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

LiDAR Surveys and Flood Mapping of Palilan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mindanao State University - Iligan Institute of Technology

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
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
MCM	
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
RCBO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
MSU-IIT	Mindanao State University - Iligan Institute of Technology
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 PALILAN RIVER

Engr. Alan Milano and Enrico C. Paringit, Dr. Eng.

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of the 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 Mindanao State University – Iligan Institute of Technology (MSU-IIT). MSU-IIT 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 16 iver basins in the Northern Mindanao Region. The university is located in Iligan City in the province of Lanao Del Norte.

1.2 Overview of the Palilan River Basin

Palilan River Basin is located in Jimenez in the Province of Misamis Occidental, Northern Mindanao under Region X, Philippines as shown in Figure 1. Palilan is one of the barangays in the municipality of Jimenez where the outlet of the river basin is to be found. The river basin traverses through the municipalities of Panaon, Jimenez and Sinacaban. Palilan is located near the narrow strip of linking northwestern Mindanao to the north island. It is bounded on the northeast by the Mindanao Sea, east by the Iligan Bay, southeast by the Panguil Bay, and west by Zamboanga del Norte and del Sur.

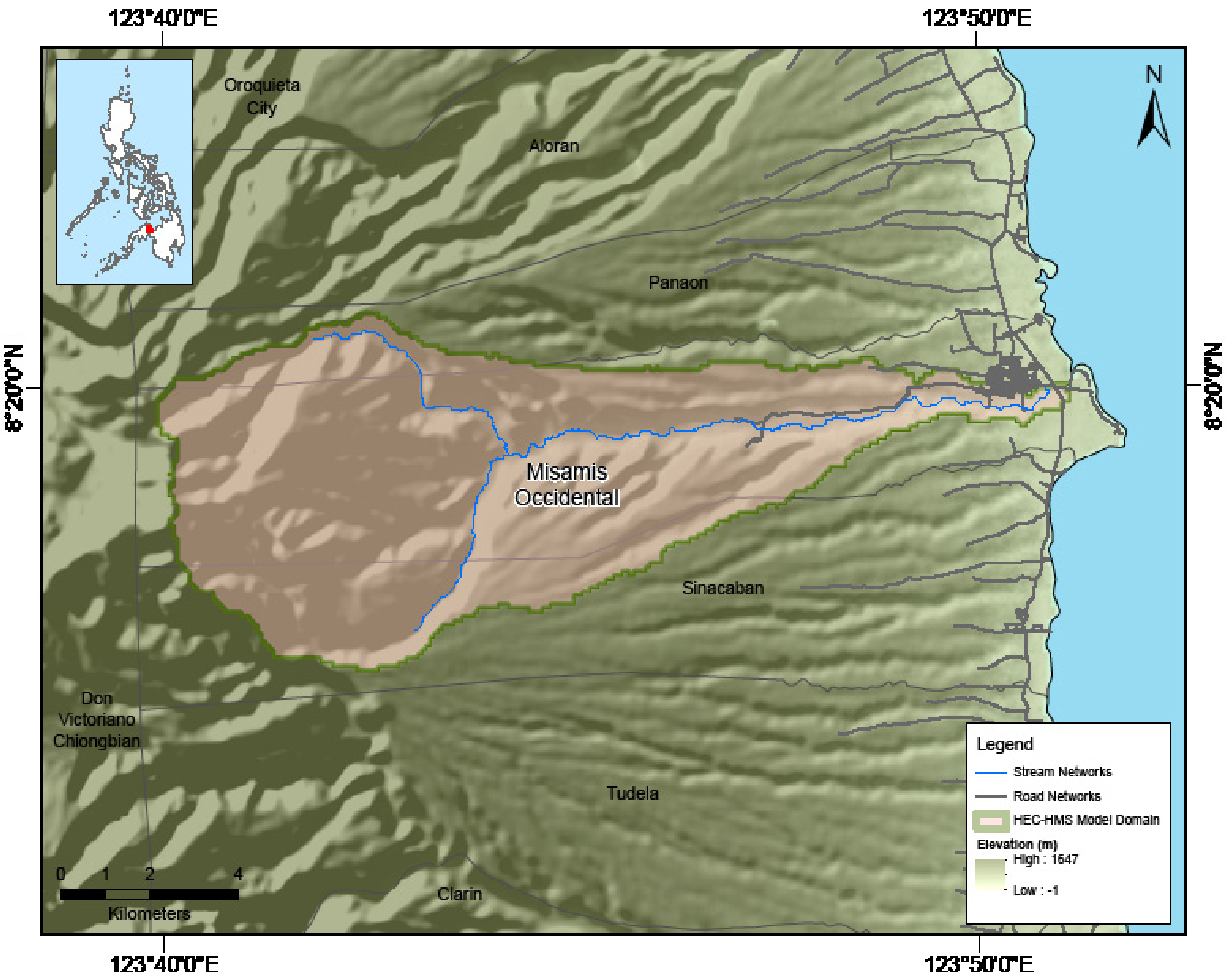

Figure 1. Map of Palilan River Basin

A large part of Jimenez is included the river basin thus it dominates the river basin. The river basin has an estimated area is 99.16 square kilometres and travels for an estimated value of 18.98 kilometers from its source to its mouth in Iligan Bay. The Palilan basin model consists of 22 sub basins, 12 reaches, and 12 junctions. The main outlet is located at Sinara Bajo Bridge, Jimenez. The barangays that can be found in the river basin are Butuay, Carmen, Corrales, Dicoloc, Makabaya, Mialem, Nacional, Naga, Palilan, Rizal, San Isidro, Santa Cruz, Seti, Sinara Bajo, Tabo-O and Taraka.

The climate belongs to the fourth type where rainfall is more or less fairly distributed throughout the year. The average rainfall in the past twenty years was recorded at 182.5 millimeters. The rainiest months are November and December; the driest are February, March and April. The entire place is outside the belt, but it is sometimes affected by freak storms.

CHAPTER 2: LIDAR ACQUISITION IN PALILAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, Engr. Frank Nicolas H. Ilejay

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 Palilan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Palilan Floodplain in Misamis Occidental. Each flight mission has an average of 12 lines and ran 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 outlined in Table 1. Figure 2 show the flight plan for Palilan floodplain survey.

Table 1. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK 69E	800	30	50	200	30	130	5
BLK 69F	800, 1000	30	50	200	30	130	5
BLK 76N	1000	30	50	200	30	130	5
BLK 76O	1000	30	50	200	30	130	5

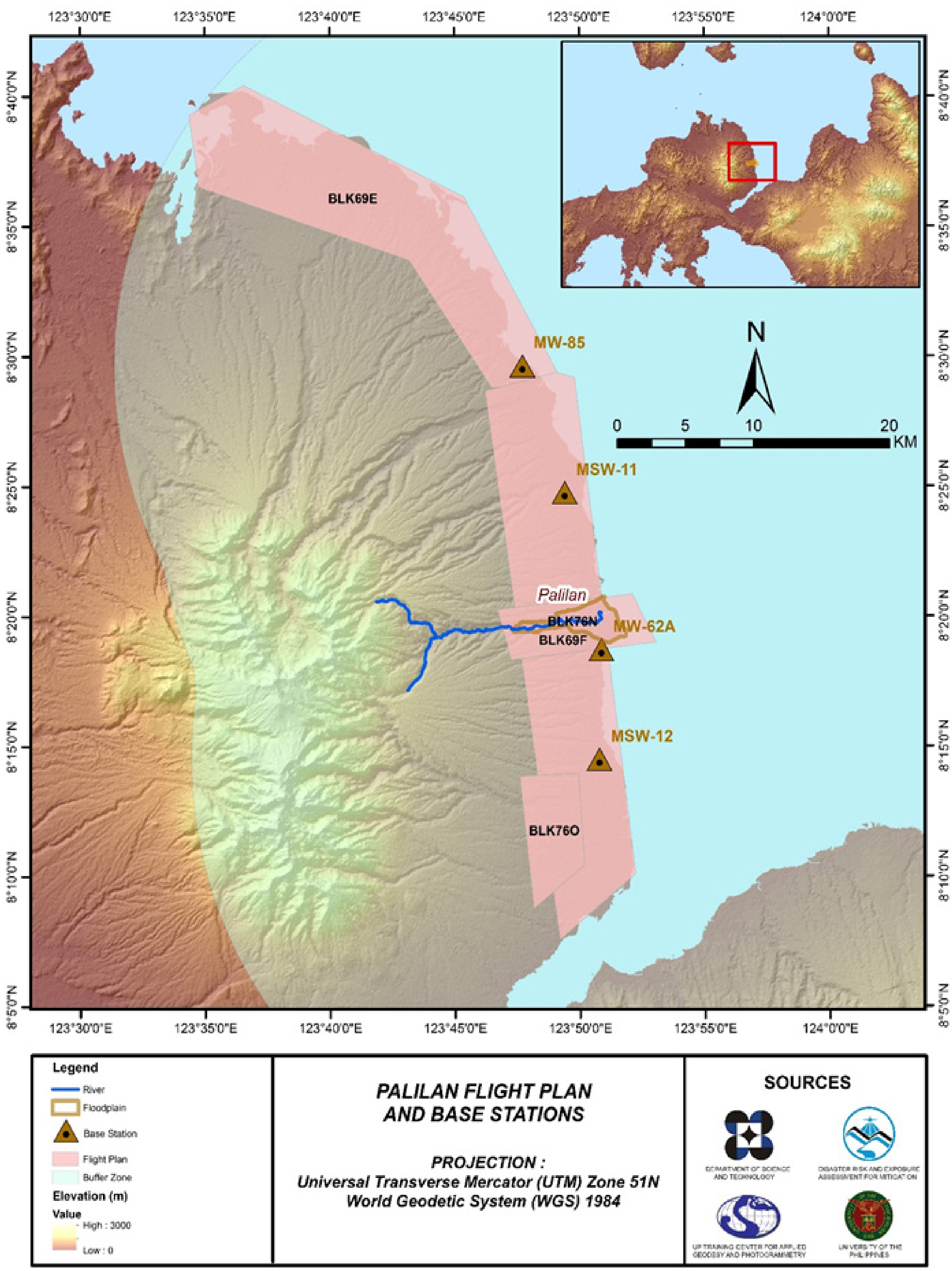

Figure 2. Flight Plan and base stations used for the Palilan Floodplain survey using Pegasus sensor.

2.2 Ground Base Station

The field team was able to recover two (2) NAMRIA ground control points: MSW-11 and MSW-12 which are of second (2nd) order accuracy. Two (2) benchmark points: MW-62A and MW-85.

The certifications for the base stations are found in Annex 2 while the baseline processing report for established point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from October 28 to November 9, 2014 and February 20, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, TRIMBLE SPS 985, and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Palilan floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Palilan Floodplain LiDAR Survey. Figure 3 to Figure 5 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 2 to Table 5 show the details about the following NAMRIA control stations and established points. Table 6, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

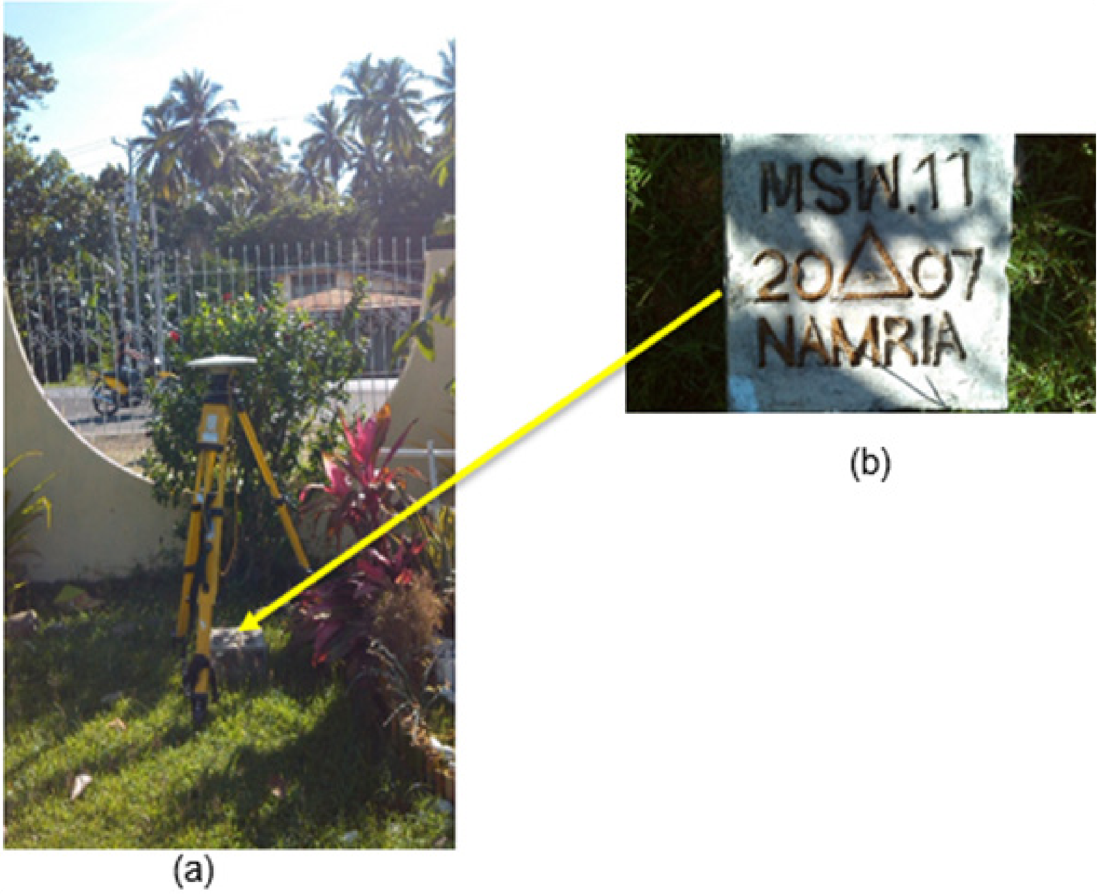

Figure 3. . GPS set-up over MSW-11 in Barangay Ospital, Aloran, Misamis Occidental (a) and NAMRIA reference point MSW-11 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MSW-11 used as base station for the LiDAR acquisition

Station Name	MSW-11	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 24' 49.21851" North 123° 49' 18.84776" East 4.399 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	590,515.033 meters 930,392.306 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°24' 45.57851" North 123° 49' 24.26581" East 70.095 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	590,483.35 meters 930,066.65 meters

Figure 4. GPS set-up over MSW-12 in Barangay Poblacion, Tudela, Misamis Occidental (a) and NAMRIA reference point MSW-12 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MSW-12 used as base station for the LiDAR acquisition.

Station Name	**MSW-12**	
Order of Accuracy	**2rd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 14’ 33.61728” North 123° 50’ 41.11353” East 5.698 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	911,485.567 meters 593,072.214 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 14’ 30.02425” North 123° 50’ 46.54685” East 71.798 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	911,166.576 meters 593,039.64 meters

Figure 5. GPS set-up over MW-62A at Sinonoc Bridge, Barangay Sinonoc, Sinacaban, Misamis Occidental (a) and NAMRIA benchmark MW-62A (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MW-62A used as base station for the LiDAR acquisition

Station Name	MW-62A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 18′ 46.72583″ North 123° 50′ 46.44781″ East 7.578 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	593,186.315 meters 918,939.972 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 18′ 43.11445″ North 123° 50′ 51.87475″ East 73.593 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	8° 18′ 46.72583″ North 123° 50′ 46.44781″ East 7.578 meters

Table 5. Details of the recovered NAMRIA horizontal control point MW-85 used as base station for the LiDAR acquisition.

Station Name	MSW-05	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 29' 41.44871" North 123° 47' 37.52758" East 4.320 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	587,366.444 meters 939,034.768 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 29' 37.78490" North 123° 47' 42.93851" East 69.779 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	8° 29' 41.44871" North 123° 47' 37.52758" East 4.320 meters

Table 6. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
28 October 2014	2133P	1BLK69FE301A	MSW-11 and MW-85
28 October 2014	2135P	1BLK69F301B	MSW-11 and MW-85
9 November 2014	2181P	1BLK69F313A	MSW-11 and MW-85
20 February 2016	23116P	1BLK76NO51A	MSW-12 and MW-62A

2.3 Flight Missions

A total of four (4) missions were conducted to complete the LiDAR data acquisition in Palilan floodplain, for a total of thirteen hours and twenty-six minutes (13+26) of flying time for RP-C9022 and RP-9122. All missions were acquired using the Pegasus LiDAR systems. Table 7 shows the total area of actual coverage per mission and the flying length for each mission and Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for the LiDAR data acquisition of the Palilan Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
28 October 2014	2133P	434.25	182.28	8.74	173.54	826	3	53
28 October 2014	2135P	240.17	47.66	1.13	46.53	NA	1	47
9 November 2014	2181P	434.25	137.12	5.85	131.28	361	3	11
20 February 2016	23116P	70.63	157.26	10.87	146.40	NA	4	35
TOTAL		**1,179.3**	**524.32**	**26.58**	**497.74**	**1187**	**13**	**26**

Table 8. Actual parameters used during the LiDAR data acquisition of the Palilan Floodplain.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2133P	800	30	50	200	30	130	5
2135P	1000	30	50	200	30	130	5
2181P	1000	30	50	200	30	130	5
23116P	1000	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Palilan floodplain (See Annex 7). It is located in the provinces of Misamis Occidental with majority of the floodplain situated within the municipality of Jimenez. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 9. The actual coverage of the LiDAR acquisition for Palilan floodplain is presented in Figure 6.

Table 9. The list of municipalities and cities surveyed of the Palilan Floodplain LiDAR acquisition.

PROVINCE	MUNICIPALITY/CITY	AREA OF MUNICIPALITY/ CITY (KM2)	TOTAL AREA SURVEYED (KM2)	PERCENTAGE OF AREA SURVEYED
MISAMIS OCCIDENTAL	JIMENEZ	78.47	27.86	36%
	CLARIN	113.99	37.62	33%
	SINACABAN	70.99	23.22	33%
	ALORAN	105.66	33.81	32%
	PANAON	52.52	15.24	29%
	TUDELA	108.93	26.34	24%
	OROQUIETA CITY	195.63	46.02	24%
	OZAMIS CITY	149.44	31.55	21%
	PLARIDEL	56.35	10.97	19%
	LOPEZ JAENA	90.54	10.86	12%
	TOTAL	1022.52	263.49	25.77%

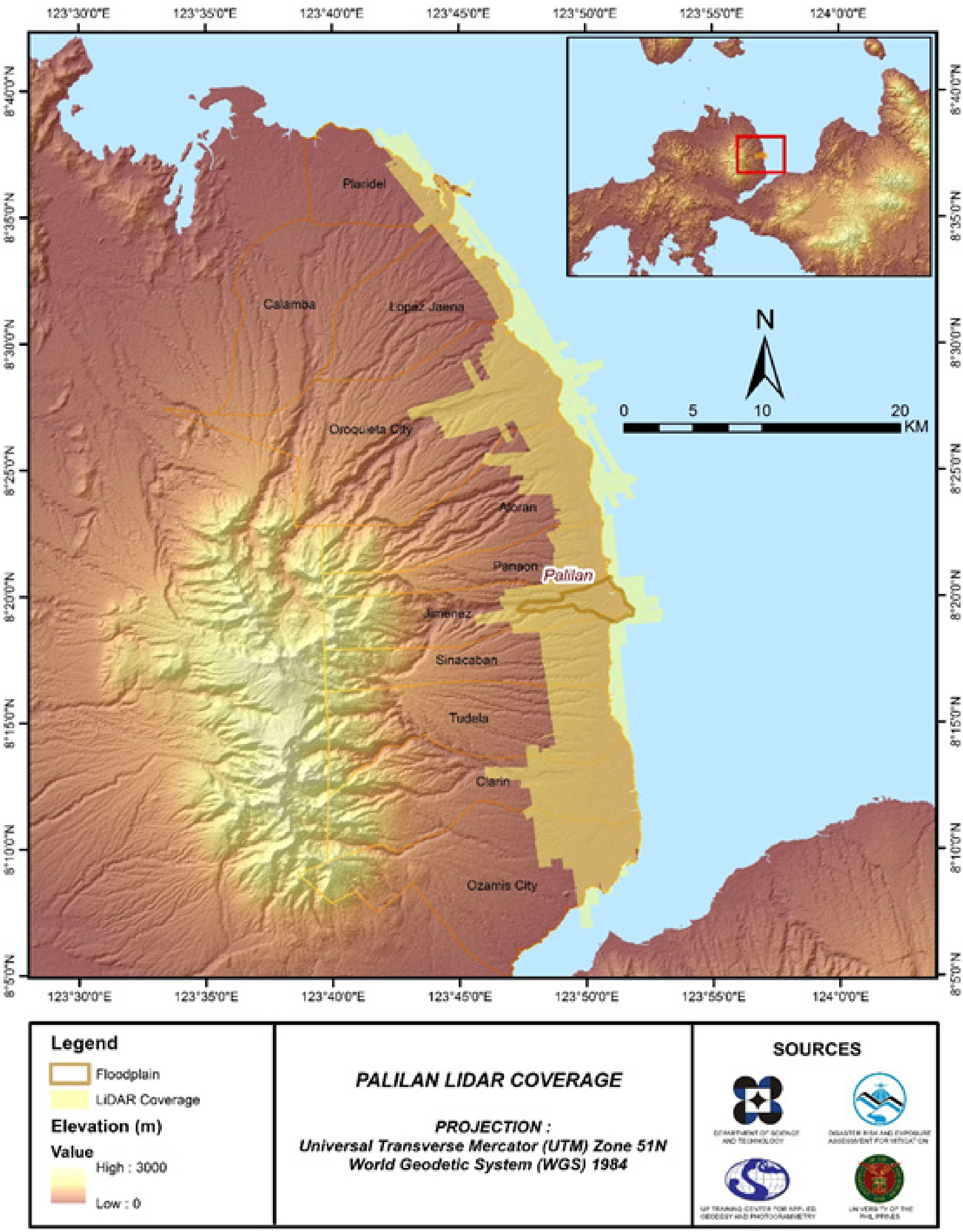

Figure 6. Actual LiDAR survey coverage of the Palilan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR PALILAN FLOODPLAIN

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

3.1 Overview of LiDAR Data Pre-Processing

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

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

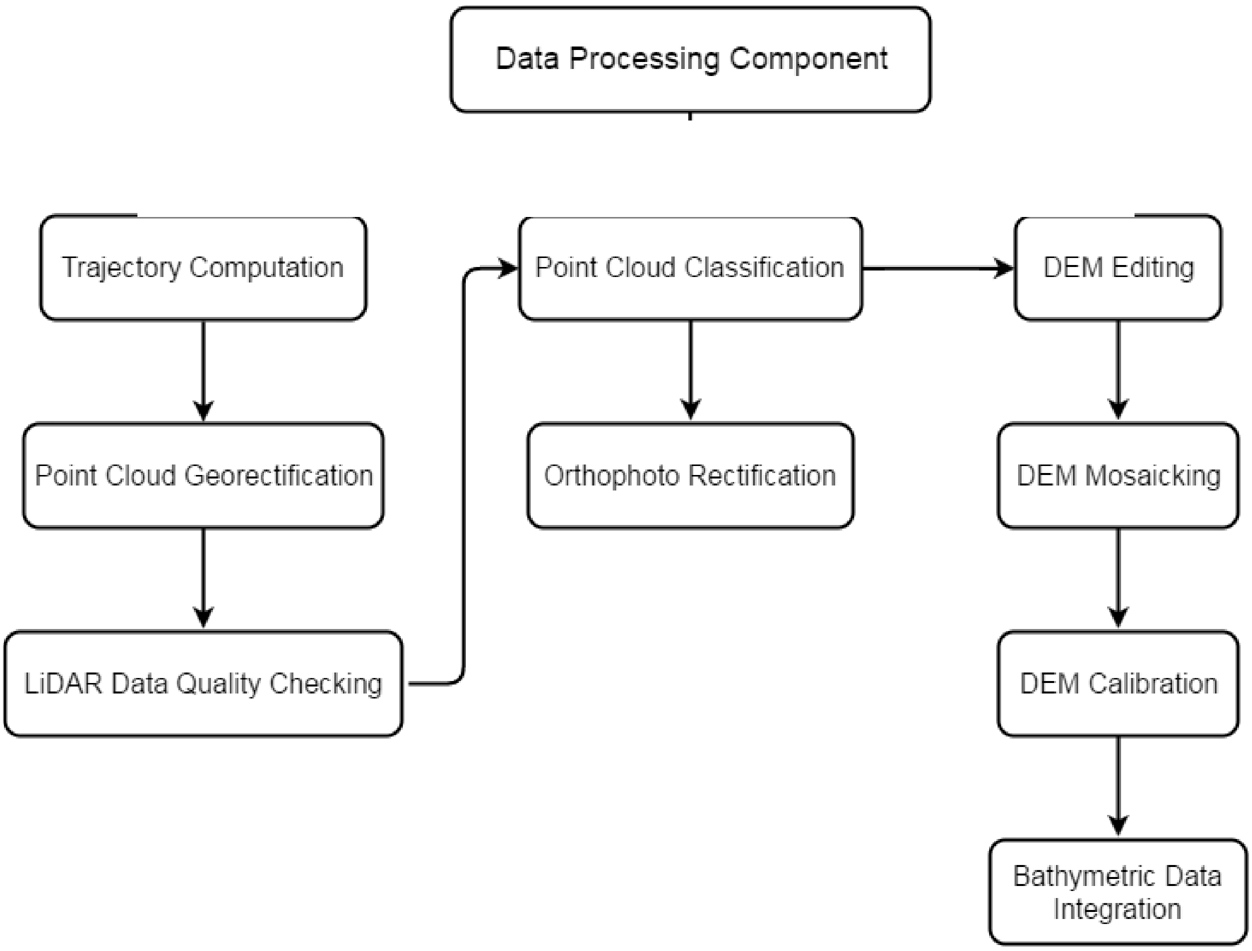

Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Palilan Floodplain can be found in Annex 5. The missions flown during the conduct of the first survey in November 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. Missions acquired during the second survey on March 2016 were flown using the same system over Dipolog and Pagadian.

The Data Acquisition Component (DAC) transferred a total of 45.00 Gigabytes of Range data, 0.80 Gigabytes of POS data, 155.40 Megabytes of GPS base station data, and 79.80 Gigabytes of raw image data to the data server on November 17, 2014 for the first survey and March 10, 2016 for the second survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Palilan Floodplain was fully transferred on March 10, 2016, as indicated on the Data Transfer Sheets for the Palilan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 23116P, one of the Palilan flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of March 7, 2016, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

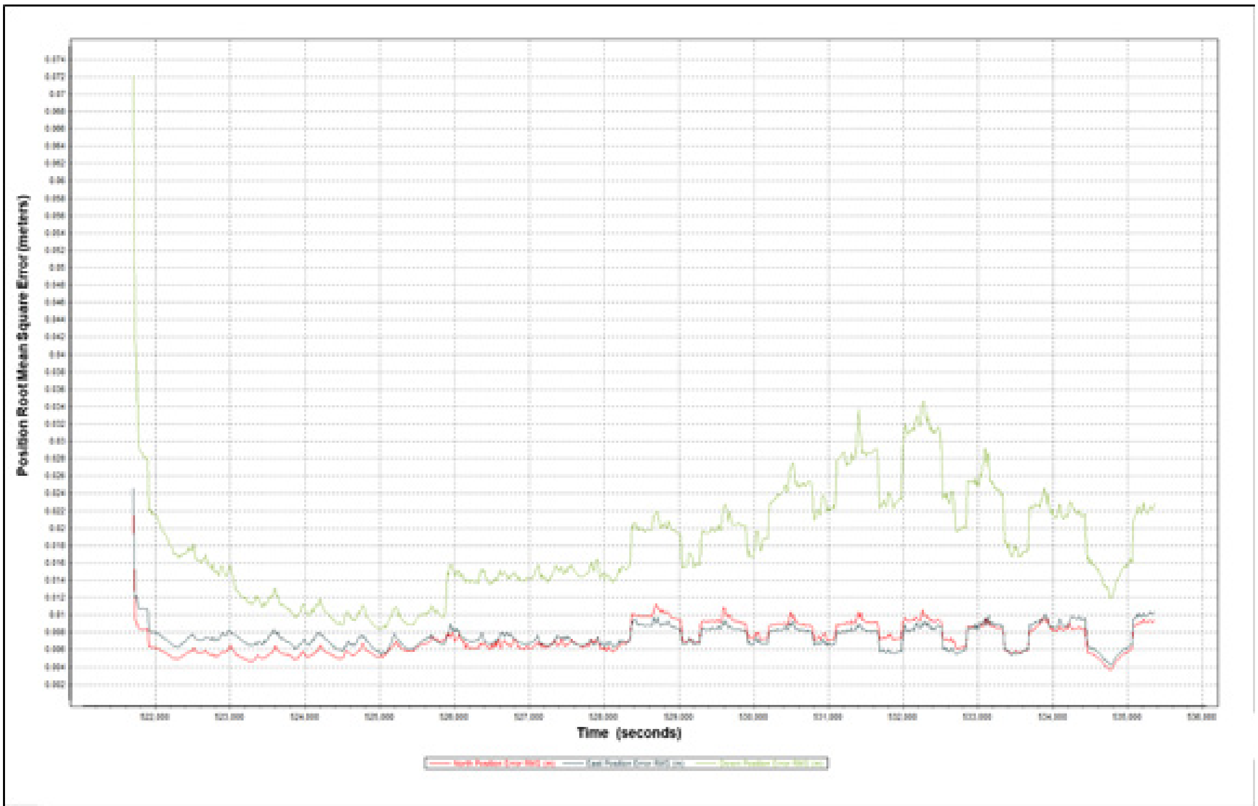

Figure 8. The Smoothed Performance Metric Parameters of Palilan Flight 23116P.

The time of flight was from 521,800 seconds to 535,400 seconds, which corresponds to afternoon of March 7, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 0.21 centimeters, the East position RMSE peaks at 0.024 centimeters, and the Down position RMSE peaks at 0.072 centimeters, which are within the prescribed accuracies described in the methodology.

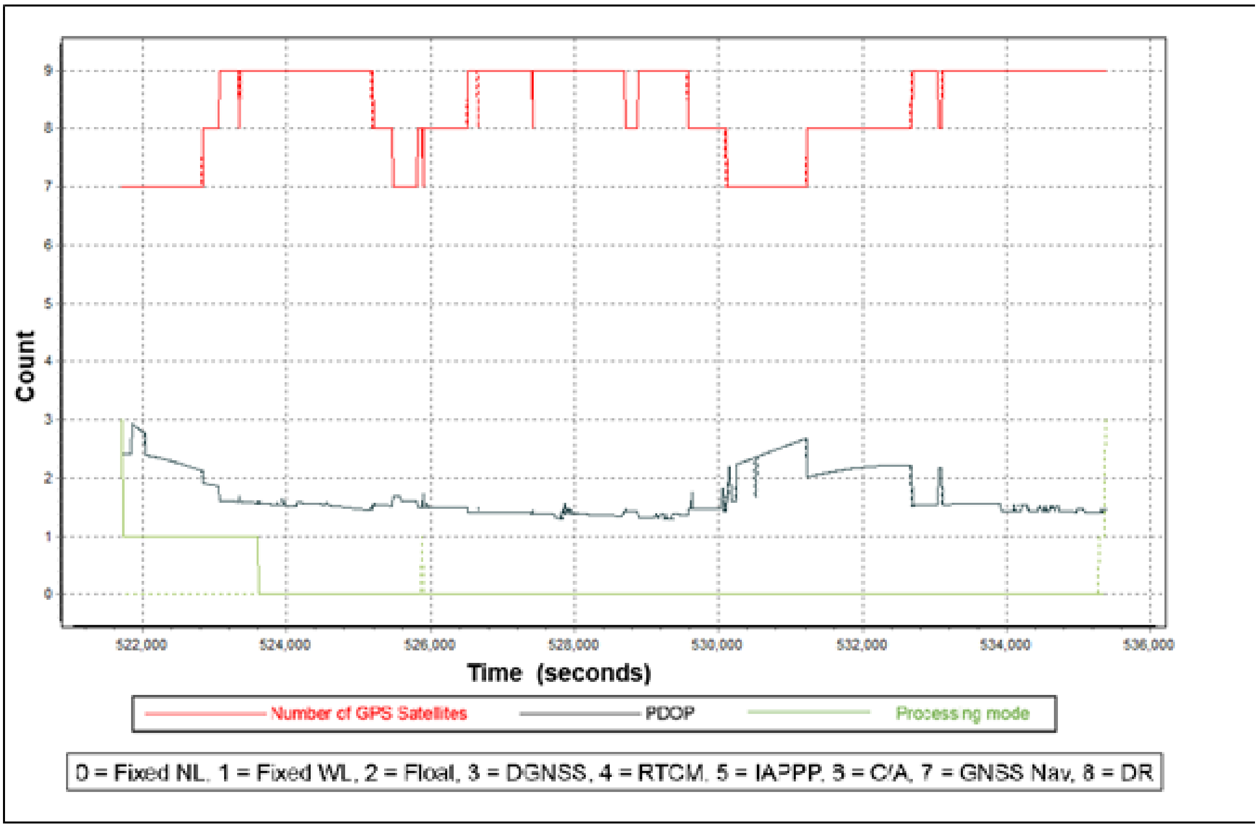

Figure 9. The Solution Status Parameters of Palilan Flight 23116P.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Palilan Flight 23116P are shown in Figure 9. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 7 and 9, not going lower than 7. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also stayed at the value of 0 for the majority of the survey stayed at the value of 0. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for the POSPAC MMS. Fundamentally, 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 Palilan flights is shown in Figure 10.

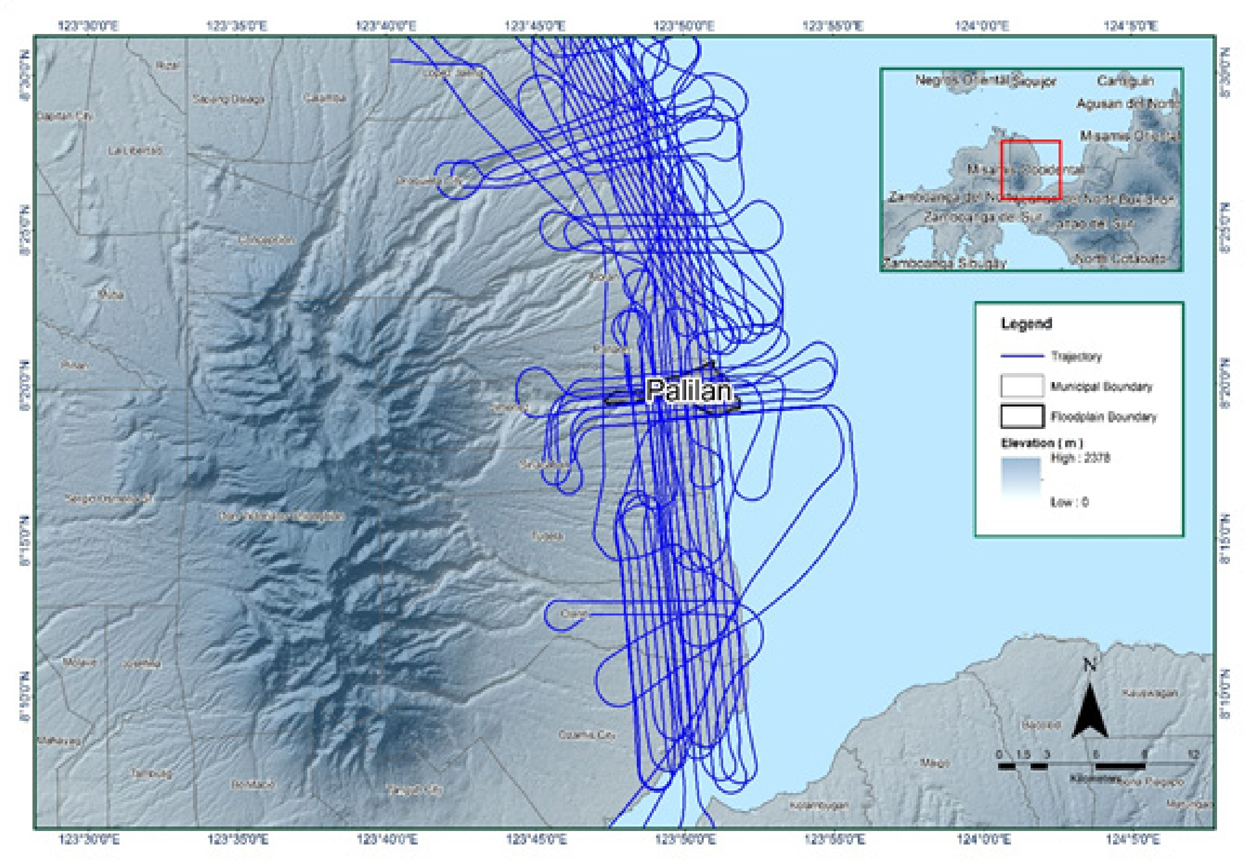

Figure 10. The Best Estimated Trajectory of the LiDAR missions conducted over the Palilan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 32 flight lines, with each flight line contains two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Palilan floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Palilan flights

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000276
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000306
GPS Position Z-correction stdev)	<0.01meters	0.0012

The optimum accuracy values for all Palilan flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (Annex 7).

