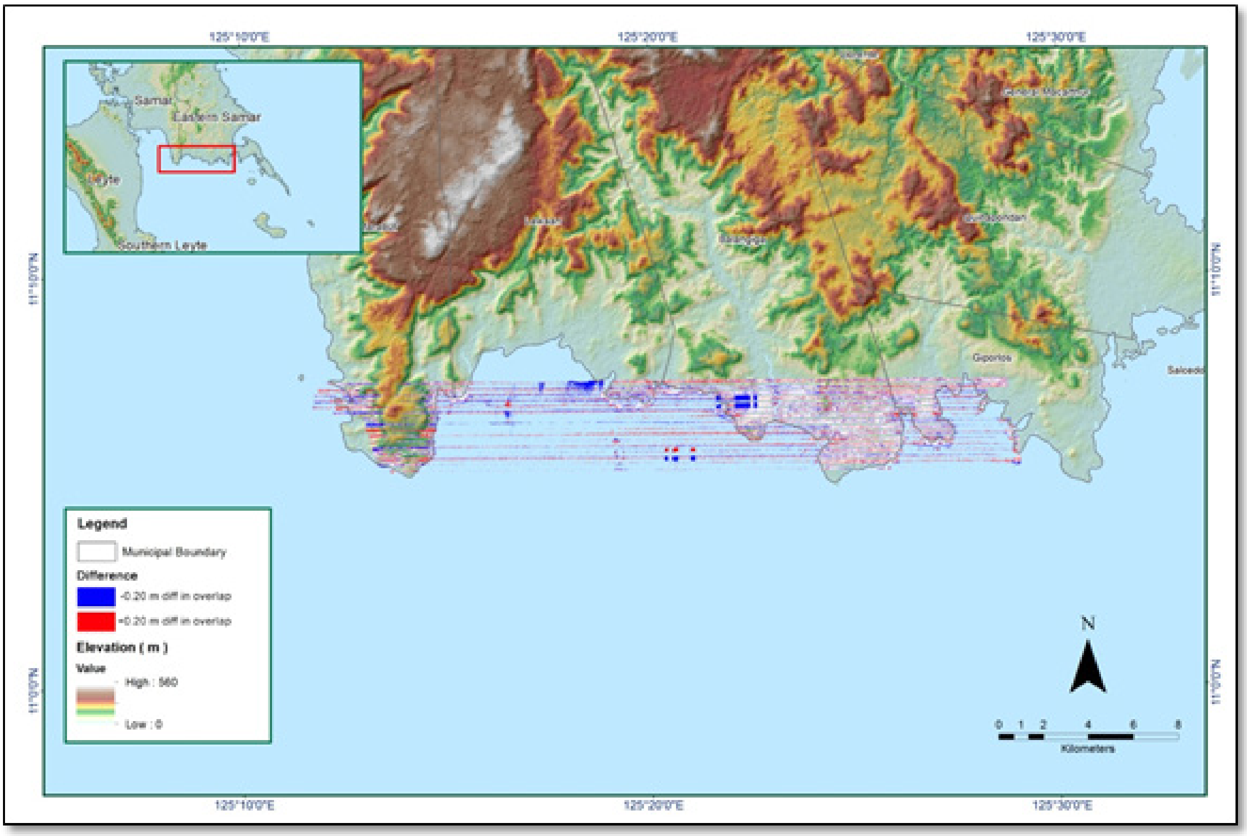


Figure A-8.49 Elevation difference between flight lines

Table A-8.8 Mission Summary Report for Mission Blk33A

Flight Area	Leyte
Mission Name	33A
Inclusive Flights	3753G, 3773A
Range data size	33 GB
POS data size	475 MB
Base data size	8.84 MB
Image	n/a
Transfer date	February 26, 2016
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)	1.2
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.003077
IMU attitude correction stdev (<0.001deg)	1.834194
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	24.13
Ave point cloud density per sq.m. (>2.0)	4.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	84
Maximum Height	443.1 m
Minimum Height	30.37 m
Classification (# of points)	
Ground	14,885,861
Low vegetation	4,505,697
Medium vegetation	78,851,683
High vegetation	169,516,292
Building	1,147,636
Orthophoto	None
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga, Jr., Alex John Escobido

