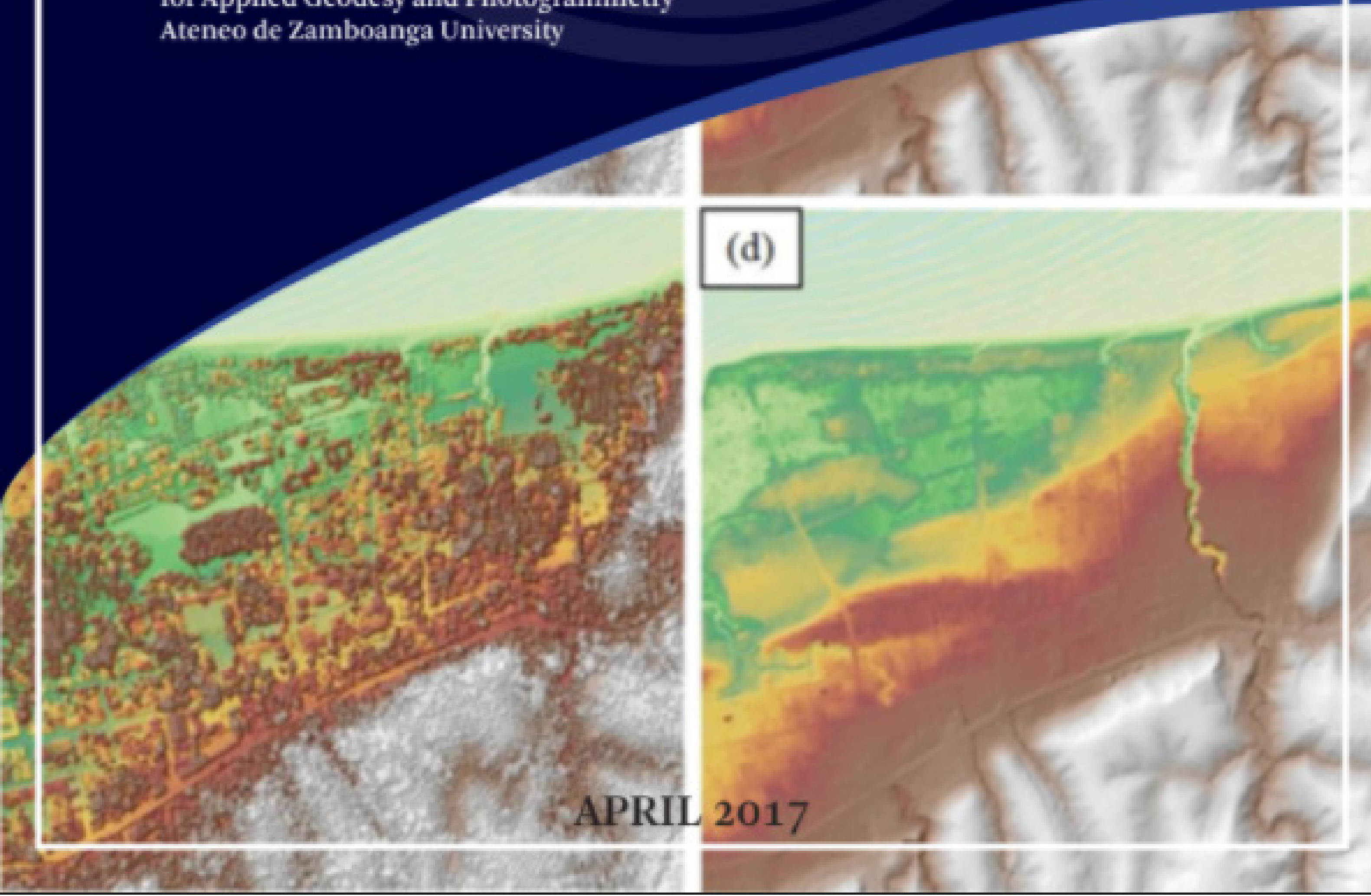
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Salug River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SALUG RIVER

1.1 Background of the Phil-LiDAR 1 Program

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

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled *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 28 river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Salug River Basin

The Salug River Basin covers two (2) municipalities in the Province of Leyte; namely, the municipalities of Hilongos and Hindang. It also covers some portions of the municipality of Inopacan. The DENR River Basin Control Office (RBCO) states that the Salug River Basin has a drainage area of 150 km² and an estimated 285 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Salug River, is among the twenty-eight (28) river systems in Eastern Visayas Region. According to the 2015 National Census of PSA, a total of 16,886 persons are residing within the immediate vicinity of the river which is distributed among barangays Pa-A, Imelda Marcos, Proteccion, Liberty, Lamak, Eastern Barangay, Central Barangay, and Atabay in the Municipality of Hilongos, Province of Leyte. In terms of economy, agriculture is the main source of livelihood in the province. As of 2014, the top three (3) agricultural crops were rice/palay, coconut, and corn (Philippine Statistics Authority, 2017). In November 7, 2013, Typhoon Yolanda, one of the strongest and disastrous tropical cyclones, intensified towards Eastern Visayas maintaining its strength and intensity which damaged properties amounting to PhP93B (infrastructure, productive, social, and cross sectoral). In terms of the number of deaths, the National Risk Reduction and Management Council (NDRRMC) confirmed the overall total of 6,300. Out of the total number, 5,902 (93%) came from Region VIII. Most deaths were due to drowning and trauma (National Disaster Risk Reduction and Management Council, 2013).

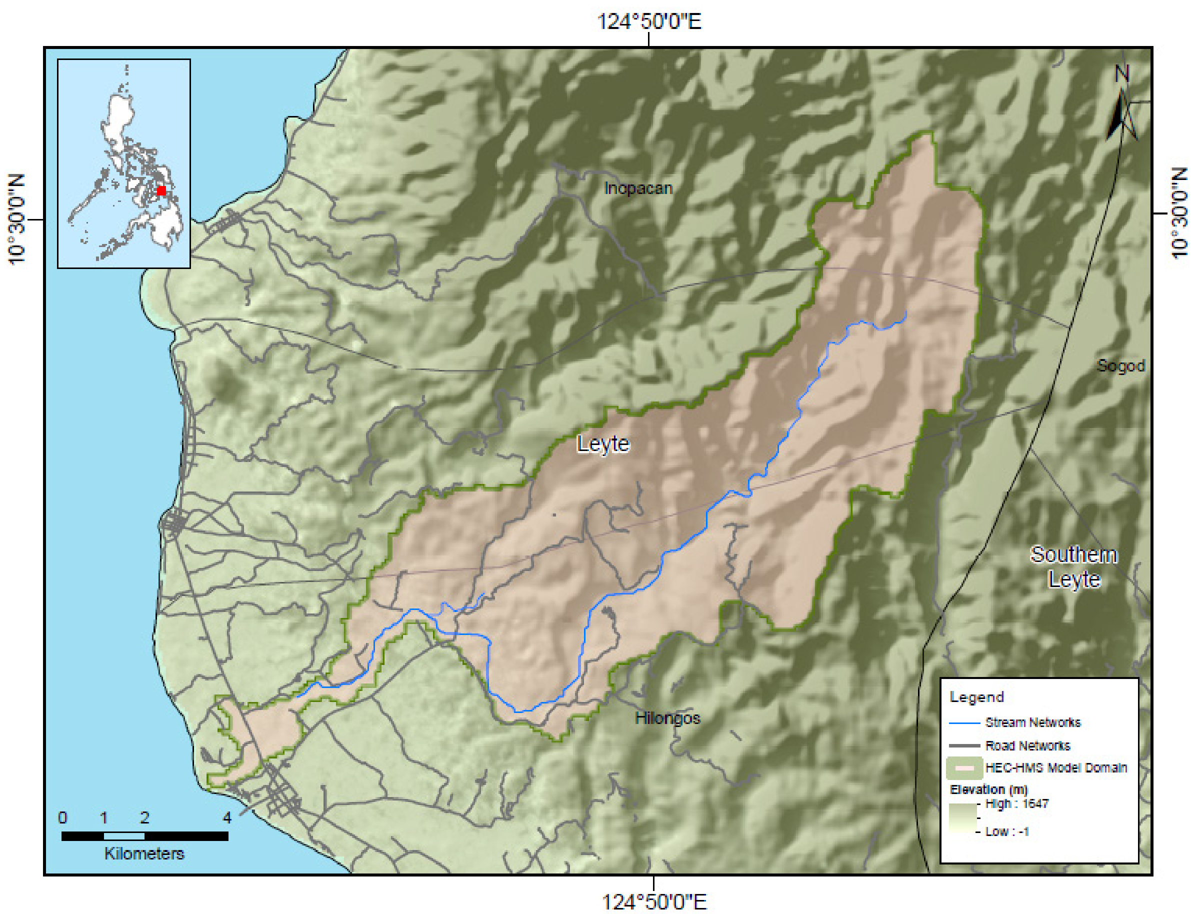


Figure 1. Map of the Salug River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN SALUG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Ms. Jonalyn S. Gonzales

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Salug Floodplain in Leyte and Southern Leyte. These missions were planned for 7 lines that run for at most four (4) hours including take-off, landing and turning time. The flight planning parameters for Aquarius and Gemini LiDAR systems are found in Table 1 and Table 2, respectively. Figure 2 shows the flight plan for Salug Floodplain survey.

Table 1. Flight planning parameters for 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)
BLK49B	600	35	36	100	45	130	5
BLK49A	600	35	36	100	45	130	5
BLK35X	500	35	36	100	45	130	5
BLK35E	600	35	36	100	45	130	5

Table 2. Flight planning parameters for 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)
BLK34A	1000	30	36	100	50	130	5
BLK49A	1000	30	36	100	50	130	5
BLK49B	1000	30	36	100	50	130	5
BLK49D	1000	30	36	100	50	130	5
BLK49E	1000	30	36	100	50	130	5
BLK34F	1000	30	36	100	50	130	5

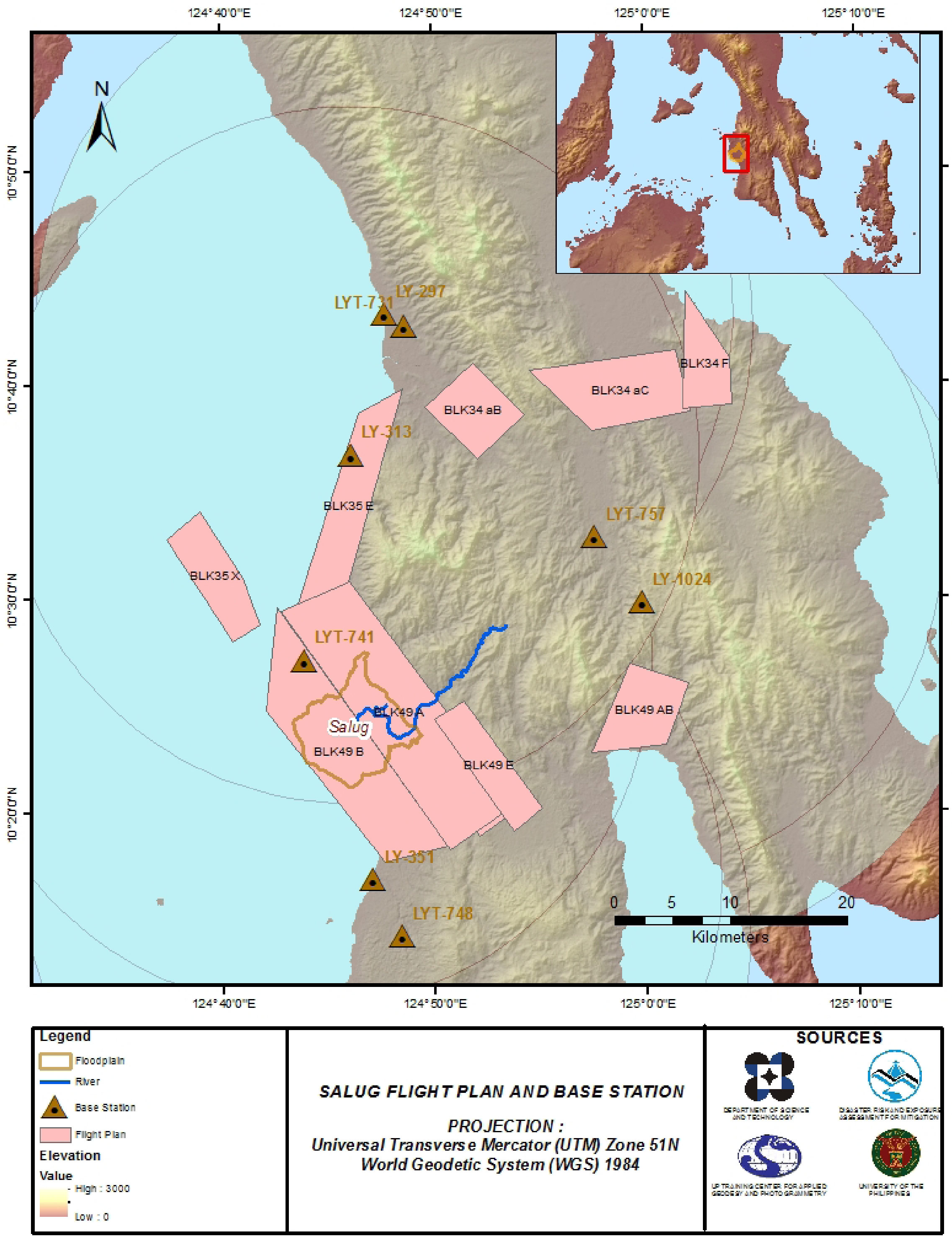
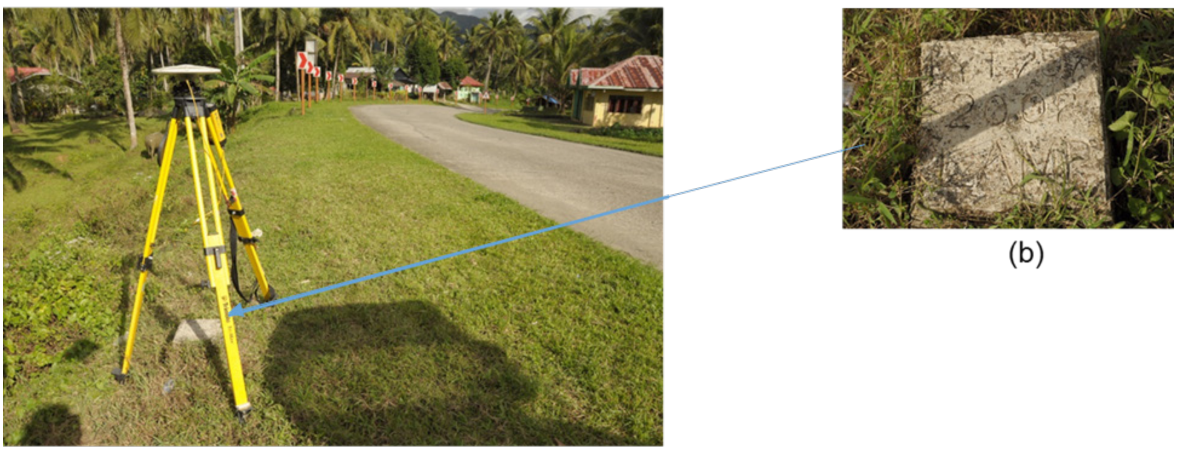


Figure 2. Flight plan and base stations for Salug Floodplain.

2.2 Ground Base Station

The project team was able to recover four (4) NAMRIA ground control points: LYT-757, LYT-748, LYT-731 and LYT-741 which are of second (2nd) order accuracy. The project team also established three (3) ground control points LY-351, LY-297 and LY-313, and re-processed one (1) benchmark LY-1024. The certifications for the base stations are found in ANNEX A-2 while the baseline processing reports for the re-processed ground control point and established points are found in ANNEX A-3. These were used as base stations during flight operations for the entire duration of the survey (January 21- February 19, 2015, February 4-18, 2016 and April 6-20, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Salug Floodplain are shown in Figure 1.

Figure 3 to Figure 6 show the recovered NAMRIA reference points and established points within the area. In addition, Table 3 to Table 10 show the details about the NAMRIA control stations while Table 11 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.



(a) (b)

Figure 3. GPS set-up over LYT-757 as recovered on the opposite side of the kilometer post 997 in barangay Mahayahay, Leyte (a) and NAMRIA reference point LYT-757 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point LYT-757 used as base station for the LiDAR acquisition

Station Name	LYT-757	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 32' 54.87" North
	Longitude	124° 57' 31.14" East
	Ellipsoidal Height	99.55 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	495474.491 meters
	Northing	1166401.318 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	10° 32' 50.77355" North
	Longitude	124° 57' 36.36037" East
	Ellipsoidal Height	163.36300 meters

Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	714331.34 meters 1166663.62 meters

Figure 4. GPS set-up over LY-1024 located at the SE end of the sidewalk of Agas-agas Bridge at KM post 1006 + 972.6 and 4 meters from the road centerline (a) and NAMRIA reference point LY-1024 (b) as recovered by the field team.

Table 4. Details of the reprocessed NAMRIA vertical control point LY-1024 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	LY-1024	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 29' 46.27905" North 124° 59' 49.85591" East 366.202 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 29' 42.20218" North 124° 59' 55.07713" East 430.223 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718586.237 meters 1160895.197 meters

(a) (b)

Figure 5. GPS set-up over LYT-748 at the back of Hitoog Elementary School, Brgy. Hitoog, Municipality of Matalom, Leyte (a) and NAMRIA reference point LYT-748 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point LYT-748 used as base station for the LiDAR acquisition.

Station Name	LYT-748	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°14’16.77457’’North 124°48’19.08041’’ East 77.51500 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	478669.714 meters 1132057.716 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°14’12.74720’’ North 124°48’24.32650’’ East 141.66500 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	697740.37 meters 1132208.87 meters

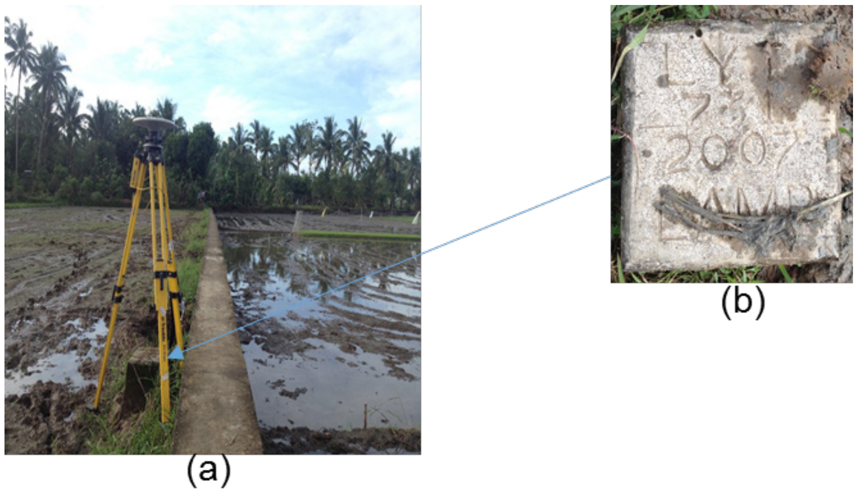


Figure 6. GPS set-up over LYT-731 in Brgy. Kansungka, Baybay City, Leyte (a) and NAMRIA reference point LYT-731(b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point LYT-731 used as base station for the LiDAR acquisition.

Station Name	LYT-731	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°42’47.59466’’ North 124°48’34.34382’’ East 15.60931 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 1992)	Easting Northing	697902.97 meters 1184777.35 meters

Table 7. Details of the established horizontal control point LY-351 with processed coordinates used as base station for the LiDAR acquisition

Station Name	LY-351	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 16' 52.30167" North 124° 47' 03.77264" East 6.886meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 16' 48.26132" North 124° 47' 09.01515" East 70.885 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	695421.839 meters 1136974.636 meters

Table 8. Details of the established horizontal control point LYT-741 with processed coordinates used as base station for the LiDAR acquisition

Station Name	LYT-741	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 27' 11.95722" North 124° 43' 45.08400" East 4.48300 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	470351.659 meters 1155878.867 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 27' 7.86786" North 124° 43' 50.311177" East 67.94500 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	689272.22 meters 1155979.90 meters

Table 9. Details of the established horizontal control point LY-313 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	LY-313	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10º 36' 46.67221" North 124º 46' 01.67926" East 6.279 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10º 36' 42.54525" North 124º 46' 06.89257" East 69.460 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	693326.992 meters 1173661.006 meters

Table 10. Details of the established horizontal control point LY-297 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	LY-297	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10º 43' 21.53694" North 124º 47' 38.67725" East 6.908 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10º 43' 17.38426" North 124º 47' 43.88062" East 69.895 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	696205.243 meters 1185810.360 meters

Table 11. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
22 January 2015	7754AC	3BLK49B022A	LYT-748 and LY-351
23 January 2015	7756AC	3BLK49A023A	LYT-748 and LY-351
28 January 2015	7767AC	3BLK35X028B	LYT-748 and LY-351
11 February 2015	7794AC	3BLK35EV042A	LYT-731 and LY-297
12 February 2016	3781G	2BLK34A043A	LY-1024 and LYT-757
10 April 2016	3921G	2BLK34A101A	LYT-741 and LY-313
10 April 2016	3923G	2BLK49AB101B	LYT-741 and LY-313
11 April 2016	3925G	2BLK49DE102A	LYT-741 and LY-313

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR Data Acquisition in Salug Floodplain, for a total of thirty hours and thirty-six minutes (30+36) of flying time for RP-C9022 and RP-C9322. All missions were acquired using the Gemini and Aquarius LiDAR systems. Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for LiDAR data acquisition in Salug Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
22 January 2015	7754AC	263.95	101.85	37.05	64.80	0	4	35
23 January 2015	7756AC	263.95	90.31	25.03	65.28	0	3	53
28 January 2015	7767AC	38.87	37.07	NA	37.07	0	2	59
11 February 2015	7794AC	229.03	75.56	2.00	73.56	0	4	11
12 February 2016	3781G	99.28	98.64	10.47	88.17	315	3	23
10 April 2016	3921G	145.1	156.70	9.88	146.82	0	4	27
10 April 2016	3923G	263.85	208.28	9.90	198.38	0	2	48
11 April 2016	3925G	234.3	76.02	27.23	48.79	0	4	20
TOTAL		1538.33	844.43	121.56	722.87	0	30	36

Table 13. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (AGL) (m)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency(Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3781G	1000	30	36	100	50	130	5
7756AC	600	35	36	100	45	130	5
7754AC	600	35	36	100	45	130	5
7794AC	600	35	36	100	45	130	5
7767AC	500	35	36	100	45	130	5
3925G	1000	30	36	100	50	130	5
3921G	1000	30	36	100	50	130	5
3923G	1000	30	36	100	50	130	5

2.4 Survey Coverage

Salug Floodplain is situated within the municipalities of Leyte and Southern Leyte. The municipality of Hilongos in Leyte is mostly covered during the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Salug Floodplain is presented in Figure 7

Table 14. List of municipalities/cities surveyed during Salug Floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Leyte	Hilongos	156.80	120.09	76.59%
	Hindang	106.77	53.30	49.92%
	Baybay City	404.37	69.57	17.20%
	Inopacan	196.05	31.06	15.84%
	Abuyog	256.67	39.62	15.44%
	Mahaplag	180.30	24.78	13.74%
	Matalom	110.13	7.54	6.85%
Southern Leyte	Sogod	217.20	40.00	18.42%
	Bontoc	89.13	8.83	9.90%
Total		1717.42	394.79	24.88%

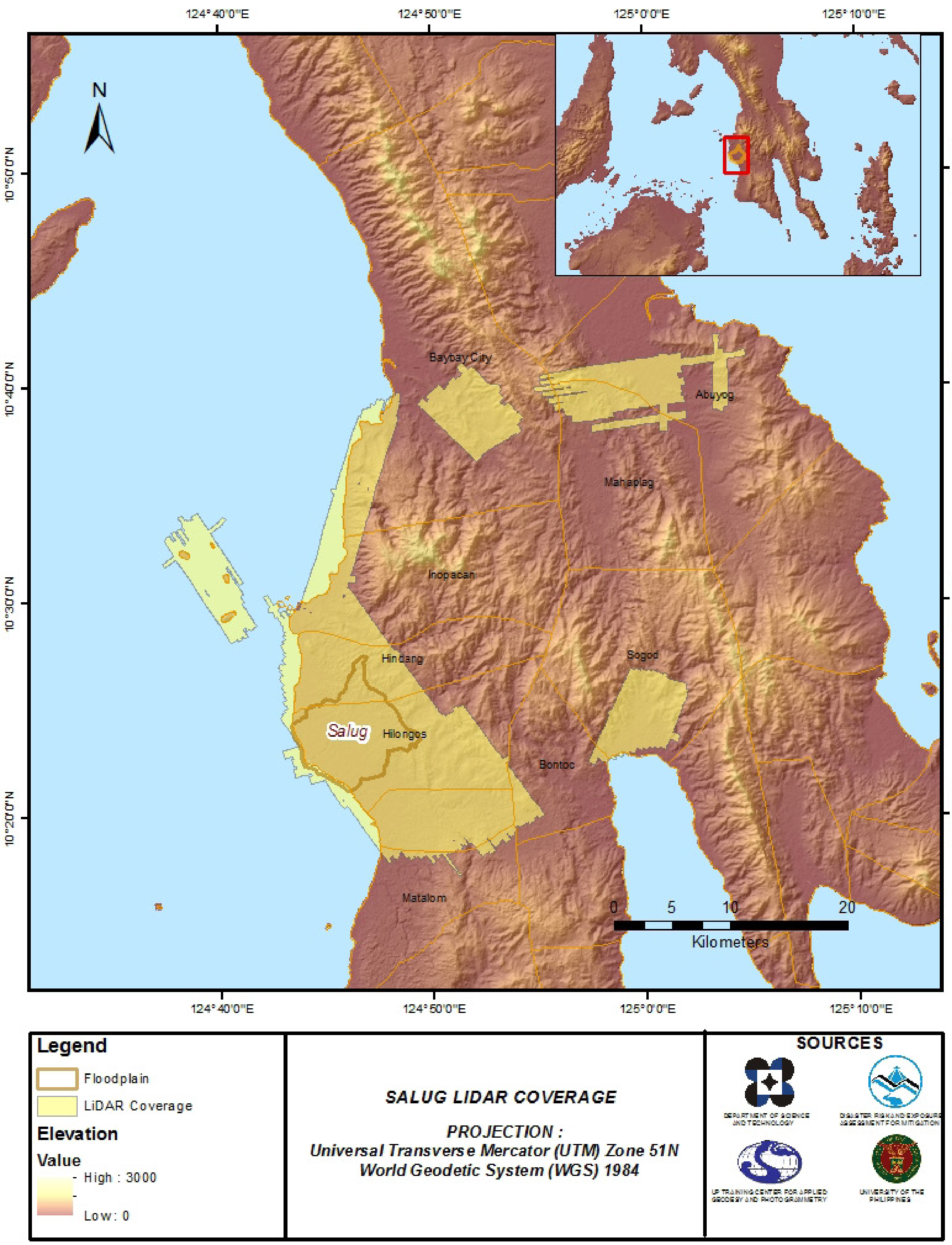


Figure 7. Actual LiDAR survey coverage for Salug Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR SALUG FLOODPLAIN

Engr. Ma. Ailyn L. Olanda, Engr. Erica Erin E. Elazegui, Jovy Anne S. Narisma, Engr. Karl Adrian P. Vergara

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 8.

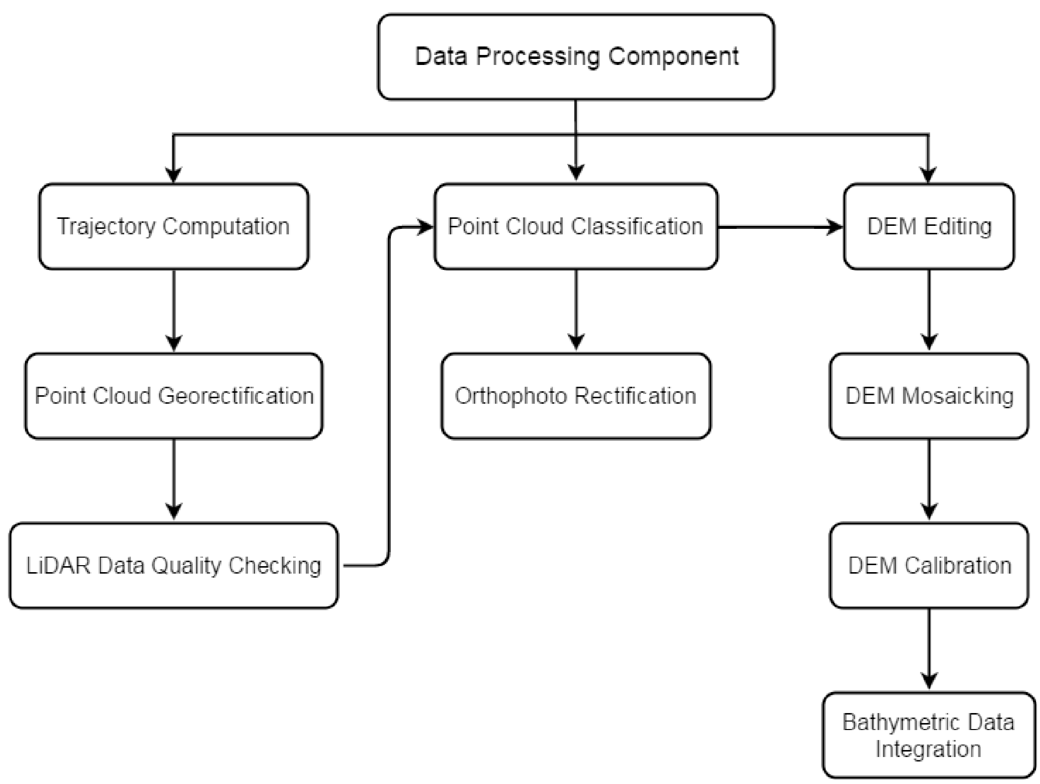


Figure 8. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Salug Floodplain can be found in ANNEX A-5. Missions flown over Hilongos, Leyte during the first survey conducted on January 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second and third surveys on February 2016 and April 2016, respectively, were flown using the Gemini system. The Data Acquisition Component (DAC) transferred a total of 92.06 Gigabytes of Range data, 1.78 Gigabytes of POS data, 209.99 Megabytes of GPS base station data, and 17 Gigabytes of raw image data to the data server on February 25, 2015 for the first survey, on March 2, 2016 for the second survey, and on May 2, 2016 for the third survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Salug was fully transferred on May 2, 2016, as indicated on the data transfer sheets for Salug Floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metric* parameters of the computed trajectory for flight 7754A, one of the Salug flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on January 22, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

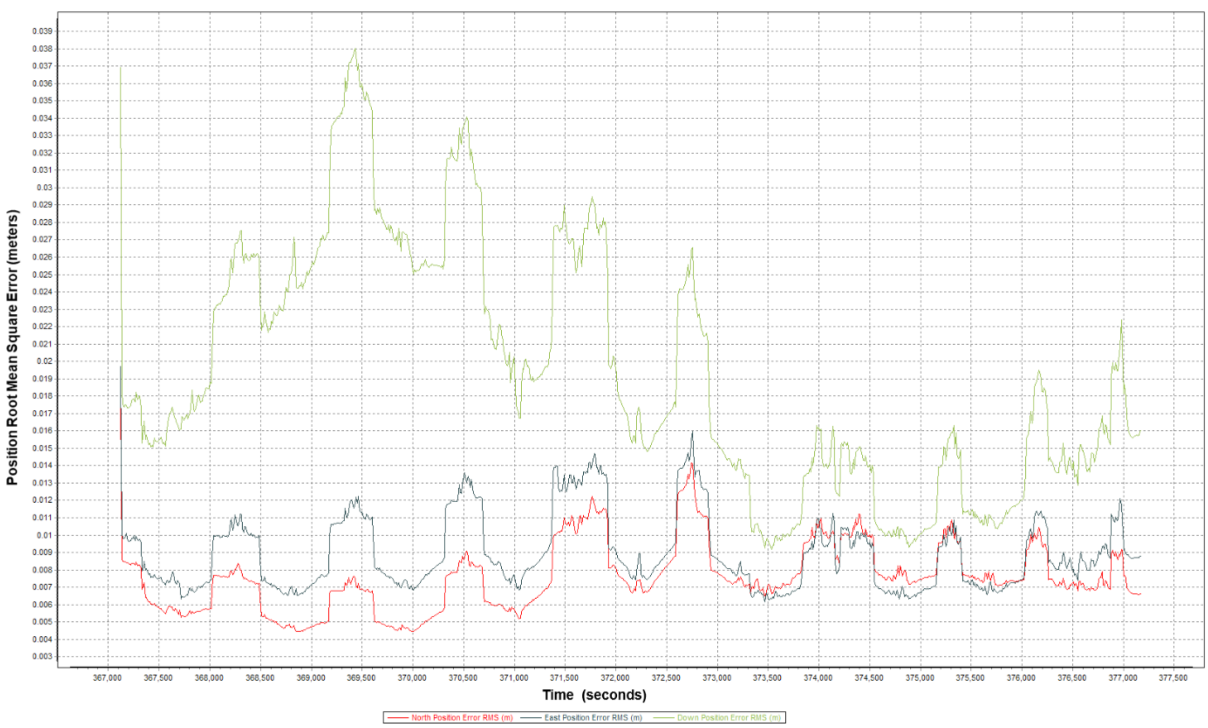


Figure 9. Smoothed Performance Metric parameters of Salug Flight 7754A.

The time of flight was from 367,000 seconds to 377,000 seconds, which corresponds to afternoon of January 22, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1. 60 centimeters, and the Down position RMSE peaks at 3.80 centimeters, which are within the prescribed accuracies described in the methodology.

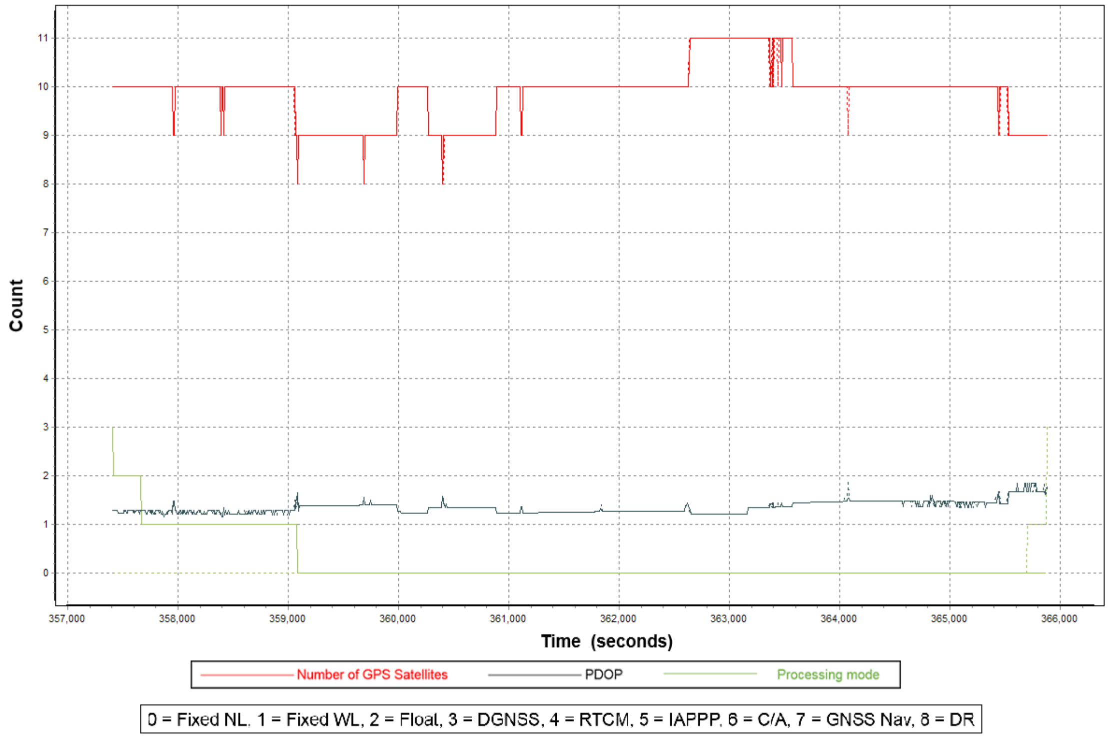


Figure 10. Solution Status parameters of Salug Flight 7754A.

The Solution Status parameters of flight 7754A, one of the Salug flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 8. Majority of the time, the number of satellites tracked was between 8 and 11. The PDOP value also did not go above the value of 2, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Salug flights is shown in Figure 11.

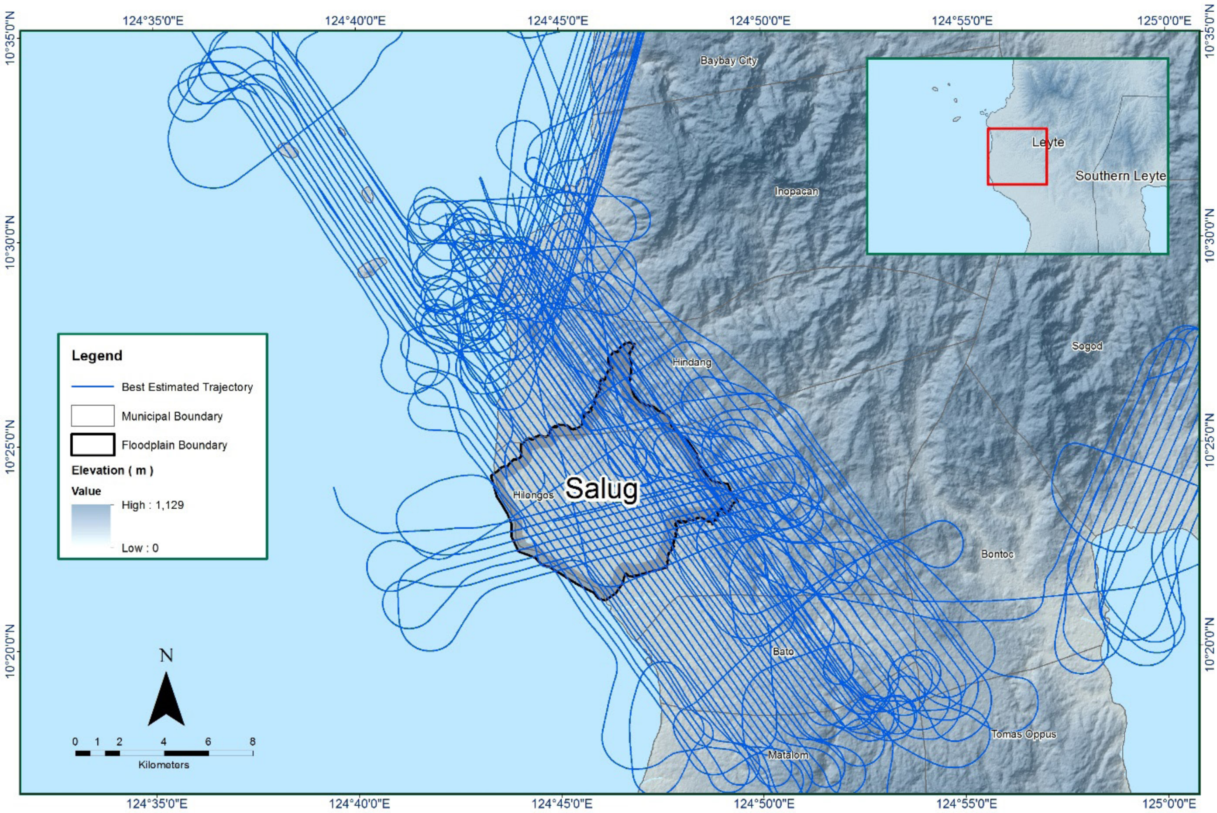


Figure 11. Best estimated trajectory of LiDAR missions conducted over Salug Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 99 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Salug Floodplain are given in Table 15.

Table 15. Self-calibration results values for Salug flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000342
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000910
GPS Position Z-correction stdev (<0.01meters)	0.0084

The optimum accuracy is obtained for all Salug flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the ANNEX B-1. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Salug Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

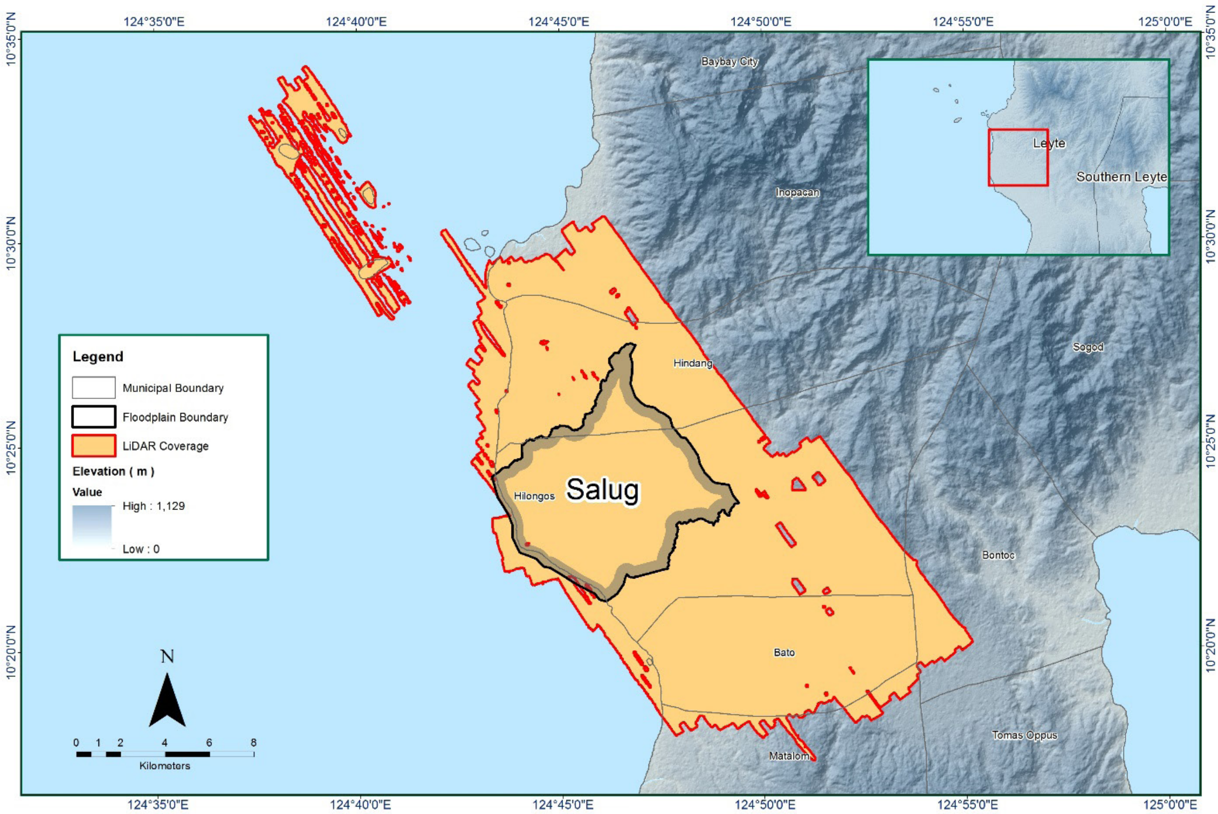


Figure 12. Boundary of the processed LiDAR data over Salug Floodplain

The total area covered by the Salug missions is 407.96 sq km that is comprised of nine (9) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 16.

Table 16.List of LiDAR blocks for Salug Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq km.)
Leyte_Blk49A_additional	3781G	27.17
Ormoc_Blk49A	7756AC	85.84
Ormoc_Blk49B	7754A	95.83
Ormoc_Blk49A_voids	7794AC	8.31
Ormoc_Blk35X	7767AC	10.74
Ormoc_South_Blk49B	3925G	31.58
Ormoc_South_Blk49A	3923G	119.53
	3921G	
Ormoc_South_Blk49A_additional	3925G	28.96
TOTAL		**407.96 sq km.**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Gemini and Aquarius systems both employ one channel, 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.

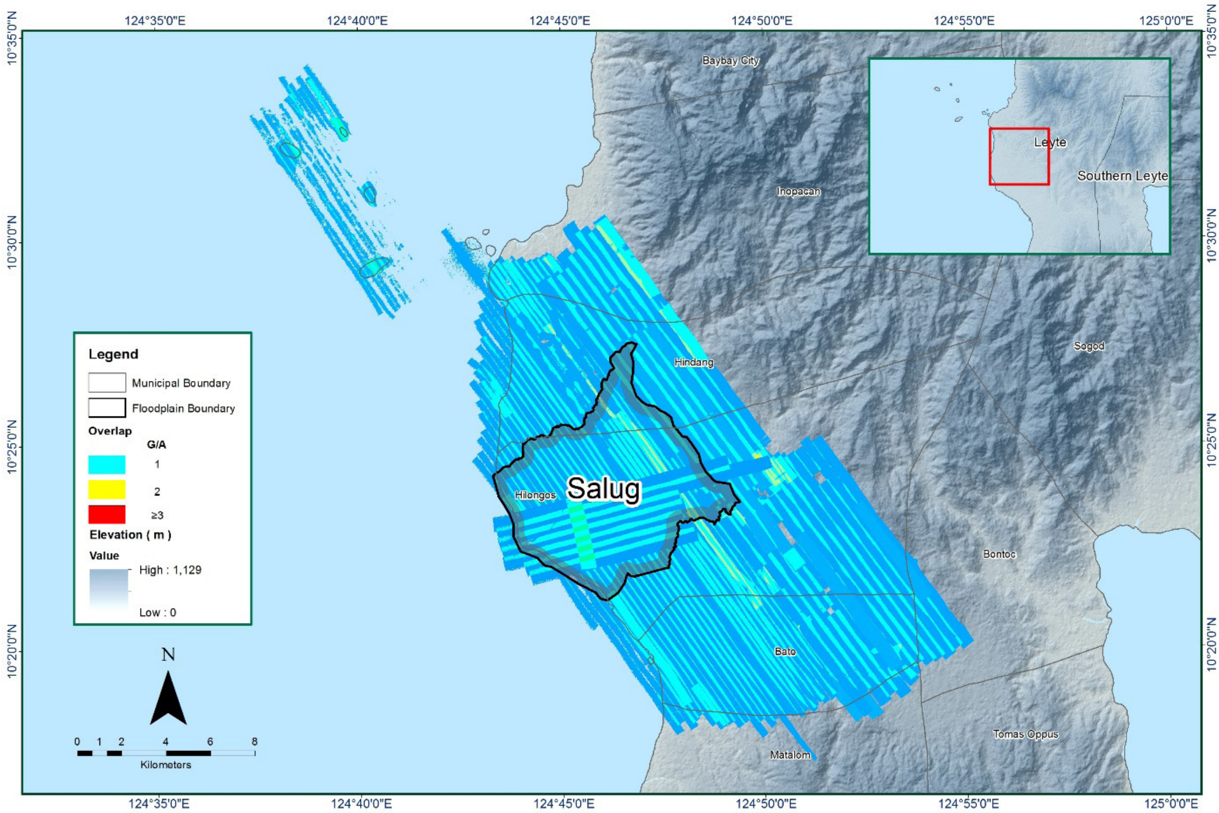


Figure 13. Image of data overlap for Salug Floodplain.

The overlap statistics per block for the Salug Floodplain can be found in ANNEX B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 31.34% and 44.81% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Salug Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.24 points per square meter.

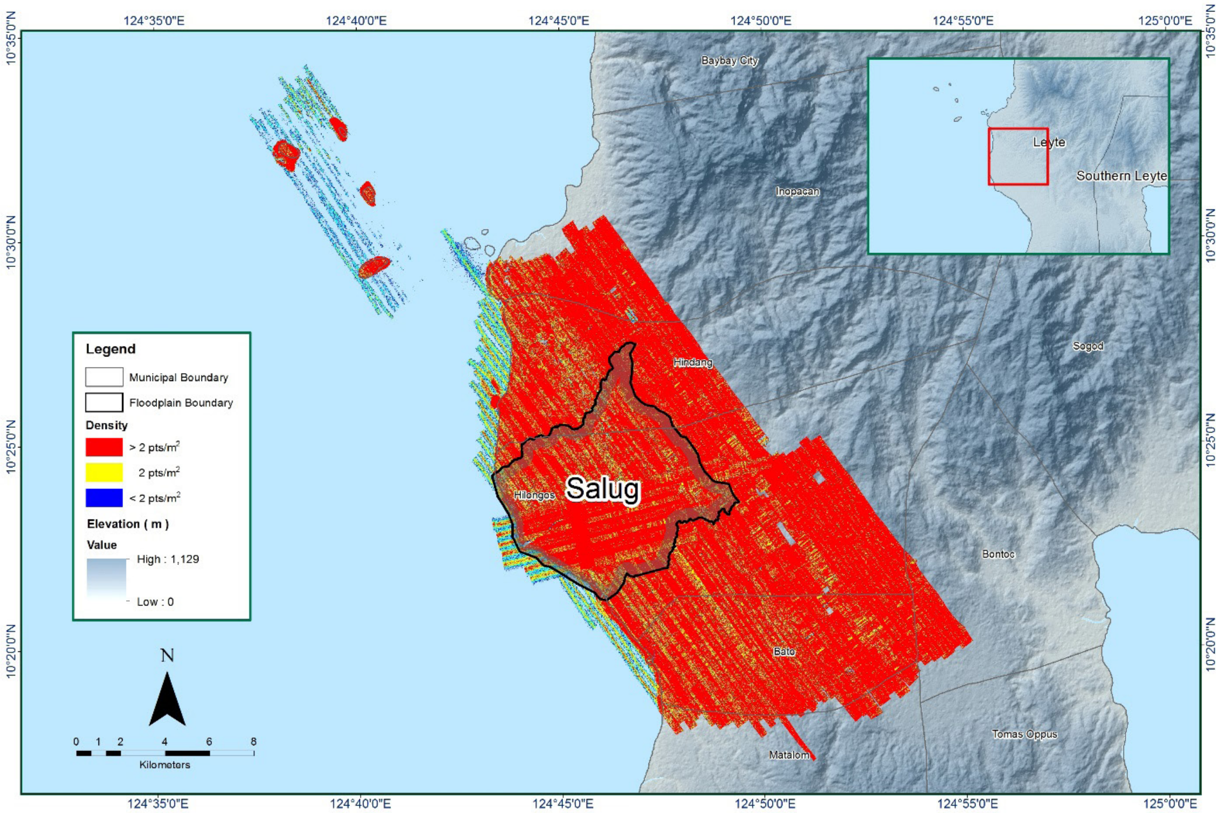


Figure 14. Pulse density map of merged LiDAR data for Salug Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

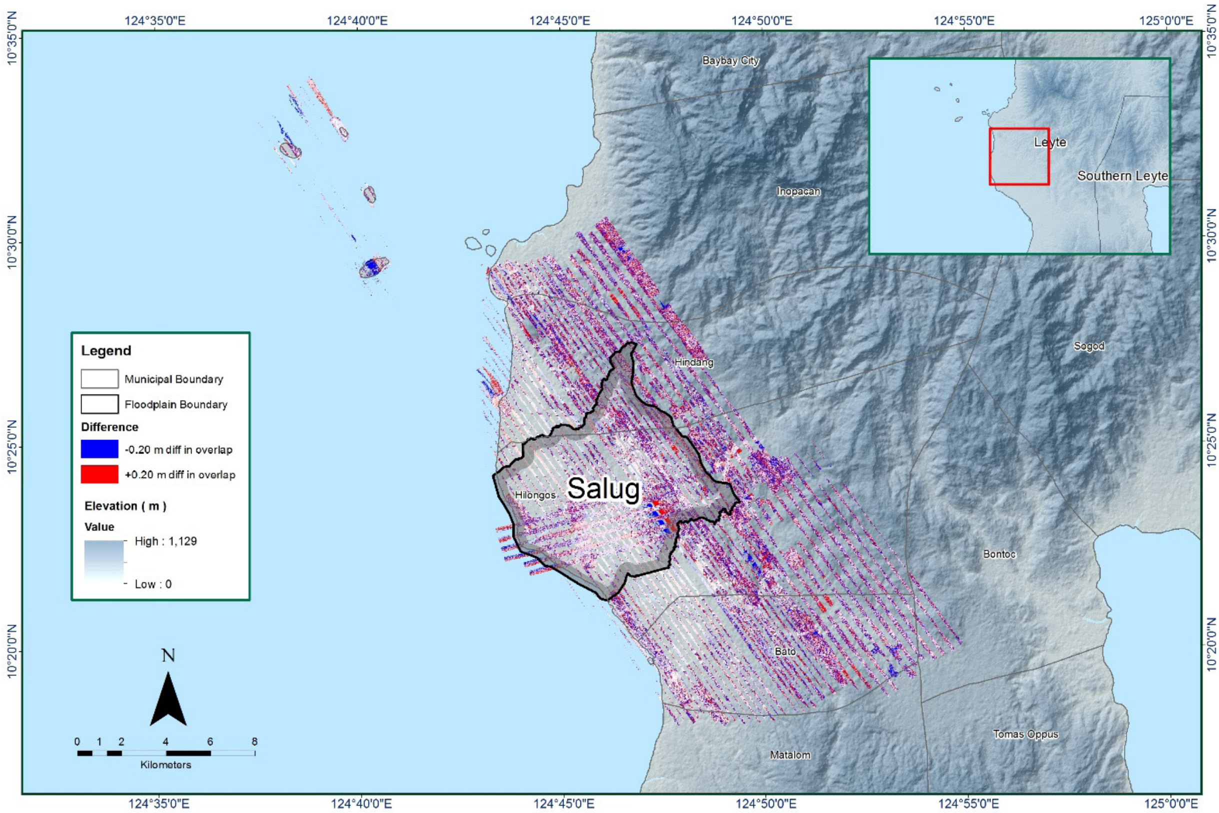


Figure 15. Elevation difference map between flight lines for Salug Floodplain.

A screen capture of the processed LAS data from Salug flight 7754A loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two 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 are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

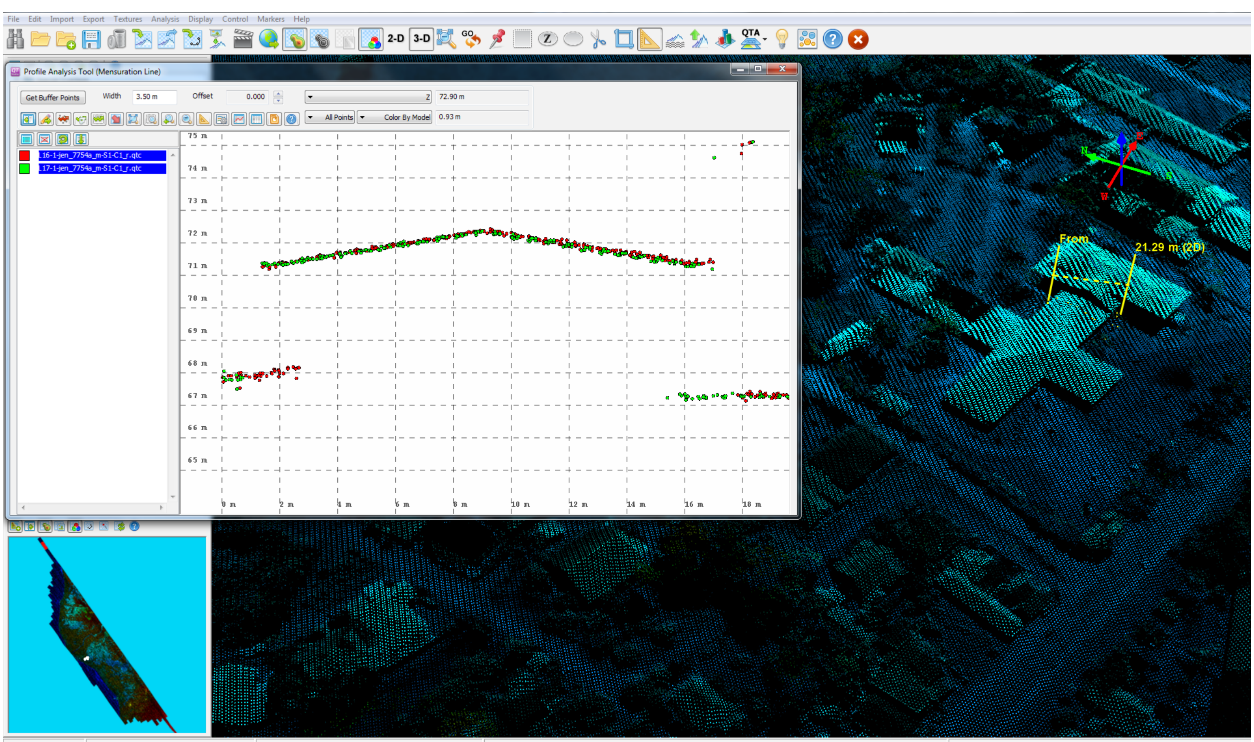


Figure 16. Quality checking for Salug flight 7754A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Salug classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	224,383,933
Low Vegetation	197,174,053
Medium Vegetation	347,465,494
High Vegetation	628,575,666
Building	8,783,313

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Salug Floodplain is shown in Figure 17. A total of 705 1km by 1km tiles were produced. The number of points classified to the pertinent catehgories is illustrated in Table 17. The point cloud has a maximum and minimum height of 480.55 meters and 48.87 meters respectively.

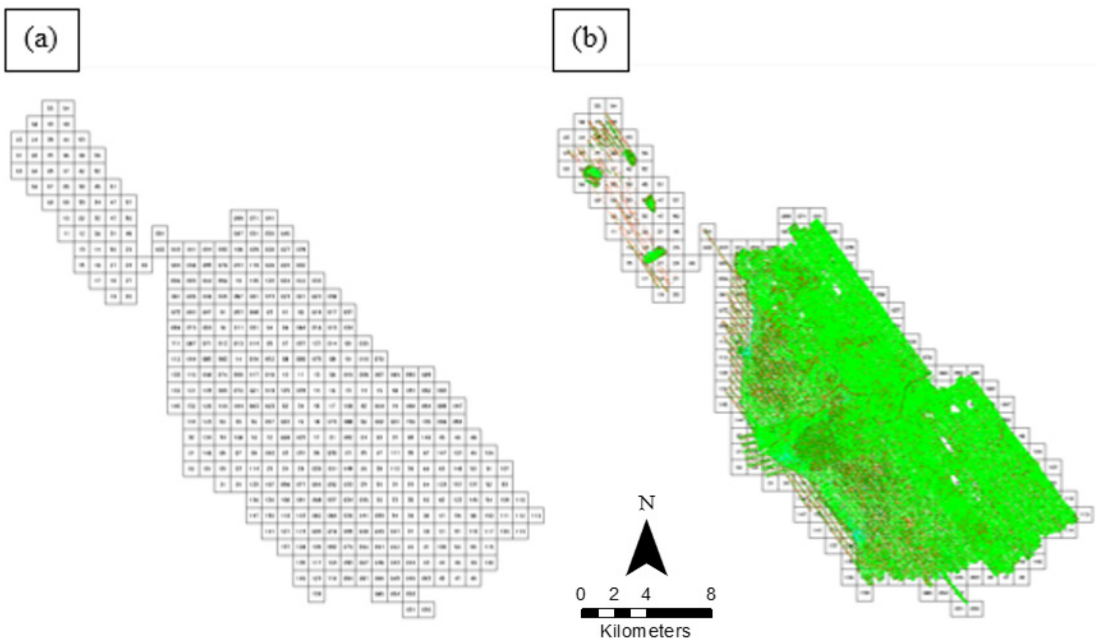


Figure 17. Tiles for Salug Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

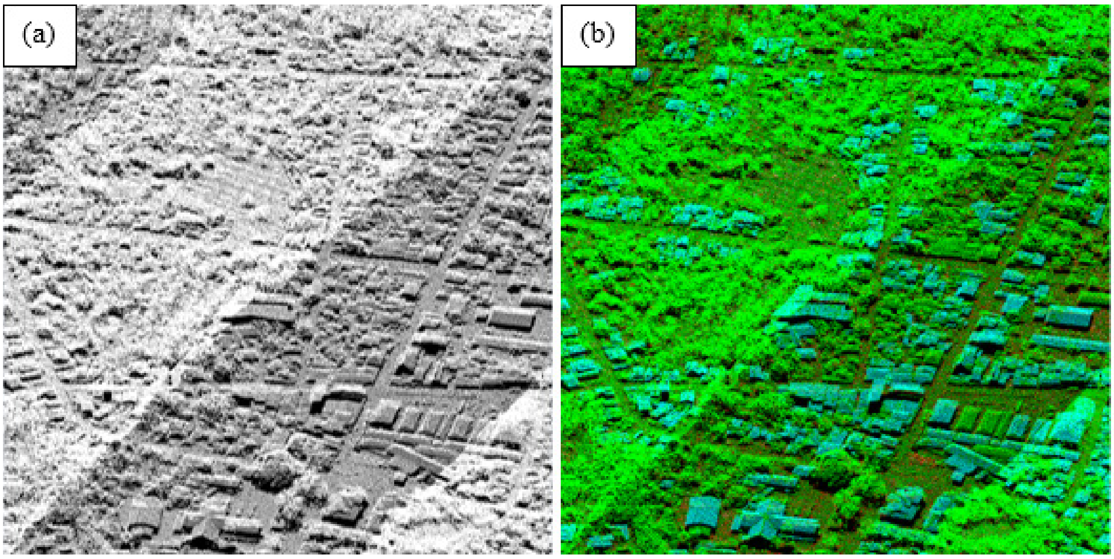


Figure 18. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

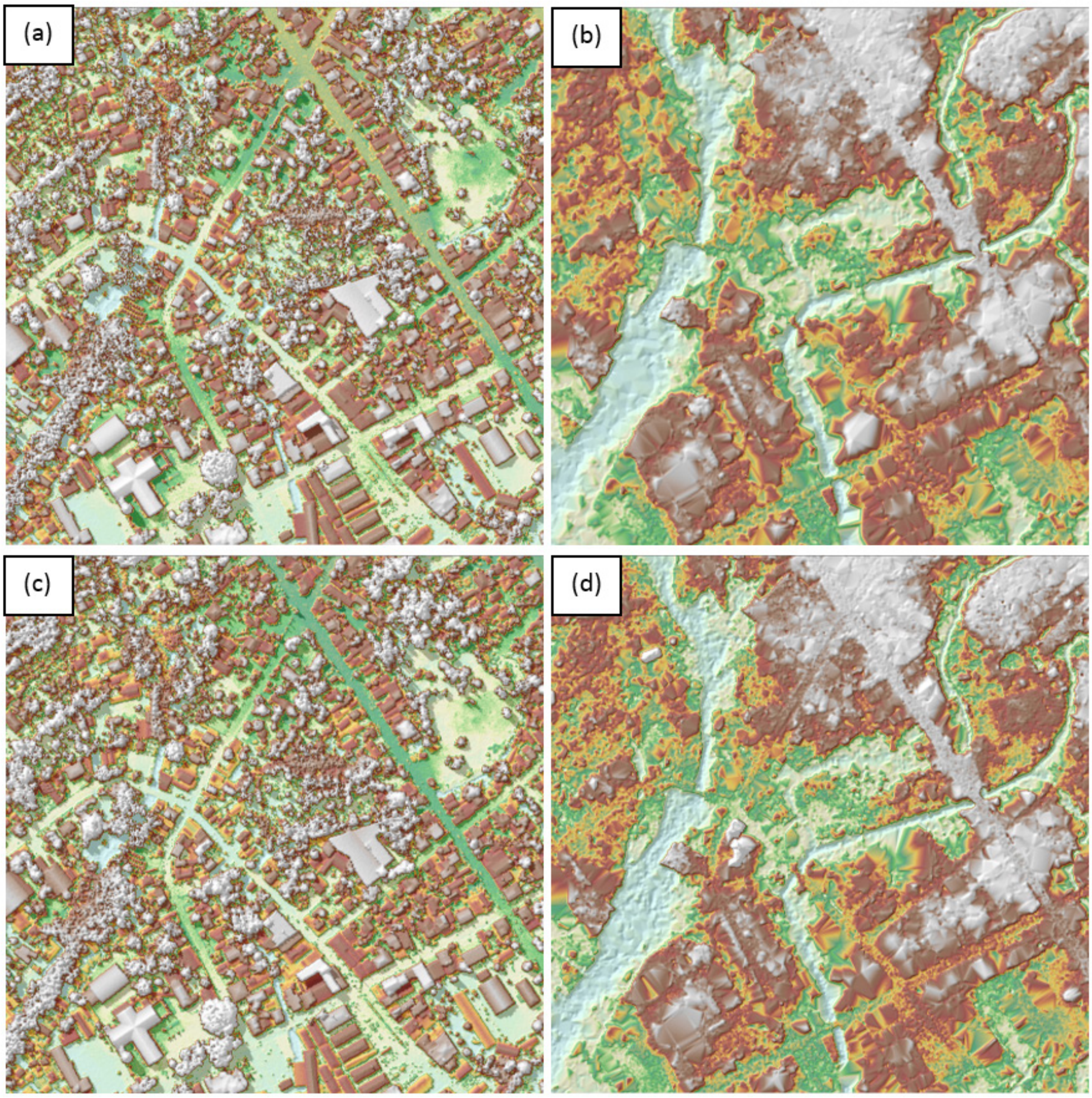


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Salug Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 55 1km by 1km tiles area covered by Salug Floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Salug Floodplain has a total of 15.33 sq km orthophotogaph coverage comprised of 66 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

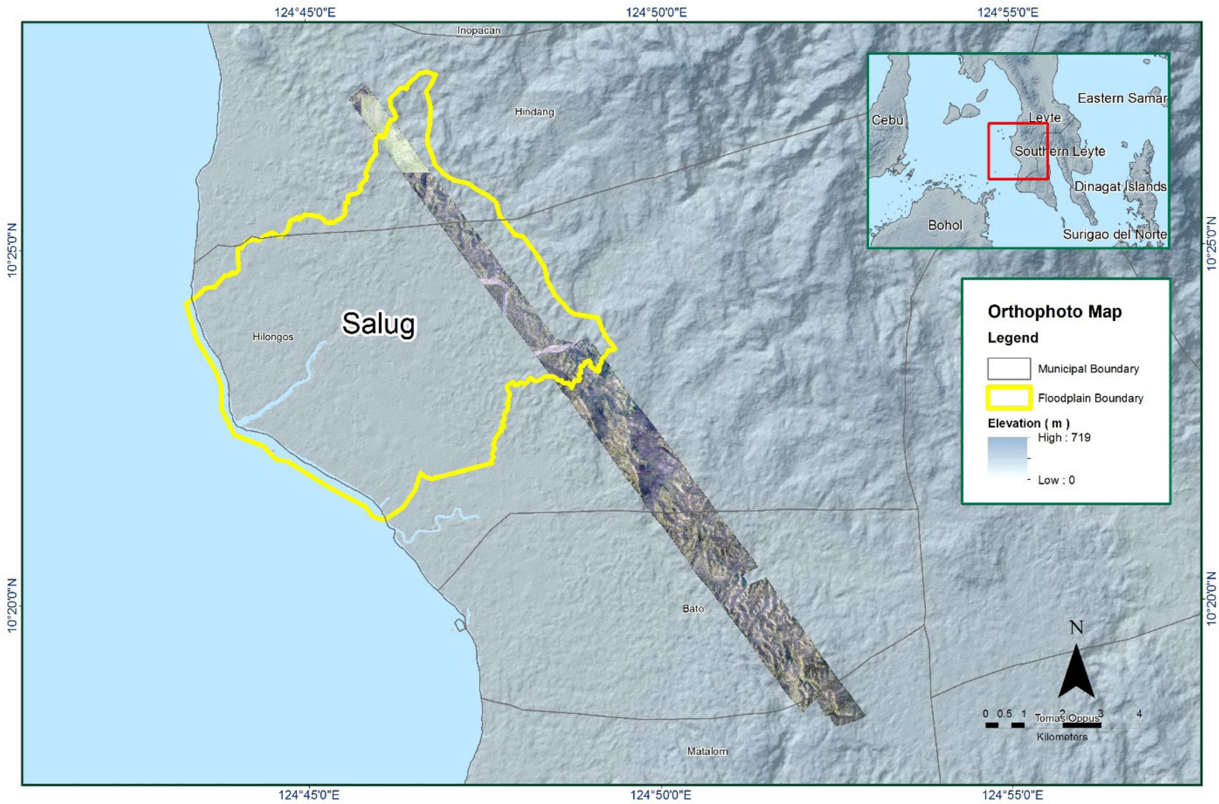


Figure 20. Salug Floodplain with available orthophotographs.

