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

LiDAR Surveys and Flood Mapping of Bayawan River

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

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For questions/queries regarding this report, contact:

Dr. Roland Emerito S. Otadoy
Project Leader, Phil-LiDAR 1 Program
University of San Carlos
Cebu City, Philippines 6000
E-mail: rolandotadoy2012@gmail.com

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

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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
UPC	University of the Philippines Cebu
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 BAYAWAN RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland 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” in 2014 or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) and the 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 methods applied in this report are thoroughly described in a separate publication entitled “Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods” (Paringit, et. al. 2017) available separately.

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

1.2 Overview of the Bayawan River Basin

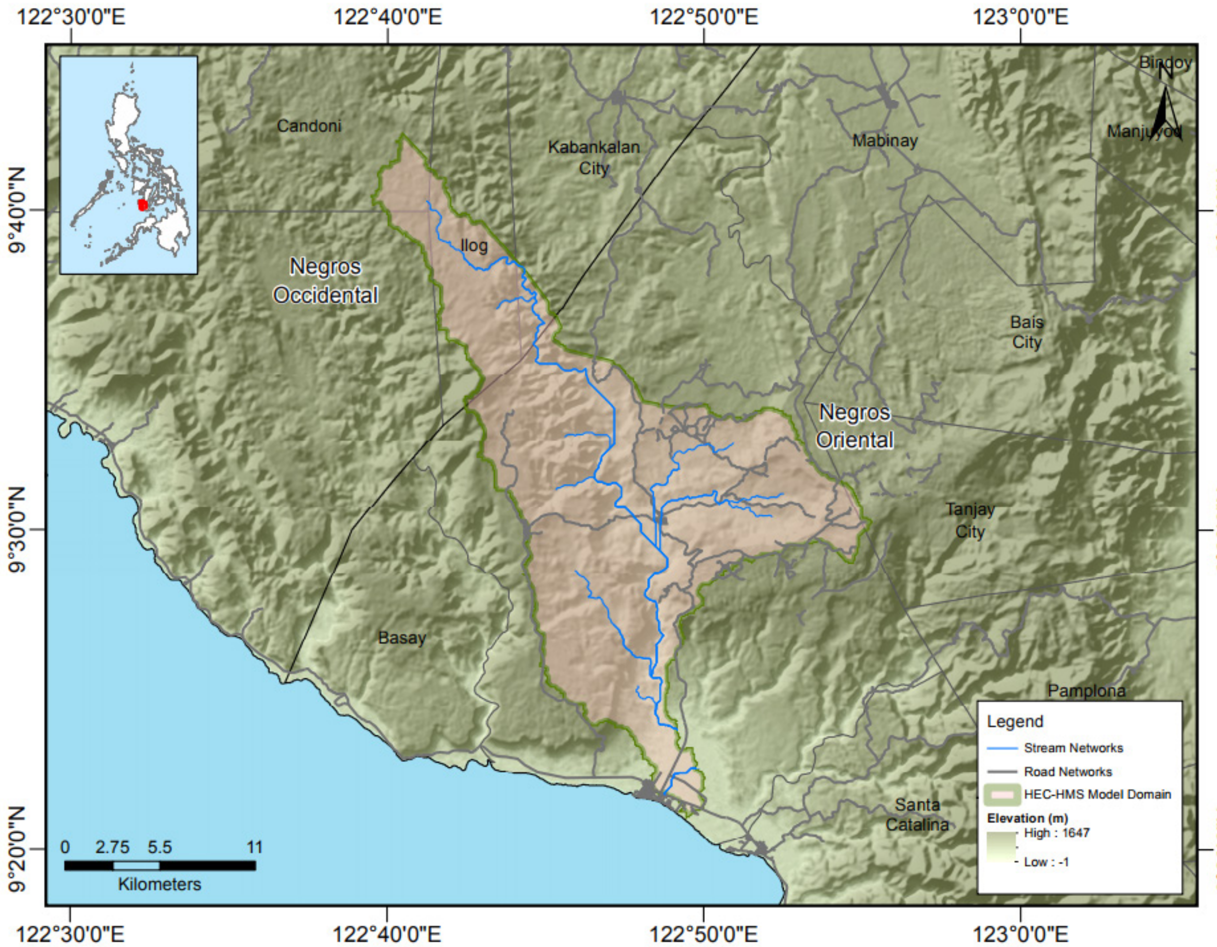


Figure 1. Map of Bayawan River Basin

The Bayawan River Basin lies in the City of Bayawan, the Agricultural Capital of Negros Oriental, located southwest of Negros Island at coordinates 9°22′00.14″ N and 122°47′59.01″ E. Bayawan Cityis a second-class component city of the third (3rd) Congressional District of the province of Negros Oriental (Wikipedia). Based on the 2015 census, it has a population of 117,900 (Bersales, 2016). It has a land area of 699.08 sq. km. Bayawan is bounded in the north by the municipality of Mabinay, in the east by the Cities of Tanjay and Bais, in the southeast by Sta. Catalina, and Basay in the northwest. It is a coastal city with a coastline of 15 km and 7 coastal barangays facing the Sulu Sea in the southwest. Bayawan City is subdivided into three development zones: i) urban area, which constitutes 2.3% (15.73 sq. km) of the total land area; ii) sub-urban, which is about 14.7% (102.60 sq. km) of the city's land area and consists of agro-industrial zones; and iii) rural area, consisting of the remaining 83.1% of the land area and is mostly agricultural.

The Bayawan River Basin coversBayawan City in Negros Oriental City, and three (3) Municipalities in Negros Occidental. The DENR River Basin Control Office identified the basinto have a drainage area of 434 km^2 and an estimated 260 million cubic meter annual run-off (RBCO, 2015).

Its main stem, Bayawan River, passes along Bayawan City. It is part of the nineteen (19) river systems in Central Visayas Region under the PHIL-LIDAR 1.A total of 18,664people are residing within the immediate vicinity of the river, which is distributed among three (3) barangays, namely:Nangka, Ubos, and Banga(NSO, 2015).Sources of livelihood of the population of Negros Oriental are focused on agriculture, particularly on the production of sugarcane, corn, and coconut. The population in the coast, on the other hand, cultivates extensive marine resources (Islands Web, 2015).

Flooding is a serious problem in Bayawan City. Sandwiched between the Bayawan and Sicopong Rivers, Bayawan City is highly susceptible to flooding during rainy days In October 13, 2013, three days of successive torrential rains brought Bayawan City to its knees. P50.9M and P40M worth of agriculture and infrastructure, respectively, were destroyed by floods. Damage to business establishments was pegged at P8M and another P1.8M for textbooks for a total of P100.1M. Six persons, including a policeman rescuer, were killed by the rampaging floodwaters. Thirty-six families lost their homes and about 20,000 people were evacuated[1].In December 2011, Typhoon Washi (local name *"Sendong"*) caused massive damages, including 37 casualties and 200 injuries. The Municipalities of Sibulan, Valencia, Pamplona, San Jose, Bacong, Amlan, Siaton, Dauin, San Jose and Tanjay Citywere the most affected during the calamity (The Negros Chronicle, 2011).

1 This account was based on the report of Alex Rey V. Pal of Metro Post dated December 13, 2013 (Pal, 2013).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BAYAWAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuña, Engr. Gerome Hipolito, For. Ma. Verlina Tonga and Jasmine Alviar

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Bayawan Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for BayawanFloodplain in Negros Oriental province. These missions were planned for 10 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 1shows the flight plan for Bayawan floodplain.

Table 1. Flight planning parameters for Gemini LiDAR

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)
BLK53F	1000	30	40	100	50	130	5
BLK53G	1000	30	40	100	50	130	5
BLK 53H	1000	30	40	100	50	130	5
BLK 53I	1000	30	40	100	50	130	5
BLK 53J	1000	30	40	100	50	130	5
BLK 53K	1000	30	40	100	50	130	5
BLK 53O	1000	30	40	100	50	130	5
BLK53V	1000	30	40	100	50	130	5
BLK55A	1000	30	40	100	50	130	5
BLK56A	1000	30	40	100	50	130	5
BLK 56B	1000	30	40	100	50	130	5
BLK 56C	1000	30	40	100	50	130	5
BLK56D	1000	30	40	100	50	130	5
BLK56E	1000	30	40	100	50	130	5

Table 2. Flight planning parameters for Aquarius LiDAR

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)
BLK56F	550	30	36	50	45	130	5

2.2 Ground Base Stations

The field team was able to recover five (5) NAMRIA horizontal ground control points of second (2nd) order accuracy, NGE-94, NGE-97, NGE-100, NGE-105 and NGE-107. Three (3) NAMRIA benchmarks were recovered: NE-90, NE-21 and NE-08 which are all of second (2nd) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the base station is found in Annex 2, while the baseline processing reports for established ground control points are found in Annex 3. These wereused as base stations during flight operations for the entire duration of the survey (September 20 – November 15, 2014 and January 21 – February 1, 2016), especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 882, SPS 985, and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Bayawan floodplain are shown in Figure 1.

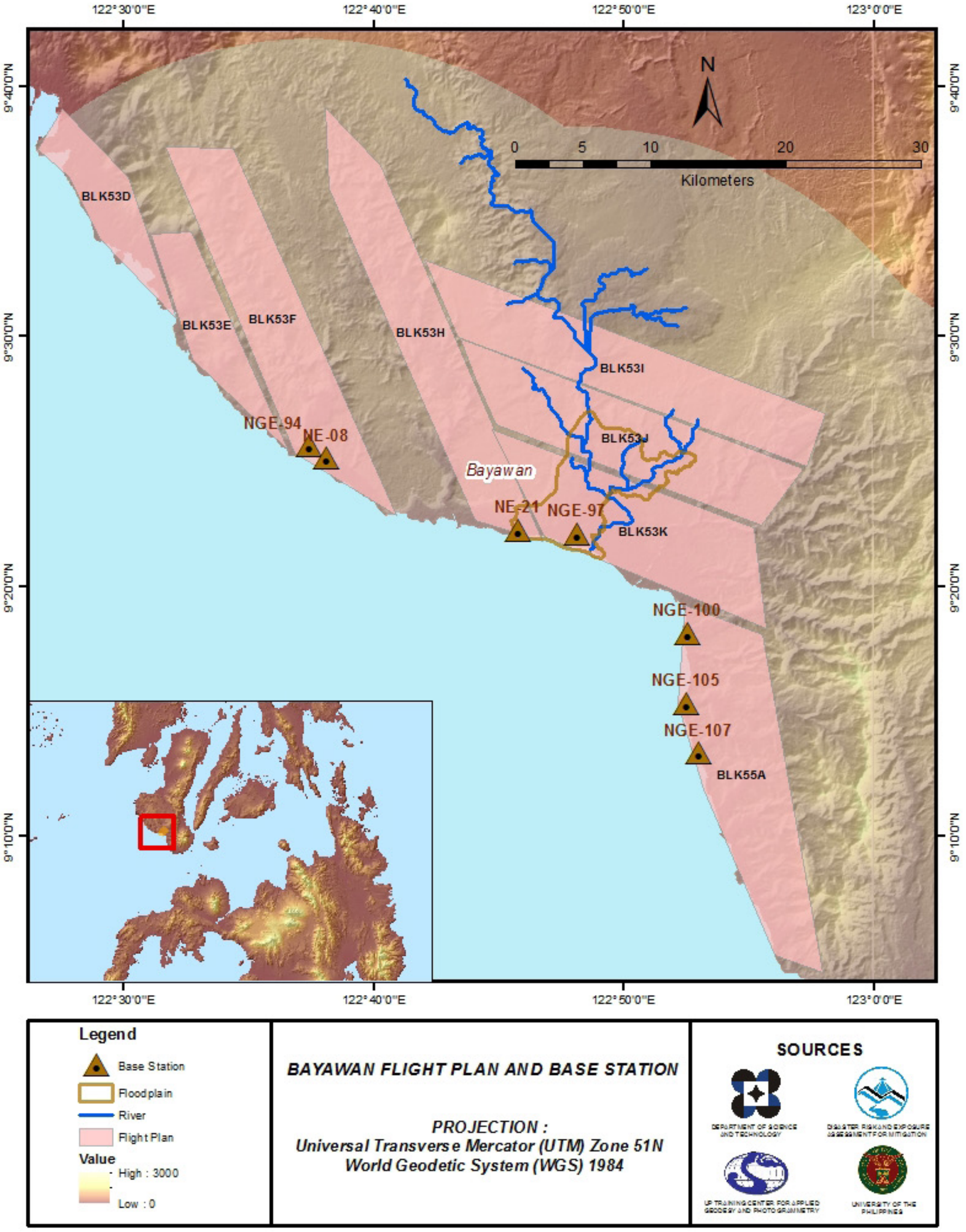


Figure 2. Flight plan used for Bayawan Floodplain

Figure 2 to Figure 8 show the recovered NAMRIA reference points within the area. In addition,Table 3 to Table 10 show the details about the following NAMRIA control stations and establishedpoints, while Table 11 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

The list of project team members can be seen in ANNEX D.

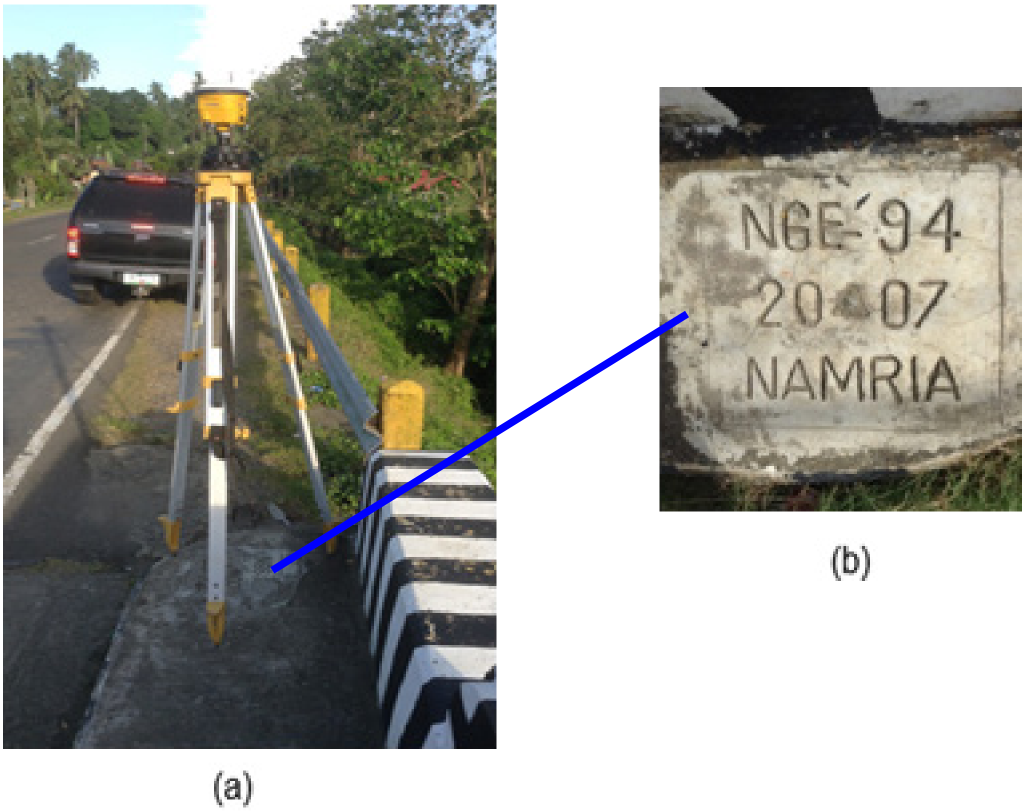


Figure 3. GPS set-up over NGE-94at the south approach of Tiabanan's bridge wing wall sidewalk in barangay Bal-Os, Municipality of Basay (a) and NAMRIA reference point NGE-94 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGE-94 used as base station for the LiDAR Acquisition.

Station Name	NGE-94	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°25'41.58333" North
	Longitude	122°37'17.78349" East
	Ellipsoidal Height	8.56700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	458444.003 meters
	Northing	1042517.096 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°25'37.57296" North
	Longitude	122°37'23.11929" East
	Ellipsoidal Height	69.14100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	458458.55 meters
	Northing	1042152.20 meters

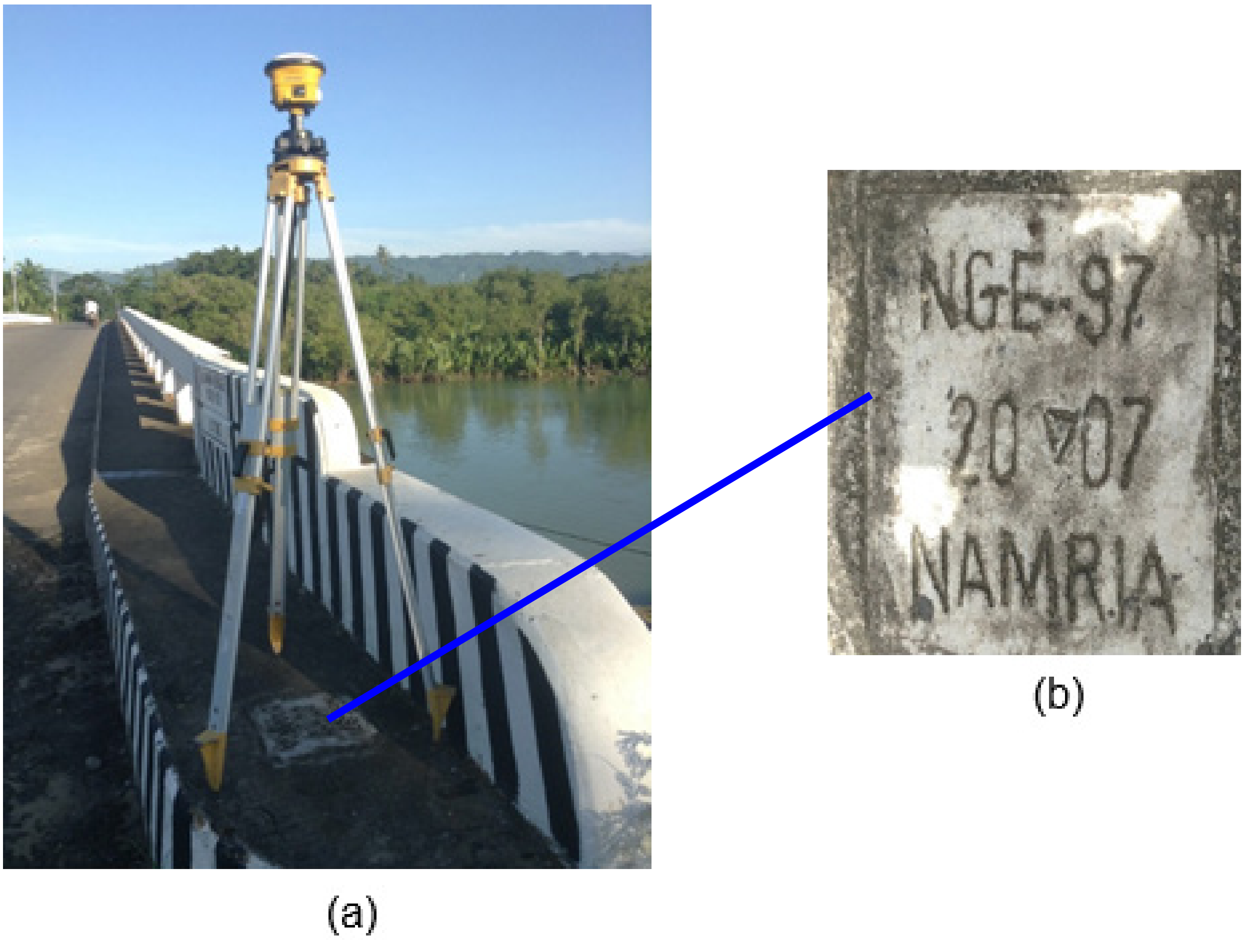
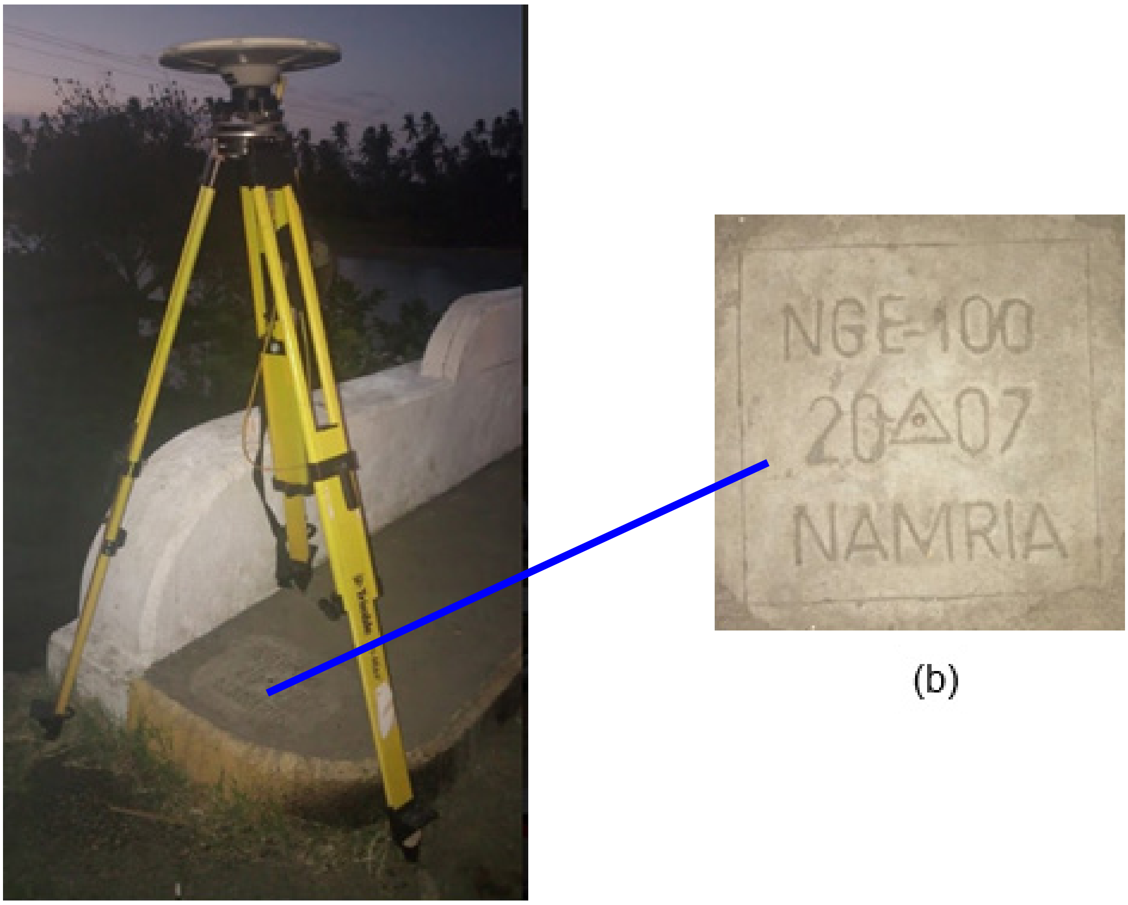


Figure 4. GPS set-up over NGE-97on the SE corner concrete sidewalk of Bayawan Bridge in Barangay Suba under the municipality of Bayawan (a) and NAMRIA reference point NGE-97 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point NGE-97used as base station for the LiDAR Acquisition.

Station Name	NGE-97	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°22’10.68255” North
	Longitude	122°48’1.35582” East
	Ellipsoidal Height	9.65300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	478073.348 meters
	Northing	1035659.36 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°22’6.70304” North
	Longitude	122°48’6.69563” East
	Ellipsoidal Height	70.79700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	478081.02 meters
	Northing	1035659.36 meters



(a) (b)

Figure 5. GPS set-up over NGE-100on the SW of Cawitan Bridge, along Dumaguete-Bayawan national highway (a) and NAMRIA reference point NGE-100 (b) as recovered by the field team.

Table 5. 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	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9° 18’ 11.02881”
	Longitude	122° 52’ 26.45331”
	Ellipsoidal Height	8.14800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	486159.164 meters
	Northing	1028656.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9° 18’ 7.07298”
	Longitude	122° 52’ 31.79856”
	Ellipsoidal Height	69.61900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	486164.01 meters
	Northing	1028296.07 meters

(a)

(b)

Figure 6. GPS set-up over NGE-105at top of the bridge wingwall SW of the Bridge main span on the left side of the 1st approach coming from Siaton on the way to Sta. Catalina. The station is located in Barangay Nagbalayen under the municipality of Sta. Catalina(a) and NAMRIA reference point NGE-105 (b) as recovered by the field team.

Table 6. Details of the recoveredNAMRIA horizontal control point NGE-105 used as base station for the LiDAR acquisition.

Station Name	NGE-105	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°15’23.79985”
	Longitude	122°52’24.36983”
	Ellipsoidal Height	8.89200 m
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	486093.752 m
	Northing	1023160.66 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°15’19.85595”
	Longitude	122°52’29.71925”
	Ellipsoidal Height	70.46200m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	486098.62 m
	Northing	1023160.66 m

(a)

(b)

Figure 7. GPS set-up over NGE-107on a concrete sidewalk on a bridge at KM. 80+569over Manalongon River in Barangay Manalongon under the municipality of Sta. Catalina (a) and NAMRIA reference point NGE-107 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point NGE-107 used as base station for the LiDAR acquisition.

Station Name	NGE-107	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°13’23.69730” North
	Longitude	122°52’53.67884” East
	Ellipsoidal Height	8.08400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	486987.067 meters
	Northing	1019829.085 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°13’19.76274” North
	Longitude	122°52’59.03119” East
	Ellipsoidal Height	69.74600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	486991.62 meters
	Northing	1019472.13 meters

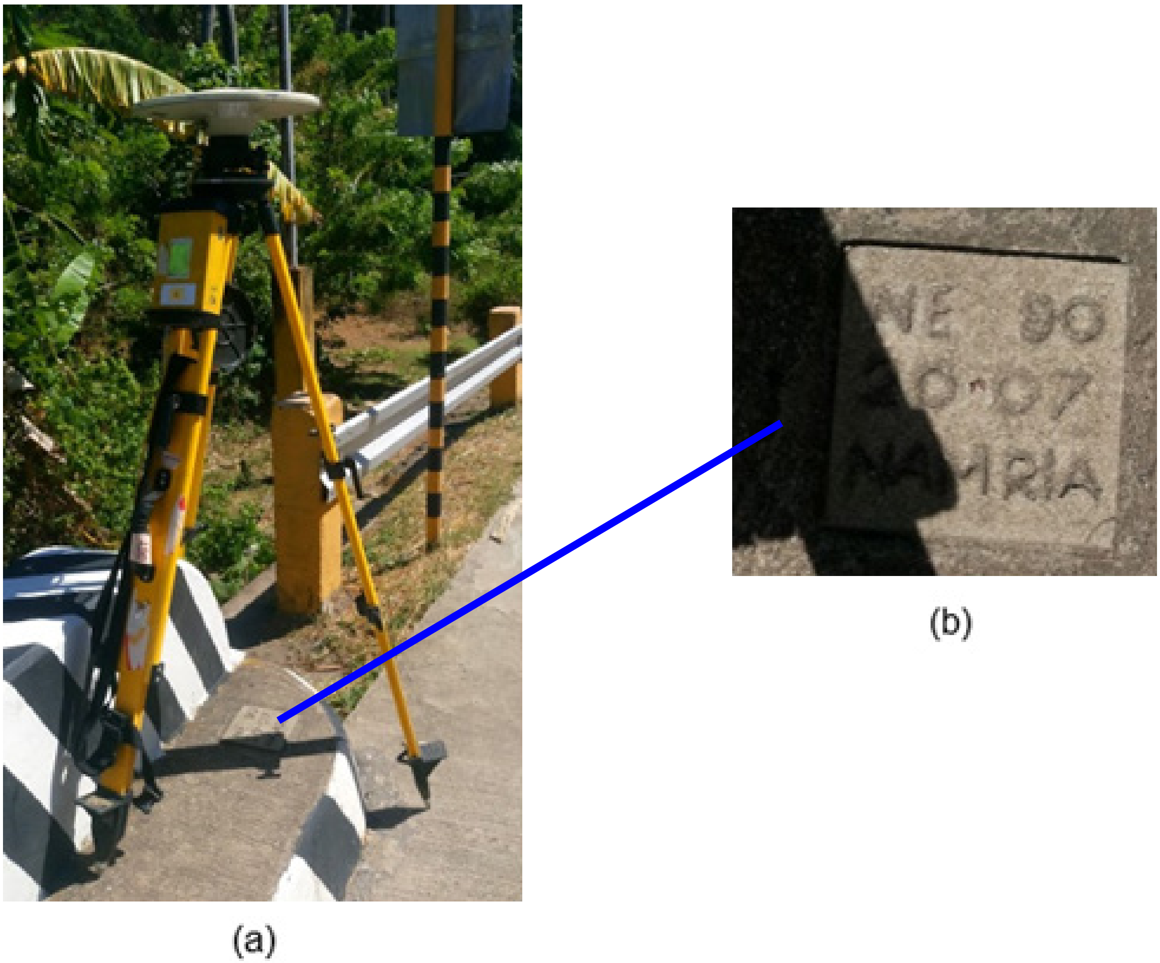


Figure 8. Set-up over NE-90on a concrete sidewalk of Guinsuan Bridge, 4 meters from the road centerline in Barangay Poblacion under the municipality of Zamboanguita (a) and NAMRIA benchmark NE-90 (b) as recovered by the field team.

Table 8. Details of established ground control point NE-90 used as vertical reference point and established base station for the LiDAR acquisition.

Station Name	NE-90	
Order of Accuracy	2nd	
Elevation	6.6968	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°6’42.32060” North
	Longitude	123°12’04.93455” East
	Ellipsoidal Height	7.358 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°6’38.44322” North
	Longitude	123°12’10.29457” East
	Ellipsoidal Height	70.052 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	522126.927 meters
	Northing	1007150.356 meters

(b)

(a)

Figure 9. GPS set-up over NE-21 on concrete sidewalk of Camaya-an Bridge about 0.30 meters above the ground and 4 meters from the road centerline. The station is located on barangay Malabogas under the municipality of Bayawan (a) and NAMRIA benchmark NE-21 (b) as recovered by the field team.

Table 9. Details of established ground control point NE-21 used as vertical reference point and established base station for the LiDAR acquisition.

Station Name	**NE-21**	
Order of Accuracy	**2nd**	
Elevation	**5.4216**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°22’18.89002” North
	Longitude	122°45’39.02590” East
	Ellipsoidal Height	7.040 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°22’14.90643” North
	Longitude	122°45’44.36578” East
	Ellipsoidal Height	68.081 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	473740.044 meters
	Northing	1035914.112 meters

Table 10. Details of established ground control point NE-08used as vertical reference point and established base station for the LiDAR acquisition.

Station Name	NE-08	
Order of Accuracy	2nd	
Elevation	2.6097	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9°25'12.20140" North
	Longitude	122°38'00.55785" East
	Ellipsoidal Height	8.582 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9°25'08.19418" North
	Longitude	122°38'05.89430" East
	Ellipsoidal Height	69.203 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	449762.045 meters
	Northing	1041248.495 meters

Table 11. Ground Control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
30-Sep-14	7526G	2BLK53O55A273A	NGE-105, NGE-107
7-Oct-14	7540G	2BLK55AS53KS280A	NGE-105, NGE-107
17-Oct-14	7560G	2BLK55A290A	NGE-105, NGE-107
18-Oct-14	7562G	2BLK53I291A	NE-21, NGE-97
20-Oct-14	7566G	2BLK53JK293A	NE-21, NGE-97
21-Oct-14	7568G	2BLK53KS294A	NE-21, NGE-97
22-Oct-14	7570G	2BLK53H295A	NE-08, NGE-94
25-Oct-14	7576G	2BLK53H298A	NE-08, NGE-94
26-Oct-14	7578G	2BLK53HSGF299A	NE-08, NGE-94
30-Jan-16	10076AC	3BLK53V030A	NE-90, NGE-97, NGE-100

2.3 Flight Missions

Nine(9) missions were conducted to complete the LiDAR data acquisition in Bayawanfloodplain, for a total of thirty seven hours and forty minutes (37+40)of flying time for RP-C9322. All missions were acquired using the Geminiand Aquarius LiDAR systems.Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while

Table13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for LiDAR data acquisition in Bayawan floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within Floodplain (km^2)	Area Surveyed Outside Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
30-Sep-14	7526G	263.24	65.53	11.63	53.90	-	2	35
7-Oct-14	7540G	381.81	107.06	19.94	87.12	-	3	29
17-Oct-14	7560G	143.39	164.21	-	164.21	-	3	47
18-Oct-14	7562G	125.11	162.44	0.25	162.18	-	4	11
20-Oct-14	7566G	238.42	156.75	30.85	125.91	-	3	35
21-Oct-14	7568G	381.81	171.88	36.04	135.84	-	4	11
22-Oct-14	7570G	126.75	148.87	5.19	143.68	-	4	23
25-Oct-14	7576G	128.58	118.46	-	118.46	-	3	53
26-Oct-14	7578G	221.47	252.32	-	252.32	-	4	23
30-Jan-16	10076AC	17.92	26.19	6.15	20.04	-	3	13
TOTAL		2028.49	1373.71	110.05	1263.66	-	37	40

Table 13. 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)
7526G	1000	30	40	100	50	130	5
7540G	1100	30	40	100	50	130	5
7560G	1000	30	40	100	50	130	5
7562G	1000	30	40	100	50	130	5
7566G	1000	30	40	100	50	130	5
7568G	1100	30	40	100	50	130	5
7570G	1000	30	40	100	50	130	5
7576G	1000	30	40	100	50	130	5
7578G	1100	30	40	100	50	130	5
10076AC	550	30	36	50	45	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the BayawanFloodplain (Refer to ANNEX G for the flight status reports). It is located in the province of Negros orientalwith majority of the floodplain situated within the city of Dumaguete and municipality of Bacong. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown inTable 14. The actual coverage of the LiDAR acquisition for Bayawanfloodplain is presented in Figure 9.

Table 14. List of municipalities and cities surveyed during Bayawan floodplain LiDAR

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Negros Oriental	Bayawan City	683.21	388.38	57%
	Basay	132.3	72.91	55%
	Santa Catalina	542.62	186.48	34%
	Siaton	312.75	41.16	13%
	Pamplona	215.09	10.5	5%
Negros Occidental	Hinoba-An	464.36	229.68	49%

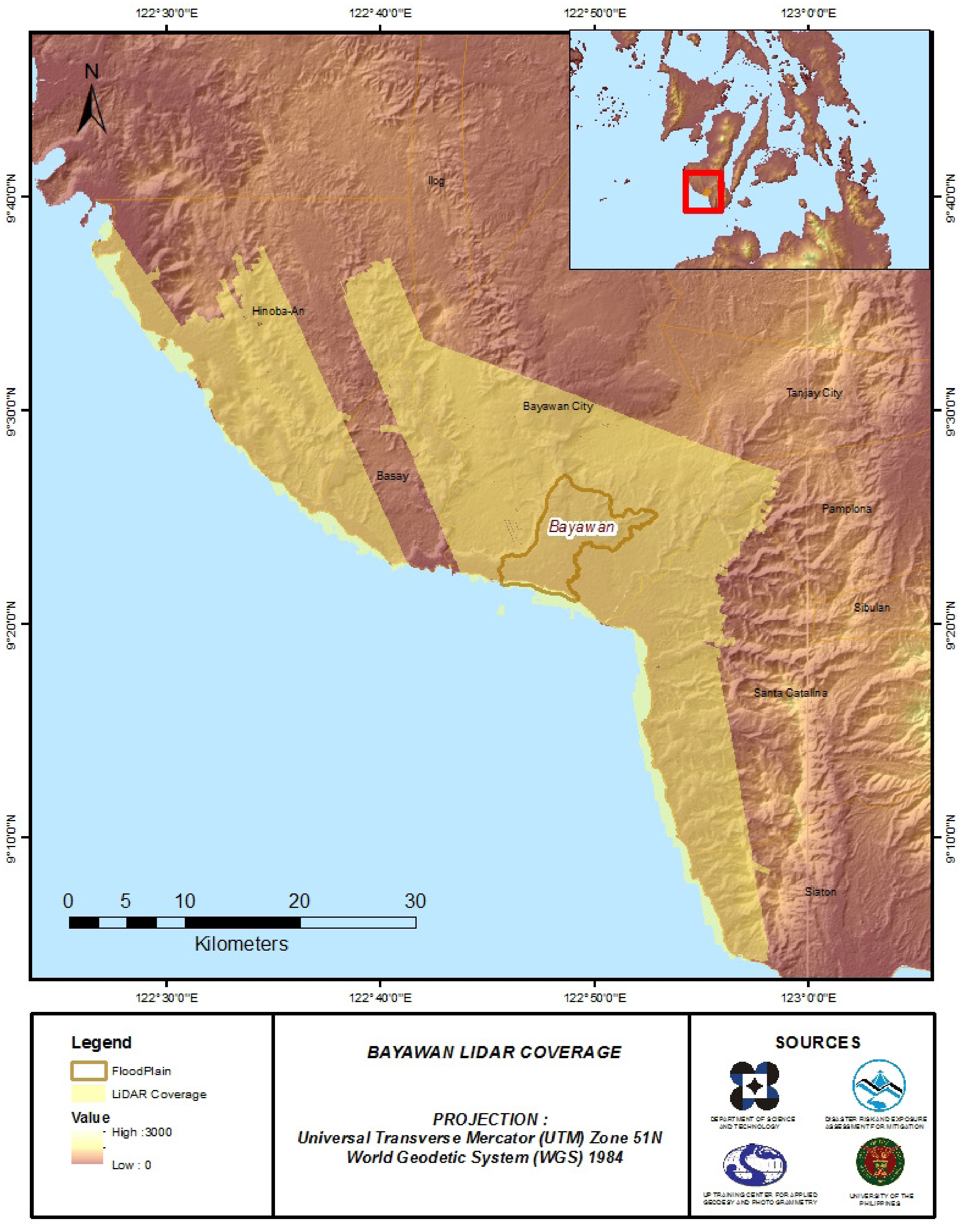


Figure 10. Actual LiDAR survey coverage for Bayawan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BAYAWAN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Joida F. Prieto , Ailyn G. Biñas , Engr. Jennifer B. Saguran, Engr. Monalyne C. Rabino, Engr. Velina Angela S. Bemida , Engr. Ma. Joanne I. Balaga and Engr. Erica Erin E. Elazegui

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

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

These processes are summarized in the flowchart shown in Figure 11.

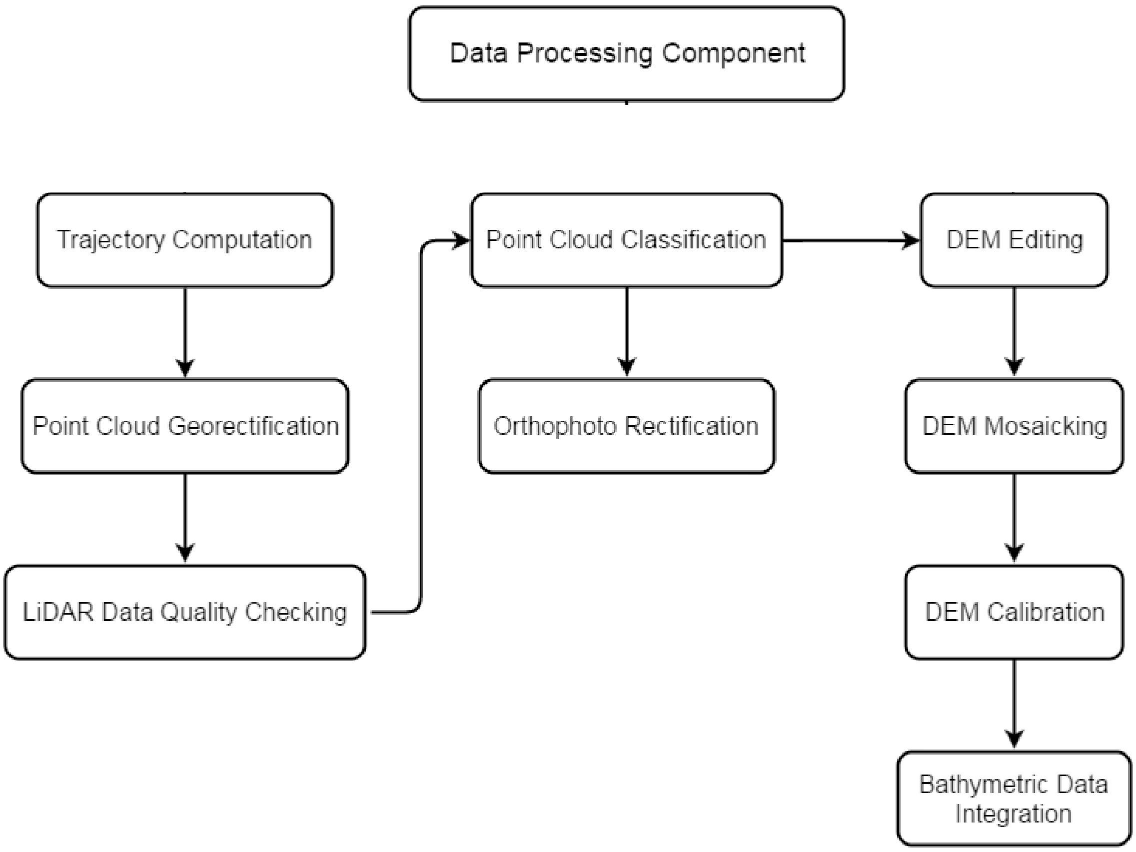


Figure 11. Schematic Diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for Bayawan floodplain can be found in ANNEXE. Missions flown during the first survey conducted on September 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.)Gemini system, while missions acquired during the second survey on January 2016 were flown using the Aquarius system over Bayawan City, Negros Oriental. TheDAC transferred a total of155.25 Gigabytes of Range data, 2.15 Gigabytes of POS data, 68.49 Megabytes of GPS base station data, and 220.10 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. TheData Pre-processing Component (DPPC)verified the completeness of the transferred data. The whole dataset for Bayawan was fully transferred on February 9, 2016, as indicated on the Data Transfer Sheets for Bayawan floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 7578G, one of the Bayawanflights, whichare the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell onOctober 25, 2014 00:00AMon that week. The y-axis is the RMSE value for that particular position.

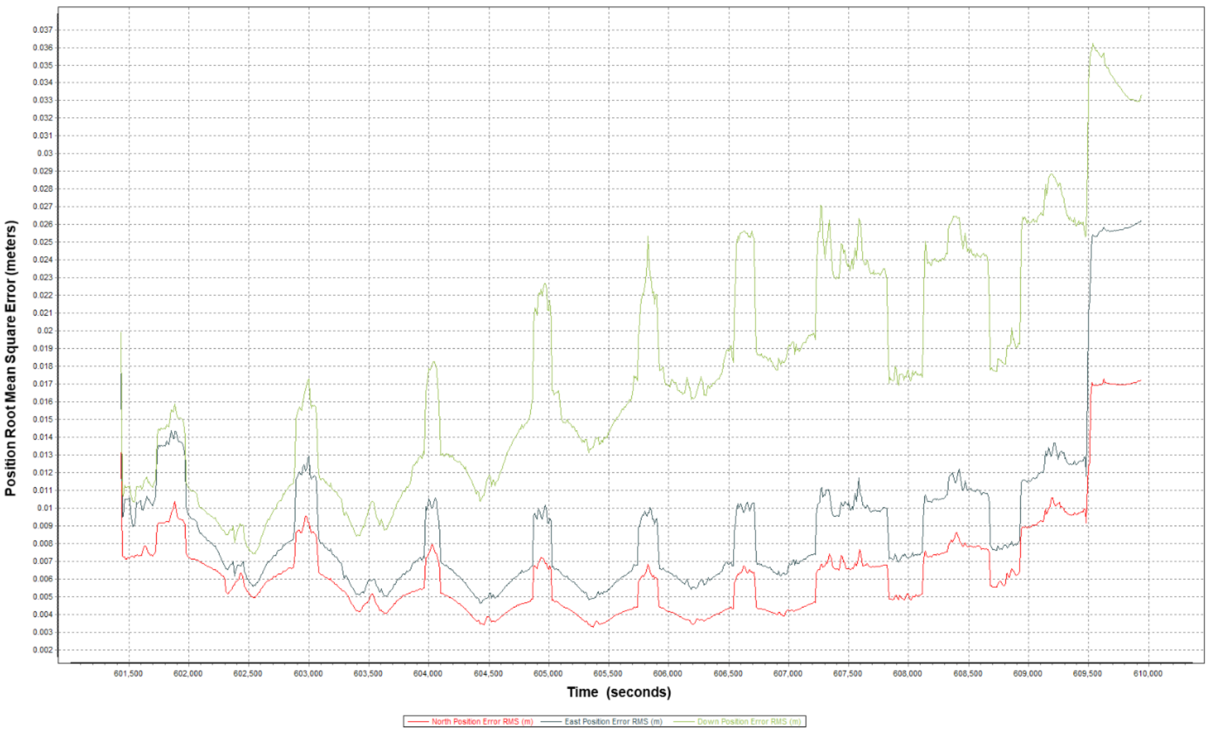


Figure 12. Smoothed Performance Metrics ofBayawan Flight 7578G.

The time of flight was from 601500 seconds to 609000 seconds, which corresponds to morning of October 25, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values 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 1.05centimeters, the East position RMSE peaks at 1.45centimeters, and the Down position RMSE peaks at 2.90centimeters, which are within the prescribed accuracies described in the methodology.

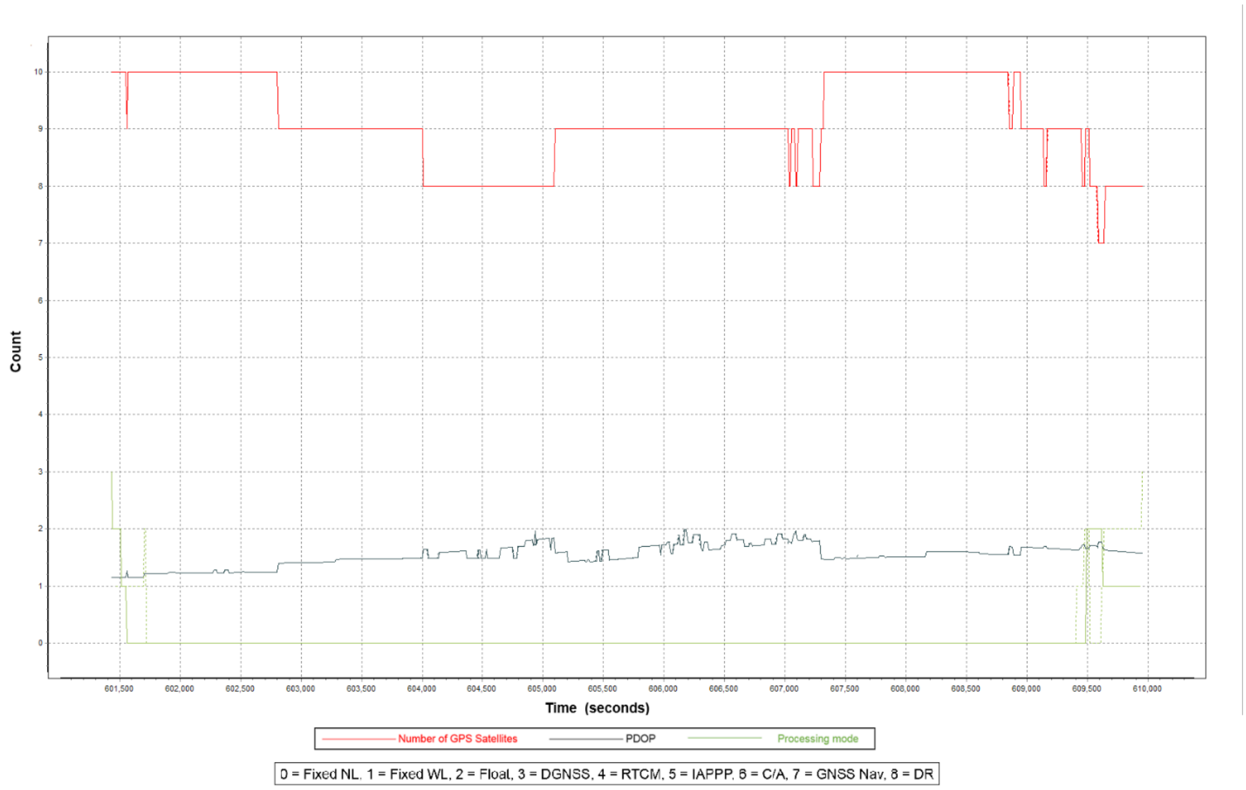


Figure 13.Solution Status Parameters of Bayawan Flight 7578G.

The Solution Statusparameters offlight 7578G,one of the Bayawanflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown inFigure 12The 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 7 and 10. The PDOP value also did not go above the value of 2, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Bayawan flights is shown in Figure 13.

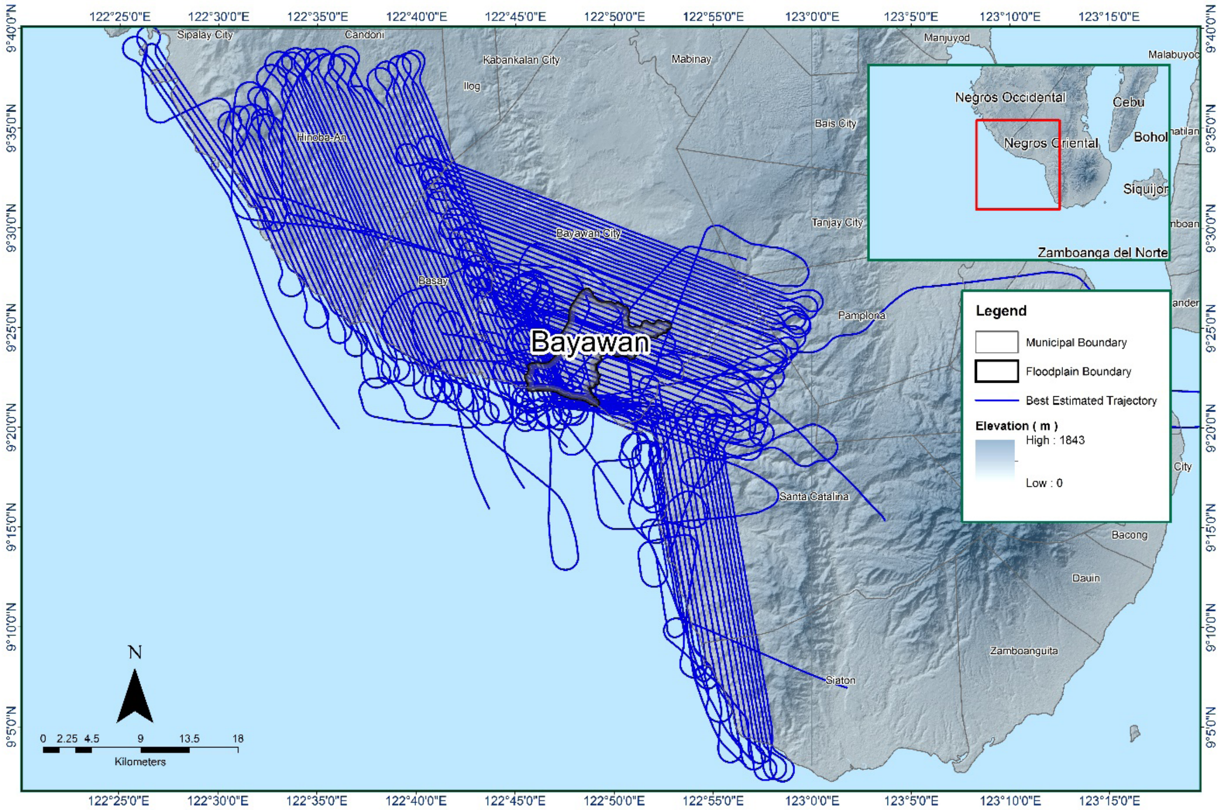


Figure 14. Best Estimated Trajectory for Bayawan Floodplain.

3.4 LiDAR Point Cloud Computation

The generatedLAS data contains 156flight lines, with each flight line containing one channel, since both the Gemini and Aquarius systemscontain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Bayawan floodplain are given in Table 15.

Table 15. Self-Calibration Results values for Bayawan flights.

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000168
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000941
GPS Position Z-correction stdev (<0.01meters)	0.0099

The optimum accuracy is obtained for all Bayawan flights based on the computed standard deviationsof the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the ANNEXH, Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Bayawan Flood plain is illustratedin Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

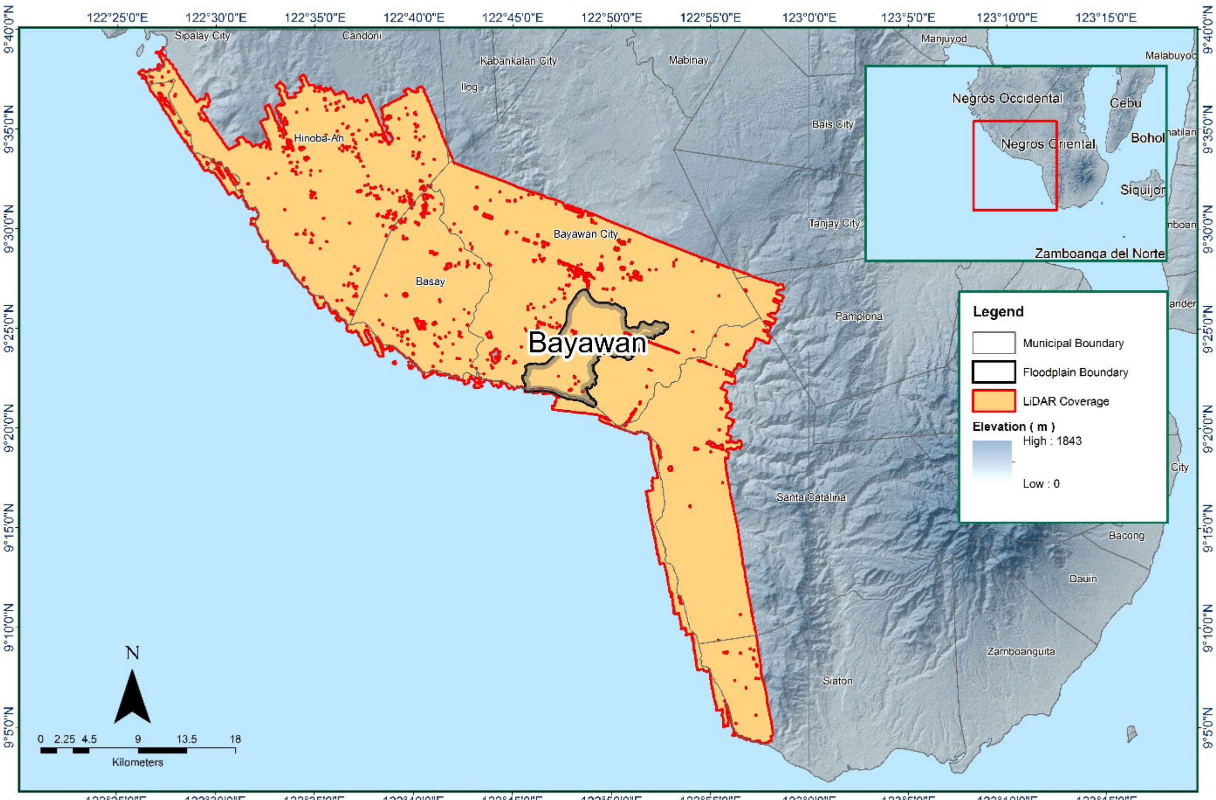


Figure 15. Boundary of the processed LiDAR data over Bayawan Floodplain.

The total area covered by the Bayawan missions is 1,186.90 sq.km, which is comprised of fourteen (14) flight acquisitions grouped and merged into seven (7) blocks, as shown in Table 16.