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Palilan Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

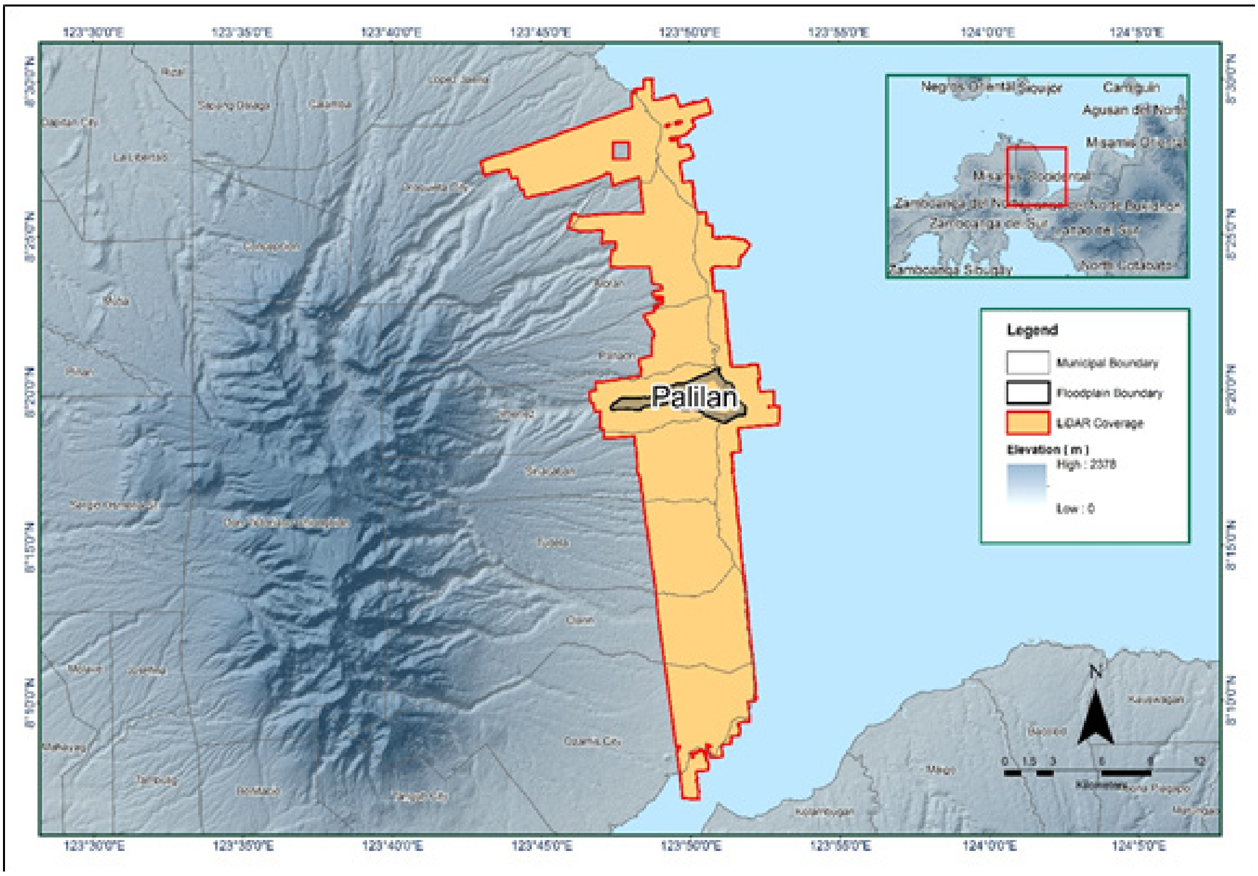

Figure 11. The boundaries of the processed LiDAR data over the Palilan Floodplain.

A total area of 270.06 square kilometers (sq. kms.) were covered by the Palilan flight missions as a result of four (4) flight acquisitions, which were grouped and merged into two (2) blocks accordingly, as portrayed in Table 11.

Table 11. List of LiDAR blocks for Palilan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dipolog_Blk69F	2133P	232.40
	2135P	
	2181P	
Pagadian_Blk76P_additional	23116P	37.66
	TOTAL	**270.06**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Pegasus system employs one channel, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

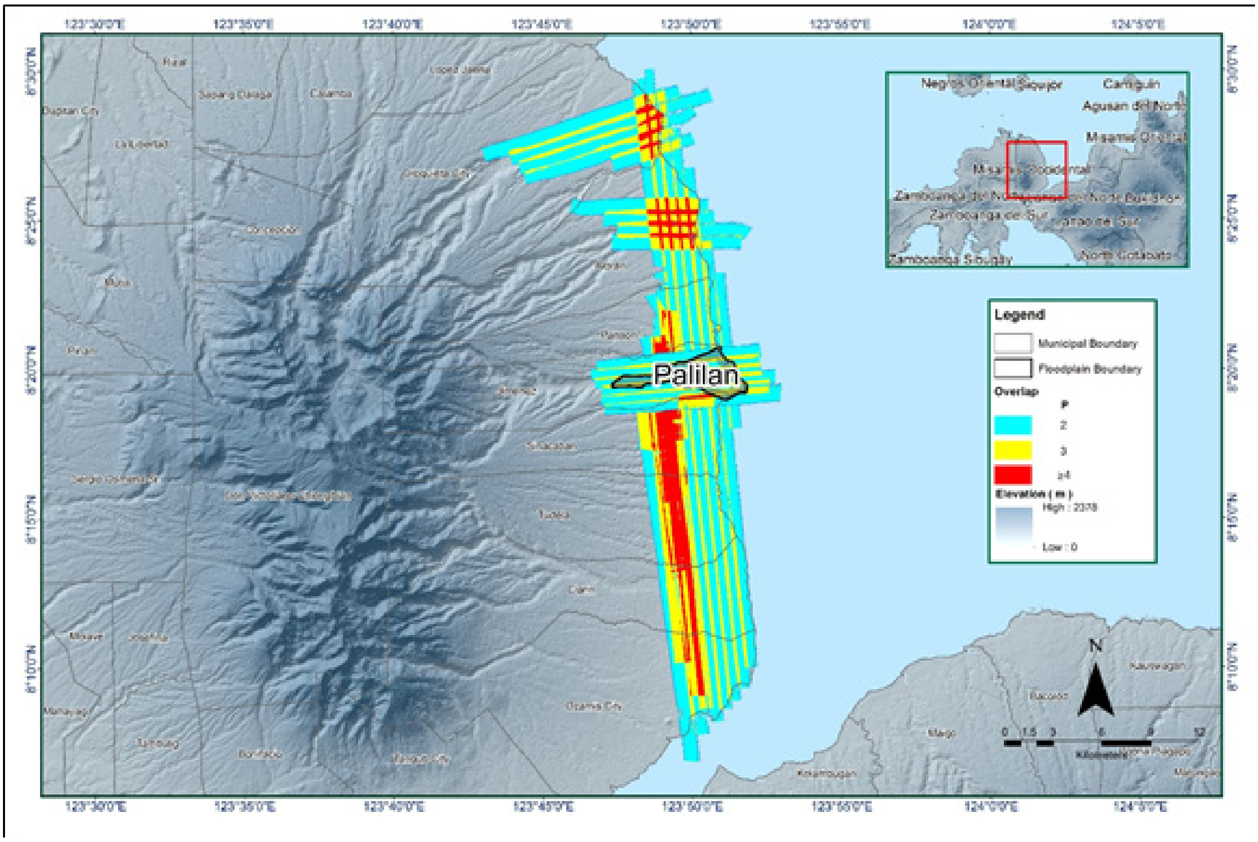

Figure 12. Data overlap between missions and flight lines for the Palilan River Floodplain Survey.

The overlap statistics per block for the Palilan Floodplain Survey can be found in the Mission Summary Reports (Annex 7). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 38.20%, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 16. As seen in the figure below, it was determined that all LiDAR data for the Palilan Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 4.16 points per square meter.

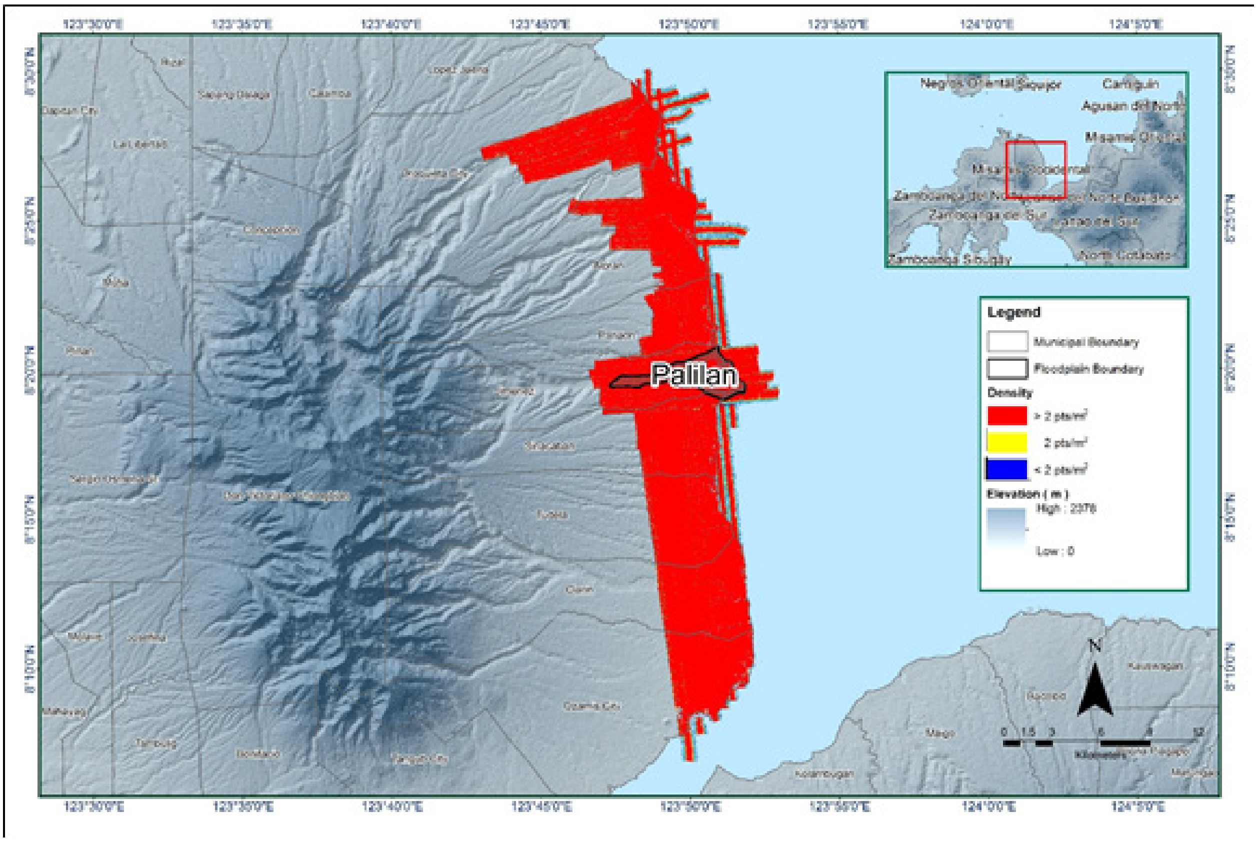

Figure 13. The pulse density map of the merged LiDAR data for the Palilan Floodplain Survey.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

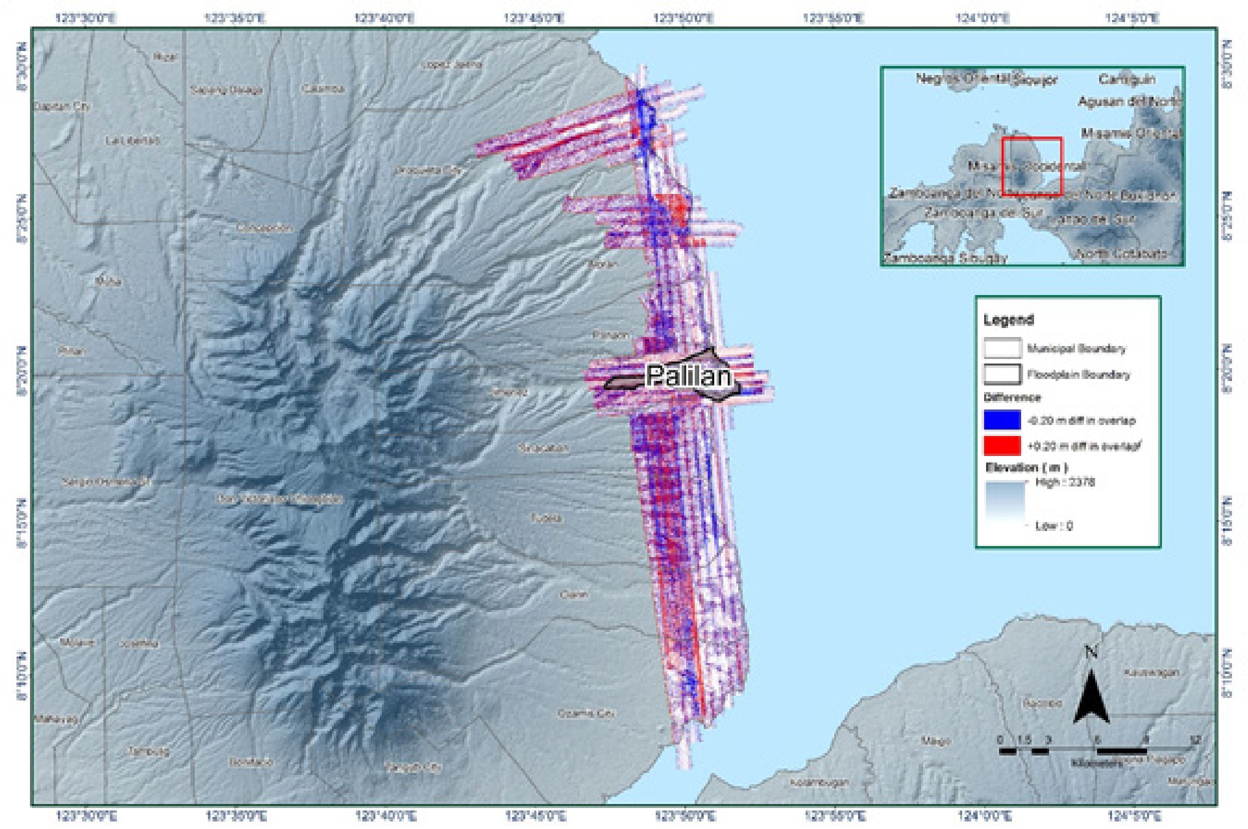

Figure 14. Map of elevation difference Map between flight lines for the Palilan Floodplain Survey.

A screen-capture of the processed LAS data from Palilan flight 23116P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red 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 generated satisfactory results. No reprocessing was done for this LiDAR dataset.

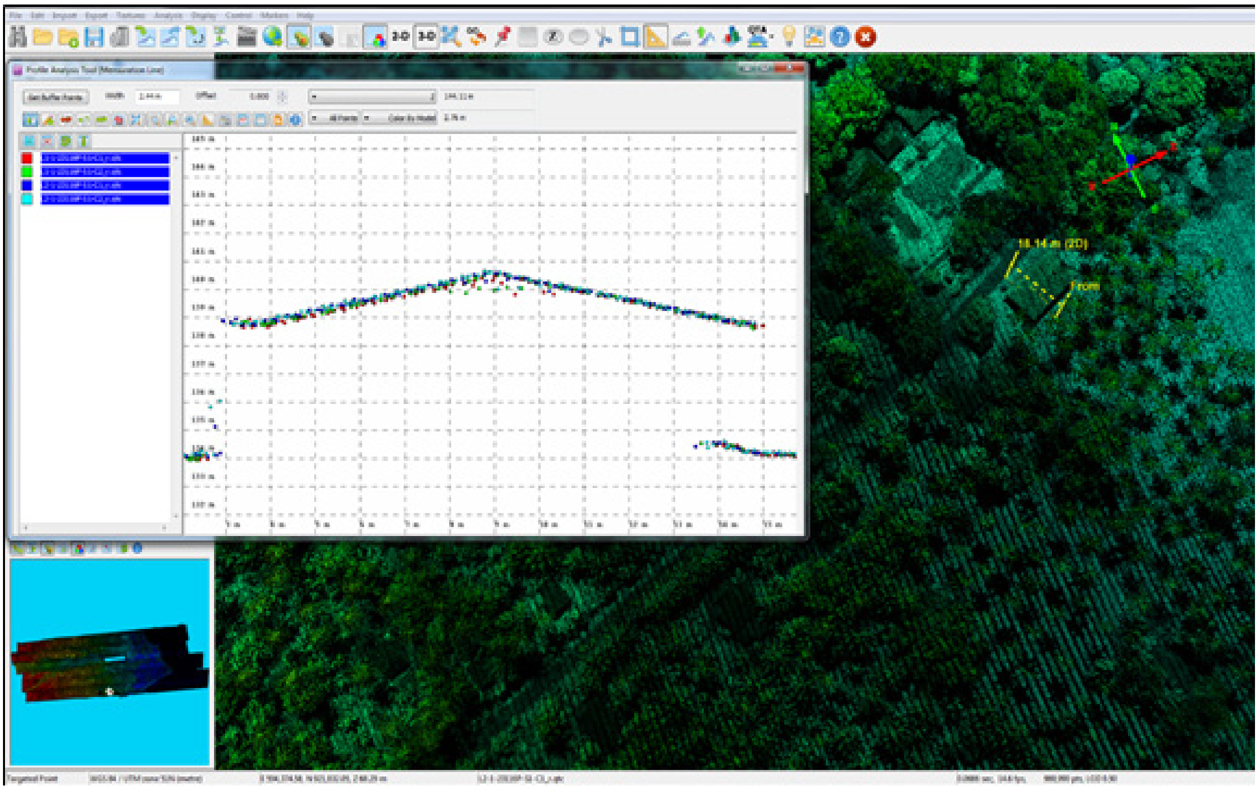

Figure 15. Screen-capture of the quality checking for Palilan Flight 23116P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. . Summary of point cloud classification results in TerraScan for Palilan River Floodplain.

Pertinent Class	Total Number of Points
Ground	303,245,758
Low Vegetation	329,594,755
Medium Vegetation	346,720,953
High Vegetation	505,919,120
Building	36,252,735

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Palilan floodplain is shown in Figure 16. A total of 365 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 12 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 367.21 meters and 53.91 meters respectively.

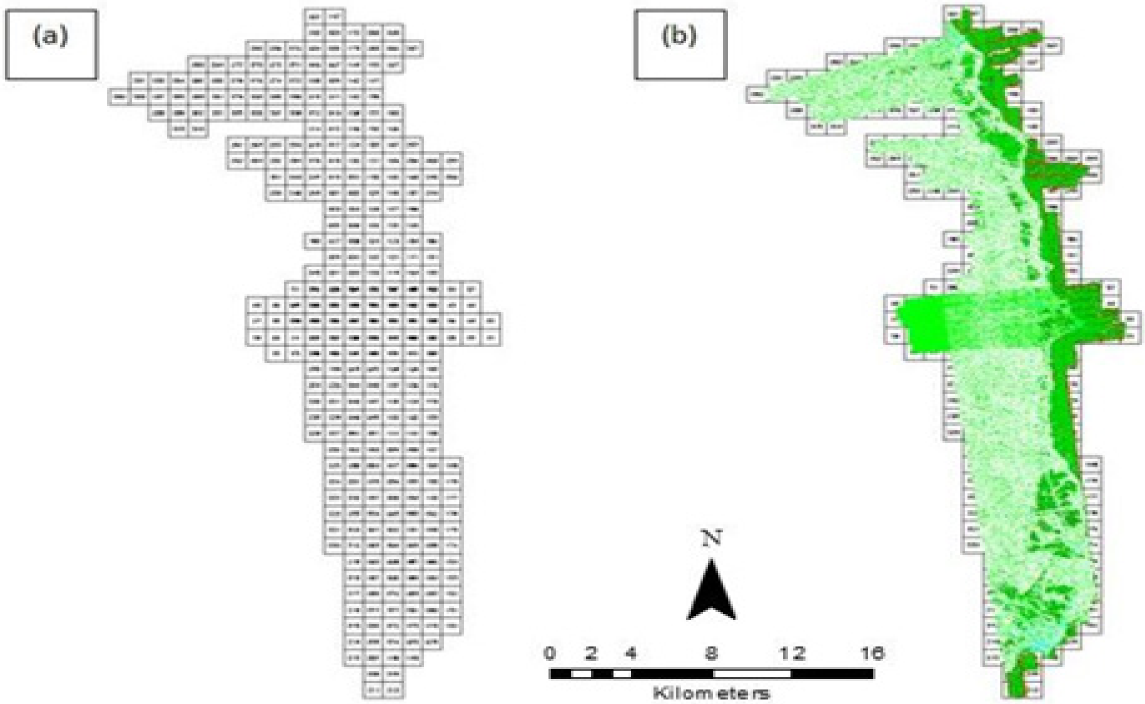

Figure 16. Tiles for Palilan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are highlighted in orange, while 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 the canopy are classified correctly, due to the density of the LiDAR data.

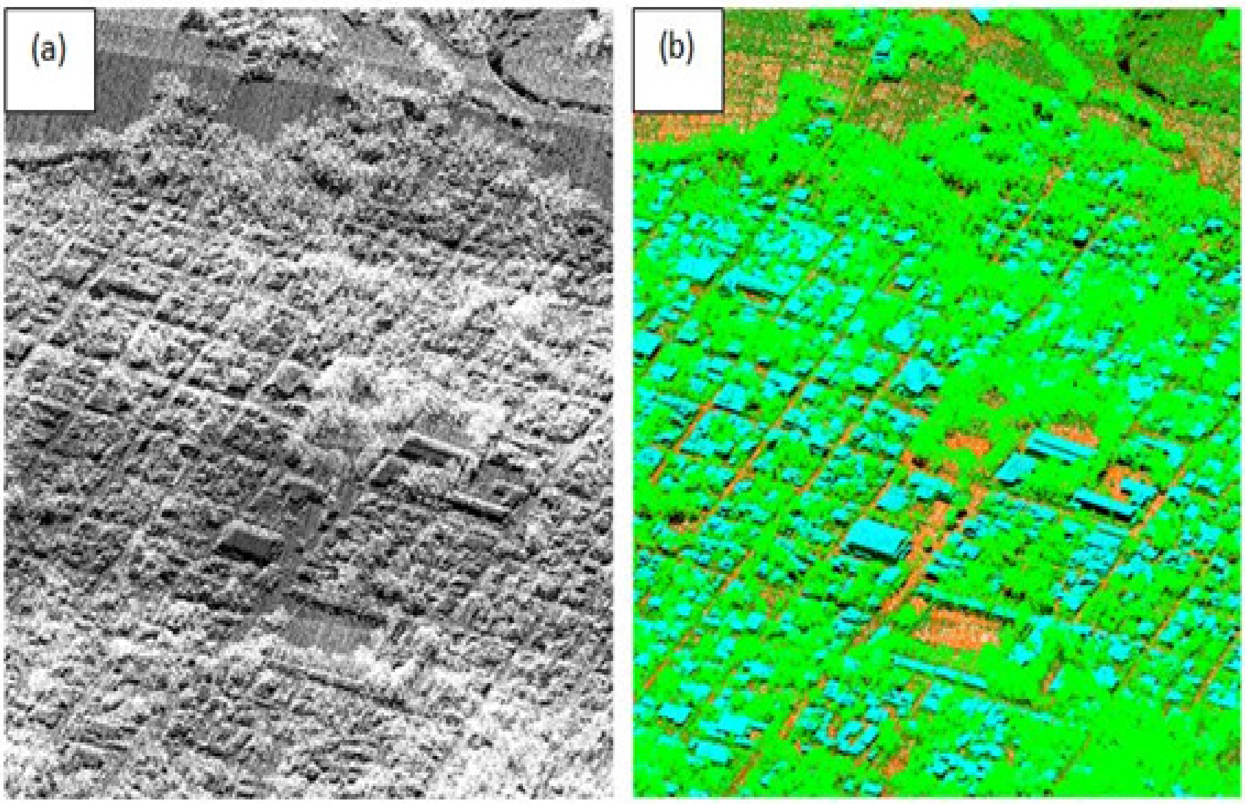

Figure 17. LiDAR Image Processing and Orthophotograph Rectification

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show in Figure 18. As seen in the figure, the DTMs represent the bare earth, while all other features, such as buildings and vegetation, are present in the DSMs.

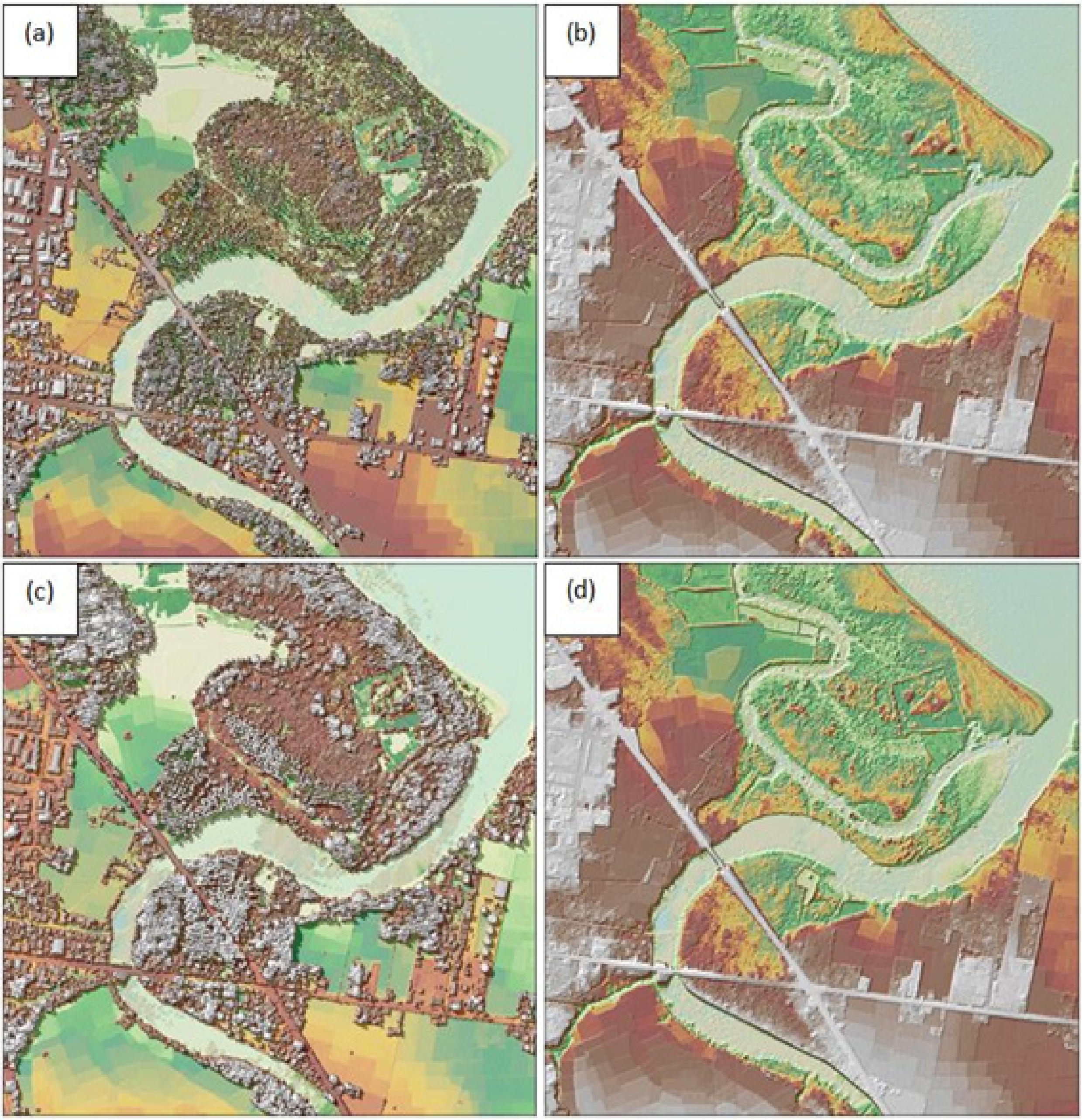

Figure 18. Photo (A) features the production of the last return DSM; (B) depicts the production of the DTM; (C) portrays the production of the first return DSM; and (D) presents the generation of the secondary DTM in some portions of the Palilan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 292 1km by 1km tiles area covered by the Palilan floodplain is shown in Figure 19. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Palilan floodplain attained a total of 221.13 sq. kms. in orthophotograph coverage comprised of 859 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

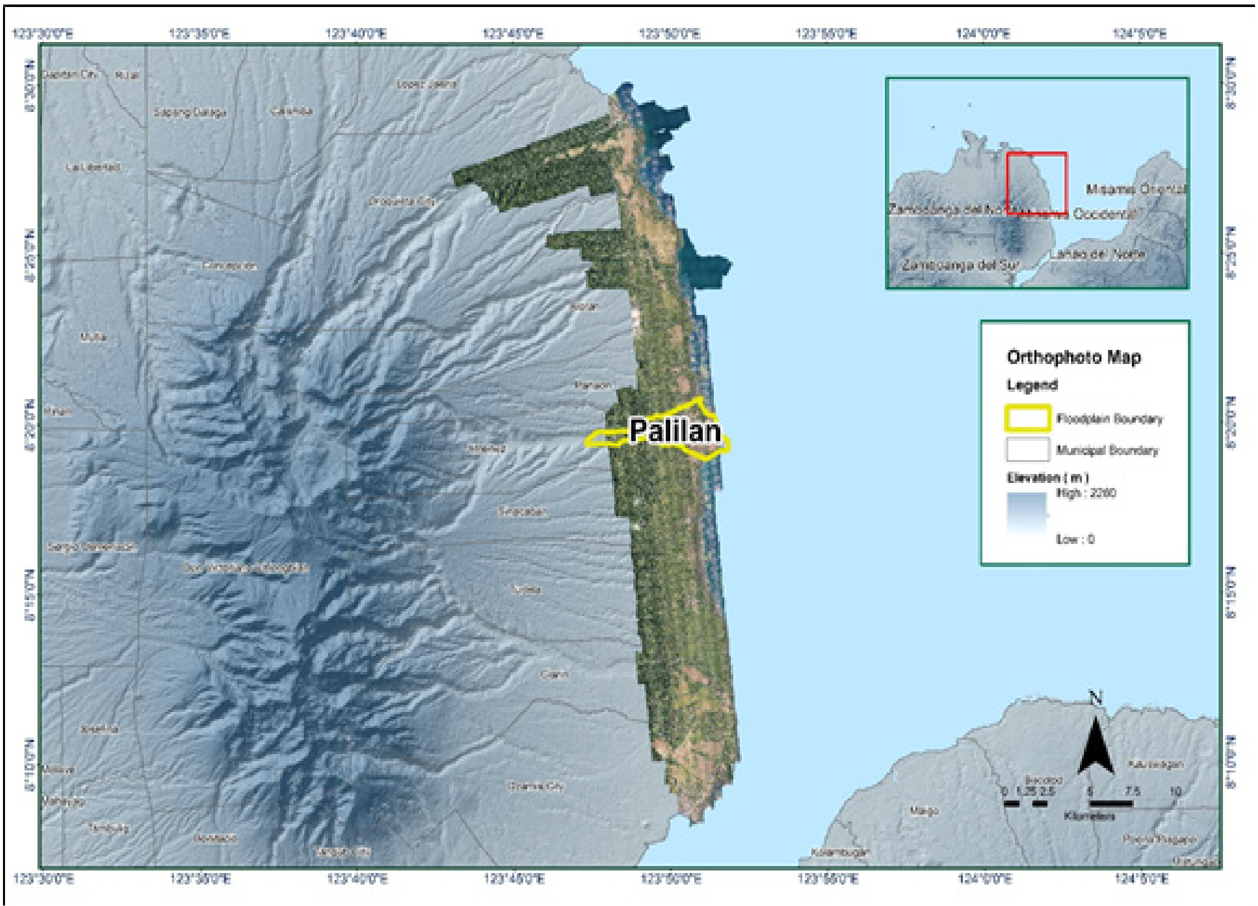

Figure 19. Palilan Floodplain with available orthophotographs.

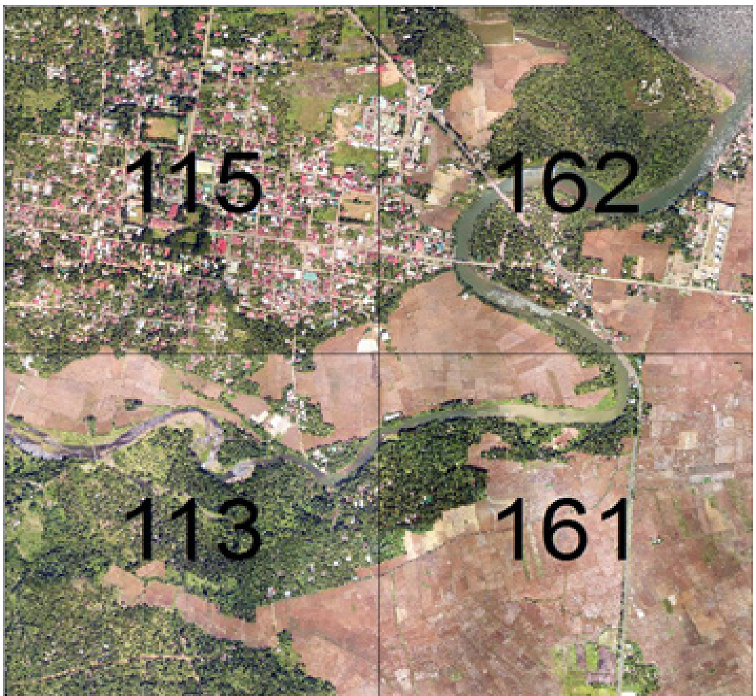

Figure 20. Sample orthophotograph tiles for the Palilan Floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for the Palilan Floodplain Survey. Essentially, these blocks are composed of 'Dipolog' and 'Pagadian' blocks, which arrive at a total area of 270.06 sq. kms. As listed in Table 13, the name and corresponding area of each block are measured out in square kilometers (sq. kms.).

Table 13. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Dipolog_Blk69F	232.40
Pagadian_Blk76P_additional	37.66
TOTAL	**270.06 sq. km**

Figure 21 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 21a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 21b). The river embankment (Figure 21c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water.