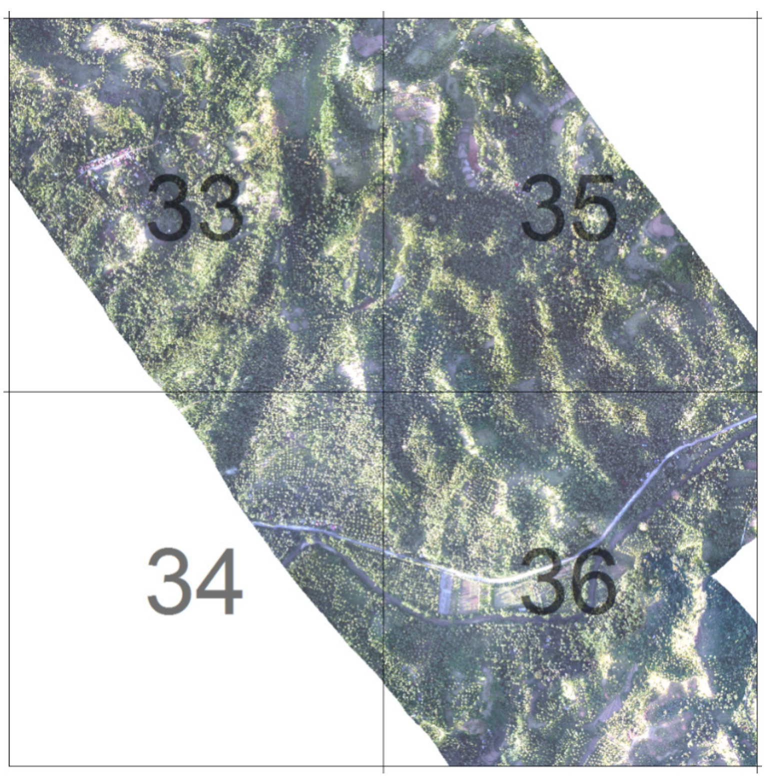


Figure 21. Sample orthophotograph tiles for Salug Floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Salug Floodplain. These blocks are composed of SamarLeyte and Leyte blocks with a total area of 407.96 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area.

LiDAR Blocks	**Area (sq km)**
Leyte_Blk49A_additional	27.17
Ormoc_Blk49A	85.84
Ormoc_Blk49B	95.83
Ormoc_Blk49A_voids	8.31
Ormoc_Blk35X	10.74
Ormoc_South_Blk49B	31.58
Ormoc_South_Blk49A	119.53
Ormoc_South_Blk49A_additional	28.96
TOTAL	**407.96 sq km.**

Portions of DTM before and after manual editing are shown in Figure 22. The bridge (Figure 22a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 22b) in order to hydro logically correct the river. The road (Figure 22c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22d) to allow the correct flow of water.

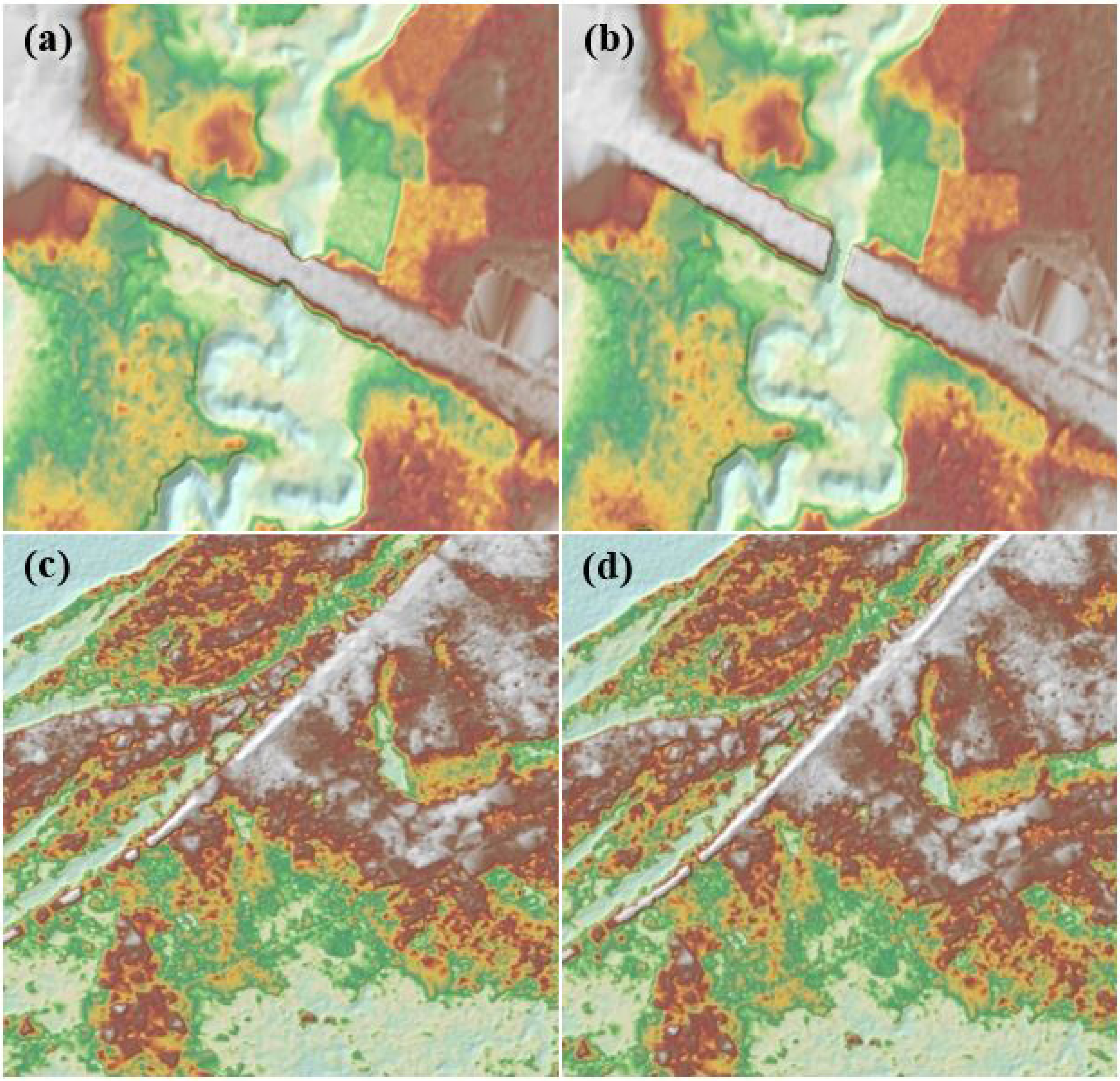


Figure 22. Portions in the DTM of Salug Floodplain – a bridge before (a) and after (b) manual editing; a road before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

Samar_Leyte_Blk35I was used as the reference block at the start of mosaicking because this was the first available block for processing in the floodplain. Table 19 shows the shift values applied to each LiDAR block during mosaicking.

Table 19. Shift values of each LiDAR Block of Salug Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Ormoc_Blk49B	-1.00	-1.00	-0.15
Ormoc_Blk49A	0.00	-1.00	-0.15
Ormoc_Blk49A_voids	0.00	-1.00	-0.15
OrmocSouth_Blk49B	-1.00	-0.50	-0.54
OrmocSouth_Blk49A_additional	0.00	-1.00	-0.29
Leyte_Blk49A_additional	0.00	-1.00	-0.11
OrmocSouth_Blk49A	0.00	-1.00	-0.63

Mosaicked LiDAR DTM for Salug Floodplain is shown in Figure 23. It can be seen that the entire Salug Floodplain is 99.66% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

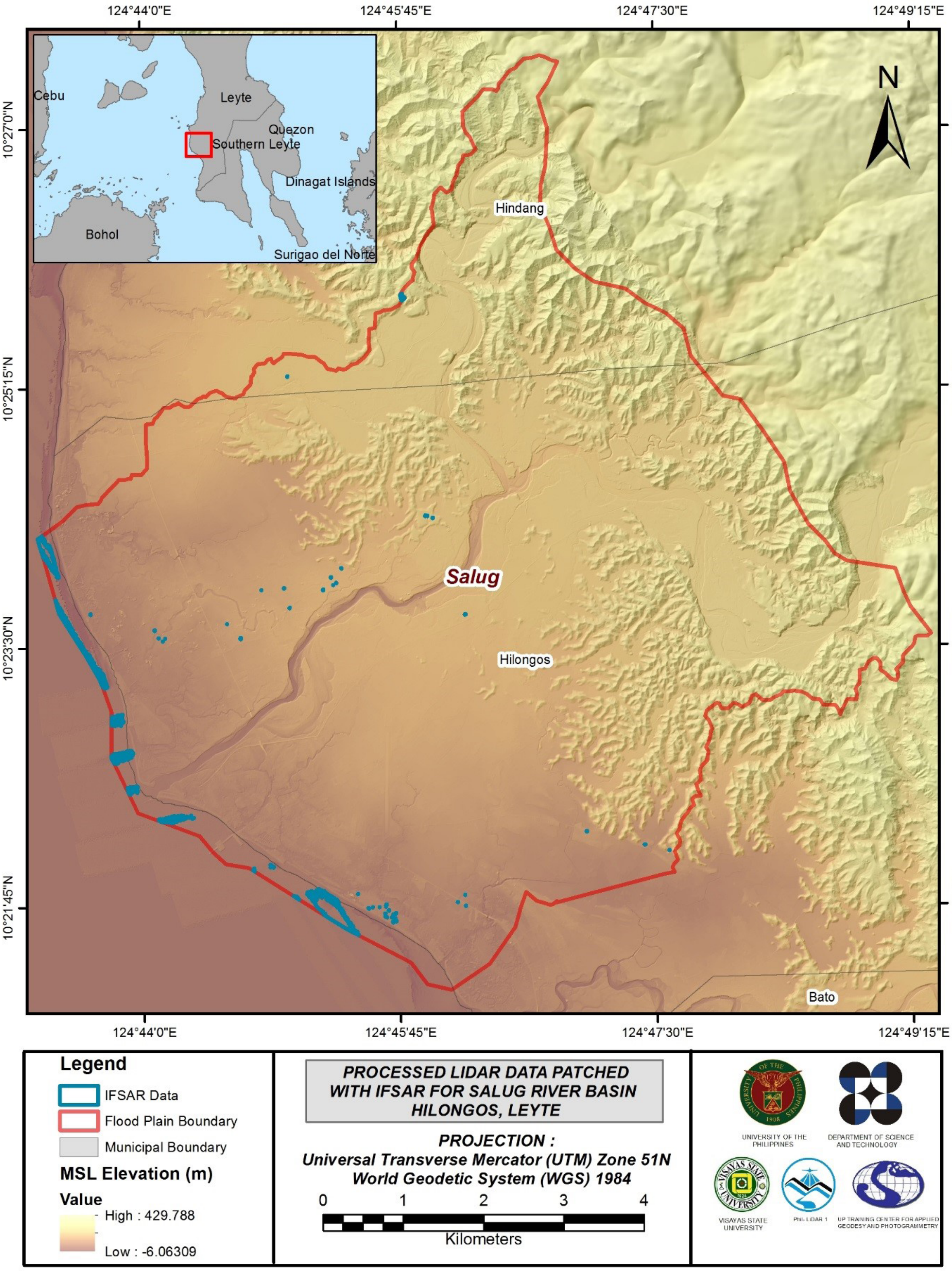


Figure 23. Map of processed LiDAR data for Salug Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ormoc City and Bato Municipality to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 25,710 survey points were gathered for all the floodplains within Ormoc City and Bato Municipality wherein the Salug 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 25. 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 0.20 meters. Calibration of the LiDAR data was done by adding the height difference value, 0.26 meters, to the mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

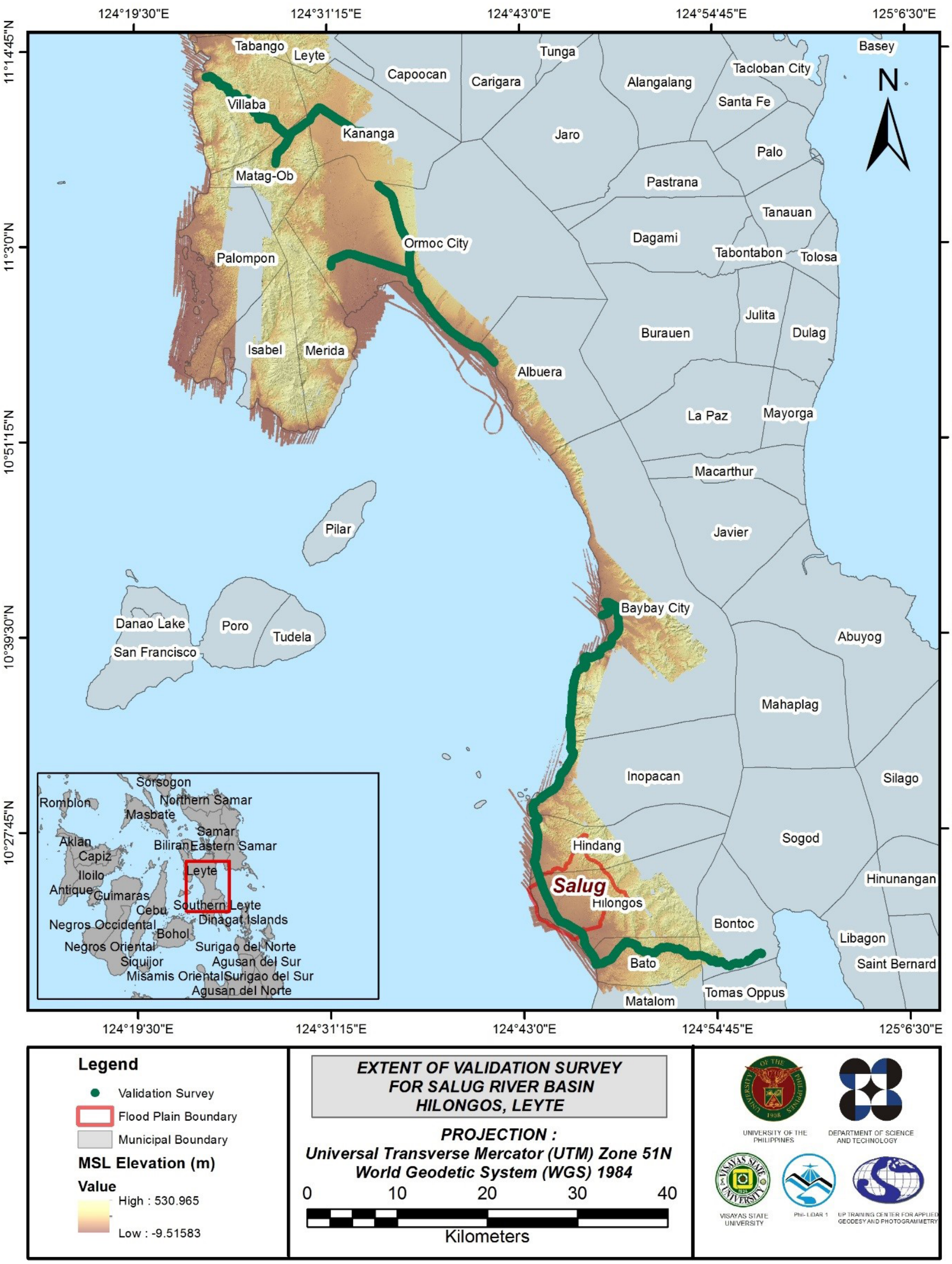


Figure 24. Map of Salug Floodplain with validation survey points in green.

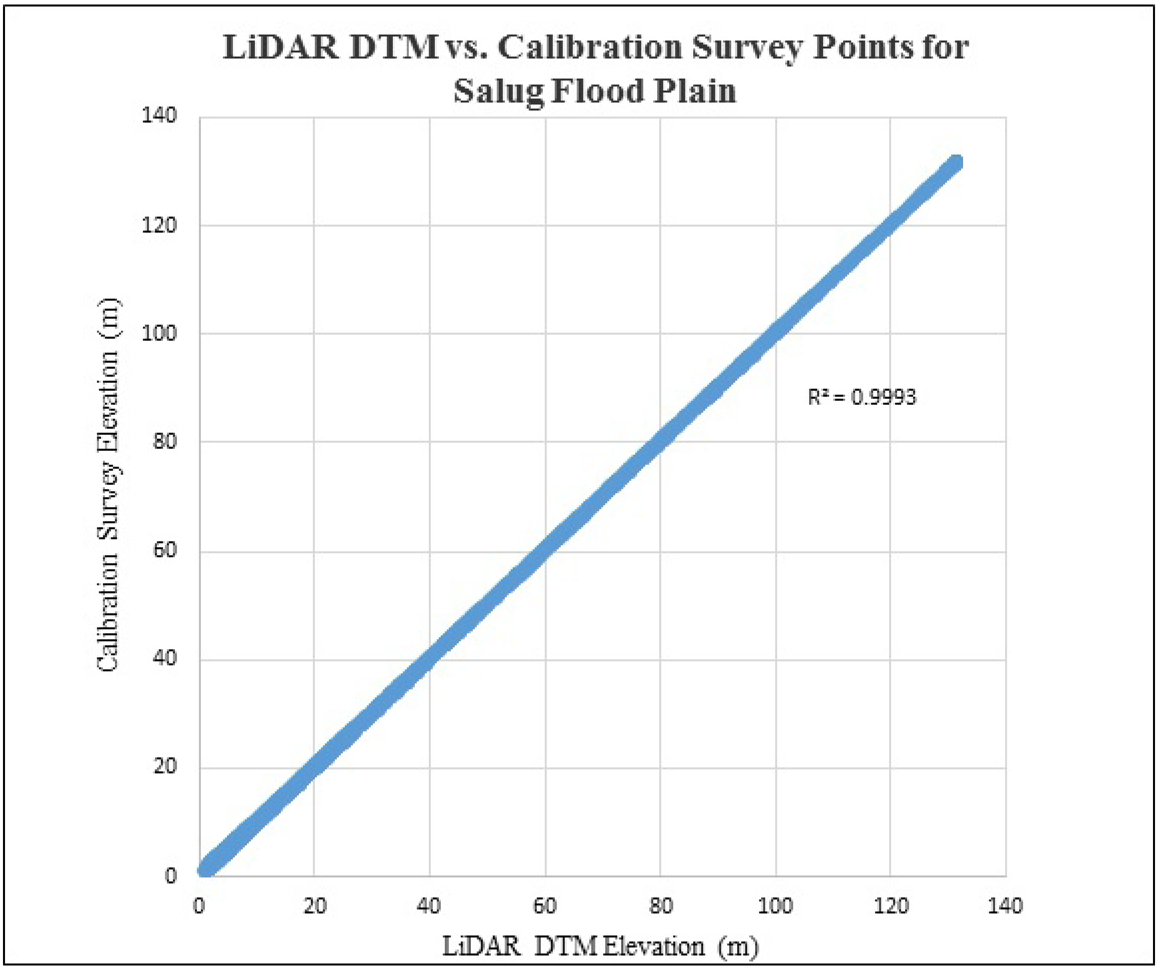


Figure 25. Correlation plot between calibration survey points and LiDAR

Table 20. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.26
Standard Deviation	0.20
Average	0.17
Minimum	-0.30
Maximum	0.60

The remaining 20% of the total survey points, resulting to 5,142 points, were used for the validation of calibrated Salug DTM. The good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.18 meters, as shown in Table 21.

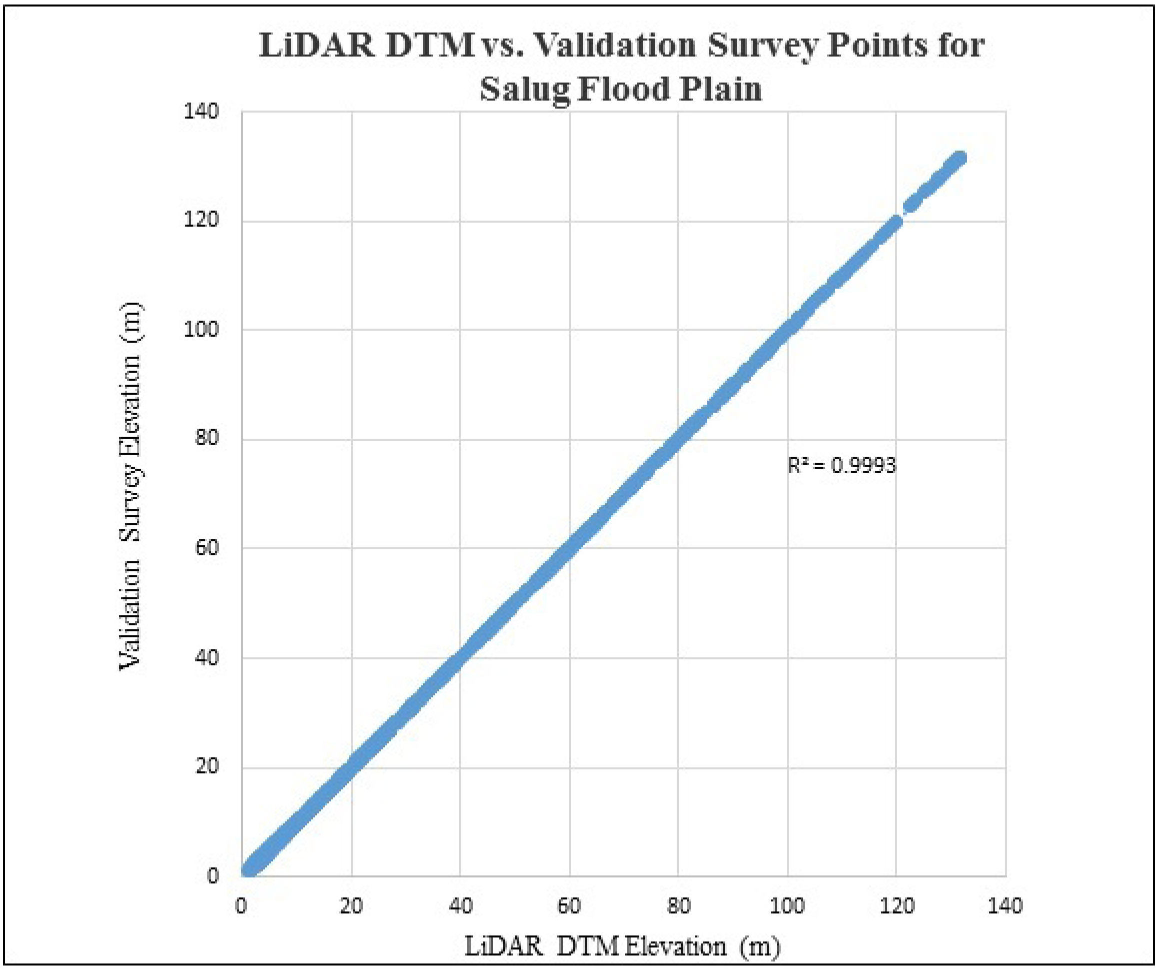


Figure 26. Correlation plot between validation survey points and LiDAR data

Table 21. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.18
Average	-0.10
Minimum	-0.47
Maximum	0.28

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only cross section data at regular intervals was available for Salug with 1,755 bathymetric survey points. The resulting raster surface produced was done by 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 0.50 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Salug integrated with the processed LiDAR DEM is shown in Figure 27.

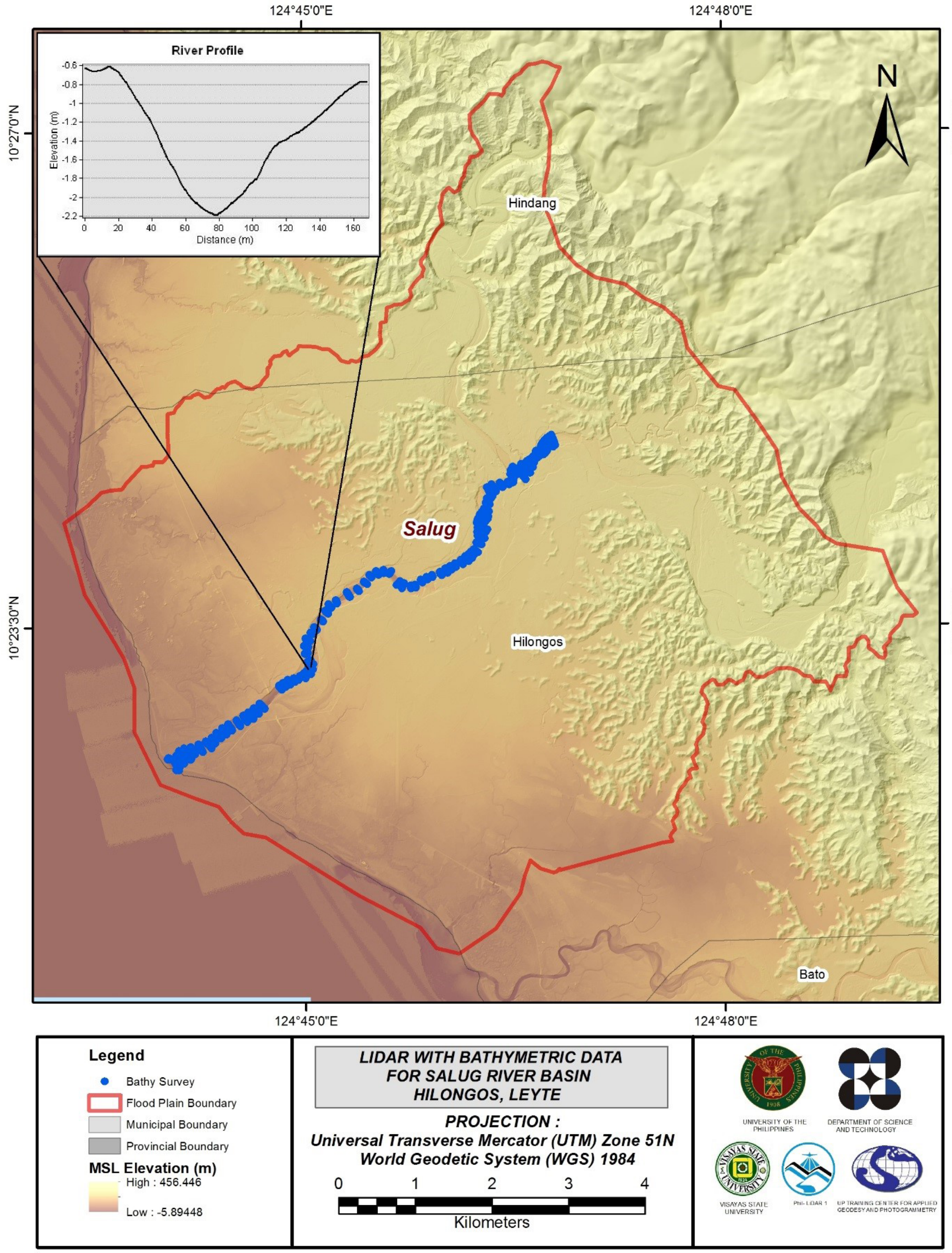


Figure 27. Map of Salug Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Salug Floodplain, including its 200 m buffer, has a total area of 69.99 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1031 building features, are considered for QC. Figure 28 shows the QC blocks for Salug Floodplain.

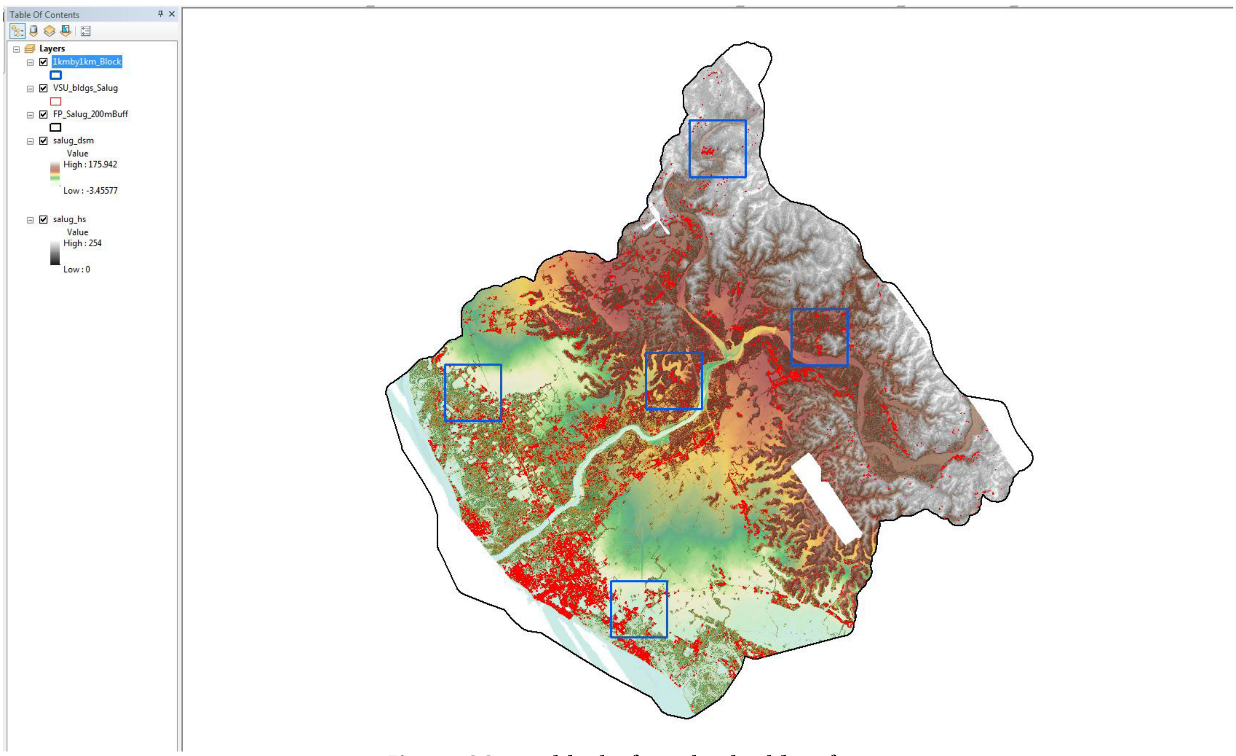


Figure 28. QC blocks for Salug building features.

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

Table 22. Quality checking ratings for Salug building features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Salug	99.20	96.12	85.94	PASSED

3.12.2 Height Extraction

Height extraction was done for 11,970 building features in Salug Floodplain. Of these building features, 89 was filtered out after height extraction, resulting to 11,970 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 14.37 m.

3.12.3 Feature Attribution

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

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

Table 23. Building features extracted for Salug Floodplain.

Facility Type	No. of Features
Residential	11,358
School	190
Market	23
Agricultural/Agro-Industrial Facilities	6
Medical Institutions	25
Barangay Hall	21
Military Institution	0
Sports Center/Gymnasium/Covered Court	30
Telecommunication Facilities	4
Transport Terminal	1
Warehouse	38
Power Plant/Substation	3
NGO/CSO Offices	14
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	49
Bank	3
Factory	0
Gas Station	7
Fire Station	0
Other Government Offices	27
Other Commercial Establishments	170
Total	**11,970**

Table 24. Total length of extracted roads for Salug Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Salug	119.08	2.27	4.00	6.88	0.00	**132.23**

Table 25. Number of extracted water bodies for Salug Floodplain

Flood-plain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Salug	23	23	0	1	0	**47**

A total of 37 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 these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

Figure 29 shows the Digital Surface Model (DSM) of Salug Floodplain overlaid with its ground features.

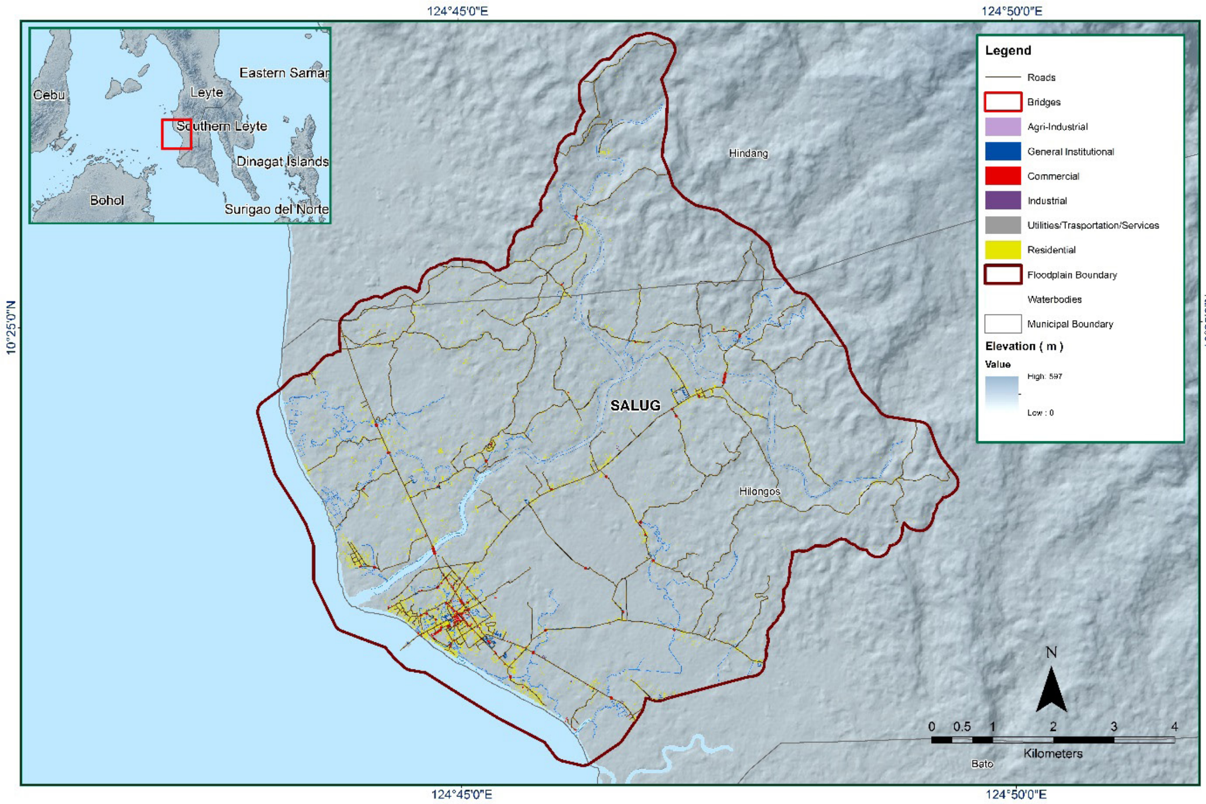


Figure 29. Extracted features for Salug Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE SALUG RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, 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

H.O. Noveloso Surveying (HONS) conducted a field survey in Salug River on December 17, 2016, March 1-2, 2017, and March 4-6, 2017; and DVBC on March 9-23, 2016 with the following scope: reconnaissance; control survey for the establishment of a control point; cross-section and as-built survey at Salug Bridge in Brgy. Central Barangay, Municipality of Hilongos, Province of Leyte; LiDAR validation and bathymetric survey from the upstream in Brgy. Pa-A, Hilongos, Leyte to the mouth of the river located in Brgy. Atabay, Hilongos, Leyte with an approximate length of 7.44 km using a dual frequency Hi-Target™ GPS (RTK) and a Sokkia™ Set CX Total Station. The entire survey extent is illustrated in Figure 30.

Figure 30. Extent of the bathymetric survey (in blue) in Salug River and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS network was established for a previous Phil-LiDAR 1 survey in Pagbanganan River occupying the following reference points: LYT-737, a second-order GCP, in Brgy. Cabulisan, Municipality of Inopacan; LYT-742, a second-order GCP, in Brgy. Tambis, Municipality of Hilongos; and LY-338, a first-order BM, in Brgy. San Juan, Municipality of Hilongos. Other points include UP-CAM at Cambanog Bridge in Brgy. Naga, Municipality of Bato; and UP-PAG at Pagbanganan Bridge in Brgy. Poblacion Zone 12, Baybay City.

The GNSS network used in Salug River was composed of a single loop established on January 27, 2017 occupying the following reference points: LYT-742, in Brgy. Tambis, Hilongos; and LY-338, in Brgy. San Juan, Hilongos; both with fixed values from previous field survey.

A control point was established along the approach of Salug Bridge namely UP-SAL in Brgy. Imelda Marcos, Municipality of Hilongos.

The summary of reference and control points and its location is summarized in Table 26, while the GNSS network established is illustrated in Figure 31.

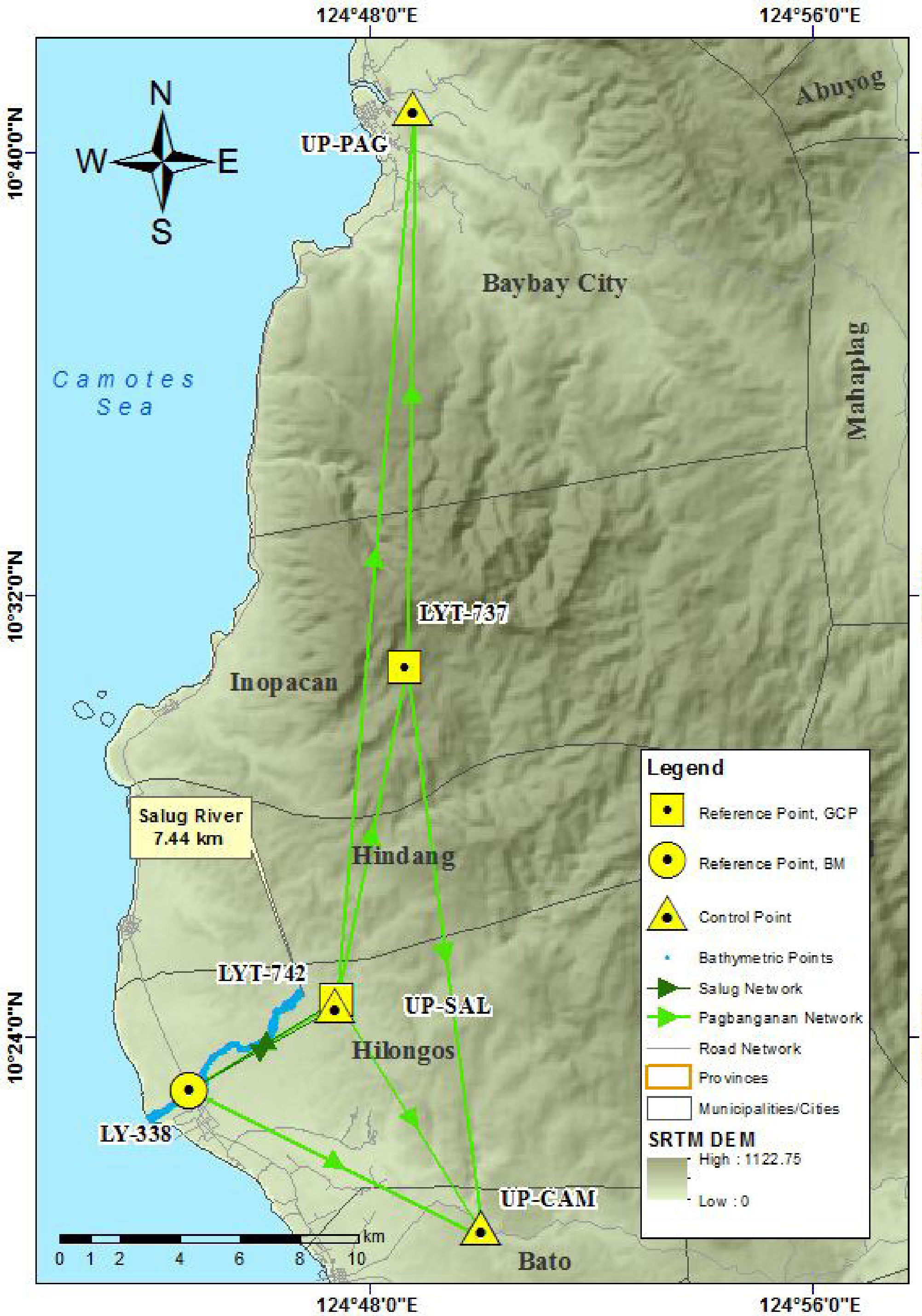


Figure 31. GNSS network covering Salug River

Table 26. List of reference and control points occupied for Salug River survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Reference Points from Pagbanganan River Survey						
LYT-737	2nd order, GCP	10°30'42.1282"N	124°48'38.7024"E	600.703	536.080	2007
LYT-742	2nd order, GCP	10°24'41.5778"N	124°47'25.4388"E	110.425	45.879	03-14-2016
LY-338	1st order, BM	10°23'01.9595"	124°44'44.5615"	73.006	8.483	2007
Control Network for Salug River Survey						
LY-338	1st order, BM	10°23'01.95952"	124°44'44.56152"	73.007	8.483	2007
LYT-742	2nd order, GCP	10°24'41.57783"	124°47'25.43884"	110.425	45.879	03-14-2016
UP-SAL-1	Established	-	-	-	-	1-27-2017

The GNSS set-ups on recovered reference points and established control points in Pagbanganan River are shown in Figure 32 to Figure 34.

Figure 32. GNSS base set up, Trimble® SPS 855, at LYT-742, located near a chapel and basketball court in Brgy. Tambis, Municipality of Hilongos, Leyte

Figure 33. GNSS receiver set up, Trimble® SPS 855, at LY-338, located at the approach of Salug Birdge along Sta. Indang-Hilongos Road in Brgy. San Juan, Municipality of Hilongos, Leyte

Figure 34. GNSS receiver set up, Trimble® SPS 855, at UP-SAL, located at Salug Bridge approach in Brgy. Imelda Marcos, Hilongos, Leyte

4.3 Baseline Processing

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

Table 27. Baseline processing summary report for Salug River survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
LY-338 --- UP-SAL	1-27-2017	Fixed	0.008	0.026	59°47’16”	15601.698
UP-SAL --- LYT-742	1-27-2017	Fixed	0.002	0.003	192°13’50”	247.966
LY-338 --- LYT-742	1-27-2017	Fixed	0.007	0.024	57°58’15”	5771.95

As shown in Table 27, a total of three baselines were processed with reference points LYT-742, and LY-338 held fixed for grid and elevation values, fixed from previous field survey. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table C-3 to 5 for complete details.

The three (3) control points, LY-338, LYT- 742, and UP-SAL were occupied and observed simultaneously to form a GNSS loop. Elevation value and coordinates of LY-338 and LYT-742 were held fixed during the processing of the control points as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 28. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LYT-742	Grid	Fixed	Fixed		Fixed
LY-338	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 29. The fixed control points LYT-742 and LY-338 have no values for grid and elevation error.

Table 29. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LY-338	691121.157	?	1148380.761	?	8.483	?	ENe
LYT-742	695997.844	?	1151468.957	?	45.879	?	ENe
UP-SAL-1	695946.679	0.001	1151226.309	0.001	22.613	0.002	

The network is fixed at reference points LYT-742 and LY-338 with known coordinates and elevation. With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

LYT-742

horizontal accuracy = Fixed
vertical accuracy = Fixed

LY-338

horizontal accuracy = Fixed
vertical accuracy = Fixed

UP-SAL

horizontal accuracy = $\sqrt{((0.1)^2 + (0.1)^2}$
= $\sqrt{(0.1 + 0.1)}$
= 0.48 cm < 20 cm
vertical accuracy = 0.02 cm < 10 cm

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

Table 30. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
LY-338	N10°23’01.95952”	E124°44’44.56152”	73.007	?	ENe
LYT-742	N10°24’41.57783”	E124°47’25.43884”	110.425	?	ENe
UP-SAL	N10°24’33.69058”	E124°47’23.71178”	87.159	0.002	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 30. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 31.

Table 31. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Reference Points used in Pagbanganan River Survey							
LYT-737	2nd order, GCP	10°30’42.1282”N	124°48’38.7024”E	600.703	1162560.388	698162.797	536.080
LYT-742	2nd order, GCP	10°24’41.5778”N	124°47’25.4388”E	110.425	1151468.957	695997.844	45.879
LY-338	1st order, BM	10°23’01.9595”N	124°44’44.5615”E	73.006	1148380.761	691121.157	8.483
Control Points used in Salug River Survey							
LY-338	1st order, BM	10°23’01.95952”	124°44’44.56152”	73.007	1148380.761	691121.157	8.483
LYT-742	2nd order, GCP	10°24’41.57783”	124°47’25.43884”	110.425	1151468.957	695997.844	45.879
UP-SAL-1	Established	10°24’33.69058”	124°47’23.71178”	87.159	1151226.309	695946.679	22.613

4.5 Bridge Cross-section and As-built Survey, and Water Level Marking

Cross-section and as-built survey of Salug Bridge was conducted on March 1 and 5, 2017 at the downstream side of the bridge in Brgy. Central Barangay, Hilongos, Leyte as shown in Figure 35. A GNSS Receiver, Hi-Target™ V30 GNSS in RTK survey technique and a Sokkia™ Set CX Total Station were utilized for this survey as illustrated in Figure 36.

Figure 35. Bridge as-built and cross-section survey of Pagbanganan Bridge

Figure 36. As-built survey of Salug Bridge

The cross-sectional line of Salug Bridge is 372.980 m with three hundred ninety-two (392) cross-sectional points using the reference point LY-338 as the GNSS base station. The location map, cross-section diagram, and bridge data form are shown from Figure 37 to Figure 39.

Linear square correlation (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R^2 value must be within 0.85 to 1. An R^2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R^2 value of 0.98 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square Correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.107 was acquired. The computed R^2 and RMSE values are within the accuracy requirement of the program.

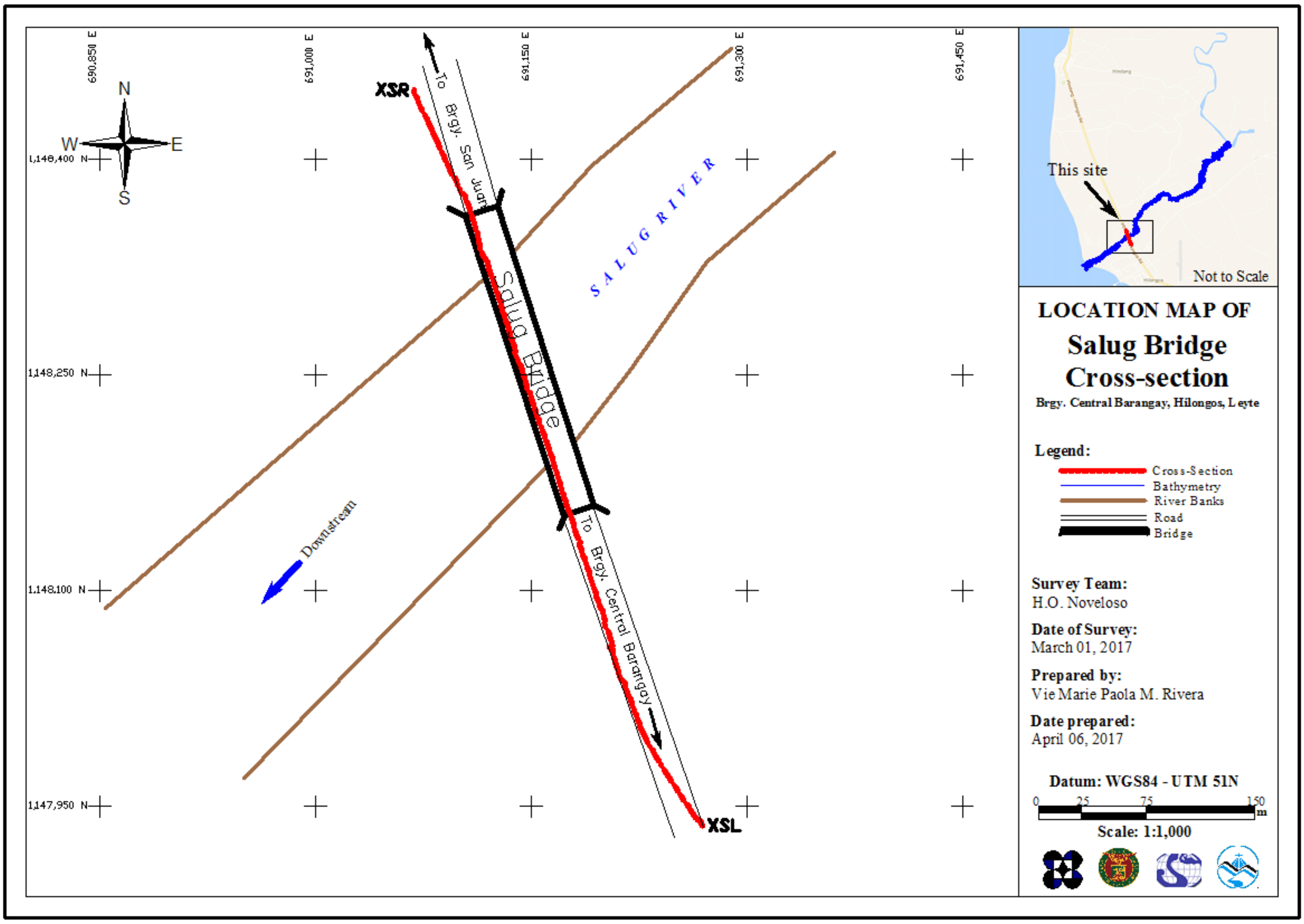


Figure 37. Location map of Salug cross-section

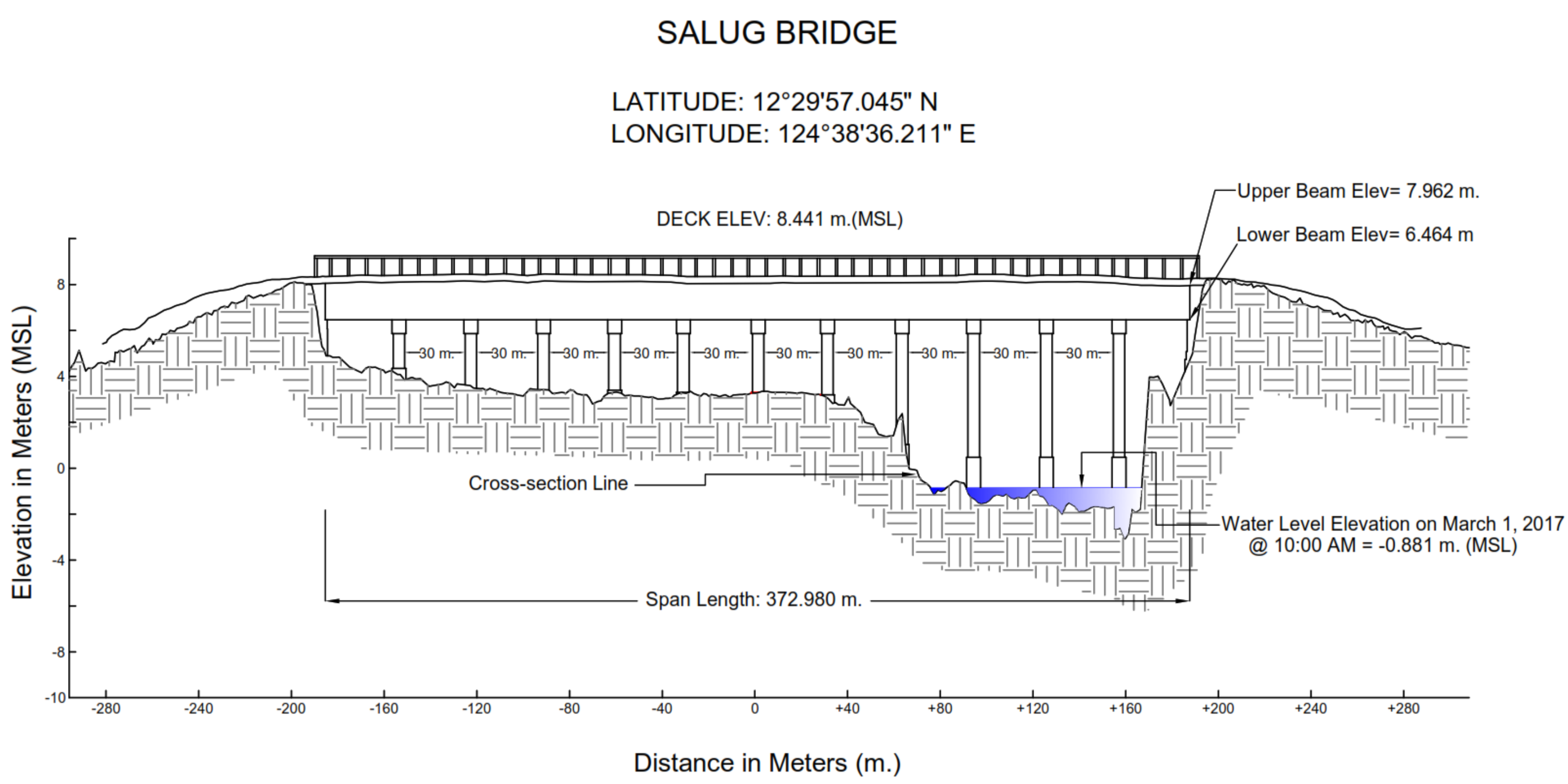


Figure 38. Salug Bridge cross-section diagram

BRIDGE DATA FORM

Bridge Name: Salug Bridge

River Name: Salug River

Location (Brgy., City, Region): Central Barangay, Hilongos, Leyte

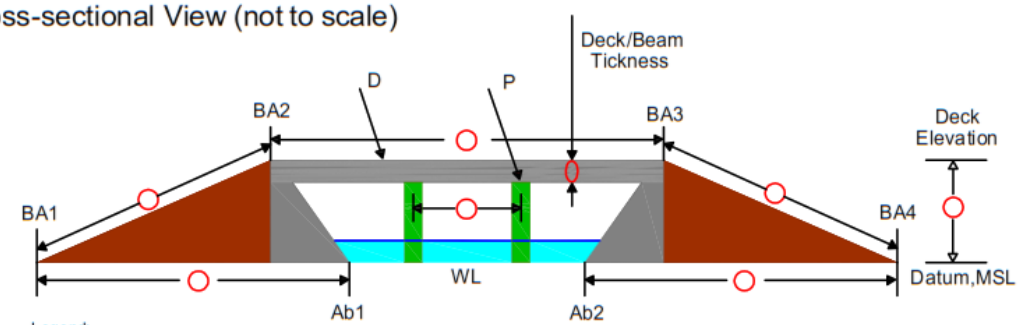
Survey Team: Julieto Cabilin, Urbano Castillo, Jefferson Orbillo, Jodel Dela Cruz, and Oscar Agustin

Date and Time: March 1, 2017 @ 7:29 am - 5:00 pm

Flow Condition: Low Normal High

Weather Condition: Fair Rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
○ = Measurement Value

Line Segment	Measurement, m	Remarks
1. BA1-BA2	1.126 m.	Concrete
2. BA2-BA3	372.982 m.	Concrete
3. BA3-BA4	1.175 m.	Concrete
4. BA1-Ab1	2.094 m.	Concrete
5. Ab2-BA4	3.275 m.	Concrete
6. Deck/Beam thickness	1.498 m.	Concrete
7. Deck Elevation	8.441 m. MSL	Concrete
8. P1-P2	30.000 m.	Concrete
9. P2-P3	30.000 m.	Concrete
10. P3-P4	30.000 m.	Concrete
11. P4-P5	30.000 m.	Concrete
12. P5-P6	30.000 m.	Concrete
13. P6-P7	30.000 m.	Concrete
14. P7-P8	30.000 m.	Concrete
15. P8-P9	30.000 m.	Concrete
16. P9-P10	30.000 m.	Concrete
16. P10-P11	30.000 m.	Concrete

Note: Observer should be facing downstream

Figure 39. Bridge as-built form of Salug Bridge

Water surface elevation of Salug River was also determined by a Sokkia™ Set-CX Total Station on March 1, 2017 at 9:00 AM at Salug Bridge area with a value of -0.881 m in MSL as shown in Figure 39. This was translated into marking on the bridge's pier, as shown in Figure 40.

Figure 40. Water level marking at Salug Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on March 10 and 11, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882 mounted on a pole which was attached to the side of vehicle as shown in Figure 41. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.929 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with LYT-742, UP-PAG, UP-CAM, and LYT-737 occupied as the GNSS base stations all throughout the conduct of the survey.

Figure 41. Validation points acquisition survey set up along Salug River Basin

The validation points acquisition survey for the Salug River Basin traversed Baybay City and the following municipalities of Leyte: Inopacan, Hindang, and Bato; as well as municipality of Bontoc in Southern Leyte. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 18,832 points with an approximate length of 75 km was acquired for the validation point acquisition survey as shown in the map in Figure 42.

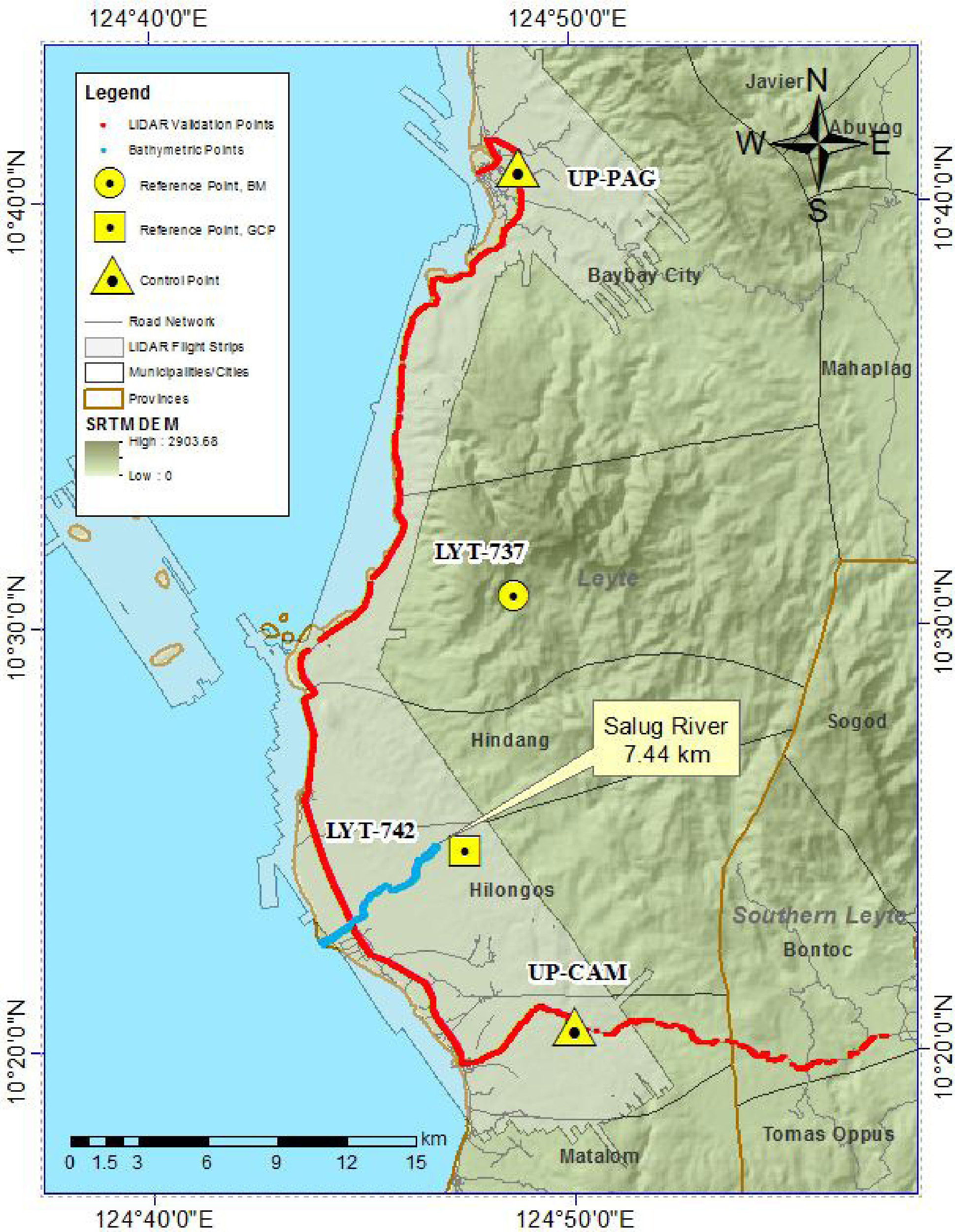


Figure 42. Validation point acquisition survey of Salug River Basin

4.7 River Bathymetric Survey

Manual Bathymetric survey of Salug River was executed on March 1 and 6, 2017 using a Hi-Target™ V30 GNSS and a Sokkia™ Set CX-105 Total Station as seen in Figure 43 and Figure 44. The survey started in Brgy. Pa-A, Hilongos, Leyte with coordinates 10°24'50.5748"N, 124°46'46.5463"E. The survey ended at the mouth of the river in Brgy. Atabay, Hilongos, Leyte with coordinates 10°22'31.9397"N, 124°44'04.4532"E. The control points UP-SAL-1 and LY-338 were used as GNSS base station all throughout the survey.

Figure 43. Manual bathymetric survey using a Hi-Target™ V30 GNSS in Salug River

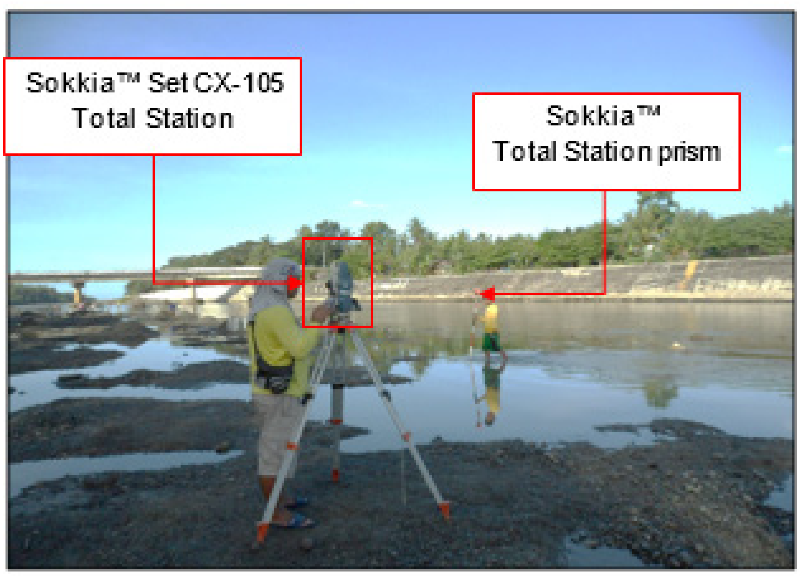


Figure 44. Manual Bathymetric survey using a Sokkia™ Set CX-105 Total Station in Salug River

The manual bathymetric survey for Salug River gathered a total of 2,011 points covering 7.44 km of the river traversing barangays Pa-A, Imelda Marcos, Proteccion, Bagong Lipunan, Liberty, Lamak, Eastern Barangay, Central Barangay, San Juan, Matapay and Atabay as shown in Figure 45. A CAD drawing was also produced to illustrate the riverbed profile of Salug River. As shown in Figure 46, the highest and lowest elevation has an 11.88 m difference. The highest elevation observed was 9.54 m above MSL located in in Brgy. Pa-A, Hilongos, Leyte while the lowest elevation was -2.34 m below MSL located in Brgy. Lamak, Hilongos, Leyte.