Table 16. List of LiDAR blocks for Bayawan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dumaguete_Blk53H	7570G	375.64
	7576G	
	7578G	
Dumaguete_Blk53J	7566G	152.57
Dumaguete_Blk53K	7540G	109.53
	7566G	
	7568G	
Dumaguete_Blk53Ks	7526G	52.64
	7540G	
Dumaguete_Blk53I	7562G	304.1
Dumaguete_Blk55A	7526G	169.1
	7540G	
	7560G	
Dumaguete_reflights_Blk53O	10076AC	23.32
	TOTAL	**1,186.90**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the Geminiand Aquarius systemsboth employ one channel, it is expected to have an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

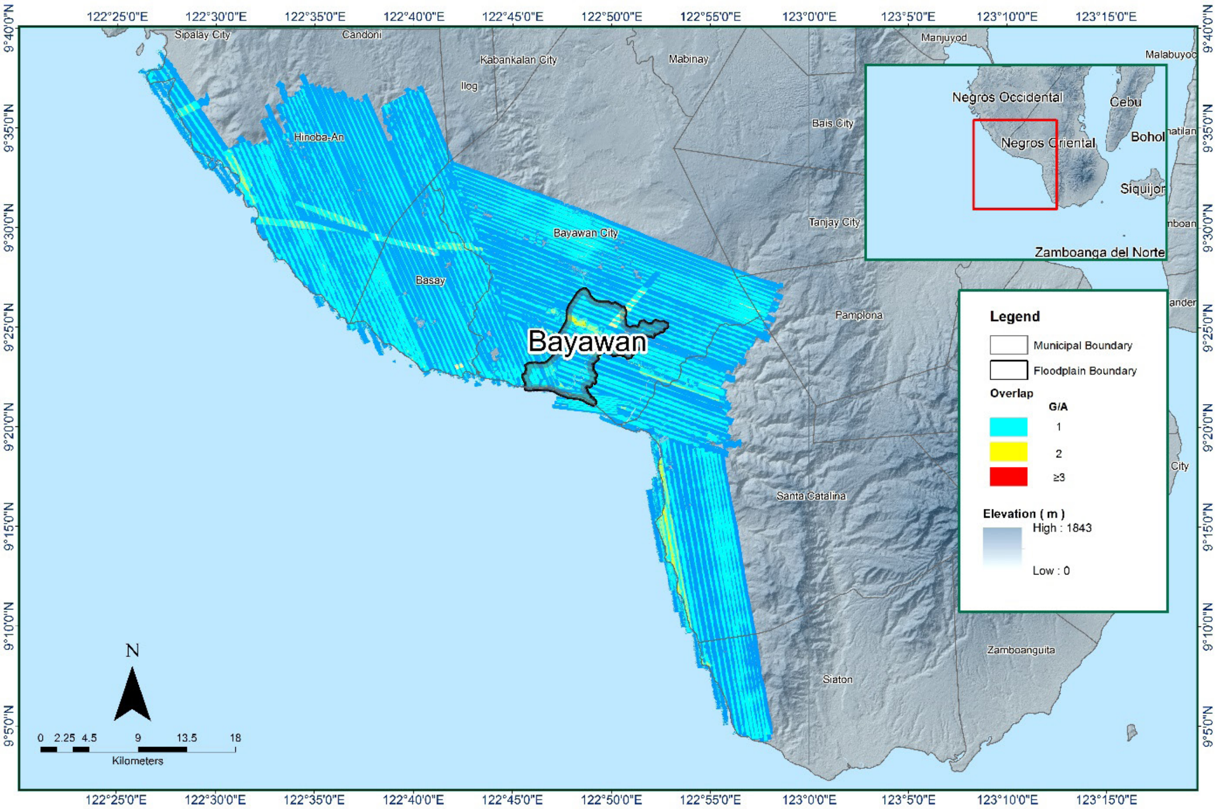


Figure 16. Image of data overlap for Bayawan floodplain.

The overlap statistics per block for the Bayawan floodplain can be found in ANNEXH. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlapsare30.01% and 47.63%respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Bayawan floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.06 points per square meter.

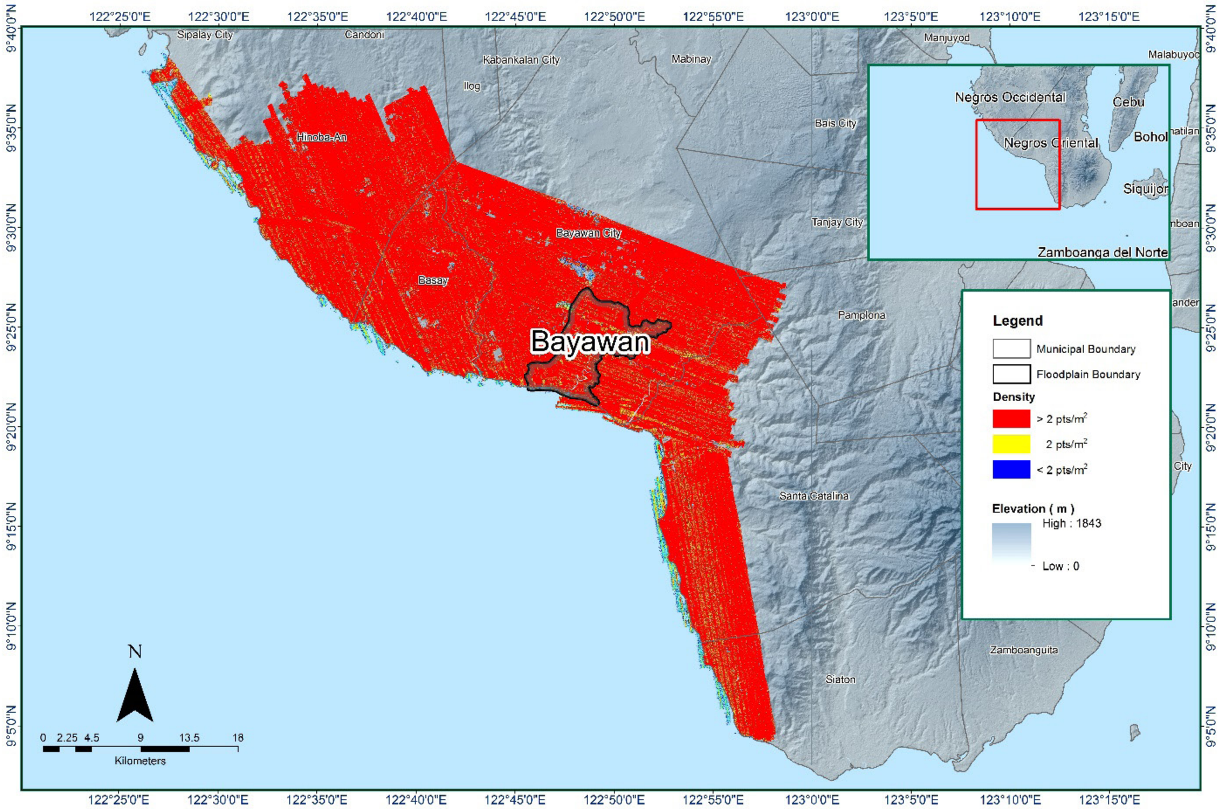


Figure 17. Density map of merged LiDAR data for Bayawan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time,are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

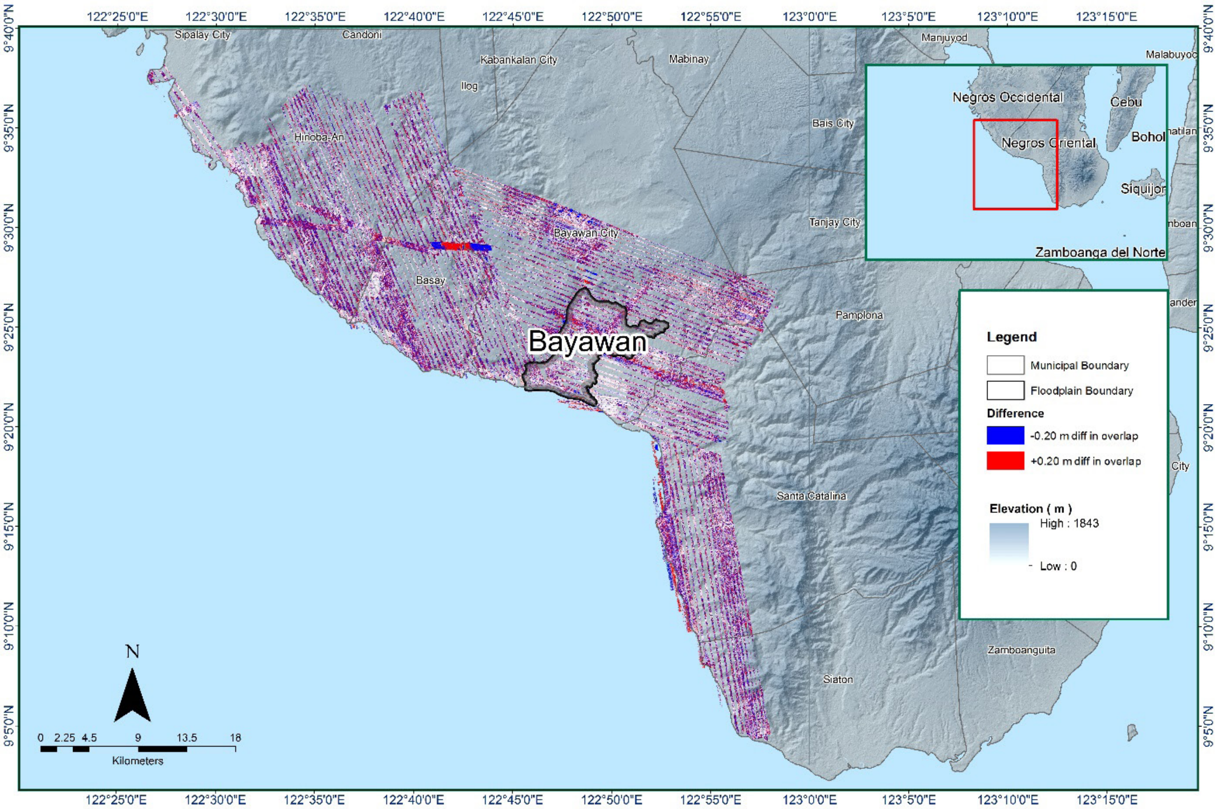


Figure 18. Elevation difference map between flight lines for Bayawan floodplain.

A screen capture of the processed LAS data from a Bayawan flight 7578G loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

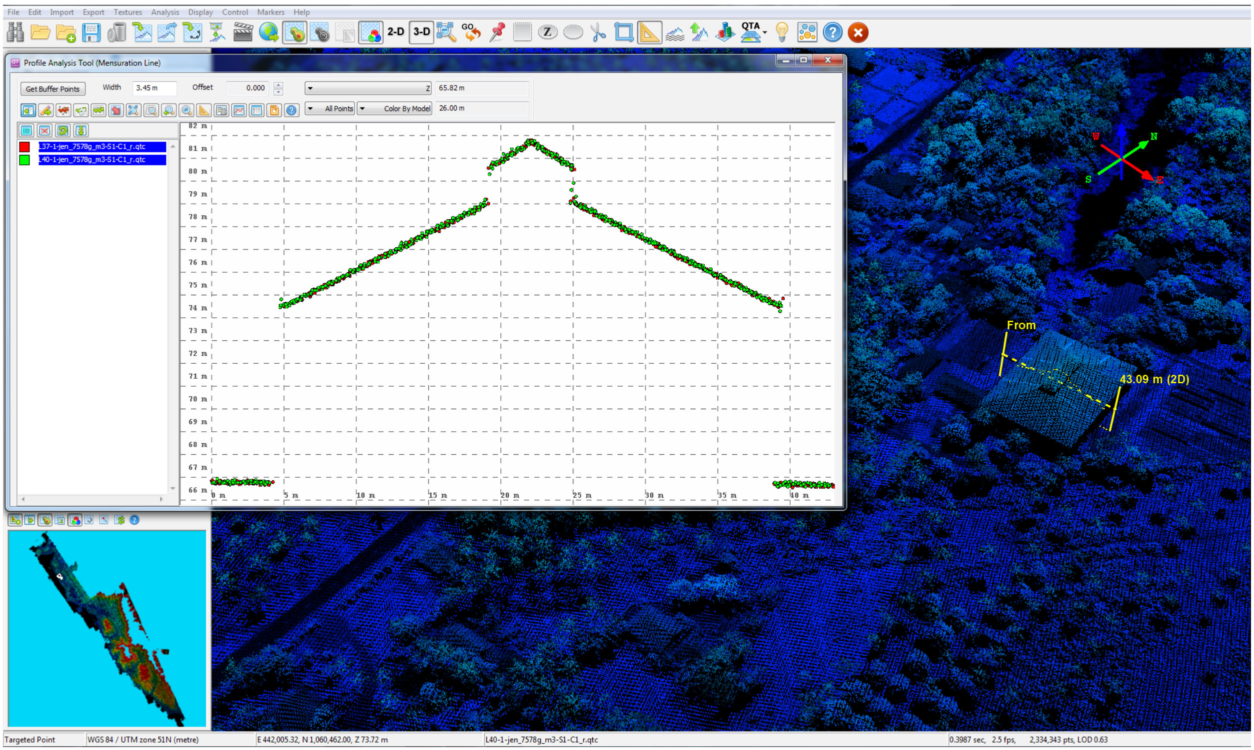


Figure 19. Quality checking for Bayawan flight 7578G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Bayawan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	550,953,235
Low Vegetation	546,998,873
Medium Vegetation	1,387,866,731
High Vegetation	1,818,739,692
Building	38,282,474

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Bayawan floodplain is shown in Figure 19. A total of 1,691 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 718.69 meters and 57.34 meters, respectively.

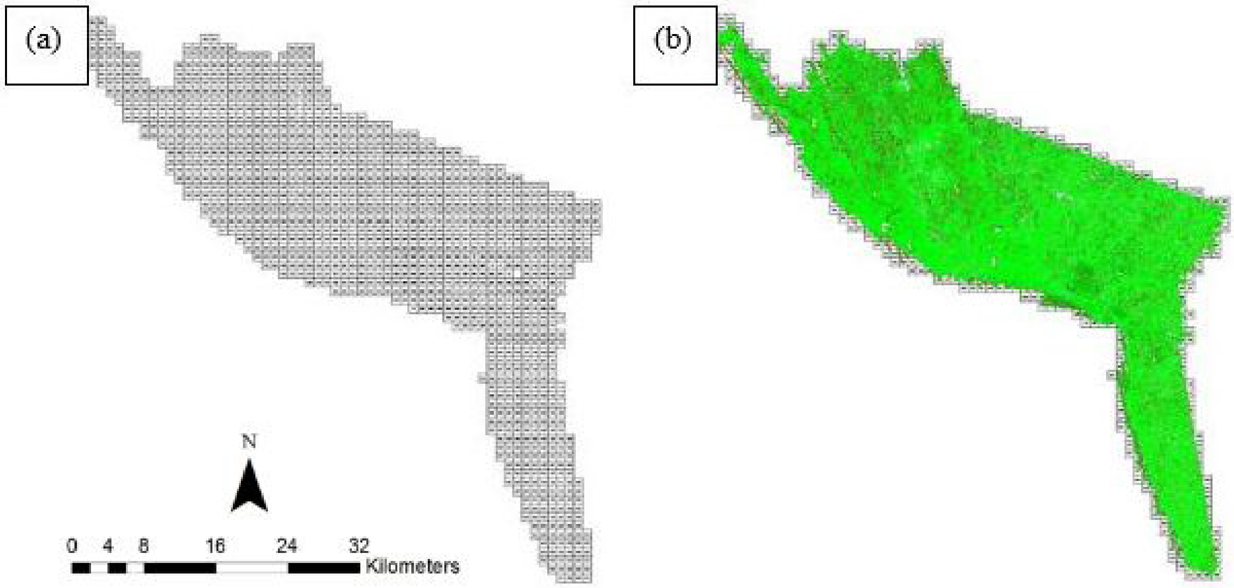


Figure 20. Tiles for Bayawan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

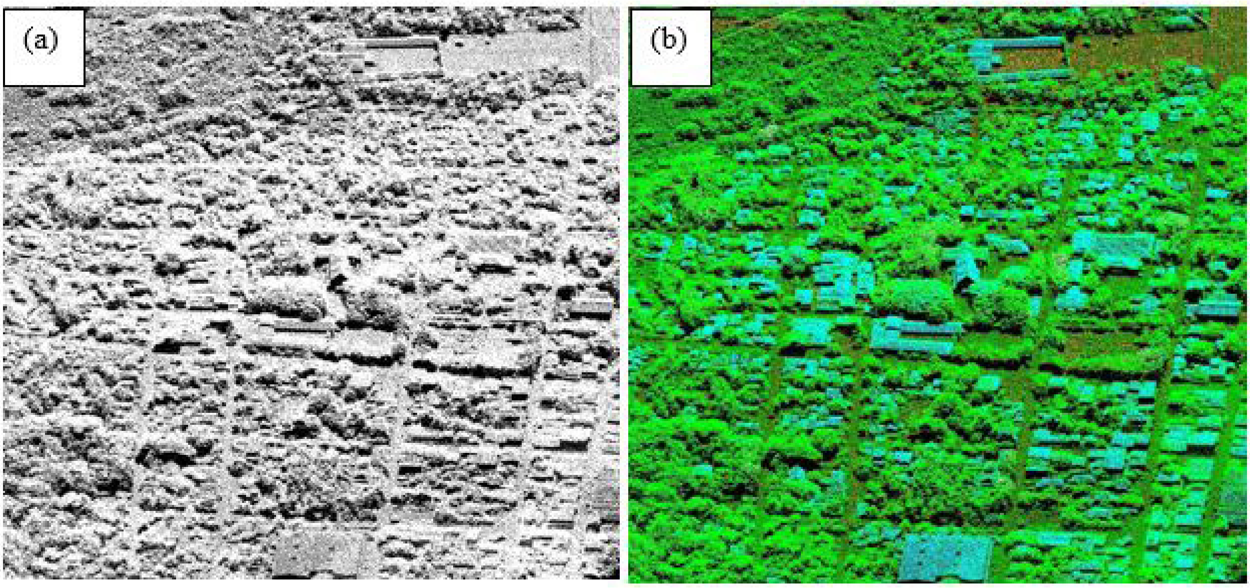


Figure 21. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 21. It reflectsthat DTMs are the representation of the bare earth, while on the DSMs, all features are present such as buildings and vegetation.

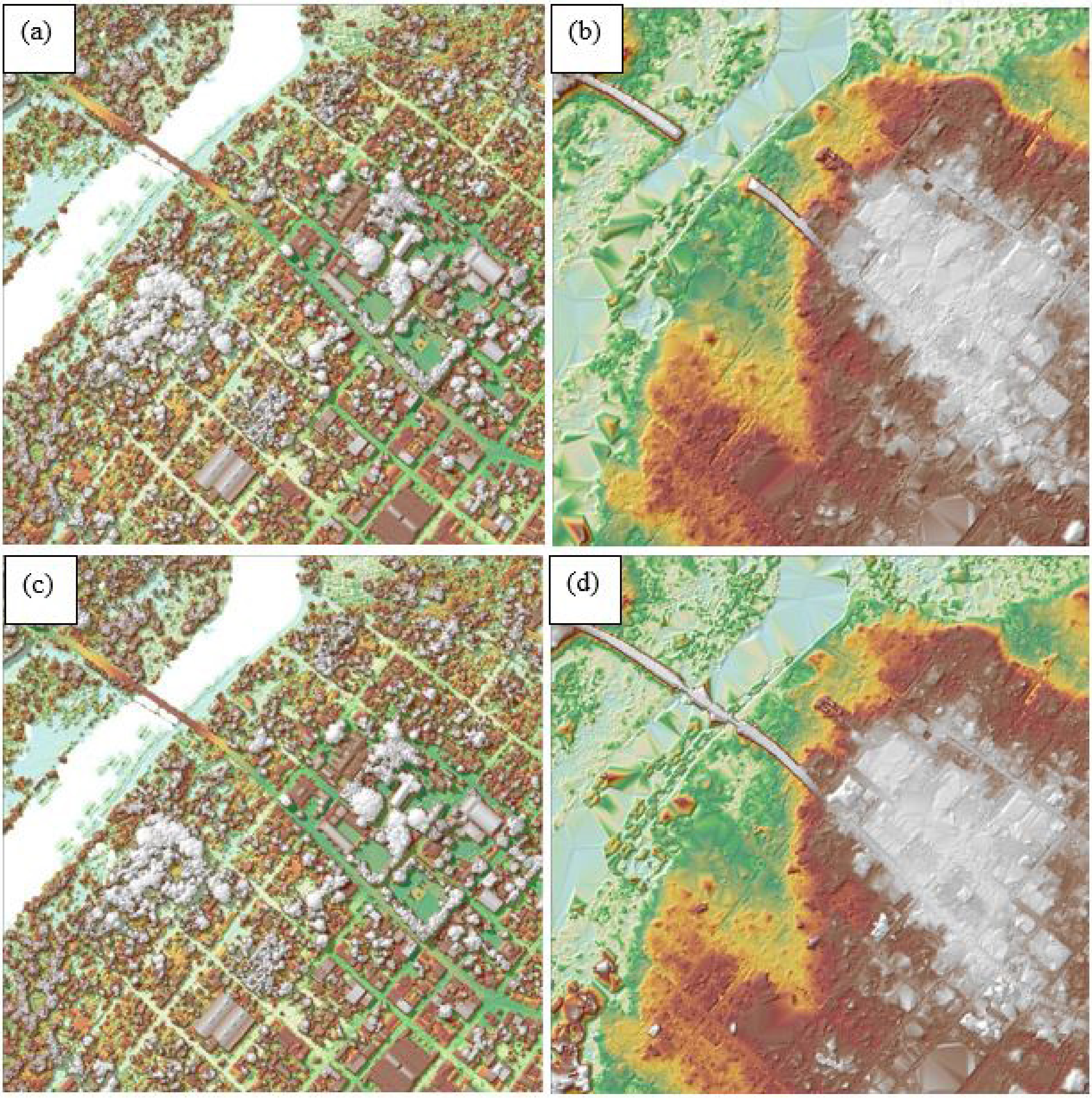


Figure 22. The production of last return DSM (a) and DTM (b) first return DSM (c) and secondary DTM (d) in some portion of Bayawan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Bayawan floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for the Bayawan flood plain. These blocks are composed of Dumaguete and Dumaguete_reflights blocks with a total area of 1,186.90 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km)
Dumaguete_Blk53H	375.64
Dumaguete_Blk53J	152.57
Dumaguete_Blk53K	109.53
Dumaguete_Blk53Ks	52.64
Dumaguete_Blk53I	304.1
Dumaguete_Blk55A	169.1
Dumaguete_reflights_Blk53O	23.32
TOTAL	**1,186.90**

Portions of DTM before and after manual editing are shown in Figure 22. The interpolated mountain (Figure 22a) has been misclassified and removed during classification process and had to be retrieved to complete the surface (Figure 22b) Also, unfilled data during processing (Figure 22c) were filled during further processing (Figure 22d). These are shown in the following figure.

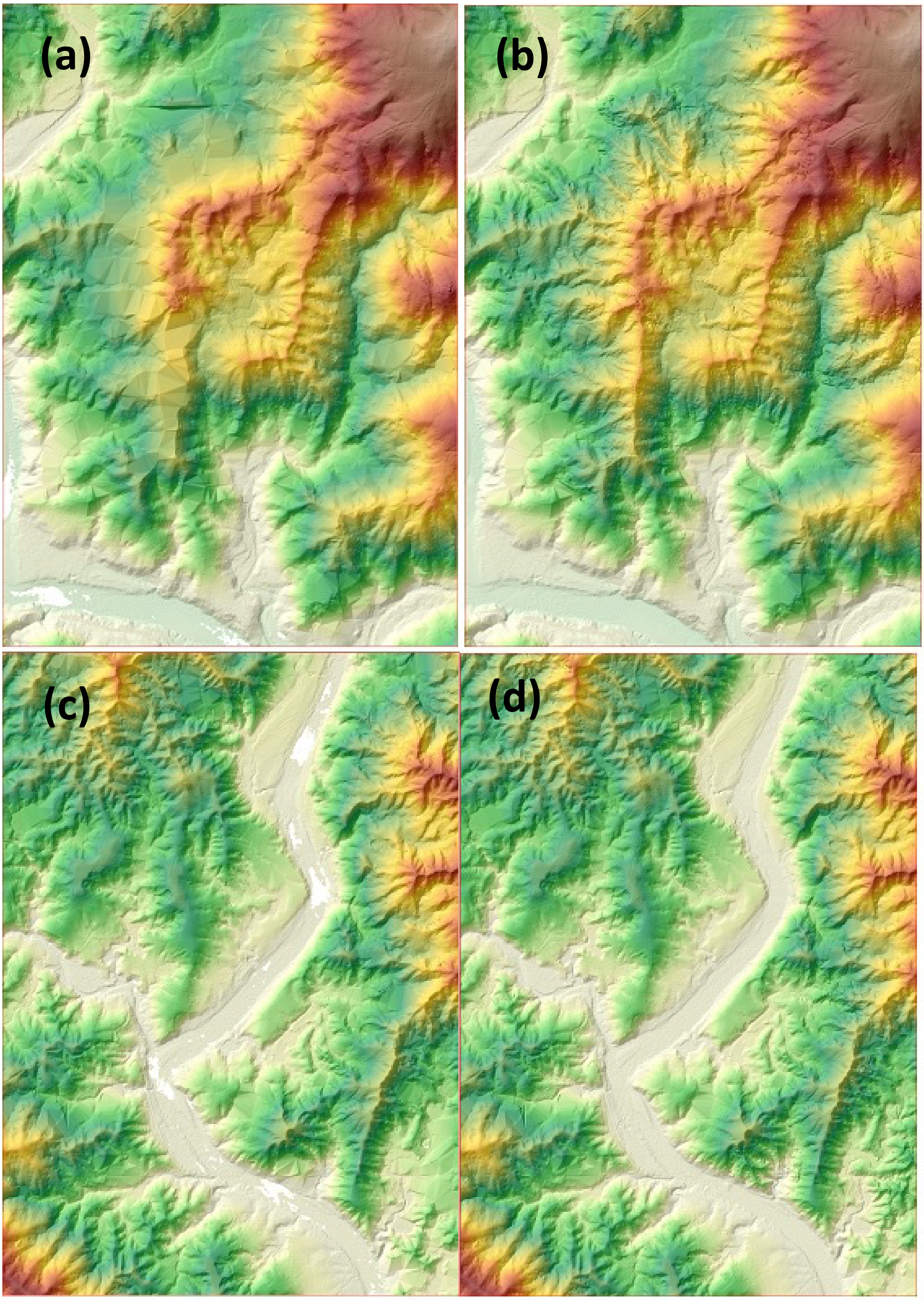


Figure 23. Portions in the DTM of Bayawan floodplain – an interpolated mountain before (a) and after (b) data retrieval; (c) before and (d) after filling data gaps.

3.9 Mosaicking of Blocks

Dumaguete_Blk53H 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 19 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Bayawan floodplain ispresented in Figure 23. It can be seen that the entire Bayawan floodplain is 100% covered by LiDAR data.

Table 19. Shift Values of each LiDAR Block of Bayawan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dumaguete_Blk53H	0.00	0.00	0.00
Dumaguete_Blk53J	0.00	0.00	-0.20
Dumaguete_Blk53K	0.00	0.00	-0.63
Dumaguete_Blk53K_supplement	0.00	0.00	-0.15
Dumaguete_Blk53I	0.00	0.00	-0.26
Dumaguete_Blk55A	0.00	0.00	-0.53
Dumaguete_reflights_Blk53O	0.00	0.00	0.00

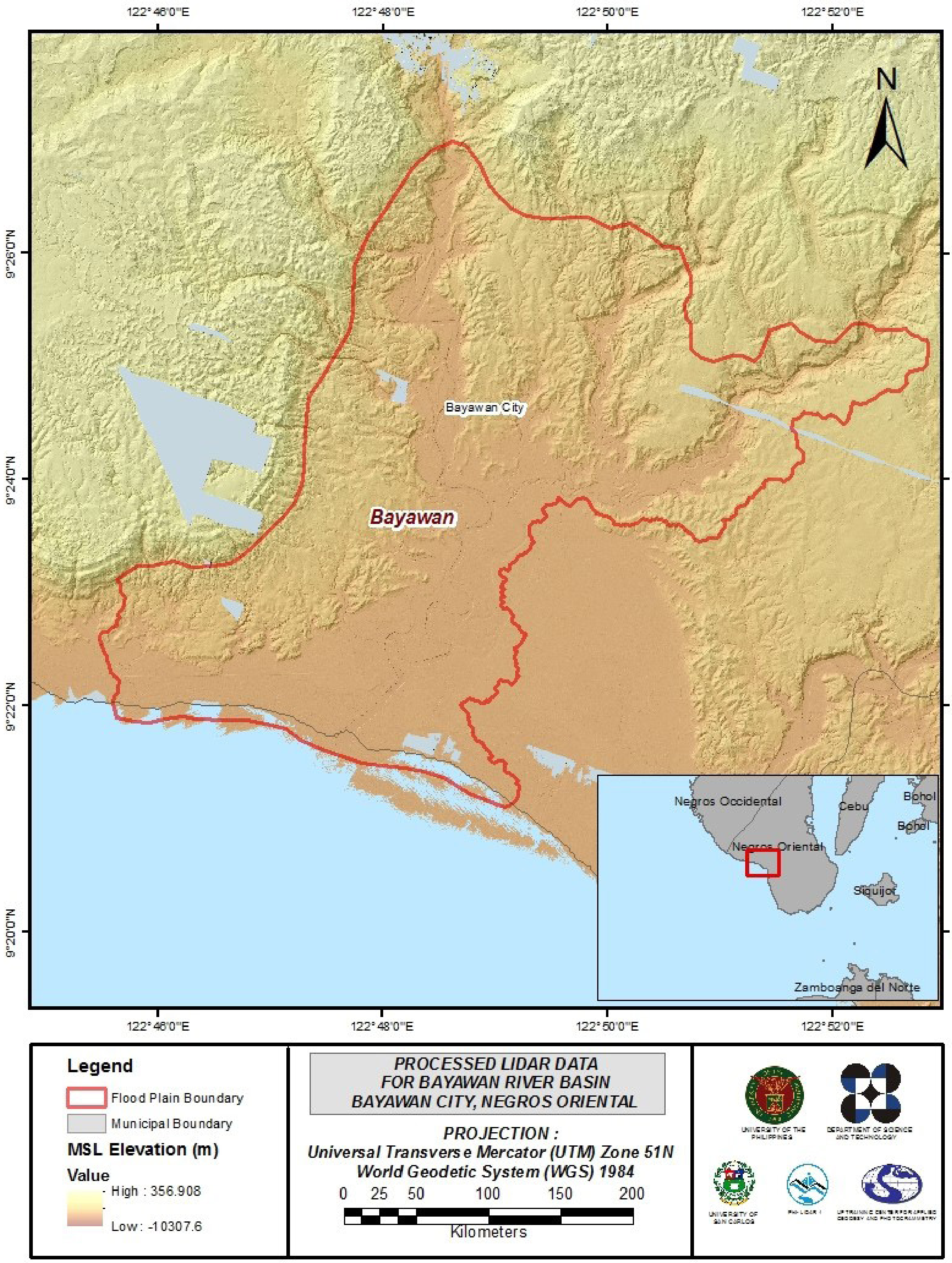


Figure 24. Map of Processed LiDAR Data for Bayawan Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Bayawan to collect points with which the LiDAR dataset is validated is shown in Figure 25. 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 Bayawan 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 26. 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 20 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

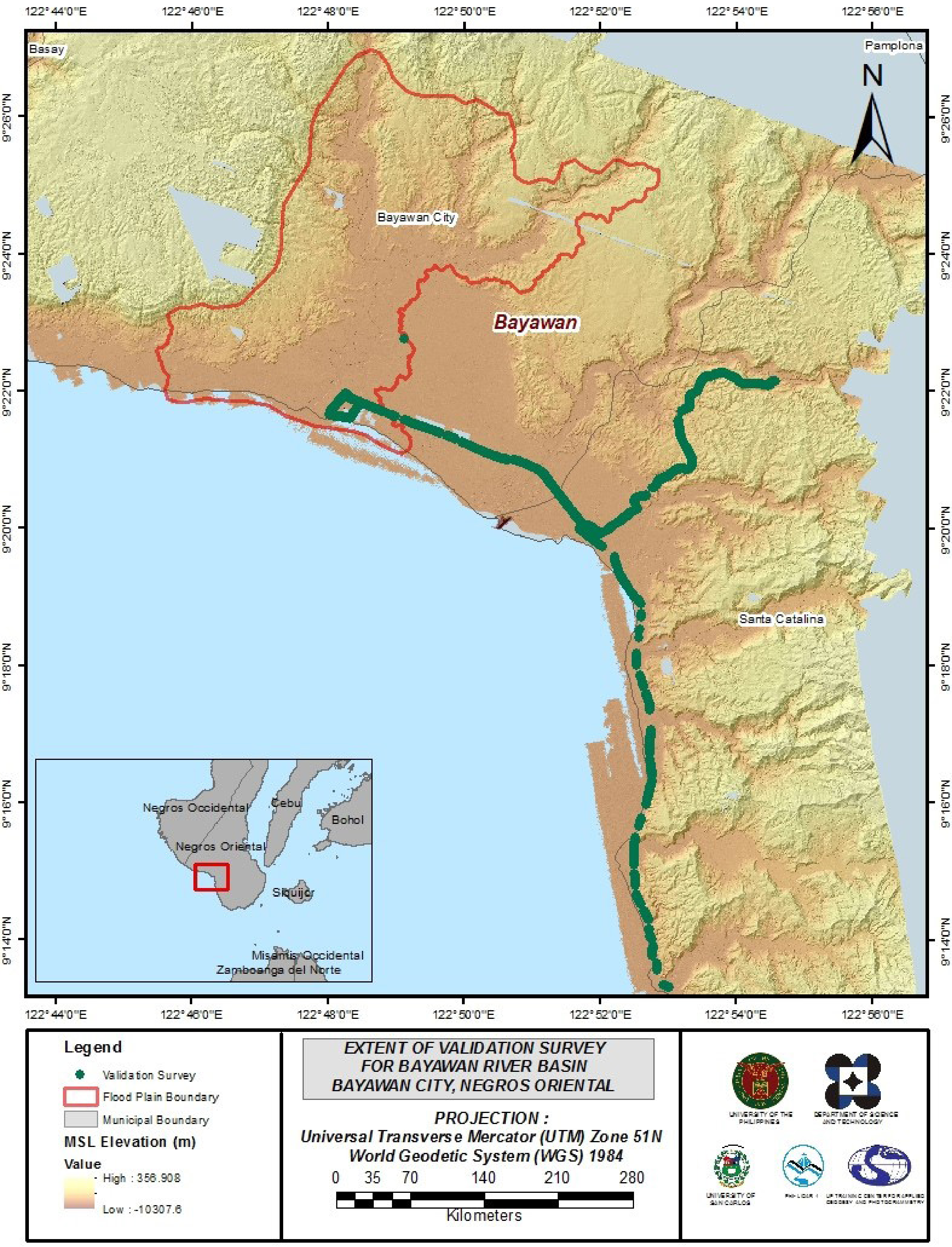


Figure 25. Map of Bayawan Flood Plain with validation survey points in green.

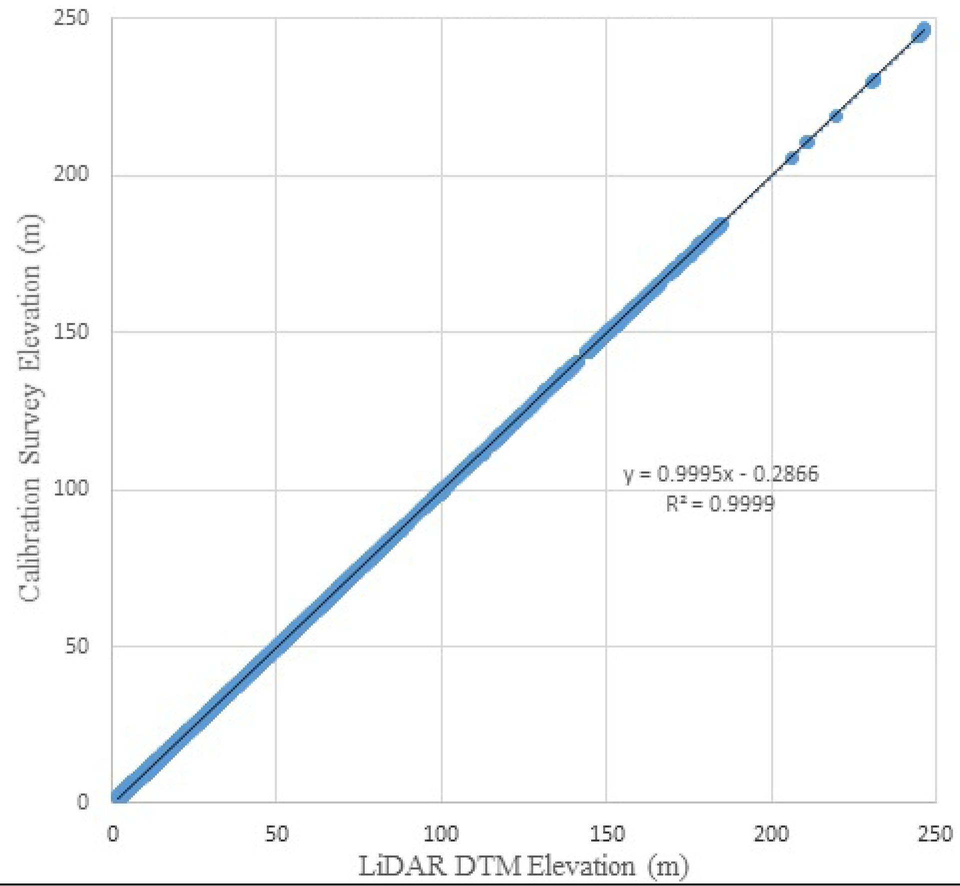


Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 20. 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 that are near Bayawan flood plain, resulting to 113 points, were used for the validation of calibrated Bayawan 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.15 meters with a standard deviation of 0.07 meters, as shown in Table 21.

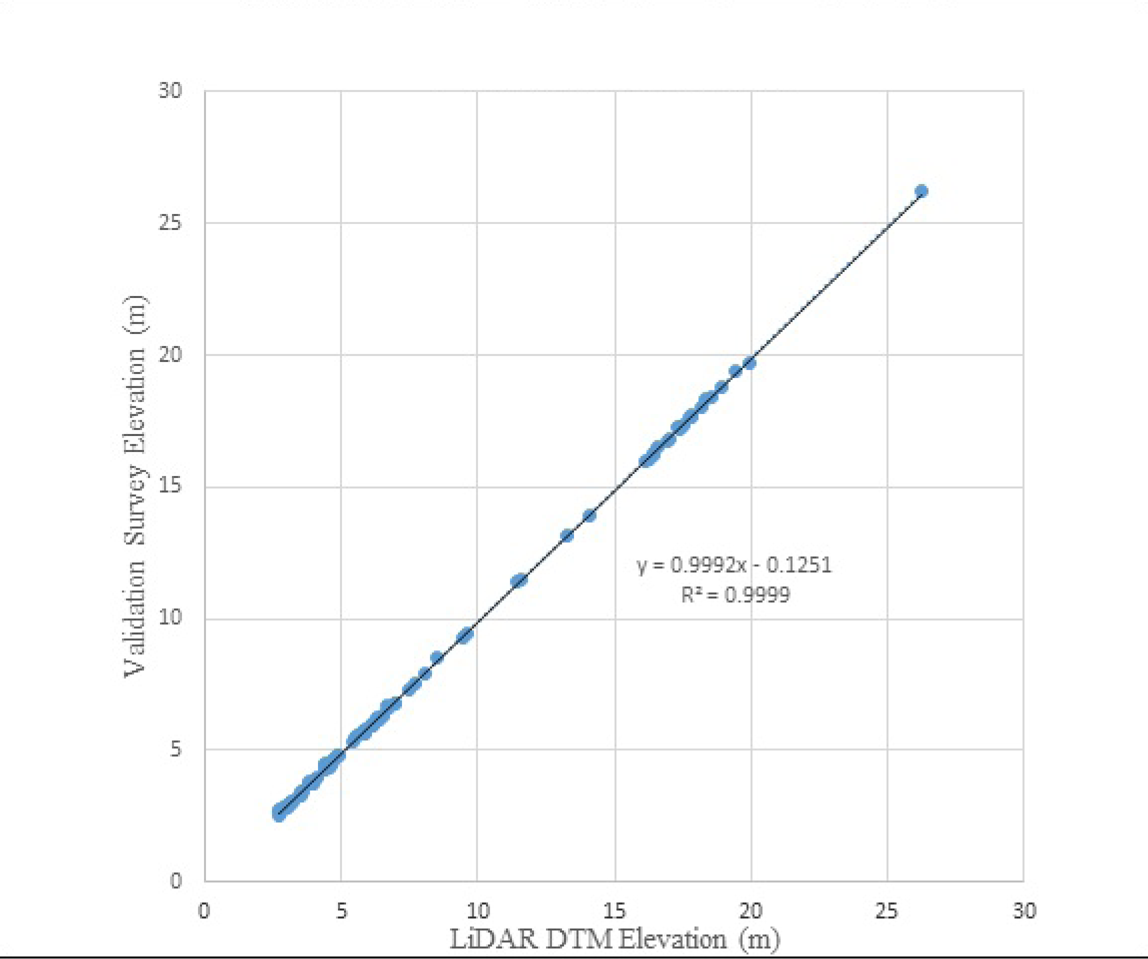


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 21. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.15
Standard Deviation	0.07
Average	-0.13
Minimum	-0.22
Maximum	0.09

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Bayawan with 17,686 bathymetric survey points. The resulting raster surface produced was accomplished through the Krigging interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 1.05 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bayawan integrated with the processed LiDAR DEM is shown in Figure 27.

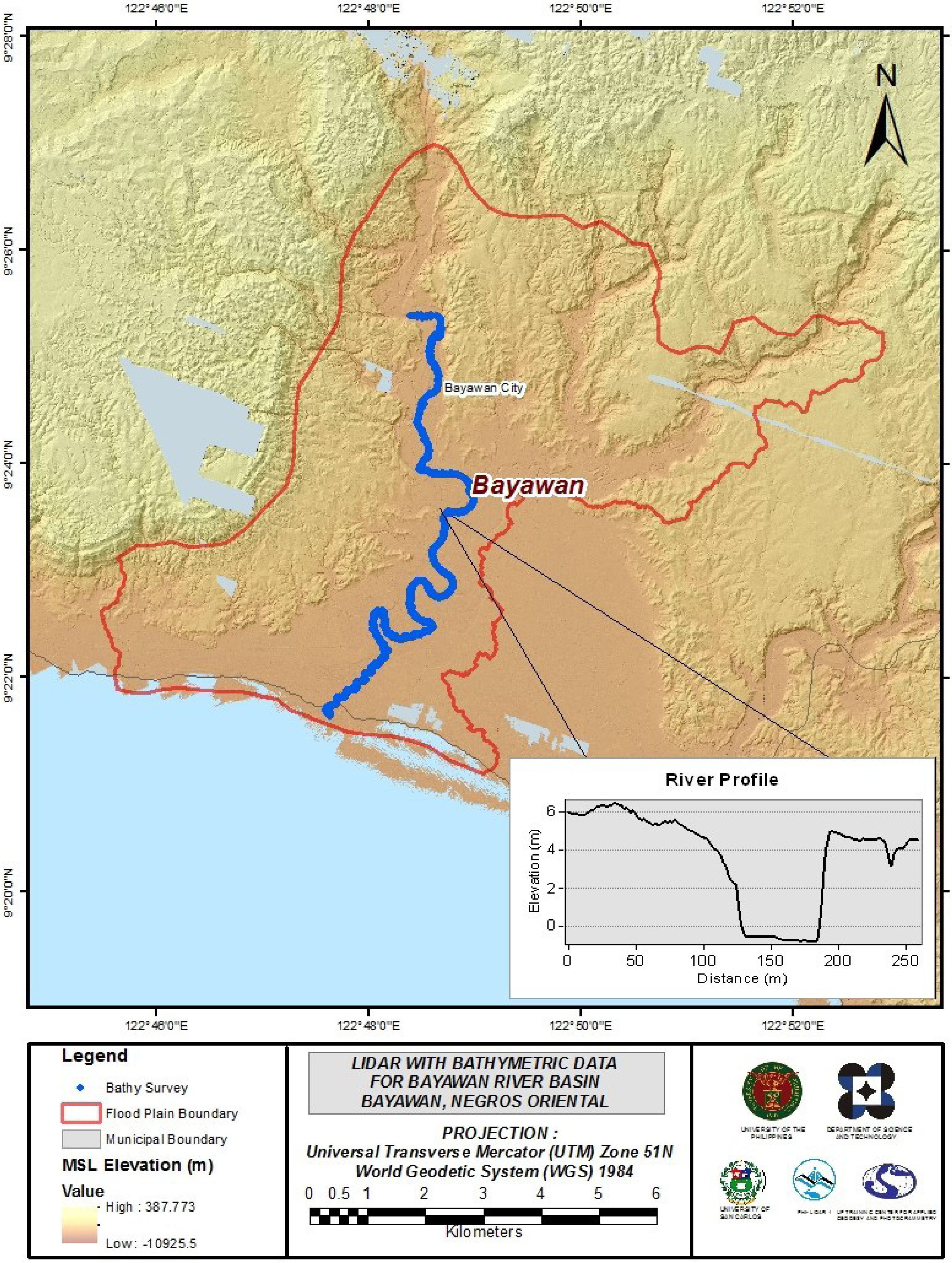


Figure 28. Map of Bayawan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, consisting of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks 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

Bayawan floodplain, including its 200-m buffer, has a total area of 68.05 sq. km. For this area, a total of 5.00 sq. km, corresponding to a total of 998 building features, are considered for QC. Figure 28 shows the QC blocks for the Bayawan floodplain.

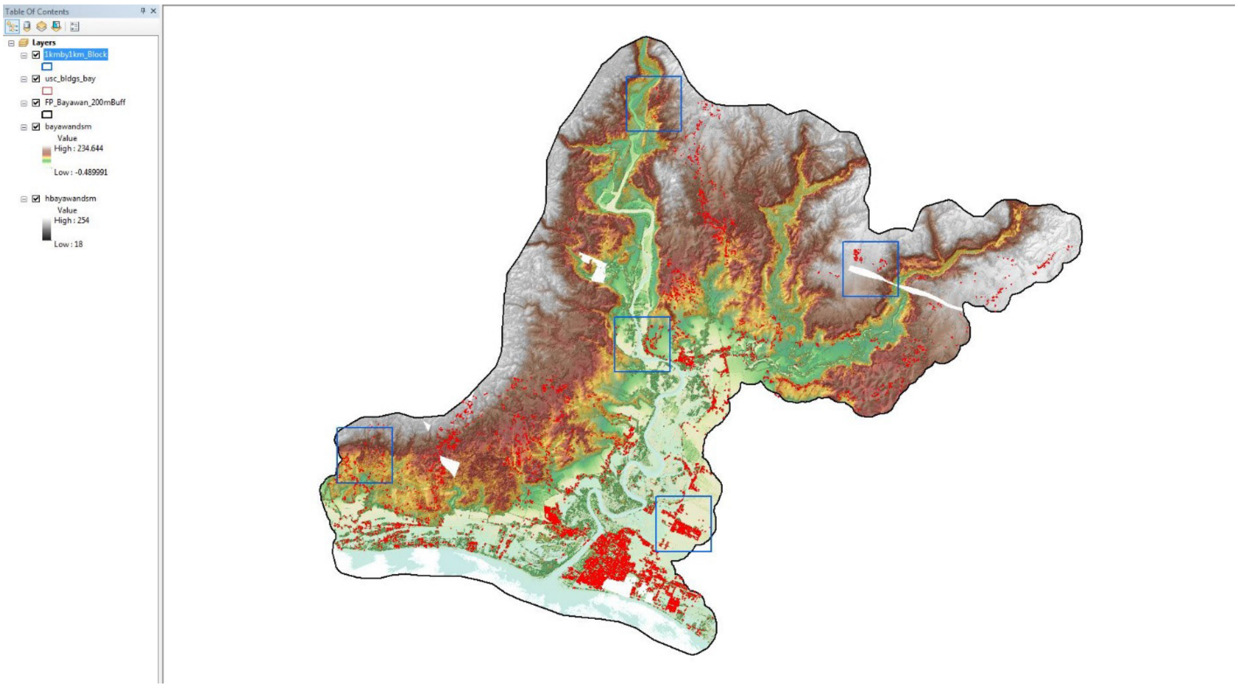


Figure 29. Blocks (in blue) of Bayawan building features that were subjected to QC.

Quality checking of the building features extracted for the Bayawan River Basin resulted in the ratings shown in Table 22.

Table 22. Quality Checking Ratings for Bayawan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Bayawan	95.23	100.00	94.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 11,291 building features in theBayawan floodplain. Of these building features, 960 were filtered out after height extraction, resulting in10,331 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 16.37 m.

3.12.3 Feature Attribution

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

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

Table 23. Building Features Extracted for Bayawan Floodplain.

Facility Type	No. of Features
Residential	9,629
School	140
Market	32
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	15
Barangay Hall	8
Military Institution	3
Sports Center/Gymnasium/Covered Court	13
Telecommunication Facilities	0
Transport Terminal	2
Warehouse	4
Power Plant/Substation	0
NGO/CSO Offices	3
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	13
Bank	8
Factory	0
Gas Station	7
Fire Station	0
Other Government Offices	135
Other Commercial Establishments	319
Total	**10,331**

Table 24. Total Length of Extracted Roads for Bayawan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Bayawan	186.10	23.79	9.43	7.13	0.00	**226.50**

Table 25. Number of Extracted Water Bodies for Bayawan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Bayawan	1	0	0	0	0	**1**

A total of 4 bridges and culverts over small channels, which 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 29 shows the Digital Surface Model (DSM) of the Bayawan floodplain overlaid with its ground features.

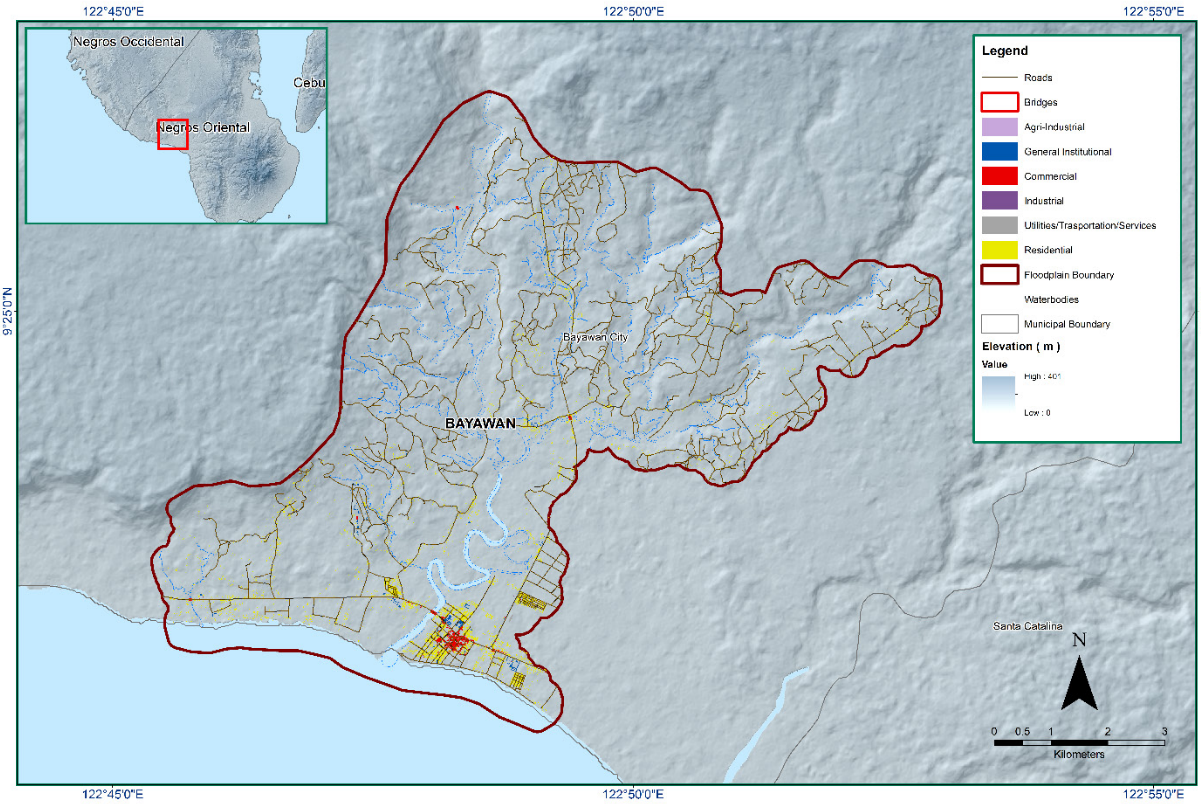


Figure 30. Extracted features for Bayawan floodplain.

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

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Joida F. Prieto , Ailyn G. Biñas , Engr. Jennifer B. Saguran, Engr. Monalyne C. Rabino, Engr. Velina Angela S. Bemida , Engr. Ma. Joanne I. Balaga and Engr. Erica Erin E. Elazegui

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

Field surveys in the Bayawan River were conducted on March 9 – 23, 2016 with the following scope of work: (i) reconnaissance; (ii) control survey; (iii) cross-section and water level marking in MSL of the depth gauge deployment site located in Barangay Calabnugan, Municipality of Sibulan, Negros Oriental, with validation points data acquisition of about 30.14 km for the areas traversing Bayawan City and the Municipality of Santa Catalina; and (iv) bathymetric survey from Brgy. Nangka, down to Brgy. Banga, both in Bayawan City, with an estimated length of 12.510 km usingOHMEX™ Sonarmite echo sounder and Trimble®SPS 882 GNSS PPK survey technique (see Figure 30).