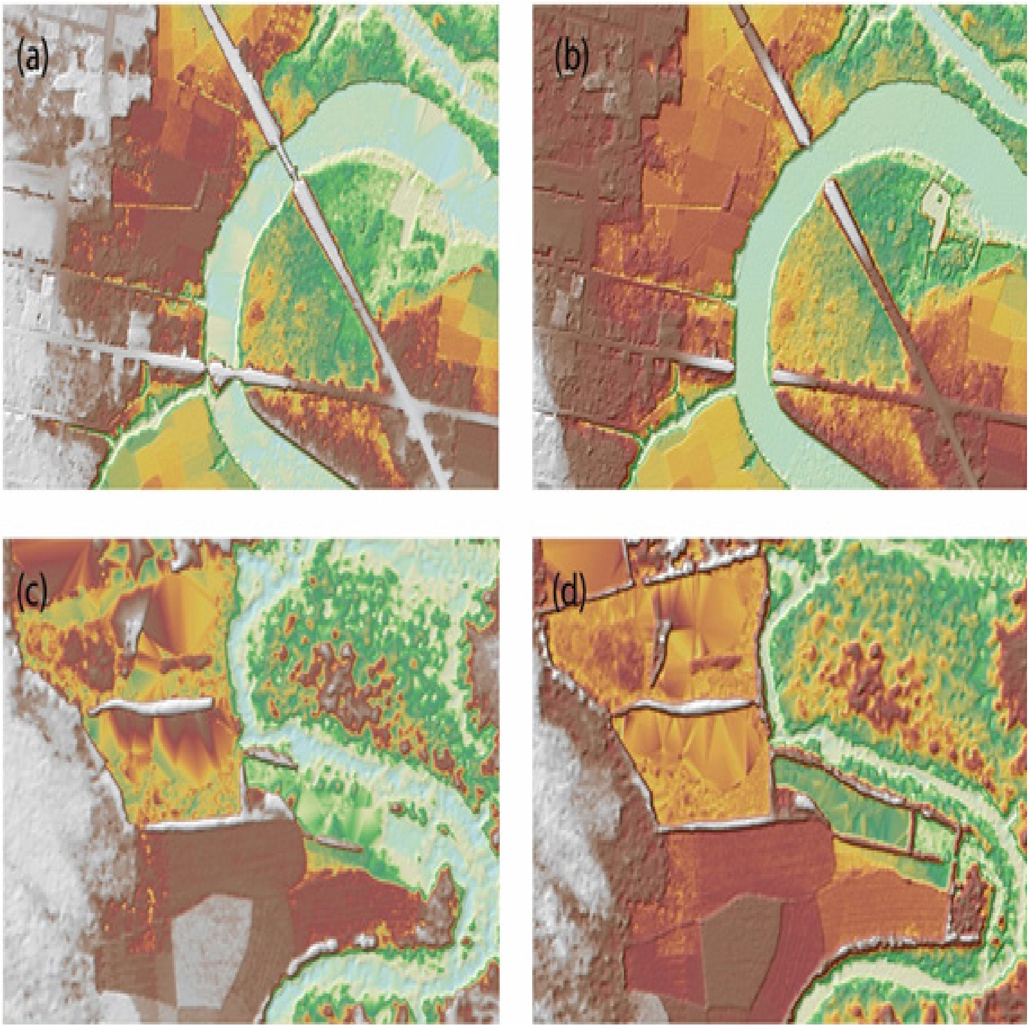

Figure 21. Portions in the DTM of the Palilan Floodplain showing (a) a bridge before undergoing manual; (b) bridge after manual editing; (c) a river embankment before undergoing manual editing;

3.9 Mosaicking of Blocks

NorthernMindanao_Blk71_Extension was used as the reference block at the start of mosaicking because it is already vertically calibrated to MSL and it overlaps Dipolog_Blk69F which is the largest DTM of Palilan river basin. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Palilan Floodplain is shown in Figure 22. It can be seen that the entire Palilan floodplain is 100% covered by LiDAR data.

Table 14. The shift values (in meters) for each LiDAR Block of the Palilan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dipolog_Blk69F	-0.15	0.21	-2.32000
Pagadian_Blk76P_additional	0.20	0.00	-2.49185

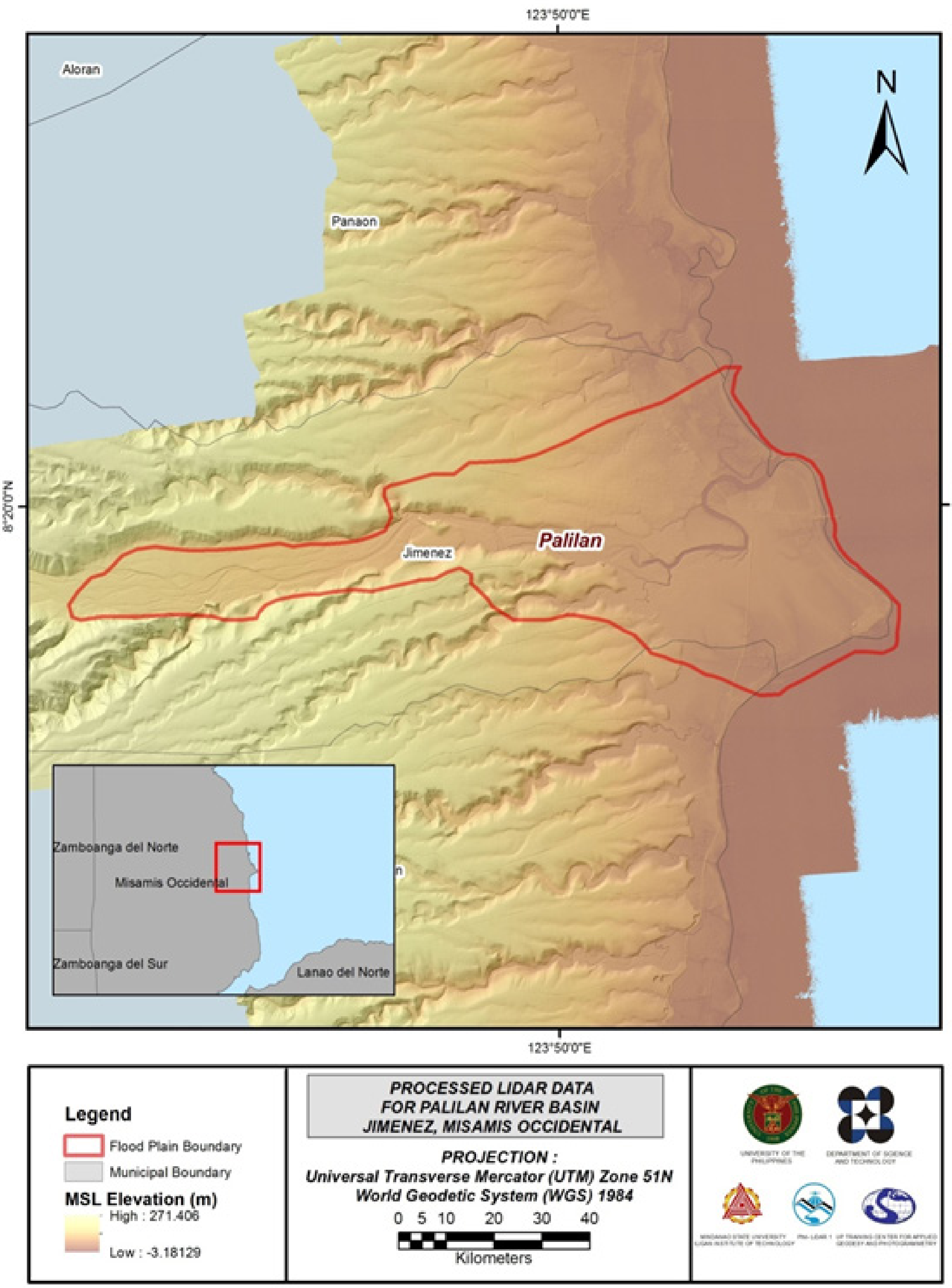

Figure 22. Map of processed LiDAR data for the Palilan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEMs

The extent of the validation survey done by the Data Validation and Bathymetry (DVBC) in Palilan to collect points with which the LiDAR dataset is validated is shown in Figure 23, with the validation survey points highlighted in green. A total of 2,003 survey points were gathered for the Palilan floodplain. Random selection of 80% of the survey points, resulting to 1,602 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and the ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of the data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 2.27 meters, with a standard deviation of 0.08 meters. The calibration of the Palilan LiDAR data was accomplished by subtracting the height difference value of 2.27 meters to the Palilan mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the Palilan LiDAR data and the calibration data.

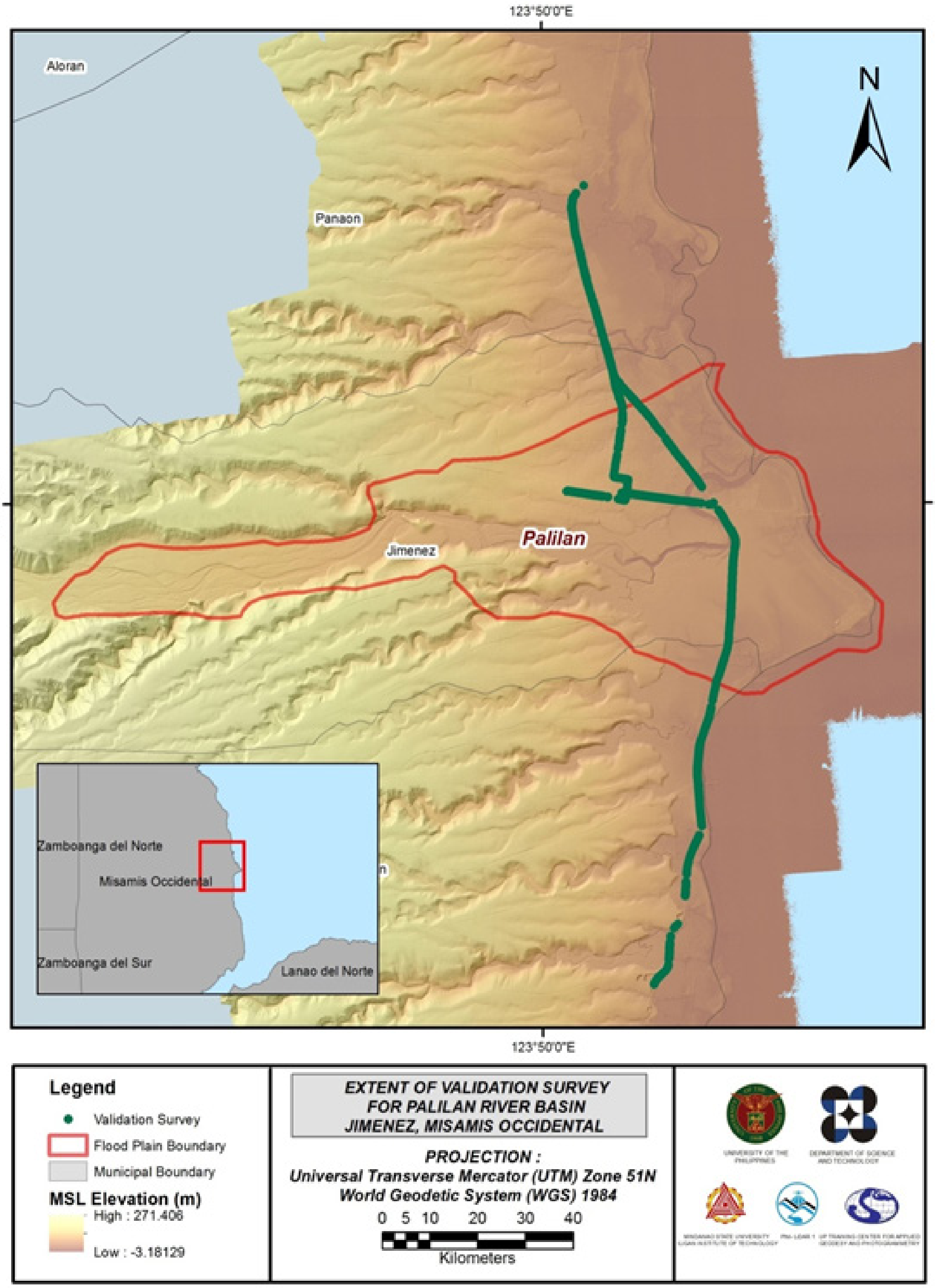

Figure 23. . Map of Palilan Floodplain with validation survey points in green.

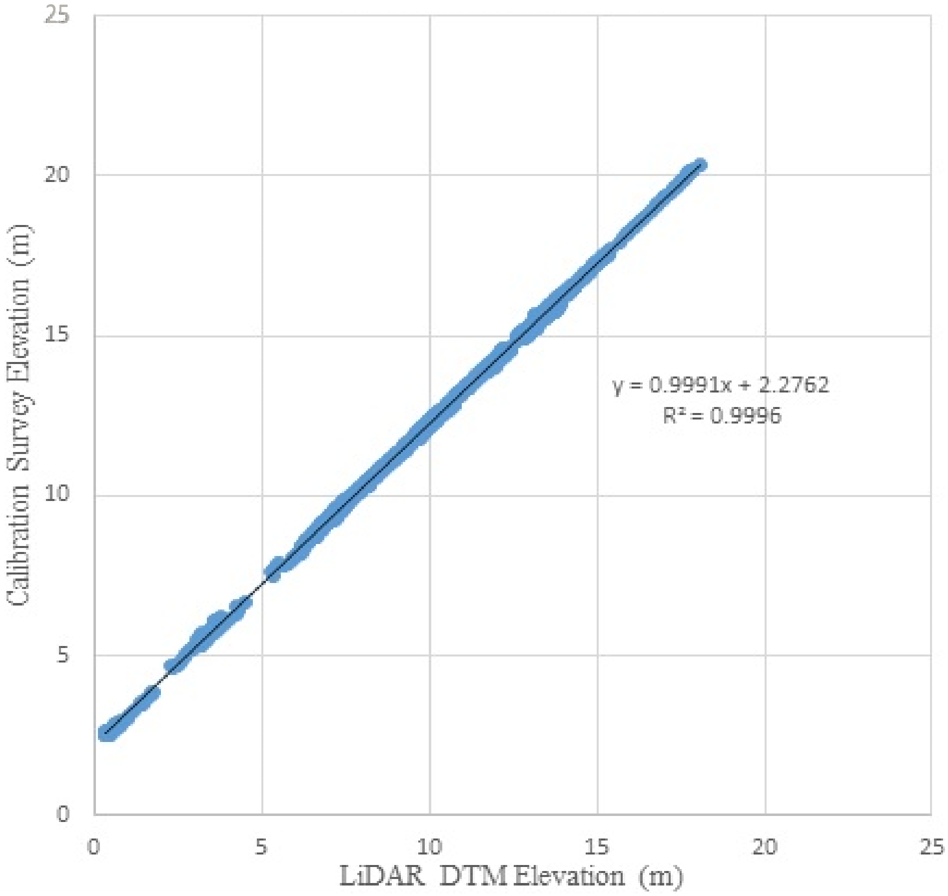

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 15. The calibration statistical measures of the compared elevation values between the Palilan LiDAR data and the calibration data.

Calibration Statistical Measures	Value (meters)
Height Difference	2.27
Standard Deviation	0.08
Average	2.27
Minimum	2.06
Maximum	2.52

A total of 294 survey points lie within the Palilan Floodplain; all of which were used to validate the calibrated Palilan DTM. A good correlation between the calibrated mosaicked LiDAR elevation and the ground survey elevation values, which point toward the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 0.08 meters with a standard deviation of 0.07 meters, as shown in Table 16.

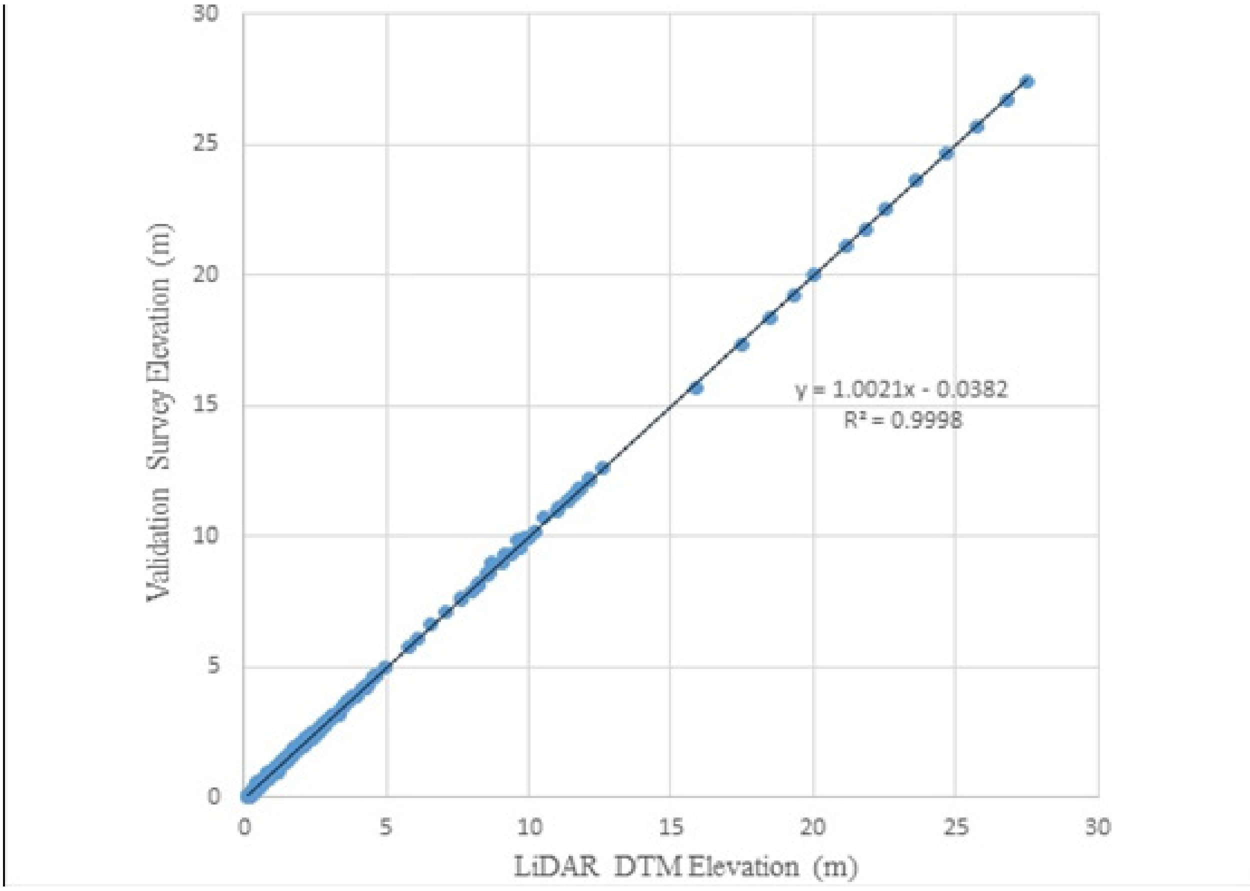

Figure 25. Correlation plot between the validation survey points and the LiDAR data.

Table 16. Statistical measures for the Palilan River Basin DTM validation.

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.07
Average	-0.03
Minimum	-0.22
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Palilan with a total of 2,369 survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.05 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Palilan integrated with the processed LiDAR DEM is shown in Figure 26.

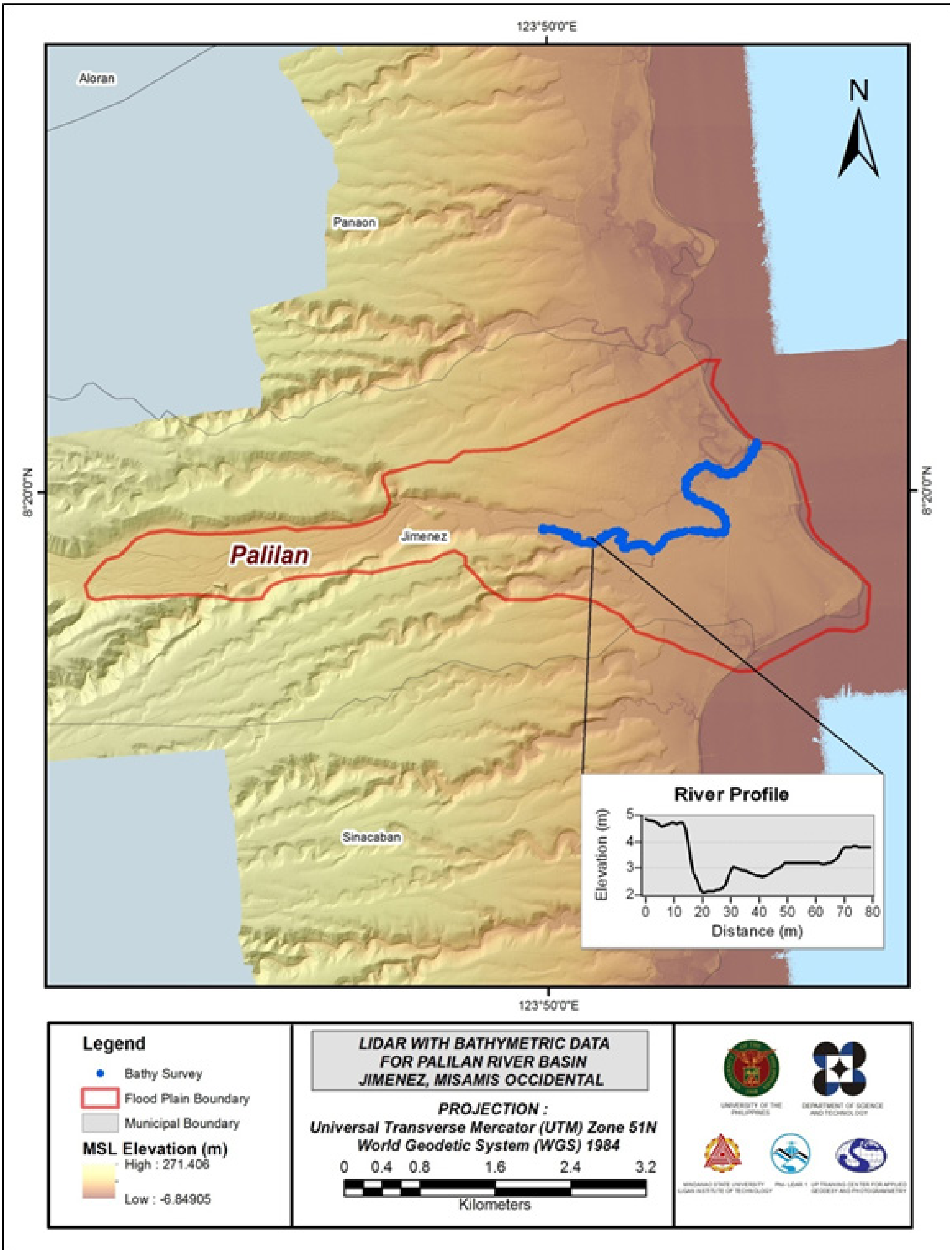

Figure 26. Extent of the bathymetric survey (in blue line) in Silay River and the LiDAR data validation survey (red).

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 DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Palilan floodplain, including its 200-m buffer, has a total area of 15.12 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 2,170 building features, were considered for QC. Figure 27 shows the QC blocks for the Palilan floodplain.

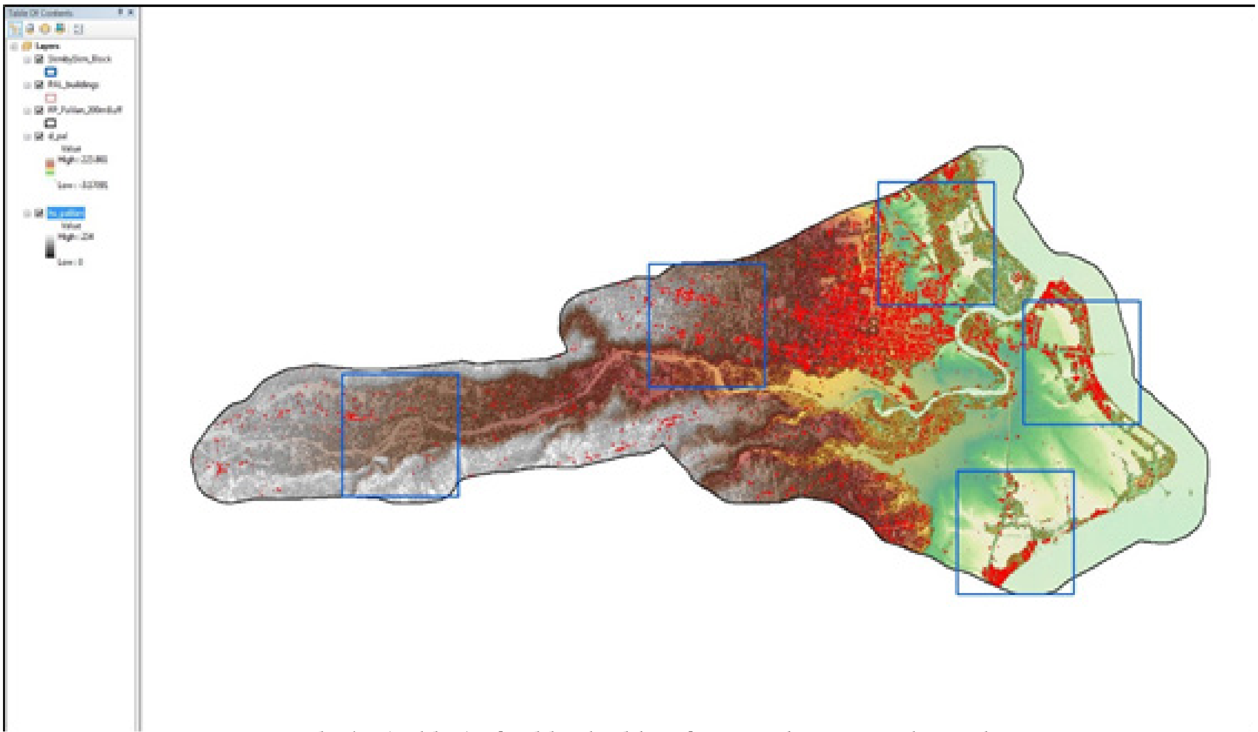

Figure 27. Blocks (in blue) of Palilan building features that were subjected to QC.

Quality checking of Palilan building features resulted in the ratings shown in Table 18.

Table 17. Details of the quality checking ratings for the building features extracted for the Palilan River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Palilan	97.28	97.14	84.61	PASSED

3.12.2 Height Extraction

Height extraction was done for 6,212 building features in Palilan floodplain. Of these building features, none was filtered out after height extraction, resulting to 6,212 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.46 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the flood plain of the river basin.

Table 18 summarizes the number of building features per type, while Table 19 shows the total length of each road type. Table 20, on the other hand, shows the number of water features extracted per type.

Table 18. Building Features Extracted for Palilan Floodplain.

Facility Type	No. of Features
Residential	5,846
School	67
Market	11
Agricultural/Agro-Industrial Facilities	20
Medical Institutions	12
Barangay Hall	13
Military Institution	2
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	3
Transport Terminal	1
Warehouse	11
Power Plant/Substation	1
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	47
Bank	4
Factory	0
Gas Station	37
Fire Station	0
Other Government Offices	57
Other Commercial Establishments	76
Total	**6,212**

Table 19. . Total length of extracted roads for the Palilan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Palilan	29.57	21.81	0.00	4.53	0.00	**55.91**

Table 20. Number of extracted water bodies in the Palilan Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Palilan	3	0	0	0	1	**4**

A total of 14 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 28 shows the completed Digital Surface Model (DSM) of the Palilan Floodplain, with all its ground features.

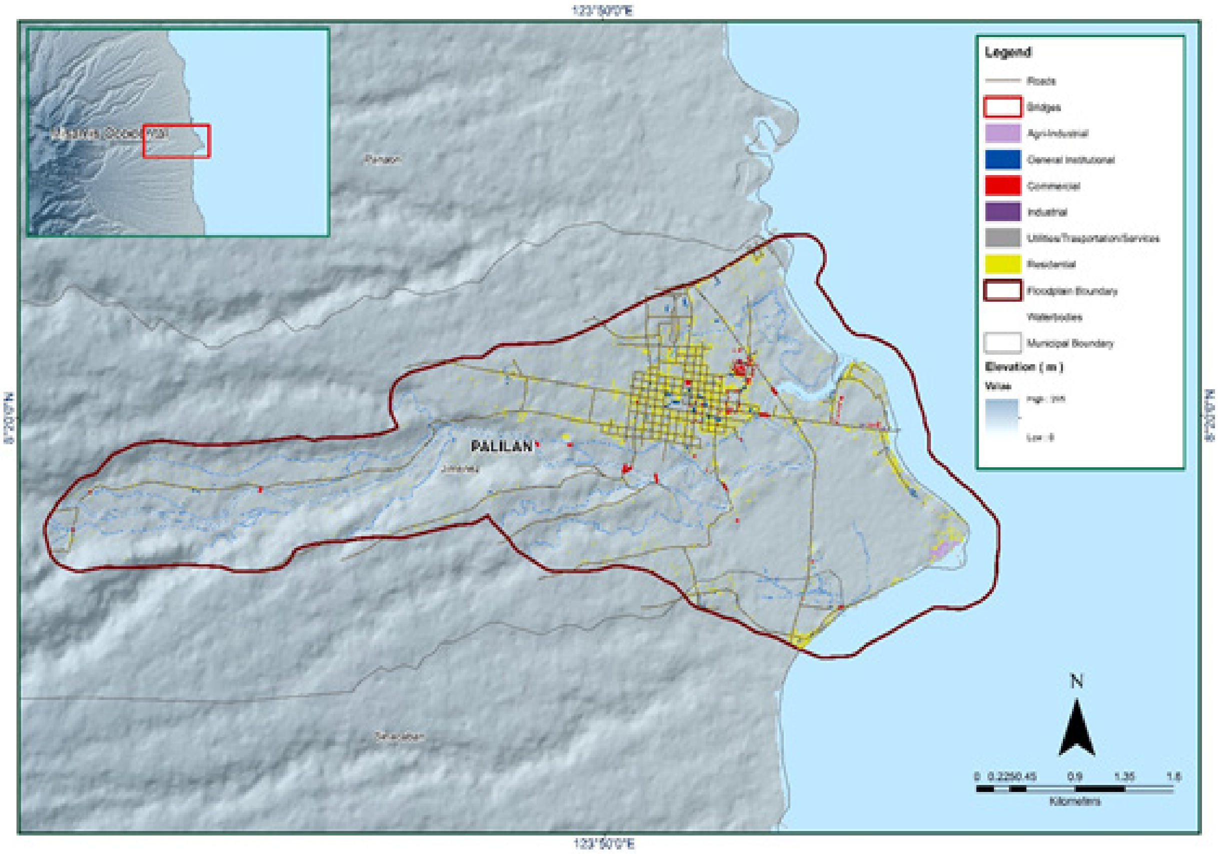

Figure 28. Extracted features for Palilan Floodplain.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE PALILAN RIVER BASIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Engr. Harmond F. Santos , Engr. Ma. Ailyn L. Olanda, Aljon Rie V. Araneta, Engr. James Kevin M. Dimaculangan , Engr. Jommer M. Medina, John Arnold C. Jaramilla

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

DVBC conducted the field survey in Palilan River from October 8 to 19, 2015 with the following scope of work: reconnaissance; courtesy call to the barangays near the survey area for information dissemination of the team's activities and to ask for a boat and a local aide's assistance; control survey for the establishment of a control point; cross-section and bridge as-built and water level marking in MSL of Sinara Bajo Hanging Bridge; ground validation data acquisition survey of about 11.3 km; bathymetric survey of Palilan River from Brgy. Corrales down to the mouth of the river in Brgy. Rizal using Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 utilizing GNSS PPK survey technique.

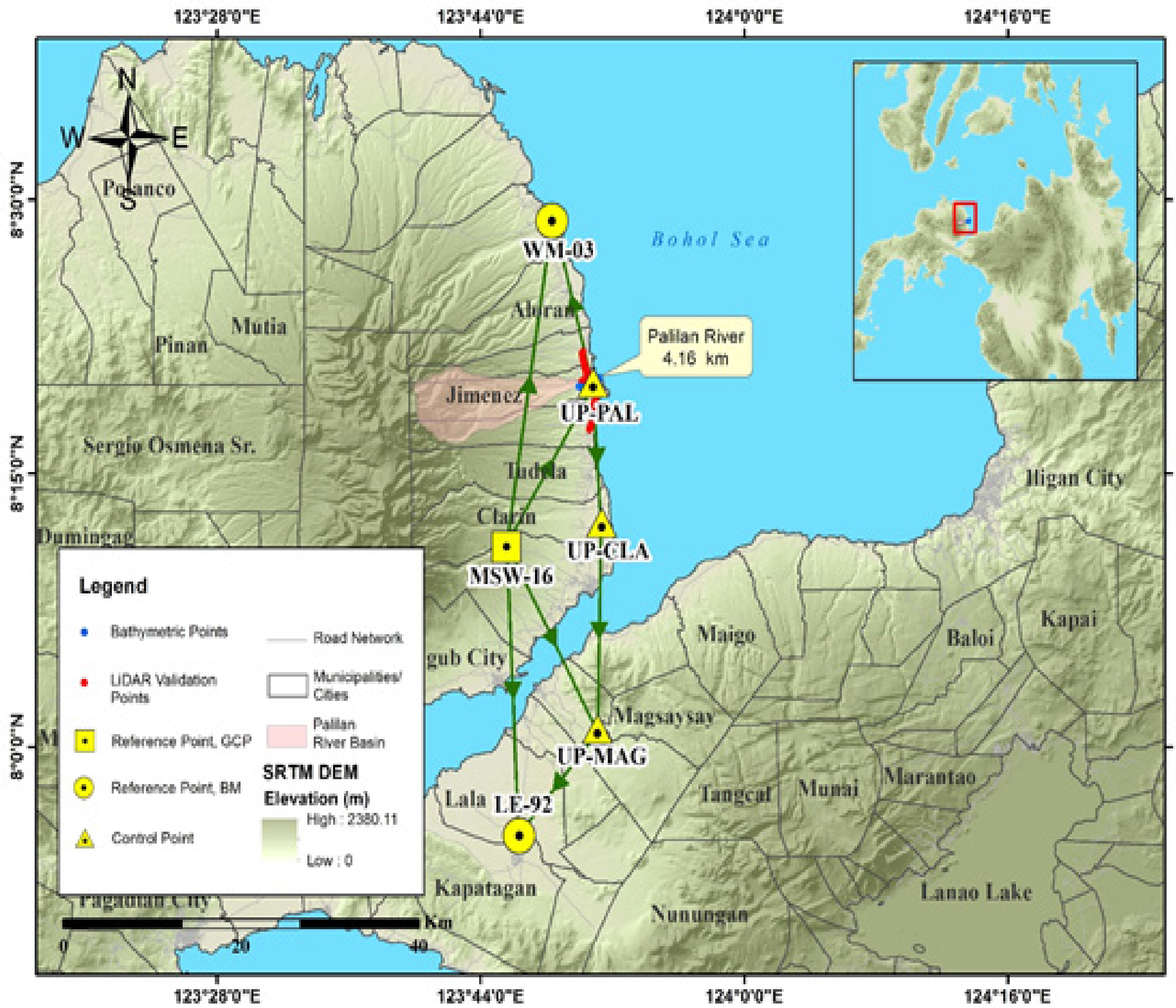

Figure 29. Extent of the bathymetric survey (in blue line) in Palilan River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Palilan River is composed of four loops established on October 9 and 16, 2015 occupying the following reference points: MSW-16, a second order GCP located in Brgy. Stimson Abordo, Ozamis City, Misamis Occidental; and LE-92, a first order BM in Brgy. Maranding, Mun. of Lala, Lanao Del Norte.