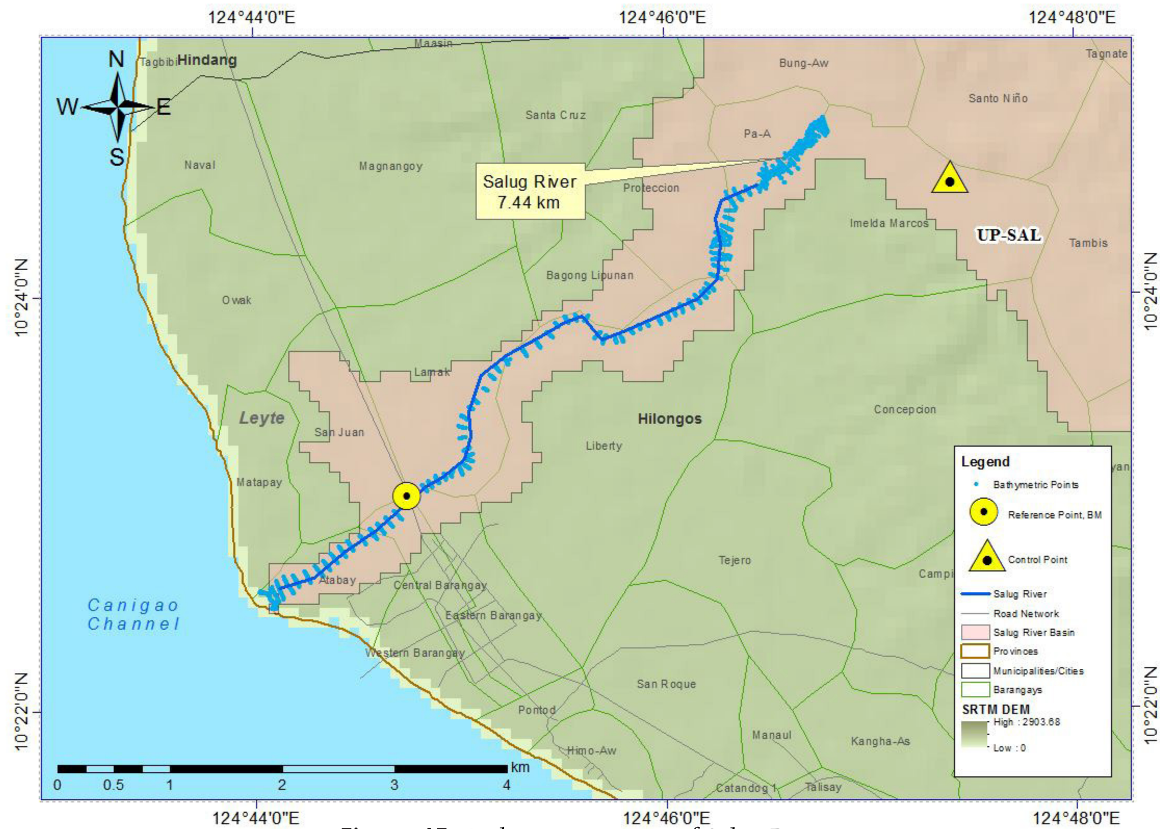


Figure 45. Bathymetric survey of Salug River

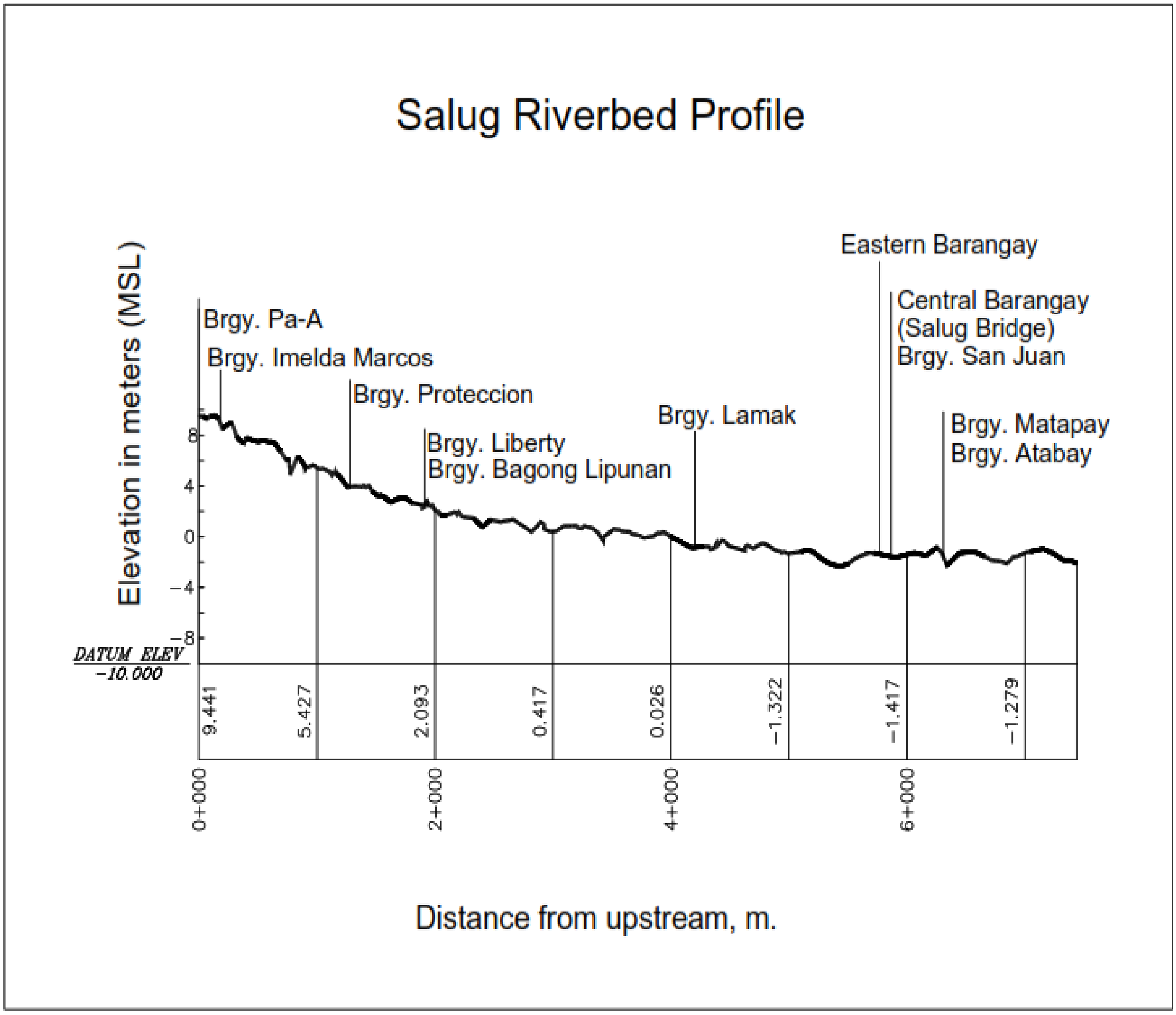


Figure 46. Salug Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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 may affect the hydrologic cycle of the Salug River Basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from the four automatic rain gauges (ARGs) deployed by the VSU Flood Modeling Component (FMC) team. The ARGs was installed in Brgy. Conception, Hilongos, Leyte. The precipitation data collection started from November 24, 2016 at 5:20 to November 25, 2016 at 14:40 with 10 minutes recording interval.

The total precipitation in Conception ARG was 92 mm. It has a peak rainfall of 4.6 mm on 24 November 2016 5:10 PM. The lag time between the peak rainfall and discharge is 8 hours and 10 minutes.

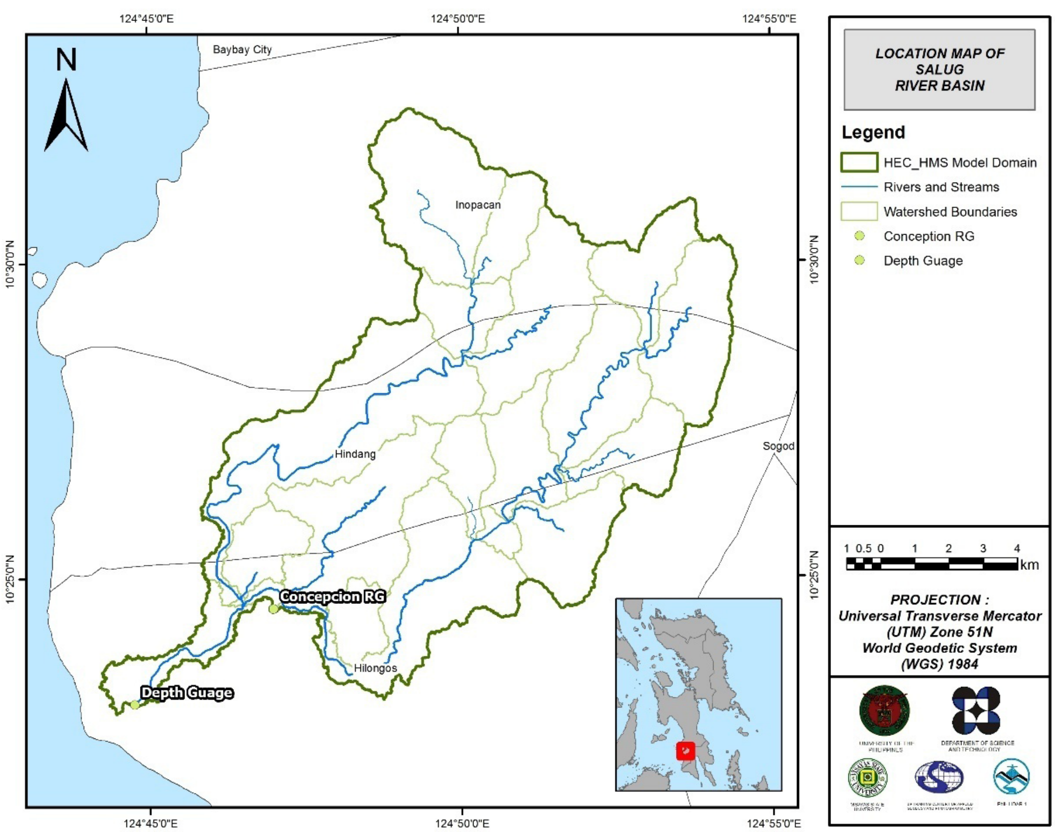


Figure 47. The location map of Salug HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Salug Bridge, Hilongos, Leyte (10°24'30.79"N, 124°46'59.14"E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

For Salug Bridge, the rating curve is expressed as $Q = 122.91H^2 + 88.384H + 1.2682$ as shown in Figure 49.

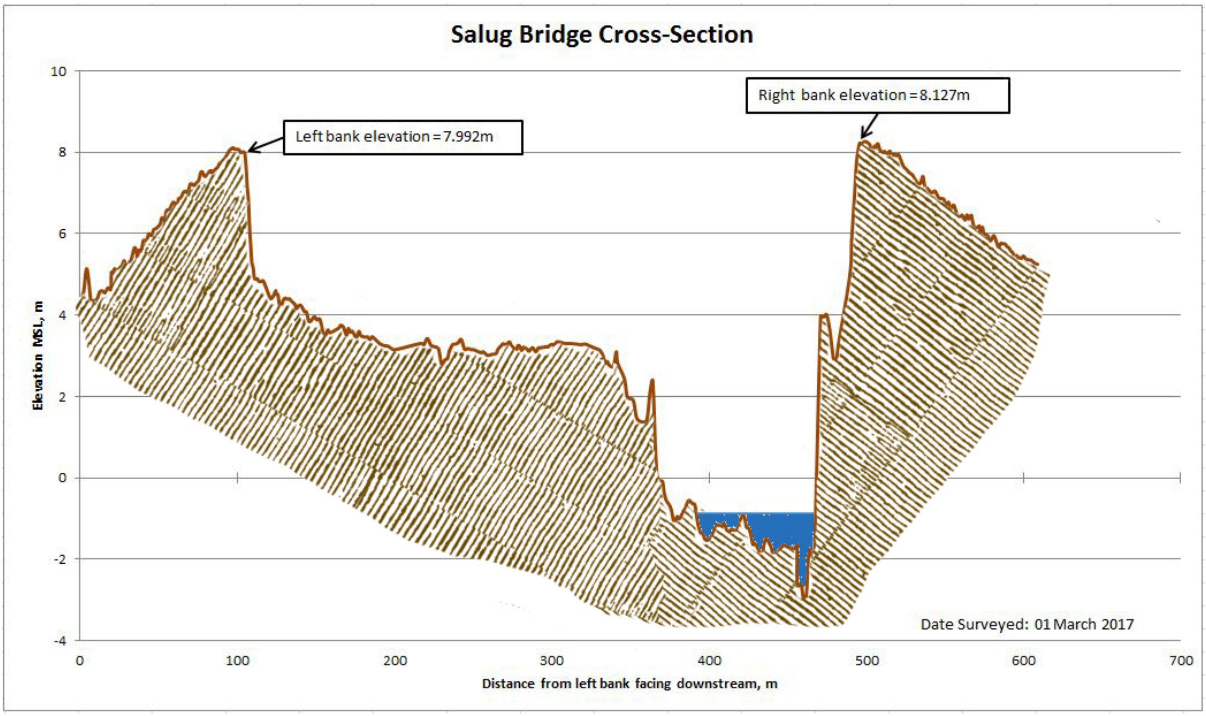


Figure 48. Cross-section plot of Salug Bridge

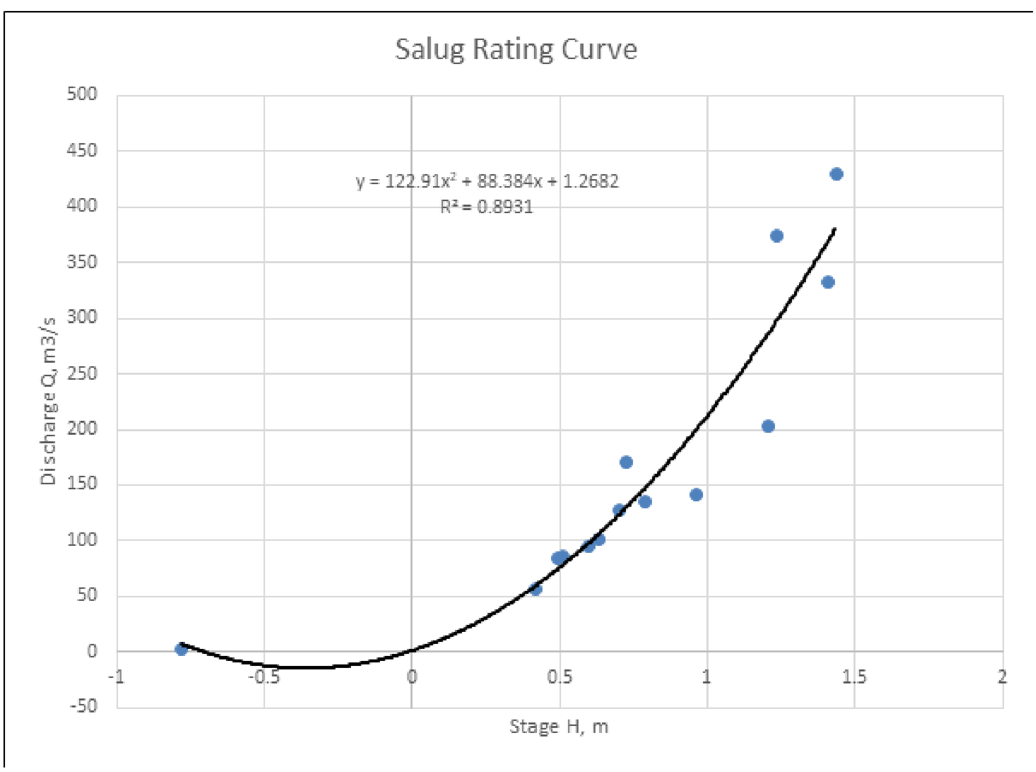


Figure 49. Rating curve at Salug Bridge

This rating curve equation was used to compute the river outflow at Salug Bridge for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 381.8 cms at 1:20 AM, November 25, 2016.

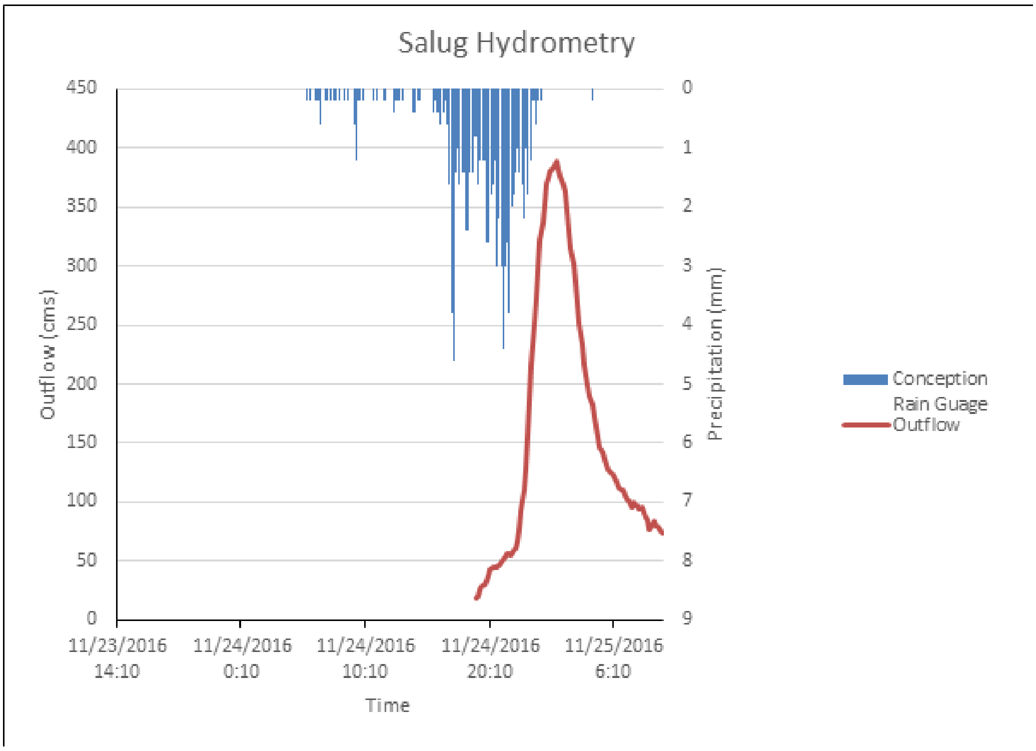


Figure 50. Rainfall and outflow data at Salug Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Maasin Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to Salug watershed. The extreme values for this watershed were computed based on a 16-year record.

Table 32. RIDF values for Maasin 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	18.5	28.1	35.6	48.1	68	82.1	104.6	124.9	145
5	25.9	38.3	63.8	63.8	90.4	108.8	137.5	165.2	190.8
10	30.8	45	74.2	74.2	105.3	126.5	159.3	191.9	221.2
15	33.5	48.8	80.1	80.1	113.7	136.5	171.5	206.9	238.4
20	35.5	51.5	84.2	84.2	119.6	143.5	180.1	217.5	250.4
25	37	53.6	87.3	87.3	124.1	148.9	186.7	225.6	259.6
50	41.5	59.9	97.1	97.1	138.1	165.5	207.1	250.6	288.1
100	46.1	66.2	106.8	106.8	151.9	181.9	227.4	275.4	316.3

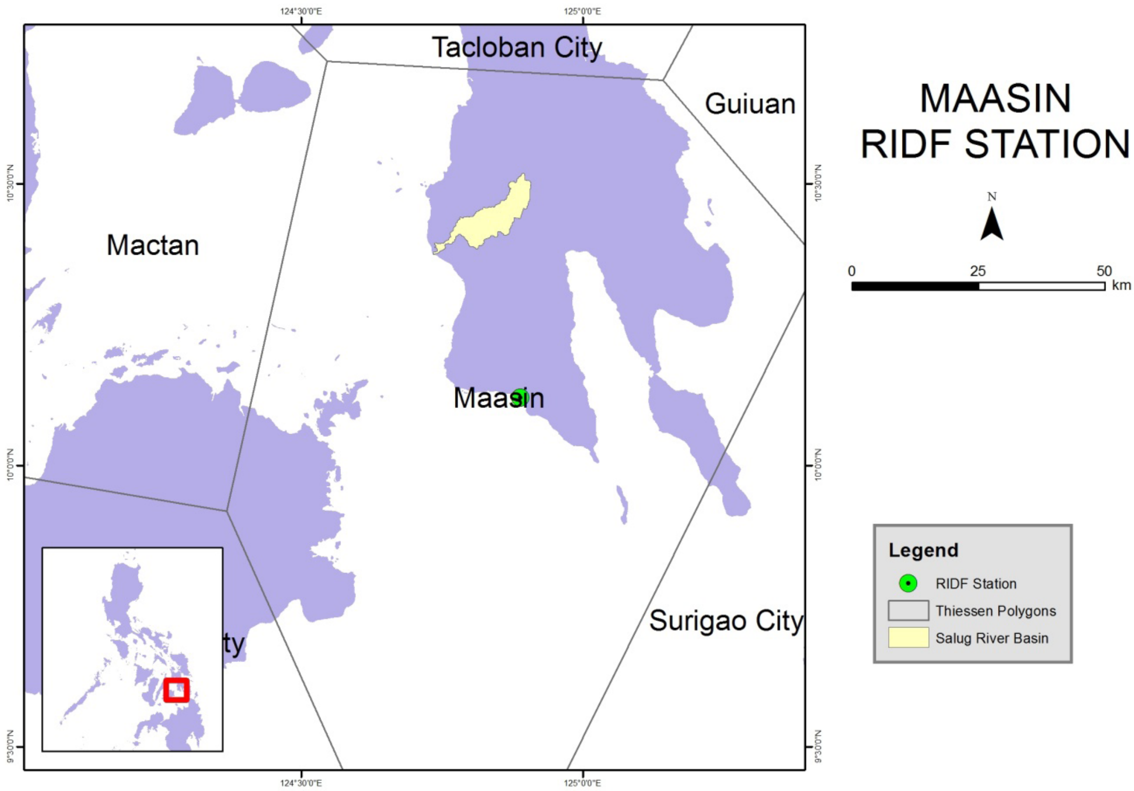


Figure 51. Location of Maasin RIDF station relative to Salug River Basin

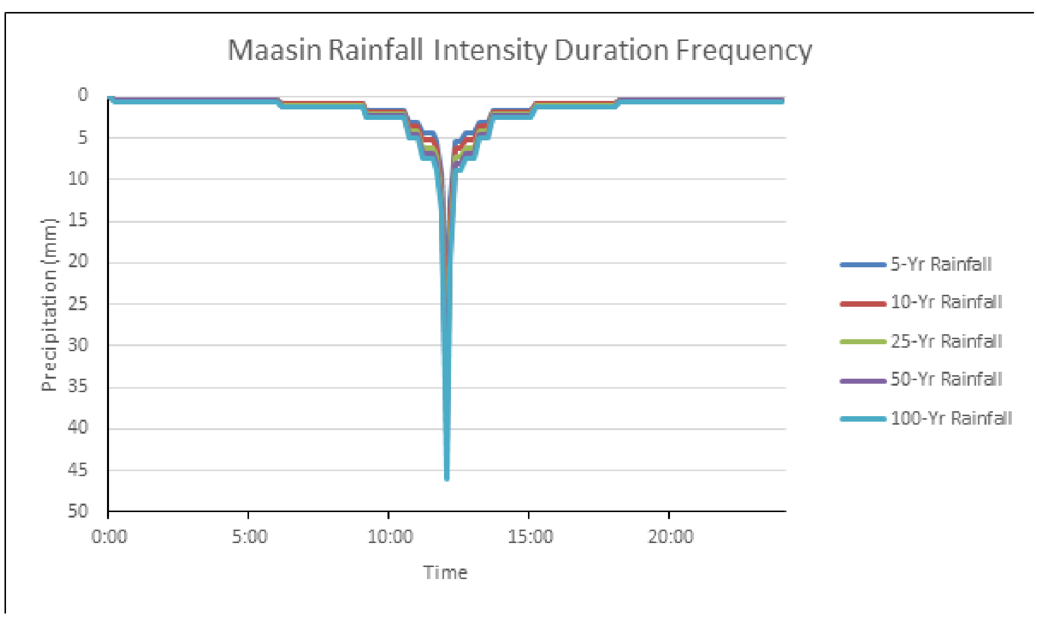


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset was taken from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Salug River Basin are shown in Figure 53 and Figure 54, respectively.

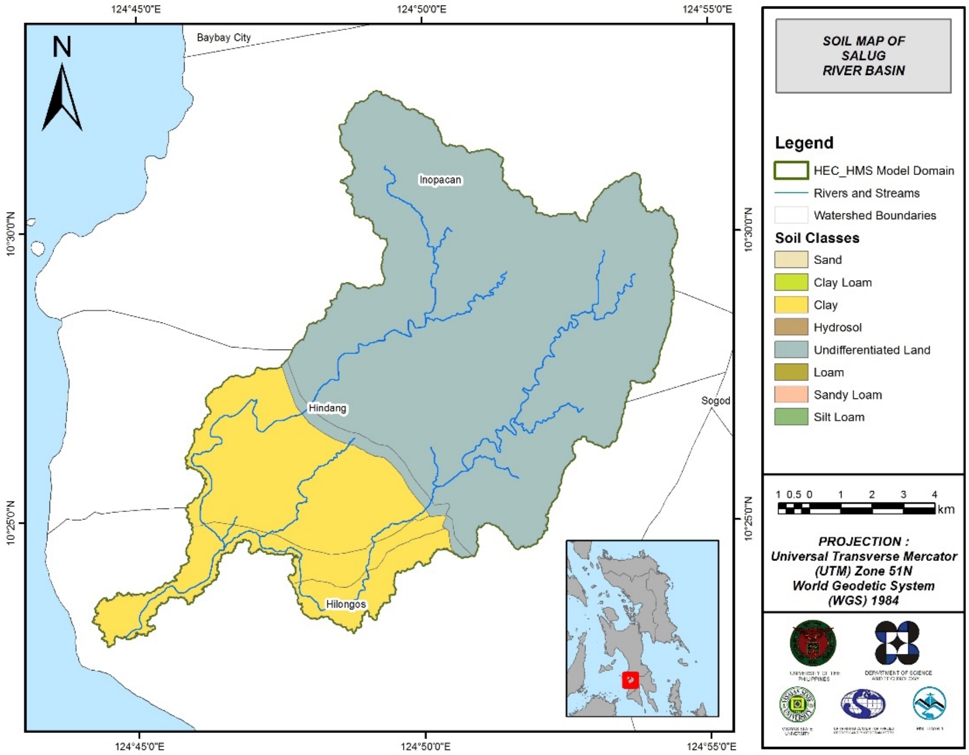


Figure 53. Soil Map of Salug River Basin

The Salug River Basin is located in the Province of Leyte and covers the municipalities of Inopacan, Hindang, and Hilongos, Leyte. It has an estimated drainage area of 62.185 square kilometers and travels 38.71 kilometers from its source to the mouth of the river. The river mouth is located near the town center of Hilongos, Leyte.

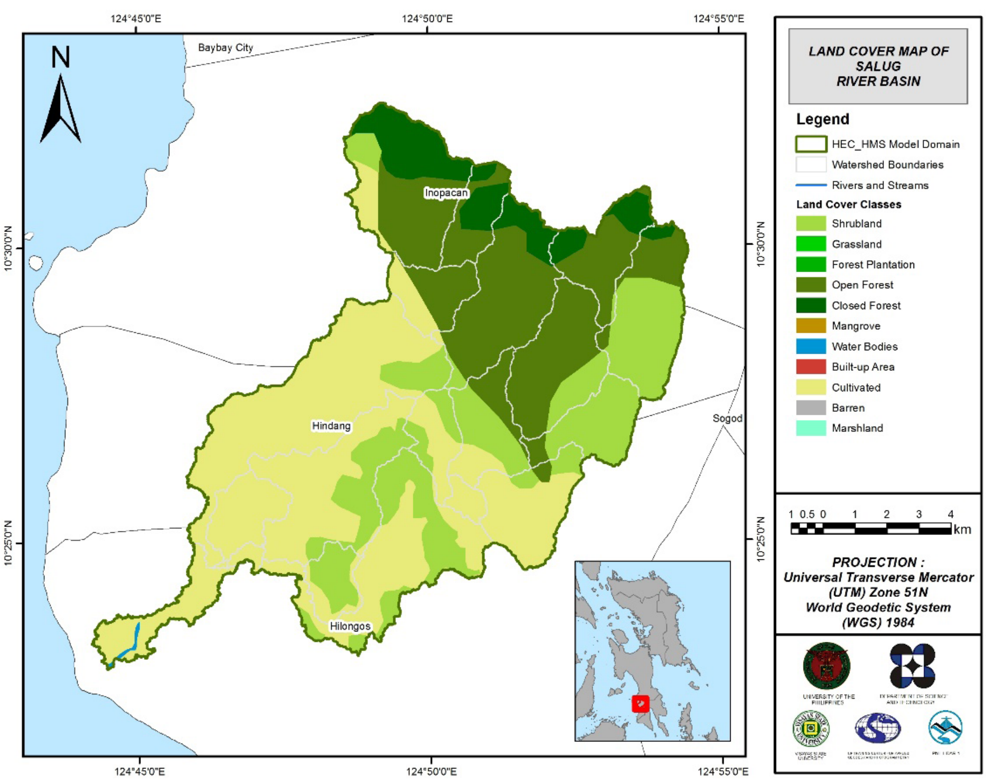


Figure 54. Land Cover Map of Salug River Basin

For Salug, the soil class identified were clay and undifferentiated land. The land cover types identified were shrubland, open forest, closed forest, and cultivated.

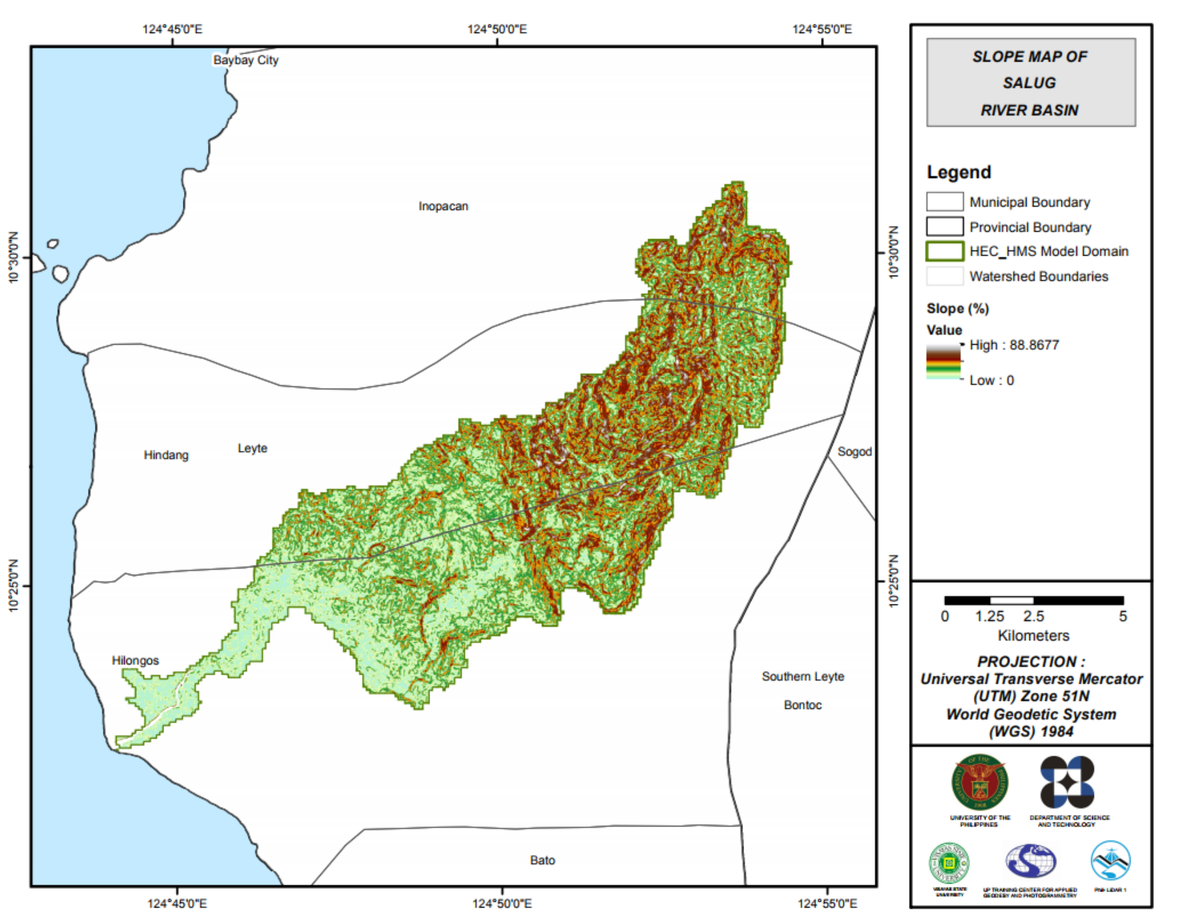


Figure 55. Slope map of Salug River Basin

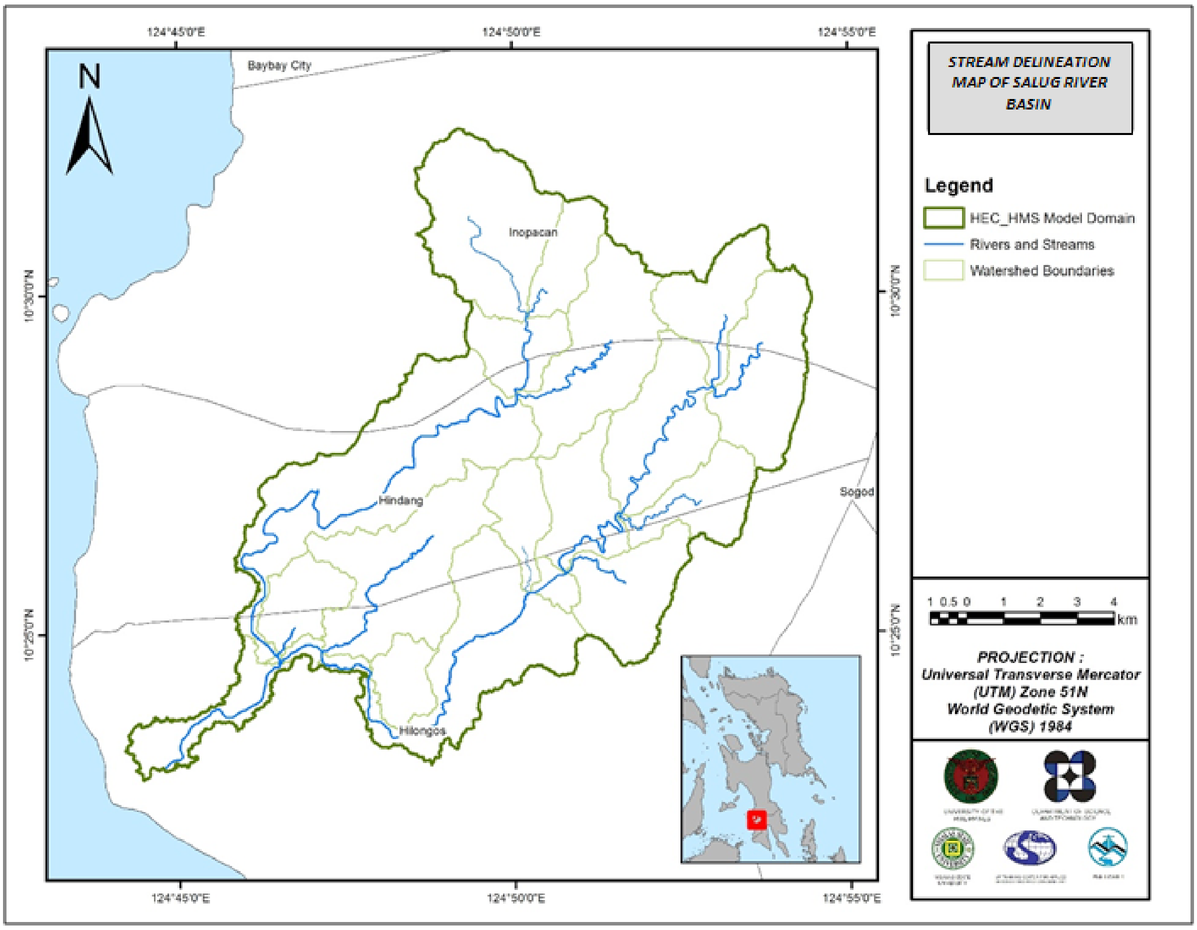


Figure 56. Stream delineation map of Salug River Basin

Using the SAR-based DEM, the Salug Basin was delineated and further subdivided into subbasins.The model consists of 21 sub basins, 10 reaches, and 10 junctions as shown in Figure 57. The main outlet is at Salug Bridge.

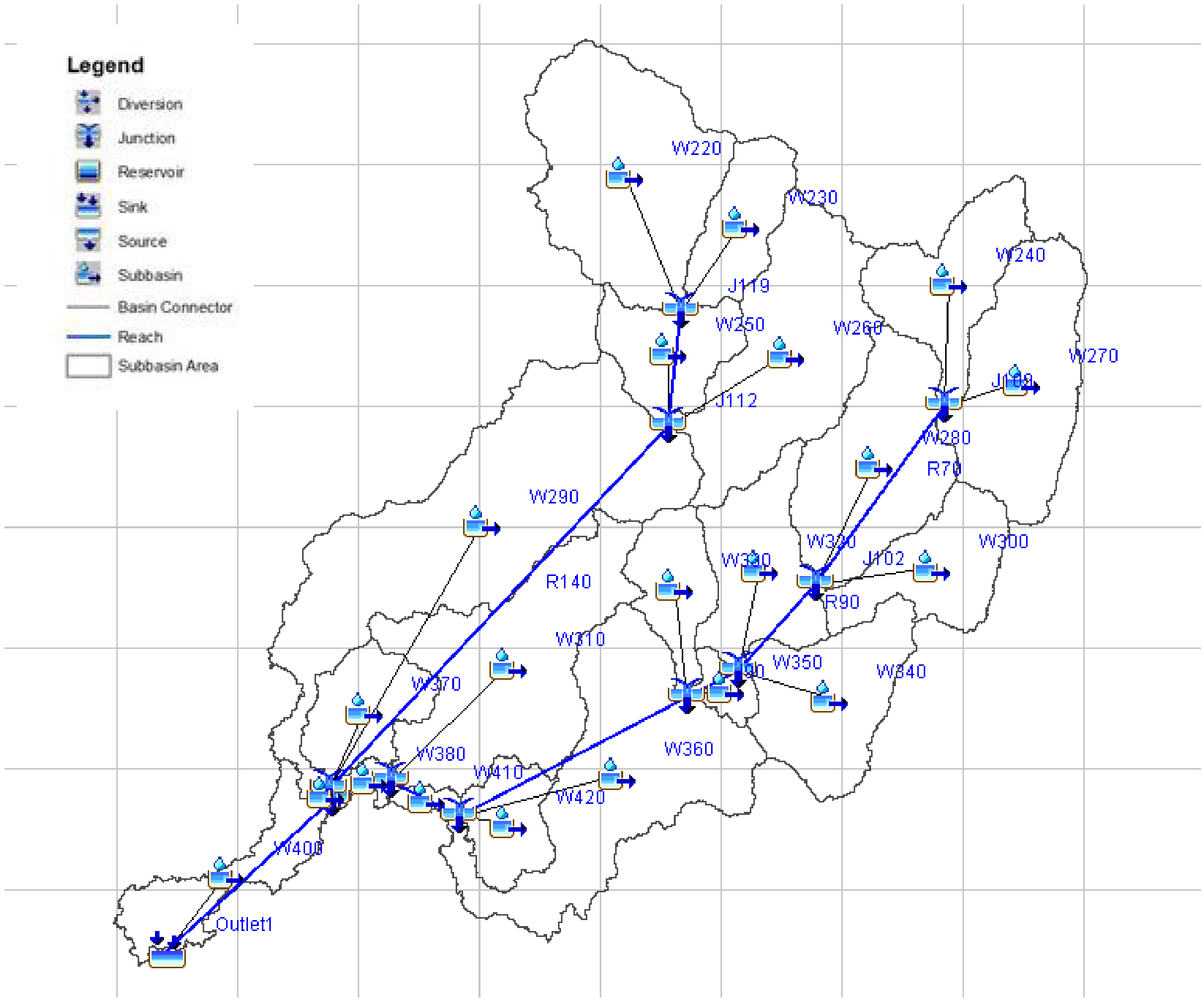


Figure 57. The Salug River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

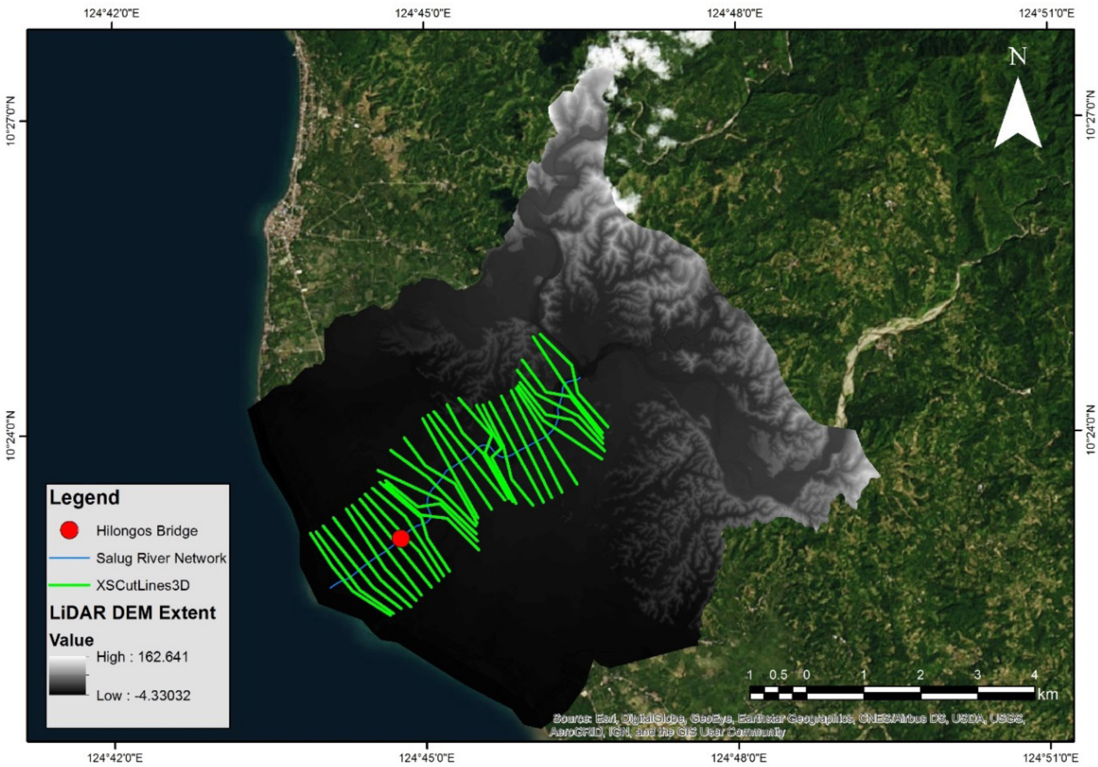


Figure 58. River cross-section of Salug River generated through ArcMap HEC GeoRAS tool

5.5 FLO-2D Model

[insert 2d report]

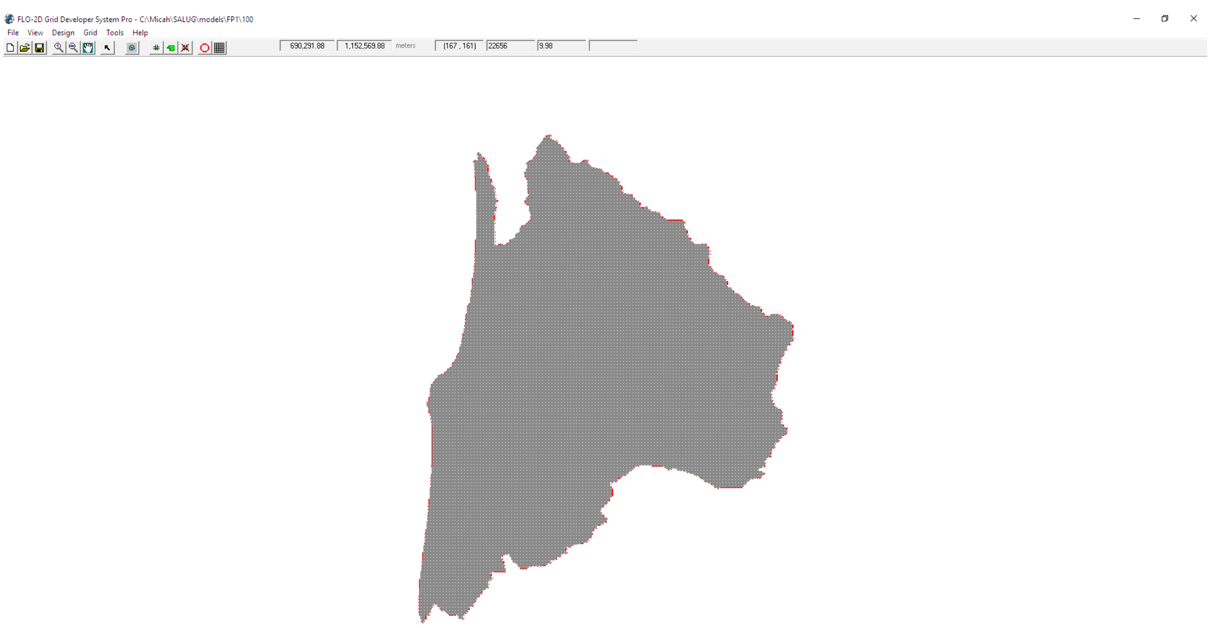


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

5.6 Results of HMS Calibration

After calibrating the Salug HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

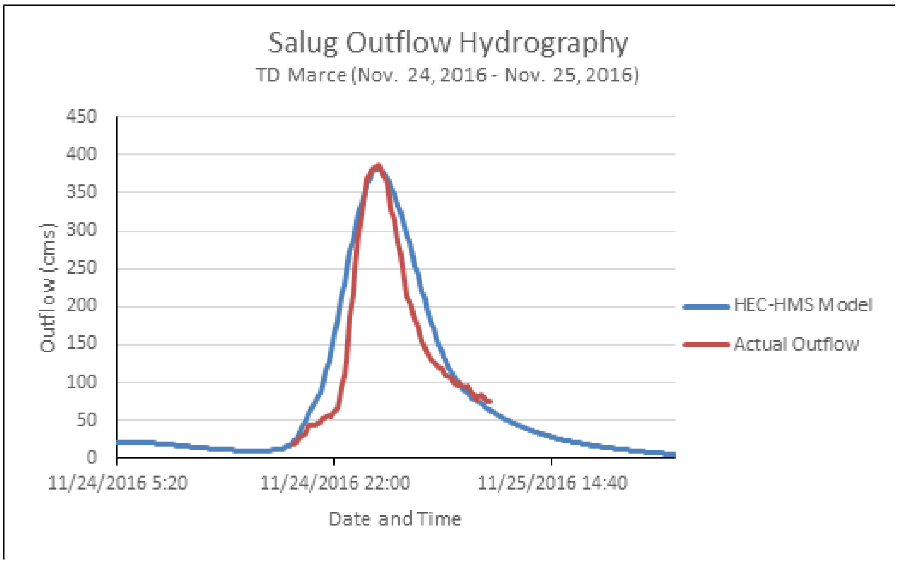


Figure 60. Outflow hydrograph of Salug Bridge generated in HEC-HMS model compared with observed outflow

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

Table 33. Range of calibrated values for Salug

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2
			Curve Number	88
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.5 - 7
			Storage Coefficient (hr)	0.02 - 0.08
	Baseflow	Recession	Recession Constant	0.01
			Ratio to Peak	0.3
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.05

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The value from 2mm means that there is minimal amount of infiltration or rainfall interception by vegetation per subbasin.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The value of 88 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 to 7 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.01 indicates that the basin is likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.1 to 0.3 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.05 is slightly higher than the common roughness Salug watershed.

Table 34. Summary of the efficiency test of Salug HMS Model

r^2	0.89
NSE	0.79
PBIAS	-21.14
RSR	0.37

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It computed as 4.9 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.89.

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 0.79.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -21.14.

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

5.7 Calculated Outflow Hydrographs and Discharge Values for Different Rainfall Return Periods

5.7.1 Hydrograph Using the Rainfall Runoff Model

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

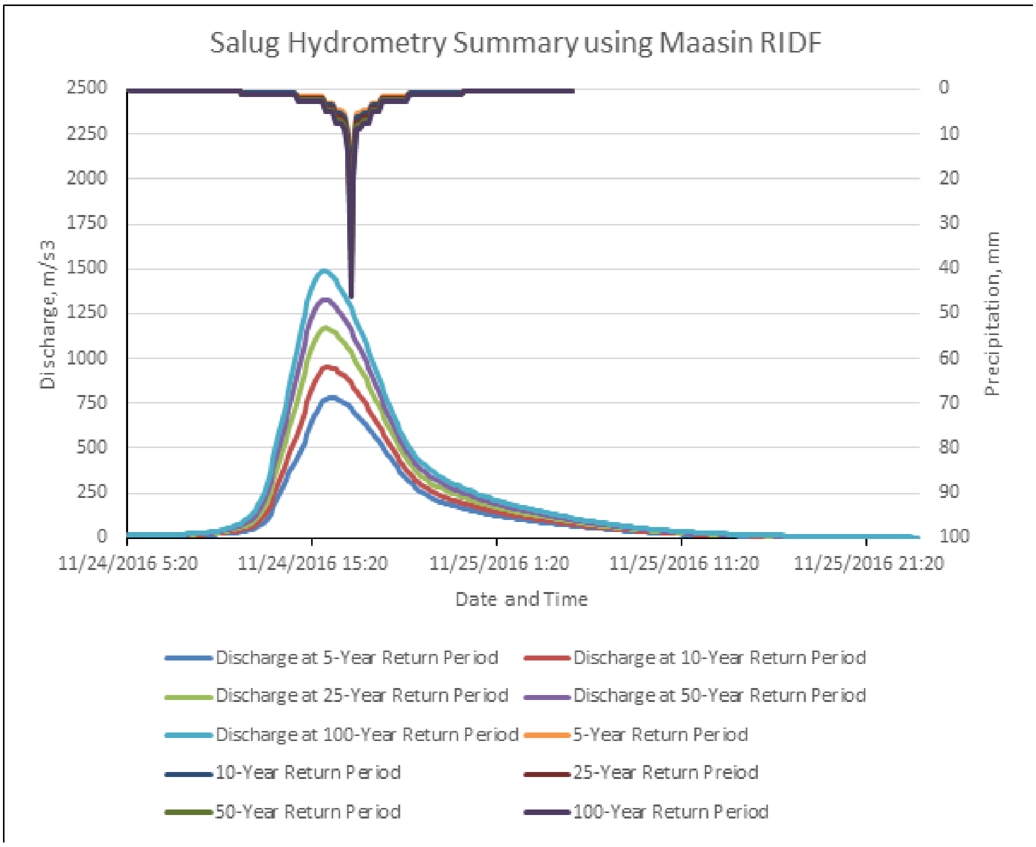


Figure 61. Outflow hydrograph at Salug Station generated using Tacloban RIDF simulated in HEC-HMS

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

Table 35. Peak values of the Salug 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	144.43	25.90	780.6	11 hours, 00 minutes
10-Year	173.32	30.80	951.7	10 hours, 50 minutes
25-Year	210.24	37.00	1169.1	10 hours, 40 minutes
50-Year	237.62	41.50	1329.5	10 hours, 40 minutes
100-Year	265.29	46.10	1489.6	10 hours, 30 minutes

Discharge data using Dr. Horritts's recommended hydrologic method

The river discharges entering the floodplain are shown in Figure 62 to Figure 63 and the peak values are summarized in Table 36 to Table 37.

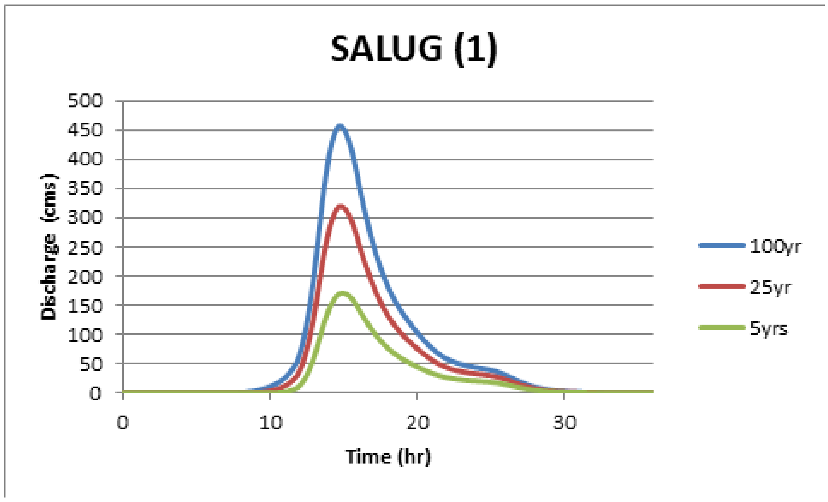


Figure 62. Salug River (1) generated discharge using 5-, 25-, and 100-year Tacloban City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

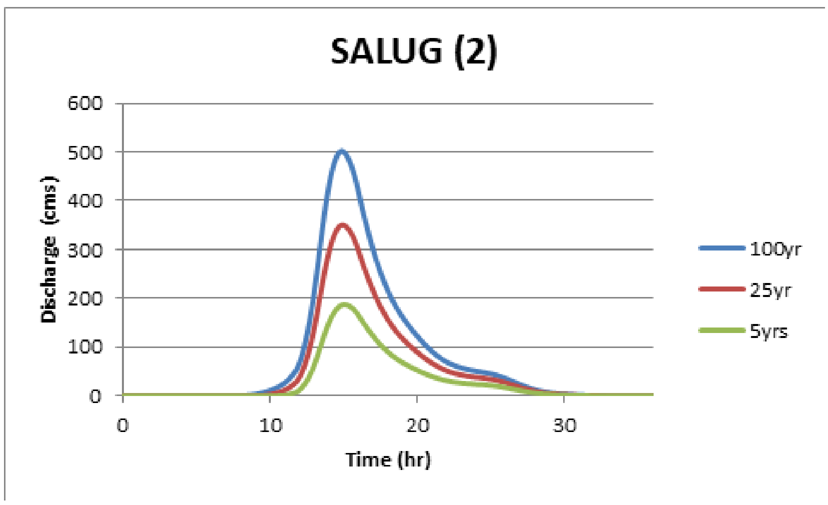


Figure 63. Salug River (2) generated discharge using 5-, 25-, and 100-year Tacloban City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 36. Summary of Salug River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	456.9	21 hours, 10 minutes
25-Year	319.2	21 hours, 10 minutes
5-Year	171.1	21 hours, 20 minutes

Table 37. Summary of Salug River (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	502.6	14 hours, 10 minutes
25-Year	350.6	14 hours, 10 minutes
5-Year	187.5	14 hours, 10 minutes

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

Table 38. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Salug (1)	150.568	153.126	42.209	Pass	Fail
Salug (2)	165.000	135.240	42.209	Pass	Fail

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

5.8 River Analysis Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the VSU-FMC base flow was calibrated. The sample generated map of Salug River using the calibrated HMS base flow is shown in Figure 64.

FIgure 64. Sample output Salug RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Salug Floodplain are shown in Figure 65 to Figure 70. The floodplain, with an area of 149.95 sq km, covers two municipalities namely Hilongos, and Hindang. Table 39 shows the percentage of area affected by flooding per municipality.

Table 39. Municipalities affected in Salug Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Hilongos	156.8	56.46	36.0077
Hindang	106.77	23.9	22.38

