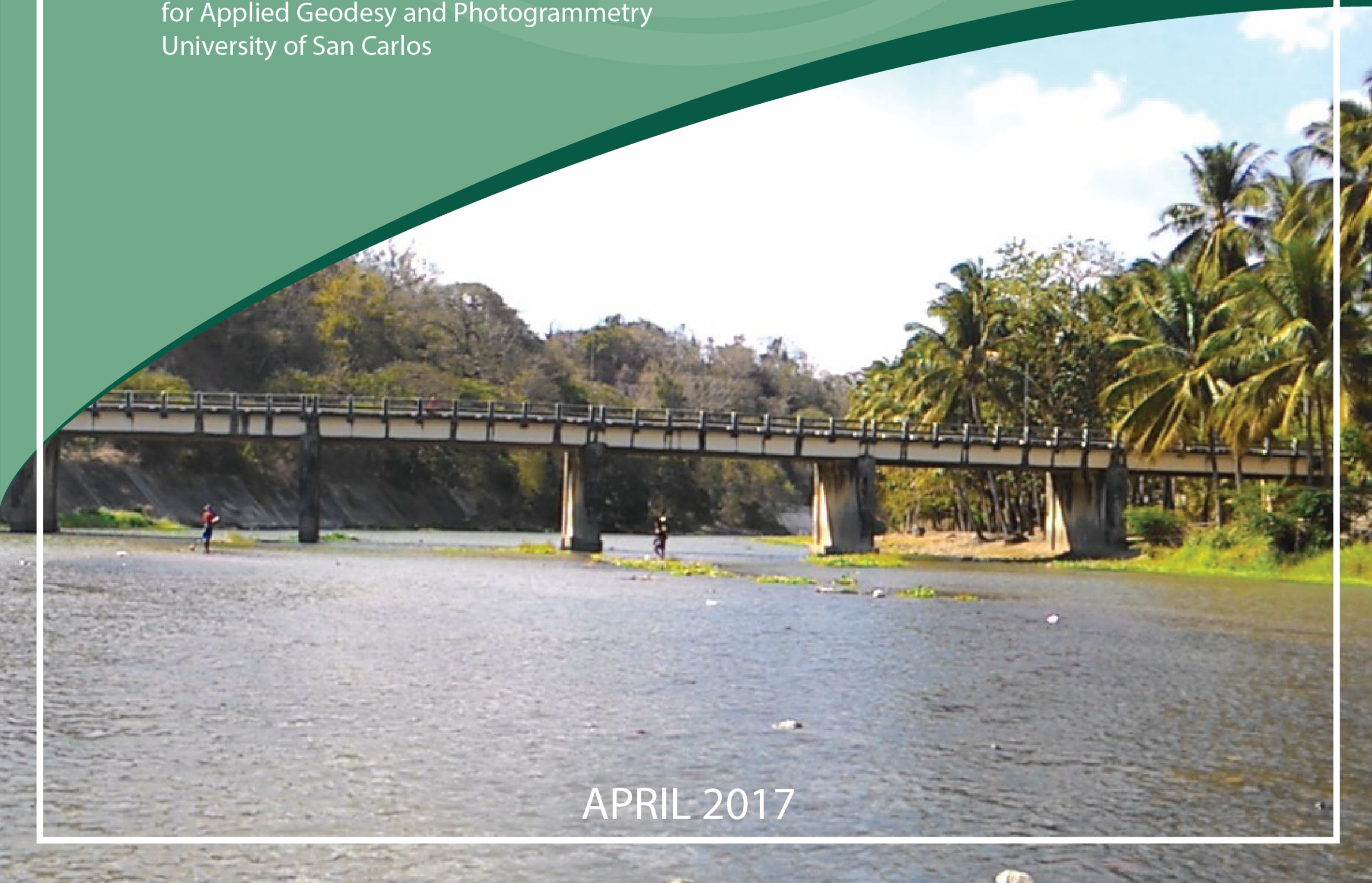
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Siaton River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of San Carlos



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SIATON RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland Emerito S. Otadoy, and Engr. Aure Flo Oraya

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos Cebu (USC). USC 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 17 river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Siaton River Basin

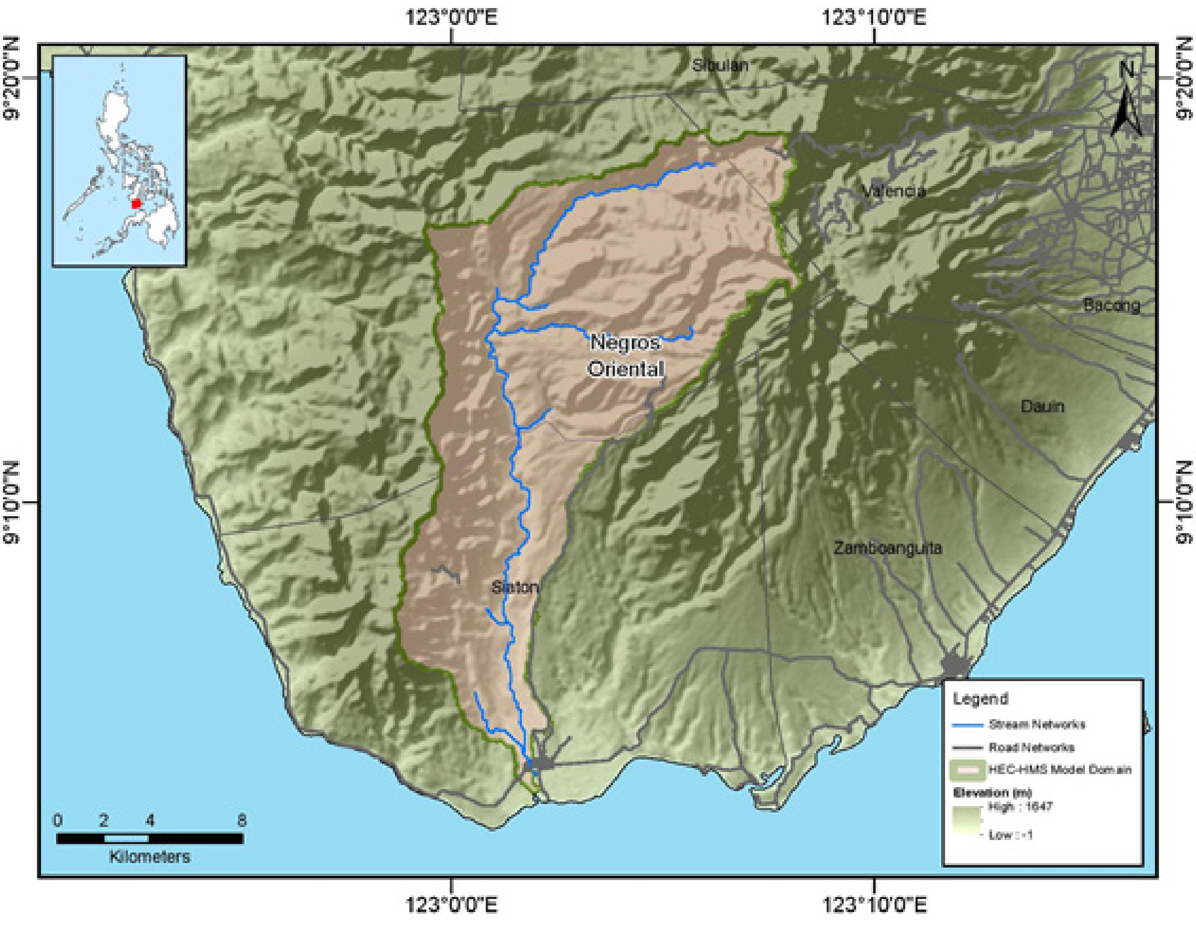

Figure 1. Map of Siaton River Basin (in brown).

The major portions of Siaton River Basin cover the Municipalities of Siaton and Sta. Catalina, and a small portion of Valencia in Negros Oriental. According to DENR -River Basin Control Office, it has a drainage area of 228 km2 and an estimated131 million cubic meter (MCM) annual run-off (RCBO, 2015).

Its main stem, Siaton River is part of the 19 river systems in Negros Island Region. According to the 2010 national census of NSO, a total of 6,377 locals reside in the immediate vicinity of the river which are distributed in Brgy. Sangke, Hinoba-an, Negros Occidental and Brgy. Bongalonan, Basay, Negros Oriental. Mat weaving is the main source of livelihood of the people of Basey. The municipality also has vast water resources where shrimps, crabs, and lobsters can be found. The major agricultural products include palay, banana, coconut, vegetables and root crops. The most recent flooding in the area was on November 2013 cause by typhoon Haiyan internationally known as “Yolanda”.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SIATON FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Siaton Floodplain in Negros Oriental. These missions were planned for 12 lines that ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the Gemini and Aquarius LiDAR systems are found in Table 1 and Table 2, respectively. Figure 2 shows the flight plans for Siaton Floodplain survey.

Table 1 Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK56A	1000	30	40	100	50	130	5
BLK56B	850, 1000	30	40, 50	100	40, 50	130	5
BLK56C	1000, 1100	30	40, 50	100, 125	40, 50	130	5
BLK56D	750, 1000, 1100	30	40, 50	100, 125	40, 50	130	5
BLK56E	1000	30	40	100	50	130	5
BLK56F	750, 1100	30	40, 50	100, 125	40, 50	130	5

Table 2 Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK56B	500	50	36	50	45	130	5
BLK56C	500	50	36	50	45	130	5
BLK56D	500	50	36	50	45	130	5
BLK56E	500	50	36	50	45	130	5
BLK56F	500	50	36	50	45	130	5

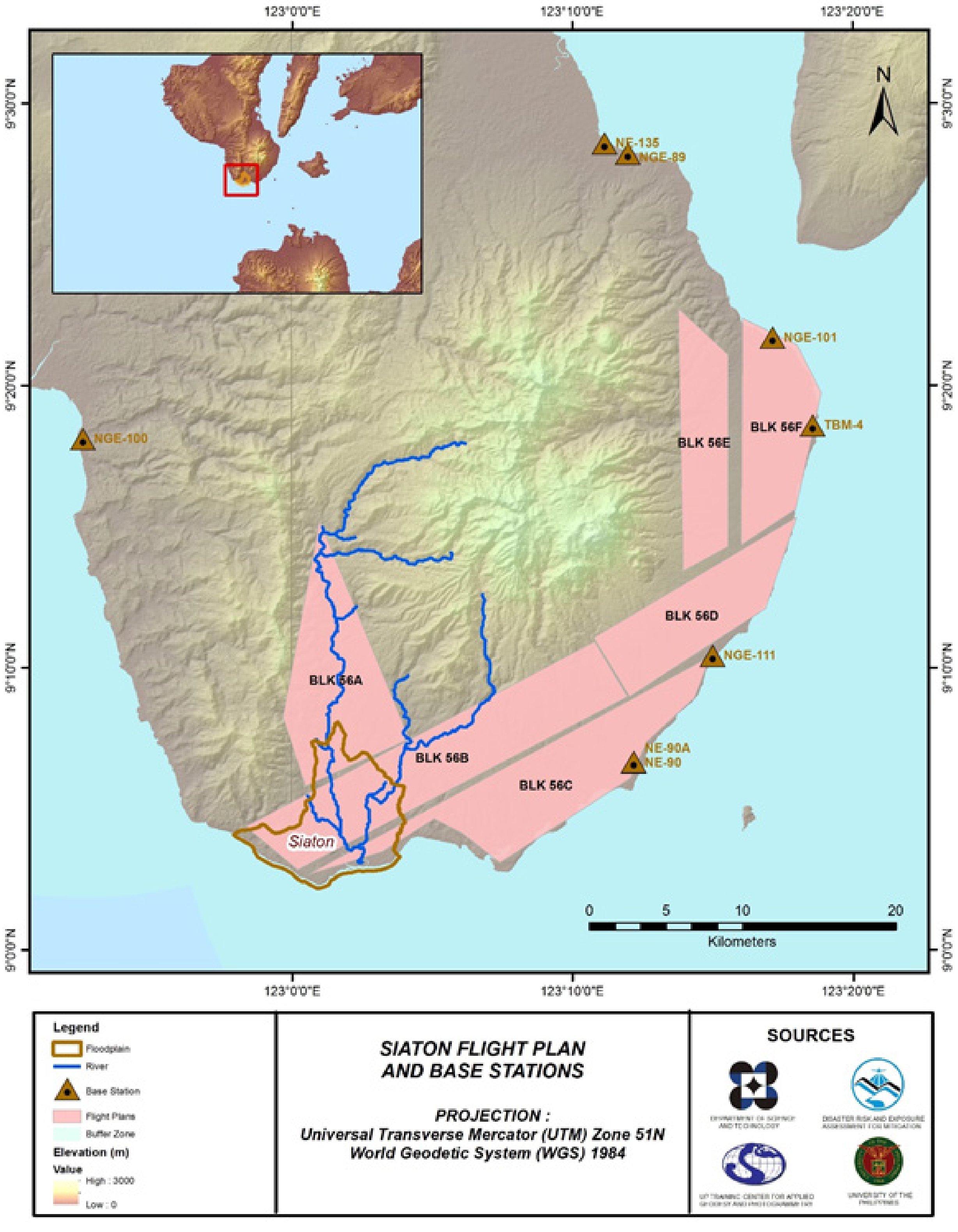


Figure 2 Flight plans and base stations used for Siaton Floodplain.

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: NGE-101, NGE-111, NGE-89, NGE-100 and NGW-126, which are all of second (2nd) order accuracy. Two (2) NAMRIA benchmarks, NE-90 and NE-135, were recovered. The project team also established two (2) ground control points: TBM-4 and NE-90A. The certification for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the benchmarks and established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (September 24 – October 28, 2014 and January 30, 2016). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852, TRIMBLE SPS 882 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Siaton Floodplain are shown in Figure 2.

Figure 3 to Figure 10 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 11 show the details about the following NAMRIA control stations, while Table 12 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3 GPS set-up over NGE-101 on the third step from the top flooring of the pier NE corner in barangay Poblacion under the municipality of Sibulan (a) and NAMRIA reference point NGE-101 (b) as recovered by the field team.

Table 3 Details of the recovered NAMRIA horizontal control point NGE-101 used as base station for the LiDAR acquisition.

Station Name	NGE-101	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°21’46.05028” North 123°17’3.45508” East 2.89700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	311,516.397 meters 1,035,718.276 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°21’42.11526” North 123°17’8.79199” East 65.25500 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	531,340.539 meters 1,034,845.884 meters

Figure 4 GPS set-up over NGE-111 as recovered on the concrete sidewalk on the NE approach of the 36 meter long Jagoba Bridge in Barangay Jagoba under the Municipality of Dauin (a) and NAMRIA reference point NGE-111 (b) as recovered by the field team.

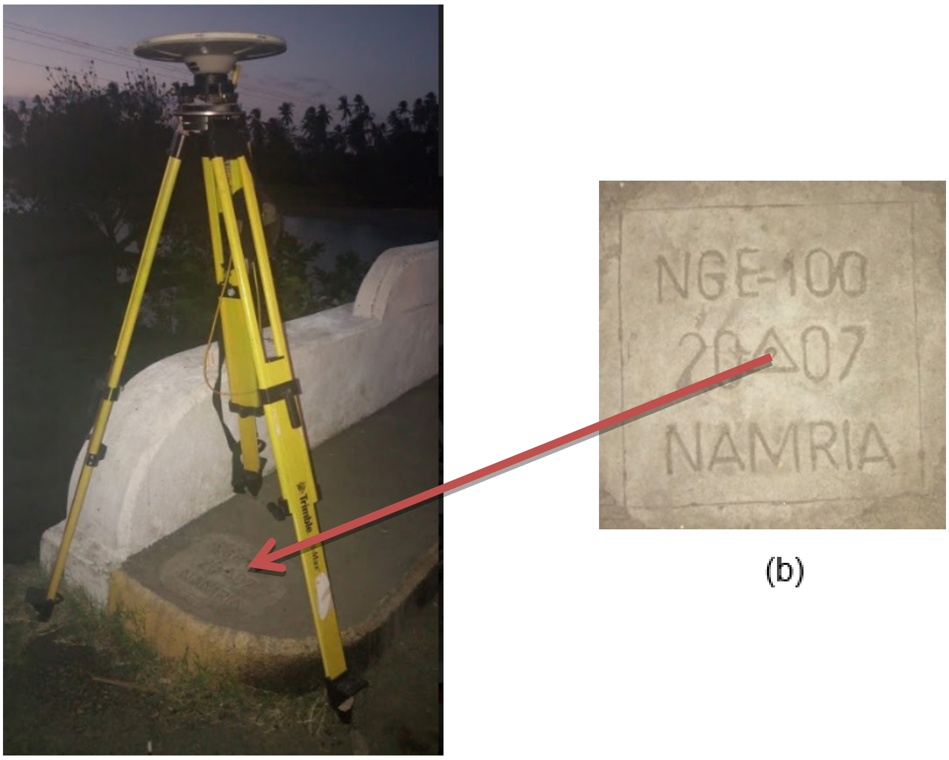
Table 4 Details of the recovered NAMRIA horizontal control point NGE-111 used as base station for the LiDAR acquisition.

Station Name	NGE-111	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 10’ 30.25228” North 123o 14’ 54.26711” East 13.11600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	307,470.632 meters 1,014,968.138 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 10’ 26.36267” North 123o 14’ 59.62110” East 75.79100 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	527,414.069 meters 1,014,090.031 meters

Figure 5 GPS set-up over NGE-89 as recovered on the SE corner of Bio-os Bridge in Barangay Bio-os under the Municipality of Amlan (a) and NAMRIA reference point NGE-89 (b) as recovered by the field team.

Table 5 Details of the recovered NAMRIA horizontal control point NGE-89 used as base station for the LiDAR acquisition.

Station Name	NGE-89	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 28' 17.93638" North 123o 11' 53.99321" East 5.92700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	302,131.943 meters 1,047,809.850 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 28' 13.96567" North 123o 11' 59.32102" East 67.20400 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	521,895.196 meters 1,046,874.129 meters



(a) (b)

Figure 6 GPS set-up over NGE-100 as recovered on the SW corner of Cawitan Bridge along the Dumaguete-Bayawan National Highway (a) and NAMRIA reference point NGE-100 (b) as recovered by the field team .

Table 6 Details of the recovered NAMRIA horizontal control point NGE-100 used as base station for the LiDAR acquisition.

Station Name	NGE-100	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 18’ 11.02881” North 122o 52’ 26.45331” East 8.14800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	486,159.164 meters 1,028,656.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 18’ 7.07298” North 122o 52’ 31.79856” East 69.61900 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	486,164.01 meters 1,028,296.07 meters

Figure 7 GPS set-up over NGW-126 as recovered on the SE corner of Maricalum Bridge which is at km 177+175 in barangay Maricalum under the municipality of Sipalay (a) and NAMRIA reference point NGW-126 (b) as recovered by the field team.

Table 7 Details of the recovered NAMRIA horizontal control point NGW-126 used as base station for the LiDAR acquisition.

Station Name	NGW-126	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 41’ 56.09927” North 122o 26’ 33.87232” East 20.29100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	219291.805 meters 1073487.816 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 41’ 52.00368” North 122o 26’ 39.18513” East 79.82600 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	438,996.109 meters 1,072,045.486 meters

Figure 8 GPS set-up over NE-90 as recovered on the concrete sidewalk of Guinsan Bridge four (4) meters from the road centerline in Barangay Poblacion under the Municipality of Zamboangita (a) and NAMRIA reference point NE-90 (b) as recovered by the field team.

Table 8 Details of the recovered NAMRIA Benchmark NE-90 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	NE-90	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 6’ 42.32060” North 123o 12’ 4.93445” East 7.358 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	302,140.874 meters 1,008,052.054 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 6’ 38.44322” North 123o 12’ 10.29457” East 70.052 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	522,126.927 meters 1,007,150.356 meters

Figure 9 GPS set-up over NE-135 as recovered in Busuang Bridge on top of concrete sidewalk in Barangay Bio-os under the Municipality of Amlan (a) and NAMRIA reference point NE-135 (b) as recovered by the field team.

Table 9 Details of the recovered NAMRIA benchmark NE-135 with processed coordinates used as base stationfor the LiDAR acquisition

Station Name	NE-135	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 28’ 39.60020” North 123o 11’ 03.44049” East 5.556 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	300,468.479 meters 1,048,547.710 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 28’ 35.62671” North 123o 11’ 08.76787” East 67.415 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	520,228.944 meters 1,047,601.845 meters

Figure 10 GPS set-up over TBM-4 on top of concrete pathway about five (5) meters from the seawall of Dumaguete City’s boulevard (a) and reference point TBM-4 (b) as established by the field team.

Table 10 Details of the established control point TBM-4 with processed coordinates used as base stationfor the LiDAR acquisition.

Station Name	TBM-4	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 18’ 39.58660” North 123o 18’ 28.47112” East 3.712 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	313,960.450 meters 1,030,039.396 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 18’ 35.66706” North 123o 18’ 33.81248” East 66.241 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	533,814.622 meters 1,029,185.290 meters

Table 11 Details of the established control point NE-90A with processed coordinates used as base station for the LiDAR acquisition.

Station Name	NE-90A	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 6' 44.56134" North 123o 12' 5.05054" East 6.617 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	522,130.430 meters 1,007,219.168 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 6' 40.68380" North 123o 12' 10.41051" East 69.311 meters

Table 12 Ground Control Points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
September 24, 2014	7514GC	2BLK56F267A	NGE-101, TBM-4
September 25, 2014	7516GC	2BLK56DC268A	NGE-111, NE-90
September 26, 2014	7518GC	2BLK56B269A	NGE-111, NE-90
October 28, 2014	7582GC	2BLK56BSES301A	NGE-89, NE-135; NGE-111, NE-90
October 28, 2014	7583GC	2BLK56ABS301B + CALIBRATION	NGE-89, NE-135; NGE-111, NE-90
January 30, 2016	10077AC	3BLK56V030B	NGE-100, NGW-126; NE-90, NE-90A

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR data acquisition in Siaton Floodplain, for a total of twenty one hours and eleven minutes (21+11) of flying time for RP-9322. The missions were acquired using the Gemini and Aquarius LiDAR systems. Table 13 shows the total area of actual coverage and the corresponding flying hours of the mission, while Table 14 presents the actual parameters used during the LiDAR data acquisition.

Table 13. Flight missions for LiDAR data acquisition in Siaton floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
September 24, 2014	7514GC	109.59	109.58	0	109.58	NA	3	47
September 25, 2014	7516GC	137.77	208.01	14.51	193.50	NA	4	5
September 26, 2014	7518GC	103.51	126.14	40.01	86.13	NA	2	59
October 28, 2014	**7582GC**	149.51	117.47	0	117.47	NA	3	23
October 28, 2014	**7583GC**	175.74	49.84	11.02	38.82	NA	3	35
TOTAL		1017.37	637.40	71.37	566.03	NA	21	11

Table 14 Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7514GC	750, 1100	30	40, 50	100, 125	40, 50	130	5
7516GC	1000, 1100	30	40, 50	100, 125	40, 50	130	5
7518GC	850, 1000	30	40, 50	100	40, 50	130	5
7582GC	1000	30	40	100	50	130	5
7583GC	1000	30	40	100	50	130	5

2.4 Survey Coverage

Siaton Floodplain is located in the province of Negros Oriental with majority of the floodplain situated within the Municipality of Siaton. Dumaguete City and the Municipality of Bacong were mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 15. The actual coverage of the LiDAR acquisition for Siaton Floodplain is presented in Figure 11.

Table 15. List of municipalities and cities surveyed during Siaton Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Negros Oriental	Dumaguete City	30.42	30.22	99.36%
	Bacong	26.07	25.68	98.49%
	Zamboanguita	152.83	113.23	74.09%
	Dauin	**80.91**	**49.8**	**61.56%**
	Siaton	**312.75**	**156.38**	**50.00%**
	San Jose	**47.09**	**19.22**	**40.81%**
	Sibulan	**165.36**	**41.29**	**24.97%**
	Valencia	**144.43**	**29.96**	**20.74%**
	Amlan	**65.67**	**1.56**	**2.37%**
Total		1025.53	467.34	45.57%

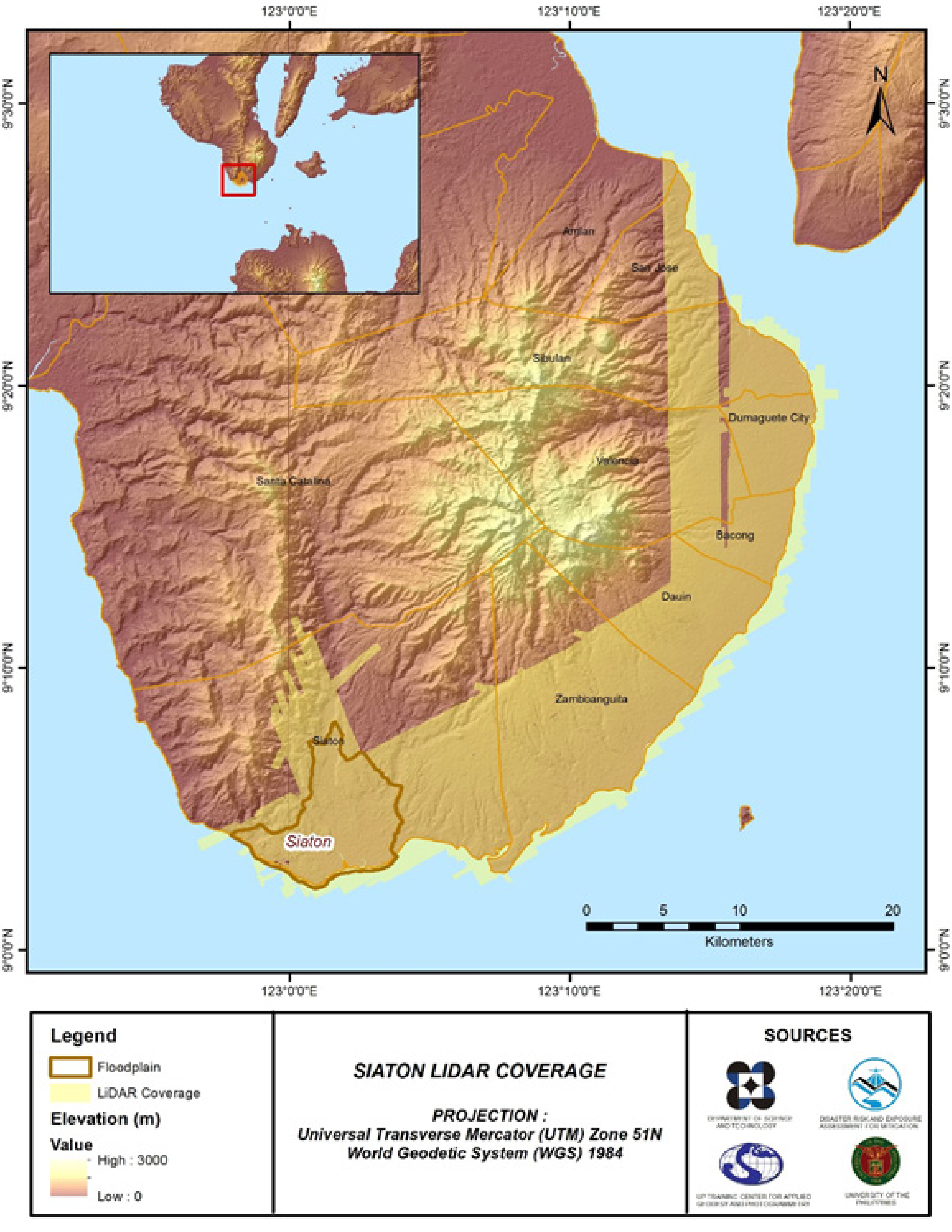


Figure 11. Actual LiDAR survey coverage for Siaton Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SIATON FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the 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 subject for quality checking 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 flow chart shown in Figure 12.

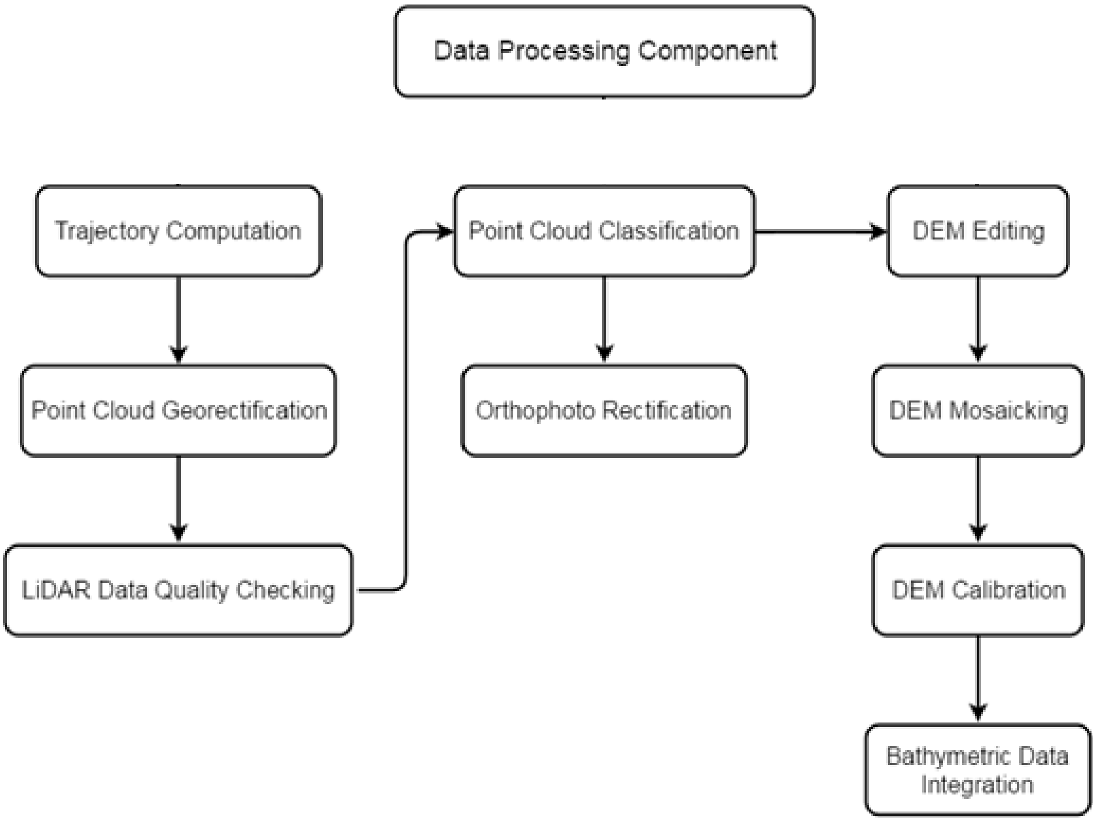


Figure 12. Schematic Diagram for Data.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Siaton Floodplain can be found in Annex 5. Missions flown during the first survey conducted on October 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the second survey on February 2016 were flown using the Aquarius system over Siaton, Negros Oriental. The Data Acquisition Component (DAC) transferred a total of 93.02 Gigabytes of Range data, 1.05 Gigabytes of POS data, 60.7 Megabytes of GPS base station data, and 34.62 Gigabytes of raw image data to the data server on November 6, 2014 for the first survey and February 9, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Siaton was fully transferred on February 9, 2016, as indicated on the Data Transfer Sheets for Siaton Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7518GC, one of the Siaton flights, which is the North, East, and Down position RMSE values are shown in Figure 13. 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 onSeptember 26, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

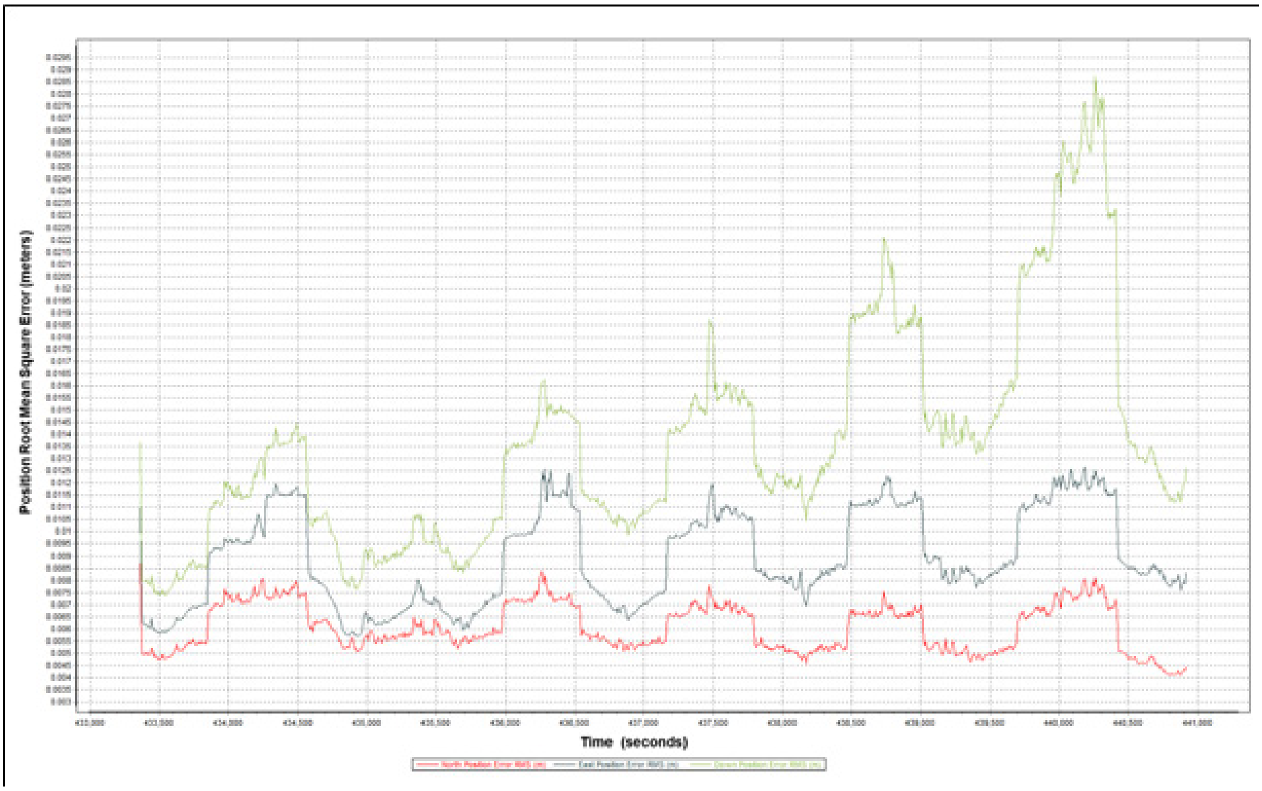


Figure 13 Smoothed Performance Metrics of a Siaton Flight 7518GC.

The time of flight was from 441,500 seconds to 451,500 seconds, which corresponds to morning of February 7, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 13 shows that the North position RMSE peaks at 0.85 centimeters, the East position RMSE peaks at 1.25 centimeters, and the Down position RMSE peaks at 2.85 centimeters, which are within the prescribed accuracies described in the methodology.

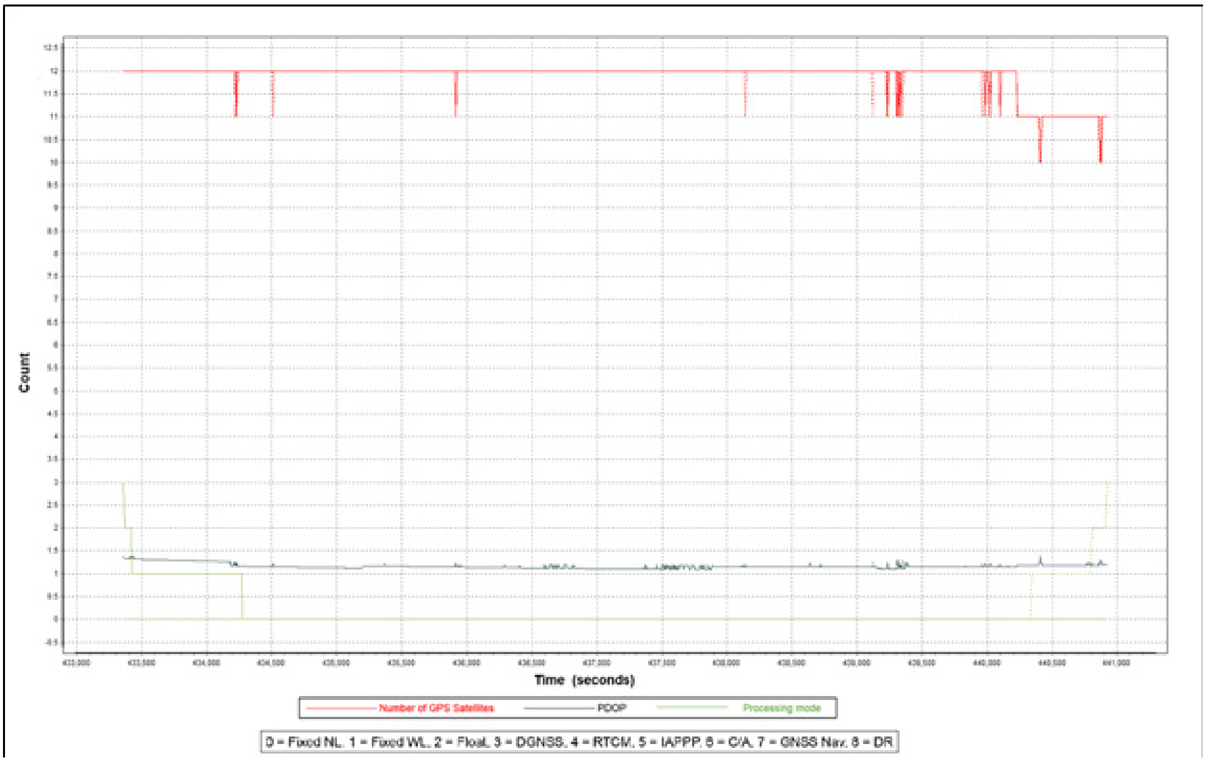


Figure 14 Solution Status Parameters of Siaton Flight 7518GC

The Solution Status parameters of flight 7518GC, one of the Siaton flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 14. The graphs indicate that the number of satellites during the acquisition did not go down to 7. Majority of the time, the number of satellites tracked was between 10 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Siaton flights is shown in Figure 15.

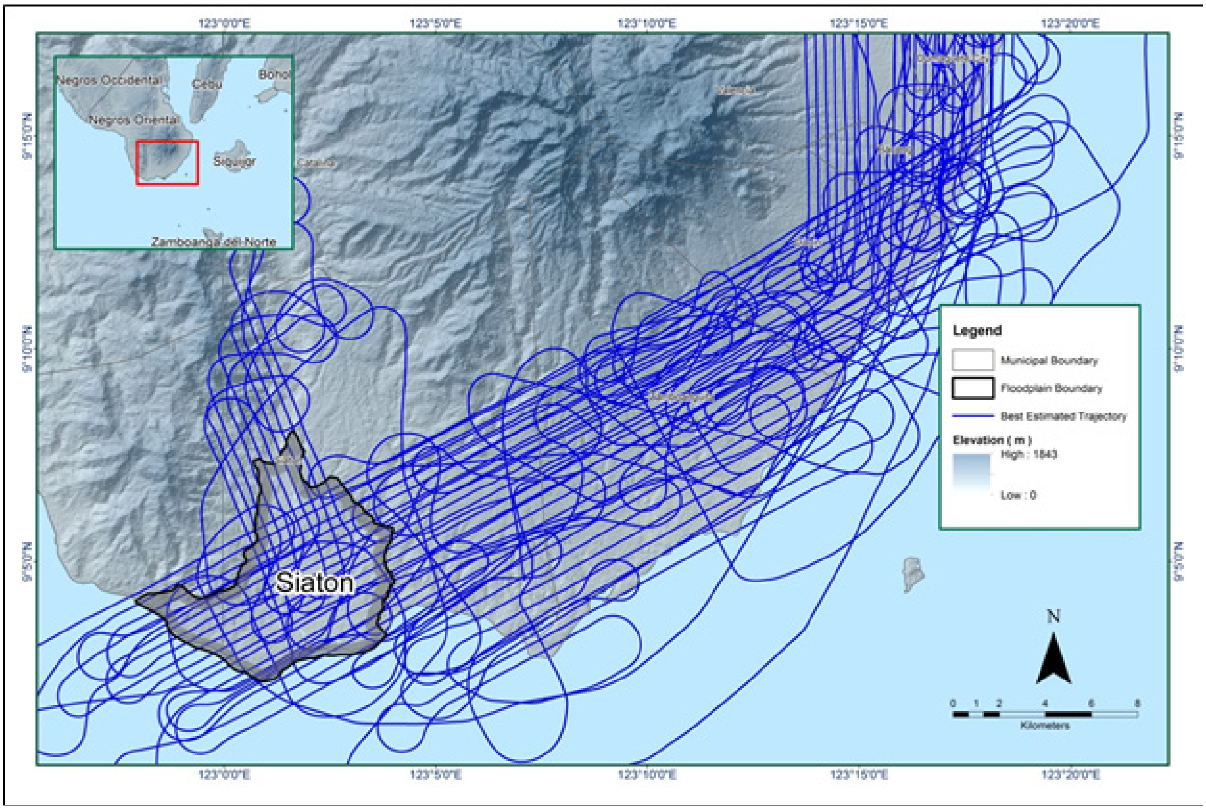


Figure 15 Best Estimated Trajectory for Siaton FloodplainFloodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 73 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 Siaton Floodplain are given in Table 16.

Table 16 Self-Calibration Results values for Siaton flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000268
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000933
GPS Position Z-correction stdev)	<0.01meters	0.0070

The optimum accuracy is obtained for all Siaton 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 Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Siaton Floodplain is shown in Figure 16. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

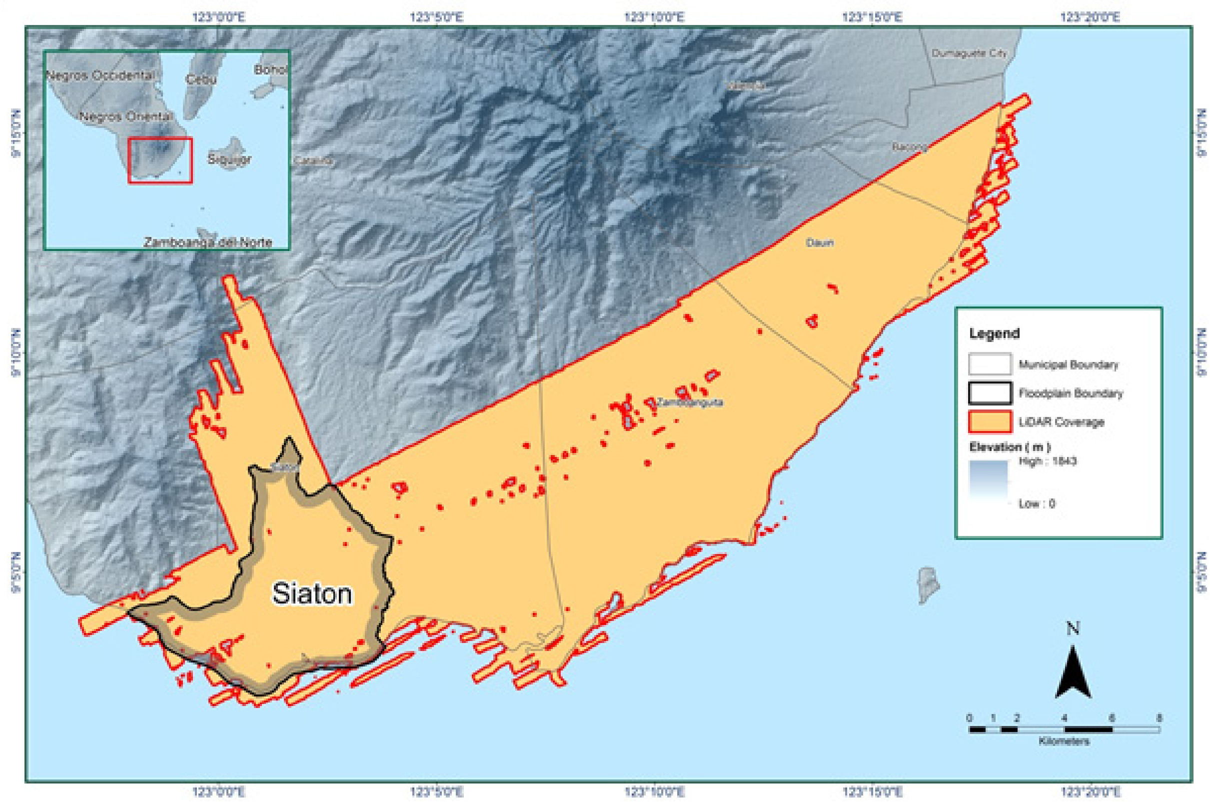


Figure 16 Boundary of the processed LiDAR data over Siaton Floodplain.

The total area covered by the Siaton missions is 377.97 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 17.

Table 17 List of LiDAR blocks for Siaton Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Dumaguete_Blk56A	7583G	37.82
Dumaguete_Blk56B	7518G	128.76
	7582G	
	7583G	
Dumaguete_Blk56CD	7516G	191.98
	7514G	
Dumaguete_reflight_Blk56C	**10077AC**	**19.41**
TOTAL		**377.97 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 17. Since the Gemini and Aquarius systems both employ one channel, an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines is expected.

