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

LiDAR Surveys and Flood Mapping of Cadac-An River

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CADAC-AN 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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1,supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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 27 river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2. Overview of the Cadac-an River Basin

Cadacan River Basin covers a major portion of the Municipalities of Abuyog, and Mahaplag and minor portions of the Municipalities of Silago and Sogod in the Province of Leyte. It has a drainage area of 458 km 2 and an estimated 870 million cubic meter annual run-off according to the DENR-RCBO.

Its main stem,Cadacan River is part of the river systems in Visayas Region under the Phil-LiDAR 1 partner HEI, Visayas State University. The 2010 census of National Sstatistics Office stated that it has a total population of 62,956 distributed among 63 barangays. According to the data gathered from local government units in Leyte, the Municipality of Abuyog has experienced four (4) significant flooding events in the past 70 years with Cadacan River as the major artery. The earliest was caused by Typhoon Amy in 1951. The event affected the whole Municipality of Abuyog which is comprised of 63 barangays. The extent of flooding covered 77,987,800 m 2 with floods reaching as high as ten (10) feet that lasted for two (2) days. The latest flooding event was caused by heavy rainfalls on December 31, 2011. This time, the extent of the flooding covered 27,642,800 m 2 but still affected all 63 barangays in Abuyog. The flood height reached six (6) feet and lasted for three (3) days.

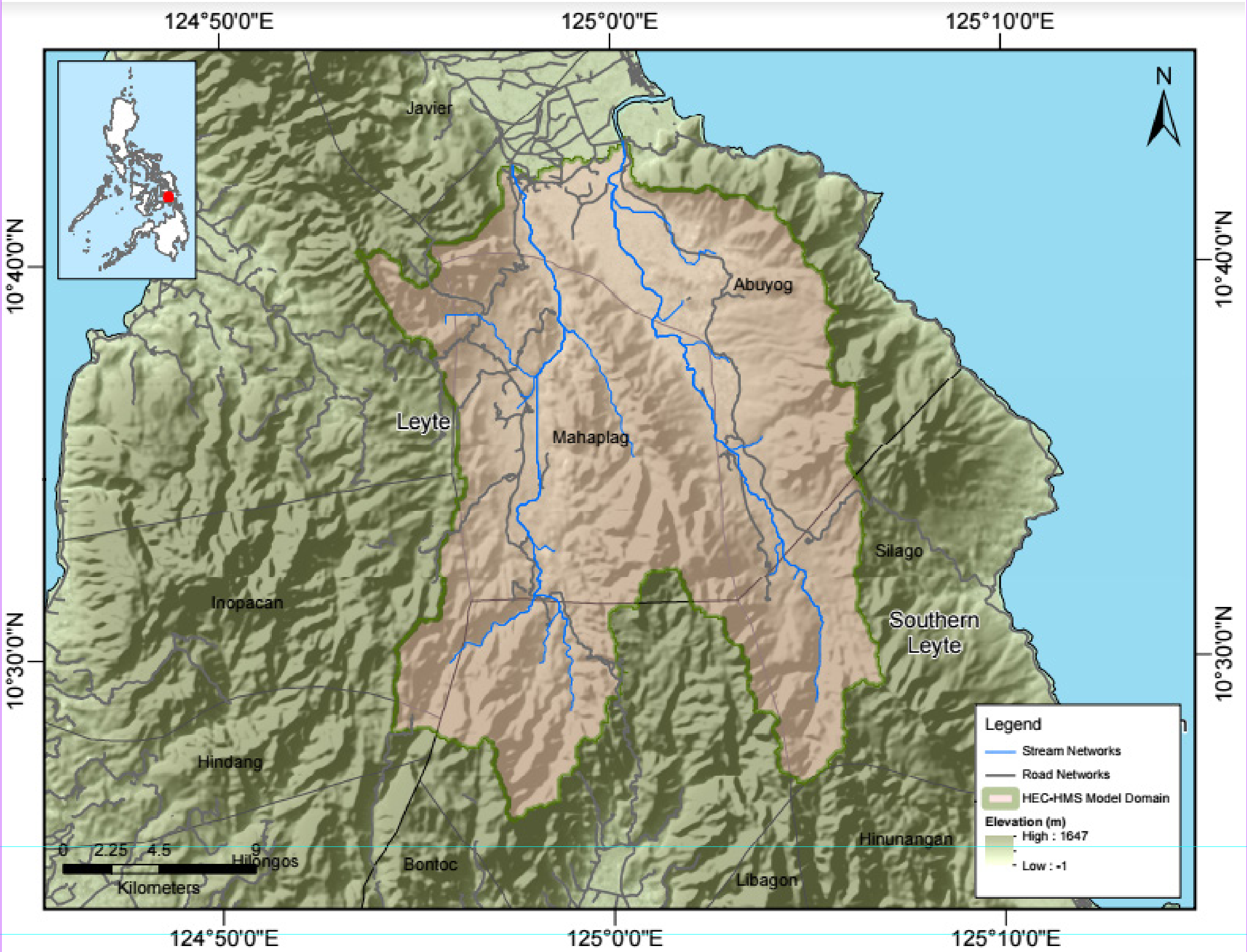

Figure 1. Map of the Cadac-an River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CADAC-AN FLOODPLAIN

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The methods applied in this Chapter were based on the DREAM methods manual (Sarmiento et al., 2014) 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 Cadac-an Floodplain in the Province of Leyte. Each flight mission has an average of sixteen(16) lines which run for at most four and a half (4.5) hours including take-off, landing and turning time. The parameters used in the LiDAR System for acquisition are found in Tables 1 and 2. Figure 2 shows the flight plan and base stations for Cadac-an Floodplain.

Table 1. Parameters used in Aquarius LiDAR System during Flight Acquisition

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)
BLK49C	600	30	36	70	50	120	5
BLK50V	600	30	36	70	50	120	5

Table 2. Parameters used in Gemini LiDAR System during Flight Acquisition

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)
BLK34G	850	30	40	125	50	130	5
BLK34H	650	30	40	125	50	130	5
BLK34K	850	30	40	125	50	130	5
BLK34J	850	30	40	125	50	130	5
BLK34F	900	30	40	125	50	130	5
BLK34L	900	30	40	125	50	130	5

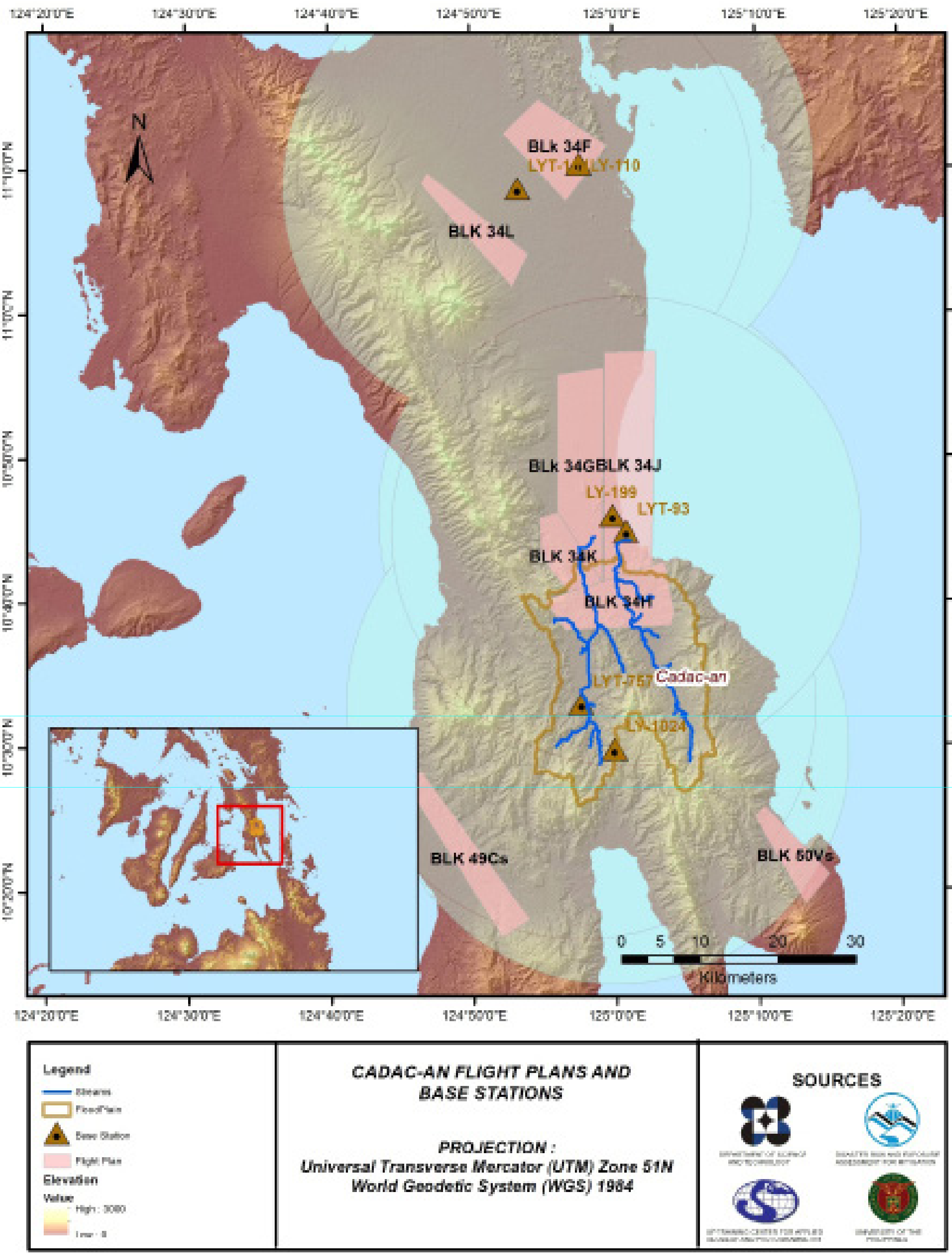

Figure 2. Flight plans and base stations for Cadac-an Floodplain

2.2 Ground Base Station

The Project Team was able to recover two (2) NAMRIA horizontal ground control points: LYT-93 and LYT-757 which are all of second (2nd) order accuracy. The Project Team also re-established ground control point LYT-104, a NAMRIA reference point of third 3rd order accuracy. Three (3) NAMRIA benchmarks were recovered: LY-199, LY-1024, and LY-110 which are all of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in ANNEX 2 while the baseline processing reports for the established control points are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (May 8 -9, 2014 and January 24 -February 12, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Cadac-an Floodplain are shown in Figure 2.

Figures 3 to 8 show the recovered NAMRIA reference points within the area. Tables 3 to 8 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

Figure 3. GPS set-up over LYT-93 as recovered within the premises of Abuyog Municipal Hall, Brgy. Sto. Abuyog, Leyte (a) and NAMRIA reference point LYT-93 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point LYT-93 used as base station for the LiDAR Acquisition

Station Name	**LYT-93**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 44’ 52.03339” North 125° 0’ 43.59630” East 2.66000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	501324.552 meters 1188433.982 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 44’ 47.89310” North 125° 0’ 48.79542” East 66.12300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	720040.44 meters 1188738.73 meters

Figure 4. GPS set-up over LYT-104 as recovered and re-established along rice paddy trail, approximately 90 meters from the centerline, east side of Pastrana-Santa Fe Road, District IV, Pastrana, Leyte (a) and NAMRIA reference point LYT-104 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point LYT-104 used as base station for the LiDAR Acquisition.

Station Name	**LYT-104**	
Order of Accuracy	**2^{nd} order**	
Relative Error (horizontal positioning)	**1:50000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 08' 38.92234" North 124° 53' 13.52786"East 33.659 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 08' 34.67033" North 124° 53' 18.69323" East 95.861 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	706089.510 m 1232496.838 m

Figure 5. GPS set-up LY-199 as recovered at Bunga Bridge, Brgy. Bungas, Abuyog, Leyte. (a) and NAMRIA reference point LY-199 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point LY-199 used as base station for the LiDAR Acquisition.

Station Name	LY-199	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 45' 58.35" North 124° 59' 47.90" East 5.43 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	499632.514 m 1190471.498 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 45' 53.60669" North 124° 59' 52.1269" East 68.789 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	718461.36 m 1190695.094 m
Elevation		4.0649 m

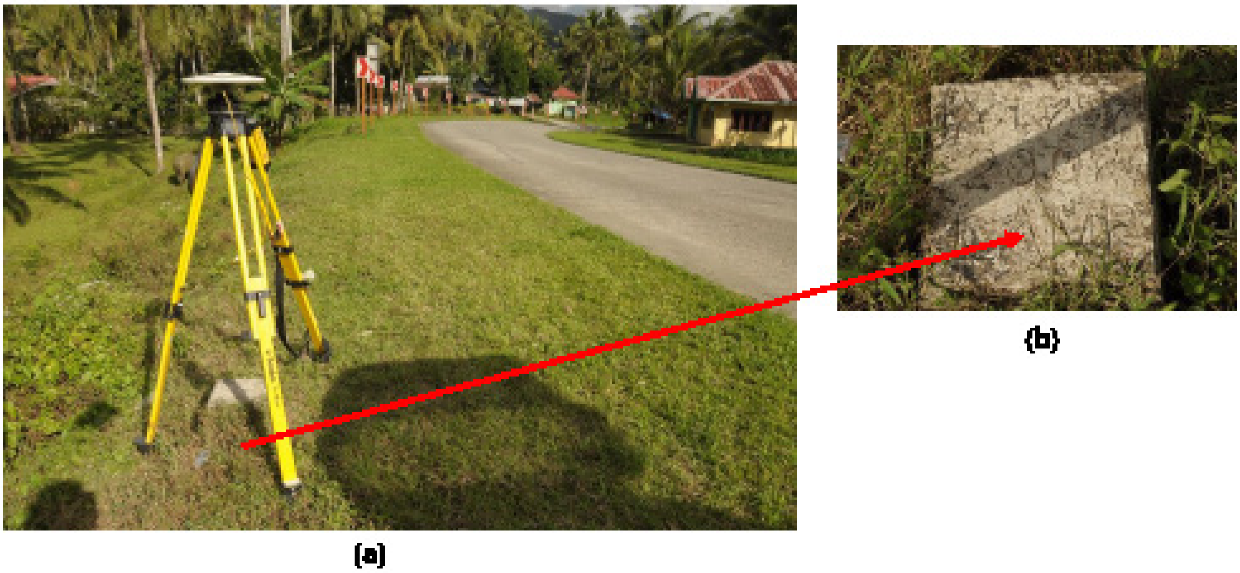

Figure 6. GPS set-up over LYT-757 as recovered on the opposite side of the kilometer post 997 in Barangay Mahayahay, Leyte. (a) and NAMRIA reference point LYT-757 (b) as recovered by the field team

Table 6. 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 Longitude Ellipsoidal Height	10° 32’ 54.87” North 124° 57’ 31.14” East 99.55 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	495474.491 m 1166401.318 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 32’ 50.77355” North 124° 57’ 36.36037” East 163.36300 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	714331.34 m 1166663.62 m
Elevation		163.36300 m

(b)

(a)

Figure 7. 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 7. Details of the recovered NAMRIA horizontal control point LY-1024 used as base station for the LiDAR Acquisition

Station Name	LY-1024	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 29' 46.27" North 124° 59' 49.85" East 366.202 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	
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 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	718586.237 m 1160895.197 m
Elevation		364.735 m

(a) (b)

Figure 8. GPS set-up over LY-110 located on a bridge about 225 meters of km post 919, Libertad, Leyte. (a) and NAMRIA reference point LY-110 (b) as recovered by the field team

Table 8. Details of the recovered NAMRIA horizontal control point LY-110 used as base station for the LiDAR Acquisition.

Station Name	LY-110	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 10’ 19.48” North 124o 57’ 32.98” East 14.336 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 10’ 15.23095” North 124o 57’ 38.14961” East 76.647 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	713942.863 m 1235638.117 m
Elevation		12.819 m

Table 9. Ground Control Points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 9, 2014	1434A	3BLK34LSM129A	LYT-93 and LY-199
May 9, 2014	1436A	3BLK34MS129B	LYT-93 and LY-199
May 8, 2014	1430A	3BLK34L128A	LYT-93 and LY-199
Feb. 7, 2016	3761G	2BLK038A	LYT-757 and LY-1024
Feb. 10, 2016	23773G	2BLK34A041A	LYT-757 and LY-1024
Feb. 12, 2016	3781G	2BLK34A043A	LYT-757 and LY-1024
Feb. 9, 2016	23771G	2BLK34A040A	LYT-757 and LY-1024
Jan. 24, 2016	3773G	2BLK34CG024A	LYT-104 and LY-110

2.3 Flight Missions

Eight (8) missions were conducted to complete LiDAR data acquisition in Cadac-an Floodplain, for a total of forty-seven hours and six minutes (47+6) of flying time for RP-C9122 and RP-C9022. All missions were acquired using Aquarius and Gemini LiDAR systems. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Cadac-an 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
May 9, 2014	1434A	180.35	125.909	21.21	104.699	1670	4	47
May 9, 2014	1436A	80.27	71.953	9.03	62.923	844	3	41
May 8, 2014	1430A	156.77	120.49	6.79	113.7	1463	4	5
Feb. 7, 2016	3761G	210.11	202	34.91	167.09	N.A.	4	5
Feb. 10, 2016	23773G	263.51	230.90	49.50	181.4	N.A.	3	23
Feb. 12, 2016	3781G	99.91	90.3	86.11	4.19	N.A.	3	23
Feb. 9, 2016	23771G	235.21	195.06	32.14	162.92	N.A.	3	11
Jan. 24, 2016	3773G	112.2	90.6	0	90.6	N.A.	4	11
TOTAL		**1338.33**	**1127.212**	**239.69**	**887.522**	**3977**	**56**	**6**

Table 11. Actual parameters used during LiDAR acquisition

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)
1430A	600	30	36	70	50	120	5
1434A	600	30	36	70	50	120	5
1436A	600	30	36	70	50	120	5
3773G	600	30	36	70	50	120	5
3761G	800	30	40	125	50	130	5
23771G	850	30	40	125	50	130	5
23773G	850	30	40	125	50	130	5
3781G	850	30	40	125	50	130	5

2.4 Survey Coverage

The Cadac-an Floodplain is located in the Province of Leyte with majority of the floodplain situated within the Municipality of Mahaplag. The Municipalities of Abuyog and Mahaplag are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Cadac-an Floodplain is presented in Figure 9.

Table 12. List of Municipalities and cities surveyed during Cadac-an Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Leyte	Mayorga	39.45	39.45	100.00
	Macarthur	57.86	32.52	56.21
	Santa Fe	57.15	30.31	53.05
	Javier	153.11	78.58	51.32
	Abuyog	256.64	124.37	48.46
	Palo	65.34	18.94	28.99
	Dulag	63.65	18.01	28.29
	La Paz	136.02	35.11	25.81
	Mahaplag	180.30	30.07	16.68
	Bato	57.55	8.24	14.32
	Dagami	134.08	18.81	14.03
	Alangalang	145.45	19.30	13.27
	Julita	57.17	4.93	8.63
	Hilongos	156.80	12.82	8.17
	Pastrana	79.17	5.49	6.94
	Hindang	106.77	5.90	5.52
	San Miguel	103.86	4.01	3.86
	Jaro	190.65	5.77	3.03
	Baybay City	404.37	6.01	1.49
	Tolosa	28.17	0.33	1.19
	Matalom	110.13	1.27	1.15
	Tacloban City	118.46	0.33	0.28
	Burauen	205.31	0.04	0.02
Samar	Basey	627.97	0.013	0.002
Southern Leyte	Hinunangan	136.38	18.75	13.75
	Hinundayan	53.28	6.95	13.04

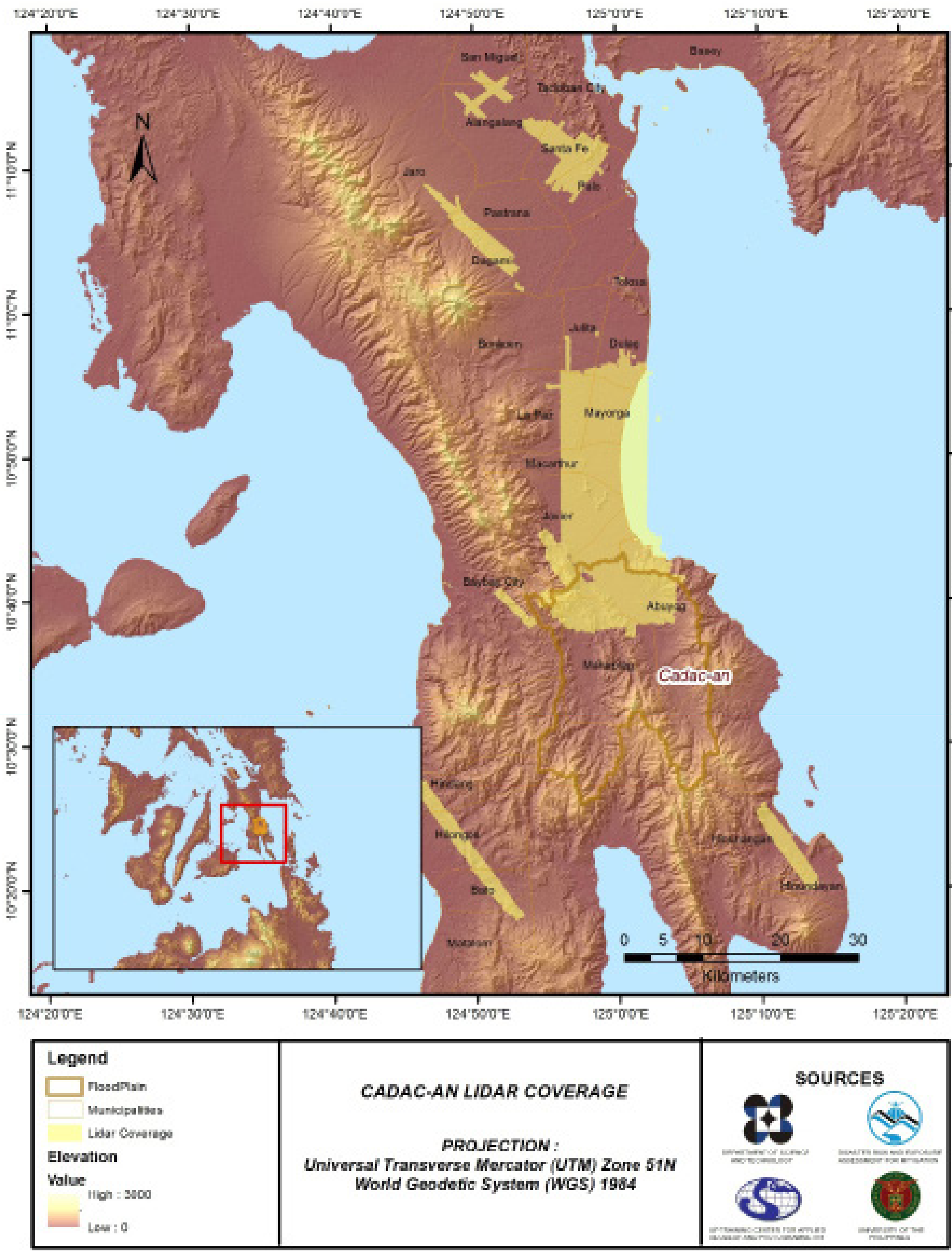

Figure 9. Actual LiDAR survey coverage for Cadac-an Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE CADAC-AN FLOODPLAIN

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The methods applied in this Chapter were based on the DREAM methods manual (Ang et al., 2014) 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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality check in order to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were 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 were calibrated. Portions of the river that were barely penetrated by the LiDAR System were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was 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 10.

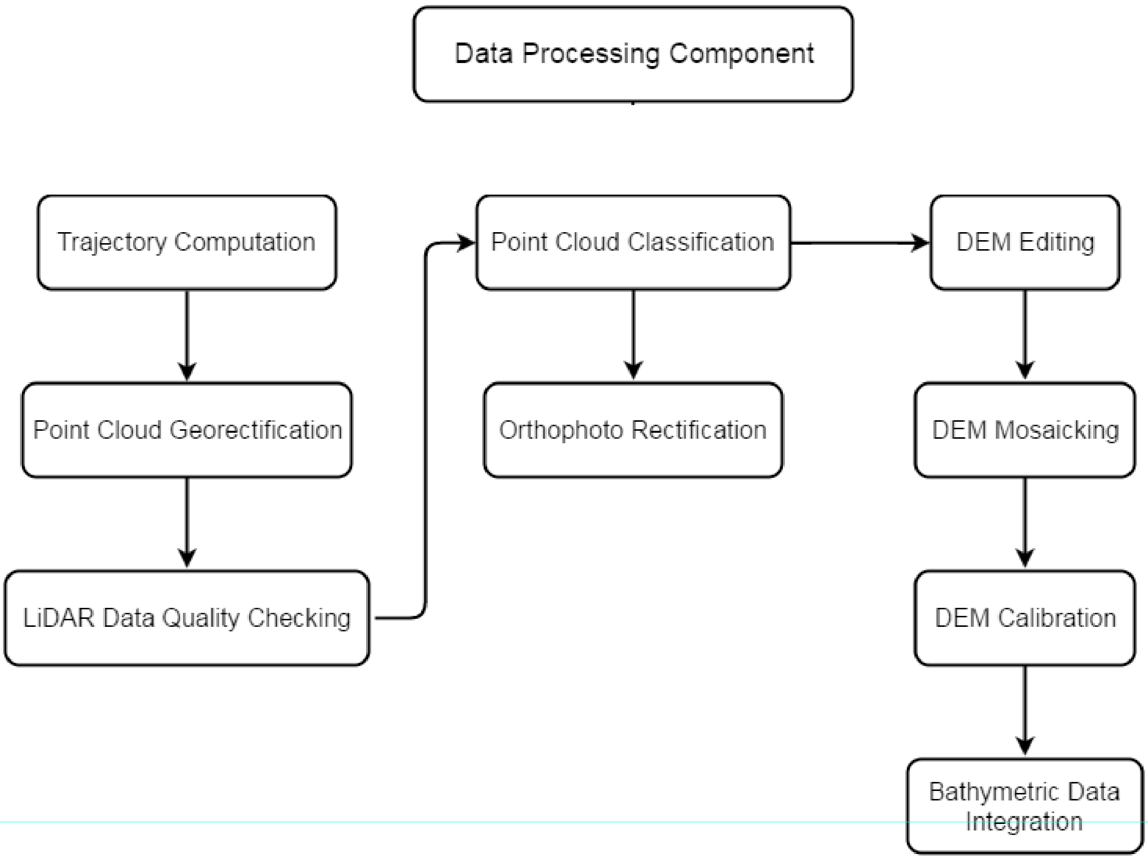


Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of the Acquired LiDAR Data

The Data Transfer Sheets for all the LiDAR missions for Cadac-an Floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius System while missions acquired during the last survey on February 2016 were flown using the Gemini System over Tacloban. The Data Acquisition Component (DAC) transferred a total of 98.43 Gigabytes of Range data, 1.79 Gigabytes of POS data, 73 Megabytes of GPS base station data, and 306.90 Gigabytes of raw image data to the data server on May 8, 2014 for the first survey and February 12, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Cadac-an was fully transferred on March 4, 2016, as indicated on the Data Transfer Sheets for Cadac-an Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1436A, one of the Cadac-an flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 9, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

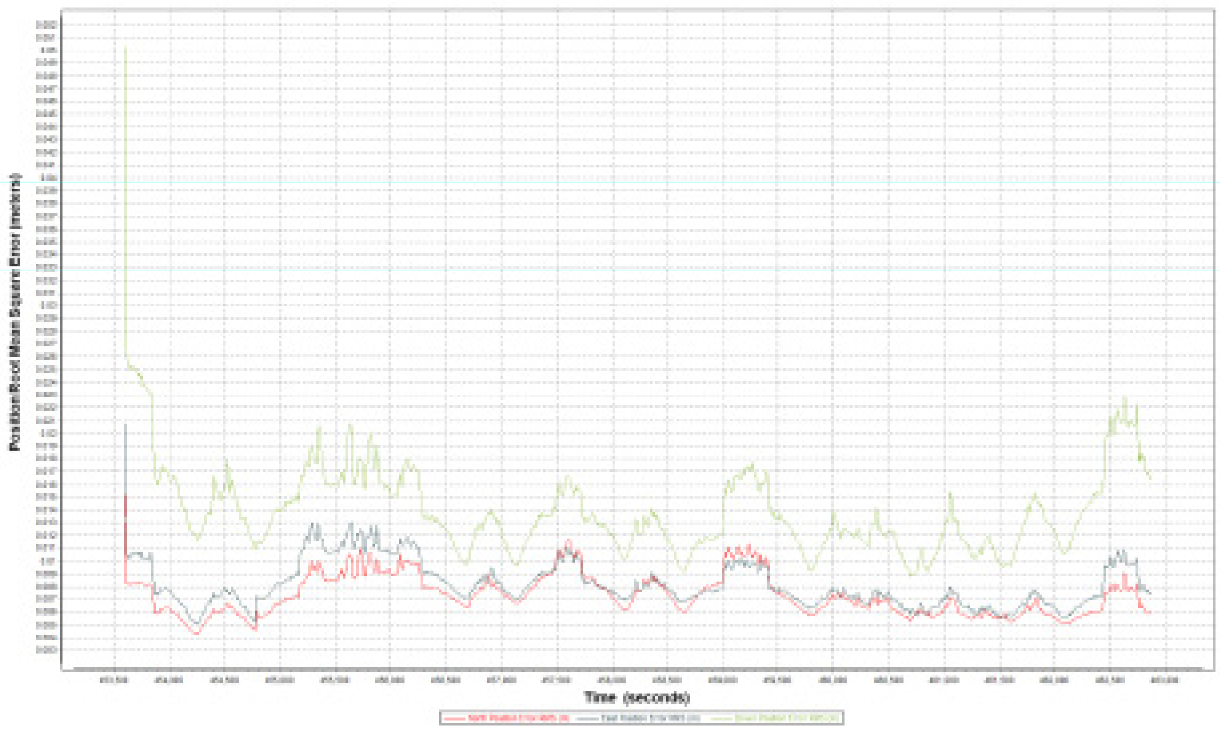


Figure 11. Smoothed Performance Metric Parameters of Cadac-an Flight 1436A

The time of flight was from 453500 seconds to 463000 seconds, which corresponds to afternoon of May 9, 2014. The initial spike seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and when the POS System started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 2.30 centimeters, which are within the prescribed accuracies described in the methodology.

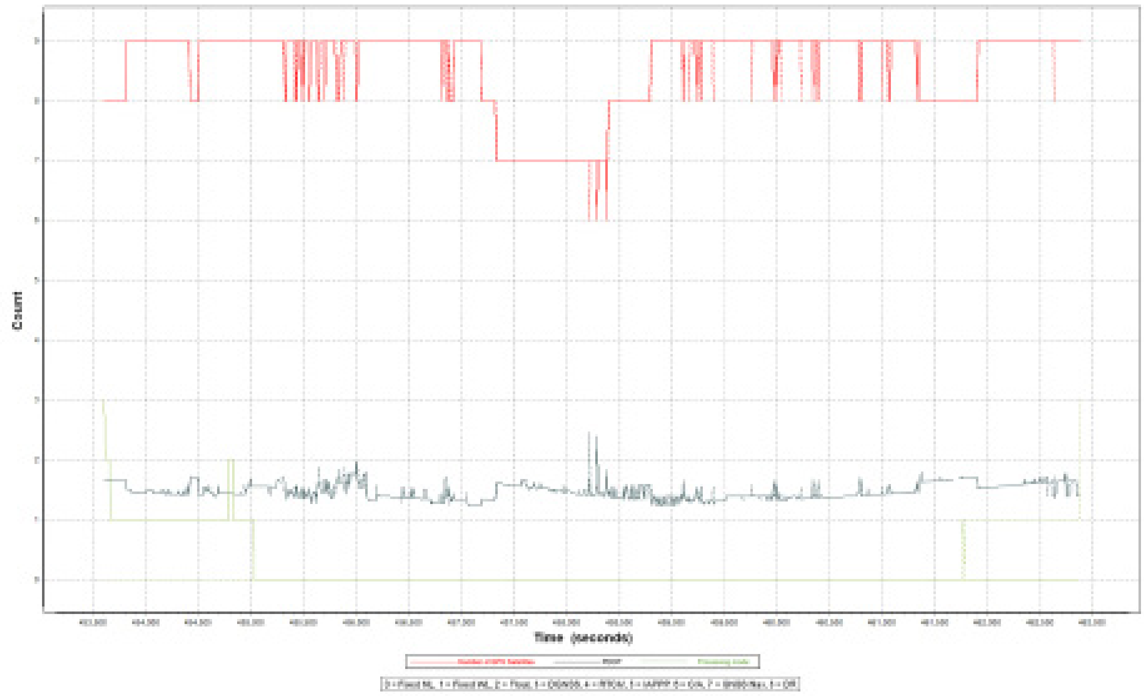


Figure 12. Solution Status Parameters of Cadac-an Flight 1436A

The Solution Status parameters of flight 1436A, one of the Cadac-an flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go below 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 or 2 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 Cadac-an flights is shown in Figure 13.

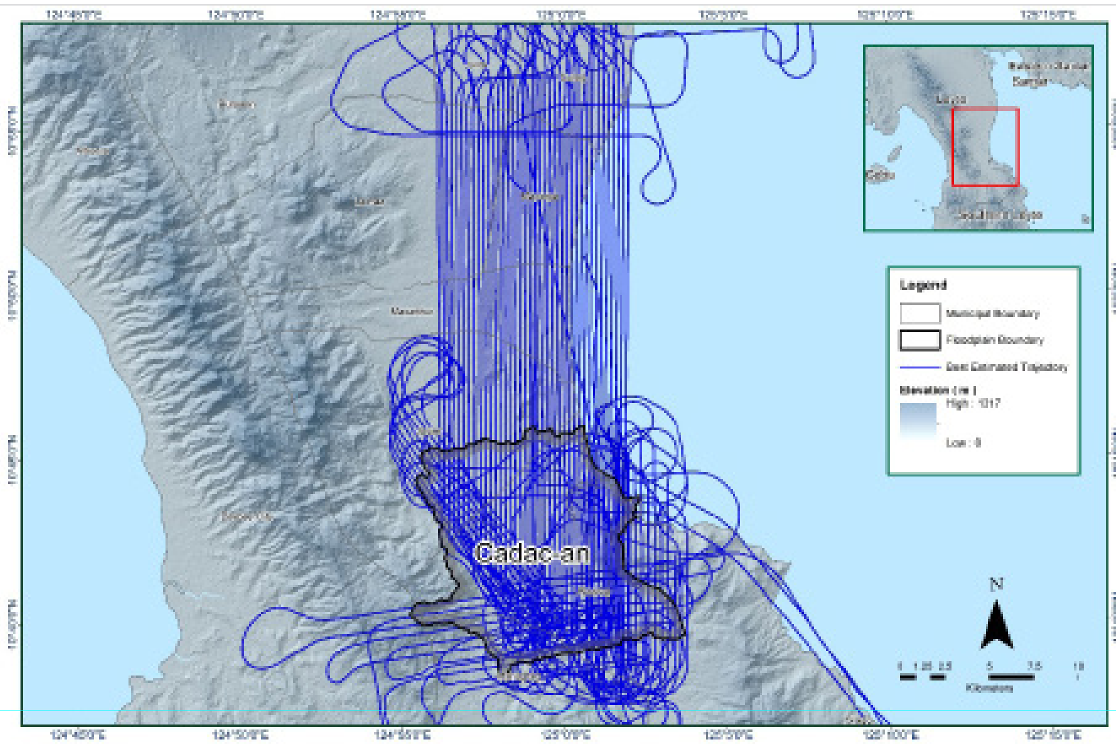


Figure 13. Best Estimated Trajectory for Cadac-an Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 94 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 Cadac-an Floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Cadac-an flights.

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000471
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000993
GPS Position Z-correction stdev (<0.01meters)	0.0080

The optimum accuracy is obtained for all Cadac-an flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the ANNEX 8. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Cadac-an Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

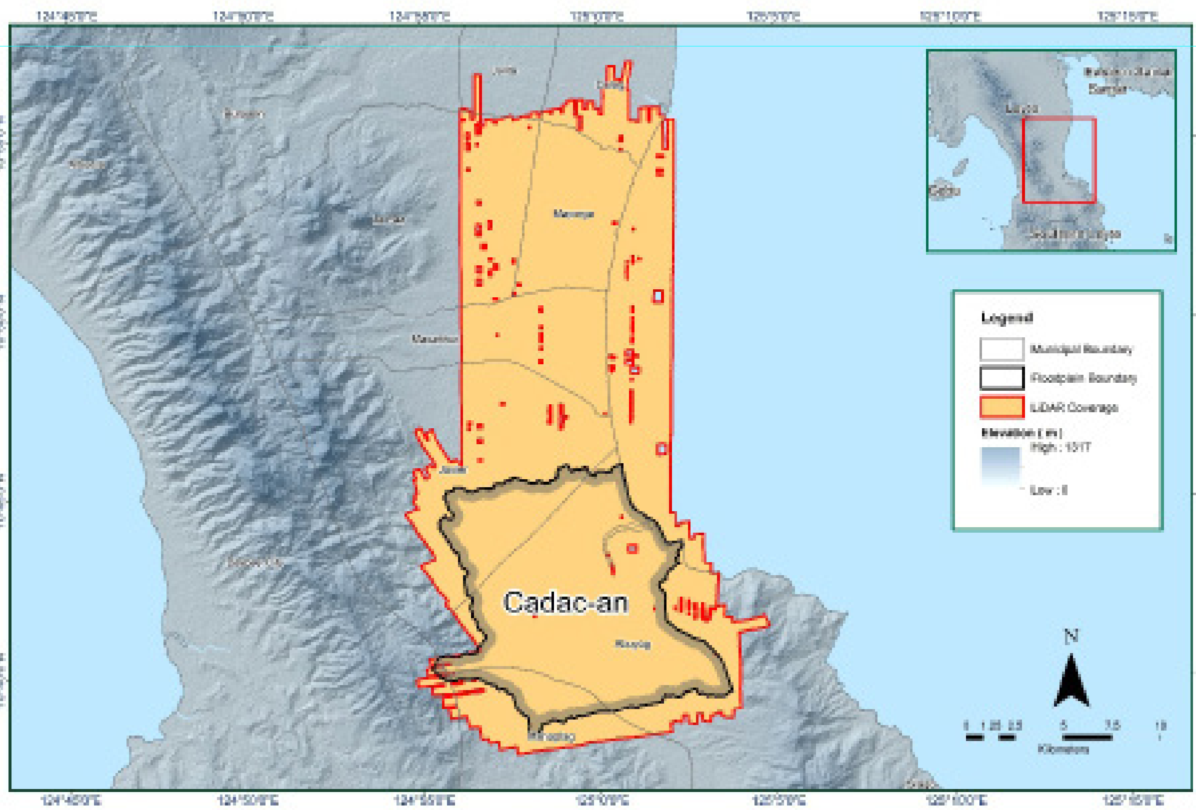


Figure 14. Boundary of the processed LiDAR data over Cadac-an Floodplain

The total area covered by the Cadac-an missions is 409.53 sq.km that is comprised of eight (8) flight acquisitions grouped and merged into six (6) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Cadac-an Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk34H	1434A	119.88
	1436A	
Samar_Leyte_Blk34G	1430A	140.20
	1434A	
Leyte Blk34G	3761G	30.86
	23773G	
Leyte Blk34K	3781G	63.69
	23773G	
Leyte Blk34H	3761G	47.00
	23771G	
Leyte Blk34G_additional	3773G	7.90
	3781G	
TOTAL		**409.53 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 15. Since the Gemini and Aquarius Systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

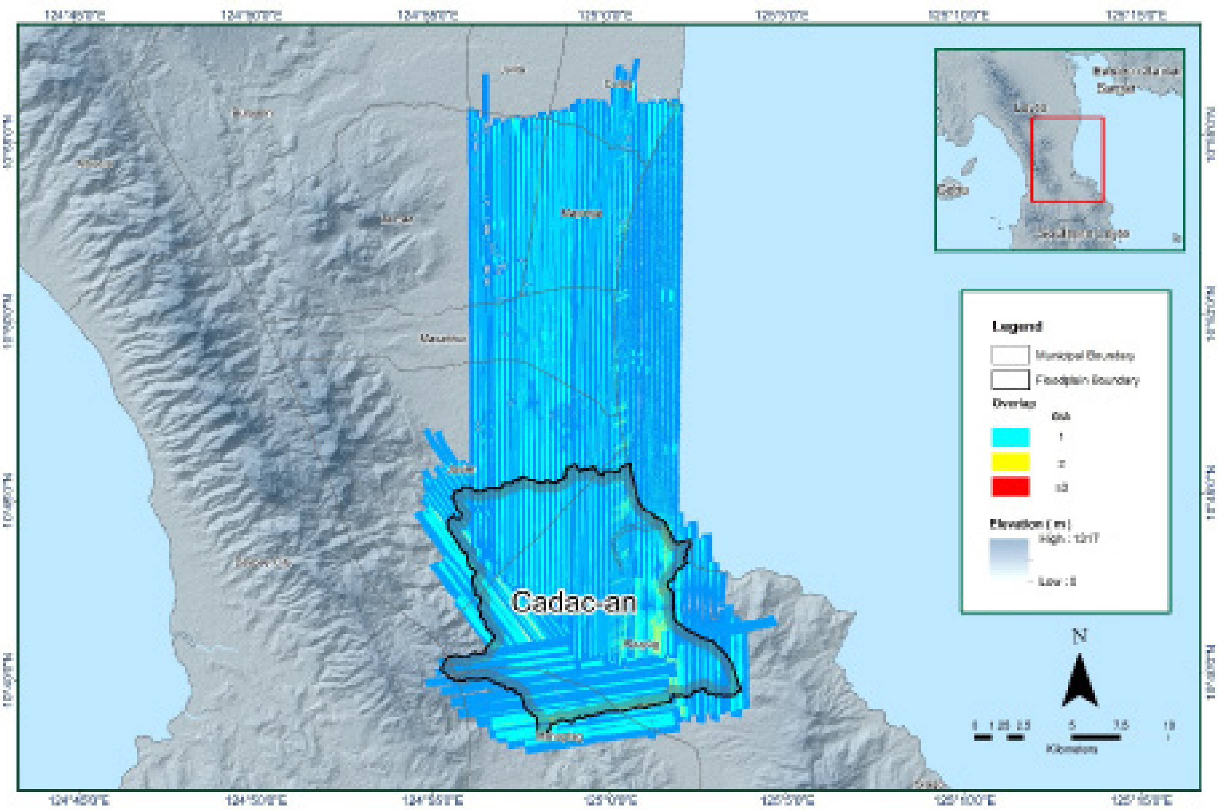


Figure 15. Image of data overlap for Cadac-an Floodplain

The overlap statistics per block for the Cadac-an floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.11% and 42.02% 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 16. It was determined that all LiDAR data for Cadac-an Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.76 points per square meter.

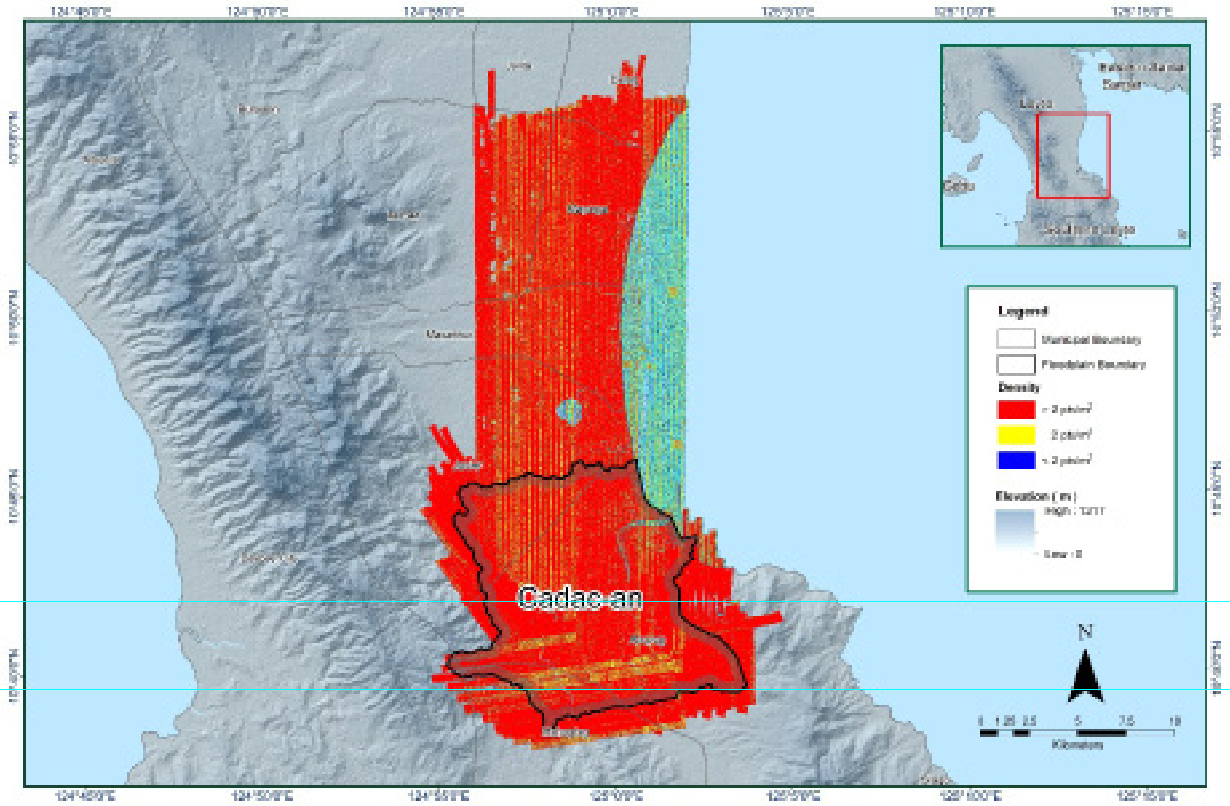


Figure 16. Pulse density map of merged LiDAR data for Cadac-an Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. 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.

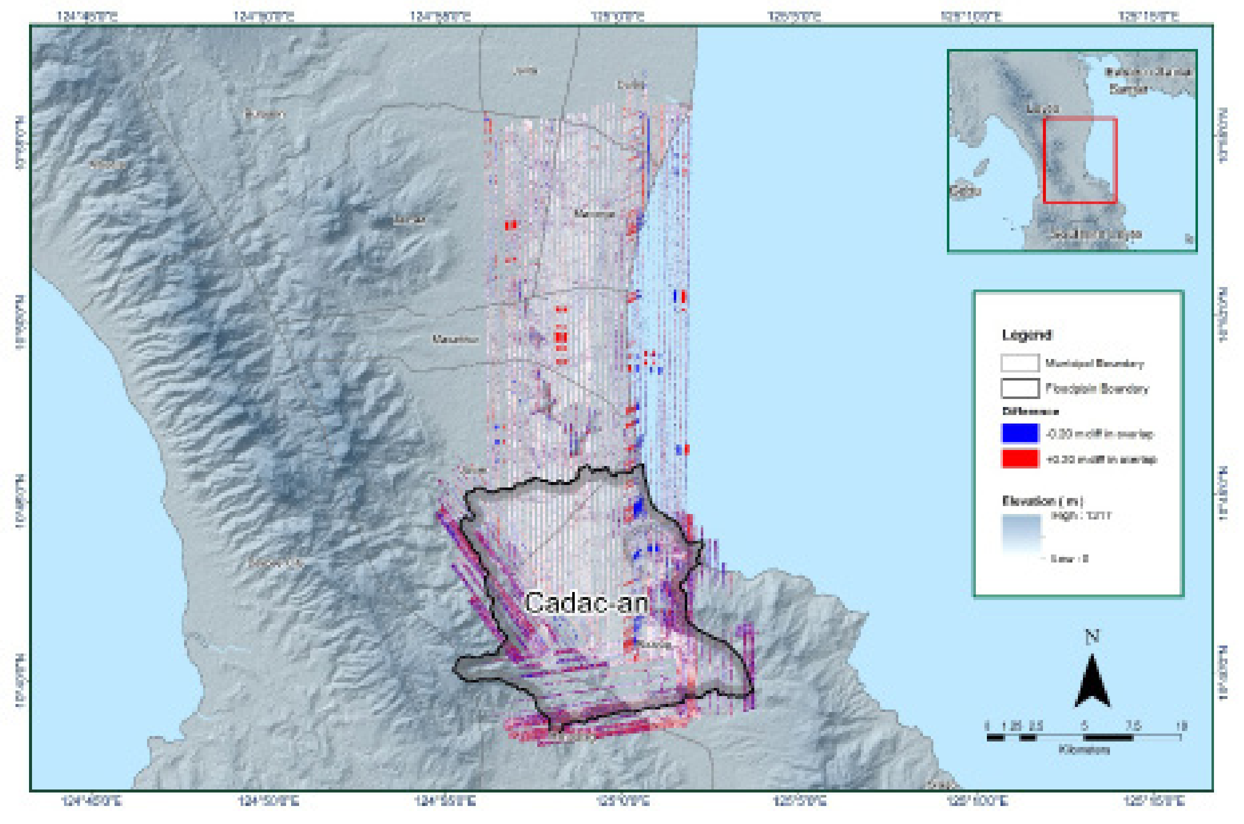


Figure 17. Elevation difference map between flight lines for Cadac-an Floodplain

A screen capture of the processed LAS data from Cadac-an flight 1436A loaded in QT Modeler is shown in Figure 18. 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.

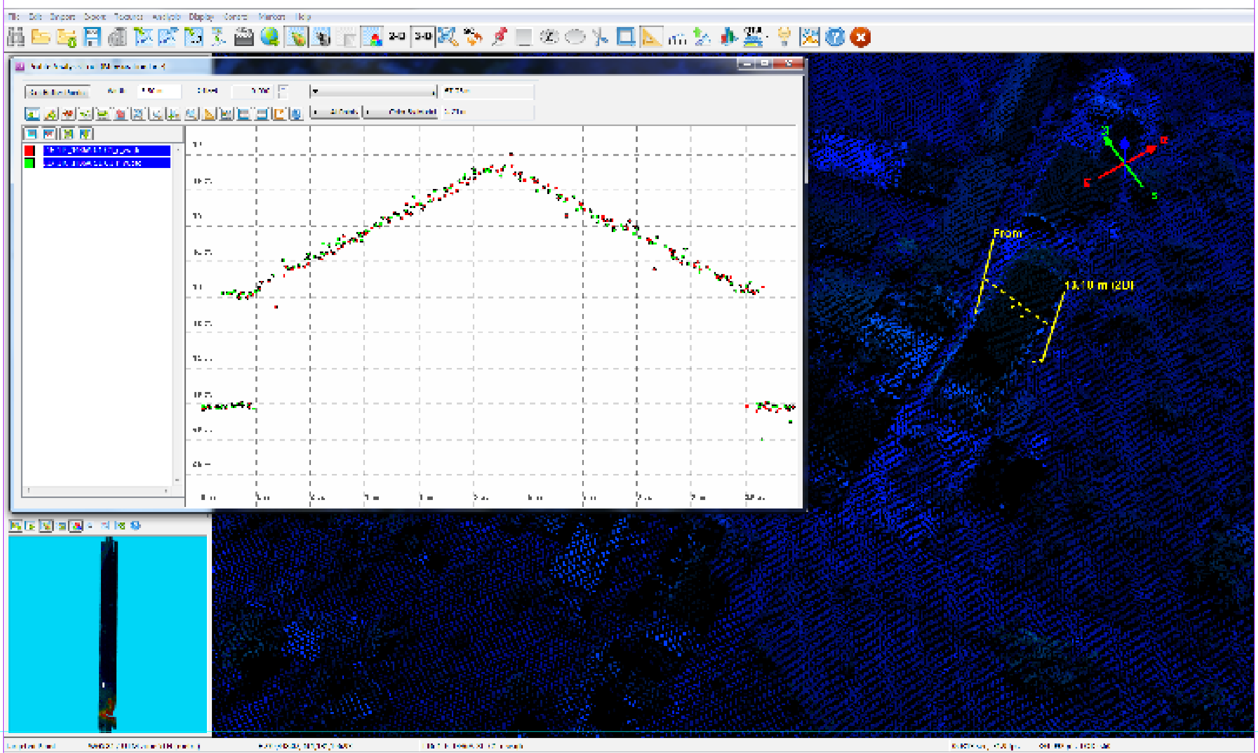


Figure 18. Quality checking for Cadac-an flight 1436A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Cadac-an classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	298,635,717
Low Vegetation	369,467,812
Medium Vegetation	561,255,836
High Vegetation	695,459,215
Building	15,272,905

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Cadac-an Floodplain is shown in Figure 19. A total of 669 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 729.81 meters and 51.73 meters respectively.

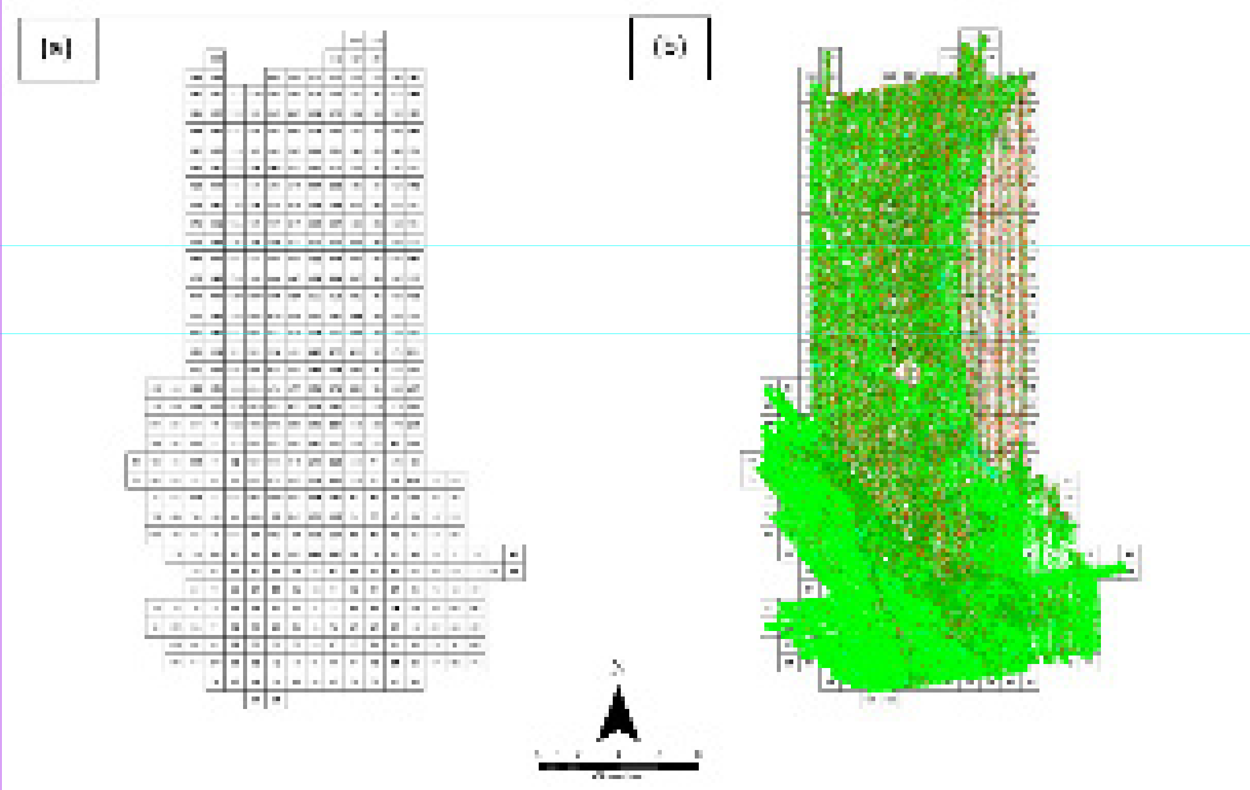


Figure 19. Tiles for Cadac-an floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

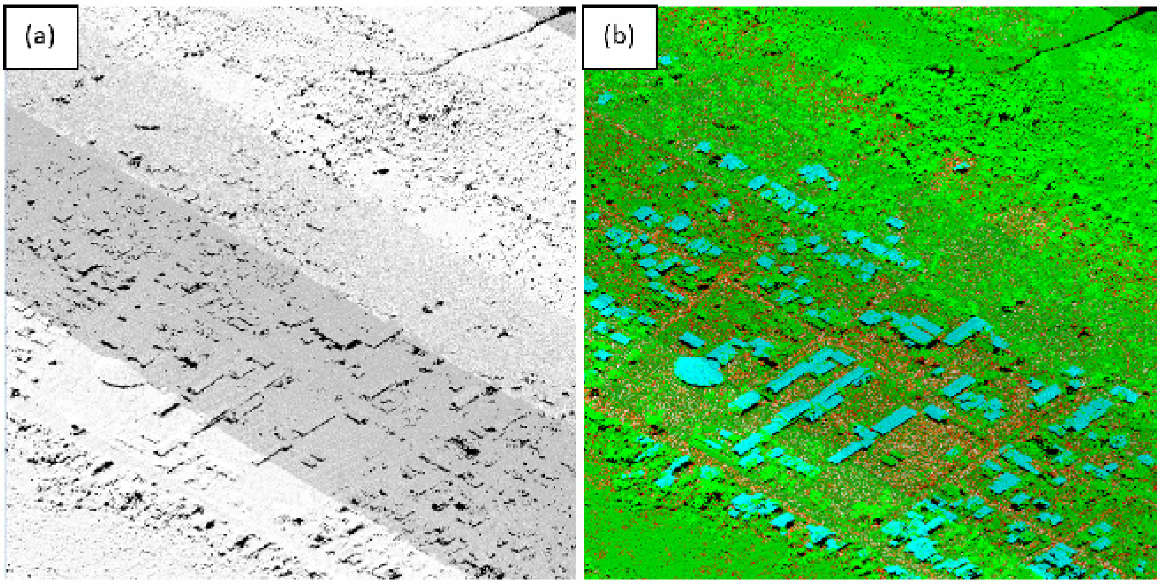


Figure 20. Point cloud before (a) and after (b) classification

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

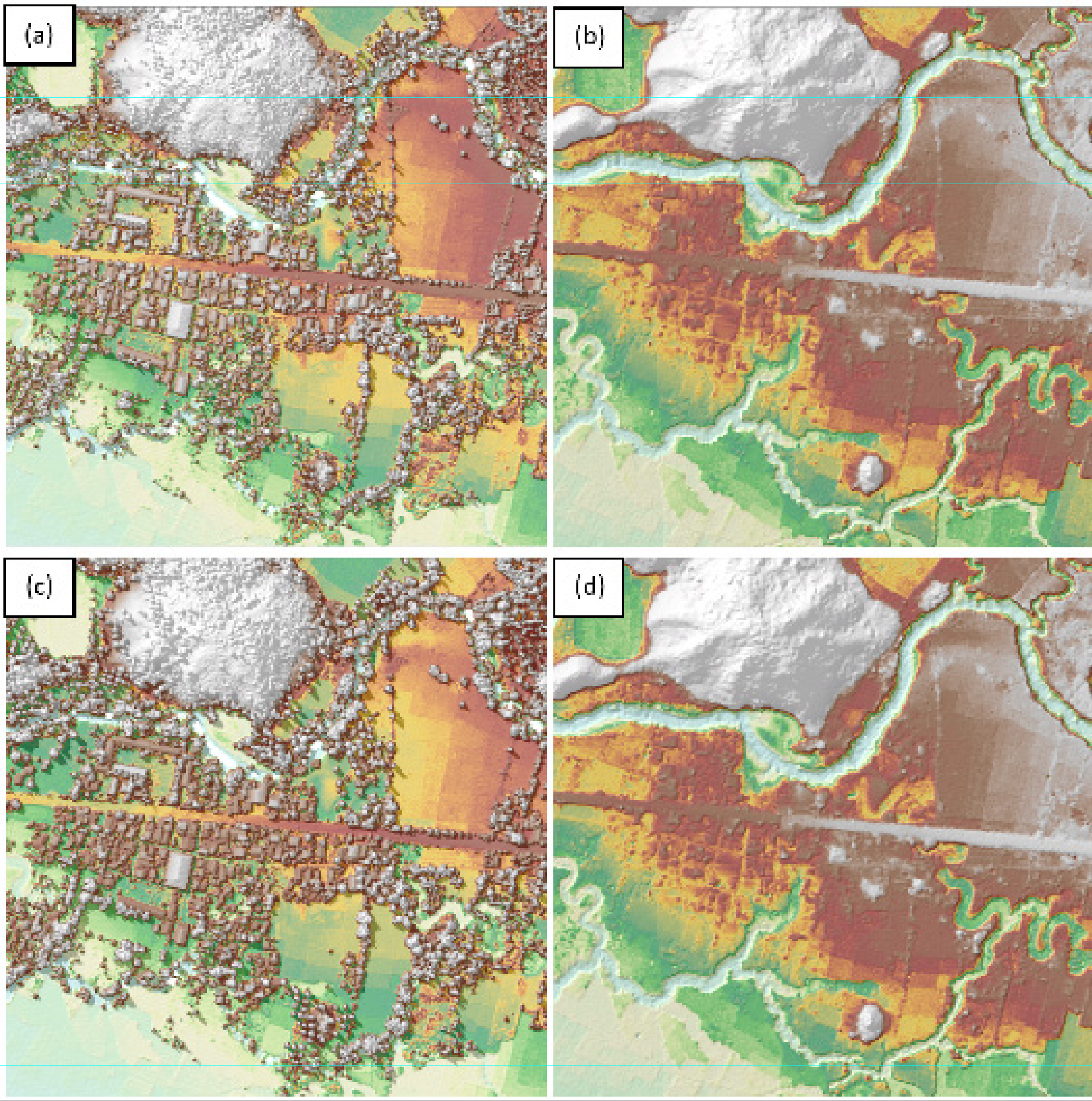


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Cadac-an Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 586 1km by 1km tiles area covered by Cadac-an Floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Cadac-an Floodplain has a total of 380.37 sq.km orthophotogaph coverage comprised of 4,547 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

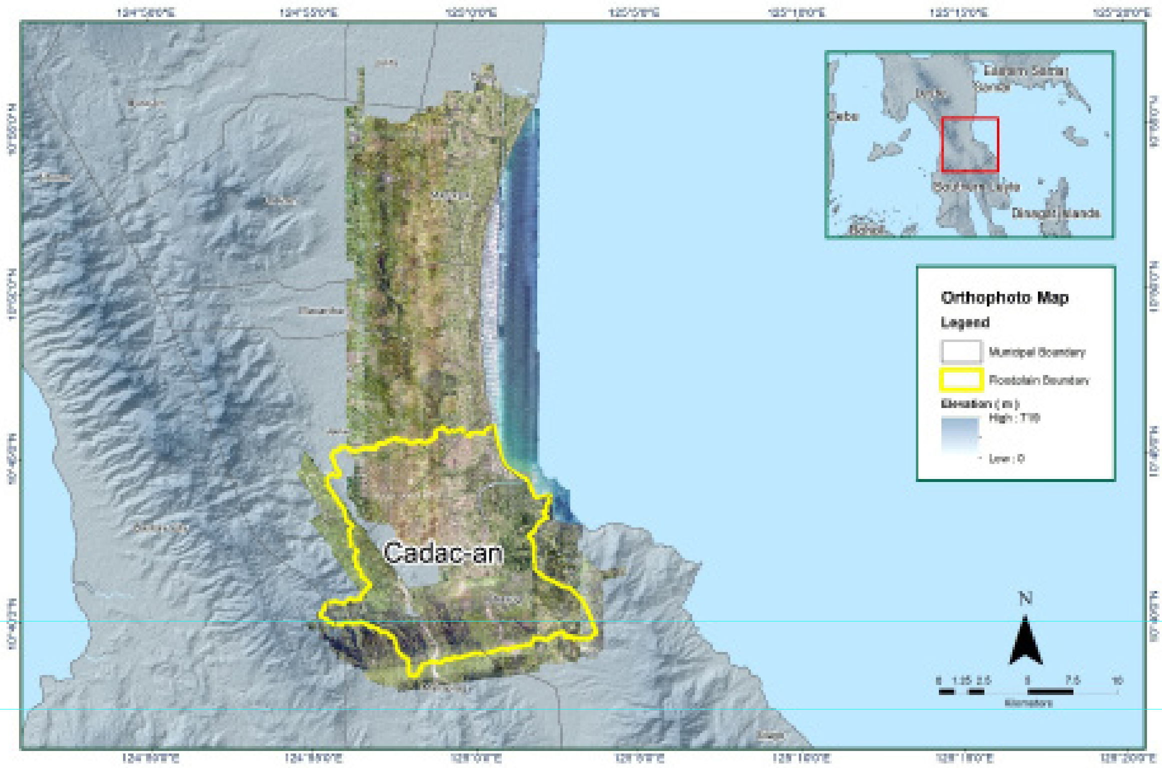


Figure 22. Cadac-an Floodplain with available orthophotographs

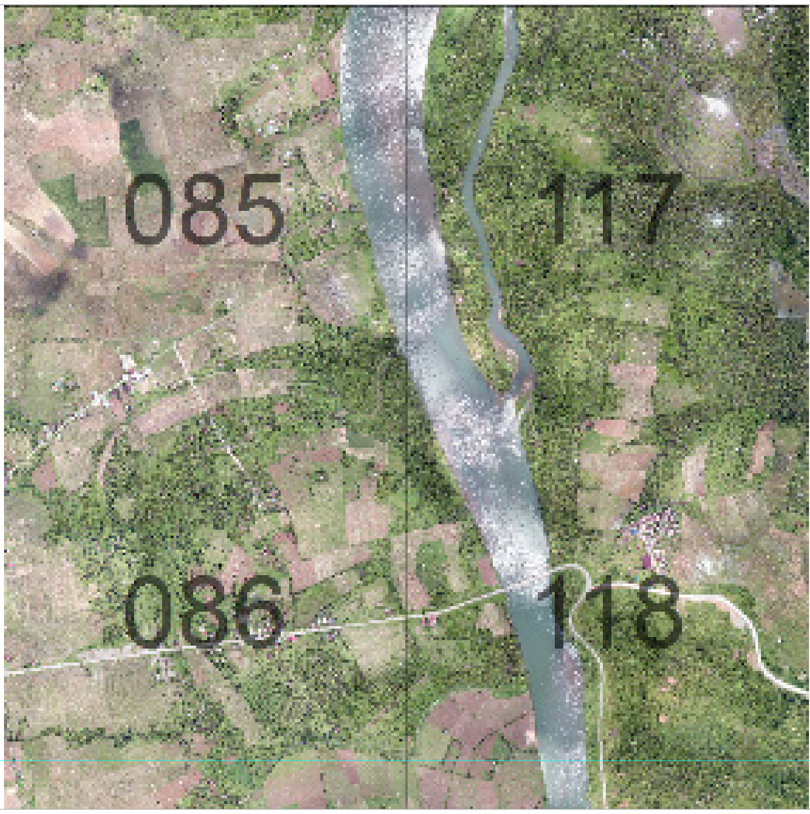


Figure 23. Sample orthophotograph tiles for Cadac-an Floodplain

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Cadac-an Floodplain. These blocks are comprised of SamarLeyte and Leyte blocks with a total area of 409.53 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
SamarLeyte_Blk34H	119.88
SamarLeyte_Blk34G	140.20
Leyte_Blk34G	30.86
Leyte_Blk34H	47.00
Leyte_Blk34K	63.69
Leyte_Blk34G_additional	7.90
TOTAL	**409.53 sq.km**

Portions of the DTM before and after manual editing are shown in Figure 24. The fishpond embankment (Figure 24a) was misclassified and removed during classification process . It was retrieved to complete the surface (Figure 24b) which would allow the correct flow of water. The bridge (Figure 24c) was also considered to be an impedance to the flow of water along the river and was thus removed (Figure 24d) in order to hydrologically correct the river.