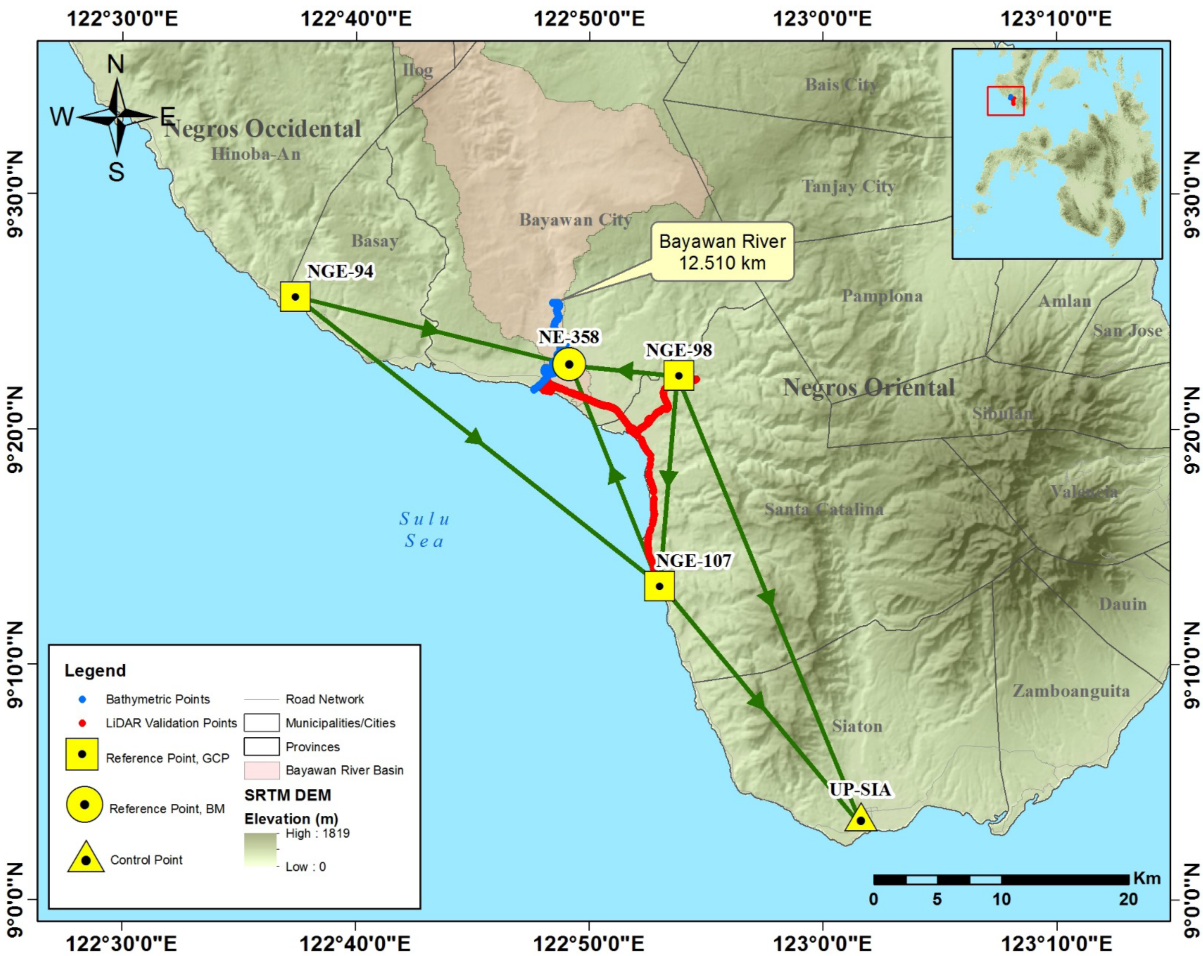


Figure 31. Extent of the bathymetric survey (blue) in Bayawan River and the LiDAR data validation survey (red).

4.2 Control Survey

The GNSS network used for this survey is composed of three (3) loops established on March 11, 2016 occupying the following reference points: NGE-107, a second order GCP located in Brgy. Manalongon, Municipality of Santa Catalina; NGE-98, a second order GCP located in Brgy. Kabulacan, Sitio Danao, Municipality of Santa Catalina; and NE-358, a first order BM in Brgy. Poblacion, Bayawan City.

One (1) control point was established namely, UP-SIA at Siaton Bridge in Brgy. Caticugan, Municipality of Siaton. The control pointNGE-94, in Brgy. Bongalonan, Municipality of Basay, established by NAMRIA, was also occupied to use as a marker for the network.

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

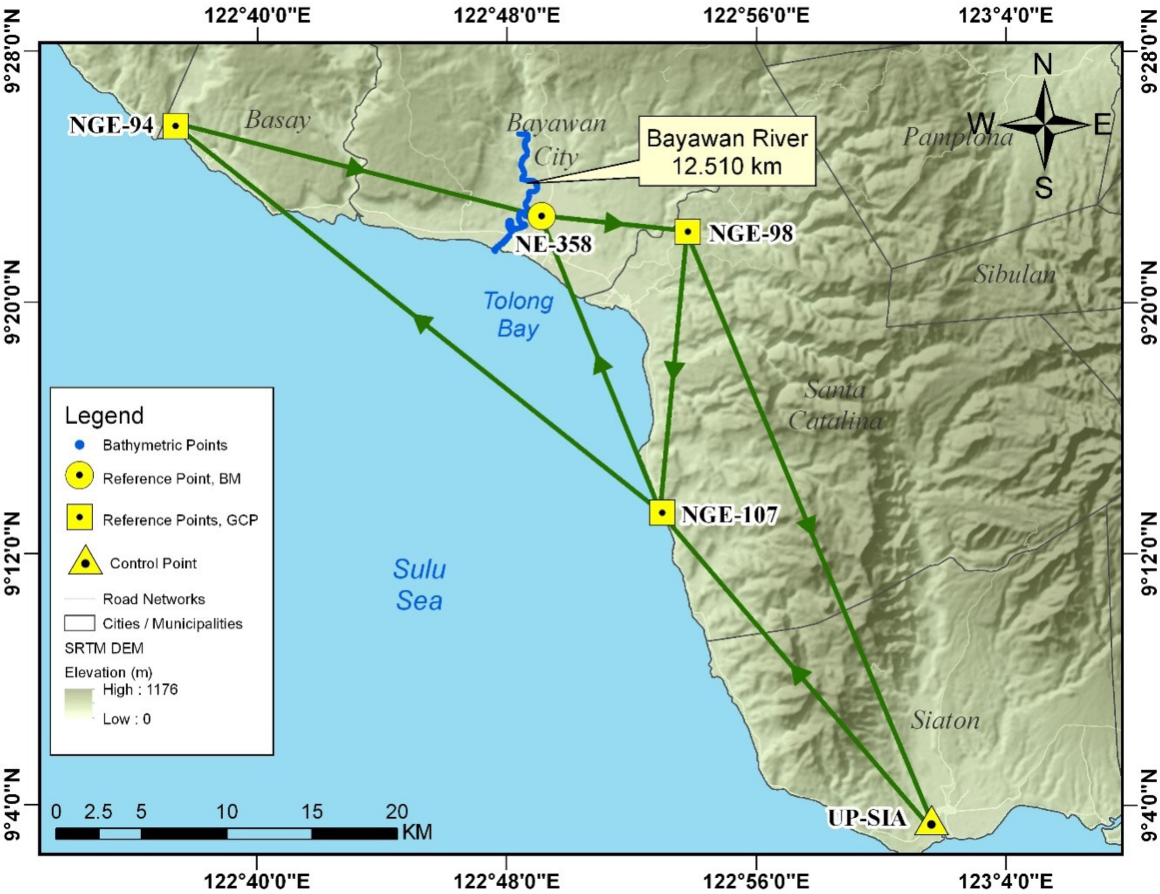


Figure 32. GNSS Network covering Bayawan River.

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
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

The GNSS set-ups on recovered reference points and established control points in the Bayawan River areshown in Figure 32 to Figure36.

Figure 33. GNSS receiver set-up, Trimble® SPS 882, at NGE-107 at the approach of Manalongon Bridge in Brgy. Manalongon, Municipality of Santa Catalina, Negros Oriental.

Figure 34. GNSS receiver setup, Trimble®SPS 852, at NGE-98 in Brgy. Kabulacan, Sitio Danao, Municipality of Santa Catalina, Negros Oriental.

Figure 35. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at NE-358
in Brgy. Poblacion, Bayawan City, Negros Oriental.

Figure 36. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at NGE-94
in Brgy. Bal-os, Municipality of Basay, Negros Oriental.

Figure 37. GNSS receiver set-up, Trimble®SPS 882 at control point UP-SIA at Siaton Bridge, Brgy. Caticugan, Municipality of 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 +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking isperformed. Masking is done by removing portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Baseline processing results of control points in the Bayawan River Basin is summarized in Table 27 generated by TBC software.

Table 27. Baseline Processing Report for Bayawan 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 27, 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:

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 28 toTable 30 for the complete details.

The five (5) control points, NGE-93, NE-119, NE-309, UP-OCOand UP-TANwere occupied and observed simultaneously to form a GNSS loop. Coordinates of points NGE-93 and NGE-107, and elevation value of NE-358 were held fixed during the processing of the control points, as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 28. Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NE-358	Grid				Fixed
NGE-107	Global	Fixed	Fixed		
NGE-98	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated inTable 29. The fixed control points NE-358, NGE-107, and NGE-98have no values for grid errors and elevation error, respectively.

Table 29. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGE-107	487155.076	?	1019415.410	?	7.670	0.058	LLh
NGE-98	488670.521	?	1035896.031	?	69.180	0.054	LLh
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	

The network isfixed at reference points NGE-107 and NGE-98 with known coordinates, and NE-358 with known elevation. As shown in Table 29, the standard errors (xe and ye) of NE-358 are 0.9 cm and 0.8 cm, NGE-94 are 1.5 cm and, and1.3, UP-SIA are 1.3 and 1.1, respectively. With the mentioned equation, for horizontal and for the vertical, the computations for the accuracy are as follows:

a. NGE-107
Horizontal Accuracy = Fixed
Vertical Accuracy = 5.8 < 10 cm

b. NGE-98
Horizontal Accuracy = Fixed
Vertical Accuracy = 5.4 < 10 cm

c. NE-358
Horizontal Accuracy = $\sqrt{((0.9)^2 + (0.8)^2}$
= $\sqrt{(0.81 +0.64)}$
= 1.20cm < 20 cm
Vertical Accuracy = Fixed

d. NGE-94
horizontal accuracy = $\sqrt{((1.5)^2 + (1.3)^2}$
= $\sqrt{(2.25 + 1.69)}$
= 1.98 cm < 20 cm
vertical accuracy = 5.8< 10 cm

e. UP-SIA
Horizontal Accuracy = $\sqrt{((1.3)^2 + (1.1)^2}$
= $\sqrt{(1.69 + 1.21)}$
= 1.70 cm < 20 cm
Vertical Accuracy = 7.0< 10 cm

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

Table 30. Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
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 NAMRIA established reference points, NGE-107, NGE-98, and NE-358 are within the required accuracy, as shown in Table 30. Based on the result of the computation, the accuracy conditions satisfied; hence, the required accuracy for the program was met.

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

Table 31. Reference and control points 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 in MSL (m)
NGE-107	2nd order GCP	9d13’19.76274”N	122d52’59.03199”E	69.527	1019415.410	487155.076	7.670
NGE-98	2nd order GCP	9d22’16.41564”N	122d53’48.54064”E	132.087	1035896.031	488670.521	69.180
NE-358	1st order BM	9d22’46.06928”N	122d49’07.51892”E	67.723	1036810.192	480099.830	5.116
NGE-94	Used as Marker	9d25’37.57022”N	122d37’23.12090”E	68.846	1042094.324	458621.676	7.244
UP-SIA	UP Established	9d03’32.50400”N	123d01’37.08746”E	70.195	1001378.367	502963.760	8.267

4.5 Cross-section and Bridge As-Built Survey and WaterLevel Marking

The cross-section survey was conducted on March 14, 2016 at the upstream portion of Bayawan Riverin Brgy. Nangka, Bayawan City using GNSS receiver Trimble® SPS 882 in PPK survey technique, as shown inFigure 37.Water surface elevation in MSL of the Bayawan River was determined on March 14, 2016 at 2:37 PM using Trimble® SPS 882 in PPK mode with a value of 3.068 m in MSL. A structure for the installation of an AWLS and water level marking shall be constructed along the non-bridge flow measuring site identified by USC.

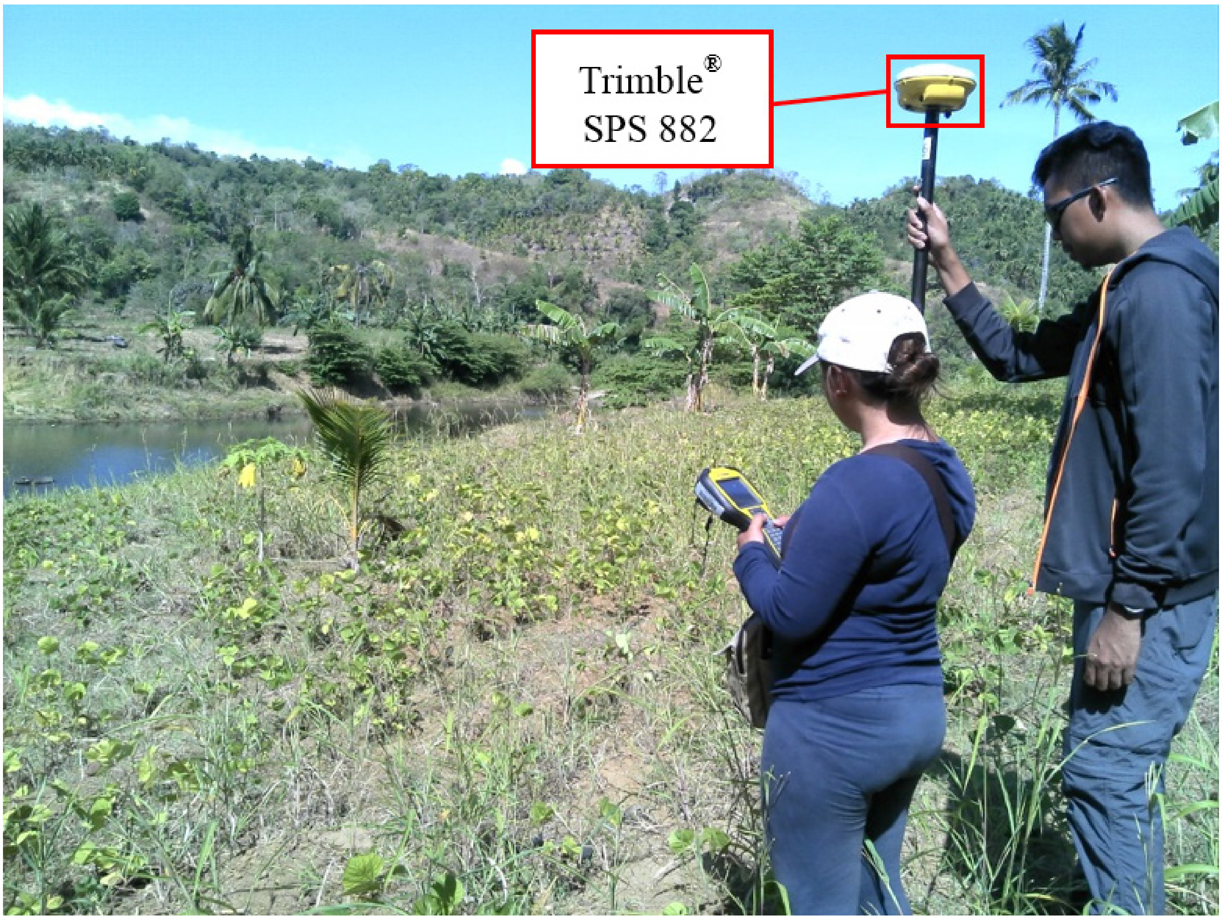


Figure 38. Cross-section survey conducted on Bawayan River in Brgy. Calabnugan, Municipality of Sibulan.

The length of cross-sectional line ofthe upstream portion of the Bayawan River is about 134 m with 36 cross-sectional points acquired using NE-358 as the GNSS base station. The cross section diagram and planimetric map are shown in Figure 38 and Figure 39.

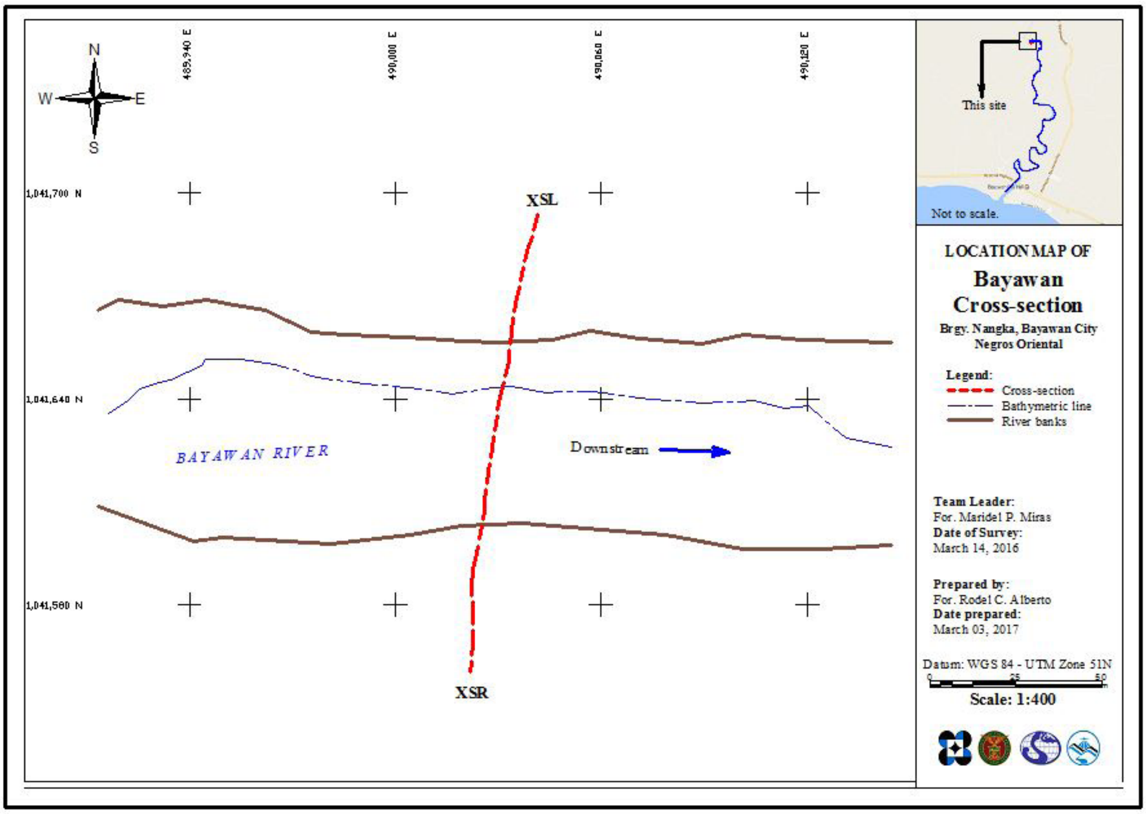


Figure 39. Location Map of Bayawan bridge cross-section

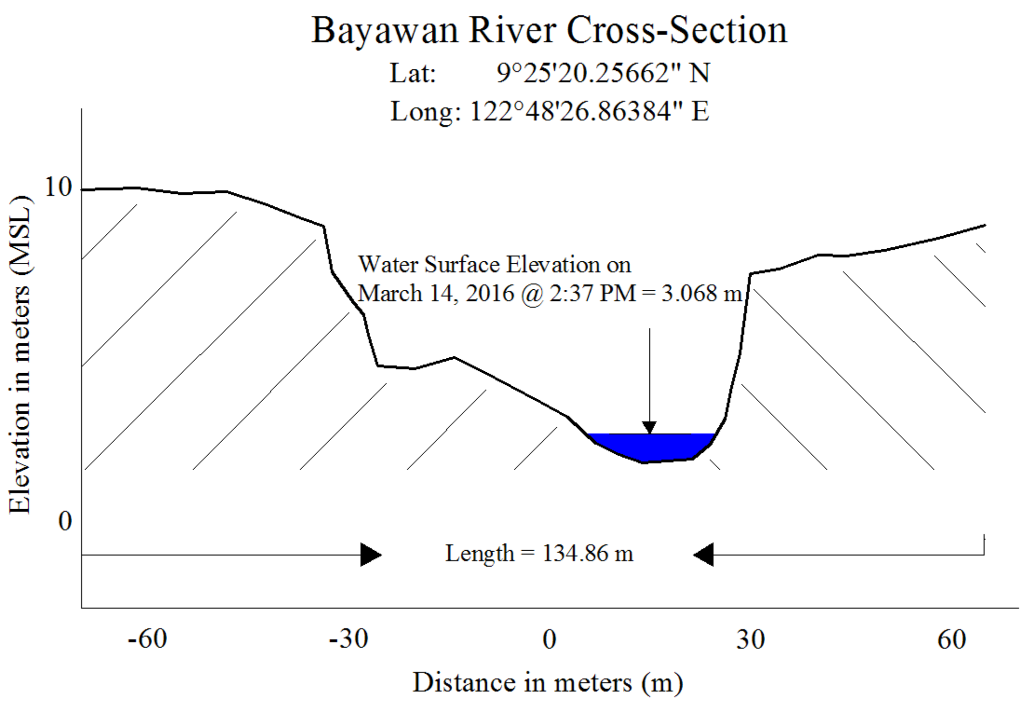


Figure 40. Bayawan river cross-section

-

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on March 14, 2016 using a survey-grade GNSS rover receiver, Trimble®SPS 882, mounted on a pole attached to the side of the vehicle as shown inFigure 40. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 2.265 m, 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 withNE-358 occupied as the GNSS base station all throughout the conduct of the survey.

Figure 41. Validation points acquisition survey set-up.

The validation points acquisition survey for the Bayawan River Basin traversed Bayawan City and the Municipality of Santa Catalina. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 43,714 points with an approximate length of 30.14 km was acquired for the validation point acquisition survey as shown in the map in Figure 41.

Figure 42. LiDAR Validation points acquisition survey for Bayawan River Basin.

4.7 Bathymetric Survey

A manual bathymetric survey using a Trimble® SPS 882 GNSS PPK technique was executed on March 14, 2016 as shown in Figure 42. The survey began in the upstream in Brgy. Nangka, Bayawan City, with coordinates 9°25'22.71489"N 122°48'23.41123"E, until reaching the deep portion of the river in the same barangay, with coordinates 9°24'03.03715"N 122°48'33.27275"E.

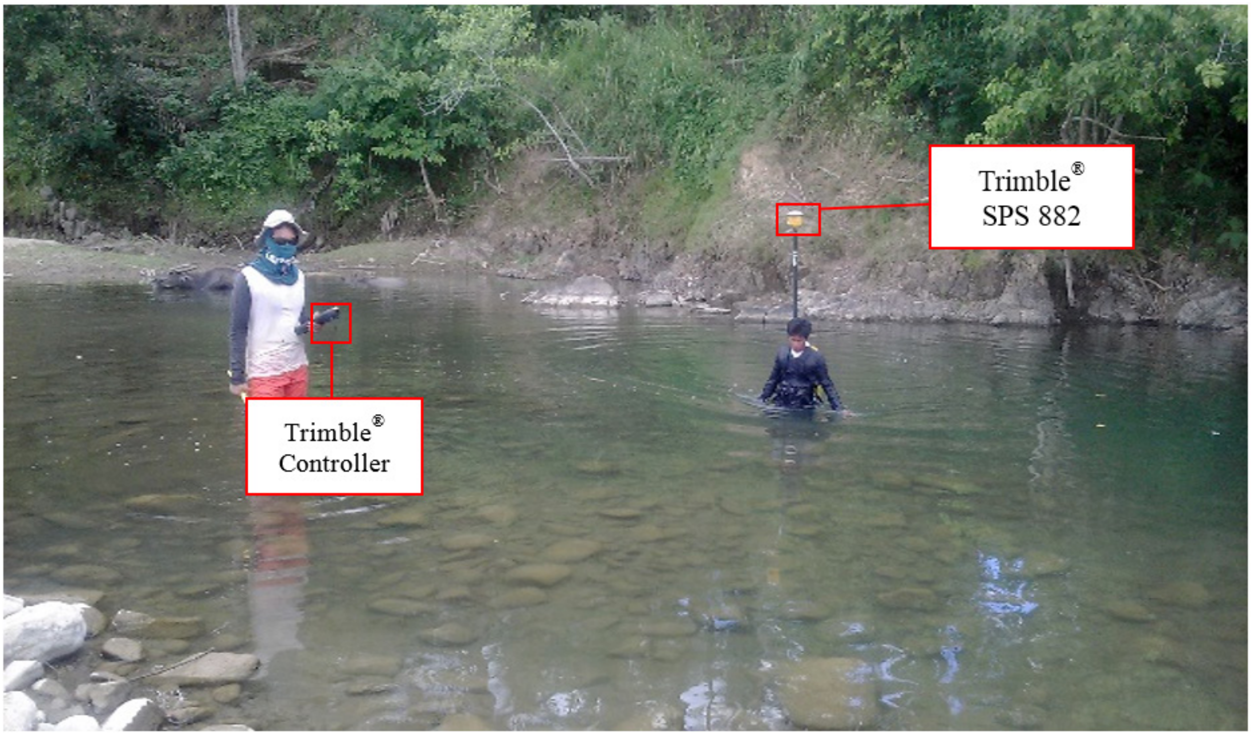


Figure 43. Manual Bathymetric Survey in Bayawan River.

On the second day of Bathymetric Survey, March 16, 2016, the survey team utilized the OHMEX™ Sonarmite echosounder and Trimble® SPS 882 GNSS PPK technique which was attached to a pole on a fishing boat for the remaining deep portions of the river as shown in Figure 43. The survey started from Brgy. Nangka, Bayawan City with coordinates 9°23'41.06839"N 122°48'59.35114"E, going to the mouth of the river to Brgy. Banga with coordinates 9°21'38.71269"N 122°47'38.10705"E. It was conducted with the assistance of personnel from the University of San Carlos.The control point NE-358 was used as base station for the whole conduct of the survey.

Figure 44. Bathymetric survey using the OHMEX Echosounder.

The bathymetric survey coverage for the Bayawan River is illustrated in Figure 44. Approximately 200 m of the delineated target bathymetric line was not covered in the upstream areadue to its inaccessibility because of very thick bushes. A CAD drawing was also produced to illustrate the Bayawan riverbed centerline profile as shown in Figure 45. There is about a 9-m change in elevation observed within the entire scope of the bathymetric data from its upstream in Brgy. Nangka, Bayawan City down to the mouth of the river in Brgy. Banga.The highest elevation observed was 2.821 m in Brgy Nangka, and the lowest elevation was -6.521 m in Brgy. Banga. The bathymetric survey gathered a total of 17,828 points covering 12.510 km of the river traversing the river upstream in Brgy. Nangka, Bayawan, Negros Oriental, down to its mouth in Brgy. Banga, also in Bayawan City, Negros Occidental.

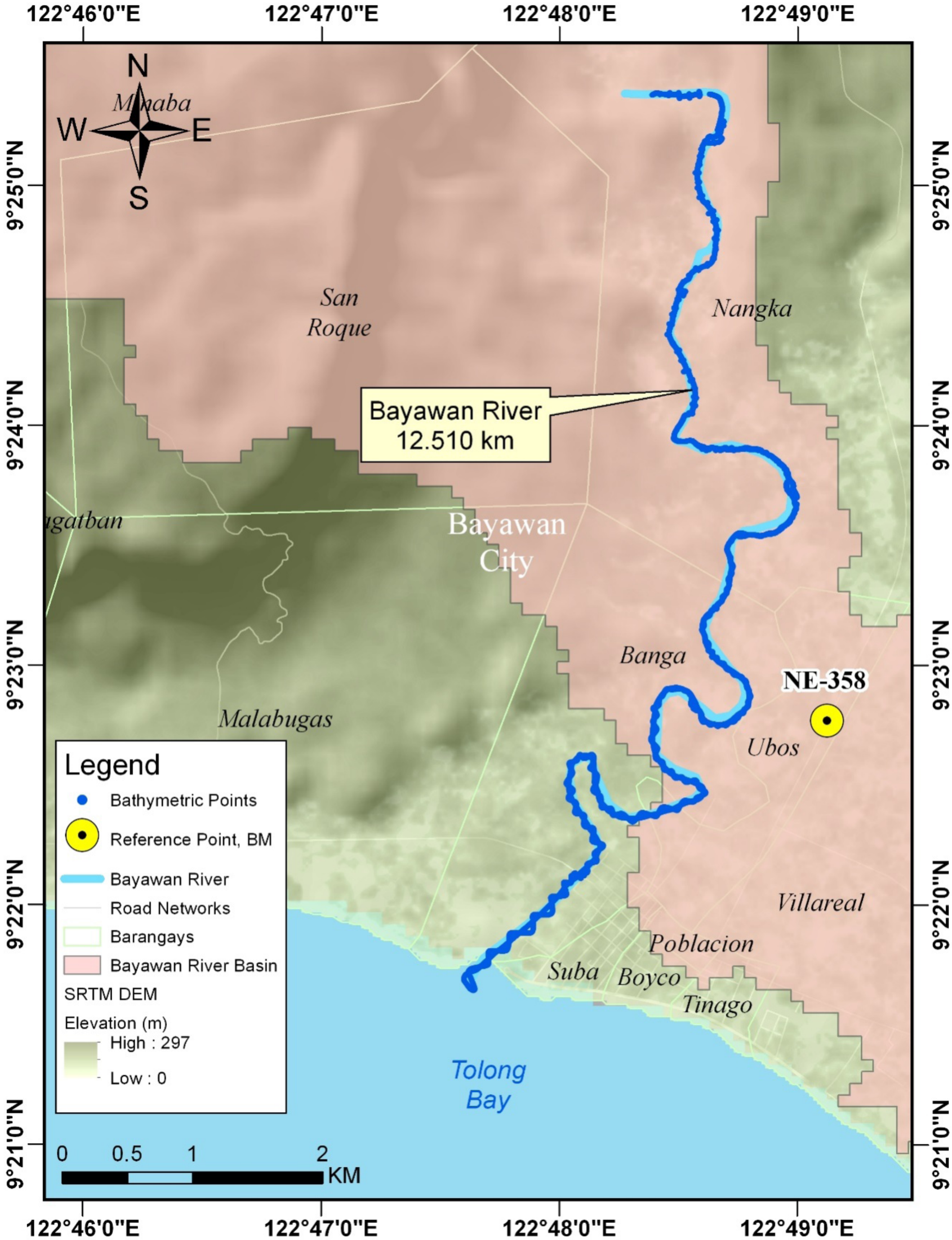


Figure 45. Bathymetric points gathered from Bayawan River.

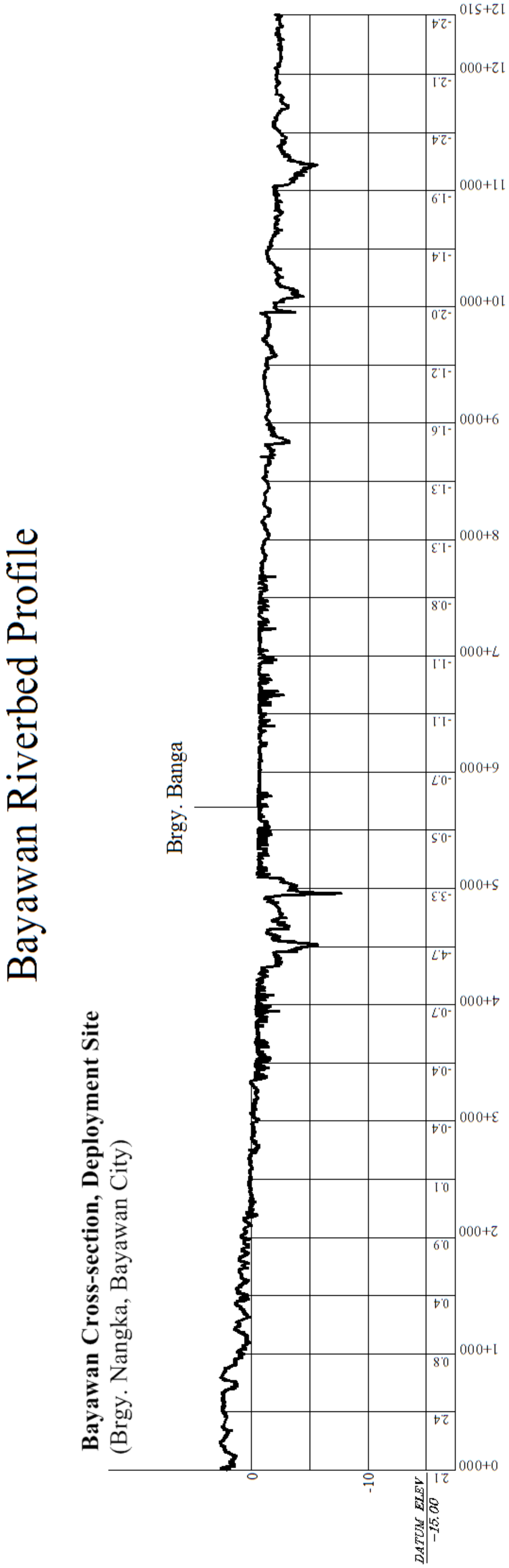


Figure 46. BayawanRiverbed Profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador and For. Rodel C. Alberto

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

All components and data that affect the hydrologic cycle of the Bayawan River Basin weremonitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Bayawan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a data logging rain gauge installed through the efforts of the local Disaster Risk Reduction Management Office of the City of Bayawan. The data was also reflected in the Predict website through coordination with the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The rain gauge was installed in Brgy. Kalumbuyan, Bayawan with geographic coordinates of 9°27’5.08”N and 122°48’37.26”E. The rain gauge records data every 10 minutes. The precipitation data used in the calibration of the model started at 6:00 PM on January 15, 2017 and ended at 10:50 PM of the same day. The location of the rain gage used in calibration in the watershed in presented in Figure 46.

The total precipitation in Brgy. Kalumbuyan Station is 25 mm. It has a peak rainfall rate of 6.5 mm at 6:50 PM on January 15, 2017. The lag time between the peak discharge and the peak rainfall is 14 hours and 10 minutes.

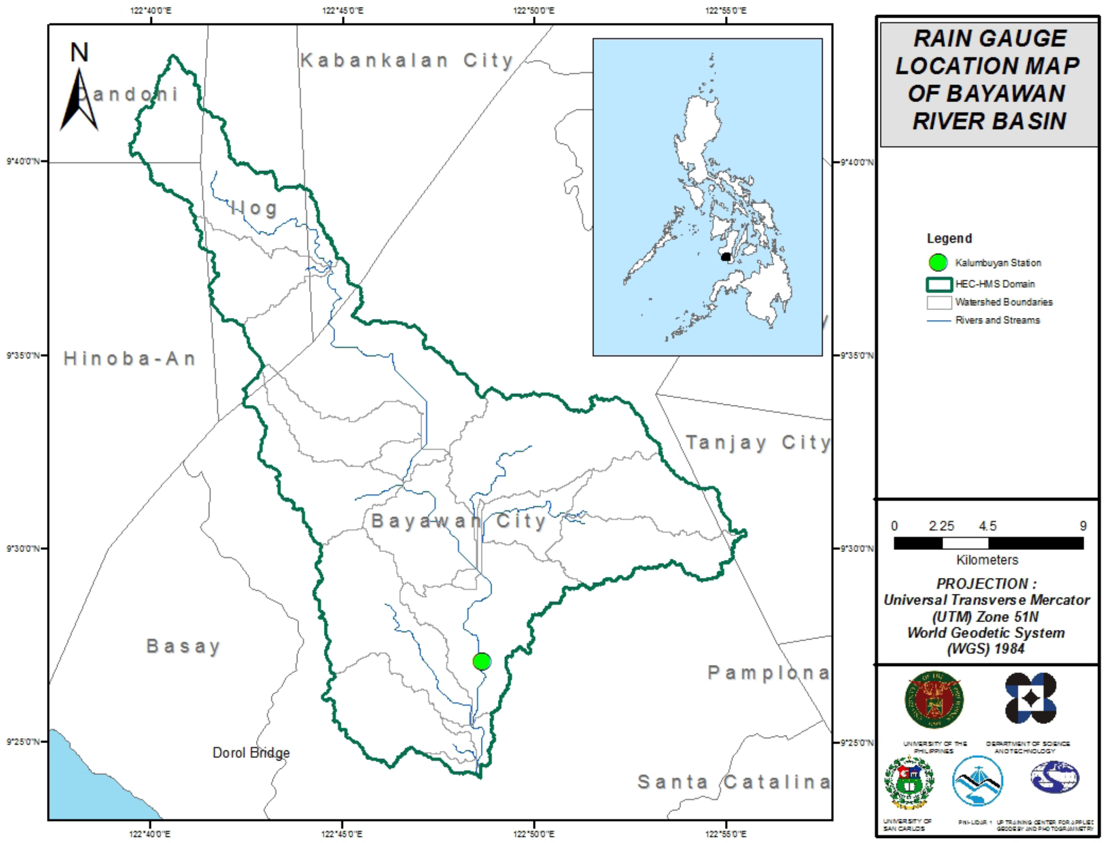


Figure 47. The location map of Bayawan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sitio Mantapi, Brgy. Nangka, Bayawan (9.423081°, 122.807481°E). This is also the location of the water level sensor to be installed by the City of Bayawan. The rating curve gives the relationship between the observed water levels and outflow of the watershed at this location.

For Sitio Mantapi, Brgy. Nangka, the rating curve is expressed as:as shown in Figure 48.

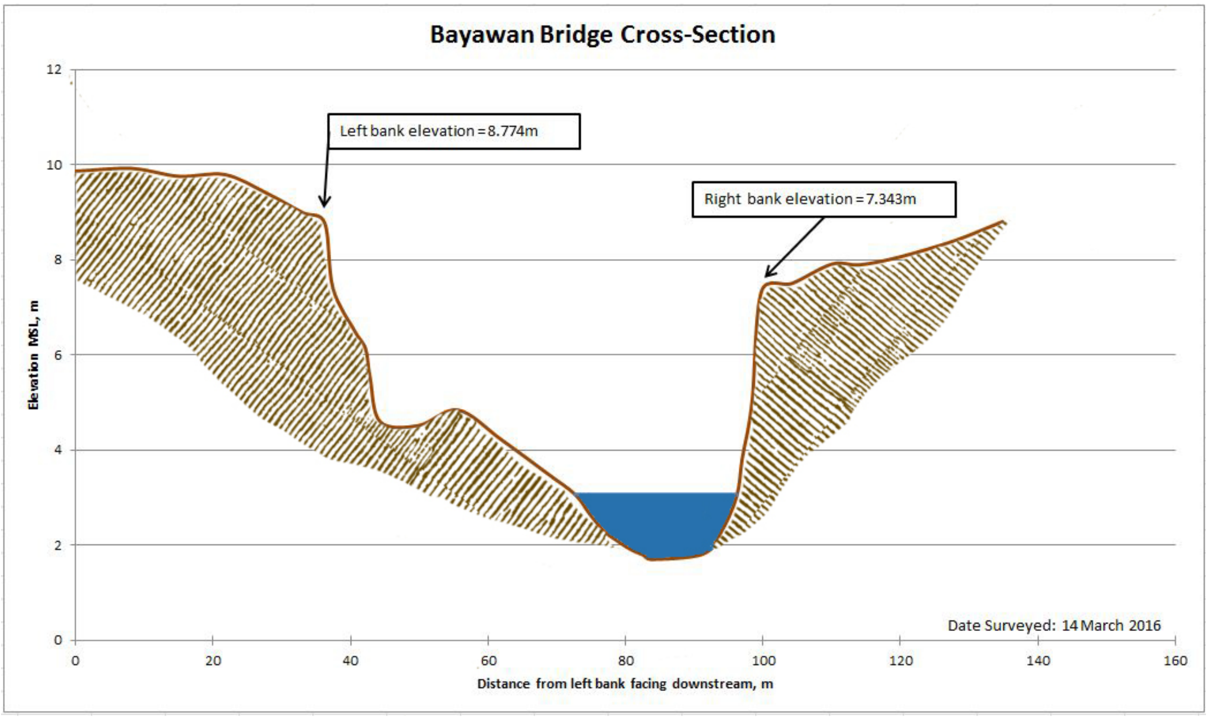


Figure 48. Cross-Section Plot of Bayawan Bridge.

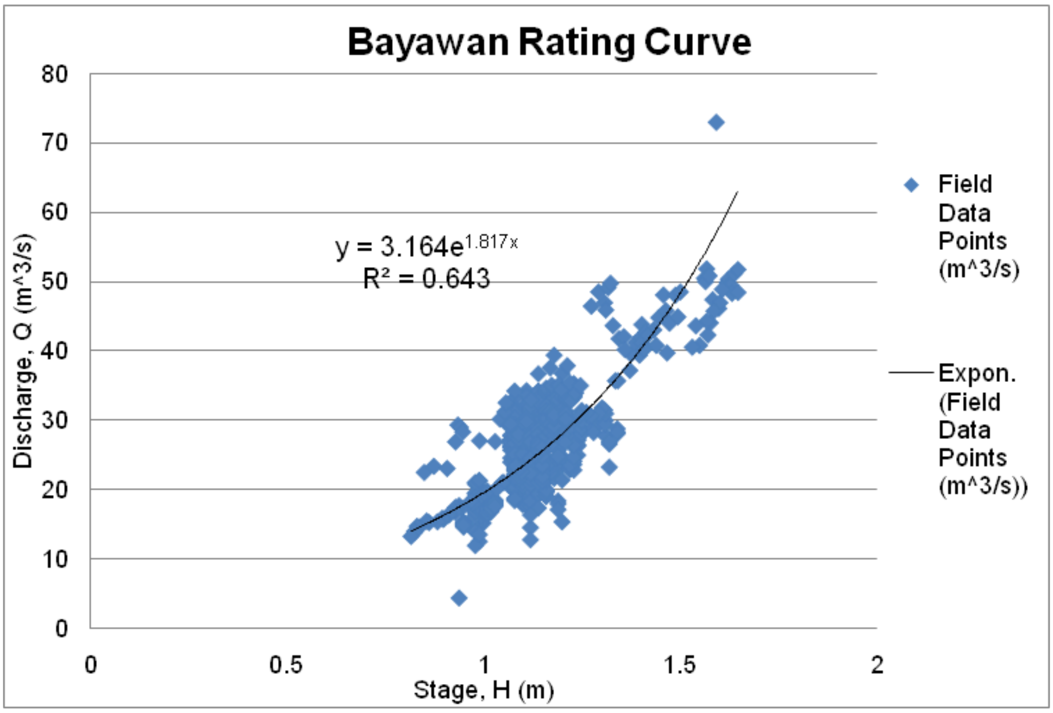


Figure 49. Rating Curve at Sitio Mantapi, Brgy. Nangka, Bayawan City.

This rating curve equation was used to compute for the river outflow atSitio Mantapi, Nangka for the calibration of the HEC-HMS model shown in Figure 49.Peak discharge is 15.4m³/s at 15:20 on August 12, 2016.

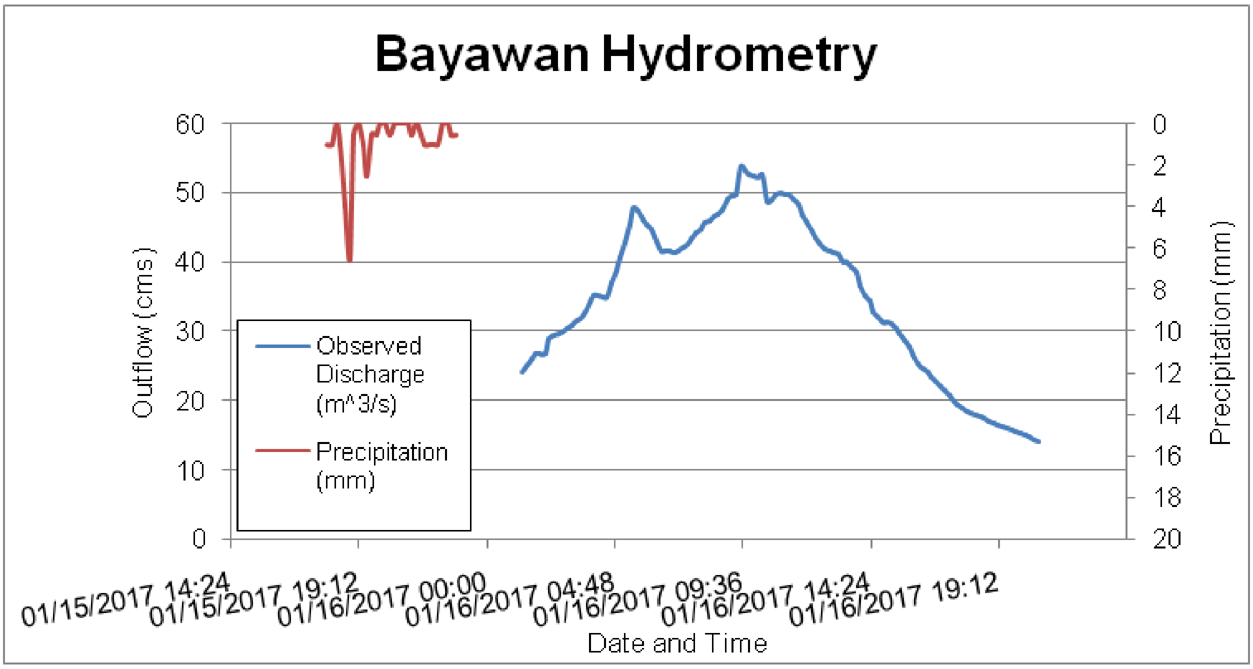


Figure 50. Rainfall and outflow data at Sitio Mantapi, Brgy. Nangka, Bayawanused for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Dumaguete Point Gauge, as shown in Table 32. This station was chosen based on its proximity to the Bayawan watershed. The extreme values for this watershed were computed based on a 35-year record.

Table 32. 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

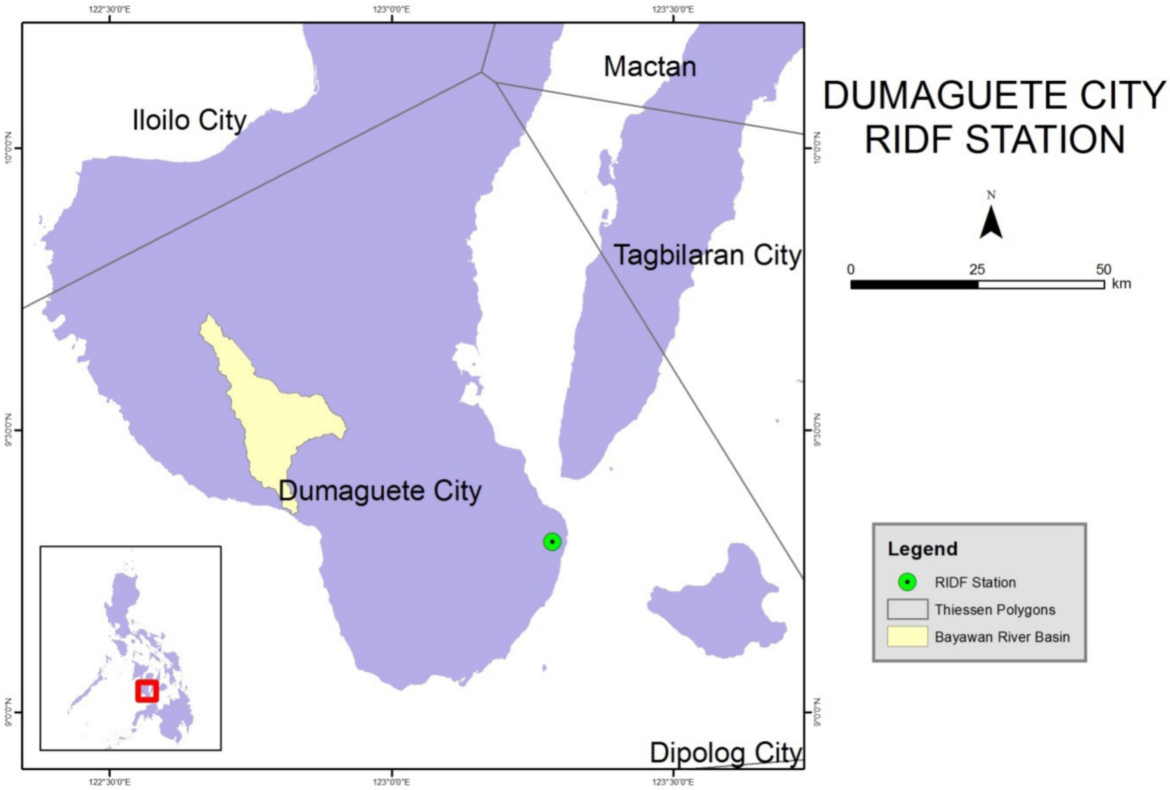


Figure 51. Dumaguete Point RIDF location relative to Bayawan River Basin.

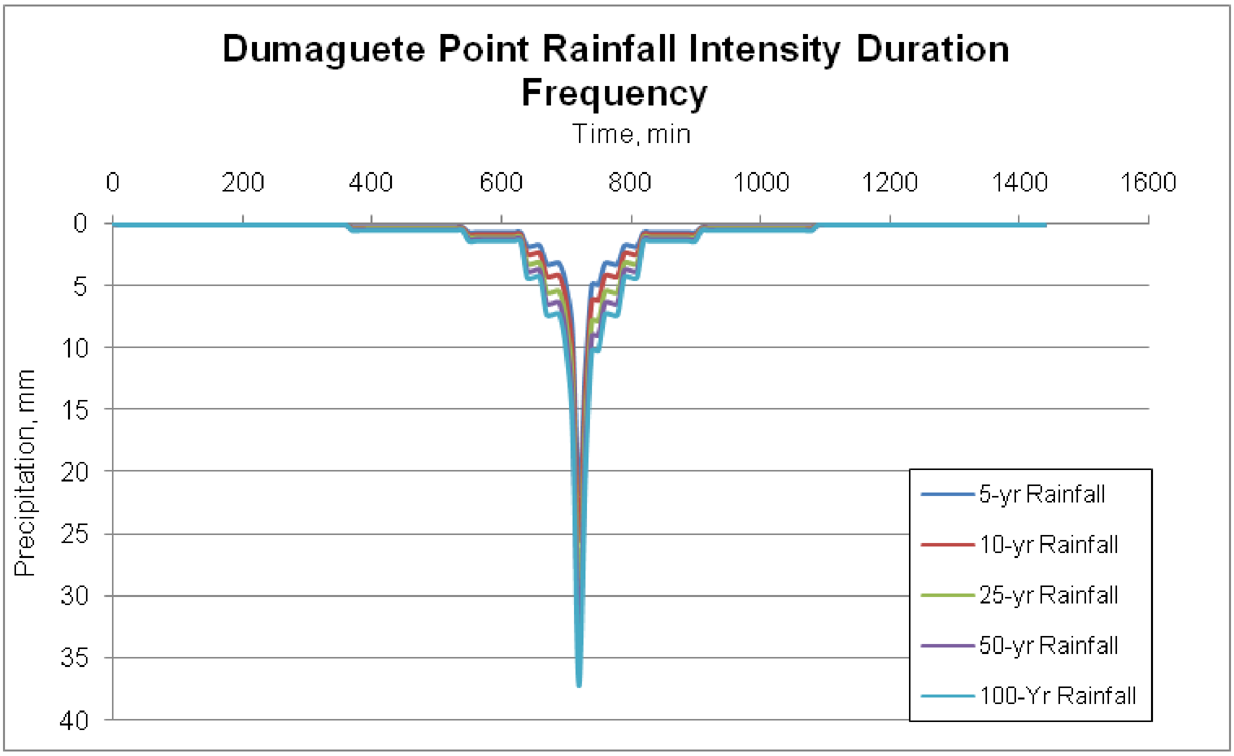


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shapefile in Figure 52was taken in 2004 from the Bureau of Soils and Water Management (BSWW), under the Department of Agriculture. The land cover datasetin Figure 53 is from the National Mapping and Resource Information Authority (NAMRIA).

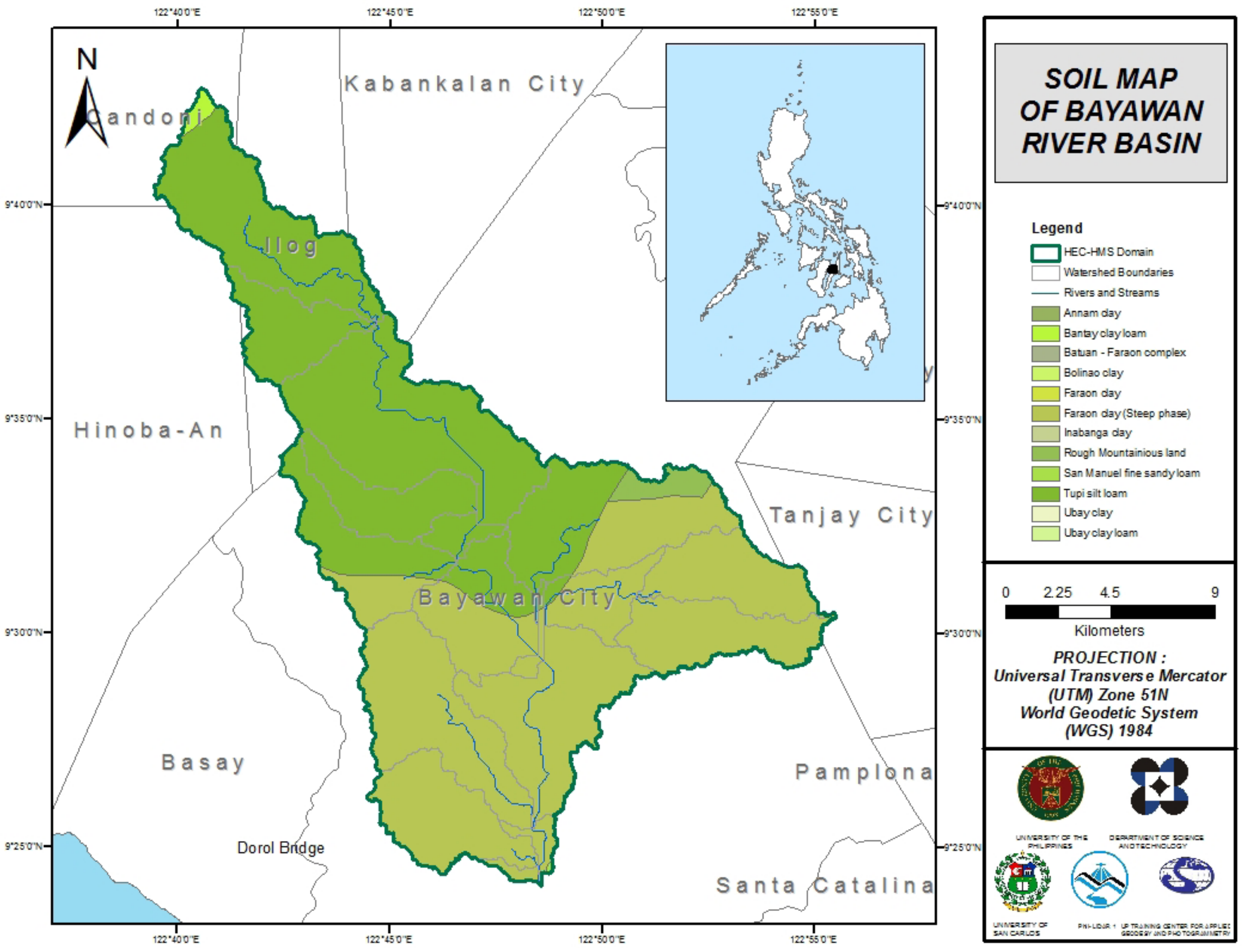


Figure 53. The soil map of the Bayawan River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and

Water Management – Department of Agriculture).

