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

LiDAR Surveys and Flood Mapping of Pagsangahan River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
BSWM	Bureau of Soils and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NDRRMC	National Disaster Risk Reduction and Management Council
NSO	National Statistics Office
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
RBCO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
VSU	Visayas State University
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND PAGSANGAHAN 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 in 2014 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 a resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 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-seven (27) river basins in the Eastern Visayas region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Pagsangahan River Basin

The Pagsangahan River Basin is located in Eastern Visayas, at the northwestern portion of the province of Leyte. It traverses through the Municipalities of Capoocan, Villaba, Kananga, Matag-ob, and the City of Ormoc. It covers an area of 406 square kilometers, and travels for approximately 31.5 kilometers from its source to its mouth in the Ormoc Bay.

The Department of Environment and Natural Resources – River Basin Control Office (DENR-RBCO) identified the Pagsangahan River Basin as one of the one hundred and forty (140) critical watersheds in the Philippines, having a drainage area of 453 km^2, and an estimated 871 million cubic meter annual run-off.

The river basin's main stem, the Pagsangahan River, is part of the twelve (12) river systems in the Visayas Region.

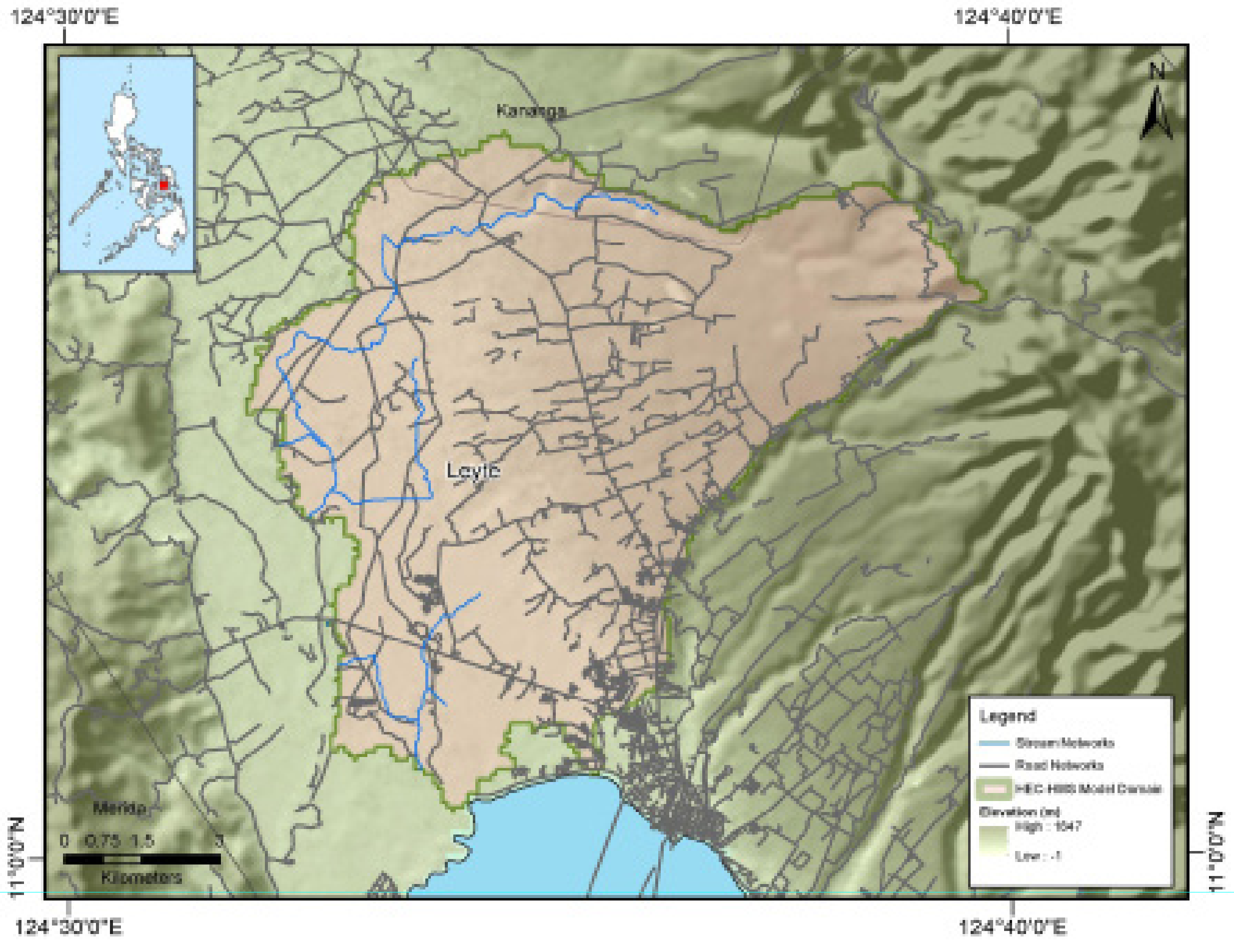

Figure 1. Location map of the Pagsangahan River Basin (in brown)

According to the 2010 national census of the National Statistics Office (NSO), the population of residents within the immediate vicinity of the river is 8,309 people, which are under the jurisdiction of two (2) barangays in Ormoc City, namely Liloan and Lao.

Settlements in the area face the constant threat of flooding due to frequent heavy rainfall, especially in the months of June to February. On November 8, 2013, Super Typhoon Haiyan (local name, Yolanda) induced a storm surge that brought about flooding and devastation in the province. The official list of the National Disaster Risk Reduction and Management Council (NDRRMC) reports that Typhoon Haiyan caused the deaths of 6,193 people, most of whom are from the provinces of Samar and Leyte.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PAGSANGAHAN 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 of the Pagsangahan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Leyte. These missions were planned for nineteen (19) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Aquarius and Gemini LiDAR systems were used for the flight missions (See ANNEX 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 2 illustrates the flight plans for the Pagsangahan floodplain survey.

Table 1. Flight planning parameters for the Aquarius LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 35A	600, 700, 550, 500	30, 35	50, 36	70, 50	40, 50, 35, 30	130	5
BLK 35B	700, 600, 550	30, 35	36	50	50, 35, 30	130	5
BLK 35C	700, 550, 600	30	36	50, 33	50, 30	130	5
BLK 35D	700, 550, 600	30	36	50, 33	50, 30	130	5
BLK 35E	700, 550, 600	30	36	50, 33	50, 30	130	5
BLK 35F	600	30	36	50	50	130	5
BLK 35G	700	30	36	50	50	130	5
BLK 35H	700, 800	30	36	50	50	130	5
BLK 35I	800, 700, 600	30, 55, 40, 50	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 (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 35A	800, 1000	30	40	100	30	130	5
BLK 35B	800, 1000	30	40	100	30	130	5
BLK 35C	1100	30	40	100	30	130	5

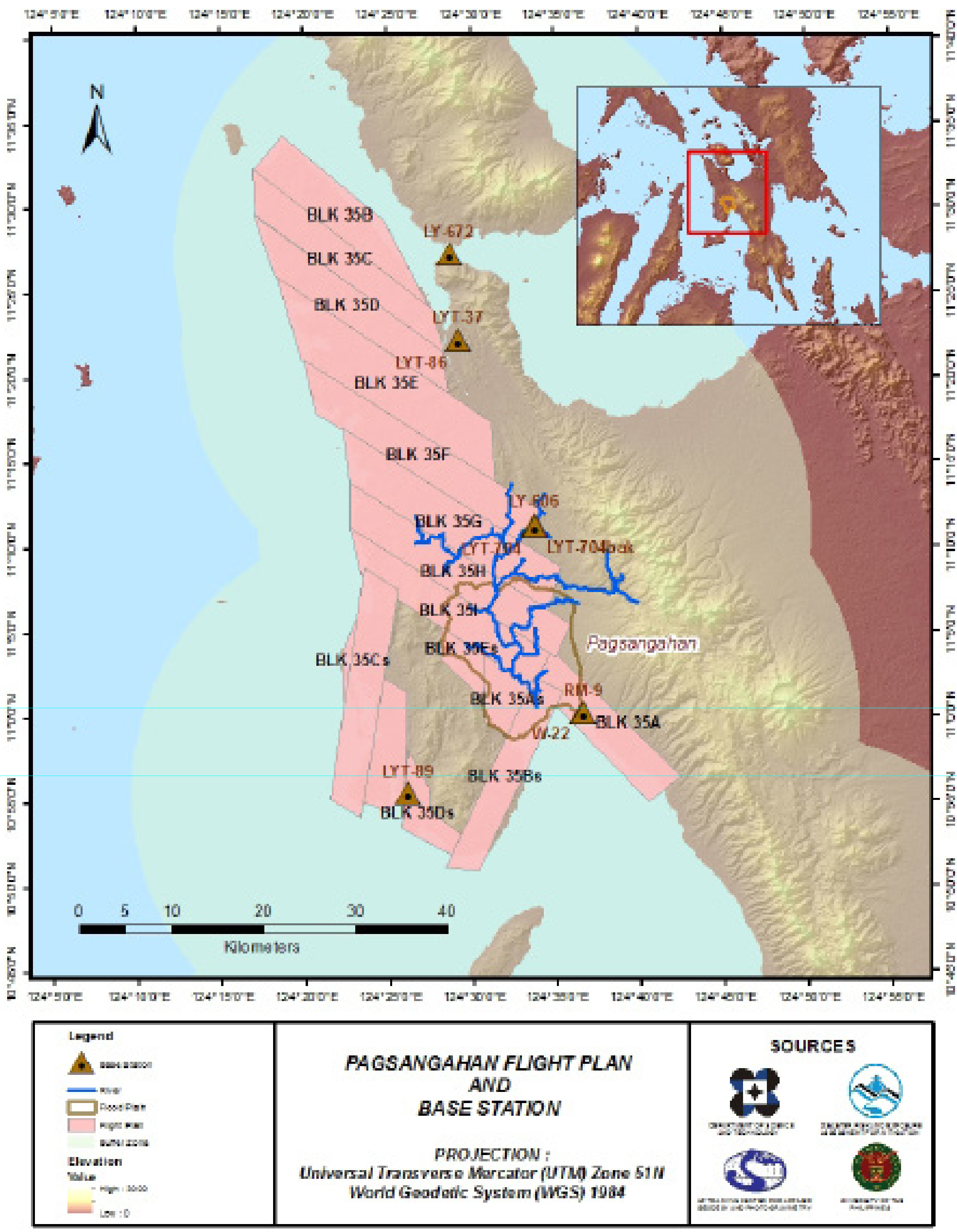


Figure 2. Flight plans and base stations used to cover the Pagsangahan floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover eight (8) NAMRIA control stations: (i.) LYT-89, which is of first (1^{st}) order accuracy; (ii.) CBU-340, (iii.) LYT-86, (iv.) LYT-90, (v.) LYT-690, (vi.) LYT-704, and (vii.) LYT-731, which are of second (2^{nd}) order accuracy; and (viii.) LYT-37, which is of fourth (4^{th}) order accuracy. The field team also established three (3) control points: RM-9, W-22 and LYT-704bak. Two (2) benchmarks were processed: LY-606 and LY-672. These were used as base stations during the flight operations for the entire duration of the survey, held on January 28, 2014; May 15-26, 2014; January 21-February 17, 2015; March 9-19, 2016; and April 16, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, SPS 882 SPS 985, and TOPCON GR-5. The flight plans and the locations of the base stations used during the aerial LiDAR acquisition in the Pagsangahan floodplain are shown in Figure 2. The certifications for the NAMRIA reference points are found in ANNEX 2, while the baseline processing reports for the established control points are provided in ANNEX 3. The composition of the project team is presented in ANNEX 4.

Figure 3 to Figure 5 exhibit the recovered NAMRIA reference points within the area. Table 3 to Table 15 provide the details about the NAMRIA control stations and established points. Table 16 lists all of the ground control points occupied during the acquisition, together with the dates of utilization during the survey.

(a) (b)

Figure 3. (a) GPS set-up over LYT-37, as recovered inside the town plaza of the Municipality of Leyte, Leyte; and (b) NAMRIA horizontal control point LYT-37, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point LYT-37, used as a base station for the LiDAR acquisition

Station Name	**LYT-37**	
Order of Accuracy	**2^{nd} Order**	
Relative Error (horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 22’ 17.79271” North 124° 29’ 07.61910” East 5.33900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	443839 meters 1257489.277 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°22’13.44918” North 124°29’12.76807” East 65.99800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	662088.45 meters 1257404.79 meters

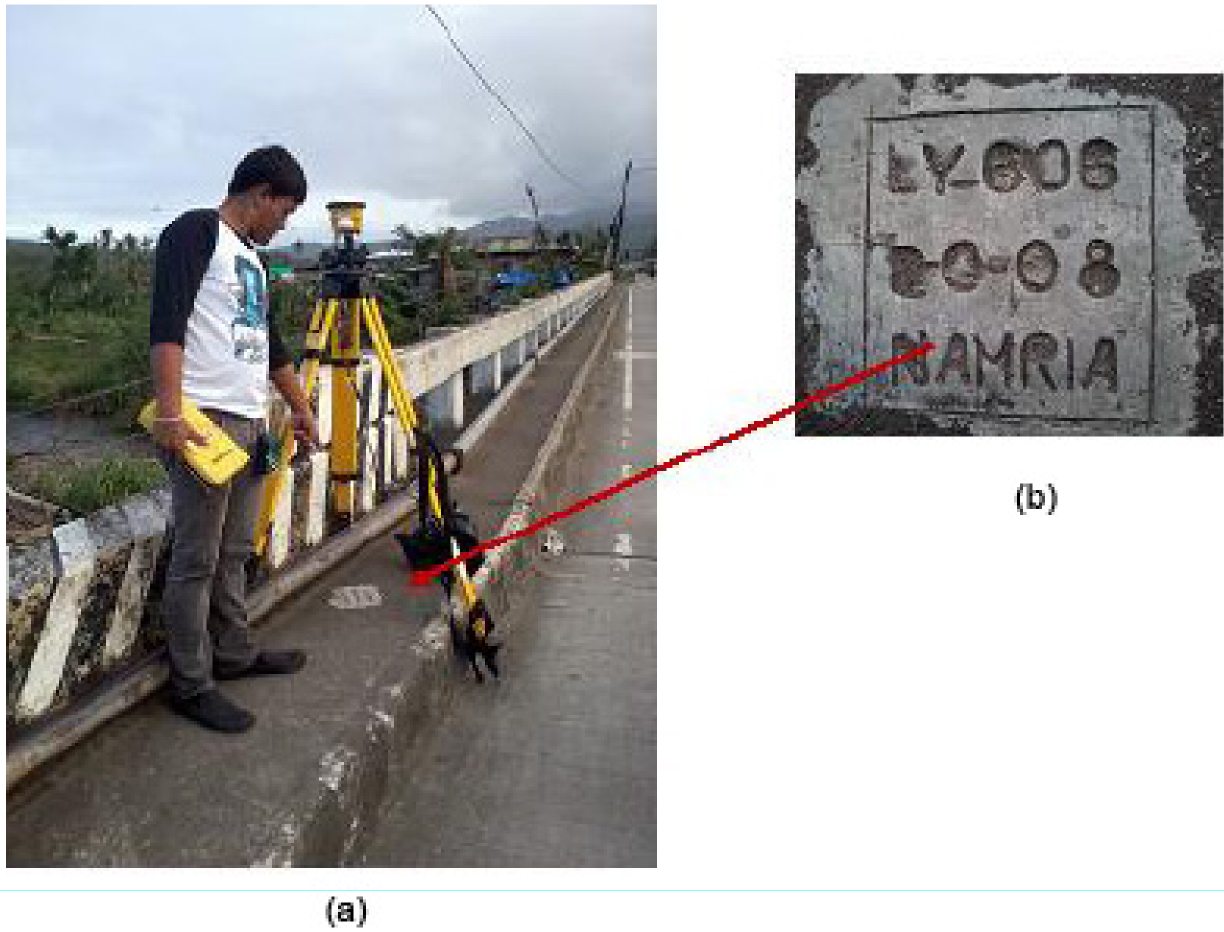


Figure 4. (a) GPS set-up over LY-606, as recovered in a bridge in Kananga, Leyte; and (b) NAMRIA benchmark LY-606, as recovered by the field team

Table 4. Details of the recovered NAMRIA benchmark LY-606, used as a base station for the LiDAR acquisition

Station Name	**LY-606**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17° 23’ 30.09” North 120° 27’ 09.94 East 19.22 meters
Grid Coordinates, Universal Transverse System 1984 Datum (WGS84)	Easting Northing	229263.009 meters 1906054.331 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	717° 13’ 24.35635” North 120° 27’ 15.02916” East 53.562 meters

(b)

(a)

Figure 5. Figure 5. (a) GPS set-up over LY-672, as recovered at the concrete sidewalk of the Biliran Bridge between the Municipality of Leyte, Leyte and the Municipality of Biliran, Biliran; and (b) NAMRIA reference point LY-672, as recovered by the field team

Table 5. Details of the recovered NAMRIA benchmark LY-672, used as a base station for the LiDAR acquisition

Station Name	**LY-672**	
Order of Accuracy	**1^{st} Order**	
Relative Error (horizontal positioning)	**1:100000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 27’ 23.02” North 124° 28’ 39.82” East 20.86 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	443013.31 meters 1266859.739 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 27’ 18.15339” North 124° 28’ 44.13652” East 81.2745 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	661327.389 meters 1266708.04 meters

Table 6. Details of the recovered NAMRIA horizontal control point CBU-340, used as a base station for the LiDAR acquisition

Station Name	**CBU-340**	
Order of Accuracy	**2^{nd} order**	
Relative Error (horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°38'14.87646" North 124°28'04.68006" East 15.533 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°38'10.71737" North 124°28'09.89389" East 77.920 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	660577.527 meters 1176200.458 meters

Table 7. Details of the recovered NAMRIA benchmark LY-672, used as a base station for the LiDAR acquisition

Station Name	**LYT-86**	
Order of Accuracy	**2^{nd} Order**	
Relative Error (horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°22'16.75118" North 124°29'08.10940" East 15.43100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	443853.897 meters 1257448.25 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°22'12.40727" North 124°29'13.25847" East 66.09100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	662103.47 meters 1257372.86 meters

Table 8. Details of the recovered NAMRIA horizontal control point LYT-89, used as a base station for the LiDAR acquisition

Station Name	**LYT-89**	
Order of Accuracy	**1st Order**	
Relative Error (horizontal positioning)	**1:100000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°55'37.75929" North 124°25'59.22187" East 2.53400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	438033.007 meters 1208330.431 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°55'33.52339" North 124°26'4.41045" East 64.14500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	656614.72 meters 1208220.77 meters

Table 9. Details of the recovered NAMRIA horizontal control point LYT-90, used as a base station for the LiDAR acquisition

Station Name	**LYT-90**	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°00'17.75728" North 124°36'28.24066" East 15.532 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°00'13.51665" North 124°36'33.42083" East 77.386 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	675667.875 meters 1216919.360 meters

Table 10. Details of the recovered NAMRIA horizontal control point LYT-690, used as a base station for the LiDAR acquisition

Station Name	LYT-690	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°00’17.68909” North 124°36’28.25530” East 4.361 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°00’13.44846” North 124°36’33.43548” East 66.214 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	67568.331 meters 1216917.267 meters

Table 11. Details of the recovered NAMRIA horizontal control point LYT-704, used as a base station for the LiDAR acquisition

Station Name	LYT-704	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°11’16.35419” North 124°33’36.47427” East 38.29100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	451959.944 meters 1237144.619 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°11'12.06307" North 124°33'41.63876" East 99.58400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	670347.64 meters 1237125.91 meters

Table 12. Details of the recovered NAMRIA horizontal control point LYT-731, used as a base station for the LiDAR acquisition

Station Name	LYT-731	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°42'47.59464" North 124°48'34.34385" East 15.61000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	479165.977 meters 1184617.338 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°42'43.44572" North 124°48'39.54791" East 78.65700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	697902.97 meters 1184777.35 meters

Table 13. Details of the established NAMRIA horizontal control point LYT-704bak, used as a base station for the LiDAR acquisition

Station Name	LYT-704bak	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°11'16.44188" North 124°33'37.00349" East 38.093 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°11'12.15076" North 124°33'42.16798" East 99.386 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	670363.675 meters 1237128.684 meters

Table 14. Details of the established NAMRIA horizontal control point RM-9, used as a base station for the LiDAR acquisition

Station Name	**RM-9**	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°00'18.53023" North 124°36'28.25559" East 4.384 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°00'14.28954" North 124°36'33.79880" East 65.114 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	675679.222 meters 1216943.169 meters

Table 15. Details of the established NAMRIA horizontal control point W-22, used as a base station for the LiDAR acquisition

Station Name	**W-22**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°00'18.93705" North 124°36'24.81698" East 7.666 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°00'14.69624" North 124°36'29.99714" East 69.516 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	675563.750 meters 1216955.050 meters

Table 16. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 28, 2014	1032A	2BLK35A028A	LY-606, LYT-704
May 15, 2014	1458A	3BLK35B135A	LYT-37, LYT-86
May 15, 2014	1460A	3BLK35CD135B	LYT-37, LYT-86
May 16, 2014	1462A	3BLK35DSE136A	LYT-37, LY-672
May 16, 2014	1464A	3BLK35ES136B	LYT-37, LY-672
May 17, 2014	1466A	3BLK35F137A	LYT-37, LY-672
May 19, 2014	1474A	3BLK35G139A	LYT-37, LY-672
May 24, 2014	1494A	3BLK35GSH144A	LY-606, LYT-704
May 25, 2014	1498A	3BLK35HSI145A	LY-606, LYT-704
May 26, 2014	1502A	3BLK35IS146A	LYT-690, LYT-704
May 26, 2014	1504A	3BLK35AIS146B	LYT-690, LYT-704
January 21, 2015	7753AC	3BLK35B021A	LYT-690
January 25, 2015	7760AC	3BLK35A025A	LYT-690, RM-9
February 04, 2015	7780AC	3BLK35AX035A	LYT-690, RM-9
February 05, 2015	7782AC	3BLK35AX036A	LYT-690, RM-9
February 15, 2015	7802AC	3BLK35SV046A	LYT-690, RM-9
February 17, 2015	7806AC	3BLK35X1048A	LYT-690, LYT-731
March 09, 2016	8389AC	3BLK35A069A	LYT-89, W-22
March 10, 2016	8391AC	3BLK35EC070A	LYT-89, W-22
March 10, 2016	8392AC	3BLK35BD070B	LYT-89, W-22
March 11, 2016	8394AC	3BLK35BD071B	LYT-90, W-22
March 19, 2016	8408AC	3BLK48BD079A	LYT-89, CBU-340
March 19, 2016	8409AC	3BLK34079B	LYT-89, CBU-340
April 16, 2016	3945G	2BLK35AB107A	LYT-704, LYT-704bak
April 16, 2016	3947G	2BLK35CS107B	LYT-704, LYT-704bak

2.3 Flight Missions

A total of twenty-five (25) flight missions were conducted to complete the LiDAR data acquisition in the Pagsangahan floodplain, for a total of one hundred hours and fifty-six minutes (100+56) of flying time for RP-C9022, RP-C9122 and RP-C9322. All missions were acquired using the Aquarius and Gemini LiDAR systems. The flight logs of the missions are found in ANNEX 6. Table 17 indicates the total area of actual coverage and the corresponding flying hours per mission, and Table 18 presents the actual parameters used during the LiDAR data acquisition.

Table 17. Flight missions for the LiDAR data acquisition in the Pagsangahan 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
28-Jan-14	1032A	84.59	86.05	27.39	58.66	867	4	41
15-May-14	1458A	97.25	108.72	NA	108.72	1174	4	35
15-May-14	1460A	176.02	119.23	NA	119.23	1128	4	35
16-May-14	1462A	240.97	115.47	NA	115.47	1347	4	41
16-May-14	1464A	151.06	119.82	NA	119.82	1258	4	11
17-May-14	1466A	116.84	124.66	NA	124.66	1383	4	47
19-May-14	1474A	124.69	124.90	NA	124.90	1189	4	53
24-May-14	1494A	110.19	113.80	16.76	97.04	1294	4	53
25-May-14	1498A	201.35	108.30	48.87	59.43	1293	4	41
26-May-14	1502A	175.76	73.08	38.54	34.54	1236	4	41
26-May-14	1504A	91.17	84.46	30.09	54.37	943	4	23
21-Jan-15	7753AC	75.59	79.73	20.38	59.35	NA	3	5
25-Jan-15	7760AC	94.30	78.99	NA	78.99	NA	4	11
04-Feb-15	7780AC	84.59	19.98	5.00	14.98	NA	1	17
05-Feb-15	7782AC	84.59	83.53	27.31	56.22	NA	4	23
15-Feb-15	7802AC	169.90	71.43	3.91	67.52	NA	4	11
17-Feb-15	7806AC	84.59	55.81	28.67	27.14	NA	3	23
09-Mar-16	8389AC	33.78	35.25	24.22	11.03	NA	4	17
10-Mar-16	8391AC	51.67	68.05	16.72	51.33	NA	4	23
10-Mar-16	8392AC	81.66	67.21	NA	67.21	NA	3	29
11-Mar-16	8394AC	81.66	33.55	NA	33.55	NA	2	47
19-Mar-16	8408AC	51.67	43.43	2.16	41.27	NA	3	35
19-Mar-16	8409AC	75.59	33.57	2.82	30.75	NA	2	5
16-Apr-16	3945G	109.37	108.02	70.92	37.1	NA	4	22
16-Apr-16	3947G	18.51	153.94	25.60	128.34	NA	4	27
TOTAL		**2667.38**	**2110.98**	**389.36**	**1721.62**	**13112**	**100**	**56**

Table 18. Actual parameters used during the LiDAR data acquisition

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)
1032A	600	30	50	70	40	130	5
1458A	700	30	36	50	50	130	5
1460A	700	30	36	50	50	130	5
1462A	700	30	36	50	50	130	5
1464A	700	30	36	50	50	130	5
1466A	600	30	36	50	50	130	5
1474A	700	30	36	50	50	130	5
1494A	700	30	36	50	50	130	5
1498A	800	30	36	50	50	130	5
1502A	700	55, 40, 50	36	50	50	130	5
1504A	600	30	36	50	50	130	5
7753AC	600	35	36	50	35	130	5
7760AC	550	35	36	50	35	130	5
7780AC	500	35	36	50	35	130	5
7782AC	600	35	36	50	35	130	5
7802AC	600	35	36	50	35	130	5
7806AC	600	35	36	50	35	130	5
8389AC	600	30	36	50	30	130	5
8391AC	550	30	36	50	30	130	5
8392AC	550	30	36	50	30	130	5
8394AC	550	30	36	50	30	130	5
8408AC	600	30	36	33	30	130	5
8409AC	600	30	36	50	30	130	5
3945G	800, 1000	30	40	100	30	130	5
3947G	1100	30	40	100	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Pagsangahan floodplain located in the province of Leyte, with majority of the floodplain situated within the municipality of Ormoc City. The Municipalities of Calubian, Merida, San Isidro, Tabango, and Villaba were mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is presented in Table 19. The actual coverage of the LiDAR acquisition for the Pagsangahan floodplain is illustrated in Figure 6. ANNEX 7 provides the flight status reports of the survey.

Table 19. List of municipalities and cities surveyed during the Pagsangahan floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Leyte	Albuera	167.61	13.43	8%
	Calubian	102.58	102.58	100%
	Isabel	102.07	93.35	91%
	Kananga	145.85	85.7	59%
	Leyte	240.2	105.78	44%
	Matag-ob	63.46	60.32	95%
	Merida	101.48	101.36	100%
	Ormoc City	451.96	198.13	44%
	Palompon	125.87	79.25	63%
	San Isidro	112.26	112.26	100%
	Tabango	115.97	115.97	100%
	Villaba	133.68	133.38	100%
Total		**1862.99**	**1201.51**	**64.49%**

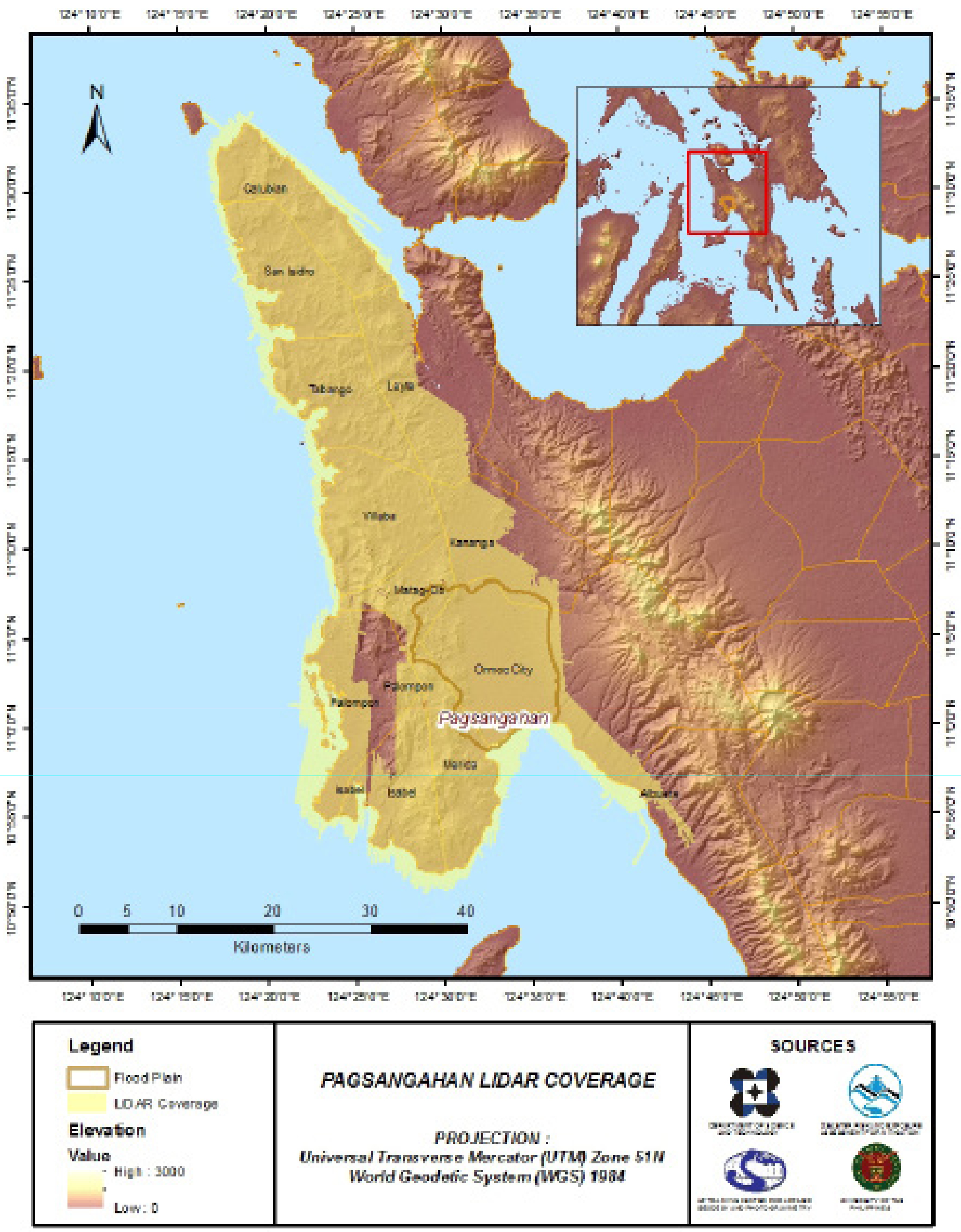


Figure 6. Actual LiDAR survey coverage of the Pagsangahan floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE PAGSANGAHAN FLOODPLAIN

Engr. Ma. Ailyn L. Olanda, Engr. Velina Angela S. Bemida, and Jovy Anne S. Narisma

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 the Digital Surface Model (DSM).

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

These processes are summarized in the diagram in Figure 7.

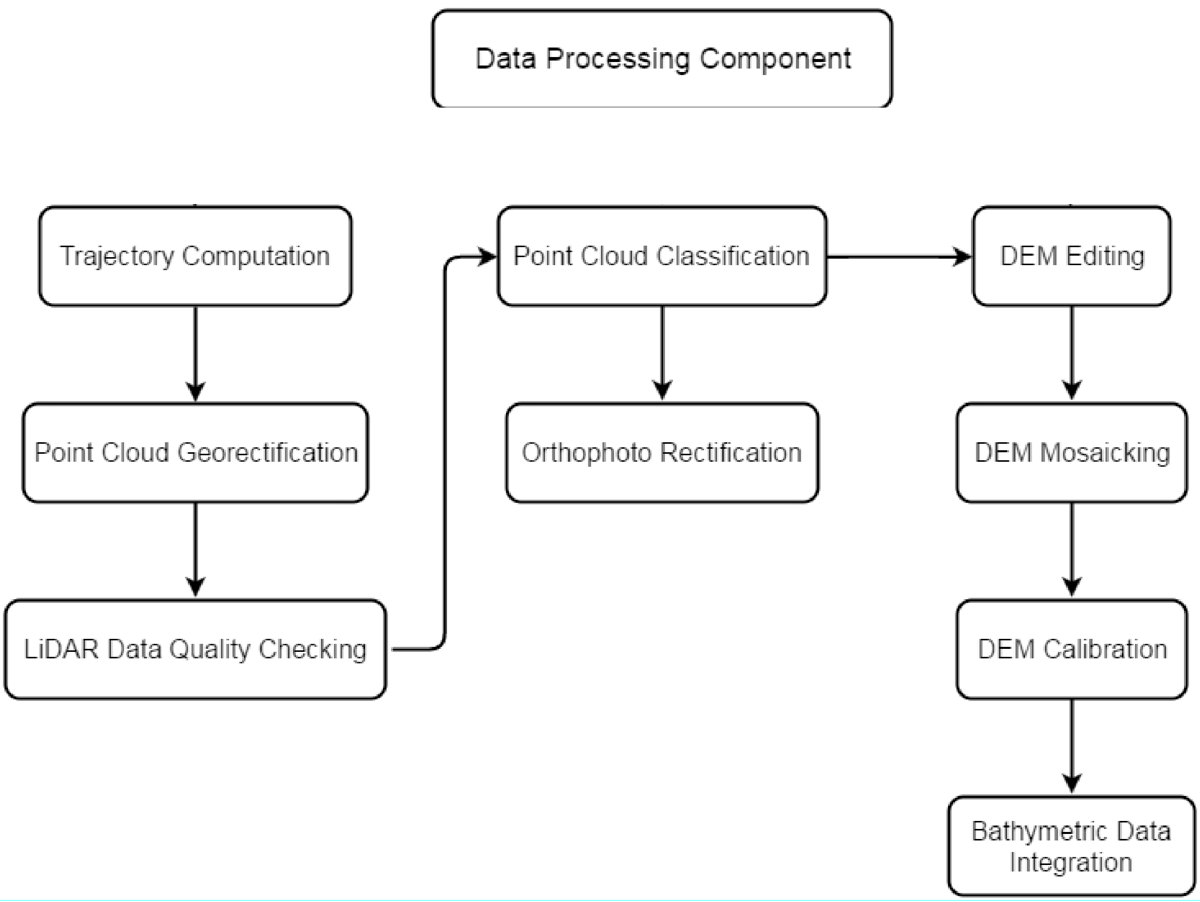


Figure 7. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Pagsangahan floodplain can be found in ANNEX 5. Missions flown during the first survey conducted in April 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 Ormoc, Leyte. The DAC transferred a total of 287.50 Gigabytes of Range data, 5.83 Gigabytes of POS data, 1600.83 Megabytes of GPS base station data, and 1175.8 Gigabytes of raw image data to the data server on January 28, 2014 for the first survey, and on April 16, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Pagsangahan River survey was fully transferred on May 6, 2016, as indicated on the data transfer sheets for the Pagsangahan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1462A, one of the Pagsangahan flights, which are the North, East, and Down position RMSE values, are demonstrated in Figure 8. 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 16, 2014 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

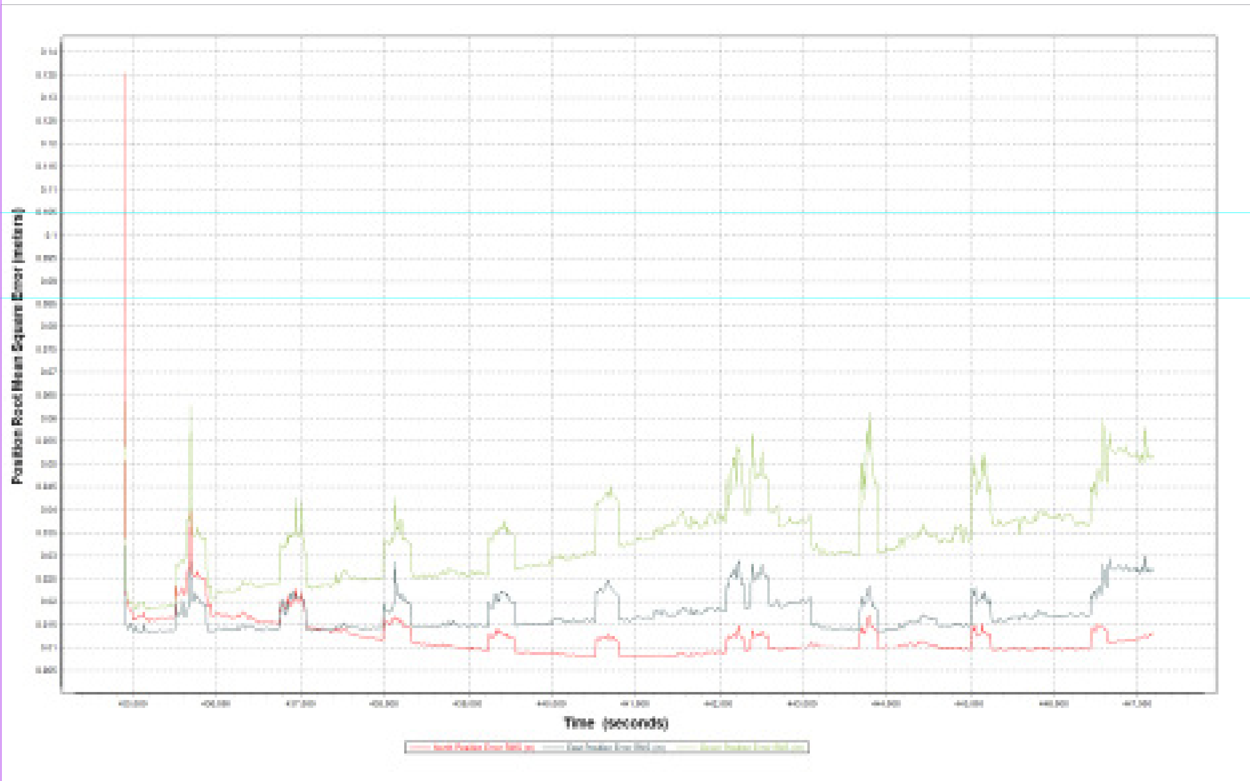


Figure 8. Smoothed Performance Metrics of a Pagsangahan Flight 1462A

The time of flight was from 435000 seconds to 447000 seconds, which corresponds to the morning of May 16, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 depicts that the North position RMSE peaked at 4.00 centimeters, the East position RMSE peaked at 3.00 centimeters, and the Down position RMSE peaked at 6.50 centimeters, which are all within the prescribed accuracies described in the methodology.

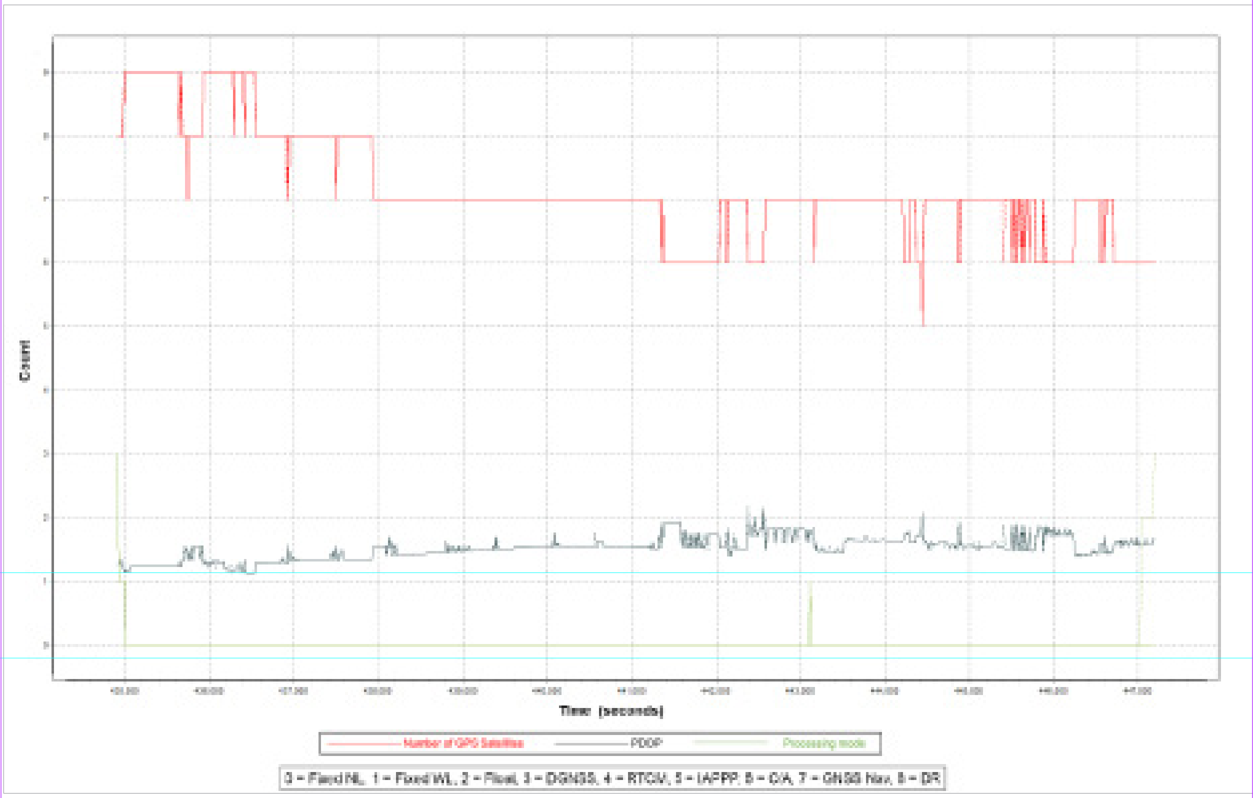


Figure 9. Smoothed Performance Metric Parameters of a Pagsangahan Flight 1462A

The Solution Status parameters of flight 1462A, one of the Pagsangahan flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are presented in Figure 9. The graphs indicate that the number of satellites during the acquisition did go down to six (6). Most of the time, the number of satellites tracked was between five (5) and nine (9). The PDOP value 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 with some peaks to up to two (2), attributed to the turns performed by the aircraft. The value of zero (0) corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Pagsangahan flights is exhibited in Figure 10.

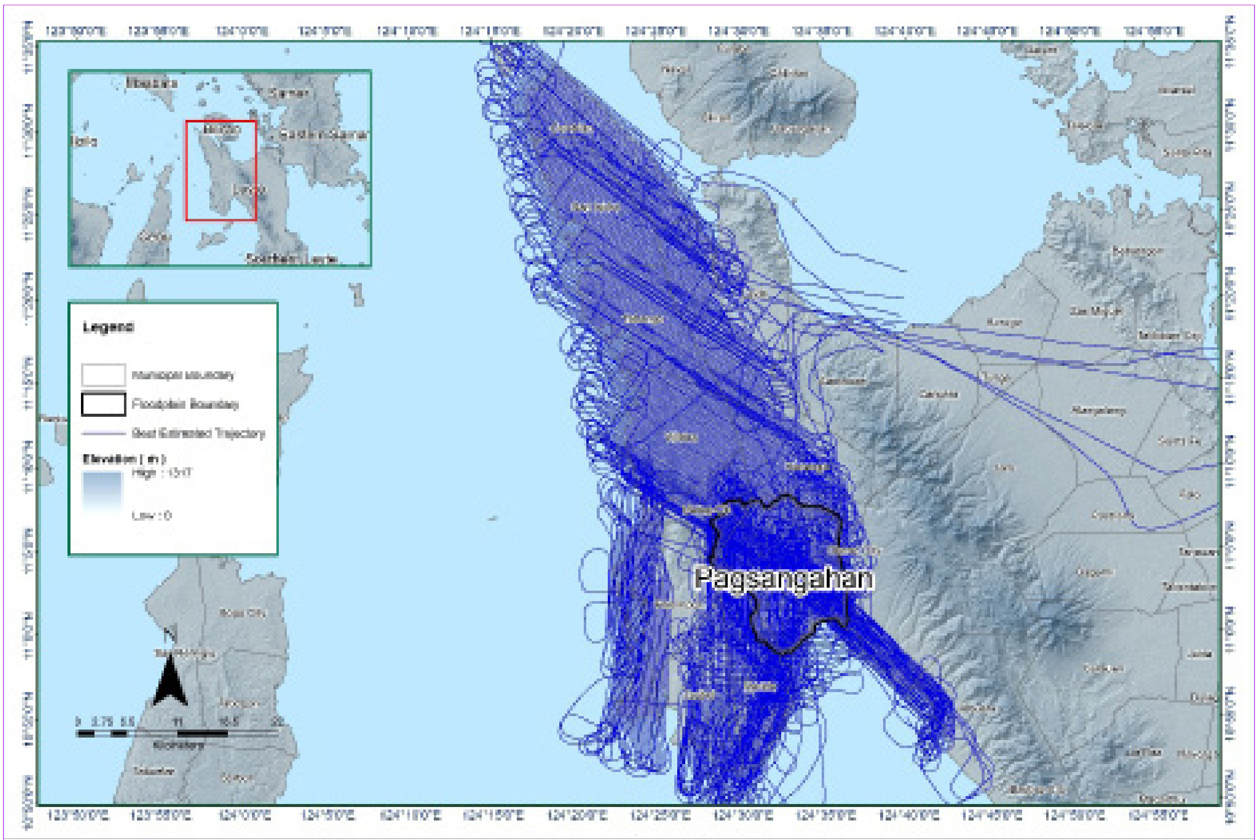


Figure 10. The best estimated trajectory conducted over the Pagsangahan floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 506 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 for all flights over the Pagsangahan floodplain, obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 20.

Table 20. Self-calibration results for the Pagsangahan flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000208
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000943
GPS Position Z-correction stdev (<0.01meters)	0.0082

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data are represented in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

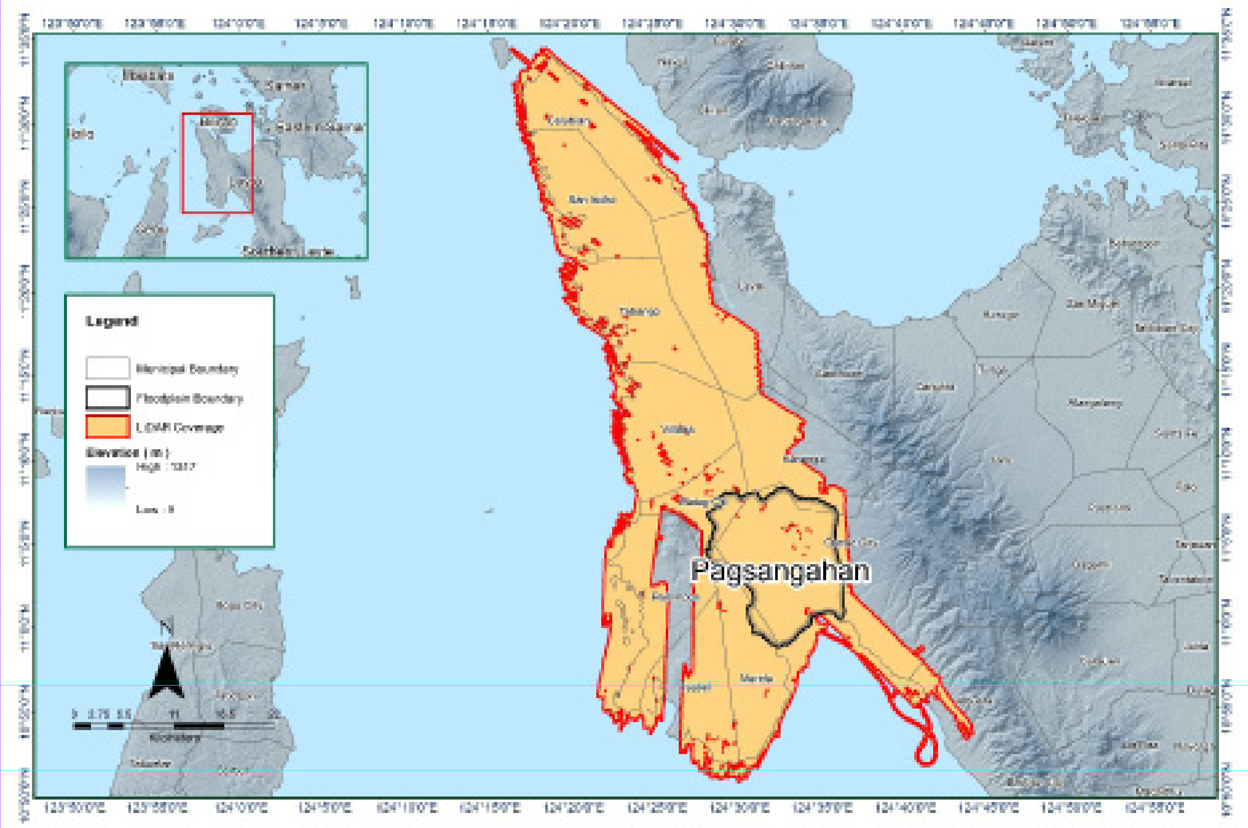


Figure 11. Boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Pagsangahan floodplain.

The total area covered by the Pagsangahan missions is 1799.76 sq. km., comprised of twenty-five (25) flight acquisitions grouped and merged into thirty (30) blocks, as reflected in Table 21.

Table 21. List of LiDAR blocks for the Pagsangahan floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk35A	1504A	68.59
Samar_Leyte_Blk35I	1502A	64.25
	1504A	
Samar_Leyte_Blk35I_additional	1502A	13.55
	1504A	
Samar_Leyte_Blk35H_supplement	1498A	104.32
Samar_Leyte_Blk35F	1466A	158.46
	1474A	
Samar_Leyte_Blk35E	1464A	116.20
	1474A	
Samar_Leyte_Blk35D	1462A	110.56
Samar_Leyte_Blk35C	1460A	118.95
	1474A	
Samar_Leyte_Blk35B	1458A	79.46
Samar_Leyte_Blk35H	1494A	108.32
Samar_Leyte_Blk35H_supplement2	1498A	0.18
Ormoc_Blk35A_supplement	7806AC	74.91
Ormoc_Blk35A	7780AC	86.29
	7782AC	
Ormoc_Blk35B	7753AC	68.76
Ormoc_Blk35A_additional	7760AC	74.78
Ormoc_Blk35B_additional	7802AC	25.57
Ormoc_Blk35CD_additional	7806AC	6.43
Ormoc_Camotes_Blk35E	8391AC	36.84
Ormoc_Camotes_Blk35E_additional	8408AC	8.87
Ormoc_Camotes_Blk35E_supplement	8389AC	61.52
Ormoc_Camotes_Bk35F	8391AC	25.65
Ormoc_Camotes_Blk35F_additional	8408AC	8.34
Ormoc_Camotes_Blk35G	8392AC	52.24
Ormoc_Camotes_Blk35H	8392AC	11.11
Ormoc_Camotes_Blk35H_supplement	8408AC	20.80
Ormoc_Camotes_Blk35J	8409AC	19.16
Ormoc_South_Blk35A	3945G	106.48
Ormoc_South_Blk35B	3945G	59.81
	3947G	
Ormoc_South_Blk35C	3947G	96.01
Tacloban_Blk1032A	1032A	13.35
TOTAL		**1799.76 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is illustrated in Figure 12. Since the Gemini and Aquarius systems both employ 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 or more overlapping flight lines.

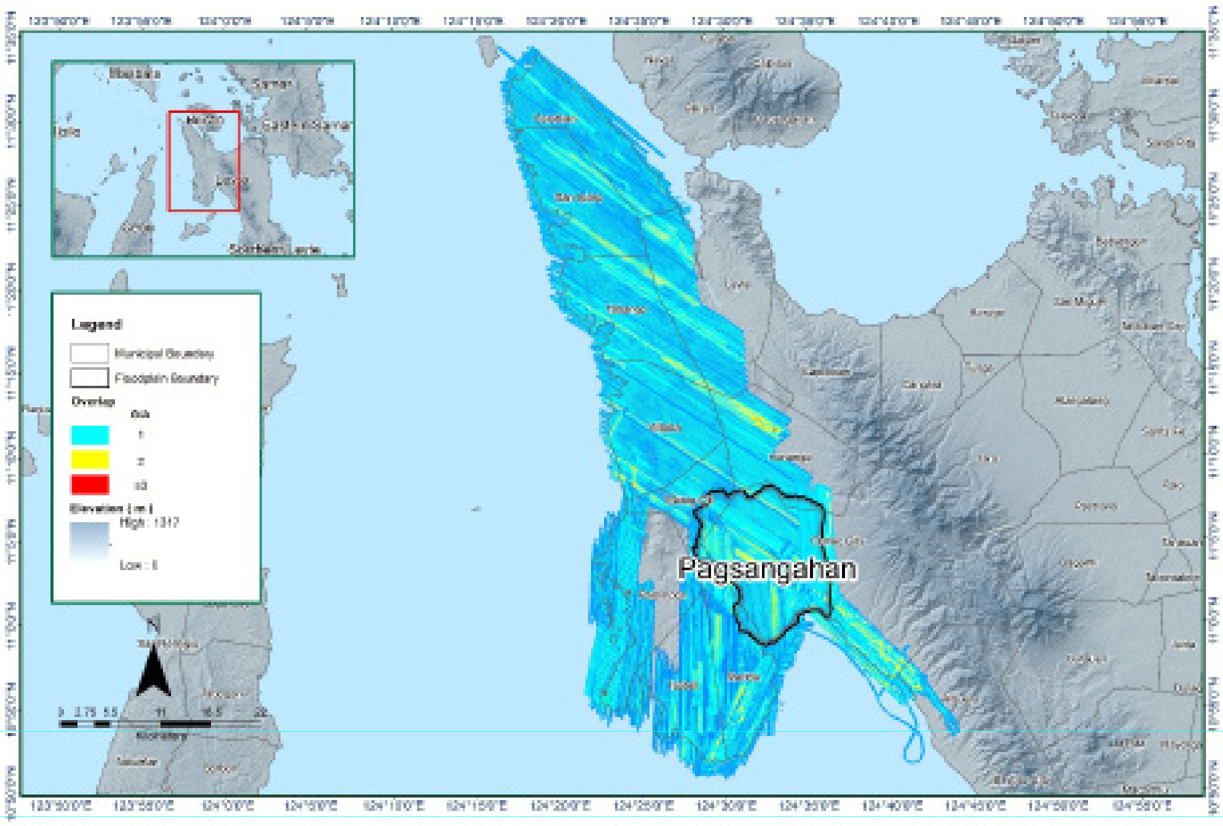


Figure 12. Image of data overlap for the Pagsangahan floodplain

The overlap statistics per block for the Pagsangahan 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 are 26.50% and 68.60%, respectively, which satisfied the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is illustrated in Figure 13. It was determined that all LiDAR data for the Pagsangahan floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.45 points per square meter.

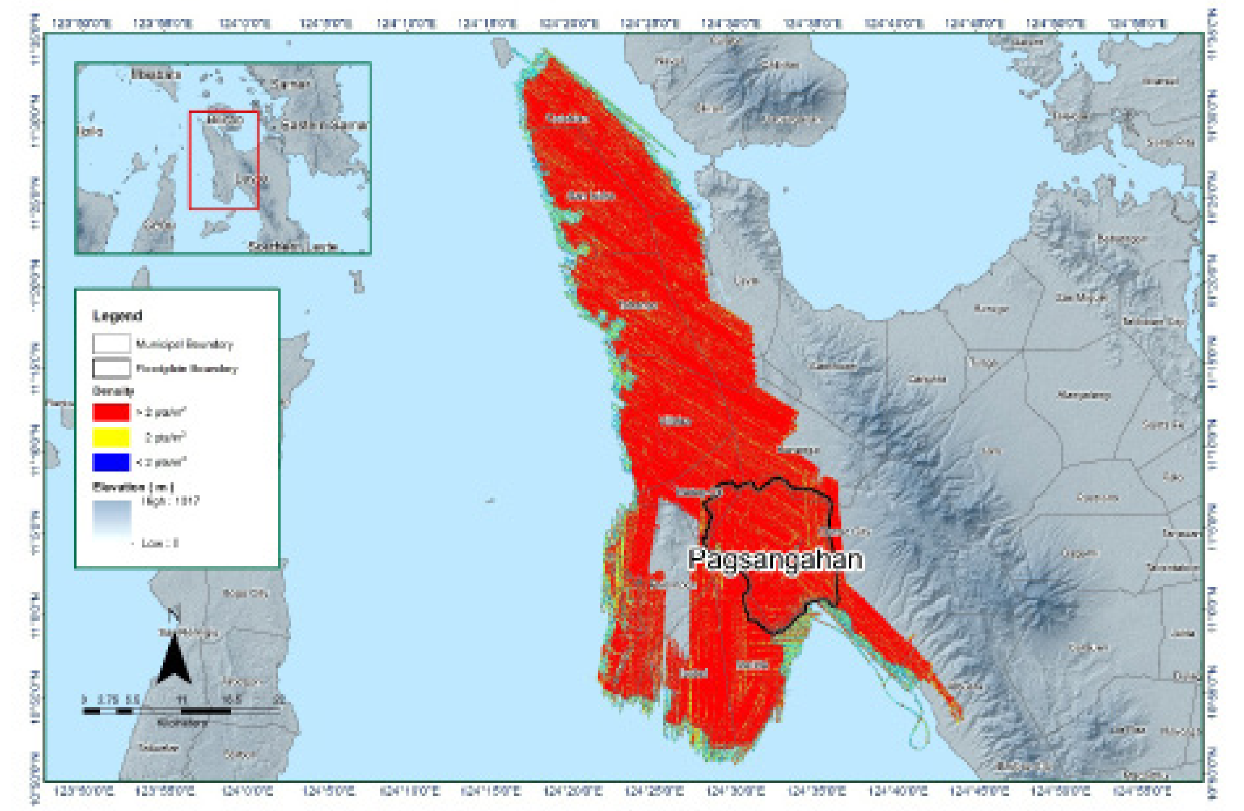


Figure 13. Pulse density map of merged LiDAR data for the Pagsangahan floodplain

The elevation difference between overlaps of adjacent flight lines is depicted in Figure 14. The default color range is from blue to red, Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to elevations of its adjacent flight line. Areas with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

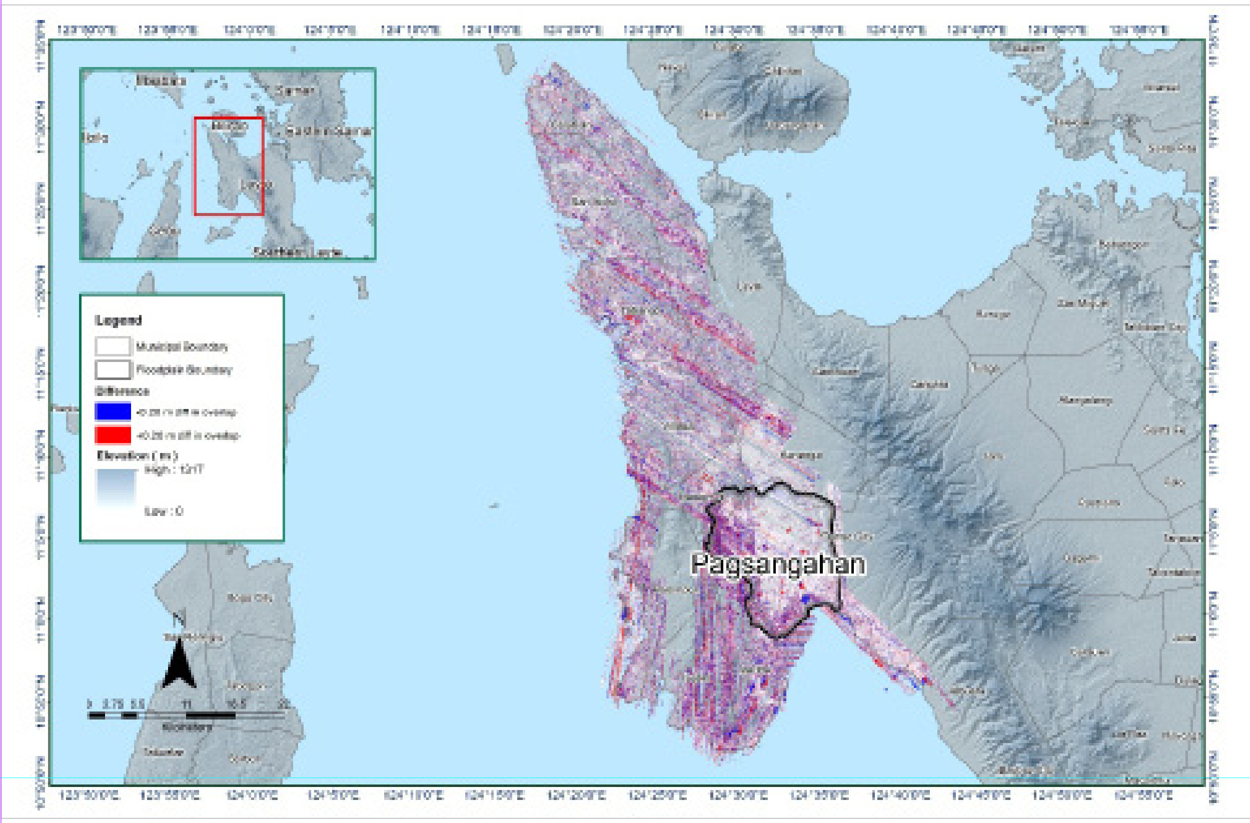


Figure 14. Pulse density map of merged LiDAR data for the Pagsangahan floodplain

A screen capture of the processed LAS data from a Pagsangahan flight 1462A loaded in the QT Modeler is provided in Figure 15. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow 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 researcher was satisfied with the quality of the LiDAR data. No reprocessing was done for this LiDAR dataset.

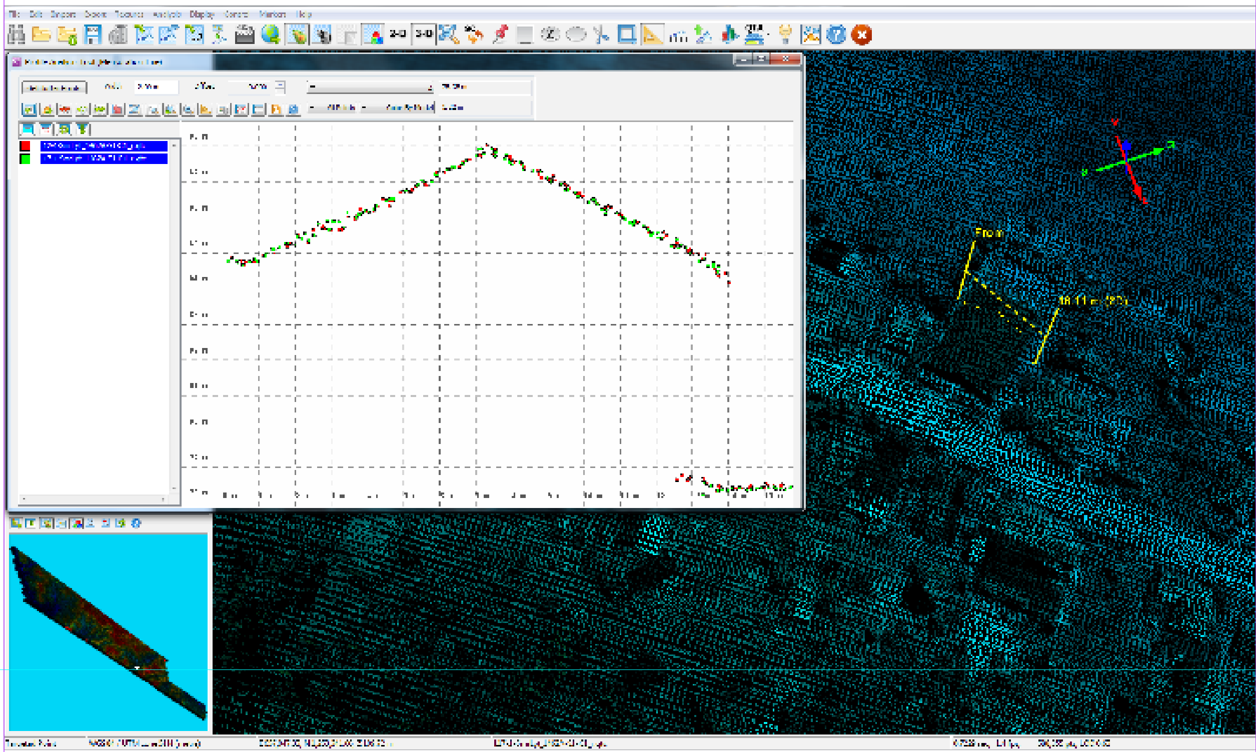


Figure 15. Quality checking for Pagsangahan flight 1462A using the Profile Tool of the QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 22. Pagsangahan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,193,199,945
Low Vegetation	1,297,574,181
Medium Vegetation	2,126,173,720
High Vegetation	1,242,378,242
Building	56,017,725

The tile system that the TerraScan employed for the LiDAR data, as well as the final classification image for a block in Pagsangahan floodplain, are presented in Figure 16. A total of 2,737 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 22. The point cloud had a maximum and minimum height of 664.42 meters and 36.39 meters, respectively.

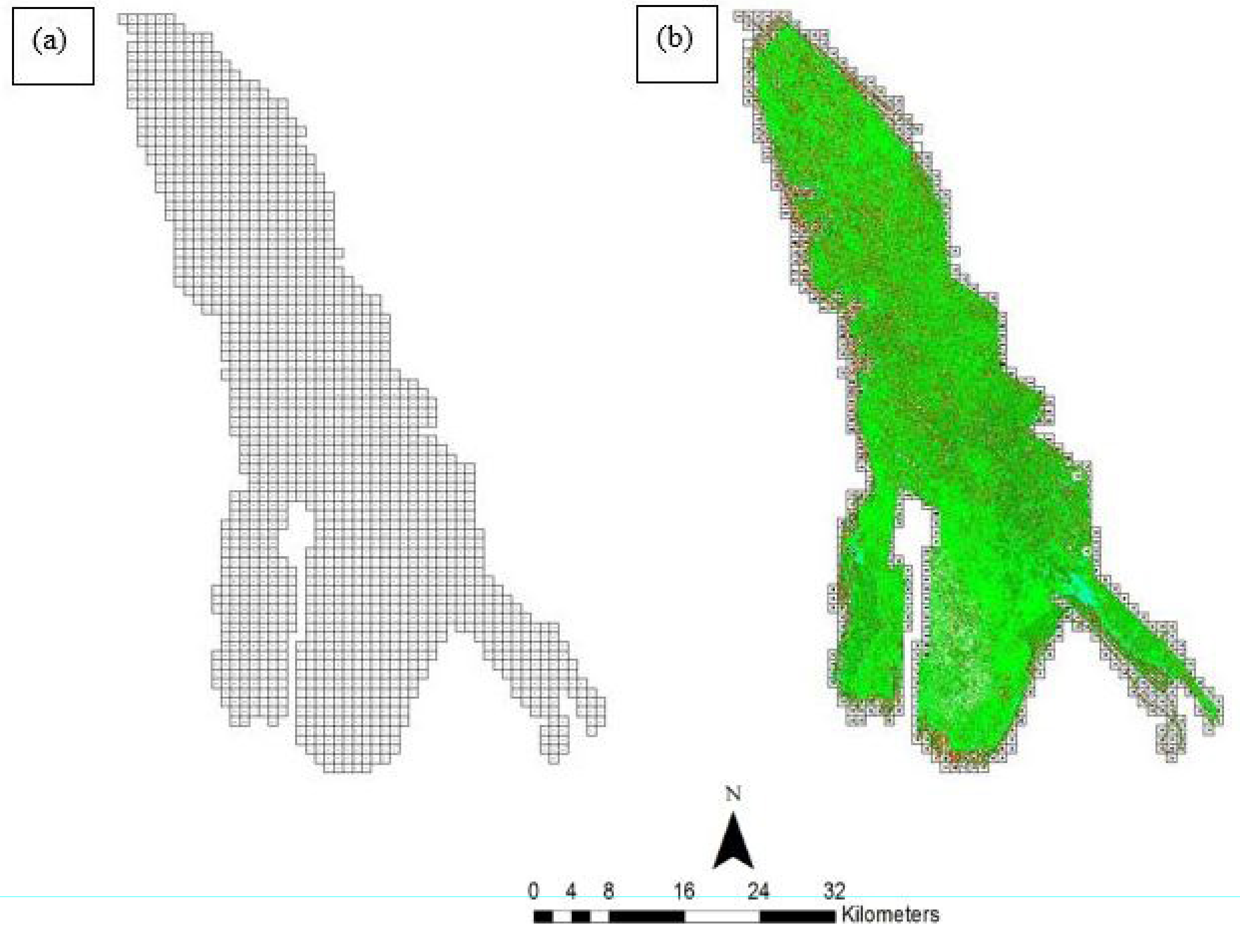


Figure 16. (a) Tiles for the Pagsangahan floodplain; and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 17. 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.

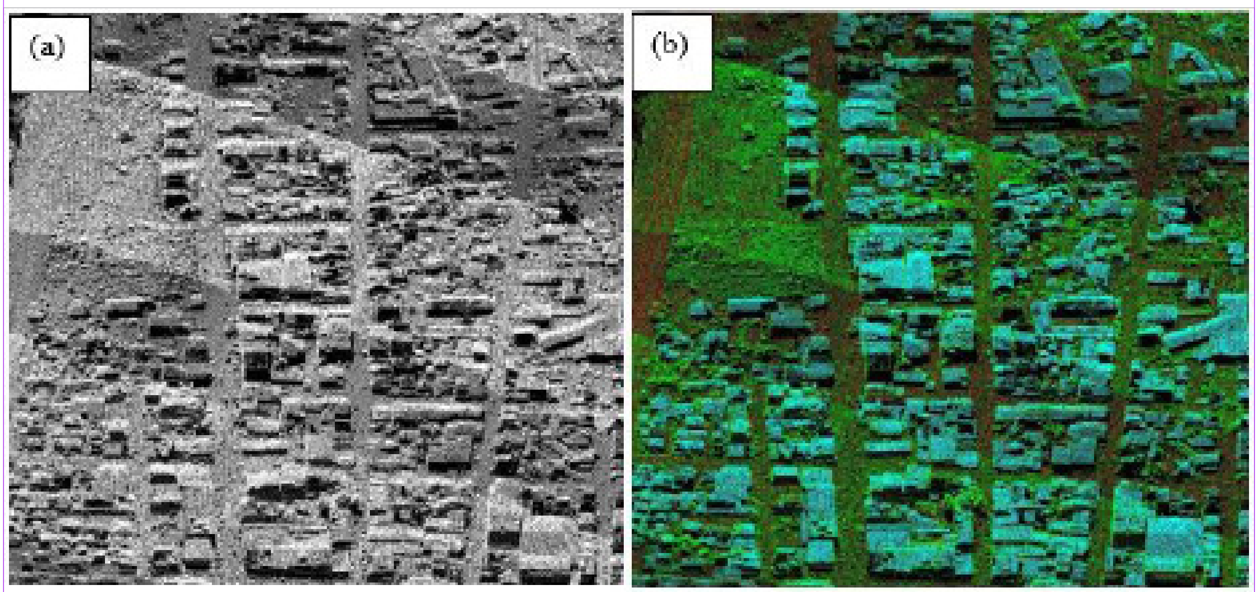


Figure 17. Point cloud (a) before and (b) after classification

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 presented in Figure 18, in top view display. It shows that DTMs are a representation of the bare earth, while the DSMs reflect all features that are present, such as buildings and vegetation.

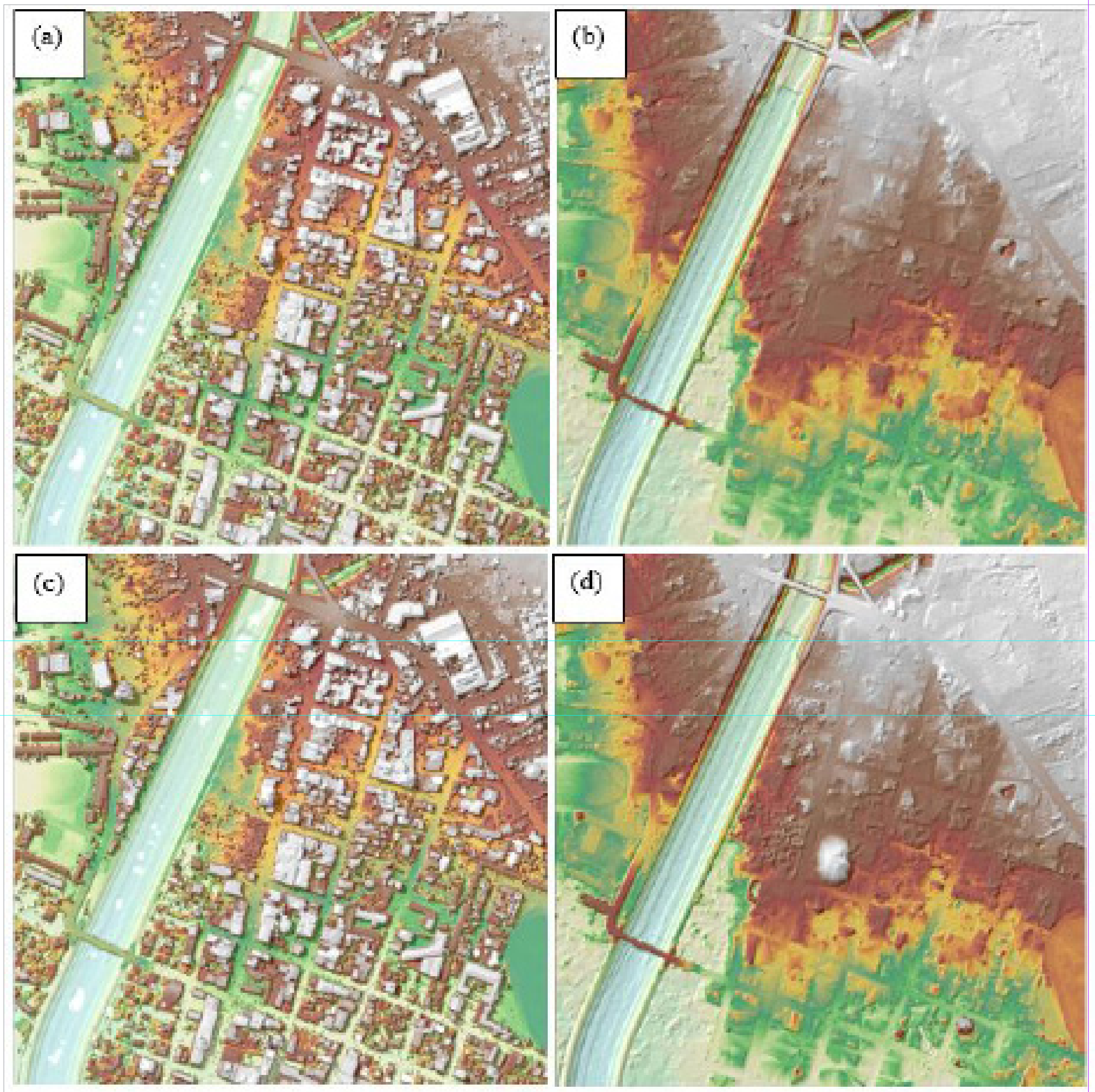


Figure 18. The production of (a) last return DSM and (b) DTM; (c) first return DSM and (d) secondary DTM in some portion of Pagsangahan floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,134 1km by 1km tiles area covered by the Pagsangahan floodplain is illustrated in Figure 19. 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 Pagsangahan floodplain survey attained a total of 774.39 sq. km. in orthophotographic coverage, comprised of 9,430 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 20.

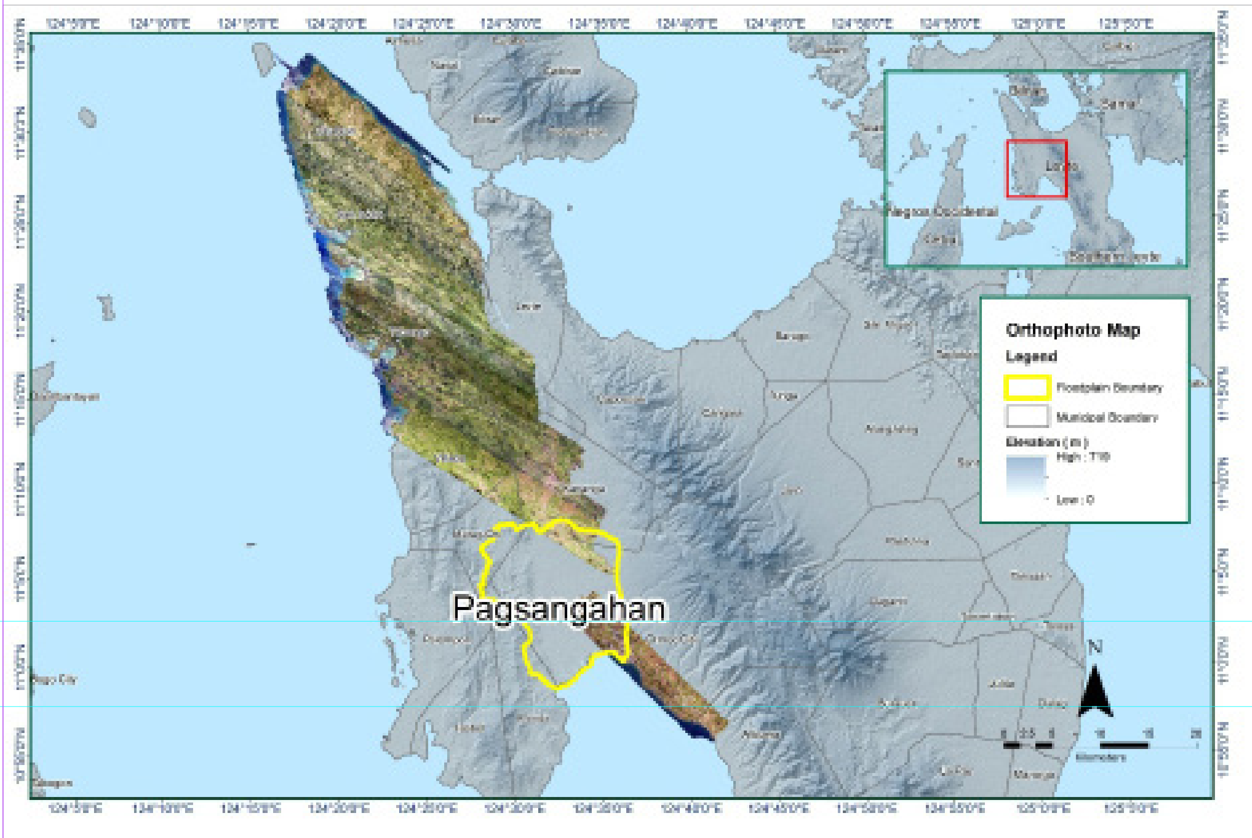


Figure 19. The Pagsangahan floodplain with available orthophotographs

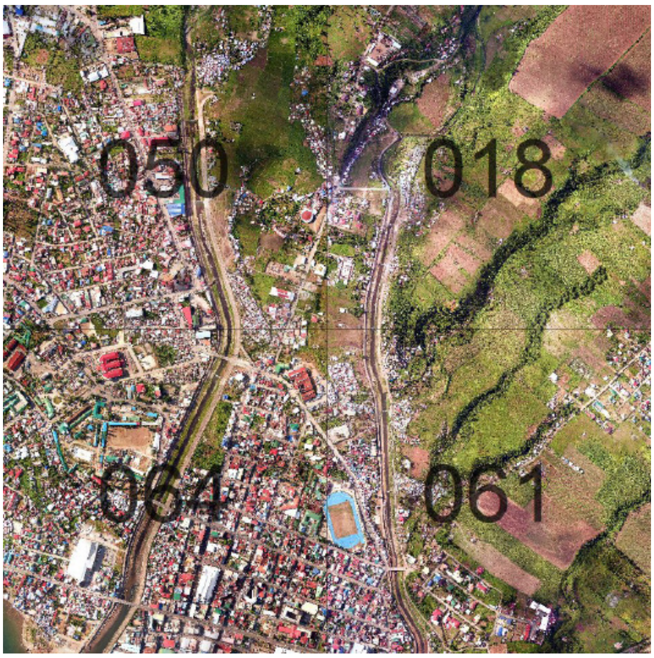


Figure 20. Sample orthophotograph tiles for the Pagsangahan floodplain

3.8 DEM Editing and Hydro-Correction

Thirty (30) mission blocks were processed for the Pagsangahan floodplain survey. These blocks are composed of Samar_Leyte, Ormoc, Ormoc_South, and Ormoc_Camotes blocks, with a total area of 1,799.76 square kilometers. Table 23 indicates the name and corresponding area of each block, in square kilometers.

Table 23. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Samar_Leyte_Blk35A	68.59
Samar_Leyte_Blk35I	64.25
Samar_Leyte_Blk35I_additional	13.55
Samar_Leyte_Blk35H_supplement	104.32
Samar_Leyte_Blk35F	158.46
Samar_Leyte_Blk35E	116.20
Samar_Leyte_Blk35D	110.56
Samar_Leyte_Blk35C	118.95
Samar_Leyte_Blk35B	79.46
Samar_Leyte_Blk35H	108.32
Samar_Leyte_Blk35H_supplement2	0.18
Ormoc_Blk35A_ supplement	74.91
Ormoc_Blk35A	86.29
Ormoc_Blk35B	68.76
Ormoc_Blk35A_ additional	74.78
Ormoc_Blk35B_ additional	25.57
Ormoc_Blk35CD_ additional	6.43
Ormoc_Camotes_Blk35E	36.84
Ormoc_Camotes_Blk35E_ additional	8.87
Ormoc_Camotes_Blk35E_ supplement	61.52
Ormoc_Camotes_Blk35F	25.65
Ormoc_Camotes_Blk35F_ additional	8.34
Ormoc_Camotes_Blk35G	52.24
Ormoc_Camotes_Blk35H	11.11
Ormoc_Camotes_Blk35H_ supplement	20.80
Ormoc_Camotes_Blk35J	19.16
Ormoc_South_Blk35A	106.48
Ormoc_South_Blk35B	59.81
Ormoc_South_Blk35C	96.01
Tacloban_Blk1032A	13.35
TOTAL	**1799.76 sq.km**

Portions of the DTM before and after manual editing are represented in Figure 21. The bridge and other misclassified objects on the river (Figure 21a) were considered to be impedances to the flow of water and had to be removed (Figure 21b) in order to hydrologically correct the river. The paddy field embankment (Figure 21c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 21d) to allow for the correct flow of water.

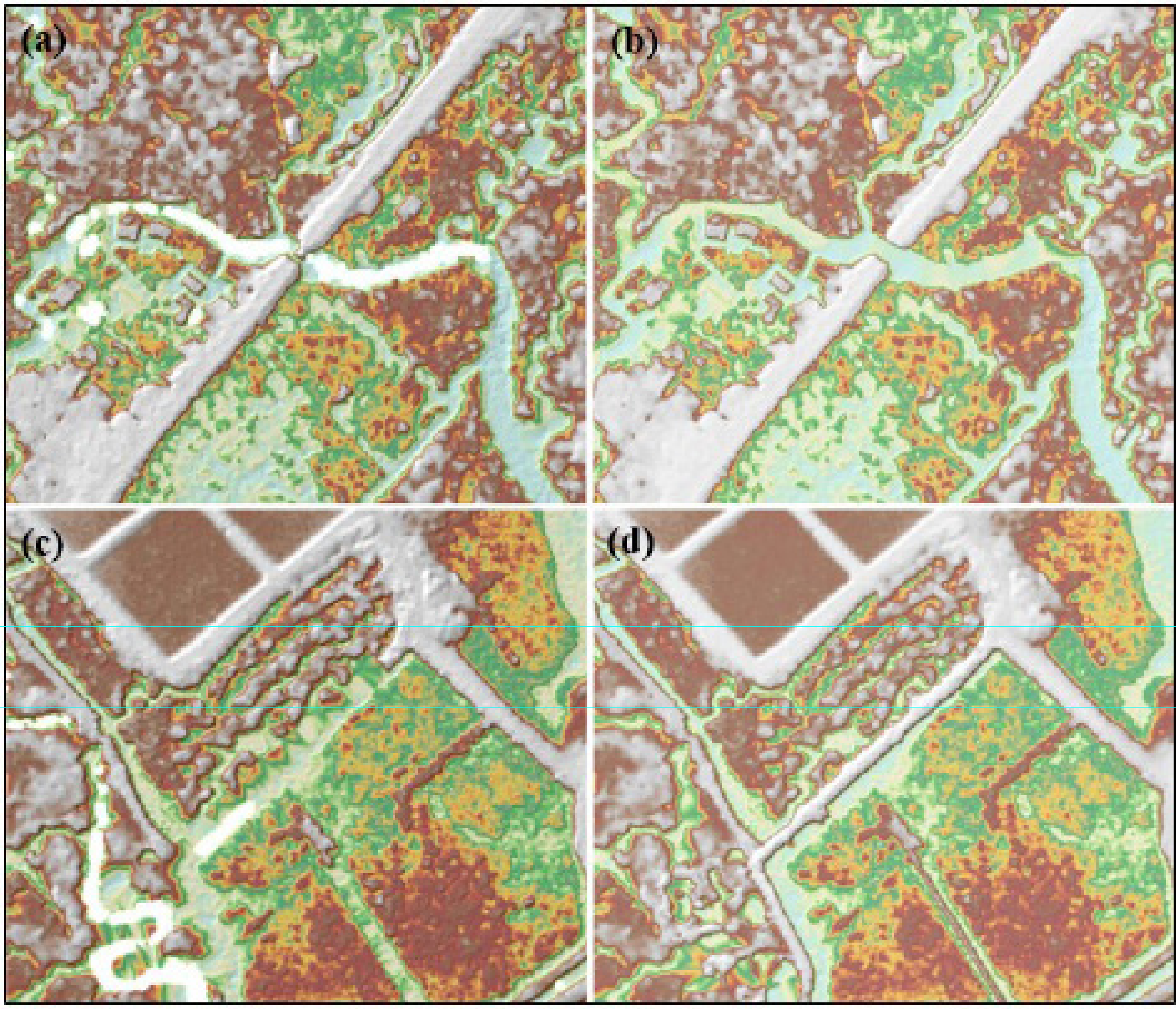


Figure 21. Figure 21. Portions in the DTM of the Pagsangahan floodplain – a bridge and other obstructions on the river (a) before and(b) after manual editing; a paddy field embankment (c) before and (d) after manual editing

3.9 Mosaicking of Blocks

The Samar_Leyte_Blk35I block was used as the reference block at the start of mosaicking, because this was the first available block for processing in the floodplain. Table 24 summarizes the shift values applied to each LiDAR block during the mosaicking process.

The mosaicked LiDAR DTM for the Pagsangahan floodplain is exhibited in Figure 22. It demonstrates that the entire Pagsangahan floodplain is 99.92% covered by LiDAR data.

Table 24. Shift values of each LiDAR block of the Pagsangahan floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Samar_Leyte_Blk35I	0.00	0.00	0.00
Ormoc_Blk35A	0.00	0.00	-0.30
Ormoc_Blk35B	0.00	0.00	-0.32
Ormoc_Blk35A_supplement	0.00	0.00	-0.18
Ormoc_Blk35A_additional	0.00	1.00	0.00
Samar_Leyte_Blk35H_supplement	0.00	0.00	0.00
Samar_Leyte_Blk35H	0.00	0.00	0.00
Samar_Leyte_Blk35F	1.00	0.00	-0.32
Samar_Leyte_Blk35E	2.00	0.00	-0.32
Samar_Leyte_Blk35D	2.00	1.00	-0.32
Samar_Leyte_Blk35C	2.00	2.00	-0.27
Samar_Leyte_Blk35B	3.00	2.00	-0.27
Ormoc_Blk35F	0.00	0.00	-0.14
Ormoc_Blk35CD_ additional	0.00	0.00	-0.69
Samar_Leyte_Blk35I_ additional	0.00	0.00	0.00
Samar_Leyte_Blk35A	0.00	0.00	0.00
Ormoc_Camotes_Blk35E	0.00	0.00	0.00
Ormoc_Camotes_Blk35E_supplement	0.00	0.00	0.03
Ormoc_Camotes_Blk35G	0.50	-0.50	0.64
Ormoc_Camotes_Blk35F_additional	0.00	0.00	0.15
Ormoc_Camotes_Blk35H_supplement	-1.00	0.50	0.30
Ormoc_Camotes_Blk35H	-2.00	0.50	0.24
Ormoc_Camotes_Blk35E_ additional	0.00	0.50	0.00
Ormoc_South_Blk35B	0.00	0.50	-0.55
Ormoc_South_Blk35A	0.00	0.00	-0.79
Ormoc_South_Blk35C	0.00	0.00	-0.60
SamarLeyte_Blk35H_ supplement2	0.00	0.00	0.00
Ormoc_Blk35B_additional	0.00	0.00	-0.31
Ormoc_Camotes_Blk35J	0.00	-2.00	-11.23
Tacloban_Blk1032A	0.00	0.00	0.00

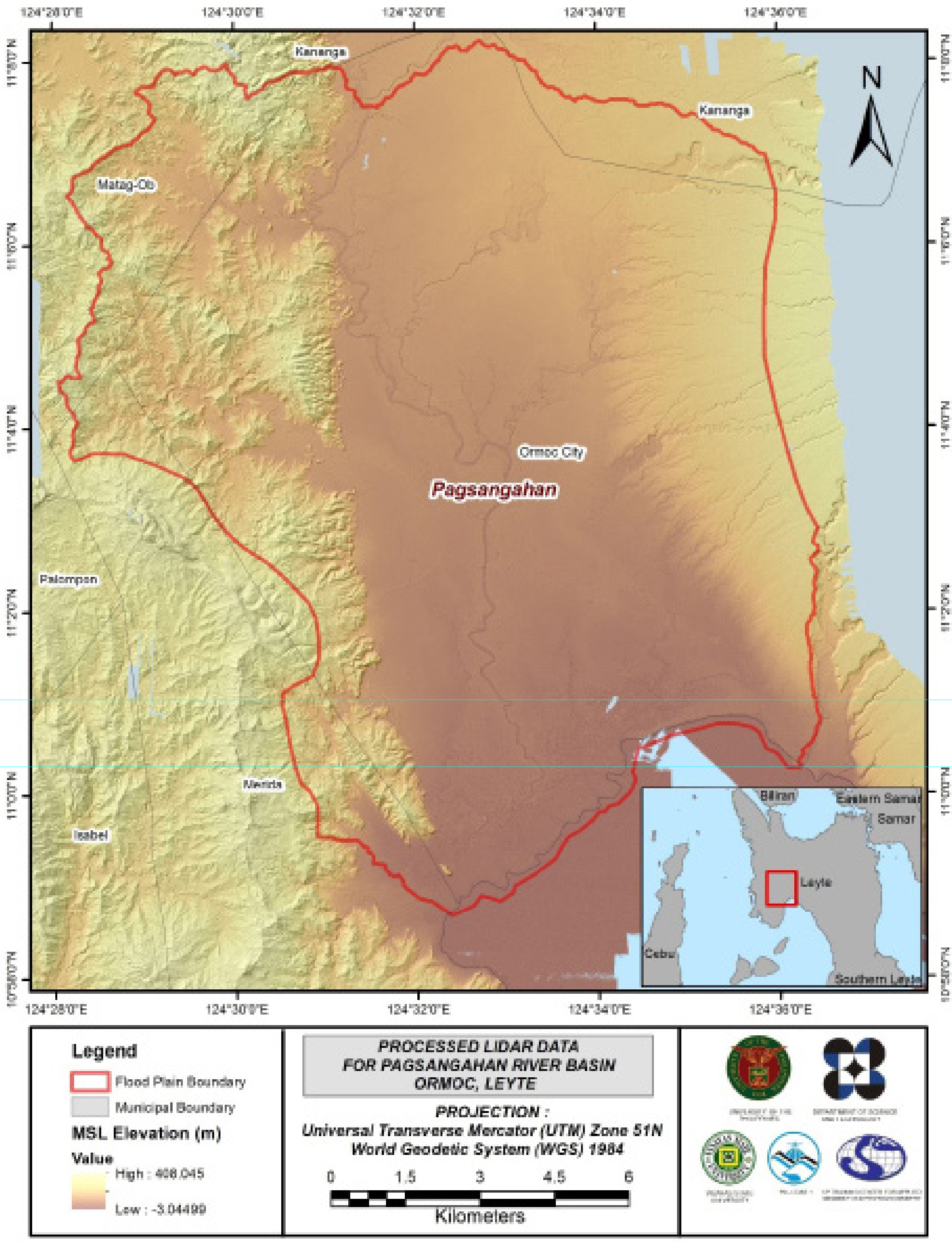


Figure 22. Map of processed LiDAR data for the Pagsangahan floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ormoc City and Bato Municipality to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 25,710 survey points were gathered for all the flood plains within Ormoc City and Bato Municipality wherein the Pagsangahan is located. Random selection of 80% of the survey points, resulting to 20,568 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.26 meters with a standard deviation of 0.19 meters. Calibration of the LiDAR data was done by adding the height difference value, 0.26 meters, to the mosaicked LiDAR data. Table 25 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

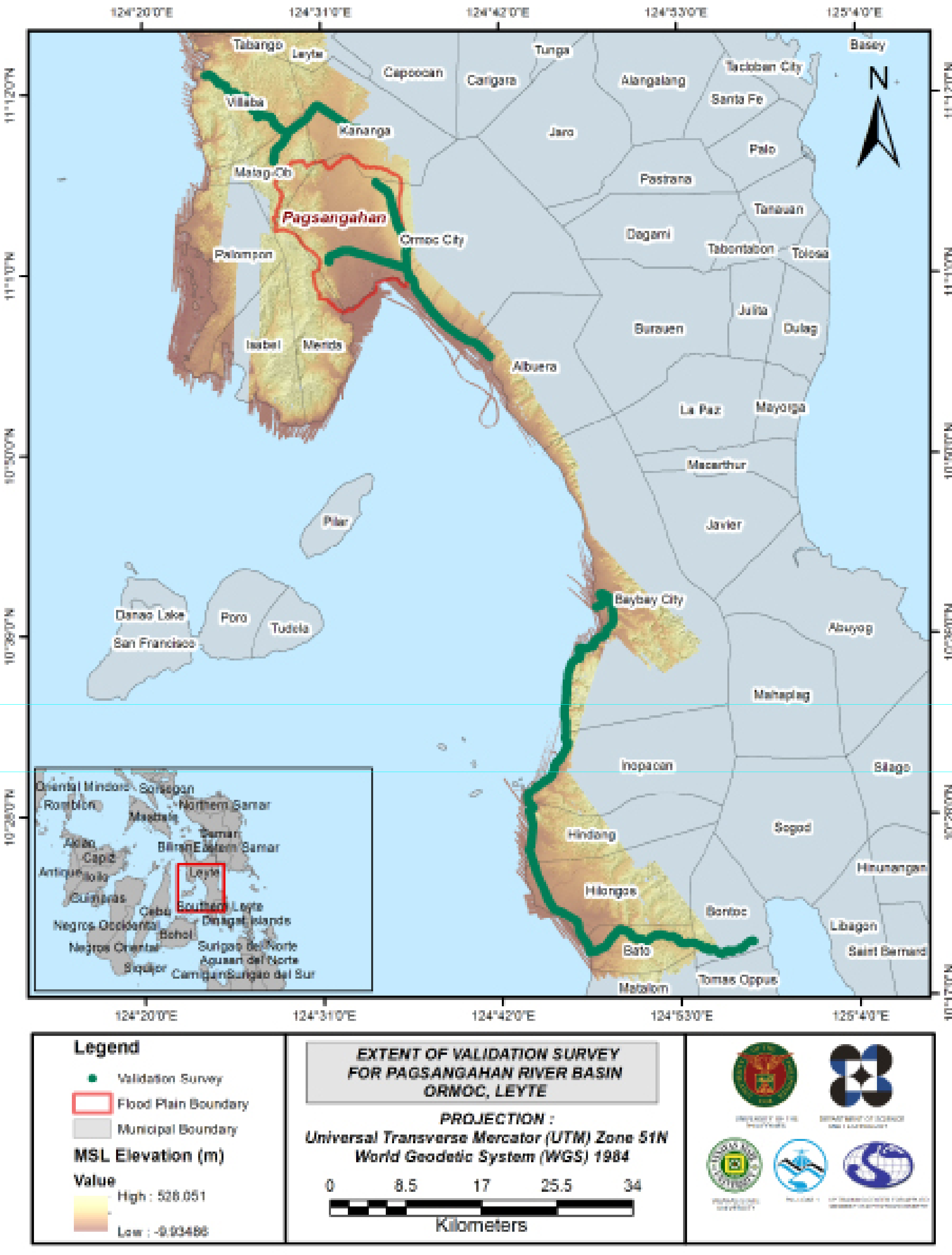


Figure 23. Map of the Pagsangahan floodplain, with validation survey points in green

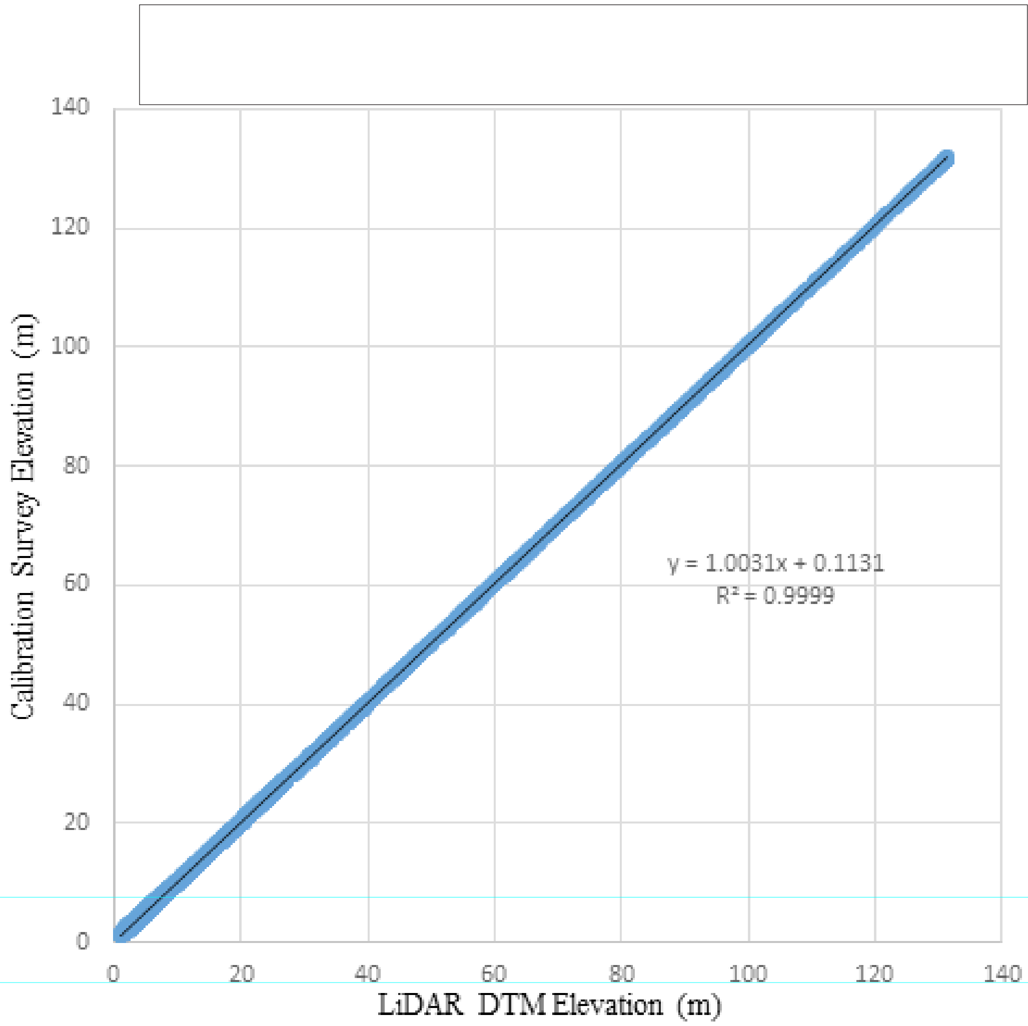


Figure 24. Correlation plot between the calibration survey points and the LiDAR data

Table 25. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.26
Standard Deviation	0.19
Average	0.16
Minimum	-0.30
Maximum	0.60

The remaining 20% of the total survey points, resulting in 5,142 points, were used for the validation of calibrated Pagsangahan 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 25. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.20 meters, with a standard deviation of 0.18 meters, as shown in Table 26.

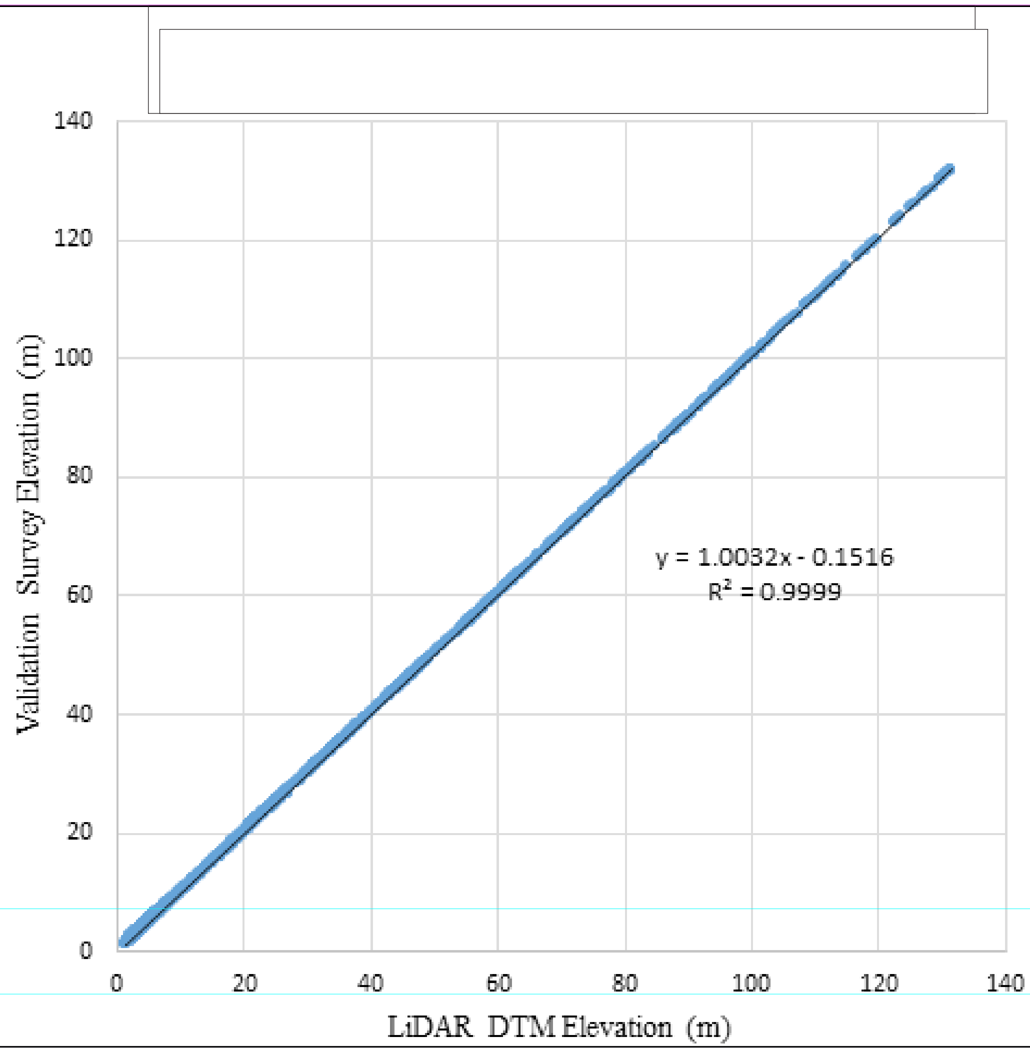


Figure 25. Correlation plot between the validation survey points and the LiDAR data.

Table 26. Validation statistical measures

Calibration Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.18
Average	-0.10
Minimum	-0.47
Maximum	0.29

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Pagsangahan, with 4,352 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.68 meters. The extent of the bathymetric survey done by the DVBC in the Pagsangahan River, integrated with the processed LiDAR DEM, is illustrated in Figure 26.

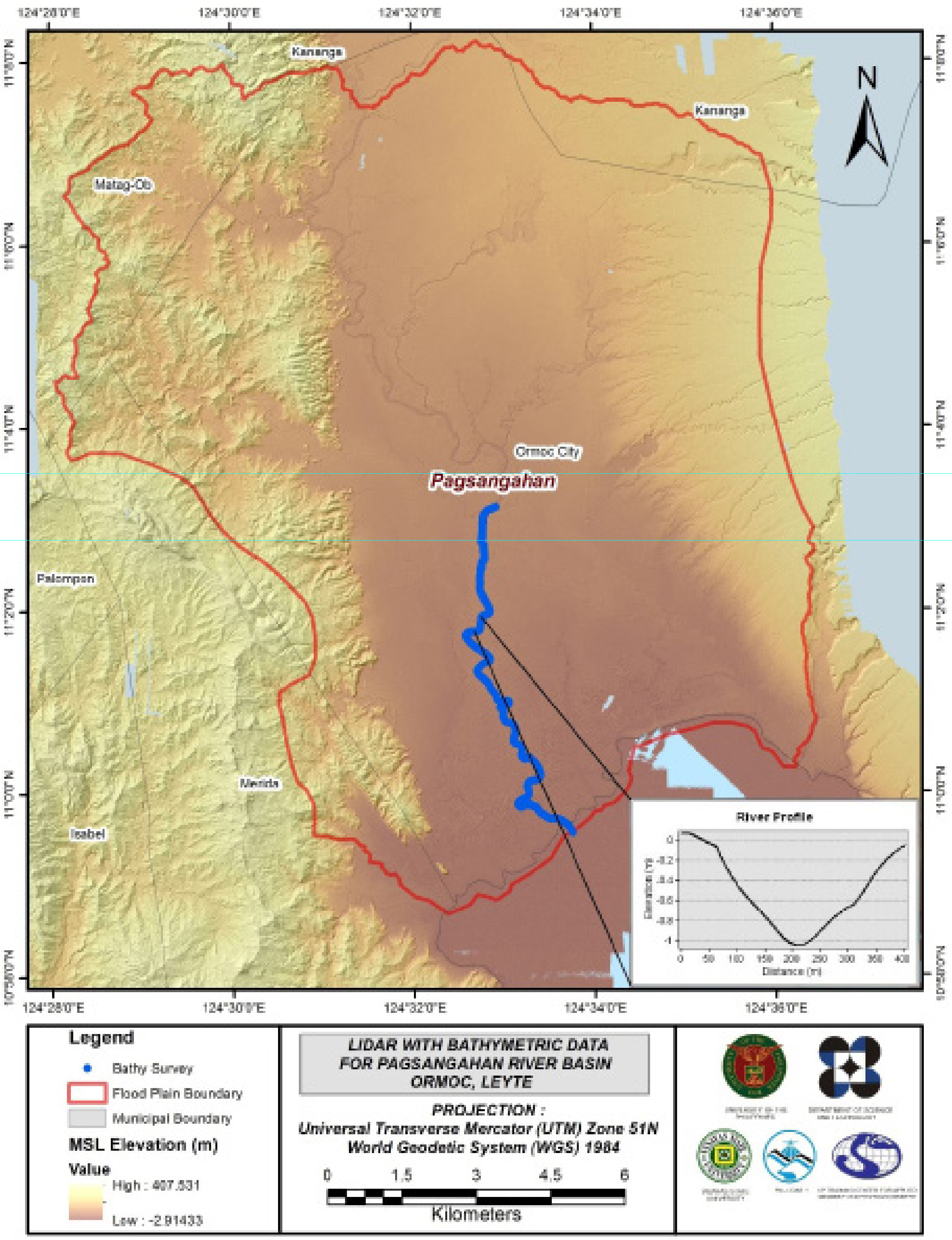


Figure 26. Map of the Pagsangahan floodplain, with bathymetric survey points in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Pagsangahan floodplain, including its 200-meter buffer zone, has a total area of 192.38 sq. km. Of this area, a total of 6.0 sq. km., corresponding to a total of 2,285 building features, was considered for quality checking (QC). Figure 27 exhibits the QC blocks for the Pagsangahan floodplain.

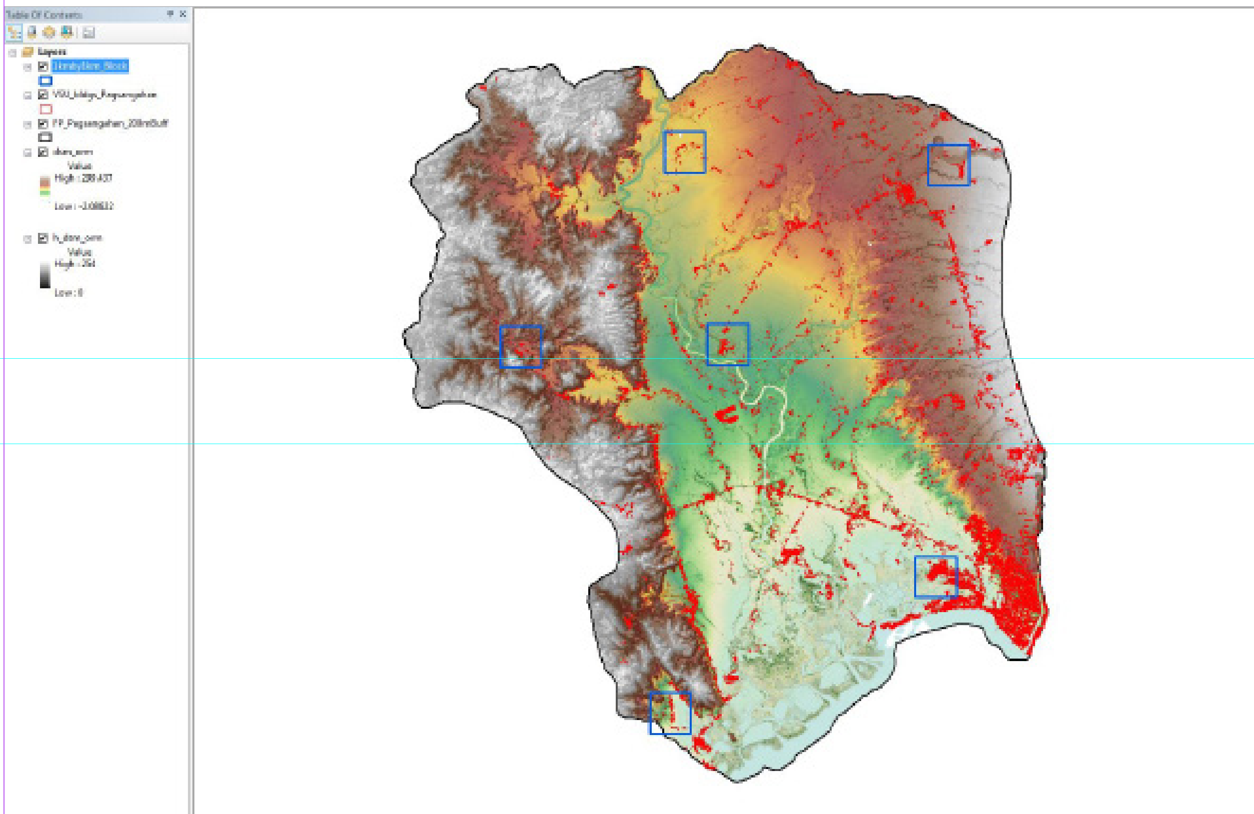


Figure 27. Blocks (in blue) of the Pagsangahan building features that were subjected to QC

Quality checking of the Pagsangahan building features resulted in the ratings presented in Table 27.

Table 27. Quality checking ratings for the Pagsangahan building features

Floodplain	Completeness	Correctness	Quality	Remarks
Pagsangahan	99.82	100.00	99.59	PASSED

3.12.2 Height Extraction

Height extraction was performed for 31,264 building features in the Pagsangahan floodplain. Of these building features, 147 were filtered out after height extraction, resulting in 31,117 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 6.73 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. A normalized DSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 28 summarizes the number of building features per type. Table 29 presents the total length of each road type, and Table 30 lists the number of water features extracted per type.

Table 28. Building features extracted for the Pagsangahan floodplain

Facility Type	No. of Features
Residential	29,464
School	656
Market	80
Agricultural/Agro-Industrial Facilities	51
Medical Institutions	40
Barangay Hall	52
Military Institution	0
Sports Center/Gymnasium/Covered Court	35
Telecommunication Facilities	1
Transport Terminal	7
Warehouse	154
Power Plant/Substation	6
NGO/CSO Offices	13
Police Station	4
Water Supply/Sewerage	17
Religious Institutions	144
Bank	5
Factory	23
Gas Station	24
Fire Station	1
Other Government Offices	99
Other Commercial Establishments	217
New Buildings	14
Abandoned Buildings	10
Total	**31,117**

Table 29. Total length of extracted roads for the Pagsangahan floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Pagsangahan	245.53	12.93	0.00	37.71	0.00	**296.17**

Table 30. Number of extracted water bodies for the Pagsangahan floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Pagsangahan	55	91	0	1	0	**147**

A total of sixty-one (61) 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 Pagsangahan floodplain. This completes the feature extraction phase of the project.

Figure 28 represents the Digital Surface Model (DSM) of the Pagsangahan floodplain, overlaid with its ground features.

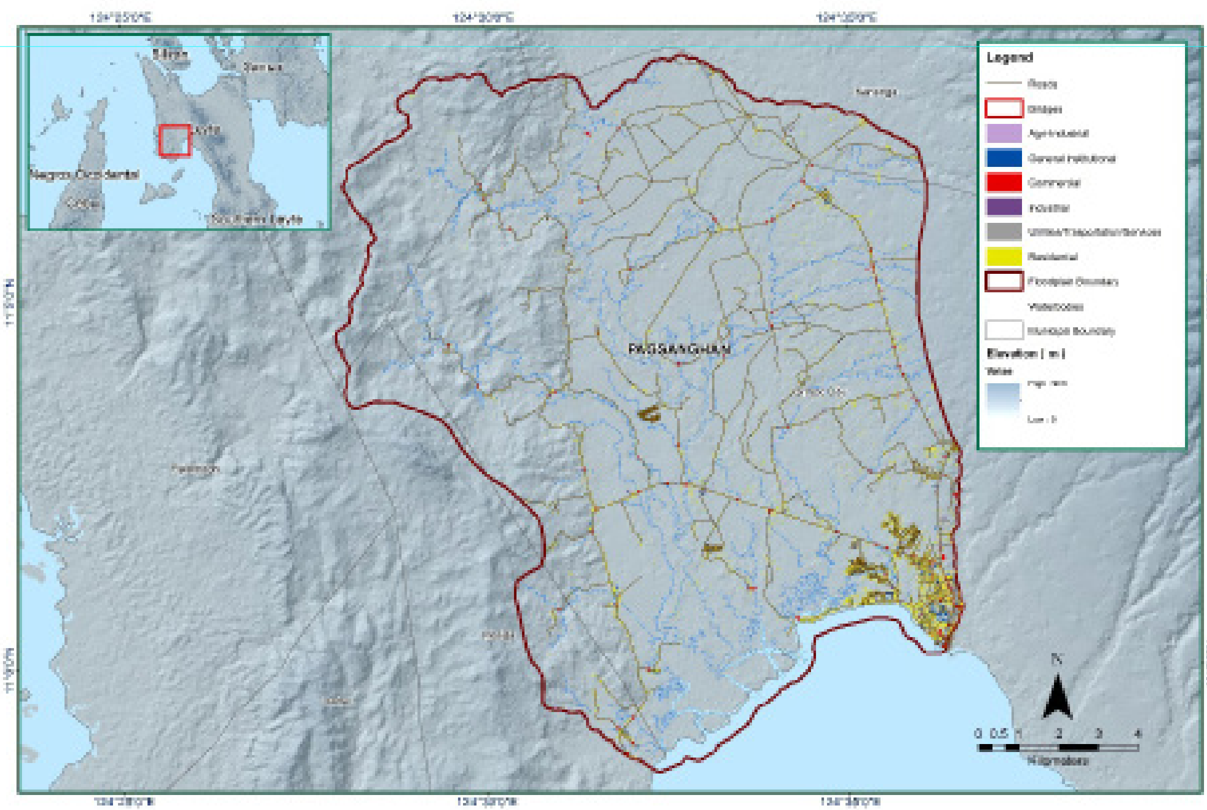


Figure 28. Extracted features for the Pagsangahan floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, and Engr. Dexter T. Lozano

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 field surveys in the Pagsangahan River on January 6-20, 2015, and on September 10-24, 2014, with the following scope of work: (i.) initial reconnaissance; (ii.) control survey for the establishment of a control point; (iii.) bridge as-built cross-section; (iv.) water level marking in MSL of the Pagsangahan Bridge in Ormoc City, Leyte; (v.) Aquarius LiDAR Validation of about 15.4 km; and (vi.) bathymetric survey from Barangay Liloan down to the mouth of the river in Barangay Lao, with an estimated length of 9.45 km., using an OHMEX™ Single Beam Echo Sounder and GNSS PPK survey technique. The extent of the survey is shown by the map in Figure 29.

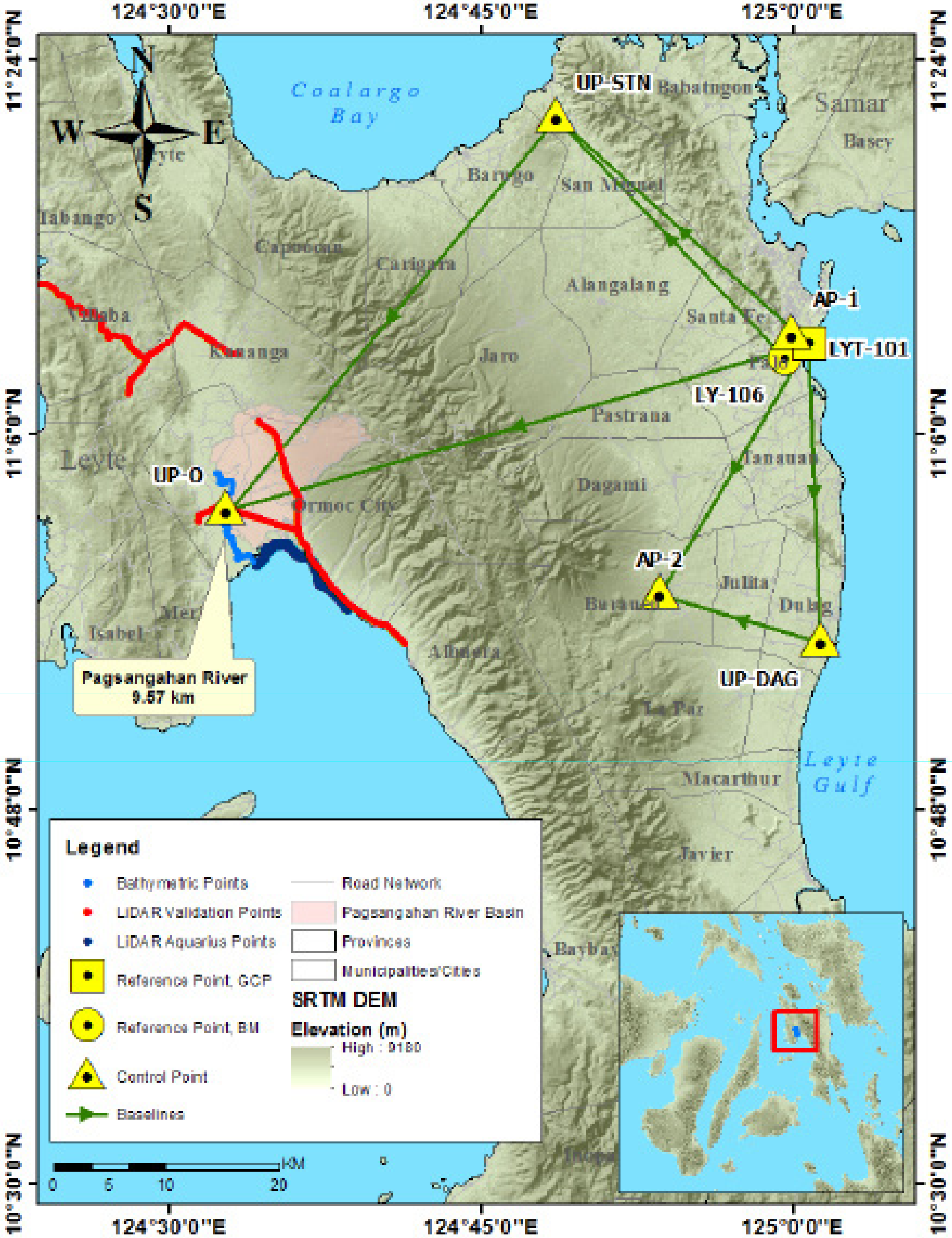


Figure 29. Extent of the bathymetric survey (in blue line) in the Pagsangahan River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Pagsangahan River Basin is composed of three (3) loops established on September 18-20, 2014, occupying the following reference points: (i.) LYT-101, a second-order GCP, located in Barangay Candahog, Municipality of Palo; and (ii.) LY-106, a second-order GCP, located in Barangay Luntad, Municipality of Palo.

Three (3) control points were established at the approach of bridges, namely: (i.) UP-DAG at the Daguitan Bridge in Barangay Fatima, Municipality of Dulag; (ii.) UP-O at the Ormoc Merida Bridge in Barangay Liloan, Ormoc City; and (iii.) UP-STN at the Calay-calay Bridge in Barangay Caraycaray, Municipality of San Miguel. Two (2) arbitrary points were also observed to complete the network, AP1 and AP2. The former is located at the corner of the Maharlika Highway and an unnamed street going to Campetic Road in Barangay Campetik, Municipality of Palo, and the latter is located inside the Burauen Church Plaza on the Julita Burauen Road corner Burauen – Dagami Road, in Barangay Poblacion VII, Municipality of Burauen, Province of Leyte.

The summary of reference and control points and their respective locations is provided in , while the GNSS network established is illustrated in .

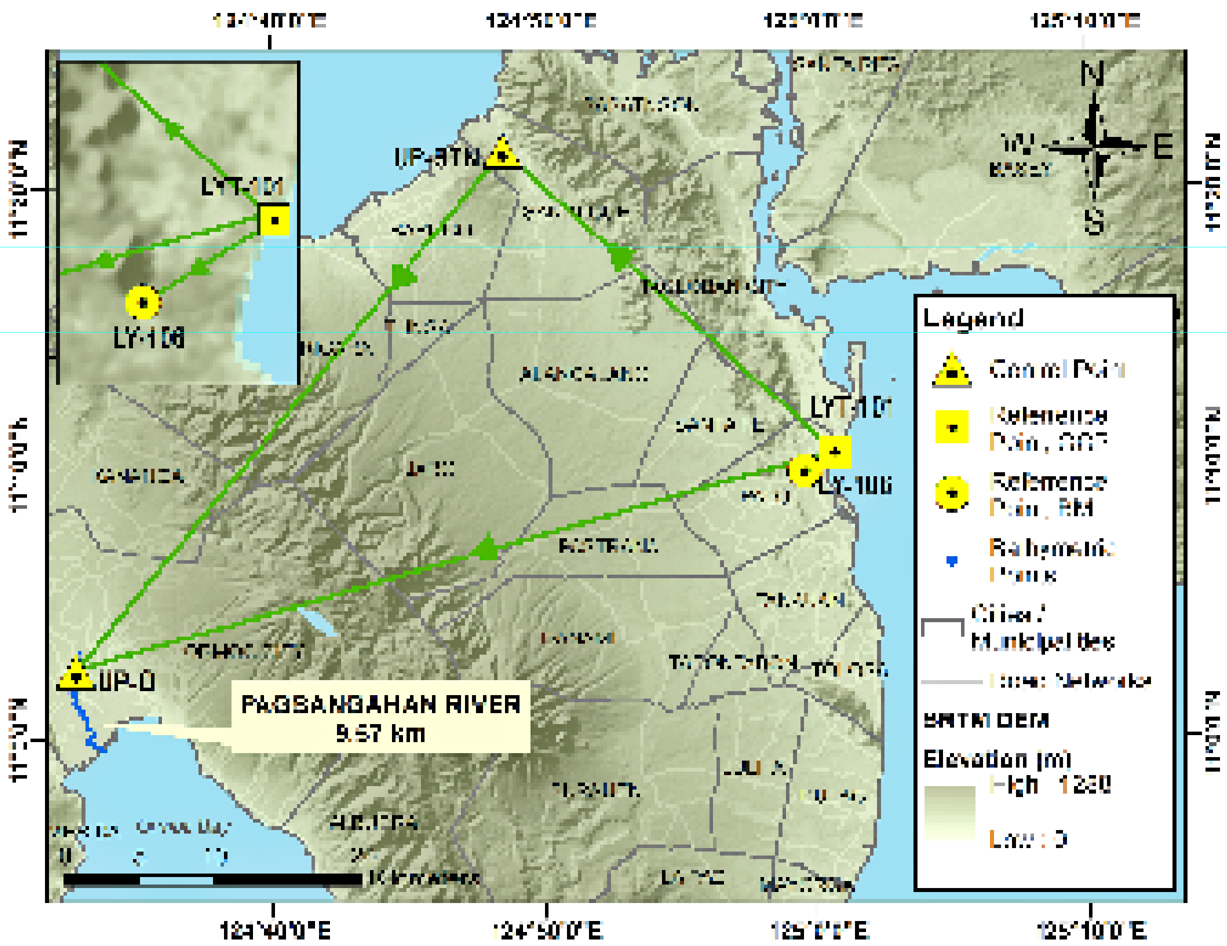


Figure 30. GNSS network for the Pagsangahan River field survey

Table 31. Table 31. List of reference and control points used in the Pagsangahan Survey on January 8, 2015 (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
LYT-101	2nd order, GCP	11°10'19.64869" N	125°00'43.78230" E	69.228	-	09-20-2014
LY-106	1st order, BM	-	-	68.051	4.028	2007
UP-DAG	UP Established	-	-	-	-	09-20-2014
UP-O	UP Established	-	-	-	-	09-19-2014
UP-STN	UP Established	-	-	-	-	09-11-2014
AP1	Arbitrary	-	-	-	-	09-18-2014
AP2	Arbitrary	-	-	-	-	09-20-2014

The GNSS set-ups established in the locations of the reference and control points are exhibited in Figure 31 to 35.

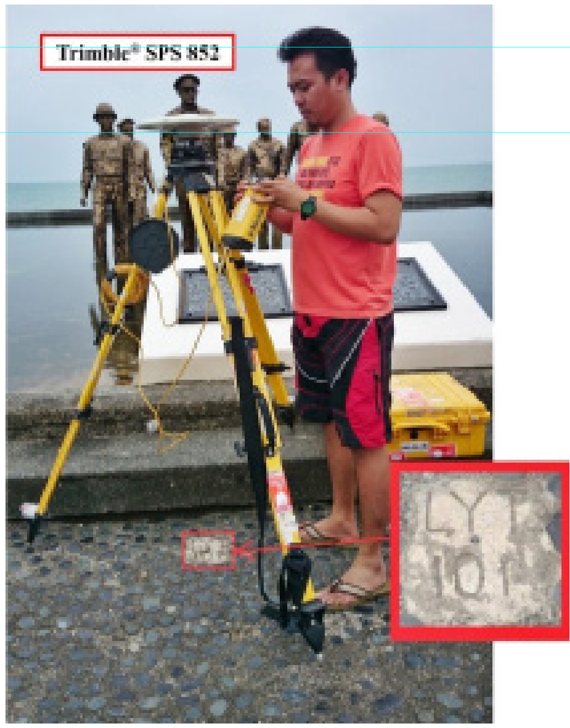


Figure 31. GNSS base set-up, Trimble® SPS 852, at LYT-101, located at the General McArthur Shrine in Barangay. Candahog, Municipality of Palo, Leyte

Figure 32. GNSS base set-up, Trimble® SPS 985, at LY-106, located at the approach of the Bernard Reed Bridge along Maharlika Highway, Barangay Luntad, Municipality of Palo, Leyte

Figure 33. GNSS receiver set-up, Trimble® SPS 985, at UP DAG, an established control point, located at the bridge approach of the Daguitan Bridge along Maharlika Highway in Barangay Fatima, Municipality of Dulag, Leyte

Figure 34. GNSS receiver set-up, Trimble® SPS 985, at UP-O, an established control point, located at the bridge approach of the Ormoc Merida Bridge along Ormoc-Merida-Isabel-Palompon Road in Barangay Liloan, City of Ormoc, Leyte

Figure 35. GNSS base set-up, Trimble® SPS 852, at UP-STN, an established control point, located at the Pagbanganan Bridge approach in Barangay Poblacion Zone 12, City of Baybay, Leyte

4.3 Baseline Processing

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

Table 32. Baseline Processing Report for the Pagsangahan River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
UP-STN --- UP-O (B2)	09-19-2014	Fixed	0.003	0.013	219°39'13”	45132.753
LY-106 --- AP1 (B4)	09-18-2014	Fixed	0.003	0.012	12°44'49"	2489.516
LY-106 --- UP-STN (B11)	09-18-2014	Fixed	0.005	0.042	317°02'38"	29477.609
LYT-101 --- UP-O (B1)	09-19-2014	Fixed	0.005	0.013	254°12'03"	52970.388
LYT-101 ---AP1 (B6)	09-18-2014	Fixed	0.002	0.003	307°32'43"	1903.266
LYT-101 --- UP-STN (B10)	09-18-2014	Fixed	0.005	0.039	312°31'18"	30045.665
LYT-101 --- UP-STN (B3)	09-18-2014	Fixed	0.003	0.011	312°31'18"	30045.649
LYT-101 --- LY-106 (B7)	09-20-2014	Fixed	0.003	0.016	238°21'43"	2417.850
LYT-101 --- LY-106 (B5)	09-20-2014	Fixed	0.002	0.004	238°21'42"	2417.858
LYT-101 --- UPDAG (B13)	09-20-2014	Fixed	0.004	0.011	177°43'46"	26154.013
LYT-101 --- AP2 (B12)	09-20-2014	Fixed	0.003	0.012	210°46'11"	25458.032
UP-DAG --- AP2 (B14)	09-20-2014	Fixed	0.004	0.014	286°51'16"	14691.113

As reflected in a total of twelve (12) baselines were processed, with reference points LYT-101 and LY-106 held fixed for grid values and elevation values, respectively. 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:

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

Where:

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

for each control point. See the Network Adjustment Report shown in [ ] to [ ] for the complete details.

The seven (7) control points – LYT-101, LY-106, UP-DAG, UP-O, UP-STN, and two (2) arbitrary points – were occupied and observed simultaneously to form a GNSS loop. The coordinates of point LYT-101 and the elevation value of LY-106 were held fixed during the processing of the control points, as presented in [ ] .

Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 33. Constraints applied to the adjustments of the control points

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
LYT-101	Local	Fixed	Fixed		
LY-106	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in . The fixed control points, LYT-101 and LY-106, have no values for grid errors and for elevation errors, respectively.

Table 34. Adjusted grid coordinates for the control points used in the Pagsangahan floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LYT-101	1235759.250	?	719729.823	?	5.141	0.040	LL
LY-106	1234476.732	0.007	717679.601	0.006	4.028	?	e
UP-DAG	1209628.100	0.013	720942.270	0.009	5.993	0.077	e
UP-O	1220991.402	0.014	668855.819	0.010	8.719	0.076	
UP-STN	1255916.567	0.009	697443.625	0.007	8.835	0.070	
AP1	1236908.994	0.007	718212.616	0.007	4.834	0.051	
AP2	1213793.946	0.012	706851.618	0.010	56.317	0.079	

The network is was fixed at reference points LYT-101 with known coordinates, and LY-106 with known elevation. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2} < 20\ cm$ for horizontal accuracy and $z_e < 10\ cm$ for the vertical accuracy,; the computations for the accuracy are as follows:

a. LYT-101

Horizontal Accuracy = Fixed
Vertical Accuracy = 4.0 cm < 10 cm

b. LY-106

Horizontal Accuracy = $\sqrt{((1.30)^2 + (0.6^2)}$
= $\sqrt{(0.49 + 0.36)}$
= 0.92 cm < 20 cm
Vertical Accuracy = Fixed

c. UP-DAG

Horizontal Accuracy = $\sqrt{((1.3)^2 + (0.90)^2)}$
= $\sqrt{(1.69 + 0.81)}$
= 1.58 cm < 20 cm
Vertical Accuracy = 7.70 cm < 10 cm

d. UP-O

Horizontal Accuracy = $\sqrt{((1.40)^2 + (1.10)^2)}$
= $\sqrt{(1.96 + 1.21)}$
= 1.78 cm < 20 cm
Vertical Accuracy = 7.60 cm < 10 cm

e. UP-STN

Horizontal Accuracy = $\sqrt{((0.90)^2 + (0.70)^2}$
= $\sqrt{(0.81 + 0.49)}$
= 1.14 cm < 20 cm
Vertical Accuracy = 7.0 cm < 10 cm

f. AP1

Horizontal Accuracy = $\sqrt{((0.70)^2 + (0.70)^2}$
= $\sqrt{(0.49 + 0.49)}$
= 0.98 cm < 20 cm
Vertical Accuracy = 5.10 cm < 10 cm

g. AP2

Horizontal Accuracy = $\sqrt{((1.20)^2 + (1.0)^2}$
= $\sqrt{(1.44 + 1.0)}$
= 1.56 cm < 20 cm
Vertical Accuracy = 7.9 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two (2) occupied control points are within the required precision.

Table 35. Table 35. Adjusted geodetic coordinates for control points used in the Pagsangahan River floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
LY-106	N11°09'38.36982"	E124°59'35.93684"	68.051	?	e
UP-DAG	N10°56'09.12671"	E125°01'17.90763"	70.609	0.077	
UP-O	N11°02'28.97646"	E124°32'44.58922"	71.626	0.076	
UP-STN	N11°21'20.28504"	E124°48'33.44650"	71.793	0.070	
AP1	N11°10'57.39411"	E124°59'54.04241"	68.821	0.051	
AP2	N10°58'27.65859"	E124°53'34.80074"	120.385	0.079	

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

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

Table 36. Reference and control points used in the Pagsangahan 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	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LYT-101	2nd Order, GCP	11°10'19.64869"	125°00'43.78230"	69.228	1235759.250	719729.823	5.141
LY-106	1st order, BM	11°09'38.36982"	124°59'35.93684"	68.051	1234476.732	717679.601	4.028
UP-DAG	UP Established	10°56'09.12671"	125°01'17.90763"	70.609	1209628.100	720942.270	5.993
UP-O	UP Established	11°02'28.97646"	124°32'44.58922"	71.626	1220991.402	668855.819	8.719
UP-STN	UP Established	11°21'20.28504"	124°48'33.44650"	71.793	1255916.567	697443.625	8.835
AP1	Arbitrary Point	11°10'57.39411"	124°59'54.04241"	68.821	1236908.994	718212.616	4.834
AP2	Arbitrary Point	10°58'27.65859"	124°53'34.80074"	120.385	1213793.946	706851.618	56.317

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

The cross-section and bridge as-built surveys were performed on September 17, 2014 along the upstream side of the Ormoc-Merida (Pagsangahan) Bridge in Ormoc City, Leyte. The survey was conducted with the application of PPK technique using a survey-grade GPS, Trimble® SPS 882, as exhibited in .

Figure 36. (a) Acquisition of water surface elevation (b) cross Section survey using Trimble® SPS 882 at Pagsangahan Bridge in City of Ormoc and (c) water level marking of bridge pier for Pagsangahan River

The length of the cross-sectional line surveyed in the Pagsangahan Bridge is about 150 meters with a total of twenty-six (26) points acquired, using UP-O as the GNSS base station. The location map, cross-section diagram, and bridge as-built form are presented in to .

The water surface elevation in MSL of the Pagsangahan River was determined using Trimble® SPS 882 in PPK mode technique on September 17, 2014 at 17:15 hrs., with a value of 1.21 m in MSL (see). This was translated into markings on one of the bridge's piers using digital levels, which were used by the VSU PHIL-LiDAR 1 Team as their reference for flow data gathering and depth gauge deployment for the Pagsangahan River (Figure 36).

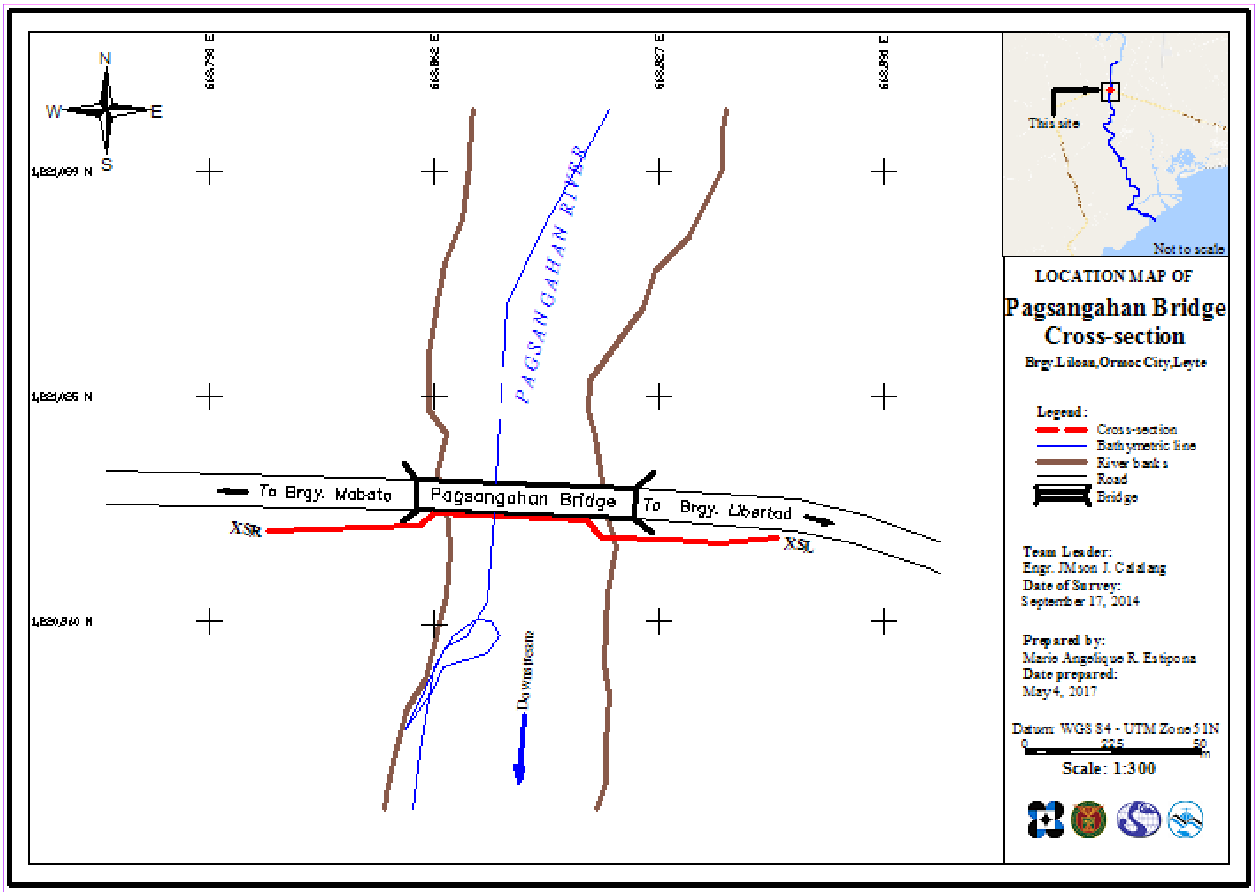


Figure 37. Pagsangahan Bridge cross-section location map

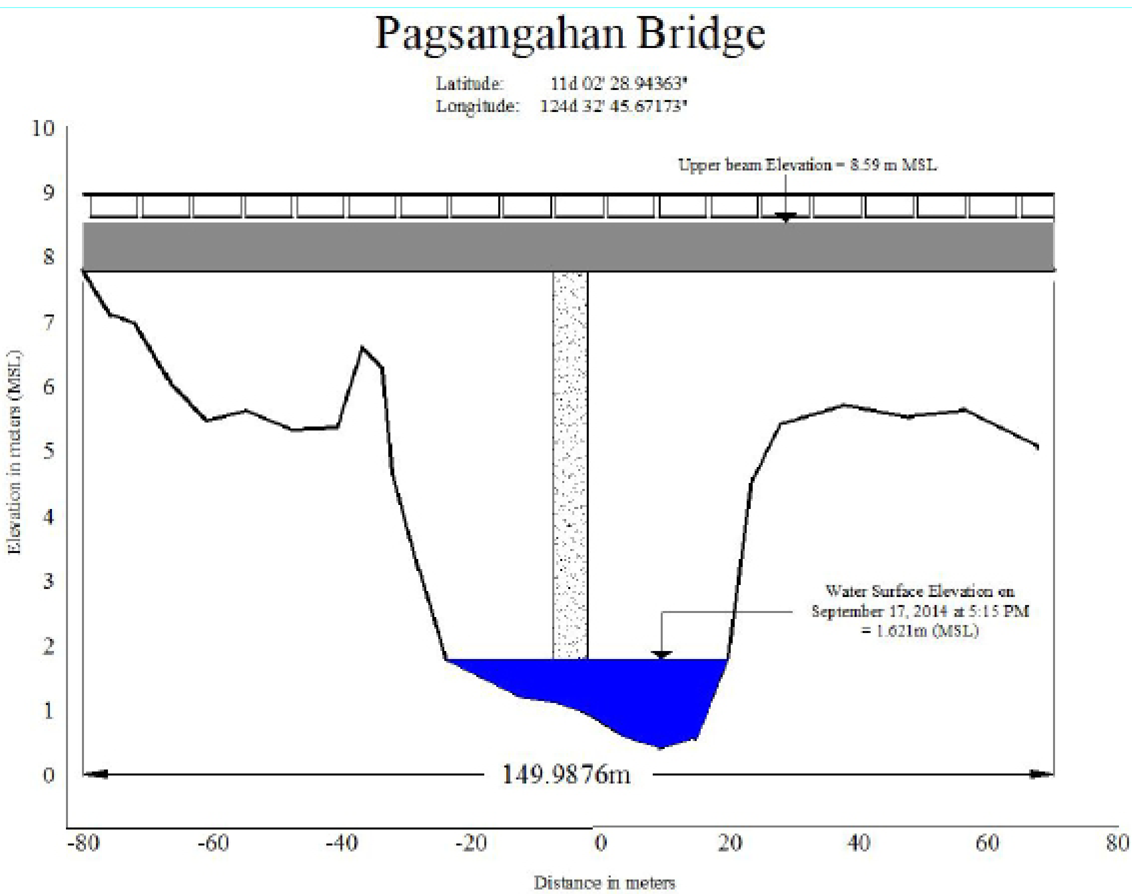


Figure 38. Pagsangahan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Pagsangahan Bridge **Date:** September 17, 2014

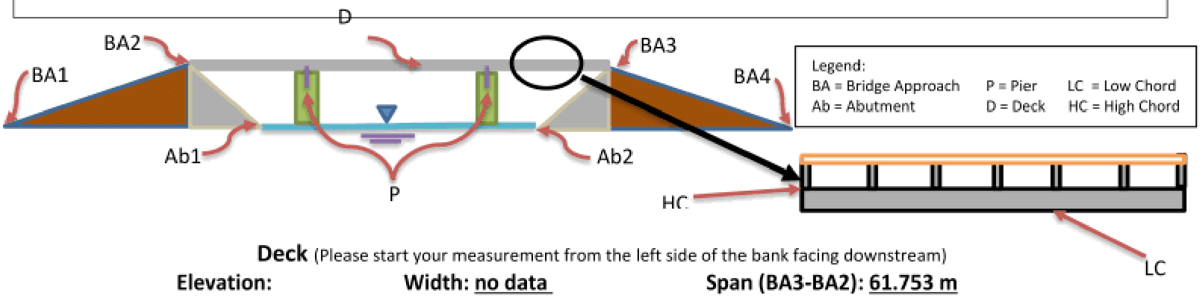
River Name: PAGSANGAHAN RIVER **Time:** 5:15 pm

Location (Brgy, City, Region): Ormoc, Leyte

Survey Team: Team JMson Calalang

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

Latitude: 11°02'28.94363"N **Longitude:** 124°32'45.67173" E



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

Elevation: **Width:** no data **Span (BA3-BA2):** 61.753 m

	Station	High Chord Elevation	Low Chord Elevation
1	9.568	8.350	7.15
2	26.054	8.333	7.133
3	40.982	8.388	7.188
4	53.801	8.338	7.138
5	72.378	8.288	7.088

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	8.12	BA3	72.37	8.49
BA2	9.568	8.35	BA4	81.297	8.29

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

	Station (Distance from BA1)	Elevation
Ab1	15.430	5.08
Ab2	72.378	4.87

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

Shape: Rectangular **Number of Piers:** one (1) **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	40.982	1.891	1.270

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

Figure 39. Pagsangahan Bridge as-built survey data form

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 23, 2014. As depicted in , a Trimble® SPS 882 was attached to the side of a vehicle to measure points, utilizing Continuous Topography Method in PPK Survey Technique. The height of the instrument was measured and noted at 2.404 meters, measured from the ground up to the bottom of the notch. Points were gathered along major concrete roads with the aid of a vehicle that moved at a speed of 20-40 kilometers per hour, cutting across the flight strips of the DAC, with the aid of available topographic maps and Google EarthTM images.

The ground validation started in the Municipality of Villaba, traversing the major roads of Matag-ob and Kananga, and ended in the City of Ormoc. The established control point UP-O was used as the base station all throughout the conduct of the survey.

Figure 40. Ground validation se-up: a Trimble® SPS 882, mounted on a 2-meter pole and attached on the side of the vehicle

The map in illustrates the extent of the ground validation survey, which acquired 6,872 ground validation points, with an approximate length of 34.9 km. using the base station UP-O.

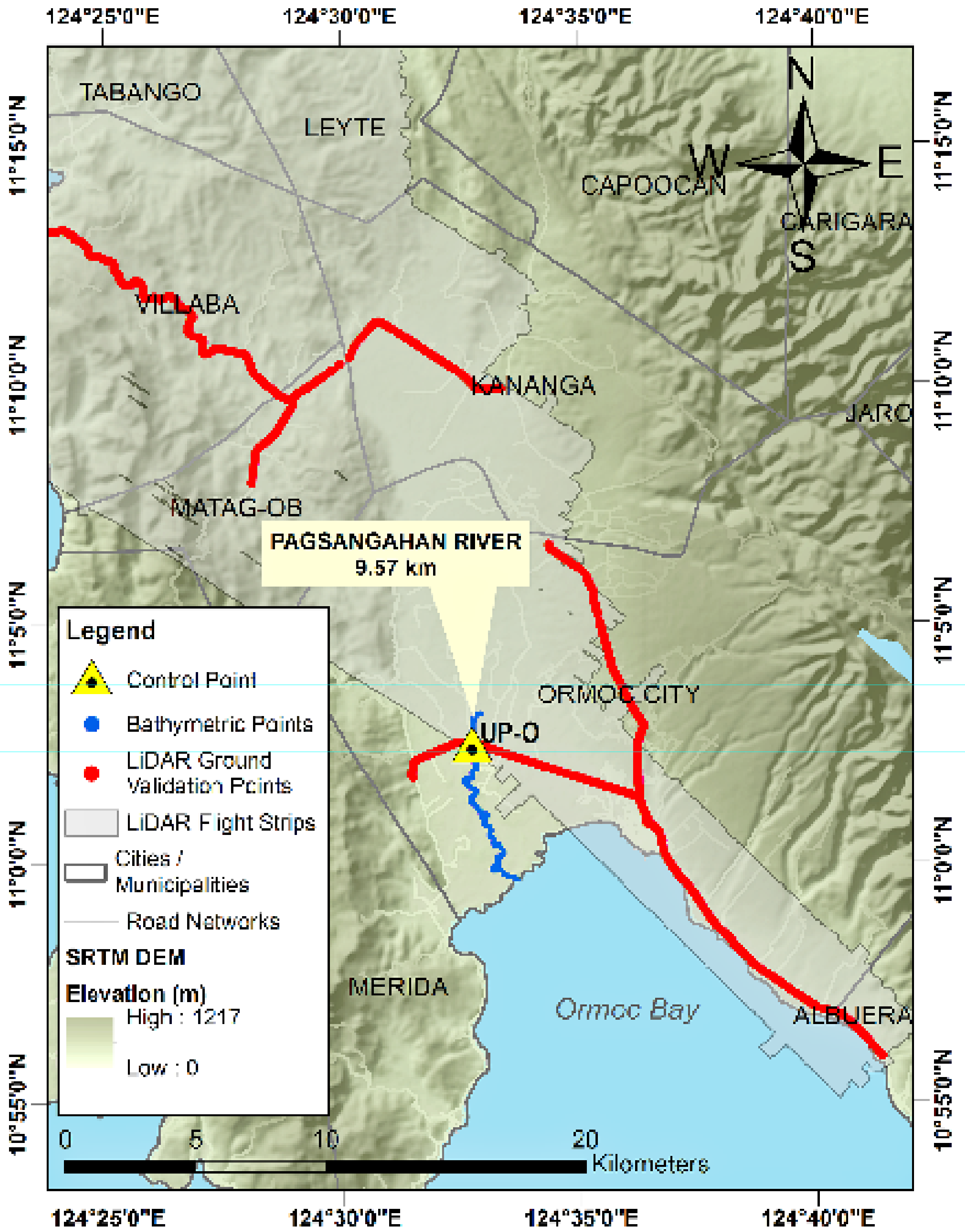


Figure 41. Extent of the LiDAR ground validation survey of the Pagsangahan River

Figure 42. Acquisition of validation points for the Aquarius LiDAR system in the Ormoc Bay

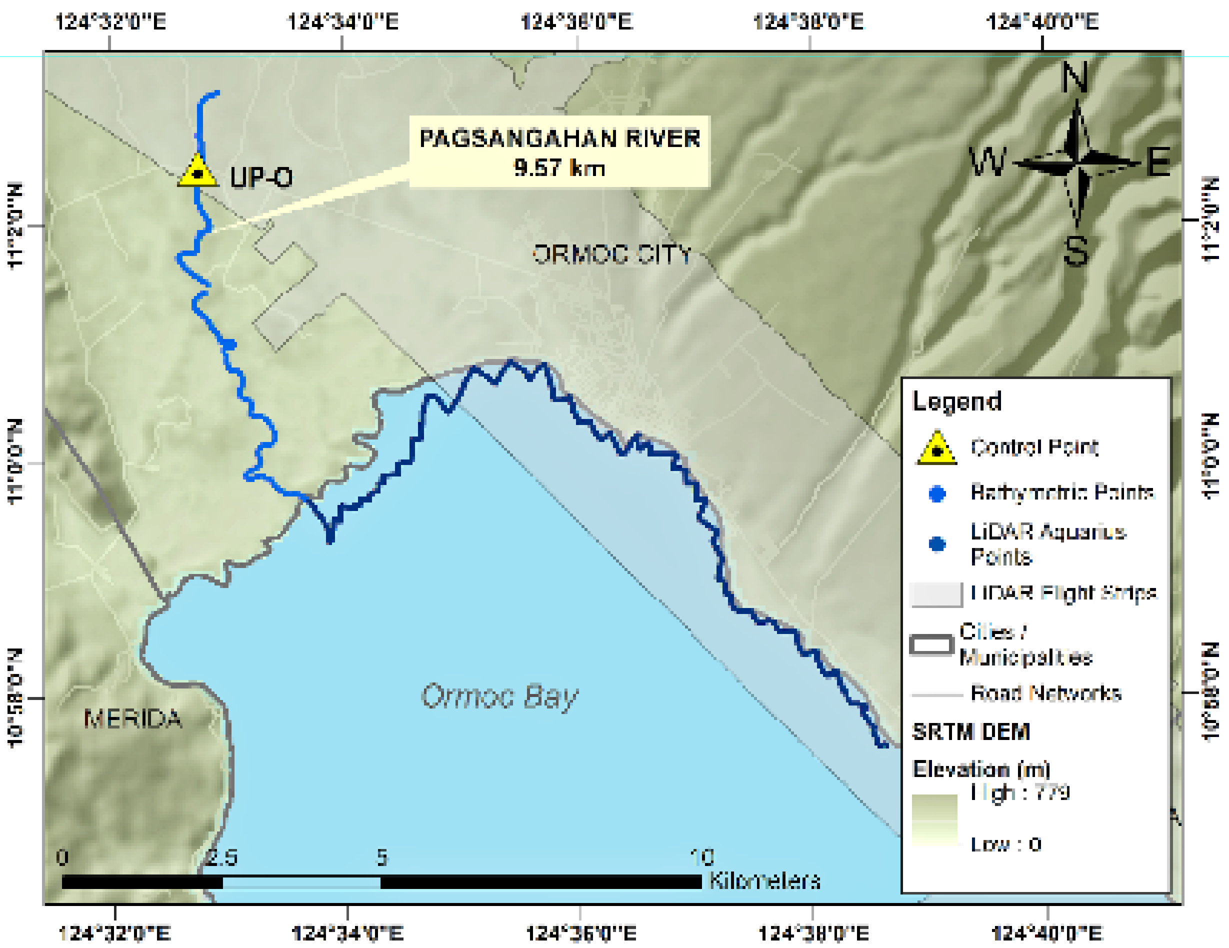


Figure 43. Extent of the Aquarius validation points acquisition survey in the Pagsangahan River Basin

In addition to the ground validation survey, an Aquarius LiDAR validation was also conducted along the coast of Ormoc City (Figure 42). The total length for the Aquarius LiDAR validation survey is 18.50 km., with a total of 8,652 points. The map in illustrates the results of the Aquarius LiDAR validation.