Three (3) control points were established along approach of bridges namely: UP-CLA along Clarin Bridge in Brgy. Poblacion IV, Mun. of Clarin, Misamis Occidental, UP-MAG along Magsaysay Briodge in Brgy. Baguiguicon, Mun. of Magsaysay, Lanao Del Norte; and UP-PAL, along Palilan Bridge in Brgy. Rizal, Mun. of Jimenez, Misamis Occidental. A NAMRIA established control point namely WM-03 in Brgy. Lower Langcangan, Oroquieta City, Misamis Occidental, was also occupied to use as marker during the survey.

Table 21 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Palilan River Survey.

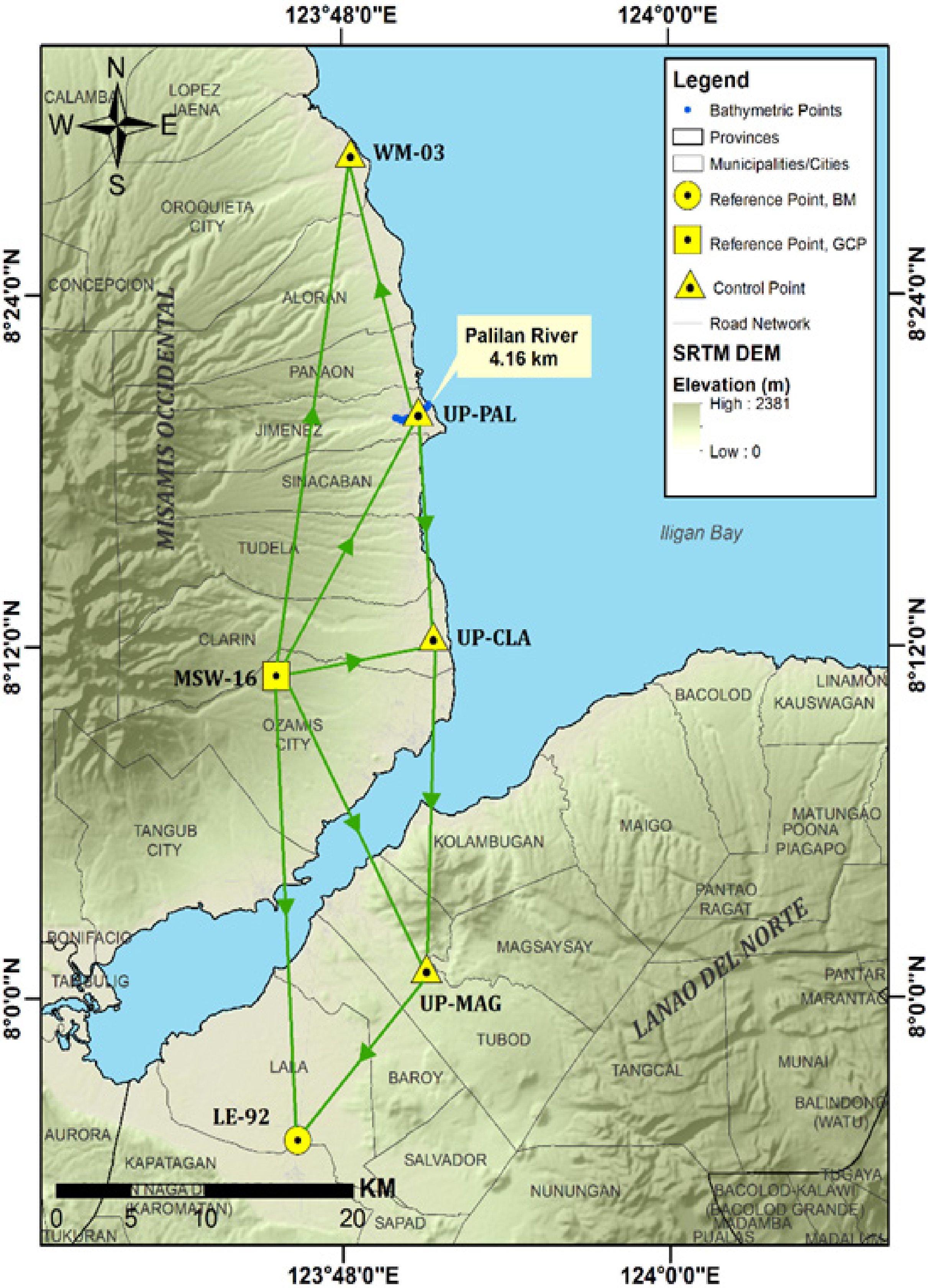

Figure 30. GNSS Network of Palilan Field Survey

Table 21. References used and control points established in the Palilan River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MSW-16	2nd Order, GCP	8°11'00.29164"N	123°45'35.16284"E	360.45	-	2007
LE-92	1st Order, BM	7°55'08.47442"N	123°46'19.89121"E	89.406	18.440	2007
WM-03	Used as Marker	-	-	71.984	-	10-09-2015
UP-CLA	UP Established	-	-	73.574	-	10-16-2015
UP-MAG	UP Established	-	-	75.086	-	10-16-2015
UP-PAL	UP Established	-	-	104.343	-	10-09-2015

Figure 31 to Figure 35 depict the setup of the GNSS on recovered reference points and established control points in the Misamis Occidental and Lanao del Norte Survey.

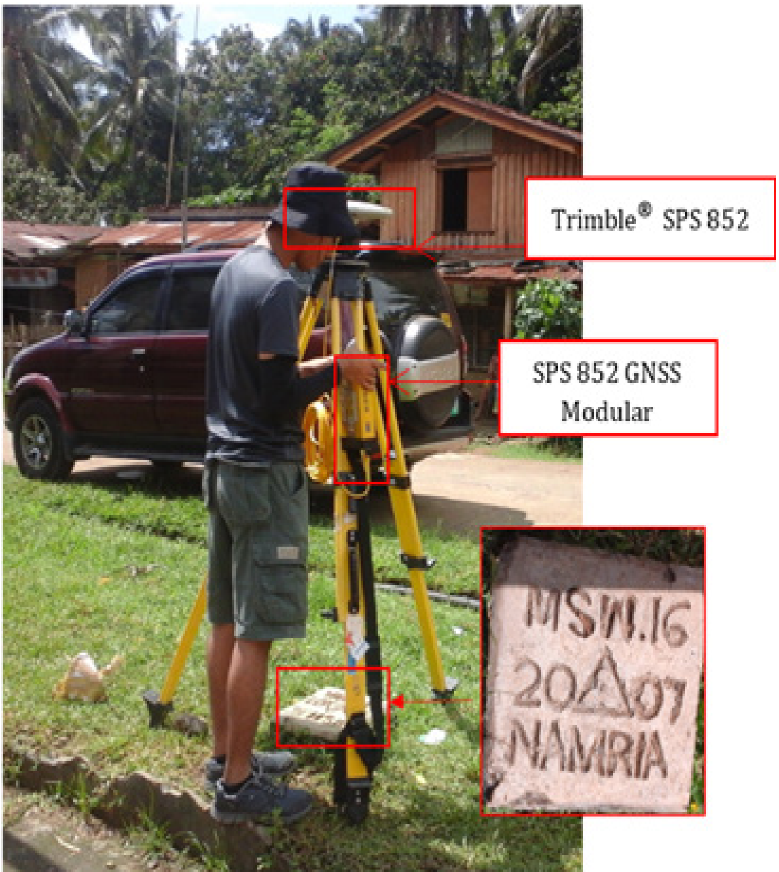

Figure 31. The GNSS base receiver setup, Trimble® SPS 852 setup at MSW-16 beside the fence of the basketball court in Brgy. Stimson Abordo, Ozamiz City, Misamis Occidental.

Figure 32. Trimble® SPS 882 setup at WM-03, G. Pelaez Bridge approach in Brgy. Langcangan Lower, Oroquieta City, Misamis Occidental.

Figure 33. Trimble® SPS 985 setup at UP-CLA, Clarin Bridge approach in Brgy. Poblacion IV, Mun. of Clarin, Misamis Occidental.

Figure 34. Trimble® SPS 852 setup at UP-MAG, Magsaysay Bridge approach in Brgy. Baguiguicon, Mun. of Magsaysay, Lanao del Norte

Figure 35. . Trimble® SPS 882 setup at UP-PAL, Palilan Bridge approach in Brgy. Rizal, Jimenez, Misamis Occidental.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 22 presents the baseline processing results of control points in the Palilan River Basin, as generated by the TBC software.

Table 22. The Baseline processing report for the Palilan River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MSW-16 --- WM-03	10-09-2015	Fixed	0.004	0.020	8°43'51"	33276.508	-288.452
UP-MAG --- LE-92	10-16-2015	Fixed	0.005	0.022	218°55'21"	13902.765	-14.918
UP-CLA --- UP-MAG	10-16-2015	Fixed	0.007	0.029	181°19'19"	20888.063	29.273
UP-PAL --- UP-CLA	10-16-2015	Fixed	0.012	0.036	176°03'05"	14161.786	1.493
UP-PAL --- WM-03	10-09-2015	Fixed	0.004	0.020	344°25'08"	16925.934	-1.589
MSW-16 --- LE-92	10-16-2015	Fixed	0.005	0.028	177°19'03"	29272.955	-271.079
UP-MAG --- MSW-16	10-16-2015	Fixed	0.004	0.028	151°15'40"	21010.700	-256.104
MSW-16 --- UP-CLA	10-16-2015	Fixed	0.014	0.022	76°54'34"	10861.490	-285.310
UP-CLA --- MSW-16	10-16-2015	Fixed	0.004	0.026	76°54'34"	10861.481	-285.415
MSW-16 --- UP-PAL	10-09-2015	Fixed	0.005	0.019	30°03'43"	19166.124	-286.892

As shown in Table 22, a total of ten (10) baselines were processed with the coordinates of MSW-16, and the elevation value of reference points LE-19 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. 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 for each control point; or in equation form:

$$\sqrt{(X\_e)2+(Y\_e)2)}<20\text{cm and } Z\_e<10 \text{ cm}$$

Where:

Xe is the Easting Error,
Ye is the Northing Error, and
Ze is the Elevation Error

For complete details, see the Network Adjustment Report shown in Table 26 to Table 29.

The five (5) control points, MSW-16, LE-92, WM-03, UP-CLA, UP-MAG, and UP-PAL were occupied and observed simultaneously to form a GNSS loop. Coordinates of MSW-16 and elevation of LE-92 were held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MSW-16	Global	Fixed	Fixed		
LE-92	Grid				Fixed
Fixed = 0.000001 (Meter)					

Table 24. . Adjusted grid coordinates for the control points used in the Palilan River flood plain survey.

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LE-92	585114.134	0.009	875424.503	0.007	20.730	0.066	
MSW-16	583690.278	?	904653.668	?	291.606	?	LLh
WM-03	588676.566	0.008	937544.108	0.006	4.964	0.051	
UP-PAL	593256.748	0.009	921254.886	0.006	5.558	0.046	
UP-CLA	594261.654	0.008	907132.926	0.007	6.428	0.043	
UP-MAG	593823.904	0.008	886255.511	0.007	35.363	0.058	

The results of the computation for accuracy are as follows:

a. **MSW-16**

Horizontal accuracy = fixed
Vertical accuracy = 6.6 cm < 10 cm

b. **LE-92**

horizontal accuracy $= \sqrt{(0.9)^2 + (0.8)^2}$
$= \sqrt{0.81 + 0.64}$
$= 1.2$ cm < 20 cm
vertical accuracy = fixed

c. **WM-03**

horizontal accuracy $= \sqrt{(0.8)^2 + (0.6)^2}$
$= \sqrt{0.64 + 0.36}$
$= 1 < 20$ cm
vertical accuracy = 8.2 cm < 10 cm

d. **UP-CLA**

horizontal accuracy $= \sqrt{(0.8)^2 + (0.7)^2}$
$= \sqrt{0.64 + 0.49}$
$= 1.06 < 20$ cm
vertical accuracy = 7.3 cm < 10 cm

e. **UP-MAG**

horizontal accuracy $= \sqrt{(0.8)^2 + (0.7)^2}$
$= \sqrt{0.64 + 0.49}$
$= 1.06 < 20$ cm
vertical accuracy = 6.0 cm < 10 cm

a. **UP-PAL**

horizontal accuracy $= \sqrt{(0.9)^2 + (0.6)^2}$
$= \sqrt{0.81 + 0.36}$
$= 1.17 < 20$ cm
vertical accuracy = 7.9 cm < 10 cm

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

Table 26. Adjusted geodetic coordinates for control points used in the Palilan River Flood Plain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
LE-92	N7°55'08.47407"	E123°46'19.89123"	87.116	?	e
MSW-16	N8°11'00.29164"	E123°45'35.16284"	358.160	0.066	LL
UP-CLA	N8°12'20.32560"	E123°51'20.80389"	72.796	0.073	
UP-MAG	N8°01'00.58291"	E123°51'05.06713"	102.053	0.060	
UP-PAL	N8°20'00.20593"	E123°50'48.94377"	71.284	0.079	
WM-03	N8°28'50.89651"	E123°48'20.30412"	69.694	0.082	

The corresponding geodetic coordinates of LE-92, WM-03, UP-PAL, UP-CLA and UP-MAG which were derived from MSW-16 are within the required accuracy as shown in Table 26. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Palilan River GNSS Static Survey are seen in Table 27.

Table 25. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MSW-16	2nd order, GCP	8°11'00.29164"	123°45'35.16284"	358.160	904653.668	583690.278	289.316
LE-92	1st order, BM	7°55'08.47407"	123°46'19.89123"	87.116	875424.492	585114.135	18.440
MW-03	Used as marker	8°28'50.89651"	123°48'20.30412"	69.694	937544.120	588676.568	2.673
UP-CLA	UP Established	8°12'20.32560"	123°51'20.80389"	72.796	907132.927	594261.657	4.138
UP-MAG	UP Established	8°01'00.58291"	123°51'05.06713"	102.053	886255.504	593823.908	33.073
UP-PAL	UP Established	8°20'00.20593"	123°50'48.94377"	71.284	921254.892	593256.751	3.268

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

The bridge cross-section and as-built surveys were conducted on October 13, 2015 along the downstream side of Sinara Bajo Hanging Bridge in Brgy. Sinara BAjo, Municipality of Jimenez using the GNSS receiver Trimble® SPS 882 in PPK Survey Technique (Figure 36).

Figure 36. Cross-section survey on the downstream side of Sinara Bajo Hanging Bridge, Brgy.Sinara Bajo, Misamis Occidental.

The cross-sectional line of Sinara Bajo Hanging Bridge is about 75.95 meters with sixty-two (62) points acquired using UP-PAL as the GNSS base station. The cross-section diagram, the location maps are shown in Figure 37 to Figure 38.

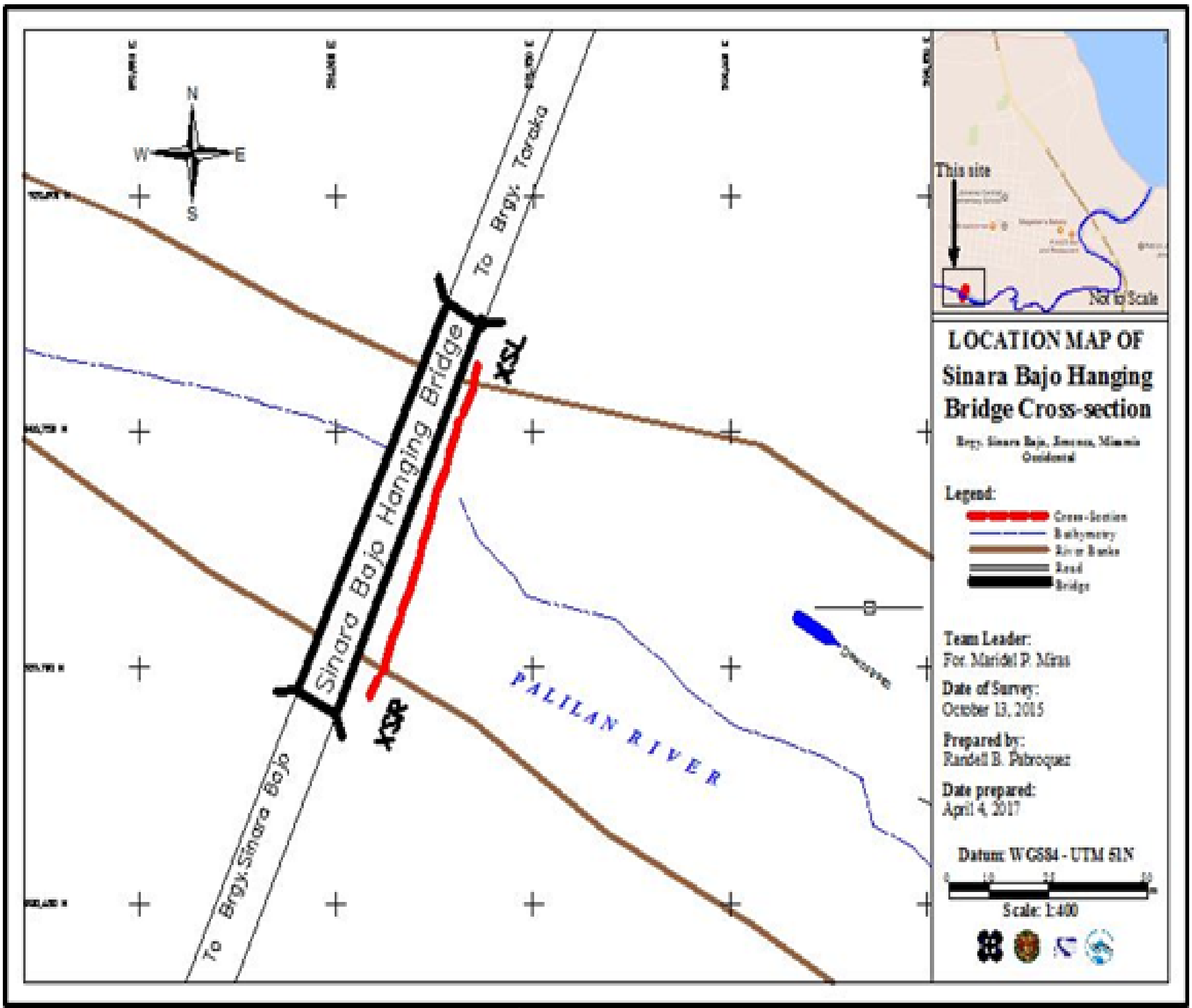

Figure 37. Location Map of Sinara Bajo Hanging bridge cross-section.

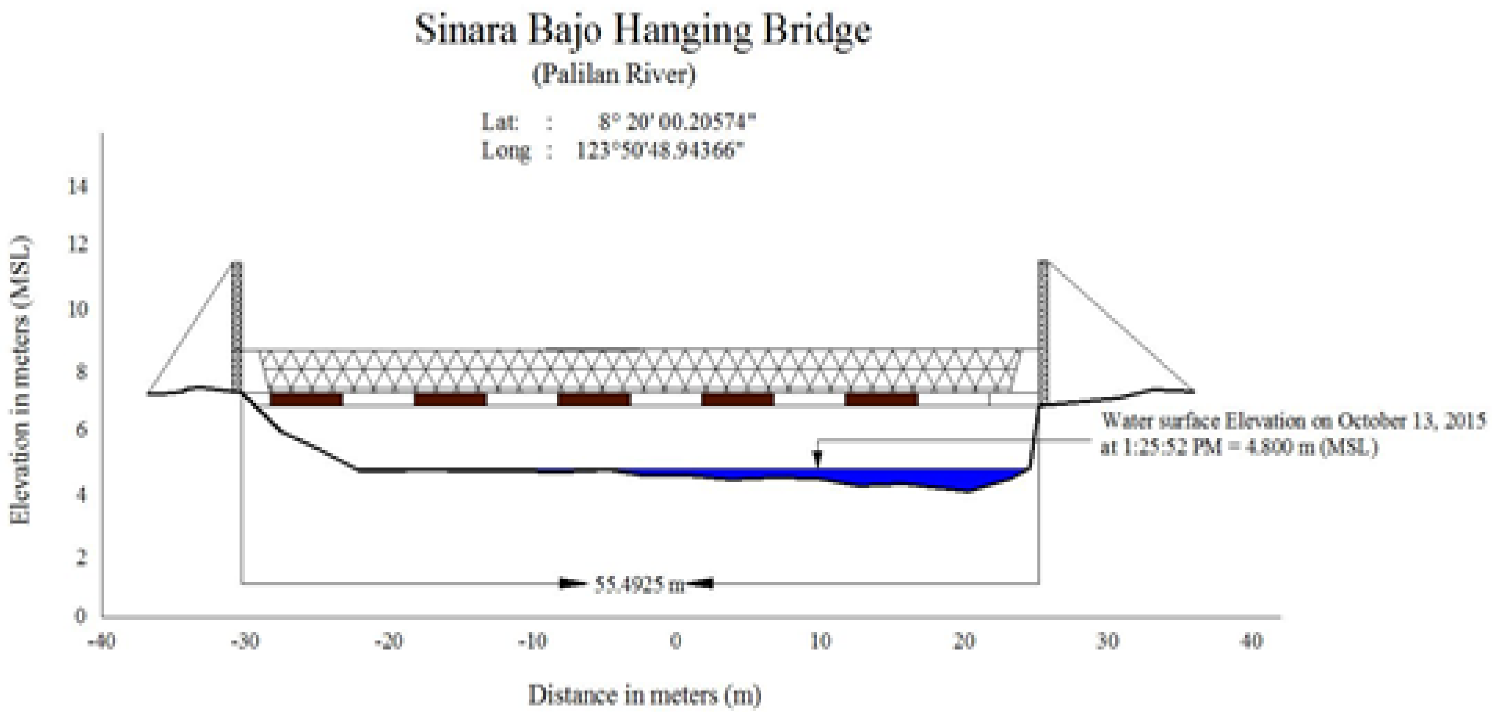

Figure 38. . The Sinara Bajo Hanging Bridge Bridge cross-section survey drawn to scale.

The water surface elevation of Palilan River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on October 13, 2015 at 1:25:52 PM at Sinara Bajo Hanging Bridge area with a value of 4.4800 m in MSL as shown in Figure 39. This was translated into marking on the bridge's pier as shown in Figure 39. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Palilan River, the MSU-IIT.

Figure 39. Water level markings on the post of Sinara Bajo Hanging Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 13, 2014 using a survey grade GNSS rover receiver Trimble® SPS 882 mounted on a pole, which was attached in back of the vehicle as shown in Figure 40. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height of 1.923 was measured from the ground up to the bottom of the notch of the GNSS rover receiver. Points were gathered along concrete roads so that data to be acquired will have a relatively minimal change in elevation, observing vehicle speed of 10 to 20 kph.

Figure 40. Trimble® SPS882 set-up on a vehicle for validation points acquisition along the major roads near Palilan River.

The base was set up at UP-PAL, UP-PAL, Palilan Bridge approach in Brgy. Rizal, Jimenez, Misamis Occidental and gathered validation points from Brgy. Poblacion, Municipality of Panaon to Brgy. Libertad Bajo, Municipality of Sinacaban. The ground validation line is approximately 11.19 km in length and with overall gathered points of 1,493. Figure 41 shows the validation points acquisition survey coverage.

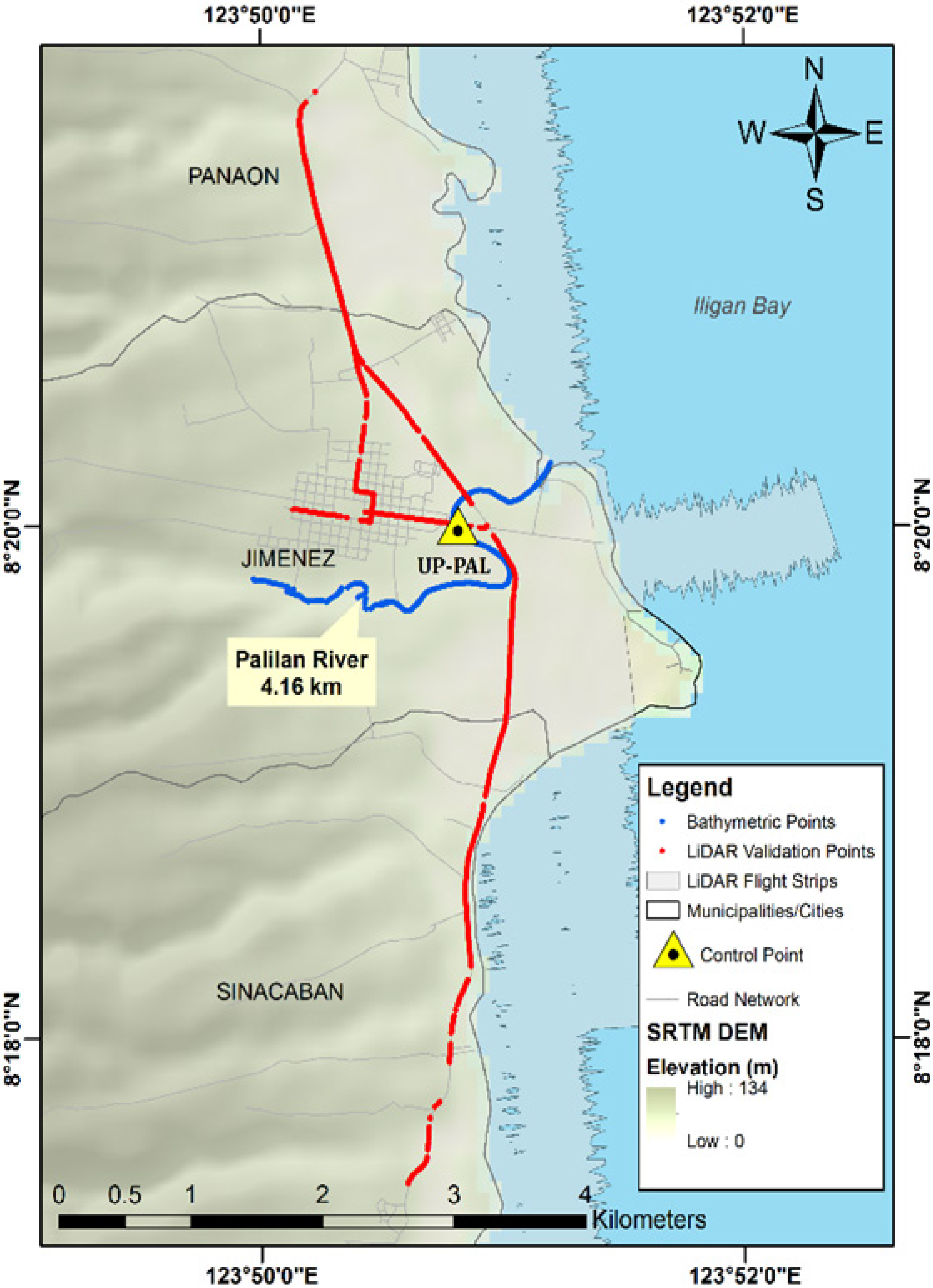

Figure 41. The extent of the LiDAR ground validation survey for Palilan River Basin

4.7 River Bathymetric Survey

A bathymetric survey was performed on October 13, using Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 in GNSS PPK survey technique, installed on the boat as shown in Figure 42. The survey started at the mid part of the river in Brgy. Naga, Municipality of Jimenez with coordinates 8°19'41.58450"N, 123°50'29.44782"E, down to the mouth of the river in Brgy. Rizal, also in Municipality of Jimenez with coordinates 8°20'16.63079"N, 123°51'12.34110"E.

Figure 42. Set up of Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver on a motor boat for the bathymetric survey in Palilan River.

Manual bathymetric survey on the other hand was conducted on October 10 and 13, 2015 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 43. The survey started from the upstream part of the river in Brgy. Corrales, Municipality of Jimenez with coordinates 8°19'47.35012"N, 123°49'58.36548"E, traversed down by foot and ended at the starting point of the bathymetric survey using boat. The control point UP-PAL was used as the GNSS base station all throughout the bathymetric survey.

Figure 43. Manual bathymetric survey in Palilan River

The entire bathymetric data coverage for Palilan River is illustrated in the map in Figure 44. The bathymetric line is approximately 4.16 km in length with 2,689 bathymetric points of the river traversing four (4) barangays in Municipality of Jimenez namely: Rizal, Naga, Taraka, and Corrales. A CAD drawing was also produced to illustrate the riverbed profile of Palilan River. As shown in Figure 45, the highest and lowest elevation value has a 14-m difference. The highest elevation value observed was 7.479 m in MSL located at the upstream portion in Brgy. Taraka, while the lowest elevation value was -7.129 m below MSL located near the UP-PAL control point in Brgy. Palilan, both in Municpality if Jimenez.

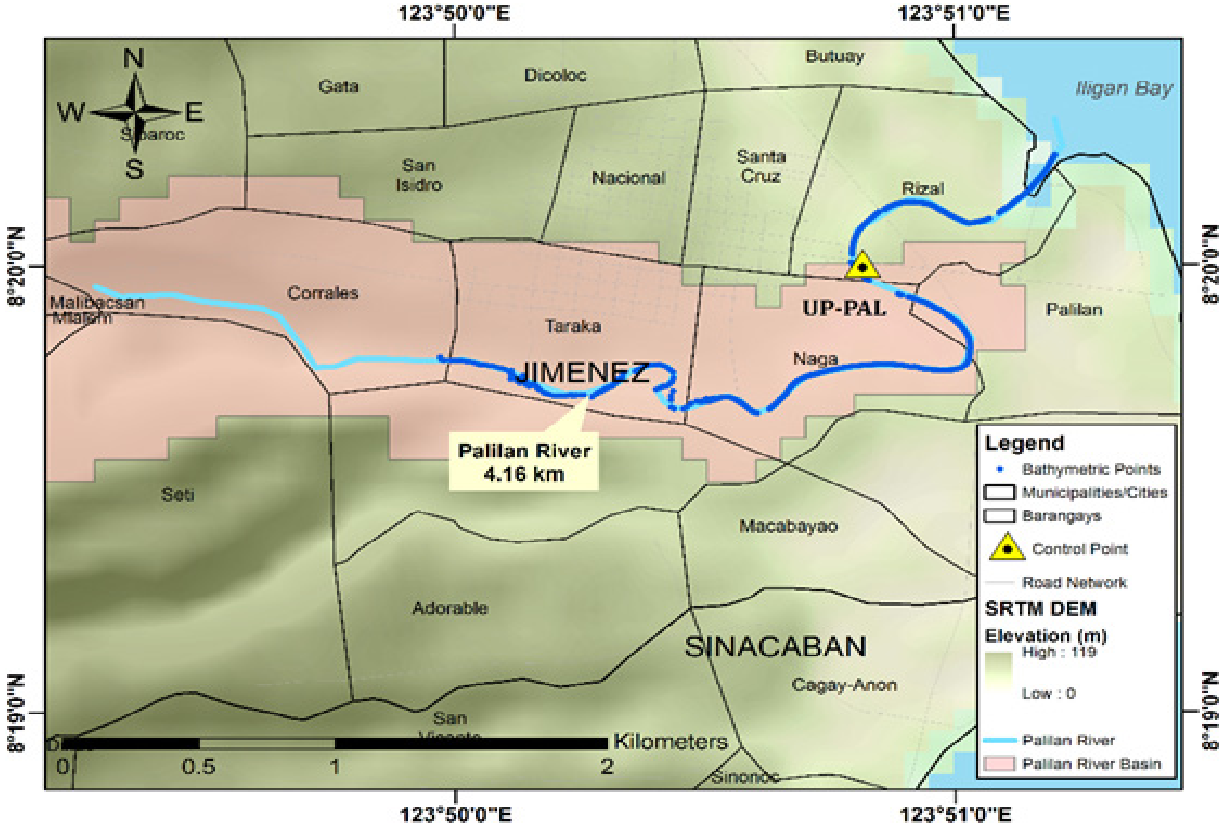

Figure 44. Figure 44. The extent of the Palilan River Bathymetry Survey.

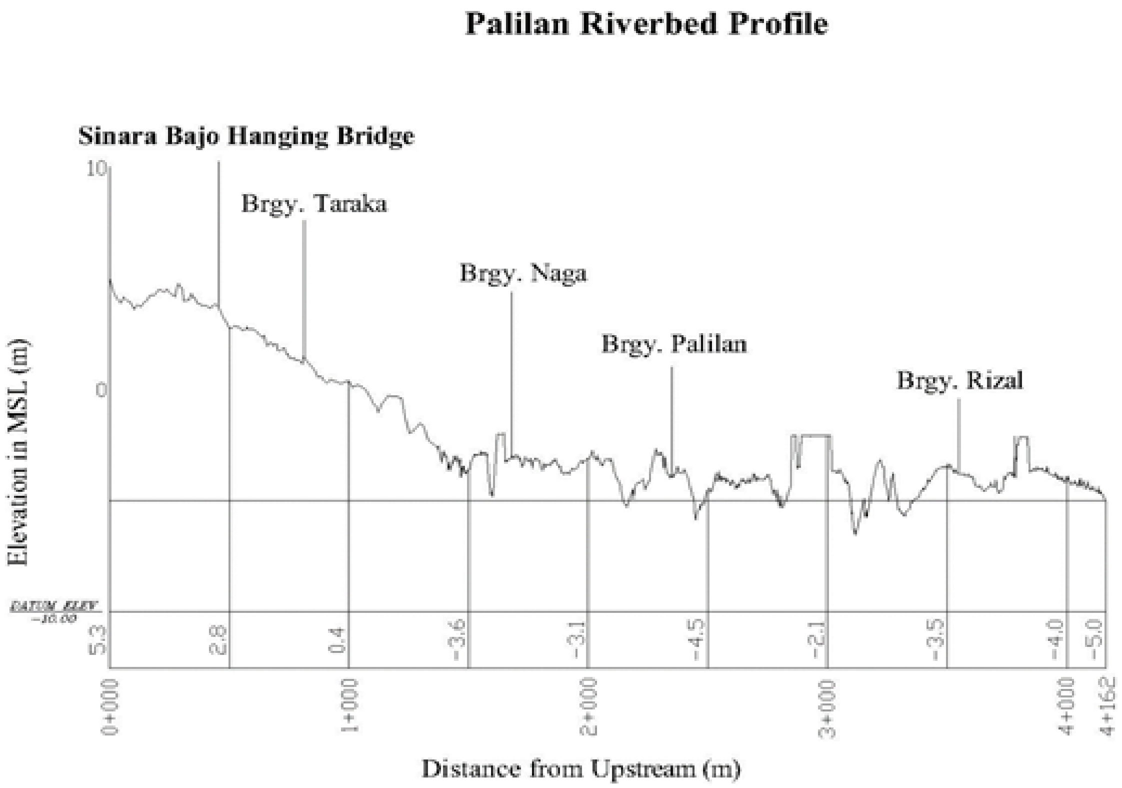

Figure 45. The Palilan river bed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Palilan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the Data Validation Component (DVC) of MSU-IIT. The ARG was specifically installed in the municipality of Palilan with coordinates 8°18’50.00”N Latitude and 123°46’29.00”E Longitude as illustrated in Figure 46.

The total precipitation for this event in Brgy. Sinara Bajo ARG was 53.6 mm. It has a peak rainfall of 14.8 mm. on July 5, 2016 at 3:00 and 3:10 in the afternoon. The lag time between the peak rainfall and discharge is 1 hour and 40 minutes.