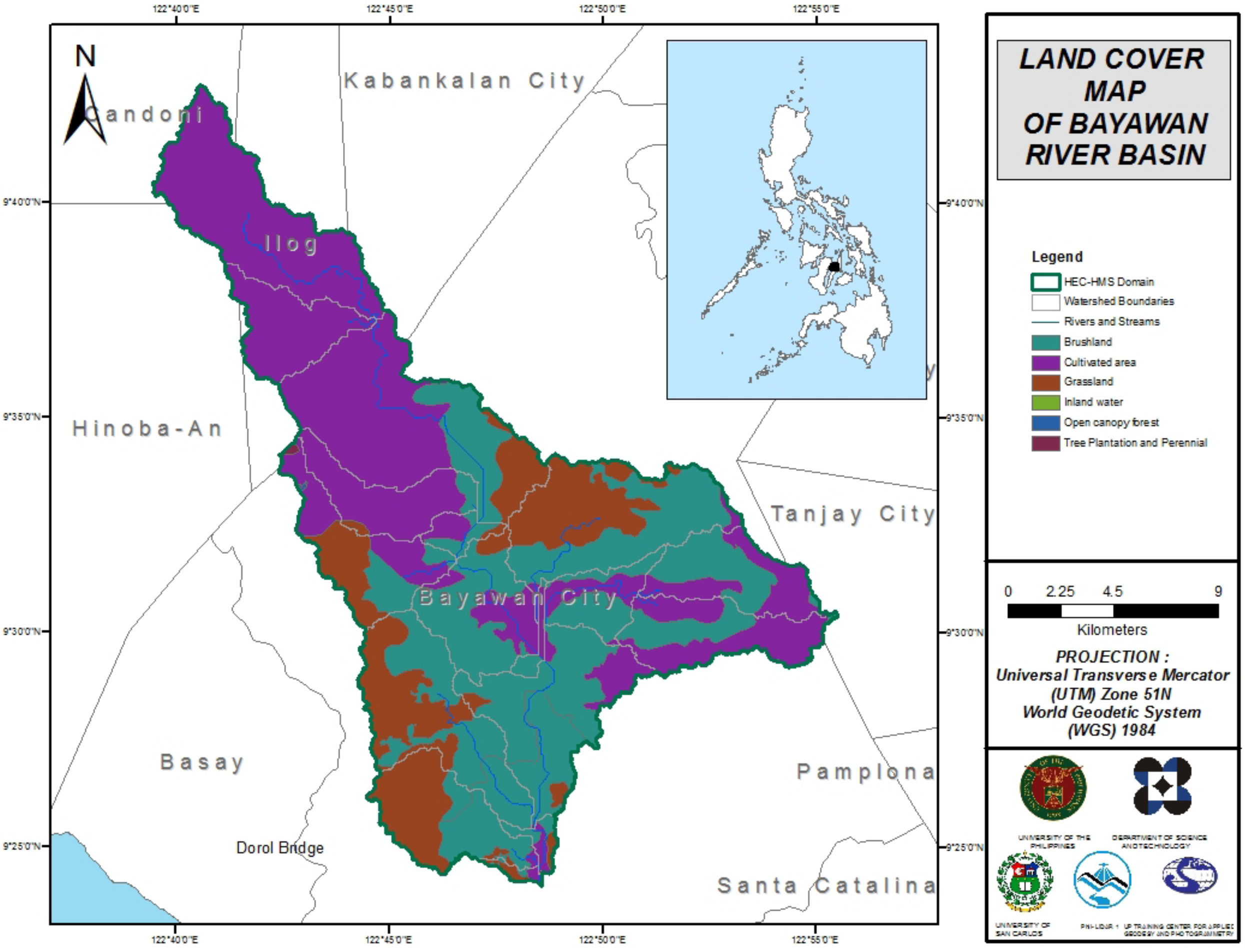


Figure 54. The land cover map of the Bayawan River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: National Mapping and Resource Information Authority).

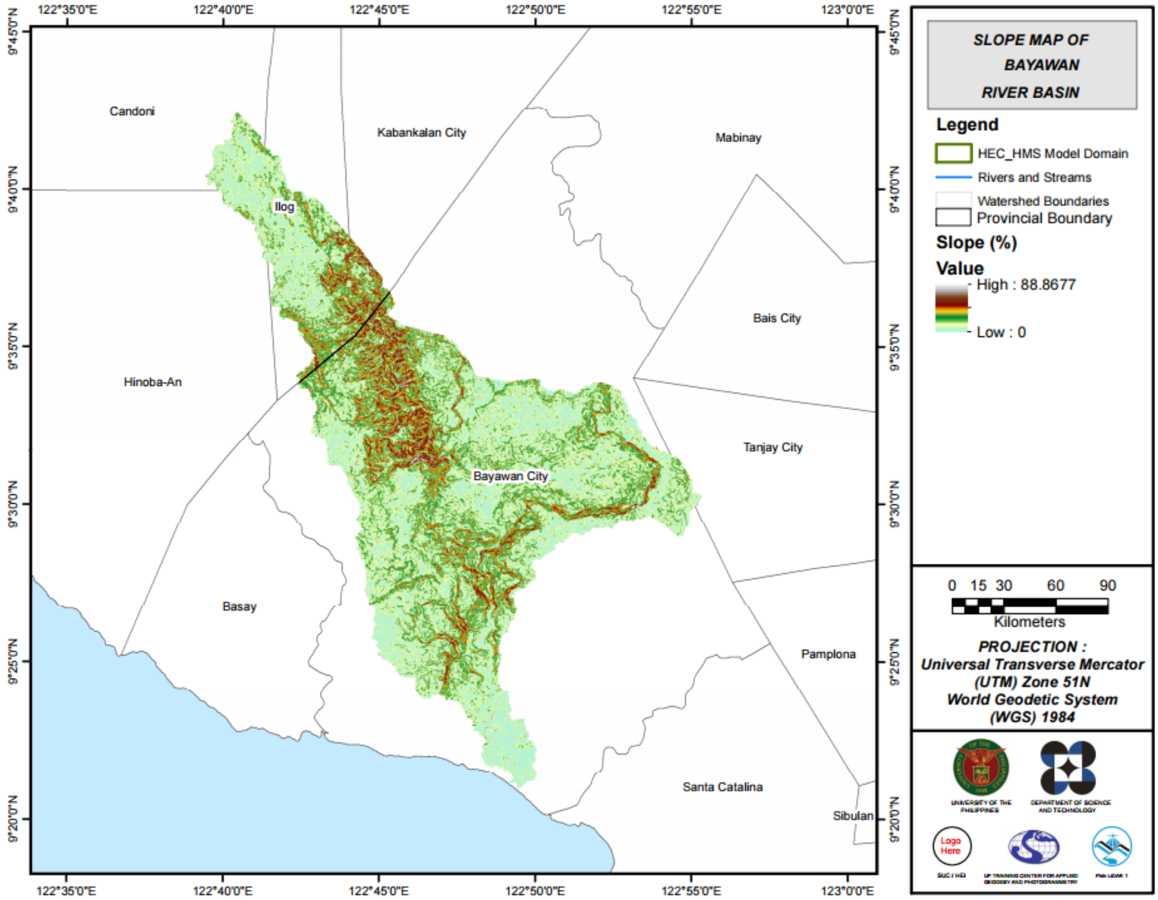


Figure 55. Slope map of Bayawan River Basin.

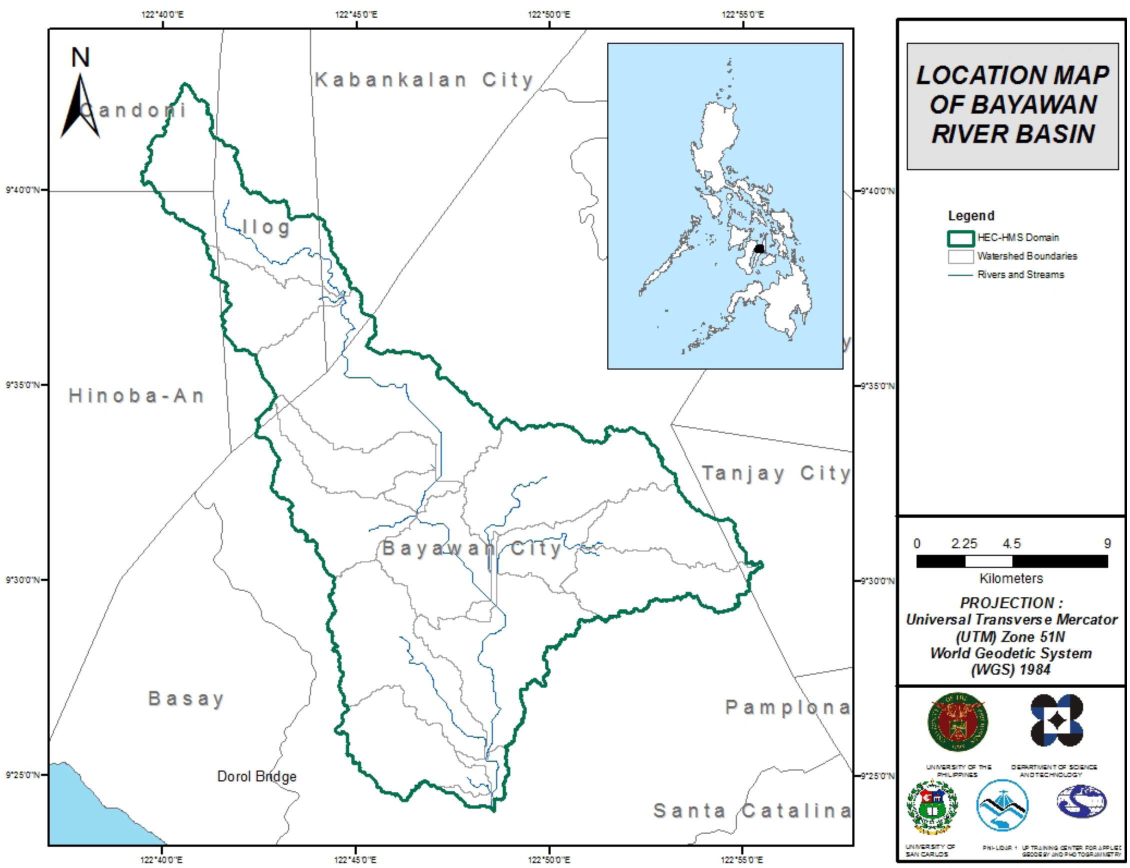


Figure 56. Stream delineation map of Bayawan River Basin.

After preprocessing of the watershed's hydrologic properties, the basin model of the watershed is then processed in HEC-HMS 3.5. HEC-HMS aims to generate the rainfall-runoff relationship in the watershed. Figure 56 shows the basin model in HEC-HMS of Bayawan River. It is composed of seventeen (17) sub-basins and eight (8) reaches.

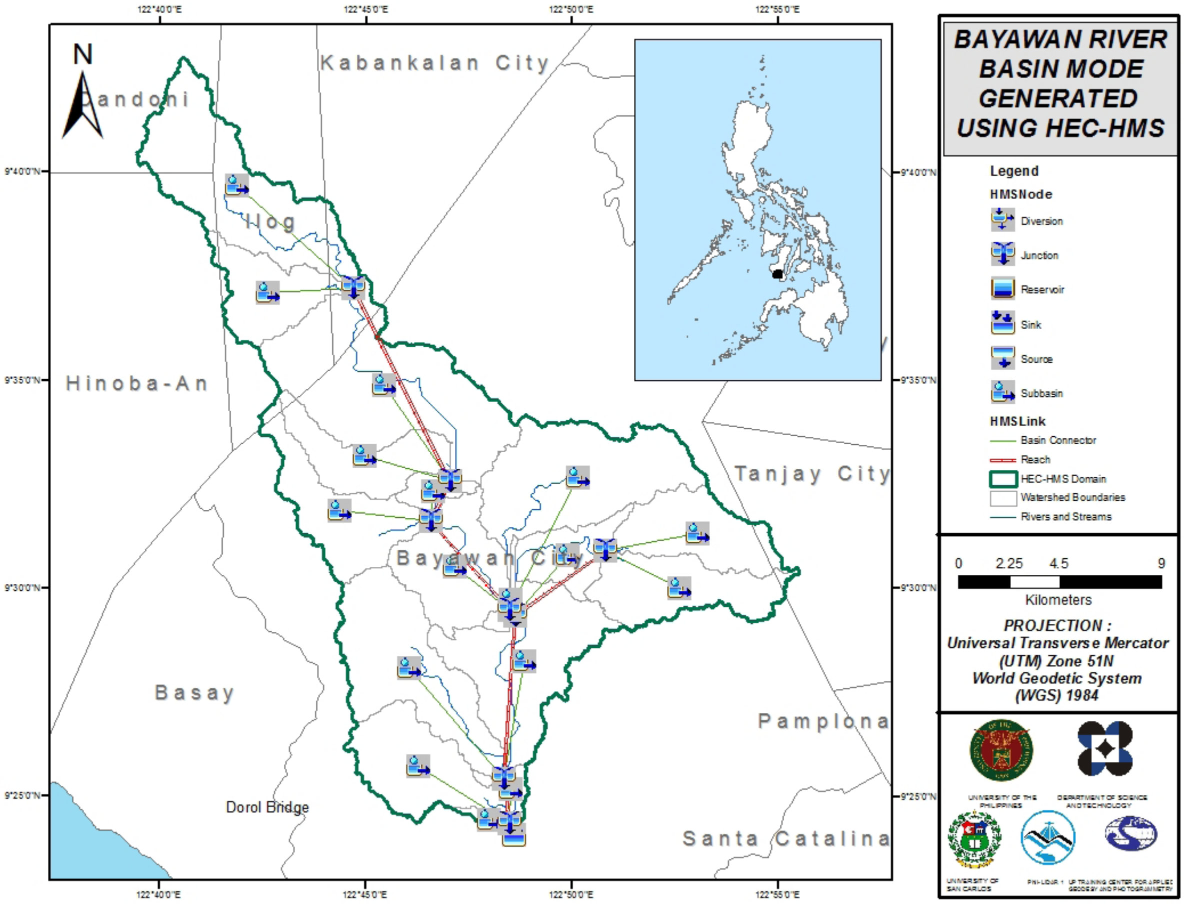


Figure 57. The Bayawan River Basin Model Domain generated using HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed, presented in Figure 57,were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived fromthe LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

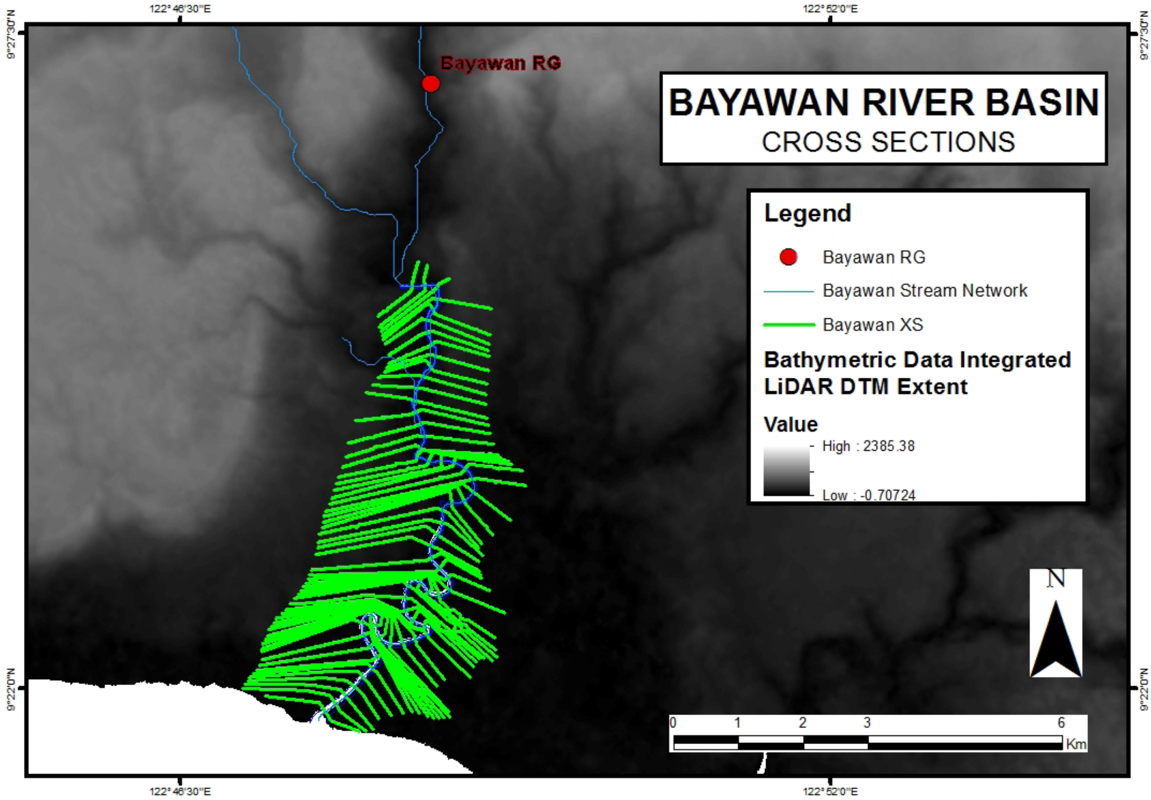


Figure 58. River cross-section of Bayawan River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

The automated modeling 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 meters by 10 meters in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

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

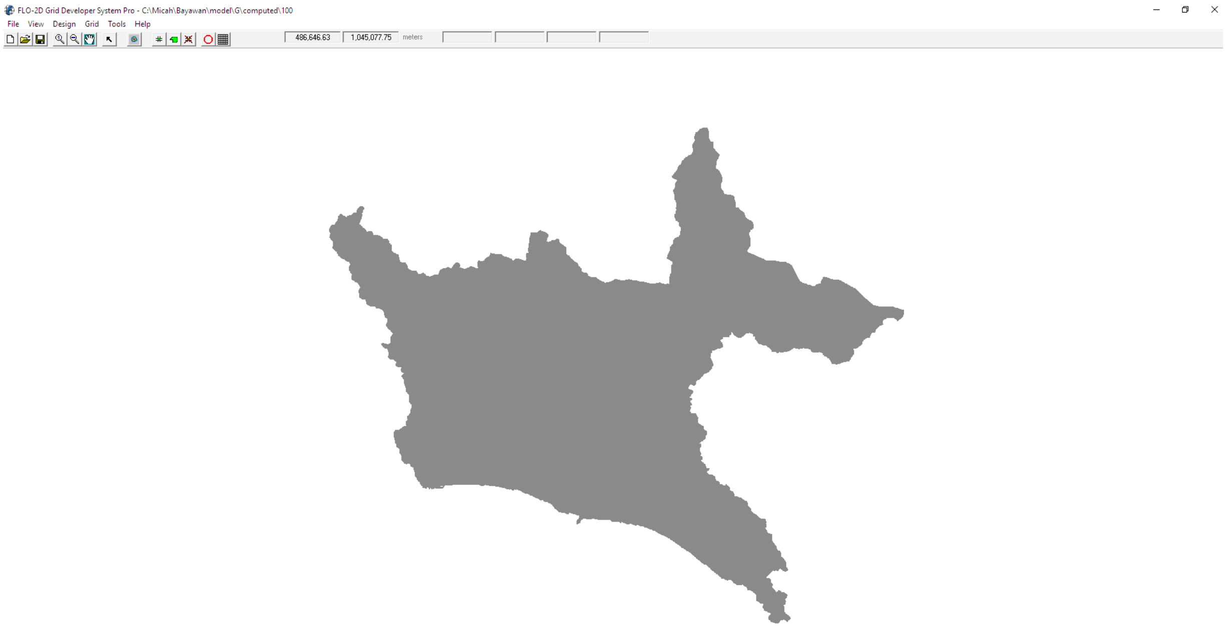


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation is then run through FLO-2D GDS Pro (Figure 58). This particular model had a computer run time of 42.24756 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.The generated hazard maps for Bayawan are in Figures 62, 64, and 66.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 51079100.00 m^2.The generated flood depth maps for Bayawan are in Figures 63, 65, and 67.

There is a total of 80278004.37 m^3 of water entering the model. Of this amount, 12582220.91 m^3 is due to rainfall while 67695783.46 m^3 is inflow from other areas outside the model. 5354857.00 m^3 of this water is lost to infiltration and interception, while 15370132.92 m^3 is stored by the flood plain. The rest, amounting up to 59553011.77 m^3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Bayawan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59shows the comparison between the two discharge data. The Bayawan Model Basin Parameters are seen on ANNEXI.

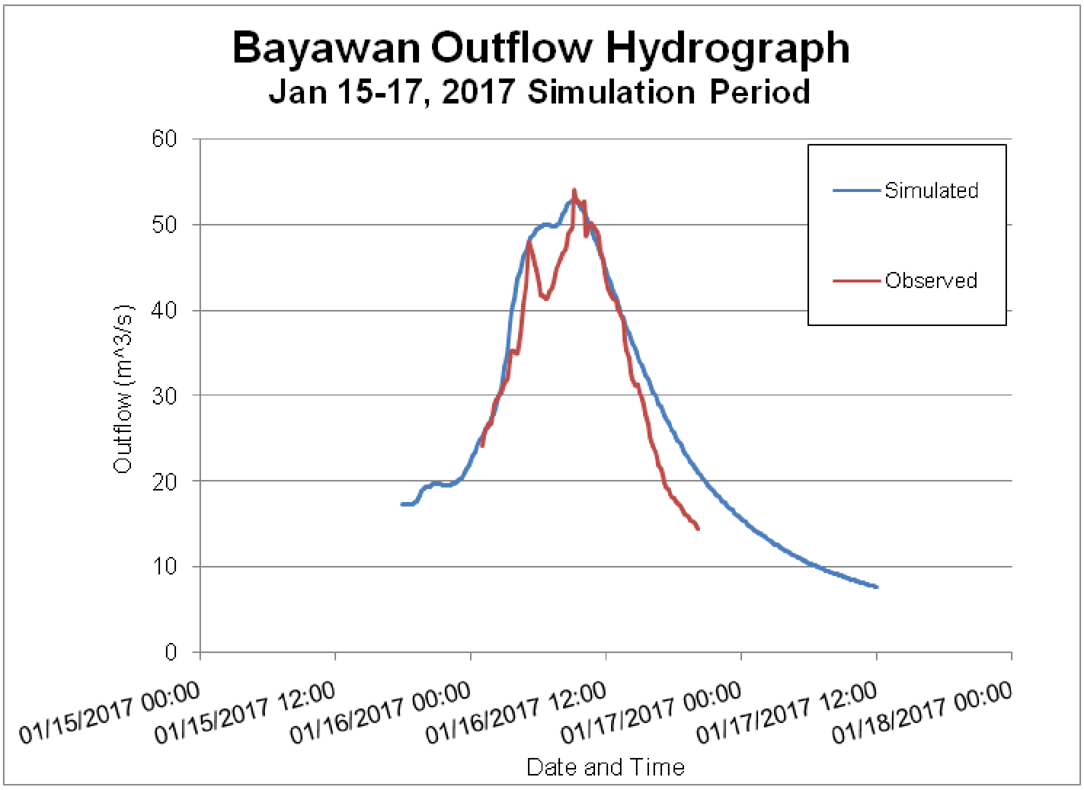


Figure 60. Outflow Hydrograph of Bayawan produced by the HEC-HMS model compared with observed outflow.

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

Table 33. Range of Calibrated Values for Bayawan.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.3 – 3.2
			Curve Number	68 - 90
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 14
			Storage Coefficient (hr)	0.8 - 12
	Baseflow	Recession	Recession Constant	0.5
			Ratio to Peak	0.0007 – 0.001
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.05 – 0.12

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 5mm to 20mm means 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. For Bayawan, the basin mostly consists of brushland, cultivated area, and grassland, and the soil consists of clay, clay loam, fine sandy loam, and siltloam.

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 2 hours to 12 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,whileratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.5 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.0007 – 0.001 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Philippine watersheds (Brunner, 2010). With this coefficient, the Bayawan river basin is determined to be cultivated with mature field crops and mangrove forest.

Table 34 presents the summary of the efficiency test of the Bayawan HMS Model.

Table 34. Summary of the Efficiency Test of Bayawan HMS Model.

RMSE	4.859
r^2	0.9335
NSE	0.823
PBIAS	-9.642
RSR	0.420

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 4.859.

The Pearson correlation coefficient (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 0.9335.

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 0.823.

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 -9.642.

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 0.420.

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 in Figure 60shows the Bayawan outflow using the Dumaguete Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return periods (5-, 10-, 25-, 50-, and 100-year rainfall time series) based on the PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a uniform duration of 24 hours and varying return periods.

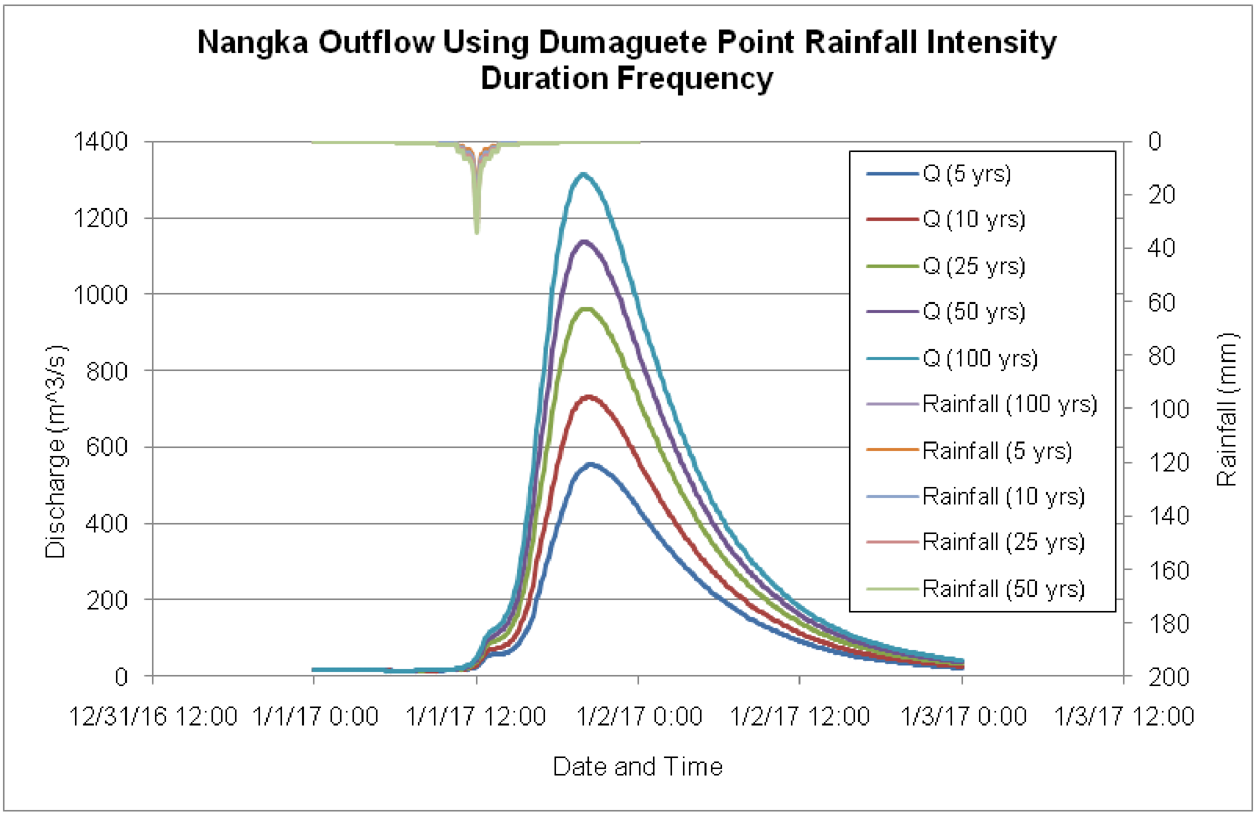


Figure 61. Outflow hydrograph at Sitio Mantapi, Brgy. Nangka, BayawanCity generated using Dumaguete PointRIDF simulated in HEC-HMS.

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

Table 35. Peak values of theBayawan HECHMS Model outflow using the Dumaguete RIDF.

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow	Time to Peak
5-year RIDF	116.5	21.8	553.398	08:30
10-year RIDF	143.3	25.6	731.152	08:20
25-year RIDF	177.2	30.3	962.23	08:10
50-year RIDF	202.4	33.8	1136.746	08:00
100-year RIDF	227.3	37.2	1311.509	08:00

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is shown. The sample generated map of the Bayawan River using the calibrated event flow is shown in Figure 61.

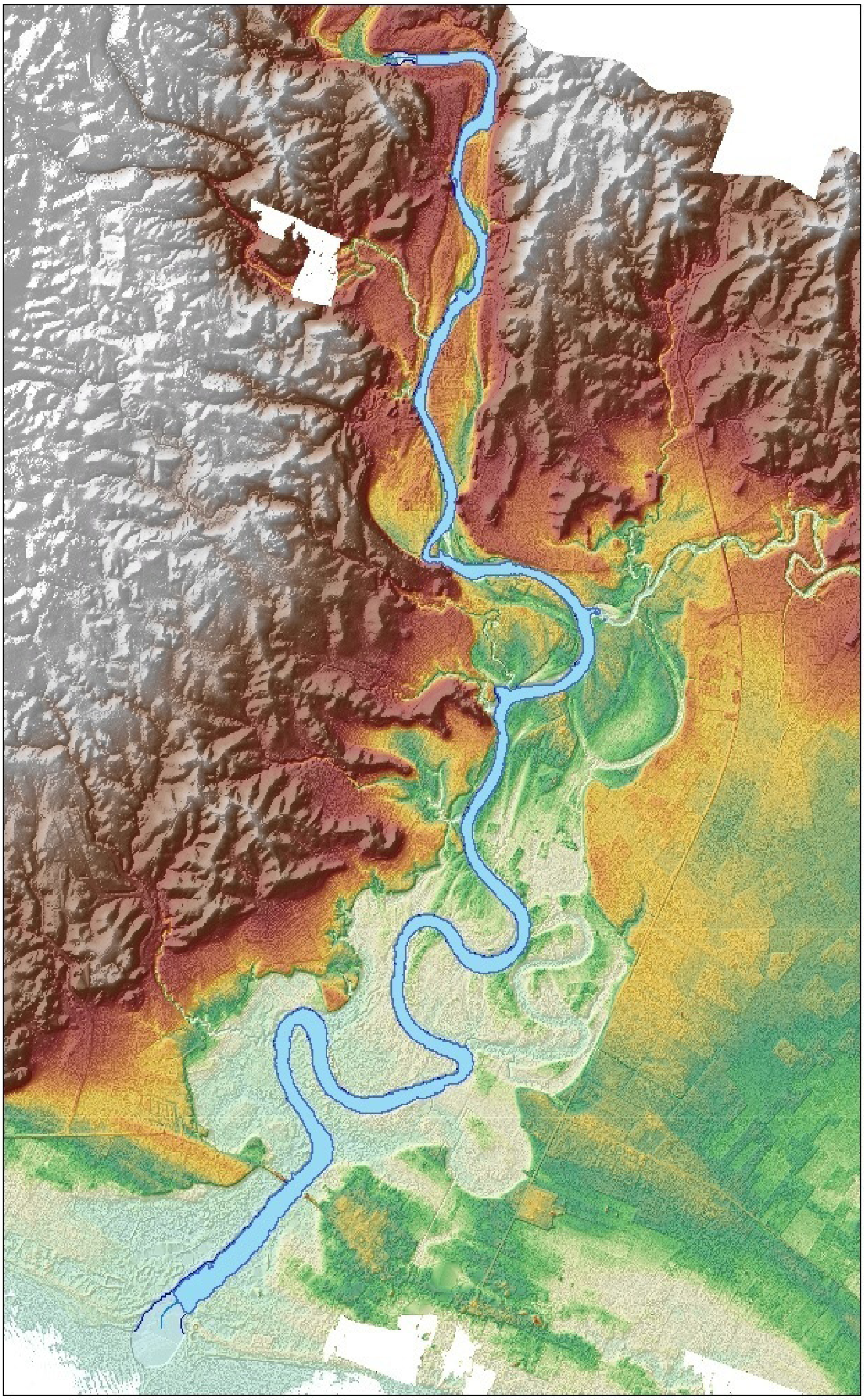


Figure 62. Sample output of BayawanRAS Model.

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figures62 to Figure67show the 5-, 25-, and 100-year rain return scenarios of the BayawanFloodplain, with an area of 50.72 sq. km. Table 36 shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Bislig floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Bayawan City	683.21	50.63	7.41

Moreover, the generated flood hazard maps for the Bayawan Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given individual assessments for each Flood Hazard Scenario (5-yr, 25-yr, and 100-yr), as presented in Table 37.

Table 37. 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	5.99	5.65	5.43
Medium	0.77	0.80	0.90
High	0.65	0.95	1.07

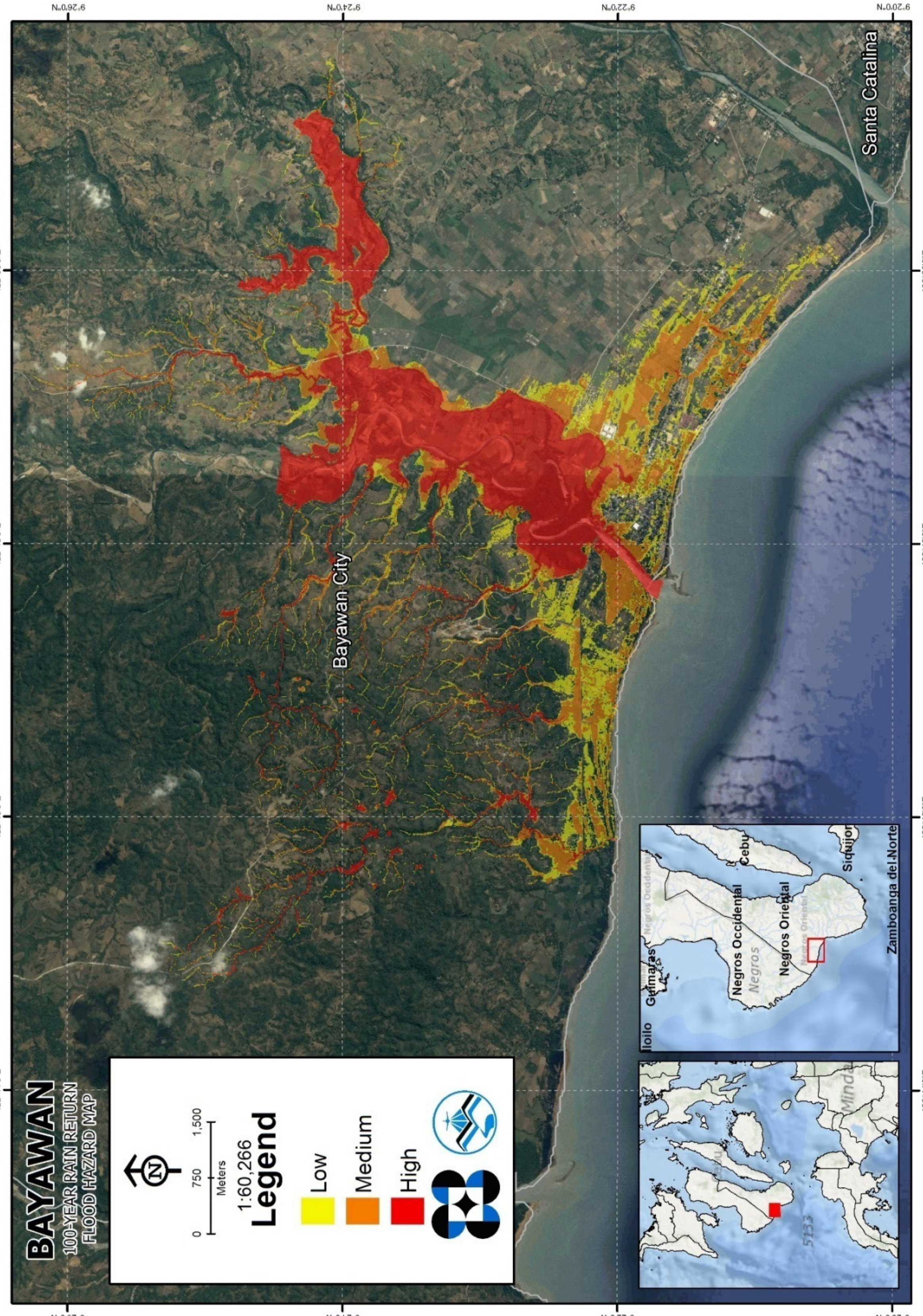


Figure 63. 100-year Flood Hazard Map for Bayawan Floodplain.

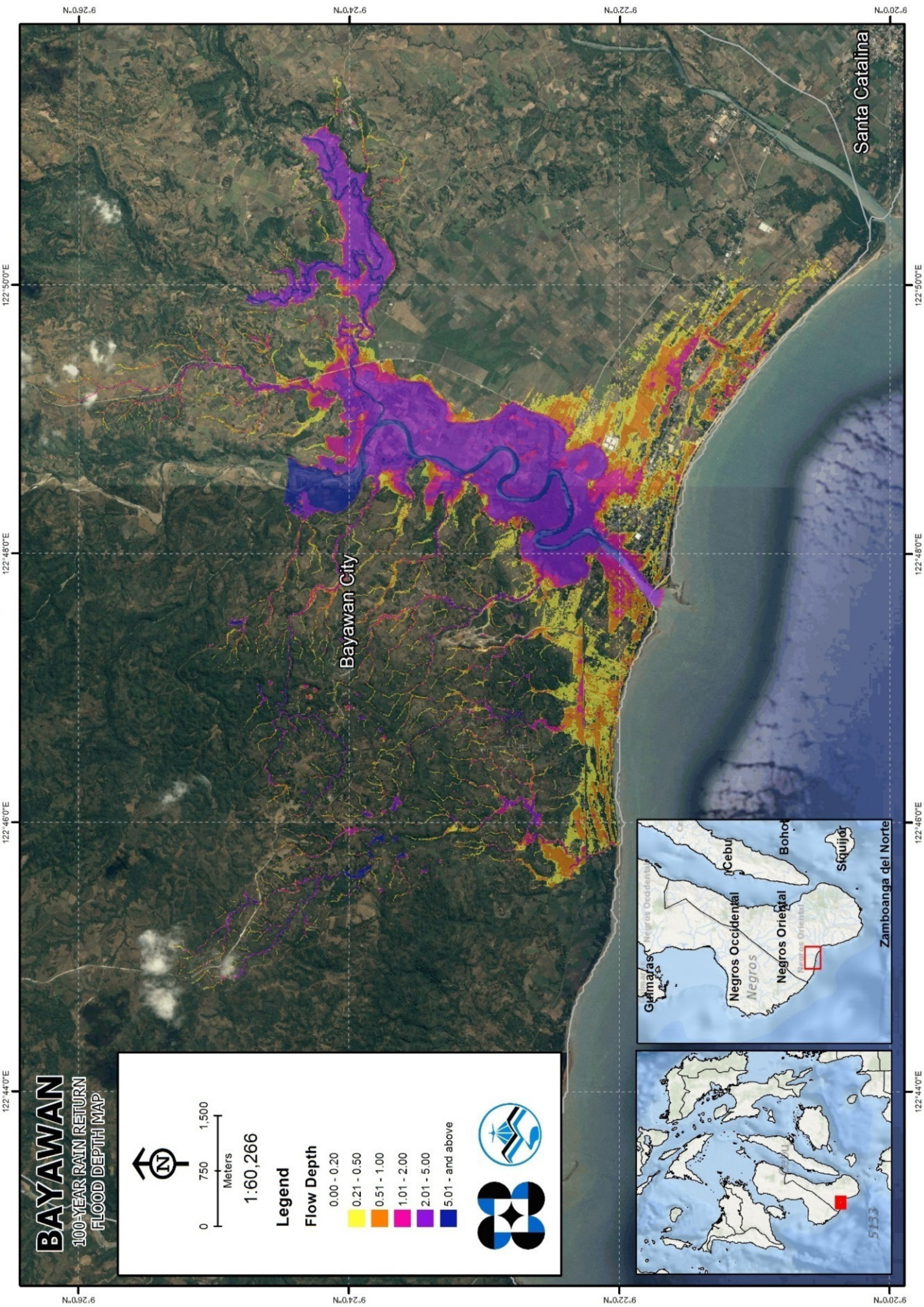


Figure 64. 100-year Flow Depth Map for BayawanFloodplain.

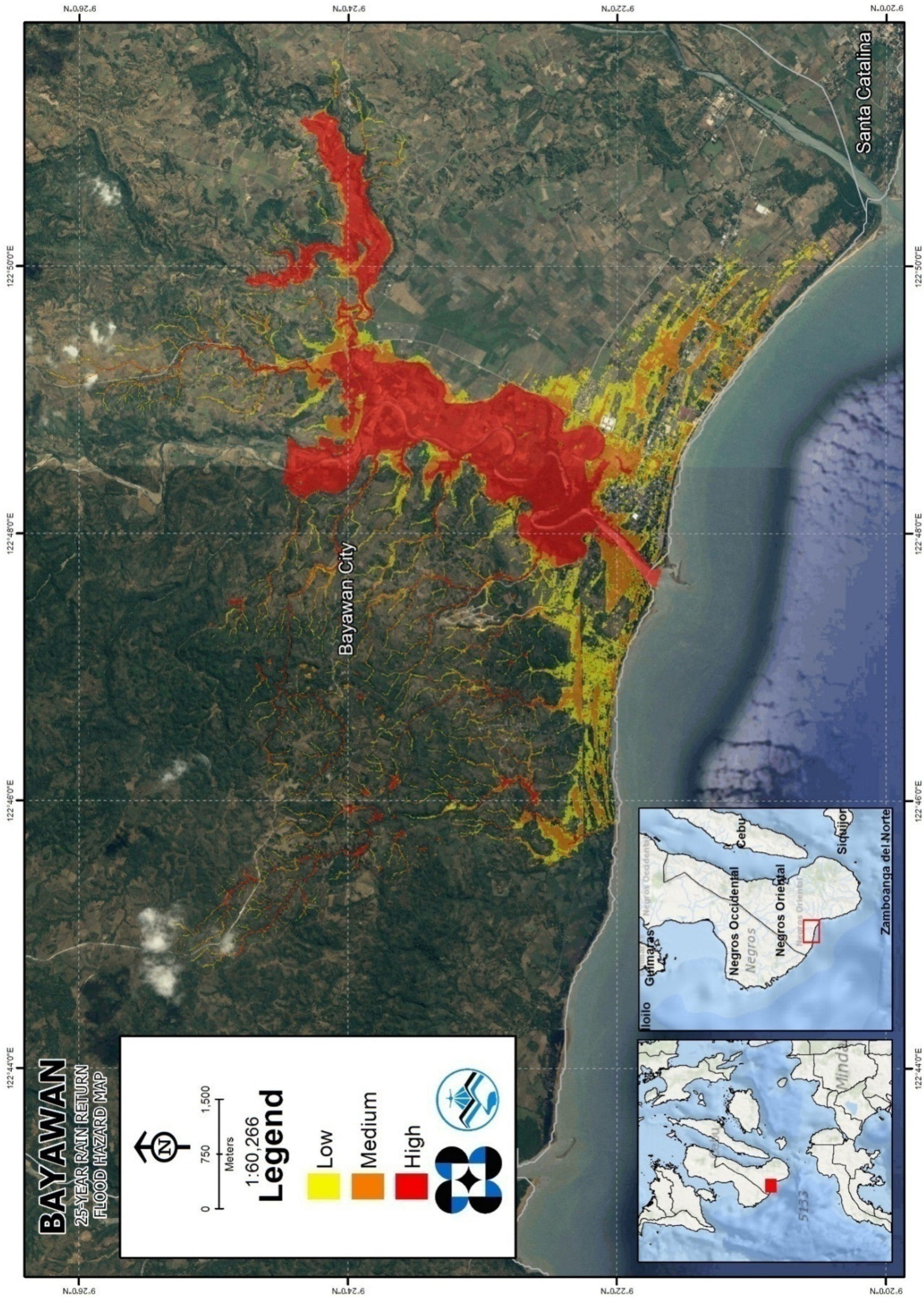


Figure 65. 25-year Flood Hazard Map for BayawanFloodplain.

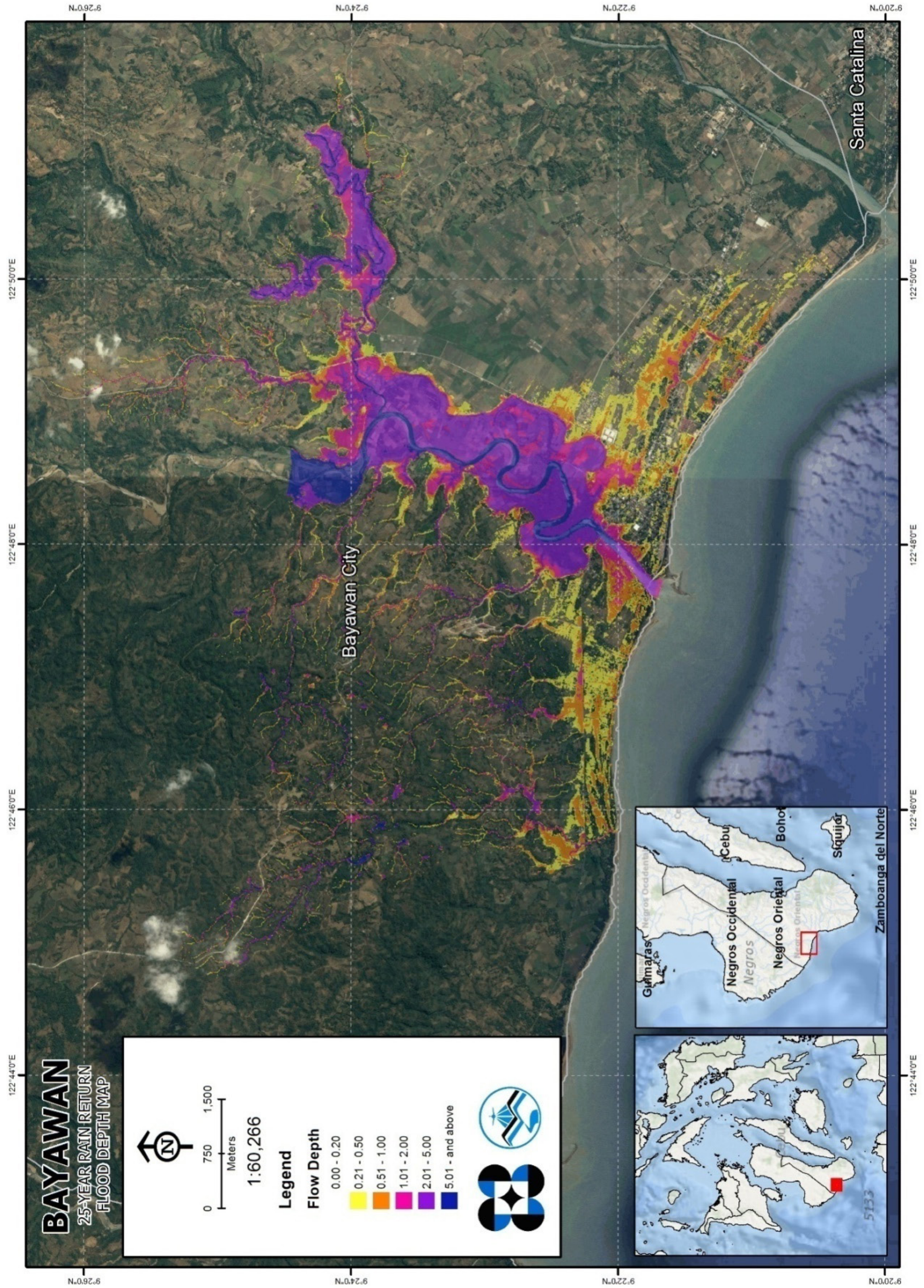


Figure 66. 25-year Flow Depth Map for Bayawan Floodplain.

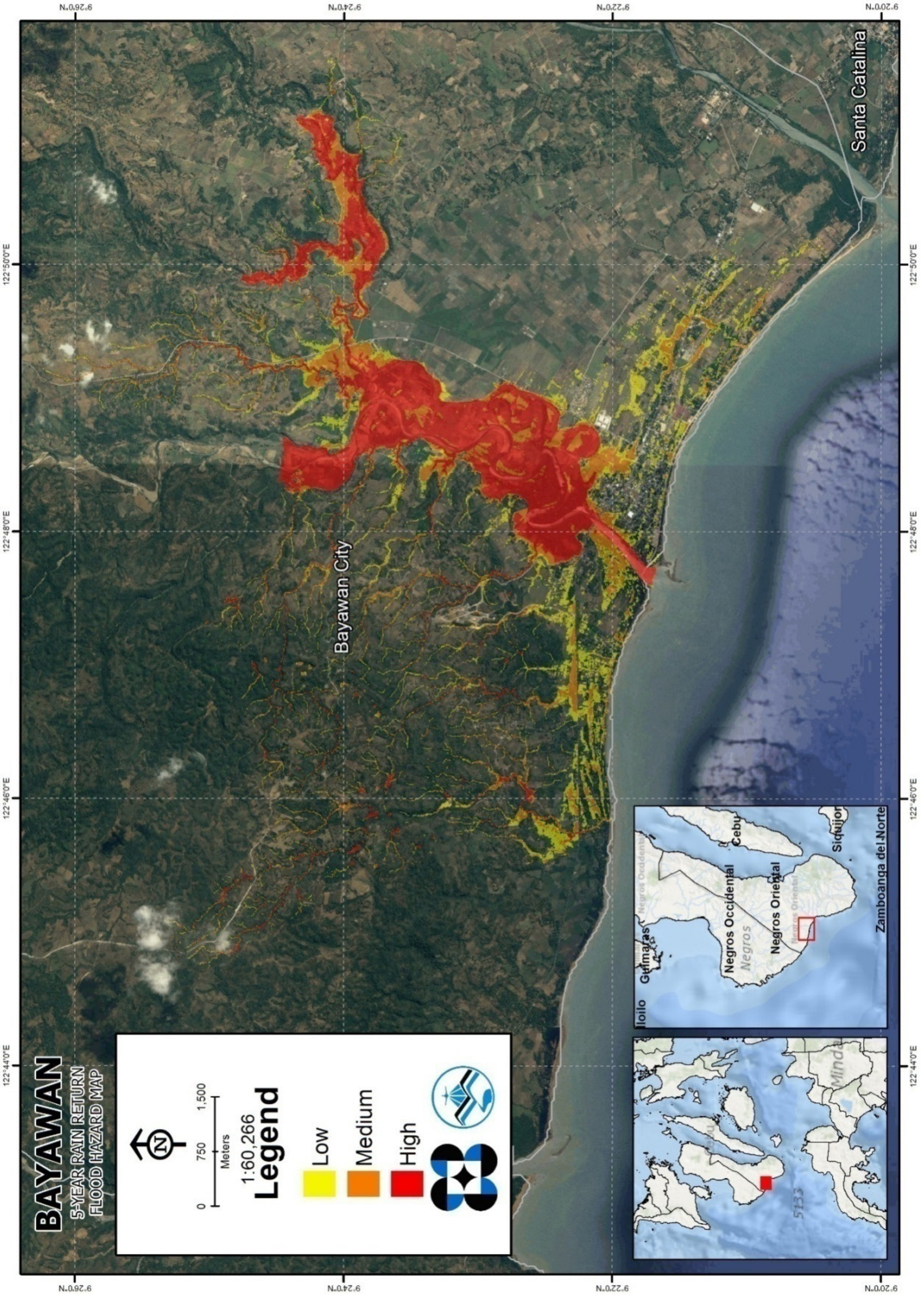


Figure 67. 5-year Flood Hazard Map for Bayawan Floodplain.

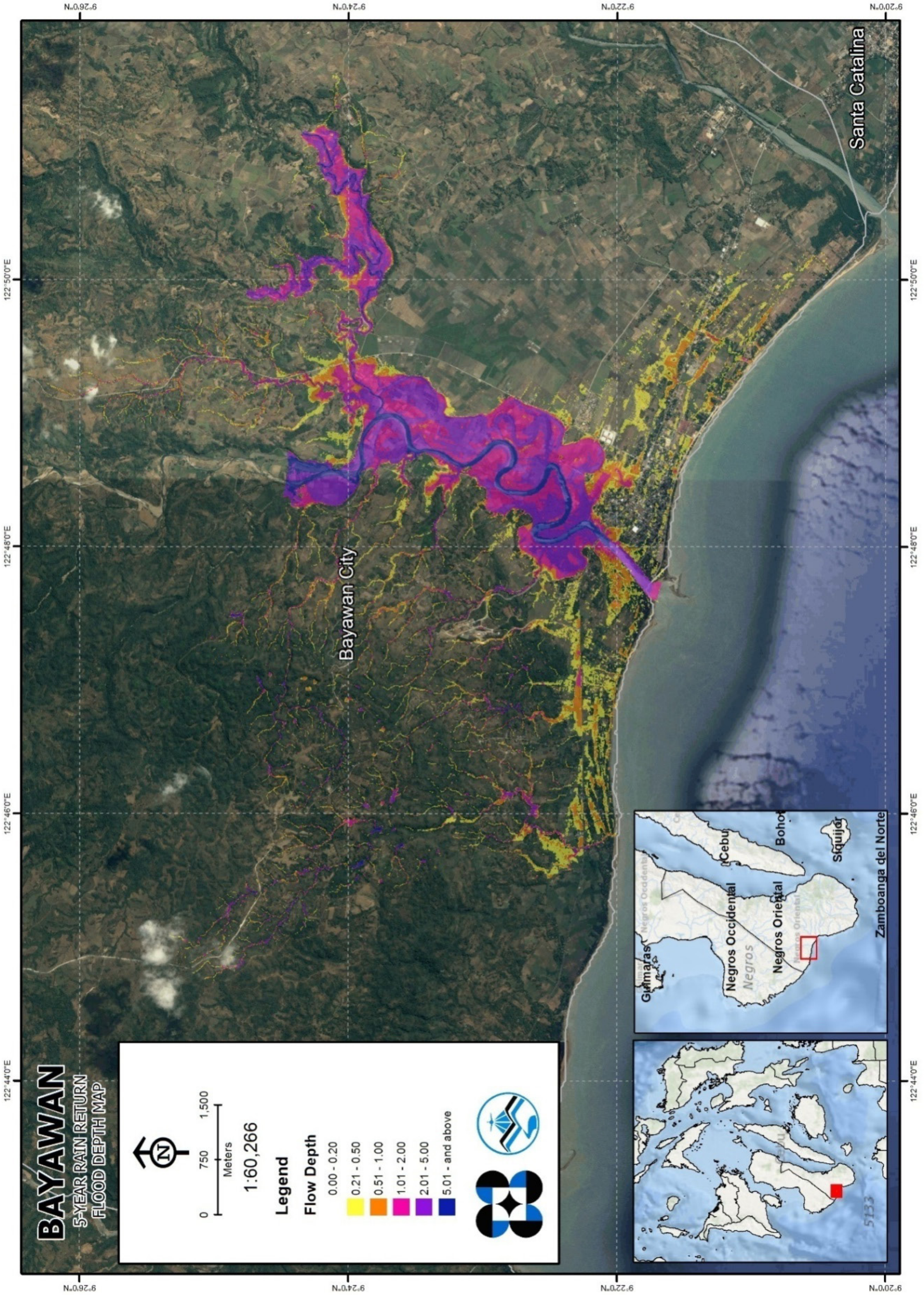


Figure 68. 5-year Flow Depth Map for BayawanFloodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Bayawan river basin, grouped by municipality, are listed below. For the said basin, one (1) city consisting of fourteen (14) barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 5.46% of Bayawan City with an area of 683.21 sq. km. will experience flood levels of less 0.20 meters. 0.53% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.30%, 0.47%, 0.53%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 – 5 meters, and above 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

The list of Educational Institutions and Health Institutions affected by flooding in the Bayawan Floodplain are presented on ANNEXES L and M.