4.7 Bathymetric Survey

A manual bathymetric survey was conducted on January 15, 2014 in the Pagsangahan River using a boat with an installed Hi-Target™ Single Beam Echo Sounder and a mounted Trimble® SPS 882 GNSS receiver in GNSS PPK survey technique, as demonstrated in . The survey began in the upstream side of the river in Barangay Liloan, Ormoc City, Leyte, with coordinates 11˚03'07.50056" 124˚32'55.32941"; and ended at the mouth of the river in Barangay Lao, Ormoc City, with coordinates 10˚59'34.20739" 124˚33'45.04847". The map in exhibits the extent of the conducted bathymetric survey.

Figure 44. Bathymetry set-up using Ohmex™ Single Beam Echo Sounder with Trimble® SPS 882

The bathymetric line of the Pagsangahan River had an estimated length of 9.57 km., gathering a total of 4,386 points acquired using UP-O as the GNSS base station. A CAD drawing was also produced to illustrate the Pagsangahan riverbed profile, presented in . The profile shows that there is no abrupt change in elevation on the riverbed, mainly because the area is on lowland. The highest elevation observed was 1.28 meters in MSL in the upstream part of the river; while the lowest elevation observed was -7.72 meters below MSL in Barangay Lao, near the mouth of the river.

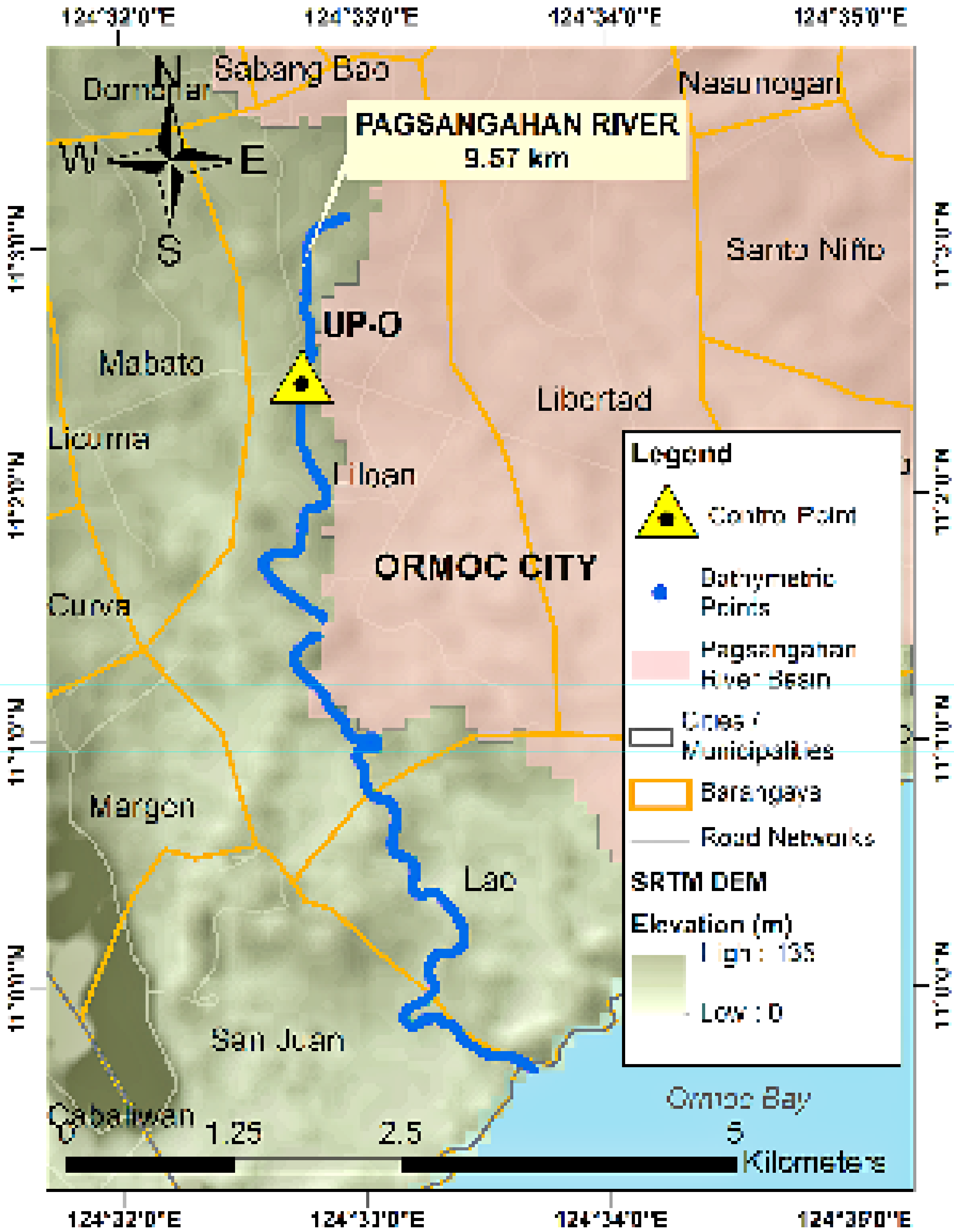


Figure 45. Extent of the bathymetric survey of the Pagsangahan River

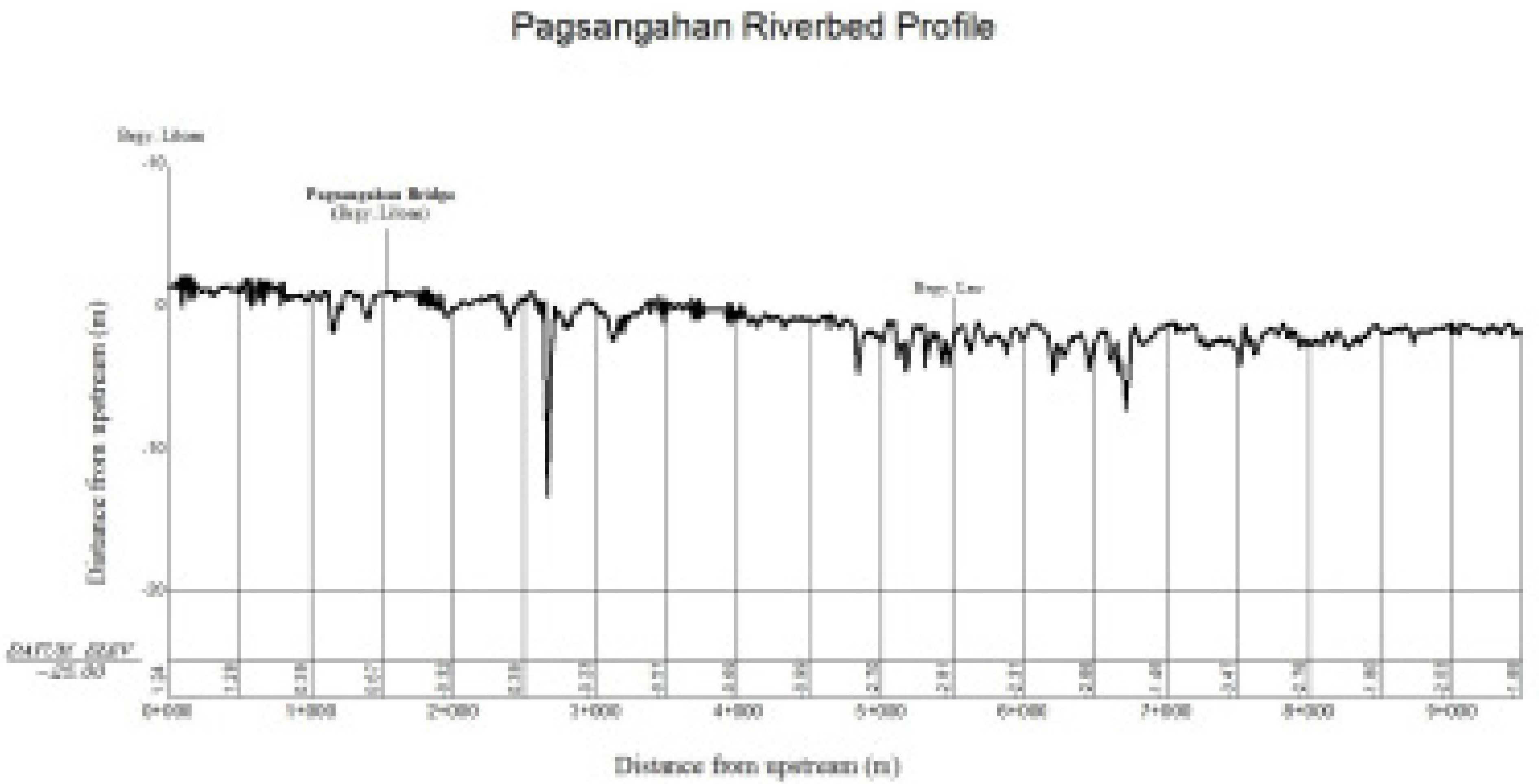


Figure 46. Riverbed profile of the Pagsangahan River

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 Pagsangahan River Basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from the automatic rain gauge (ARG) installed by the Flood Modeling Component (FMC) at Barangay Libungao, Kananga, Leyte. The location of the rain gauge is seen in Figure 47.

Total rain from the Libungao rain gauge was 52.4 mm. It peaked at 10.8 mm on 29 July 2016 at 4:20 hours. The lag time between the peak rainfall and discharge was five (5) hours and fifty (50) minutes.

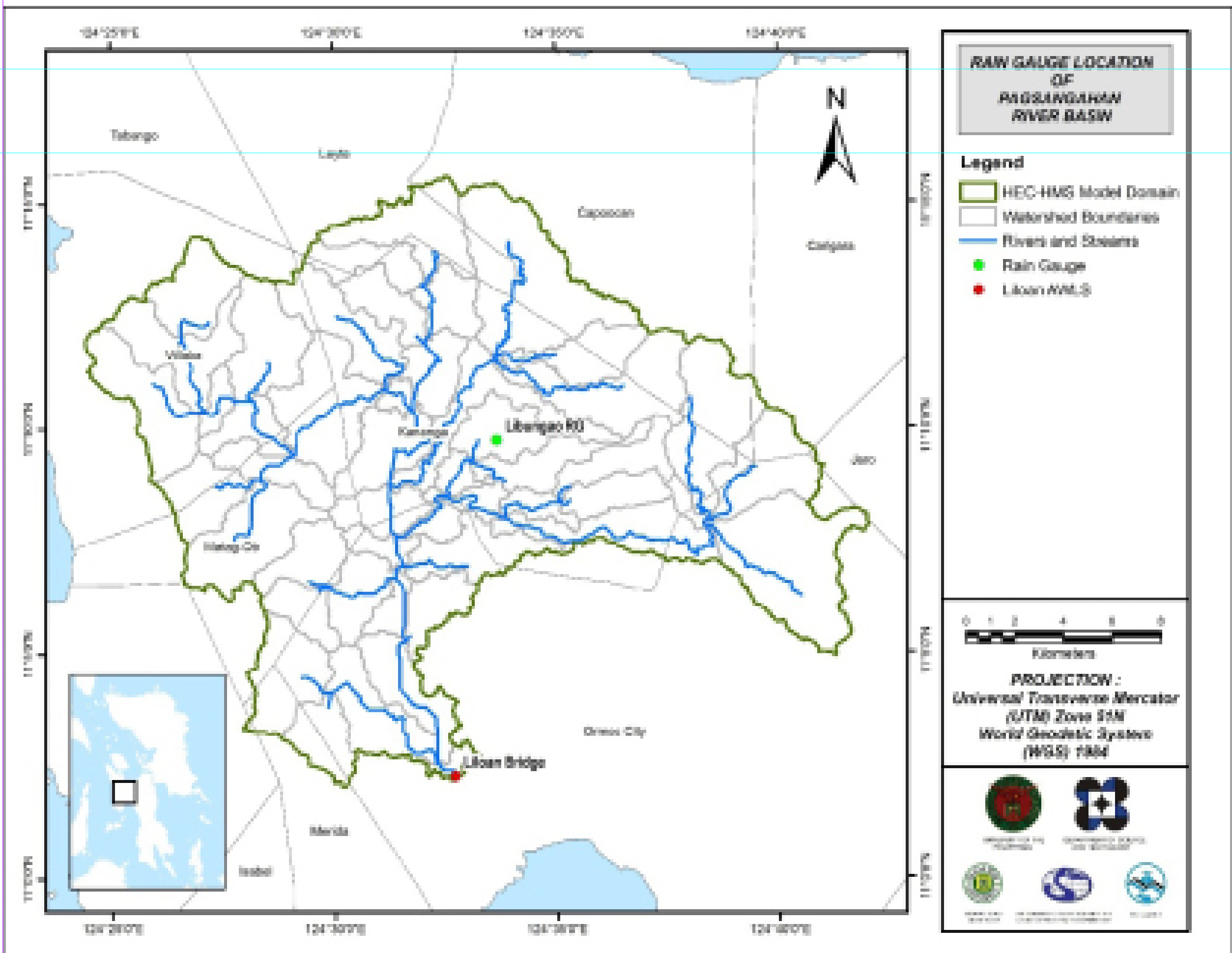


Figure 47. Location map of the Pagsangahan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48) at the Liloan Bridge, Barangay Liloan, Ormoc City, Leyte, to establish the relationship between the observed water levels (H) at the Liloan Bridge and the outflow (Q) of the watershed at this location.

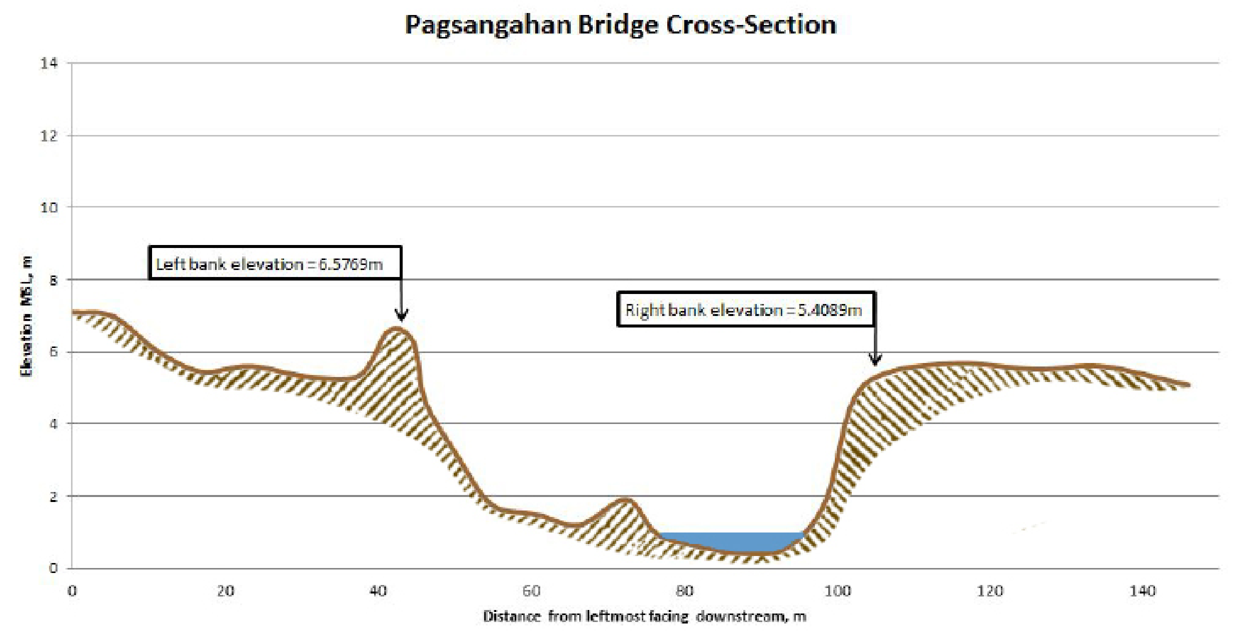


Figure 48. Cross-Section Plot of Liloan Bridge

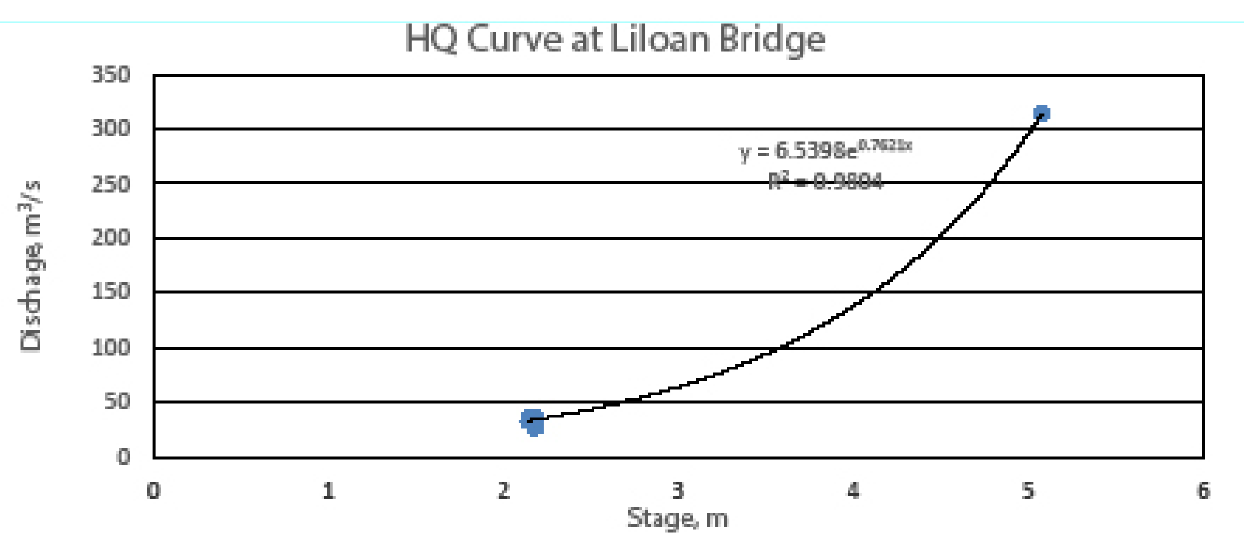


Figure 49. Rating curve at the Liloan Bridge, Barangay Bago, Bato, Leyte

This rating curve equation was used to compute for the river outflow at the Liloan Bridge, for the calibration of the HEC-HMS model. Peak discharge was at 58.7 cu.m/s on July 30, 2016 11:30 hrs.

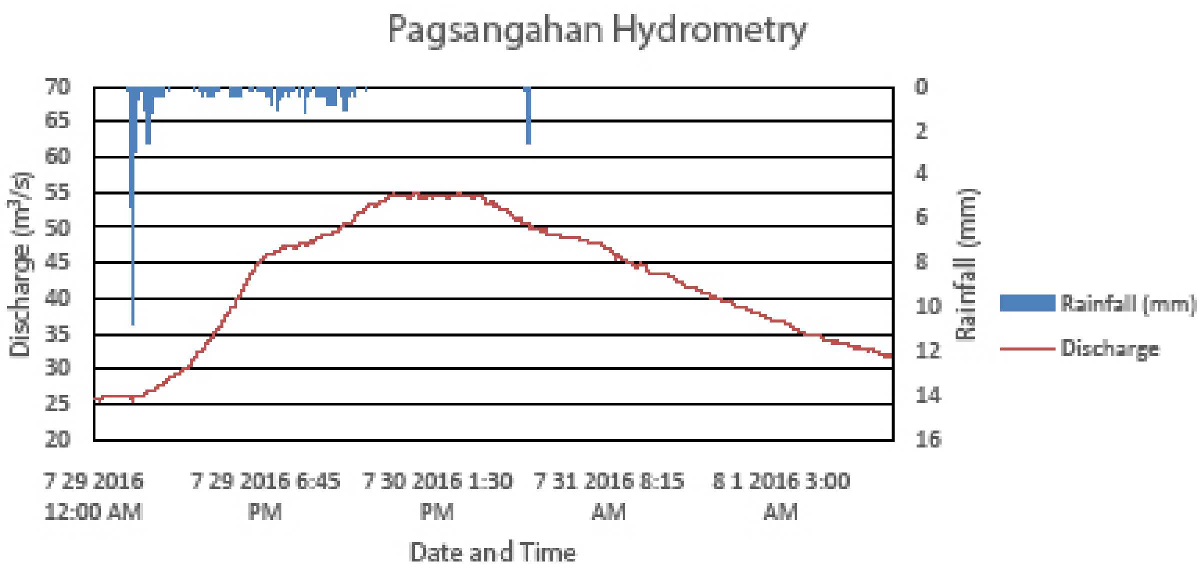


Figure 50. Rainfall and outflow data at Pagsangahan used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Tacloban Rain Gauge (Table 37). This station chosen based on its proximity to the Pagsangahan watershed (Figure 51). 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. The extreme values for this watershed were computed based on a 59-year record.

Table 37. 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

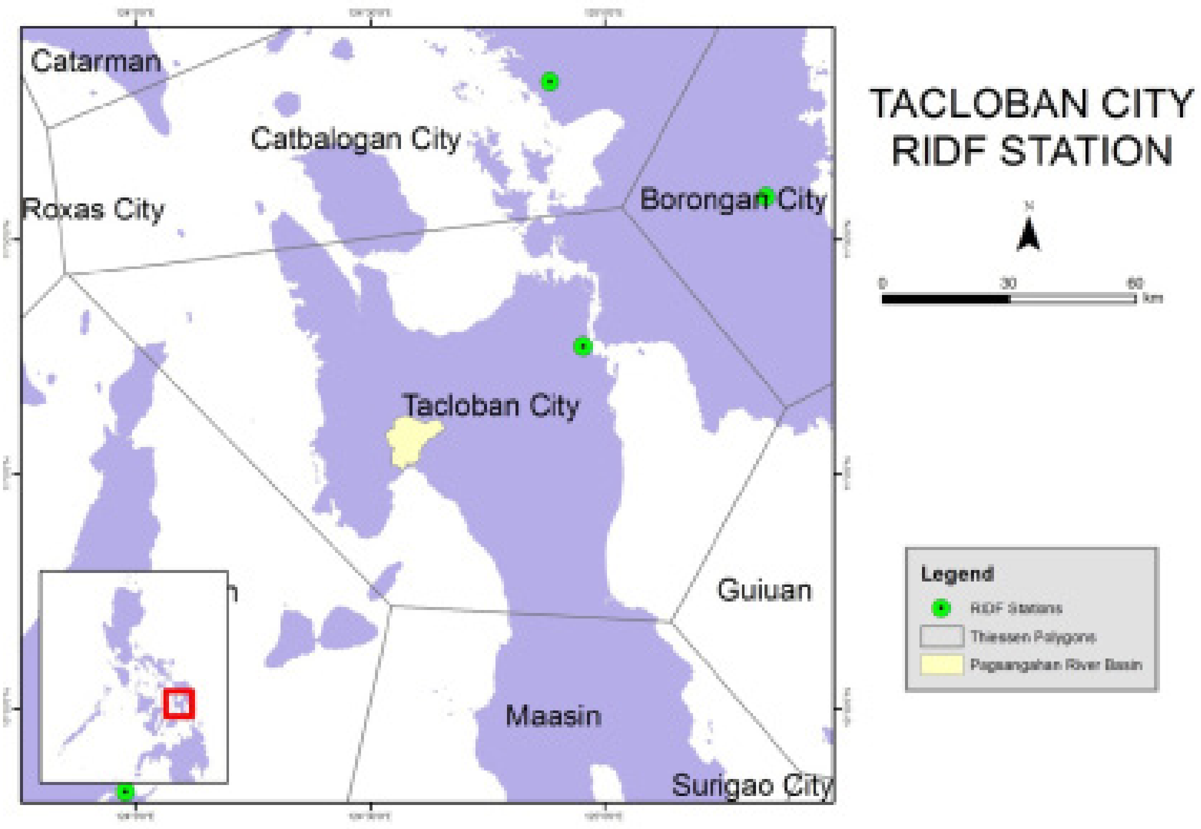


Figure 51. Location of the Tacloban RIDF Station relative to the Pagsangahan River Basin

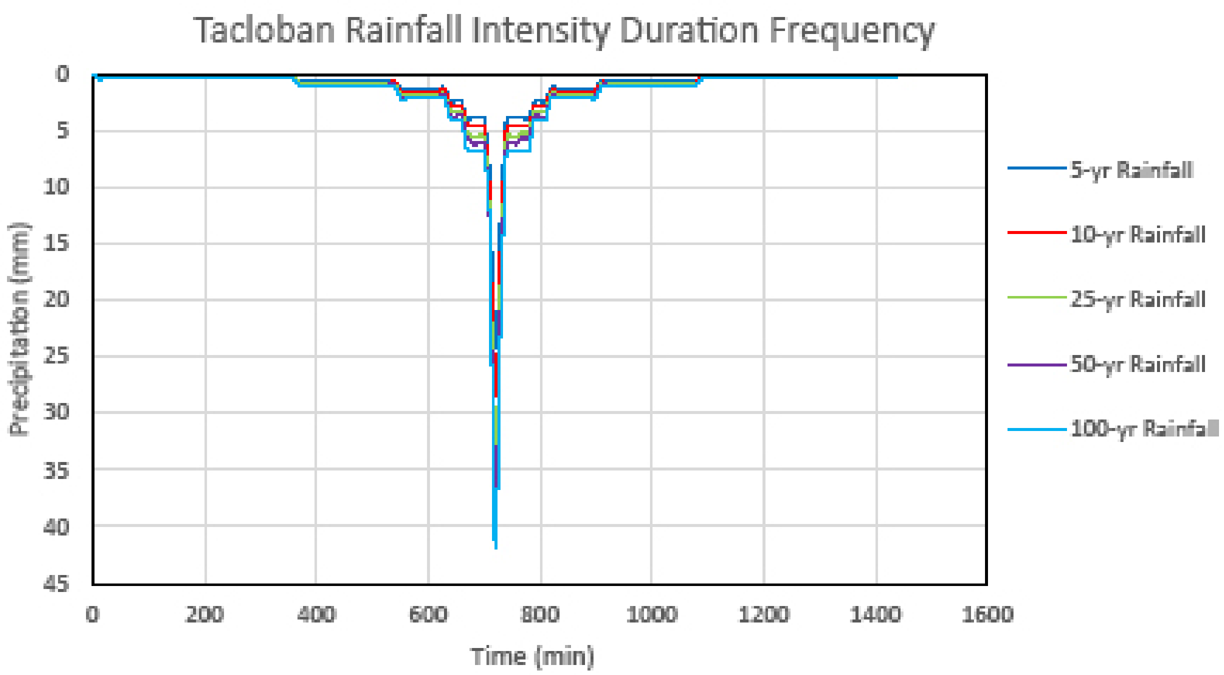


Figure 52. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were obtained before 2004. The soil and land cover maps of the Pagsangahan River Basin are presented in Figures 53 and 54, respectively.

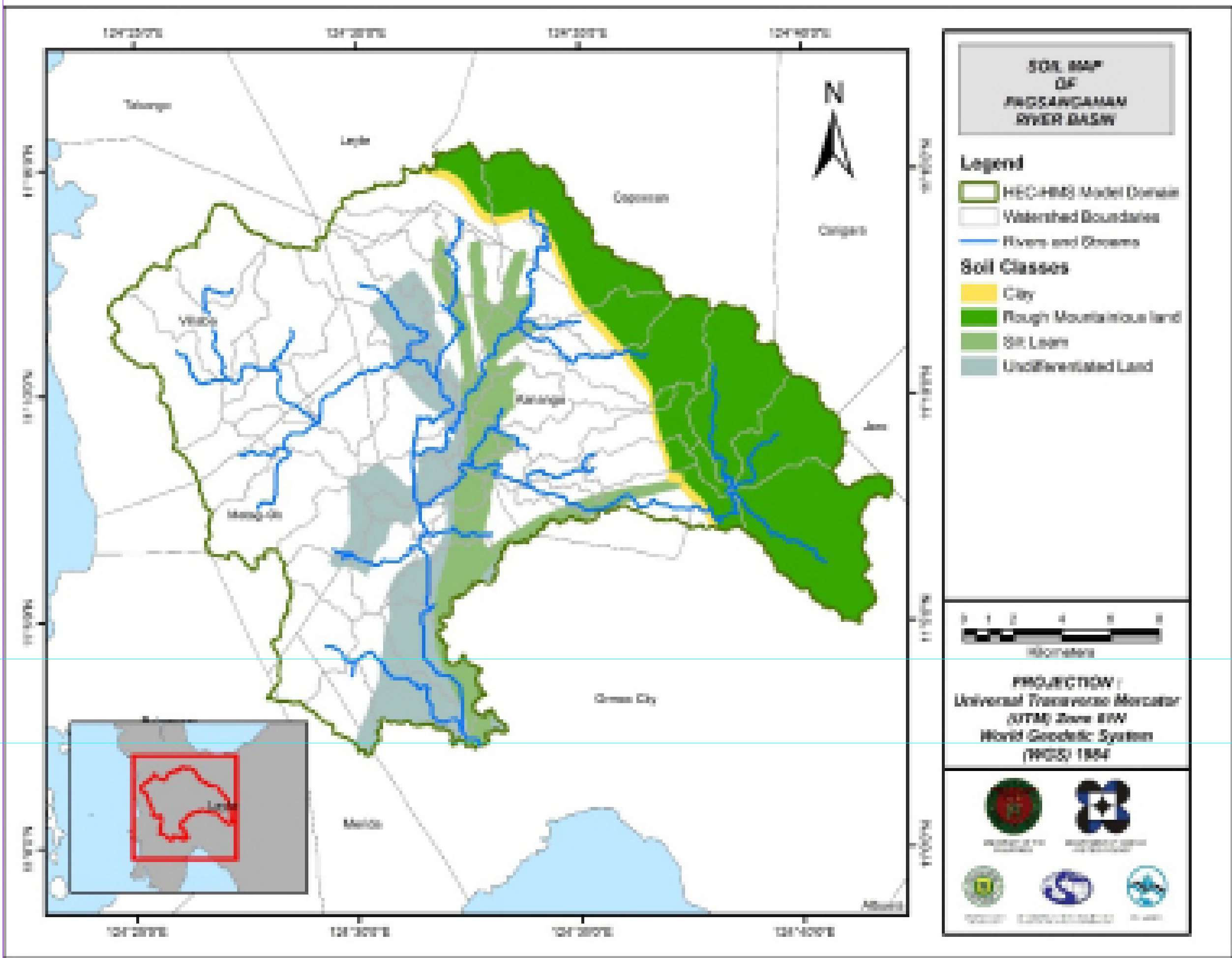


Figure 53. Soil map of the Pagsangahan River Basin (Source: DA)

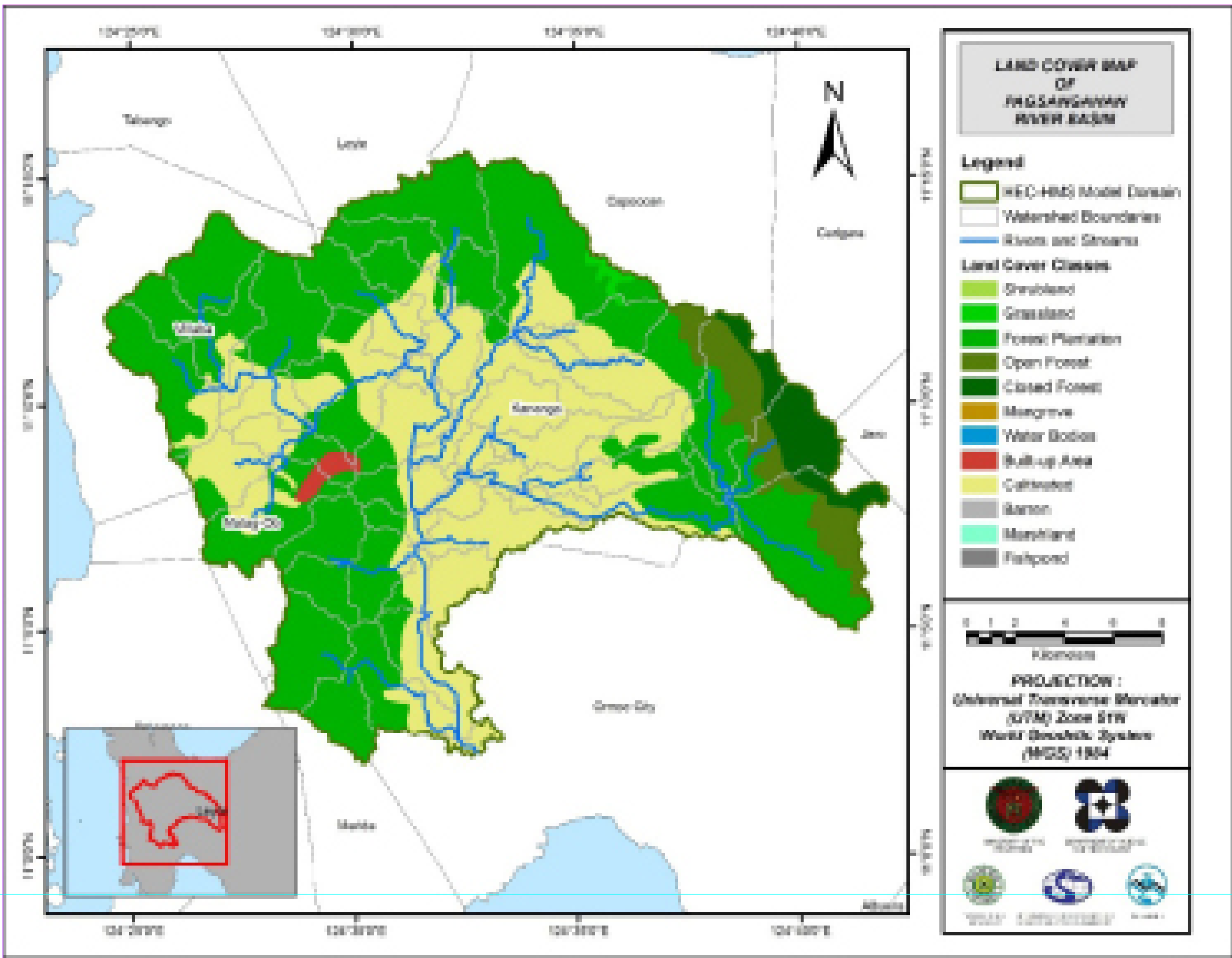


Figure 54. Land cover map of the Pagsangahan River Basin (Source: NAMRIA)

For the Pagsangahan River Basin, the soil classes identified were clay, rough mountainous land, silt loam, and undifferentiated land. The land cover types identified were grasslands, forest plantations, open forests, closed forests, built-up areas, and cultivated land.

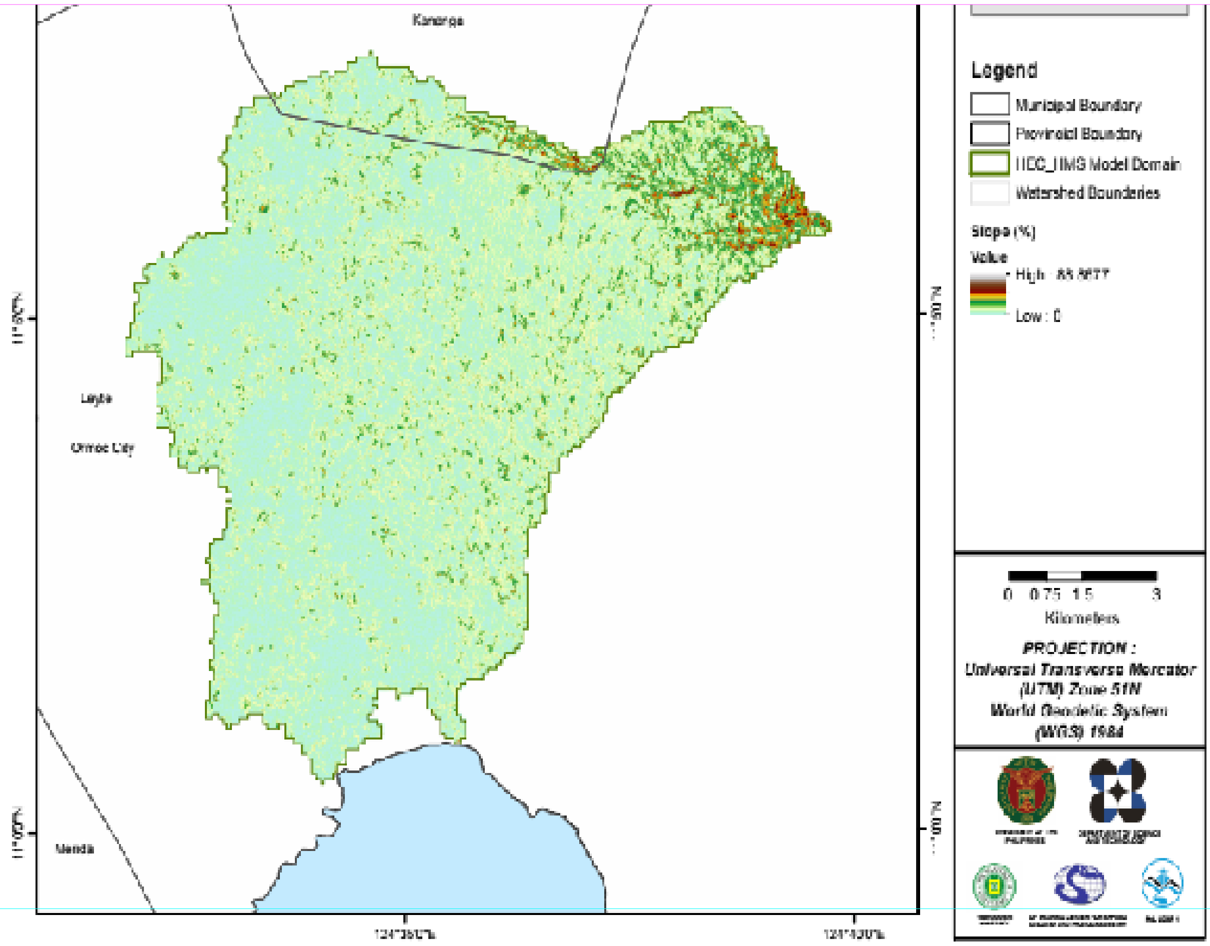


Figure 55. Slope map of the Pagsangahan River Basin

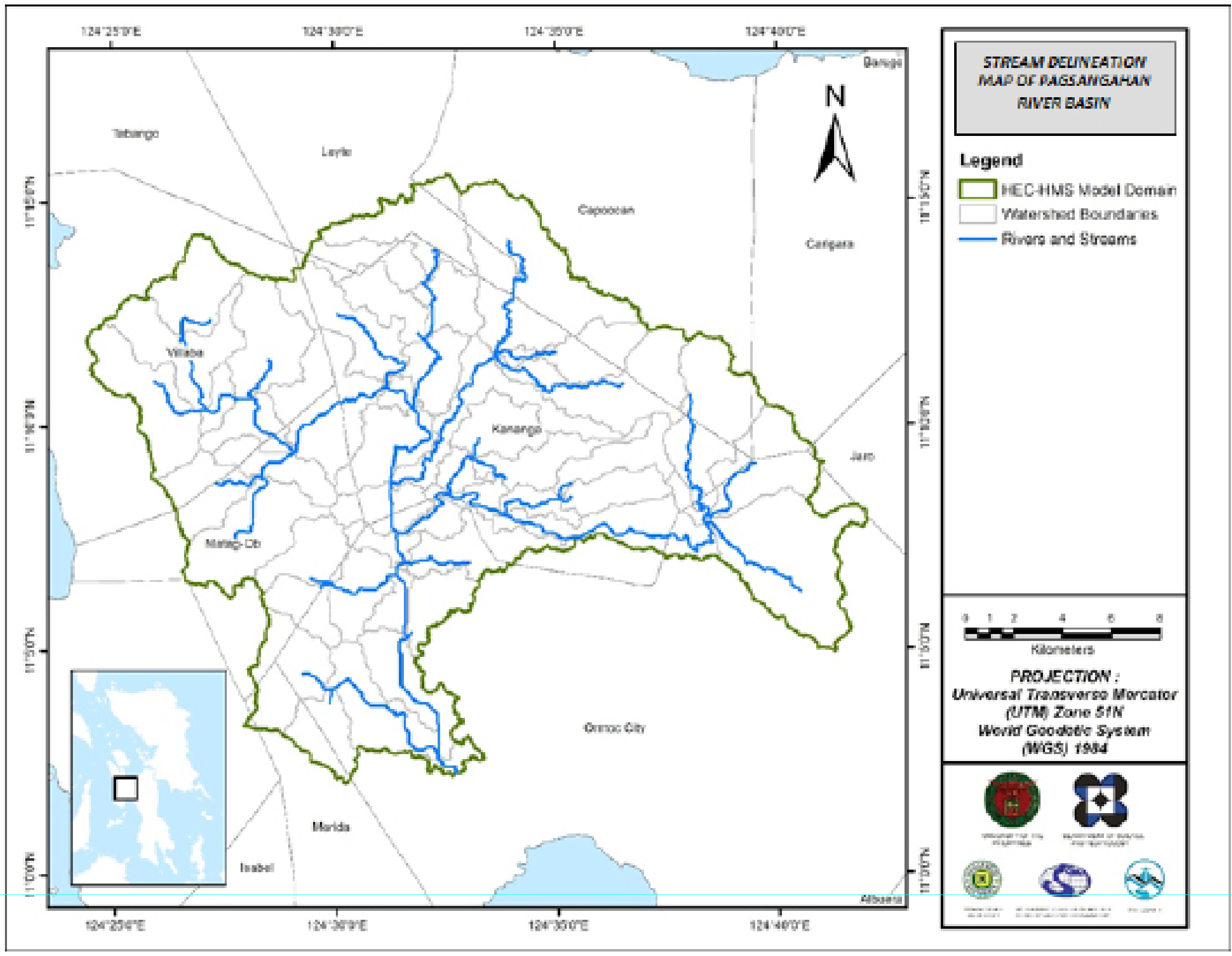


Figure 56. Stream delineation map of the Pagsangahan River Basin

Using the SAR-based DEM, the Pagsangahan basin was delineated and further subdivided into sub-basins. The model consists of fifty-one (51) sub-basins, twenty-five (25) reaches, and fifty-five (55) junctions. The main outlet is at the Liloan Bridge. See ANNEX 10 for the Pagsangahan Model Reach Parameters

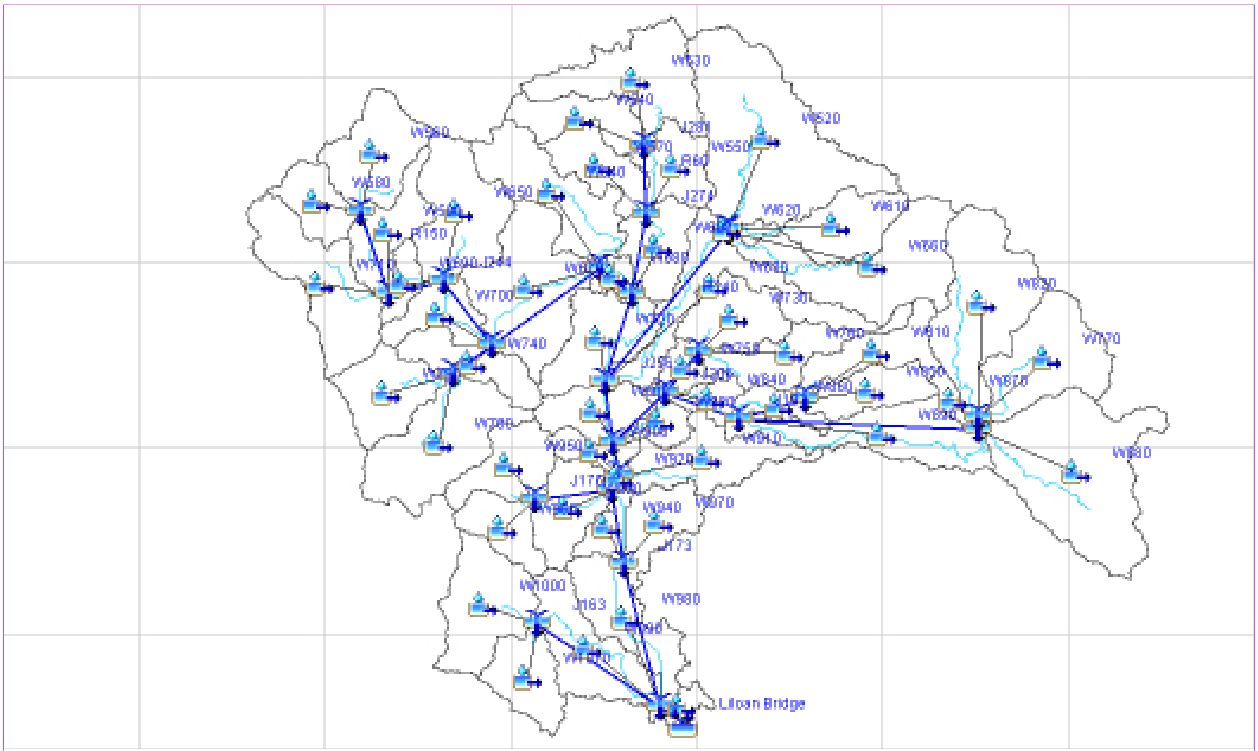


Figure 57. The Pagsangahan River Basin model, generated using HEC-HMS

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 were derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 58).

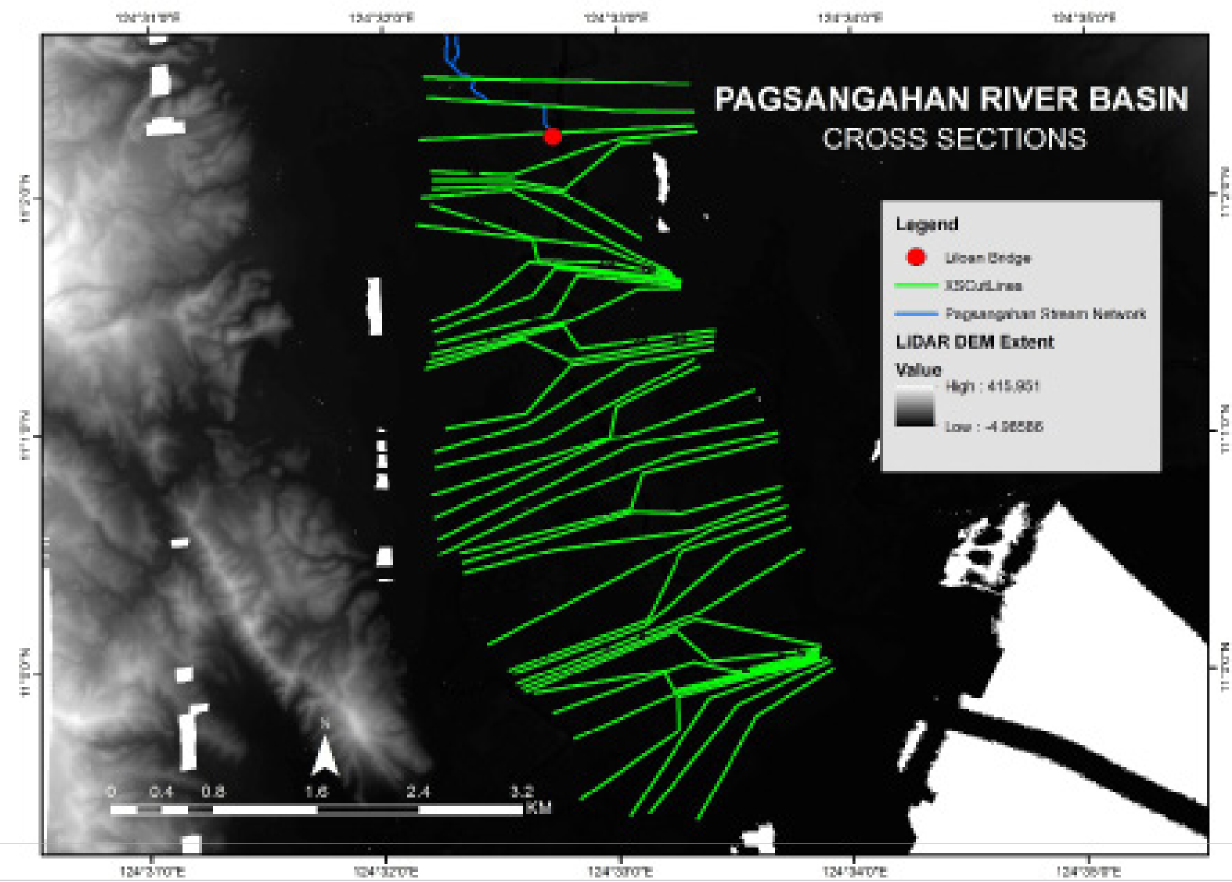


Figure 58. River cross-section of the Pagsangahan River, generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

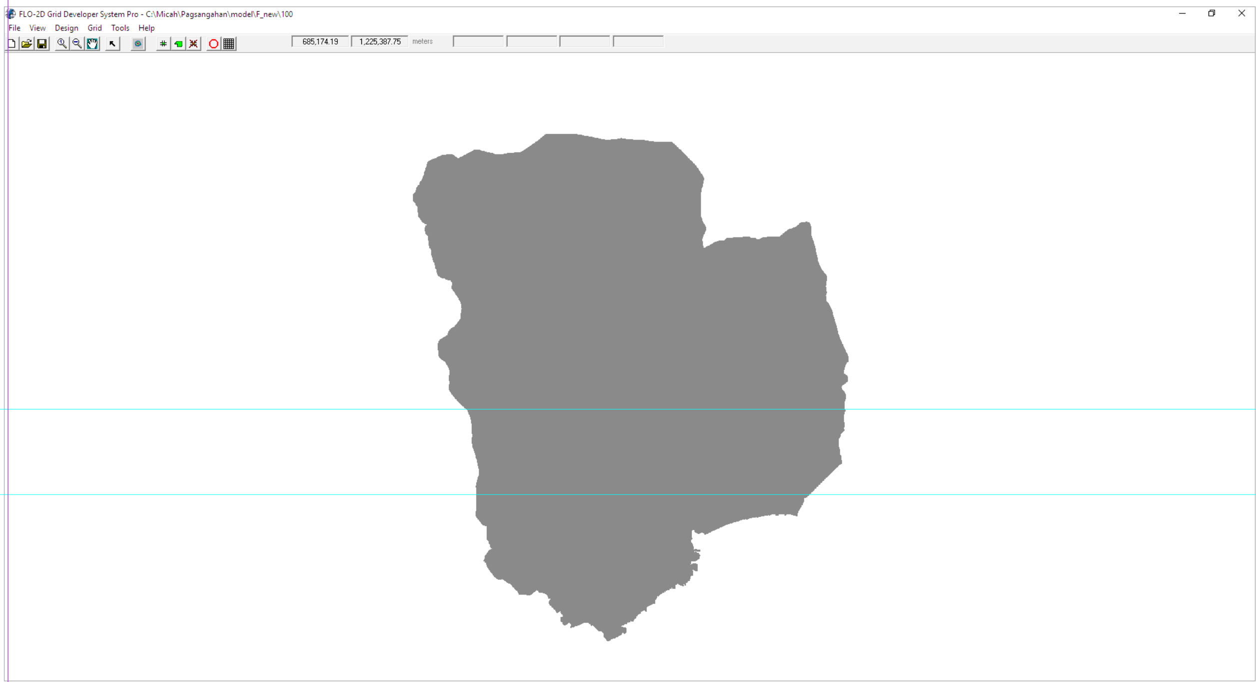


Figure 59. Screenshot of a sub-catchment with the computational area to be modeled in the FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 81.55957 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 94 945 000.00 m2.

There is a total of 51 334 327.54 m3 of water entering the model. Of this amount, 24 436 414.50 m3 is due to rainfall while 26 897 913.04 m3 is inflow from other areas outside the model. 13 151 253.00 m3 of this water is lost to infiltration and interception, while 29 852 675.29 m3 is stored by the flood plain. The rest, amounting up to 8 330 411.25 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Pagsangahan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 demonstrates the comparison between the two (2) discharge data. ANNEX 9 presents the Pagsangahan Model Basin Parameters.

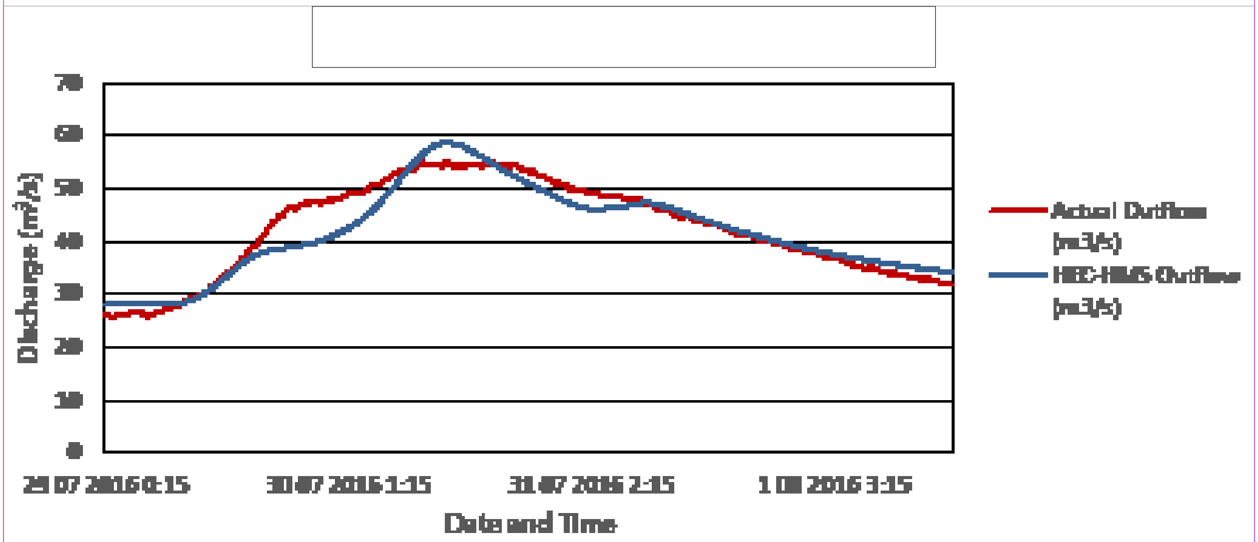


Figure 60. Outflow hydrograph of Pagsangahan produced by the HEC-HMS model, compared with observed outflow

Enumerated in Table 38 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 38. Range of calibrated values for the Pagsangahan River Basin Model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	
			Curve Number	
	Transform	Clark Unit Hydrograph	Time of Concentration (hr.)	
			Storage Coefficient (hr.)	
	Baseflow	Recession	Recession Constant	
			Ratio to Peak	
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values from 9 to 30 mm for initial abstraction means that there is a minimal to average amount of infiltration or rainfall interception by vegetation, per sub-basin.

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 40 to 60 for the curve number is relatively low compared to the advisable values for Philippine watersheds, depending on the soil and land cover of the area.

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 0.2 to 9 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.98 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 to 0.3 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.04 corresponds to the common roughness of the Pagsangahan watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 39. Summary of the Efficiency Test of the Pagsangahan HMS Model

Accuracy measure	Value
RMSE	2.9
r^2	0.89
NSE	0.88
PBIAS	0.84
RSR	0.34

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 2.9 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value 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 0.89.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here, the optimal value is 1. The model attained an efficiency coefficient of 0.88.

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 0.84.

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 0.34.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 61) reflects the Pagsangahan outflow using the Tacloban RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

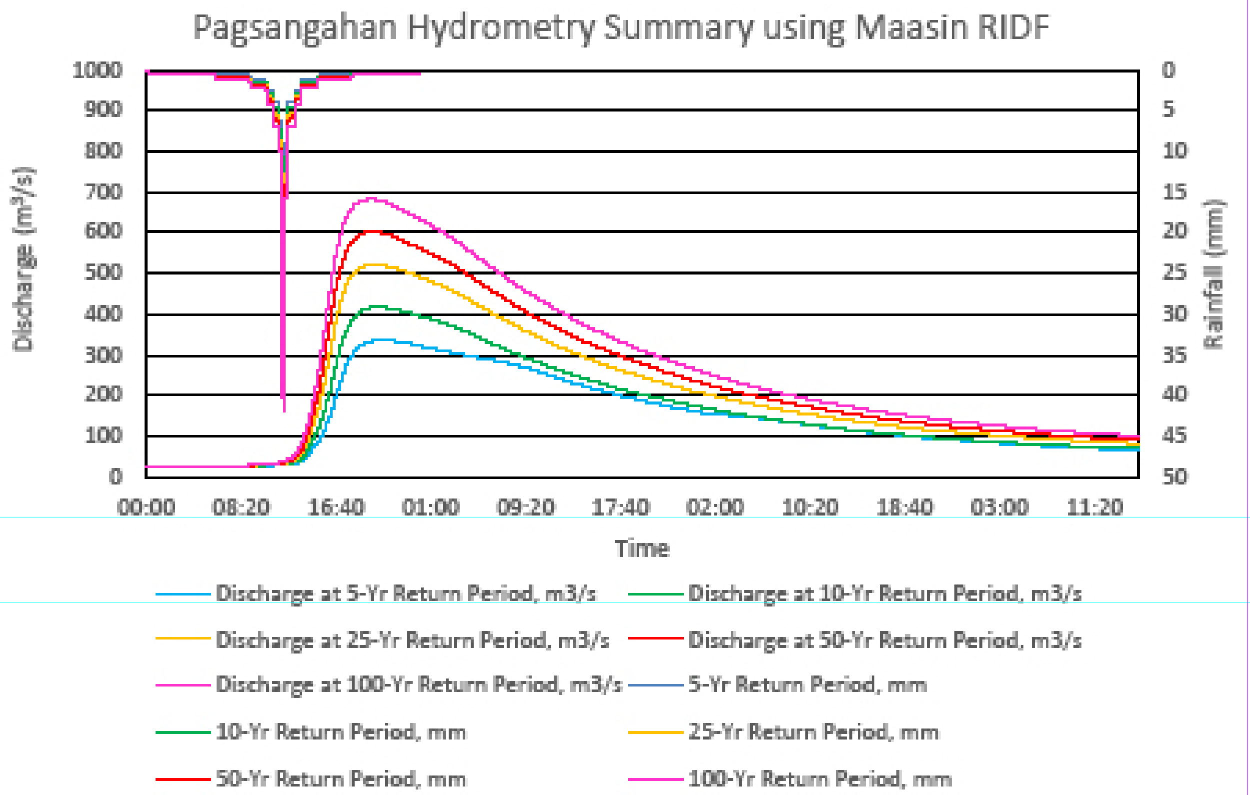


Figure 61. Outflow hydrograph at Pagsangahan Station generated using Tacloban RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Pagsangahan discharge using the Tacloban RIDF curves in five (5) different return periods is outlined in Table 40.

Table 40. Peak values of the Pagsangahan HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	161.4	24.3	336.7	8 hours, 45 minutes
10-Year	188.4	28.5	417.4	8 hours, 15 minutes
25-Year	222.6	33.9	522.6	8 hours, 00 minutes
50-Year	247.9	37.9	601.3	7 hours, 45 minutes
100-Year	273.0	41.8	681.9	7 hours, 45 minutes

5.7.2 Discharge data using Dr. Horritts' recommended hydrologic method

The river discharge values for the nine (9) rivers entering the floodplain are shown in [ ] to [ ]., and the peak values are summarized in [ ] to [ ].

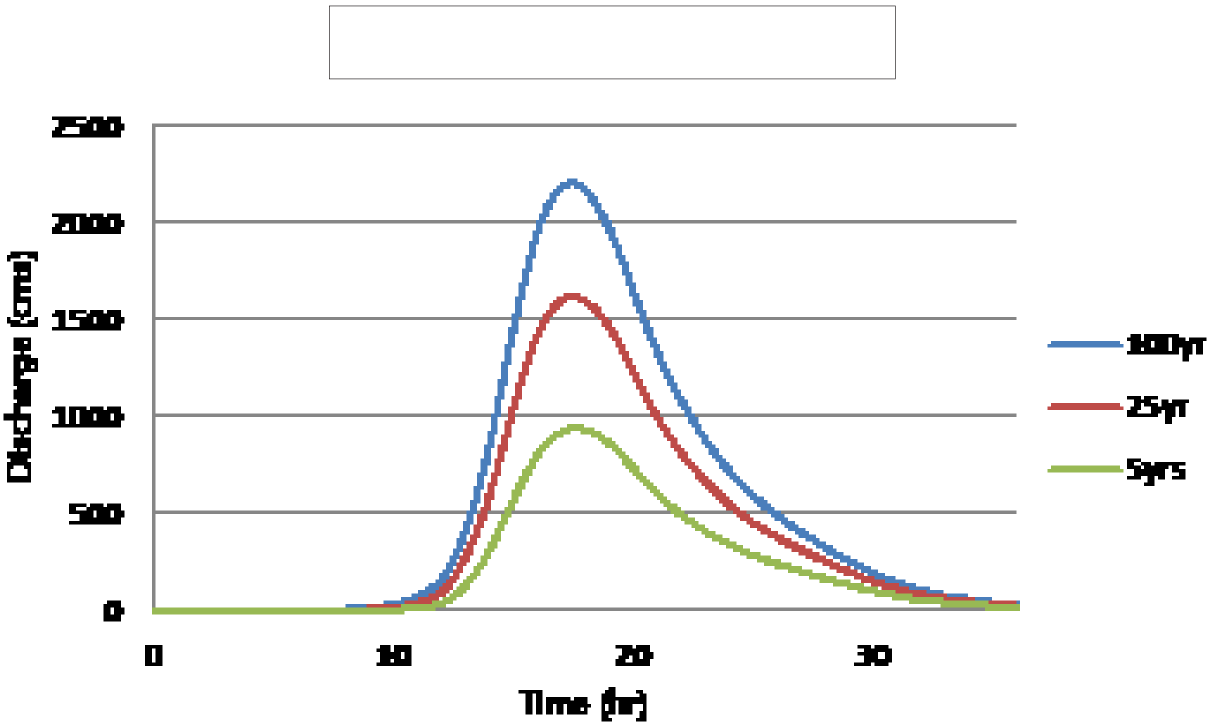


Figure 62. Pagsangahan river (1) generated discharge using 5-, 25-, and 100-year Tacloban RIDF in HEC-HMS

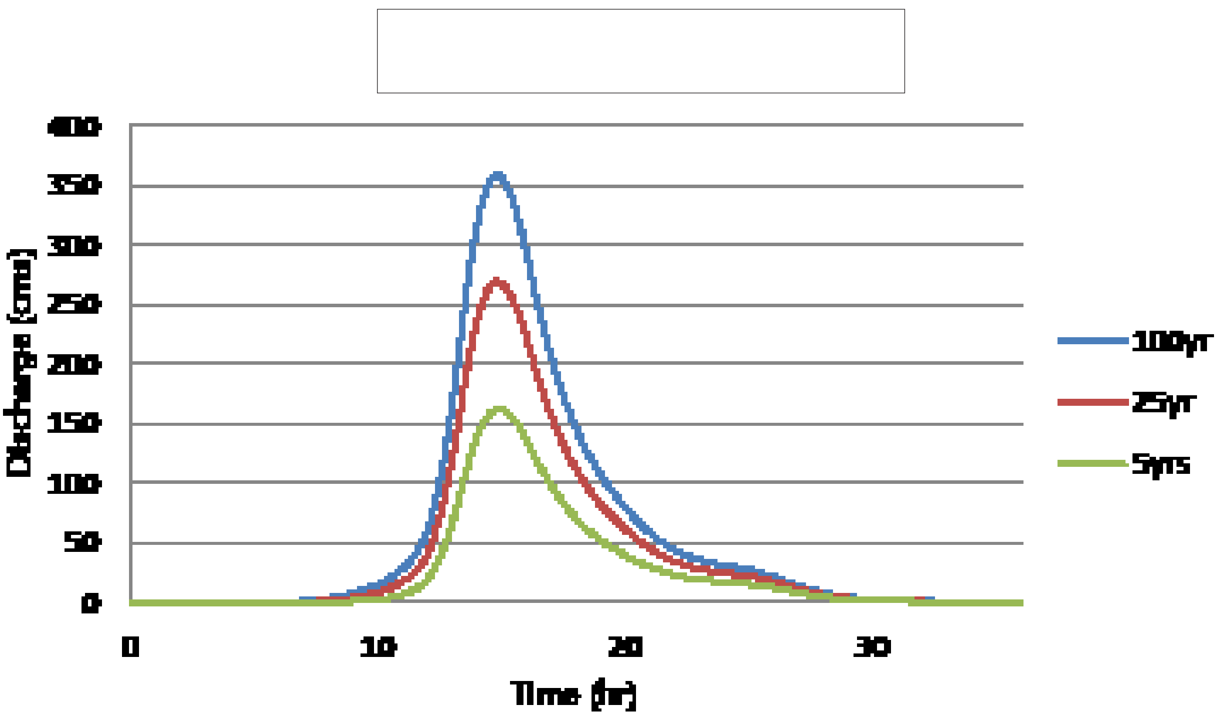


Figure 63. Pagsangahan River (2) generated discharge using 5-, 25-, and 100-year Tacloban RIDF in HEC-HMS

Table 41. Summary of the Pagsangahan River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2206.7	17 hours, 30 minutes
25-Year	1621.3	17 hours, 30 minutes
5-Year	936.7	17 hours, 30 minutes

Table 42. Summary of the Pagsangahan River (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	359.1	14 hours, 50 minutes
25-Year	269.8	14 hours, 50 minutes
5-Year	162.1	14 hours, 50 minutes

Table 43. Validation of river discharge estimates

				VALIDATION	
Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	Bankful Discharge	Specific Discharge
Pagsangahan (1)	824.296	846.408	525.539	Pass	Fail
Pagsangahan (2)	142.648	99.949	127.626	Pass	Pass

Two (2) values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the Bankful method; and one did not satisfy the specific discharge methods and will need recalculation. The passing values are based on theory but are supported by other discharge computation methods; thus, they are applicable for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain the actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the extent of real-time flood inundation of the river, after it has been automated and uploaded on the DREAM website. For this publication, a sample output for the river flow during Typhoon Carina is provided, since the model was calibrated from this event. The sample generated map of the Pagsangahan River using the calibrated HEC-HMS model for Typhoon Carina is presented in Figure 64.

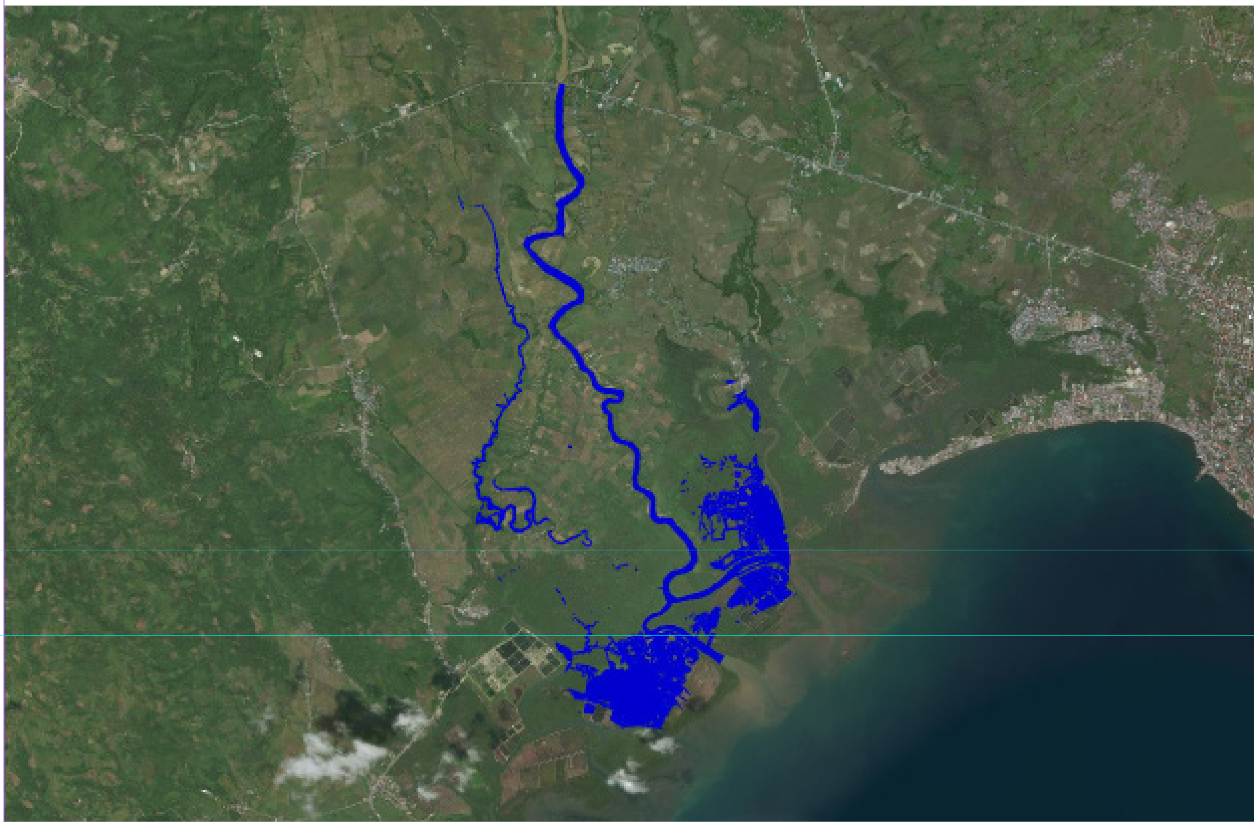


Figure 64. Sample output map of the Pagsangahan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps for the 5-year, 25-year, and 100-year rain return scenarios of the Pagsangahan floodplain are exhibited in Figure 65 to 70. The floodplain, with an area of 96.71 sq. km., covers four (4) municipalities, namely Matag-Ob, Merida, Ormoc City, and Palompon. Table 44 enumerates the percentage of area affected by flooding per municipality.

Table 44. Municipalities affected in the Pagsangahan floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Matag-Ob	63.4592	2.334299	367.84%
Merida	101.477	13.51544	1331.87%
Ormoc City	451.96	80.6196	1783.78%
Palompon	125.866	0.113434	9.01%

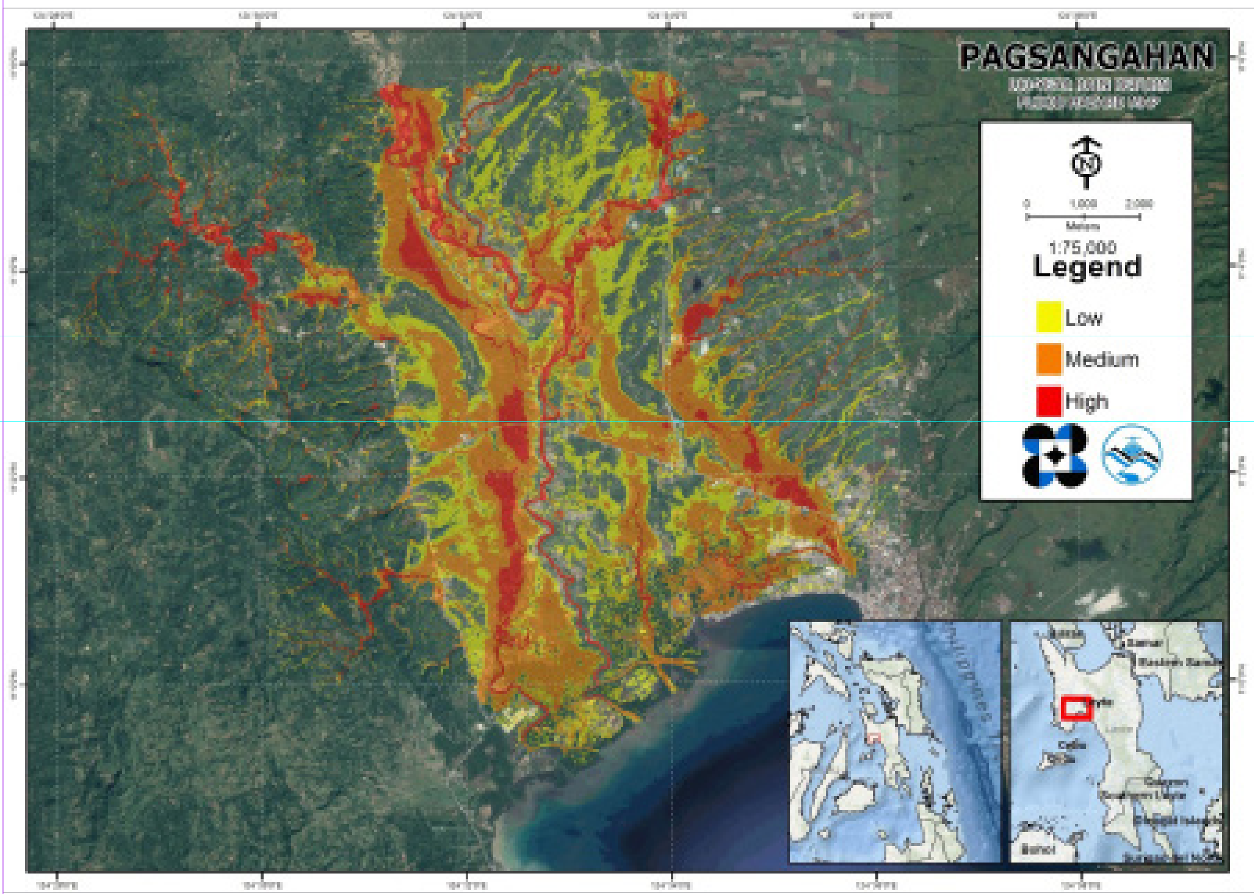


Figure 65. 100-year flood hazard map for the Pagsangahan floodplain

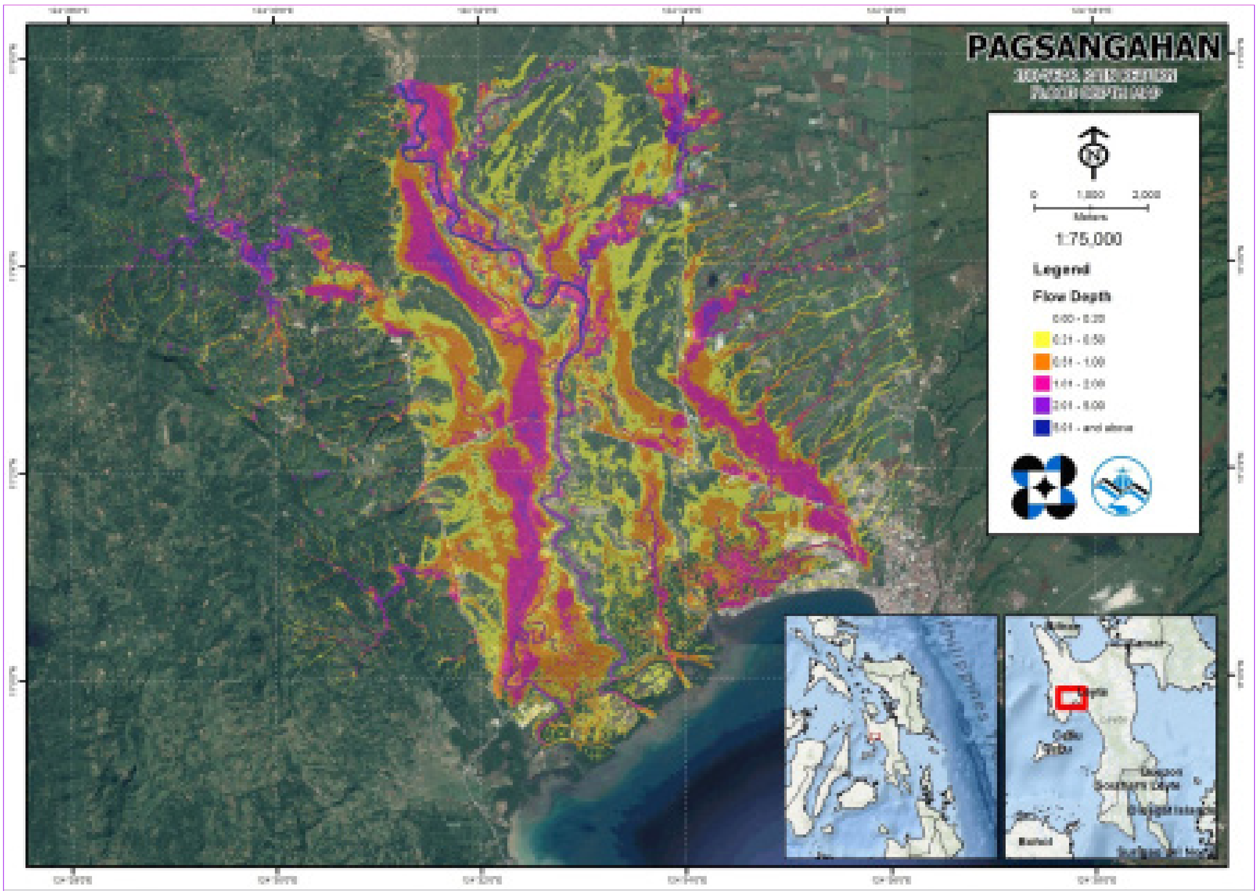


Figure 66. 100-year flow depth map for the Pagsangahan floodplain

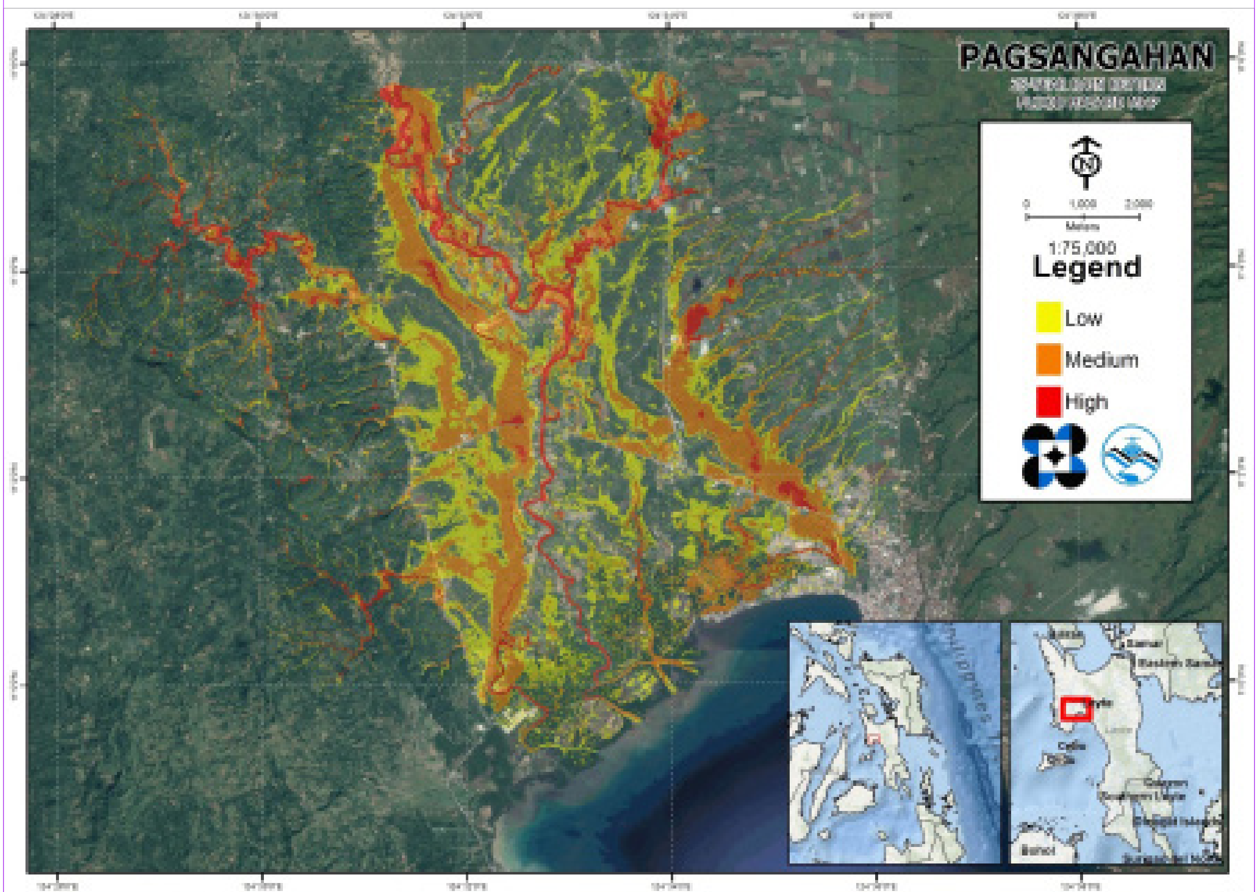


Figure 67. 25-year flood hazard map for the Pagsangahan floodplain

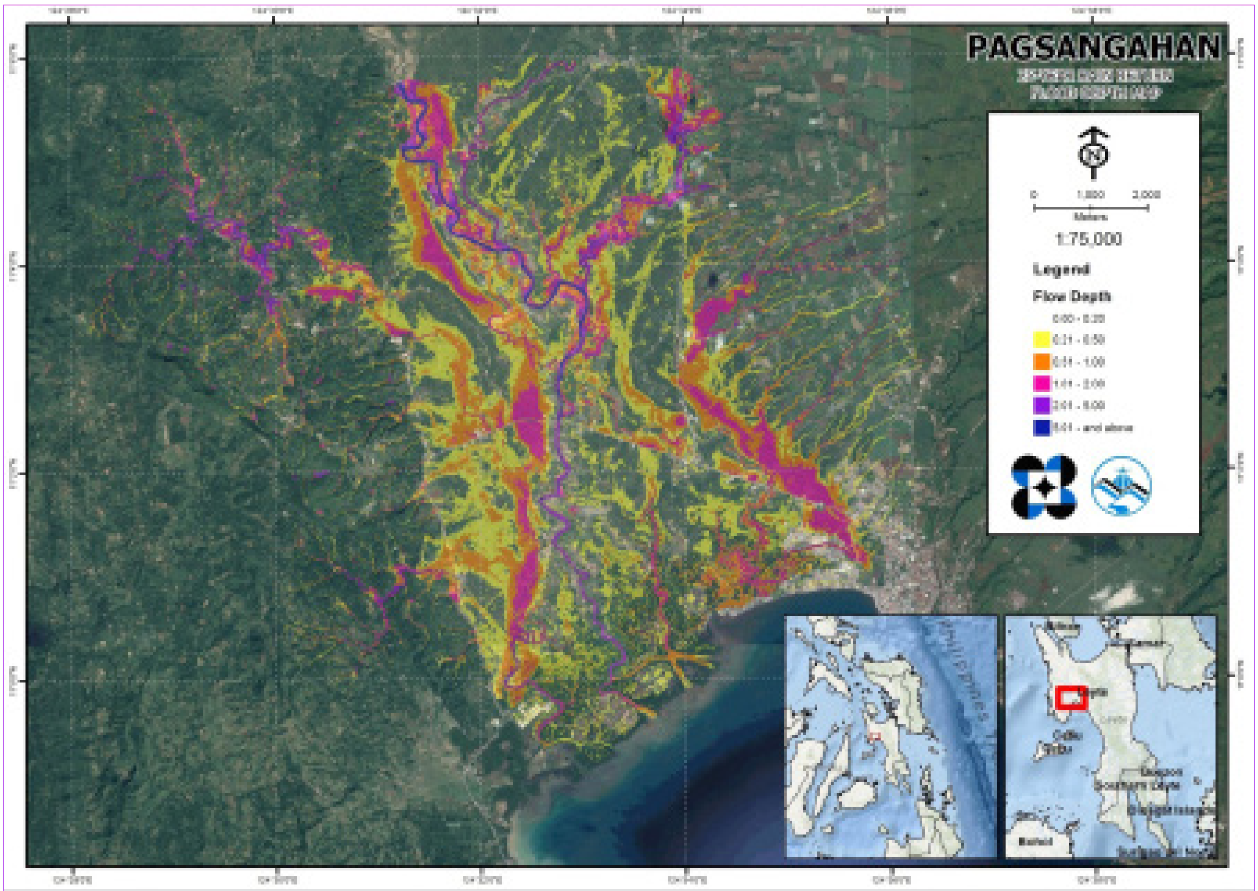


Figure 68. 25-year flow depth map for the Pagsangahan floodplain

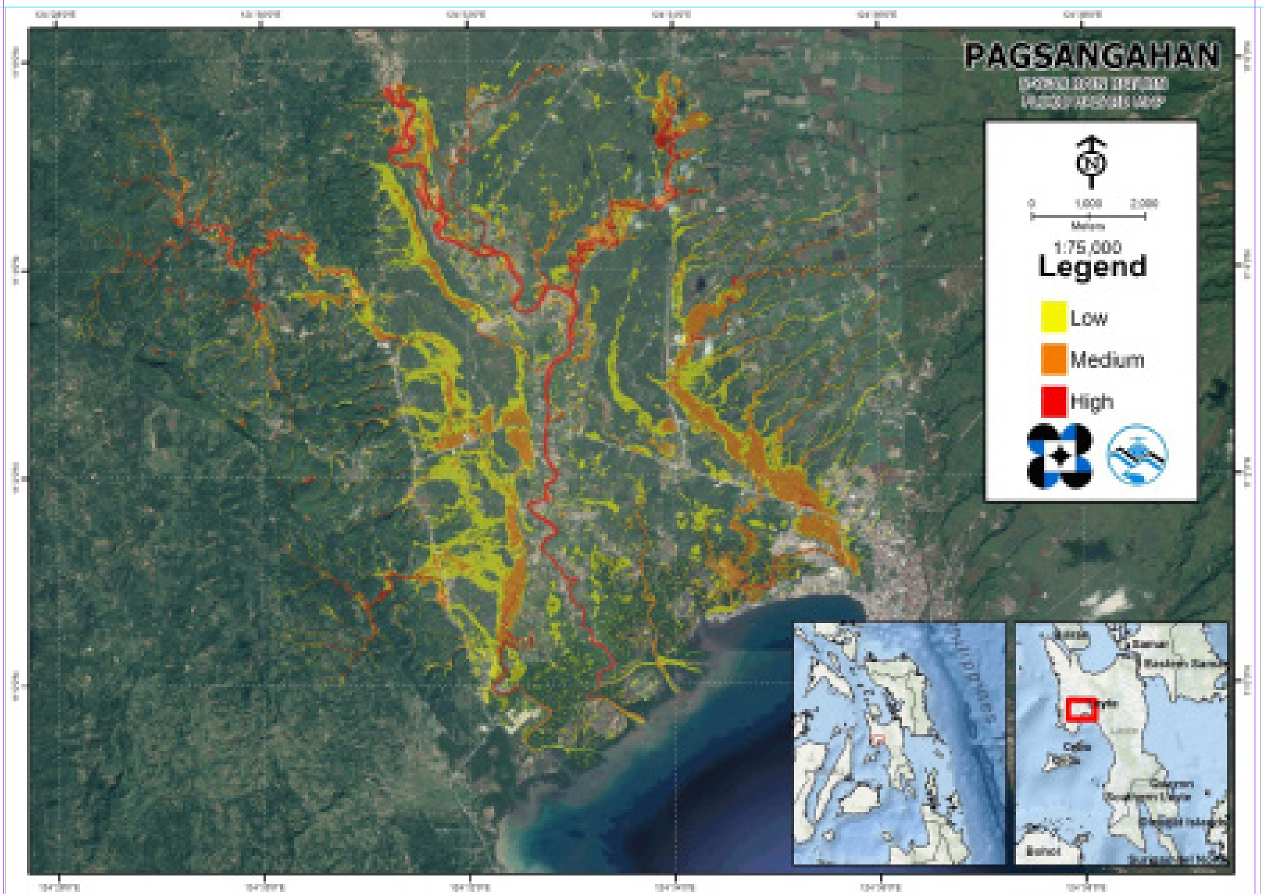


Figure 69. 5-year flood hazard map for the Pagsangahan floodplain

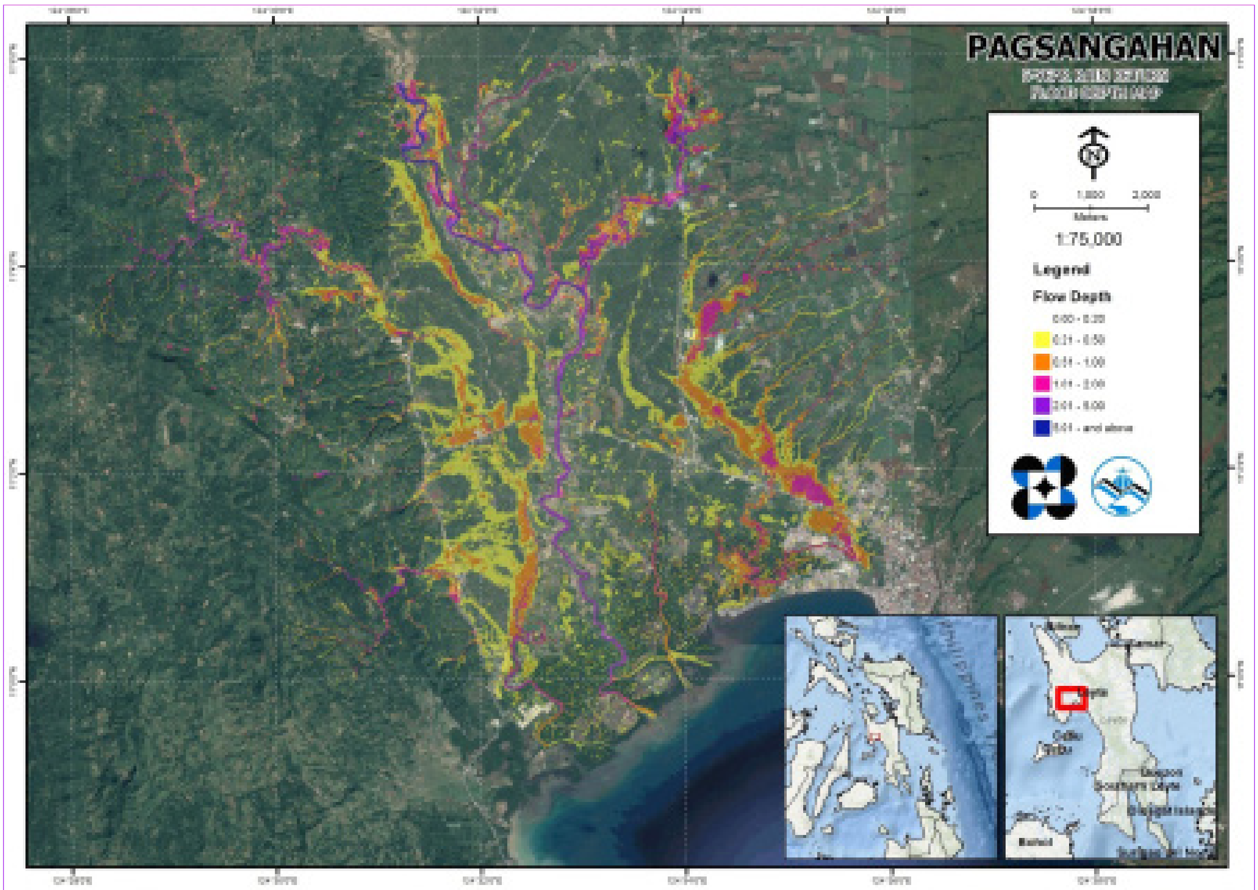


Figure 70. 5-year flow depth map for the Pagsangahan floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected in the Pagsangahan River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of thirty (30) barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 3.50% of the Municipality of Matag-Ob, with an area of 63.46 sq. km., will experience flood levels of less than 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.03%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 45 depicts the areas affected in Matag-Ob, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Matag-Ob, Leyte during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Matag-Ob (in sq. km.)
	Santa Rosa
0.03-0.20	2.22
0.21-0.50	0.059
0.51-1.00	0.032
1.01-2.00	0.019
2.01-5.00	0.0082
> 5.00	0

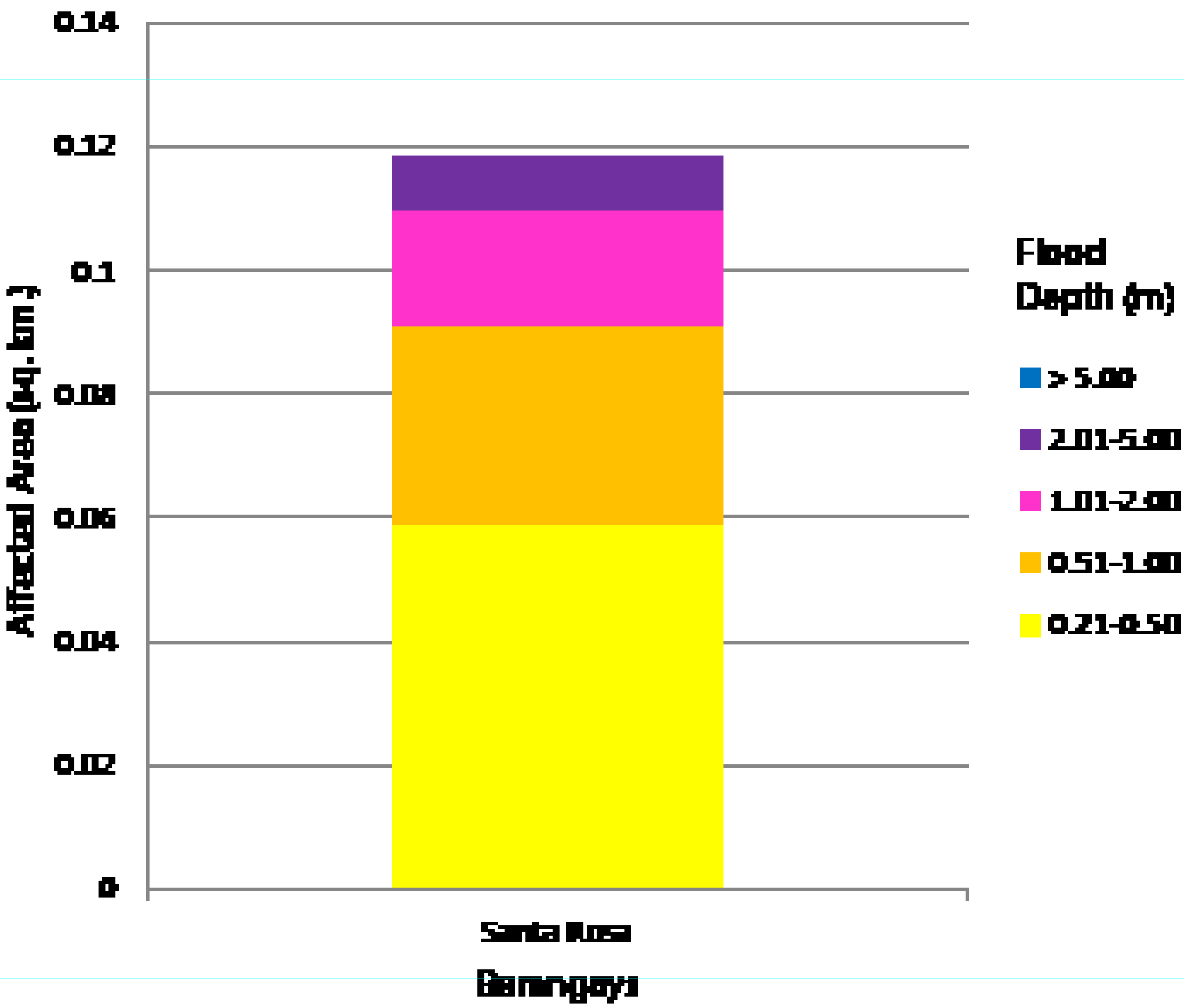


Figure 71. Affected areas in Matag-Ob, Leyte during a 5-year rainfall return period

For the Municipality of Merida, with an area of 101.48 sq. km., 12.38% will experience flood levels of less than 0.20 meters. 0.44% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.22%, 0.18%, 0.10%, and 0.002% 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.

[ ] depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Merida, Leyte during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Merida (in sq. km.)	
	Cabaliwan	Mahayag
0.03-0.20	5.91	6.65
0.21-0.50	0.22	0.23
0.51-1.00	0.11	0.11
1.01-2.00	0.093	0.089
2.01-5.00	0.049	0.052
> 5.00	0	0.002

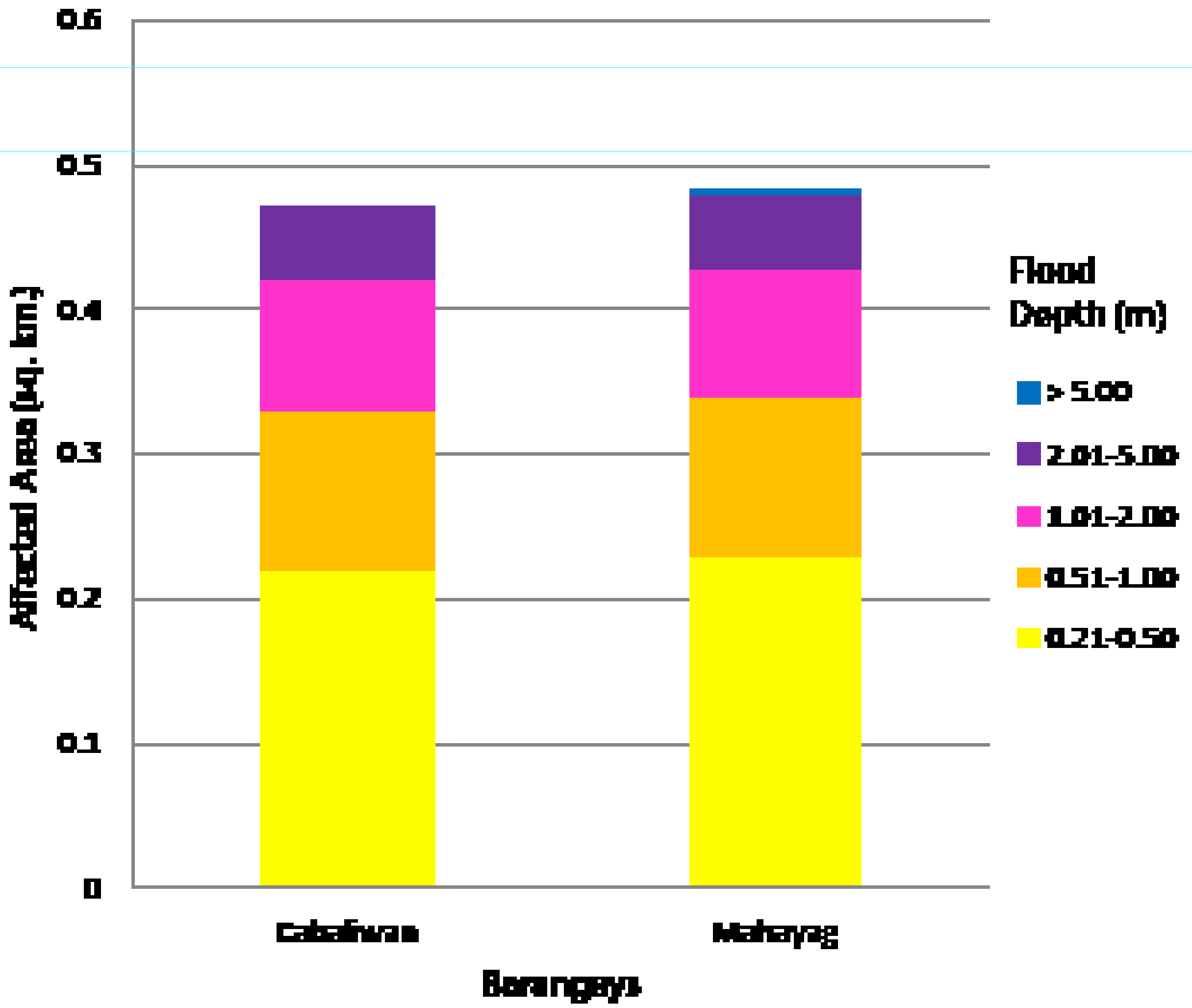


Figure 72. Affected areas in Merida, Leyte during a 5-year rainfall return period

For the Municipality of Ormoc City, with an area of 451.96 sq. km., 9.14% will experience flood levels of less than 0.20 meters. 2.23% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.45%, 2.47%, 1.41%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Tables 47-49 depict the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Ormoc City, Leyte during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)							
	Airport	Bayog	Catmon	Curva	Domonar	Esperanza	Green Valley	Guintigui-An
0.03-0.20	1.11	0.19	1.56	2.08	0.44	5.35	1.4	0.039
0.21-0.50	0.16	0.14	0.2	0.36	0.16	0.27	0.37	0.0001
0.51-1.00	0.066	0.22	0.24	0.093	0.35	0.23	0.27	0
1.01-2.00	0.097	0.27	0.24	0.027	0.9	0.32	0.59	0
2.01-5.00	0.1	0.44	0.12	0.015	0.42	0.23	1.04	0
> 5.00	0.0045	0.024	0.0011	0	0.079	0	0.032	0

Table 48. Affected areas in Ormoc City, Leyte during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)							
	Labrador	Lao	Leondoni	Libertad	Licuma	Liloan	Mabato	Manlilinao
0.03-0.20	1.41	1.89	0.57	2.2	2.4	1.37	0.46	2.26
0.21-0.50	0.47	0.68	0.088	0.64	0.64	2.49	0.64	0.076
0.51-1.00	0.47	0.71	0.08	1.16	0.13	2.96	1.2	0.063
1.01-2.00	0.35	0.63	0.17	0.4	0.04	2.75	1.46	0.074
2.01-5.00	0.19	0.096	0.4	0.0008	0.0078	1.2	0.72	0.031
> 5.00	0.029	0.001	0.097	0	0.0021	0.21	0	0.0002

Table 49. Affected areas in Ormoc City, Leyte during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)								
	Margen	Mas-In	Nasunogan	Nueva Sociedad	Rufina M. Tan	Sabang Bao	San Jose	San Juan	San Vicente
0.03-0.20	1.97	2.41	0.49	1.92	0.64	0.85	3.42	1.21	3.65
0.21-0.50	0.6	0.28	0.068	0.065	0.06	0.62	0.3	0.56	0.15
0.51-1.00	0.35	0.24	0.005	0.027	0.047	0.88	0.038	1.18	0.077
1.01-2.00	0.36	0.11	0.0059	0.015	0.24	0.63	0.017	1.41	0.041
2.01-5.00	0.23	0.0067	0.0043	0.0032	0.45	0.4	0.0017	0.24	0.0095
> 5.00	0	0	0	0	0.11	0.13	0	0	0.0001

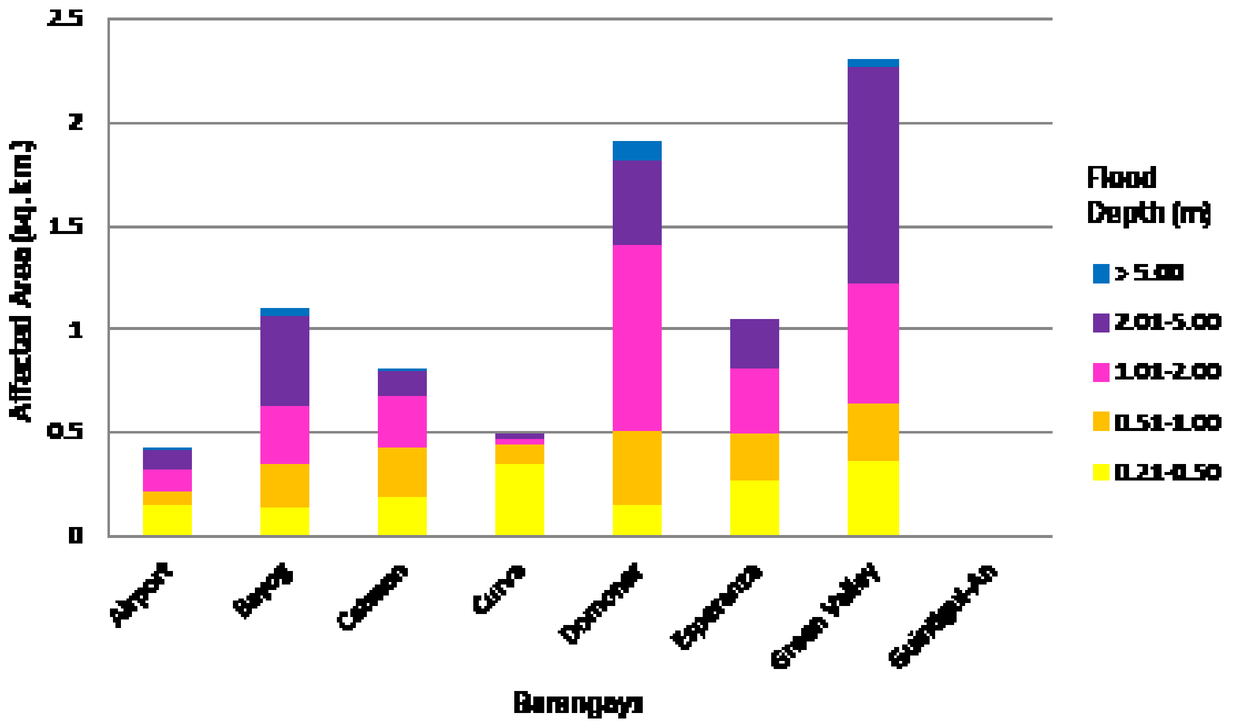


Figure 73. Affected areas in Ormoc City, Leyte during a 5-year rainfall return period

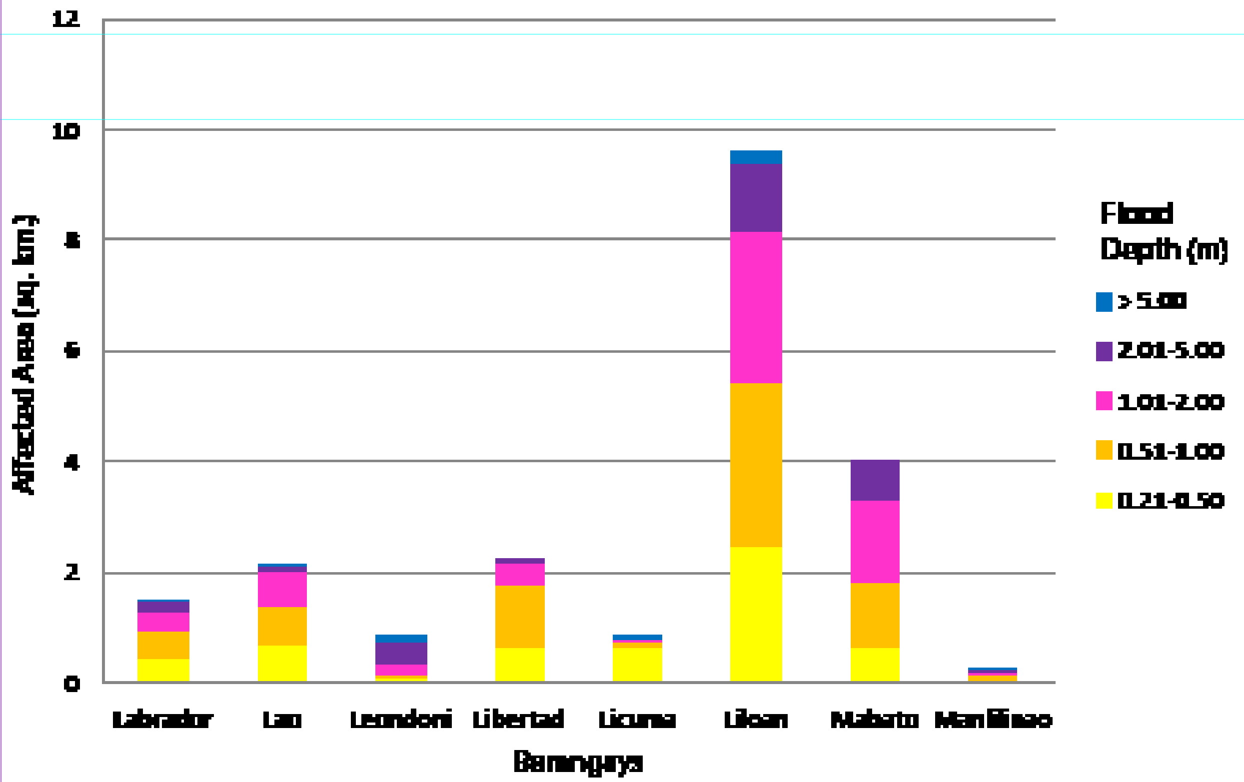


Figure 74. Affected areas in Ormoc City, Leyte during a 5-year rainfall return period

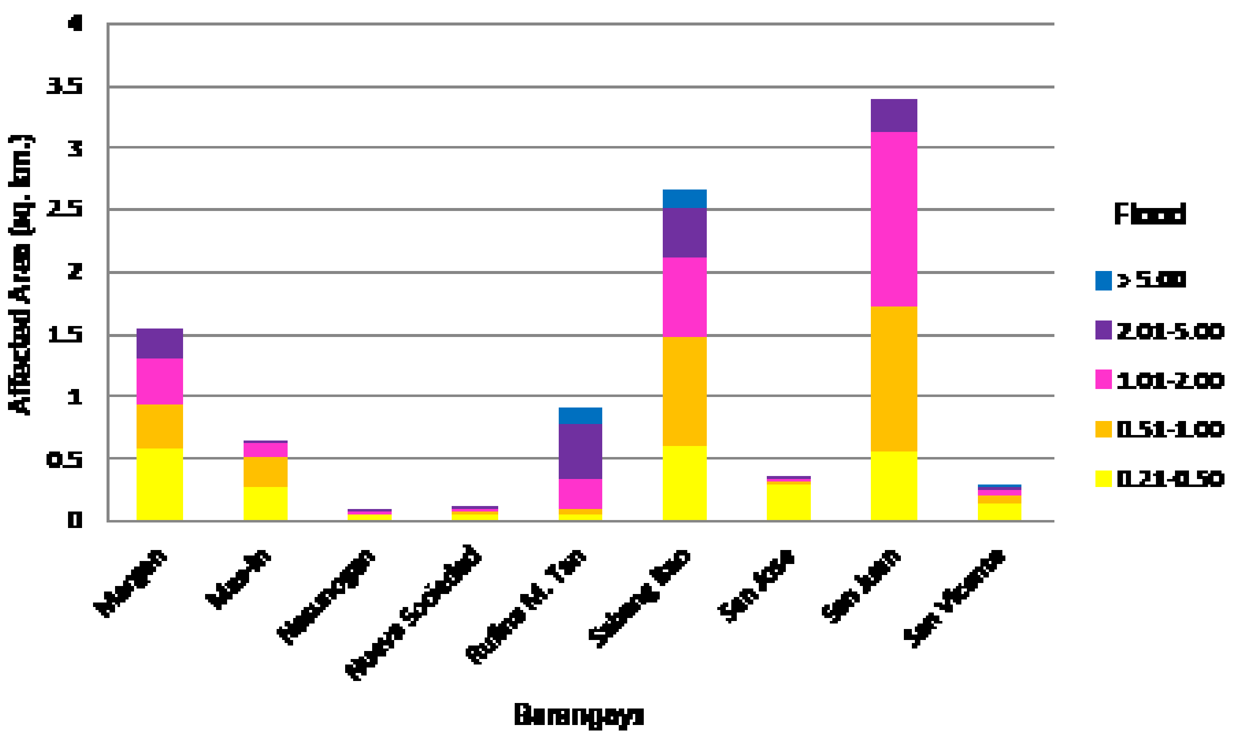


Figure 75. Affected areas in Ormoc City, Leyte during a 5-year rainfall return period

For the Municipality of Palompon, with an area of 125.87 sq. km., 0.09% will experience flood levels of less than 0.20 meters. 0.001% of the area will experience flood levels of 0.21 to 0.50 meters, and 0.0001% of the area will experience flood depths of 0.51 to 1 meter. Table 50 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Palompon, Leyte during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Palompon (in sq. km.)	
	Cambakbak	Mabini
0.03-0.20	0.043	0.069
0.21-0.50	0.00016	0.0016
0.51-1.00	0.000013	0.00015
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

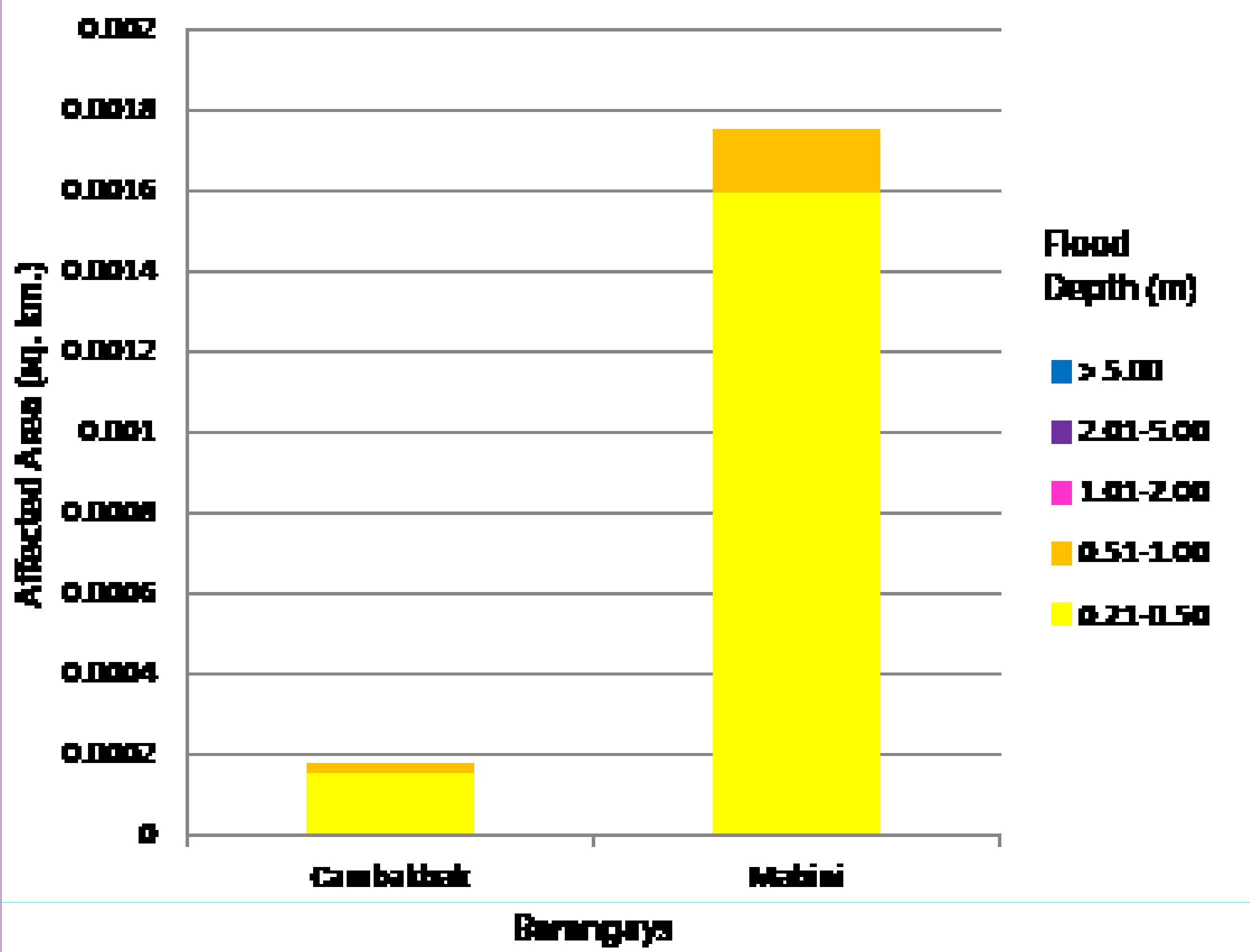


Figure 76. Affected areas in Palompon, Leyte during a 5-year rainfall return period

For the 25-year return period, 3.44% of the Municipality of Matag-Ob, with an area of 63.46 sq. km., will experience flood levels of less than 0.20 meters, while 0.11% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.07%, 0.04%, 0.02%, and 0.0005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 51 depicts the areas affected in Matag-Ob, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Matag-Ob, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Matag-Ob (in sq. km.)
	Santa Rosa
0.03-0.20	2.18
0.21-0.50	0.072
0.51-1.00	0.042
1.01-2.00	0.027
2.01-5.00	0.013
> 5.00	0.0003

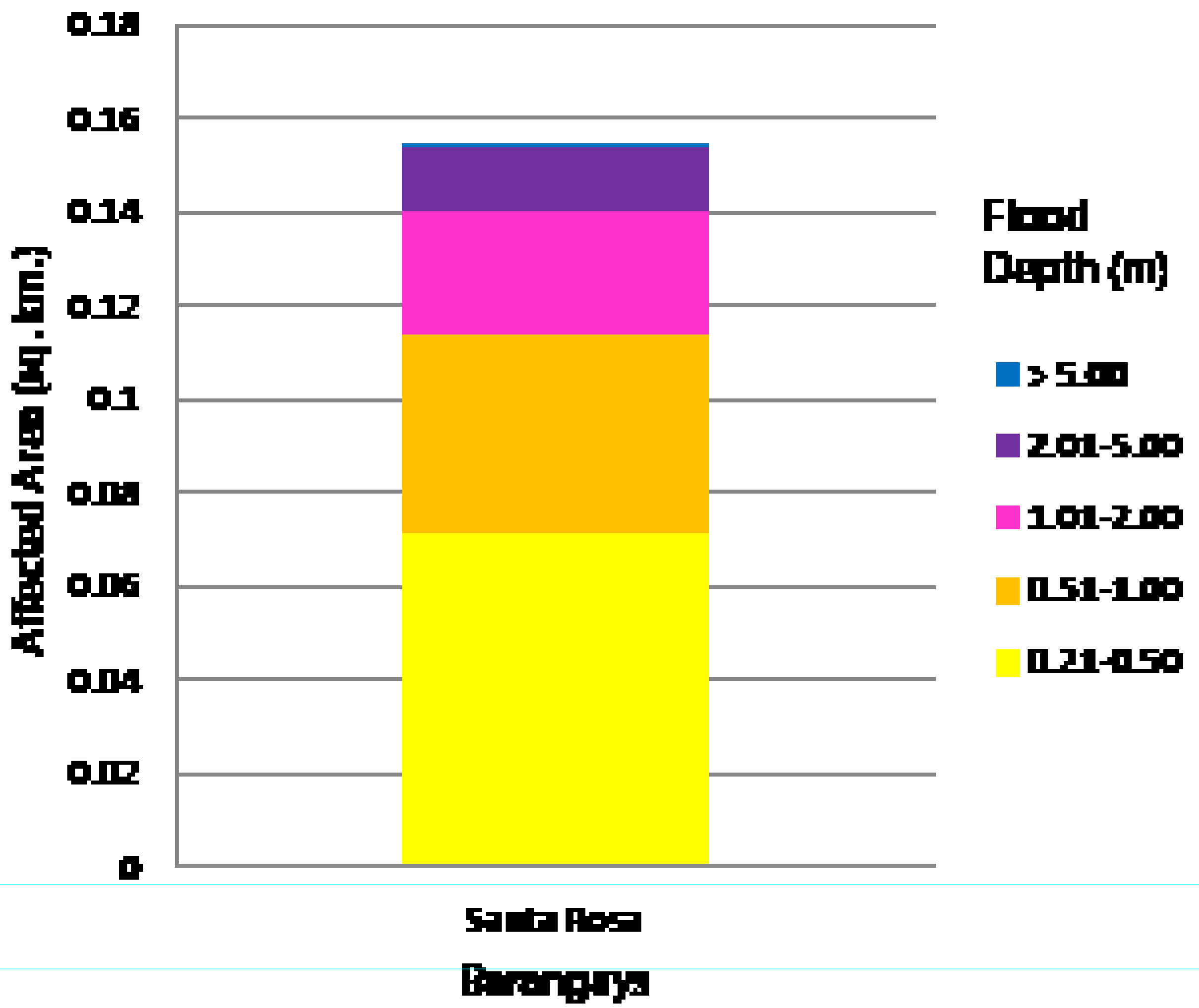


Figure 77. Affected areas in Matag-Ob, Leyte during a 25-year rainfall return period

For the Municipality of Merida, with an area of 101.48 sq. km., 12.09% will experience flood levels of less than 0.20 meters. 0.53% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.29%, 0.21%, 0.18%, and 0.006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 52 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Merida, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Merida (in sq. km.)	
	Cabaliwan	Mahayag
0.03-0.20	5.77	6.5
0.21-0.50	0.26	0.28
0.51-1.00	0.14	0.15
1.01-2.00	0.11	0.1
2.01-5.00	0.091	0.091
> 5.00	0.0005	0.0057

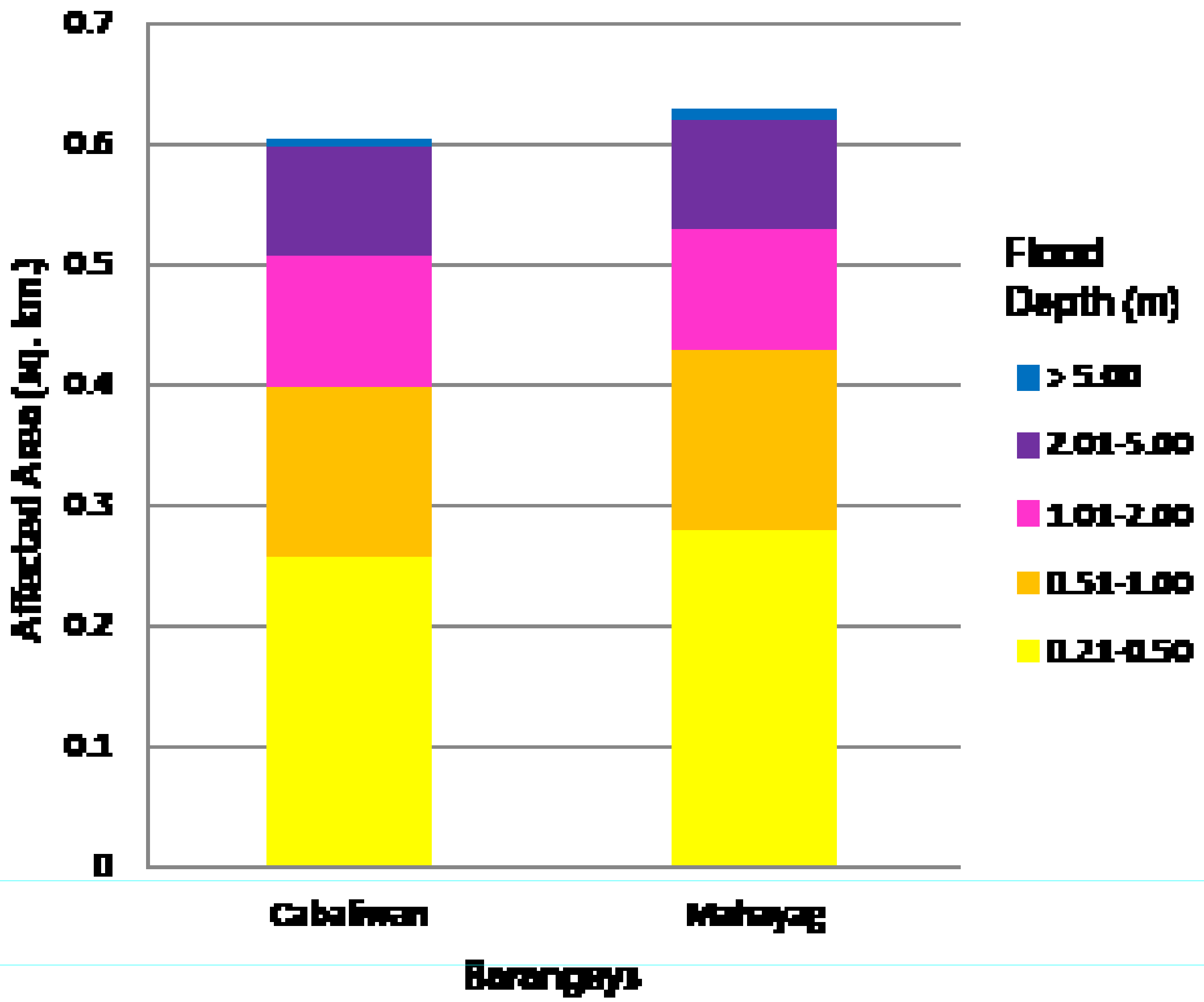


Figure 78. Affected areas in Merida, Leyte during a 25-year rainfall return period

For the Municipality of Ormoc City, with an area of 451.96 sq. km., 7.19% will experience flood levels of less than 0.20 meters. 1.78% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.32%, 4.06%, 2.27%, and 0.22% 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. Tables 53-55 depict the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Ormoc City, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)							
	Airport	Bayog	Catmon	Curva	Domonar	Esperanza	Green Valley	Guintigui-An
0.03-0.20	0.73	0.042	1.15	1.72	0.23	5.01	1.21	0.039
0.21-0.50	0.33	0.037	0.36	0.48	0.19	0.23	0.28	0.00021
0.51-1.00	0.21	0.089	0.21	0.29	0.19	0.28	0.33	0
1.01-2.00	0.12	0.44	0.37	0.05	0.85	0.4	0.42	0
2.01-5.00	0.14	0.62	0.25	0.03	0.81	0.45	1.4	0
> 5.00	0.018	0.055	0.011	0.0002	0.086	0.016	0.043	0

Table 54. Affected areas in Ormoc City, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)							
	Labrador	Lao	Leondoni	Libertad	Licuma	Liloan	Mabato	Manlilinao
0.03-0.20	0.56	0.88	0.38	1.42	2.06	0.21	0.19	2.21
0.21-0.50	0.71	0.76	0.11	0.56	0.7	0.53	0.23	0.08
0.51-1.00	0.5	1.01	0.098	0.69	0.36	2.43	0.89	0.066
1.01-2.00	0.79	1.23	0.15	1.68	0.08	5.49	1.85	0.089
2.01-5.00	0.32	0.12	0.48	0.036	0.016	2.08	1.32	0.063
> 5.00	0.039	0.0006	0.17	0	0.0027	0.23	0.0005	0.0008

Table 55. Affected areas in Ormoc City, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)								
	Margen	Mas-In	Nasunogan	Nueva Sociedad	Rufina M. Tan	Sabang Bao	San Jose	San Juan	San Vicente
0.03-0.20	1.74	2.18	0.45	1.88	0.6	0.21	2.88	0.94	3.56
0.21-0.50	0.5	0.25	0.093	0.087	0.047	0.2	0.58	0.51	0.17
0.51-1.00	0.55	0.29	0.01	0.035	0.043	0.5	0.2	1.09	0.11
1.01-2.00	0.4	0.28	0.0047	0.02	0.07	1.66	0.11	1.75	0.058
2.01-5.00	0.32	0.056	0.0081	0.0082	0.65	0.77	0.022	0.29	0.021
> 5.00	0.0002	0	0	0	0.14	0.16	0	0	0.0001

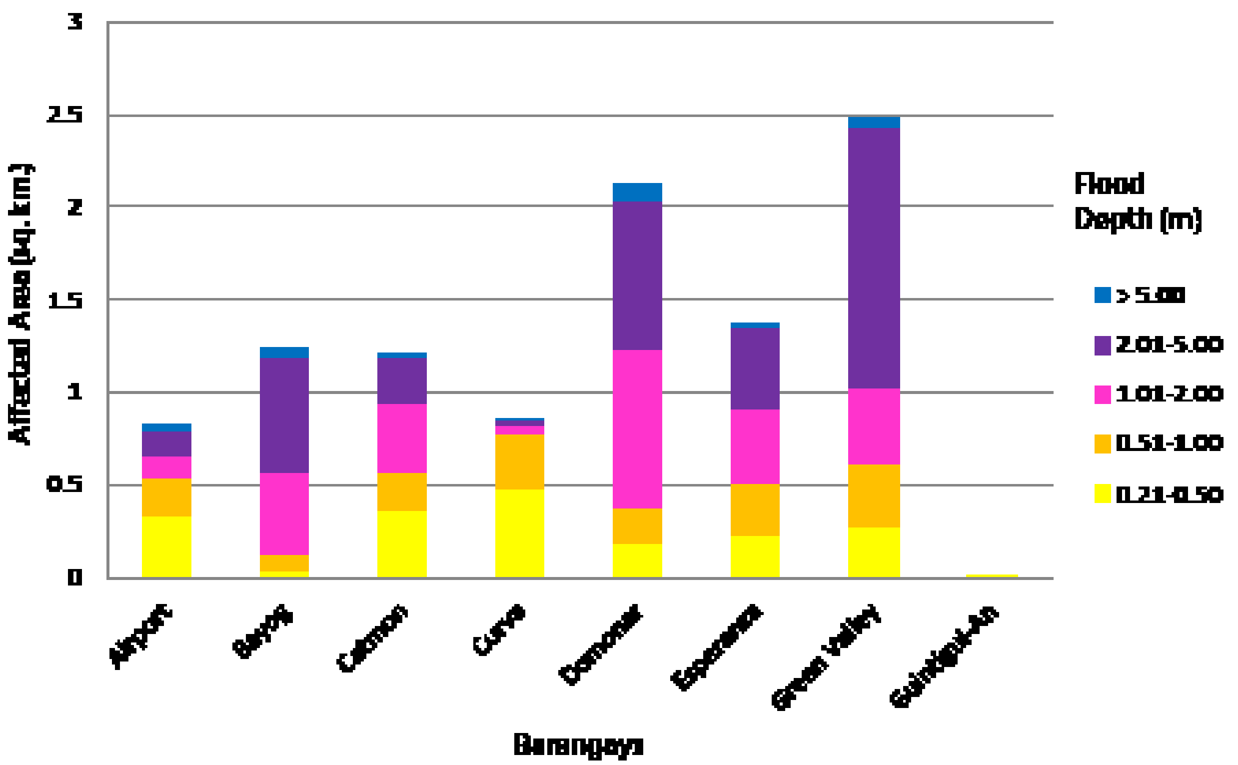


Figure 79. Affected areas in Ormoc City, Leyte during a 25-year rainfall return period

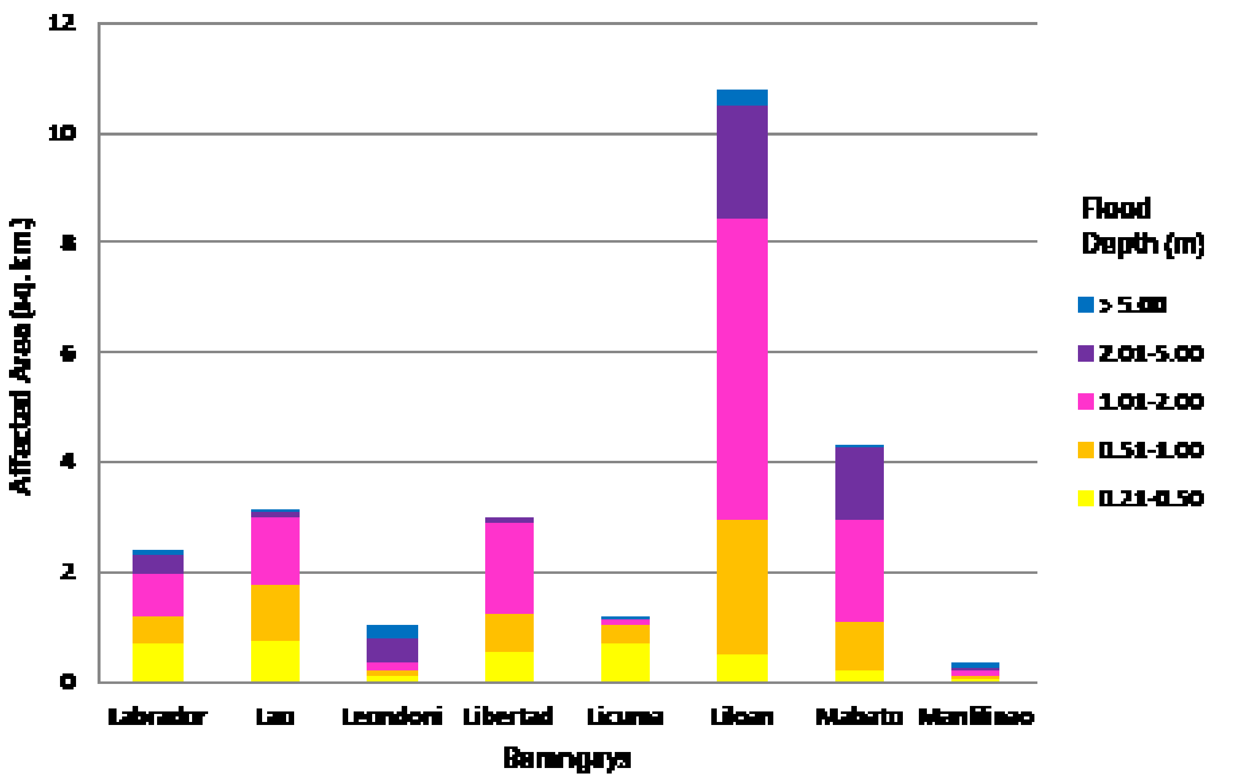


Figure 80. Affected areas in Ormoc City, Leyte during a 25-year rainfall return period

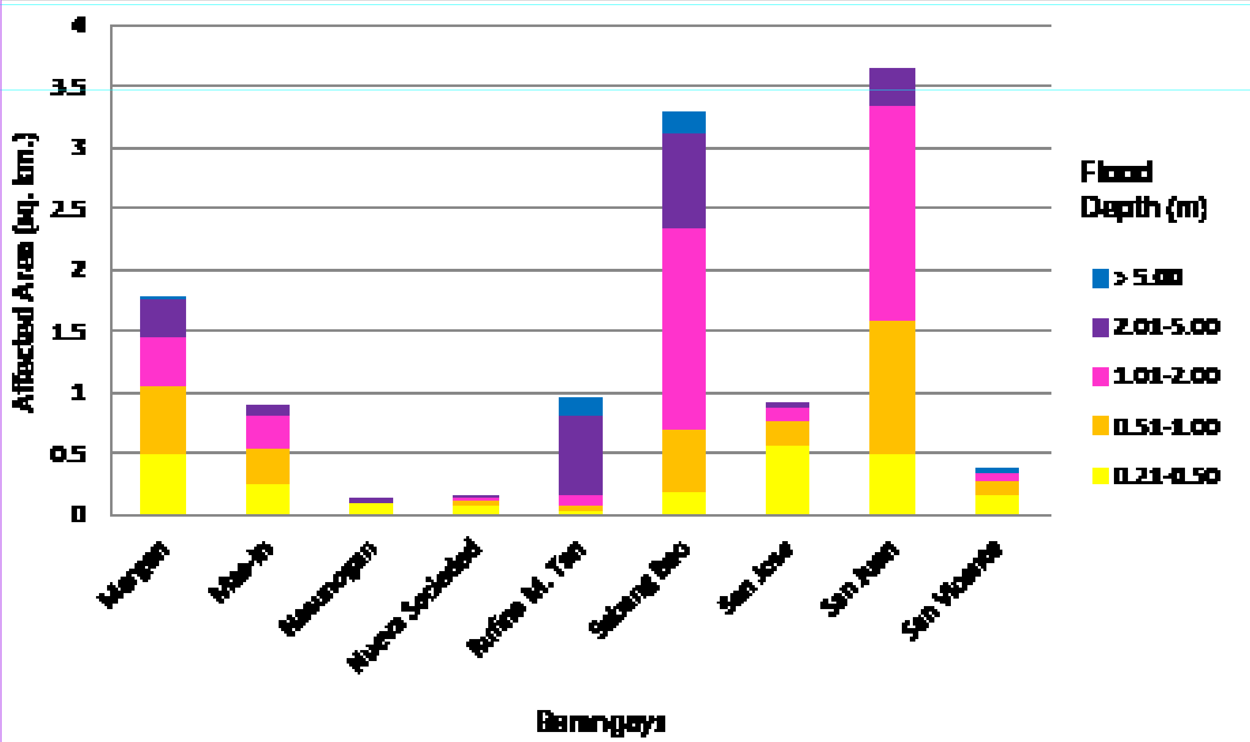


Figure 81. Affected areas in Ormoc City, Leyte during a 25-year rainfall return period

For the Municipality of Palompon, with an area of 125.87 sq. km., 0.09% will experience flood levels of less than 0.20 meters. 0.002% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.0003%, and 0.00002% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Table 56 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in Palompon, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Palompon (in sq. km.)	
	Cambakbak	Mabini
0.03-0.20	0.043	0.068
0.21-0.50	0.00037	0.0024
0.51-1.00	0	0.00034
1.01-2.00	0.000013	0.000014
2.01-5.00	0	0
> 5.00	0	0

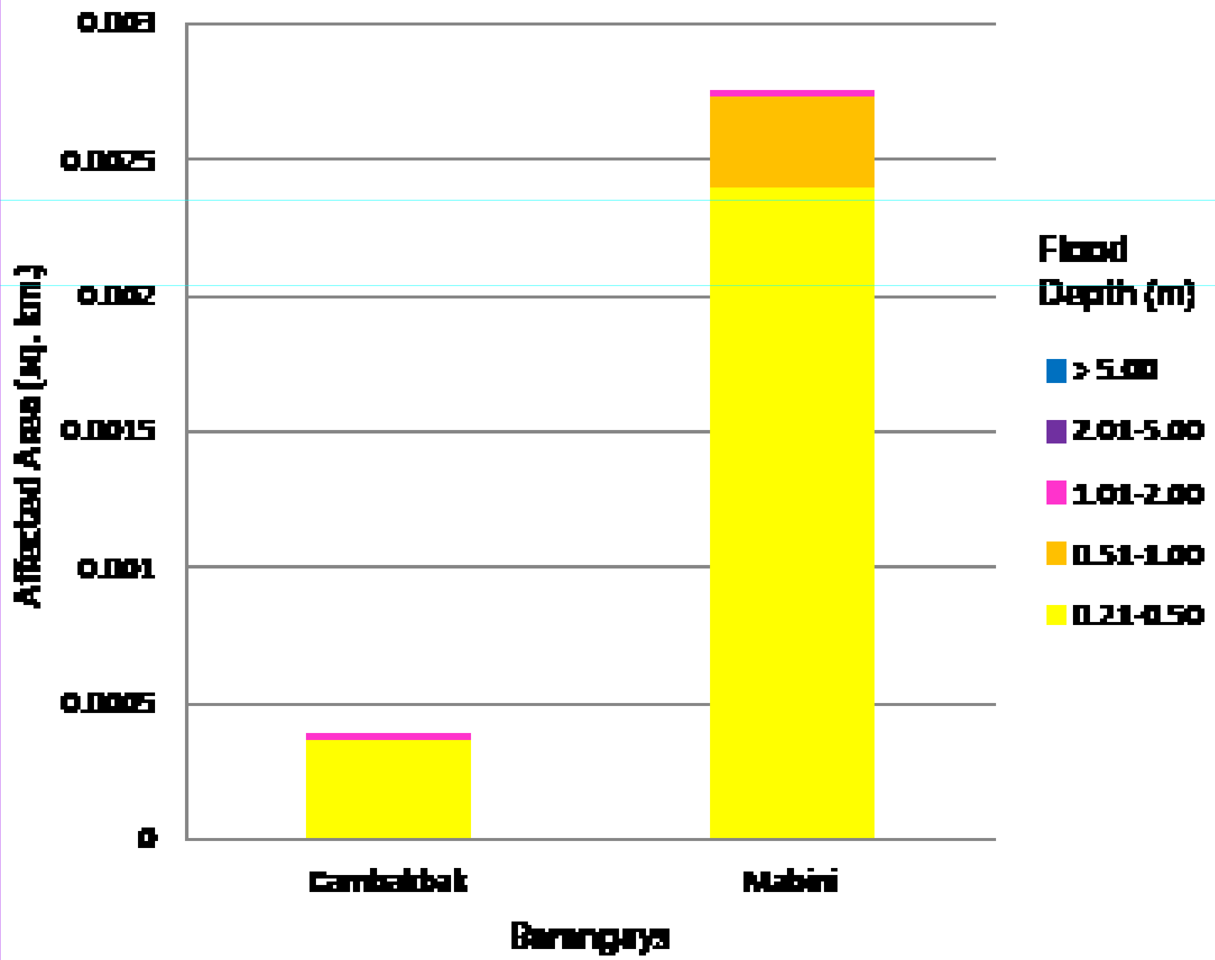


Figure 82. Affected areas in Palompon, Leyte during a 25-year rainfall return period

For the 100-year return period, 3.40% of the Municipality of Matag-Ob, with an area of 63.46 sq. km., will experience flood levels of less than 0.20 meters, while 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.07%, 0.05%, 0.03%, and 0.0007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 57 depicts the areas affected in Matag-Ob, in square kilometers, by flood depth per barangay.

Table 57. Affected areas in Matag-Ob, Leyte during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Matag-Ob (in sq. km.)
	Santa Rosa
0.03-0.20	2.16
0.21-0.50	0.079
0.51-1.00	0.046
1.01-2.00	0.032
2.01-5.00	0.017
> 5.00	0.00047

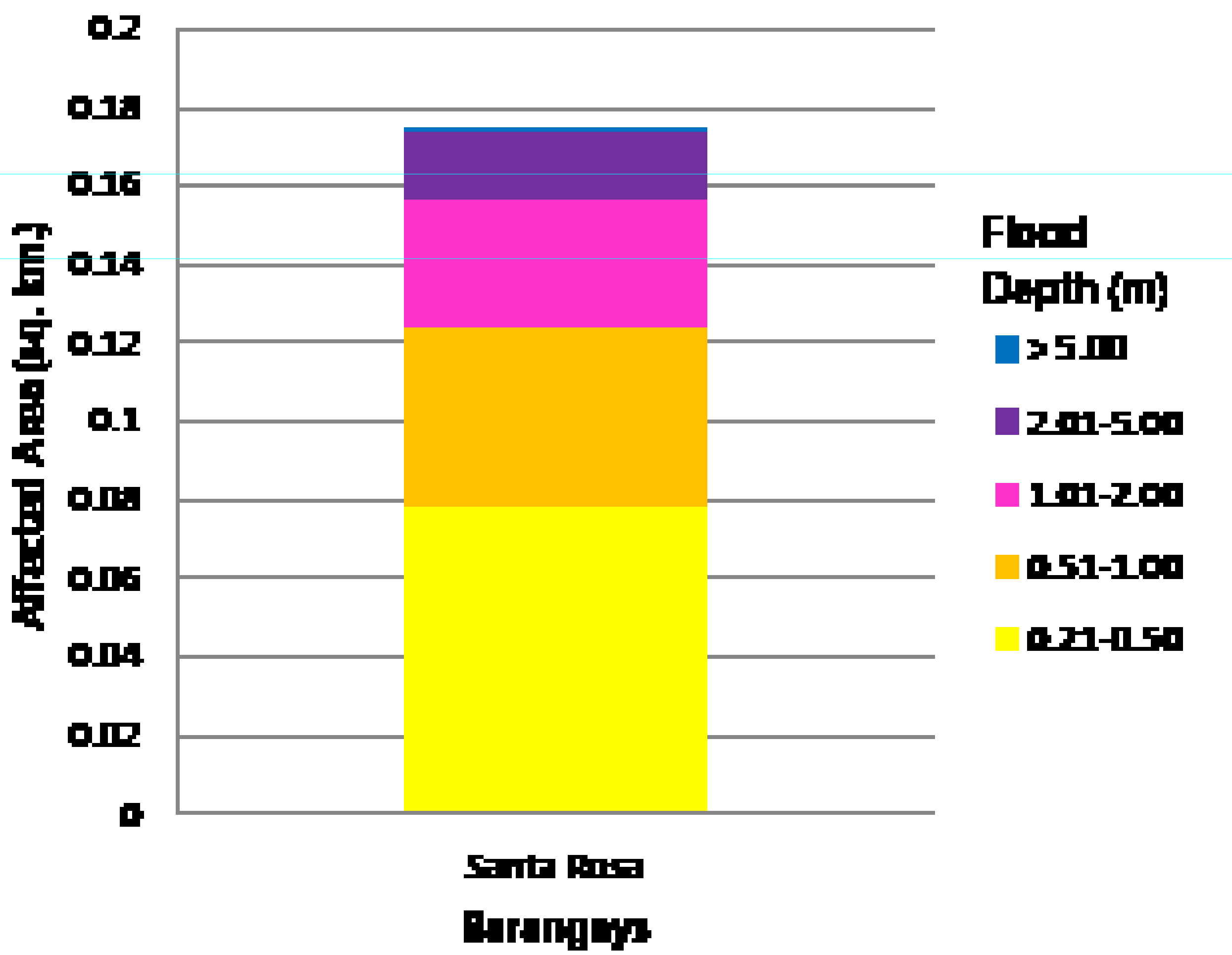


Figure 83. Affected areas in Matag-Ob, Leyte during a 100-year rainfall return period

For the Municipality of Merida, with an area of 101.48 sq. km., 11.93% will experience flood levels of less than 0.20 meters. 0.59% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.33%, 0.23%, 0.23%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 58 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 58. Affected areas in Merida, Leyte during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Merida (in sq. km.)	
	Cabaliwan	Mahayag
0.03-0.20	5.7	6.41
0.21-0.50	0.29	0.31
0.51-1.00	0.16	0.17
1.01-2.00	0.12	0.11
2.01-5.00	0.12	0.11
> 5.00	0.0019	0.011

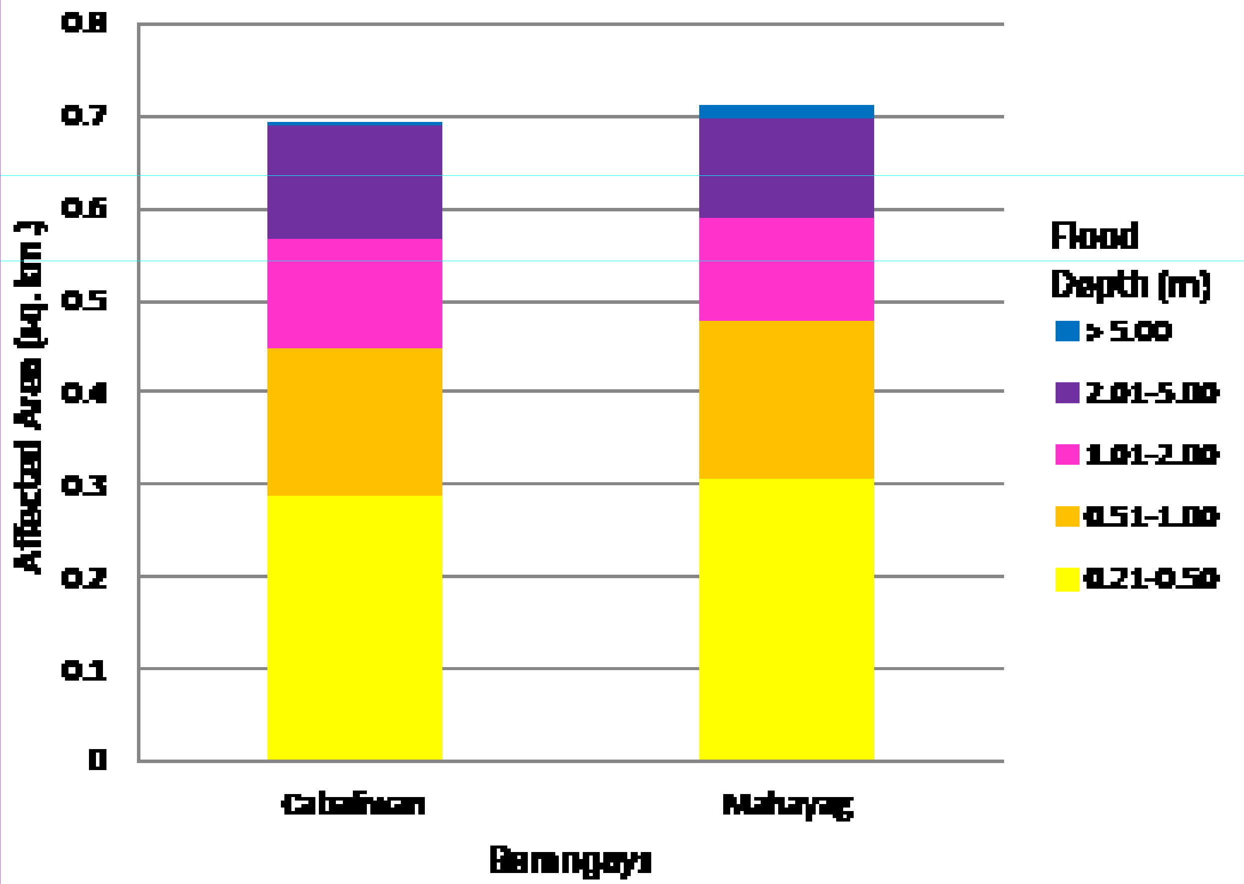


Figure 84. Affected areas in Merida, Leyte during a 25-year rainfall return period

For the Municipality of Ormoc City, with an area of 451.96 sq. km., 6.40% will experience flood levels of less than 0.20 meters. 1.64% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2%, 4.38%, 3.12%, and 0.30% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Tables 59-61 depict the affected areas, in square kilometers, by flood depth per barangay.