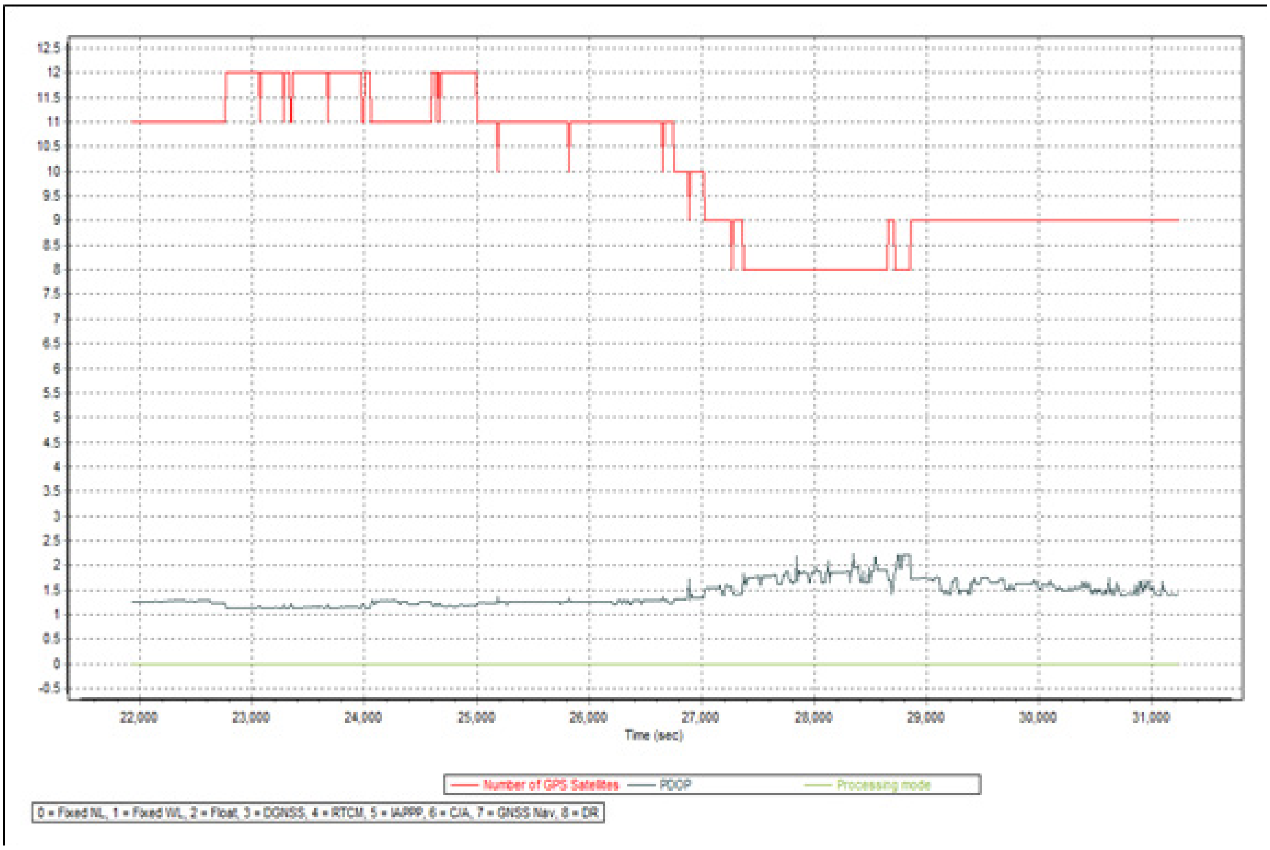


Figure A-8.50 Solution Status

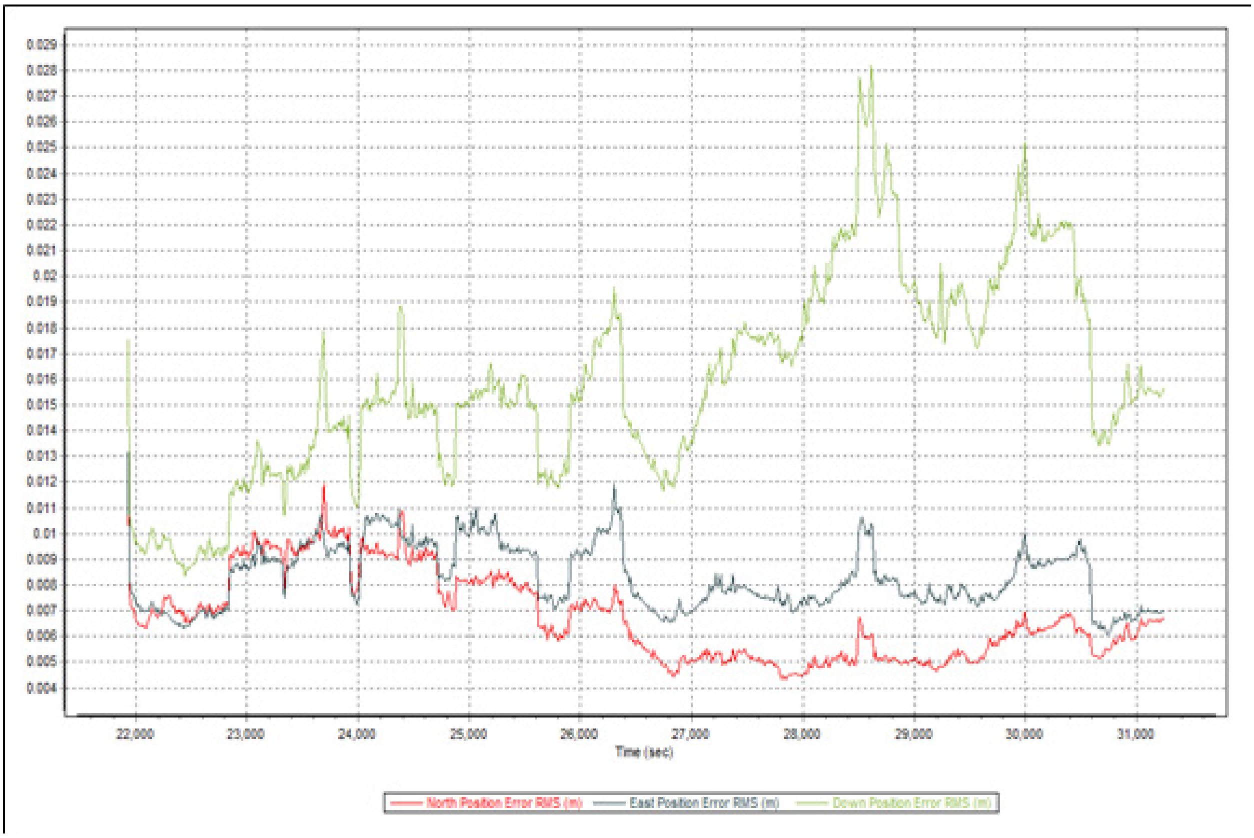


Figure A-8.51 Smoothed Performance Metric Parameters

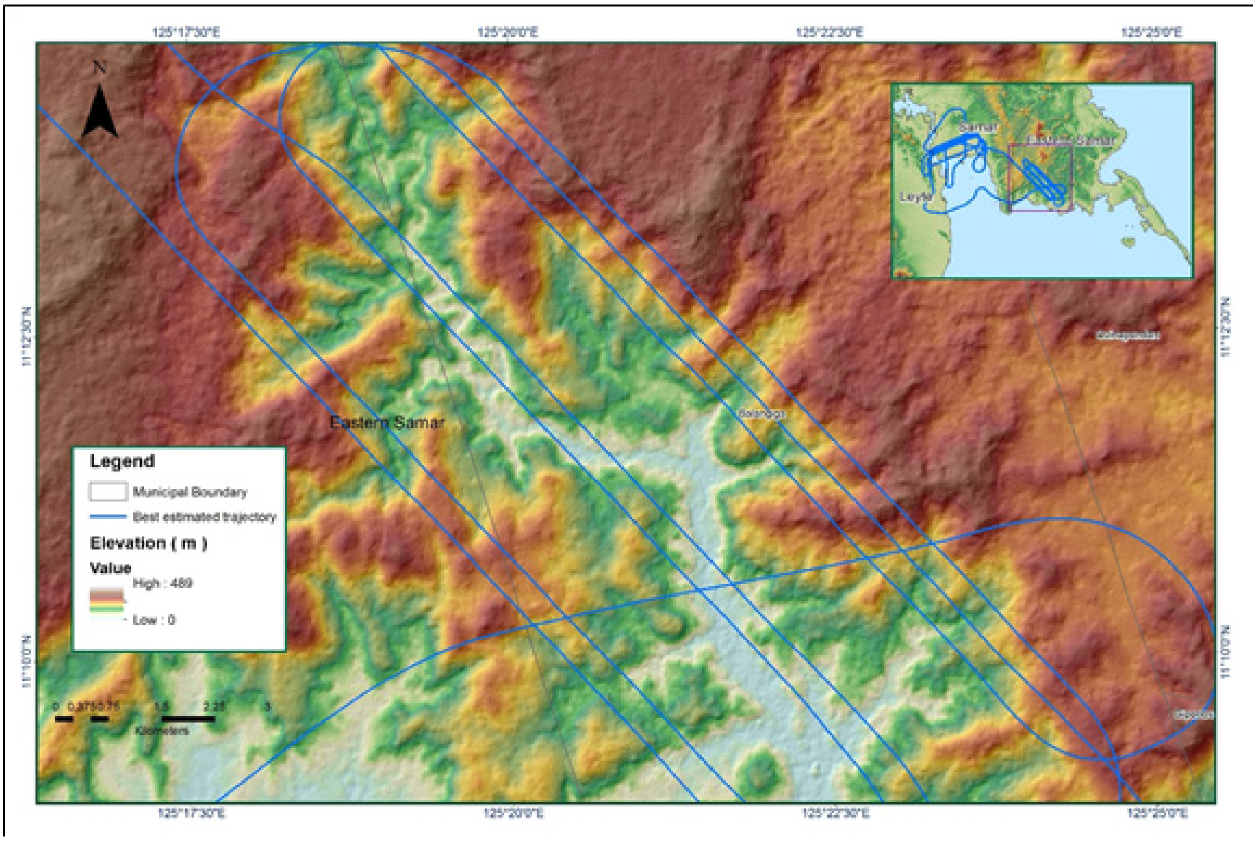


Figure A-8.52 Best Estimated Trajectory

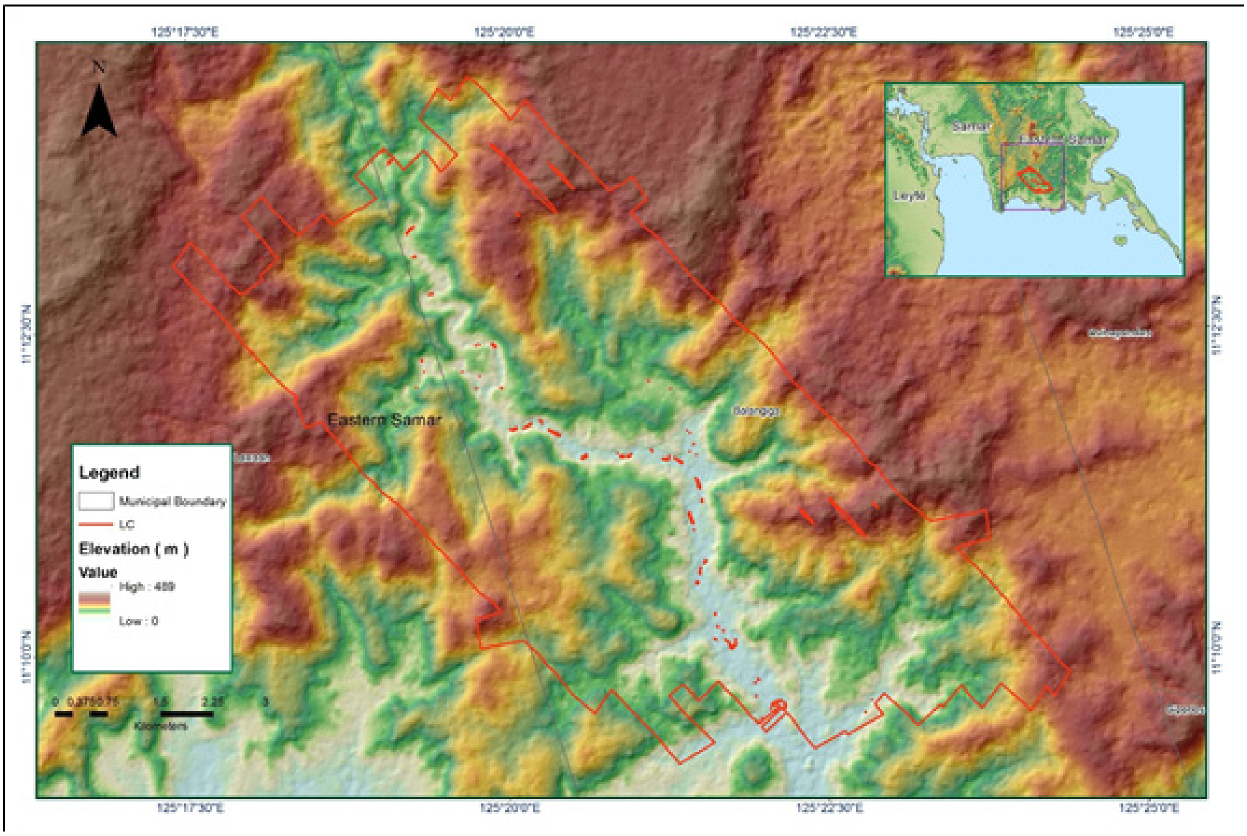


Figure A-8.53 Coverage of LiDAR data

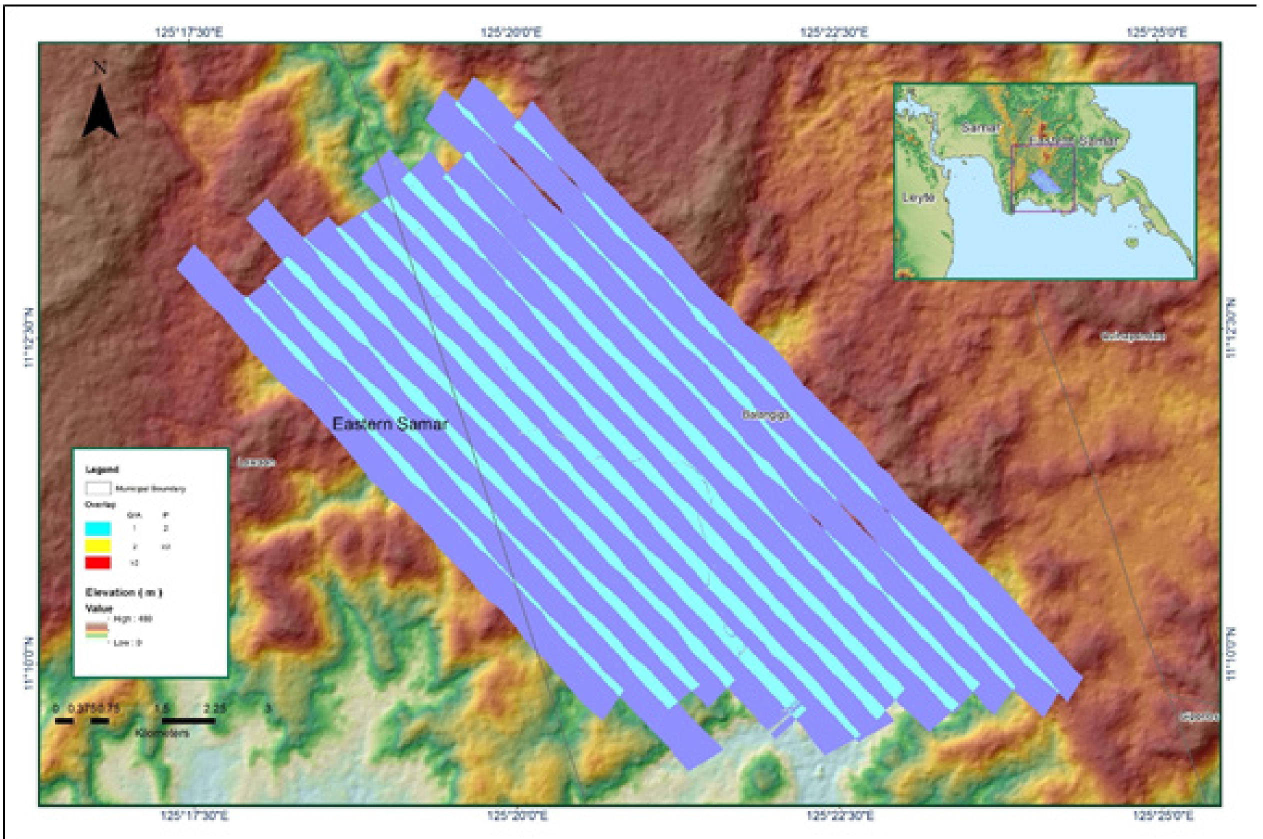


Figure A-8.54 Image of Data Overlap

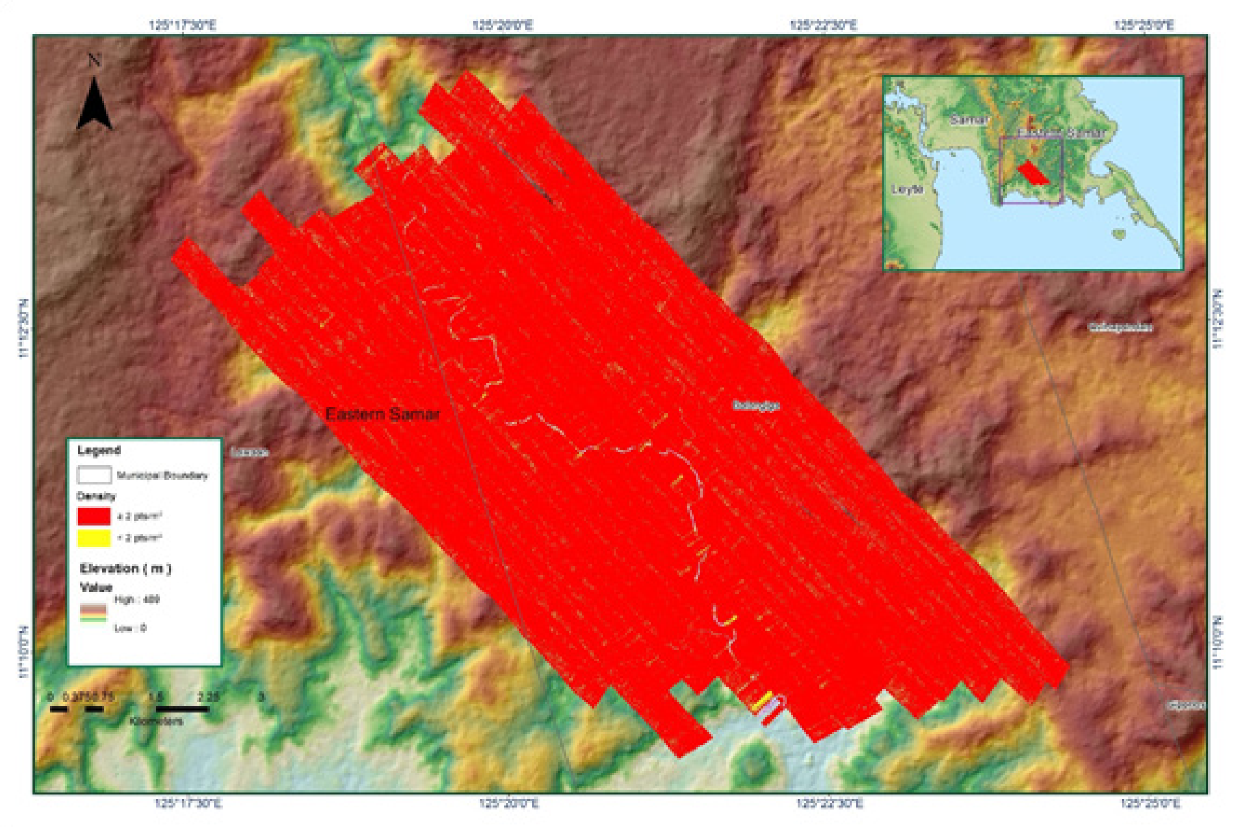


Figure A-8.55 Density map of merged LiDAR data

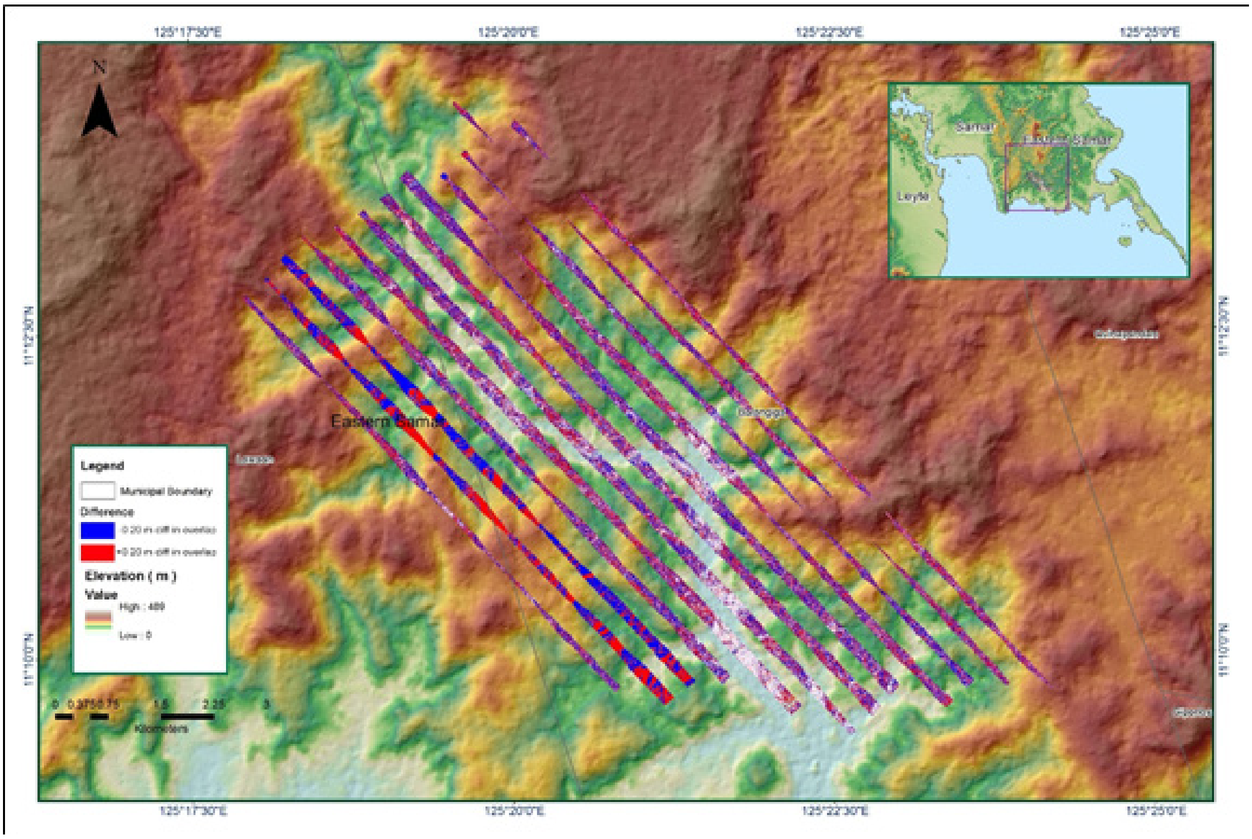


Figure A-8.56 Elevation difference between flight lines

Table A-8.9 Mission Summary Report for Mission Blk33A_Supplement

Flight Area	Leyte
Mission Name	33A_Supplement
Inclusive Flights	3753G, 3773A
Range data size	33 GB
POS data size	475 MB
Base data size	8.84 MB
Image	n/a
Transfer date	February 26, 2016
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)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.003077
IMU attitude correction stdev (<0.001deg)	1.834194
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	35.78
Ave point cloud density per sq.m. (>2.0)	5.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	39
Maximum Height	840.73
Minimum Height	66.48
Classification (# of points)	
Ground	10,843,737
Low vegetation	7,184,617
Medium vegetation	46,361,070
High vegetation	34,921,274
Building	227,769
Orthophoto	None
Processed by	Engr. Irish Cortez, Erica Erin Elazegui, Wilbert Ian San Juan