Table 38. Affected Areas in Bayawan City, Negros Oriental during 5-Year Rainfall Return Period

Affected Area (sq. km.)	Affected Barangays in Bayawan City													
	Banga	Boyco	Malabugas	Maninihon	Minaba	Nangka	Pagatban	Poblacion	San Miguel	San Roque	Suba	Tinago	Ubos	Villareal
0.03-0.20	2.15	0.23	9.33	1.04	2.79	8.15	1.15	0.072	0.052	7.39	0.36	0.26	0.25	4.07
0.21-0.50	0.38	0.042	1.16	0.053	0.079	0.62	0.051	0.021	0.00047	0.28	0.048	0.064	0.10	0.75
0.51-1.00	0.31	0.0044	0.50	0.04	0.058	0.56	0.02	0.023	0.000053	0.19	0.0015	0.013	0.13	0.20
1.01-2.00	0.99	0	0.19	0.067	0.066	1.29	0.011	0.0086	0.0002	0.10	0.00018	0.0018	0.44	0.012
2.01-5.00	1.24	0	0.08	0.096	0.051	1.70	0.0081	0	0	0.064	0.00086	0	0.35	0.006
> 5.00	0.38	0	0.0029	0.025	0.010	0.41	0.0045	0	0	0.004	0	0	0.019	0.0003

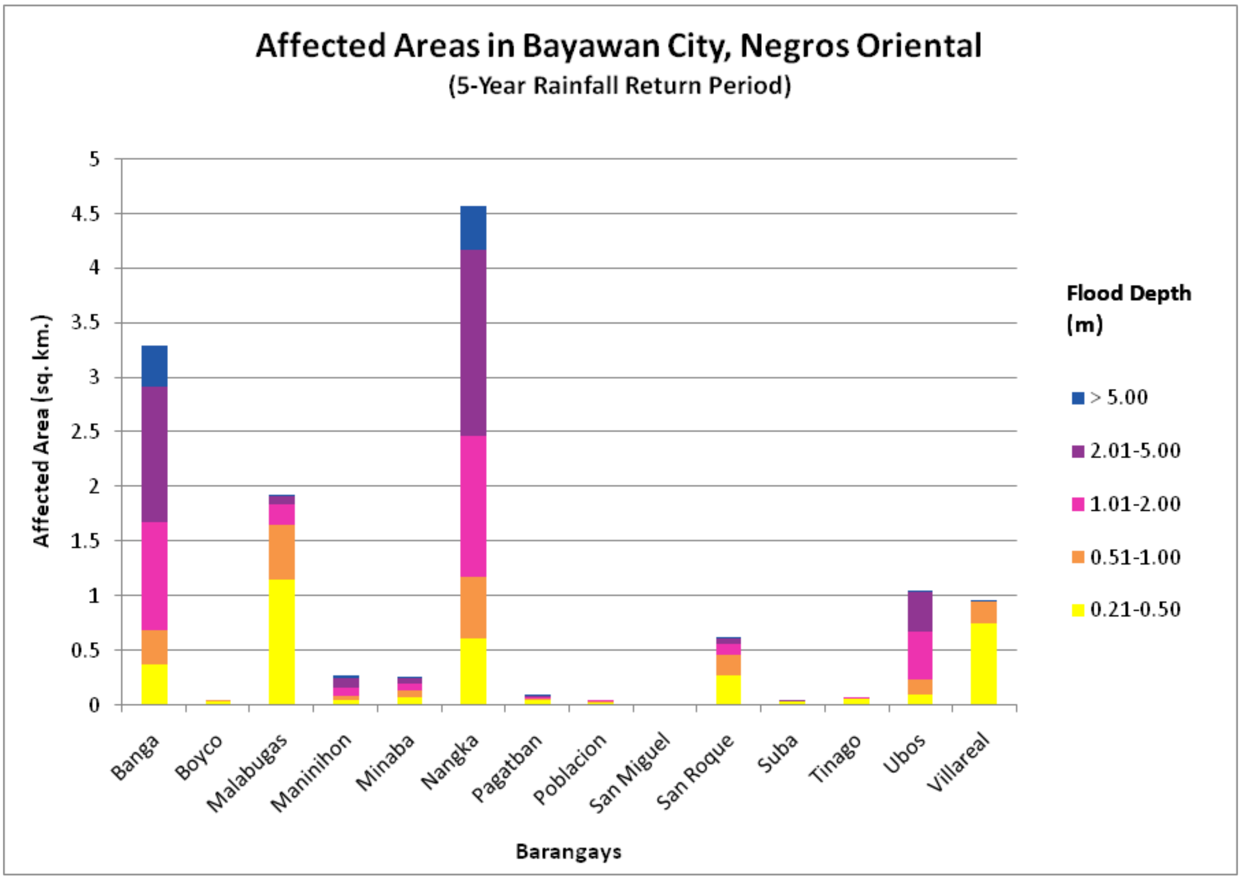


Figure 69. Affected Areas in Bayawan City, Negros Oriental during 5-Year Rainfall Return Period.

For the 25-year return period, 5.02% of Bayawan City with an area of 683.21 sq. km. will experience flood levels of less 0.20 meters. 0.63% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.43%, 0.38%, 0.77%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 – 5 meters, and above 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Bayawan City, Negros Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in Bayawan City													
	Banga	Boyco	Malabugas	Maninihon	Minaba	Nangka	Pagatban	Poblacion	San Miguel	San Roque	Suba	Tinago	Ubos	Villareal
0.03-0.20	1.78	0.17	8.73	1.02	2.75	7.52	1.13	0.028	0.052	7.28	0.32	0.20	0.11	3.21
0.21-0.50	0.39	0.075	1.36	0.056	0.08	0.58	0.056	0.037	0.00074	0.28	0.074	0.092	0.1	1.14
0.51-1.00	0.39	0.033	0.78	0.035	0.06	0.52	0.031	0.037	0.00018	0.21	0.0085	0.043	0.16	0.60
1.01-2.00	0.61	0.0006	0.26	0.06	0.076	1.01	0.011	0.022	0.0002	0.14	0.00018	0.0069	0.30	0.086
2.01-5.00	1.89	0	0.12	0.12	0.07	2.31	0.011	0	0	0.097	0.00096	0	0.61	0.0046
> 5.00	0.40	0	0.0061	0.029	0.025	0.77	0.0096	0	0	0.011	0	0	0.019	0.0019

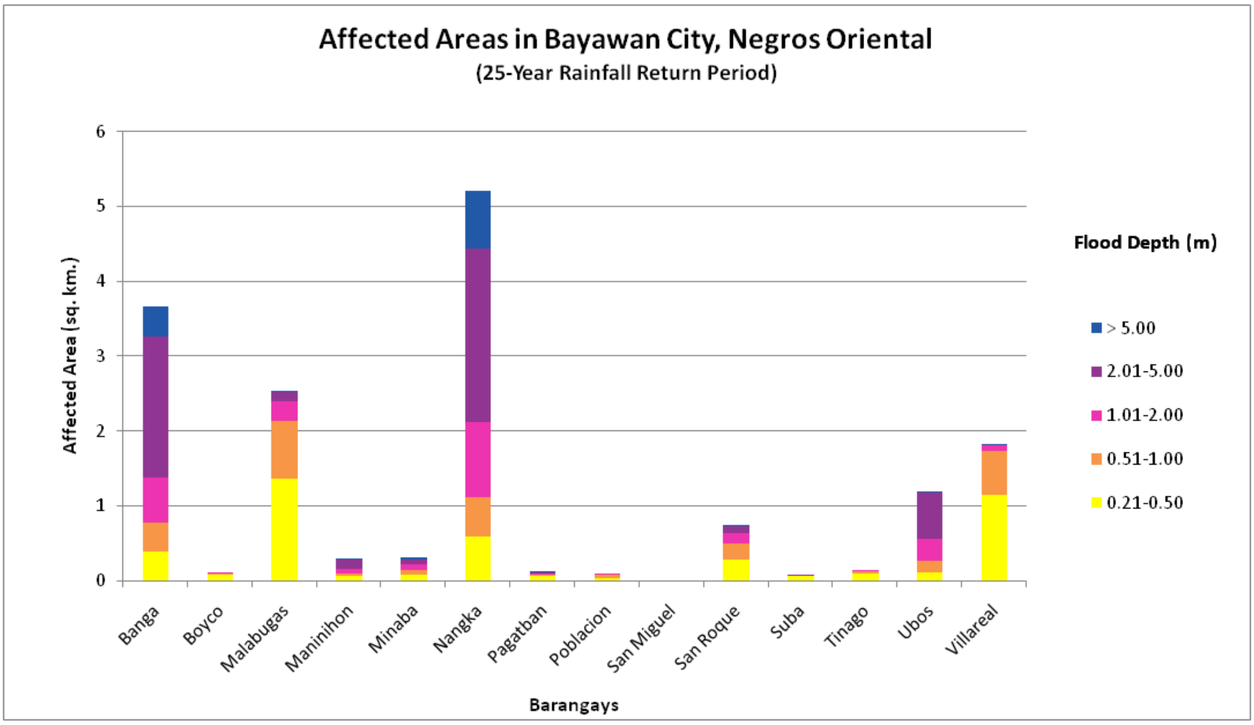


Figure 70. Affected Areas in Bayawan City, Negros Oriental during 25-Year Rainfall Return Period.

For the 100-year return period, 5.02% of Bayawan City with an area of 683.21 sq. km. will experience flood levels of less 0.20 meters. 0.63% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.43%, 0.38%, 0.77%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 – 5 meters, and above 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Bayawan City, Negros Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.)	Affected Barangays in Bayawan City													
	Banga	Boyco	Malabugas	Maninihon	Minaba	Nangka	Pagatban	Poblacion	San Miguel	San Roque	Suba	Tinago	Ubos	Villareal
0.03-0.20	1.64	0.14	8.36	1	2.71	7.27	1.11	0.015	0.052	7.2	0.29	0.17	0.067	2.68
0.21-0.50	0.38	0.079	1.45	0.058	0.09	0.55	0.059	0.034	0.00095	0.29	0.091	0.093	0.083	1.16
0.51-1.00	0.40	0.062	0.96	0.033	0.063	0.52	0.036	0.041	0.00024	0.22	0.022	0.065	0.17	0.95
1.01-2.00	0.55	0.0014	0.32	0.047	0.078	0.87	0.013	0.033	0.0002	0.17	0.00018	0.0095	0.28	0.24
2.01-5.00	2.07	0	0.16	0.15	0.083	2.63	0.012	0.00031	0	0.13	0.00096	0	0.69	0.0044
> 5.00	0.41	0	0.0081	0.032	0.037	0.87	0.015	0	0	0.019	0	0	0.019	0.0025

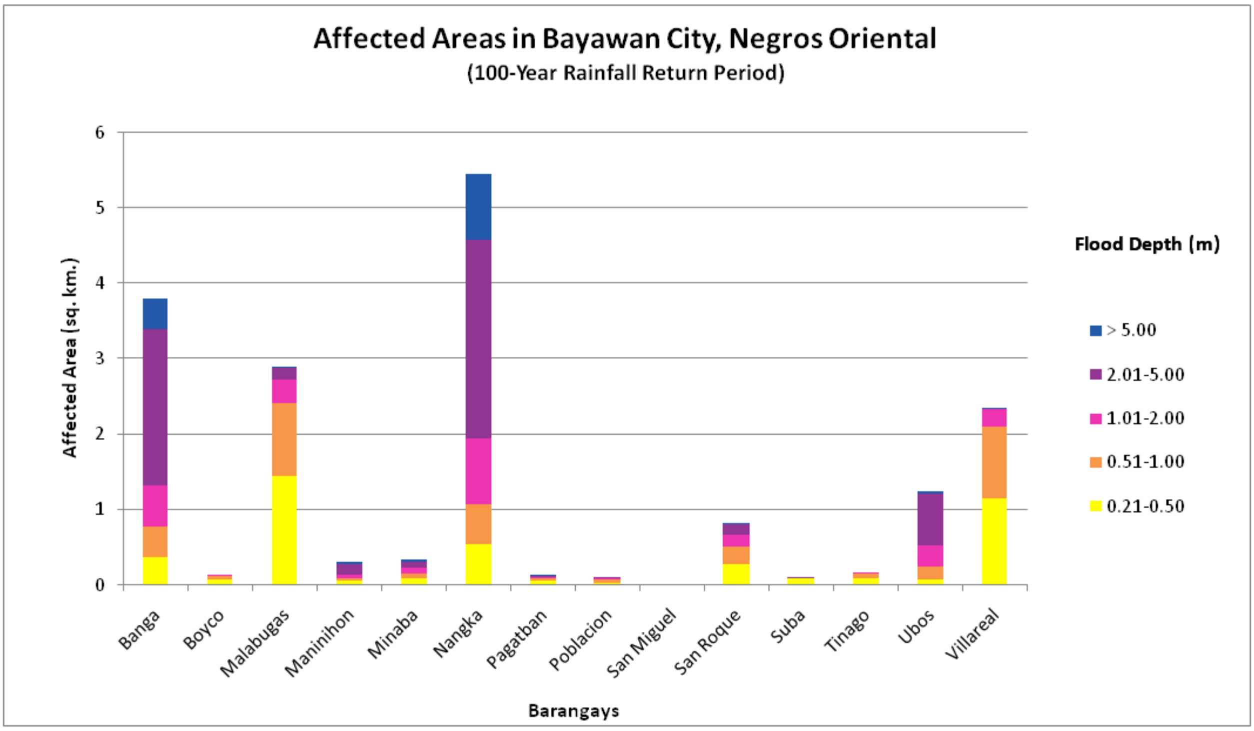


Figure 71. Affected Areas in Bayawan City, Negros Oriental during 100-Year Rainfall Return Period.

Among the Barangays of Bayawan City, Nangka is projected to have the highest percentage of area that will experience flood levels at 1.86%. Meanwhile, Malabugas posted the second highest percentage of area that may be affected by flood depths, at 1.65%.

Of the twenty-one (21) identified Education Institutes in the Bayawan Floodplain, three (3) schools were assessed to be exposed to low level flooding during a 5-year scenario, while three (3) schools are exposed to medium level, and another two (2) are exposed to high level flooding in the same scenario. In the 25-year scenario, three (3) schools were assessed to be exposed to low level flooding, while one (1) and five (5) schools were assessed to be exposed to medium and high levels of flooding, respectively. For the 100-year scenario, five (5) schoolswere assessed to be exposed to low level flooding, and three (3) schools exposed medium level of flooding. In the same scenario, five (5) schools were assessed to be exposed to high level flooding. These schools are located in Brgy. Banga, Brgy. Nangka, and Brgy. Ubos.

Four (4) Medical Institutions were identified in the Bayawan Floodplain.Only one (1) was assessed to be exposed to medium level flooding in the 25- and 100-year scenarios in Brgy. Banga.Ubos Barangay Health Center, which is also located in Brgy. Banga in Bayawan Citywas assessed to beexposed to high level of flooding in the three different scenarios.

5.11 Flood Validation

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

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

The validation personnel visited the specified points identified in theriver basin to gather data regarding the actual flood level in each location. Data gathering was done through the assistance of local DRRM officesinobtaining maps or situation reports about the past flooding events, or through the conduct of interviews with some residents with knowledge or experience of flooding in the particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced, and to improve on the results of the flood map.

During validation, the team was assisted by the local Disaster Risk Reduction and Management representative from the City of Bayawan. Residents along the floodplain were interviewed on the historical flood events that they have 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 2.137 was obtained.

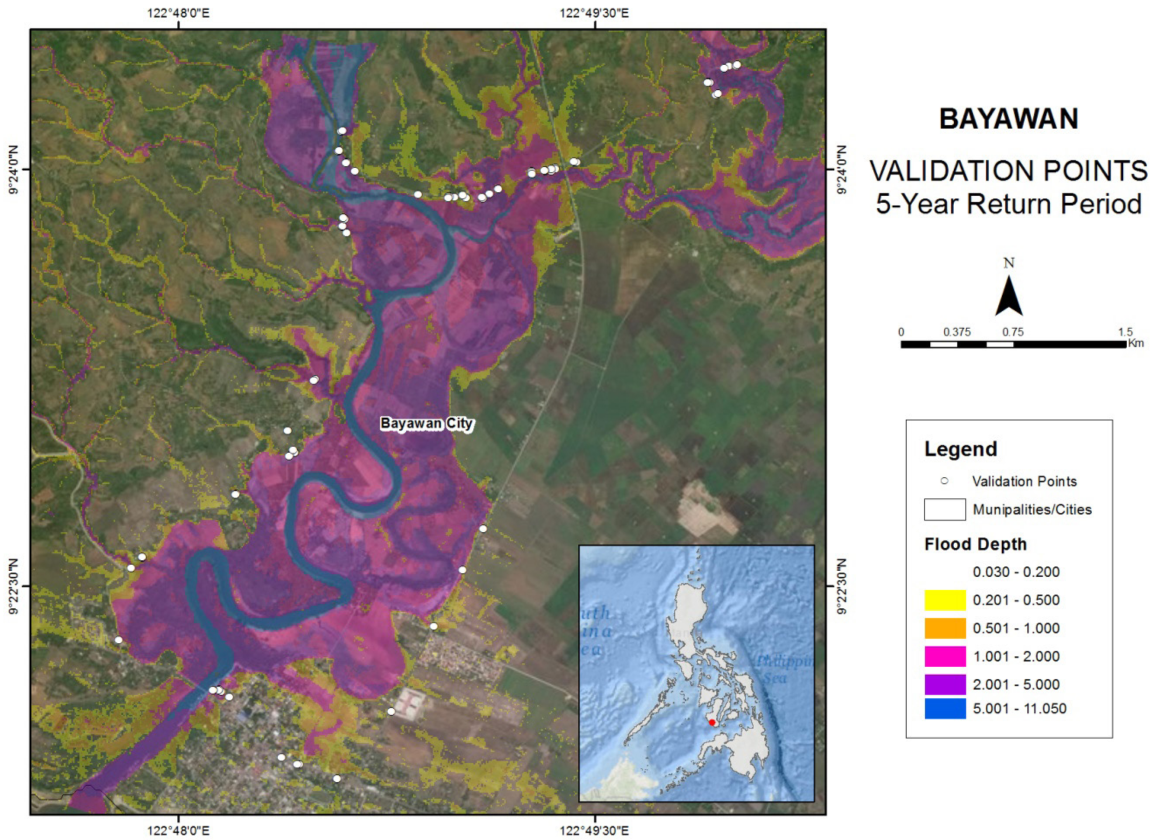


Figure 72. Validation points for 5-year Flood Depth Map of Bayawan Floodplain.

Table 41. Actual Flood Depth vs Simulated Flood Depth in Bayawan.

BAYAWAN BASIN 0-0.20		Modeled Flood Depth (m)						
		0.21-0.50	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**	
Actual Flood Depth (m)	0-0.20	3	1	2	4	2	0	12
	0.21-0.50	9	1	1	3	3	2	19
	0.51-1.00	5	1	3	4	7	2	22
	1.01-2.00	1	6	3	9	11	3	33
	2.01-5.00	3	1	0	1	1	0	6
	> 5.00	0	0	0	0	0	0	0
	Total	21	10	9	21	24	7	92

The overall accuracy generated by the flood model is estimated at 18.48%, with 17 points correctly matching the actual flood depths. In addition, there were 31 points estimated one (1) level above and below the correct flood depths while there were 26 points and 18 points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood. A total of 45 points were overestimated, while a total of 30 points were underestimated in the modeled flood depths of Bayawan.

Table 42. Summary of Accuracy Assessment in Bayawan.

	No. of Points	%
Correct	17	**18.48**
Overestimated	45	48.91
Underestimated	30	32.61
Total	92	100.00

REFERENCES

ANNEXES

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

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

Parameter	Specification
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

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 Certification of Reference Points used in the LiDAR Survey

NGE-94

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 ORIENTAL**
Station Name: **NGE-94**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BASAY**
Barangay: **BAL-OS**
MSL Elevation:

		PRS92 Coordinates			
Latitude:	**9° 25' 41.58333"**	Longitude:	**122° 37' 17.78349"**	Ellipsoidal Hgt:	**8.56700 m.**
		WGS84 Coordinates			
Latitude:	**9° 25' 37.57296"**	Longitude:	**122° 37' 23.11929"**	Ellipsoidal Hgt:	**69.14100 m.**
		PTM / PRS92 Coordinates			
Northing:	**1042517.096 m.**	Easting:	**458444.003 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,042,152.20**	Easting:	**458,458.55**	Zone:	**51**

Location Description

NGE-94
The station is located on the SE of south approach of the Tiabanan's bridge wingwall sidewalk. It is about 6.4 km from the provincial boundary of Negros Oriental & Occidental, along the Sipalay-Dumaguete national road. 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 sidewalk with inscriptions "NGE-94; 2007; NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2594**

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

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NGE-97

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-97**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **SUBA**	
Municipality: **BAYAWAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 22' 10.68255"**	Longitude: **122° 48' 1.35582"**	Ellipsoidal Hgt: **9.65300 m.**
	WGS84 Coordinates	
Latitude: **9° 22' 6.70304"**	Longitude: **122° 48' 6.69563"**	Ellipsoidal Hgt: **70.79700 m.**
	PTM / PRS92 Coordinates	
Northing: **1036021.986 m.**	Easting: **478073.348 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,035,659.36**	Easting: **478,081.02**	Zone: **51**

Location Description

NGE-97

The station is located on the SE corner of Bayawan Bridge which is at KM 102+198. Mark is the head of 4" copper nail flushed at the center of a 30cm x 30cm cement putty embedded on the bridge's concrete sidewalk with inscription "NGE-97 2007 NAMRIA."

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2468**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NGE-100

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:	**9º 18' 11.02881"**	Longitude:	**122º 52' 26.45331"**	Ellipsoidal Hgt:	**8.14800 m.**

WGS84 Coordinates

Latitude:	**9º 18' 7.07298"**	Longitude:	**122º 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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NGE-105

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-105**
Order: **2nd**

Island: **VISAYAS**
Municipality: **STA CATALINA**
Barangay: **NAGBALAYEN**
MSL Elevation:

PRS92 Coordinates

Latitude:	**9° 15' 23.79985"**	Longitude:	**122° 52' 24.36983"**	Ellipsoidal Hgt:	**8.89200 m.**

WGS84 Coordinates

Latitude:	**9° 15' 19.85595"**	Longitude:	**122° 52' 29.71925"**	Ellipsoidal Hgt:	**70.46200 m.**

PTM / PRS92 Coordinates

Northing:	**1023518.905 m.**	Easting:	**486093.752 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,023,160.66**	Easting:	**486,098.62**	Zone:	**51**

Location Description

NGE-105
The station is located on top of the bridge wingwall SW of the Bridge main span. It is on the left side of the 1st approach coming from Siaton on the way to Sta Catalina. The height of the wingwall is about 1.00 m. from the road pavement. The bridge is at Km. 84+627. The station is along the Dumaguete-Bayawan national highway. 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 concrete bridge's wingwall with inscriptions "NGE-105; 2007; NAMRIA".

Requesting Party:	**Phil-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075810 I**
T.N.:	**2014-2462**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NGE-107

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-107**
Order: **2nd**

Island: **VISAYAS**	Barangay: **MANALONGON**	
Municipality: **STA CATALINA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 13' 23.69730"**	Longitude: **122° 52' 53.67884"**	Ellipsoidal Hgt: **8.08400 m.**
	WGS84 Coordinates	
Latitude: **9° 13' 19.76274"**	Longitude: **122° 52' 59.03119"**	Ellipsoidal Hgt: **69.74600 m.**
	PTM / PRS92 Coordinates	
Northing: **1019829.085 m.**	Easting: **486987.067 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,019,472.13**	Easting: **486,991.62**	Zone: **51**

Location Description

NGE-107
The bridge is at Km.80+569 over Manalongon river. The barangay hall complex is on the NE of the bridge, about 60 m. from the station. The station is located on top of the sidewalk of Manalongon bridge, near the Manalongon barangay complex. It is located on the left approach of the bridge coming from Sta Catalina heading to Dumaguete City. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 03 cm. cement putty embedded on concrete bridge's sidewalk with inscriptions "NGE-107; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2464**

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

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NE-90

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: **NE-90**	
Island: **VISAYAS**	Municipality: **ZAMBOANGUITA**	Barangay: **POBLACION**
Elevation: **6.6968 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **9° 6' 38.50000"**	Longitude: **123° 12' 10.10000"**	

Location Description

NE – 90, is in the Province of Negros Oriental, Municipality of Zamboanguita, Barangay Poblacion, along National road.

Station is located on concrete sidewalk, Southeast end of Guinsuan bridge, 0.30 meter above the ground, 4 meters East of the road centerline, 180 meters North of KM Post 27.

Mark is the head of a 4" copper nail, set on a drilled hole and flushed to a 6" x 6" cement putty with inscription "NE – 90, 2007, NAMRIA".

Requesting Party:	**Phil-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075810 I**
T.N.:	**2014-2469**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NE-21

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: **NE-21**

Island: **VISAYAS**	Municipality: **BAYAWAN**	Barangay: **MALABOGAS**
Elevation: **5.4216 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **9° 22' 14.90000"**	Longitude: **122° 45' 44.30000"**	

Location Description

NE – 21 is in the Province of Negros Oriental, City of Bayawan, Barangay Malabogas, Sitio Camaya-an, along Basay – Bayawan Highway.

Station is located on concrete sidewalk, Southwest end of Camaya-an bridge, 0.30 meter above the ground, 4 meters South of the road centerline, 440 meters East of KM Post 107, about 500 meters West of KM Post 106, and 150 meters Southwest of barangay hall of Malabogas.

Mark is the head of a 4" copper nail, set on a drilled hole and flushed to a 6" x 6" cement putty with inscription "NE – 21, 2007, NAMRIA".

Requesting Party:	**Phil-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075810 I**
T.N.:	**2014-2472**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

NE-08

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

December 09, 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: **NE-08**

Island: **VISAYAS**	Municipality: **BASAY**	Barangay: **NAGBO-ALAO**
Elevation: **2.6097 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **9° 24' 22.00000"**	Longitude: **122° 38' 55.30000"**	

Location Description

NE-08 is in the Province of Negros Oriental, Municipality of Basay, Barangay Nagbualao, Sitio Daro, along Hinobaan – Bayawan road.

Station is located on top center of reinforced concrete pipe culvert railing, leveled on the ground, 7 meters Southwest of the road centerline, 100 meters Northwest of KM Post 121.

Mark is the head of a 4" copper nail, set on a drilled hole and flushed to a 6" x 6" cement putty with inscription "NE-08, 2007, NAMRIA".

Requesting Party: **Christopher Cruz**
Purpose: **Reference**
OR Number: **8077396 I**
T.N.: **2014-2976**

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

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

1. NE-90

NE-90 - NGE-111 (7:40:35 AM-11:39:53 AM) (S1)

Baseline observation:	NE-90 --- NGE-111 (B1)
Processed:	11/3/2014 11:10:47 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.011 m
RMS:	0.003 m
Maximum PDOP:	1.667
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	9/25/2014 7:40:39 AM (Local: UTC+8hr)
Processing stop time:	9/25/2014 11:39:49 AM (Local: UTC+8hr)
Processing duration:	03:59:10
Processing interval:	5 seconds

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-21

NGE-97 - NE-21 (6:29:33 AM-9:38:04 AM) (S1)

Baseline observation:	NGE-97 --- NE-21 (B1)
Processed:	11/3/2014 11:39:15 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.016 m
RMS:	0.019 m
Maximum PDOP:	1.766
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	10/20/2014 6:29:39 AM (Local: UTC+8hr)
Processing stop time:	10/20/2014 9:38:04 AM (Local: UTC+8hr)
Processing duration:	03:08:25
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	NGE-97				
Grid		**Local**		**Global**	
Easting	478081.022 m	**Latitude**	N9°22'10.68255"	**Latitude**	N9°22'06.70304"
Northing	1035659.360 m	**Longitude**	E122°48'01.35582"	**Longitude**	E122°48'06.69563"
Elevation	8.347 m	**Height**	9.653 m	**Height**	70.797 m

To:	NE-21				
Grid		**Local**		**Global**	
Easting	473740.044 m	**Latitude**	N9°22'18.89002"	**Latitude**	N9°22'14.90643"
Northing	1035914.112 m	**Longitude**	E122°45'39.02590"	**Longitude**	E122°45'44.36578"
Elevation	5.801 m	**Height**	7.040 m	**Height**	68.081 m

Vector					
ΔEasting	-4340.979 m	**NS Fwd Azimuth**	273°19'34"	**ΔX**	3674.857 m
ΔNorthing	254.752 m	**Ellipsoid Dist.**	4350.156 m	**ΔY**	2314.666 m
ΔElevation	-2.546 m	**ΔHeight**	-2.613 m	**ΔZ**	248.233 m

Standard Errors

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

3. NE-08

NE-08 - NGE-94 (6:17:24 AM-10:26:38 AM) (S1)

Baseline observation:	NE-08 --- NGE-94 (B1)
Processed:	11/3/2014 11:50:43 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.004 m
RMS:	0.001 m
Maximum PDOP:	2.470
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	10/22/2014 6:17:34 AM (Local: UTC+8hr)
Processing stop time:	10/22/2014 10:26:34 AM (Local: UTC+8hr)
Processing duration:	04:09:00
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	NGE-94				
Grid		Local		Global	
Easting	458458.548 m	Latitude	N9°25'41.58333"	Latitude	N9°25'37.57296"
Northing	1042152.197 m	Longitude	E122°37'17.78349"	Longitude	E122°37'23.11929"
Elevation	7.540 m	Height	8.568 m	Height	69.141 m

To:	NE-08				
Grid		Local		Global	
Easting	459762.045 m	Latitude	N9°25'12.20140"	Latitude	N9°25'08.19418"
Northing	1041248.495 m	Longitude	E122°38'00.55785"	Longitude	E122°38'05.89430"
Elevation	7.528 m	Height	8.582 m	Height	69.203 m

Vector					
ΔEasting	1303.497 m	NS Fwd Azimuth	124°40'16"	ΔX	-1178.739 m
ΔNorthing	-903.702 m	Ellipsoid Dist.	1586.723 m	ΔY	-579.131 m
ΔElevation	-0.012 m	ΔHeight	0.015 m	ΔZ	-890.435 m

Standard Errors

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

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

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. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME HIPOLITO	UP-TCAGP
		AUBREY MATIRA-PAGADOR	UP-TCAGP
LiDAR Operation	Research Associate (RA)	MA. VERLINA E. TONGA	UP-TCAGP
		MA. REMEDIOS VILLANUEVA	
		JONALYN GONZALES	
Ground Survey, Data Download and Transfer		JONATHAN ALMALVEZ	UP-TCAGP
		GEF SORIANO	
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINI	PHILIPPINE AIR FORCE (PAF)
		SSG ERWIN DELOS SANTOS	
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
	Pilot	CAPT. BRYAN DONGUINES	
		CAPT. NEIL ACHILLES AGAWIN	
		CAPT. MARK TANGONAN	
	Pilot	CAPT. JEROME MOONEY	

Annex 5. Data Transfer Sheets for the Bayawan Floodplain Flights

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	2B1K56DC268A	GEMINI	18.2	285	630	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	2BLK53O55A273A	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	3/4	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. Joaquin
Position:
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	2BLK55AS53BS280A	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	121	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	617 KB	210	70.5 GB	118 KB	19	N/A	6.05	1 KB	1 KB	371 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	418 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	480 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	2BLK55H5GF299A	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	2BLK56ES8LK55FS300A	GEMINI-CASI	2.10 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	2BLK56BSFS301A	GEMINI-CASI	12.7 GB	272 KB	344 KB	165	7.62 GB	61.1 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: IRIDA PRIETO
POSITION: CSRS
SIGNATURE:

DATE: NOV/06/2014

DATA TRANSFER SHEET
Dumaguete 2/5/16

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	3BLK53BS028A	Aquarius	NA	231	508	227	40.3	44.3	16.5	140	9.99	1KB	1KB	3KB	8KB	Z:\DAC\RAW DATA
29-Jan	10074AC	3BLK53A029A	Aquarius	NA	45	375	247	36	190	7.74	na	10	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
29-Jan	10075AC	3BLK53S029B	Aquarius	NA	28	392	215	18	42.3/198	5.4	na	10	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
30-Jan	10076AC	3BLK53V030A	Aquarius	NA	99	302	193	53.1	150/42.3/198	6.06	68	18.4	1KB	NA	19KB	28KB	Z:\DAC\RAW DATA
30-Jan	10077AC	3BLK53V030B	Aquarius	NA	83	391	195	27	140/26.7037	5.40	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
Signature

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 7526G Mission

Flight Log No.: 7526

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: MVE Tongco	2 ALTM Model: Gemini and Casi	3 Mission Name: 2BLK530S5A273A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Aquino	9 Route:			
10 Date: Sept. 30, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete City	12 Airport of Arrival (Airport, City/Province):			
13 Engine On: 0707	14 Engine Off: 0942	15 Total Engine Time: 02 35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 3 lines of BLK530 and 4 lines of BLK53A.

21 Problems and Solutions:

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

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

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

Lidar Operator
Signature over Printed Name

2. Flight Log for 7540G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log Gemini +

Flight Log No.: 7540

1 LIDAR Operator: MR Villanueva	2 ALTM Model: CASI	3 Mission Name: 2BLK55AS53DS280A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9322
7 Pilot: N. Agawin	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: October 7, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0657	14 Engine Off: 1026	15 Total Engine Time: 0329	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Surveyed 11 lines.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Larry Acuña	Raymund Domini	Neil Agawin	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

1. Flight Log for 7560G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log   Gen +   Flight Log No.: 7560

1 LiDAR Operator: MVE Tonga	2 ALTM Model: CASI	3 Mission Name: 2BLK54A290A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: Oct 17, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:53	14 Engine Off: 10:40	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Remarks:

Mission completed with minimal voids

21 Problems and Solutions:

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

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

Pilot-in-Command
D. SAMAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

2. Flight Log for 7562G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log 6cm + 2BLK 53M 291 A **Flight Log No.:** 7562

1 LiDAR Operator: MR Villanueva	2 ALTM Model: CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: K. Samar	8 Co-Pilot: N. Aguin	9 Route:			
10 Date: Oct 19, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:35	14 Engine Off: 10:46	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					
20 Remarks: mission completed but voids were encountered during the survey					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Larry Acuña	Raymund Domine	R. Samar II	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 7566G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log   Gem ?   2BLK53M 293A   Flight Log No.: 7566

1 LIDAR Operator: MVE Tonga	2 ALTM Model: CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Aquino	9 Route:			
10 Date: Oct 30, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:33	14 Engine Off: 10:08	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Remarks:

Mission completed (with CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Loven Aguirre	Raymund Domino	R. Samar	Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 7568G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log   Gem + CASI   2BLK 530S 299 A   Flight Log No.: 7568

1 LiDAR Operator: Mr. Villanueva	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Garay	8 Co-Pilot: O. Agawin	9 Route:			
10 Date: Oct 21, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:33	14 Engine Off: 10:44	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: Mission completed (with CASI -- first line)					

21 Problems and Solutions:

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

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

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

Lidar Operator
MR. Villanueva
Signature over Printed Name

5. Flight Log for 7570G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7570

1 LiDAR Operator: MVE Tongo	2 ALTM Model: GMS	3 Mission Name: 2BLK63J295A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: Oct 22, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:14	14 Engine Off: 10:37	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					

20 Remarks:

Mission completed (with GAS)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuna	Raymond Domini	R. Samar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 7576G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7576

1 LIDAR Operator: MR Villanueva	2 ALTM Model: GC	3 Mission Name: 2BLK53H298A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: October 25, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0613	14 Engine Off: 1006	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Fair				

20 Remarks: Surveyed lines of BLK53H (without CASI due to intermittent grounding connection).

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito		R. Samar	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

7. Flight Log for 7578G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 7578

1 LIDAR Operator: MVE Tonga	2 ALTM Model: GC	3 Mission Name: 2BLK53HSGP299A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Aguam	9 Route:			
10 Date: October 26, 2014		12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):	
13 Engine On: 0617	14 Engine Off: 1040	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Fair				

20 Remarks:

Completed the rest of BLK53H and whole plan of BLK53G and surveyed lines of BLK53F (without CASI due to intermittent 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)	R. Samar II Signature over Printed Name	Signature over Printed Name

8. Flight Log for 10076AC Mission

D R E A M | Data Acquisition Flight Log 2BLK53V030A

Flight Log No.: 10076

1 LiDAR Operator: J. Gonzales	2 ALTM Model: Aquarius	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9522
7 Pilot: R. Tangonan	8 Co-Pilot: J. Mooney	9 Route:			
10 Date: January 30, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:35	14 Engine Off: 11:48	15 Total Engine Time: 3+13	16 Take off: 8:40	17 Landing: 11:43	18 Total Flight Time: 3+03
19 Weather: fine					

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
- ○ DREAM Admin Activities

21 Remarks

Covered 21 lines (voids) of BLK 53

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	SGT ERWIN REYES SANTOS PAF Signature over Printed Name (PAF Representative)	JEFFREY MOONEY Signature over Printed Name	JONATHAN GONZALES Signature over Printed Name	N/A Signature over Printed Name

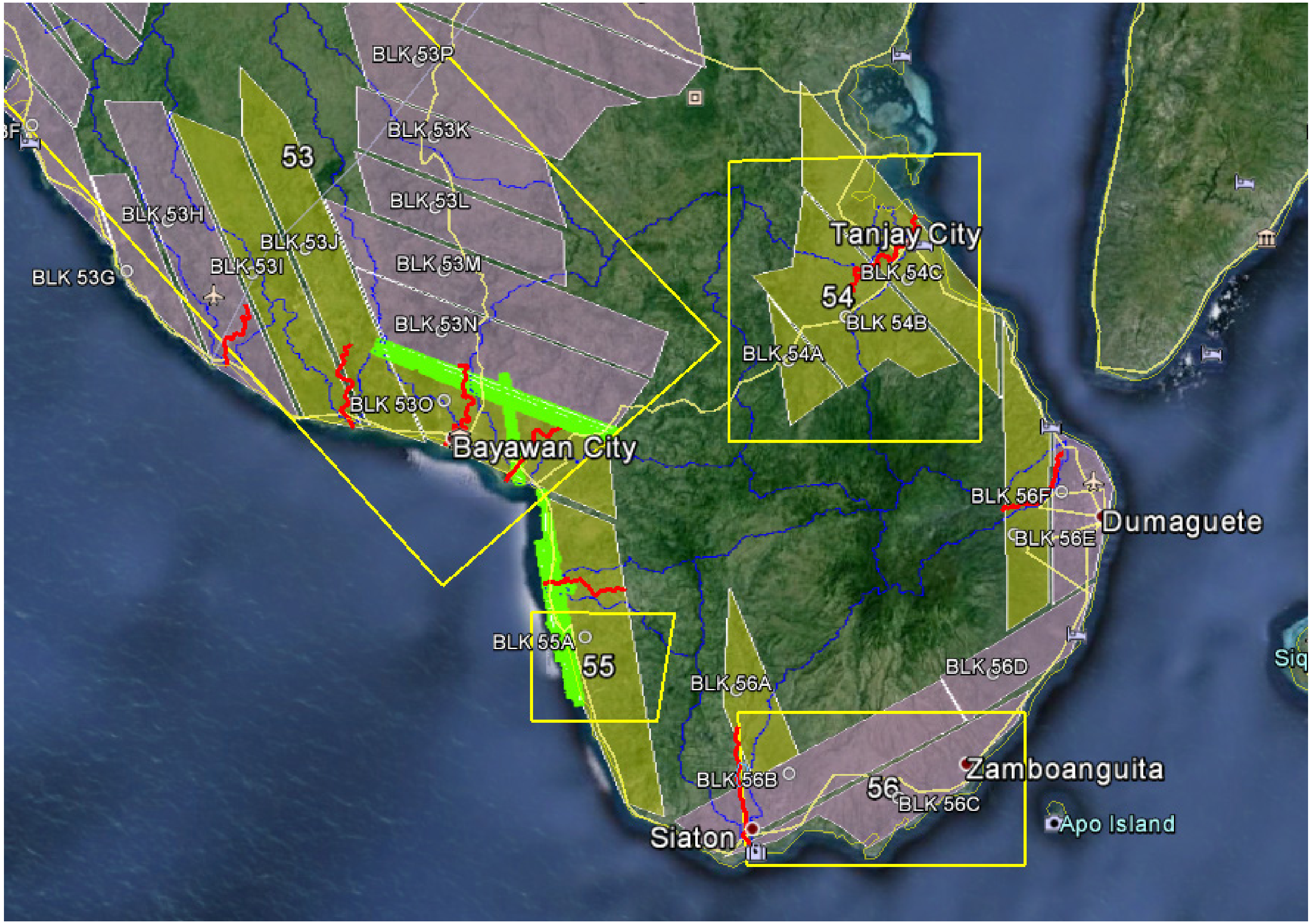
Annex 7. Flight Status Reports

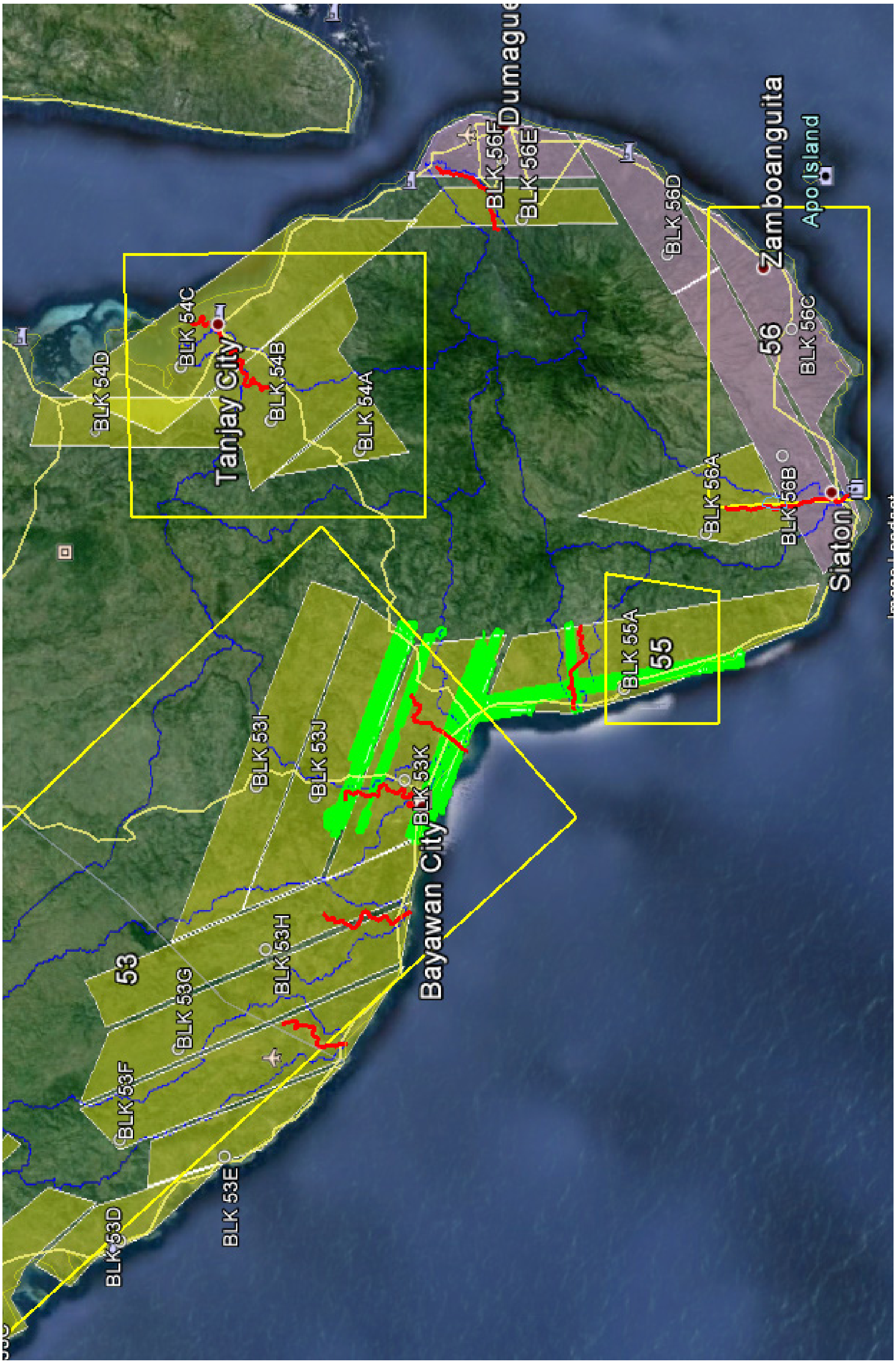
Negros Oriental Mission
September 20 – November 15, 2014 and January 21–February 1, 2016

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7526 G	BLK 53O & BLK 55A	2BLK53O55A273A	MVE Tonga	9/30/14	Surveyed 3 line of BLK53O and 4 lines of BLK55A
7540 G	BLK 55A & BLK 53K	2BLK55AS53KS280A	MR Villanueva	10/7/14	Surveyed 11 lines
7560 G	BLK 55A	2BLK55A290A	MVE Tonga	10/17/14	Mission completed with minimal voids
7562 G	BLK 53I	2BLK53I291A	MR Villanueva	10/18/14	Mission completed but there were voids encountered during the survey
7566 G	BLK 53K & BLK 53J	2BLK53JK293A	MVE Tonga	10/20/14	Mission completed with CASI
7568 G	BLK 53K	2BLK53KS294A	MR Villanueva	10/21/14	Mission completed
7570 G	BLK 53H	2BLK53H295A	MVE Tonga	10/22/14	Mission completed (with CASI)
7576 G	BLK53H	2BLK53H298A	MR Villanueva	10/25/14	Surveyed lines of BLK53H
7578 G	BLK53H & BLK53FG	2BLK53HSGF299A	MVE Tonga	10/26/14	Completed the rest of BLK53H and whole plan of BLK53G and surveyed lines of BLK53F
10076 G	BLK53 Voids	3BLK53V030A	J. Gonzales	1/30/16	Covered voids over BLK 53 CDEF

SWATH PER FLIGHT MISSION

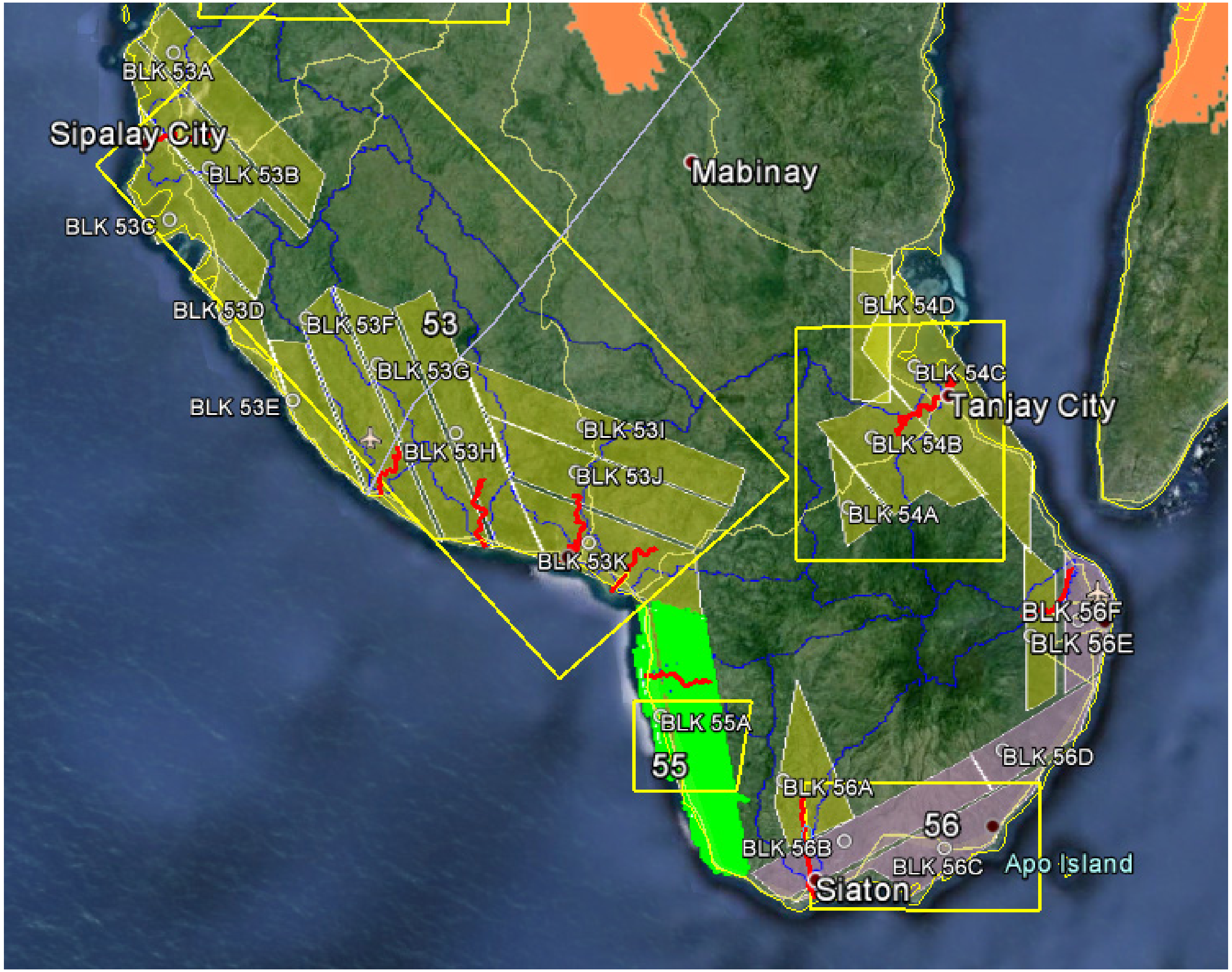
Flight No. : 7526
Area: BLK53O & BLK55A
Mission Name: 2BLK53O55A273A (BLK53K)



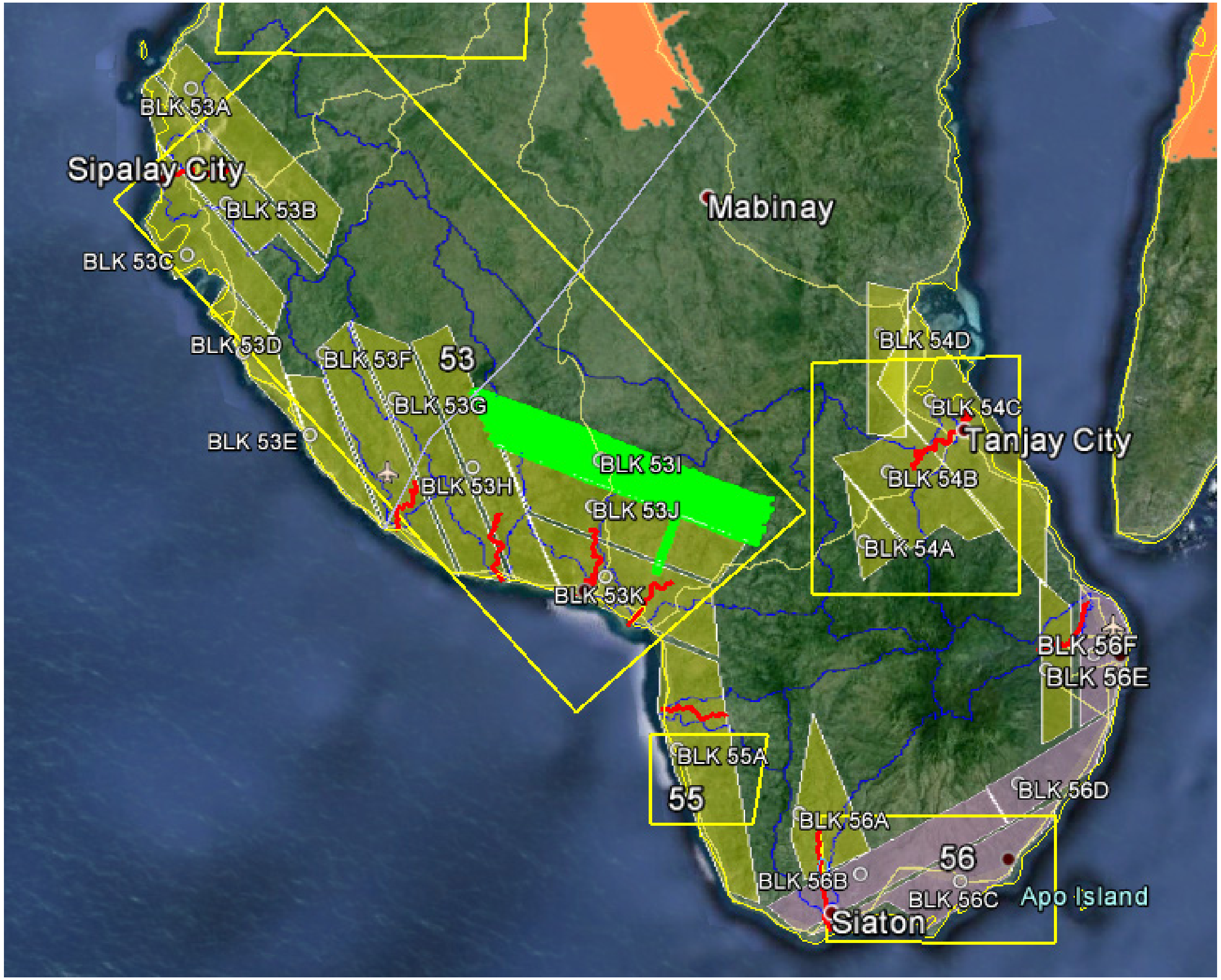


Flight No. : 7540
Area: BLK 55A and BLK 53K
Mission Name: 2BLK55AS53KS280A

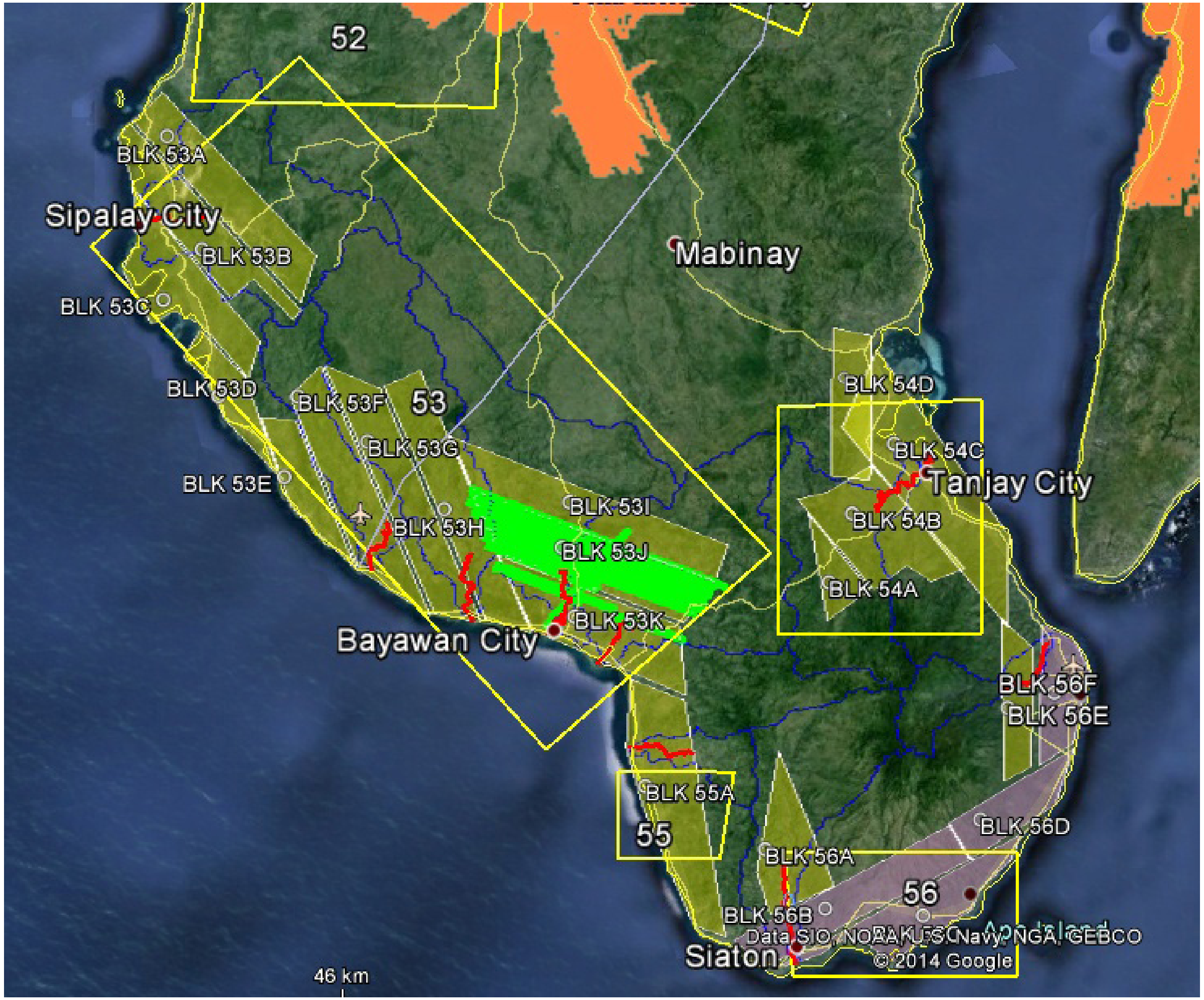
Flight No. :	7560
Area:	BLK 55A
Mission Name:	2BLK55A290A