Table 59. Affected areas in Ormoc City, Leyte during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)							
	Airport	Bayog	Catmon	Curva	Domonar	Esperanza	Green Valley	Guintigui-An
0.03-0.20	0.64	0.0045	0.82	1.55	0.15	4.89	1.13	0.039
0.21-0.50	0.24	0.023	0.55	0.48	0.12	0.21	0.22	0.00025
0.51-1.00	0.36	0.054	0.27	0.39	0.24	0.2	0.39	0
1.01-2.00	0.11	0.35	0.38	0.11	0.61	0.45	0.36	0
2.01-5.00	0.17	0.74	0.33	0.041	1.14	0.59	1.54	0
> 5.00	0.027	0.11	0.016	0.0026	0.092	0.05	0.055	0

Table 60. Affected areas in Ormoc City, Leyte during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)							
	Labrador	Lao	Leondoni	Libertad	Licuma	Liloan	Mabato	Manlilinao
0.03-0.20	0.28	0.52	0.27	1.04	1.86	0.075	0.063	2.18
0.21-0.50	0.64	0.64	0.091	0.59	0.67	0.19	0.14	0.085
0.51-1.00	0.48	1.09	0.13	0.59	0.53	1.14	0.55	0.067
1.01-2.00	0.9	1.57	0.16	1.82	0.14	6.28	1.92	0.09
2.01-5.00	0.57	0.19	0.46	0.35	0.023	3.03	1.81	0.086
> 5.00	0.053	0.0005	0.28	0	0.0028	0.25	0.0015	0.0014

Table 61. Affected areas in Ormoc City, Leyte during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ormoc City (in sq. km.)								
	Margen	Mas-In	Nasunogan	Nueva Sociedad	Rufina M. Tan	Sabang Bao	San Jose	San Juan	San Vicente
0.03-0.20	1.65	2.11	0.44	1.86	0.57	0.036	2.37	0.85	3.52
0.21-0.50	0.42	0.2	0.093	0.097	0.043	0.14	0.87	0.48	0.18
0.51-1.00	0.61	0.25	0.02	0.044	0.044	0.2	0.21	1.05	0.12
1.01-2.00	0.46	0.33	0.0051	0.022	0.047	1.44	0.29	1.87	0.074
2.01-5.00	0.37	0.15	0.0094	0.011	0.62	1.48	0.039	0.33	0.03
> 5.00	0.0009	0	0	0	0.22	0.2	0.0001	0	0.0001

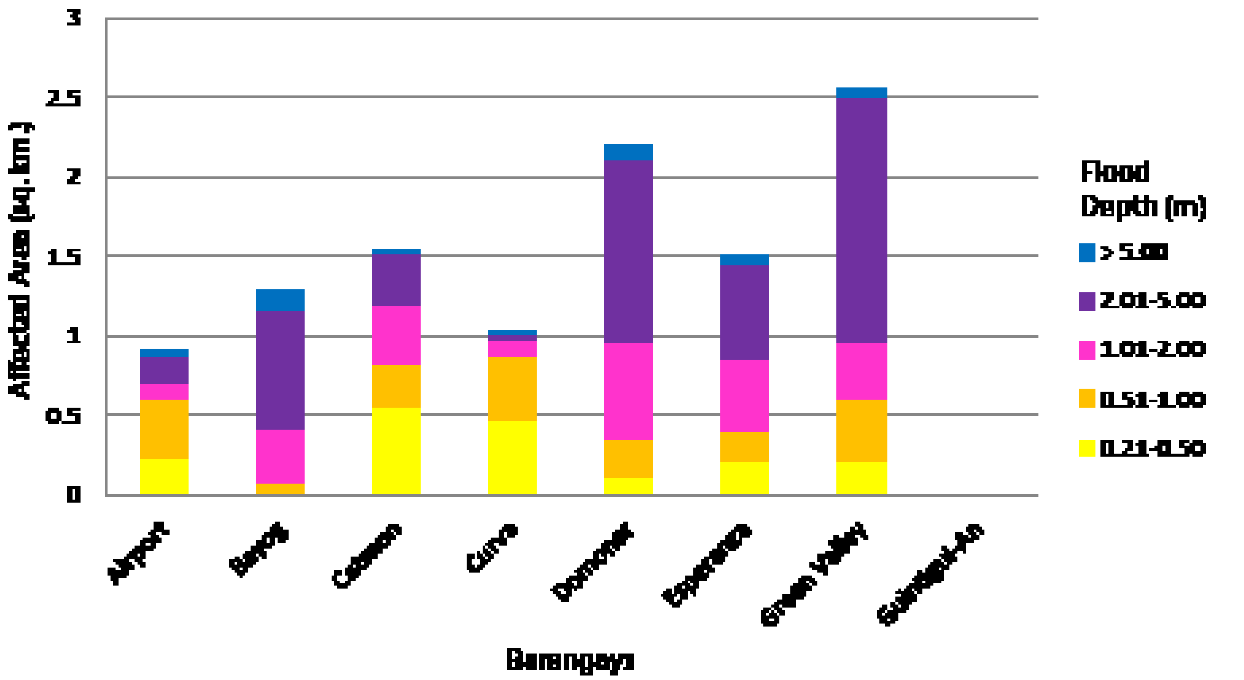


Figure 85. Affected areas in Ormoc City, Leyte during a 100-year rainfall return period

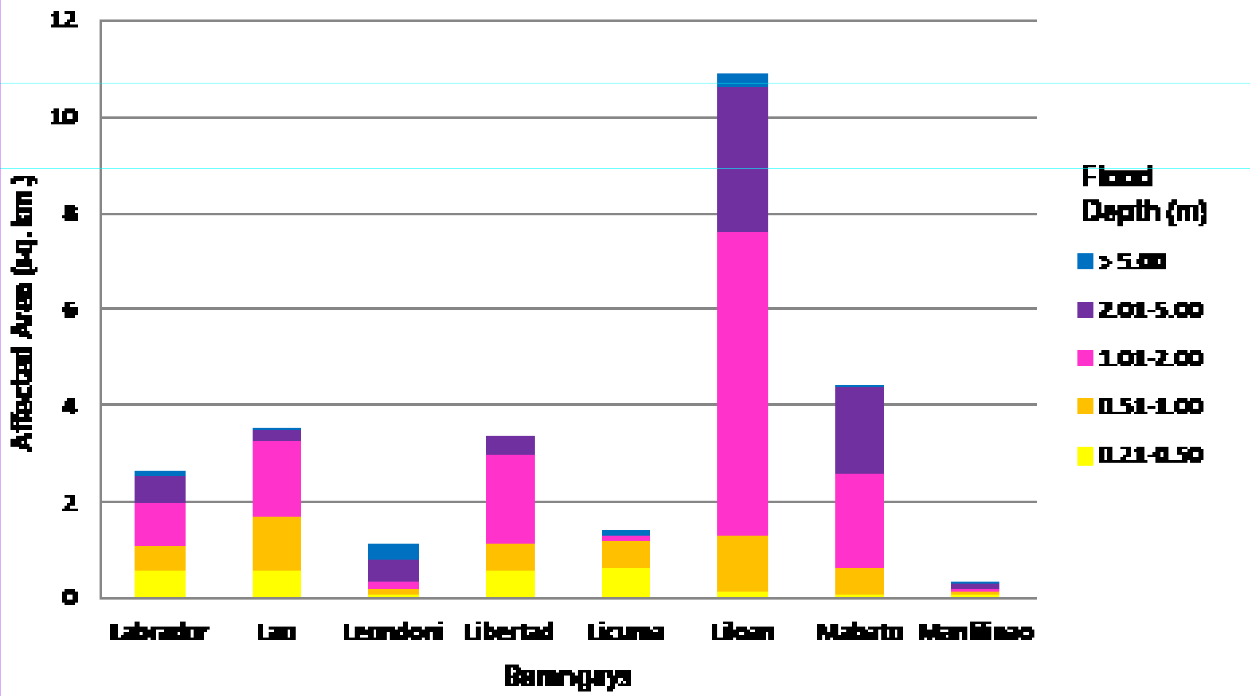


Figure 86. Affected areas in Ormoc City, Leyte during a 100-year rainfall return period

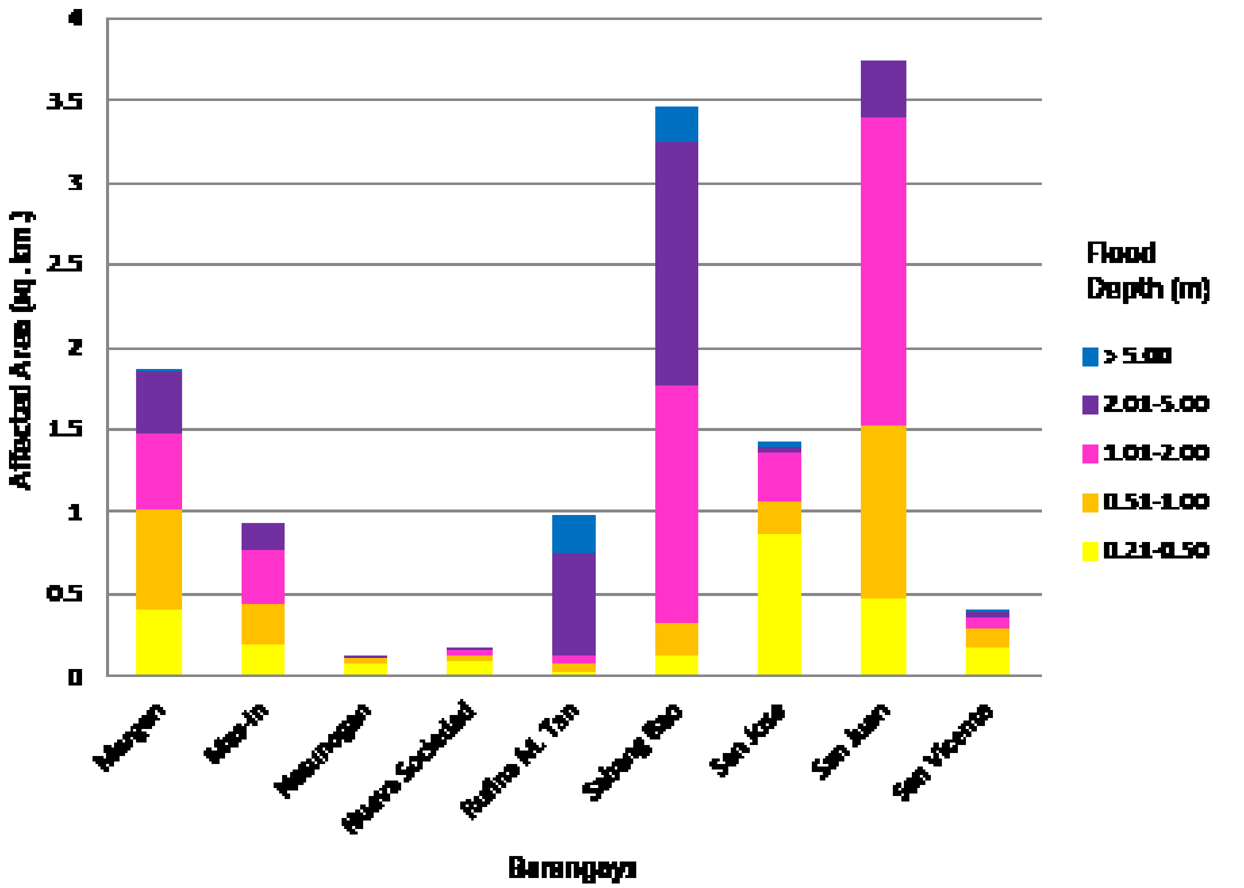


Figure 87. Affected areas in Ormoc City, Leyte during a 100-year rainfall return period

For the Municipality of Palompon, with an area of 125.87 sq. km., 0.09% will experience flood levels of less than 0.20 meters. 0.003% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.0003%, and 0.00002% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Table 62 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 62. Affected areas in Palompon, Leyte during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Palompon (in sq. km.)	
	Cambakbak	Mabini
0.03-0.20	0.042	0.066
0.21-0.50	0.0006	0.0037
0.51-1.00	0.000031	0.00034
1.01-2.00	0.000013	0.000014
2.01-5.00	0	0
> 5.00	0	0

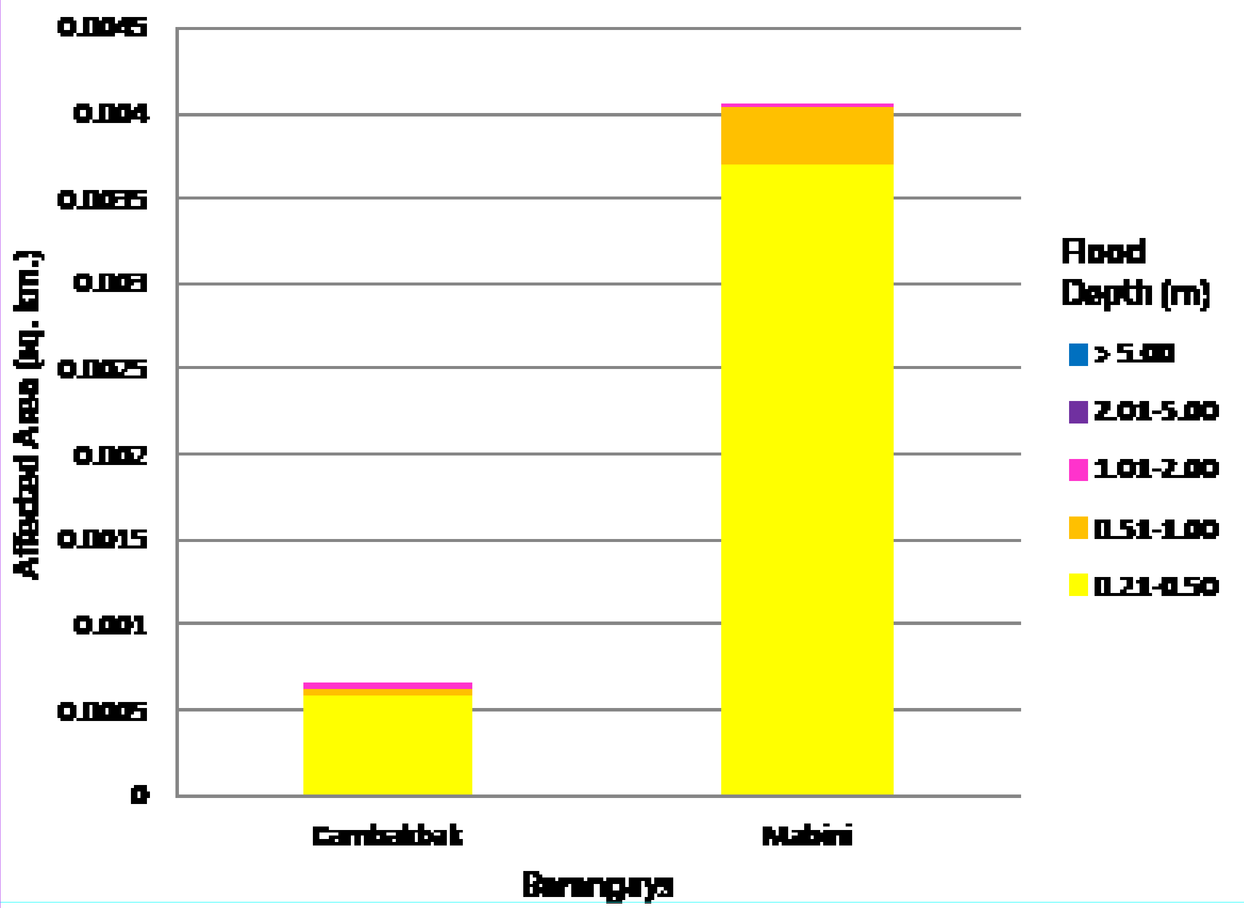


Figure 88. Affected areas in Palompon, Leyte during a 100-year rainfall return period

Among the barangays in the Municipality of Matag-Ob, Santa Rosa is projected to have the highest percentage of area that will experience flood levels, at 3.68%.

Among the barangays in the Municipality of Merida, Mahayag is projected to have the highest percentage of area that will experience flood levels, at 7.03%. On the other hand, Cabaliwan posted the second highest percentage of area that may be affected by flood depths, at 6.29%.

Among the barangays in the Municipality of Ormoc City, Liloan is projected to have the highest percentage of area that will experience flood levels, at 2.43%. On the other hand, Ezperanza posted the second highest percentage of area that may be affected by flood depths, at 1.42%.

Among the barangays in the Municipality of Palompon, Mabini is projected to have the highest percentage of area that will experience flood levels, at 0.06%. On the other hand, Cambakbak posted the second highest percentage of area that may be affected by flood depths, at 0.03%.

The generated flood hazard maps for the Pagsangahan floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood 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 63. 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	10.60	8.66	8.13
Medium	18.42	22.40	19.65
High	11.48	18.55	25.59

Of the thirty (30) identified educational institutions in the Pagsangahan floodplain, seven (7) schools were assessed to be exposed to Low-level flooding during a 5-year scenario; while six (6) schools were assessed to be exposed to Medium-level flooding, and one (1) school was assessed to be exposed to High-level flooding in the same scenario. In the 25-year scenario, three (3) schools were assessed to be exposed to Low-level flooding, thirteen (13) to Medium-level flooding, and one (1) to High-level flooding. For the 100-year scenario, two (2) schools were assessed to be exposed to Low-level flooding, and fifteen (15) schools to Medium-level flooding. In the same scenario, three (3) schools are expected to be exposed to High-level flooding. See ANNEX 12 for a detailed enumeration of schools exposed to flooding within the Pagsangahan floodplain.

Of the eight (8) identified medical institutions in the Pagsangahan floodplain, four (4) were assessed to be exposed to Medium-level flooding during a 5-year scenario. In the 25-year scenario, three (3) institutions were assessed to be exposed to Medium-level flooding, while one (1) was assessed to be exposed to High-level flooding. For the 100-year scenario, two (2) centers were assessed to be exposed to Low-level flooding, and one (1) to Medium-level flooding. In the same scenario, three (3) were assessed to be subjected to High-level flooding, which are health centers in Barangay Green Valley, Liloan, and Mabato. See ANNEX 13 for a detailed enumeration of the medical institutions exposed to flooding within the Pagsangahan 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 went to the specified points identified in a 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.

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 results of the flood map. The points in the flood maps versus the corresponding validation depths are illustrated in Figures 92-94.

The flood validation consists of 243 points, randomly selected all over the Pagsangahan floodplain. The points were grouped depending on the RIDF return period of the event. The field validation points are available in ANNEX 11.

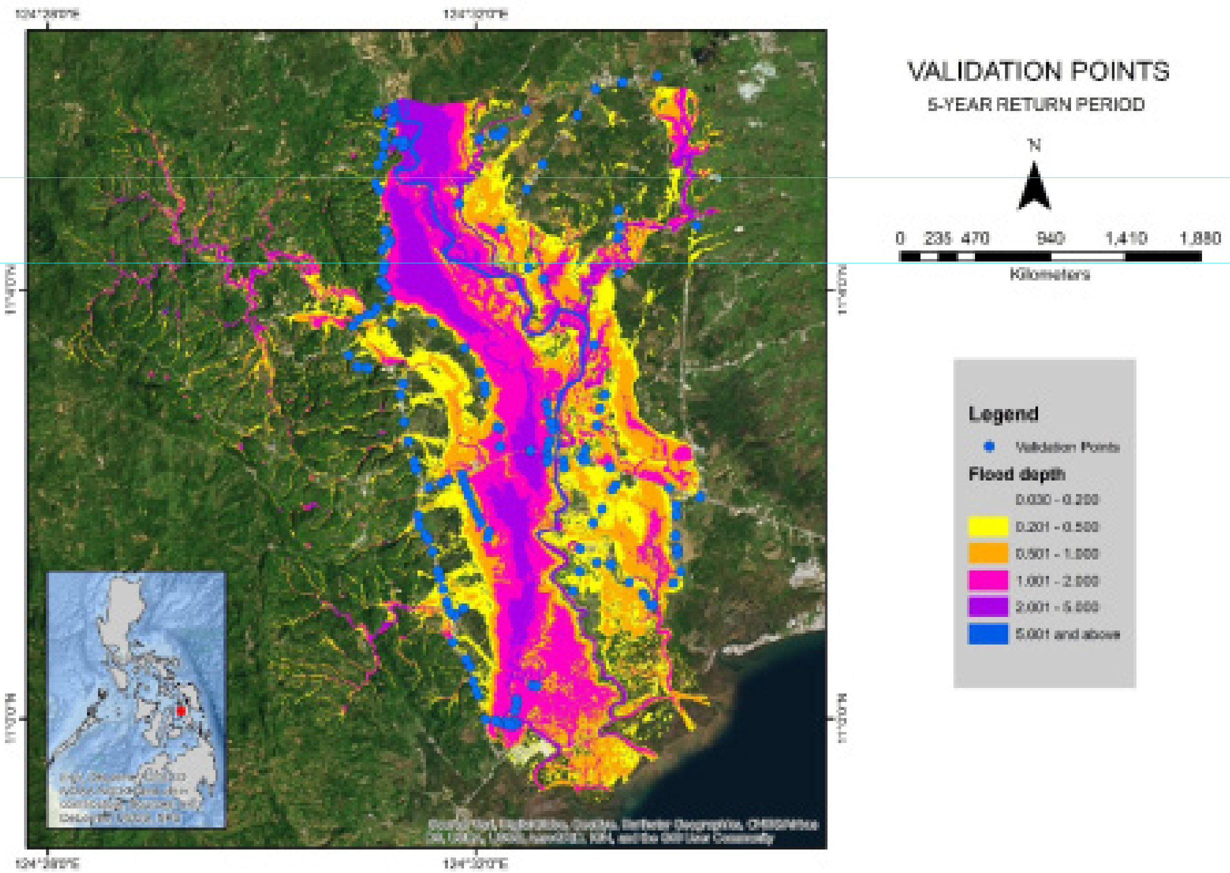


Figure 89. Validation points for the 5-year flood depth map of the Pagsangahan floodplain

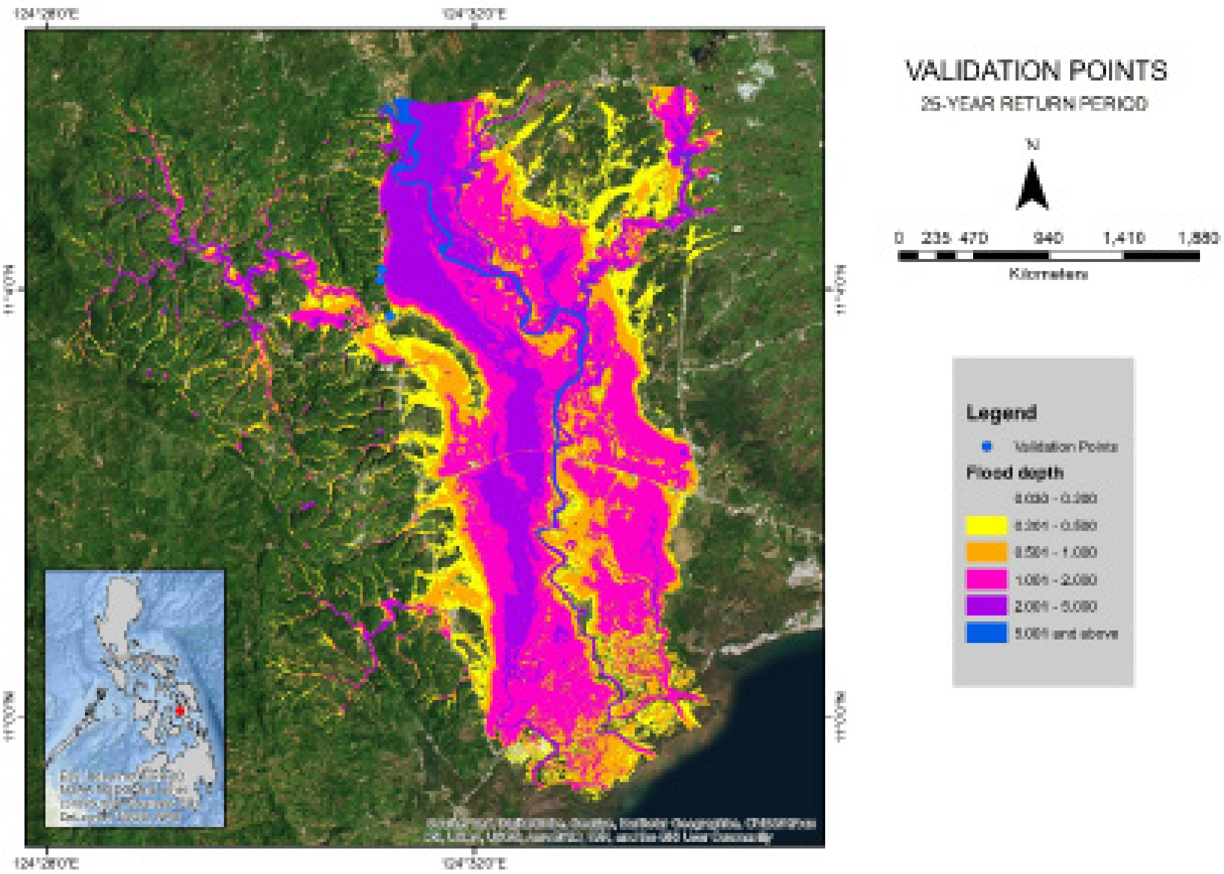


Figure 90. Validation points for the 25-year flood depth map of the Pagsangahan floodplain

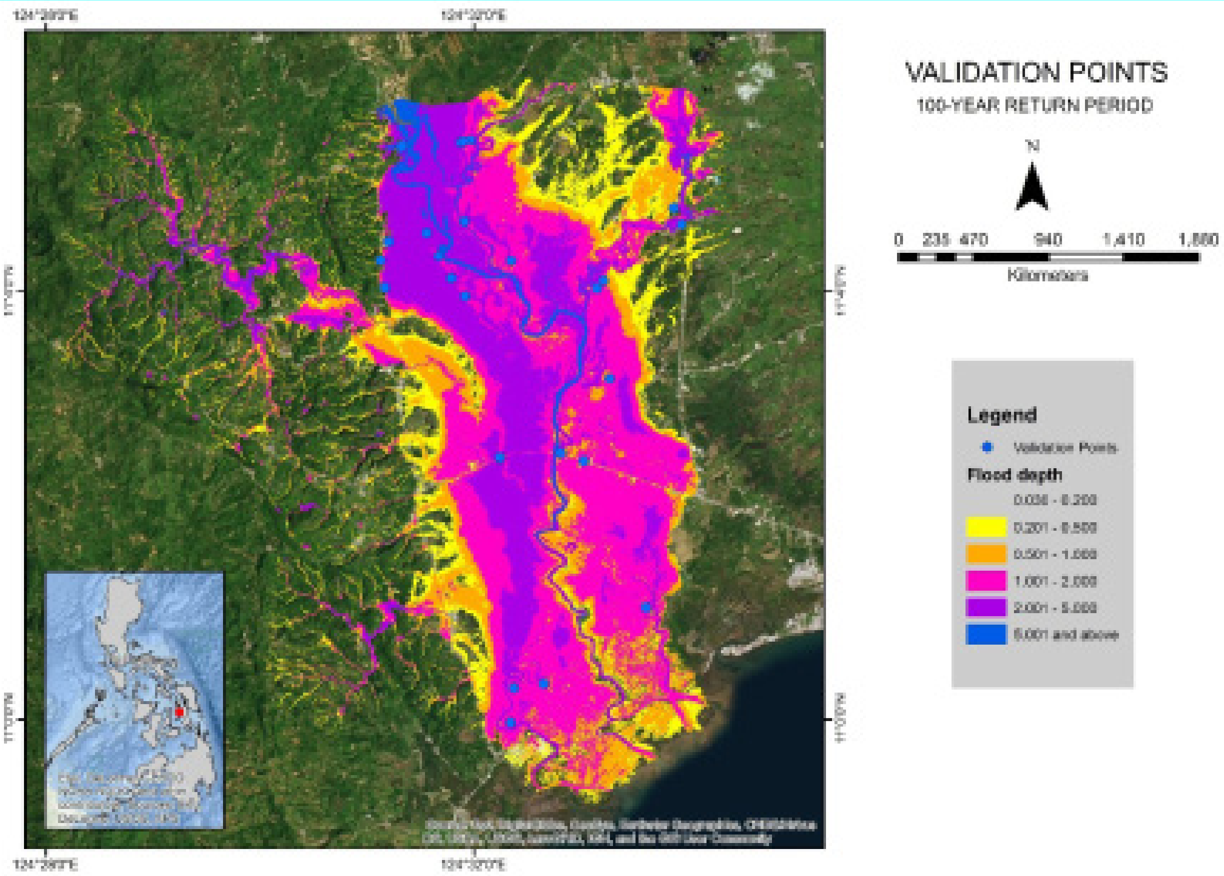


Figure 91. Validation points for the 100-year flood depth map of the Pagsangahan floodplain

The RMSE values for the flood depth maps are listed in Table 64:

Table 64. RMSE values for each return period of flood depth map

Return Period	RMSE
5-year	0.54
25-year	0.79
100-year	1.18

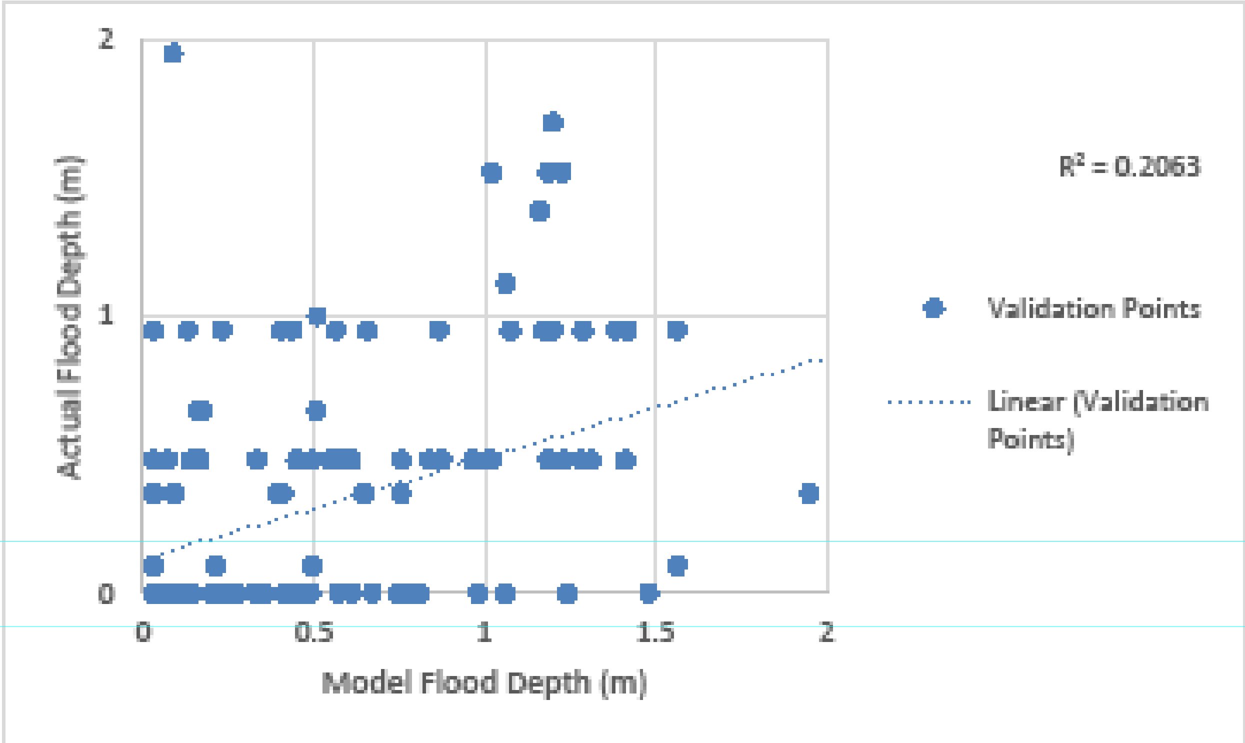


Figure 92. Flood map depth vs. actual flood depth for a 5-year return period

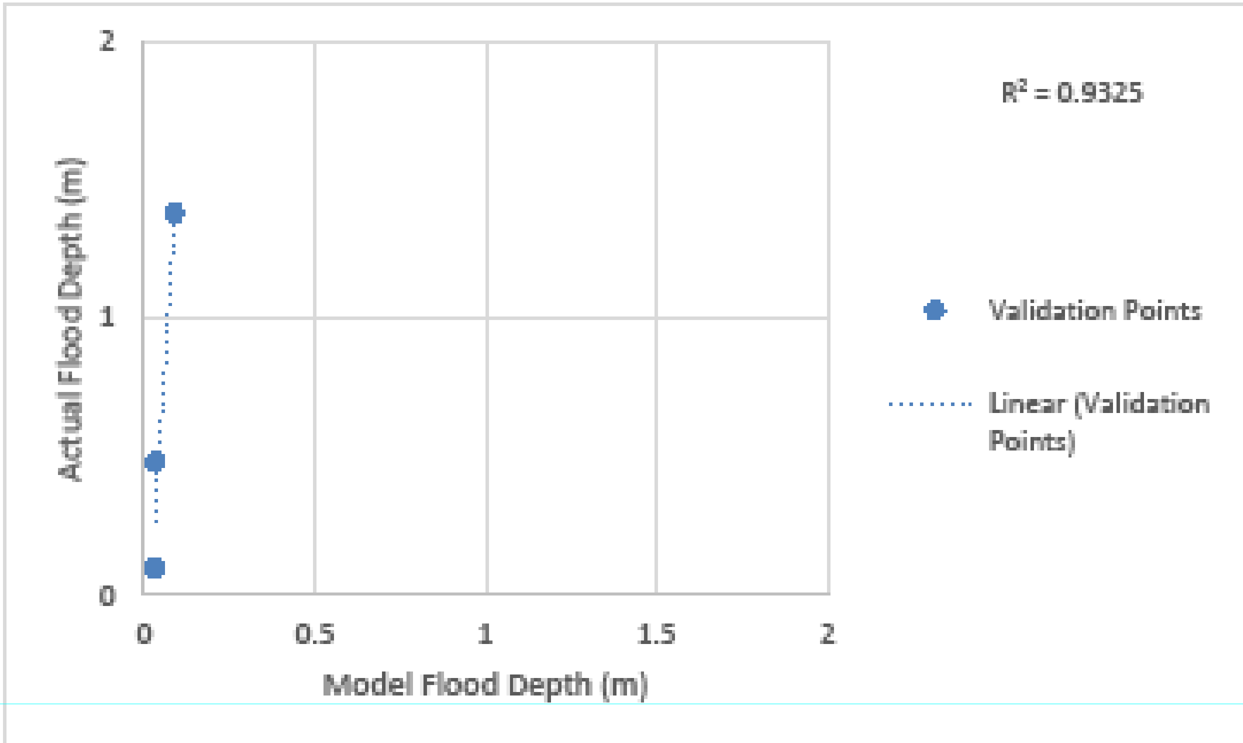


Figure 93. Flood map depth vs. actual flood depth for a 25-year return period

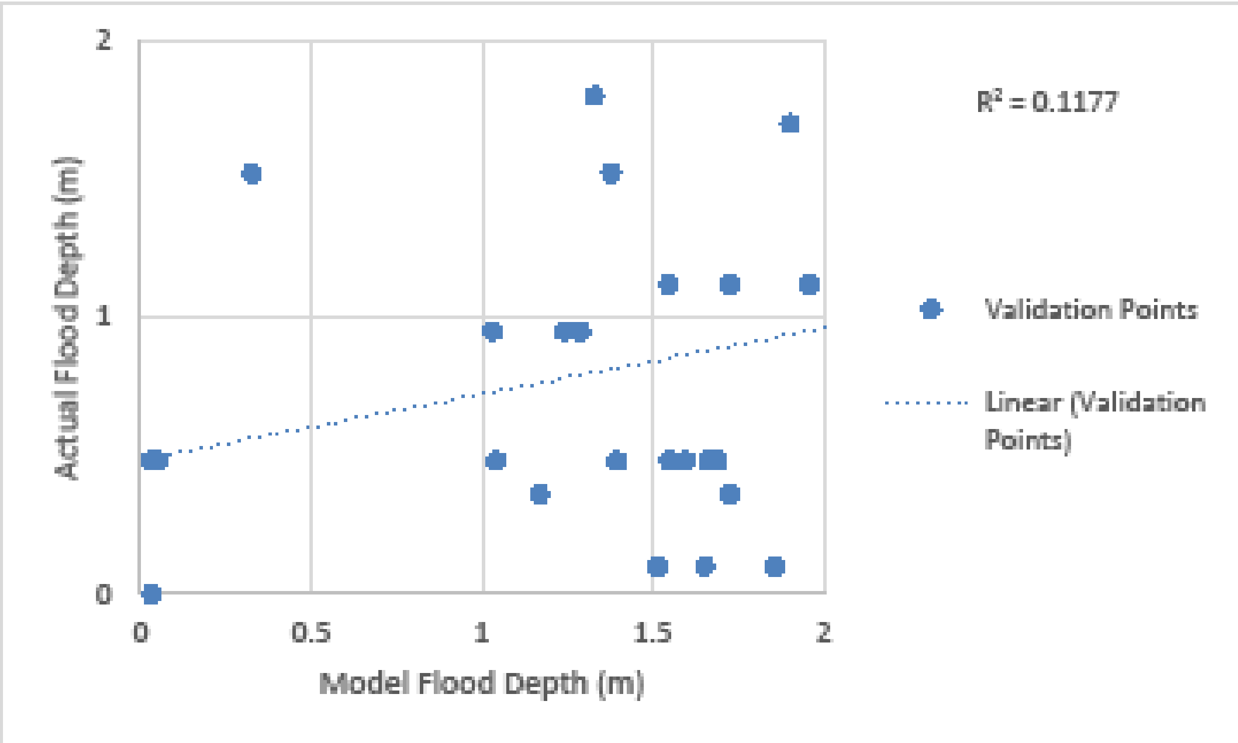


Figure 94. Flood map depth vs. actual flood depth for a 100-year return period

Table 65. Actual flood depth vs. Simulated flood depth in Pagsangahan, in the 5-year return scenario

PAGSANGAHAN BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	91	21	8	4	1	0	125
	0.21-0.50	14	5	11	8	3	0	41
	0.51-1.00	5	3	5	10	0	0	23
	1.01-2.00	1	0	0	6	0	0	7
	2.01-5.00	0	0	0	1	0	0	1
	> 5.00	0	0	0	0	0	0	0
	Total	111	29	24	29	4	0	197

The overall accuracy generated by the flood model in the 5-year return scenario is estimated at 54.31%. with one hundred and seven (107) points correctly matching the actual flood depths. There were fifty-seven (57) points estimated one (1) level above and below the correct flood depths. On the other hand, there were twenty-one (21) points and nine (9) points that were estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of twenty-four (24) points were underestimated in the modeled flood depths of the Pagsangahan floodplain.

Table 66. Summary of Accuracy Assessment in the Pagsangahan River Basin Survey for the 5-year return scenario

	No. of Points	%
Correct	81	44.75
Overestimated	56	30.94
Underestimated	44	24.31
Total	**181**	**100**

Table 67. Actual flood depth vs. Simulated flood depth in Pagsangahan, in the 25-year return scenario

PAGSANGAHAN BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	1	0	0	0	0	0	**1**
	0.21-0.50	1	0	0	0	0	0	**1**
	0.51-1.00	0	0	0	0	0	0	**0**
	1.01-2.00	1	0	0	0	0	0	**1**
	2.01-5.00	0	0	0	0	0	0	**0**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**3**	**0**	**0**	**0**	**0**	**0**	**3**

The overall accuracy generated by the flood model for the 25-year return scenario is estimated at 33.33%, with one (1) point correctly matching the actual flood depths. There was one (1) point estimated one (1) level above and below the correct flood depths; while there were zero (0) points and one (1) point estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of two (2) points were underestimated in the modeled flood depths of the Pagsangahan floodplain.

Table 68. Summary of Accuracy Assessment in the Pagsangahan River Basin Survey for the 25-year return scenario

	No. of Points	%
Correct	1	33.33
Overestimated	0	0.00
Underestimated	2	66.67
Total	**3**	**100.00**

Table 69. Actual flood depth vs. Simulated flood depth in Pagsangahan, in the 25-year return scenario

PAGSANGAHAN BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	1	0	0	3	0	0	**4**
	0.21-0.50	2	0	0	9	2	0	**13**
	0.51-1.00	0	0	0	3	0	0	**3**
	1.01-2.00	0	1	0	6	4	0	**11**
	2.01-5.00	0	0	0	1	0	0	**1**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**3**	**1**	**0**	**22**	**6**	**0**	**32**

The overall accuracy generated by the flood model for the 100-year return scenario is estimated at 21.88%, with seven (7) points correctly matching the actual flood depths. Additionally, there were ten (10) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were ten (10) points and five (5) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of four (4) points were underestimated in the modeled flood depths of the Pagsangahan River Basin survey.

Table 70. Summary of Accuracy Assessment in the Pagsangahan River Basin Survey for the 100-year return scenario

	No. of Points	%
Correct	7	21.88
Overestimated	21	65.63
Underestimated	4	12.50
Total	**32**	**100.00**

REFERENCES

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

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

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.

ANNEX

ANNEX 1. Technical Specifications of the LiDAR Sensors used in the Pagsangahan Floodplain Survey

1. AQUARIUS SENSOR

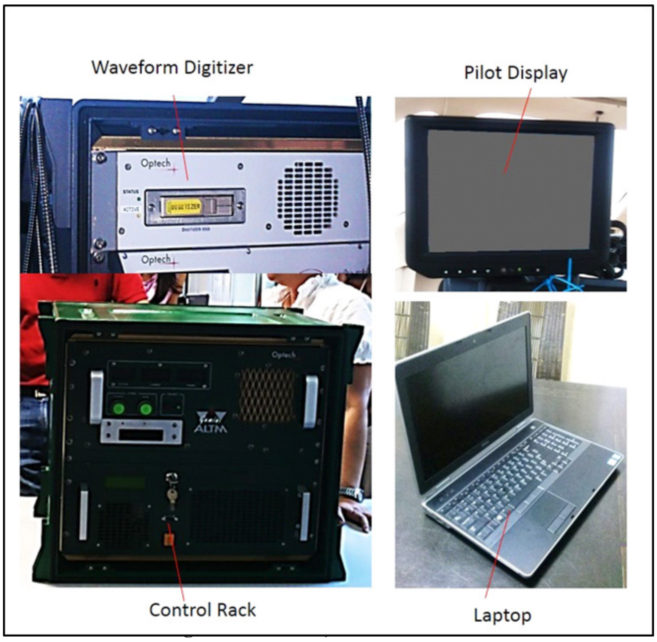


Table A-1.1. Technical specifications of the Aquarius sensor

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

Table A-1.2. Technical specifications of the Gemini sensor

Figure A-1.2. Gemini Sensor

Table A-1.2. Technical specifications of the Gemini sensor

Parameter	Specification
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	300-2500
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. LYT-37

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

April 23, 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: **LEYTE**
Station Name: **LYT-37**
Order: **4th**

Island: **VISAYAS**
Municipality: **LEYTE**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **11° 22' 17.79271"**	Longitude: **124° 29' 7.61910"**	Ellipsoidal Hgt: **5.33900 m.**

WGS84 Coordinates

Latitude: **11° 22' 13.44918"**	Longitude: **124° 29' 12.76807"**	Ellipsoidal Hgt: **65.99800 m.**

PTM Coordinates

Northing: **1257480.277 m.**	Easting: **443839.088 m.**	Zone: **5**

UTM Coordinates

Northing: **1,257,404.79**	Easting: **662,088.45**	Zone: **51**

Location Description

LYT-37
Is located at the town proper of Leyte, province of Northern Leyte. It is situated on the S corner of a 62 cm square concrete base foundation of a steel lamp post inside the town plaza in between the park and the basketball court. Station is about 22.3 mts. SSE of the centerline of Gabaldon Street, 75 cm SW of the CHB wall of the basketball court and 10 cm above the ground. Mark is the head of a 4" copper nail centered on a 10 cm square cement putty with inscription, LYT-37, 1997, NAMRIA.

Requesting Party:	**Engr. Christopher Cruz/ UP-DREAM**
Pupose:	**Reference**
OR Number:	**8796021 A**
T.N.:	**2014-918**

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. LYT-37

2. LYT-86

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

April 23, 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: **LEYTE**	
	Station Name: **LYT-86 (686)**	
	Order: **2nd**	
Island: **VISAYAS**		Barangay: **POBLACION**
Municipality: **LEYTE**		
	PRS92 Coordinates	
Latitude: **11° 22' 16.75118"**	Longitude: **124° 29' 8.10940"**	Ellipsoidal Hgt: **5.43100 m.**
	WGS84 Coordinates	
Latitude: **11° 22' 12.40727"**	Longitude: **124° 29' 13.25847"**	Ellipsoidal Hgt: **66.09100 m.**
	PTM Coordinates	
Northing: **1257448.25 m.**	Easting: **443853.897 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,257,372.86**	Easting: **662,103.47**	Zone: **51**

Location Description

LYT-86
From Tacloban City, travel 78kms. NW to Leyte. Station is located in the town plaza southern part of the multi-purpose covered court SE of the municipal hall and NE of the church. Mark is the head of a copper nail embedded and set flush to a concrete monument 0.30m x 0.30m x 1.20m protruding 0.20m above the ground with inscriptions "LYT-86 2006 NAMRIA."

Requesting Party:	**Engr. Christopher Cruz/ UP-DREAM**
Pupose:	**Reference**
OR Number:	**8796021 A**
T.N.:	**2014-917**

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-2.2. LYT-86

3. LYT-89

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

March 11, 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: **LEYTE**		
	Station Name: **LYT-89**		
	Order: **1st**		
Island: **VISAYAS**	Barangay: **SANTO NIÑO (POB.)**		
Municipality: **ISABEL**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **10° 55' 37.75929"**	Longitude: **124° 25' 59.22187"**	Ellipsoidal Hgt:	**2.53400 m.**
	WGS84 Coordinates		
Latitude: **10° 55' 33.52339"**	Longitude: **124° 26' 4.41046"**	Ellipsoidal Hgt:	**64.14500 m.**
	PTM / PRS92 Coordinates		
Northing: **1208330.431 m.**	Easting: **438033.007 m.**	Zone:	**5**
	UTM / PRS92 Coordinates		
Northing: **1,208,220.77**	Easting: **656,614.72**	Zone:	**51**

Location Description

LYT-89
From Tacloban City travel SW to Isabel for 150km. Station is located on top of the pavement SW of the municipal hall, 14m away from the right side of Rizal monument. Mark is the head of a copper nail embedded on a cement putty 0.30m x 0.30m protruding 1" from the ground with inscription "LYT-89 2006 NAMRIA."

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8090013 I**
T.N.: **2016-0614**

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-2.3. LYT-89

4. LYT-704

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

April 23, 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: **LEYTE**
Station Name: **LYT-704**
Order: **2nd**

Island: **VISAYAS**
Municipality: **KANANGA**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **11° 11' 16.35419"**	Longitude: **124° 33' 36.47427"**	Ellipsoidal Hgt: **38.29100 m.**

WGS84 Coordinates

Latitude: **11° 11' 12.06307"**	Longitude: **124° 33' 41.63876"**	Ellipsoidal Hgt: **99.58400 m.**

PTM Coordinates

Northing: **1237144.619 m.**	Easting: **451959.944 m.**	Zone: **5**

UTM Coordinates

Northing: **1,237,125.91**	Easting: **670,347.64**	Zone: **51**

Location Description

Mark is the head of a 4" copper nail embedded in a cement block with inscriptions "LYT 704, 2007, NAMRIA."

From the Municipality of Kananga, the NAMRIA monument was established about 25 m. north inside Kananga Elementary School, 4 m. northwest away from the school's entrance gate, 4 m. northwest near the basketball court, 15 m. away from the school building, 20 m. away from the school stage and entrance gate going to National Road, and along the way going to Ormoc City and to Brgy. Lemon about 5 m. north.

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-916**

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

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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

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Figure A-2.4. LYT-704

5. LYT-731

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

February 05, 2015

CERTIFICATION

To whom it may concern:

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

Province: LEYTE
Station Name: LYT-731
Order: 2nd

Island: VISAYAS
Municipality: BAYBAY
Barangay: KANSUNGKA
MSL Elevation:

PRS92 Coordinates

Latitude: 10° 42' 47.59464" Longitude: 124° 48' 34.34385" Ellipsoidal Hgt: 15.61000 m.

WGS84 Coordinates

Latitude: 10° 42' 43.44572" Longitude: 124° 48' 39.54791" Ellipsoidal Hgt: 78.65700 m.

PTM / PRS92 Coordinates

Northing: 1184617.338 m. Easting: 479165.977 m. Zone: 5

UTM / PRS92 Coordinates

Northing: 1,184,777.35 Easting: 697,902.97 Zone: 51

Location Description

LYT-731
From Babay City going to municipality of Albuera, from a bridge near babay city, Brgy. Kansungka is located on the 3rd junction on the right side of the highway, then passing thru Brgy. Candadau straight to a steel bridge near brgy. San Isidro then left to Brgy. Kasungka the control point is located near the house of ex-brgy. captain aring. The mark is a 3 inches cocnrete nail, embedded on a 40x40x100 cm. cocnrete monument having 40 cm height above the ground and is marked with LYT-731, 2007, LAMP.

Requesting Party: PHIL-LIDAR I
Purpose: Reference
OR Number: 8077605 I
T.N.: 2015-0216

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
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Figure A-2.5. LYT-731

6. LY-606

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

February 04, 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: **LEYTE**
Station Name: **LY-606**

Island: **Visayas**	Municipality: **KANANGA**	Barangay: **POBLACION**
Elevation: **42.0860 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LY-606 is located in the Municipality Kanangga, Leyte, Brgy. Ionoy. Located at the concrete sidewalk of 40m. long bridge, 4.1 m. South West from the centerline of the road.

Mark is the head of a "copper nail, set and centered on a 10 cm x 10 cm cement putty protruding about 1.0 cm above the surface of the concrete sidewalk of Canawagan bridge with inscriptions, "LY-606, 2008, NAMRIA".

It can be reached approximately by 1hr. and 52 minutes drive from Tacloban City going to Capoocan tc kanangga.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-195**

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

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CIP/4700/12/09/814

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

Figure A-2.6. LY-606

7. 7. LY-672

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: **BILIRAN**
Station Name: **LY-672**

Island: **Visayas**	Municipality: **BILIRAN**	Barangay:
Elevation: **19.7522 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

(RECOMPUTED MARCH 2014)
LY-672
Is located in the Municipality Biliran, Brgy. Bachaw. Located at the concrete sidewalk of the bridge, 30m after KM post 1006, 3.5m from the centerline of the road. Mark is the head of a 4" copper nail, set and centered on a 10cm x 10cm cement putty protruding about 1.0cm above the surface of the concrete sidewalk of Biliran bridge, with inscriptions, "LY-672, 2008 NAMRIA". It can be reached approximately by 3 hours and 27 minutes drive from Tacloban City going to Capoocan to Biliran.

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**8796290 A**
T.N.:	**2014-1294**

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

9 9 0 6 0 6 2 0 1 4 1 6 4 2 0 2

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

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Figure A-2.7. LY-672

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

1. LY-606

Table A-3.1. LY-606

LY-606 - LYT-704 (7:59:03 AM-1:36:37 PM) (S1)

Baseline observation:	LY-606 --- LYT-704 (B1)
Processed:	10/21/2014 5:29:42 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.520
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	1/28/2014 7:59:03 AM (Local: UTC+8hr)
Processing stop time:	1/28/2014 1:36:37 PM (Local: UTC+8hr)
Processing duration:	05:37:34
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYT-704				
Grid		Local		Global	
Easting	670347.639 m	Latitude	N11°11'16.32654"	Latitude	N11°11'12.03642"
Northing	1237125.056 m	Longitude	E124°33'36.47427"	Longitude	E124°33'41.63876"
Elevation	37.077 m	Height	38.292 m	Height	99.584 m

To:	LY-606				
Grid		Local		Global	
Easting	670395.829 m	Latitude	N11°11'28.07069"	Latitude	N11°11'23.77869"
Northing	1237486.135 m	Longitude	E124°33'38.12565"	Longitude	E124°33'43.28985"
Elevation	40.261 m	Height	41.477 m	Height	102.763 m

Vector					
ΔEasting	48.190 m	NS Fwd Azimuth	7°54'17"	ΔX	-3.302 m
ΔNorthing	361.079 m	Ellipsoid Dist.	364.296 m	ΔY	-83.507 m
ΔElevation	3.184 m	ΔHeight	3.186 m	ΔZ	354.597 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

2. LY-672

Table A-3.2. LY-672

LYT-37 - LY-672 (8:25:12 AM-1:23:02 PM) (S1)

Baseline observation:	LYT-37 --- LY-672 (B1)
Processed:	6/17/2014 10:02:52 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.015 m
RMS:	0.003 m
Maximum PDOP:	2.424
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	5/19/2014 8:25:27 AM (Local: UTC+8hr)
Processing stop time:	5/19/2014 1:23:02 PM (Local: UTC+8hr)
Processing duration:	04:57:35
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYT-37				
Grid		Local		Global	
Easting	662088.439 m	Latitude	N11°22'17.79317"	Latitude	N11°22'13.44918"
Northing	1257404.801 m	Longitude	E124°29'07.61902"	Longitude	E124°29'12.76807"
Elevation	4.299 m	Height	5.339 m	Height	65.998 m

To:	LY-672				
Grid		Local		Global	
Easting	661172.874 m	Latitude	N11°27'22.51942"	Latitude	N11°27'18.15341"
Northing	1266762.334 m	Longitude	E124°28'38.99619"	Longitude	E124°28'44.13687"
Elevation	19.616 m	Height	20.793 m	Height	81.224 m

Vector					
ΔEasting	-915.565 m	NS Fwd Azimuth	354°42'21"	ΔX	1755.906 m
ΔNorthing	9357.533 m	Ellipsoid Dist.	9402.938 m	ΔY	-1023.439 m
ΔElevation	15.317 m	ΔHeight	15.454 m	ΔZ	9180.687 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

3. LYT-90

Table A-3.3. LYT-90

Vector Components (Mark to Mark)

From:	CBU-340				
Grid		Local		Global	
Easting	660577.527 m	Latitude	N10°38'14.87646"	Latitude	N10°38'10.71737"
Northing	1176200.458 m	Longitude	E124°28'04.68006"	Longitude	E124°28'09.89389"
Elevation	14.571 m	Height	15.533 m	Height	77.920 m

To:	LYT-90				
Grid		Local		Global	
Easting	675667.875 m	Latitude	N11°00'17.75728"	Latitude	N11°00'13.51665"
Northing	1216919.360 m	Longitude	E124°36'28.24066"	Longitude	E124°36'33.42083"
Elevation	14.187 m	Height	15.532 m	Height	77.386 m

Vector					
ΔEasting	15090.348 m	NS Fwd Azimuth	20°36'38"	ΔX	-8272.921 m
ΔNorthing	40718.902 m	Ellipsoid Dist.	43427.367 m	ΔY	-14957.504 m
ΔElevation	-0.384 m	ΔHeight	-0.001 m	ΔZ	39921.998 m

4. LYT-690

Table A-3.4. LYT-690

Vector Components (Mark to Mark)

From:	LYT-704				
Grid		Local		Global	
Easting	670347.634 m	Latitude	N11°11'16.35419"	Latitude	N11°11'12.06307"
Northing	1237125.905 m	Longitude	E124°33'36.47427"	Longitude	E124°33'41.63876"
Elevation	37.077 m	Height	38.292 m	Height	99.584 m

To:	LYT-690				
Grid		Local		Global	
Easting	675668.331 m	Latitude	N11°00'17.68909"	Latitude	N11°00'13.44846"
Northing	1216917.267 m	Longitude	E124°36'28.25530"	Longitude	E124°36'33.43548"
Elevation	3.015 m	Height	4.361 m	Height	66.214 m

Vector					
ΔEasting	5320.697 m	NS Fwd Azimuth	165°32'59"	ΔX	-6484.391 m
ΔNorthing	-20208.638 m	Ellipsoid Dist.	20897.960 m	ΔY	219.769 m
ΔElevation	-34.062 m	ΔHeight	-33.931 m	ΔZ	-19865.343 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

5. RM-9

Table A-3.5. RM-9

RM-9 - LYT-690 (1:21:40 PM-5:25:55 PM) (S1)

Baseline observation:	RM-9 --- LYT-690 (B1)
Processed:	2/25/2015 4:28:35 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.003 m
RMS:	0.002 m
Maximum PDOP:	2.189
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	1/25/2015 1:22:03 PM (Local: UTC+8hr)
Processing stop time:	1/25/2015 5:25:55 PM (Local: UTC+8hr)
Processing duration:	04:03:52
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYT-690				
Grid		Local		Global	
Easting	675668.340 m	Latitude	N11°00'17.68890"	Latitude	N11°00'13.44827"
Northing	1216917.262 m	Longitude	E124°36'28.25559"	Longitude	E124°36'33.43578"
Elevation	3.039 m	Height	4.384 m	Height	66.238 m

To:	RM-9				
Grid		Local		Global	
Easting	675679.222 m	Latitude	N11°00'18.53023"	Latitude	N11°00'14.28954"
Northing	1216943.169 m	Longitude	E124°36'28.61863"	Longitude	E124°36'33.79880"
Elevation	1.915 m	Height	3.260 m	Height	65.114 m

Vector					
ΔEasting	10.882 m	NS Fwd Azimuth	23°05'28"	ΔX	-5.641 m
ΔNorthing	25.908 m	Ellipsoid Dist.	28.101 m	ΔY	-11.228 m
ΔElevation	-1.124 m	ΔHeight	-1.123 m	ΔZ	25.180 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'06"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

2

6. LYT-704bak

Table A-3.6. LYT-704bak

Vector Components (Mark to Mark)

From:	LYT-704				
Grid		Local		Global	
Easting	670347.634 m	Latitude	N11°11'16.35419"	Latitude	N11°11'12.06307"
Northing	1237125.905 m	Longitude	E124°33'38.47427"	Longitude	E124°33'41.63876"
Elevation	37.077 m	Height	38.292 m	Height	99.584 m

To:	LYT-704bak				
Grid		Local		Global	
Easting	670363.675 m	Latitude	N11°11'16.44188"	Latitude	N11°11'12.15076"
Northing	1237128.684 m	Longitude	E124°33'37.00349"	Longitude	E124°33'42.16798"
Elevation	36.879 m	Height	38.093 m	Height	99.386 m

Vector					
ΔEasting	16.041 m	NS Fwd Azimuth	80°28'28"	ΔX	-12.816 m
ΔNorthing	2.779 m	Ellipsoid Dist.	16.281 m	ΔY	-9.699 m
ΔElevation	-0.198 m	ΔHeight	-0.198 m	ΔZ	2.605 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'04"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000004270		
Y	-0.0000001498	0.0000005232	
Z	-0.0000000477	0.0000000726	0.0000001116

2

7. CBU-340

Table A-3.7. CBU-340

LYT-89 - CBU-340 (11:38:45 AM-4:56:27 PM) (S3)

Baseline observation:	LYT-89 --- CBU-340 (B3)
Processed:	3/30/2016 6:34:43 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.013 m
RMS:	0.003 m
Maximum PDOP:	2.939
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/19/2016 11:38:45 AM (Local: UTC+8hr)
Processing stop time:	3/19/2016 4:56:27 PM (Local: UTC+8hr)
Processing duration:	05:17:42
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	CBU-340				
Grid		Local		Global	
Easting	660577.527 m	Latitude	N10°38'14.87646"	Latitude	N10°38'10.71737"
Northing	1176200.458 m	Longitude	E124°28'04.68006"	Longitude	E124°28'09.89389"
Elevation	14.571 m	Height	15.533 m	Height	77.920 m

To:	LYT-89				
Grid		Local		Global	
Easting	656614.260 m	Latitude	N10°55'37.82577"	Latitude	N10°55'33.58987"
Northing	1208222.807 m	Longitude	E124°25'59.20715"	Longitude	E124°26'04.39573"
Elevation	12.453 m	Height	13.758 m	Height	75.389 m

Vector					
ΔEasting	-3963.267 m	NS Fwd Azimuth	353°13'09"	ΔX	6536.228 m
ΔNorthing	32022.349 m	Ellipsoid Dist.	32269.539 m	ΔY	-2787.852 m
ΔElevation	-2.118 m	ΔHeight	-1.775 m	ΔZ	31477.438 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

2

8. W-22

Table A-3.8. W-22

Vector Components (Mark to Mark)

From:	W-22				
Grid		Local		Global	
Easting	675563.750 m	Latitude	N11°00'18.93705"	Latitude	N11°00'14.69624"
Northing	1216955.050 m	Longitude	E124°36'24.81698"	Longitude	E124°36'29.99714"
Elevation	6.321 m	Height	7.666 m	Height	69.516 m

To:	LYT-89				
Grid		Local		Global	
Easting	656614.289 m	Latitude	N10°55'37.85585"	Latitude	N10°55'33.61994"
Northing	1208223.732 m	Longitude	E124°25'59.20825"	Longitude	E124°26'04.39683"
Elevation	6.075 m	Height	7.380 m	Height	68.991 m

Vector					
ΔEasting	-18949.461 m	NS Fwd Azimuth	245°34'01"	ΔX	14718.902 m
ΔNorthing	-8731.318 m	Ellipsoid Dist.	20865.492 m	ΔY	12117.344 m
ΔElevation	-0.246 m	ΔHeight	-0.286 m	ΔZ	-8478.938 m

ANNEX 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
		JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	PAULINE JOANNE ARCEO	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		GRACE SINDJAN	UP-TCAGP
		LARAH KRISELLE PARAGAS	UP-TCAGP
		JONALYN GONZALES	UP-TCAGP
		FRANK NICOLAS ILEJAY	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	IRO NIEL ROXAS	UP-TCAGP
		FRANK NICOLAS ILEJAY	UP-TCAPG
		DAN CHRISTOFFER ALDOVINO	UP-TCAGP
		JERIEL PAUL ALAMBAN, GEOL.	UP-TCAPG
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		SSG. RANDY SISON	PAF
		TSG. SANDY UY	PAF
	Pilot	CAPT. JACKSON JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JEFFREY JEREMY ALAJAR	AAC
		CAPT. NIEL ACHILLES AGAWIN	AAC
		CAPT. JEROME MOONEY	AAC
		CAPT. ANTHONY DAYO	AAC
		CAPT. FERDINAND DE OCAMPO	AAC

ANNEX 5. Data Transfer Sheets for the Pagsangahan Floodplain Flights

DATA TRANSFER SHEET

Feb 3, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
28-Jan-14	1032A	3BLK3SAC28A	Aquarius	N/A	N/A	927 KB	54.6 MB	26.4 GB	246 KB	13.7 GB	30.1 GB	10.8 MB	86 BYTES	651 BYTES	4.09 KB	546 KB	Y:\Airborne_Raw\1032A
29-Jan-14	1036A	3BLK33DS029A	Aquarius	N/A	N/A	541 KB	117 MB	27.2 GB	201 KB	6.12 GB	28.7 GB	18.2 MB	73 BYTES	369 BYTES	2.86 KB	243 KB	Y:\Airborne_Raw\1036A
30-Jan-14	1040A	3BLK33MVO30A	Aquarius	N/A	N/A	724 KB	217 MB	36.2 GB	302 KB	9.33 GB	1.14 GB	11.7 MB	305 BYTES	1.46 KB	6.89 KB	396 KB	Y:\Airborne_Raw\1040A

Received from

Name: Patricia Alcantara

Position: RA

Signature:

Received by

Name: JOIDA F. PRIETO

Position: SSRS

Signature:

Figure A-5.1. Data Transfer Sheet for Pagsangahan Floodplain – A

DATA TRANSFER SHEET
[illegible]

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
4/28/2014	[illegible]	[illegible]	AQUARIUS	NA	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]	1KB	1KB	[illegible]	[illegible]	Z:\Airborne_Raw\[illegible]
4/28/2014	[illegible]	[illegible]	AQUARIUS	NA	NA	[illegible]	[illegible]	41.1GB	[illegible]	[illegible]	NA	[illegible]	1KB	1KB	[illegible]	[illegible]	Z:\Airborne_Raw\[illegible]
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Received from

Name
Position
Signature

Received by

Name JOIDA F. PRIETO
Position
Signature

[illegible]

Figure A-5.2. Data Transfer Sheet for Pagsangahan Floodplain – B

DATA TRANSFER SHEET
[illegible]

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	733	1.24	277	91.7	590	13.3	NA	14.6	1KB	1KB	6	13	Z:\Airborne_Raw\1458A
5/17/2014	1466A	3BLK35F137A	AQUARIUS	na	680	1.29	244	94.7	130/503	16	181	7.88	1KB	1KB	4	NA	Z:\Airborne_Raw\1466A
5/19/2014	1474A	3BLK35G138A	AQUARIUS	na	1484	1.61	291	90.2	598	14	218	8.7	1KB	1KB	6	NA	Z:\Airborne_Raw\1474A
5/24/2014	1494A	3BLK35GSH144A	AQUARIUS	na	813/989	1.25	292	88.2	508	14.7	182	7.04	1KB	1KB	6	NA	Z:\Airborne_Raw\1494A
5/25/2014	1498A	3BLK35HSI145A	AQUARIUS	na	1822	1.7	292	88.7	554	5.29	8.47	8.04	1KB	1KB	5	NA	Z:\Airborne_Raw\1498A
5/26/2014	1502A	3BLK35I5146A	AQUARIUS	na	785	1.2	276	86.7	484	13.8	107	15.7	1KB	1KB	6	NA	Z:\Airborne_Raw\1502A
5/26/2014	1504A	3BLK35AIS146B	AQUARIUS	na	613/989	1.37	255	91.3	480	11.4	20.8	18.7	1KB	1KB	3	NA	Z:\Airborne_Raw\1504A
5/27/2014	1506A	3BLK33U147A	AQUARIUS	na	394	1.34	278	97.2	737	14.4	98.2/202.5	15	1KB	1KB	4	NA	Z:\Airborne_Raw\1506A
5/27/2014	1508A	3BLK33UST147B	AQUARIUS	na	249/1240	2	232	5.1/51.6	403/328	11.5	NA	15	1KB	1KB	5	NA	Z:\Airborne_Raw\1508A
5/28/2014	1510A	3BLK33TSV148A	AQUARIUS	na	818/172	1.61	288	114	534	15.5	189	8.65	1KB	1KB	5	NA	Z:\Airborne_Raw\1510A

Received from

Name C. JOAQUIN
Position
Signature

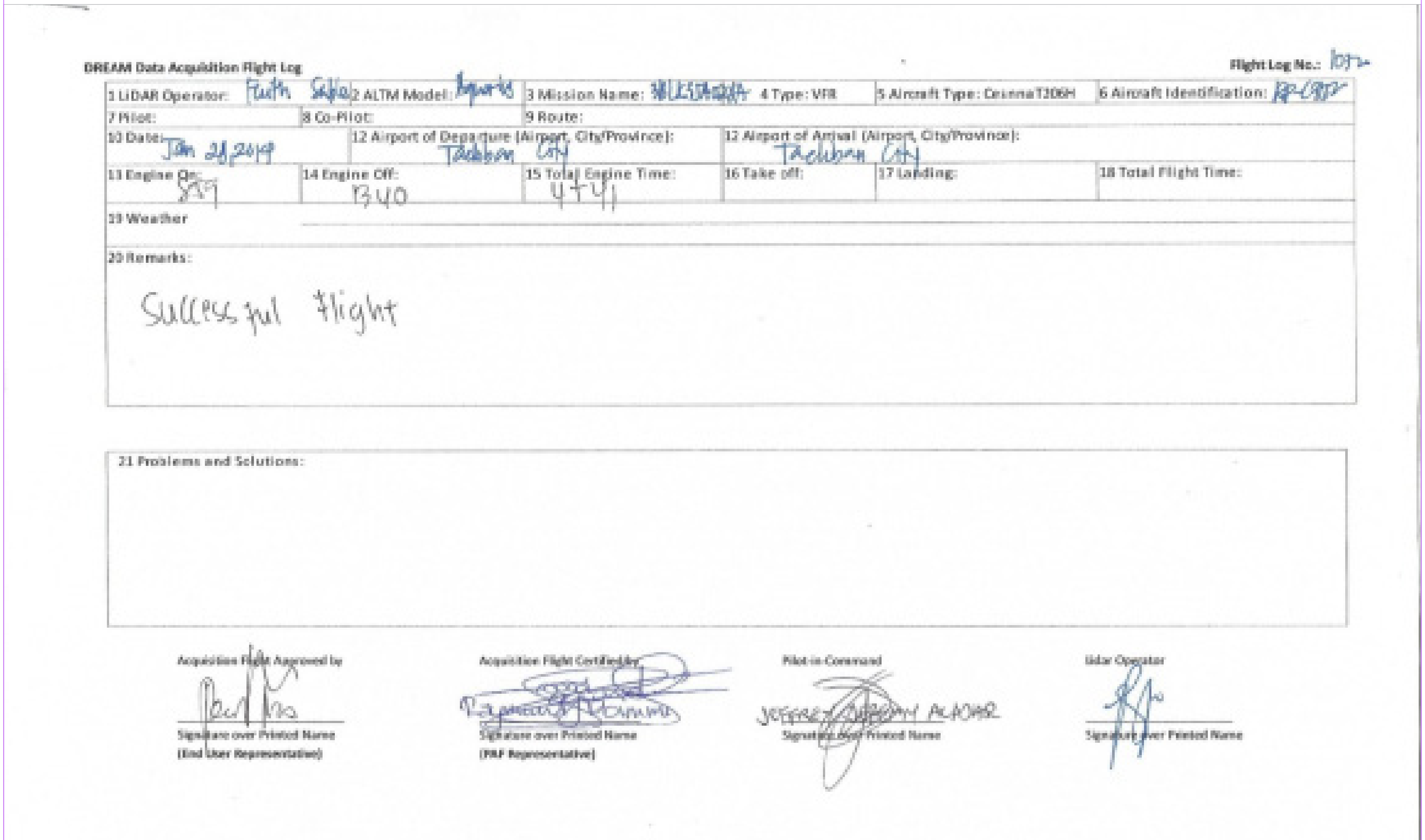
Received by

Name JONAH F. PRIETO 6/10/14
Position
Signature

Figure A-5.3. Data Transfer Sheet for Pagsangahan Floodplain – C

ANNEX 6. Flight Logs for the Flight Missions

1. Flight Log for 1032A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1032

1 LiDAR Operator: Ruth Salva	2 ALTM Model: Aquarius	3 Mission Name: 3BLK57A028A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: Jan 28, 2014	12 Airport of Departure (Airport, City/Province): Tacloban City		12 Airport of Arrival (Airport, City/Province): Tacloban City		
13 Engine On: 859	14 Engine Off: 1340	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Successful flight

21 Problems and Solutions:

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

Figure A-6.1. Flight Log for Mission 1032A

2. Flight Log for 1458A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1458

1 LIDAR Operator: Joe Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK34A135A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Jaime	8 Co-Pilot: N. Aquino	9 Route:			
10 Date: 15 May 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 751	14 Engine Off: 1226	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

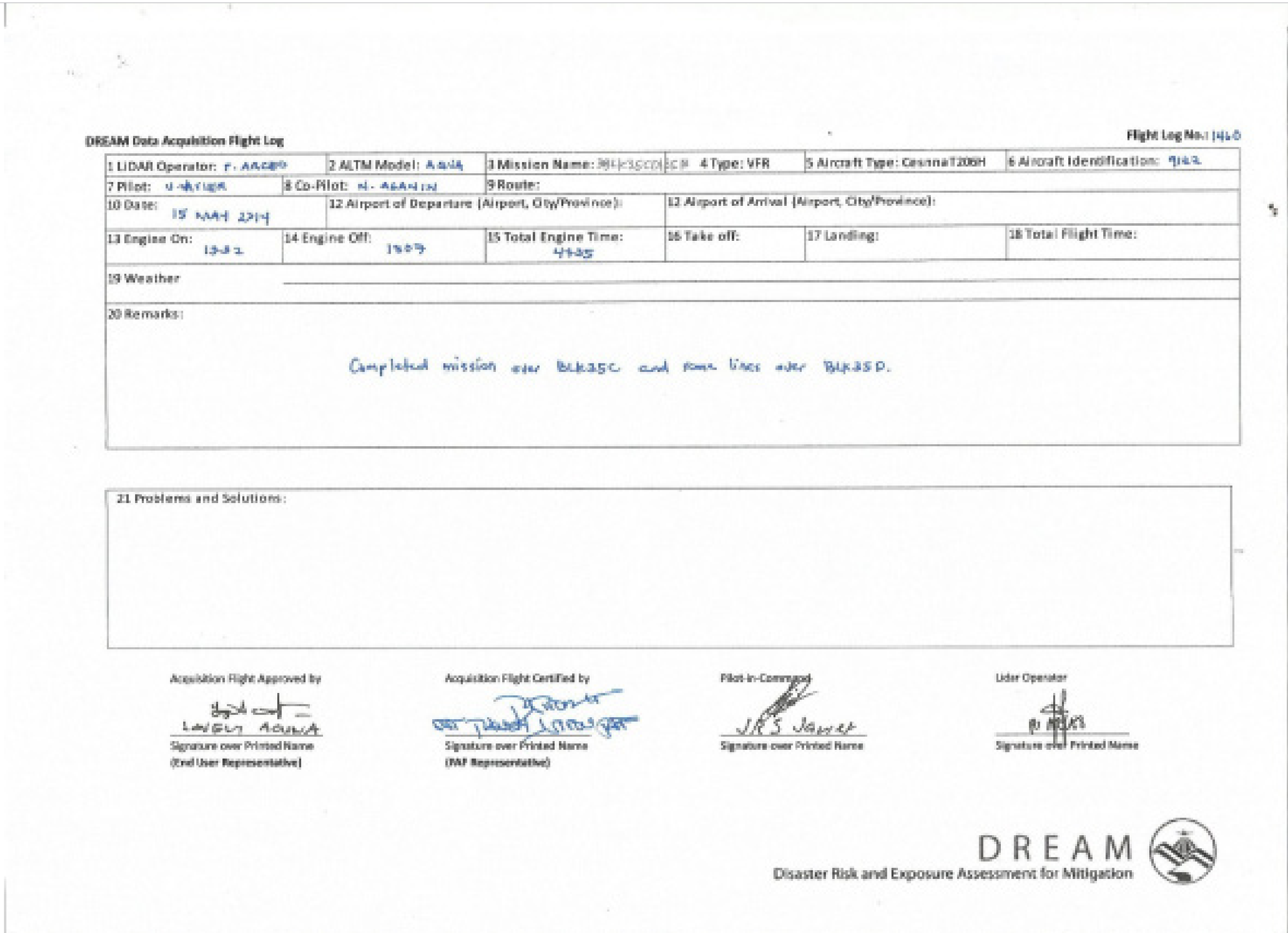
Completed mission over BLK35B

21 Problems and Solutions:

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

Figure A-6.2. Flight Log for Mission 1458A

3. Flight Log for 1460A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1460

1 LiDAR Operator: F. Agcaoili	2 ALTM Model: Aquarius	3 Mission Name: 3BLK35CD135A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Jamero	8 Co-Pilot: N. Adanza	9 Route:			
10 Date: 15 May 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1332	14 Engine Off: 1809	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK35C and some lines over BLK35D.					

21 Problems and Solutions:

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

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

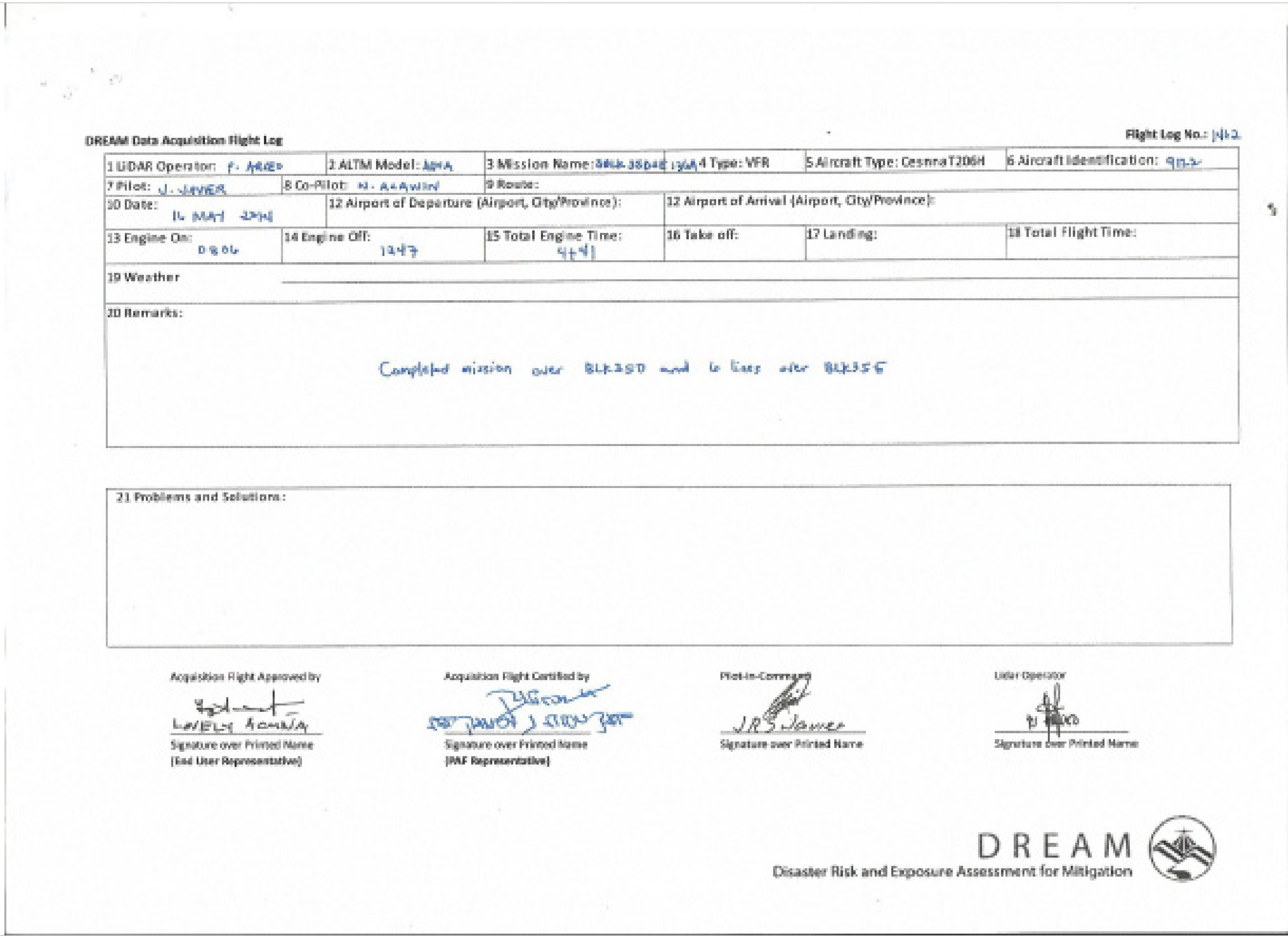
Pilot-in-Command: J.R.S. Jamero, Signature over Printed Name

Lidar Operator: Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1460A

4. Flight Log for 1462A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1462

1 LiDAR Operator: F. ARIES	2 ALTM Model: AQUA	3 Mission Name: 3BLK38D&E 136A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALAWIN	9 Route:			
10 Date: 16 MAY 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0806	14 Engine Off: 1247	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK38D and 6 lines over BLK38E					
21 Problems and Solutions:					

Acquisition Flight Approved by

LOVELY ACUÑA

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

SSG JANCEN J SIRON PAF

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

JRS Javier

Signature over Printed Name

Lidar Operator

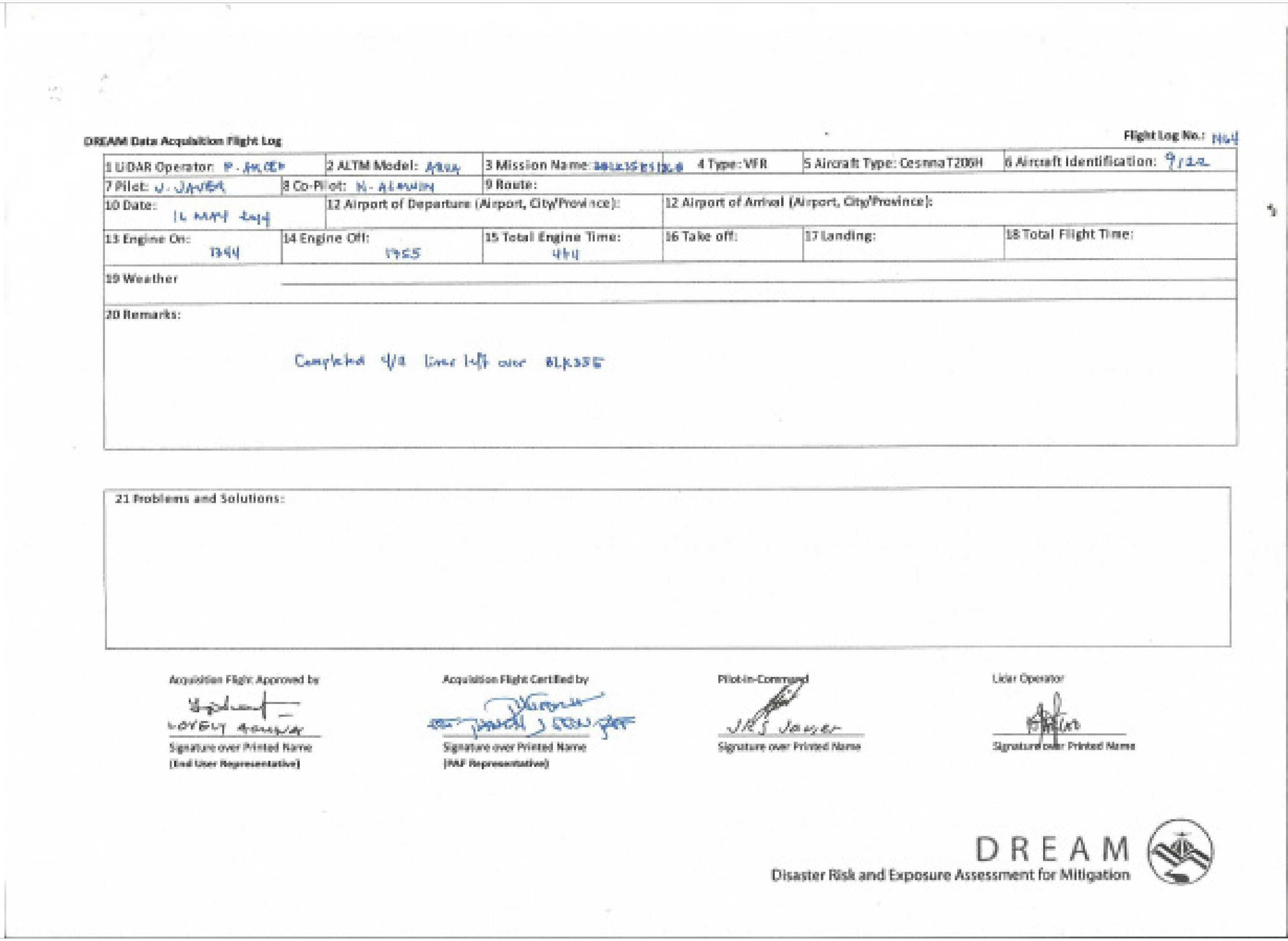
FI ARIES

Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4. Flight Log for Mission 1462A

5. Flight Log for 1464A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1464

1 LIDAR Operator: P. ANCEP	2 ALTM Model: AQUA	3 Mission Name: 1BLK35E135A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALMALVIN	9 Route:			
10 Date: 16 MAY 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1344	14 Engine Off: 1755	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 4/12 lines left over BLK35E

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)

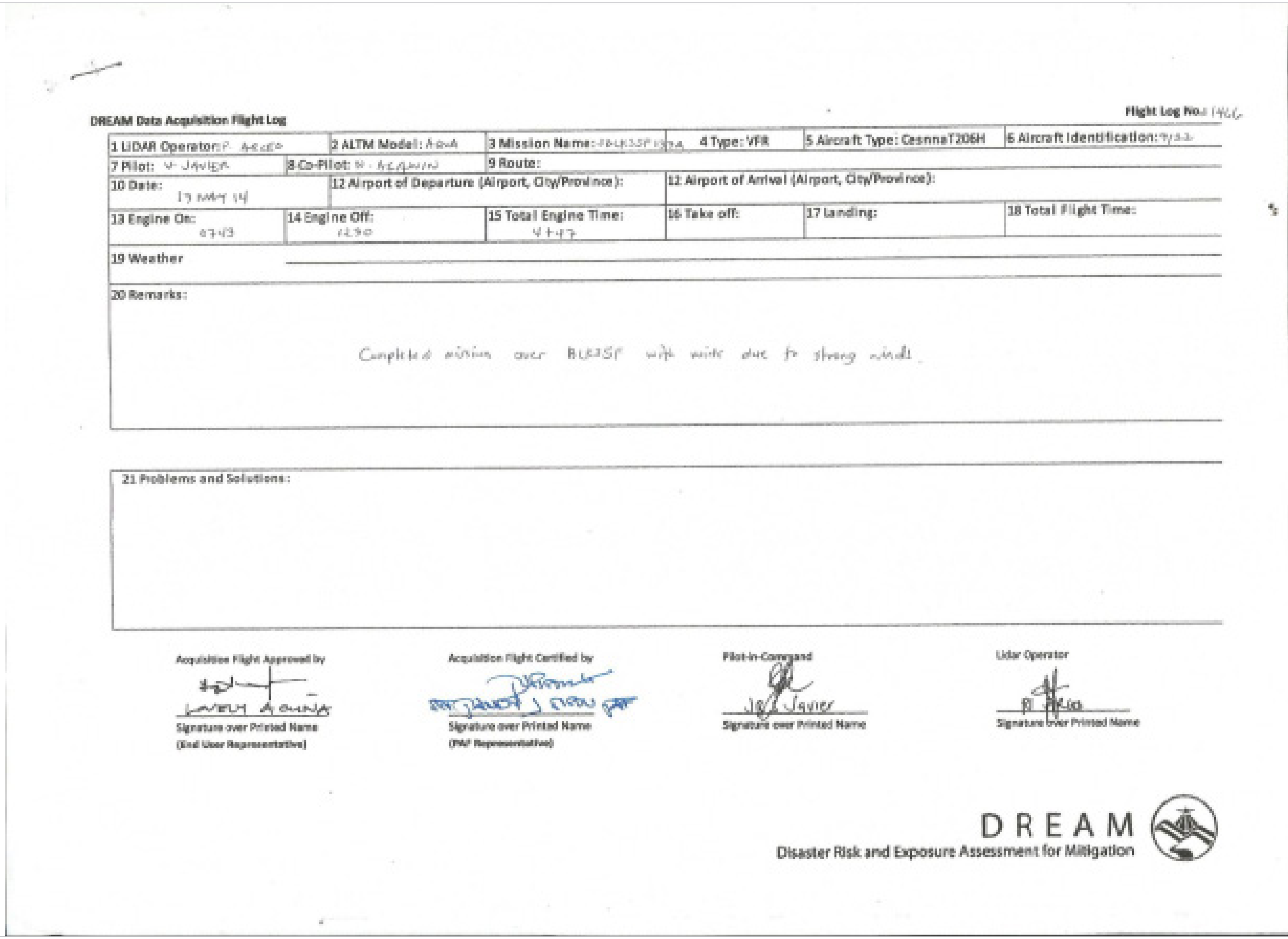
Pilot-in-Command: J.R.S. JAVIER — Signature over Printed Name

Lidar Operator: Signature over Printed Name

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.5. Flight Log for Mission 1464A

6. Flight Log for 1466A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1466

1 LiDAR Operator: P. ARCEO	2 ALTM Model: AQUA	3 Mission Name: 2BLK35F134A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: V. JAVIER	8 Co-Pilot: N. ACJUAN	9 Route:			
10 Date: 13 MAY 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0743	14 Engine Off: 1230	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission over BLK35F with voids due to strong winds

21 Problems and Solutions:

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

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

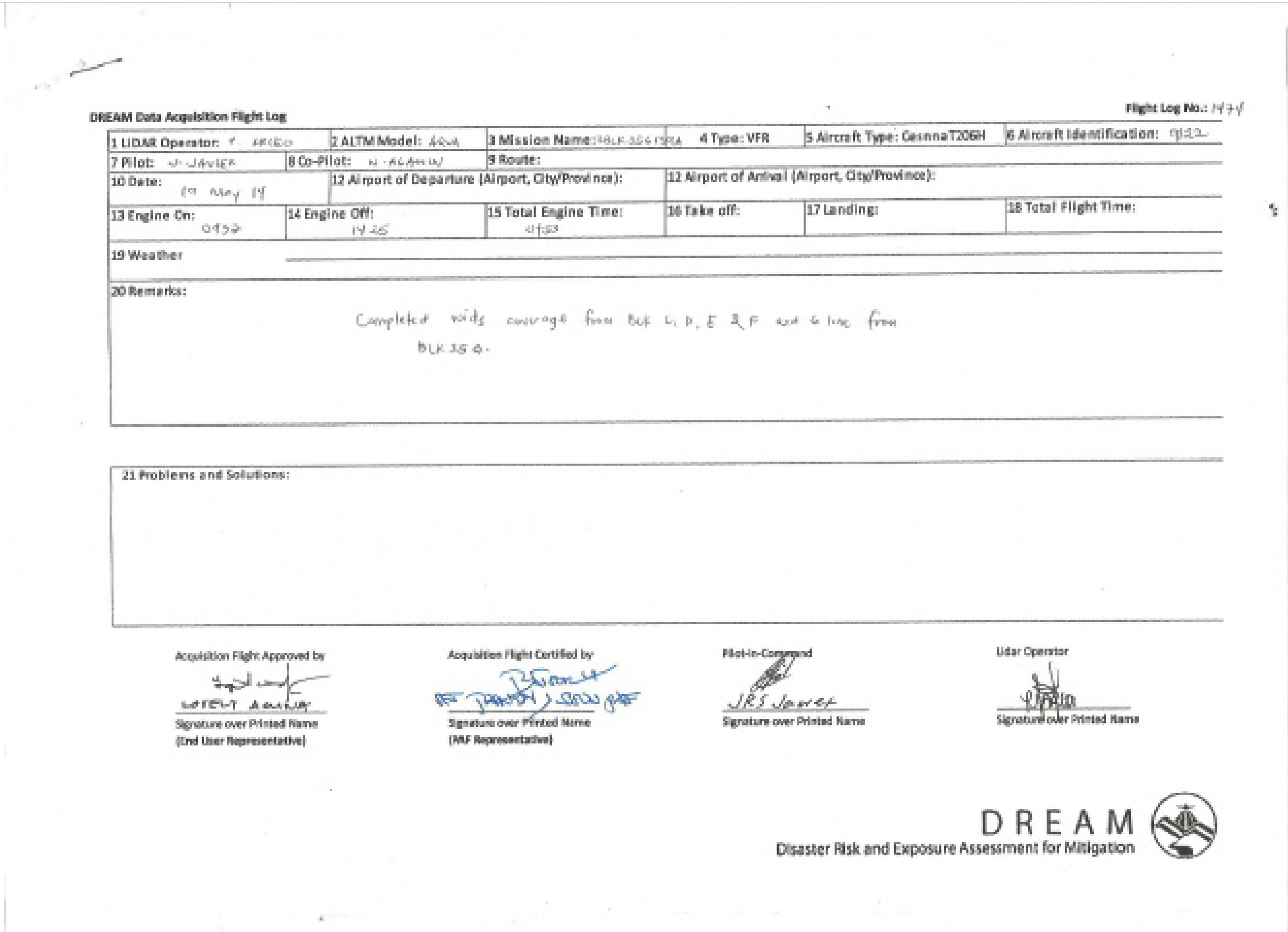
Pilot-in-Command — V. Javier — Signature over Printed Name

Lidar Operator — P. Arceo — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.6. Flight Log for Mission 1466A

7. Flight Log for 1474A Mission



Flight Log No.: 1474

DREAM Data Acquisition Flight Log

1 LIDAR Operator: F. ARCEO	2 ALTM Model: AQUA	3 Mission Name: 1BLK35G135A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ACAMIN	9 Route:			
10 Date: 15 May 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0932	14 Engine Off: 1425	15 Total Engine Time: 4+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed voids coverage from BLK L, D, E & F and 6 line from BLK 35 G.					
21 Problems and Solutions:					

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

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

Pilot-in-Command
J.R.S. JAVIER
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.7. Flight Log for Mission 1474A

8. Flight Log for 1494A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: [illegible]

1 LIDAR Operator: [illegible]	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: [illegible]
7 Pilot: [illegible]	8 Co-Pilot: [illegible]	9 Route:			
10 Date: [illegible]	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0743	14 Engine Off: 1239	15 Total Engine Time: [illegible]	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Completed mission over BLK35G and 4 lines over BLK35B.

21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.8. Flight Log for Mission 1494A

9. Flight Log for 1498A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1498

1 LiDAR Operator: P. Arceo & C. Malicdem	2 ALTM Model: Aqua	3 Mission Name: 3BLK35PRB124	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Jimenez	8 Co-Pilot: N. Acampin	9 Route:			
10 Date: 04 MAY 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0950	14 Engine Off: 1231	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK35A and 4 lines over BLK35E.					
21 Problems and Solutions:					

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

Acquisition Flight Certified by: SSgt. Darwin J. Opungan PAF — Signature over Printed Name (PAF Representative)

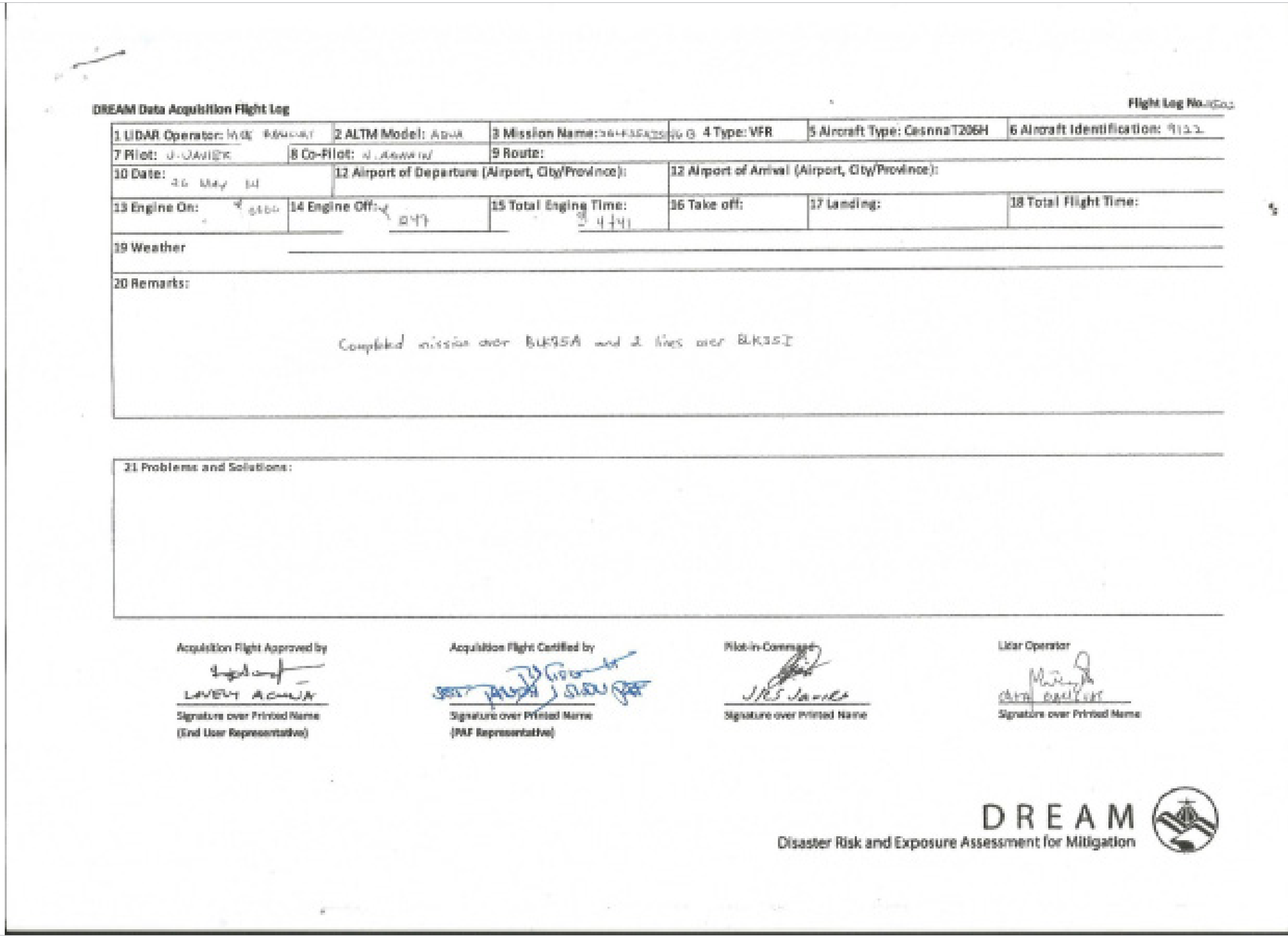
Pilot-in-Command: J.R.S. Jimenez — Signature over Printed Name

Lidar Operator: Catherine Malicdem — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.9. Flight Log for Mission 1498A

10. Flight Log for 1502A Mission



DREAM Data Acquisition Flight Log

Flight Log No.:

1 LIDAR Operator:	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:	9 Route:			
10 Date: 26 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: Completed mission over BLK95A and 2 lines over BLK35I					
21 Problems and Solutions:					

Acquisition Flight Approved by
LAVENY ACUNA
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
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.10. Flight Log for Mission 1502A

11. Flight Log for 1504A Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1504

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

20 Remarks:

Completed mission over BLK35I.

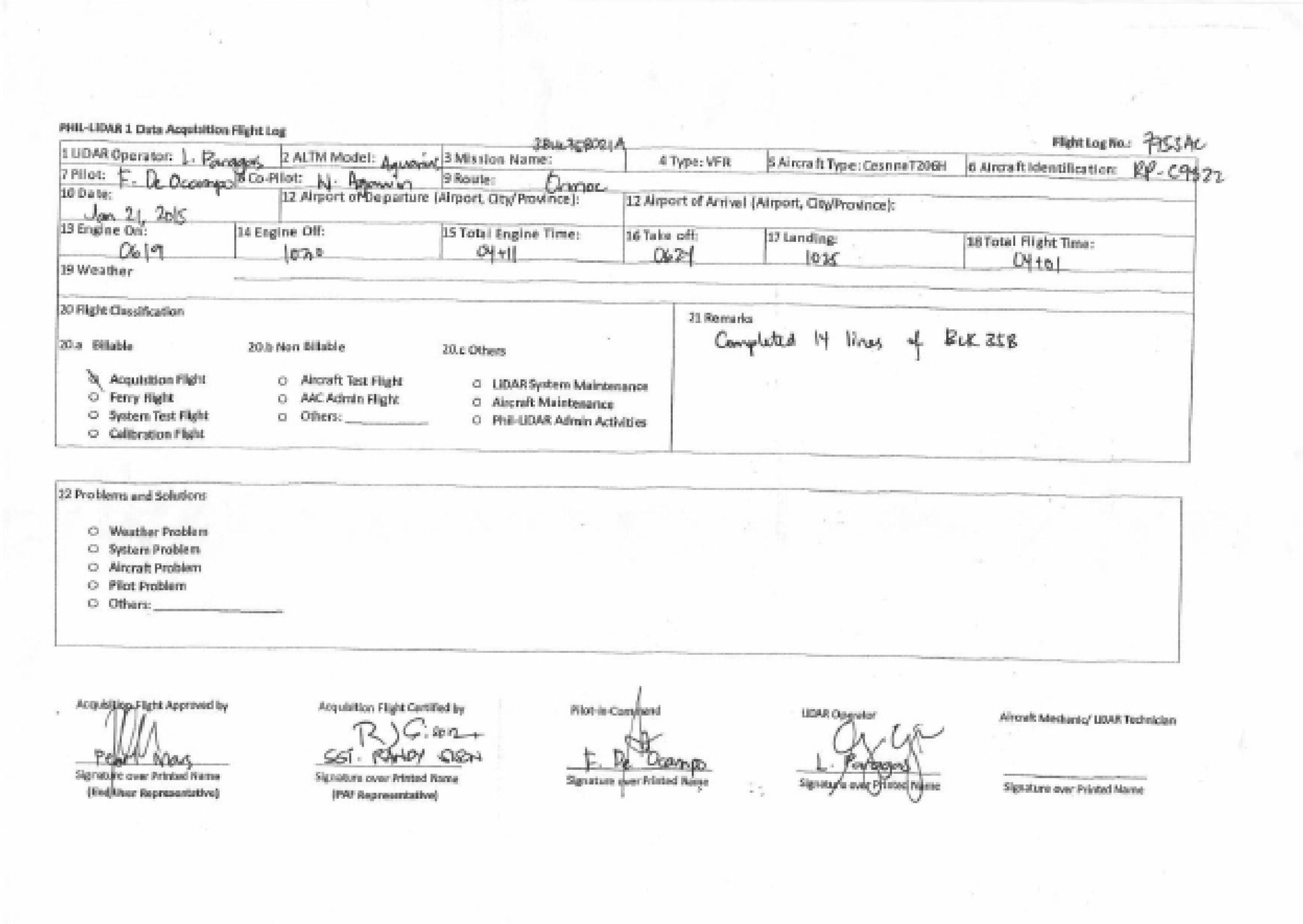
21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.11. Flight Log for Mission 1504A

12. Flight Log for 7753AC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7753AC

1 LIDAR Operator: L. Paragas	2 ALTM Model: Aquarius	3 Mission Name: 2BLK35B021A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: F. De Ocampo	8 Co-Pilot: N. Aguwin	9 Route: Ormoc			
10 Date: Jan 21, 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0619	14 Engine Off: 1030	15 Total Engine Time: 04+11	16 Take off: 0624	17 Landing: 1025	18 Total Flight Time: 04+01
19 Weather					

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 14 lines of BLK 35B

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

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

Acquisition Flight Certified by: SGT. RANDY SIGN, Signature over Printed Name (PAF Representative)

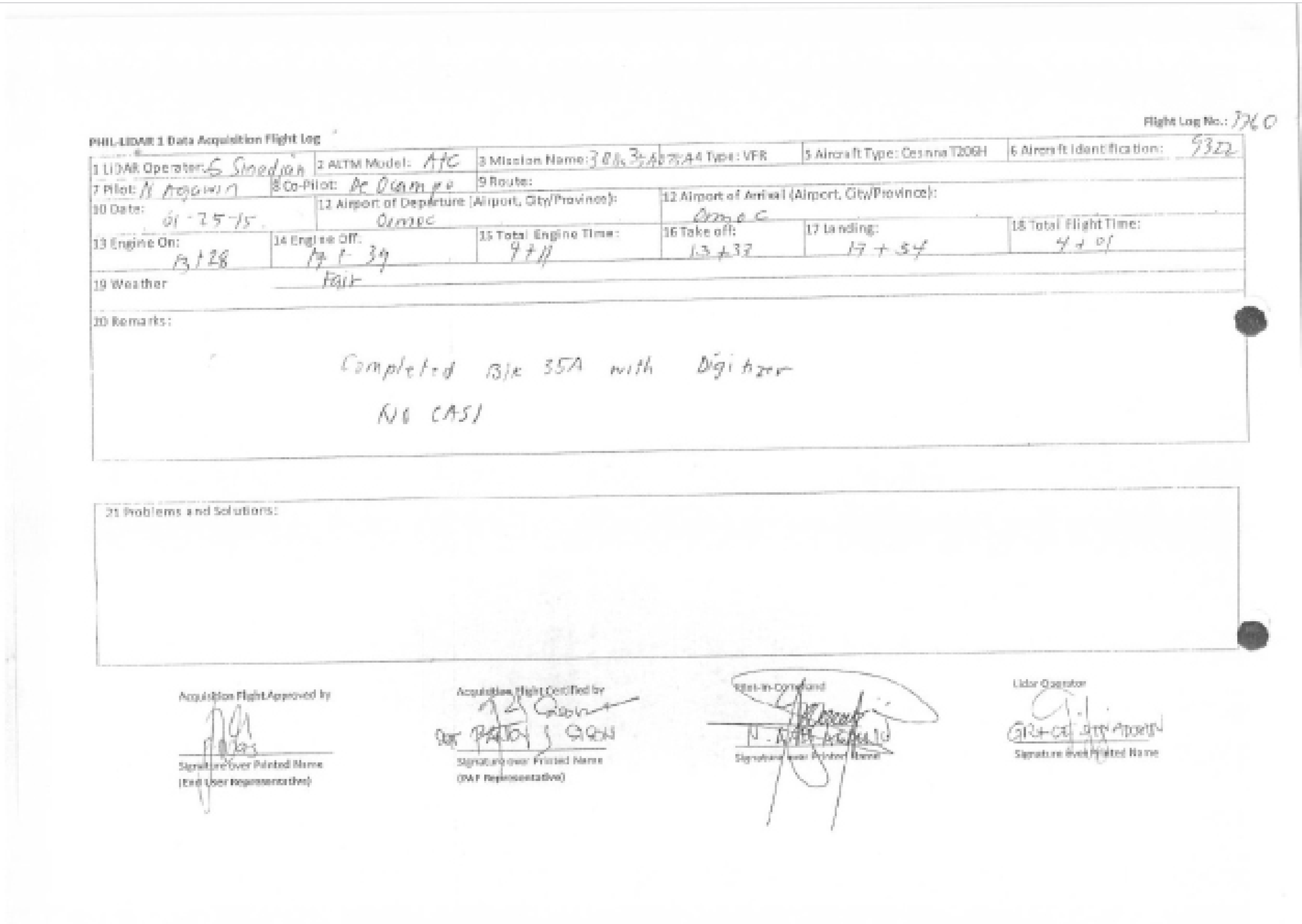
Pilot-in-Command: F. De Ocampo, Signature over Printed Name

LIDAR Operator: L. Paragas, Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.12. Flight Log for Mission 7753AC

13. Flight Log for 7760AC Mission



Flight Log No.: 7760

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: AQ	3 Mission Name: 3BLK35A25A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: N. Arguin	8 Co-Pilot: A. Ocampo	9 Route:		
10 Date: 01-25-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc	
13 Engine On: 13+28	14 Engine Off: 17+39	15 Total Engine Time: 4+11	16 Take off: 13+33	17 Landing: 17+34	18 Total Flight Time: 4+01
19 Weather: Fair					

20 Remarks:

Completed Blk 35A with Digitizer

No CASI

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

Signature over Printed Name (PAF Representative)

Pilot-in-Command

N. Arguin

Signature over Printed Name

Lidar Operator

Grace Sinadjan

Signature over Printed Name

Figure A-6.13. Flight Log for Mission 7760AC

14. Flight Log for 7780AC Mission

Flight Log No.: 7780

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: G. Sinadjan	2 ALTM Model: AQ	3 Mission Name: 3BLK3CAX	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route: 035A			
10 Date: 02-04-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 9+54	14 Engine Off: 11+11	15 Total Engine Time: 1+17	16 Take off: 9+59	17 Landing: 11+07	18 Total Flight Time: 1+08
19 Weather	Fair & Windy				

20 Remarks:

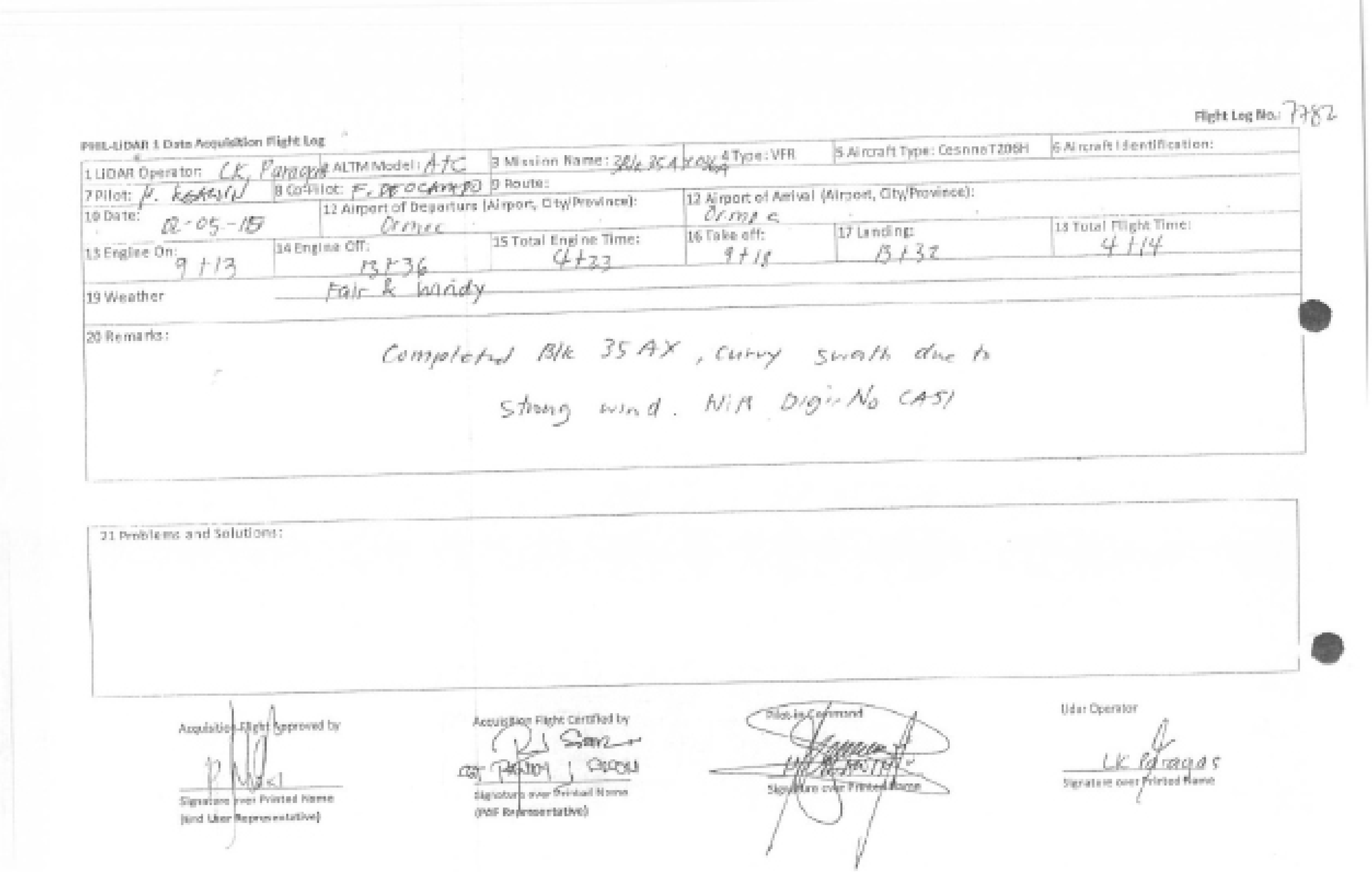
Flight aborted due to strong wind

21 Problems and Solutions:

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

Figure A-6.14. Flight Log for Mission 7780AC

15. Flight Log for 7782AC Mission



Flight Log No.: 7782

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: LK Paragas	2 ALTM Model: AQ	3 Mission Name: 3BLK35AX336A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: F. Kahanan	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: 12-05-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 9+13	14 Engine Off: 13+36	15 Total Engine Time: 4+23	16 Take off: 9+18	17 Landing: 13+32	18 Total Flight Time: 4+14
19 Weather	Fair & windy				

20 Remarks:

Completed Blk 35AX, curvy swath due to strong wind. N/A Digi. No CASI

21 Problems and Solutions:

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

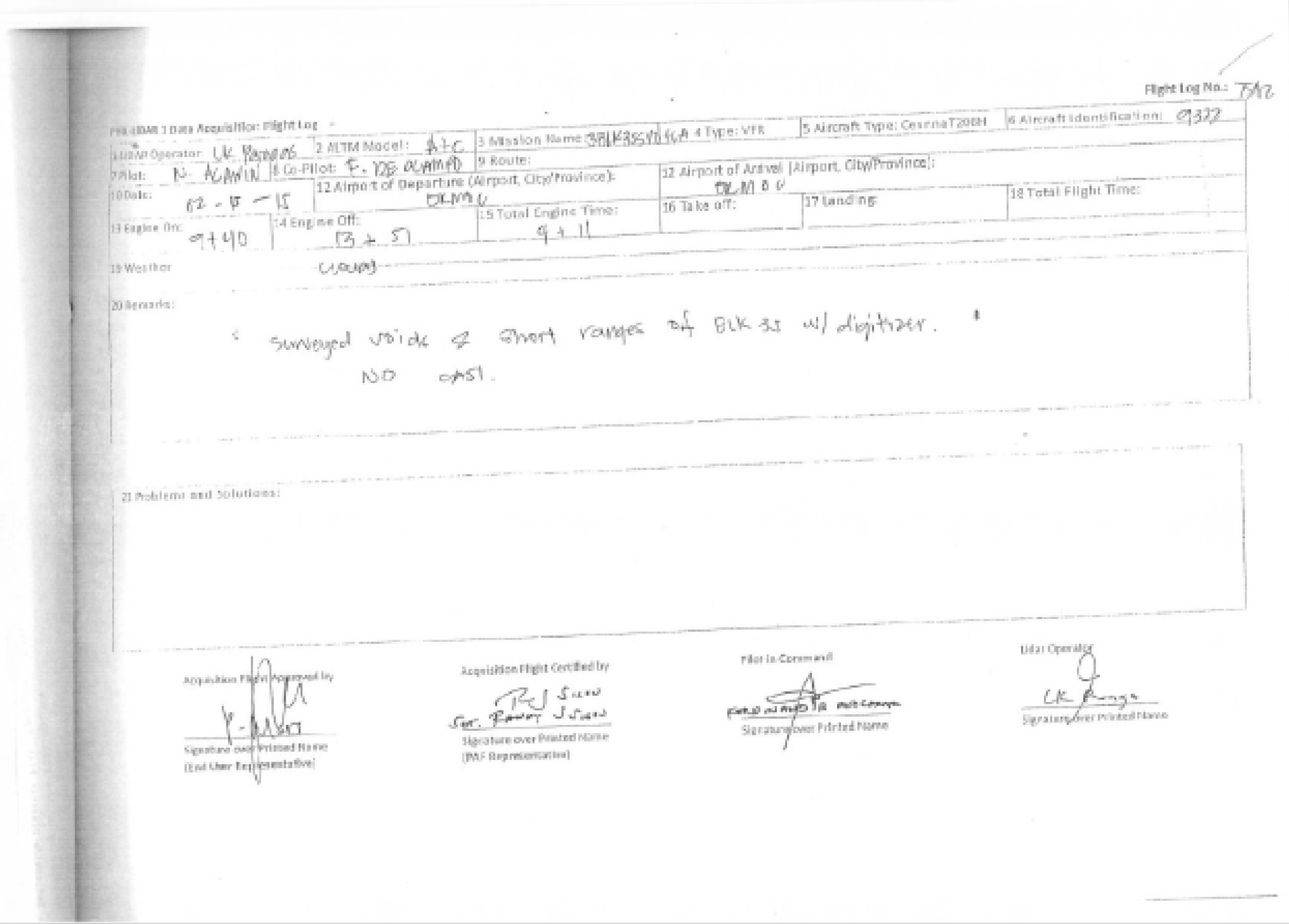
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure A-6.15. Flight Log for Mission 7782AC

16. Flight Log for 7802AC Mission



Flight Log No.: 7802

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQC	3 Mission Name: 3BLK35V166A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: N. Alamin	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: 02-15-15	12 Airport of Departure (Airport, City/Province): BLMAU		12 Airport of Arrival (Airport, City/Province): BLMAU		
13 Engine On: 9+40	14 Engine Off: 13+51	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

surveyed voids & short ranges of BLK 35 w/ digitizer.
NO GASI.

21 Problems and Solutions:

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

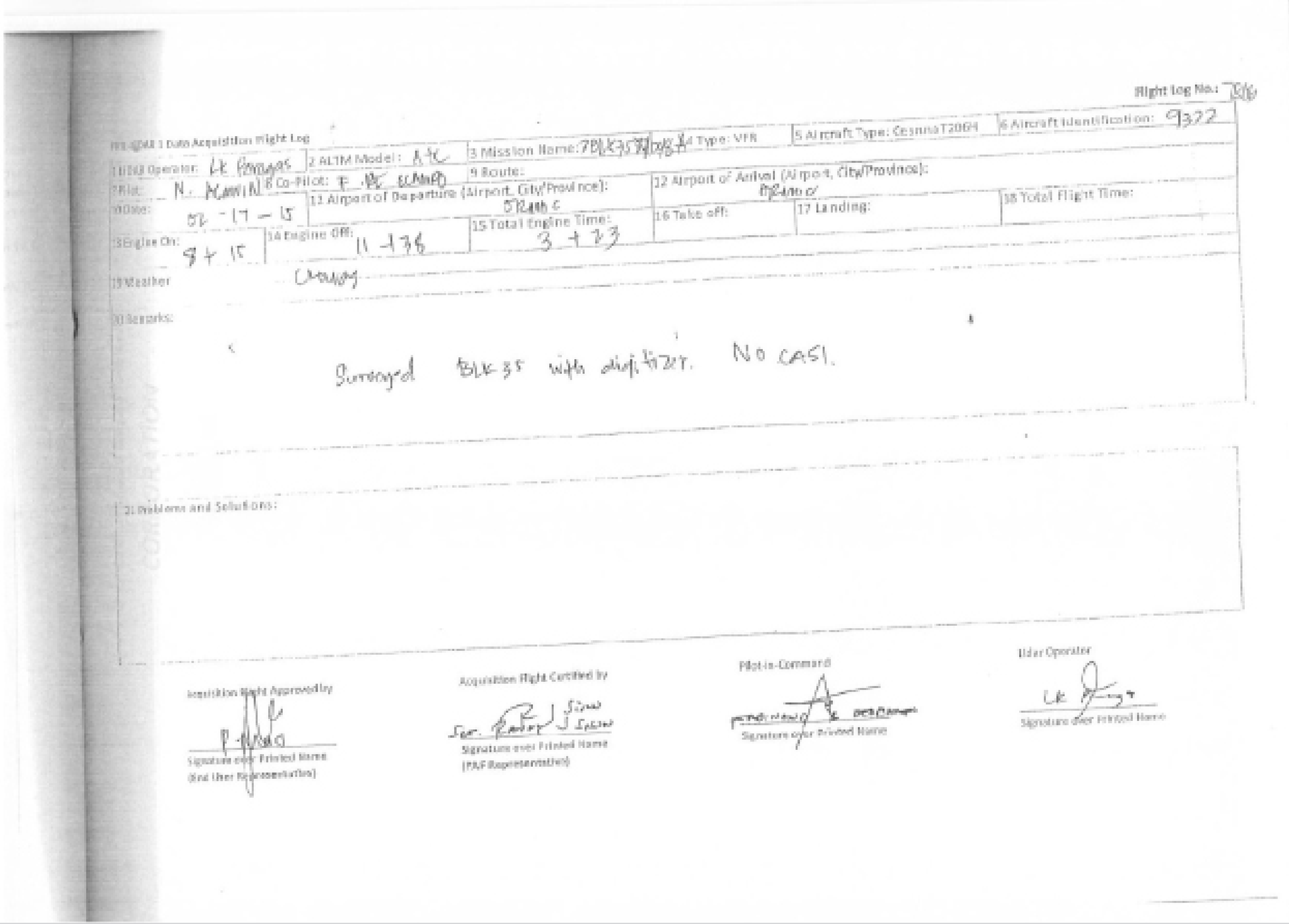
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure A-6.16. Flight Log for Mission 7802AC

17. Flight Log for 7806AC Mission



Flight Log No.:

DREAM 1 Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas | 2 ALTM Model: AQ | 3 Mission Name: 7BLK35 | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: 9322

7 Pilot: N. Maunin | 8 Co-Pilot: F. Elamd | 9 Route:

10 Date: 02-17-15 | 12 Airport of Departure (Airport, City/Province): Iloilo | 12 Airport of Arrival (Airport, City/Province): Iloilo

13 Engine On: 8+15 | 14 Engine Off: 11+38 | 15 Total Engine Time: 3+23 | 16 Take off: | 17 Landing: | 18 Total Flight Time:

19 Weather: Cloudy

20 Remarks:

Surveyed BLK 35 with digitizer. No CASI.

21 Problems and Solutions:

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

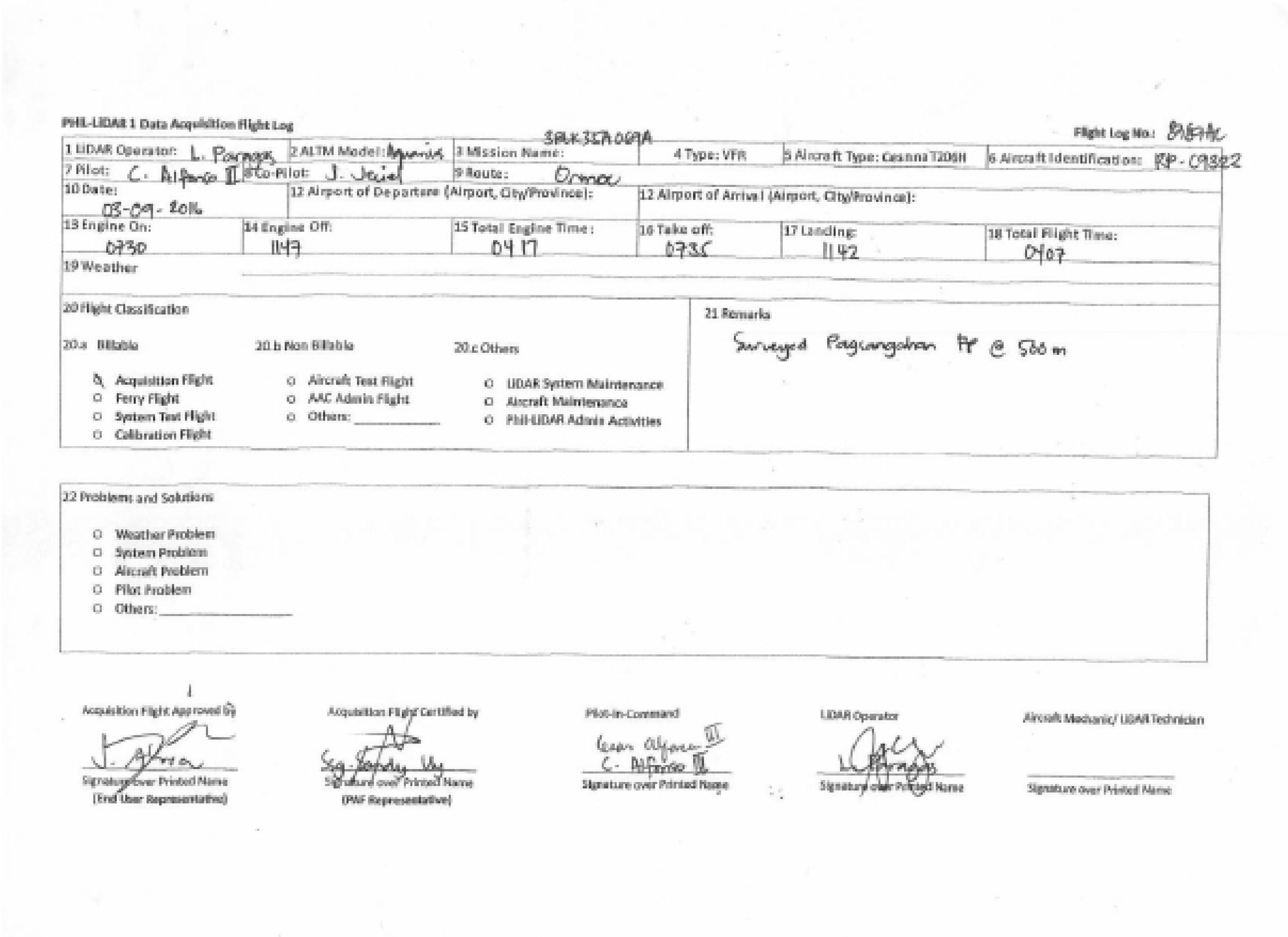
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.17. Flight Log for Mission 7806AC

18. Flight Log for 8389AC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 8389AC

1 LIDAR Operator: L. Paragas	2 ALTM Model: Aquarius	3 Mission Name: 5BLK35A069A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jeciel	9 Route: Ormoc			
10 Date: 03-09-2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0730	14 Engine Off: 1147	15 Total Engine Time: 0417	16 Take off: 0735	17 Landing: 1142	18 Total Flight Time: 0407
19 Weather					

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

Surveyed Pagsangahan FP @ 500 m

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

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

Acquisition Flight Certified by: Sgt. Sandy Uy — Signature over Printed Name (PAF Representative)

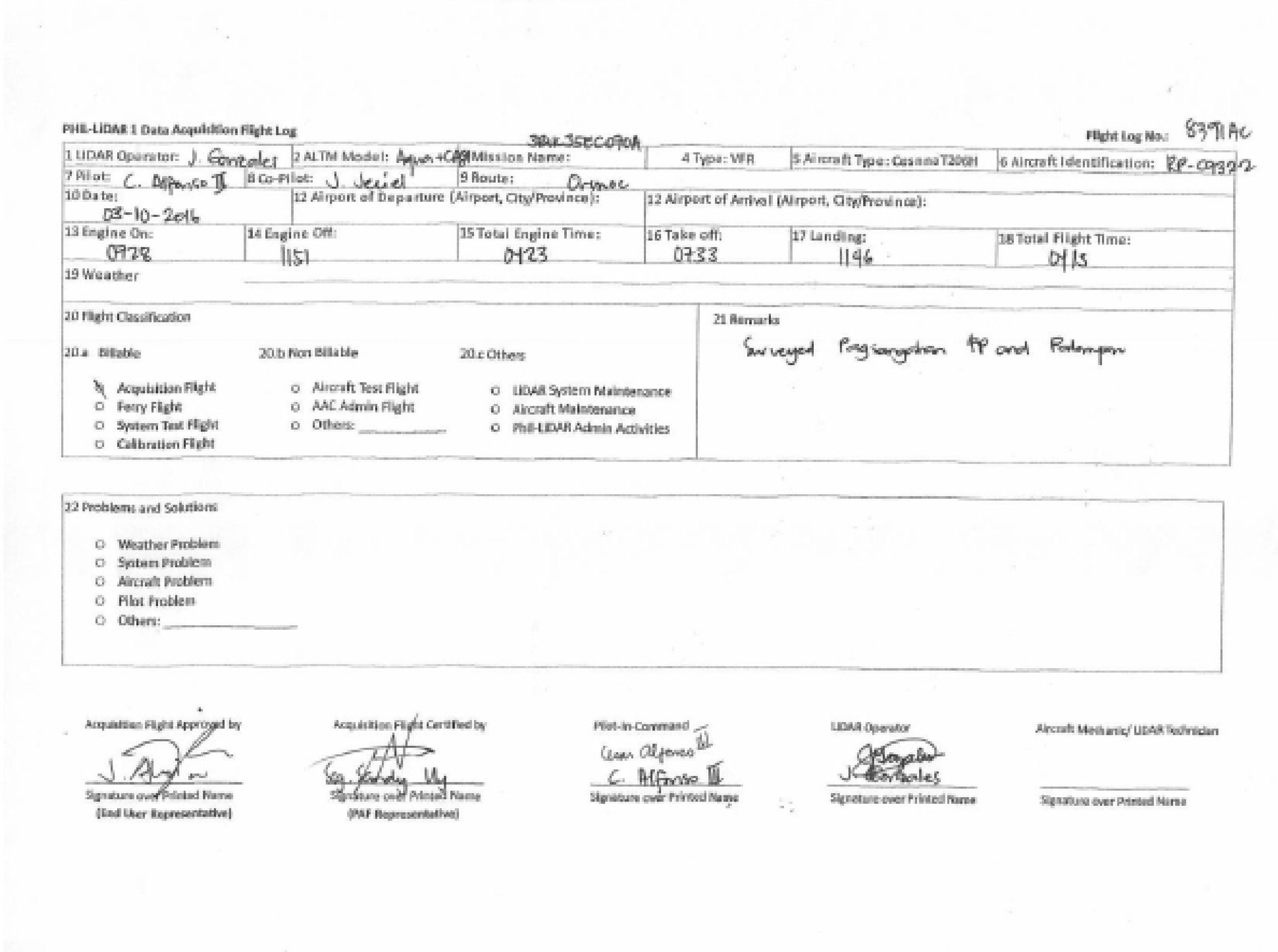
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LIDAR Operator: L. Paragas — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.18. Flight Log for Mission 8389AC

19. Flight Log for 8391AC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 8391AC

1 LIDAR Operator: J. Gonzales
2 ALTM Model: Aquarius + CASI
3 Mission Name: 3BLK35ECO70A
4 Type: VFR
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: RP-C9322
7 Pilot: C. Alfonso III
8 Co-Pilot: J. Jeciel
9 Route: Ormoc
10 Date: 03-10-2016
12 Airport of Departure (Airport, City/Province):
12 Airport of Arrival (Airport, City/Province):
13 Engine On: 0728
14 Engine Off: 1151
15 Total Engine Time: 0423
16 Take off: 0733
17 Landing: 1146
18 Total Flight Time: 0413
19 Weather

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

Surveyed Pagsangahan FP and Palompon

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

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

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

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

LIDAR Operator
J. Gonzales
Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name

Figure A-6.19. Flight Log for Mission 8391AC

20. Flight Log for 8392AC Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 8392AC

1 LIDAR Operator: L. Paragas	2 ALTM Model: Aquarius CAG1	3 Mission Name: 3BLK35BD070B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Janiel	9 Route: Ormoc			
10 Date: 03-10-2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1423	14 Engine Off: 1752	15 Total Engine Time: 03+29	16 Take off: 1428	17 Landing: 1747	18 Total Flight Time: 03+19
19 Weather					

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

Surveyed Western Leyte coast

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

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

Acquisition Flight Certified by: Eng. Kendy Uy — Signature over Printed Name (PAF Representative)

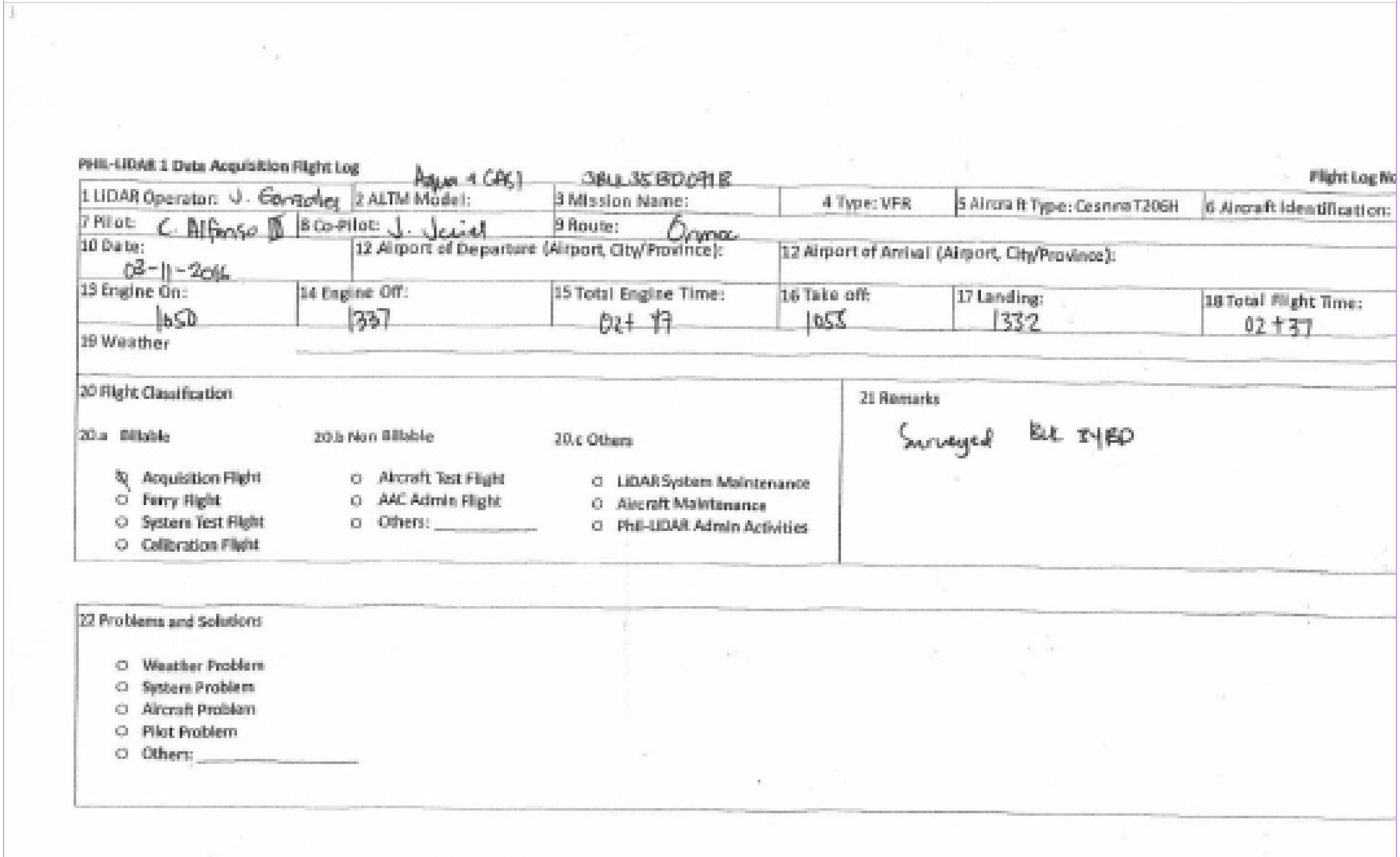
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LIDAR Operator: L. Paragas — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.20. Flight Log for Mission 8392AC

21. Flight Log for 8394AC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No

1 LIDAR Operator: J. Gonzales	2 ALTM Model: Aqua 4 CAS1	3 Mission Name: 3BLK35BD091B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jeciel	9 Route: Ormoc			
10 Date: 03-11-2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1050	14 Engine Off: 1337	15 Total Engine Time: 02+47	16 Take off: 1055	17 Landing: 1332	18 Total Flight Time: 02+37
19 Weather					

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

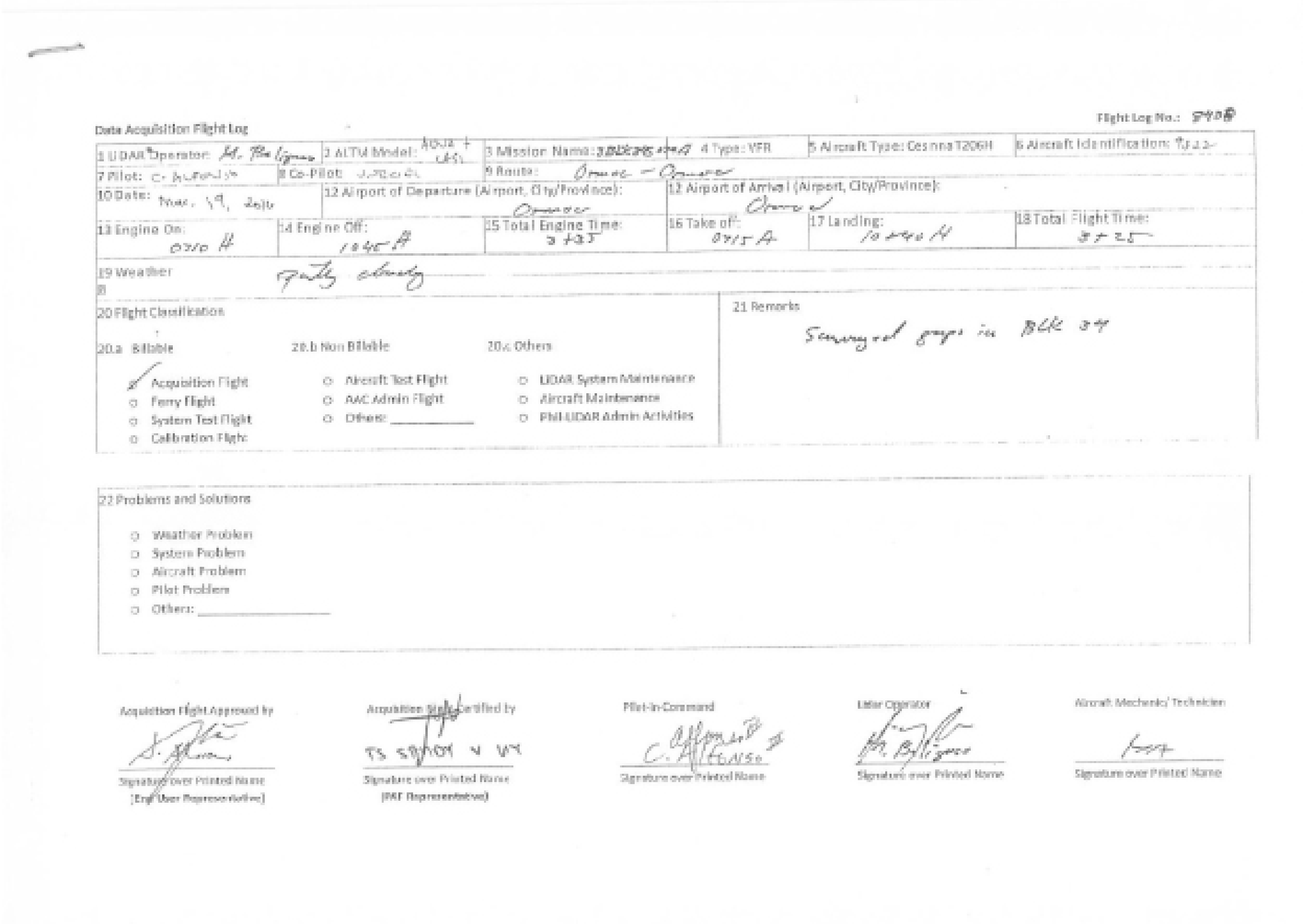
21 Remarks

Surveyed BLK 35BD

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

Figure A-6.21. Flight Log for Mission 8394AC

22. Flight Log for 8408AC Mission


Data Acquisition Flight Log

Flight Log No.: 8408

1 LIDAR Operator: M. Bo. Ligunas	2 ALTM Model: AQUA + CAS	3 Mission Name: 3BLK34S	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Ponce	9 Route: Ormoc – Ormoc			
10 Date: Nov. 19, 2016	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 0710 H	14 Engine Off: 1045 H	15 Total Engine Time: 3+35	16 Take off: 0715 H	17 Landing: 1040 H	18 Total Flight Time: 3+25
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

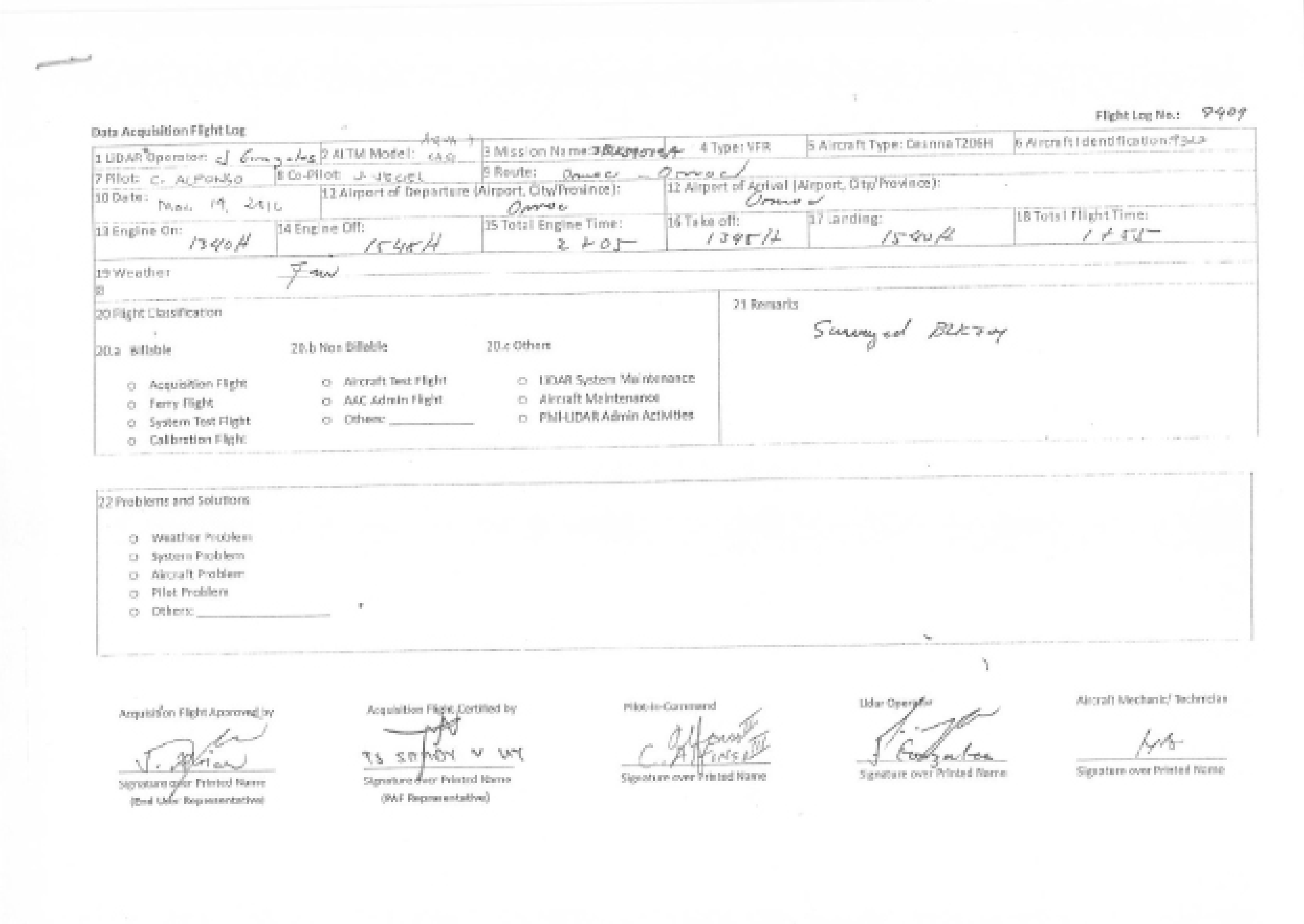
Surveyed gaps in BLK 34

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/ Technician
S. Alvarez	TS Sapyor V Vy	C. Alfonso III	M. Bo. Ligunas	[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-6.22. Flight Log for Mission 8408AC

23. Flight Log for 8409AC Mission



Flight Log No.: 9409

Data Acquisition Flight Log

1 LIDAR Operator: J. Gonzales	2 ALTM Model: Aquarius	3 Mission Name: 3BLK74	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9322
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route: Ormoc – Ormoc			
10 Date: Mar. 19, 2016		12 Airport of Departure (Airport, City/Province): Ormoc	12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 1340H	14 Engine Off: 1545H	15 Total Engine Time: 2+05	16 Take off: 1345H	17 Landing: 1540H	18 Total Flight Time: 1+55
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK74

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

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

Acquisition Flight Certified by: TS Sandy V Uy — Signature over Printed Name (PAF Representative)

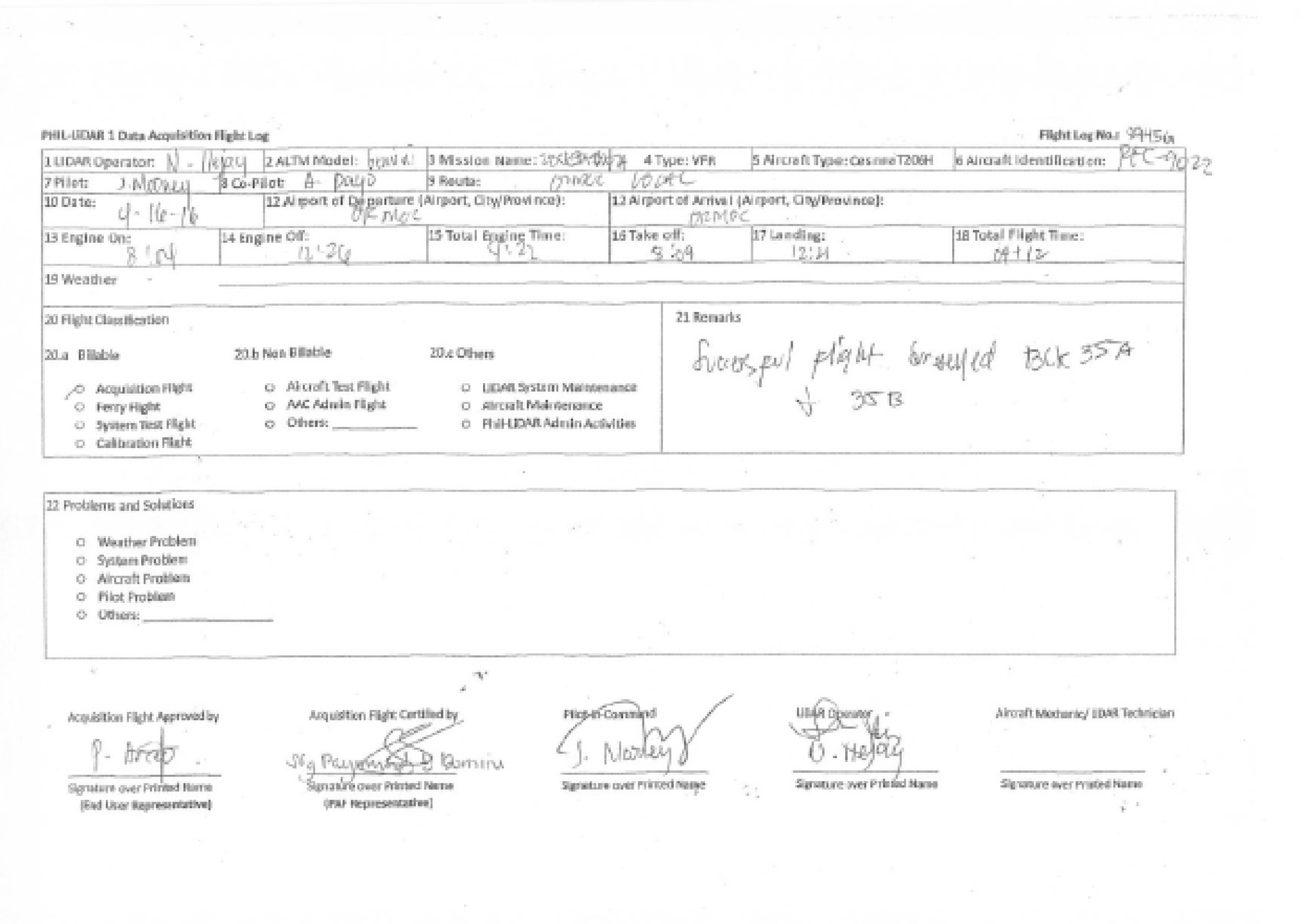
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

Lidar Operator: J. Gonzales — Signature over Printed Name

Aircraft Mechanic/ Technician — Signature over Printed Name

Figure A-6.23. Flight Log for Mission 8409AC

24. Flight Log for 3945G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3945G

1 LIDAR Operator: N. Hejay	2 ALTM Model: Gemini	3 Mission Name: 2BLK35A+B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: J. Mooney	8 Co-Pilot: A. Payo	9 Route: Ormoc - Ormoc			
10 Date: 4-16-16	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 8:04	14 Engine Off: 12:26	15 Total Engine Time: 4:22	16 Take off: 8:09	17 Landing: 12:21	18 Total Flight Time: 04+12
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

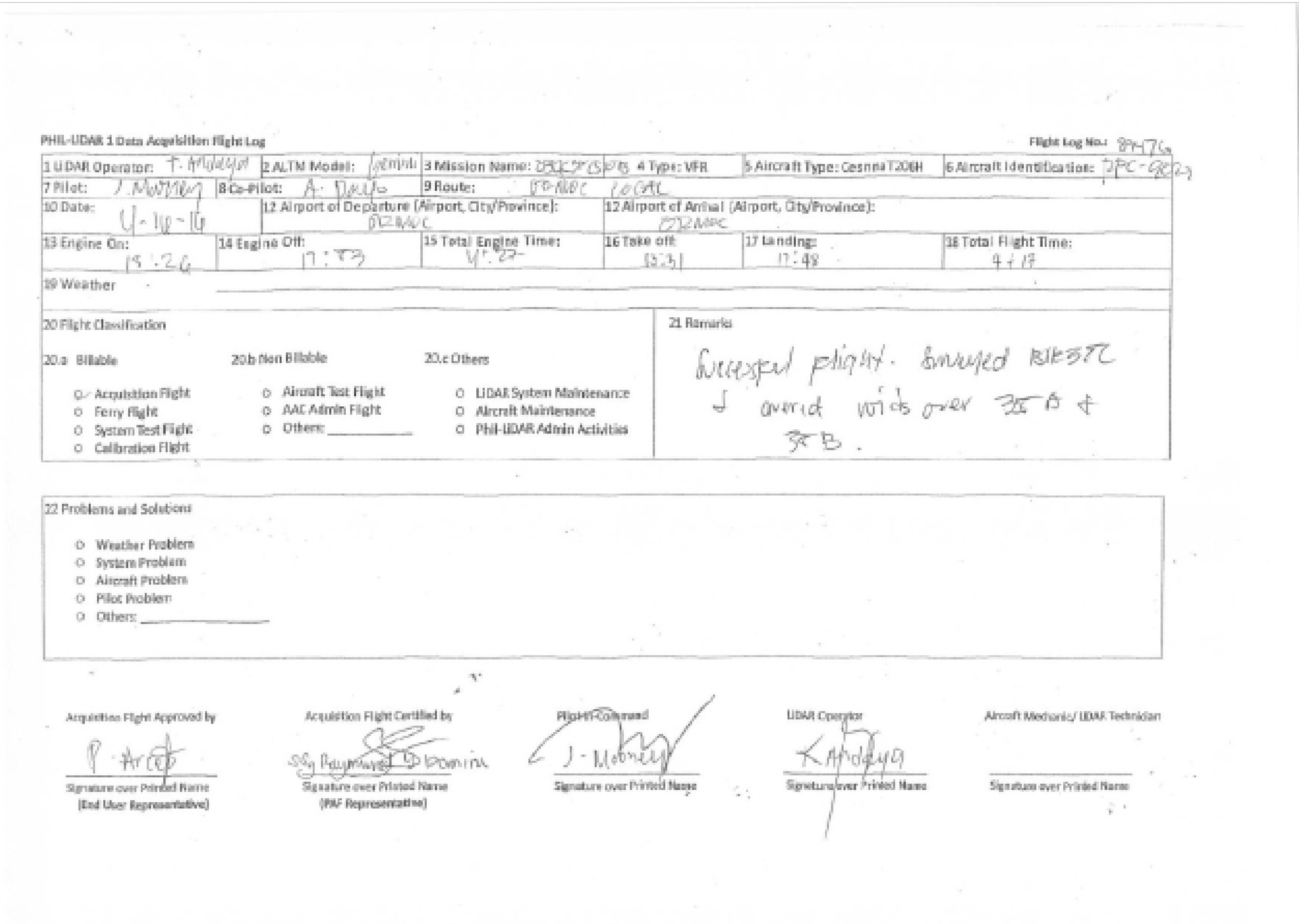
Successful flight covered BLK 35A & 35B

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. Arado	Sgt Raymund Bamiro	J. Mooney	N. Hejay	
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-6.24. Flight Log for Mission 3945G

25. Flight Log for 3947G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3947G

1 LIDAR Operator: [illegible]	2 ALTM Model: Gemini	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC-[illegible]
7 Pilot: J. [illegible]	8 Co-Pilot: A. [illegible]	9 Route: [illegible] LOCAL			
10 Date: [illegible]	12 Airport of Departure (Airport, City/Province): [illegible]	12 Airport of Arrival (Airport, City/Province): [illegible]			
13 Engine On: 13:26	14 Engine Off: 17:53	15 Total Engine Time: 4+27	16 Take off: 13:31	17 Landing: 17:48	18 Total Flight Time: 4+17
19 Weather					

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. Surveyed BLK 37C & covered voids over 35B & 37B.