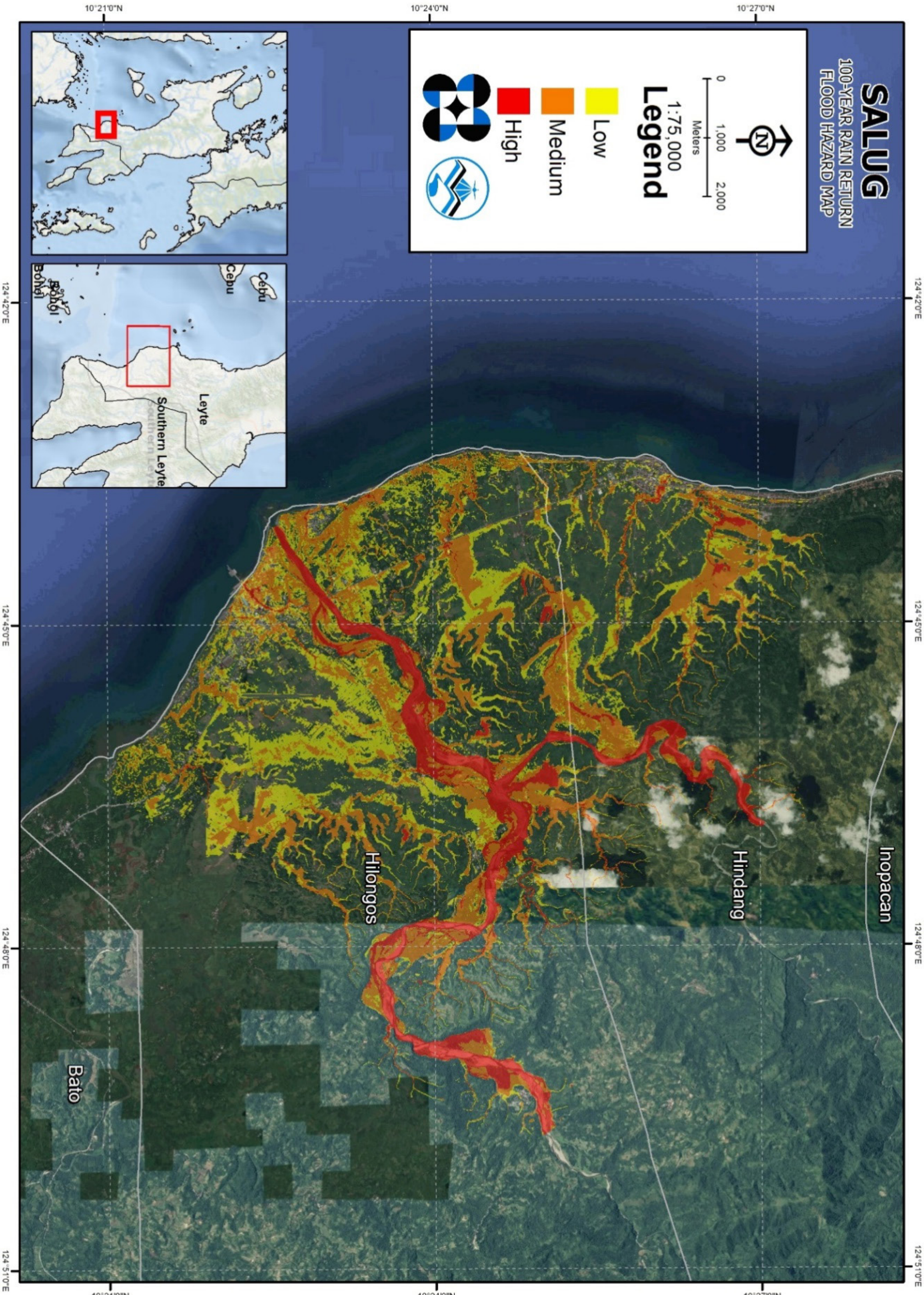


Figure 65. 100-year flood hazard map for Salug Floodplain

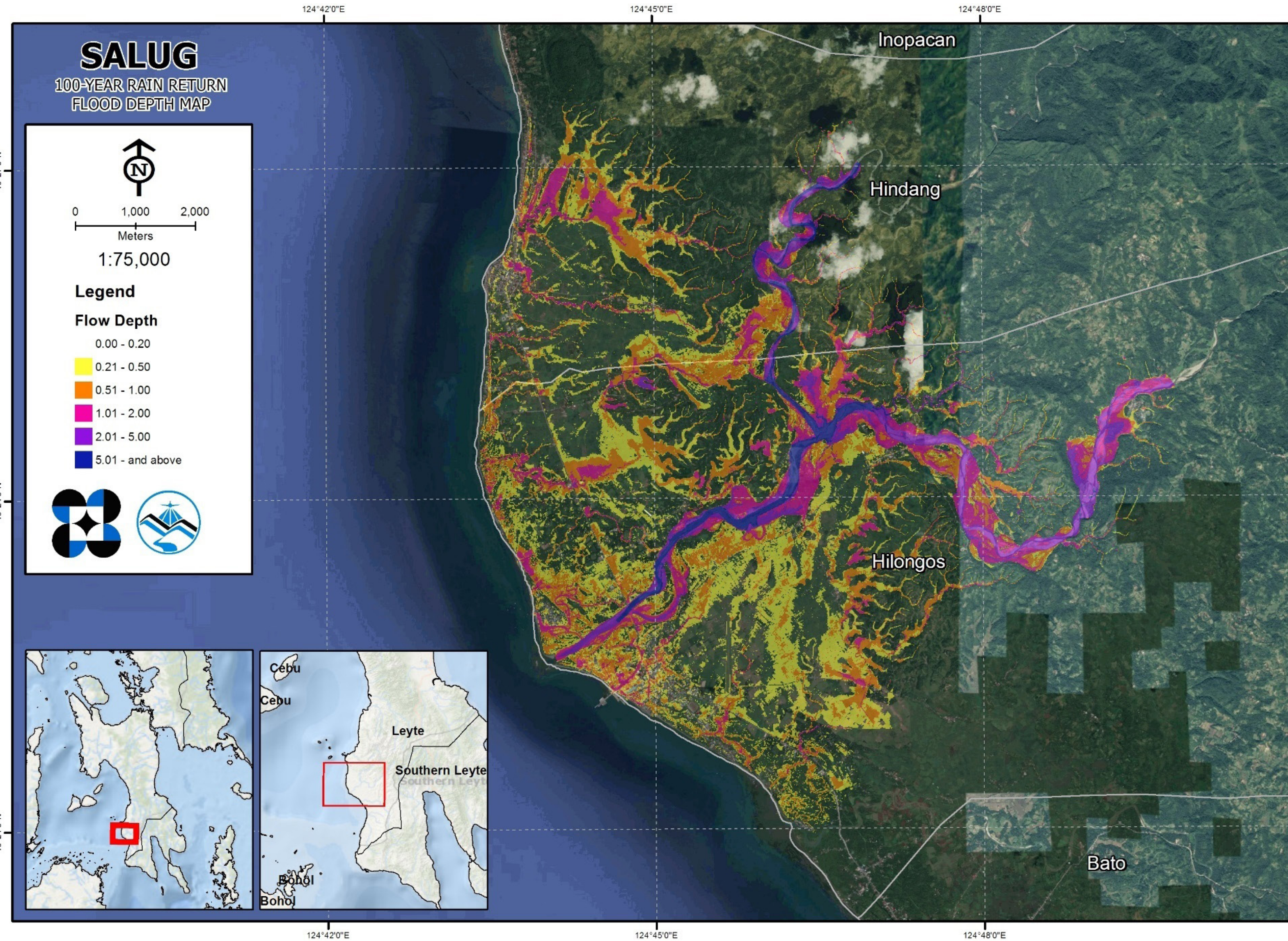


Figure 66. 100-year flow depth map for Salug Floodplain

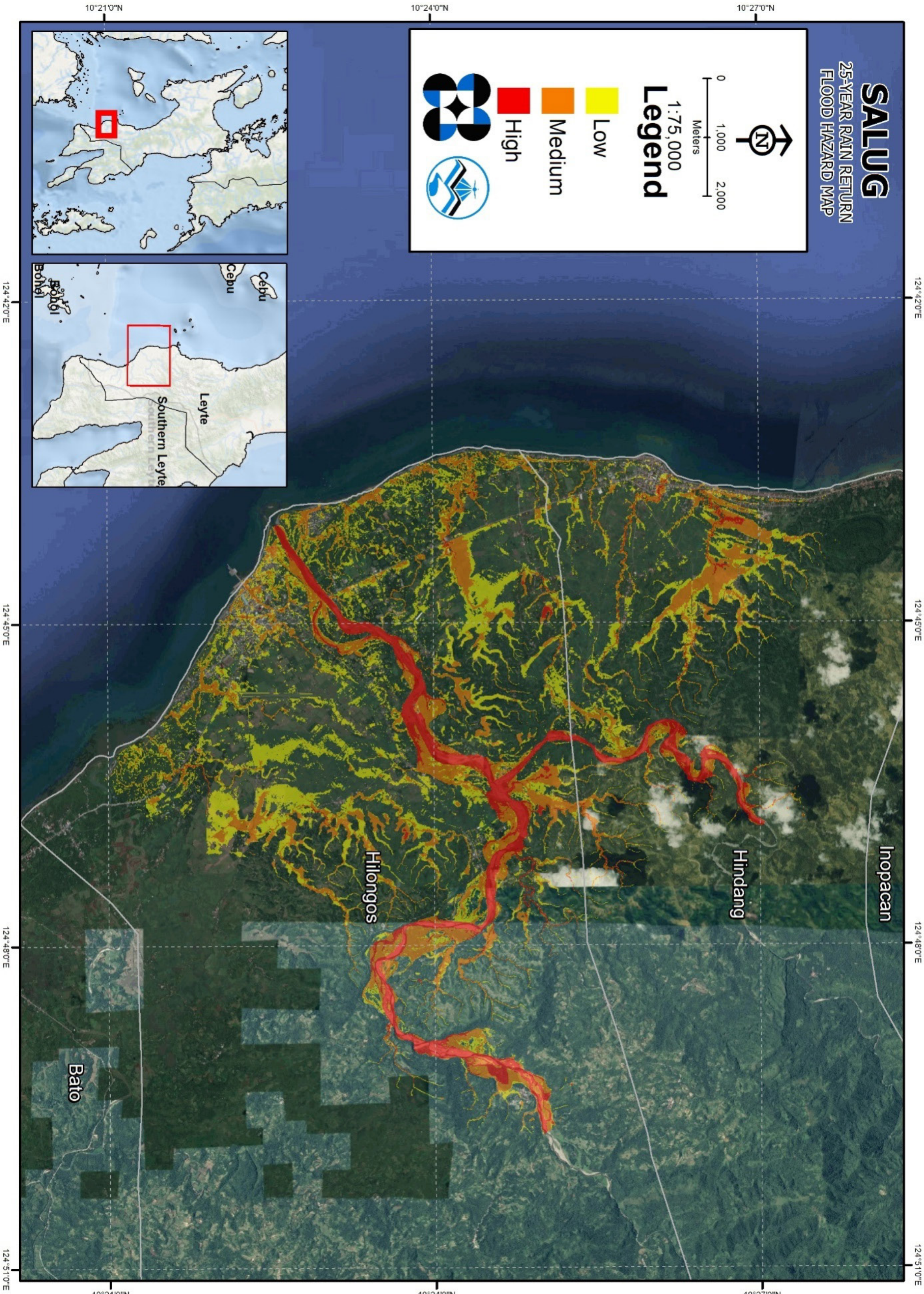


Figure 67. 25-year flood hazard map for Salug Floodplain

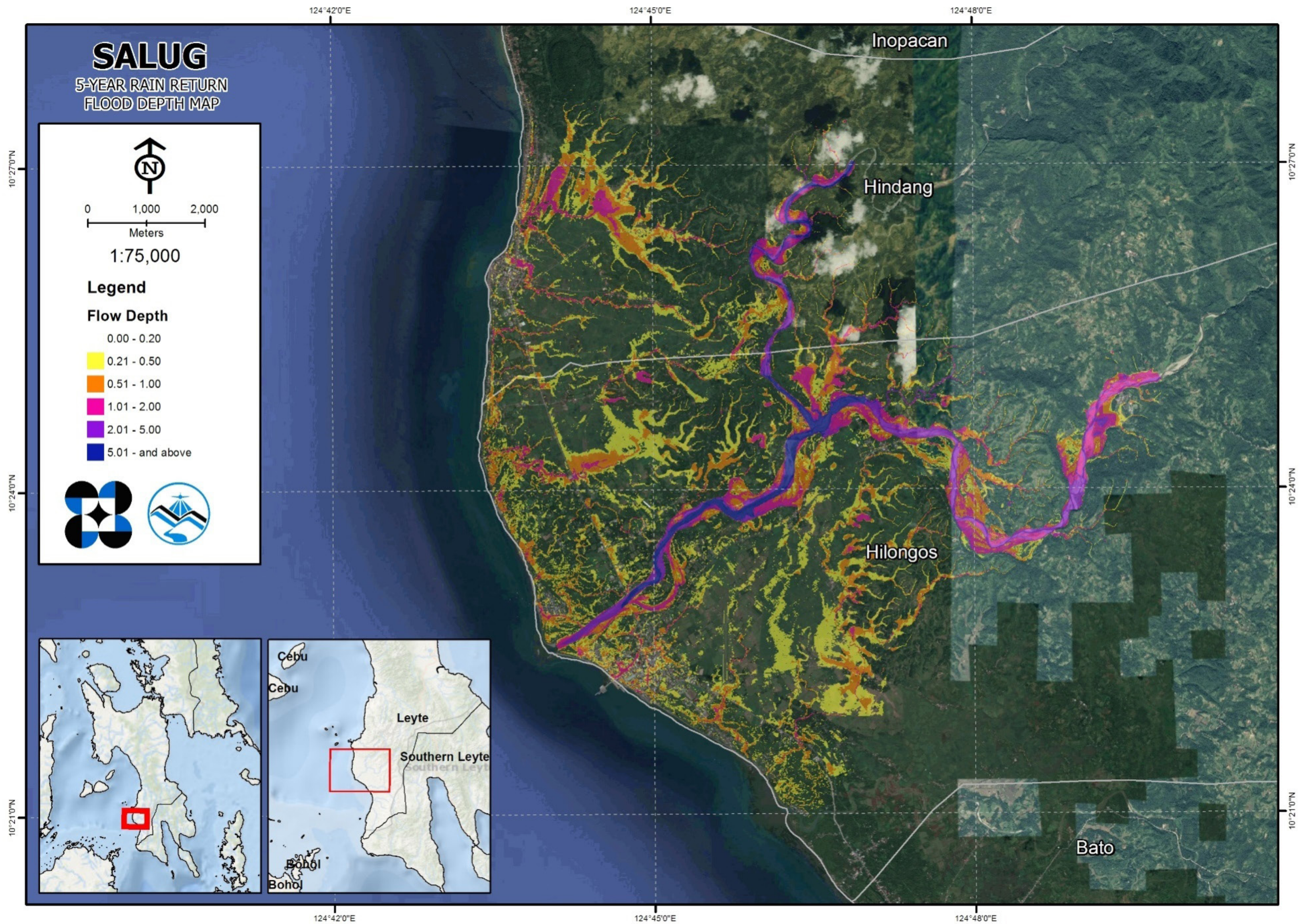


Figure 68. 25-year flow depth map for Salug Floodplain

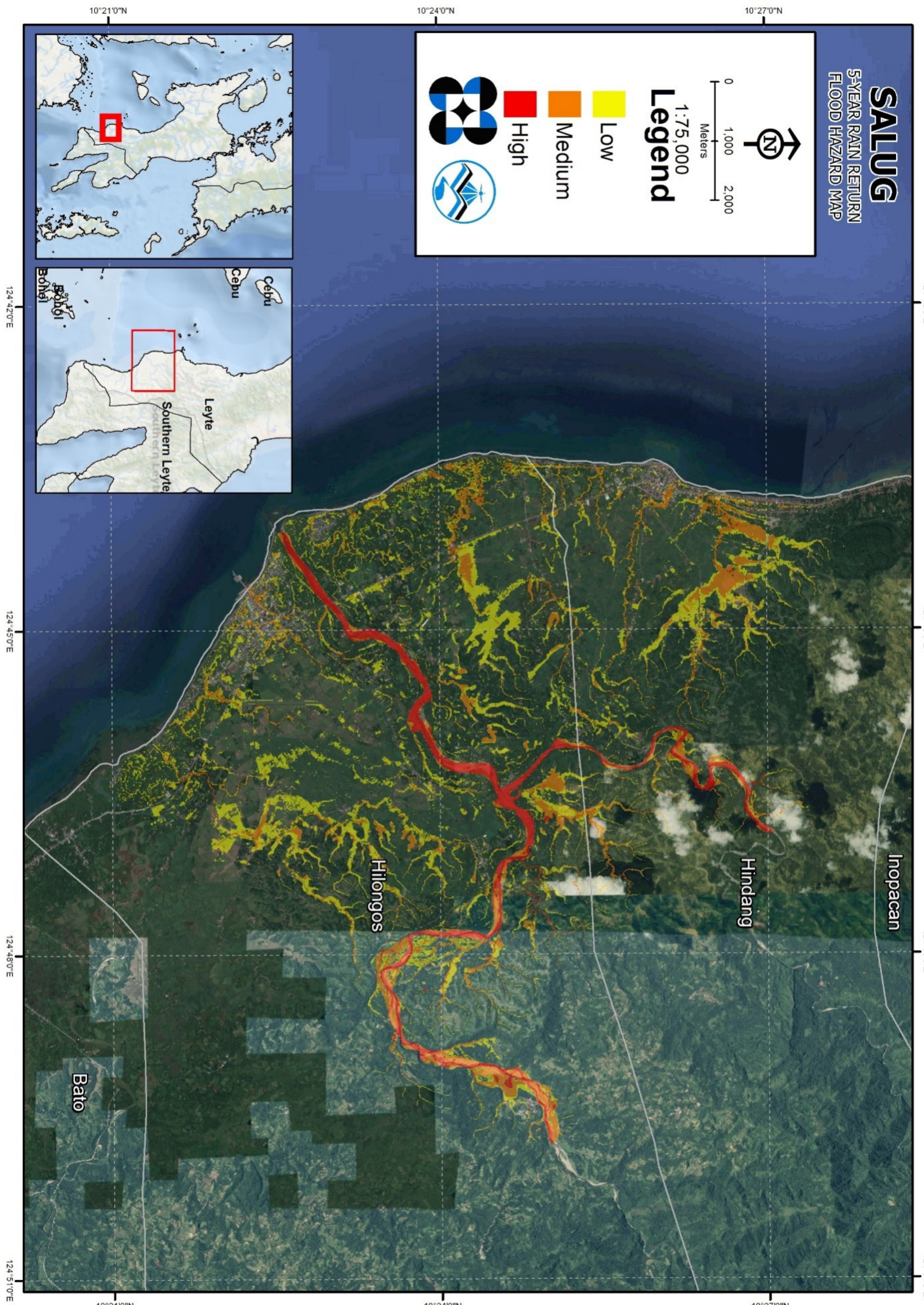


Figure 69. 5-year flood hazard map for Salug Floodplain

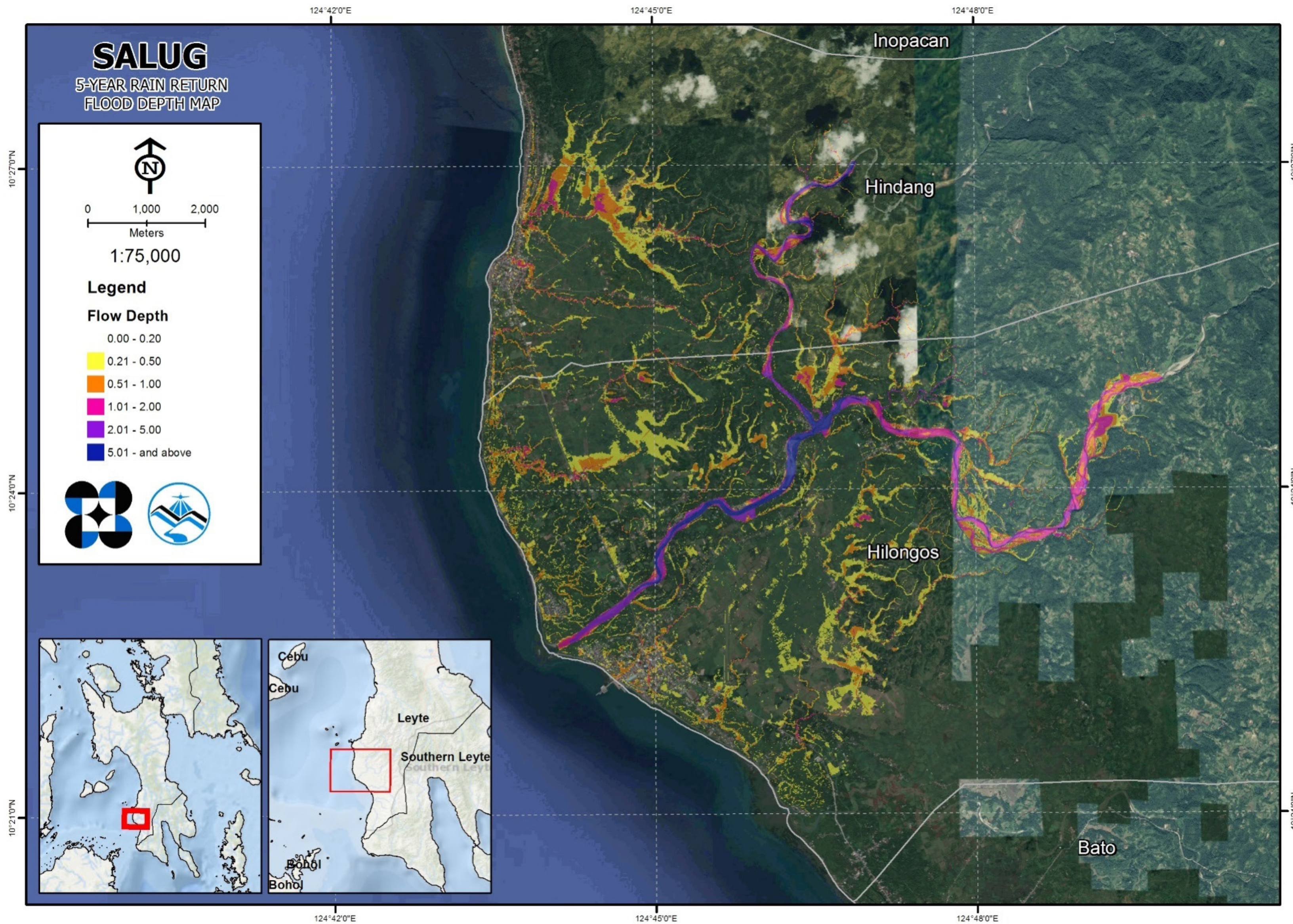


Figure 70. 5-year flow depth map for Salug Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Salug River Basin, grouped by municipality, are listed below. For the said basin, 2 municipalities consisting of 49 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 28.67% of the municipality of Hilongos with an area of 156.796 sq km will experience flood levels of less 0.20 meters. 4.05% of the area will experience flood levels of 0.21 to 0.50 meters while 1.6%, 0.84%, 0.5% and 0.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 40 to Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Atabay	Bagong Lipunan	Bagum-bayan	Bantigue	Bung-Aw	Campina	Catandog 1	Catandog 2	Central Brgy
Affected Area (sq km.)	0.03-0.20	0.59	0.65	2.42	0.18	1.12	0.89	0.67	0.013	0.43
	0.21-0.50	0.086	0.1	0.13	0.036	0.21	0.22	0.12	0	0.074
	0.51-1.00	0.032	0.075	0.16	0.0066	0.15	0.071	0.027	0	0.031
	1.01-2.00	0.043	0.0065	0.24	0	0.041	0.017	0.0018	0	0.0098
	2.01-5.00	0.077	0.0075	0.091	0	0.006	0.0003	0	0	0.055
	> 5.00	0	0.00079	0	0	0	0	0	0	0

Table 41. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Concepcion	Eastern Barangay	Hi-mo-Aw	Imelda Marcos	Kang-ha-As	Lamak	Liberty	Mag-nangoy	Manaul
Affected Area (sq km.)	0.03-0.20	4.22	0.85	0.43	2.82	0.29	1.91	4.04	3.26	0.41
	0.21-0.50	0.7	0.11	0.08	0.29	0.12	0.18	0.31	0.73	0.05
	0.51-1.00	0.26	0.051	0.052	0.13	0.006	0.031	0.064	0.17	0.016
	1.01-2.00	0.08	0.0094	0.0027	0.23	0.0023	0.04	0.039	0.03	0.0055
	2.01-5.00	0.019	0.011	0	0.12	0	0.093	0.1	0.0006	0.0001
	> 5.00	0	0	0	0.11	0	0.072	0.18	0	0

Table 42. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Marangog	Matapay	Naval	Owak	Pa-A	Pontod	Proteccion	San Isidro	San Juan
Affected Area (sq km.)	0.03-0.20	0.025	0.74	1.29	1.47	0.35	0.24	1.29	0.23	1.25
	0.21-0.50	0.0001	0.16	0.14	0.31	0.08	0.058	0.19	0.0048	0.17
	0.51-1.00	0	0.037	0.06	0.18	0.053	0.013	0.052	0.00081	0.059
	1.01-2.00	0	0.0004	0.014	0.038	0.025	0.00045	0.006	0.00036	0.0006
	2.01-5.00	0	0	0.0003	0.001	0.041	0	0.026	0.00012	0
	> 5.00	0	0	0	0	0.092	0	0.084	0	0

Table 43. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		San Roque	Santa Cruz	Santa Margarita	Santo Niño	Tagnate	Talisay	Tambis	Tejero	Western Brgy
Affected Area (sq km.)	0.03-0.20	1.77	1.68	0.81	1.8	0.76	0.32	3.23	2.11	0.41
	0.21-0.50	0.23	0.2	0.1	0.12	0.027	0.044	0.43	0.45	0.075
	0.51-1.00	0.037	0.044	0.18	0.049	0.051	0.001	0.25	0.06	0.051
	1.01-2.00	0.013	0.022	0.14	0.038	0.11	0	0.11	0.0027	0.0061
	2.01-5.00	0	0.027	0.019	0.021	0.02	0	0.053	0	0
	> 5.00	0	0.0002	0	0	0	0	0	0	0

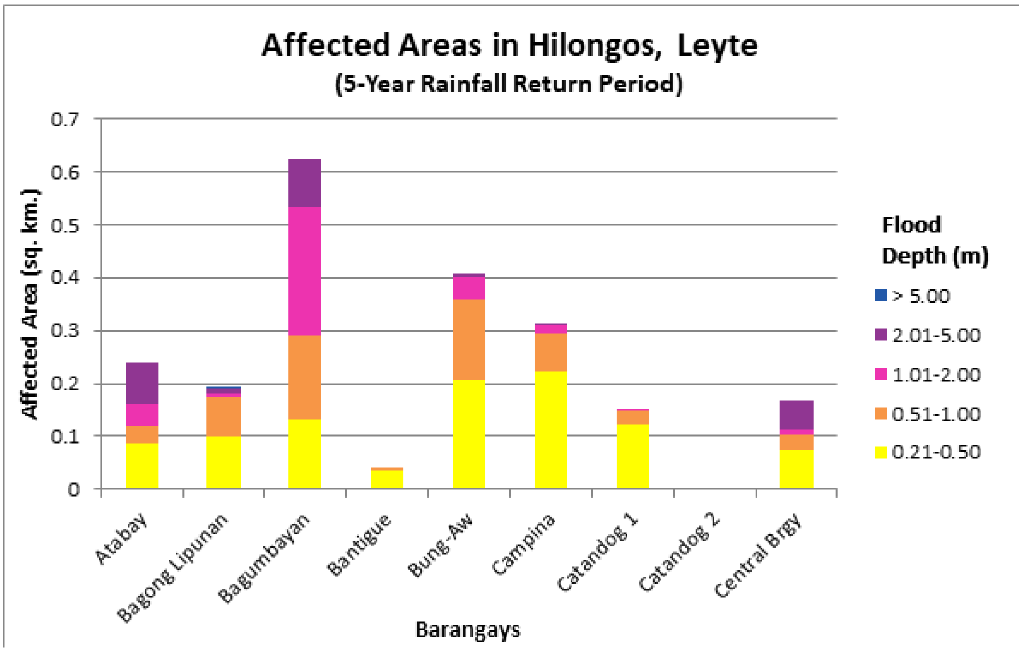


Figure 71. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

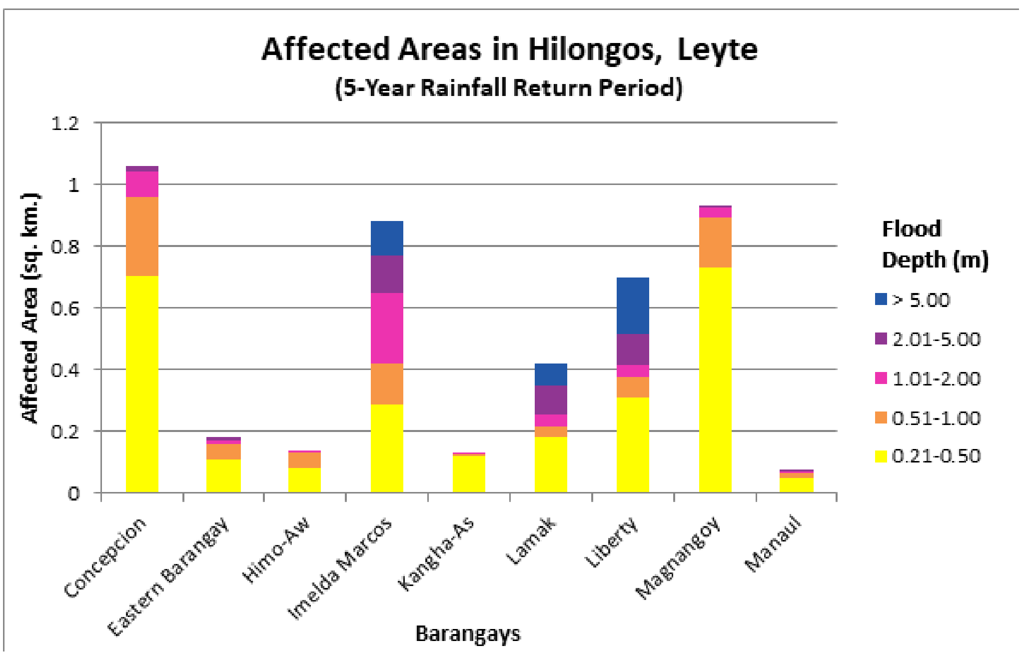


Figure 72. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

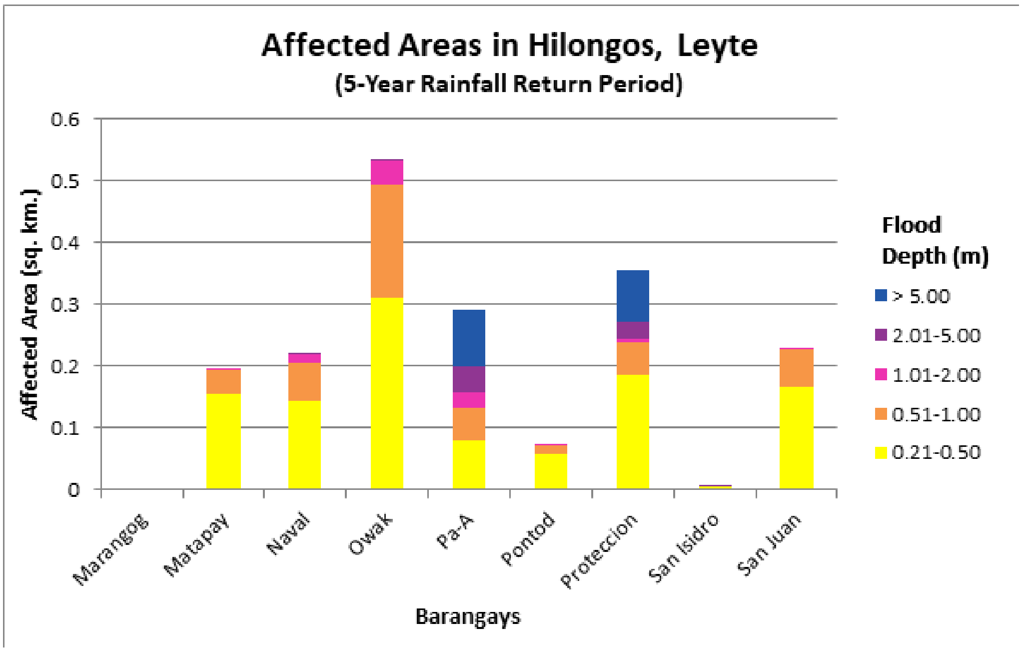


Figure 73. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

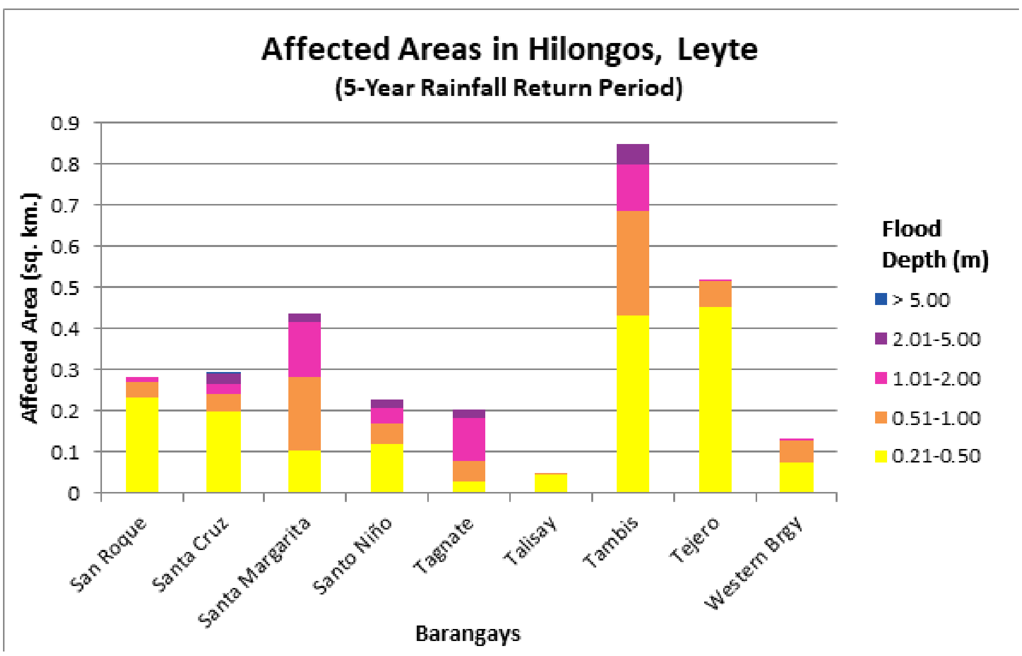


Figure 74. Affected areas in Hilongos, Leyte Samar during 5-year rainfall return period

For the municipality of Hindang, with an area of 106.765 sq km, 18.81% will experience flood levels of less 0.20 meters. 1.84% of the area will experience flood levels of 0.21 to 0.50 meters while 1.06%, 0.42%, 0.17% and 0.072% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 44 and Table 45 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected areas in Hindang, Leyte Samar during 5-year rainfall return period

SALUG BASIN		Area of affected barangays in Hindang (in sq km.)					
		Anahaw	Bontoc	Doos Del Norte	Doos Del Sur	Himacugo	Katipunan
Affected Area (sq km.)	0.03-0.20	1.2	0.0035	0.56	0.51	2.19	3.46
	0.21-0.50	0.17	0	0.1	0.19	0.08	0.15
	0.51-1.00	0.065	0	0.011	0.14	0.065	0.13
	1.01-2.00	0.0035	0	0.0003	0.018	0.063	0.051
	2.01-5.00	0	0	0	0	0.08	0.0093
	> 5.00	0	0	0	0	0.07	0.0049

Table 45. Affected areas in Hindang, Leyte Samar during 5-year rainfall return period

SALUG BASIN		Area of affected barangays in Hindang (in sq km.)						
		Maasin	Mabagon	Poblacion 1	Poblacion 2	San Vicente	Tabok	Tagbibi
Affected Area (sq km.)	0.03-0.20	4.88	2.26	0.34	1.02	0.51	1.46	1.7
	0.21-0.50	0.42	0.47	0.034	0.076	0.015	0.14	0.13
	0.51-1.00	0.14	0.29	0.028	0.035	0.0031	0.15	0.077
	1.01-2.00	0.087	0.11	0.015	0.022	0.0006	0.073	0.015
	2.01-5.00	0.047	0.048	0.0003	0.0002	0.0001	0.0003	0.0002
	> 5.00	0.00086	0.0024	0	0	0	0	0

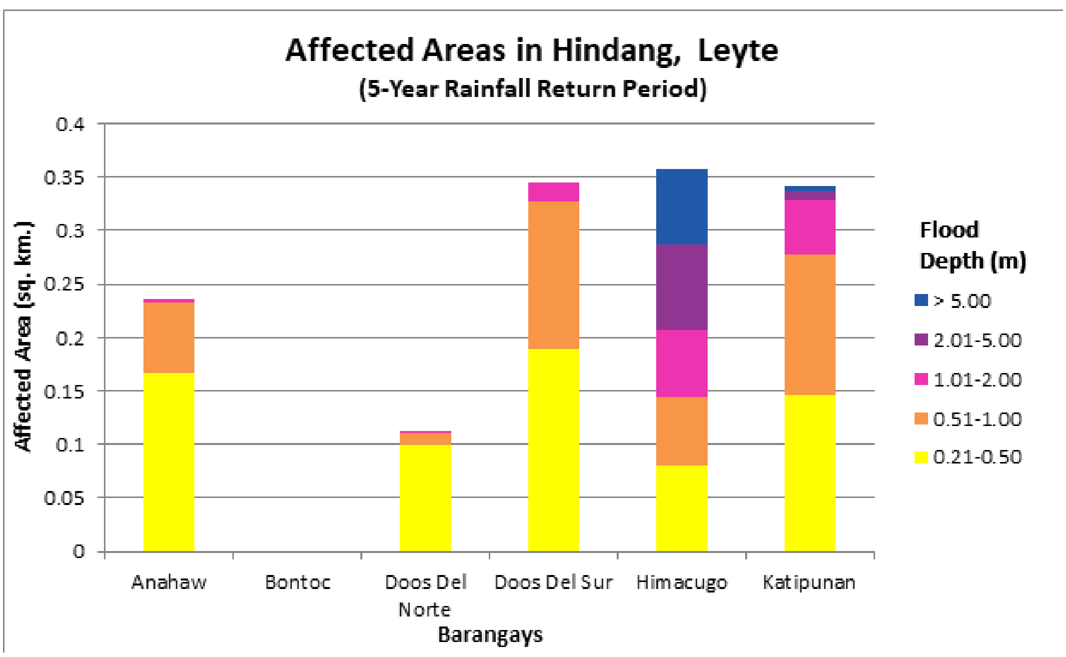


Figure 75. Affected areas in Hindang, Leyte Samar during 5-year rainfall return period

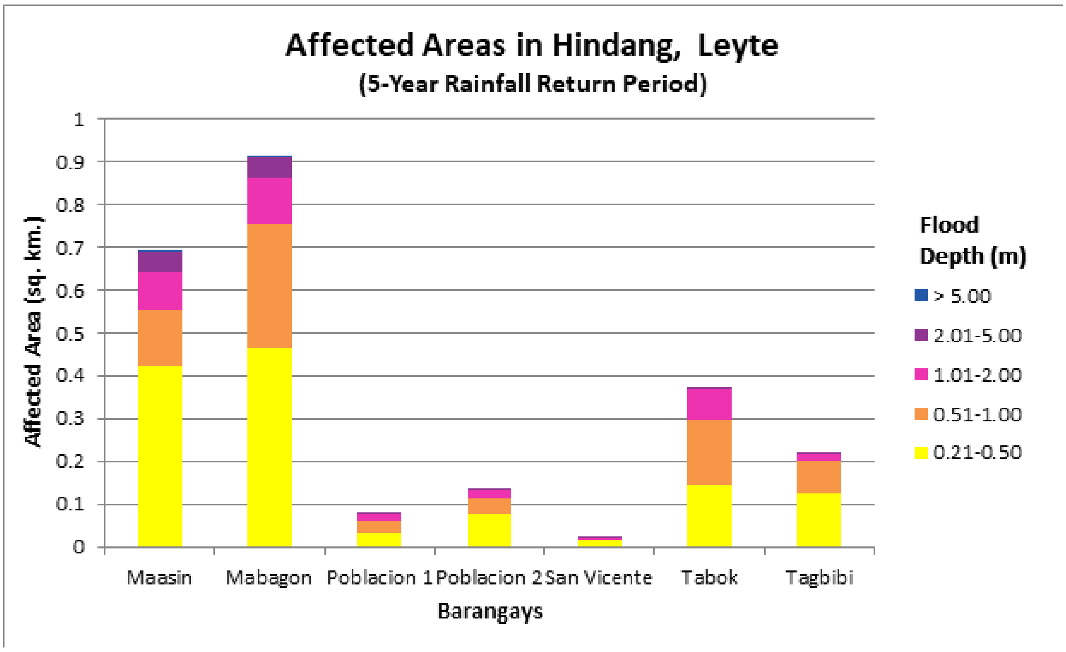


Figure 76. Affected areas in Hindang, Leyte Samar during 5-year rainfall return period

For the 25-year return period, 24.34% of the municipality of Hilongos with an area of 156.796sq km will experience flood levels of less 0.20 meters. 5.45% of the area will experience flood levels of 0.21 to 0.50 meters while 3.05%, 1.68%, 0.96% and 0.52% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 46 to Table 49 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Atabay	Bagong Lipunan	Bagum-bayan	Bantigue	Bung-Aw	Campina	Catandog 1	Catandog 2	Central Brgy
Affected Area (sq km.)	0.03-0.20	0.29	0.47	2.29	0.14	1.03	0.78	0.59	0.013	0.31
	0.21-0.50	0.21	0.089	0.14	0.056	0.16	0.22	0.16	0	0.11
	0.51-1.00	0.15	0.19	0.12	0.019	0.2	0.17	0.069	0	0.078
	1.01-2.00	0.07	0.072	0.22	0.0001	0.12	0.028	0.0055	0	0.035
	2.01-5.00	0.1	0.013	0.28	0	0.014	0.0009	0	0	0.046
	> 5.00	0	0.004	0	0	0.0035	0	0	0	0.013

Table 47. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Concepcion	Eastern Barangay	Hi-mo-Aw	Imelda Marcos	Kang-ha-As	Lamak	Liberty	Magnangoy	Manaul
Affected Area (sq km.)	0.03-0.20	3.85	0.71	0.39	1.91	0.18	1.59	3.37	2.78	0.36
	0.21-0.50	0.73	0.16	0.079	0.52	0.21	0.34	0.56	0.95	0.086
	0.51-1.00	0.48	0.086	0.084	0.43	0.036	0.098	0.21	0.36	0.028
	1.01-2.00	0.16	0.054	0.016	0.3	0.0032	0.075	0.22	0.098	0.0073
	2.01-5.00	0.05	0.012	0	0.36	0	0.11	0.14	0.0024	0.00056
	> 5.00	0	0.0083	0	0.17	0	0.11	0.24	0	0

Table 48. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Marangog	Matapay	Naval	Owak	Pa-A	Pontod	Proteccion	San Isidro	San Juan
Affected Area (sq km.)	0.03-0.20	0.025	0.57	1.18	1.19	0.14	0.2	1.17	0.23	1.1
	0.21-0.50	0.0002	0.2	0.19	0.43	0.1	0.086	0.22	0.0068	0.25
	0.51-1.00	0.0001	0.14	0.11	0.27	0.13	0.029	0.084	0.00084	0.12
	1.01-2.00	0	0.022	0.029	0.1	0.097	0.0018	0.056	0.00053	0.013
	2.01-5.00	0	0	0.0008	0.003	0.039	0	0.015	0.00028	0
	> 5.00	0	0	0	0	0.13	0	0.11	0	0

Table 49. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		San Roque	Santa Cruz	Santa Margarita	Santo Niño	Tagnate	Talisay	Tambis	Tejero	Western Brgy
Affected Area (sq km.)	0.03-0.20	1.54	1.47	0.74	1.73	0.7	0.28	2.9	1.64	0.31
	0.21-0.50	0.42	0.34	0.058	0.14	0.049	0.07	0.25	0.83	0.12
	0.51-1.00	0.069	0.079	0.11	0.076	0.034	0.016	0.51	0.15	0.061
	1.01-2.00	0.019	0.022	0.26	0.051	0.12	0	0.31	0.0083	0.046
	2.01-5.00	0.00054	0.041	0.081	0.038	0.064	0	0.1	0	0
	> 5.00	0	0.014	0	0.0015	0	0	0	0	0

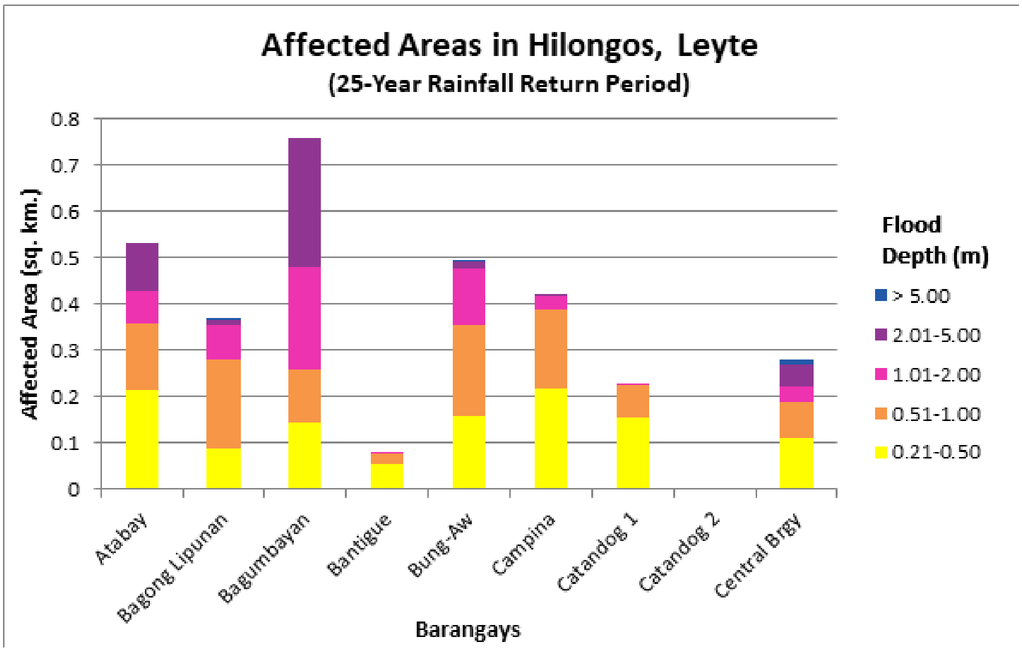


Figure 77. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

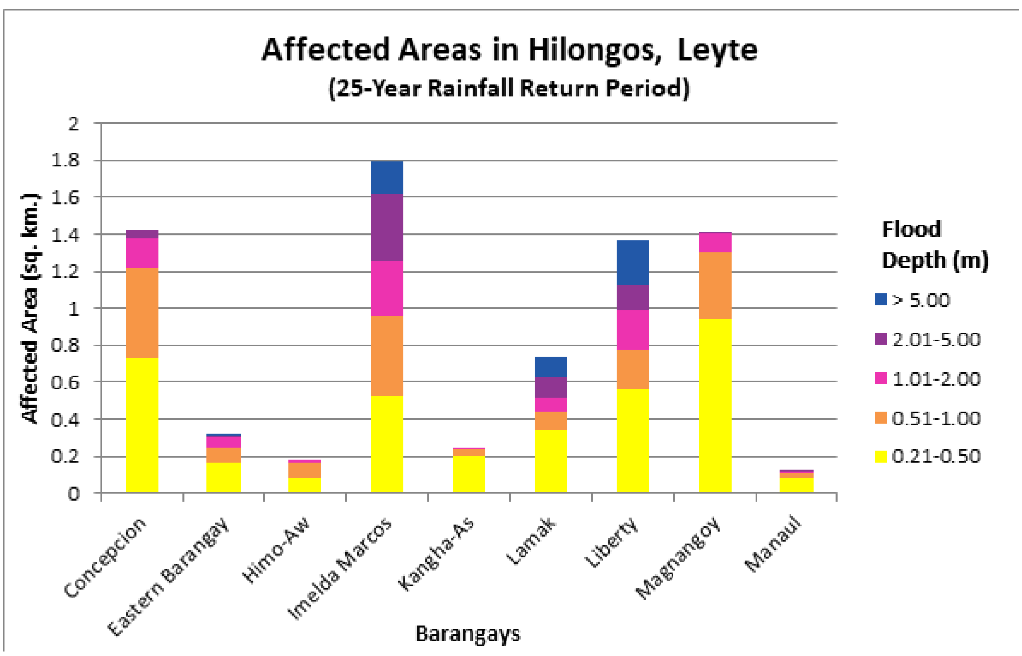


Figure 78. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

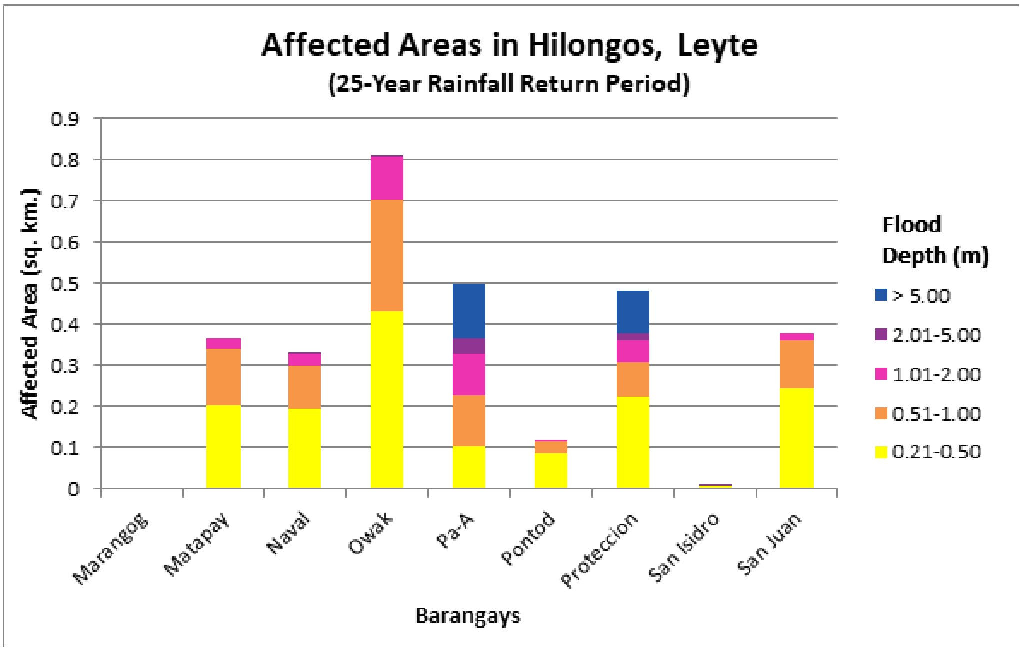


Figure 79. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

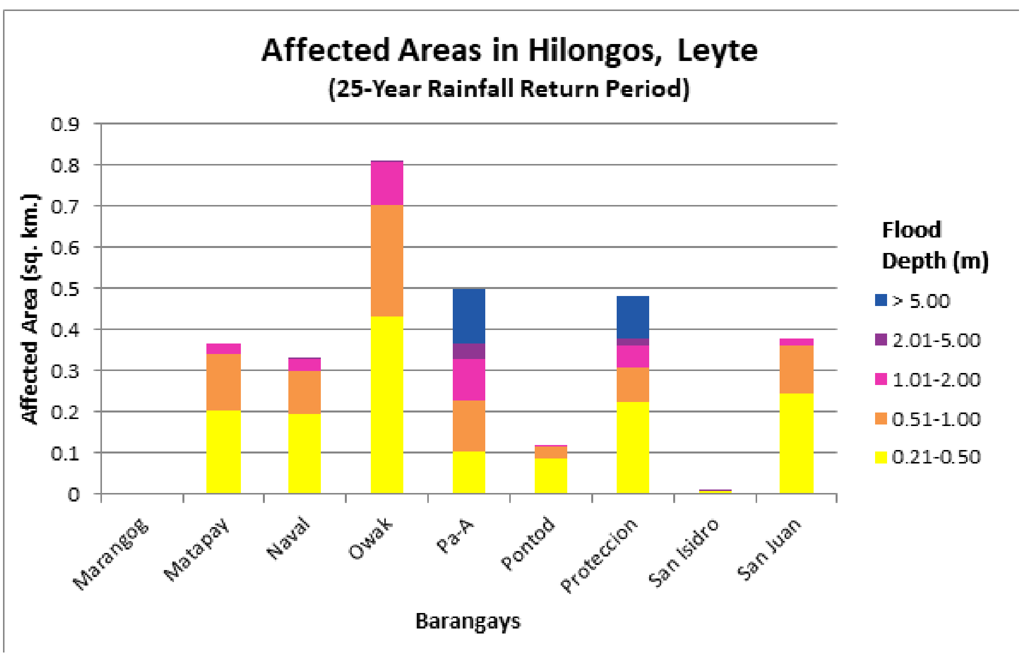


Figure 80. Affected areas in Hilongos, Leyte Samar during 25-year rainfall return period

For the municipality of Hindang, with an area of 106.765 sq km, 17.26% will experience flood levels of less 0.20 meters. 2.23% of the area will experience flood levels of 0.21 to 0.50 meters while 1.53%, 0.89%, 0.33% and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 50 and Table 51 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected areas in Hindang, Leyte Samar during 25-year rainfall return period

SALUG BASIN		Area of affected barangays in Hindang (in sq km.)					
		Anahaw	Bontoc	Doos Del Norte	Doos Del Sur	Hi-macugo	Kati-punan
Affected Area (sq km.)	0.03-0.20	1.13	0.0035	0.53	0.42	2.05	3.4
	0.21-0.50	0.18	0	0.1	0.16	0.064	0.13
	0.51-1.00	0.11	0	0.04	0.2	0.082	0.15
	1.01-2.00	0.014	0	0.0004	0.082	0.13	0.093
	2.01-5.00	0	0	0	0	0.12	0.015
	> 5.00	0	0	0	0	0.1	0.0078

Table 51. Affected areas in Hindang, Leyte Samar during 25-year rainfall return period

SALUG BASIN		Area of affected barangays in Hindang (in sq km.)						
		Maasin	Maba-gon	Pobla-cion 1	Pobla-cion 2	San Vicen-te	Tabok	Tagbibi
Affected Area (sq km.)	0.03-0.20	4.23	2.02	0.31	0.96	0.5	1.26	1.6
	0.21-0.50	0.72	0.42	0.053	0.11	0.019	0.23	0.19
	0.51-1.00	0.3	0.39	0.019	0.05	0.0073	0.19	0.093
	1.01-2.00	0.14	0.24	0.037	0.037	0.0008	0.14	0.036
	2.01-5.00	0.14	0.077	0.0021	0.0033	0.0001	0.0048	0.0002
	> 5.00	0.032	0.024	0	0	0	0	0

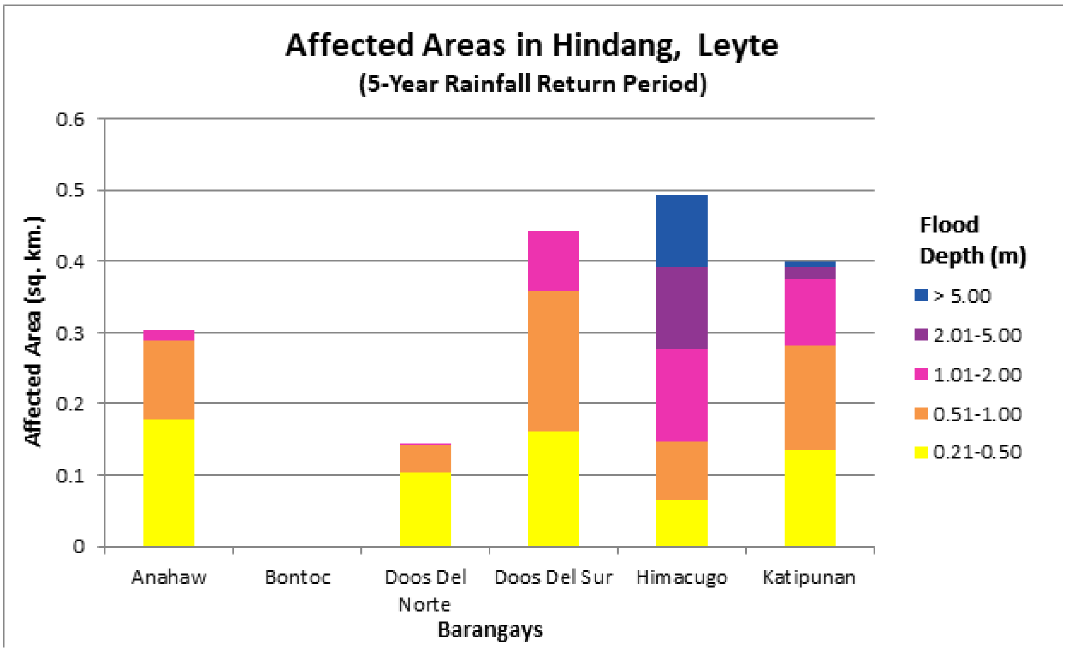


Figure 81. Affected areas in Hindang, Leyte Samar during 25-year rainfall return period

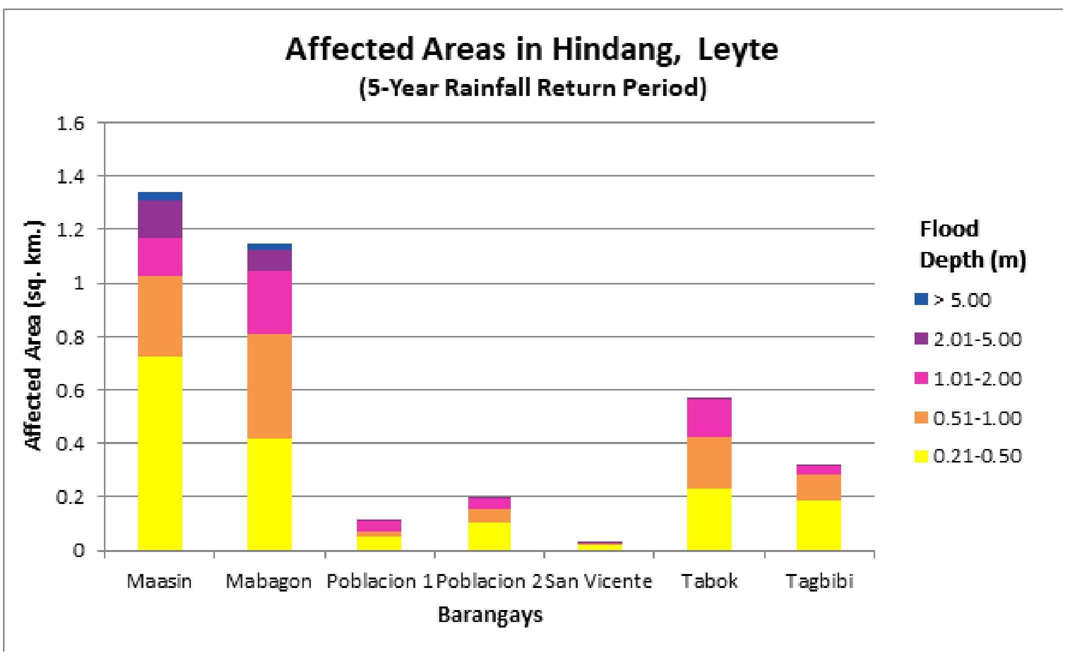


Figure 82. Affected areas in Hindang, Leyte Samar during 25-year rainfall return period

For the 100-year return period, 20.03% of the municipality of Hilongos with an area of 156.796sq km will experience flood levels of less 0.20 meters. 6.63% of the area will experience flood levels of 0.21 to 0.50 meters while 4.59%, 2.73%, 1.43% and 0.59% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 52 to Table 55 are the affected areas in square kilometres by flood depth per barangay.

Table 52. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Atabay	Bagong Lipunan	Bagum-bayan	Bantigue	Bung-Aw	Campina	Catandog 1	Catandog 2	Central Brgy
Affected Area (sq km.)	0.03-0.20	0.13	0.36	2.2	0.13	0.96	0.74	0.53	0.013	0.18
	0.21-0.50	0.22	0.089	0.12	0.061	0.11	0.17	0.17	0	0.16
	0.51-1.00	0.26	0.17	0.15	0.033	0.2	0.24	0.1	0	0.12
	1.01-2.00	0.11	0.18	0.22	0.0004	0.18	0.041	0.01	0	0.073
	2.01-5.00	0.11	0.037	0.35	0	0.062	0.0014	0.000097	0	0.04
	> 5.00	0	0.0073	0.013	0	0.009	0	0	0	0.021

Table 53. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Concepcion	Eastern Barangay	Hi-mo-Aw	Imelda Marcos	Kang-ha-As	Lamak	Liberty	Magnangoy	Manaul
Affected Area (sq km.)	0.03-0.20	3.61	0.58	0.35	1.31	0.13	1.19	1.84	2.35	0.32
	0.21-0.50	0.7	0.22	0.085	0.53	0.22	0.54	1.51	0.93	0.11
	0.51-1.00	0.66	0.12	0.097	0.59	0.064	0.24	0.56	0.68	0.042
	1.01-2.00	0.24	0.076	0.034	0.63	0.004	0.12	0.32	0.18	0.0088
	2.01-5.00	0.071	0.03	0	0.45	0.0001	0.12	0.25	0.036	0.0016
	> 5.00	0	0.0095	0	0.19	0	0.13	0.27	0	0

Table 54. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		Marangog	Matapay	Naval	Owak	Pa-A	Pontod	Protec-cion	San Isidro	San Juan
Affected Area (sq km.)	0.03-0.20	0.025	0.33	1.09	1	0.038	0.17	1.07	0.22	0.67
	0.21-0.50	0.00024	0.23	0.23	0.52	0.062	0.099	0.23	0.0076	0.46
	0.51-1.00	0.0001	0.25	0.13	0.3	0.15	0.039	0.12	0.002	0.28
	1.01-2.00	0	0.12	0.044	0.18	0.19	0.0042	0.096	0.00074	0.067
	2.01-5.00	0	0	0.0012	0.0056	0.057	0	0.02	0.00038	0.0004
	> 5.00	0	0	0	0	0.14	0	0.11	0	0

Table 55. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

SALUG BASIN		Area of affected barangays in Hilongos (in sq km.)								
		San Roque	Santa Cruz	Santa Margarita	Santo Niño	Tag-nate	Talisay	Tambis	Tejero	Western Brgy
Affected Area (sq km.)	0.03-0.20	1.26	1.14	0.71	1.67	0.66	0.26	2.8	1.19	0.18
	0.21-0.50	0.64	0.28	0.05	0.15	0.029	0.075	0.17	1.06	0.15
	0.51-1.00	0.12	0.39	0.061	0.094	0.058	0.026	0.36	0.34	0.14
	1.01-2.00	0.026	0.085	0.26	0.066	0.098	0.0001	0.51	0.035	0.077
	2.01-5.00	0.0022	0.033	0.16	0.047	0.12	0	0.23	0	0.0002
	> 5.00	0	0.03	0	0.0043	0	0	1.5E-06	0	0

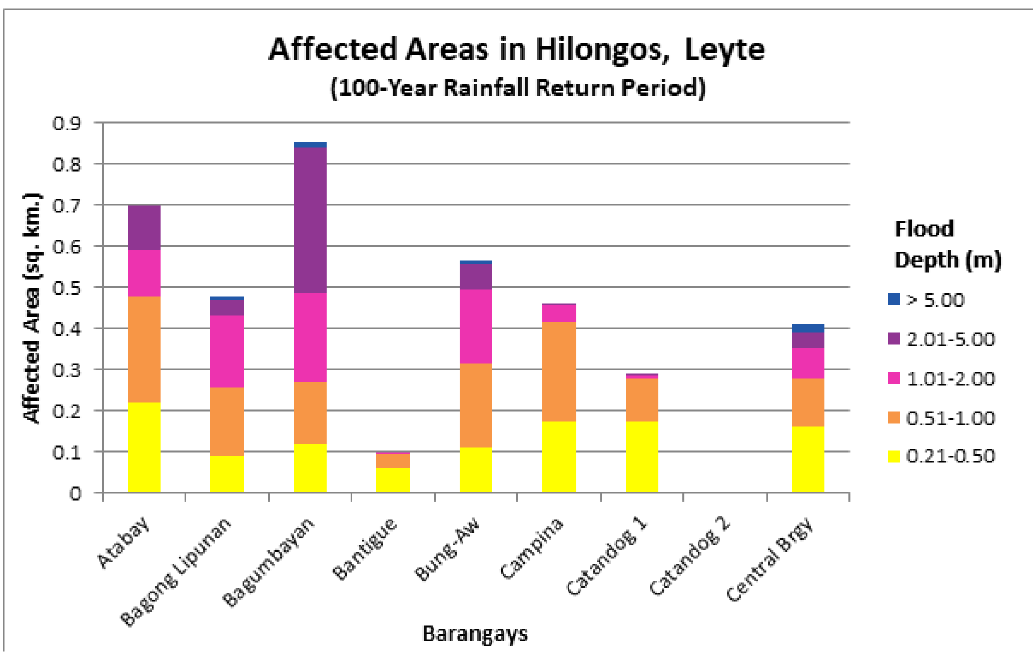


Figure 83. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

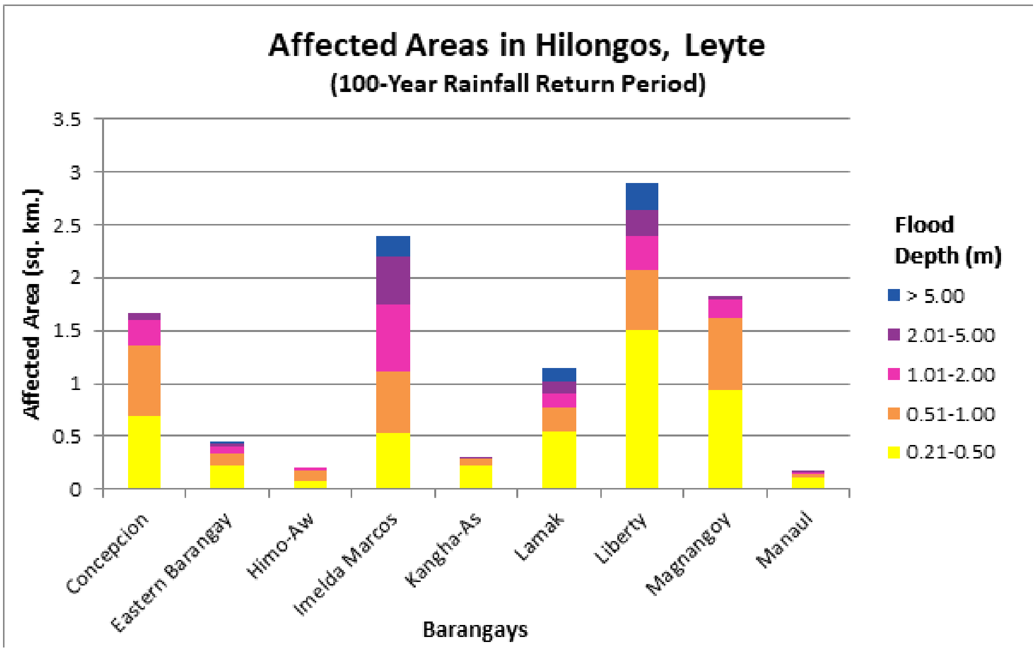


Figure 84. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

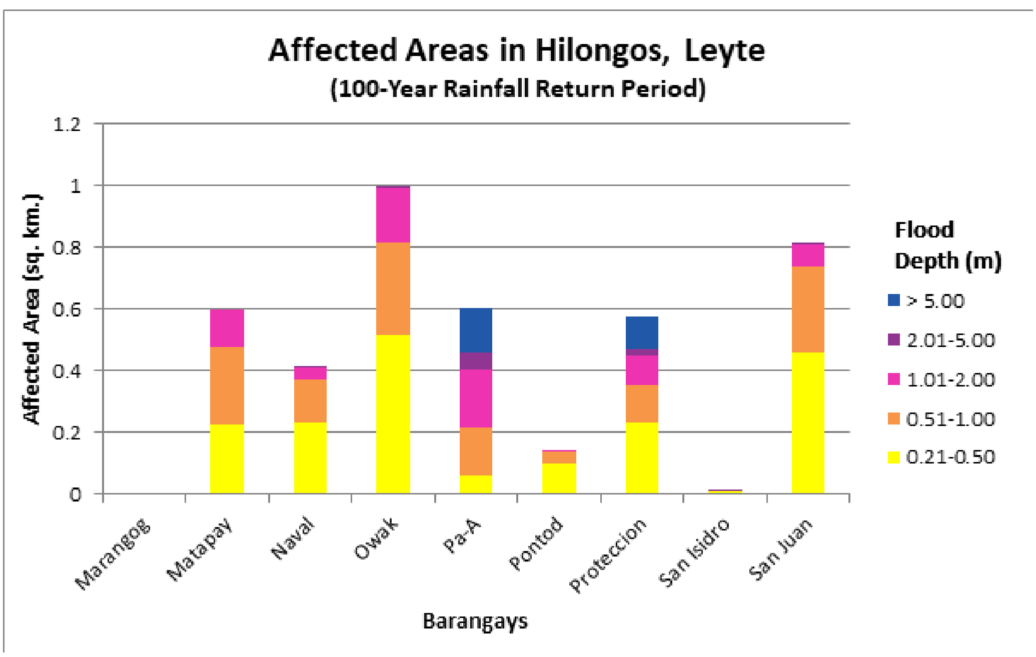


Figure 85. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

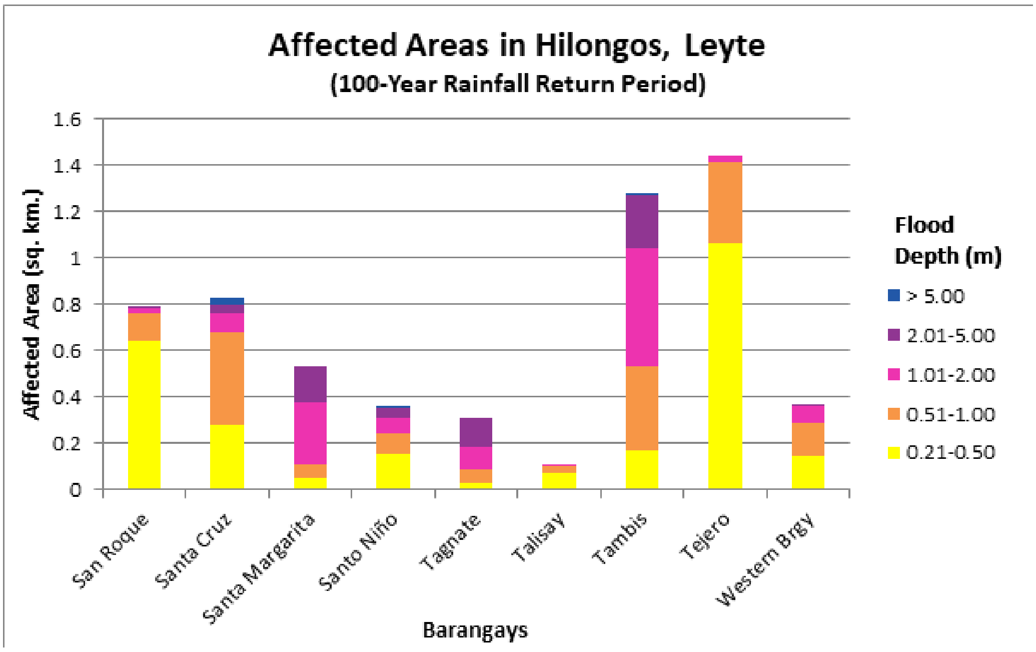


Figure 86. Affected areas in Hilongos, Leyte Samar during 100-year rainfall return period

For the municipality of Hindang, with an area of 106.765 sq km, 15.91% will experience flood levels of less 0.20 meters. 2.41% of the area will experience flood levels of 0.21 to 0.50 meters while 2.1%, 1.26%, 0.49% and 0.23% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 56 and Table 57 are the affected areas in square kilometres by flood depth per barangay.

Table 56. Affected areas in Hindang, Leyte Samar during 100-year rainfall return period

SALUG BASIN		Area of affected barangays in Hindang (in sq km.)					
		Anahaw	Bontoc	Doos Del Norte	Doos Del Sur	Himacugo	Katipunan
Affected Area (sq km.)	0.03-0.20	1.09	0.0035	0.5	0.37	2.03	3.36
	0.21-0.50	0.17	0	0.11	0.12	0.051	0.13
	0.51-1.00	0.15	0	0.062	0.23	0.049	0.14
	1.01-2.00	0.026	0	0.00074	0.13	0.12	0.13
	2.01-5.00	0	0	0	0.0001	0.19	0.024
	> 5.00	0	0	0	0	0.12	0.0091

Table 57. Affected areas in Hindang, Leyte Samar during 100-year rainfall return period

SALUG BASIN		Area of affected barangays in Hindang (in sq km.)						
		Maasin	Mabagon	Poblacion 1	Poblacion 2	San Vicente	Tabok	Tagbibi
Affected Area (sq km.)	0.03-0.20	3.4	1.92	0.28	0.9	0.49	1.11	1.52
	0.21-0.50	0.86	0.37	0.064	0.14	0.024	0.29	0.24
	0.51-1.00	0.75	0.44	0.028	0.059	0.0088	0.21	0.11
	1.01-2.00	0.32	0.27	0.041	0.047	0.001	0.2	0.051
	2.01-5.00	0.15	0.13	0.0061	0.0085	0.0001	0.014	0.0005
	> 5.00	0.086	0.034	0	0	0	0	0

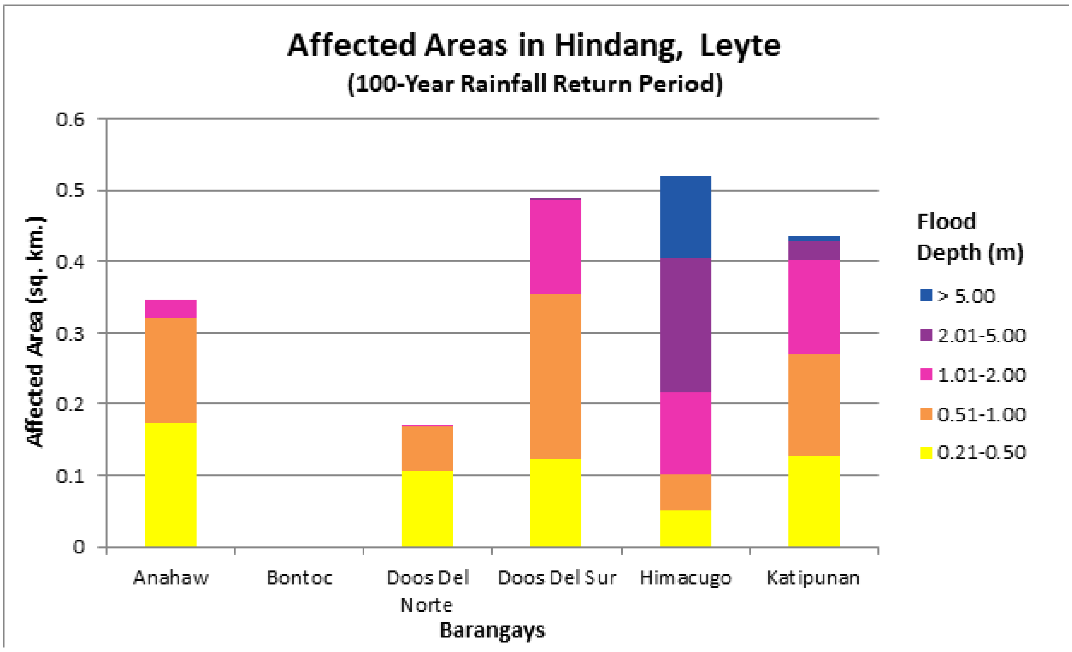


Figure 87. Affected areas in Hindang, Leyte Samar during 100-year rainfall return period

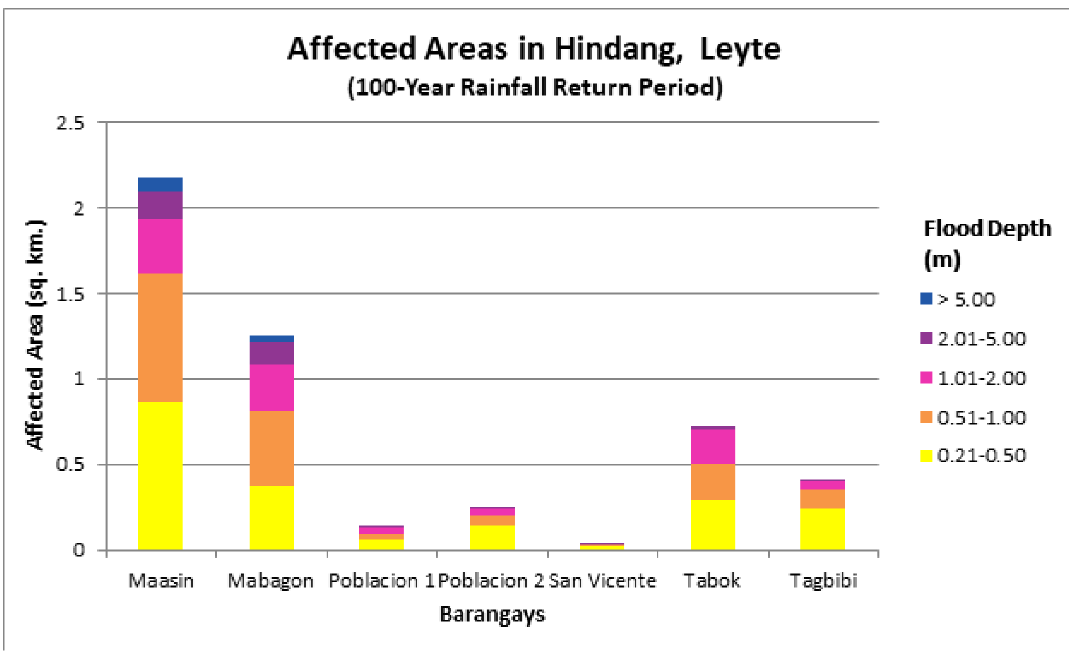


Figure 88. Affected areas in Hindang, Leyte Samar during 100-year rainfall return period

Among the barangays in the municipality of Hilongos, Concepcion is projected to have the highest percentage of area that will experience flood levels at 3.36%. Meanwhile, Liberty posted the second highest percentage of area that may be affected by flood depths at 3.02%.