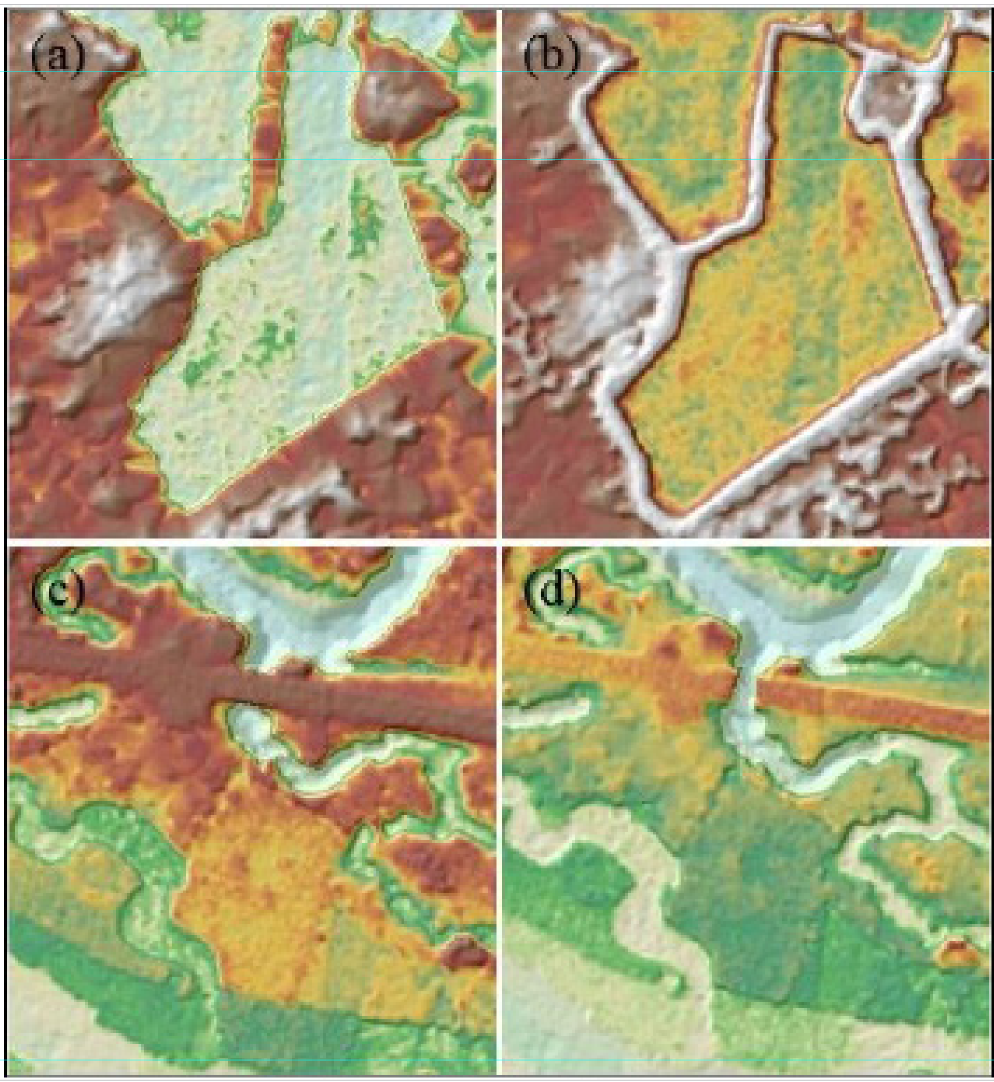


Figure 24. Portions in the DTM of Cadac-an Floodplain – a fishpond embankment before (a) and after (b) data retrieval and a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

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

Mosaicked LiDAR DTM for Cadac-an Floodplain is shown in Figure 25. The entire Cadac-an Floodplain is 99.63% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 17. Shift Values of each LiDAR Block of Cadac-an Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
SamarLeyte_Blk34H	0.00	0.00	-0.52
SamarLeyte_Blk34G	0.00	0.00	-0.54
Leyte_Blk34H	0.00	0.00	-1.21
Leyte_Blk34K	0.00	0.00	-1.16
Leyte_Blk34G	0.00	0.00	-1.30
Leyte_Blk34G_additional	0.00	0.00	-1.22

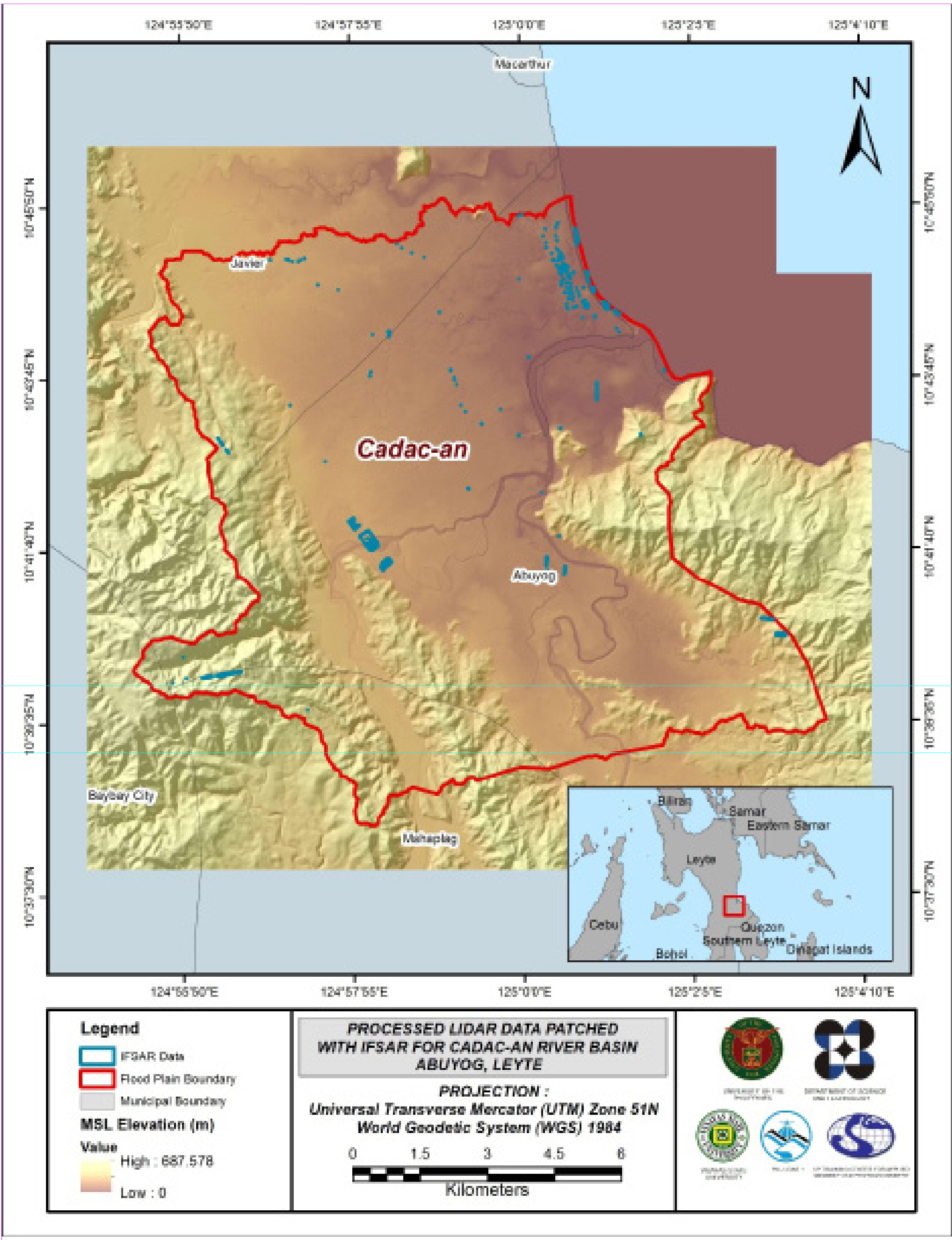


Figure 25. Map of Processed LiDAR Data for Cadac-an Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Cadac-an to collect points with which the LiDAR dataset was validated is shown in Figure 26. A total of 3,735 survey points were gathered for the Cadac-an Floodplain. However, the point dataset was not used for the calibration of the LiDAR data for Cadac-an because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Cadac-an can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and ground survey elevation values is shown in Figure 27. 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 0.14 meters with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, to Tacloban mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Cadac-an DEM.

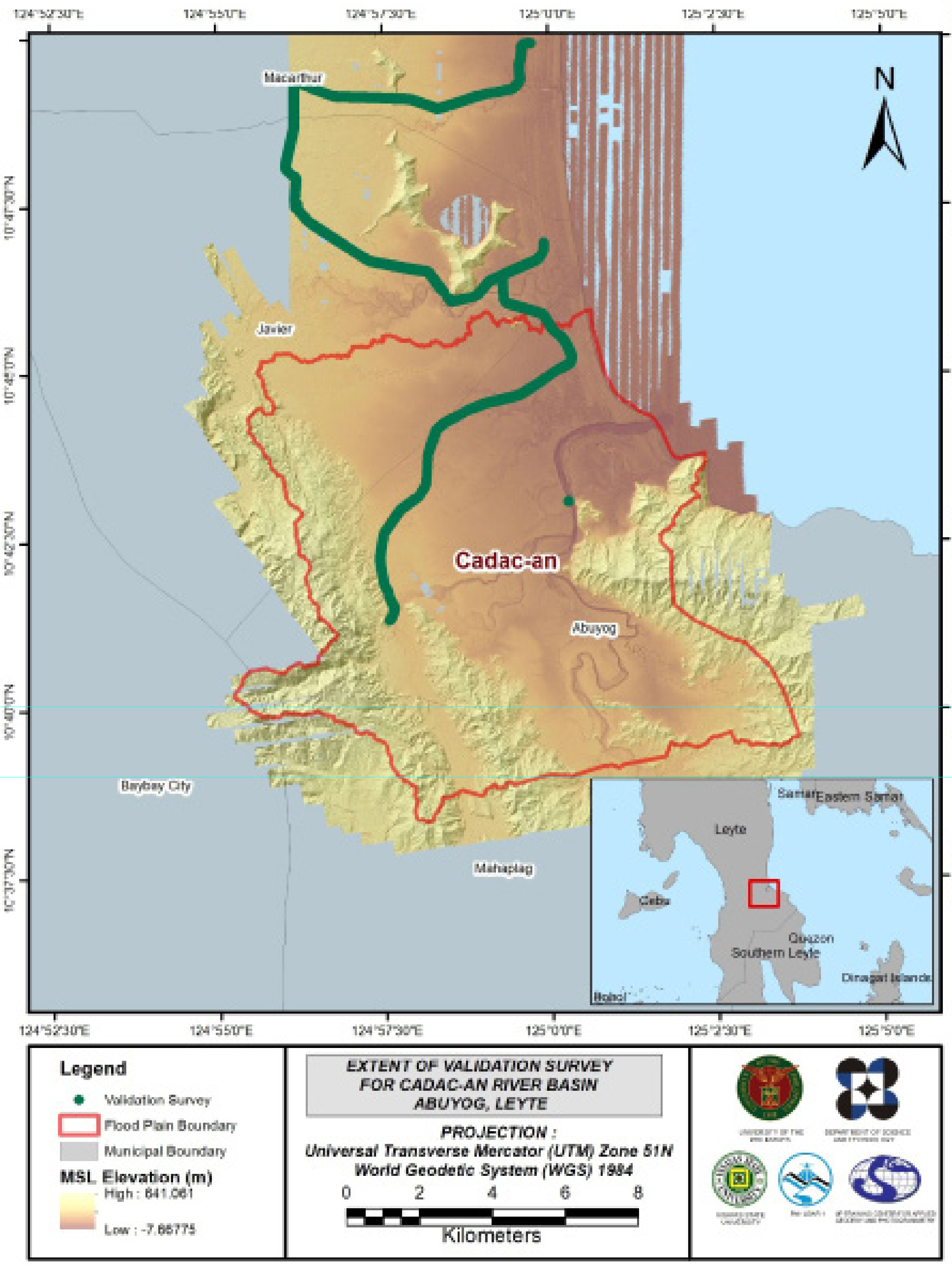


Figure 26. Map of Cadac-an Floodplain with validation survey points in green

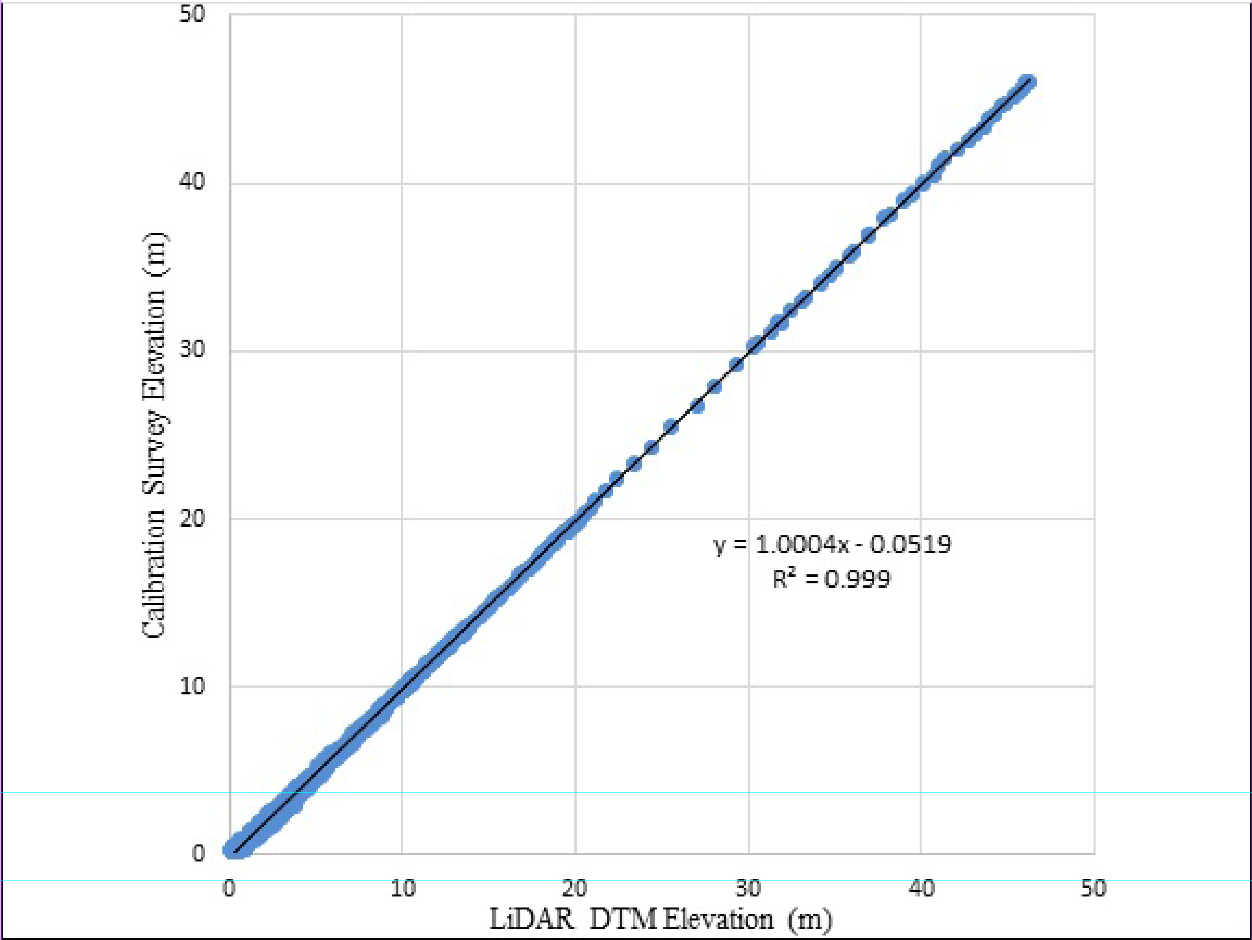


Figure 27. Correlation plot between calibration survey points and LiDAR data

Table 18. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.32
Maximum	0.22

A total of 1,074 survey points that lie within Cadac-an Floodplain and were used for the validation of the calibrated Cadac-an DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.10 meters with a standard deviation of 0.04 meters, as shown in Table 19.

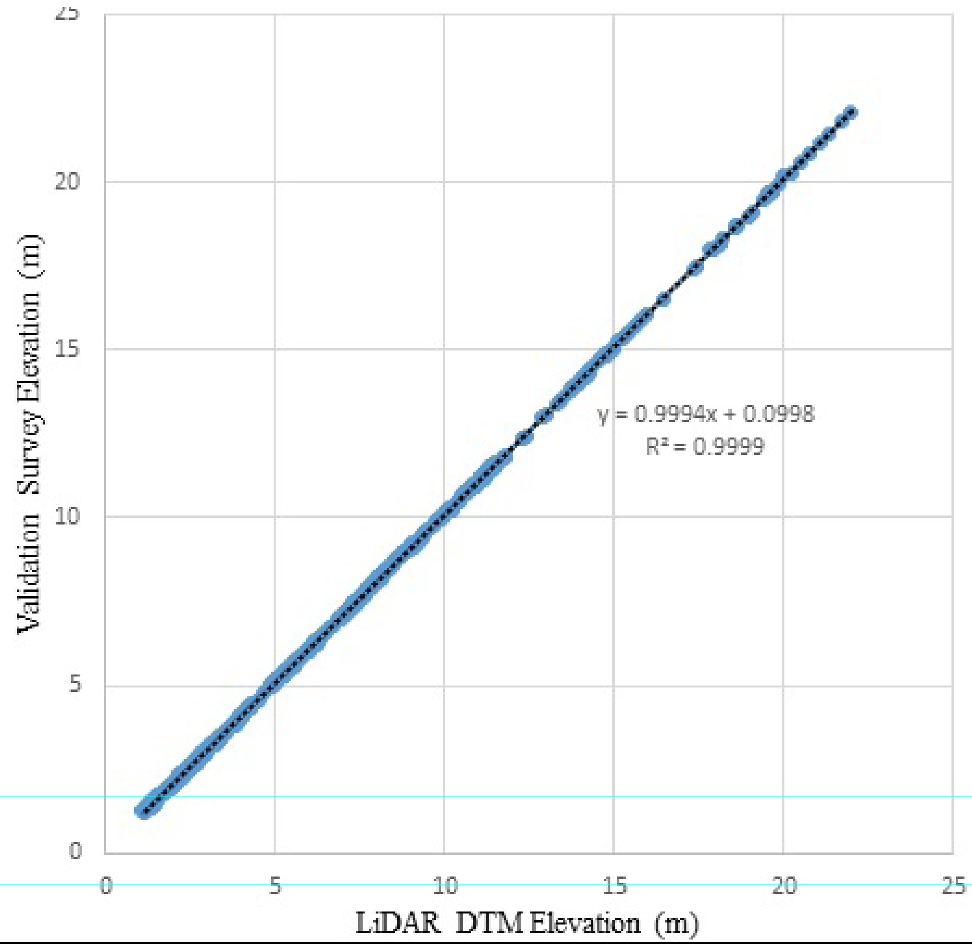


Figure 28. Correlation plot between validation survey points and LiDAR data

Table 19. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.10
Standard Deviation	0.04
Average	-0.10
Minimum	-0.18
Maximum	-0.02

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data were available for Cadac-an with 4,078 bathymetric survey points. The resulting raster surface produced was done by Spline with Barriers interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.38 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Cadac-an integrated with the processed LiDAR DEM is shown in Figure 29.

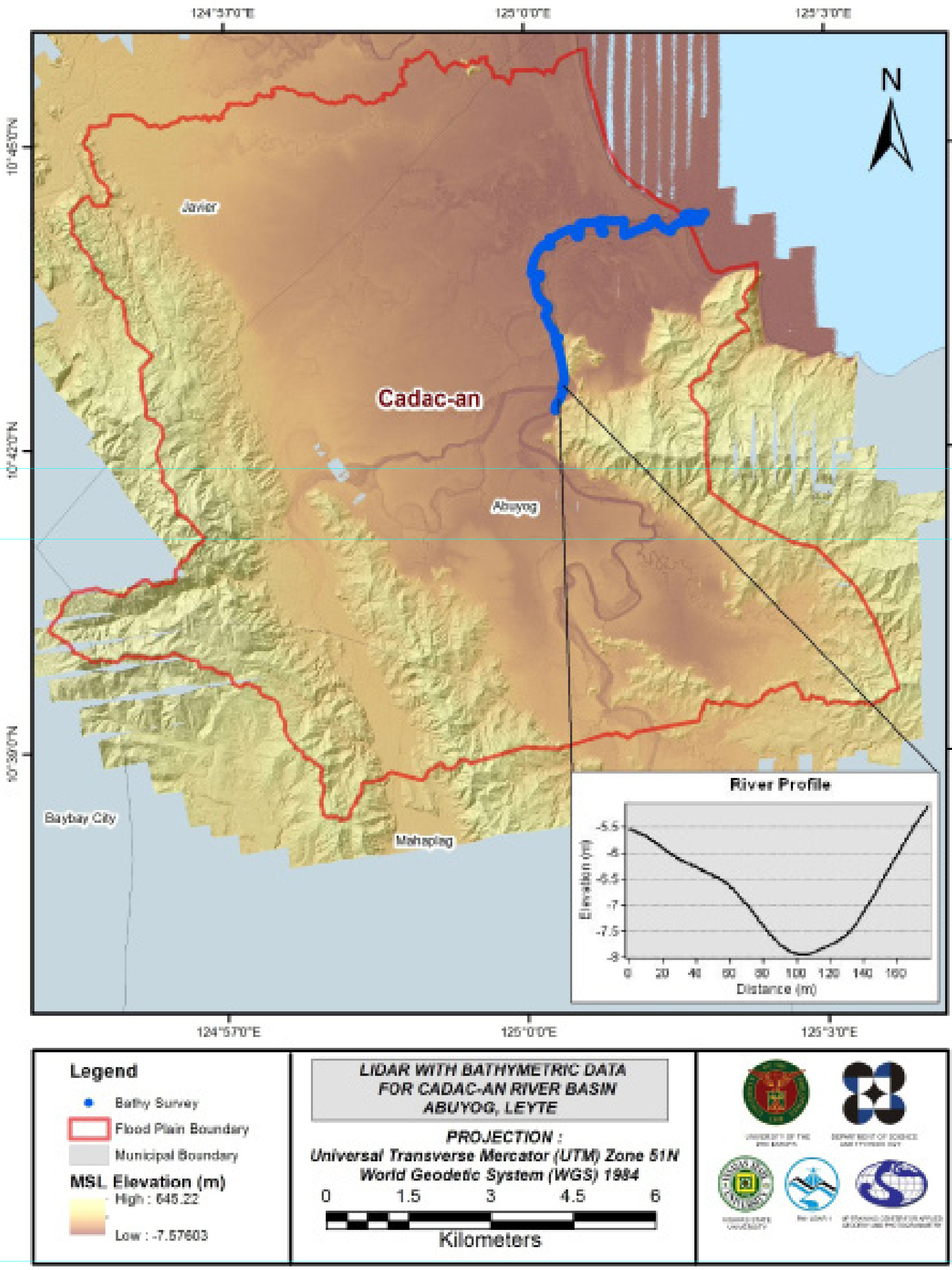


Figure 29. Map of Cadac-an Floodplain with bathymetric survey points shown in blue

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, consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks, comprised of main thoroughfares such as highways and municipal and barangay roads 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

The Cadac-an Floodplain, including its 200 m buffer, has a total area of 143.06 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1308 building features, are considered for QC. Figure 30 shows the QC blocks for Cadac-an Floodplain.

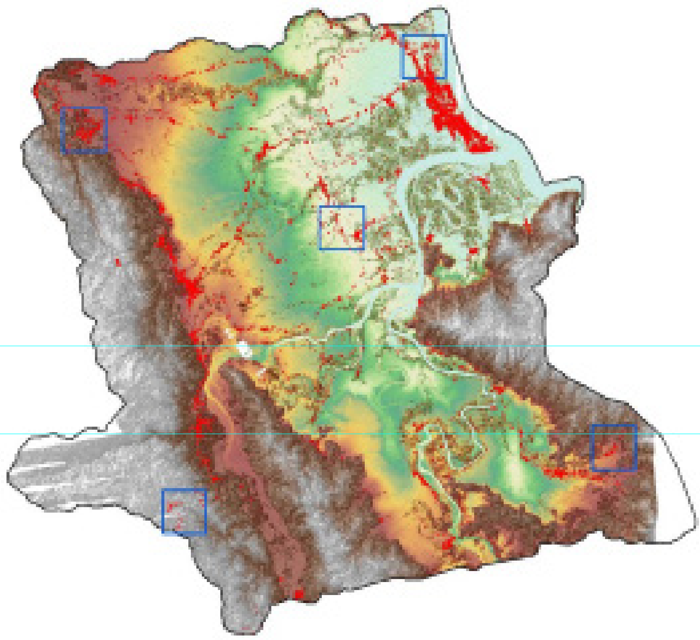


Figure 30. QC blocks for Cadac-an building features

Quality checking of Cadac-an building features resulted in the ratings shown in Table 20.

Table 20. Quality Checking Ratings for Cadac-an Building Features

Floodplain	Completeness	Correctness	Quality	Remarks
Cadac-an	96.79	94.42	82.19	PASSED

3.12.2 Height Extraction

Height extraction was done for 13,273 building features in Cadac-an Floodplain. Of these building features, 258 were filtered out after height extraction, resulting to 13,015 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 12.10 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 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building Features Extracted for Cadac-an Floodplain

Facility Type	No. of Features
Residential	11,813
School	319
Market	14
Agricultural/Agro-Industrial Facilities	177
Medical Institutions	47
Barangay Hall	39
Military Institution	0
Sports Center/Gymnasium/Covered Court	23
Telecommunication Facilities	1
Transport Terminal	2
Warehouse	107
Power Plant/Substation	0
NGO/CSO Offices	6
Police Station	1
Water Supply/Sewerage	12
Religious Institutions	143
Bank	3
Factory	0
Gas Station	7
Fire Station	1
Other Government Offices	107
Other Commercial Establishments	193
Total	**13,015**

Table 22. Total Length of Extracted Roads for Cadac-an Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Cadac-an	75.73	18.39	19.60	37.37	0.00	**151.10**

Table 23. Number of Extracted Water Bodies for Cadac-an Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cadac-an	69	43	0	0	0	**112**

A total of 62 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 31 shows the Digital Surface Model (DSM) of Cadac-an Floodplain overlaid with its ground features.

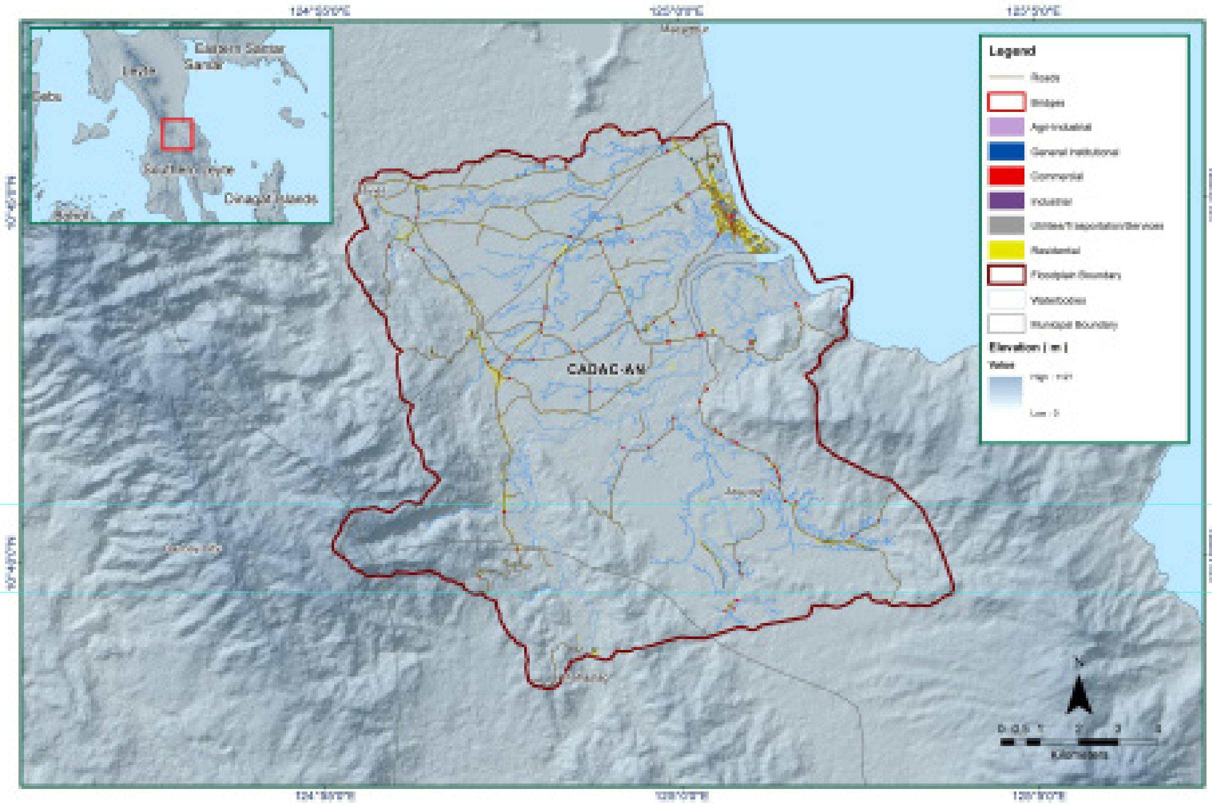


Figure 31. Extracted features for Cadac-an Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE CADAC-AN RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, Vie Marie Paola M. Rivera

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

4.1 Summary of Activities

In line with this, DVBC conducted a field survey in Cadacan River on September 10-24, 2014 and January 6 to 20, 2015 with the following scope of work: reconnaissance, control survey, bridge as-built and cross-section survey, bathymetric and aquarius validation survey, and ground validation survey. The bathymetric survey started in Brgy. Tadoc and finished in Brgy. Buenavista, Municipality of Abuyog. An Ohmex™ Single

Beam Echo Sounder and a GNSS receiver was used utilizing GNSS PPK survey technique for both the LiDAR Aquarius validation (10.70 km) and the bathymetric survey(8.74 km).

4.2 Control Survey

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

Five (5) control points were established at the approach of bridges namely: UP-ABG at Cadacan Bridge, in Brgy. Pagsang-An, Municipality of Abuyog; UP-B at Pagbangaran Bridge in Brgy. Poblacion, Baybay City, Leyte UP-DAG at Daguitan Bridge, in Brgy. Fatima, Municipality of Dulag; UP-O at Ormoc Merida Bridge, in Brgy. Liloan, Ormoc City; and UP-STN at Calay-calay Bridge, in Brgy. Caraycaray, Municipality of San Miguel. Two (2) arbitrary points were also observed to complete the network. AP1 and AP2 are located at the corner of Maharlika Highway and an unnamed street going to Campetic Road, in Brgy. Campetik, Municipality of Palo and inside Burauen Church Plaza, Julita Burauen Road corner Burauen – Dagami Road, Brgy. Poblacion VII, Municipality of Burauen, Province of Leyte, respectively.

The summary of reference and control points and its location is summarized in Table 24.

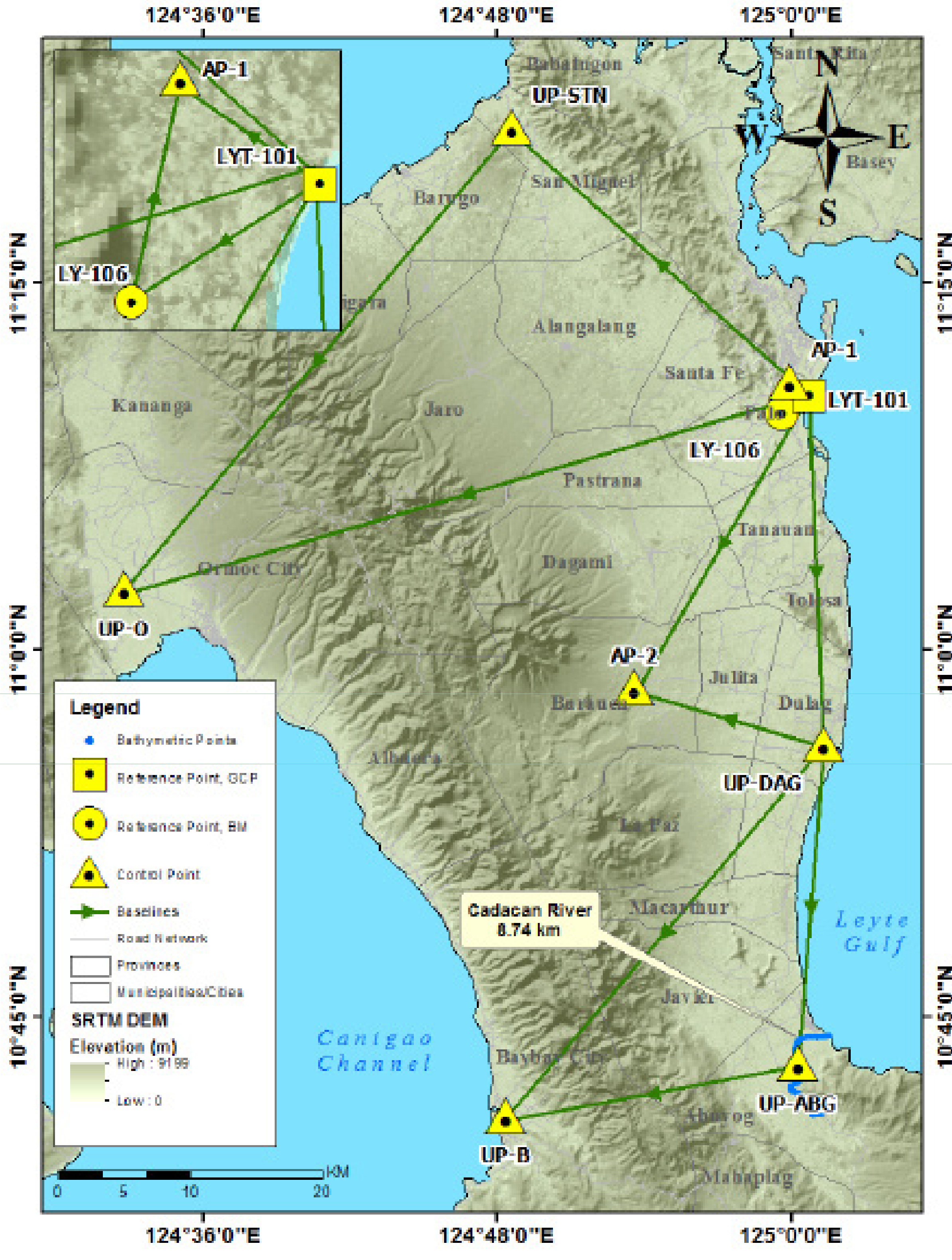


Figure 32. GNSS network for Cadacan River Survey

Table 24. List of references and control points used in Cadacan River survey in Leyte (Source: NAMRIA and UP TCAGP)

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

The GNSS set up made in the location of the reference and control points are exhibited are shown in Figures 33 to 38.

Figure 33. GNSS base set up, Trimble® SPS 852, at LYT-101, located at the General McArthur Shrine in Brgy. Candahog, Municipality of Palo, Leyte

Figure 34. GNSS base set up, Trimble® SPS 985, at LY-106, located at the approach of Bernard Reed Bridge along Maharlika Highway , Brgy. Luntad, Municipality of Palo, Leyte

Figure 35. Trimble® SPS 985 GNSS set up at UP-ABG in Cadacan Bridge, Abuyog, Leyte

Figure 36. GNSS receiver set up, Trimble® SPS 985, at UP DAG, an established control point, located at the bridge approach of the Daguitan Bridge along Maharlika Highway in Brgy. Fatima, Municipality of Dulag, Province of Leyte

Figure 37. GNSS receiver set up, Trimble® SPS 985, at UP-O, an established control point, located at the bridge approach of the Ormoc Merida Bridge along Ormoc-Merida-Isabel-Palompon Road in Brgy. Liloan, City of Ormoc, Province of Leyte

Figure 38. GNSS base set up, Trimble® SPS 852, at UP-STN, an established control point, located at Calaycalay Bridge approach in Brgy. Brgy. Poblacion Zone 12, City of Baybay, 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 Cadacan River Basin is summarized in Table 25 generated by TBC software.

Table 25. Baseline Processing Report for Cadacan River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
LY106 --- ARB18	09-19-2014	Fixed	0.003	0.012	12°44'49"	2489.516	0.757
LYT101---LY106	09-18-2014	Fixed	0.002	0.010	238°21'43"	2417.860	-1.175
LYT101---ARB18	09-18-2014	Fixed	0.002	0.003	307°32'43"	1903.266	-0.401
LYT101---ARB20	09-19-2014	Fixed	0.003	0.012	210°46'11"	25458.032	51.162
UP-ABG---UPB	09-18-2014	Fixed	0.005	0.015	79°44'17"	22116.420	0.508
UPDAG --- UPB	09-18-2014	Fixed	0.004	0.015	220°10'40"	36642.838	2.200
UP-DAG---UPABG	09-18-2014	Fixed	0.004	0.014	184°27'15"	24145.040	2.687
LYT101---UPDAG	09-20-2014	Fixed	0.004	0.011	177°43'46"	26154.013	1.377
UPDAG---ARB20	09-20-2014	Fixed	0.004	0.014	286°51'16"	14691.113	49.771
LYT101---UPO	09-20-2014	Fixed	0.005	0.013	254°12'03"	52970.388	2.405
UPSTN --- UPO	09-20-2014	Fixed	0.003	0.013	219°39'13”	45132.753	-0.174
LYT101 --- UPSTN	09-20-2014	Fixed	0.003	0.011	312°31'18"	30045.648	2.573

As shown in Table 25, a total of twelve (12) baselines were processed with reference points LYT-101 and LY-106 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates Table 26 of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Tables to 28 for the complete details.

The nine (9) control points, LYT-101, LY-106, UP-ABG, UP-B, UP-DAG, UP-O, UP-STN, and two (2) arbitrary points were occupied and observed simultaneously to form a GNSS loop. The coordinates of point LYT-101 and elevation value of LY-106 were held fixed during the processing of the control points as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Control Point Constraints

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

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 27. The fixed control points LYT-101 has no values for grid errors; and LY-106, for elevation error.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ARB18	718212.616	0.003	1236908.993	0.003	4.830	0.016	
ARB20	706851.618	0.005	1213793.946	0.004	56.309	0.026	
LY106	717679.600	0.003	1234476.728	0.003	4.028	?	e
LYT101	719729.823	?	1235759.250	?	5.133	0.015	LL
UPABG	719226.477	0.007	1185539.275	0.005	8.419	0.035	
UPB	697484.285	0.008	1181471.356	0.005	8.449	0.035	
UPDAG	720942.270	0.005	1209628.100	0.003	5.984	0.025	
UPO	668855.826	0.005	1220991.405	0.004	8.715	0.026	
UPSTN	697443.635	0.004	1255916.571	0.003	8.836	0.024	

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

a. LYT-101

horizontal accuracy	= Fixed
vertical accuracy	= 1.5 cm < 10 cm

b. LY-106

horizontal accuracy	= √((0.3)² + (0.3)²)
	= √ (0.9 + 0.9)
	= 1.34 cm < 20 cm
vertical accuracy	= Fixed

c. UP-DAG

horizontal accuracy	= √((0.5)² + (0.3)²)
	= √ (0.25 + 0.9)
	= 1.07 cm < 20 cm
vertical accuracy	= 2.5 cm < 10 cm

d. UP-O

horizontal accuracy	= √((0.5)² + (0.4)²)
	= √ (0.25 + 0.16)
	= 0.64 cm < 20 cm
vertical accuracy	= 2.6 cm < 10 cm

e. UP-STN

horizontal accuracy	= √((0.5)² + (0.3)²
	= √ (0.25 + 0.9)
	= 1.07 cm < 20 cm
vertical accuracy	= 2.4 cm < 10 cm

f. AP1

horizontal accuracy	= √((0.3)² + (0.3)²
	= √ (0.9 + 0. 9)
	= 1.34 cm < 20 cm
vertical accuracy	= 1.6 cm < 10 cm

g. AP2

horizontal accuracy	= √((0.5)² + (0.4)²
	= √ (0.25 + 0.16)
	= 0.64 cm < 20 cm
vertical accuracy	= 2.6 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 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
ARB18	N11°10'57.39406"	E124°59'54.04240"	68.818	0.016	
ARB20	N10°58'27.65859"	E124°53'34.80074"	120.377	0.026	
LY106	N11°09'38.36969"	E124°59'35.93682"	68.051	?	e
LYT101	N11°10'19.64869"	E125°00'43.78230"	69.220	0.015	LL
UPABG	N10°43'05.67945"	E125°00'16.19836"	73.294	0.035	
UPB	N10°40'57.67514"	E124°48'19.99520"	72.795	0.035	
UPDAG	N10°56'09.12671"	E125°01'17.90763"	70.601	0.025	
UPO	N11°02'28.97655"	E124°32'44.58945"	71.623	0.026	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. 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 29.

Table 29. 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	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LYT-101	2nd Order, GCP	11°10'19.64869"	125°00'43.78230"	69.22	1235759.25	719729.823	5.133
LY-106	1st order, BM	11°09'38.36969"	124°59'35.93682"	68.051	1234476.728	717679.6	4.028
UP-ABG	UP Established	10°43'05.67945"	125°00'16.19836"	73.294	1185539.275	719226.477	8.419
UP-B	UP Established	10°40'57.67514"	124°48'19.99520"	72.795	1181471.356	697484.285	8.449
UP-DAG	UP Established	10°56'09.12671"	125°01'17.90763"	70.601	1209628.1	720942.27	5.984
UP-O	UP Established	11°02'28.97655"	124°32'44.58945"	71.623	1220991.405	668855.826	8.715
UP-STN	UP Established	11°21'20.28517"	124°48'33.44682"	71.794	1255916.571	697443.635	8.836
AP1	Arbitrary Point	11°10'57.39406"	124°59'54.04240"	68.818	1236908.993	718212.616	4.83
AP2	Arbitrary Point	10°58'27.65859"	124°53'34.80074"	120.377	1213793.946	706851.618	56.309

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

Cross-section and as-built survey were conducted on September 16, 2014 along the downstream side of Cadacan Bridge in Brgy. Pagsang-An, Abuyog, Leyte using a GNSS receiver, Trimble® SPS 882 utilizing PPK survey technique as shown in Figure 39.

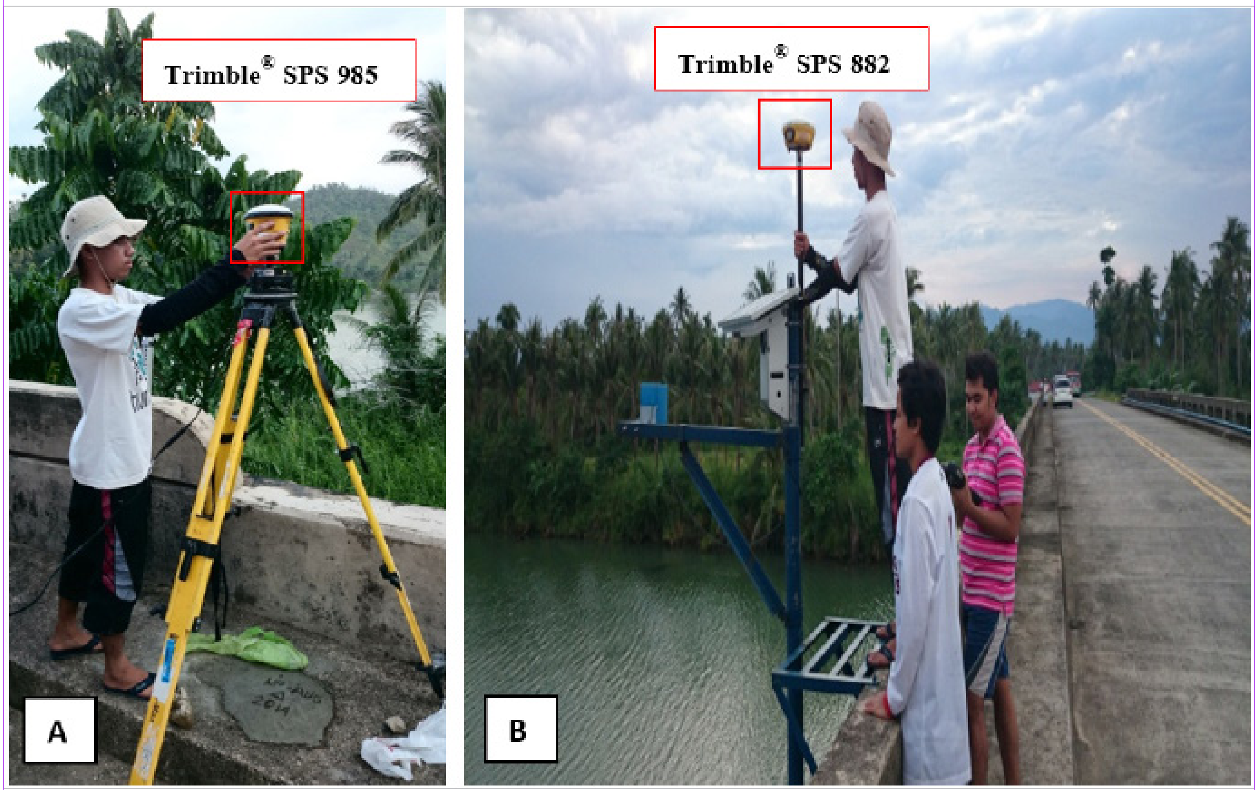


Figure 39. (A) Base set-up at UP-ABG and (B) Acquiring AWLS elevation at Cadacan Bridge, Abuyog, Leyte

The cross-sectional line for Cadacan Bridge is about 265.47 m with a total of 32 cross-section points gathered using UP-ABG as GNSS base station. Figures 40 to 42 show the summary of gathered cross-section, its location map, and as-built data.

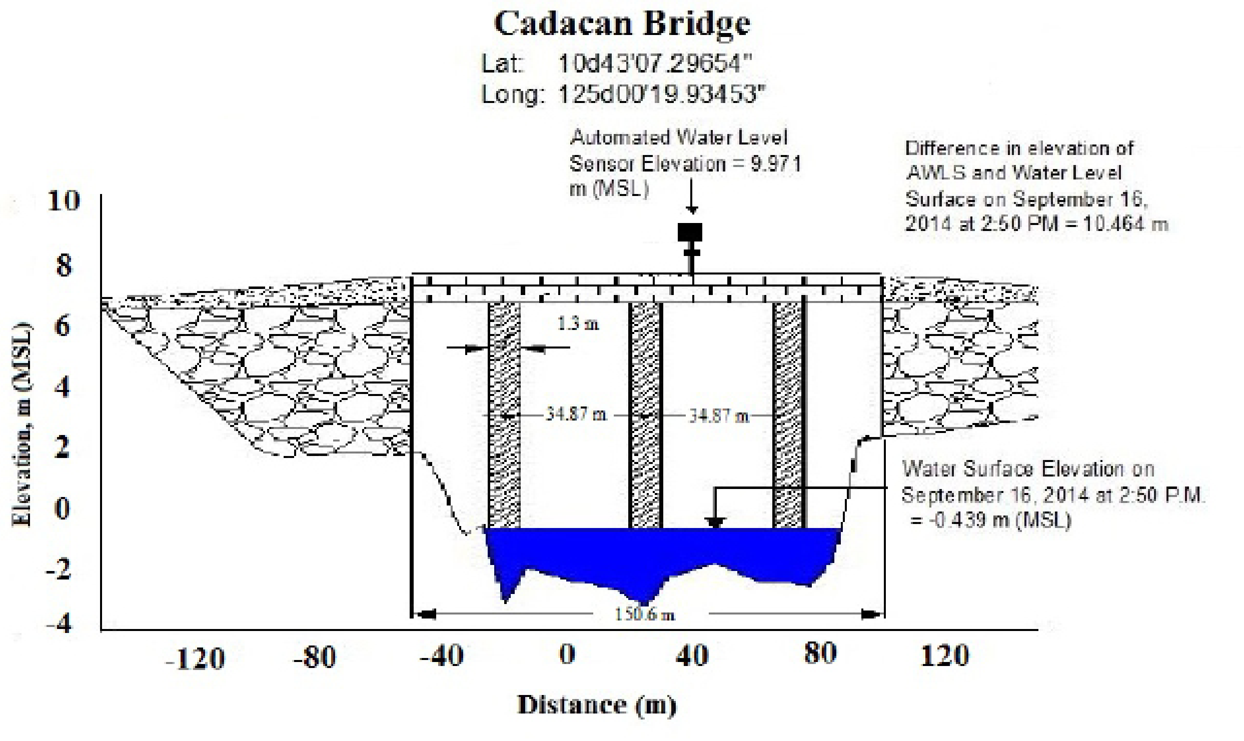


Figure 40. Cadacan Bridge cross-section diagram

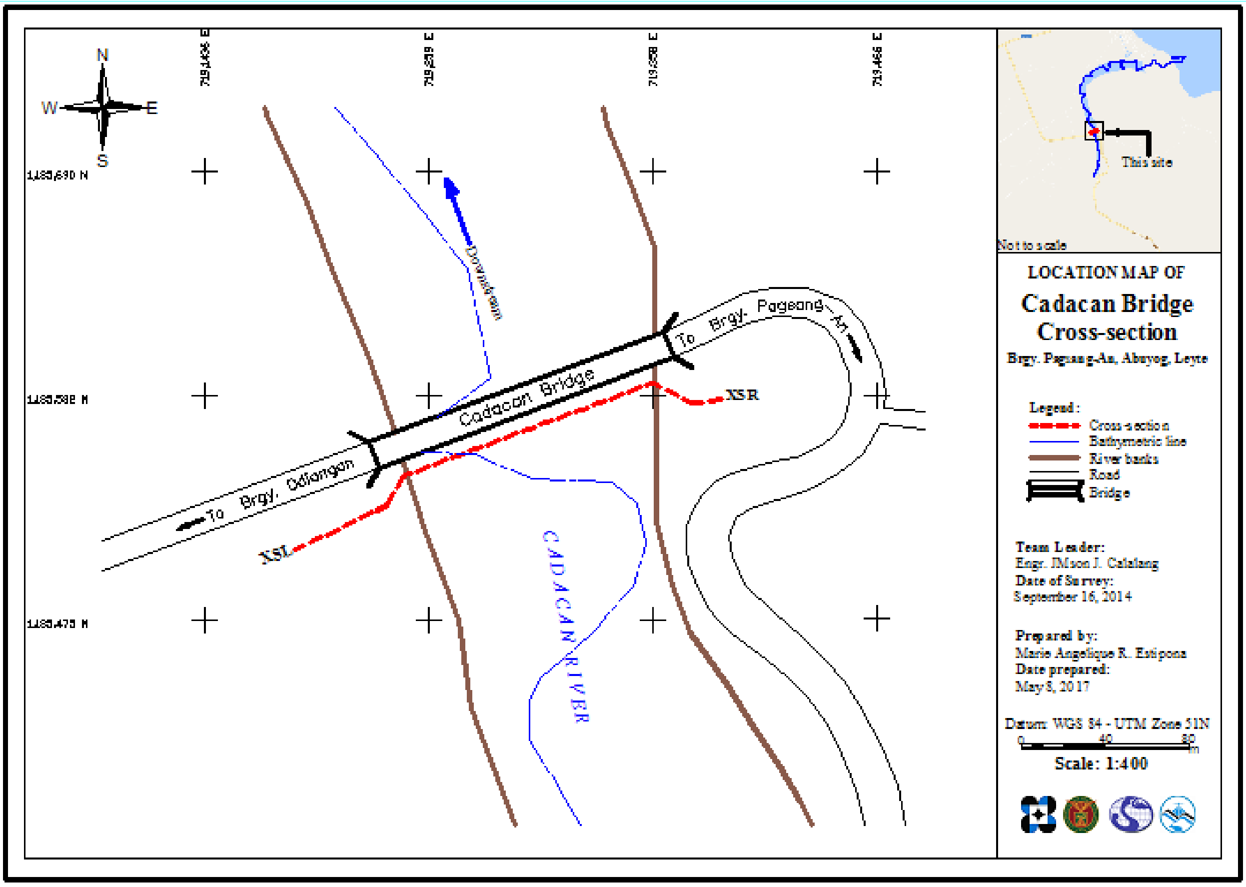


Figure 41. Cadacan bridge cross-section location map

Bridge Data Form

Bridge Name: Cadacan Bridge | Date: 9/16/14

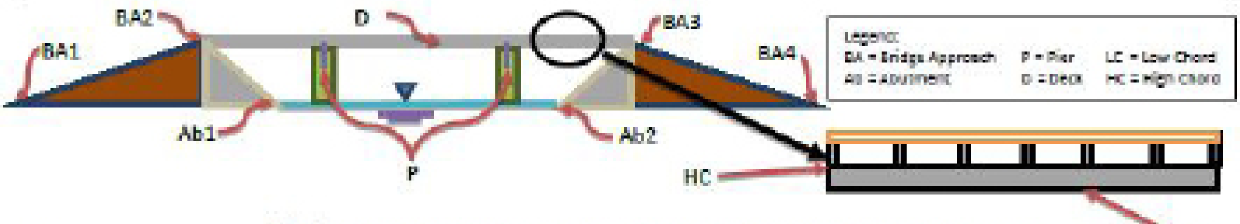
River Name: River | Time: ____________

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

Survey Team: ____________

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

Latitude: 10d43'07.29654" | Longitude: 125d00'19.93453"



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

Elevation: ____________ Width: m. Span (BA3-BA2): 158.838 m.

	Station (Distance from BA1)	High Chord Elevation	Low Chord Elevation
1	45.34361	8.264	5.364
2	83.53421	8.406	5.506
3	128.4314	8.358	5.458
4	173.745	8.400	5.5
5	204.1818	8.339	5.439

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	7.89	BA3	204.1818	8.34
BA2	45.34361	8.26	BA4	226.7754	8.43

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

	Station (Distance from BA1)	Elevation
Ab1	53.40081	0.10
Ab2	196.984	1.16

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

Shape: Rectangular Number of Piers: 3

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	83.53421	-2.4441	1.3
Pier 2	128.4314	-3.2711	1.3
Pier 3	173.745	-3.1361	1.3

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

Figure 42. AS-Built form of Cadacan Bridge

4.6 Validation Points Acquisition Survey

The Validation Points Acquisition survey was conducted On September 21, 2014 using a survey-grade GPS Rover, Trimble® SPS 882, mounted on a pole which was attached in front of a vehicle as shown in Figure 43. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GPS Rover which is 2.404 m.

The ground validation survey traversed the municipalities of Macarthur, Javier, and Abuyog with a total length of approximately 32.85 km with 3,734 points acquired using the control point UP-ABG as the GNSS base station throughout the conduct of survey. Figure 44 shows the gathered data for this survey.

Figure 43. Validation points acquisition survey using Trimble® SPS 882 in Leyte

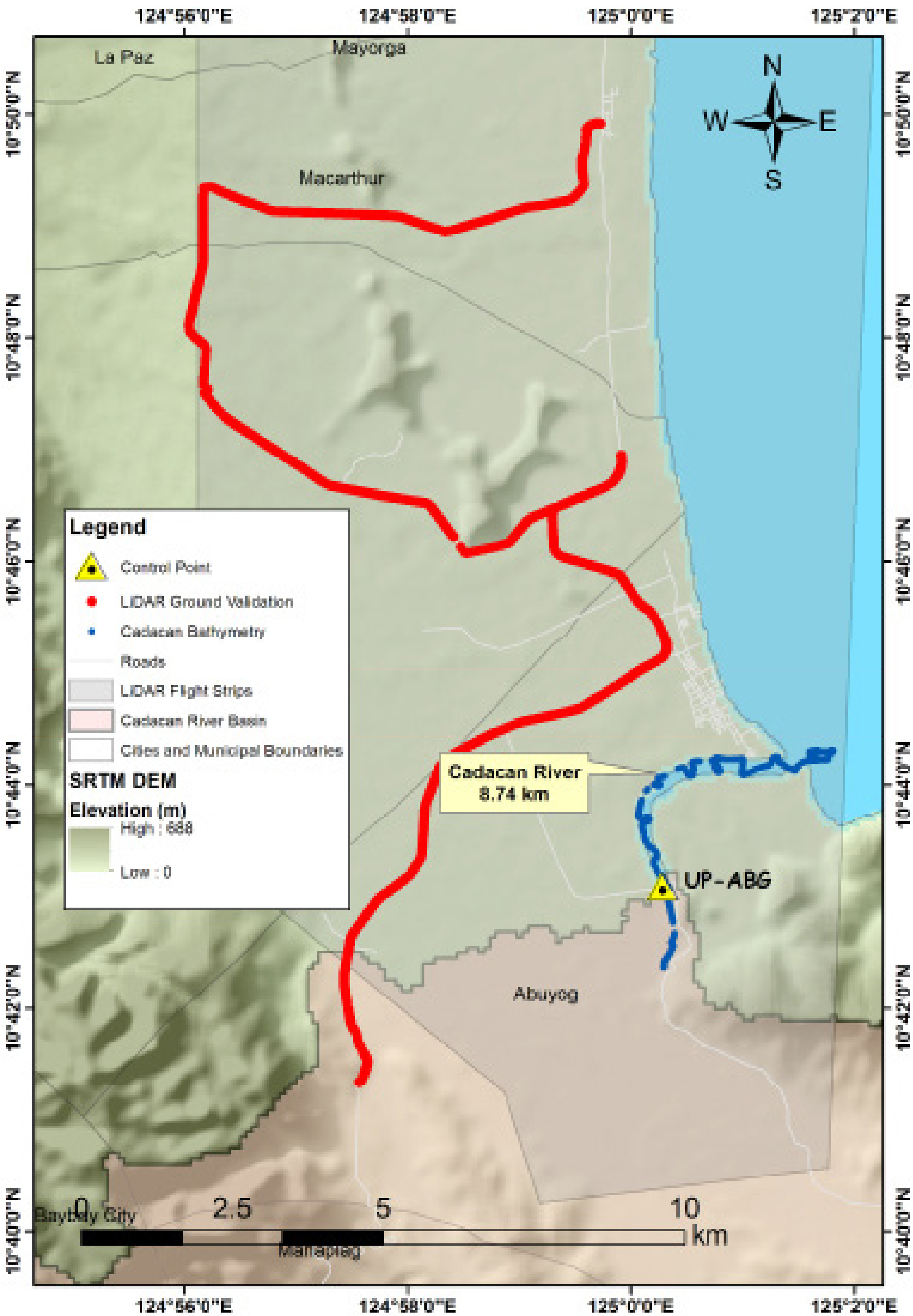


Figure 44. Validation points acquisition survey coverage for Cadac-an River Basin

In addition to ground validation survey, the validation points acquisition survey for Aquarius LiDAR was executed on January 18, 2014. The setup of instruments is similar to that of the bathymetric survey, with an OHMEX™ Single Beam Echo Sounder and a mounted Trimble® SPS 982 in PPK technique to acquire seabed elevation as shown in Figure 45.