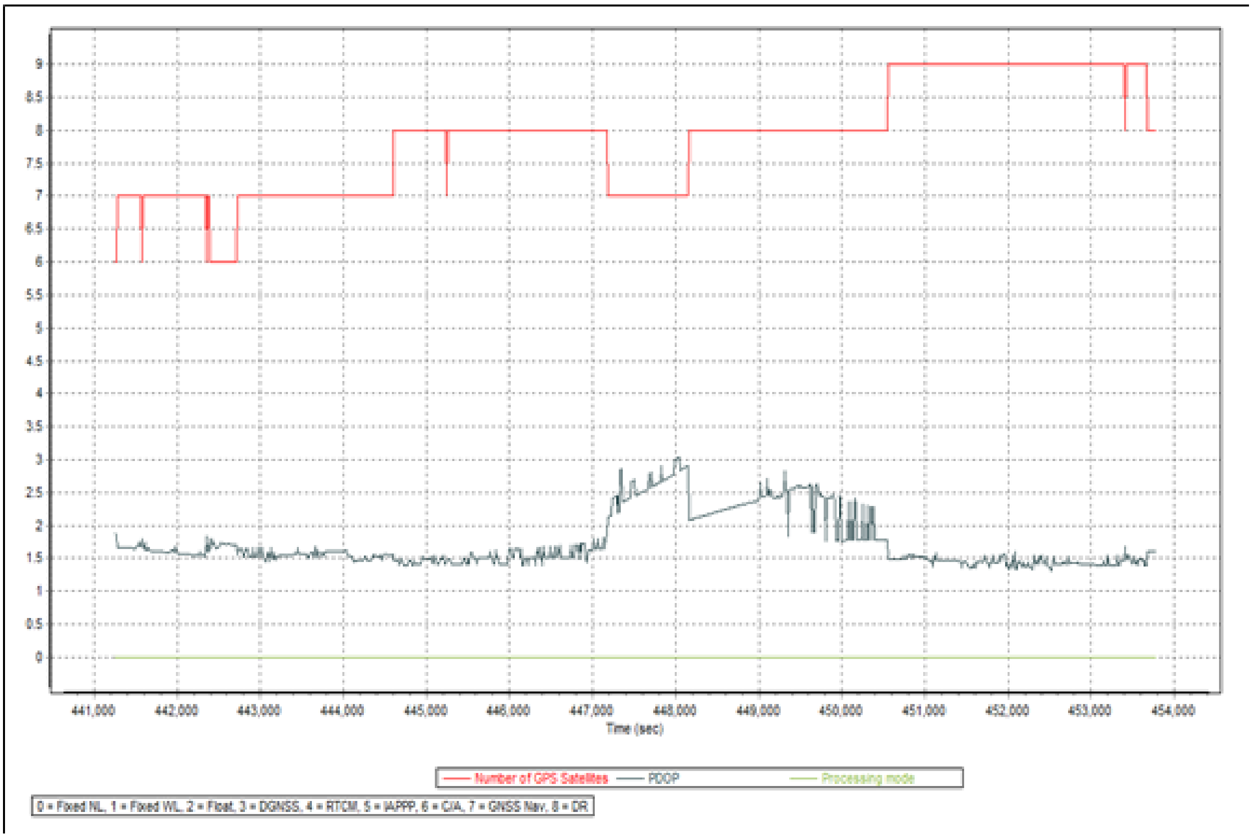


Figure A-8.57 Solution Status

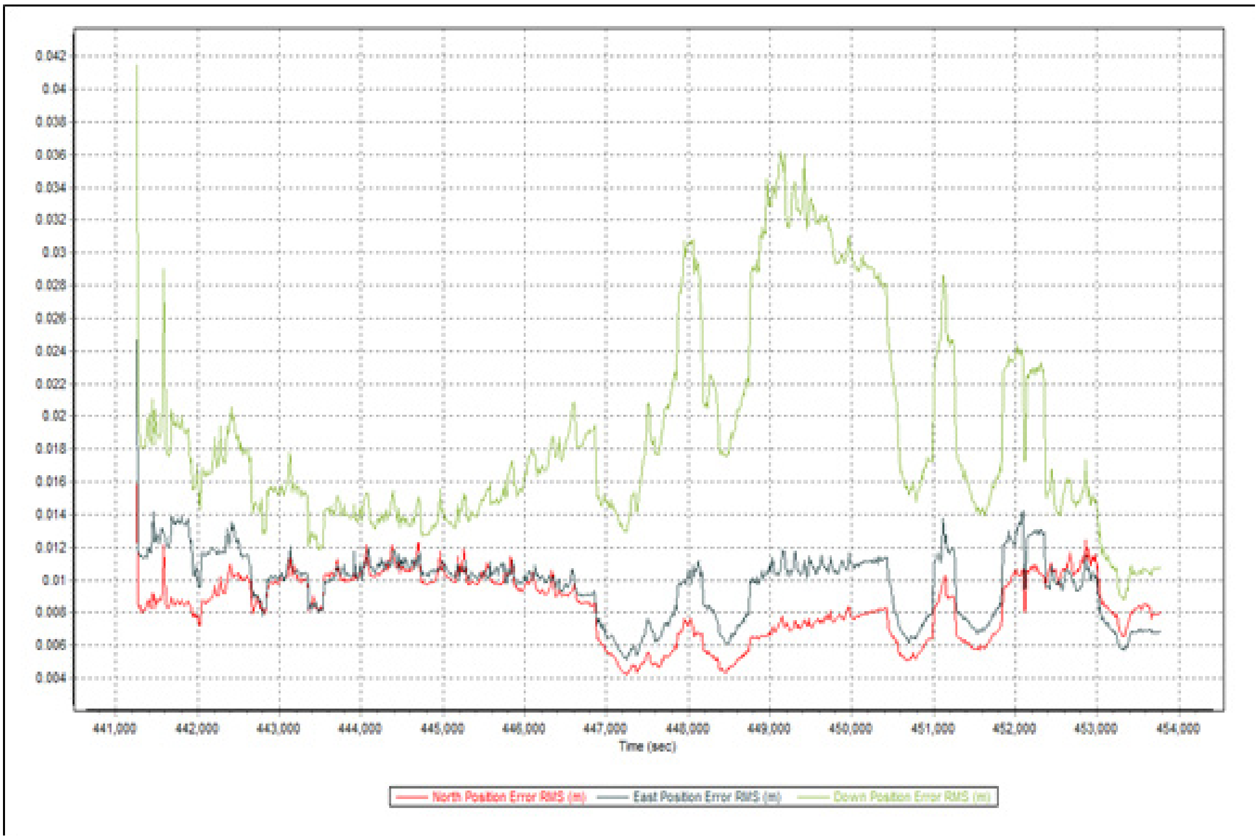


Figure A-8.58 Smoothed Performance Metric Parameters

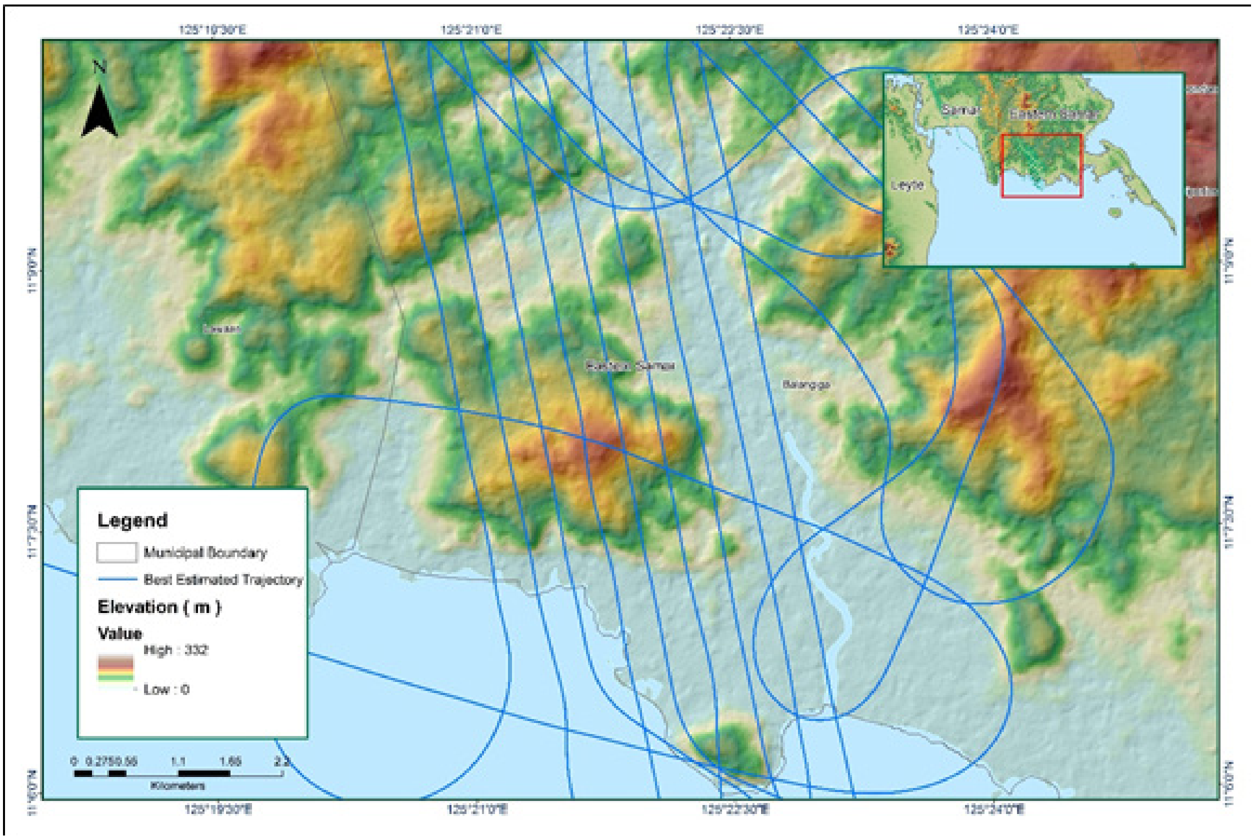


Figure A-8.59 Best Estimated Trajectory

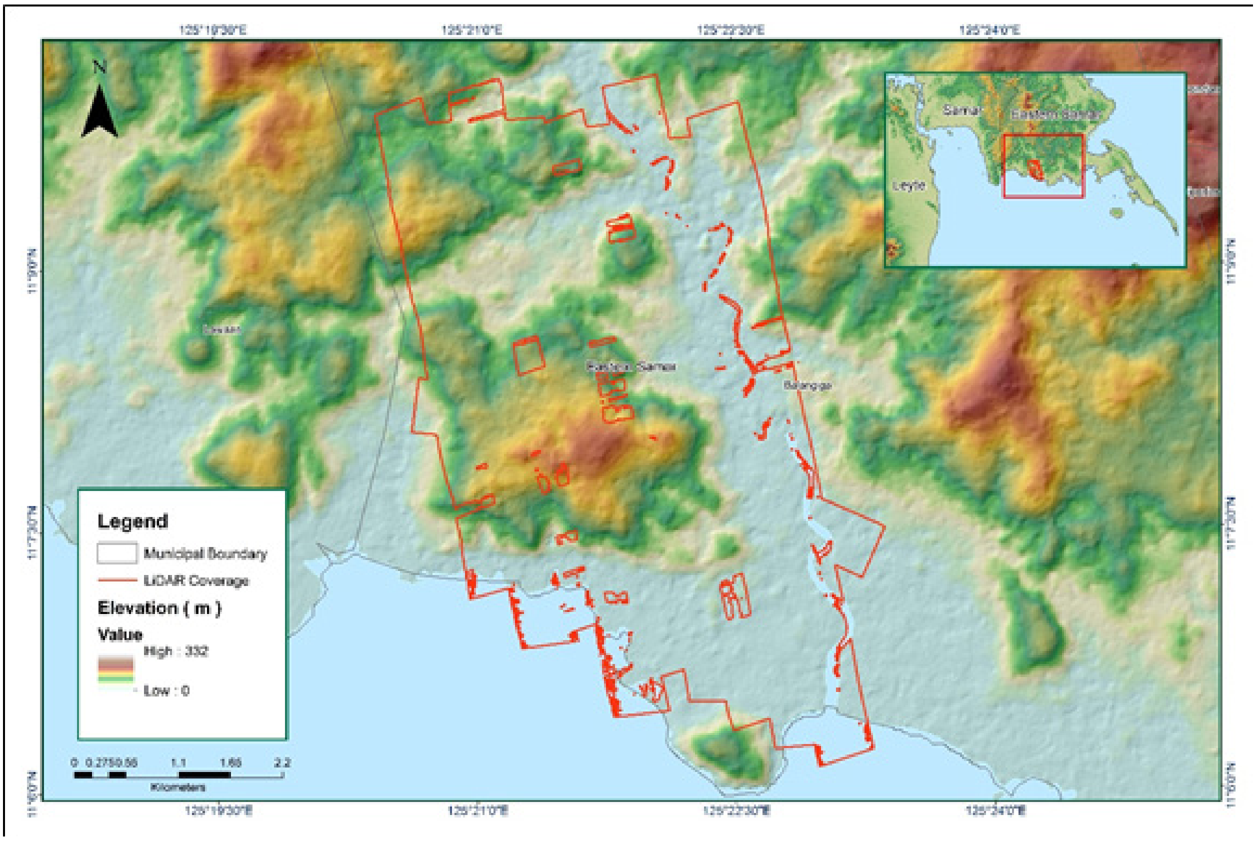


Figure A-8.60 Coverage of LiDAR data

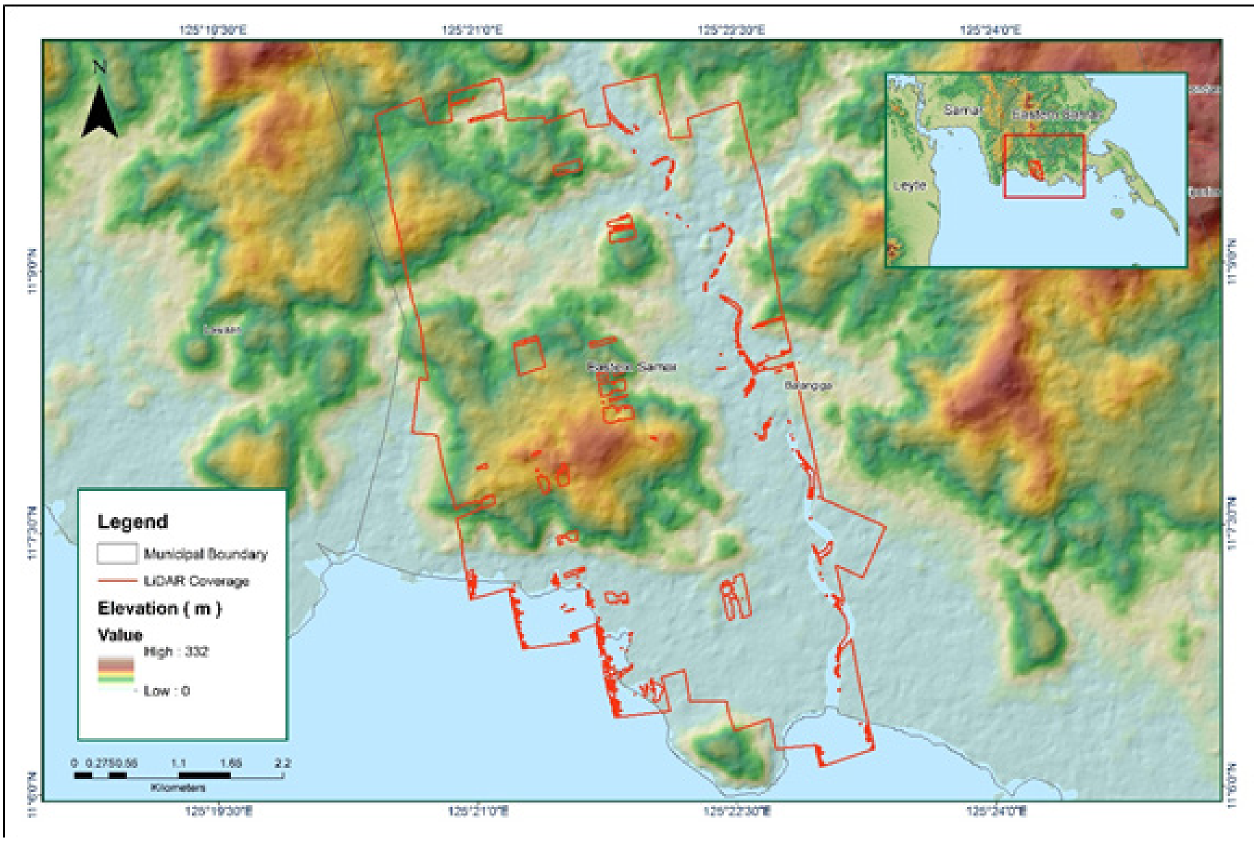


Figure A-8.61 Image of Data Overlap

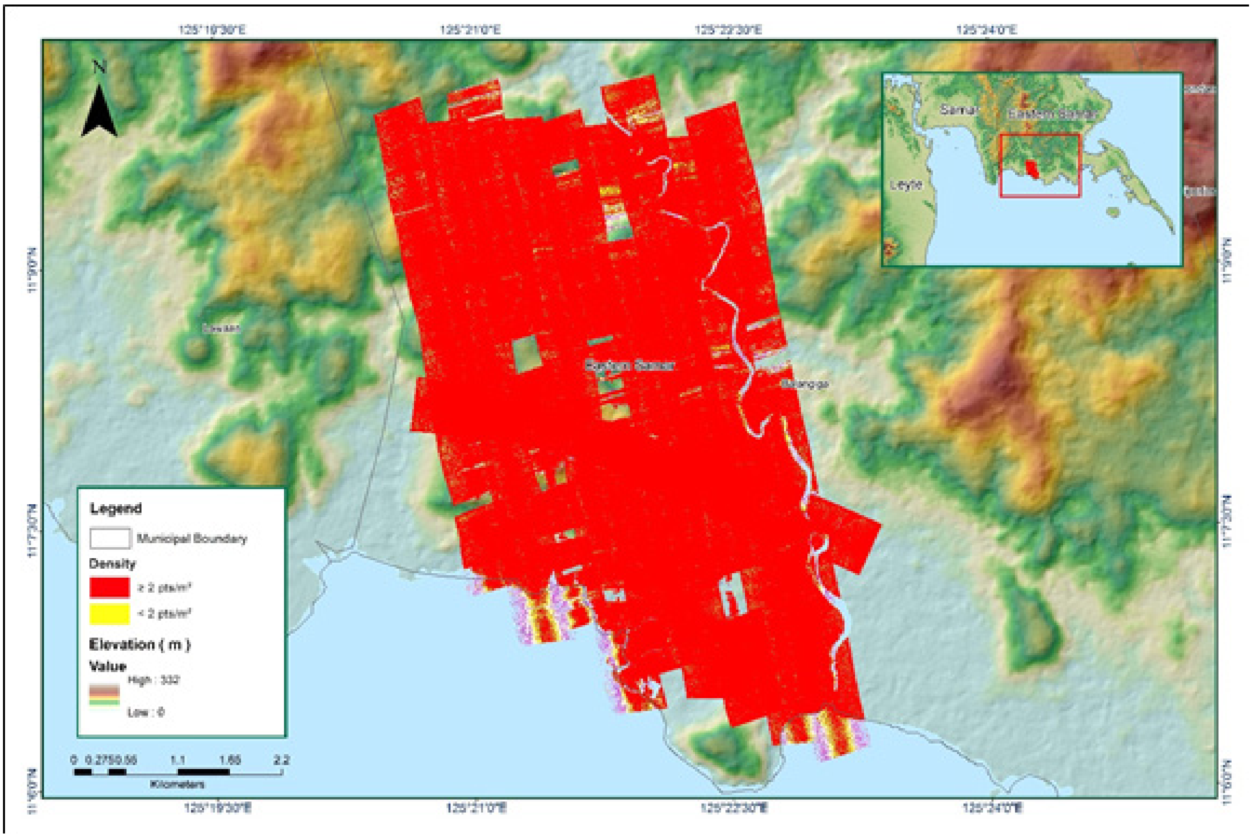


Figure A-8.62 Density map of merged LiDAR data

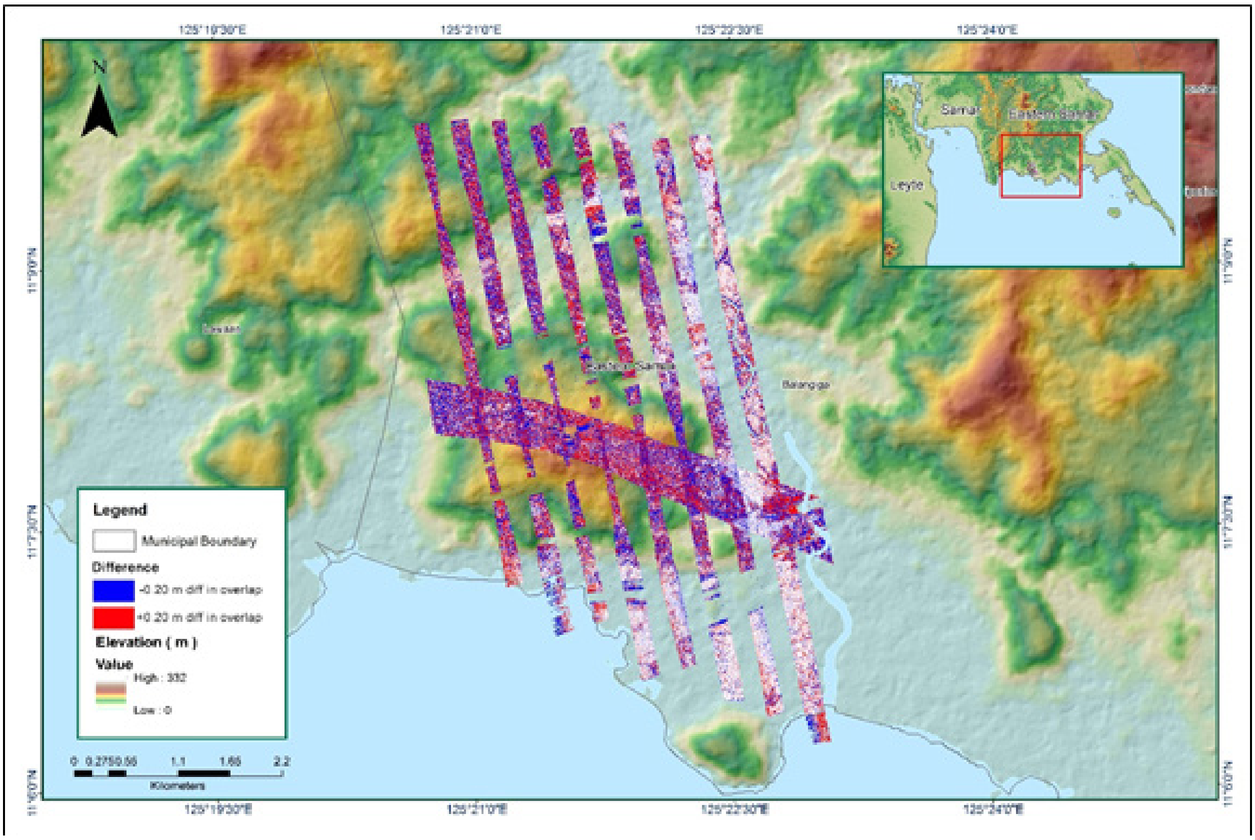


Figure A-8.63 Elevation difference between flight lines

Annex 9. Balangiga Model Basin Parameters

Table A-9.1 Balangiga Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cu.m./S)	Recession Constant	Threshold Type	Ratio to Peak
W280	30.343	62.60	0	2.834	7.400	Discharge	0.1015	0.5	Ratio to Peak	0.01
W290	37.737	57.37	0	1.055	2.755	Discharge	0.0276	0.5	Ratio to Peak	0.01
W300	45.412	52.80	0	0.289	0.755	Discharge	0.0019	0.5	Ratio to Peak	0.01
W310	29.485	63.27	0	1.146	2.994	Discharge	0.0211	0.5	Ratio to Peak	0.01
W320	26.290	65.89	0	1.056	2.759	Discharge	0.0284	0.5	Ratio to Peak	0.01
W330	36.248	58.35	0	1.341	3.504	Discharge	0.0431	0.5	Ratio to Peak	0.01
W340	45.412	52.80	0	1.074	2.805	Discharge	0.0308	0.5	Ratio to Peak	0.01
W350	45.402	52.80	0	1.755	4.584	Discharge	0.0554	0.5	Ratio to Peak	0.01
W360	45.412	52.80	0	1.162	3.035	Discharge	0.0209	0.5	Ratio to Peak	0.01
W370	41.444	55.07	0	2.129	5.559	Discharge	0.0628	0.5	Ratio to Peak	0.01
W380	41.890	54.80	0	1.512	3.949	Discharge	0.0215	0.5	Ratio to Peak	0.01
W390	19.372	72.39	0	2.241	5.853	Discharge	0.0760	0.5	Ratio to Peak	0.01
W400	35.115	59.12	0	1.585	4.140	Discharge	0.0702	0.5	Ratio to Peak	0.01
W410	12.457	80.30	0	0.722	1.887	Discharge	0.0248	0.5	Ratio to Peak	0.01
W420	12.463	80.300	0	0.304	0.794	Discharge	0.0023	0.5	Ratio to Peak	0.01
W430	12.463	80.300	0	1.196	3.123	Discharge	0.0618	0.5	Ratio to Peak	0.01
W440	11.353	81.733	0	0.529	1.382	Discharge	0.0300	0.5	Ratio to Peak	0.01
W450	12.463	80.300	0	0.123	0.322	Discharge	.00056	0.5	Ratio to Peak	0.01
W460	11.515	81.521	0	0.671	1.754	Discharge	0.0417	0.5	Ratio to Peak	0.01
W470	12.462	80.301	0	1.114	2.909	Discharge	0.0496	0.5	Ratio to Peak	0.01
W480	5.6818	89.940	0	0.413	1.080	Discharge	0.0122	0.5	Ratio to Peak	0.01