Among the barangays in the municipality of Hindang, Maasin is projected to have the highest percentage of area that will experience flood levels at 5.23%. Meanwhile, Katipunan posted the second highest percentage of area that may be affected by flood depths at 3.56%.

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

Table 58. 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	8.64	11.24	13.12
Medium	4.83	9.02	13.33
High	2.29	4.03	5.99

Of the 41 identified education institutions in Salug Floodplain, 4 schools were assessed to be exposed to the low level flooding during a 5 year scenario while 1 school was assessed to be exposed to medium level flooding. In the 25 year scenario, 11 schools were assessed to be exposed to the low level flooding while 2 schools were assessed to be exposed to medium level flooding. For the 100 year scenario, 11 schools were assessed for low level flooding and 12 schools for medium level flooding. See Apppendix D for a detailed enumeration of schools inside Salug Floodplain.

Of the 15 identified Medical institutions in Salug Floodplain, 2 were assessed to be exposed to the low level flooding during a 5 year scenario while 1 was assessed to be exposed to medium level flooding. In the 25 year scenario, 1 was assessed to be exposed to the low level flooding while 2 were assessed to be exposed to medium level flooding. For the 100 year scenario, 1 school was assessed for low level flooding and 3 for medium level flooding. See Apppendix E for a detailed enumeration of medical insitutions inside Salug Floodplain.

5.11 Flood Validation

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

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

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

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

The flood validation consists of 218 points randomly selected all over the Pagsangahan Floodplain. The points were grouped depending on the RIDF return period of the event.

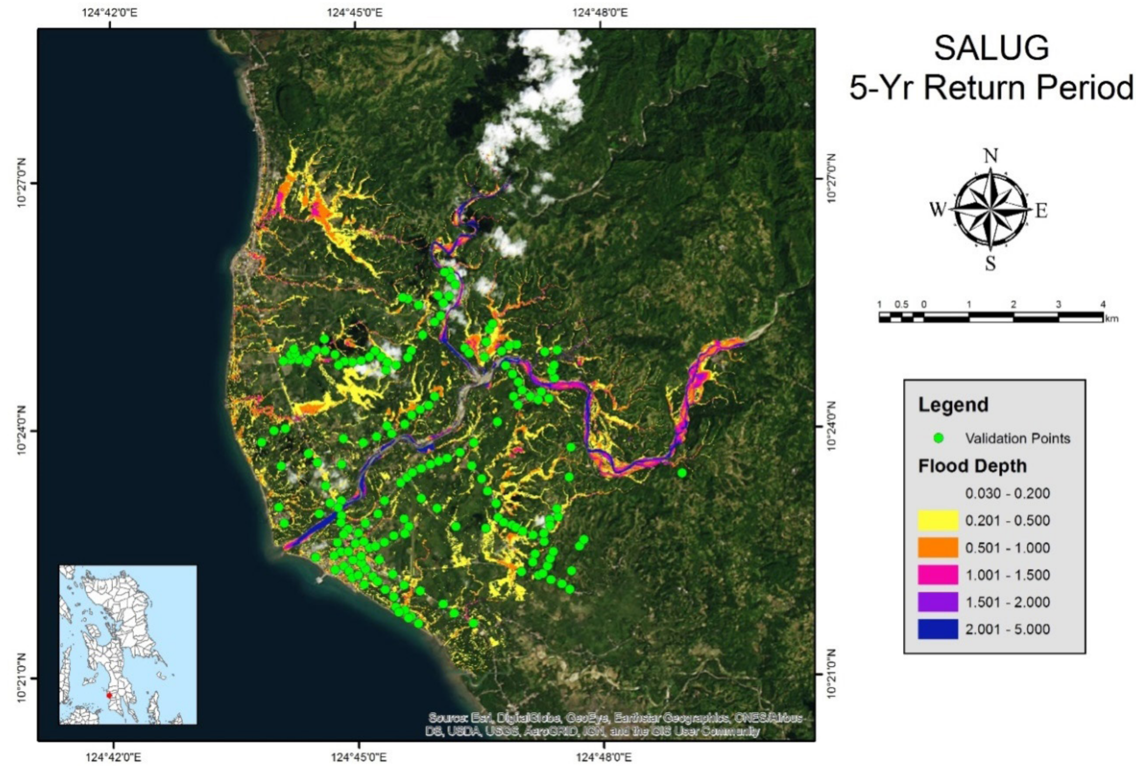


Figure 89. Validation points for 5-year flood depth map of Salug Floodplain

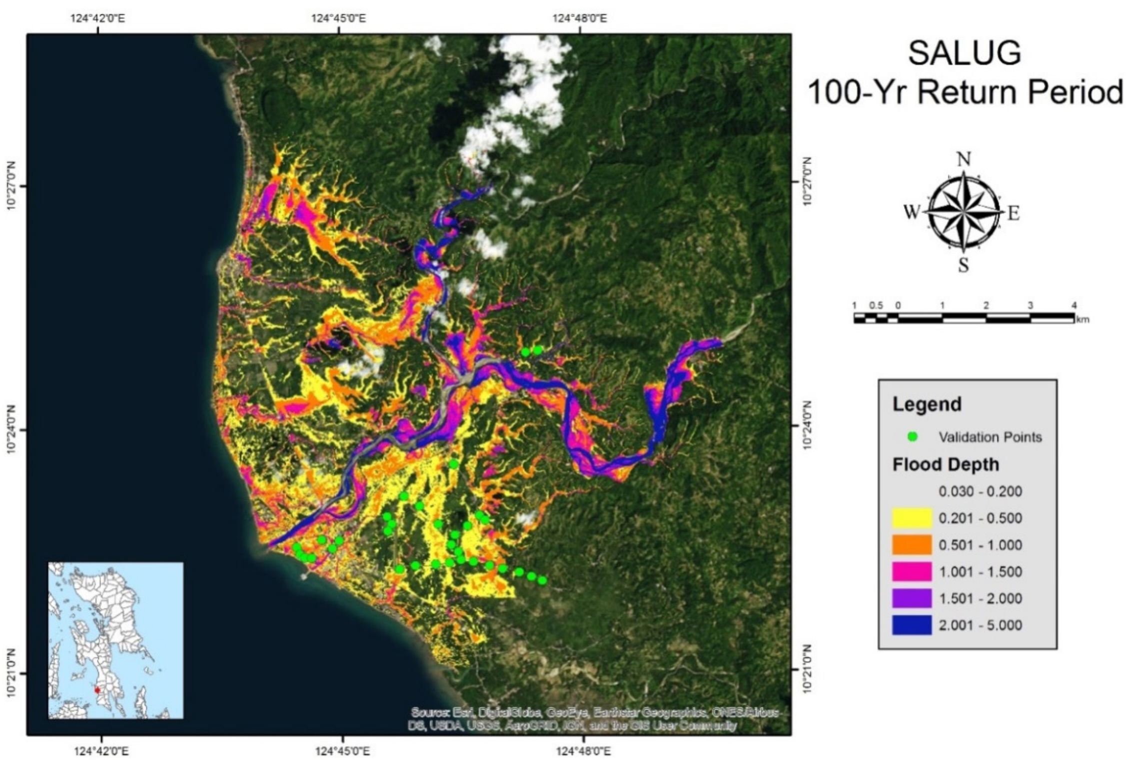


Figure 90. Validation points for 100-year flood depth map of Salug Floodplain

The RMSE value for each flood depth map is listed in the Table below:

Table 59. RMSE values for each return period of flood depth map

Return Period	RMSE
5-year	0.32
100-year	0.39

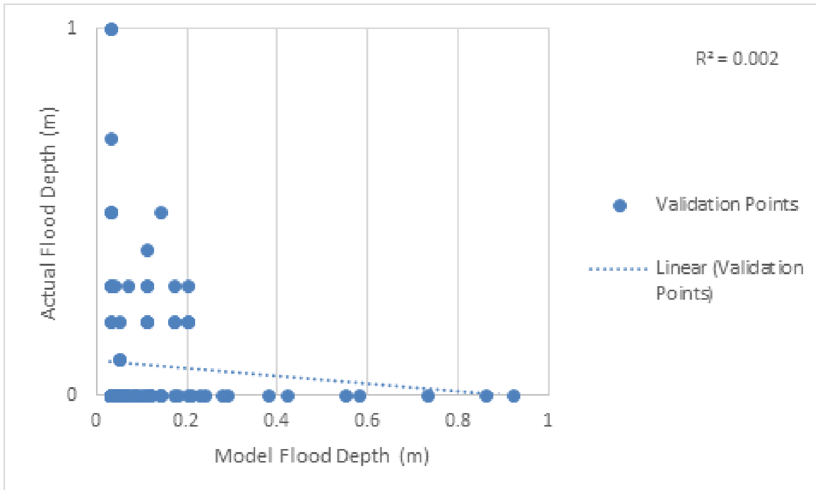


Figure 91. Flood map depth vs actual flood depth for 5-year return period

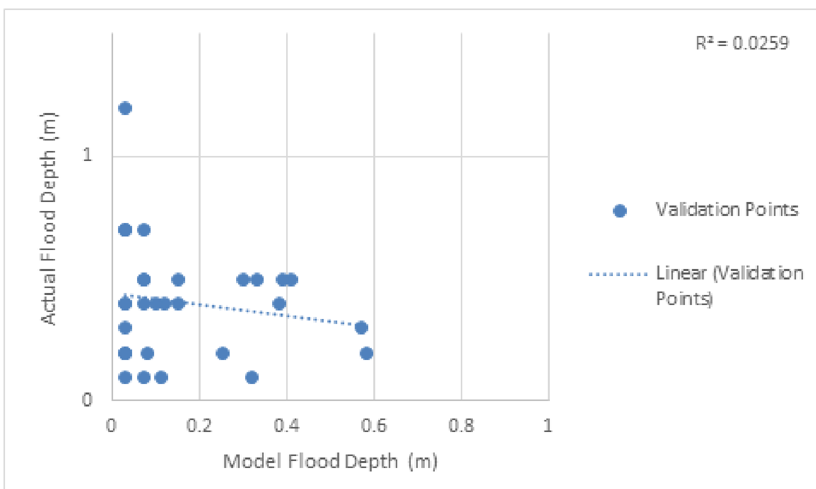


Figure 92. Flood map depth vs actual flood depth for 100-year return period

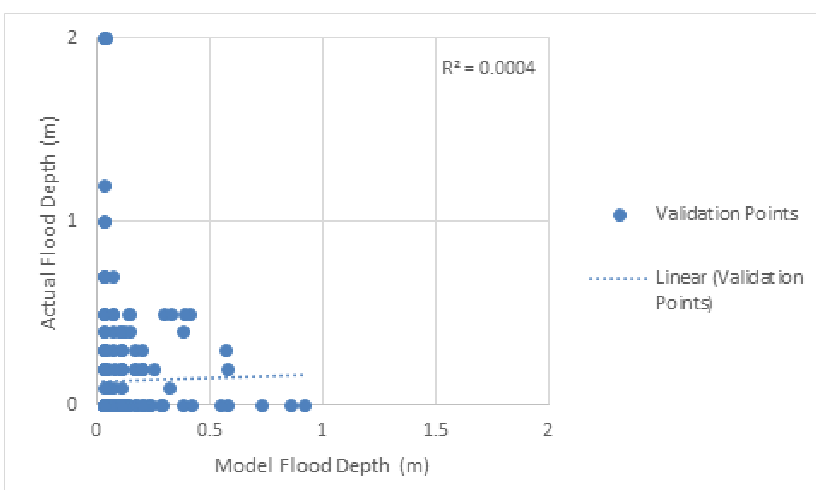


Figure 93. Flood map depth vs actual flood depth compiled

Table 59. Actual flood depth vs simulated flood depth in Salug 5yr

SALUG 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**	151	11	5	0	0	0	167
	0.21-0.50	13	1	0	0	0	0	14
	0.51-1.00	3	0	0	0	0	0	3
	1.01-2.00	3	0	0	0	0	0	3
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	170	12	5	0	0	0	187

The overall accuracy generated by the flood model is estimated at 81.28% with 152 points correctly matching the actual flood depths. In addition, there were 24 points estimated one level above and below the correct flood depths while there were 8 points and 3 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 19 points were underestimated in the modelled flood depths of Salug.

Table 60. Summary of accuracy assessment in Salug

No. of Points		%
Correct	152	**81.28**
Overestimated	16	**8.56**
Underestimated	19	**10.16**
Total	187	**100.00**

Table 61. Actual flood depth vs simulated flood depth in Salug 100yr

SALUG 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**	7	2	1	0	0	0	10
	0.21-0.50	10	5	1	0	0	0	16
	0.51-1.00	4	0	0	0	0	0	4
	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	22	7	2	0	0	0	31

The overall accuracy generated by the flood model is estimated at 38.71% with 12 points correctly matching the actual flood depths. In addition, there were 13 points estimated one level above and below the correct flood depths while there were 5 points and 1 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 15 points were underestimated in the modelled flood depths of Salug.

Table 62. Summary of accuracy assessment in Salug

No. of Points		%
Correct	12	**38.71**
Overestimated	4	**12.90**
Underestimated	15	**48.39**
Total	31	**100.00**

Table 63. Actual flood depth vs simulated flood depth in Salug compiled

SALUG 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	162	9	6	0	0	0	177
	0.21-0.50	24	5	1	0	0	0	30
	0.51-1.00	7	0	0	0	0	0	7
	1.01-2.00	4	0	0	0	0	0	4
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	197	14	7	0	0	0	218

The overall accuracy generated by the flood model is estimated at 76.61% with 167 points correctly matching the actual flood depths. In addition, there were 34 points estimated one level above and below the correct flood depths while there were 13 points and 4 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 35 points were underestimated in the modelled flood depths of Salug.

Table 64. Summary of accuracy assessment in Salug

No. of Points		%
Correct	167	**76.61**
Overestimated	16	**7.34**
Underestimated	35	**16.06**
Total	218	**100.00**

REFERENCES

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

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

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

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

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

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

ANNEXES

ANNEX A-1. OPTECH TECHNICAL SPECIFICATION

AQUARIUS

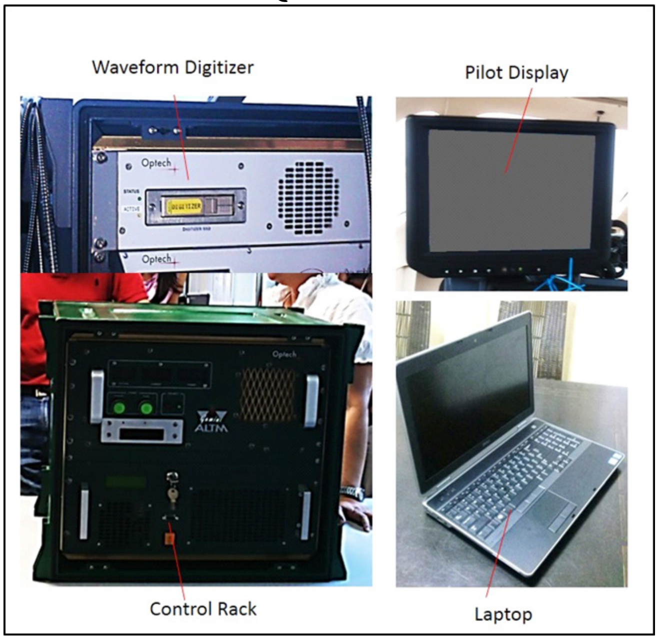


Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specifications of Aquarius Sensor

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

GEMINI

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specifications of Gemini Sensor

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

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

1. LYT-757

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

January 27, 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-757**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**MAHAYAHAY**		
Municipality:	**MAHAPLAG**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**10° 32' 54.86740"**	Longitude:	**124° 57' 31.14319"**	Ellipsoidal Hgt:	**99.55943 m.**
		WGS84 Coordinates			
Latitude:	**10° 32' 50.77355"**	Longitude:	**124° 57' 36.36037"**	Ellipsoidal Hgt:	**163.36300 m.**
		PTM / PRS92 Coordinates			
Northing:	**1166401.318 m.**	Easting:	**495474.491 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**1,166,663.62**	Easting:	**714,331.34**	Zone:	**51**

Location Description

LYT-757
About 7.0 km. from poblacion mahaplag taking the national road to southern leyte, there is a restaurant named "Dragonfly restaurant" located at the right side of the highway and on the left isde is the junction going to the proper of brgy. mahayahay. The LYT-757 is located on the left side, 30 meters before you reach the junction. LYT-757 is almost on the opposite side of the kilometer post # 997. 30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-757, 2007, LAMP".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089687 I**
T.N.:	**2016-0239**

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

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

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-757

2. LYT-741

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

April 14, 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-741**		
	Order: **2nd**		
Island: **VISAYAS**	Barangay: **DOOS DEL NORTE**		
Municipality: **HINDANG**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **10° 27' 11.95722"**	Longitude: **124° 43' 45.08400"**	Ellipsoidal Hgt:	**4.48300 m.**
	WGS84 Coordinates		
Latitude: **10° 27' 7.86786"**	Longitude: **124° 43' 50.31177"**	Ellipsoidal Hgt:	**67.94500 m.**
	PTM / PRS92 Coordinates		
Northing: **1155878.867 m.**	Easting: **470351.659 m.**	Zone:	**5**
	UTM / PRS92 Coordinates		
Northing: **1,155,979.90**	Easting: **689,272.22**	Zone:	**51**

Location Description

LYT-741
Brgy. doos del norte is about 2.6 km. from the poblacion pf hindang taking the national road to babay. upon reaching the said barangay, locate the brgy. hall, The LYT-741 is located on the opposite side of the road for about 36 m. far from the gate of the brgy hall.30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-741, 2007, LAMP".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0916**

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-741

3. LYT-748

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-748**
Order: **2nd**

Island: **VISAYAS**
Municipality: **MATALOM**
Barangay: **HITOOG**
MSL Elevation:

PRS92 Coordinates

Latitude: **10° 14' 16.77457"** Longitude: **124° 48' 19.08041"** Ellipsoidal Hgt: **77.51500 m.**

WGS84 Coordinates

Latitude: **10° 14' 12.74720"** Longitude: **124° 48' 24.32650"** Ellipsoidal Hgt: **141.66500 m.**

PTM / PRS92 Coordinates

Northing: **1132057.716 m.** Easting: **478669.714 m.** Zone: **5**

UTM / PRS92 Coordinates

Northing: **1,132,208.87** Easting: **697,740.37** Zone: **51**

Location Description

LYT-748
From the Matalom proper, go to brgy. caridad del sur 500 meters along the highway taking the road to maasin city. you'll fin a junction to the right is going to matalom hospital and to the left is going to brgy. hitdog. from the highway, brgy. hitdog is about 6 km. far. you will pass through 3 junctions along the way but always take the way to the right, and on the 4th junction, take the left turn. upon reaching the brgy. hall and basketaballcourt of Brgy. Hitdog, you will have to take a walk for about 300 meters to "hitdog elemetary school". LYT-748 is located 50 meters behind the said school. 30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-748, 2007, LAMP".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8077605 I**
T.N.: **2015-0215**

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

9902052015145616

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

NAMRIA OFFICES:
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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-748

4. 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**	Barangay: **KANSUNGKA**		
Municipality: **BAYBAY**	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

9 9 0 2 0 5 2 0 1 5 1 4 5 6 3 5

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. LYT-731

Annex 3. Baseline Processing Reports of Reference Points Used in the LiDAR Survey

1. LY-1024

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT-757 --- LY-1024 (B2)	LYT-757	LY-1024	Fixed	0.004	0.018	143°56'41"	7166.614	266.642
LYT-757 --- LY-1024 (B1)	LYT-757	LY-1024	Fixed	0.005	0.015	143°56'41"	7166.626	266.671
LYT-757 --- LY-1024 (B3)	LYT-757	LY-1024	Fixed	0.004	0.015	143°56'41"	7166.633	266.676

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

Vector Components (Mark to Mark)

From:	LYT-757				
Grid		Local		Global	
Easting	714331.338 m	Latitude	N10°32'54.86738"	Latitude	N10°32'50.77355"
Northing	1166663.617 m	Longitude	E124°57'31.14322"	Longitude	E124°57'36.36037"
Elevation	98.243 m	Height	99.559 m	Height	163.363 m

To:	LY-1024				
Grid		Local		Global	
Easting	718586.237 m	Latitude	N10°29'46.27905"	Latitude	N10°29'42.20218"
Northing	1160895.197 m	Longitude	E124°59'49.85591"	Longitude	E124°59'55.07713"
Elevation	364.735 m	Height	366.202 m	Height	430.223 m

Vector					
ΔEasting	4254.899 m	NS Fwd Azimuth	143°56'41"	ΔX	-4212.979 m
ΔNorthing	-5768.419 m	Ellipsoid Dist.	7166.614 m	ΔY	-1336.202 m
ΔElevation	266.492 m	ΔHeight	266.642 m	ΔZ	-5648.050 m

Figure A-3.1. LY-1024

2. LY-313

Project information		Coordinate System	
Name:	F:\Doc\DAC\2016\Fieldwork\2016-4-6_20 Ormoc\ly-313 vs lyt-741.vce	Name:	UTM
Size:	339 KB	Datum:	PRS 92
Modified:	4/15/2016 6:26:41 PM (UTC:8)	Zone:	51 North (123E)
Time zone:	Taipei Standard Time	Geoid:	egmPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LY-313 --- LYT-741 (B3)	LYT-741	LY-313	Fixed	0.003	0.014	13°13'57"	18139.132	1.796
LY-313 --- LYT-741 (B2)	LYT-741	LY-313	Fixed	0.005	0.014	13°13'57"	18139.104	1.786
LY-313 --- LYT-741 (B4)	LYT-741	LY-313	Fixed	0.005	0.014	13°13'57"	18139.125	1.802

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

Vector Components (Mark to Mark)

From:	LYT-741				
Grid		Local		Global	
Easting	689272.210 m	Latitude	N10°27'11.95721"	Latitude	N10°27'07.86786"
Northing	1155979.897 m	Longitude	E124°43'45.08400"	Longitude	E124°43'50.31177"
Elevation	3.600 m	Height	4.482 m	Height	67.945 m

To:	LY-313				
Grid		Local		Global	
Easting	693326.992 m	Latitude	N10°36'46.67221"	Latitude	N10°36'42.54525"
Northing	1173661.007 m	Longitude	E124°46'01.67926"	Longitude	E124°46'06.89257"
Elevation	5.229 m	Height	6.279 m	Height	69.460 m

Vector					
ΔEasting	4054.782 m	NS Fwd Azimuth	13°13'57"	ΔX	-1573.287 m
ΔNorthing	17681.110 m	Ellipsoid Dist.	18139.132 m	ΔY	-5017.663 m
ΔElevation	1.629 m	ΔHeight	1.796 m	ΔZ	17360.172 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

Figure A-3.2. LY-313

3. LY-351

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT-748 --- LY-351 (B1)	LYT-748	LY-351	Fixed	0.004	0.012	334°22'44"	5299.406	-70.629
LYT-748 --- LY-351 (B2)	LYT-748	LY-351	Fixed	0.003	0.011	334°22'44"	5299.406	-70.551

Vector Components (Mark to Mark)

From:	LYT-748				
Grid		Local		Global	
Easting	697740.363 m	Latitude	N10°14'16.77457"	Latitude	N10°14'12.74720"
Northing	1132208.868 m	Longitude	E124°48'19.08040"	Longitude	E124°48'24.32650"
Elevation	77.125 m	Height	77.515 m	Height	141.665 m

To:	LY-351				
Grid		Local		Global	
Easting	695421.839 m	Latitude	N10°16'52.30167"	Latitude	N10°16'48.26132"
Northing	1136974.636 m	Longitude	E124°47'03.77264"	Longitude	E124°47'09.01515"
Elevation	6.314 m	Height	6.886 m	Height	70.885 m

Vector					
ΔEasting	-2318.524 m	NS Fwd Azimuth	334°22'44"	ΔX	2407.375 m
ΔNorthing	4765.768 m	Ellipsoid Dist.	5299.406 m	ΔY	551.878 m
ΔElevation	-70.810 m	ΔHeight	-70.629 m	ΔZ	4689.241 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000101466		
Y	-0.0000137204	0.0000248169	
Z	-0.0000039125	0.0000060432	0.0000023641

Figure A-3.3. LY-351

4. LY-297

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT-731 --- LY-297 (B1)	LYT-731	LY-297	Fixed	0.002	0.003	301°39'21"	1987.143	-8.702
LYT-731 --- LY-297 (B2)	LYT-731	LY-297	Fixed	0.002	0.003	301°39'21"	1987.153	-8.688

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	LYT-731				
Grid		Local		Global	
Easting	697902.966 m	Latitude	N10°42'47.59464"	Latitude	N10°42'43.44572"
Northing	1184777.350 m	Longitude	E124°48'34.34385"	Longitude	E124°48'39.54791"
Elevation	14.266 m	Height	15.609 m	Height	78.657 m

To:	LY-297				
Grid		Local		Global	
Easting	696205.243 m	Latitude	N10°43'21.53694"	Latitude	N10°43'17.38426"
Northing	1185810.360 m	Longitude	E124°47'38.67725"	Longitude	E124°47'43.88062"
Elevation	5.568 m	Height	6.908 m	Height	69.895 m

Vector					
ΔEasting	-1697.723 m	NS Fwd Azimuth	301°39'21"	ΔX	1504.544 m
ΔNorthing	1033.009 m	Ellipsoid Dist.	1987.143 m	ΔY	799.170 m
ΔElevation	-8.698 m	ΔHeight	-8.702 m	ΔZ	1022.982 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000012108		
Y	-0.0000006864	0.0000020301	
Z	-0.0000001551	0.0000003202	0.0000004901

Figure A-3.4. LY-297

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-team</th><th>Designation</th><th>Name</th><th>Agency/Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Data Acquisition Component Leader</td><td rowspan="2">Data Component Project Leader –I</td><td>ENGR. CZAR JAKIRI S. SARMIENTO</td><td>UP TCAGP</td></tr>
<tr><td>ENGR. LOUIE P. BALICANTA</td><td>UP TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUNA</td><td>UP TCAGP</td></tr>
<tr><td>ENGR. LOVELYN ASUNCION</td><td>UP TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="9">LiDAR Operation</td><td rowspan="3">Senior Science Research Specialist (SSRS)</td><td>JULIE PEARL MARS</td><td>UP TCAGP</td></tr>
<tr><td>JASMINE ALVIAR</td><td>UP TCAGP</td></tr>
<tr><td>PAULINE JOANNE ARCEO</td><td>UP TCAGP</td></tr>
<tr><td rowspan="6">Research Associate</td><td>ENGR. LARAH KRISELLE PARAGAS</td><td>UP TCAGP</td></tr>
<tr><td>ENGR. GRACE SINADJAN</td><td>UP TCAGP</td></tr>
<tr><td>ENGR. KENNETH QUISADO</td><td>UP TCAGP</td></tr>
<tr><td>KRISTINE JOY ANDAYA</td><td>UP TCAGP</td></tr>
<tr><td>JONATHAN ALMALVEZ</td><td>UP TCAGP</td></tr>
<tr><td>JERIEL PAUL ALAMBAN</td><td>UP TCAGP</td></tr>
<tr><td rowspan="2">Ground Survey, Data Download and Transfer</td><td rowspan="2">Research Associate</td><td>ENGR. FRANK NICOLAS ILEJAY</td><td>UP TCAGP</td></tr>
<tr><td>ENGR. IRO NIEL ROXAS</td><td>UP TCAGP</td></tr>
<tr><td rowspan="8">LiDAR Operation</td><td rowspan="2">Airborne Security</td><td>SSG RANDY SISON</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td>SSG RAYMUND DOMINE</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="6">Pilot</td><td>CAPT. ALBERT PAUL LIM</td><td>ASIAN AEROSPACE CORP (AAC)</td></tr>
<tr><td>CAPT. RANDY LAGCO</td><td>ASIAN AEROSPACE CORP (AAC)</td></tr>
<tr><td>CAPT. JACKSON JAVIER</td><td>ASIAN AEROSPACE CORP (AAC)</td></tr>
<tr><td>CAPT. NIEL AGAWIN</td><td>ASIAN AEROSPACE CORP (AAC)</td></tr>
<tr><td>CAPT. NEIL ACHILLES AGAWIN</td><td>ASIAN AEROSPACE CORP (AAC)</td></tr>
<tr><td>CAPT. FERDINAND DE OCAMPO</td><td>ASIAN AEROSPACE CORP (AAC)</td></tr>
</table>

Annex 5. Data Transfer Sheet for Salug Floodplain

DATA TRANSFER SHEET
02/13/2015(ORMOC)

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	
21-Jan-15	7753AC	3BLK35B21A	AQUARIUS	NA	270	527	167	NA	NA	11.1	NA	29.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
22-Jan-15	7754AC	3BLK49B022A	AQUARIUS	NA	280	566	258	NA	NA	12	NA	66.1	1KB	1KB	4	NA	Z:\DAC\RAW DATA
23-Jan-15	7756AC	3BLK49A023A	AQUARIUS	NA	279	548	231	NA	NA	11.9	NA	34	1KB	1KB	3	NA	Z:\DAC\RAW DATA
25-Jan-15	7760AC	3BLK35A025A	AQUARIUS	NA	289	671	243	NA	NA	12.3	223	26.4	1KB	1KB	4	NA	Z:\DAC\RAW DATA
27-Jan-15	7764AC	3BLK35CD027A	GEMINI	NA	169/107	611	228	NA	NA	11.7	207	37.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7766AC	3BLK49CD028A	AQUARIUS	NA	136	366	216	NA	NA	6.71	185MB	27.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7767AC	3BLK35X028B	AQUARIUS	NA	123	310	148	NA	NA	6.4	98.6	18.5	1KB	1KB	3	NA	Z:\DAC\RAW DATA
29-Jan-15	7768AC	3BLK50A029A	AQUARIUS	NA	152	360	234	NA	NA	7.39	111	40.2	1KB	1KB	3	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat 2/13/15
Position SSRS
Signature

15-08

Figure A-5.1. Data Transfer Sheet (A)

DATA TRANSFER SHEET
02/25/2015(ORMOC)

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	
4-Feb-15	7780AC	3BLK35AX035A	AQUARIUS	NA	56	139	62.4	NA	NA	3.62	NA	18.6	1KB	1KB	5	NA	Z:\DAC\RAW DATA
5-Feb-15	7782AC	3BLK35AX036A	AQUARIUS	NA	370	797	252	NA	NA	15.3	275	8.76	1KB	1KB	5	354	Z:\DAC\RAW DATA
7-Feb-15	7786AC	3BLK34AX038A	AQUARIUS	NA	279	570	254	NA	NA	11.8	213	9.48	1KB	1KB	5	NA	Z:\DAC\RAW DATA
9-Feb-15	7790AC	3BLK50B040A	AQUARIUS	NA	105	254	225	NA	NA	5.67	44	14.8	1KB	1KB	3/2	NA	Z:\DAC\RAW DATA
9-Feb-15	7791AC	3BLK50CDE040B	AQUARIUS	NA	135	358	179	NA	NA	6.96	105	14.8	1KB	1KB	2/3/3	NA	Z:\DAC\RAW DATA
10-Feb-15	7792AC	3BLK35FV041A	AQUARIUS	NA	225	525	238	NA	NA	10.3	NA	9.46	1KB	1KB	3/11	NA	Z:\DAC\RAW DATA
11-Feb-15	7794AC	3BLK35EV042A	AQUARIUS	NA	276	585	252	NA	NA	11.9	150	37.5	1KB	1KB	10	NA	Z:\DAC\RAW DATA
13-Feb-15	7798AC	3BLK34AV044A	AQUARIUS	NA	198	418	186	NA	NA	7.81	111	31.8	1KB	1KB	11	NA	Z:\DAC\RAW DATA
15-Feb-15	7802AC	3BLK35SV046A	AQUARIUS	NA	224	550	254	NA	NA	9.94	157	35.4	1KB	1KB	15	NA	Z:\DAC\RAW DATA
17-Feb-15	7806AC	3BLK35X1048A	AQUARIUS	NA	187	479	195	NA	NA	8.2	131	27	1KB	1KB	6	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat
Position SSRS
Signature

15-12

Figure A-5.2. Data Transfer Sheet (B)

DATA TRANSFER SHEET
TACLOBAN 3/2/2016

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	
07-Feb-16	3761G	2BLK34038A	GEMINI	NA	210	462	245	NA	NA	16.3	NA	7.73	1KB	1KB	67	NA	Z:\DAC\RAW DATA
09-Feb-17	23771G	2BLK34040A	GEMINI	NA	142	16.9	161	10.1	56	6.25	NA	5.06	1KB	NA	26/25/67	NA	Z:\DAC\RAW DATA
10-Feb-18	23773G	2BLK34041A	GEMINI	NA	360	519	195	17.7	157	9.06	NA	4.7	1KB	1KB	26/25/76	NA	Z:\DAC\RAW DATA
12-Feb-19	3781G	2BLK34F043A	GEMINI	NA	42	448	191	17	90	11.3	NA	8.87	1KB	1KB	26/25/76	NA	Z:\DAC\RAW DATA

Received from

Name RENAN PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRJ
Signature 5/4/16

ok

16-16

Figure A-5.3. Data Transfer Sheet (C)

DATA TRANSFER SHEET

ORMOC(SOUTH LEYTE) 5/2/2016

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	
April 10,2016	3921G	2BLK34a101A	GEMINI	NA	270	673	275	NA	NA	20.5	NA	19.1	1KB	1KB	23	NA	Z:\DAC\RAW DATA
April 10,2016	3923G	2BLK49AB101B	GEMINI	NA	375	377	168	NA	NA	8.5	NA	19.1	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 11,2016	3925G	2BLK49DE102A	GEMINI	NA	138	570	252	NA	NA	9.56	NA	6.82	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 13,2016	3933G	2BLK50ABC104A	GEMINI	NA	581	474	262	NA	NA	16.2	NA	17.4	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 14,2016	3937G	2BLK50DS105A	GEMINI	NA	763	557	292	NA	NA	14.7	NA	10.5	1KB	1KB	28	NA	Z:\DAC\RAW DATA
April 16,2016	3945G	2BLK35AB107A	GEMINI	NA	216	940	267	NA	NA	17.1	NA	19.5	1KB	1KB	6	NA	Z:\DAC\RAW DATA
April 16,2016	3947G	2BLK35CS107B	GEMINI	NA	492	1.03	278	NA	NA	21	NA	19.5	1KB	1KB	10	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

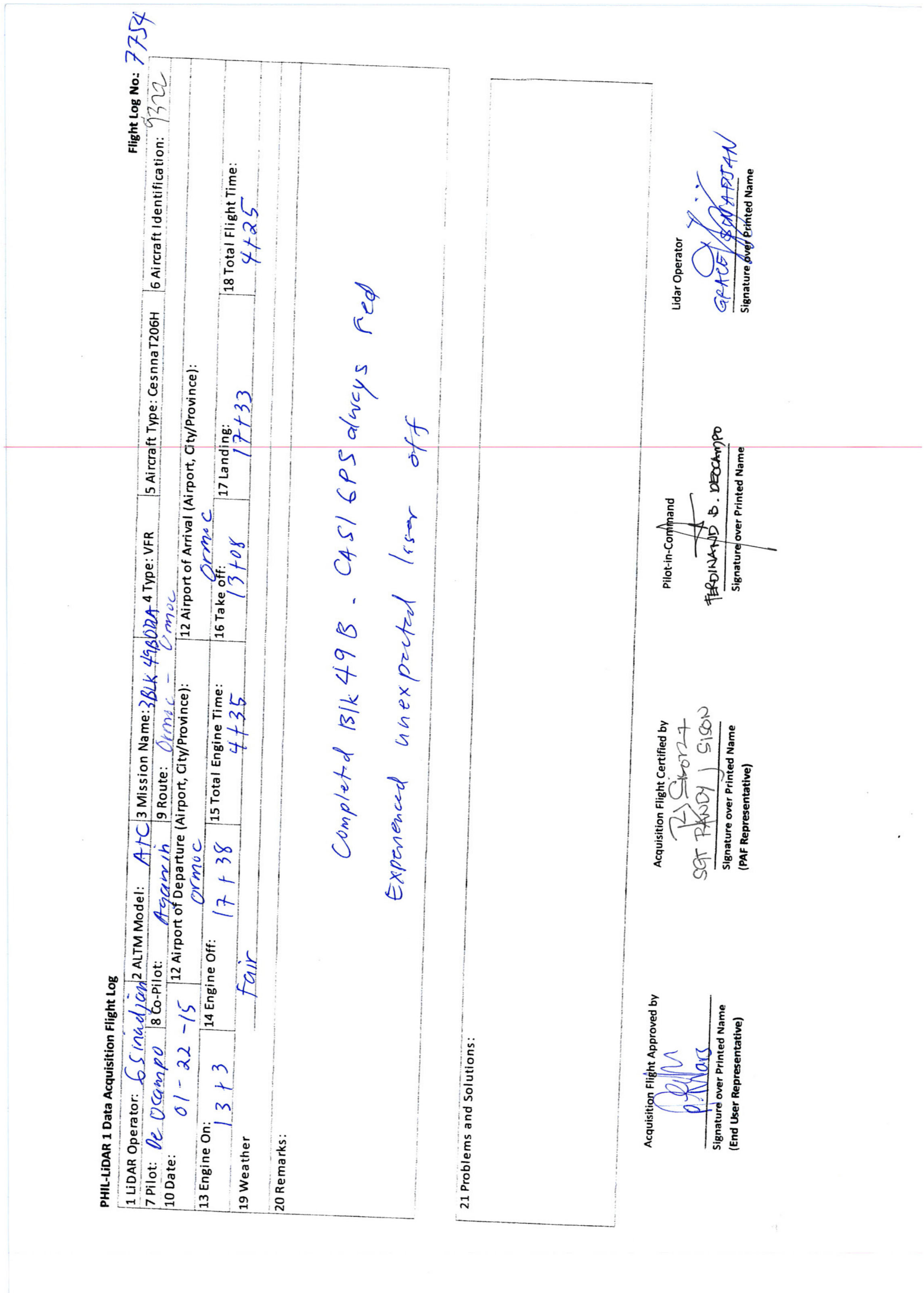
Name AC Bongat
Position SSRS
Signature 5/6/16

16-27

Figure A-5.4. Data Transfer Sheet (D)

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 7754AC Mission


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No: 7754

1 LiDAR Operator: G Sinadjan	2 ALTM Model: ATC	3 Mission Name: 3BLK49BDBA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: De Ocampo	8 Co-Pilot: Agawin	9 Route: Ormoc - Ormoc			
10 Date: 01-22-15	12 Airport of Departure (Airport, City/Province): Ormoc	12 Airport of Arrival (Airport, City/Province): Ormoc			
13 Engine On: 13+3	14 Engine Off: 17+38	15 Total Engine Time: 4+35	16 Take off: 13+08	17 Landing: 17+33	18 Total Flight Time: 4+25
19 Weather: Fair					

20 Remarks:

Completed Blk 49B. CASI GPS always red

Experienced unexpected lasor off

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

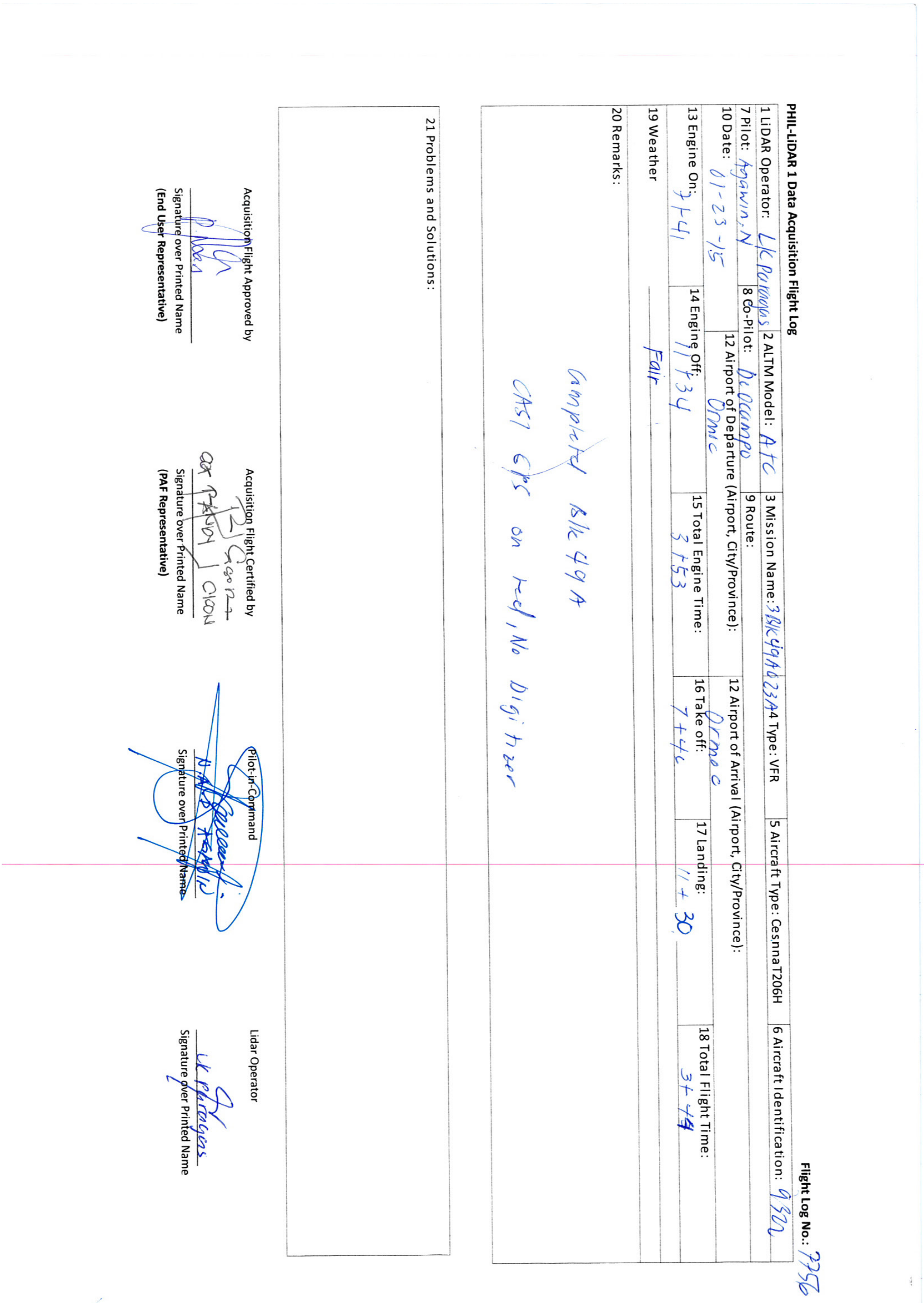
Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.1. Flight Log for 7754AC Mission

2. Flight Log for 7756 AC Mission



Flight Log No.: 7756

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas	2 ALTM Model: ATC	3 Mission Name: 3BLK49A023A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Agawin, N	8 Co-Pilot: Dc Ocampo	9 Route:			
10 Date: 01-23-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 7+41	14 Engine Off: 11+34	15 Total Engine Time: 3+53	16 Take off: 7+46	17 Landing: 11+30	18 Total Flight Time: 3+44
19 Weather: Fair					

20 Remarks:

Completed Blk 49A

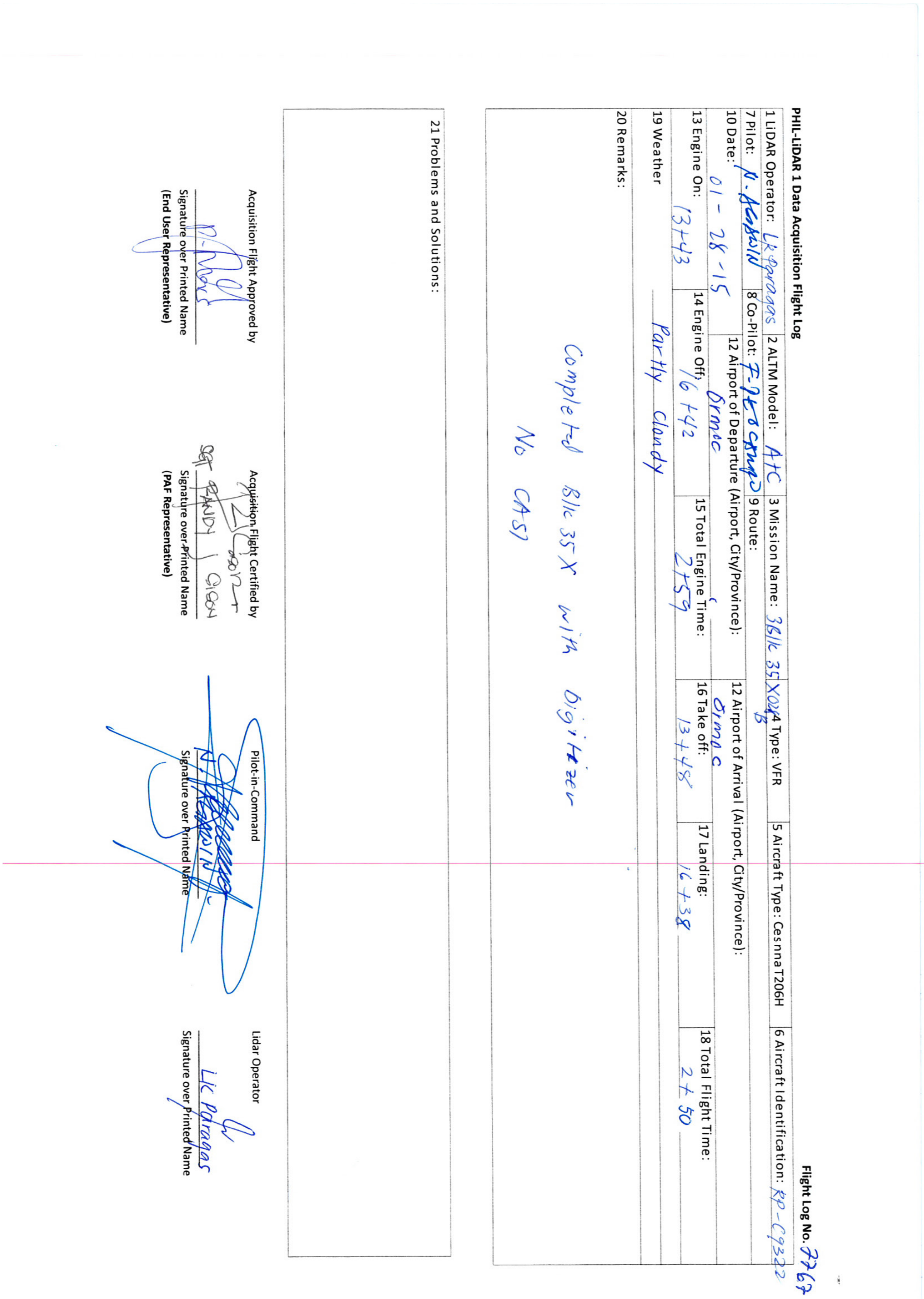
CASI GPS on red, No Digitizer

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
P. Noas	CAPT RANDY J CIPON	N AGAWIN	LK Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for 7756 AC Mission

3. Flight log for 7767AC Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No. 7767

1 LiDAR Operator: LK Paragas	2 ALTM Model: ATC	3 Mission Name: 3Blk 35X024B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: N. Azarcon	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: 01-28-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 13+43	14 Engine Off: 16+42	15 Total Engine Time: 2+59	16 Take off: 13+48	17 Landing: 16+38	18 Total Flight Time: 2+50
19 Weather: Partly cloudy					
20 Remarks: Completed Blk 35X 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. Azarcon — Signature over Printed Name

Lidar Operator: LK Paragas — Signature over Printed Name

Figure A-6.3. Flight log for 7767AC Mission

4. Flight log for 7794AC Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7794

1 LiDAR Operator: LK Paragas
2 ALTM Model: AtC
3 Mission Name: 3BlK35EV042A
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification:
7 Pilot: A. Jamin
8 Co-Pilot: D. Ocampo
9 Route:
10 Date: 02-11-15
12 Airport of Departure (Airport, City/Province): Ormoc
12 Airport of Arrival (Airport, City/Province): Ormoc
13 Engine On: 8+00
14 Engine Off: 12+11
15 Total Engine Time: 4+11
16 Take off: 8+05
17 Landing: 12+07
18 Total Flight Time: 4+02
19 Weather: Fair
20 Remarks:

Completed Blk 35E and voids with Digitizer
No CASI

21 Problems and Solutions:

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

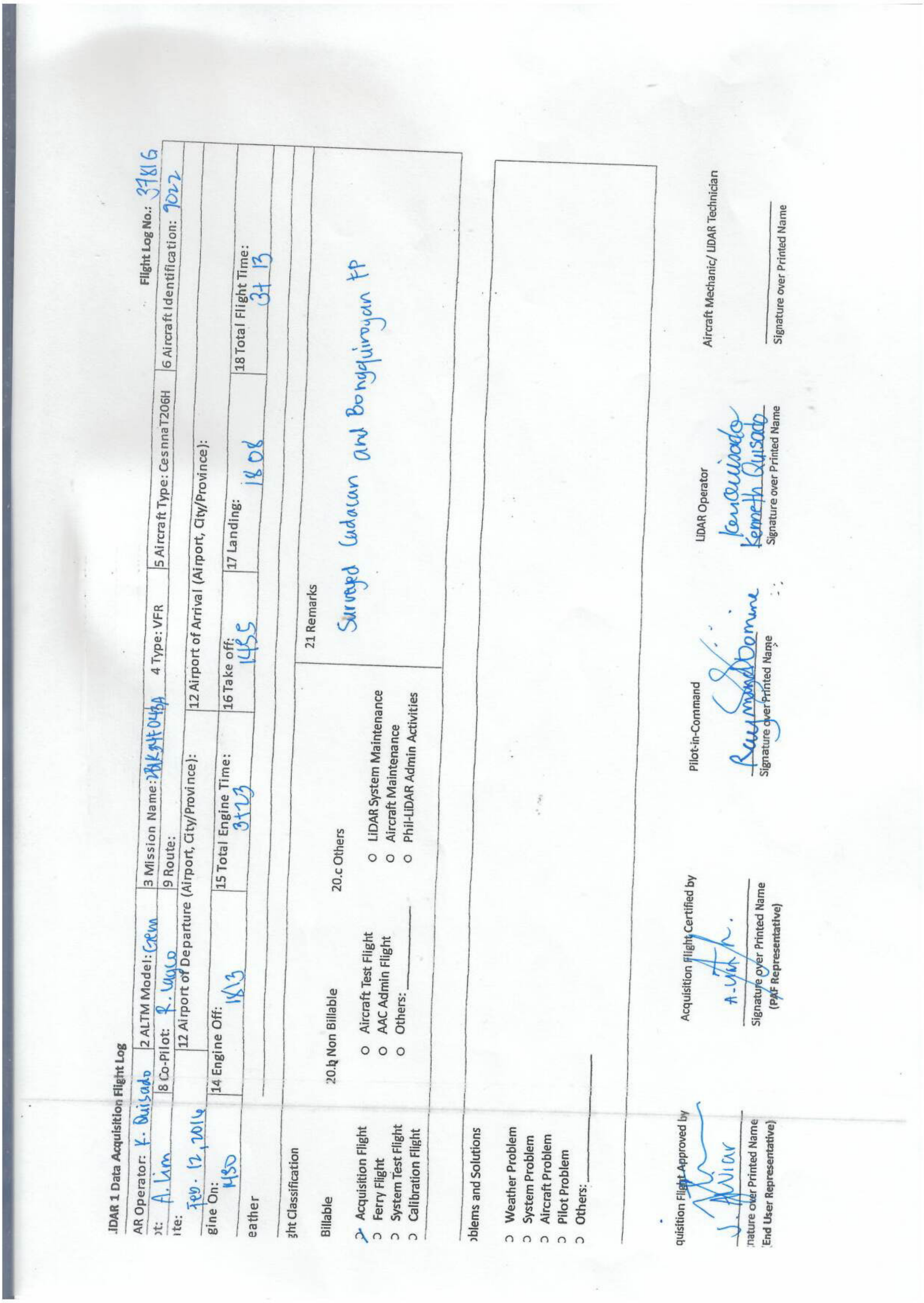
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

Figure A-6.4. Flight log for 7794AC Mission

5. Flight log for 3781G Mission



LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3781G

1 LiDAR Operator: K. Quisado	2 ALTM Model: Gemini	3 Mission Name: 2BLK94D048A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: A. Lim	8 Co-Pilot: R. Ugalo	9 Route:			
10 Date: Feb. 12, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1450	14 Engine Off: 1813	15 Total Engine Time: 3+23	16 Take off: 1455	17 Landing: 1808	18 Total Flight Time: 3+13
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 Cadacan and Bongquinyan FP

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: A. Vida
Signature over Printed Name (PAF Representative)

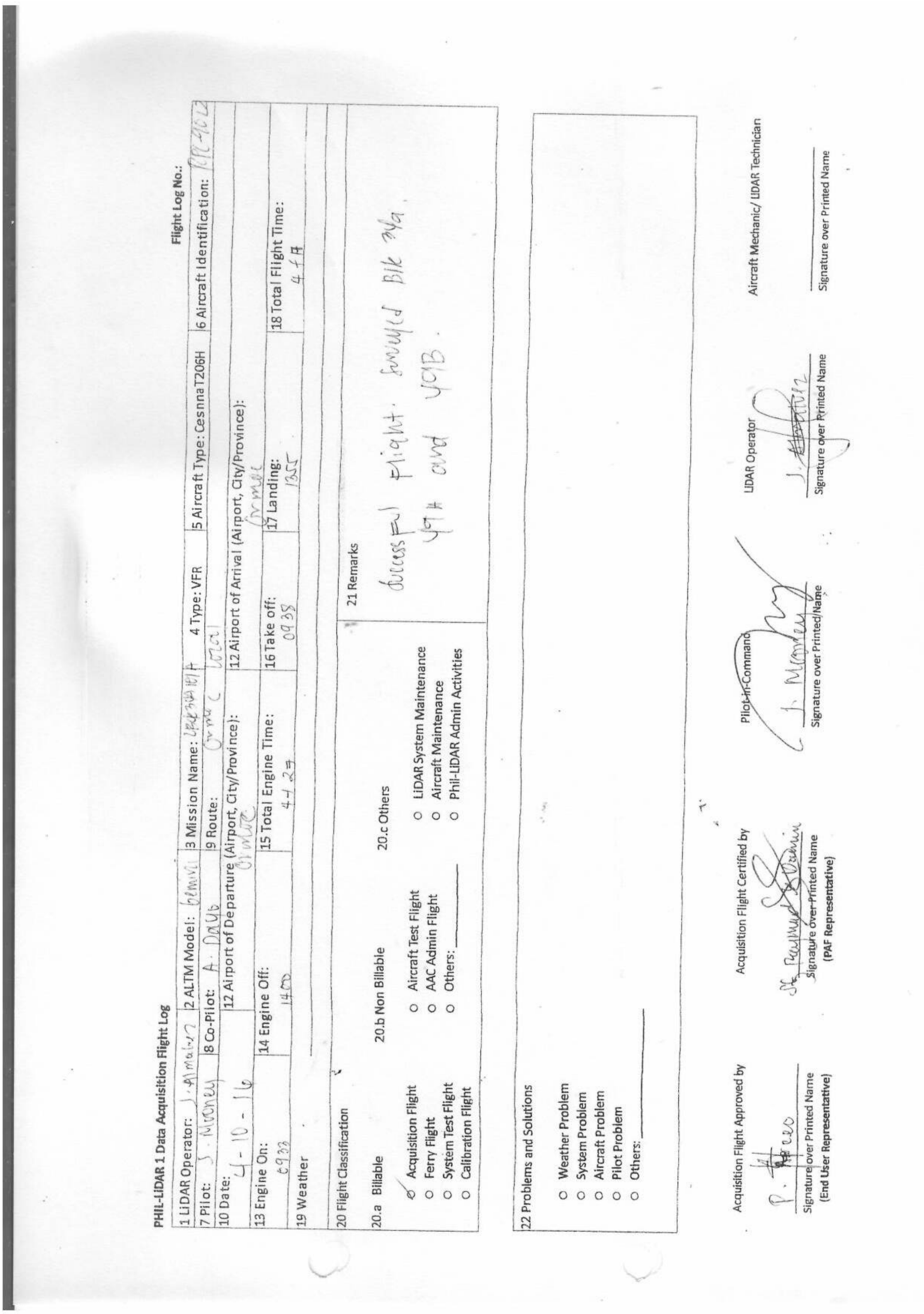
Pilot-in-Command: Raymund Domine
Signature over Printed Name

LiDAR Operator: Kenneth Quisado
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name

Figure A-6.5. Flight log for 3781G Mission

6. Flight log for 3921G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: J. Mooney	8 Co-Pilot: A. Dayo	9 Route: Ormoc Local			
10 Date: 4-10-16	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 0933	14 Engine Off: 1400	15 Total Engine Time: 4+27	16 Take off: 0938	17 Landing: 1355	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 34a, 49A and 49B.

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)

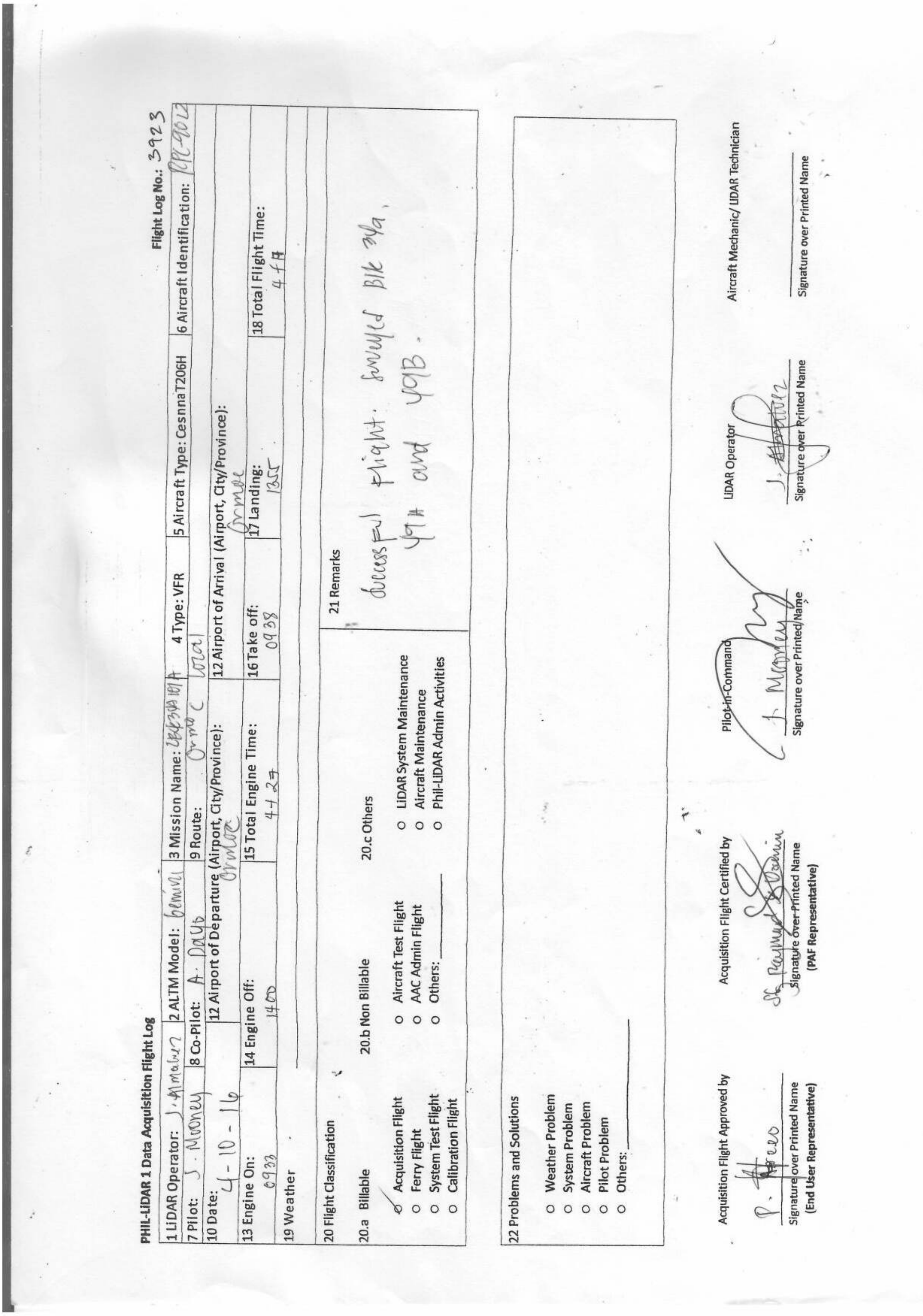
Pilot-in-Command — J. Mooney — Signature over Printed Name

LiDAR Operator — J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.6. Flight log for 3921G Mission

7. Flight log for 3923G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3923

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK39A101A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC-9022
7 Pilot: J. Mooney	8 Co-Pilot: A. Dayo	9 Route: Ormoc Local			
10 Date: 4-10-16	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 0933	14 Engine Off: 1400	15 Total Engine Time: 4+27	16 Take off: 0938	17 Landing: 1355	18 Total Flight Time: 4+17
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Successful flight. Surveyed BLK 39a, 49A and 49B.

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

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

Acquisition Flight Certified by: Sg. Raymund S. Dominic — Signature over Printed Name (PAF Representative)

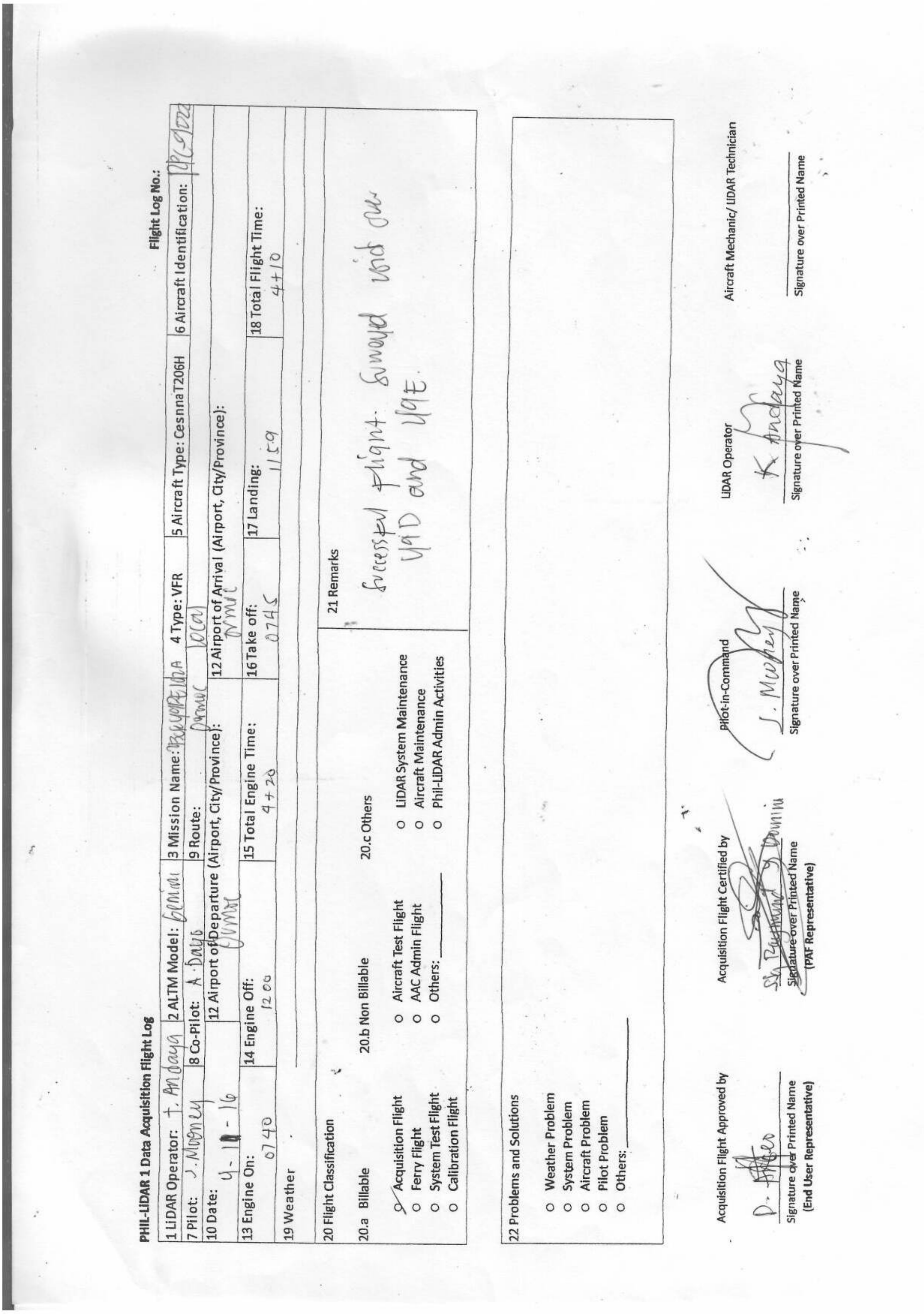
Pilot-in-Command: J. Mooney — Signature over Printed Name

LiDAR Operator: J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.7. Flight log for 3923G Mission

8. Flight log for 3925G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: T. Andaya	2 ALTM Model: Gemini	3 Mission Name: 3BLK39[illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Mooney	8 Co-Pilot: A. Dayo	9 Route: [illegible]			
10 Date: 4-10-16	12 Airport of Departure (Airport, City/Province): [illegible]		12 Airport of Arrival (Airport, City/Province): [illegible]		
13 Engine On: 0740	14 Engine Off: 1200	15 Total Engine Time: 4+20	16 Take off: 0745	17 Landing: 1159	18 Total Flight Time: 4+10
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 void over U4D and U4E.