The survey was conducted along the shores of the municipalities of Mayorga, Macarthur, and Dulag. An approximate length of 10.75 km was covered with a total of 6,270 points. Figure 46 shows the result coverage of the validation points acquisition for Aquarius LiDAR Aquarius data.

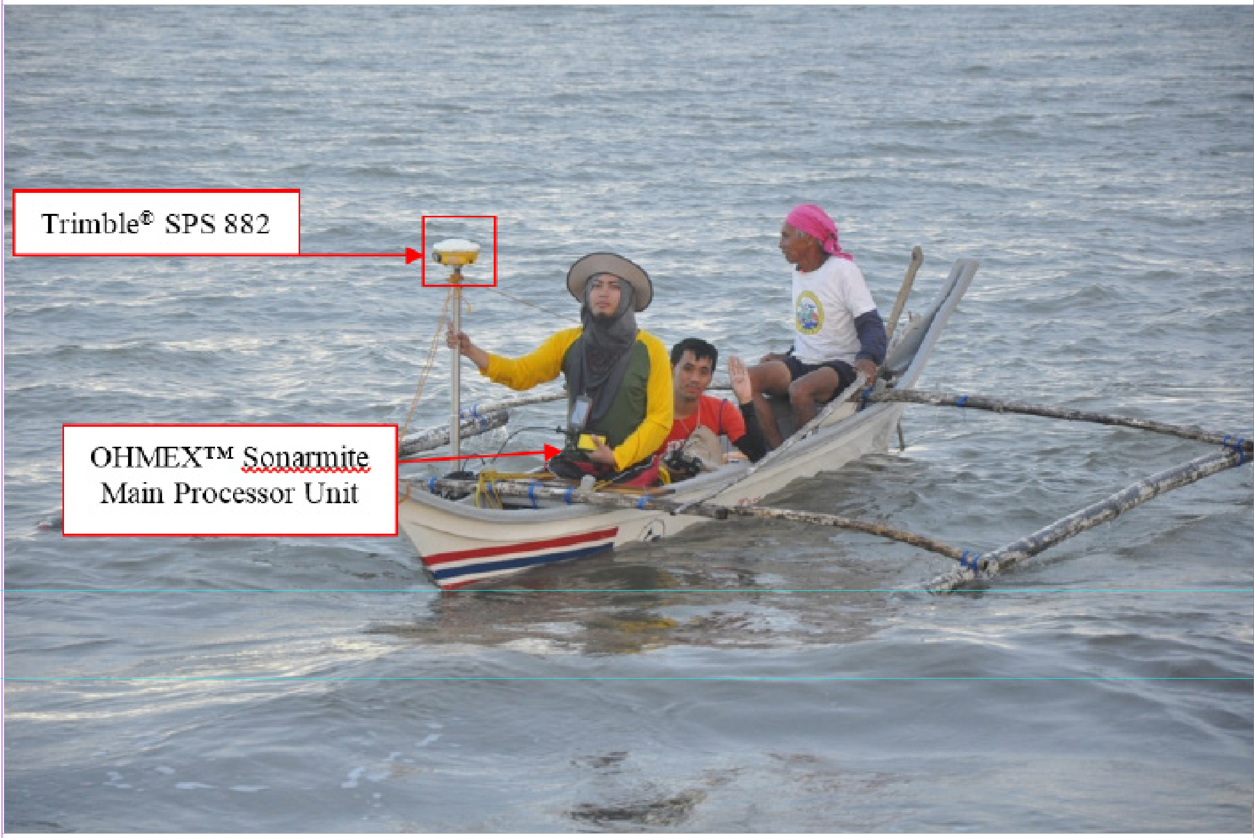


Figure 45. Bathymetric Survey for LiDAR Aquarius validation

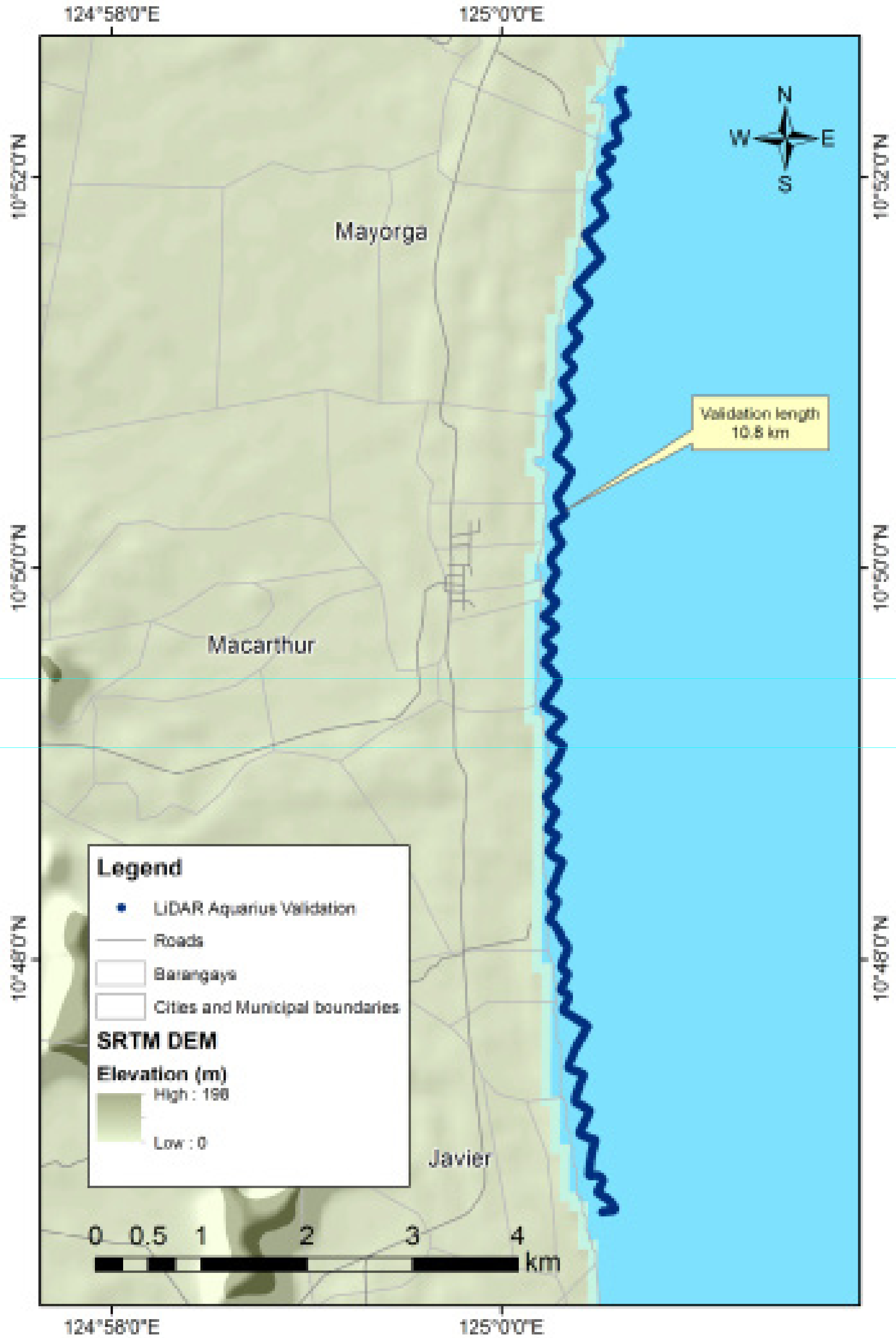


Figure 46. Gathered points for LiDAR Aquarius validation

4.7 River Bathymetric Survey

The Bathymetric survey was conducted on January 13, 2015 using a GPS receiver, Trimble® SPS 882 in GNS PPK survey technique and an OHMEX™ Single Beam Echo Sounder mounted on the side of a boat as shown in Figure 47. The survey started in the upstream part of the river in Brgy. Tadoc, Municipality of Abuyog with coordinates 10°42'22.07230" 125°00'17.80640", down to the mouth of the river in Brgy. Buenavista and Sto. Niño with coordinates 10°44'16.35183" 125°01'36.64810".

The bathymetry line length is about 5.70 km with a total of 3,995 bathymetric points acquired using UP-ABG as the GNSS base station. The processed data were generated into a map using GIS software as shown in Figure 48.

Figure 47. Bathymetric survey along Cadacan River

A CAD drawing was also produced to illustrate the riverbed profile of Cadacan River. As presented in Figure 49, the Riverbed profile of Cadacan shows no abrupt change in elevation as the survey area because of its proximity to the mouth of the river. The highest elevation observed was -1.073 m in MSL while the lowest was -6.314 m below MSL both of which are located in Brgy. Tadoc. The gaps in bathymetric line were due to dense canopy resulting to poor satellite signal.

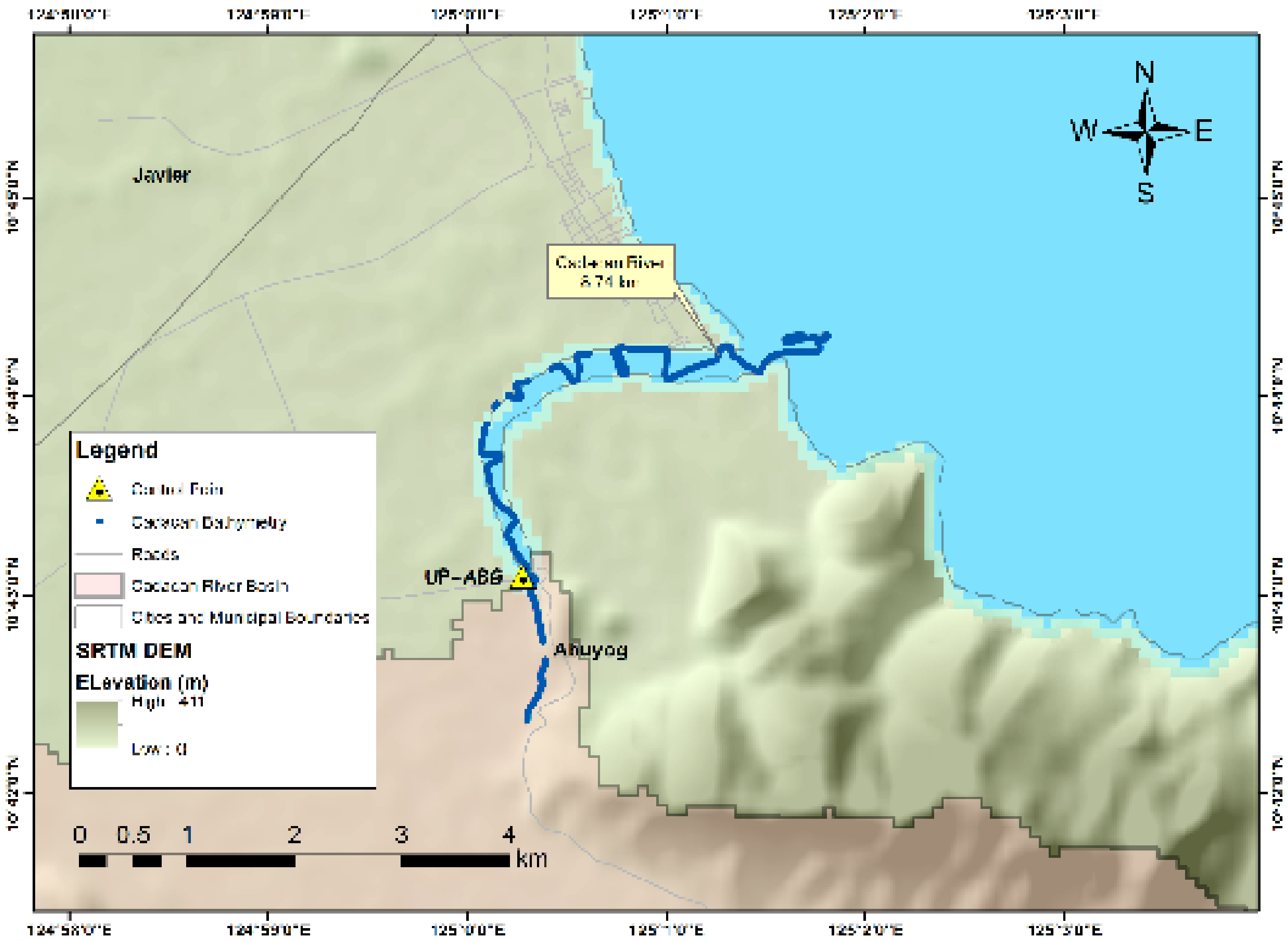


Figure 48. Bathymetric points gathered in Cadacan River

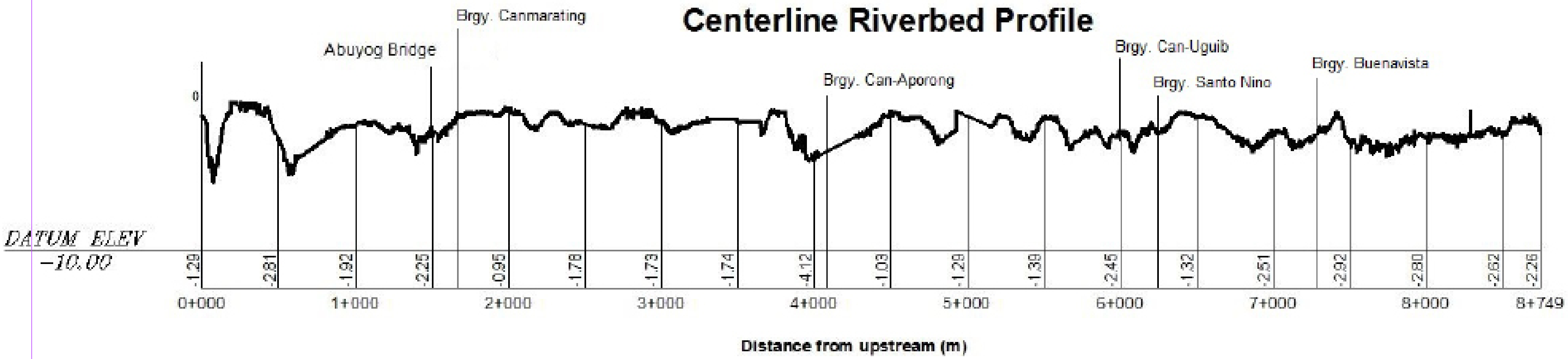


Figure 49. Riverbed profile of Cadacan River

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) further enhanced and updated in Paringit, et al. (2017).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

The components and data that affect the hydrologic cycle of the river basin were monitored, collected, and analyzed. These include the rainfall, water level, and the flow in a certain period of time.

5.1.2 Precipitation

The precipitation data were taken from Abuyog Automatic Rain Gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The location of the rain gauge is seen in Figure 50.

Total rain from Abuyog rain gauge is 126 mm. It peaked to 17 mm on 24 November 2016 at 20:30. The lag time between the peak rainfall and discharge is 5 hours and 40 minutes.

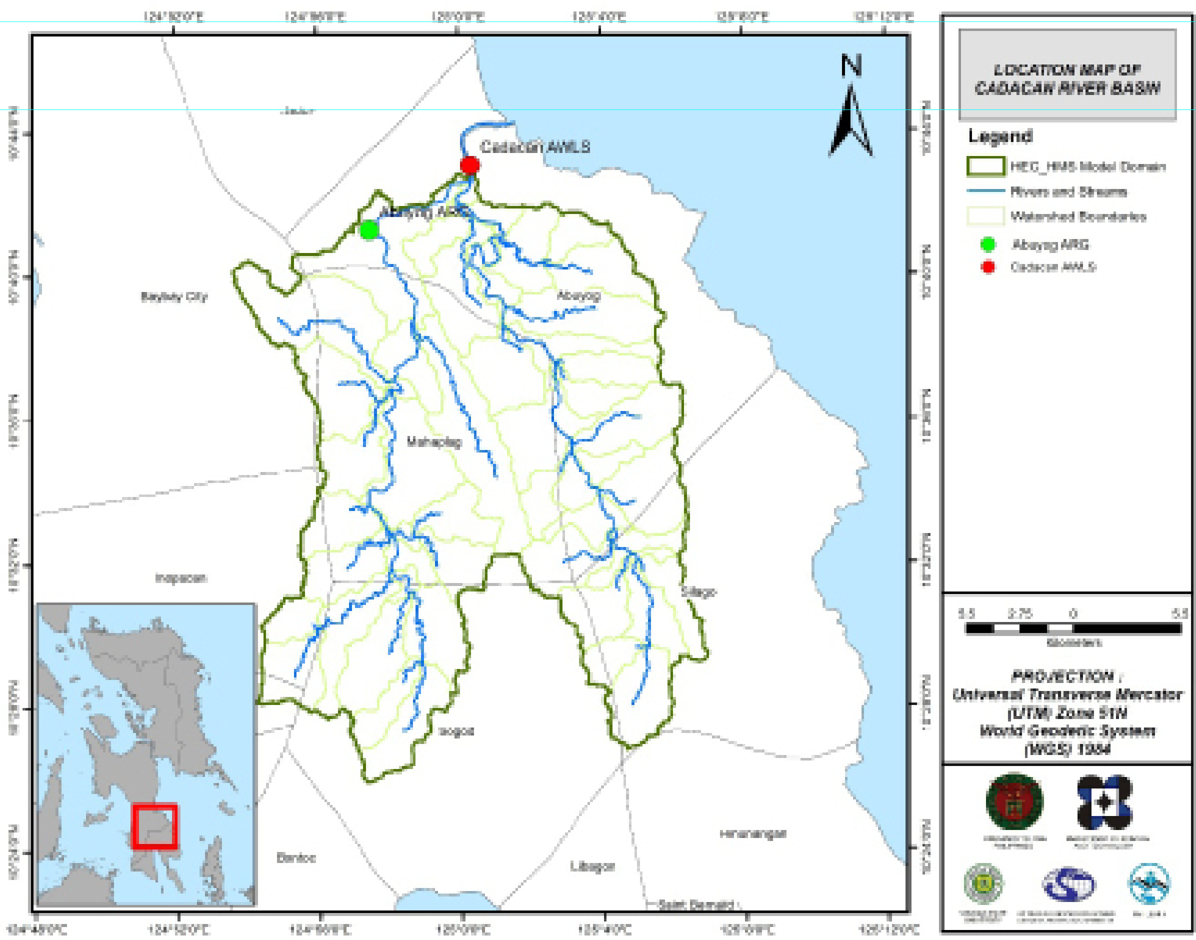


Figure 50. Location map of Cadacan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Cadacan Bridge, Baybay City, Leyte (10°40'55.33"N, 124°48'18.96"E). It gives the relationship between the observed water levels at Cadacan Bridge and outflow of the watershed at this location.

For Cadacan Bridge, the rating curve is expressed as $Q = 16.418e^{0.5939h}$ as shown in Figure 52.

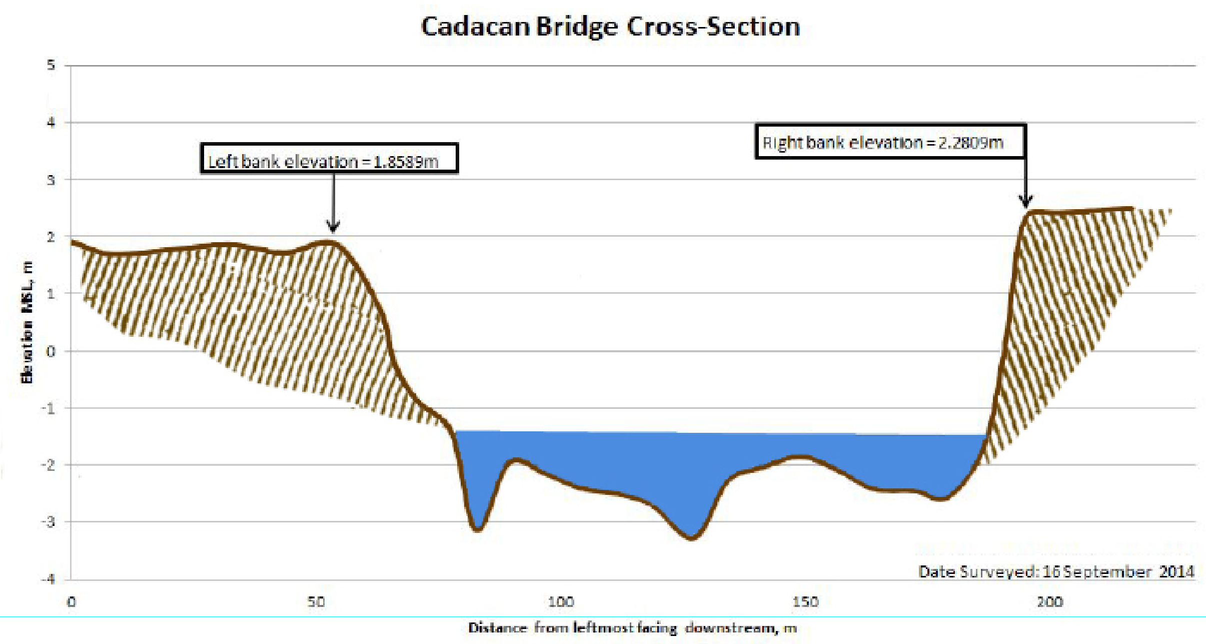


Figure 51. Cross-Section Plot of Cadacan Bridge

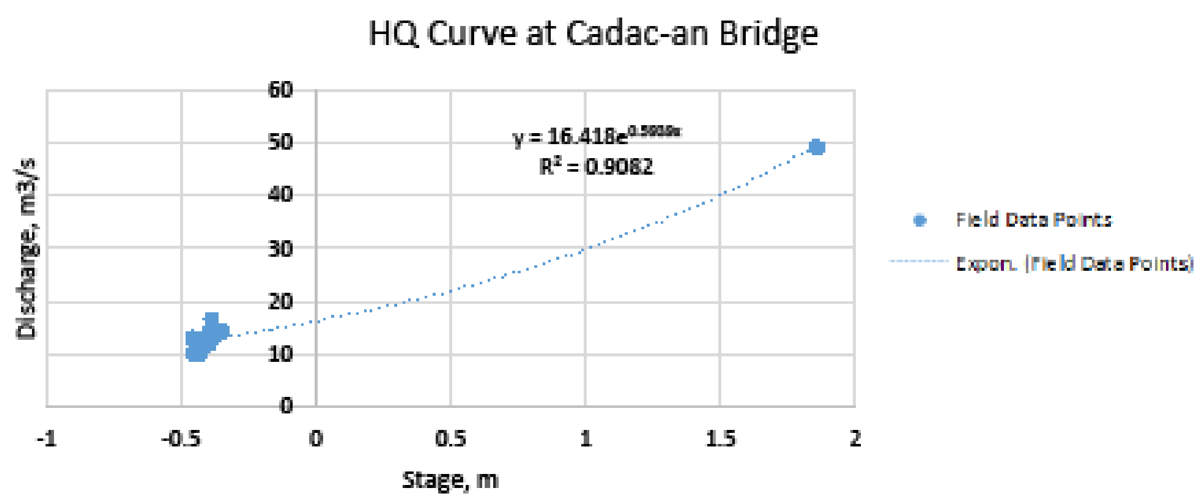


Figure 52. Rating Curve at Cadacan Bridge Sta. Rita, Samar

This rating curve equation was used to compute the river outflow at Cadacan Bridge for the calibration of the HEC-HMS model shown in Figure 53.

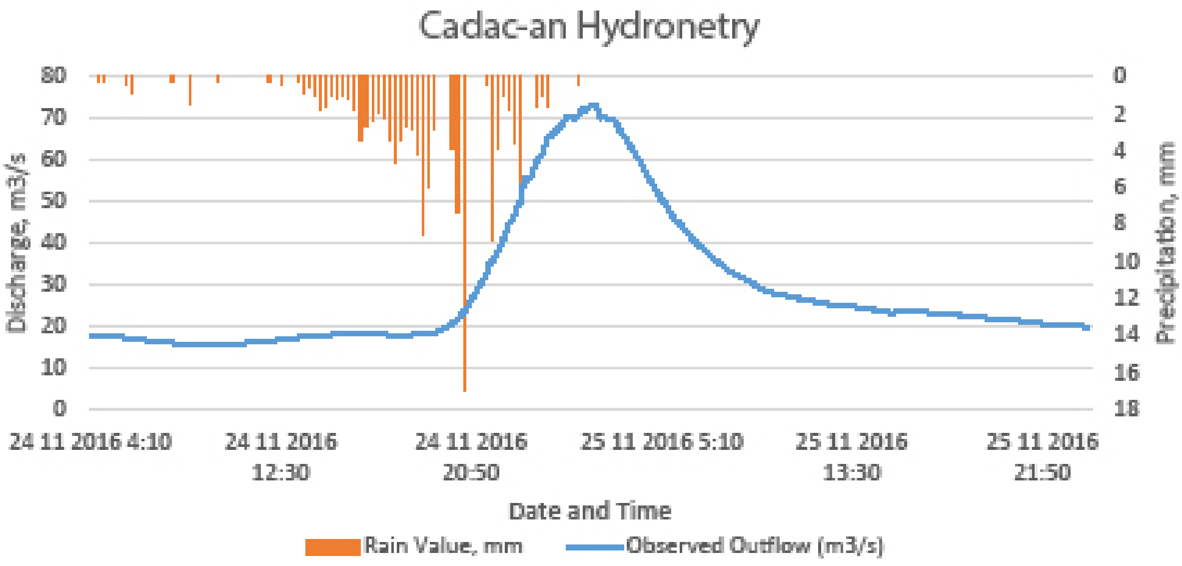


Figure 53. Rainfall and outflow data at Cadacan used for modeling

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 Subangdaku watershed. The extreme values for this watershed were computed based on a 16-year record.

Table 30. 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

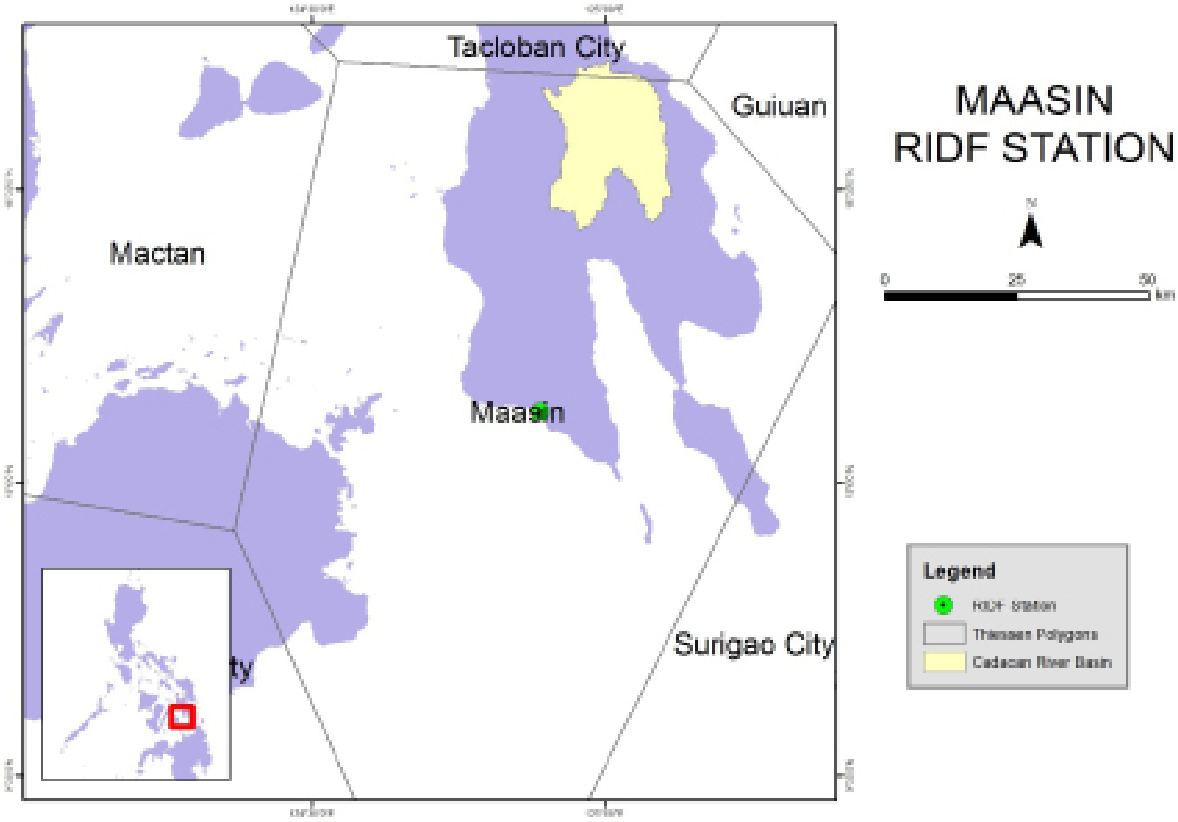


Figure 54. Location of Maasin RIDF Station relative to Cadacan River Basin

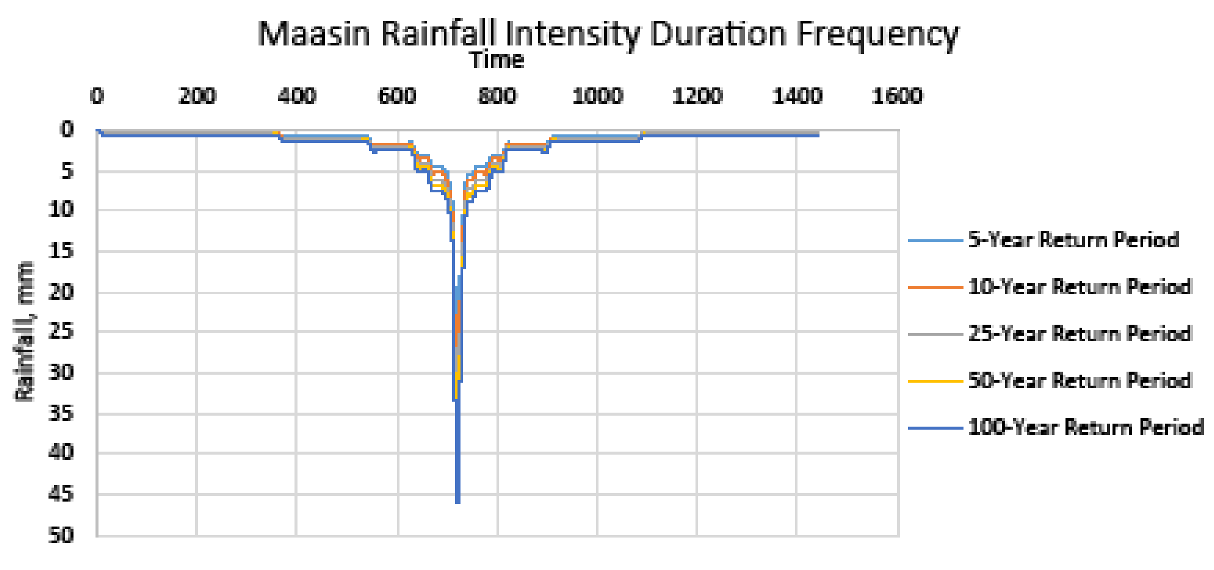


Figure 55. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset, taken in 2004, was sourced out from the Bureau of Soils under the Department of Agriculture. The land cover data, on the other hand, was taken from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Cadacan River Basin are shown in Figures 56 and 57, respectively.

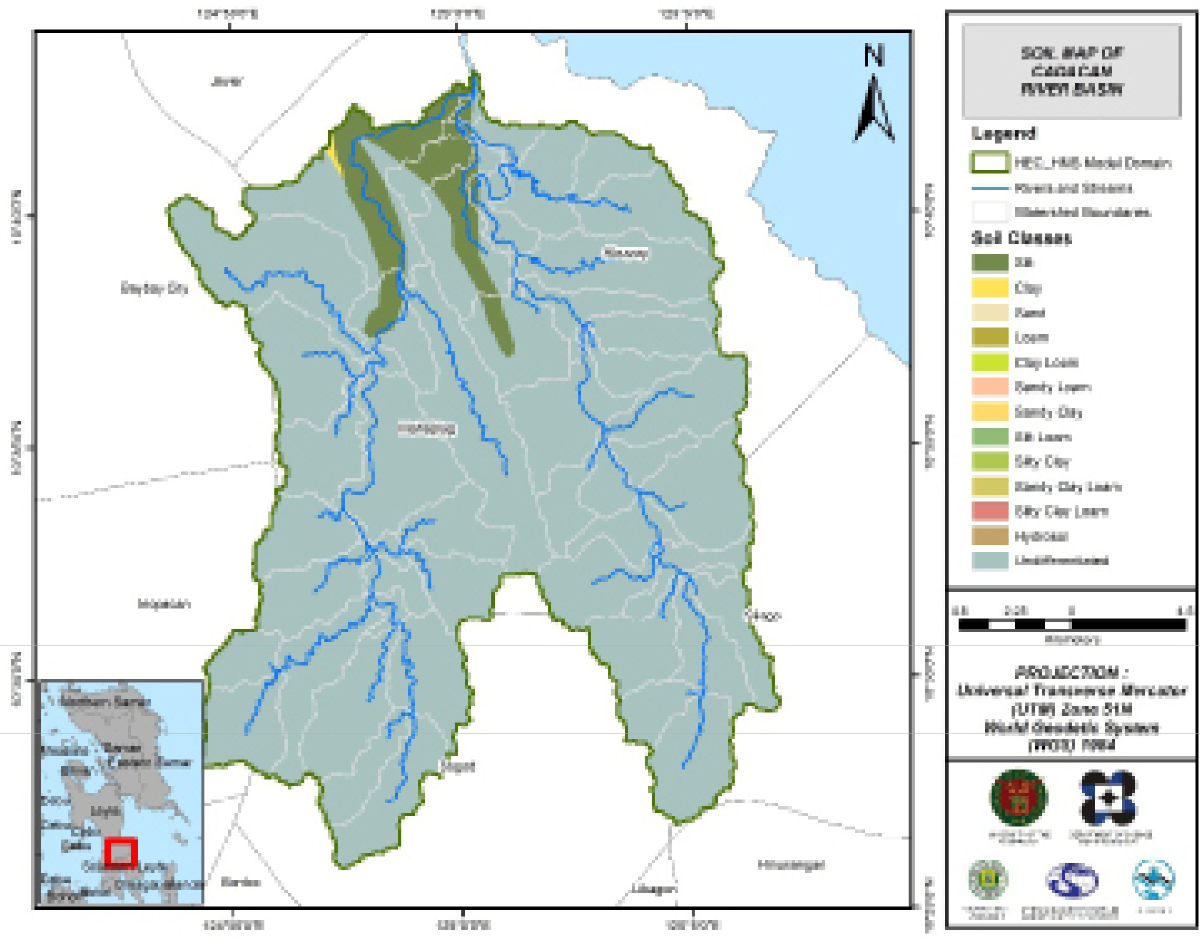


Figure 56. Soil Map of Cadacan River Basin

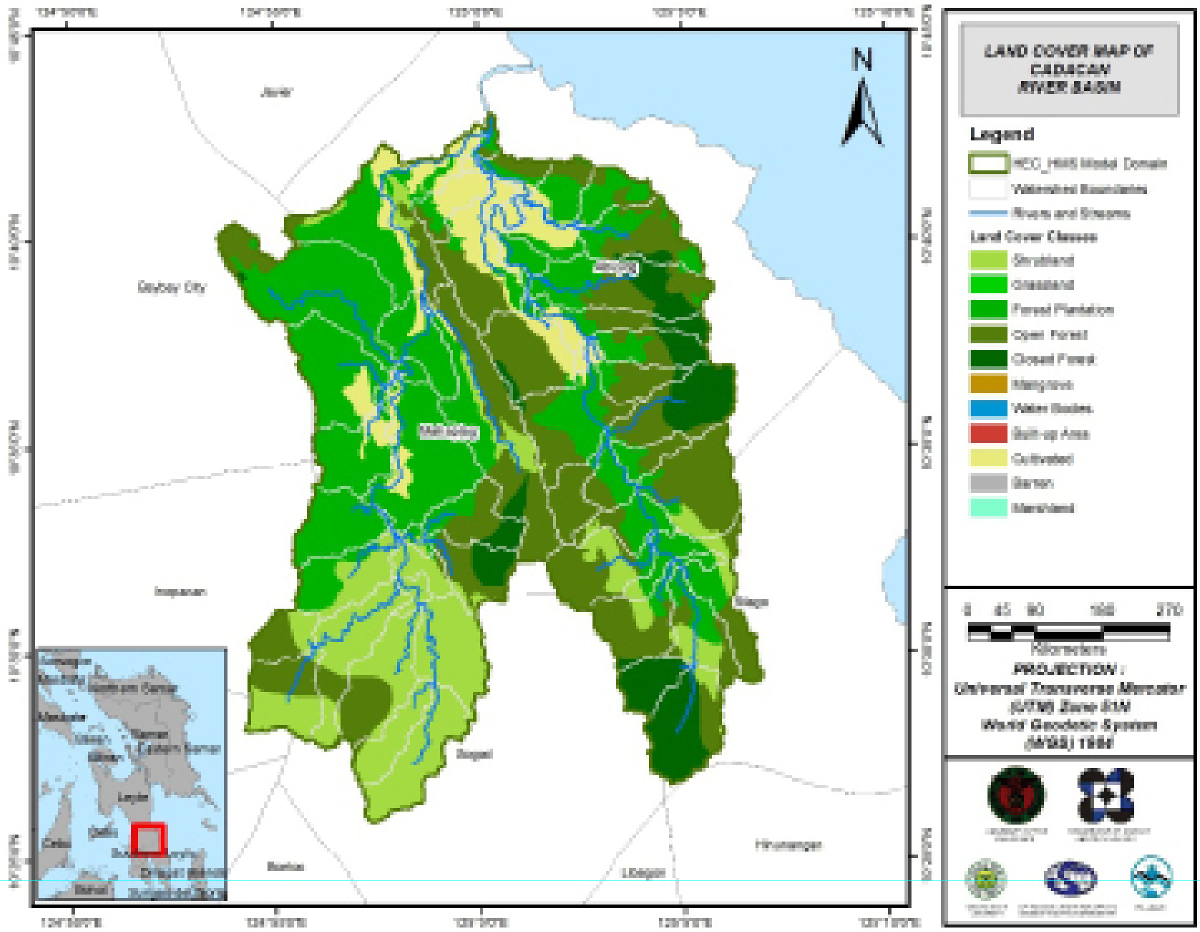


Figure 57. Land Cover Map of Cadacan River Basin

For Cadacan, the soil classes identified were clay, loam, and undifferentiated. The land cover types identified were shrubland, grassland, forest plantation, open forest, and closed forest, and cultivated.

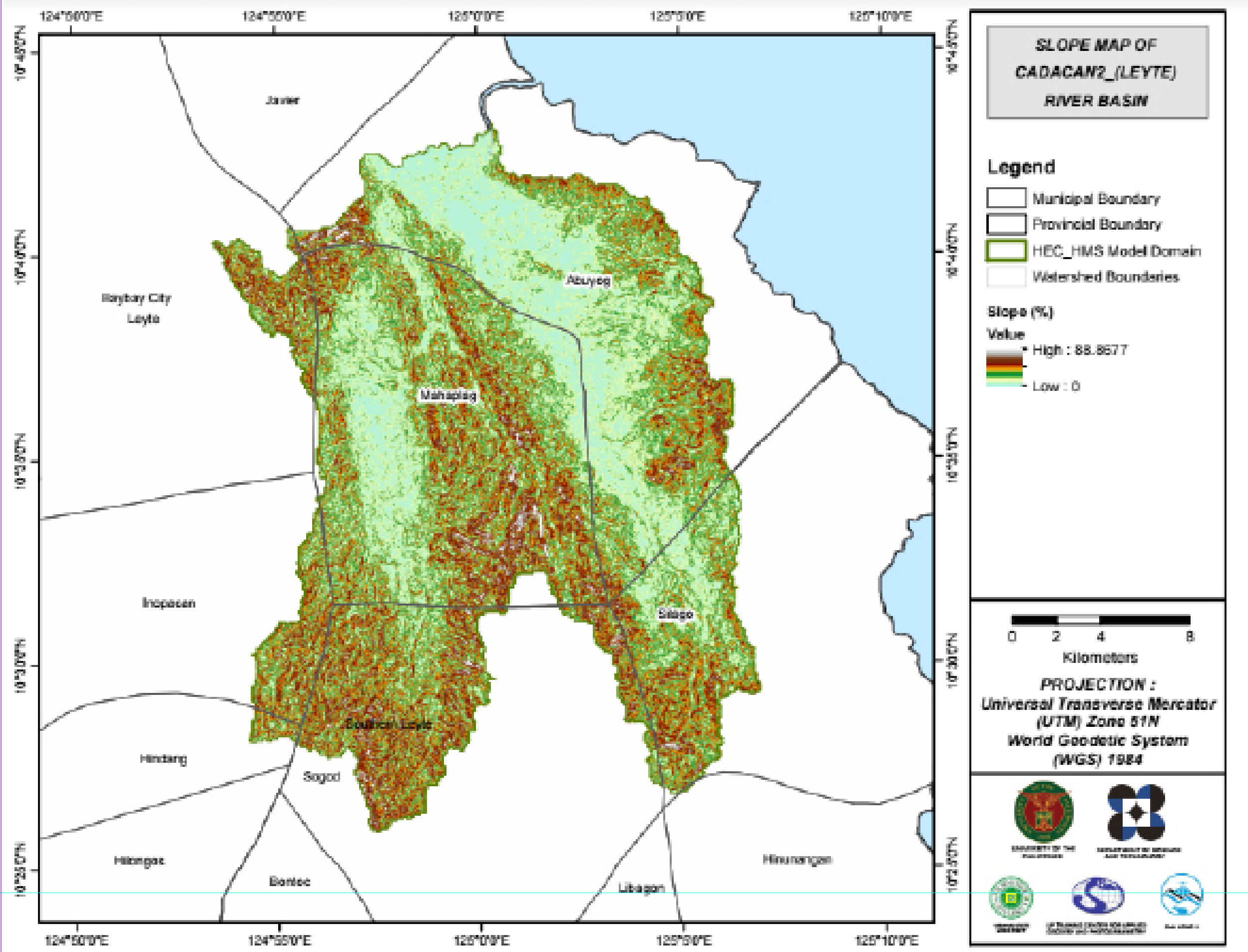


Figure 58. Slope Map of the Cadacan River Basin

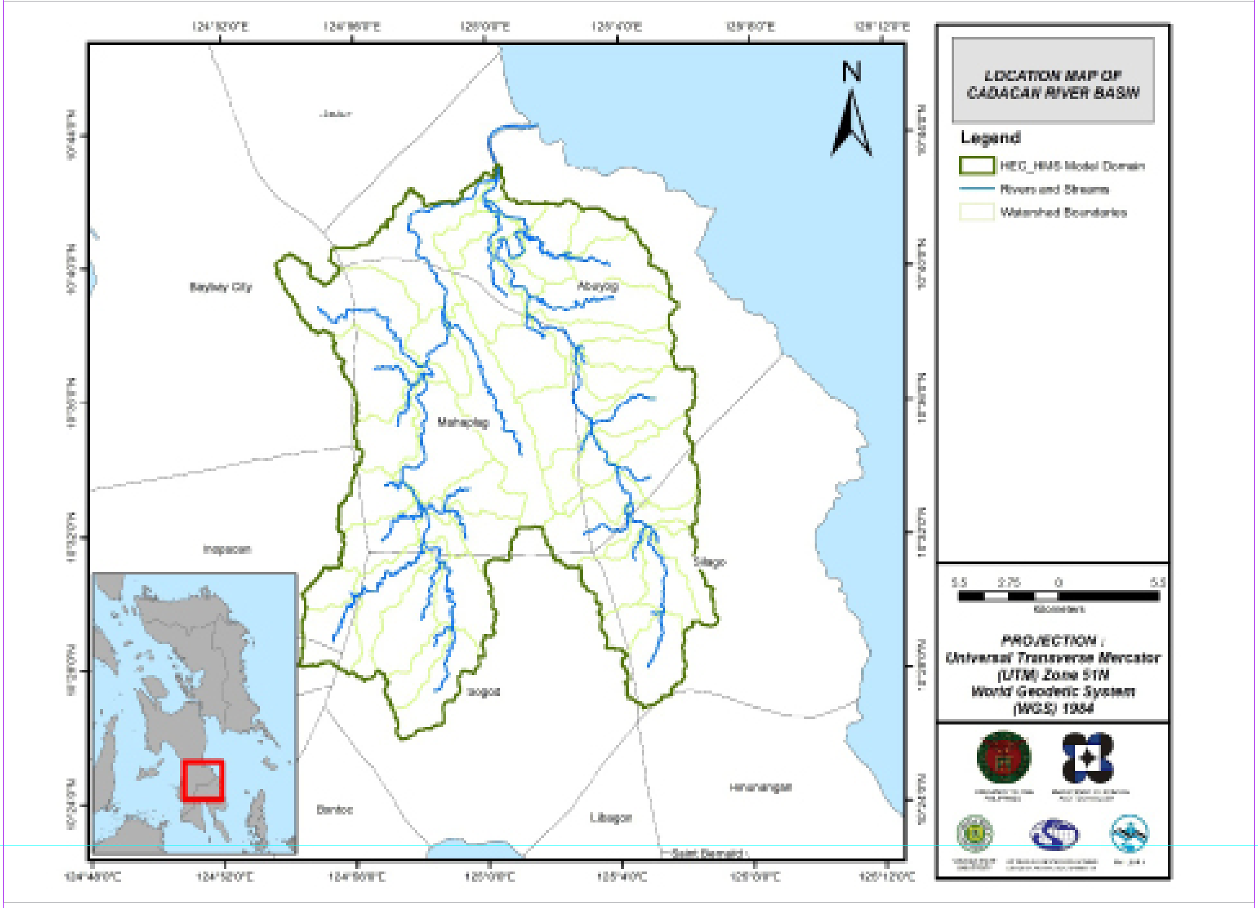


Figure 59. Stream Delineation Map of the Cadacan River Basin

Using the SAR-based DEM, the Cadacan Basin was delineated and further subdivided into subbasins. The model consists of 57 sub basins, 28 reaches, and 28 junctions. The main outlet is Cadacan Bridge.

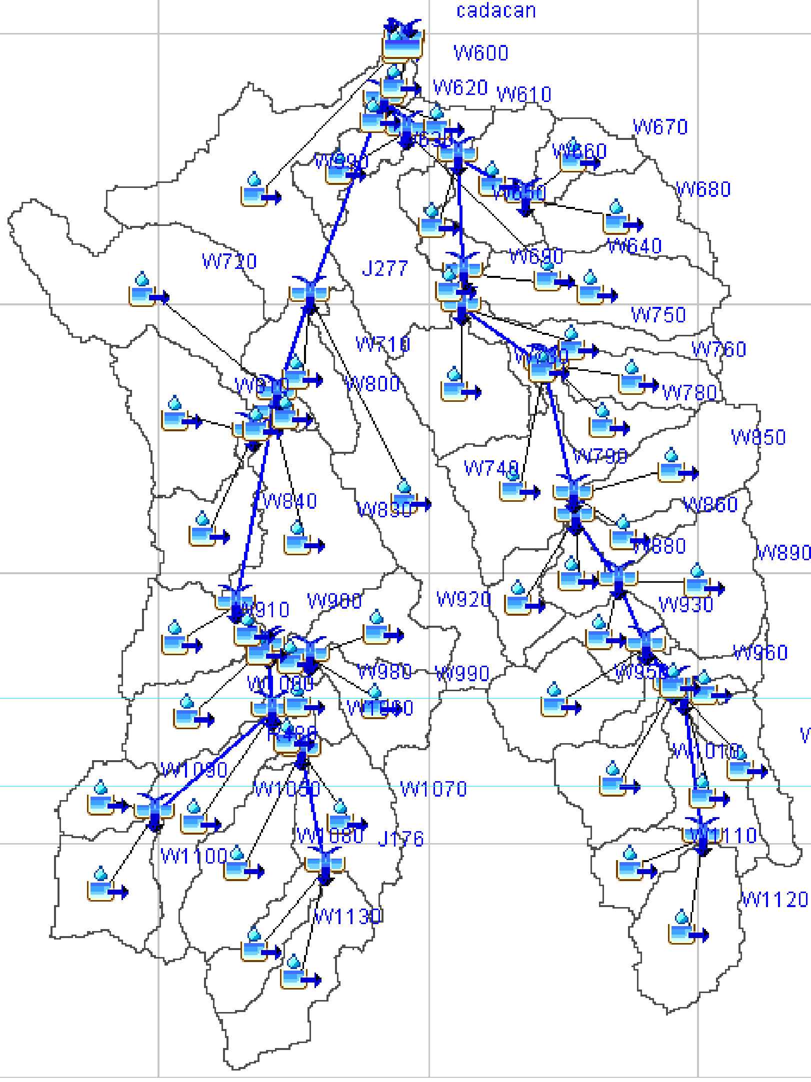


Figure 60. The Cadacan River Basin model generated using HEC-HMS

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.

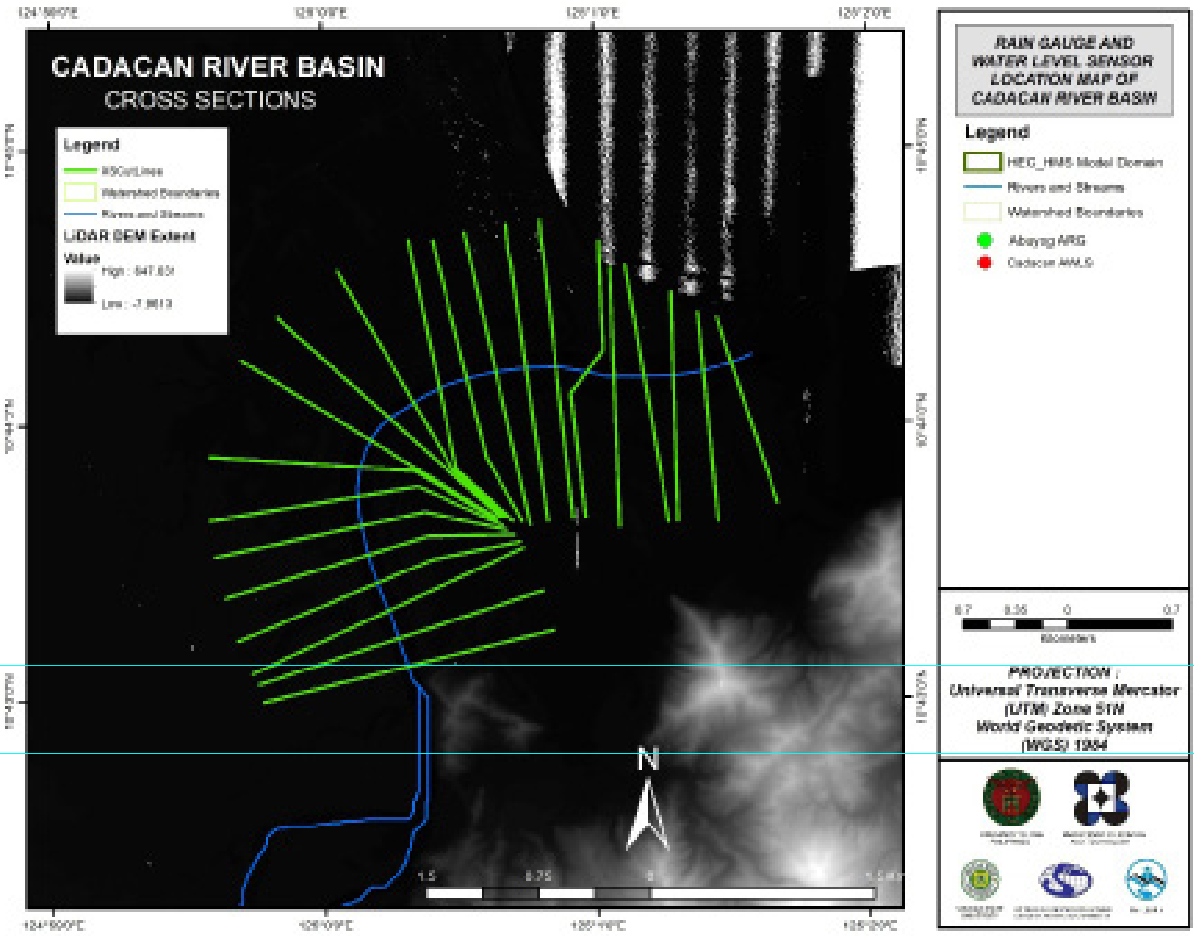


Figure 61. River cross-section of Cadacan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

[insert 2D report]

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

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

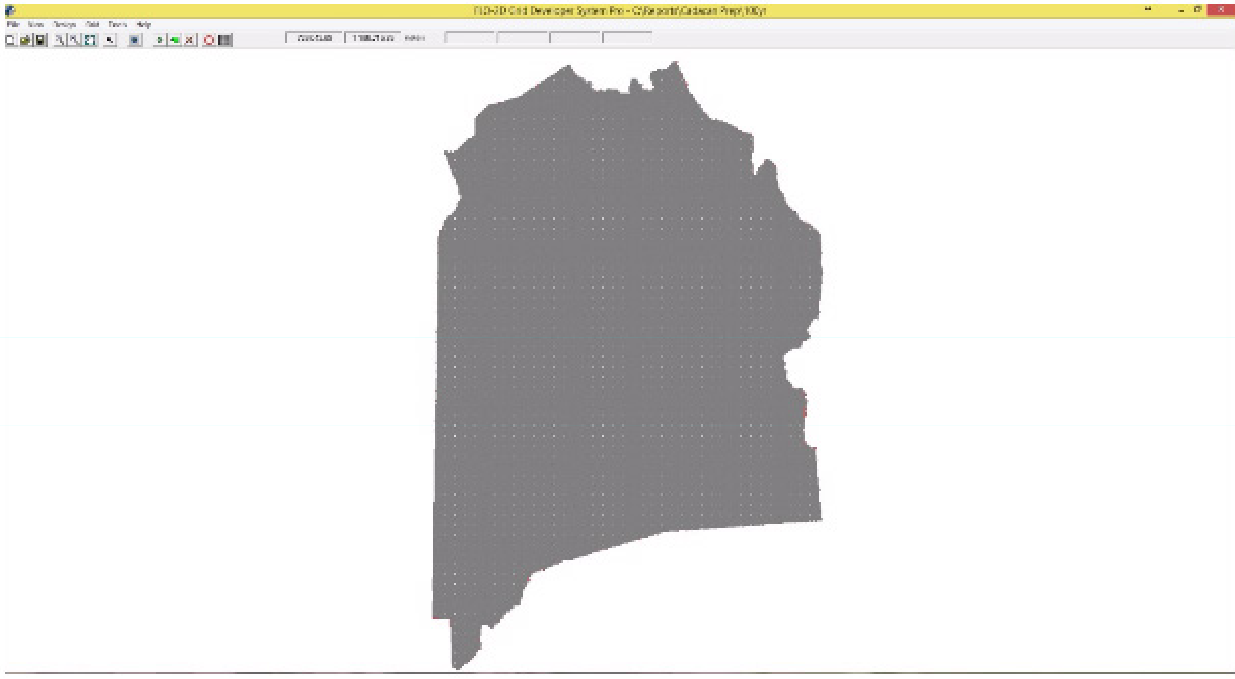


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 51.83252 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m 2 /s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 35130600.00 m 2 .

There is a total of 153902524.79 m 3 of water entering the model. Of this amount, 11100739.33 m 3 is due to rainfall while 142801785.47 m 3 is inflow from other areas outside the model. 11017657.00 m 3 of this water is lost to infiltration and interception, while 57560319.71 m 3 is stored by the flood plain. The rest, amounting up to 85324543.70 m 3 , is outflow.

5.6 Results of HMS Calibration

After calibrating the Cadacan HEC-HMS River Basin Model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

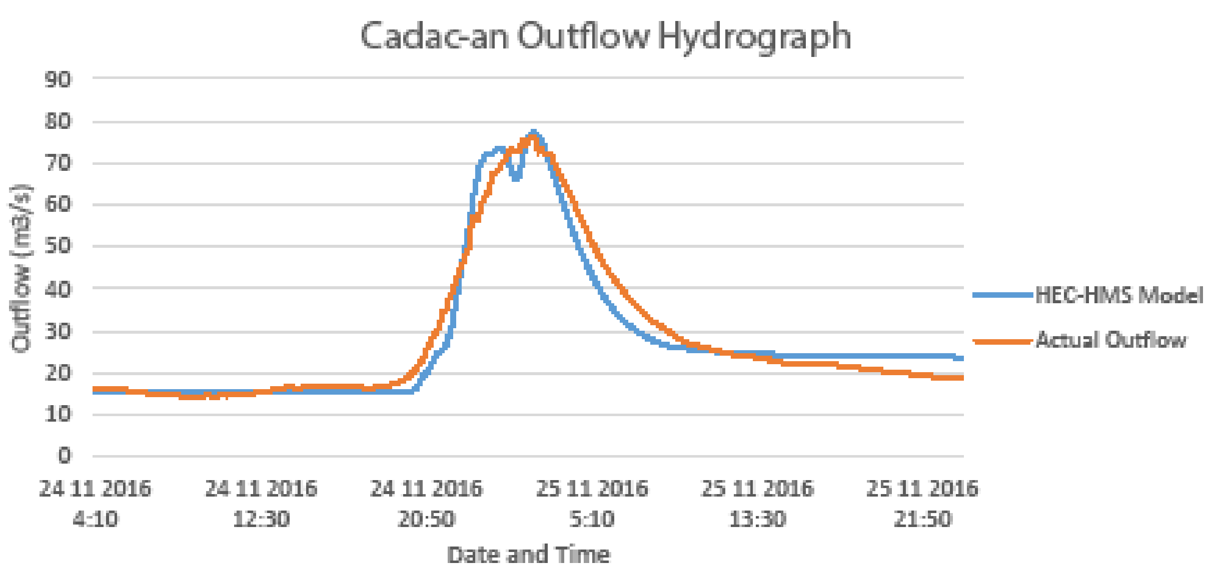


Figure 63. Outflow Hydrograph of Cadacan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of Calibrated Values for Cadacan

Hydrologic Element	Method	Parameter	Range of Calibrated Values
Loss	SCS Curve number	Initial Abstraction (mm)	55 - 196
		Curve Number	47 - 81
Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1 - 1.82
		Storage Coefficient (hr)	0.09 - 1.57
Baseflow	Recession	Recession Constant	1
		Ratio to Peak	0.11
Routing	Muskingum-Cunge	Slope	0.00006 - 0.02
		Manning's n	0.03

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 55mm to 196mm means that there is a considerably high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 47 to 81 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 0.1 hour to 1.82 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 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.03 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.03 leads more to the common roughness of Philippine watersheds. Cadacan River Basin is determined to have cultivated areas with no or minimal crops.

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

Accuracy measure	Value
RMSE	3.7
r^2	0.9082
NSE	0.95477
PBIAS	1.40165
RSR	0.21268

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 3.7 (m^3/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 0.9082.

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 0.95477.

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 1.40165.

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 0.21268.

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 64) shows the Cadacan outflow using the Maasin 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.

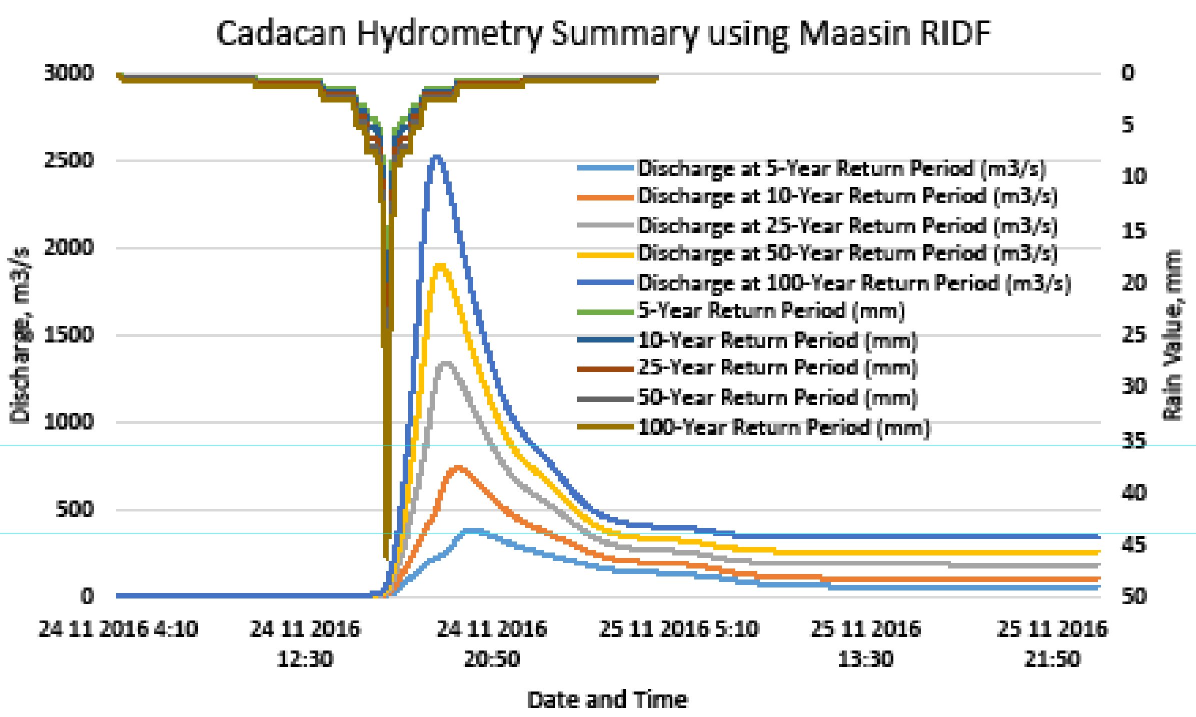


Figure 64. Outflow hydrograph at Cadacan Station generated using Maasin RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Cadacan discharge using the Maasin Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. Peak values of the Cadacan HEC-HMS Model outflow using the Maasin RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	190.8	25.9	390	3 hours, 50 minutes
10-Year	221.2	30.8	740.6	3 hours, 10 minutes
25-Year	259.6	37	1344	2 hours, 50 minutes
50-Year	288.1	41.5	1904.6	2 hours, 20 minutes
100-Year	316.3	46.1	2530.3	2 hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the VSU-FMC base flow was calibrated. The sample generated map of Cadacan River using the calibrated HMS base flow is shown in Figure 65.