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

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

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

Pilot-in-Command — J. [illegible] — Signature over Printed Name

LIDAR Operator — K. Andaya — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.25. Flight Log for Mission 3947G

ANNEX 7. Flight Status Reports

Table A-7-1. Flight Status Report

PAGSANGAHAN FLOODPLAIN

(January 28, May 15-26, 2014; January 21-February 17, 2015; March 9-19, April 16, 2016)

Flight No	Area	Mission	Operator	Date Flown	Remarks
1032A	BLK 35A	2BLK35A028A	F. Sable	28-Jan-14	Successful flight
1458A	BLK 35B	3BLK35B135A	I. Roxas	15-May-14	Completed mission over BLK35B
1460A	BLK 35C & 35D	3BLK35CD135B	P. Arceo	15-May-14	Completed mission over BLK35C and some lines over BLK35D
1462A	BLK 35D & 35E	3BLK35DSE136A	P. Arceo	16-May-14	Completed mission over BLK35D and 6 lines over BLK35E
1464A	BLK 35E	3BLK35ES136B	P. Arceo	16-May-14	Completed 14/22 lines left over BLK35E
1466A	BLK 35F	3BLK35F137A	P. Arceo	17-May-14	Completed mission over BLK35F with voids due to strong winds.
1474A	BLK 35G	3BLK35G139A	P. Arceo	19-May-14	Completed voids coverage from BLK C, D, E & F AND 6 lines from BLK 35G.
1494A	BLK 35G & 35H	3BLK35GSH144A	P. Arceo	24-May-14	Completed mission over BLK 35G and four lines over BLK 35H.
1498A	BLK 35H & 35I	3BLK35HSI145A	P. Arceo	25-May-14	Completed mission over BLK 35H and four lines over BLK 35I.
1502A	BLK 35I	3BLK35IS146A	P. Arceo	26-May-14	Completed mission over BLK 35I
1504A	BLK 35A & 35I	3BLK35AIS146B	M. Baliguas	26-May-14	Completed mission over BLK 35A and 2 lines over BLK 35I
7753AC	BLK 35B	3BLK35B021A	L. Paragas	21-Jan-15	Completed 14 lines of Blk35B. Experienced red swath (short ranges).
7760AC	BLK 35A	3BLK35A025A	G. Sinadjan	25-Jan-15	Completed Blk35A with digitizer. Experienced red swath (short ranges) No CASI
7780AC	BLK 35A	3BLK35AX035A	G. Sinadjan	04-Feb-15	Completed 3 lines. Flight aborted due to strong winds. With digitizer. No CASI
7782AC	BLK 35A	3BLK35AX036A	L. Paragas	05-Feb-15	Over Ormoc. Flight aborted due to strong winds. With digitizer. No CASI
7802AC	BLK 35 Voids	3BLK35SV046A	L. Paragas	15-Feb-15	Surveyed voids and short ranges of BLK35 with digitizer. No CASI
7806AC	BLK 35 Voids	3BLK35X1048A	L. Paragas	17-Feb-15	Surveyed voids and short ranges of BLK35 with digitizer. No CASI
8389AC	BLK 35A	3BLK35A069A	L. Paragas	09-Mar-16	Surveyed BLK 35A
8391AC	BLK 35EC	3BLK35EC070A	J. Gonzales	10-Mar-16	Surveyed BLK 35EC
8392AC	BLK 35BD	3BLK35BD070B	L. Paragas	10-Mar-16	Surveyed BLK 35BD

Flight No	Area	Mission	Operator	Date Flown	Remarks
8394AC	BLK 35BD	3BLK35BD071B	J. Gonzales	11-Mar-16	Surveyed BLK 35BD
8408AC	BLK 35DCE	3BLK48BD079A	M. Baliguas	19-Mar-16	Surveyed BLK 35DCE
8409AC	BLK 48DS	3BLK34079B	J. Gonzales	19-Mar-16	Surveyed coastal area west of Ormoc Bay
3945G	BLK 35AB	2BLK35AB107A	F. Ilejay	16-Apr-16	Surveyed BLK 35A and 35B
3947G	BLK 35CS	2BLK35CS107B	K. Andaya	16-Apr-16	Surveyed BLK 35C and covered voids over BLK 35A and 35B

SWATH PER FLIGHT MISSION

Flight No. : 1032A
Area: BLK 35A
Mission Name: 2BLK35A028A
Parameters:
Altitude: 600
Scan Frequency: 40
Scan Angle: 25
Overlap: 30

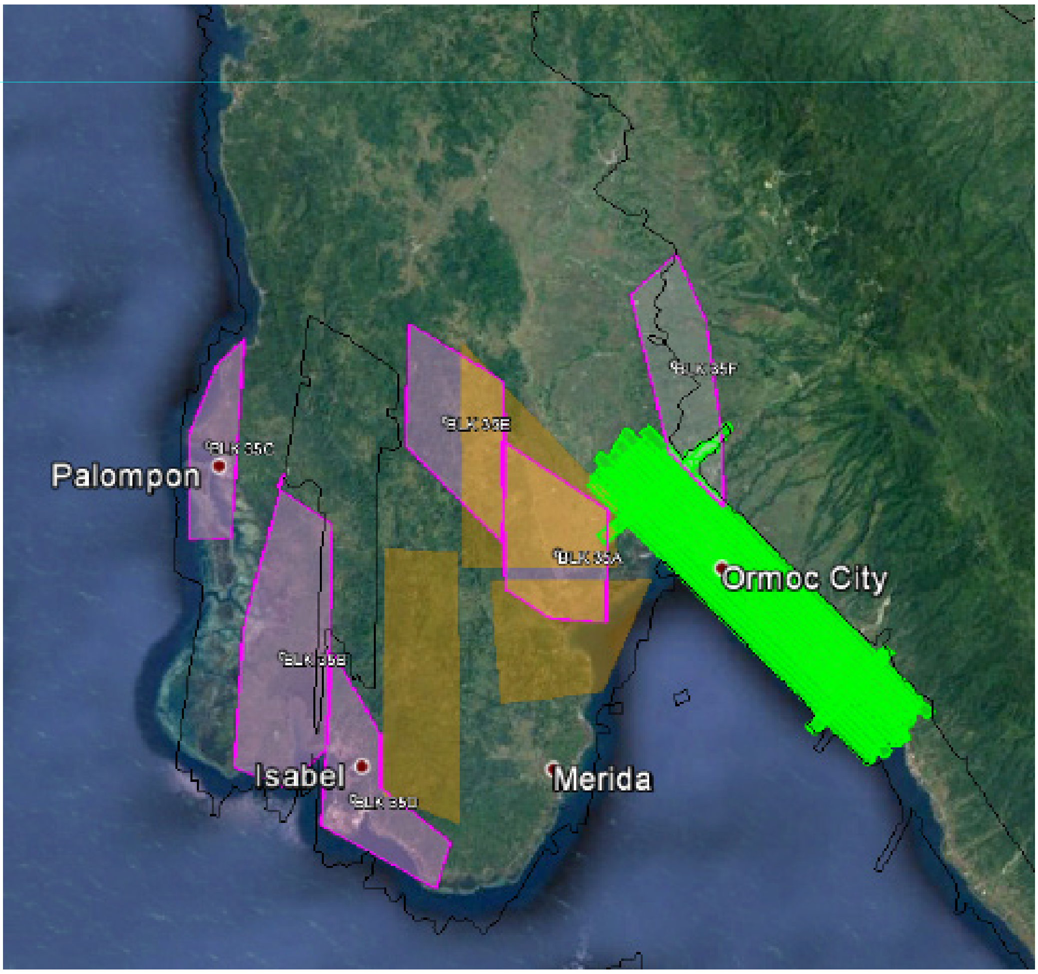


Figure A-7.1. Swath for Flight No. 1032A

Flight No. : 1458A
Area: BLK 35B
Mission Name: 3BLK35B135A
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

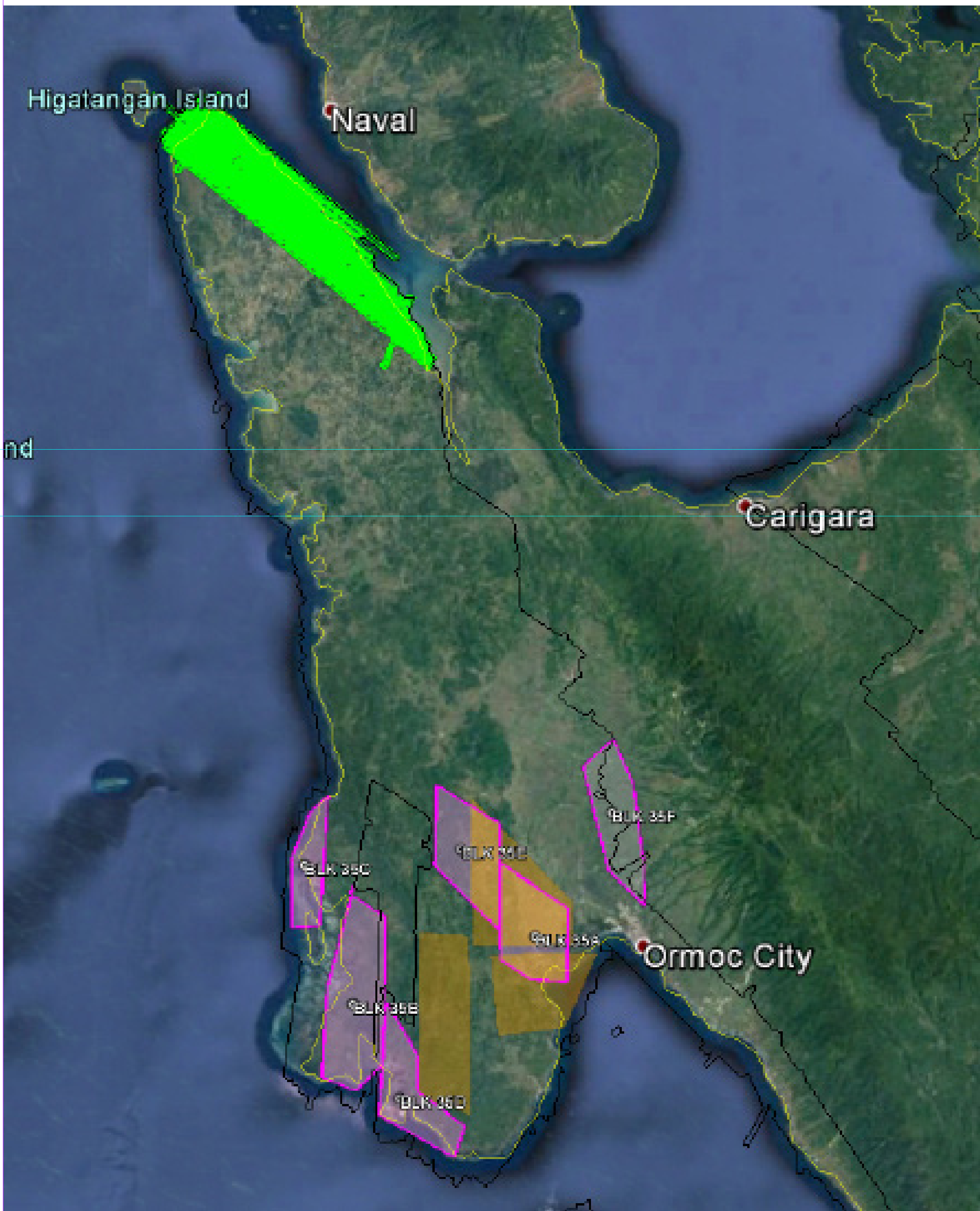


Figure A-7.2. Swath for Flight No. 1458A

Flight No. : 1460A
Area: BLK 35C & 35D
Mission Name: 3BLK35CD135B
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

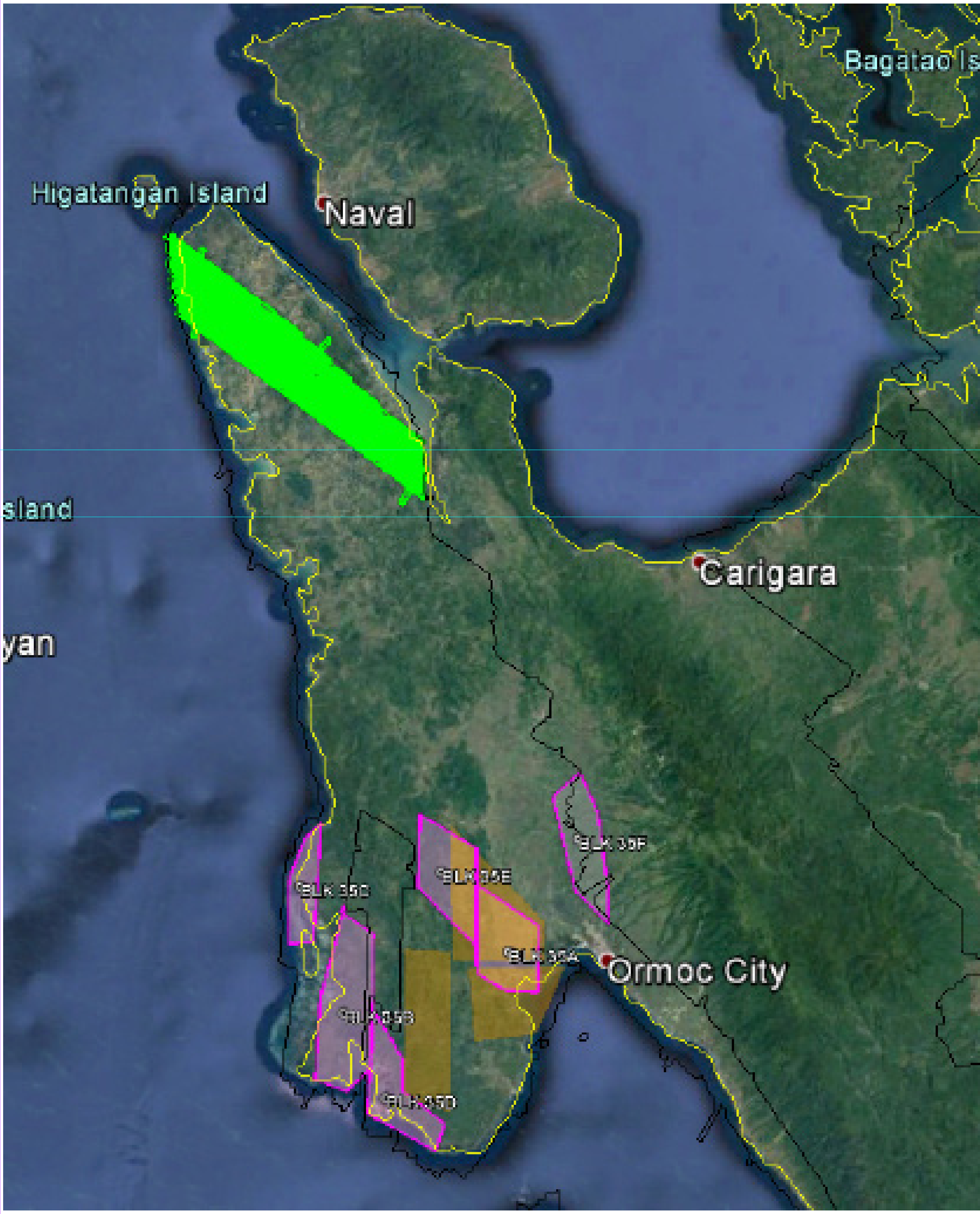


Figure A-7.3. Swath for Flight No. 1460A

Flight No. : 1462A
Area: BLK 35D & 35E
Mission Name: 3BLK35DSE136A
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

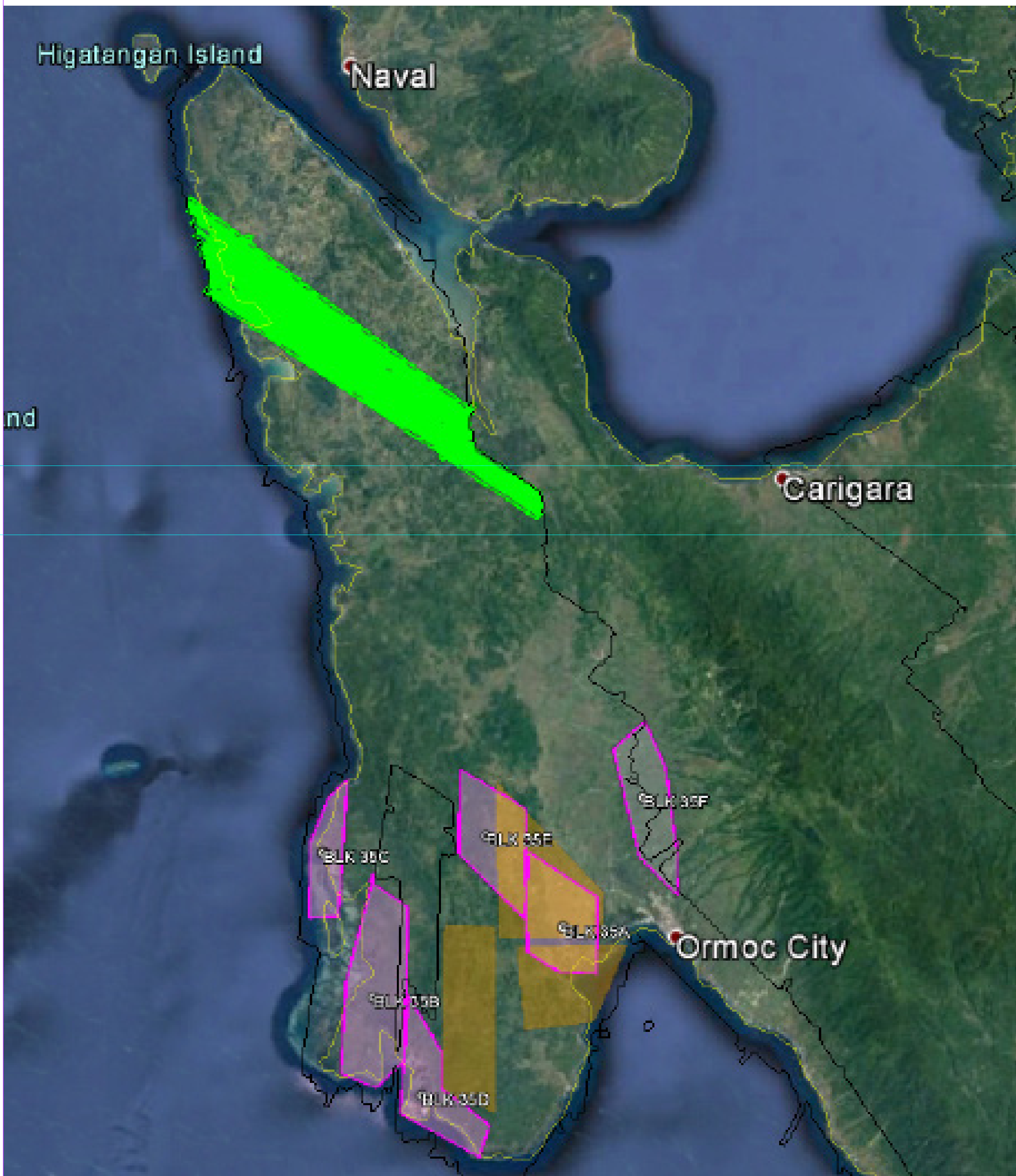


Figure A-7.4. Swath for Flight No. 1462A

Flight No. : 1464A
Area: BLK 35E
Mission Name: 3BLK35ES136B
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

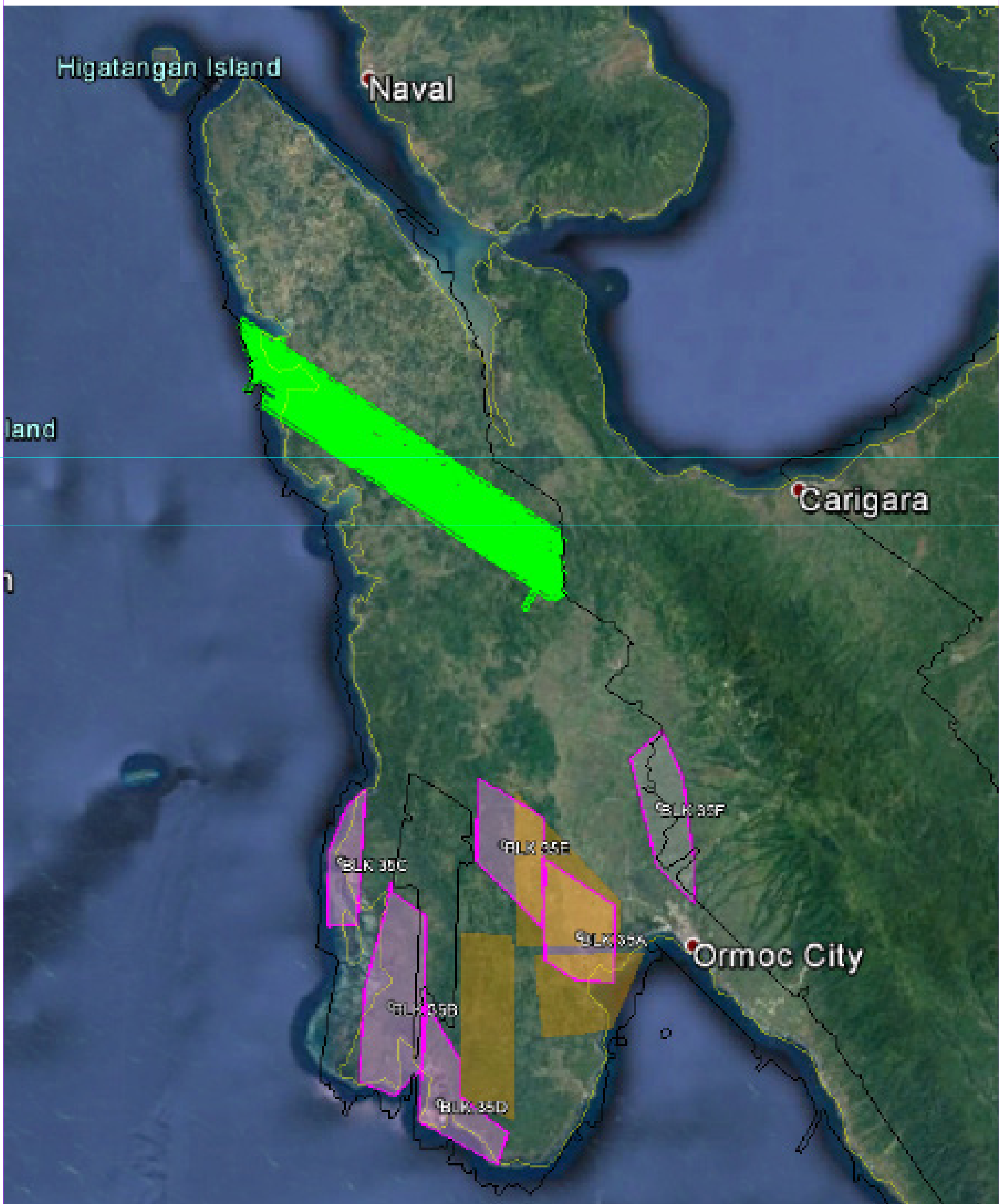


Figure A-7.5. Swath for Flight No. 1464A

Flight No. : 1466A
Area: BLK 35F
Mission Name: 3BLK35F137A
Parameters:
Altitude: 600
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

Figure A-7.6. Swath for Flight No. 1466A

Flight No. : 1474A
Area: BLK 35G
Mission Name: 3BLK35G139A
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

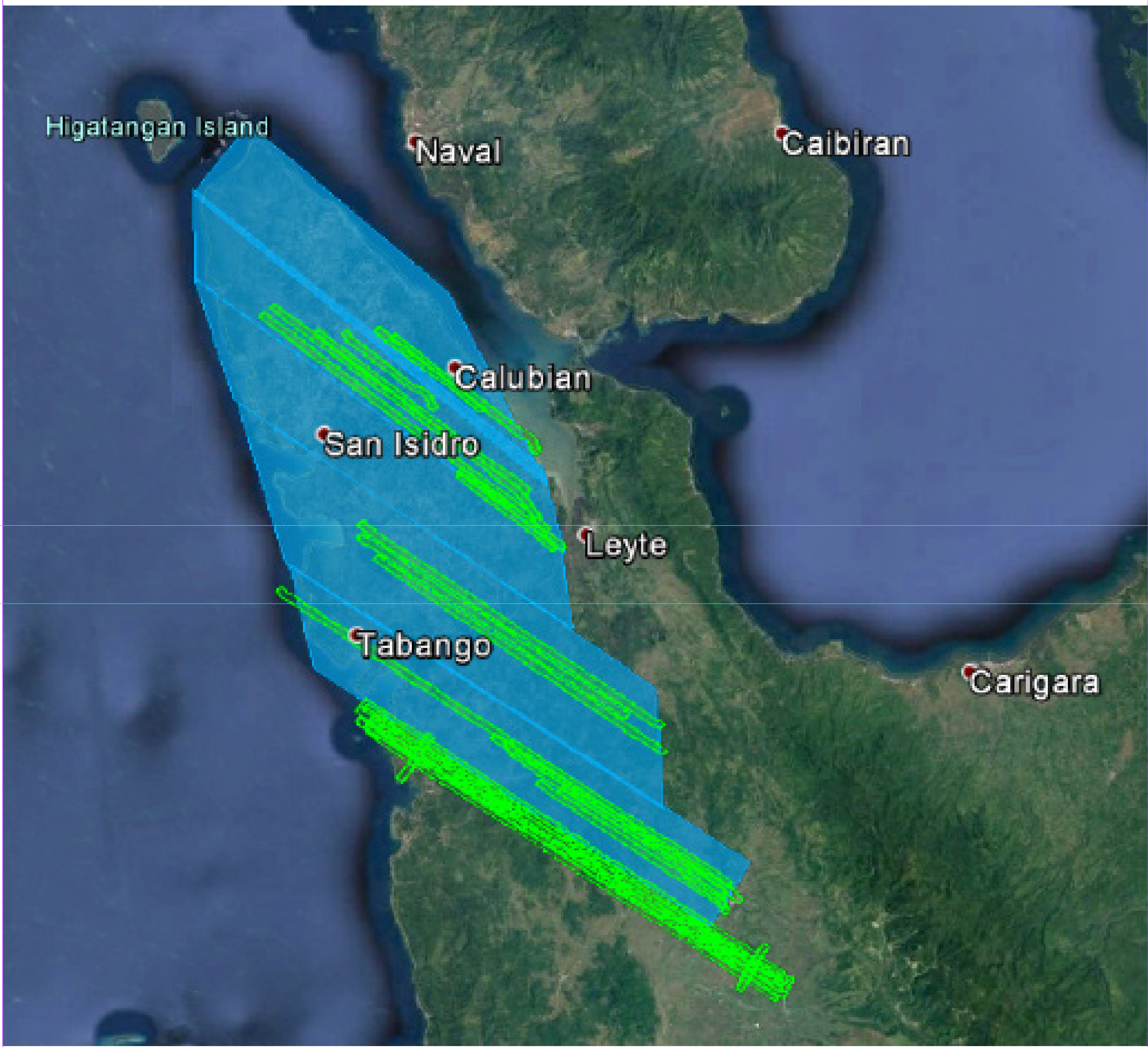


Figure A-7.7. Swath for Flight No. 1474A

Flight No. : 1494A
Area: BLK 35G & 35H
Mission Name: 3BLK35GSH144A
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

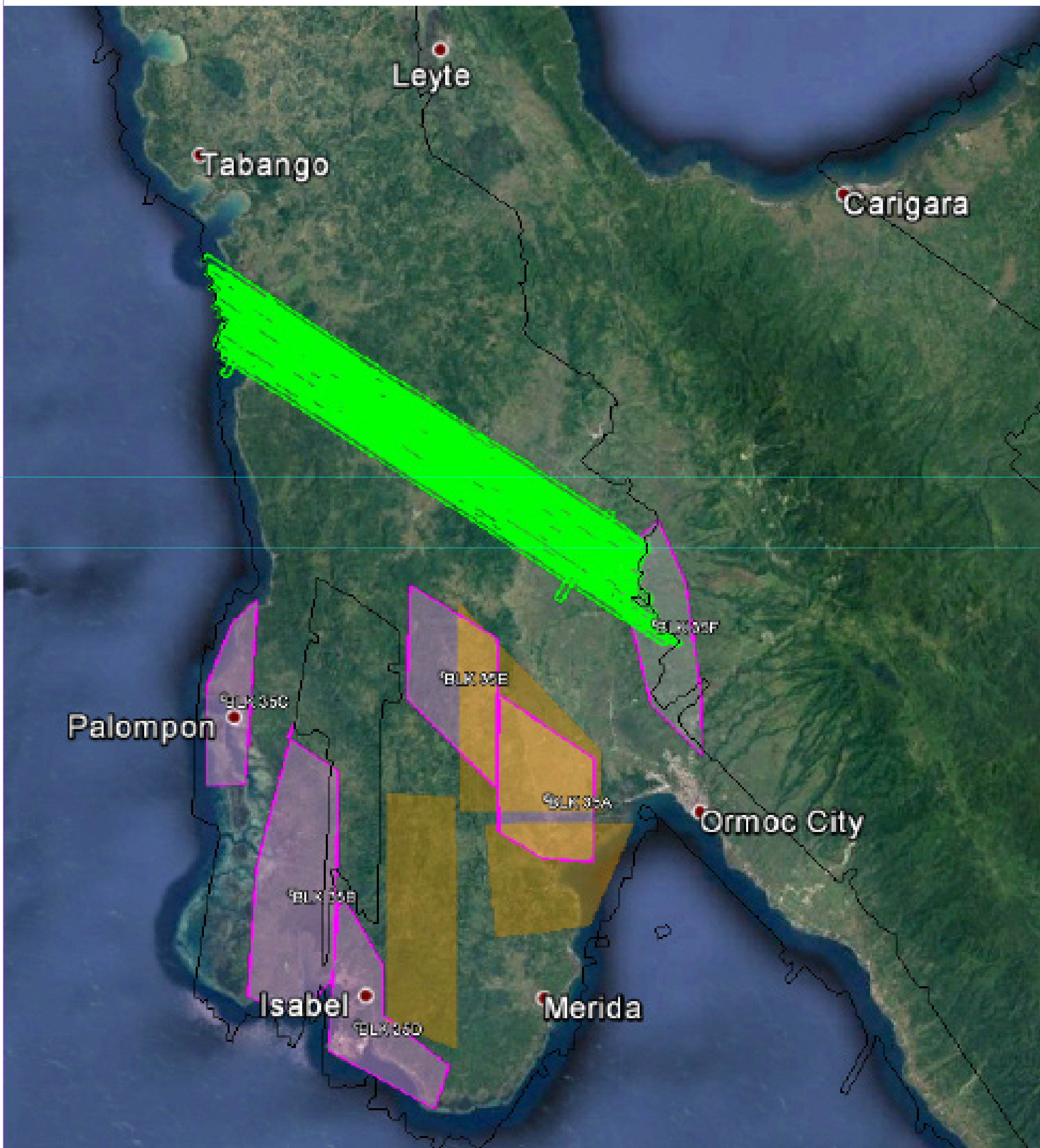


Figure A-7.8. Swath for Flight No. 1494A

Flight No. : 1498A
Area: BLK 35H & 35I
Mission Name: 3BLK35HSI145A
Parameters:
Altitude: 800
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

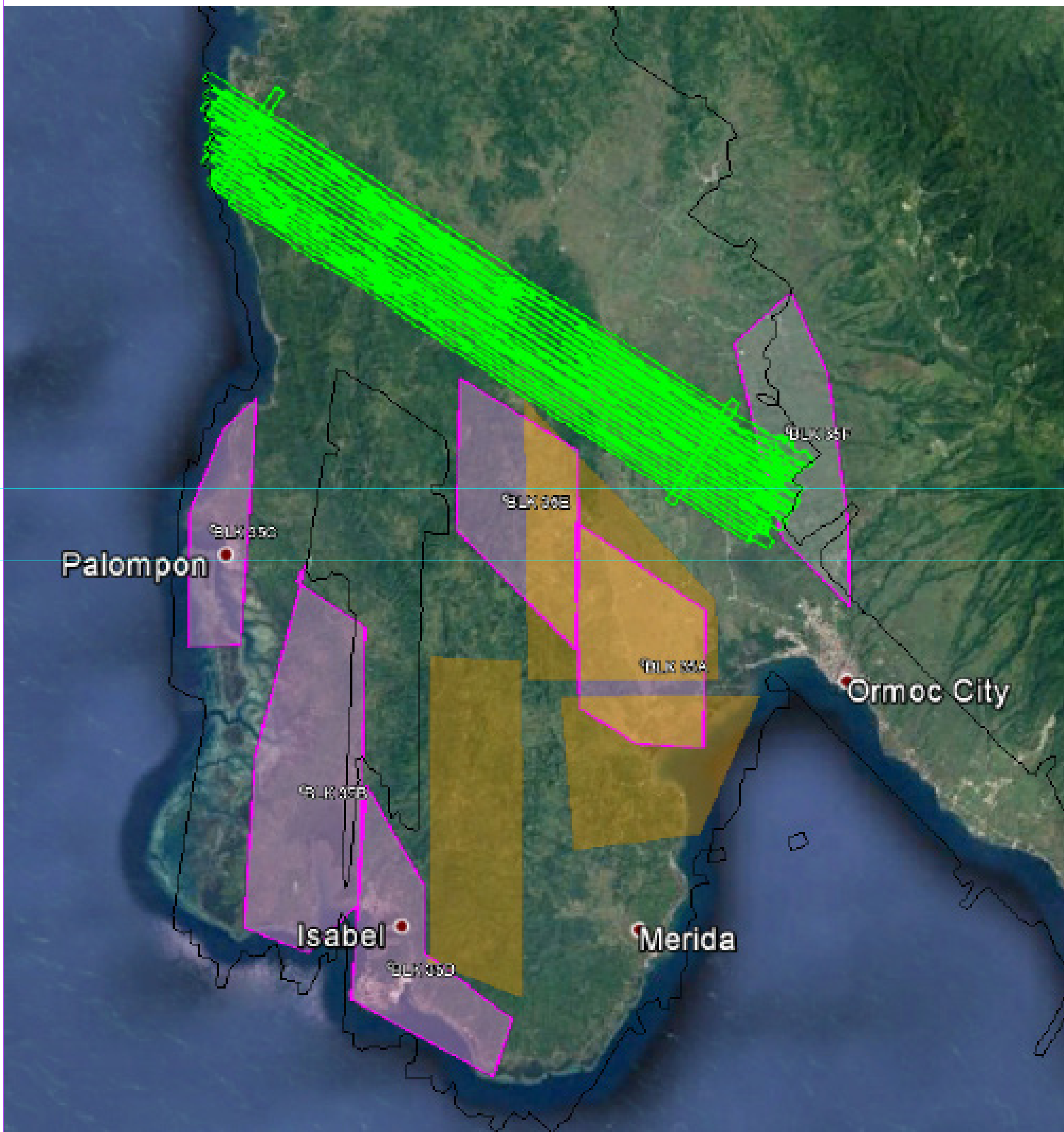


Figure A-7.9. Swath for Flight No. 1498A

Flight No. : 1502A
Area: BLK 35A & 35I
Mission Name: 3BLK35AIS146B
Parameters:
Altitude: 700
Scan Frequency: 50
Scan Angle: 18
Overlap: 55, 40, 50

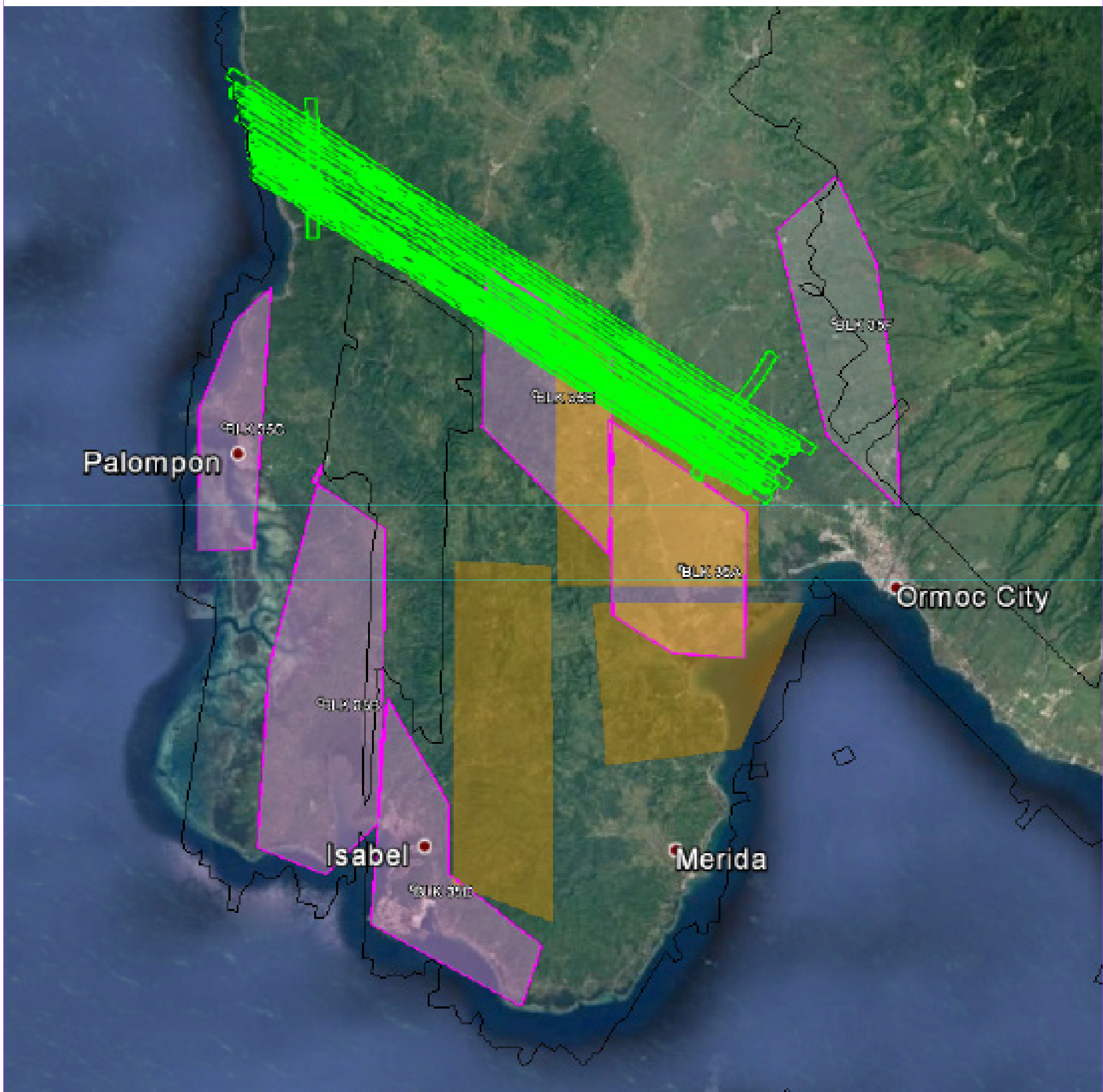


Figure A-7.10. Swath for Flight No. 1502A

Flight No. : 1504A
Area: BLK 35I
Mission Name: 3BLK35IS146A
Parameters:
Altitude: 600
Scan Frequency: 50
Scan Angle: 18
Overlap: 30

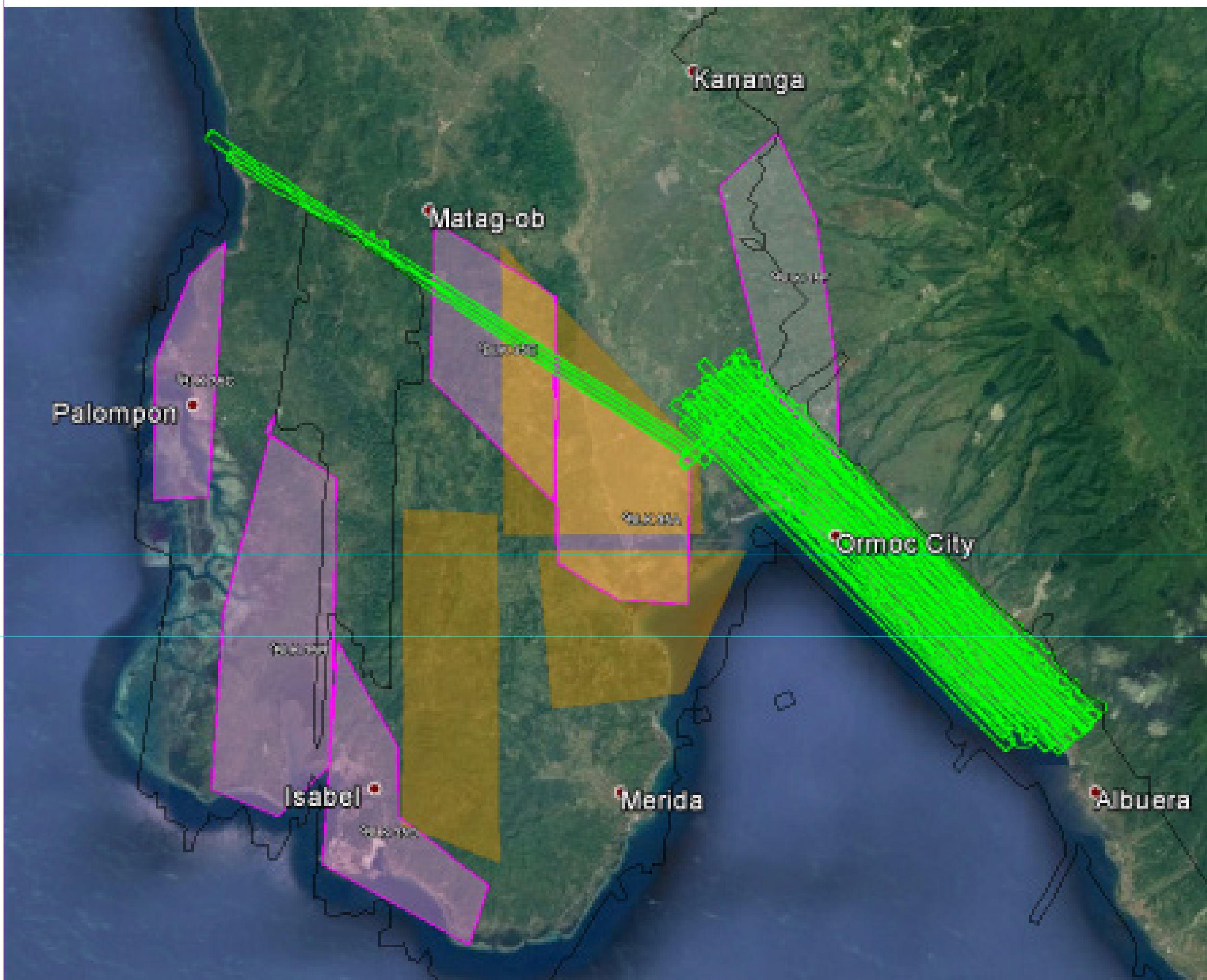


Figure A-7.11. Swath for Flight No. 1504A

Flight No. : 7753AC
Area: BLK 35B
Mission Name: 3BLK35B21A
Parameters:
Altitude: 600 m
Scan Frequency: 45
Scan Angle: 18
Overlap: 35

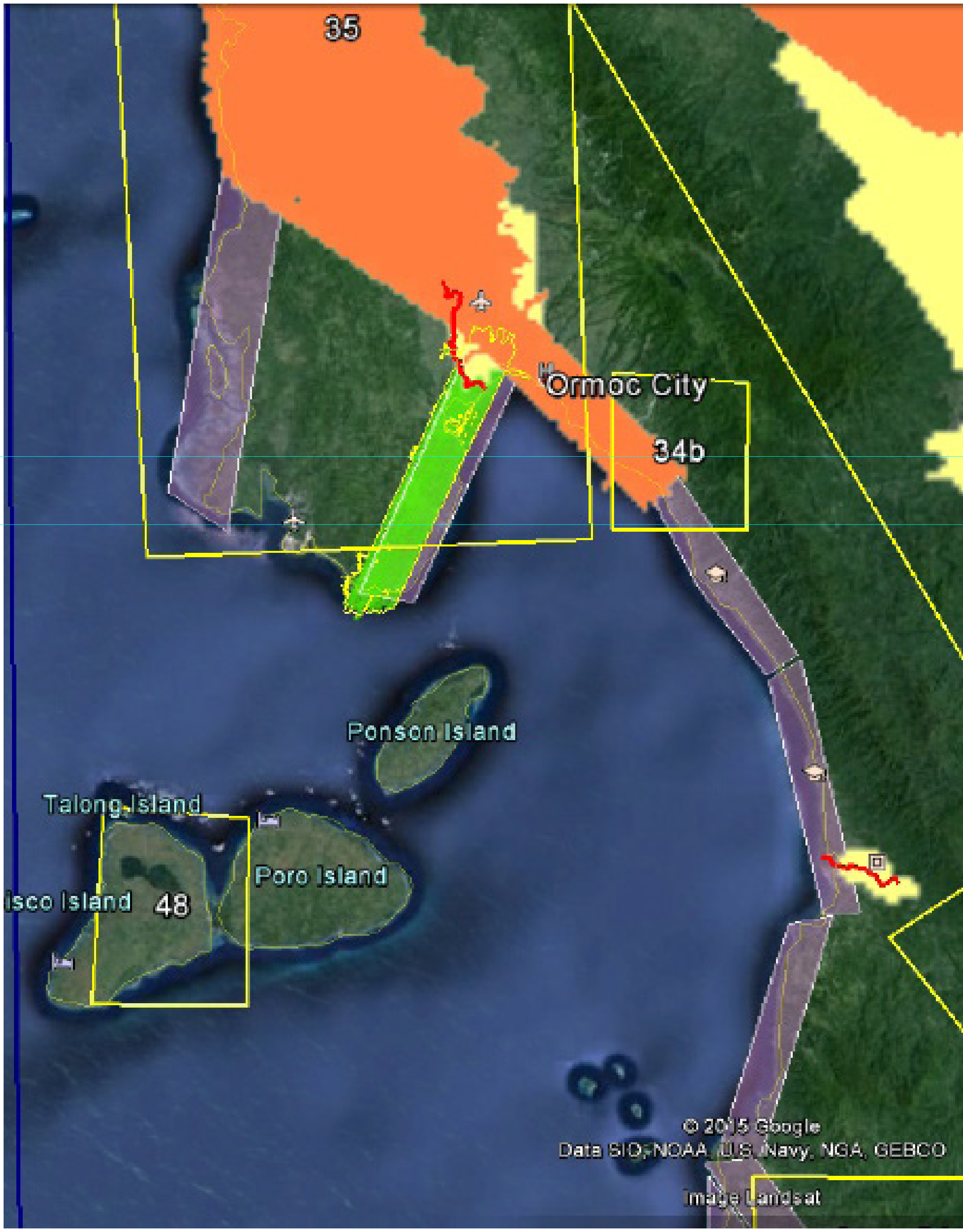


Figure A-7.12. Swath for Flight No. 7753AC

Flight No. : 7760AC
Area: BLK 35A
Mission Name: 3BLK35A025A
Parameters:
Altitude: 550
Scan Frequency: 45
Scan Angle: 18
Overlap: 35

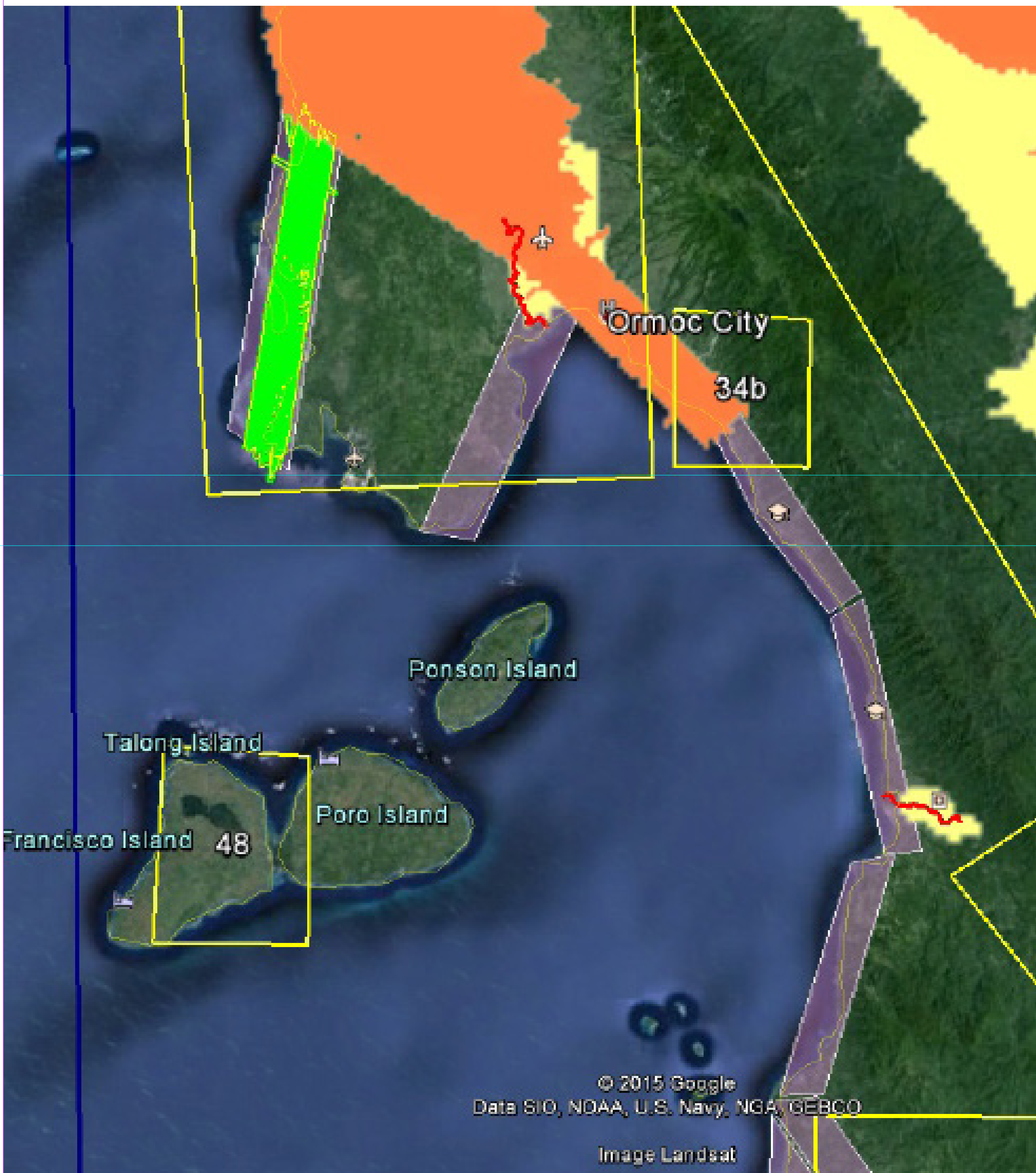


Figure A-7.13. Swath for Flight No. 7760AC

Flight No. : 7780AC
Area: BLK 35A
Mission Name: 3BLK35AX035A
Parameters:
Altitude: 500
Scan Frequency: 45
Scan Angle: 18
Overlap: 35

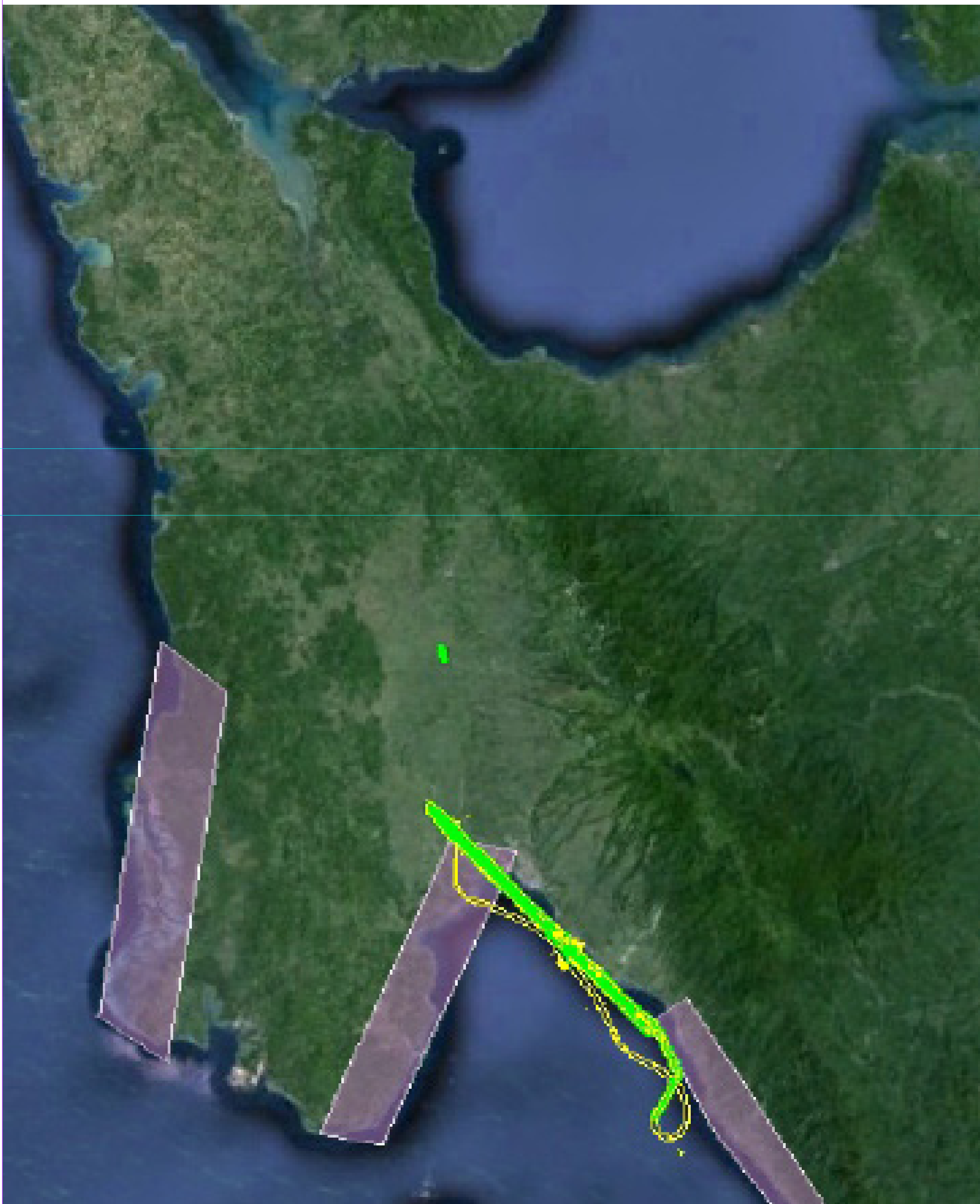


Figure A-7.14. Swath for Flight No. 7780AC

Flight No. : 7782AC
Area: BLK 35A
Mission Name: 3BLK35AX036A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 35

Figure A-7.15. Swath for Flight No. 7782AC

Flight No. : 7802AC
Area: BLK 35 Voids
Mission Name: 3BLK35SV046A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 35

Figure A-7.16. Swath for Flight No. 7802AC

Flight No. : 7806AC
Area: BLK 35 Voids
Mission Name: 3BLK35X1048A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 35

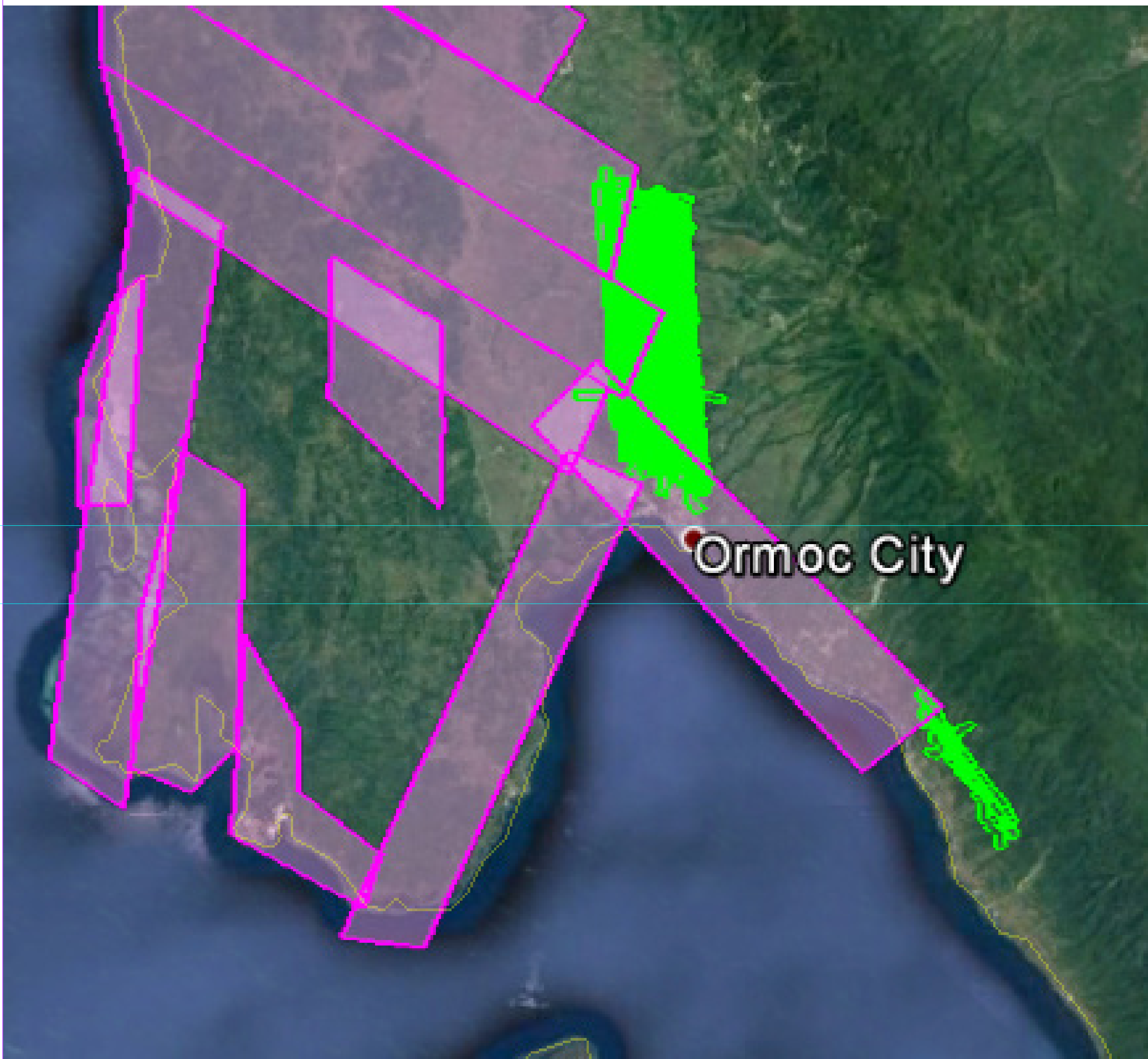


Figure A-7.17. Swath for Flight No. 7806AC

Flight No. : 8389AC
Area: BLK 35A
Mission Name: 3BLK35A068A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 30

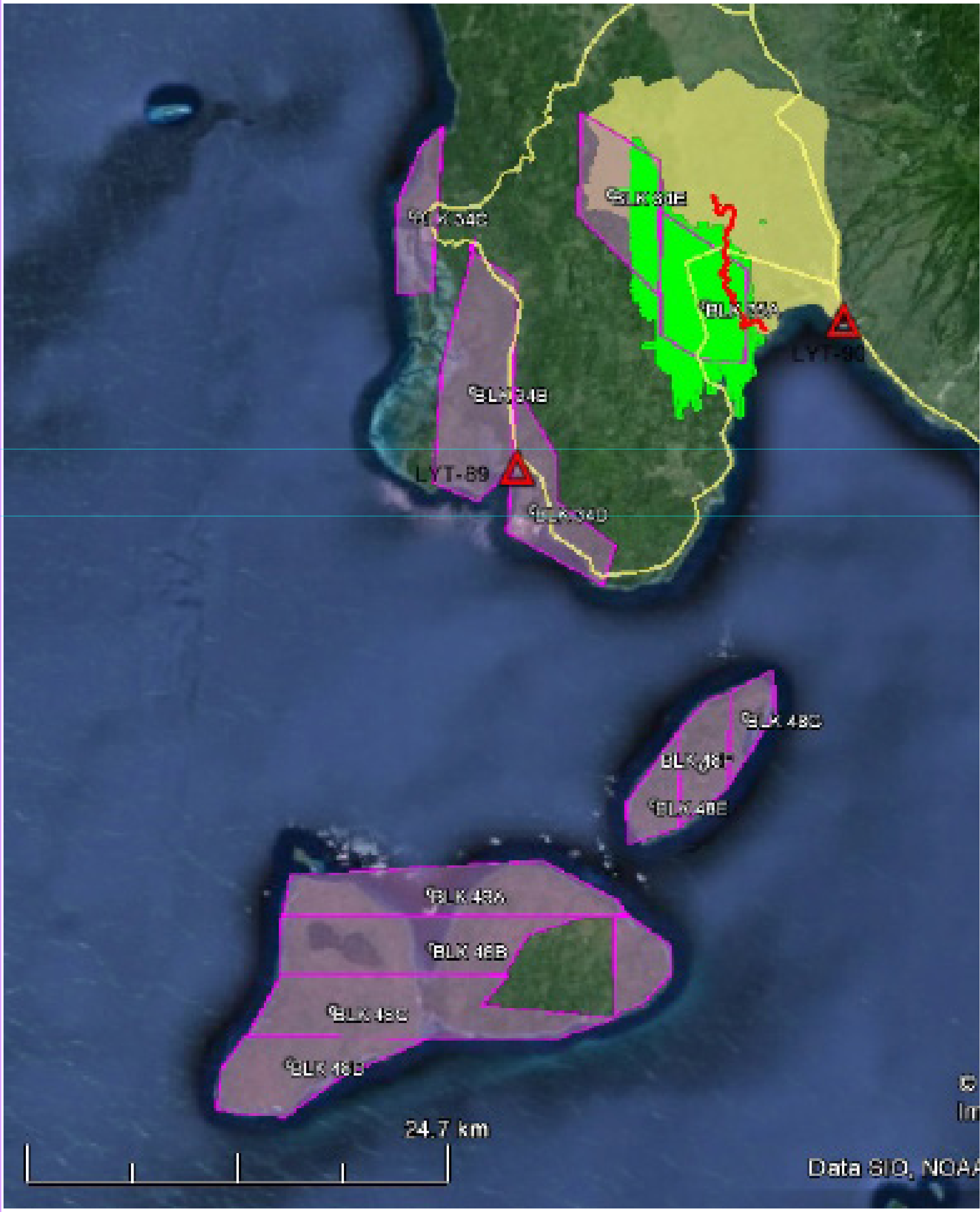


Figure A-7.18. Swath for Flight No. 8389AC

Flight No. : 8391AC
Area: BLK 35EC
Mission Name: 3BLK35EC069A
Parameters:
Altitude: 550
Scan Frequency: 45
Scan Angle: 18
Overlap: 30

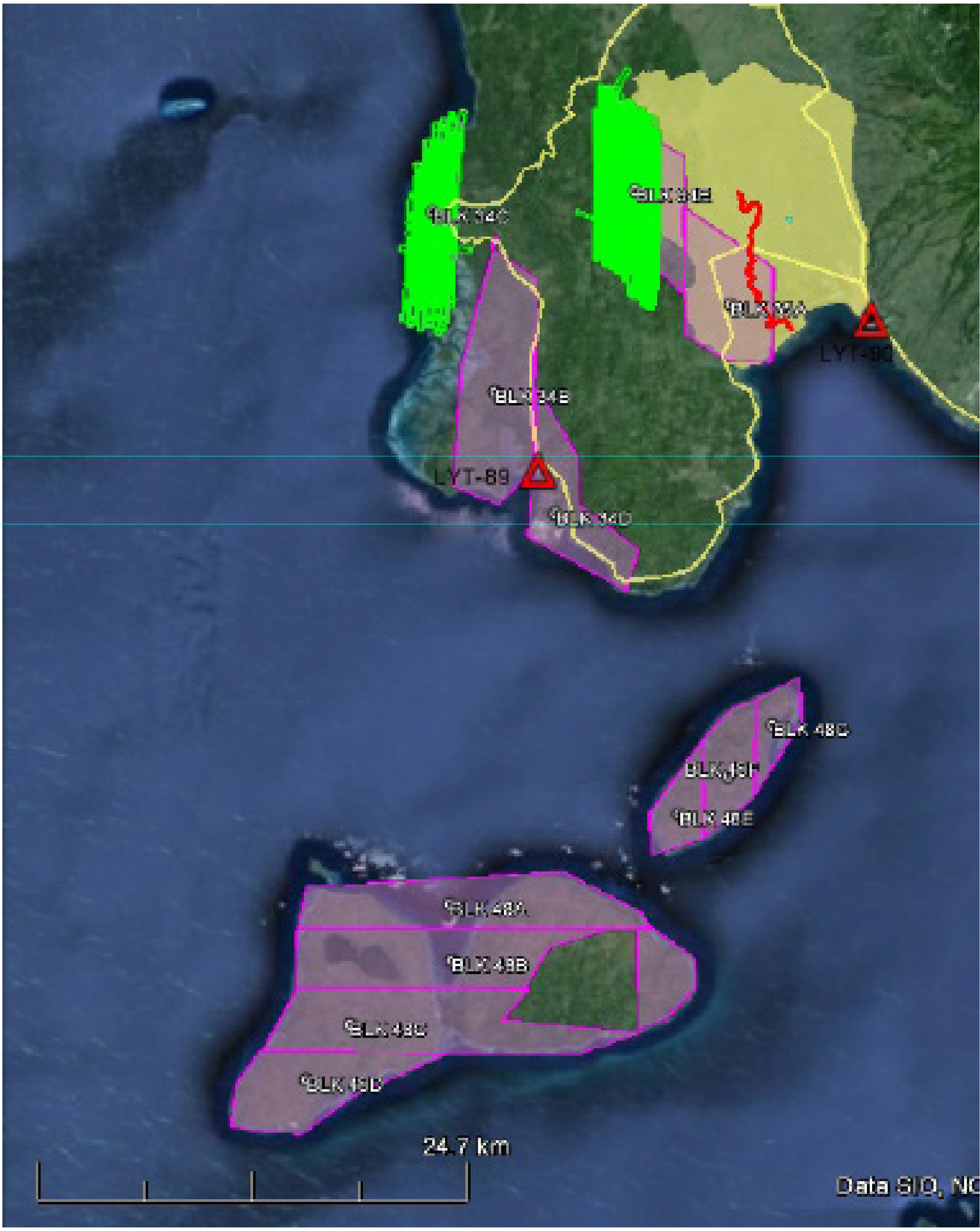


Figure A-7.19. Swath for Flight No. 8391AC

Flight No. : 8392AC
Area: BLK 35BD
Mission Name: 3BLK35BD069B
Parameters:
Altitude: 550
Scan Frequency: 45
Scan Angle: 18
Overlap: 30

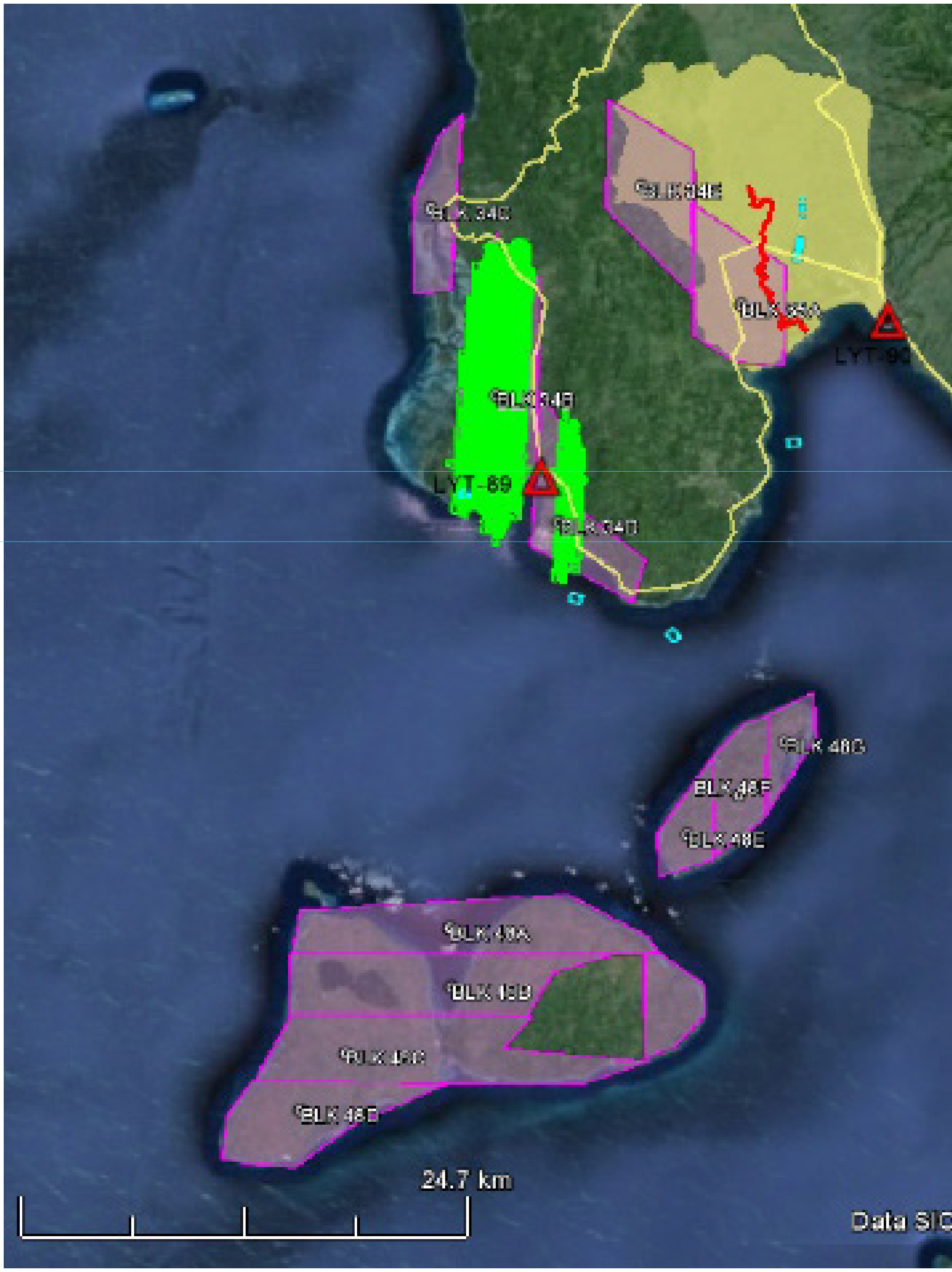


Figure A-7.20. Swath for Flight No. 8392AC

Flight No. : 8394AC
Area: BLK 35BD
Mission Name: 3BLK35BD070B
Parameters:
Altitude: 550
Scan Frequency: 45
Scan Angle: 18
Overlap: 30

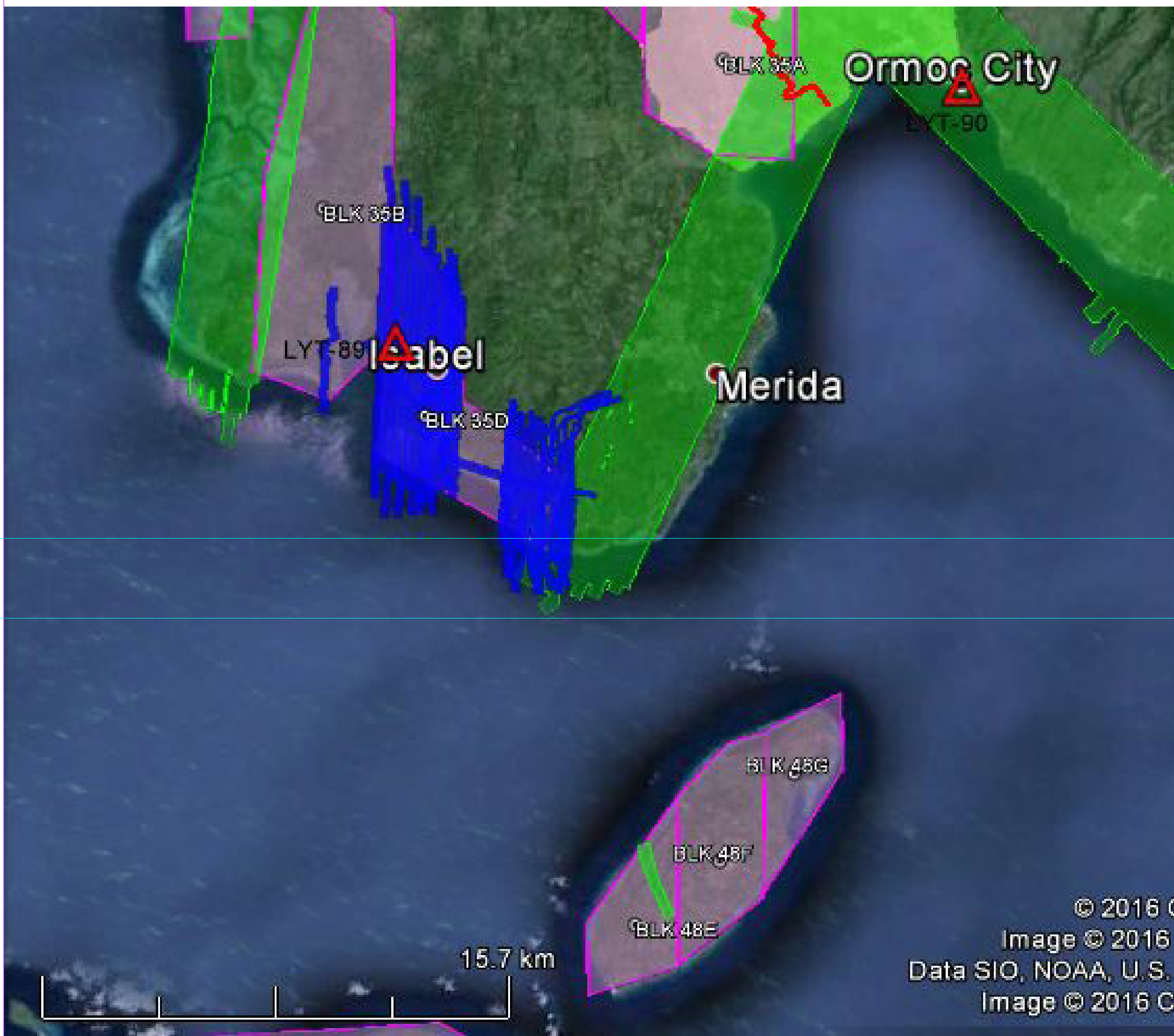


Figure A-7.21. Swath for Flight No. 8394AC

Flight No. : 8408AC
Area: BLK 35DCE
Mission Name: 3BLK35S079A
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 30

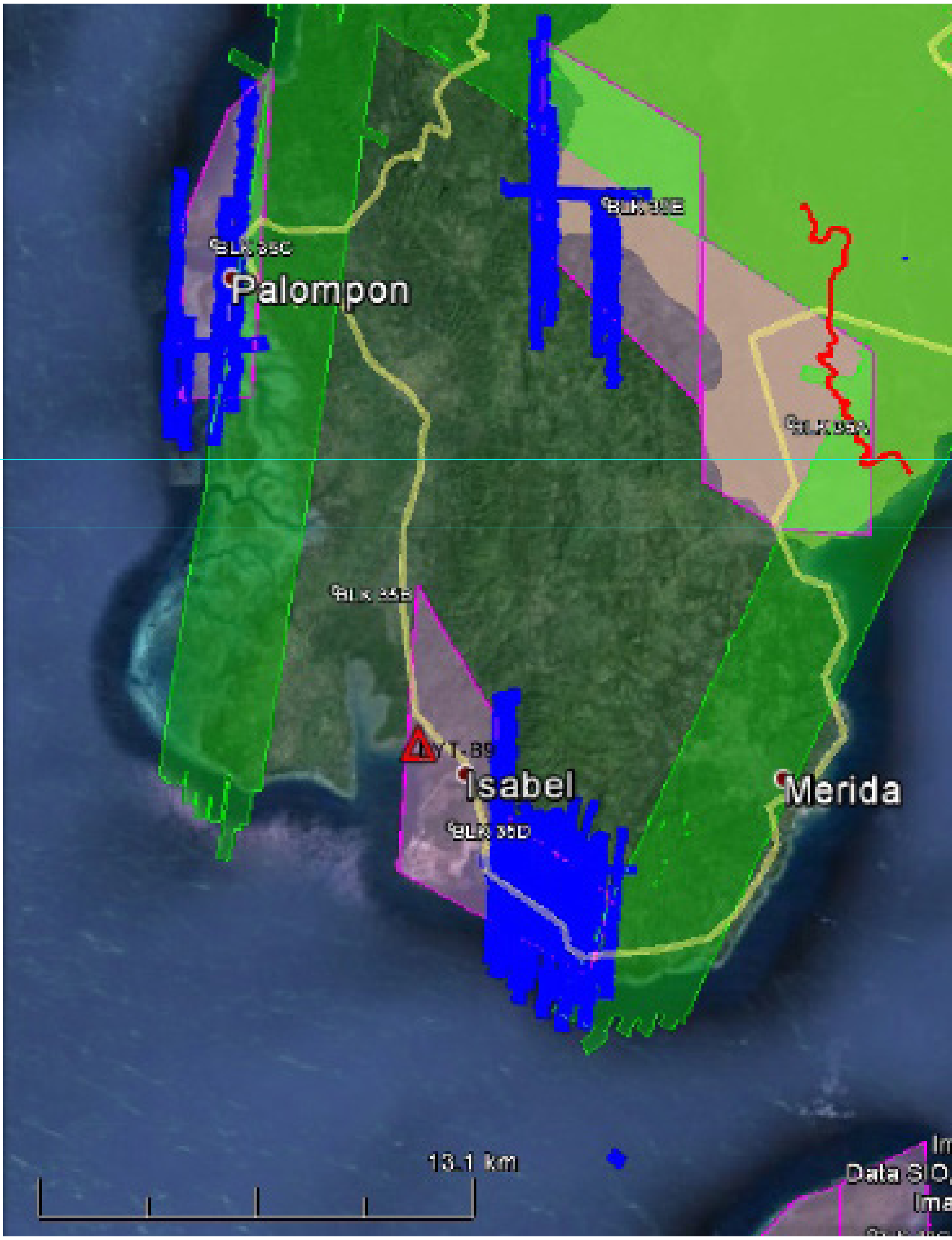


Figure A-7.22. Swath for Flight No. 8408AC

Flight No. : 8409AC
Area: BLK 48DS
Mission Name: 3BLK35S079B
Parameters:
Altitude: 600
Scan Frequency: 45
Scan Angle: 18
Overlap: 30

Figure A-7.23. Swath for Flight No. 8409AC

Flight No. : 3945G
Area: BLK 35A and 35B
Mission Name: 2BLK35AB107A
Parameters:
Altitude: 800, 1000
Scan Frequency: 45
Scan Angle: 20
Overlap: 30

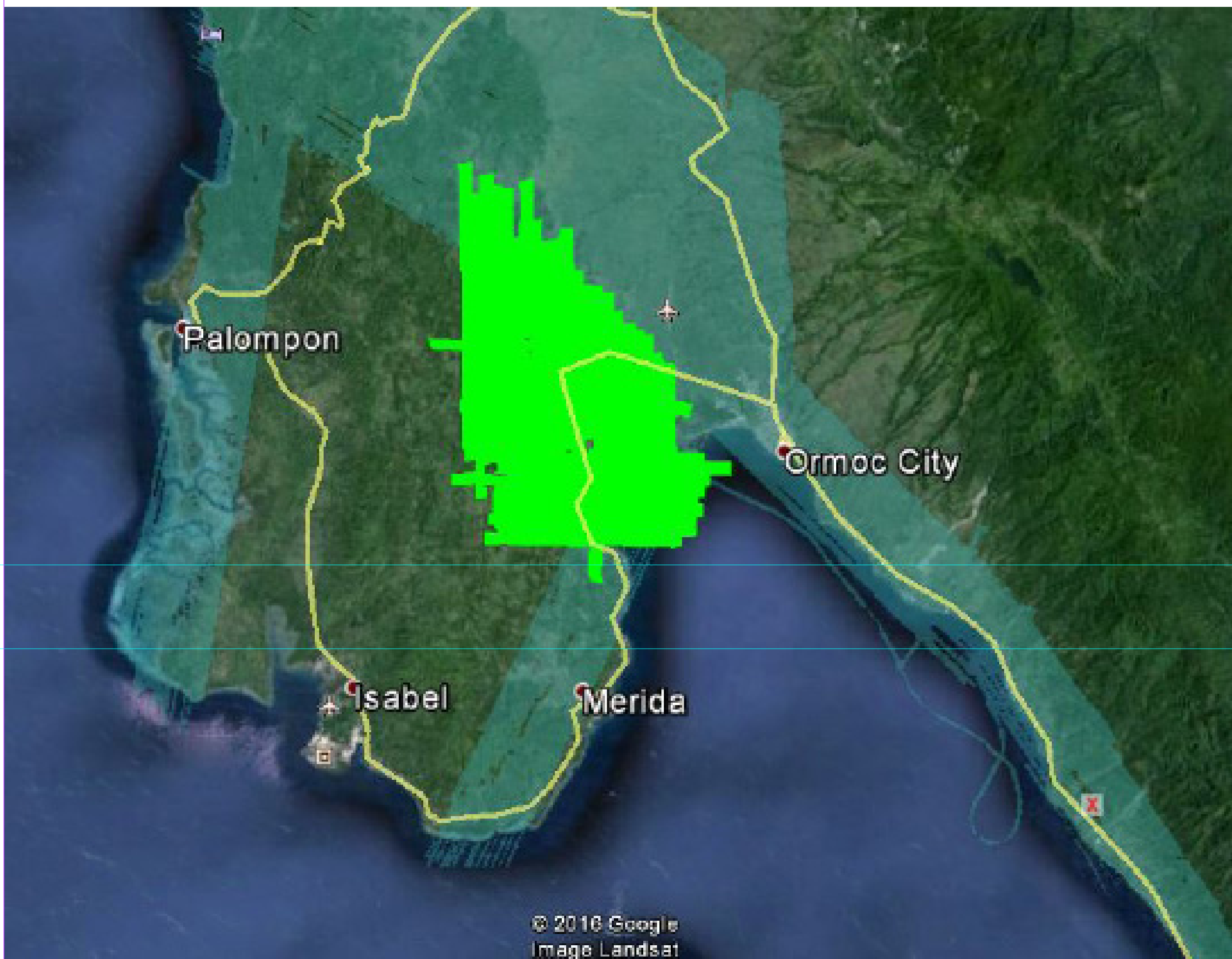


Figure A-7.24. Swath for Flight No. 3945G

Flight No. : 3947G
Area: BLK 35CS
Mission Name: 2BLK35CS107B
Parameters:
Altitude: 1100
Scan Frequency: 45
Scan Angle: 20
Overlap: 30

Figure A-7.25. Swath for Flight No. 3947G

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk35A

Flight Area	Samar-Leyte
Mission Name	Blk35A
Inclusive Flights	1504A
Range data size	11.4 GB
POS	265 MB
Image	15.7 MB
Transfer date	61.3 GB
	June 10, 2014
Solution Status	
Number of Satellites (>6)	
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	1.9
	2.5
Boresight correction stdev (<0.001deg)	
IMU attitude correction stdev (<0.001deg)	0.000264
GPS position stdev (<0.01m)	0.001690
	0.0085
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	52.02%
Elevation difference between strips (<0.20 m)	3.13
	Yes
Number of 1km x 1km blocks	
Maximum Height	107
Minimum Height	184.83 m
	57.11 m
Classification (# of points)	
Ground	
Low vegetation	51,584,742
Medium vegetation	65,607,742
High vegetation	63,615,309
Building	9,673,867
	5,271,987
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Jeffrey Delica

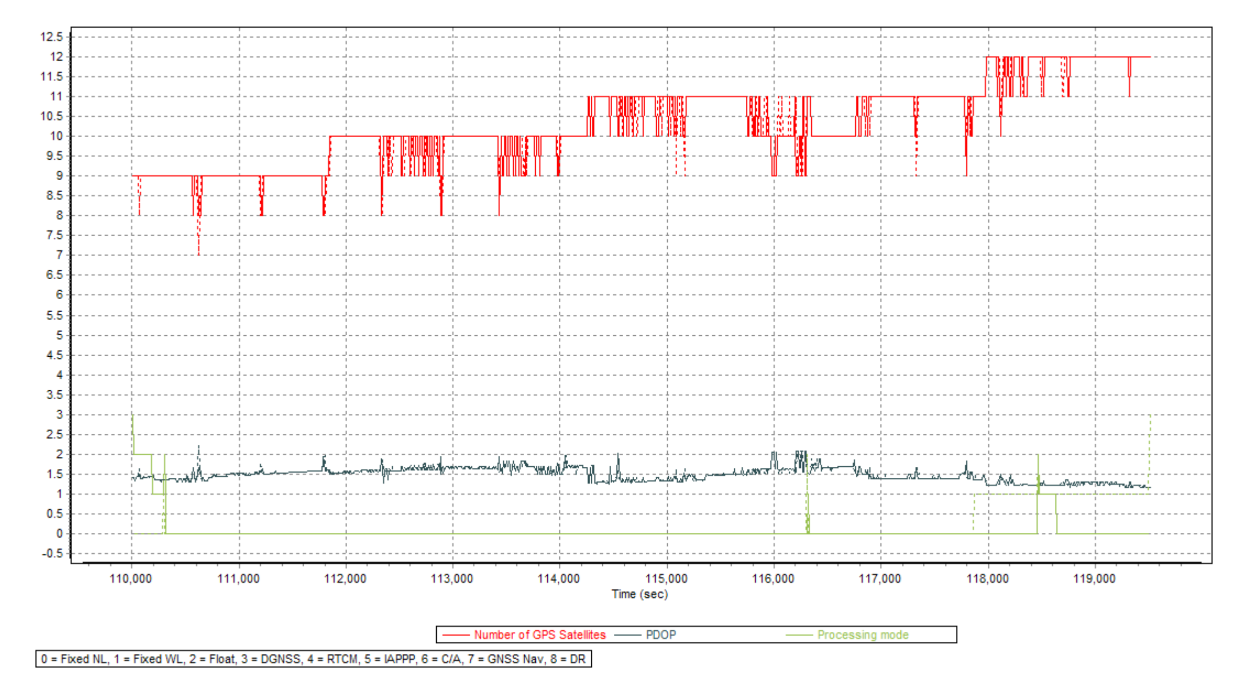


Figure A-8.1. Solution Status

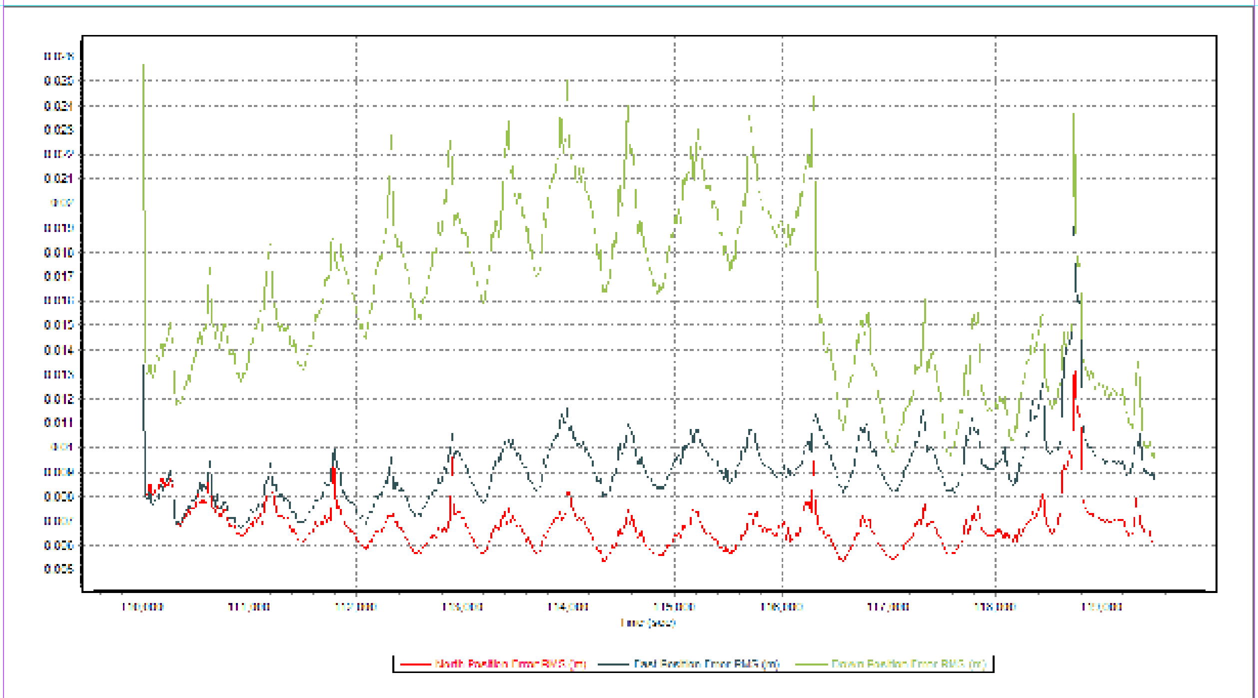


Figure A-8.2. Smoothed Performance Metrics Parameters

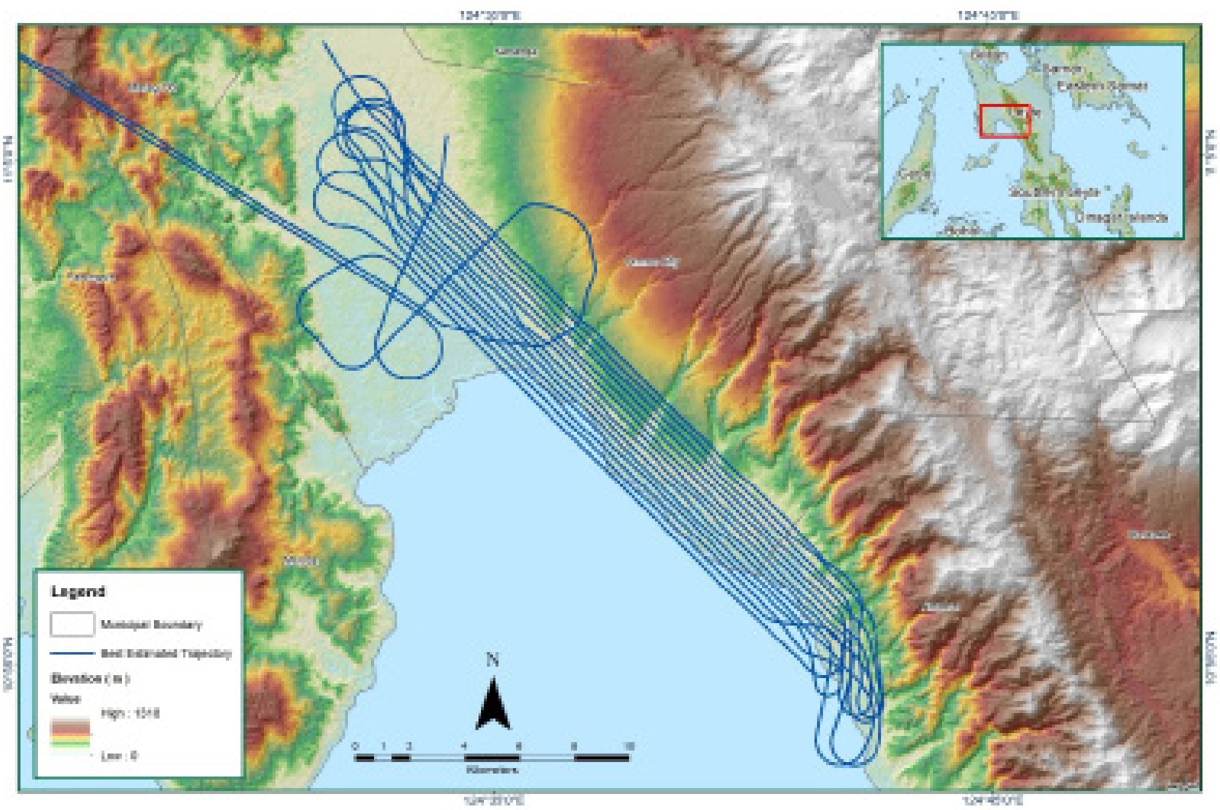


Figure A-8.3. Best Estimated Trajectory

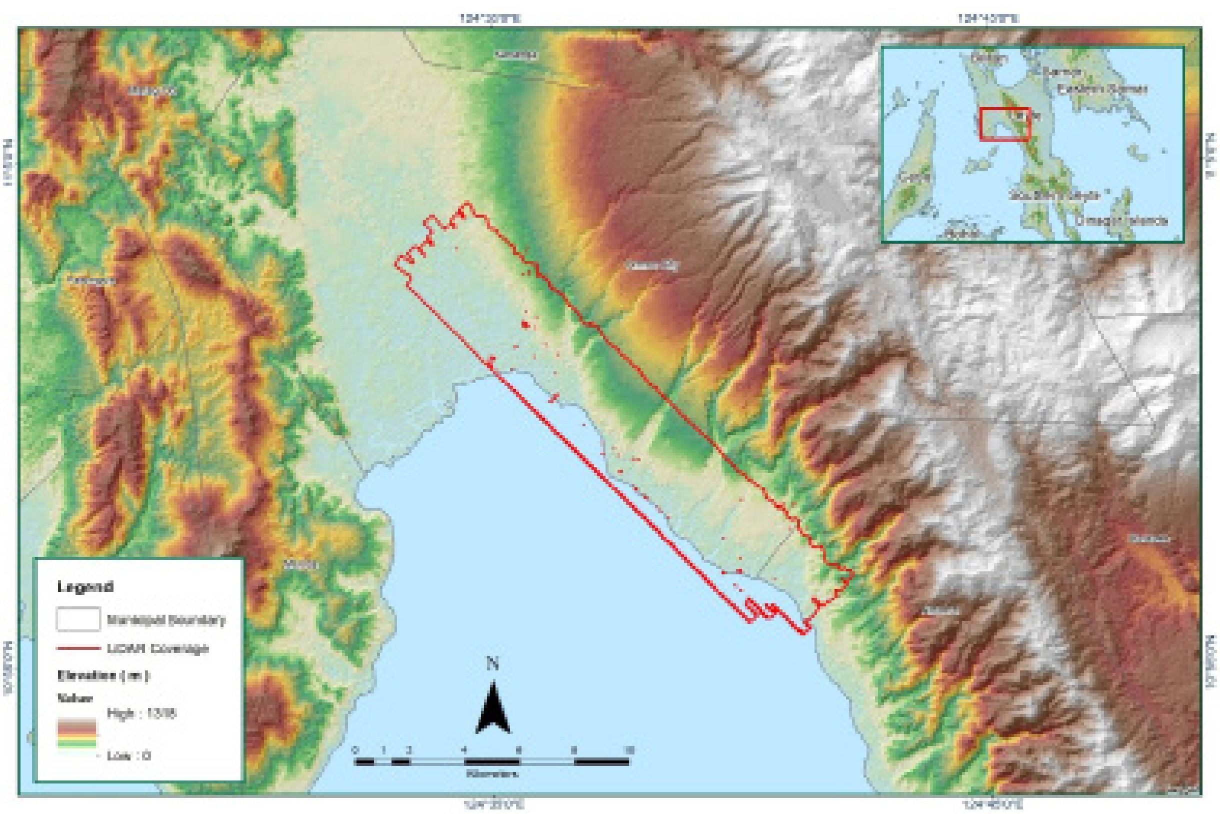


Figure A-8.3. Best Estimated Trajectory

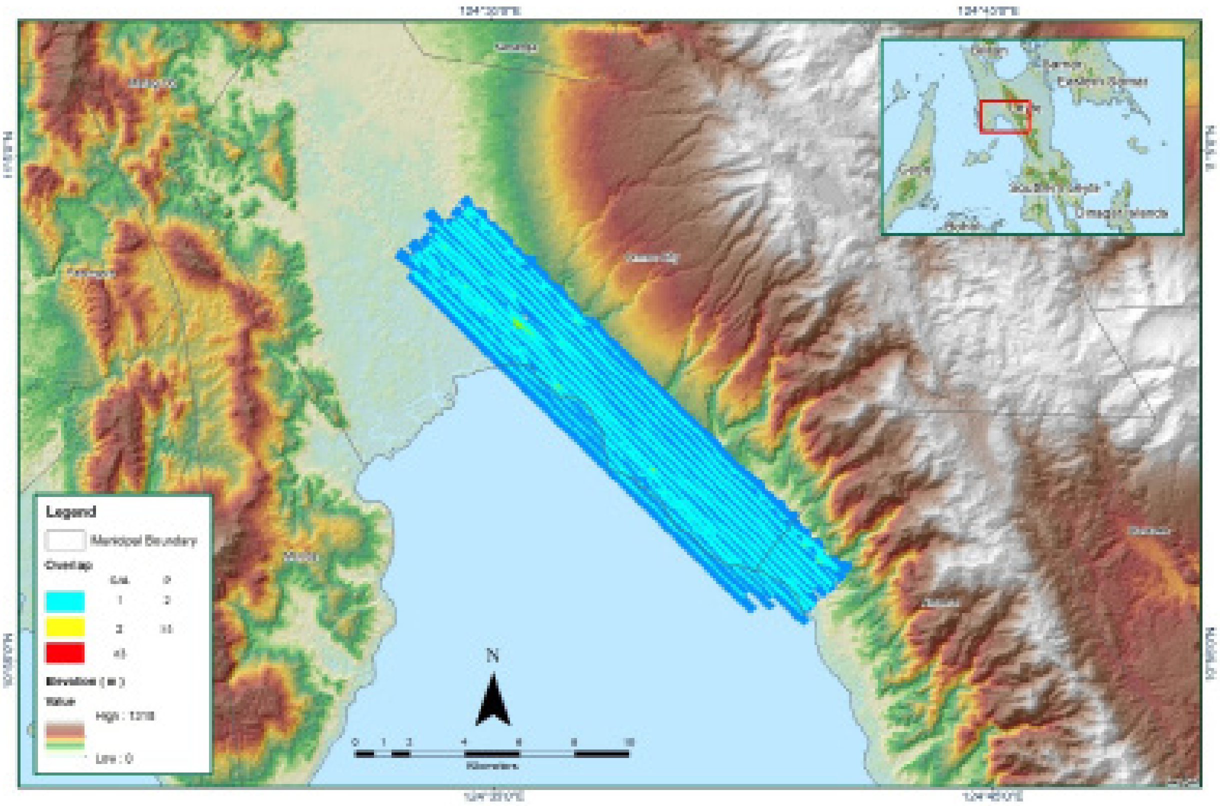


Figure A-8.5. Image of data overlap

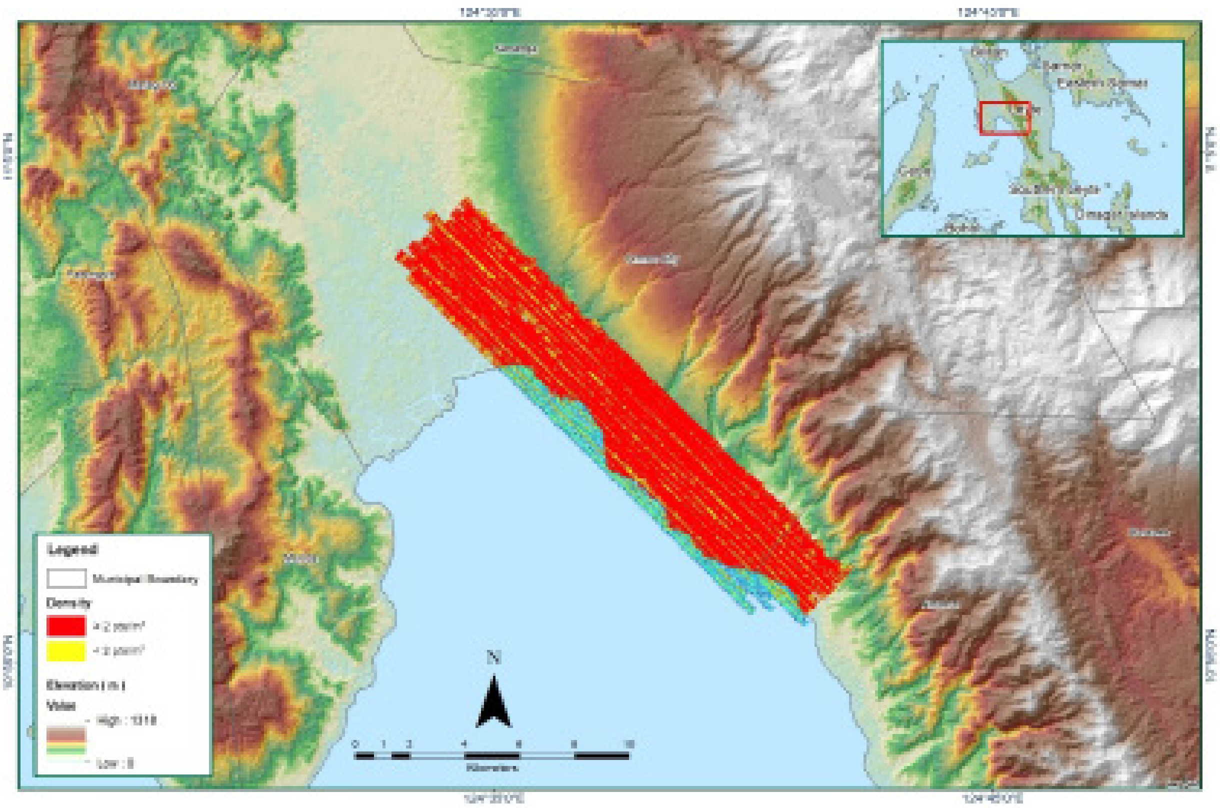


Figure A-8.6. Density map of merged LiDAR data

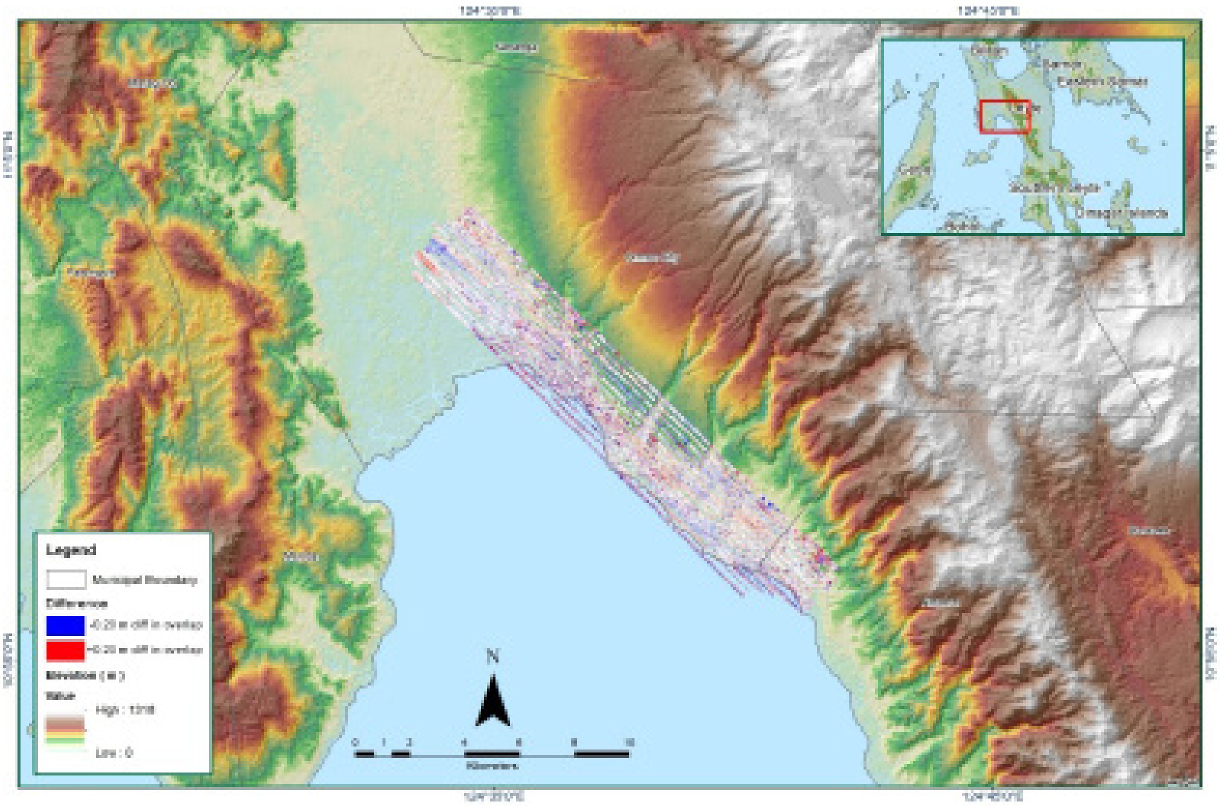


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk35I

Flight Area	Samar-Leyte
Mission Name	Blk35I
Inclusive Flights	1502A, 1504A
Range data size	25.3 GB
POS data size	543 MB
Base data size	31.4 MB
Image	148 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	Figure A-8.1. Solution Status
RMSE for North Position (<4.0 cm)	2.945
RMSE for East Position (<4.0 cm)	2.56
RMSE for Down Position (<8.0 cm)	5.176
Boresight correction stdev (<0.001deg)	
IMU attitude correction stdev (<0.001deg)	
GPS position stdev (<0.01m)	
Minimum % overlap (>25)	68.60%
Ave point cloud density per sq.m. (>2.0)	5.18
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	109
Maximum Height	514.41 m
Minimum Height	52.26 m
Classification (# of points)	
Ground	55,725,687
Low vegetation	70,544,651
Medium vegetation	140,006,924
High vegetation	51,430,148
Building	1,264,171
Figure A-8.2. Smoothed Performance Metrics Parameters	
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

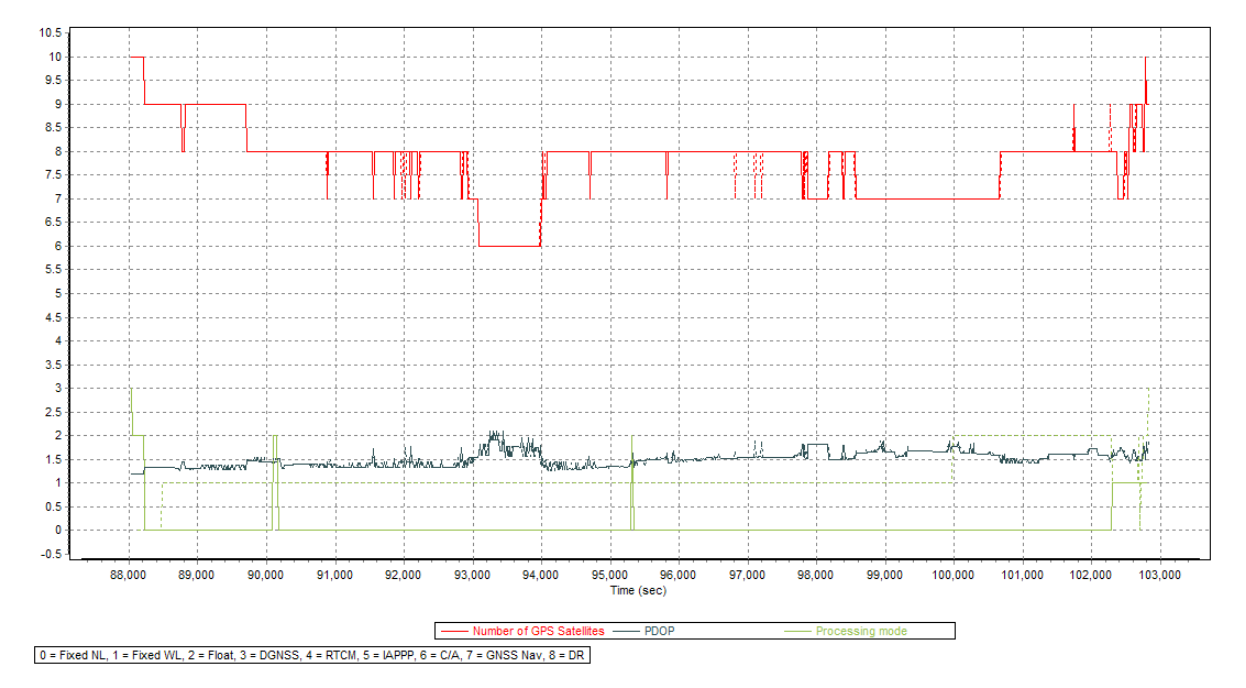


Figure A-8.8. Solution Status

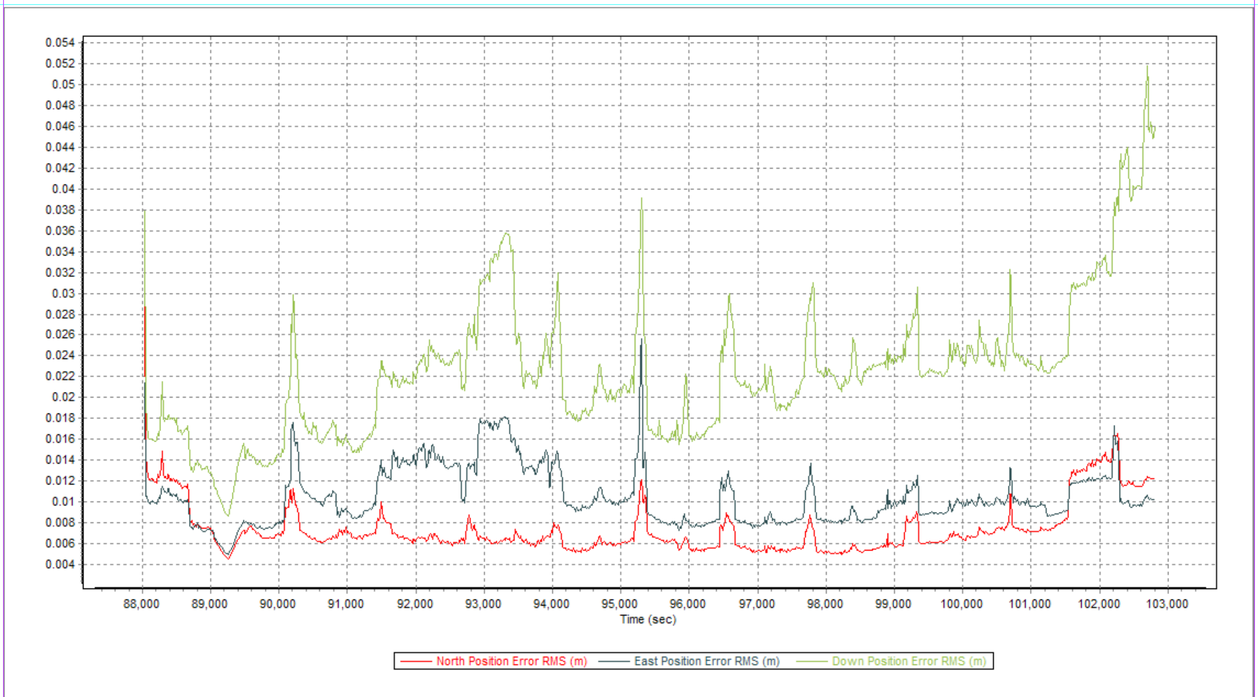


Figure A-8.9. Smoothed Performance Metrics Parameters

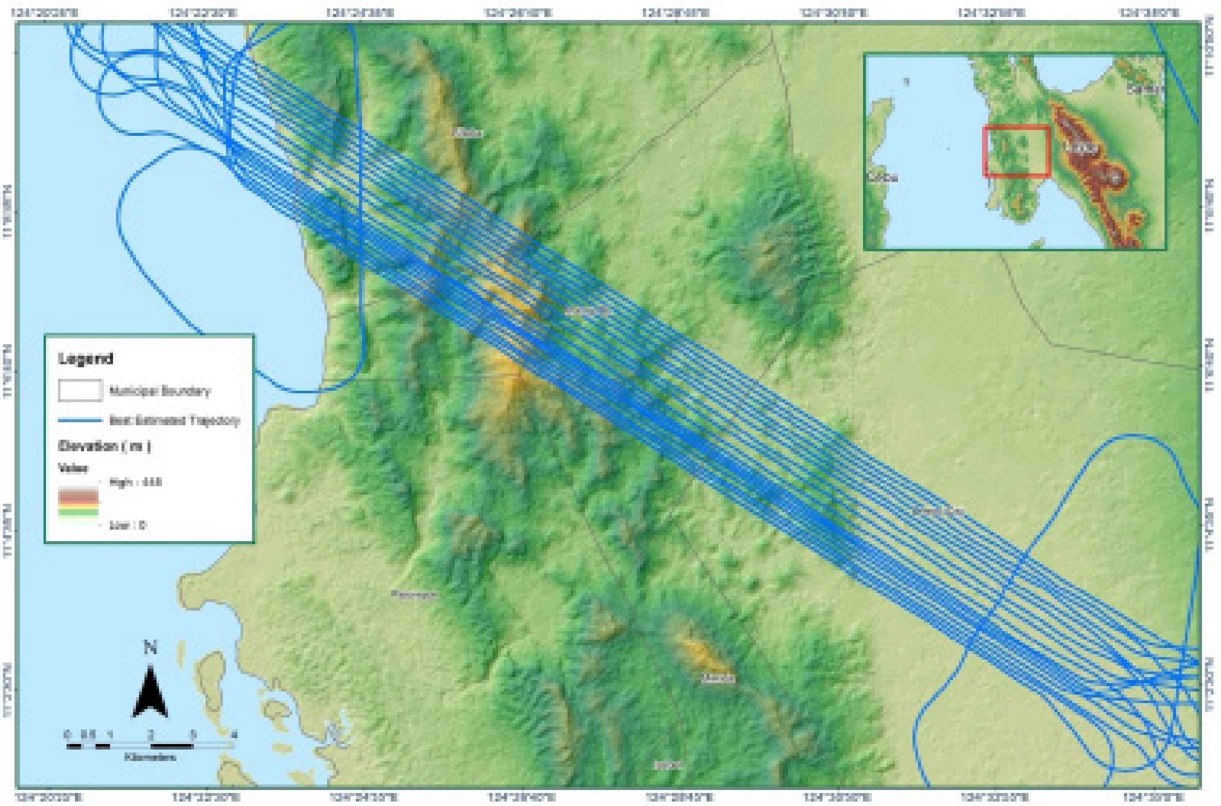


Figure A-8.10. Best Estimated Trajectory

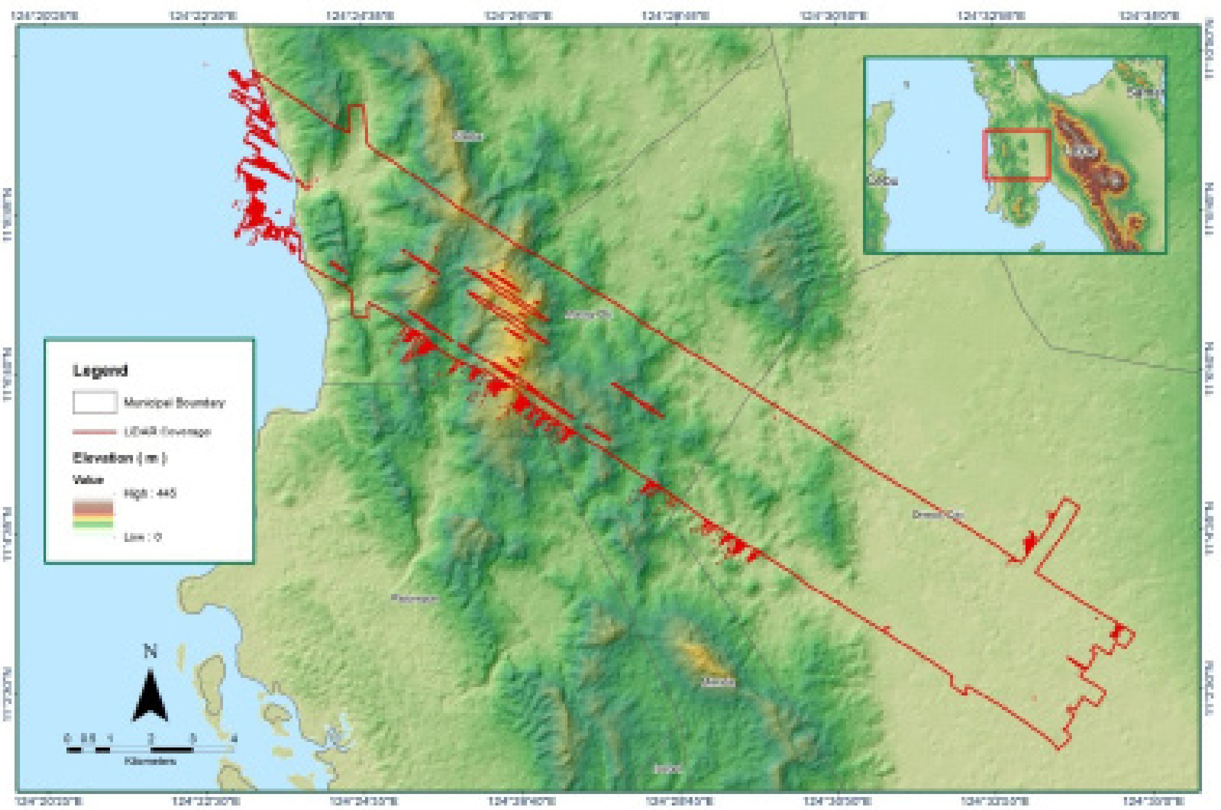


Figure A-8.11. Coverage of LiDAR data

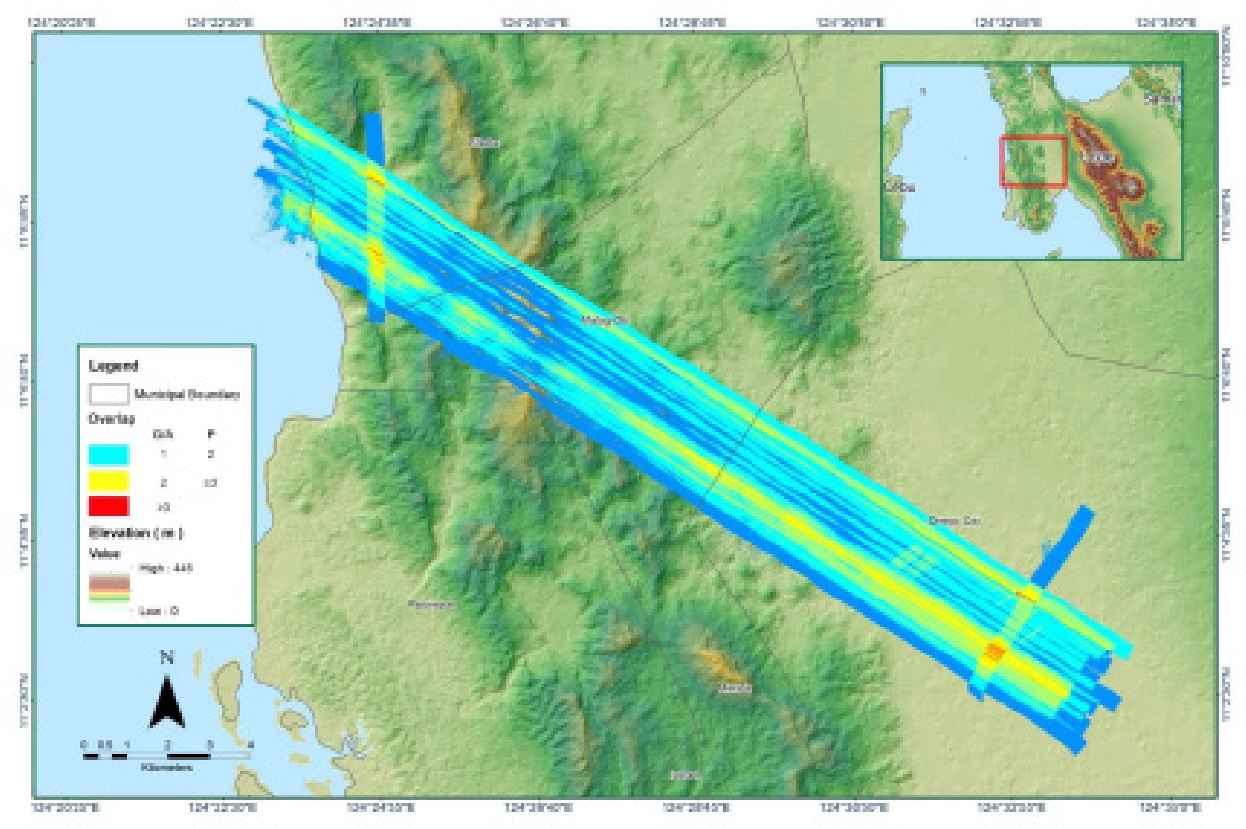


Figure A-8.12. Image of data overlap

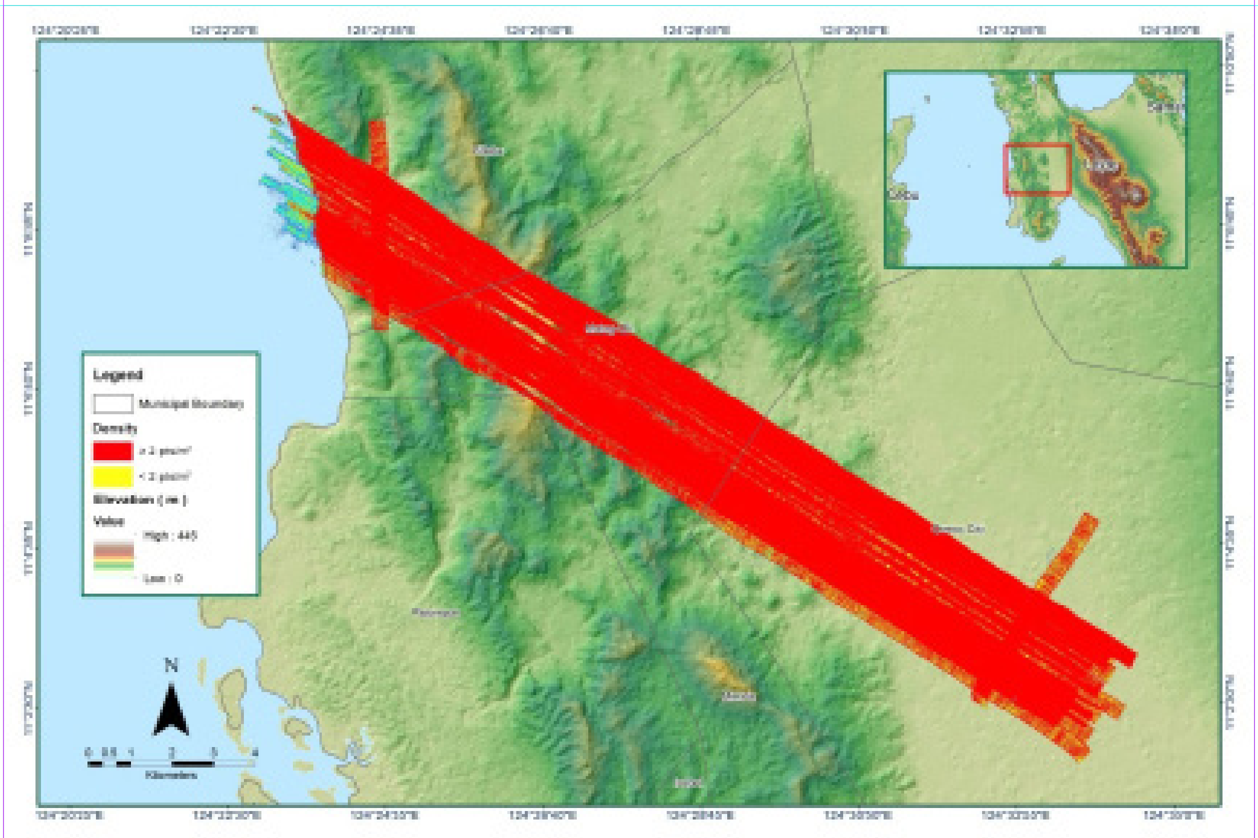


Figure A-8.13. Density map of merged LiDAR data

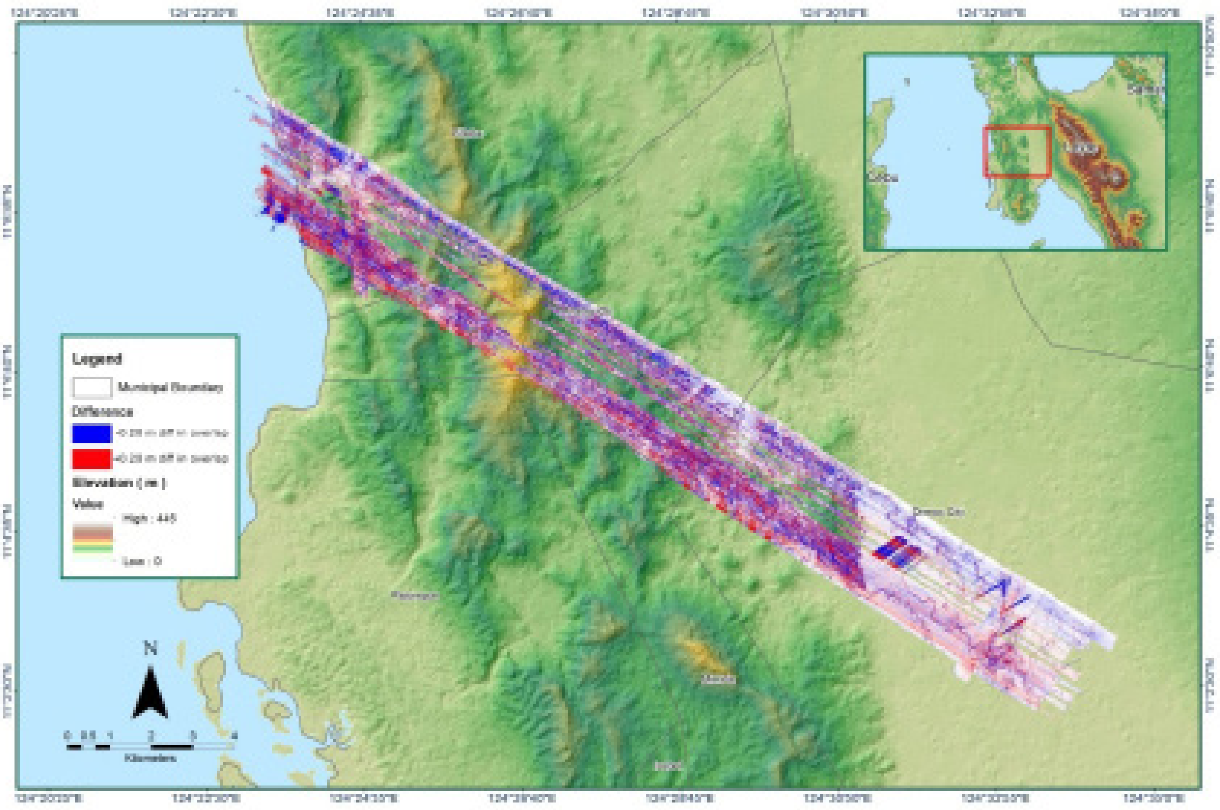


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk35H_Supplement

Flight Area	Samar-Leyte
Mission Name	Blk35H_Supplement
Inclusive Flights	1498A
Range data size	3.23 GB
POS data size	282 MB
Base data size	8.04 MB
Image	88.7 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.34
RMSE for East Position (<4.0 cm)	3.776
RMSE for Down Position (<8.0 cm)	4.315
Boresight correction stdev (<0.001deg)	0.000283
IMU attitude correction stdev (<0.001deg)	0.000568
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	51.18%
Ave point cloud density per sq.m. (>2.0)	3.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	151
Maximum Height	433.53 m
Minimum Height	53.21 m
Classification (# of points)	
Ground	77,606,477
Low vegetation	87,206,288
Medium vegetation	130,999,621
High vegetation	43,330,044
Building	1,222,961
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Jovy Narisma

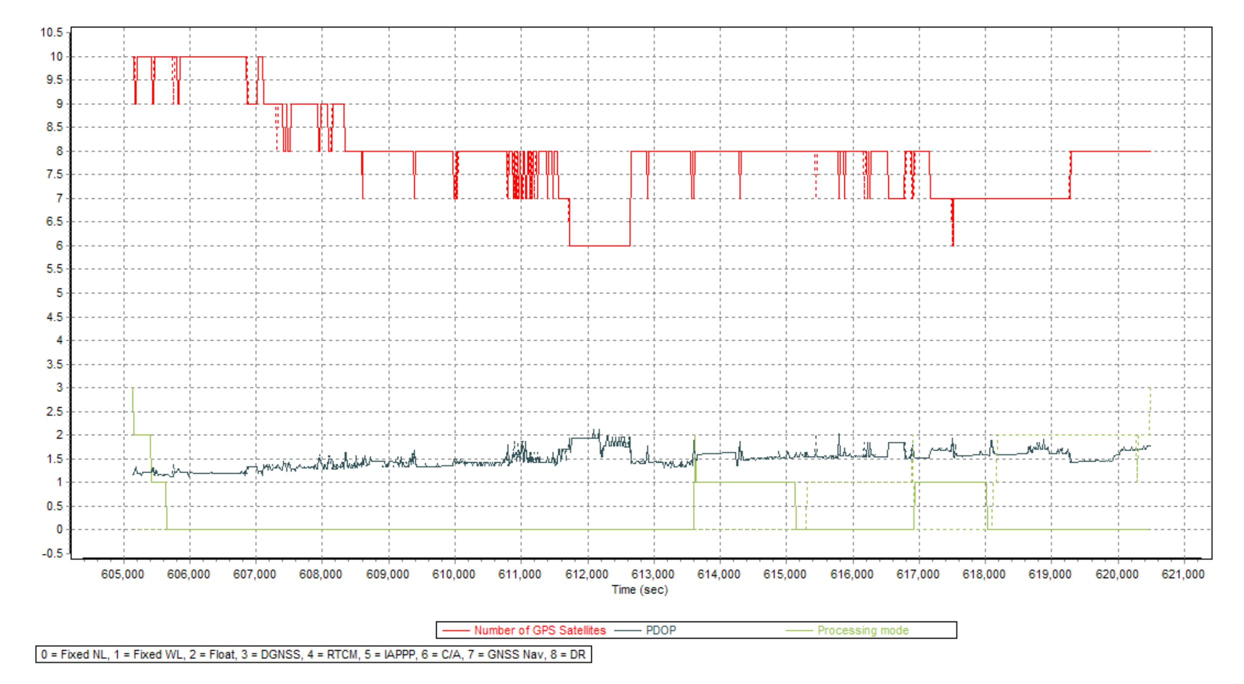


Figure A-8.15. Solution Status

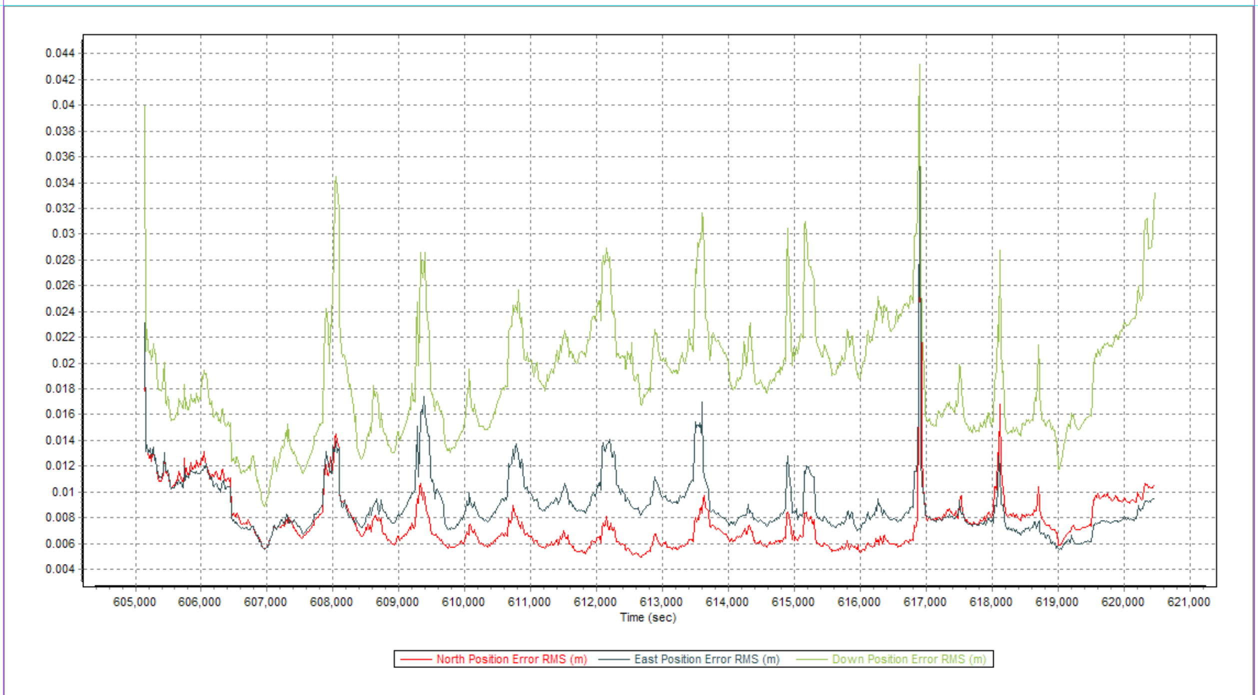


Figure A-8.16. Smoothed Performance Metrics Parameters

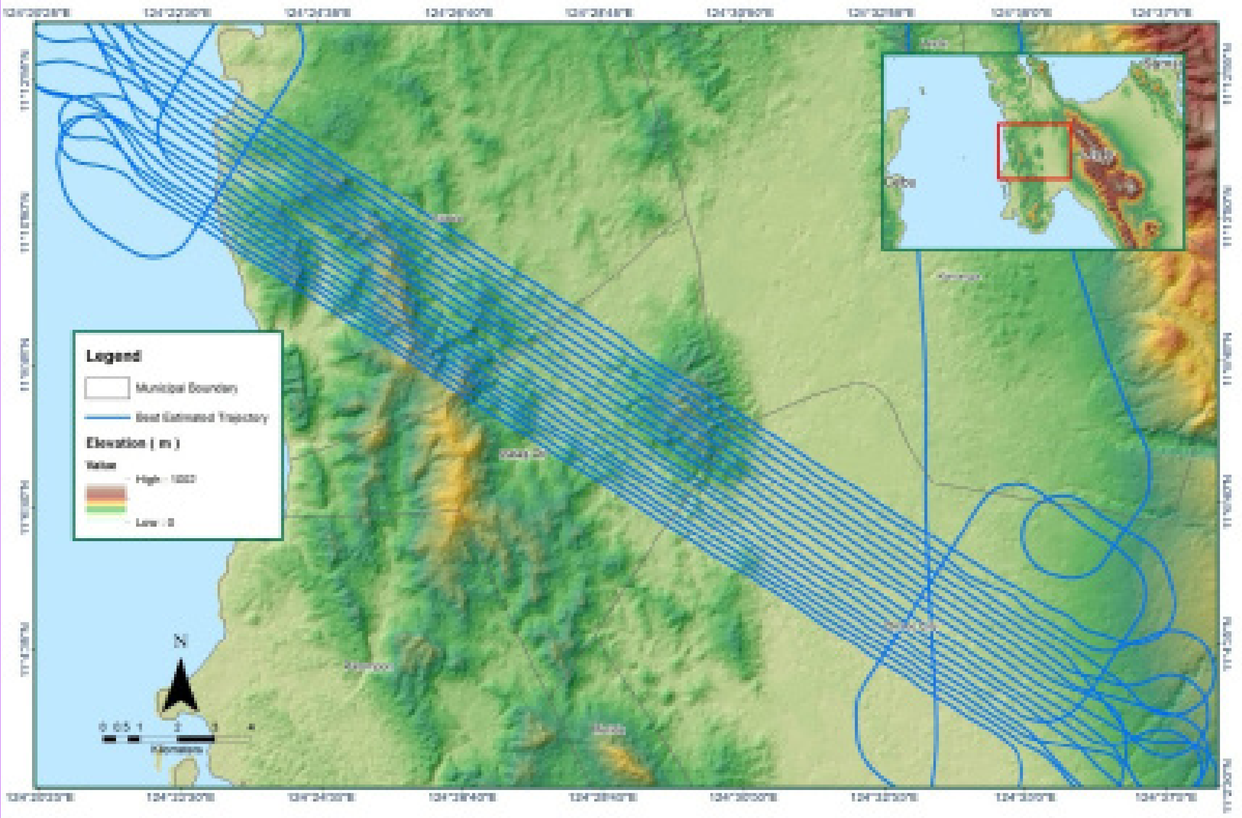


Figure A-8.17. Best Estimated Trajectory

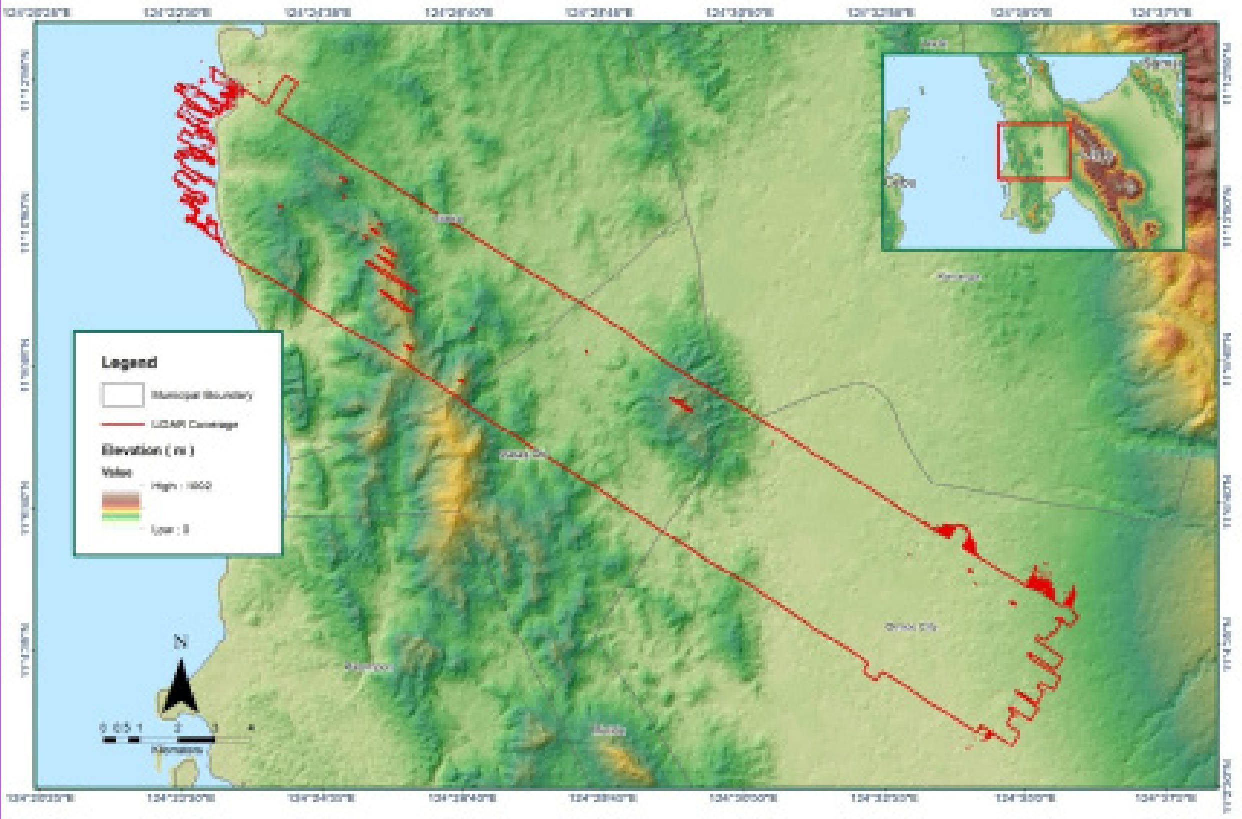


Figure A-8.18. Best Estimated Trajectory

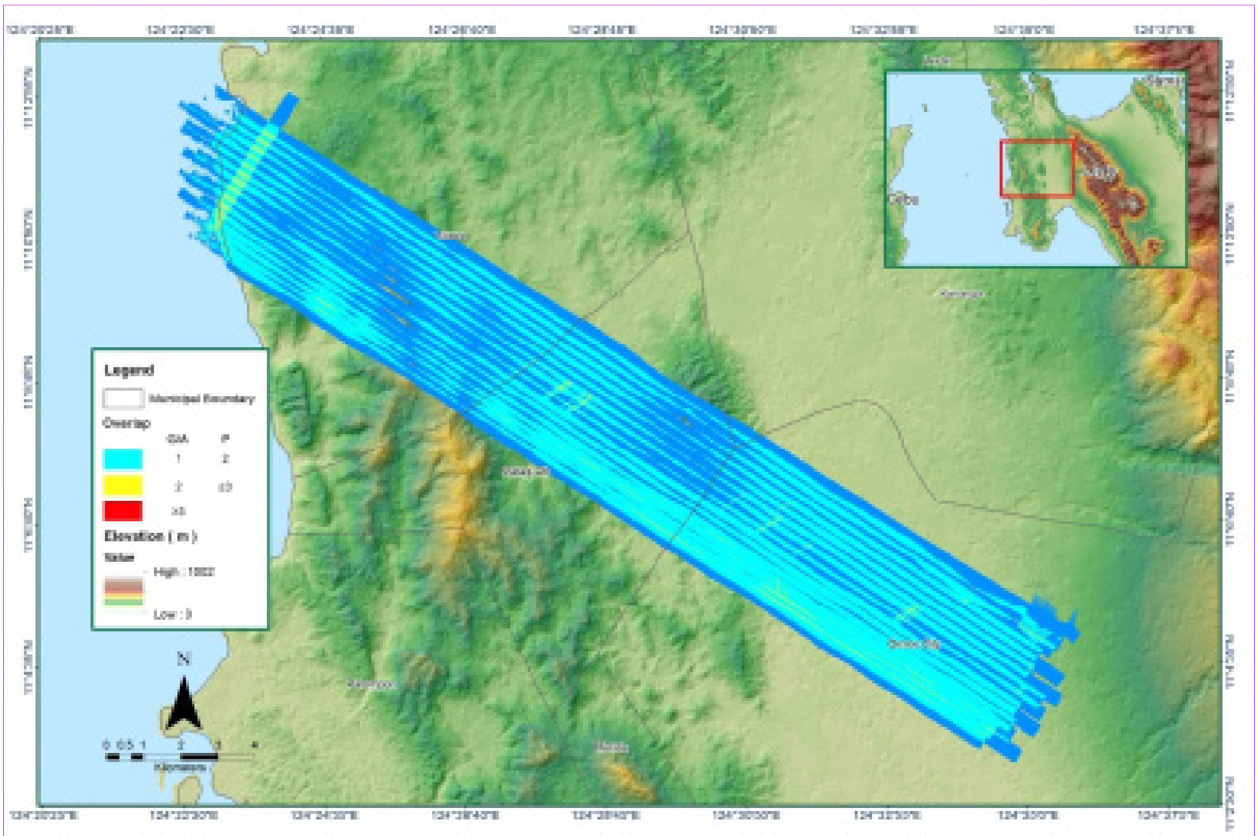


Figure A-8.19. Image of data overlap

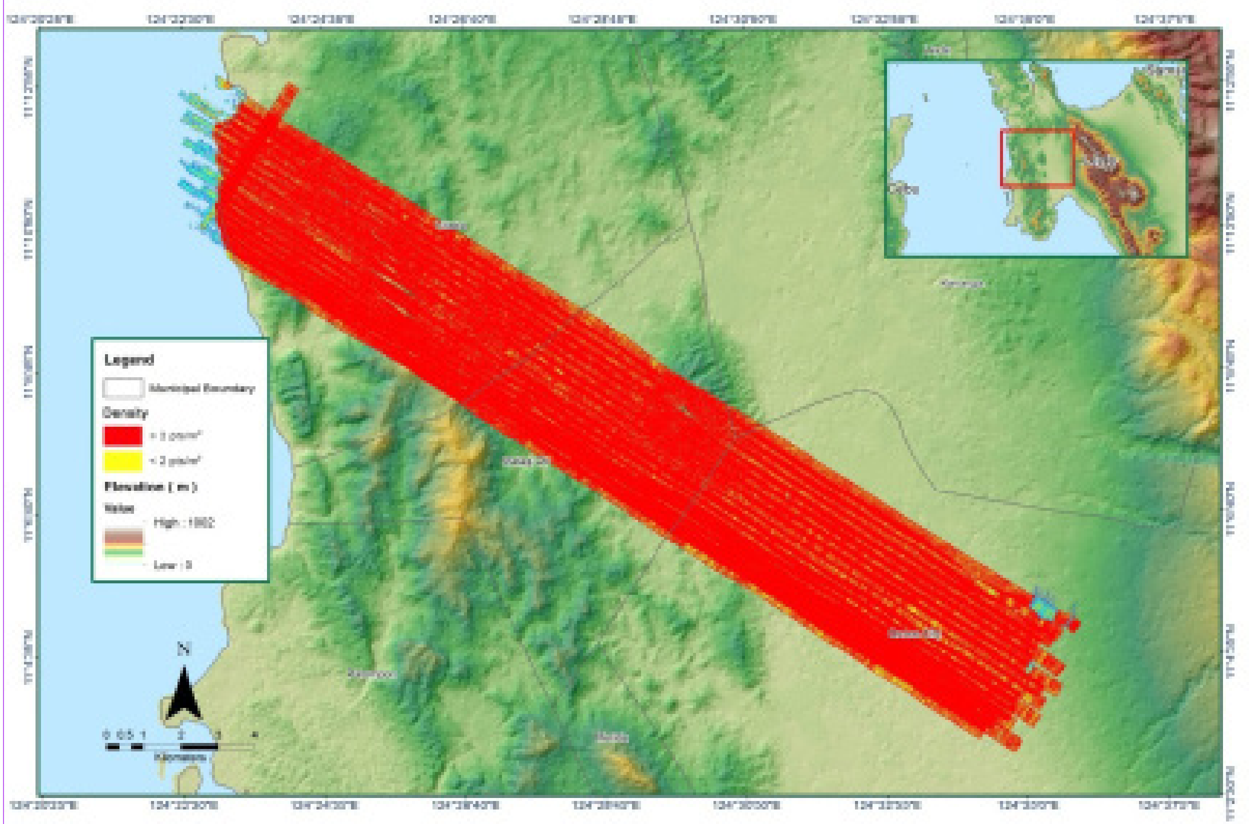


Figure A-8.20. Density map of merged LiDAR data

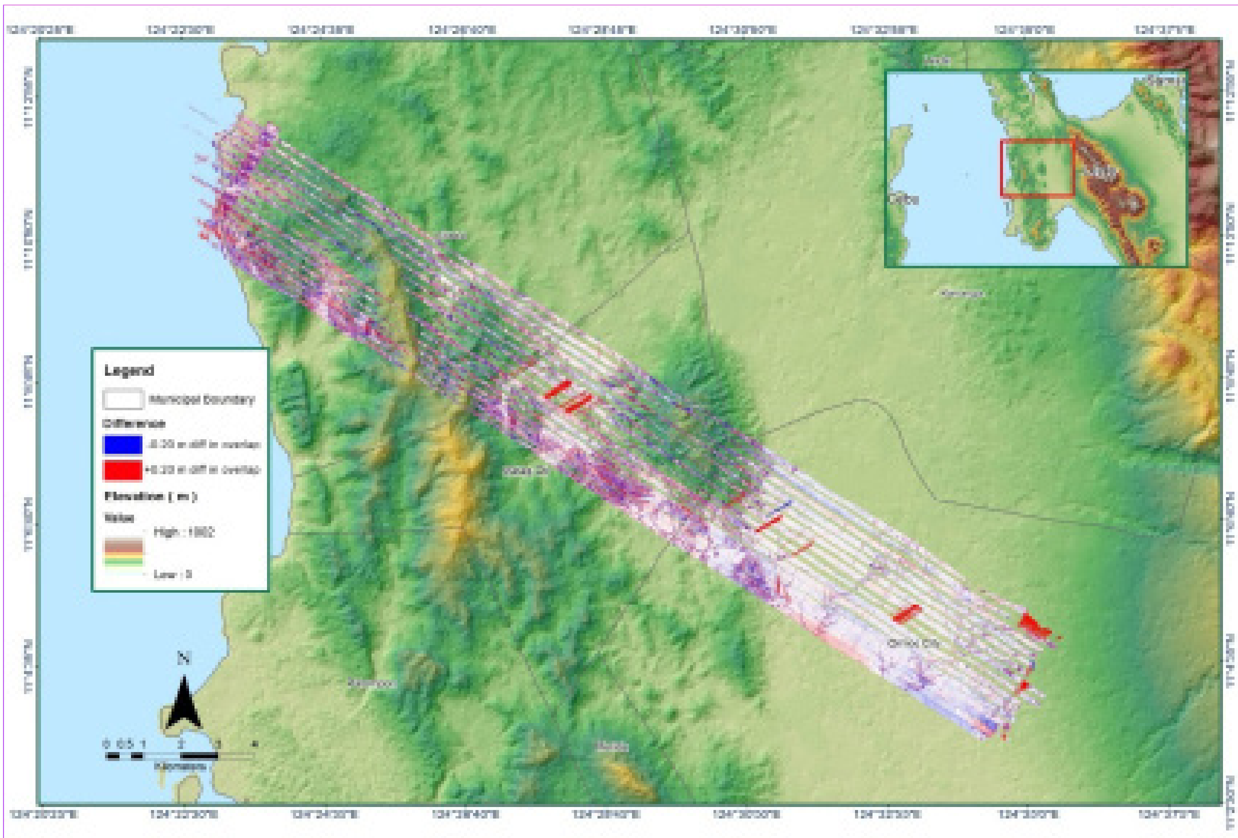


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk 35F

Flight Area	Samar-Leyte
Mission Name	Blk 35F
Inclusive Flights	1474A,1466A
Range data size	30 GB
POS data size	575 MB
Base data size	17.65 MB
Image	174.9 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.9
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000407
IMU attitude correction stdev (<0.001deg)	0.002146
GPS position stdev (<0.01m)	0.0037
Minimum % overlap (>25)	56.25%
Ave point cloud density per sq.m. (>2.0)	3.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	223
Maximum Height	311.59 m
Minimum Height	53.60 m
Classification (# of points)	
Ground	116,883,933
Low vegetation	125,309,279
Medium vegetation	226,434,578
High vegetation	62,847,226
Building	1,471,558
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