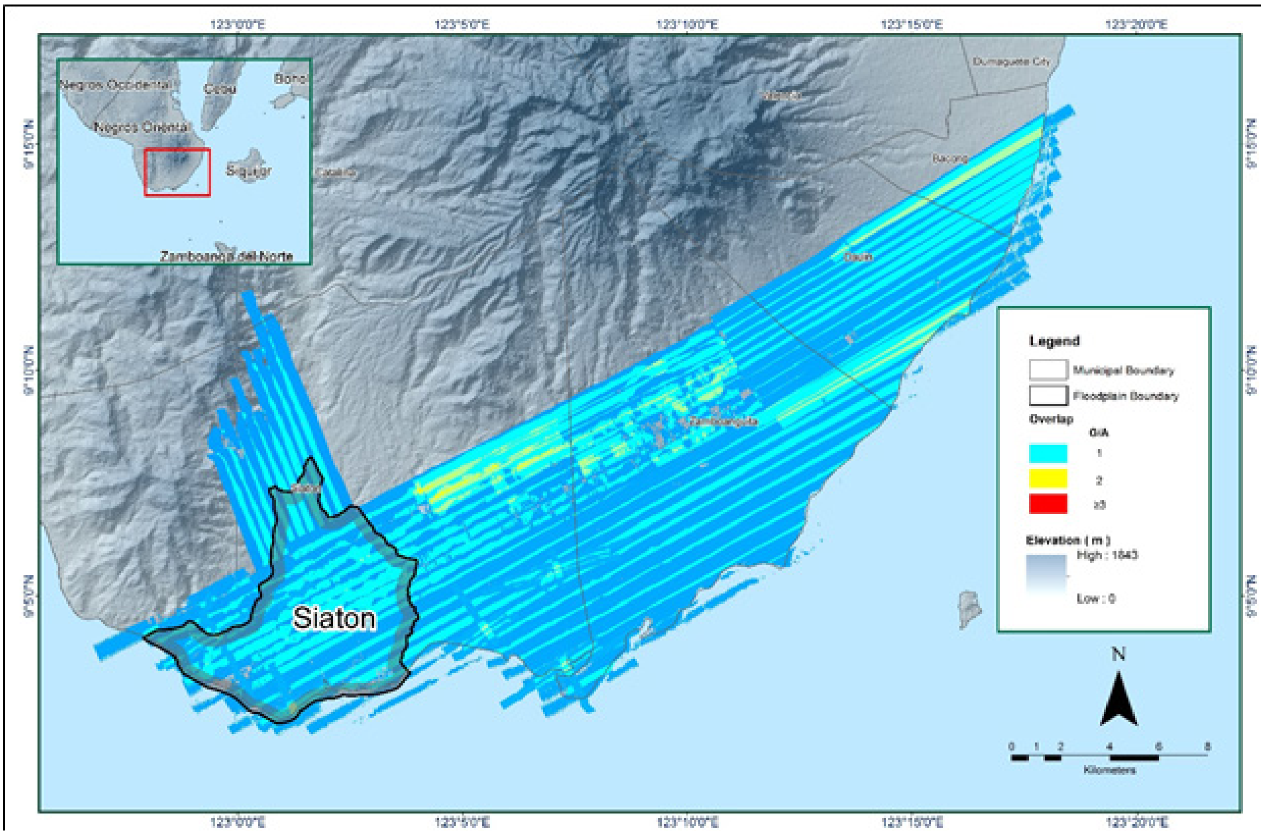


Figure 17 Image of data overlap for Siaton Floodplain

The overlap statistics per block for the Siaton Floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 30.09% and 48.38% 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 18. It was determined that all LiDAR data for Siaton Floodplain satisfied the point density requirement, and the average density for the entire survey area is 3.95 points per square meter.

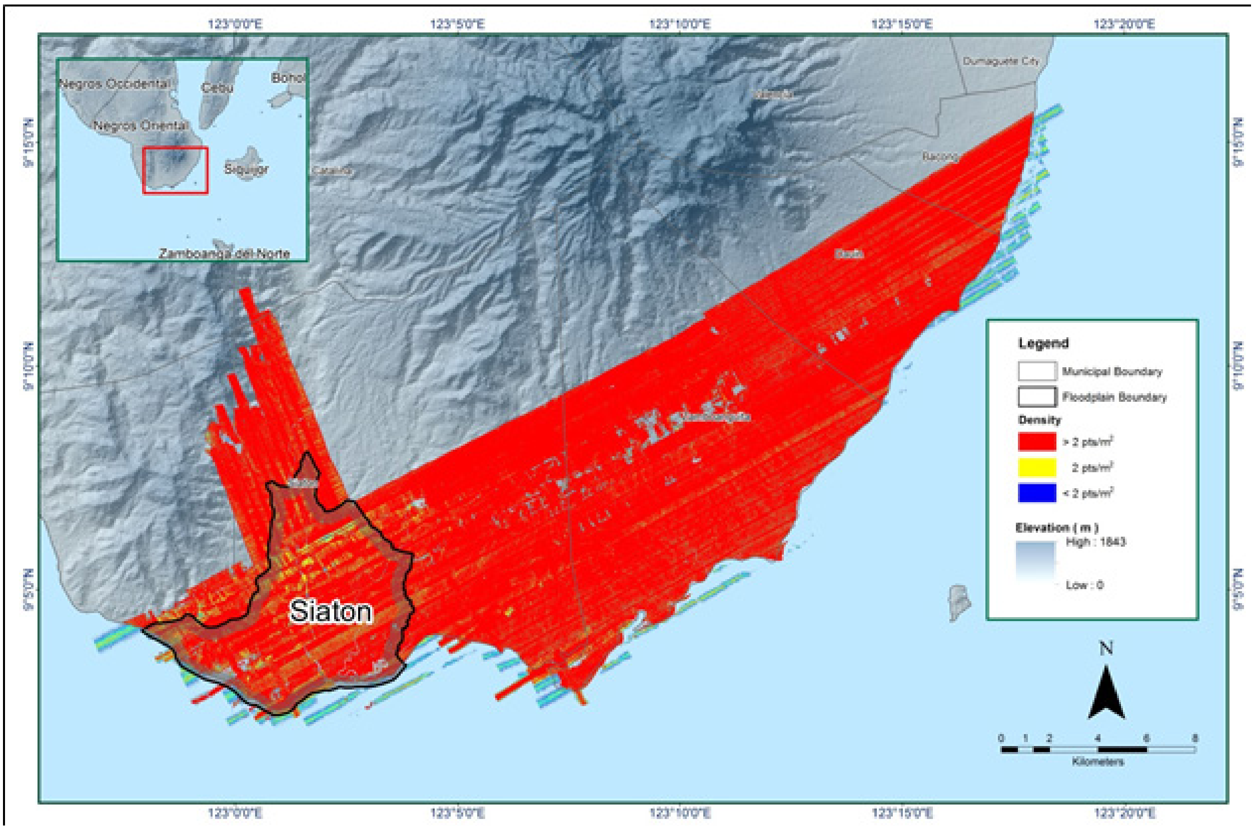


Figure 18 Pulse density map of merged LiDAR data for Siaton Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 19. 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 0.20 m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m 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.

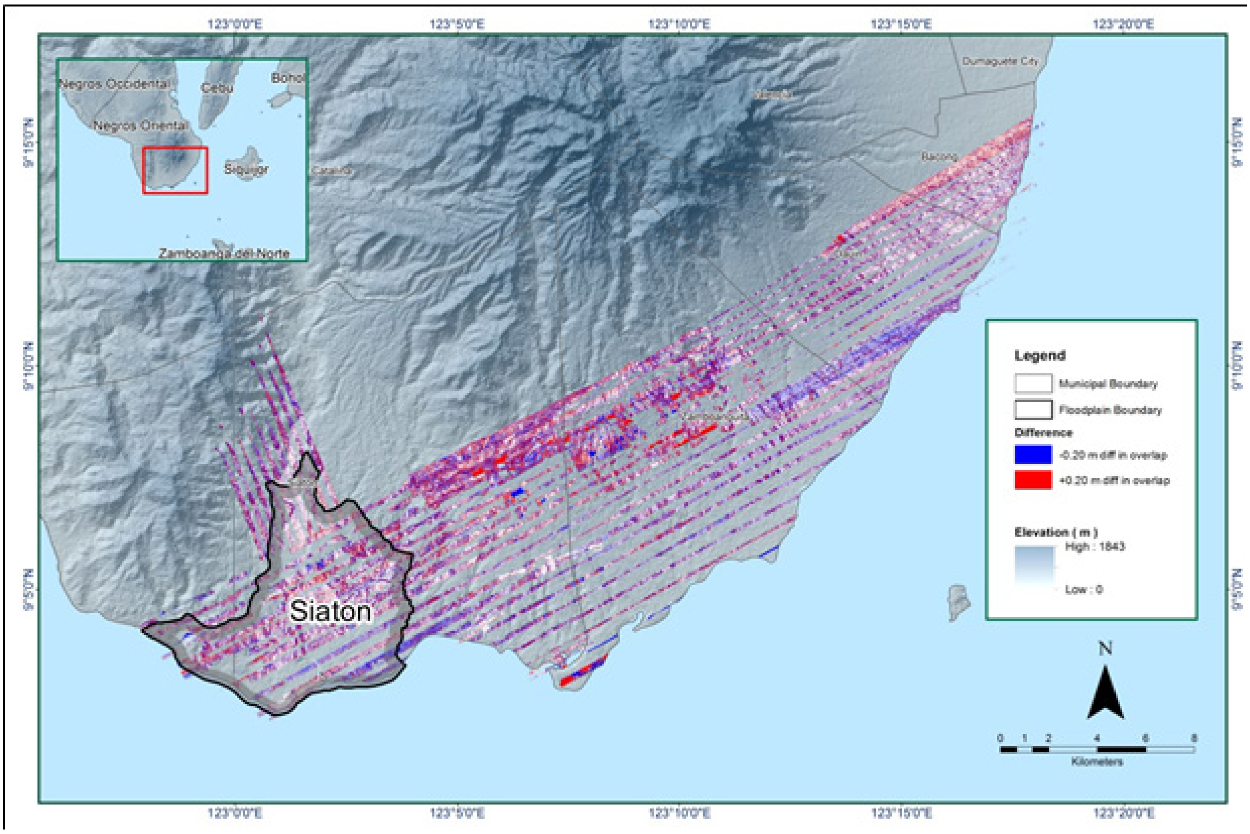


Figure 19 Elevation difference map between flight lines for Siaton Floodplain.

A screen capture of the processed LAS data from a Siaton flight 7518GC loaded in QT Modeler is shown in Figure 20. 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 was evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

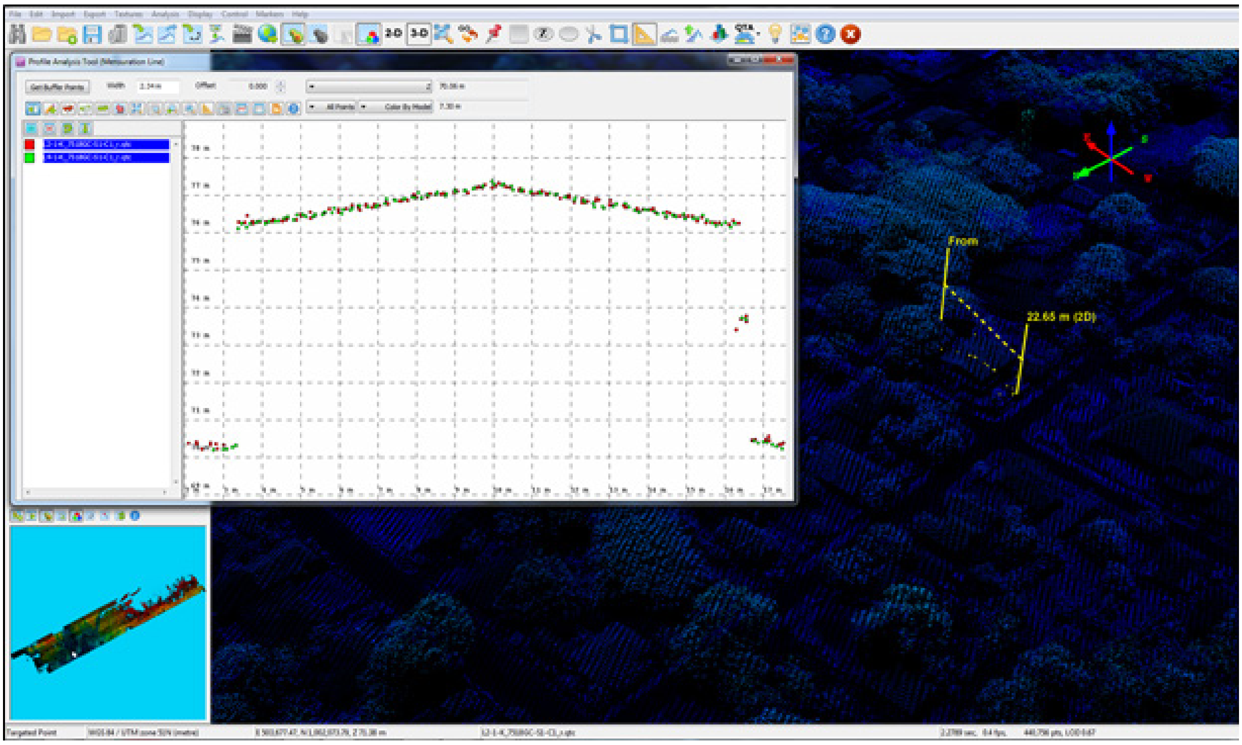


Figure 20 Quality checking for a Siaton flight 7518GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 18. Siaton classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	165,834,042
Low Vegetation	166,420,211
Medium Vegetation	509,783,875
High Vegetation	448,392,114
Building	65,348,371

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Siaton Floodplain is shown in Figure 21. A total of 600 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 18. The point cloud had a maximum and minimum height of 766.06 meters and 22.69 meters respectively.

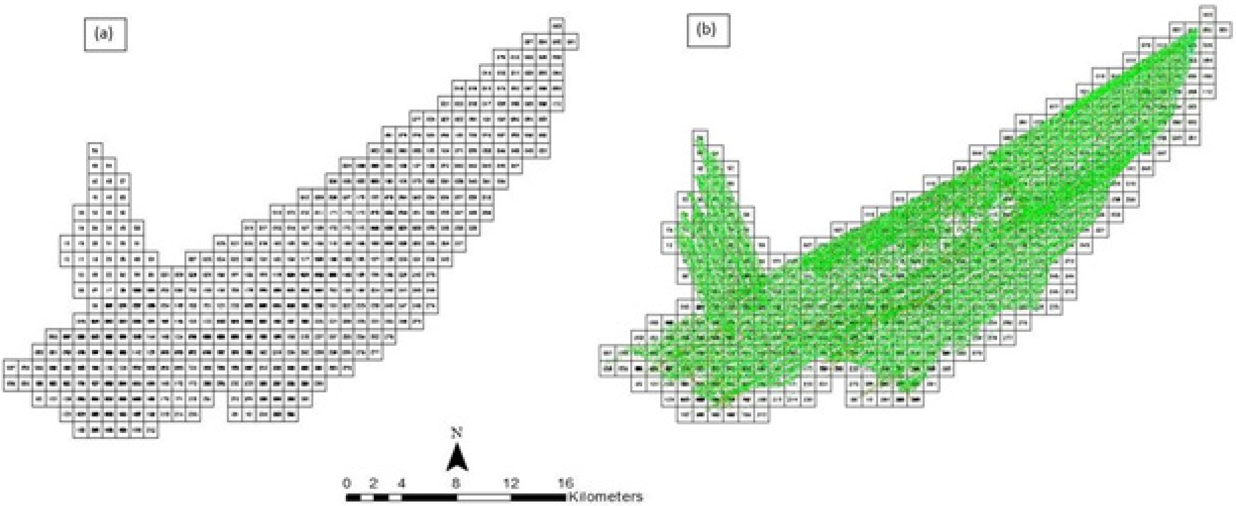


Figure 21. Tiles for Siaton Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 22. 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.

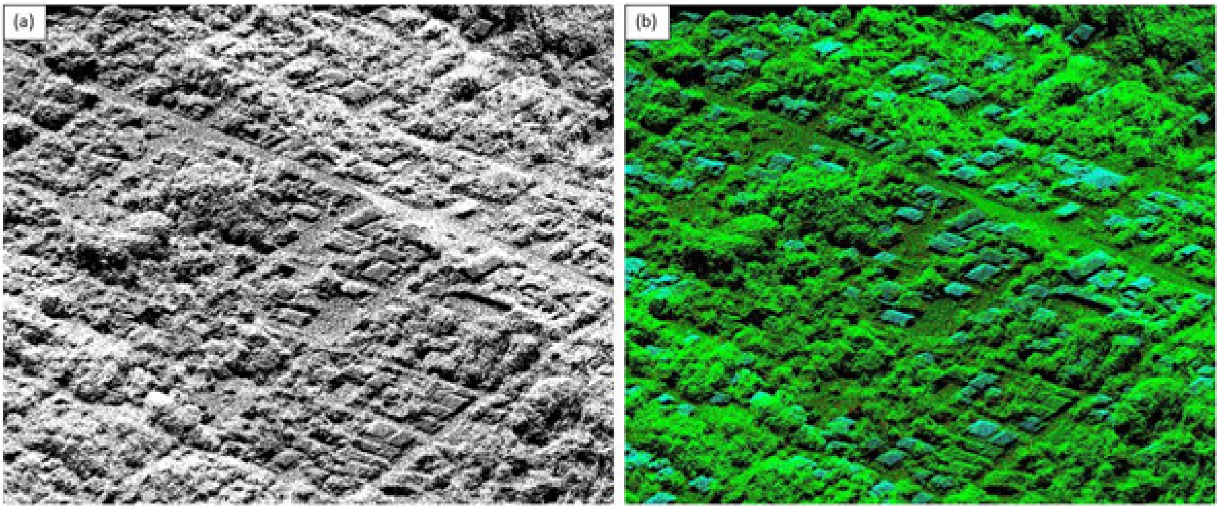


Figure 22 Point cloud before (a) and after (b) classification.

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

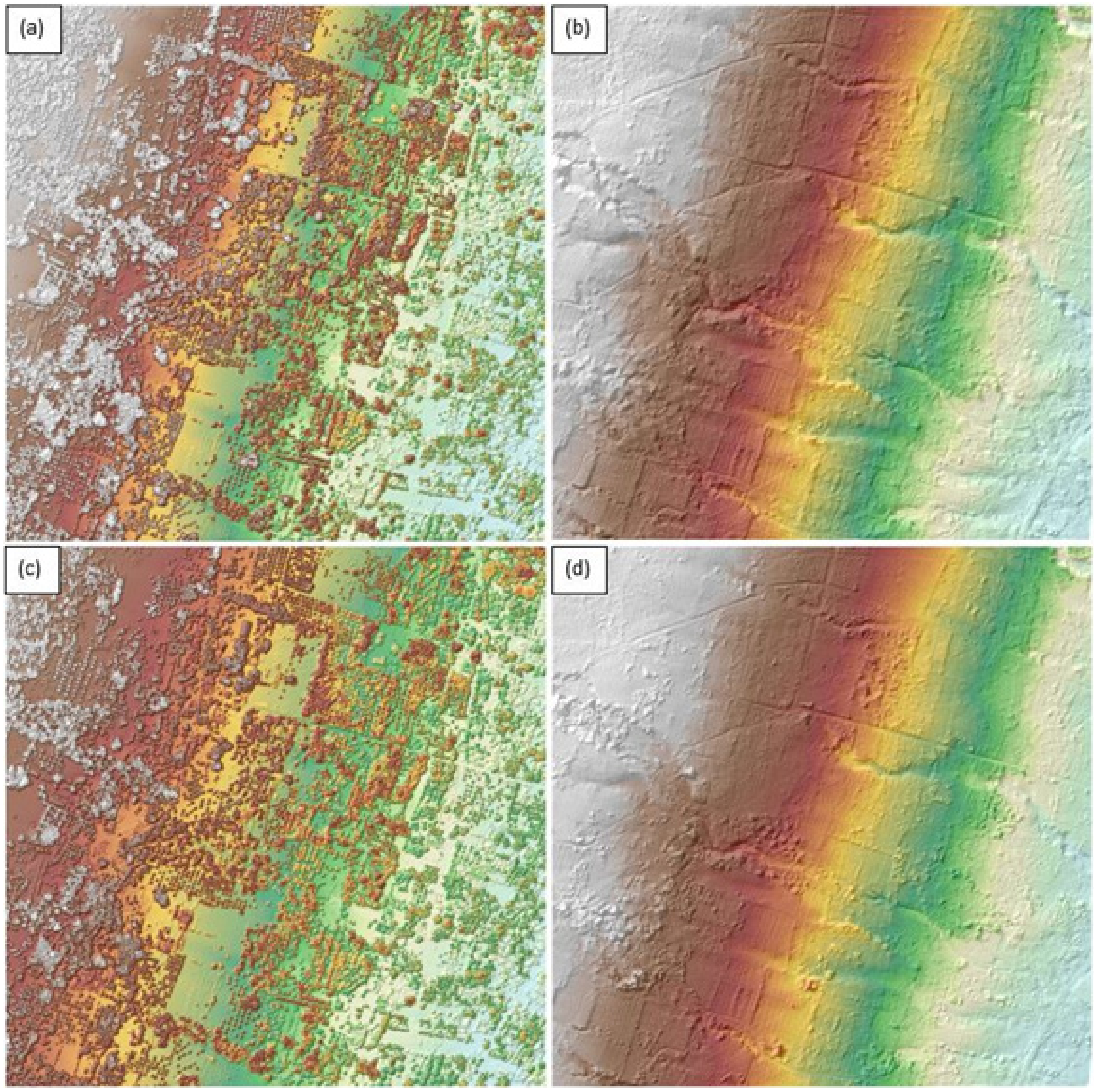


Figure 23 The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Siaton Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Siaton Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Siaton Floodplain. These blocks are composed of Dumaguete and Dumaguete_reflights blocks with a total area of 377.97 square kilometers. Table 19 shows the name and corresponding area of each block in square kilometers.

Table 19. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
Dumaguete_Blk56A	37.82
Dumaguete_Blk56B	128.76
Dumaguete_Blk56CD	191.98
Dumaguete_reflight_Blk56C	19.41
TOTAL	377.97 sq.km

Portions of DTM before and after manual editing are shown in Figure 24. The interpolated area (Figure 24a) had been misclassified during classification process and had to be retrieved to complete the surface (Figure 24b). The bridge (Figure 24c) was also considered to be an impedance to the flow of water and had to be removed (Figure 24d) in order to hydrologically correct the river. These are shown in the figure below.

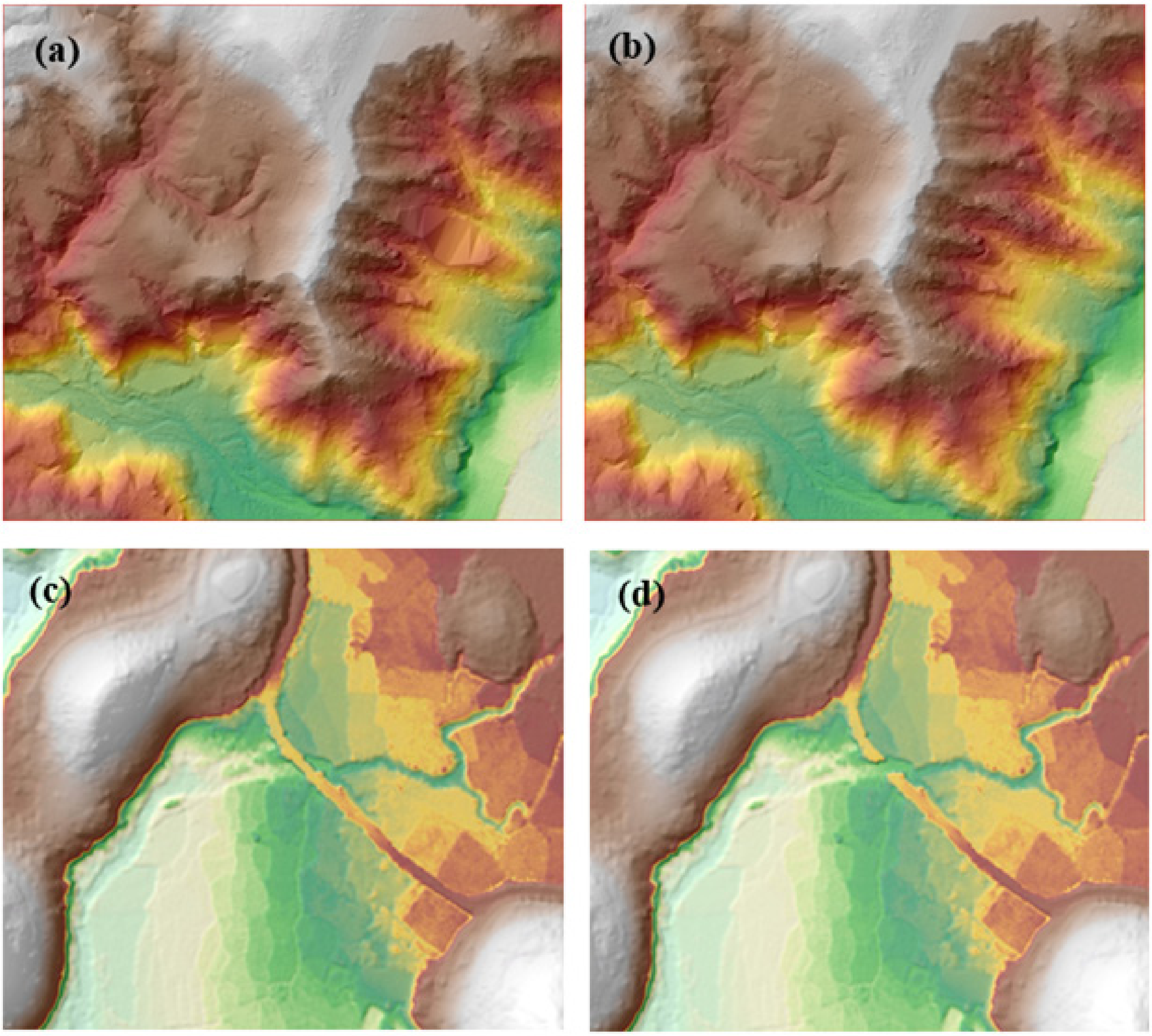


Figure 24 Portions in the DTM of Siaton Floodplain – (a) before and (b) after object retrieval; (c) before and (d) after manual editing.

3.9 Mosaicking of Blocks

Dumaguete_reflights_Blk56D was used as the reference block at the start of mosaicking due to the presence of more fixed built-up areas like roads on the flight block compared to the other. Table 20 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Siaton Floodplain shown in Figure 25. It can be seen that the entire Siaton Floodplain is 100% covered by LiDARdata.

Table 20 Shift Values of each LiDAR Block of Siaton Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Dumaguete_Blk56A	0.00	0.00	-0.92
Dumaguete_Blk56B	0.00	0.00	-0.47
Dumaguete_Blk56CD	0.00	0.00	-0.22
Dumaguete_reflight_Blk56C	0.00	0.00	0.57

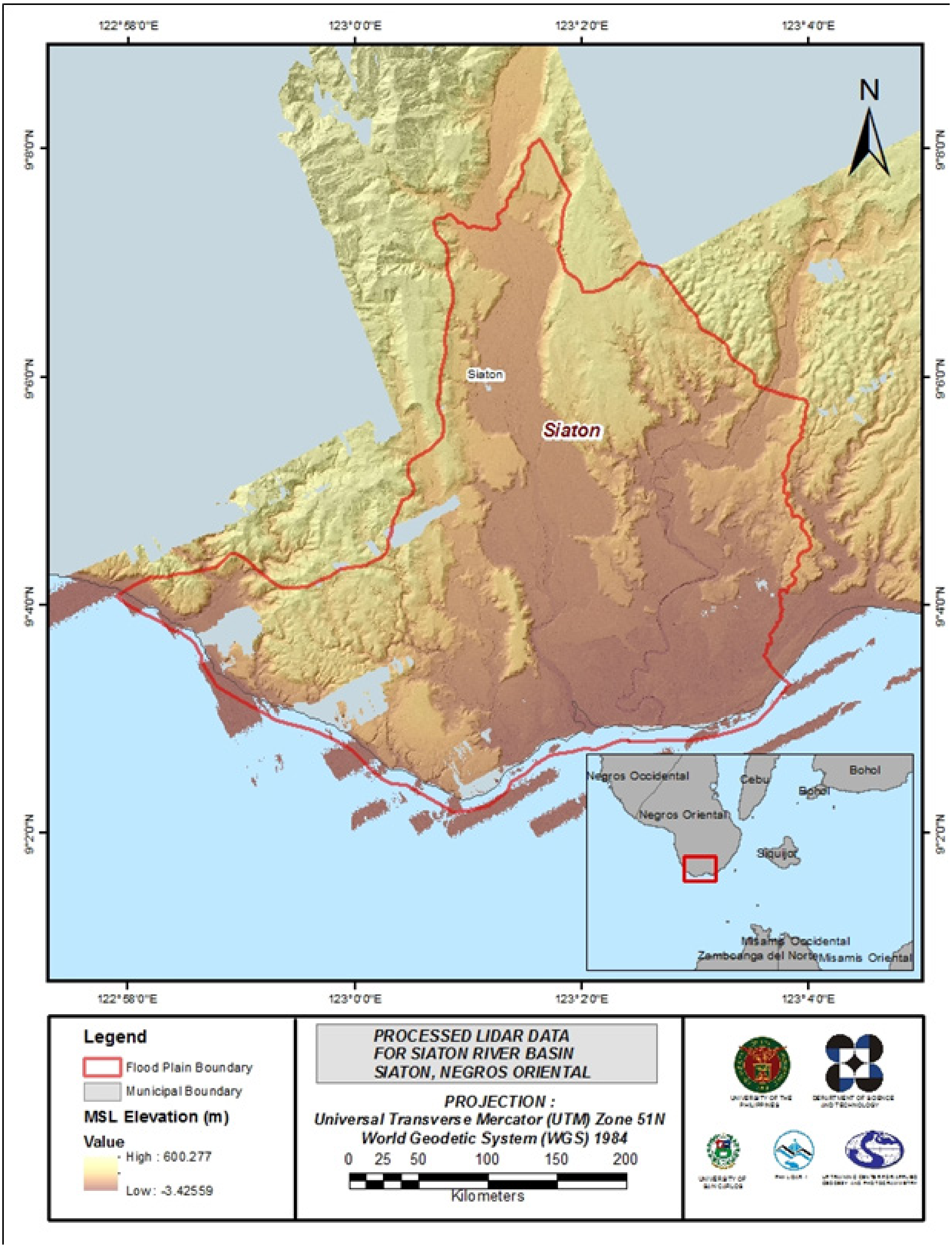


Figure 25 Map of Processed LiDAR Data for Siaton Floodplain.

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 Siaton to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 14,047 survey points were gathered for all the flood plains within the provinces of Negros Oriental and Negros Occidental wherein the Siaton floodplain is located. Random selection of 80% of the survey points, resulting to 11,237 points, was used for calibration.

A good correlation between the uncalibrated mosaicked 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 0.35 meters with a standard deviation of 0.18 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 0.35 meters, to the mosaicked LiDAR data. Table 21 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

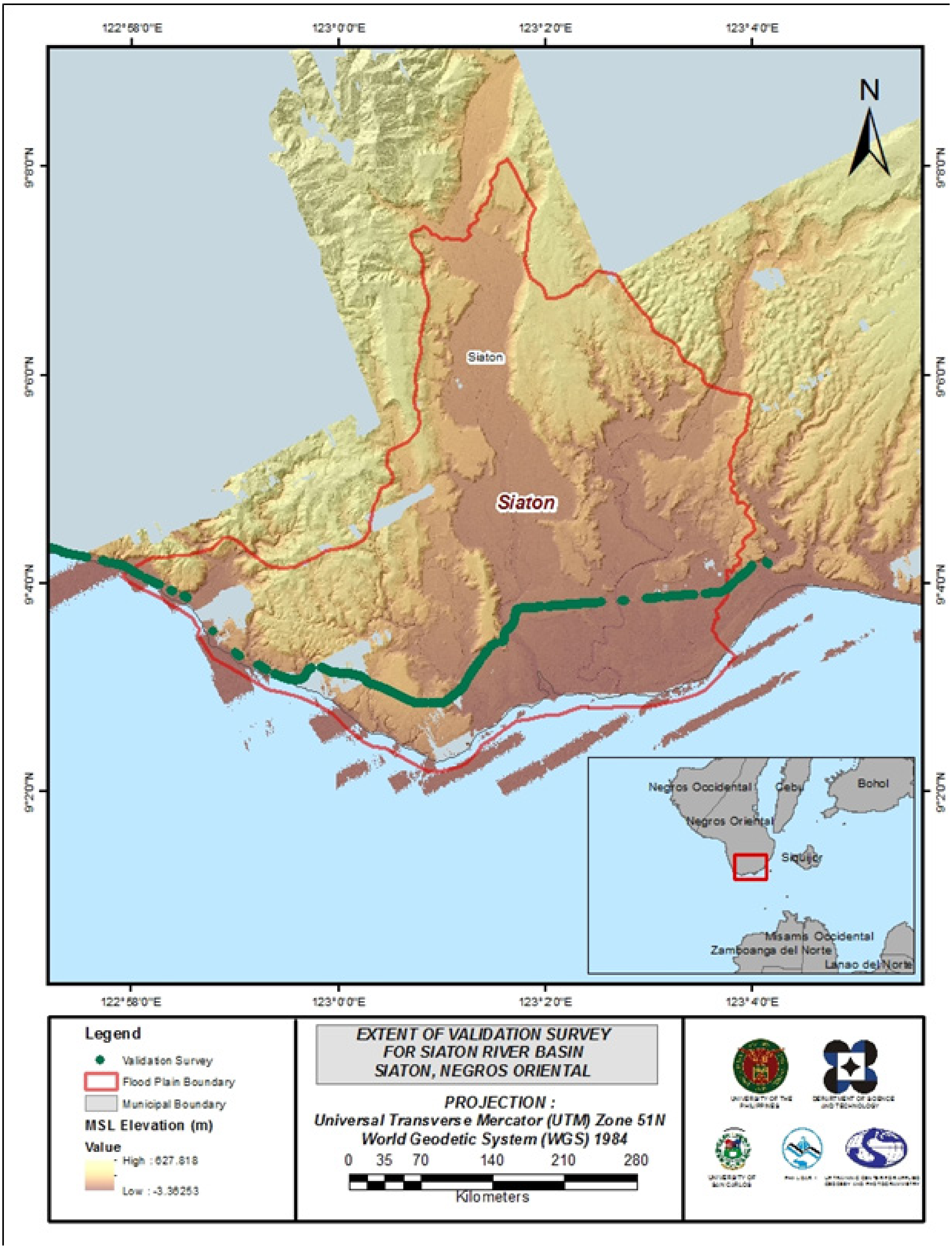


Figure 26 Map of Siaton Floodplain with validation survey points in green.

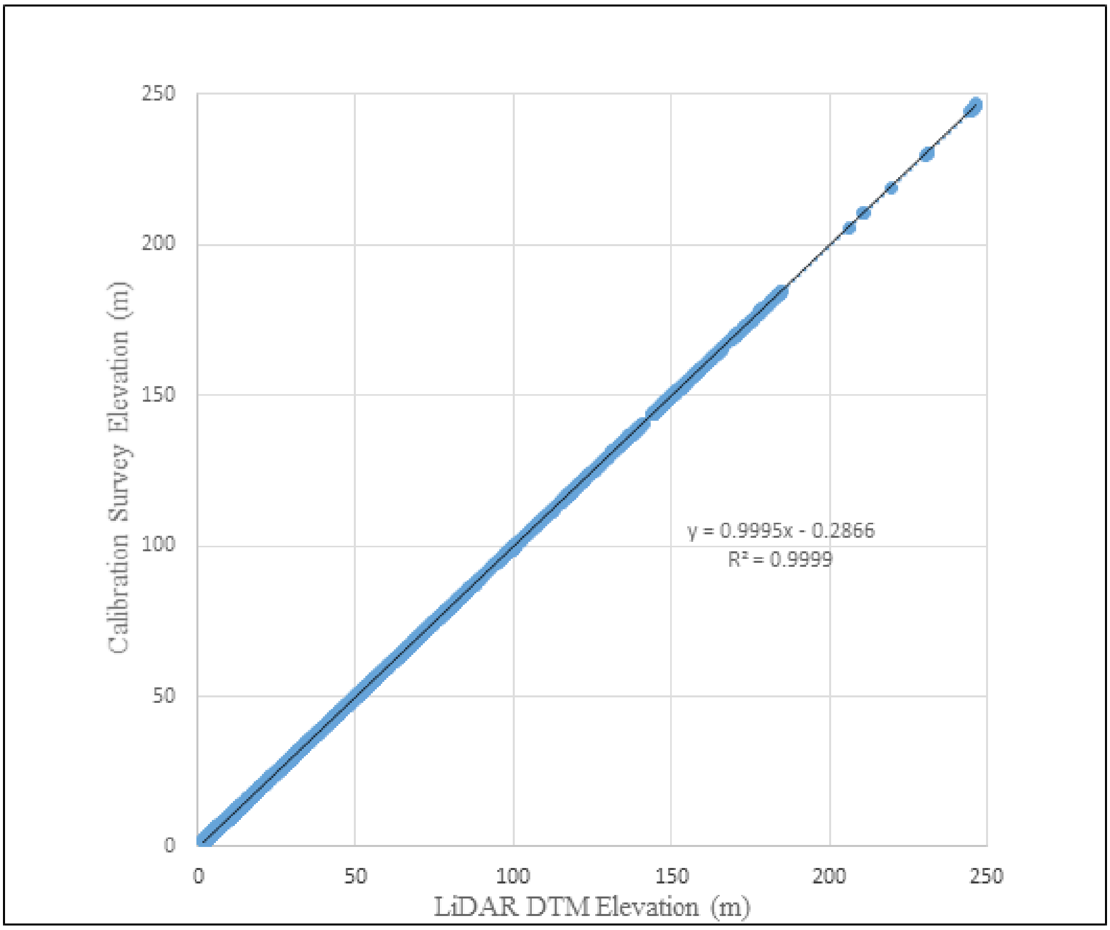


Figure 27 Correlation plot between calibration survey points and LiDAR data.

Table 21 Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.35
Standard Deviation	0.18
Average	-2.30
Minimum	-0.57
Maximum	0.30

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 231 points, were used for the validation of calibrated Siaton 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 0.19 meters with a standard deviation of 0.13 meters, as shown in Table 22.

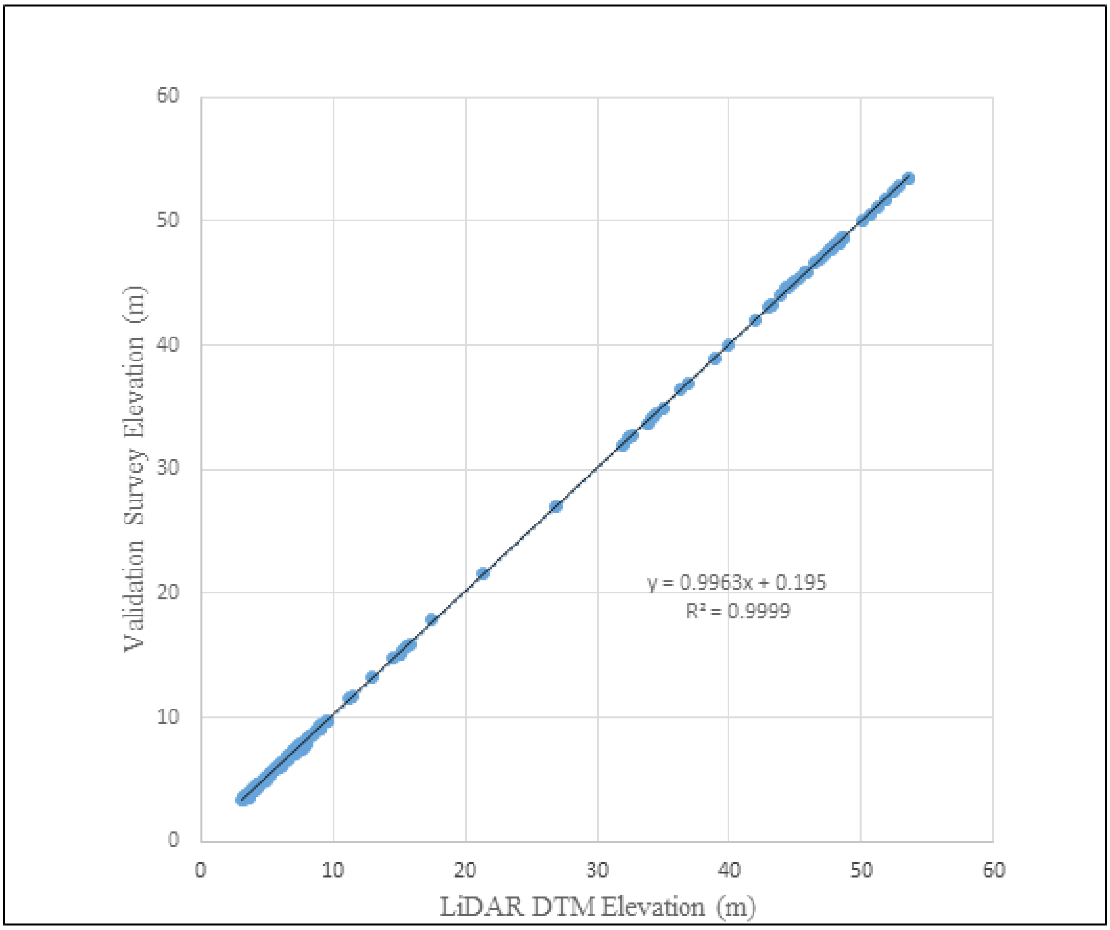


Figure 28 Correlation plot between validation survey points and LiDAR data.

Table 22 Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.13
Average	0.14
Minimum	-0.19
Maximum	0.39

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Siaton with 947 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface was represented by the computed RMSE value of 0.07 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Siaton integrated with the processed LiDAR DEM is shown in Figure 29.

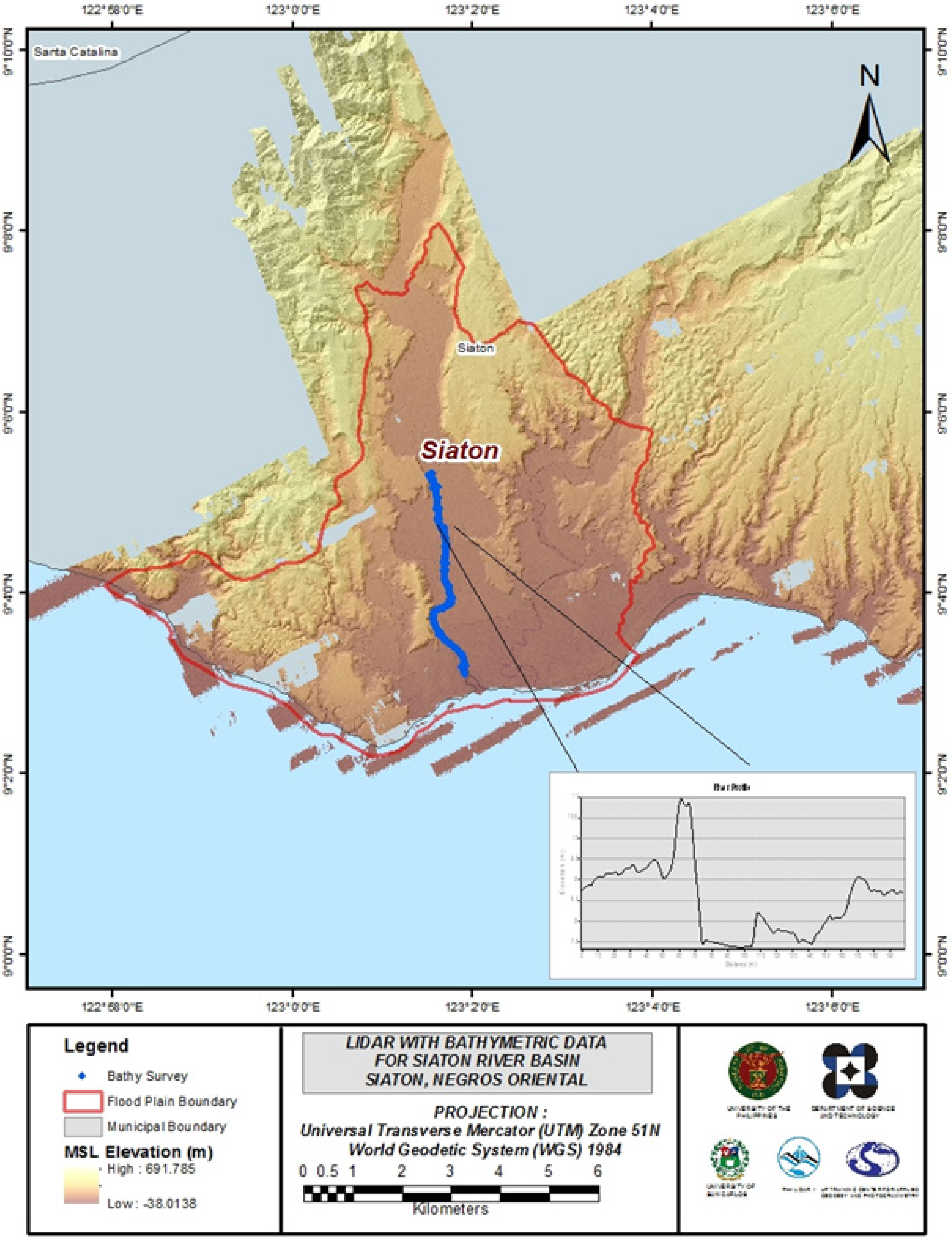


Figure 29 Map of Siaton Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Siaton Floodplain, including its 200 m buffer, has a total area of 64.23 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 712 building features, were considered for QC. Figure 30 shows the QC blocks for Siaton Floodplain.