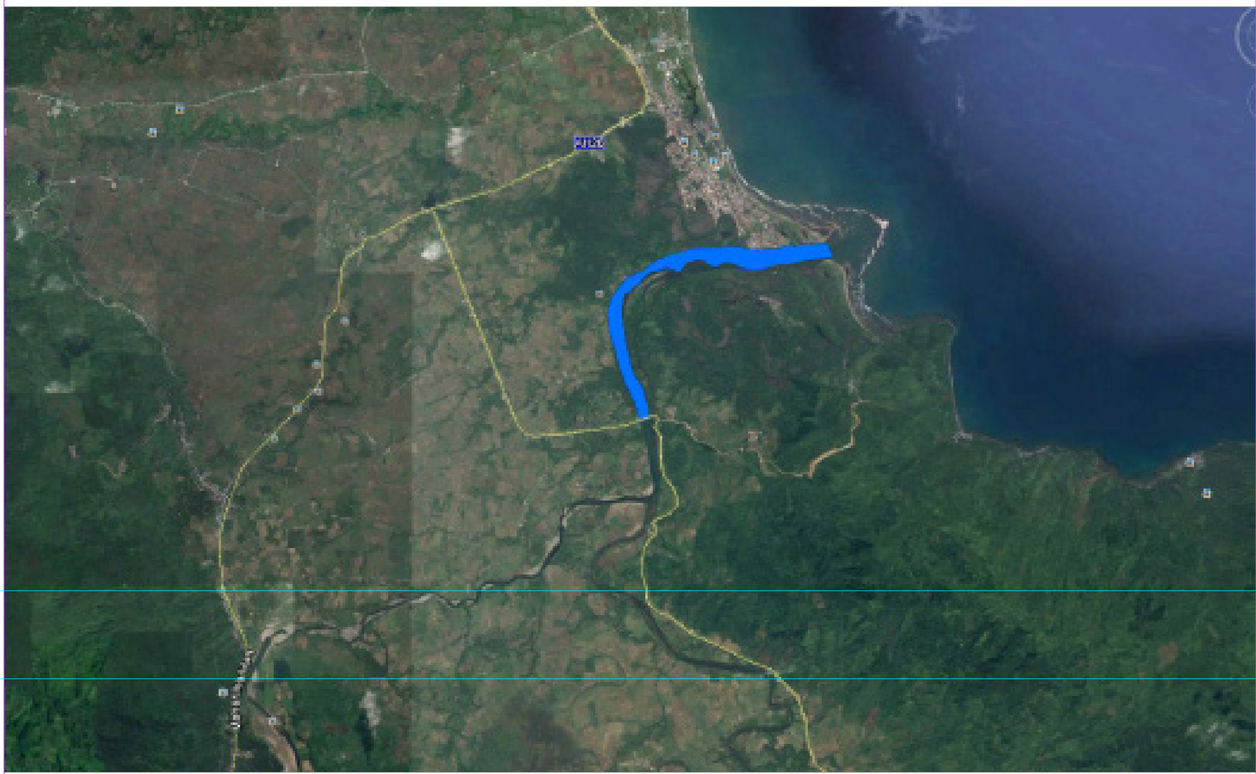


Figure 65. Sample output of Cadacan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 66 to 71 shows the 5-, 25-, and 100-year rain return scenarios of the Cadacan Floodplain.

The floodplain, with an area of 35.13 sq. km., covers one municipality which is Abuyog. Table shows the percentage of area affected by flooding.

Table 34. Municipalities affected in Cadacan Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Cadacan	256.64	34.21	13%

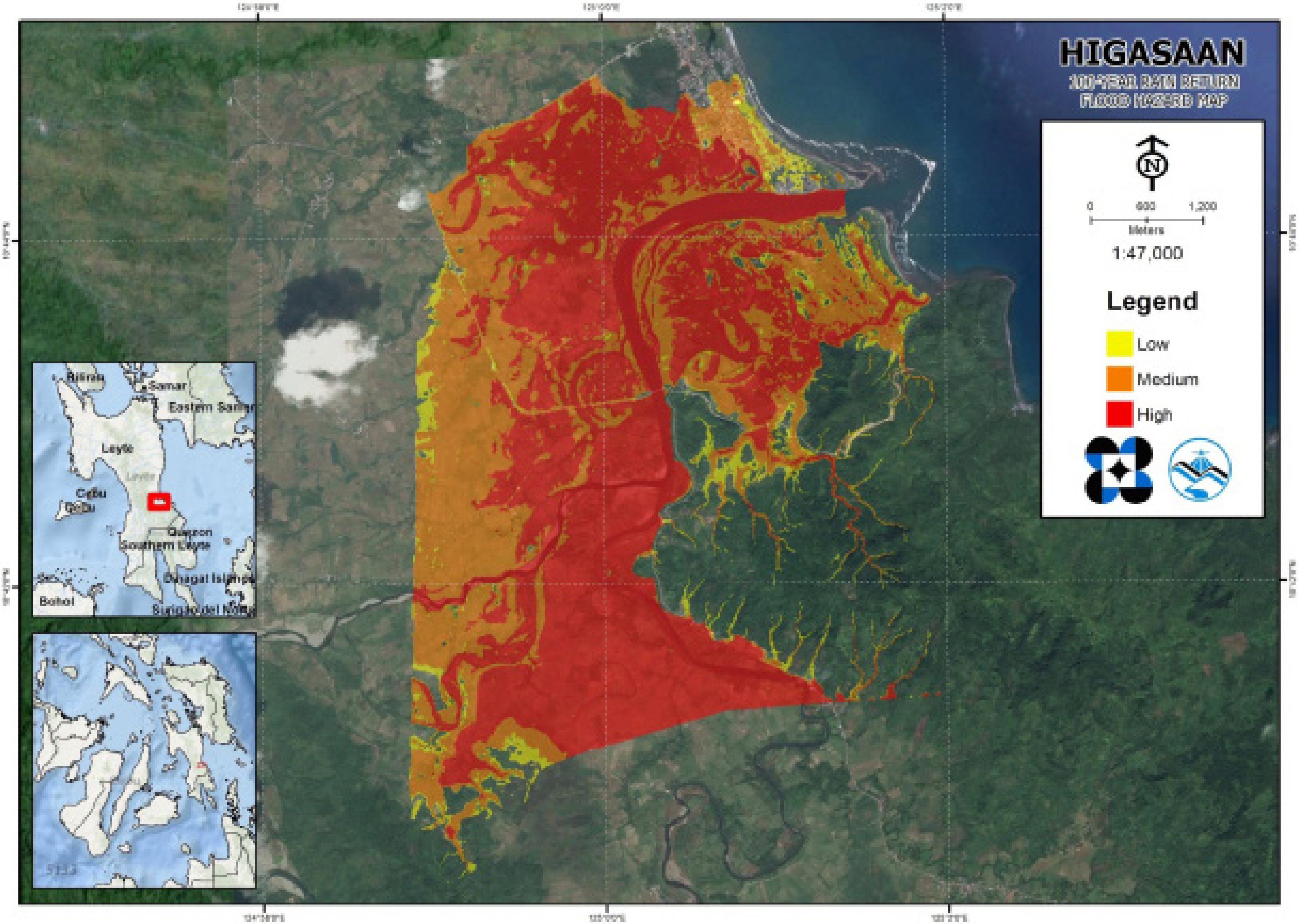


Figure 66. 100-year Flood Hazard Map for Cadacan (Higasaan) Floodplain overlaid in Google Earth imagery

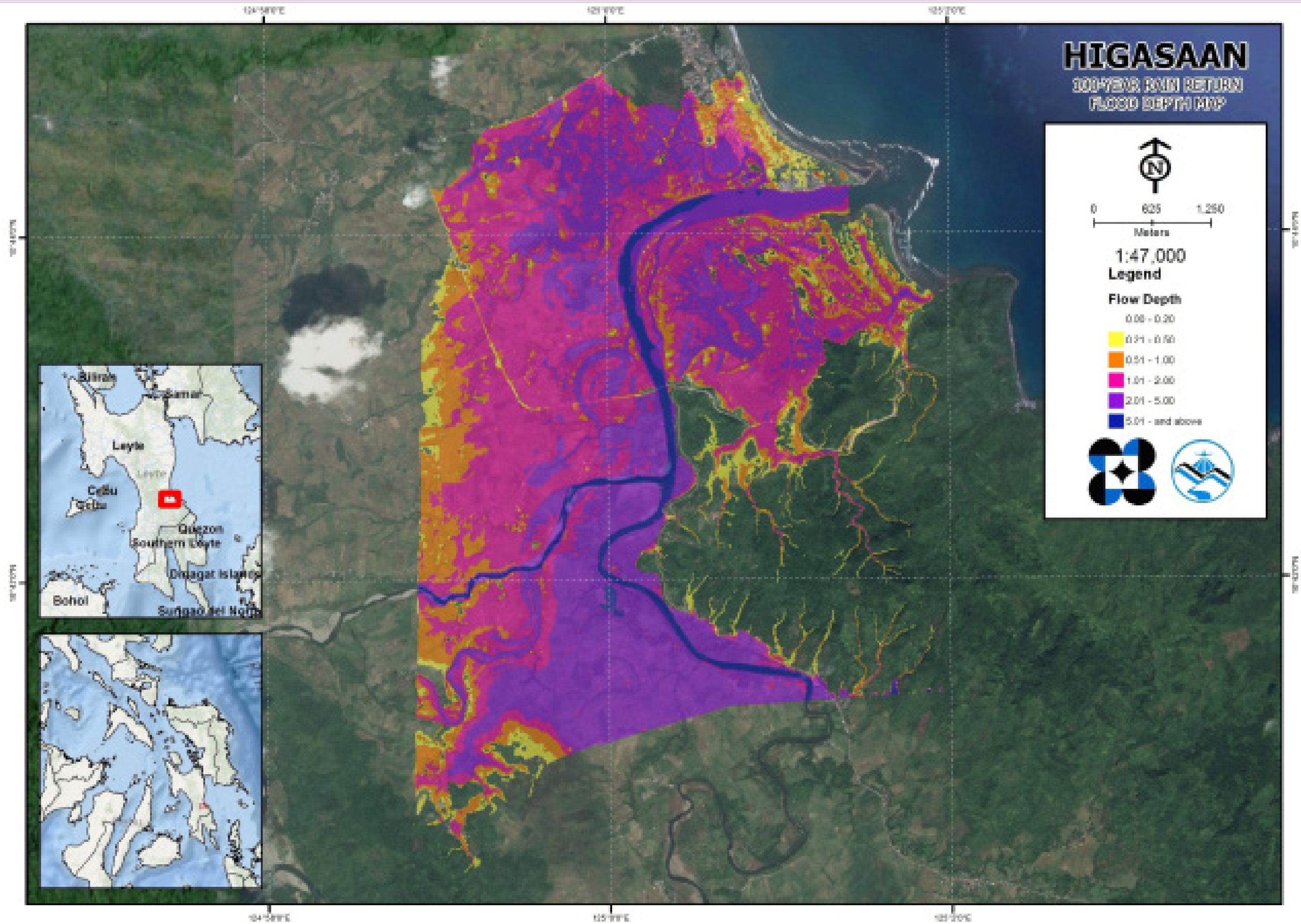


Figure 67. 100-year Flow Depth Map for Cadacan (Higasaan) Floodplain overlaid in Google Earth imagery

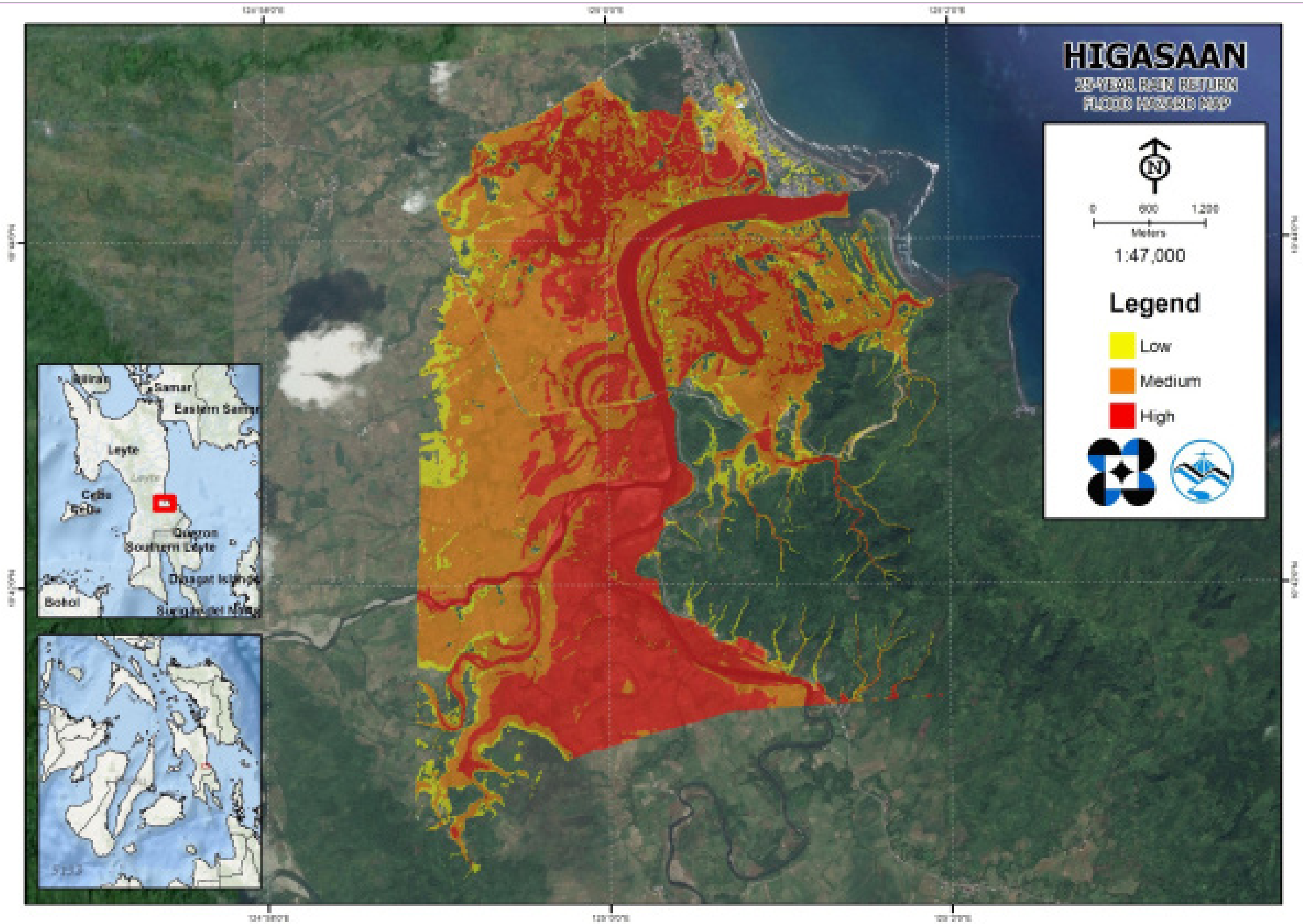


Figure 68. 25-year Flood Hazard Map for Cadacan (Higasaan) Floodplain overlaid in Google Earth imagery

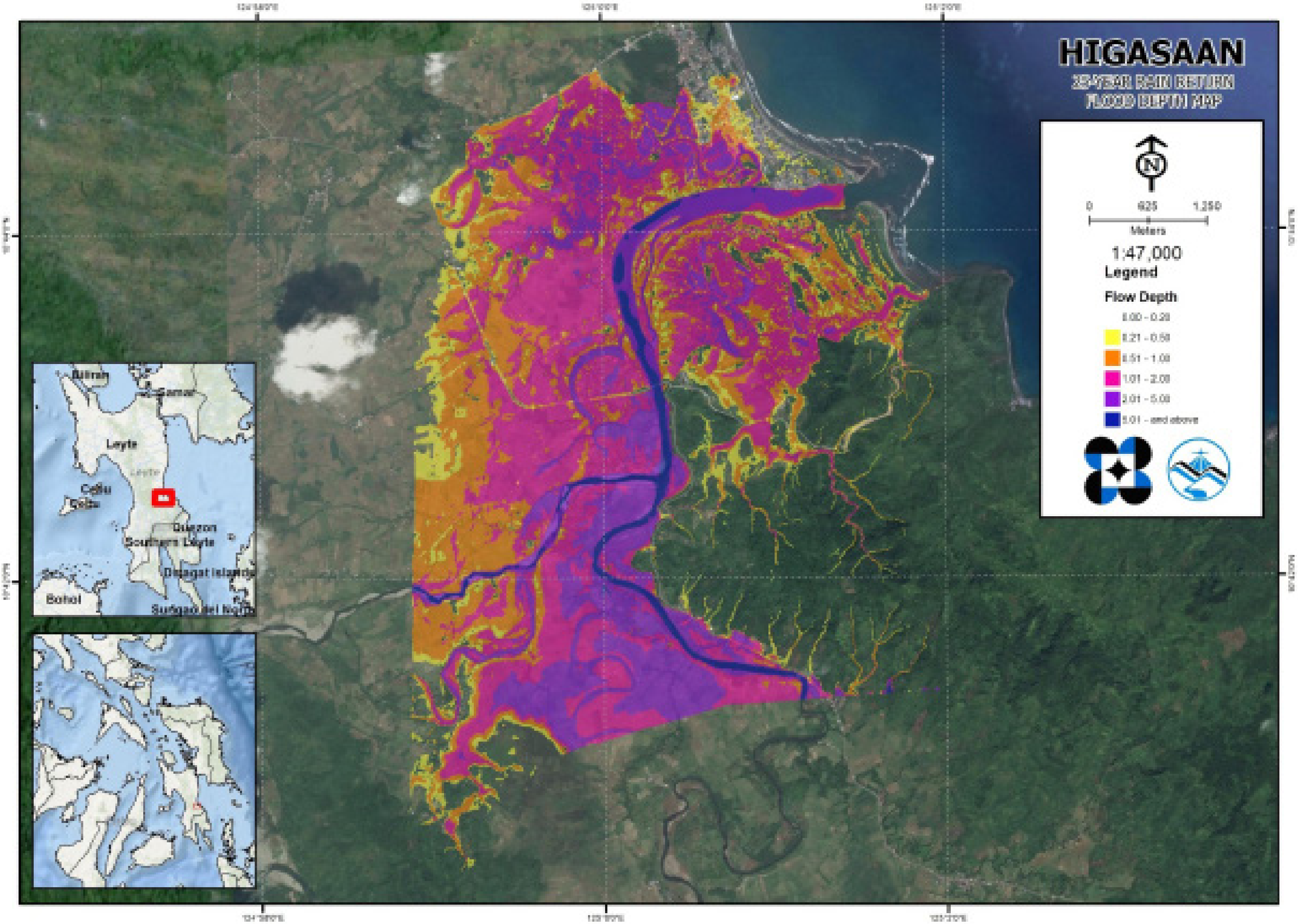


Figure 69. 25-year Flow Depth Map for Cadacan (Higasaan) Floodplain overlaid in Google Earth imagery

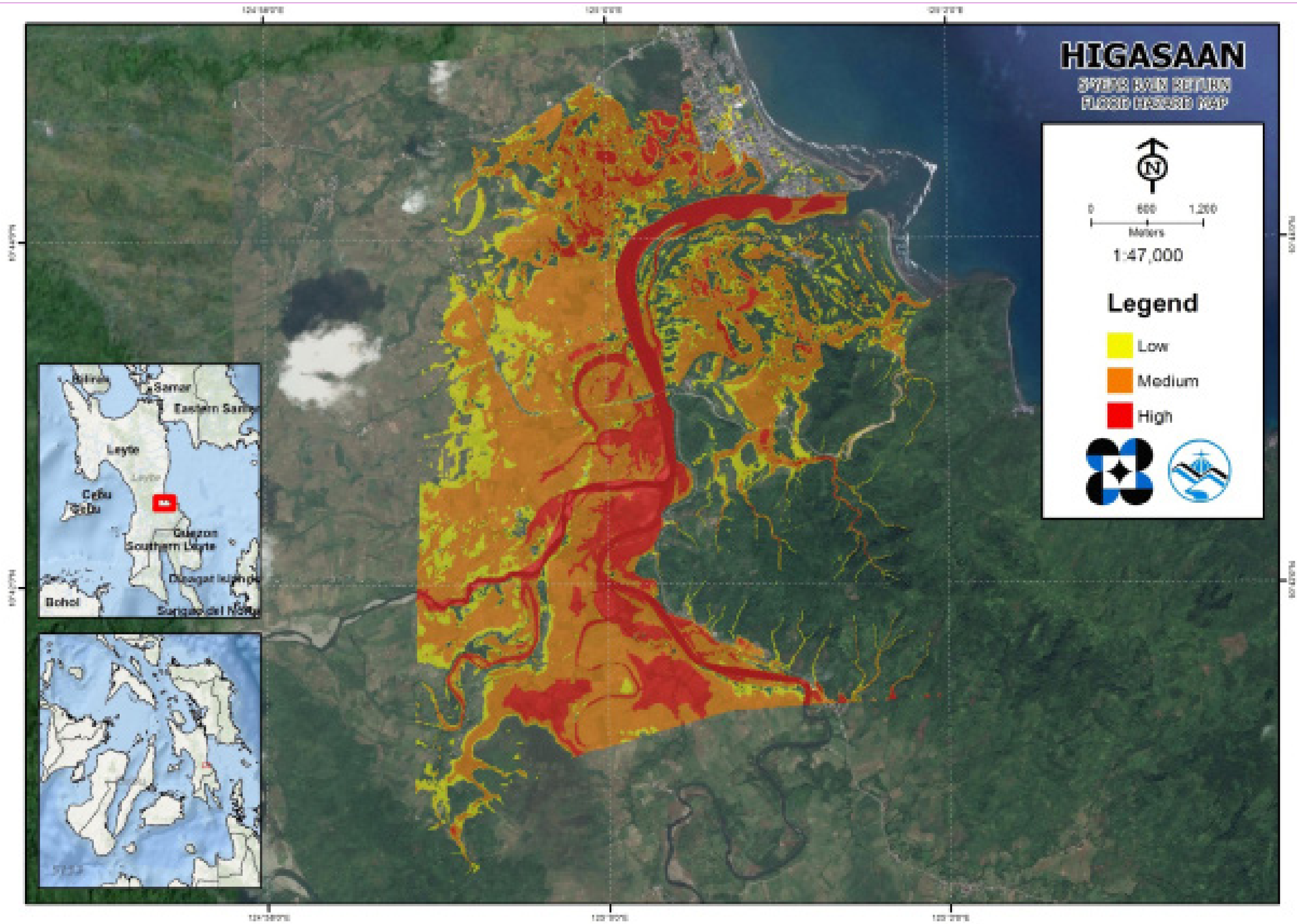


Figure 70. 5-year Flood Hazard Map for Cadacan (Higasaan) Floodplain overlaid in Google Earth imagery

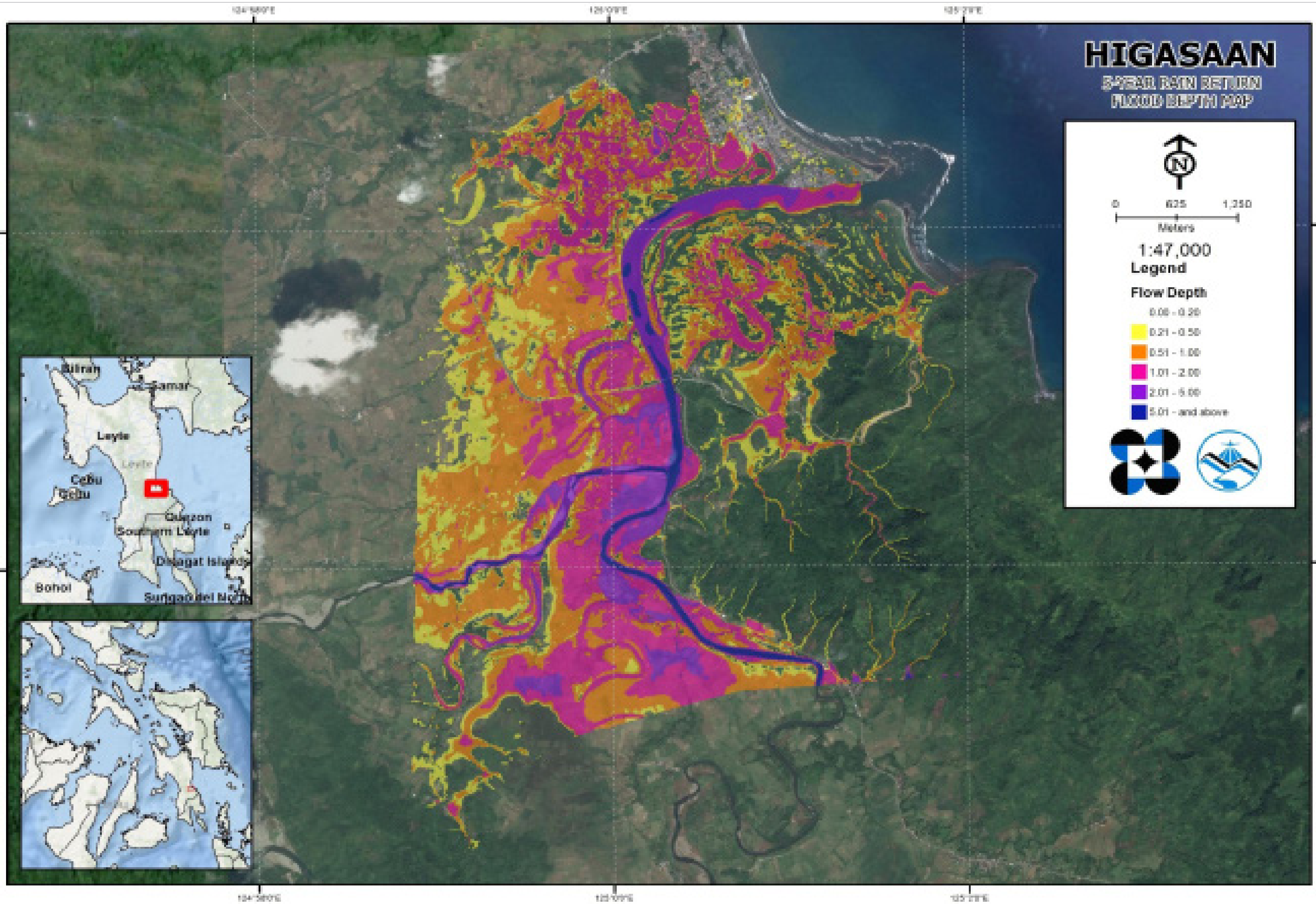


Figure 71. 5-year Flood Depth Map for Cadacan (Higasaan) Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Cadac-an river basin, grouped by Municipality, are listed below. For the said basin, the municipality of Abuyog consisting of 27 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 5.93% of the municipality of Abuyog with an area of 256.64 sq. km. will experience flood levels of less 0.20 meters. 1.68% of the area will experience flood levels of 0.21 to 0.50 meters while 2.77%, 2.22% 0.58%, 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 more than 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Abuyog, Leyte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Bahay	Balocawehay	Barayong	Buenavista	Buntay	Burubud-An	Cadac-An	Can-Aporong	Can-Uguib
0.03-0.20	0.0055750	0.01248580	0.12274363	1.02196379	0.11300601	1.61345505	0.52469845	0.32261787	0.12120659
0.21-0.50	0	0.0015	0.06262275	0.21267224	0.01794589	0.17207780	0.33879686	0.12113824	0.02175894
0.51-1.00	0	0	0.15706593	0.11144544	0.004	0.36688475	0.50647630	0.19003219	0.02180740
1.01-2.00	0	0	0.05066793	0.03937748	0	0.54135997	0.40504825	0.36432524	0.04739264
2.01-5.00	0	0	0	0	0	0.24953443	0	0.04230696	0.00169892
> 5.00	0	0	0	0	0	0.16835928	0	0.00076234	0

Table 36. Affected Areas in Abuyog, Leyte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Canmarating	Capilian	Lawa-An	Loyonsawang	Mag-Atubang	Maitum	Nalibunan	Odiongan	Pagsang-An
0.03-0.20	1.26477842	0.03400376	0.28259077	0.17150627	0.09148602	0.31980767	0.13196969	0.42630083	0.21707485
0.21-0.50	0.96787434	0.03672015	0.00929091	0.034936721	0.11310458	0.06441540	0.01800740	0.68094311	0.10290532
0.51-1.00	1.41041360	0.02591605	0.00595495	0.006457627	0.33900116	0.00899975	0.0006	1.31061913	0.46072167
1.01-2.00	0.67972661	0	0.00043165	0.002294473	0.44467968	0.0003	6.2347E-06	0.22400211	0.97080660
2.01-5.00	0.11647088	0	0	0	0.01654585	0	0	0.04429273	0.50206348
> 5.00	0.01104659	0	0	0	0	0	0	0	0.14469702

Table 37. Affected Areas in Abuyog, Leyte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Picas Sur	Pilar	Salvacion	Santa Fe	Santo Niño	Tabigue	Tadoc	Tinalian	Pagsang-An
0.03-0.20	1.7646718	2.20146004	0.38399004	0.07493692	0.04068160	0.41135566	0.96422580	2.54589461	0.21707485
0.21-0.50	0.6737403	0.05025762	0.01552562	0.00989651	0.00153472	0.10885165	0.16734428	0.31174586	0.10290532
0.51-1.00	1.5274314	0.02064489	0.01845761	0.0032	0.00736742	0.07313923	0.06779044	0.45318321	0.46072167
1.01-2.00	1.6311166	0.00680944	0.0067	0	0.00313952	0.02897843	0.05332269	0.18572184	0.97080660
2.01-5.00	0.4227397	0.0001	0.00893090	0	3.86542E-06	0	0.08370096	0.0003	0.50206348
> 5.00	0.0457	0	0.00259999	0	0	0	0.01857505	0	0.14469702

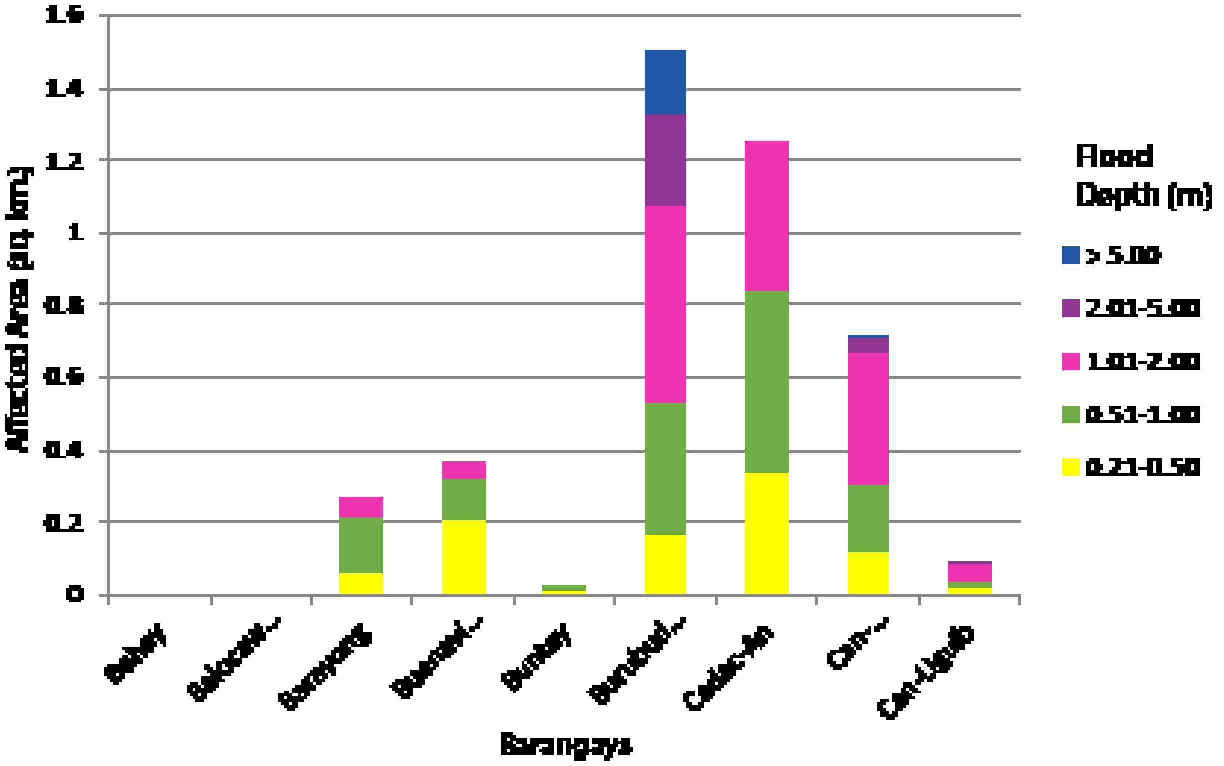


Figure 72. Affected Areas in Abuyog, Leyte during 5-Year Rainfall Return Period

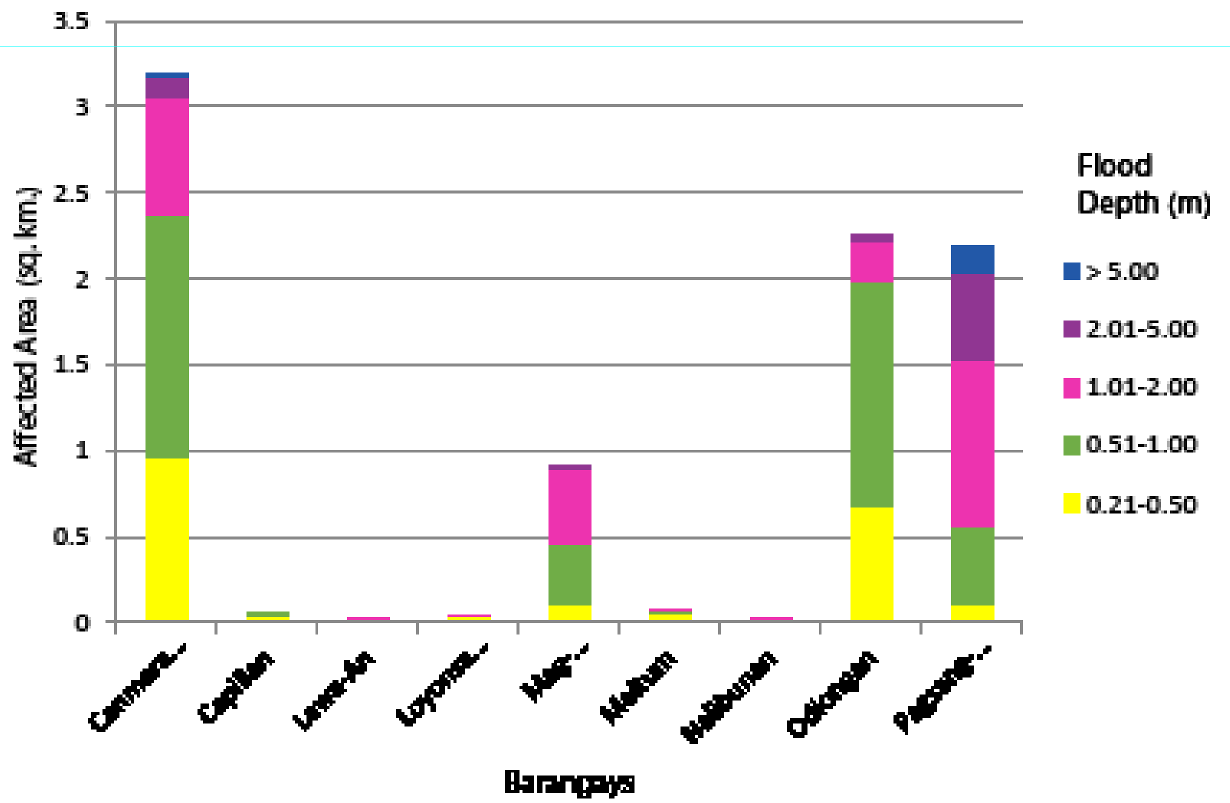


Figure 73. Affected Areas in Abuyog, Leyte during 5-Year Rainfall Return Period

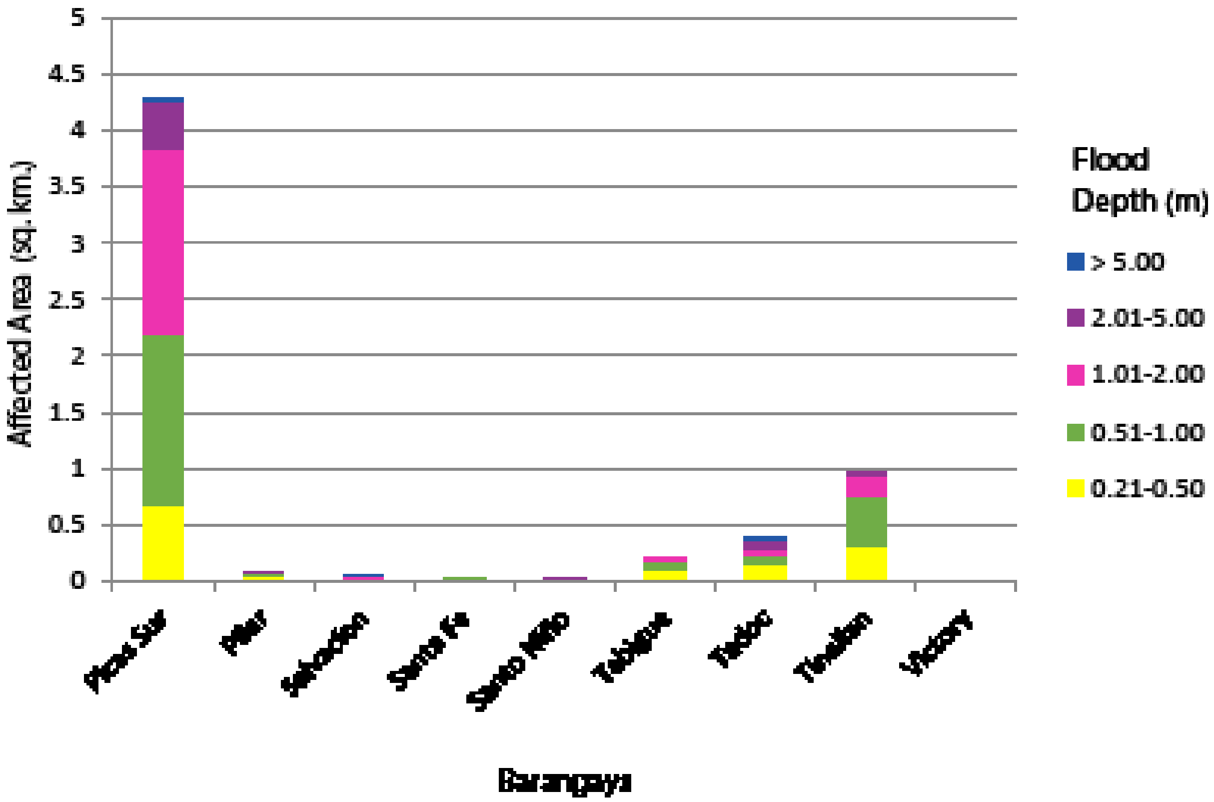


Figure 74. Affected Areas in Abuyog, Leyte during 5-Year Rainfall Return Period

For the 25-year return period, 4.25% of the municipality of Abuyog with an area of 256.64 sq. km. will experience flood levels of less 0.20 meters. 1.01% of the area will experience flood levels of 0.21 to 0.50 meters while 2.29%, 3.79%, 1.79% and 0.020% 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 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Abuyog, Leyte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Bahay	Balocawehay	Barayong	Buenavista	Buntay	Burubud-An	Cadac-An	Can-Aporong	Can-Uguib
0.03-0.20	0.0055750	0.005942544	0.01713648	0.46762182	0.05632175	1.50555058	0.10406397	0.06142527	0.05056067
0.21-0.50	0	0.006533616	0.02788179	0.25345419	0.04765317	0.09227547	0.10057336	0.09313271	0.02842479
0.51-1.00	0	0.001509645	0.08319844	0.40153118	0.02867698	0.06676784	0.36125075	0.19331246	0.04382202
1.01-2.00	0	0	0.24755457	0.25004618	0.0023	0.55968228	0.96978616	0.37641037	0.05378887
2.01-5.00	0	0	0.01732895	0.01280557	0	0.68888068	0.23934562	0.30828739	0.03726814
> 5.00	0	0	0	0	0	0.19851444	0	0.00861464	0

Table 39. Affected Areas in Abuyog, Leyte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Canmarating	Capilian	Lawa-An	Loyonsawang	Mag-Atubang	Maitum	Nalibunan	Odiongan	Pagsang-An
0.03-0.20	0.3184419	0.0214345	0.27765983	0.077774304	0.006526643	0.26900110	0.12238347	0.12151981	0.19111810
0.21-0.50	0.4445326	0.0208530	0.01020185	0.061779576	0.016773959	0.08119428	0.02703794	0.27995854	0.01665943
0.51-1.00	1.2929673	0.0543523	0.00745303	0.06567199	0.080443164	0.04107901	0.00112520	1.28304538	0.14918119
1.01-2.00	2.0724625	0	0.00295357	0.009969225	0.618736782	0.00224843	3.0485E-05	0.92860719	1.07415339
2.01-5.00	0.2942308	0	0	0	0.282336764	0	6.23472E-06	0.07302698	0.78163041
> 5.00	0.0276749	0	0	0	0	0	0	0	0.18552641

Table 40. Affected Areas in Abuyog, Leyte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Picas Sur	Pilar	Salvacion	Santa Fe	Santo Niño	Tabigue	Tadoc	Tinalian	Victory
0.03-0.20	1.196192407	2.180593116	0.376816687	0.07018775	0.035816829	0.078465853	0.849101231	2.391277212	0.042341233
0.21-0.50	0.357163345	0.060686775	0.013459978	0.013913498	0.002549888	0.118118983	0.186418482	0.23522762	0.005851875
0.51-1.00	0.975658325	0.027082354	0.020096333	0.003932184	0.003187992	0.218162492	0.132399107	0.330499861	0
1.01-2.00	1.775908415	0.010309763	0.009300281	0	0.00901363	0.184751313	0.063434249	0.520757149	0
2.01-5.00	1.704279198	0.0006	0.012230909	0	0.00215881	0.022826338	0.098652251	0.019083695	0
> 5.00	0.056198406	0	0.004299999	0	0	0	0.024953921	0	0

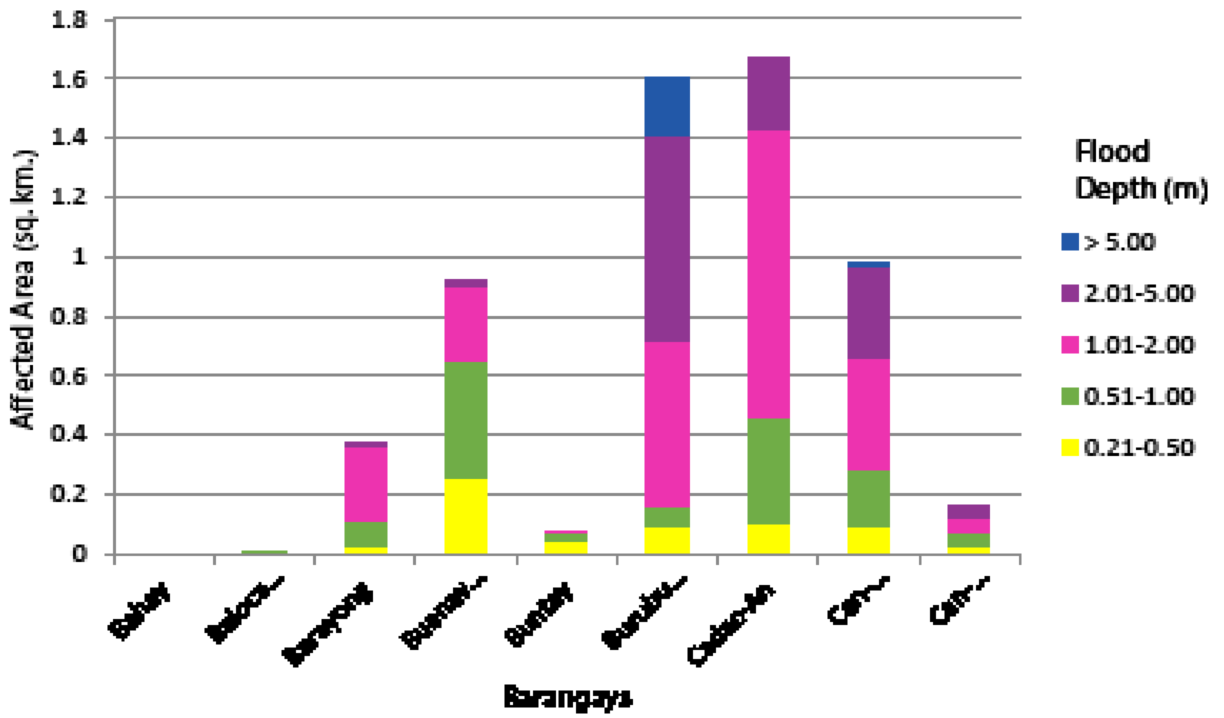


Figure 75. Affected Areas in Abuyog, Leyte during 25-Year Rainfall Return Period

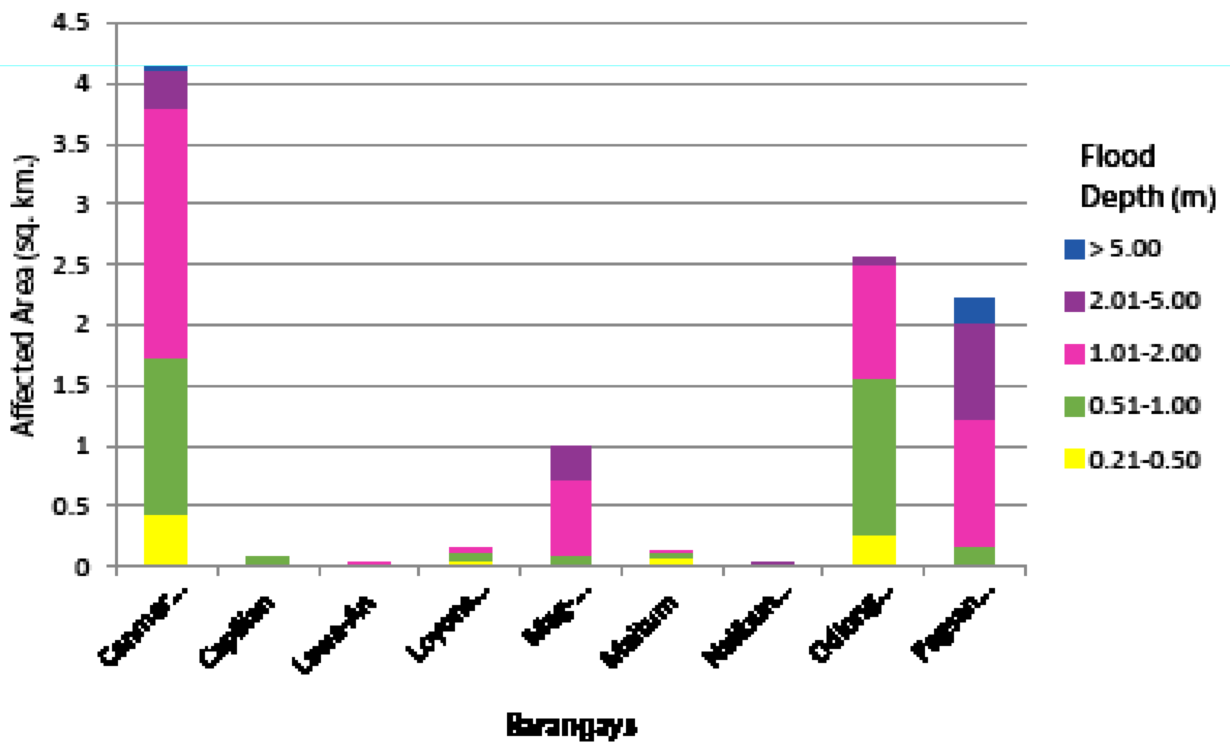


Figure 76. Affected Areas in Abuyog, Leyte during 25-Year Rainfall Return Period

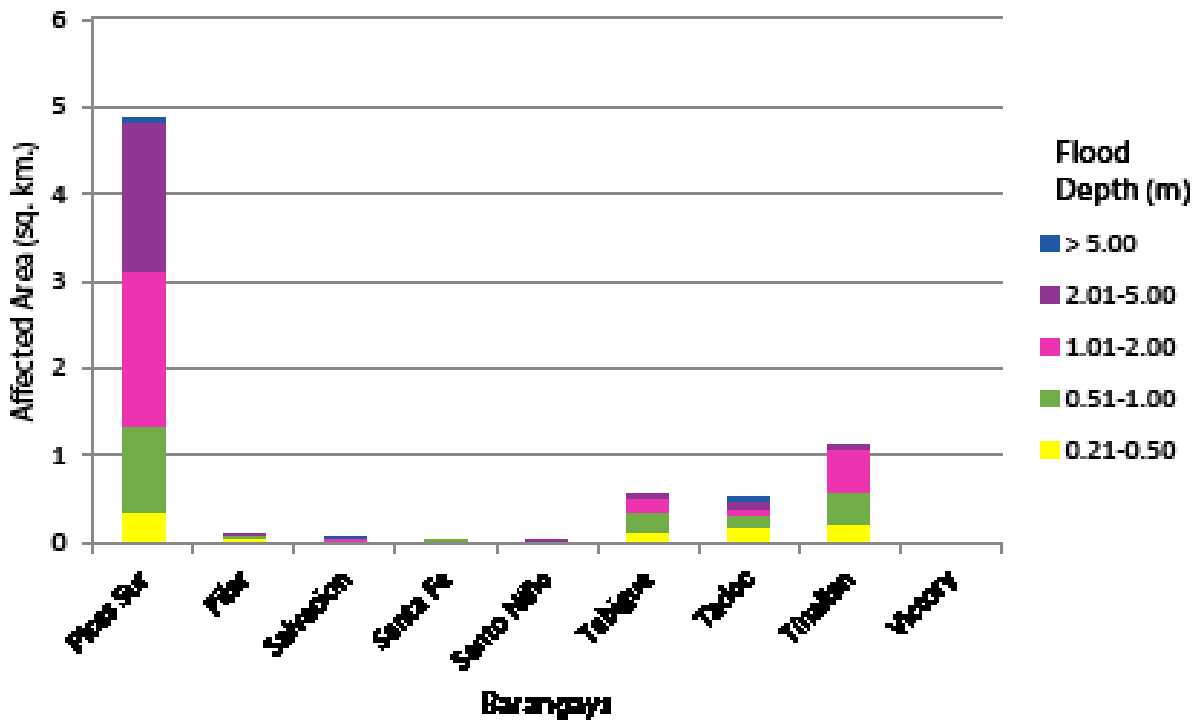


Figure 77. Affected Areas in Abuyog, Leyte during 25-Year Rainfall Return Period

For the 100-year return period, 3.24% of the municipality of Abuyog with an area of 256.64 sq. km. will experience flood levels of less 0.20 meters. 0.47% of the area will experience flood levels of 0.21 to 0.50 meters while 0.80%, 1.86%, 2.26%, and 0.14% 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 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Abuyog, Leyte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Bahay	Balocawehay	Barayong	Buenavista	Buntay	Burubud-An	Cadac-An	Can-Aporong	Can-Uguib
0.03-0.20	0.005575096	0.002031097	0.000689544	0.236949183	0.01392945	1.46207164	0.040341039	0.012395905	0.013115764
0.21-0.50	0	0.002546237	0.006606651	0.188240129	0.030593436	0.096141396	0.039330122	0.022931424	0.024536817
0.51-1.00	0	0.002499634	0.037634108	0.391606291	0.071250309	0.037213015	0.136320102	0.126589297	0.045691006
1.01-2.00	0	0.006908837	0.213746983	0.499167583	0.019178715	0.113408584	0.919401148	0.410166609	0.067660078
2.01-5.00	0	0	0.13442297	0.069495775	0	1.178131121	0.639627473	0.455233629	0.06286085
> 5.00	0	0	0	0	0	0.224705551	0	0.013866003	0

Table 42. Affected Areas in Abuyog, Leyte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Canmarating	Capilian	Lawa-An	Loyonsawang	Mag-Atubang	Maitum	Nalibunan	Odiongan	Pagsang-An
0.03-0.20	0.109170261	0.016904952	0.271114685	0.023085149	0	0.121408463	0.058518125	0.027833996	0.18349804
0.21-0.50	0.162696367	0.010595336	0.009726785	0.042606313	0.001323543	0.062094509	0.062820552	0.100522286	0.006495379
0.51-1.00	0.623959996	0.06467907	0.010789128	0.086688799	0.021763556	0.142025949	0.028882735	0.715374364	0.037360161
1.01-2.00	2.538930153	0.004460609	0.006486133	0.059216313	0.366549036	0.066326091	0.000355691	1.695015918	0.838786442
2.01-5.00	0.96947391	0	0.000151565	0.003598522	0.615181175	0.001667822	6.23472E-06	0.147411358	1.111281699
> 5.00	0.046079775	0	0	0	0	0	0	4.6278E-10	0.220847235

Table 43. Affected Areas in Abuyog, Leyte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Abuyog								
	Picas Sur	Pilar	Salvacion	Santa Fe	Santo Niño	Tabigue	Tadoc	Tinalian	Victory
0.03-0.20	0.767492363	2.167179099	0.368648483	0.054164571	0.032829082	0.008140021	0.802809336	2.29120133	0.027911887
0.21-0.50	0.266795959	0.067594456	0.015038216	0.028836677	0.003603849	0.021589949	0.153124856	0.219266199	0.019781221
0.51-1.00	0.700800683	0.029244115	0.017828967	0.004332184	0.002001602	0.114882595	0.098395018	0.247697291	0.0005
1.01-2.00	1.315436715	0.013454337	0.014357612	0.0007	0.007206679	0.388670315	0.160373723	0.634063172	0
2.01-5.00	2.919891628	0.0018	0.013730909	0	0.007085938	0.089042101	0.111412109	0.104617546	0
> 5.00	0.094982749	0	0.006599999	0	0	0	0.028844198	0	0

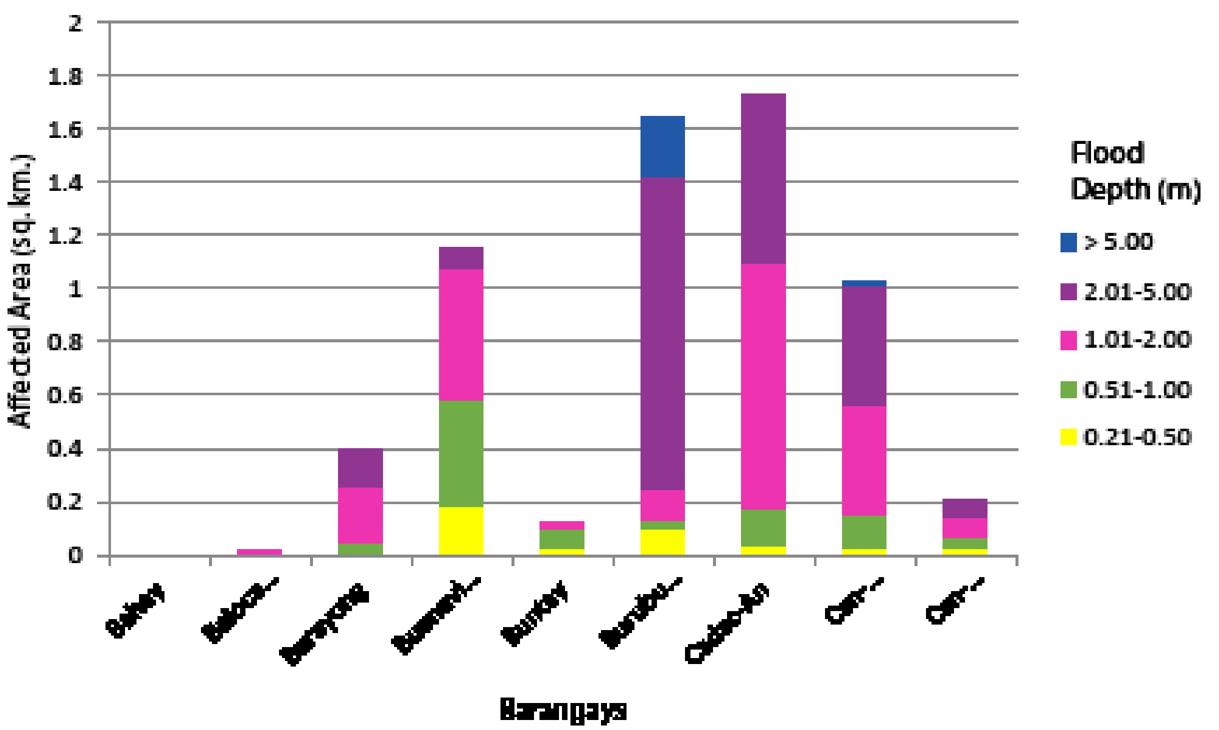


Figure 78. Affected Areas in Abuyog, Leyte during 100-Year Rainfall Return Period

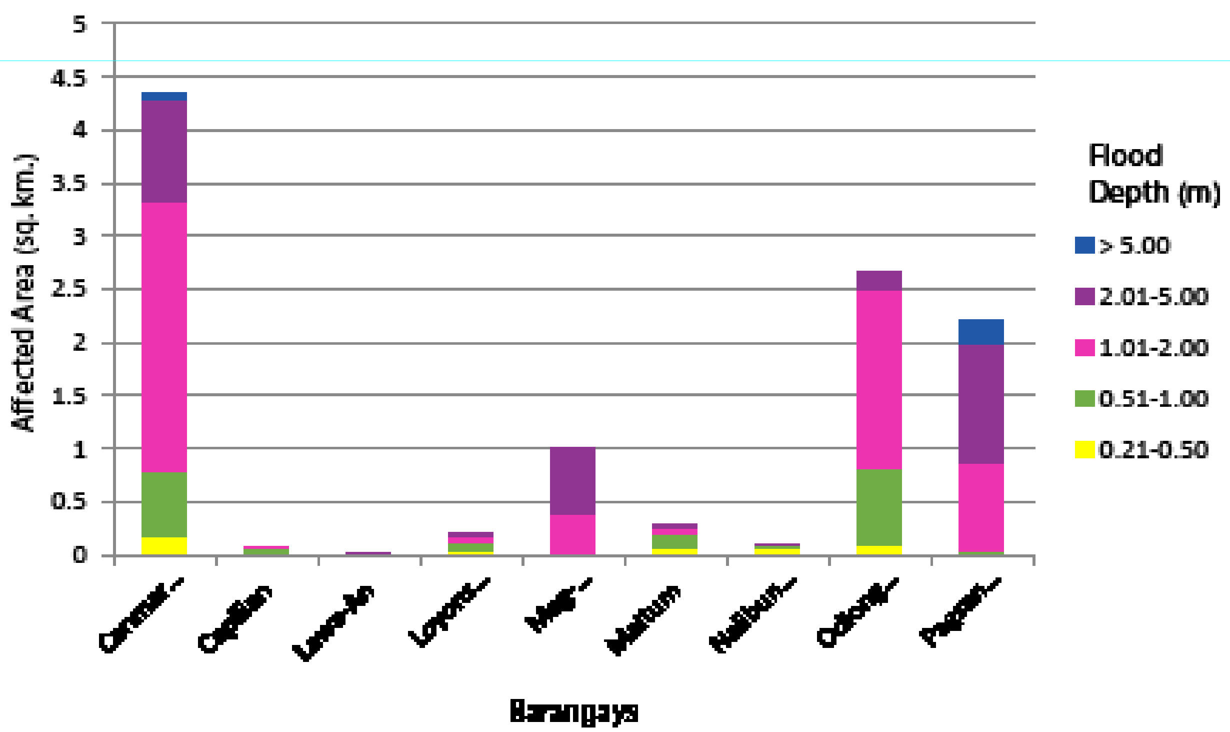


Figure 79. Affected Areas in Abuyog, Leyte during 100-Year Rainfall Return Period

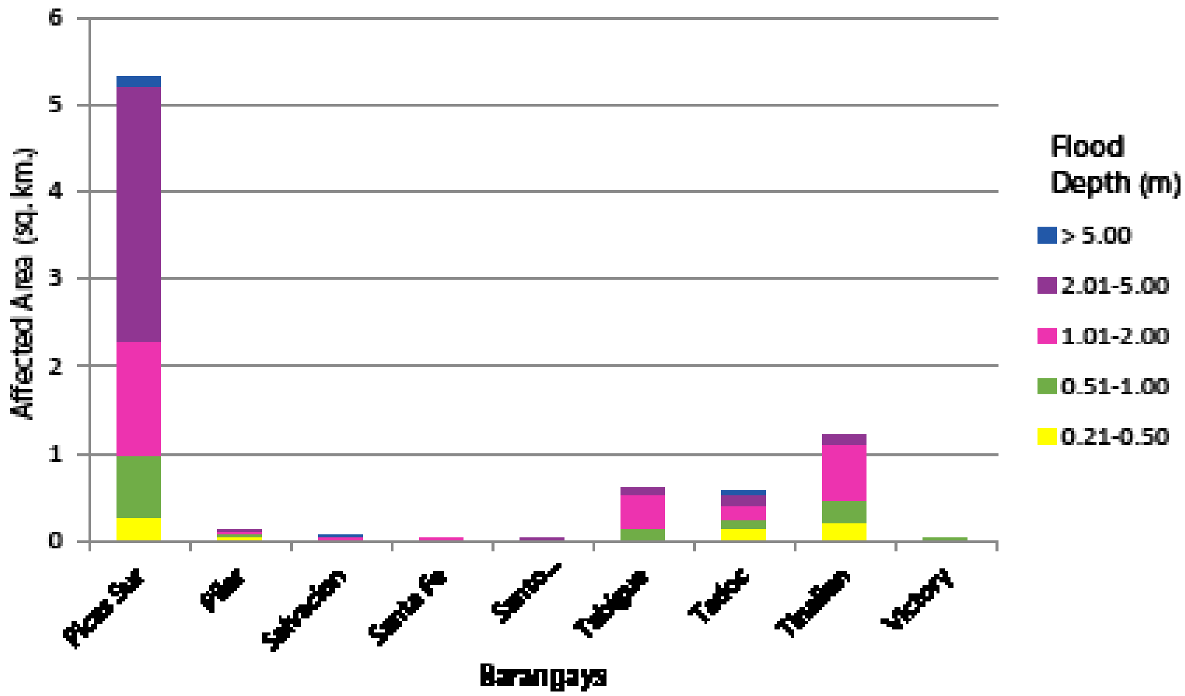


Figure 80. Affected Areas in Abuyog, Leyte during 100-Year Rainfall Return Period

Among the barangays in the Municipality of Abuyog, Picas Sur is projected to have the highest percentage of area that will experience flood levels at 2.36%. Meanwhile, Canmarating posted the second highest percentage of area that may be affected by flood depths at 1.73%.