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. Mooney — Signature over Printed Name

LiDAR Operator: K. Andaya — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: Signature over Printed Name

Figure A-6.8. Flight log for 3925G Mission

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Reports

LEYTE AND SOUTHERN LEYTE

(January 22- February 11, 2015, February 12, 2016 and April 10-11, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7754AC	BLK49B	3BLK49B022A	G. SINADJAN	22 JAN 2015	Completed Blk49B. CASI GPS always red. Experienced unexpected laser off
7756AC	BLK49A	3BLK49A023A	LK PARAGAS	23 JAN 2015	Completed Blk49A. CASI GPS always red.
7767AC	BLK35X	3BLK35X028B	LK PARAGAS	28 JAN 2015	Completed Blk35X with digitizer. Experienced red swath (short ranges). No CASI
7794AC		3BLK35EV042A	LK Paragas	11 FEB 15	Completed Blk35E and some voids with digitizer. No CASI
3781G	BLK 34F BLK 49A	2BLK34F043A	K QUISADO	12 February 2016	SURVEYED CADACAN AND BONGQUIROGAN FPs
3921G	ORMOC	2BLK34a101A	J.ALMALVEZ	10 APRIL 2016	SURVEYED BLK34a, 49A and 49B
3923G	ORMOC	2BLK49AB101b	K. ANDAYA	10 APRIL 2016	SURVEYED VOIDS OVER BLK 49A AND 49B
3925G	ORMOC	2BLK49DE102A	K. ANDAYA	11 APRIL 2016	SURVEYED VOIDS OVER BLK 49D AND 49E

LAS/ SWATH BOUNDARIES PER FLIGHT

Flight No. : 7754
Area: BLK49B
Mission name: 3BLK49B022A
Parameters: Altitude:600 ; Scan Frequency: 45; Scan Angle: 18; Overlap: 35%
Area covered: 75.84sq km.

LAS/ SWATH

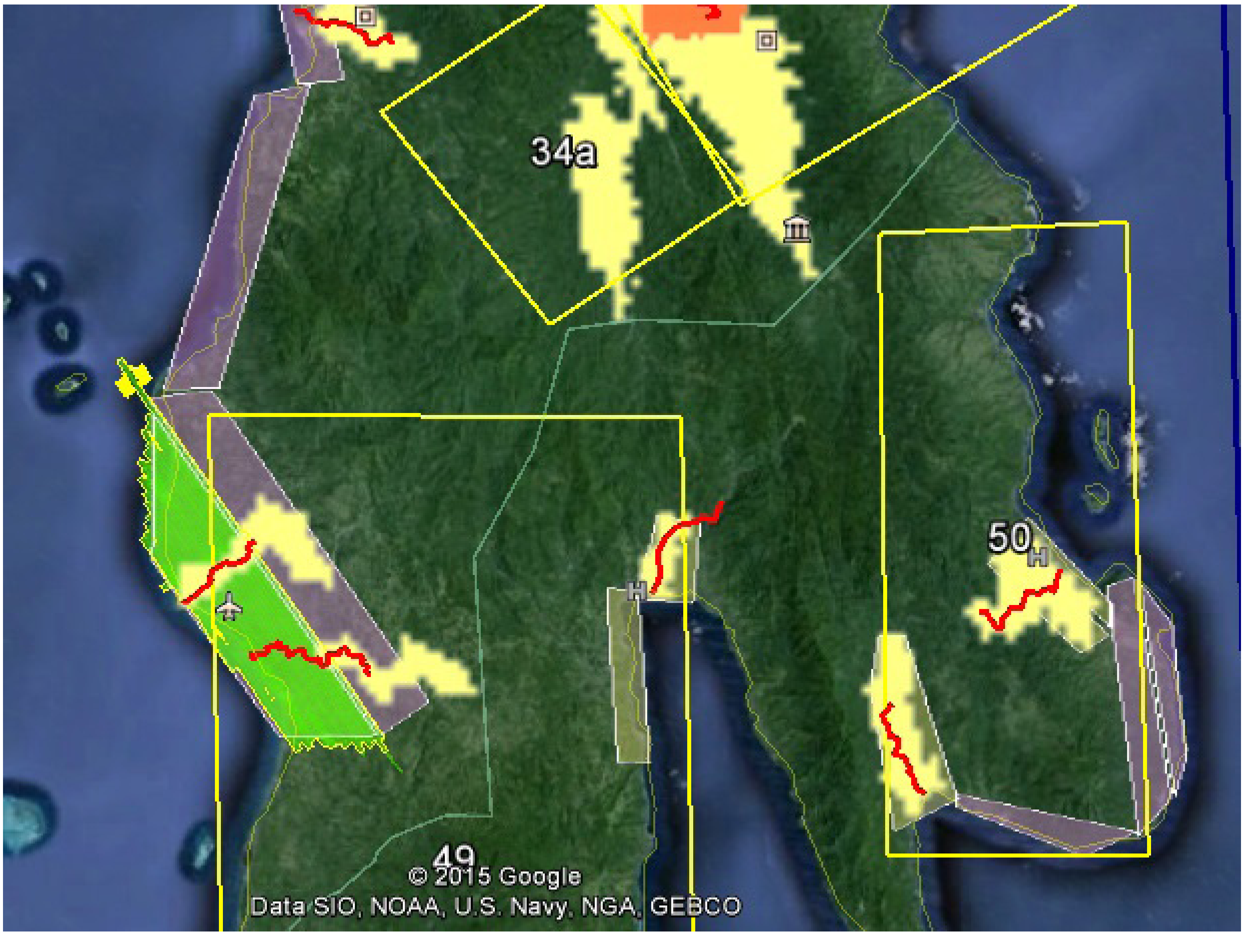


Figure A-7.1. Swath for Flight No. 7754

Flight No. : 7756
Area: BLK49A
Mission name: 3BLK49A023A
Parameters: Altitude:600 ; Scan Frequency: 45; Scan Angle: 18; Overlap: 35%
Area covered: 97.327sq km.

LAS/ SWATH

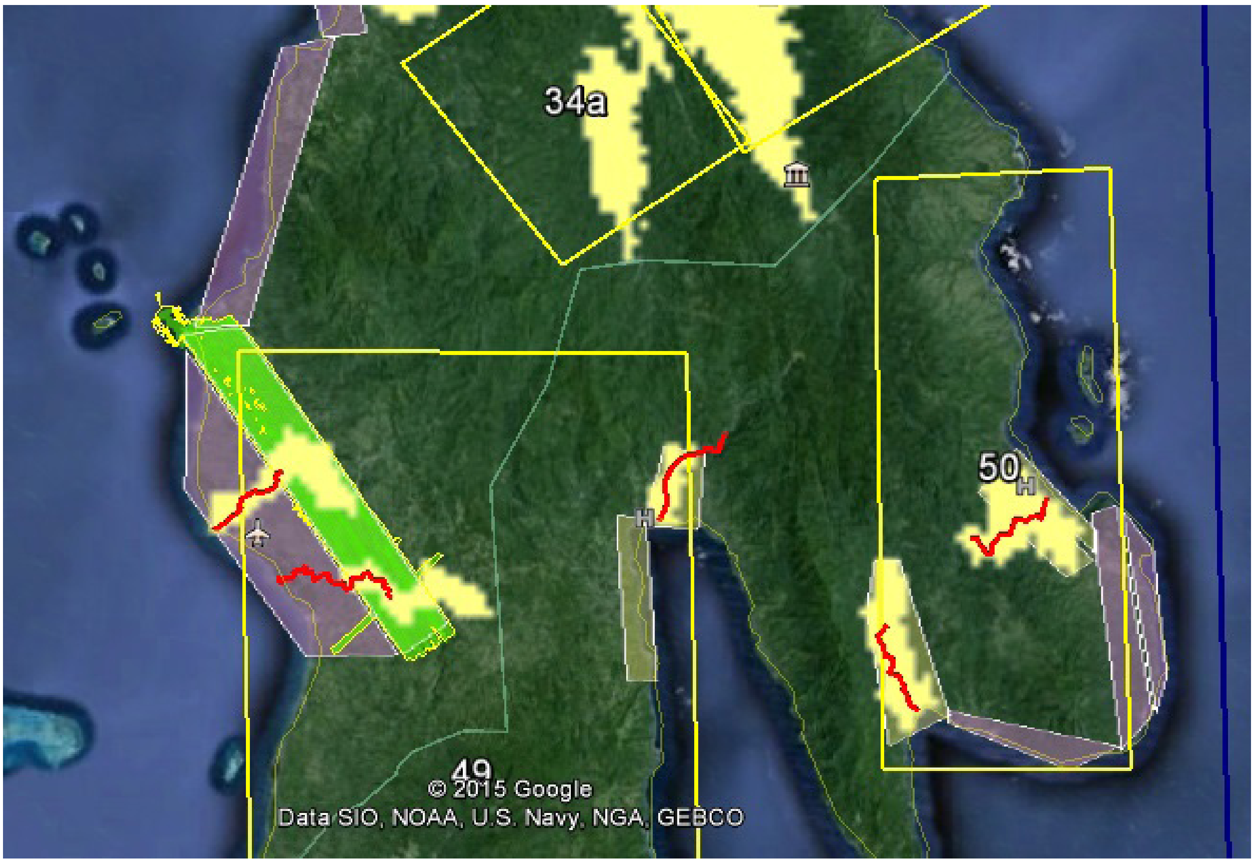


Figure A-7.2. Swath for Flight No. 7756

Flight No. :	7767
Area:	BLK35X
Mission name:	3BLK35X028B
Parameters:	Altitude:500 ; Scan Frequency: 45; Scan Angle: 18; Overlap: 35%
Area covered:	38.589sq km.

LAS/ SWATH

Figure A-7.3. Swath for Flight No. 7767

Flight No. :	7794
Area:	BLK35E+VOIDS
Mission name:	3BLK35EV042A
Parameters:	Altitude:600 ; Scan Frequency: 45; Scan Angle: 18; Overlap: 35%
Area covered:	59.596sq km.

LAS/ SWATH

Figure A-7.4. Swath for Flight No. 7794

FLIGHT NO.:	3921	
AREA:	Ormoc	
MISSION NAME:	2BLK34a101A	
ALT: 1000m	SCAN FREQ: 50	SCAN ANGLE: 18
SURVEYED AREA:	144.9	

LAS/ SWATH

Figure A-7.5. Swath for Flight No. 3921

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
02:05:33.1	02:07:34.609	1	1111	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:10:01.723	02:11:43.463	6	1087	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:14:50.586	02:16:56.781	2	1123	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:19:42.155	02:21:29.779	7	1095	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:23:41.438	02:25:49.017	3	1122	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:28:22.016	02:30:16.016	8	1132	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:32:42.64	02:34:57.529	4	1155	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:37:57.298	02:39:44.017	9	1138	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:42:49.011	02:44:56.505	5	1149	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:47:10.729	02:48:53.899	10	1137	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:51:47.018	02:53:54.412	11	1111	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:56:21.616	02:58:02.305	12	1119	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
03:00:35.014	03:01:04.074	6	1176	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:00:35.014	03:01:04.074	6	1176	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:01:54.559	03:02:13.244	3	1098	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
03:01:54.559	03:02:13.244	3	1095	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
03:06:04.217	03:06:50.957	3	1144	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:06:04.217	03:06:50.957	3	1146	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:06:04.217	03:06:50.957	3	1147	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:10:02.621	03:11:36.505	3	1093	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:18:13.908	03:22:06.016	79	1127	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
03:23:36.821	03:27:27.709	71	1115	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
03:29:17.513	03:33:29.302	78	1106	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
03:36:07.101	03:39:47.599	77	1122	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
03:43:09.538	03:47:32.242	76	1149	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
03:51:14.24	03:55:00.629	75	1095	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
03:58:42.967	04:03:15.441	74	1124	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:06:40.999	04:07:54.154	74	1104	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:11:49.773	04:15:09.861	80	1126	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:18:10.825	04:21:19.444	87	1155	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:24:39.103	04:27:54.602	81	1107	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:29:34.691	04:32:35.83	88	1096	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:34:59.099	04:38:10.863	82	1132	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:39:36.802	04:42:55.156	89	1115	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:44:52.04	04:48:02.579	83	1080	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:50:02.949	04:53:17.752	90	1130	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:55:22.692	04:58:34.186	84	1093	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
05:00:20.07	05:03:06.489	91	1074	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
05:05:46.578	05:09:05.297	85	1082	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
05:12:04.956	05:15:06.41	92	1077	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
05:18:17.014	05:21:44.073	86	1113	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
05:24:47.357	05:26:42.751	86	1098	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln

Figure A-7.6. Data for Flight No. 3921

FLIGHT NO.: 3923
AREA: Ormoc
MISSION NAME: 2BLK49AB101B
ALT: 1000m SCAN FREQ: 50 SCAN ANGLE: 18
SURVEYED AREA: 59.94

LAS/ SWATH

Figure A-7.7. Swath for Flight No. 3923

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
07:45:34.483	07:47:59.837	35	1119	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
07:55:24.15	07:57:49.149	36	1170	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
08:05:13.486	08:07:47.05	37	1113	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
08:09:41.155	08:11:17.154	46	1118	100	50.00	18.00	OFF	NAR	ON	OFF	204.00	Default.pln
08:14:27.698	08:16:59.837	38	1160	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
08:18:49.596	08:20:33.246	45	1129	100	50.00	18.00	OFF	NAR	ON	OFF	204.00	Default.pln
08:23:58.91	08:26:23.049	39	1153	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
08:28:00.388	08:29:48.633	44	1130	100	50.00	18.00	OFF	NAR	ON	OFF	204.00	Default.pln
08:33:44.216	08:36:00.95	40	1135	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
08:37:54.46	08:39:42.309	43	1123	100	50.00	18.00	OFF	NAR	ON	OFF	204.00	Default.pln
08:43:52.283	08:46:02.802	41	1120	100	50.00	18.00	OFF	NAR	ON	OFF	24.00	Default.pln
08:47:02.601	08:49:04.706	42	1142	100	50.00	18.00	OFF	NAR	ON	OFF	204.00	Default.pln
08:51:51.32	08:53:42.284	35	1101	100	50.00	18.00	OFF	NAR	ON	OFF	204.00	Default.pln
09:00:36.811	09:04:34.775	73	1111	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
09:06:57.599	09:10:58.388	72	1101	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
09:13:18.532	09:15:24.706	71	1138	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
09:17:07.465	09:17:50.465	71	1120	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln

Figure A-7.8. Data for Flight No. 3923

FLIGHT NO.:	3925	
AREA:	Ormoc	
MISSION NAME:	2BLK49DE102A	
ALT: 1000m	SCAN FREQ: 50	SCAN ANGLE: 18
SURVEYED AREA:	73.96	

LAS/ SWATH

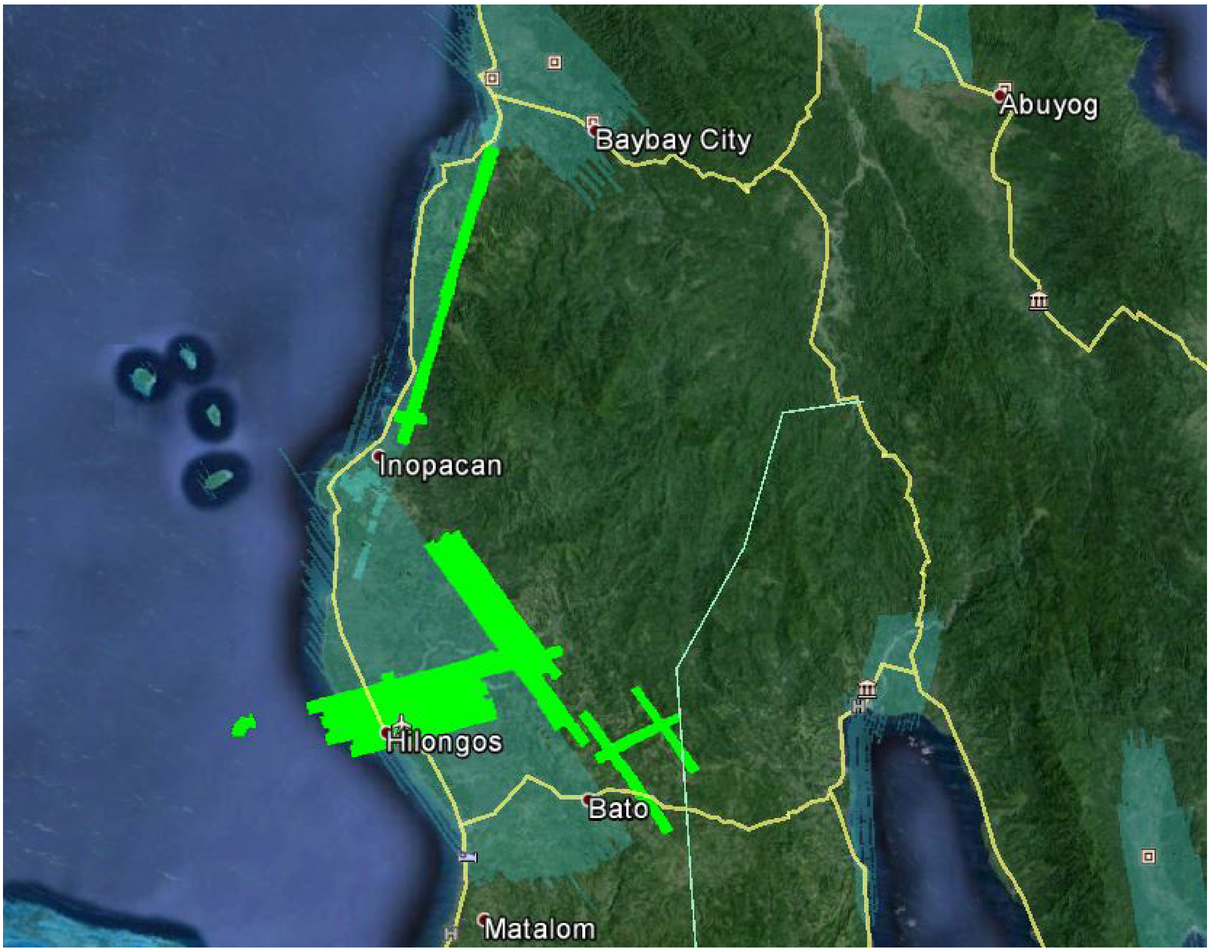


Figure A-7.9. Swath for Flight No. 3925

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
01:34:50.152	01:37:57.256	27	1124	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
01:40:24.36	01:42:36.014	29	1122	100	50.00	18.00	OFF	NAR	ON	OFF	255.00	Default.pln
01:46:06.222	01:48:36.221	30	1122	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
01:51:58.05	01:54:09.819	31	1112	100	50.00	18.00	OFF	NAR	ON	OFF	255.00	Default.pln
01:57:49.433	02:00:15.467	32	1142	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
02:03:42.471	02:05:46.215	33	1150	100	50.00	18.00	OFF	NAR	ON	OFF	255.00	Default.pln
02:09:34.644	02:13:19.982	28	1130	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
02:17:19.401	02:18:22.785	27	1113	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
02:22:27.159	02:25:07.613	73	1120	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
02:28:44.542	02:31:05.546	74	1097	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
02:34:44.79	02:38:42.018	75	1115	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
02:42:04.582	02:42:25.127	75	1122	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
02:45:53.406	02:49:11.755	76	1141	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
02:54:44.373	02:56:20.512	80	1126	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
02:59:45.236	03:01:54.27	87	1142	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
03:05:45.409	03:07:15.303	87	1135	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
03:15:36.235	03:20:12.764	95	1036	100	50.00	18.00	OFF	NAR	ON	OFF	17.00	Default.pln
03:23:25.993	03:25:43.962	95	956	100	50.00	18.00	OFF	NAR	ON	OFF	197.00	Default.pln
03:28:33.341	03:29:05.346	95	1092	100	50.00	18.00	OFF	NAR	ON	OFF	197.00	Default.pln

Figure A-7.10. Data for Flight No. 3925

Flight No. : 3781G
Area: BLK 34aC, 34aB, 49A – Cadacan 2 AND BONGQUIROGAN FPs
Mission Name: 2BLK34043A
Parameters: PRF 100 SF50 SCAN ANGLE: 18

LAS/ SWATH

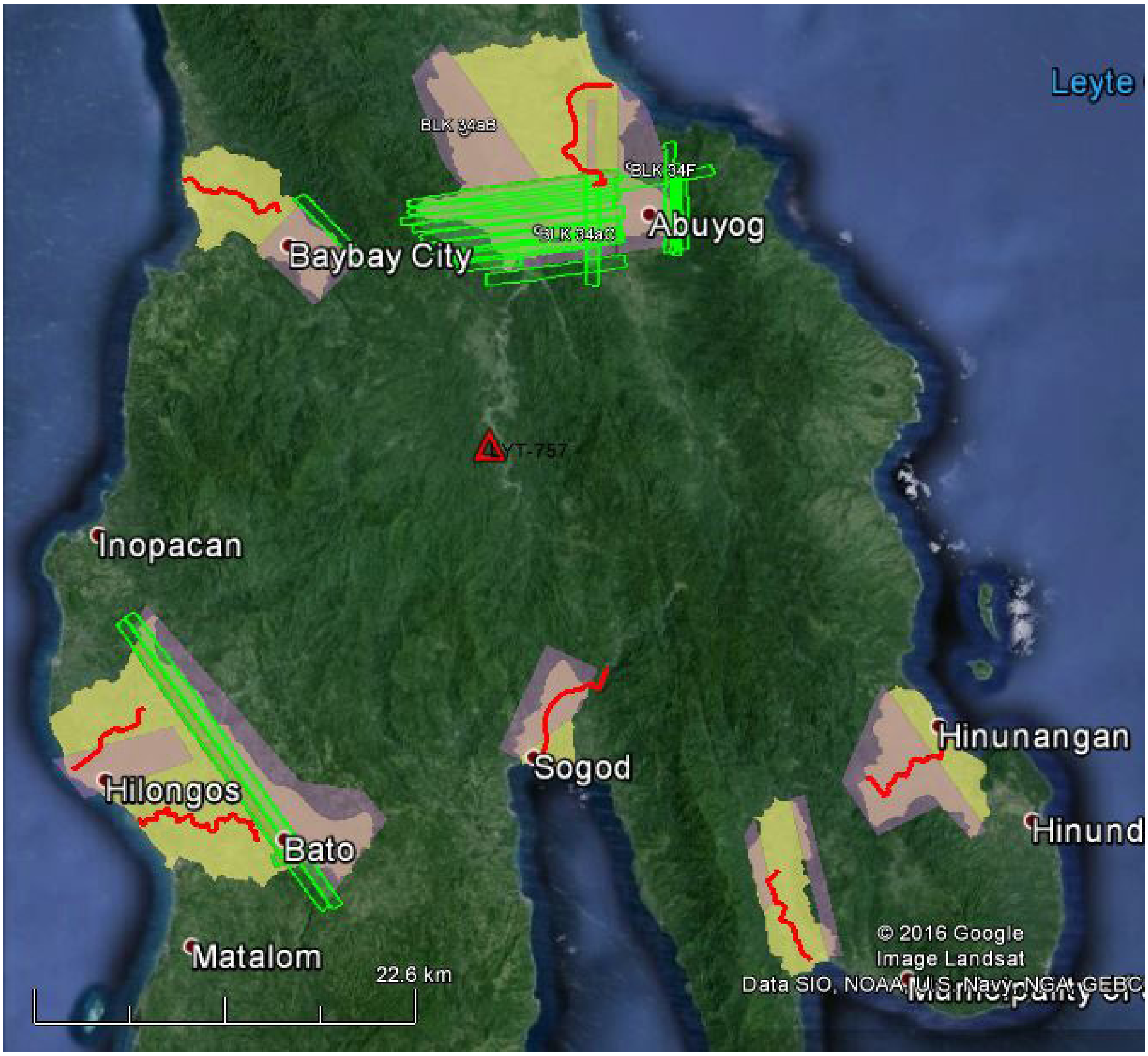


Figure A-7.11. Swath for Flight No. 3781G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission

Flight Area	Leyte
Mission Name	49A_Additional
Inclusive Flights	3781G
Range data size	11.3 GB
Base data size	8.87 MB
POS	191 MB
Image	n/a
Transfer date	March 04, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000966
IMU attitude correction stdev (<0.001deg)	0.001913
GPS position stdev (<0.01m)	0.0079
Minimum % overlap (>25)	0.12
Ave point cloud density per sq.m. (>2.0)	3.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	347.41 m
Minimum Height	73.84 m
Classification (# of points)	
Ground	9,887,748
Low vegetation	5,981,068
Medium vegetation	21,000,152
High vegetation	47,560,273
Building	64,860
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Melanie Hingpit, Engr. Karl Adrian Vergara

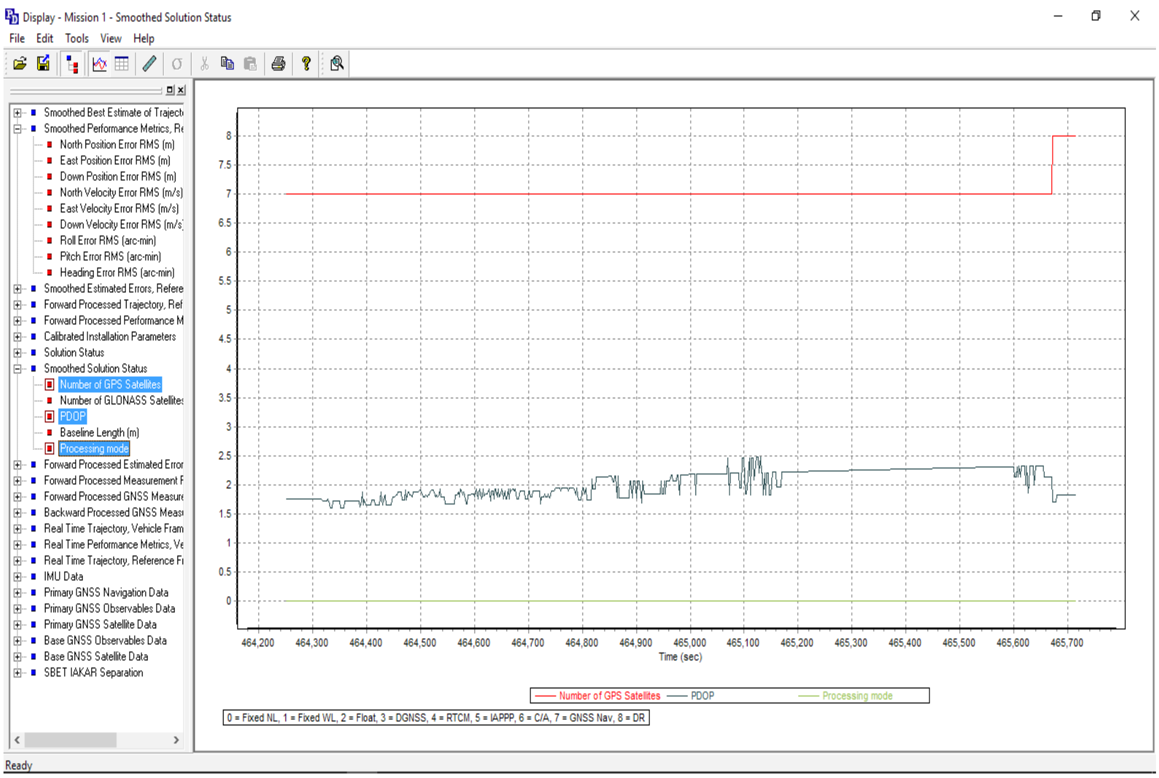


Figure A-8.1. Solution Status

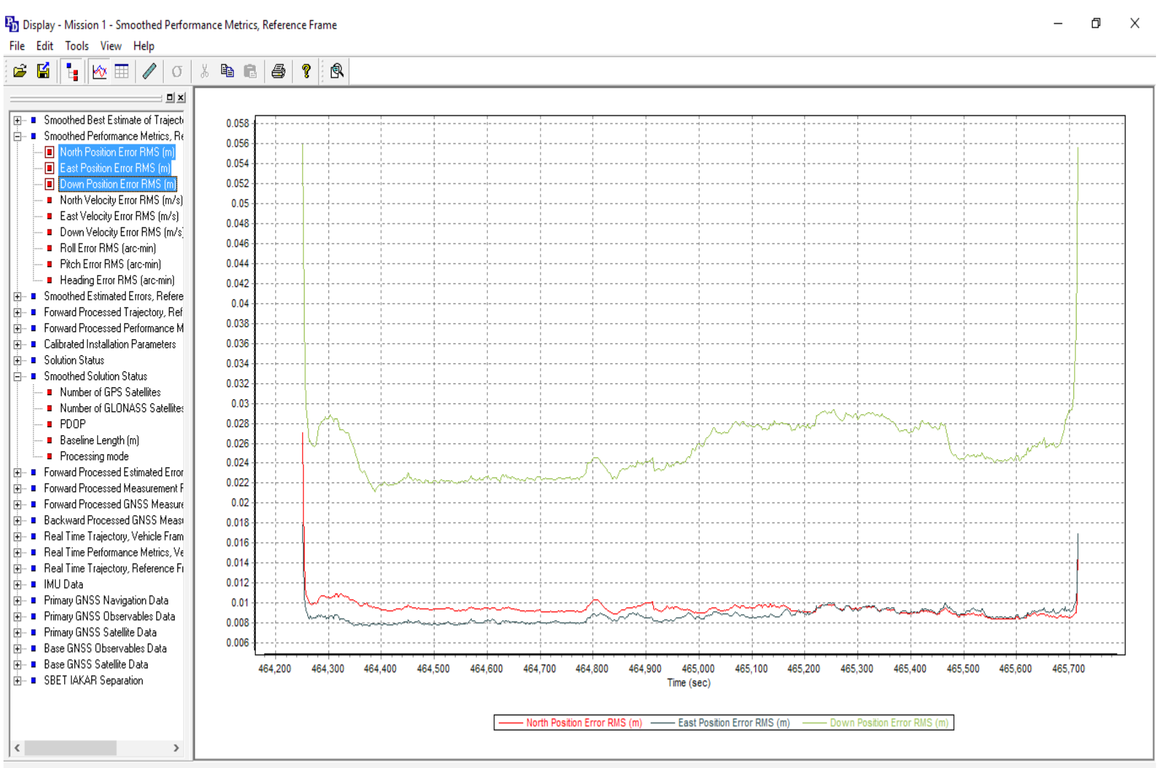


Figure A-8.2. Smoothed Performance Metric Parameters

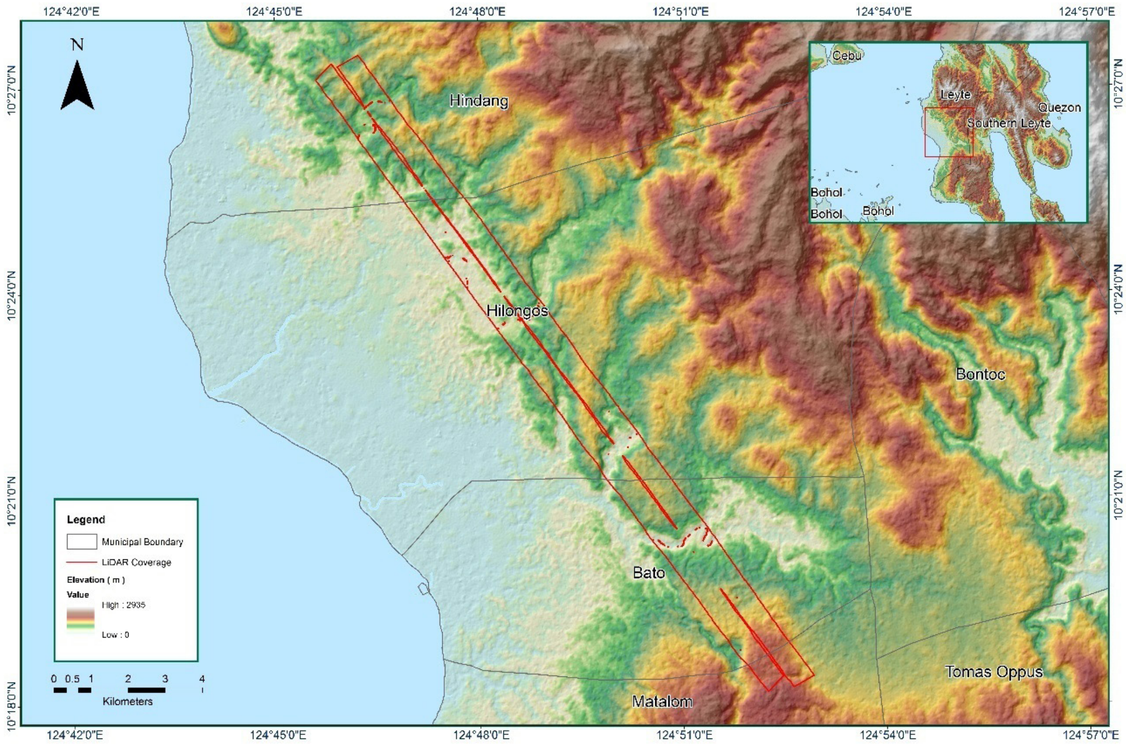


Figure A-8.3. Best Estimated Trajectory

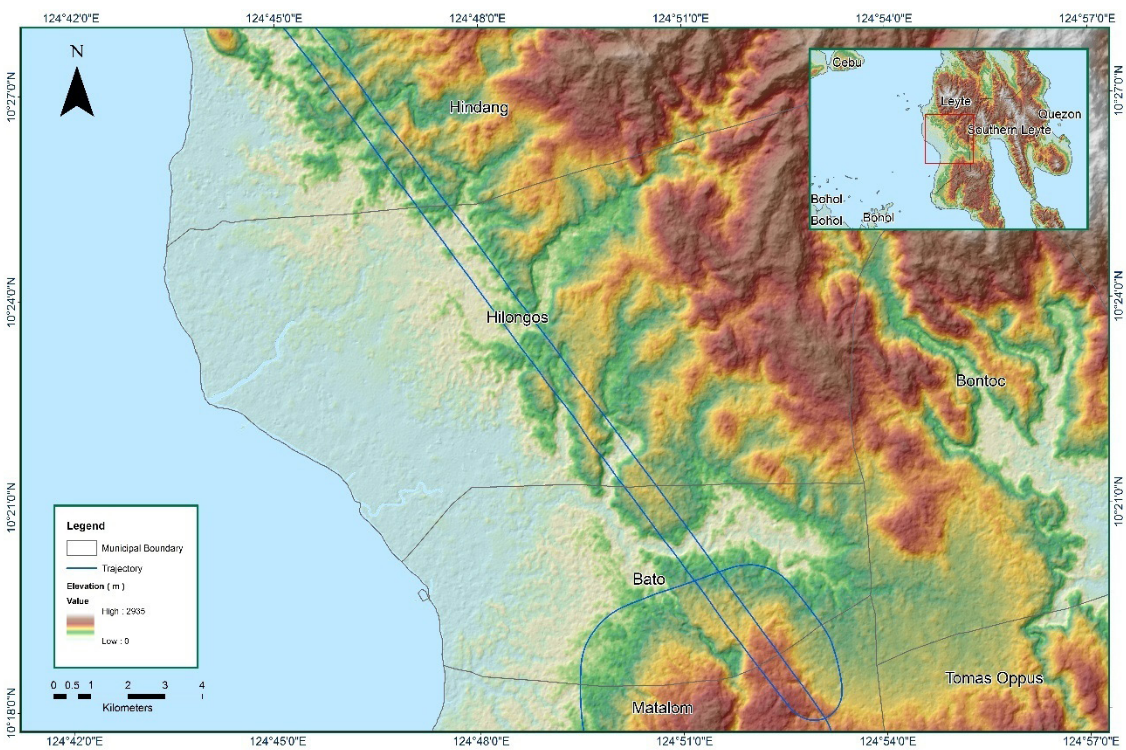


Figure A-8.4. Coverage of LiDAR data

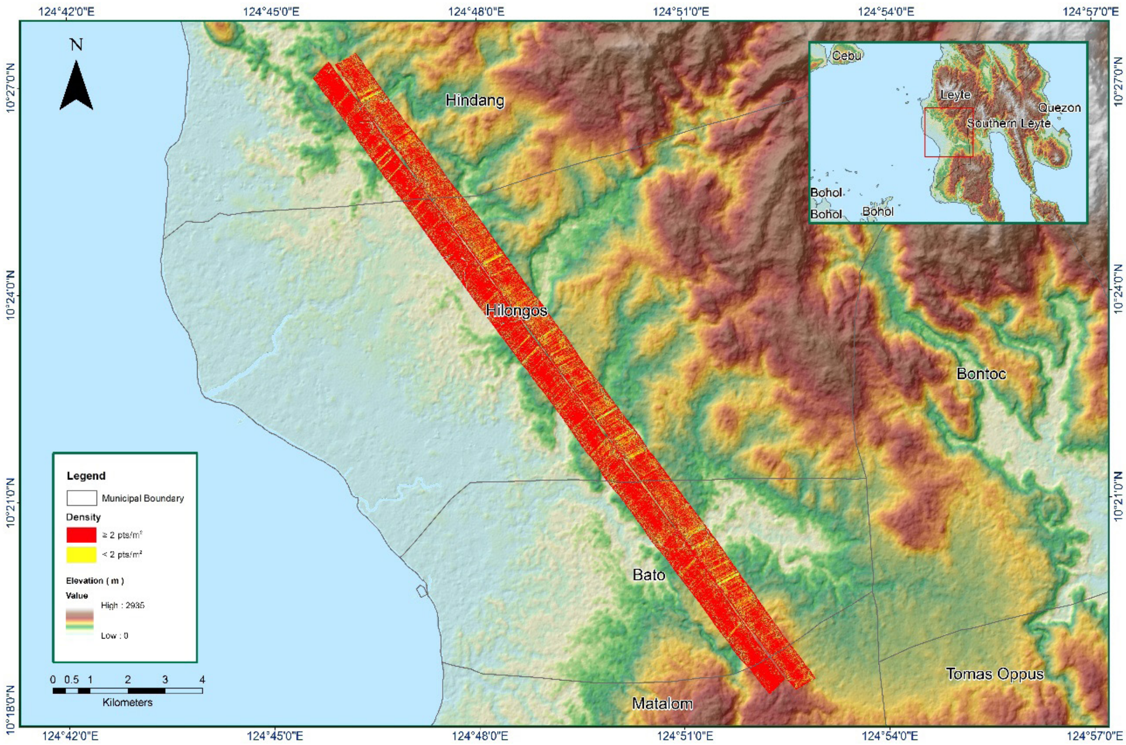


Figure A-8.5. Image of data overlap

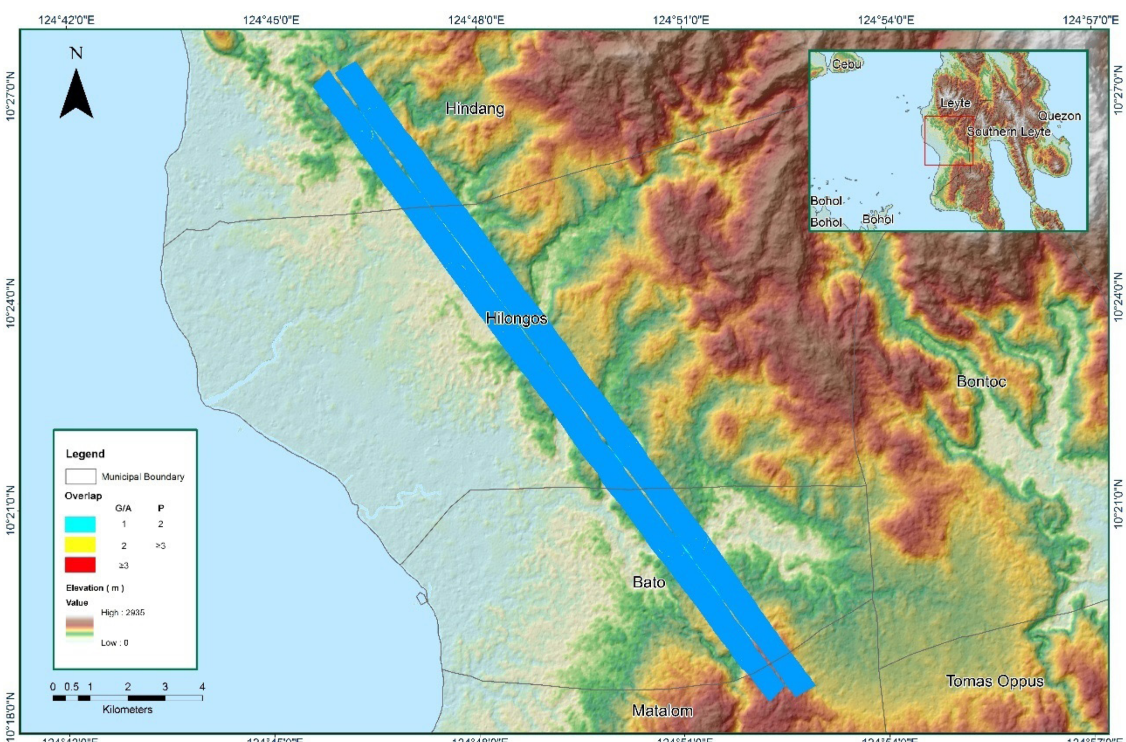


Figure A-8.6. Density map of merged LiDAR data

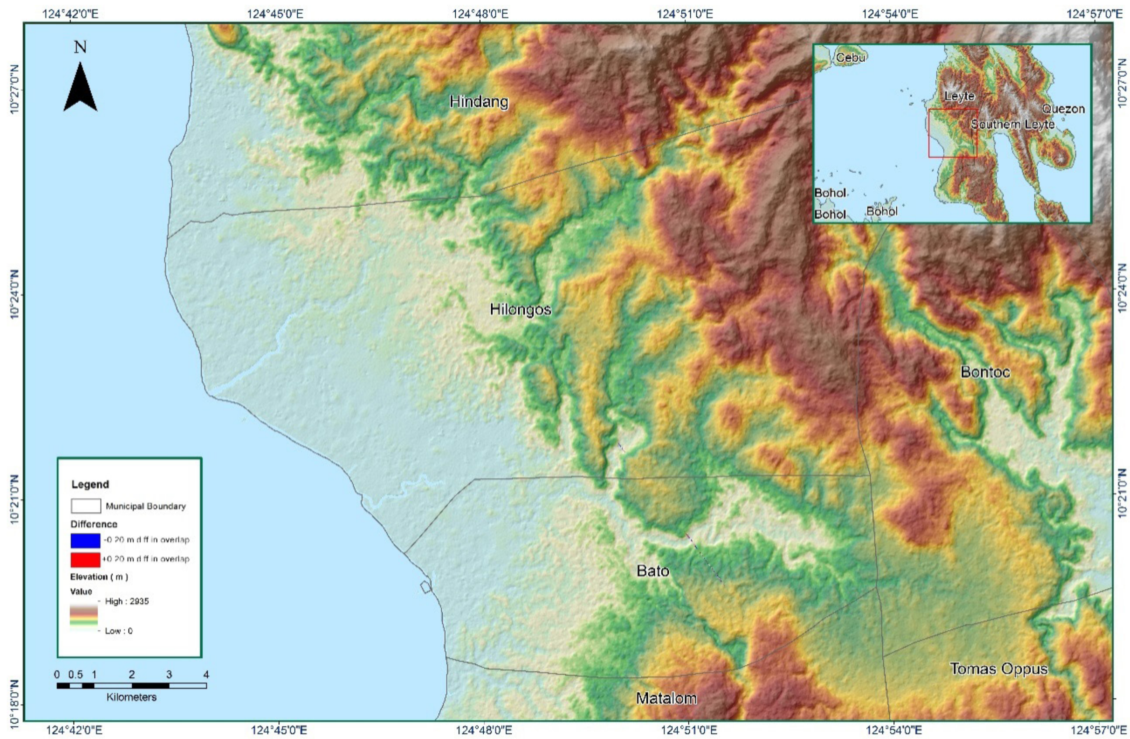


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission

Flight Area	Ormoc
Mission Name	Blk49A
Inclusive Flights	7756AC
Range data size	11.9 GB
Base data size	34 MB
POS	231 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)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.98
RMSE for East Position (<4.0 cm)	0.98
RMSE for Down Position (<8.0 cm)	2.10
Boresight correction stdev (<0.001deg)	0.000260
IMU attitude correction stdev (<0.001deg)	0.000627
GPS position stdev (<0.01m)	0.0095
Minimum % overlap (>25)	44.81
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	125
Maximum Height	294.65 m
Minimum Height	52.68 m
Classification (# of points)	
Ground	53,265,686
Low vegetation	48,235,650
Medium vegetation	77,404,104
High vegetation	122,939,501
Building	2,393,404
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Antonio Chua Jr., Engr. Melissa Fernandez

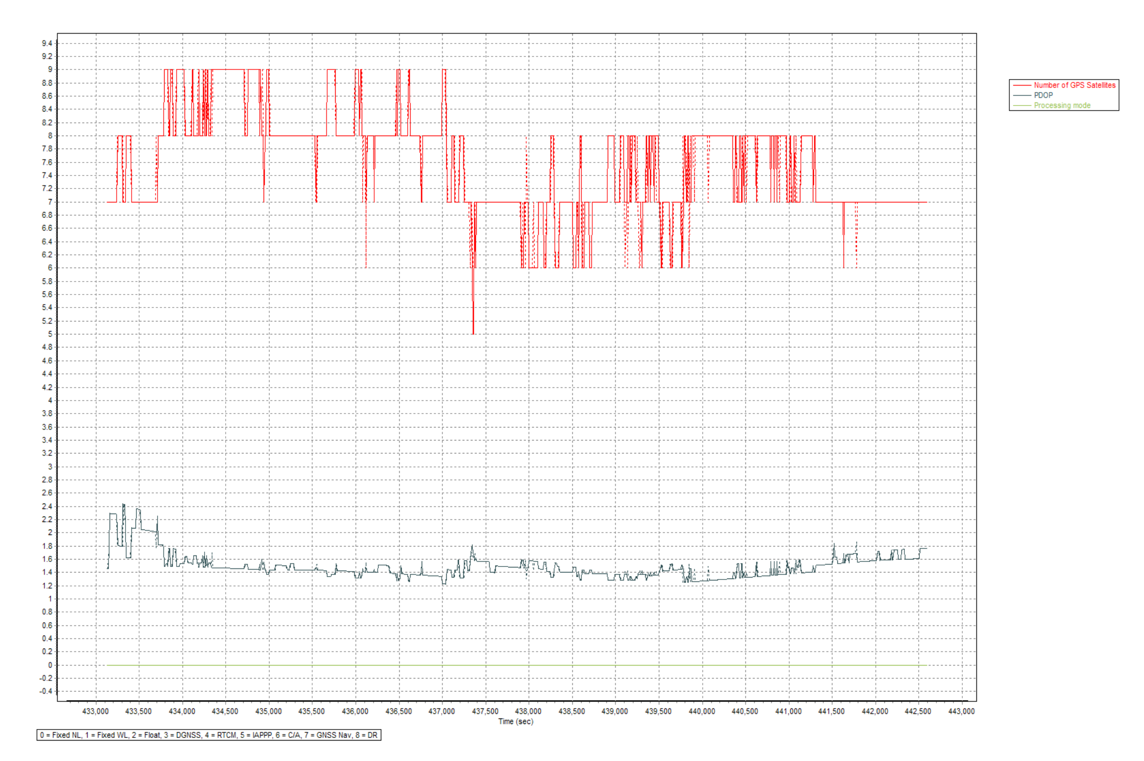


Figure A-8.8. Solution Status

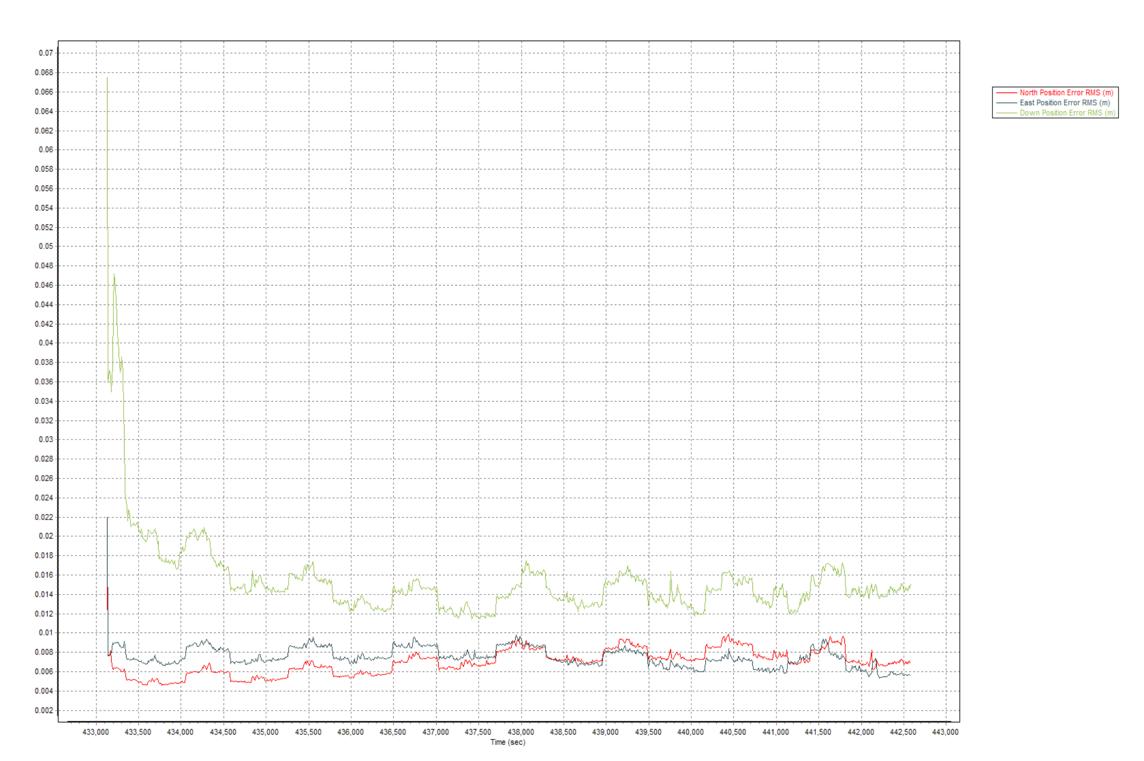


Figure A-8.9. Smoothed Performance Metric Parameters

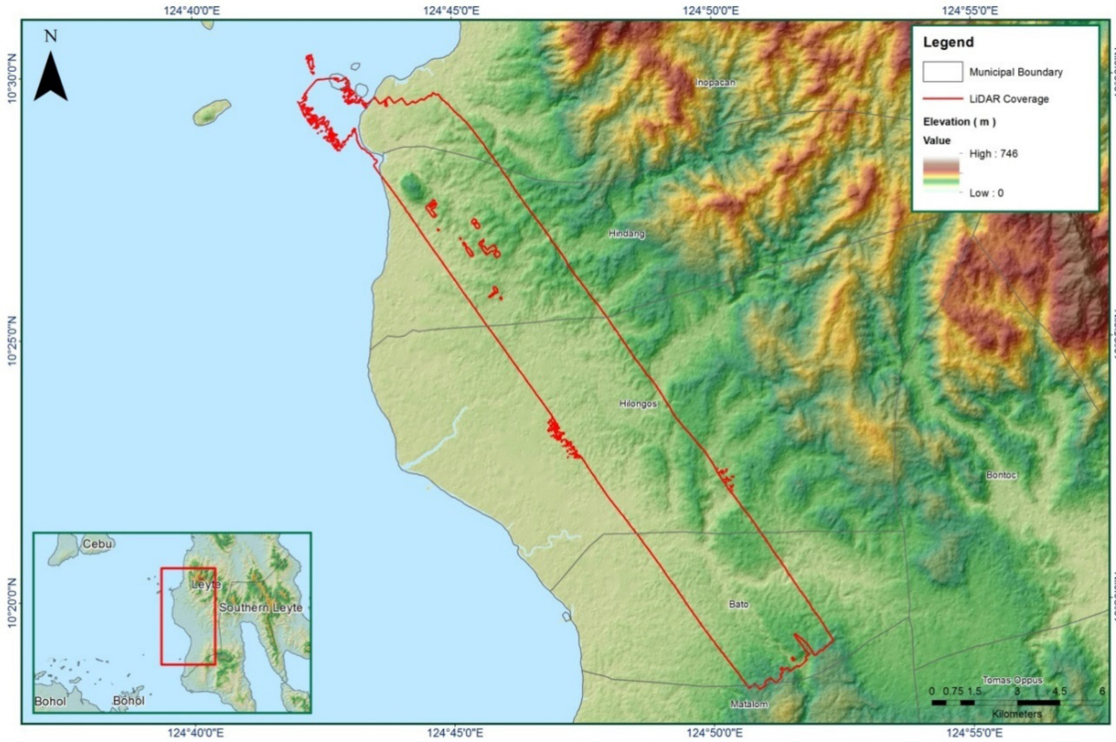


Figure A-8.10. Best Estimated Trajectory

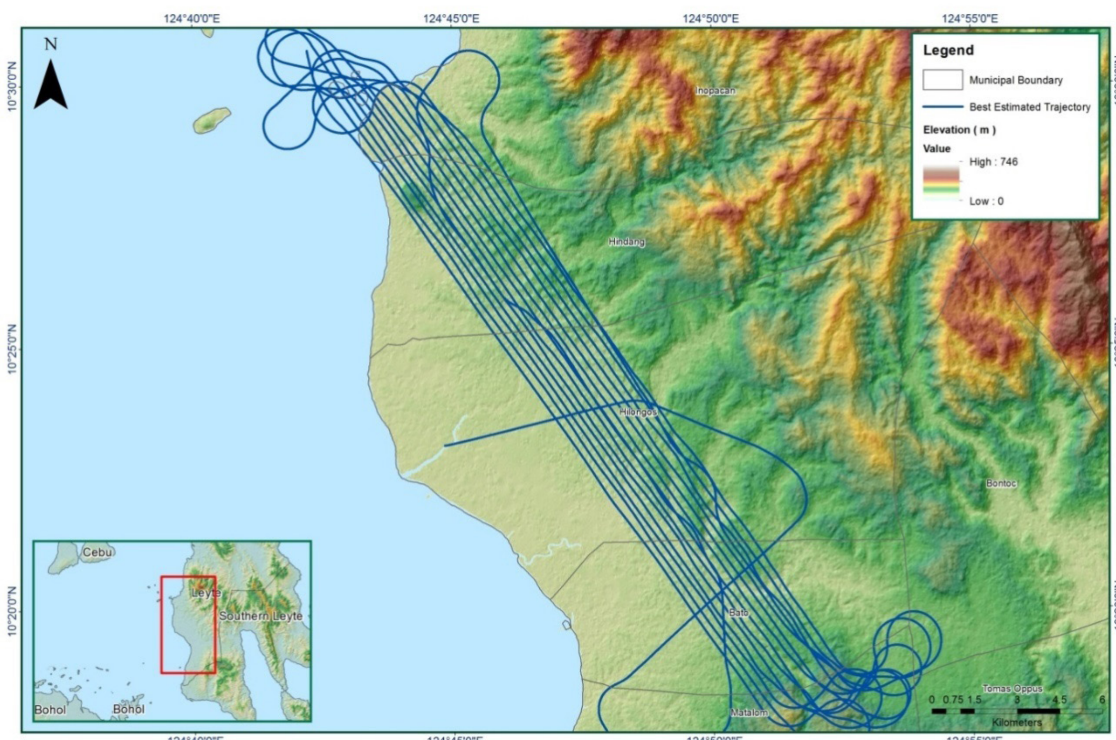


Figure A-8.11. Coverage of LiDAR data

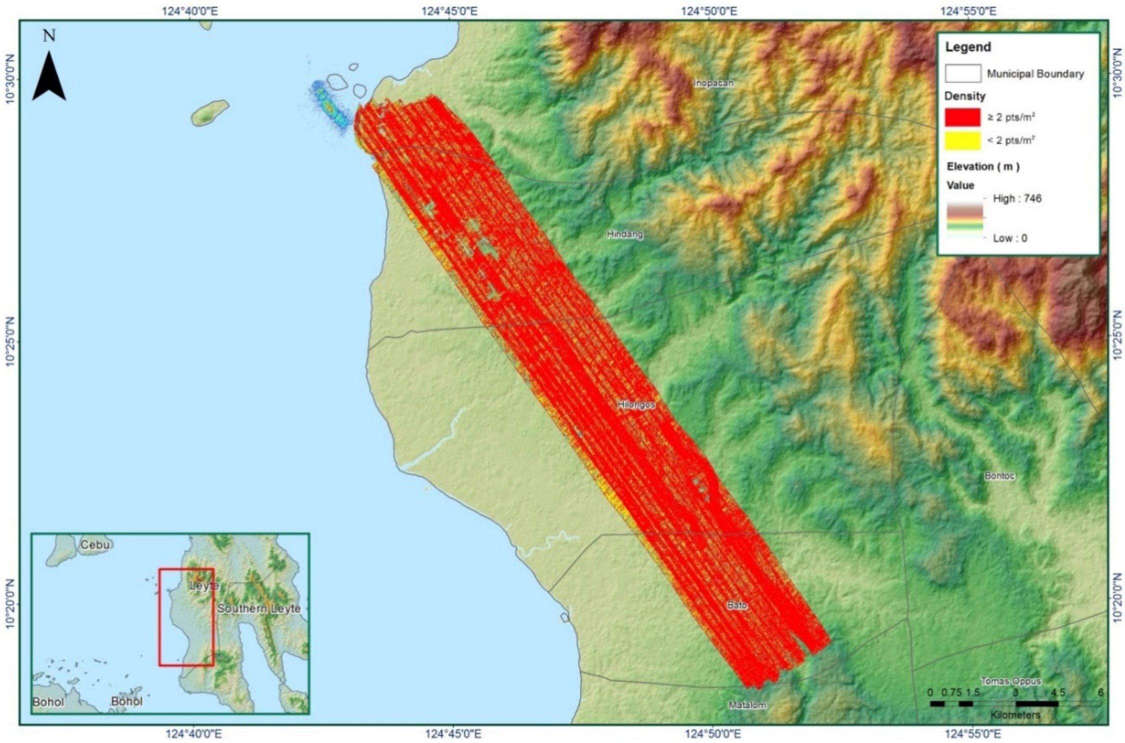


Figure A-8.12. Image of data overlap

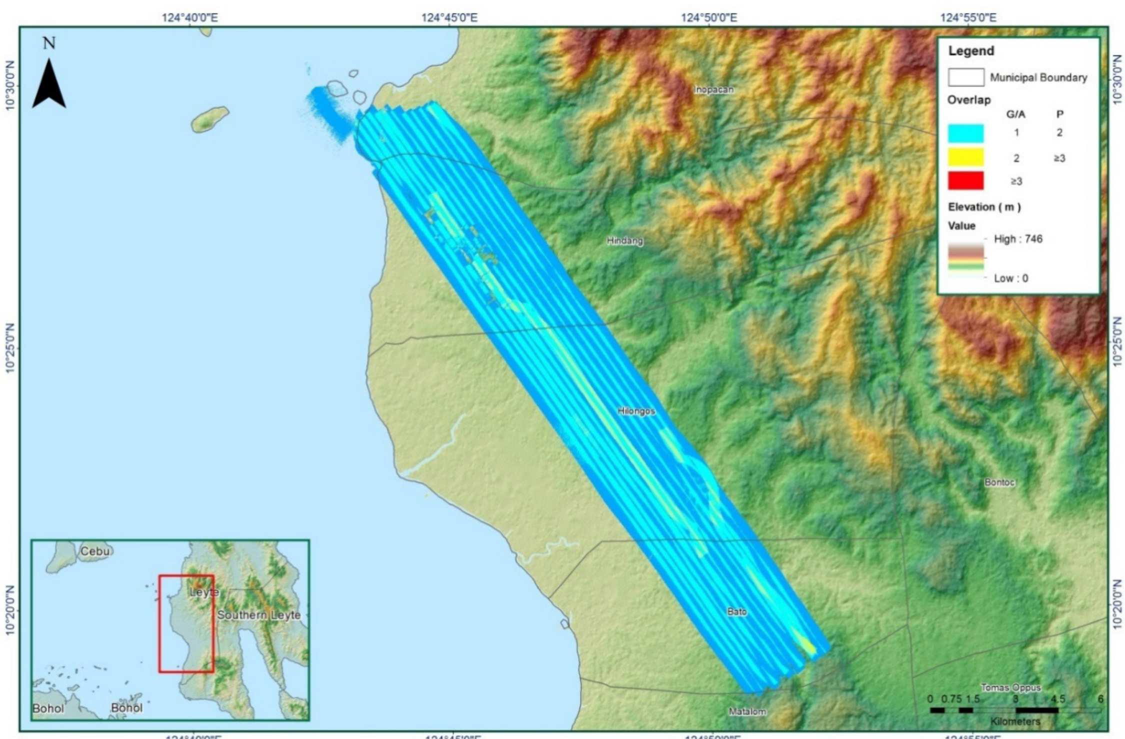


Figure A-8.13. Density map of merged LiDAR data

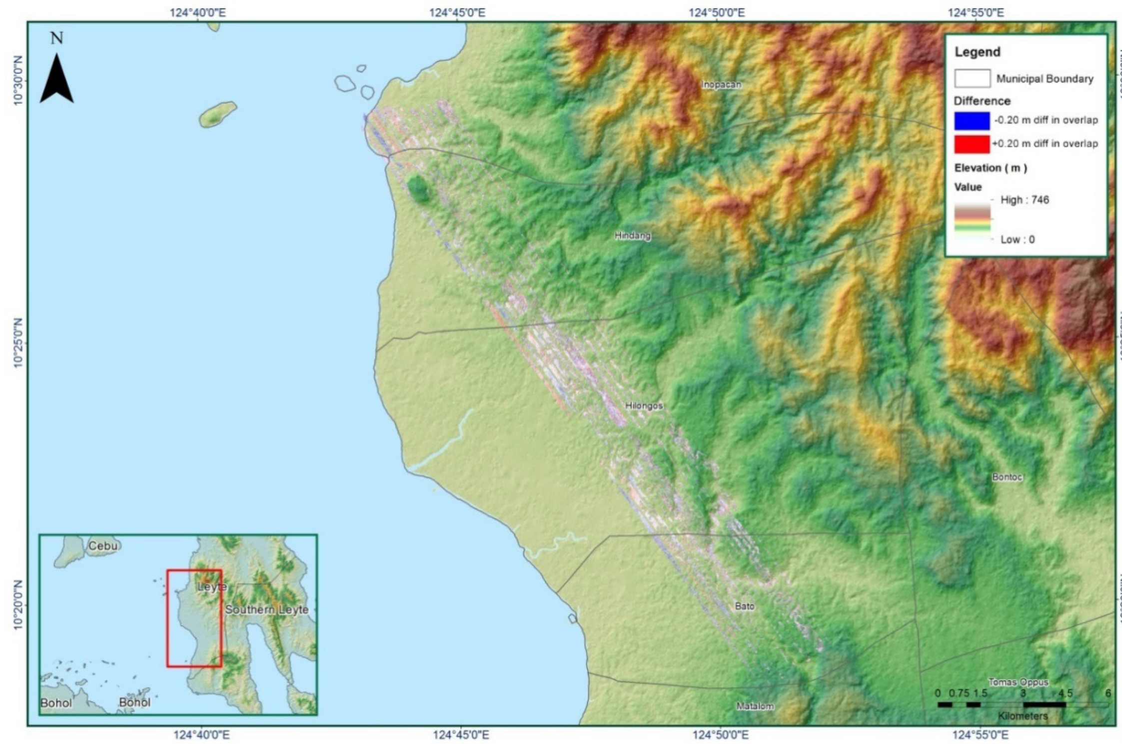


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission

Flight Area	Ormoc
Mission Name	Blk49B
Inclusive Flights	7754AC
Range data size	12.0 GB
Base data size	66.1 MB
POS	258 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)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.42
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	3.80
Boresight correction stdev (<0.001deg)	0.000342
IMU attitude correction stdev (<0.001deg)	0.002225
GPS position stdev (<0.01m)	0.0084
Minimum % overlap (>25)	31.63
Ave point cloud density per sq.m. (>2.0)	2.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	147
Maximum Height	433.58 m
Minimum Height	56.86 m
Classification (# of points)	
Ground	59,726,113
Low vegetation	67,930,344
Medium vegetation	37,488,409
High vegetation	46,296,894
Building	4,163,025
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Engr. Krisha Mae Bautista