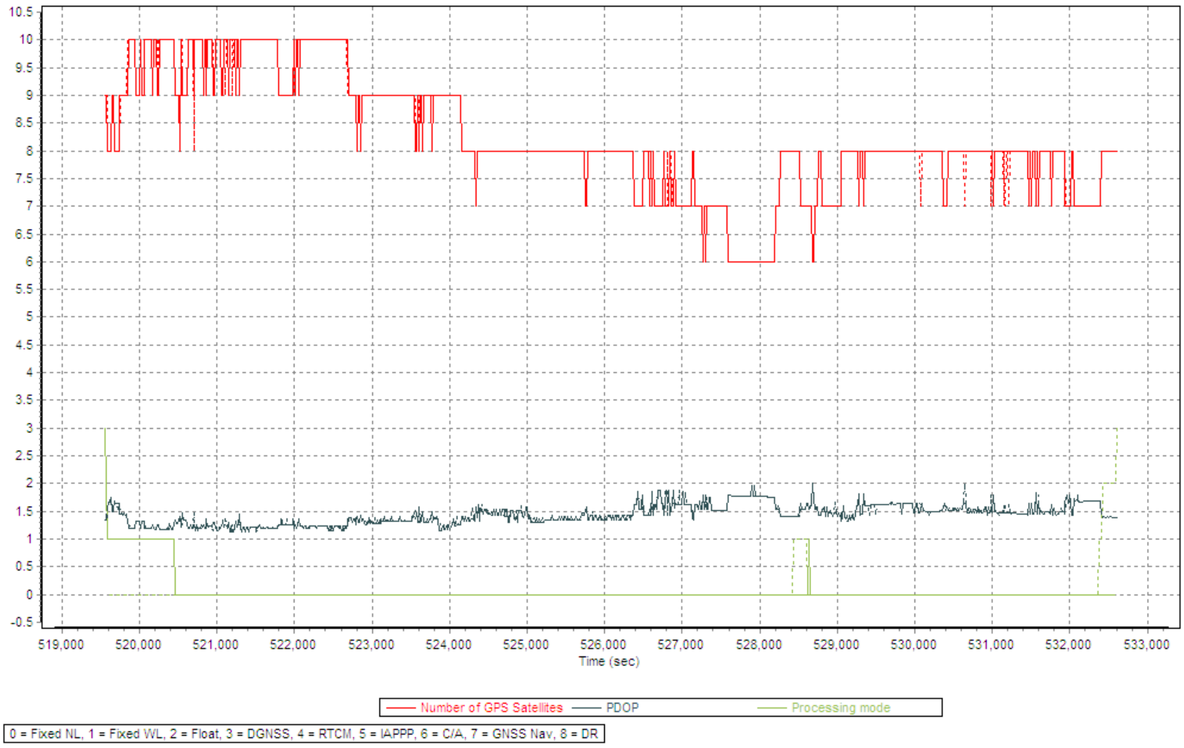


Figure A-8.22. Solution Status

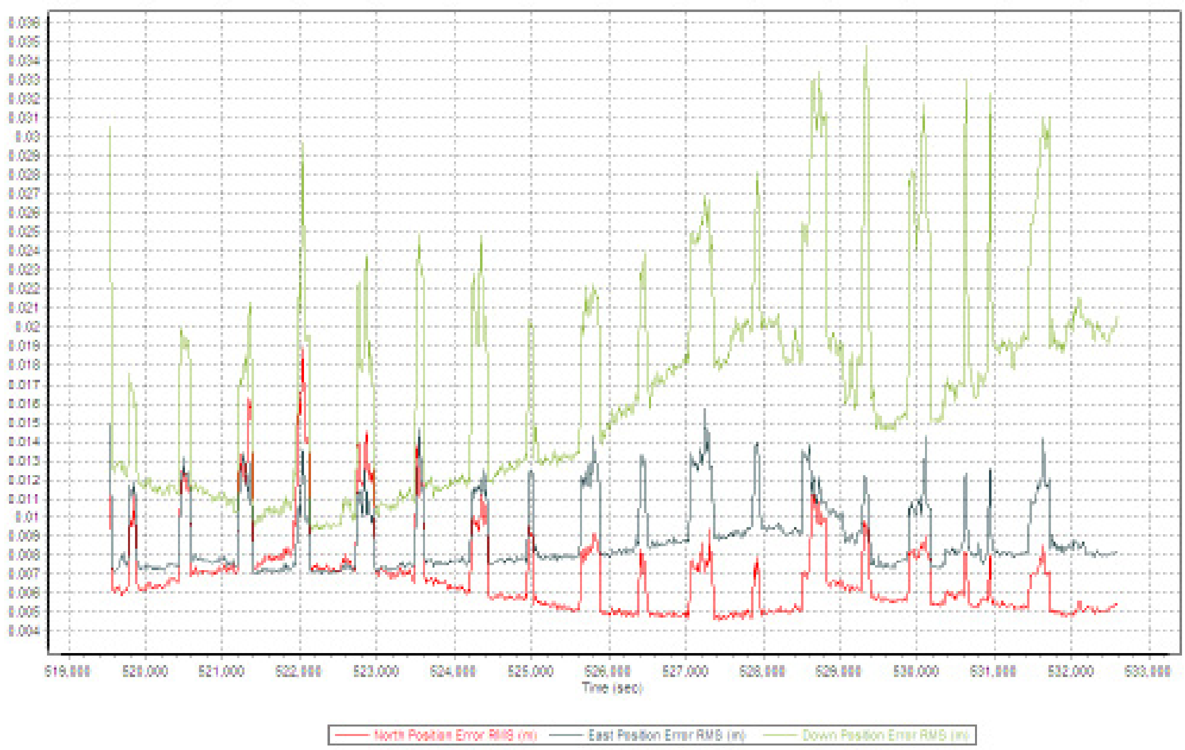


Figure A-8.23. Smoothed Performance Metrics Parameters

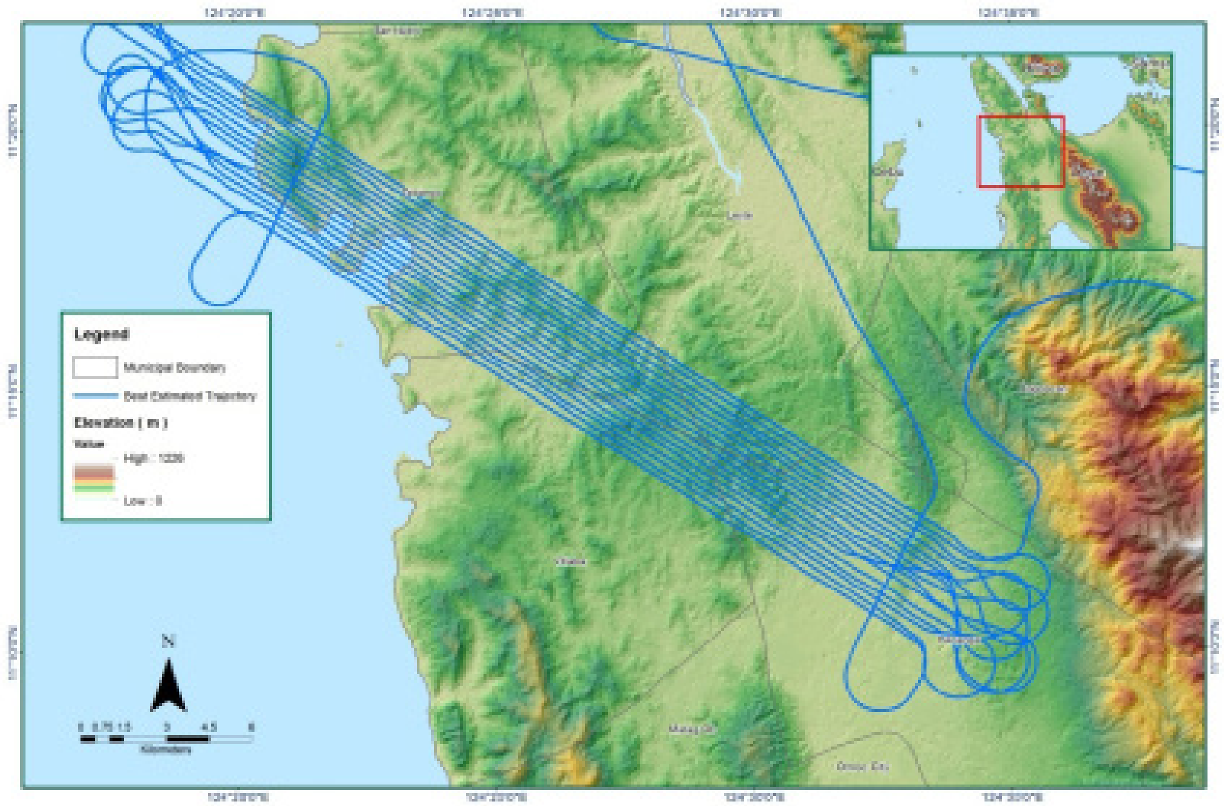


Figure A-8.24. Best Estimated Trajectory

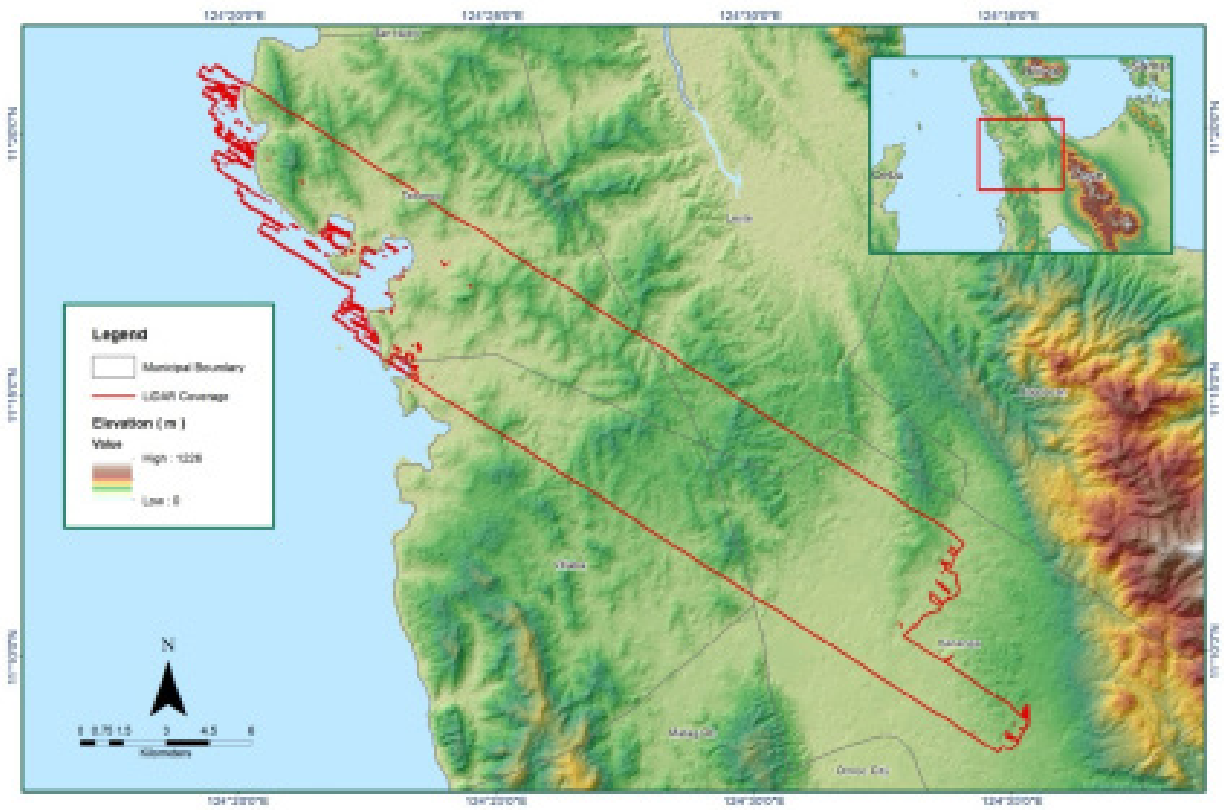


Figure A-8.25. Coverage of LiDAR data

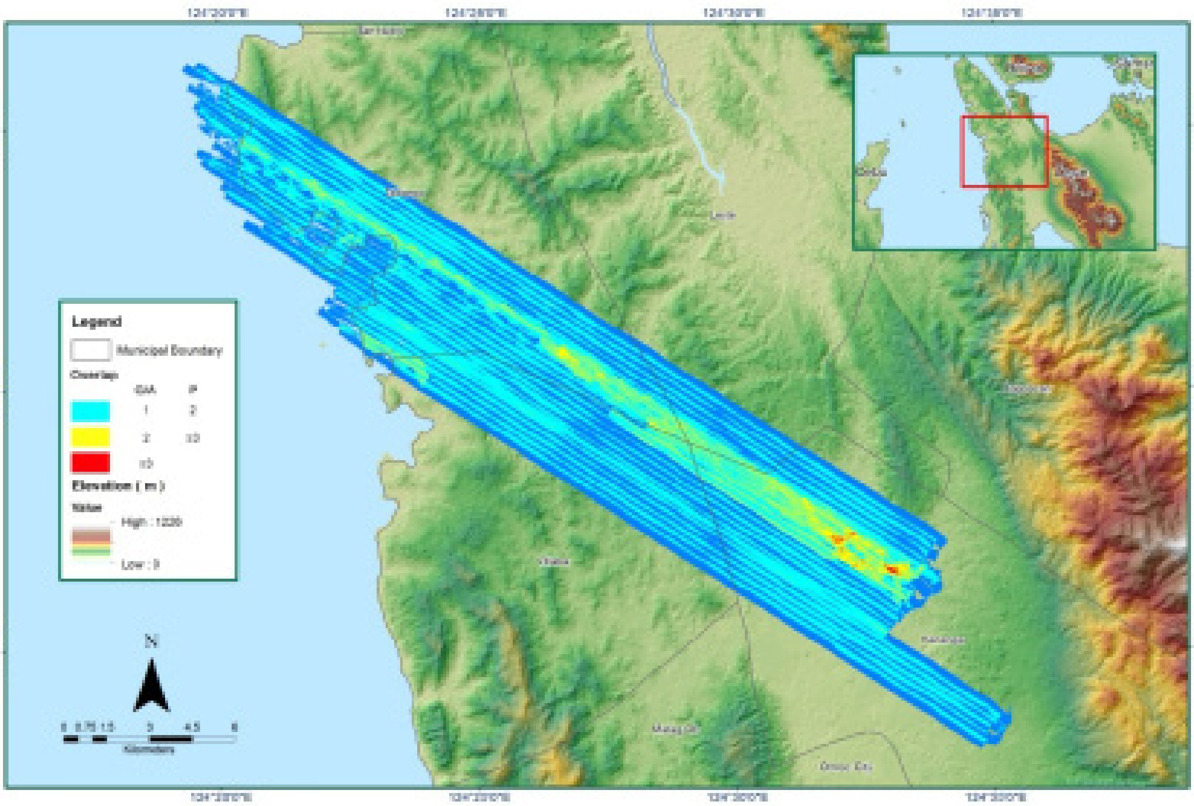


Figure A-8.26. Image of data overlap

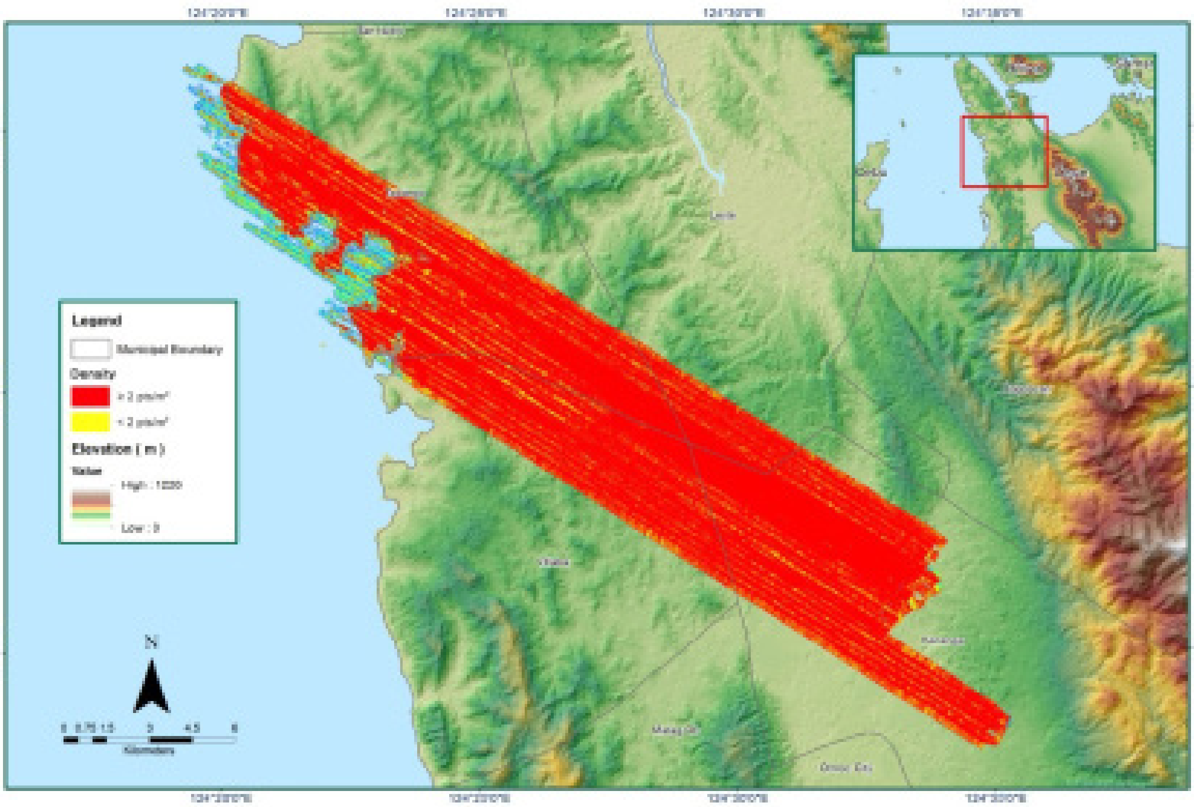


Figure A-8.27. Density map of merged LiDAR data

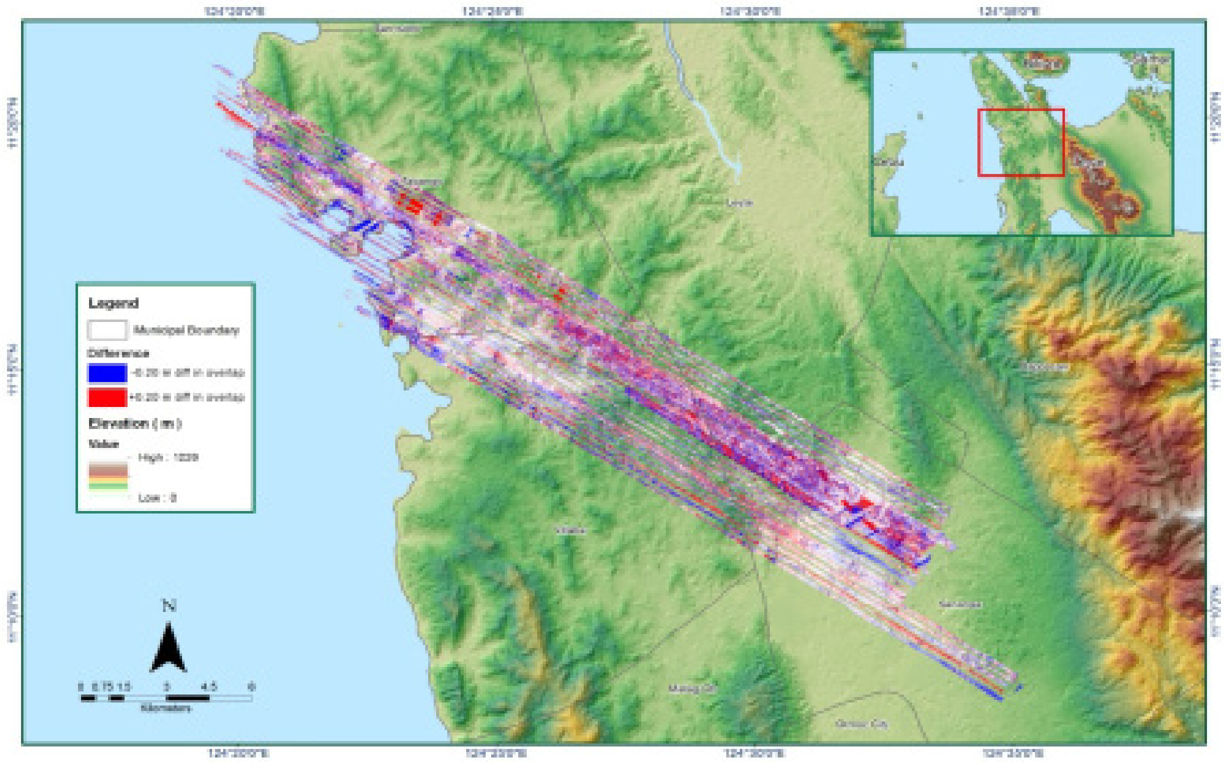


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk 35E

Flight Area	Samar-Leyte
Mission Name	Blk 35E
Inclusive Flights	1464A,1474A
Range data size	28 GB
POS data size	542 MB
Base data size	21.1 MB
Image	157.1 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000213
IMU attitude correction stdev (<0.001deg)	0.001121
GPS position stdev (<0.01m)	0.0095
Minimum % overlap (>25)	46.83%
Ave point cloud density per sq.m. (>2.0)	3.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	163
Maximum Height	349.46 m
Minimum Height	51.38 m
Classification (# of points)	
Ground	79,052,774
Low vegetation	66,377,258
Medium vegetation	141,587,277
High vegetation	63,584,547
Building	638,371
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Angelo Carlo Bongat, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

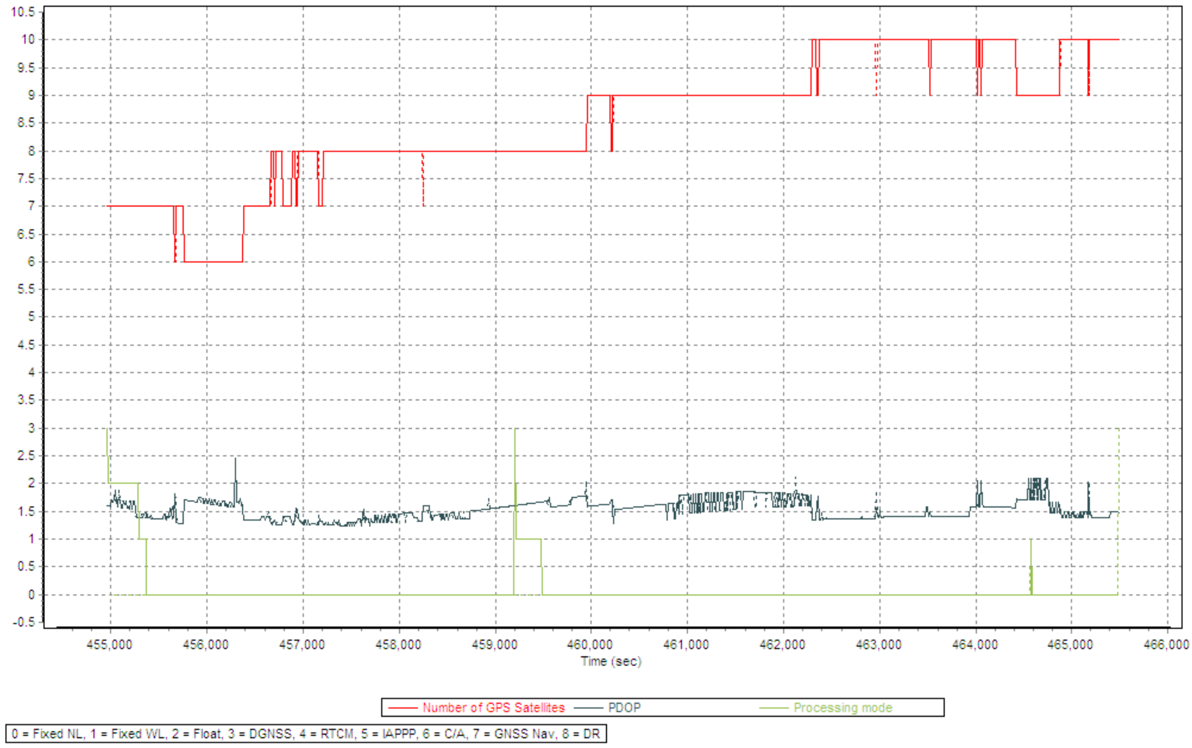


Figure A-8.29. Solution Status

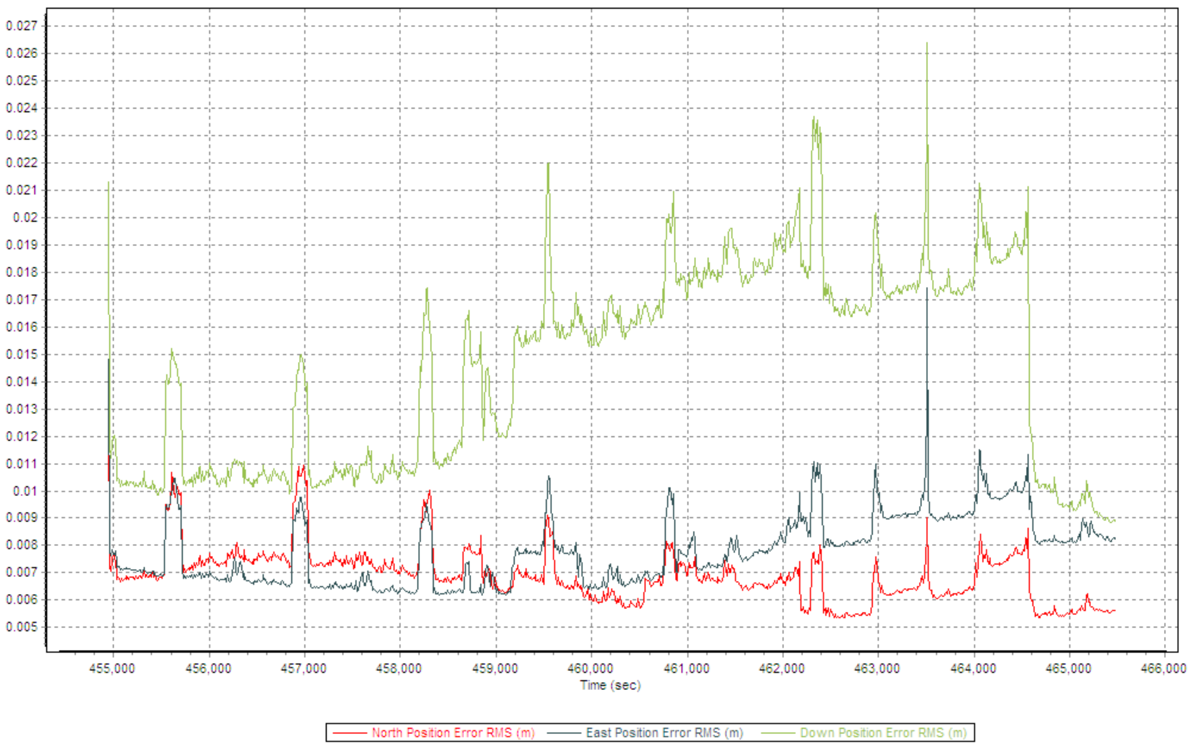


Figure A-8.30. Smoothed Performance Metrics Parameters

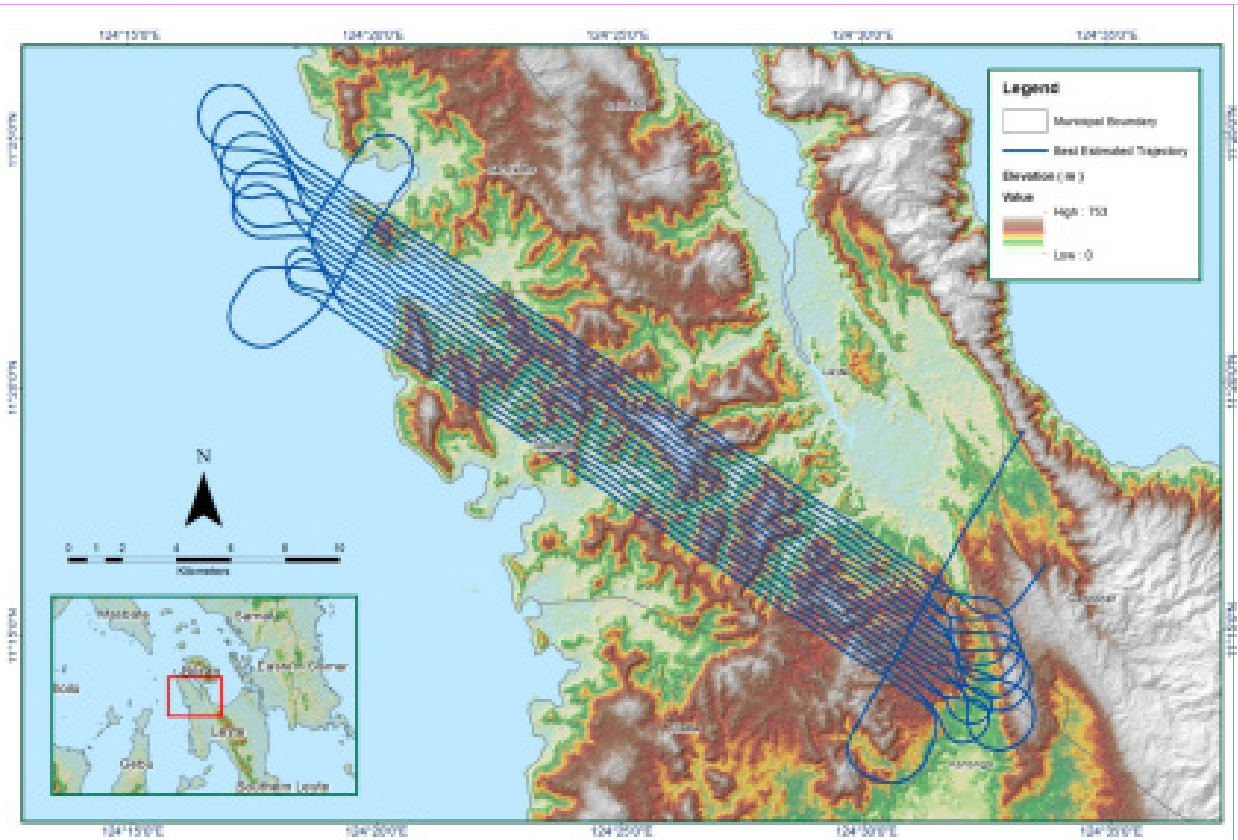


Figure A-8.31. Best Estimated Trajectory

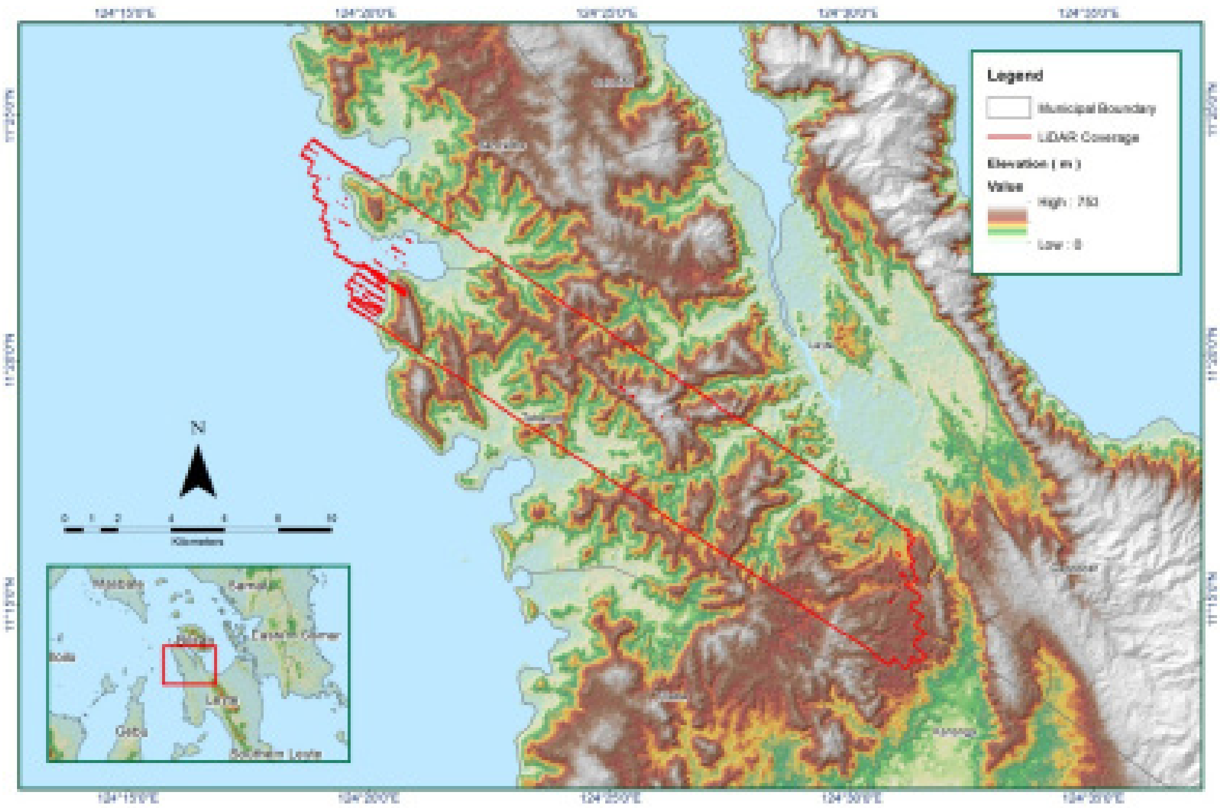


Figure A-8.32. Best Estimated Trajectory

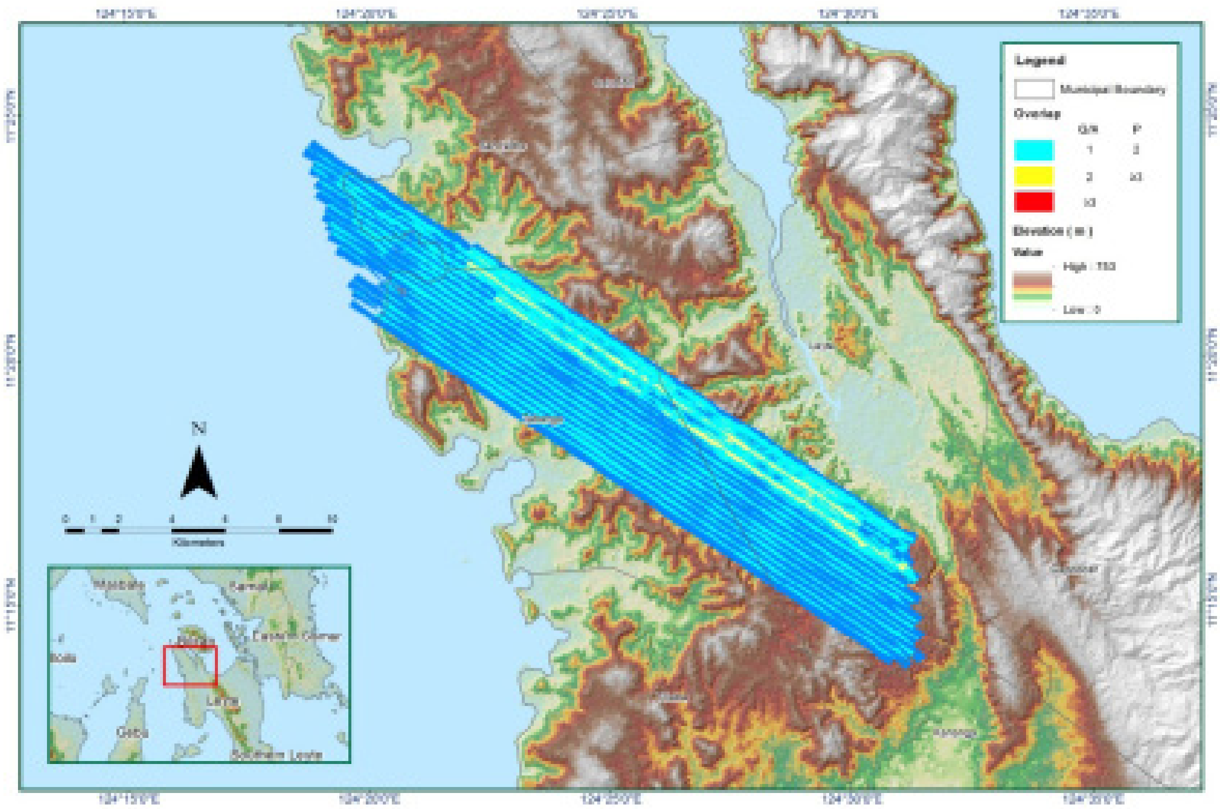


Figure A-8.33. Image of data overlap

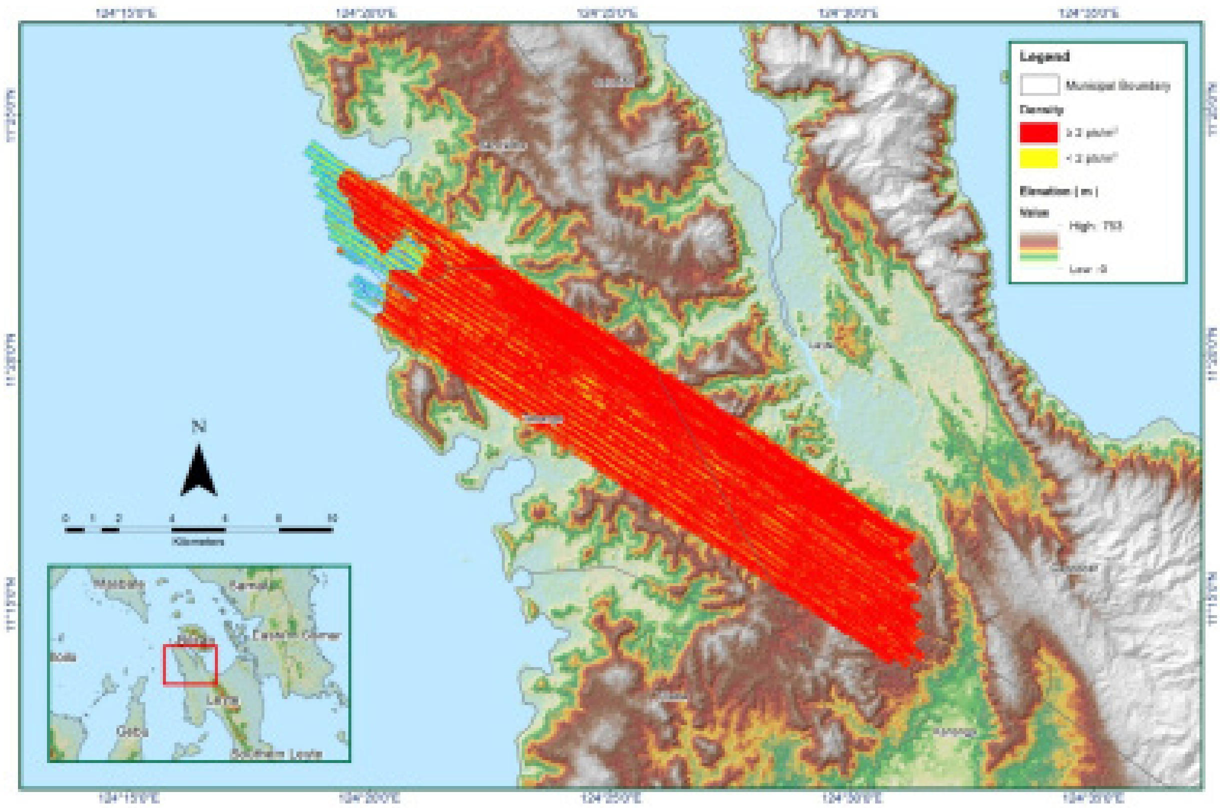


Figure A-8.34. Density map of merged LiDAR data

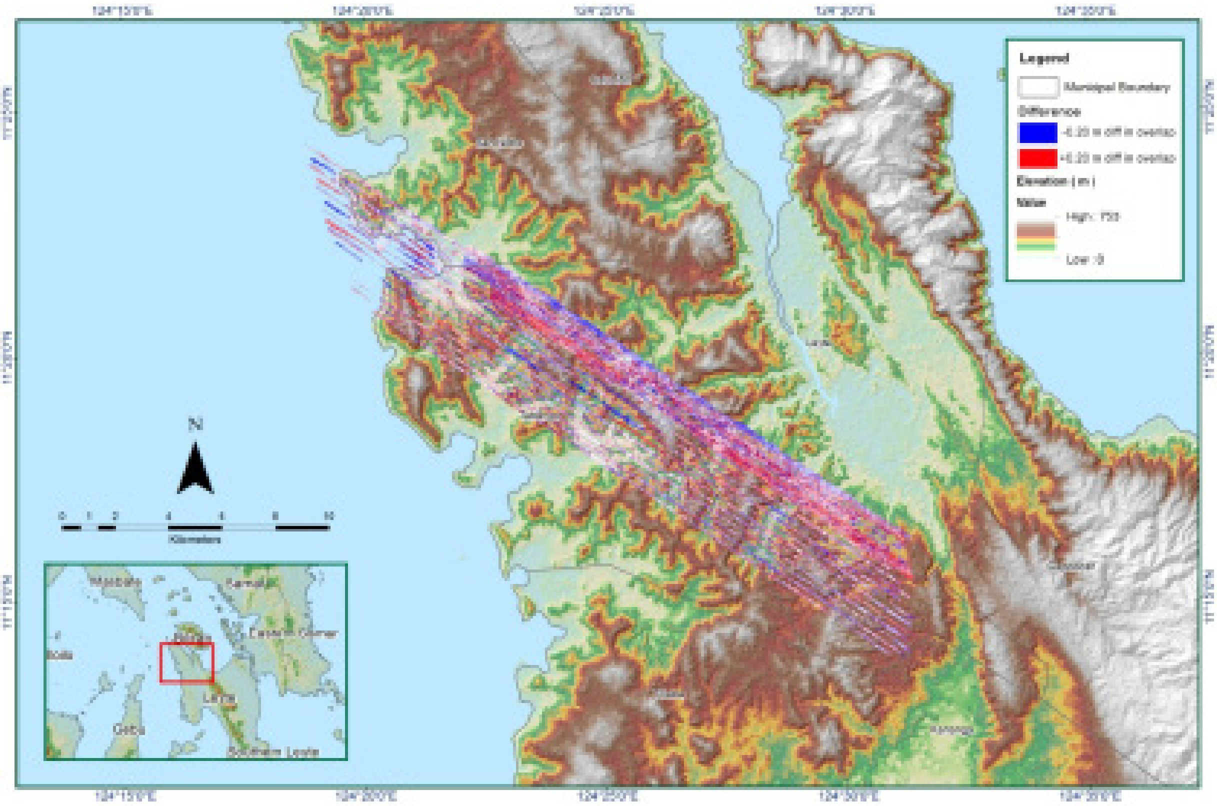


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk 35D

Flight Area	Samar-Leyte
Mission Name	Blk 35D
Inclusive Flights	1462A
Range data size	15.2 GB
POS data size	275 MB
Base data size	11.6 MB
Image	91.2 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
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)	3.2
RMSE for Down Position (<8.0 cm)	6.5
Boresight correction stdev (<0.001deg)	0.000208
IMU attitude correction stdev (<0.001deg)	0.000943
GPS position stdev (<0.01m)	0.0082
Minimum % overlap (>25)	43.84%
Ave point cloud density per sq.m. (>2.0)	3.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	169
Maximum Height	302.81 m
Minimum Height	52.60 m
Classification (# of points)	
Ground	53,485,834
Low vegetation	77,120,403
Medium vegetation	115,497,563
High vegetation	68,908,955
Building	1,177,955
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Chelou Prado, Engr. Gladys Mae Apat

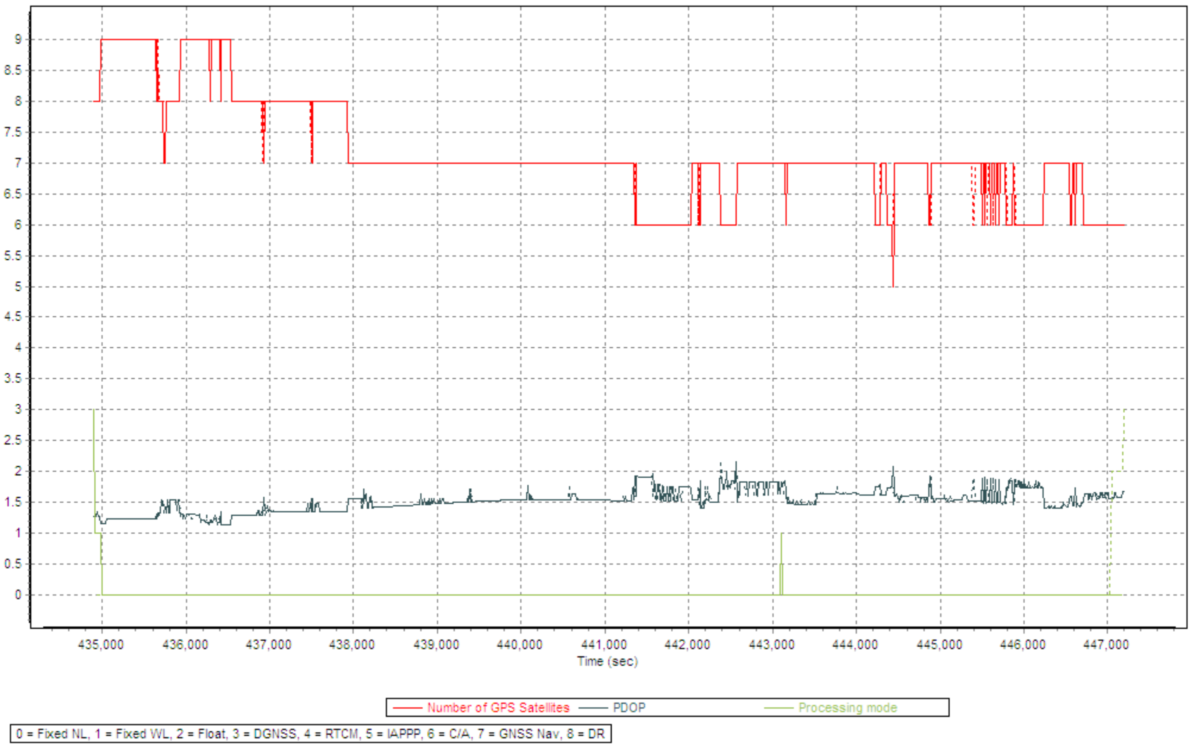


Figure A-8.36. Solution Status

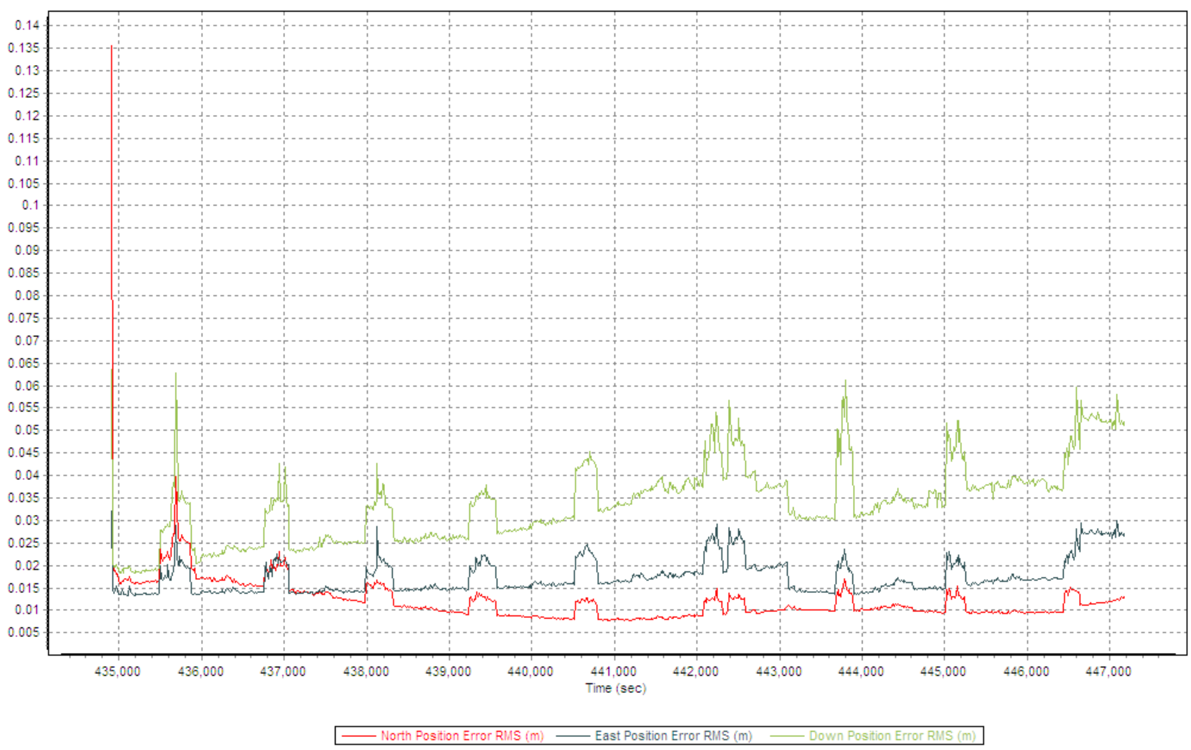


Figure A-8.37. Smoothed Performance Metrics Parameters

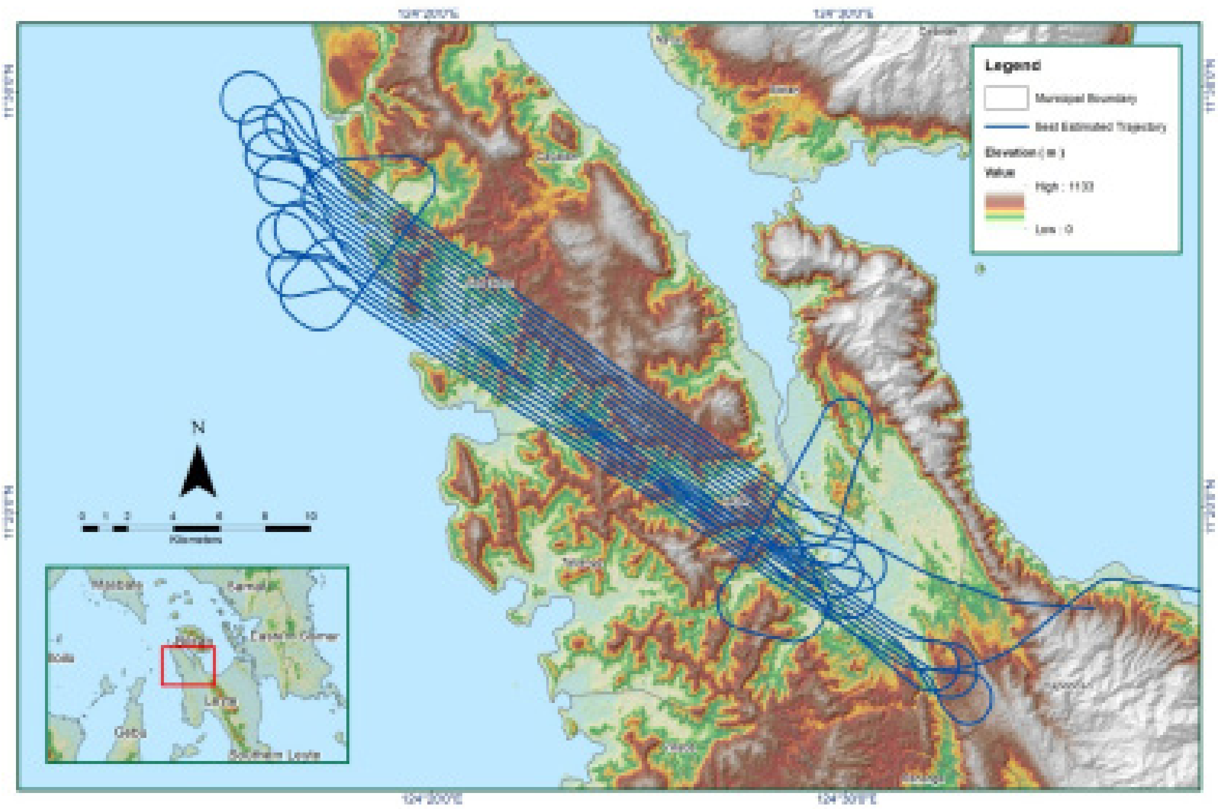


Figure A-8.38. Best Estimated Trajectory

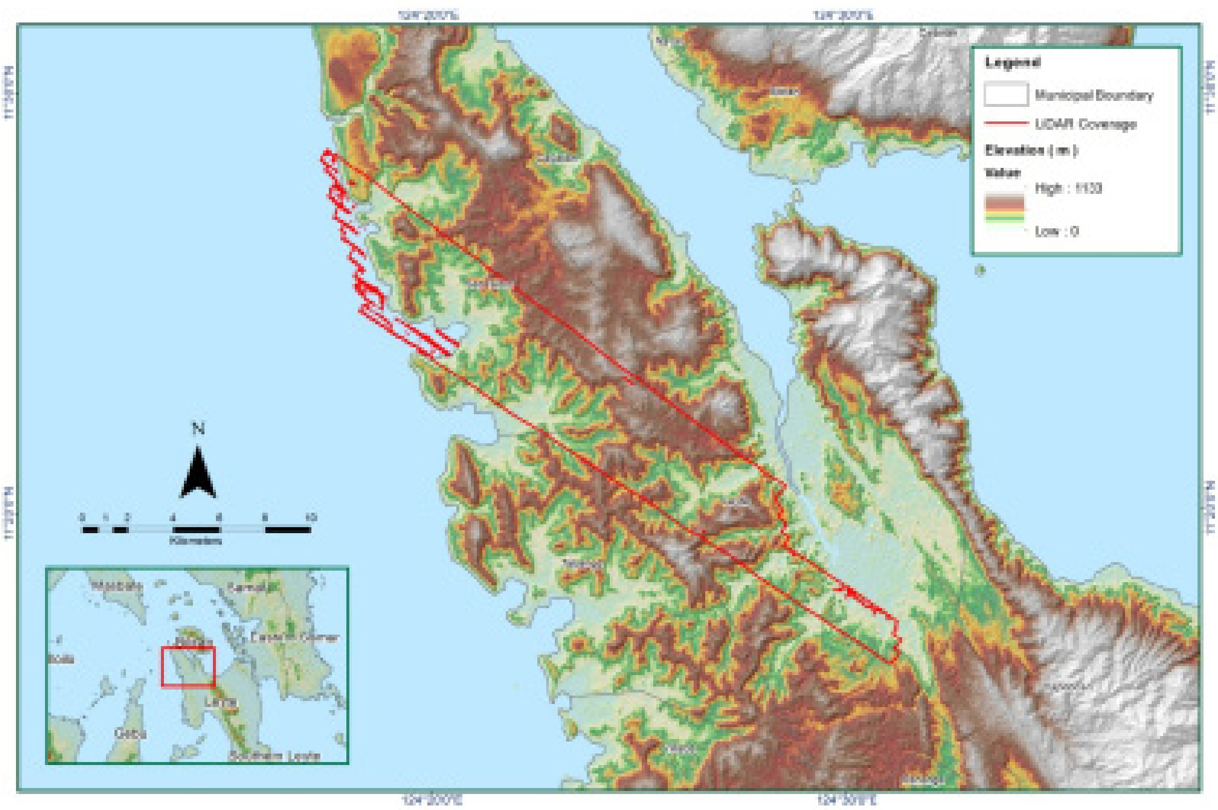


Figure A-8.39. Coverage of LiDAR data

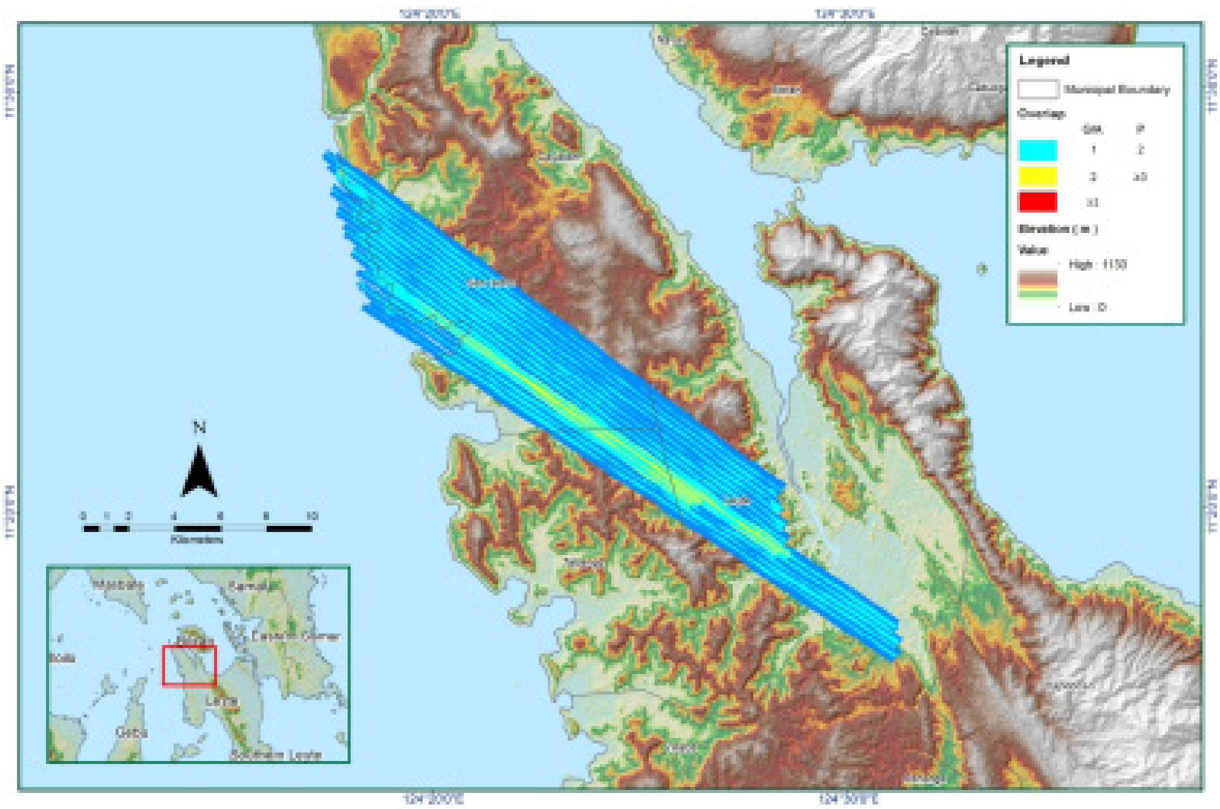


Figure A-8.40. Image of data overlap

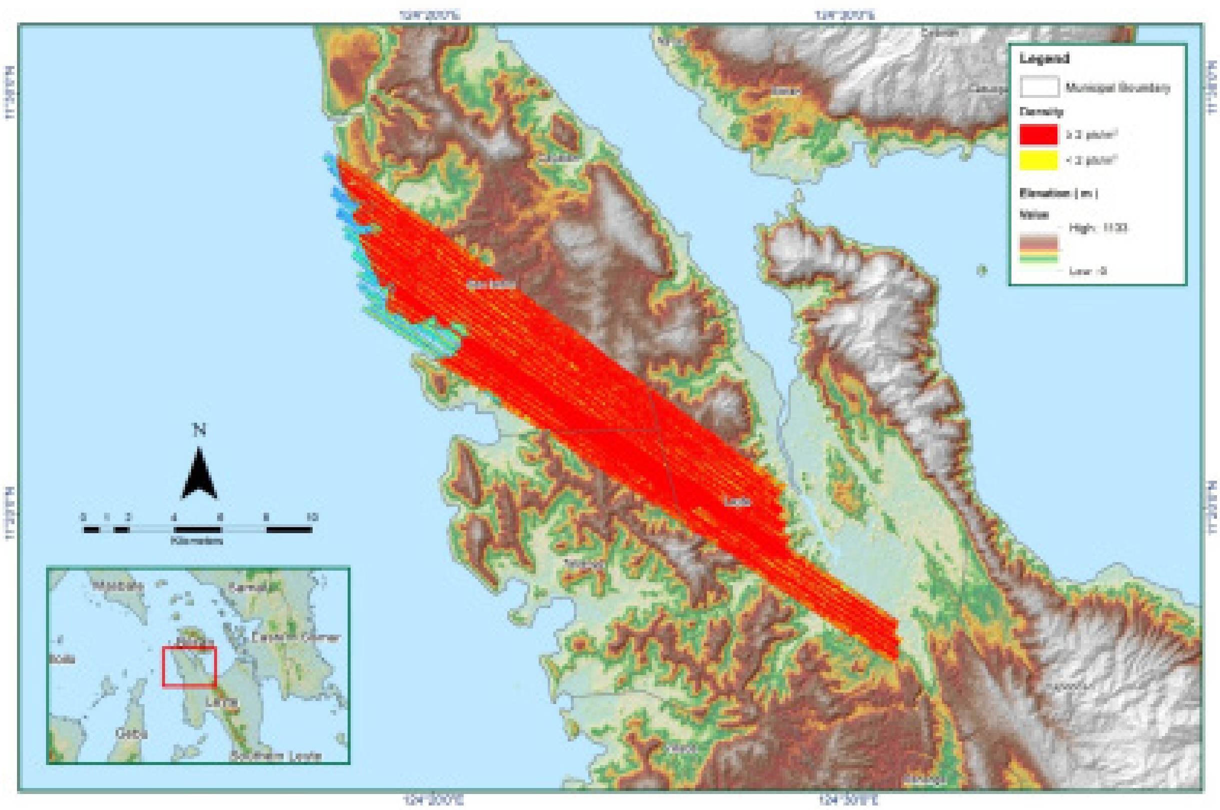


Figure A-8.41. Density map of merged LiDAR data

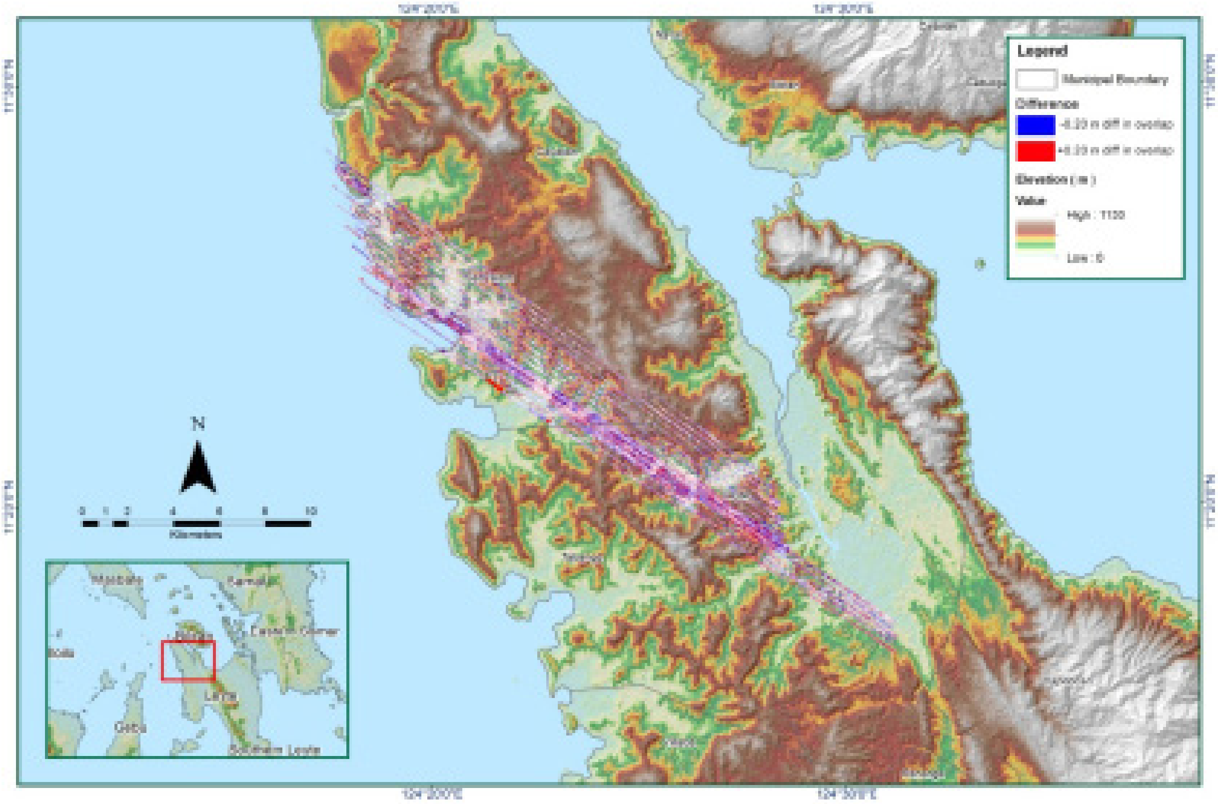


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk 35C

Flight Area	Samar-Leyte
Mission Name	Blk 35C
Inclusive Flights	1460A,1474A
Range data size	28.1 GB
POS data size	564 MB
Base data size	21.1 MB
Image	155 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
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)	1.7
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000328
IMU attitude correction stdev (<0.001deg)	0.002158
GPS position stdev (<0.01m)	0.0033
Minimum % overlap (>25)	44.94%
Ave point cloud density per sq.m. (>2.0)	3.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	174
Maximum Height	387.55 m
Minimum Height	50.52 m
Classification (# of points)	
Ground	96,313,140
Low vegetation	89,828,817
Medium vegetation	138,400,766
High vegetation	97,602,353
Building	1,270,216
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Chelou Prado, Engr. Gladys Mae Apat

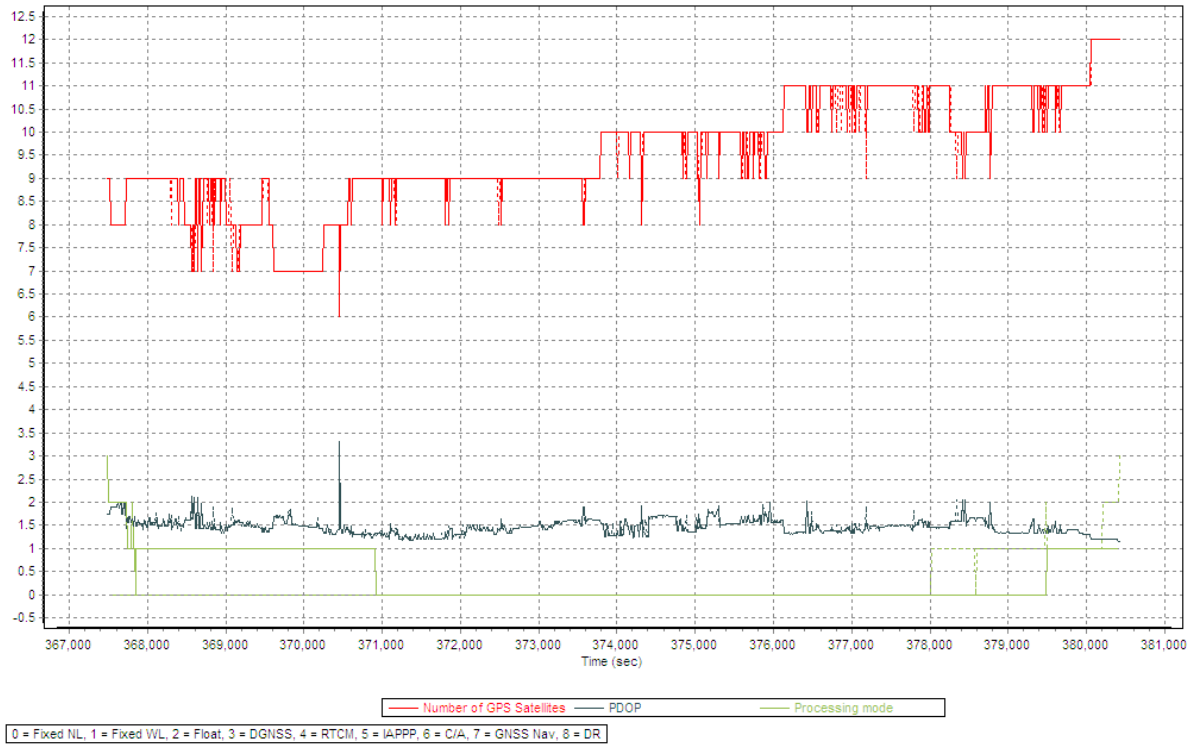


Figure A-8.43. Solution Status

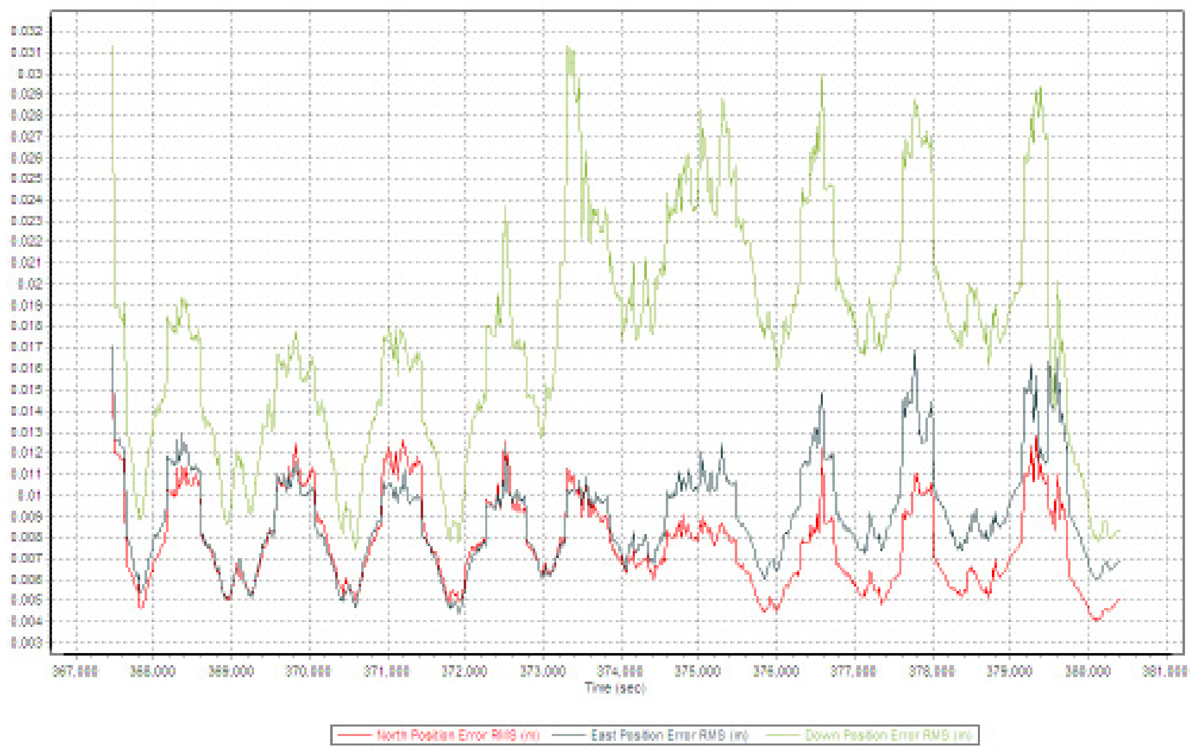


Figure A-8.44. Smoothed Performance Metrics Parameters

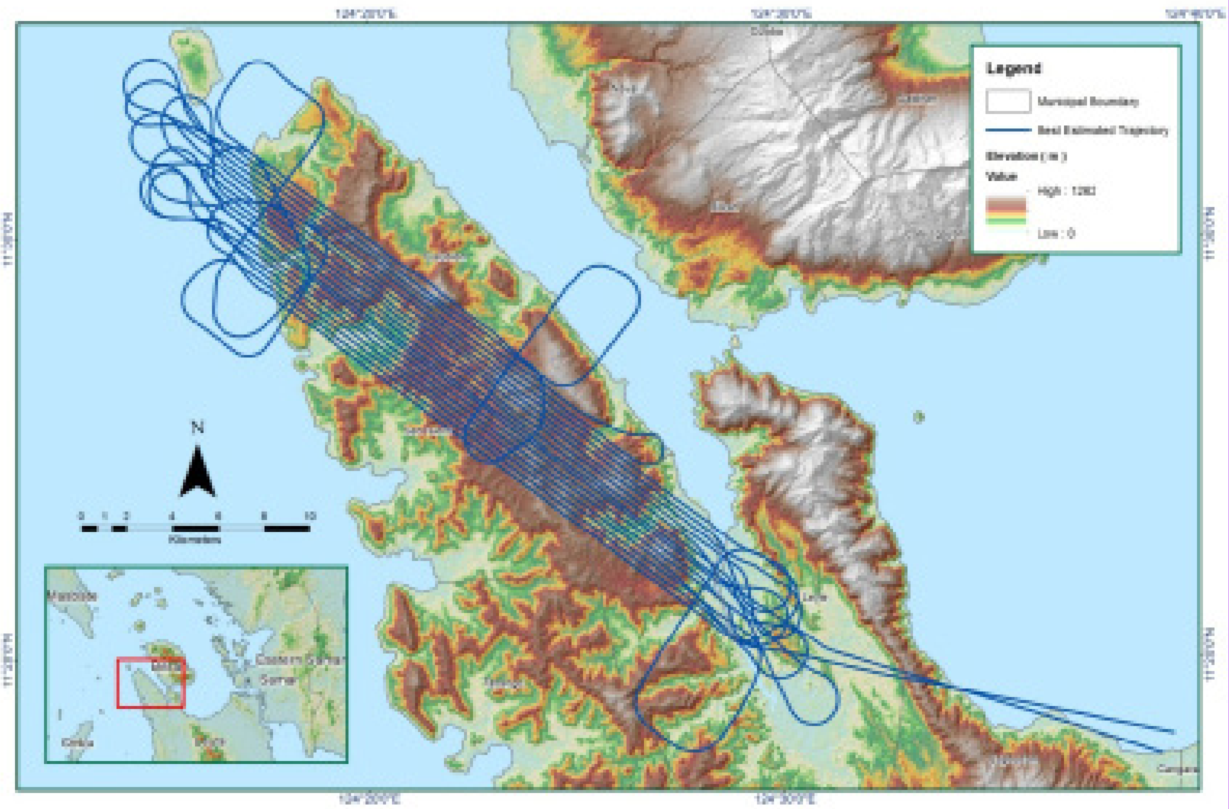


Figure A-8.45. Best Estimated Trajectory

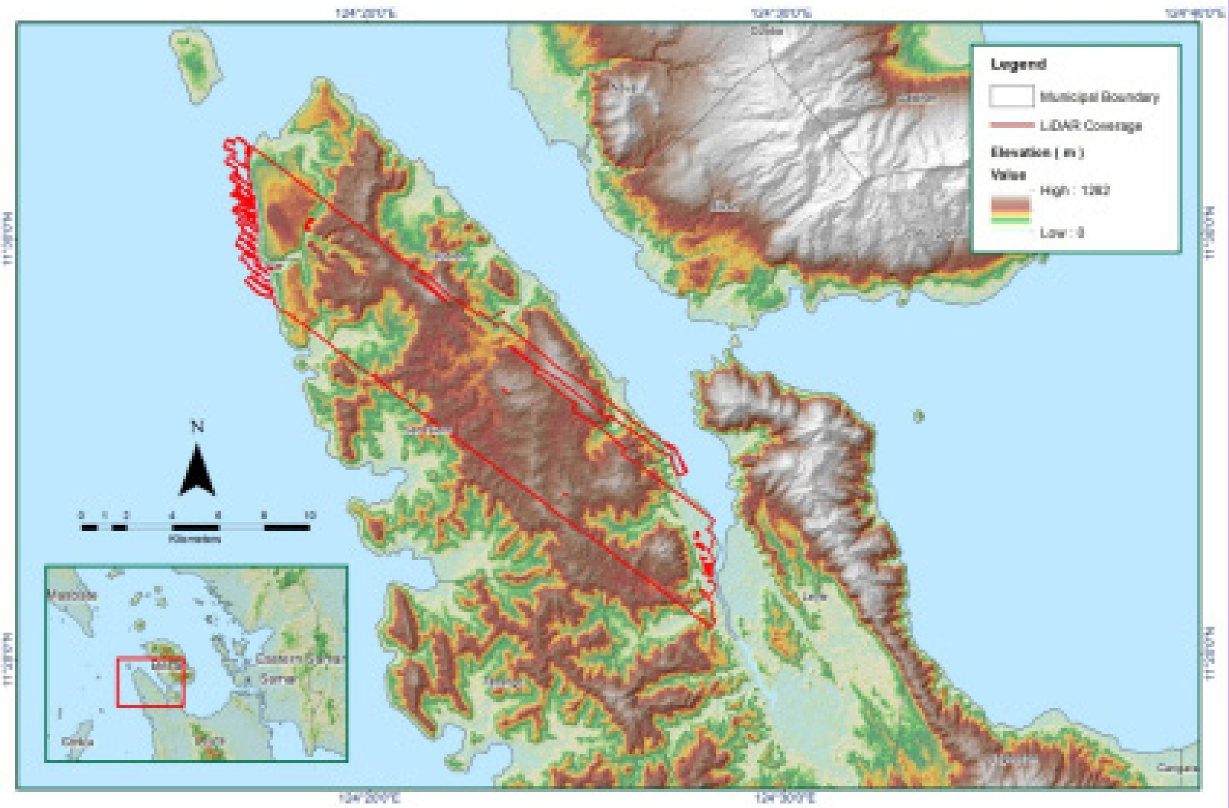


Figure A-8.46. Best Estimated Trajectory

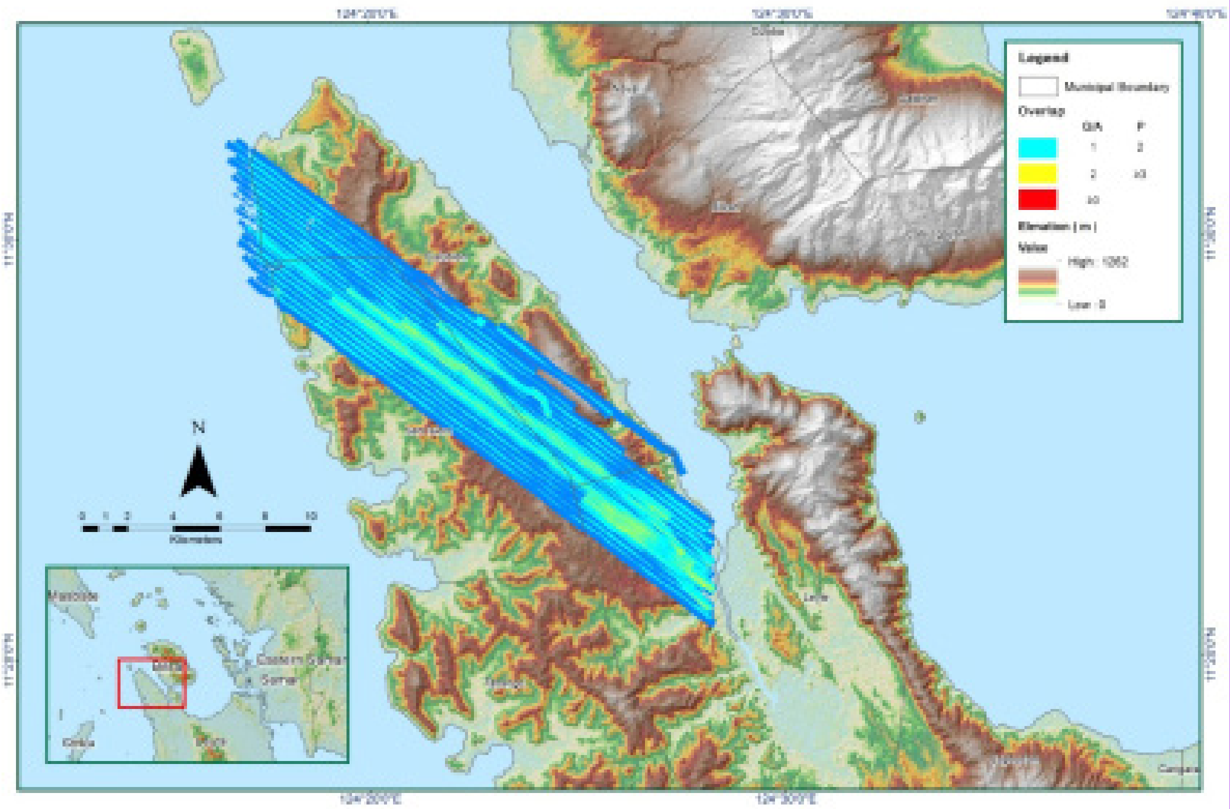


Figure A-8.47. Image of data overlap

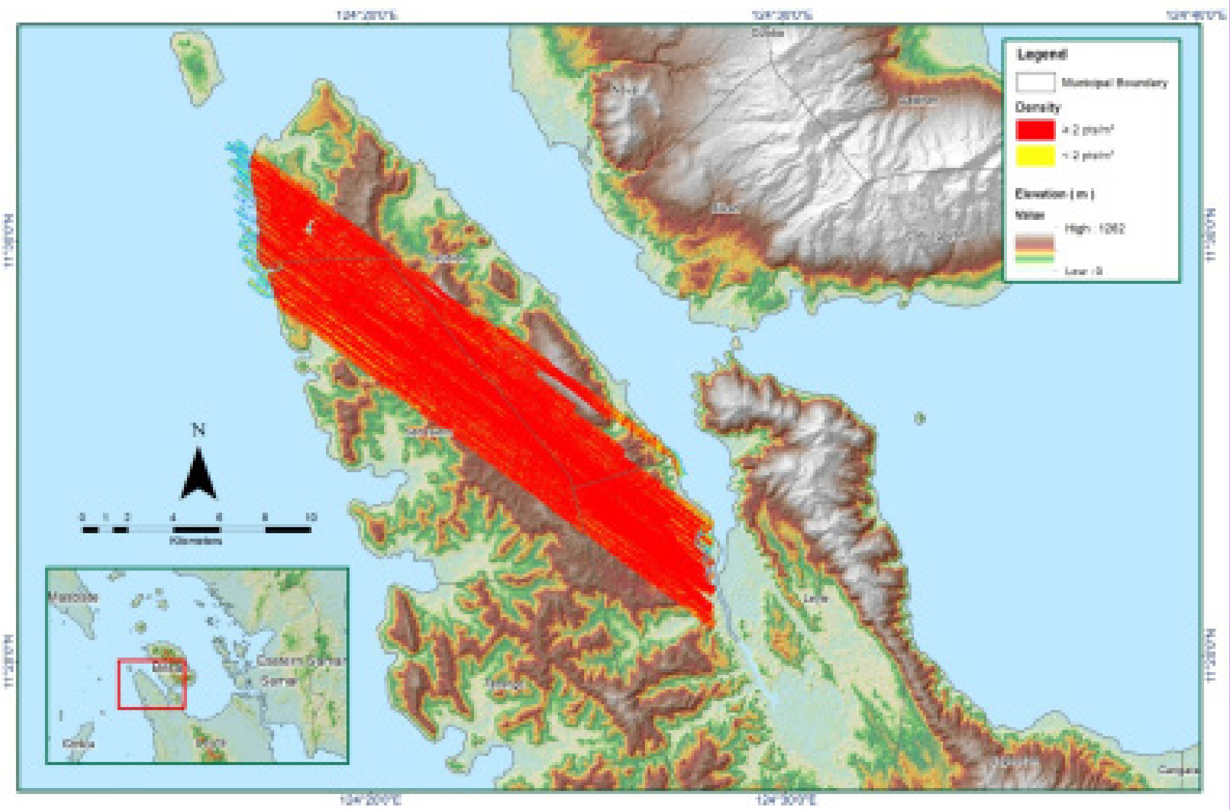


Figure A-8.48. Density map of merged LiDAR data

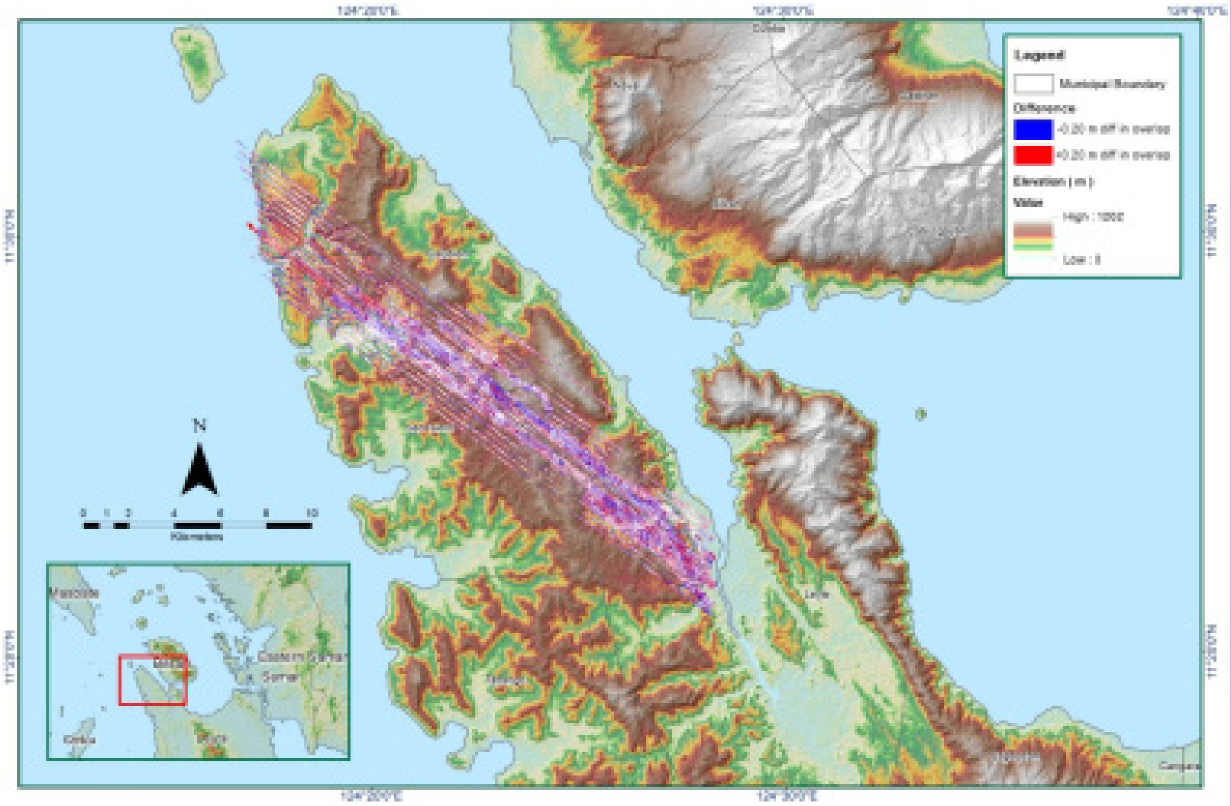


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk 35B

Flight Area	Samar-Leyte
Mission Name	Blk 35B
Inclusive Flights	1458A
Range data size	13.3 GB
POS data size	277 MB
Base data size	14.6 MB
Image	81.7 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)	1.6
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000294
IMU attitude correction stdev (<0.001deg)	0.006535
GPS position stdev (<0.01m)	0.0036
Minimum % overlap (>25)	33.13%
Ave point cloud density per sq.m. (>2.0)	2.90
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	147
Maximum Height	387.51 m
Minimum Height	51.24 m
Classification (# of points)	
Ground	94,275,309
Low vegetation	78,485,696
Medium vegetation	117,061,039
High vegetation	90,631,637
Building	2,390,506
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Chelou Prado, Engr. Gladys Mae Apat

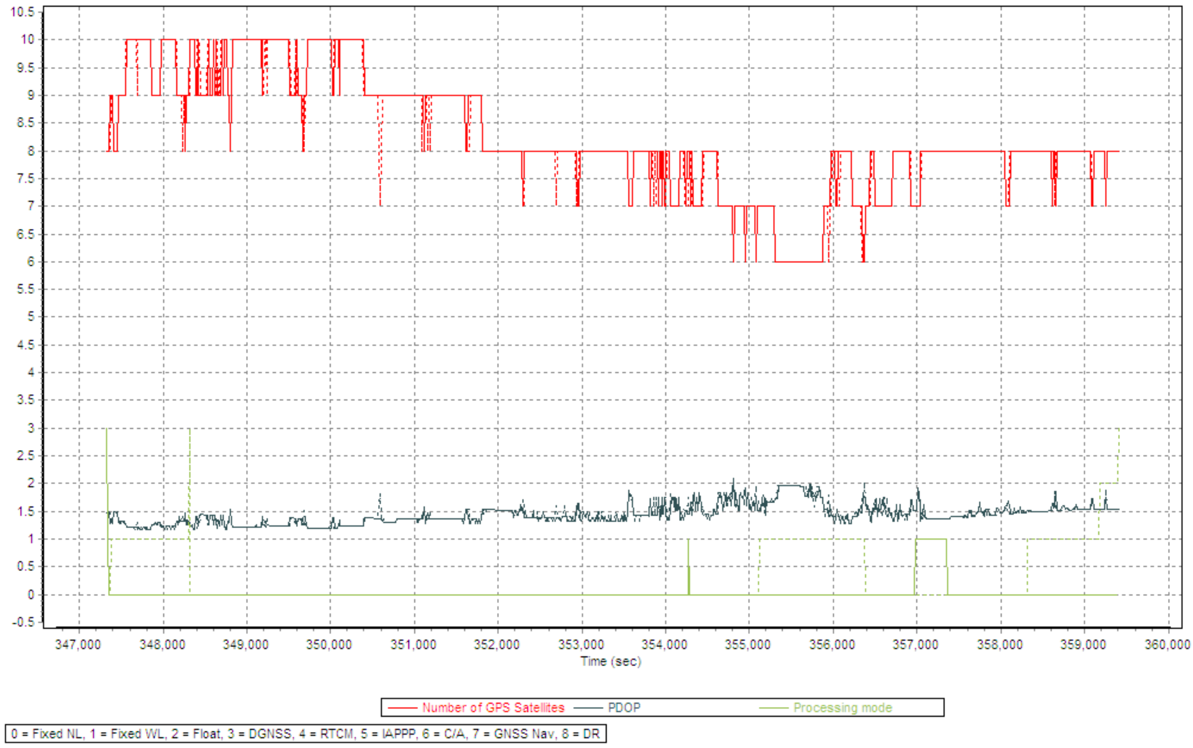


Figure A-8.50. Solution Status

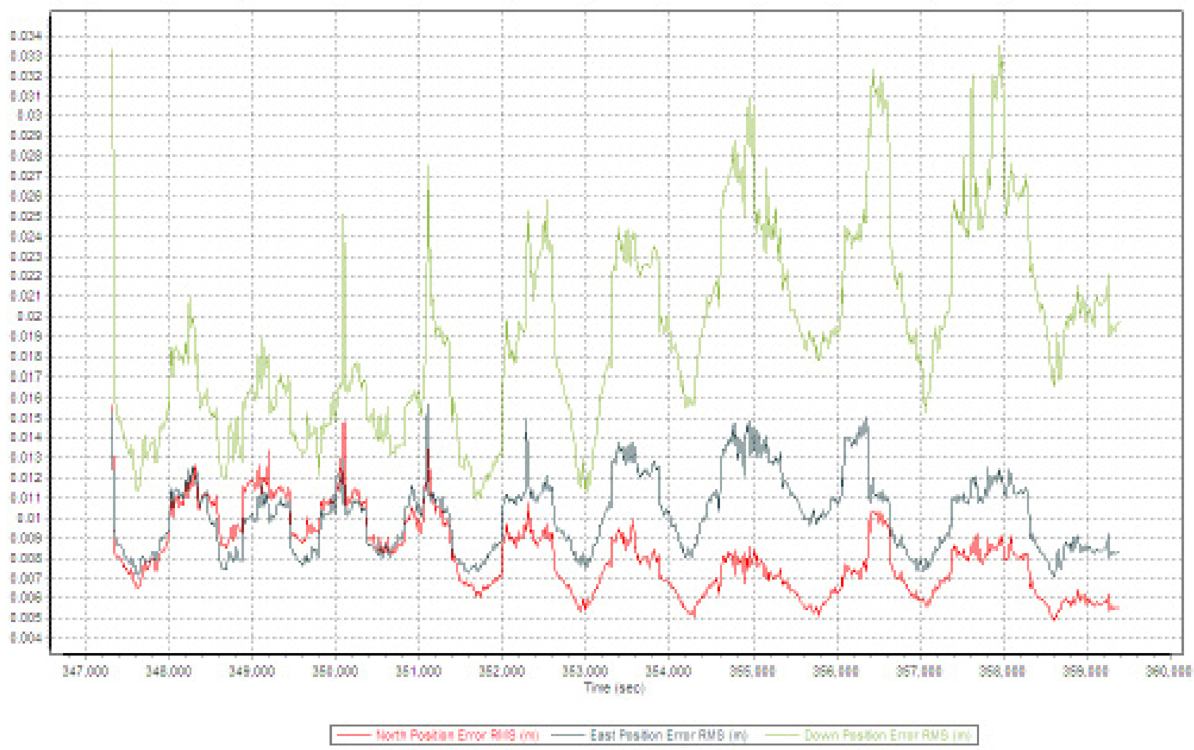


Figure A-8.51. Smoothed Performance Metrics Parameters

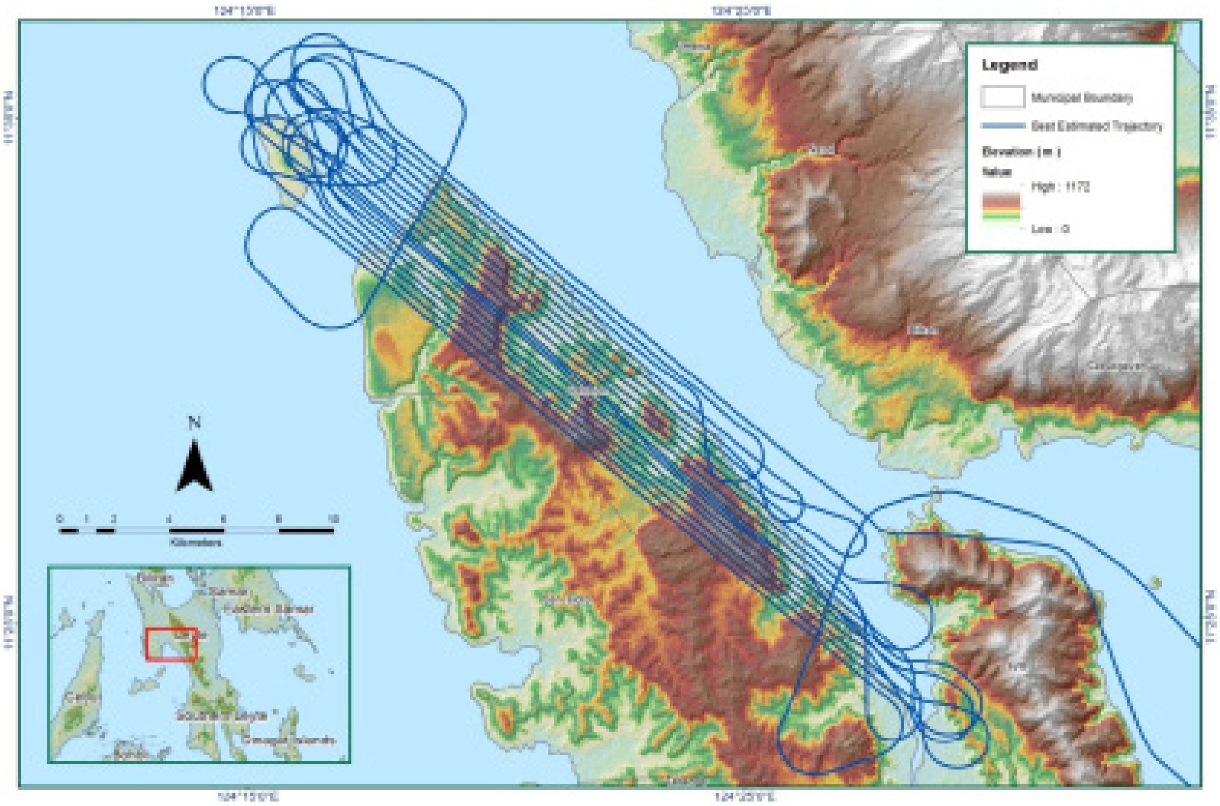


Figure A-8.52. Best Estimated Trajectory

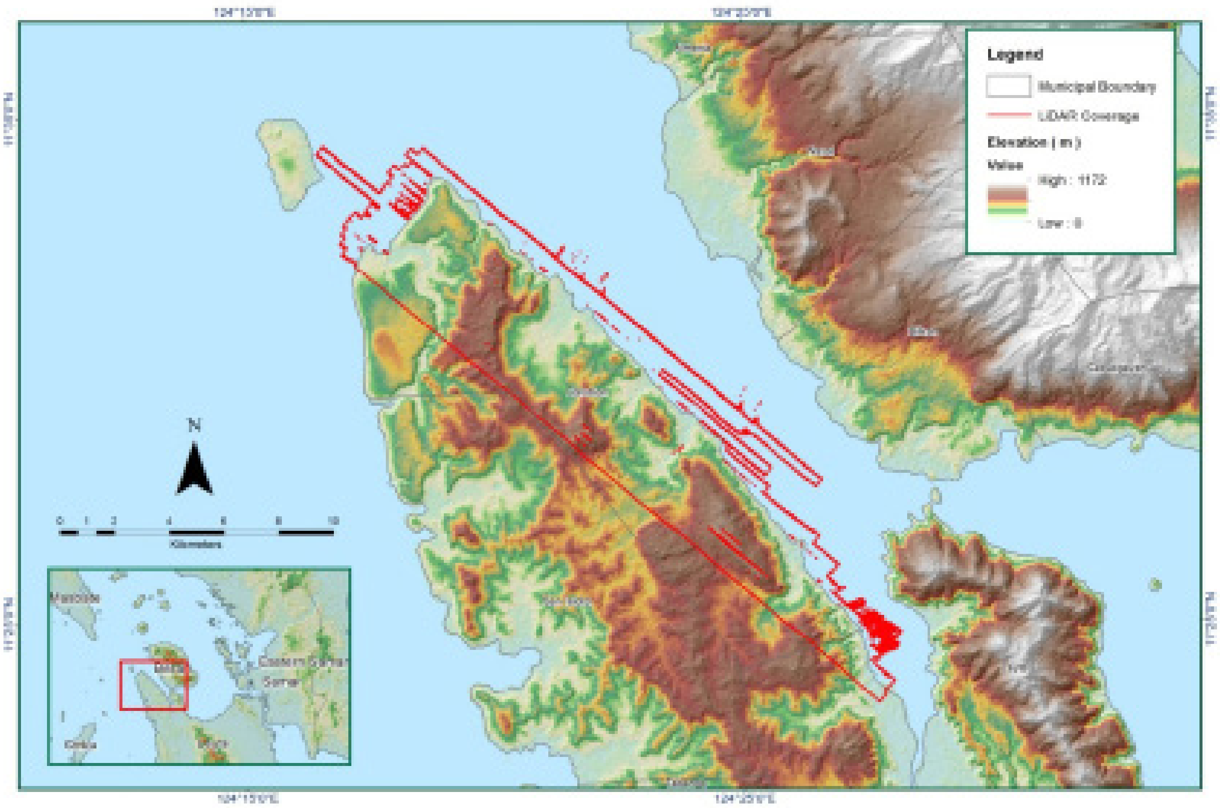


Figure A-8.53. Coverage of LiDAR data

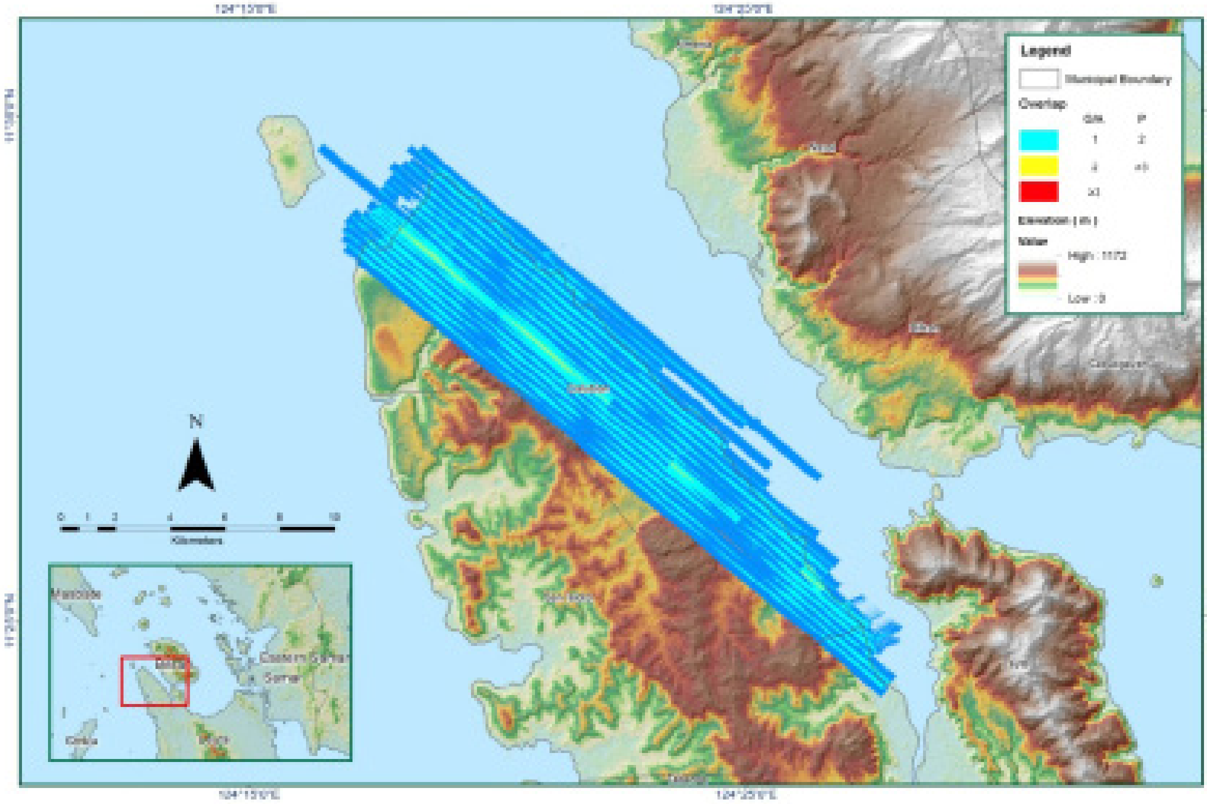


Figure A-8.54. Image of data overlap

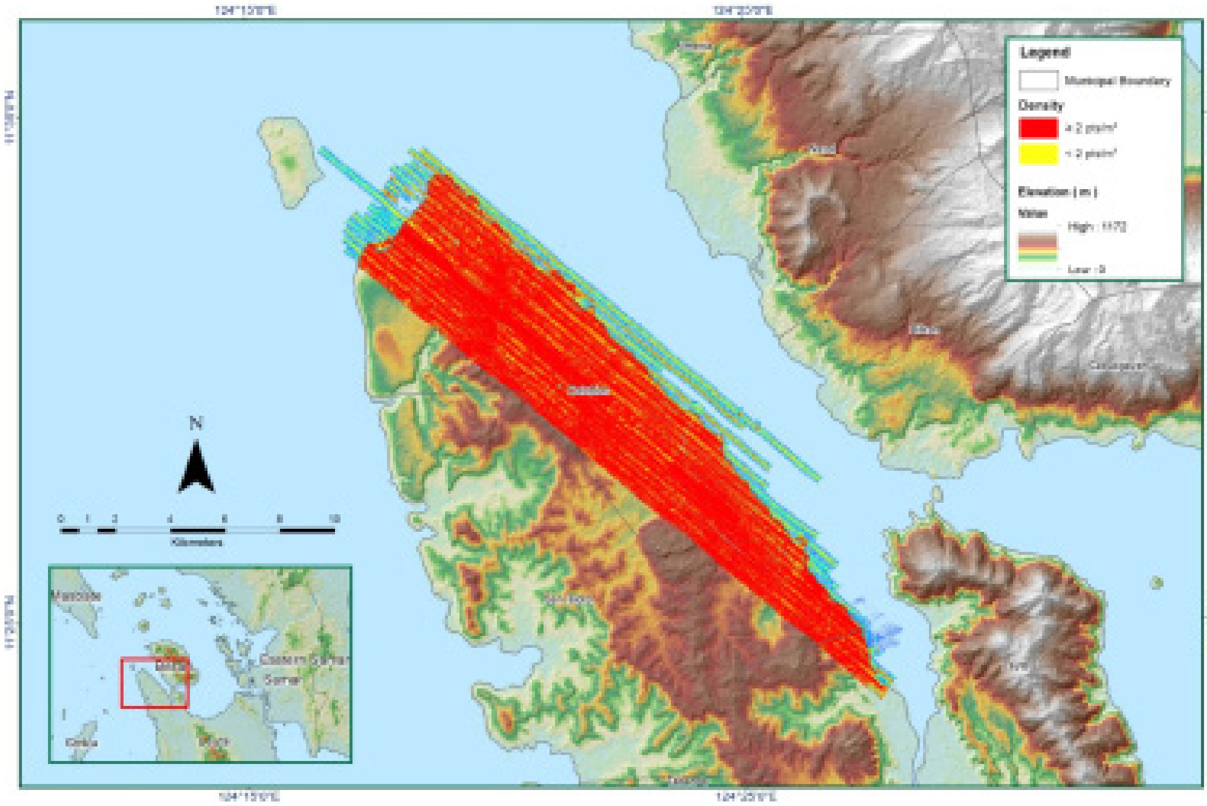


Figure A-8.55. Density map of merged LiDAR data

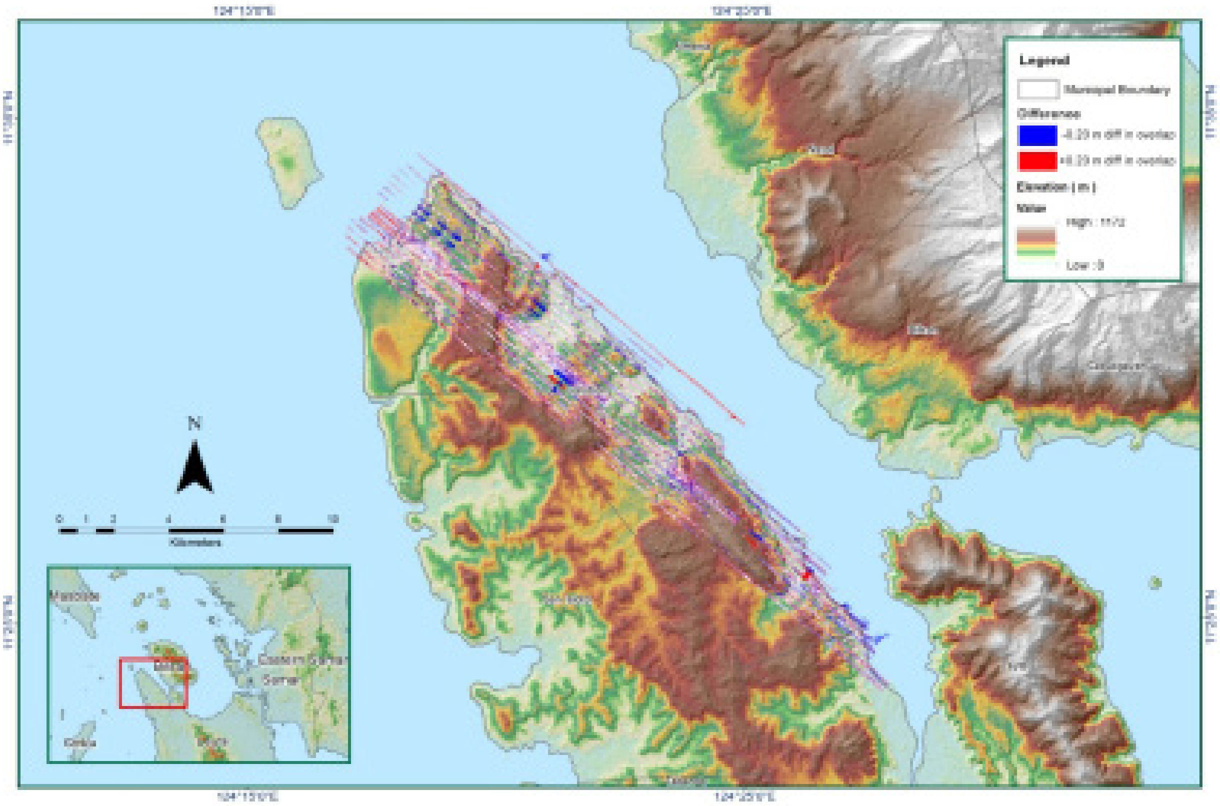


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk35H

Flight Area	Samar-Leyte
Mission Name	Blk35H
Inclusive Flights	1494A
Range data size	14.7 GB
POS data size	282 MB
Base data size	7.64 MB
Image	89.2 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.674
RMSE for Down Position (<8.0 cm)	4.64
Boresight correction stdev (<0.001deg)	0.000283
IMU attitude correction stdev (<0.001deg)	0.000568
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	52.72%
Ave point cloud density per sq.m. (>2.0)	3.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	158
Maximum Height	376.65 m
Minimum Height	36.39 m
Classification (# of points)	
Ground	82,689,374
Low vegetation	99,097,253
Medium vegetation	126,198,163
High vegetation	25,741,043
Building	1,206,583
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

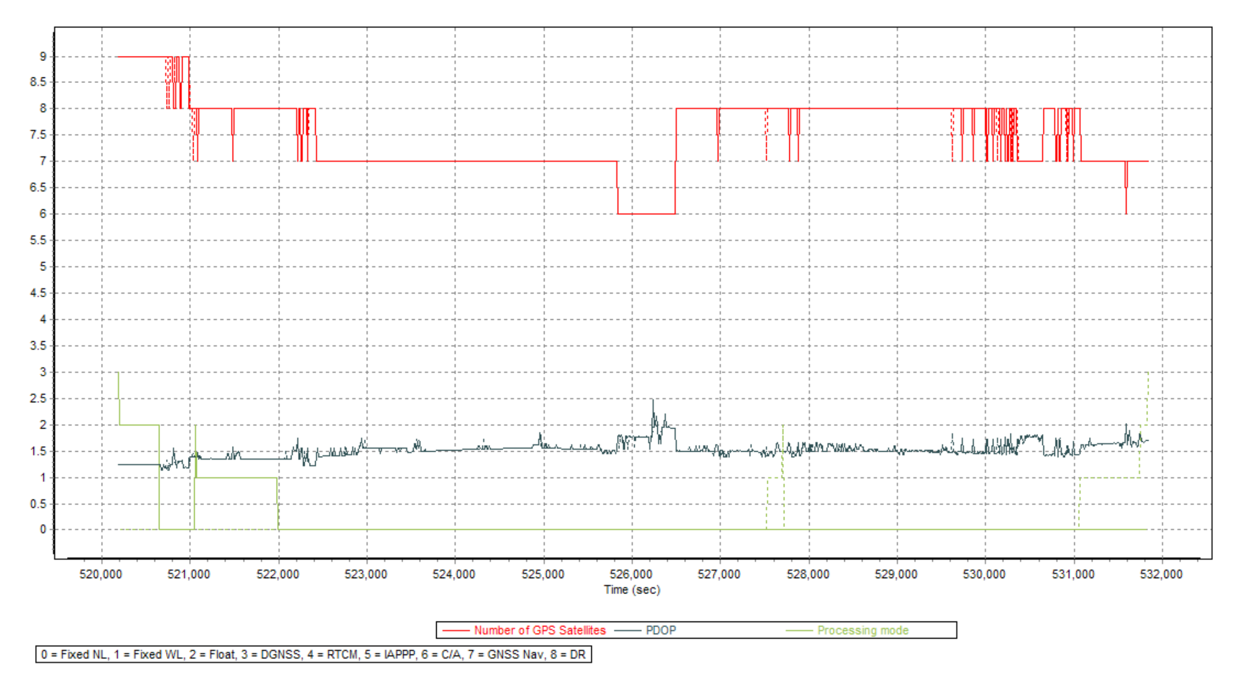


Figure A-8.57. Solution Status

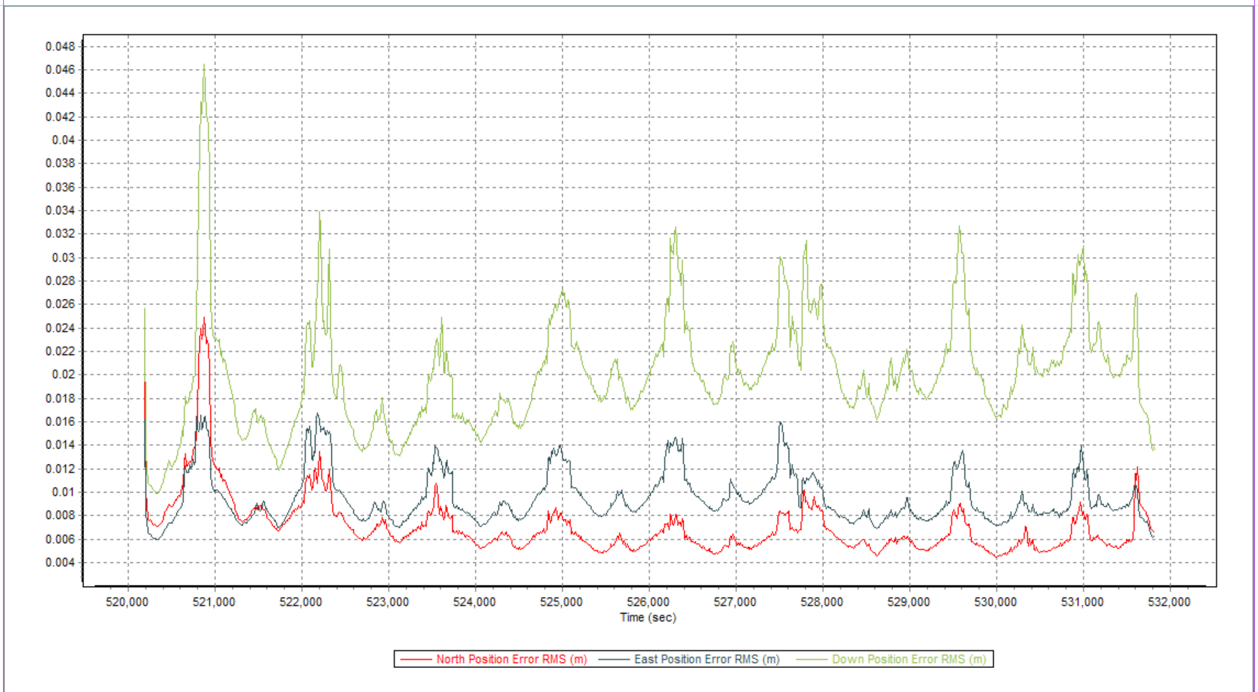


Figure A-8.58. Smoothed Performance Metrics Parameters

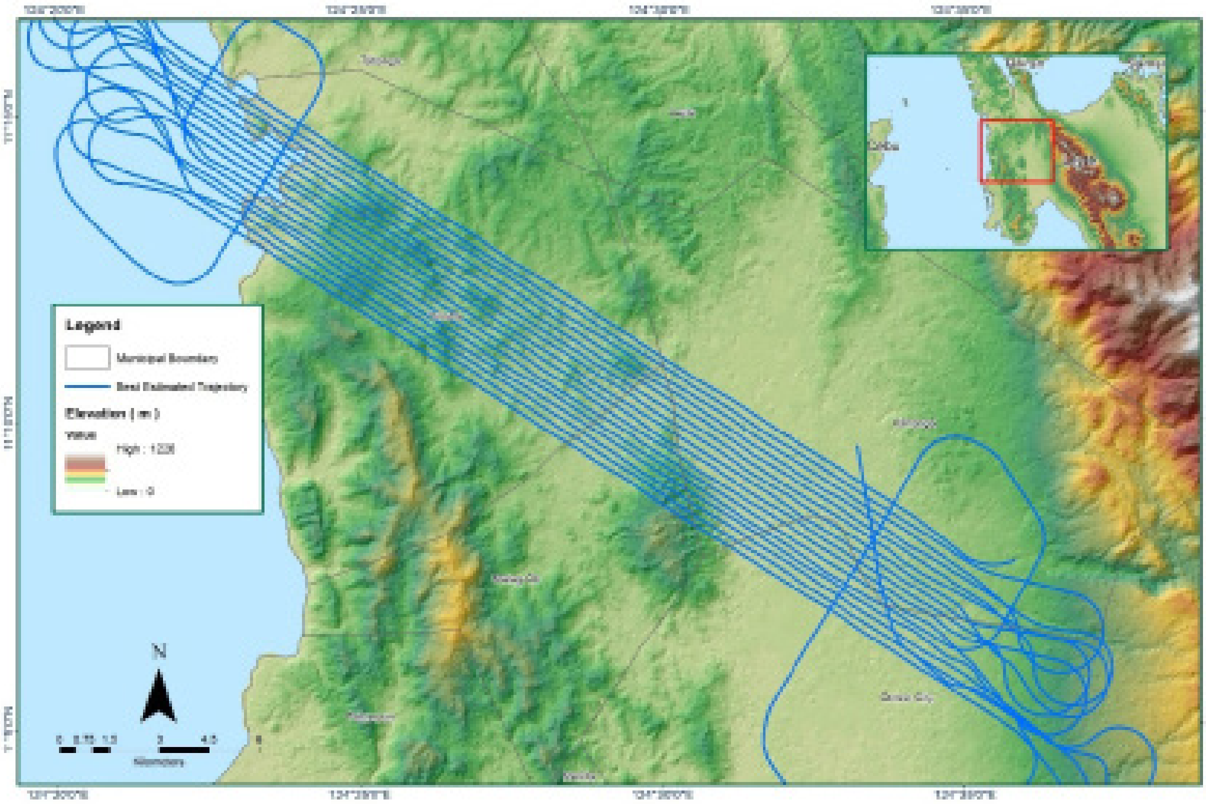


Figure A-8.59. Best Estimated Trajectory

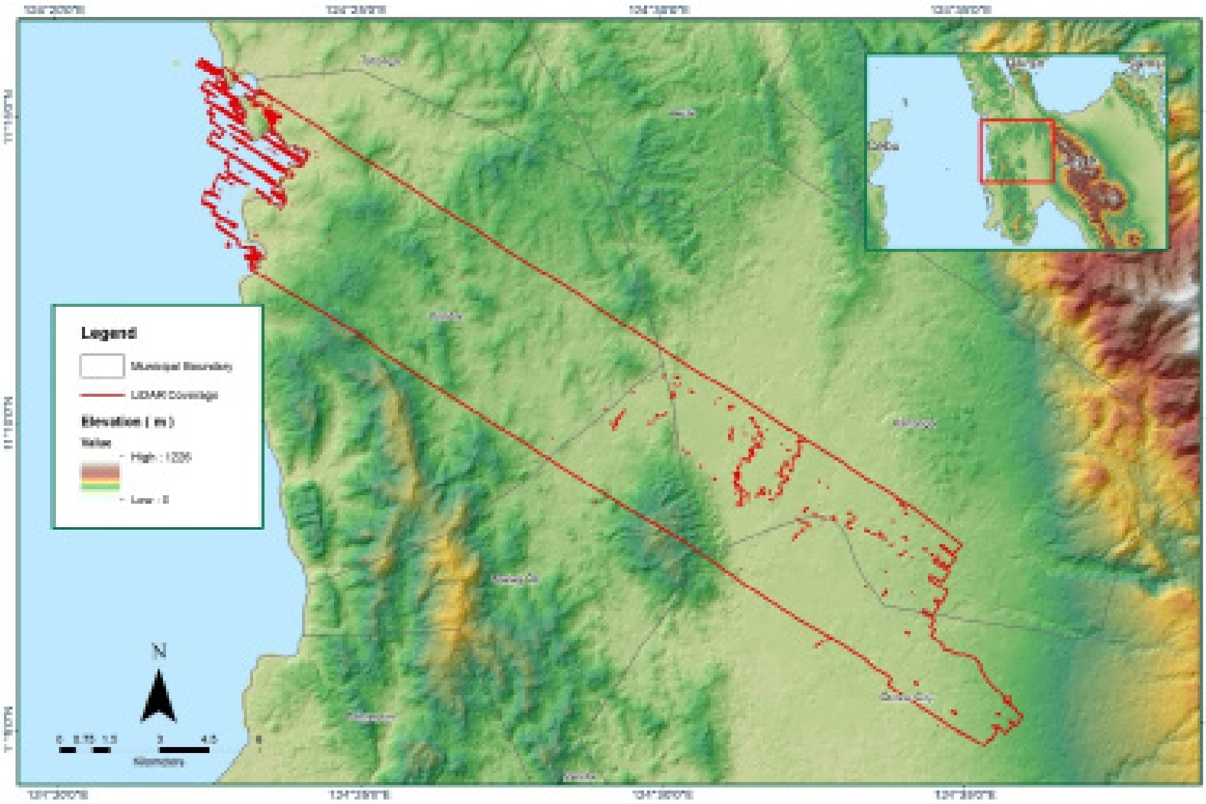


Figure A-8.60. Best Estimated Trajectory

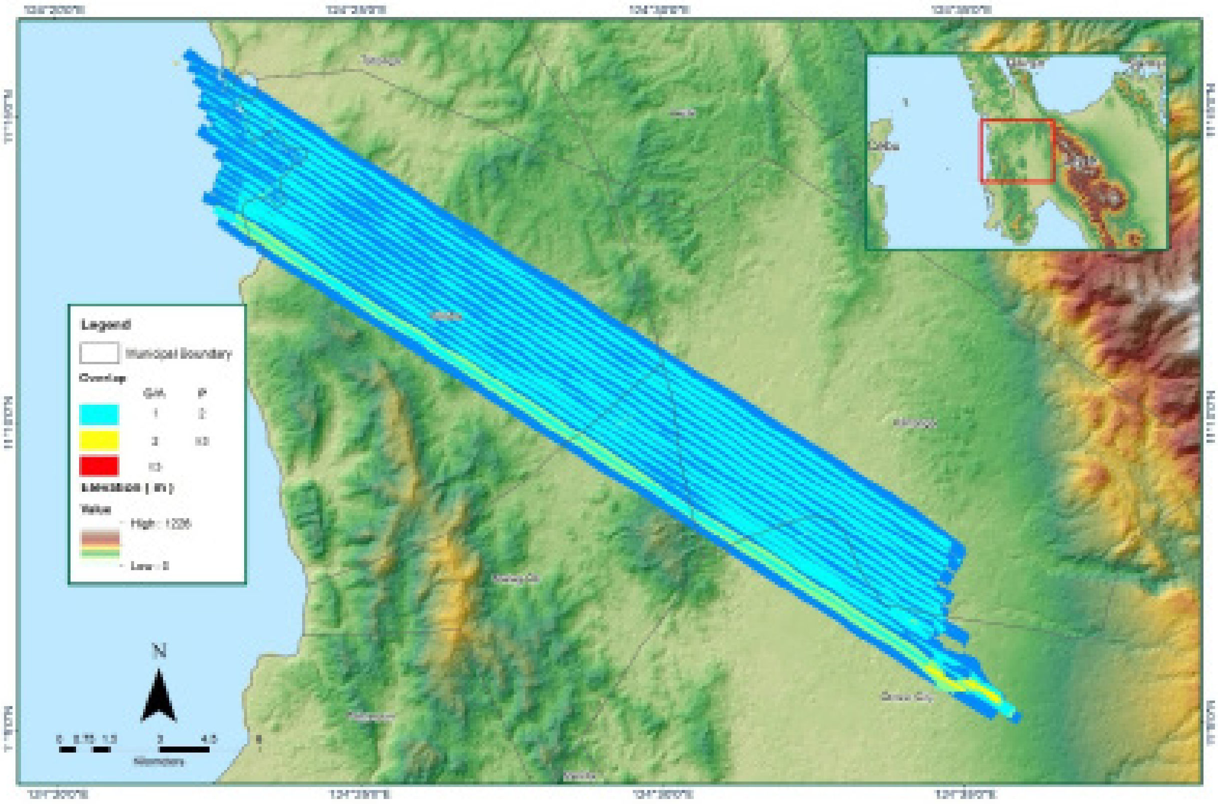


Figure A-8.61. Image of data overlap

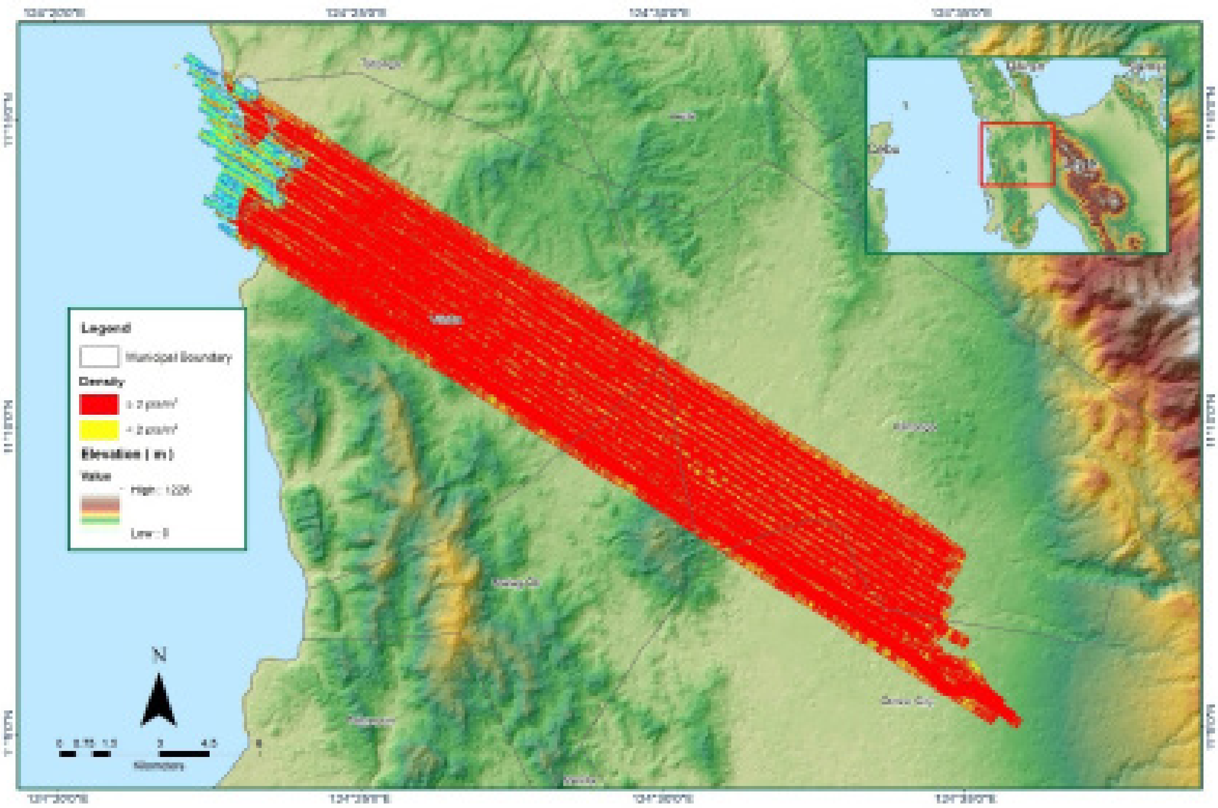


Figure A-8.62. Density map of merged LiDAR data

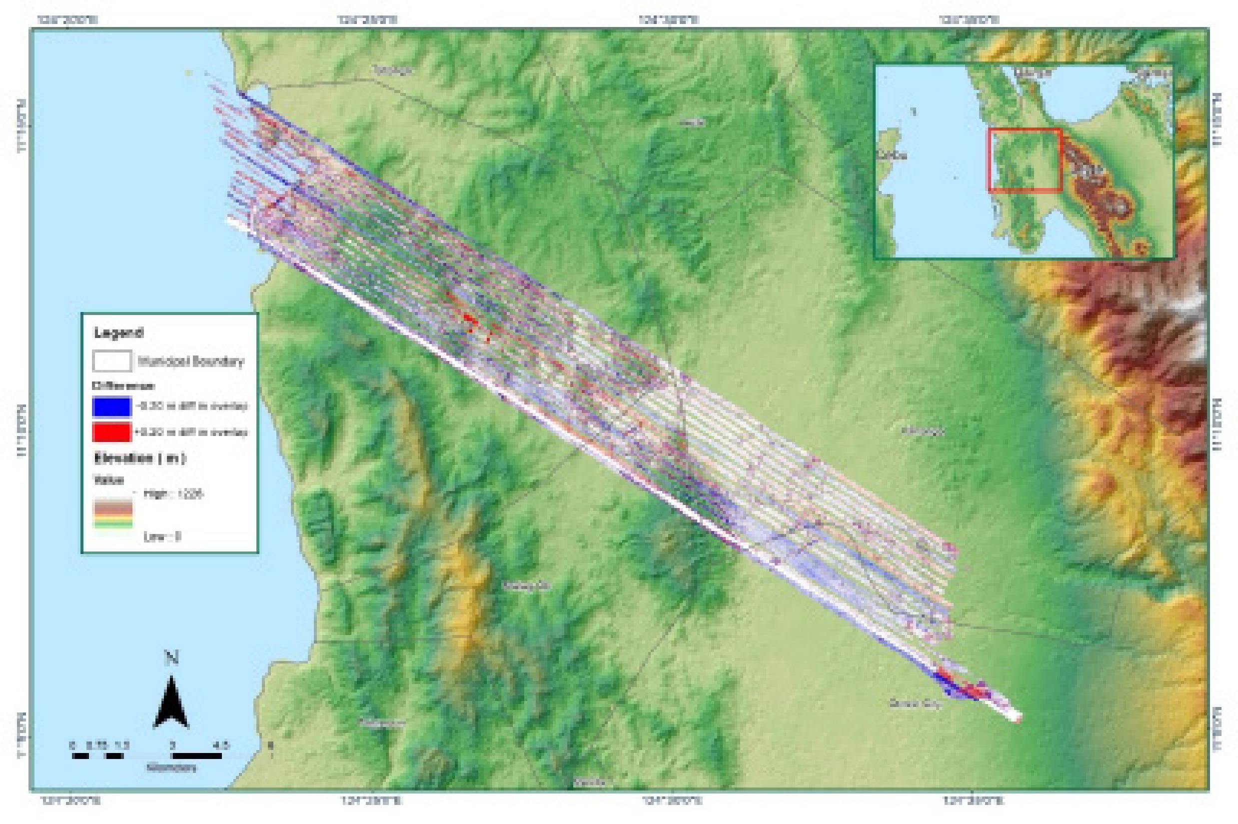


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk35H_Supplement2

Flight Area	Samar-Leyte
Mission Name	Blk35H_Supplement2
Inclusive Flights	1498A
Range data size	3.23 GB
POS data size	282 MB
Base data size	8.04 MB
Image	88.7 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.3
RMSE for East Position (<4.0 cm)	3.7
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000283
IMU attitude correction stdev (<0.001deg)	0.000568
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	11.00%
Ave point cloud density per sq.m. (>2.0)	2.40
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	3
Maximum Height	107.84 m
Minimum Height	80.85 m
Classification (# of points)	
Ground	121,532
Low vegetation	138,860
Medium vegetation	116,706
High vegetation	15,470
Building	1,666
Orthophoto	No
Processed by	Engr. Irish Cortez, Aljon Rie Araneta, Engr. Gladys Mae Apat

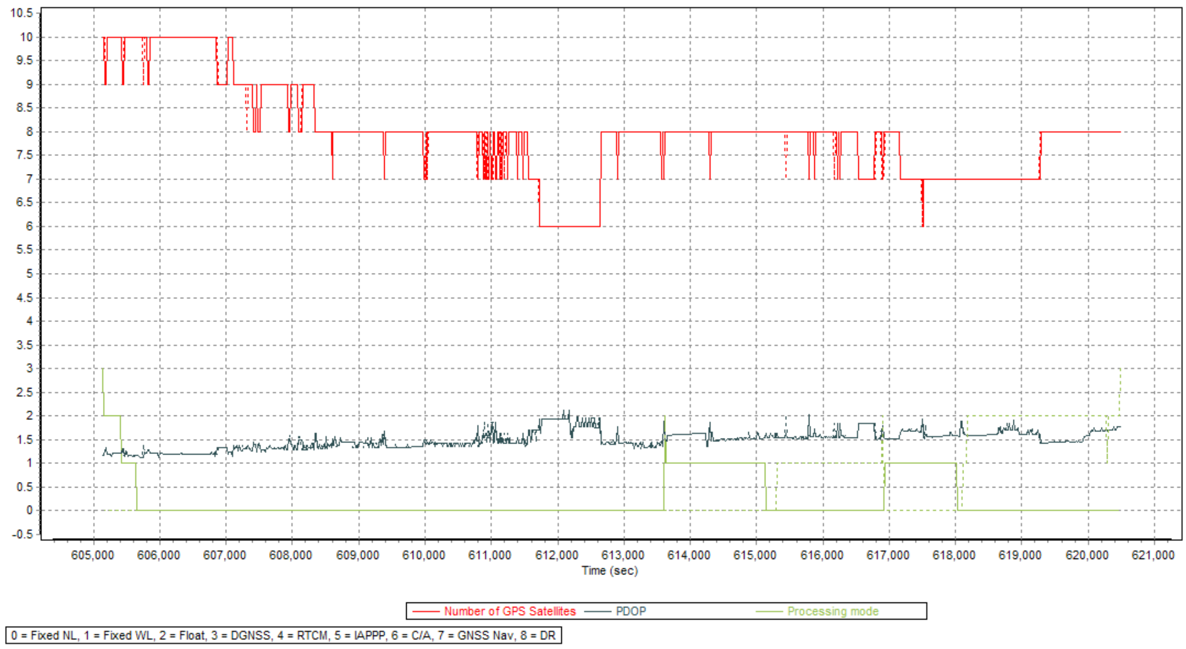


Figure A-8.64. Solution Status

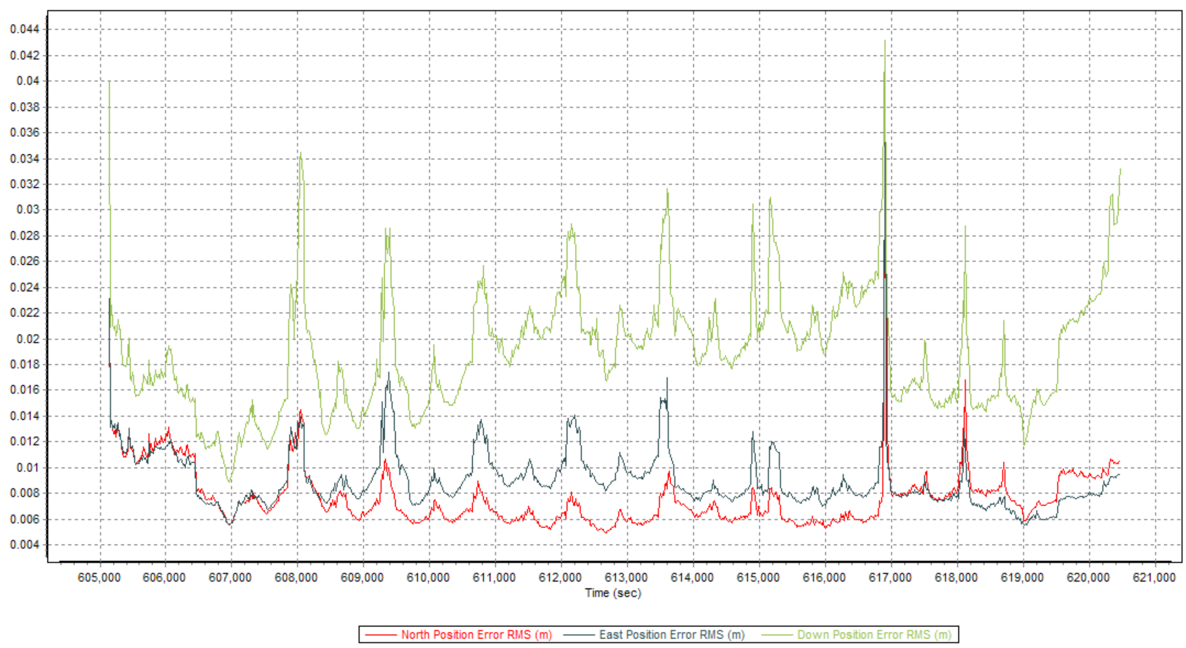


Figure A-8.65. Smoothed Performance Metrics Parameters

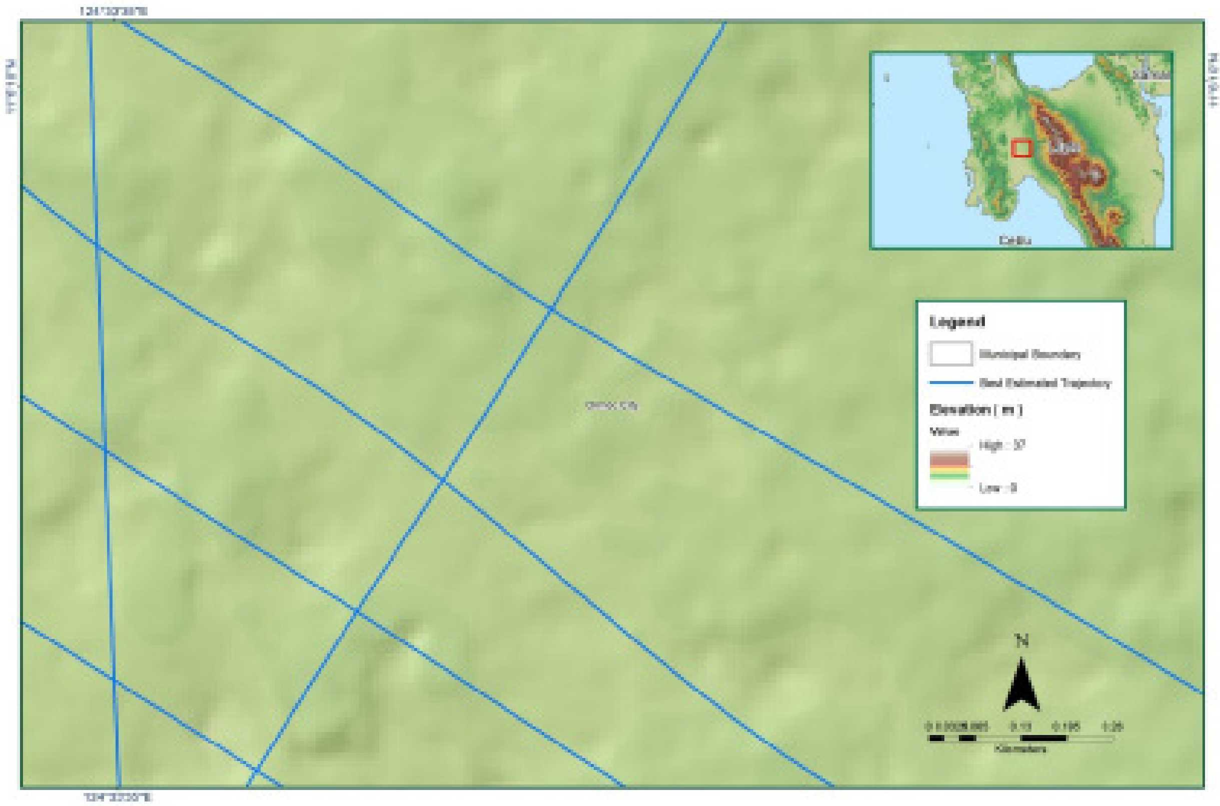


Figure A-8.66. Best Estimated Trajectory

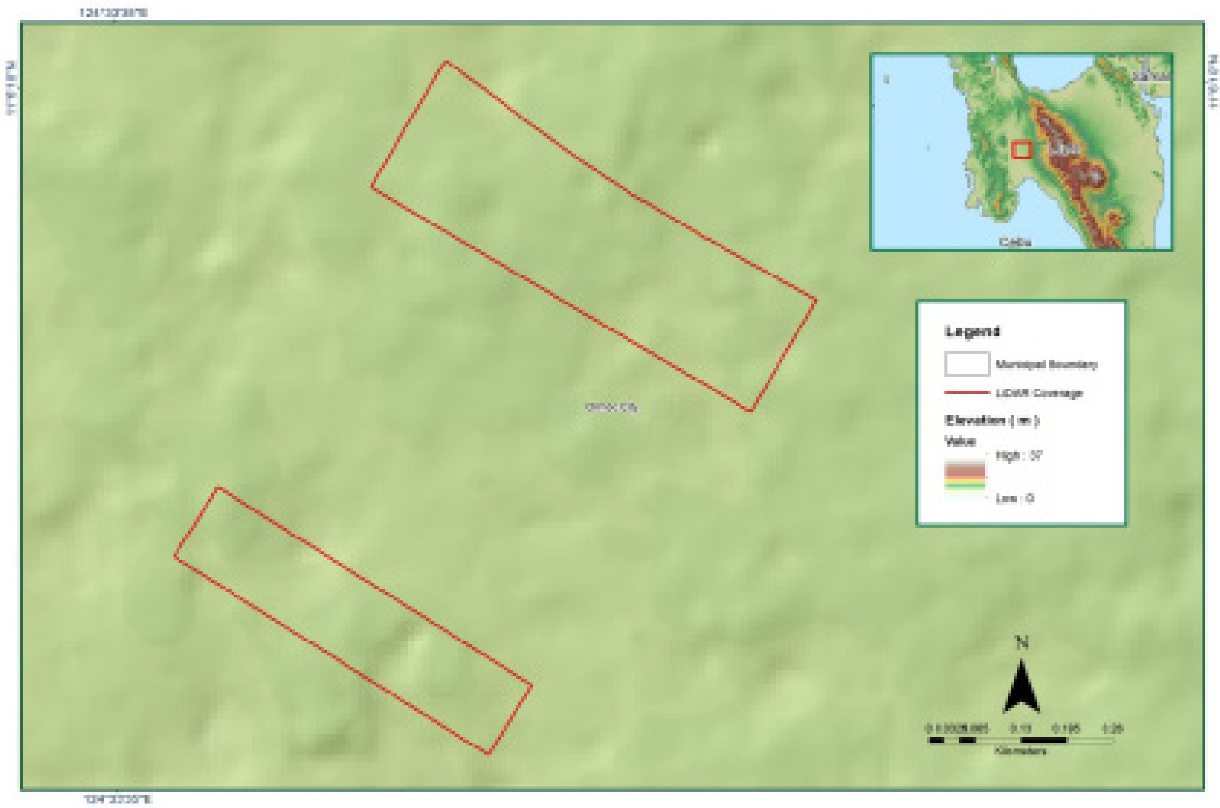


Figure A-8.67. Coverage of LiDAR data

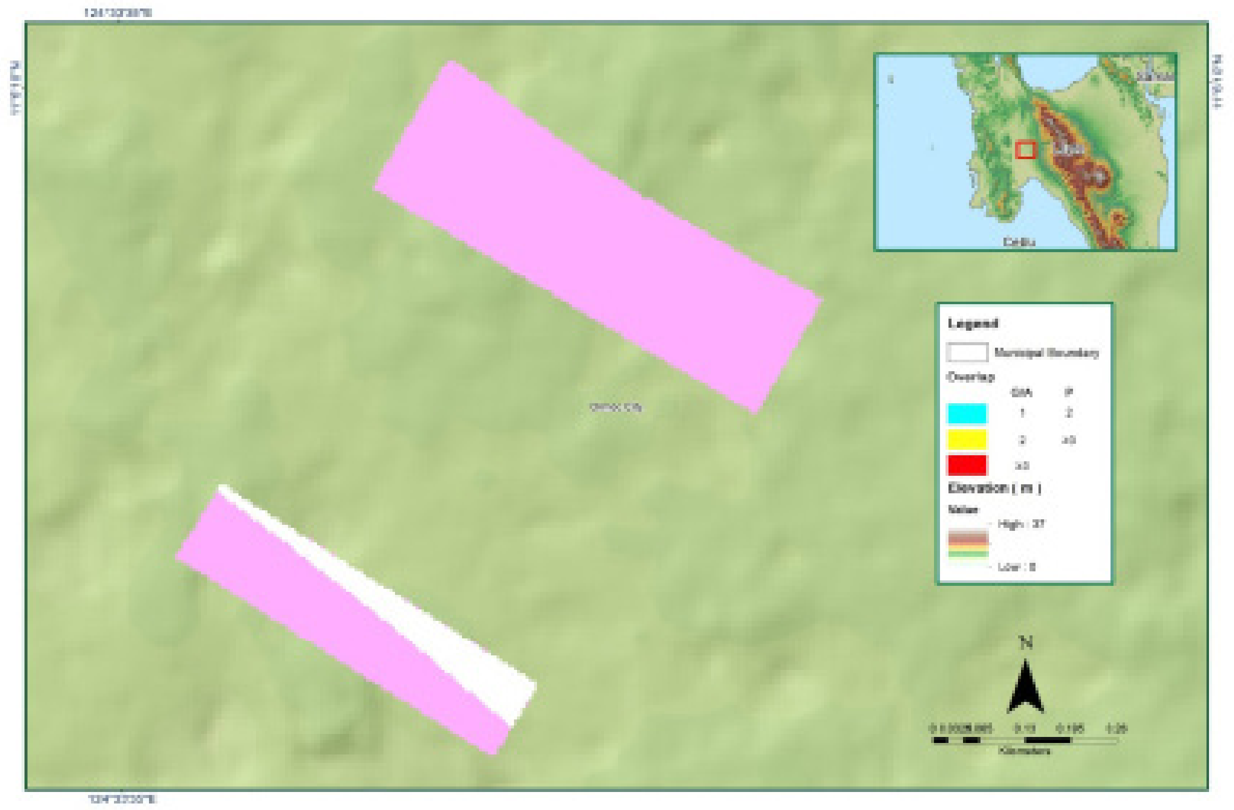


Figure A-8.68. Image of data overlap

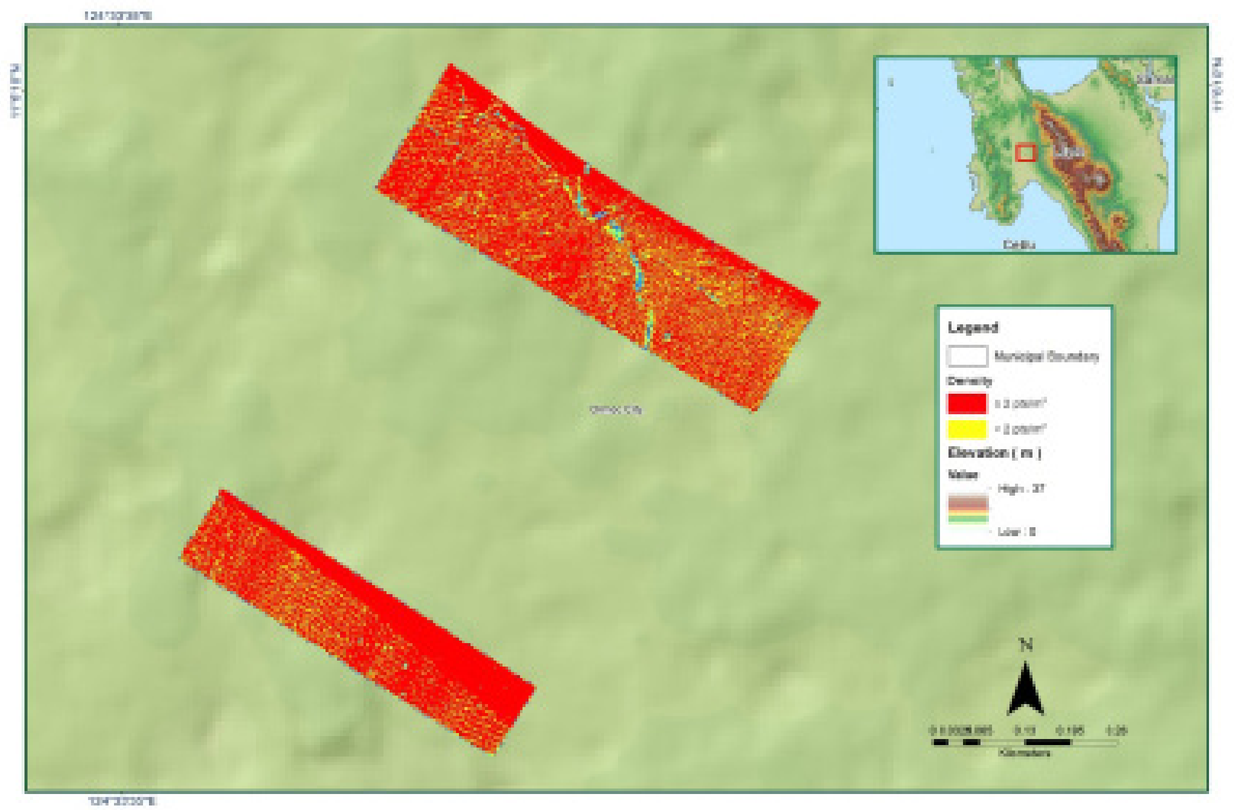


Figure A-8.69. Density map of merged LiDAR data

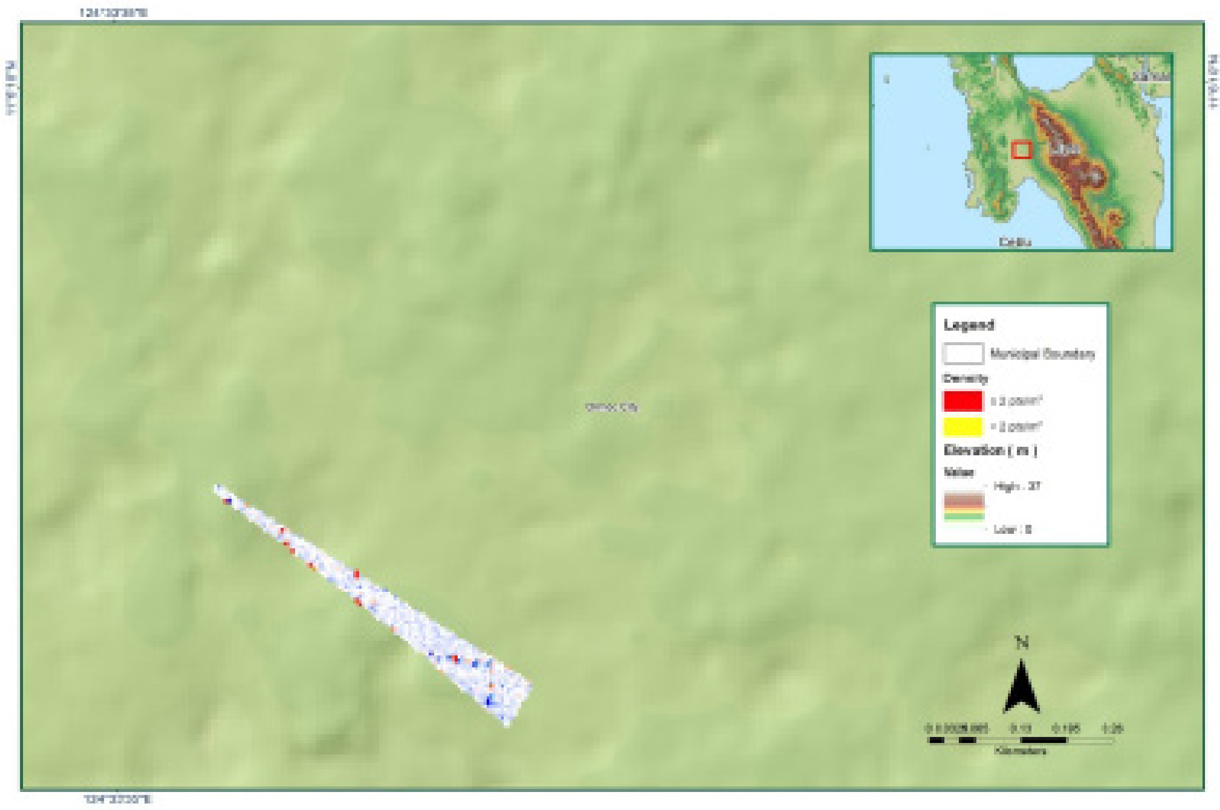


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk35A_supplement

Flight Area	Ormoc
Mission Name	Blk35A_supplement
Inclusive Flights	7806AC
Range data size	8.2 GB
POS data size	195 MB
Base data size	27 MB
Image	NA
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.398
RMSE for East Position (<4.0 cm)	1.825
RMSE for Down Position (<8.0 cm)	2.963
Boresight correction stdev (<0.001deg)	0.000271
IMU attitude correction stdev (<0.001deg)	0.000619
GPS position stdev (<0.01m)	0.0071
Minimum % overlap (>25)	38.68
Ave point cloud density per sq.m. (>2.0)	3.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	138
Maximum Height	273.06
Minimum Height	57.10
Classification (# of points)	
Ground	48,561,341
Low vegetation	55,772,317
Medium vegetation	72,199,910
High vegetation	12,108,287
Building	5,014,837
Orthophoto	None
Processed by	Engr. Abigail Joy Ching, Engr. Antonio Chua, Jr., Engr. Krisha Marie Bautista