Moreover, the generated flood hazard maps for the Cadacan 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 44. 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	4.32	2.58	1.66
Medium	11.22	11.32	9.16
High	4.36	10.32	15.18

Of the 37 identified Education Institutions in Cadacan Flood plain, 9 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 6 schools were assessed to be exposed to Medium level flooding and 1 schools were assessed to be exposed to High level flooding in the same scenario. In the 25 year scenario, 8 schools were assessed to be exposed to the Low level flooding while 15 schools were assessed to be exposed to Medium level flooding and 2 schools were assessed to be exposed to High level flooding in the same scenario. For the 100 year scenario, 6 schools were assessed for Low level flooding and 18 schools for Medium level flooding. In the same scenario, 5 schools were assessed to be exposed to High level flooding. See ANNEX 12 for a detailed enumeration of schools inside Cadacan Floodplain.

Of the 17 identified Medical Institutions in Cadacan Flood plain, 7 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 same scenario. In the 25 year scenario, 3 were assessed to be exposed to the Low level flooding while 11 were assessed to be exposed to Medium level flooding. For the 100 year scenario, 14 schools were assessed for Medium level flooding and 1 for High level flooding. See ANNEX 13 for a detailed enumeration of medical insitutions inside Cadacan Floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there was 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 wee identified for validation.

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to whom maps or situation reports about the past flooding events or interviews of some residents with knowledge of or have had experienced flooding in a particular area were obtained.

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve what was needed.

The flood validation consists of 300 points randomly selected all over the Cadacan Floodplain. It has an RMSE value of 0.64.

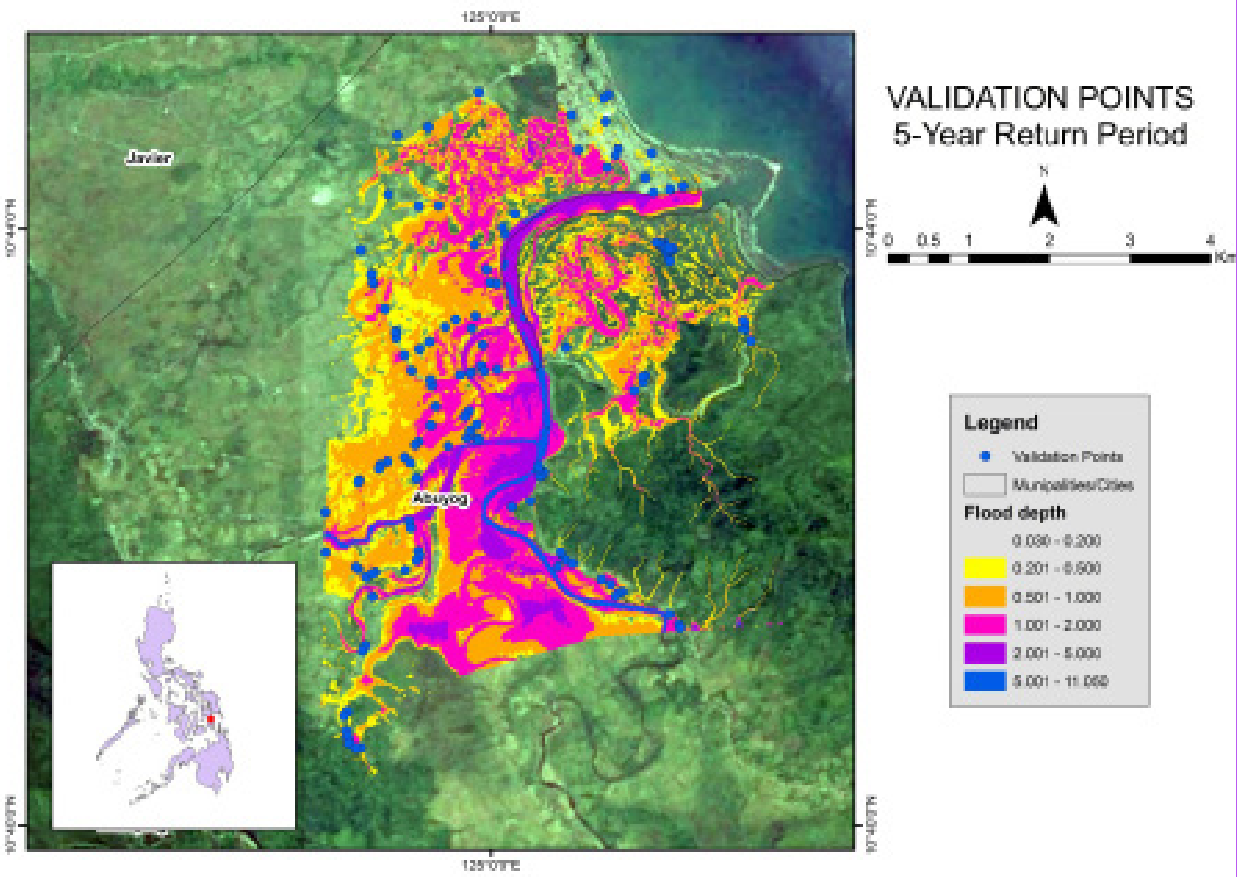


Figure 81. Validation points for 5-year Flood Depth Map of Cadacan Floodplain

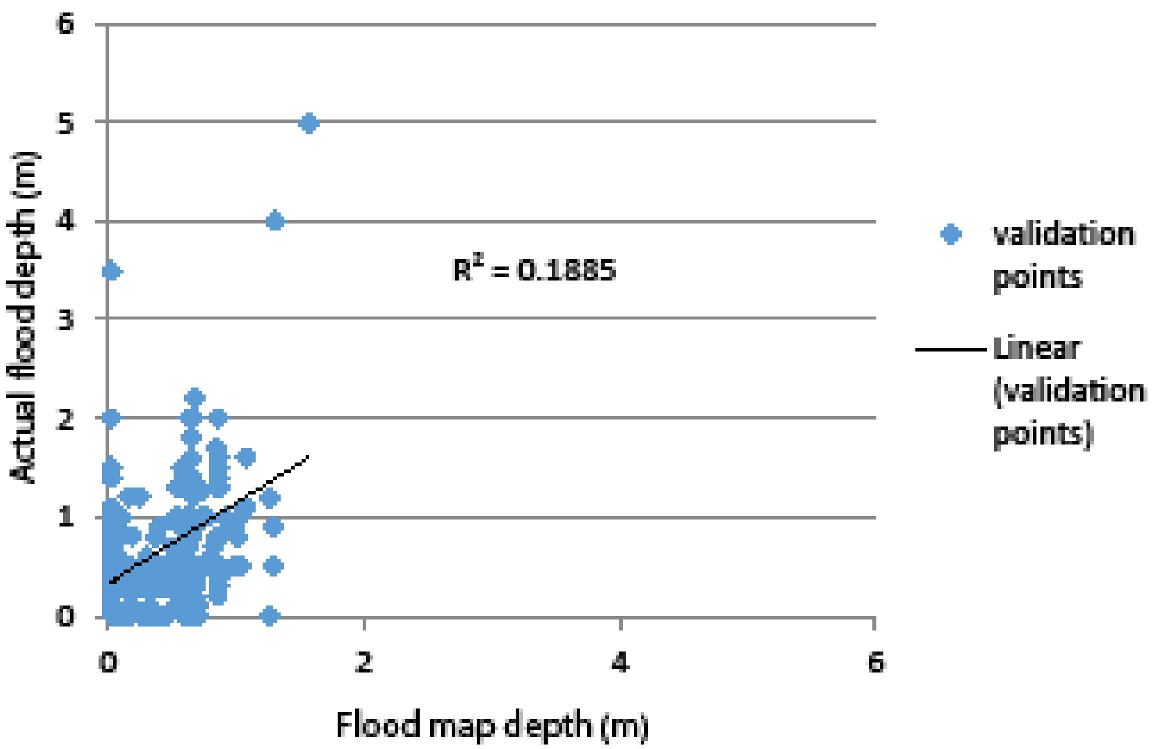


Figure 82. Flood map depth vs actual flood depth

Table 45. Actual Flood Depth vs Simulated Flood Depth in Cadac-an

CADAC-AN 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	55	11	13	1	0	0	**80**
	0.21-0.50	44	21	27	2	0	0	**94**
	0.51-1.00	25	9	39	5	0	0	**78**
	1.01-2.00	13	2	24	4	0	0	**43**
	2.01-5.00	1	0	1	3	0	0	**5**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**138**	**43**	**104**	**15**	**0**	**0**	**300**

The overall accuracy generated by the flood model is estimated at 39.67%, with 119 points correctly matching the actual flood depths. In addition, there were 123 points estimated one level above and below the correct flood depths while there were 43 points and 15 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 59 points were overestimated while a total of 122 points were underestimated in the modelled flood depths of Cadac-an.

Table 46. Summary of Accuracy Assessment in Cadac-an

	No. of Points	%
Correct	119	39.67
Overestimated	59	19.67
Underestimated	122	40.67
Total	**300**	**100**

REFERENCES

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

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

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

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

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

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

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

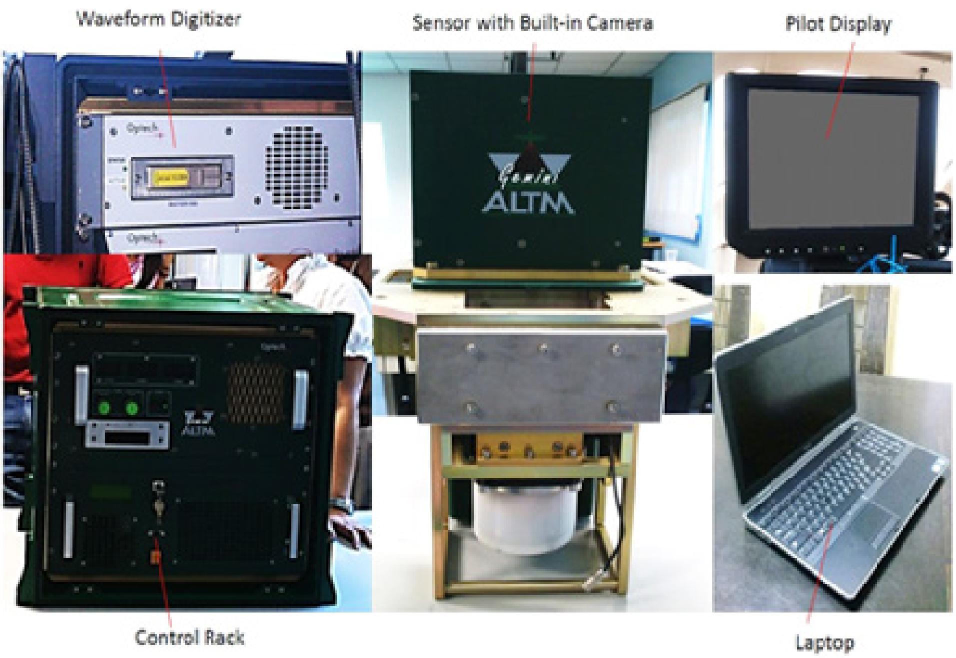
ANNEX

ANNEX 1. Technical Specifications of the LiDAR Sensors Used In The Cadac-an Floodplain Survey

1. Aquarius

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

2. Gemini



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-93

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

April 23, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LYT-93**
Order: **1st**

Island: **VISAYAS**		Barangay: **SANTO NIÑO (POB.)**
Municipality: **ABUYOG**		
	PRS92 Coordinates	
Latitude: **10° 44' 52.03339"**	Longitude: **125° 0' 43.59630"**	Ellipsoidal Hgt: **2.66000 m.**
	WGS84 Coordinates	
Latitude: **10° 44' 47.89310"**	Longitude: **125° 0' 48.79542"**	Ellipsoidal Hgt: **66.12300 m.**
	PTM Coordinates	
Northing: **1188433.982 m.**	Easting: **501324.552 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,188,738.73**	Easting: **720,040.44**	Zone: **51**

Location Description

LYT-93
From Tacloban City travel 60kms S until you reach Abuyog Municipal Hall. From the gate near the post office walk 100m SE until you reach the office of the Municipal Engineer. Station is about 35m S of the S corner of the Municipal Engineer's building. Mark is the head of a 4" copper nail centered on a 0.30m x 0.30m x 1.00m concrete monument protruding 0.10m above the ground with inscription "LYT-93 2006 NAMRIA."

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-915**

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

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

ISO 9001:2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. 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' 50.77365"**	Longitude:	**124° 57' 36.36037"**	Ellipsoidal Hgt:	**163.36309 m.**
		PTM / PRS92 Coordinates			
Northing:	**1166461.318 m.**	Easting:	**405474.491 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**1,166,063.62**	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. concrete 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

NAMRIA OFFICES:
Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines
Branch: 421 Barraca St. San Nicolas, 1010 Manila, Philippines
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. LY-1024

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SOUTHERN LEYTE**		
Station Name: **LY-1024**		
Island: **Visayas**	Municipality: **SOGOD**	Barangay: **KAHUPIAN**
Elevation: **364.7756 +/- 0.07**	Accuracy Class at 95% C.L: **7 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

BM-LY-1024 is in the Province of Leyte, Municipality of Sogod, Brgy. Kahupian along the Mahaplag-Sogod National Highway. The station is located at the SE end of the sidewalk of Agas-agas Bridge at KM post 1006 + 972.6 and 4 m from the road centerline.

Mark is the head of a 4 in copper nail set flush on a 15 cm x 15 cm cement putty with inscriptions "LY-1024, 2012, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0331**

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

4. LY-110

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: **LY-110**		
Island: **Visayas**	Municipality: **PALO**	Barangay: **LIBERTAD**
Elevation: **12.9339 +/- 0.03 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

LY-110
Is in the Province of Leyte, Municipality of Palo, Brgy. Libertad. It is about 225m West of km post 919, 4.15 North of Centerline of the road leading to Ormoc, at the Northwest end of a 42.0m long bridge. A 24 minutes drive from Tacloban City going to South to Ormoc on a bridge located about 225 meters of km post 919. Mark is a 4" copper nail, drilled on hole on top of concrete footwalk at the top of culvert headwall and cemented flush with inscription "LY-110 2007 NAMRIA".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089607 I**
T.N.:	**2016-0240**

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

5. LY-199

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LY-199**

Island: **Visayas**	Municipality: **JAVIER (BUGHO)**	Barangay: **PICAS NORTE**
Elevation: **4.0649 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LY-199 is located in the Municipality of Abuyog, Leyte, Brgy. Bungas. It is at the SW end of the 28 m span Bunga Bridge, 5 m S from the centerline of the road leading to Abuyog.

M ark is the head of a 4" copper nail, drilled on hole on top of concrete footwalk of Bunga Bridge and cemented flush with inscription LY-199, 2007, NAMRIA".

Recomputed March 2014

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1292**

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

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

1. LYT-104

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-53 --- LYT-104 (B1)	SMR-53	LYT-104	Fixed	0.008	0.017	200°40'31"	42653.401	7.525
SMR-53 --- LYT-104 (B2)	SMR-53	LYT-104	Fixed	0.004	0.016	200°40'31"	42653.384	7.601

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SMR-53				
Grid		Local		Global	
Easting	720874.133 m	Latitude	N11°30'17.85656"	Latitude	N11°30'13.52495"
Northing	1272513.396 m	Longitude	E125°01'29.83738"	Longitude	E125°01'34.96980"
Elevation	24.750 m	Height	26.134 m	Height	87.787 m

To:	LYT-104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

Vector					
ΔEasting	-14784.623 m	NS Fwd Azimuth	200°40'31"	ΔX	7839.600 m
ΔNorthing	-40016.558 m	Ellipsoid Dist.	42653.401 m	ΔY	15051.644 m
ΔElevation	7.561 m	ΔHeight	7.525 m	ΔZ	-39131.928 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

2. 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

3. LY-110

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT 104 --- LY 110 (B1)	LYT 104	LY 110	Fixed	0.004	0.013	68°33'52"	8457.064	-19.323
LY 110 --- LYT 104 (B2)	LYT 104	LY 110	Fixed	0.004	0.015	68°33'52"	8457.047	-19.343

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	LYT 104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

To:	LY 110				
Grid		Local		Global	
Easting	713942.863 m	Latitude	N11°10'19.48389"	Latitude	N11°10'15.23095"
Northing	1235638.117 m	Longitude	E124°57'32.98736"	Longitude	E124°57'38.14961"
Elevation	12.819 m	Height	14.336 m	Height	76.647 m

Vector					
ΔEasting	7853.353 m	NS Fwd Azimuth	68°33'52"	ΔX	-6101.546 m
ΔNorthing	3141.279 m	Ellipsoid Dist.	8457.064 m	ΔY	-5012.598 m
ΔElevation	-19.492 m	ΔHeight	-19.323 m	ΔZ	3027.816 m

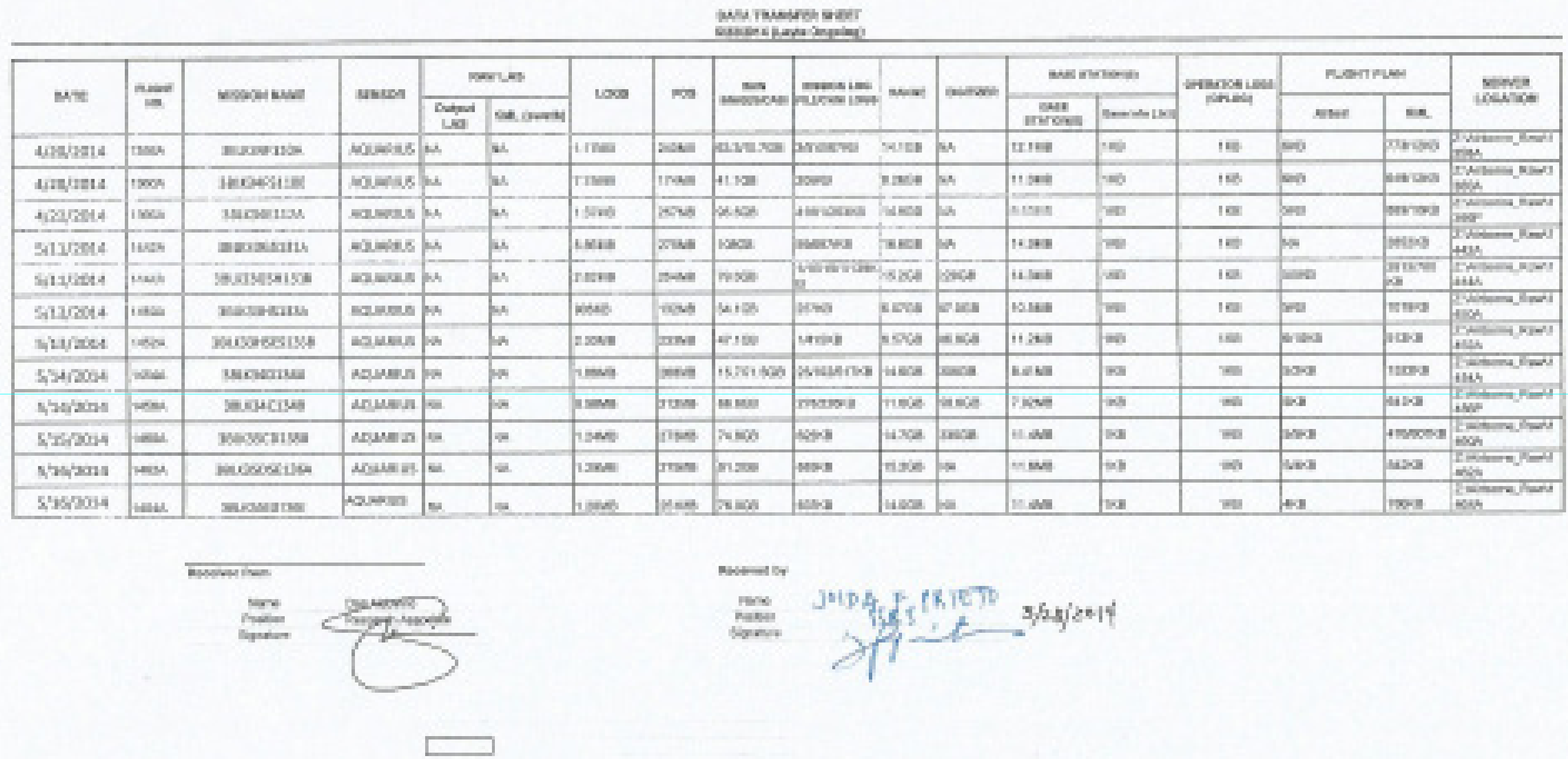
Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

ANNEX 4. 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 PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Data Acquisition Component Leader</td><td>Data Component Project Leader - I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td>Data Component Project Leader – I</td><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 ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td></td><td>Senior Science Research Specialist (SSRS)</td><td>JULIE PEARL MARS</td><td></td></tr>
<tr><td rowspan="5">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS) 2016/ RA (2014)</td><td>JASMINE ALVIAR & PAULINE JOANNE ARCEO</td><td rowspan="5">UP-TCAGP</td></tr>
<tr><td rowspan="4">Research Associate (RA)</td><td>KRISTIN JOY ANDAYA</td></tr>
<tr><td>JONATHAN ALMALVEZ</td></tr>
<tr><td>ENGR. KENNETH QUISADO</td></tr>
<tr><td>ENGR. IRO NIEL ROXAS</td></tr>
<tr><td>Ground Survey</td><td>Research Associate (RA)</td><td>ENGR. FRANK NICOLAS ILEJAY</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="6">LiDAR Operation</td><td rowspan="2">Airborne Security</td><td>SSG RANDY SISON</td><td rowspan="2">Philippine Air Force (PAF)</td></tr>
<tr><td>SSG RAYMUND DOMINE</td></tr>
<tr><td rowspan="4">Pilot</td><td>CAPT. ALBERT PAUL LIM</td><td>Asian Aerospace Corporation (AAC)</td></tr>
<tr><td>CAPT. RANDY LAGCO</td><td>AAC</td></tr>
<tr><td>CAPT. JACKSON JAVIER</td><td>AAC</td></tr>
<tr><td>CAPT. NIEL AGAWIN</td><td>AAC</td></tr>
</table>

ANNEX 5. Data Transfer Sheet for Cadac-an Floodplain



DATA TRANSFER SHEET

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS: Output LAS	RAW LAS: KML (swath)	LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S): BASE STATIONS	BASE STATION(S): Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN: Actual	FLIGHT PLAN: KML	SERVER LOCATION
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5/11/2014	[illegible]	[illegible]	AQUARIUS	NA	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]	1KB	1KB	NA	[illegible]	Z:\Airborne_Raw\[illegible]
5/11/2014	[illegible]	[illegible]	AQUARIUS	NA	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1KB	1KB	[illegible]	[illegible]	Z:\Airborne_Raw\[illegible]
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5/13/2014	[illegible]	[illegible]	AQUARIUS	NA	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1KB	1KB	[illegible]	[illegible]	Z:\Airborne_Raw\[illegible]
5/14/2014	[illegible]	[illegible]	AQUARIUS	NA	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1KB	1KB	[illegible]	[illegible]	Z:\Airborne_Raw\[illegible]
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Received from
Name
Position
Signature

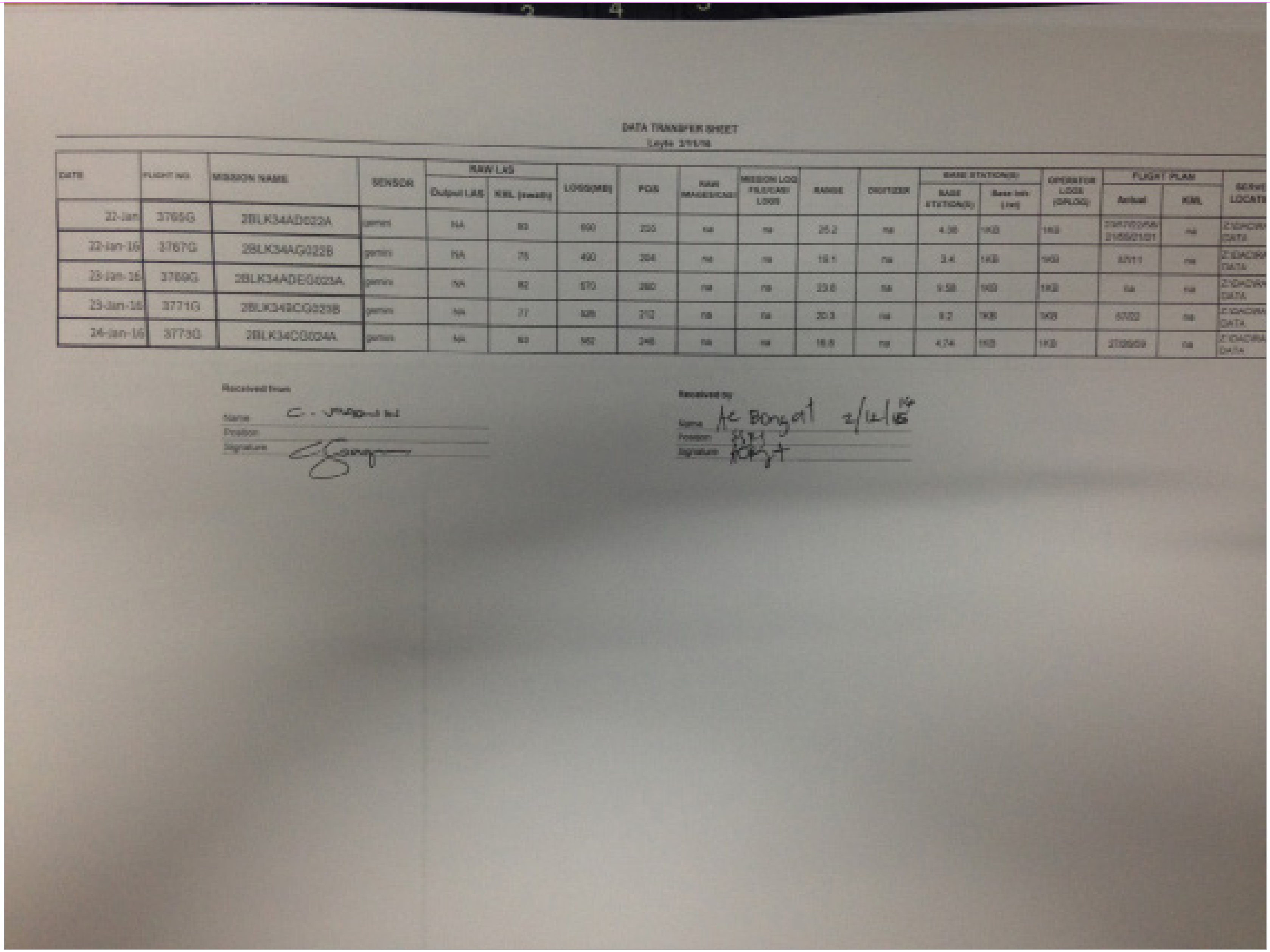
Received by
Name
Position
Signature

DATA TRANSFER SHEET
5/19/2014 (Leyte-Samar Pending)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Apr 30, 2014	1400A	AQUATACTF120B	AQUARIUS	NA	NA	318KB	161MB	NA	NA	3.93GB	NA	14.0MB	1KB	1KB	67KB	105KB	X:\Airborne_Raw\1400A
May 2, 2014	1406A	AQUATACTF123A	AQUARIUS	NA	NA	452KB	184MB	NA	NA	4.58GB	21.1GB	7.19MB	1KB	1KB	71KB	247KB	X:\Airborne_Raw\1406A
May 3, 2014	1410A	AQUATACTF123A	AQUARIUS	NA	NA	1.37MB	281MB	51GB	1029/1KB	15.3GB	NA	7.61MB	1KB	1KB	85/85/339/182/182 KB	569KB	X:\Airborne_Raw\1410A
May 4, 2014	1414A	AQUATACTF124A	AQUARIUS	NA	NA	875KB	177MB	41.6GB	1KB	7.73GB	43.9GB	8.94MB	1KB	1KB	NA	978/7KB	X:\Airborne_Raw\1414A
May 5, 2014	1418A	AQUATACTF125A	AQUARIUS	NA	114KB	484KB	110MB	NA	NA	3.28GB	3.80GB	NA	NA	1KB	350KB	NA	X:\Airborne_Raw\1418A
May 6, 2014	1422A	AQUACALIB126A	AQUARIUS	NA	NA	187KB	140MB	6.09GB	1/1149KB	2.83GB	28.2GB	5.39MB	1KB	1KB	23/23/12KB	66KB	X:\Airborne_Raw\1422A
May 8, 2014	1430A	3BLK34L128A	AQUARIUS	NA	NA	1.30MB	242MB	92.8GB	738KB	13.6GB	224GB	7.90MB	1KB	1KB	272KB	881/11KB	X:\Airborne_Raw\1430A
May 9, 2014	1434A	3BLK34CDM129A	AQUARIUS	NA	NA	3.13MB	286MB	118GB	850KB	15.8GB	297GB	17MB	1KB	1KB	NA	1879KB	X:\Airborne_Raw\1434A
May 9, 2014	1436A	3BLK34MS129B	AQUARIUS	NA	NA	1.14MB	219MB	51.3GB	1/1429KB	9.32GB	66.1GB	17MB	1KB	1KB	172KB	520KB	X:\Airborne_Raw\1436A
May 10, 2014	1438A	3BLK34G130A	AQUARIUS	NA	NA	1.86MB	279MB	123GB	906KB	17.2GB	87.2/129GB	17.5MB	1KB	1KB	479KB	1081KB	X:\Airborne_Raw\1438A
May 10, 2014	1440A	3BLK34OSF130B	AQUARIUS	NA	NA	4.72MB	184MB	66.8GB	1460/1KB	11.4GB	144GB	17.5MB	1KB	1KB	818KB	1700KB	X:\Airborne_Raw\1440A

Received from
Name: Jonathan Almalvez
Position: RA
Signature: [signature]

Received by
Name: JOIDA F. PRIETO
Position: SRS
Signature: [signature] 5/28/2014



DATA TRANSFER SHEET
Leyte 2/11/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
22-Jan	3765G	2BLK34AD022A	gemini	NA	83	600	233	na	na	25.2	na	4.36	1KB	1KB	[illegible]	na	Z:\DAC\RA\ DATA
22-Jan-16	3767G	2BLK34AG022B	gemini	NA	75	490	264	na	na	19.1	na	3.4	1KB	1KB	[illegible]	na	Z:\DAC\RA\ DATA
23-Jan-16	3769G	2BLK34ADEG023A	gemini	NA	82	570	260	na	na	23.6	na	5.58	1KB	1KB	na	na	Z:\DAC\RA\ DATA
23-Jan-16	3771G	2BLK34BCG023B	gemini	NA	77	526	212	na	na	20.3	na	8.2	1KB	1KB	[illegible]	na	Z:\DAC\RA\ DATA
24-Jan-16	3773G	2BLK34CG024A	gemini	NA	63	582	246	na	na	18.8	na	4.74	1KB	1KB	[illegible]	na	Z:\DAC\RA\ DATA

Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat 2/12/16
Position
Signature

DATA TRANSFER SHEET
TACLOBAN [illegible]

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
07-Feb-16	3761G	2BLK34O38A	GEMINI	NA	210	[illegible]	[illegible]	NA	NA	10.2	NA	7.73	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
09-Feb-16	23773G	2BLK34O40A	GEMINI	NA	142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]	1KB	NA	[illegible]	NA	Z:\DAC\RAW DATA
10-Feb-16	23779G	2BLK34O41A	GEMINI	NA	[illegible]	[illegible]	[illegible]	17.7	[illegible]	[illegible]	NA	4.7	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
12-Feb-16	3783G	2BLK34P043A	GEMINI	NA	[illegible]	[illegible]	[illegible]	17	[illegible]	11.2	NA	[illegible]	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA

Received from

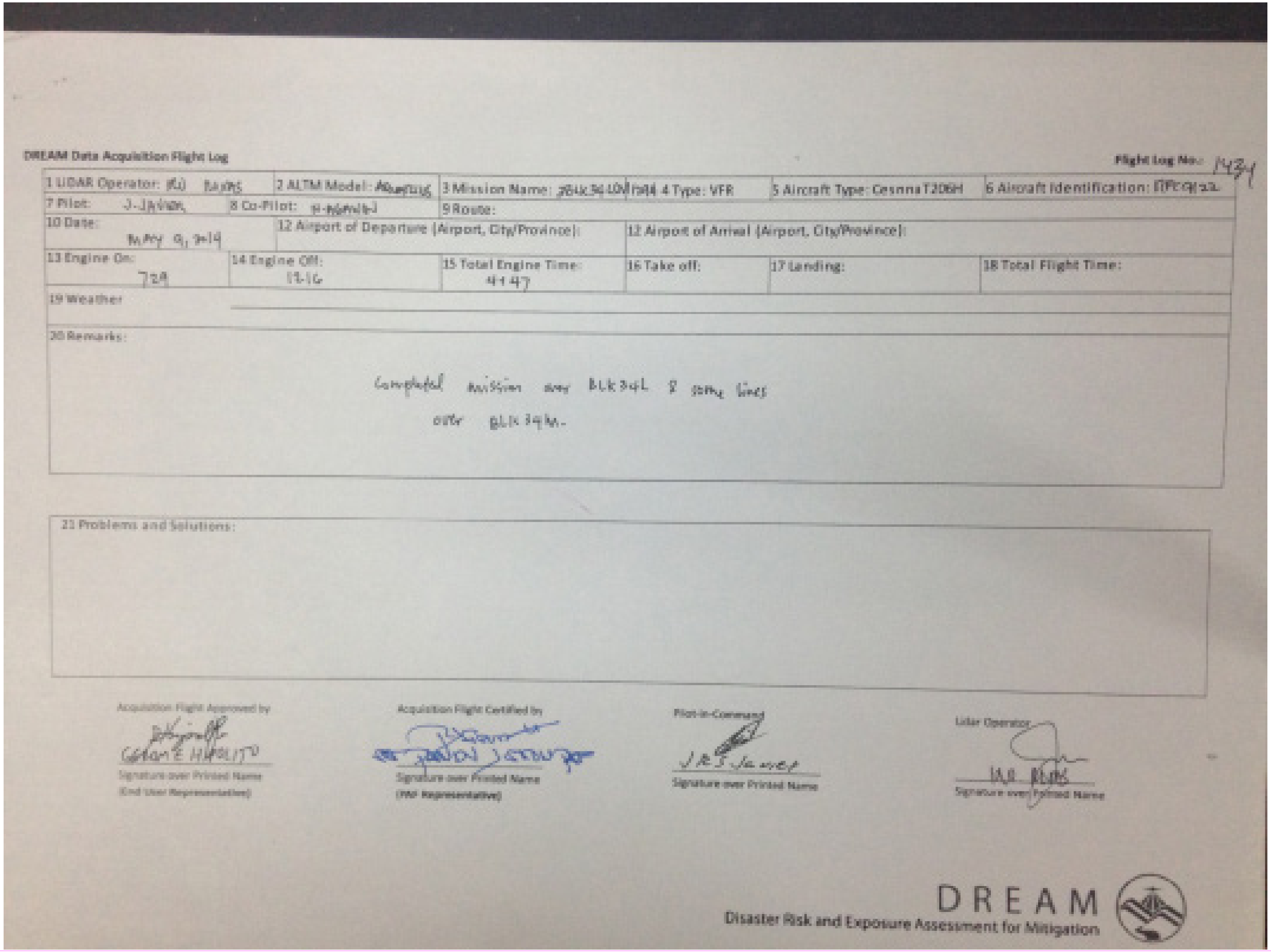
Name [illegible]
Position RA
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature] 3/4/16

ANNEX 6. Flight logs for the Cadac-an Flight Missions

1. Flight Log for 1434A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1434

1 LIDAR Operator:
2 ALTM Model:
3 Mission Name:
4 Type: VFR
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification:
7 Pilot:
8 Co-Pilot:
9 Route:
10 Date: May 9, 2014
12 Airport of Departure (Airport, City/Province):
12 Airport of Arrival (Airport, City/Province):
13 Engine On: 724
14 Engine Off: 11:16
15 Total Engine Time: 4+47
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather
20 Remarks:

Completed mission over BLK34L & some lines over BLK34M.

21 Problems and Solutions:

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

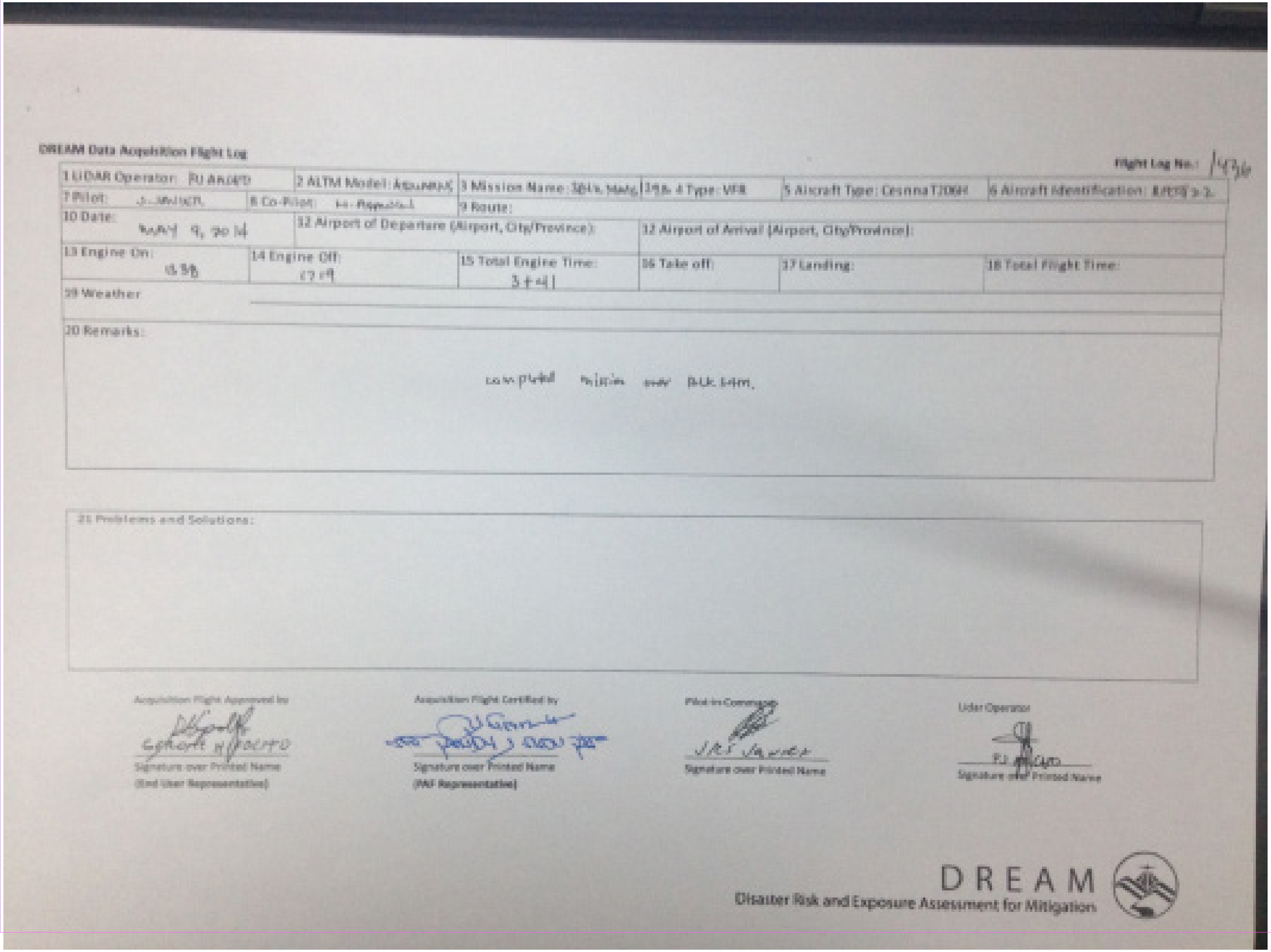
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

2. [ ]



DREAM Data Acquisition Flight Log

Flight Log No.: 1436

1 LIDAR Operator: PJ ARCEO	2 ALTM Model: Aquarius	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Javier	8 Co-Pilot:	9 Route:			
10 Date: May 9, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

21 Problems and Solutions:

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

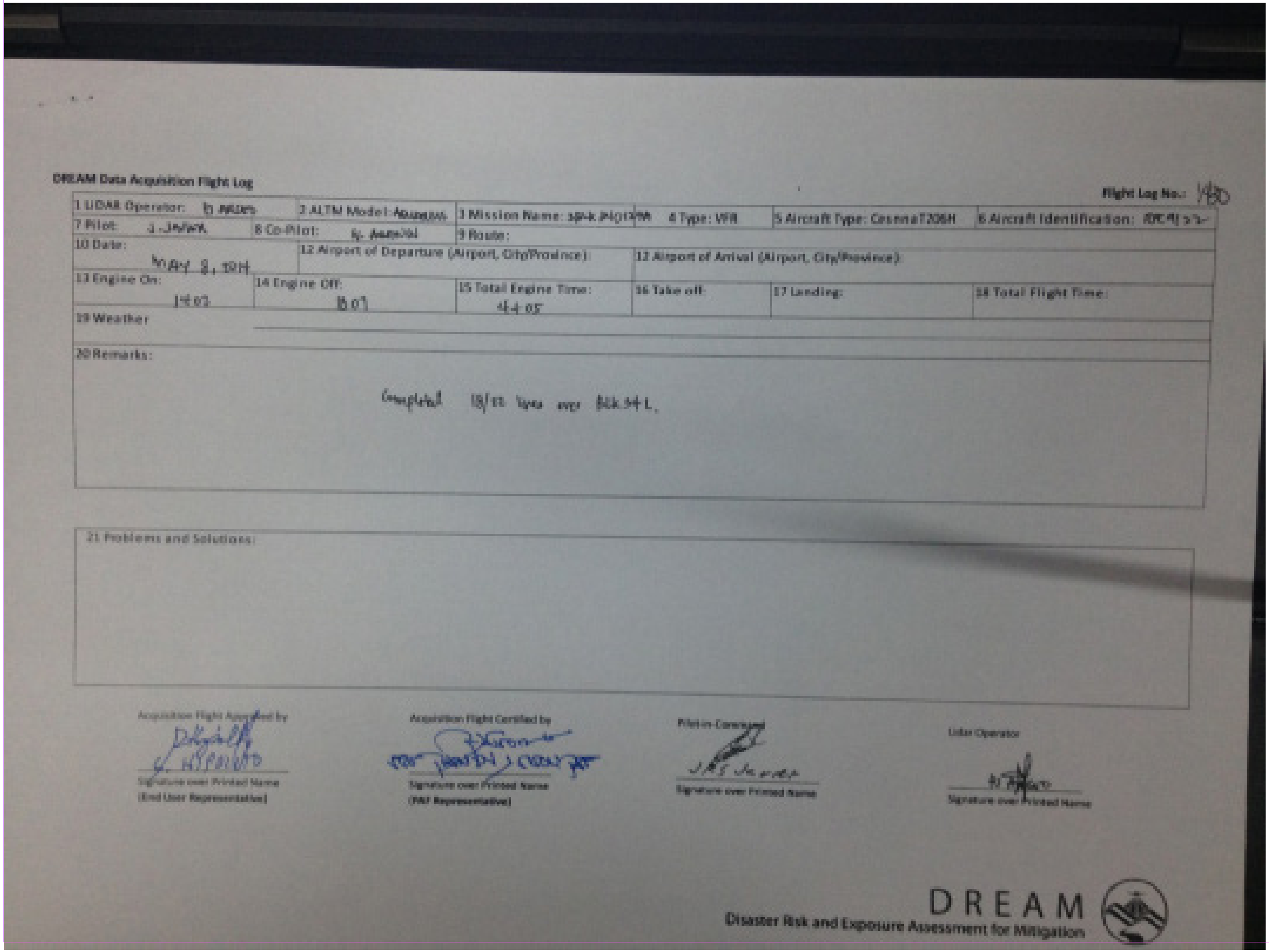
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J. Javier
Signature over Printed Name

Lidar Operator
PJ Arceo
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1430A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1430

1 LIDAR Operator:	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date:	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1403	14 Engine Off: 1803	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

4. Flight Log for 2BLK34038A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3761

1 LIDAR Operator: J. Alviar	2 ALTM Model: Gemini	3 Mission Name: 2BLK34038A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lacsa	9 Route: Tacloban - Tacloban			
10 Date: Feb 7, 2016	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 0741 H	14 Engine Off: 1146 H	15 Total Engine Time: 4+05	16 Take off: 0746 H	17 Landing: 1141 H	18 Total Flight Time: 3+55
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed at Cadac-an

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

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

5. Flight Log for 2BLK34040A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3771

1 LIDAR Operator: K. Quijada	2 ALTM Model: Gemini	3 Mission Name: 2BLK34040A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: A. Lim	8 Co-Pilot: K. Lopez	9 Route: Tacloban - Tacloban			
10 Date: Feb 9, 2016	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 1407H	14 Engine Off: 1718H	15 Total Engine Time: 3+11	16 Take off: 1412H	17 Landing: 1713H	18 Total Flight Time: 3+01
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 34A

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others ____________

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

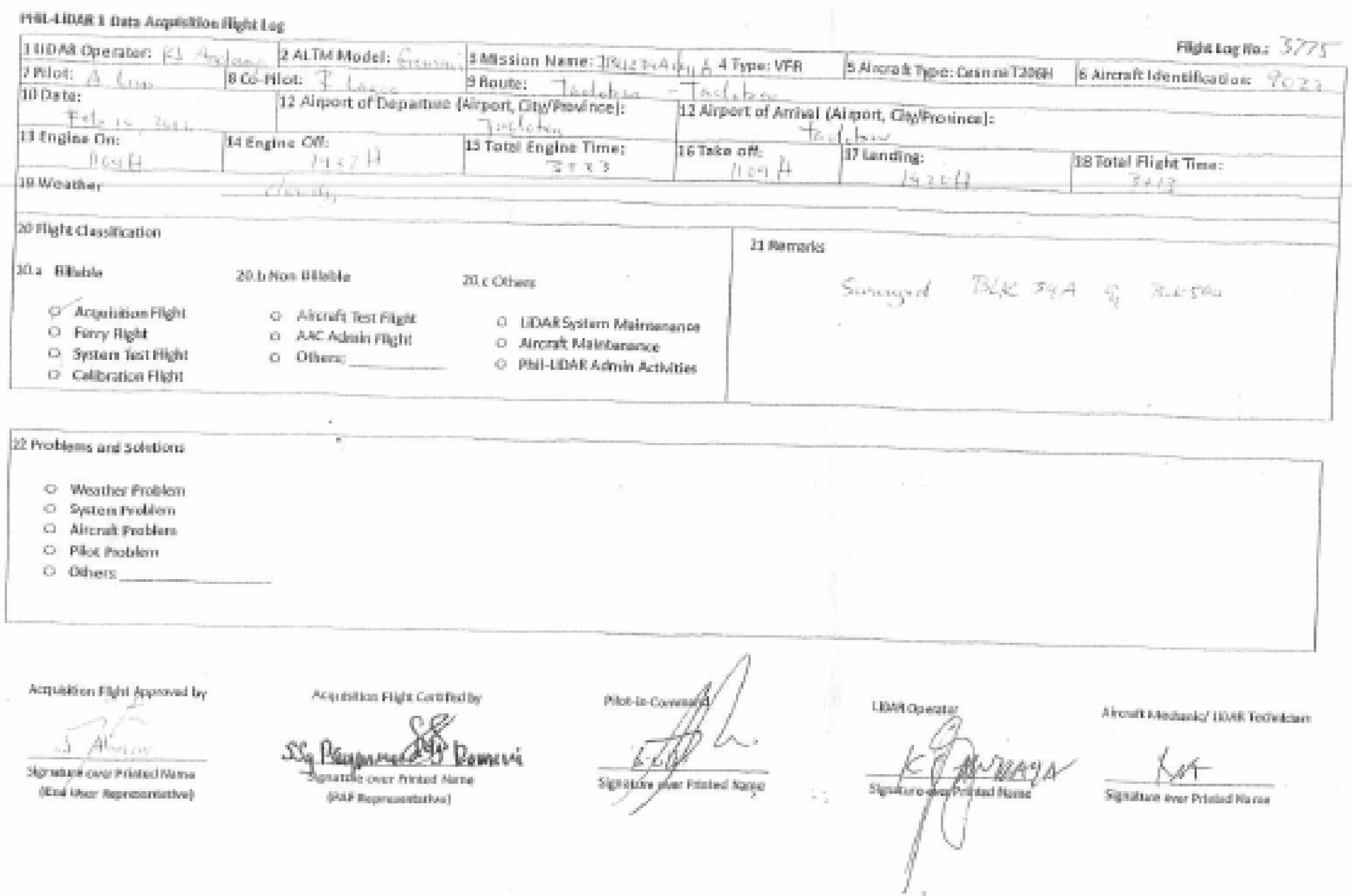
Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

Pilot-in-Command: [signature] — Signature over Printed Name

LIDAR Operator: K. Quijada — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: [signature] — Signature over Printed Name

6. Flight Log for 2BLK34F043A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3775

1 LIDAR Operator: [illegible] | 2 ALTM Model: [illegible] | 3 Mission Name: [illegible] | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: [illegible]

7 Pilot: [illegible] | 8 Co-Pilot: [illegible] | 9 Route: [illegible]

10 Date: Feb 19, 2016 | 12 Airport of Departure (Airport, City/Province): [illegible] | 12 Airport of Arrival (Airport, City/Province): [illegible]

13 Engine On: 1104 H | 14 Engine Off: 1427 H | 15 Total Engine Time: [illegible] | 16 Take off: 1109 H | 17 Landing: [illegible] | 18 Total Flight Time: [illegible]

19 Weather: [illegible]

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 34A [illegible]

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 — Signature over Printed Name

LIDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

7. Flight Log for 2BLK34CG024A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3705

1 LIDAR Operator: J. Almonte[?]	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: [illegible]
7 Pilot: Albert Lim[?]	8 Co-Pilot: [illegible]	9 Route: Tacloban[?] Local			
10 Date: 1-24-16	12 Airport of Departure (Airport, City/Province): Tacloban[?]		12 Airport of Arrival (Airport, City/Province): Tacloban[?]		
13 Engine On: 7:55	14 Engine Off: 12:06	15 Total Engine Time: 4 H11[?]	16 Take off: 8:00	17 Landing: 12:01	18 Total Flight Time: 4+01
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful Flight.

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

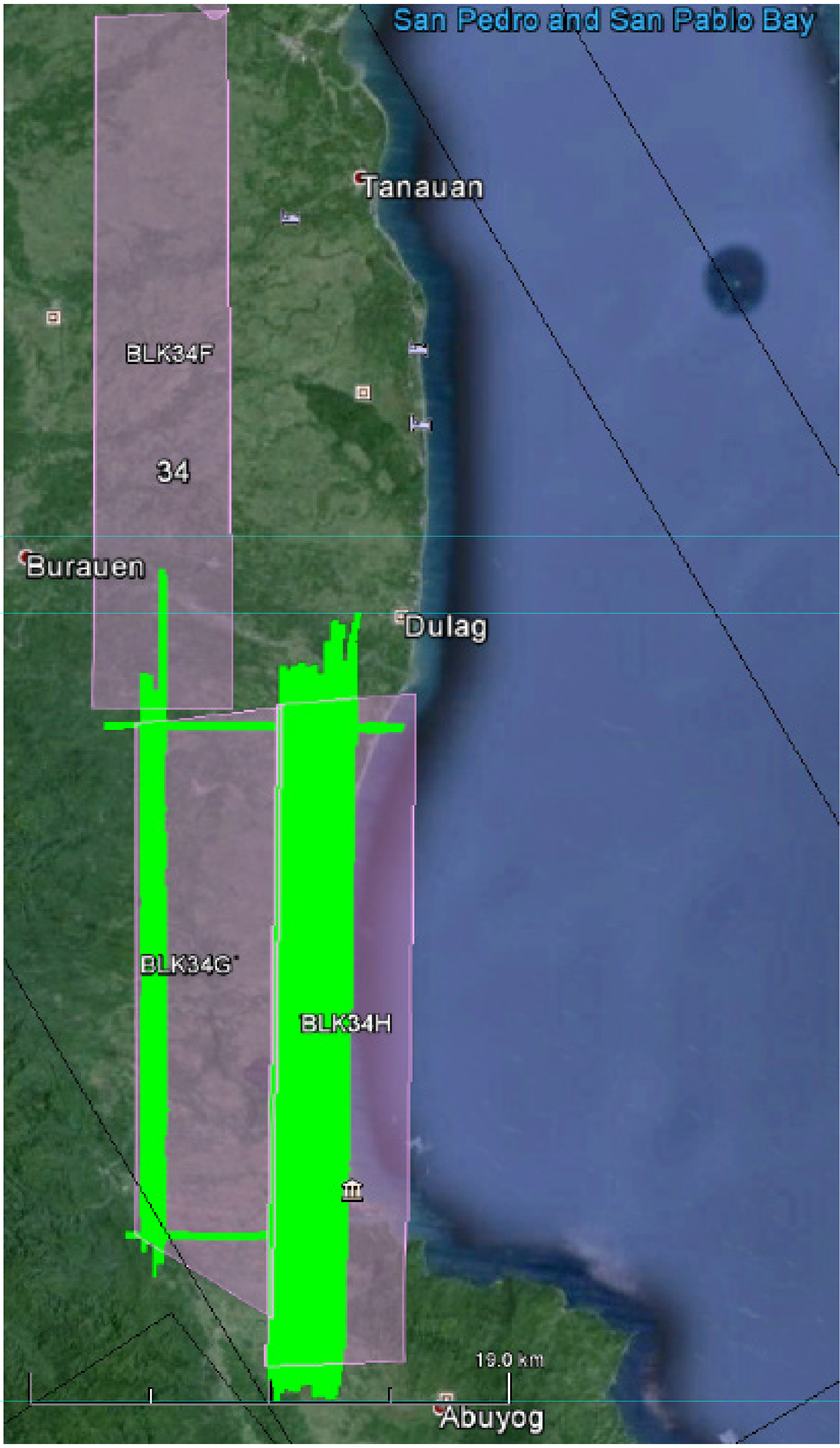
Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Paolin[?] Arce[?]	[illegible]	Albert Lim[?]	J. Almonte[?]	[illegible]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

ANNEX 7. Flight status reports

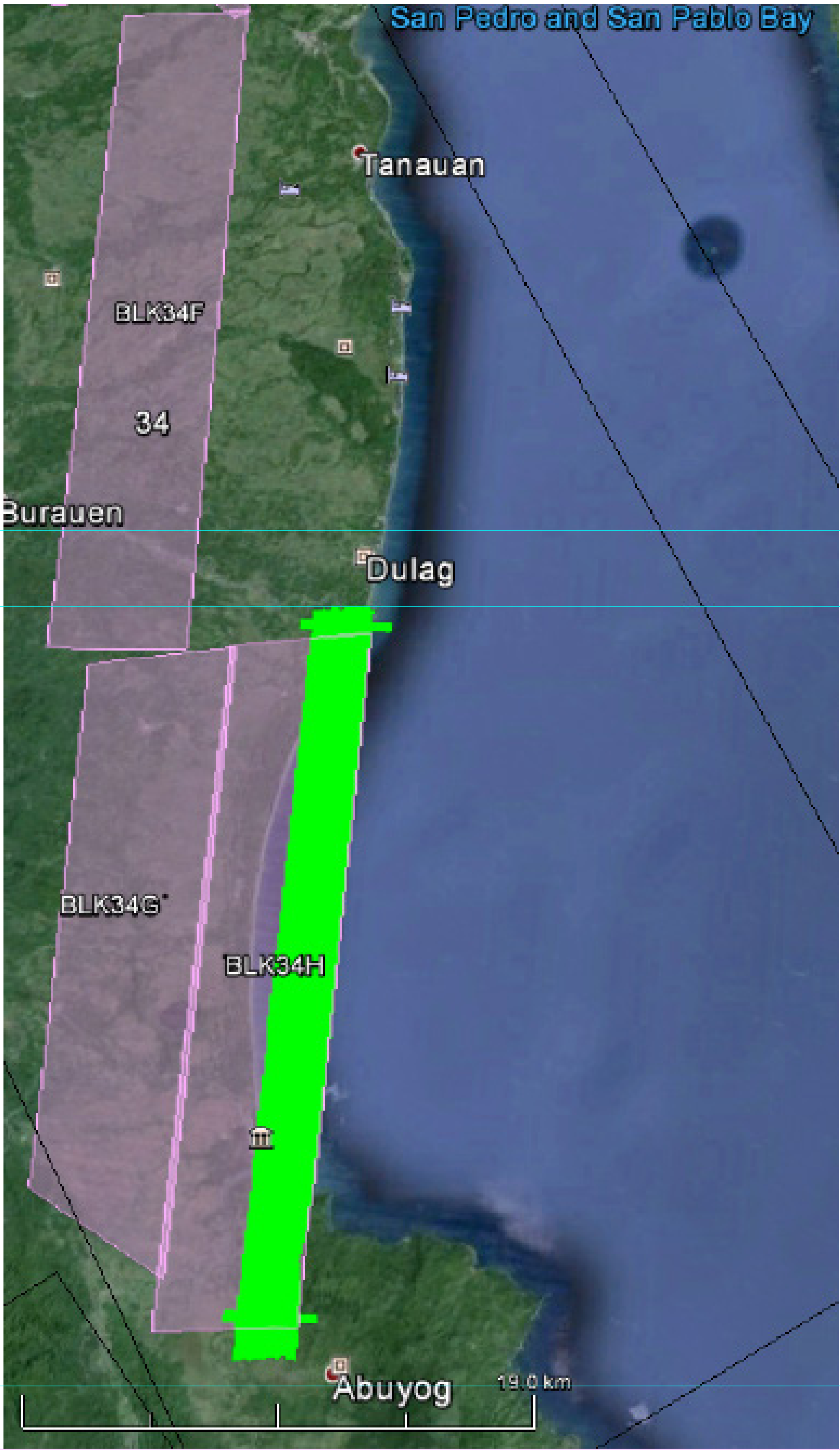
FLIGHT STATUS REPORT
TACLOBAN
May 8 -9, 2014 and January 24 -February 12, 2016

Flight No	Area	Mission	Operator	Date Flown	Remarks
1430A	BLK34G	3BLK34G128A	PJ ARCEO	May 8, 2014	Completed 18/22 lines over BLK34G.
1434A	BLK33G BLK33H	3BLK34GSH129A	IN ROXAS	May 9, 2014	Completed mission over BLK33G and few lines in BLK33H.
1436A	BLK34H	3BLK34HS129B	PJ ARCEO	May 9, 2014	Completed mission over BLK34H.
3773G	BLK34C BLK34G	2BLK34CG024A	J. ALMALVEZ	January 24, 2016	Completed BLK34C and BLK34G.
3761G	BLK 34aC, 34aB, 34F	2BLK34038A	J ALVIAR	February 7, 2016	SURVEYED CADACAN FP REMAINING AREAS
23771G	BLK 34F	2BLK34040A	K QUISADO	February 9, 2016	SURVEYED CADACAN FP
23773G	BLK 34aC, BLK 50A	2BLK34041A	KJ ANDAYA	February 10, 2016	SURVEYED CADACAN AND BISAY FPs
3781G	BLK 34F BLK 49A	2BLK34F043A	K QUISADO	February 12, 2016	SURVEYED CADACAN AND BONGQUIROGAN FPs

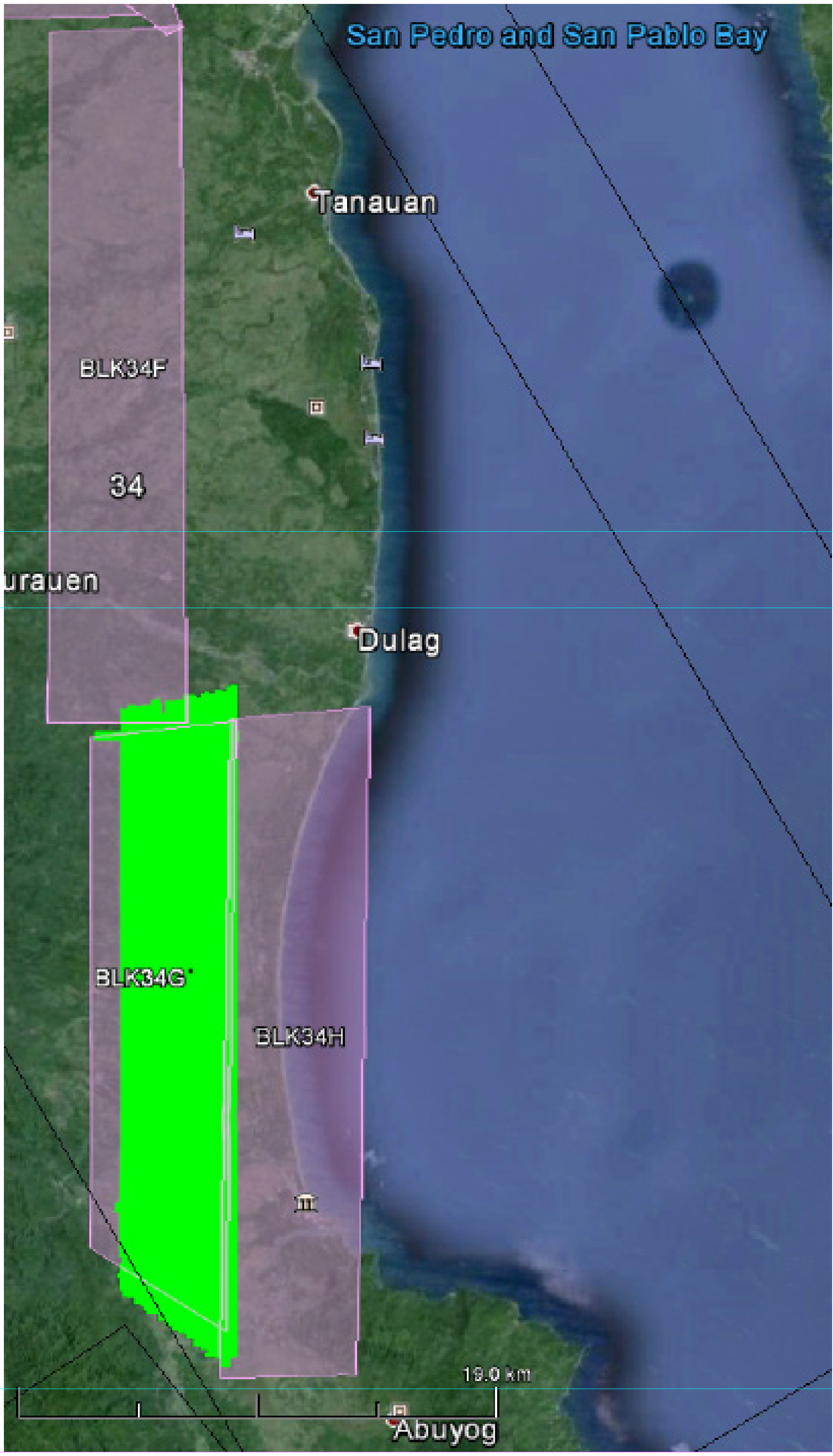
Flight No. :	1434A		
Area:	BLK34G & BLK34H		
Mission Name:	3BLK34GSH129A		
Total Area:	125.909 sq km		
Altitude:	500m		
PRF:	50 kHz	SCF:	50 Hz
LiDAR FOV:	18 deg	Sidelap:	30%