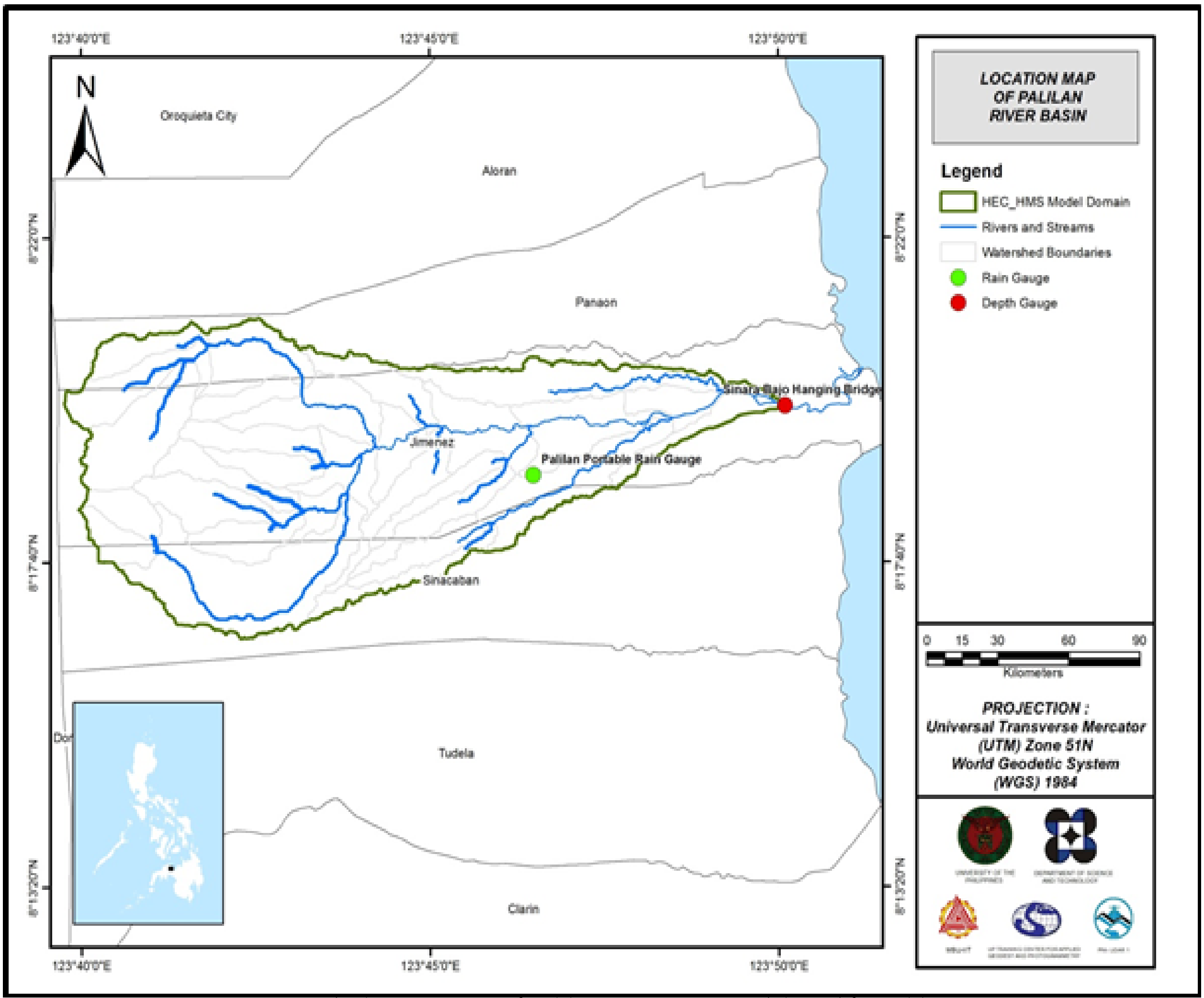

Figure 46. The location map of Palilan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

HQ curve analysis is important in determining the equation to be used in establishing Q values with R-Squared values closer to 1. A trendline is more accurate if the R-Squared value is closer or at 1.

Figure 48 shows the highest R-Squared value of 0.945 compared to the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

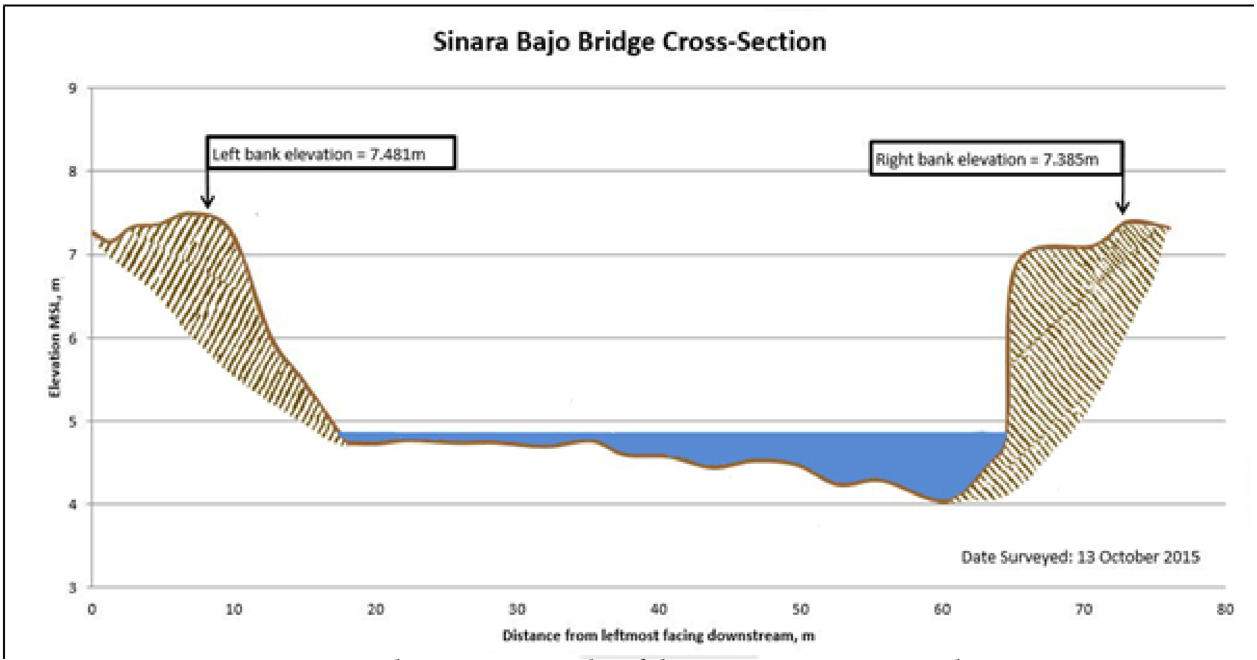

Figure 47. The cross-section plot of the Sinara Bajo Hanging Bridge.

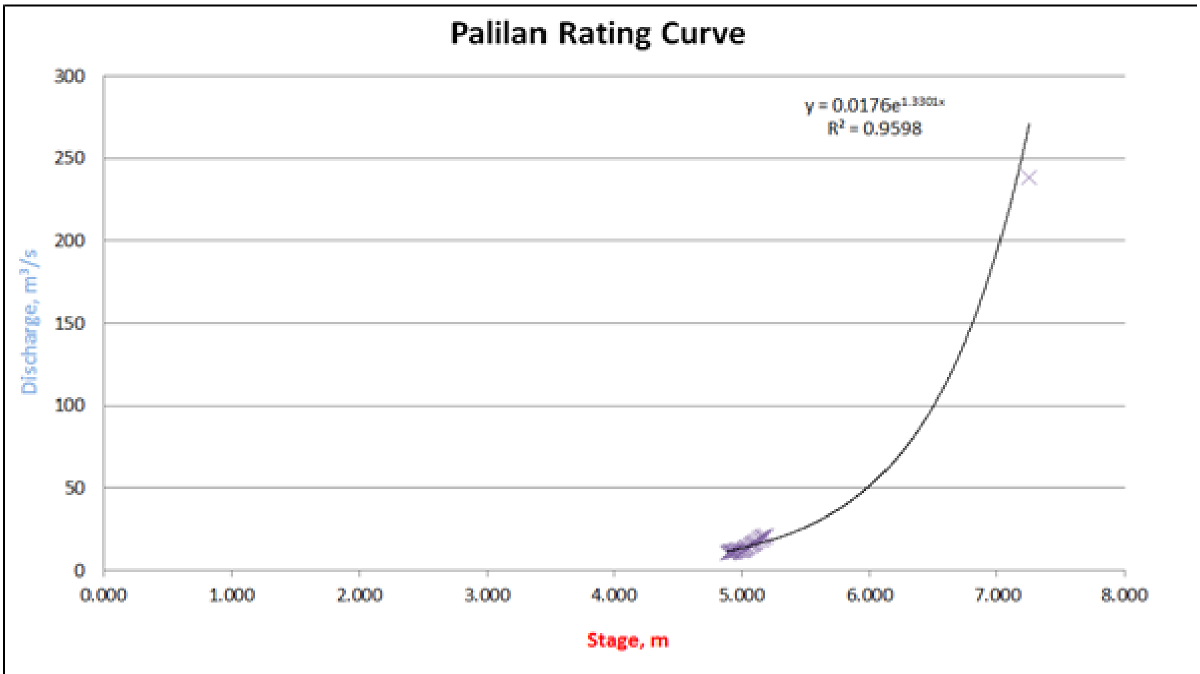

Figure 48. The rating curve plot of the Sinara Bajo Hanging Bridge.

This rating curve equation was used to compute the river outflow at Sinara Bajo Hanging Bridge for the calibration of the HEC-HMS model shown in Figure 49. The peak discharge is 17.4274 cms at 4:40 in the afternoon, July 5, 2016 .

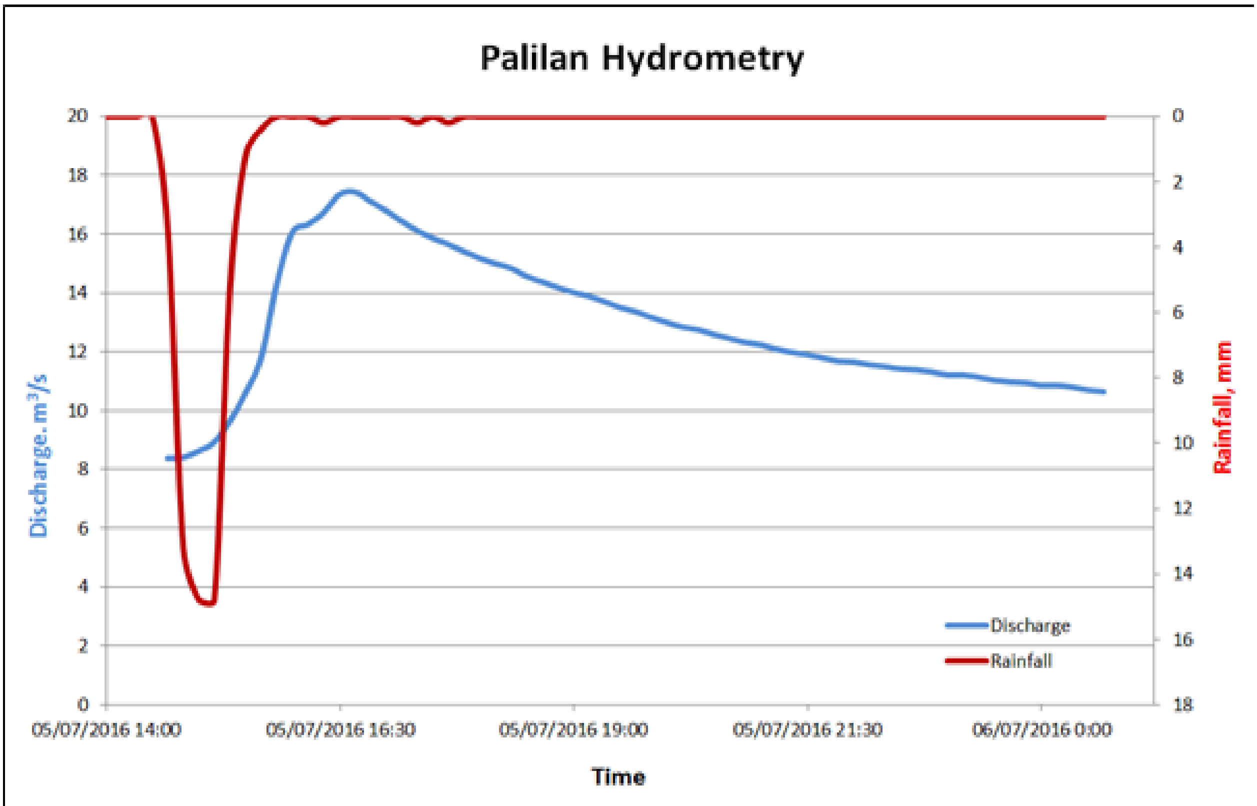

Figure 49. Rainfall and outflow data of the Palilan River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Dipolog Rain Gauge (Table 27). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 51). This station was selected based on its proximity to the Palilan watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 27. RIDF values for Dipolog 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	19.7	30.9	38.7	53.8	73.6	85.5	105.7	120.3	136.2
5	25.9	39.6	50.1	72.6	99.7	117.3	140.9	158.3	178.5
10	30	45.4	57.6	85.1	117	138.3	164.3	183.4	206.5
15	32.3	48.6	61.8	92.1	126.8	150.2	177.4	197.6	222.4
20	34	50.9	64.8	97.1	133.6	158.5	186.6	207.6	233.4
25	35.2	52.7	67.1	100.9	138.9	164.9	193.7	215.2	242
50	39	58.1	74.1	112.5	155.1	184.6	215.6	238.8	268.3
100	42.9	63.4	81.1	124.1	171.2	204.2	237.3	262.1	294.4

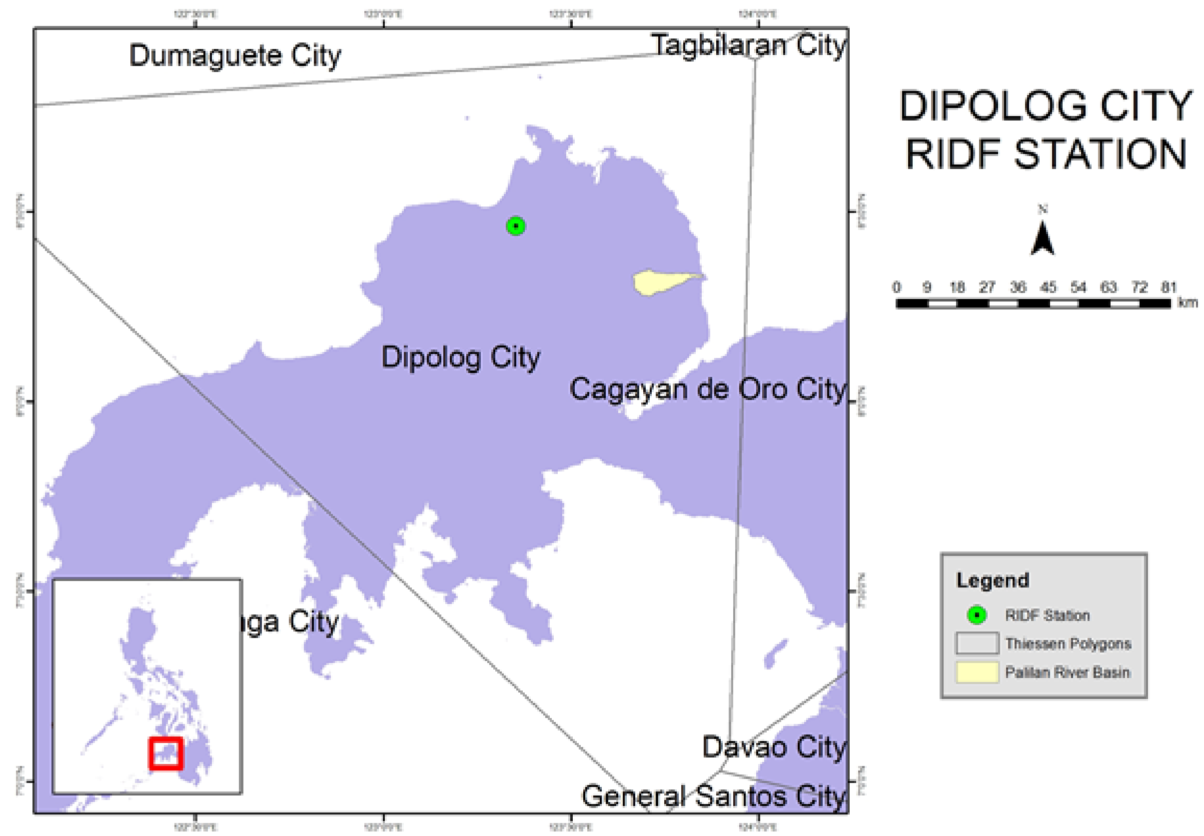

Figure 50. The location of the Dipolog RIDF station relative to the Palilan River Basin.

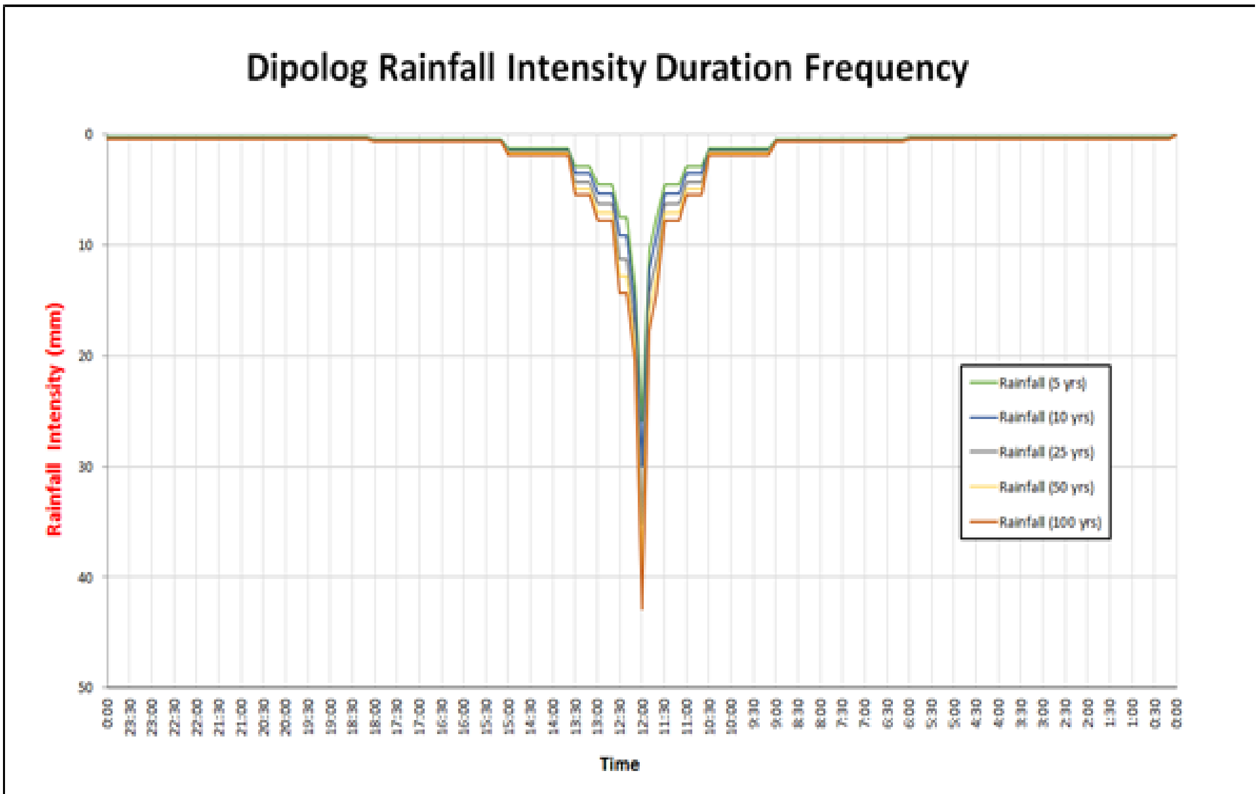

Figure 51. The synthetic storm generated for a 24-hour period rainfall for various return periods.

5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is under the Department of Environment and Natural Resources Management (DENR). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Palilan River Basin are shown in Figure 52 and Figure 53, respectively.

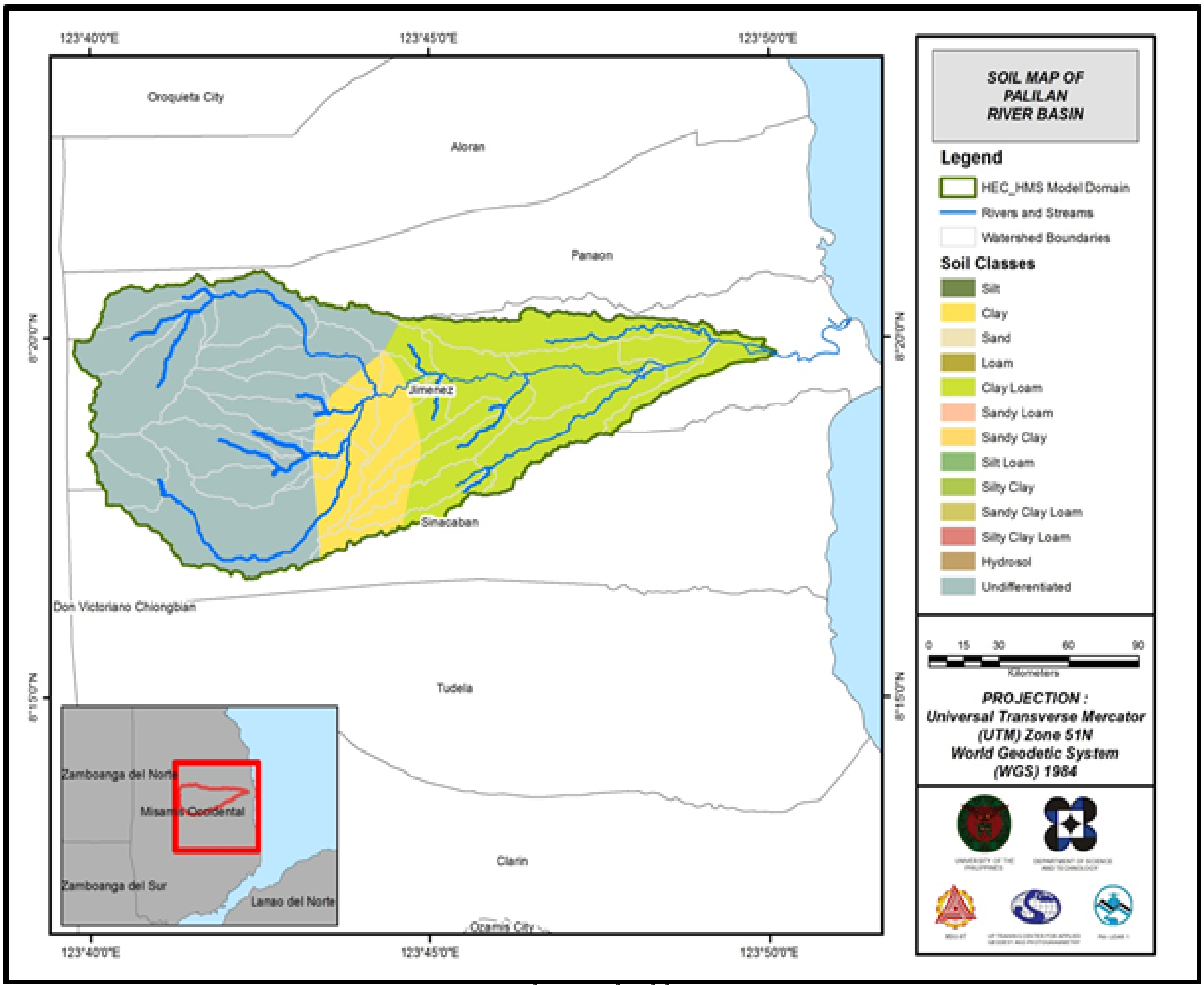

Figure 52. Soil Map of Palilan River Basin.

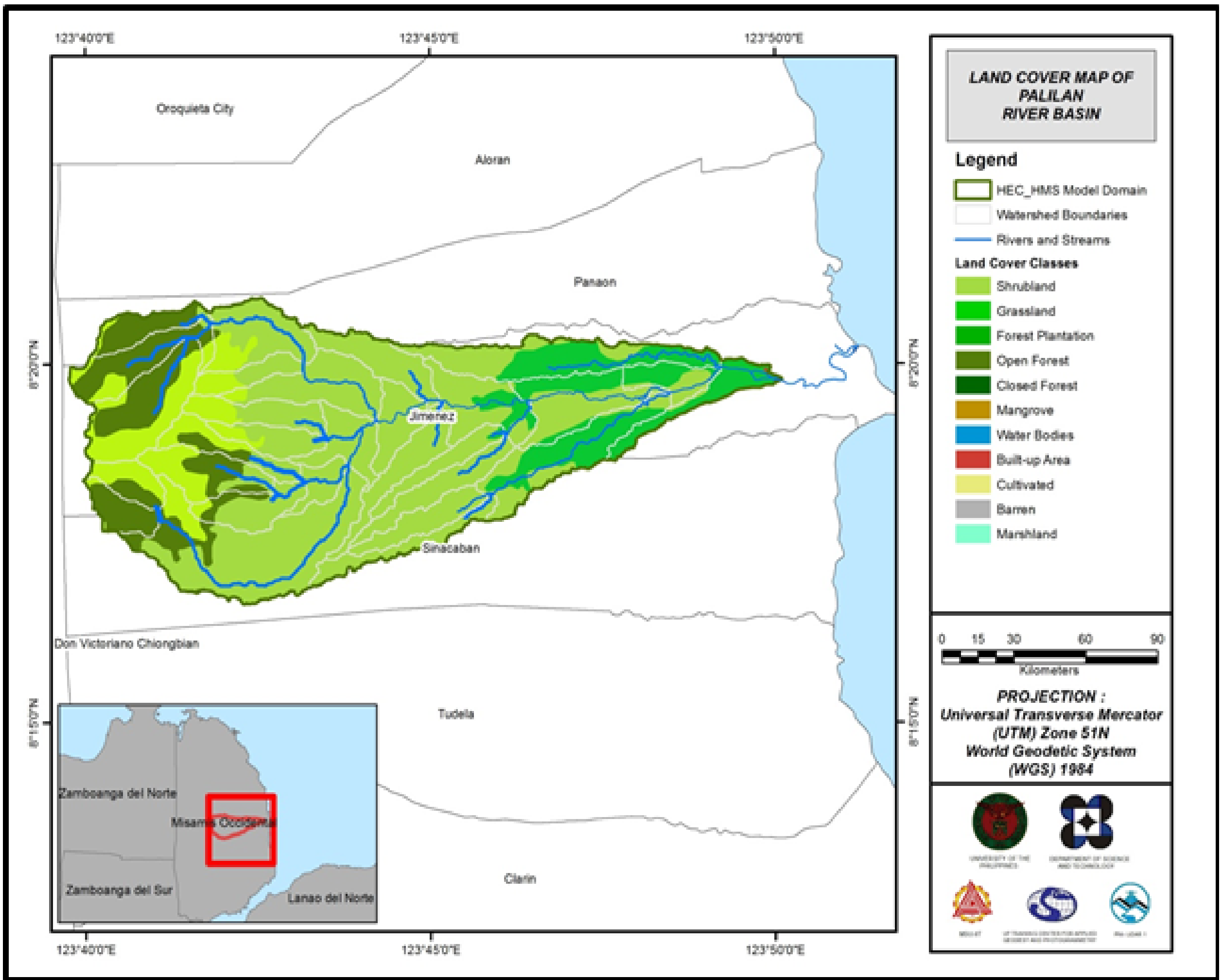

Figure 53. Land Cover Map of Palilan River Basin.

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

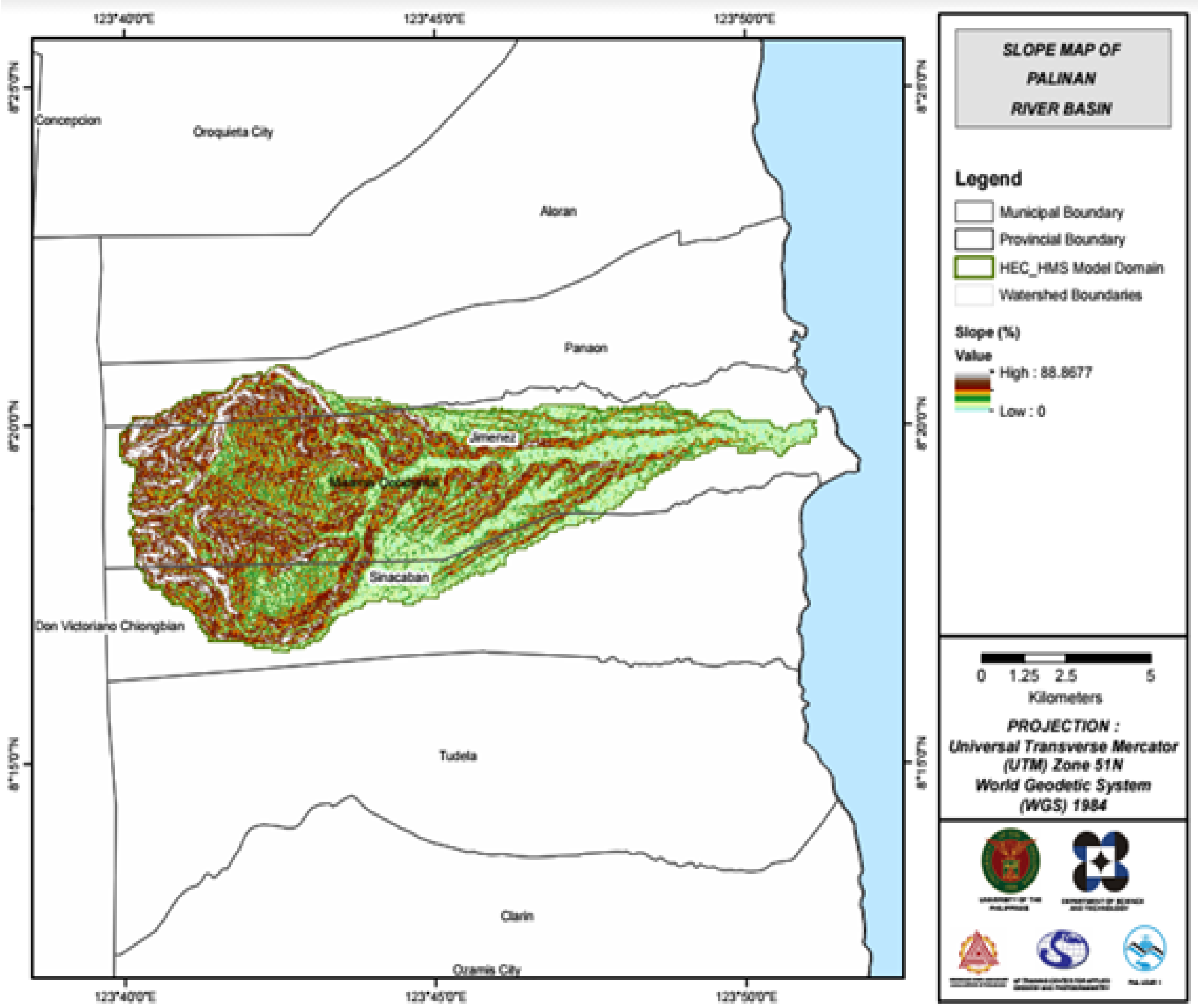

Figure 54. Slope Map of the Palilan River Basin.

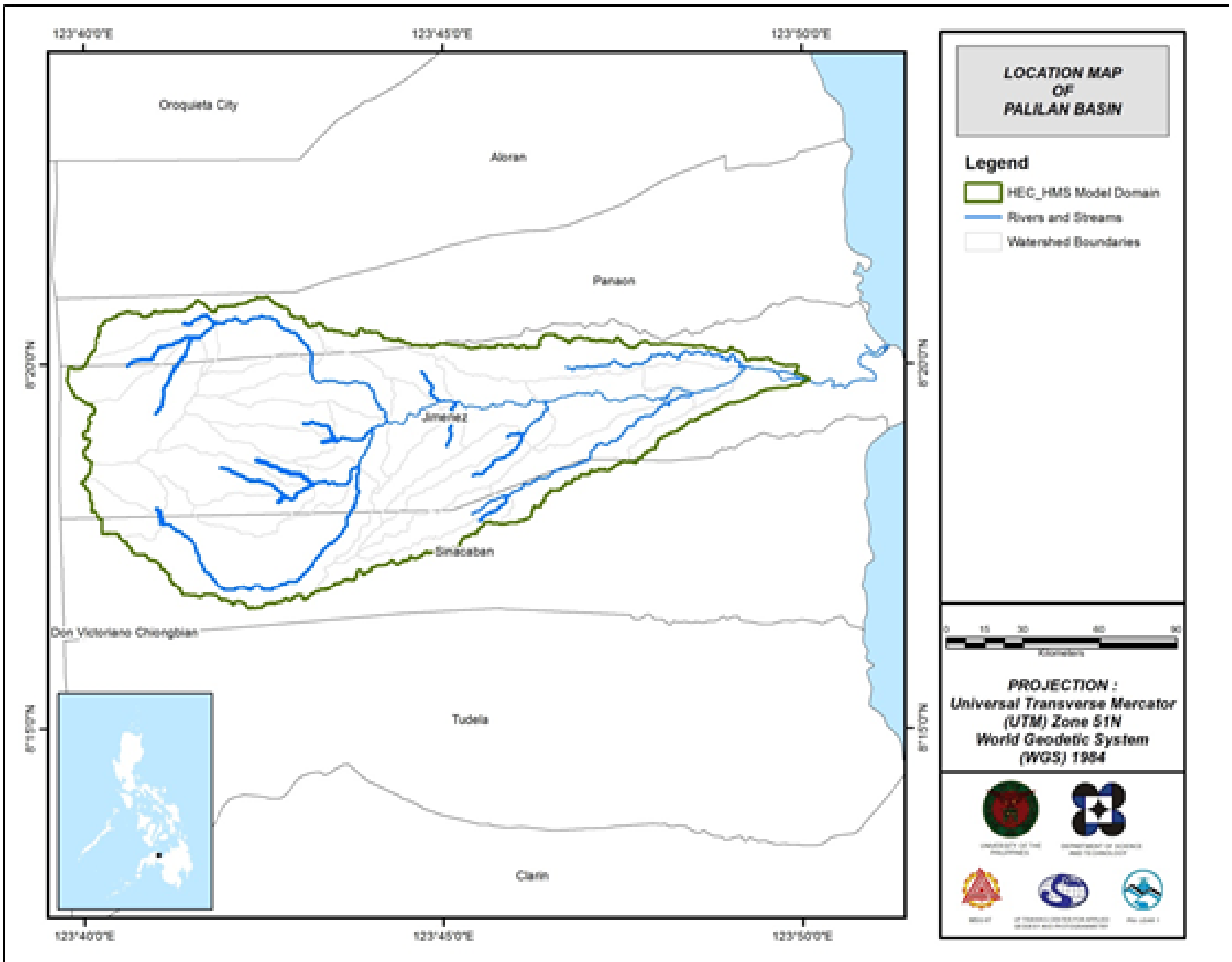

Figure 55. Stream Delineation Map of the Palilan River Basin

Using the SAR-based DEM, the Palilan basin was delineated and further subdivided into subbasins. The model consists of 22 sub basins, 12 reaches, and 12 junctions. The main outlet is located at Sinara Bajo Bridge, Jimenez. This basin model is illustrated in Figure 56. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Sinara Bajo Bridge.