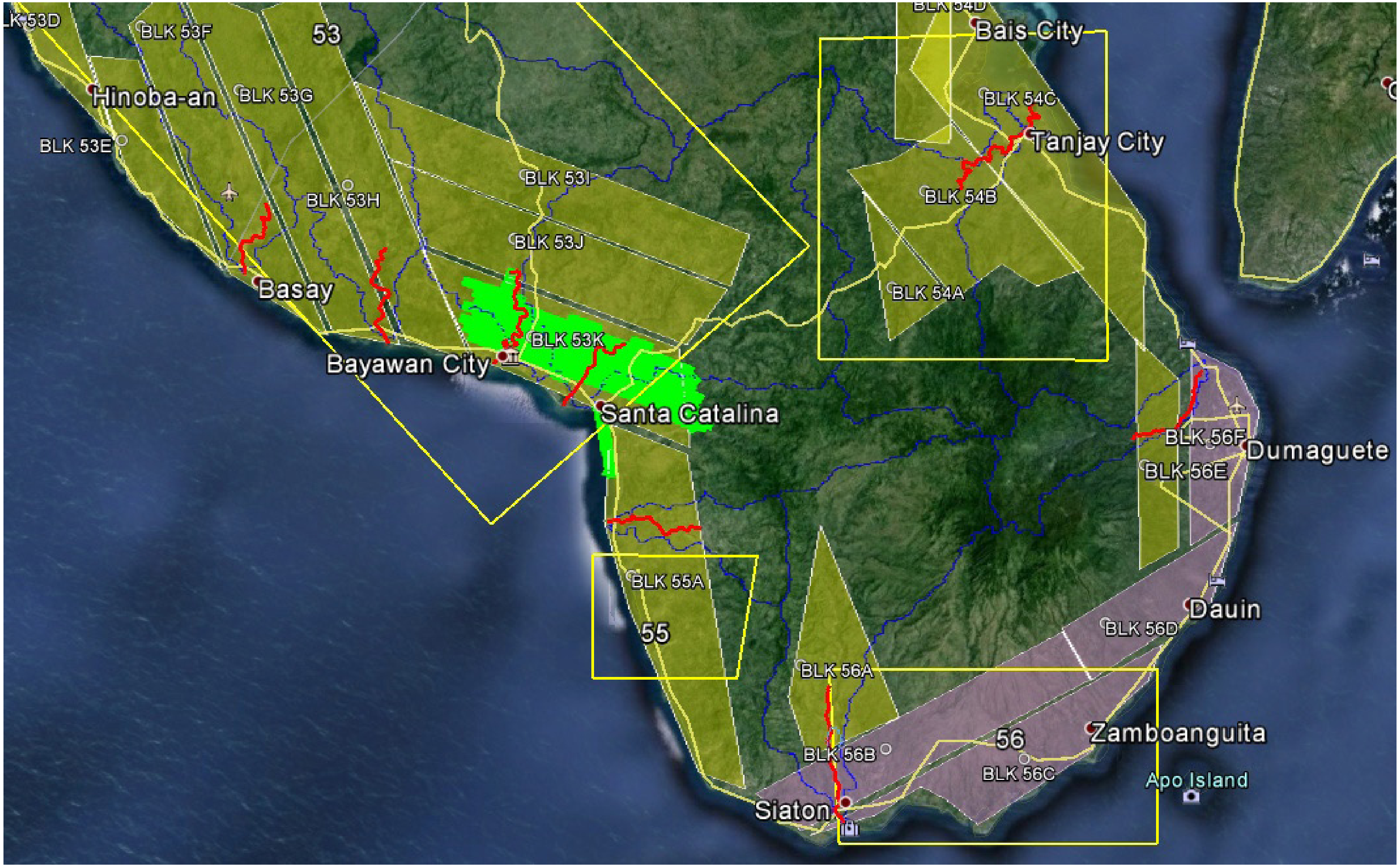
Flight No. :	7562
Area:	BLK 53I
Mission Name:	2BLK53I291A



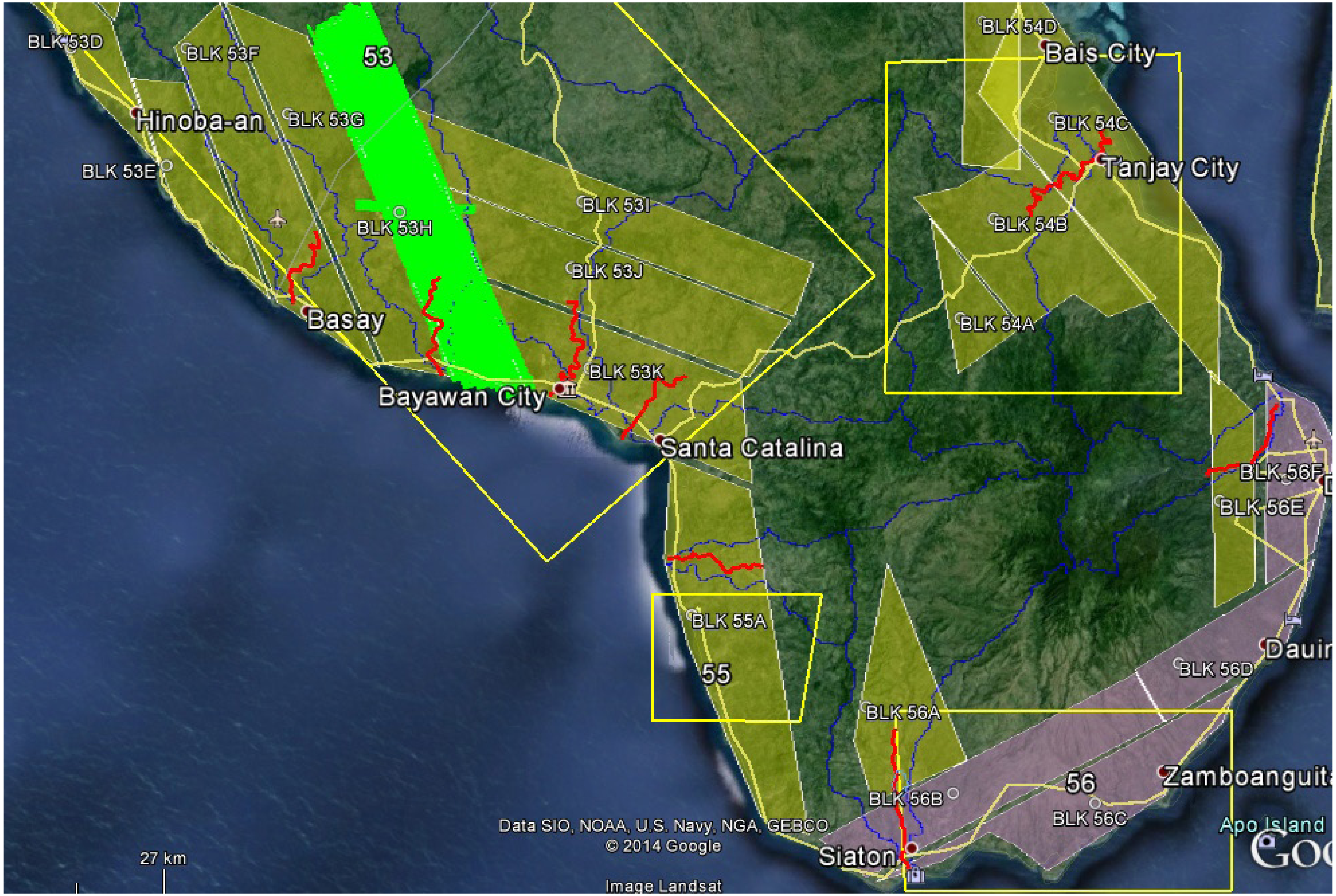
Flight No: 7566
Area: BLK 53K & BLK 53J
Mission Name: 2BLK53JK293A



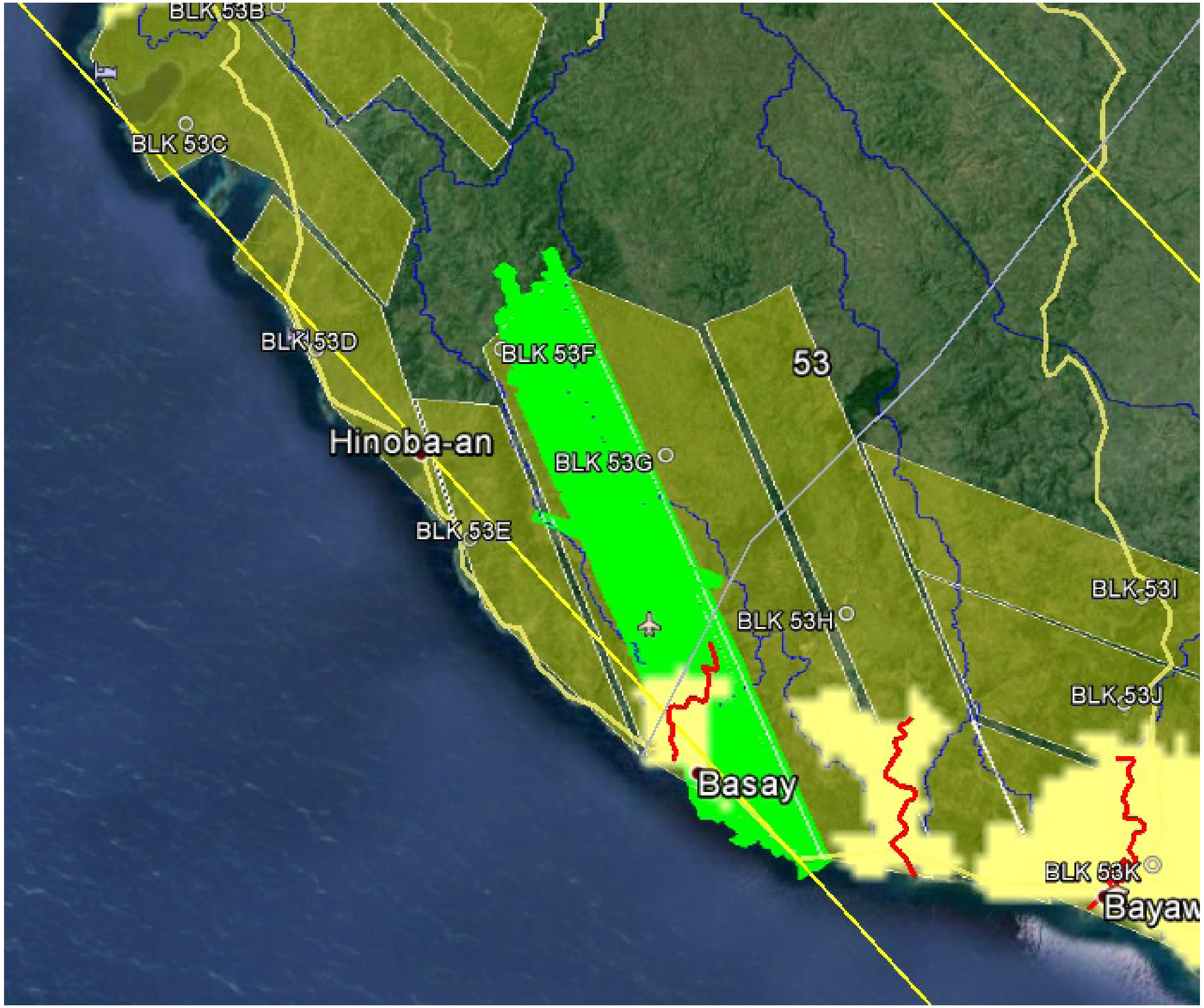
Flight No. : 7568
Area: BLK 53K
Mission Name: 2BLK53KS294A



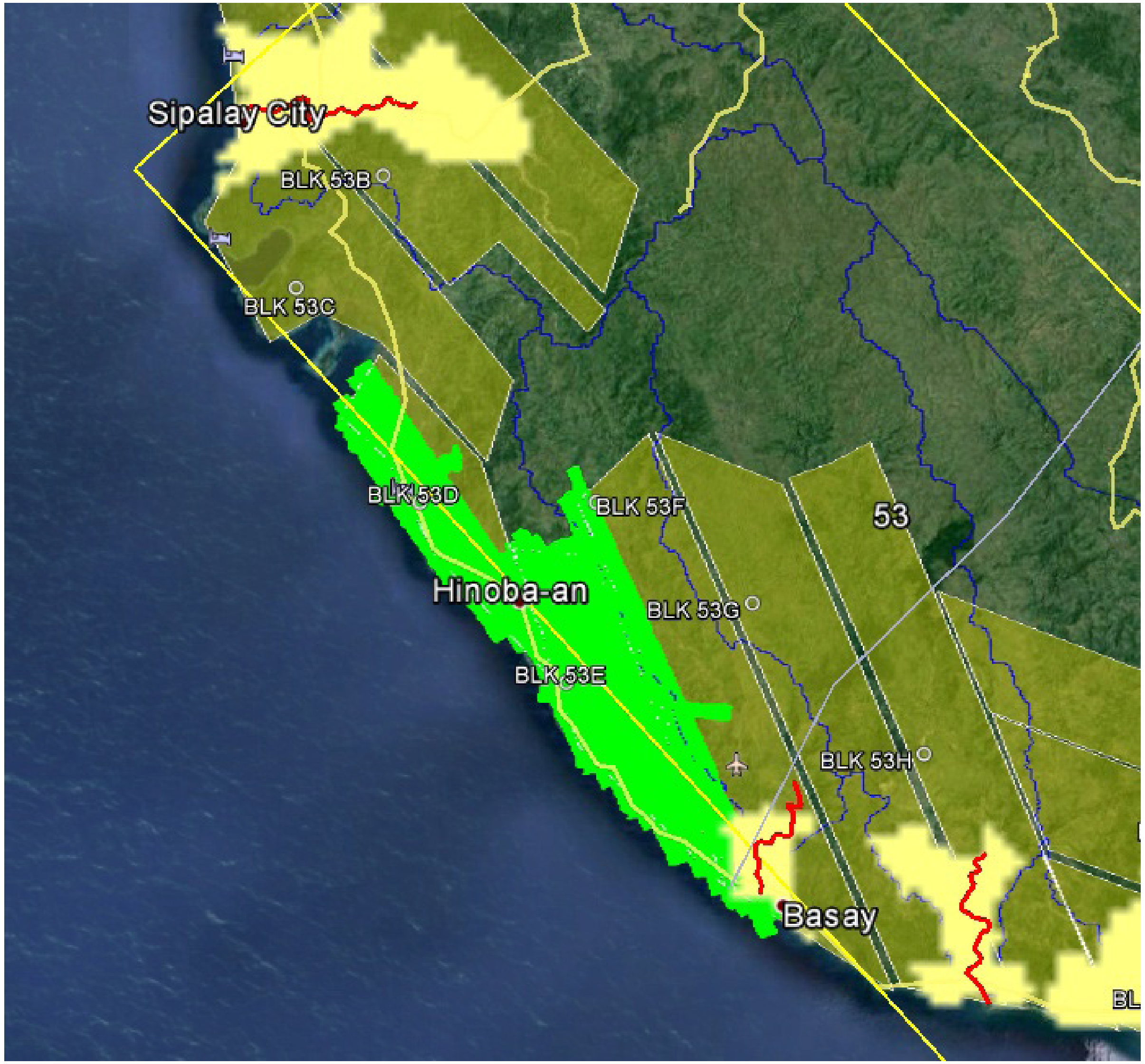
Flight No. : 7570
Area: BLK 53H
Mission Name: 2BLK53H295A

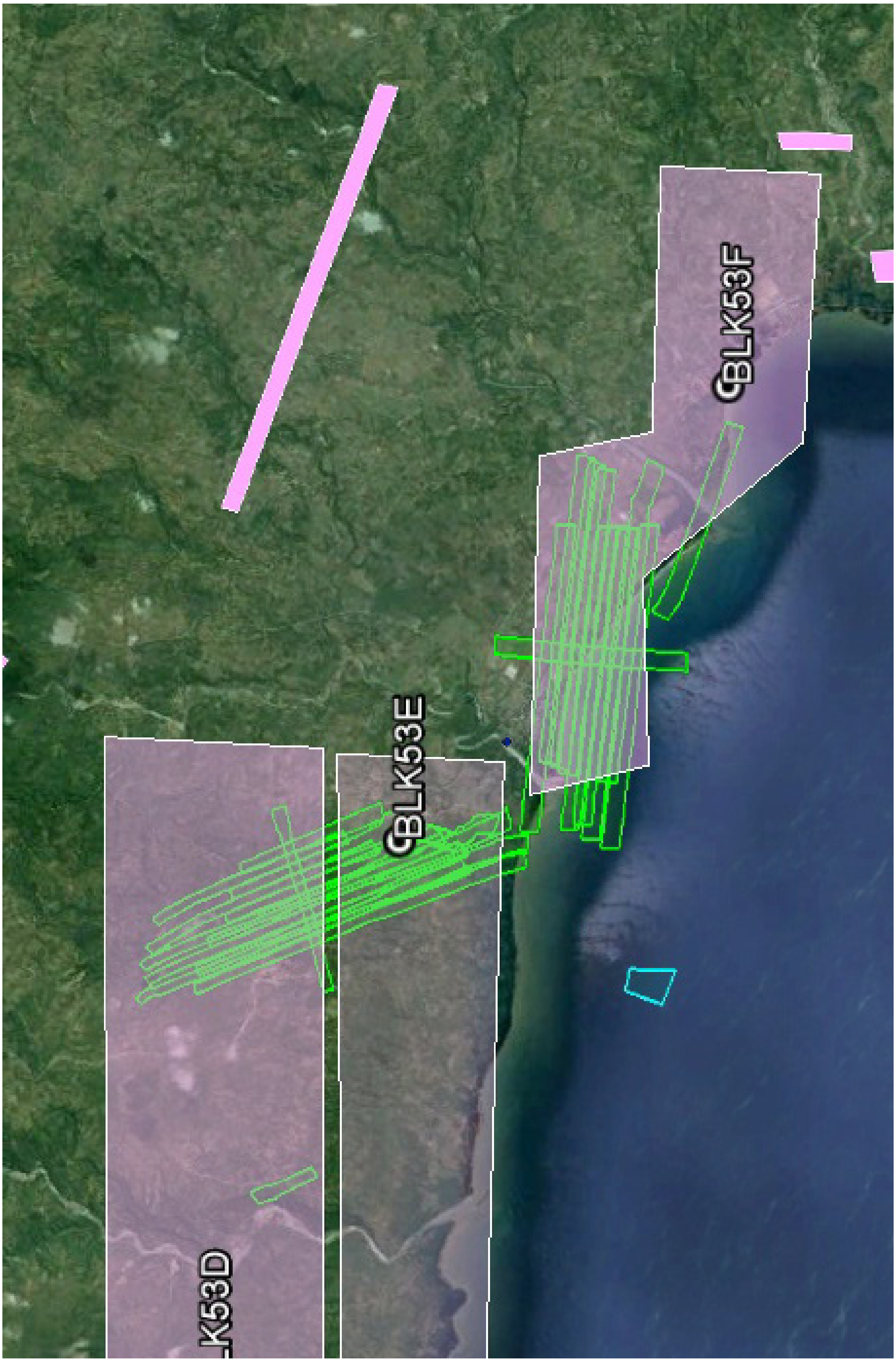


Flight No. :	7576
Area:	BLK 53F
Mission Name:	2BLK53F298A



Flight No. :	7578
Area:	BLK 53F, BLK 53E, BLK53D
Mission Name:	2BLK53FSED299A





Flight No.: 10076
Area: BLK53 VOIDS
Mission Name: 3BLK53V030A

Annex 8. Mission Summary Reports

Flight Area	Dumaguete
Mission Name	Blk53H
Inclusive Flights	7570G,7576G,7578G
Range data size	56.7 GB
POS	733 MB
Image	na
Base data size	17.66 MB
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)	0.095
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	2.4
Boresight correction stdev (<0.001deg)	0.000168
IMU attitude correction stdev (<0.001deg)	0.000941
GPS position stdev (<0.01m)	0.0163
Minimum % overlap (>25)	42.05%
Ave point cloud density per sq.m. (>2.0)	4.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	513
Maximum Height	566.13 m
Minimum Height	60.29
Classification (# of points)	
Ground	160,627,756
Low vegetation	155,917,160
Medium vegetation	429,917,645
High vegetation	622,384,647
Building	15,103,346
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Engr. Jeffrey Delica

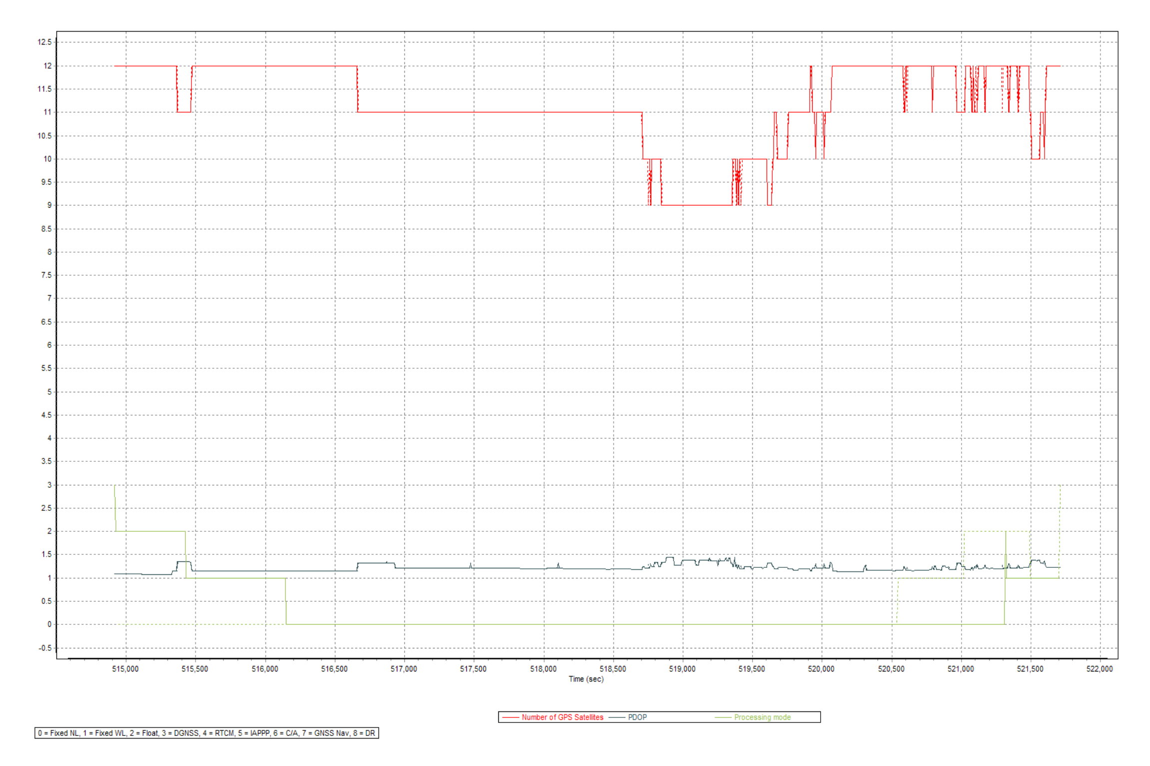


Figure 1.1.1 Solution Status

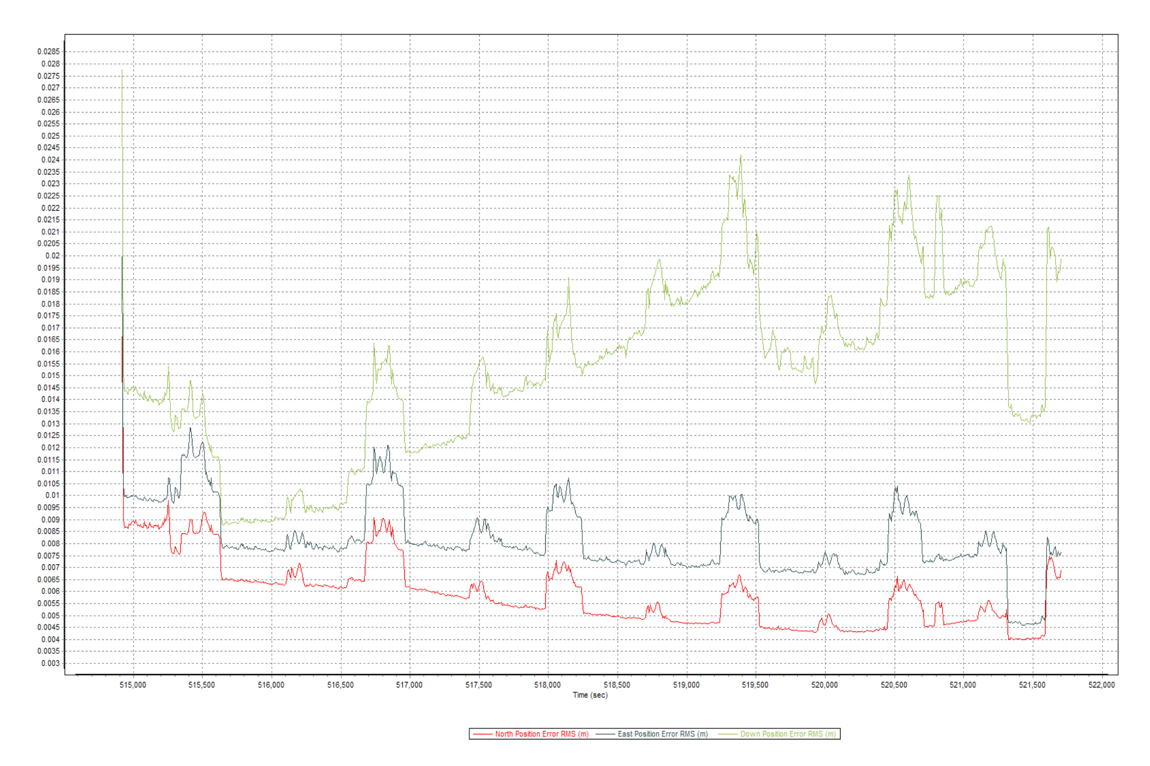


Figure 1.1.2 Smoothed Performance Metric Parameters

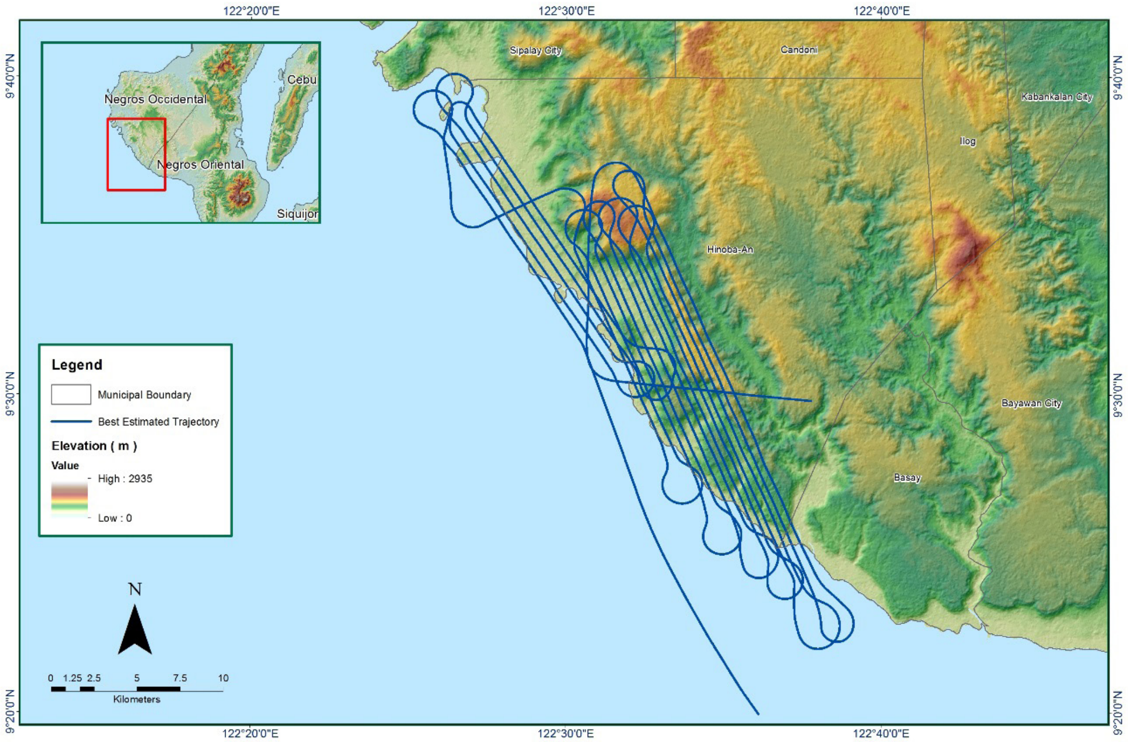


Figure 1.1.3 Best Estimated Trajectory

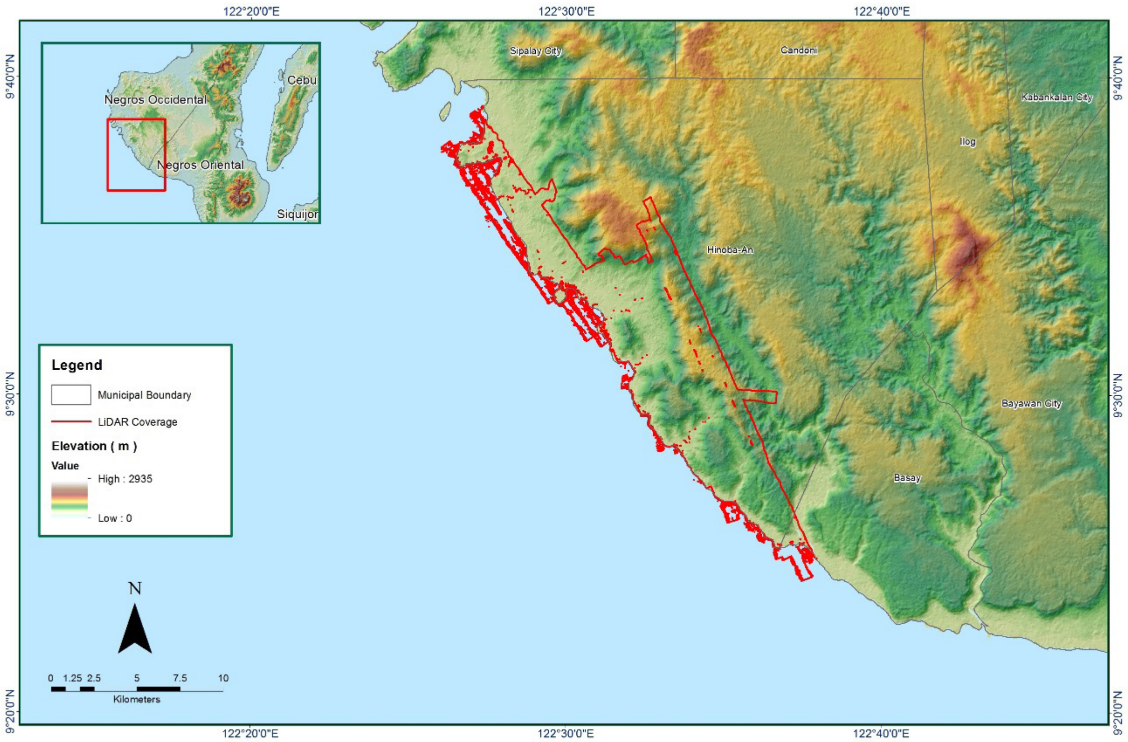


Figure 1.1.4 Coverage of LiDAR data

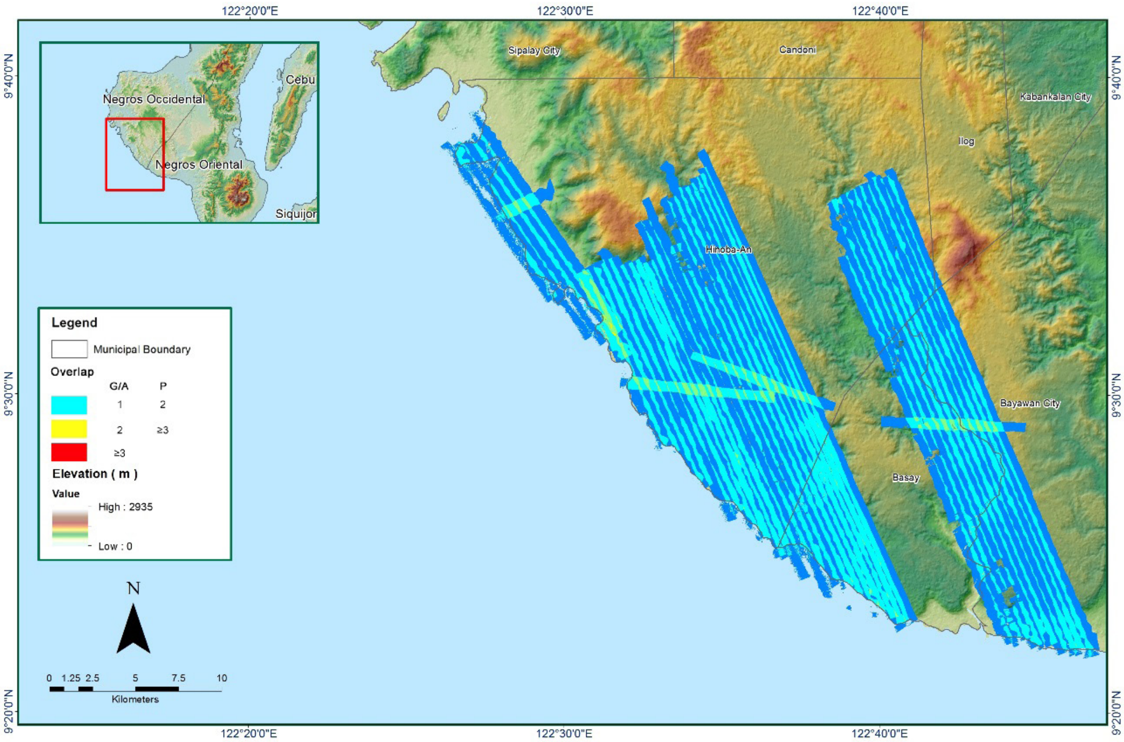


Figure 1.1.5 Image of Data Overlap

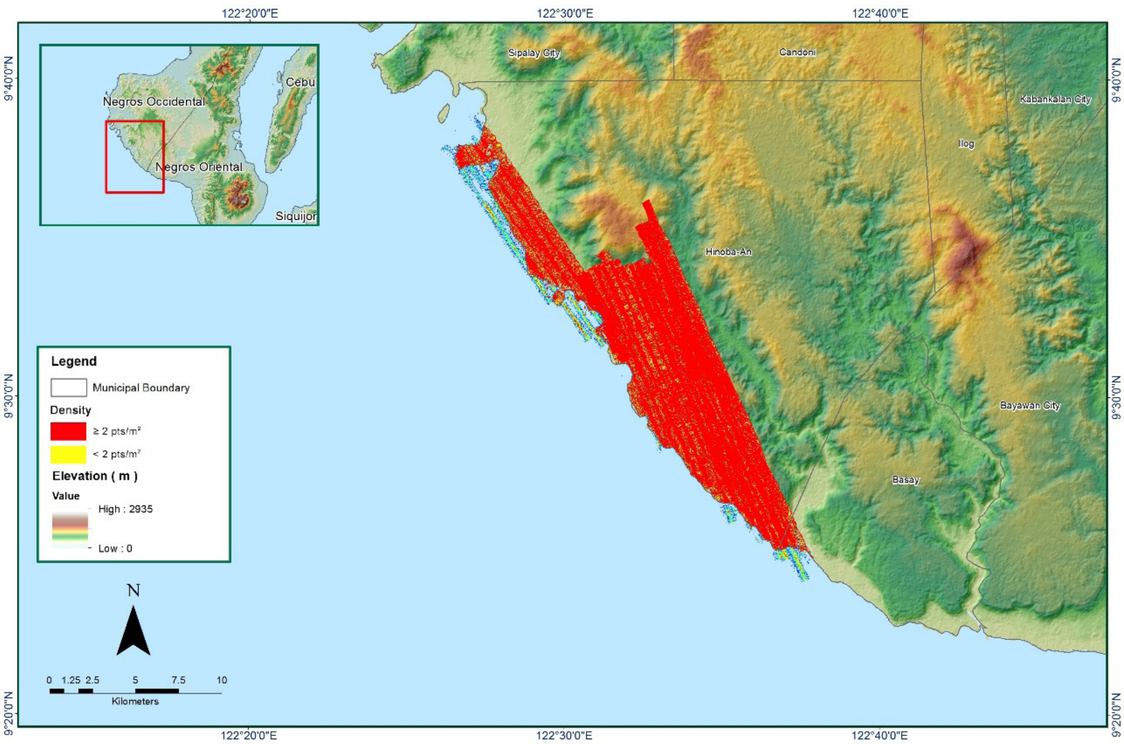


Figure 1.1.6 Density map of merged LiDAR data

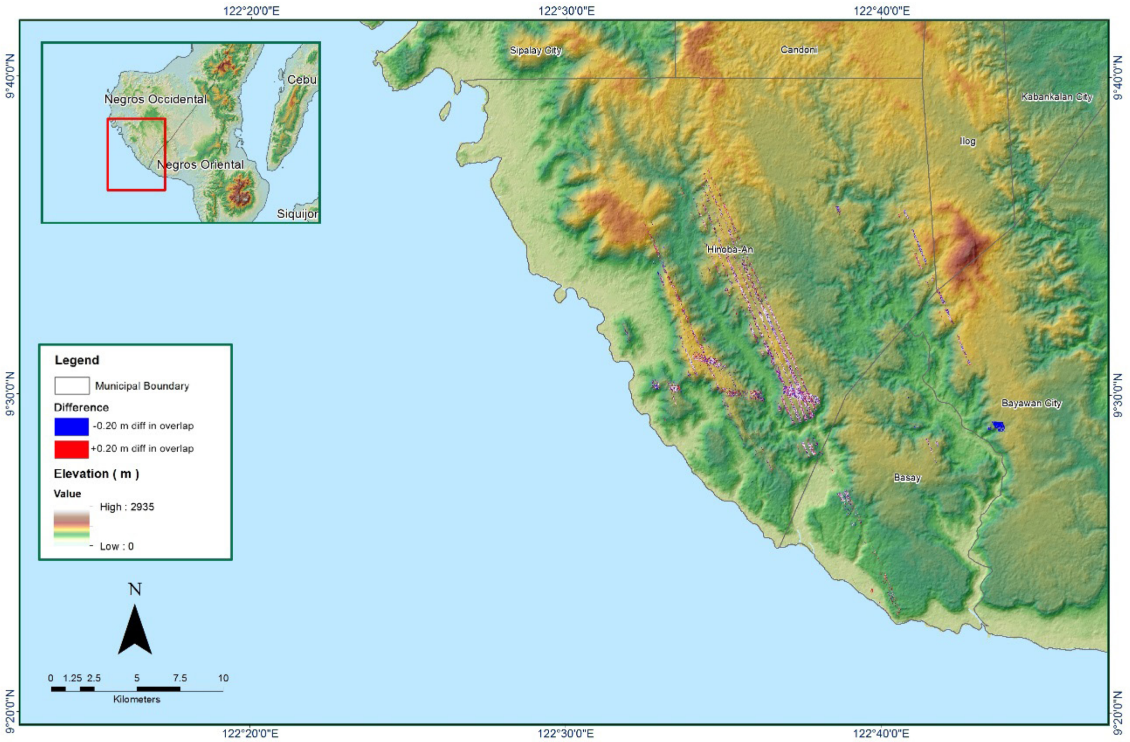


Figure 1.1.7 Elevation Difference between Flight Lines

Flight Area	Dumaguete
Mission Name	**Blk53J**
Inclusive Flights	7566G
Range data size	19.0 GB
POS	210 MB
Image	na
Base data size	6.05 MB
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)	1.25
RMSE for East Position (<4.0 cm)	3.0
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000126
IMU attitude correction stdev (<0.001deg)	0.000301
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	30.01%
Ave point cloud density per sq.m. (>2.0)	3.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	440.16 m
Minimum Height	62.84 m
Classification (# of points)	
Ground	70,438,370
Low vegetation	63,300,697
Medium vegetation	166,611,886
High vegetation	213,423,896
Building	2,735,569
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Jeffrey Delica

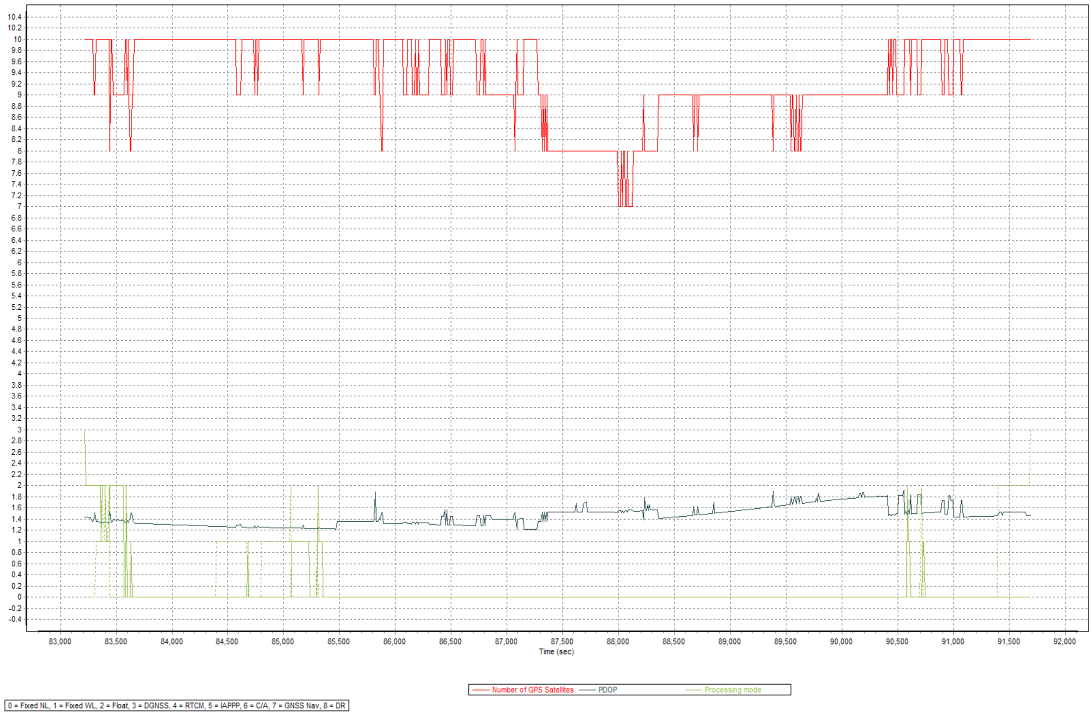


Figure 1.2.1 Solution Status

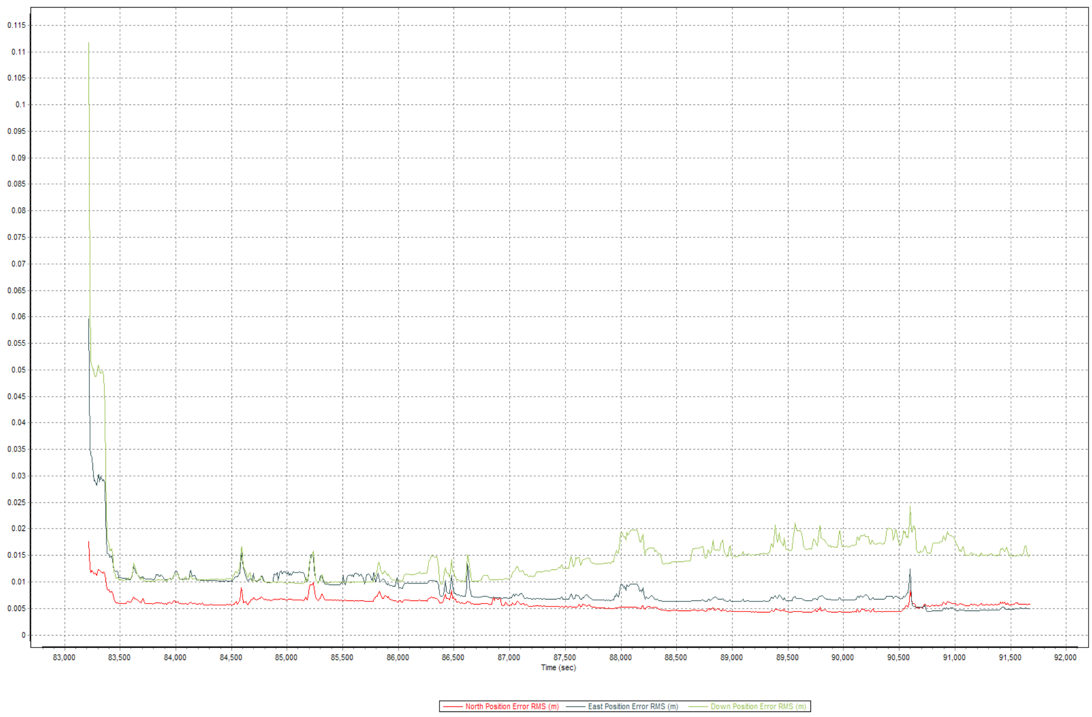


Figure 1.2.2 Smoothed Performance Metric Parameters

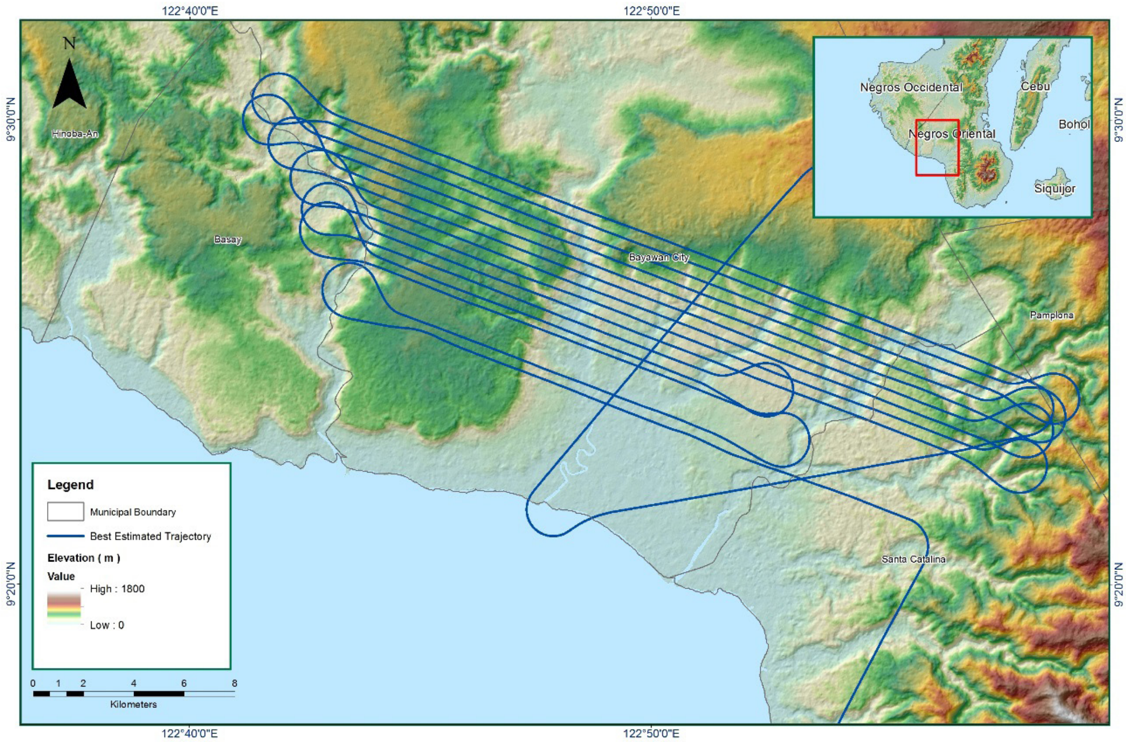


Figure 1.2.3 Best Estimated Trajectory

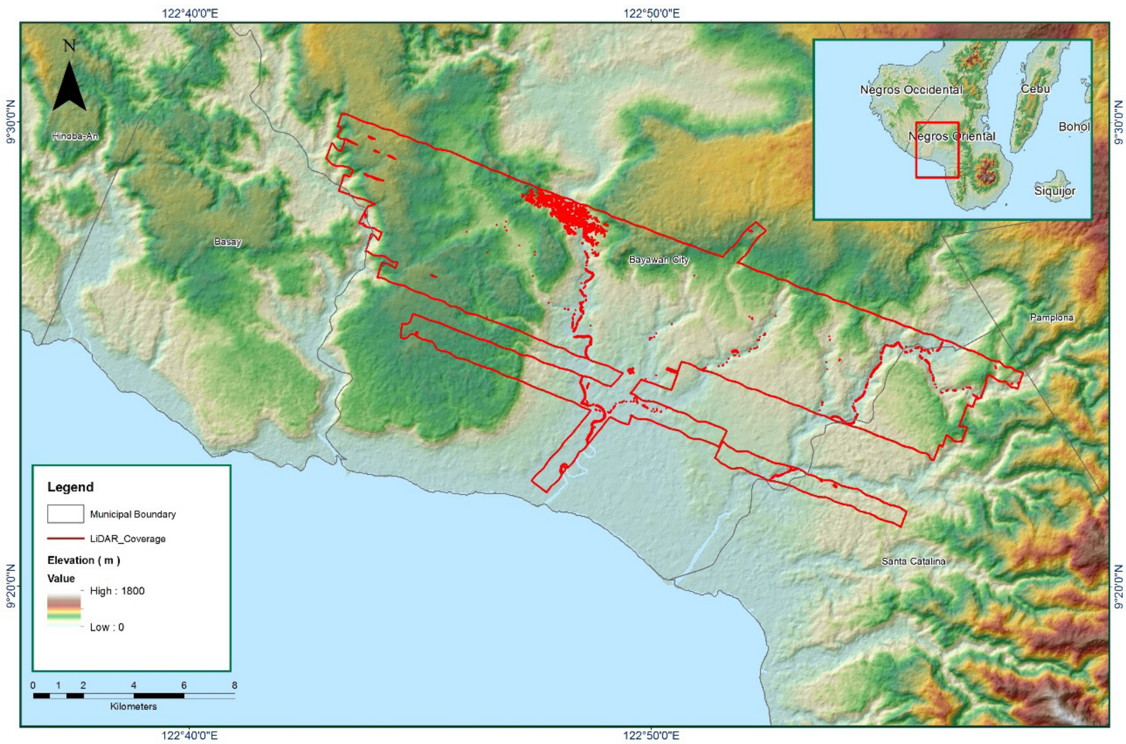


Figure 1.2.4 Coverage of LiDAR Data

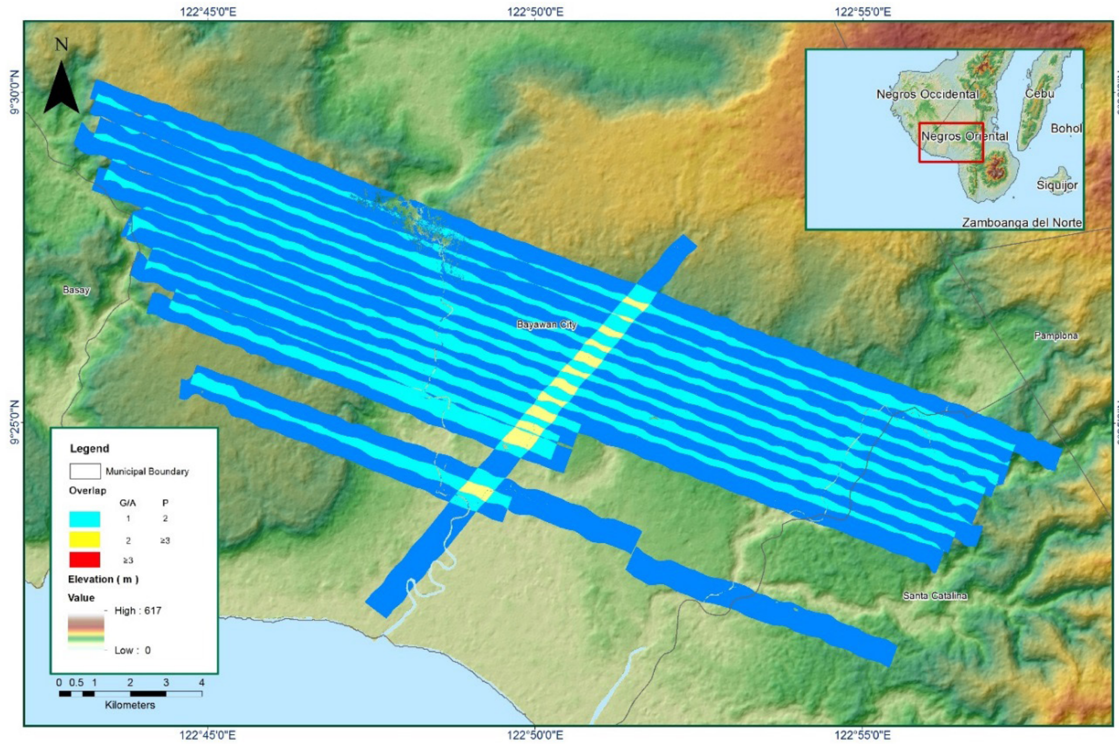


Figure 1.2.5 Image of Data Overlap

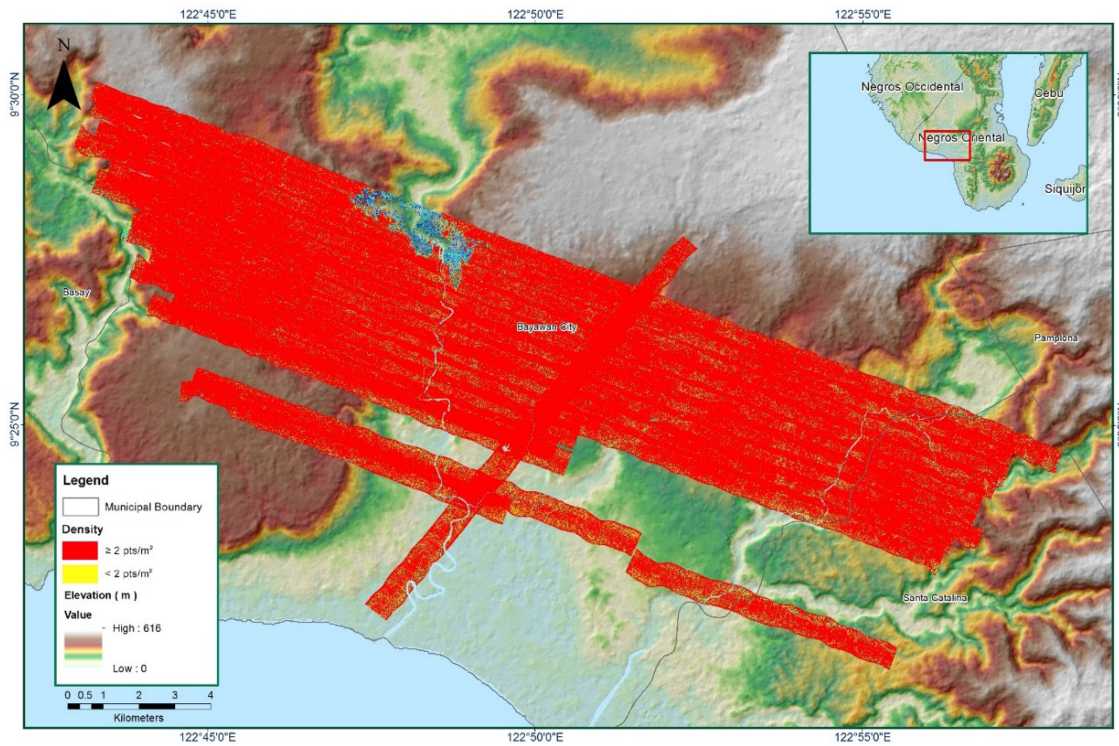


Figure 1.2.6 Density map of merged LiDAR data

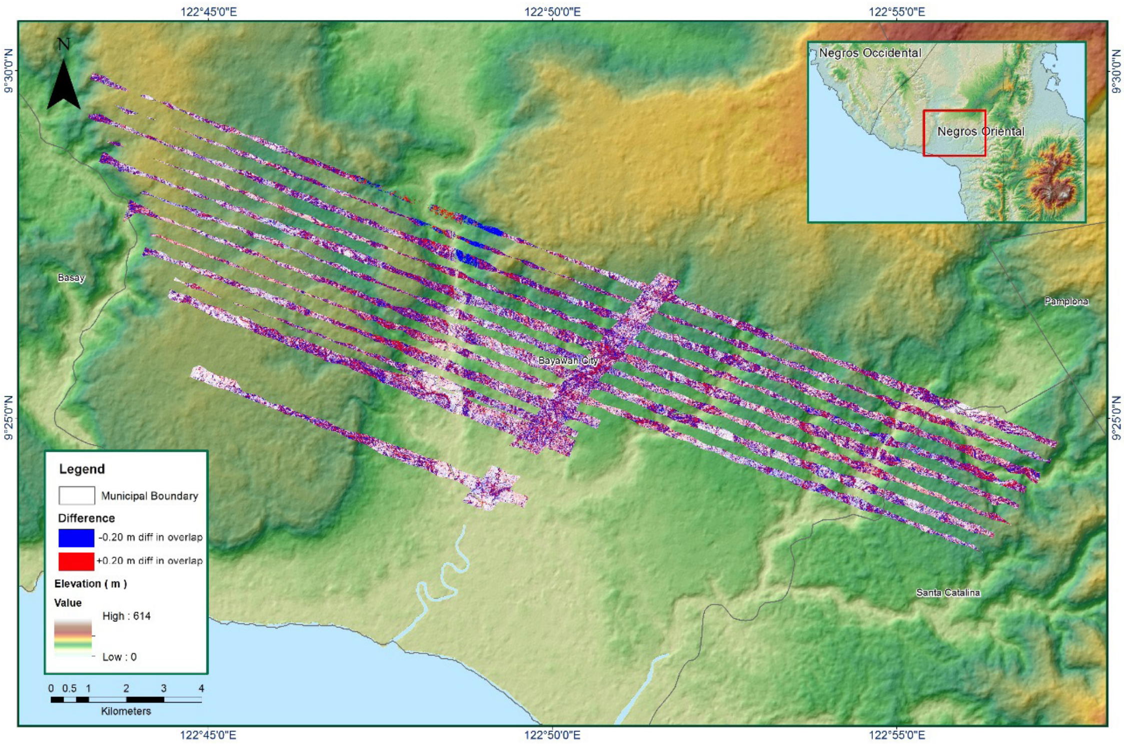


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Dumaguete
Mission Name	**Blk53K**
Inclusive Flights	7540G,7566G,7568G
Range data size	41.99 GB
POS	610 MB
Image	na
Base data size	17.0 MB
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)	1.0
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000194
IMU attitude correction stdev (<0.001deg)	0.157208
GPS position stdev (<0.01m)	0.0132
Minimum % overlap (>25)	46.62%
Ave point cloud density per sq.m. (>2.0)	3.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	442.28 m
Minimum Height	62.23 m
Classification (# of points)	
Ground	52,875,981
Low vegetation	63,446,538
Medium vegetation	142,908,519
High vegetation	123,701,134
Building	3,086,316
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Christy Lubiano, Jovy Narisma