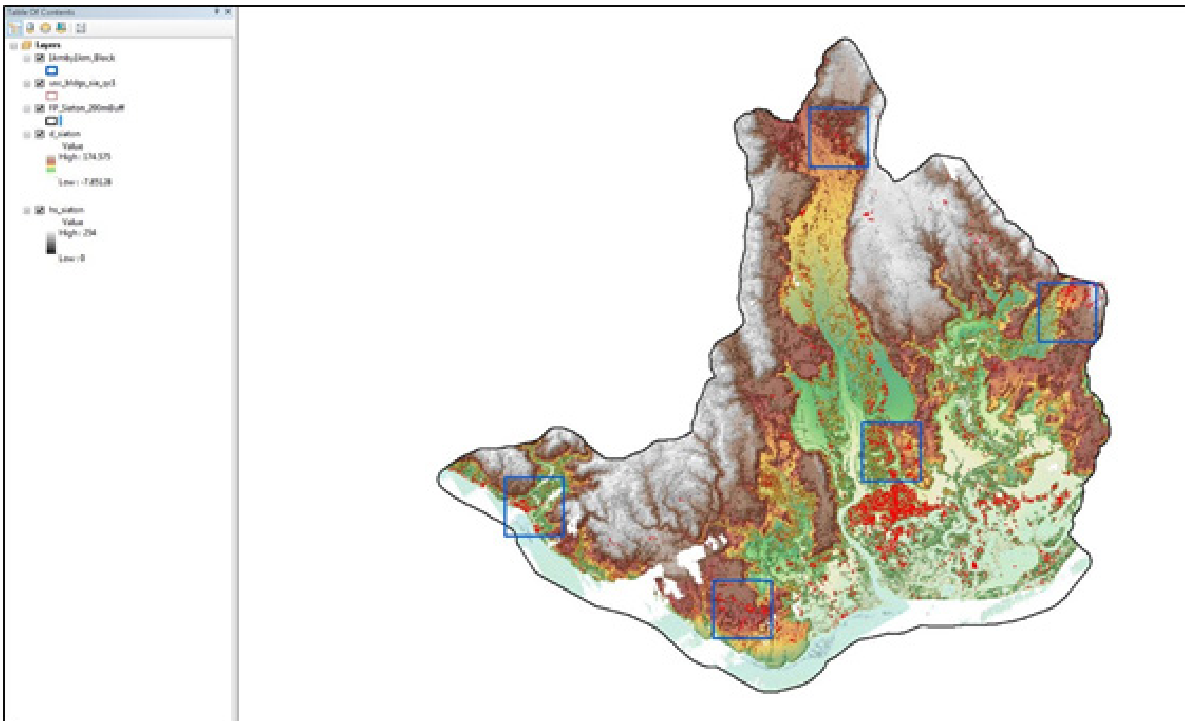


Figure 30 QC blocks for Siaton building features

Quality checking of Siaton building features resulted in the ratings shown in Table 23.

Table 23 Quality Checking Ratings for Siaton Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Siaton	99.86	100.00	82.44	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,532 building features in Siaton Floodplain. Of these building features, 203 were filtered out after height extraction, resulting to 4,329 buildings with height attributes. The lowest building height was at 2.00 m, while the highest building was at 13.00 m.

3.12.3 Feature Attribution

In attribution, combination of participatory mapping and actual field validation was done. Representatives from LGU were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

Table 24 summarizes the number of building features per type. On the other hand, Table 25 shows the total length of each road type, while Table 26 shows the number of water features extracted per type.

Table 24 Building Features Extracted for Siaton Floodplain.

Facility Type	No. of Features
Residential	4,225
School	50
Market	4
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	3
Barangay Hall	4
Military Institution	0
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	0
Transport Terminal	4
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	6
Bank	1
Factory	5
Gas Station	1
Fire Station	0
Other Government Offices	1
Other Commercial Establishments	14
Total	**4,329**

Table 25 Total Length of Extracted Roads for Siaton Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Siaton	15.82	41.14	0.00	11.52	0.00	8.48

Table 26 Number of Extracted Water Bodies for Siaton Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Siaton	17	0	0	0	3	20

A total of 5 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

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

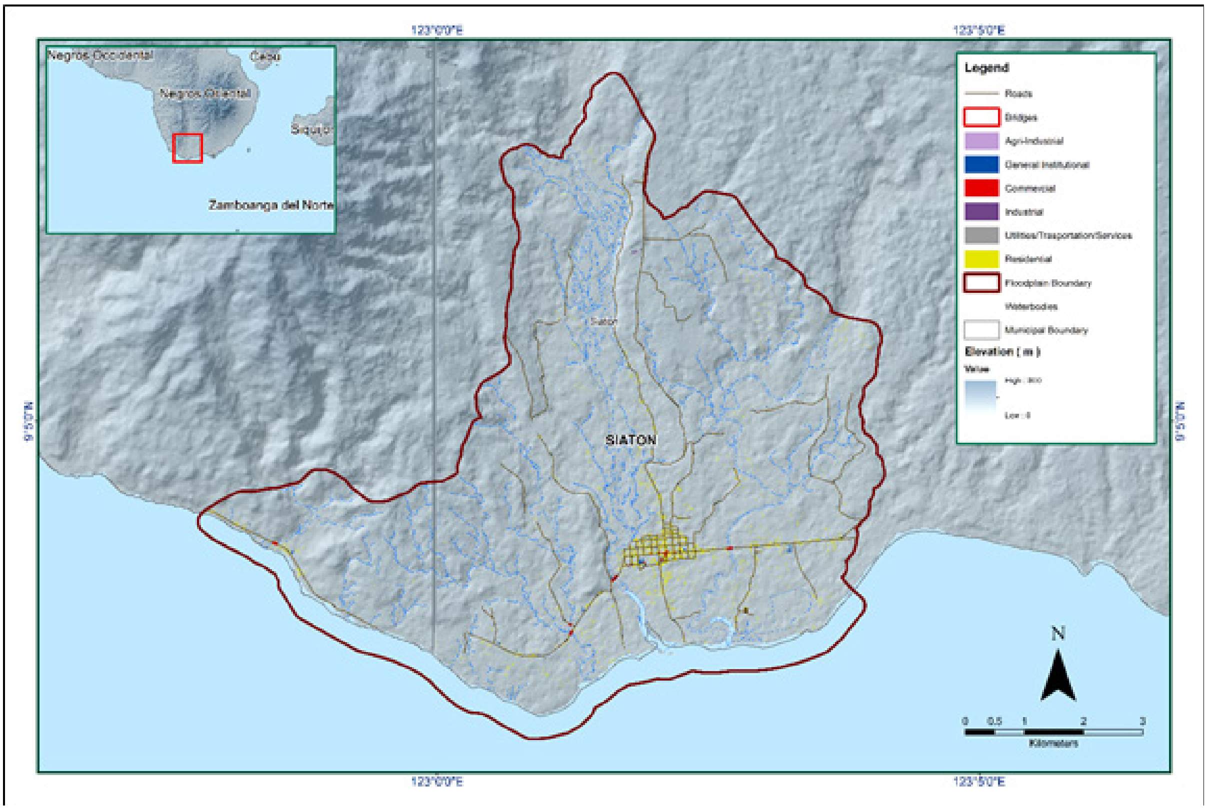


Figure 31 Extracted features for Siaton Floodplain.

CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE SIATON RIVER BASIN

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Siaton River on March 9 to 23, 2016 with the following scope of work: reconnaissance; control survey; cross-section and bridge as-built survey of Siaton Bridge located in Barangay Caticugan, Siaton, Negros Oriental; LiDAR Validation point acquisition of about 45 km covering the survey area; and bathymetric survey from upstream in Brgy. Caticugan down to the mouth of the river in Brgy. Mantuyop, Municipality of Siaton, with an approximate length of 4.780 km using Trimble® SPS 882 GNSS PPK survey technique (Figure 32).

Figure 32 Survey extent for Siaton River Basin.

4.2 Control Survey

The GNSS network used for Siaton River Basin is composed of three (3) loops established on March 11, 2016 occupying the following reference points: NGE-98, a second-order GCP, in Brgy. Caranoche, Municipality of Santa Catalina; NGE-107, a second-order GCP, in Brgy. Manalongon, also in Municipality of Santa Catalina; and NE-358, a first-order BM, in Brgy. Ubos, Bayawan City.

A control point was established along the approach of Siaton Bridge, namely UP-SIA, in Brgy. Caticugan, Municiality of Siaton. A NAMRIA established control point, NGE-94 located in Brgy. Bongalonan, Municipality of Basay; was also occupied and used as marker for the network.

The summary of reference and control points and its location is summarized in Table 28 while GNSS network established is illustrated in Figure 33.

Table 27 List of reference and control points occupied for Siaton River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
Control Survey on December 10, 2016						
NGE-107	2nd Order, GCP	9°13'19.76274"N	122°52'59.03199"E	69.527	-	2007
NGE-98	2nd Order, GCP	9°22'16.41564"N	122°53'48.54064"E	132.087	7.414	2007
NE-358	1st Order, BM	-	-	67.723	5.116	2008
NGE-94	used as marker	-	-	-	-	2007
UP-SIA	Used as marker	-	-	-	-	March 2016

Figure 33 GNSS Network of Siaton River field survey.

The GNSS set up made in the location of the reference and control points are exhibited in Figure 34 to Figure 38.

Figure 34 GNSS base set-up, Trimble® SPS 852, at NGE-98 a second-order GCP located on top of a concrete block along Sta. Catalia-Pamplona Provincial Road, in Brgy. Caranoche, Sta. Catalina, Negros Oriental

Figure 35 GNSS base set-up, Trimble® SPS 882, at NGE-107, a second order GCP located at the approach of Manalongon Bridge, in Brgy. Manalongon, Sta. Catalina, Negros Oriental.

Figure 36 GNSS base set-up, Trimble® SPS 855, at NE-358, a first-order BM, located on a culvert along Sta. Caalina-Bayawan Road in Brgy. Ubos, Bayawn City, Negros Oriental

Figure 37 GNSS base set-up, Trimble® SPS 855, at NGE-94, a GCP used as marker, located at the approach of Tiabanan's bridge in Brgy. Bongalonan, Basay, Negros Oriental

Figure 38 GNSS receiver set-up, Trimble® SPS 882, at UP-SIA, an established control point, located at the approach of Siaton Bridge in Brgy. Caticugan, Siaton, Negros Oriental

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking was done by removing/masking portions of these baseline data using the same processing software. It was repeatedly processed until all baseline requirements were met. If the reiteration yielded out of the required accuracy, resurvey was initiated.

Baseline processing result of control points in Siaton River Basin is summarized in Table 29 generated by TBC software.

Table 28 Baseline Processing Report for Siaton River Basin Static Survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NE-358 --- NGE-98	03-11-2016	Fixed	0.004	0.020	276°04'18"	-64.370	-64.370
NGE-98 --- UP-SIA	03-11-2016	Fixed	0.003	0.019	157°29'24"	-61.895	-61.895
NGE-98 --- NGE-107	03-11-2016	Fixed	0.003	0.020	185°14'15"	-62.546	-62.546
NE-358 --- NGE-94	03-11-2016	Fixed	0.005	0.021	103°45'37"	-1.108	-1.108
NE-358 --- NGE-107	03-11-2016	Fixed	0.005	0.032	337°54'15"	-1.830	1.830
UP-SIA --- NGE-107	03-11-2016	Fixed	0.004	0.023	318°46'17"	-0.673	-0.673
NGE-94 --- NGE-107	03-11-2016	Fixed	0.003	0.029	128°25'03"	0.653	0.653

As shown in Table 29, a total of seven (7) baselines were processed with reference points NE-358 fixed for elevation; and NGE-98 and NGE 107 held fixed for grid values. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates table 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:

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 30 to Table 35 for the complete details.

The five (5) control points,NE-358, NGE-98, NE-107, NGE-94 and UP-SIA were occupied and observed simultaneously to form a GNSS loop. Elevation value of NE-358 and coordinates of points NGE-98 and NGE-107 were held fixed during the processing of the control points as presented in Table 30. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 29 Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGE-98	Global	Fixed	Fixed		
NGE-107	Global	Fixed	Fixed		
NE-358	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 31. The fixed control point NE-358 has no values for elevation error; while NGE-98 and NGE-107 have no values for grid errors.

Table 30 Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGE-98	488670.521	?	1035896.031	?	69.180	0.054	LL
NGE-107	487155.076	?	1019415.410	?	7.670	0.058	LL
NE-358	480099.830	0.009	1036810.192	0.008	5.116	?	e
NGE-94	458621.676	0.015	1042094.324	0.013	7.244	0.058	
UP-SIA	502963.760	0.013	1001378.367	0.011	8.267	0.070	

With the mentioned equation, $\sqrt{((x\_e)^2+(y\_e)^2)}<20cm$ for horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

a. NGE-98

horizontal accuracy	=	Fixed
vertical accuracy	=	5.40< 10 cm

b. NGE-107

horizontal accuracy	=	Fixed
vertical accuracy	=	5.80 cm < 10 cm

c. NE-358

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm < 20 cm
vertical accuracy	=	Fixed

d. NGE-94

horizontal accuracy	=	$\sqrt{((1.50)^2 + (1.30)^2}$
	=	$\sqrt{(2.25 + 1.69)}$
	=	1.98 cm < 20 cm
vertical accuracy	=	5.80 cm < 10 cm

e. UP-SIA

horizontal accuracy	=	$\sqrt{((1.30)^2 + (1.10)^2}$
	=	$\sqrt{(1.69 + 1.21)}$
	=	1.70 cm < 20 cm
vertical accuracy	=	7.0 cm < 10 cm

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

Table 31 Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
NGE-107	N9°13'19.76274"	E122°52'59.03199"	69.527	0.058	LL
NGE-98	N9°22'16.41564"	E122°53'48.54064"	132.087	0.054	LL
NE-358	N9°22'46.06928"	E122°49'07.51892"	67.723	?	e
NGE-94	N9°25'37.57022"	E122°37'23.12090"	68.846	0.058	
UP-SIA	N9°03'32.50400"	E123°01'37.08746"	70.195	0.070	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 32. Based on the result of the computation, the accuracy condition was satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 33.

Table 32 Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
NGE-98	2nd order, GCP	9°22'16.41564"N	122°53'48.54064"E	132.087	1035896.031	488670.521	69.180
NGE-107	Used as marker	9°13'19.76274"N	122°52'59.03199"E	69.527	1019415.410	487155.076	7.670
NE-358	1st order, BM	9°22'46.06928"N	122°49'07.51892"E	67.723	1036810.192	480099.830	5.116
NGE-94	UP Established	9°25'37.57022"N	122°37'23.12090"E	68.846	1042094.324	458621.676	7.244
UP-SIA	UP-Established	9°03'32.50400"N	123°01'37.08746"E	70.195	1001378.367	502963.760	8.267

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

The cross-section survey was conducted at the upstream portion of Siaton Bridge in Brgy. Caticugan, Siaton on March 17 and 20, 2016 using a GNSS receiver, Trimble® SPS 882, in PPK survey technique as shown in Figure C-40.

Figure 39 Cross-section and as-built survey for Siaton Bridge

The cross-sectional length of Siaton Bridge is about 148.944m with 163 cross-sectional points acquired using UP-SIA as the GNSS base station. The cross section diagram, location map, and the bridge data form are shown in Figure 40 to Figure 41, respectively.

Siaton Bridge was installed with an Automated Water Level Sensor (AWLS). Its sensor had an elevation of 9.195 m MSL. Water level data gathered by the AWLS was used by the partner HEI in charge for Siaton River, University of San Carlos.

Water surface elevation in MSL of Siaton River, as shown in Figure 40, was determined using Trimble® SPS 882 in PPK mode technique on March 17, 2016 at 2:45PM with a value of 1.313 m in MSL.

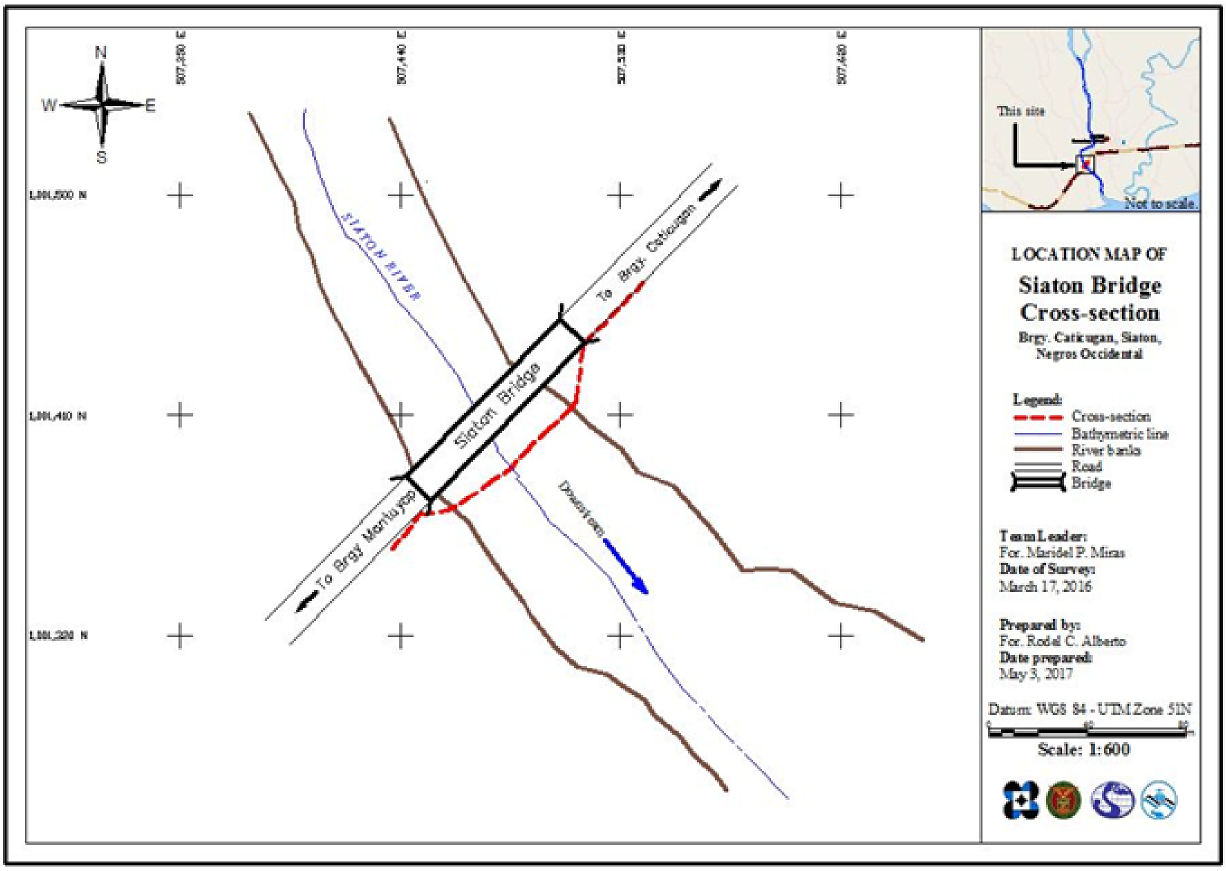


Figure 41 Siaton Bridge cross-section location map

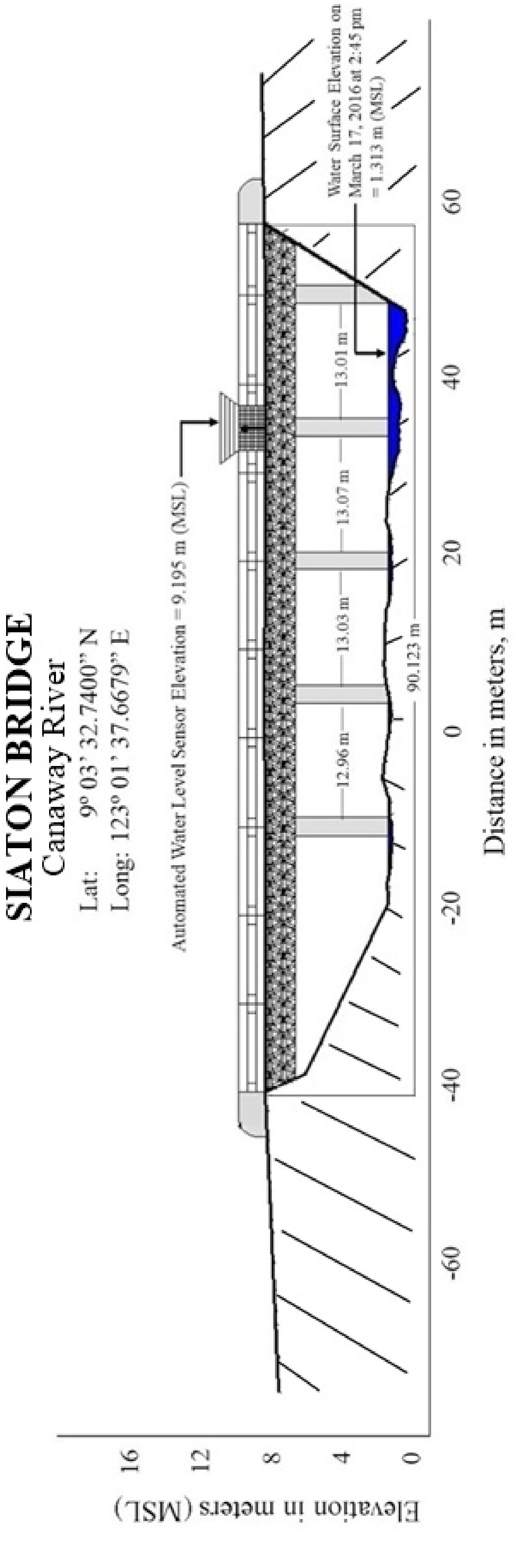


Figure 40 Siaton Bridge cross-section diagram.

Bridge Data Form

Bridge Name: SIATON BRIDGE **Date:** March 17, 2016

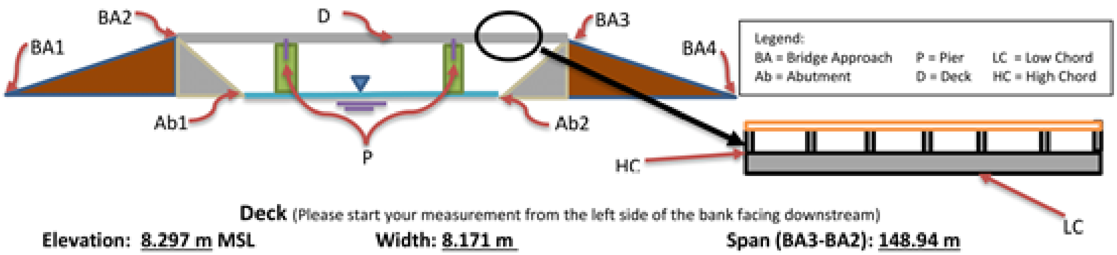
River Name: CANAWAY RIVER **Time:** 2:45 pm

Location (Brgy, City, Region): Brgy. Caticugan, Siaton, Negros Oriental

Survey Team: Negros Oriental Team © Team Mike and Mady

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

Latitude: 9° 03' 32.7400" N **Longitude:** 123° 01' 37.6679" E



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

Elevation: 8.297 m MSL **Width:** 8.171 m **Span (BA3-BA2):** 148.94 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	8.264	
2	Pier 2	8.293	
3	Pier 3	8.321	
4	Pier 4	8.310	
5	Pier 5	8.298	

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	7.537	**BA3**	123.971	8.281
BA2	33.8364	8.296	**BA4**	148.9222	8.474

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

	Station (Distance from BA1)	Elevation
Ab1	35.913	5.966
Ab2	129.795	6.552

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

Shape: Rectangular **Number of Piers:** pier (5) **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	Pier 1	8.264	
Pier 2	Pier 2	8.293	
Pier 3	Pier 3	8.321	
Pier 4	Pier 4	8.310	
Pier 5	Pier 5	8.298	

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

Figure 42 Siaton Bridge Diagram Data Form.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on March 17 and 18, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the side of vehicle as shown in Figure 43. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.265 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with

Figure 43 Validation points acquisition survey set-up for Siaton River Survey.

The survey started from Brgy. Poblacion in the Municipality of Santa Catalina going south traversing 19 barangays towards the Municipality of Siaton and ended in Brgy. Inalad. This route aimed to cut flight strips perpendicularly. It gathered 3,270 points with approximate length of 45km using UP-SIA as GNSS base for the entire extent validation points acquisition survey as illustrated in the map inFigure 44.

Figure 44 Validation point acquisition survey for the Siaton River Basin

4.7 River Bathymetric Survey

Manual bathymetric survey was also executed on March 17, 2016 using a Trimble® SPS 882 GNSS PPK survey technique as illustrated in Figure 45. The extent of the survey began from the upstream portion of the river in Brgy. Caticugan with coordinates 9°05'17.74303"N, 123°01'30.97004"E; traversed manually by foot down and ended at the mouth of the river in Brgy. Mantuyop, also in Municipality of Siaton with coordinates 9°03'06.16570"N, 123°01'55.12231"E. The control point UP-SIA was occupied as the GNSS base station all throughout the survey.

Figure 45 Bathymetry survey set up for Siaton River survey.

A CAD drawing was also produced to illustrate the riverbed profile of Siaton River. As shown in Figure 47, the highest and lowest elevation has a 14-meter difference. The highest elevation observed was 13.376 m above MSL located in the upmost portion of the river in Brgy. Caticugan while the lowest elevation observed was -0.829 m below MSL located at the mouth of the river in Brgy. Mantuyop. The bathymetric survey gathered a total of 9,981 points covering 4.780 km of the river traversing the two mentioned barangays of Siaton, Negros Oriental. The 6 km planned bathymetric survey was not covered as advised by USC because the area is not prone to flooding according to them and based on the field reconnaissance.

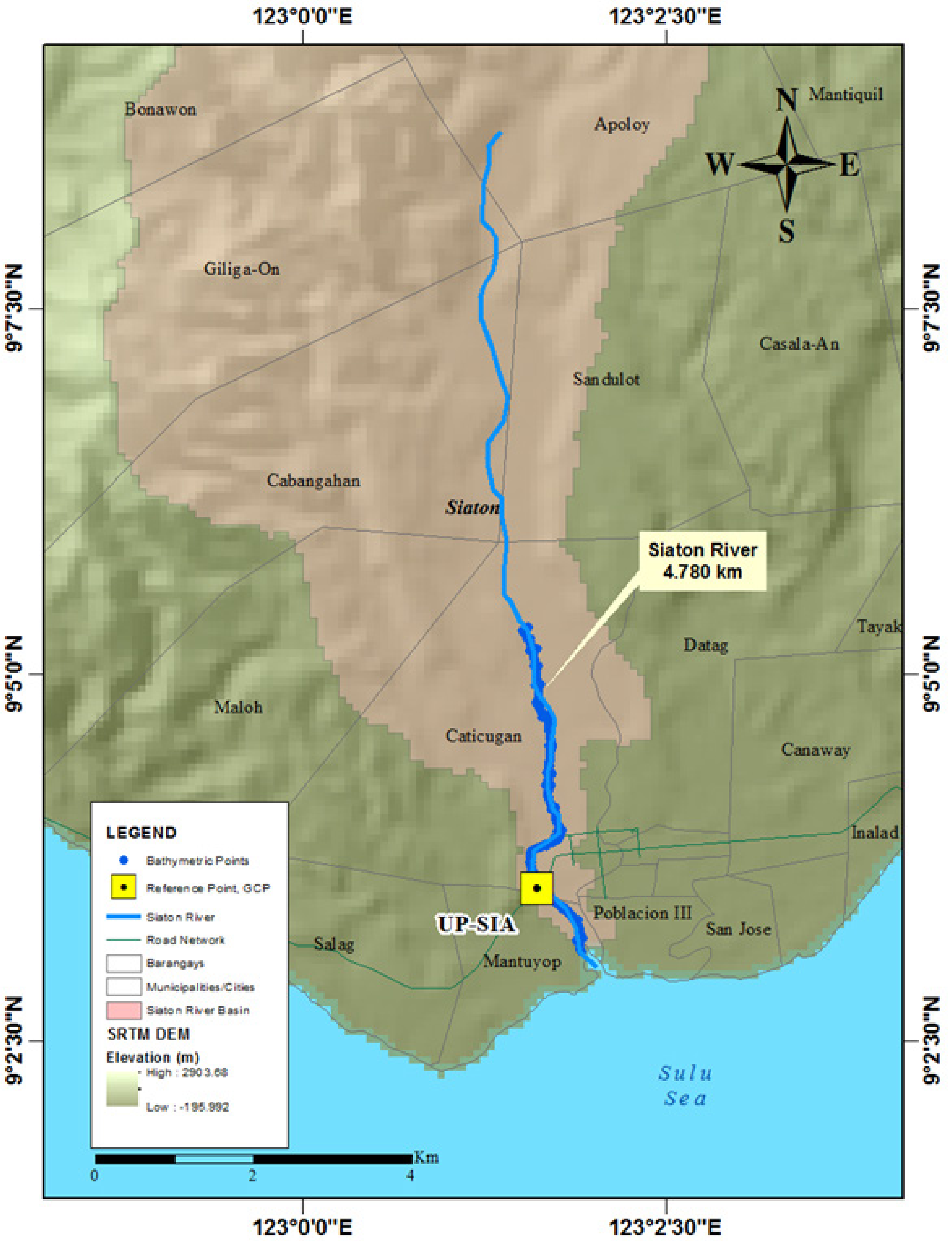


Figure 46 Bathymetric survey of Siaton River.

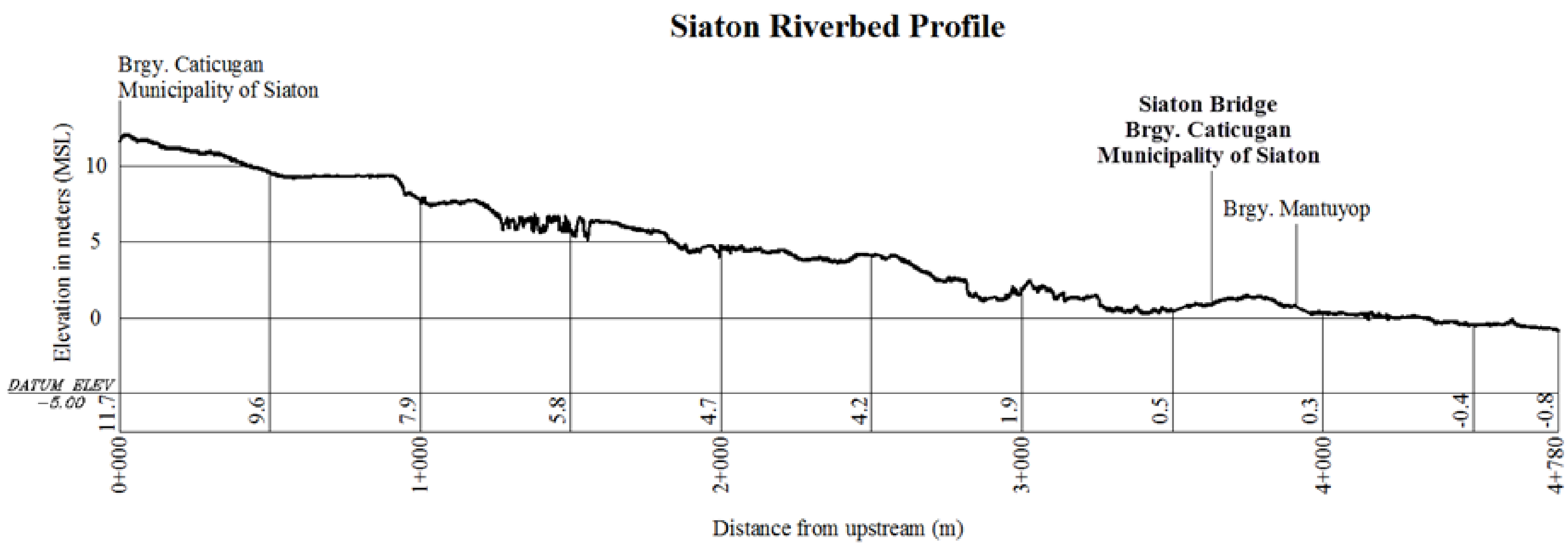


Figure 47 Riverbed profile of Siaton River

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, and Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a data logging rain gauge installed by the USC Phil LIDAR 1. The rain gauge was installed in Sitio Cambonbon, Brgy. Balanan, Siaton with geographic coordinates of 9°7'18.3"N and 123°0'7.20"E. The location of the rain gage in the watershed in presented in Figure 48. The total precipitation data used for calibration is 42.6mm. The rainfall event started at 9:10 in the morning and ended at 11:50 in the morning on January 16, 2017.

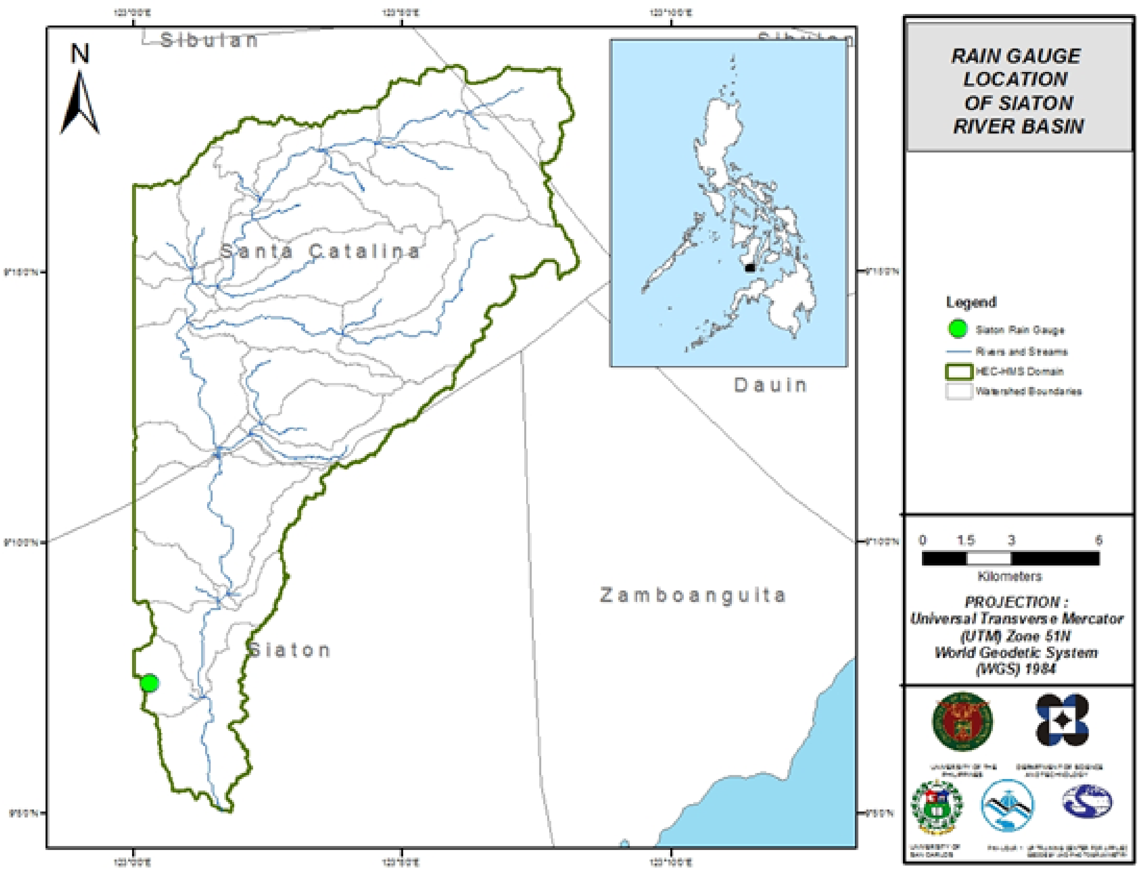


Figure 48 The location map of Siaton HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Brgy. Caticugan (9°25'22.51"N and 122°48'21.6"E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

For Brgy. Caticugan, the rating curve is expressed y=1.0534e^10.345xas shown in Figure 49.

This image is not available for this river basin.

Figure 49 Cross-section plot of the SIaton River

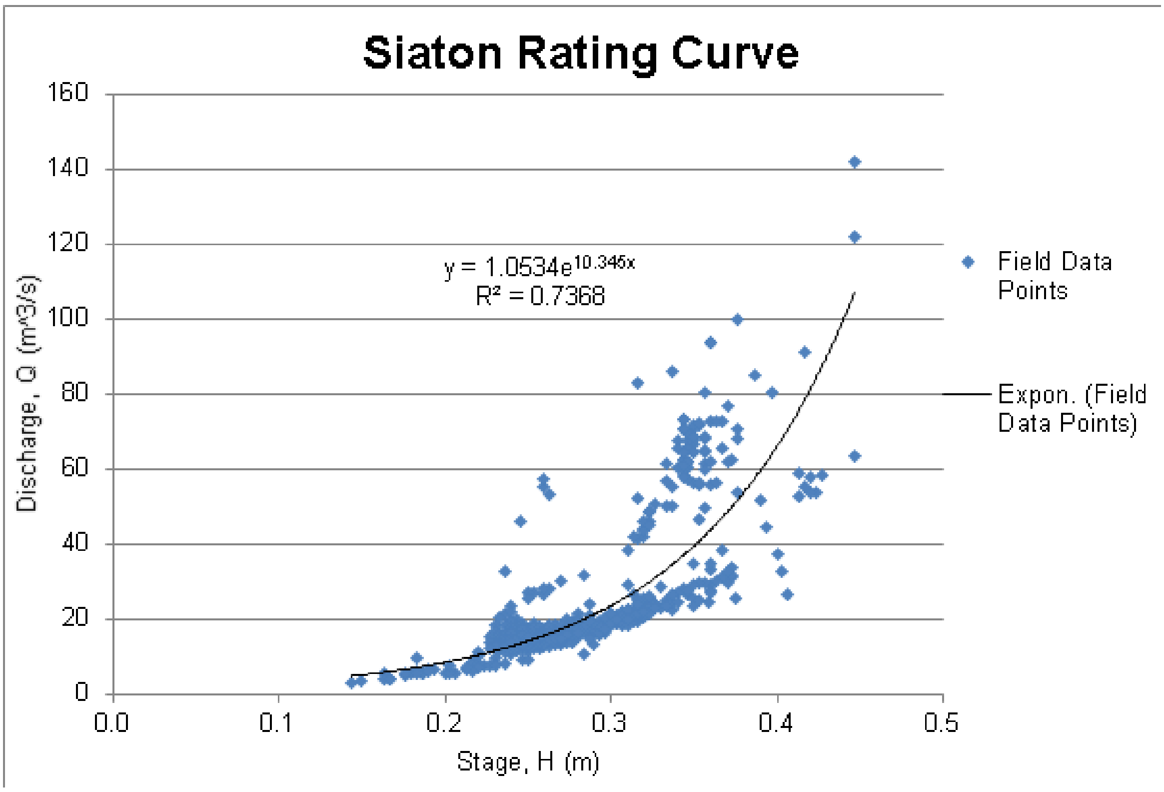


Figure 50 Rating Curve at Brgy. Caticigan in Siaton River.

This rating curve equation was used to compute the river outflow at Brgy. Caticigan for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge was 57.266m3/s at 17:10, January 16, 2017.

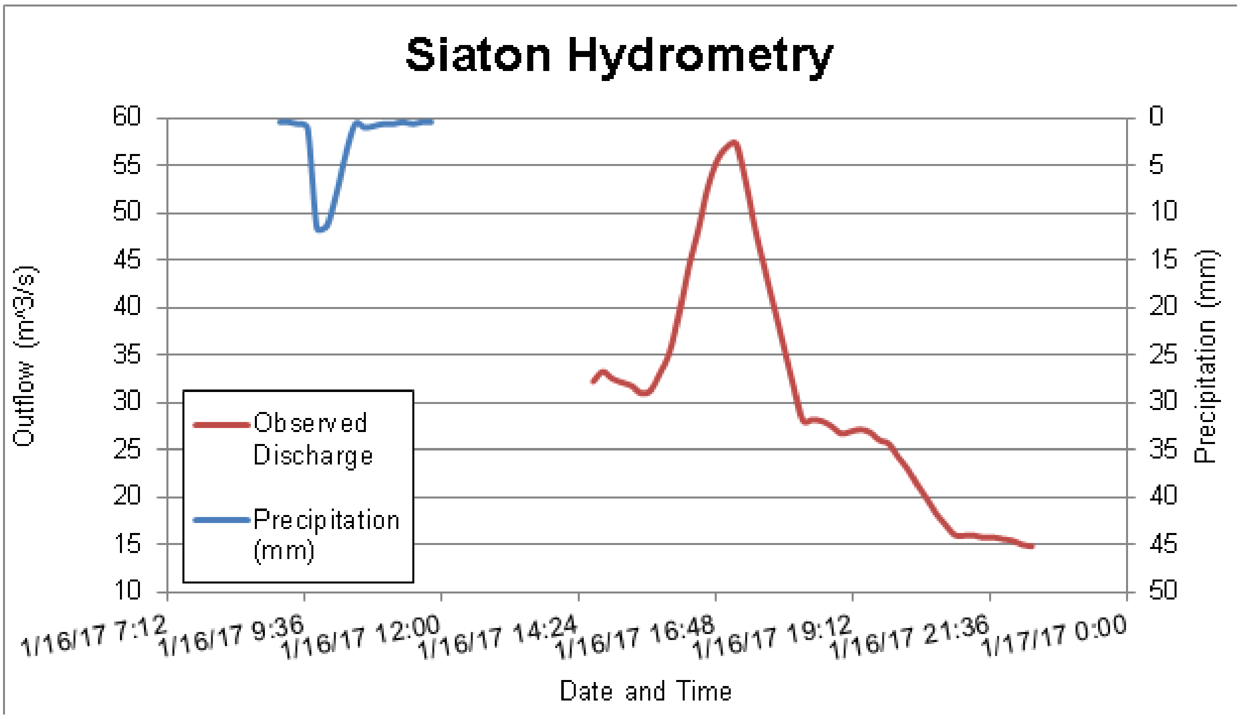


Figure 51 Rainfall and outflow data at Brgy. Caticugan used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Dumaguete Point Gauge. This station was chosen based on its proximity to the Siaton watershed. Siaton extreme values for this watershed were computed based on a 35-year record.