W490	9.6095	84.092	0	0.926	2.419	Discharge	0.0694	0.5	Ratio to Peak	0.01
W500	12.308	80.496	0	1.037	2.710	Discharge	0.0377	0.5	Ratio to Peak	0.01
W510	3.3595	93.797	0	0.537	1.403	Discharge	0.0177	0.5	Ratio to Peak	0.01
W520	6.8041	88.188	0	0.414	1.082	Discharge	0.0250	0.5	Ratio to Peak	0.01
W530	5.7150	89.887	0	0.889	2.321	Discharge	0.0459	0.5	Ratio to Peak	0.01
W540	7.6240	86.950	0	0.553	1.444	Discharge	0.0188	0.5	Ratio to Peak	0.01

Annex 10. Balangiga Model Reach Parameters

Table A-10.1 Balangiga Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	3938.6	0.0031	0.04	Trapezoid	30	1
R140	Automatic Fixed Interval	684.41	0.0037	0.04	Trapezoid	30	1
R150	Automatic Fixed Interval	3940.0	0.0048	0.04	Trapezoid	30	1
R160	Automatic Fixed Interval	165.21	0.0073	0.04	Trapezoid	30	1
R190	Automatic Fixed Interval	3314.4	.00063	0.04	Trapezoid	30	1
R210	Automatic Fixed Interval	1919.9	.00058	0.04	Trapezoid	30	1
R230	Automatic Fixed Interval	986.34	.00047	0.04	Trapezoid	30	1
R250	Automatic Fixed Interval	1741.0	.00047	0.04	Trapezoid	30	1
R270	Automatic Fixed Interval	4768.5	0.0047	0.04	Trapezoid	30	1
R30	Automatic Fixed Interval	316.57	0.0006	0.04	Trapezoid	30	1
R50	Automatic Fixed Interval	2801.1	0.0453	0.04	Trapezoid	30	1
R70	Automatic Fixed Interval	4348.9	0.0034	0.04	Trapezoid	30	1
R80	Automatic Fixed Interval	2379.8	0.0090	0.04	Trapezoid	30	1

Annex 11. Balangiga Field Validation Points

Table A-11.1 Balangiga 5-yr Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
2	11.1190	125.3650	0.28	0.5	-0.22	Seniang	December 29, 2014	5Yr
5	11.1164	125.3690	0.03	0.4	-0.37	Ruby	December 06, 2014	5Yr
6	11.1161	125.3700	0.69	0.9	-0.16	Seniang	December 29, 2014	5Yr
9	11.1141	125.3740	0.28	0.2	0.08	Seniang	December 29, 2014	5Yr
11	11.1173	125.3760	0.03	0.4	-0.37	Seniang	December 29, 2014	5Yr
13	11.1112	125.3790	0.03	0.2	-0.17	Ruby	December 06, 2014	5Yr
17	11.1106	125.3810	0.14	0.0	0.14	Seniang	December 29, 2014	5Yr
21	11.1104	125.3840	0.03	0.3	-0.27	Ruby	December 06, 2014	5Yr
22	11.1104	125.3840	0.03	1.4	-1.37	Seniang	December 28, 2014	5Yr
23	11.1111	125.3840	0.03	0.2	-0.17	Ruby	December 06, 2014	5Yr
26	11.1112	125.3820	0.29	0.1	0.19	Ruby	December 06, 2014	5Yr
27	11.1119	125.3820	0.03	0.0	0.03	Ruby/Seniang	December 28, 2014	5Yr