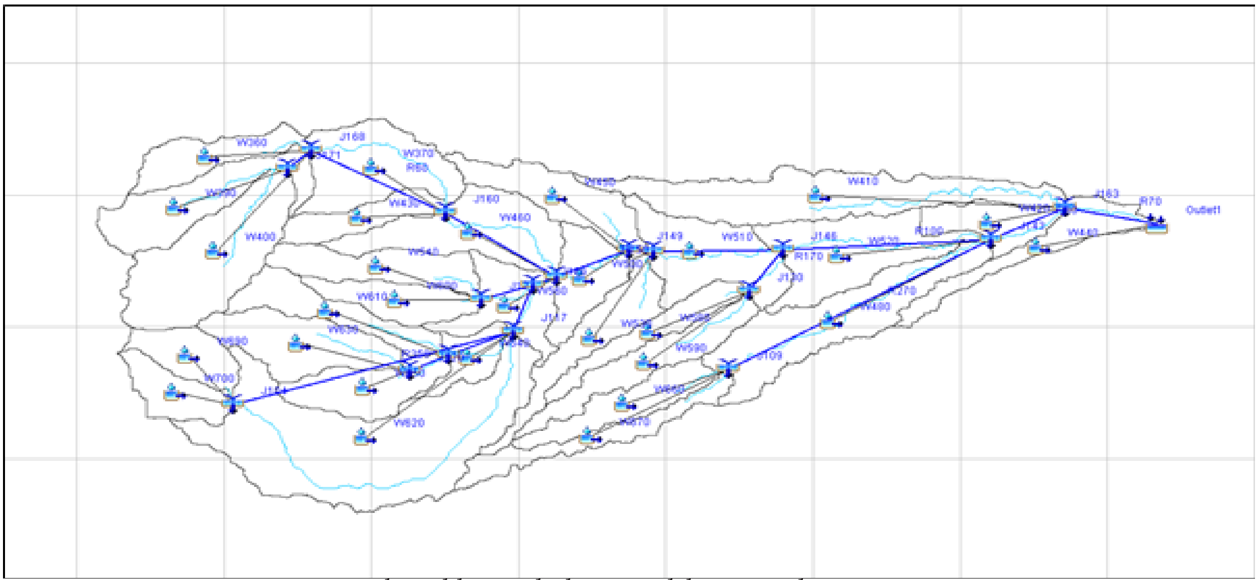

Figure 56. The Palilan Hydrologic Model generated in HEC-GeoHMS

5.4 Cross-section Data

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

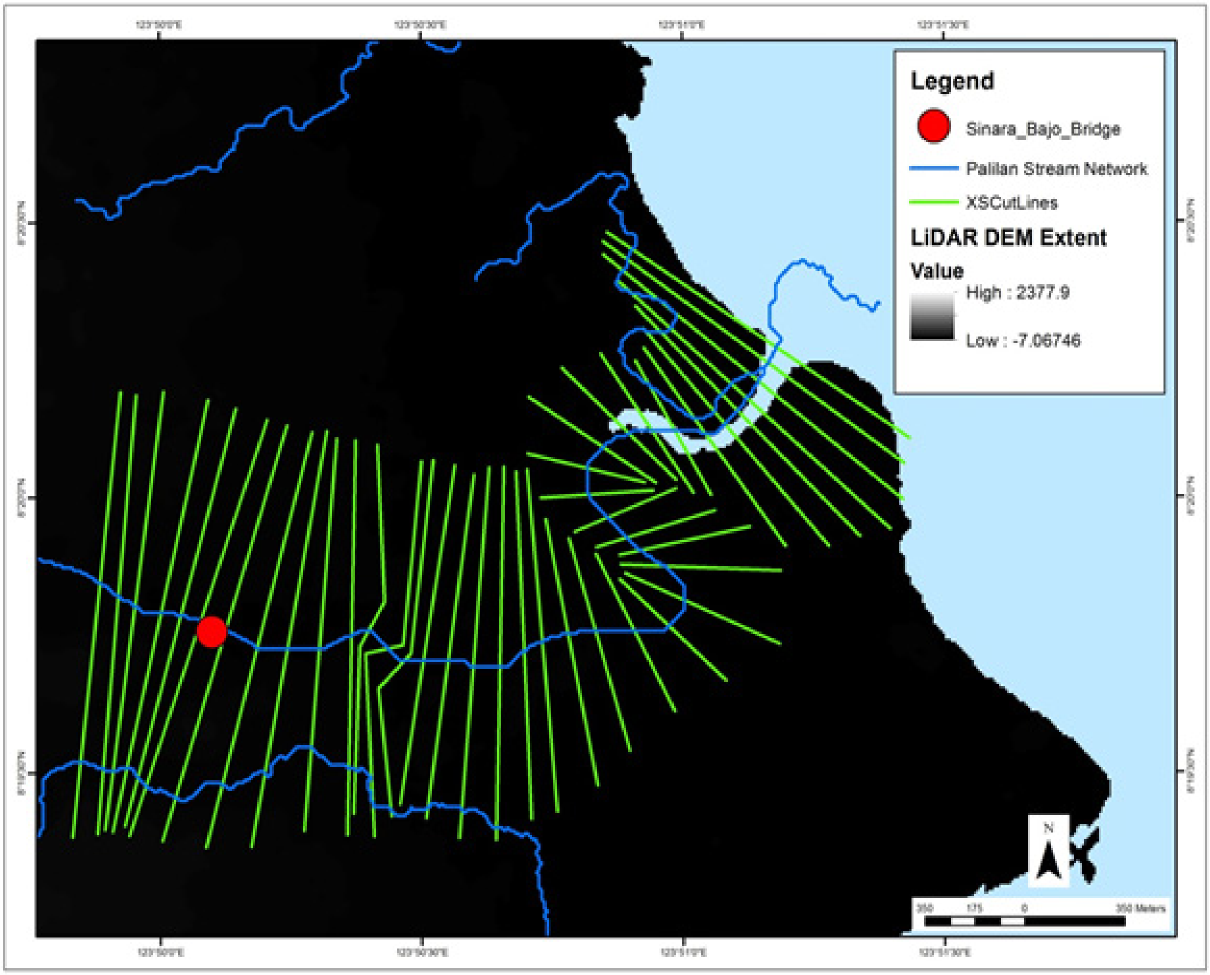

Figure 57. River cross-section of the Palilan River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

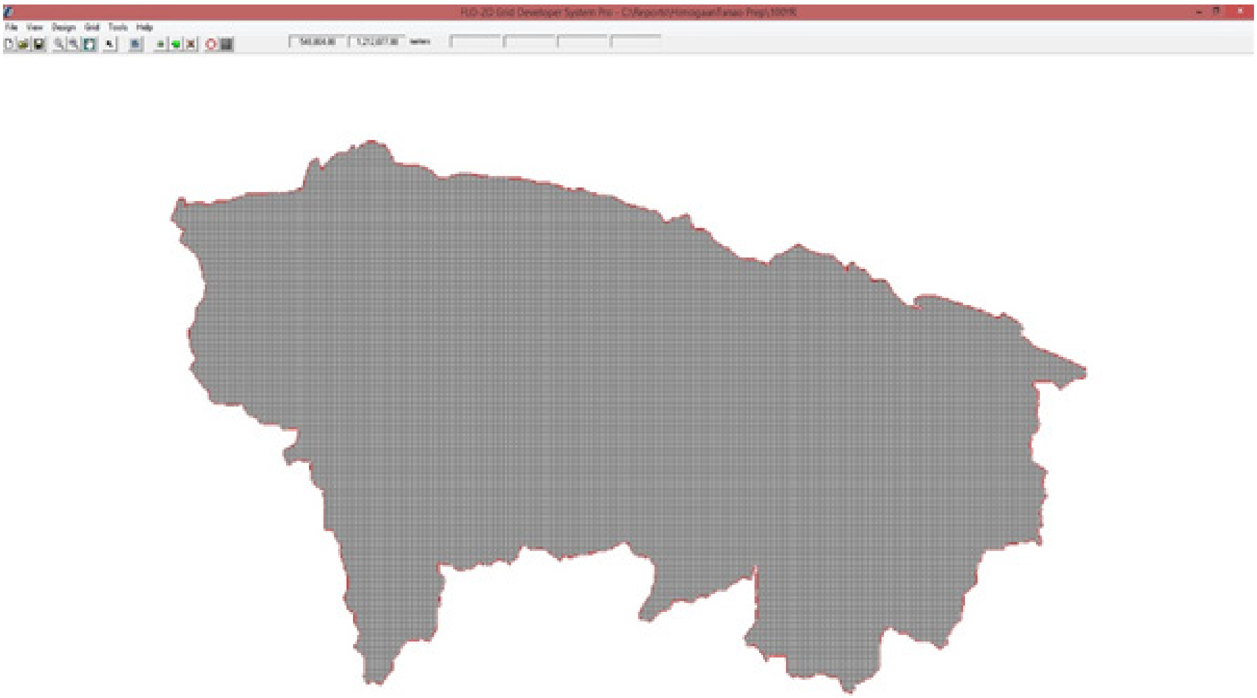

Figure 58. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer S ystem Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 22.20007 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 flood 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 Palilan are in Figure 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 22958400.00 m2. The generated flood depth maps for Palilan are in Figure 63, 65 and 67.

There is a total of 61783670.89 m3 of water entering the model. Of this amount, 6072171.66 m3 is due to rainfall while 55711499.22 m3 is inflow from other areas outside the model 4363573.50 m3 of this water is lost to infiltration and interception, while 33831397.31 m3 is stored by the flood plain. The rest, amounting up to 23588699.98 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Palilan HEC-HMS river basin model, its accuracy was measured against the observed values (See Annex 9). Figure 59 shows the comparison between the two discharge data.

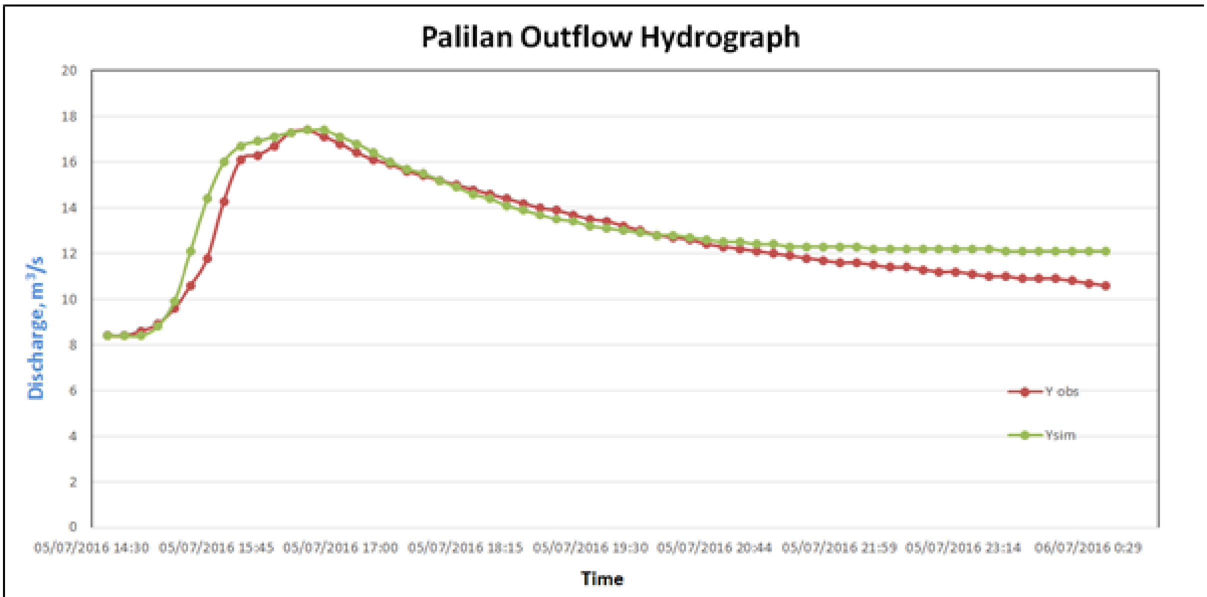

Figure 59. Outflow Hydrograph of Palilan produced by the HEC-HMS model compared with observed outflow.

Table 28 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of Calibrated Values for Palilan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	22 - 106
			Curve Number	50 - 83
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1 – 0.8
			Storage Coefficient (hr)	1 - 5
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.035

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 22 to 106mm means that there is a diverse amount of infiltration or rainfall interception by vegetation per subbasin. Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 50 to 83 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.1 to 5 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.5 indicates a relatively average steepness of receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.035 corresponds to the common roughness of Palilan watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 29. Summary of the Efficiency Test of the Palilan HMS Model

RMSE	0.76
r2	0.93
NSE	0.89
PBIAS	-3.32
RSR	0.32

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.76 (m3/s).

The Pearson correlation coefficient (r2) 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 0.93.

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 0.89.

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 -3.32.

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 0.32.

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

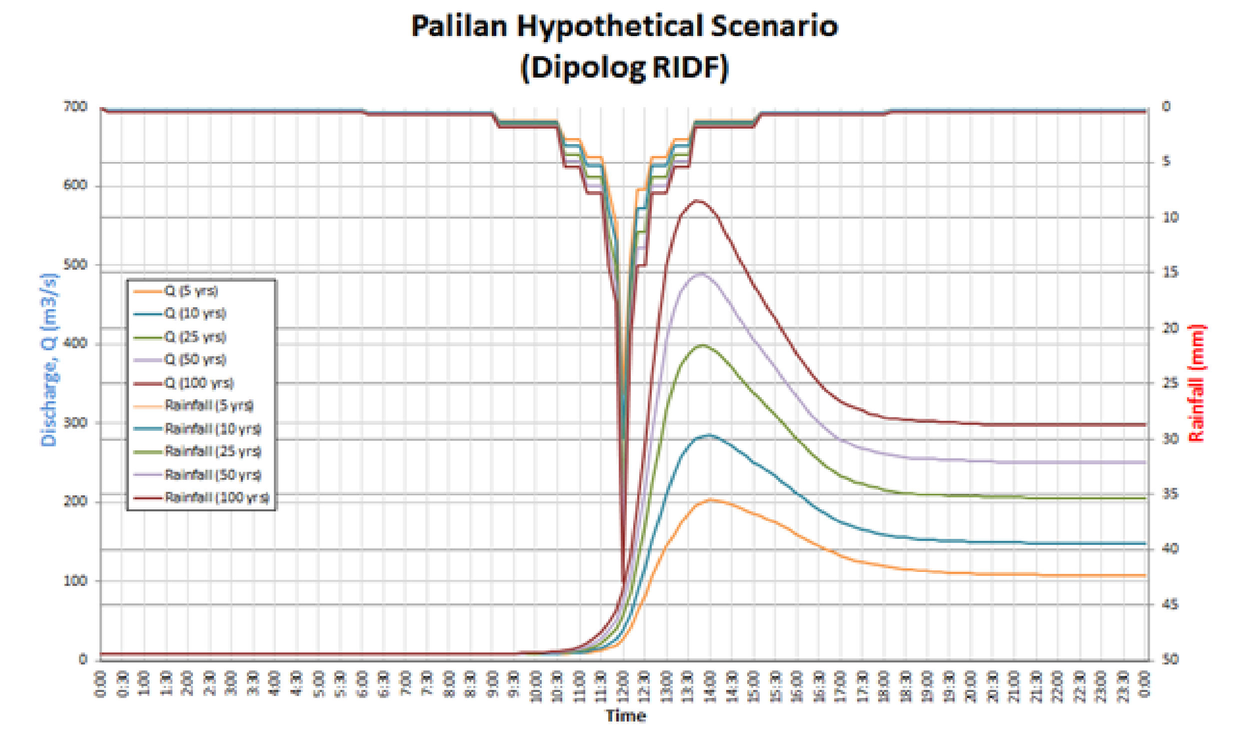

Figure 60. The Outflow hydrograph at the Palilan Station, generated using the Dipolog RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Palilan discharge using the Dipolog Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. The peak values of the Palilan HEC-HMS Model outflow using the Dipolog RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	178.32	25.9	202.5	3 hours, 10 minutes
10-Year	206.37	30	284.4	4 hours, 30 minutes
25-Year	241.91	35.2	398.4	4 hours, 10 minutes
50-Year	268.14	39	487.8	3 hours, 40 minutes
100-Year	294.55	42.9	581	3 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

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

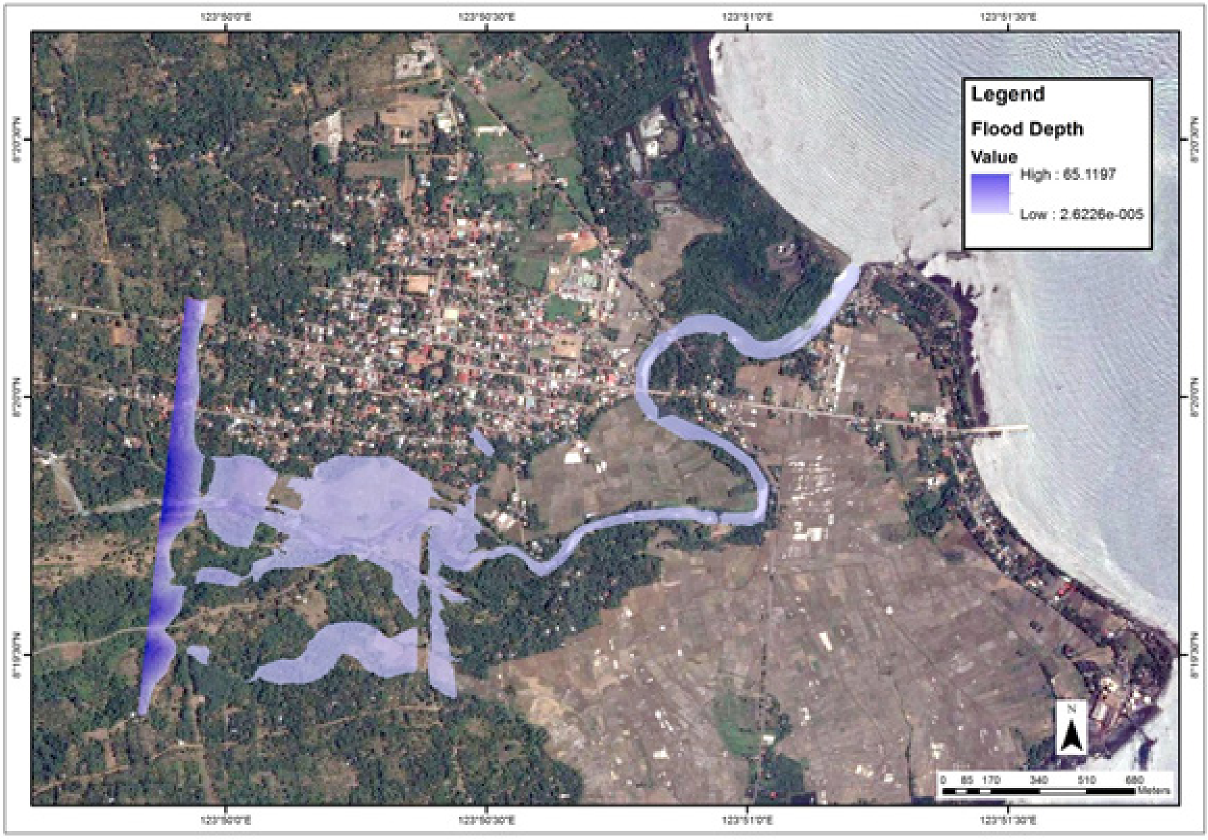

Figure 61. The sample output map of the Palilan RAS Model.

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Palilan floodplain are shown in Figure 62 to Figure 67. The floodplain, with an area of 21.40 sq. km., covers three municipalities namely Jimenez, Panaon, and Sinacaban. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Palilan floodplain.

City / Municipality	Total Area	Area Flooded	% Flooded
Jimenez	78.4747	18.22	23%
Panaon	52.5238	2.67	5.1%
Sinacaban	70.989	0.48	1%

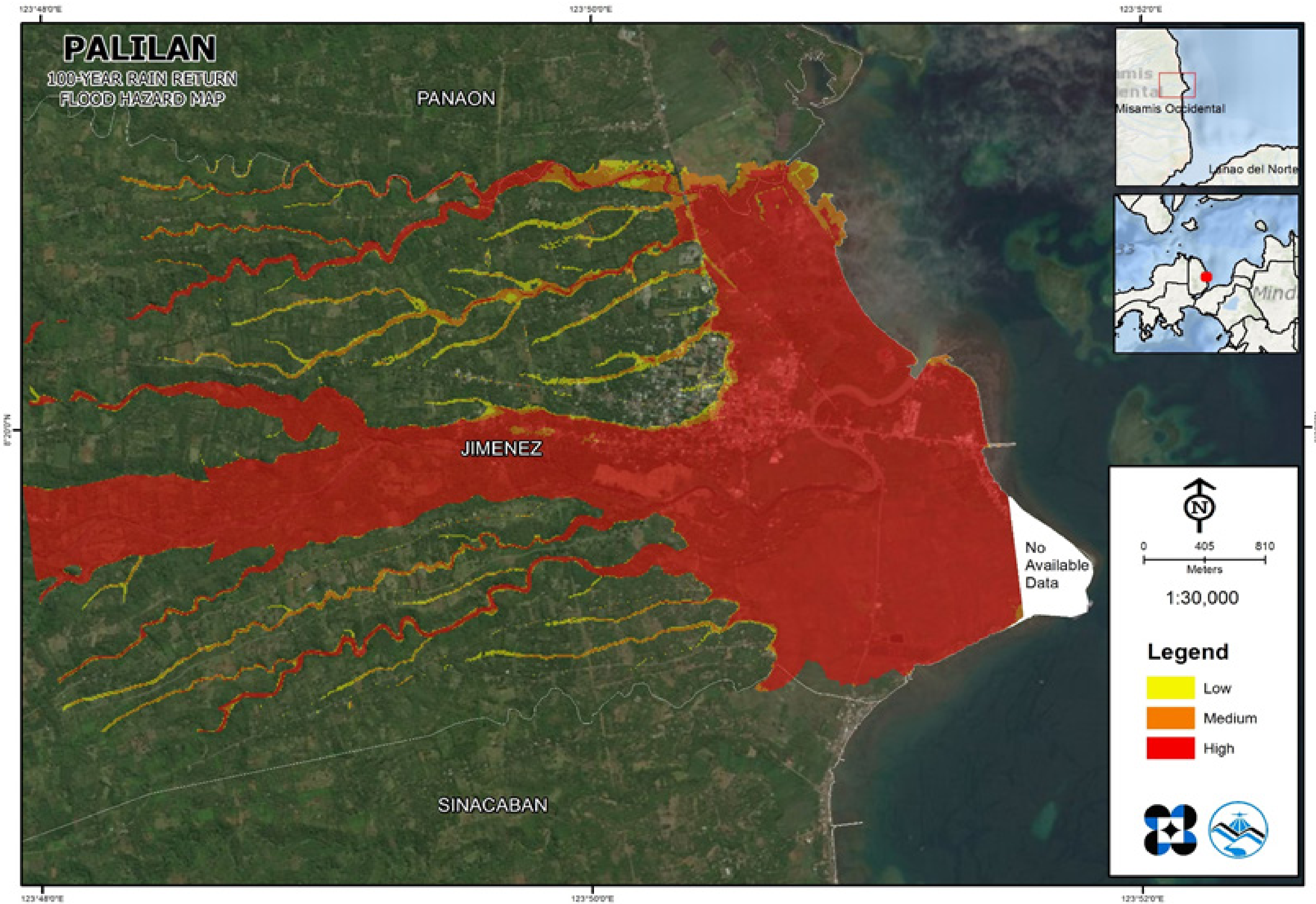

Figure 62. A 100-year Flood Hazard Map for Palilan Floodplain overlaid on Google Earth imagery.

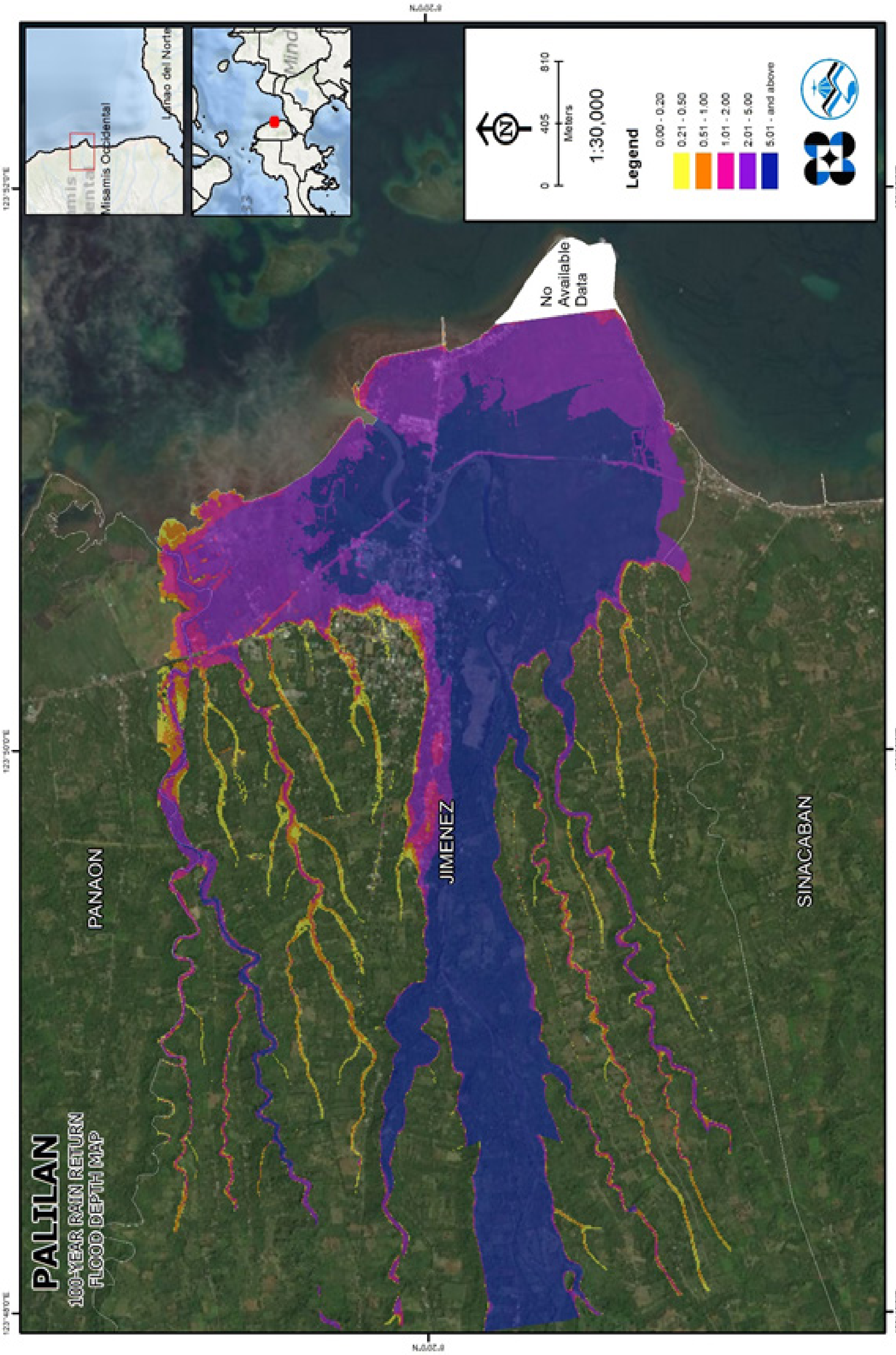

Figure 63. A 100-year Flood Depth Map for Palilan Floodplain overlaid on Google Earth imagery.

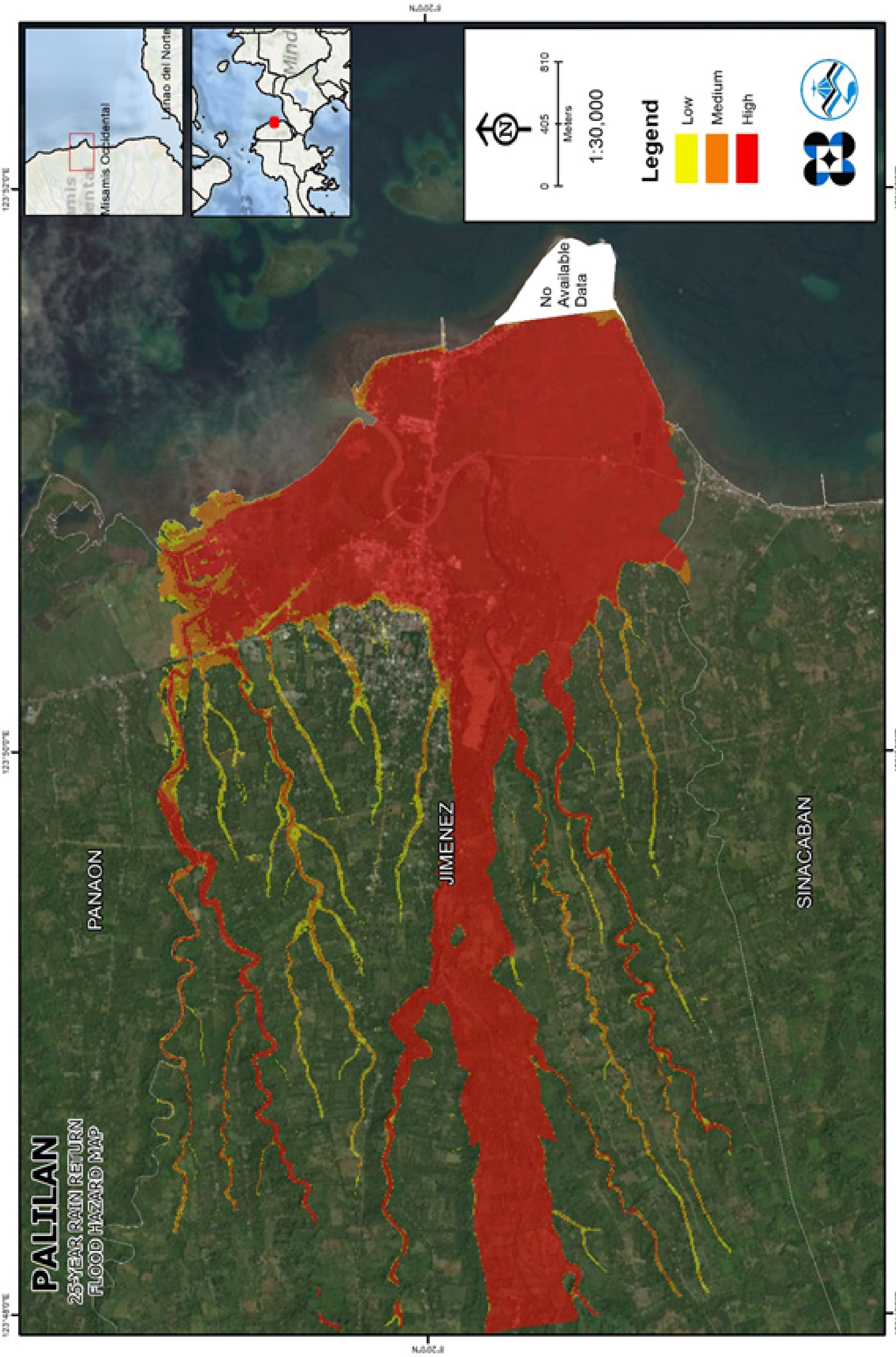

Figure 64. A 25-year Flood Hazard Map for Palilan Floodplain overlaid on Google Earth imagery.

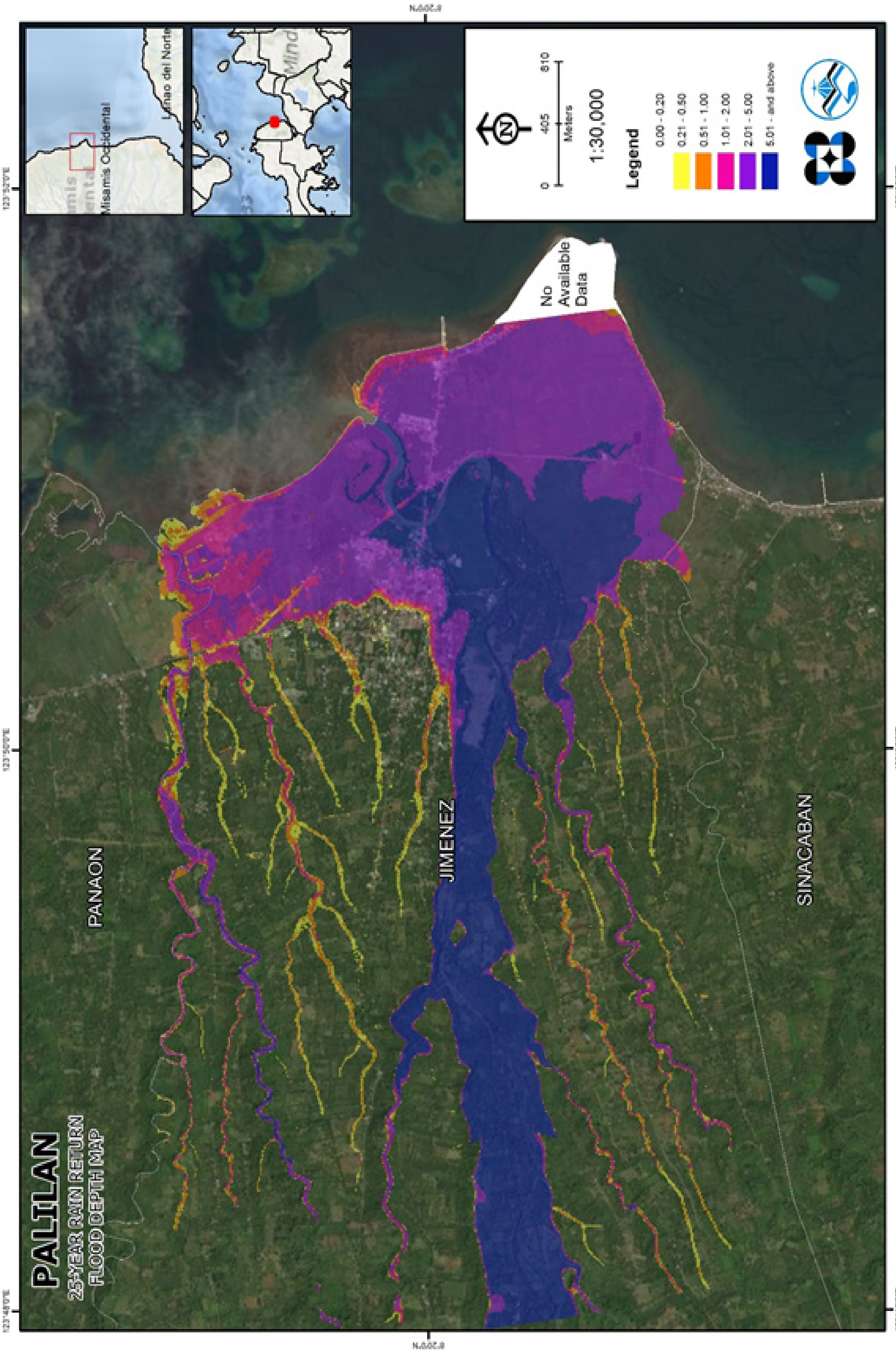

Figure 65. A 25-year Flood Depth Map for Palilan Floodplain overlaid on Google Earth imagery.