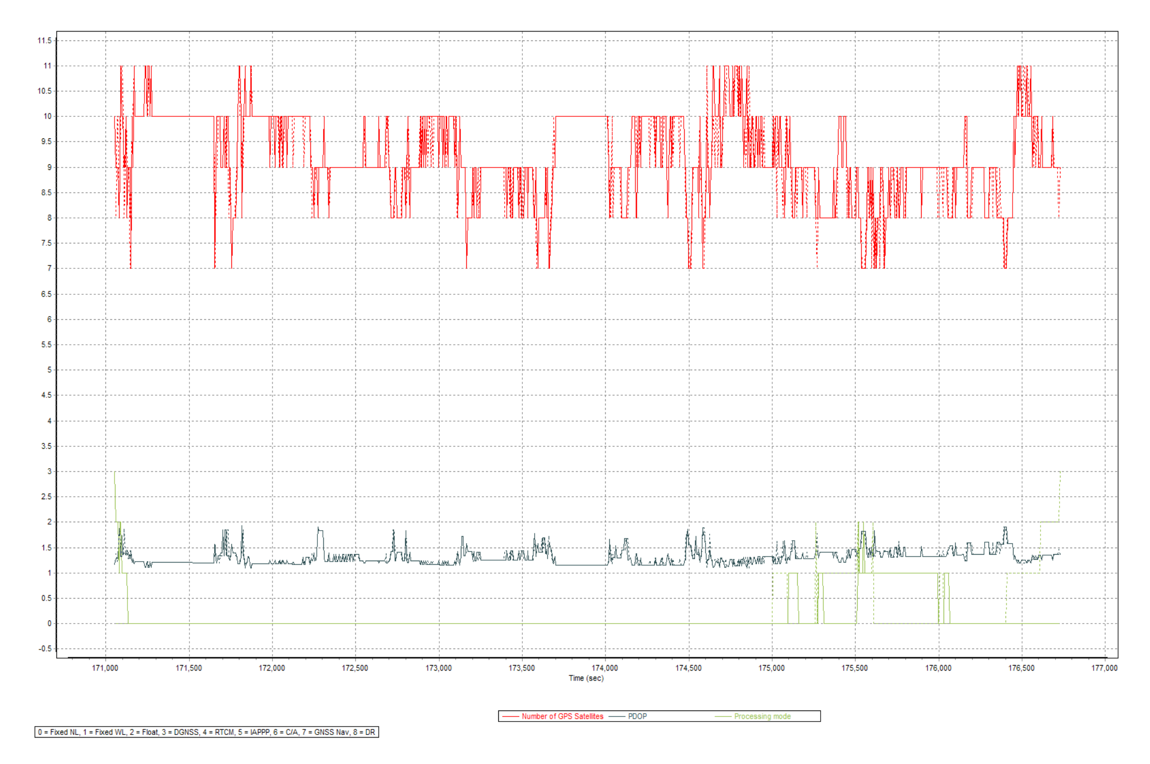


Figure 1.3.1 Solution Status

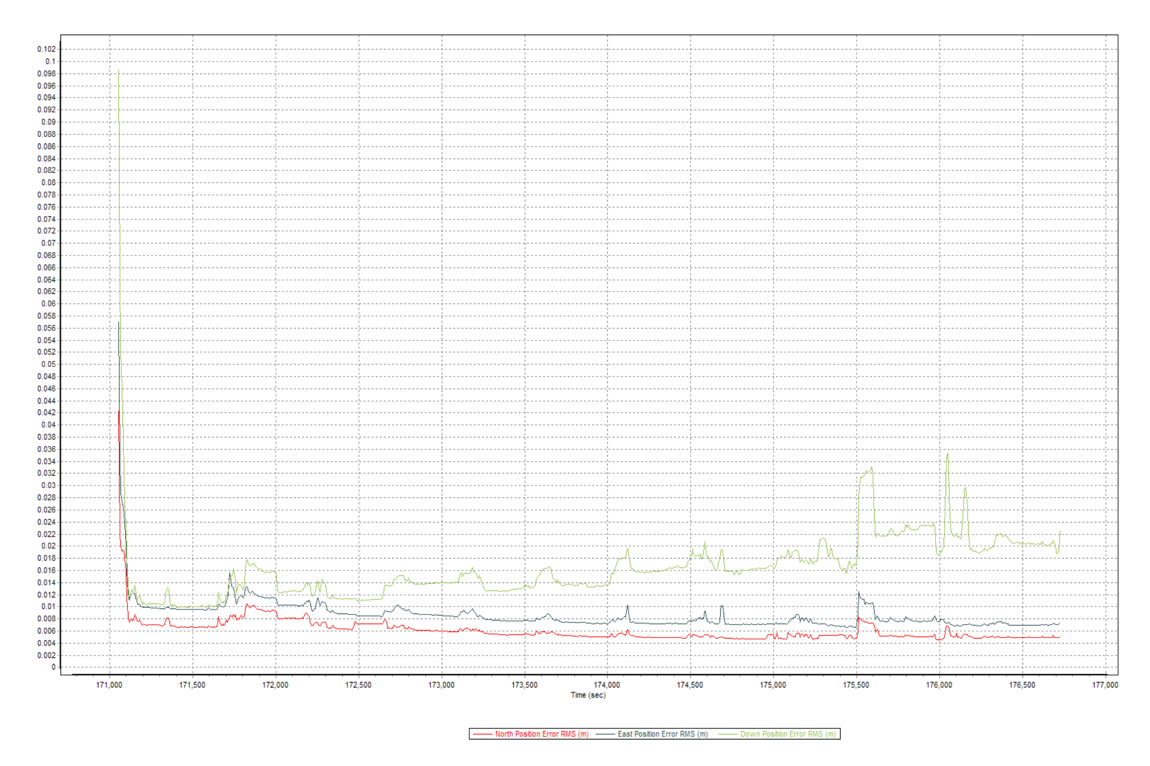


Figure 1.3.2 Smoothed Performance Metric Parameters

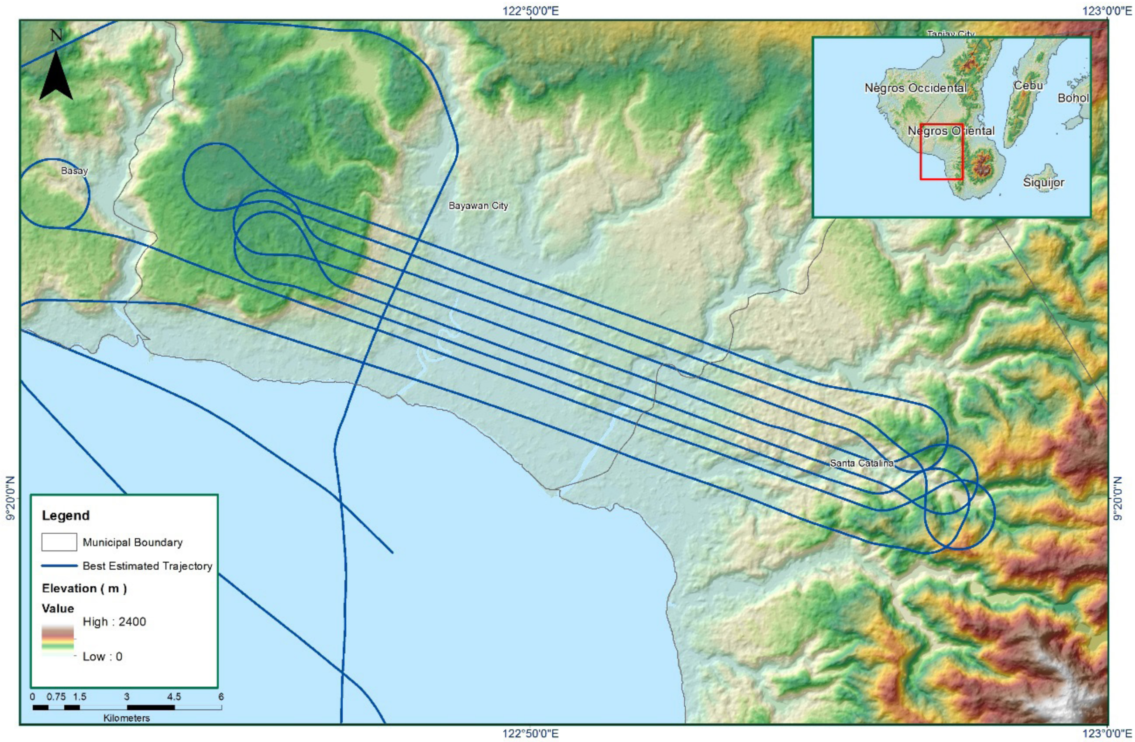


Figure 1.3.3 Best Estimated Trajectory

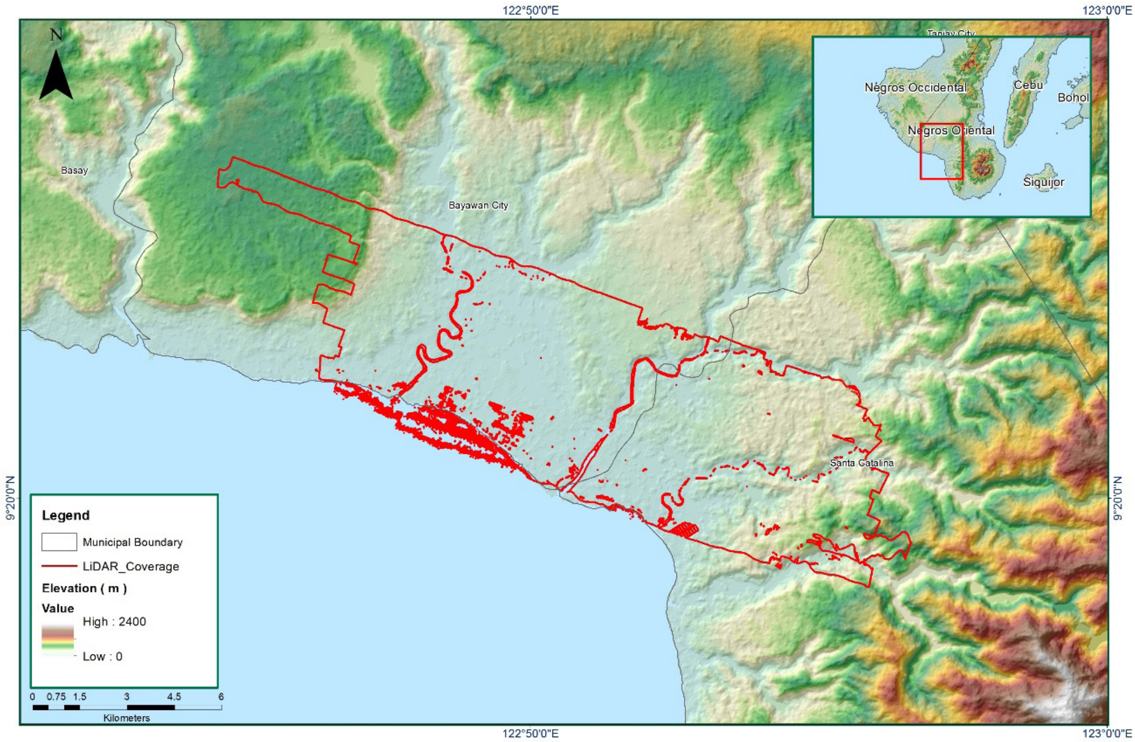


Figure 1.3.4 Coverage of LiDAR Data

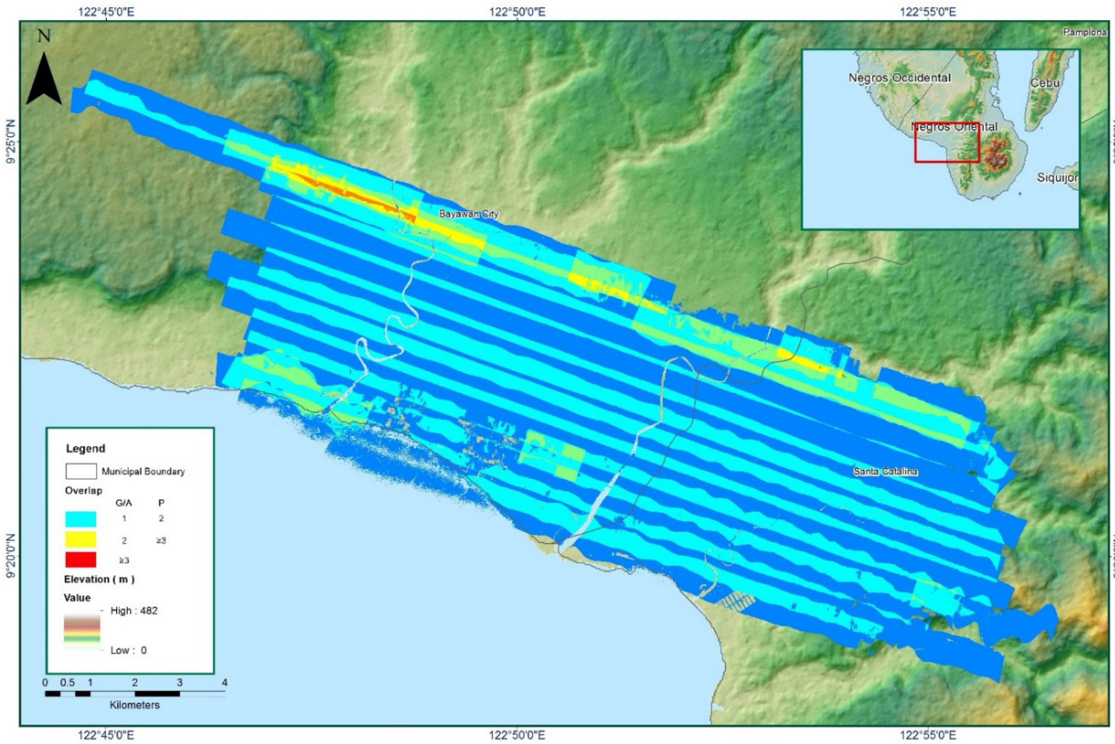


Figure 1.3.5 Image of Data Overlap

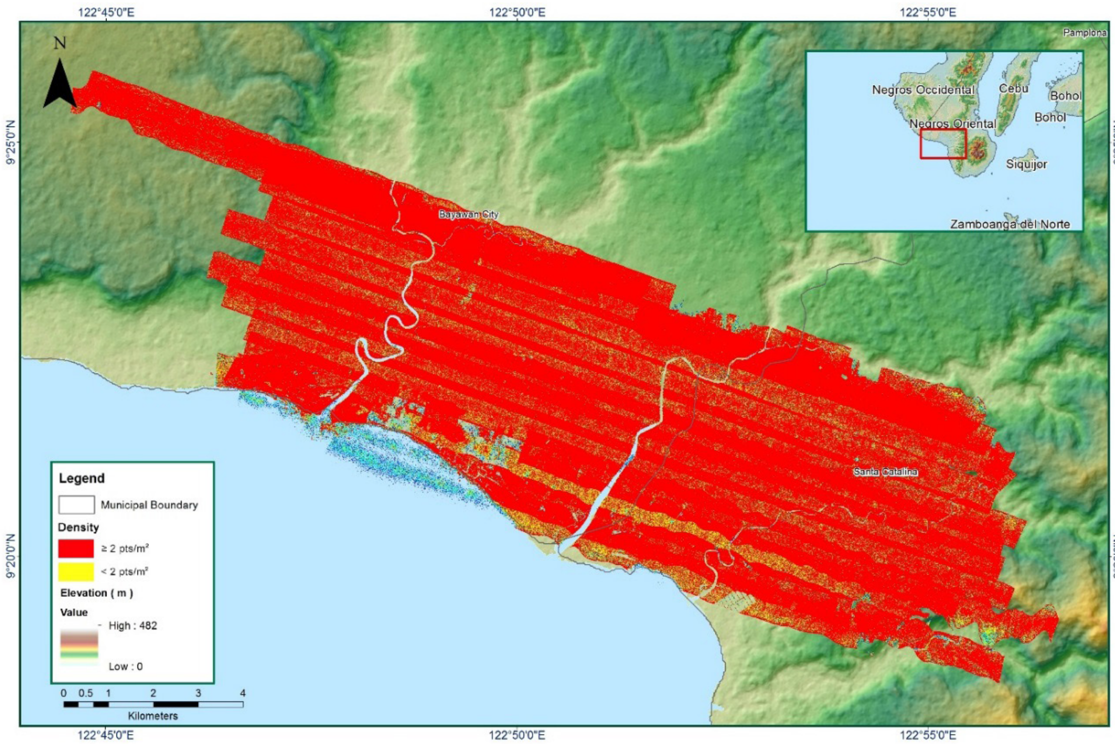


Figure 1.3.6 Density map of merged LiDAR data

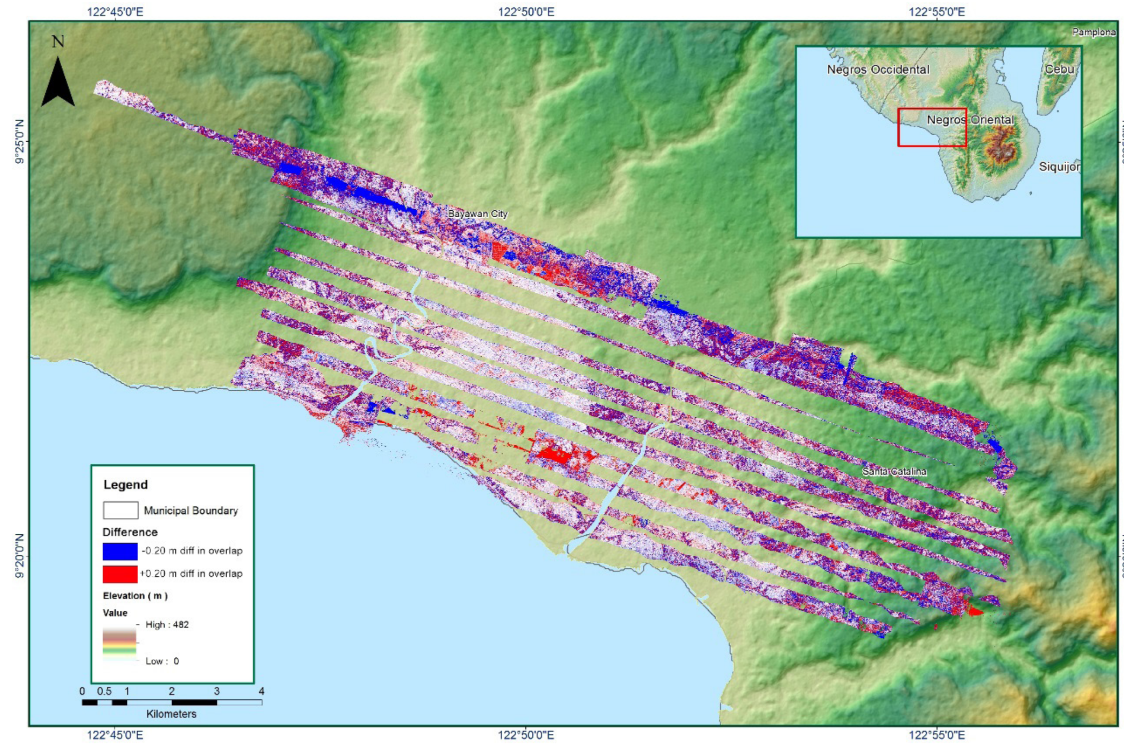


Figure 1.3.7 Elevation difference between flight lines

Flight Area	Dumaguete
Mission Name	Blk53Ks
Inclusive Flights	7526G,7540G
Range data size	20.9 GB
POS	352 MB
Image	na
Base data size	8.85 MB
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)	0.082
RMSE for East Position (<4.0 cm)	1.05
RMSE for Down Position (<8.0 cm)	1.9
Boresight correction stdev (<0.001deg)	0.000571
IMU attitude correction stdev (<0.001deg)	0.001794
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	47.63%
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	93
Maximum Height	383.29 m
Minimum Height	64.07 m
Classification (# of points)	
Ground	21,234,446
Low vegetation	22,518,129
Medium vegetation	75,022,634
High vegetation	65,449,423
Building	801,385
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Ailyn Biňas

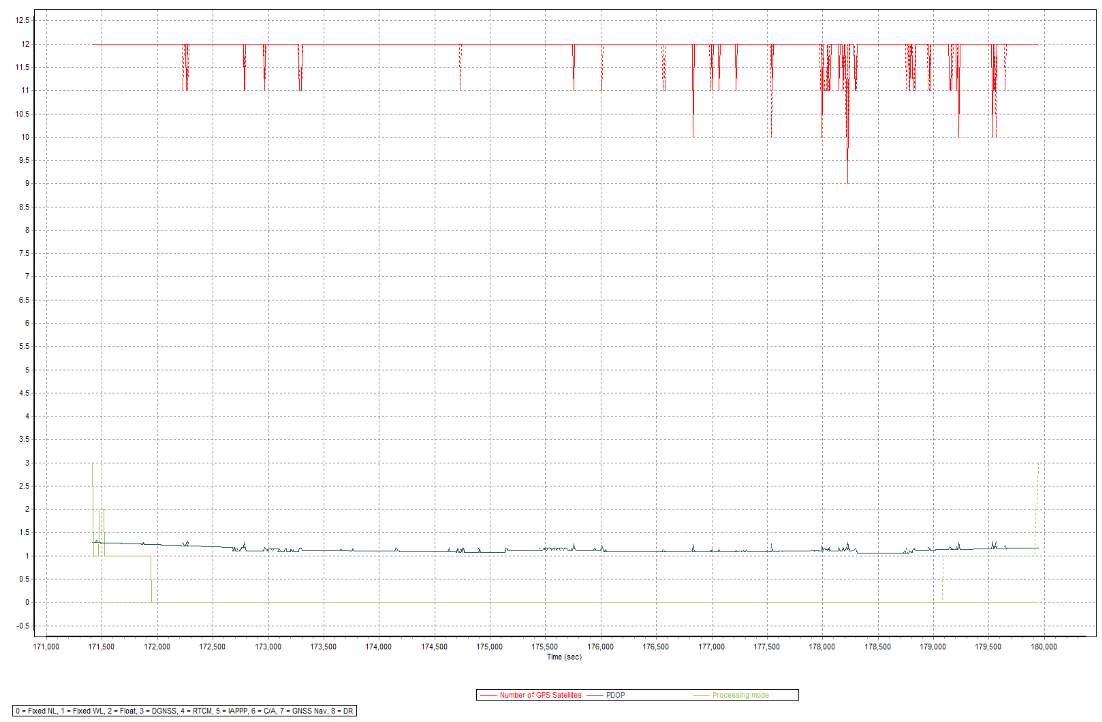


Figure 1.4.1 Solution Status

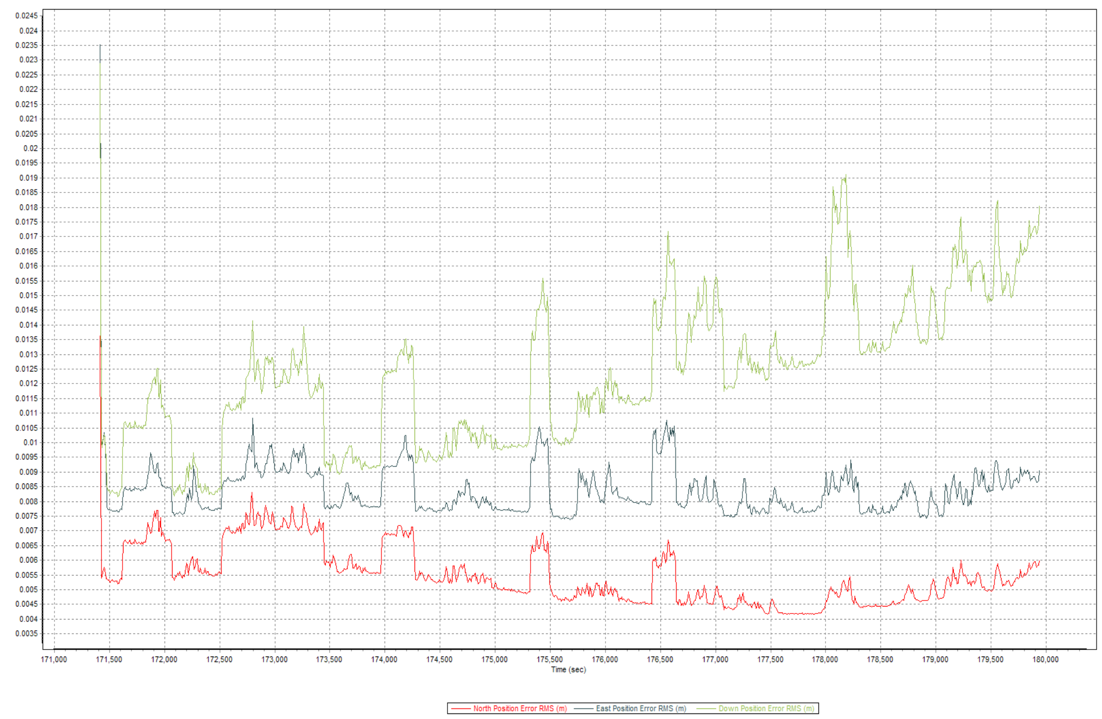


Figure 1.4.2 Smoothed Performance Metric Parameters

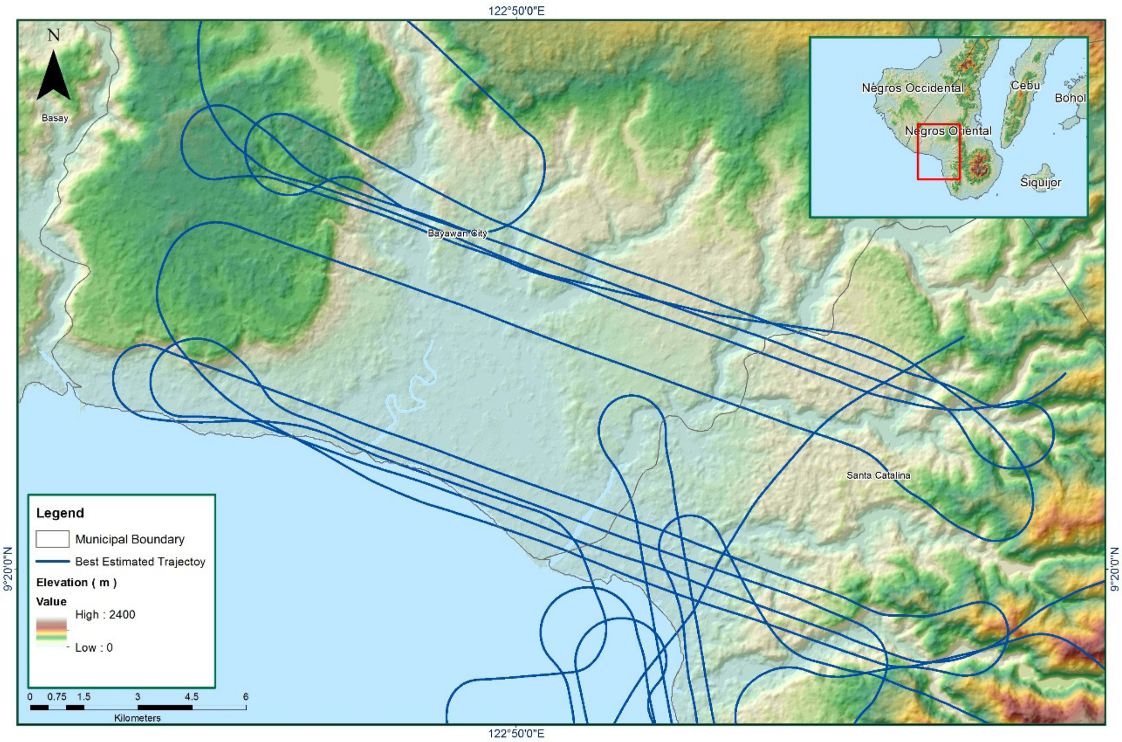


Figure 1.4.3 Best Estimated Trajectory

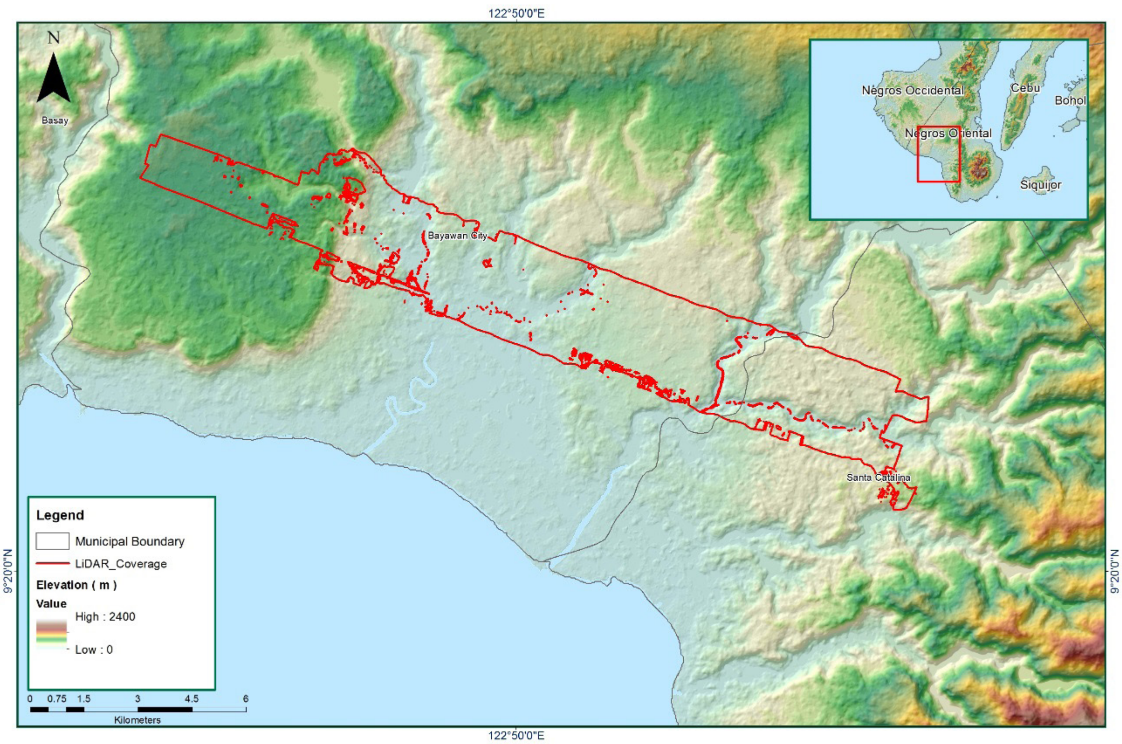


Figure 1.4.4 Coverage of LiDAR data

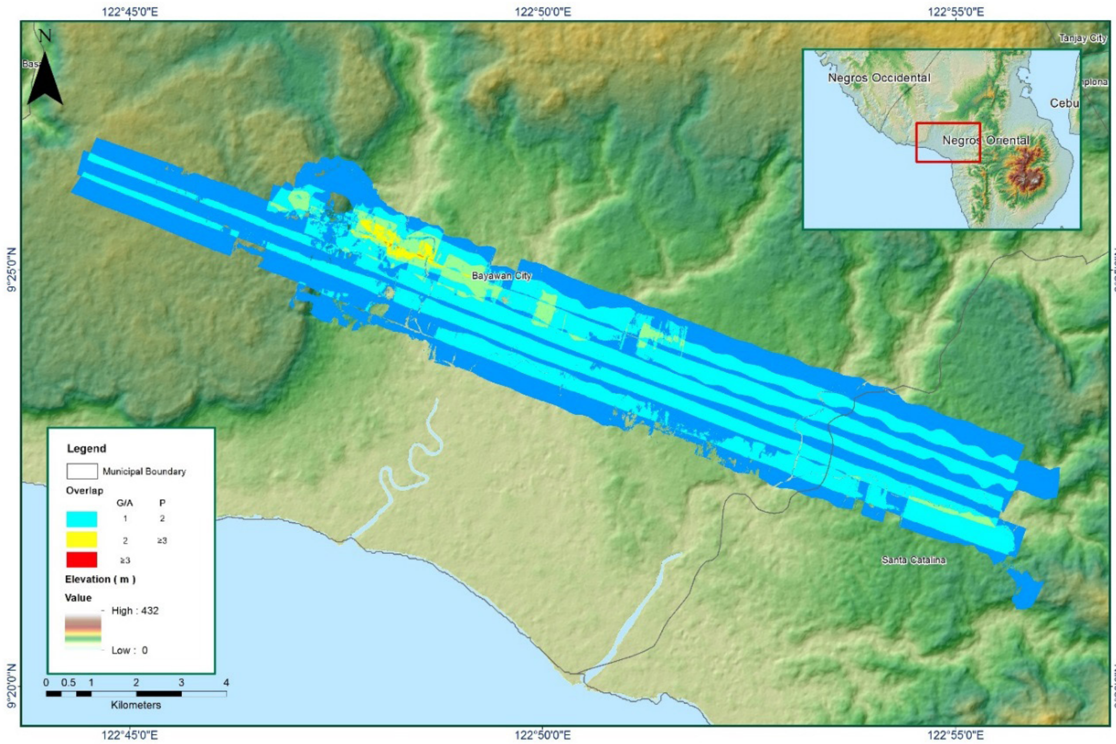


Figure 1.4.5 Image of data overlap

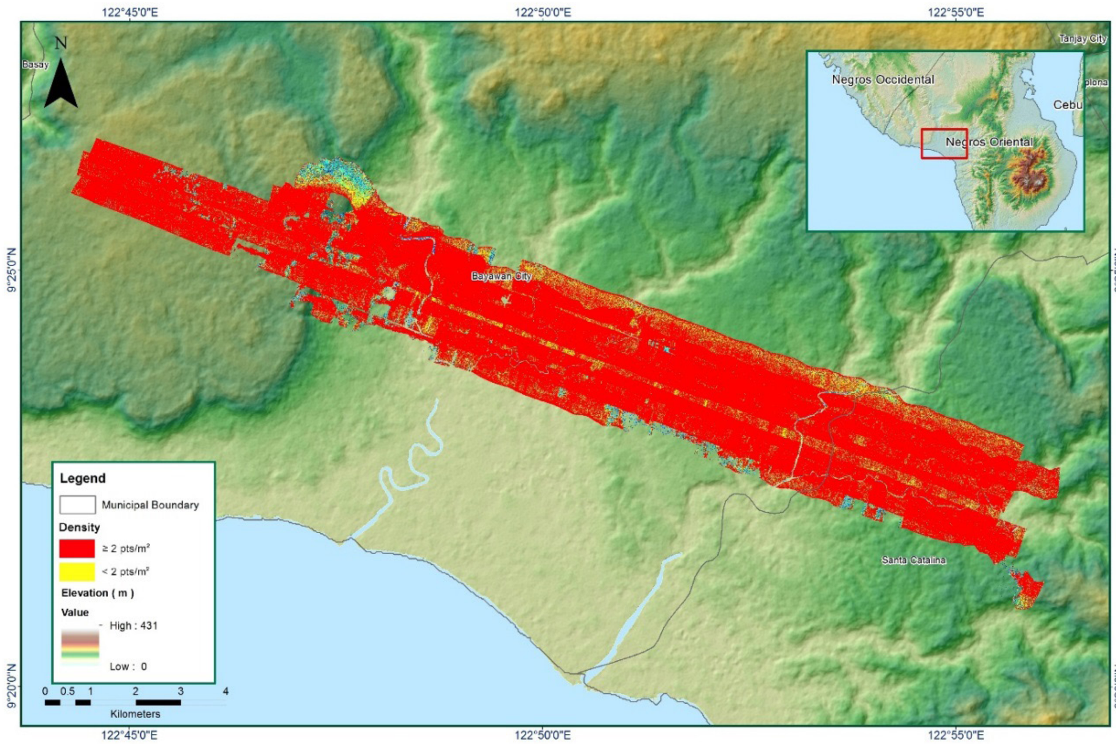


Figure 1.4.6 Density map of merged LiDAR data

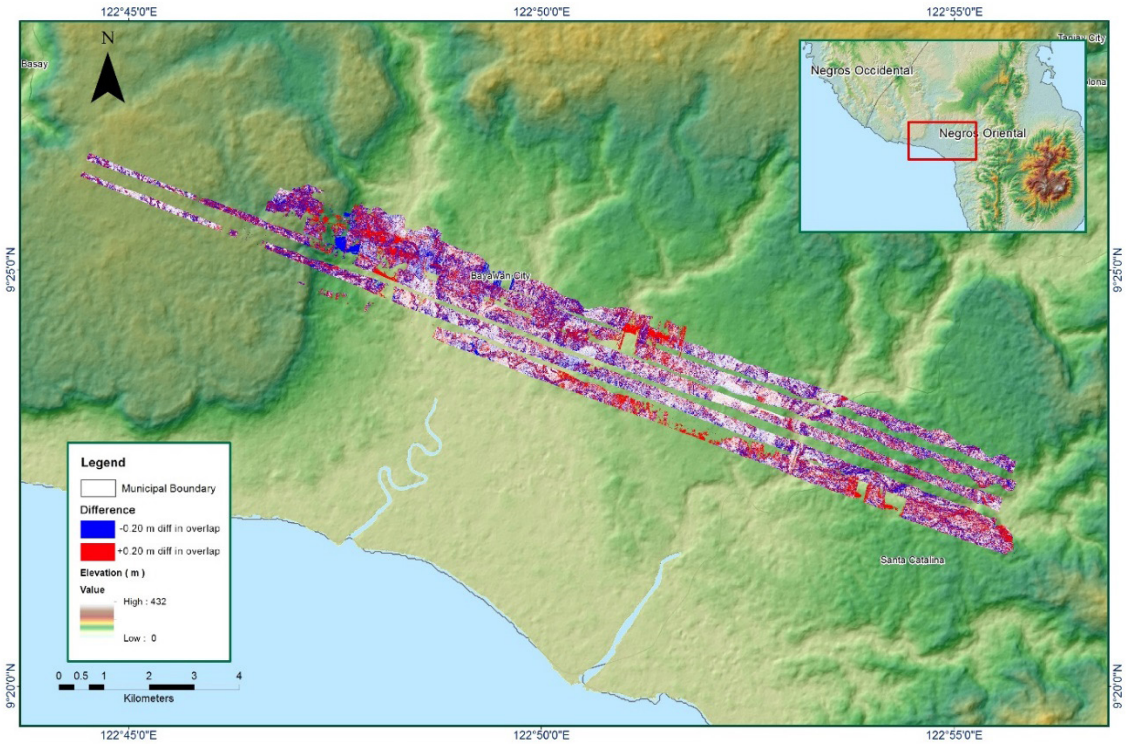


Figure 1.4.7 Elevation difference between flight lines

Flight Area	Dumaguete
Mission Name	**Blk53I**
Inclusive Flights	7562G, 7574G
Range data size	44.3 GB
POS	506 MB
Image	na
Base data size	12.27 MB
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)	2.6
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000167
IMU attitude correction stdev (<0.001deg)	0.000962
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	36.98%
Ave point cloud density per sq.m. (>2.0)	4.22
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	419
Maximum Height	583.91 m
Minimum Height	61.34 m
Classification (# of points)	
Ground	142,510,622
Low vegetation	138,131,902
Medium vegetation	387,773,870
High vegetation	480,080,109
Building	9,091,742
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga, Jr., Engr. Jeffrey Delica

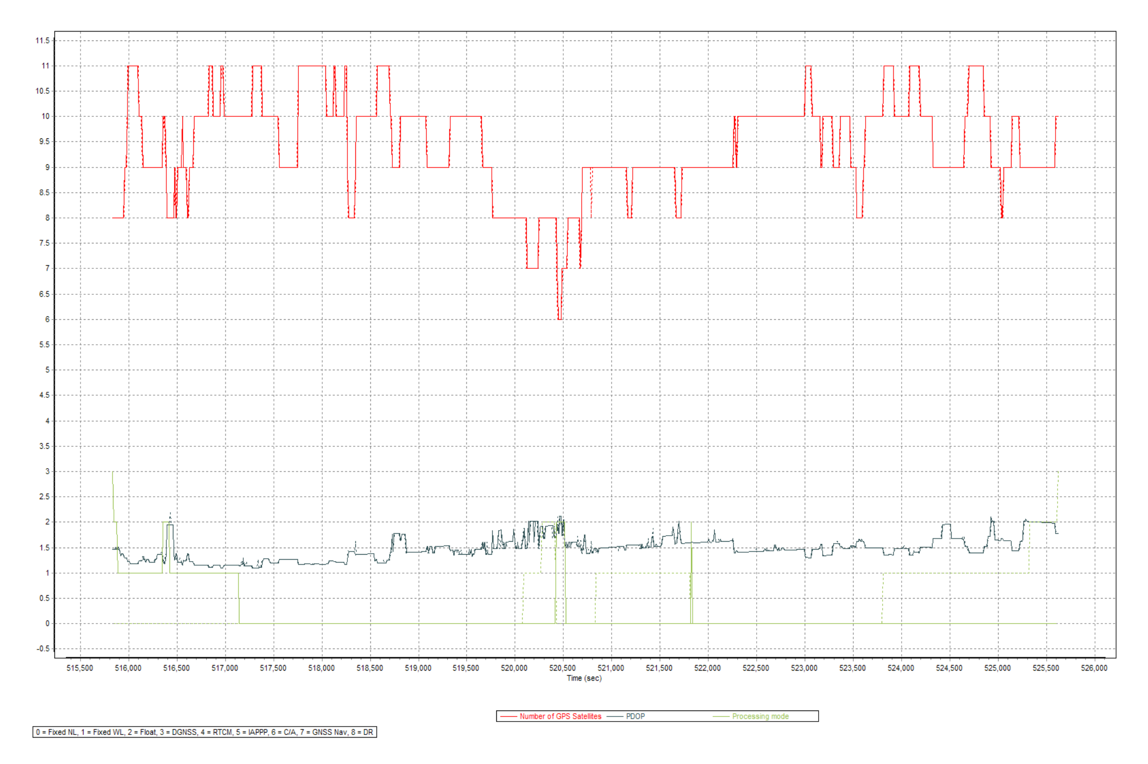


Figure 1.5.1 Solution Status

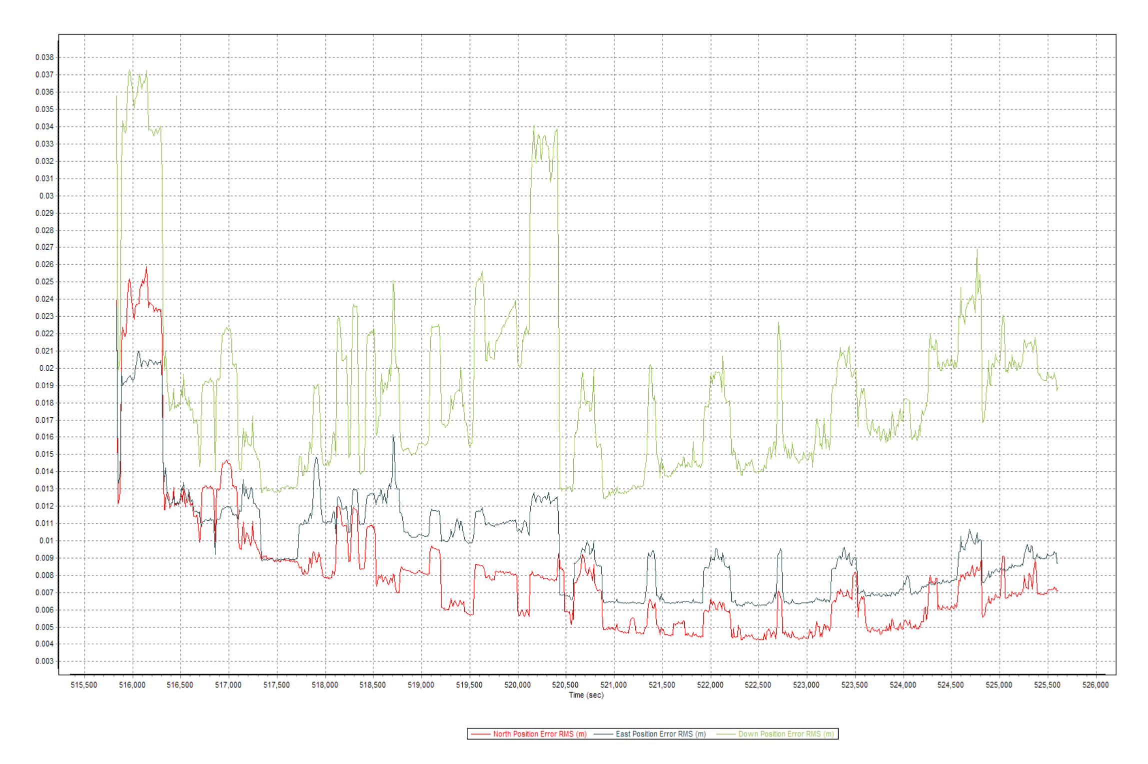


Figure 1.5.2 Smoothed Performance Metric Parameters

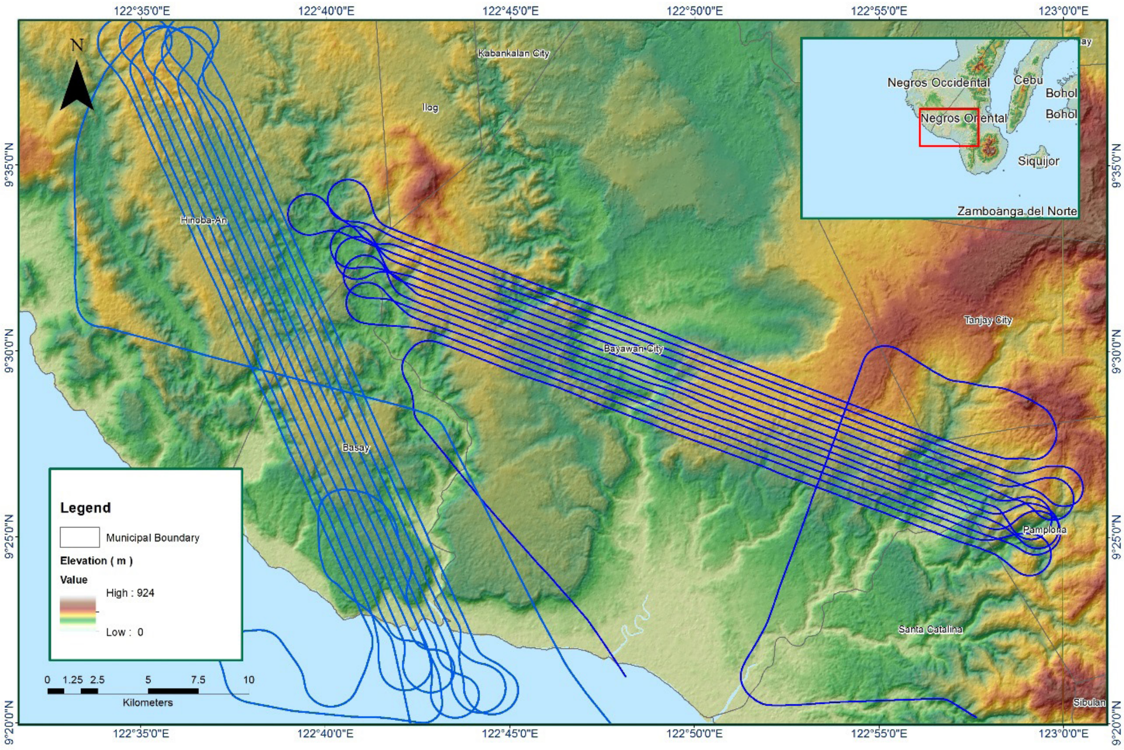


Figure 1.5.3 Best Estimated Trajectory

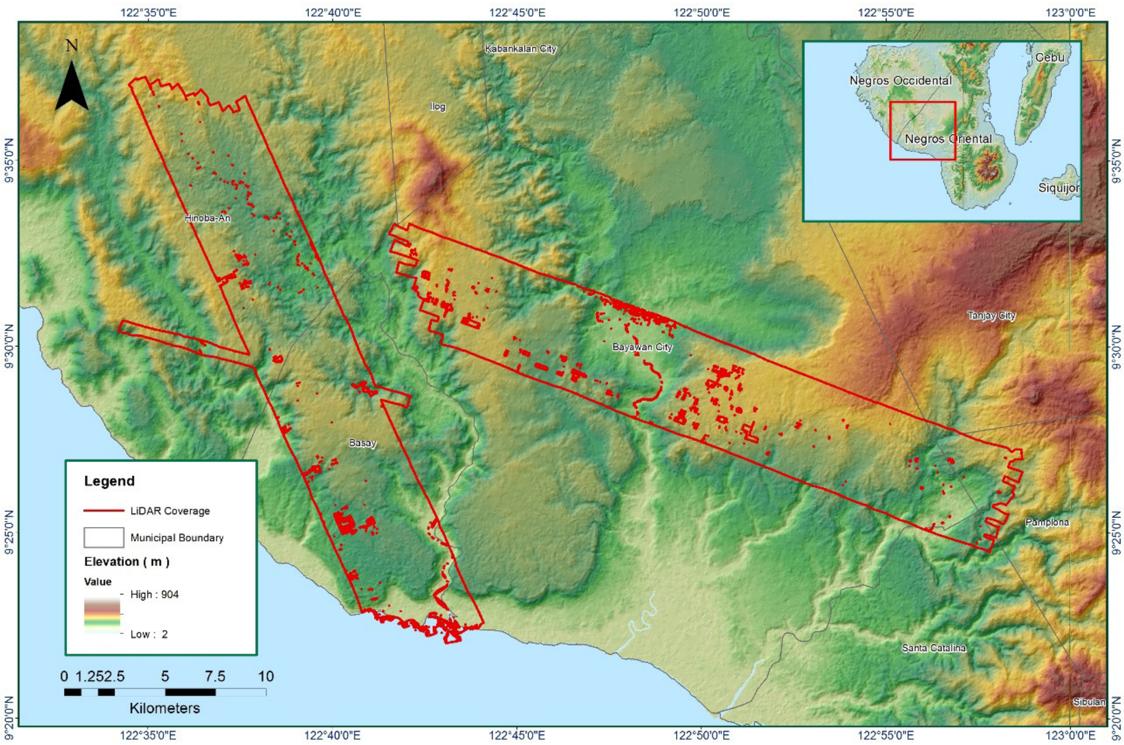


Figure 1.5.4 Coverage of LiDAR data

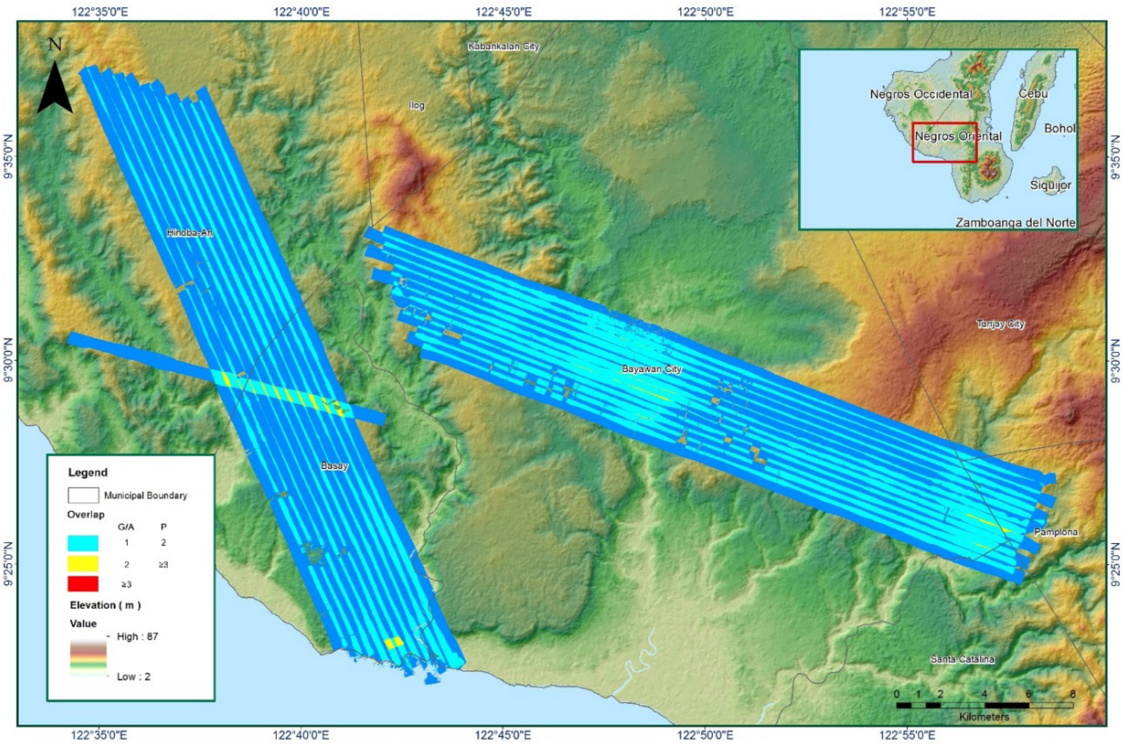


Figure 1.5.5 Image of data overlap

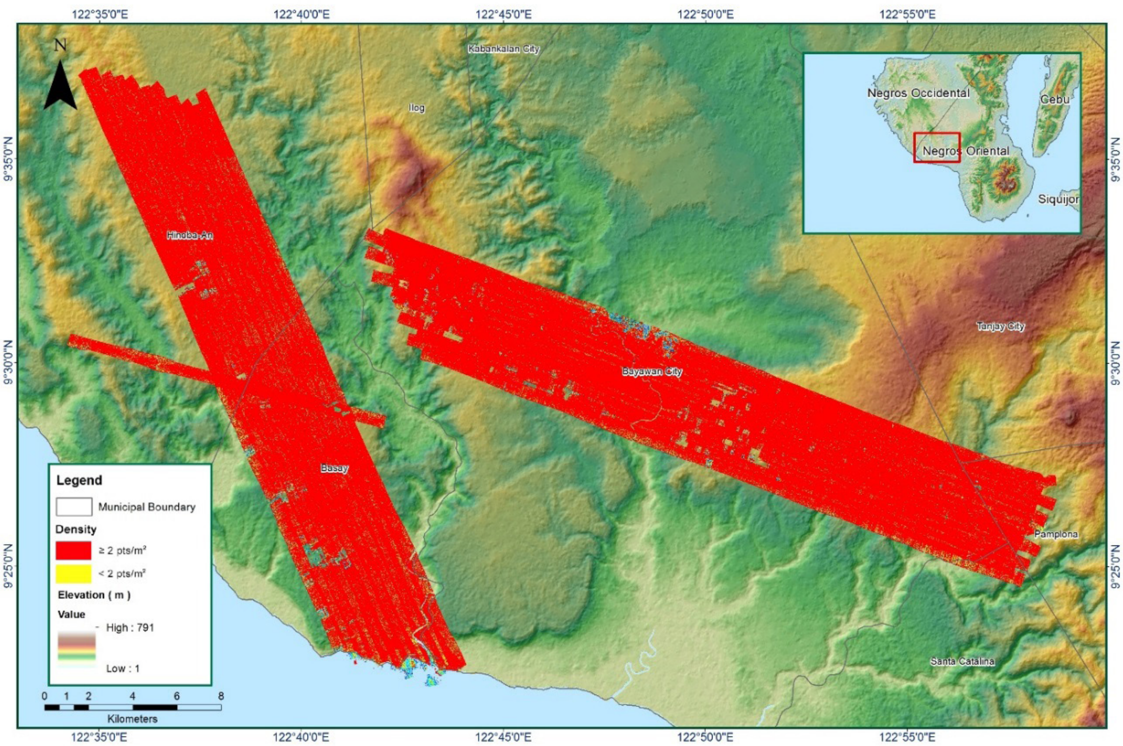


Figure 1.5.6 Density map of merged LiDAR data

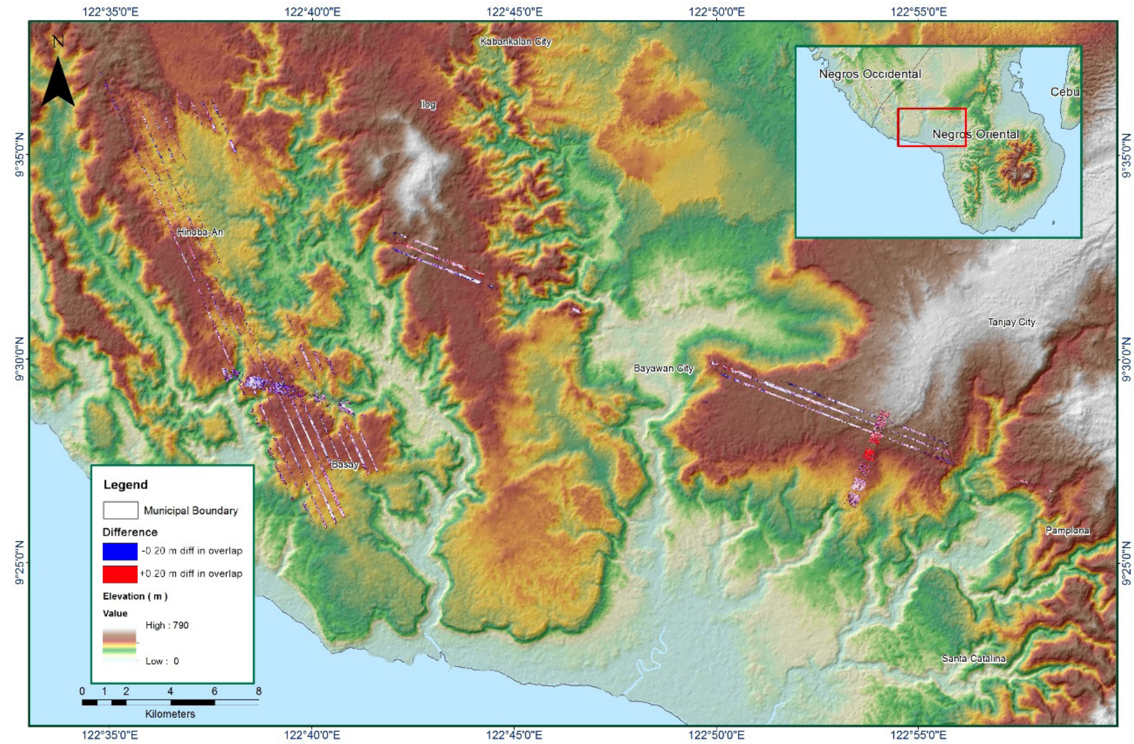


Figure 1.5.7 Elevation difference between flight lines

Flight Area	**Dumaguete**
Mission Name	**Blk55A**
Inclusive Flights	7526G,7540G,7560G
Range data size	59.7 GB
POS	667 MB
Image	na
Base data size	13.88 MB
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)	0.088
RMSE for East Position (<4.0 cm)	1.32
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000170
IMU attitude correction stdev (<0.001deg)	0.001080
GPS position stdev (<0.01m)	0.0066
Minimum % overlap (>25)	47.00%
Ave point cloud density per sq.m. (>2.0)	3.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	225
Maximum Height	719.03 m
Minimum Height	60.3 m
Classification (# of points)	
Ground	84661907
Low vegetation	80144926
Medium vegetation	161689840
High vegetation	275799941
Building	5058695
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga, Jr., Engr. Ellaine Lopez