30	11.1112	125.3820	0.24	0.2	0.04	Low Pressure	2007	5Yr
31	11.1105	125.3810	0.09	0.3	-0.21	Ruby	December 06, 2014	5Yr
33	11.1101	125.3820	0.04	0.4	-0.36	Ruby	December 06, 2014	5Yr
37	11.1092	125.3830	0.03	0.0	0.03	Ruby	December 06, 2014	5Yr
55	11.1425	125.3770	4.73	2.0	2.73	Ruby	December 06, 2014	5Yr
57	11.1422	125.3770	4.30	0.5	3.8	Ruby	December 06, 2014	5Yr
58	11.1422	125.3770	4.30	1.4	2.9	Low Pressure	2007	5Yr
61	11.1425	125.3770	3.04	0.0	3.04	Ruby	December 06, 2014	5Yr
78	11.1422	125.3770	4.56	0.6	3.96	Ruby	December 06, 2014	5Yr
88	11.1188	125.3870	1.04	0.1	0.94	Low Pressure	January of 2007	5Yr
90	11.1195	125.3890	0.51	0.4	0.11	Low Pressure	January of 2007	5Yr
99	11.1075	125.3920	0.03	0.2	-0.17	Low Pressure	Jan-16	5Yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
103	11.1066	125.3870	0.03	0.4	-0.37	Ruby	December 06, 2014	5Yr
106	11.1064	125.3880	0.10	0.9	-0.8	Ruby	December 06, 2014	5Yr
109	11.1062	125.3900	0.03	1.2	-1.17	Undang	November 07, 1984	5Yr
110	11.1062	125.3900	0.03	1.2	-1.17	Amy	December 08, 1951	5Yr
111	11.1060	125.3910	0.03	1.4	-1.37	Yuning	1990	5Yr
113	11.1059	125.3920	0.03	1.0	-0.97	Amy	December 08, 1951	5Yr
115	11.1071	125.3880	0.31	0.4	-0.09	Low Pressure	January of 2016	5Yr
117	11.1069	125.3890	0.37		0.37	Amy	December 08, 1951	5Yr
119	11.1069	125.3890	0.39	0.1	0.29	Low Pressure	January 18, 2016	5Yr
121	11.1074	125.3890	0.12	0.1	0.02	Ruby	December 06, 2014	5Yr
123	11.1092	125.3862	0.10	0.0	0.1	Ruby	December 06, 2014	5Yr
125	11.1068	125.3863	0.03	0.6	-0.57	Ruby	December 06, 2014	5Yr
126	11.1068	125.3863	0.03	0.6	-0.57	Seniang	December 28, 2014	5Yr
132	11.1083	125.3859	0.19	0.0	0.19	Ruby	December 06, 2014	5Yr
138	11.1082	125.3897	0.07	0.3	-0.23	Ruby	December 06, 2014	5Yr
156	11.1114	125.3858	0.30	0.3	0	Ruby	December 06, 2014	5Yr
158	11.1112	125.3870	0.29	0.0	0.29	Ruby	December 06, 2014	5Yr
175	11.1118	125.3873	0.03	0.3	-0.27	Ruby	December 06, 2014	5Yr
176	11.1118	125.3873	0.03	0.3	-0.27	Seniang	December 28, 2014	5Yr
180	11.1101	125.3873	0.03	1.0	-0.97	Ruby	December 06, 2014	5Yr
181	11.1101	125.3873	0.03	1.0	-0.97	Seniang	December 28, 2014	5Yr
187	11.1164	125.3876	2.00	0.2	1.8	Yolanda	November 08, 2013	5Yr
188	11.1164	125.3876	2.00	0.0	2	Ruby	December 06, 2014	5Yr
189	11.1150	125.3865	2.00	0.0	2	Yolanda	November 08, 2013	5Yr