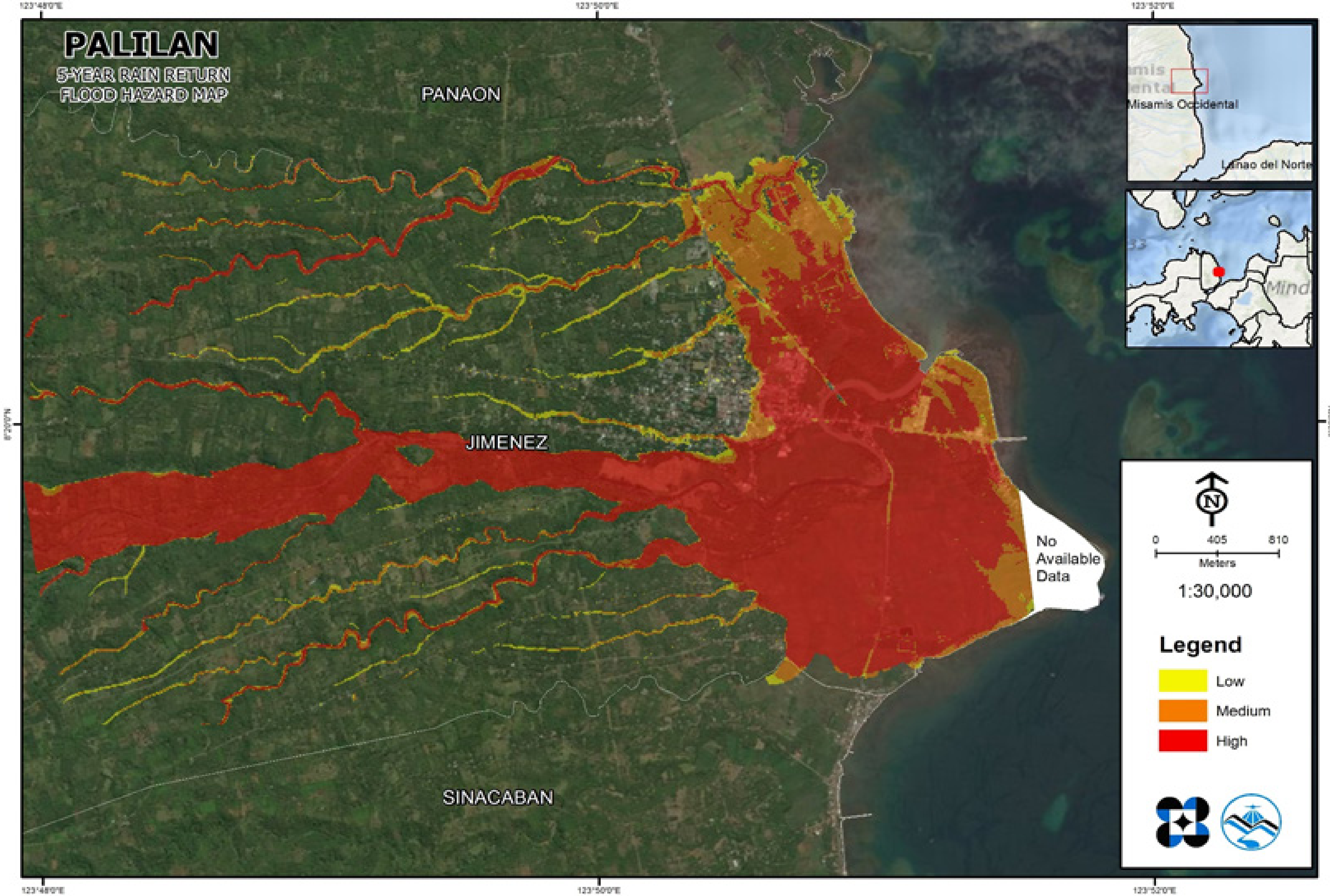

Figure 66. A 5-year Flood Hazard Map for Palilan Floodplain overlaid on Google Earth imagery.

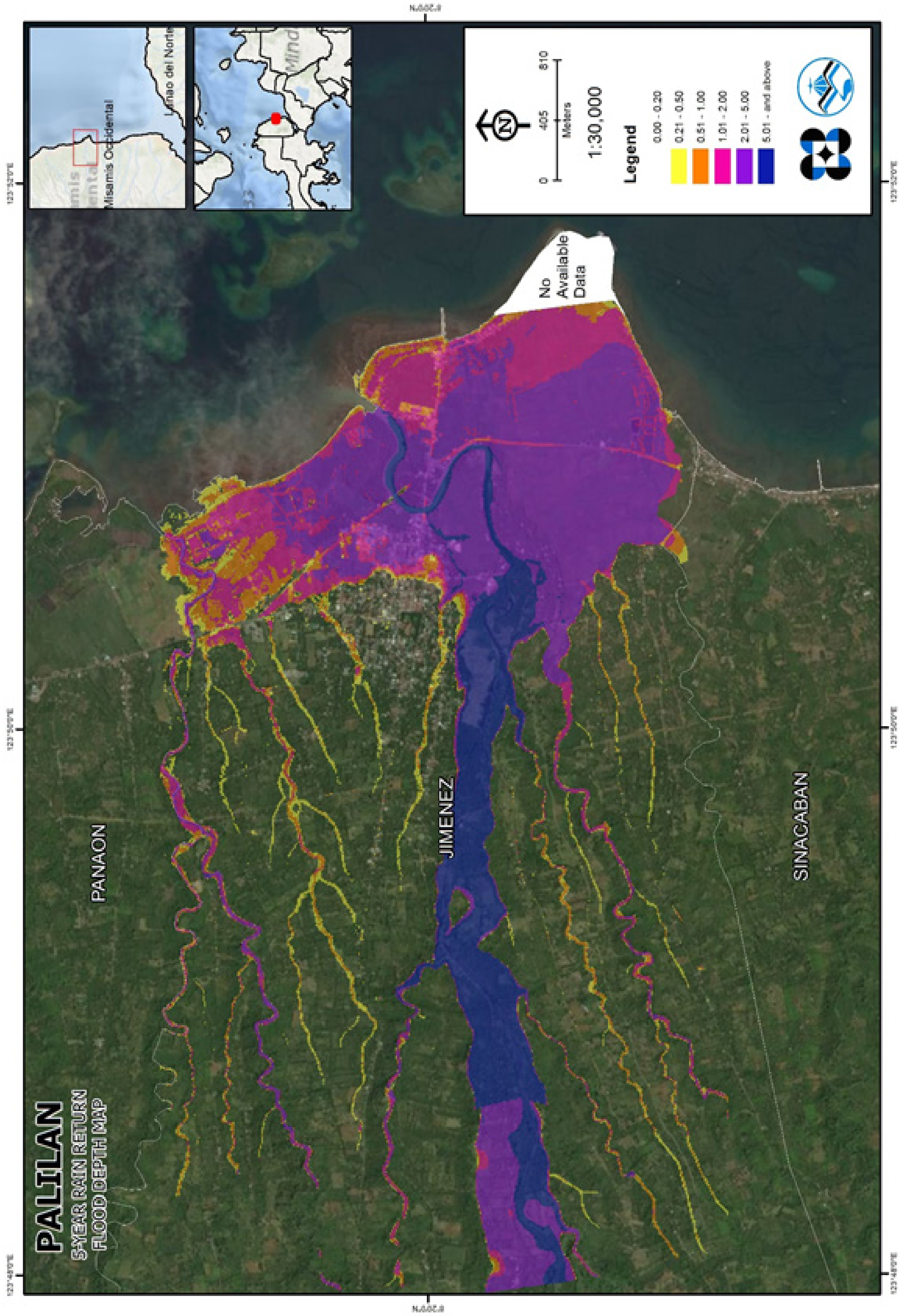

Figure 67. A 5-year Flood Depth Map for Palilan Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Palilan river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 29 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 13.97% of the municipality of Jimenez with an area of 78.47 sq. km. will experience flood levels of less 0.20 meters. 0.60% of the area will experience flood levels of 0.21 to 0.50 meters while 0.75%, 1.76%, 4.11%, and 2.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Jimenez, Misamis Occidental during 5-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Jimenez											
	Adorable	Butuay	Carmen	Corrales	Dicoloc	Gata	Macabayao	Malibacsan	Matugas Alto	Matugas Bajo	Mialem	Nacio-nal
0.03-0.20	0.64	0.012	0.17	0.47	0.67	0.75	0.043	0.75	0.12	0.86	0.26	0.3
0.21-0.50	0.025	0.021	0.0019	0.02	0.054	0.054	0.0058	0.0015	0.002	0.02	0.0063	0.014
0.51-1.00	0.022	0.15	0.0051	0.0062	0.045	0.02	0.0053	0.00076	0.0031	0.011	0.0071	0.0098
1.01-2.00	0.0014	0.31	0.014	0.0063	0.052	0.0081	0.011	0.0023	0.0044	0.023	0.02	0.00054
2.01-5.00	0.0059	0.13	0.12	0.014	0.00097	0.00096	0.37	0.0051	0.0014	0.014	0.31	0
> 5.00	0	0	0.031	0.22	0	0	0.0002	0.041	0	0	0.57	0

Affected area (sq.km.)	Affected Barangays in Jimenez										
	Naga	Palilan	Rizal	San Isidro	Santa Cruz	Seti	Sibaroc	Sinara Alto	Sinara Bajo	Tabo-O	Taraka
0.03-0.20	0.64	0.012	0.17	0.47	0.67	0.75	0.043	0.75	0.12	0.86	0.26
0.21-0.50	0.025	0.021	0.0019	0.02	0.054	0.054	0.0058	0.0015	0.002	0.02	0.0063
0.51-1.00	0.022	0.15	0.0051	0.0062	0.045	0.02	0.0053	0.00076	0.0031	0.011	0.0071
1.01-2.00	0.0014	0.31	0.014	0.0063	0.052	0.0081	0.011	0.0023	0.0044	0.023	0.02
2.01-5.00	0.0059	0.13	0.12	0.014	0.00097	0.00096	0.37	0.0051	0.0014	0.014	0.31
> 5.00	0	0	0.031	0.22	0	0	0.0002	0.041	0	0	0.57

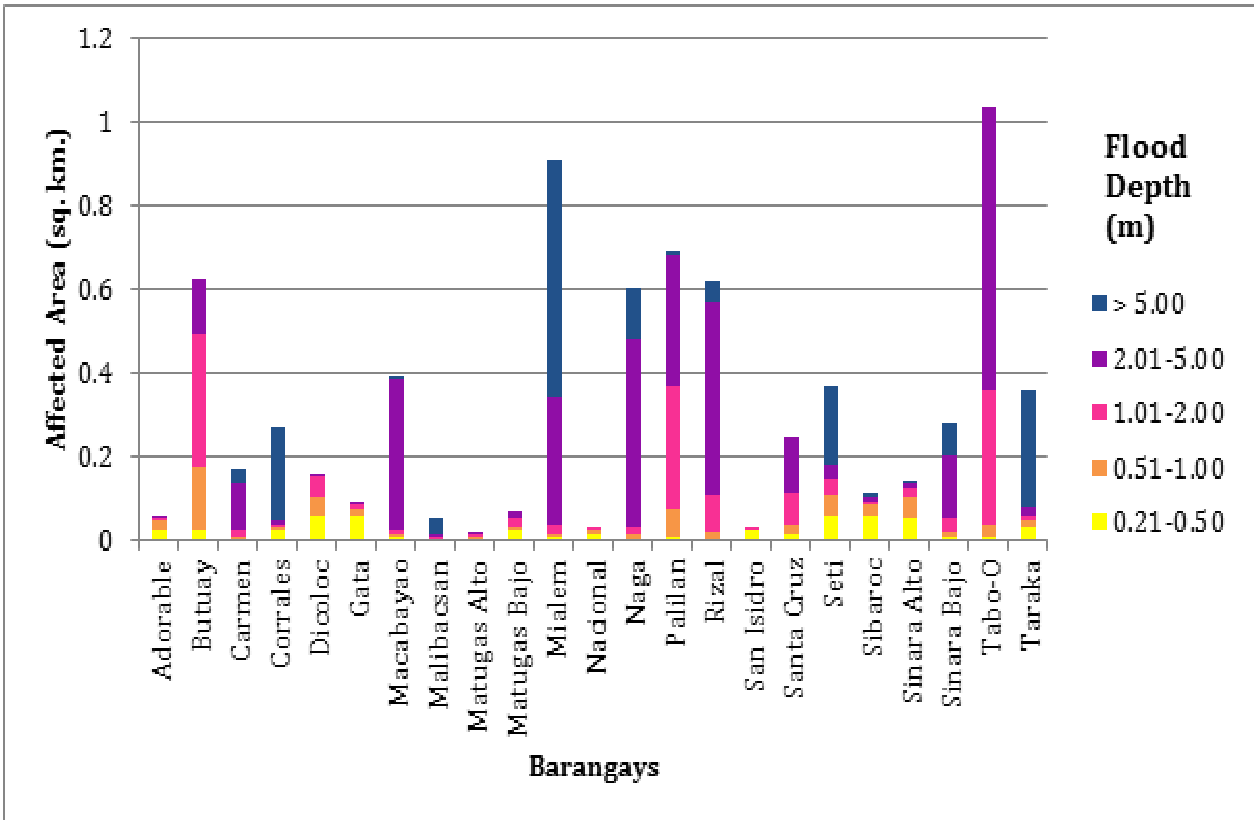

Figure 68. Affected Areas in Jimenez, Misamis Occidental during 5-Year Rainfall Return Period.

For the municipality of Panaon, with an area of 52.52 sq. km., 4.06% will experience flood levels of less 0.20 meters. 0.24% of the area will experience flood levels of 0.21 to 0.50 meters while 0.30%, 0.28%, 0.21%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Panaon, Misamis Occidental during 5-Year Rainfall Return Period.

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)				
	Bangko	Magsaysay	Salimpuno	Sumasap	Sigayan
0.03-0.20	0.59	0.89	0.44	0.21	6.4
0.21-0.50	0.015	0.016	0.015	0.079	0.34
0.51-1.00	0.017	0.023	0.026	0.094	0.21
1.01-2.00	0.01	0.027	0.047	0.063	0.12
2.01-5.00	0.0096	0.028	0.029	0.042	0.022
> 5.00	0.0004	0.0002	0.0005	0	0

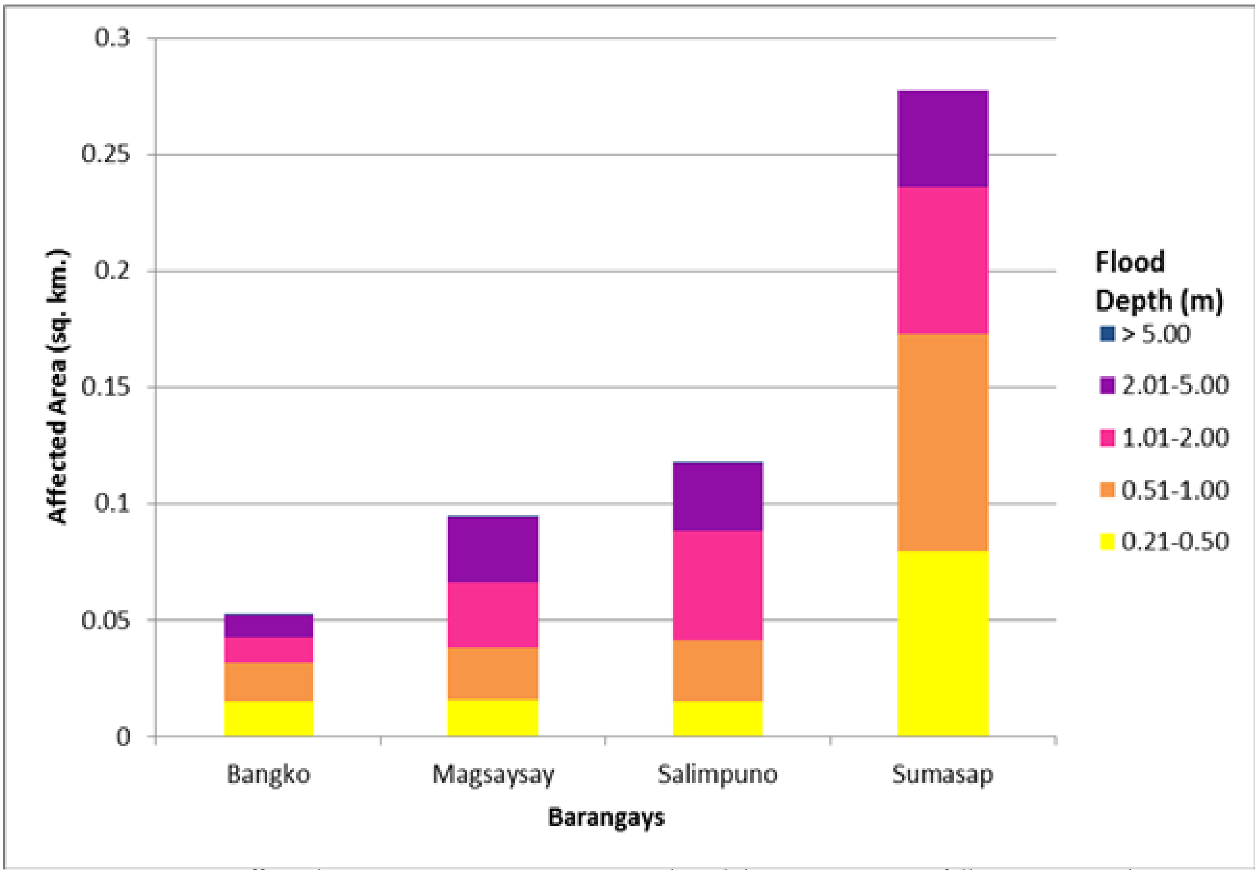

Figure 69. Affected Areas in Panaon, Misamis Occidental during 5-Year Rainfall Return Period.

For the municipality of Sinacaban, with an area of 70.989 sq. km., 0.19% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03.%, 0.09%, and 0.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 34 are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Katipunan, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.)	Affected Barangays in Sinacaban	
	Cagay-Anon	San Vicente
0.03-0.20	0.12	0.014
0.21-0.50	0.0087	0.00013
0.51-1.00	0.019	0
1.01-2.00	0.062	0
2.01-5.00	0.25	0
> 5.00	0	0

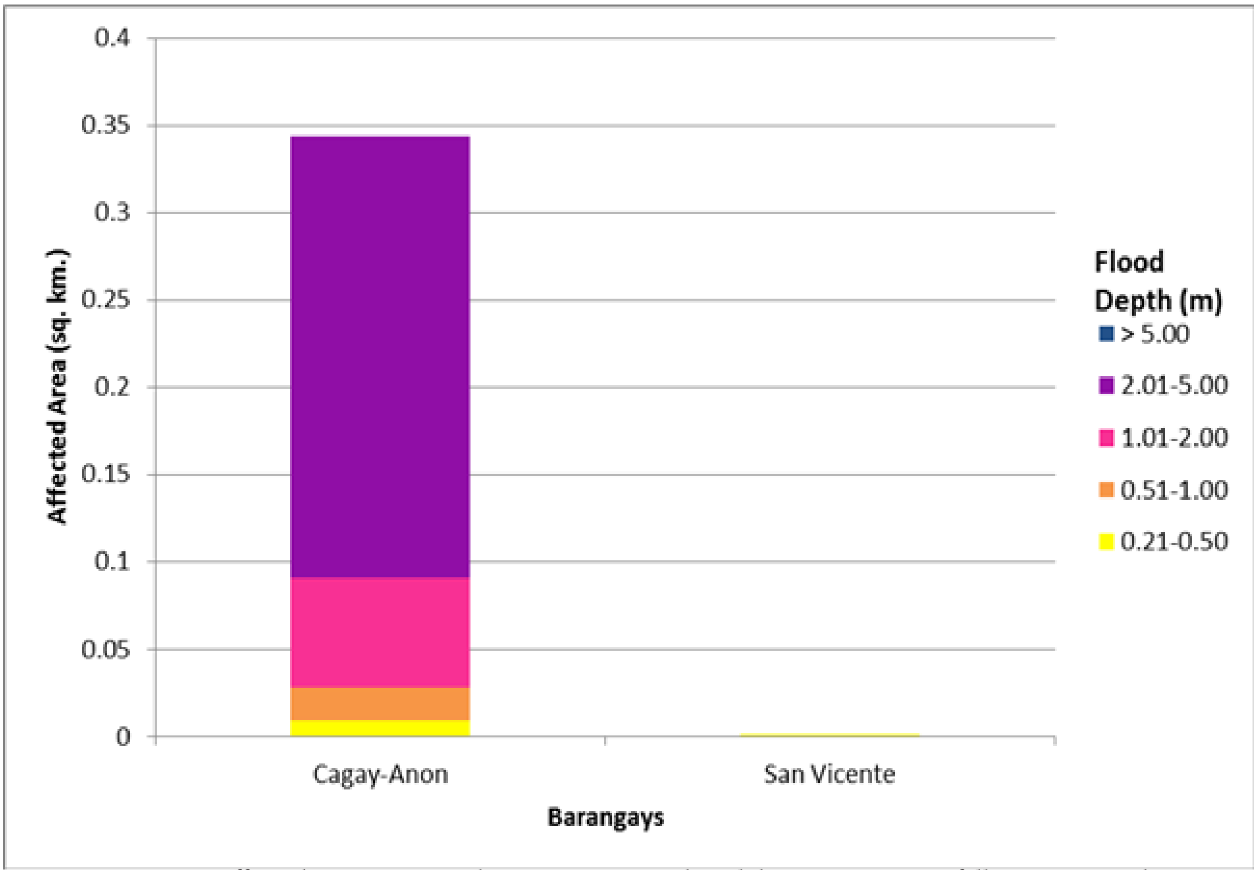

Figure 70. Affected Areas in Sinacaban, Misamis Occidental during 5-Year Rainfall Return Period.

For the 25-year return period, 13.03% of the municipality of Jimenez with an area of 78.47 sq. km. will experience flood levels of less 0.20 meters. 0.55% of the area will experience flood levels of 0.21 to 0.50 meters while 0.47%, 0.84%, 3.68%, and 4.66% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Jimenez, Misamis Occidental during 25-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Jimenez											
	Adorable	Butuay	Carmen	Corrales	Dicoloc	Gata	Macabayao	Malibacsan	Matugas Alto	Matugas Bajo	Mialem	Nacional
0.03-0.20	0.62	0.0001	0.16	0.41	0.63	0.72	0.031	0.7	0.12	0.83	0.17	0.29
0.21-0.50	0.027	0.0017	0.00088	0.024	0.05	0.062	0.0018	0.0019	0.0028	0.019	0.0051	0.015
0.51-1.00	0.028	0.015	0.0018	0.0096	0.043	0.028	0.0047	0.0014	0.002	0.014	0.0042	0.015
1.01-2.00	0.0052	0.21	0.0028	0.0079	0.079	0.015	0.0064	0.0026	0.0049	0.015	0.0086	0.0026
2.01-5.00	0.0024	0.41	0.018	0.016	0.013	0.0037	0.085	0.0089	0.0041	0.032	0.031	0.00017
> 5.00	0.0057	0	0.15	0.27	0	0	0.3	0.08	0	0.01	0.94	0

Affected area (sq.km.)	Affected Barangays in Jimenez										
	Naga	Palilan	Rizal	San Isidro	Santa Cruz	Seti	Sibaroc	Sinara Alto	Sinara Bajo	Tabo-O	Taraka
0.03-0.20	0	0.0005	0	0.44	0.038	1.7	1.09	1.71	0.44	0.000001	0.11
0.21-0.50	0	0.00025	0	0.032	0.0073	0.056	0.06	0.048	0.0063	0.00035	0.014
0.51-1.00	0	0.0058	0.0013	0.0062	0.012	0.049	0.044	0.049	0.0084	0.0044	0.02
1.01-2.00	0.00064	0.068	0.011	0.0017	0.022	0.051	0.0077	0.04	0.019	0.057	0.026
2.01-5.00	0.046	0.6	0.4	0	0.24	0.046	0.007	0.017	0.054	0.77	0.088
> 5.00	0.56	0.024	0.21	0	0.011	0.28	0.053	0.0088	0.23	0.21	0.31

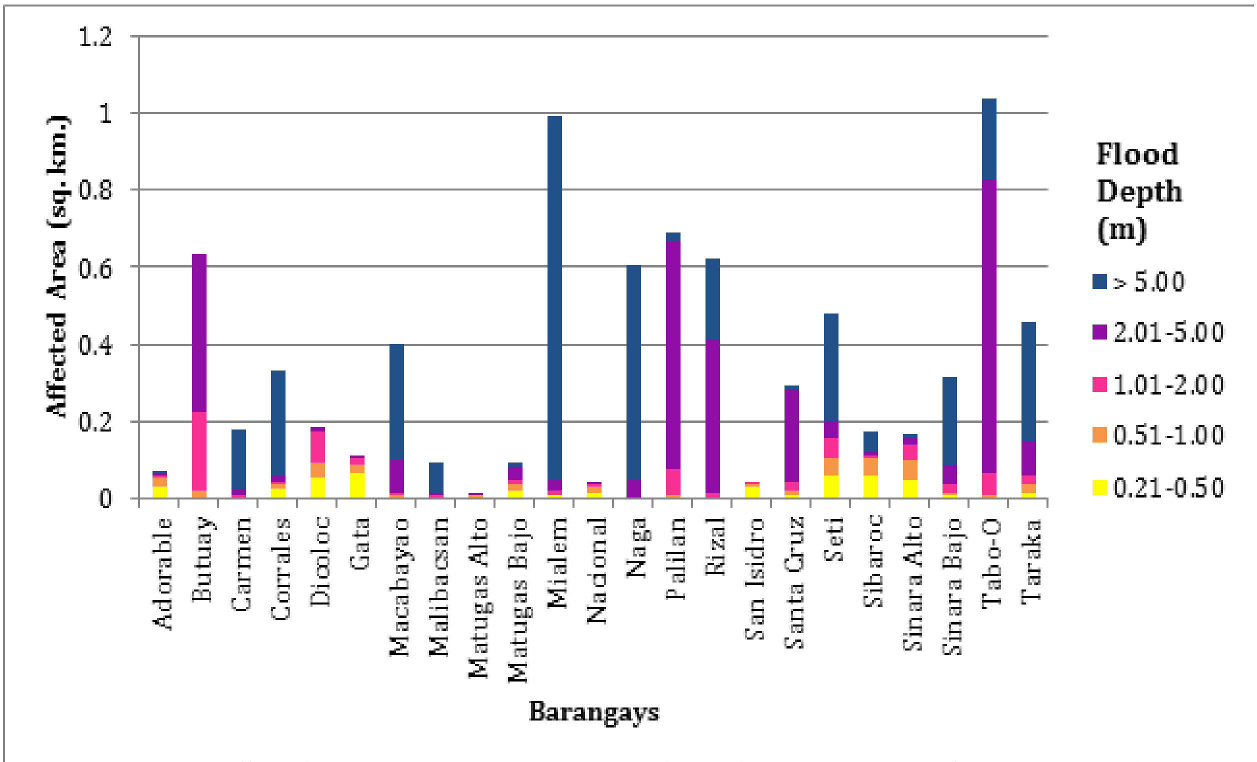

Figure 71. Affected Areas in Jimenez, Misamis Occidental during 25-Year Rainfall Return Period.

For the municipality of Panaon, with an area of 52.52 sq. km., 3.77% will experience flood levels of less 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.41%, 0.37%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. . Affected Areas in Panaon, Misamis Occidental during 25-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Panaon				
	Bangko	Magsaysay	Salim-puno	Sumasap	Sigayan
0.03-0.20	0.58	0.87	0.41	0.12	6.15
0.21-0.50	0.011	0.017	0.011	0.062	0.33
0.51-1.00	0.019	0.02	0.022	0.1	0.29
1.01-2.00	0.013	0.03	0.038	0.13	0.21
2.01-5.00	0.014	0.035	0.072	0.071	0.099
> 5.00	0.0041	0.016	0.0073	0.0003	0

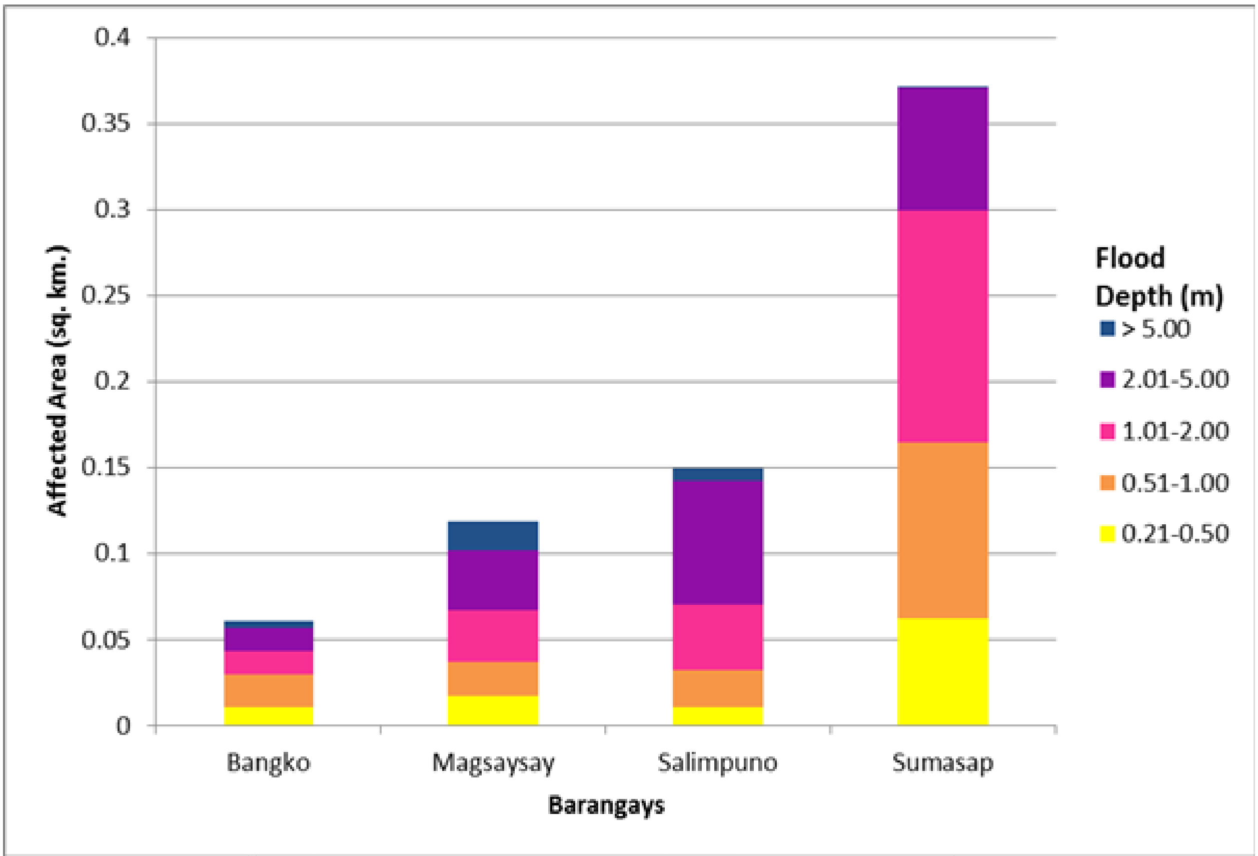

Figure 72. Affected Areas in Panaon, Misamis Occidental during 25-Year Rainfall Return Period.

For the municipality of Sinacaban, with an area of 70.989 sq. km., 0.17% will experience flood levels of less 0.20 meters. 0.002% of the area will experience flood levels of 0.21 to 0.50 meters while 0.009.%, 0.03%, 0.40%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Sinacaban, Misamis Occidental during 25-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Sinacaban	
	Cagay-Anon	San Vicente
0.03-0.20	0.11	0.014
0.21-0.50	0.0015	0.00011
0.51-1.00	0.0066	0.000025
1.01-2.00	0.024	0
2.01-5.00	0.28	0
> 5.00	0.036	0

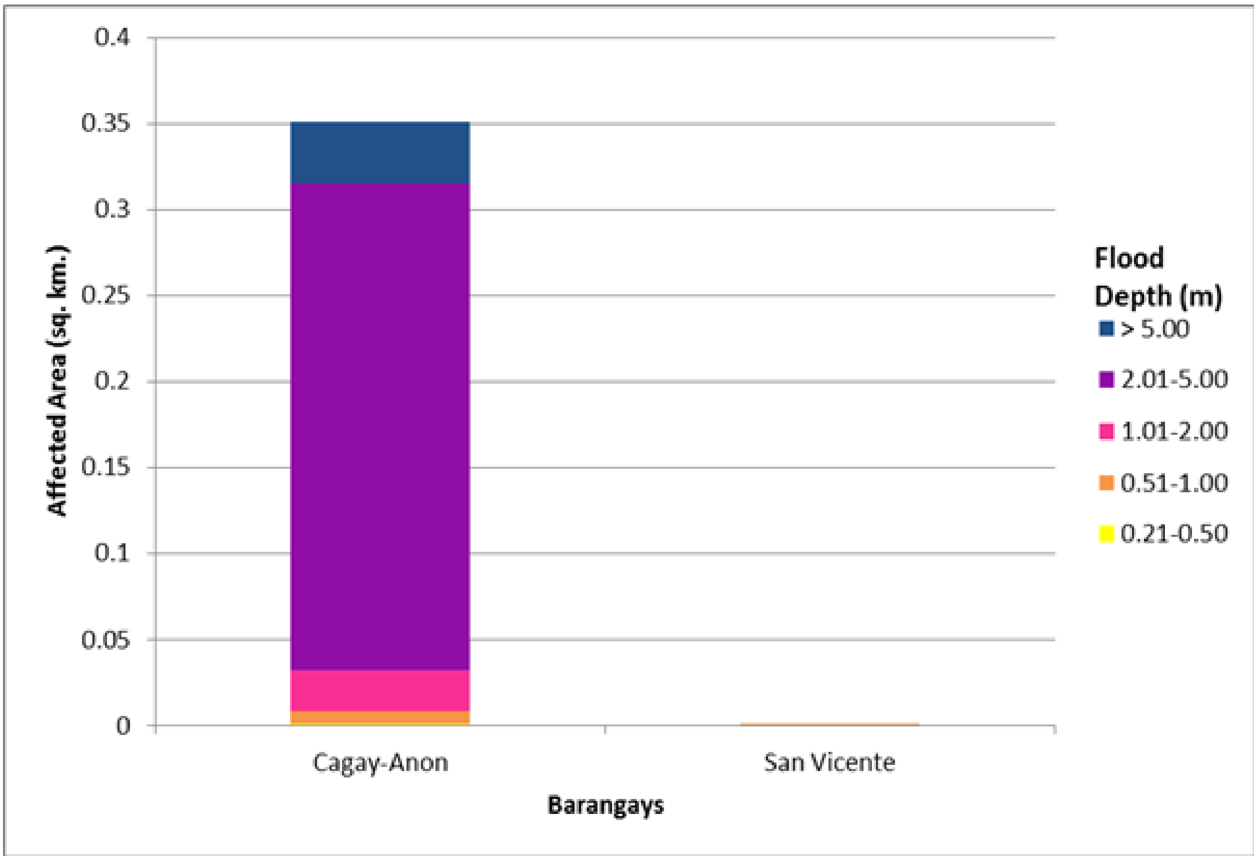

Figure 73. Affected Areas in Sinacaban, Misamis Occidental during 25-Year Rainfall Return Period.