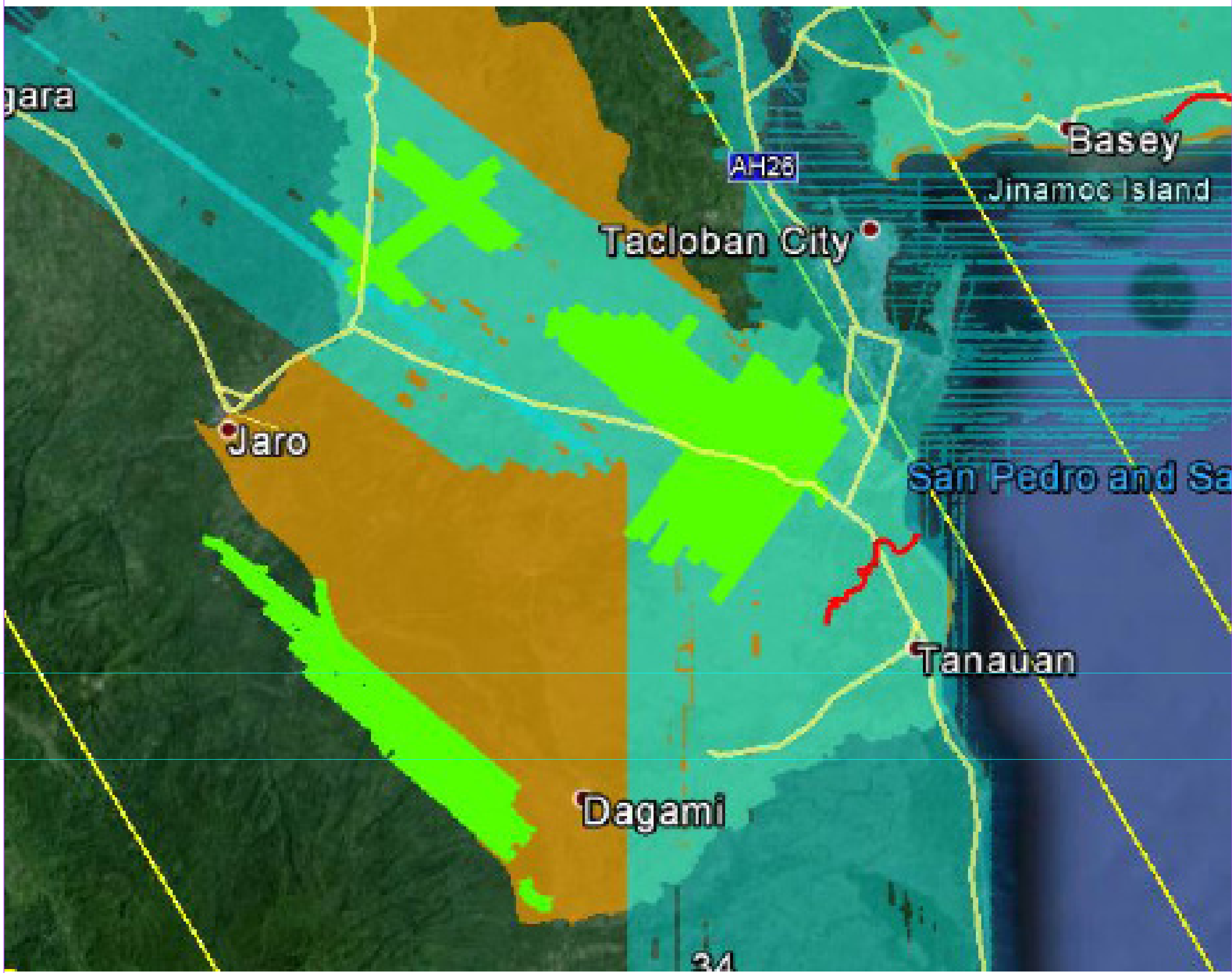
Flight No. :	1436A		
Area:	BLK34H		
Total area:	71.953 sq km		
Mission Name:	3BLK34HS129B		
Altitude:	500m		
PRF:	50 kHz	SCF:	50 Hz
LiDAR FOV:	18 deg	Sidelap:	30%



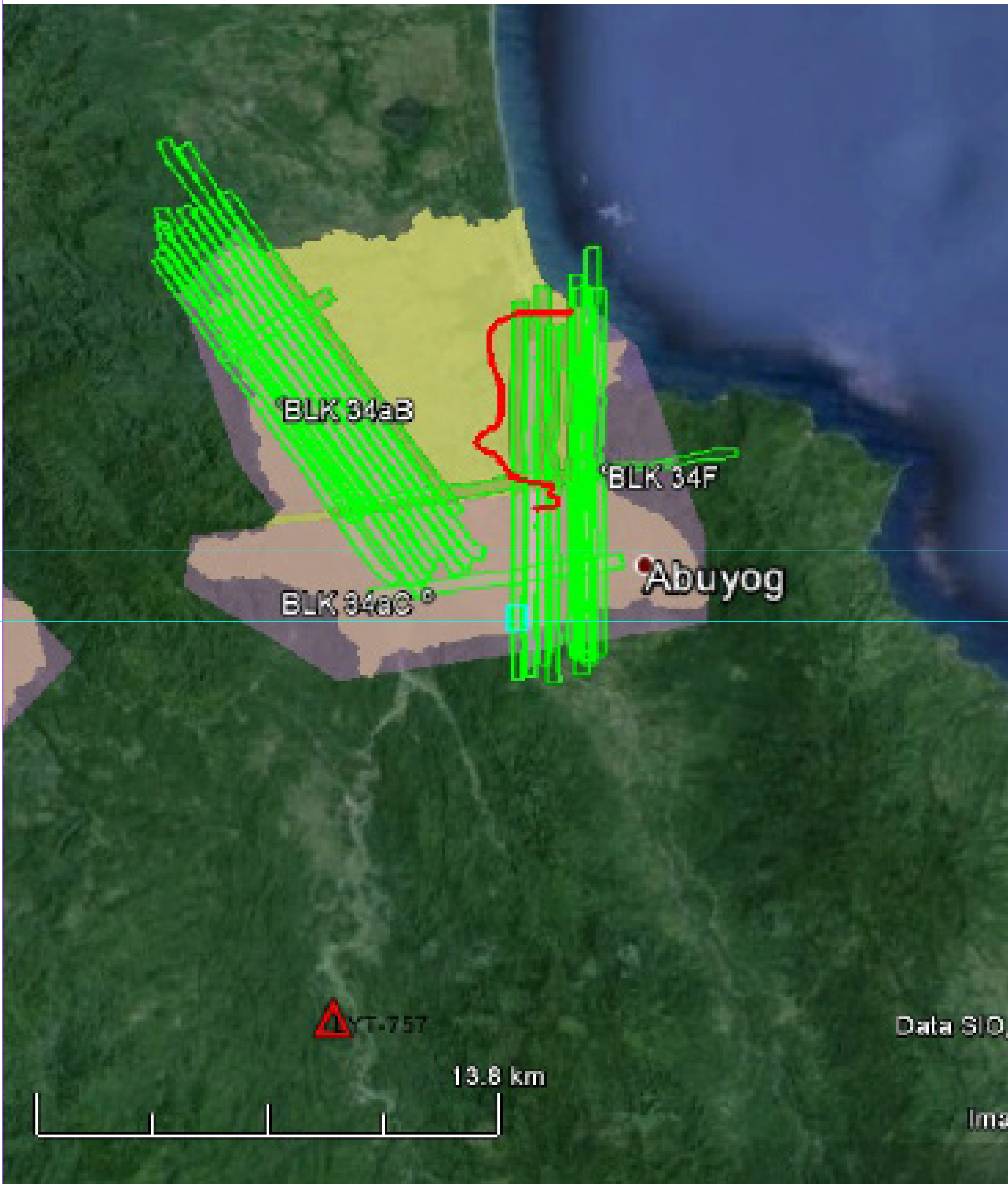
Flight No. :	1430A		
Area:	BLK34G		
Mission Name:	3BLK34G128A		
Total Area:	120.49 sq. km.		
Altitude:	500m		
PRF:	50 kHz	SCF:	50 Hz
LiDAR FOV:	18 deg	Sidelap:	30%



FLIGHT NO.: 3773
AREA: Leyte
MISSION NAME: 2BLK34CG024A
ALT: 600 m SCAN FREQ: 40 SCAN ANGLE: 25
SURVEYED AREA: 90.6 km^2

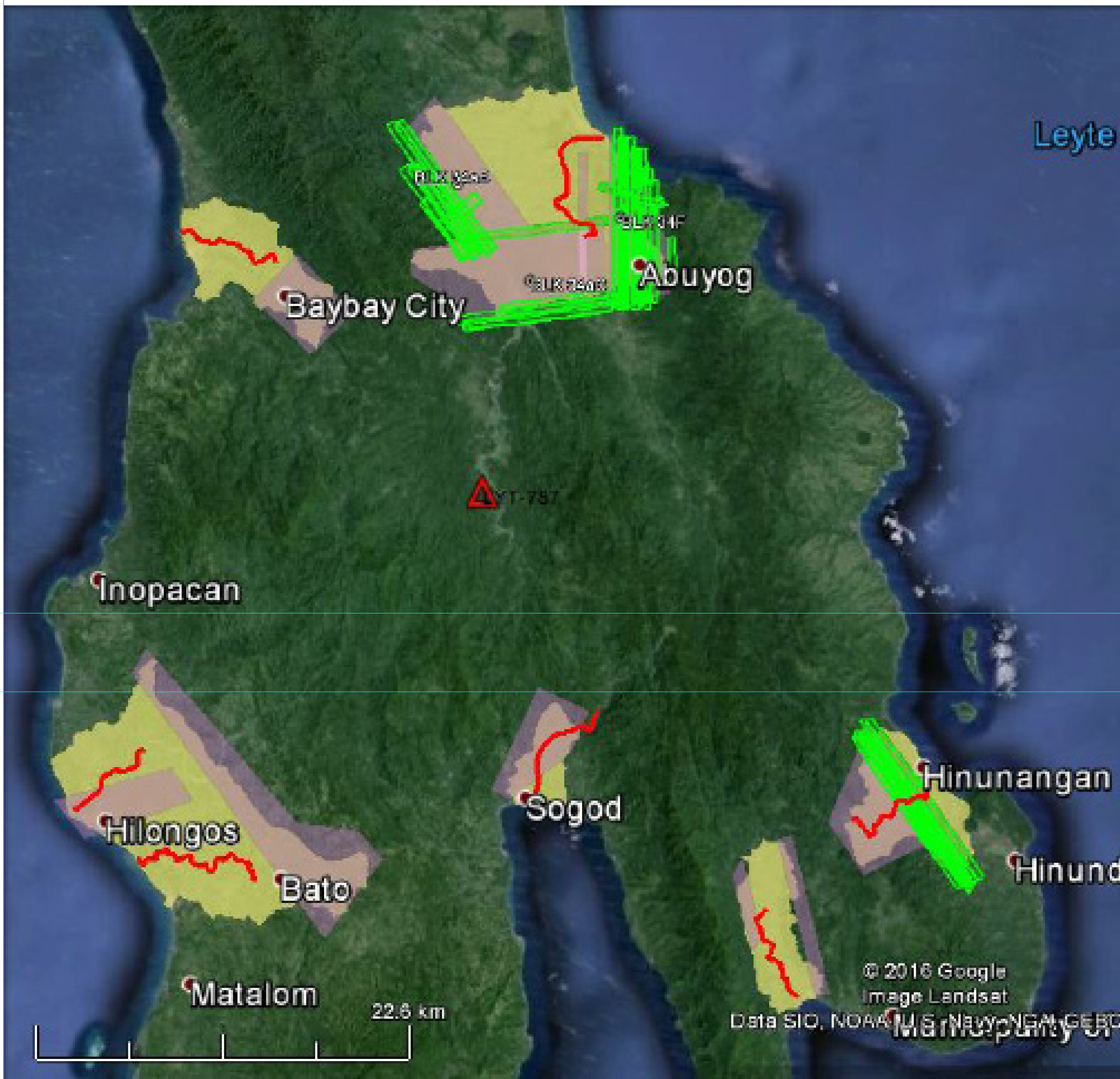


Flight No. :	3761G
Area:	BLK 34aC, 34aB, 34F – Cadacan 2 FP
Mission Name:	2BLK34038A
Parameters:	PRF 100 SF 50 SCA 18

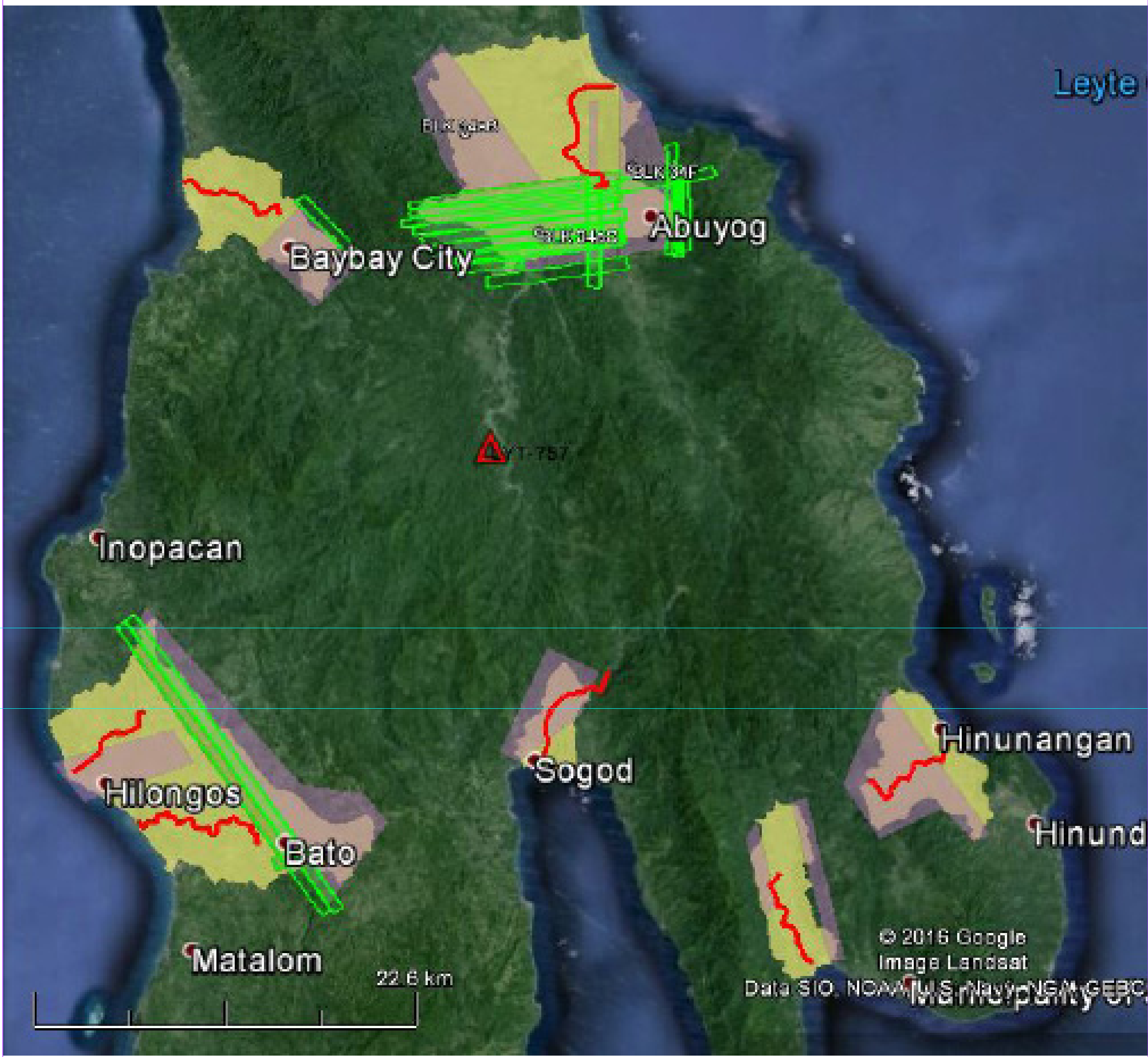


Flight No. :	23771G				
Area:	BLK 34aC, 34aB, 34F – Cadacan 2 FP				
Mission Name:	2BLK34040A				
Parameters:	PRF 100	SF	50	SCA	18

Flight No. :	23773G
Area:	BLK 34F – Cadacan 2 AND BISAY FPs
Mission Name:	2BLK34041A
Parameters:	PRF 100 SF 50 SCA 18



Flight No. :	23781G
Area:	BLK 34aC, 34aB, 49A – Cadacan 2 AND BONGQUIROGAN FPs
Mission Name:	2BLK34043A
Parameters:	PRF 100 SF 50 SCA 18



ANNEX 8. Mission Summary Reports

Flight Area	Samar-Leyte
Mission Name	Blk34H
Inclusive Flights	1434A, 1436A
Range data size	25.12 GB
POSdata size	505 MB
Base data size	MB
Image	169.3 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000471
IMU attitude correction stdev (<0.001deg)	0.002510
GPS position stdev (<0.01m)	0.0080
Minimum % overlap (>25)	32.26%
Ave point cloud density per sq.m. (>2.0)	2.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	215
Maximum Height	425.31 m
Minimum Height	51.73 m
Classification (# of points)	
Ground	95,490,667
Low vegetation	112,453,327
Medium vegetation	107,624,730
High vegetation	55,639,375
Building	2,285,212
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Gladys Mae Apat

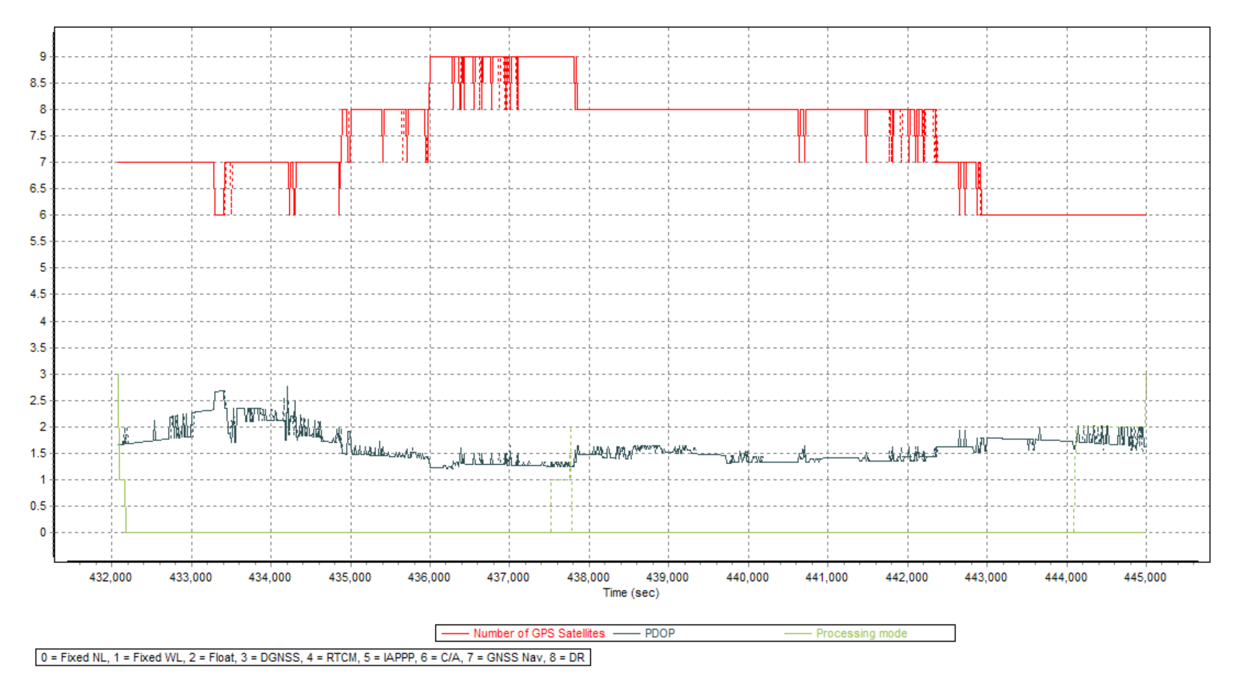


Figure 1.1.1. Solution Status

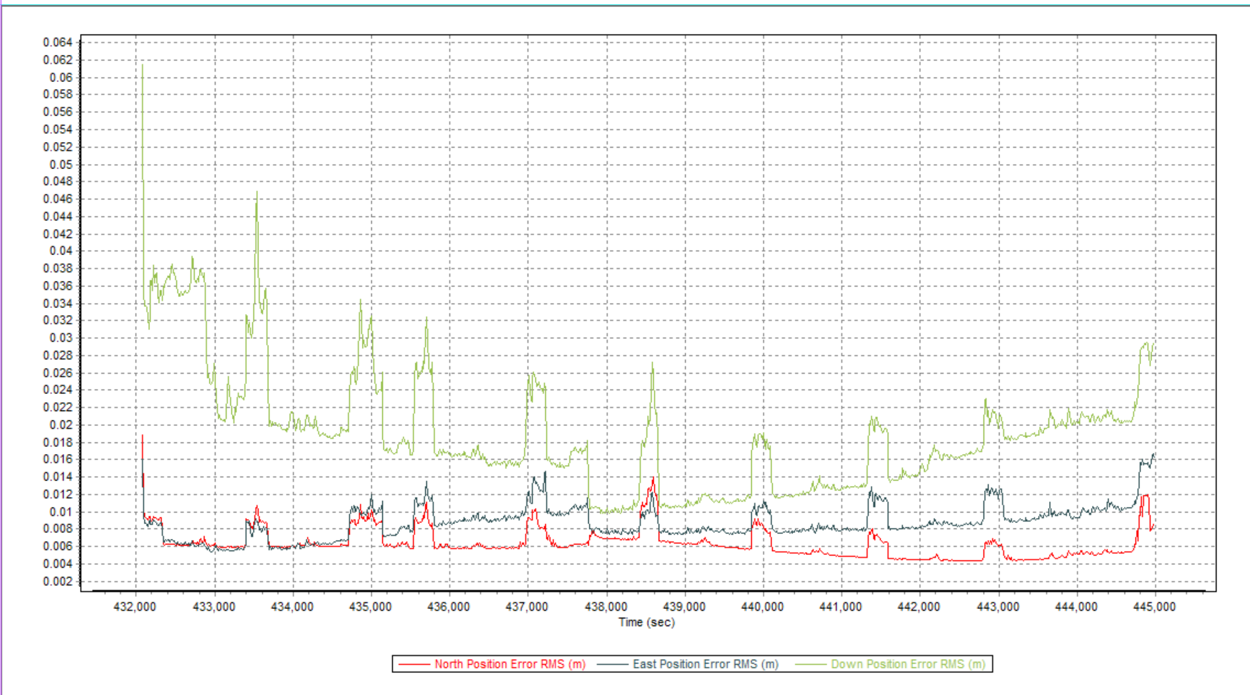


Figure 1.1.2. Smoothed Performance Metrics Parameters

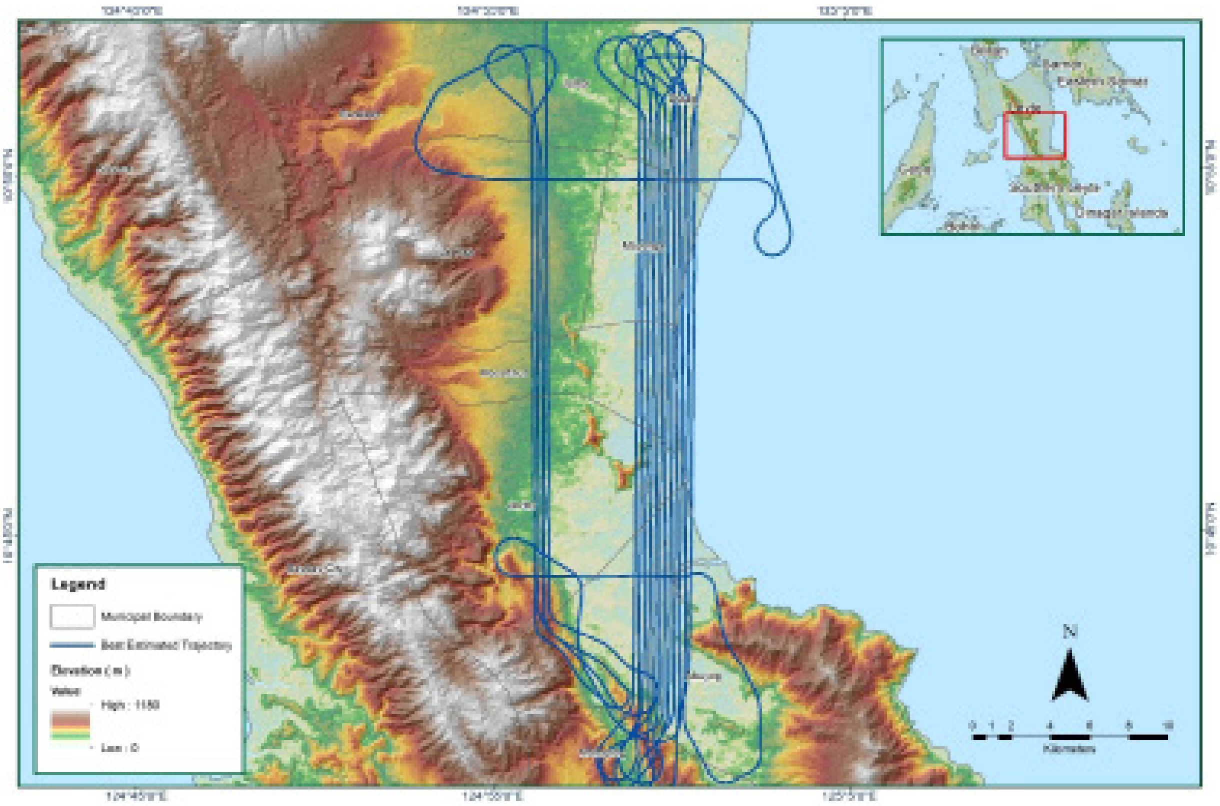


Figure 1.1.3. Best Estimated Trajectory

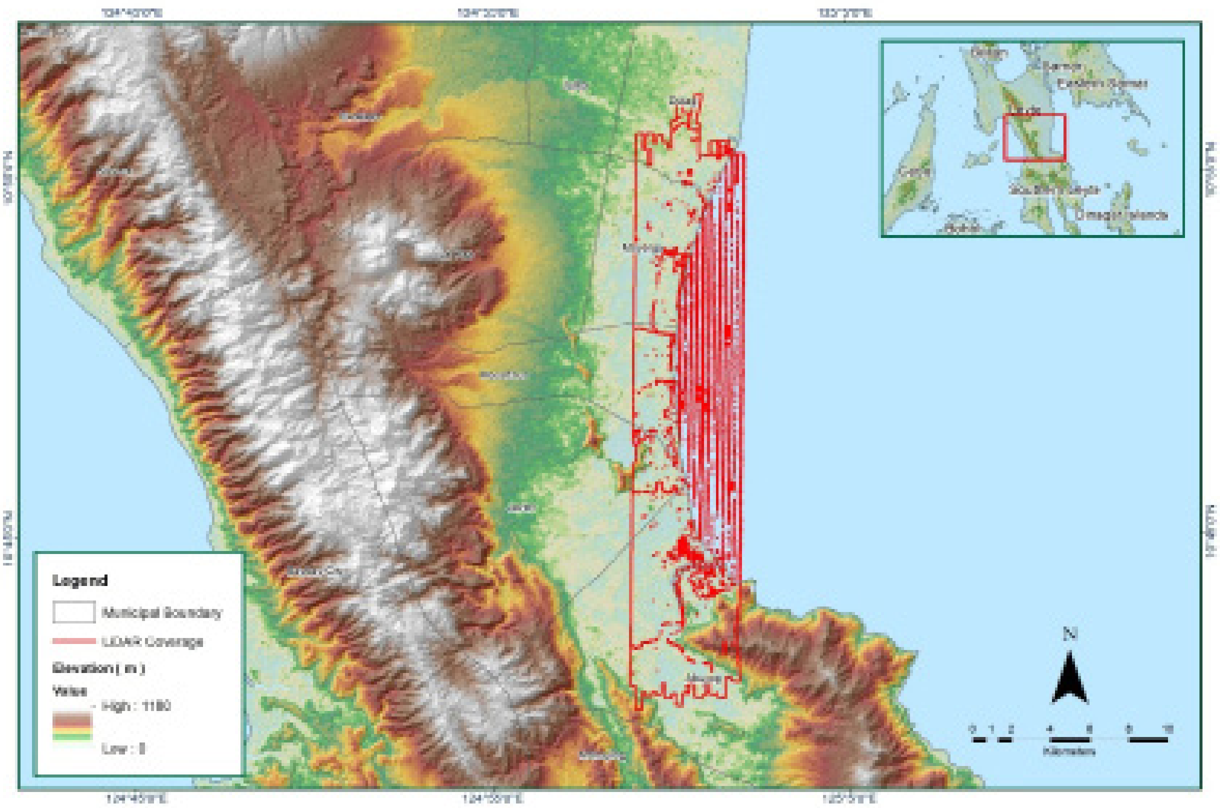


Figure 1.1.4. Coverage of LiDAR data

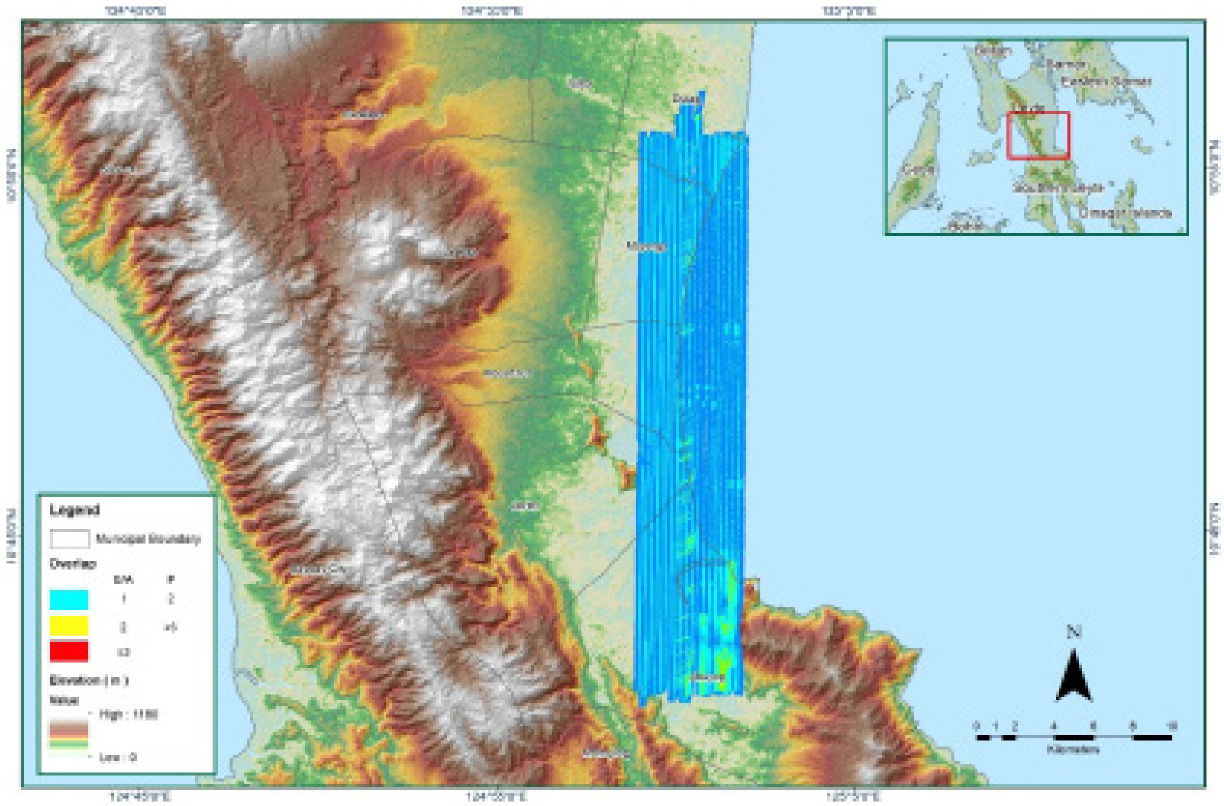


Figure 1.1.5. Image of data overlap

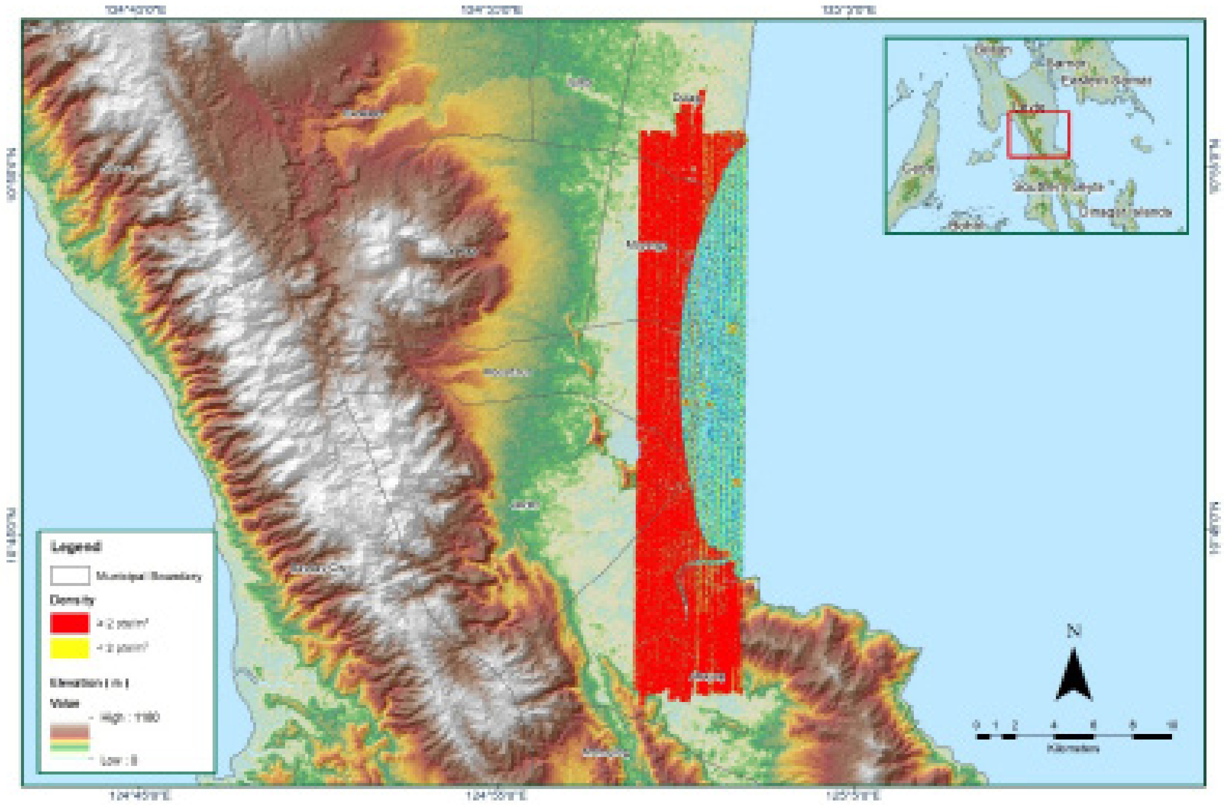


Figure 1.1.6. Density map of merged LiDAR data

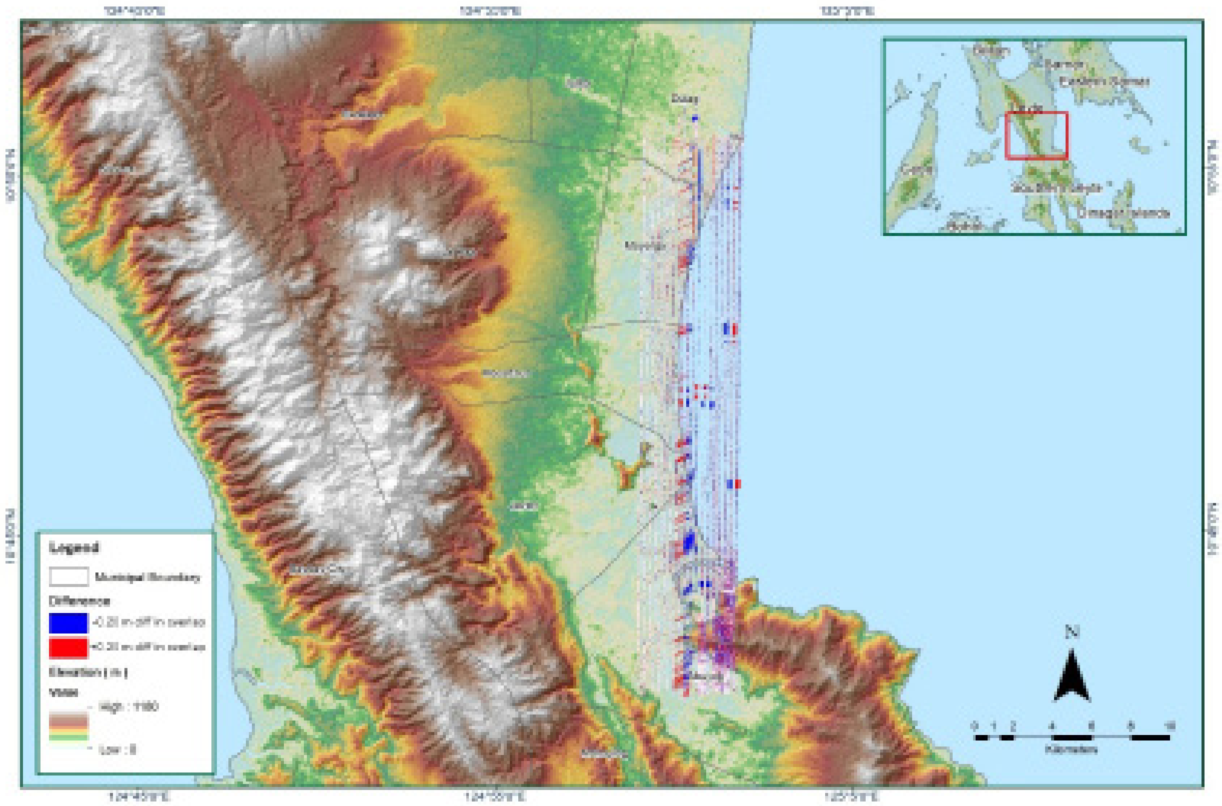


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk34G
Inclusive Flights	1430A, 1434A
Range data size	29.4 GB
POSdata size	528 MB
Base data size	MB
Image	210.8 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000492
IMU attitude correction stdev (<0.001deg)	0.001939
GPS position stdev (<0.01m)	0.0085
Minimum % overlap (>25)	42.02%
Ave point cloud density per sq.m. (>2.0)	3.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	186
Maximum Height	292.03 m
Minimum Height	63.56 m
Classification (# of points)	
Ground	113,885,129
Low vegetation	135,911,604
Medium vegetation	106,013,368
High vegetation	43,429,000
Building	1,436,140
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Antonio Chua, Jr., Engr. Gladys Mae Apat

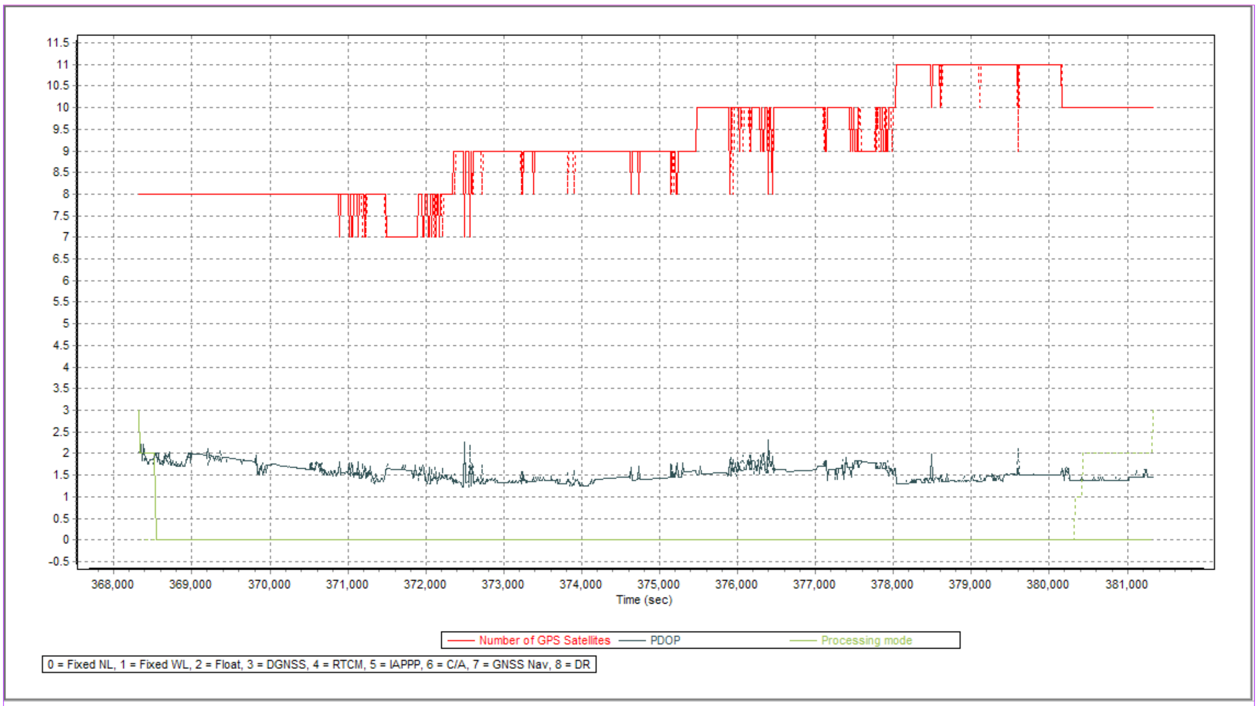


Figure 1.2.1. Solution Status

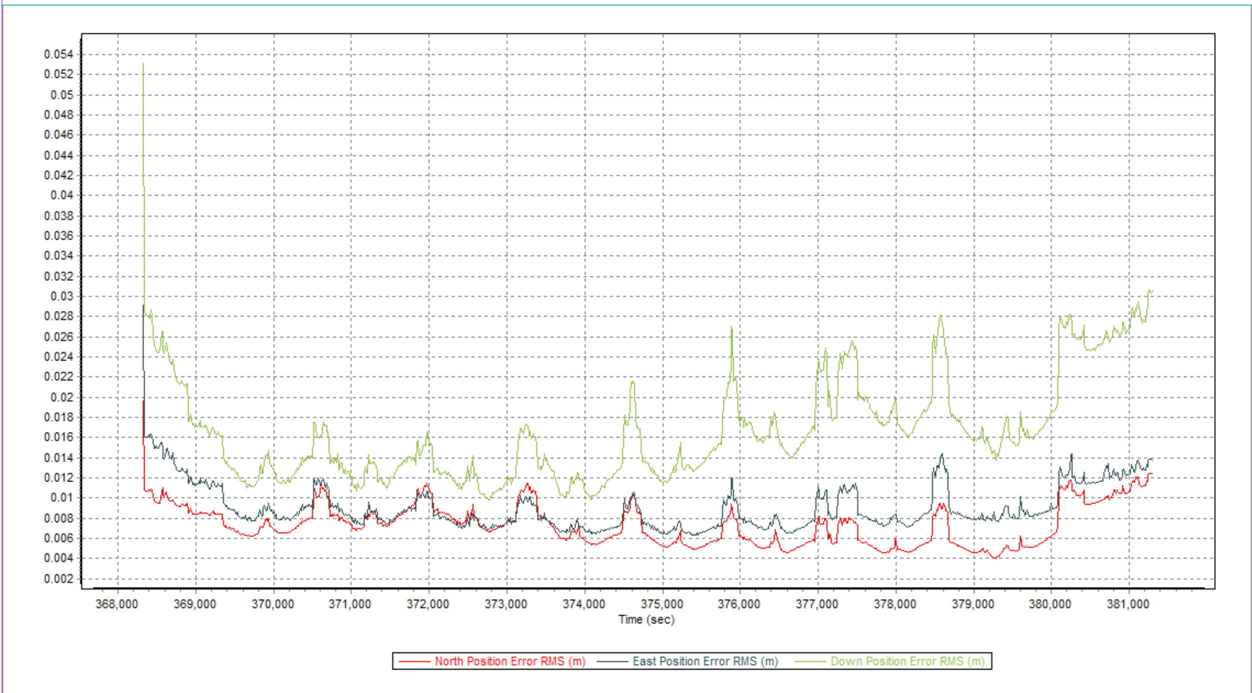


Figure 1.2.2. Smoothed Performance Metrics Parameters

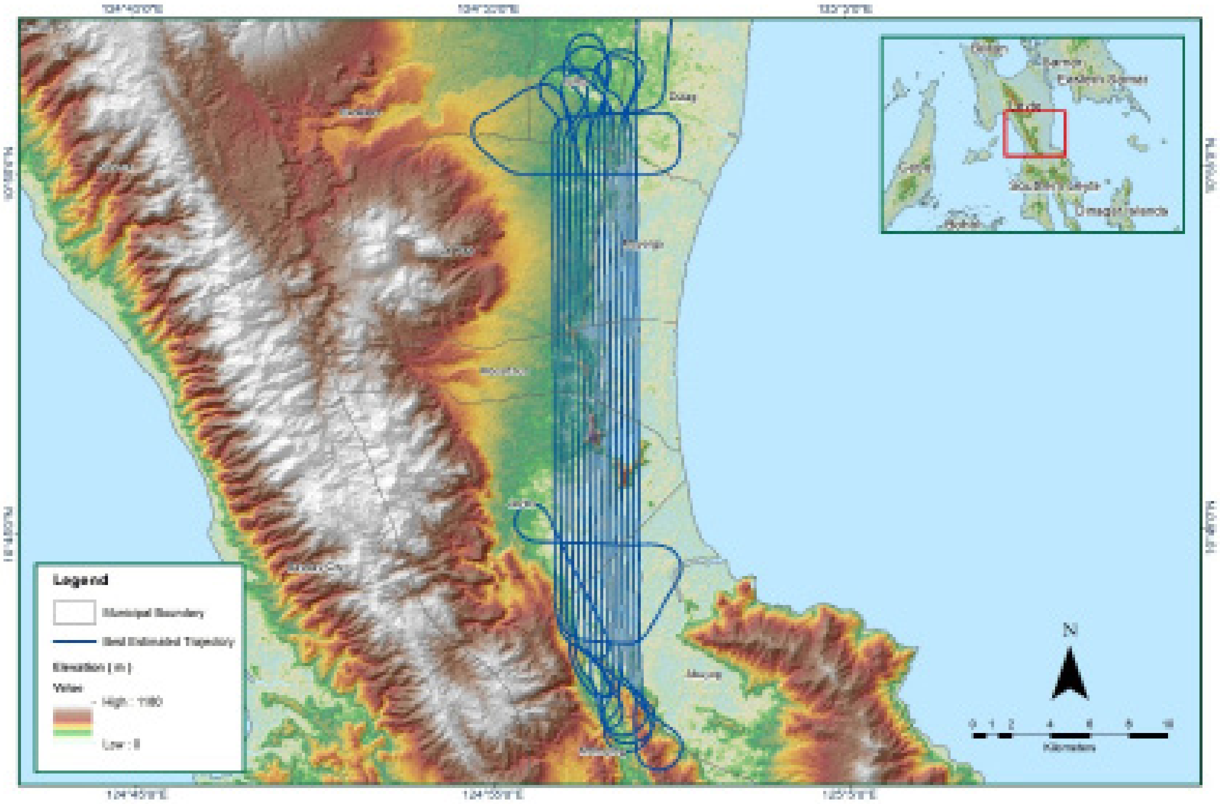


Figure 1.2.3. Best Estimated Trajectory

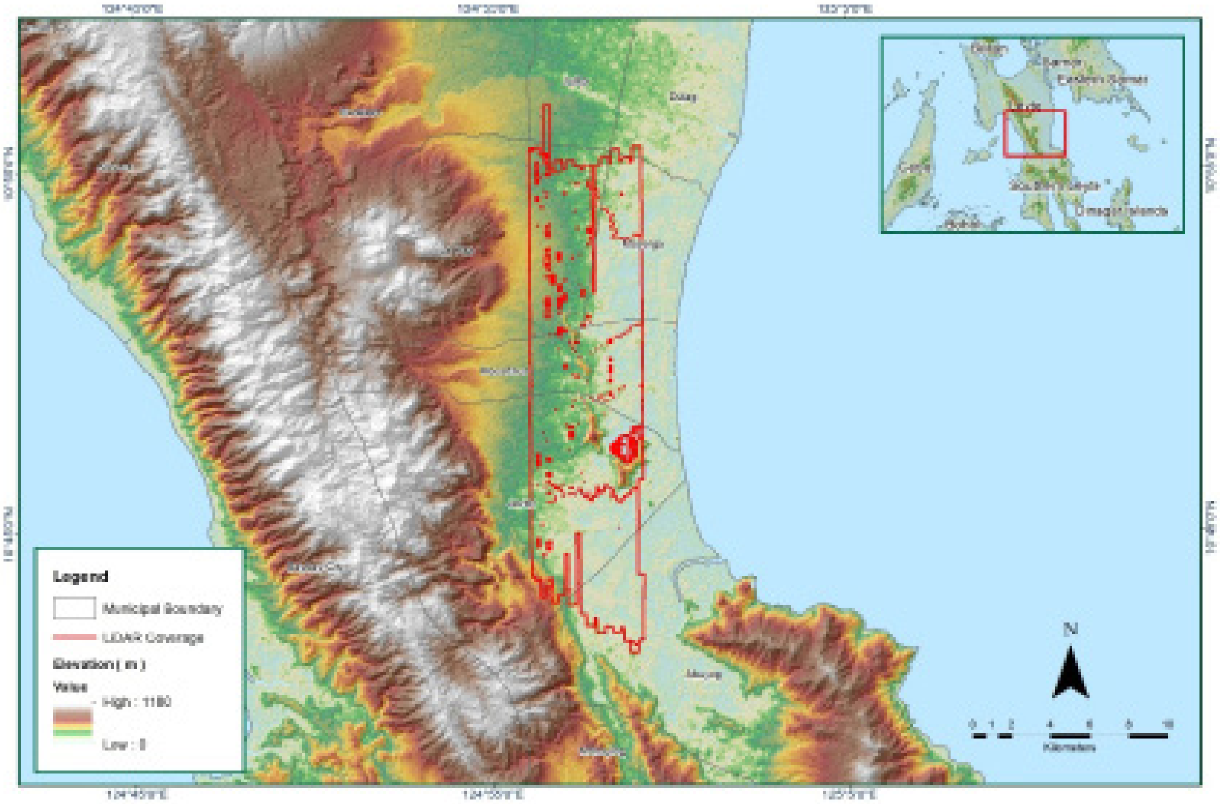


Figure 1.2.4. Coverage of LiDAR data

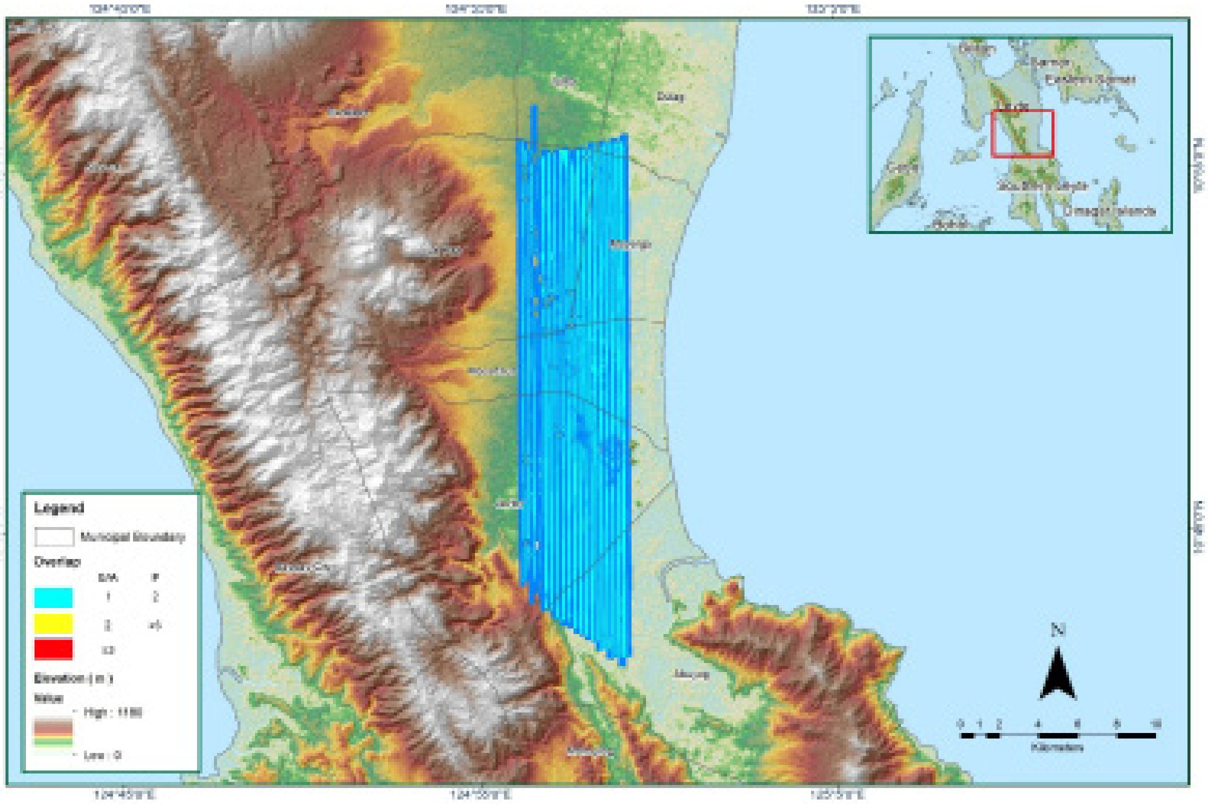


Figure 1.2.5. Image of data overlap

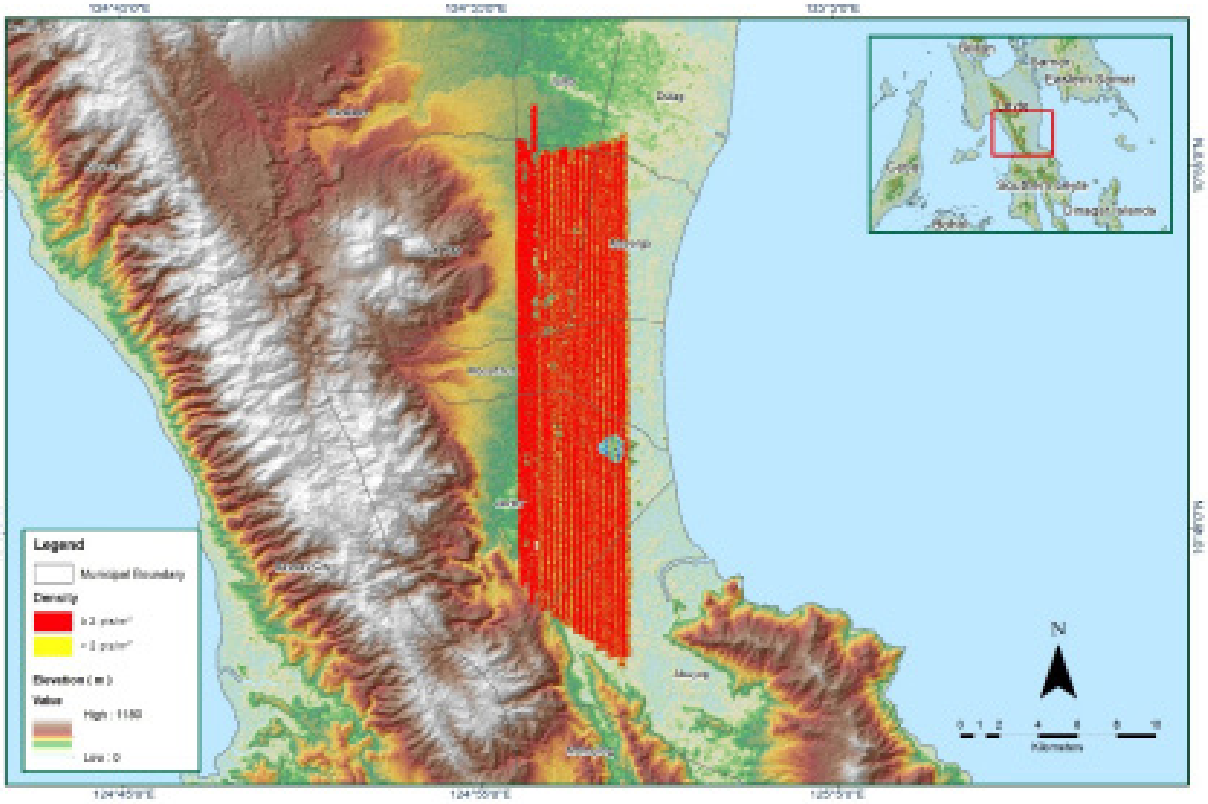


Figure 1.2.6. Density map of merged LiDAR data

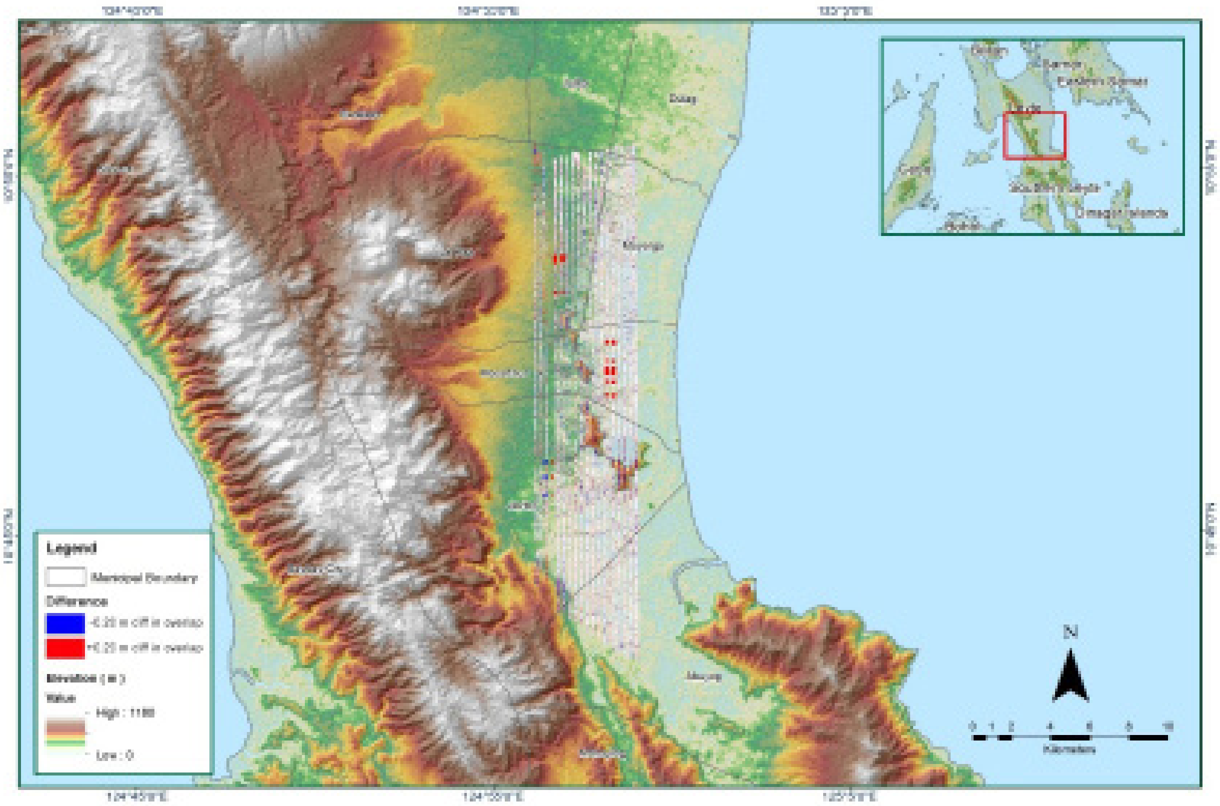


Figure 1.2.7. Elevation difference between flight lines

Flight Area	Leyte
Mission Name	Blk34G
Inclusive Flights	3761G, 23773G
Range data size	25.36 GB
POS data size	440 MB
Base data size	12.43 MB
Image	n/a
Transfer date	March 04, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.000724
IMU attitude correction stdev (<0.001deg)	7.381745
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	31.86
Ave point cloud density per sq.m. (>2.0)	6.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	81
Maximum Height	590.69 m
Minimum Height	65.96 m
Classification (# of points)	
Ground	25,426,447
Low vegetation	43,936,942
Medium vegetation	97,744,358
High vegetation	169,210,036
Building	4,615,452
Orthophoto	None
Processed by	Engr. Irish Cortez, Engr. Jovelle Anjeanette Canlas, Marie Denise Bueno