Table 33 RIDF values for Dumaguete Point 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	16.2	24.8	30.6	39.7	50	55.3	63.4	69.1	76
5	21.8	33.6	42.3	57.1	76.5	87.3	100	109.5	116.5
10	25.6	39.4	50	68.6	94	108.5	124.3	136.3	143.3
15	27.7	42.7	54.3	75.1	103.9	120.5	138	151.4	158.4
20	29.1	45	57.4	79.7	110.8	128.9	147.5	162	169
25	30.3	46.8	59.7	83.2	116.1	135.3	154.9	170.2	177.2
50	33.8	52.3	66.9	94	132.5	155.2	177.6	195.3	202.4
100	37.2	57.7	74.1	104.8	148.8	174.9	200.2	220.2	227.3

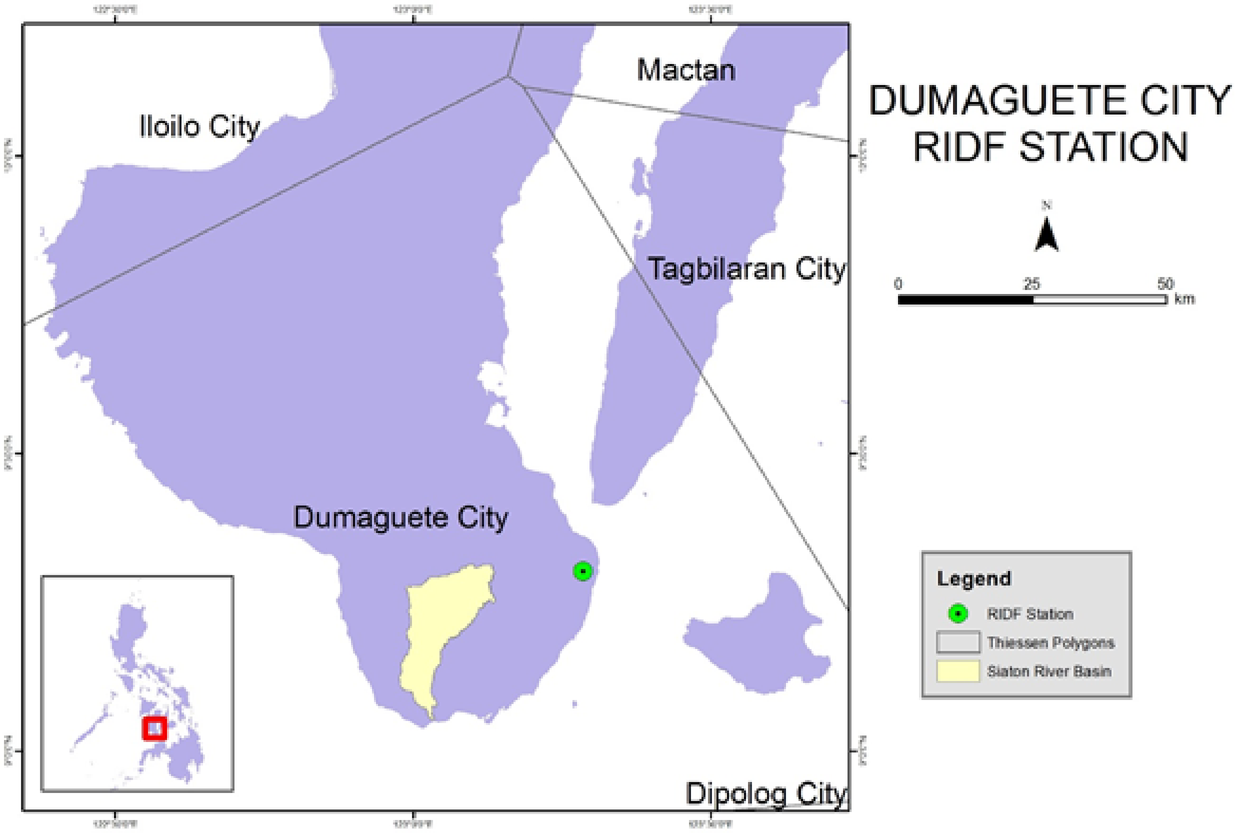


Figure 52 Dumaguete Point RIDF location relative to Siaton River Basin.

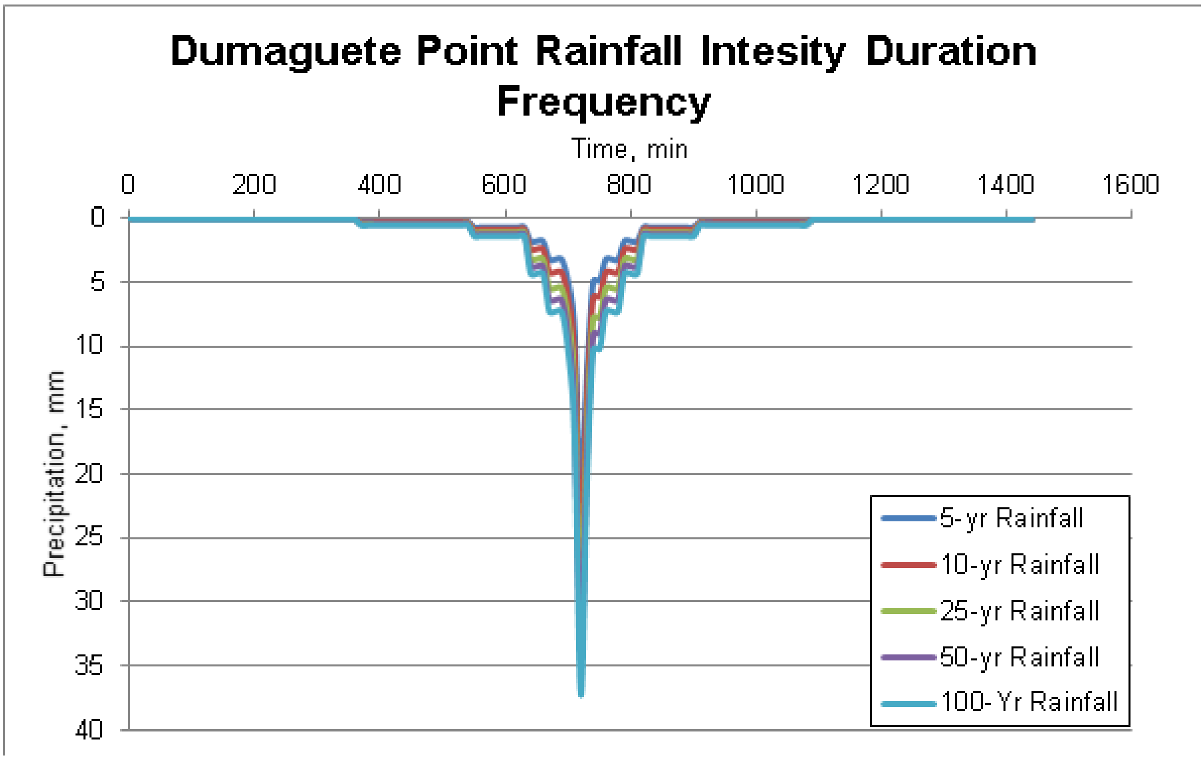


Figure 53 Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA).

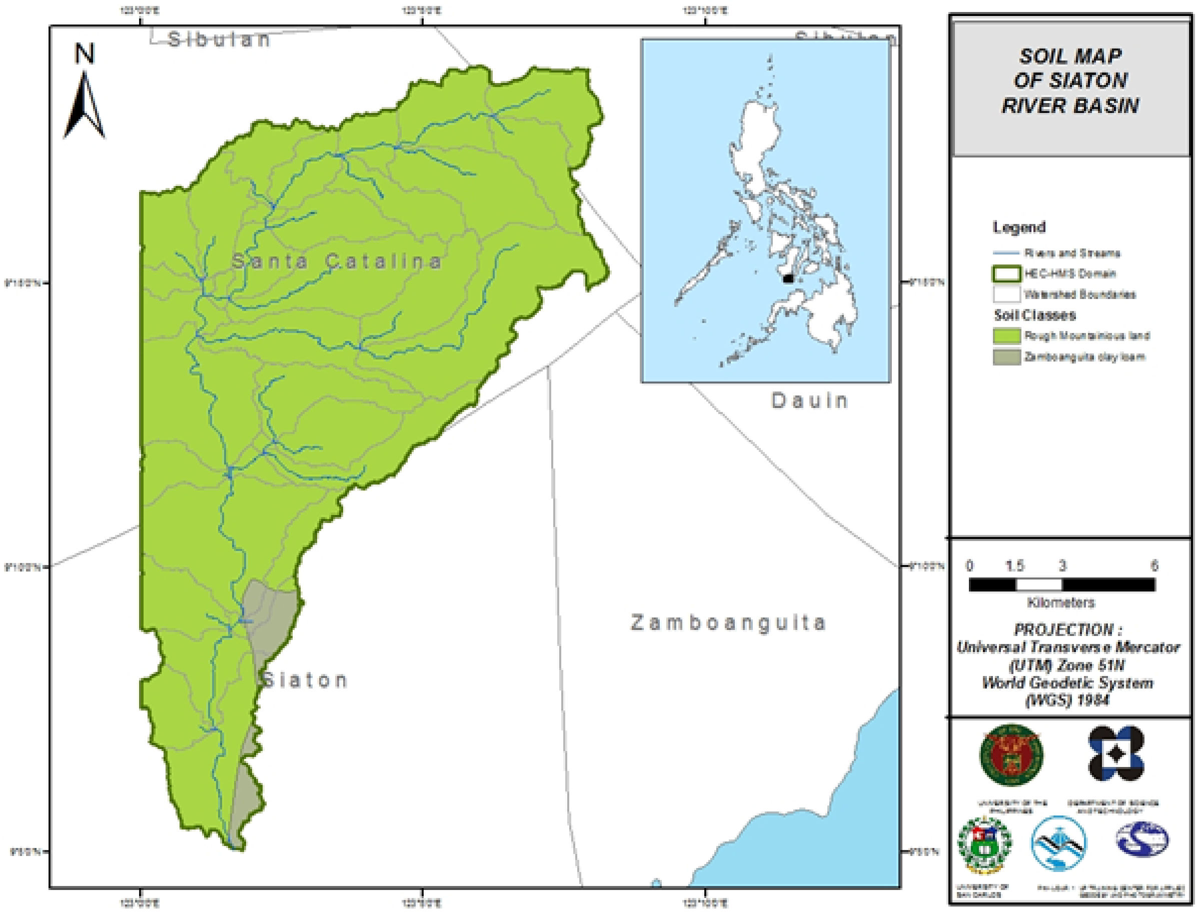


Figure 54 The soil map of the Siaton River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture).

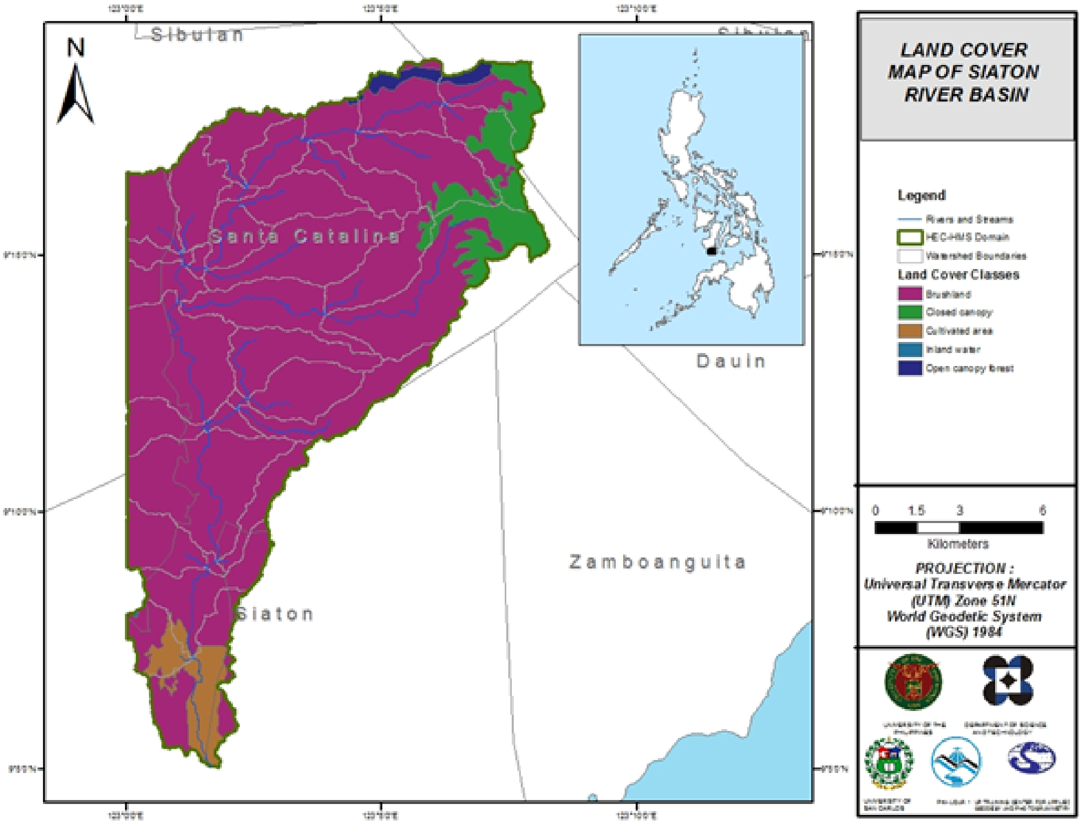


Figure 55 The land cover map of the Siaton River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: National Mapping and Resource Information Authority)

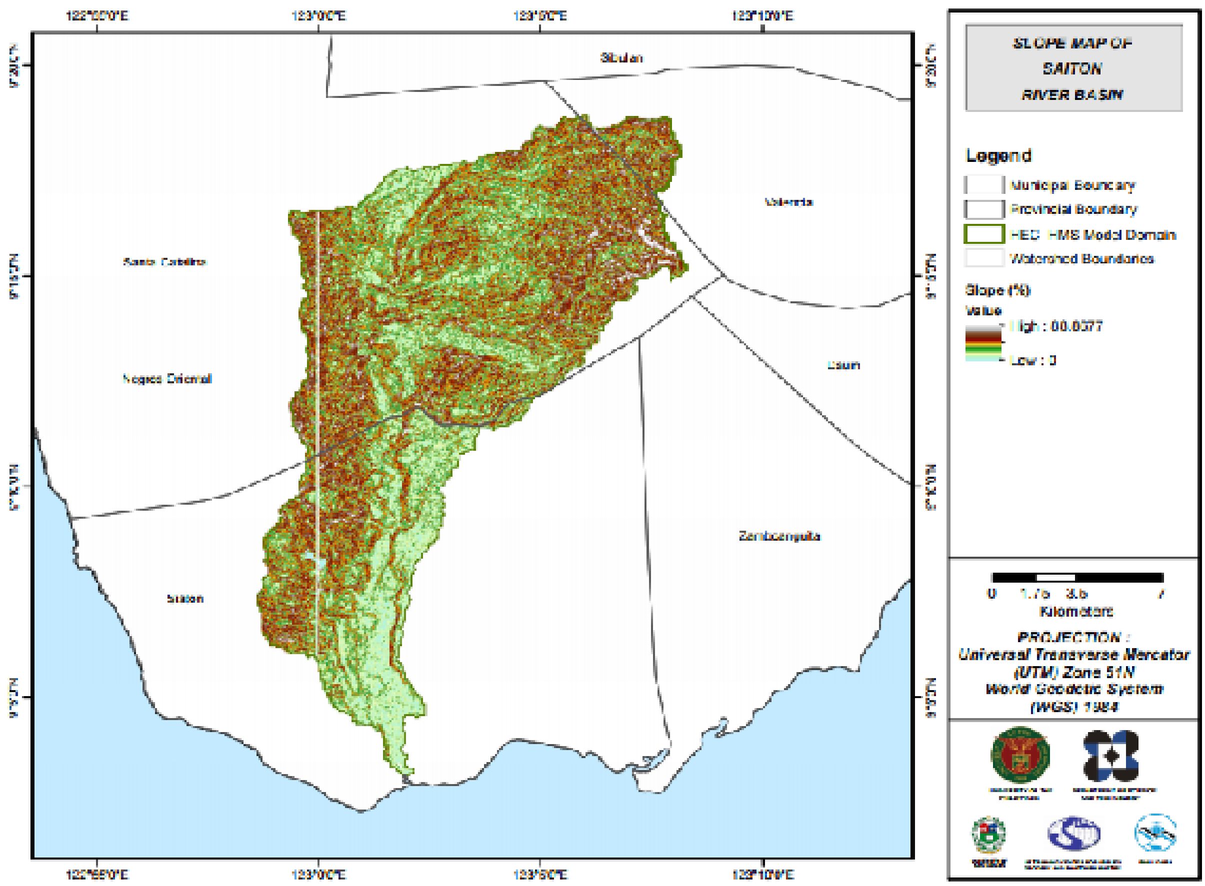


Figure 56 Slope Map of Siaton RIver Basin

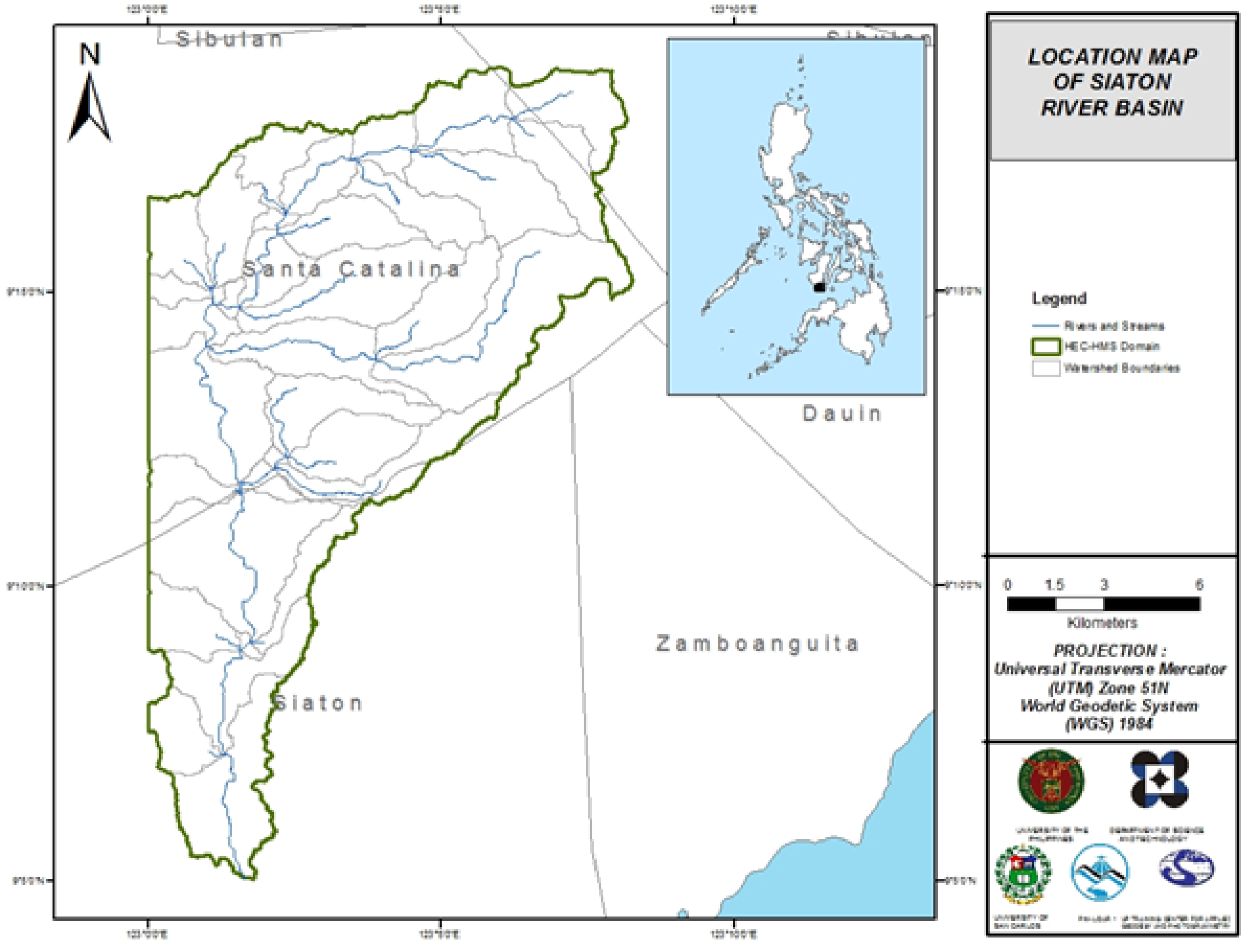


Figure 57 Stream delineation map of Siaton River Basin.

The Siaton basin model comprises 35 sub basins, 17 reaches, and 17 junctions. The main outlet is outlet 1. This basin model is illustrated in Figure 58. The basins were identified based on soil and land cover characteristic of the area. Precipitation was taken from an installed Rain Gauge near and inside the river basin. Finally, it was calibrated using the data from actual discharge flow gathered in the Brgy. Caticugan, Siaton.

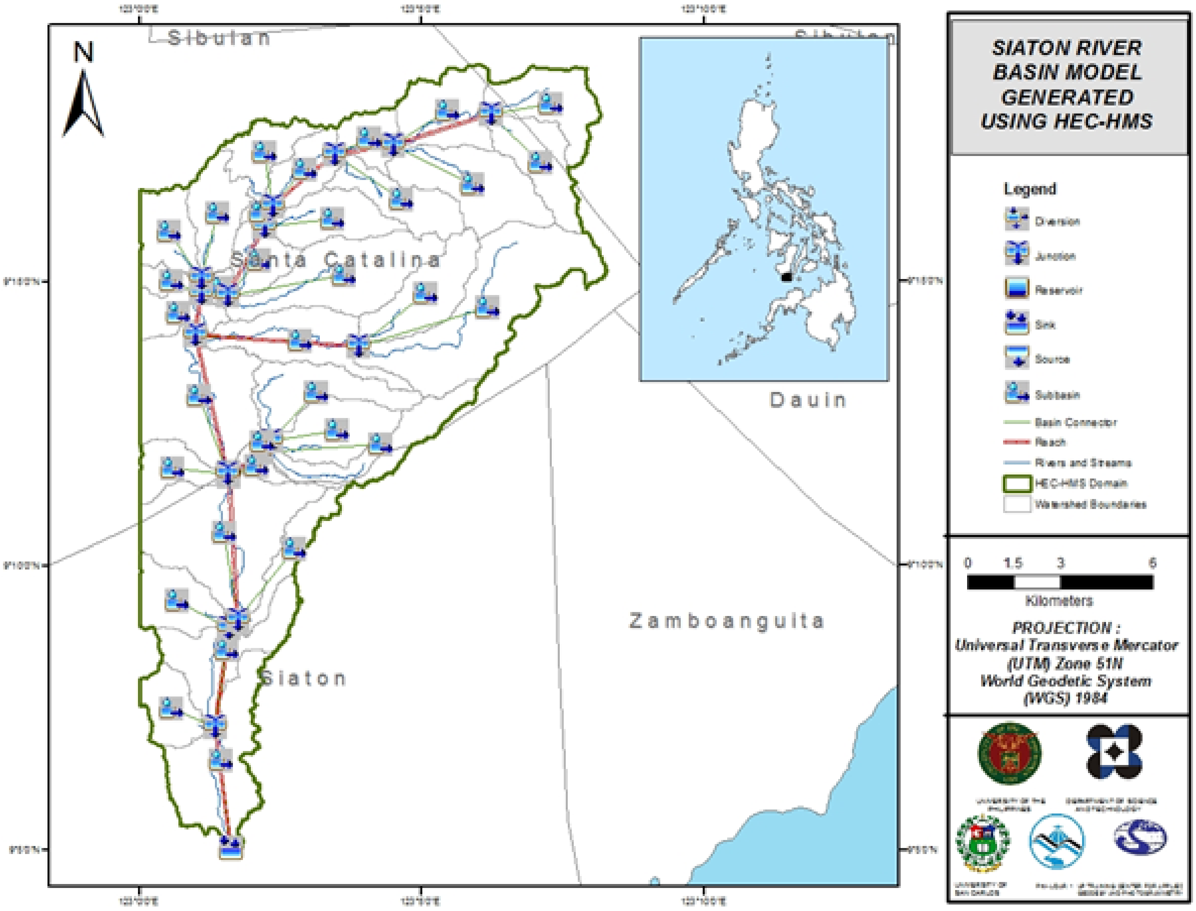


Figure 58 The Siaton River Basin Model Domain generated using HEC-HMS.

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.

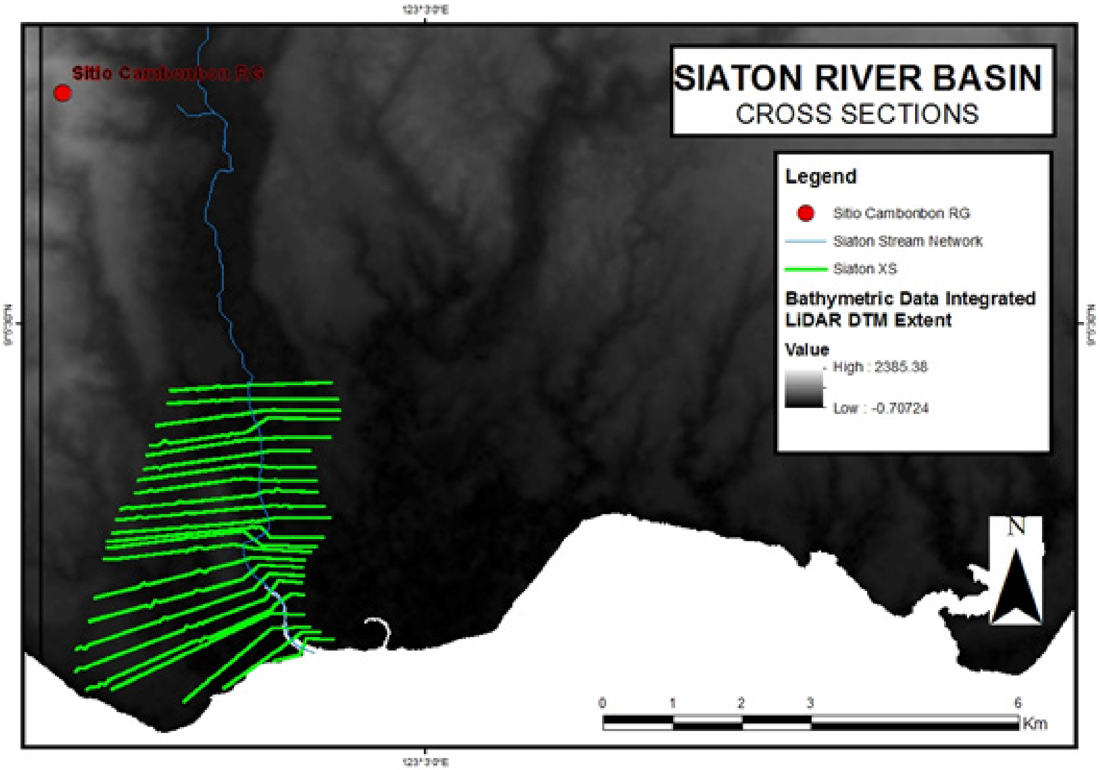


Figure 59 River cross-section of Siaton River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

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

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

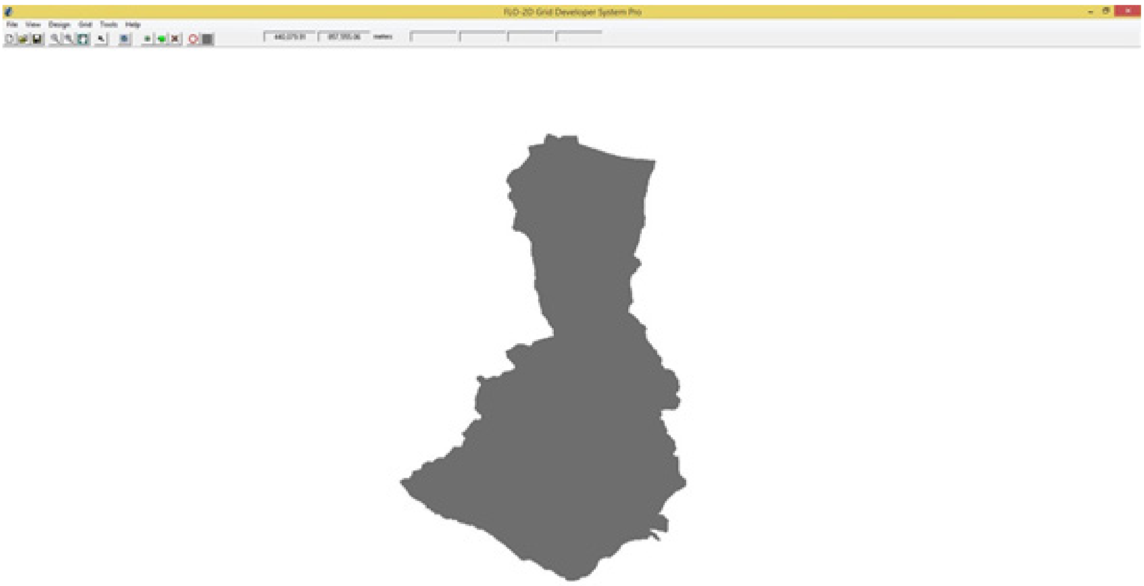


Figure 60 Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 23.91504 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that showed 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 created the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) was set at 0 m2/s.

The creation of a flood hazard map from the model also automatically created a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts cover a maximum land area of 38,515,400.00m2.

There is a total of 36,519,889.86m3 of water entering the model. Of this amount, 7,884,112.82 m3 is due to rainfall while 28,635,777.03 m3 is inflow from other areas outside the model. 3,314,226.25 m3 of this water is lost to infiltration and interception, while 1,945,968.08 m3 is stored by the flood plain. The rest, amounting up to 31,259,694.77 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Siaton HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data.

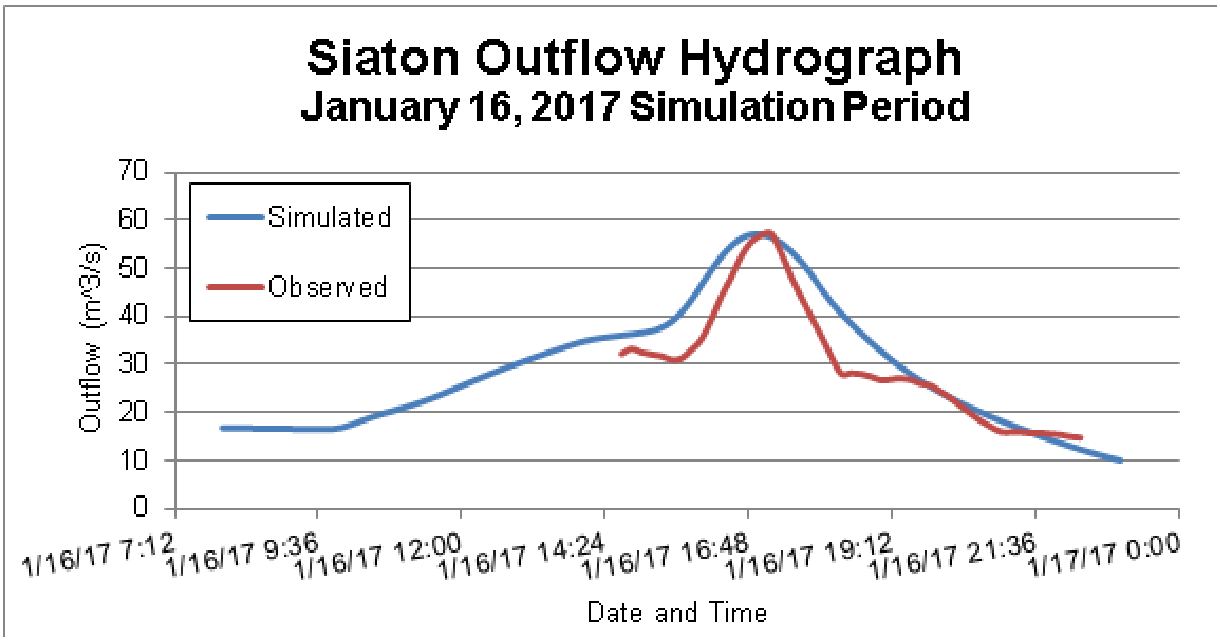


Figure 61 Outflow Hydrograph of Siaton produced by the HEC-HMS model compared with observed outflow.

Table 34 Range of calibrated values for the Siaton River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	2.69-48.12
			Curve Number	35.45-87.81
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.35-19.26
			Storage Coefficient (hr)	0.03-1.96
	Baseflow	Recession	Recession Constant	0-0.08
			Ratio to Peak	0.01-0.13
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.01-0.58

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 2.69 to 48.12mm signifies that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Siaton, the basin mostly consists of brushlands and the soil consists of clay loam and mountain soil, the curve number is 35.45 to 87.81.

The 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 0.35 to 19.26 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, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0 to 0.08 indicates that the basin will quickly go back to its original discharge. Ratio to peak of 0.01 to 0.13 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.01 to 0.58 corresponds to the common roughness in Siaton watershed, which is determined to be mostly brushland, closed canopy forests and cultivated areas (Brunner, 2010).

Table 35 Summary of the Efficiency Test of Siaton HMS Model

Accuracy measure	Value
RMSE	5.82
r2	0.96
NSE	0.77
PBIAS	-13.22
RSR	0.48

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 5.8182.

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 0.9601.

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 0.7741.

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 -13.2202.

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 0.4753.

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 show the Siaton outflow using the Dumaguete Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-, 10-, 25-, 50-, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results revealed significant increase in outflow magnitude as the rainfall intensity increases for a uniform duration of 24 hours and varying return periods.

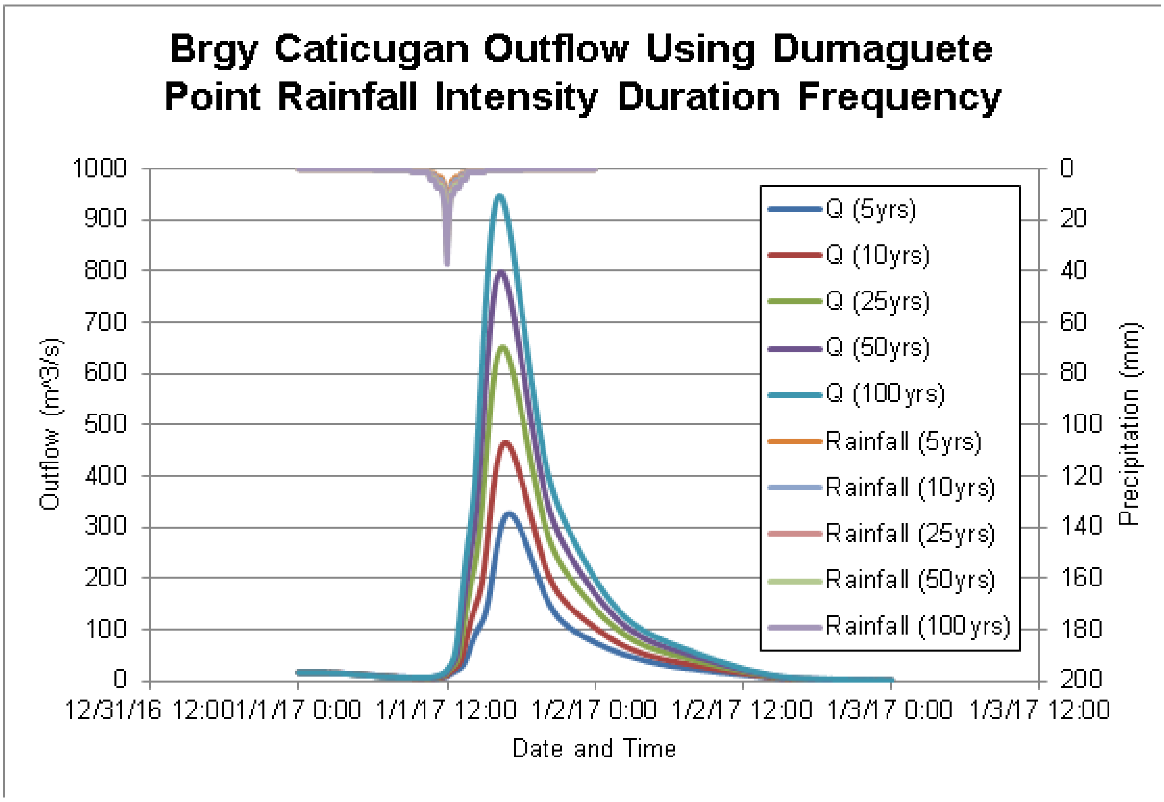


Figure 62 Outflow hydrograph at Brgy. Caticugan, Siaton generated using Dumaguete PointRIDF simulated in HEC-HMS.

Figure 62 Outflow hydrograph at Brgy. Caticugan, Siaton generated using Dumaguete Point RIDF simulated in HEC-HMS.

Table 36 Peak values of the Siaton HEC HMS Model outflow using the Dumaguete RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	116.5	21.800	327.273	5 hours
10-Year	143.3	25.600	465.146	4 hours and 40 minutes
25-Year	177.2	30.300	651.743	4 hours and 30 minutes
50-Year	202.4	33.800	798.089	4 hours and 20 minutes
100-Year	227.3	37.200	946.645	4 hours and 20 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 is shown. The sample generated map of Siaton River using the calibrated event flow is shown in Figure 63.

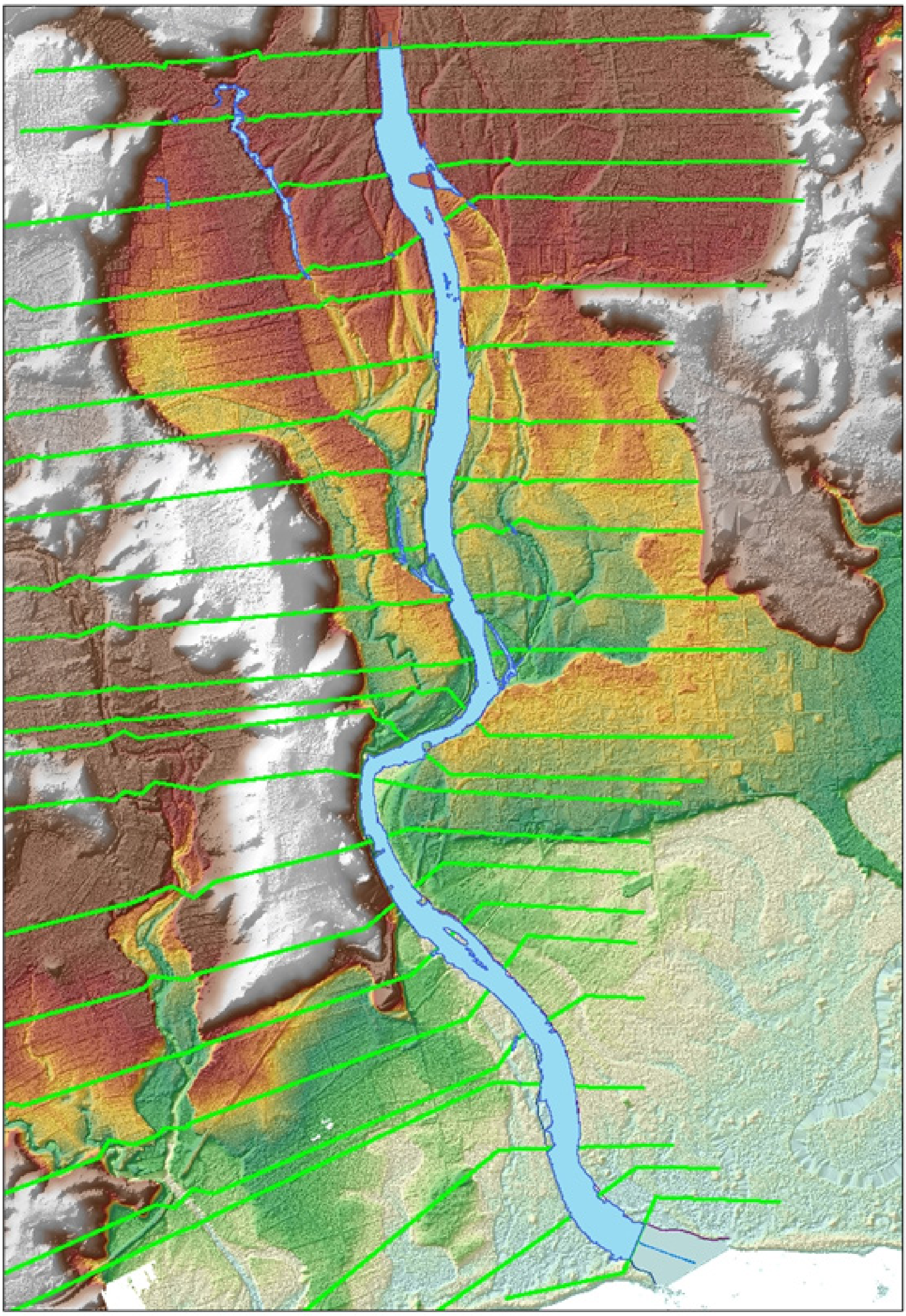


Figure 63 Sample output of Siaton RAS Model .

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figure 64 to Figure 69 shows the 5-, 25-, and 100-year rain return scenarios of the Siaton Floodplain.

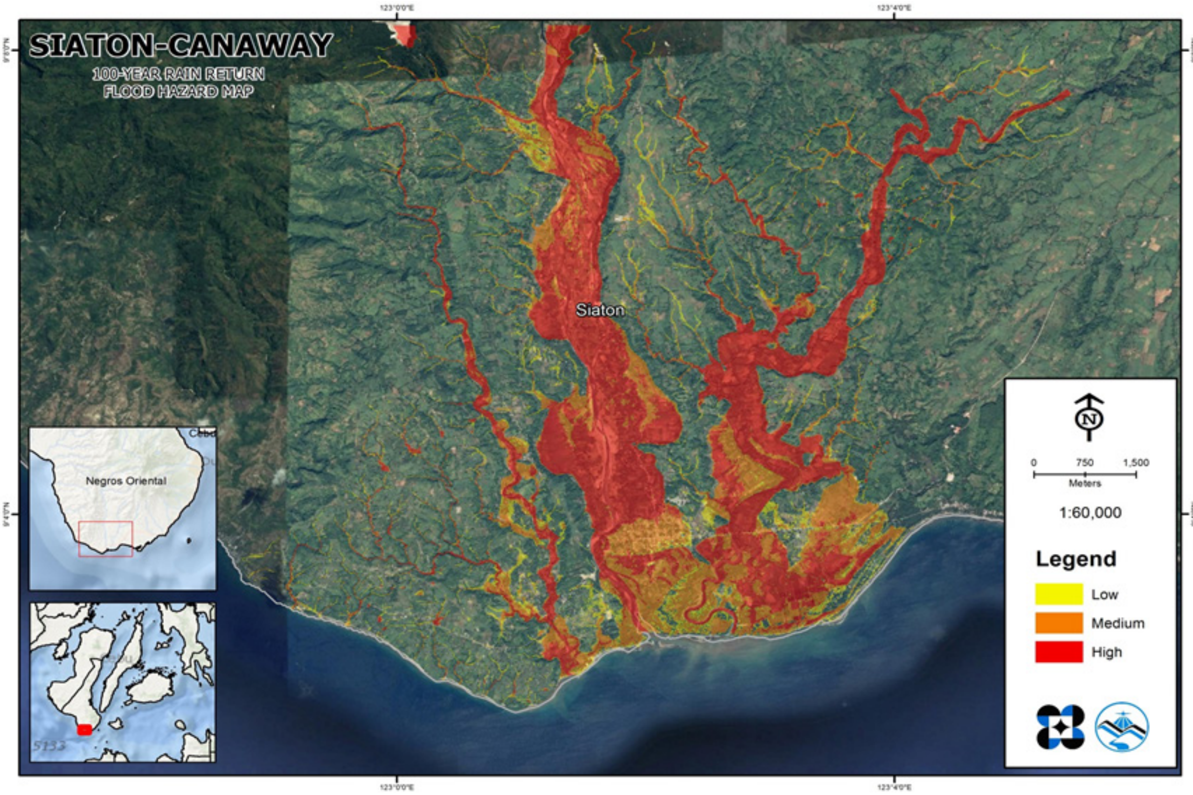


Figure 64 100-year Flood Hazard Map for Siaton-Canaway Floodplain.

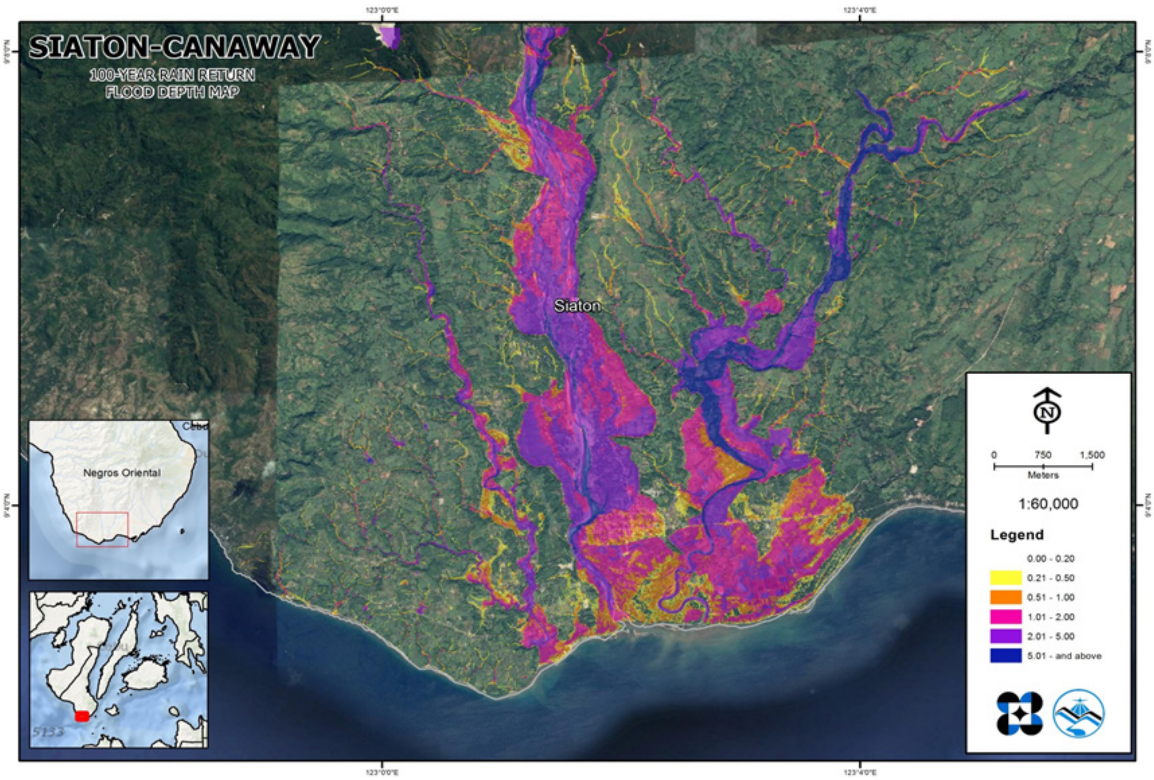


Figure 65 100-year Flood Depth Map for Siaton-Canaway Floodplain.