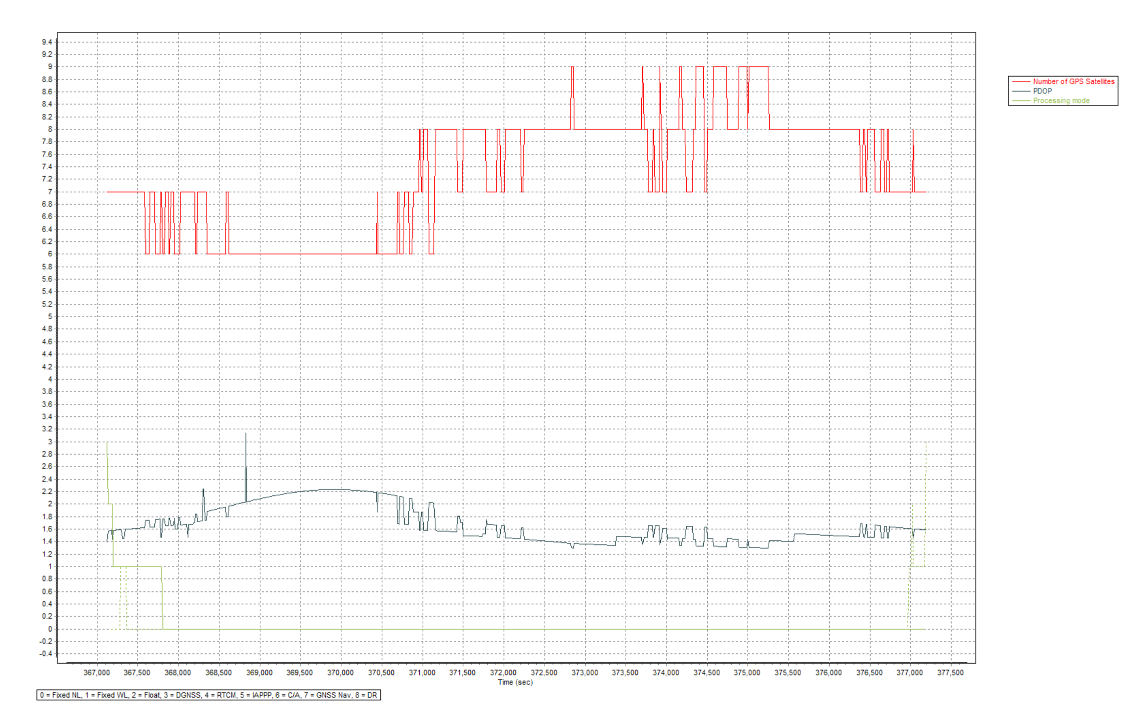


Figure A-8.15. Solution Status

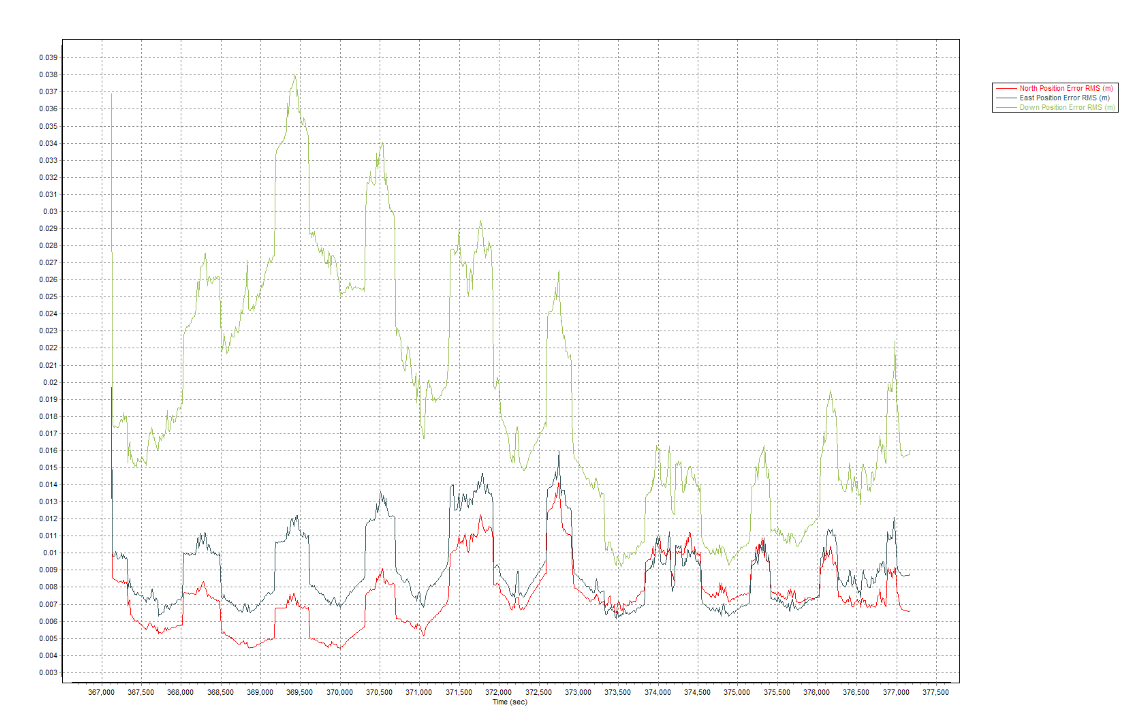


Figure A-8.16. Smoothed Performance Metric Parameters

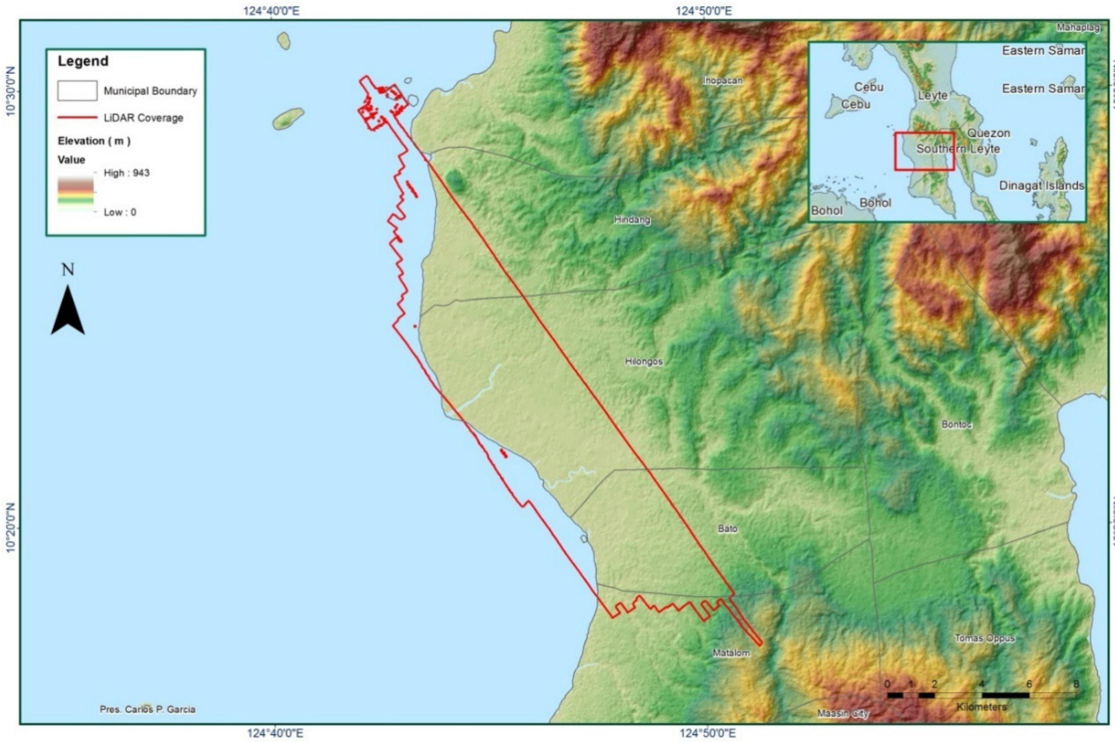


Figure A-8.17. Best Estimated Trajectory

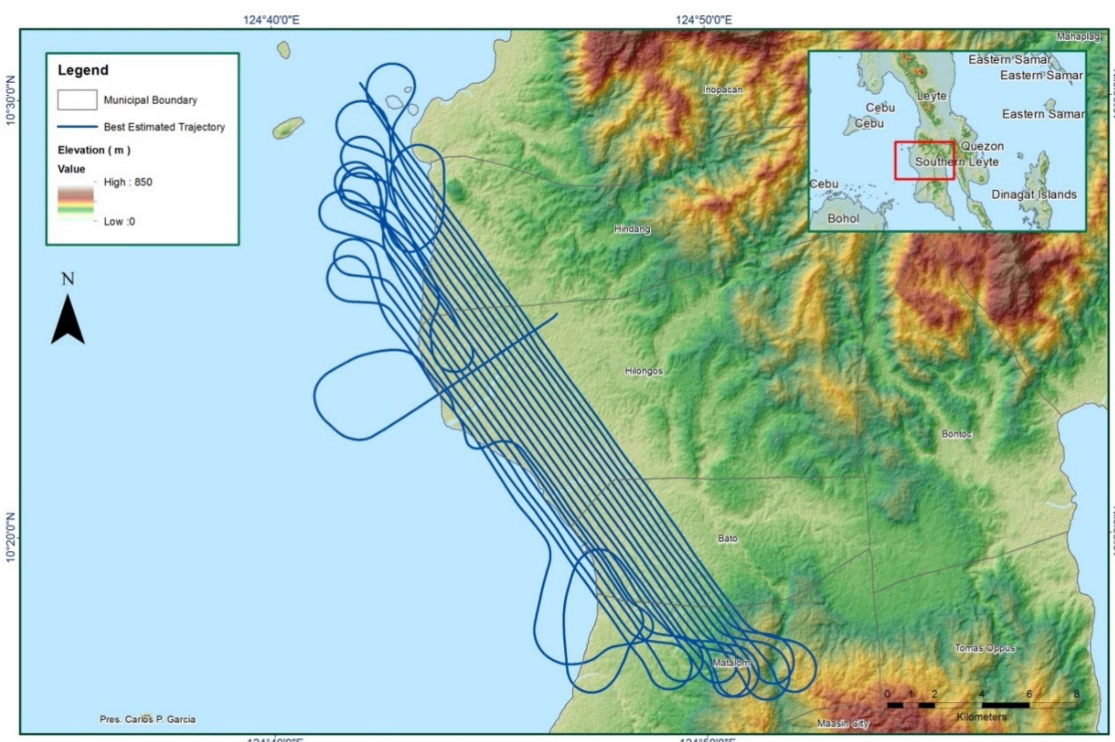


Figure A-8.18. Coverage of LiDAR data

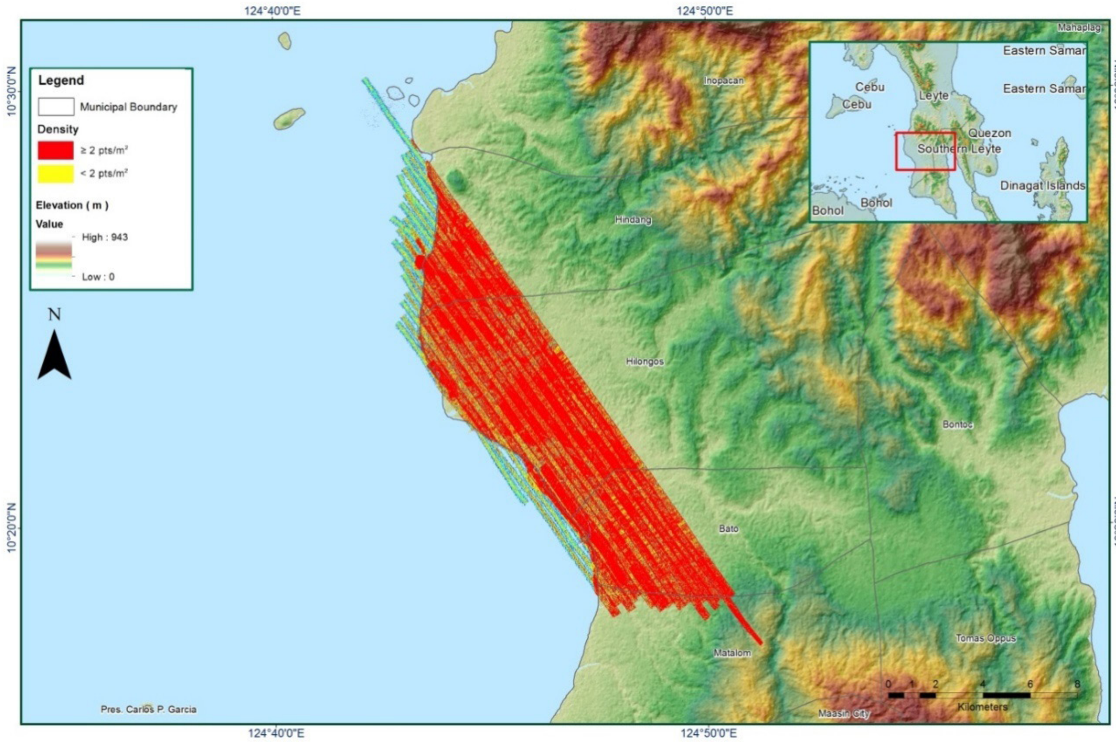


Figure A-8.19. Image of data overlap

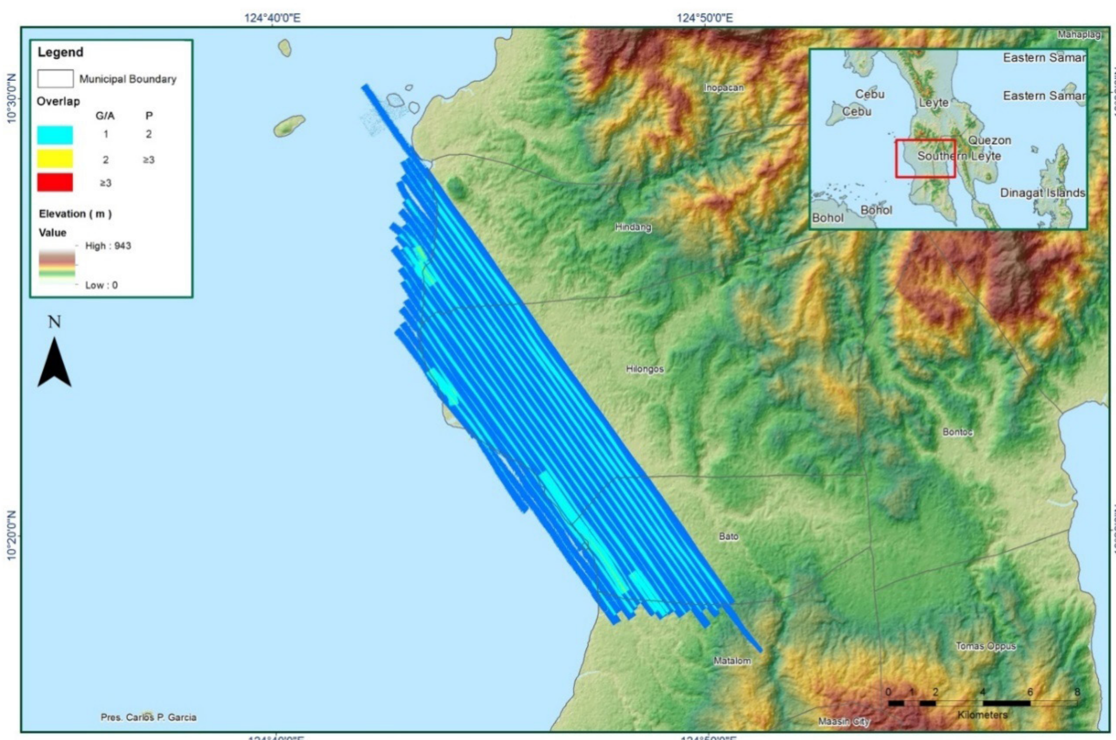


Figure A-8.20. Density map of merged LiDAR data

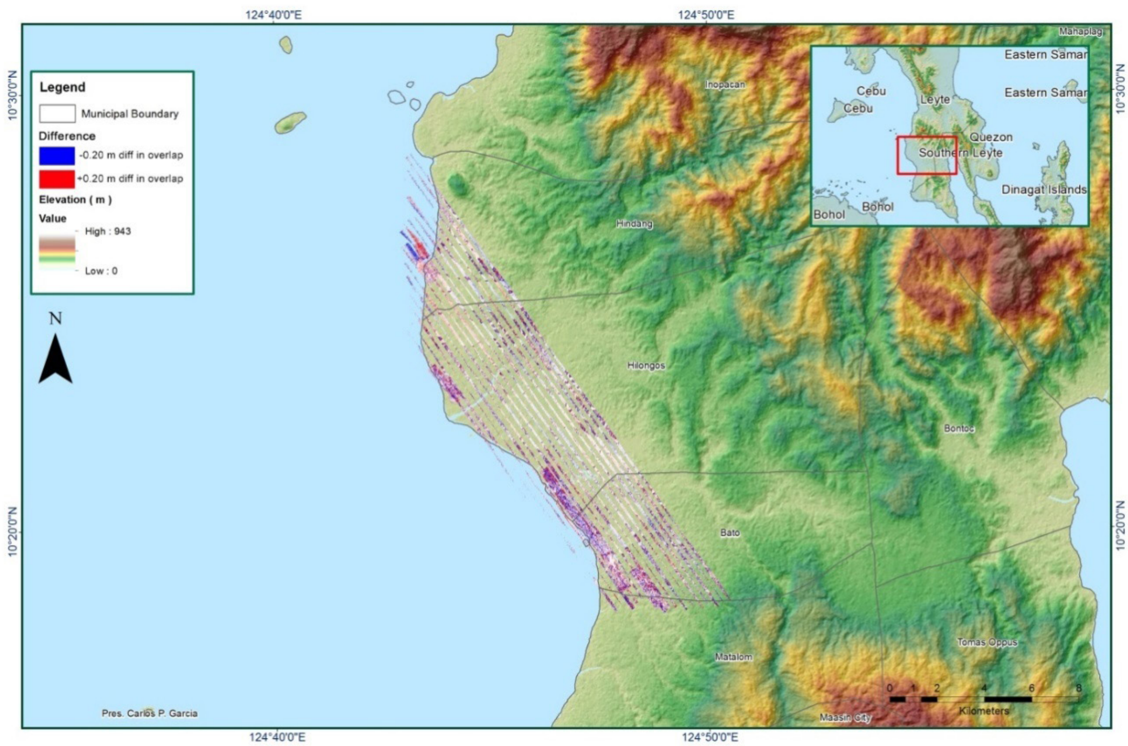


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission

Flight Area	Ormoc
Mission Name	Blk49A_voids
Inclusive Flights	7794AC
Range data size	11.9 GB
Base data size	37.5 MB
POS	252 MB
Image	n/a
Transfer date	February 25, 2015
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)	2.226
RMSE for East Position (<4.0 cm)	3.444
RMSE for Down Position (<8.0 cm)	5.151
Boresight correction stdev (<0.001deg)	0.000273
IMU attitude correction stdev (<0.001deg)	0.001690
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	9.59
Ave point cloud density per sq.m. (>2.0)	2.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	24
Maximum Height	276.52 m
Minimum Height	65.22 m
Classification (# of points)	
Ground	5,803,423
Low vegetation	2,161,013
Medium vegetation	3,109,868
High vegetation	9,280,761
Building	92,424
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Engr. Sueden Lyle Magtalas

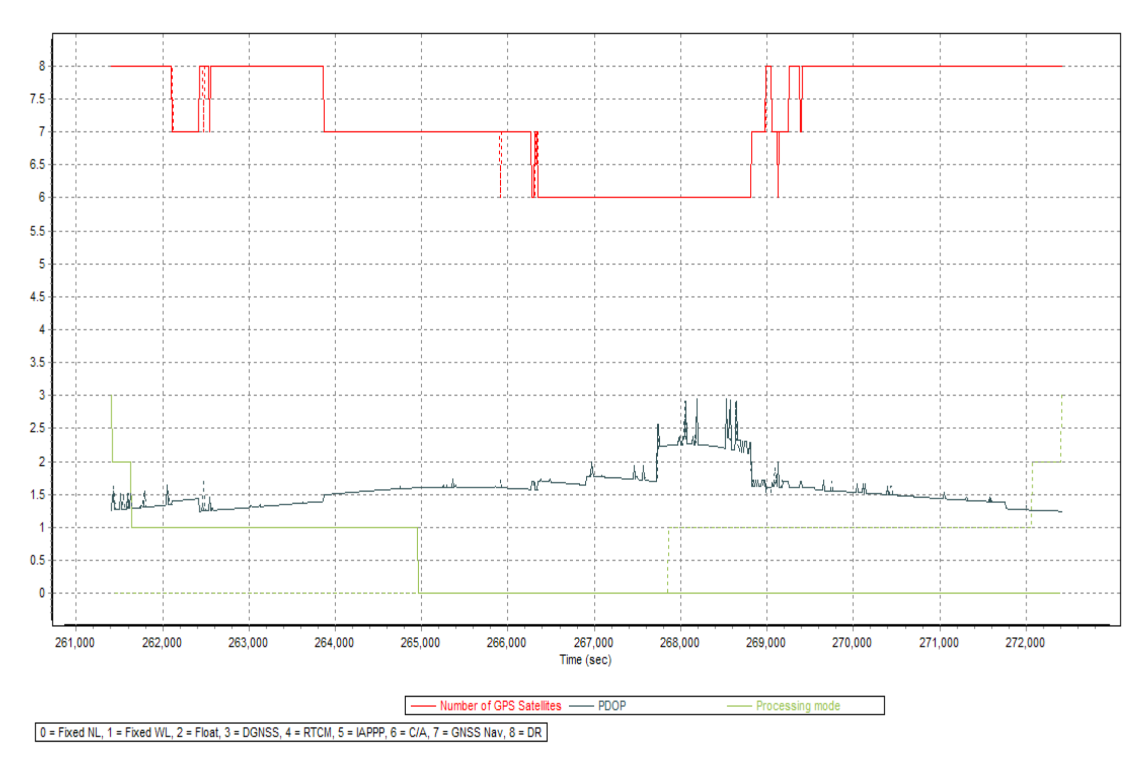


Figure A-8.22. Solution Status

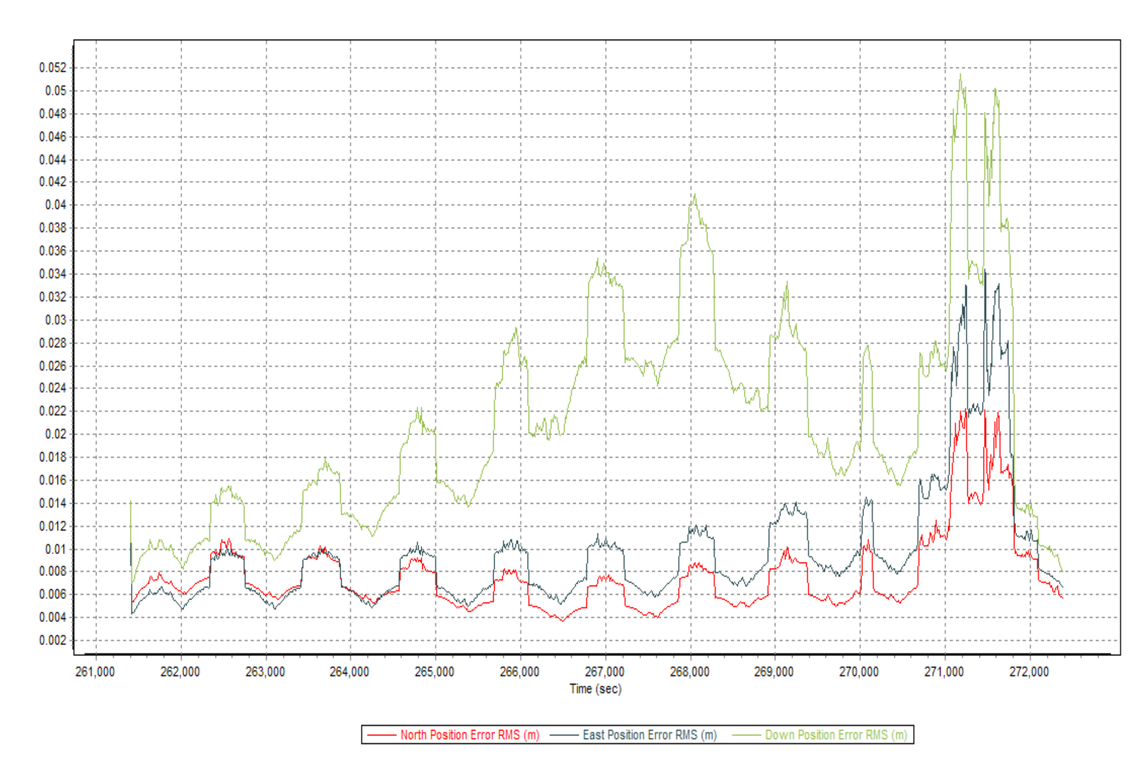


Figure A-8.23. Smoothed Performance Metric Parameters

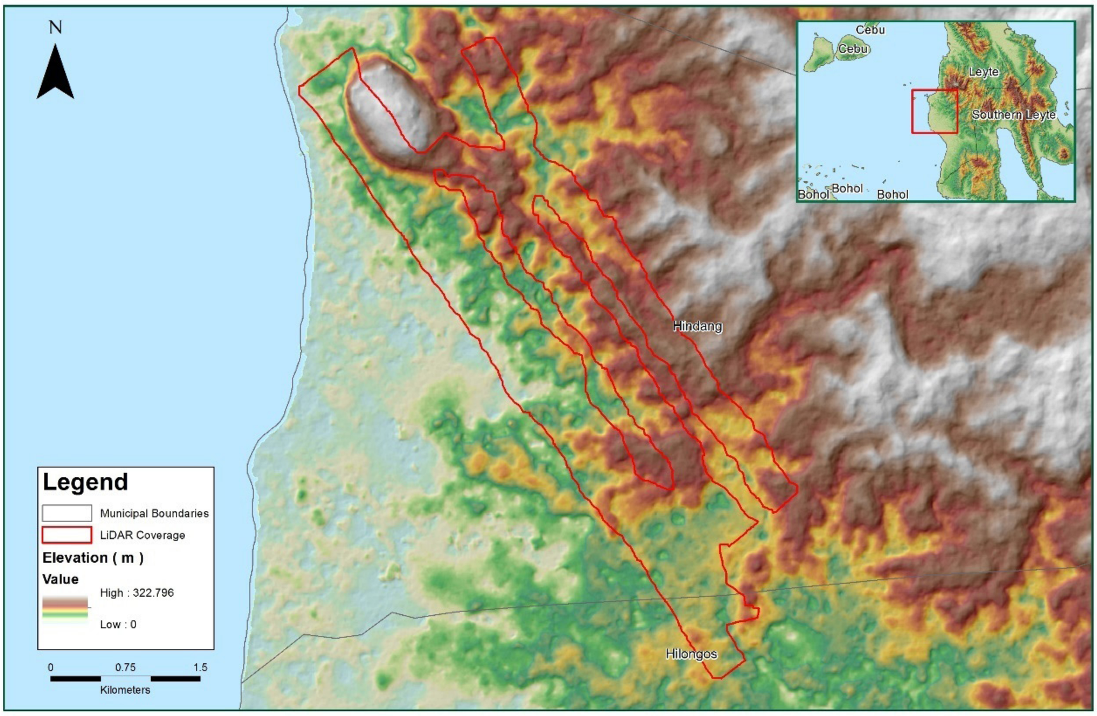


Figure A-8.24. Best Estimated Trajectory

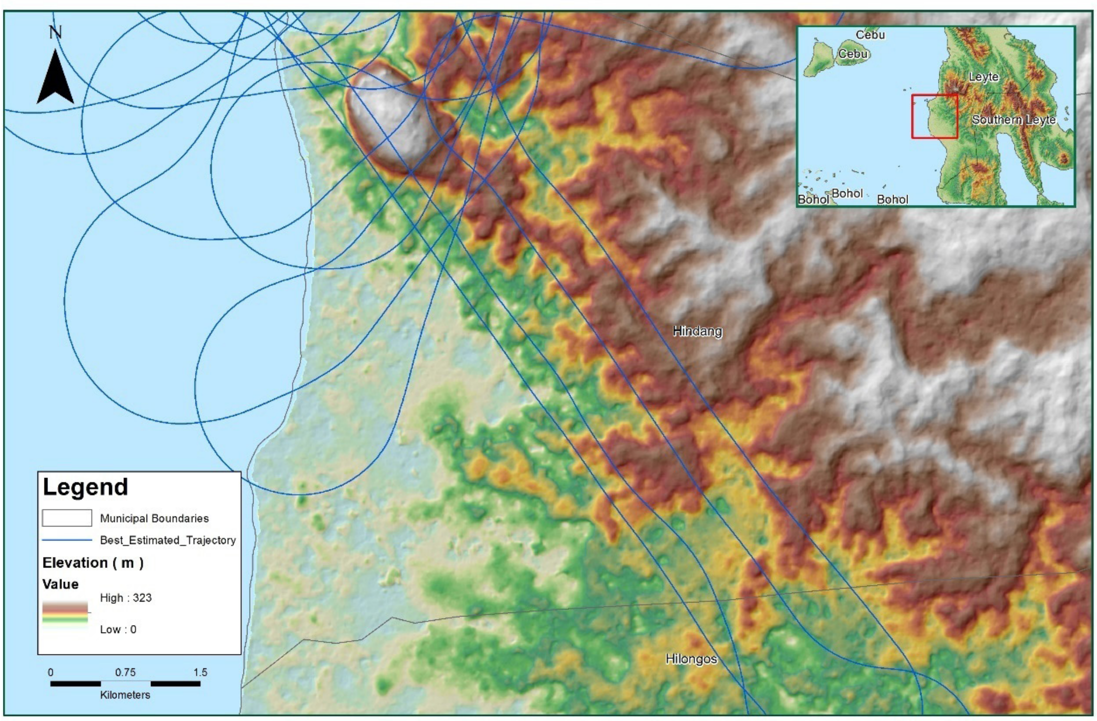


Figure A-8.25. Coverage of LiDAR data

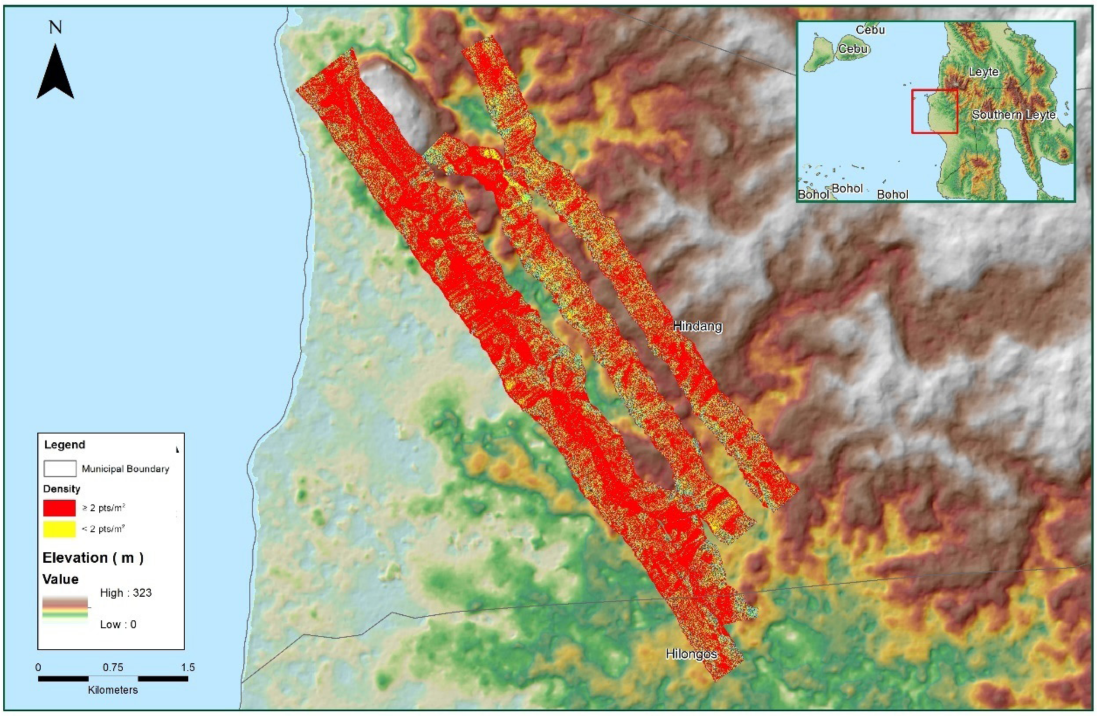


Figure A-8.26. Image of data overlap

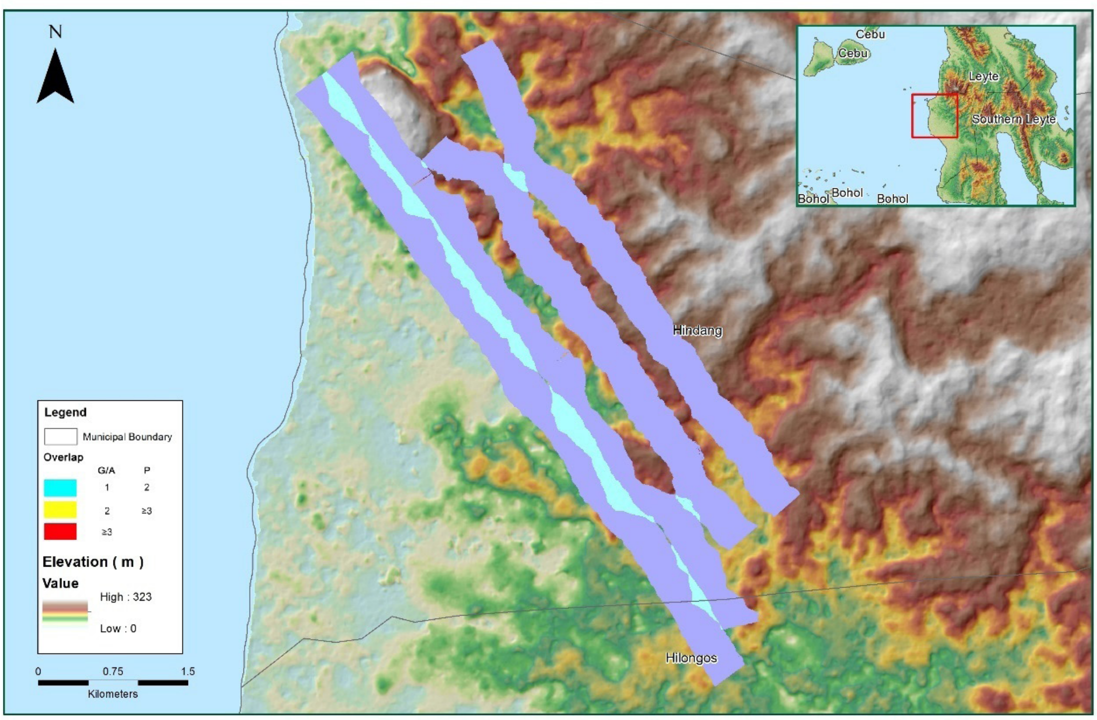


Figure A-8.27. Density map of merged LiDAR data

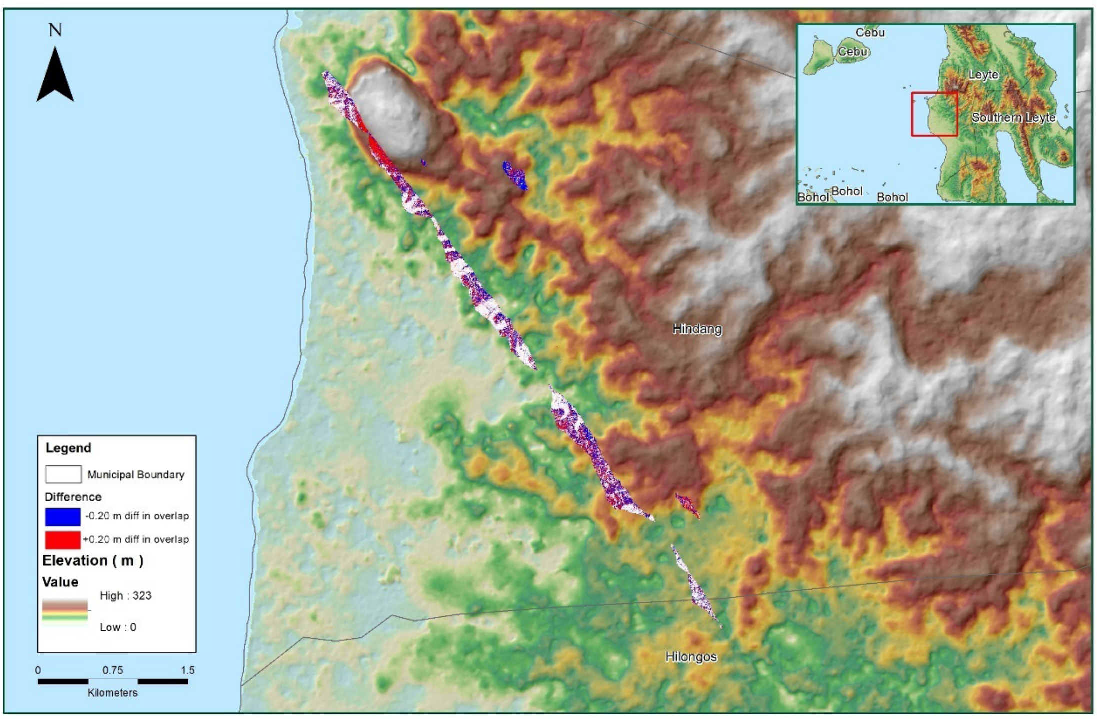


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission

Flight Area	Ormoc
Mission Name	Blk35X
Inclusive Flights	7767AC
Range data size	6.40 GB
Base data size	18.5 MB
POS	148 MB
Image	0 GB
Transfer date	March 9 2015
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)	1.06
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.75
Boresight correction stdev (<0.001deg)	0.001906
IMU attitude correction stdev (<0.001deg)	0.008205
GPS position stdev (<0.01m)	0.0216
Minimum % overlap (>25)	15.72
Ave point cloud density per sq.m. (>2.0)	1.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	58
Maximum Height	159.49 m
Minimum Height	48.87 m
Classification (# of points)	
Ground	8,653,736
Low vegetation	7,123,127
Medium vegetation	5,282,209
High vegetation	3,833,070
Building	364,065
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Alex John Escobido

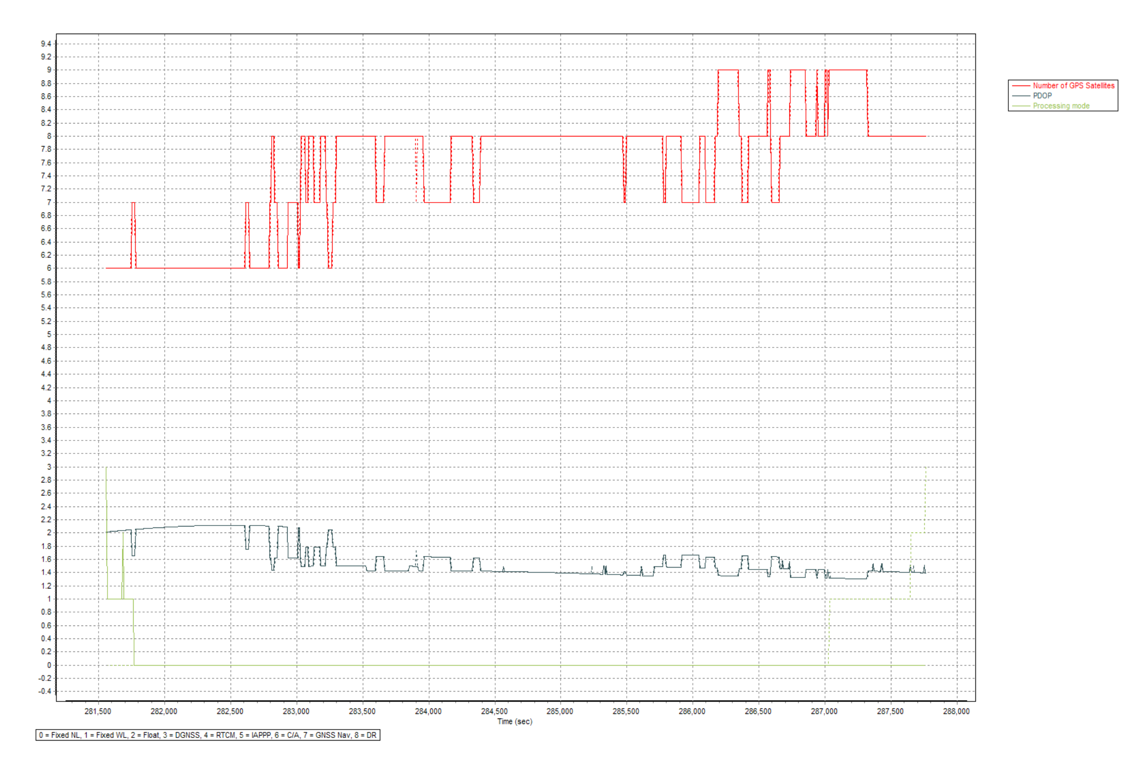


Figure A-8.29. Solution Status

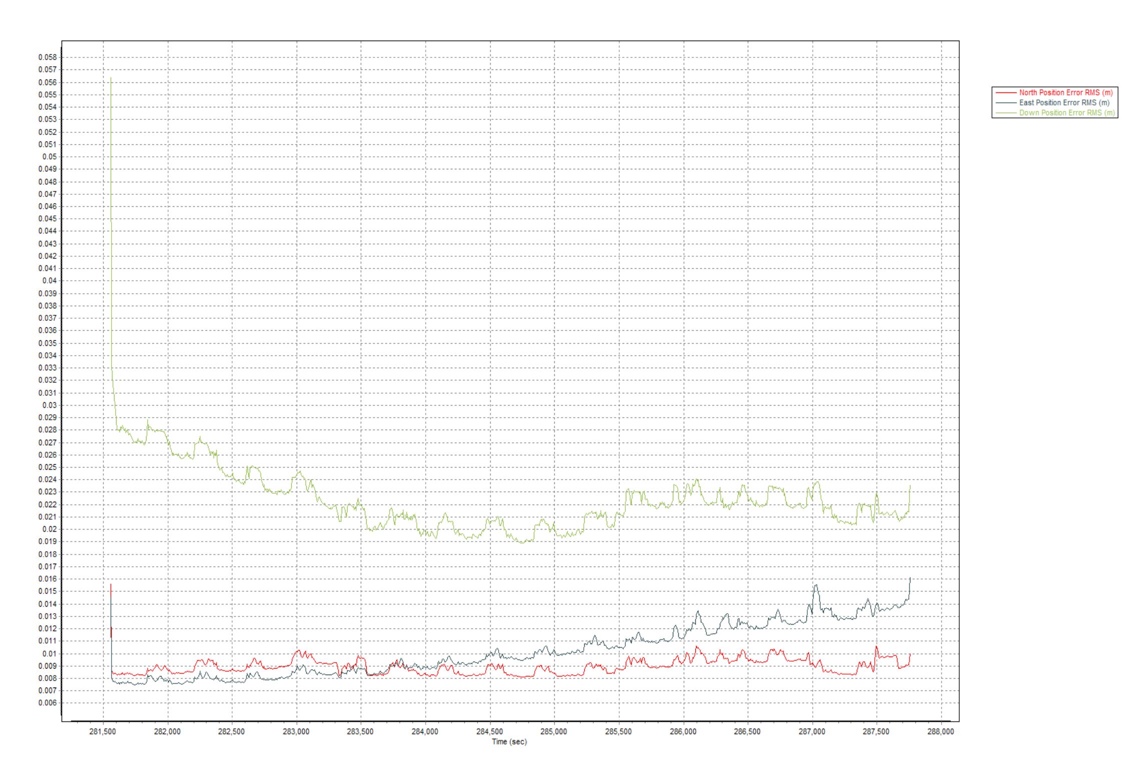


Figure A-8.30. Smoothed Performance Metric Parameters

Figure A-8.31. Best Estimated Trajectory

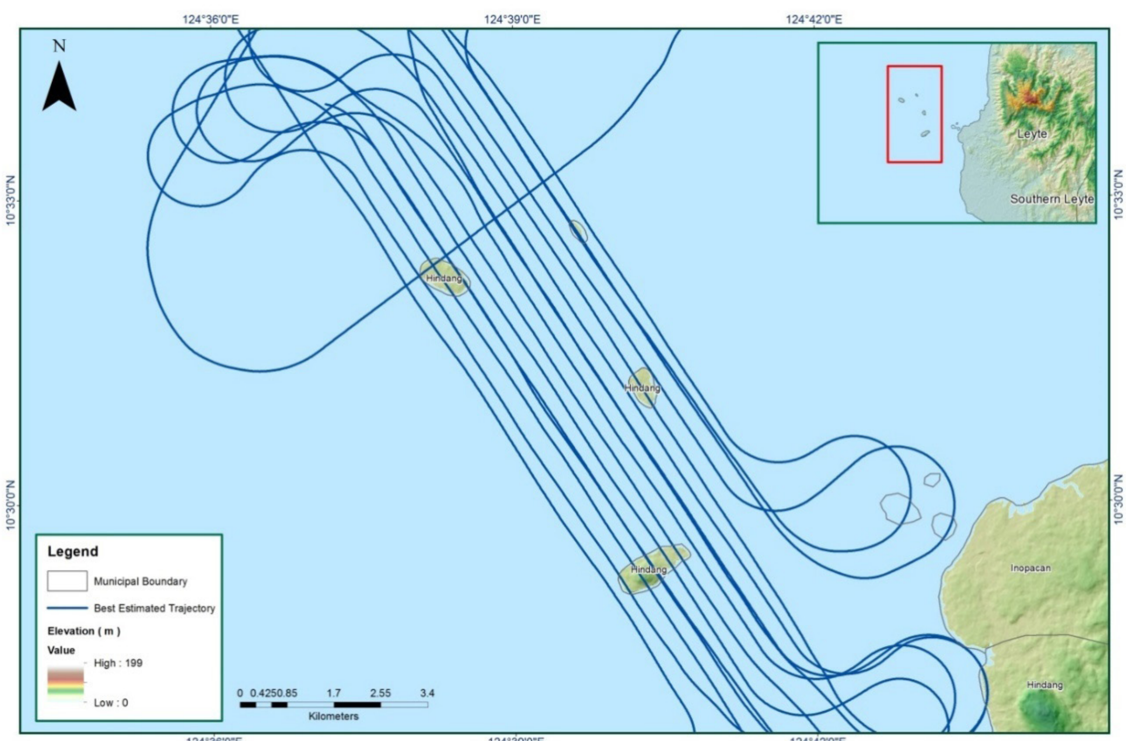


Figure A-8.32. Coverage of LiDAR data

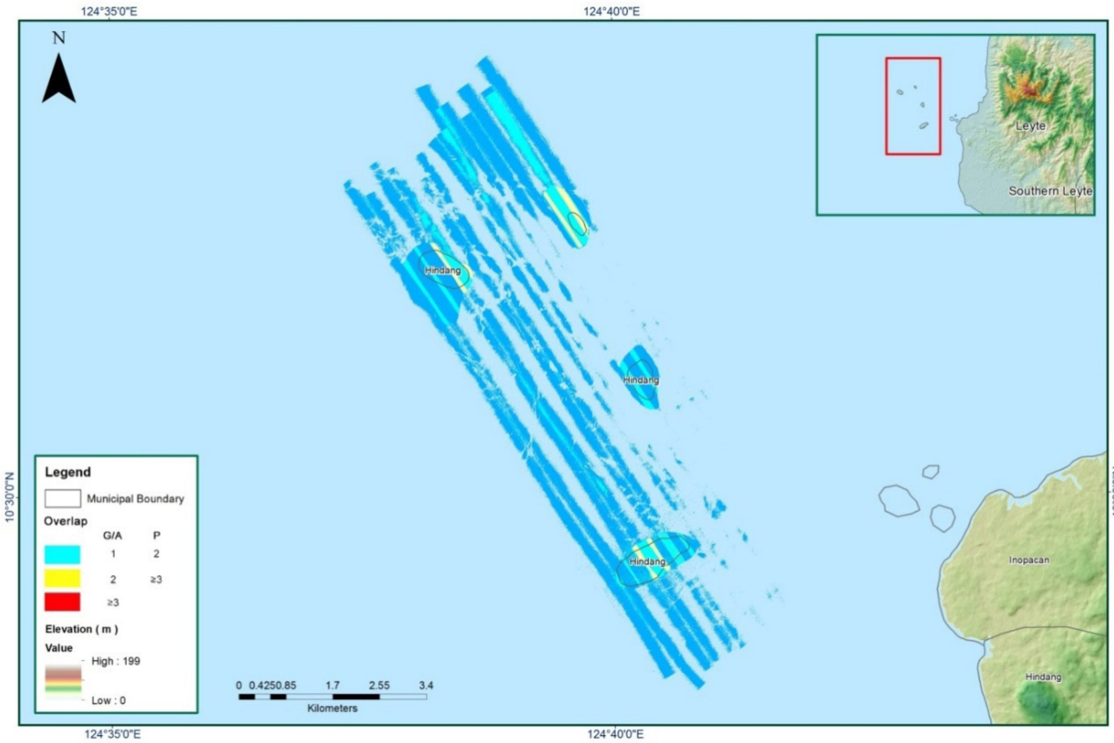


Figure A-8.33. Image of data overlap

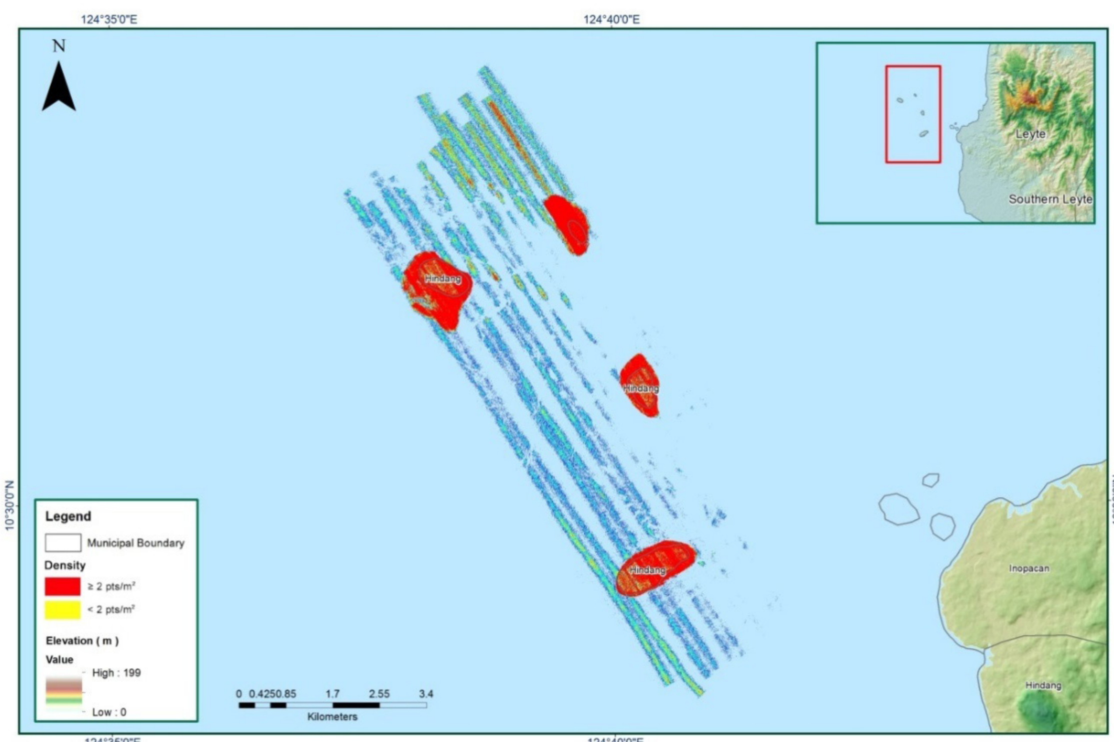


Figure A-8.34. Density map of merged LiDAR data

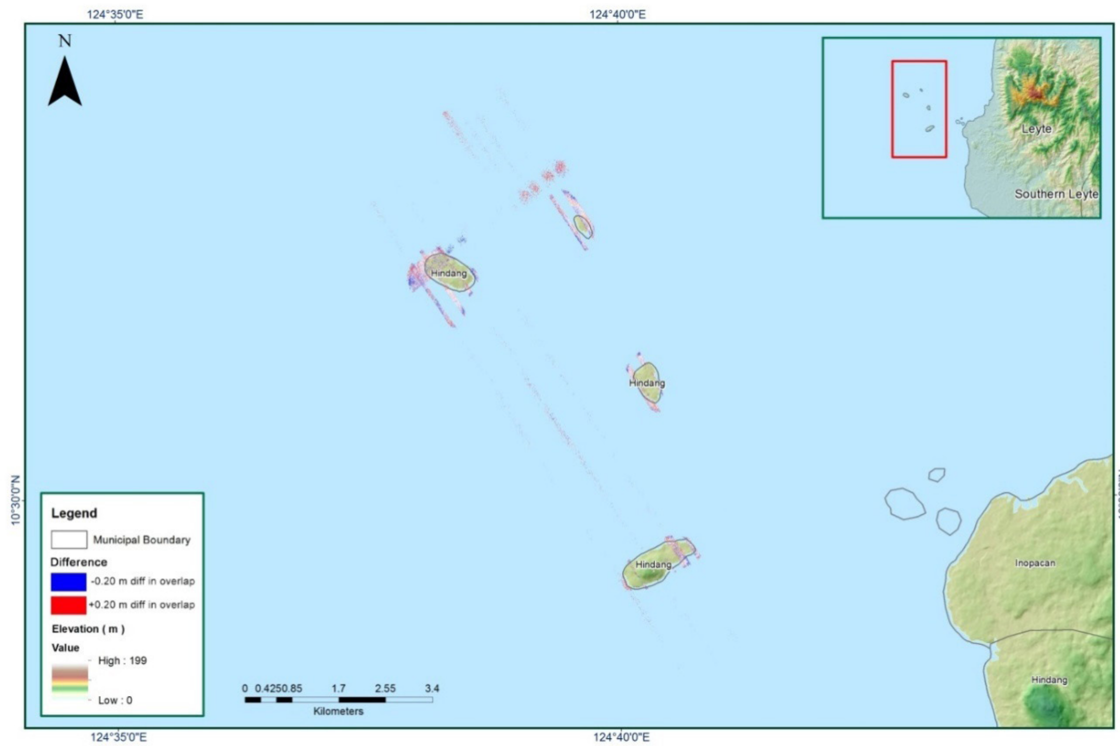


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission

Flight Area	Ormoc South
Mission Name	Blk49B
Inclusive Flights	3925G
Range data size	9.56 GB
Base data size	6.82 MB
POS	252 MB
Image	n/a
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.11
RMSE for East Position (<4.0 cm)	1.28
RMSE for Down Position (<8.0 cm)	2.98
Boresight correction stdev (<0.001deg)	0.000490
IMU attitude correction stdev (<0.001deg)	0.000662
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	17.47
Ave point cloud density per sq.m. (>2.0)	3.62
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	53
Maximum Height	291.27 m
Minimum Height	62.43 m
Classification (# of points)	
Ground	17,573,377
Low vegetation	19,151,419
Medium vegetation	35,326,556
High vegetation	37,079,112
Building	956,549
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan

Figure A-8.36. Solution Status

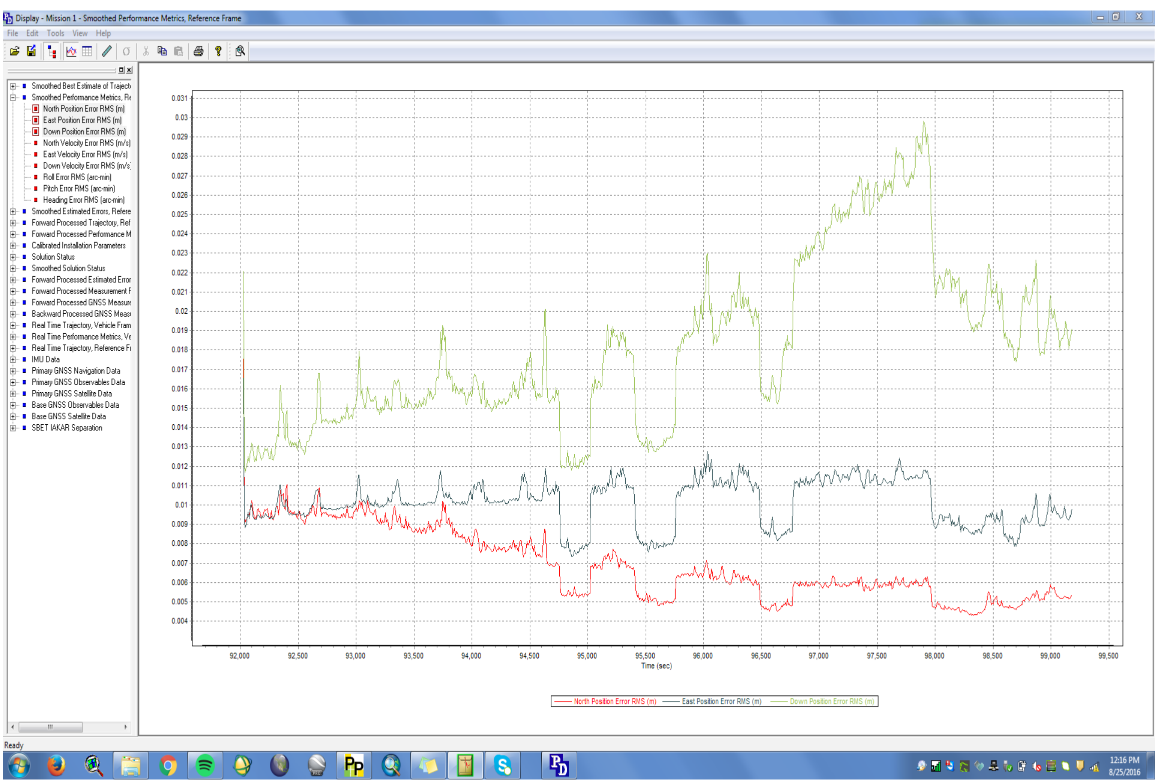


Figure A-8.37. Smoothed Performance Metric Parameters

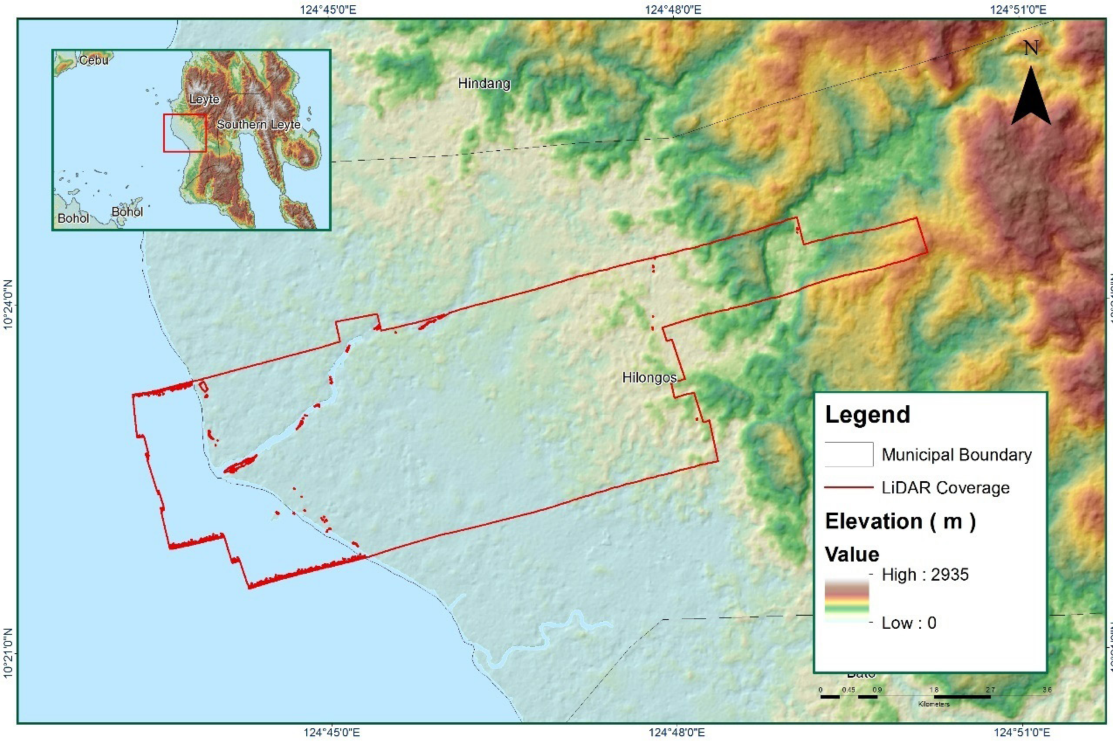


Figure A-8.38. Best Estimated Trajectory

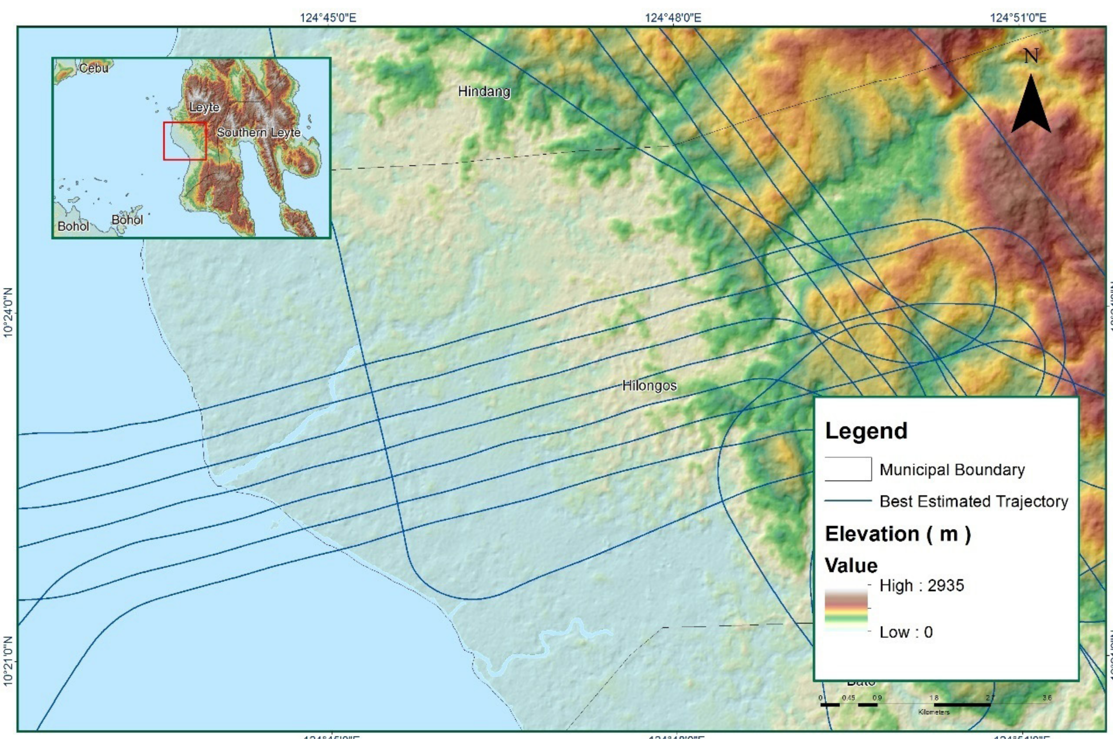


Figure A-8.39. Coverage of LiDAR data

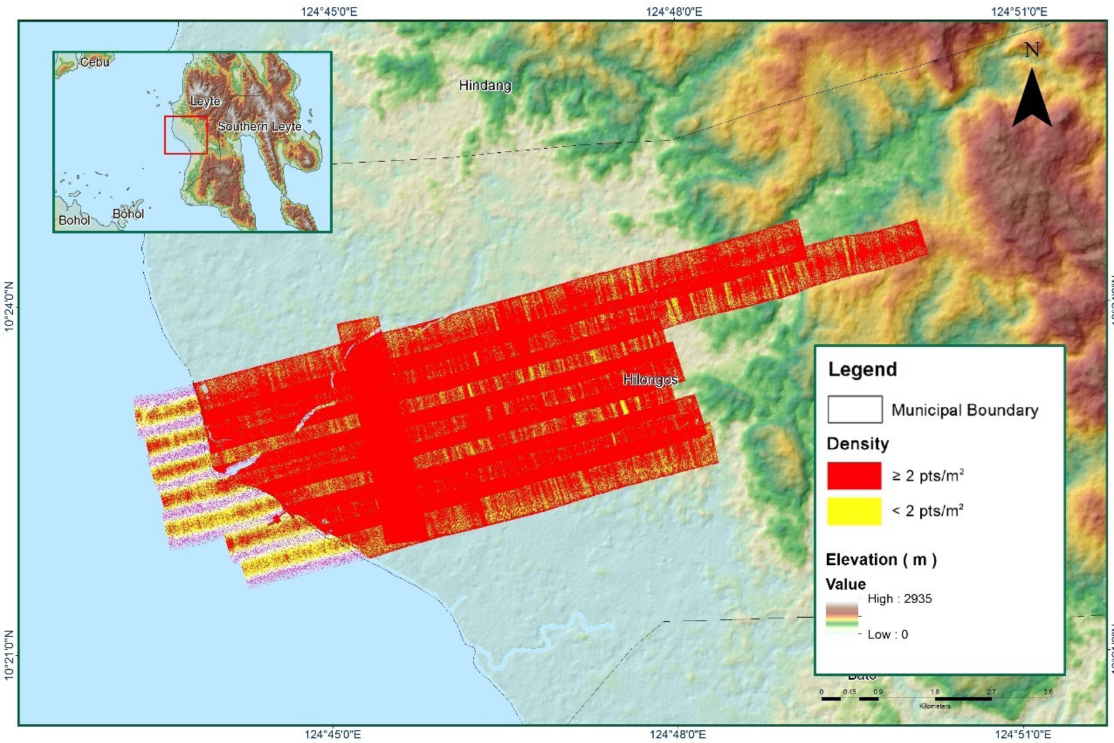


Figure A-8.40. Image of data overlap

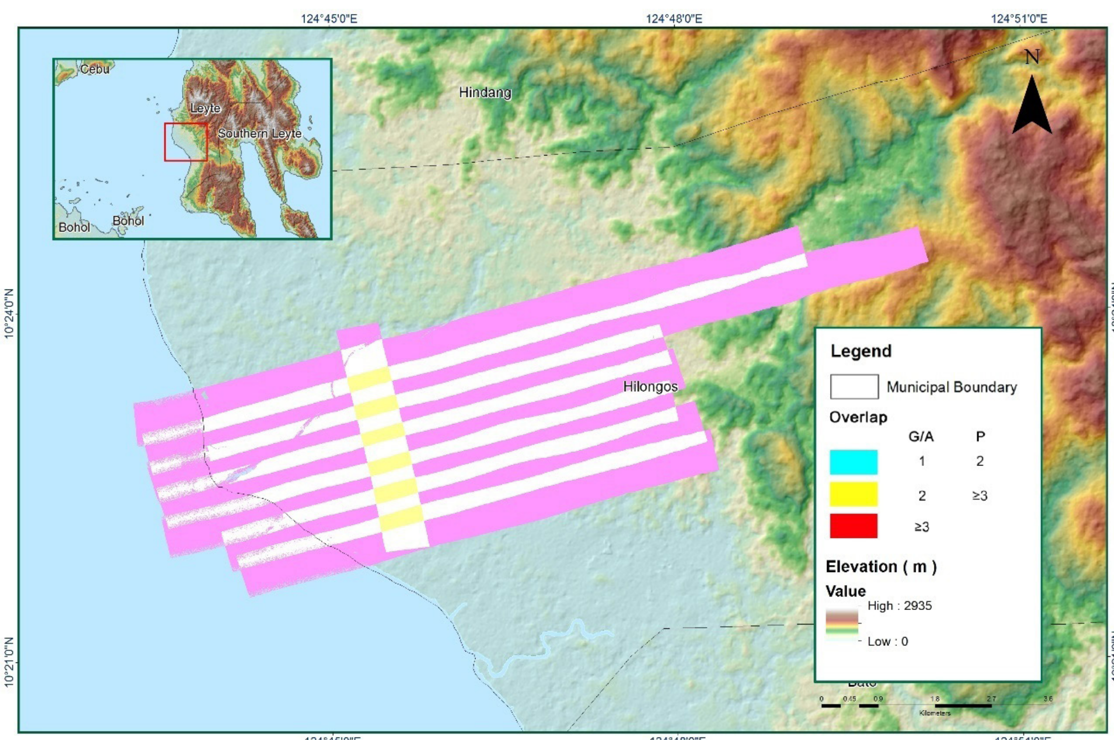


Figure A-8.41. Density map of merged LiDAR data

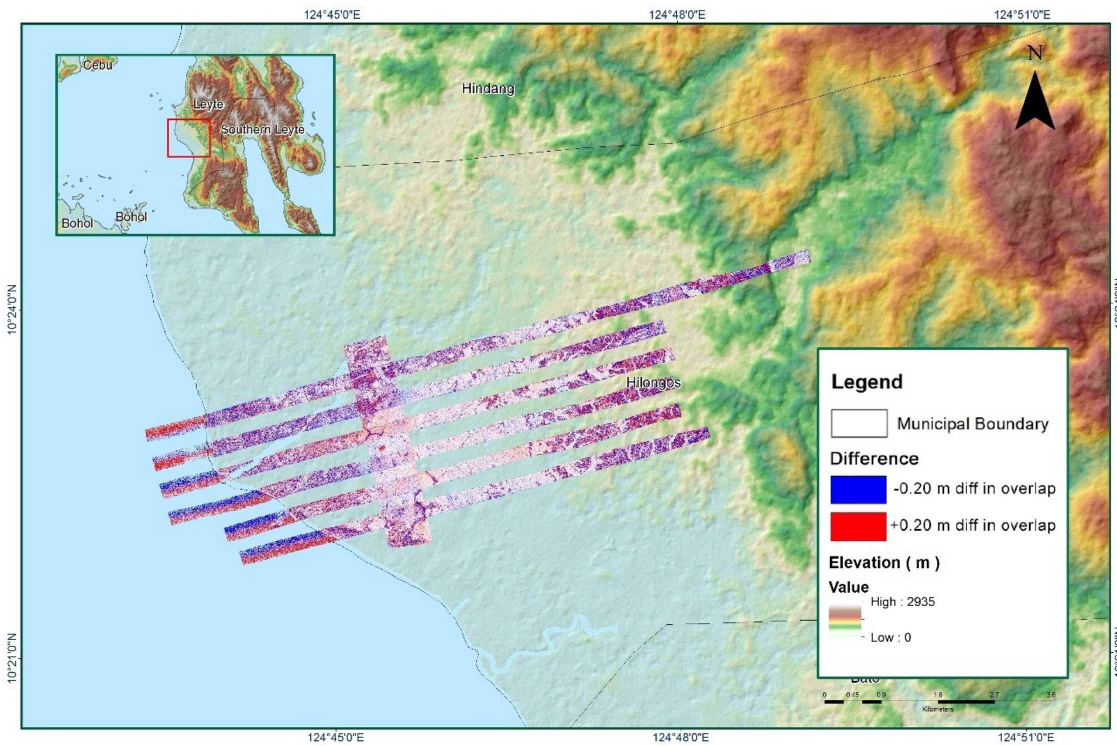


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission

Flight Area	Ormoc South
Mission Name	Blk49A
Inclusive Flights	3921G, 3923G
Range data size	29 GB
Base data size	38.2 MB
POS	443 MB
Image	n/a
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)	1.21
RMSE for East Position (<4.0 cm)	1.75
RMSE for Down Position (<8.0 cm)	2.76
Boresight correction stdev (<0.001deg)	0.000174
IMU attitude correction stdev (<0.001deg)	0.000700
GPS position stdev (<0.01m)	0.0065
Minimum % overlap (>25)	31.34
Ave point cloud density per sq.m. (>2.0)	4.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	169
Maximum Height	480.55 m
Minimum Height	65.17 m
Classification (# of points)	
Ground	51,839,234
Low vegetation	37,957,751
Medium vegetation	140,088,597
High vegetation	297,623,794
Building	650,432
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Analyn Naldo, Engr. Velina Angela Bemida, Engr. Monalyne Rabino