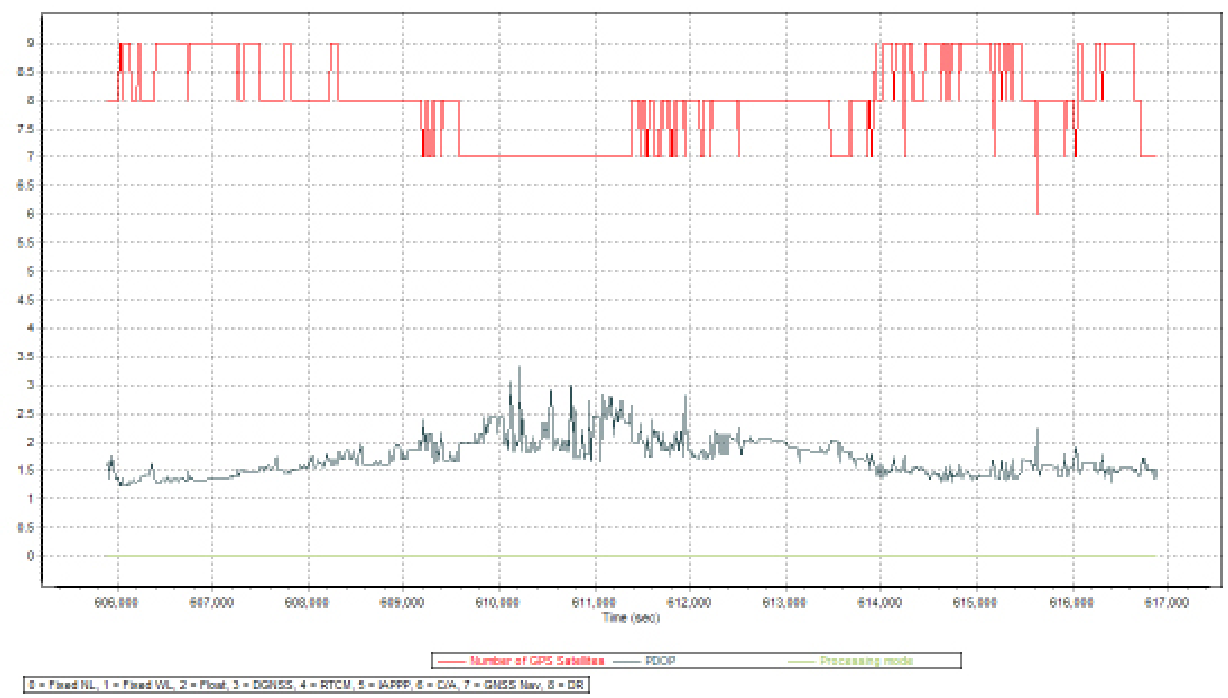


Figure 1.3.1. Solution Status

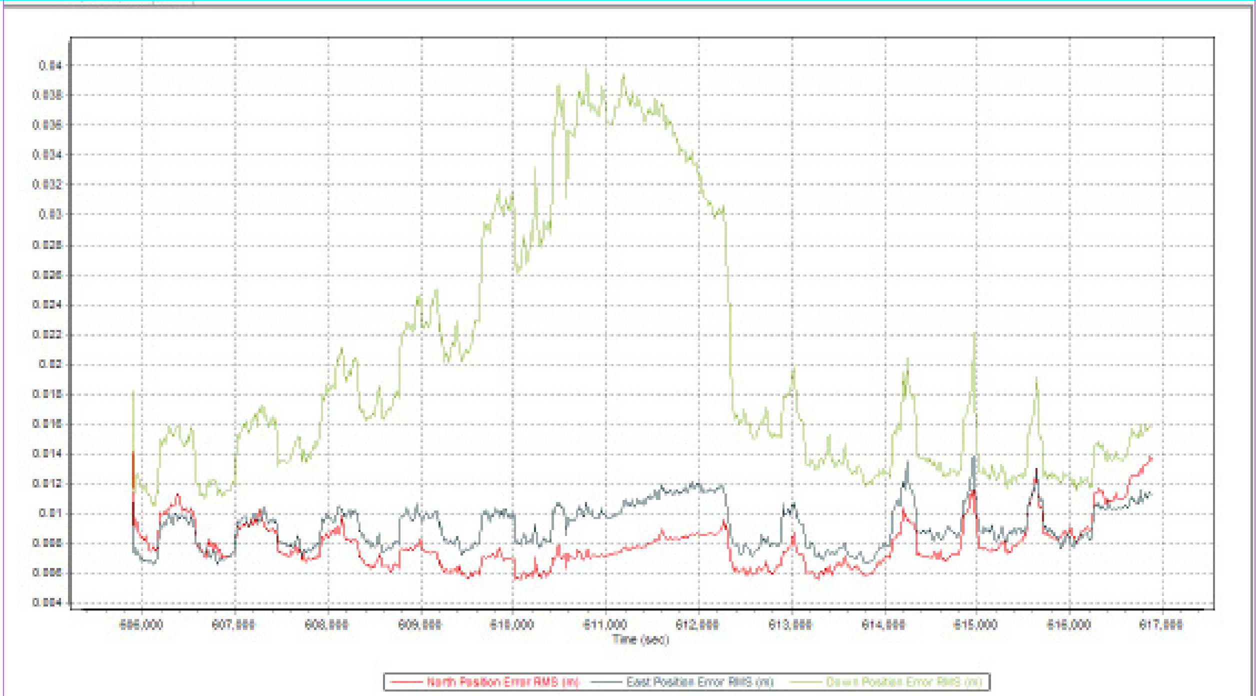


Figure 1.3.2. Smoothed Performance Metrics Parameters

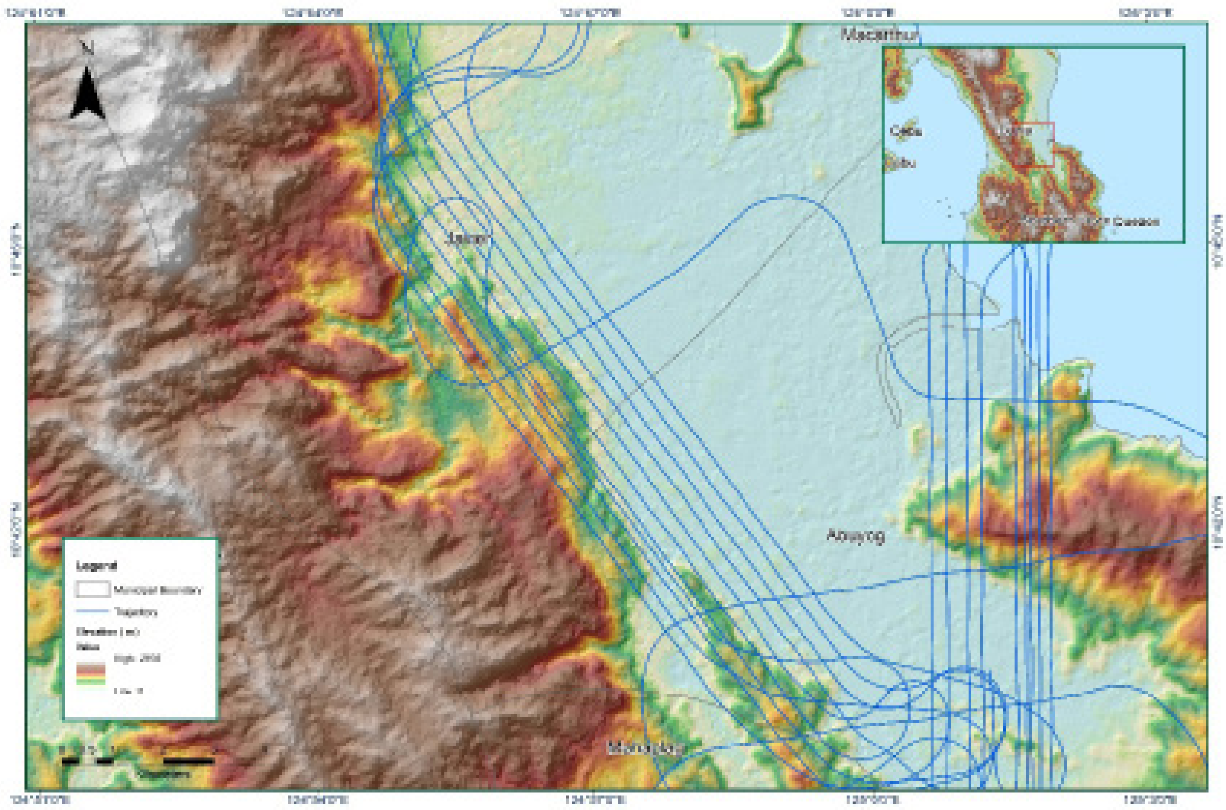


Figure 1.3.3. Best Estimated Trajectory

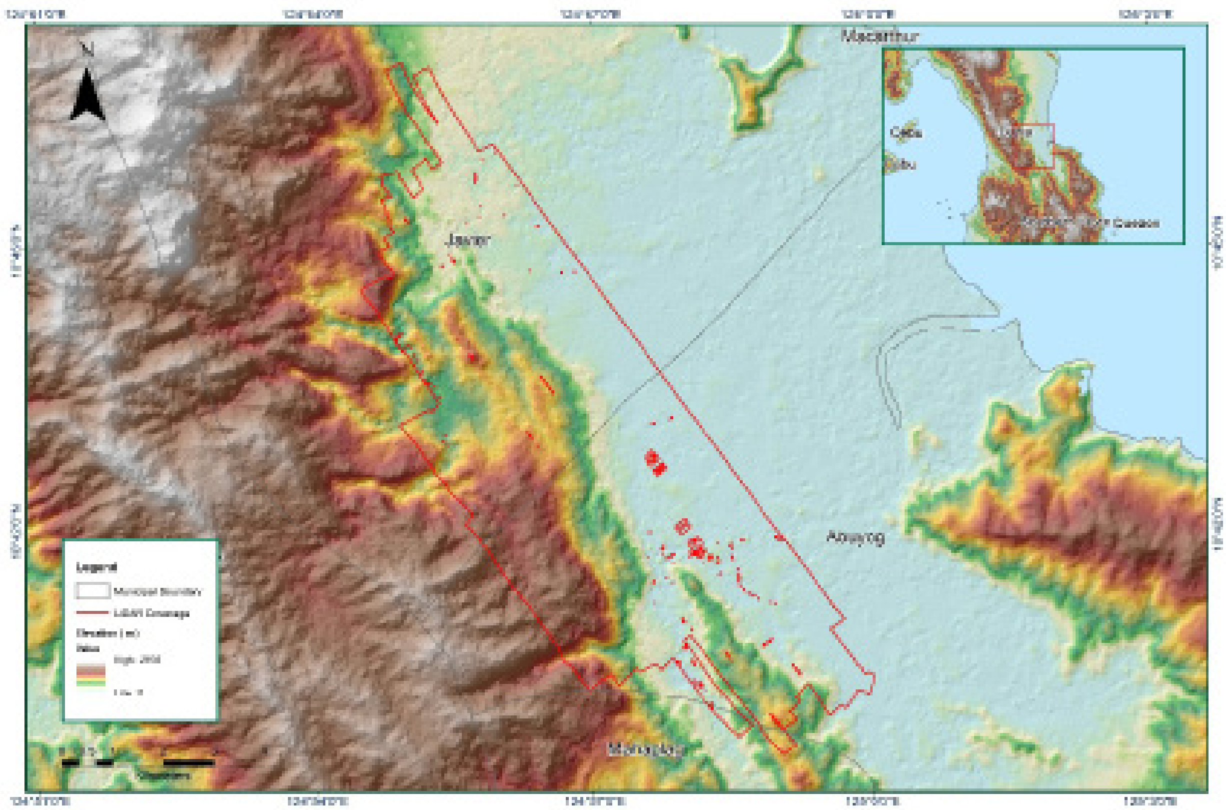


Figure 1.3.4. Coverage of LiDAR data

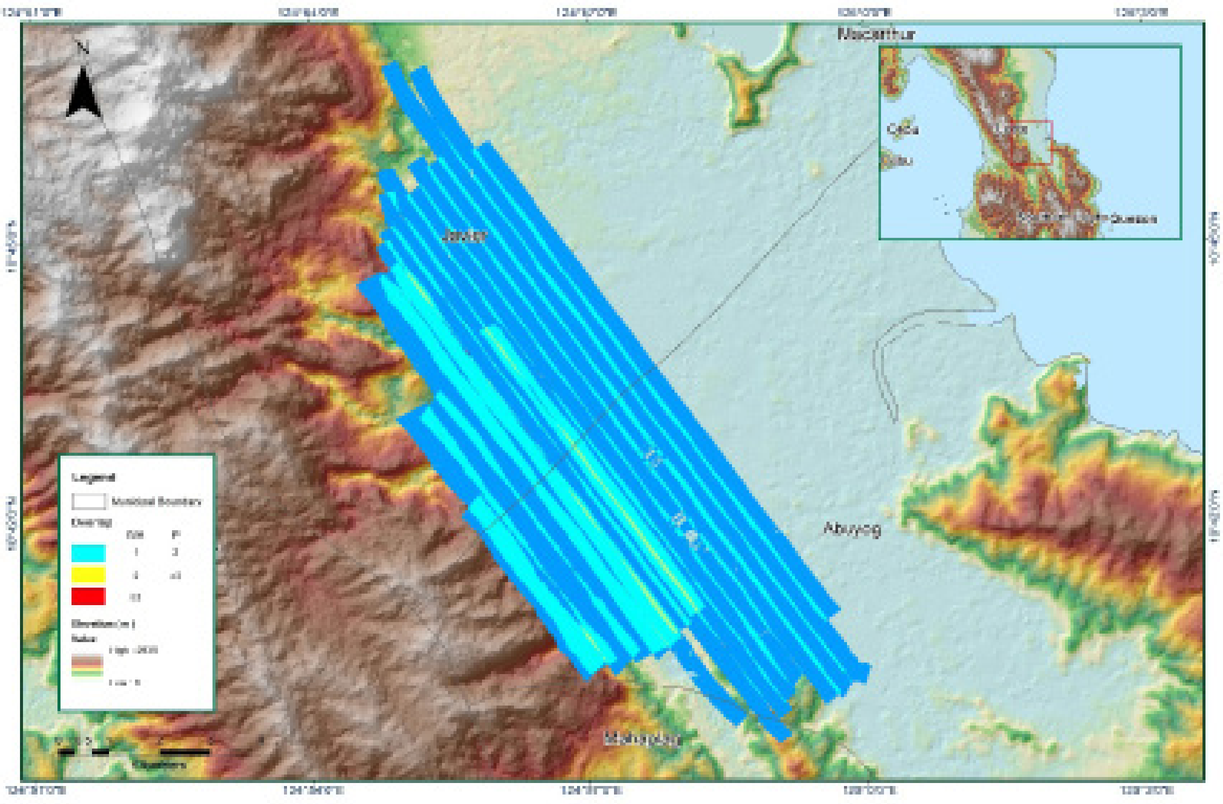


Figure 1.3.5. Image of data overlap

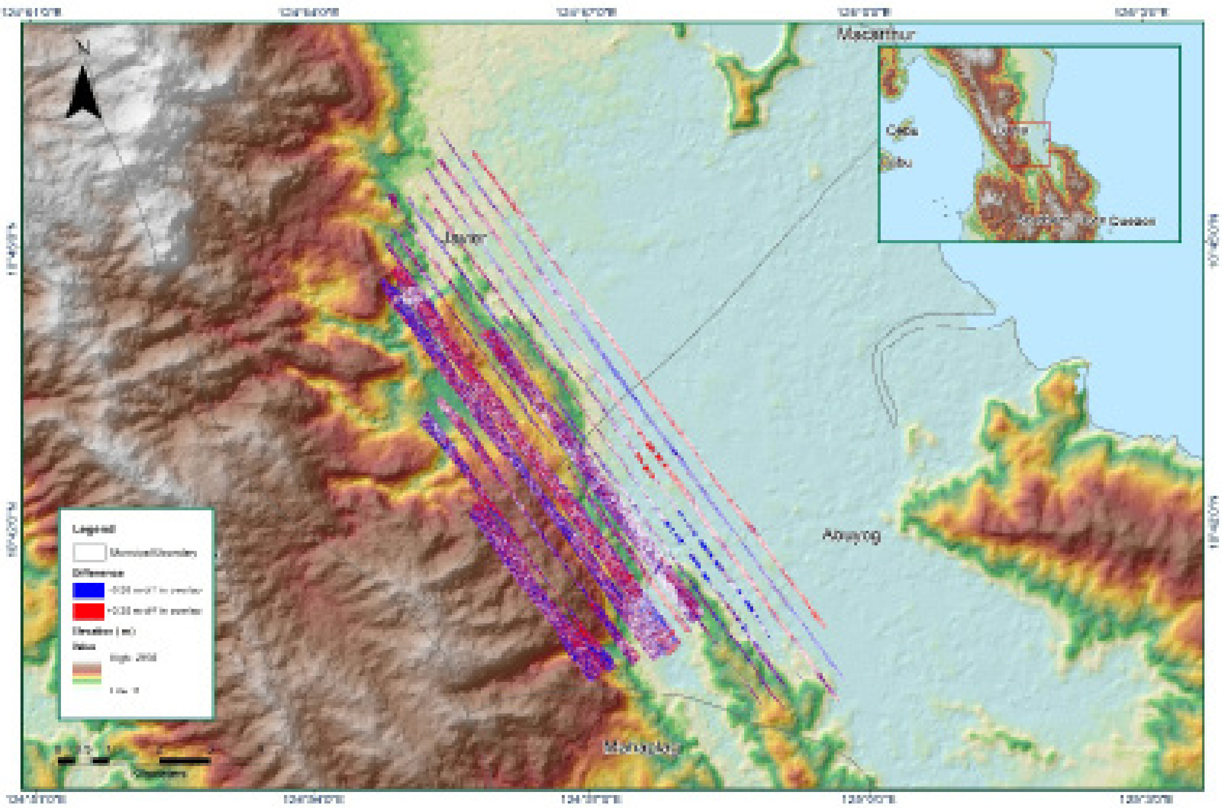


Figure 1.3.6. Density map of merged LiDAR data

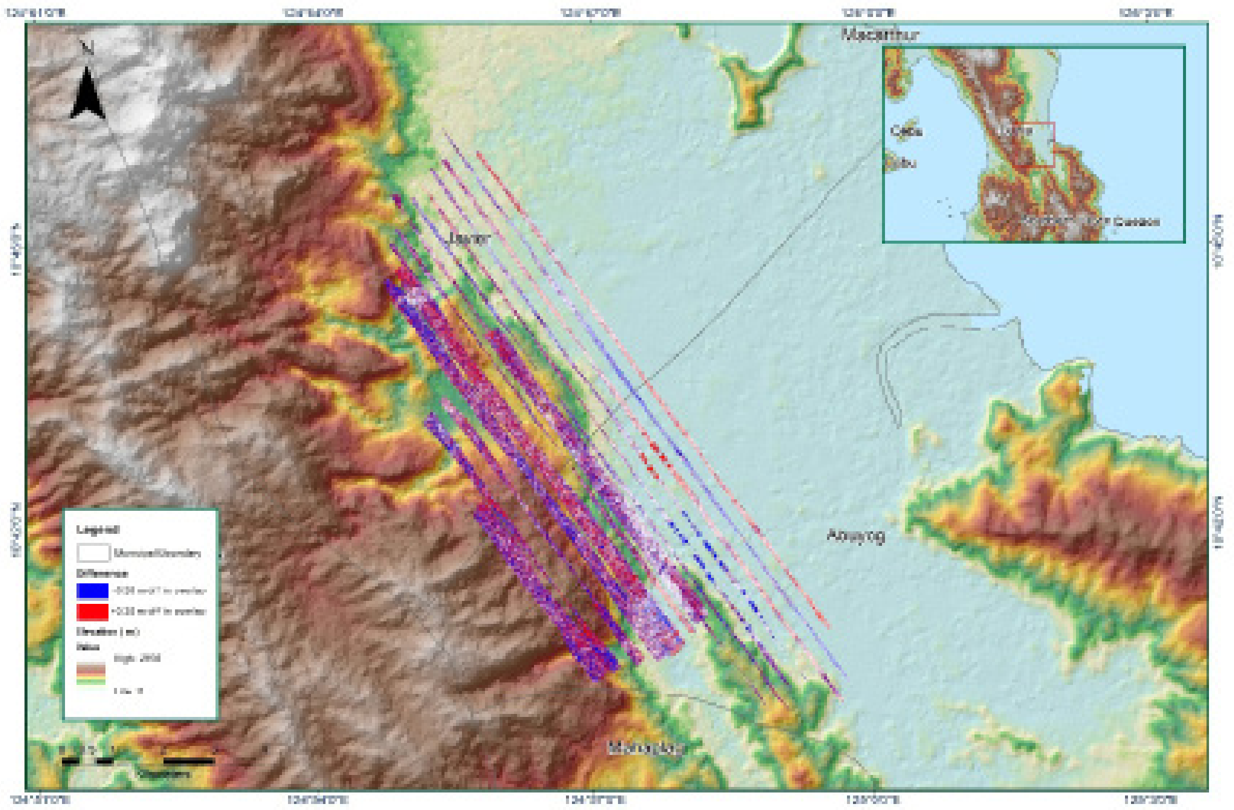


Figure 1.3.7. Elevation difference between flight lines

Flight Area	Leyte
Mission Name	Blk34K
Inclusive Flights	3781G, 23773G
Range data size	20.36 GB
POS data size	386 MB
Base data size	13.57 MB
Image	n/a
Transfer date	March 04, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.001088
IMU attitude correction stdev (<0.001deg)	0.001628
GPS position stdev (<0.01m)	0.0114
Minimum % overlap (>25)	32.29
Ave point cloud density per sq.m. (>2.0)	4.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	94
Maximum Height	729.81 m
Minimum Height	65.05 m
Classification (# of points)	
Ground	35,103,713
Low vegetation	37,639,230
Medium vegetation	130,351,793
High vegetation	298,555,747
Building	4,921,085
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Melanie Hingpit, Jovy Narisma

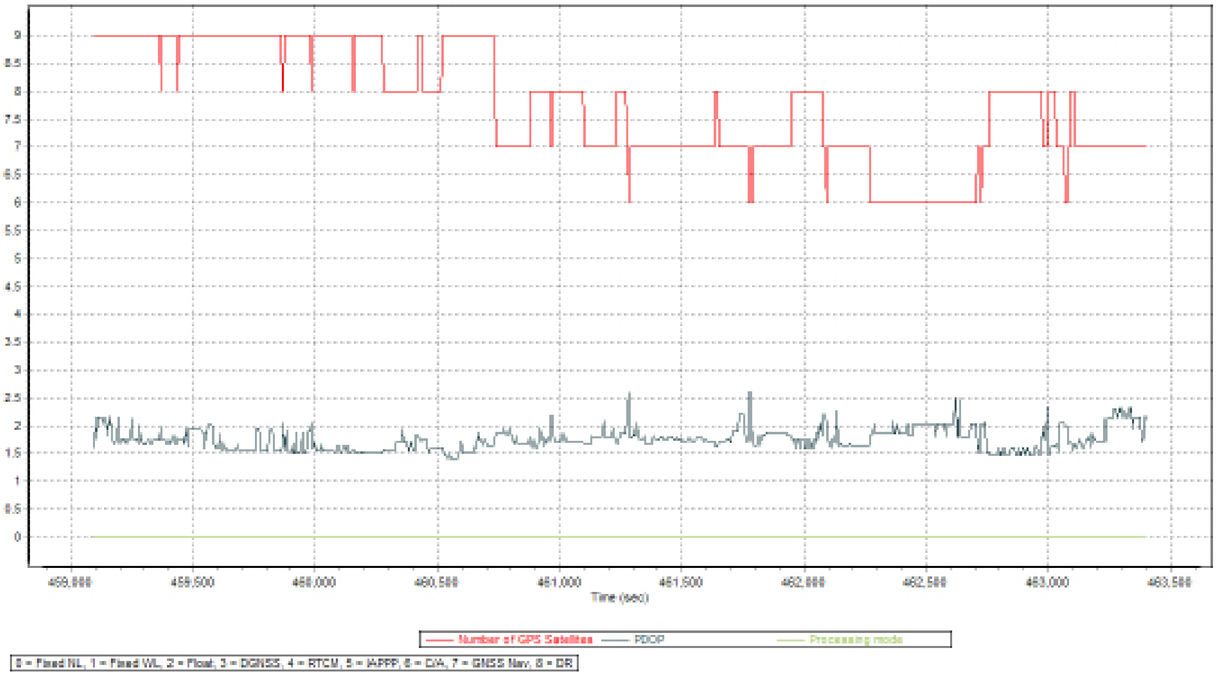


Figure 1.4.1. Solution Status

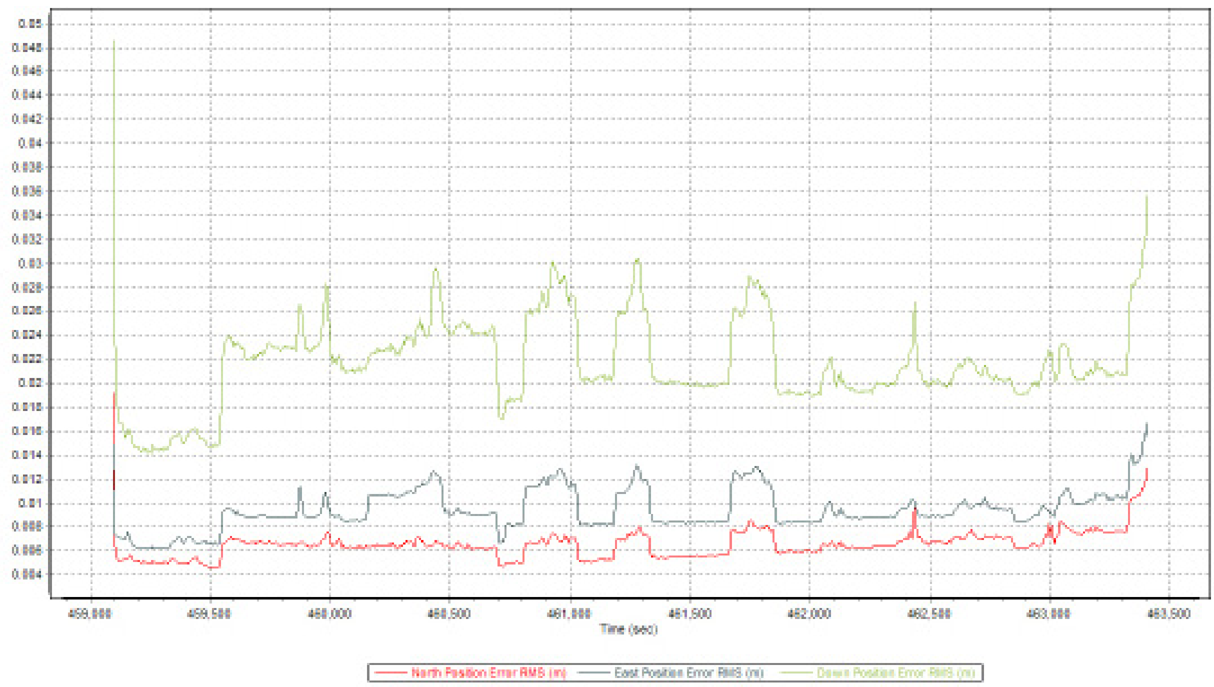


Figure 1.4.2. Smoothed Performance Metrics Parameters

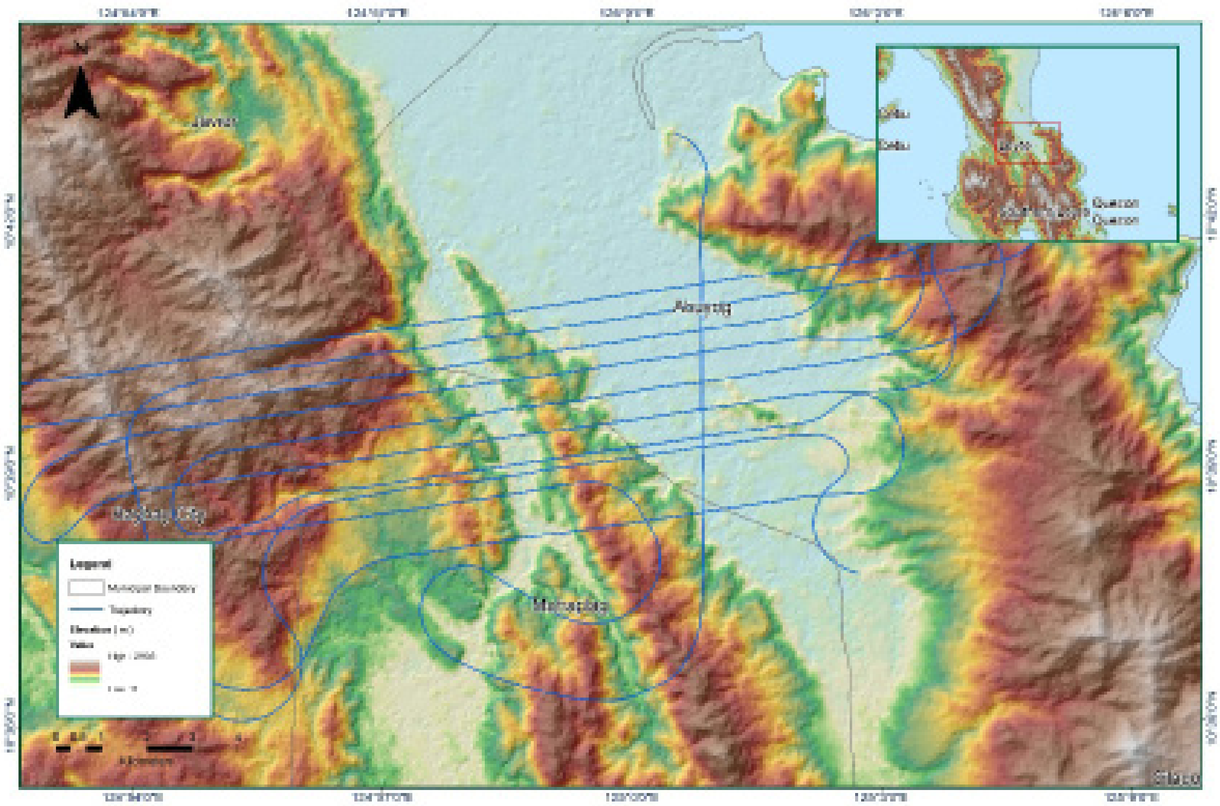


Figure 1.4.3. Best Estimated Trajectory

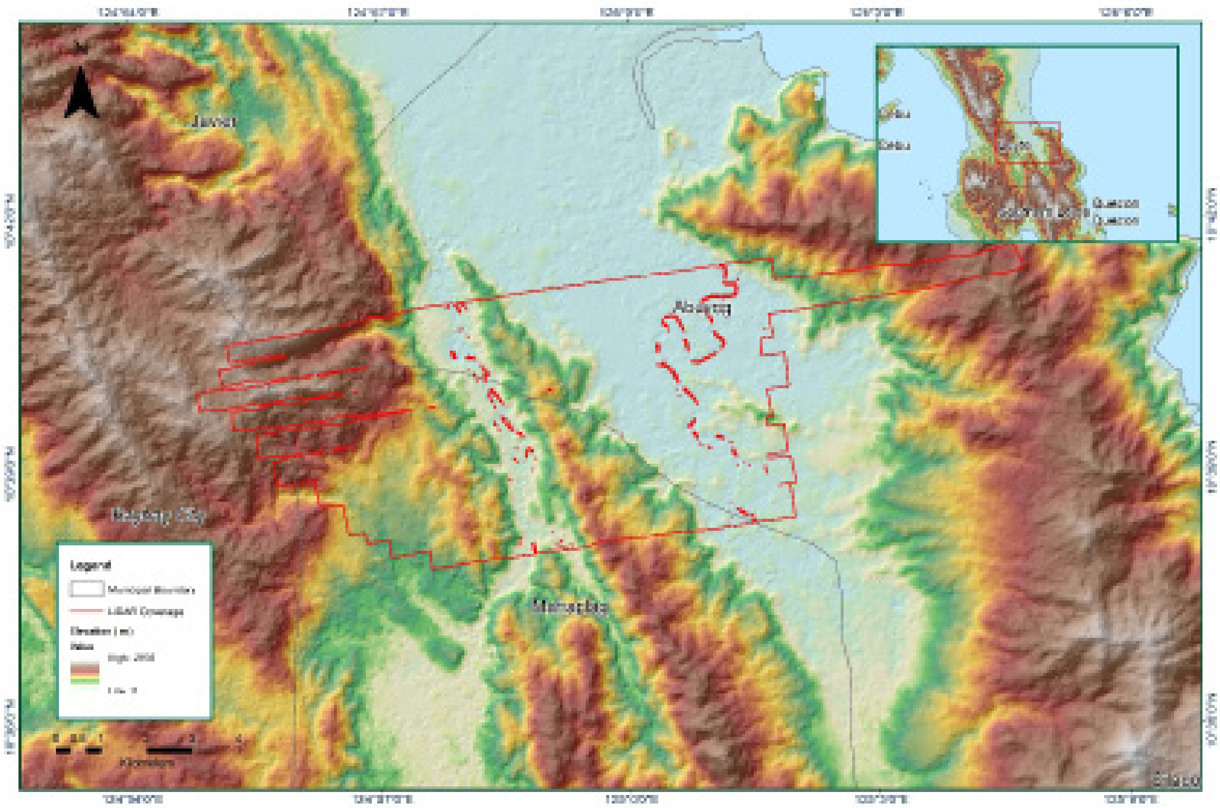


Figure 1.4.4. Coverage of LiDAR data

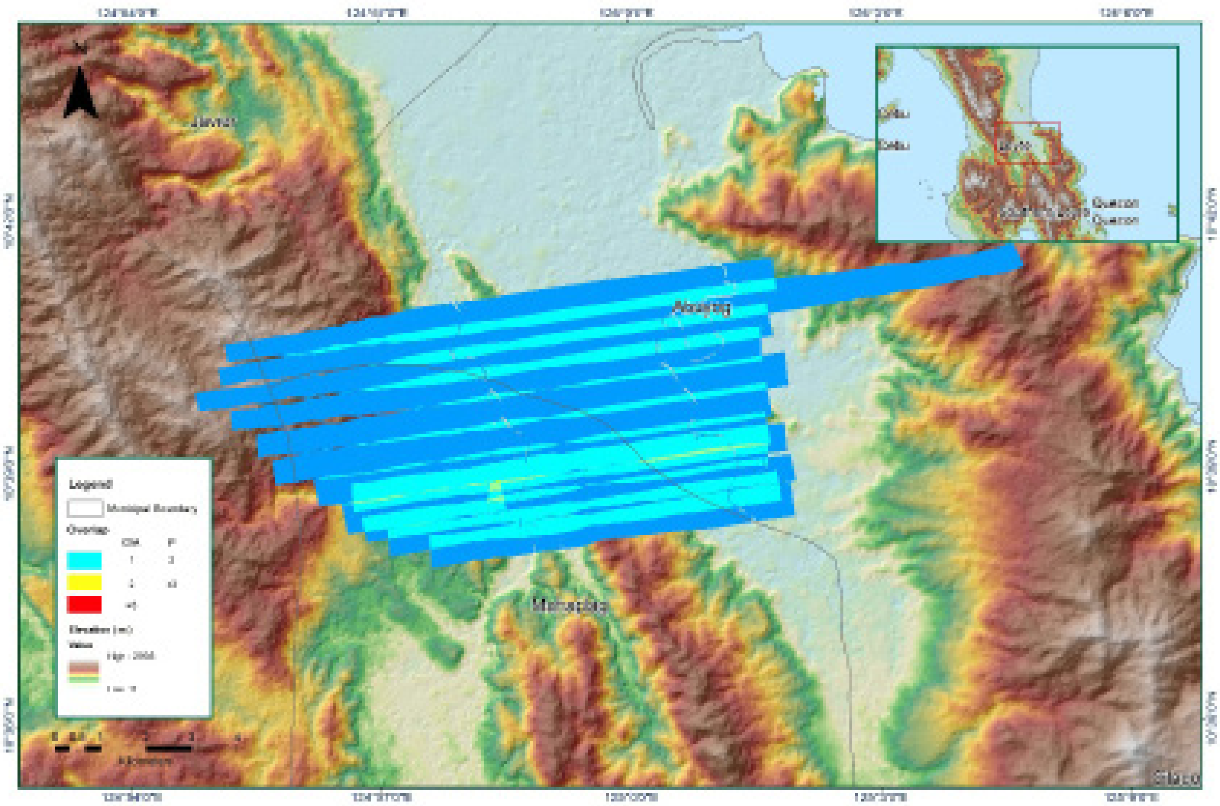


Figure 1.4.5. Image of data overlap

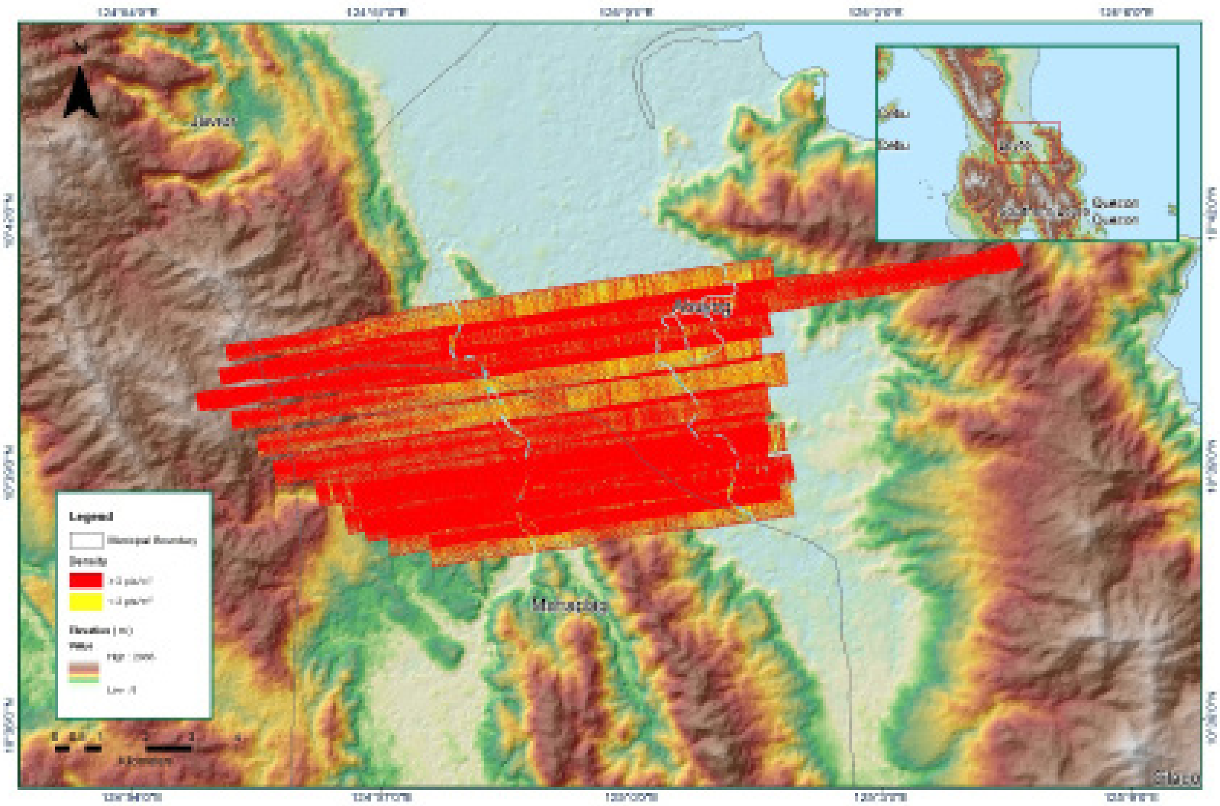


Figure 1.4.6. Density map of merged LiDAR data

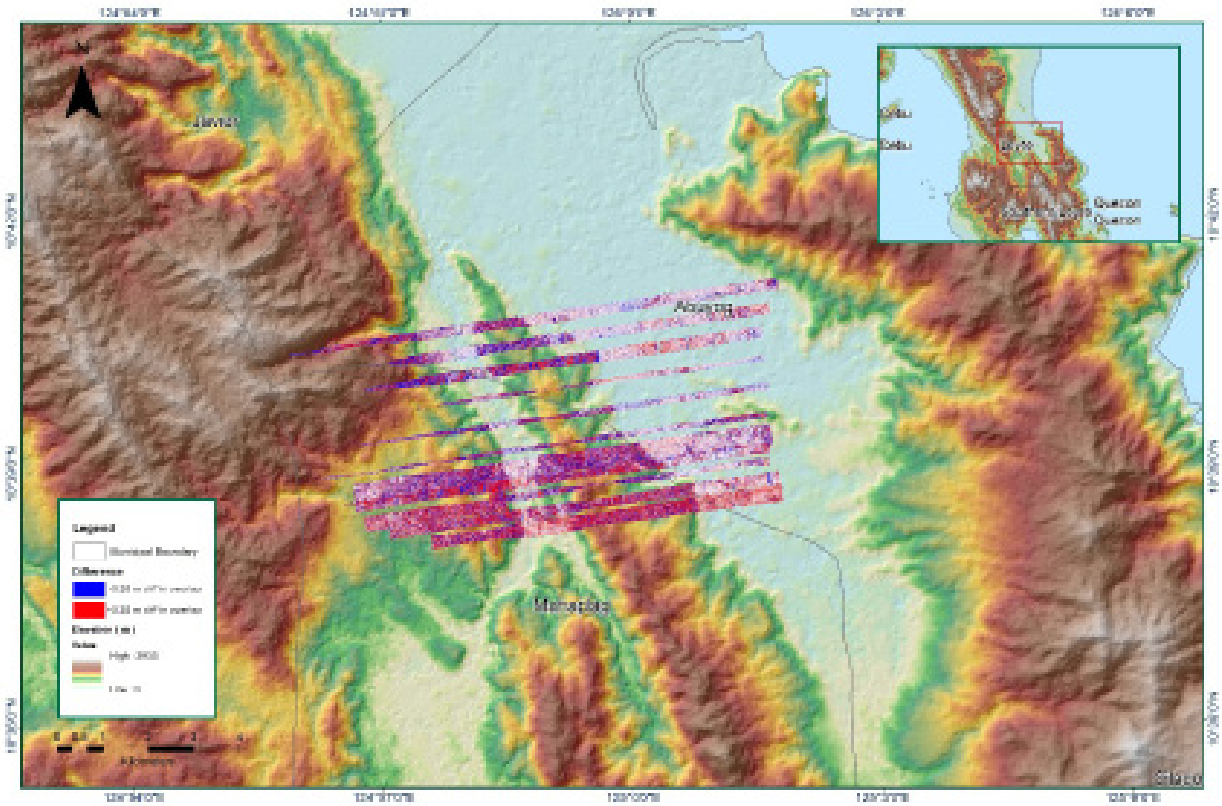


Figure 1.4.7. Elevation difference between flight lines

Flight Area	Leyte
Mission Name	Blk34H
Inclusive Flights	3761G, 23771G
Range data size	22.55 GB
POS data size	406 MB
Base data size	12.79 MB
Image	n/a
Transfer date	March 04, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.000823
IMU attitude correction stdev (<0.001deg)	0.037743
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	30.65
Ave point cloud density per sq.m. (>2.0)	6.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	74
Maximum Height	722.37 m
Minimum Height	63.00 m
Classification (# of points)	
Ground	26,491,392
Low vegetation	38,912,589
Medium vegetation	110,137,282
High vegetation	102,202,220
Building	1,927,173
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Ma. Joanne Balaga, Maria Tamsyn Malabanan

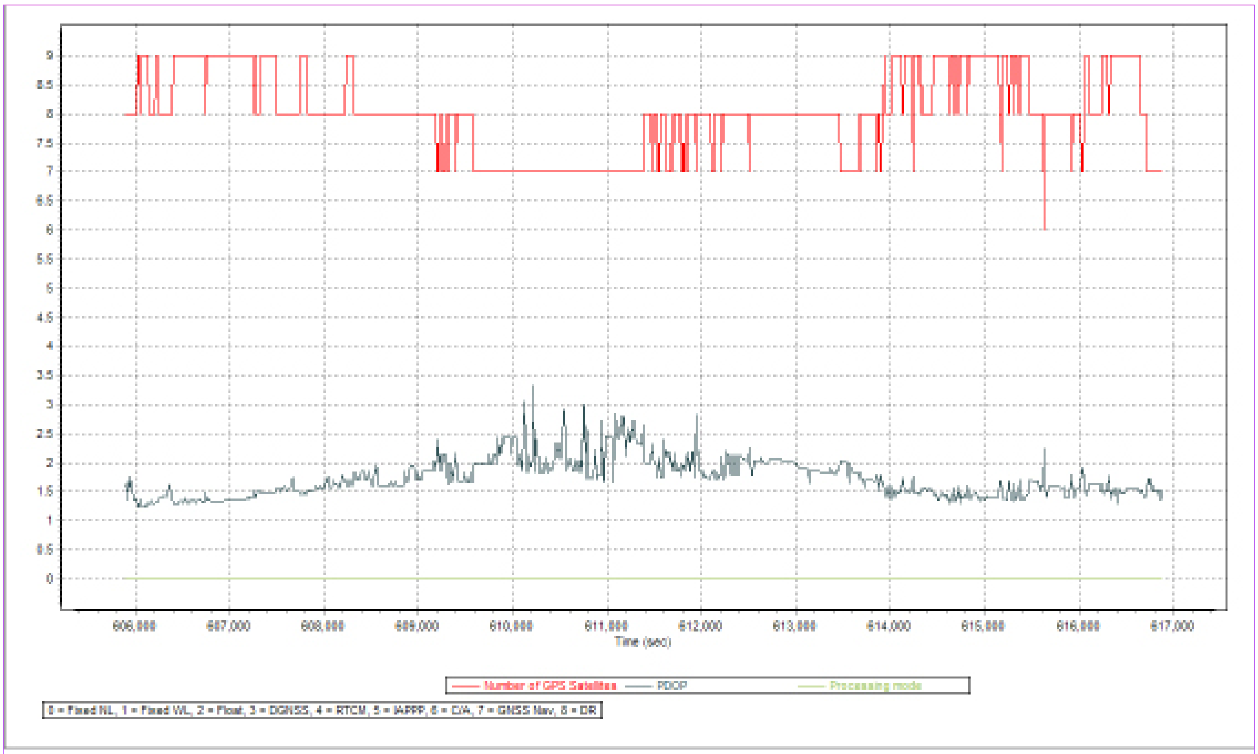


Figure 1.5.1. Solution Status

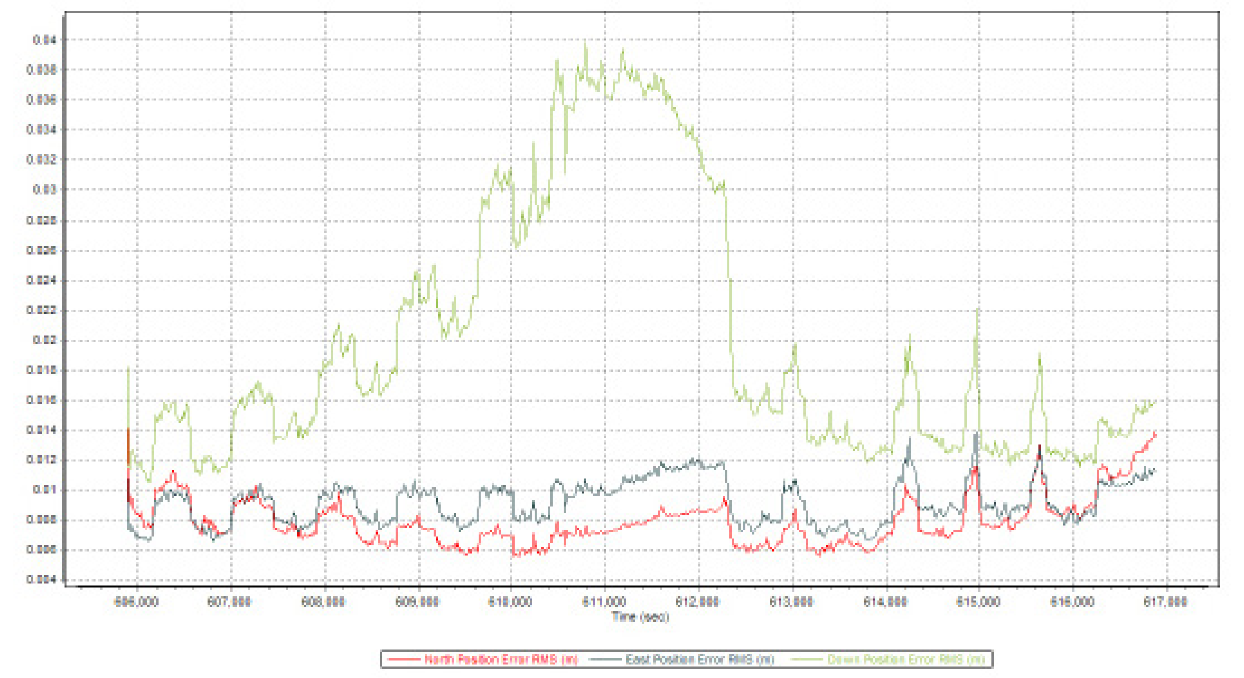


Figure 1.5.2. Smoothed Performance Metrics Parameters

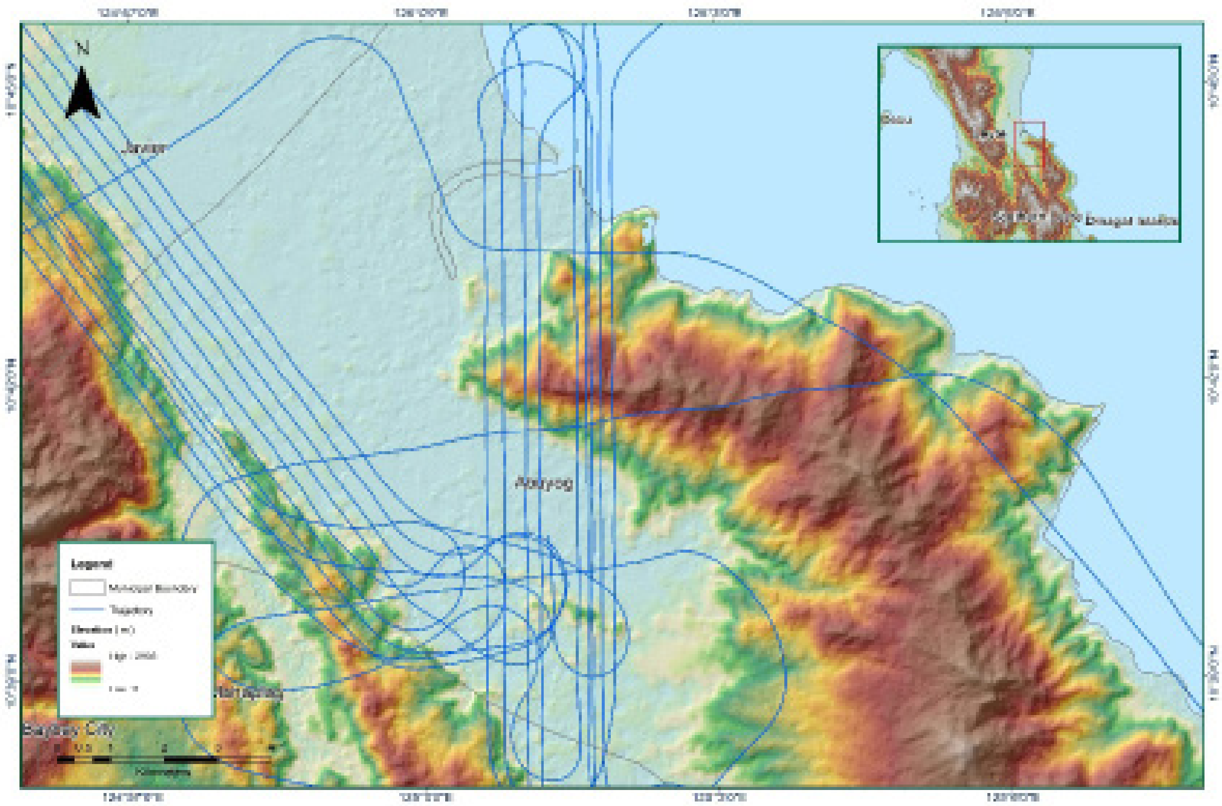


Figure 1.5.3. Best Estimated Trajectory

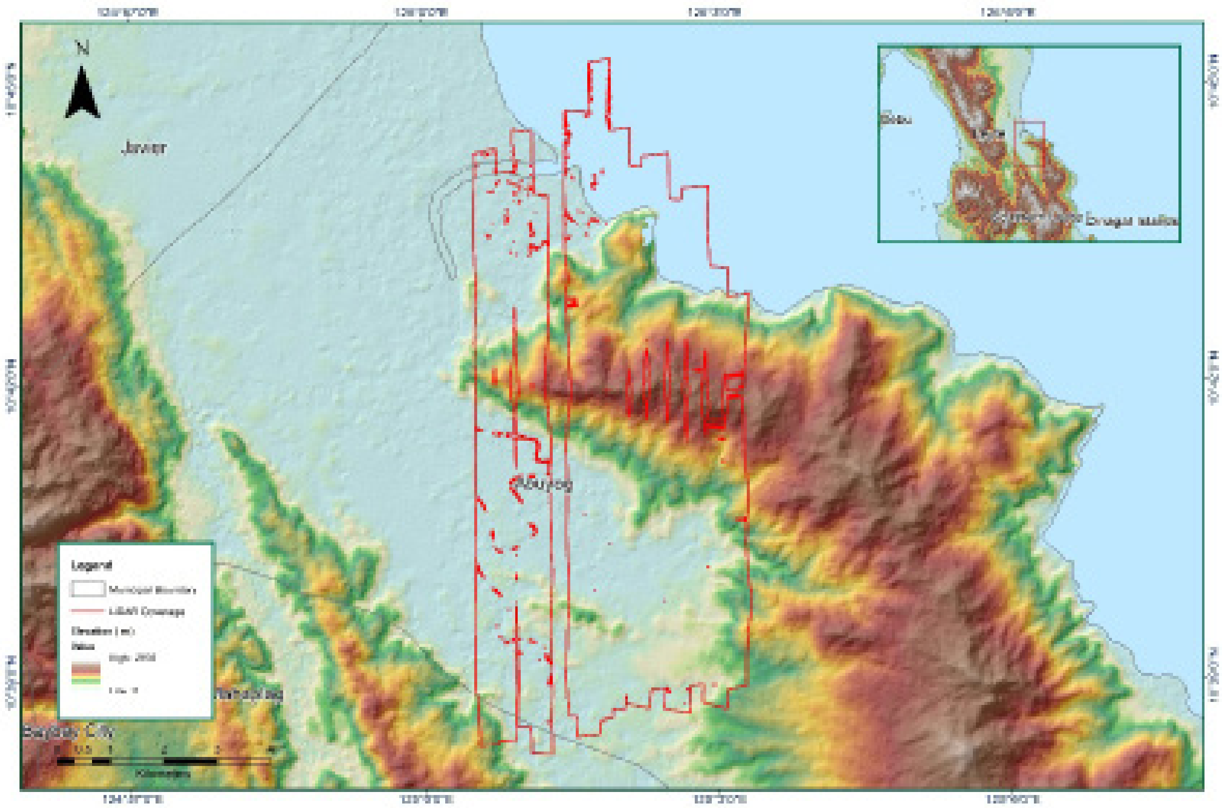


Figure 1.5.4. Coverage of LiDAR data

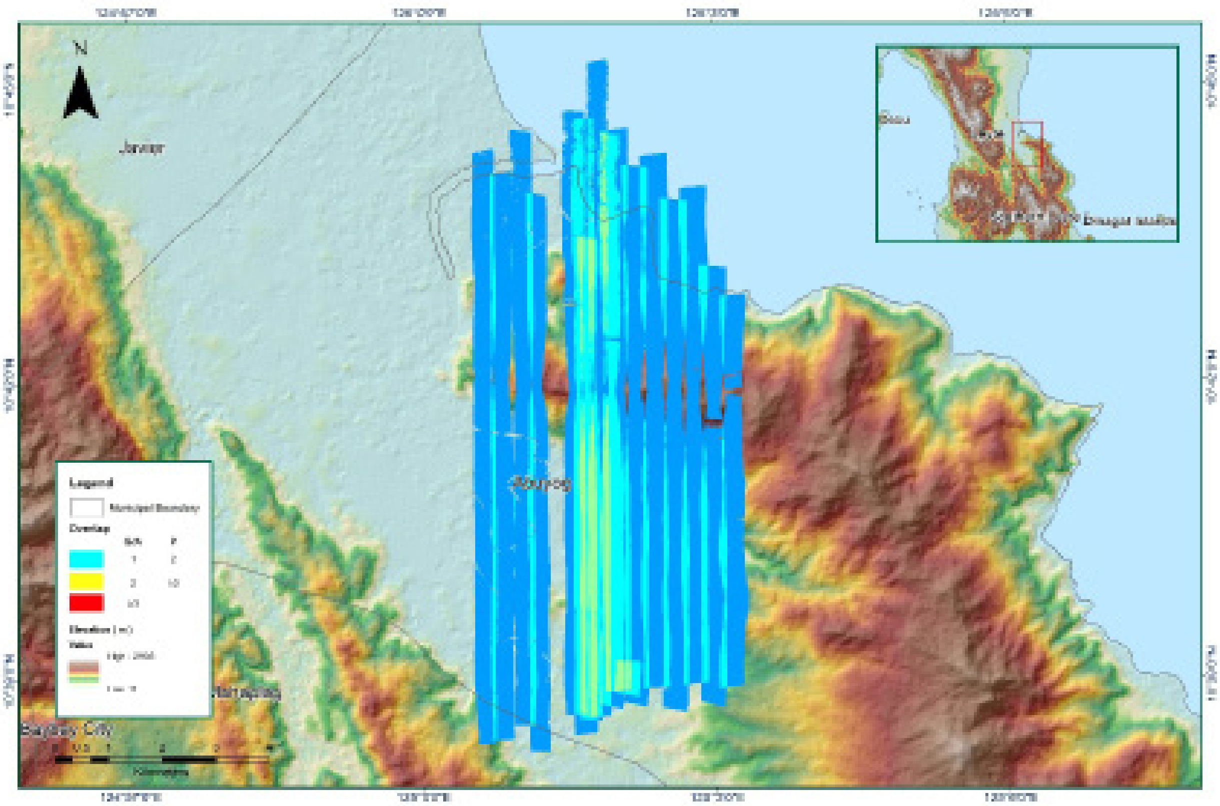


Figure 1.5.5. Image of data overlap

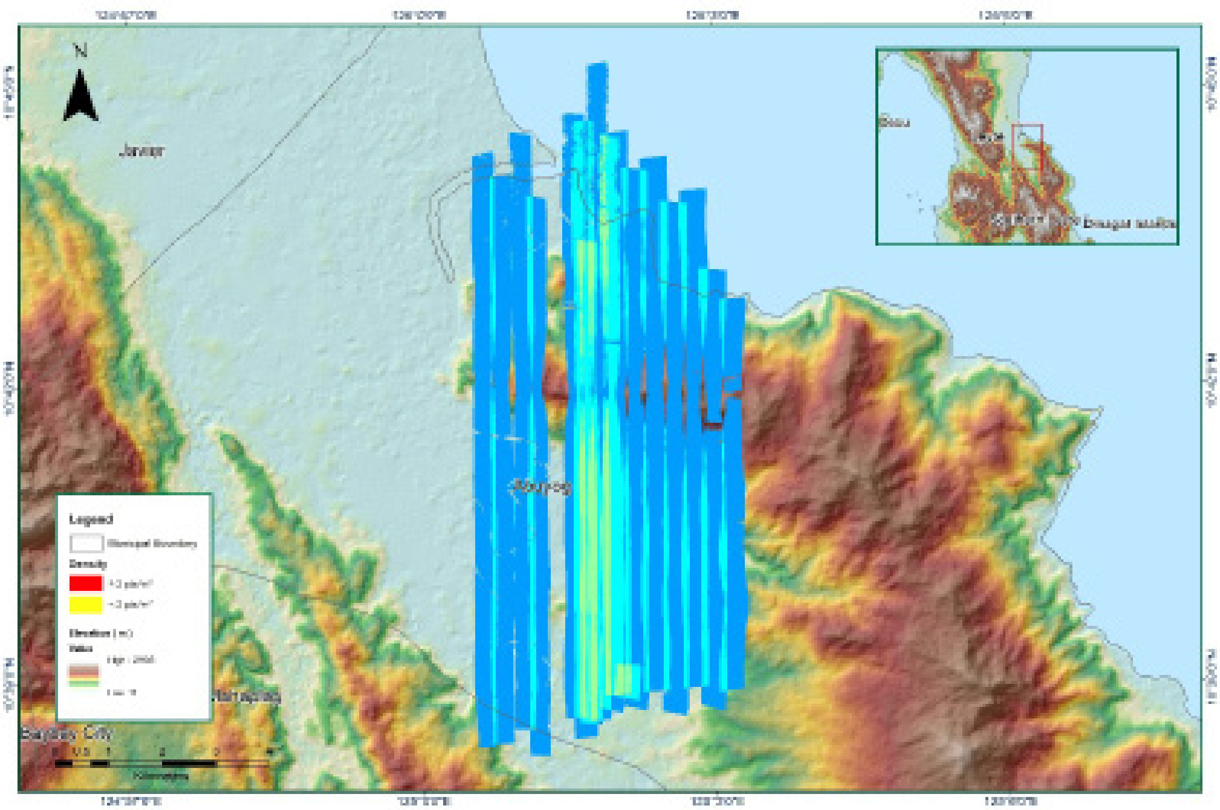


Figure 1.5.6. Density map of merged LiDAR data

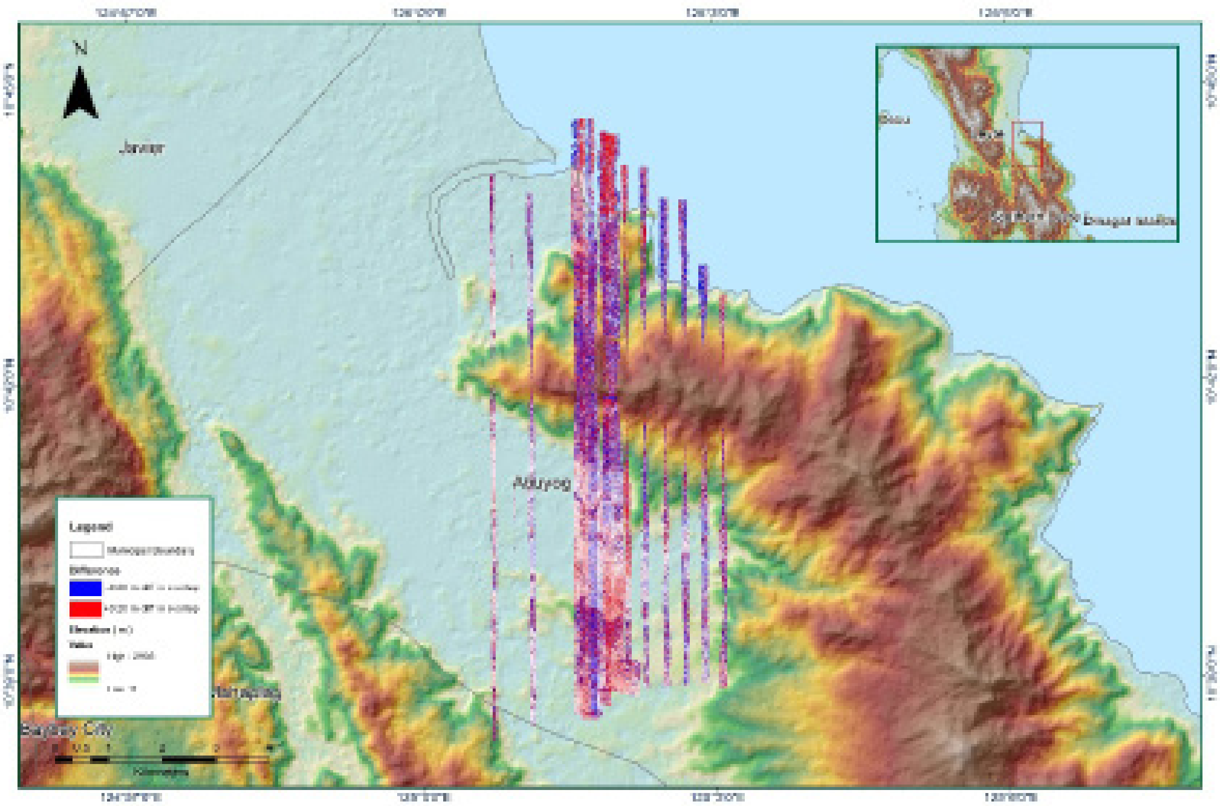


Figure 1.5.7. Elevation difference between flight lines

Flight Area	Leyte
Mission Name	Blk34G_Additional
Inclusive Flights	3781G
Range data size	11.3 GB
POS data size	191 MB
Base data size	8.87 MB
Image	n/a
Transfer date	March 04, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	30.11
Ave point cloud density per sq.m. (>2.0)	4.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	19
Maximum Height	519.61 m
Minimum Height	84.54 m
Classification (# of points)	
Ground	2,238,369
Low vegetation	614,120
Medium vegetation	9,384,305
High vegetation	26,422,837
Building	87,843
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Irish Cortez, Engr. Velina Angela Bemida, Karl Adrian Vergara