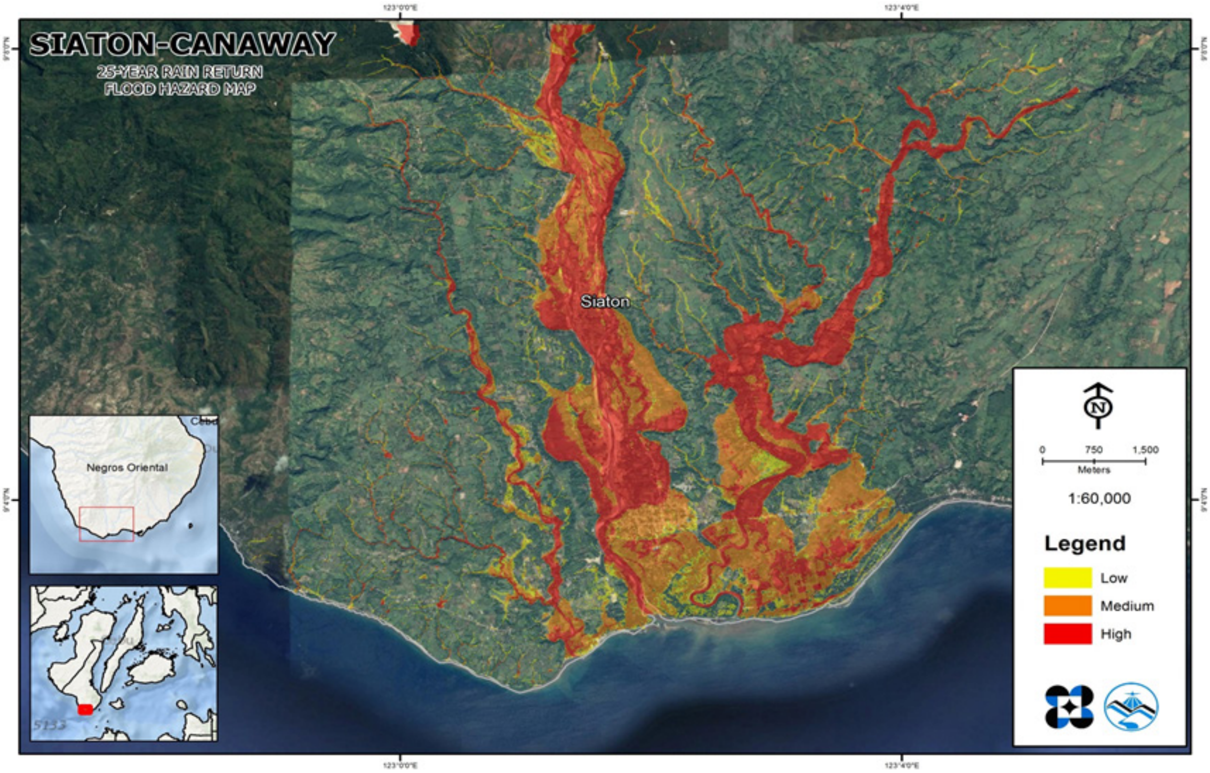


Figure 66 25-year Flood Hazard Map for Siaton-Canaway Floodplain

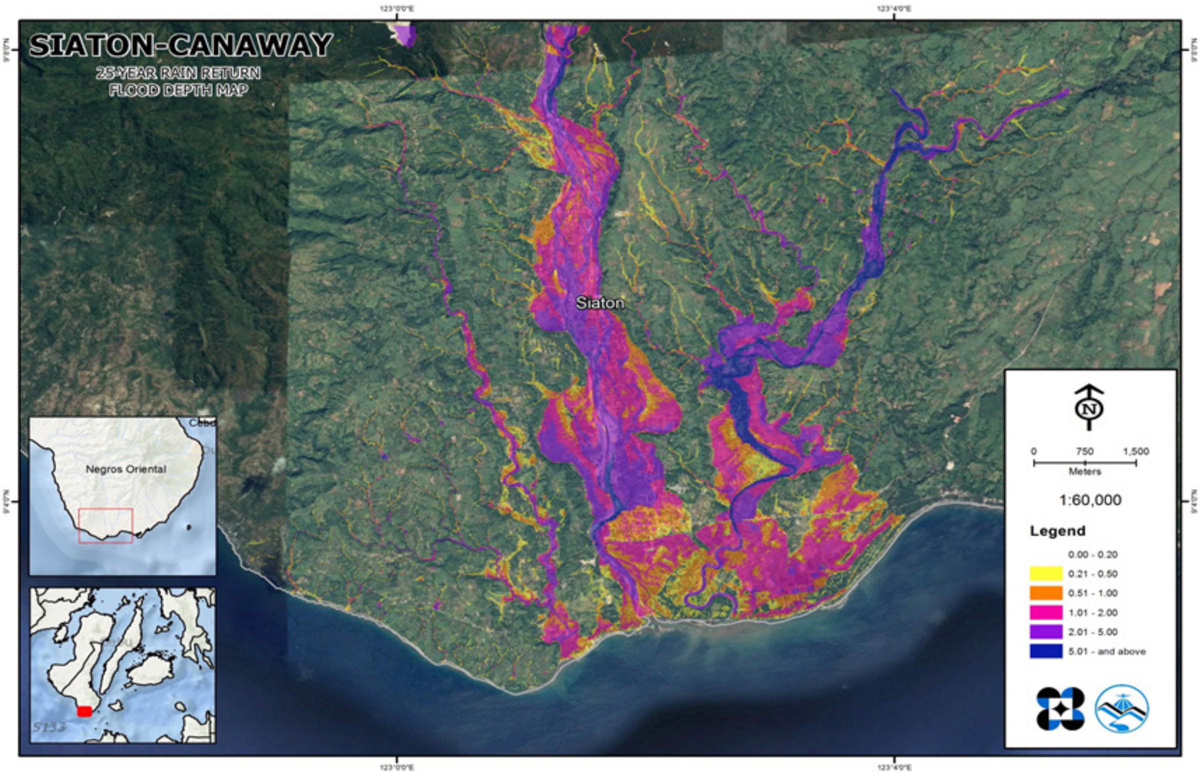


Figure 67 25-year Flood Depth Map for Siaton-Canaway Floodplain

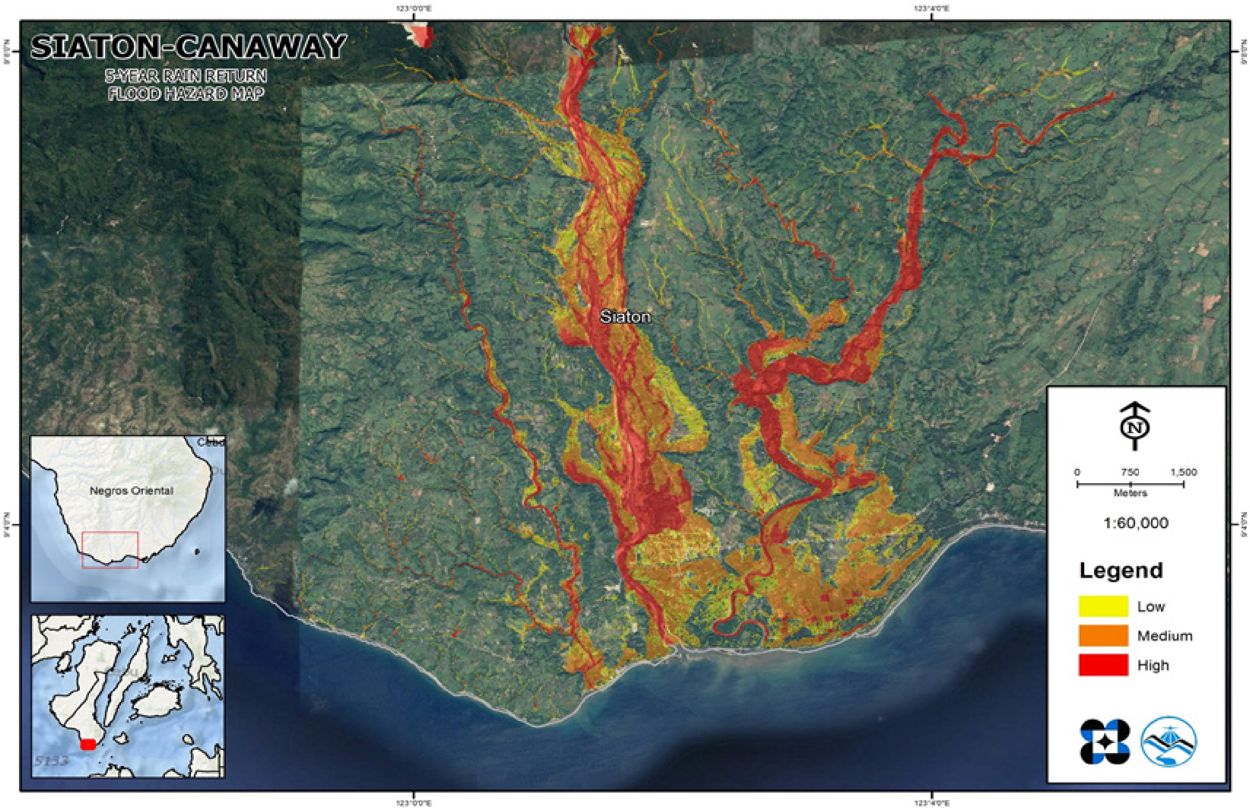


Figure 68 5-year Flood Hazard Map for Siaton-Canaway Floodplain.

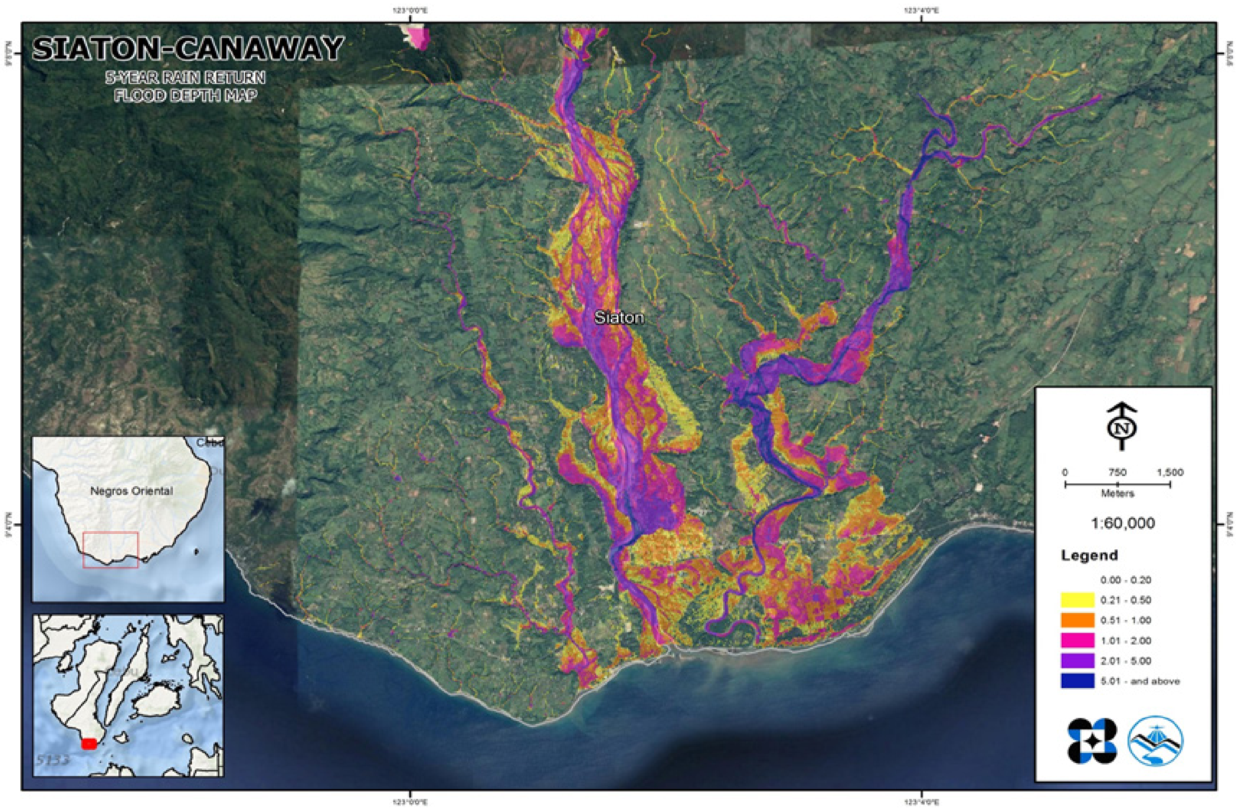


Figure 69 5-year Flood Depth Map for Siaton-Canaway Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Siaton (Canaway-Siaton) river basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 19 barangays is expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 13.24% of the municipality of Asturias with an area of 427.32 sq. km. will experience flood levels of less 0.20 meters. 1.19% of the area will experience flood levels of 0.21 to 0.50 meters while 1.39%, 1.27%, 0.93%, and 0.17% 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 are the affected areas in square kilometers by flood depth per barangay.

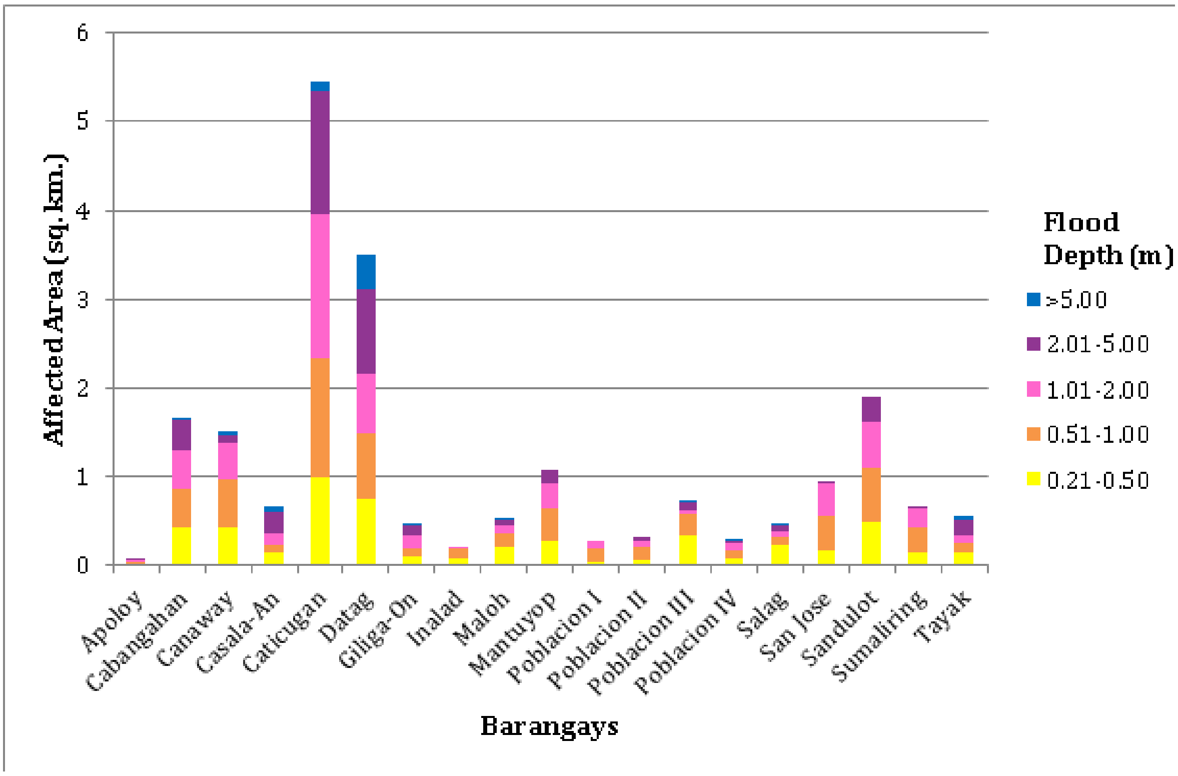


Figure 70 Affected Areas in Siaton, Negros Oriental during 5-Year Rainfall Return Period

Table 37 Affected Areas in Siaton, Negros Oriental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)									
	Apoloy	Cabanga-han	Cana-way	Casa-la-An	Cati-cugan	Datag	Giliga-On	Inal-ad	Maloh	Mantuy-op
0.03-0.20	0.37	6.08	2.76	4.57	7.94	5.45	4.08	0.42	5.19	1.75
0.21-0.50	0.011	0.43	0.42	0.14	0.98	0.74	0.1	0.09	0.21	0.28
0.51-1.00	0.015	0.44	0.54	0.092	1.36	0.74	0.082	0.095	0.15	0.36
1.01-2.00	0.027	0.41	0.42	0.12	1.62	0.67	0.16	0.011	0.088	0.29
2.01-5.00	0.016	0.34	0.09	0.23	1.4	0.97	0.092	0	0.061	0.14
> 5.00	0	0.021	0.047	0.082	0.1	0.38	0.0022	0	0.0028	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)								
	Poblacion I	Poblacion II	Poblacion III	Poblacion IV	Salag	San Jose	Sandu-lot	Sumaliring	Tay-ak
0.03-0.20	0.049	0.036	0.58	0.22	5.3	0.22	6.51	0.43	4.65
0.21-0.50	0.04	0.053	0.33	0.073	0.23	0.17	0.49	0.14	0.15
0.51-1.00	0.14	0.15	0.24	0.082	0.095	0.38	0.6	0.3	0.099
1.01-2.00	0.086	0.078	0.058	0.096	0.068	0.37	0.54	0.21	0.09
2.01-5.00	0	0.031	0.069	0.018	0.056	0.021	0.26	0.0069	0.16
> 5.00	0	0	0.0007	0.0079	0.0007	0	0	0	0.063

For the 25-year return period, 12.39% of the municipality of Asturias with an area of 427.32 sq. km. will experience flood levels of less 0.20 meters. 0.85% of the area will experience flood levels of 0.21 to 0.50 meters while 1.15%, 1.93%, 1.53%, and 0.35% 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 kilometers by flood depth per barangay.

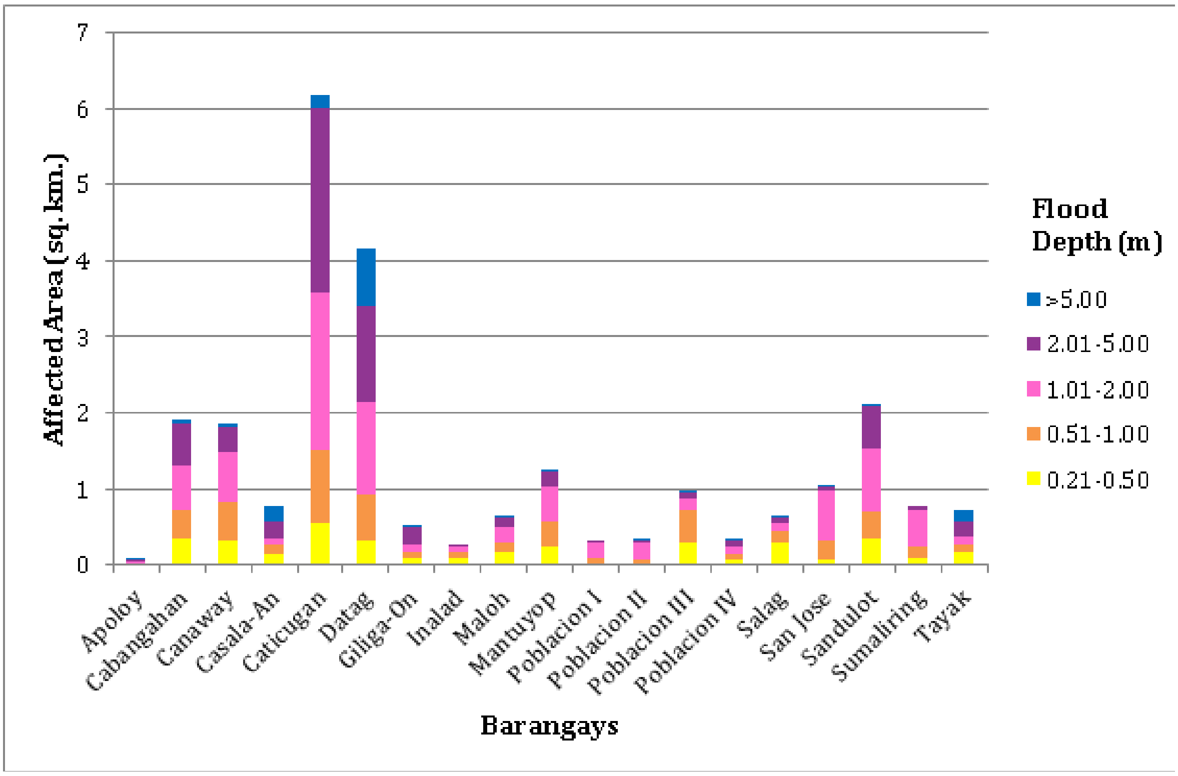


Figure 71 Affected Areas in Siaton, Negros Oriental during 25-Year Rainfall Return Period.

Table 38 Affected Areas in Siaton, Negros Oriental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)									
	Apoloy	Cabanga-han	Cana-way	Casa-la-An	Cati-cugan	Datag	Giliga-On	Inalad	Maloh	Mantuy-op
0.03-0.20	0.36	5.82	2.43	4.46	7.21	4.78	4.01	0.36	5.08	1.58
0.21-0.50	0.011	0.34	0.32	0.15	0.56	0.32	0.094	0.08	0.17	0.24
0.51-1.00	0.014	0.39	0.5	0.11	0.96	0.62	0.075	0.099	0.13	0.33
1.01-2.00	0.024	0.57	0.65	0.072	2.06	1.2	0.1	0.074	0.2	0.45
2.01-5.00	0.024	0.55	0.33	0.24	2.42	1.26	0.22	0.0001	0.11	0.22
> 5.00	0.0062	0.062	0.054	0.2	0.19	0.77	0.02	0	0.0087	0.0014

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)								
	Poblacion I	Poblacion II	Poblacion III	Poblacion IV	Salag	San Jose	Sandu-lot	Sumaliring	Tay-ak
0.03-0.20	0.021	0.015	0.33	0.15	5.12	0.12	6.31	0.3	4.5
0.21-0.50	0.019	0.012	0.28	0.057	0.29	0.078	0.34	0.088	0.16
0.51-1.00	0.067	0.065	0.43	0.089	0.15	0.24	0.35	0.16	0.12
1.01-2.00	0.2	0.21	0.15	0.11	0.097	0.65	0.84	0.49	0.094
2.01-5.00	0.0028	0.035	0.09	0.076	0.084	0.071	0.56	0.043	0.2
> 5.00	0	0.0043	0.001	0.014	0.0012	0.002	0.0004	0	0.15

For the 100-year return period, 12.03% of the municipality of Asturias with an area of 427.32 sq. km. will experience flood levels of less 0.20 meters. 0.79% of the area will experience flood levels of 0.21 to 0.50 meters while 0.89%, 1.93%, 2.05%, and 0.5% 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 39 are the affected areas in square kilometers by flood depth per barangay.

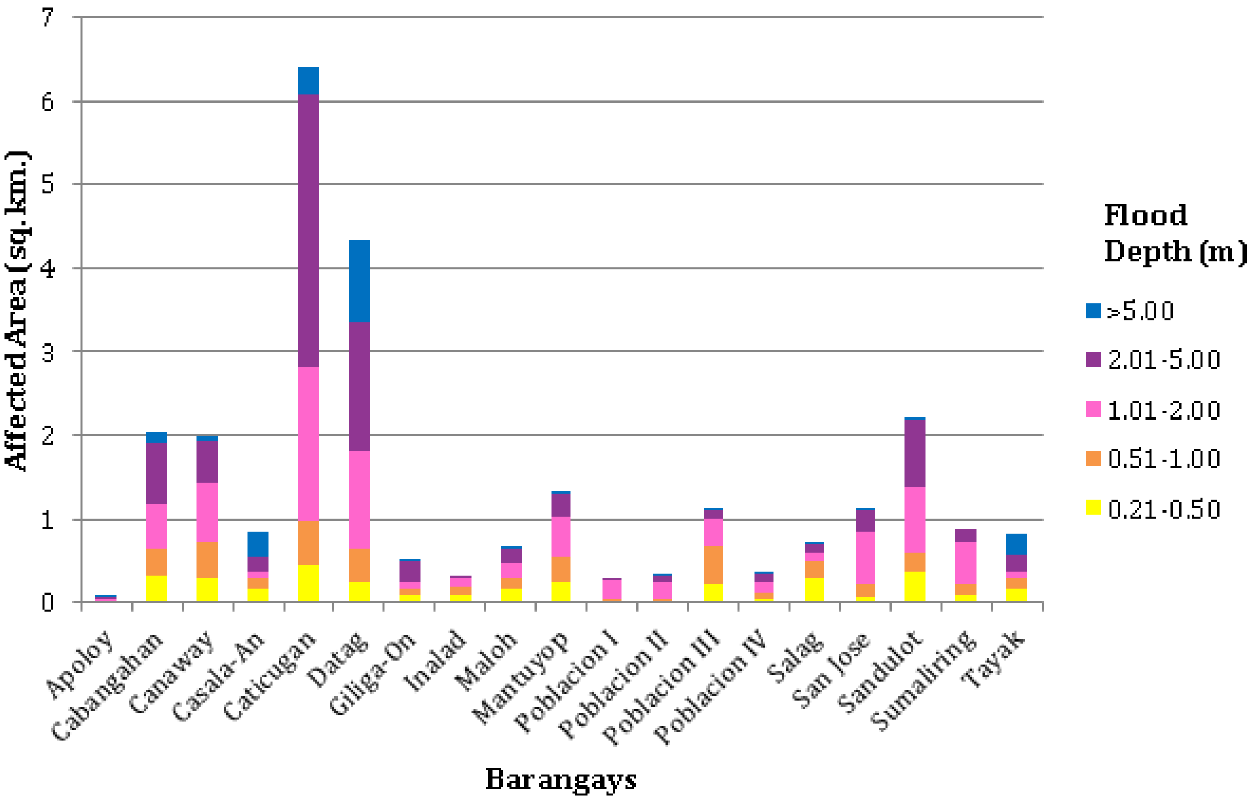


Figure 72 Affected Areas in Siaton, Negros Oriental during 100-Year Rainfall Return Period

Table 39 Affected Areas in Siaton, Negros Oriental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)									
	Apoloy	Cabanga-han	Cana-way	Casa-la-An	Cati-cugan	Datag	Giliga-On	Inalad	Maloh	Mantuy-op
0.03-0.20	0.35	5.68	2.3	4.4	6.98	4.61	3.98	0.31	5.02	1.5
0.21-0.50	0.0087	0.33	0.29	0.16	0.43	0.25	0.093	0.097	0.18	0.25
0.51-1.00	0.01	0.31	0.44	0.13	0.53	0.39	0.067	0.096	0.11	0.3
1.01-2.00	0.02	0.55	0.7	0.087	1.85	1.17	0.097	0.1	0.18	0.49
2.01-5.00	0.036	0.74	0.49	0.18	3.26	1.55	0.23	0.0017	0.19	0.28
> 5.00	0.0075	0.12	0.059	0.29	0.34	0.97	0.043	0	0.016	0.0037

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)								
	Poblacion I	Poblacion II	Poblacion III	Poblacion IV	Salag	San Jose	Sandu-lot	Sumaliring	Tayak
0.03-0.20	0.016	0.012	0.18	0.13	5.03	0.062	6.21	0.21	4.4
0.21-0.50	0.0098	0.0043	0.21	0.053	0.3	0.061	0.37	0.11	0.17
0.51-1.00	0.044	0.03	0.47	0.074	0.19	0.16	0.22	0.12	0.12
1.01-2.00	0.22	0.2	0.32	0.11	0.12	0.64	0.8	0.5	0.091
2.01-5.00	0.029	0.085	0.099	0.11	0.1	0.24	0.8	0.14	0.19
> 5.00	0	0.012	0.0015	0.014	0.0046	0.0028	0.0059	0	0.24

Among the barangays in the municipality of Siaton, Caticungan is projected to have the highest percentage of area that will experience flood levels at 3.13%. Meanwhile, Sandulot posted the second highest percentage of area that may be affected by flood depths at 1.97%.

Moreover, the generated flood hazard maps for the SIaton (Canaway-Siaton) 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 40 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	5.04	3.61	3.37
Medium	9.32	9.48	7.84
High	7.00	11.90	15.33
TOTAL	21.36	24.99	26.54

Of the 10 identified Education Institutions in the Siaton Flood plain, 2 schools were assessed to be exposed to medium level flooding during a 5 year scenario. In the 25 year scenario, 1 school was assessed to be exposed to low level flooding, while 2 schools were assessed to be exposed to medium level flooding in the same scenario. In the 100 year scenario, 2 schools were assessed to be exposed to medium level flooding, while 1 school was assessed to be exposed to high level flooding in the same scenario. See Appendix 12 for a detailed enumeration of schools in the Siaton Floodplain.

Of the 3 identified Medical Institutions in the Siaton Floodplain, 1 medical institution was assessed to be exposed to low level flooding during a 5 year scenario, while 1 medical institution was assessed to be exposed to medium level flooding in the same scenario. In the 25 year scenario, 3 medical institutions were assessed to be exposed to medium level flooding. In the 100 year scenario, 3 medical institutions were assessed to be exposed to medium level flooding. See Appendix 13 for a detailed enumeration of hospitals and clinics in the Siaton Floodplain.

The validation data were obtained on Dec 5-6, 2016.

5.11 Flood Validation

Survey was done along the floodplain of Siaton River to validate the generated flood maps. The team gathered secondary data regarding flood occurrence in the area. Ground validation points were acquired as well as the other necessary details like date of occurrence, name of typhoon and actual flood depth.

During validation, the team was assisted by the local Disaster Risk Reduction and Management representative from the Municipality of Siaton. Residents along the floodplain were interviewed of the historical flood events they experienced.

Actual flood depth acquired from the ground validation were then computed and compared to the flood depth simulated by the model. An RMSE value of 1.28 was obtained.

Table 41 Actual flood vs simulated flood depth at diffrenent levels in the Siaton River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	0	0	0	4	2	0	6
0.21-0.50	0	0	2	13	7	0	22
0.51-1.00	0	0	0	6	4	0	10
1.01-2.00	2	0	1	6	4	0	13
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	2	0	3	29	17	0	51

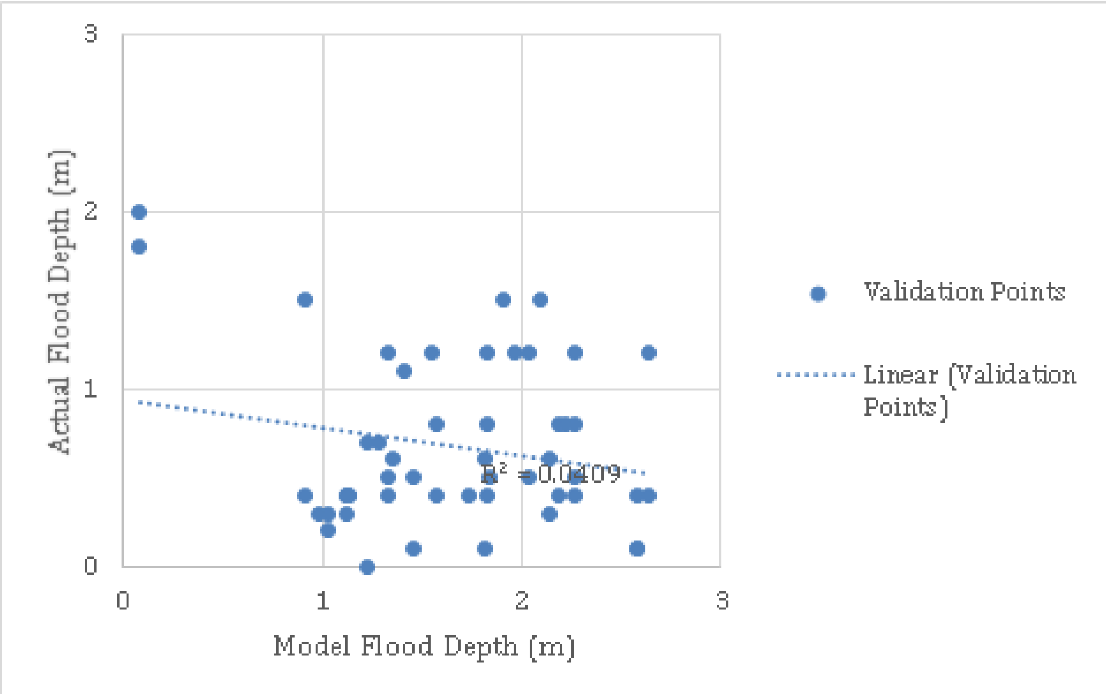


Figure 73 Flood map depth vs actual flood depth

The overall accuracy generated by the flood model is estimated at 11.76% with 6 points correctly matching the actual flood depths. In addition, there were 13 points estimated one level above and below the correct flood depths while there were 17 points and 15 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 3 points were underestimated in the modelled flood depths of Siaton.

Table 42 Summary of the Accuracy Assessment in the Siaton River Basin Survey

	No. of Points	%
Correct	6	11.76
Overestimated	42	82.35
Underestimated	3	5.88
Total	51	100.00

REFERENCES

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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.

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

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

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

ANNEXES

Annex 1. Optech Technical Specifications

1. GEMINI SENSOR

Table A-1.2 Parameters and Specifications of Gemini Sensor

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

2. AQUARIUS SENSOR

Table A-1.2 Parameters and Specifications of Aquarius Sensor

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

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

1. NGE-101

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

October 15, 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: **NEGROS ORIENTAL**	
	Station Name: **NGE-101**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **POBLACION**	
Municipality: **SIBULAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 21' 46.05028"**	Longitude: **123° 17' 3.45508"**	Ellipsoidal Hgt: **2.89700 m.**
	WGS84 Coordinates	
Latitude: **9° 21' 42.11526"**	Longitude: **123° 17' 8.79199"**	Ellipsoidal Hgt: **65.25500 m.**
	PTM / PRS92 Coordinates	
Northing: **1035271.672 m.**	Easting: **531227.453 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,034,909.31**	Easting: **531,216.52**	Zone: **51**

Location Description

NGE-101
The station was established in coordination with the PPA Port manager. The station is on the 3rd step from the top flooring of the pier NE corner. It is on the east side of the Sibulan Town proper, along the shoreline of Tañon Strait, inside the Sibulan Ferry Terminal compound. Mark is the head of a 4" copper nail at the center of a 30 x 30 cm. cement putty embedded on the concrete stairs with inscriptions "NGE-101; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2466**

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

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

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

Figure A-2.1. NGE- 101

2. NGE-111

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

October 15, 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: **NEGROS ORIENTAL**
Station Name: **NGE-111**
Order: **2nd**

Island: **VISAYAS**
Municipality: **DAUIN**
Barangay: **JAGOBA**
MSL Elevation:

PRS92 Coordinates

Latitude:	**9° 10' 30.25228"**	Longitude:	**123° 14' 54.26711"**	Ellipsoidal Hgt:	**13.11600 m.**

WGS84 Coordinates

Latitude:	**9° 10' 26.36267"**	Longitude:	**123° 14' 59.62110"**	Ellipsoidal Hgt:	**75.79100 m.**

PTM / PRS92 Coordinates

Northing:	**1014508.213 m.**	Easting:	**527300.168 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,014,153.12**	Easting:	**527,290.61**	Zone:	**51**

Location Description

NGE-111

The station is located on the NE approach of the 36 m. long Jagoba bridge at Km.17+930. The station is about 40 m. SW of km.post # 18. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on the concrete sidewalk with inscriptions "NGE-111; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2465**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. NGE- 111

3. NGE-89

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

October 15, 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: **NEGROS ORIENTAL**
Station Name: **NGE-89**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**BIO-OS**		
Municipality:	**AMLAN (AYUQUITAN)**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**9° 28' 17.93638"**	Longitude:	**123° 11' 53.99321"**	Ellipsoidal Hgt:	**5.29700 m.**
		WGS84 Coordinates			
Latitude:	**9° 28' 13.96567"**	Longitude:	**123° 11' 59.32102"**	Ellipsoidal Hgt:	**67.20400 m.**
		PTM / PRS92 Coordinates			
Northing:	**1047303.984 m.**	Easting:	**521778.353 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,046,937.41**	Easting:	**521,770.73**	Zone:	**51**

Location Description

NGE-89
The station is on the SE corner of Bio-os Bridge, at km. 23+56. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on the concrete pavement of the bridge's sidewalk with inscriptions "NGE-89; 2007; NAMRIA".

The station is located along the Dumaguete-San Carlos national road, between the municipalities of Tanjay and Amlan.

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2467**

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. NGE- 89

4. NGE-100

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: **NEGROS ORIENTAL**
Station Name: **NGE-100**
Order: **2nd**

Island: **VISAYAS**		Barangay: **CAWITAN**			
Municipality: **STA CATALINA**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**9° 18' 11.02881"**	Longitude:	**122° 52' 26.45331"**	Ellipsoidal Hgt:	**8.14800 m.**
		WGS84 Coordinates			
Latitude:	**9° 18' 7.07298"**	Longitude:	**122° 52' 31.79856"**	Ellipsoidal Hgt:	**69.61900 m.**
		PTM / PRS92 Coordinates			
Northing:	**1028656.115 m.**	Easting:	**486159.164 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,028,296.07**	Easting:	**486,164.01**	Zone:	**51**

Location Description

NGE-100
The station is located on the SW corner of Cawitan Bridge, along the Dumaguete- Bayawan national highway. Mark is the head of a 4" copper nail drilled and grouted at the center of 30 x 30 cm. cement putty embedded on the concrete sidewalk with inscriptions "NGE-100; 2007; NAMRIA". The station is about 7 km. from Sta Catalina heading to Siaton.

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089687 I**
T.N.:	**2016-0242**

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

9901272016151240

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. NGE- 100

5. NGW-126

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

October 30, 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: **NEGROS OCCIDENTAL**			
		Station Name: **NGW-126**			
		Order: **2nd**			
Island: **VISAYAS**		Barangay: **MARICALUM**			
Municipality: **SIPALAY**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**9° 41' 56.09927"**	Longitude:	**122° 26' 33.87232"**	Ellipsoidal Hgt:	**20.29100 m.**
		WGS84 Coordinates			
Latitude:	**9° 41' 52.00368"**	Longitude:	**122° 26' 39.18513"**	Ellipsoidal Hgt:	**79.82600 m.**
		PTM / PRS92 Coordinates			
Northing:	**1072482.031 m.**	Easting:	**438848.628 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,072,106.64**	Easting:	**438,870.03**	Zone:	**51**

Location Description

NGW-126
The station is located on the SE corner of Maricalum bridge which is at the km 177+175. Mark is the head of a 4" copper nail flushed at the center of a 30 x 30 cm. cement putty embedded on the bridge sidewalk with inscriptions "NGW-126; 2007; NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2590**

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

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www.namria.gov.ph

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CIP/4701/12/09/834

Figure A-2.5. NGW - 126

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

1. NE-90

Table A-3.1. BM-105

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NE-90 --- NGE-111 (B1)	NGE-111	NE-90	Fixed	0.003	0.011	216°26'37"	8704.123	-5.758
NGE-111 --- NE-90 (B2)	NGE-111	NE-90	Fixed	0.005	0.025	216°26'38"	8704.148	-5.719

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	NGE-111				
Grid		Local		Global	
Easting	527290.613 m	Latitude	N9°10'30.25228"	Latitude	N9°10'26.36267"
Northing	1014153.117 m	Longitude	E123°14'54.26711"	Longitude	E123°14'59.62110"
Elevation	12.583 m	Height	13.116 m	Height	75.791 m

To:	NE-90				
Grid		Local		Global	
Easting	522126.927 m	Latitude	N9°06'42.32060"	Latitude	N9°06'38.44322"
Northing	1007150.356 m	Longitude	E123°12'04.93455"	Longitude	E123°12'10.29457"
Elevation	7.044 m	Height	7.358 m	Height	70.052 m

Vector					
ΔEasting	-5163.685 m	NS Fwd Azimuth	216°26'37"	ΔX	3718.151 m
ΔNorthing	-7002.762 m	Ellipsoid Dist.	8704.123 m	ΔY	3758.805 m
ΔElevation	-5.538 m	ΔHeight	-5.758 m	ΔZ	-6914.376 m

Standard Errors

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

2. NE-135

Table A-3.2. BM-107

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NE-135 --- NGE-89 (B1)	NGE-89	NE-135	Fixed	0.006	0.006	293°20'47"	1679.526	0.259
NGE-89 --- NE-135 (B3)	NGE-89	NE-135	Fixed	0.004	0.006	293°20'47"	1679.528	0.236

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	NGE-89				
Grid		Local		Global	
Easting	521770.730 m	Latitude	N9°28'17.93638"	Latitude	N9°28'13.96567"
Northing	1046937.409 m	Longitude	E123°11'53.99321"	Longitude	E123°11'59.32102"
Elevation	3.905 m	Height	5.297 m	Height	67.204 m

To:	NE-135				
Grid		Local		Global	
Easting	520228.944 m	Latitude	N9°28'39.60020"	Latitude	N9°28'35.62671"
Northing	1047601.845 m	Longitude	E123°11'03.44049"	Longitude	E123°11'08.76787"
Elevation	4.101 m	Height	5.556 m	Height	67.415 m

Vector					
ΔEasting	-1541.786 m	NS Fwd Azimuth	293°20'47"	ΔX	1350.288 m
ΔNorthing	664.437 m	Ellipsoid Dist.	1679.526 m	ΔY	752.714 m
ΔElevation	0.196 m	ΔHeight	0.259 m	ΔZ	656.467 m

Standard Errors

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

3. TBM-4

Table A-3.3. TBM - 4

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
T-BM4 --- NGE-101 (B1)	NGE-101	T-BM4	Fixed	0.005	0.017	155°37'59"	6288.490	0.815
T-BM4 --- NGE-101 (B2)	NGE-101	T-BM4	Fixed	0.004	0.009	155°37'59"	6288.479	0.804

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	NGE-101				
Grid		Local		Global	
Easting	531216.523 m	Latitude	N9°21'46.05028"	Latitude	N9°21'42.11526"
Northing	1034909.308 m	Longitude	E123°17'03.45508"	Longitude	E123°17'08.79199"
Elevation	2.110 m	Height	2.897 m	Height	65.255 m

To:	T-BM4				
Grid		Local		Global	
Easting	533814.622 m	Latitude	N9°18'39.58660"	Latitude	N9°18'35.66706"
Northing	1029185.290 m	Longitude	E123°18'28.47112"	Longitude	E123°18'33.81248"
Elevation	3.094 m	Height	3.712 m	Height	66.241 m

Vector					
ΔEasting	2598.099 m	NS Fwd Azimuth	155°37'59"	ΔX	-2679.198 m
ΔNorthing	-5724.018 m	Ellipsoid Dist.	6288.490 m	ΔY	-646.804 m
ΔElevation	0.985 m	ΔHeight	0.815 m	ΔZ	-5652.309 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

4. NE-90A

Table A-3.4. NE-90A

NE 90 - NE 90A1 (4:33:53 PM-6:08:49 PM) (S1)

Baseline observation:	NE 90 --- NE 90A1 (B1)
Processed:	2/23/2016 5:58:20 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.007 m
RMS:	0.001 m
Maximum PDOP:	2.945
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	1/30/2016 4:33:54 PM (Local: UTC+8hr)
Processing stop time:	1/30/2016 6:08:49 PM (Local: UTC+8hr)
Processing duration:	01:34:55
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	NE 90				
Grid		Local		Global	
Easting	522126.927 m	Latitude	N9°06'42.32060"	Latitude	N9°06'38.44322"
Northing	1007150.356 m	Longitude	E123°12'04.93454"	Longitude	E123°12'10.29457"
Elevation	7.044 m	Height	7.358 m	Height	70.052 m

To:	NE 90A1				
Grid		Local		Global	
Easting	522130.430 m	Latitude	N9°06'44.56131"	Latitude	N9°06'40.68377"
Northing	1007219.167 m	Longitude	E123°12'05.05055"	Longitude	E123°12'10.41052"
Elevation	6.278 m	Height	6.597 m	Height	69.290 m

Vector					
ΔEasting	3.502 m	NS Fwd Azimuth	2°56'44"	ΔX	3.419 m
ΔNorthing	68.812 m	Ellipsoid Dist.	68.928 m	ΔY	-11.689 m
ΔElevation	-0.766 m	ΔHeight	-0.761 m	ΔZ	67.848 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'05"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.002 m
σ ΔElevation	0.003 m	σ ΔHeight	0.003 m	σ ΔZ	0.001 m