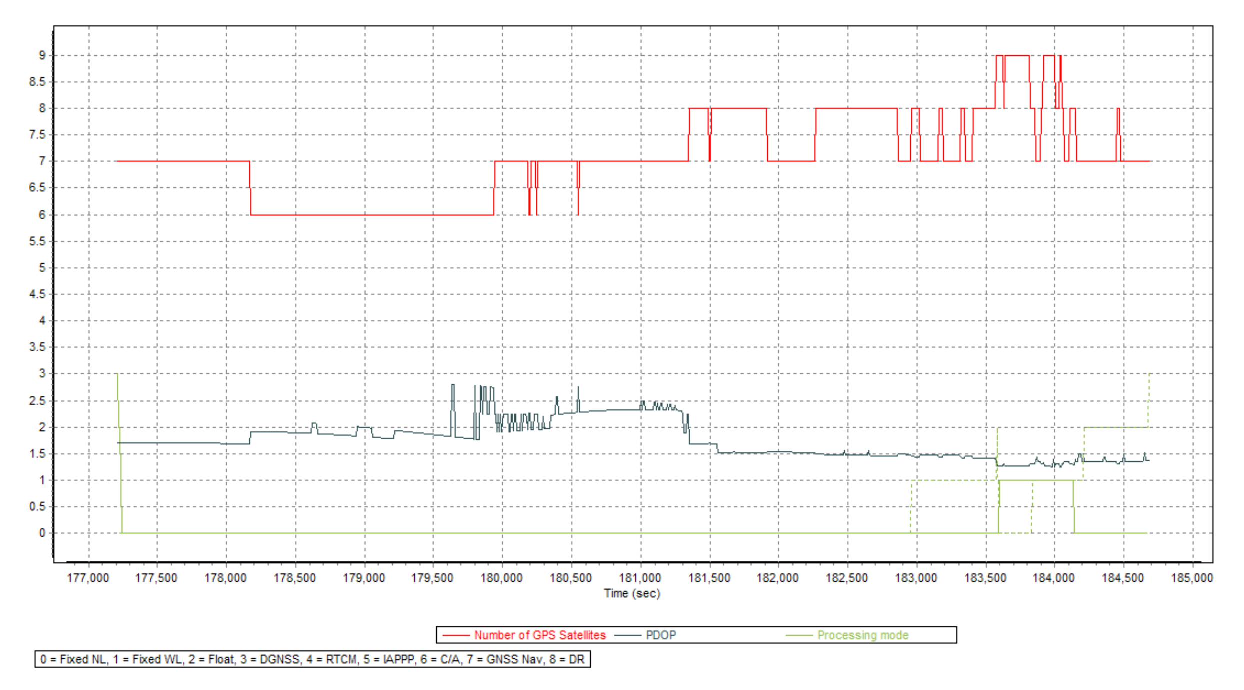


Figure A-8.71. Solution Status

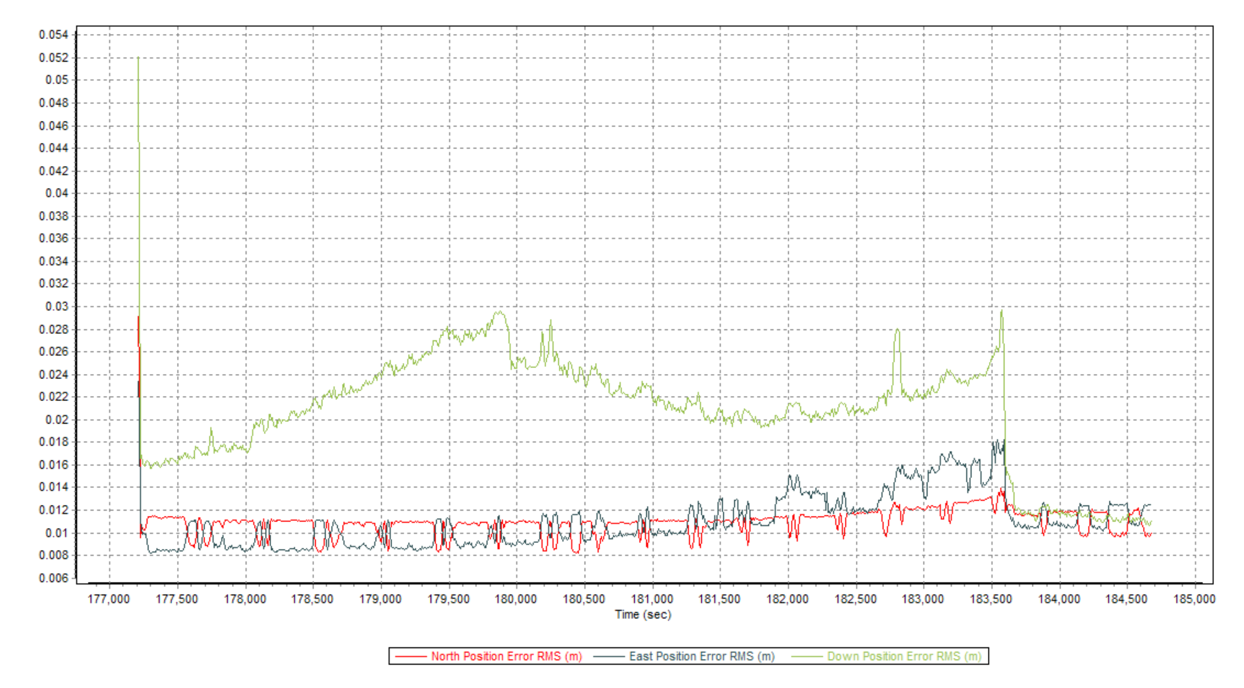


Figure A-8.72. Smoothed Performance Metrics Parameters

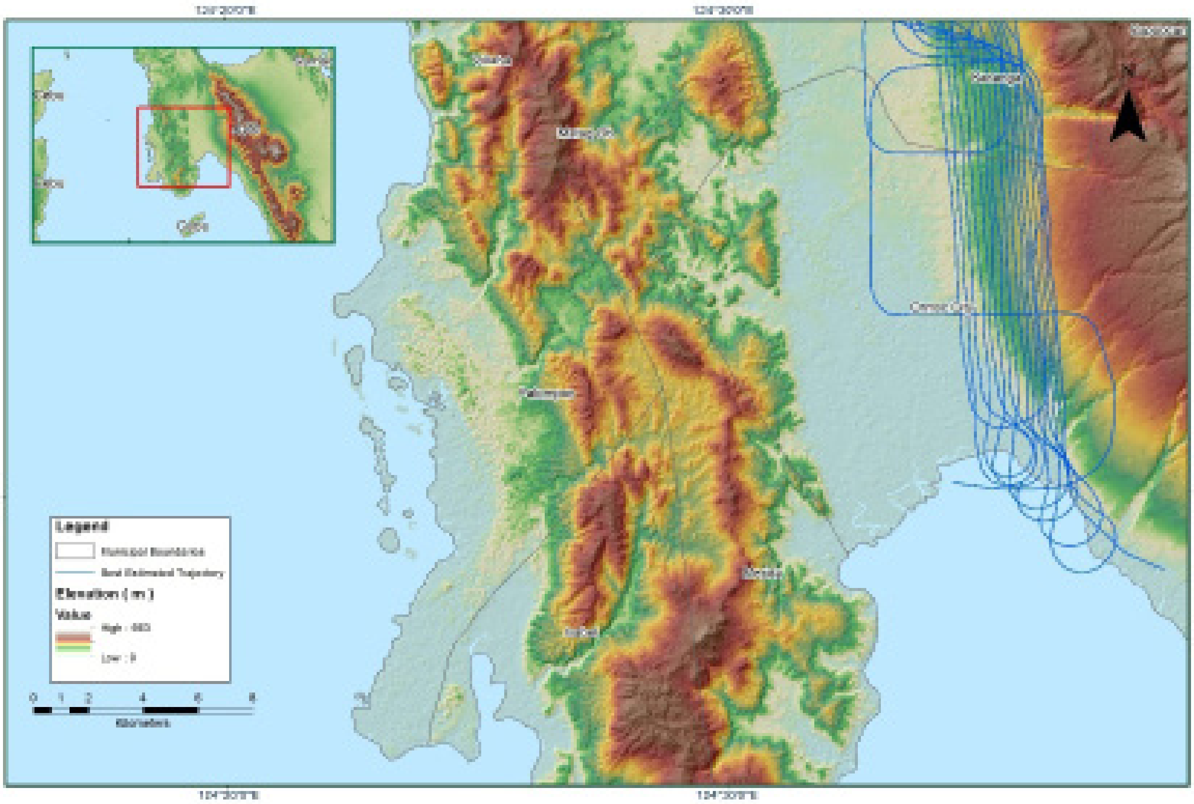


Figure A-8.73. Best Estimated Trajectory

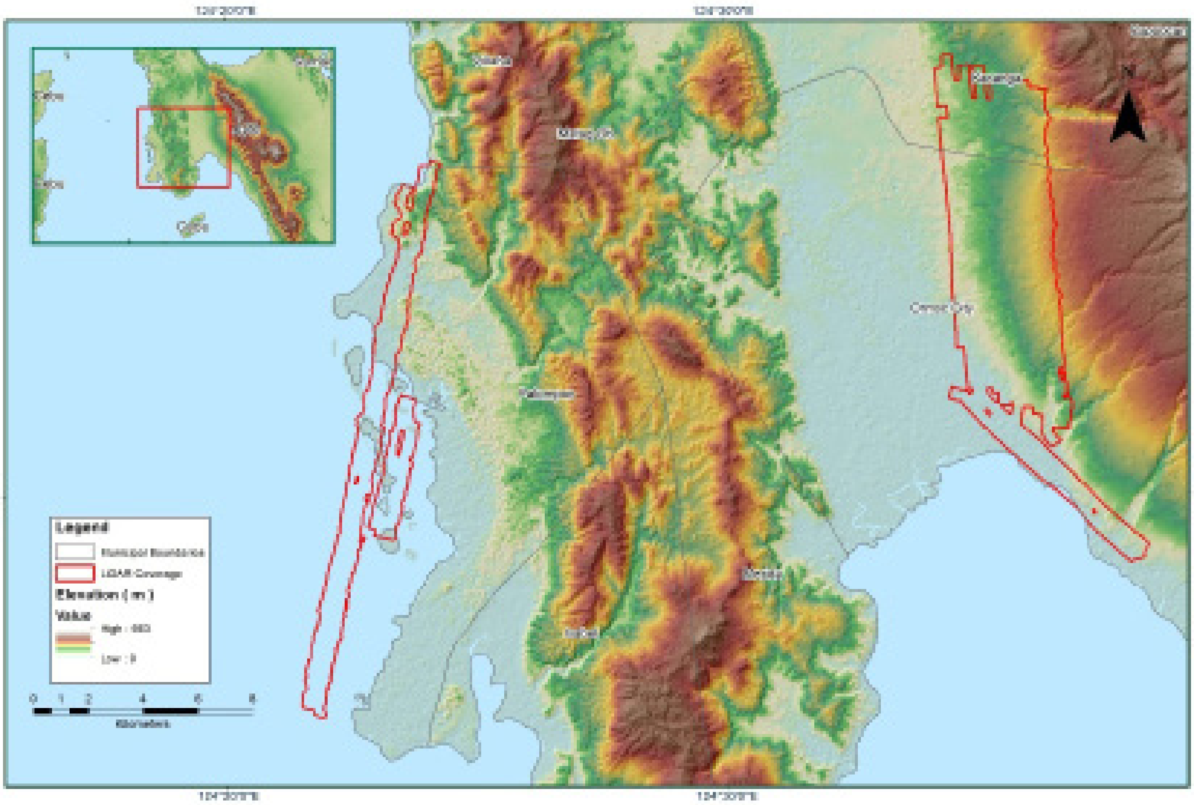


Figure A-8.74. Best Estimated Trajectory

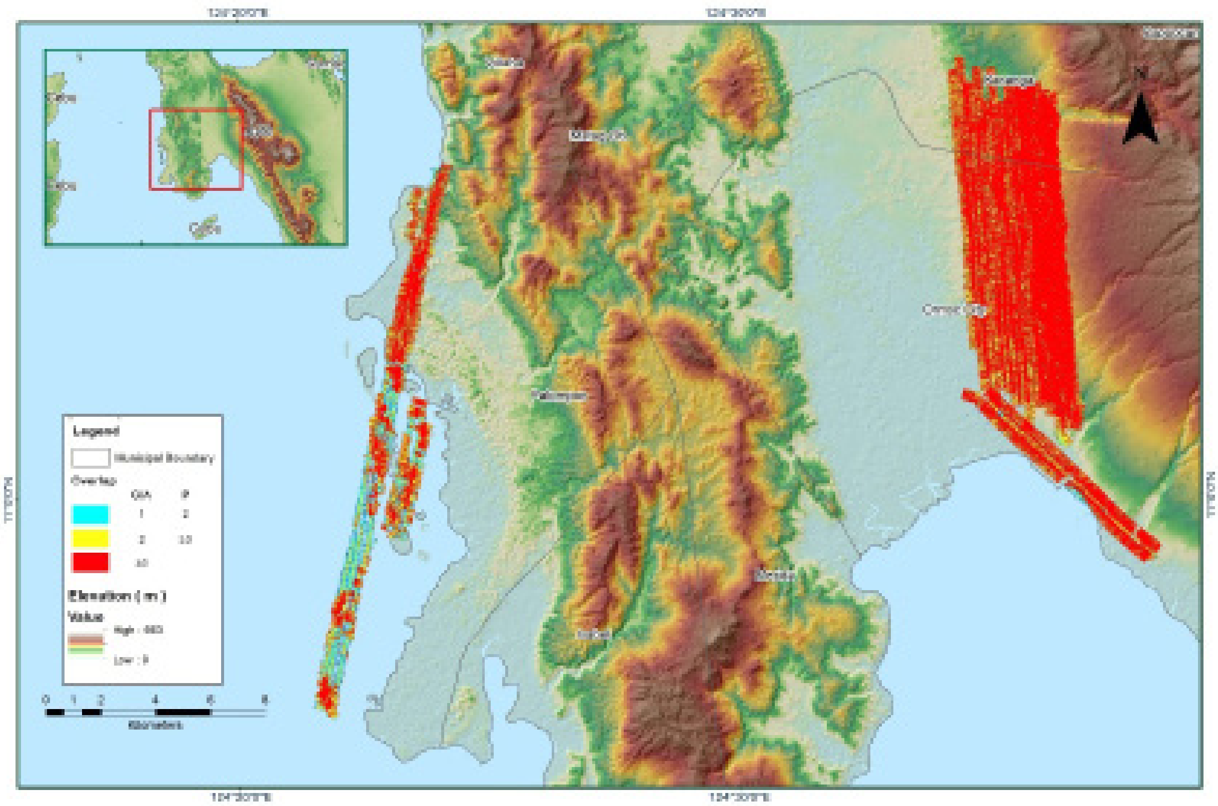


Figure A-8.75. Image of data overlap

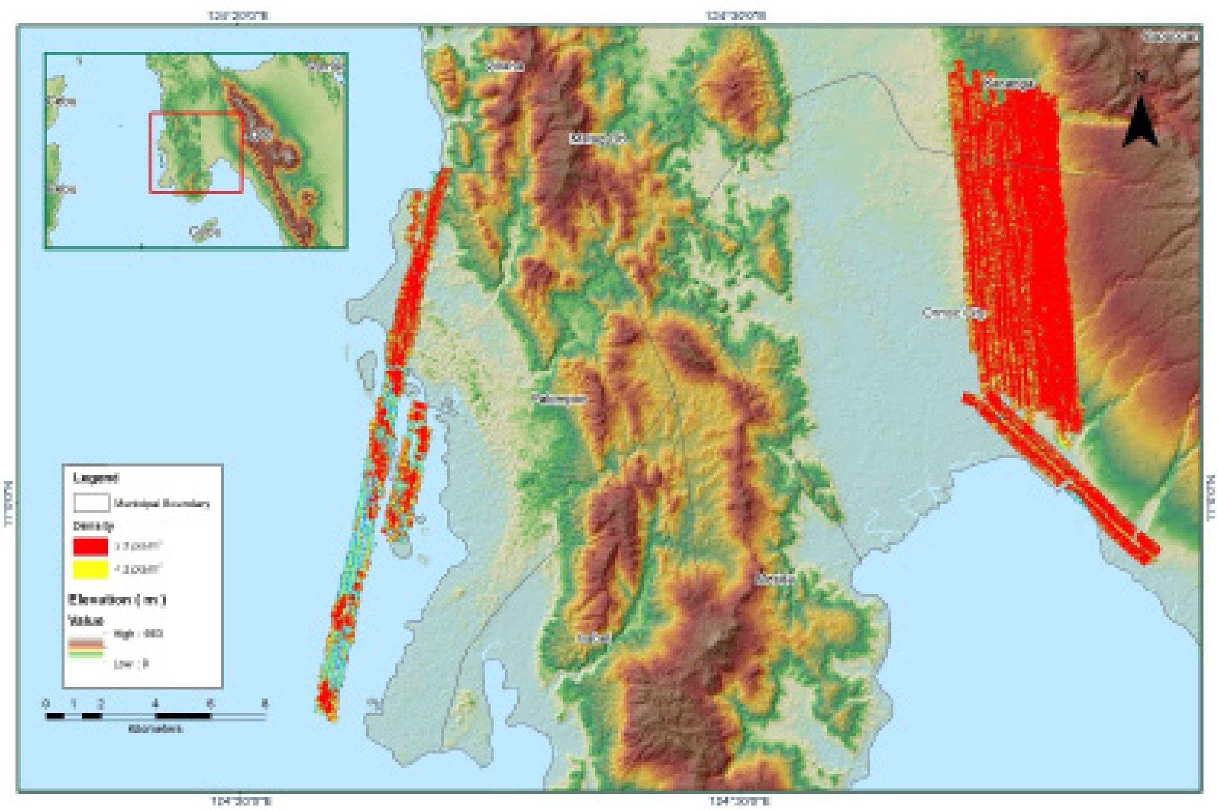


Figure A-8.76. Density map of merged LiDAR data

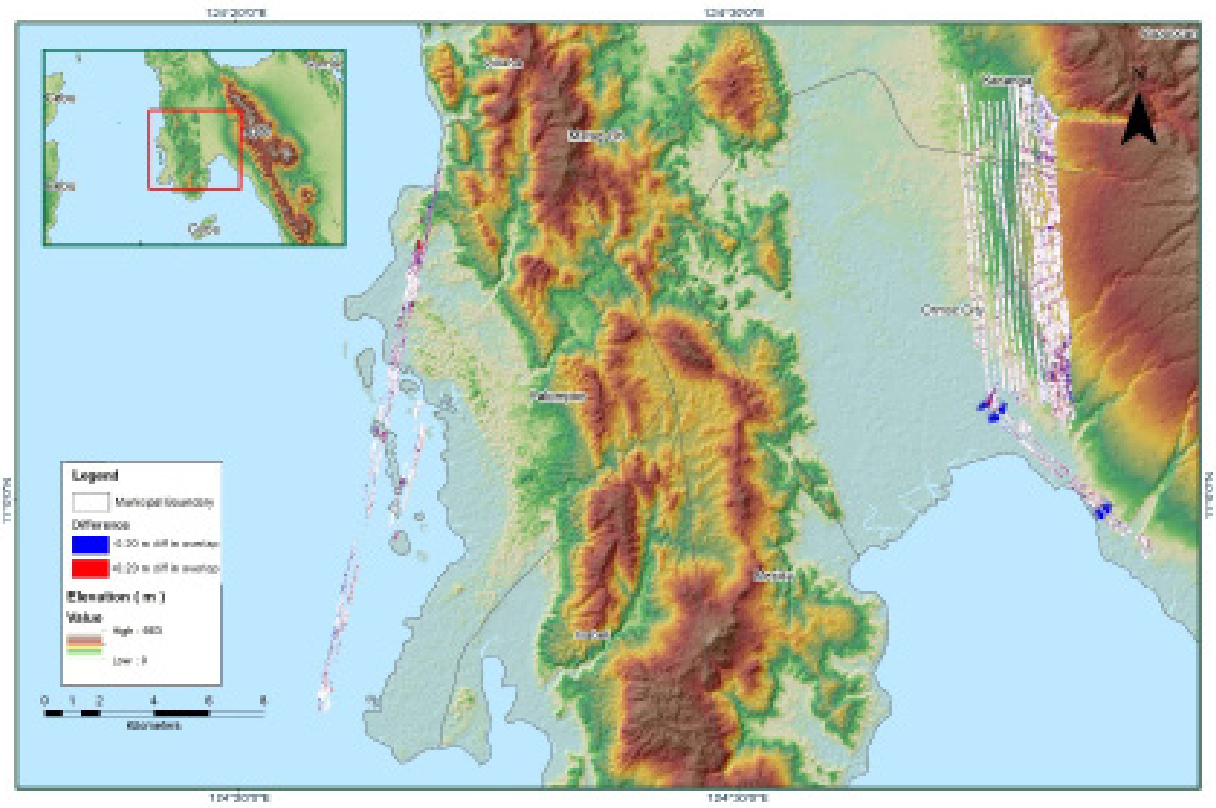


Figure A-8.77. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission Blk35A

Flight Area	Ormoc
Mission Name	Blk35A
Inclusive Flights	7780AC, 7782AC
Range data size	18.92 GB
POS	314.4 MB
Image	0 GB
Transfer date	March 9 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.19
RMSE for East Position (<4.0 cm)	1.51
RMSE for Down Position (<8.0 cm)	3.00
Boresight correction stdev (<0.001deg)	0.000320
IMU attitude correction stdev (<0.001deg)	0.002289
GPS position stdev (<0.01m)	0.0035
Minimum % overlap (>25)	68.46
Ave point cloud density per sq.m. (>2.0)	4.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	160
Maximum Height	178.37 m
Minimum Height	57.53 m
Classification (# of points)	
Ground	72,108,209
Low vegetation	118,219,687
Medium vegetation	115,199,347
High vegetation	21,276,179
Building	10,881,118
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Kathryn Claudyn Zarate

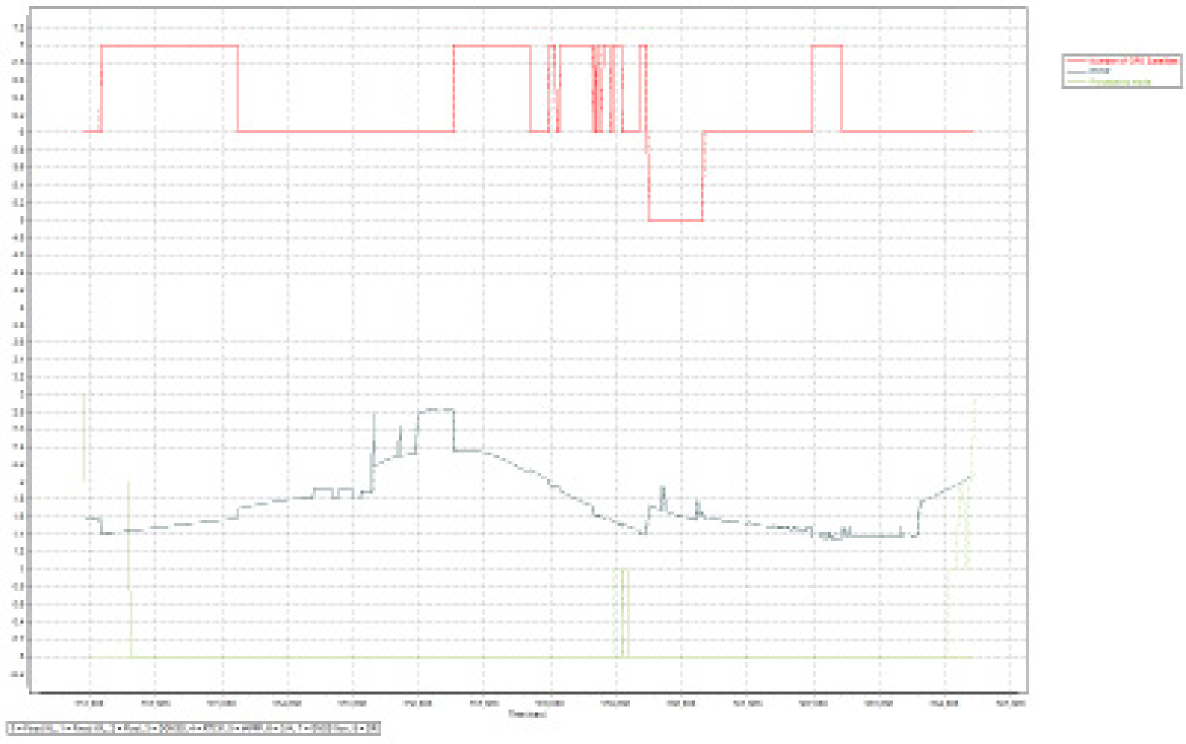


Figure A-8.78. Solution Status

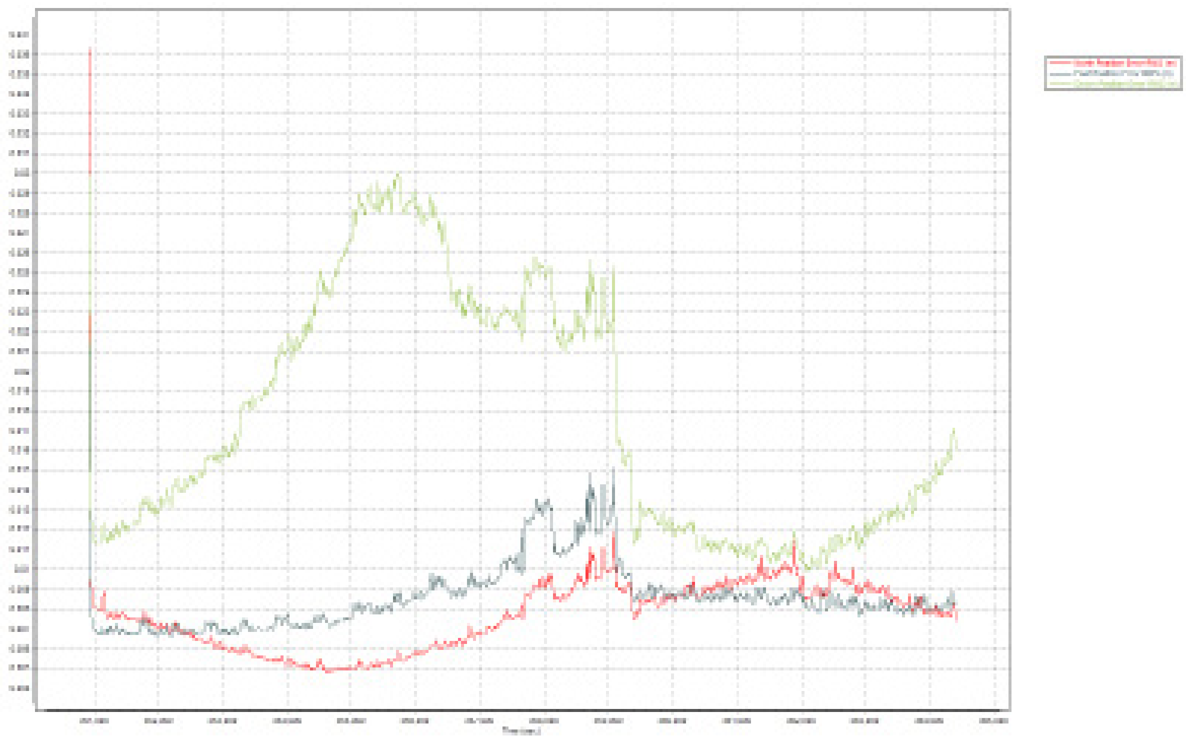


Figure A-8.79. Smoothed Performance Metrics Parameters

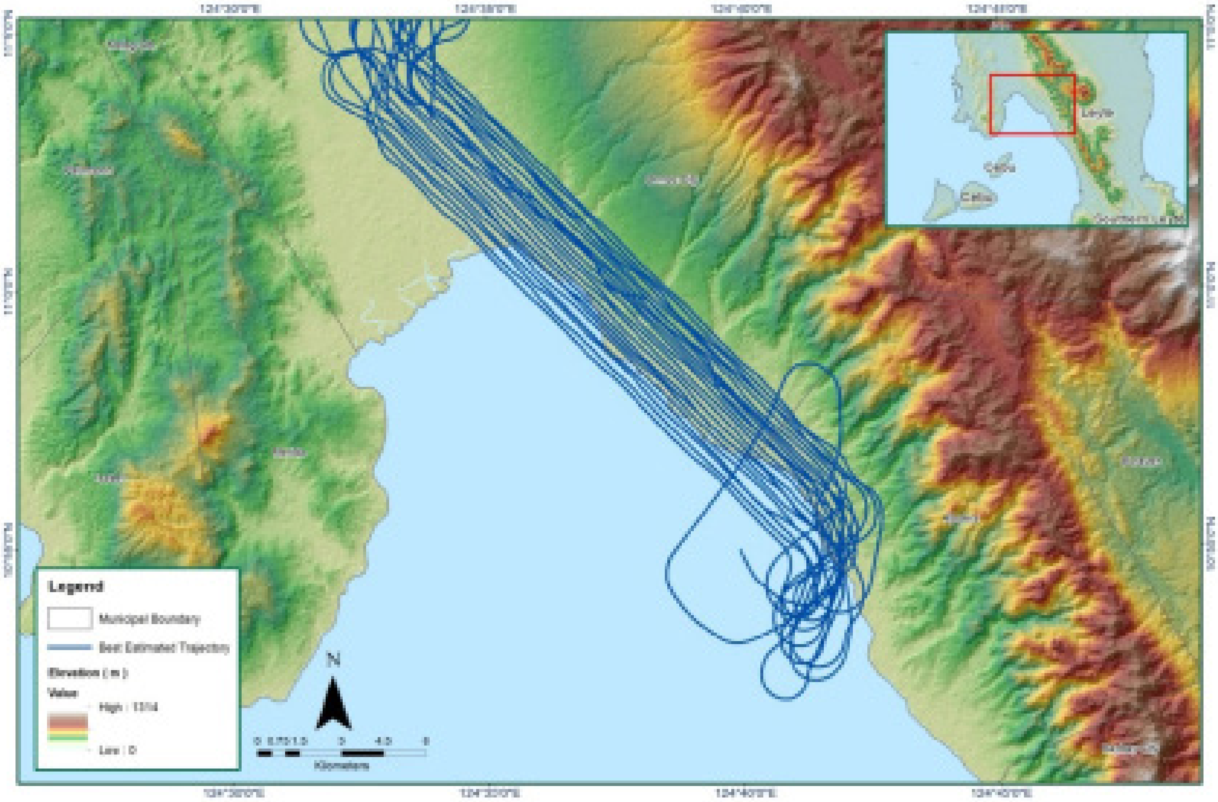


Figure A-8.80. Best Estimated Trajectory

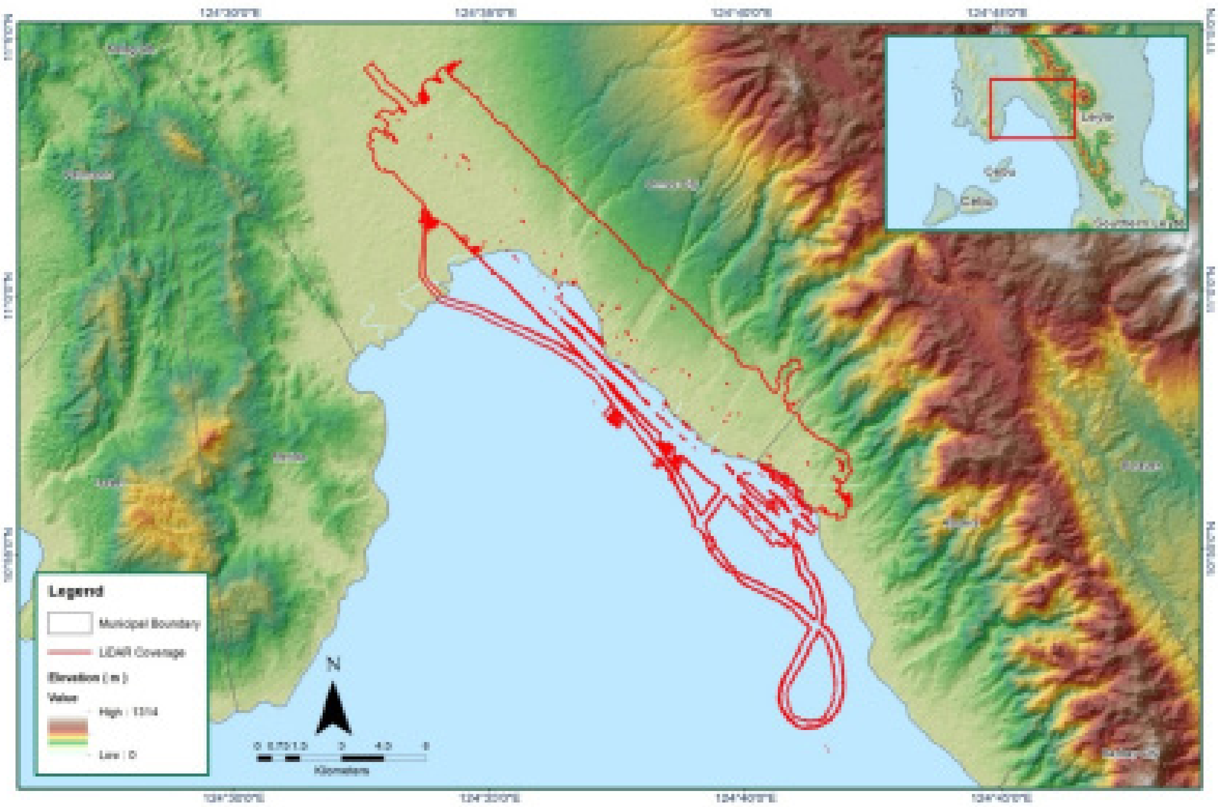


Figure A-8.81. Coverage of LiDAR data

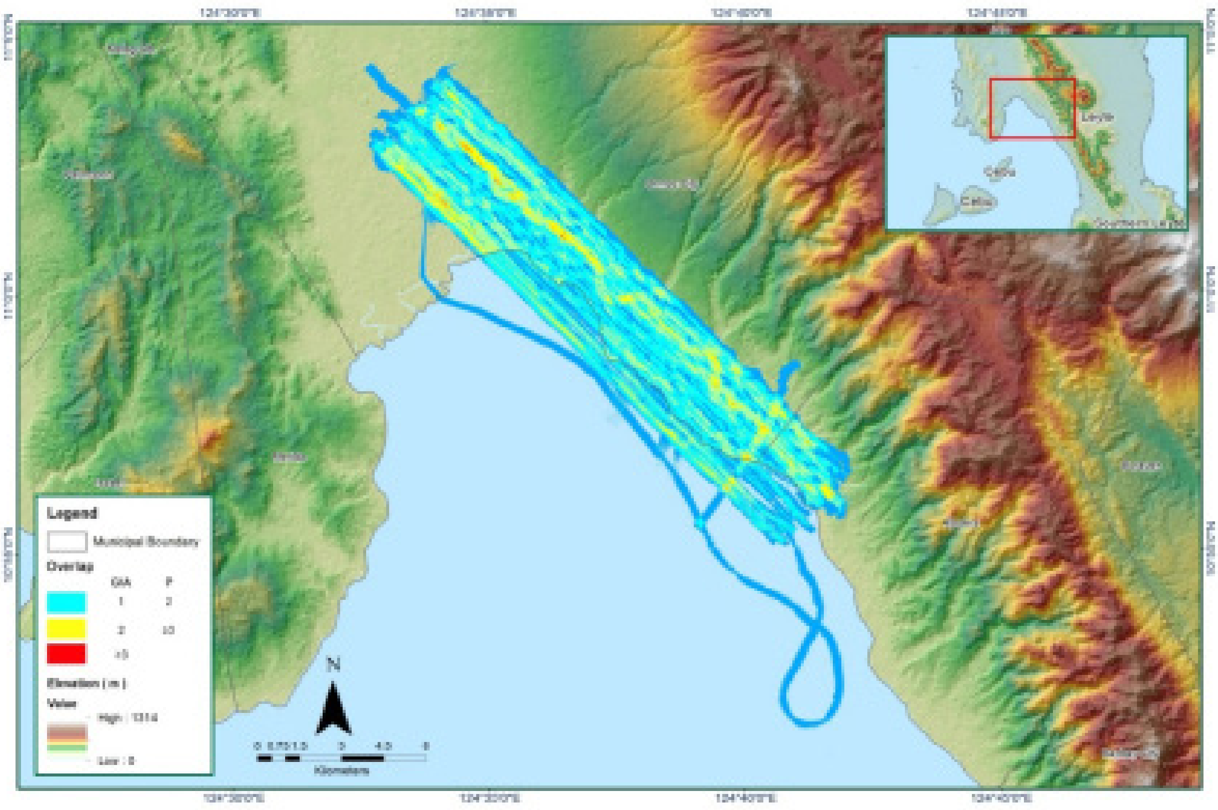


Figure A-8.82. Image of data overlap

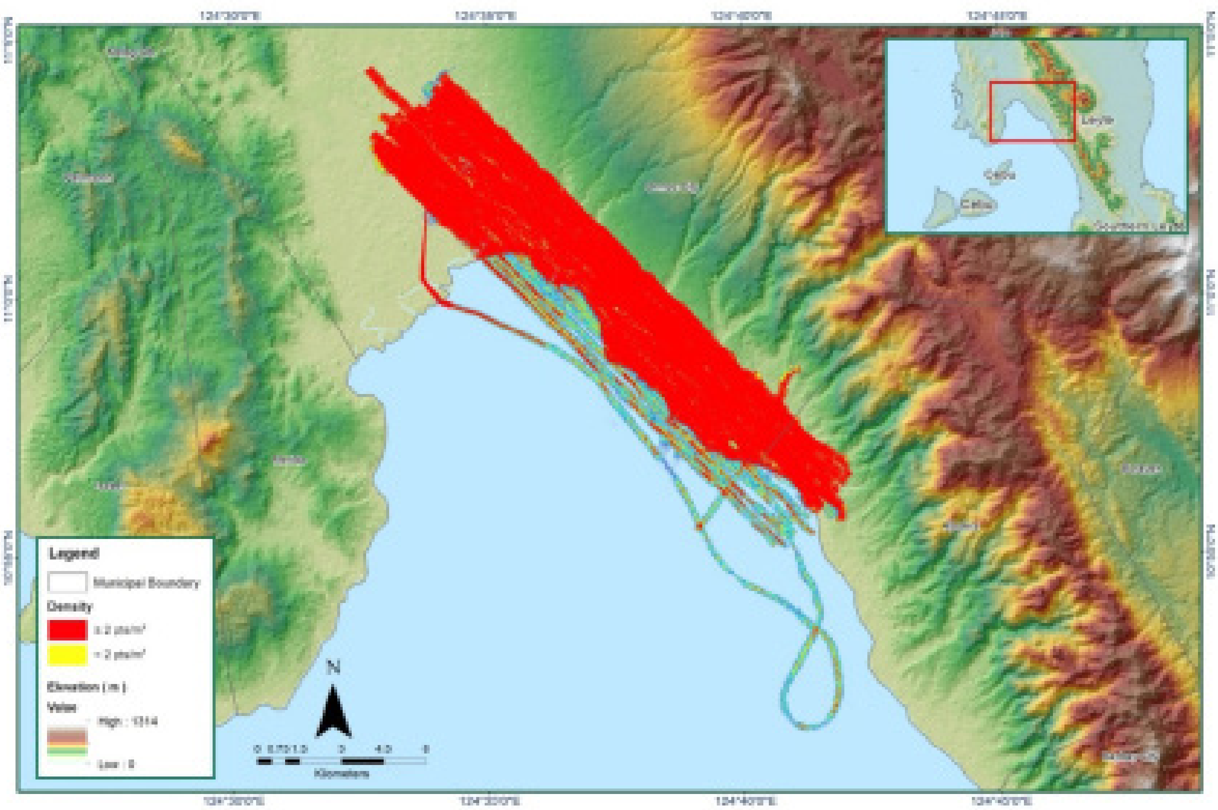


Figure A-8.83. Density map of merged LiDAR data

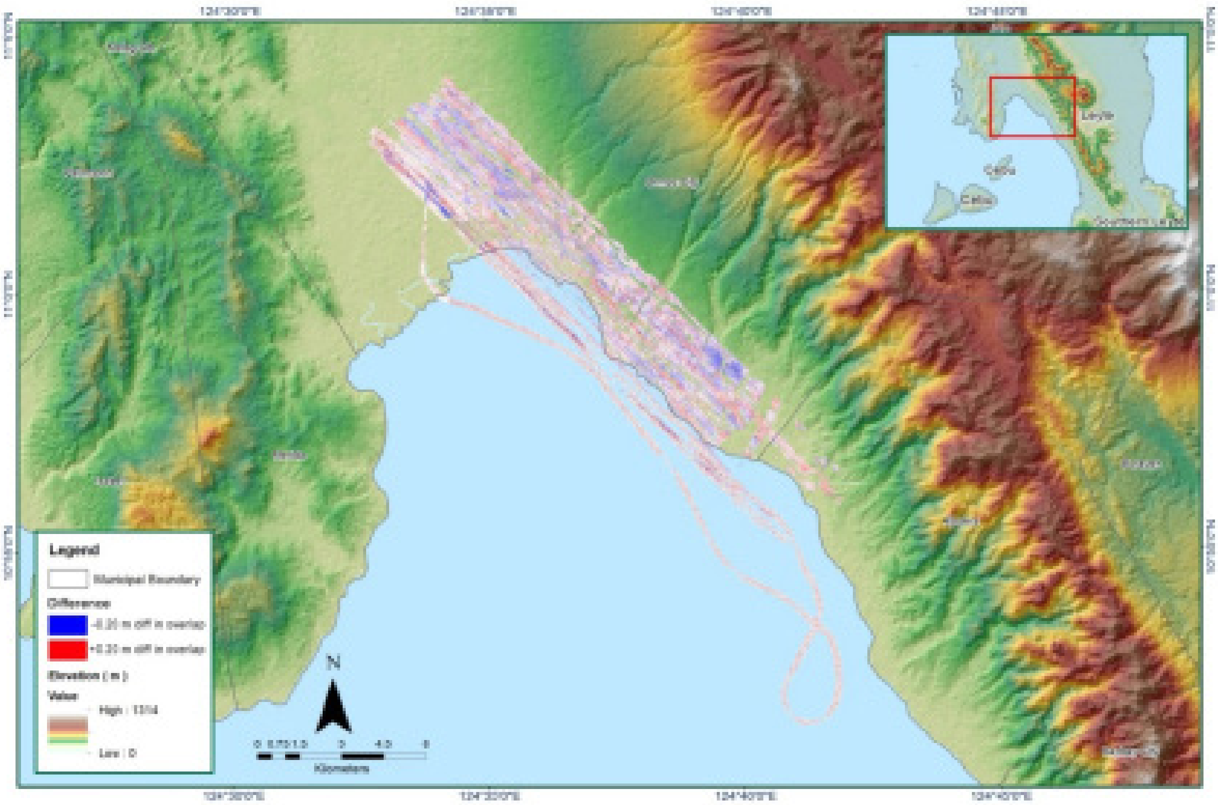


Figure A-8.84. Elevation difference between flight lines

Table A-8.13. Mission Summary Report for Mission Blk35B

Flight Area	Ormoc
Mission Name	Blk35B
Inclusive Flights	7753AC
Range data size	11.1 GB
POS	167 MB
Image	0 GB
Transfer date	March 9 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.75
RMSE for East Position (<4.0 cm)	1.37
RMSE for Down Position (<8.0 cm)	3.50
Boresight correction stdev (<0.001deg)	0.000324
IMU attitude correction stdev (<0.001deg)	0.001085
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	57.13
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	110
Maximum Height	425.68 m
Minimum Height	52.98 m
Classification (# of points)	
Ground	45,306,584
Low vegetation	54,011,189
Medium vegetation	95,593,512
High vegetation	50,856,382
Building	2,030,444
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista

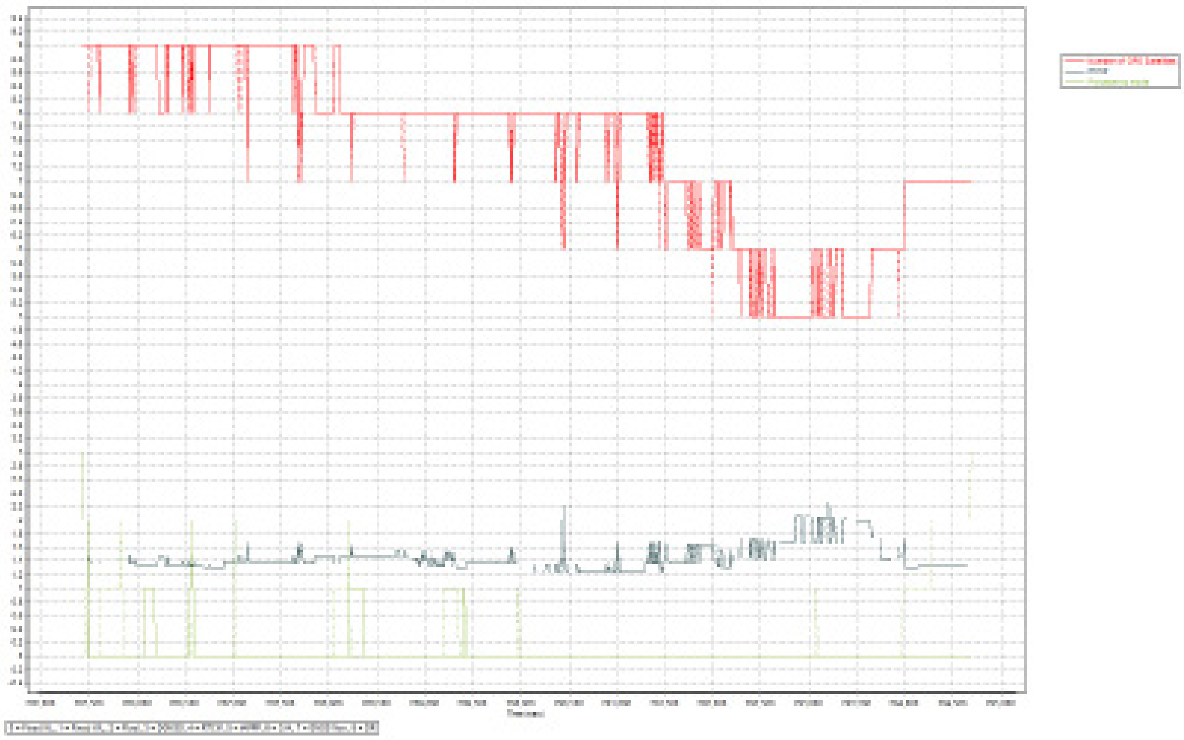


Figure A-8.85. Solution Status

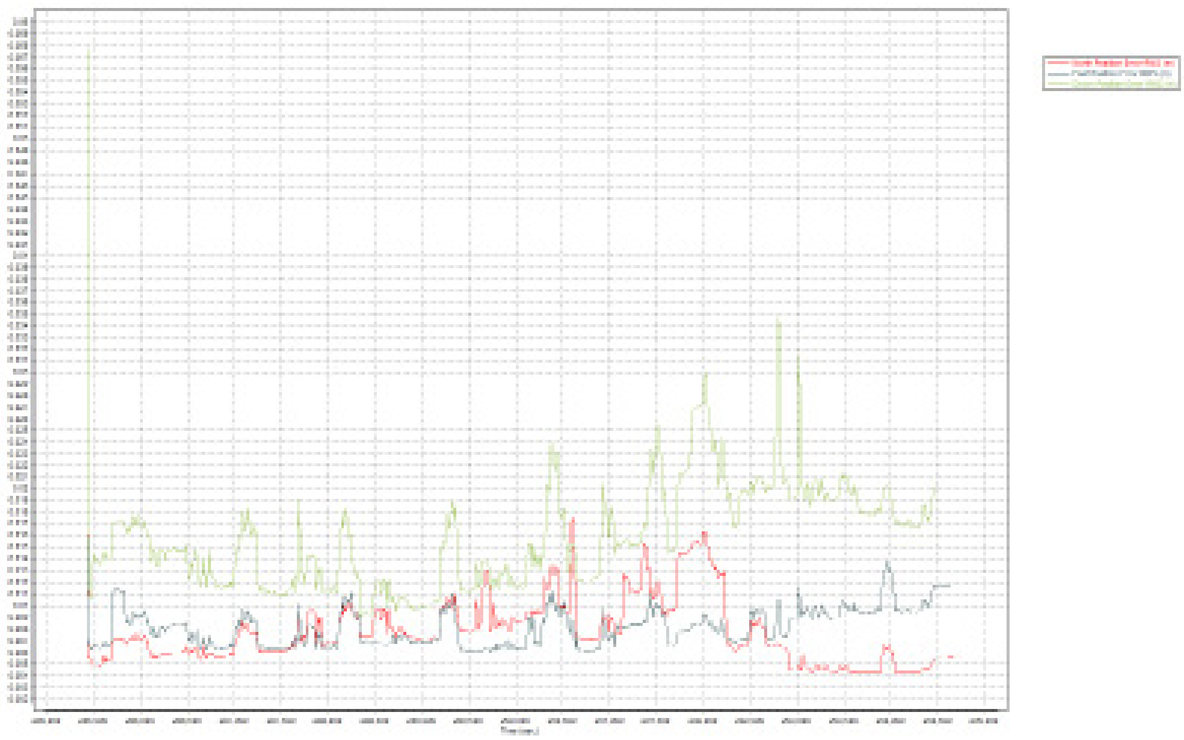


Figure A-8.86. Smoothed Performance Metrics Parameters

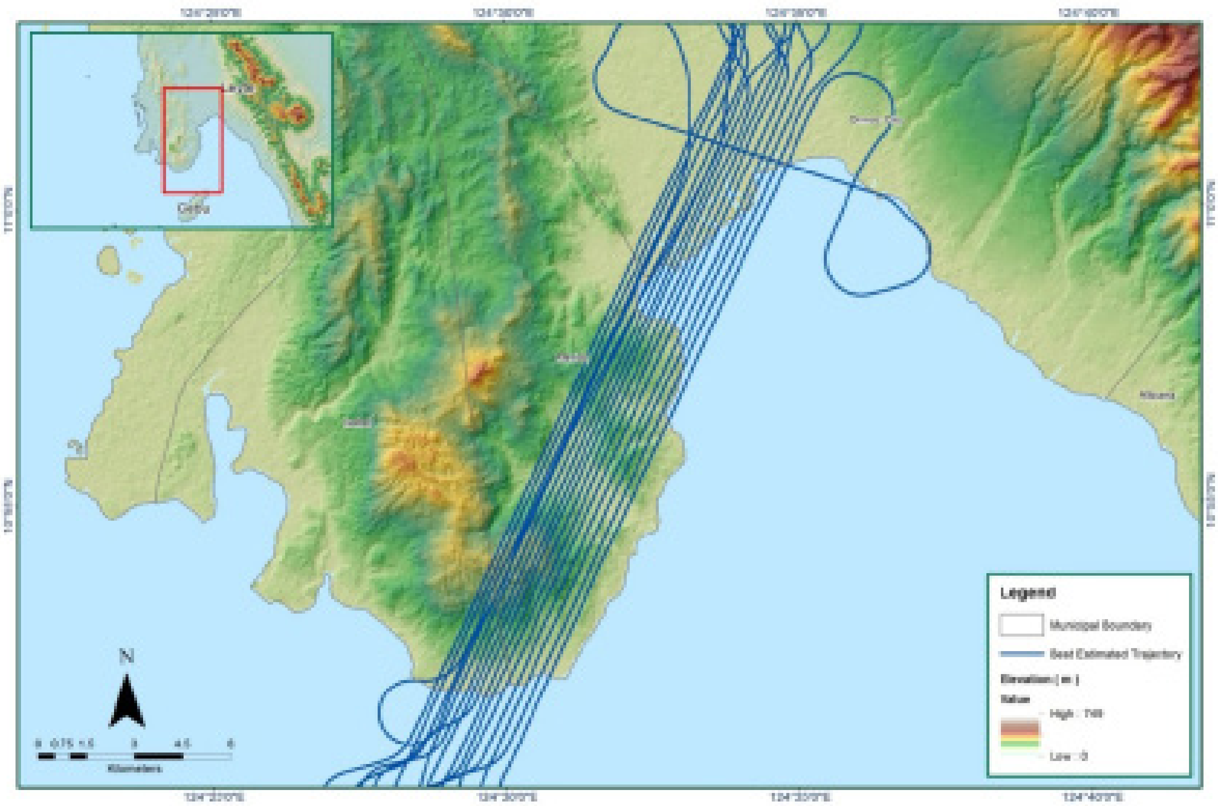


Figure A-8.87. Best Estimated Trajectory

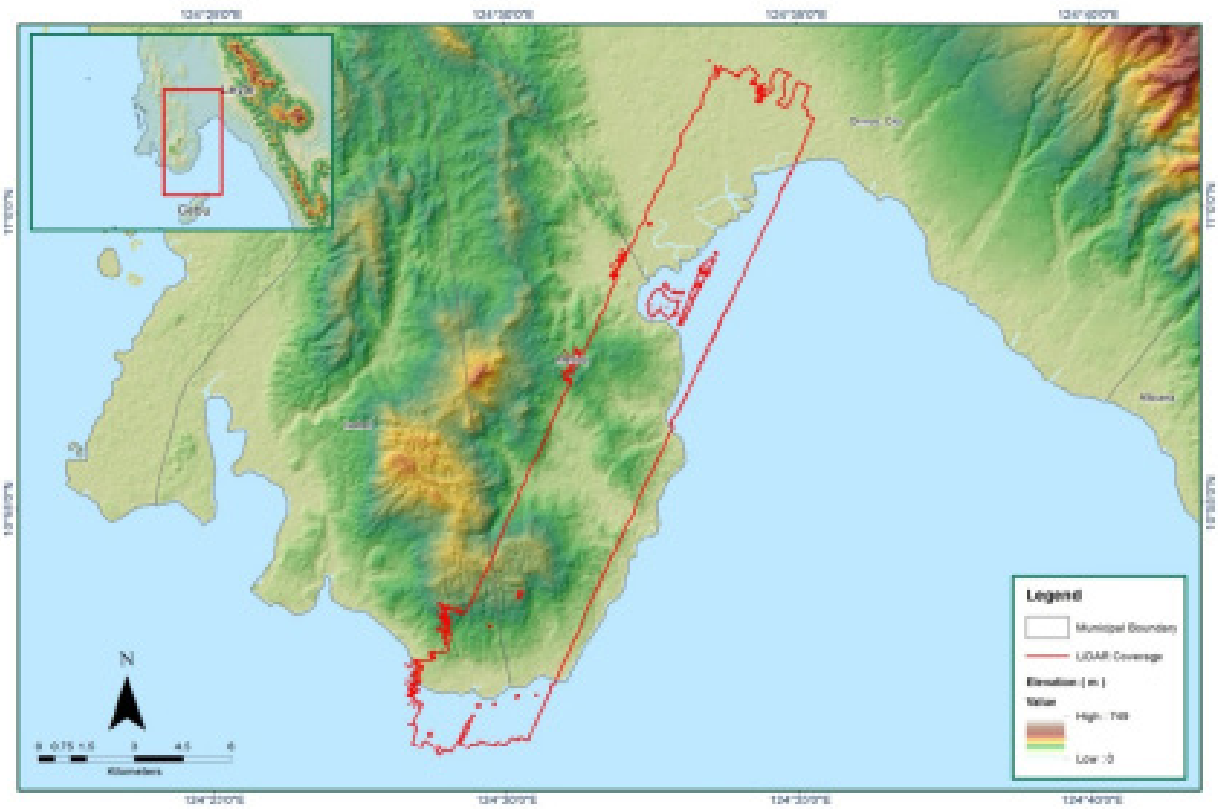


Figure A-8.88. Best Estimated Trajectory

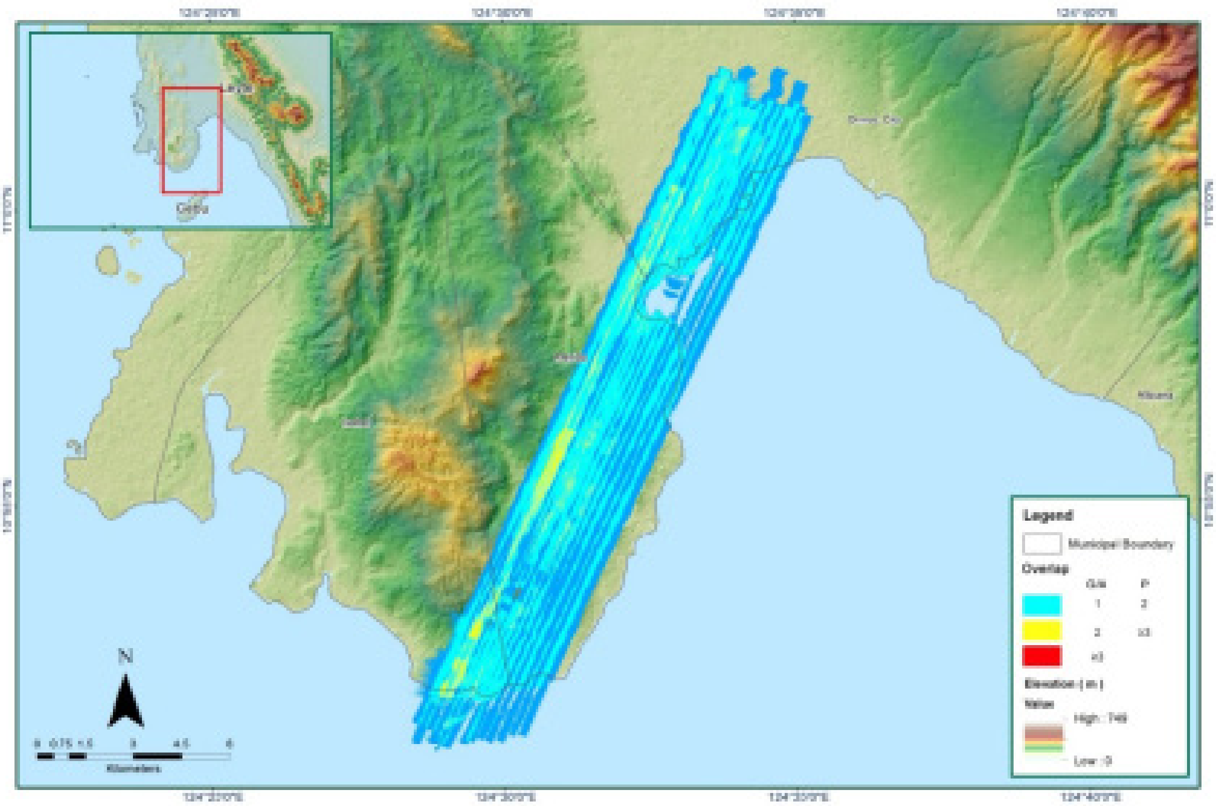


Figure A-8.89. Image of data overlap

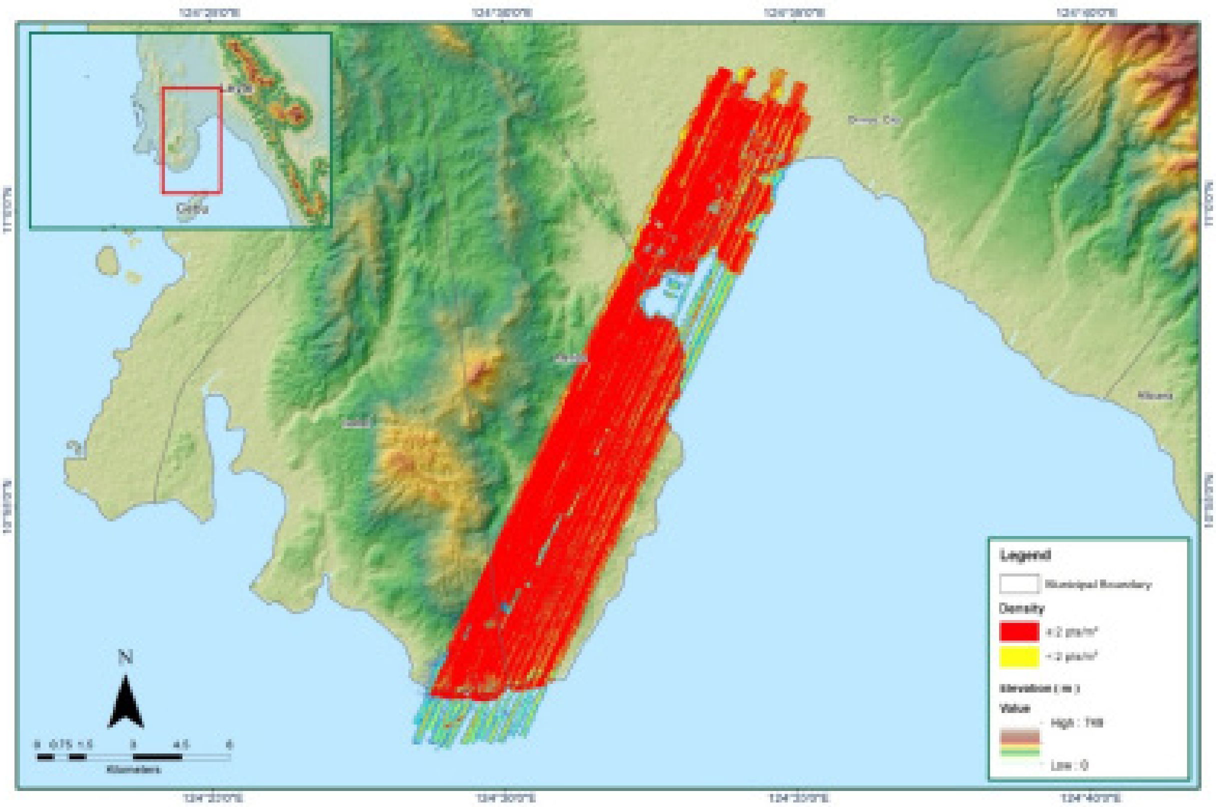


Figure A-8.90. Density map of merged LiDAR data

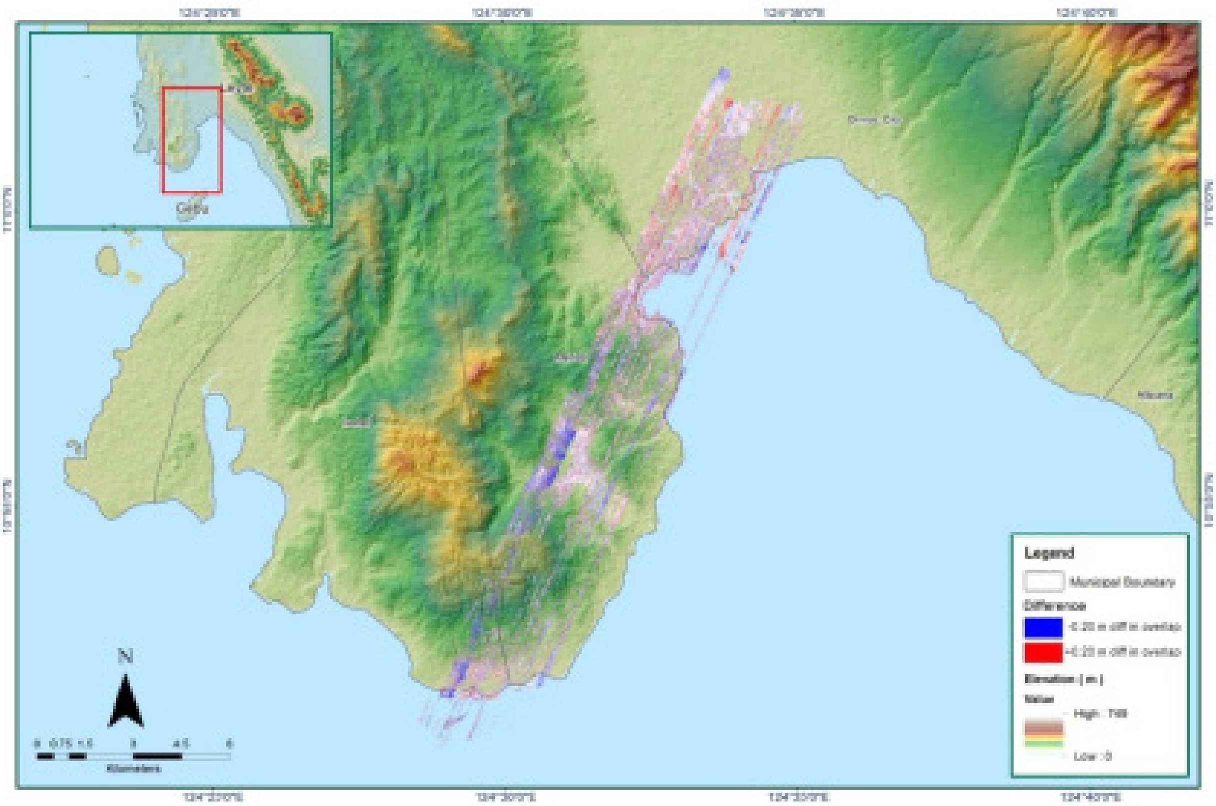


Figure A-8.91. Elevation difference between flight lines

Table A-8.14. Mission Summary Report for Mission Blk35A_additional

Flight Area	Ormoc
Mission Name	Blk35A_additional
Inclusive Flights	7760AC
Range data size	12.3 GB
POS	243 MB
Image	0 GB
Transfer date	March 9 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.17
RMSE for East Position (<4.0 cm)	1.48
RMSE for Down Position (<8.0 cm)	3.67
Boresight correction stdev (<0.001deg)	0.000414
IMU attitude correction stdev (<0.001deg)	0.000958
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	54.20
Ave point cloud density per sq.m. (>2.0)	3.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	116
Maximum Height	389.88 m
Minimum Height	50.29 m
Classification (# of points)	
Ground	42,406,724
Low vegetation	50,448,477
Medium vegetation	104,381,565
High vegetation	58,830,359
Building	2,371,309
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Kathryn Claudyn Zarate

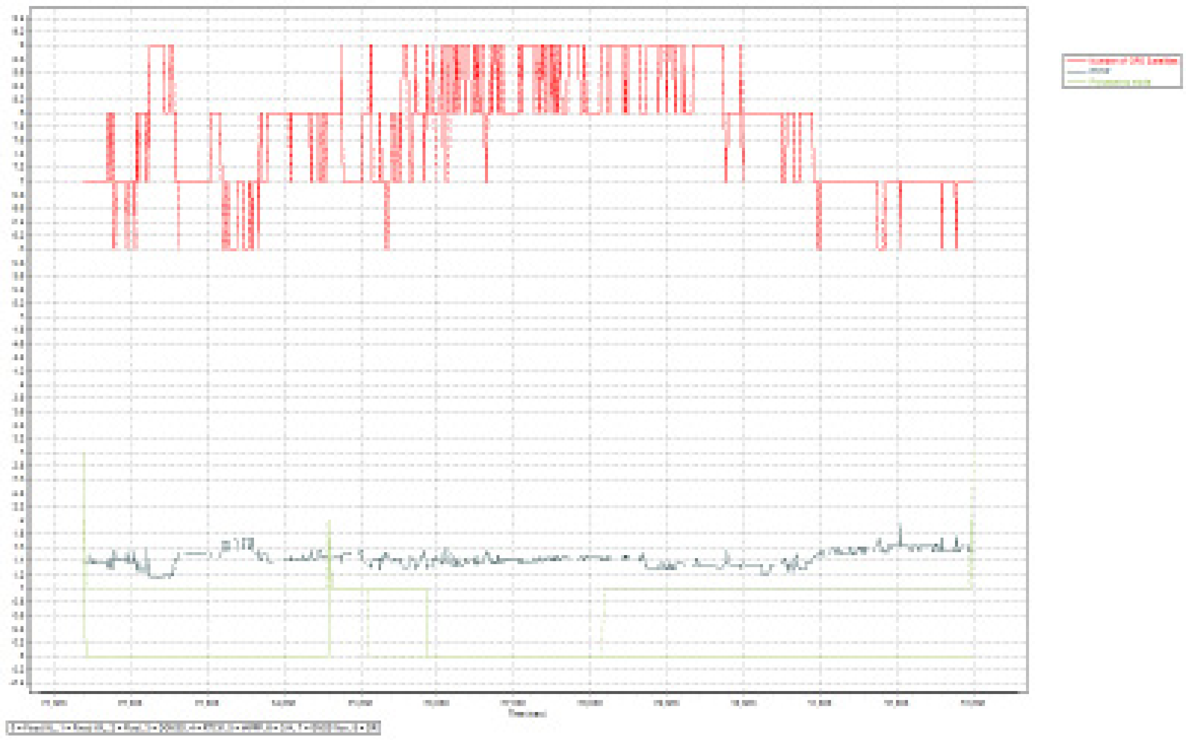


Figure A-8.92. Solution Status

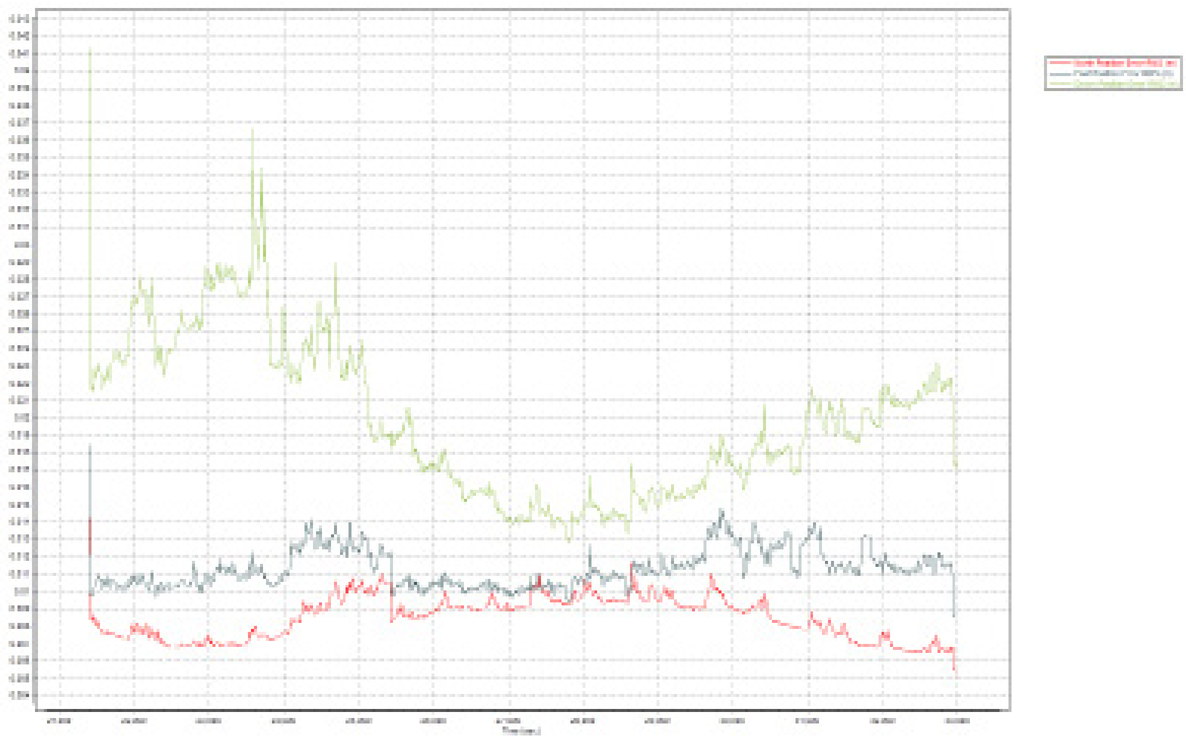


Figure A-8.93. Smoothed Performance Metrics Parameters

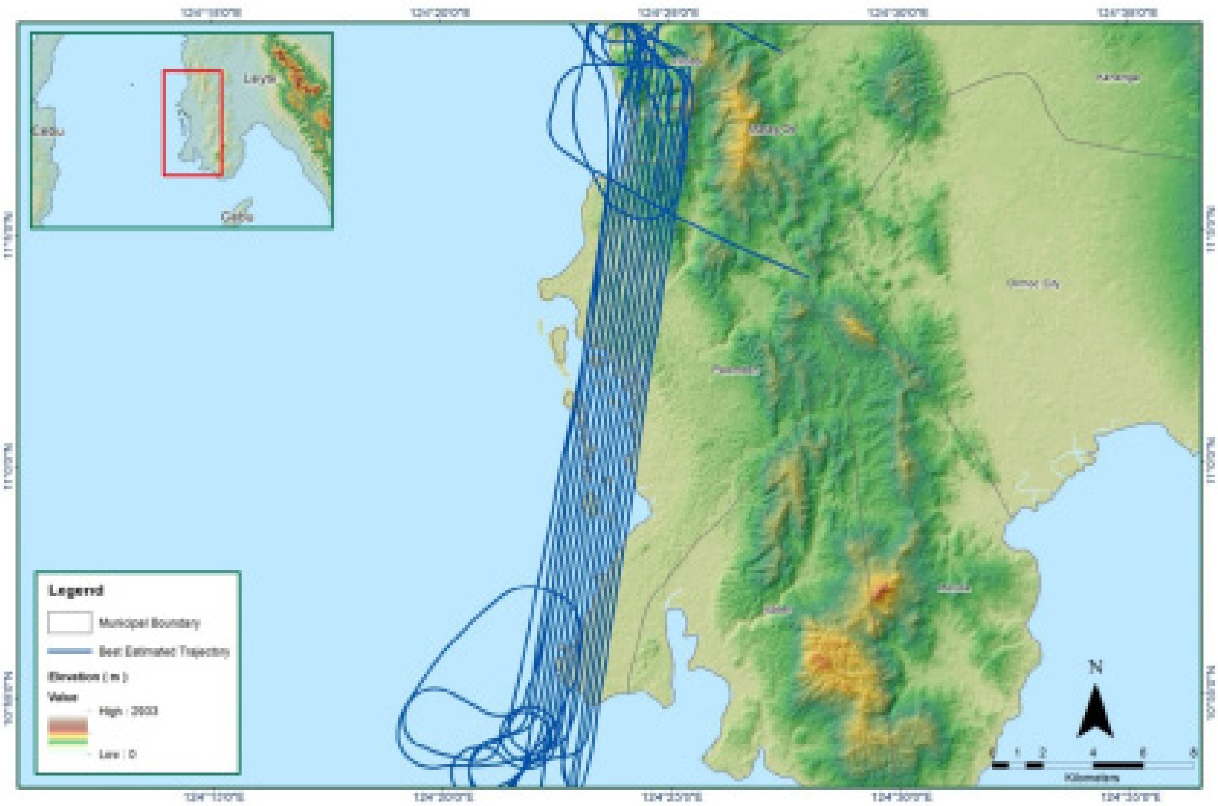


Figure A-8.94. Best Estimated Trajectory

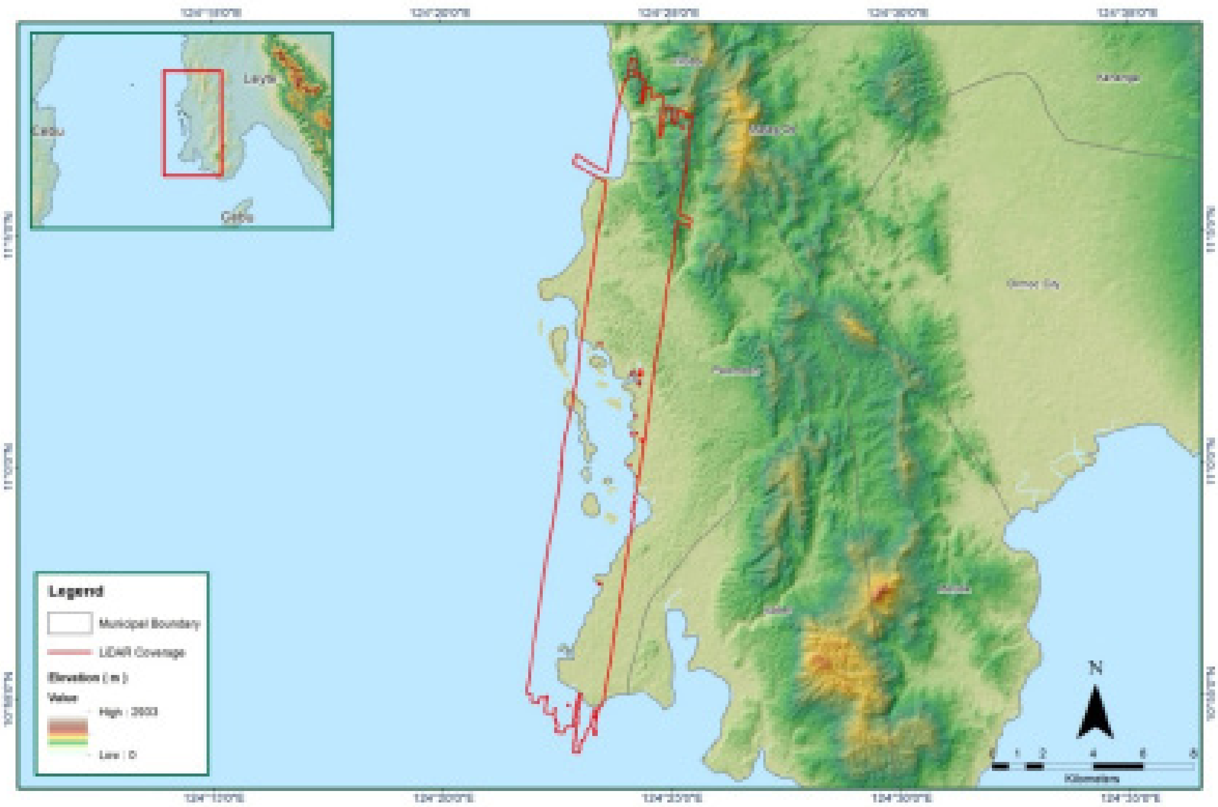


Figure A-8.95. Coverage of LiDAR data

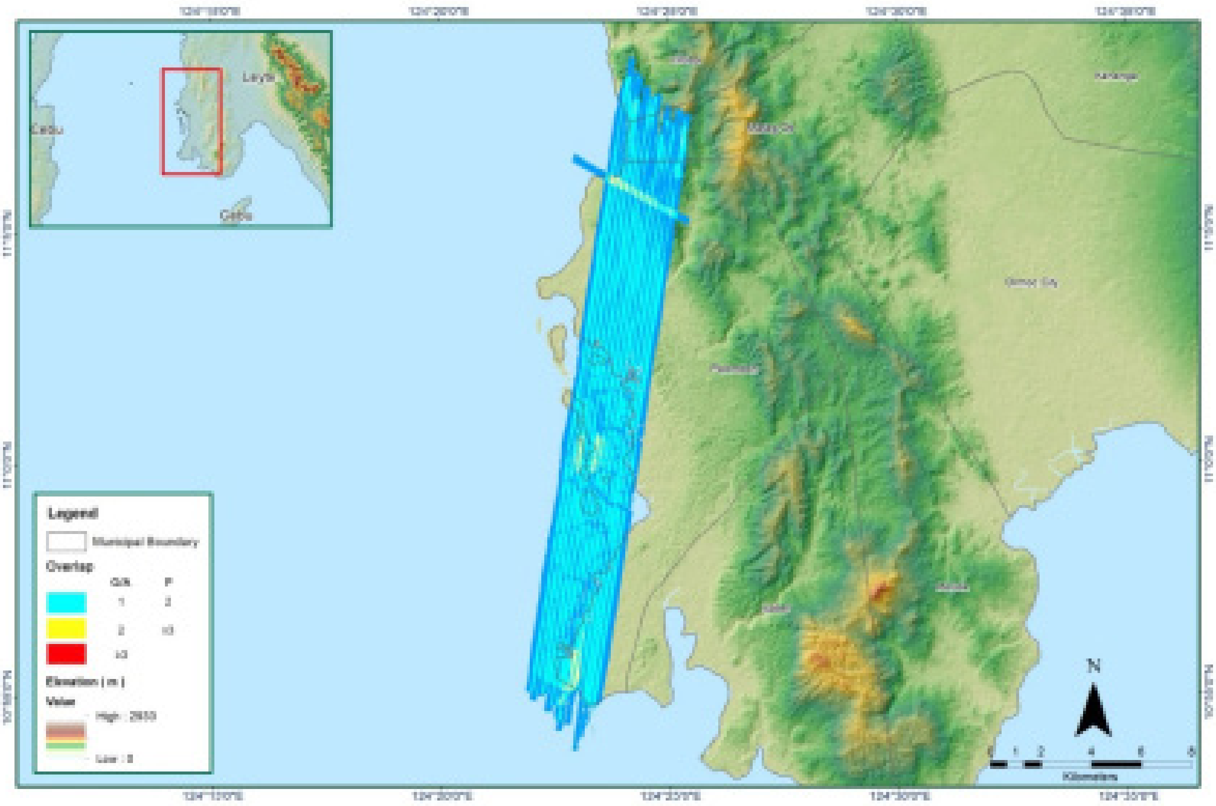


Figure A-8.96. Image of data overlap

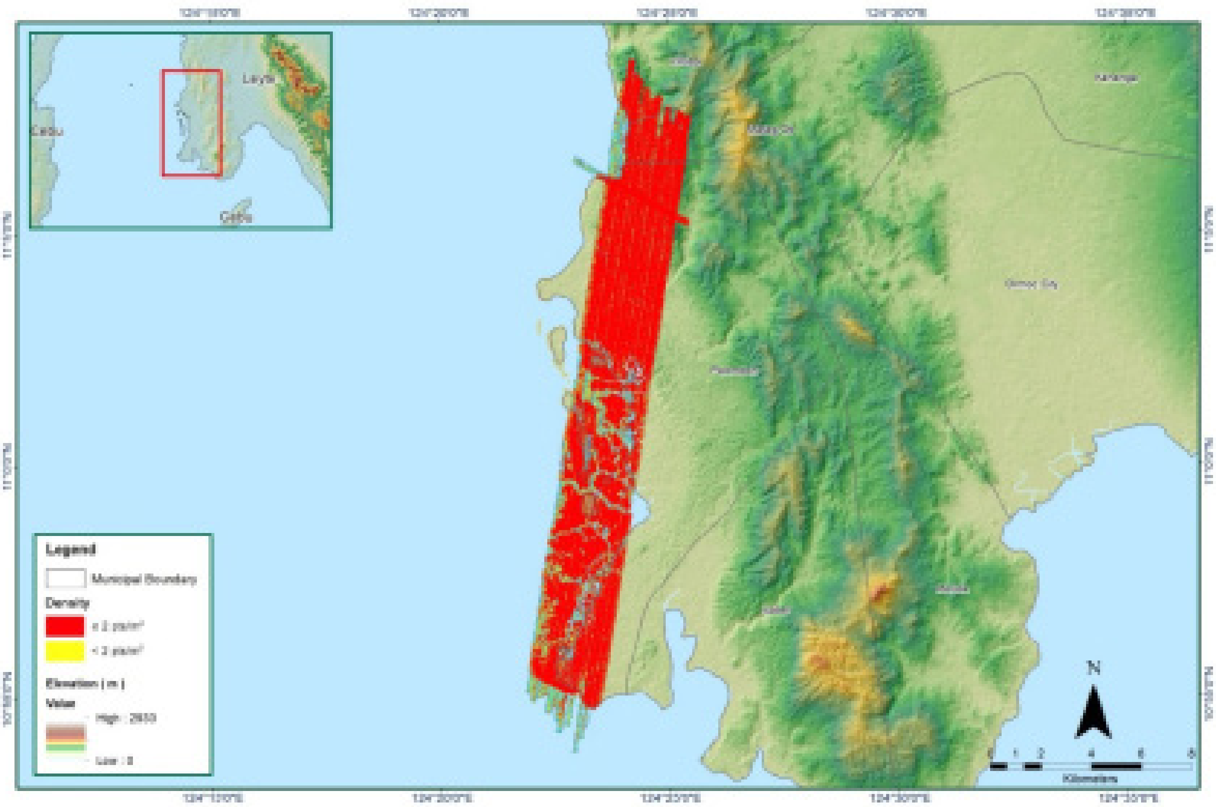


Figure A-8.97. Density map of merged LiDAR data

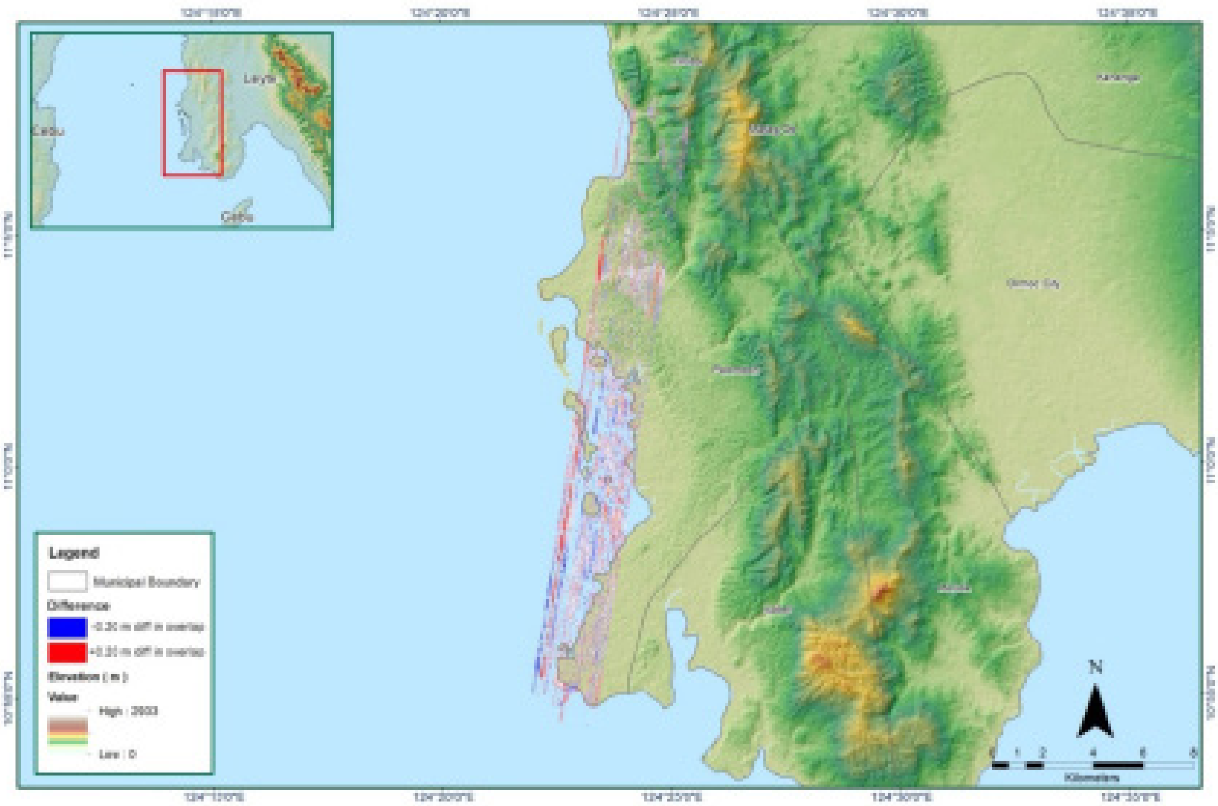


Figure A-8.98. Elevation difference between flight lines

Table A-8.15. Mission Summary Report for Mission Blk35B_additional

Flight Area	Ormoc
Mission Name	Blk35B_additional
Inclusive Flights	7802AC
Range data size	9.94 GB
POS data size	254 MB
Base data size	35.4 MB
Image	NA
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.349
RMSE for East Position (<4.0 cm)	1.998
RMSE for Down Position (<8.0 cm)	2.512
Boresight correction stdev (<0.001deg)	0.000216
IMU attitude correction stdev (<0.001deg)	0
GPS position stdev (<0.01m)	0.0153
Minimum % overlap (>25)	43.97
Ave point cloud density per sq.m. (>2.0)	3.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	399.07
Minimum Height	55.36
Classification (# of points)	
Ground	14,773,181
Low vegetation	13,469,860
Medium vegetation	34,698,250
High vegetation	19,171,212
Building	948,615
Orthophoto	None
Processed by	Engr. Regis Guhiting, Engr. Erica Erin Elazegui, Alex John Escobido

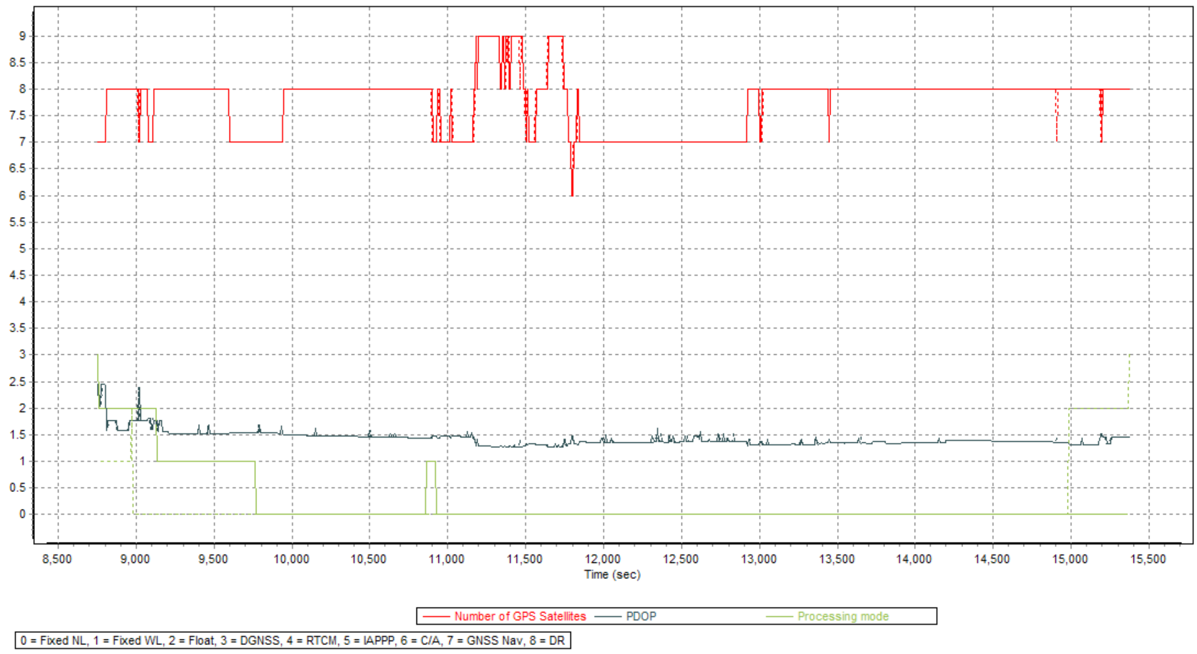


Figure A-8.99. Solution Status

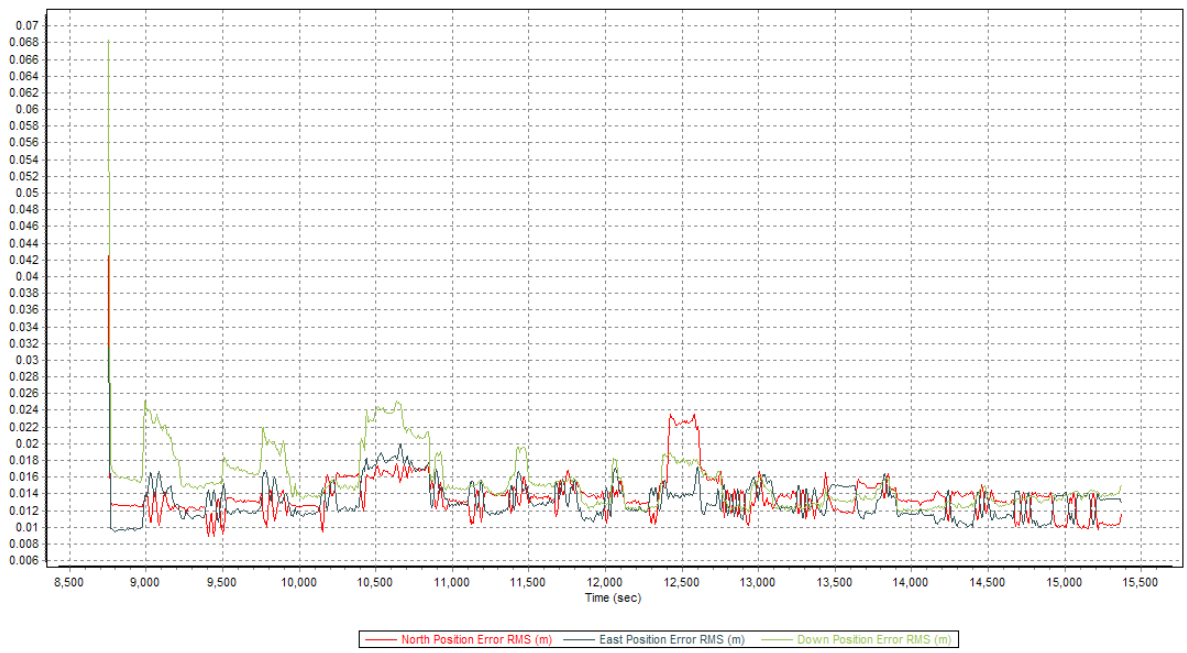


Figure A-8.100. Smoothed Performance Metrics Parameters

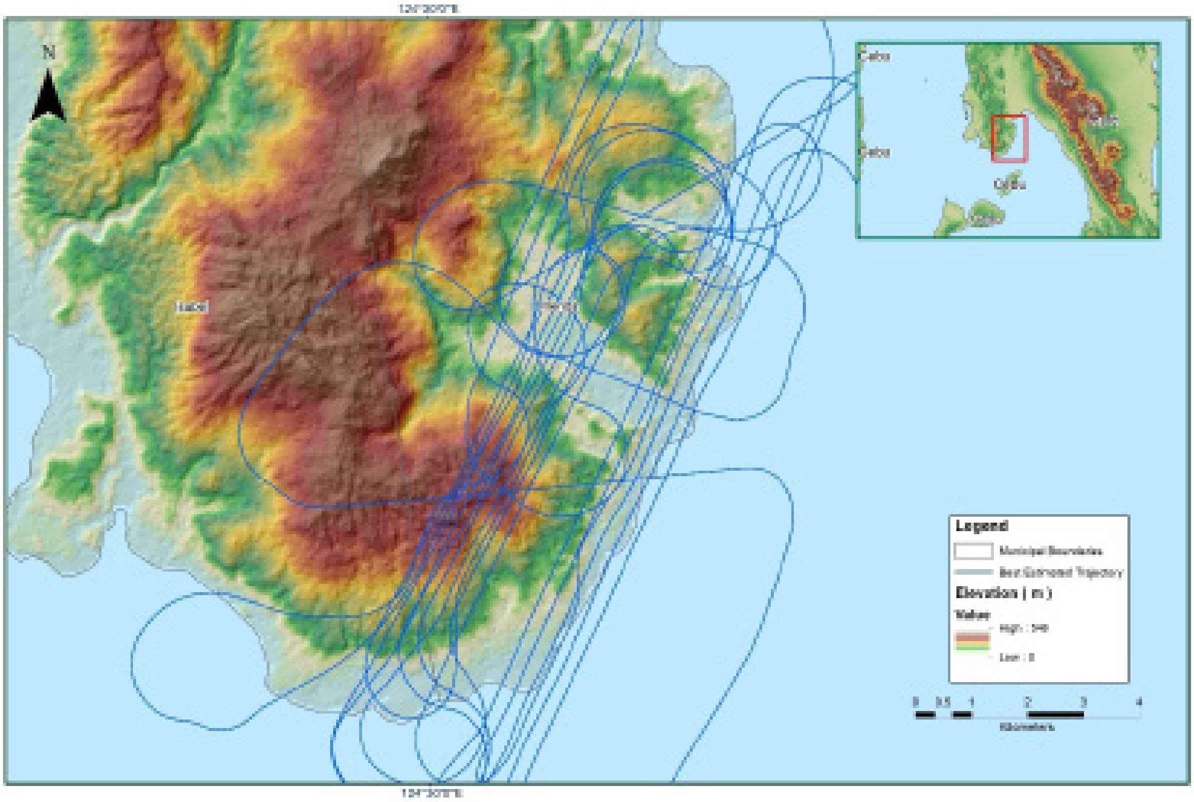


Figure A-8.101. Best Estimated Trajectory

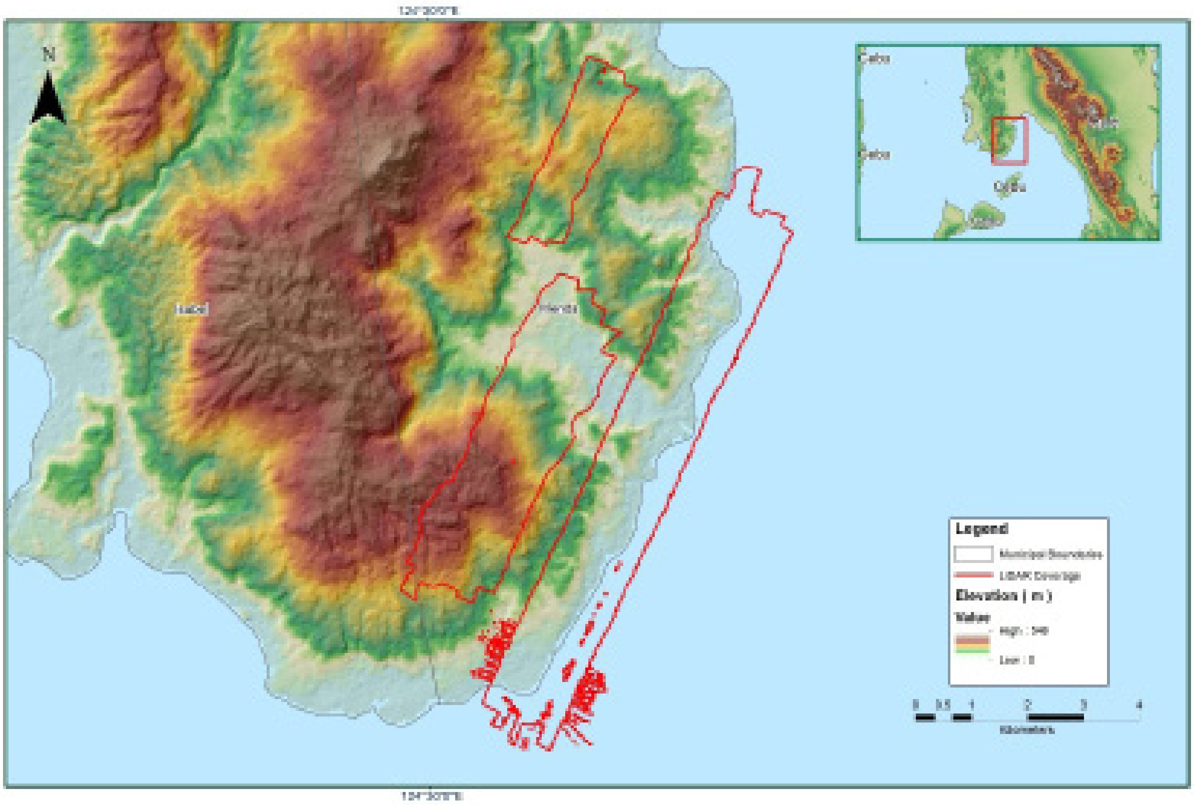


Figure A-8.102. Best Estimated Trajectory

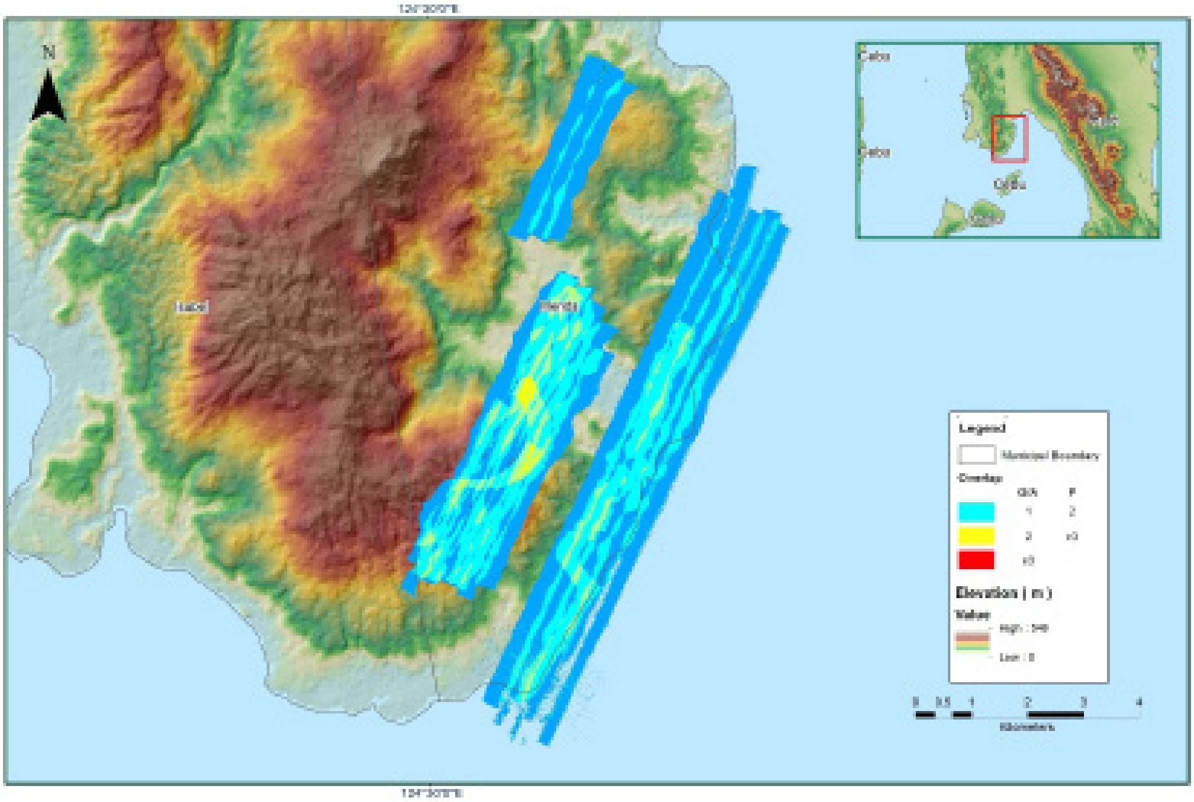


Figure A-8.103. Image of data overlap

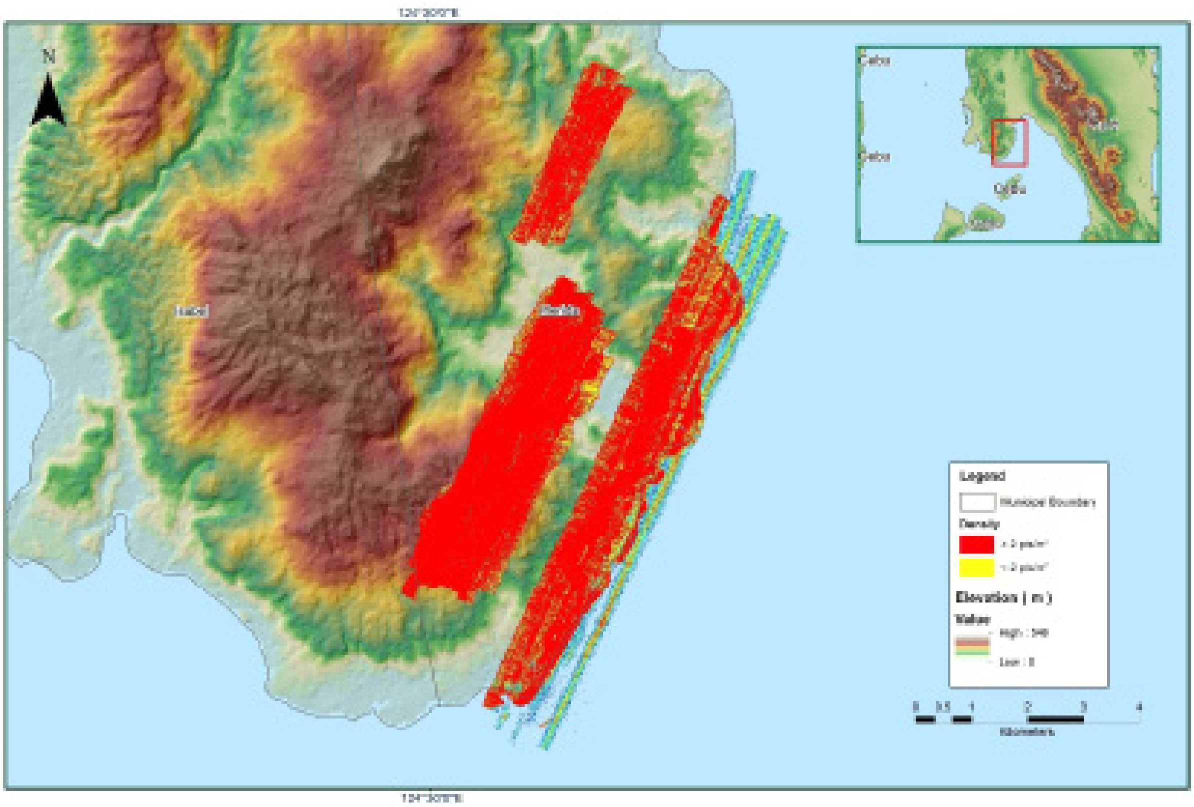


Figure A-8.104. Density map of merged LiDAR data

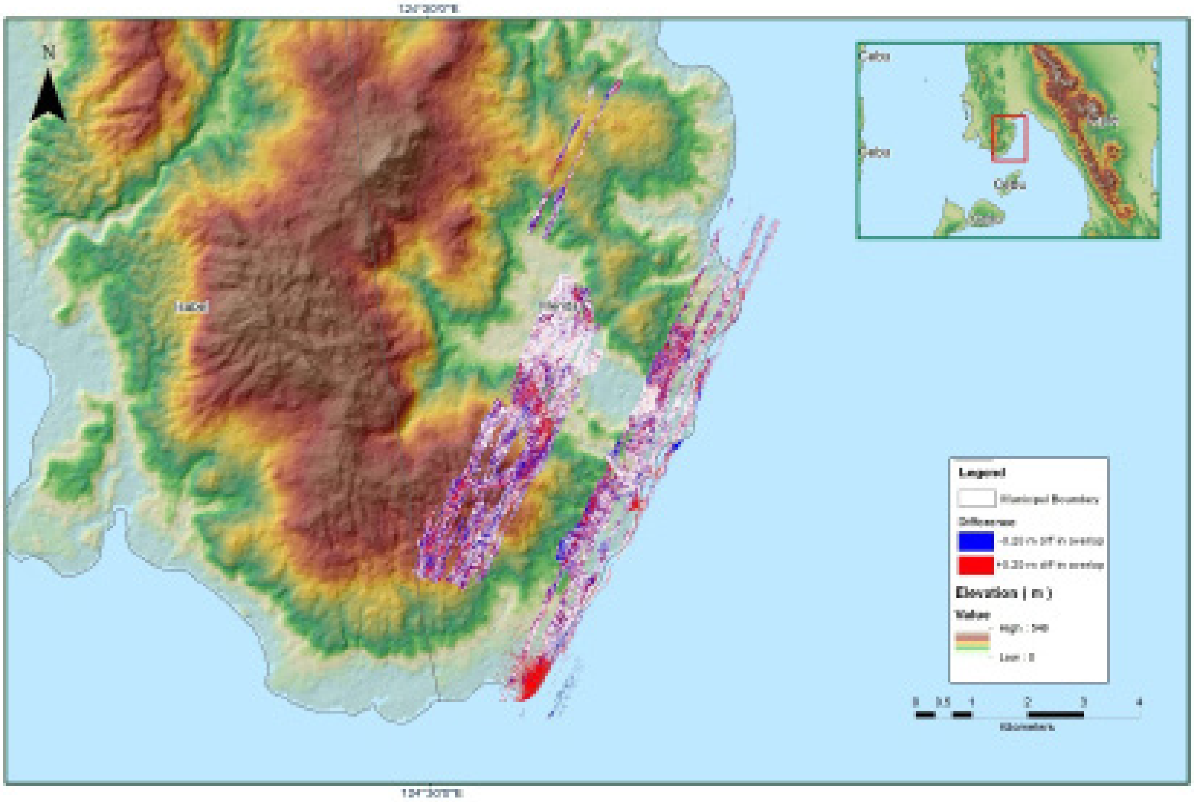


Figure A-8.105. Elevation difference between flight lines

Table A-8.16. Mission Summary Report for Mission Blk35CD_additional

Flight Area	Ormoc
Mission Name	Blk35CD_additional
Inclusive Flights	7806AC
Range data size	8.2 GB
POS data size	195 MB
Base data size	27 MB
Image	NA
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.103
RMSE for East Position (<4.0 cm)	5.754
RMSE for Down Position (<8.0 cm)	7.546
Boresight correction stdev (<0.001deg)	0.000271
IMU attitude correction stdev (<0.001deg)	0.000619
GPS position stdev (<0.01m)	0.0071
Minimum % overlap (>25)	19.58
Ave point cloud density per sq.m. (>2.0)	2.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	19
Maximum Height	294.94
Minimum Height	75.43
Classification (# of points)	
Ground	2,556,122
Low vegetation	1,524,276
Medium vegetation	4,461,264
High vegetation	3,251,822
Building	31,704
Orthophoto	None
Processed by	Engr. Abigail Joy Ching, Engr. Melanie Hingpit, Engr. Melissa Fernandez

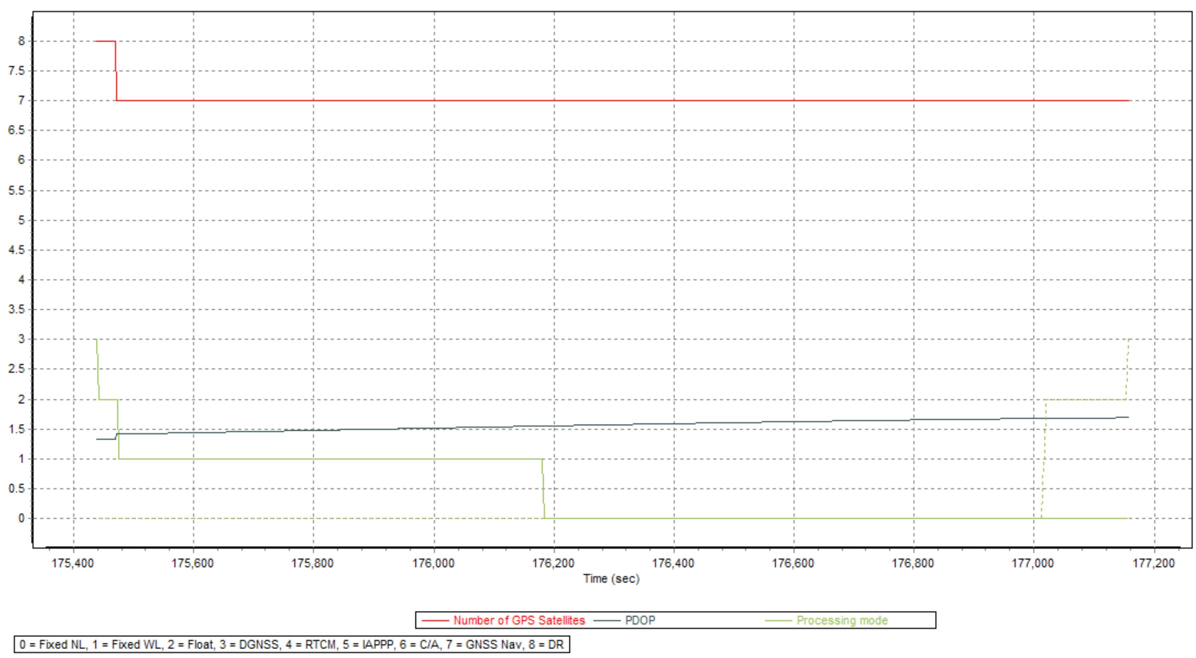


Figure A-8.106. Solution Status

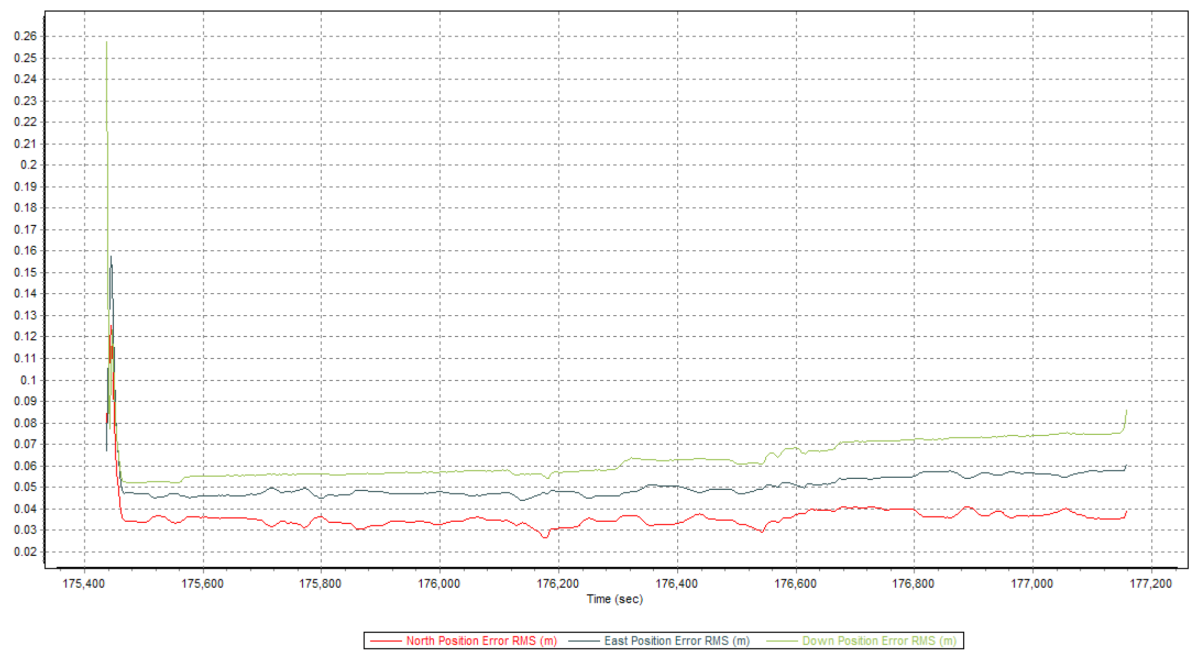


Figure A-8.107. Smoothed Performance Metrics Parameters

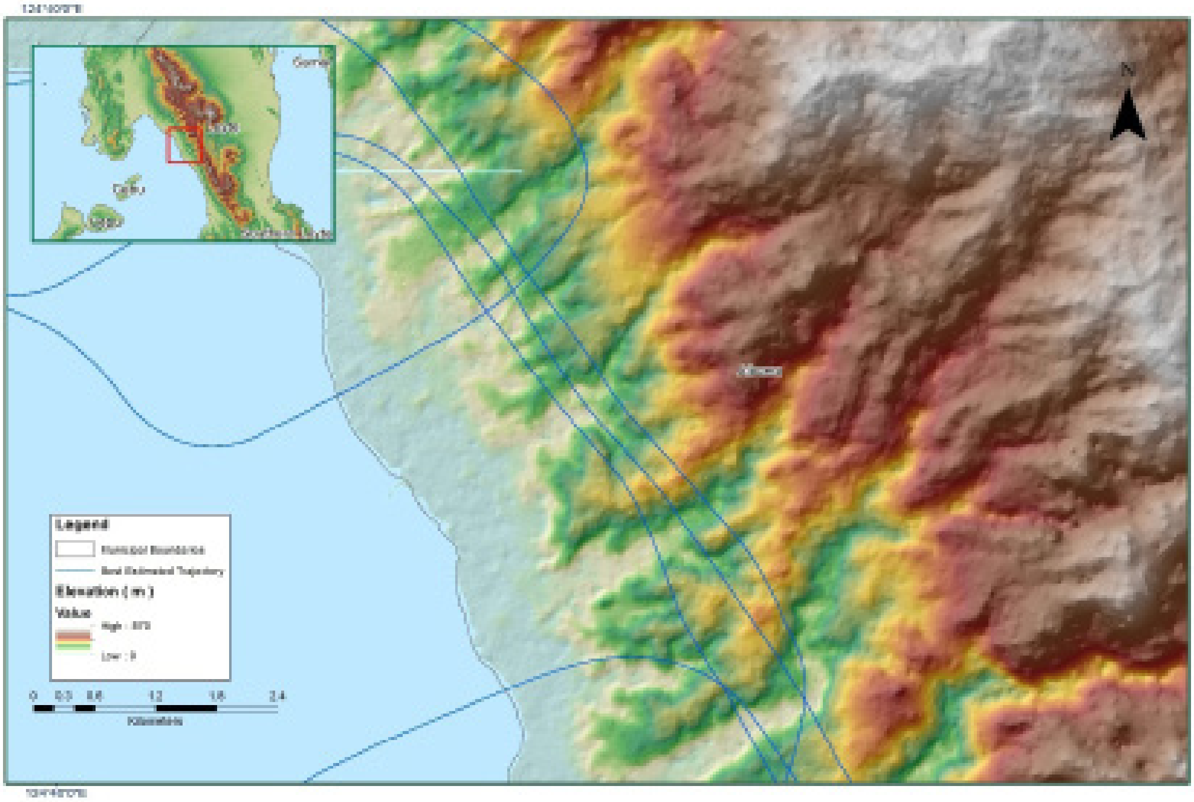


Figure A-8.108. Best Estimated Trajectory

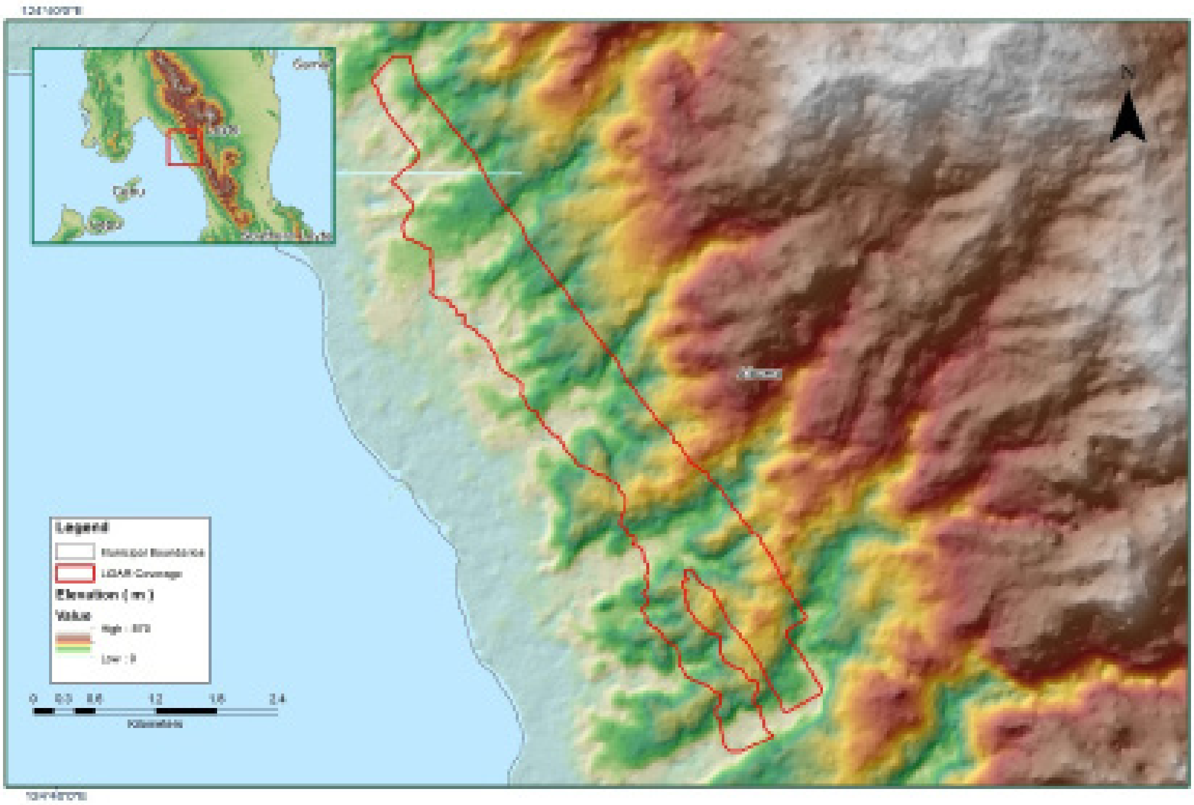


Figure A-8.109. Coverage of LiDAR data

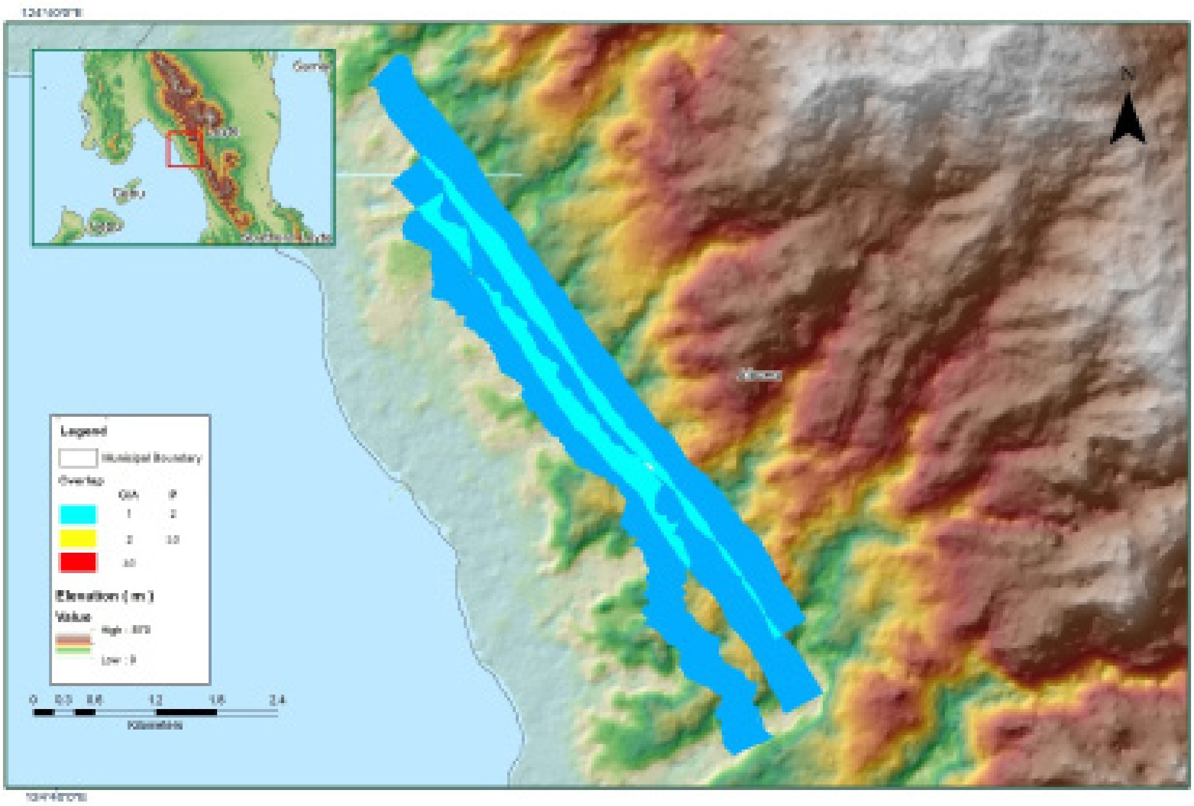


Figure A-8.110. Image of data overlap

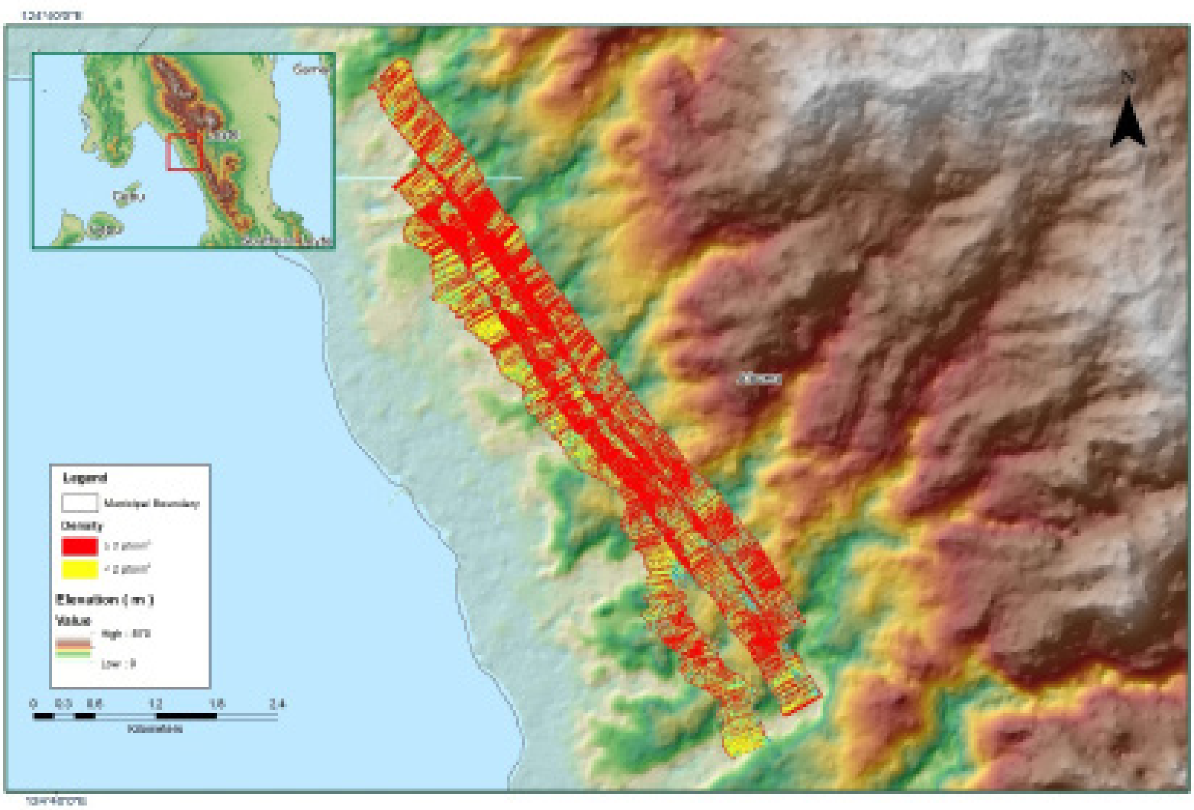


Figure A-8.111. Density map of merged LiDAR data

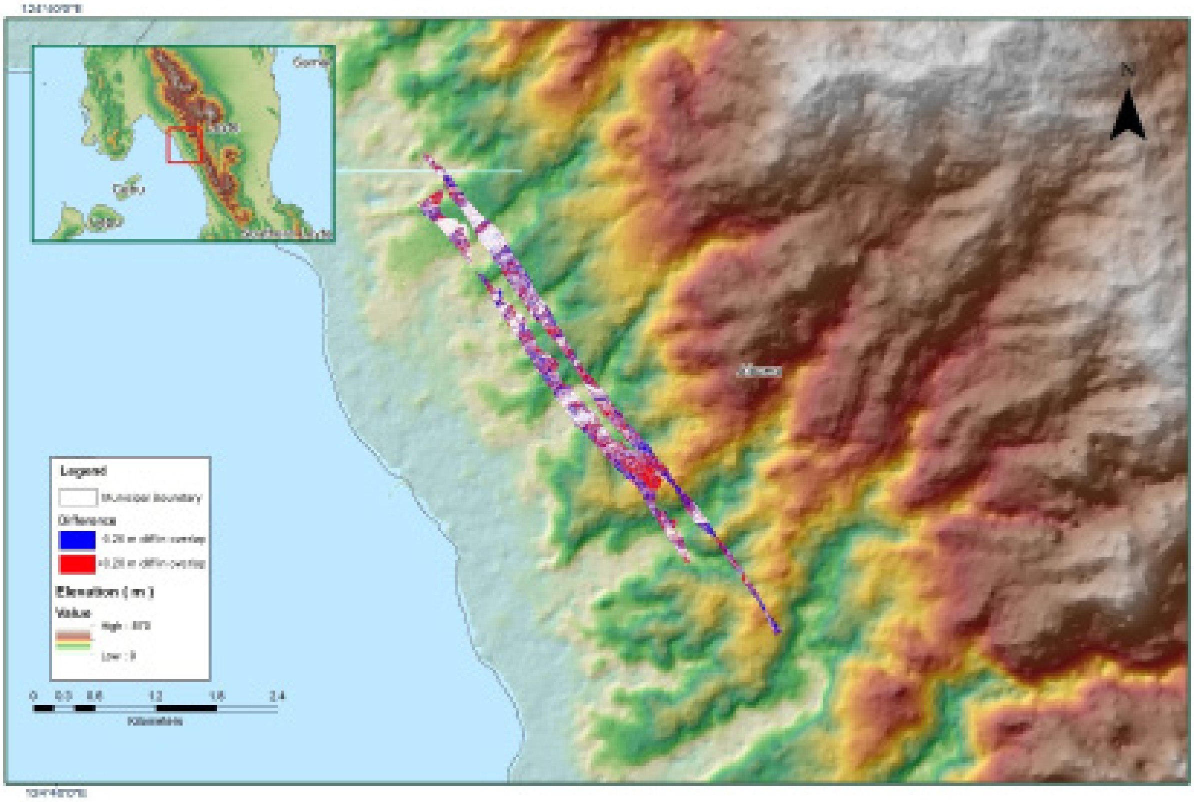


Figure A-8.112. Elevation difference between flight lines

Table A-8.17. Mission Summary Report for Mission Blk35E

Flight Area	Ormoc_Camotes
Mission Name	Blk35E
Inclusive Flights	8391AC
Range data size	11.2 GB
POS	263 MB
Image	35.5 MB
Base Station	265 MB
Transfer date	March 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.24
RMSE for Down Position (<8.0 cm)	2.64
Boresight correction stdev (<0.001deg)	0.000304
IMU attitude correction stdev (<0.001deg)	0.001996
GPS position stdev (<0.01m)	0.0106
Minimum % overlap (>25)	48.98
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	60
Maximum Height	480.27
Minimum Height	75.57
Classification (# of points)	
Ground	30,839,262
Low vegetation	17,960,389
Medium vegetation	48,134,275
High vegetation	73,775,914
Building	4,266,466
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado, Marie Denise Bueno

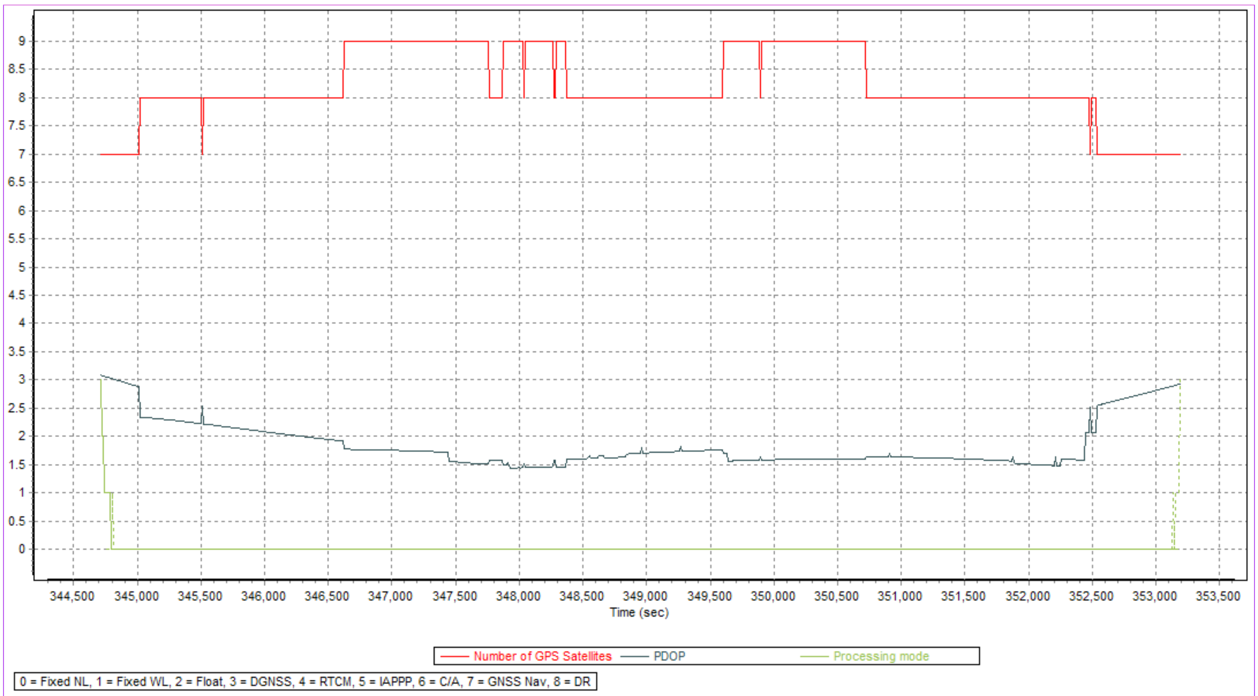


Figure A-8.113. Solution Status

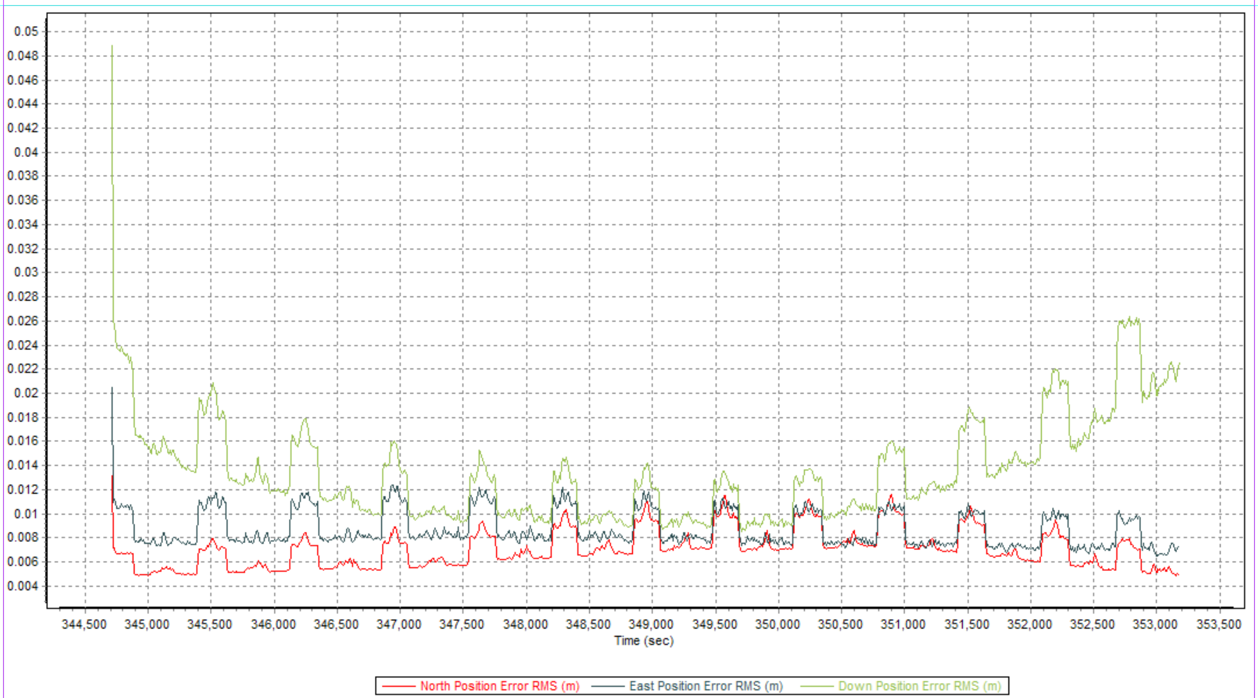


Figure A-8.114. Smoothed Performance Metrics Parameters

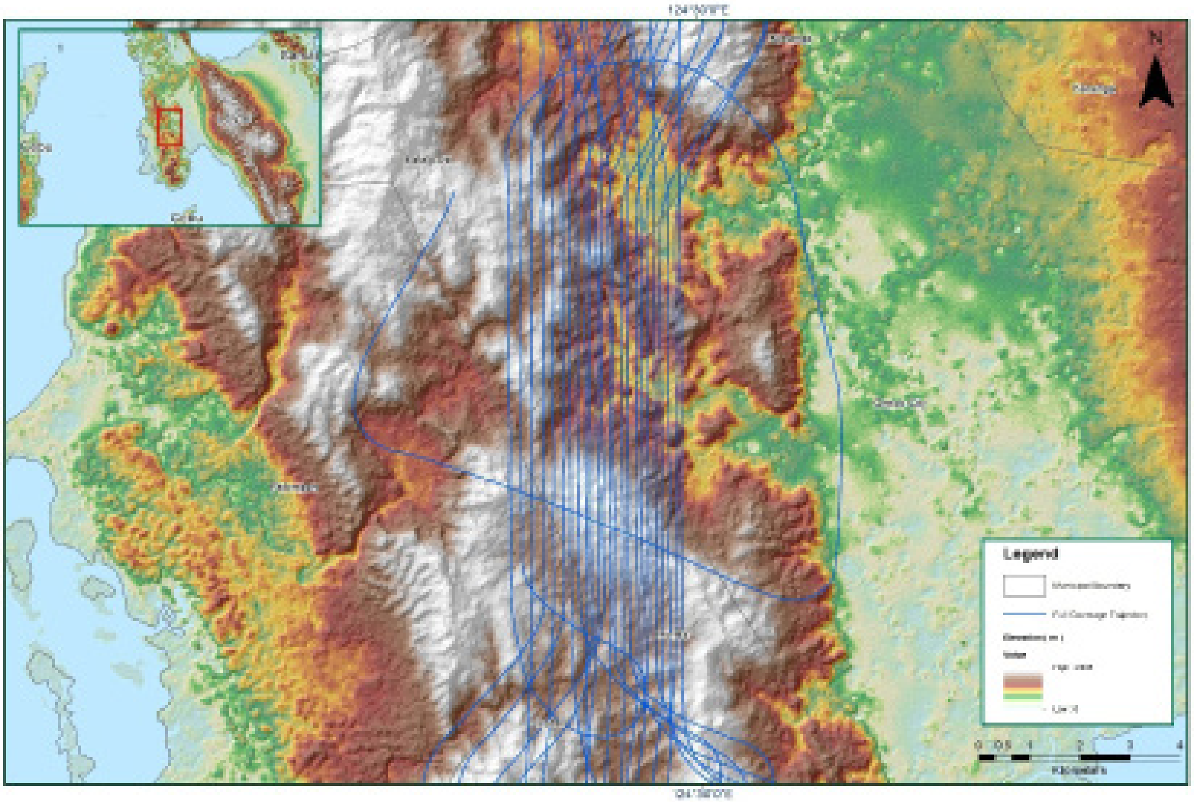


Figure A-8.115. Best Estimated Trajectory

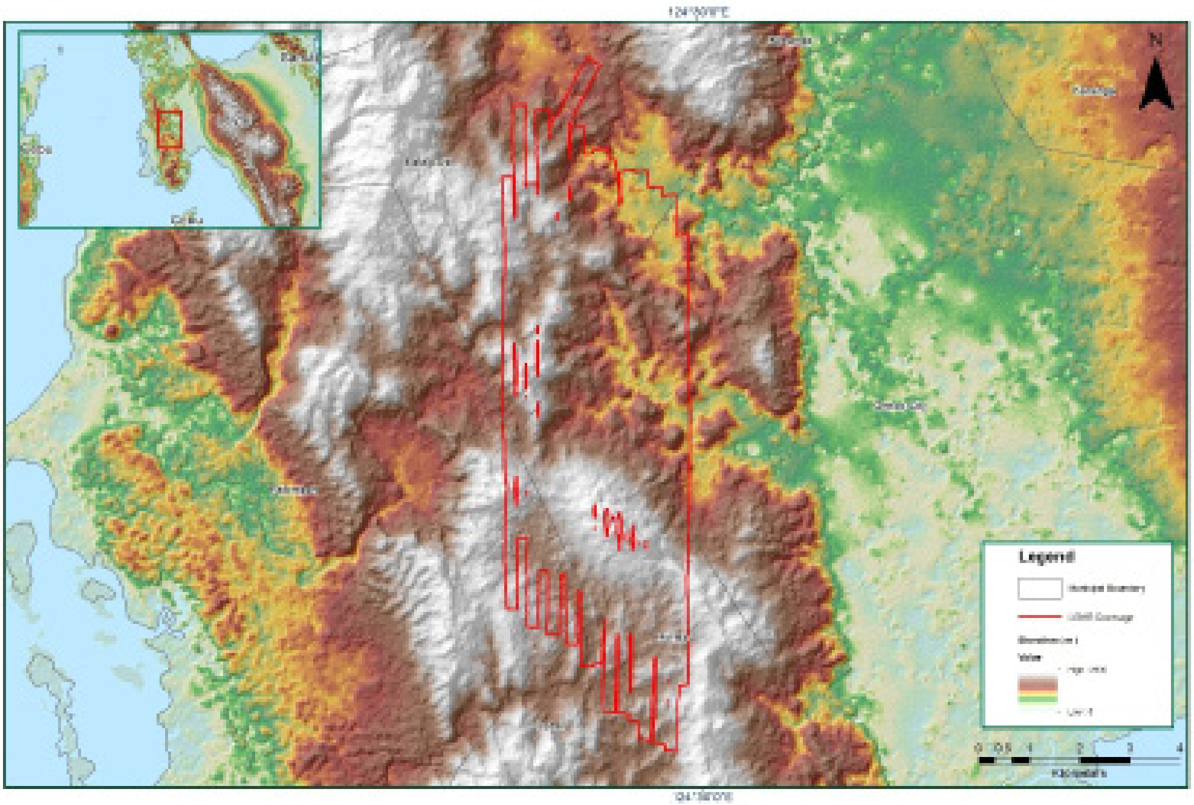


Figure A-8.116. Best Estimated Trajectory

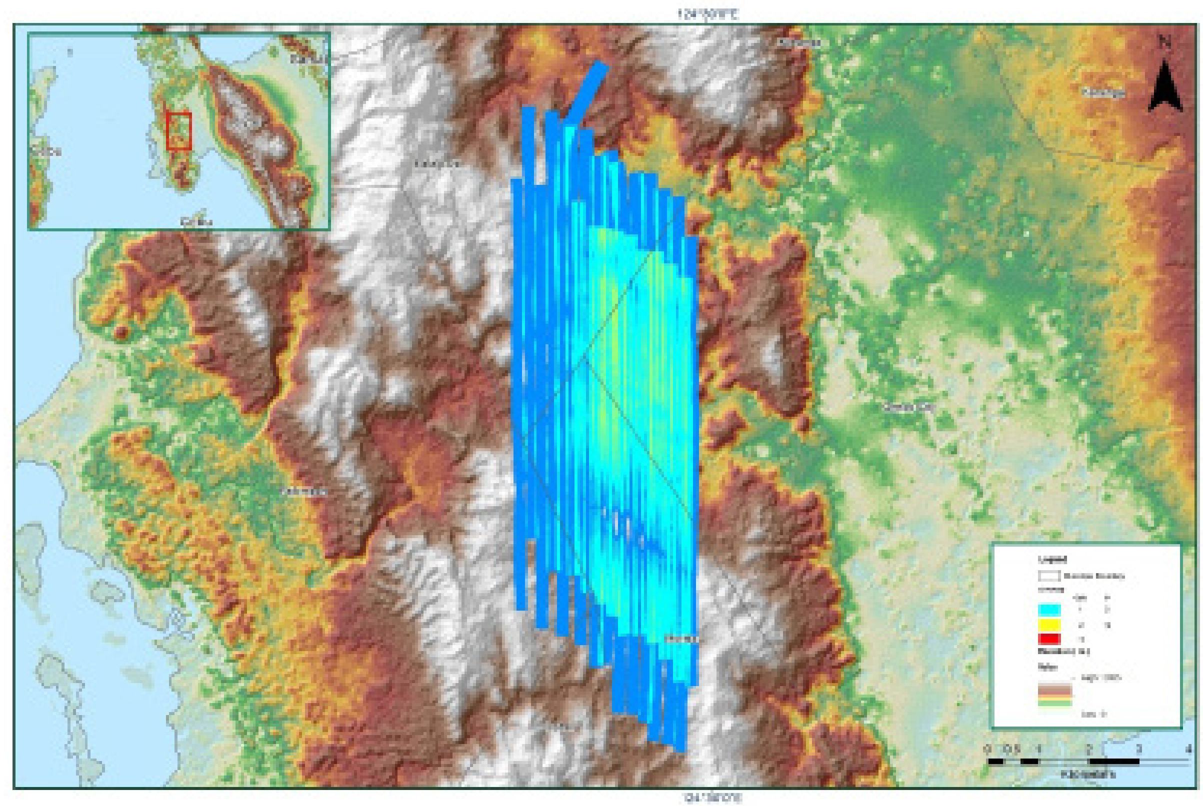


Figure A-8.117. Image of data overlap

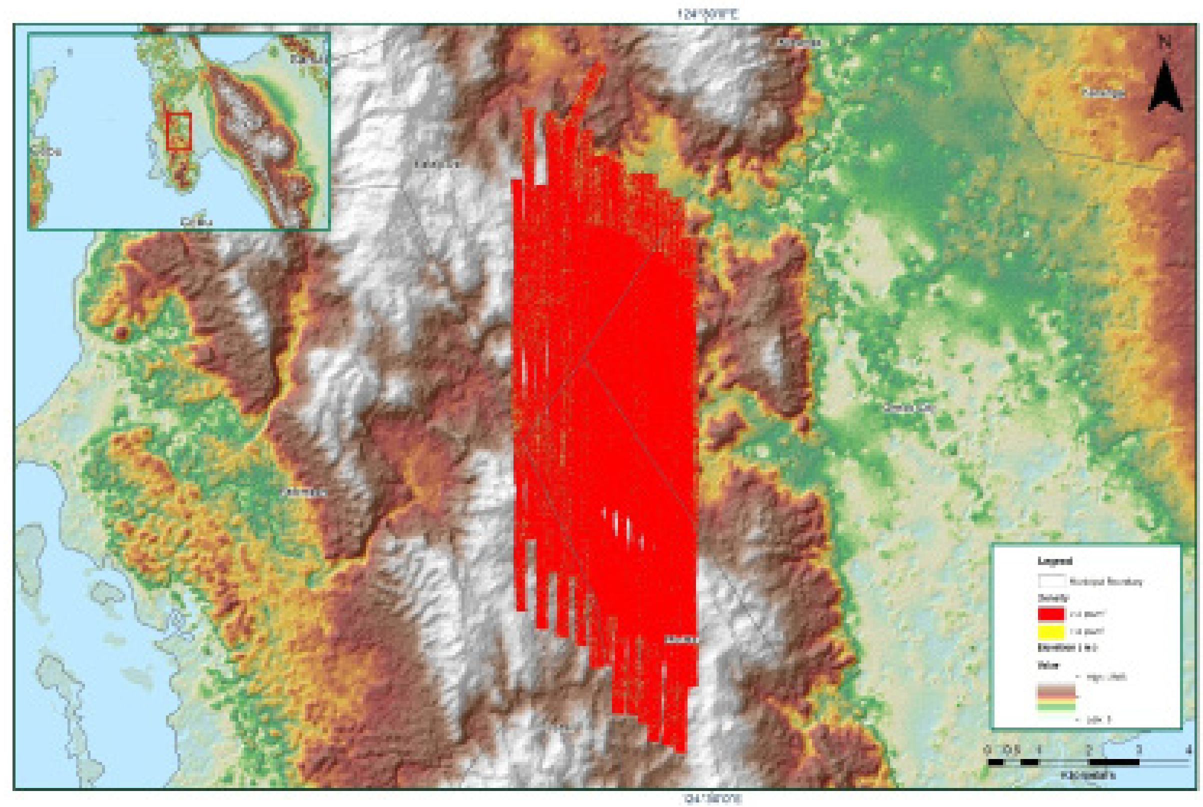


Figure A-8.118. Density map of merged LiDAR data

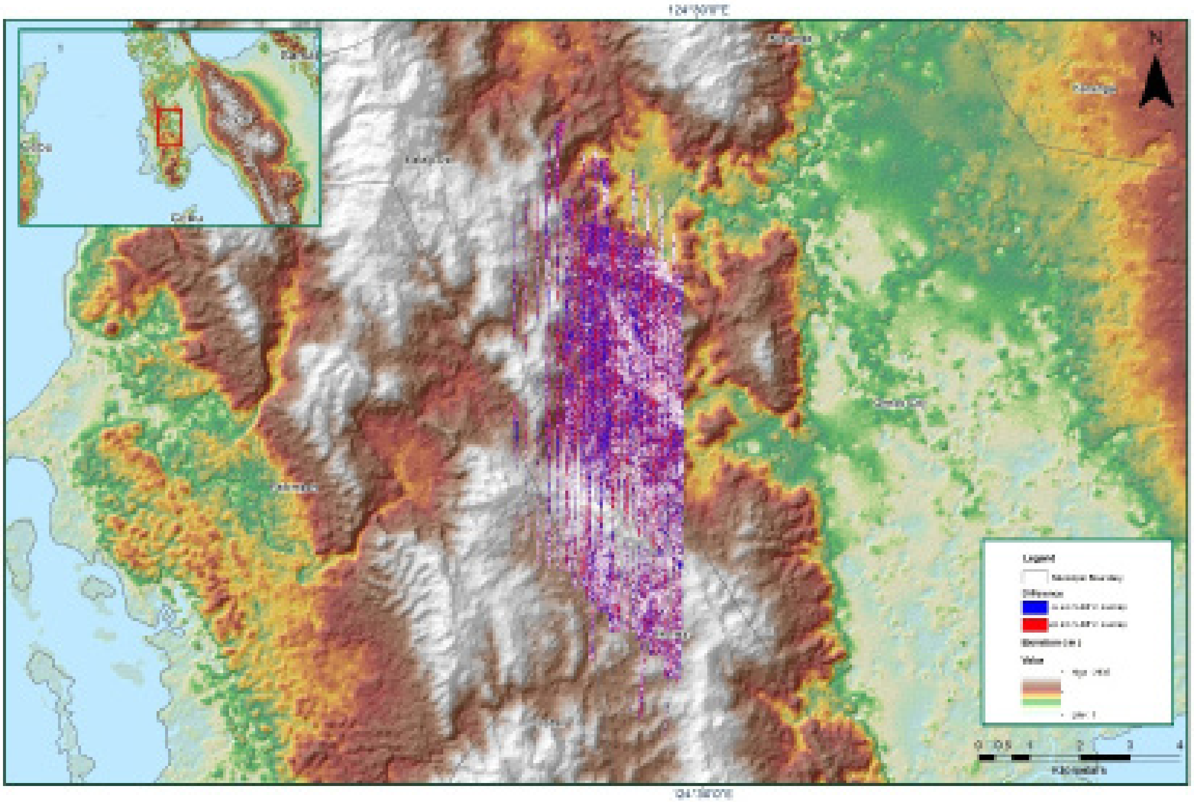


Figure A-8.119. Elevation difference between flight lines

Table A-8.18. Mission Summary Report for Mission Blk35E_Additional

Flight Area	Ormoc_Camotes
Mission Name	Blk35E_Additional
Inclusive Flights	8408AC
Range data size	5.14 GB
POS	208 MB
Image	56.3 MB
Base Station	263 MB
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.03
RMSE for East Position (<4.0 cm)	1.24
RMSE for Down Position (<8.0 cm)	3.59
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	20.63
Ave point cloud density per sq.m. (>2.0)	3.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	30
Maximum Height	480.27
Minimum Height	75.57
Classification (# of points)	
Ground	30,839,262
Low vegetation	17,960,389
Medium vegetation	48,134,275
High vegetation	73,775,914
Building	4,266,466
Orthophoto	None
Processed by	Engr. Regis Guhiting, Aljon Rie Araneta, Marie Denise Bueno