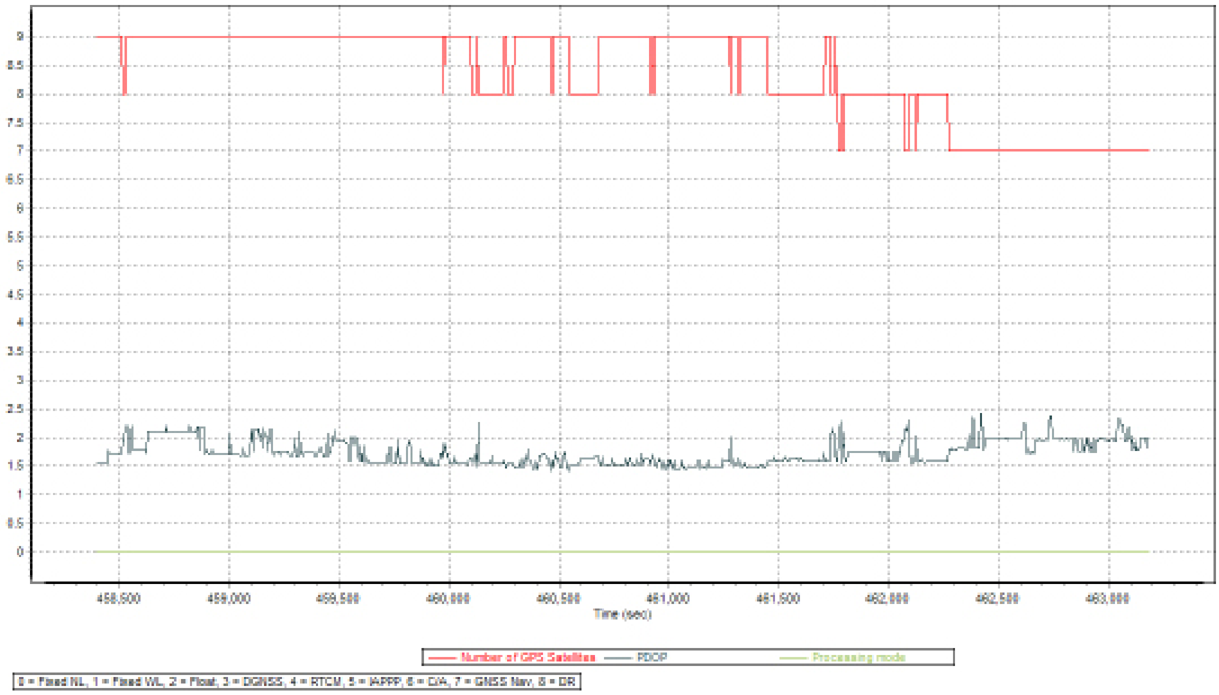


Figure 1.6.1. Solution Status

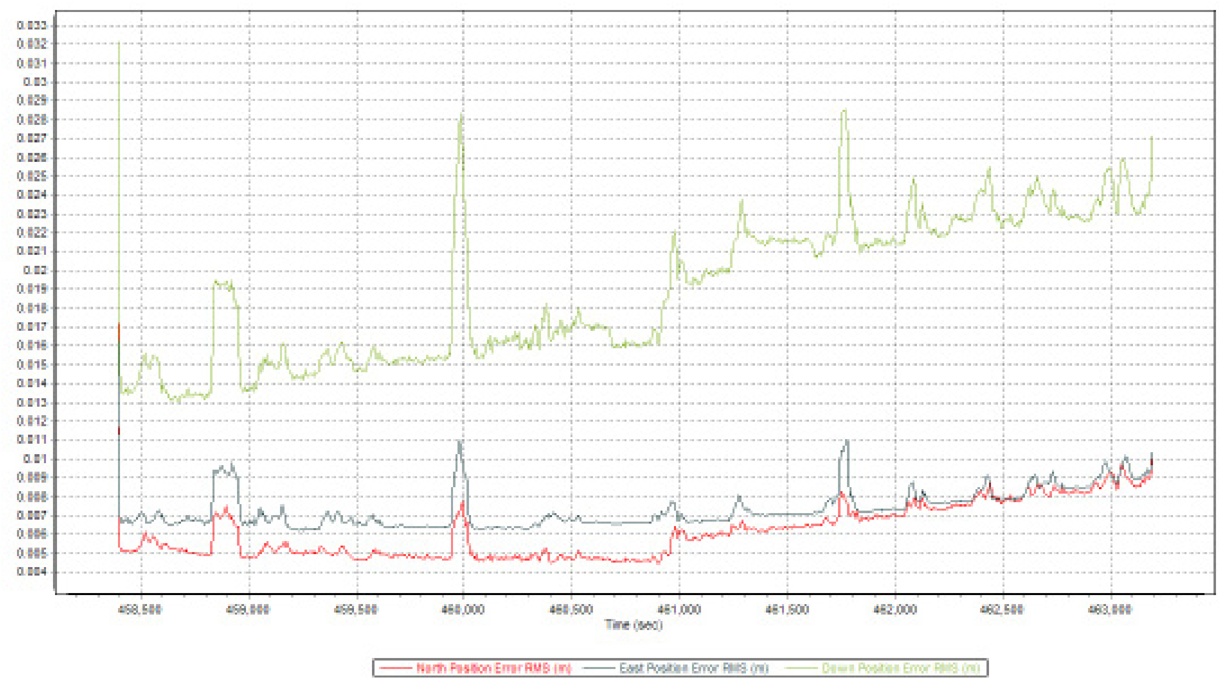


Figure 1.6.2. Smoothed Performance Metrics Parameters

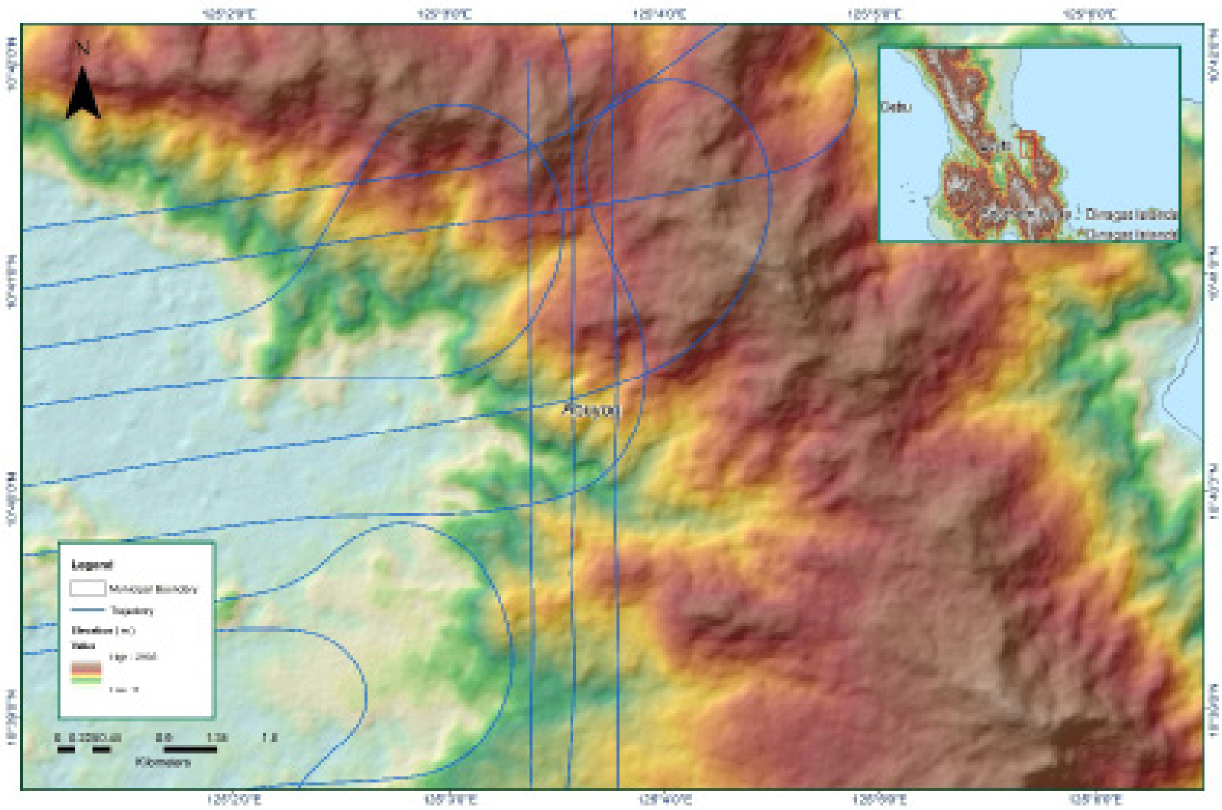


Figure 1.6.3. Best Estimated Trajectory

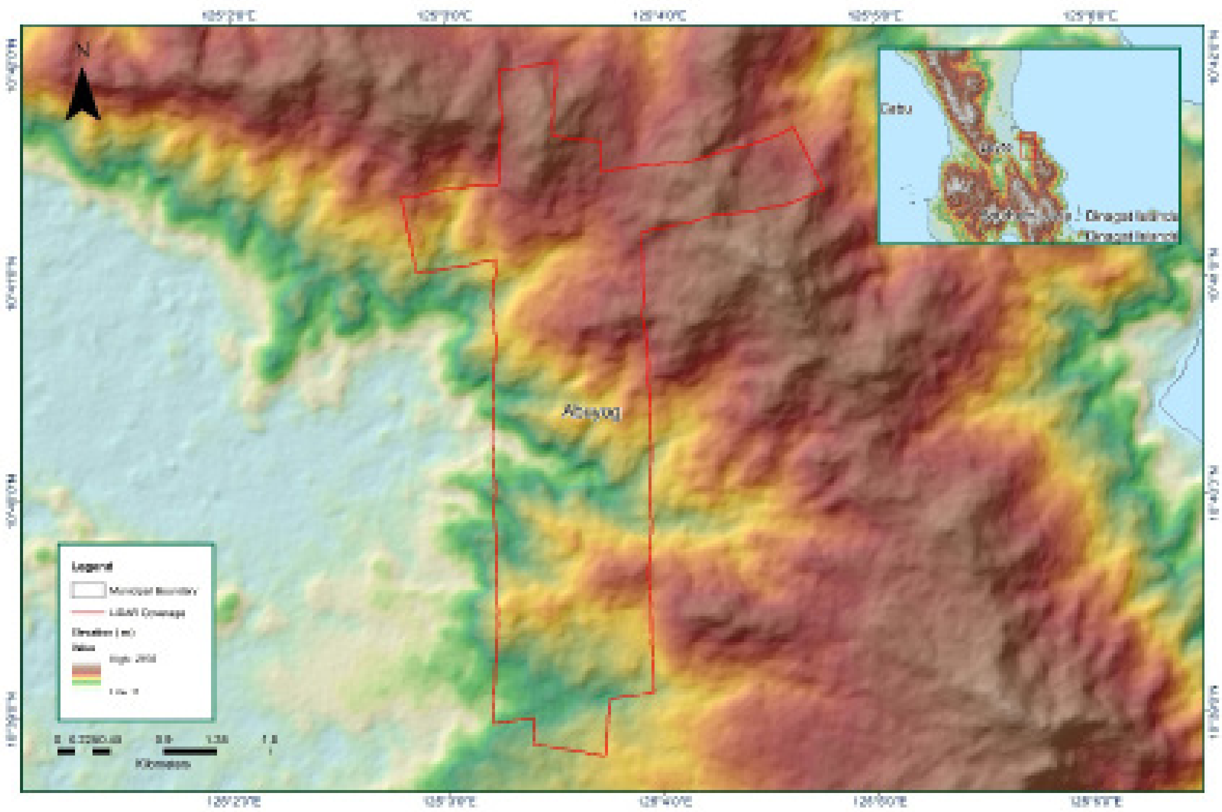


Figure 1.6.4. Coverage of LiDAR data

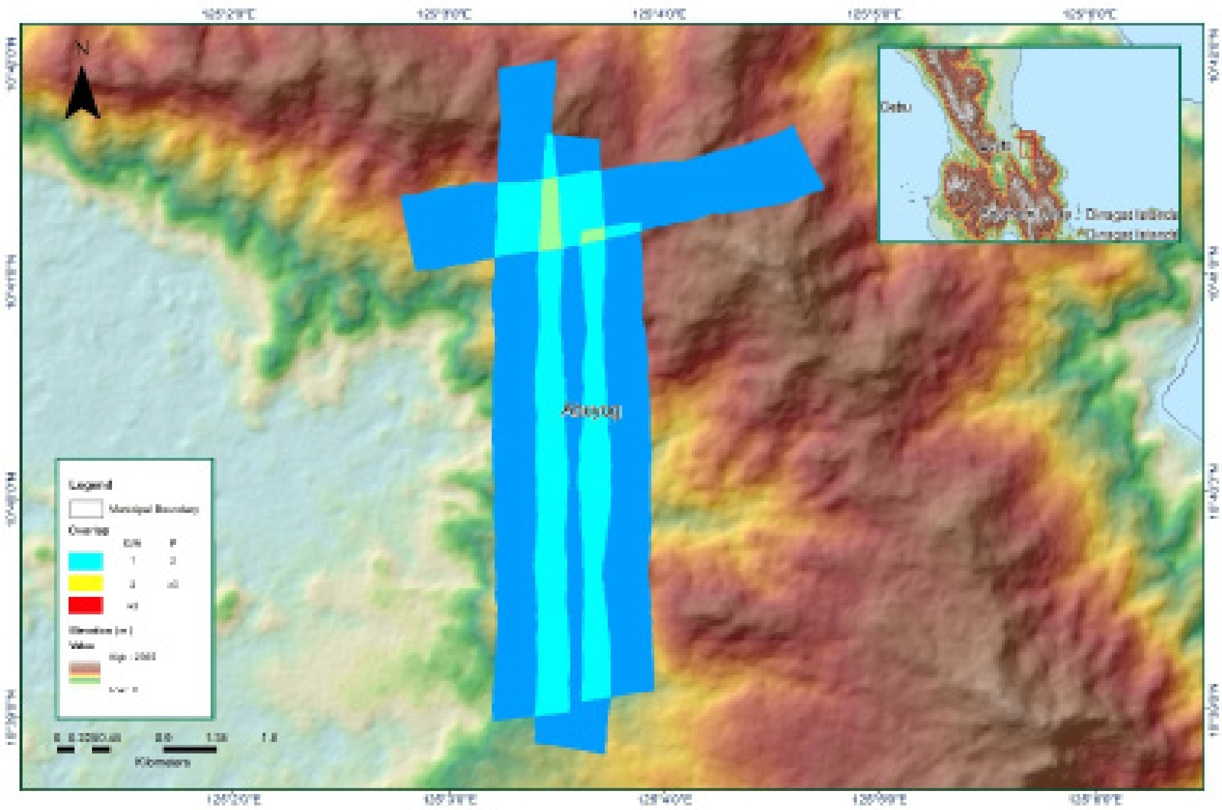


Figure 1.6.5. Image of data overlap

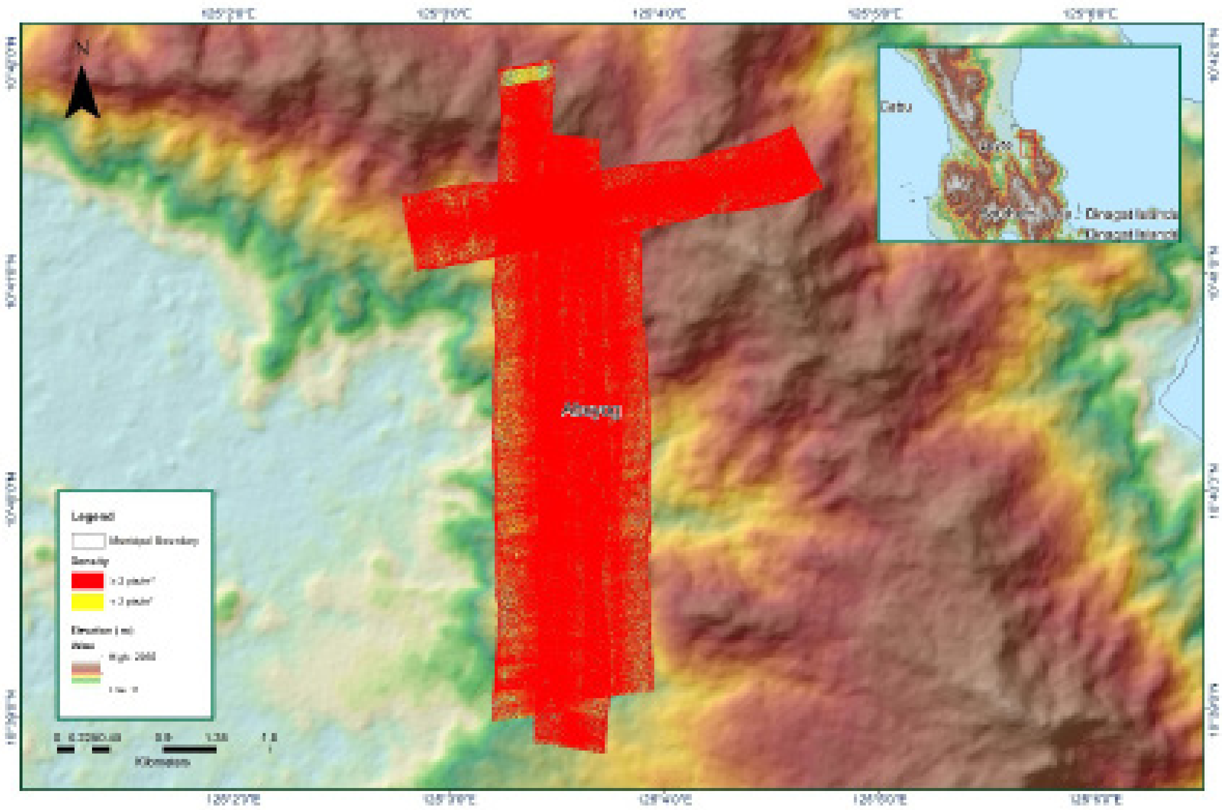


Figure 1.6.6. Density map of merged LiDAR data

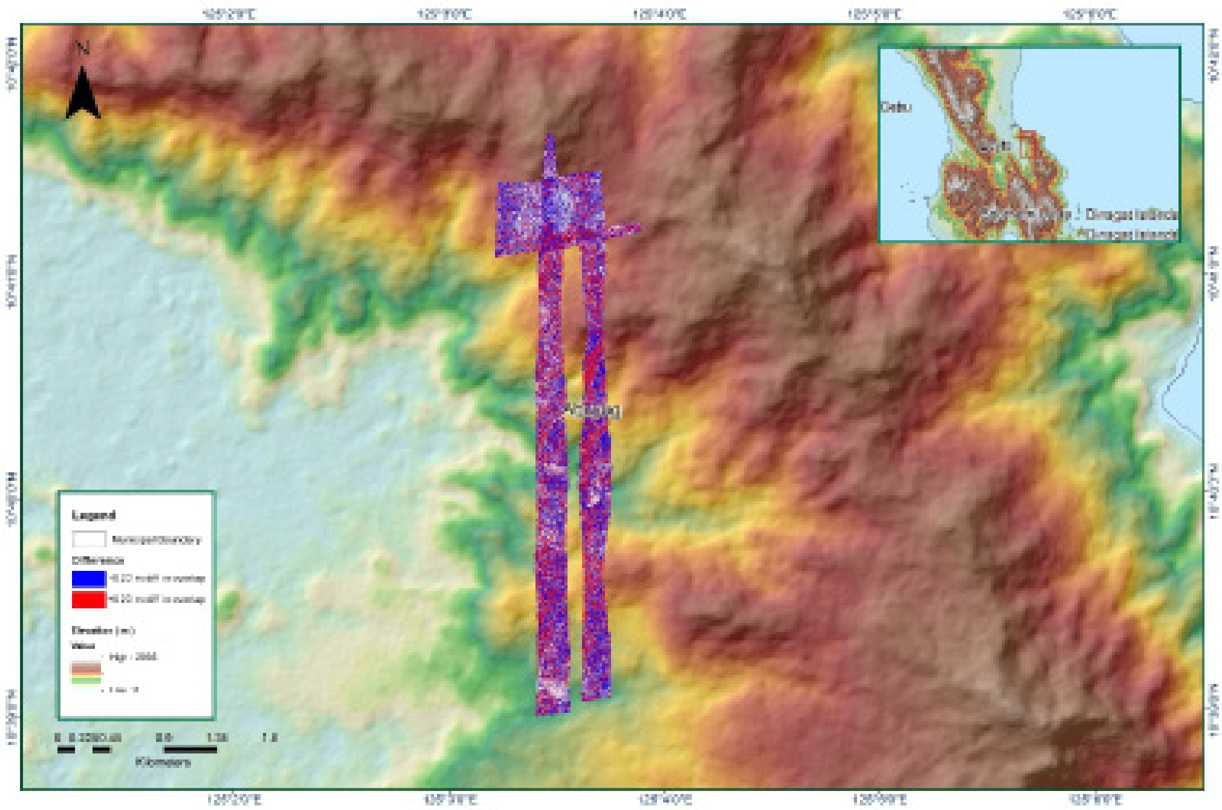


Figure 1.6.7. Elevation difference between flight lines

ANNEX 9. Cadac-an Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1120	147.47	53	0	0.76215	0.6596	Discharge	0.42829	1	Ratio to Peak	0.105
W1110	145	54	0	0.47	0.4072	Discharge	0.17461	1	Ratio to Peak	0.105
W1040	125.44	57	0	0.813	0.7036	Discharge	0.29406	1	Ratio to Peak	0.105
W1030	165	60	0	0.768	0.6643	Discharge	0.23138	1	Ratio to Peak	0.105
W1010	123.53	58	0	0.66455	0.5751	Discharge	0.32182	1	Ratio to Peak	0.105
W1020	153.9	62	0	0.2811	0.2433	Discharge	0.0346122	1	Ratio to Peak	0.105
W950	136.41	55	0	0.91627	0.7929	Discharge	0.36631	1	Ratio to Peak	0.105
W960	112.69	57	0	0.9088	0.7865	Discharge	0.18266	1	Ratio to Peak	0.105
W890	110.45	58	0	1.01773	0.8807	Discharge	0.47489	1	Ratio to Peak	0.105
W930	105.69	61	0	0.46826	0.4052	Discharge	0.19493	1	Ratio to Peak	0.105
W870	119.17	58	0	0.66847	0.5785	Discharge	0.17778	1	Ratio to Peak	0.105
W880	103.67	62	0	0.56414	0.4882	Discharge	0.13802	1	Ratio to Peak	0.105
W850	134.7	56	0	0.8729	0.7554	Discharge	0.42012	1	Ratio to Peak	0.105
W860	106	61	0	0.57	0.495	Discharge	0.12606	1	Ratio to Peak	0.105
W790	154.32	61	0	0.955	0.8261	Discharge	0.47799	1	Ratio to Peak	0.105
W760	98.74	59	0	0.631	0.5461	Discharge	0.24001	1	Ratio to Peak	0.105
W780	137.62	62	0	0.698	0.604	Discharge	0.1809	1	Ratio to Peak	0.105
W770	176.51	64	0	0.13763	0.1191	Discharge	0.000493973	1	Ratio to Peak	0.105
W730	98.17	61	0	0.9007	0.7795	Discharge	0.40025	1	Ratio to Peak	0.105
W750	118.87	63	0	0.9992	0.8647	Discharge	0.26688	1	Ratio to Peak	0.105

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W700	63.37	59	0	1.39771	1.2096	Discharge	0.55495	1	Ratio to Peak	0.105
W690	106.42	69	0	0.4701	0.4068	Discharge	0.0125406	1	Ratio to Peak	0.105
W680	99.142	61	0	0.92406	0.7997	Discharge	0.36008	1	Ratio to Peak	0.105
W670	111.69	63	0	0.48361	0.4185	Discharge	0.17412	1	Ratio to Peak	0.105
W660	85.322	69	0	1.05227	0.9106	Discharge	0.33887	1	Ratio to Peak	0.105
W650	98.92	71	0	1.723	1.491	Discharge	0.16609	1	Ratio to Peak	0.105
W640	83.443	66	0	1.066949	0.9233	Discharge	0.47362	1	Ratio to Peak	0.105
W630	71.109	70	0	0.62412	0.5401	Discharge	0.17447	1	Ratio to Peak	0.105
W610	99.865	62	0	0.566487	0.4902	Discharge	0.10858	1	Ratio to Peak	0.105
W620	79.154	75	0	0.77131	0.6675	Discharge	0.0217938	1	Ratio to Peak	0.105
W1140	195.92	47	0	1.112	0.9627	Discharge	0.38308	1	Ratio to Peak	0.105
W1130	180.22	49	0	0.838	0.7252	Discharge	0.21388	1	Ratio to Peak	0.105
W1080	161.11	51	0	1.10694	0.9579	Discharge	0.43744	1	Ratio to Peak	0.105
W1070	195.92	47	0	1.286	1.1133	Discharge	0.3969	1	Ratio to Peak	0.105
W1100	154.6	52	0	1.245	1.0777	Discharge	0.34324	1	Ratio to Peak	0.105
W1090	135.31	55	0	0.55864	0.4834	Discharge	0.17377	1	Ratio to Peak	0.105
W1050	184.08	48	0	1.643	1.422	Discharge	0.41038	1	Ratio to Peak	0.105
W1060	195.92	47	0	0.674	0.5834	Discharge	0.0584509	1	Ratio to Peak	0.105
W920	111.85	60	0	0.57429	0.497	Discharge	0.2814	1	Ratio to Peak	0.105
W990	132.44	56	0	0.688	0.5952	Discharge	0.26505	1	Ratio to Peak	0.105
W980	189.2	47	0	0.86	0.7449	Discharge	0.12149	1	Ratio to Peak	0.105

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W970	122.56	58	0	0.409	0.3542	Discharge	0.0405823	1	Ratio to Peak	0.105
W1000	180	58	0	1.2	1.0129	Discharge	0.33662	1	Ratio to Peak	0.105
W940	139.75	64	0	0.10208	0.08834	Discharge	0.000454056	1	Ratio to Peak	0.105
W910	93.563	64	0	0.859556	0.7438	Discharge	0.3089	1	Ratio to Peak	0.105
W900	93.485	64	0	0.757973	0.6559	Discharge	0.0122969	1	Ratio to Peak	0.105
W810	135	65	0	0.968	0.838	Discharge	0.46896	1	Ratio to Peak	0.105
W840	85.89	66	0	1.05754	0.9152	Discharge	0.33352	1	Ratio to Peak	0.105
W830	139.5	66	0	1.1909	1.0306	Discharge	0.66592	1	Ratio to Peak	0.105
W820	132	64	0	0.5	0.4454	Discharge	0.0067468	1	Ratio to Peak	0.105
W720	89.2	63	0	1.59	1.3726	Discharge	0.81737	1	Ratio to Peak	0.105
W800	105.16	65	0	0.211	0.1829	Discharge	0.0386496	1	Ratio to Peak	0.105
W740	105.44	59	0	1.799	1.557	Discharge	0.87636	1	Ratio to Peak	0.105
W710	116.57	65	0	0.75044	0.6494	Discharge	0.27628	1	Ratio to Peak	0.105
W590	89.618	65	0	1.81819	1.573	Discharge	0.87261	1	Ratio to Peak	0.105
W600	65.137	71	0	0.395181	0.342	Discharge	0.0408775	1	Ratio to Peak	0.105
W580	55.546	81	0	0.18522	0.1603	Discharge	0.0015776	1	Ratio to Peak	0.105

ANNEX 10. Cadac-an Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R500	Automatic Fixed Interval	4409.52	0.0220453	0.03	Trapezoid	19.38	1
R400	Automatic Fixed Interval	449.1380634	0.016532	0.03	Trapezoid	30.55	1
R390	Automatic Fixed Interval	1477.1	0.0124621	0.03	Trapezoid	29.03	1
R340	Automatic Fixed Interval	2184.29	0.010114	0.03	Trapezoid	30.18	1
R300	Automatic Fixed Interval	2356.25	0.008539	0.03	Trapezoid	30.18	1
R270	Automatic Fixed Interval	690.8871109	0.006993	0.03	Trapezoid	30.35	1
R240	Automatic Fixed Interval	4045.25	0.0044284	0.03	Trapezoid	35.17	1
R170	Automatic Fixed Interval	183.44	0.0050125	0.03	Trapezoid	35.17	1
R160	Automatic Fixed Interval	3143.41	0.0015523	0.03	Trapezoid	65.67	1
R130	Automatic Fixed Interval	1101.37	0.0012393	0.03	Trapezoid	60.35	1
R90	Automatic Fixed Interval	3507.6	0.00054135	0.03	Trapezoid	60.35	1
R70	Automatic Fixed Interval	2422.65	0.000805794	0.03	Trapezoid	70.04	1
R50	Automatic Fixed Interval	2903.5	5.67E-05	0.03	Trapezoid	70.04	1

ANNEX 11. Cadac-an Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	10.709551	124.991889	0.73	1	-0.27	Yolanda / November 08,2013	5-Year
2	10.709152	124.991535	0.56	0.6	-0.04	Yolanda / November 08, 2013	5-Year
3	10.709152	124.991535	0.56	0.6	-0.04	Yolanda / November 08, 2013	5-Year
4	10.709152	124.991535	0.56	0.6	-0.04	Yolanda / November 08, 2013	5-Year
5	10.707763	124.990362	0.54	0.5	0.04	Yolanda / November 08, 2013	5-Year
6	10.707763	124.990362	0.54	0.5	0.04	Yolanda / November 08, 2013	5-Year
7	10.707763	124.990362	0.54	0.5	0.04	Yolanda / November 08, 2013	5-Year
8	10.707173	124.990992	0.06	0.3	-0.24	Yolanda / November 08, 2013	5-Year
9	10.707173	124.990992	0.06	0.3	-0.24	Yolanda / November 08, 2013	5-Year
10	10.707173	124.990992	0.06	0.3	-0.24	Yolanda / November 08, 2013	5-Year
11	10.70729	124.988418	0.78	1	-0.22	Ruby / December 06, 2014	5-Year
12	10.70729	124.988418	0.78	1	-0.22	Ruby / December 06, 2014	5-Year
13	10.706915	124.9876	0.6	1.4	-0.8	Caloy / March 2014	5-Year
14	10.706915	124.9876	0.6	1.4	-0.8	Caloy / March 2014	5-Year
15	10.70653	124.987472	0.52	1	-0.48	Caloy / March 2014	5-Year
16	10.70653	124.987472	0.52	1	-0.48	Caloy / March 2014	5-Year
17	10.70653	124.987472	0.52	1	-0.48	Caloy / March 2014	5-Year
18	10.705246	124.985254	0.43	0.5	-0.07	Seniang / December 28, 2014	5-Year
19	10.705246	124.985254	0.43	0.5	-0.07	Seniang / December 28, 2014	5-Year
20	10.705246	124.985254	0.43	0.5	-0.07	Seniang / December 28, 2014	5-Year
21	10.705026	124.985143	0.23	0.3	-0.07	Ruby / December 06, 2014	5-Year
22	10.705026	124.985143	0.23	0.3	-0.07	Ruby / December 06, 2014	5-Year
23	10.705026	124.985143	0.23	0.3	-0.07	Ruby / December 06, 2014	5-Year
24	10.701603	124.981467	0.51	0.5	0.01	Caloy / March 2014	5-Year
25	10.701603	124.981467	0.51	0.5	0.01	Caloy / March 2014	5-Year
26	10.701603	124.981467	0.51	0.5	0.01	Caloy / March 2014	5-Year
27	10.705451	124.99166	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
28	10.705451	124.99166	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
29	10.700584	124.990895	0.5	0.7	-0.2	Yolanda / November 08, 2013	5-Year
30	10.700584	124.990895	0.5	0.7	-0.2	Yolanda / November 08, 2013	5-Year
31	10.699904	124.991054	0.37	0.5	-0.13	Seniang / December 28, 2014	5-Year
32	10.697311	124.991894	0.4	0.9	-0.5	Seniang / December 28, 2014	5-Year
33	10.69681	124.992037	0.16	1.2	-1.04	Seniang / December 28, 2014	5-Year
34	10.69681	124.992037	0.16	1.2	-1.04	Seniang / December 28, 2014	5-Year
35	10.69681	124.992037	0.16	1.2	-1.04	Seniang / December 28, 2014	5-Year
36	10.696239	124.991687	0.31	0.6	-0.29	Yolanda / November 08, 2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
37	10.696239	124.991687	0.31	0.6	-0.29	Yolanda / November 08, 2013	5-Year
38	10.695116	124.990426	0.11	1	-0.89	Yolanda / November 08, 2013	5-Year
39	10.695116	124.990426	0.11	1	-0.89	Yolanda / November 08, 2013	5-Year
40	10.69492	124.987077	0.18	0	0.18	Yolanda / November 08, 2013	5-Year
41	10.69492	124.987077	0.18	0	0.18	Yolanda / November 08, 2013	5-Year
42	10.694755	124.986718	0.2	0.3	-0.1	Yolanda / November 08, 2013	5-Year
43	10.694755	124.986718	0.2	0.3	-0.1	Yolanda / November 08, 2013	5-Year
44	10.694377	124.986018	0.4	0.3	0.1	Seniang / December 28, 2014	5-Year
45	10.695241	124.985169	0.91	1	-0.09	Seniang / December 28, 2014	5-Year
46	10.694755	124.986718	0.2	0.3	-0.1	Yolanda / November 08, 2013	5-Year
47	10.694755	124.986718	0.2	0.3	-0.1	Yolanda / November 08, 2013	5-Year
48	10.695475	124.984893	0.87	0.5	0.37	Yolanda / November 08, 2013	5-Year
49	10.695475	124.984893	0.87	0.5	0.37	Yolanda / November 08, 2013	5-Year
50	10.697176	124.981496	0.58	0.6	-0.02	Ruby / December 06, 2014	5-Year
51	10.697176	124.981496	0.58	0.6	-0.02	Ruby / December 06, 2014	5-Year
52	10.697176	124.981496	0.58	0.6	-0.02	Ruby / December 06, 2014	5-Year
53	10.692229	124.986802	0.03	0.3	-0.27	Ruby / December 06, 2014	5-Year
54	10.692229	124.986802	0.03	0.3	-0.27	Ruby / December 06, 2014	5-Year
55	10.686743	124.985933	0.03	0.5	-0.47	Ruby / December 06, 2014	5-Year
56	10.686743	124.985933	0.03	0.5	-0.47	Ruby / December 06, 2014	5-Year
57	10.686141	124.985629	0.03	1.5	-1.47	Ruby / December 06, 2014	5-Year
58	10.686141	124.985629	0.03	1.5	-1.47	Ruby / December 06, 2014	5-Year
59	10.686141	124.985629	0.03	1.5	-1.47	Ruby / December 06, 2014	5-Year
60	10.679406	124.983978	0.33	0.25	0.08	Ruby / December 06, 2014	5-Year
61	10.678962	124.983604	0.1	0.5	-0.4	Yolanda / November 08, 2013	5-Year
62	10.677196	124.983891	0.28	0	0.28	Yolanda / November 08, 2013	5-Year
63	10.677196	124.983891	0.28	0	0.28	Yolanda / November 08, 2013	5-Year
64	10.676523	124.984022	0.03	0	0.03	Yolanda / November 08, 2013	5-Year
65	10.675743	124.984176	0.06	0	0.06	Yolanda / November 08, 2013	5-Year
66	10.675258	124.984887	0.03	0.4	-0.37	Yolanda / November 08, 2013	5-Year
67	10.675258	124.984887	0.03	0.4	-0.37	Yolanda / November 08, 2013	5-Year
68	10.675296	124.985418	0.32	0.5	-0.18	Yolanda / November 08, 2013	5-Year
69	10.675258	124.984887	0.03	0.4	-0.37	Yolanda / November 08, 2013	5-Year
70	10.720018	125.008458	0.03	0.2	-0.17	Ruby / December 06, 2014	5-Year
71	10.715184	125.016017	0.64	0.15	0.49	Ruby / December 06, 2014	5-Year
72	10.720781	125.029026	0.47	0	0.47	Ruby / December 06, 2014	5-Year
73	10.722052	125.028473	0.51	0.25	0.26	Ruby / December 06, 2014	5-Year
74	10.722052	125.028473	0.51	0.5	0.01	Seniang / December 28, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
75	10.722115	125.028231	0.18	0	0.18	Ruby / December 06, 2014	5-Year
76	10.722115	125.028231	0.18	0.1	0.08	Seniang / December 28, 2014	5-Year
77	10.72282	125.028364	1.02	0.8	0.22	Seniang / December 28, 2014	5-Year
78	10.723063	125.028251	1.04	1	0.04	Seniang / December 28, 2014	5-Year
79	10.723063	125.028251	1.04	0.5	0.54	Ruby / December 06, 2014	5-Year
80	10.716149	125.016998	0.06	0	0.06	Ruby / December 06, 2014	5-Year
81	10.716964	125.01717	0.33	0.1	0.23	Ruby / December 06, 2014	5-Year
82	10.716792	125.016925	0.43	0	0.43	Ruby / December 06, 2014	5-Year
83	10.706037	125.005919	0.14	0	0.14	Ruby / December 06, 2014	5-Year
84	10.705672	125.00547	0.69	0.3	0.39	Caloy / March 2014	5-Year
85	10.706391	125.005366	0.03	1.4	-1.37	Ruby / December 06, 2014	5-Year
86	10.706391	125.005366	0.03	3.5	-3.47	Seniang / December 28, 2014	5-Year
87	10.706765	125.005289	0.03	0.6	-0.57	Ruby / December 06, 2014	5-Year
88	10.702907	125.004423	0.31	0	0.31	Ruby / December 06, 2014	5-Year
89	10.702207	125.002354	1.08	1.1	-0.02	Ruby / December 06, 2014	5-Year
90	10.702207	125.002354	1.08	1.6	-0.52	Seniang / December 28, 2014	5-Year
91	10.696978	125.007845	0.1	0.4	-0.3	Seniang / December 28, 2014	5-Year
92	10.697222	125.007784	0.18	0	0.18	Ruby / December 06, 2014	5-Year
93	10.695547	125.007463	0.83	0.7	0.13	Ruby / December 06, 2014	5-Year
94	10.696223	125.008428	0.61	0.8	-0.19	Ruby / December 06, 2014	5-Year
95	10.695904	125.009145	0.6	0.3	0.3	Ruby / December 06, 2014	5-Year
96	10.693589	125.013369	0.64	0.1	0.54	Ruby / December 06, 2014	5-Year
97	10.692763	125.014677	0.03	0.95	-0.92	Ruby / December 06, 2014	5-Year
98	10.692763	125.014677	0.03	0.3	-0.27	Seniang / December 28, 2014	5-Year
99	10.690257	125.019971	0.03	0	0.03	Ruby / December 06, 2014	5-Year
100	10.689062	125.02102	0.7	0	0.7	Ruby / December 06, 2014	5-Year
101	10.688728	125.021156	0.66	0.5	0.16	Ruby / December 06, 2014	5-Year
102	10.692579	125.014236	0.77	0.5	0.27	Ruby / December 06, 2014	5-Year
103	10.692291	125.013884	0.26	0	0.26	Ruby / December 06, 2014	5-Year
104	10.694138	125.012363	0.1	0	0.1	Ruby / December 06, 2014	5-Year
105	10.709966	124.998406	0.84	1.7	-0.86	Ruby / December 06, 2014	5-Year
106	10.709966	124.998406	0.84	0.5	0.34	Seniang / December 28, 2014	5-Year
107	10.709943	124.997311	0.18	0.2	-0.02	Ruby / December 06, 2014	5-Year
108	10.709943	124.997311	0.18	0.2	-0.02	Seniang / December 28, 2014	5-Year
109	10.709016	124.995207	0.54	0.6	-0.06	Ruby / December 06, 2014	5-Year
110	10.711363	124.993258	0.81	0.6	0.21	Ruby / December 06, 2014	5-Year
111	10.713477	124.993771	0.73	1.25	-0.52	Ruby / December 06, 2014	5-Year
112	10.715781	124.993365	0.98	0.9	0.08	Ruby / December 06, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
113	10.715781	124.993365	0.98	0.5	0.48	Seniang / December 28, 2014	5-Year
114	10.731735	125.019521	0.03	0.5	-0.47	Ruby / December 06, 2014	5-Year
115	10.731735	125.019521	0.03	0.5	-0.47	Seniang / December 28, 2014	5-Year
116	10.731528	125.019214	0.03	0.6	-0.57	Ruby / December 06, 2014	5-Year
117	10.731528	125.019214	0.03	0	0.03	Seniang / December 28, 2014	5-Year
118	10.731457	125.019195	0.03	0.4	-0.37	Ruby / December 06, 2014	5-Year
119	10.731233	125.019336	0.11	0	0.11	Ruby / December 06, 2014	5-Year
120	10.730721	125.019559	0.12	0	0.12	Ruby / December 06, 2014	5-Year
121	10.730721	125.019559	0.12	0	0.12	Seniang / December 28, 2014	5-Year
122	10.730231	125.019816	0.07	0	0.07	Ruby / December 06, 2014	5-Year
123	10.730231	125.019816	0.07	0.3	-0.23	Seniang / December 28, 2014	5-Year
124	10.729886	125.019924	0.07	0.6	-0.53	Ruby / December 06, 2014	5-Year
125	10.729709	125.020027	0.05	0	0.05	Ruby / December 06, 2014	5-Year
126	10.729709	125.020027	0.05	0	0.05	Seniang / December 28, 2014	5-Year
127	10.730964	125.020222	0.08	0	0.08	Ruby / December 06, 2014	5-Year
128	10.730964	125.020222	0.08	0	0.08	Seniang / December 28, 2014	5-Year
129	10.731138	125.020421	0.06	0.5	-0.44	Seniang / December 28, 2014	5-Year
130	10.731275	125.020277	0.03	0.3	-0.27	Ruby / December 06, 2014	5-Year
131	10.731201	125.019894	0.04	0.5	-0.46	Seniang / December 28, 2014	5-Year
132	10.731607	125.018993	0.07	0.5	-0.43	Ruby / December 06, 2014	5-Year
133	10.731771	125.018769	0.03	0.5	-0.47	Ruby / December 06, 2014	5-Year
134	10.731771	125.018769	0.03	1.5	-1.47	Seniang / December 28, 2014	5-Year
135	10.731834	125.018426	0.03	0.5	-0.47	Ruby / December 06, 2014	5-Year
136	10.738105	125.021478	0.03	0.4	-0.37	Ruby / December 06, 2014	5-Year
137	10.738105	125.021478	0.03	0.4	-0.37	Seniang / December 28, 2014	5-Year
138	10.738105	125.021478	0.03	0.8	-0.77	Yolanda / November 08, 2013	5-Year
139	10.737767	125.020004	0.03	0.3	-0.27	Ruby / December 06, 2014	5-Year
140	10.737767	125.020004	0.03	0.3	-0.27	Seniang / December 28, 2014	5-Year
141	10.737393	125.018134	0.03	0	0.03	Ruby / December 06, 2014	5-Year
142	10.737393	125.018134	0.03	0	0.03	Seniang / December 28, 2014	5-Year
143	10.737393	125.018134	0.03	0	0.03	Yolanda / November 08, 2013	5-Year
144	10.739043	125.017241	0.3	0.3	1.19E-08	Ruby / December 06, 2014	5-Year
145	10.739043	125.017241	0.3	0.3	1.19E-08	Seniang / December 28, 2014	5-Year
146	10.739043	125.017241	0.3	0.3	1.19E-08	Amihan / Jan-Feb 2016	5-Year
147	10.741729	125.017943	0.06	0	0.06	Ruby / December 06, 2014	5-Year
148	10.741729	125.017943	0.06	0	0.06	Seniang / December 28, 2014	5-Year
149	10.742265	125.014193	0.03	0.6	-0.57	Ruby / December 06, 2014	5-Year
150	10.742265	125.014193	0.03	2	-1.97	Yolanda / November 08, 2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
151	10.742235	125.014199	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
152	10.742212	125.01422	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
153	10.741495	125.013941	0.03	0.2	-0.17	Ruby / December 06, 2014	5-Year
154	10.741495	125.013941	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
155	10.741495	125.013941	0.03	0.3	-0.27	Habagat	5-Year
156	10.741485	125.013924	0.03	0.3	-0.27	Amihan / Jan-Feb 2016	5-Year
157	10.745312	125.012743	0.11	0.3	-0.19	Ruby / December 06, 2014	5-Year
158	10.745312	125.012743	0.11	0.3	-0.19	Seniang / December 28, 2014	5-Year
159	10.745312	125.012743	0.11	0.3	-0.19	Amihan / Jan-Feb 2016	5-Year
160	10.748232	125.013109	0.03	0.7	-0.67	Ruby / December 06, 2014	5-Year
161	10.748232	125.013109	0.03	0	0.03	Seniang / December 28, 2014	5-Year
162	10.748232	125.013109	0.03	0	0.03	Yolanda / November 08, 2013	5-Year
163	10.748232	125.013109	0.03	0	0.03	Amihan / Jan-Feb 2016	5-Year
164	10.747872	125.012569	0.43	0.3	0.13	Amihan / Jan-Feb 2016	5-Year
165	10.747872	125.012569	0.43	0.5	-0.07	Ruby / December 06, 2014	5-Year
166	10.747872	125.012569	0.43	0.5	-0.07	Seniang / December 28, 2014	5-Year
167	10.747872	125.012569	0.43	0	0.43	Yolanda / November 08, 2013	5-Year
168	10.746063	125.009009	0.03	1	-0.97	Amihan / Jan-Feb 2016	5-Year
169	10.746063	125.009009	0.03	0	0.03	Ruby / December 06, 2014	5-Year
170	10.746063	125.009009	0.03	0	0.03	Yolanda / November 08, 2013	5-Year
171	10.746063	125.009009	0.03	0.8	-0.77	After Yolanda / November 08, 2013	5-Year
172	10.742153	125.009747	0.04	0.4	-0.36	Ruby / December 06, 2014	5-Year
173	10.742153	125.009747	0.04	0.4	-0.36	Seniang / December 28, 2014	5-Year
174	10.742153	125.009747	0.04	0.6	-0.56	Amihan / Jan-Feb 2016	5-Year
175	10.740157	125.012946	0.65	0.8	-0.15	Ruby / December 06, 2014	5-Year
176	10.740157	125.012946	0.65	1.6	-0.95	Basyang	5-Year
177	10.740157	125.012946	0.65	1.4	-0.75	Yolanda / November 08, 2013	5-Year
178	10.740157	125.012946	0.65	0.5	0.15	Amihan / Jan-Feb 2016	5-Year
179	10.748568	124.998608	0.03	0.8	-0.77	Ruby / December 06, 2014	5-Year
180	10.748568	124.998608	0.03	0.8	-0.77	Seniang / December 28, 2014	5-Year
181	10.748568	124.998608	0.03	2	-1.97	Yolanda / November 08, 2013	5-Year
182	10.748568	124.998608	0.03	0	0.03	Amihan / Jan-Feb 2016	5-Year
183	10.74473	124.992969	0.03	0.2	-0.17	Ruby / December 06, 2014	5-Year
184	10.74473	124.992969	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
185	10.74473	124.992969	0.03	0.4	-0.37	December before Yolanda / November 08, 2013 & Sendong / December 2011	5-Year
186	10.74383	124.989535	0.03	0.2	-0.17	Ruby / December 06, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
187	10.74383	124.989535	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
188	10.74383	124.989535	0.03	0.2	-0.17	Amihan / Jan-Feb 2016	5-Year
189	10.737198	124.988458	0.03	0.8	-0.77	Amihan / Jan-Feb 2016	5-Year
190	10.737198	124.988458	0.03	0.8	-0.77	Ruby / December 06, 2014	5-Year
191	10.737198	124.988458	0.03	0.2	-0.17	Seniang / December 28, 2014	5-Year
192	10.737198	124.988458	0.03	1.4	-1.37	Sendong / December 2011	5-Year
193	10.737198	124.988458	0.03	1.4	-1.37	Basyang	5-Year
194	10.735811	124.991924	0.37	0.8	-0.43	Ruby / December 06, 2014	5-Year
195	10.735811	124.991924	0.37	0	0.37	Amihan / Jan-Feb 2016	5-Year
196	10.735867	124.994109	0.57	1.3	-0.73	Amihan / Jan-Feb 2016	5-Year
197	10.735867	124.994109	0.57	0.6	-0.03	Ruby / December 06, 2014	5-Year
198	10.735867	124.994109	0.57	1.3	-0.73	Amihan / December - January	5-Year
199	10.735867	124.994109	0.57	1.5	-0.93	December 2012	5-Year
200	10.730957	124.985433	0.03	0	0.03	Ruby / December 06, 2014	5-Year
201	10.730957	124.985433	0.03	0	0.03	Seniang / December 28, 2014	5-Year
202	10.728168	124.986609	0.03	0.4	-0.37	Ruby / December 06, 2014	5-Year
203	10.728168	124.986609	0.03	0.2	-0.17	Amihan / December - January	5-Year
204	10.727208	124.986824	0.19	0.5	-0.31	Amihan / Jan-Feb 2016	5-Year
205	10.727208	124.986824	0.19	0.8	-0.61	Ruby / December 06, 2014	5-Year
206	10.727322	124.986782	0.11	0.8	-0.69	Ruby / December 06, 2014	5-Year
207	10.727322	124.986782	0.11	0	0.11	Seniang / December 28, 2014	5-Year
208	10.724391	124.988143	0.62	0.9	-0.28	Every December	5-Year
209	10.724391	124.988143	0.62	0.5	0.12	Amihan / Jan-Feb 2016	5-Year
210	10.724391	124.988143	0.62	0.9	-0.28	Ruby / December 06, 2014	5-Year
211	10.724391	124.988143	0.62	0.9	-0.28	Seniang / December 28, 2014	5-Year
212	10.724391	124.988143	0.62	0.8	-0.18	Yolanda / November 08, 2013	5-Year
213	10.721119	124.989389	0.03	0	0.03	Ruby / December 06, 2014	5-Year
214	10.721119	124.989389	0.03	0	0.03	Seniang / December 28, 2014	5-Year
215	10.721846	124.989366	0.03	0	0.03	Yolanda / November 08, 2013	5-Year
216	10.721775	124.989331	0.03	0.5	-0.47	Ruby / December 06, 2014	5-Year
217	10.7192	124.990344	0.03	0.3	-0.27	Ruby / December 06, 2014	5-Year
218	10.7192	124.990344	0.03	0.1	-0.07	Amihan / Jan-Feb 2016	5-Year
219	10.719872	124.992021	0.31	0.55	-0.24	Amihan / December 2015	5-Year
220	10.719872	124.992021	0.31	0.55	-0.24	Ruby / December 06, 2014	5-Year
221	10.719872	124.992021	0.31	0.55	-0.24	Every December	5-Year
222	10.720671	124.993097	0.57	0.9	-0.33	Amihan / Jan-Feb 2016	5-Year
223	10.720671	124.993097	0.57	0.9	-0.33	Ruby / December 06, 2014	5-Year
224	10.722302	124.994873	0.59	0.4	0.19	Ruby / December 06, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
225	10.722302	124.994873	0.59	0	0.59	Amihan / Jan-Feb 2016	5-Year
226	10.722302	124.994873	0.59	0.6	-0.01	Sendong / December 2011	5-Year
227	10.723184	124.996094	0.33	0.3	0.03	Amihan / Jan-Feb 2016	5-Year
228	10.723184	124.996094	0.33	0	0.33	Amihan / December 2015	5-Year
229	10.723184	124.996094	0.33	0.3	0.03	Ruby / December 06, 2014	5-Year
230	10.723631	124.998232	0.6	0.6	2.38E-08	Amihan / December 2015	5-Year
231	10.723631	124.998232	0.6	0.6	2.38E-08	Amihan / Jan-Feb 2016	5-Year
232	10.723631	124.998232	0.6	0.6	2.38E-08	Ruby / December 06, 2014	5-Year
233	10.727304	124.99992	0.68	1.3	-0.62	Amihan / December	5-Year
234	10.727304	124.99992	0.68	0.1	0.58	Ruby / December 06, 2014	5-Year
235	10.727304	124.99992	0.68	0.4	0.28	Sendong / December 2011	5-Year
236	10.72717	125.000641	0.86	1.4	-0.54	Amihan / December	5-Year
237	10.72717	125.000641	0.86	1.6	-0.74	Ruby / December 06, 2014	5-Year
238	10.72717	125.000641	0.86	1.4	-0.54	Amihan / Jan-Feb 2016	5-Year
239	10.72717	125.000641	0.86	1.4	-0.54	Sendong / December 2011	5-Year
240	10.72717	125.000641	0.86	1.5	-0.64	Heavy Rain / June 2012	5-Year
241	10.72717	125.000641	0.86	2	-1.14	Basyang	5-Year
242	10.72717	125.000641	0.86	1.3	-0.44	Amihan / December 2015	5-Year
243	10.728762	124.999476	0.67	0.9	-0.23	every amihan	5-Year
244	10.728762	124.999476	0.67	1.2	-0.53	Ruby / December 06, 2014	5-Year
245	10.728762	124.999476	0.67	2	-1.33	Amihan / November 2015	5-Year
246	10.728762	124.999476	0.67	2.2	-1.53	Sendong / December 2011	5-Year
247	10.731579	124.998167	1.26	1.2	0.06	Amihan / January 29, 2016	5-Year
248	10.731579	124.998167	1.26	0	1.26	Ruby / December 06, 2014	5-Year
249	10.731579	124.998167	1.26	1.2	0.06	Amihan / December 2015	5-Year
250	10.732777	125.001559	0.25	1.2	-0.95	Amihan / Jan -Feb 2016	5-Year
251	10.732777	125.001559	0.25	0.5	-0.25	Ruby / December 06, 2014	5-Year
252	10.732777	125.001559	0.25	0	0.25	Yolanda / November 08, 2013	5-Year
253	10.732777	125.001559	0.25	1.2	-0.95	every amihan / December	5-Year
254	10.733489	125.001319	0.62	0	0.62	Amihan / Jan-Feb 2016	5-Year
255	10.733489	125.001319	0.62	1.3	-0.68	Ruby / December 06, 2014	5-Year
256	10.733489	125.001319	0.62	1.3	-0.68	Seniang / December 28, 2014	5-Year
257	10.733489	125.001319	0.62	1	-0.38	evey amihan / December	5-Year
258	10.734995	125.002707	0.03	0.5	-0.47	evey amihan / December	5-Year
259	10.734995	125.002707	0.03	0.7	-0.67	Ruby / December 06, 2014	5-Year
260	10.734995	125.002707	0.03	0.7	-0.67	Amihan / Jan-Feb 2016	5-Year
261	10.722146	124.997859	1.29	0.9	0.39	Ruby / December 06, 2014	5-Year
262	10.722146	124.997859	1.29	0.9	0.39	Amihan / Jan-Feb 2016	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
263	10.722146	124.997859	1.29	0.9	0.39	Amihan / December 2015	5-Year
264	10.722146	124.997859	1.29	0.5	0.79	Sendong / December 2011	5-Year
265	10.720305	124.999056	0.87	0.8	0.07	every amihan / December	5-Year
266	10.720305	124.999056	0.87	0.5	0.37	Amihan / Jan-Feb 2016	5-Year
267	10.720305	124.999056	0.87	0.3	0.57	Ruby / December 06, 2014	5-Year
268	10.720305	124.999056	0.87	0.4	0.47	Yolanda / November 08, 2013	5-Year
269	10.718021	124.998904	0.67	0.2	0.47	Amihan / Jan-Feb 2016	5-Year
270	10.717397	124.999227	0.65	1	-0.35	Amihan / December 2014	5-Year
271	10.717397	124.999227	0.65	1.8	-1.15	Basyang / 1972	5-Year
272	10.717397	124.999227	0.65	0	0.65	Ruby / December 06, 2014	5-Year
273	10.717638	125.000664	0.7	0.5	0.2	every amihan / December	5-Year
274	10.717638	125.000664	0.7	0.1	0.6	Ruby / December 06, 2014	5-Year
275	10.717338	124.997842	0.85	0.2	0.65	Amihan / Jan-Feb 2016	5-Year
276	10.717338	124.997842	0.85	0.8	0.05	Amihan / December 2015	5-Year
277	10.717221	124.997655	1.31	4	-2.69	Amihan / December 2015	5-Year
278	10.717046	124.996561	0.54	1.3	-0.76	Amihan / December 2014	5-Year
279	10.716424	124.993214	0.03	0.8	-0.77	every amihan / December	5-Year
280	10.716424	124.993214	0.03	1.1	-1.07	Ruby / December 06, 2014	5-Year
281	10.716424	124.993214	0.03	0.6	-0.57	Amihan / Jan-Feb 2016	5-Year
282	10.710809	124.997667	0.54	0.1	0.44	Amihan / December 2015	5-Year
283	10.710809	124.997667	0.54	0.1	0.44	Amihan / Jan-Feb 2016	5-Year
284	10.710809	124.997667	0.54	0.2	0.34	Ruby / December 06, 2014	5-Year
285	10.70983	124.998592	1.57	5	-3.43	Ruby / December 06, 2014	5-Year
286	10.70983	124.998592	1.57	5	-3.43	every amihan / December	5-Year
287	10.711464	124.998402	0.34	0.3	0.04	Amihan / Jan-Feb 2016	5-Year
288	10.711464	124.998402	0.34	0.3	0.04	Amihan / December 2015	5-Year
289	10.712987	124.997543	0.55	0.6	-0.05	Amihan / Jan-Feb 2016	5-Year
290	10.712987	124.997543	0.55	0.6	-0.05	Amihan / December 2015	5-Year
291	10.712987	124.997543	0.55	1	-0.45	Ruby / December 06, 2014	5-Year
292	10.712987	124.997543	0.55	0.4	0.15	Yolanda / November 08, 2013	5-Year
293	10.712356	124.997102	0.63	0.4	0.23	every amihan / December	5-Year
294	10.712356	124.997102	0.63	0.4	0.23	Amihan / Jan-Feb 2016	5-Year
295	10.712356	124.997102	0.63	0.7	-0.07	Ruby / December 06, 2014	5-Year
296	10.712356	124.997102	0.63	2	-1.37	Yolanda / November 08, 2013	5-Year
297	10.71748	124.991152	0.03	0	0.03	Amihan / Jan-Feb 2016	5-Year
298	10.71748	124.991152	0.03	0.9	-0.87	Ruby / December 06, 2014	5-Year
299	10.71748	124.991152	0.03	0.9	-0.87	Seniang / December 28, 2014	5-Year
300	10.71748	124.991152	0.03	0.9	-0.87	Sendong / December 2011	5-Year

ANNEX 12. Educational Institutions Affected by Flooding in Cadac-an Floodplain

LEYTE				
ABUYOG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Buenavista Elementary School	Buenavista		Medium	Medium
Day Care Center	Buenavista	Low	Medium	Medium
Abuyog Fundamental Baptist Church School	Buntay		Low	Medium
Abuyog South Central School	Buntay		Medium	Medium
Gabaldon Central School	Buntay		Medium	Medium
Notre Dame of Abuyog	Buntay			
Burubud-an Primary School	Burubud-An			
Day Care Center	Burubud-An	Low	Low	Low
Abuyog Fundamental Baptist Church School	Can-Aporong		Low	Medium
Day Care Center	Can-Aporong		Medium	Medium
UCCP Learning Center	Can-Aporong			Medium
Can-aporong Day Care Center	Canmarating	Medium	High	High
Can-aporong Elementary School	Canmarating	Low	Medium	High
Day Care Center	Canmarating	Low	Medium	High
Mag-atubang Elelmentary School	Canmarating		Medium	Medium
Tabigue Elementary School	Canmarating			Low
Abuyog South Central School	Loyonsawang	Low	Medium	Medium
Learning Center	Loyonsawang		Low	Medium
Maitum Elementary School	Maitum			
Abuyog National High School	Nalibunan			
Day Care Center	Nalibunan	Low	Low	Low
Sta. Fe- Sto. Niño Elementary School	Nalibunan	Low	Low	Medium
Canmarating Elementary School	Odiongan	Low	Medium	Medium
Nursery & Training Center	Odiongan	Medium	Medium	Medium
Pagsang-an Elementary School	Odiongan	Medium	Medium	Medium
Cadac-an Primary School	Pagsang-An			
Day Care Center	Pagsang-An			
Capilian Elementary School	Picas Sur	Medium	Medium	Medium
Day Care Center	Picas Sur	Medium	Medium	Medium
Salvacion Elementary School	Salvacion	High	High	High
Abuyog National High School	Santa Fe			Low
Day Care Center	Tadoc		Low	Medium
Tadoc Elementary School	Tadoc			
Day Care Center	Tinalian			
Lawa-an Elementary School	Tinalian	Low	Low	Low
Tinalian Elementary School	Tinalian	Medium	Medium	High
Day Care Center	Victory			Low

ANNEX 13. Health Institutions Affected by Flooding in Cadac-an Floodplain

Aklan				
Ibajay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Buenavista Health Center	Buenavista		Medium	Medium
RHU-Morgue	Buntay	Low	Medium	Medium
Rural Health Unit	Buntay	Low	Medium	Medium
Health Center	Burubud-An			Medium
Core Diagnostic Center	Can-Uguib	Low	Medium	Medium
Can-aporong Health Center	Canmarating	Medium	Medium	High
Health Center	Canmarating		Medium	Medium
Eleuteria Laher Clinic	Loyonsawang		Low	Medium
Gracoz Pharmacy Office	Loyonsawang		Medium	Medium
Gracz Pharmacy	Loyonsawang		Medium	Medium
New Botica Balaga	Loyonsawang	Low	Medium	Medium
Rural Health Unit	Nalibunan			
Health Center	Odiongan	Low	Medium	Medium
Health Center	Pagsang-An			
Health Center	Picas Sur	Low	Low	Medium
Health Center	Tadoc		Low	Medium
Health Center	Tinalian	Low	Medium	Medium