Annex 4. The LiDAR Survey Team Composition

Table A-1.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS) 2014	ENGR. GEROME HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016	AUBREY MATIRA PAGADOR	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
		MA. REMEDIOS VILLANUEVA	UP-TCAGP
		JONALYN GONZALES	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JONATHAN ALMALVEZ	UP-TCAGP
		ENGR. GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERWIN DELOS SANTOS	PHILIPPINE AIR FORCE (PAF)
		SSG. RAYMUND DOMINE	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC
		CAPT. MARK TANGONAN	AAC
		CAPT. NEIL ACHILLES AGAW-IN	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. Data Transfer Sheet for Libertad Floodplain

DATA TRANSFER SHEET
10/20/2014(Dumaguete ready)

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	
24-Sep-14	7514	2BLK56F267A	GEMINI	14.1	198	450	228	NA	NA	20	NA	12	1KB	1KB	3	7/8	Z:\DAC\RAW DATA
24-Sep-14	7515	2BLK54C267B	GEMINI	9.1	119	254	162	NA	NA	12.7	NA	12	1KB	1KB	NA	11	Z:\DAC\RAW DATA
25-Sep-14	7516	2BLK56DC268A	GEMINI	18.2	285	536	236	NA	NA	25.5	NA	7.82	1KB	1KB	3	7	Z:\DAC\RAW DATA
26-Sep-14	7518	2BLK56B269A	GEMINI	14.1	193	173	72.5	NA	NA	15.5	NA	5.54	1KB	1KB	3	8	Z:\DAC\RAW DATA
29-Sep-14	7524	2BLK54C272A	GEMINI	16.8	303	535	248	NA	NA	27	NA	6.07	1KB	1KB	4	8/9	Z:\DAC\RAW DATA
30-Sep-14	7526	2BLK53OS5A273A	GEMINI	5.37	91	173	144	NA	NA	7.8	NA	3.6	1KB	1KB	3/8	21	Z:\DAC\RAW DATA
1-Oct-14	7528	2BLK54B274A	GEMINI	7.91	115	219	122	NA	NA	9.25	NA	3.91	1KB	1KB	5/4	12	Z:\DAC\RAW DATA
2-Oct-14	7530	2BLK54BS56E275A	GEMINI	7.09	115	226	132	NA	NA	8.74	NA	3.7	1KB	1KB	3/4	12/7	Z:\DAC\RAW DATA

Received from

Name C. Joson III
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 10/20/2014

DATA TRANSFER SHEET
DUMAGUETE (11/06/2014)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS (MB)	RAW IMAGES / CASI	MISSION LOG FILE / CASI LOGS	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION/S	BASE INFO (.txt)		ACTUAL	KML	
6-Oct-14	7538	2BLK54BS279A	GEMINI-CASI	N/A	64.3 KB	136 KB	109	N/A	N/A	5.59	N/A	3.61	1 KB	1 KB	4 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
7-Oct-14	7540	2BLK55AS53KS280A	GEMINI-CASI	N/A	157 KB	299 KB	208	N/A	N/A	13.1	N/A	4.94	1 KB	1 KB	116 KB	6.76 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
17-Oct-14	7560	2BLK55A290A	GEMINI-CASI	N/A	257 KB	N/A	221	N/A	N/A	19.6	N/A	5.34	1 KB	1 KB	366 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
18-Oct-14	7562	2BLK53I291A	GEMINI-CASI	N/A	302 KB	511 KB	248	N/A	N/A	24.1	N/A	6.49	1 KB	1 KB	236	7.6 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
20-Oct-14	7566	2BLK53JK293A	GEMINI-CASI	17.1 GB	293 KB	827 KB	210	70.5 GB	118 KB	19	N/A	6.05	1 KB	1 KB	372 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
21-Oct-14	7568	2BLK53KS294A	GEMINI-CASI	7.4 GB	265 KB	224 KB	192	21 GB	101 KB	9.89	N/A	6.01	1 KB	1 KB	198 KB	20.3 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
22-Oct-14	7570	2BLK53H295A	GEMINI-CASI	18 GB	242 KB	416 KB	246	75.5	106 KB	21.5	N/A	6.57	1 KB	1 KB	352 KB	7.84 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
24-Oct-14	7574	2BLK53I297A	GEMINI-CASI	18.2 GB	490 KB	433 KB	258	N/A	N/A	20.2	N/A	5.78	1 KB	1 KB	351 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
25-Oct-14	7576	2BLK53H298A	GEMINI-CASI	14.6 GB	208 KB	354 KB	228	N/A	N/A	17.1	N/A	4.91	1 KB	1 KB	151 KB	8.55 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
26-Oct-14	7578	2BLK53HSGF299A	GEMINI-CASI	6.74 GB	426 KB	411 KB	259	N/A	N/A	18.1	N/A	6.18	1 KB	1 KB	672 KB	16.4 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
27-Oct-14	7580	2BLK56ESBLK53FS300A	GEMINI-CASI	2.30 GB	122 KB	240 KB	229	N/A	N/A	10.9	N/A	5.16	1 KB	1 KB	141 KB	7.89 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
28-Oct-14	7582	2BLK56BSES301A	GEMINI-CASI	12.7 GB	272 KB	344 KB	165	7.62 GB	63.1 KB	16.7	N/A	8.47	1 KB	1 KB	193 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
28-Oct-14	7583	2BLK56ABS301B	GEMINI-CASI	N/A	82.1 KB	307 KB	145	N/A	N/A	9.86	N/A	8.47	1 KB	1 KB	N/A	11.8 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA

RECEIVED FROM:

NAME: C. Joaquin
POSITION:
SIGNATURE:

RECEIVED BY:

NAME: JOIDA PRIETO
POSITION: SSRS
SIGNATURE:

DATE: NOV/06/2014

DATA TRANSFER SHEET
Dumaguete 2/9/16

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	
25-Jan	10066AC	3BLK54AB025A	Aquarius	NA	114	342	157	27.6	211	5.25	na	3.97	1KB	1KB	10KB	15KB	Z:\DAC\RAW DATA
28-Jan	10072AC	3BLK53B028A	Aquarius	NA	231	508	227	43.3	44.3	10.5	140	9.96	1KB	1KB	3KB	8KB	Z:\DAC\RAW DATA
29-Jan	10074AC	3BLK53A029A	Aquarius	NA	45	375	247	35	150	7.74	na	18	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
29-Jan	10075AC	3BLK53S029B	Aquarius	NA	28	292	215	18	42.3/198	5.4	na	18	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
30-Jan	10076AC	3BLK53V030A	Aquarius	NA	99	302	193	53.1	150/42.3/198	5.06	68	18.4	1KB	NA	16KB	28KB	Z:\DAC\RAW DATA
30-Jan	10077AC	3BLK56V030B	Aquarius	NA	83	391	198	27	145/26.7/237	5.46	na	18.4	1KB	NA	24KB	37KB	Z:\DAC\RAW DATA

Received from

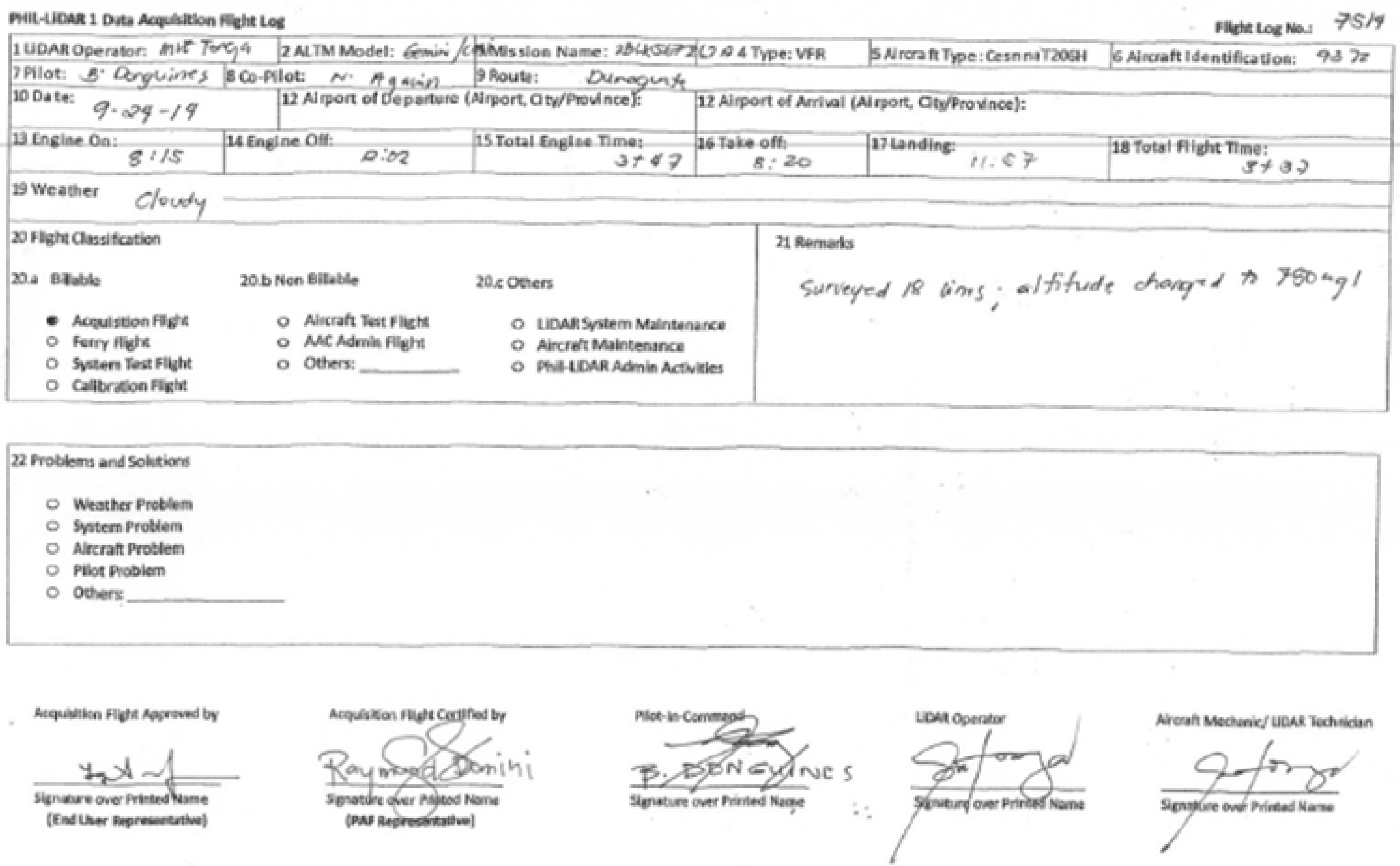
Name Jonalyn S. Gonzales
Position Research Associate
Signature

Received by

Name AC Bongat
Position SRS
Signature

Annex 6. Flight logs for the flight missions

Flight Log for 7514GC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7514

1 LIDAR Operator: MR Tong4	2 ALTM Model: Gemini	3 Mission Name: 2BLKS6P272A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9372
7 Pilot: B. Donguines	8 Co-Pilot: N. Aguirre	9 Route: Dumaguete			
10 Date: 9-29-19	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:15	14 Engine Off: 12:02	15 Total Engine Time: 3+47	16 Take off: 8:20	17 Landing: 11:57	18 Total Flight Time: 3+37
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 18 lines; altitude changed to 780 agl

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 — Raymond Domini — Signature over Printed Name (PAF Representative)

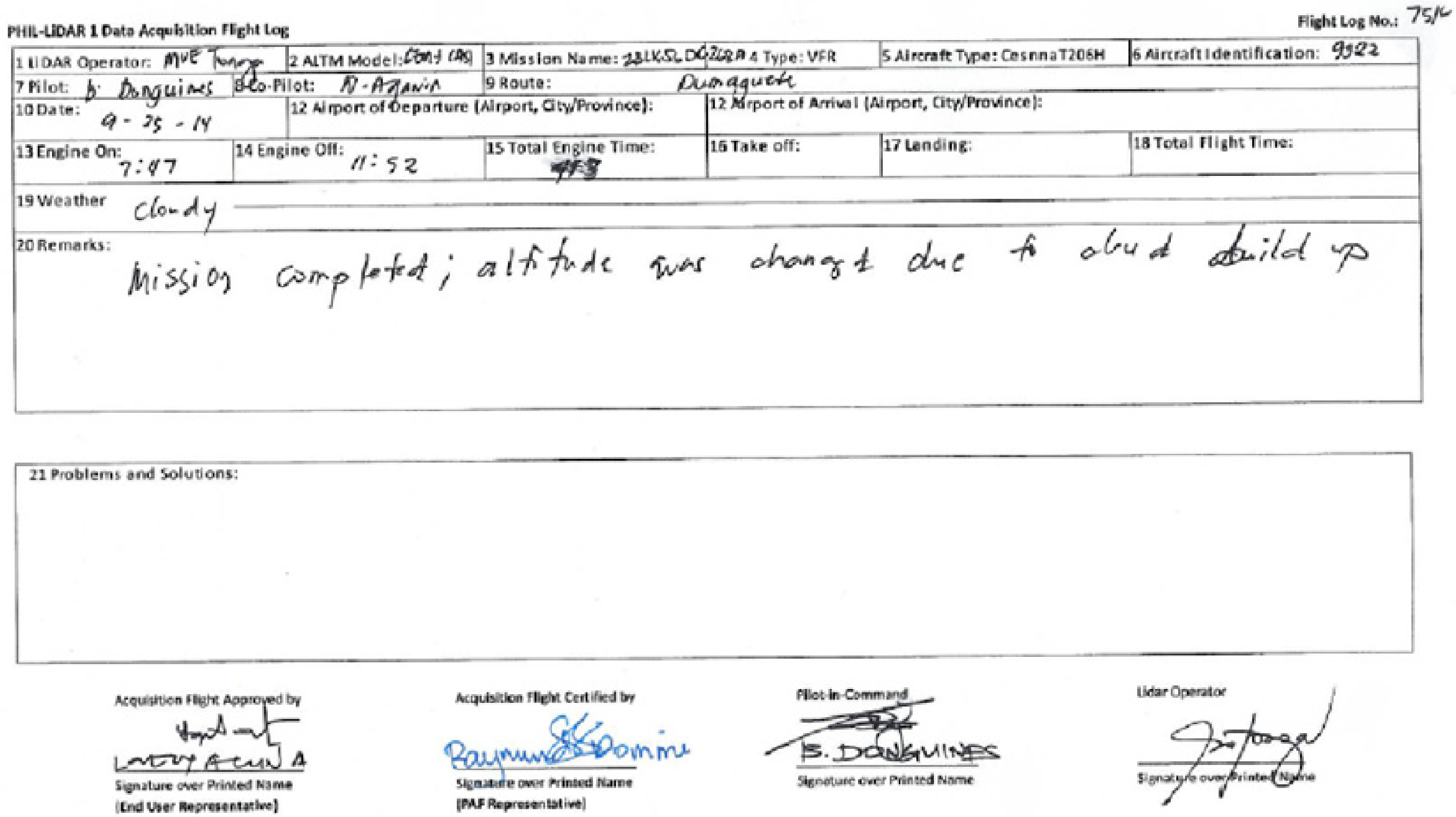
Pilot-in-Command — B. DONGUINES — Signature over Printed Name

LIDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-5.1. Flight Log for 7514GC Mission

Flight Log for 7516GC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7516

1 LIDAR Operator: MVE Tongco	2 ALTM Model: Gem+ (AQ)	3 Mission Name: 2BLK5L D0268A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: B. Donguines	8 Co-Pilot: R. Azarcon	9 Route: Dumaguete			
10 Date: 9-25-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:47	14 Engine Off: 11:52	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Mission completed; altitude was changed due to cloud build up					

21 Problems and Solutions:

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

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

Pilot-in-Command: B. DONGUINES — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-5..2. Flight Log for 7516GC Mission

Flight Log for 7518GC Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7518

1 LiDAR Operator: MVE Tong	2 ALTM Model: ~~Gem~~ GMS	3 Mission Name: 2BLK6LB269A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9077
7 Pilot: B. Donguines	8 Co-Pilot: N. Agmin	9 Route: Dumaguete			
10 Date: 9-26-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:56	14 Engine Off: 10:55	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 11 lines; heavy cloud build-up

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	Raymund Dominic	B. DONGUINES	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-5..3. Flight Log for 7518GC Mission

Flight Log for 7582GC Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7582GC

1 LIDAR Operator: MVE Tongga	2 ALTM Model: Gem1CASI	3 Mission Name: 2BLK36BSES301A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route: Dumaguete			
10 Date: Oct 28, 2014		12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province): Dumaguete	
13 Engine On: 0604	14 Engine Off: 0927	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Mission completed (without CASI due to intermitent grounding connection)

21 Problems and Solutions:

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

Figure A-5..4.Flight Log for 7582GC Mission

Flight Log for 7583GC Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7583GC

28LXF6ABS301B+

1 LIDAR Operator: MR Villanueva	2 ALTM Model: Gemini	3 Mission Name: CALIBRATION	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route: Dumaguete			
10 Date: Oct 28, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province): Dumaguete		
13 Engine On: 1355	14 Engine Off: 1730	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Fair				

20 Remarks:

Mission completed plus calibration of Gemini (without CASI due to intermittent grounding connection)

21 Problems and Solutions:

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

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

Pilot-in-Command
R. Samar
Signature over Printed Name

Lidar Operator
MR Villanueva
Signature over Printed Name

Figure A-5..5 Flight Log for 7583GC Mission

Annex 7. Flight status reports

Table A-7.1. Flight Status Report

NEGROS ORIENTAL
(September 24 – October 28, 2014 and January 30, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7514GC	BLK 56D; BLK 56F	2BLK56F267A	MV Tonga	September 24, 2014	Surveyed 18 lines; altitude changed to 750m AGL
7516GC	BLK 54C; BLK 56D	2BLK56DC268A	MV Tonga	September 25, 2014	Mission completed; altitude was changed due to cloud build-up
7518GC	BLK 56B	2BLK56B269A	MV Tonga	September 26, 2014	Surveyed 11 lines; heavy build-up
7582GC	BLK 56B; BLK 56E	2BLK56BSES301A	MV Tonga	October 28, 2014	Mission completed (without CASI due to intermittent grounding connec-tion)
7583GC	BLK 56A; BLK 56B	2BLK56ABS301B + CALIBRATION	MR Villanue-va	October 28, 2014	Mission completed plus calibration of Gemini (without CASI due to inter-mittent grounding connection)
10077AC	BLK 56B; BLK 56C; BLK 56D; BLK 56E; BLK 56F	3BLK56V030B	MV Tonga	January 30, 2016	Covered voids over BLK 56

LAS BOUNDARIES PER FLIGHT

Flight No.:	7514GC			
Area:	BLK 56D; BLK 56F			
Mission Name:	2BLK56F267A			
Parameters:	Altitude:	750/1100 m;	Scan Frequency:	40/50 Hz;
	Scan Angle:	20/25deg;	Overlap:	30%

LAS

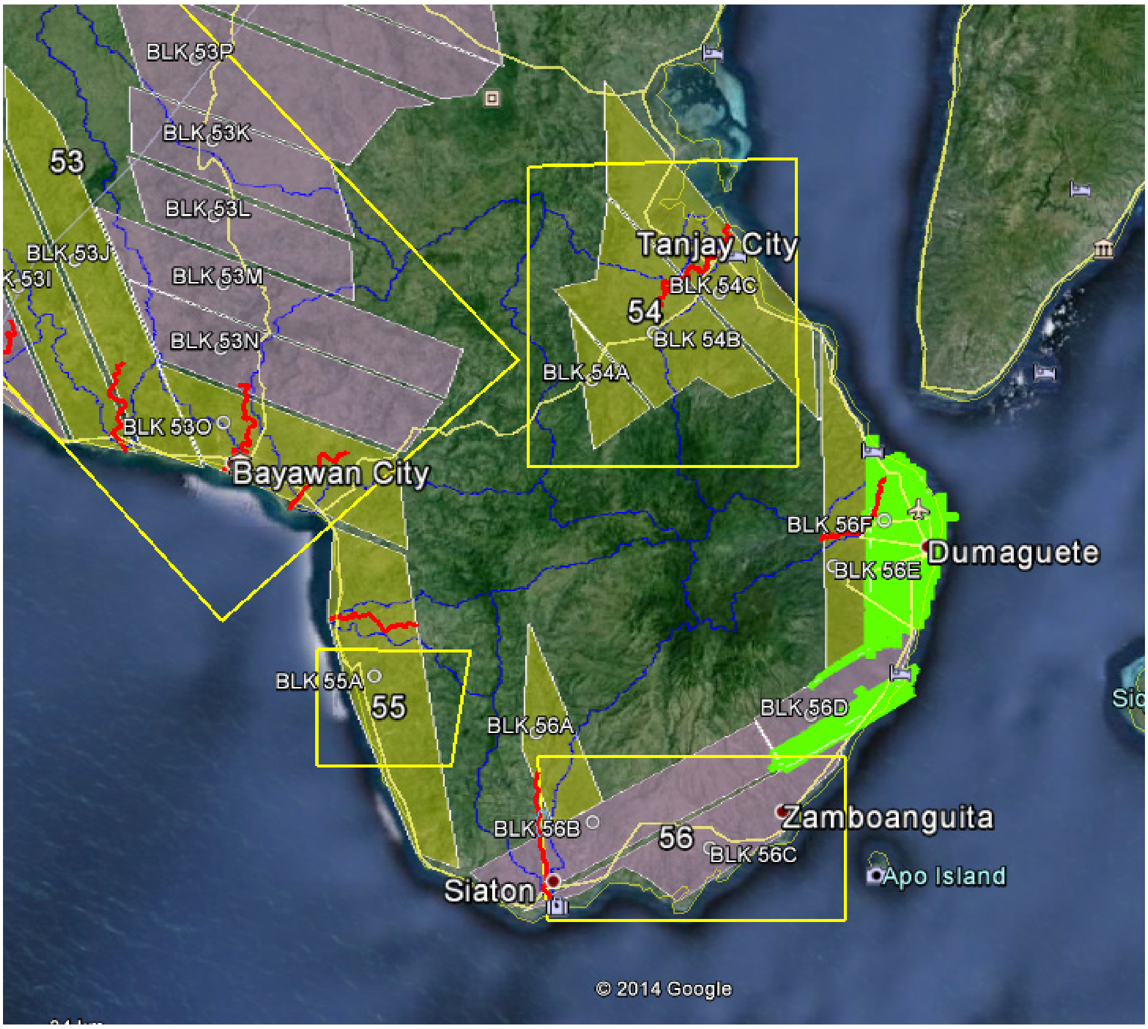


Figure A-7.1. 7514GC

Flight No.:	7516GC			
Area:	BLK 56C; BLK 56D			
Mission Name:	2BLK56DC268A			
Parameters:	Altitude:	1000/1100 m;	Scan Frequency:	40/50 Hz;
	Scan Angle:	20/25 deg;	Overlap:	30%

LAS

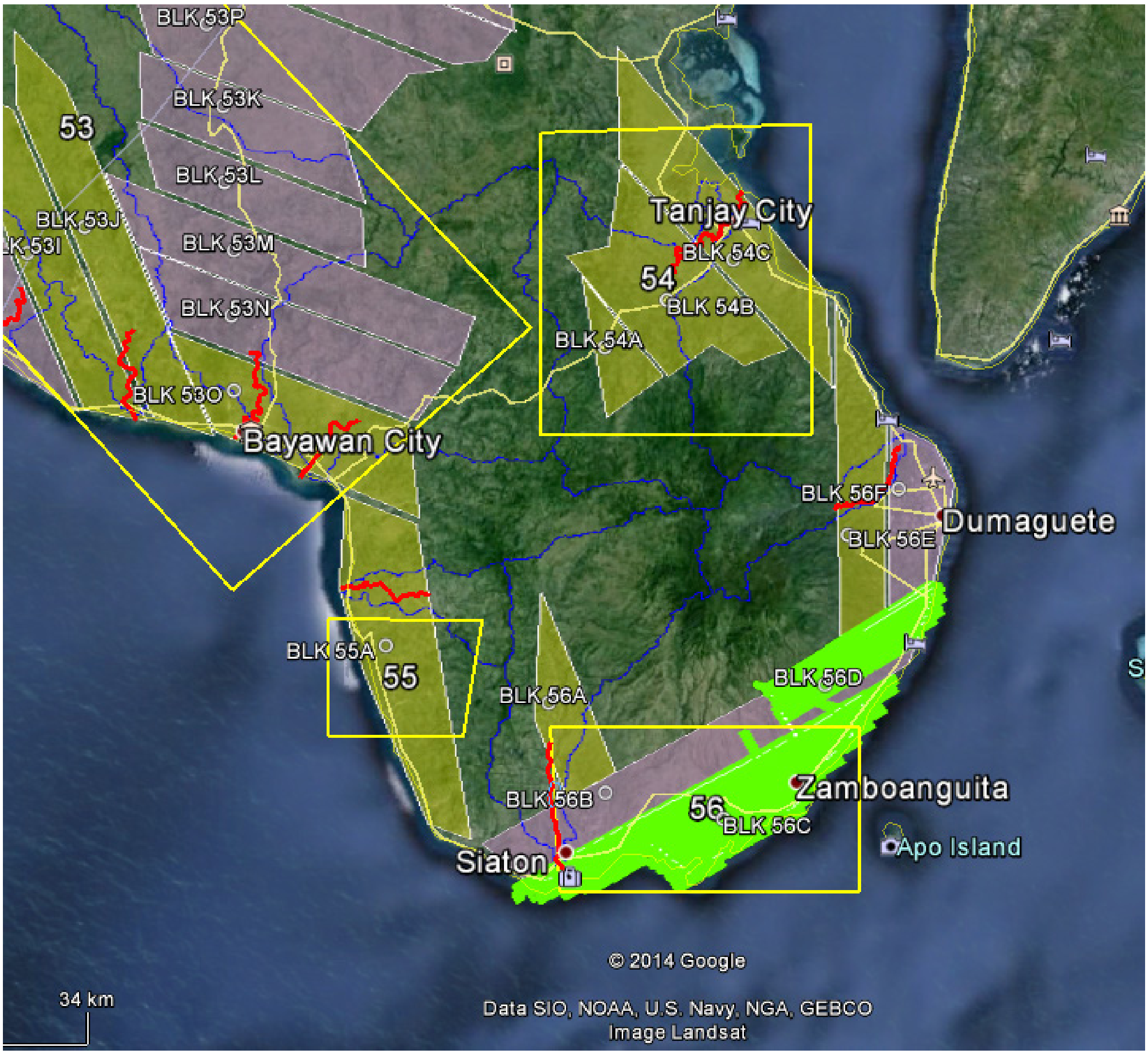


Figure A-7.2. 7516GC

Flight No.:	518GC				
Area:	BLK 56B				
Mission Name:	2BLK56B269A				
Parameters:	Altitude:	850/1000 m;		Scan Frequency:	40/50 Hz;
	Scan Angle:	20/25 deg;		Overlap:	30%

LAS

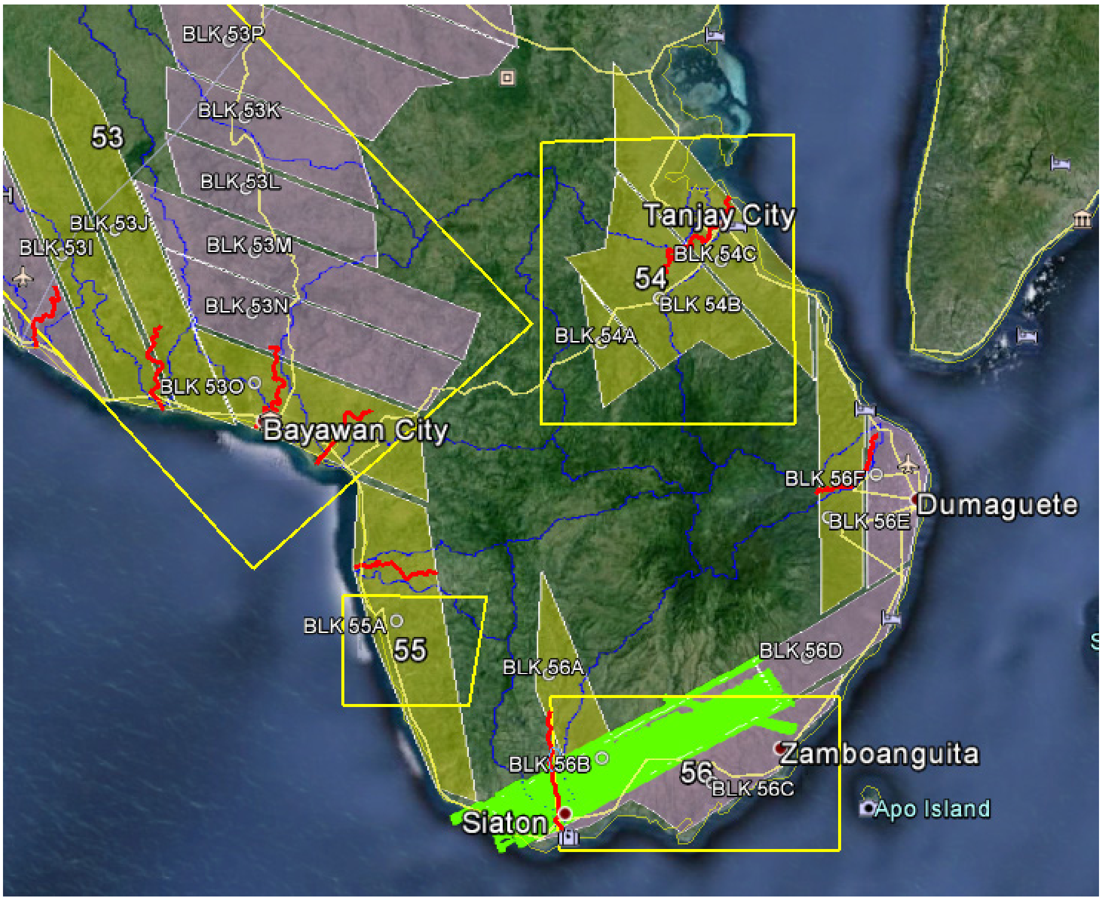


Figure A-7.3. 518GC

Flight No.: 7582GC
Area: BLK 56B; BLK 56E
Mission Name: 2BLK56BSES301A
Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;
Scan Angle: 20 deg; Overlap: 30%

LAS

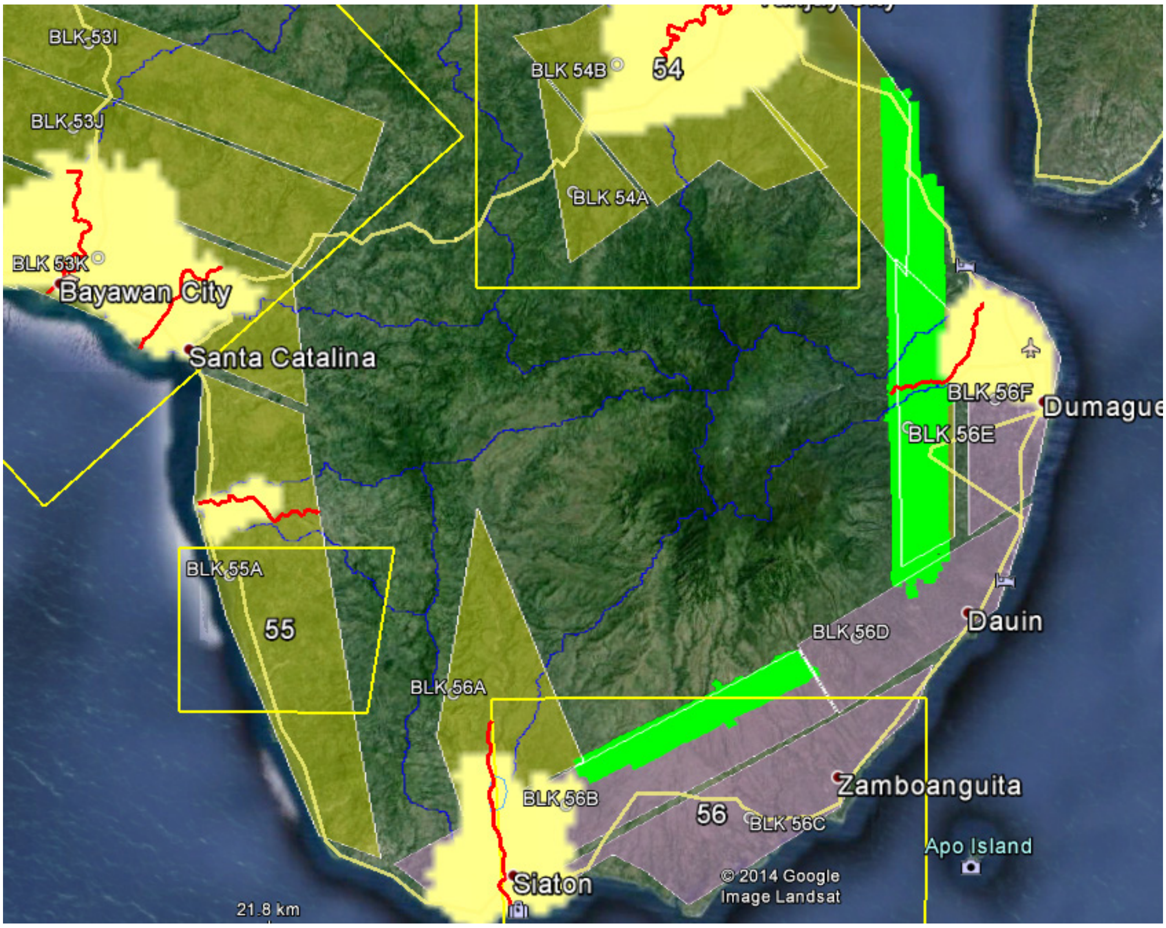


Figure A-7.4. 7582GC

Flight No.: 7583GC
Area: BLK 56A; BLK 56B
Mission Name: 2BLK56ABS301B + CALIBRATION
Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;
Scan Angle: 20 deg; Overlap: 30%

LAS

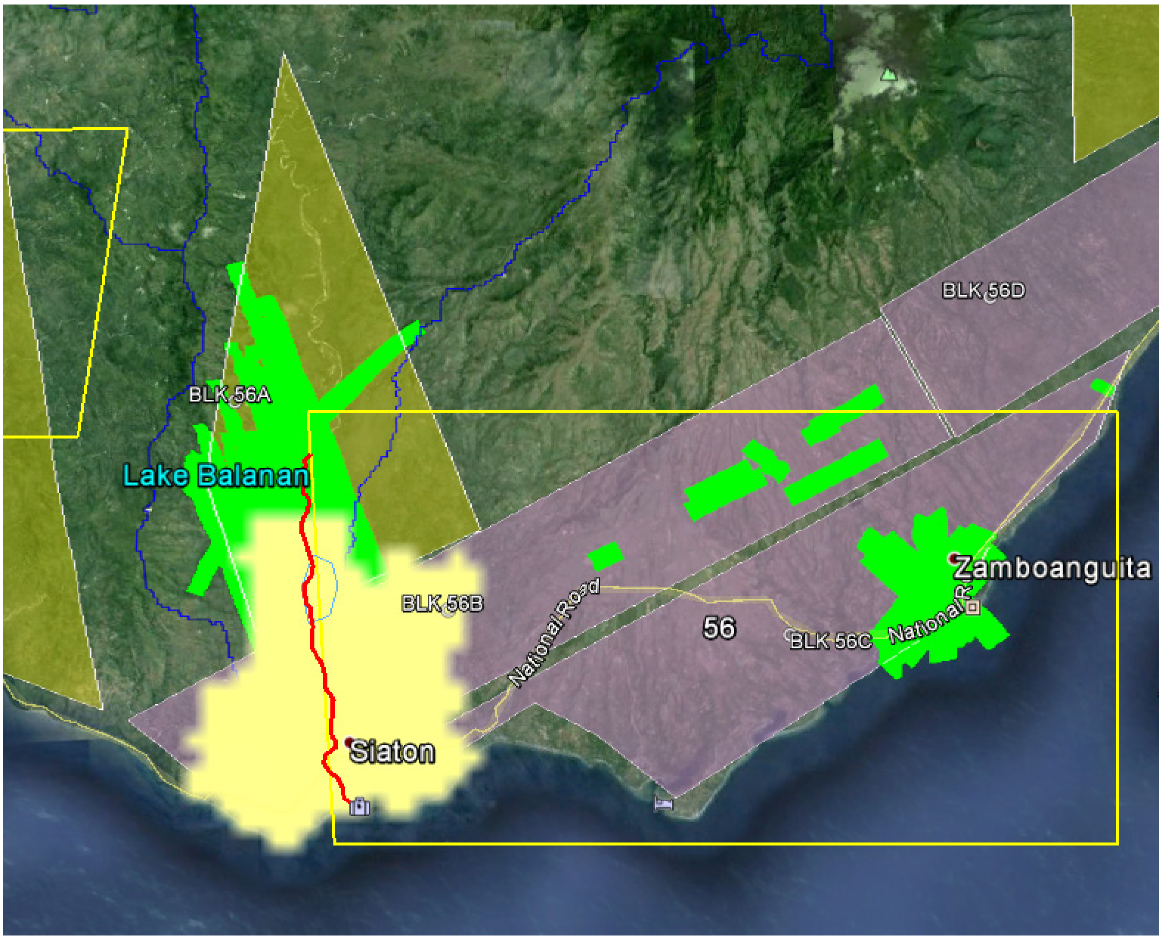


Figure A-7.5. 7583GC

Flight No.:	10077AC			
Area:	BLK 56B; BLK 56C; BLK 56D; BLK 56E; BLK 56F			
Mission Name:	3BLK56V030B			
Parameters:	Altitude:	500m;	Scan Frequency:	45 Hz;
	Scan Angle:	18 deg;	Overlap:	50%

LAS

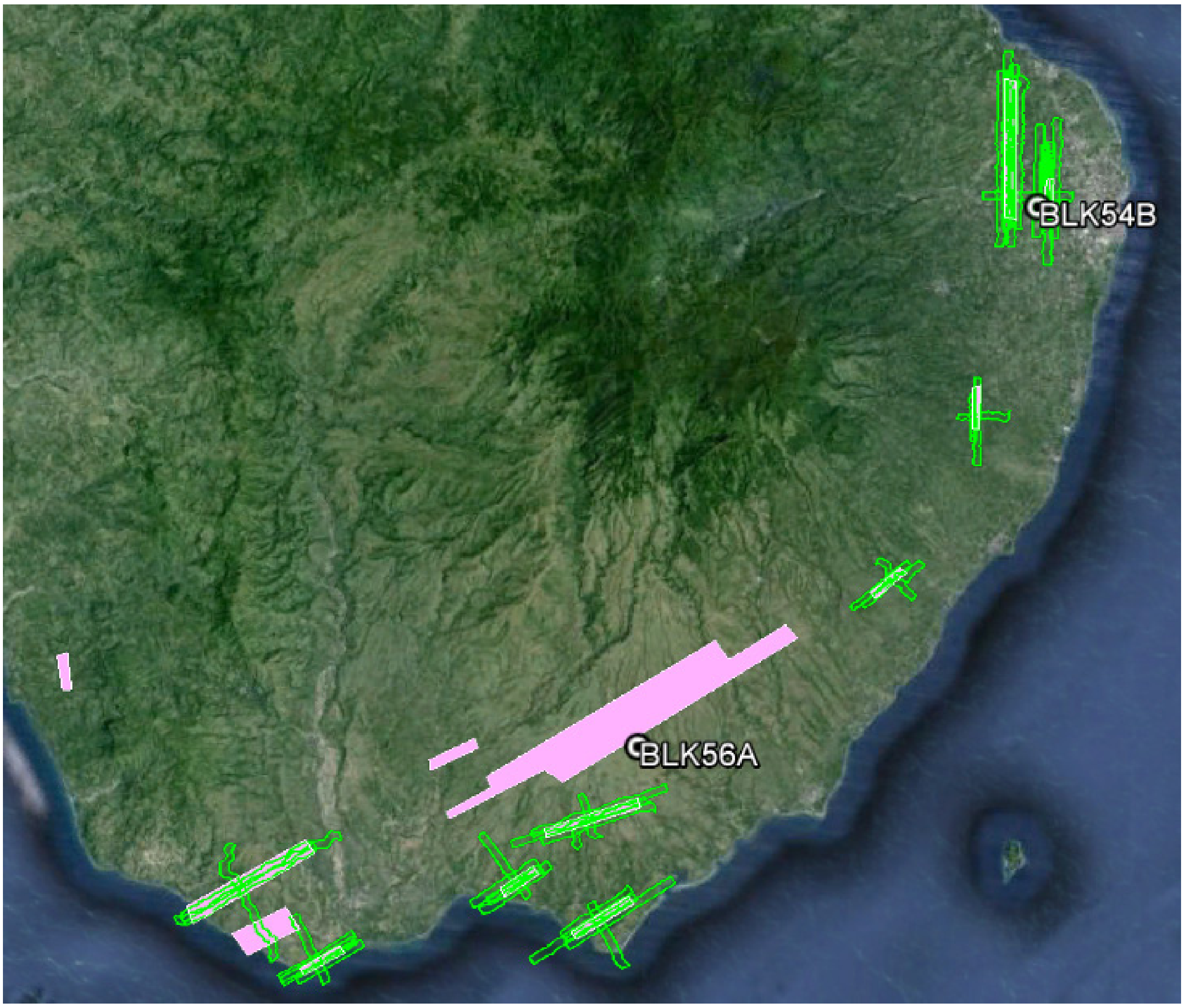


Figure A-7.6. 10077AC

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk56A

Flight Area	Dumaguete
Mission Name	Blk56A
Inclusive Flights	7583G
Range data size	9.86 GB
POS data size	145 MB
Base data size	8.47 MB
Image	na
Transfer date	November 6, 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)	1.15
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.15
Boresight correction stdev (<0.001deg)	0.000212
IMU attitude correction stdev (<0.001deg)	0.000358
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	30.09%
Ave point cloud density per sq.m. (>2.0)	3.61
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	59
Maximum Height	766.06 m
Minimum Height	70.85 m
Classification (# of points)	
Ground	15596658
Low vegetation	14714328
Medium vegetation	45897016
High vegetation	52003822
Building	848685
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Christy Lu-biano, Jovy Narisma