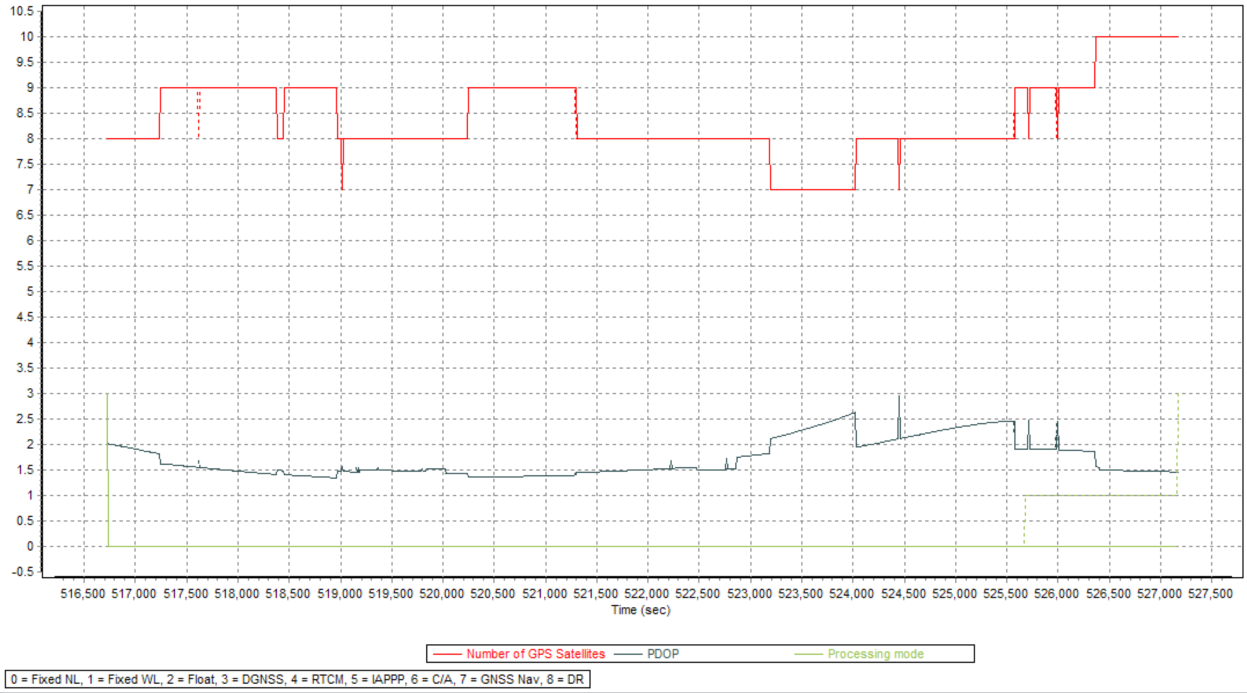


Figure A-8.120. Solution Status

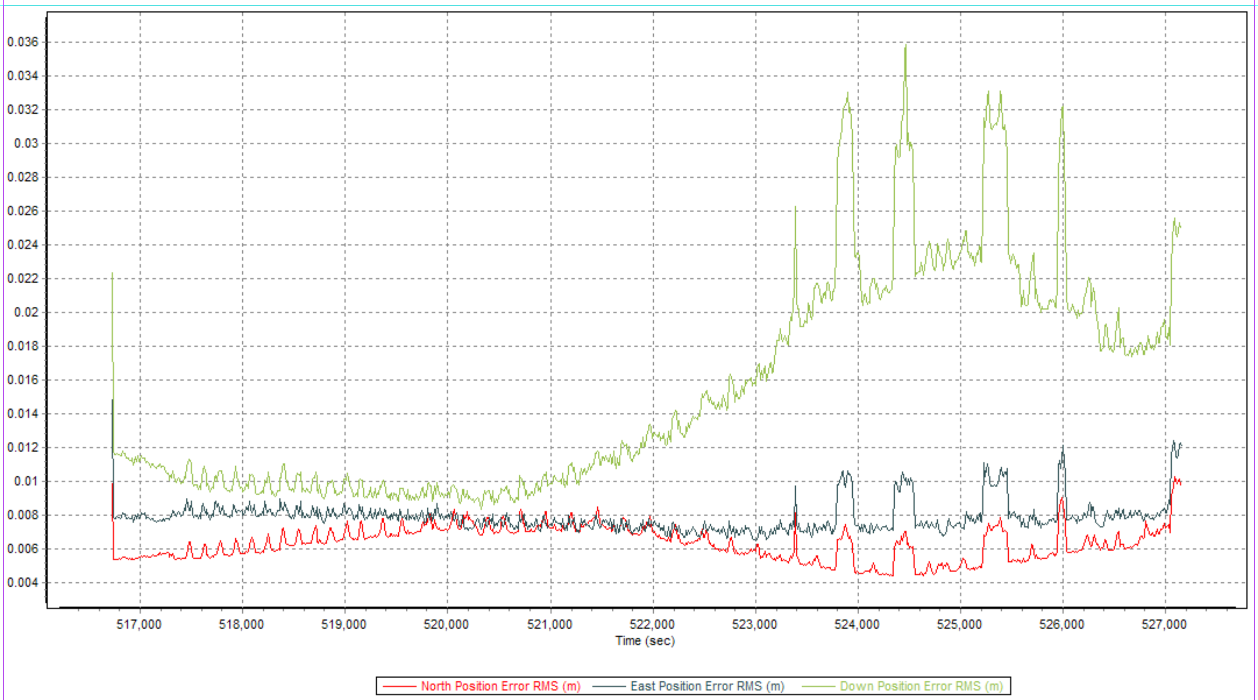


Figure A-8.121. Smoothed Performance Metrics Parameters

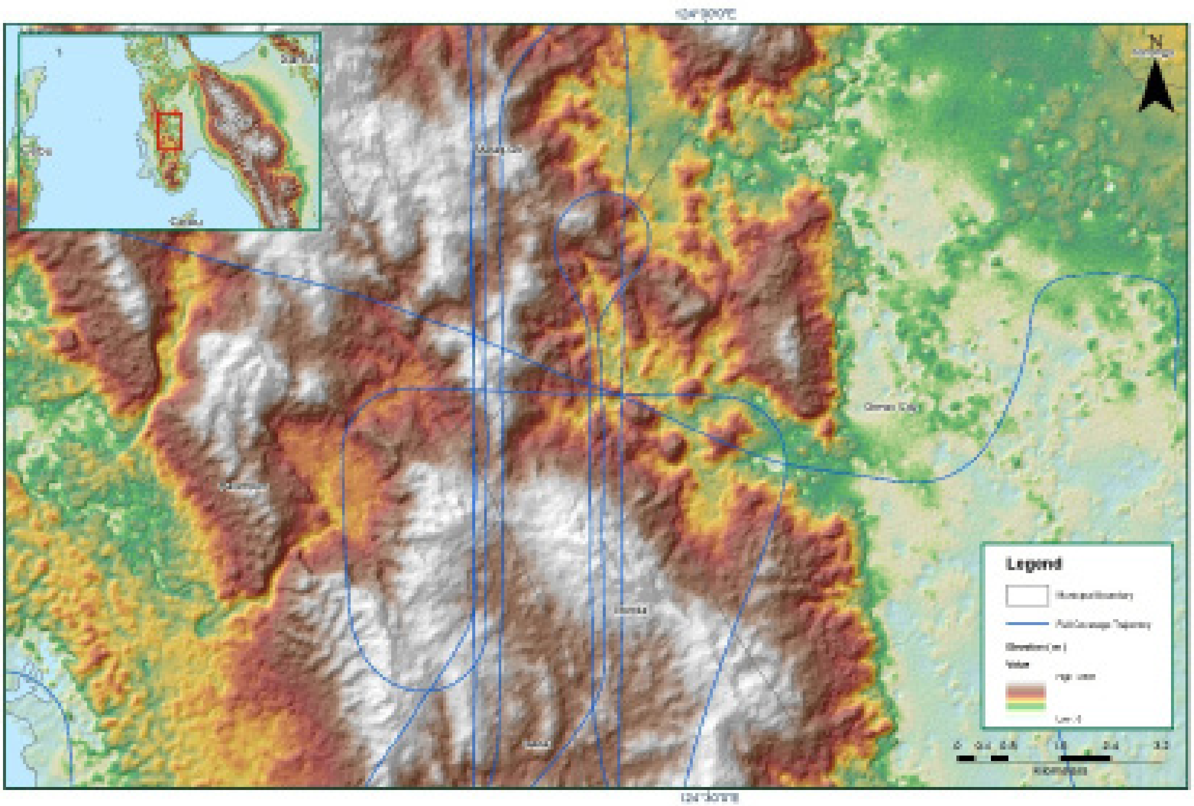


Figure A-8.122. Best Estimated Trajectory

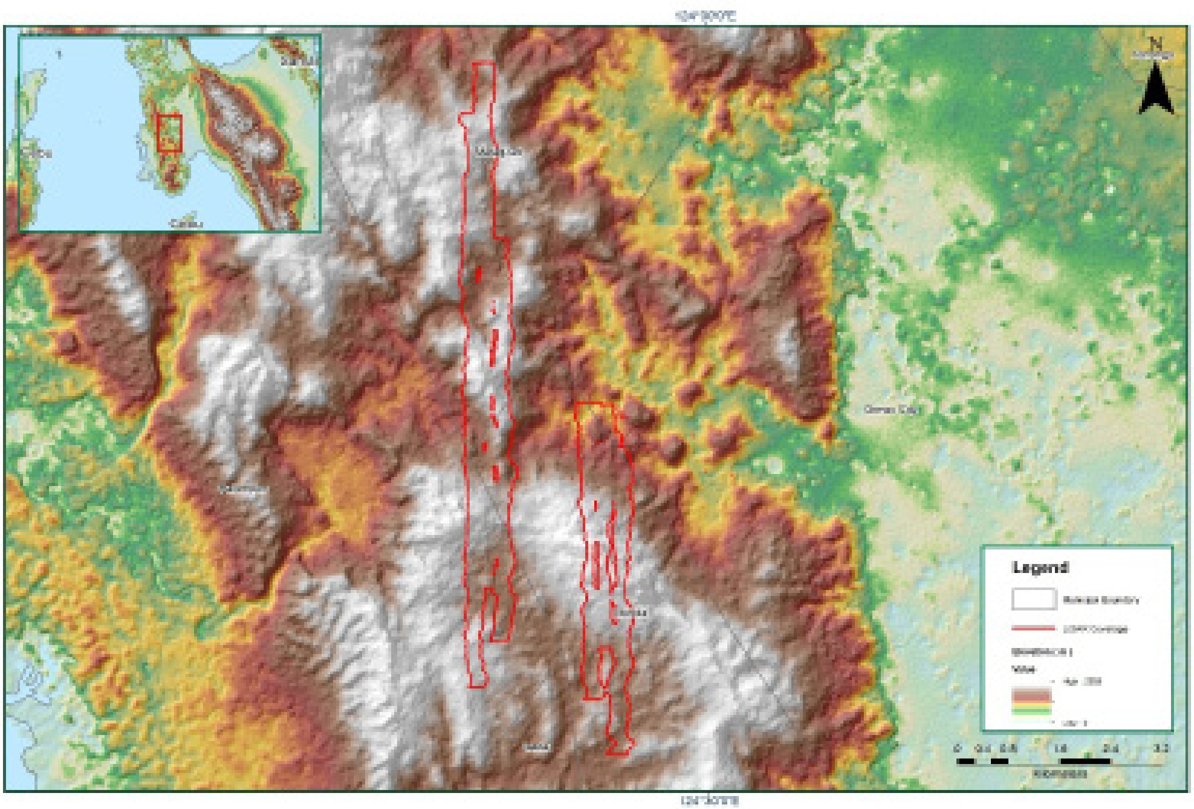


Figure A-8.123. Coverage of LiDAR data

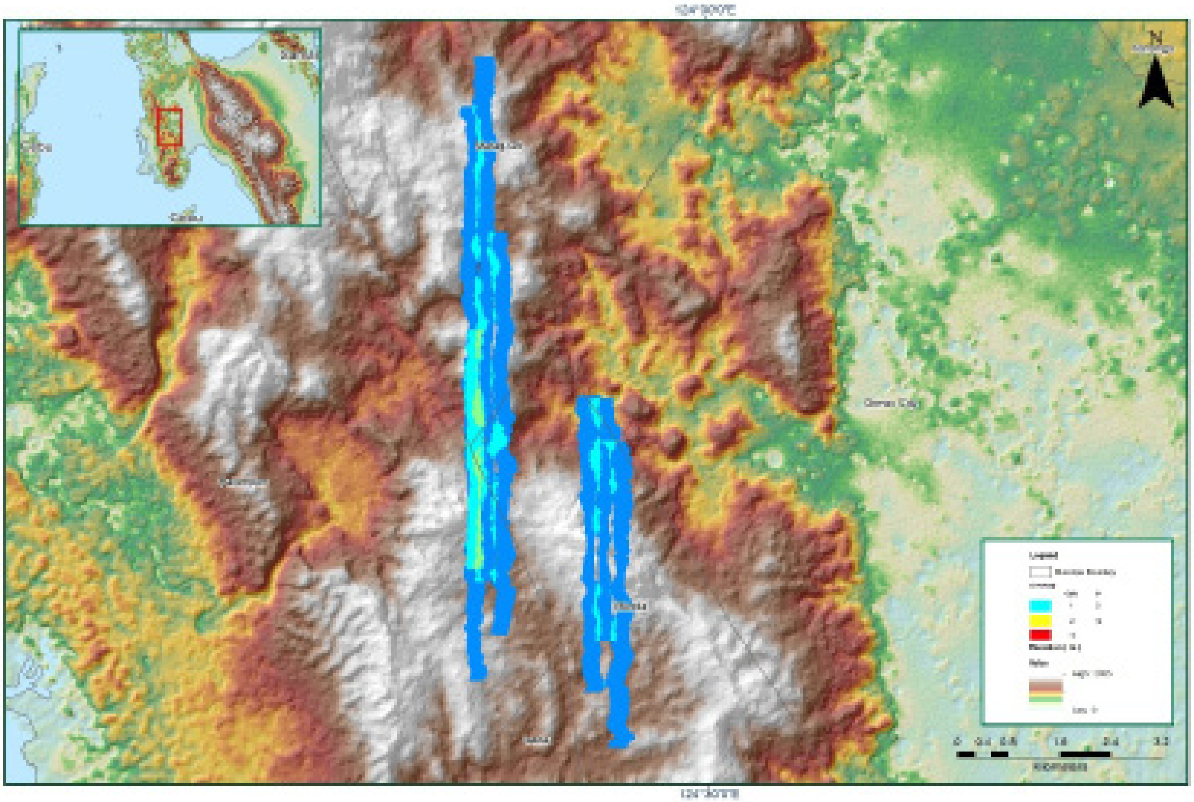


Figure A-8.124. Image of data overlap

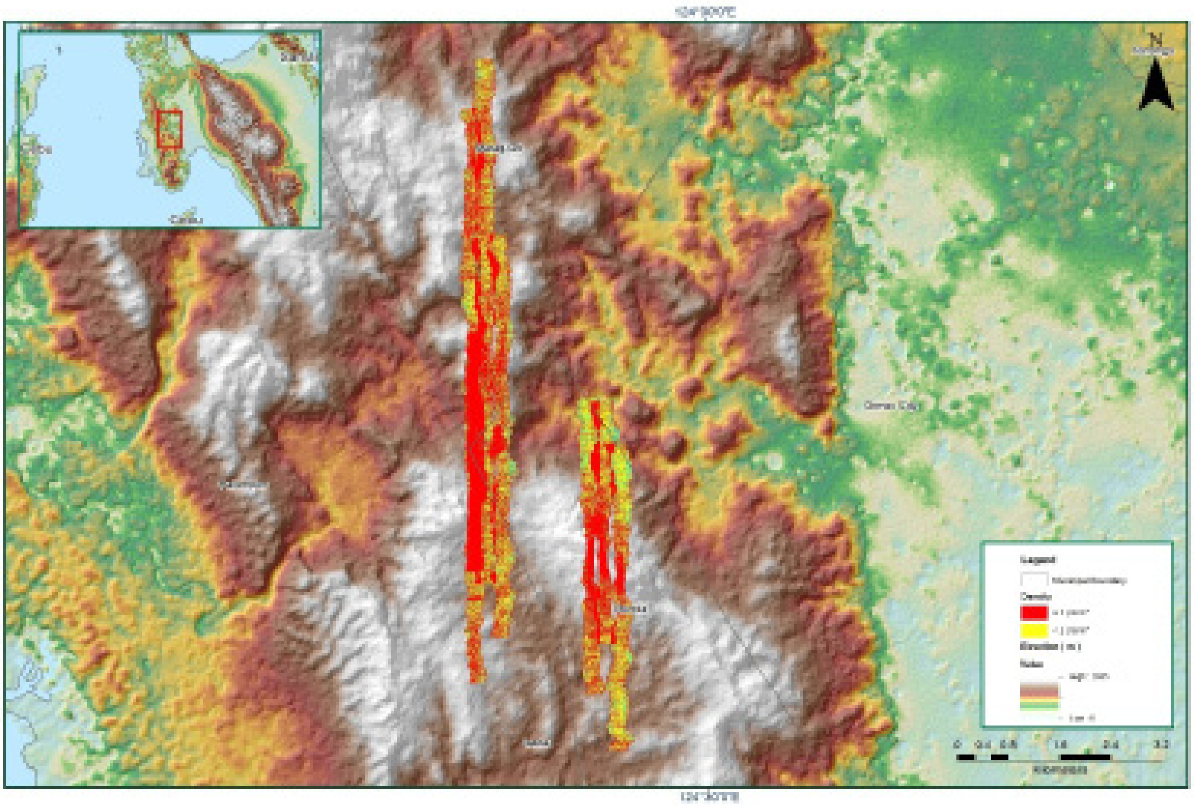


Figure A-8.125. Density map of merged LiDAR data

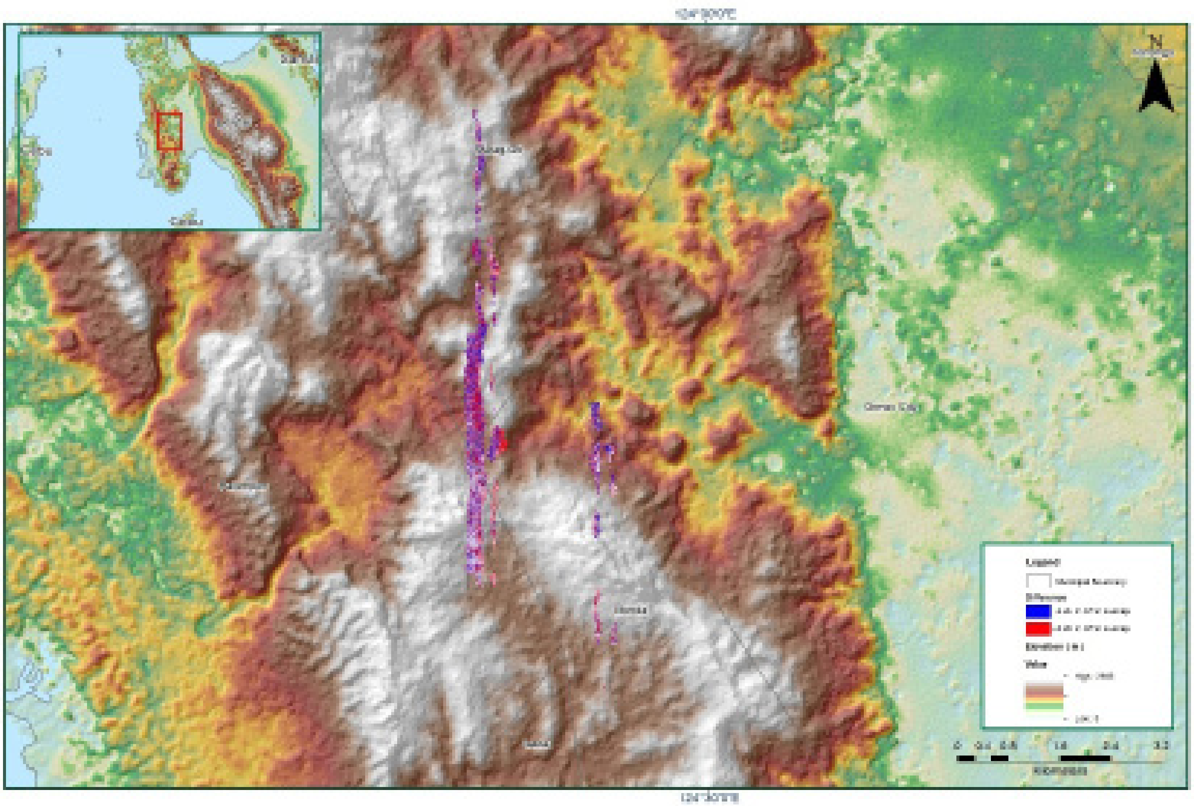


Figure A-8.126. Elevation difference between flight lines

Table A-8.19. Mission Summary Report for Mission Blk35E_Supplement

Flight Area	Ormoc_Camotes
Mission Name	Blk35E_Supplement
Inclusive Flights	8389AC
Range data size	10.7 GB
POS	259 MB
Image	44.9 MB
Base Station	228 MB
Transfer date	March 28, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.21
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	4.13
Boresight correction stdev (<0.001deg)	0.000431
IMU attitude correction stdev (<0.001deg)	0.006621
GPS position stdev (<0.01m)	0.0098
Minimum % overlap (>25)	51.84
Ave point cloud density per sq.m. (>2.0)	4.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	89
Maximum Height	377.21
Minimum Height	57.60
Classification (# of points)	
Ground	52,094,139
Low vegetation	63,380,558
Medium vegetation	67,477,309
High vegetation	83,244,354
Building	6,560,538
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Aljon Rie Araneta, Engr. Krisha Marie Bautista

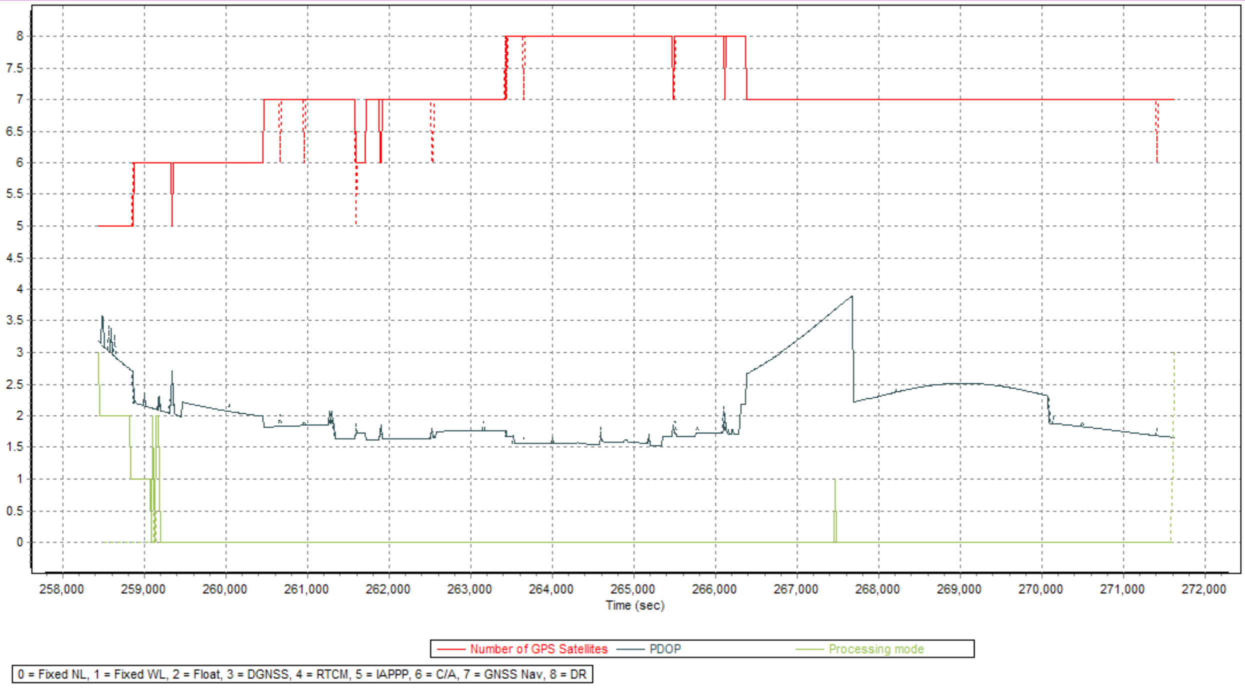


Figure A-8.127. Solution Status

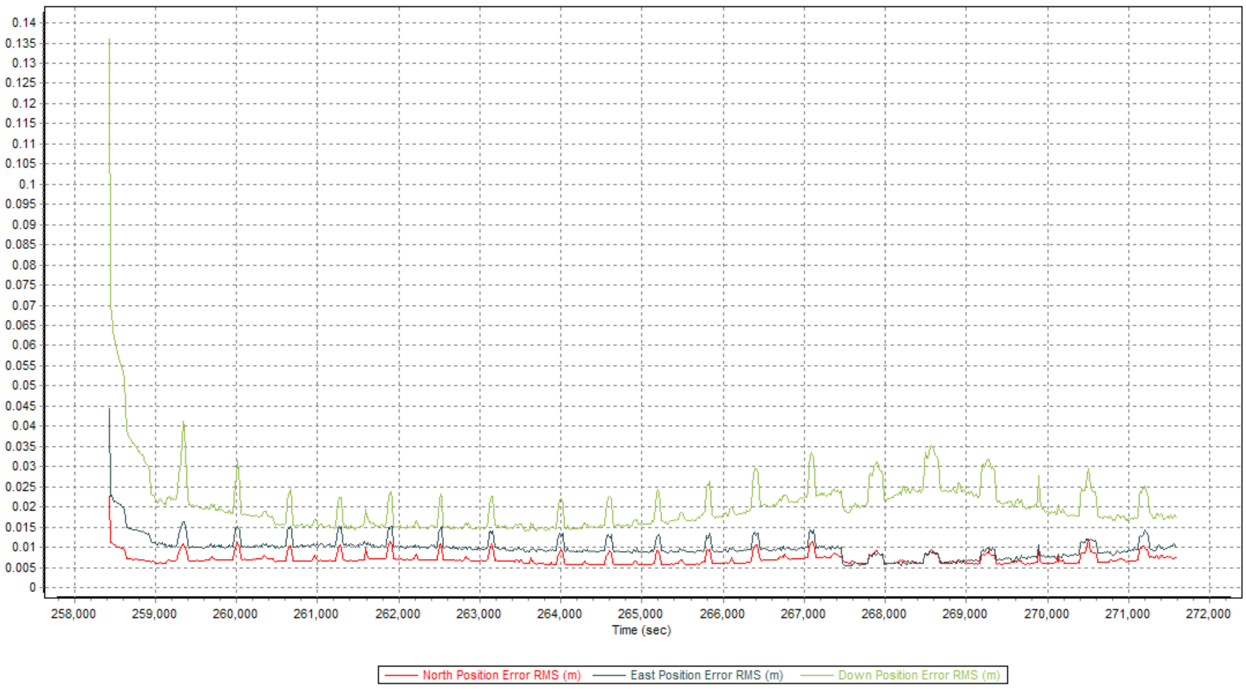


Figure A-8.128. Smoothed Performance Metrics Parameters

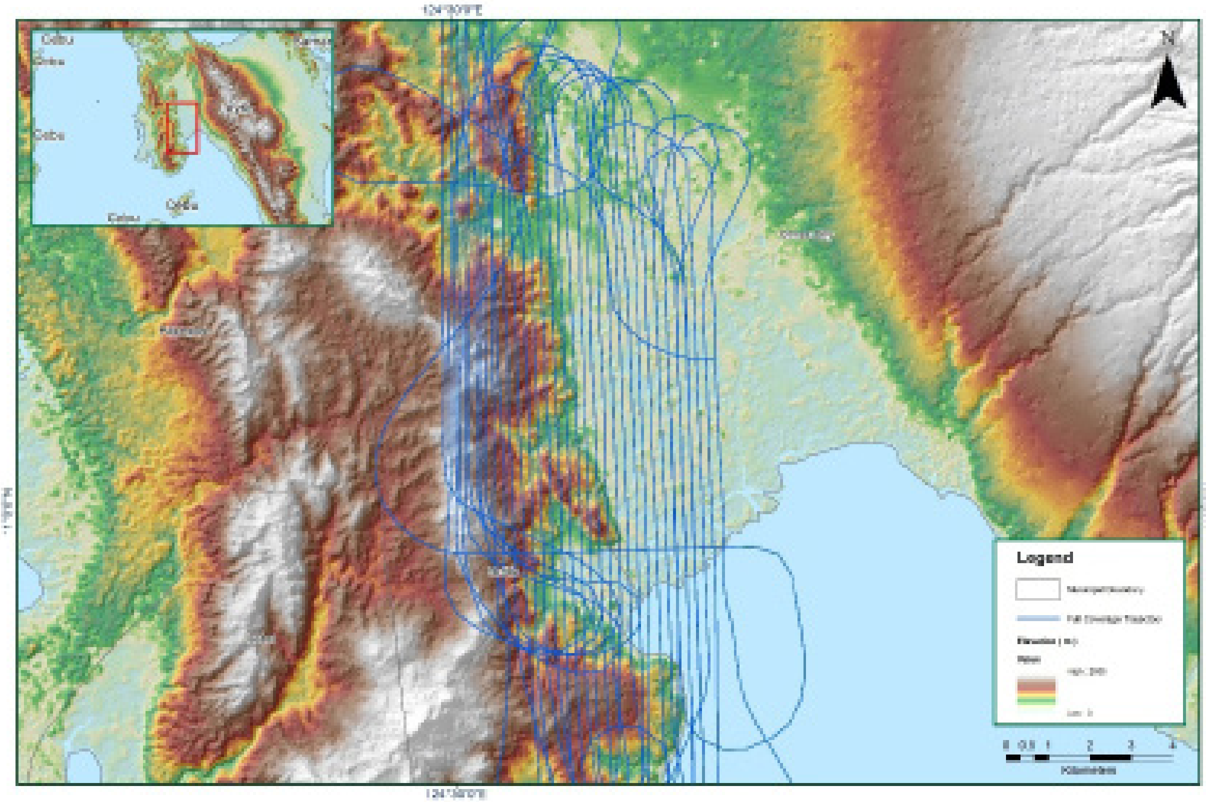


Figure A-8.129. Best Estimated Trajectory

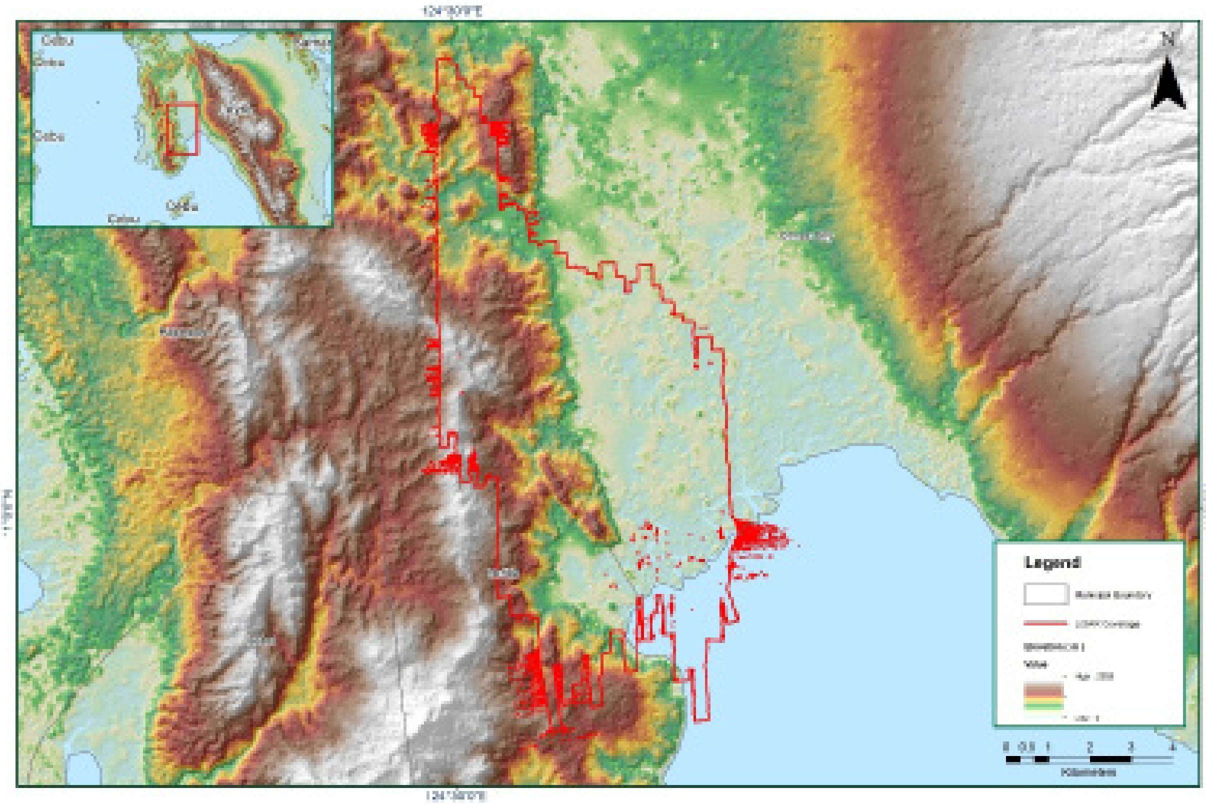


Figure A-8.130. Best Estimated Trajectory

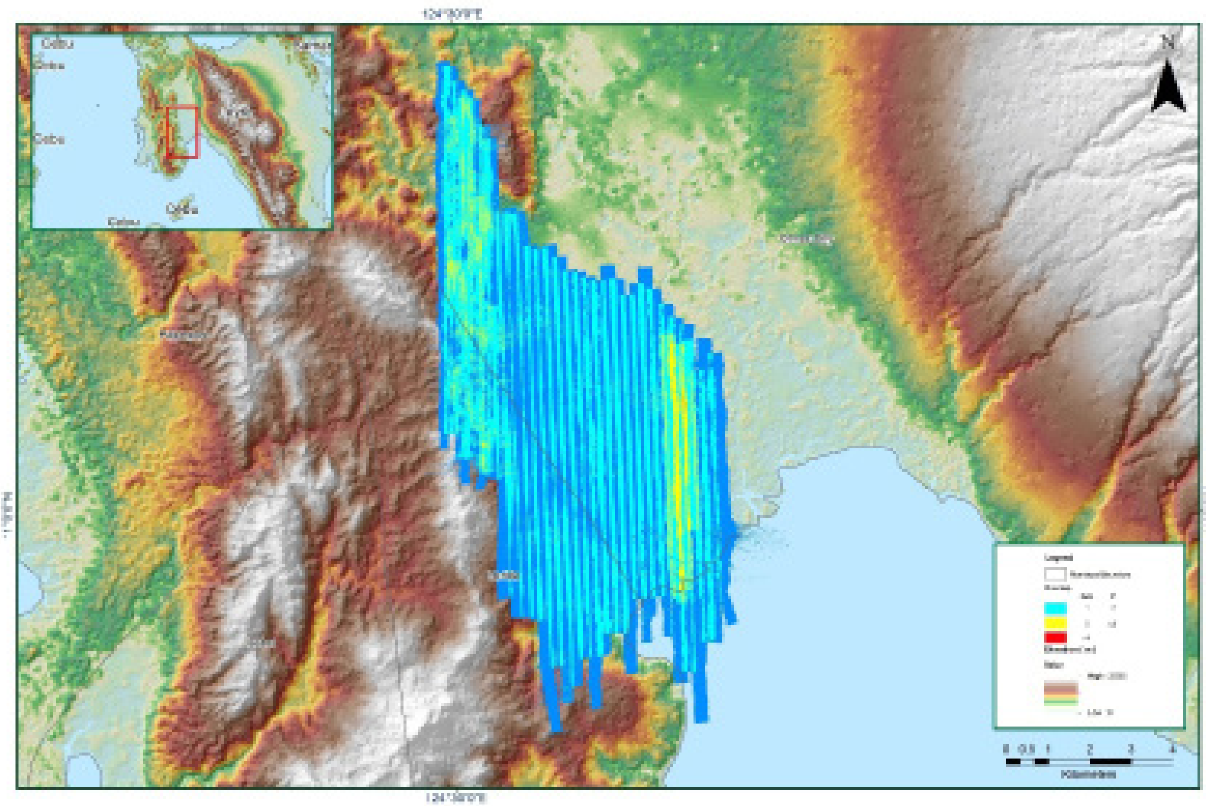


Figure A-8.131. Image of data overlap

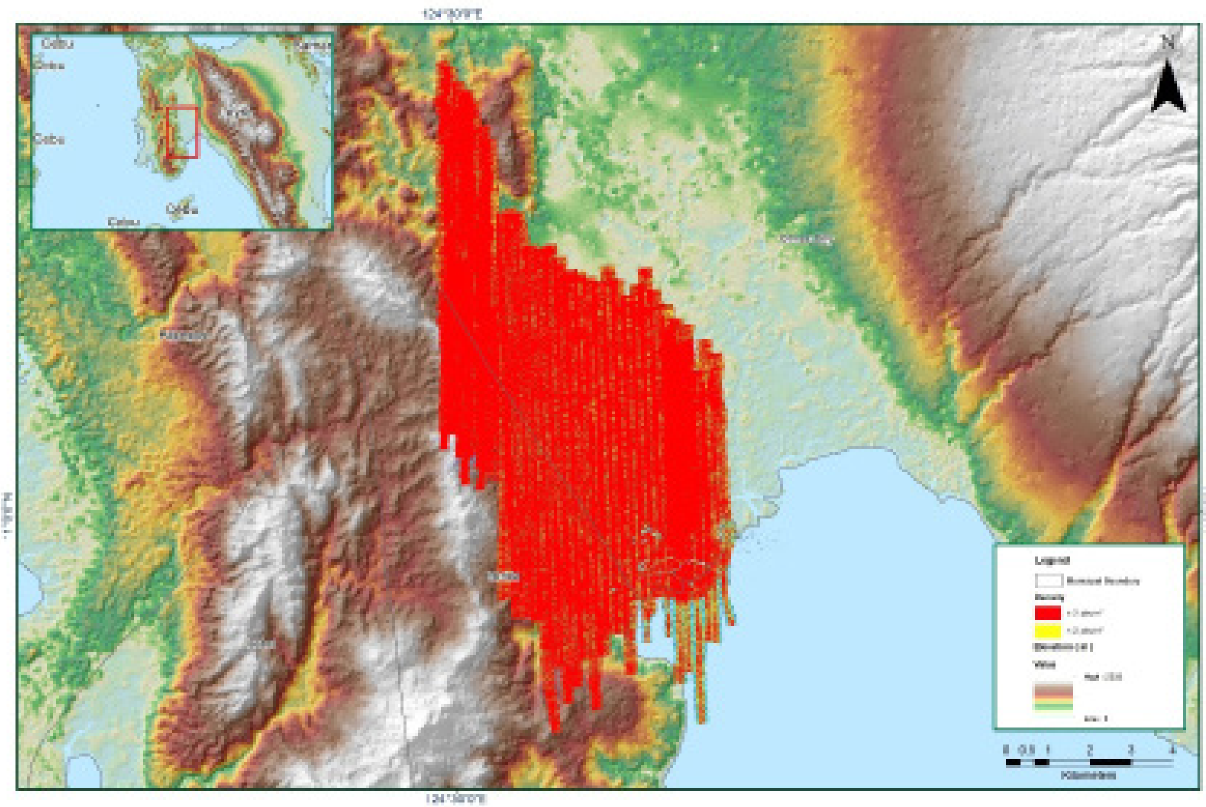


Figure A-8.132. Density map of merged LiDAR data

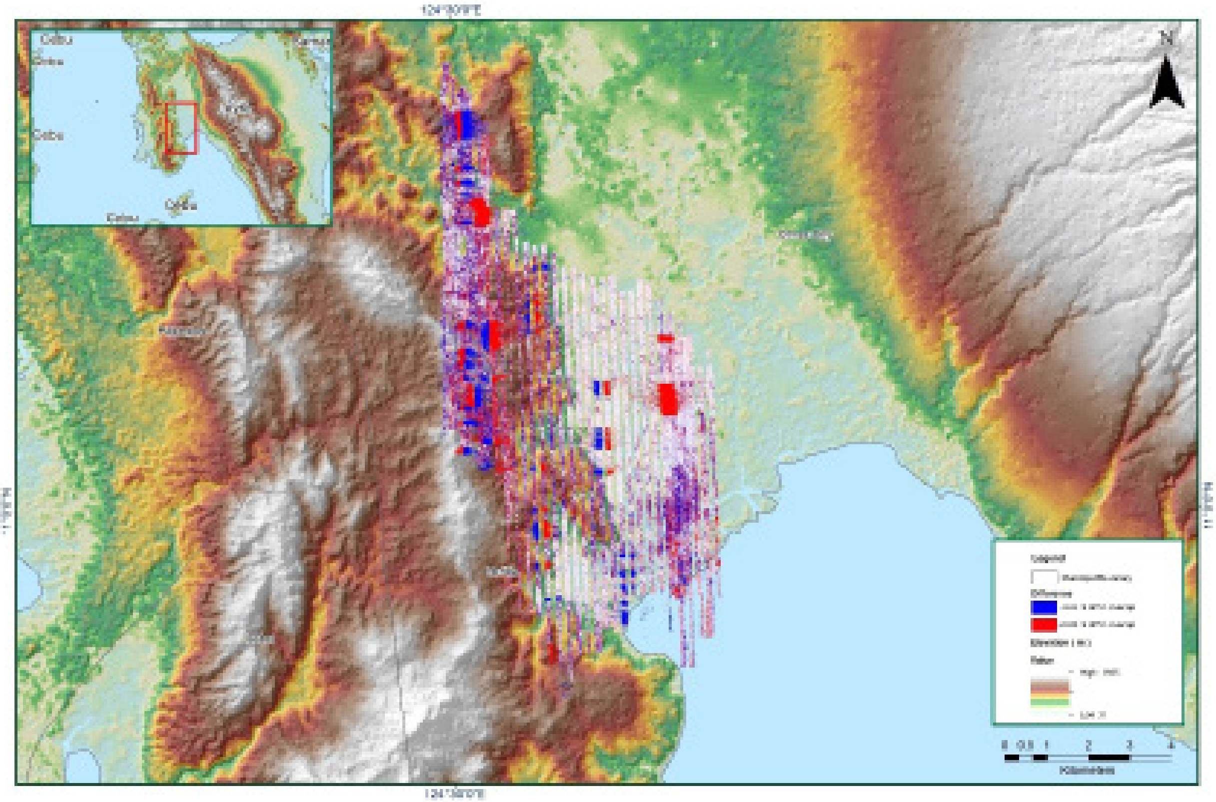


Figure A-8.133. Elevation difference between flight lines

Table A-8.20. Mission Summary Report for Mission Blk35F

Flight Area	Ormoc_Camotes
Mission Name	Blk35F
Inclusive Flights	8391AC
Range data size	11.2 GB
POS	263 MB
Image	35.5 MB
Base Station	265 MB
Transfer date	March 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.93
RMSE for East Position (<4.0 cm)	1.02
RMSE for Down Position (<8.0 cm)	3.06
Boresight correction stdev (<0.001deg)	0.001039
IMU attitude correction stdev (<0.001deg)	0.008915
GPS position stdev (<0.01m)	0.0151
Minimum % overlap (>25)	23.34
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	51
Maximum Height	152.26
Minimum Height	52.15
Classification (# of points)	
Ground	13,689,498
Low vegetation	16,455,690
Medium vegetation	12,313,010
High vegetation	6,985,085
Building	2,211,564
Orthophoto	None
Processed by	Engr. Analyn Naldo, Aljon Rie Araneta, Alex John Escobido

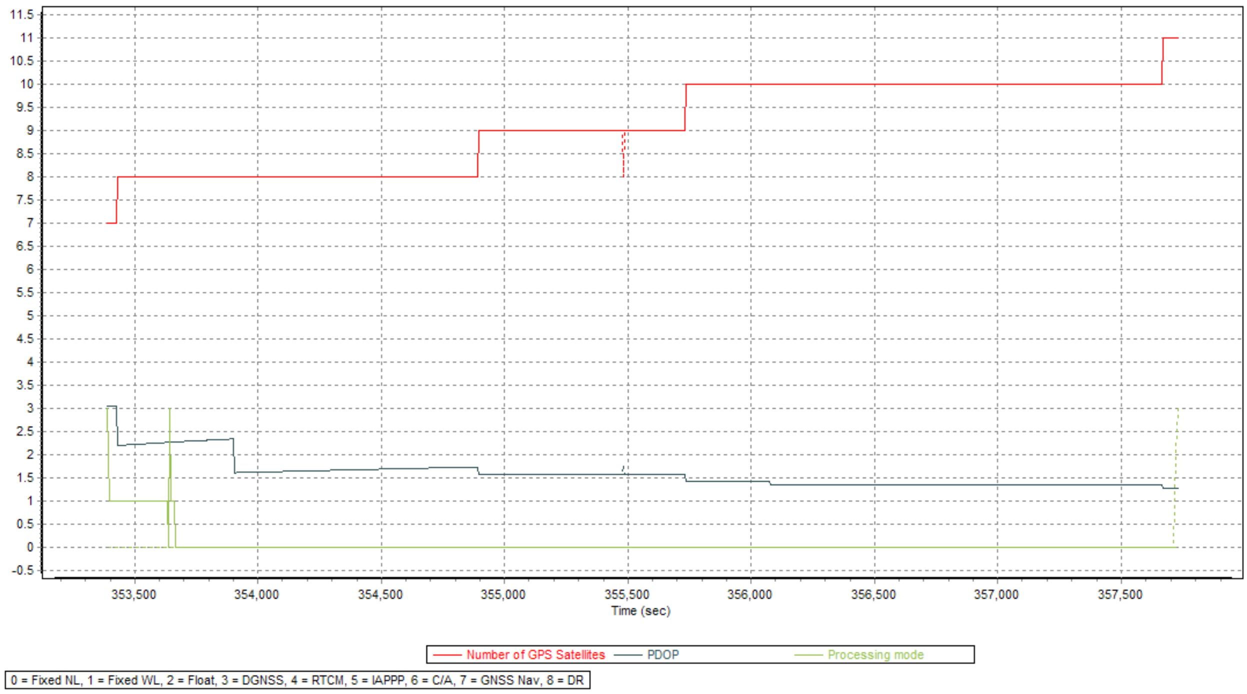


Figure A-8.134. Solution Status

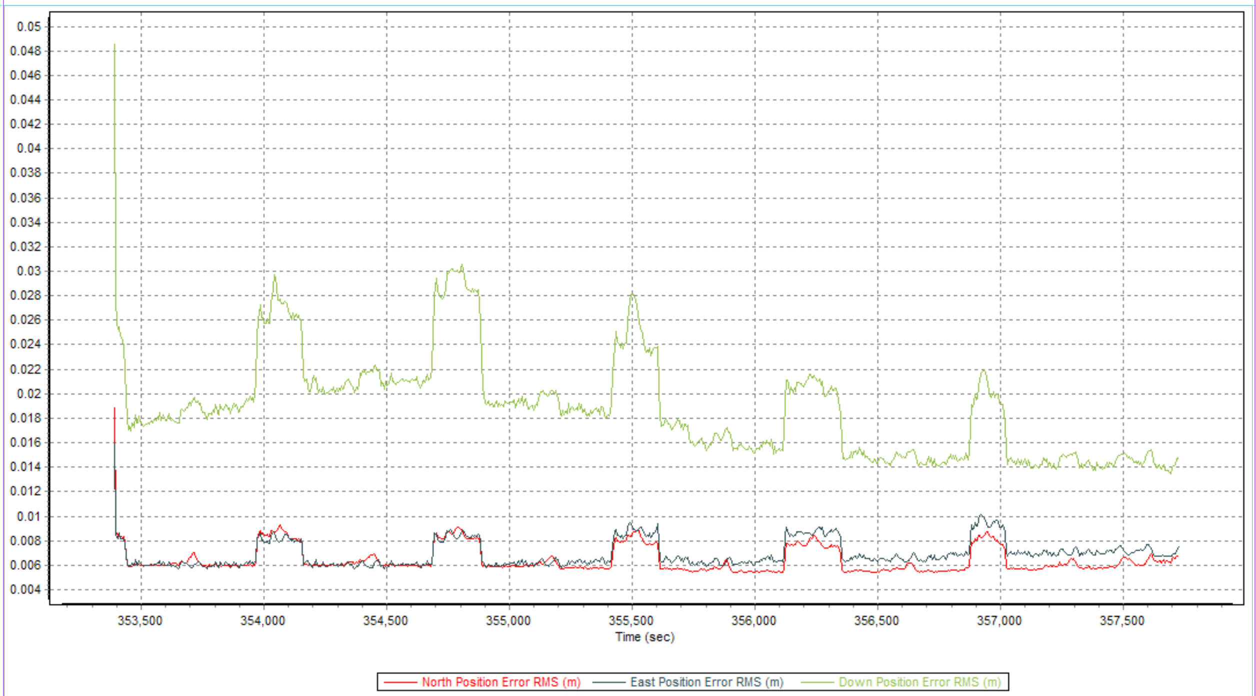


Figure A-8.135. Smoothed Performance Metrics Parameters

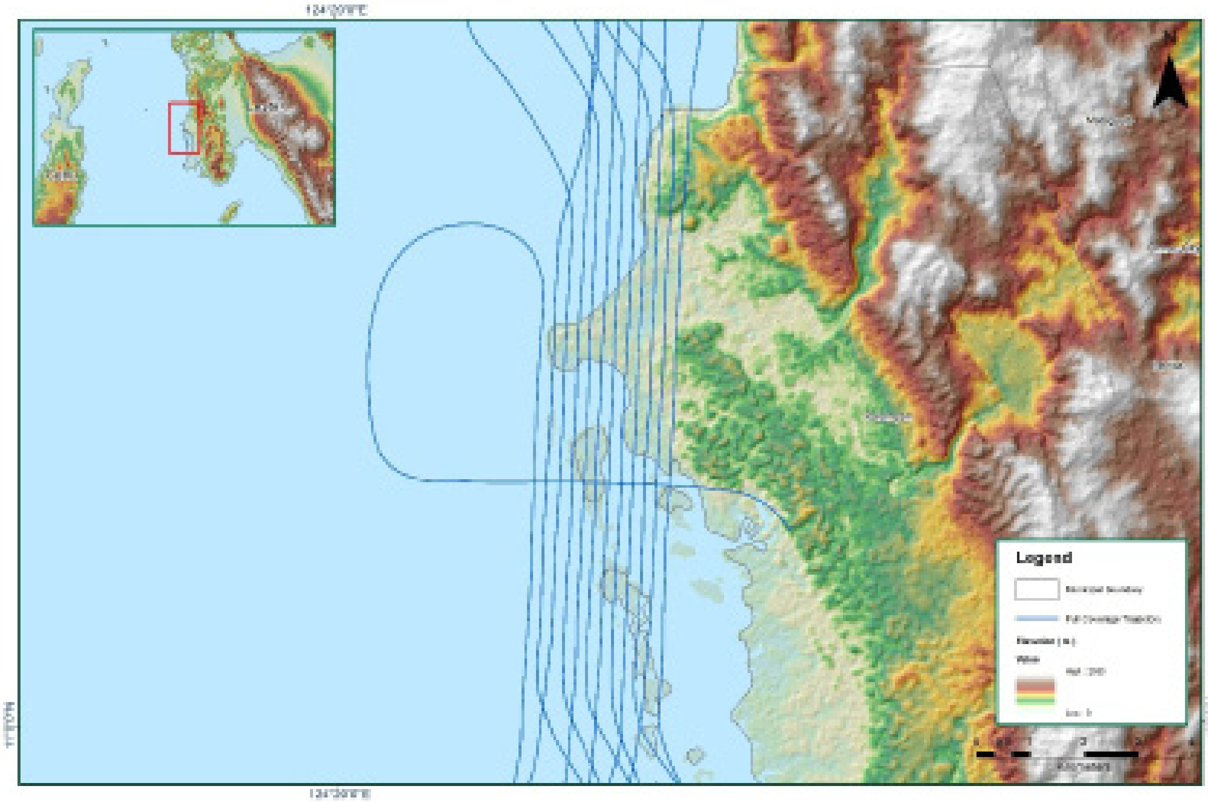


Figure A-8.136. Best Estimated Trajectory

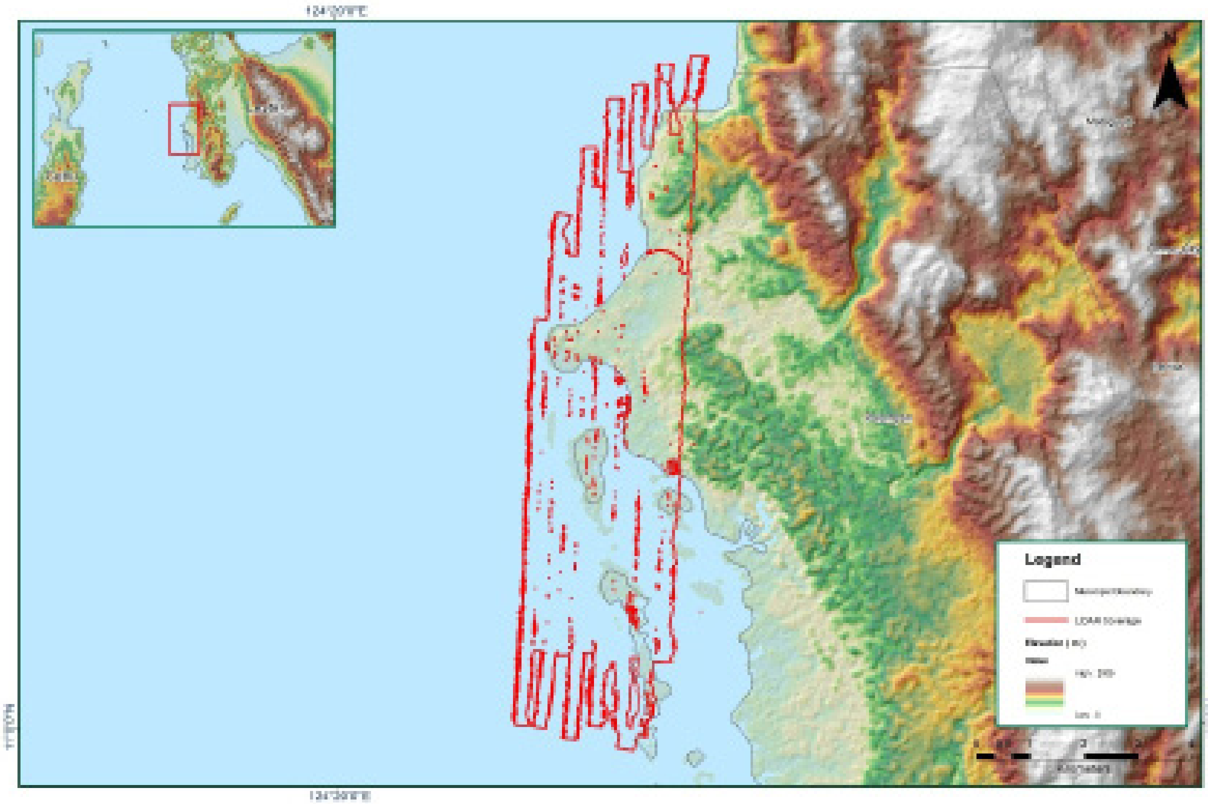


Figure A-8.137. Coverage of LiDAR data

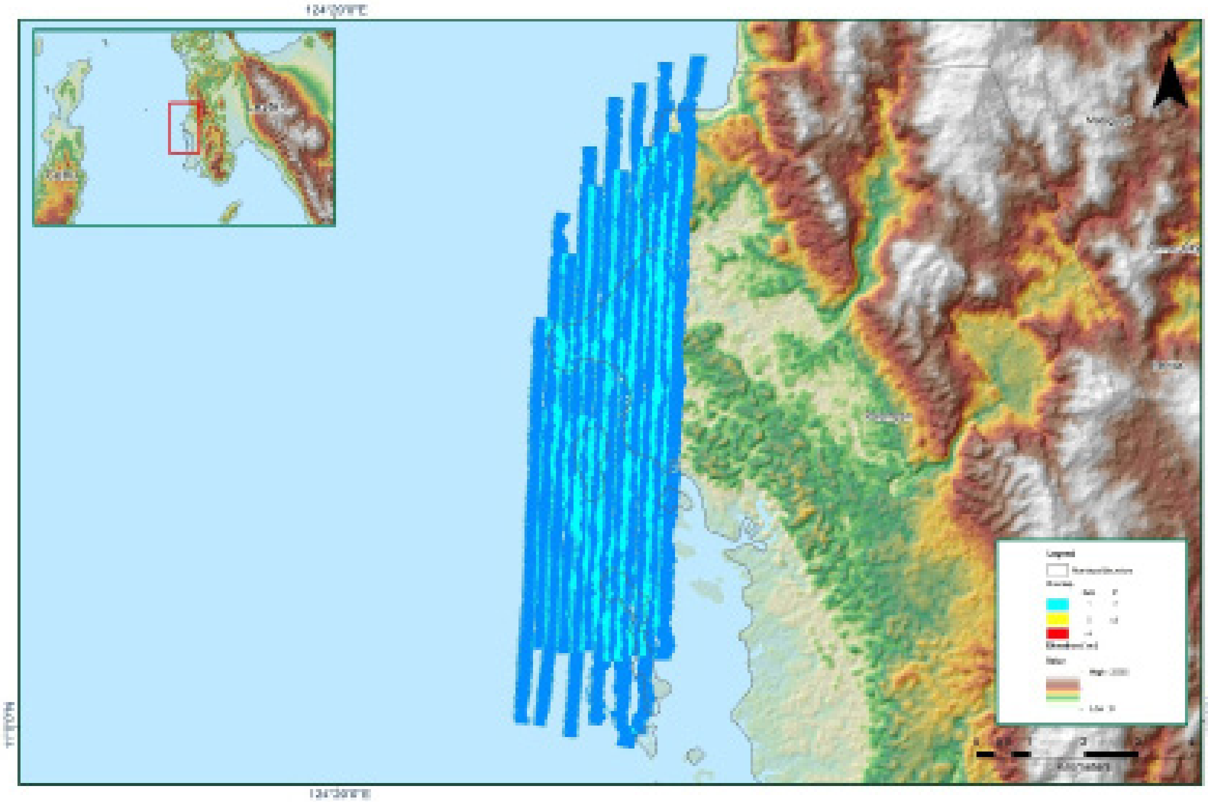


Figure A-8.138. Image of data overlap

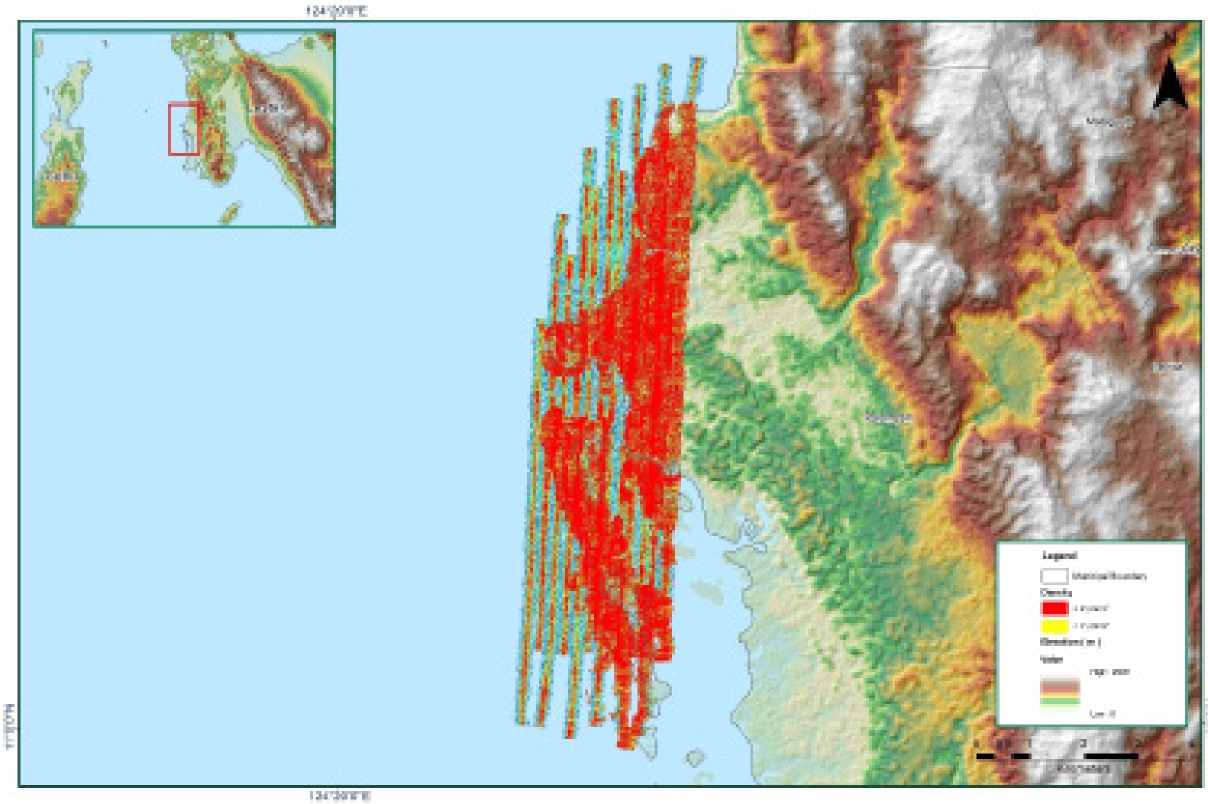


Figure A-8.139. Density map of merged LiDAR data

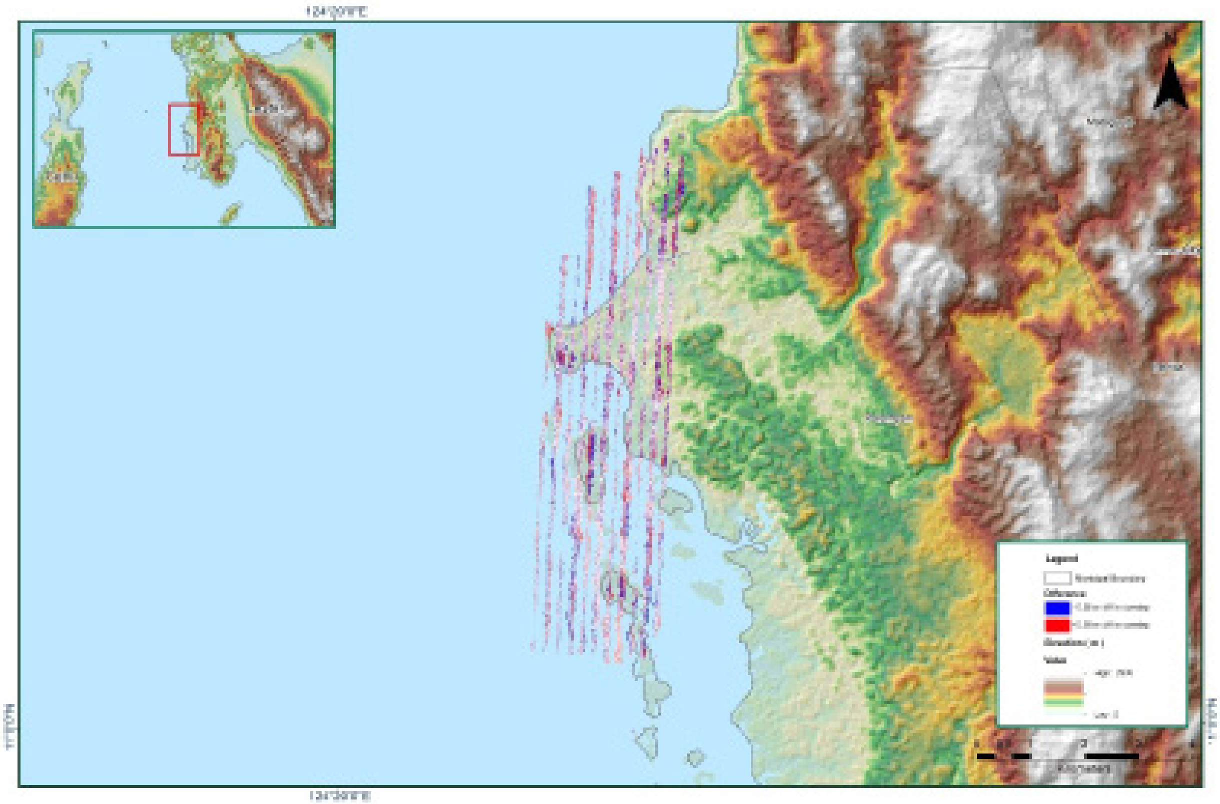


Figure A-8.140. Elevation difference between flight lines

Table A-8.21. Mission Summary Report for Mission Blk35F_Additional

Flight Area	Ormoc_Camotes
Mission Name	Blk35F_Additional
Inclusive Flights	8408AC
Range data size	5.14 GB
POS	208 MB
Image	56.3 MB
Base Station	263 MB
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.03
RMSE for East Position (<4.0 cm)	1.24
RMSE for Down Position (<8.0 cm)	3.59
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	0.51
Ave point cloud density per sq.m. (>2.0)	1.53
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	29
Maximum Height	115.99
Minimum Height	47.35
Classification (# of points)	
Ground	5,179,756
Low vegetation	2,398,009
Medium vegetation	1,450,198
High vegetation	1,916,365
Building	532,466
Orthophoto	None
Processed by	Engr. Regis Guhiting, Engr. Jovelle Anjeanette Canlas, Engr. Melissa Fernandez

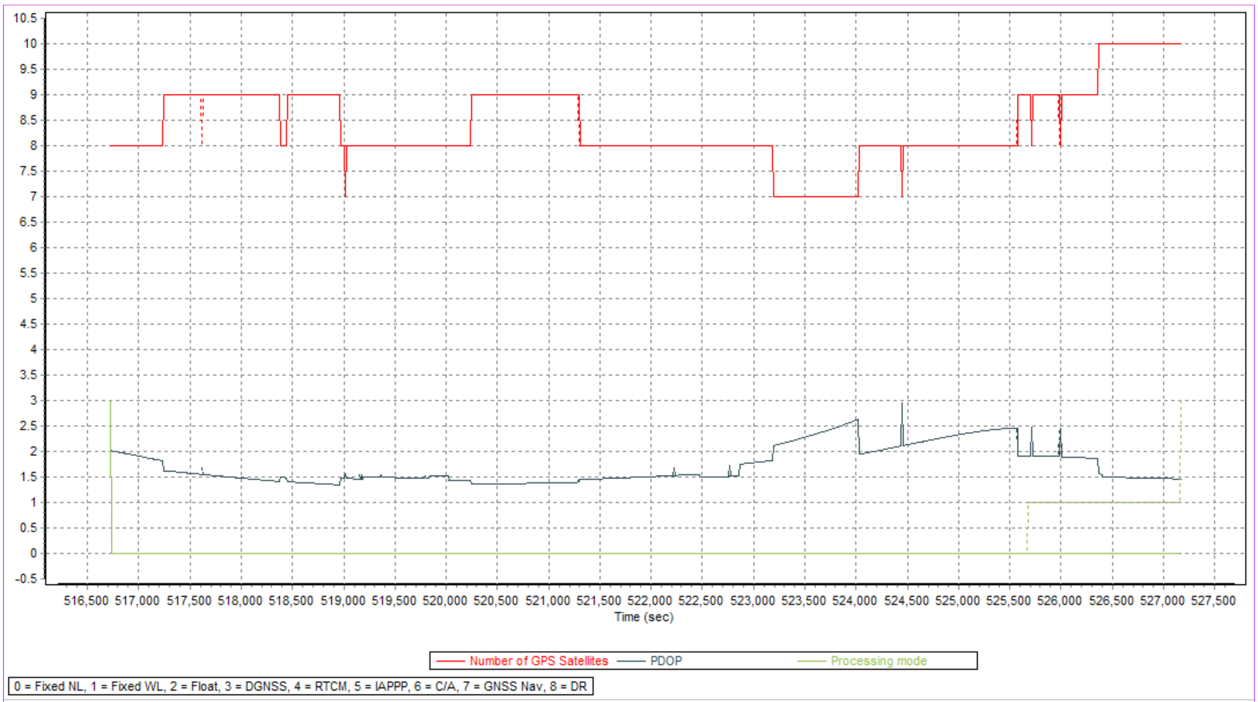


Figure A-8.141. Solution Status

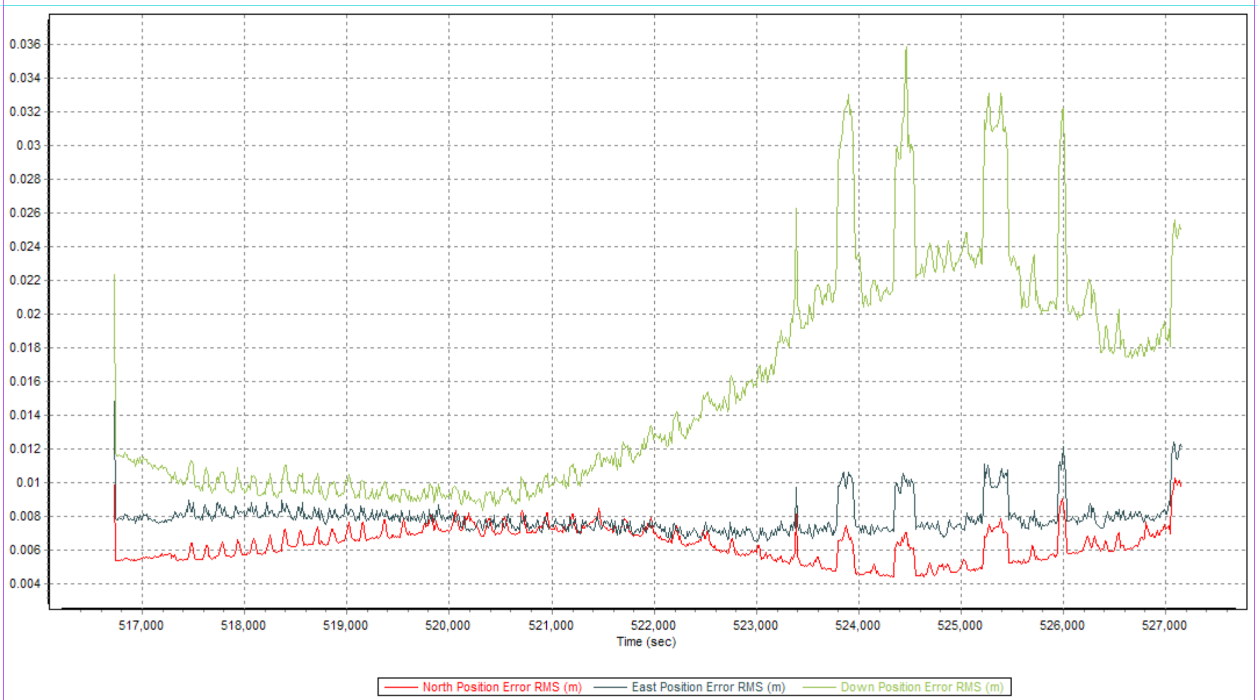


Figure A-8.142. Smoothed Performance Metrics Parameters

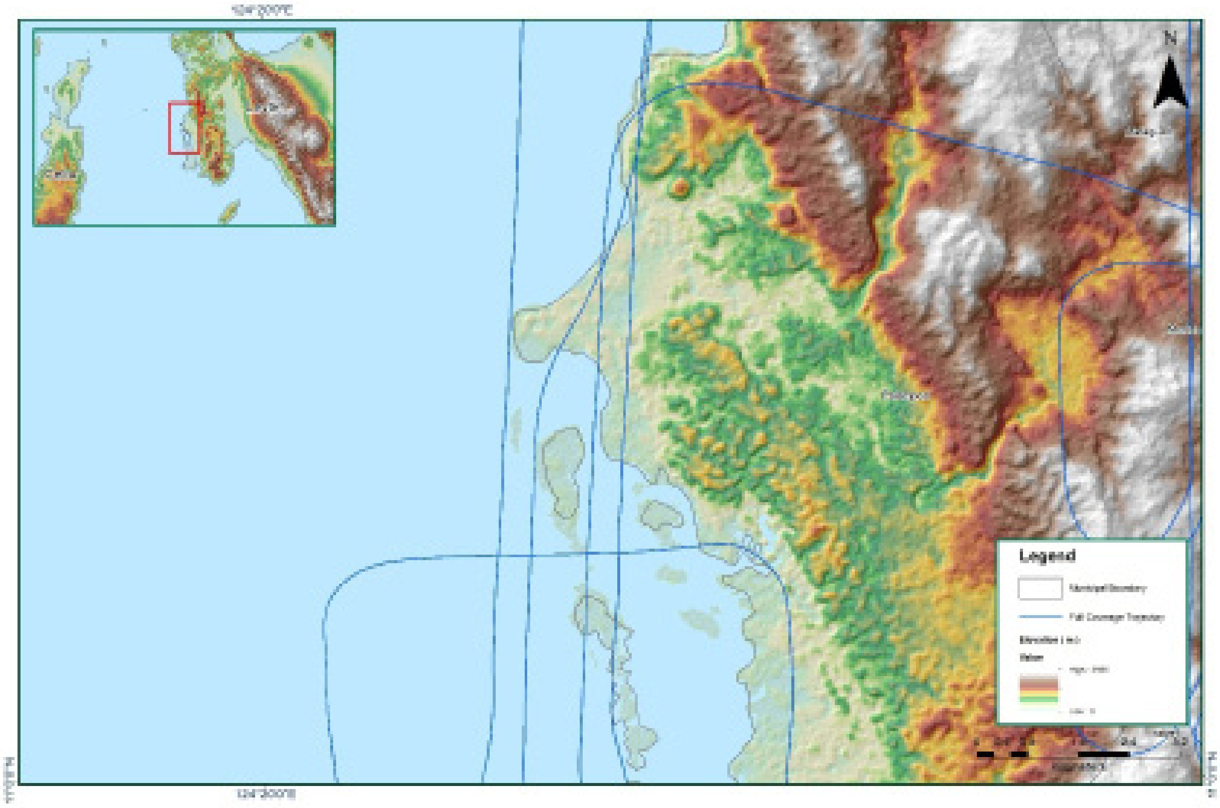


Figure A-8.143. Best Estimated Trajectory

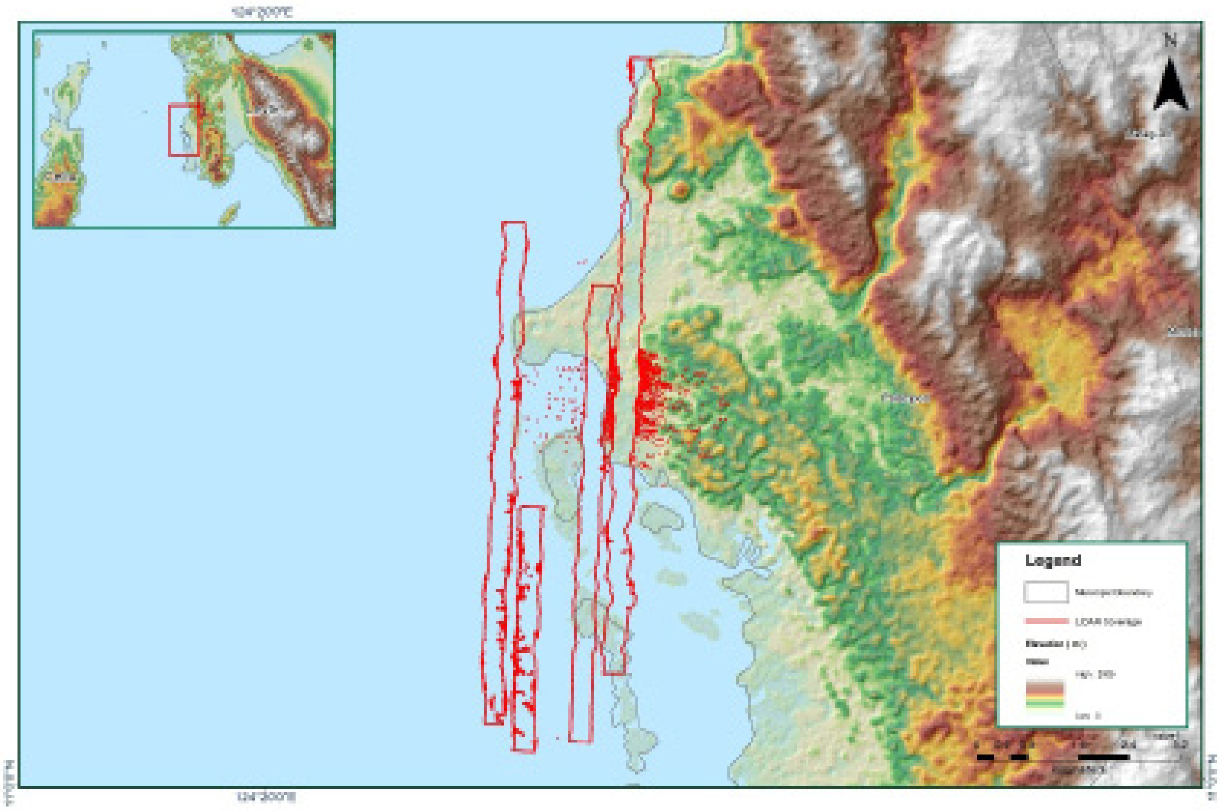


Figure A-8.144. Best Estimated Trajectory

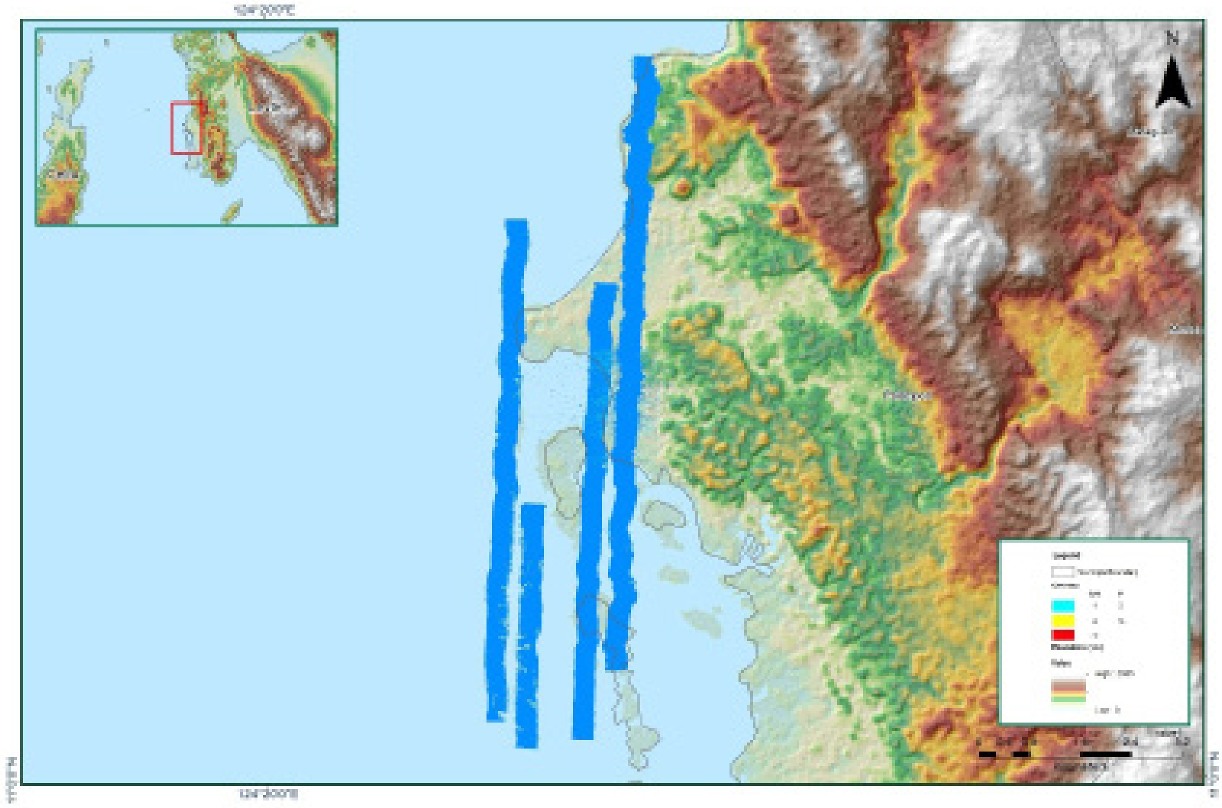


Figure A-8.145. Image of data overlap

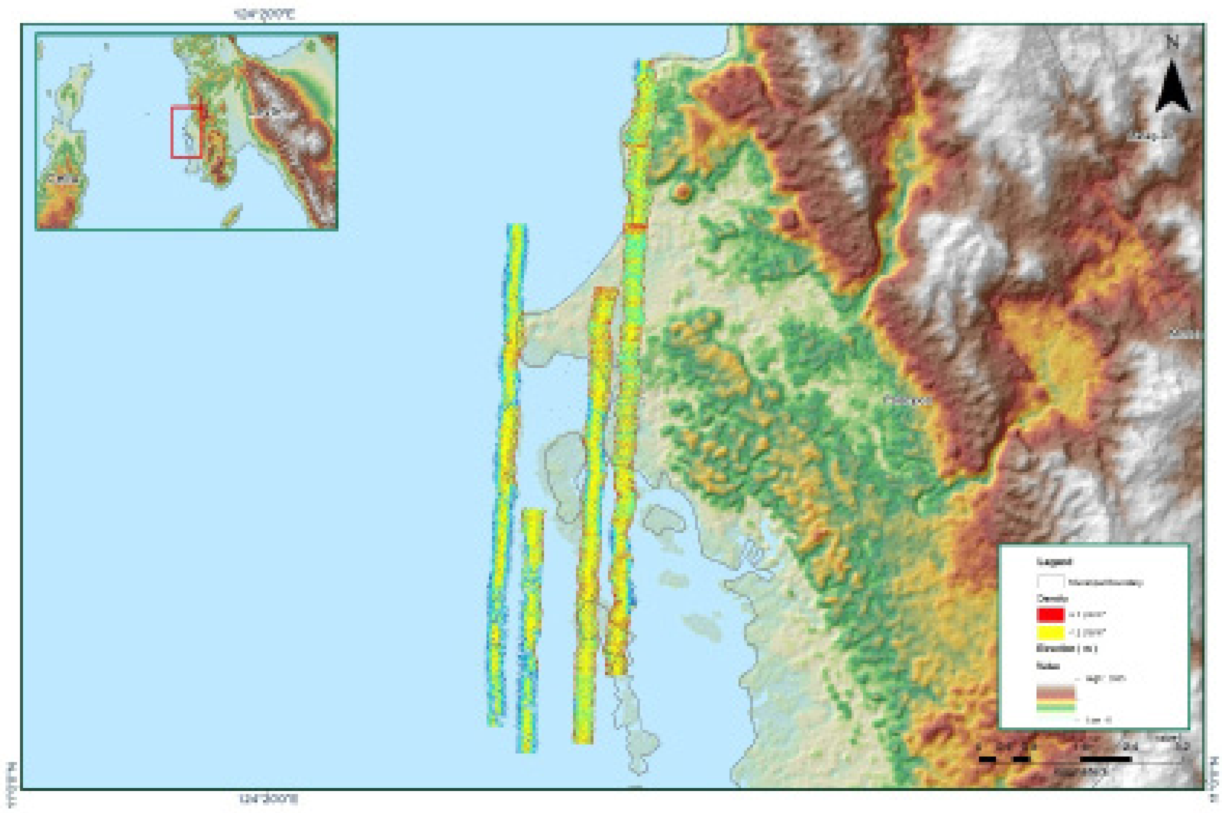


Figure A-8.146. Density map of merged LiDAR data

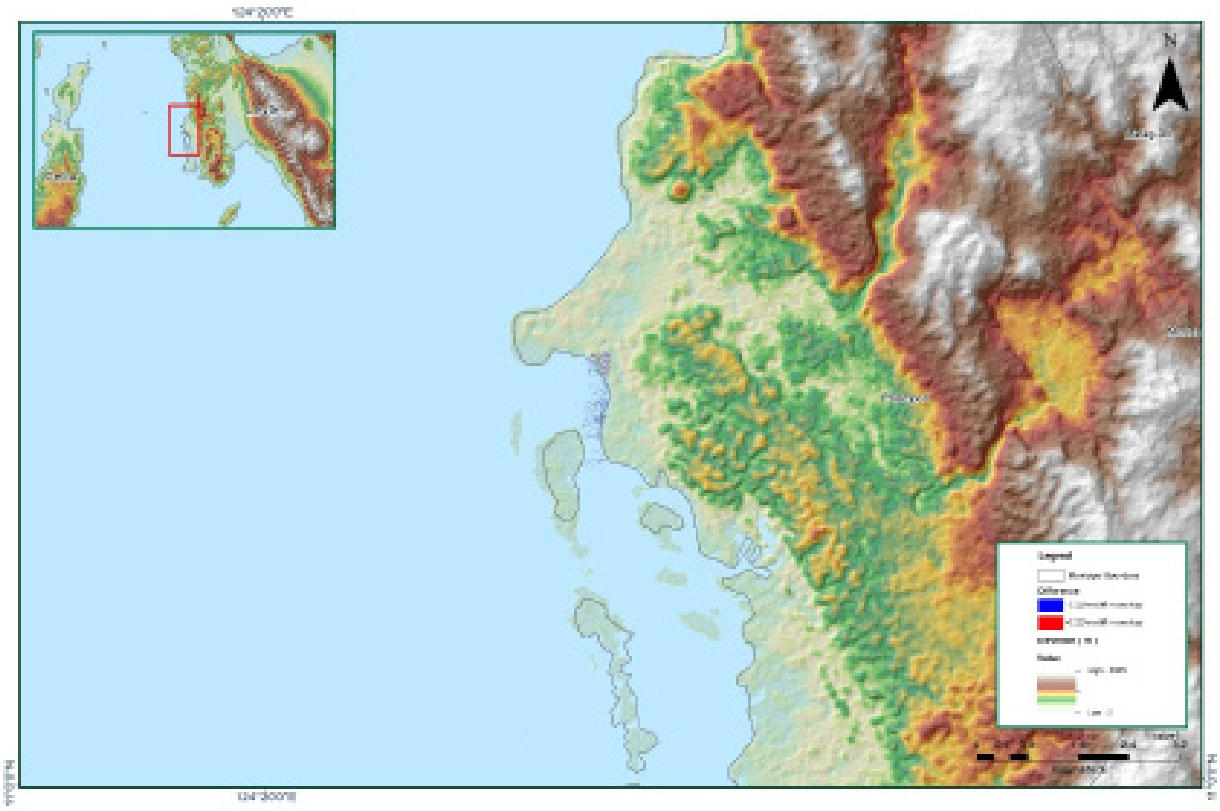


Figure A-8.147. Elevation difference between flight lines

Table A-8.22. Mission Summary Report for Mission Blk35G

Flight Area	Ormoc_Camotes
Mission Name	Blk35G
Inclusive Flights	8392AC
Range data size	9.68 GB
POS	198 MB
Image	37.6 MB
Base Station	265 MB
Transfer date	March 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.09
RMSE for Down Position (<8.0 cm)	2.63
Boresight correction stdev (<0.001deg)	0.000461
IMU attitude correction stdev (<0.001deg)	0.002204
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	37.05
Ave point cloud density per sq.m. (>2.0)	3.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	76
Maximum Height	167.26
Minimum Height	51.39
Classification (# of points)	
Ground	23,865,146
Low vegetation	25,929,146
Medium vegetation	44,569,409
High vegetation	34,437,062
Building	780,530
Orthophoto	None
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Jovy Narisma

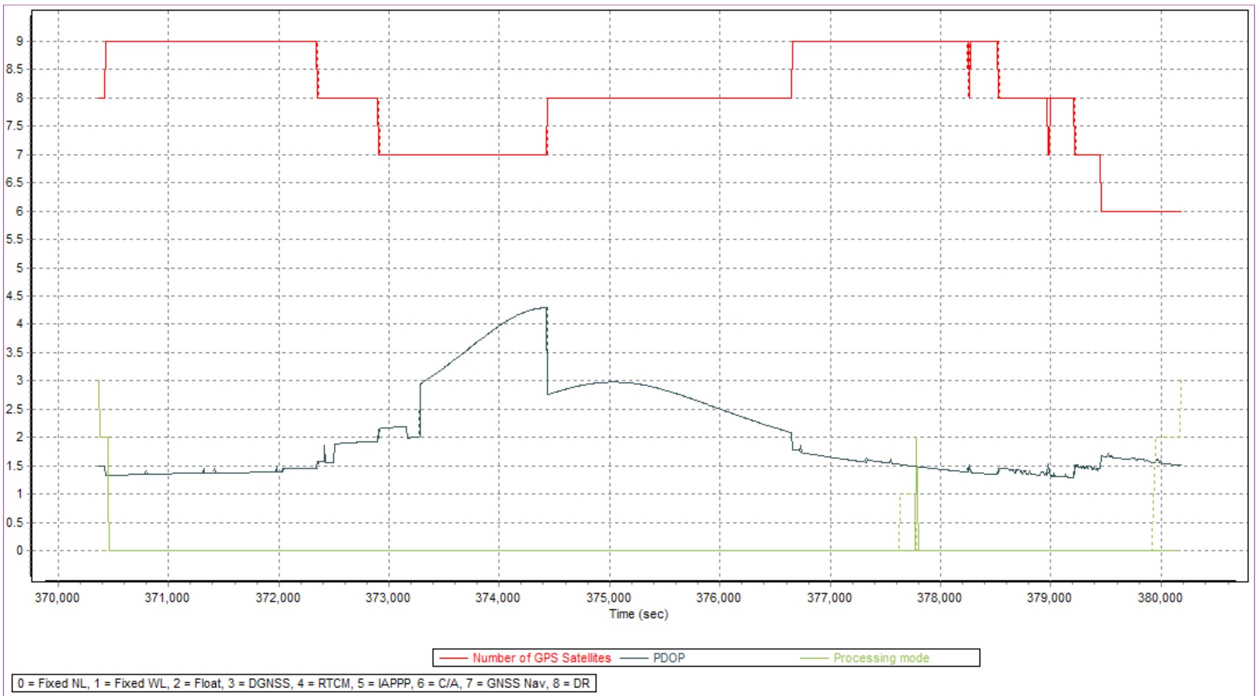


Figure A-8.148. Solution Status

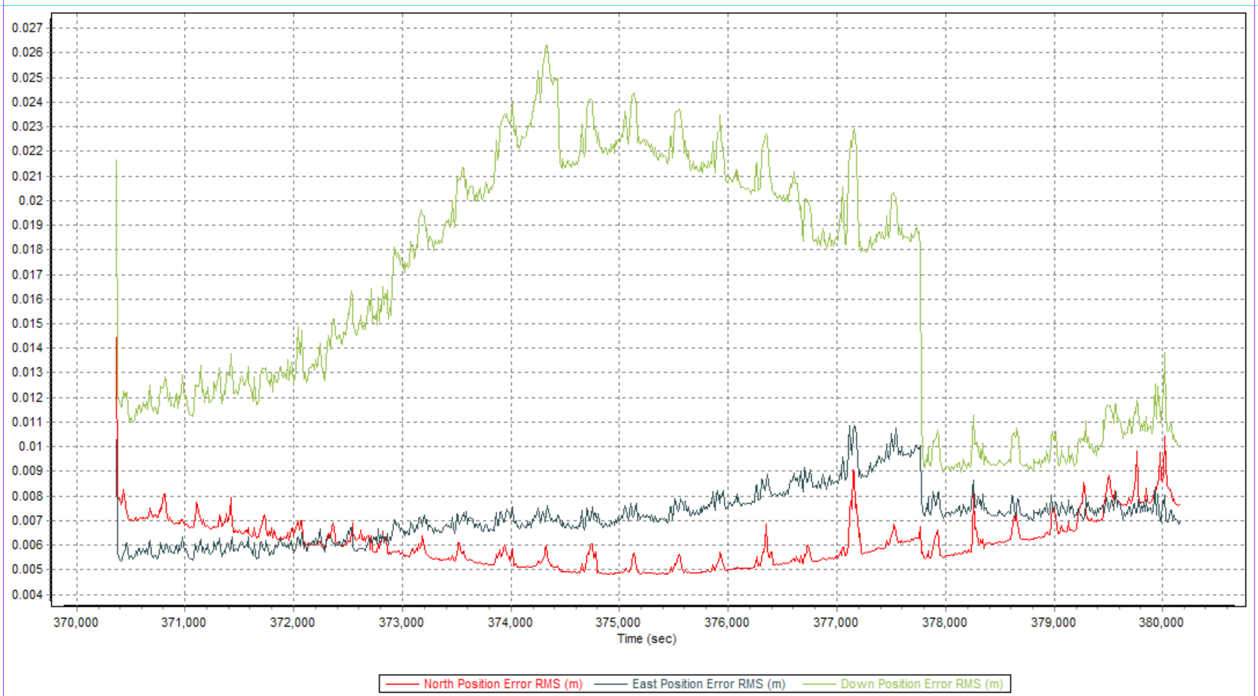


Figure A-8.149. Smoothed Performance Metrics Parameters

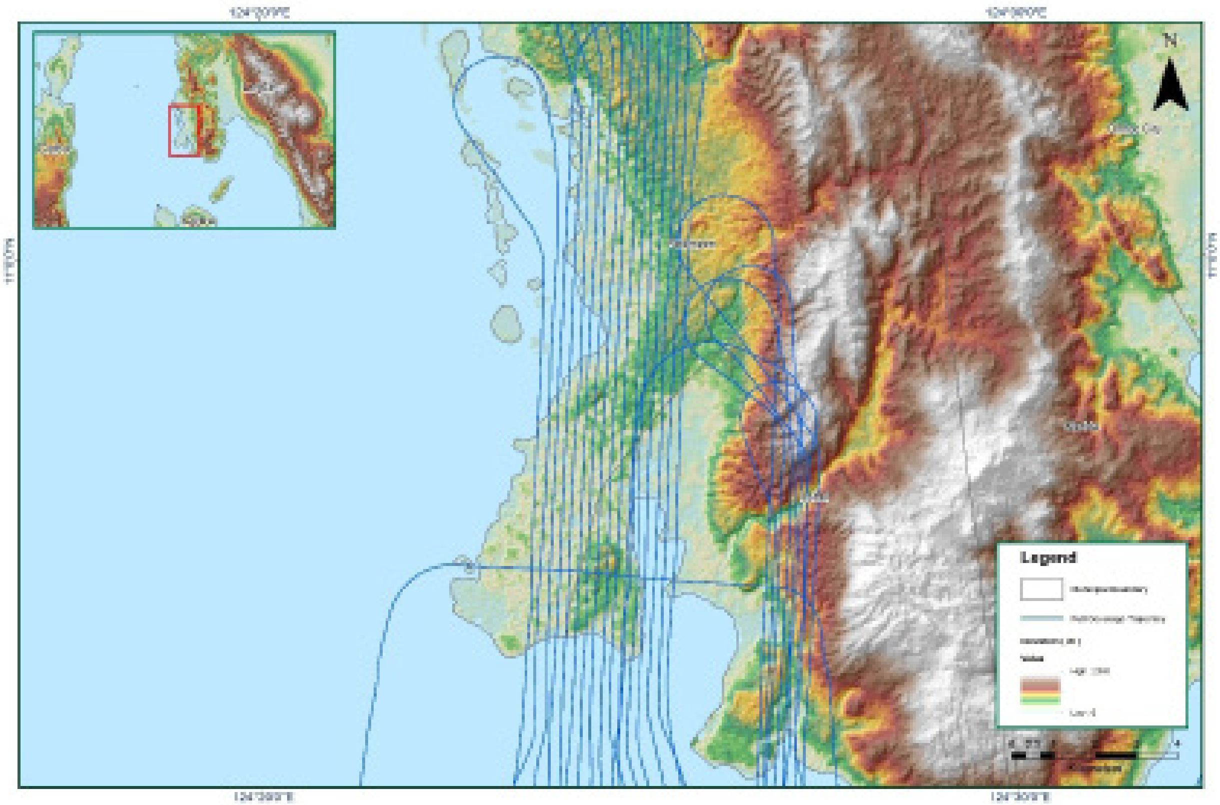


Figure A-8.150. Best Estimated Trajectory

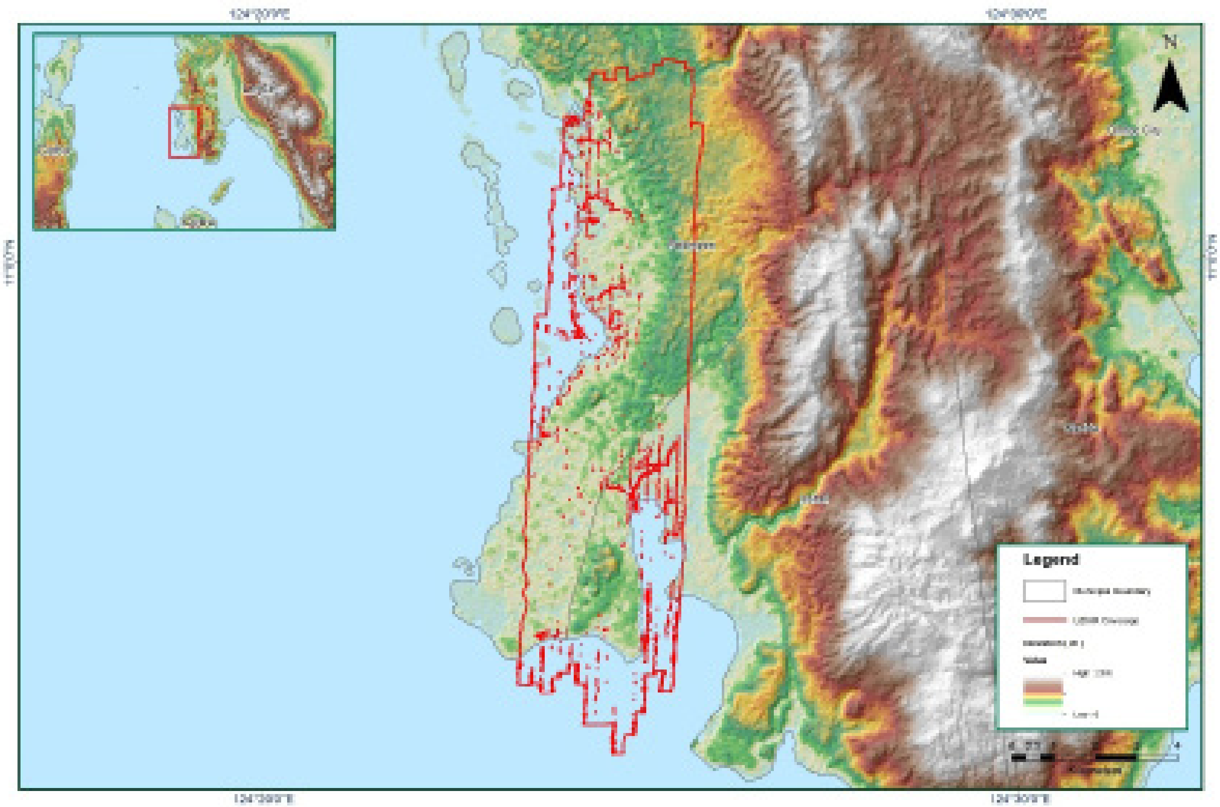


Figure A-8.151. Coverage of LiDAR data

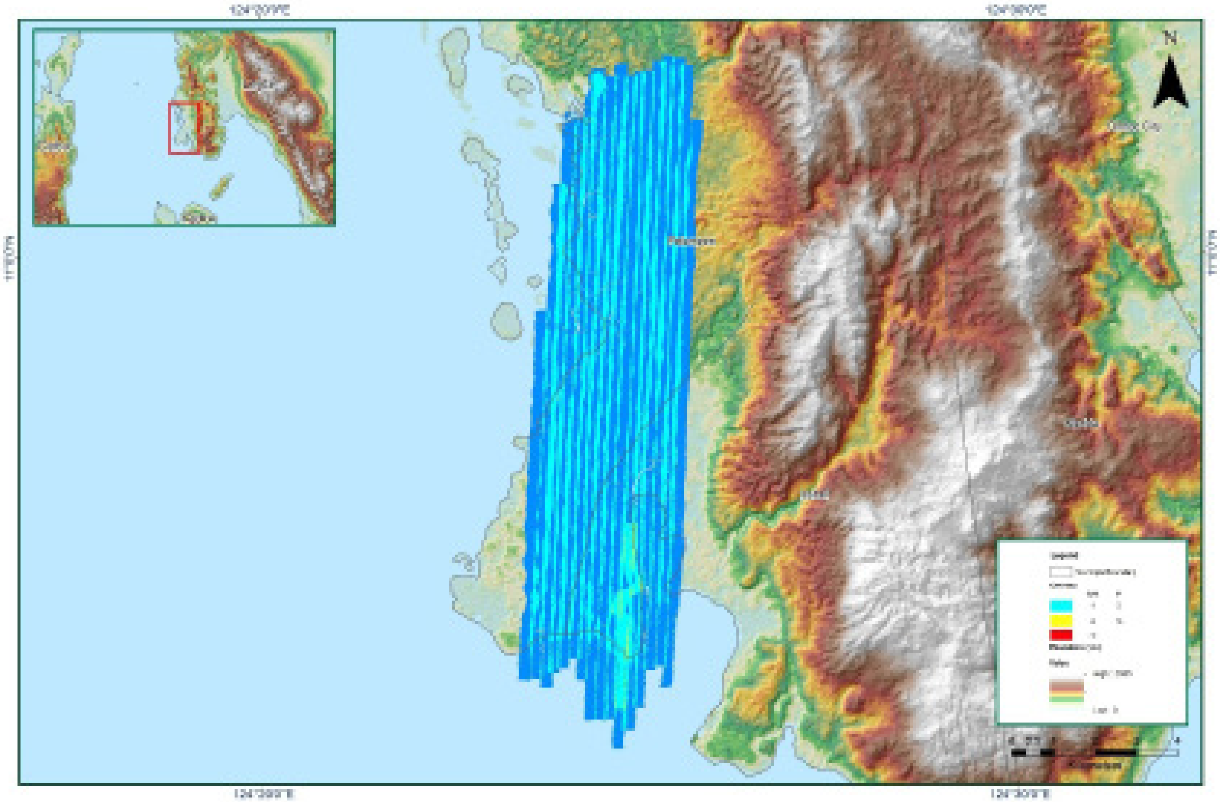


Figure A-8.152. Image of data overlap

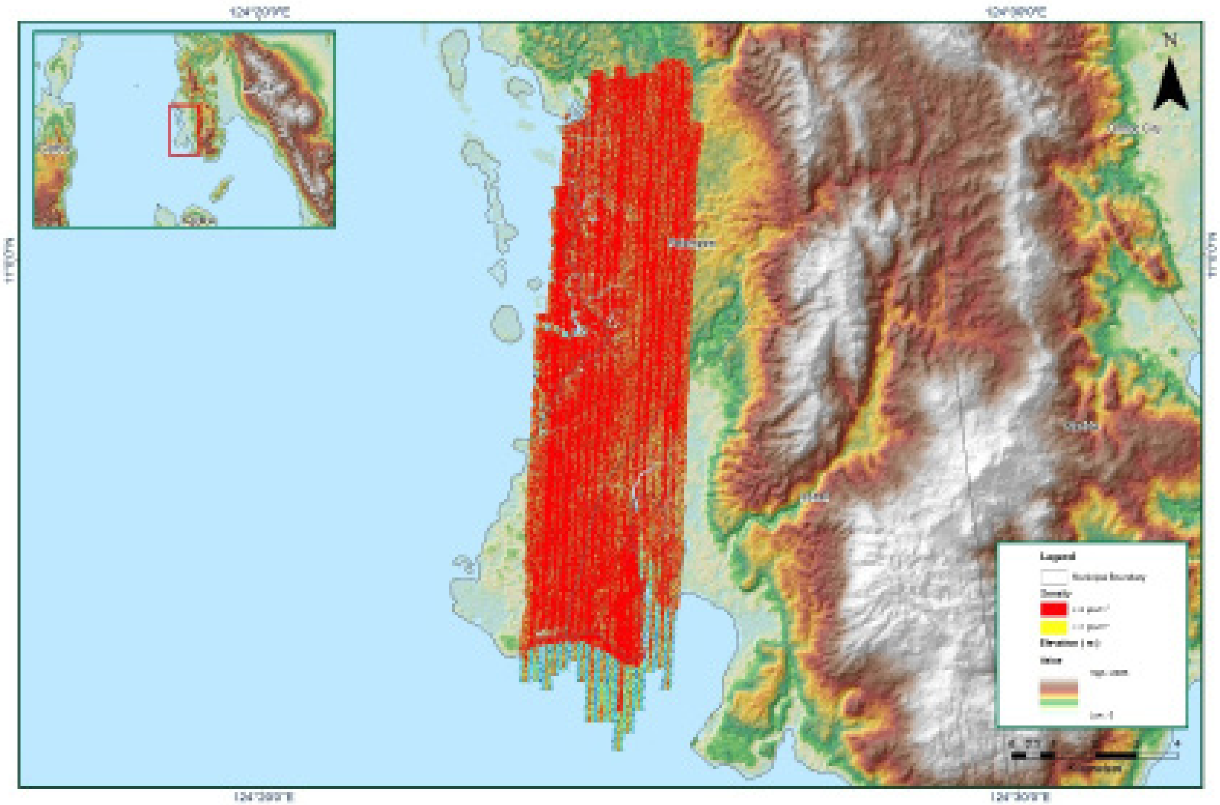


Figure A-8.153. Density map of merged LiDAR data

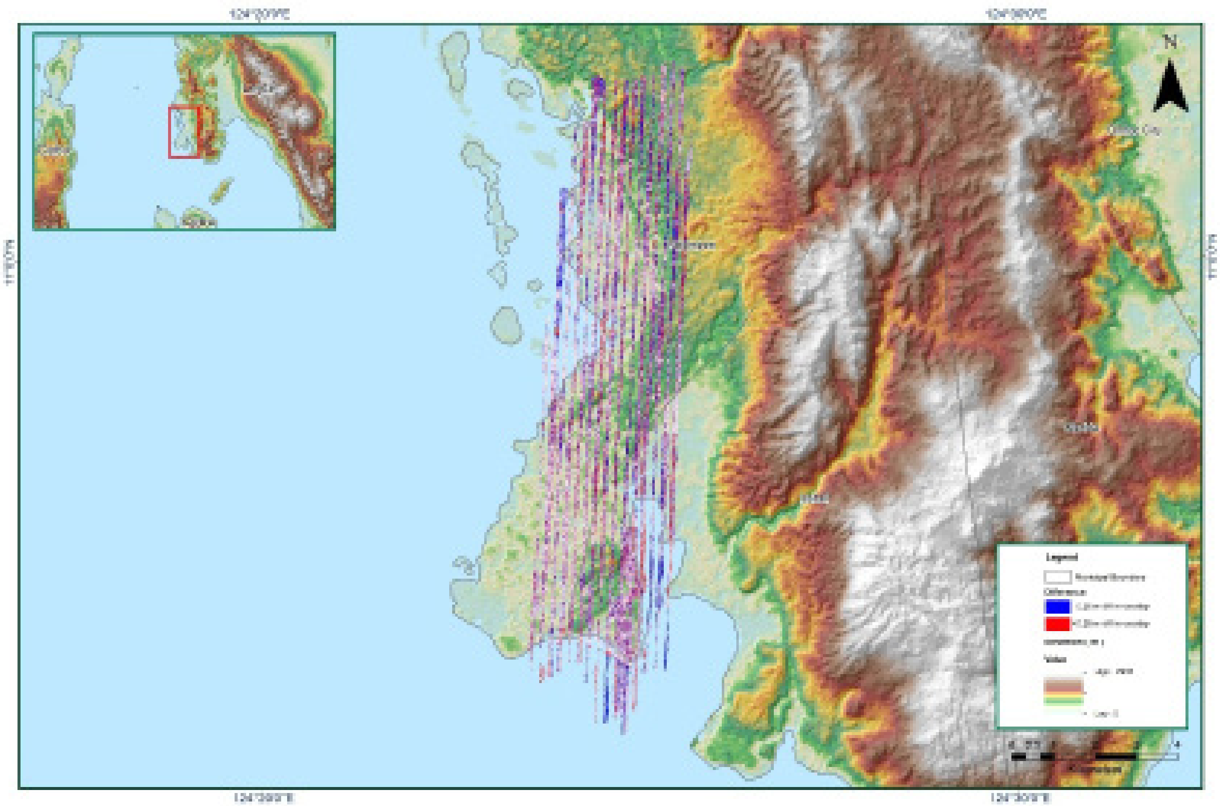


Figure A-8.154. Elevation difference between flight lines

Table A-8.23. Mission Summary Report for Mission Blk35H

Flight Area	Ormoc_Camotes
Mission Name	Blk35H
Inclusive Flights	8392A
Range data size	9.68 GB
POS	198 MB
Image	37.6 MB
Base Station	265 MB
Transfer date	March 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.09
RMSE for Down Position (<8.0 cm)	2.63
Boresight correction stdev (<0.001deg)	0.000461
IMU attitude correction stdev (<0.001deg)	0.002204
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	56.10
Ave point cloud density per sq.m. (>2.0)	3.96
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	28
Maximum Height	277.27
Minimum Height	56.77
Classification (# of points)	
Ground	8,304,789
Low vegetation	8,090,694
Medium vegetation	12,141,801
High vegetation	16,625,105
Building	1,890,226
Orthophoto	None
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Elainne Lopez

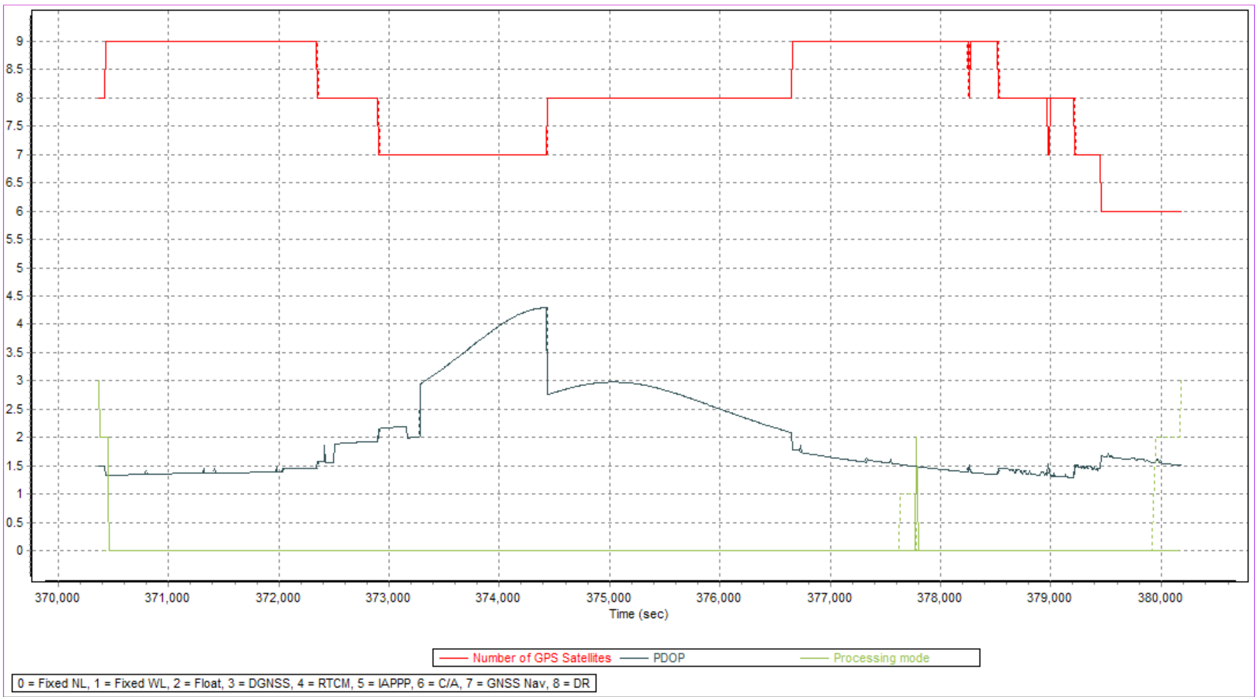


Figure A-8.155. Solution Status

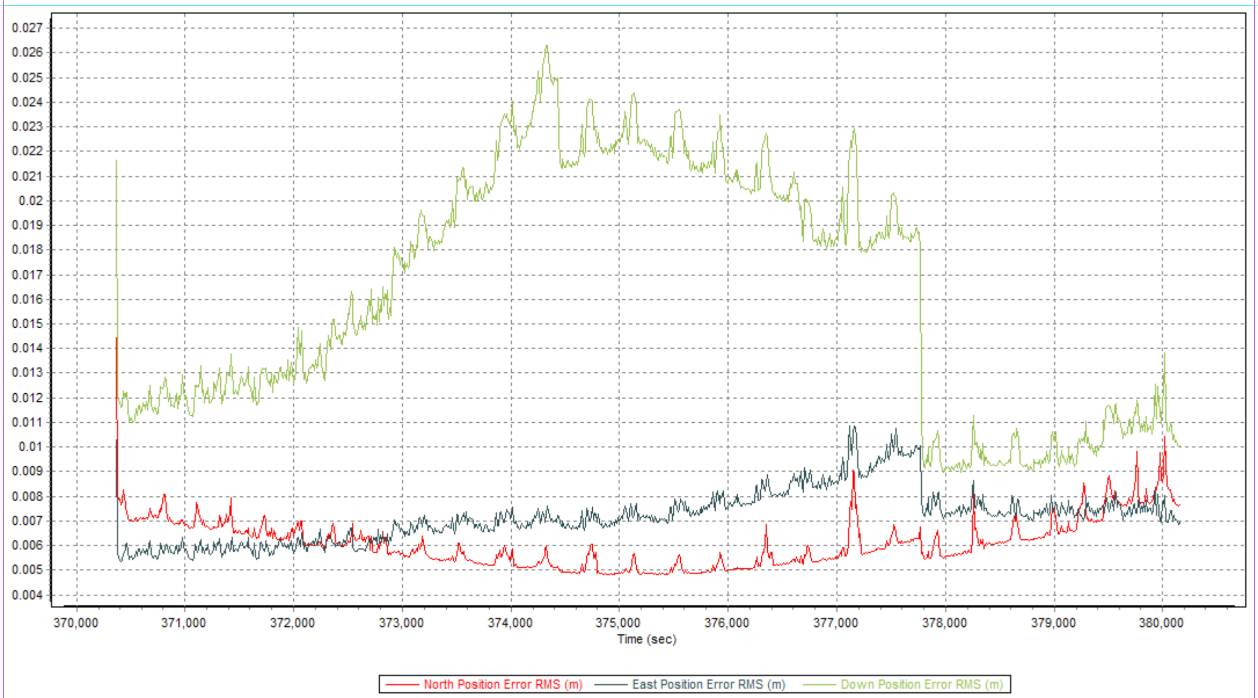


Figure A-8.156. Smoothed Performance Metrics Parameters

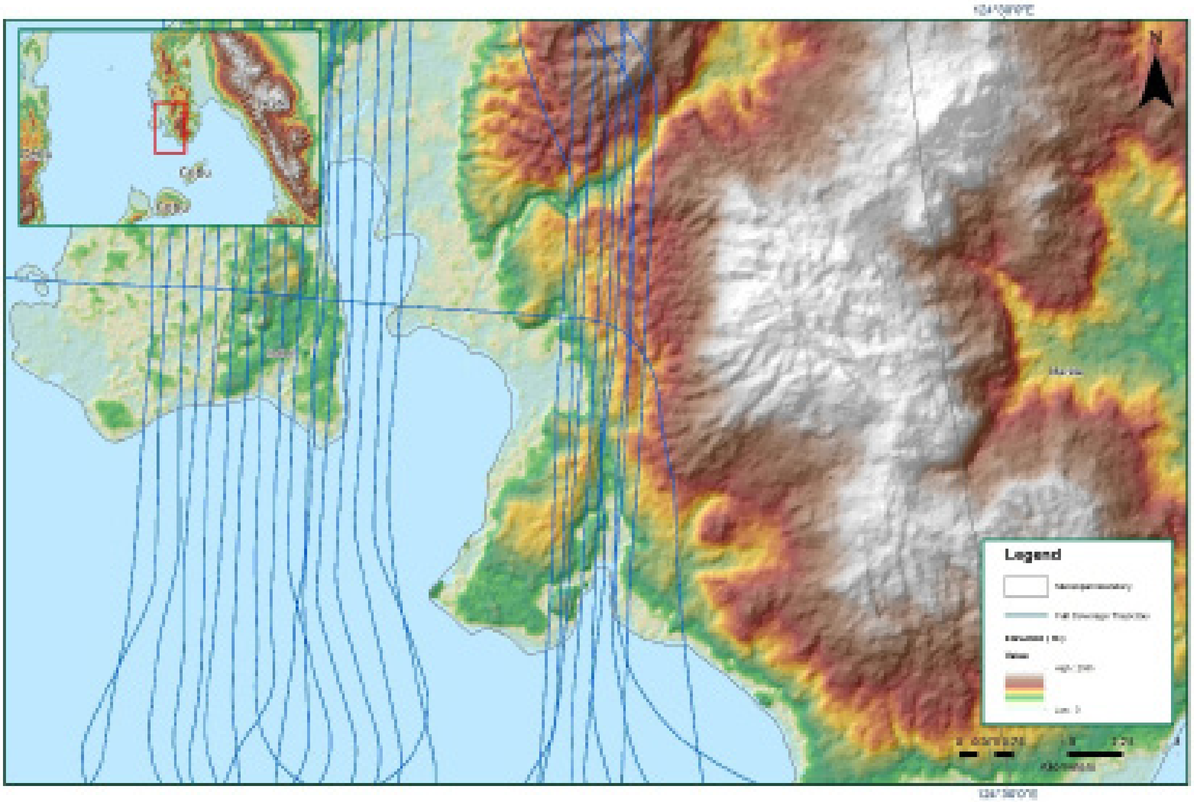


Figure A-8.157. Best Estimated Trajectory

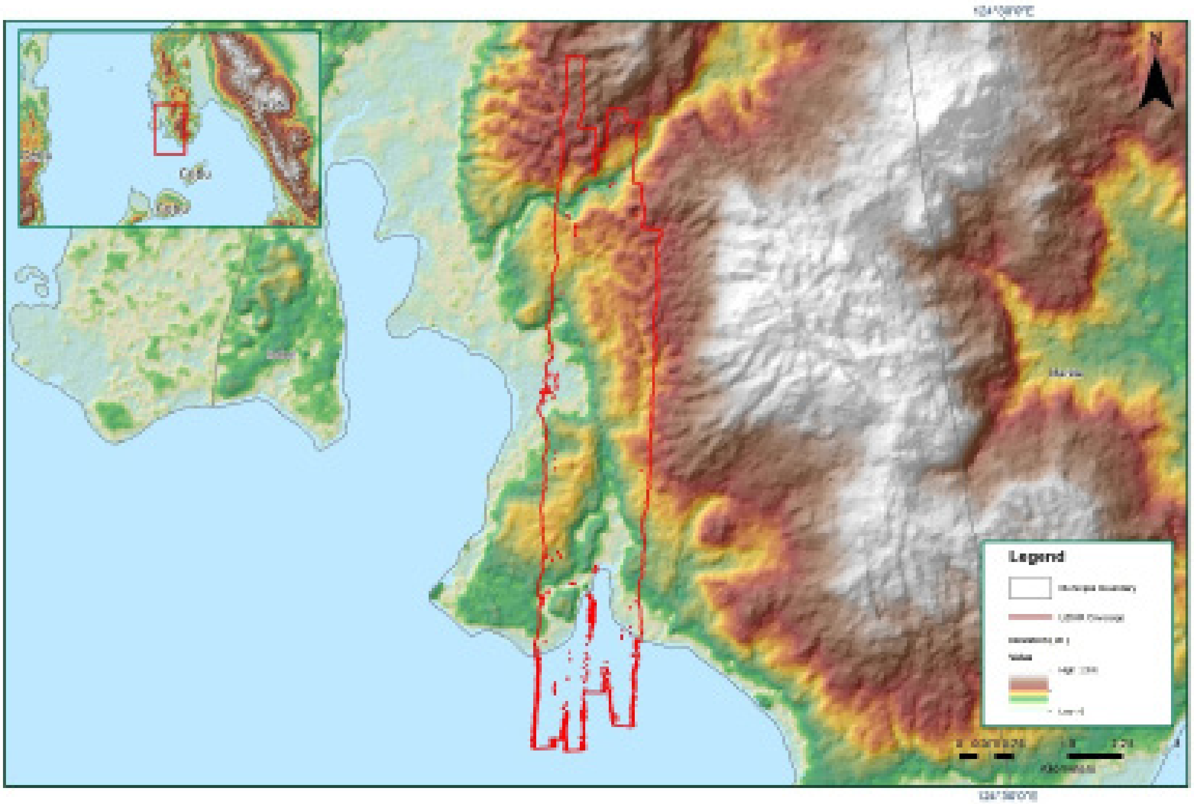


Figure A-8.158. Best Estimated Trajectory

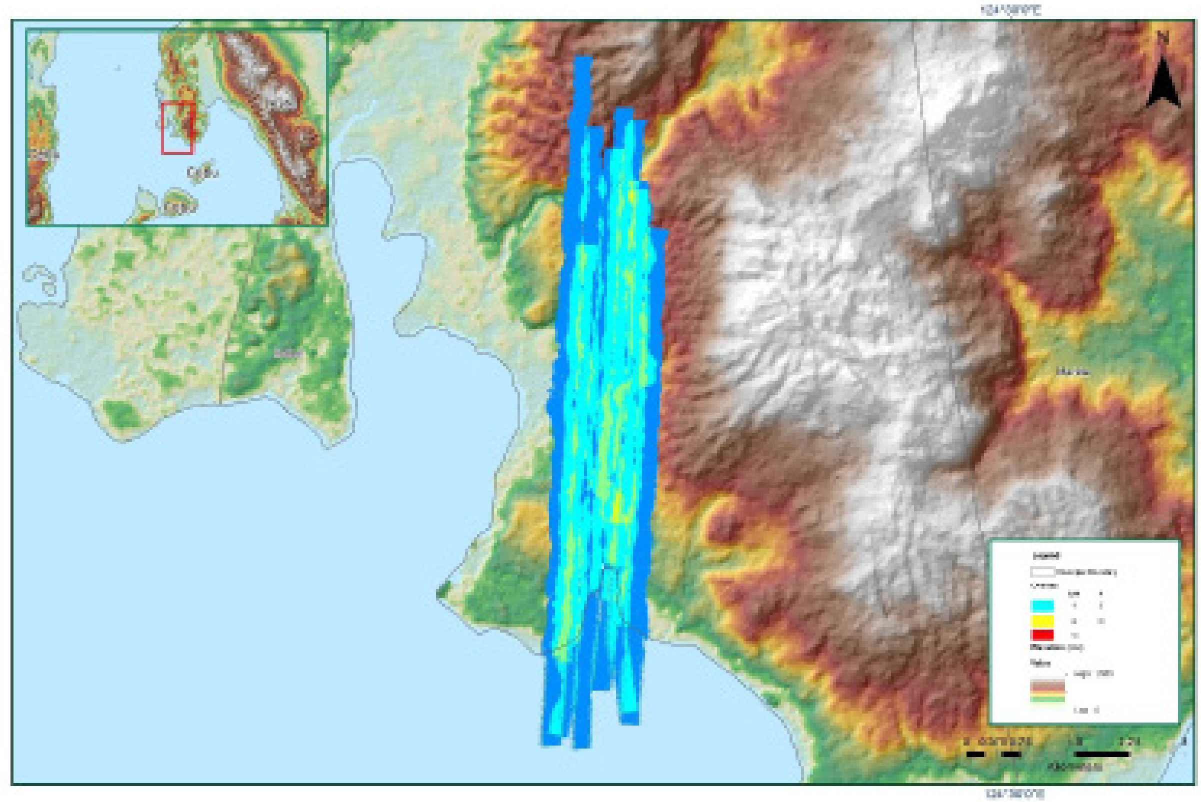


Figure A-8.159. Image of data overlap

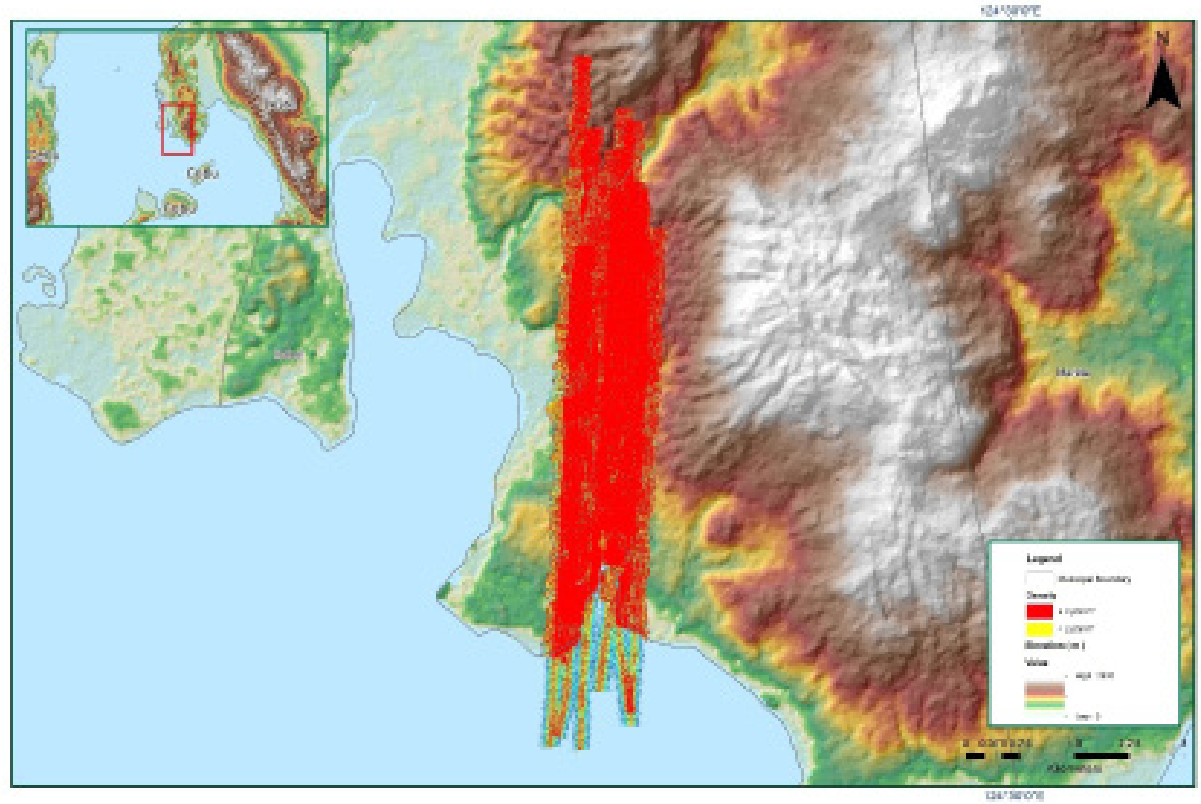


Figure A-8.160. Density map of merged LiDAR data

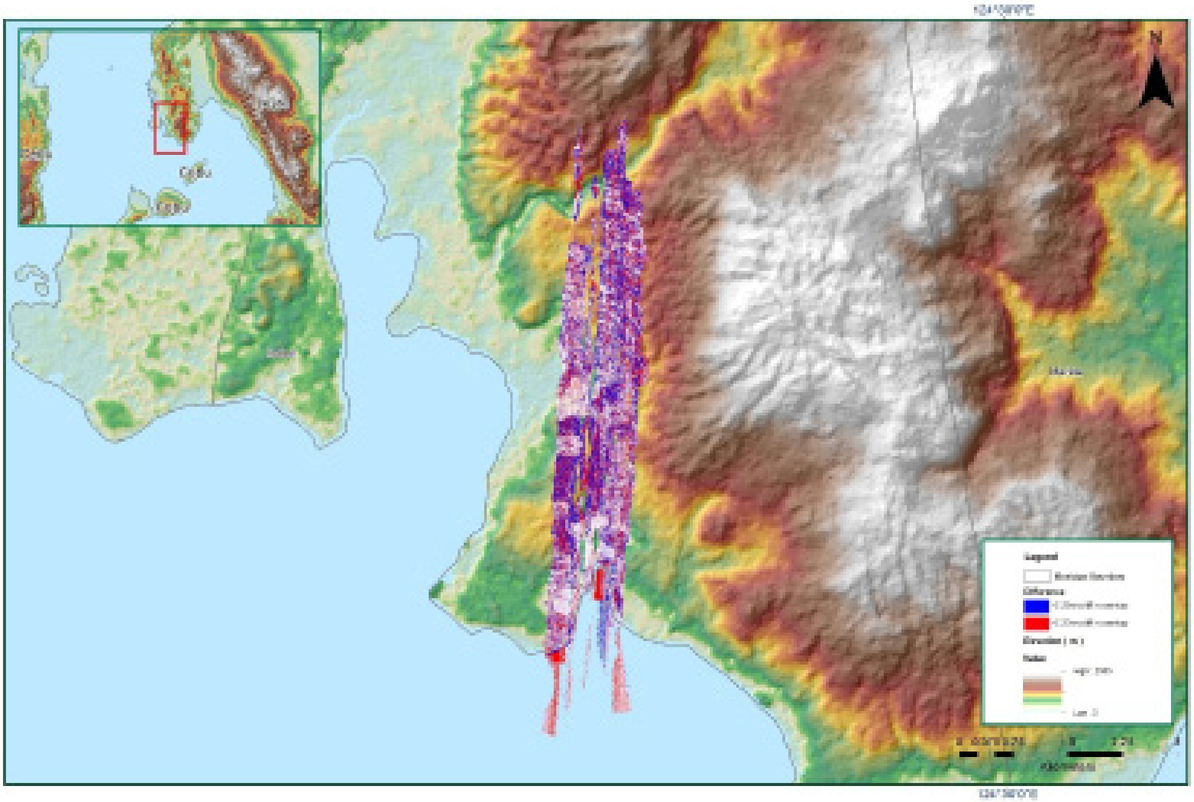


Figure A-8.161. Elevation difference between flight lines

Table A-8.24. Mission Summary Report for Mission Blk35H_Supplement

Flight Area	Ormoc_Camotes
Mission Name	Blk35H_Supplement
Inclusive Flights	8408AC
Range data size	5.14 GB
POS	208 MB
Image	56.3 MB
Base Station	263 MB
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.03
RMSE for East Position (<4.0 cm)	1.24
RMSE for Down Position (<8.0 cm)	3.59
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	41.06
Ave point cloud density per sq.m. (>2.0)	2.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	42
Maximum Height	438.66
Minimum Height	45.93
Classification (# of points)	
Ground	13,820,590
Low vegetation	6,300,170
Medium vegetation	12,967,315
High vegetation	22,021,720
Building	859,613
Orthophoto	None
Processed by	Engr. Regis Guhiting, Aljon Rie Araneta, Engr. Czarina Jean Añonuevo

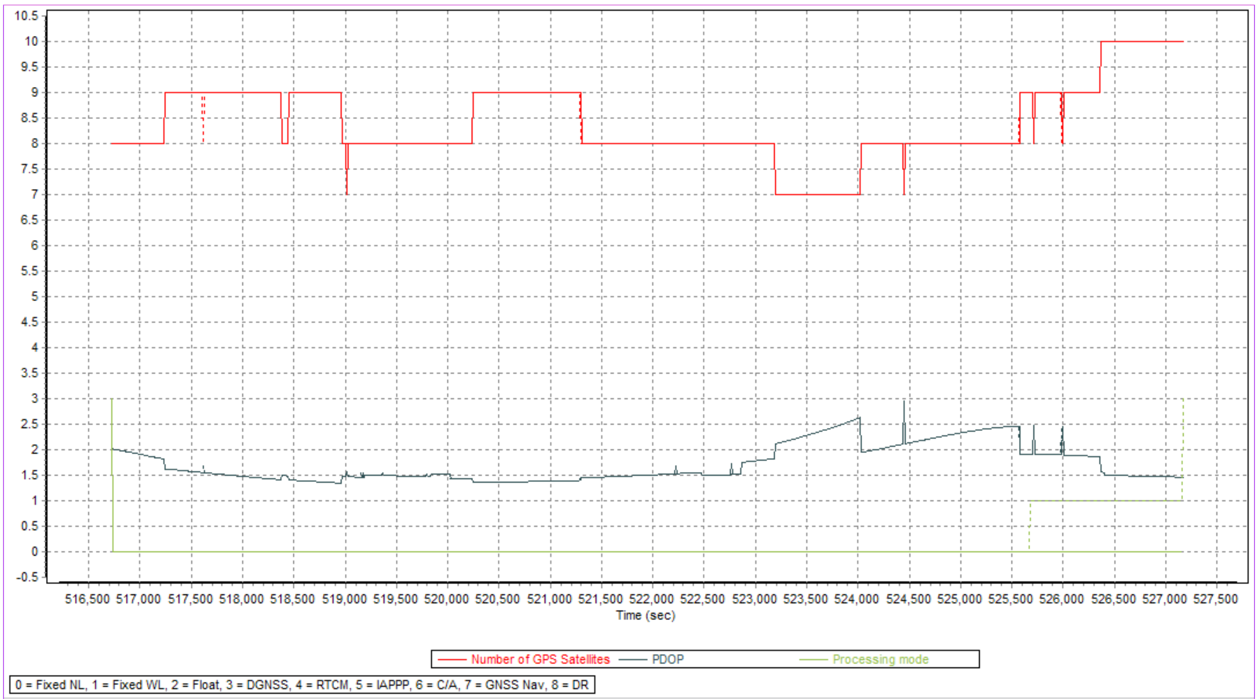


Figure A-8.162. Solution Status

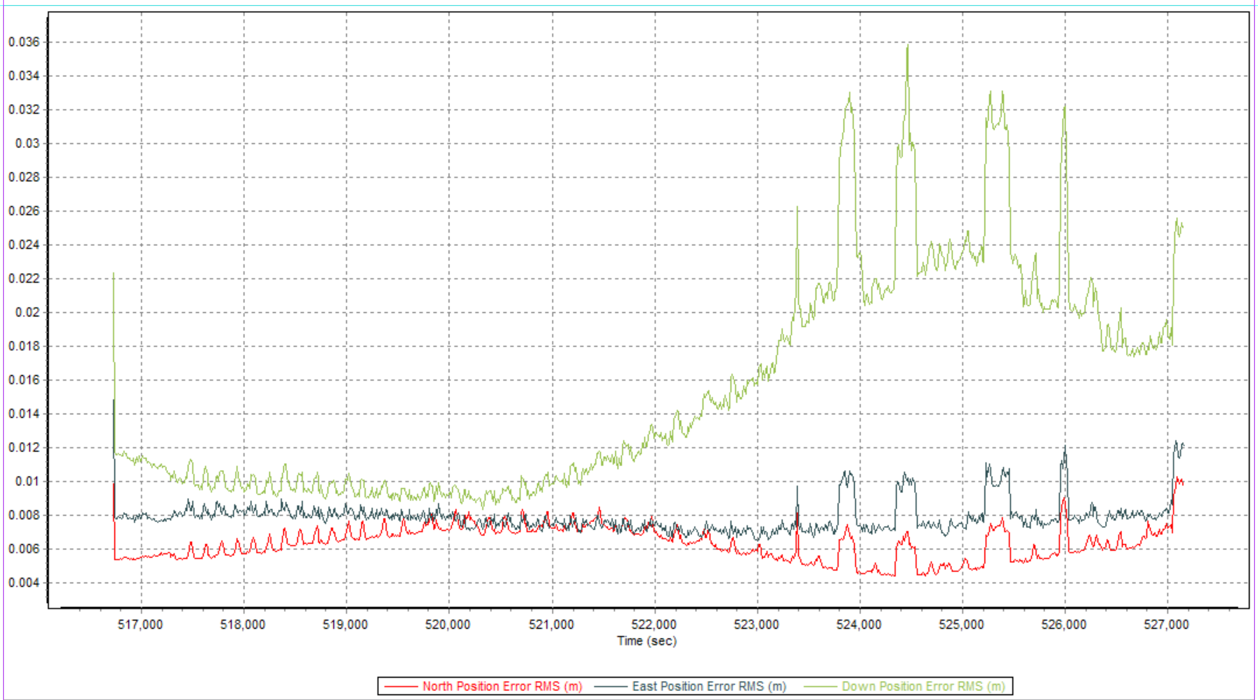


Figure A-8.163. Smoothed Performance Metrics Parameters

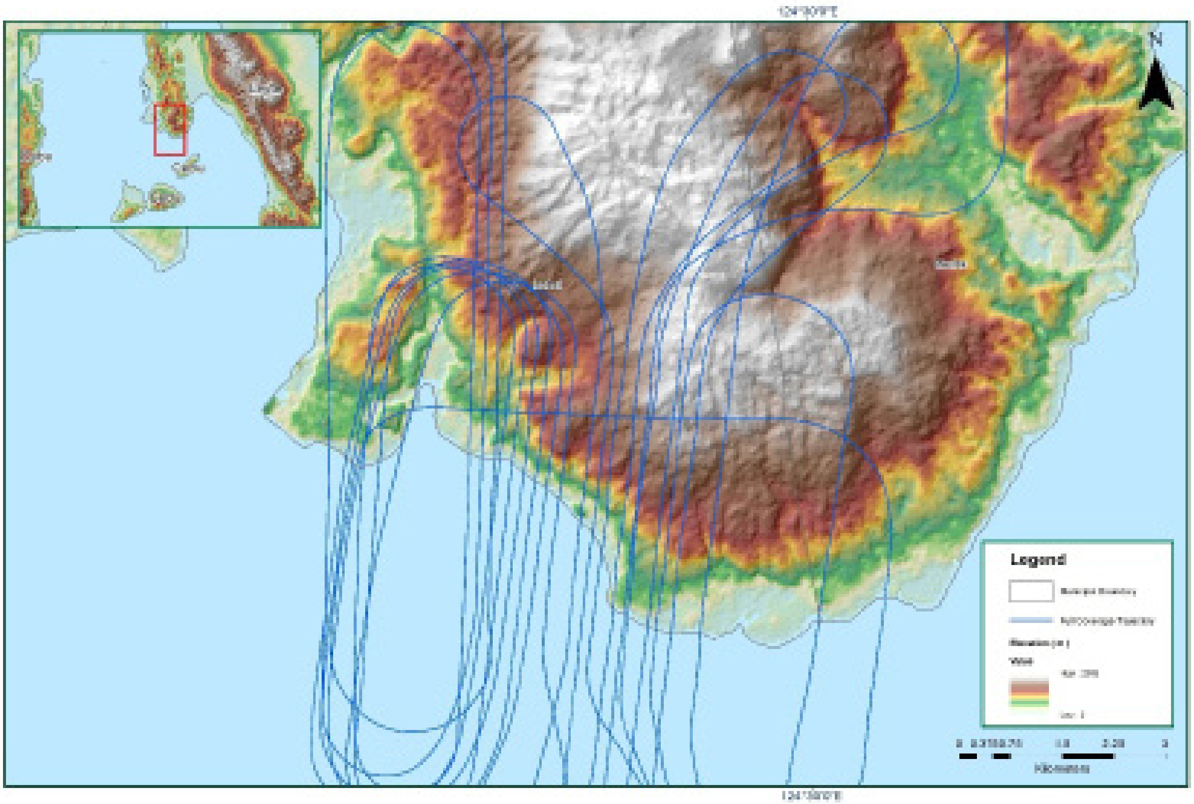


Figure A-8.164. Best Estimated Trajectory

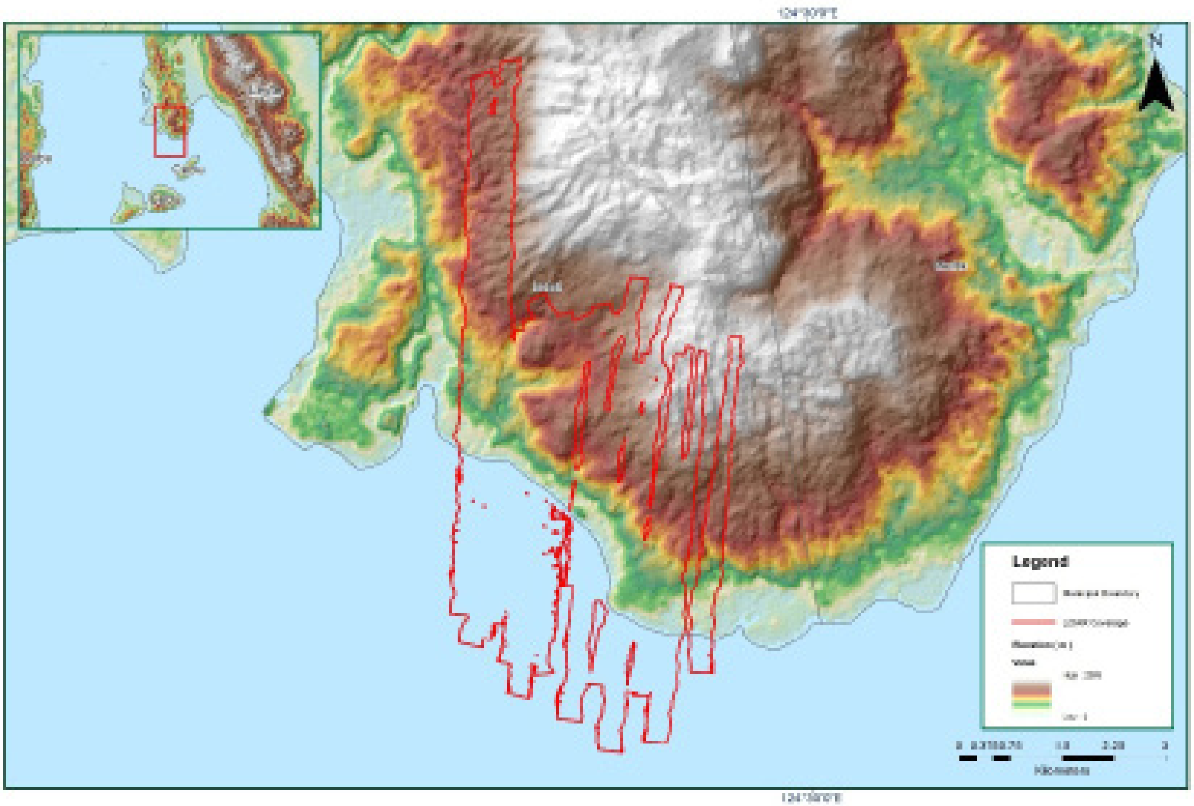


Figure A-8.165. Coverage of LiDAR data

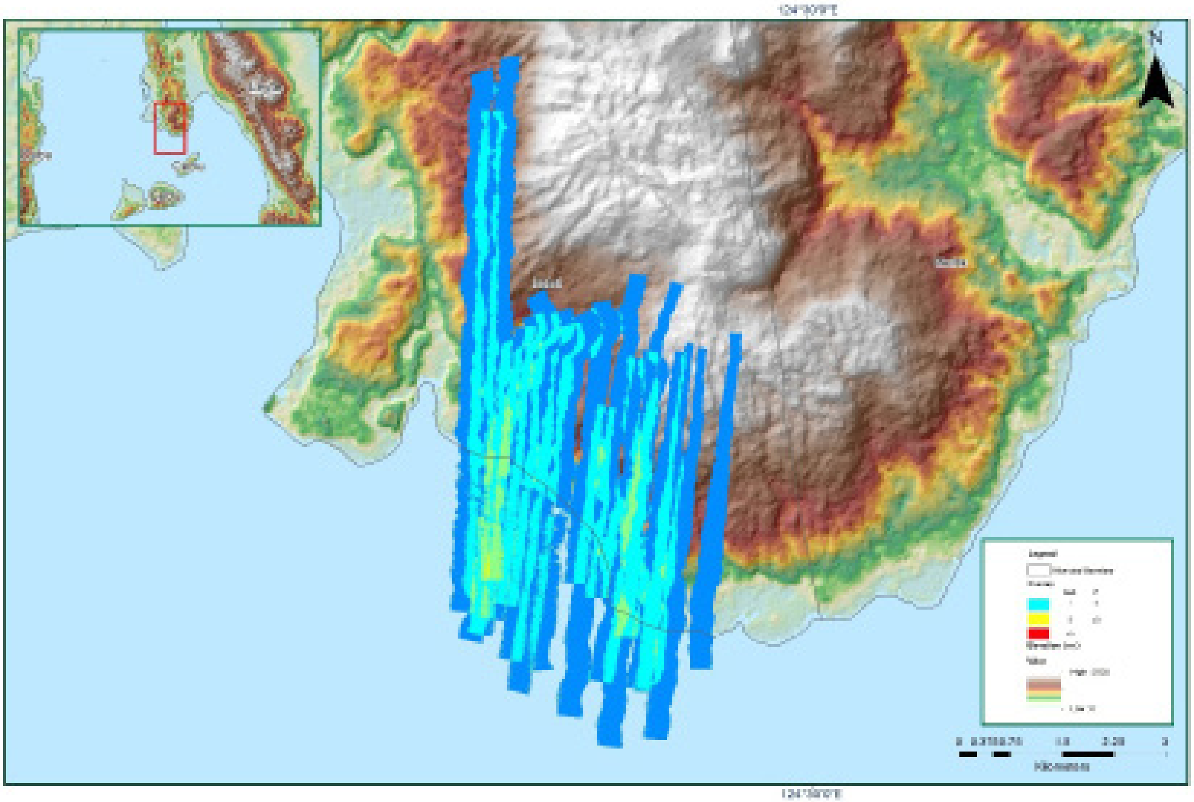


Figure A-8.166. Image of data overlap

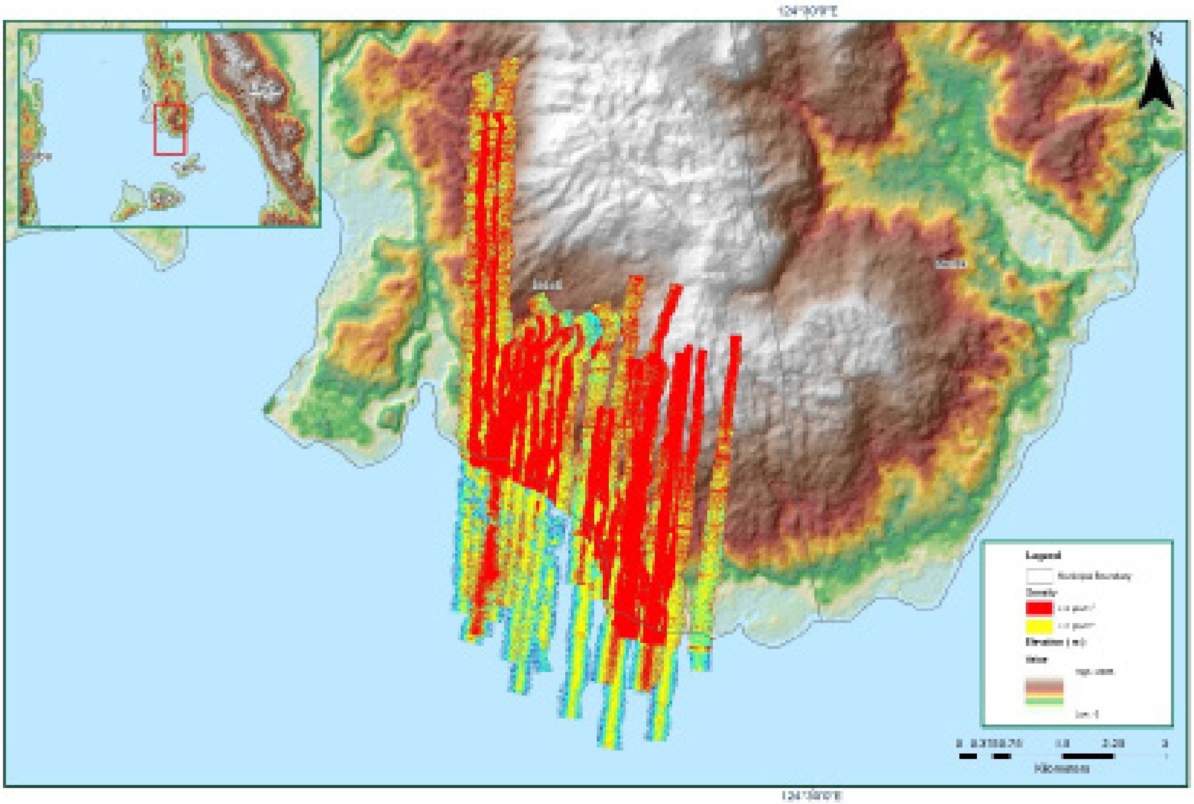


Figure A-8.167. Density map of merged LiDAR data

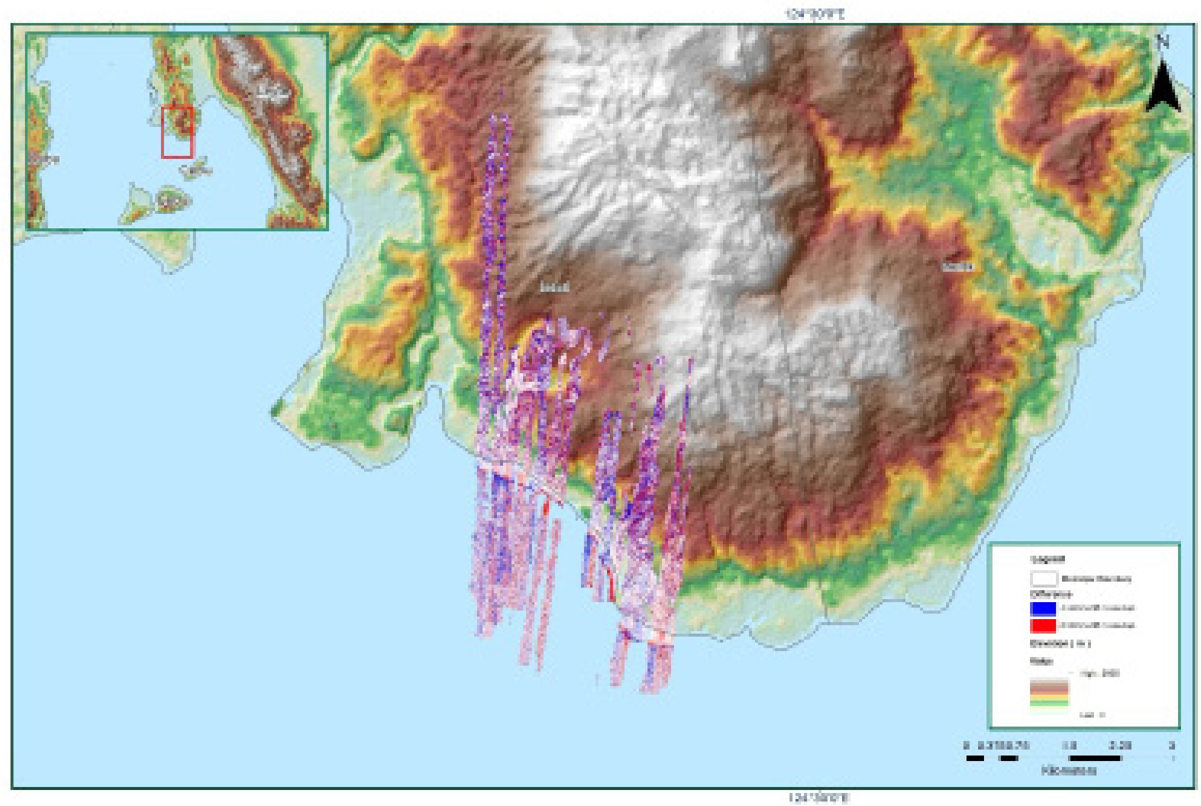


Figure A-8.168. Elevation difference between flight lines

Table A-8.25. Mission Summary Report for Mission Blk35J

Flight Area	Ormoc_Camotes
Mission Name	Blk35J
Inclusive Flights	8409AC_2
Range data size	4.86 GB
POS	87.4 MB
Image	35.4 MB
Base Station	263 MB
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.07
RMSE for East Position (<4.0 cm)	1.02
RMSE for Down Position (<8.0 cm)	3.55
Boresight correction stdev (<0.001deg)	0.000307
IMU attitude correction stdev (<0.001deg)	0.002496
GPS position stdev (<0.01m)	0.0196
Minimum % overlap (>25)	29.46
Ave point cloud density per sq.m. (>2.0)	3.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	44
Maximum Height	242.26
Minimum Height	60.52
Classification (# of points)	
Ground	11,888,555
Low vegetation	12,280,429
Medium vegetation	16,442,055
High vegetation	23,149,620
Building	1,462,594
Orthophoto	None
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Alex John Escobido