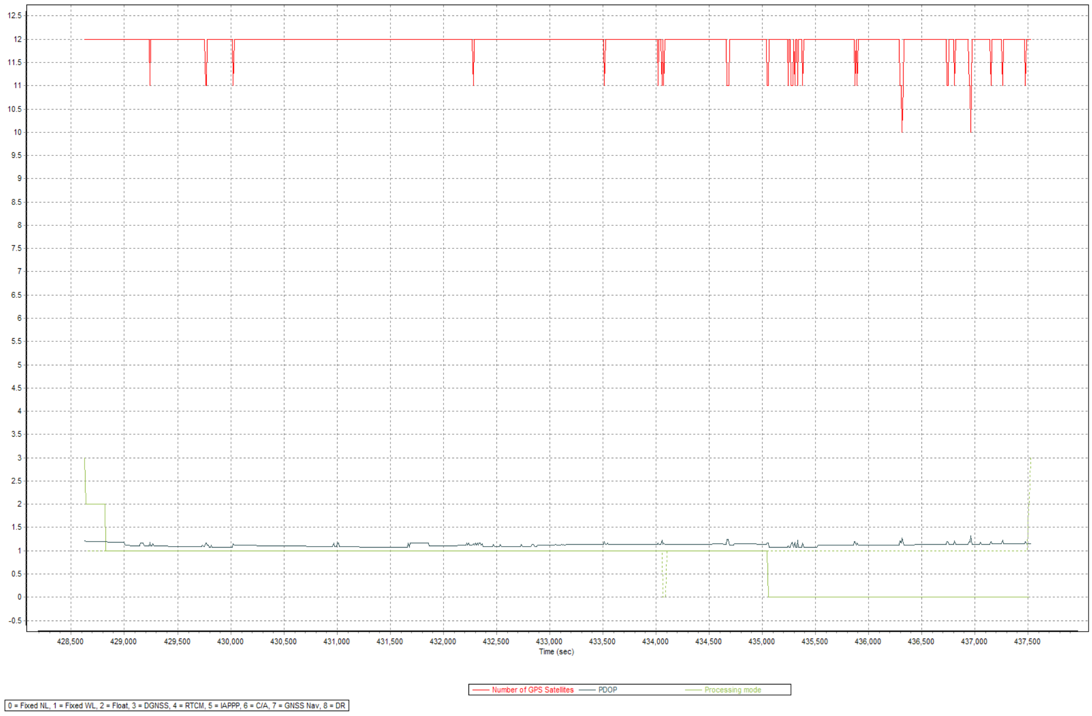


Figure 1.6.1 Solution Status

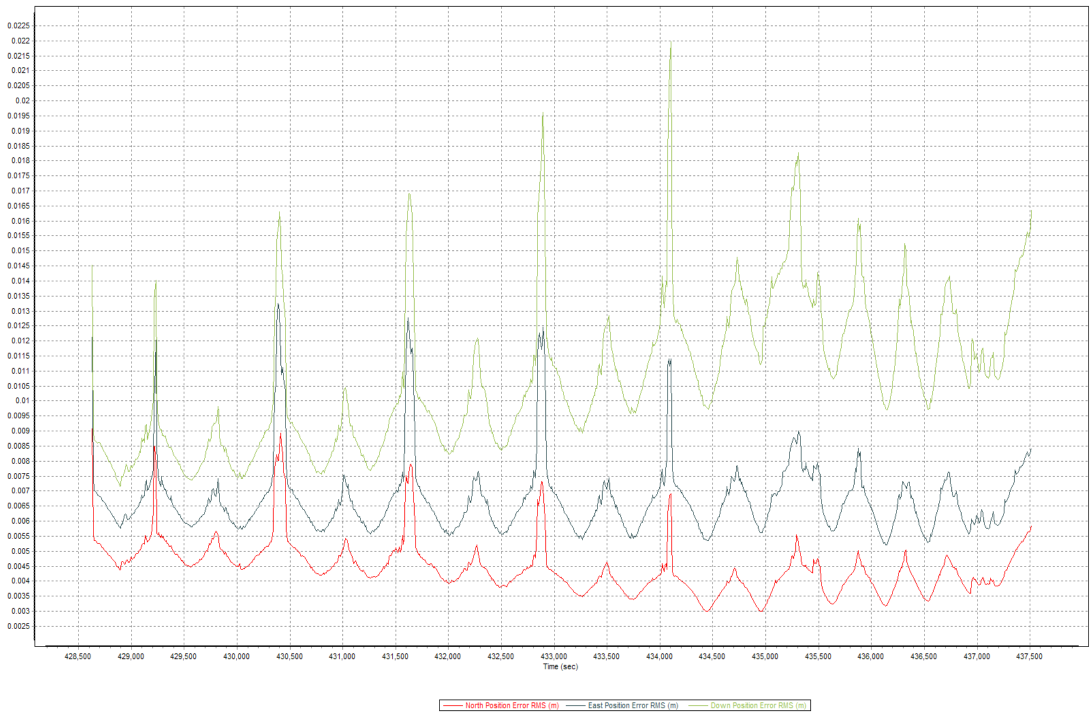


Figure 1.6.2 Smoothed Performance Metric Parameters

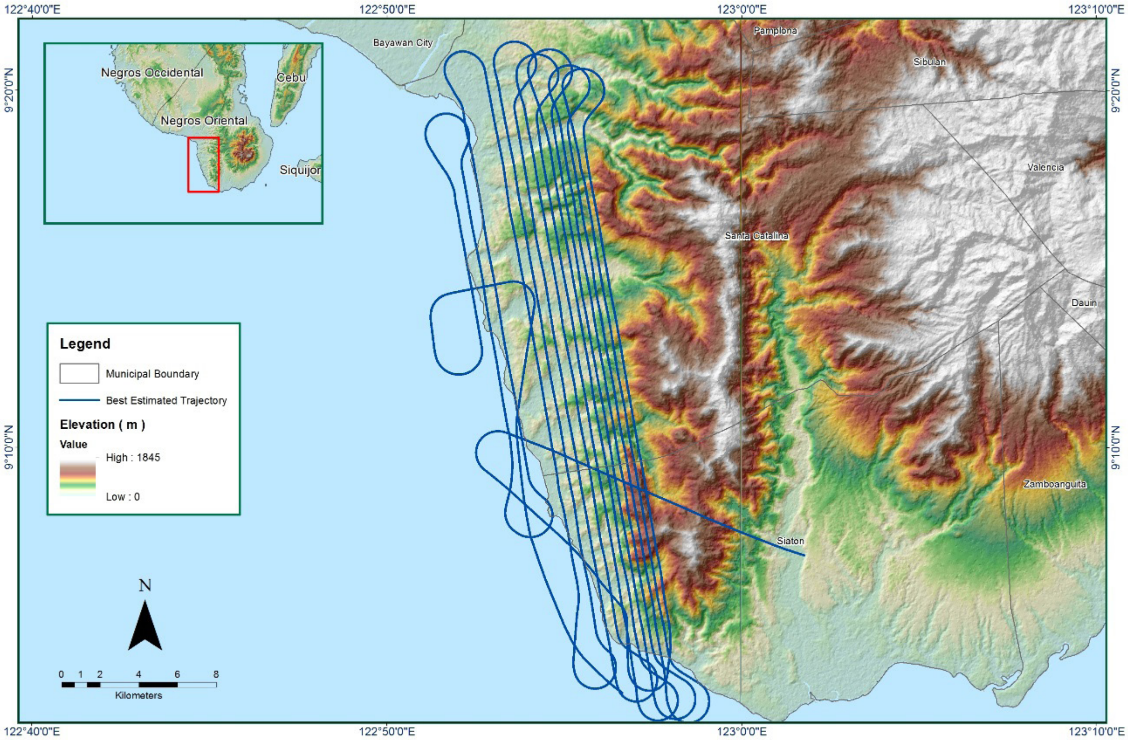


Figure 1.6.3 Best Estimated Trajectory

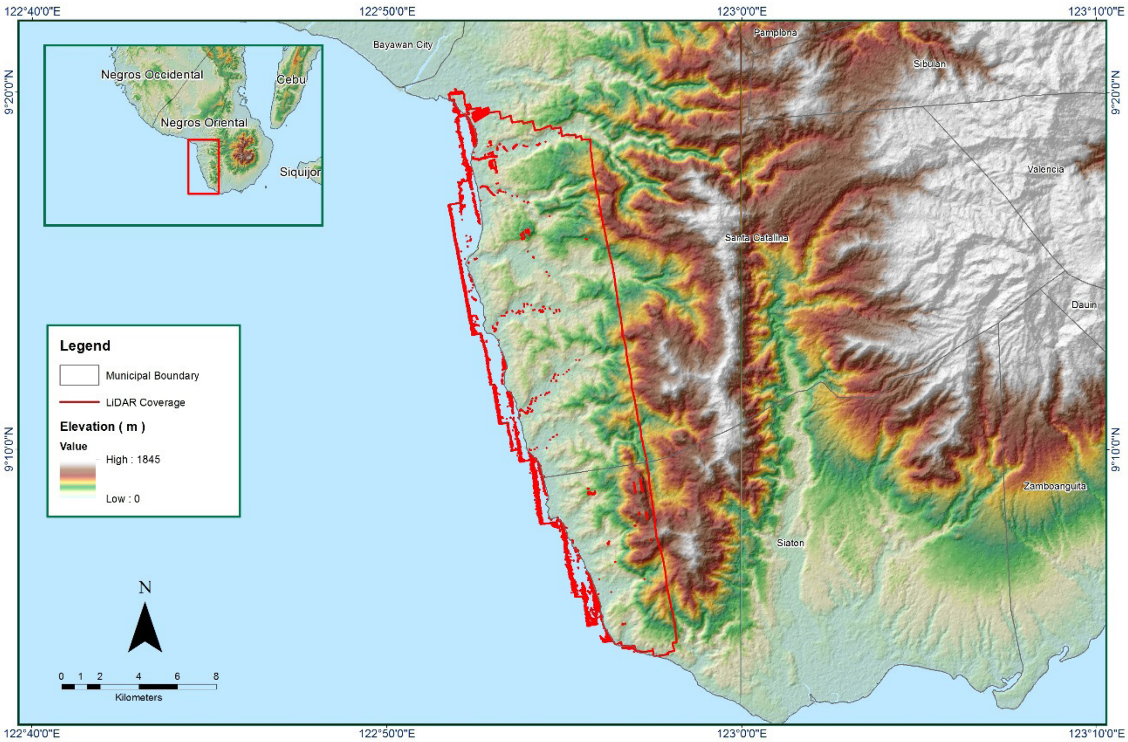


Figure 1.6.4 Coverage of LiDAR data

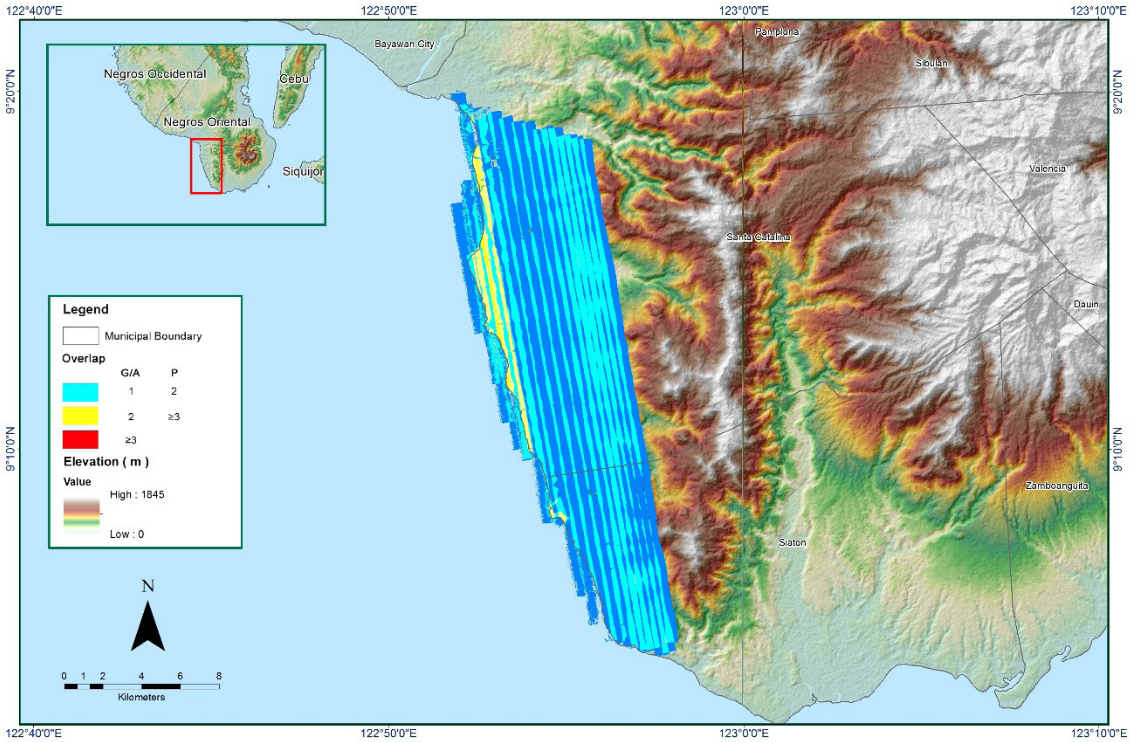


Figure 1.6.5 Image of data overlap

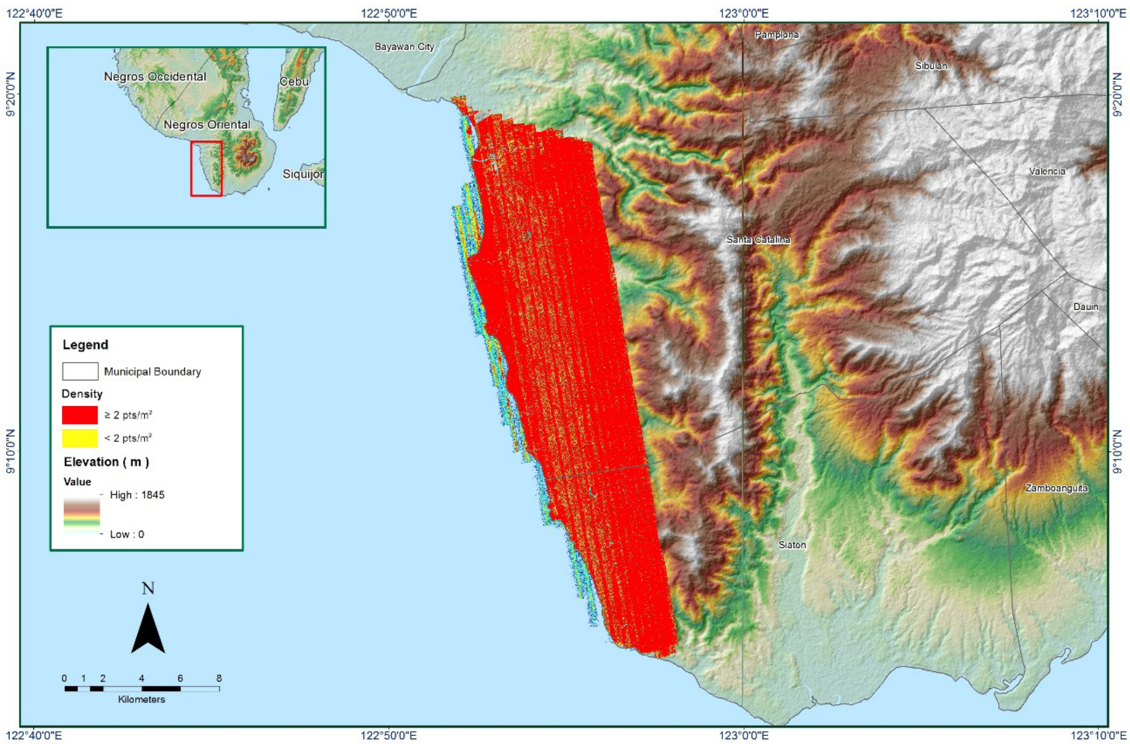


Figure 1.6.6 Density map of merged LiDAR data

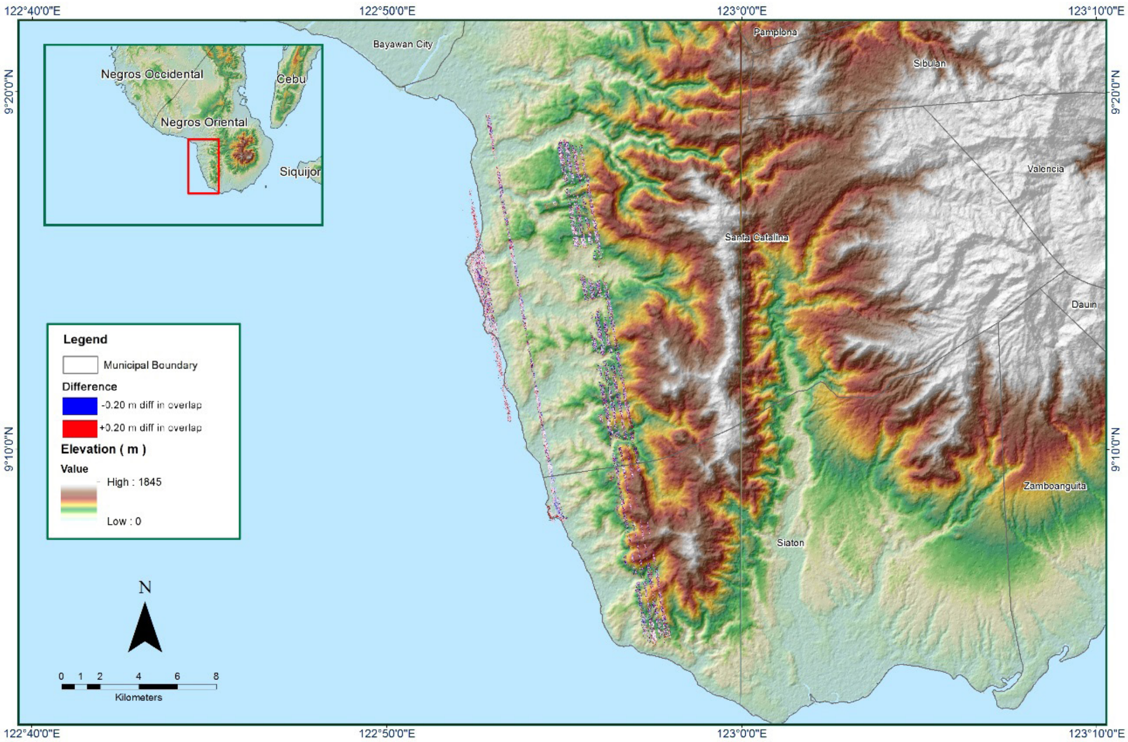


Figure 1.6.7 Elevation difference between flight lines

Flight Area	Dumaguete Reflights
Mission Name	**Blk53O**
Inclusive Flights	10076AC
Range data size	5.06 GB
POS	193 MB
Image	53.1 MB
Base data size	18.4 MB
Transfer date	February 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.99
RMSE for East Position (<4.0 cm)	1.40
RMSE for Down Position (<8.0 cm)	3.10
Boresight correction stdev (<0.001deg)	0.003474
IMU attitude correction stdev (<0.001deg)	0.023343
GPS position stdev (<0.01m)	0.0152
Minimum % overlap (>25)	36.44%
Ave point cloud density per sq.m. (>2.0)	4.90
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	52
Maximum Height	371.94 m
Minimum Height	57.34 m
Classification (# of points)	
Ground	18,604,153
Low vegetation	23,569,521
Medium vegetation	23,942,337
High vegetation	37,900,542
Building	2,405,421
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Velina Angela Bemida, Engr. Krisha Marie Bautista

Figure 1.7.1. Solution Status

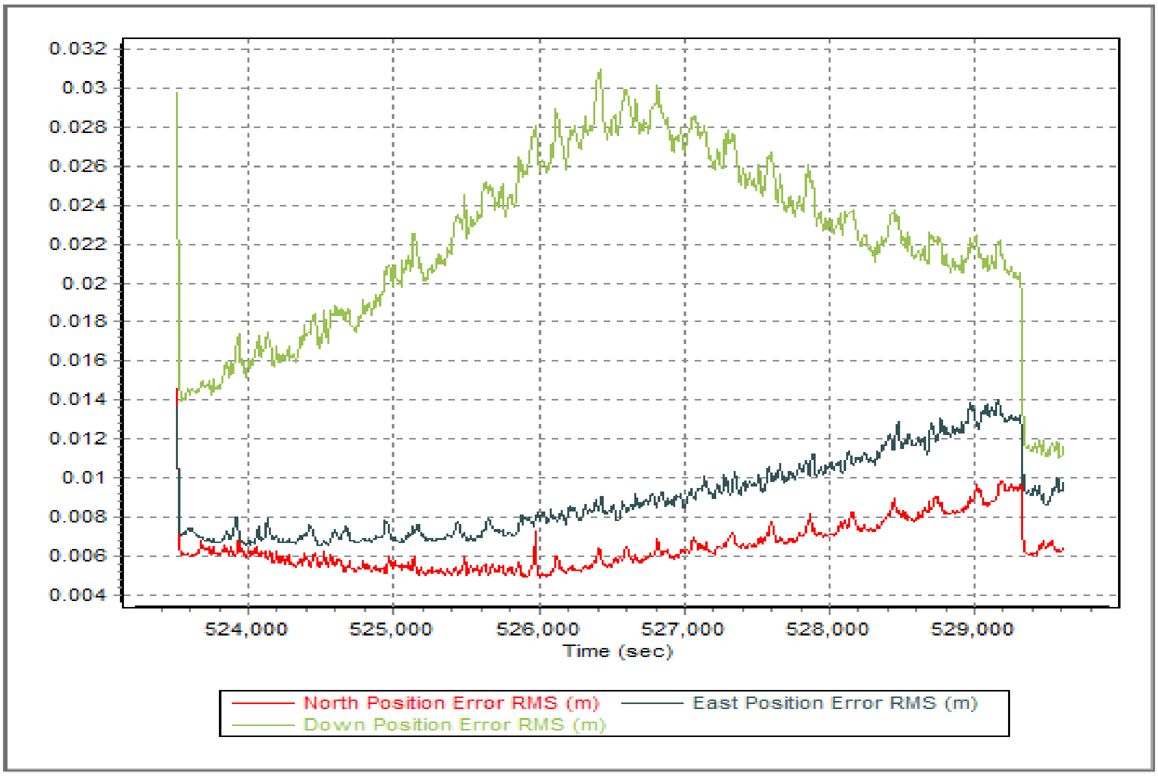


Figure 1.7.2. Smoothed Performance Metric Parameters

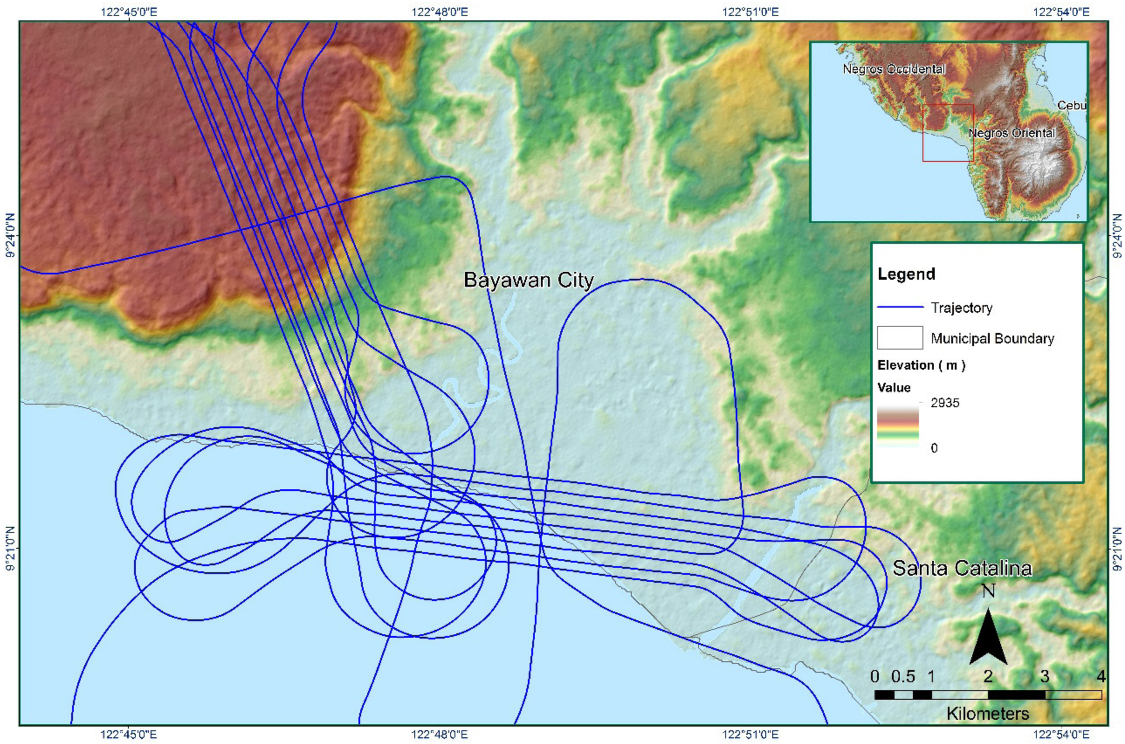


Figure 1.7.3 Best Estimated Trajectory

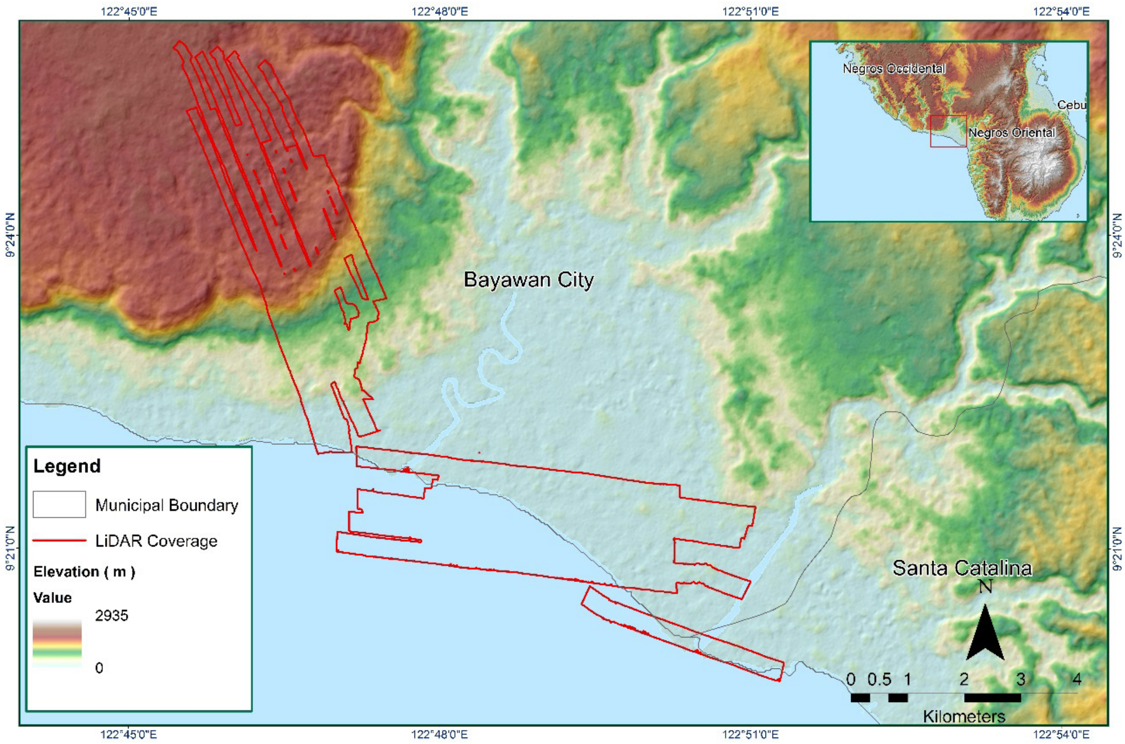


Figure 1.7.4 Coverage of LiDAR data

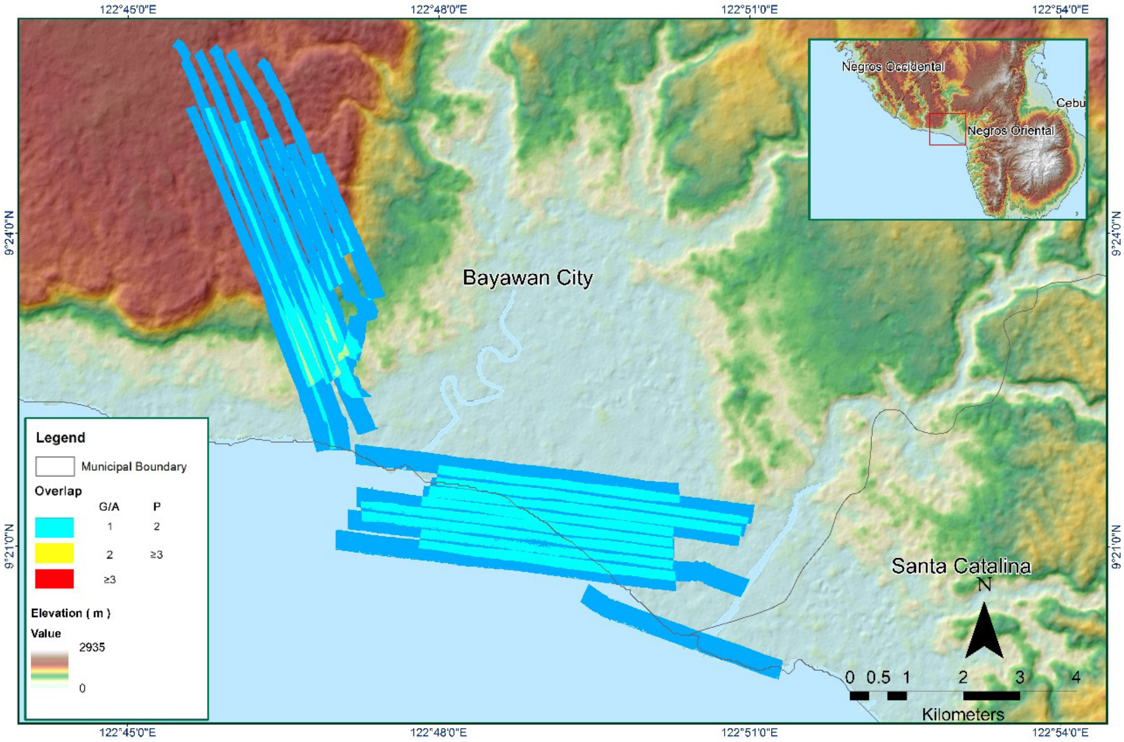


Figure 1.7.5 Image of data overlap

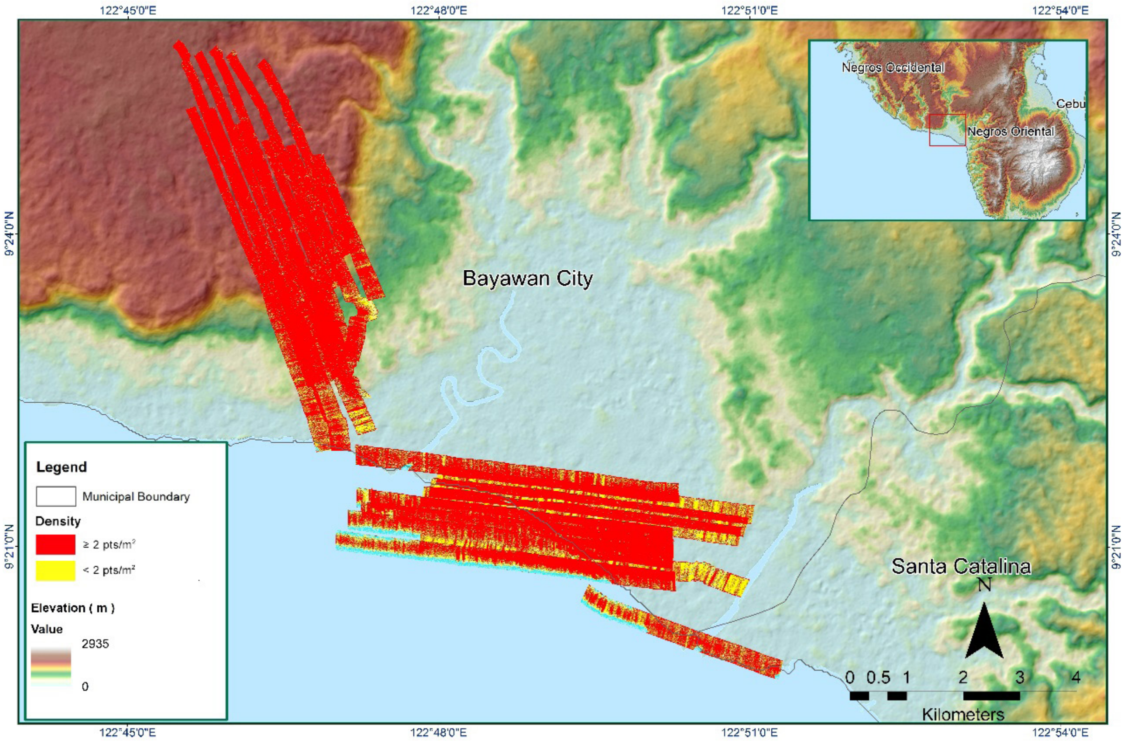


Figure 1.7.6 Density map of merged LiDAR data

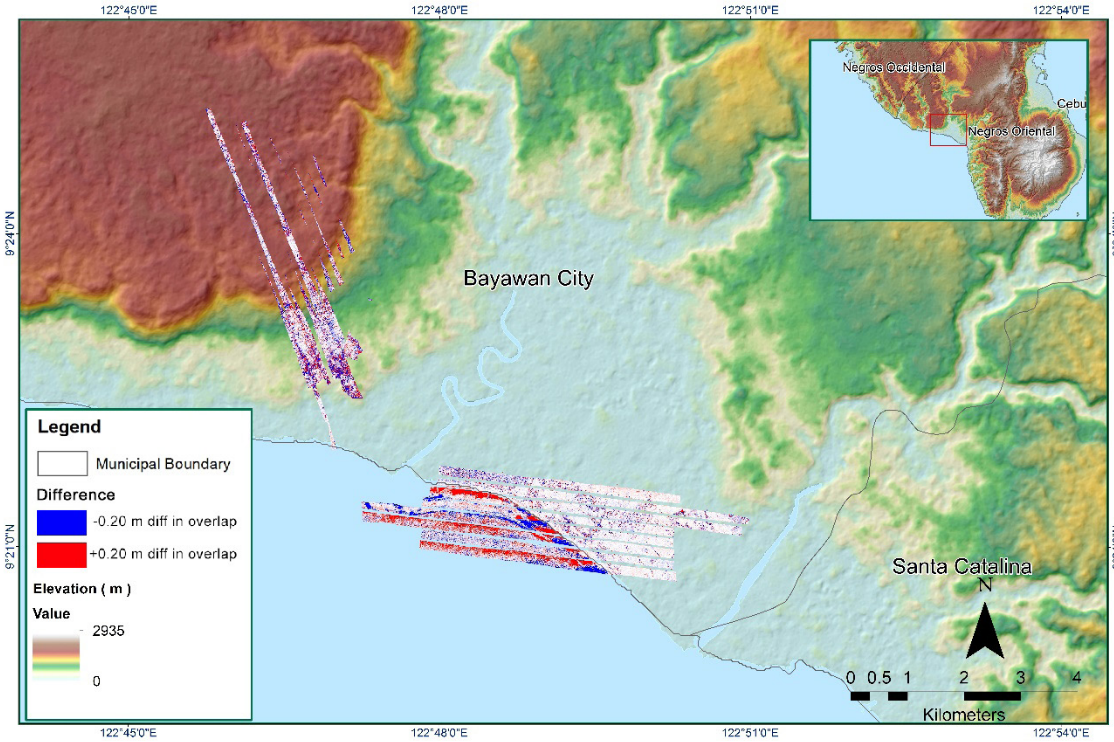


Figure 1.7.7 Elevation difference between flight lines

Annex 9. Bayawan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph		Recession Baseflow				
	Initial Abstraction	Curve Number	Impervious (%)	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W180	1.291491	84.515	0	7.3546	5.1714	Discharge	1.07	0.49	Ratio to Peak	0.000697
W190	1.439826	84.084	0	7.5672	1.8007	Discharge	0.63713	0.49	Ratio to Peak	0.000995
W200	2.275059	75.129	0	13.52	7.7881	Discharge	2.9928	0.49	Ratio to Peak	0.001
W210	1.622664	82.285	0	6.9142	6.6993	Discharge	0.63551	0.49	Ratio to Peak	0.00098
W220	3.08388	67.831	0	14.172	12.144	Discharge	1.4997	0.49	Ratio to Peak	0.001
W230	2.552199	72.467	0	6.4973	1.6394	Discharge	0.11462	0.49	Ratio to Peak	0.000941
W240	3.212871	76.922	0	5.7149	3.2105	Discharge	1.2725	0.49	Ratio to Peak	0.001
W250	2.229396	75.031	0	8.1193	4.492	Discharge	1.3627	0.49	Ratio to Peak	0.001
W260	1.586766	83.198	10	7.3044	4.1069	Discharge	0.66658	0.49	Ratio to Peak	0.001
W270	1.372587	85.836	10	5.7394	3.2544	Discharge	1.1195	0.49	Ratio to Peak	0.00096
W280	1.398534	90.106	10	6.0097	3.4064	Discharge	0.84449	0.49	Ratio to Peak	0.000956
W290	1.499346	83.797	10	6.9007	2.5602	Discharge	0.1155	0.49	Ratio to Peak	0.000667
W300	1.728498	81.931	10	10.708	5.9269	Discharge	1.3665	0.49	Ratio to Peak	0.001
W310	1.696041	83.063	10	11.306	6.41	Discharge	2.0498	0.49	Ratio to Peak	0.001
W320	1.495068	83.853	10	0.9606	0.78421	Discharge	0.15746	0.5	Ratio to Peak	0.001015
W330	1.634568	82.05	10	13.801	3.4805	Discharge	1.3291	0.49	Ratio to Peak	0.001
W340	1.540824	83.657	10	1.4596	0.81256	Discharge	0.077404	0.49	Ratio to Peak	0.001015

Annex 10. Bayawan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	353.55	0.0001	0.12075	Trapezoid	30	1
R120	Automatic Fixed Interval	8021.9	0.003818	0.092575	Trapezoid	30	1
R140	Automatic Fixed Interval	9126.8	0.00478	0.07889	Trapezoid	30	1
R160	Automatic Fixed Interval	2644.4	0.002442	0.07889	Trapezoid	30	1
R170	Automatic Fixed Interval	589.56	0.0001	0.12075	Trapezoid	30	1
R40	Automatic Fixed Interval	13327	0.002838	0.080378	Trapezoid	30	1
R50	Automatic Fixed Interval	2134.5	0.025959	0.053667	Trapezoid	30	1
R90	Automatic Fixed Interval	6644.4	0.004614	0.07889	Trapezoid	30	1

Annex 11. Bayawan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
1	122.833	9.40621	0.03	0.35	-0.32	Ramil	5 - Year
2	122.8328	9.406069	0.03	0.5	-0.47	Ramil	5 - Year
3	122.8334	9.406215	0.08	1.8	-1.72	Ramil	5 - Year
4	122.8335	9.406197	3.05	0.6	2.45	Ruping	100-Year
5	122.8335	9.406282	2.407	1.3	1.107	Ramil	5 - Year
6	122.8318	9.405238	2.407	0.4	2.007	Ramil	5 - Year
7	122.8318	9.405258	2.14	0.4	1.74	Zoraida	100-Year
8	122.8319	9.405208	2.94	1	1.94	Ruping	100-Year
9	122.8318	9.405199	1.91	0.4	1.51	Ursula	100-Year
10	122.8323	9.40445	0.03	0	0.03	Ramil	5 - Year
11	122.8324	9.404544	0.03	0.2	-0.17	Ramil	5 - Year
12	122.8238	9.400413	0.03	0.8	-0.77	Ramil	5 - Year
13	122.8238	9.400428	0.54	0.3	0.24	Ursula	100-Year
14	122.8238	9.400429	0.54	0.1	0.44	Milenyo	100-Year
15	122.8239	9.400447	0.162	0.8	-0.638	Ramil	5 - Year
16	122.8237	9.400467	0.238	0.65	-0.412	Ramil	5 - Year
17	122.8226	9.400078	0.238	1.6	-1.362	Ramil	5 - Year
18	122.8226	9.400082	1.28	1.2	0.08	Ruping	100-Year
19	122.8226	9.400032	1.4	0.75	0.65	Ursula	100-Year
20	122.8224	9.400033	0.669	1.45	-0.781	Ramil	5 - Year
21	122.8224	9.399894	2.03	0.71	1.32	Milenyo	100-Year
22	122.8224	9.400015	1.39	0.05	1.34	Yolanda	100-Year
23	122.822	9.399892	0.481	2.17	-1.689	Ramil	5 - Year
24	122.822	9.399945	0.481	0.46	0.021	Ramil	5 - Year
25	122.822	9.399941	1.45	1.6	-0.15	Ursula	100-Year
26	122.8212	9.399879	1.163	1.7	-0.537	Ramil	5 - Year
27	122.8212	9.399884	1.85	1.3	0.55	Ruping	100-Year
28	122.8212	9.399862	1.85	0.9	0.95	Ursula	100-Year
29	122.8212	9.399732	1.026	2.2	-1.174	Ramil	5 - Year
30	122.8192	9.398831	1.026	2	-0.974	Ramil	5 - Year
31	122.8191	9.398806	2.63	1.8	0.83	Ruping	100-Year
32	122.8192	9.398833	2.38	1.25	1.13	Ursula	100-Year
33	122.8186	9.398527	2.371	0.67	1.701		100-Year
34	122.8182	9.398235	2.371	2.6	-0.229	Ramil	5 - Year
35	122.8182	9.398269	2.94	1.9	1.04	Ursula	100-Year
36	122.8182	9.398275	2.94	1.1	1.84		100-Year
37	122.8183	9.398291	2.97	1.4	1.57	Ruping	100-Year
38	122.8183	9.398238	2.97	0.7	2.27	Yolanda	100-Year
39	122.8182	9.398337	0.03	2.5	-2.47	Ramil	5 - Year
40	122.8172	9.398286	0.03	0.3	-0.27	Ramil	5 - Year
41	122.817	9.398448	0.03	0.9	-0.87	Ramil	5 - Year
42	122.8166	9.398349	0.194	0.5	-0.306	Ramil	5 - Year
43	122.8163	9.398357	0.149	0.9	-0.751	Ramil	5 - Year
44	122.8162	9.398358	1.8	0.1	1.7	Ruping	100-Year
45	122.8161	9.398288	0.234	1.3	-1.066	Ramil	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
46	122.8162	9.398307	1.64	0.6	1.04	Ursula	100-Year
47	122.8144	9.398494	0.429	1.1	-0.671	Ramil	5 - Year
48	122.8106	9.399881	3.377	0	3.377	Ramil	5 - Year
49	122.8101	9.400416	3.377	1.35	2.027	Ramil	5 - Year
50	122.8101	9.400393	5.03	0.5	4.53	Ursula	100-Year
51	122.8096	9.401095	10.089	1.3	8.789	Ramil	5 - Year
52	122.8096	9.401149	7.97	1	6.97	Ursula	100-Year
53	122.8098	9.402281	4.967	1.7	3.267	Ramil	5 - Year
54	122.8098	9.402316	7.65	0.7	6.95	Ursula	100-Year
55	122.8183	9.378414	1.122	0.05	1.072	Ramil	5 - Year
56	122.817	9.37597	0.719	0.8	-0.081	Ramil	5 - Year
57	122.8153	9.372595	0.03	0.5	-0.47	Ramil	5 - Year
58	122.8128	9.367491	0.182	0.4	-0.218	Ramil	5 - Year
59	122.8095	9.363436	0.03	0.5	-0.47	Ramil	5 - Year
60	122.8073	9.364295	0.03	0.3	-0.27	Ramil	5 - Year
61	122.8071	9.364292	0.34	0.2	0.14	Ursula	100-Year
62	122.8062	9.364717	0.621	0.2	0.421	Ramil	5 - Year
63	122.7972	9.376079	1.796	0.6	1.196	Ramil	5 - Year
64	122.8082	9.387355	1.796	1.9	-0.104	Ramil	5 - Year
65	122.8082	9.387403	4.12	0.5	3.62	Ursula	100-Year
66	122.8081	9.387311	2.23	0.6	1.63	Ruping	100-Year
67	122.8101	9.396187	1.426	0.15	1.276	Ramil	5 - Year
68	122.8098	9.396551	1.426	0.5	0.926	Ramil	5 - Year
69	122.8098	9.396621	1.425	1.4	0.025	Ramil	5 - Year
70	122.8098	9.396586	4.03	0	4.03	Ursula	100-Year
71	122.81	9.397053	1.425	2	-0.575	Ramil	5 - Year
72	122.81	9.397014	2.56	0.9	1.66	Quedan	100-Year
73	122.8099	9.397087	0.032	1	-0.968	Ramil	5 - Year
74	122.8066	9.384342	0.03	0.1	-0.07	Ramil	5 - Year
75	122.807	9.383022	0.03	2.2	-2.17	Ramil	5 - Year
76	122.807	9.383007	0.6	0.9	-0.3	Ursula	100-Year
77	122.8069	9.383034	0.35	1.2	-0.85		100-Year
78	122.8069	9.383025	0.48	1.75	-1.27	Ruping	100-Year
79	122.8066	9.382842	0.03	2.47	-2.44	Ramil	5 - Year
80	122.8066	9.382801	2.28	1.62	0.66	Ursula	100-Year
81	122.8069	9.38317	0.878	1	-0.122	Ramil	5 - Year
82	122.8035	9.380547	0.878	1.8	-0.922	Ramil	5 - Year
83	122.8034	9.380486	0.92	1.5	-0.58	Ursula	100-Year
84	122.7978	9.376722	0.251	1.8	-1.549	Ramil	5 - Year
85	122.7978	9.376732	1.38	1.34	0.04	Ursula	100-Year
86	122.7964	9.371751	0.03	0.3	-0.27	Ramil	5 - Year
87	122.803	9.368325	1.566	0.4	1.166	Ramil	5 - Year
88	122.8026	9.368673	6.489	1.7	4.789	Ramil	5 - Year
89	122.8024	9.368781	6.489	1.85	4.639	Ramil	5 - Year
90	122.8024	9.368764	2.499	2	0.499	Ramil	5 - Year
91	122.8021	9.368735	3.45	1.89	1.56	Ramil	5 - Year

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Annex 12. Educational Institutions Affected by Flooding in Bayawan Floodplain

Bayawan City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BANGA CENTRAL SCHOOL	Banga			
BAYAWAN COLLEGE	Banga	Medium	High	High
CANGSI-ID ELEMENTARY SCHOOL	Banga			Low
ST. AUGUSTINE ACADEMY	Banga			
UBOS DAYCARE ENTER	Banga	High	High	High
BAYAWAN CITY SCIENCE AND TECHNOLOGY CENTER	Malabugas			
BULI-BULI PRIMARY SCHOOL	Malabugas			
Telesforo Gargantiel Memorial Elementary School	Malabugas			Low
GUISOCON ELEMENTARY SCHOOL	Nangka			
NANGKA ELEMENTARY SCHOOL	Nangka	Medium	High	High
BULI-BULI PRIMARY SCHOOL	San Roque	Low	Low	Medium
Asian College of Science and Technology (Acsat)	Suba			
EARLY READERS MONTESSORIANS SCHOOL	Suba	Low	Medium	Medium
GAMAO ELEMENTARY SCHOOL	Suba			
SDY CENTRAL PHILIPPINES COMPETENCY	Suba			Low
BAYAWAN NATIONAL HIGH SCHOOL	Tinago			
KALAMTUKAN ELEMENTARY SCHOOL	Tinago		Low	Low
BAYAWAN COLLEGE	Ubos	Medium	High	High
BRGY. MOBILE VOCATIONAL SCHOOL	Ubos		Low	Medium
HOLY FAMILY ELEMENTARY SCHOOL	Ubos	High	High	High
BAYAWAN NATIONAL HIGH SCHOOL	Villareal	Low	Low	Low

Annex 13. Medical Institutions Affected by Flooding in Bayawan Floodplain

Bayawan City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BAYAWAN DISTRICT HOSPITAL	Banga			
SUBA HEALTH CENTER	Banga		Medium	Medium
UBOS BARANGAY HEALTH CENTER	Banga	High	High	High
MALABUGAS BARANGAY HEALTH CENTER	Malabugas			