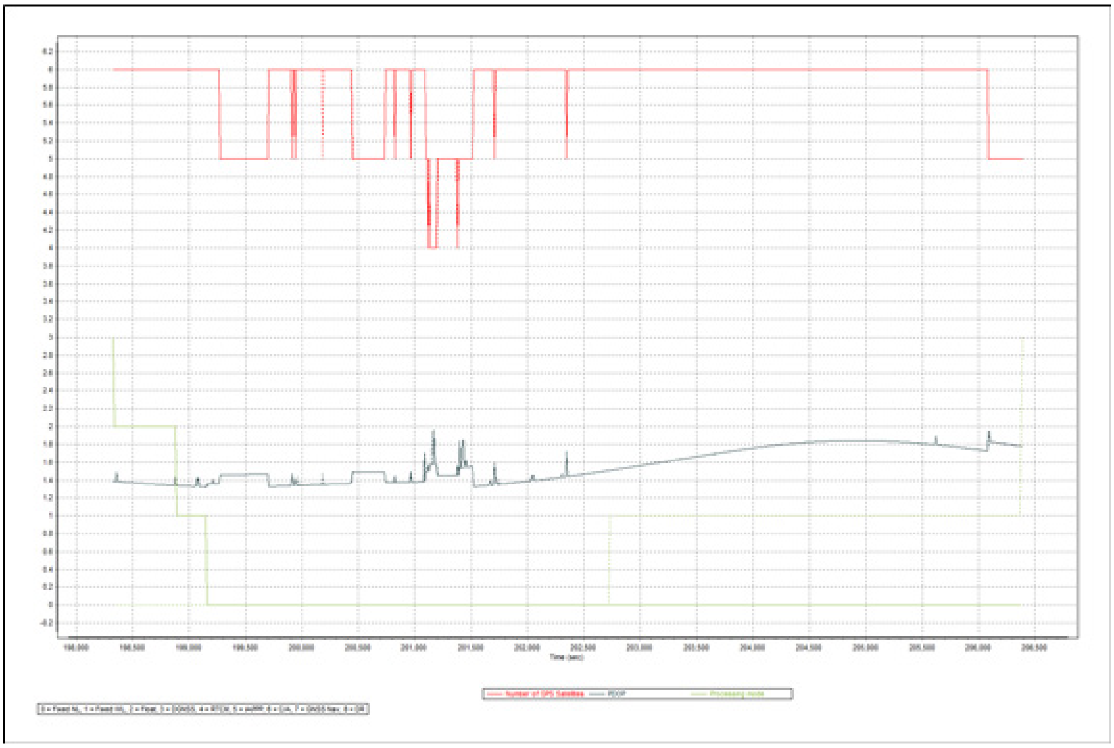


Figure A-8.1 Solution Status

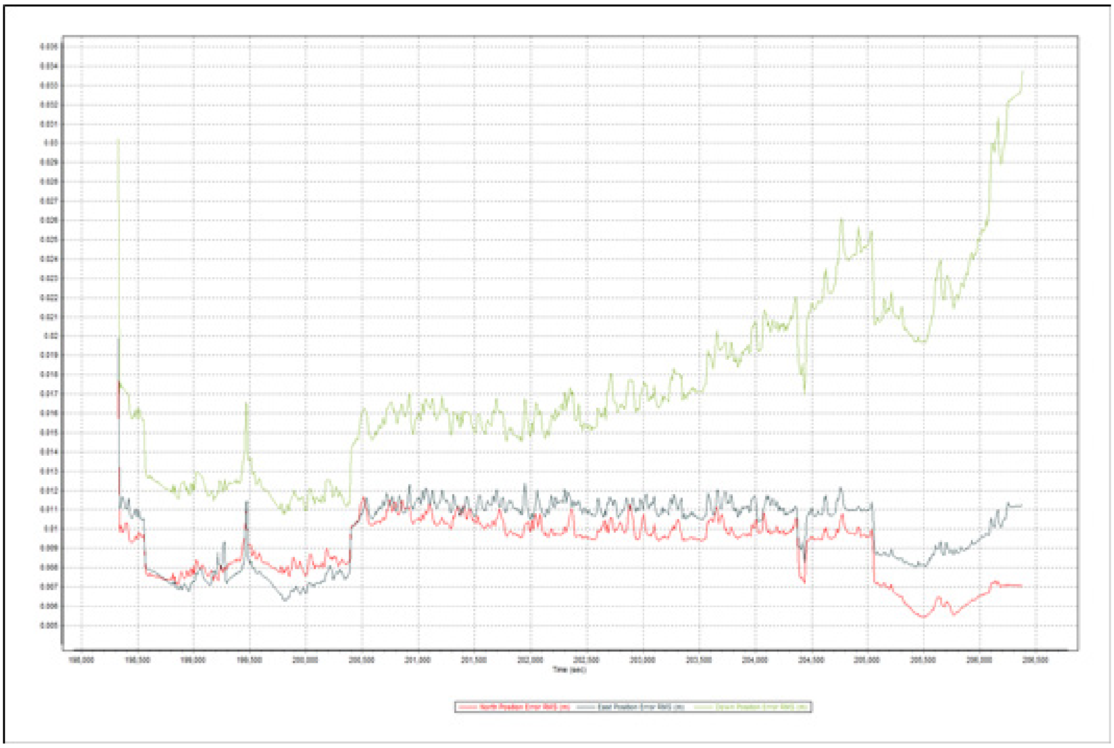


Figure A-8.2. Smoothed Performance Metric Parameters

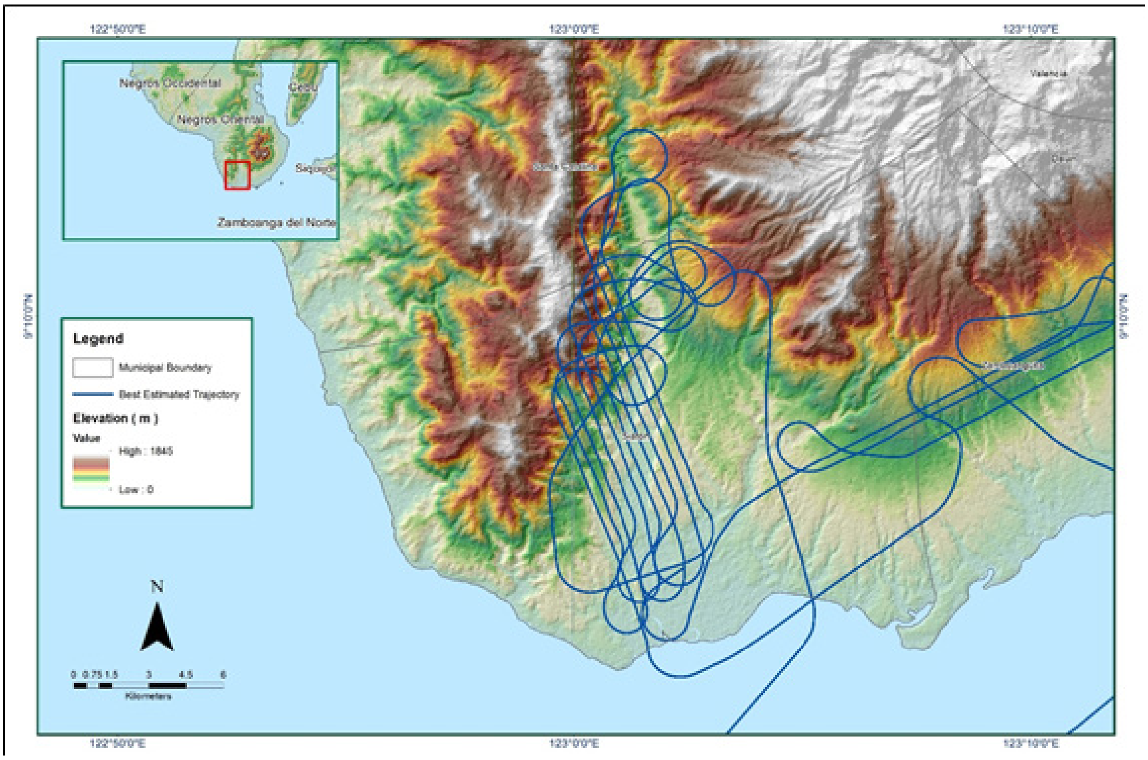


Figure A-8.3. Best Estimated Trajectory

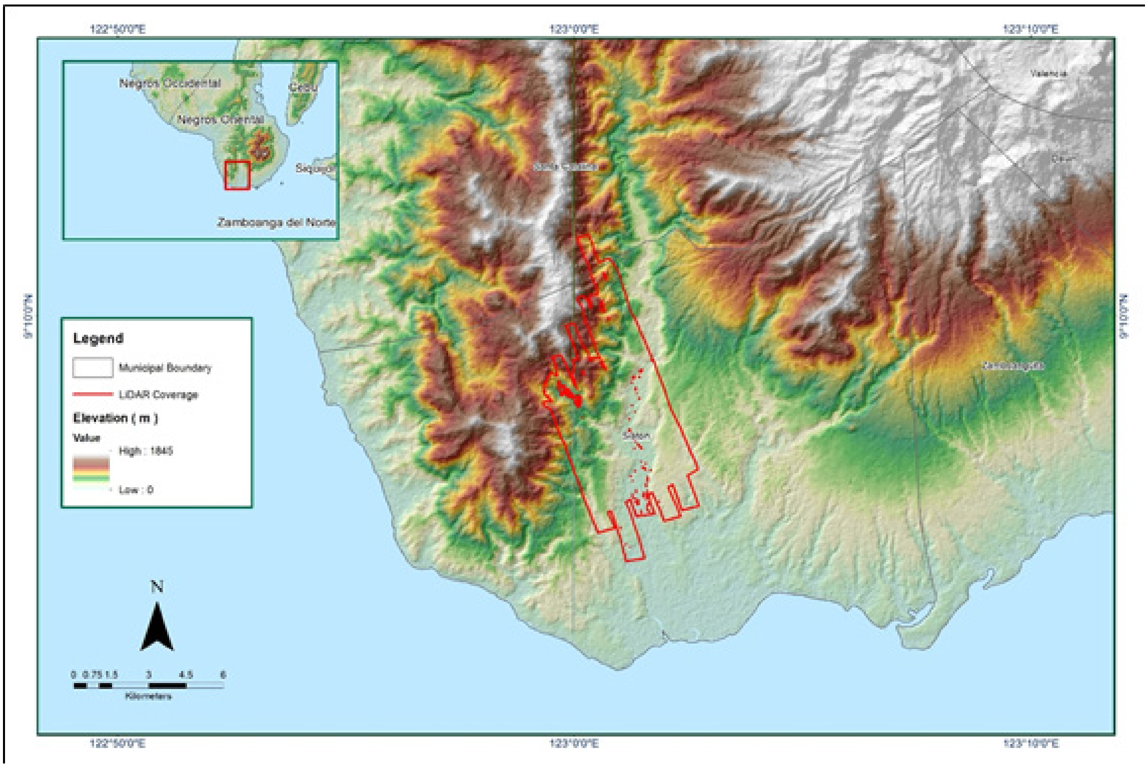


Figure A-8.4. Coverage of LiDAR data

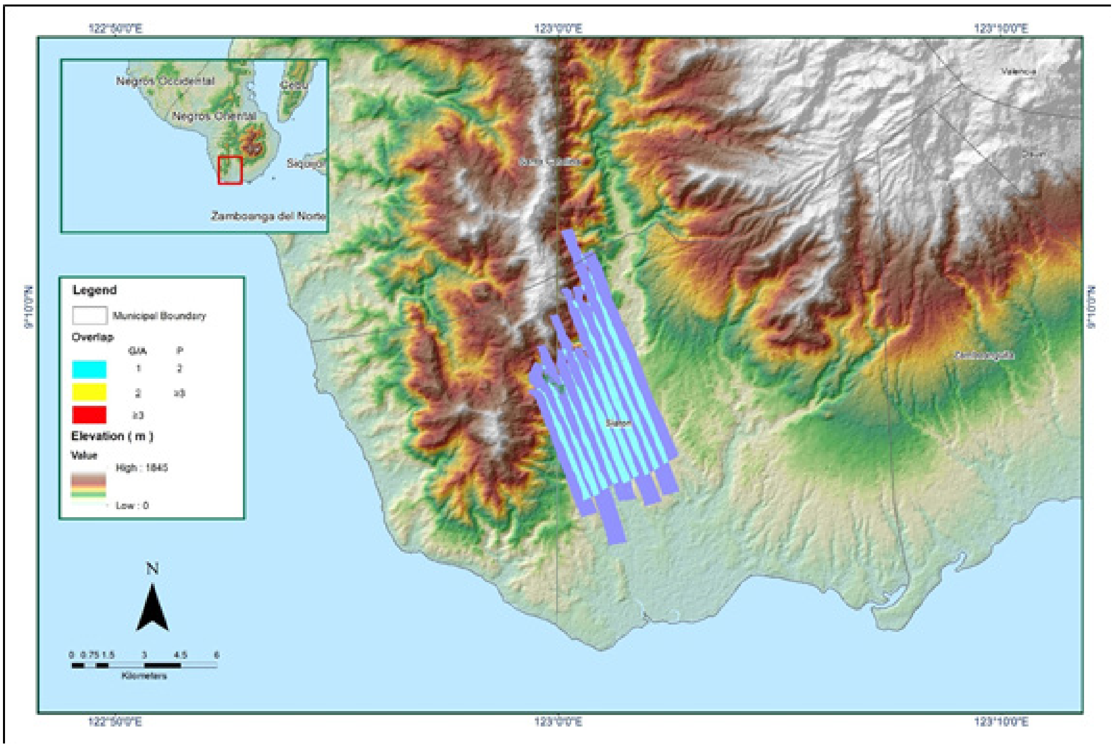


Figure A-8.5. Image of data overlap

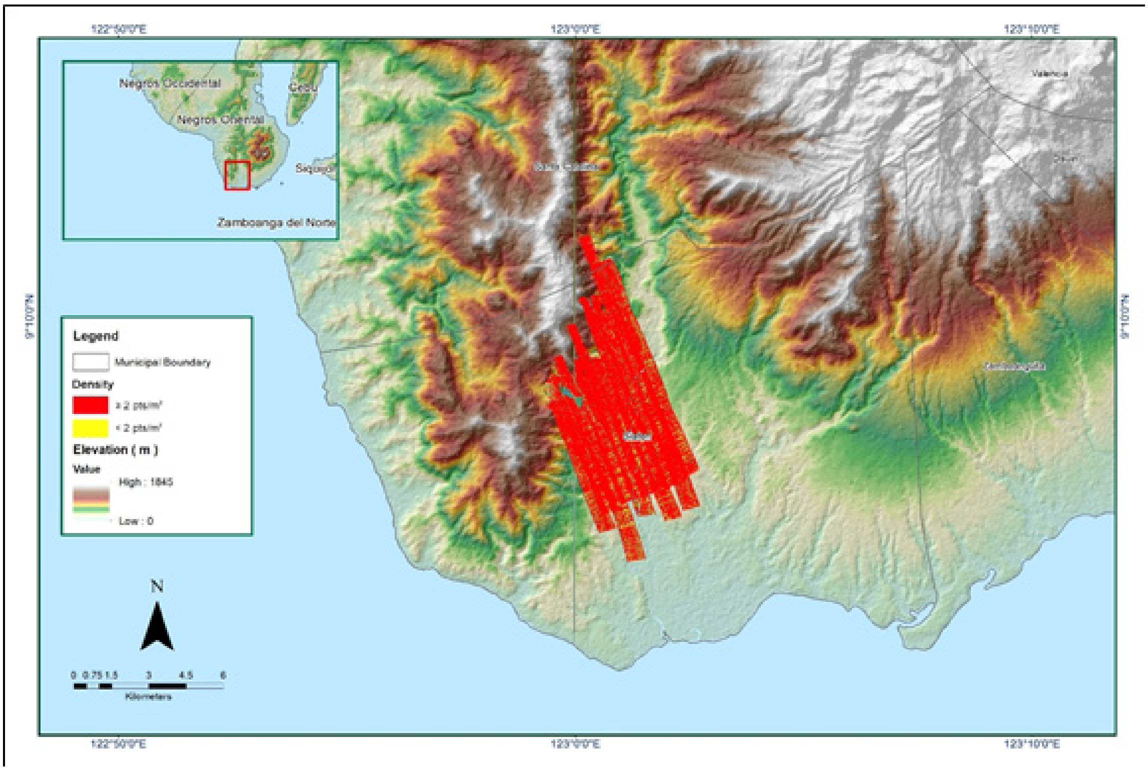


Figure A-8.6. Density map of merged LiDAR data

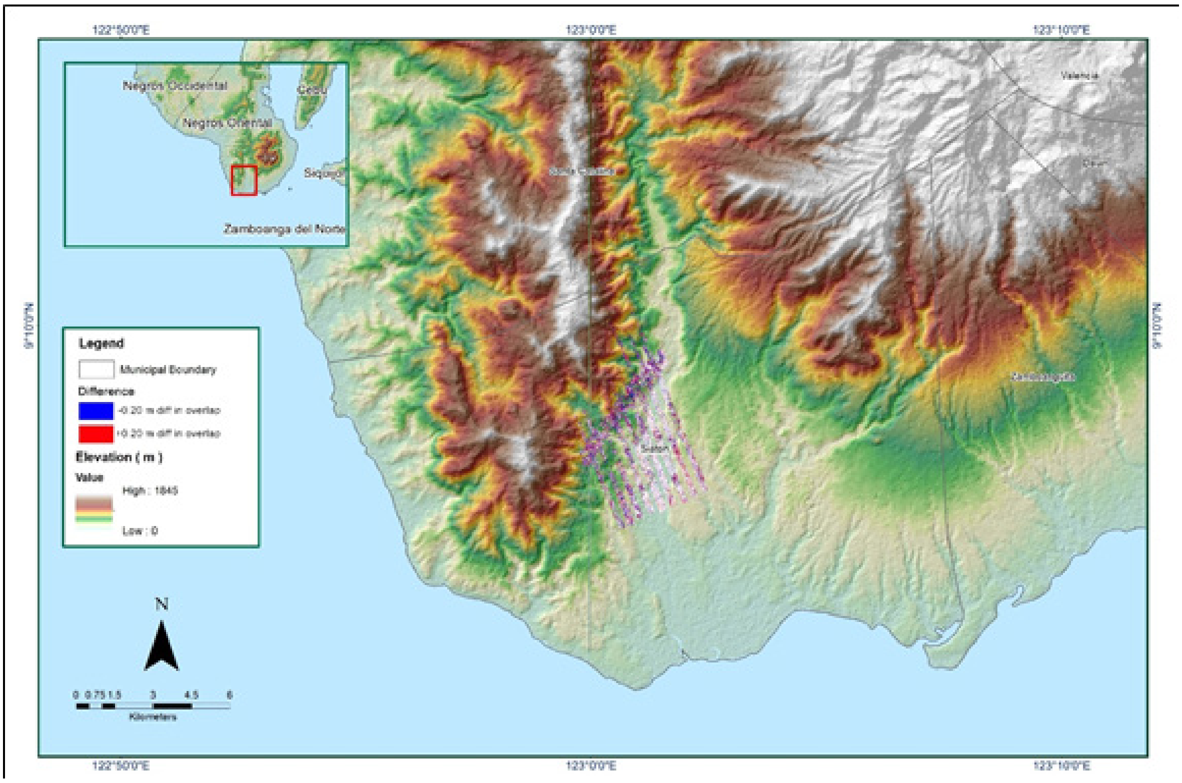


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk46A

Flight Area	Dumaguete
Mission Name	Blk56B
Inclusive Flights	7518G,7582G,7583G
Range data size	42.06 GB
POS data size	483 MB
Base data size	22.48 MB
Image	na
Transfer date	October 20, 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)	0.084
RMSE for East Position (<4.0 cm)	1.26
RMSE for Down Position (<8.0 cm)	2.85
Boresight correction stdev (<0.001deg)	0.000268
IMU attitude correction stdev (<0.001deg)	0.0042
GPS position stdev (<0.01m)	0.0070
Minimum % overlap (>25)	48.38%
Ave point cloud density per sq.m. (>2.0)	4.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	182
Maximum Height	576.01
Minimum Height	59.74
Classification (# of points)	
Ground	58567635
Low vegetation	63718874
Medium vegetation	199599866
High vegetation	131154661
Building	2517030
Orthophoto	No
Processed by	Engr. Kenneth Solidum,Engr. Chelou Prado, Engr. Jeffrey Delica

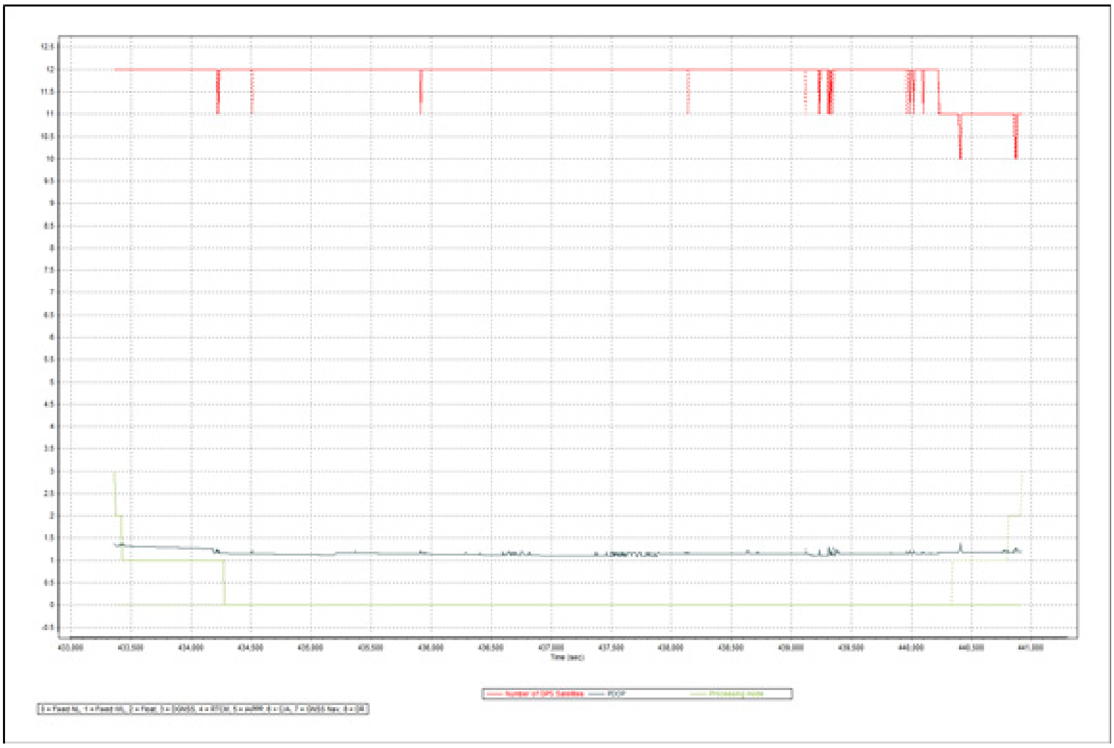


Figure A-8.8. Solution Status

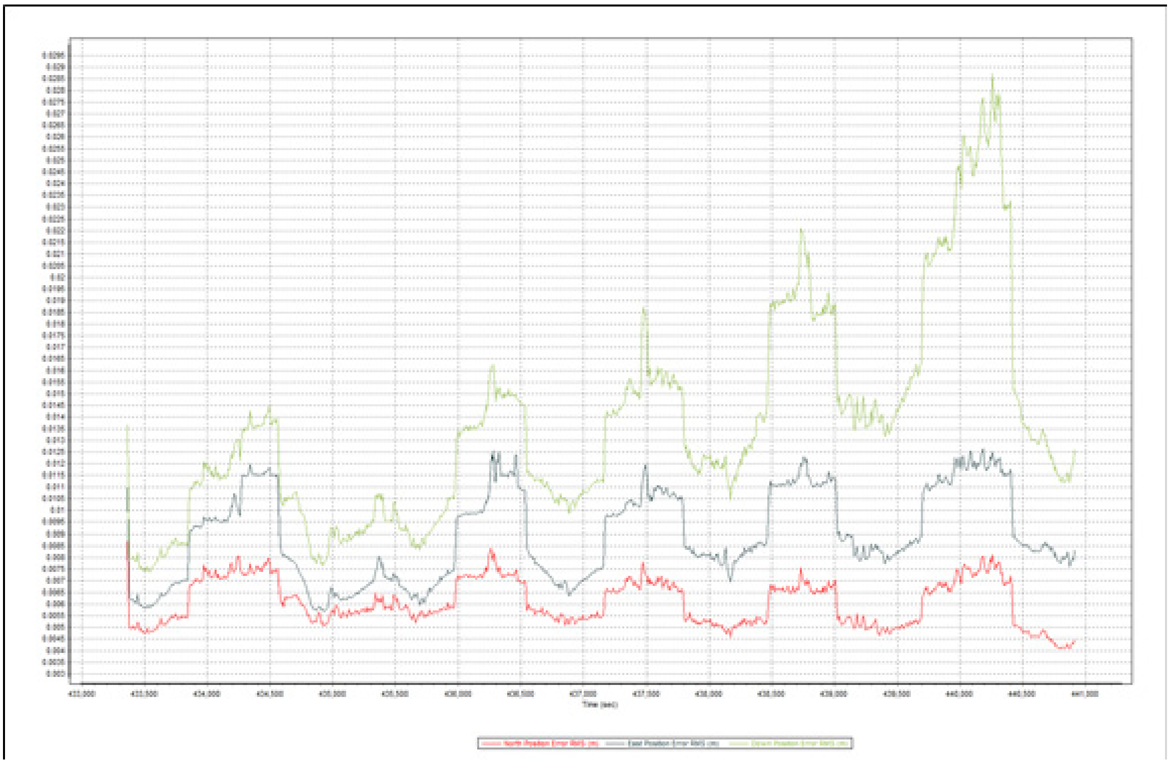


Figure A-8.9. Smoothed Performance Metric Parameters

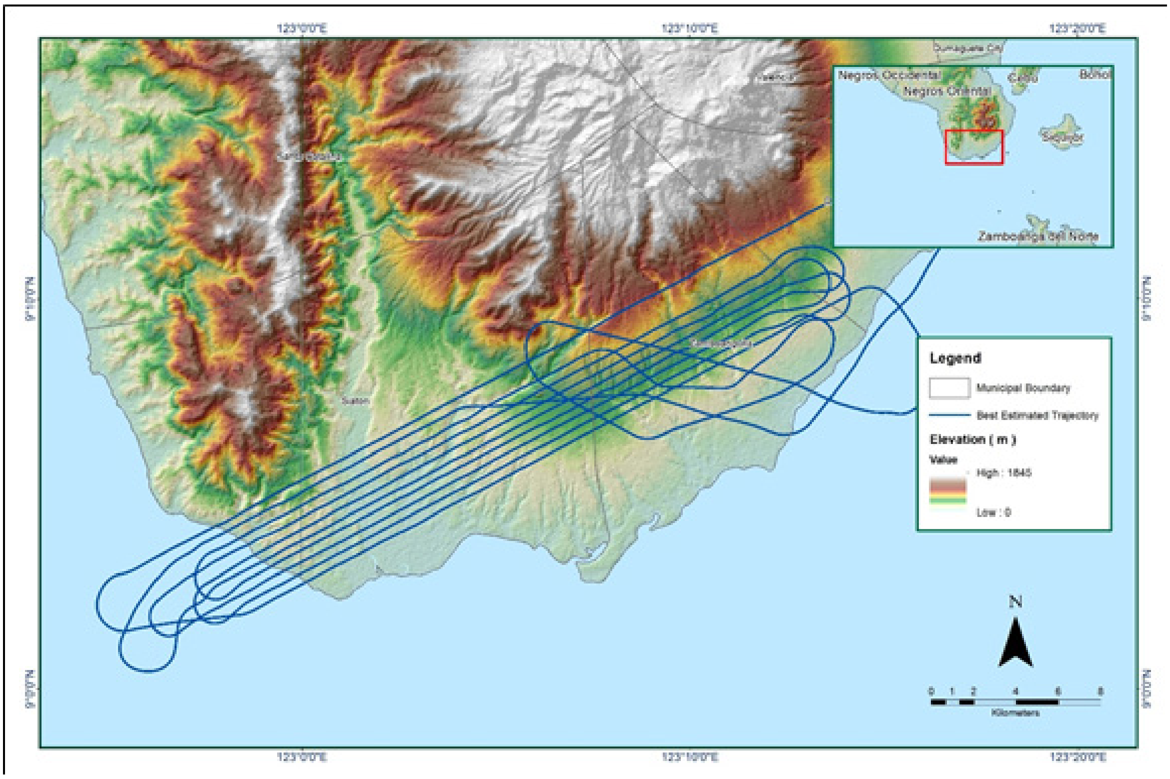


Figure A-8.10. Best Estimated Trajectory

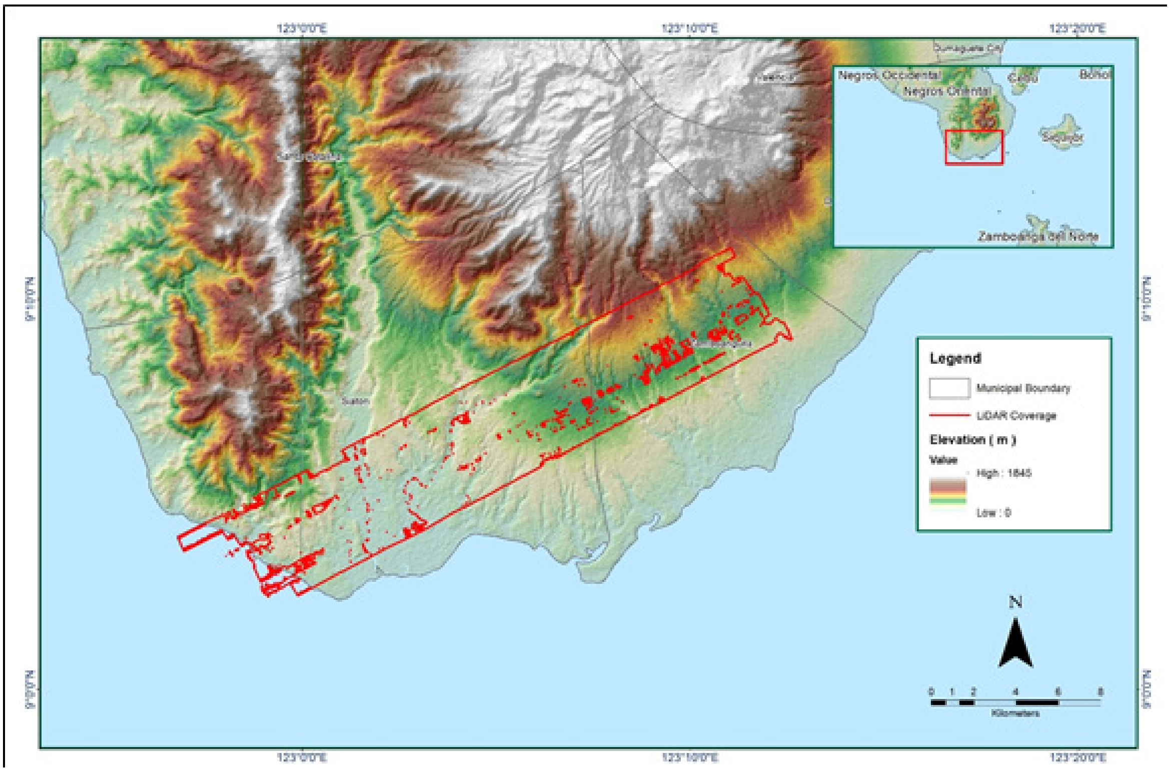


Figure A-8.11. Coverage of LiDAR data

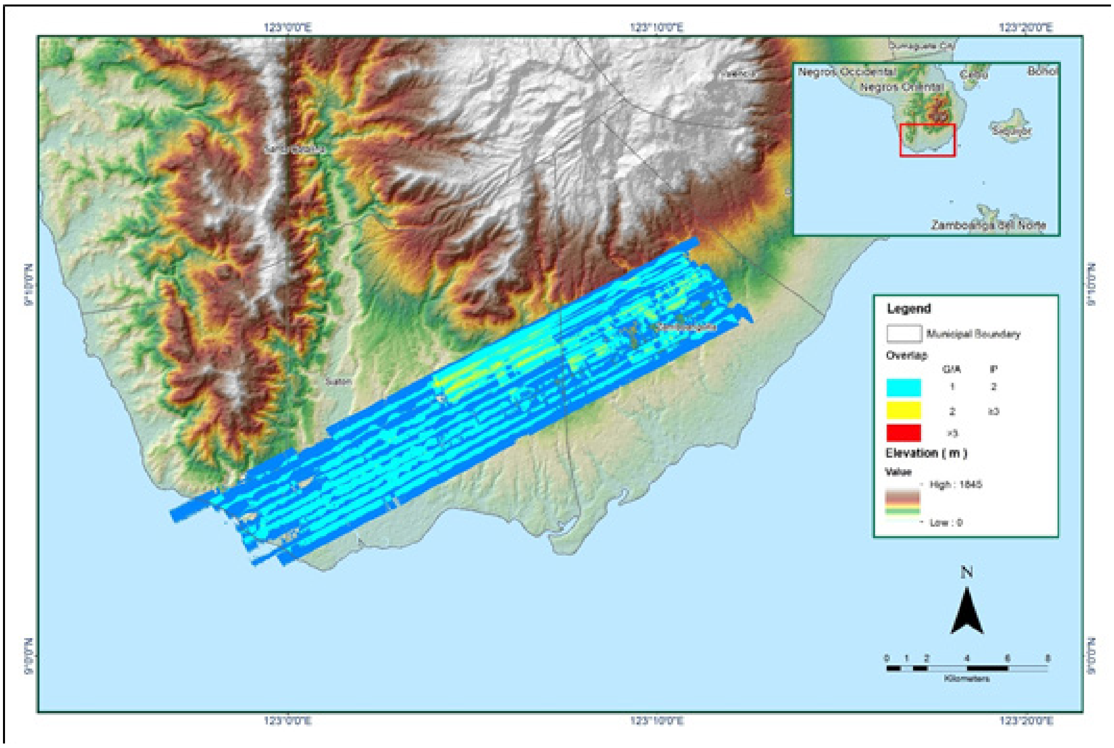


Figure A-8.12. Image of data overlap

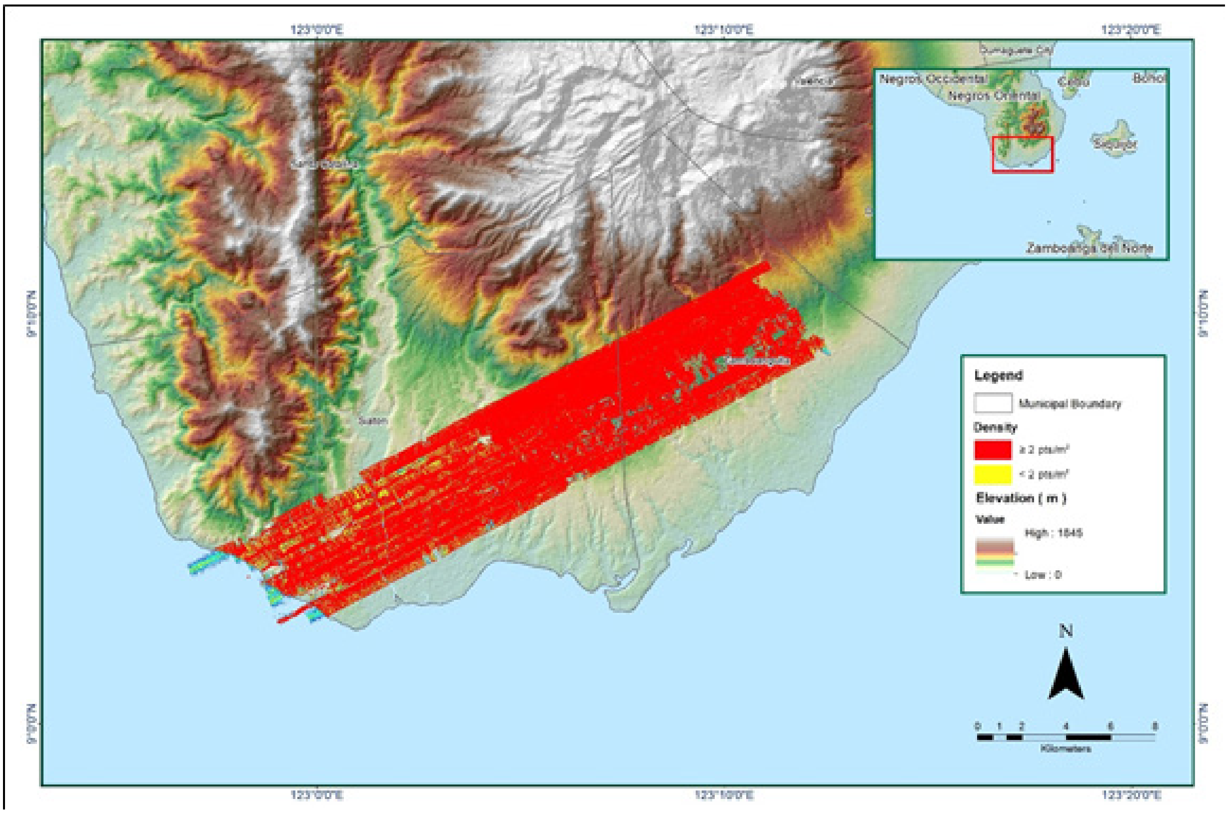


Figure A-8.13. Density map of merged LiDAR data

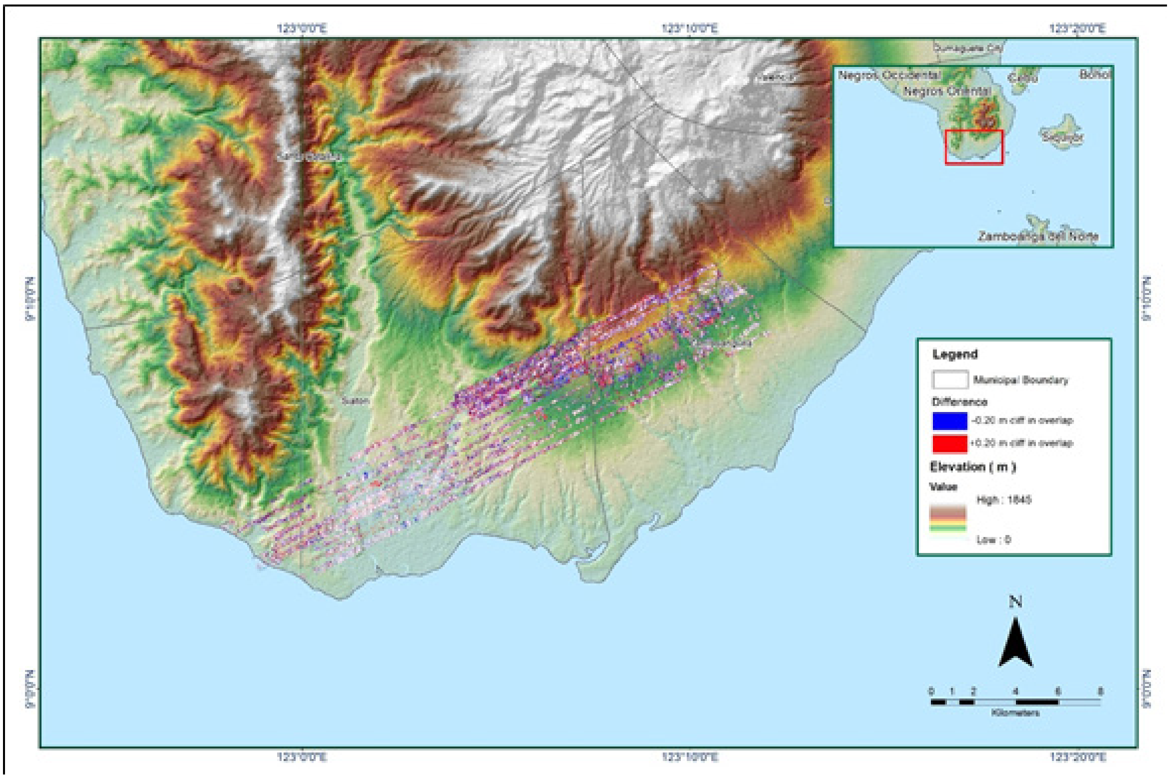


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk56CD

Flight Area	Dumaguete
Mission Name	Blk56CD
Inclusive Flights	7516G,7514G
Range data size	61 GB
POS data size	464 MB
Base data size	19.82 MB
Image	na
Transfer date	October 20, 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)	0.093
RMSE for East Position (<4.0 cm)	1.58
RMSE for Down Position (<8.0 cm)	2.95
Boresight correction stdev (<0.001deg)	0.000279
IMU attitude correction stdev (<0.001deg)	2.024948
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	33.02%
Ave point cloud density per sq.m. (>2.0)	3.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	284
Maximum Height	561.01 m
Minimum Height	22.69 m
Classification (# of points)	
Ground	67459329
Low vegetation	75476828
Medium vegetation	253361960
High vegetation	262909449
Building	6198265
Orthophoto	No
Processed by	Engr. Angelo Bongat, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda