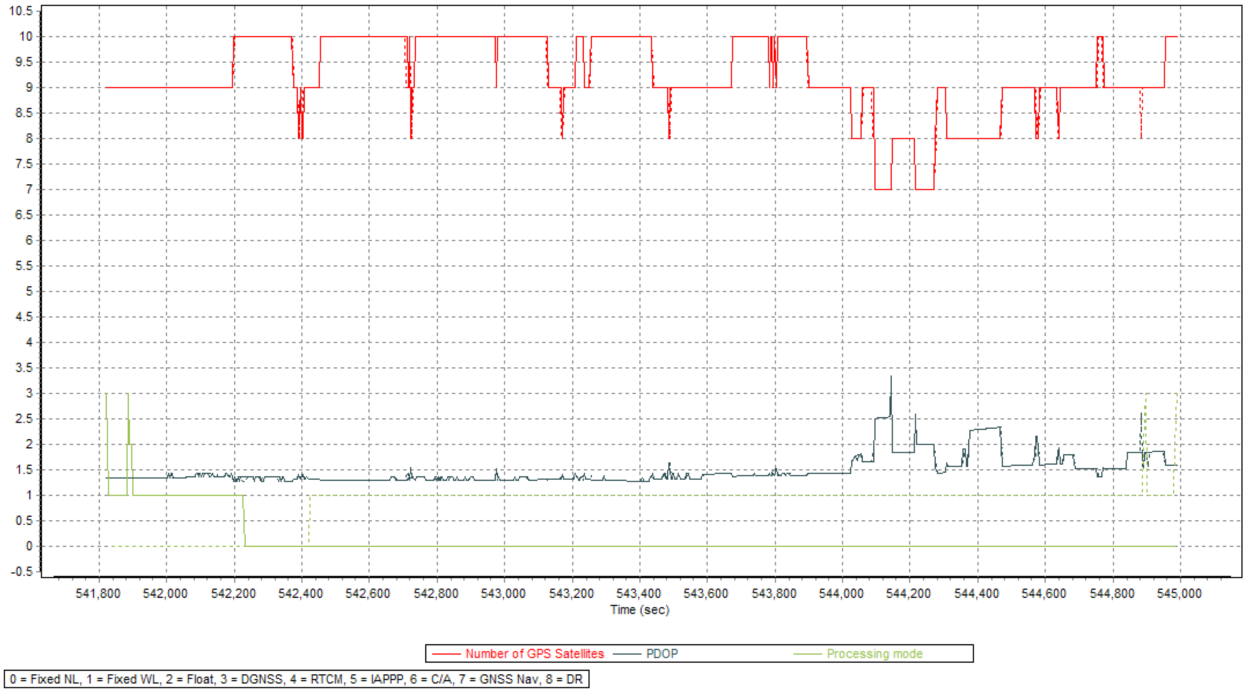


Figure A-8.169. Solution Status

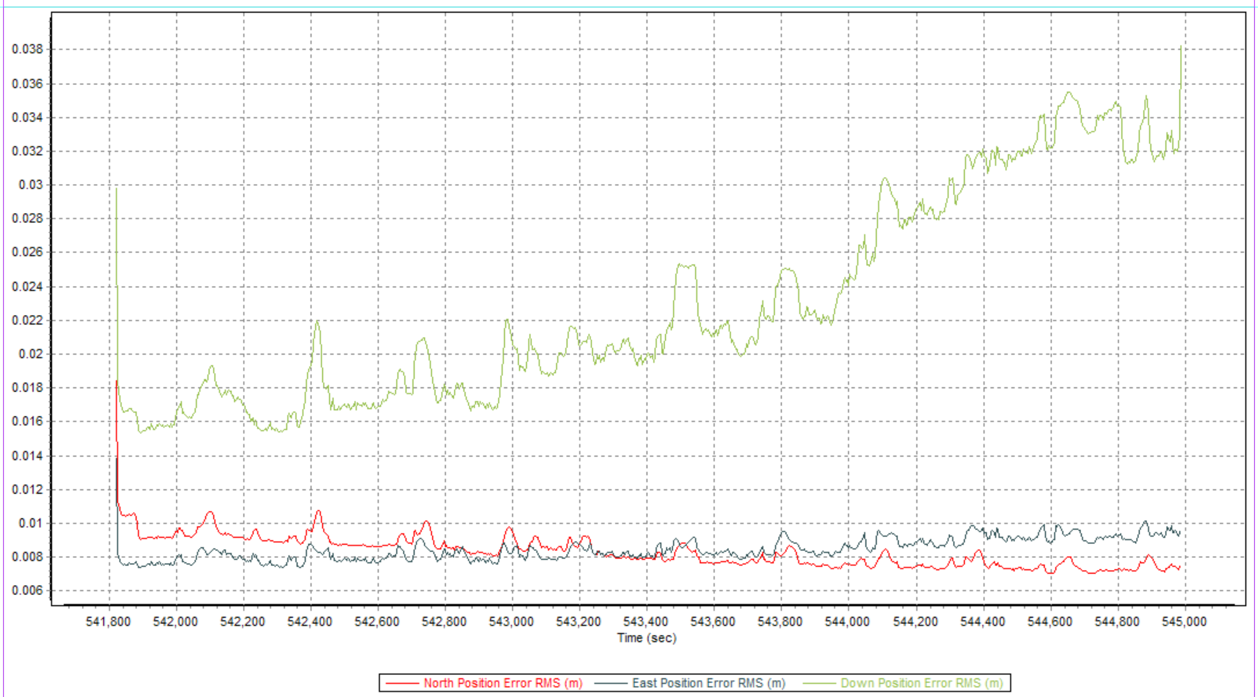


Figure A-8.170. Smoothed Performance Metrics Parameters

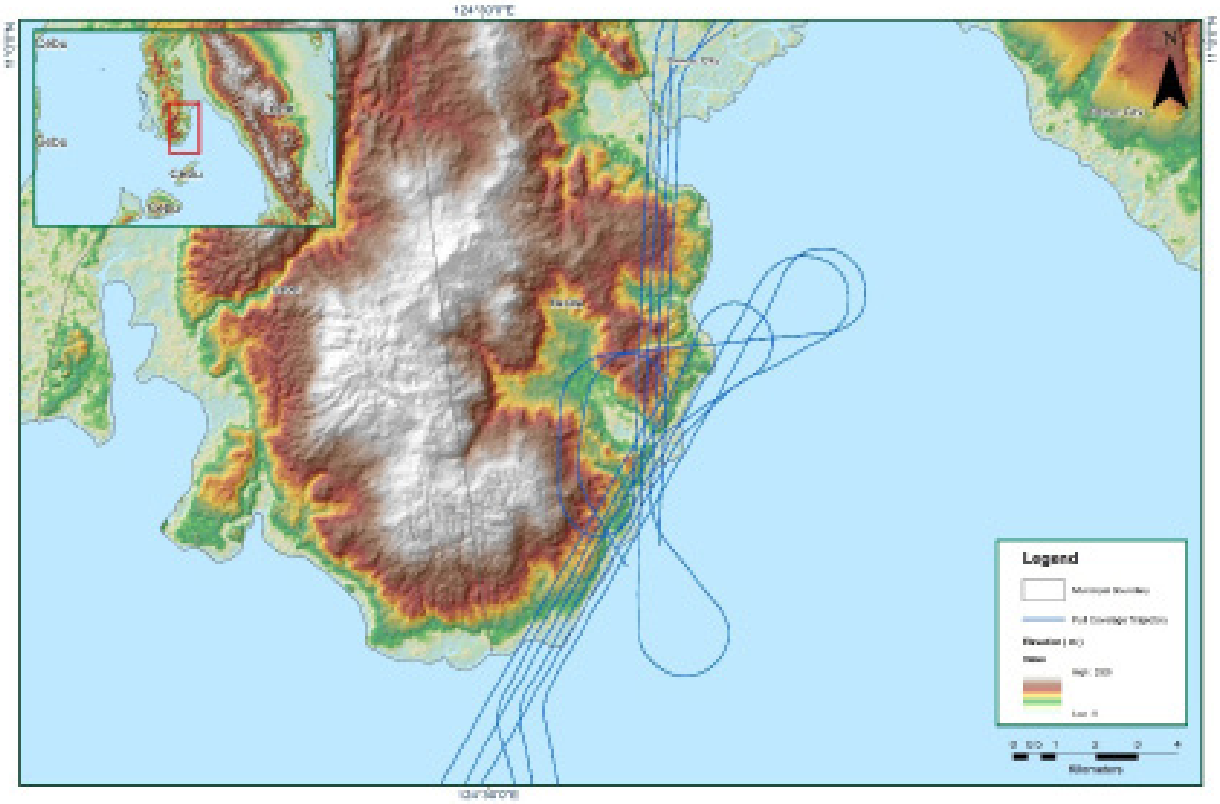


Figure A-8.171. Best Estimated Trajectory

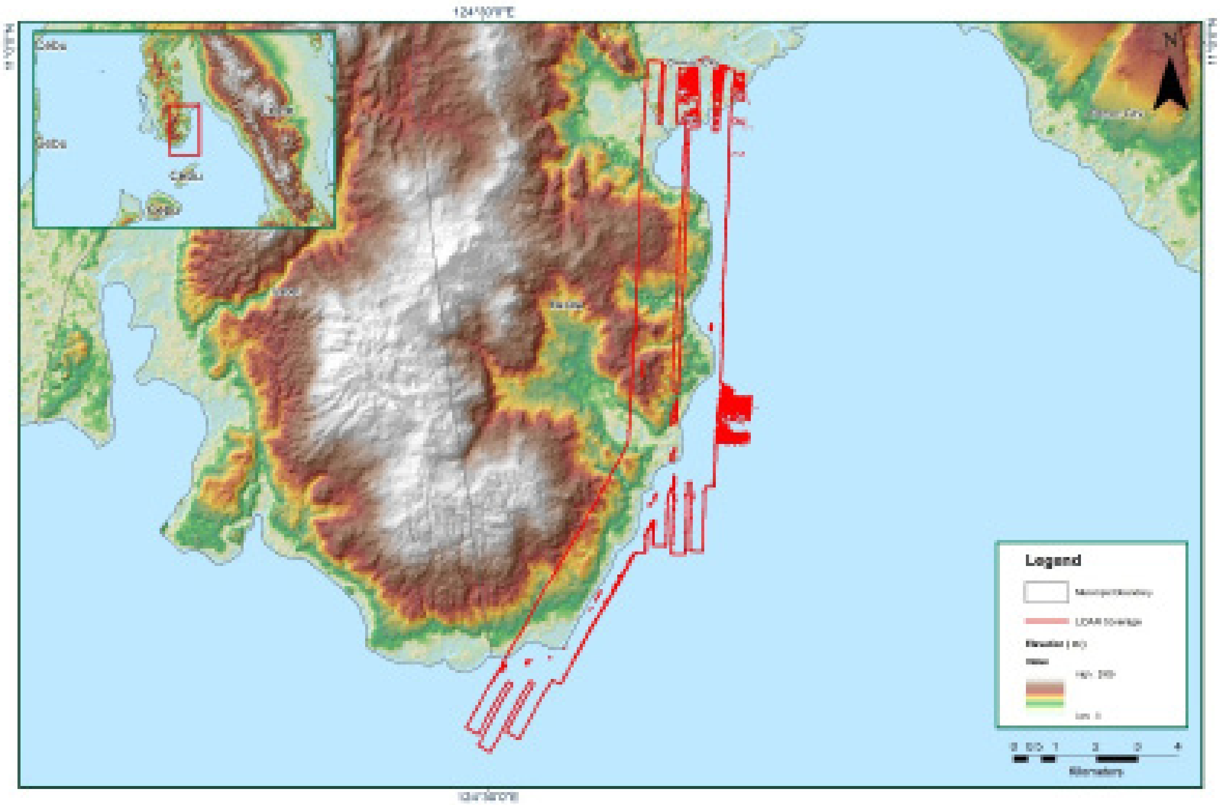


Figure A-8.172. Best Estimated Trajectory

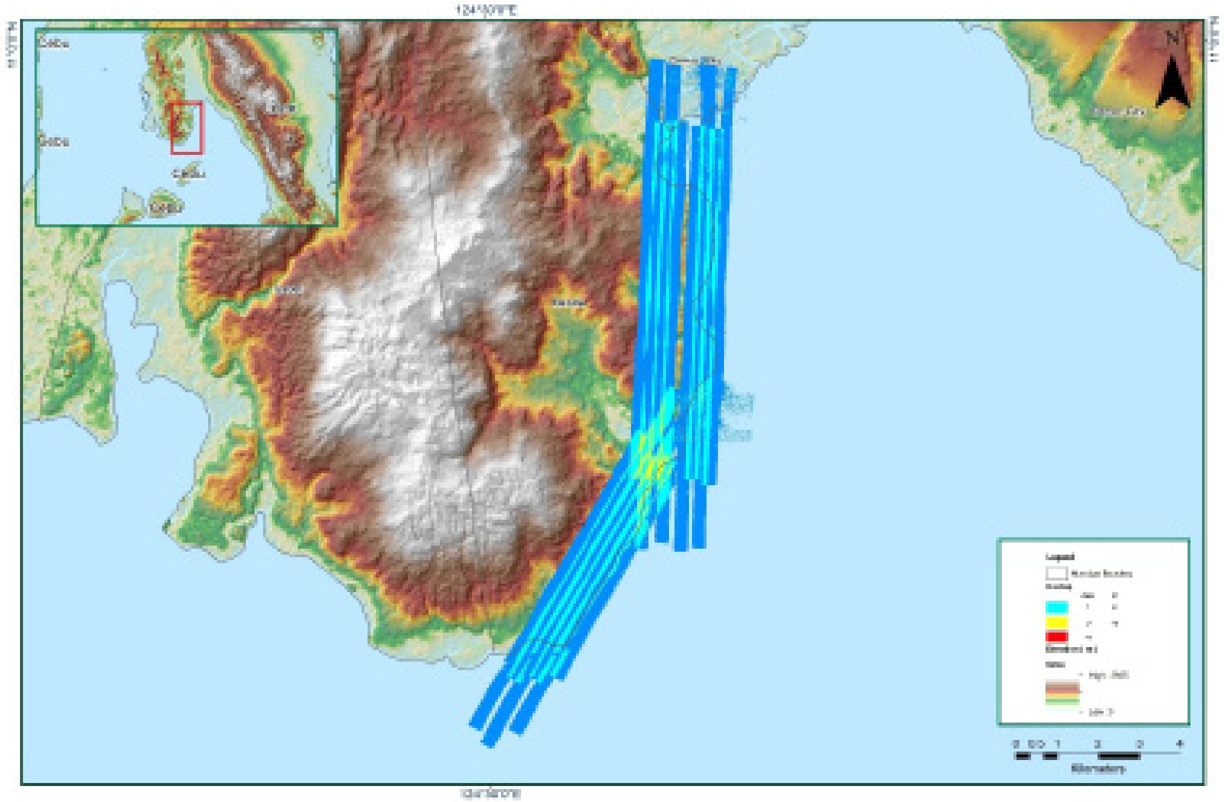


Figure A-8.173. Image of data overlap

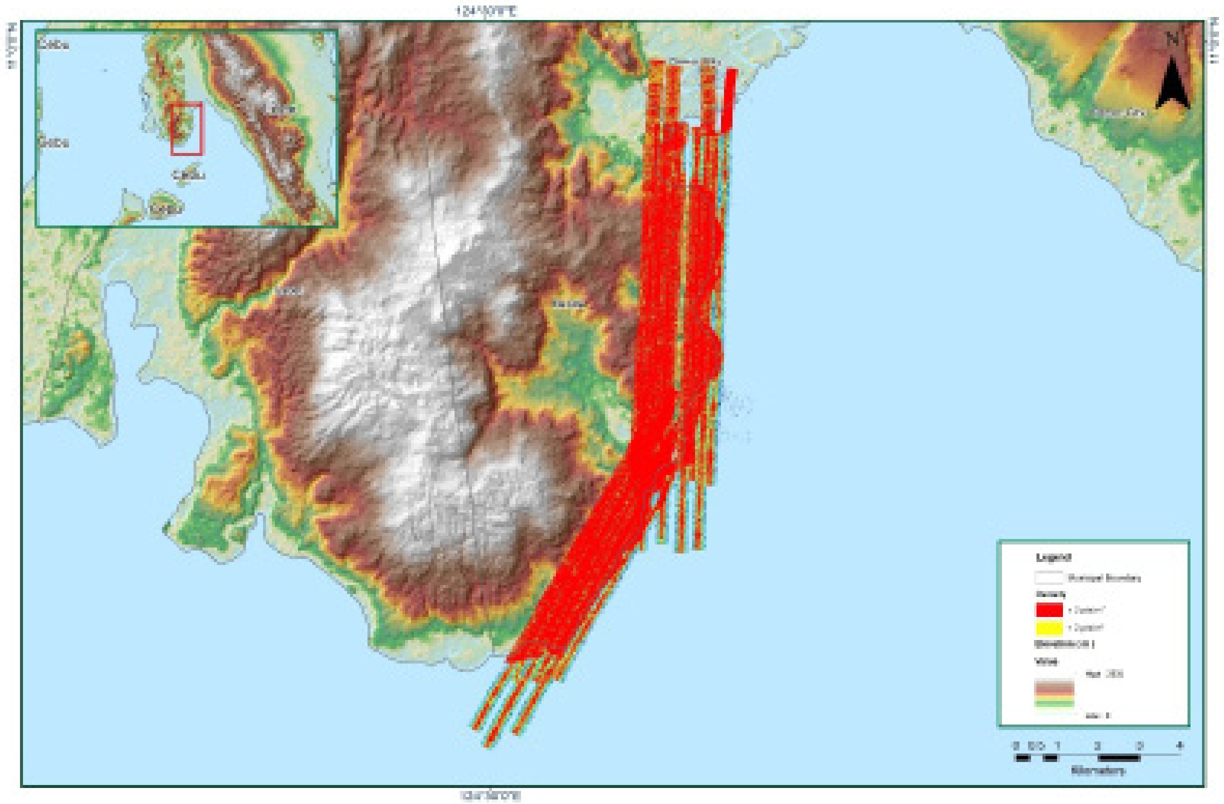


Figure A-8.174. Density map of merged LiDAR data

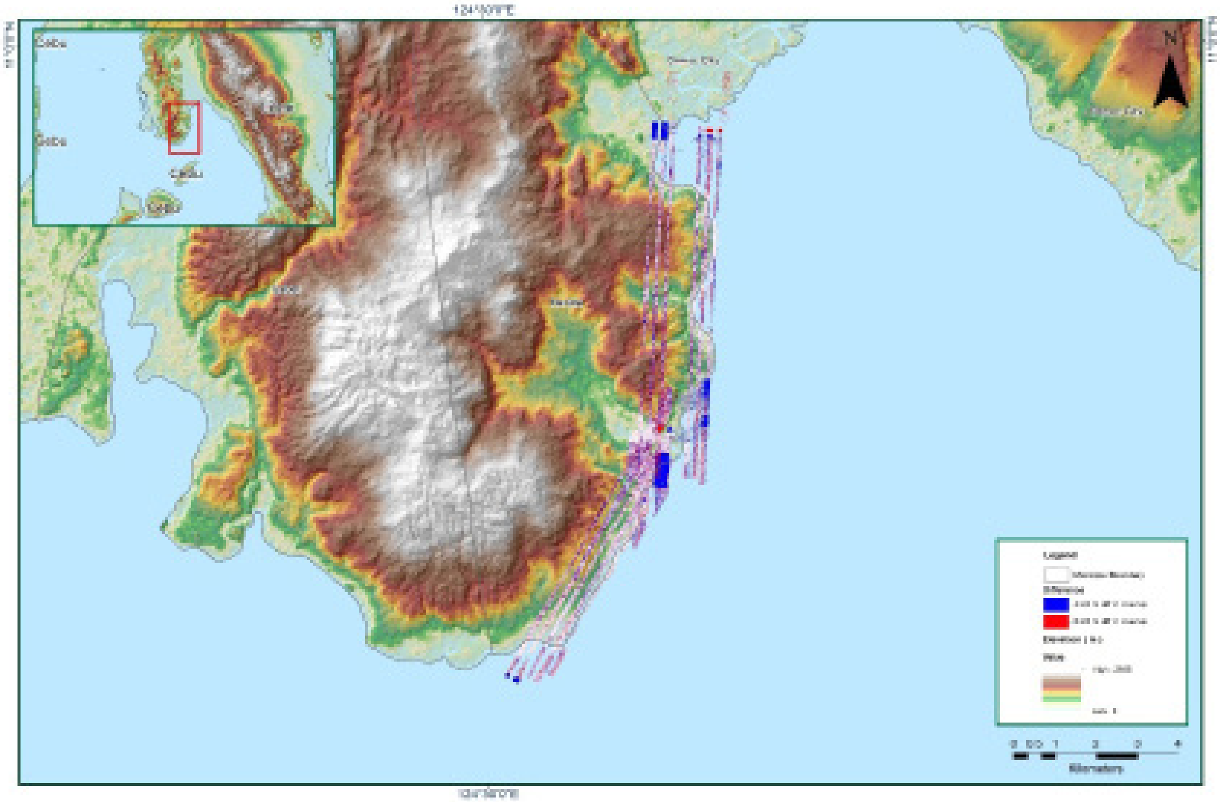


Figure A-8.175. Elevation difference between flight lines

Table A-8.26. Mission Summary Report for Mission Blk35A

Flight Area	Ormoc South
Mission Name	Blk35A
Inclusive Flights	3945G
Range data size	17.1 GB
POS data size	267 MB
Base data size	19.5 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.36
RMSE for East Position (<4.0 cm)	1.29
RMSE for Down Position (<8.0 cm)	3.25
Boresight correction stdev (<0.001deg)	0.000280
IMU attitude correction stdev (<0.001deg)	0.001977
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	43.31
Ave point cloud density per sq.m. (>2.0)	4.53
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	137
Maximum Height	431.88 m
Minimum Height	60.28 m
Classification (# of points)	
Ground	62,206,138
Low vegetation	88,553,270
Medium vegetation	168,431,674
High vegetation	144,388,933
Building	1,926,447
Orthophoto	No
Processed by	Engr. Irish Cortez, Aljon Rie Araneta, Engr. Melissa Fernandez

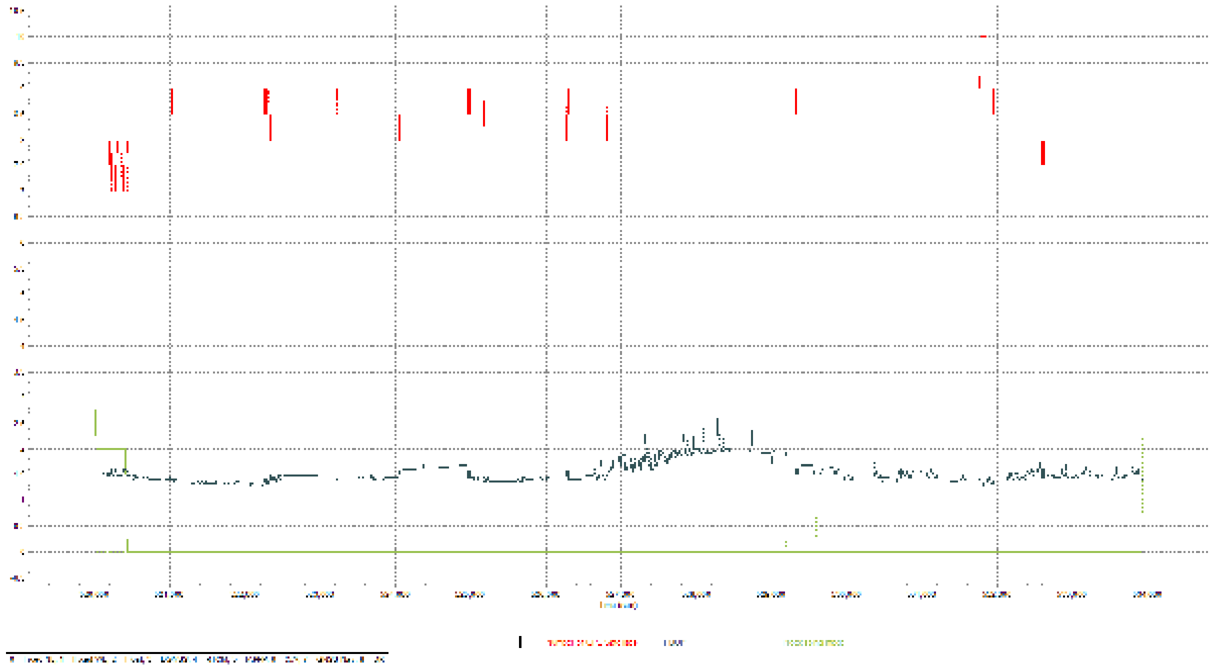


Figure A-8.176. Solution Status

Figure A-8.177. Smoothed Performance Metrics Parameters

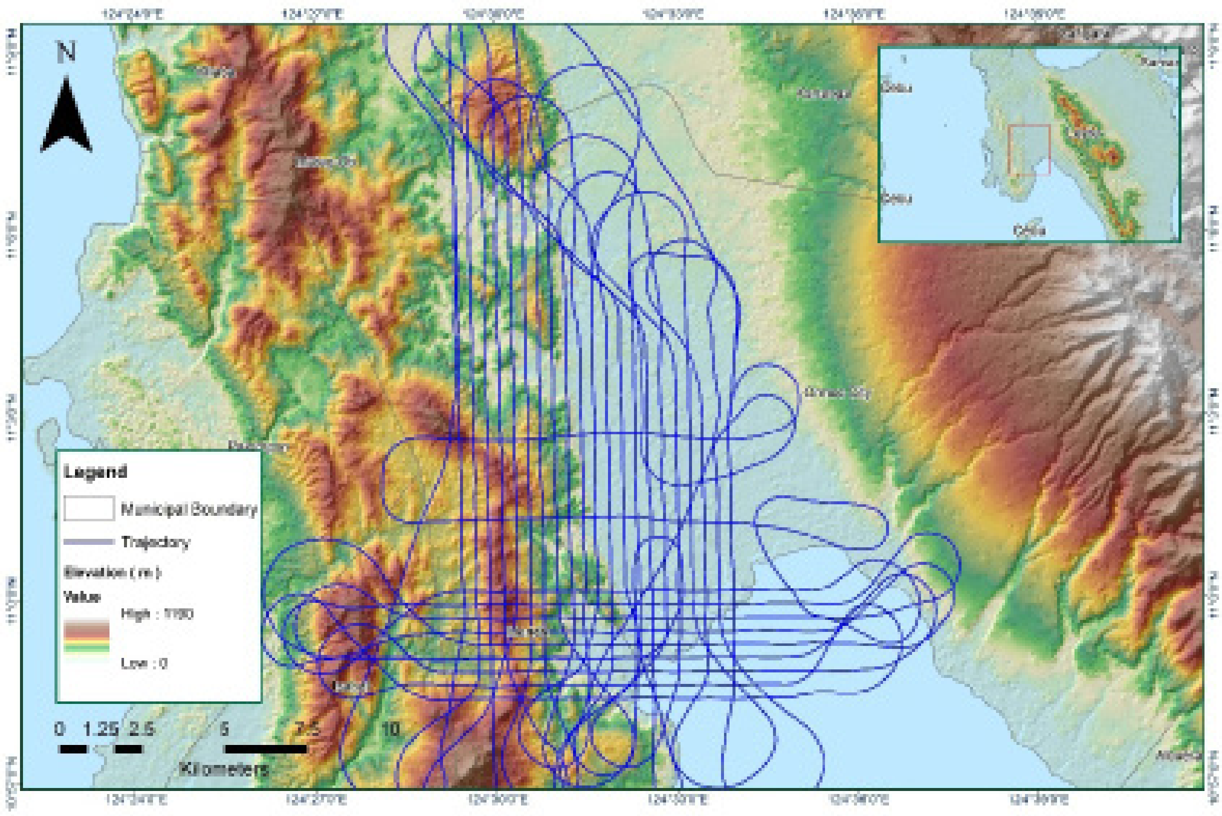


Figure A-8.178. Best Estimated Trajectory

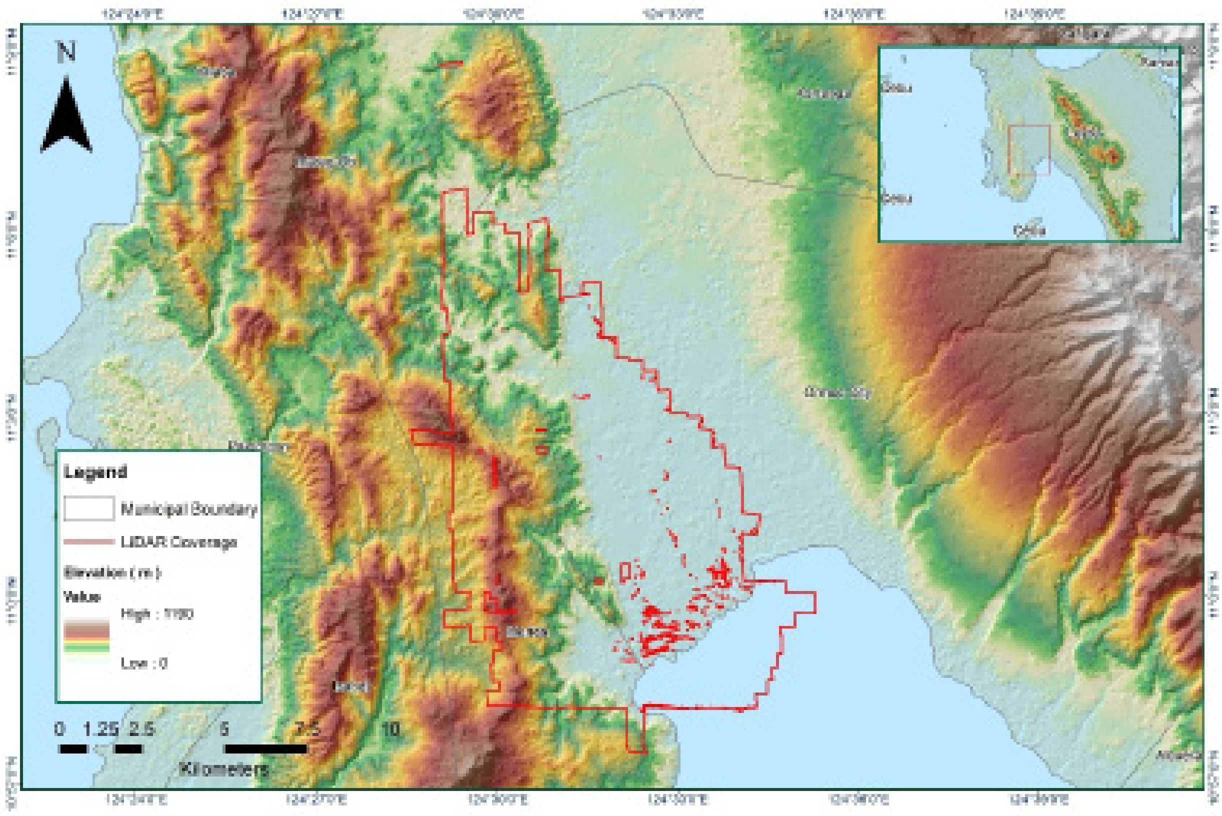


Figure A-8.179. Coverage of LiDAR data

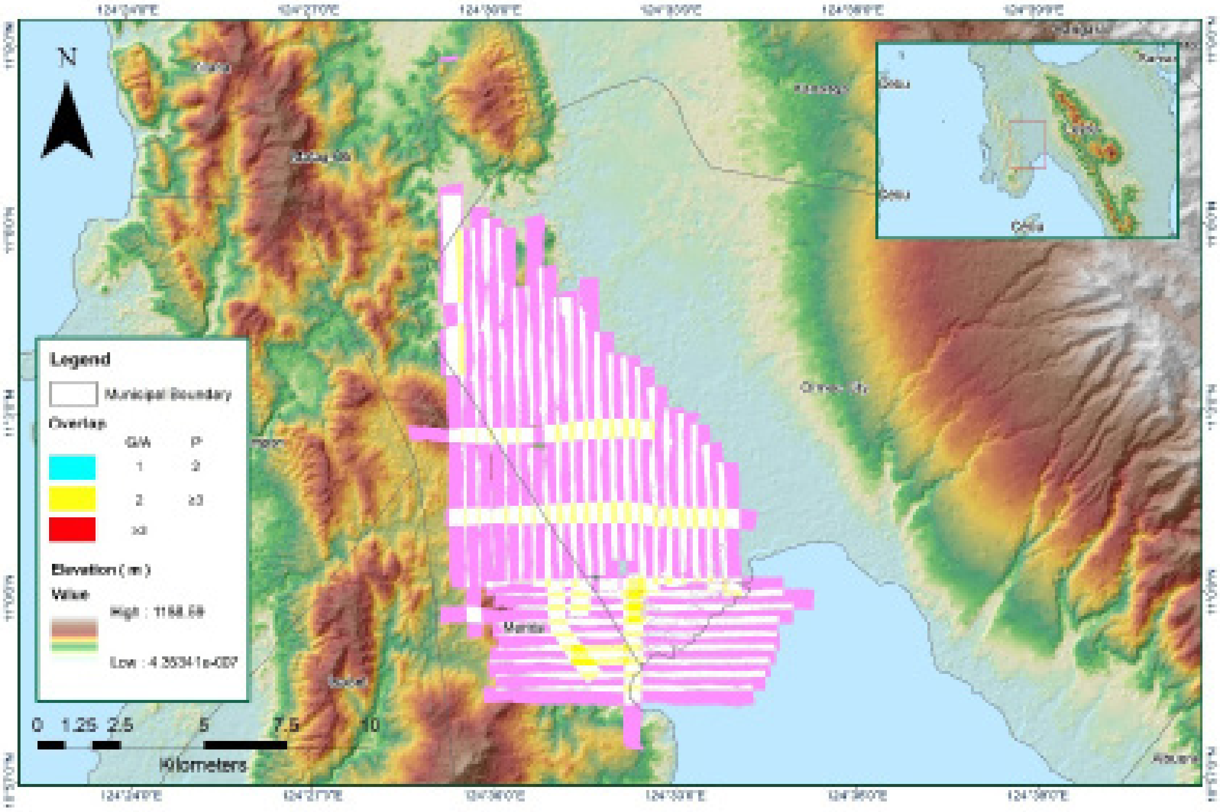


Figure A-8.180. Image of data overlap

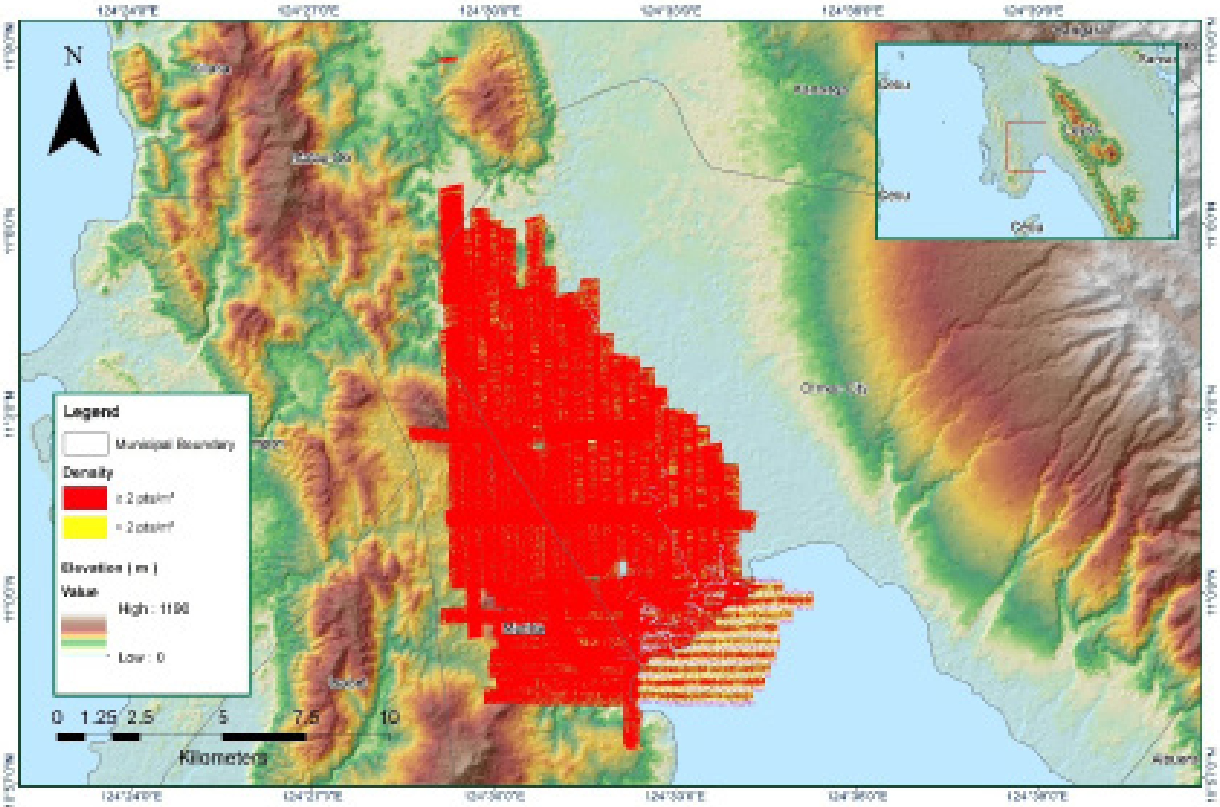


Figure A-8.181. Density map of merged LiDAR data

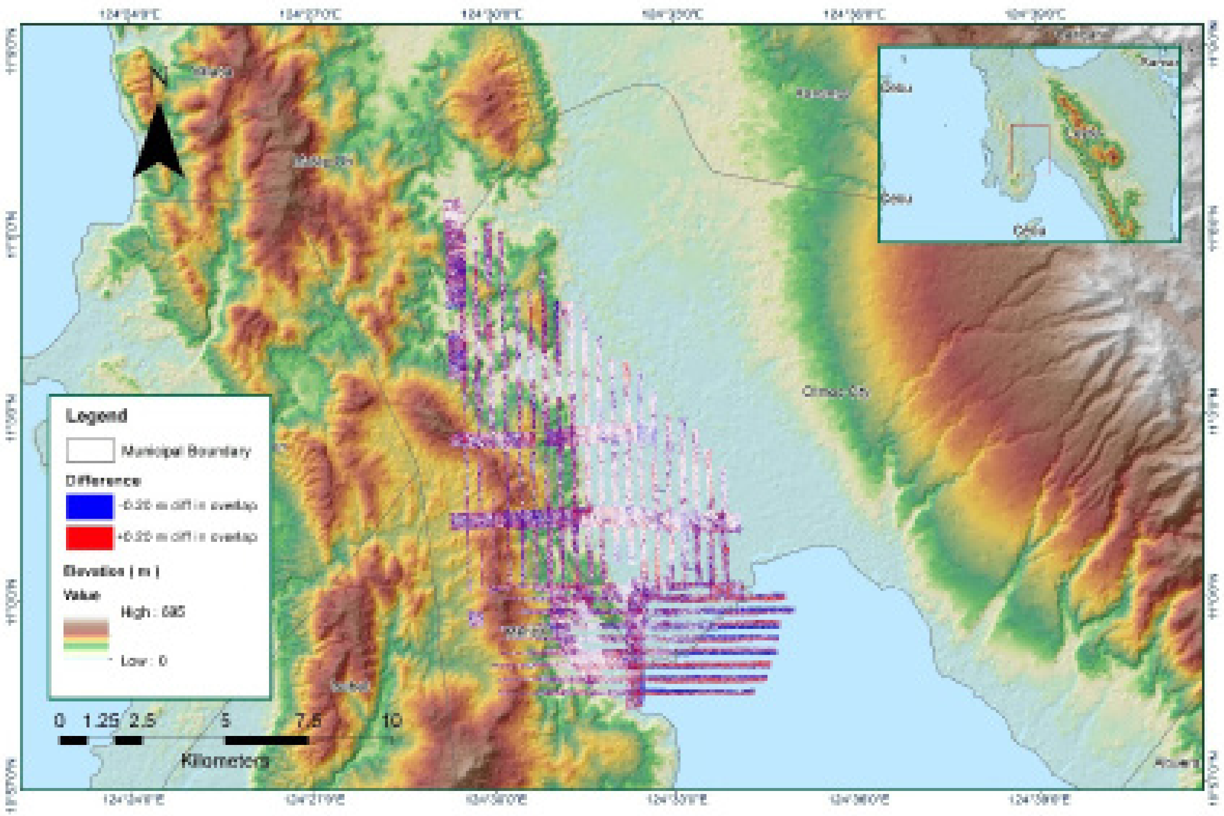


Figure A-8.182. Elevation difference between flight lines

Table A-8.27. Mission Summary Report for Mission Blk35B

Flight Area	Ormoc South
Mission Name	Blk35B
Inclusive Flights	3945G, 3947G
Range data size	38.1 GB
POS data size	545 MB
Base data size	39 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.03
RMSE for East Position (<4.0 cm)	1.32
RMSE for Down Position (<8.0 cm)	3.25
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	38.65
Ave point cloud density per sq.m. (>2.0)	3.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	78
Maximum Height	567.81 m
Minimum Height	60.87 m
Classification (# of points)	
Ground	28,967,711
Low vegetation	27,502,827
Medium vegetation	74,982,705
High vegetation	65,341,688
Building	393,179
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Aljon Rie Araneta, Engr. Monalyne Rabino

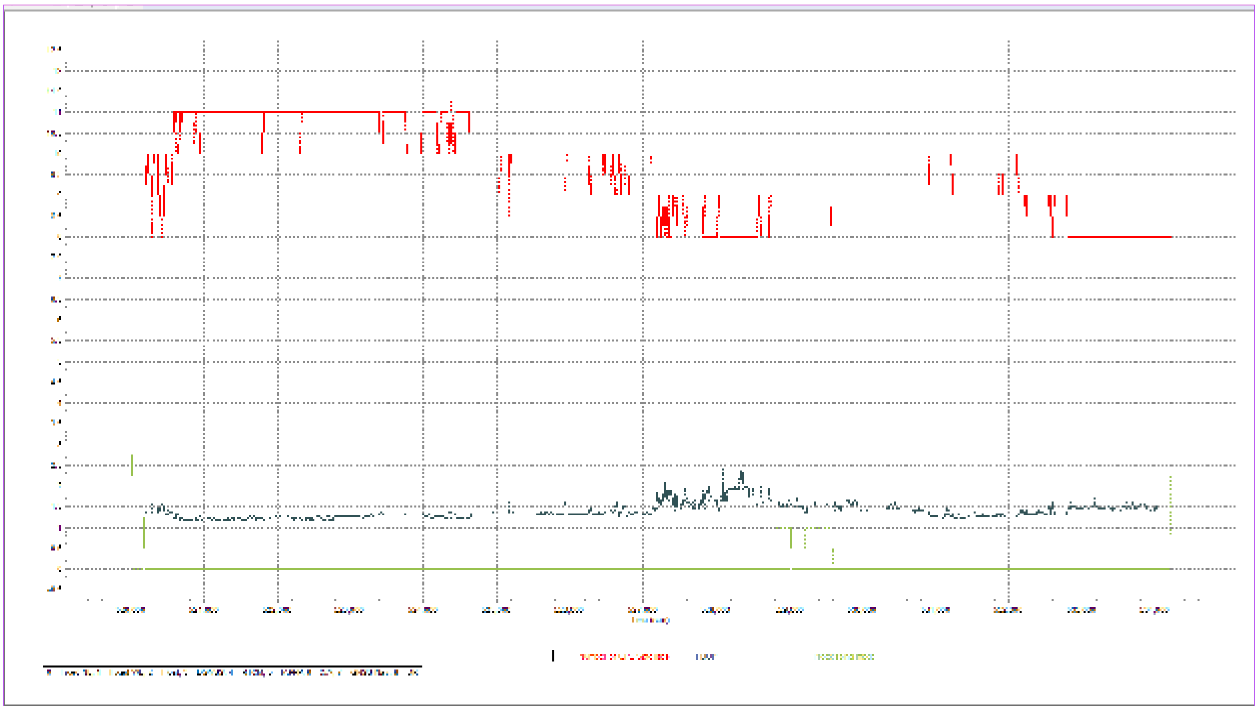


Figure A-8.183. Solution Status

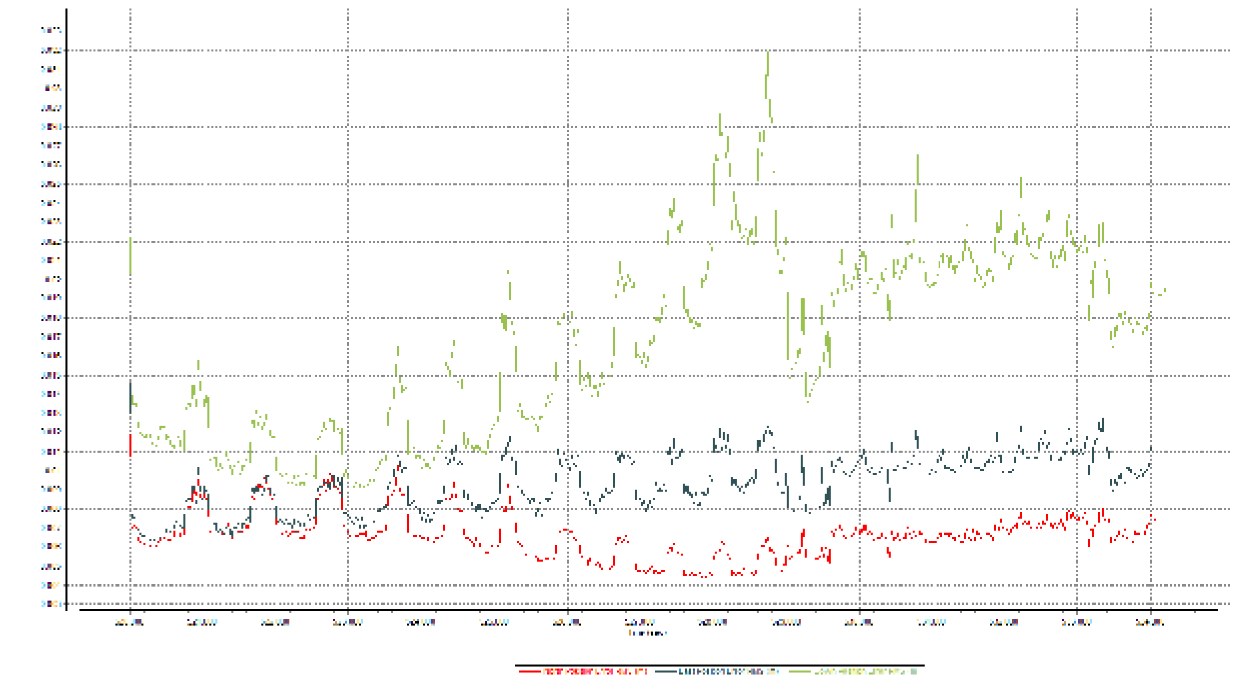


Figure A-8.184. Smoothed Performance Metrics Parameters

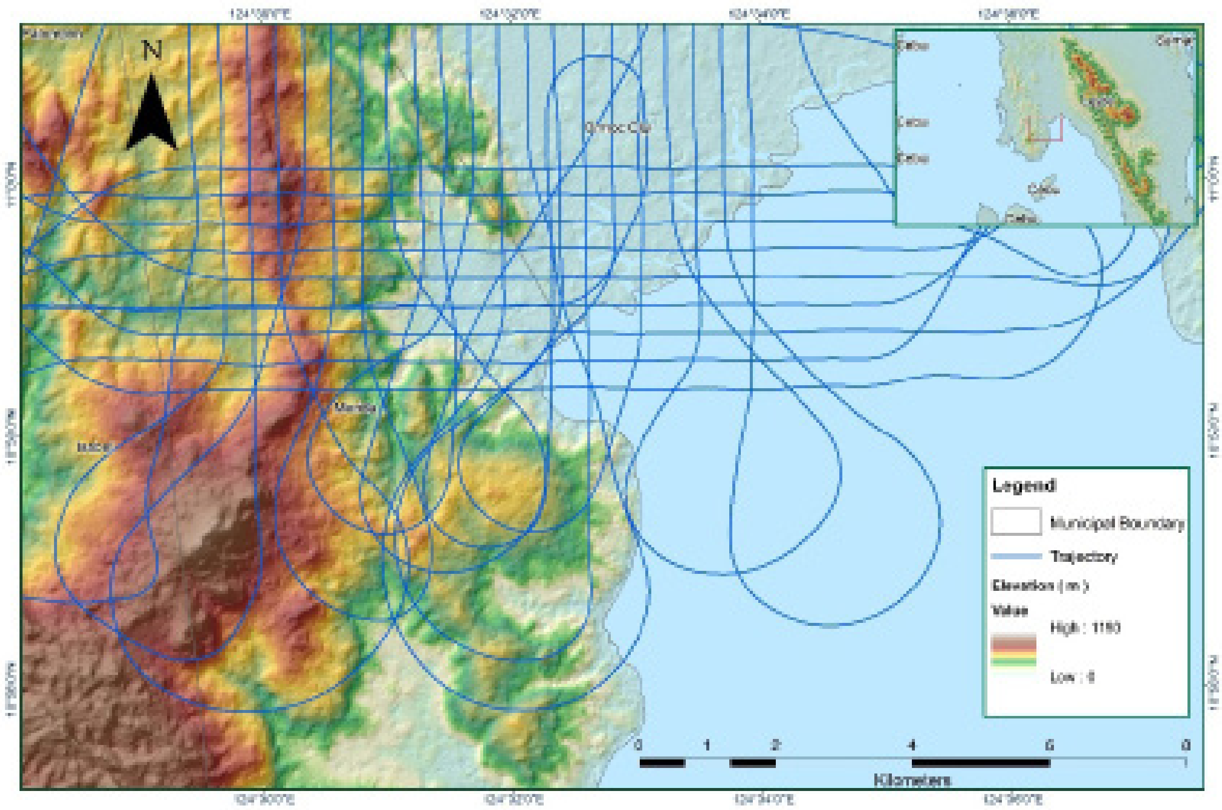


Figure A-8.185. Best Estimated Trajectory

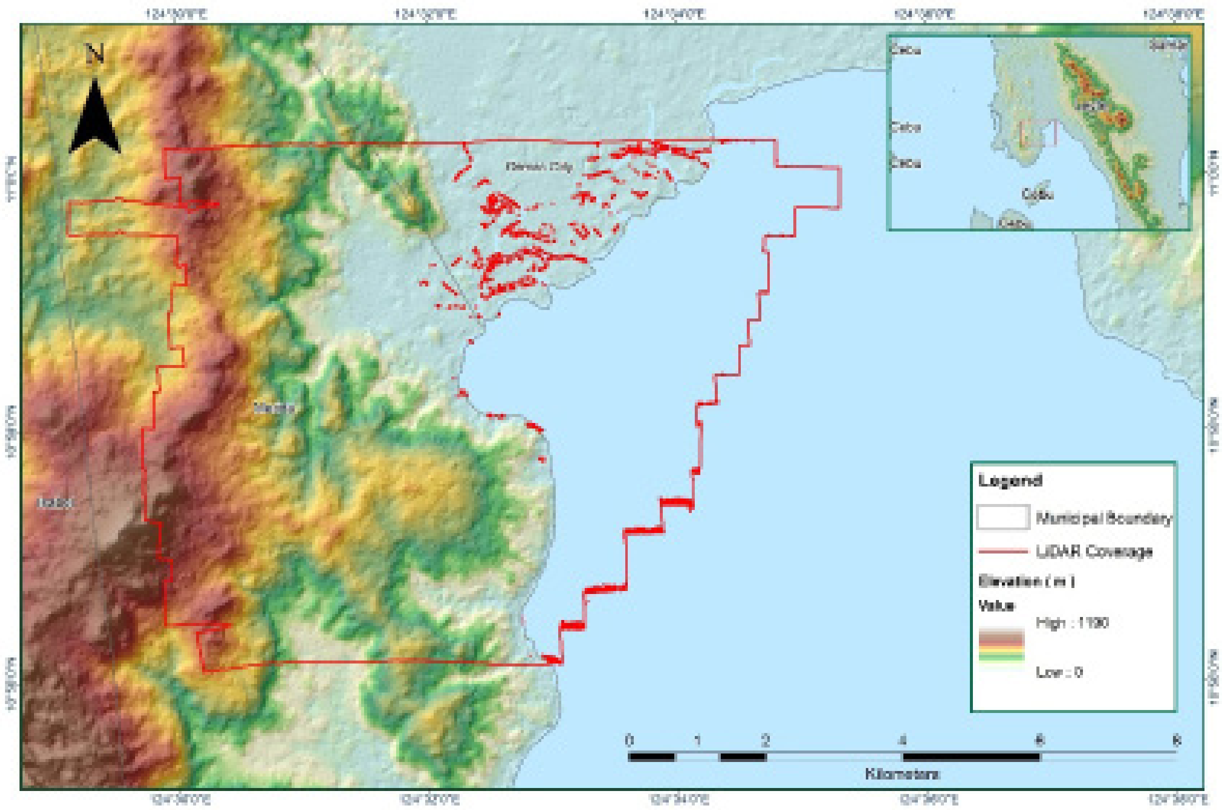


Figure A-8.186. Best Estimated Trajectory

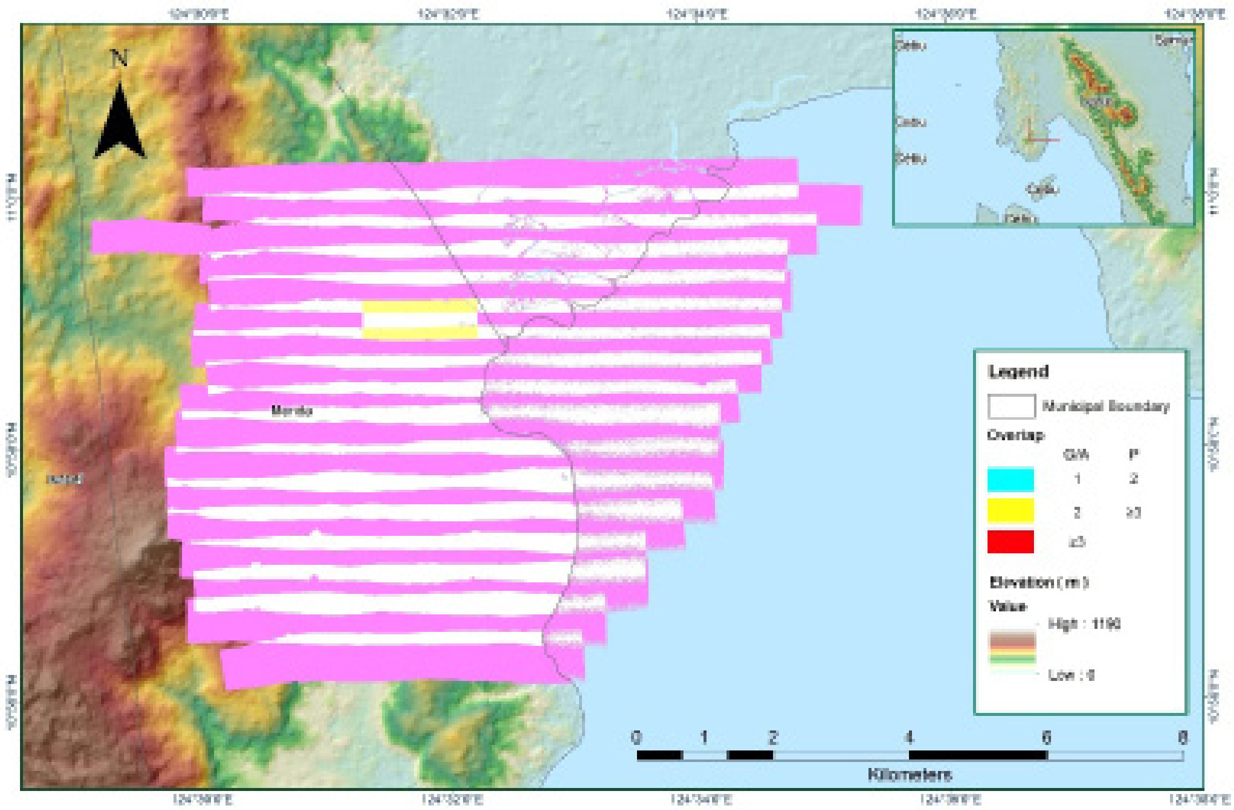


Figure A-8.187. Image of data overlap

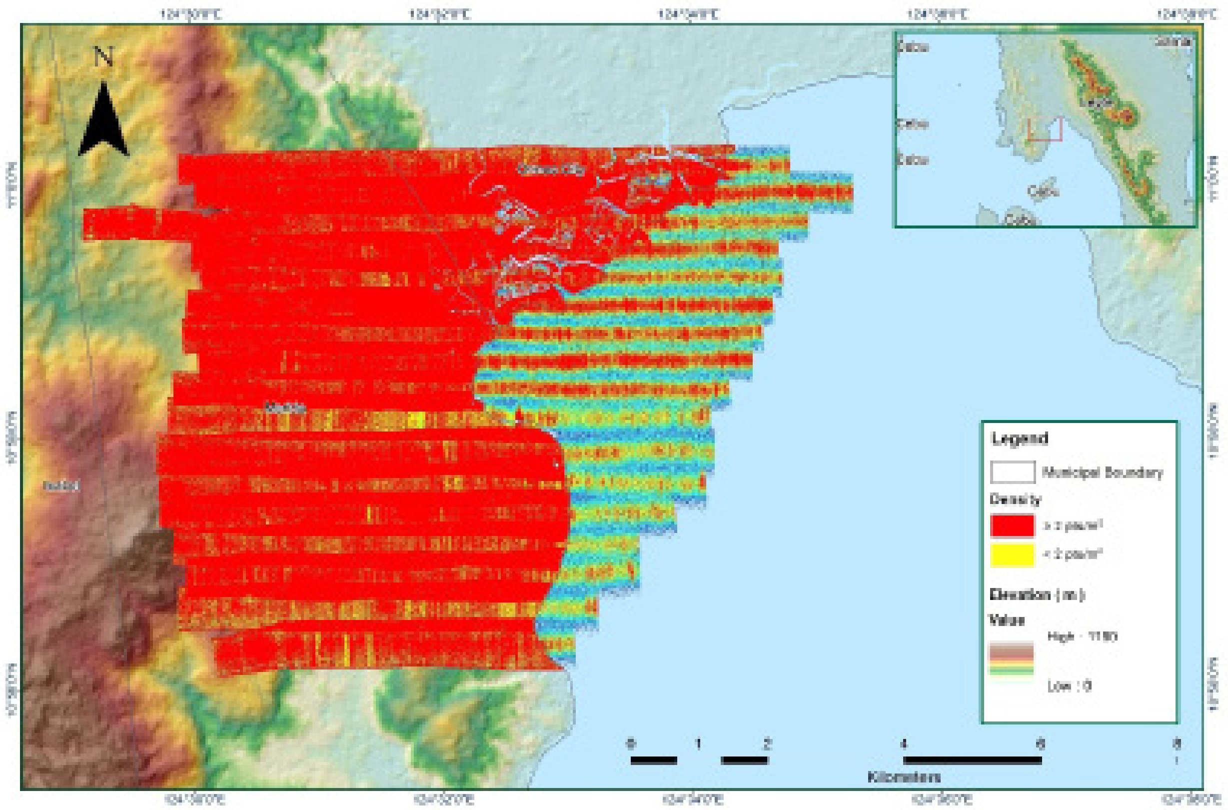


Figure A-8.188. Density map of merged LiDAR data

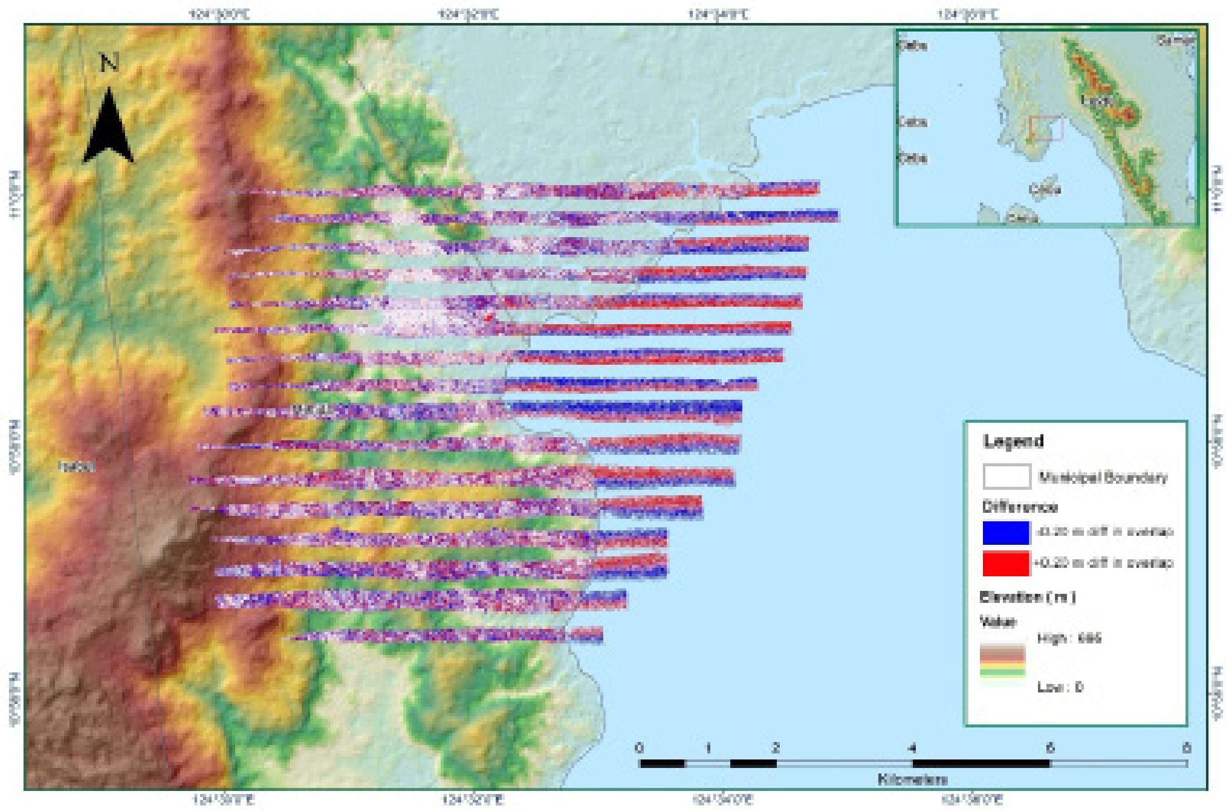


Figure A-8.189. Elevation difference between flight lines

Table A-8.28. Mission Summary Report for Mission Blk35C

Flight Area	Ormoc South
Mission Name	Blk35C
Inclusive Flights	3947G
Range data size	21 GB
POS data size	278 MB
Base data size	19.5 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.29
RMSE for East Position (<4.0 cm)	1.43
RMSE for Down Position (<8.0 cm)	3.07
Boresight correction stdev (<0.001deg)	0.001347
IMU attitude correction stdev (<0.001deg)	0.007265
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	46.44
Ave point cloud density per sq.m. (>2.0)	4.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	130
Maximum Height	664.42 m
Minimum Height	45.81 m
Classification (# of points)	
Ground	55,143,313
Low vegetation	41,566,187
Medium vegetation	160,423,665
High vegetation	124,246,531
Building	187,280
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Engr. Justine Francisco, Engr. Monalyne Rabino

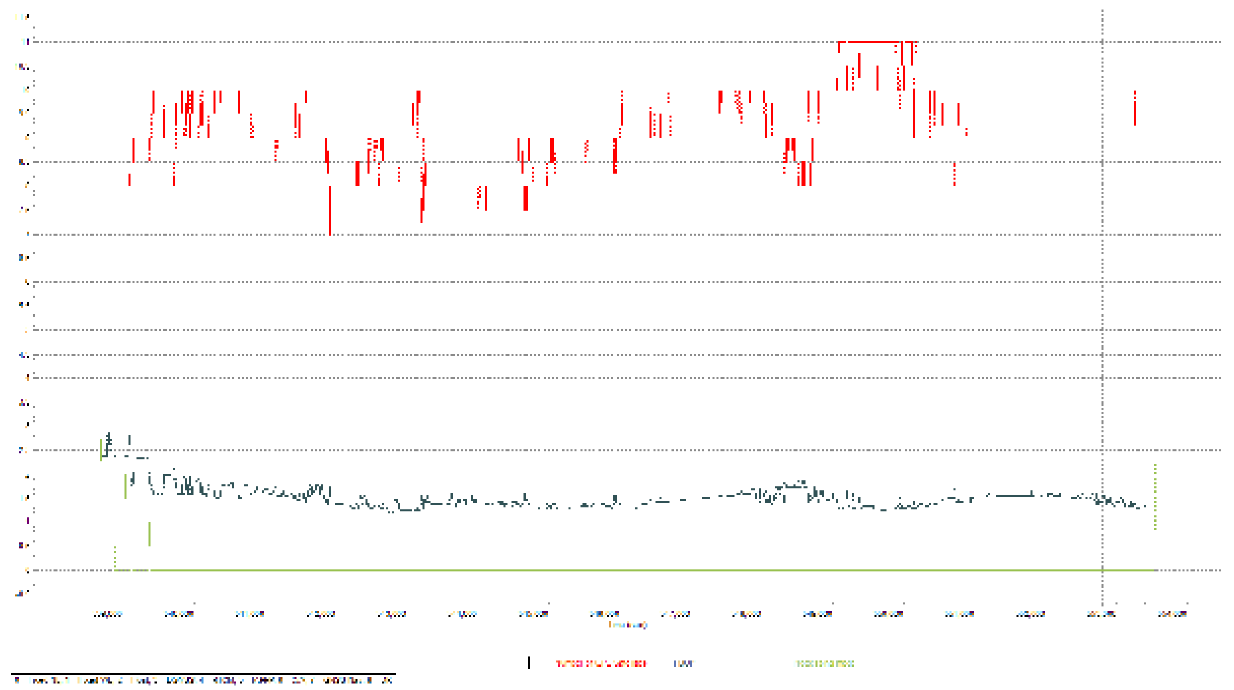


Figure A-8.190. Solution Status

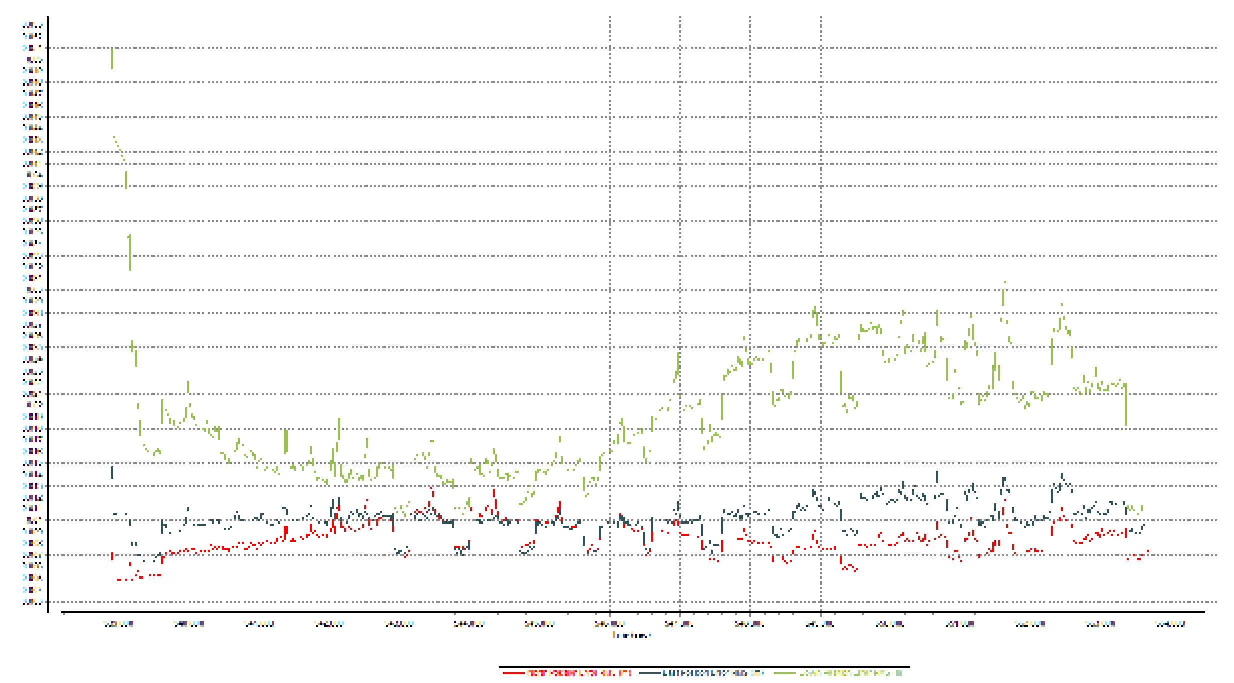


Figure A-8.191. Smoothed Performance Metrics Parameters

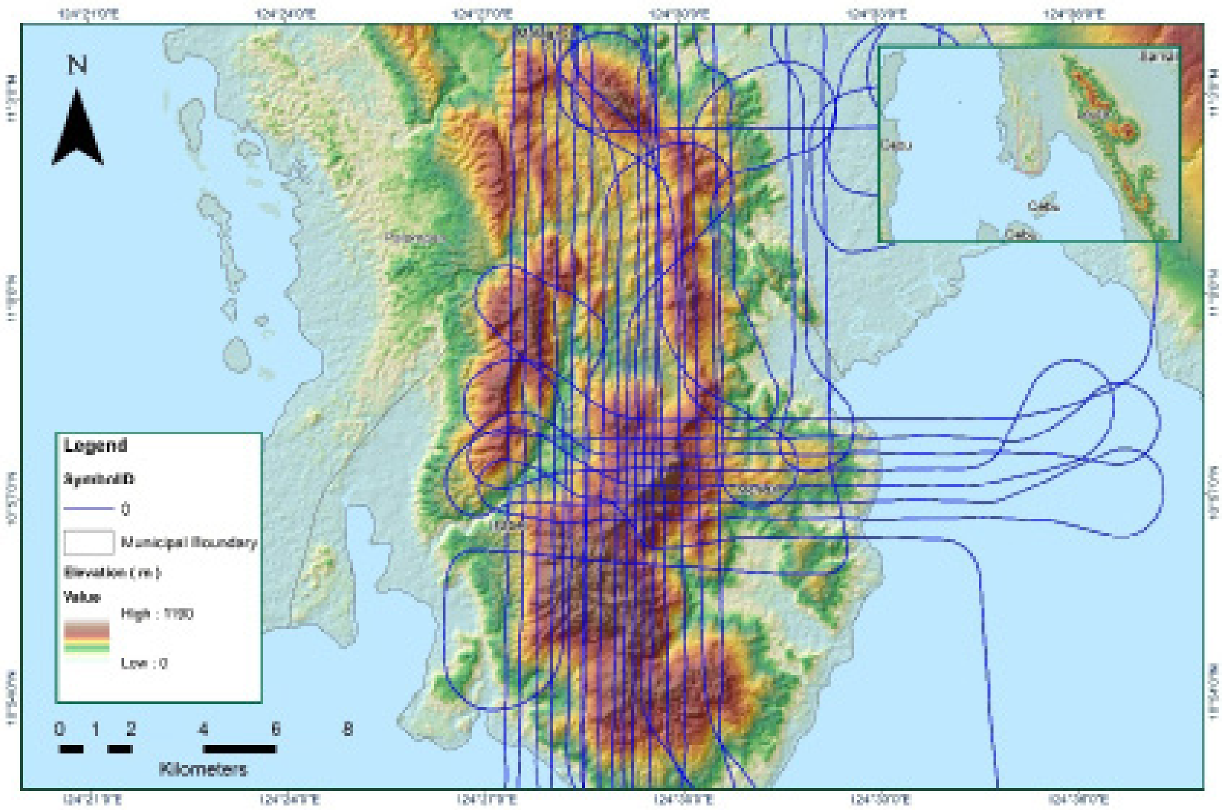


Figure A-8.192. Best Estimated Trajectory

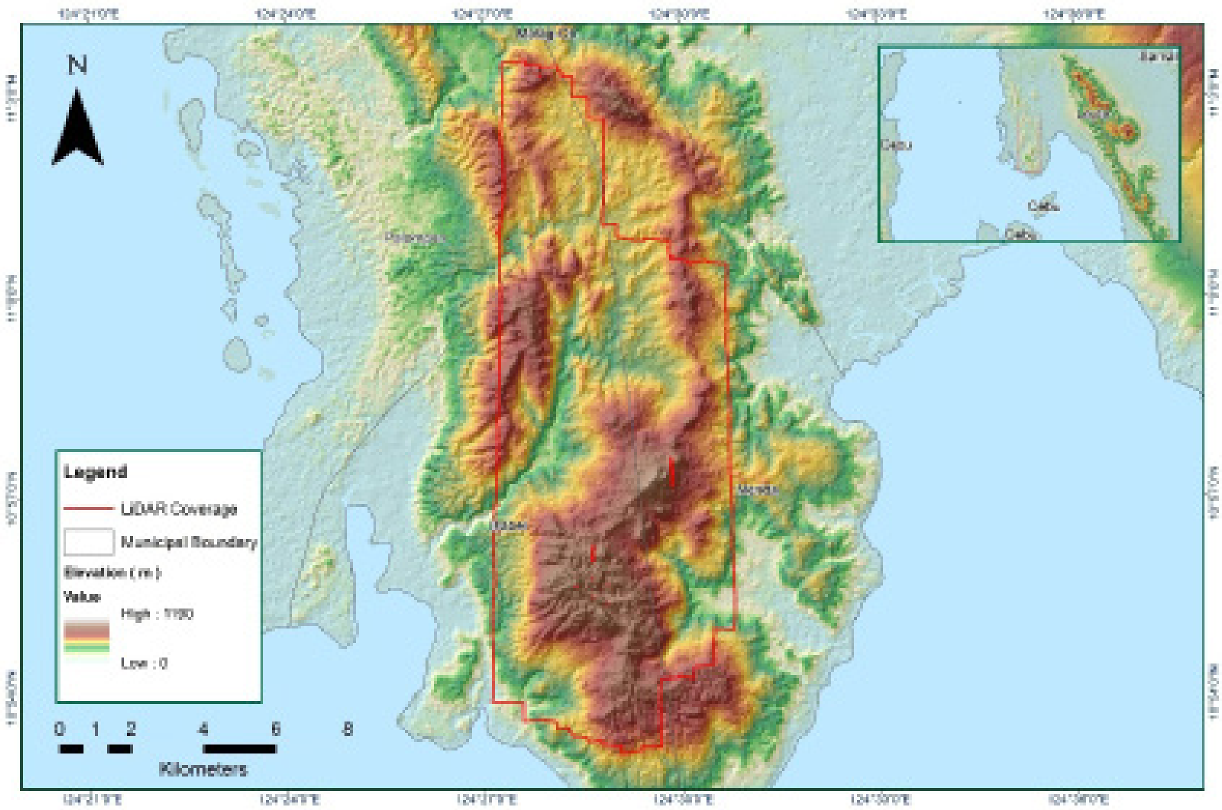


Figure A-8.193. Coverage of LiDAR data

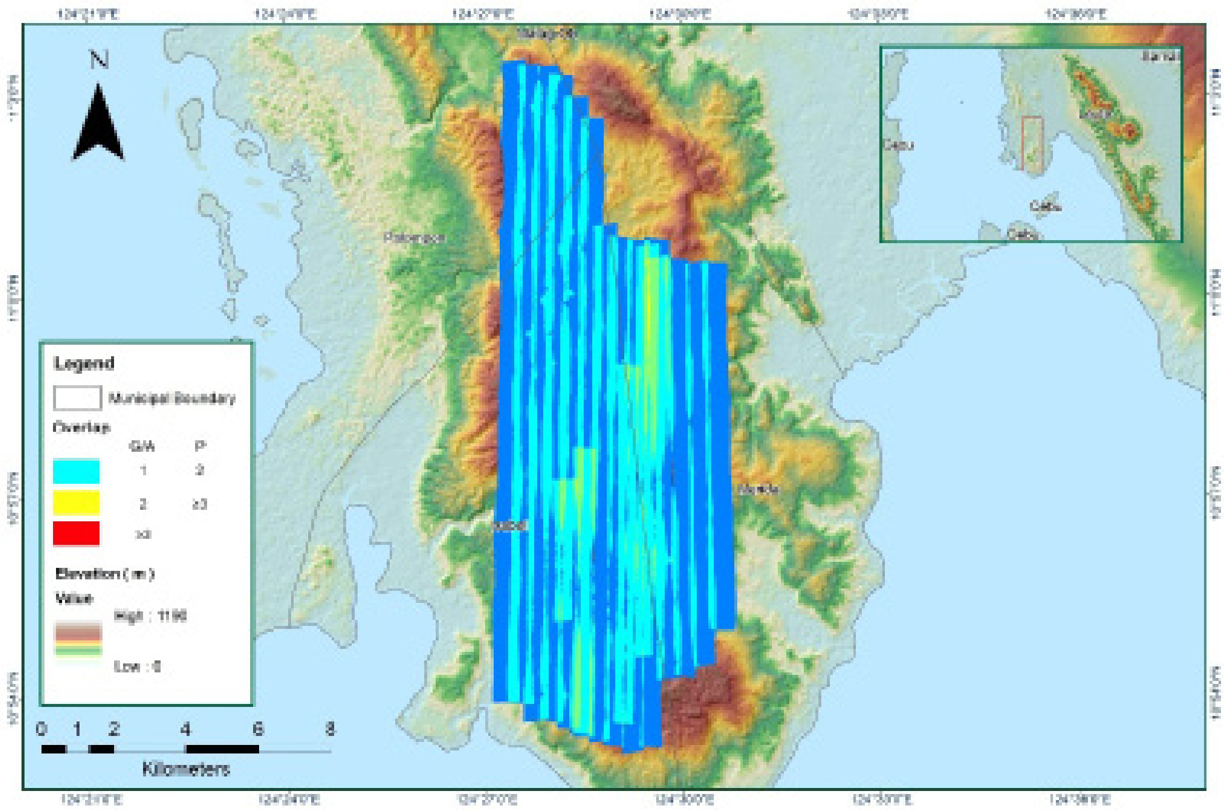


Figure A-8.194. Image of data overlap

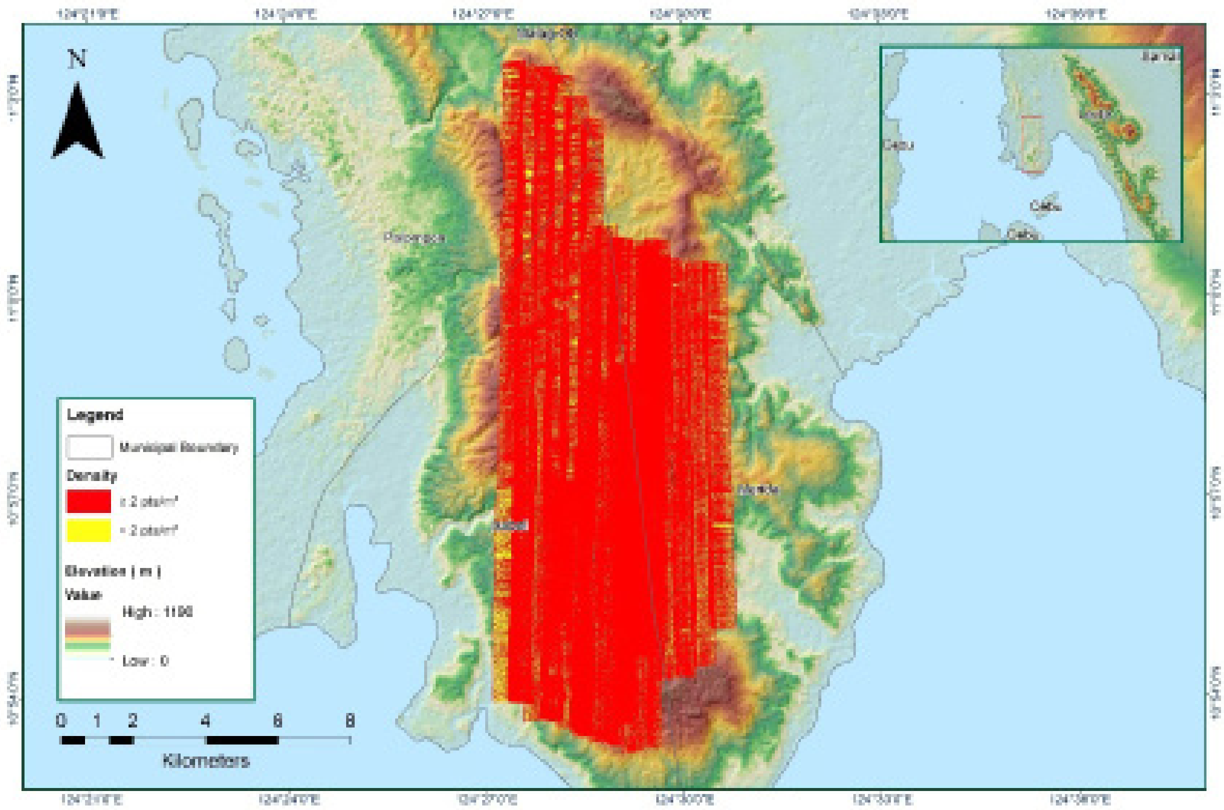


Figure A-8.195. Density map of merged LiDAR data

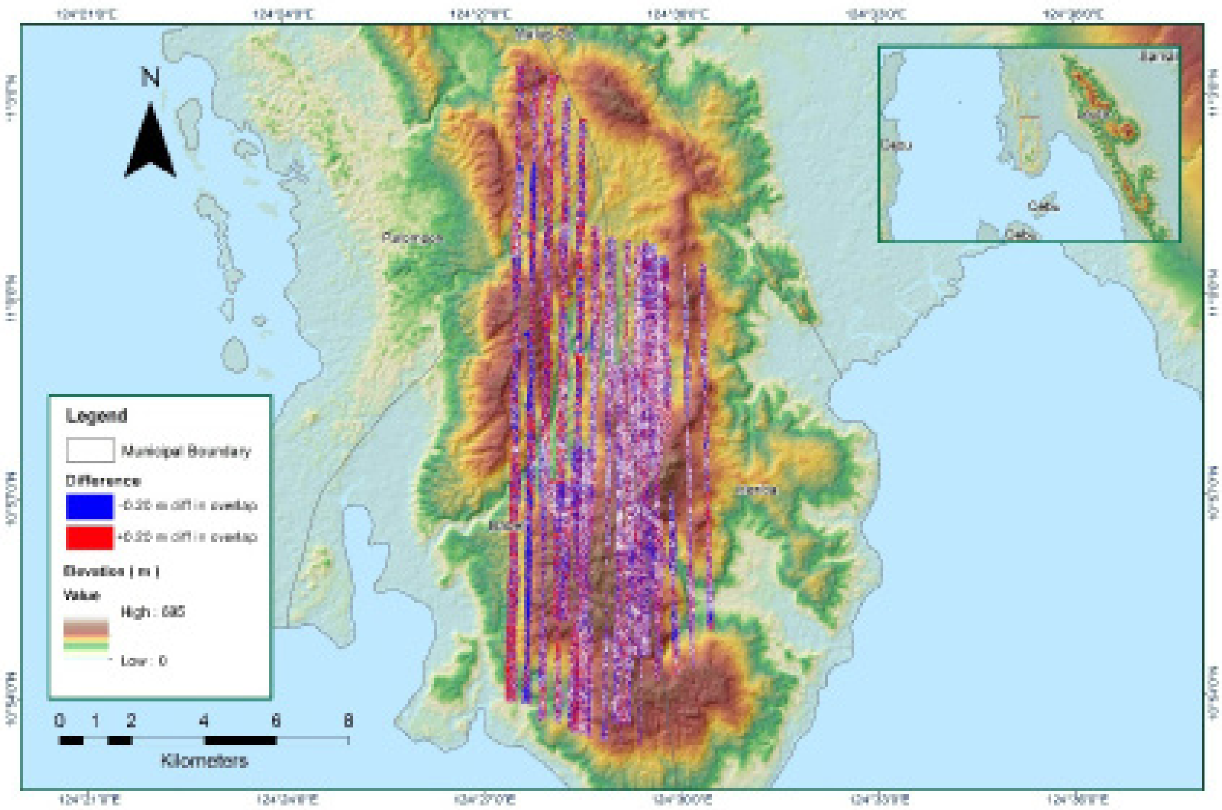


Figure A-8.196. Elevation difference between flight lines

Table A-8.29. Mission Summary Report for Mission 1032A

Flight Area	Tacloban
Mission Name	1032A
Inclusive Flights	1032A
Range data size	13.7 GB
POS data size	54.6 MB
Base data size	10.8 MB
Image	24.4 GB
Transfer date	February 3, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.007721
IMU attitude correction stdev (<0.001deg)	0.005490
GPS position stdev (<0.01m)	0.0036
Minimum % overlap (>25)	26.50%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	47
Maximum Height	171.52 m
Minimum Height	68.07 m
Classification (# of points)	
Ground	4,251,370
Low vegetation	3,342,368
Medium vegetation	14,184,838
High vegetation	246,147
Building	93,165
Orthophoto	No
Processed by	Engr. Irish Cortez, Celina Rosete, Ailyn Biñas

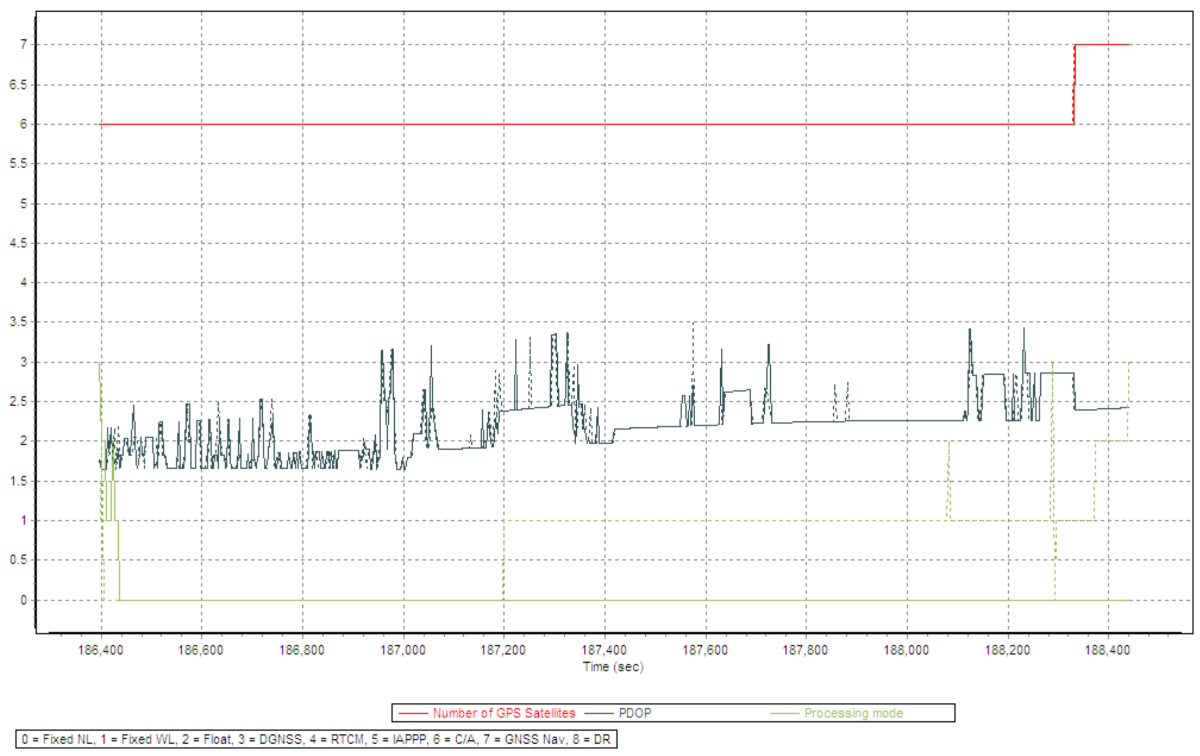


Figure A-8.197. Solution Status

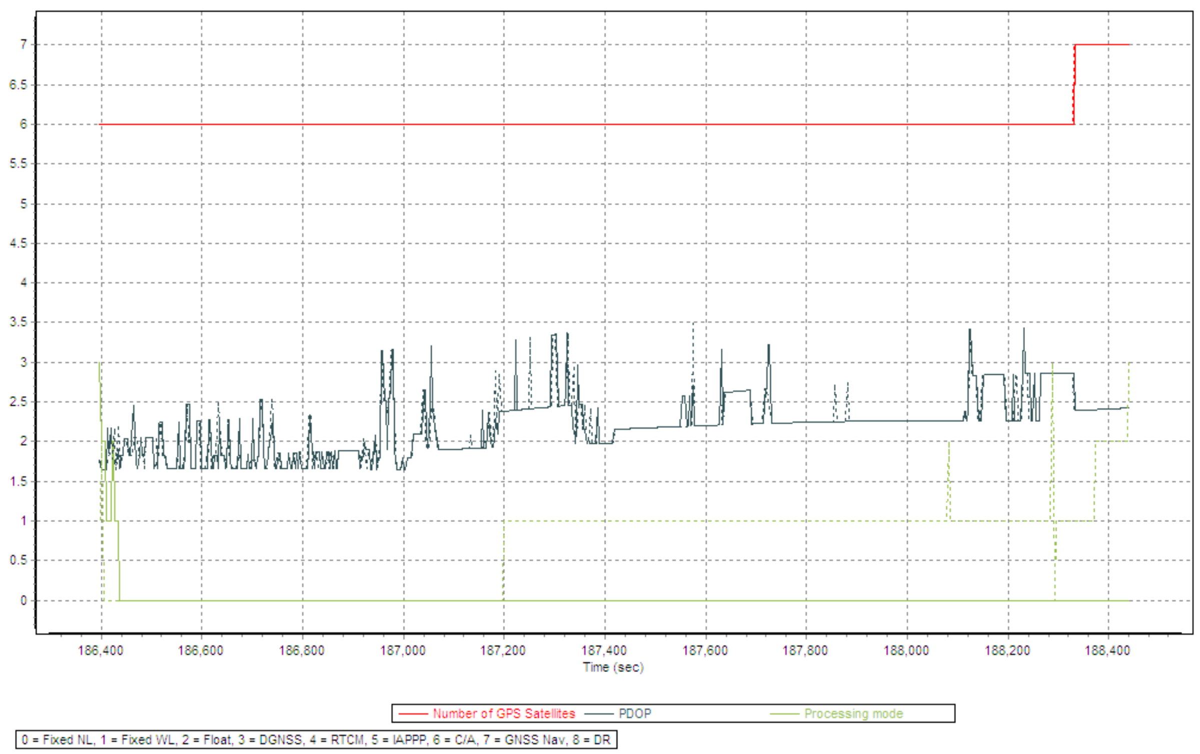


Figure A-8.198. Smoothed Performance Metrics Parameters

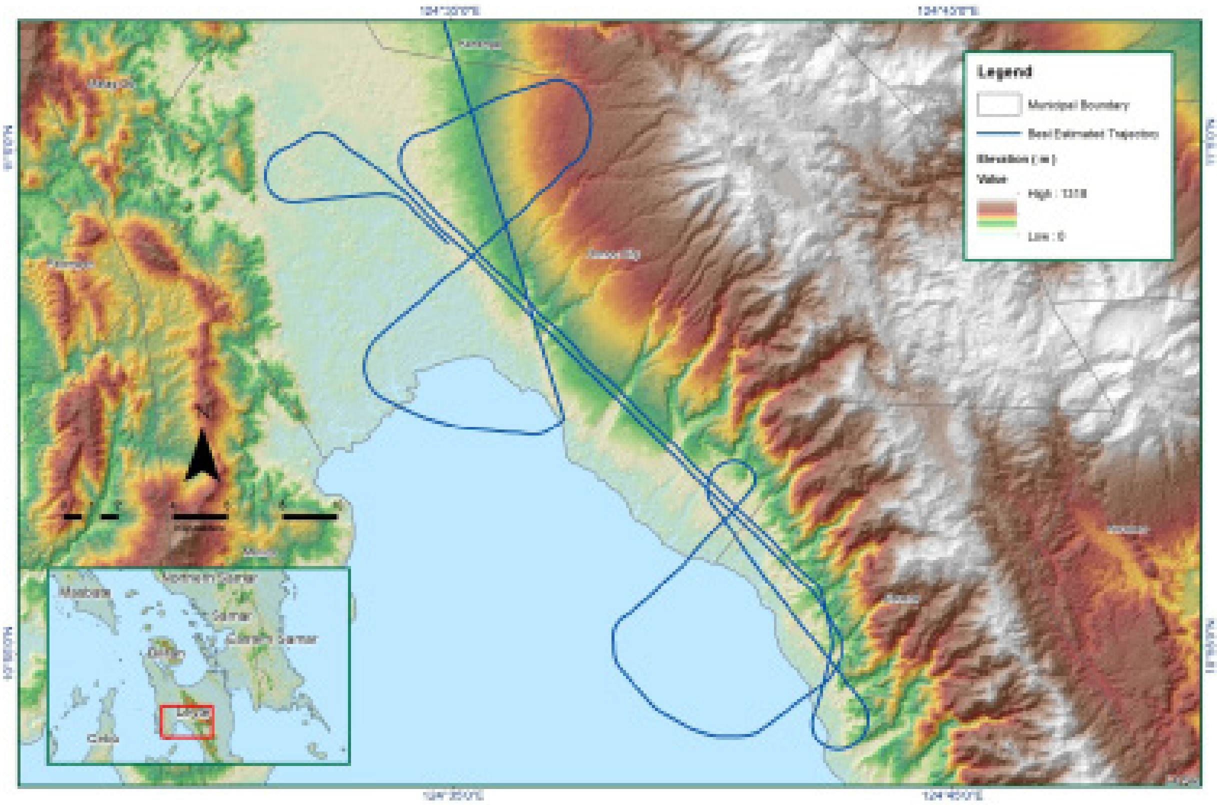


Figure A-8.199. Best Estimated Trajectory

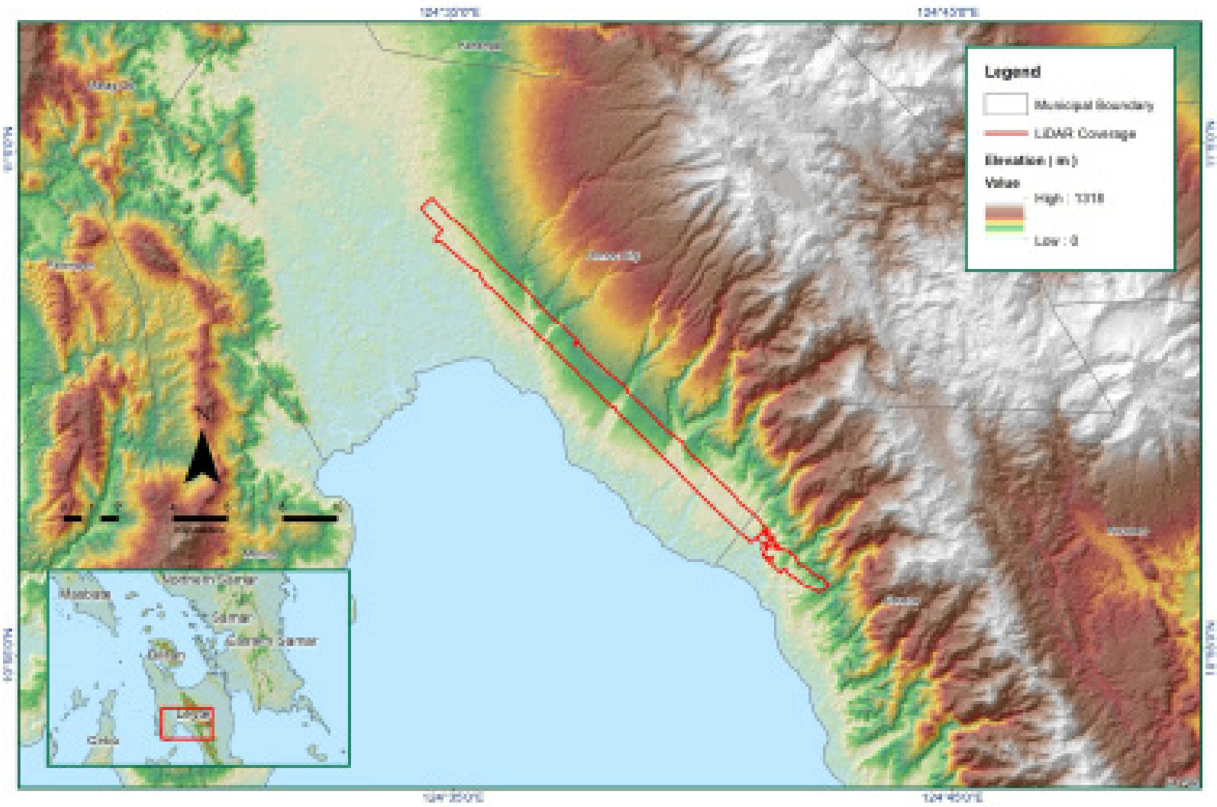


Figure A-8.200. Best Estimated Trajectory

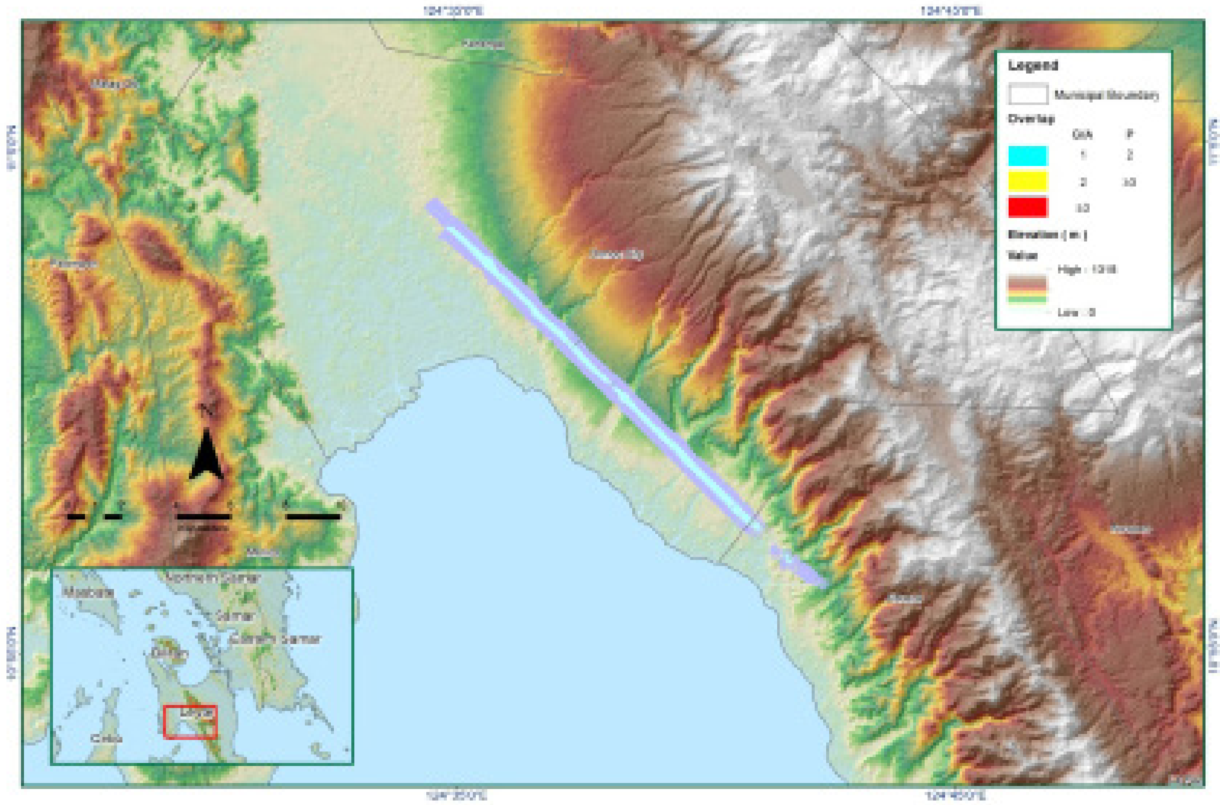


Figure A-8.201. Image of data overlap

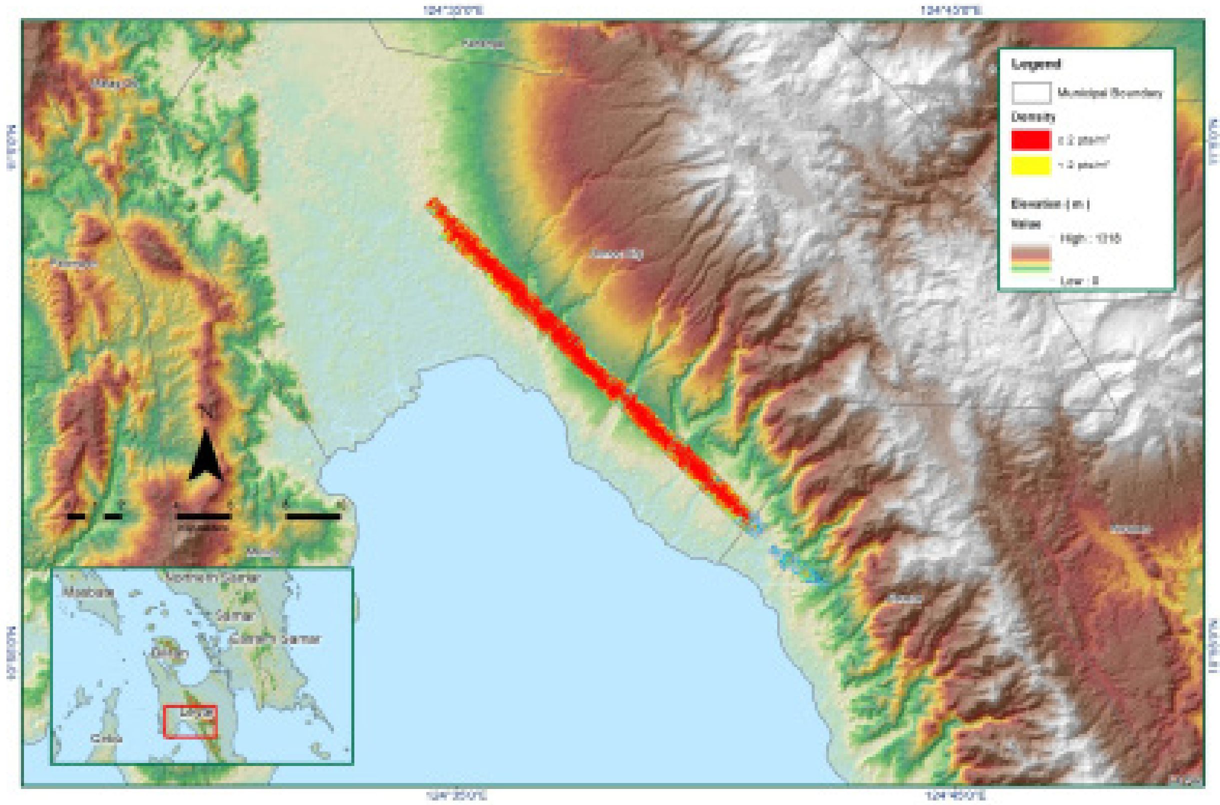


Figure A-8.202. Density map of merged LiDAR data

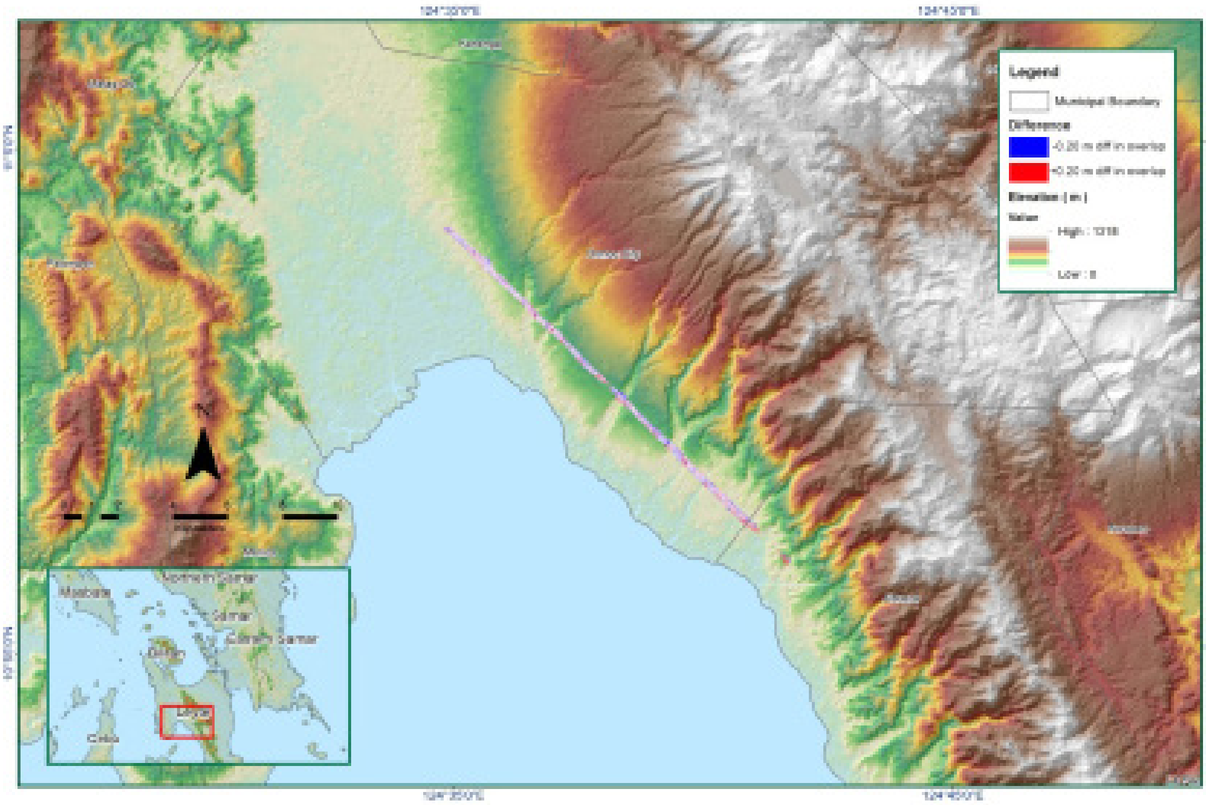


Figure A-8.203. Elevation difference between flight lines

Table A-8.30. Mission Summary Report for Mission Blk35I_additional

Flight Area	Samar-Leyte
Mission Name	Blk35I_additional
Inclusive Flights	1502A
Range data size	13.9 GB
POS	278 MB
Image	86.7 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.945
RMSE for East Position (<4.0 cm)	2.56
RMSE for Down Position (<8.0 cm)	5.176
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	34.24%
Ave point cloud density per sq.m. (>2.0)	3.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	51
Maximum Height	426.96 m
Minimum Height	55.88 m
Classification (# of points)	
Ground	13,787,383
Low vegetation	8,617,597
Medium vegetation	14,734,063
High vegetation	6,099,763
Building	85,084
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

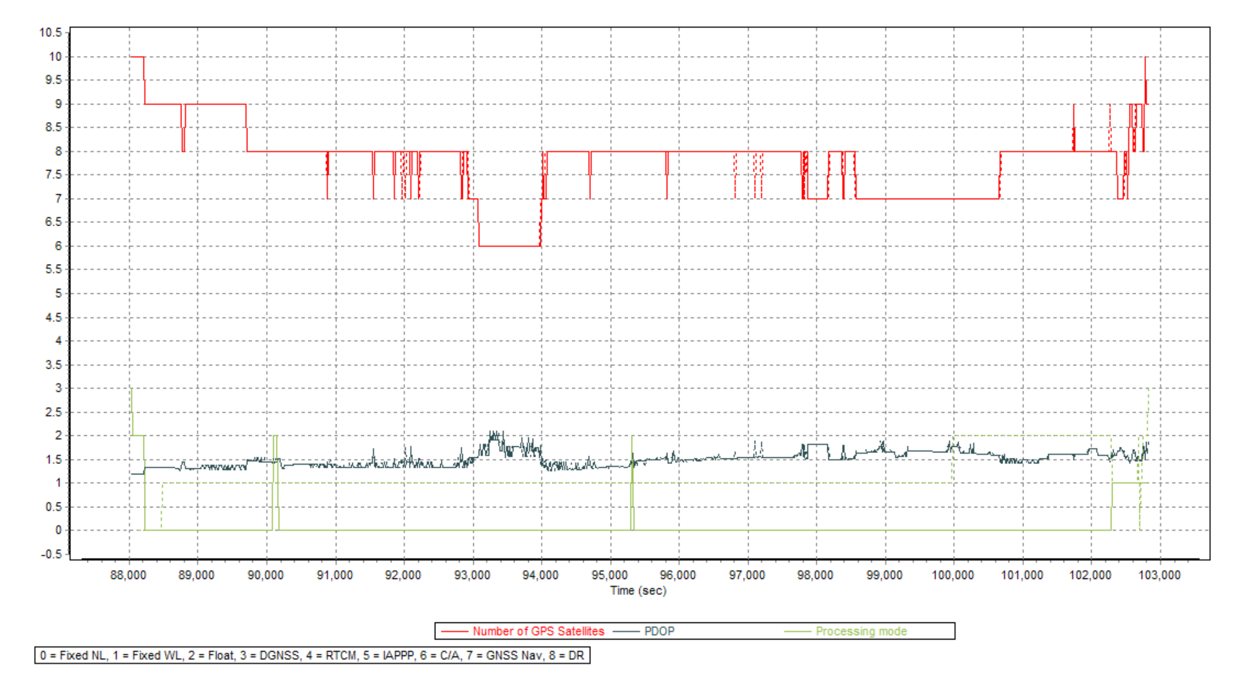


Figure A-8.204. Solution Status

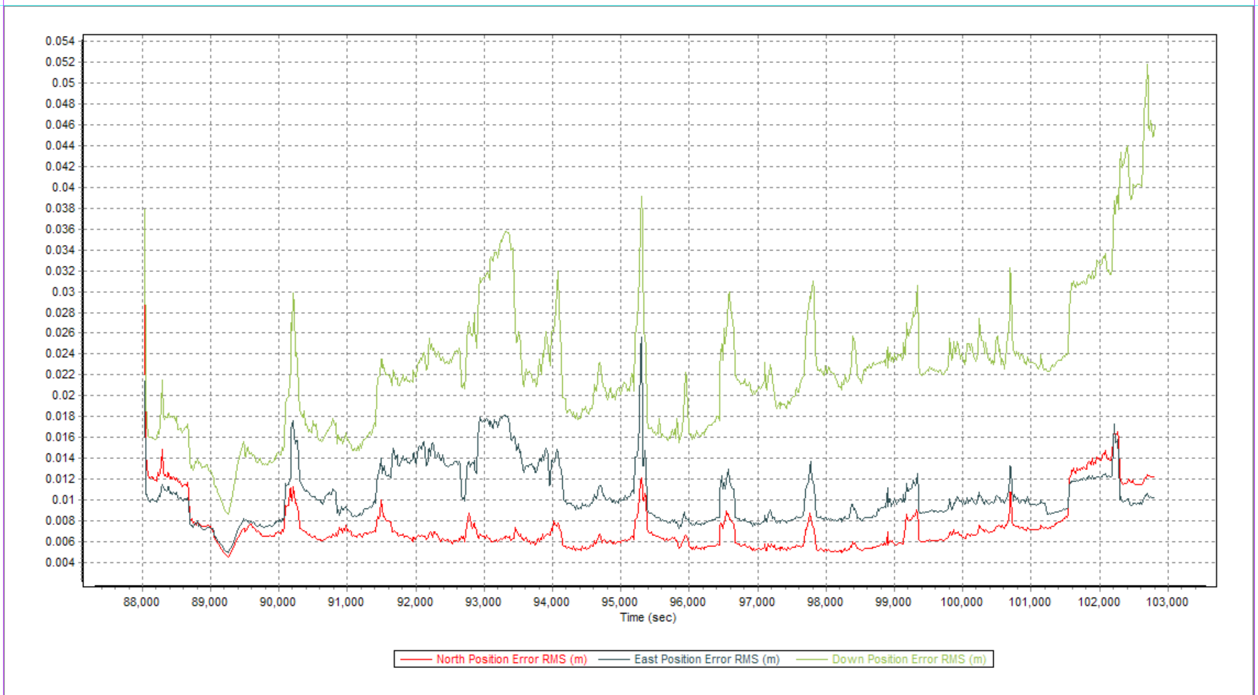


Figure A-8.205. Smoothed Performance Metrics Parameters

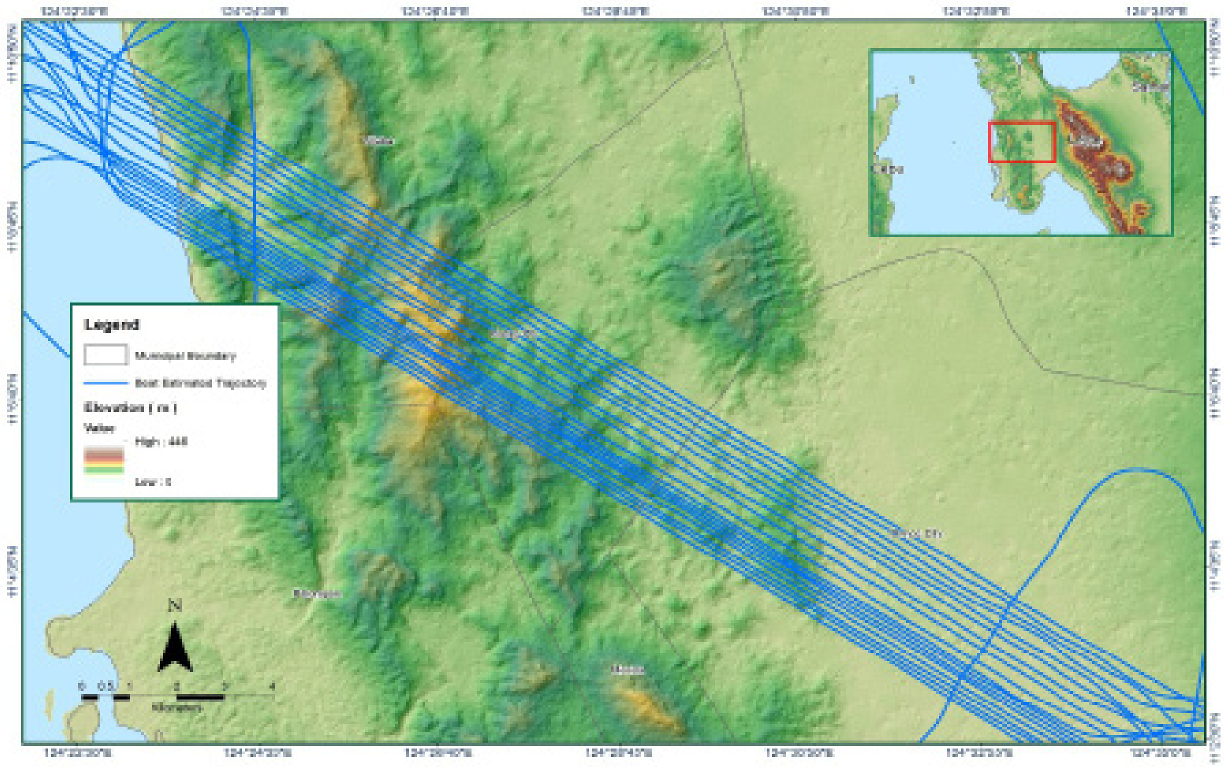


Figure A-8.206. Best Estimated Trajectory

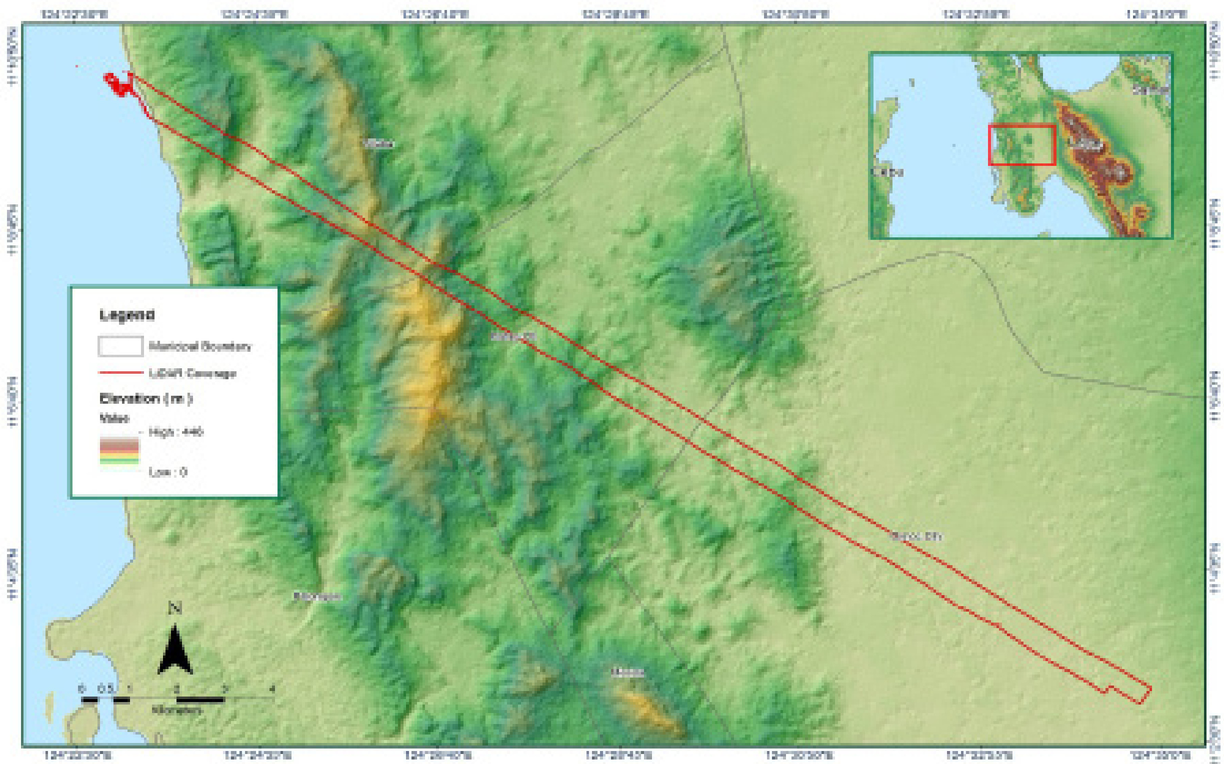


Figure A-8.207. Coverage of LiDAR data

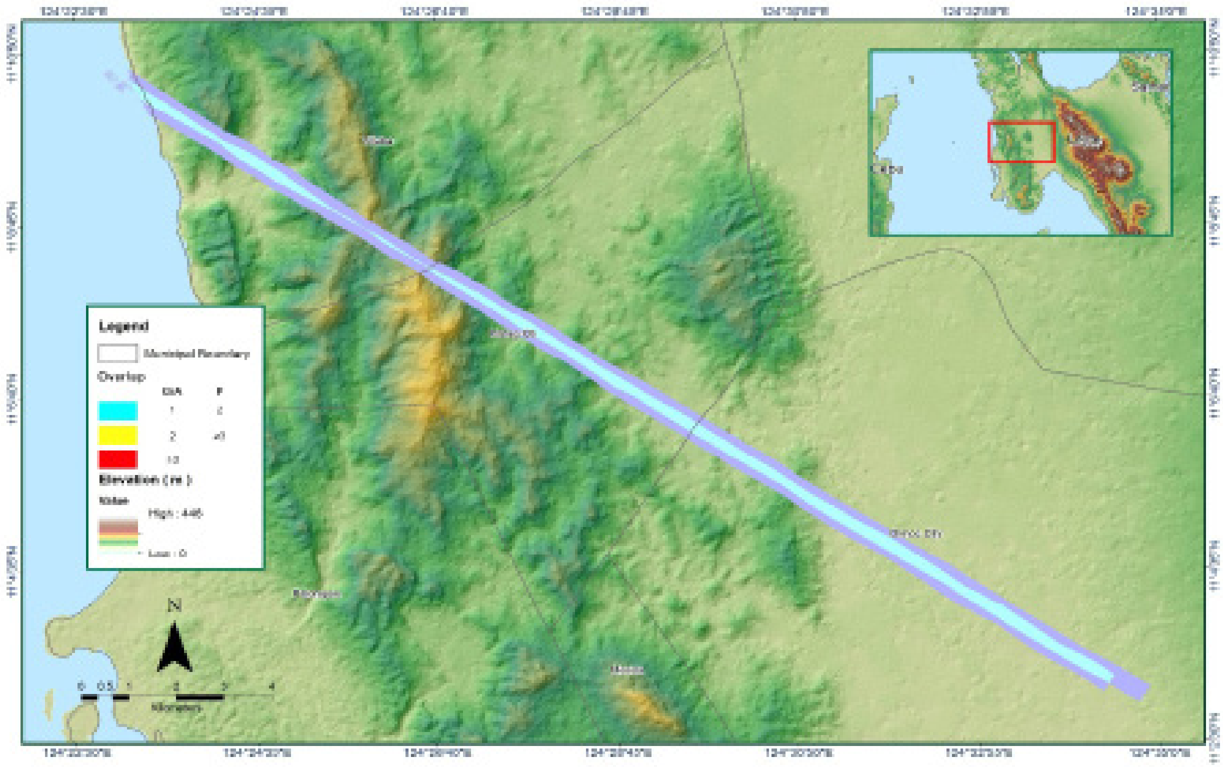


Figure A-8.208. Image of data overlap

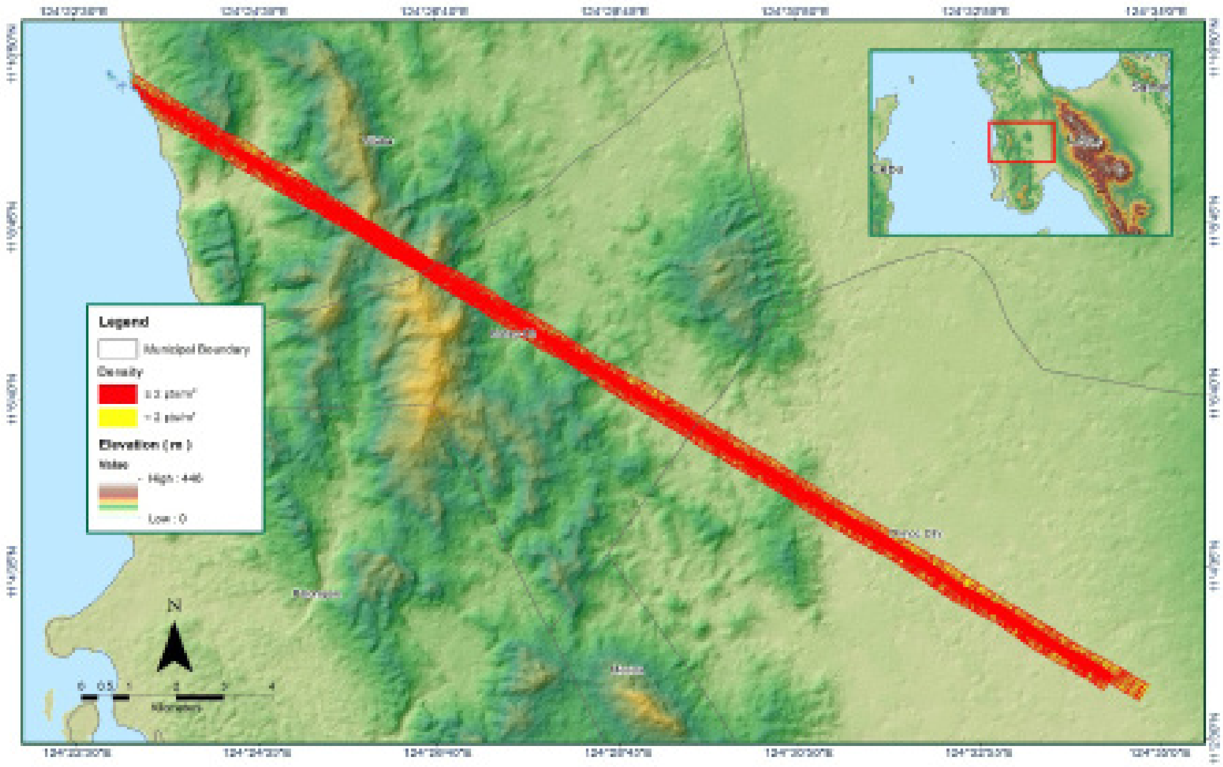


Figure A-8.209. Density map of merged LiDAR data

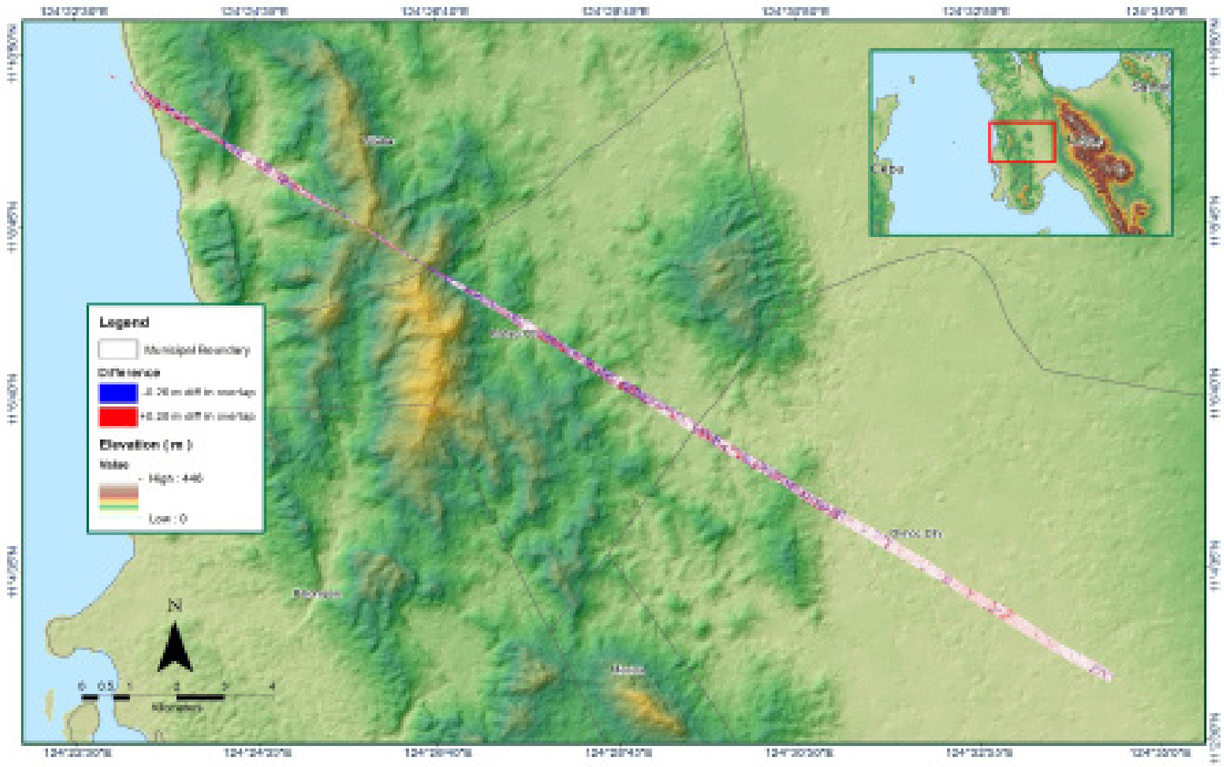


Figure A-8.210. Elevation difference between flight lines

ANNEX 9. Pagsangahan Model Basin Parameters

Table A-9.1. Pagsangahan 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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1000	12.892	78.850	0	1.3659	16.719	Discharge	0.751	1	Ratio to Peak	0.1
W1010	11.023	75.897	0	1.1530	14.113	Discharge	0.449	1	Ratio to Peak	0.1
W1020	10.729	74.100	0	1.9129	23.414	Discharge	0.110	1	Ratio to Peak	0.1
W520	11.874	68.037	0	2.5941	31.752	Discharge	1.840	1	Ratio to Peak	0.1
W530	19.004	74.586	0	2.6583	32.538	Discharge	0.849	1	Ratio to Peak	0.1
W540	26.947	78.015	0	2.1199	25.947	Discharge	0.416	1	Ratio to Peak	0.1
W550	11.457	73.325	0	1.5118	18.504	Discharge	0.399	1	Ratio to Peak	0.1
W560	13.233	78.850	0	2.1081	25.803	Discharge	0.643	1	Ratio to Peak	0.1
W570	10.945	76.536	0	1.9855	24.303	Discharge	0.422	1	Ratio to Peak	0.1
W580	16.616	78.850	0	1.4128	17.293	Discharge	0.349	1	Ratio to Peak	0.1
W590	9.3840	79.226	0	2.7966	34.231	Discharge	0.469	1	Ratio to Peak	0.1
W600	14.986	77.779	0	1.7972	21.998	Discharge	0.447	1	Ratio to Peak	0.1
W610	7.1679	69.835	0	1.6001	19.586	Discharge	0.552	1	Ratio to Peak	0.1
W620	7.1010	62.700	0	0.0335	0.4107	Discharge	0.001	1	Ratio to Peak	0.1
W630	10.534	78.301	0	4.7507	58.148	Discharge	0.812	1	Ratio to Peak	0.1
W640	9.5862	76.128	0	3.1826	38.954	Discharge	0.780	1	Ratio to Peak	0.1
W650	9.7383	78.950	0	2.5654	31.401	Discharge	0.812	1	Ratio to Peak	0.1
W660	7.3841	72.308	0	1.6599	20.317	Discharge	1.074	1	Ratio to Peak	0.1
W670	14.759	80.997	0	2.3515	28.782	Discharge	1.097	1	Ratio to Peak	0.1
W680	7.8413	74.100	0	2.6710	32.692	Discharge	0.111	1	Ratio to Peak	0.1

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W690	37.239	84.094	0	0.99106	12.131	Discharge	0.169	1	Ratio to Peak	0.1
W700	9.0972	84.191	0	1.3828	16.925	Discharge	0.358	1	Ratio to Peak	0.1
W710	7.7202	79.478	0	2.2154	27.117	Discharge	0.906	1	Ratio to Peak	0.1
W720	17.551	80.726	0	4.5477	55.664	Discharge	0.629	1	Ratio to Peak	0.1
W730	10.824	80.523	0	1.7411	21.311	Discharge	0.509	1	Ratio to Peak	0.1
W740	31.376	83.781	0	1.2765	15.624	Discharge	0.430	1	Ratio to Peak	0.1
W750	14.730	74.356	0	2.2954	28.096	Discharge	0.170	1	Ratio to Peak	0.1
W760	9.5024	83.128	0	2.1629	26.474	Discharge	0.485	1	Ratio to Peak	0.1
W770	10.805	55.370	0	1.6764	20.519	Discharge	0.839	1	Ratio to Peak	0.1
W780	7.0467	81.385	0	1.8009	22.043	Discharge	0.979	1	Ratio to Peak	0.1
W790	26.947	83.300	0	1.3442	16.453	Discharge	0.549	1	Ratio to Peak	0.1
W800	30.385	71.320	0	1.2022	14.714	Discharge	0.413	1	Ratio to Peak	0.1
W810	13.762	79.105	0	1.5404	18.854	Discharge	0.436	1	Ratio to Peak	0.1
W820	18.108	59.321	0	2.8130	34.431	Discharge	1.132	1	Ratio to Peak	0.1
W830	10.973	74.389	0	2.5650	31.395	Discharge	0.200	1	Ratio to Peak	0.1
W840	6.8552	80.838	0	2.4979	30.574	Discharge	0.170	1	Ratio to Peak	0.1
W850	14.757	79.130	0	1.2412	15.192	Discharge	0.385	1	Ratio to Peak	0.1
W860	17.475	84.270	0	0.6558	8.0275	Discharge	0.196	1	Ratio to Peak	0.1
W870	14.718	62.700	0	0.5855	7.1675	Discharge	0.098	1	Ratio to Peak	0.1
W880	12.037	60.045	0	2.0935	25.625	Discharge	1.639	1	Ratio to Peak	0.1
W890	14.836	75.505	0	1.7666	21.623	Discharge	0.814	1	Ratio to Peak	0.1
W900	18.088	70.743	0	1.0241	12.535	Discharge	0.200	1	Ratio to Peak	0.1

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W910	17.768	78.913	0	3.6438	44.600	Discharge	0.634	1	Ratio to Peak	0.1
W920	6.2787	84.550	0	0.6346	7.7682	Discharge	0.009	1	Ratio to Peak	0.1
W930	14.101	74.359	0	1.8075	22.123	Discharge	0.474	1	Ratio to Peak	0.1
W940	16.792	71.399	0	2.5141	30.772	Discharge	0.202	1	Ratio to Peak	0.1
W950	14.062	74.403	0	1.2805	15.673	Discharge	0.475	1	Ratio to Peak	0.1
W960	11.409	77.577	0	1.1234	13.750	Discharge	0.35737	1	Ratio to Peak	0.1
W970	14.180	74.269	0	3.8842	47.5423654	Discharge	0.40618	1	Ratio to Peak	0.1
W980	17.399	70.763	0	3.0016	36.740	Discharge	0.61078	1	Ratio to Peak	0.1
W990	17.082	71.094	0	3.323893	40.684	Discharge	0.71920	1	Ratio to Peak	0.1

ANNEX 10. Pagsangahan Model Reach Parameters

Table A-10.1. Pagsangahan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R130	Automatic Fixed Interval	1806.5	0.0007	0.5175	Trapezoid	30	45
R140	Automatic Fixed Interval	3761.6	0.0015	0.1459	Trapezoid	30	45
R150	Automatic Fixed Interval	3512.3	0.0022	0.3649	Trapezoid	30	45
R160	Automatic Fixed Interval	2685.4	0.0028	0.0129	Trapezoid	30	45
R180	Automatic Fixed Interval	3376.5	0.0014	0.0583	Trapezoid	30	45
R190	Automatic Fixed Interval	5795.5	0.0024	0.0257	Trapezoid	30	45
R210	Automatic Fixed Interval	1955.8	0.0010	0.1611	Trapezoid	30	45
R230	Automatic Fixed Interval	5125.2	0.0006	0.0964	Trapezoid	30	45
R240	Automatic Fixed Interval	9314.2	0.0008	0.0325	Trapezoid	30	45
R260	Automatic Fixed Interval	2428.4	0.0029	0.1623	Trapezoid	30	45
R300	Automatic Fixed Interval	3832.9	0.0008	0.0129	Trapezoid	30	45
R310	Automatic Fixed Interval	3312.8	0.3146	0.1621	Trapezoid	30	45
R330	Automatic Fixed Interval	501.84	0.0318	0.0622	Trapezoid	30	45
R340	Automatic Fixed Interval	2267.4	0.0029	0.4026	Trapezoid	30	45
R350	Automatic Fixed Interval	3259.3	0.0017	1	Trapezoid	30	45
R370	Automatic Fixed Interval	12095	0.0152	0.0331	Trapezoid	30	45
R380	Automatic Fixed Interval	1300.8	0.0008	0.1220	Trapezoid	30	45
R400	Automatic Fixed Interval	694.56	0.0067	0.0899	Trapezoid	30	45
R440	Automatic Fixed Interval	3378.4	0.0046	0.1016	Trapezoid	30	45
R450	Automatic Fixed Interval	2793.7	0.0008	0.0446	Trapezoid	30	45
R490	Automatic Fixed Interval	7343.5	0.0031	0.1011	Trapezoid	30	45
R500	Automatic Fixed Interval	6193.3	0.0010	0.0141	Trapezoid	30	45
R510	Automatic Fixed Interval	1157.5	0.0008	0.1425	Trapezoid	30	45
R60	Automatic Fixed Interval	2858.7	0.0026	0.0712	Trapezoid	30	45
R80	Automatic Fixed Interval	114.85	0.0008	0.2442	Trapezoid	30	45

ANNEX 11. Pagsangahan Field Validation Points

Table A-11.1. Pagsangahan Field Validation Points for the 5-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
2	11.071	124.54	0.061	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
4	11.075	124.53	0.754	0.36	0.39	Typhoon Ruby/ December 07, 2014	5 -Year
7	11.080	124.53	3.532	0.1	3.43	Typhoon Yolanda/ November 8, 2013	5 -Year
9	11.070	124.54	0.589	0.48	0.11	Typhoon Yolanda/ November 8, 2013	5 -Year
10	11.068	124.54	1.021	0.48	0.54	Typhoon Yolanda/ November 8, 2013	5 -Year
11	11.075	124.56	0.030	0.95	-0.92	Typhoon Yolanda/ November 8, 2013	5 -Year
12	11.075	124.56	0.030	0.1	-0.07	Typhoon Yolanda/ November 8, 2013	5 -Year
13	11.077	124.56	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
14	11.079	124.56	0.030	0.1	-0.07	Typhoon Ruby/ December 07, 2014	5 -Year
17	11.077	124.57	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
18	11.069	124.56	0.340	0	0.34	Typhoon Ruby/ December 07, 2014	5 -Year
21	11.076	124.54	0.030	0.1	-0.07	Typhoon Ruby/ December 07, 2014	5 -Year
22	11.082	124.54	0.030	0.95	-0.92	Typhoon Yolanda/ December 07, 2014	5 -Year
23	11.086	124.54	0.056	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
24	11.094	124.55	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
25	11.098	124.55	0.035	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
26	11.099	124.56	0.035	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
27	11.100	124.56	0.035	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
28	11.095	124.54	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
29	11.095	124.54	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
30	11.092	124.54	0.039	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
31	11.091	124.54	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
32	11.090	124.53	0.424	0	0.42	Typhoon Ruby/ December 07, 2014	5 -Year
36	11.091	124.54	0.127	0	0.13	Typhoon Ruby/ December 07, 2014	5 -Year
37	11.058	124.55	0.510	1	-0.49	Typhoon Ruby/ December 07, 2014	5 -Year
40	11.050	124.55	0.139	0.48	-0.34	Typhoon Ruby/ December 07, 2014	5 -Year
41	11.048	124.55	0.550	0.48	0.07	Typhoon Ruby/ December 07, 2014	5 -Year
42	11.046	124.55	0.494	0.48	0.01	Typhoon Ruby/ December 07, 2014	5 -Year
43	11.041	124.55	0.030	0.48	-0.45	Typhoon Ruby/ December 07, 2014	5 -Year
44	11.042	124.55	0.160	0.66	-0.50	Typhoon Ruby/ December 07, 2014	5 -Year
45	11.042	124.55	0.404	0.95	-0.55	Typhoon Ruby/ December 07, 2014	5 -Year
46	11.040	124.55	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
47	11.034	124.57	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
48	11.036	124.56	0.437	0.95	-0.51	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
49	11.036	124.55	0.339	0	0.34	Typhoon Ruby/ December 07, 2014	5 -Year
50	11.036	124.55	0.339	0	0.34	Typhoon Ruby/ December 07, 2014	5 -Year
51	11.033	124.55	0.172	0.66	-0.49	Typhoon Ruby/ December 07, 2014	5 -Year
52	11.030	124.55	0.509	0.66	-0.15	Typhoon Ruby/ December 07, 2014	5 -Year
53	11.026	124.55	0.409	0.36	0.05	Typhoon Ruby/ December 07, 2014	5 -Year
54	11.024	124.55	0.390	0.36	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
55	11.024	124.55	0.030	0.36	-0.33	Typhoon Ruby/ December 07, 2014	5 -Year
56	11.024	124.55	0.030	0.36	-0.33	Typhoon Ruby/ December 07, 2014	5 -Year
57	11.021	124.56	0.092	0.36	-0.27	Typhoon Ruby/ December 07, 2014	5 -Year
58	11.020	124.56	0.756	0.48	0.28	Typhoon Ruby/ December 07, 2014	5 -Year
59	11.018	124.56	0.166	0.48	-0.31	Typhoon Ruby/ December 07, 2014	5 -Year
60	11.018	124.56	0.131	0.95	-0.82	Typhoon Ruby/ December 07, 2014	5 -Year
62	11.019	124.56	0.334	0.48	-0.15	Typhoon Ruby/ December 07, 2014	5 -Year
63	11.020	124.55	0.071	0.48	-0.41	Typhoon Ruby/ December 07, 2014	5 -Year
64	11.023	124.55	0.030	0.48	-0.45	Typhoon Ruby/ December 07, 2014	5 -Year
65	11.039	124.55	0.874	0.48	0.39	Typhoon Ruby/ December 07, 2014	5 -Year
67	11.040	124.55	0.230	0.95	-0.72	Typhoon Ruby/ December 07, 2014	5 -Year
68	11.039	124.55	0.658	0.95	-0.29	Typhoon Ruby/ December 07, 2014	5 -Year
70	11.042	124.54	0.866	0.95	-0.08	Typhoon Ruby/ December 07, 2014	5 -Year
71	11.043	124.54	1.074	0.95	0.12	Typhoon Ruby/ December 07, 2014	5 -Year
72	11.045	124.55	0.610	0.48	0.13	Typhoon Ruby/ December 07, 2014	5 -Year
73	11.049	124.54	1.233	0.48	0.75	Typhoon Ruby/ December 07, 2014	5 -Year
74	11.048	124.54	0.964	0.48	0.48	Typhoon Ruby/ December 07, 2014	5 -Year
75	11.046	124.55	1.008	0.48	0.53	Typhoon Ruby/ December 07, 2014	5 -Year
76	11.043	124.54	1.198	0.95	0.25	Typhoon Ruby/ December 07, 2014	5 -Year
77	11.042	124.54	1.562	0.1	1.46	Typhoon Ruby/ December 07, 2014	5 -Year
78	11.042	124.54	1.562	0.95	0.61	Typhoon Ruby/ December 07, 2014	5 -Year
79	11.041	124.54	1.411	0.48	0.93	Typhoon Ruby/ December 07, 2014	5 -Year
80	11.041	124.54	1.285	0.48	0.80	Typhoon Ruby/ December 07, 2014	5 -Year
81	11.040	124.54	1.310	0.48	0.83	Typhoon Ruby/ December 07, 2014	5 -Year
84	11.042	124.54	1.185	1.52	-0.34	Typhoon Ruby/ December 07, 2014	5 -Year
85	11.045	124.54	1.185	0.48	0.70	Typhoon Ruby/ December 07, 2014	5 -Year
86	11.045	124.54	0.839	0.48	0.36	Typhoon Ruby/ December 07, 2014	5 -Year
87	11.051	124.53	0.030	0.48	-0.45	Typhoon Ruby/ December 07, 2014	5 -Year
88	11.052	124.53	0.030	0.48	-0.45	Typhoon Ruby/ December 07, 2014	5 -Year
89	11.054	124.53	0.030	0.36	-0.33	Typhoon Ruby/ December 07, 2014	5 -Year
90	11.058	124.53	0.030	0.48	-0.45	Typhoon Ruby/ December 07, 2014	5 -Year
91	11.062	124.53	0.268	0	0.27	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
92	11.036	124.56	0.038	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
93	11.033	124.56	0.030	0.48	-0.45	Typhoon Ruby/ December 07, 2014	5 -Year
94	11.032	124.56	0.030	0.36	-0.33	Typhoon Ruby/ December 07, 2014	5 -Year
95	11.029	124.56	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
96	11.026	124.56	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
97	11.023	124.57	0.030	0.1	-0.07	Typhoon Ruby/ December 07, 2014	5 -Year
98	11.021	124.56	0.644	0.36	0.28	Typhoon Ruby/ December 07, 2014	5 -Year
99	11.026	124.56	0.644	0.36	0.28	Typhoon Yolanda/ November 8, 2013	5 -Year
105	11.074	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
107	11.076	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
108	11.082	124.52	0.034	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
109	11.083	124.52	0.211	0	0.21	Typhoon Ruby/ December 07, 2014	5 -Year
110	11.086	124.52	0.257	0	0.26	Typhoon Ruby/ December 07, 2014	5 -Year
111	11.088	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
112	11.089	124.52	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
113	11.091	124.52	0.032	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
114	11.090	124.52	1.952	0.36	1.59	Typhoon Ruby/ December 07, 2014	5 -Year
115	11.090	124.52	2.088	0.48	1.61	Typhoon Yolanda/ November 8, 2013	5 -Year
118	11.089	124.52	2.306	0.48	1.83	Typhoon Ruby/ December 07, 2014	5 -Year
119	11.090	124.52	2.222	0.48	1.74	Typhoon Ruby/ December 07, 2014	5 -Year
120	11.093	124.52	0.112	0	0.11	Typhoon Ruby/ December 07, 2014	5 -Year
121	11.093	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
122	11.094	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
123	11.095	124.52	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
124	11.074	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
125	11.073	124.52	0.579	0.48	0.10	Typhoon Ruby/ December 07, 2014	5 -Year
127	11.071	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
129	11.070	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
130	11.068	124.52	0.127	0	0.13	Typhoon Ruby/ December 07, 2014	5 -Year
131	11.068	124.52	0.327	0	0.33	Typhoon Ruby/ December 07, 2014	5 -Year
133	11.068	124.52	0.032	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
134	11.067	124.52	0.248	0	0.25	Typhoon Ruby/ December 07, 2014	5 -Year
136	11.065	124.52	0.100	0	0.10	Typhoon Ruby/ December 07, 2014	5 -Year
137	11.062	124.52	0.045	0	0.05	Typhoon Ruby/ December 07, 2014	5 -Year
139	11.064	124.52	0.094	0	0.09	Typhoon Ruby/ December 07, 2014	5 -Year
140	11.063	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
141	11.063	124.52	0.788	0	0.79	Typhoon Ruby/ December 07, 2014	5 -Year
142	11.062	124.52	0.488	0	0.49	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
143	11.061	124.51	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
144	11.057	124.51	0.061	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
145	11.055	124.51	0.092	0	0.09	Typhoon Ruby/ December 07, 2014	5 -Year
146	11.055	124.52	0.060	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
147	11.052	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
148	11.050	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
149	11.046	124.52	0.217	0	0.22	Typhoon Ruby/ December 07, 2014	5 -Year
150	11.043	124.52	0.199	0	0.20	Typhoon Ruby/ December 07, 2014	5 -Year
151	11.040	124.52	0.032	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
152	11.039	124.52	0.093	0	0.09	Typhoon Ruby/ December 07, 2014	5 -Year
153	11.036	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
154	11.037	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
155	11.038	124.53	0.139	0	0.14	Typhoon Ruby/ December 07, 2014	5 -Year
156	10.999	124.54	0.564	0.95	-0.39	Typhoon Ruby/ December 07, 2014	5 -Year
157	10.999	124.54	1.199	1.7	-0.50	Typhoon Ruby/ December 07, 2014	5 -Year
158	10.999	124.54	0.087	1.95	-1.86	Typhoon Ruby/ December 07, 2014	5 -Year
159	11.001	124.54	1.153	2.74	-1.59	Typhoon Ruby/ December 07, 2014	5 -Year
160	11.002	124.54	1.226	1.52	-0.29	Typhoon Ruby/ December 07, 2014	5 -Year
161	11.003	124.54	1.064	1.12	-0.06	Typhoon Ruby/ December 07, 2014	5 -Year
163	11.005	124.54	1.022	1.52	-0.50	Typhoon Ruby/ December 07, 2014	5 -Year
164	11.005	124.54	1.200	0.95	0.25	Typhoon Ruby/ December 07, 2014	5 -Year
167	11.000	124.54	1.288	0.95	0.34	Typhoon Ruby/ December 07, 2014	5 -Year
168	11.000	124.54	1.077	0.95	0.13	Typhoon Ruby/ December 07, 2014	5 -Year
169	10.999	124.54	1.418	0.95	0.47	Typhoon Ruby/ December 07, 2014	5 -Year
170	10.999	124.54	1.386	0.95	0.44	Typhoon Ruby/ December 07, 2014	5 -Year
171	10.999	124.54	1.171	0.95	0.22	Typhoon Ruby/ December 07, 2014	5 -Year
172	10.999	124.54	1.286	0.95	0.34	Typhoon Ruby/ December 07, 2014	5 -Year
173	11.000	124.54	1.162	1.38	-0.22	Typhoon Ruby/ December 07, 2014	5 -Year
174	11.000	124.53	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
175	11.004	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
176	11.004	124.53	0.041	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
177	11.006	124.53	0.061	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
178	11.008	124.53	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
179	11.009	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
180	11.012	124.53	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
181	11.016	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
182	11.017	124.53	0.071	0	0.07	Typhoon Ruby/ December 07, 2014	5 -Year
183	11.016	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
184	11.017	124.53	0.060	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
185	11.018	124.53	0.246	0	0.25	Typhoon Ruby/ December 07, 2014	5 -Year
186	11.020	124.53	0.353	0	0.35	Typhoon Ruby/ December 07, 2014	5 -Year
187	11.022	124.53	0.100	0	0.10	Typhoon Ruby/ December 07, 2014	5 -Year
188	11.023	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
189	11.026	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
190	11.028	124.53	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
191	11.030	124.52	0.119	0	0.12	Typhoon Ruby/ December 07, 2014	5 -Year
192	11.032	124.52	0.982	0	0.98	Typhoon Ruby/ December 07, 2014	5 -Year
193	11.037	124.53	0.076	0	0.08	Typhoon Ruby/ December 07, 2014	5 -Year
194	11.037	124.53	0.215	0.1	0.12	Typhoon Ruby/ December 07, 2014	5 -Year
195	11.036	124.53	0.493	0.1	0.39	Typhoon Ruby/ December 07, 2014	5 -Year
196	11.033	124.53	0.449	0.48	-0.03	Typhoon Ruby/ December 07, 2014	5 -Year
197	11.028	124.54	0.671	0	0.67	Typhoon Ruby/ December 07, 2014	5 -Year
198	11.029	124.54	0.759	0	0.76	Typhoon Ruby/ December 07, 2014	5 -Year
199	11.031	124.53	0.462	0	0.46	Typhoon Ruby/ December 07, 2014	5 -Year
200	11.032	124.53	0.491	0	0.49	Typhoon Ruby/ December 07, 2014	5 -Year
201	11.032	124.53	0.416	0	0.42	Typhoon Ruby/ December 07, 2014	5 -Year
202	11.012	124.52	0.042	0	0.04	Typhoon Ruby/ December 07, 2014	5 -Year
203	11.020	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
204	11.028	124.52	0.142	0	0.14	Typhoon Ruby/ December 07, 2014	5 -Year
205	11.038	124.51	0.572	0	0.57	Typhoon Ruby/ December 07, 2014	5 -Year
206	11.046	124.49	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
207	11.058	124.47	0.232	0	0.23	Typhoon Ruby/ December 07, 2014	5 -Year
208	11.078	124.49	0.047	0	0.05	Typhoon Ruby/ December 07, 2014	5 -Year
209	11.080	124.49	1.244	0	1.24	Typhoon Ruby/ December 07, 2014	5 -Year
210	11.073	124.49	0.811	0	0.81	Typhoon Ruby/ December 07, 2014	5 -Year
211	11.071	124.49	0.743	0	0.74	Typhoon Ruby/ December 07, 2014	5 -Year
212	11.060	124.50	1.480	0	1.48	Typhoon Ruby/ December 07, 2014	5 -Year
213	11.017	124.52	1.059	0	1.06	Typhoon Ruby/ December 07, 2014	5 -Year
214	11.011	124.52	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
215	11.027	124.50	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
216	11.042	124.49	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
217	11.038	124.50	0.097	0	0.10	Typhoon Ruby/ December 07, 2014	5 -Year
218	11.058	124.47	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
219	11.052	124.49	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
220	11.042	124.50	0.141	0	0.14	Typhoon Ruby/ December 07, 2014	5 -Year
221	11.072	124.49	0.045	0	0.05	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
222	11.063	124.50	0.056	0	0.06	Typhoon Ruby/ December 07, 2014	5 -Year
223	11.037	124.51	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
224	11.027	124.51	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
225	11.019	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
226	11.017	124.52	0.031	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year
227	11.044	124.50	0.611	0	0.61	Typhoon Ruby/ December 07, 2014	5 -Year
228	11.071	124.49	0.055	0	0.05	Typhoon Ruby/ December 07, 2014	5 -Year
229	11.027	124.51	0.350	0	0.35	Typhoon Ruby/ December 07, 2014	5 -Year
230	11.038	124.51	0.275	0	0.28	Typhoon Ruby/ December 07, 2014	5 -Year
231	11.066	124.51	0.141	0	0.14	Typhoon Ruby/ December 07, 2014	5 -Year
232	11.073	124.49	0.030	0	0.03	Typhoon Ruby/ December 07, 2014	5 -Year

Table A-11.2. Pagsangahan Field Validation Points for the 25-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
331	11.0698005	124.51904	0.0890	1.38	-1.2910	Typhoon Ondoy/ September 26, 2009	25 -Year
335	11.0680972	124.518745	0.033	0.48	-0.4470	Typhoon Ondoy/ September 26, 2009	25 -Year
341	11.0625382	124.520273	0.030999	0.1	-0.0690	Typhoon Ondoy/ September 26, 2009	25 -Year

Table A-11.3. Pagsangahan Field Validation Points for the 100-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
194	11.0731586	124.537136	1.652	0.1	1.552	Typhoon Frank/ June 20, 2008	100 -Year
196	11.0739883	124.536171	2.748	1.12	1.628	Typhoon Seniang/ December 30, 2014	100 -Year
200	11.0764902	124.532948	1.690	0.48	1.210	Typhoon Seniang/ December 30, 2014	100 -Year
201	11.077506	124.531884	1.661	0.48	1.181	Typhoon Frank/ June 20, 2008	100 -Year
204	11.0714307	124.539152	1.595	0.48	1.115	Typhoon Frank/ June 20, 2008	100 -Year
211	11.0795594	124.564493	0.052	0.48	-0.428	Typhoon Frank/ June 20, 2008	100 -Year
212	11.0770543	124.565777	0.034	0	0.034	Typhoon Frank/ June 20, 2008	100 -Year
215	11.0683038	124.553576	1.041	0.48	0.561	Typhoon Frank/ June 20, 2008	100 -Year
216	11.0671126	124.55257	1.168	0.36	0.808	Typhoon Frank/ June 20, 2008	100 -Year
229	11.0902126	124.532783	1.549	0.48	1.069	Typhoon Frank/ June 20, 2008	100 -Year
230	11.0898163	124.531231	2.200	0.48	1.720	Typhoon Frank/ June 20, 2008	100 -Year
231	11.0900129	124.531712	2.308	0.48	1.828	Typhoon Frank/ June 20, 2008	100 -Year
234	11.0530604	124.554523	1.396	0.48	0.916	Typhoon Frank/ June 20, 2008	100 -Year
235	11.0530596	124.554524	1.396	0.48	0.916	Typhoon Frank/ June 20, 2008	100 -Year
260	11.0174344	124.56024	1.378	1.52	-0.142	Typhoon Frank/ June 20, 2008	100 -Year
265	11.0402137	124.550544	0.327	1.52	-1.193	Typhoon Frank/ June 20, 2008	100 -Year
269	11.0414193	124.546882	1.032	0.95	0.082	Typhoon Frank/ June 20, 2008	100 -Year
282	11.0406902	124.537444	1.289	0.95	0.339	Typhoon Seniang/ December 30, 2014	100 -Year
283	11.0407649	124.537422	1.903	1.70	0.203	Typhoon Seniang/ December 30, 2014	100 -Year
303	11.0658895	124.532	1.727	0.36	1.367	Typhoon Frank/ June 20, 2008	100 -Year
304	11.0658915	124.532003	1.727	1.12	0.607	Typhoon Frank/ June 20, 2008	100 -Year
305	11.0686817	124.529823	1.960	1.12	0.840	Typhoon Frank/ June 20, 2008	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
306	11.0721085	124.52791	1.515	0.1	1.415	Typhoon Frank/ June 20, 2008	100 -Year
307	11.0757496	124.526081	2.240	1.12	1.120	Typhoon Frank/ June 20, 2008	100 -Year
309	11.0744592	124.520135	1.856	0.1	1.756	Typhoon Frank/ June 20, 2008	100 -Year
319	11.0894876	124.52225	4.297	1.70	2.597	Typhoon Frank/ June 20, 2008	100 -Year
320	11.0891136	124.522071	4.137	2	2.137	Typhoon Frank/ June 20, 2008	100 -Year
329	11.0714839	124.518913	0.032	0.48	-0.448	Typhoon Seniang/ December 30, 2014	100 -Year
338	11.0672168	124.51952	1.243	0.95	0.293	Typhoon Frank/ June 20, 2008	100 -Year
368	11.0048218	124.539583	1.548	1.12	0.428	Typhoon Seniang/ December 30, 2014	100 -Year
371	11.005468	124.544272	1.329	1.8	-0.471	Typhoon Frank/ June 20, 2008	100 -Year
372	10.9995359	124.5391	1.288	2.74	-1.452	Typhoon Frank/ June 20, 2008	100 -Year

ANNEX 12. Educational Institutions Affected by Flooding in Pagsangahan Floodplain

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

LEYTE				
ORMOC CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Catmon Elementary School	Airport			
Catmon Garnet Daycare Center	Airport			
Bayog Daycare Center	Bayog			Medium
Diego Silang Daycare Center	Esperanza	Medium	Medium	Medium
Esperanza Elementary School	Esperanza			
Green Valley Elementary School	Esperanza			
RM Tan Elementary School	Green Valley	High	High	High
Labrador Elementary School	Labrador			Low
Lao Elementary School	Lao	Low	Medium	Medium
Curva Elementary School	Licuma			
San Vicente Elementary School	Licuma			
Jica-Lao Elementary School	Liloan		Medium	Medium
Lao Elementary School	Liloan	Low	Medium	Medium
Liloan Daycare Center	Liloan	Low	Medium	Medium
Liloan Elementary School	Liloan	Low	Medium	Medium
Liloan National High School	Liloan	Medium	Medium	High
Licuma Daycare Center	Mabato	Low	Medium	Medium
Licuma Elementary School	Mabato		Low	Medium
Margen Elementary School	Margen			
Margen National High School	Margen	Medium	Medium	Medium
Mas-in Elementary School	Mas-In	Medium	Medium	Medium
Catmon Elementary School	Nasunogan			
Inaad Elementary School	Nueva Sociedad			
Rustico Capahi Sr. Memorial National School	Sabang Bao	Medium	Medium	High
Sabang Bao Elementary School	Sabang Bao	Low	Medium	Medium
Bayog Elementary School	San Jose			Medium
G. Lurenana National High School	San Jose	Low	Low	Medium
San Jose Elementary School	San Jose		Low	Low
San Juan Elementary School	San Juan	Medium	Medium	Medium
Curva Elementary School	San Vicente			

ANNEX 13. Medical Institutions Affected by Flooding in Pagsangahan Floodplain

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

LEYTE				
ORMOC CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Catmon Health Center	Airport			
Bayog Health Center	Bayog			Low
Esperanza Health Center	Esperanza			
RM Tan Health Center	Green Valley	Medium	High	High
Curva District Health Center	Licuma			Low
Liloan Health Center	Liloan	Medium	Medium	High
Licuma Health Center	Mabato	Medium	Medium	High
Mas-in Health Center	Mas-In	Medium	Medium	Medium