Point Num-ber	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
190	11.1150	125.3865	2.00	0.0	2	Ruby	December 06, 2014	5Yr
191	11.1129	125.3873	2.00	0.0	2	Ruby	December 06, 2014	5Yr
192	11.1152	125.3864	3.00	0.0	3	Yolanda	November 08, 2013	5Yr
193	11.1152	125.3864	3.00	0.0	3	Ruby	December 06, 2014	5Yr
194	11.1158	125.3865	3.00	0.0	3	Ruby	December 06, 2014	5Yr
195	11.1158	125.3865	3.00	0.0	3	Yolanda	November 08, 2013	5Yr
196	11.1162	125.3864	3.00	0.4	2.65	Yolanda	November 08, 2013	5Yr
197	11.1162	125.3864	3.00	0.0	3	Ruby	December 06, 2014	5Yr
198	11.1161	125.3869	2.00	0.0	2	Yolanda	November 08, 2013	5Yr
199	11.1161	125.3869	2.00	0.0	2	Ruby	December 06, 2014	5Yr
200	11.1166	125.3864	3.00	0.4	2.6	Yolanda	November 08, 2013	5Yr
201	11.1166	125.3864	3.00	0.2	2.8	Ruby	December 06, 2014	5Yr
202	11.1178	125.3864	3.00	0.5	2.5	Yolanda	November 08, 2013	5Yr
203	11.1178	125.3864	3.00	0.0	3	Ruby	December 06, 2014	5Yr
204	11.1121	125.3865	1.00	0.0	1	Yolanda	November 08, 2013	5Yr
205	11.1121	125.3865	1.00	0.0	1	Ruby	December 06, 2014	5Yr
206	11.1123	125.3861	2.00	0.4	1.6	Yolanda	November 08, 2013	5Yr
207	11.1123	125.3861	2.00	0.0	2	Ruby	December 06, 2014	5Yr
208	11.1122	125.3859	3.00	1.3	1.7	Yolanda	November 08, 2013	5Yr
209	11.1122	125.3859	3.00		3	Ruby	December 06, 2014	5Yr
210	11.1158	125.3947	2.00	0.0	2	Ruby	December 06, 2014	5Yr
211	11.1098	125.3954	2.00	0.3	1.7	Ruby	December 06, 2014	5Yr
212	11.1098	125.3954	2.00	1.2	0.8	Yolanda	November 08, 2013	5Yr
213	11.1103	125.3957	1.00	0.0	1	Yolanda	November 08, 2013	5Yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
214	11.1103	125.3957	1.00	0.0	1	Ruby	December 06, 2014	5Yr
215	11.1108	125.3947	2.00	0.0	2	Ruby	December 06, 2014	5Yr
216	11.1152	125.3864	3.00	0.5	2.5	Ruby	December 06, 2014	5Yr
217	11.1156	125.3865	3.00	0.7	2.28	Ruby	December 06, 2014	5Yr
218	11.1099	125.3943	2.00	0.4	1.6	Yolanda	November 08, 2013	5Yr
219	11.1099	125.3943	2.00	0.4	1.6	Amihan		5Yr
220	11.1118	125.3873	0.00	0.3	-0.3	Ruby	December 06, 2014	5Yr
221	11.1118	125.3873	0.00	0.3	-0.3	Seniang	December 28, 2014	5Yr
222	11.1120	125.3871	2.00	0.3	1.7	Ruby	December 06, 2014	5Yr
223	11.1121	125.3872	2.00	0.0	2	Ruby	December 06, 2014	5Yr
224	11.1124	125.3867	2.00	0.0	2	Ruby	December 06, 2014	5Yr
225	11.1135	125.3870	2.00	0.4	1.65	Ruby	December 06, 2014	5Yr
226	11.1170	125.3882	2.00	0.2	1.8	Ruby	December 06, 2014	5Yr
227	11.1163	125.3878	2.00	0.4	1.6	Ruby	December 06, 2014	5Yr
228	11.1163	125.3881	2.00	0.1	1.95	Yolanda	November 08, 2013	5Yr
229	11.1131	125.3865	3.00	0.1	2.9	Yolanda	November 08, 2013	5Yr
230	11.1135	125.3862	3.00	0.2	2.8	Ruby	December 06, 2014	5Yr
231	11.1150	125.3869	2.00	0.2	1.8	Ruby	December 06, 2014	5Yr
232	11.1150	125.3869	2.00	0.5	1.5	Yolanda	November 08, 2013	5Yr
233	11.1166	125.3862	3.00	0.1	2.9	Ruby	December 06, 2014	5Yr
234	11.1166	125.3862	3.00	0.9	2.1	Yolanda	November 08, 2013	5Yr
235	11.1134	125.3858	3.00	0.1	2.95	Yolanda	November 08, 2013	5Yr