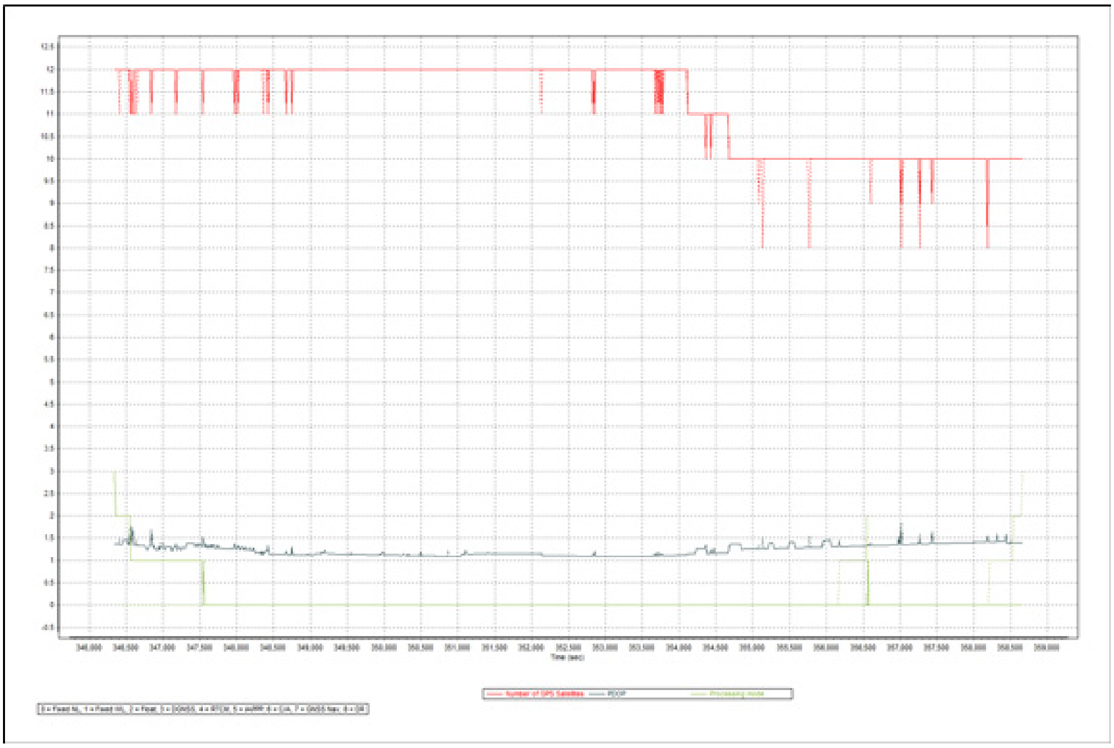


Figure A-8.15 Solution Status

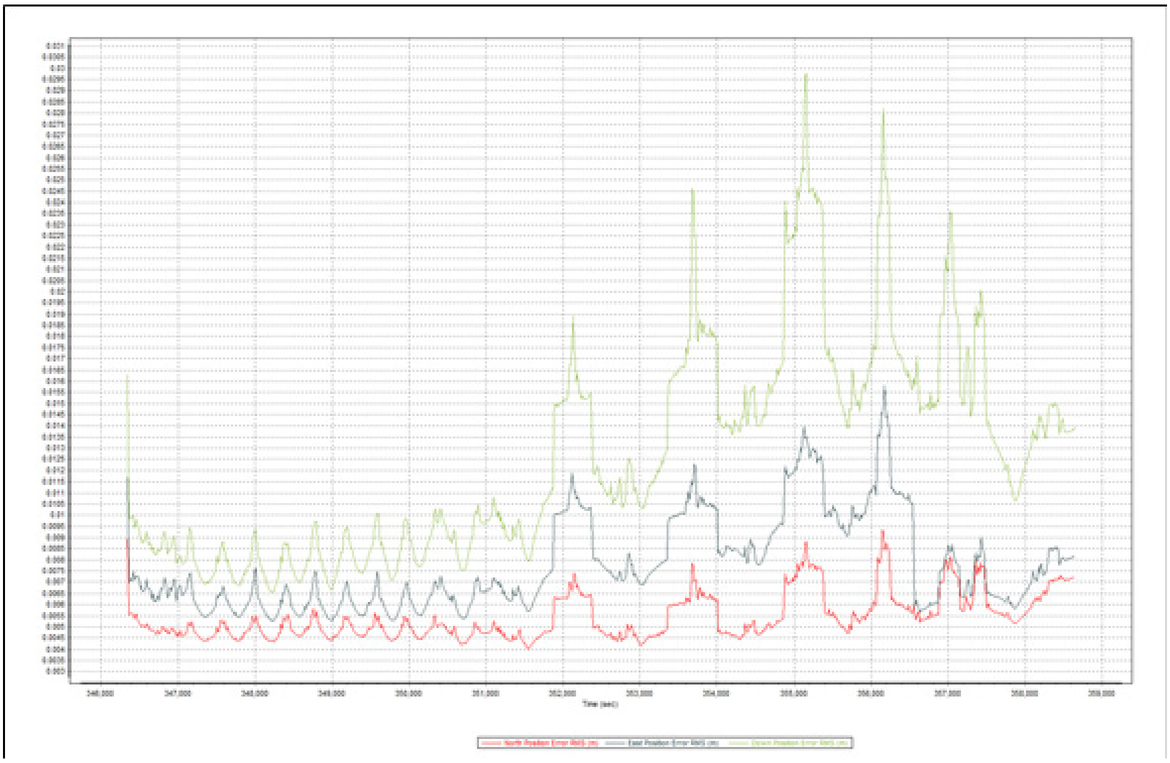


Figure A-8.16 Smoothed Performance Metric Parameters

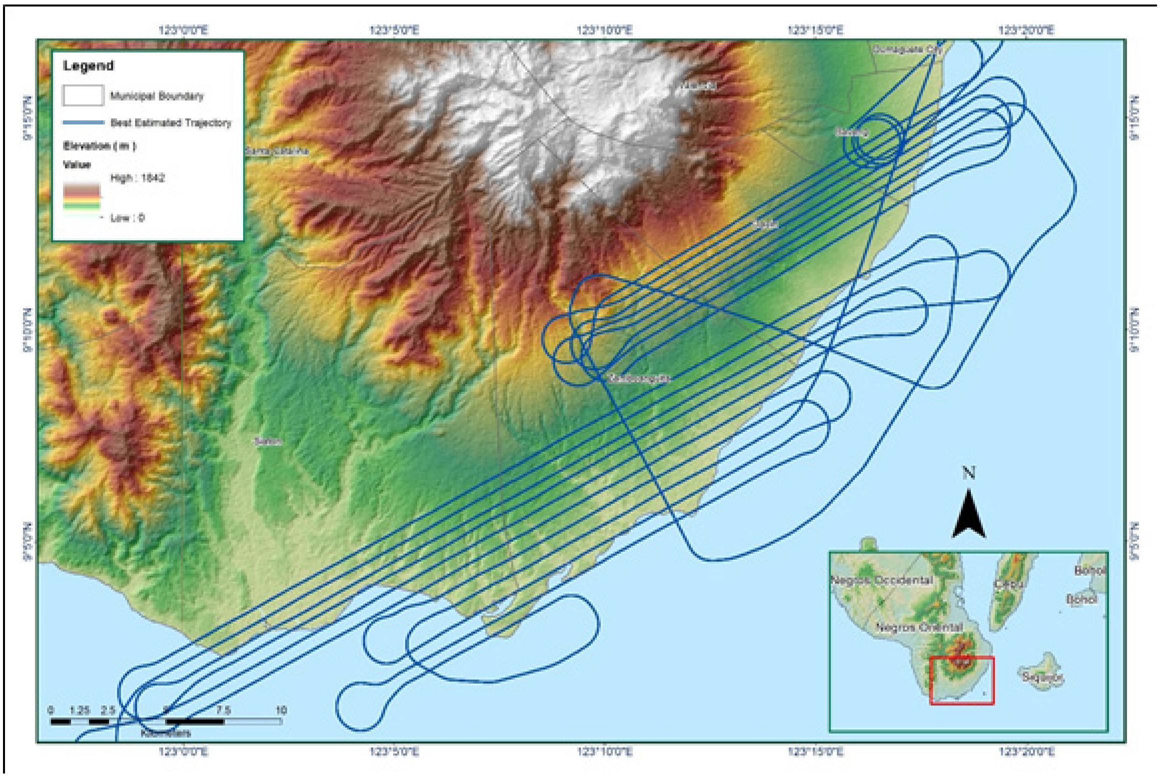


Figure A-8.17 Best Estimated Trajectory

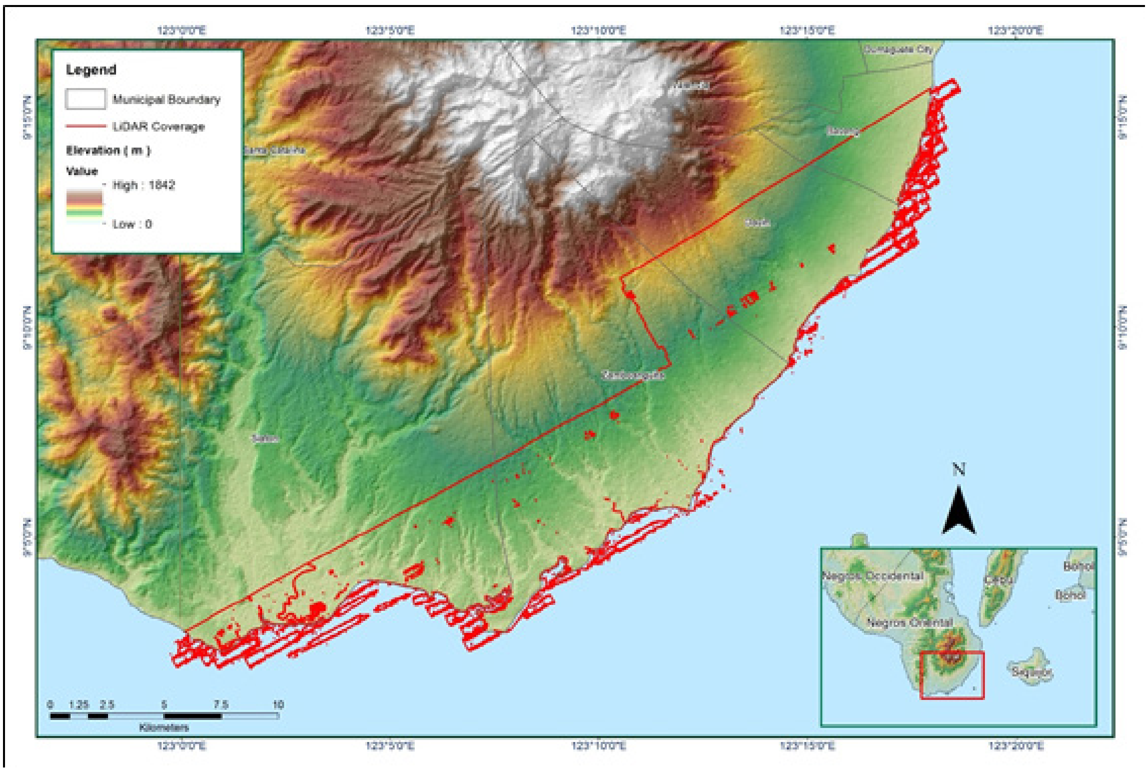


Figure A-8.18 Coverage of LiDAR data

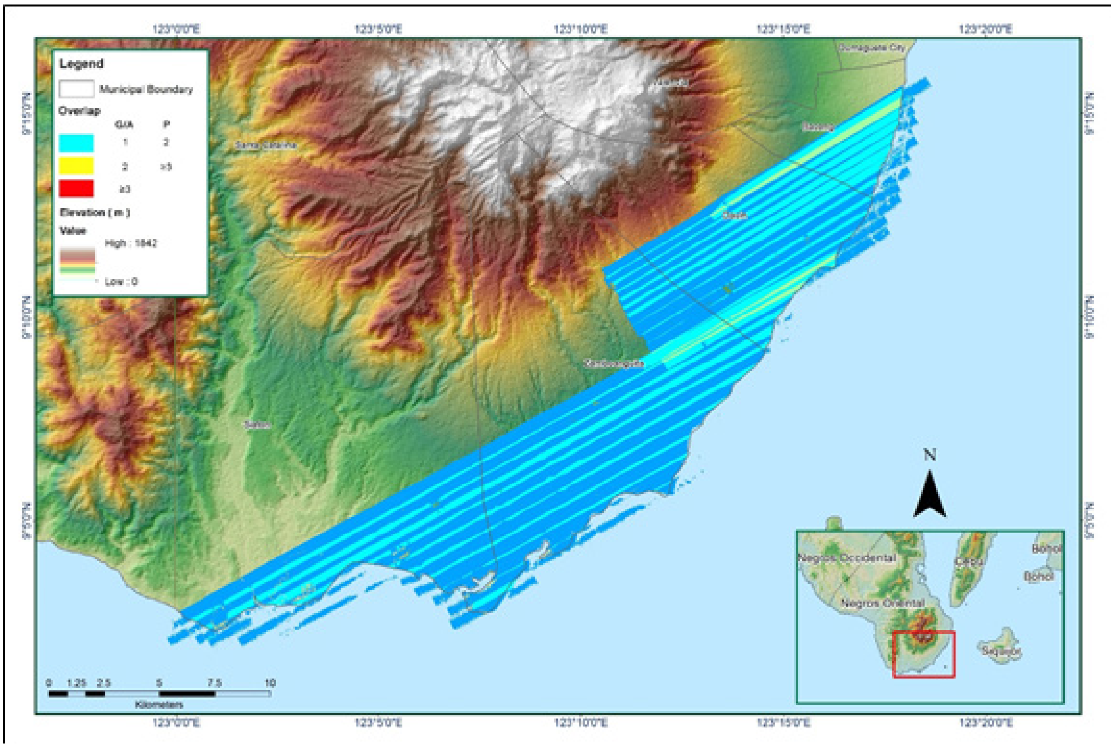


Figure A-8.19 Image of data overlap

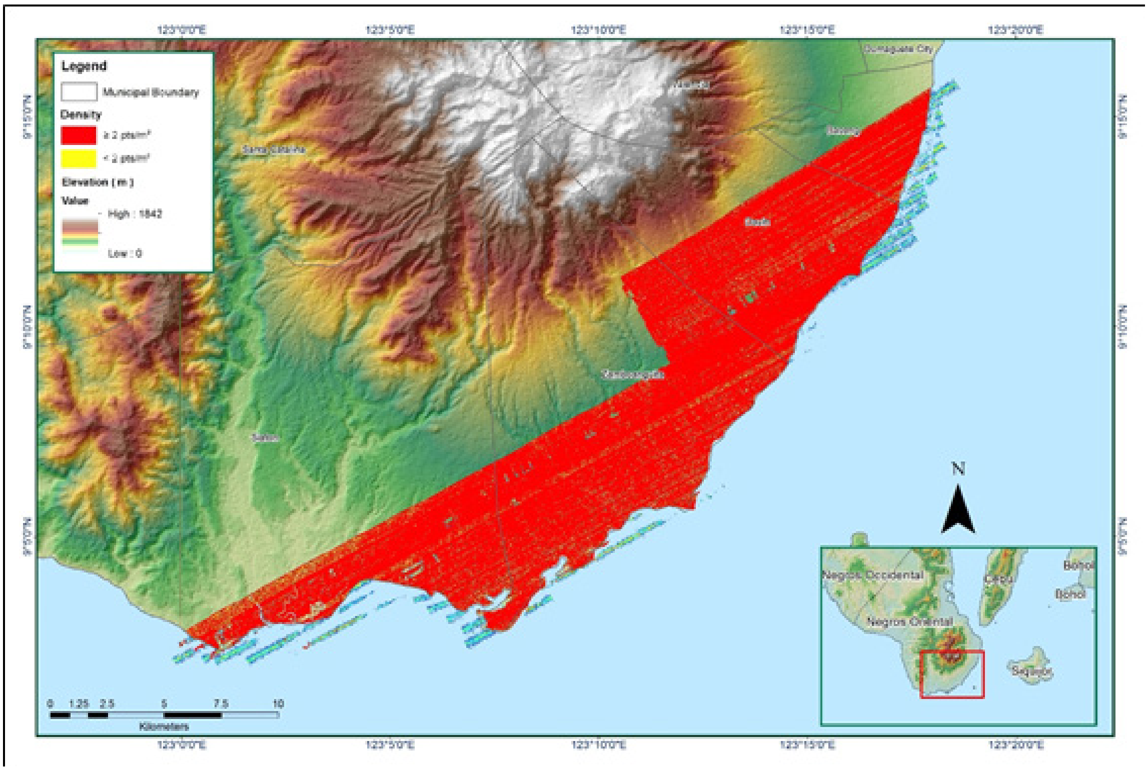


Figure A-8.20 Density map of merged LiDAR data

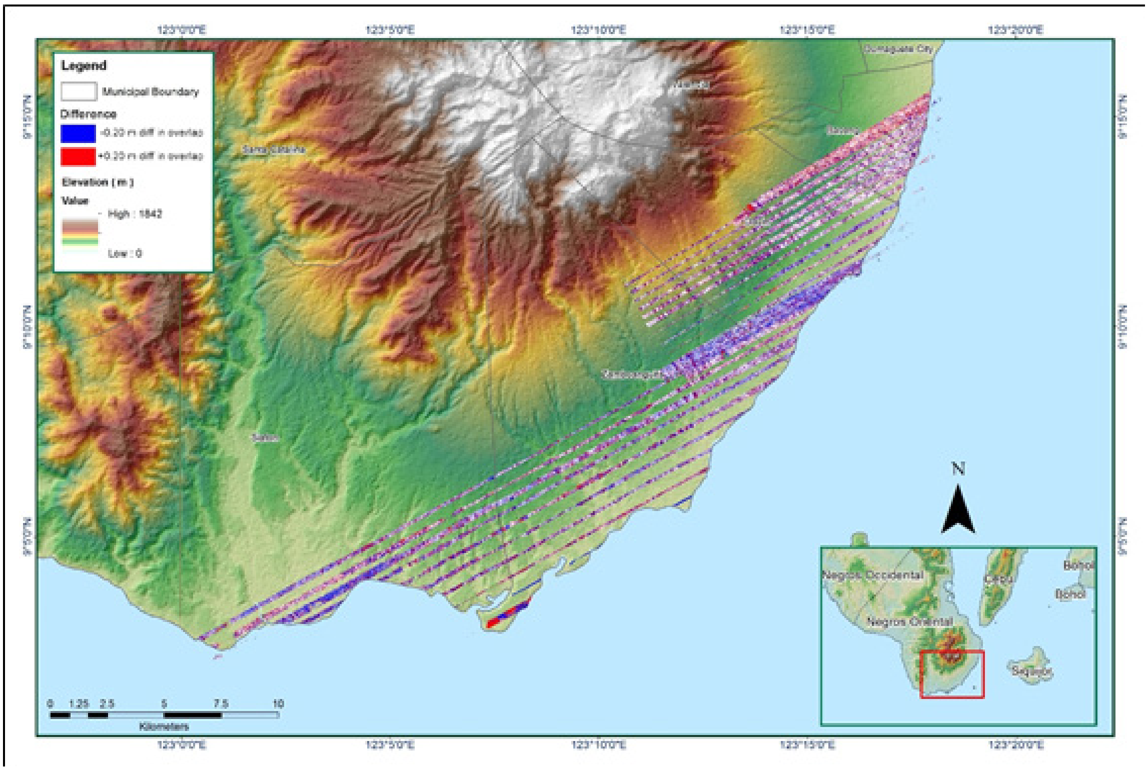


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk-56C (Dumaguete Reflights)

Flight Area	Dumaguete Reflights
Mission Name	Blk56C
Inclusive Flights	10077AC
Range data size	5.46 GB
POS data size	198 MB
Base data size	18.4 MB
Image	27 MB
Transfer date	February 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.23
RMSE for Down Position (<8.0 cm)	2.32
Boresight correction stdev (<0.001deg)	0.000600
IMU attitude correction stdev (<0.001deg)	0.002069
GPS position stdev (<0.01m)	0.0239
Minimum % overlap (>25)	20.88%
Ave point cloud density per sq.m. (>2.0)	3.80
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	74
Maximum Height	275.61 m
Minimum Height	51.59 m
Classification (# of points)	
Ground	24,210,420
Low vegetation	12,510,181
Medium vegetation	10,925,033
High vegetation	2,324,182
Building	0
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Merven Mat-thew Natino, Alex John Escobido

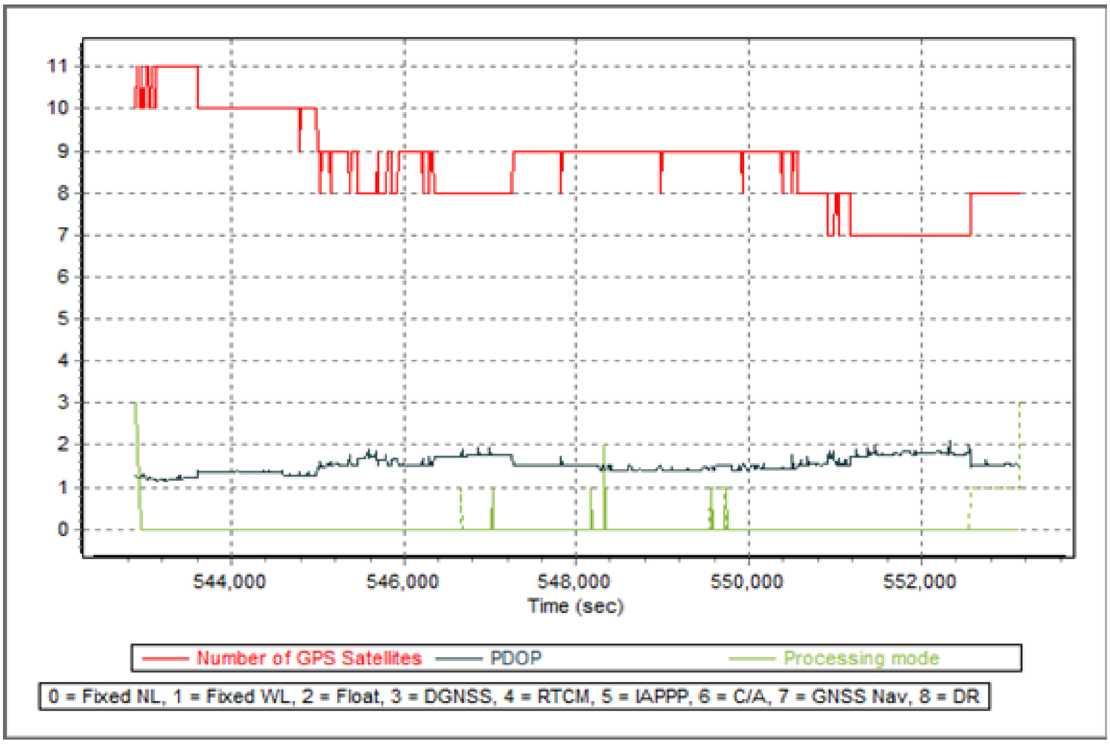


Figure A-8.22 Solution Status

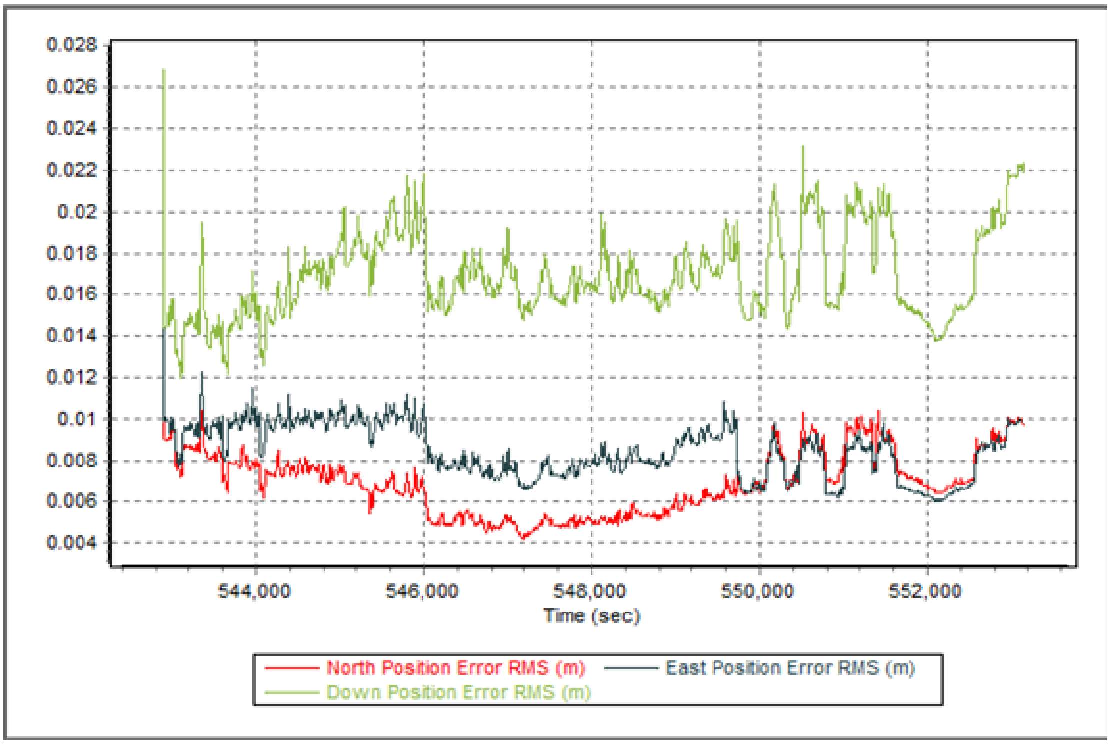


Figure A-8.23 Smoothed Performance Metric Parameters

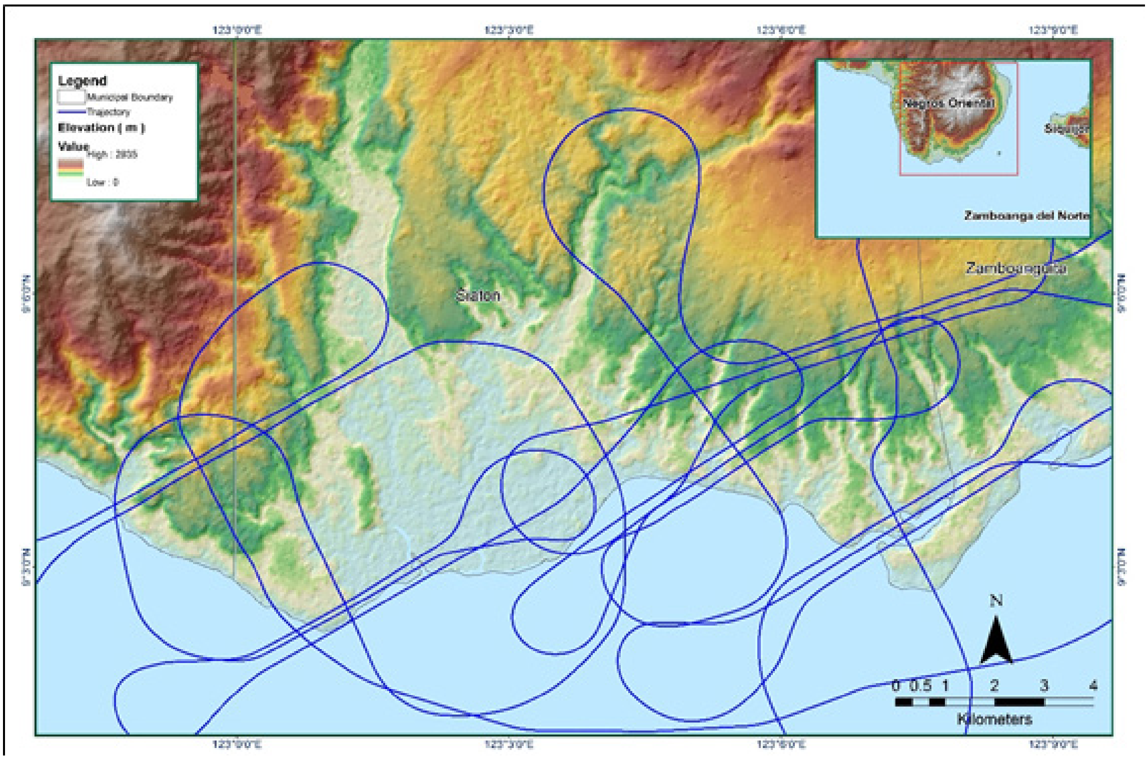


Figure A-8.24 Best Estimated Trajectory

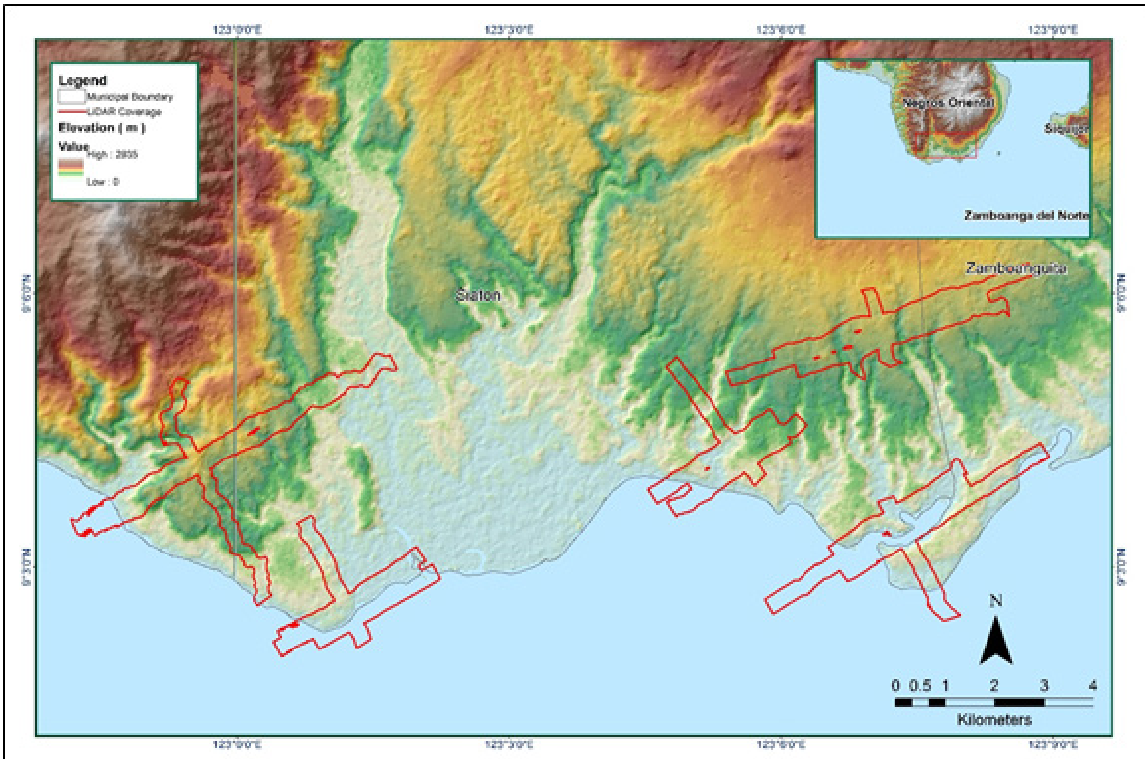


Figure A-8.25 Coverage of LiDAR data

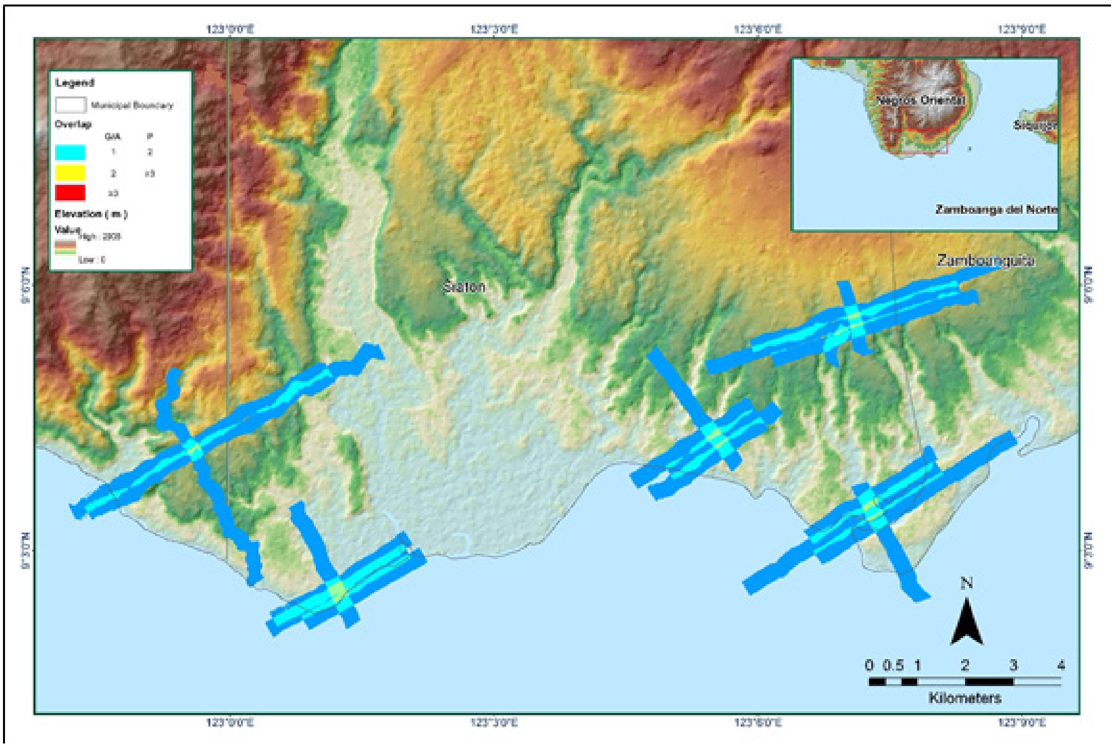


Figure A-8.26 Image of data overlap

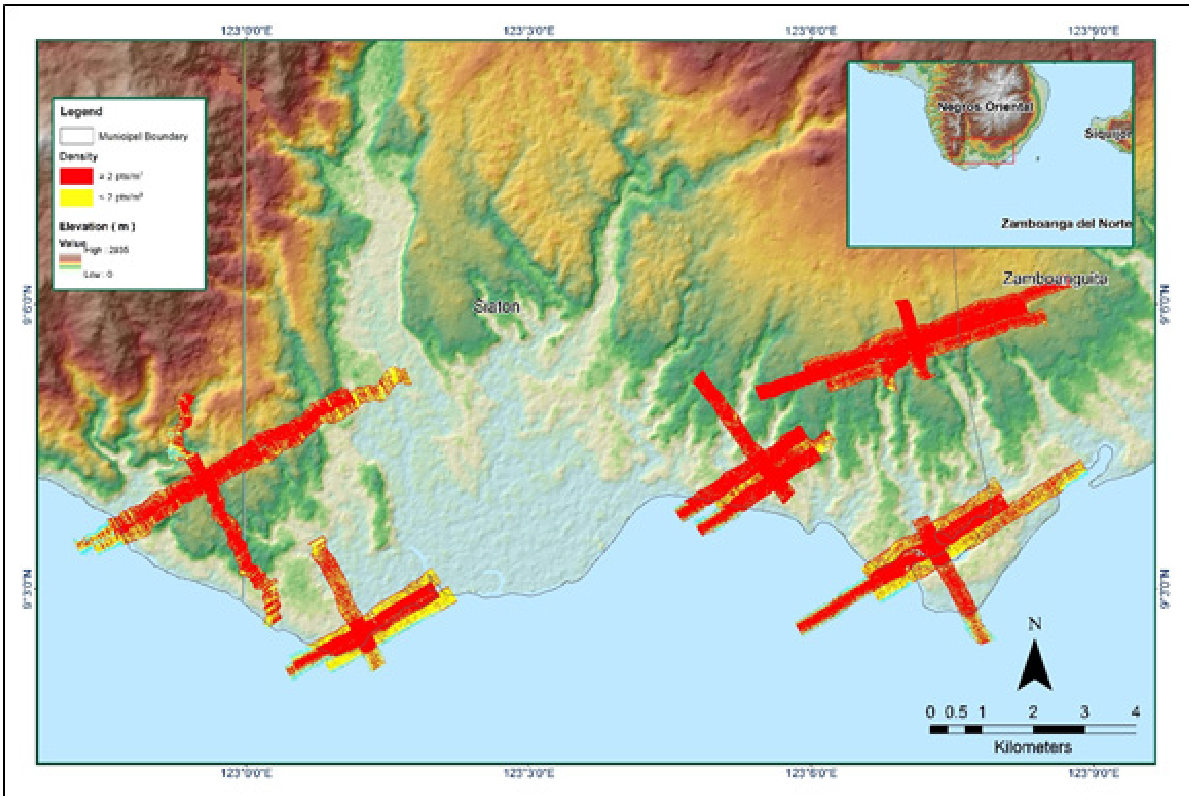


Figure A-8.27 Density map of merged LiDAR data

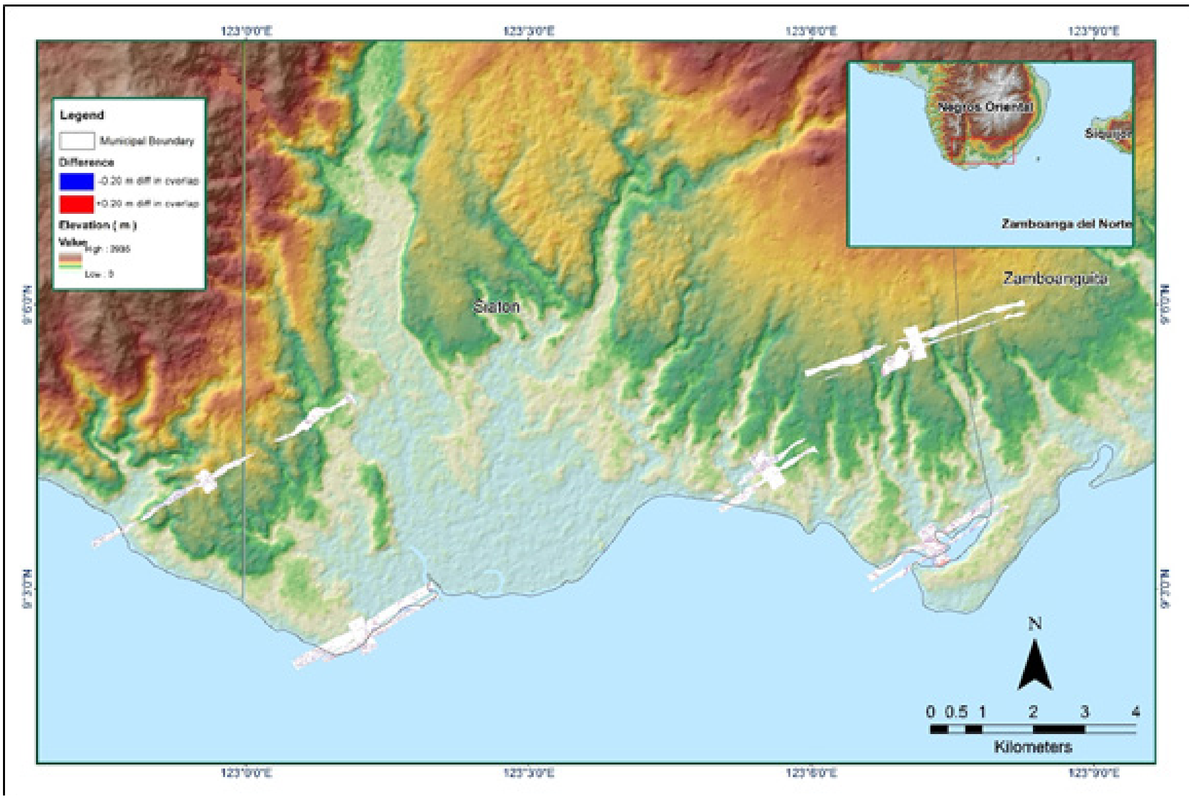


Figure A-8.28 Elevation difference between flight lines

Annex 9. Siaton Model Basin Parameters

Table A-9.1.Siaton Model Basin Parameters

Basin Number	SCS Curve Number Loss Model			Clark Transform Model		Recession Constant Baseflow Model				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W360	43.69722	77.2581	0	9.4283	0.70999	Discharge	0.5313	0.0556008	Ratio to Peak	0.049
W370	2.687356	81.1756	0	4.3664	0.32096	Discharge	0.57083	0.0239694	Ratio to Peak	0.0353
W380	3.681566	58.866	0	2.3294	0.0945267	Discharge	0.48927	0.081724	Ratio to Peak	0.03757
W390	4.09934	80.0958	0	2.7305	0.1352596	Discharge	0.25504	0.0155175	Ratio to Peak	0.01286
W400	10.4664	35.4483	0	16.005	0.235592	Discharge	0.78729	0.0525471	Ratio to Peak	0.03333
W410	6.092366	49.2287	0	2.7078	0.1736364	Discharge	0.32602	0.0151328	Ratio to Peak	0.02178
W420	15.54378	37.8711	0	10.736	0.2362192	Discharge	0.44276	0.0229473	Ratio to Peak	0.03333
W430	4.316606	76.4667	0	3.2671	0.2329264	Discharge	0.33917	0.0104703	Ratio to Peak	0.01988
W440	9.90192	64.5889	0	1.3098	0.0650087	Discharge	0.0546245	0.0157568	Ratio to Peak	0.01459
W450	10.0548	38.6564	0	6.4653	0.3182158	Discharge	0.45687	0.0102943	Ratio to Peak	0.04753
W460	9.700334	65.191	0	4.1971	0.20196	Discharge	0.32198	0.0135532	Ratio to Peak	0.02805
W470	15.70254	43.938	0	7.8618	0.57622	Discharge	0.45658	0.0047638	Ratio to Peak	0.01661
W480	32.68006	67.5611	0	19.256	1.44207	Discharge	1.5066	0.0105045	Ratio to Peak	0.05
W490	4.307786	66.2121	0	4.2372	0.23799	Discharge	0.38153	0.0070031	Ratio to Peak	0.0167
W500	36.25902	64.5889	0	9.4374	0.31955	Discharge	0.94579	0.0068295	Ratio to Peak	0.05
W510	9.659664	66.1858	0	3.9216	0.13076	Discharge	0.12996	0.0046459	Ratio to Peak	0.01255
W520	6.90851	44.5978	0	8.3265	0.39591	Discharge	0.28673	0.0031605	Ratio to Peak	0.12801
W530	9.85194	76.9505	0	3.8012	0.0561309	Discharge	0.0536301	0.0047525	Ratio to Peak	0.01556
W540	6.115984	67.2413	0	3.0098	0.2930494	Discharge	0.57054	0.0130221	Ratio to Peak	0.01959
W550	16.94616	51.5776	0	3.5842	0.39008	Discharge	0.67314	0.0069689	Ratio to Peak	0.03152
W560	16.26408	43.938	0	9.3648	1.595538	Discharge	1.146	0.0031605	Ratio to Peak	0.04802
W570	16.3072	65.9075	0	11.028	0.8270122	Discharge	0.5682	0.0031605	Ratio to Peak	0.05
W580	10.95248	64.5889	0	0.35155	0.0428986	Discharge	0.0273845	0.0031605	Ratio to Peak	0.00953

W590	26.50704	62.0366	0	4.1932	0.0943196	Discharge	0.52384	0.0031605	Ratio to Peak	0.03267
W600	16.33562	64.5889	0	3.9213	0.0567122	Discharge	0.10681	0.0071111	Ratio to Peak	0.02102
W610	10.9319	66.2101	0	7.6418	0.2554174	Discharge	0.28533	0.0042667	Ratio to Peak	0.02187
W620	10.95346	64.5889	0	0.52159	0.0265085	Discharge	0.0020738	0.0031605	Ratio to Peak	0.00668
W630	24.3824	43.937	0	17.52	1.962646	Discharge	0.54655	0.0046459	Ratio to Peak	0.05
W640	10.42426	67.3921	0	6.3588	0.0612422	Discharge	1.3541	0.0047161	Ratio to Peak	0.01339
W650	36.41778	64.5889	0	1.4801	0.0484421	Discharge	0.42064	0.0068295	Ratio to Peak	0.01501
W660	9.1728	70.5243	5	5.8856	0.0574152	Discharge	0.29459	0.0046459	Ratio to Peak	0.00968
W670	34.89584	66.0198	5	1.0342	0.0459561	Discharge	0.0301467	0.0046459	Ratio to Peak	0.0093
W680	7.692804	78.1416	5	7.2197	0.0724817	Discharge	0.6346	0.0047407	Ratio to Peak	0.00626
W690	48.11604	83.4384	5	1.6373	0.0543657	Discharge	0.33428	0.0069689	Ratio to Peak	0.00922
W700	5.37628	87.8133	5	7.9872	0.053427	Discharge	0.93678	0.0104533	Ratio to Peak	0.00632

Annex 10. Siaton Model Reach Parameters

Table A-10.1.Siaton Model Reach Parameters

Reach Number	Muskingum Cunge Routing Model						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R130	Automatic Fixed Interval	509.71	0.0220938	0.42702	Trapezoid	25	0.5
R140	Automatic Fixed Interval	3355.6	0.0278951	0.1134	Trapezoid	25	0.5
R150	Automatic Fixed Interval	907.99	0.0259259	0.0641313	Trapezoid	25	0.5
R170	Automatic Fixed Interval	1722.4	0.0135565	0.10968	Trapezoid	25	0.5
R190	Automatic Fixed Interval	6502.9	0.0396811	0.0816694	Trapezoid	25	0.5
R230	Automatic Fixed Interval	535.98	0.0672158	0.42945	Trapezoid	25	0.5
R240	Automatic Fixed Interval	6128.4	0.0161919	0.0792507	Trapezoid	25	0.5
R260	Automatic Fixed Interval	120.71	0.001	0.0473494	Trapezoid	25	0.5
R270	Automatic Fixed Interval	1724.4	0.0309994	0.19087	Trapezoid	25	0.5
R290	Automatic Fixed Interval	6154.3	0.0079063	0.12688	Trapezoid	25	0.5
R30	Automatic Fixed Interval	4235.5	0.0504903	0.0108064	Trapezoid	25	0.5
R320	Automatic Fixed Interval	407.7	0.00073042	0.0825092	Trapezoid	25	0.5
R330	Automatic Fixed Interval	4005.6	0.0084374	0.0846477	Trapezoid	25	0.5
R350	Automatic Fixed Interval	4787.3	0.001	0.0656522	Trapezoid	25	0.5
R40	Automatic Fixed Interval	2185.1	0.0387439	0.0893008	Trapezoid	25	0.5
R80	Automatic Fixed Interval	3269.5	0.0294204	0.077915	Trapezoid	25	0.5
R90	Automatic Fixed Interval	804.26	0.0203913	0.58218	Trapezoid	25	0.5

Annex 11. Siaton Field Validation Points

Table A-11.1.Siaton Field Validatin Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
1	123.02058	9.109718	1.22	0.7	0.27	Milenyo	100-Year
2	123.02062	9.109722	1.28	0.7	0.336	Ruping	100-Year
3	123.02061	9.109719	1.22	0	1.488	Yolanda	100-Year
4	123.02056	9.109258	1.03	0.2	0.689	Milenyo	100-Year
5	123.02058	9.109228	1.03	0.3	0.533	Seniang	100-Year
6	123.02097	9.107709	0.98	0.3	0.462	Ruping	100-Year
7	123.02099	9.107686	1.12	0.3	0.672	Milenyo	100-Year
8	123.02055	9.105937	1.13	0.4	0.533	Ruping	100-Year
9	123.02052	9.105939	1.13	0.4	0.533	Unsang	100-Year
10	123.02067	9.105924	1.12	0.4	0.518	Ruping	100-Year
11	123.02068	9.105915	1.12	0.4	0.518	Unsang	100-Year
12	123.02009	9.1046	1.57	0.4	1.369	Seniang	100-Year
13	123.02009	9.104599	1.57	0.8	0.593	Unsang	100-Year
14	123.01984	9.102262	2.58	0.4	4.752	Ruping	100-Year
15	123.01984	9.102258	2.58	0.1	6.15	Seniang	100-Year
16	123.01985	9.102256	2.58	0.1	6.15	Yolanda	100-Year
17	123.01979	9.101366	2.26	0.5	3.098	Seniang	100-Year
18	123.0198	9.101379	2.64	1.2	2.074	Ruping	100-Year
19	123.01982	9.101372	2.64	0.4	5.018	Lawin	100-Year
20	123.01975	9.101377	2.26	0.8	2.132	Unsang	100-Year
21	123.02171	9.098936	1.73	0.4	1.769	Lawin	100-Year
22	123.0217	9.098935	0.91	0.4	0.26	Sendong	100-Year
23	123.0217	9.098946	0.91	1.5	0.348	Ruping	100-Year
24	123.02209	9.098239	2.14	0.6	2.372	Ruping	100-Year
25	123.02209	9.098236	2.14	0.3	3.386	Unsang	100-Year
26	123.02039	9.099746	1.82	1.2	0.384	Ruping	100-Year
27	123.02037	9.099759	1.82	0.4	2.016	Ondoy	100-Year
28	123.02037	9.099754	1.82	0.8	1.04	Unsang	100-Year
29	123.02543	9.085074	0.08	2	3.686	Ruping	100-Year
30	123.02543	9.085088	0.08	1.8	2.958	Unsang	100-Year
31	123.02546	9.085094	1.91	1.5	0.168	Seniang	100-Year
32	123.02545	9.085031	2.09	1.5	0.348	Sendong	100-Year
33	123.02568	9.084574	2.18	0.4	3.168	Sendong	100-Year
34	123.02568	9.084591	2.18	0.8	1.904	Ruping	100-Year
35	123.02569	9.084609	2.22	0.8	2.016	Ondoy	100-Year
36	123.02539	9.080223	1.46	0.5	0.922	Ruping	100-Year
37	123.0254	9.080233	1.46	0.1	1.85	Ondoy	100-Year
38	123.02565	9.078862	1.41	1.1	0.096	Ruping	100-Year
39	123.02569	9.078902	1.33	1.2	0.017	Unsang	100-Year
40	123.02569	9.078914	1.33	0.4	0.865	Ondoy	100-Year
41	123.02568	9.078912	1.33	0.5	0.689	Seniang	100-Year

42	123.02623	9.077149	2.03	1.2	0.689	Ruping	100-Year
43	123.0262	9.077121	2.03	0.5	2.341	Unsang	100-Year
44	123.02507	9.077415	2.26	1.2	1.124	Ruping	100-Year
45	123.02506	9.07742	2.26	0.4	3.46	Seniang	100-Year
46	123.02509	9.077404	1.96	1.2	0.578	Unsang	100-Year
47	123.03122	9.058046	1.35	0.6	0.563	Ruping	100-Year
48	123.03225	9.058178	1.84	0.5	1.796	Yolanda	100-Year
49	123.03227	9.058177	1.81	0.6	1.464	Sendong	100-Year
50	123.03226	9.058176	1.81	0.1	2.924	Seniang	100-Year
51	123.03422	9.058009	1.55	1.2	0.123	Ruping	100-Year

Annex 12. Educational Institutions affected by flooding in Siaton Flood Plain

Table A-12.1.Educational Institutions Affected by flooding in Siaton Flood Plain

Negros Oriental				
Siaton				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sandulot Elementary School	Cabanga-han		Low	Medium
Inalad Elementary School	Canaway			
Sumaliring High School	Canaway			
Caticugan Elementary School	Caticugan			
Datagelem School	Caticugan	Medium	Medium	High
Felipe Tayco Memorial ES	Caticugan	Medium	Medium	Medium
Canaway Elementary School	Datag			
Mantuyop Elem School	Mantuyop			
Siaton Science High School	Mantuyop			
Salag Elementary School	Salag			

Annex 13. Health institutions affected by flooding in Siaton Floodplain

Table A-13.1.Medical Institutions Affected by flooding in Siaton Flood Plain

Negros Oriental				
Siaton				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sumaliring Barangay Health Center	Canaway		Medium	Medium
DatagBrgy Health Center	Caticugan	Low	Medium	Medium