Figure A-8.43. Solution Status

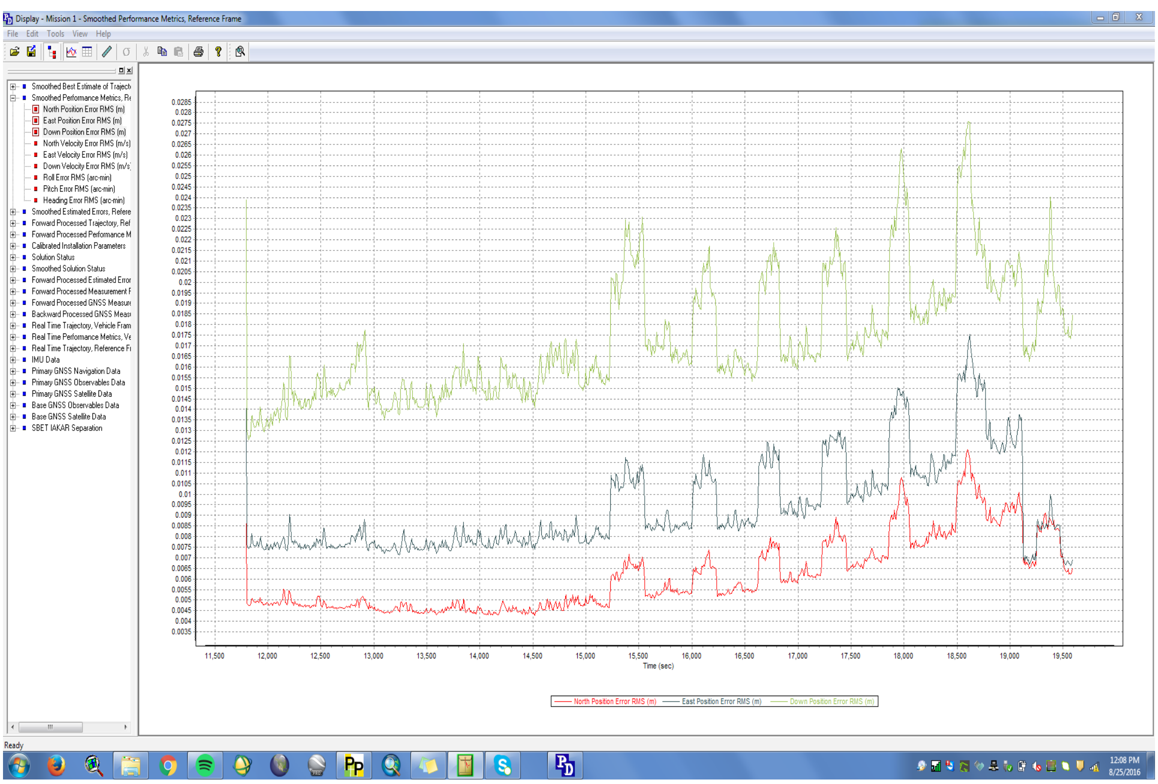


Figure A-8.44. Smoothed Performance Metric Parameters

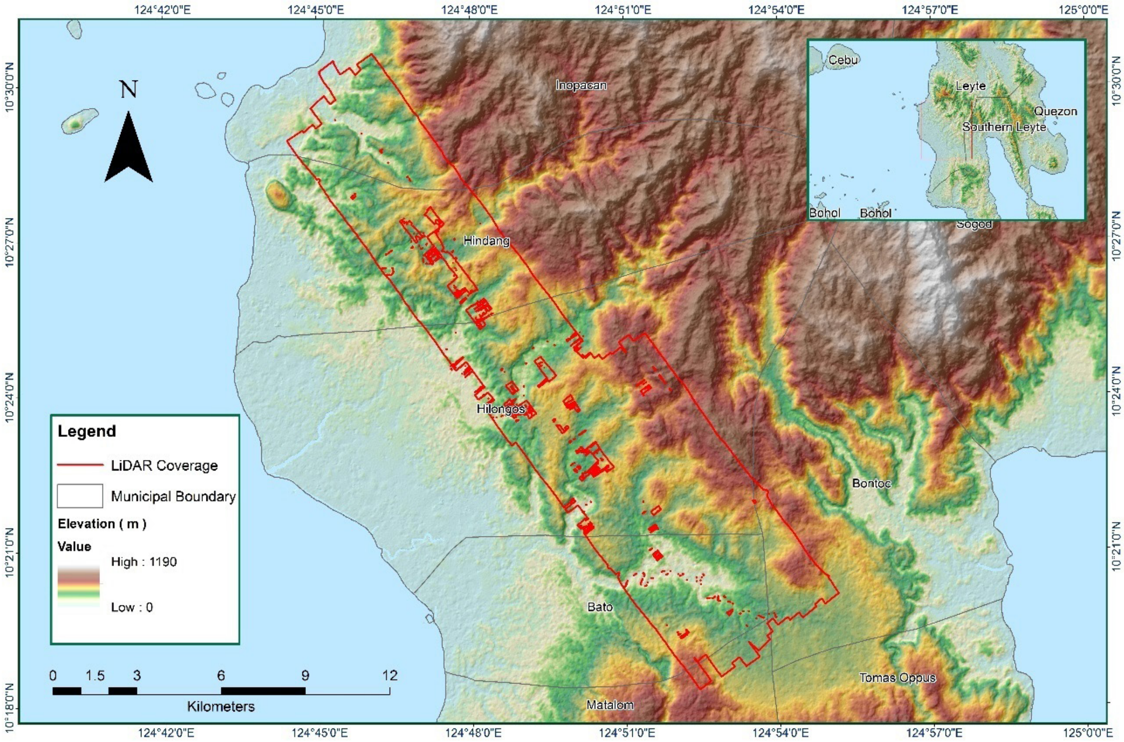


Figure A-8.45. Best Estimated Trajectory

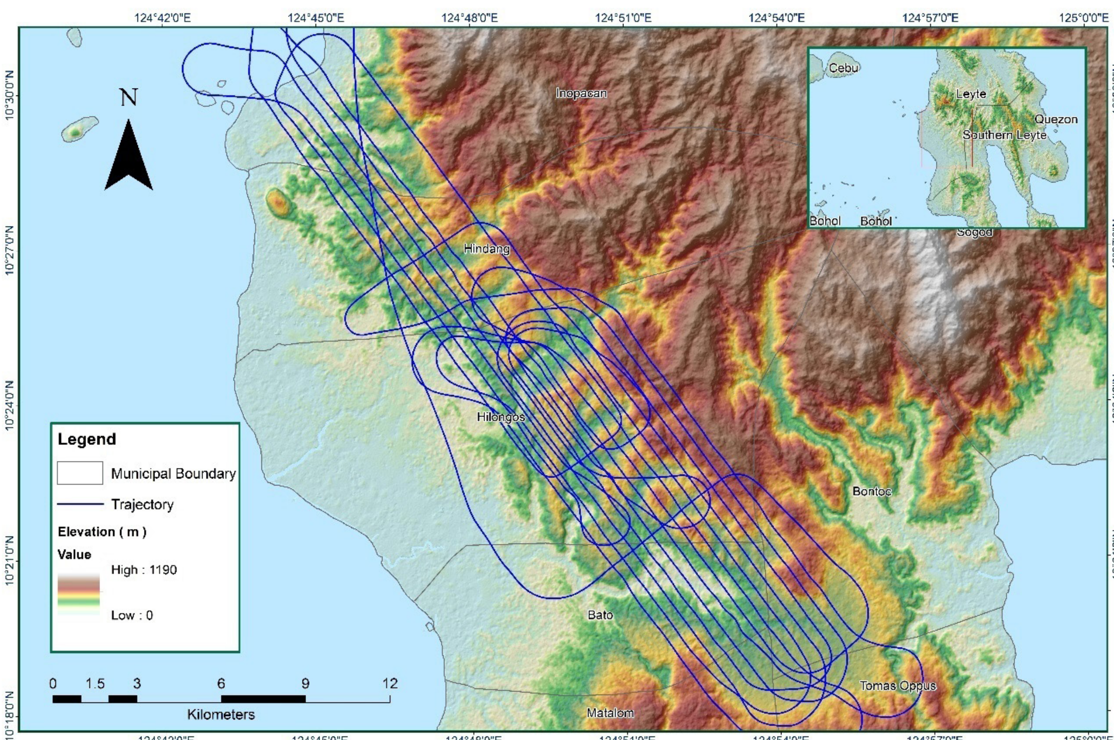


Figure A-8.46. Coverage of LiDAR data

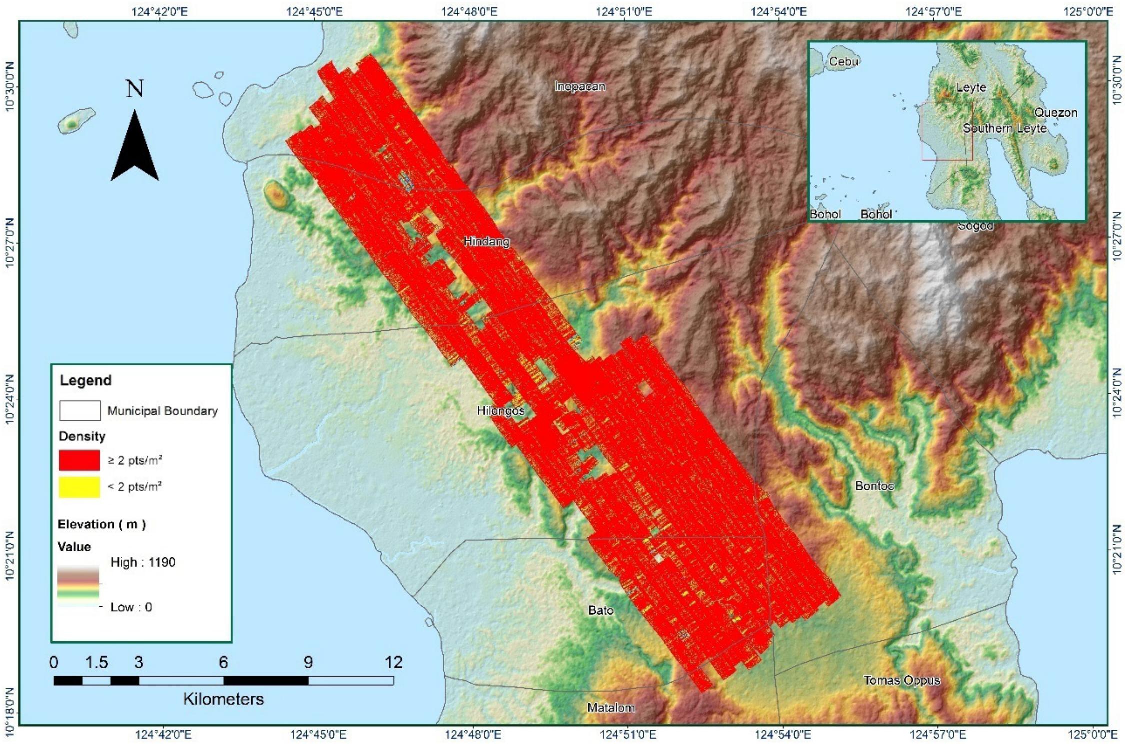


Figure A-8.47. Image of data overlap

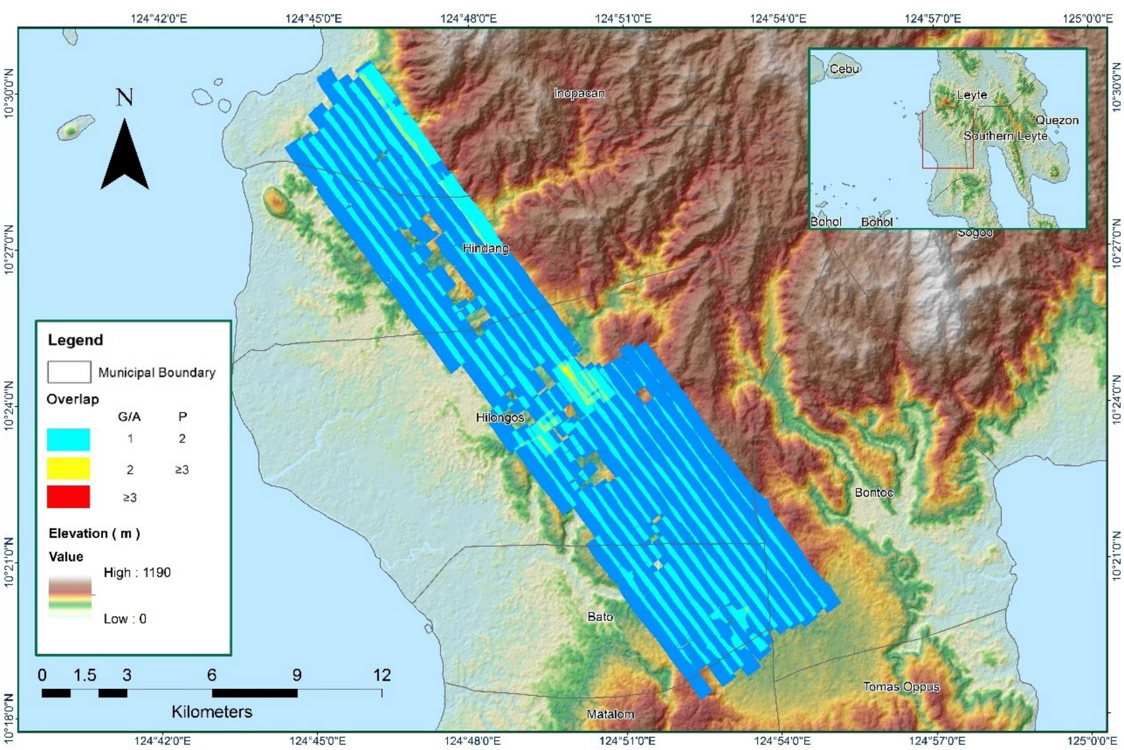


Figure A-8.48. Density map of merged LiDAR data

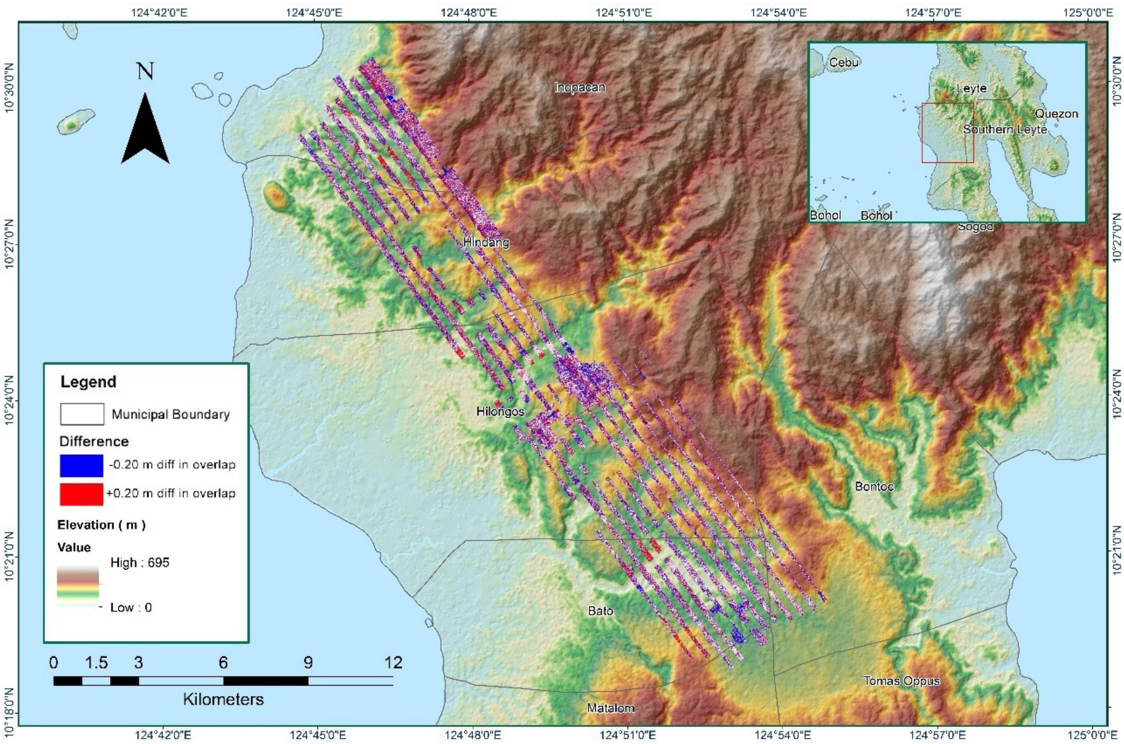


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission

Flight Area	Ormoc South
Mission Name	Blk49A_additional
Inclusive Flights	3925G
Range data size	9.56 GB
Base data size	6.82 MB
POS	252 MB
Image	n/a
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)	0.977
RMSE for East Position (<4.0 cm)	1.22
RMSE for Down Position (<8.0 cm)	1.89
Boresight correction stdev (<0.001deg)	0.000818
IMU attitude correction stdev (<0.001deg)	0.018148
GPS position stdev (<0.01m)	0.0273
Minimum % overlap (>25)	31.34
Ave point cloud density per sq.m. (>2.0)	4.21
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	68
Maximum Height	429.74 m
Minimum Height	80.81 m
Classification (# of points)	
Ground	17,634,616
Low vegetation	8,633,681
Medium vegetation	27,765,599
High vegetation	63,962,261
Building	98,554
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Engr. Karl Adrian Vergara

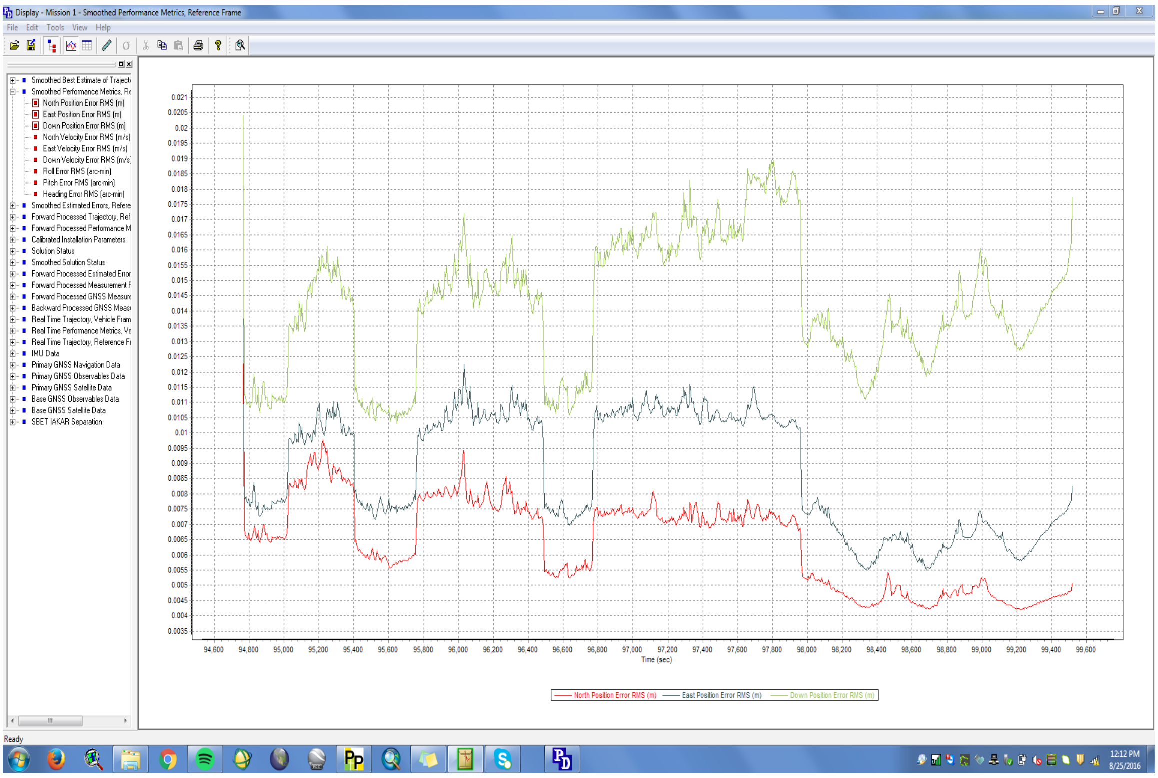


Figure A-8.50. Solution Status

Figure A-8.51. Smoothed Performance Metric Parameters

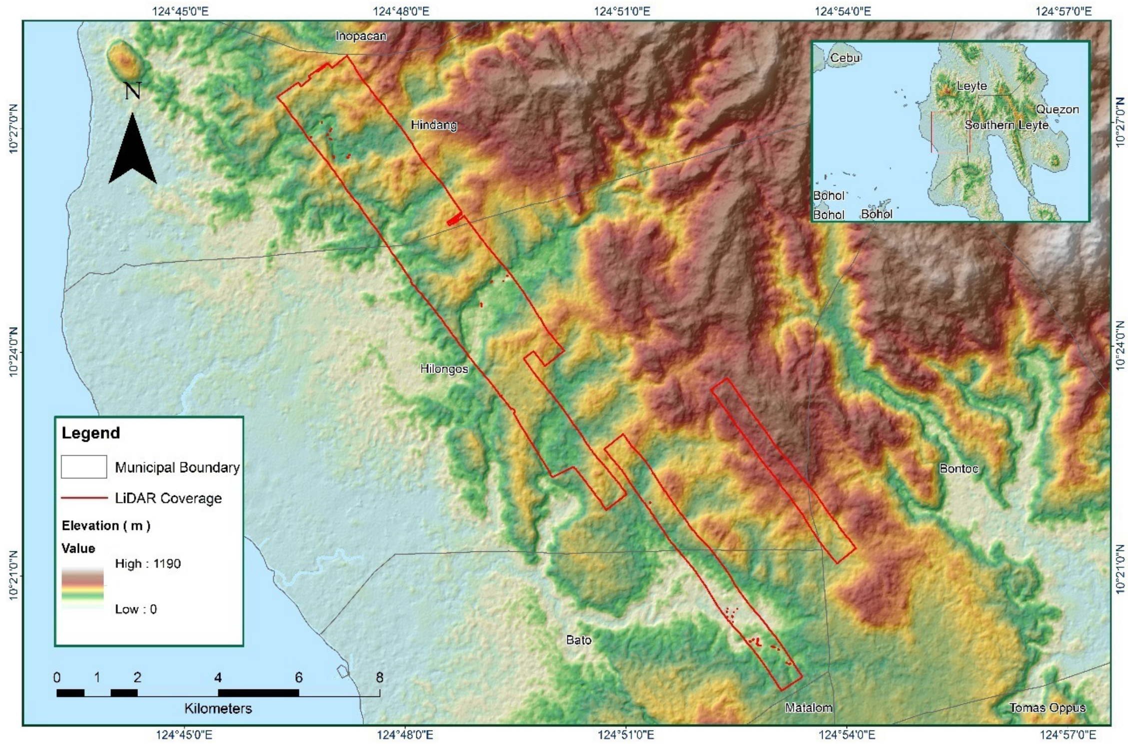


Figure A-8.52. Best Estimated Trajectory

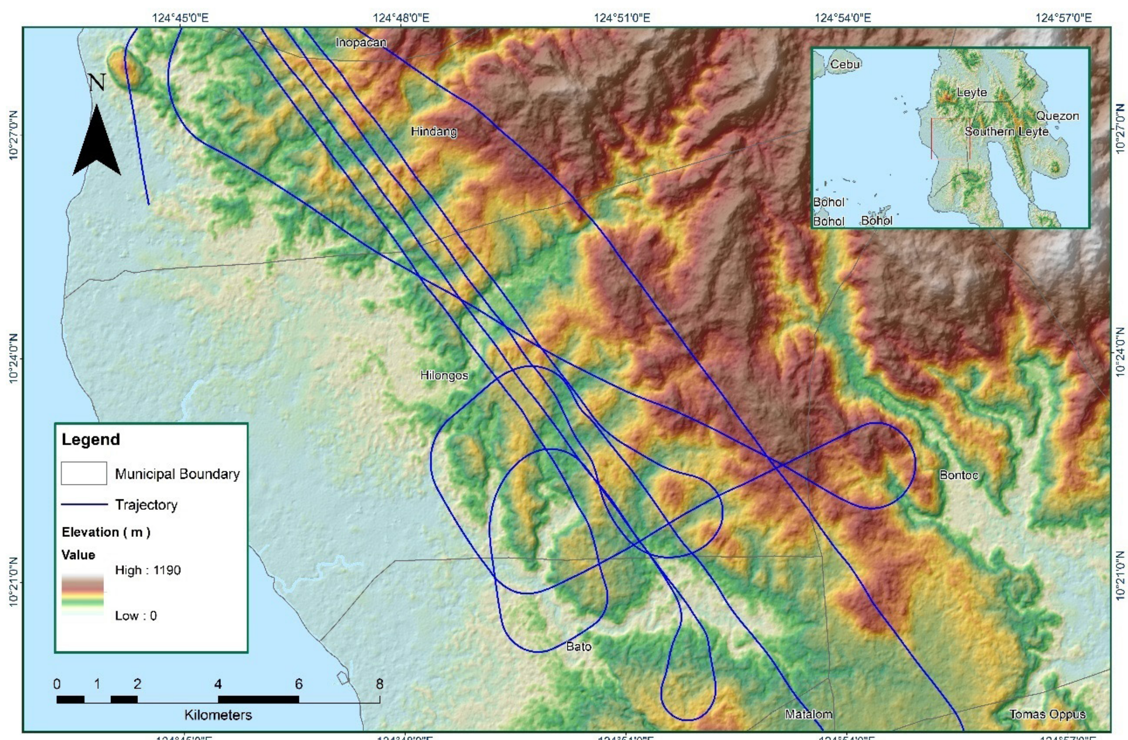


Figure A-8.53. Coverage of LiDAR data

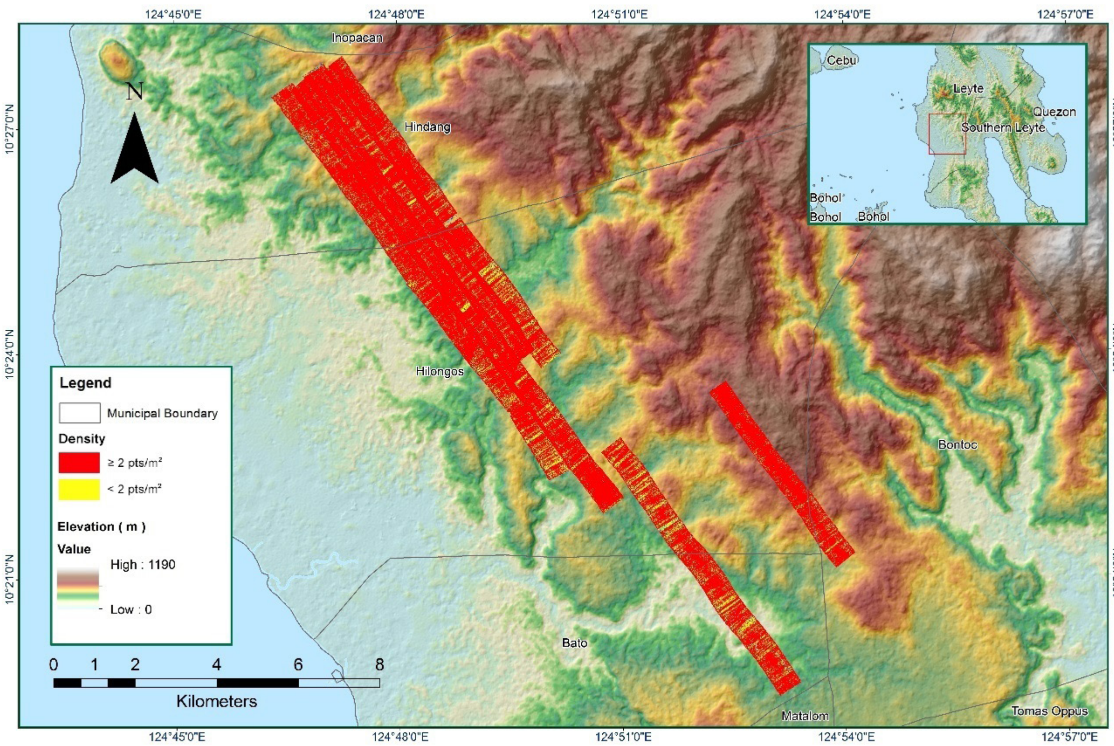


Figure A-8.54. Image of data overlap

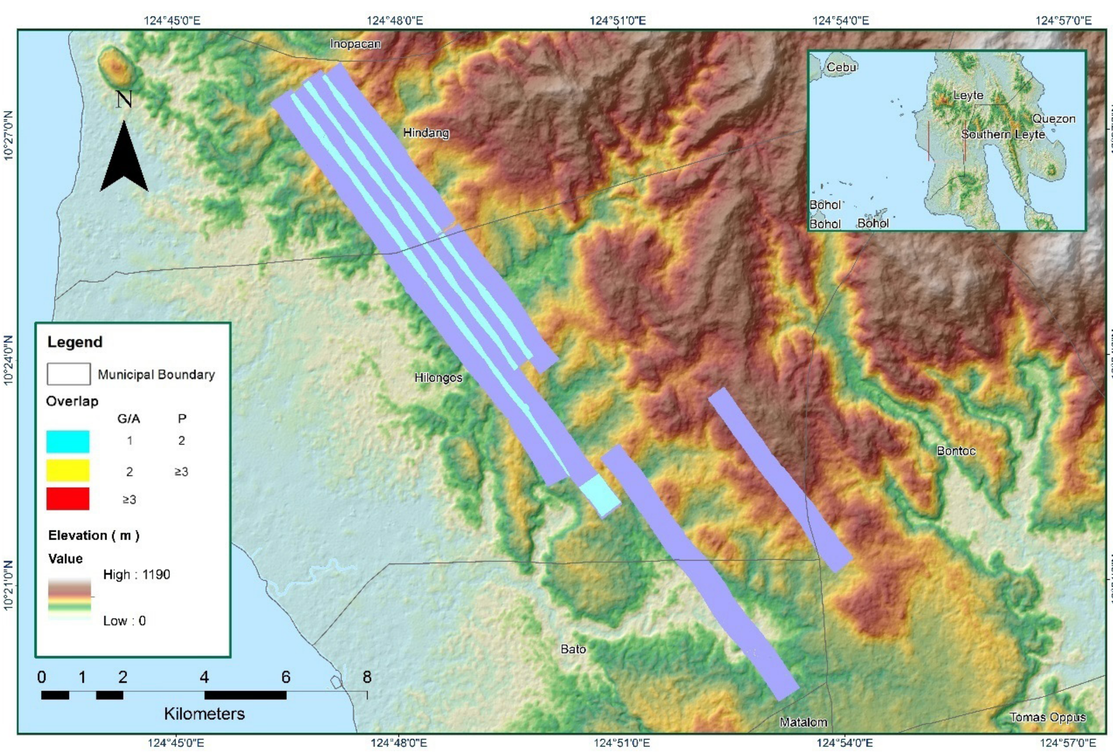


Figure A-8.55. Density map of merged LiDAR data

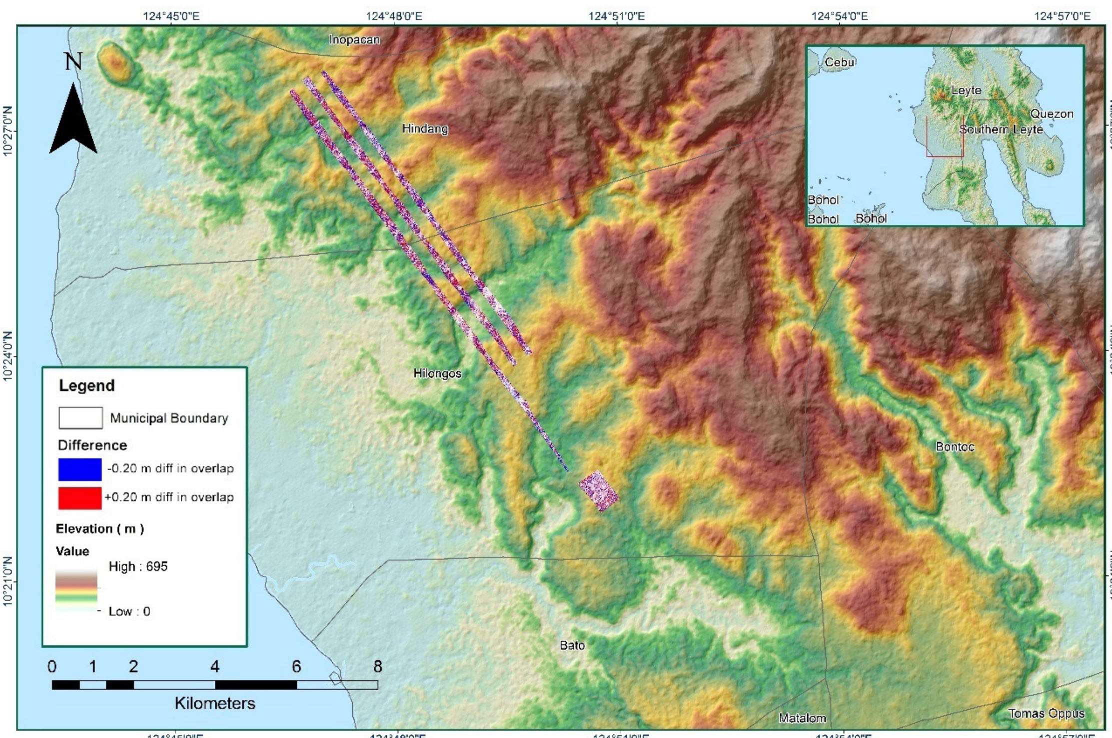


Figure A-8.56. Elevation difference between flight lines

Annex 9. Salug Model Basin Parameters

Table A-9.1. Salug 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 (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W420	2	88	0	1.7032	0.018531	Discharge	0.47324	0.01	Ratio to Peak	0.3
W410	2	88	0	2.0059	0.021824	Discharge	0.0825159	0.01	Ratio to Peak	0.3
W400	2	88	0	5.643	0.0613958	Discharge	0.67509	0.01	Ratio to Peak	0.3
W390	2	88	0	0.55245	0.0231785	Discharge	0.0097621	0.01	Ratio to Peak	0.3
W380	2	88	0	2.1304	0.0231785	Discharge	0.0888128	0.01	Ratio to Peak	0.3
W370	2	88	0	2.1946	0.0238774	Discharge	0.63156	0.01	Ratio to Peak	0.3
W360	2	88	0	6.055	0.0658787	Discharge	2.1381	0.01	Ratio to Peak	0.3
W350	2	88	0	1.0171	0.0231785	Discharge	0.17012	0.01	Ratio to Peak	0.3
W340	2	88	0	3.3328	0.0362609	Discharge	1.0973	0.01	Ratio to Peak	0.3
W330	2	88	0	2.5286	0.0275113	Discharge	0.5494857	0.01	Ratio to Peak	0.3
W320	2	88	0	6.7164	0.073074	Discharge	0.9317	0.01	Ratio to Peak	0.3
W310	2	88	0	3.6549	0.039765	Discharge	2.0128	0.01	Ratio to Peak	0.3
W300	2	88	0	5.4353	0.0591358	Discharge	0.81204	0.01	Ratio to Peak	0.3
W290	2	88	0	7.41	0.0806212	Discharge	3.2563	0.01	Ratio to Peak	0.3
W280	2	88	0	5.5967	0.0608922	Discharge	1.4202	0.01	Ratio to Peak	0.3
W270	2	88	0	4.9812	0.0541951	Discharge	1.4556	0.01	Ratio to Peak	0.3
W260	2	88	0	6.1385	0.0667867	Discharge	1.7571	0.01	Ratio to Peak	0.3
W250	2	88	0	2.1507	0.0234	Discharge	0.65687	0.01	Ratio to Peak	0.3
W240	2	88	0	4.1179	0.0448024	Discharge	0.91988	0.01	Ratio to Peak	0.3
W230	2	88	0	3.0459	0.0331389	Discharge	0.61022	0.01	Ratio to Peak	0.3
W220	2	88	0	4.3628	0.0474669	Discharge	1.9562	0.01	Ratio to Peak	0.3

Annex 10. Salug Model Reach Parameters

Table A-10.1. Salug Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R50	Automatic Fixed Interval	2887	0.0169075	0.05	Trapezoid	30	10
R70	Automatic Fixed Interval	6957.1	0.0181663	0.05	Trapezoid	30	10
R90	Automatic Fixed Interval	4780.4	0.0091876	0.05	Trapezoid	30	10
R120	Automatic Fixed Interval	1228.3	0.0204435	0.05	Trapezoid	30	10
R140	Automatic Fixed Interval	17462	0.0079235	0.05	Trapezoid	30	10
R160	Automatic Fixed Interval	257.63	0.007148	0.05	Trapezoid	30	10
R170	Automatic Fixed Interval	1544.7	0.0050163	0.05	Trapezoid	30	10
R180	Automatic Fixed Interval	2122	0.002687	0.05	Trapezoid	30	10
R200	Automatic Fixed Interval	9397.3	0.0039458	0.05	Trapezoid	30	10
R210	Automatic Fixed Interval	5433.6	0.0015554	0.05	Trapezoid	30	10

Annex 11. Salug Field Validation Points

Table A-11.1. Salug Field Validation Points (A)

Point Number	Latitude	Longitude	Model Var (m)	Actual Flood Depth	Error	Event	Date of Occurrence	Rain Return / Scenario
287	10.40240661	124.7369384	0.07	0.3	-0.23	Ruby	2014	5Yr
288	10.37520382	124.746609	0.029999999	0	0.03			5Yr
296	10.37523852	124.7480353	0.029999999	0	0.03			5Yr
306	10.37684717	124.749461	0.119999997	0	0.12			5Yr
306	10.37684717	124.749461	0.119999997	0	0.12			5Yr
326	10.37350195	124.7489935	0.579999983	0	0.58			5Yr
336	10.37228339	124.7471602	0.289999992	0	0.29			5Yr
346	10.37160672	124.7452954	0.029999999	0	0.03			5Yr
356	10.3712007	124.7481538	0.029999999	0	0.03			5Yr
366	10.3699461	124.7488092	0.920000017	0	0.92			5Yr
376	10.37044273	124.7500954	0.029999999	0	0.03			5Yr
386	10.37166607	124.7515483	0.029999999	0	0.03			5Yr
396	10.37289544	124.7507169	0.730000019	0	0.73			5Yr
406	10.37015238	124.7529754	0.090000004	0	0.09			5Yr
420	10.40011056	124.7353043	0.140000001	0.5	-0.36	Basyang	2010	5Yr
426	10.36916943	124.7539432	0.029999999	0	0.03			5Yr
436	10.36752968	124.7555159	0.109999999	0.4	-0.29	Senyang	2015	5Yr
436	10.36752968	124.7555159	0.109999999	0.2	-0.09	January (LP)	2017	5Yr
446	10.36604877	124.7572143	0.029999999	0.5	-0.47	Senyang	2015	5Yr
446	10.36604877	124.7572143	0.029999999	0.3	-0.27	January (LP)	2017	5Yr
456	10.36393753	124.7576422	0.029999999	0.5	-0.47	Senyang	2015	5Yr
456	10.36393753	124.7576422	0.029999999	0.3	-0.27	January (LP)	2017	5Yr
466	10.36331995	124.7594407	0.029999999	0	0.03			5Yr
476	10.36204725	124.7607711	0.029999999	0	0.03			5Yr
486	10.36061184	124.7622289	0.029999999	0	0.03			5Yr
496	10.36174877	124.7602534	0.090000004	0	0.09			5Yr
570	10.39973186	124.7330271	0.029999999	0	0.03			5Yr
620	10.39735903	124.7305051	0.029999999	0	0.03			5Yr
636	10.37096551	124.7832842	0.029999999	0.7	-0.67	Ruby	2014	5Yr
636	10.37096551	124.7832842	0.029999999	1	-0.97	Senyang	2015	5Yr
636	10.37096551	124.7832842	0.029999999	1	-0.97	January (LP)	2017	5Yr
646	10.37025271	124.7868227		0	Not Covered on Map			5Yr
656	10.3693483	124.7892905		0	Not Covered on Map			5Yr

Point Number	Latitude	Longitude	Model Var (m)	Actual Flood Depth	Error	Event	Date of Occurrence	Rain Return / Scenario
666	10.36848933	124.7915599		0	Not Covered on Map			5Yr
676	10.36737571	124.7931348		0	Not Covered on Map			5Yr
676	10.36737571	124.7931348		0	Not Covered on Map			5Yr
720	10.39254388	124.7344298	0.029999999	0	0.03			5Yr
726	10.38196483	124.7786063	0.200000003	0.2	0.00	January (LP)	2017	5Yr
736	10.38097878	124.779736	0.029999999	0.2	-0.17	January (LP)	2017	5Yr
746	10.38039096	124.7814877	0.029999999	0	0.03			5Yr
756	10.3799209	124.7822273	0.029999999	0	0.03			5Yr
766	10.37912722	124.7835947	0.029999999	0	0.03			5Yr
776	10.37837536	124.7857088	0.029999999	0	0.03			5Yr
786	10.37704725	124.7879247	0.029999999	0	0.03			5Yr
796	10.37456403	124.7861347	0.029999999	0	0.03			5Yr
806	10.37291422	124.7856488	0.029999999	0	0.03			5Yr
820	10.39500749	124.7399925	0.029999999	0	0.03			5Yr
826	10.3760949	124.7951575		0	Not Covered on Map			5Yr
836	10.37739283	124.7960697		0	Not Covered on Map			5Yr
846	10.37064641	124.7570947	0.029999999	0	0.03			5Yr
856	10.37357362	124.7543445	0.050000001	0	0.05			5Yr
866	10.37596657	124.7523729	0.140000001	0	0.14			5Yr
876	10.37726669	124.7512222	0.029999999	0	0.03			5Yr
886	10.378974	124.7501436	0.029999999	0	0.03			5Yr
896	10.38093276	124.7515265	0.140000001	0	0.14			5Yr
906	10.38282766	124.7541202	0.029999999	0	0.03			5Yr
920	10.39320571	124.741788	0.109999999	0	0.11			5Yr
936	10.38900739	124.7587481	0.039999999	0	0.04			5Yr
946	10.39017532	124.7600983	0.029999999	0	0.03			5Yr
956	10.39107621	124.7611651	0.029999999	0	0.03			5Yr
966	10.39192915	124.7629662	0.170000002	0	0.17			5Yr
976	10.39273272	124.7648953	0.029999999	0	0.03			5Yr
986	10.39335625	124.766563	0.180000007	0	0.18			5Yr
996	10.39396721	124.7683486	0.029999999	0	0.03			5Yr
1007	10.39514822	124.7709143	0.029999999	0	0.03			5Yr

Point Number	Latitude	Longitude	Model Var (m)	Actual Flood Depth	Error	Event	Date of Occurrence	Rain Return / Scenario
1020	10.38849475	124.7434357	0.029999999	0	0.03			5Yr
1027	10.3897512	124.7753139	0.029999999	0	0.03			5Yr
1037	10.38731047	124.7764837	0.379999995	0	0.38			5Yr
1046	10.38475592	124.7782085	0.029999999	0	0.03			5Yr
1056	10.38587641	124.7629778	0.050000001	0.1	-0.05	Ruby	2014	5Yr
1056	10.38587641	124.7629778	0.050000001	0.1	-0.05	Senyang	2015	5Yr
1056	10.38587641	124.7629778	0.050000001	0.2	-0.15	January (LP)	2017	5Yr
1066	10.38388428	124.7661815	0.109999999	0.2	-0.09	Ruby	2014	5Yr
1066	10.38388428	124.7661815	0.109999999	0.2	-0.09	Senyang	2015	5Yr
1066	10.38388428	124.7661815	0.109999999	0.3	-0.19	January (LP)	2017	5Yr
1076	10.38019801	124.7699842	0.170000002	0.2	-0.03	Ruby	2014	5Yr
1076	10.38019801	124.7699842	0.170000002	0.2	-0.03	Senyang	2015	5Yr
1076	10.38019801	124.7699842	0.170000002	0.3	-0.13	January (LP)	2017	5Yr
1086	10.38177556	124.7594104	0.109999999	0.3	-0.19	Ruby	2014	5Yr
1096	10.38025584	124.7603964	0.039999999	0.3	-0.26	Ruby	2014	5Yr
1126	10.38502305	124.7443396	0.029999999	2	-1.97	Basyang	2010	5Yr
1127	10.37705722	124.7554539	0.059999999	0	0.06			5Yr
1136	10.3762373	124.7536173	0.039999999	0	0.04			5Yr
1146	10.39287128	124.7467399	0.100000001	0	0.10			5Yr
1156	10.39716222	124.7511866	0.239999995	0	0.24			5Yr
1166	10.39838917	124.75391	0.140000001	0	0.14			5Yr
1176	10.400576	124.7560455	0.860000014	0	0.86			5Yr
1186	10.39894505	124.7570267	0.029999999	0	0.03			5Yr
1196	10.40086434	124.759663	0.029999999	0	0.03			5Yr
1206	10.40275203	124.7611076	0.029999999	0	0.03			5Yr
1220	10.38288399	124.7421939	0.029999999	2	-1.97	Basyang	2010	5Yr
1226	10.40463226	124.7645902	0.029999999	0	0.03			5Yr
1236	10.40645625	124.7658199	0.029999999	0	0.03			5Yr
1246	10.39802648	124.7471724	0.029999999	0	0.03			5Yr
1286	10.41569654	124.7610632	0.029999999	0	0.03			5Yr
1296	10.41431839	124.7603854	0.029999999	0	0.03			5Yr
1306	10.41281409	124.7579773	0.029999999	0	0.03			5Yr
1320	10.38097375	124.7350086	0.039999999	2	-1.96	Basyang	2010	5Yr
1326	10.41182083	124.7559146	0.029999999	0	0.03			5Yr
1334	10.41450505	124.7549294	0.029999999	0	0.03			5Yr
1346	10.4156843	124.7536944	0.029999999	0	0.03			5Yr
1356	10.4144639	124.7525611	0.029999999	0	0.03			5Yr
1366	10.41373199	124.750872	0.029999999	0	0.03			5Yr
1376	10.41344097	124.7490618	0.029999999	0	0.03			5Yr

Point Num-ber	Latitude	Longitude	Model Var (m)	Actual Flood Depth	Error	Event	Date of Occur-rence	Rain Return / Scenario
1386	10.41359193	124.7474178	0.029999999	0	0.03			5Yr
1396	10.41289992	124.746279	0.029999999	0	0.03			5Yr
1406	10.41502188	124.745561	0.029999999	0	0.03			5Yr
1420	10.38427915	124.7339293	0.029999999	0	0.03			5Yr
1426	10.41599317	124.7416161	0.029999999	0	0.03			5Yr
1436	10.41476883	124.7405403	0.119999997	0	0.12			5Yr
1446	10.41408143	124.7392138	0.050000001	0	0.05			5Yr
1456	10.41403332	124.738101	0.029999999	0	0.03			5Yr
1466	10.41395763	124.7365154	0.056000002	0	0.06			5Yr
1476	10.41378932	124.7349626	0.029999999	0	0.03			5Yr
1486	10.41505876	124.7365624	0.27700001	0	0.28			5Yr
1496	10.41524635	124.7374762	0.029999999	0	0.03			5Yr
1506	10.4161609	124.7371983	0.029999999	0	0.03			5Yr
1520	10.38549277	124.746662	0.550000012	0	0.55			5Yr
1523	10.41349168	124.7398819	0.039999999	0	0.04			5Yr
1546	10.41885342	124.7634034	0.029999999	0	0.03			5Yr
1556	10.4214741	124.7658686	0.059999999	0	0.06			5Yr
1576	10.42492342	124.7626422	0.029999999	0	0.03			5Yr
1586	10.42618993	124.760438	0.030999999	0	0.03			5Yr
1596	10.42641213	124.7594169	0.030999999	0	0.03			5Yr
1606	10.42678705	124.7665808	0.029999999	0	0.03			5Yr
1606	10.38413641	124.7460239	0.029999999	0	0.03			5Yr
1620	10.43158687	124.7689395	0.029999999	0	0.03			5Yr
1636	10.43030645	124.7692379	0.029999999	0	0.03			5Yr
1646	10.42900926	124.7701058	0.029999999	0	0.03			5Yr
1656	10.42668798	124.7688861	0.029999999	0	0.03			5Yr
1666	10.42531352	124.7676822	0.029999999	0	0.03			5Yr
1686	10.4227458	124.7671737	0.029999999	0	0.03			5Yr
1696	10.41621949	124.7720348	0.029999999	0	0.03			5Yr
1706	10.4151166	124.7729254	0.059999999	0	0.06			5Yr
1720	10.3824773	124.7466861	0.029999999	0	0.03			5Yr
1726	10.41742581	124.7763485	0.029999999	0	0.03			5Yr
1736	10.41996745	124.7770354	0.029999999	0	0.03			5Yr
1746	10.42110681	124.7776775	0.029999999	0	0.03			5Yr
1756	10.4125856	124.7803026	0.029999999	0	0.03			5Yr
1756	10.41088625	124.781725	0.039999999	0	0.04			5Yr
1786	10.41088625	124.781725	0.039999999	0	0.04			5Yr
1796	10.40929352	124.7829156	0.029999999	0	0.03			5Yr
1806	10.40759568	124.7836499	0.039999999	0	0.04			5Yr
1820	10.38109261	124.746543	0.119999997	0	0.12			5Yr
1826	10.40459714	124.782821	0.029999999	0	0.03			5Yr

Point Number	Latitude	Longitude	Model Var (m)	Actual Flood Depth	Error	Event	Date of Occurrence	Rain Return / Scenario
1836	10.40636363	124.7852951	0.029999999	0	0.03			5Yr
1846	10.40728446	124.7875446	0.029999999	0	0.03			5Yr
1856	10.40998746	124.7902477	0.029999999	0	0.03			5Yr
1866	10.41154054	124.7897199	0.029999999	0	0.03			5Yr
1876	10.41261166	124.7901764	0.230000004	0	0.23			5Yr
1884	10.41564725	124.790849	0.029999999	0	0.03			5Yr
1896	10.41532204	124.7883191	0.029999999	0	0.03			5Yr
1906	10.41683564	124.7825964	0.029999999	0	0.03			5Yr
1920	10.37977229	124.7480458	0.029999999	0	0.03			5Yr
1926	10.41553175	124.779479	0.029999999	0	0.03			5Yr
1936	10.40128897	124.7785563	0.029999999	0	0.03			5Yr
1945	10.39705032	124.7737044	0.029999999	0	0.03			5Yr
2020	10.37870452	124.7471144	0.029999999	0	0.03			5Yr
2026	10.40590438	124.7890953	0.029999999	0	0.03			5Yr
2120	10.37708321	124.7458691	0.050000001	0	0.05			5Yr
2276	10.37059377	124.7876679		0	Not Covered on Map			5Yr
2286	10.37213277	124.7886302		0	Not Covered on Map			5Yr
2296	10.3736654	124.7892234		0	Not Covered on Map			5Yr
2306	10.37502746	124.7898649		0	Not Covered on Map			5Yr
2336	10.38146954	124.7890993	0.029999999	0	0.03			5Yr
2346	10.38030018	124.7891657	0.029999999	0	0.03			5Yr
2356	10.38197564	124.790821	0.029999999	0	0.03			5Yr
2366	10.38366375	124.7905545	0.029999999	0	0.03			5Yr
2420	10.37413663	124.7413363	0.029999999	0	0.03			5Yr
2712	10.37445288	124.7451567	0.079999998	0	0.08			5Yr
3111	10.37435205	124.7506298	0.209999993	0	0.21			5Yr
4111	10.36860625	124.7512666	0.07	0	0.07			5Yr
5015	10.36294268	124.7582813	0.029999999	0	0.03			5Yr
5115	10.36062274	124.7734401	0.029999999	0	0.03			5Yr
5215	10.36268821	124.769536	0.029999999	0	0.03			5Yr
5315	10.36451027	124.7673026	0.419999987	0	0.42			5Yr
5415	10.36718703	124.7626404	0.079999998	0	0.08			5Yr
5515	10.36839696	124.7593686	0.029999999	0	0.03			5Yr
7110	10.37976651	124.7760832	0.200000003	0.2	0.00	Ruby	2014	5Yr
7110	10.37976651	124.7760832	0.200000003	0.2	0.00	Senyang	2015	5Yr

Point Number	Latitude	Longitude	Model Var (m)	Actual Flood Depth	Error	Event	Date of Occurrence	Rain Return / Scenario
7110	10.37976651	124.7760832	0.200000003	0.3	-0.10	January (LP)	2017	5Yr
8110	10.37114731	124.7934954		0	Not Covered on Map			5Yr
9110	10.38543544	124.7554337	0.029999999	0	0.03			5Yr
10110	10.39239066	124.7733063	0.07	0	0.07			5Yr
11011	10.37879814	124.7595595	0.029999999	0.5	-0.47	Bising	1998	5Yr
11011	10.37840243	124.7573013	0.029999999	0.3	-0.27	Ruby	2014	5Yr
11110	10.40383782	124.7628165	0.029999999	0.2	-0.17	Ruby	2014	5Yr
12110	10.41341029	124.756215	0.029999999	0	0.03			5Yr
13110	10.41579578	124.7435143	0.029999999	0	0.03			5Yr
14110	10.41816543	124.7433834	0.108999997	0	0.11			5Yr
15110	10.4315406	124.7679637	0.029999999	0	0.03			5Yr
16110	10.41438586	124.7760209	0.200000003	0	0.20			5Yr
17110	10.40636128	124.7819208	0.029999999	0	0.03			5Yr
18110	10.41661251	124.7810228	0.029999999	0	0.03			5Yr
19110	10.40567908	124.7869563	0.029999999	0	0.03			5Yr
20110	10.38999746	124.7931685	0.029999999	0	0.03			5Yr
20110	10.39073498	124.8161323	0.029999999	0	0.03			5Yr
23110	10.37867568	124.7878718	0.029999999	0	0.03			5Yr
23110	10.39607886	124.7935106	0.029999999	0	0.03			5Yr

Table A-11.2. Salug Field Validation Points (B)

Point No.	Latitude	Longitude	Model Var	Actual Flood Depth	Error	Event	Date of Occurrence	Return Period of Event
287	10.40240661	124.7369384	0.119999997	0.4	-0.28	Yolanda	2013	100Yr
296	10.37523852	124.7480353	0.300000012	0.5	-0.2	Yolanda	2013	100Yr
306	10.37684717	124.749461	0.150000006	0.5	-0.35	Yolanda	2013	100Yr
576	10.3717151	124.7652351	0.25	0.2	0.05	Yolanda	2013	100Yr
586	10.37195055	124.7694426	0.079999998	0.2	-0.12	Yolanda	2013	100Yr
596	10.37229655	124.7723037	0.07	0.5	-0.43	Yolanda	2013	100Yr
606	10.37284381	124.7747235	0.07	0.7	-0.63	Yolanda	2013	100Yr
626	10.37169331	124.7806472	0.029999999	0.2	-0.17	Yolanda	2013	100Yr
636	10.37096551	124.7832842	0.029999999	1.2	-1.17	Yolanda	2013	100Yr
646	10.37025271	124.7868227		0.3	Not Covered on Map	Yolanda	2013	100Yr
656	10.3693483	124.7892905		0.3	Not Covered on Map	Yolanda	2013	100Yr
666	10.36848933	124.7915599		0.5	Not Covered on Map	Yolanda	2013	100Yr
686	10.37445556	124.7741772	0.029999999	0.7	-0.67	Yolanda	2013	100Yr
696	10.37596582	124.7727038	0.029999999	0.7	-0.67	Yolanda	2013	100Yr
706	10.37792517	124.7734653	0.029999999	0.7	-0.67	Yolanda	2013	100Yr
726	10.38196483	124.7786063	0.579999983	0.2	0.38	Yolanda	2013	100Yr
736	10.38097878	124.779736	0.029999999	0.2	-0.17	Yolanda	2013	100Yr
1056	10.38587641	124.7629778	0.07	0.4	-0.33	Yolanda	2013	100Yr
1066	10.38388428	124.7661815	0.379999995	0.4	-0.02	Yolanda	2013	100Yr
1076	10.38019801	124.7699842	0.409999996	0.5	-0.09	Yolanda	2013	100Yr
1086	10.38177556	124.7594104	0.150000006	0.4	-0.25	Yolanda	2013	100Yr
1096	10.38025584	124.7603964	0.07	0.5	-0.43	Yolanda	2013	100Yr
1884	10.41564725	124.790849	0.029999999	0.4	-0.37	Yolanda	2013	100Yr
1896	10.41532204	124.7883191	0.029999999	0.3	-0.27	Yolanda	2013	100Yr
2120	10.37708321	124.7458691	0.07	0.1	-0.03	Yolanda	2013	100Yr
2320	10.37558486	124.7406737	0.029999999	0.1	-0.07	Yolanda	2013	100Yr
2420	10.37413663	124.7413363	0.109999999	0.1	0.01	Yolanda	2013	100Yr
2516	10.37339685	124.7423239	0.569999993	0.3	0.27	Yolanda	2013	100Yr
2615	10.37334991	124.7437849	0.319999993	0.1	0.22	Yolanda	2013	100Yr
5610	10.37096098	124.7619779	0.029999999	0.2	-0.17	Yolanda	2013	100Yr
6110	10.37245682	124.7772686	0.100000001	0.4	-0.3	Yolanda	2013	100Yr
7110	10.37976651	124.7760832	0.389999986	0.5	-0.11	Yolanda	2013	100Yr
11011	10.39239066	124.7733063	0.330000013	0.5	-0.17	Yolanda	2013	100Yr
11110	10.37879814	124.7595595	0.029999999	0.4	-0.37	Yolanda	2013	100Yr

Annex 12. Educational Institutions Affected by Flooding in Salug Floodplain

Table A-12.1. Educational Institutions Affected

LEYTE				
HILONGOS				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
MLG College of Learning Inc.	Atabay		Low	Low
Bagong Bayan Elementary School	Bagumbayan		Low	Medium
Brgy. Bagong Bayan Day Care Center	Bagumbayan			
Campina Primary School	Campina			
Central Brgy. Day Care Center	Central Barangay			Low
Nursery Tutorial Center Southville Assumption School	Central Barangay		Low	Medium
Tejero Elementary School	Concepcion			
Hilongos Fundamental School	Eastern Barangay			
Hilongos National Vocational School	Eastern Barangay		Low	Low
Hilongos South Central School	Eastern Barangay	Medium	Medium	Medium
Himo-aw Elementary School	Himo-Aw			
Brgy. Concepcion Day Care Center	Imelda Marcos			
Concepcion Elementary School	Imelda Marcos			Low
Concepcion National High School	Imelda Marcos			Low
Talisay Elementary School	Kangha-As			
Brgy. Lipunan Day Care Center	Lamak	Low	Low	Low
Lamak Central School	Lamak			
Brgy. Day Care Center	Liberty			
Brgy. Liberty Day Care Center	Liberty			Medium
Liberty Elementary School	Liberty			Medium
Magnangoy Primary School	Magnangoy			
Matapay Elementary School	Matapay			Low
Bgy. Owak Covered Basketball Court	Owak			
Owak Elementary School	Owak		Low	Low
Proteccion Elementary School	Proteccion			
Brgy. San Juan Day Care Center	San Juan			
San Juan Primary School	San Juan			
San Roque Primary School	San Roque			
Bung-aw Elementary School	Santa Cruz		Low	Medium
Bung-aw National High School	Santa Cruz			Medium
Sta Cruz Elementary School	Santa Cruz			
Brgy. Imelda Day Care Center	Santo Niño	Low	Medium	Medium
Talisay Elementary School	Talisay			Low
Brgy. Tejero Day Care Center	Tejero			
Mana-ul Elementary School	Tejero			
Atabay Elementary School	Western Barangay			Medium
Brgy. Papa Siwa Day Care Center	Western Barangay		Low	Low
Brgy. Pontod Elementary School	Western Barangay		Low	Low
Saint Teresa School	Western Barangay	Low	Low	Medium

LEYTE							
HINDANG							
Building Name	Barangay	Rainfall Scenario					
		5-year	25-year	100-year			
Brgy. Bung-aw Day Care Center	Maasin			Medium			
Bung-aw Elementary School	Maasin	Low	Low	Medium			

Annex 13. Health Institutions Affected in Salug Floodplain

Table A-13.1. Health Institutions Affected

LEYTE				
HILONGOS				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Campina Health Center	Campina			
Didon Dental Clinic	Central Barangay			
Villa Flor Clinic	Central Barangay			
BHS Eastern Health Center	Eastern Barangay	Medium	Medium	Medium
Leyte Baptist Hospital	Eastern Barangay			
Sto. Niño Clinic	Eastern Barangay	Low	Low	Low
Villa Flor Clinic	Eastern Barangay	Low	Medium	Medium
Brgy. Concepcion Rural Health Unit II	Imelda Marcos			
Brgy. Lamak Health Center	Lamak			
Brgy. Magnangoy Health Center	Magnangoy			
Brgy. Owak Health Center	Owak			
Hilongos District Hospital	Pontod			
Brgy. Tejero Health Center	Tejero			
Rural Health Unit	Western Barangay			

LEYTE				
HINDANG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Bung-aw Rural Health Unit II	Maasin			Medium