Table A-11.2 Balangiga 100-yr Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
1	11.1206	125.3620	0.05	1.2	-1.15	Yolanda	November 08, 2013	100Yr
3	11.1190	125.3650	0.79	2.0	-1.21	Yolanda	November 08, 2013	100Yr
4	11.1164	125.3690	0.03	2.0	-1.97	Yolanda	November 08, 2013	100Yr
7	11.1161	125.3700	1.37	2.0	-0.63	Yolanda	November 08, 2013	100Yr
8	11.1141	125.3740	0.64	0.9	-0.26	Yolanda	November 08, 2013	100Yr
10	11.1173	125.3760	0.03	2.0	-1.97	Yolanda	November 08, 2013	100Yr
12	11.1112	125.3790	0.03	0.3	-0.27	Yolanda	November 08, 2013	100Yr
14	11.1107	125.3800	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
15	11.1100	125.3810	0.29	0.0	0.29	Yolanda	November 08, 2013	100Yr
16	11.1106	125.3810	0.55	0.4	0.15	Yolanda	November 08, 2013	100Yr
18	11.1112	125.3810	0.69	0.3	0.39	Yolanda	November 08, 2013	100Yr
19	11.1111	125.3810	0.05	0.3	-0.25	Yolanda	November 08, 2013	100Yr
20	11.1104	125.3840	0.03	3.0	-2.97	Yolanda	November 08, 2013	100Yr
24	11.1111	125.3840	0.03	2.0	-1.97	Yolanda	November 08, 2013	100Yr
25	11.1112	125.3820	0.73	0.2	0.53	Yolanda	November 08, 2013	100Yr
28	11.1127	125.3830	1.44	0.0	1.44	Yolanda	November 08, 2013	100Yr
29	11.1122	125.3830	0.77	0.4	0.37	Yolanda	November 08, 2013	100Yr
32	11.1101	125.3820	0.41	2.0	-1.59	Yolanda	November 08, 2013	100Yr
34	11.1109	125.3830	0.62	0.3	0.32	Yolanda	November 08, 2013	100Yr
35	11.1099	125.3830	0.42	0.0	0.42	Yolanda	November 08, 2013	100Yr
36	11.1092	125.3830	0.03	0.3	-0.27	Yolanda	November 08, 2013	100Yr
38	11.1094	125.3830	0.31	0.0	0.31	Yolanda	November 08, 2013	100Yr
51	11.1455	125.3760	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
52	11.1435	125.3760	2.23	0.0	2.23	Yolanda	November 08, 2013	100Yr
53	11.1429	125.3770	7.41	0.0	7.41	Yolanda	November 08, 2013	100Yr
54	11.1425	125.3770	6.94	3.0	3.94	Yolanda	November 08, 2013	100Yr
56	11.1422	125.3770	6.50	4.0	2.5	Yolanda	November 08, 2013	100Yr
59	11.1424	125.3770	6.33	0.8	5.53	Yolanda	November 08, 2013	100Yr
60	11.1425	125.3770	5.24	0.6	4.64	Yolanda	November 08, 2013	100Yr
62	11.1419	125.3780	3.23	0.1	3.13	Yolanda	November 08, 2013	100Yr
63	11.1423	125.3790	2.81	0.6	2.21	Yolanda	November 08, 2013	100Yr
64	11.1426	125.3790	2.87	1.0	1.87	Yolanda	November 08, 2013	100Yr
65	11.1416	125.3790	2.58	0.0	2.58	Yolanda	November 08, 2013	100Yr
66	11.1414	125.3790	2.68	0.8	1.88	Yolanda	November 08, 2013	100Yr
67	11.1412	125.3780	2.95	0.5	2.45	Yolanda	November 08, 2013	100Yr
68	11.1398	125.3790	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
69	11.1394	125.3790	0.43	0.0	0.43	Yolanda	November 08, 2013	100Yr
70	11.1395	125.3790	0.04	0.0	0.04	Yolanda	November 08, 2013	100Yr
71	11.1393	125.3790	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
72	11.1397	125.3780	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
73	11.1400	125.3780	0.04	0.0	0.04	Yolanda	November 08, 2013	100Yr
74	11.1400	125.3780	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
75	11.1406	125.3780	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
76	11.1413	125.3770	5.44	1.0	4.44	Yolanda	November 08, 2013	100Yr
77	11.1422	125.3770	6.75	1.6	5.15	Yolanda	November 08, 2013	100Yr
79	11.1385	125.3790	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
80	11.1383	125.3790	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
81	11.1369	125.3800	0.03	0.0	0.03	Yolanda	November 08, 2013	100Yr
82	11.1255	125.3860	2.01	0.1	1.91	Yolanda	November 08, 2013	100Yr
83	11.1225	125.3870	2.01	1.4	0.61	Yolanda	November 08, 2013	100Yr
84	11.1209	125.3860	2.01	1.1	0.91	Yolanda	November 08, 2013	100Yr
85	11.1200	125.3870	0.50	0.0	0.5	Yolanda	November 08, 2013	100Yr
86	11.1186	125.3870	1.18	0.0	1.18	Yolanda	November 08, 2013	100Yr
87	11.1188	125.3870	2.42	0.1	2.32	Yolanda	November 08, 2013	100Yr
89	11.1192	125.3880	1.21	0.4	0.81	Yolanda	November 08, 2013	100Yr
91	11.1188	125.3880	0.08	0.0	0.08	Yolanda	November 08, 2013	100Yr
92	11.1186	125.3880	1.03	0.6	0.43	Yolanda	November 08, 2013	100Yr
93	11.1038	125.3970	0.38	0.1	0.28	Yolanda	November 08, 2013	100Yr
94	11.1040	125.3960	0.37	2.2	-1.83	Yolanda	November 08, 2013	100Yr
95	11.1044	125.3960	0.46	0.5	-0.04	Yolanda	November 08, 2013	100Yr
96	11.1053	125.3940	0.29	0.1	0.19	Yolanda	November 08, 2013	100Yr
97	11.1071	125.3950	0.04	0.0	0.04	Yolanda	November 08, 2013	100Yr
98	11.1075	125.3920	0.25	0.9	-0.65	Yolanda	November 08, 2013	100Yr
100	11.1079	125.3910	0.38	0.2	0.18	Yolanda	November 08, 2013	100Yr
101	11.1077	125.3910	0.57	0.2	0.37	Yolanda	November 08, 2013	100Yr
102	11.1066	125.3870	0.13	3.5	-3.37	Yolanda	November 08, 2013	100Yr
104	11.1065	125.3880	0.25	1.7	-1.45	Yolanda	November 08, 2013	100Yr
105	11.1064	125.3880	0.51	1.4	-0.89	Yolanda	November 08, 2013	100Yr
107	11.1064	125.3890	0.35	1.2	-0.85	Yolanda	November 08, 2013	100Yr
108	11.1062	125.3900	0.31	5.0	-4.69	Yolanda	November 08, 2013	100Yr
112	11.1059	125.3920	0.47	1.5	-1.03	Yolanda	November 08, 2013	100Yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
114	11.1071	125.3880	0.68	1.0	-0.32	Yolanda	November 08, 2013	100Yr
116	11.1069	125.3890	0.82	0.8	0.02	Yolanda	November 08, 2013	100Yr
118	11.1069	125.3890	0.87	1.1	-0.23	Yolanda	November 08, 2013	100Yr
120	11.1074	125.3890	0.63	0.7	-0.07	Yolanda	November 08, 2013	100Yr
122	11.1075	125.3890	0.87	0.4	0.47	Yolanda	November 08, 2013	100Yr
124	11.1068	125.3863	0.04	2.0	-1.96	Yolanda	November 08, 2013	100Yr
127	11.1074	125.3863	0.61	0.9	-0.29	Yolanda	November 08, 2013	100Yr
128	11.1077	125.3854	0.41	0.9	-0.49	Yolanda	November 08, 2013	100Yr
129	11.1081	125.3850	0.03	0.9	-0.87	Yolanda	November 08, 2013	100Yr
130	11.1080	125.3853	0.40	0.9	-0.5	Yolanda	November 08, 2013	100Yr
131	11.1080	125.3853	0.40	0.5	-0.1	Yolanda	November 08, 2013	100Yr
133	11.1081	125.3866	0.30	0.3	0	Yolanda	November 08, 2013	100Yr
134	11.1077	125.3871	0.33	0.9	-0.57	Yolanda	November 08, 2013	100Yr
135	11.1081	125.3873	0.51	0.3	0.21	Yolanda	November 08, 2013	100Yr
136	11.1085	125.3879	0.42	0.0	0.42	Yolanda	November 08, 2013	100Yr
137	11.1082	125.3897	0.35	0.9	-0.55	Yolanda	November 08, 2013	100Yr
139	11.1081	125.3902	0.24	0.5	-0.26	Yolanda	November 08, 2013	100Yr
140	11.1081	125.3902	0.32	0.5	-0.18	Yolanda	November 08, 2013	100Yr
141	11.1083	125.3906	0.54	0.5	0.04	Yolanda	November 08, 2013	100Yr
142	11.1087	125.3907	0.16	0	0.16	Yolanda	November 08, 2013	100Yr
143	11.1089	125.3870	0.03	0	0.03	Yolanda	November 09, 2013	100Yr
144	11.1094	125.3870	0.25	0	0.25	Yolanda	November 10, 2013	100Yr
145	11.1097	125.3860	0.37	0	0.37	Yolanda	November 11, 2013	100Yr
146	11.1098	125.3857	1.11	1.5	-0.39	Yolanda	November 08, 2013	100Yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
147	11.1101	125.3850	0.03	1	-0.97	Yolanda	November 08, 2013	100Yr
148	11.1096	125.3851	0.03	1.5	-1.47	Yolanda	November 08, 2013	100Yr
149	11.1092	125.3850	0.11	2	-1.89	Yolanda	November 08, 2013	100Yr
150	11.1100	125.3854	1.1	1	0.1	Yolanda	November 08, 2013	100Yr
151	11.1107	125.3856	1.1	0.5	0.6	Yolanda	November 08, 2013	100Yr
152	11.1108	125.3857	1.18	0.3	0.88	Yolanda	November 08, 2013	100Yr
153	11.1110	125.3857	1.93	3	-1.07	Yolanda	November 08, 2013	100Yr
154	11.1111	125.3855	1.26	0	1.26	Yolanda	November 08, 2013	100Yr
155	11.1114	125.3858	0.93	0.5	0.43	Yolanda	November 08, 2013	100Yr
157	11.1112	125.3870	0.9	0.5	0.4	Yolanda	November 08, 2013	100Yr
159	11.1108	125.3868	0.68	0	0.68	Yolanda	November 08, 2013	100Yr
160	11.1106	125.3869	0.67	0	0.67	Yolanda	November 08, 2013	100Yr
161	11.1097	125.3865	0.03	0.1	-0.07	Yolanda	November 08, 2013	100Yr
162	11.1099	125.3865	0.25	0.1	0.15	Yolanda	November 08, 2013	100Yr
163	11.1102	125.3867	0.57	0.1	0.47	Yolanda	November 08, 2013	100Yr
164	11.1103	125.3864	0.41	0.1	0.31	Yolanda	November 08, 2013	100Yr
165	11.1112	125.3863	0.49	0.1	0.39	Yolanda	November 08, 2013	100Yr
166	11.1114	125.3863	0.25	0.2	0.05	Yolanda	November 08, 2013	100Yr
167	11.1115	125.3864	0.31	0	0.31	Yolanda	November 08, 2013	100Yr
168	11.1120	125.3865	0.45	0.3	0.15	Yolanda	November 08, 2013	100Yr
169	11.1113	125.3865	0.63	0.1	0.53	Yolanda	November 08, 2013	100Yr
170	11.1105	125.3874	1.82	0.1	1.72	Yolanda	November 08, 2013	100Yr
171	11.1105	125.3877	0.38	0.1	0.28	Yolanda	November 08, 2013	100Yr
172	11.1105	125.3878	0.33	0.1	0.23	Yolanda	November 08, 2013	100Yr

Point Num-ber	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
173	11.1113	125.3879	0.76	0.5	0.26	Yolanda	November 08, 2013	100Yr
174	11.1117	125.3878	0.74	0	0.74	Yolanda	November 08, 2013	100Yr
177	11.1103	125.3871	0.53	0	0.53	Yolanda	November 08, 2013	100Yr
178	11.1100	125.3869	0.35	0	0.35	Yolanda	November 08, 2013	100Yr
179	11.1101	125.3873	0.03	2	-1.97	Yolanda	November 08, 2013	100Yr
182	11.1094	125.3871	0.03	0	0.03	Yolanda	November 08, 2013	100Yr
183	11.1089	125.3870	0.03	0.1	-0.07	Yolanda	November 08, 2013	100Yr
184	11.1087	125.3870	0.33	0.2	0.13	Yolanda	November 08, 2013	100Yr
185	11.1085	125.3869	0.03	0.1	-0.07	Yolanda	November 08, 2013	100Yr
186	11.1082	125.3866	0.03	0.1	-0.07	Yolanda	November 08, 2013	100Yr

Annex 12. Educational Institutions Affected by Flooding in Balangiga Floodplain

Table A-12.1 Educational institutions in Balangiga, Eastern Samar affected by flooding in Balangiga Floodplain

EASTERN SAMAR				
BALANGIGA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Balangiga National Agricultural School (TESDA)	Barangay Poblacion II	Low	Medium	Medium
Brgy. 1, Day Care Center	Barangay Poblacion II		Medium	Medium
Southern Samar National Comprehensive High School	Barangay Poblacion II	Medium	Medium	Medium
Balangiga National Agricultural School (TESDA)	Barangay Poblacion III	Low	Low	Medium
Southern Samar National Comprehensive High School	Barangay Poblacion III	Low	Low	Low
Brgy. 6, Day Care Center	Barangay Poblacion IV	Low	Medium	Medium
Balangiga Central elementary School	Barangay Poblacion V			Low
Balangiga Central Elementary School	Barangay Poblacion V			Low
Brgy. 2, Day Care Center	Barangay Poblacion V	Low	Medium	High
Brgy. 5 , Day Care Center	Barangay Poblacion V		Low	Low
San Miguel Barangay Elementary School	San Miguel	Low	Medium	Medium
San Miguel Day Care Center	San Miguel			Low
Brgy. Sta. Rosa DayCare Center	Santa Rosa			
Sta. Rosa Elementary School	Santa Rosa			

Annex 13. Health Institutions affected by flooding in Balangiga Floodplain

Table A-13.1 Health institutions in Balangiga, Eastern Samar affected by flooding in Balangiga Floodplain

EASTERN SAMAR				
BALANGIGA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Albino M. Duran Memorial Hospital	Barangay Poblacion V		Low	Medium