For the 100-year return period, 11.91% of the municipality of Jimenez with an area of 78.47 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 0.46%, 0.58%, 2.93%, and 6.82% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Jimenez, Misamis Occidental during 100-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Jimenez											
	Adorable	Butuay	Carmen	Corrales	Dicoloc	Gata	Macabayao	Malibacsan	Matugas Alto	Matugas Bajo	Mialem	Nacional
0.03-0.20	0.61	0	0.15	0.15	0.61	0.7	0.022	0.63	0.12	0.78	0.14	0.25
0.21-0.50	0.029	0	0.001	0.016	0.045	0.067	0.0023	0.004	0.0028	0.017	0.0031	0.025
0.51-1.00	0.03	0.000043	0.00069	0.017	0.042	0.036	0.0029	0.0031	0.002	0.014	0.0048	0.024
1.01-2.00	0.011	0.035	0.0024	0.069	0.056	0.019	0.0053	0.0042	0.0048	0.01	0.0069	0.014
2.01-5.00	0.0045	0.56	0.0078	0.12	0.064	0.0046	0.023	0.015	0.0056	0.025	0.02	0.0056
> 5.00	0.0072	0.043	0.17	0.37	0	0.00021	0.37	0.14	0	0.081	0.99	0

Affected area (sq.km.)	Affected Barangays in Jimenez										
	Naga	Palilan	Rizal	San Isidro	Santa Cruz	Seti	Sibaroc	Sinara Alto	Sinara Bajo	Tabo-O	Taraka
0.03-0.20	0	0.00042	0	0.44	0.0023	1.56	1.05	1.67	0.42	0	0.036
0.21-0.50	0	0.00017	0	0.034	0.0041	0.053	0.061	0.045	0.0061	0.000001	0.0032
0.51-1.00	0	0.001	0.00017	0.0098	0.0074	0.049	0.053	0.051	0.0071	0.00087	0.0056
1.01-2.00	0	0.024	0.0037	0.0023	0.019	0.056	0.013	0.046	0.016	0.017	0.019
2.01-5.00	0.0046	0.42	0.14	0	0.11	0.062	0.0053	0.029	0.046	0.53	0.1
> 5.00	0.6	0.25	0.48	0	0.18	0.39	0.084	0.031	0.26	0.49	0.41

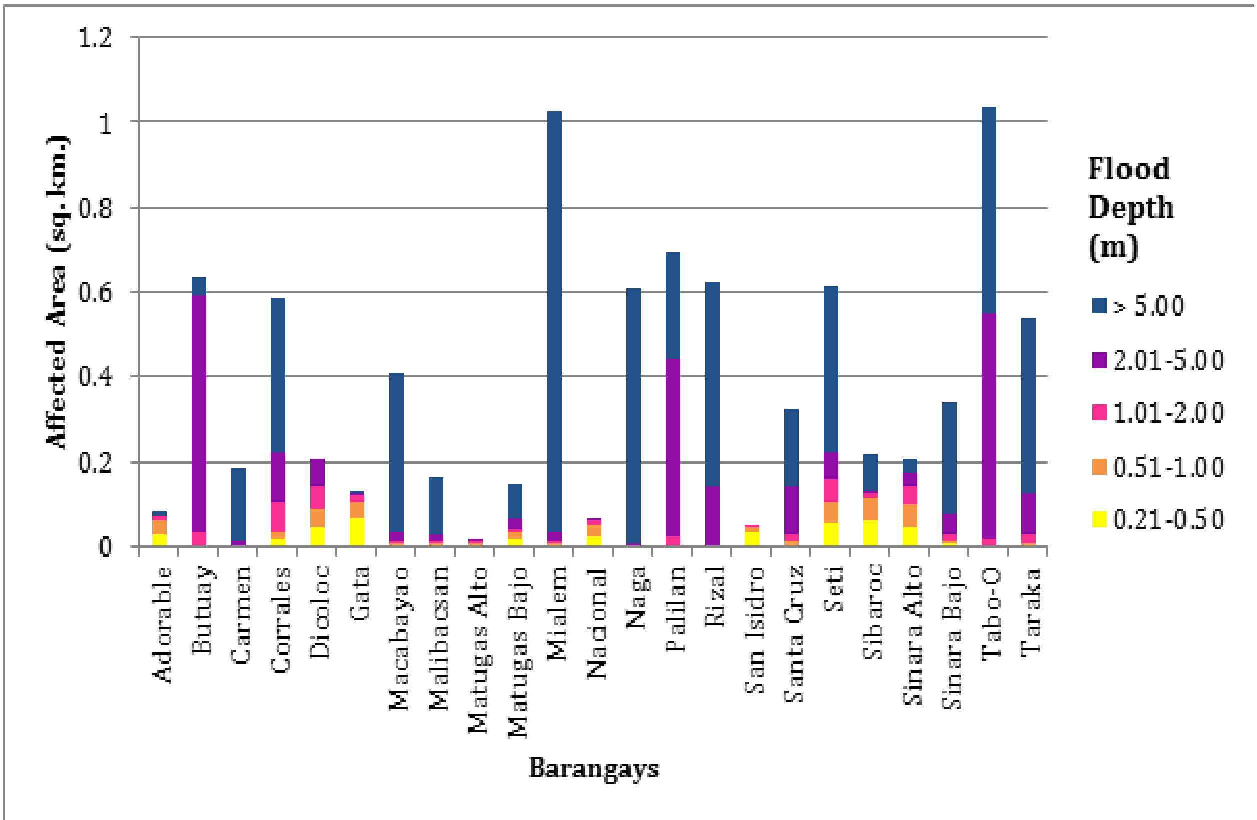

Figure 74. Affected Areas in Jimenez, Misamis Occidental during 100-Year Rainfall Return Period.

For the municipality of Panaon, with an area of 52.52 sq. km., 3.61% will experience flood levels of less 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.30%, 0.45%, 0.46%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Panaon, Misamis Occidental during 100-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Panaon			
	Bangko	Magsaysay	Salimpuno	Sumasap
0.03-0.20	0.57	0.85	0.4	0.073
0.21-0.50	0.011	0.018	0.0064	0.044
0.51-1.00	0.018	0.018	0.017	0.1
1.01-2.00	0.016	0.031	0.035	0.15
2.01-5.00	0.015	0.03	0.085	0.12

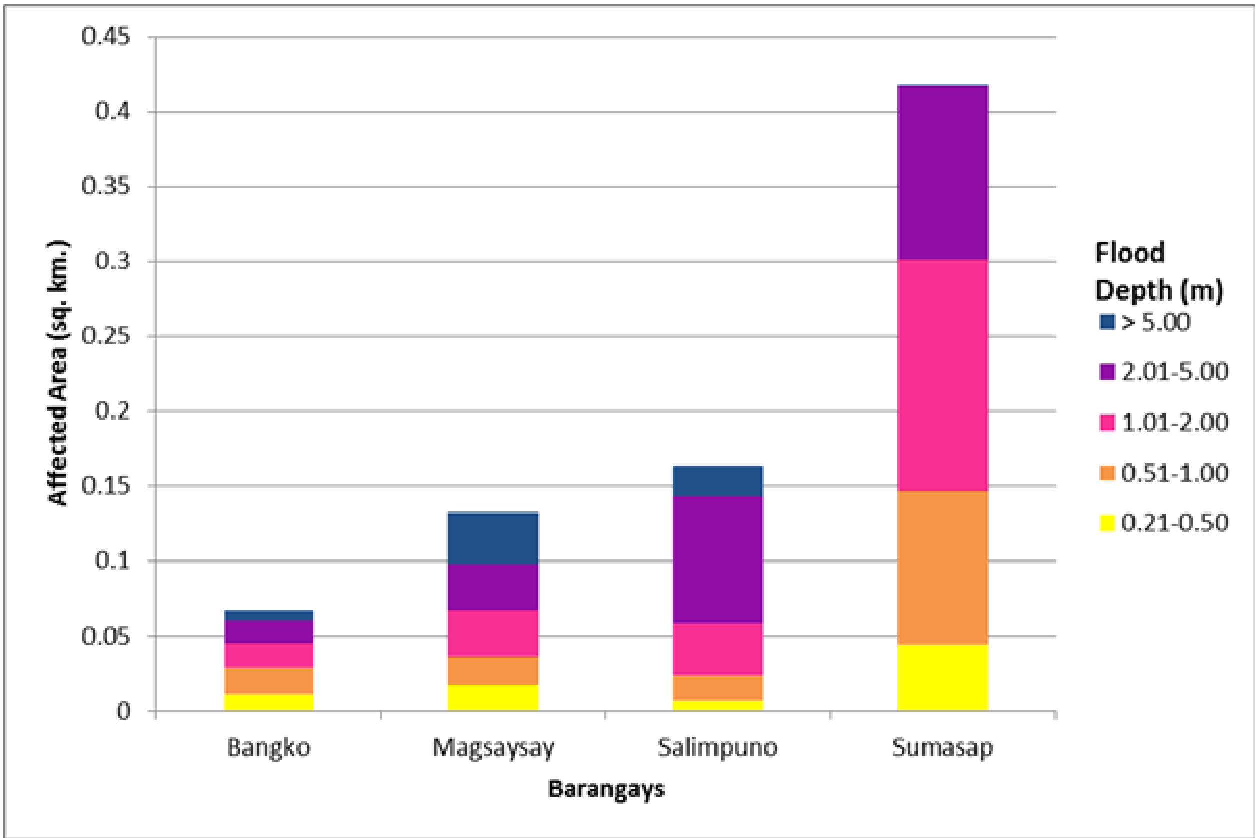

Figure 75. Affected Areas in Panaon, Misamis Occidental during 100-Year Rainfall Return Period.

For the municipality of Sinacaban, with an area of 70.989 sq. km., 0.16% will experience flood levels of less 0.20 meters. 0.005% of the area will experience flood levels of 0.21 to 0.50 meters while 0.004.%, 0.02%, 0.23%, and 0.24% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Sinacaban, Misamis Occidental during 100-Year Rainfall Return Period.

Affected area (sq.km.)	Affected Barangays in Sinacaban	
	Cagay-Anon	San Vicente
0.03-0.20	0.1	0.014
0.21-0.50	0.0032	0.00014
0.51-1.00	0.003	0.000025
1.01-2.00	0.017	0
2.01-5.00	0.16	0
> 5.00	0.17	0

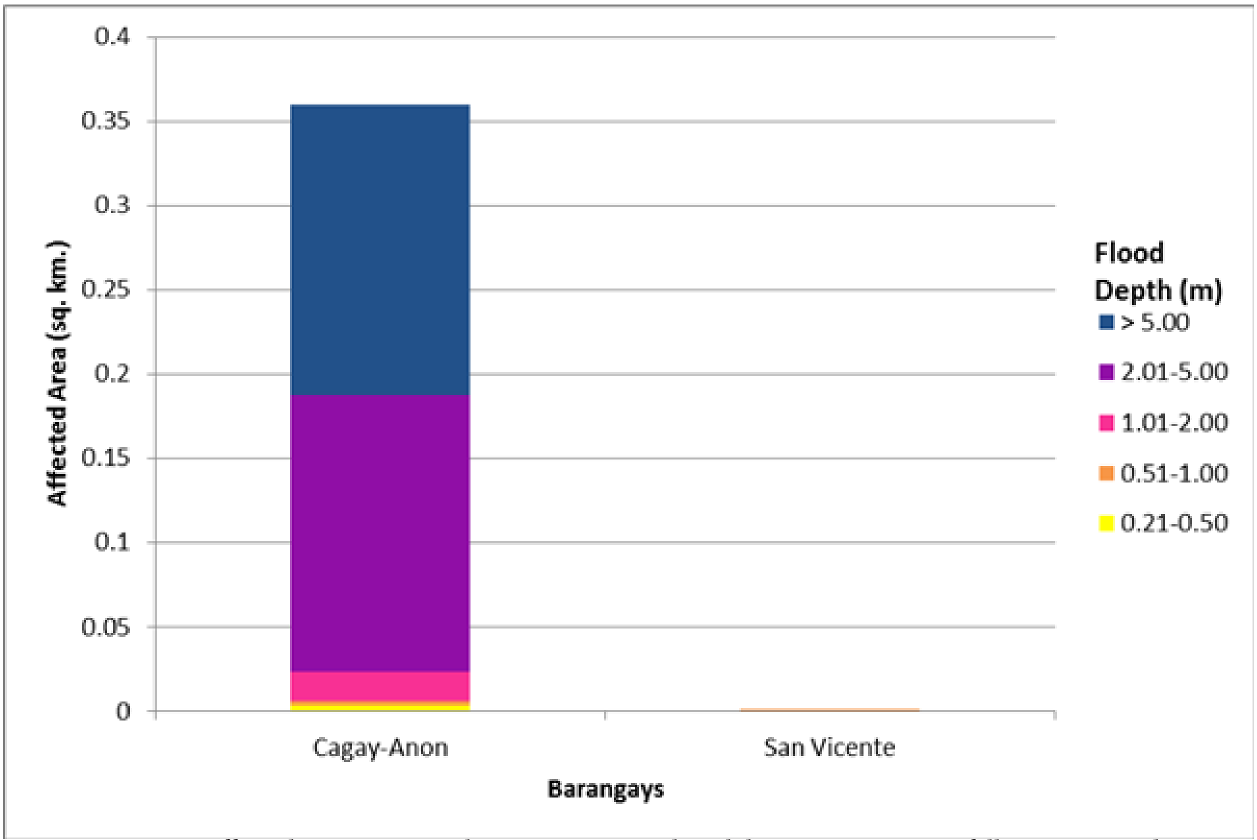

Figure 76. Affected Areas in Sinacaban, Misamis Occidental during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Jimenez, Seti is projected to have the highest percentage of area that will experience flood levels at 2.78%. Meanwhile, Sinara Alto posted the second highest percentage of area that may be affected by flood depths at 2.39%.

Among the barangays in the municipality of Panaon, Magsaysay is projected to have the highest percentage of area that will experience flood levels at 1.88%. Meanwhile, Bangko posted the second highest percentage of area that may be affected by flood depths at 1.22%.

Among the barangays in the municipality of Sinacaban, Cagay-Anon is projected to have the highest percentage of area that will experience flood levels at 0.65%. Meanwhile, San Vicente posted the second highest percentage of area that may be affected by flood depths at 0.02%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field 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. The points in the flood map versus its corresponding validation depths are shown in Figure 77.

The flood validation consists of 152 points randomly selected all over the Palilan flood plain (Figure 78). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 2.29m. Table 41 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

The flood validation data were obtained on November 2016

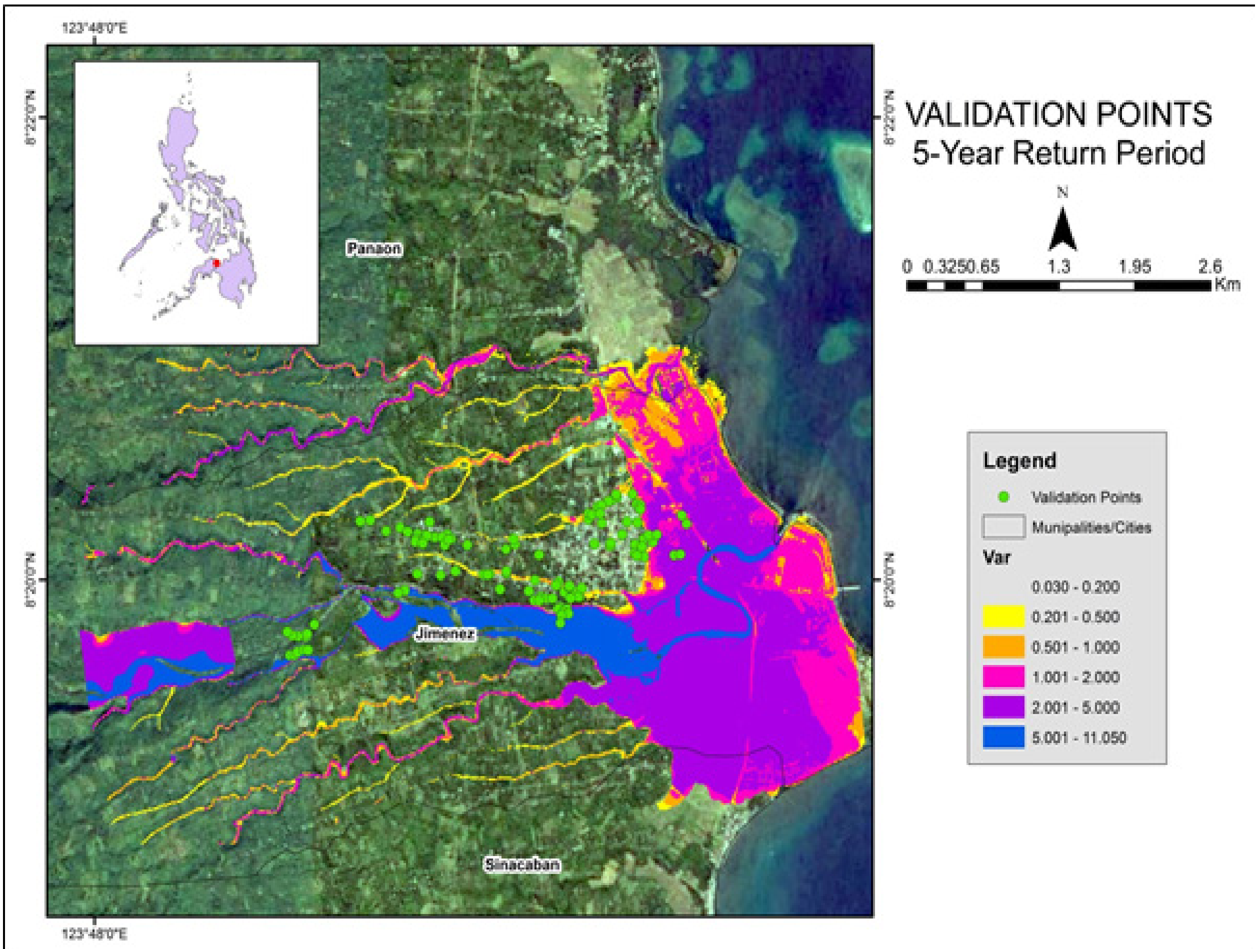

Figure 77. The Validation Points for a 5-year Flood Depth Map of the Palilan Floodplain.

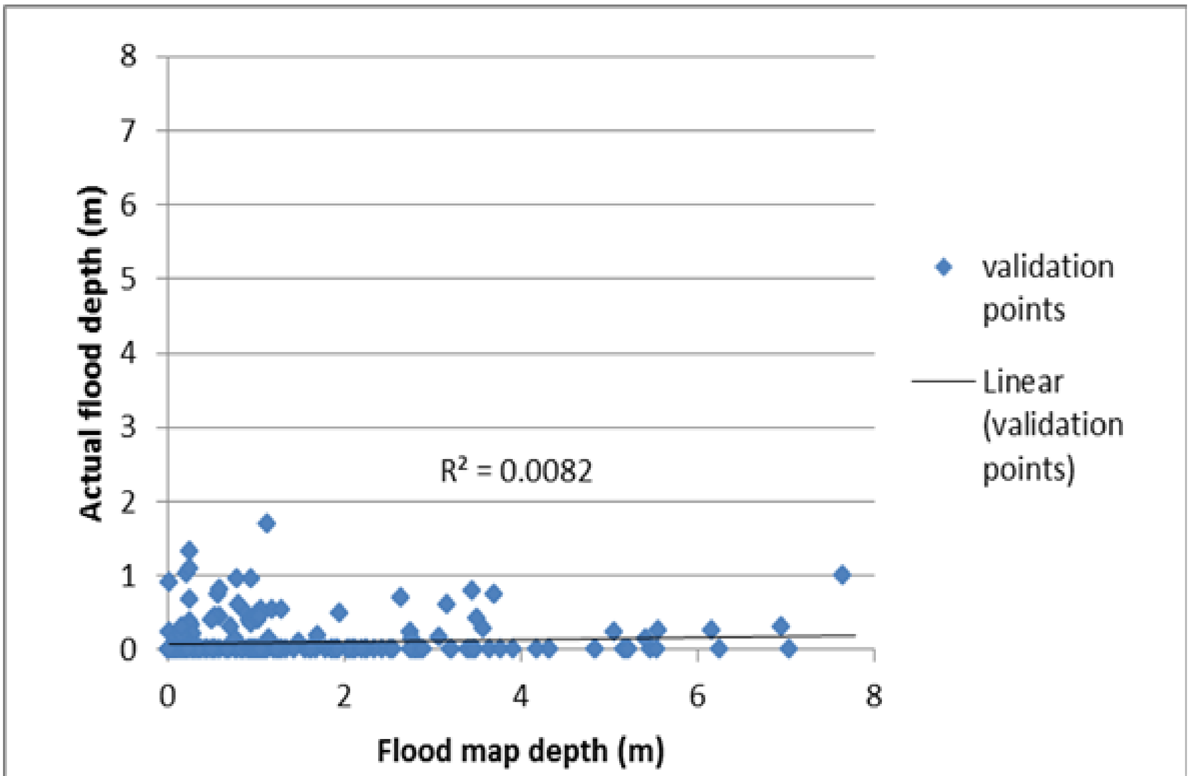

Figure 78. Flood map depth versus actual flood depth.

Table 41. Actual Flood Depth versuss Simulated Flood Depth at different levels in the Palilan River Basin.

Palilan BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	85	26	27	31	38	15	222
	0.21-0.50	2	4	5	4	3	9	27
	0.51-1.00	1	1	6	3	4	4	19
	1.01-2.00	0	3	0	1	0	0	4
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	1	0	0	0	0	1
	Total	88	35	38	39	45	28	273

On the whole, the overall accuracy generated by the flood model is estimated at 35.16%, with 96 points correctly matching the actual flood depths. In addition, there were 37 points estimated one level above and below the correct flood depths while there were 39 points and 101 points estimated two levels above and below. A total of 169 points were overestimated while a total of 8 points were underestimated in the modelled flood depths of Palilan. Table 42 depicts the summary of the Accuracy Assessment in the Palilan River Basin Flood Depth Map.

Table 42. The summary of the Accuracy Assessment in the Palilan River Basin Survey

	No. of Points	%
Correct	96	35.16
Overestimated	169	61.90
Underestimated	8	2.93
Total	273	100

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Annex 1. Technical Specifications of the LIDAR Sensors used in the Palilan Floodplain Survey

Table A-1.1. Parameters and Specifications of Aquarius Sensor

1. PEGASUS SENSOR

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	112-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

1. Target reflectivity ≥20%
2. Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3. Angle of incidence ≤20˚
4. Target size ≥ laser footprint5 Dependent on system configuration

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

1.MSW-11

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: **MISAMIS OCCIDENTAL**
Station Name: **MSW-11**
Order: **2nd**

Island: **MINDANAO**
Municipality: **ALORAN**
Barangay: **OSPITAL (POB.)**
MSL Elevation:

PRS92 Coordinates

Latitude:	**8° 24' 49.21851"**	Longitude:	**123° 49' 18.84776"**	Ellipsoidal Hgt:	**4.39900 m.**

WGS84 Coordinates

Latitude:	**8° 24' 45.57851"**	Longitude:	**123° 49' 24.26581"**	Ellipsoidal Hgt:	**70.09500 m.**

PTM / PRS92 Coordinates

Northing:	**930392.306 m.**	Easting:	**590515.033 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**930,066.65**	Easting:	**590,483.35**	Zone:	**51**

Location Description

MSW-11
Is located beside the fence inside Aloran Trade High School compound. It is about 100 m. from the school main bldg. Mark is the head of a 4 in. copper nail embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "MSW-11 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2582**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MSW-11

2. MSW-12

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: **MISAMIS OCCIDENTAL**

Station Name: **MSW-12**

Order: **2nd**

Island: **MINDANAO**		Barangay:			
Municipality: **TUDELA**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**8° 14' 33.61728"**	Longitude:	**123° 50' 41.11353"**	Ellipsoidal Hgt:	**5.69800 m.**
		WGS84 Coordinates			
Latitude:	**8° 14' 30.02425"**	Longitude:	**123° 50' 46.54685"**	Ellipsoidal Hgt:	**71.79800 m.**
		PTM / PRS92 Coordinates			
Northing:	**911485.567 m.**	Easting:	**593072.214 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**911,166.53**	Easting:	**593,039.64**	Zone:	**51**

Location Description

MSW-12
Is located on the open ground in Brgy. Poblacion, Mun. of Tudela. It is situated in the middle of the houses and about 100 m. from the tennis court. Mark is the head of a 4 in. copper nail embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "MSW-12 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2583**

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

9910302014133552

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 MSW-12

Annex 3. Baseline Processing Report of Reference Points Used

1. MW-62A

Vector Components (Mark to Mark)

From:	MSW-12				
Grid		Local		Global	
Easting	593039.637 m	Latitude	N8°14'33.61728"	Latitude	N8°14'30.02425"
Northing	911166.531 m	Longitude	E123°50'41.11353"	Longitude	E123°50'46.54685"
Elevation	3.251 m	Height	5.698 m	Height	71.798 m

To:	MW-62A				
Grid		Local		Global	
Easting	593186.315 m	Latitude	N8°18'46.72583"	Latitude	N8°18'43.11445"
Northing	918939.972 m	Longitude	E123°50'46.44781"	Longitude	E123°50'51.87475"
Elevation	5.373 m	Height	7.578 m	Height	73.539 m

Vector					
ΔEasting	146.678 m	NS Fwd Azimuth	1°12'09"	ΔX	487.058 m
ΔNorthing	7773.441 m	Ellipsoid Dist.	7777.102 m	ΔY	-1019.004 m
ΔElevation	2.121 m	ΔHeight	1.880 m	ΔZ	7694.655 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.008 m
σ ΔElevation	0.010 m	σ ΔHeight	0.010 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000310428		
Y	-0.0000426646	0.0000655996	
Z	-0.0000079883	0.0000114693	0.0000036657

Figure A-3.1. MW-62A

2. MW-85

Vector Components (Mark to Mark)

From:	MSW 11				
Grid		Local		Global	
Easting	590483.351 m	Latitude	N8°24'49.21851"	Latitude	N8°24'45.57851"
Northing	930066.653 m	Longitude	E123°49'18.84777"	Longitude	E123°49'24.26581"
Elevation	2.616 m	Height	4.400 m	Height	70.095 m

To:	MW 85 AM				
Grid		Local		Global	
Easting	587366.444 m	Latitude	N8°29'41.44871"	Latitude	N8°29'37.78490"
Northing	939034.768 m	Longitude	E123°47'37.52758"	Longitude	E123°47'42.93851"
Elevation	2.812 m	Height	4.320 m	Height	69.779 m

Vector					
ΔEasting	-3116.907 m	NS Fwd Azimuth	340°57'21"	ΔX	3309.807 m
ΔNorthing	8968.115 m	Ellipsoid Dist.	9497.194 m	ΔY	627.878 m
ΔElevation	0.196 m	ΔHeight	-0.079 m	ΔZ	8879.615 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.007 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000422712		
Y	-0.0000580578	0.0000865740	
Z	-0.0000102507	0.0000149780	0.0000042223

Figure A-3.2. MW-85

Annex 4. The Survey Team

Table A-4.1. The LiDAR Survey Team Composition

v

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
Phil-LiDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. RENAN PUNTO	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
		KRISTINE JOY ANDAYA	UP-TCAGP
		ENGR. KENNETH QUISADO	UP-TCAGP
		ENGR. GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
		JASMIN DOMINGO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. RONALD MONTINEGRO	PHILIPPINE AIR FORCE (PAF)
		SSG. LEE JAY PUNZALAN	PAF
	Pilot	CAPT. BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FERDINAND DE OCAMPO	AAC
		CAPT. JUSTINE REI JOYA	AAC
		CAPT. CESAR SHERWIN ALFONSO III	AAC

Annex 5. Data Transfer Sheet for Palilan Floodplain

DATA TRANSFER SHEET
11/17/2014(dipolog)

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	
19-Oct	2099P	1BLK69CALIB292A	PEGASUS	106	na	3.84	113	9.11	83	3.84	na	4.08	1KB	1KB	47/23	na	Z:\DAC\RAW DATA
22-Oct	2111P	1BLK69B295A	PEGASUS	2.01	453	12.4	236	29.5	292	22.2	na	7.59	1KB	1KB	292/48/58	na	Z:\DAC\RAW DATA
23-Oct	2113P	1BLK69B296A	PEGASUS	1.62	394	10	216	36.4	260	19.4	na	15.1	1KB	1KB	48/51/44/61	na	Z:\DAC\RAW DATA
23-Oct	2115P	1BLK6970A296B	PEGASUS	754	171	6.26	105	13.6	115	8.18	na	15.1	1KB	1KB	40/51/25	na	Z:\DAC\RAW DATA
24-Oct	2117P	1BLK69B297A	PEGASUS	1.24	237	5.73	113	18.6	164	12.4	na	7.64	1KB	1KB	48/51/50	na	Z:\DAC\RAW DATA
26-Oct	2125P	1BLK69C299A	PEGASUS	1.5	267	8.41	211	32	239	15.4	na	37.4	1KB	1KB	48/51/50/41/56/43/22	na	Z:\DAC\RAW DATA
26-Oct	2127P	1BLK6970A299B	PEGASUS	2.54	na	5.91	114	16	1	12.9	na	37.4	1KB	1KB	27/1	na	Z:\DAC\RAW DATA
28-Oct	2133P	1BLK69FE301A	PEGASUS	2.05	244/454	10.2	225	57.4	343	na	na	37.3	1KB	1KB	73/51/81/39	na	Z:\DAC\RAW DATA
28-Oct	2135P	1BLK69F301B	PEGASUS	268	1701/87	3.42	94.6	na	na	5.4	na	37.3	1KB	1KB	92	na	Z:\DAC\RAW DATA
29-Oct	2137P	1BLK70D302A	PEGASUS	1.05	453/220	7.37	190	28.3	181	11.2	na	19.4	1KB	1KB	106/93/82/75	na	Z:\DAC\RAW DATA
31-Oct	2145P	1BLk69C304A	PEGASUS	2.33	1118/434	9.11	182	48.6	342	22.8	na	6.52	1KB	1KB	74	na	Z:\DAC\RAW DATA
1-Nov	2149P	1BLK70B305A	PEGASUS	1.79	338	7.39	192	32.1	227	20.3	na	29.2	1KB	1KB	54/79	na	Z:\DAC\RAW DATA
3-Nov	2157P	1BLK70C307A	PEGASUS	2.26	198	11.3	240	40.6	295	25.1	na	35.5	1KB	1KB	33	na	Z:\DAC\RAW DATA
6-Nov	2169P	1BLK73A310A	PEGASUS	3.01	523	12.1	240	62.9	na	26.9	na	21.3	1KB	1KB	80	na	Z:\DAC\RAW DATA
8-Nov	2177P	1BLK70C312A	PEGASUS	1.75	327	8.89	199	23.1	na	17.5	na	17.8	1KB	1KB	60/53/57	na	Z:\DAC\RAW DATA
9-Nov	2181P	1BLK69F313A	PEGASUS	1.46	291	8.11	182	22.4	182	15.2	na	17	1KB	1KB	65/62/51	na	Z:\DAC\RAW DATA

Received from
Name C. JOAQUIN
Position RA
Signature

Received by
Name Angelo Carlo Bongat
Position SSRS
Signature ACBongat 11/19/2014

Figure A-5.1. Transfer Sheet for Agsalin Floodplain (A)

DATA TRANSFER SHEET

PAGADIAN 3/7/16

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	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/8 2	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/8 7/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/5 7	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/10/16

Figure A-5.2. Transfer Sheet for Agsalin Floodplain (B)

DATA TRANSFER SHEET
DIPOLOG 12/8/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 28, 2016	23590P	1BLK73DEF333A	PEGASUS	1.56	NA	7.69	203	32.6	298	16.6	NA	42.3	1KB	1KB	1.19	NA	Z:\DAC\RAW DATA
November 30, 2016	23598P	1BLK76A335A	PEGASUS	600	NA	6.93	239	NA	NA	7.85	NA	48.2	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA
December 01, 2016	23602P	1BLK76AB336A	PEGASUS	1.56	NA	9.08	287	NA	NA	16.5	NA	53.9	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

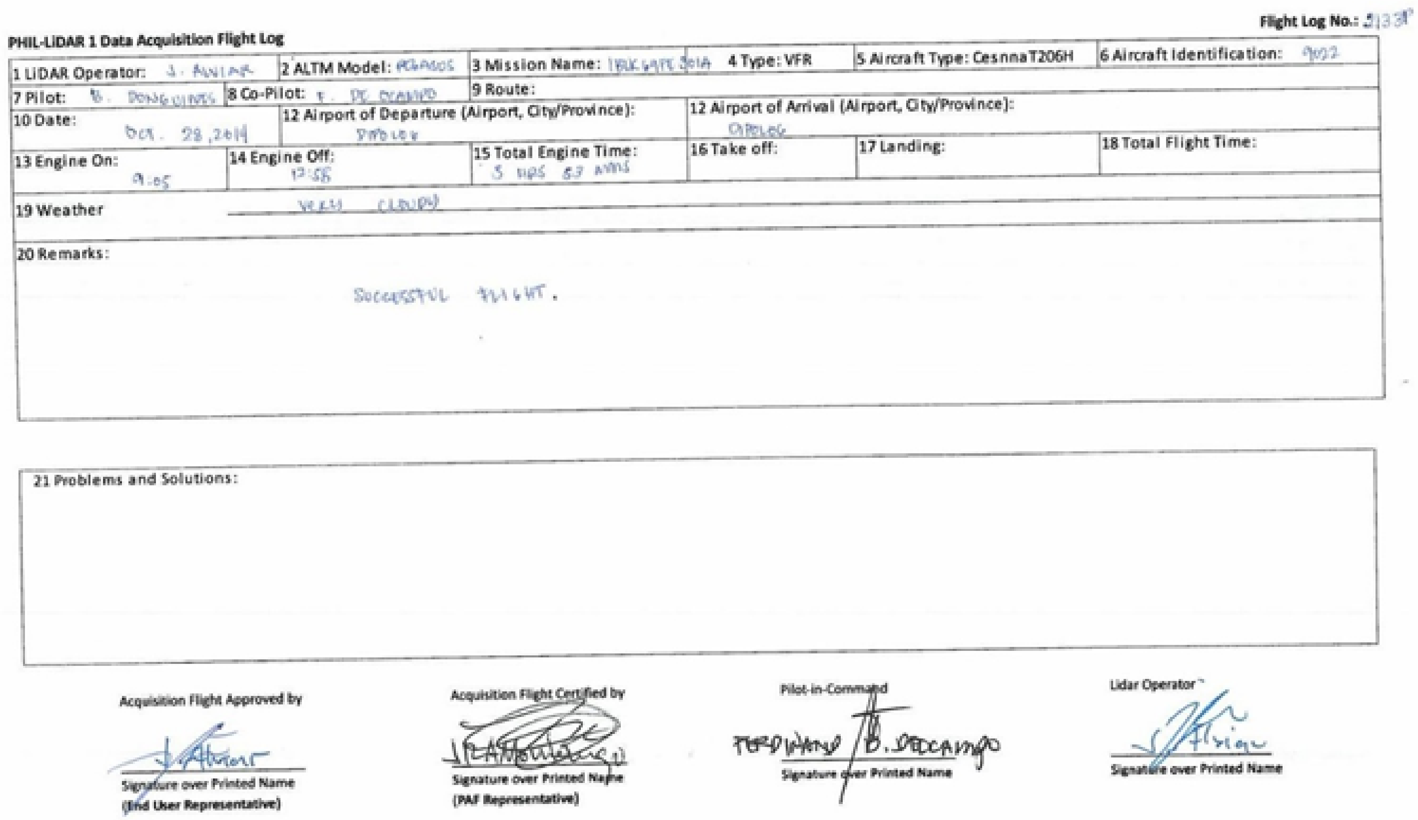
Received by

Name KE Bongat
Position SSRS
Signature 12/8/16

Figure A-5.3. Transfer Sheet for Agsalin Floodplain (C Figure A-6.1. Flight Log for Mission 1054A)

Annex 6. Flight Logs

Flight Log for 1BLK69FE301A Mission



Flight Log No.: 2133P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: J. ALVIAR	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK69FE301A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: OCT. 28, 2014	12 Airport of Departure (Airport, City/Province): PIVOLEX		12 Airport of Arrival (Airport, City/Province): OIPOLOG		
13 Engine On: 9:05	14 Engine Off: 12:58	15 Total Engine Time: 3 HRS 53 MINS	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: VERY CLOUDY					
20 Remarks: SUCCESSFUL FLIGHT.					

21 Problems and Solutions:

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

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

Pilot-in-Command: FERDINAND B. DE OCAMPO — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.1. Flight Log for 1BLK69FE301A Mission

Flight Log for 1BLK69F301B Mission

Flight Log No.: 2185

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK69F301B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: B. Donguines	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: Oct. 28, 2014	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 3:29	14 Engine Off: 5:16	15 Total Engine Time: 1 HR. 47 MINS	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Very cloudy					

20 Remarks:

Successful flight.

21 Problems and Solutions:

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

Figure A-6.2. Flight Log for 1BLK69F301B Mission

Flight Log for 1BLK69F313A Mission

Flight Log No.: 2181P

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK69F313A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: P. DE OCAMPO	9 Route:			
10 Date: Nov. 9, 2014	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 13:15	14 Engine Off: 16:24	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Successful flight.					
21 Problems and Solutions:					

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

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

Pilot-in-Command
B. Dongguines
Signature over Printed Name

Lidar Operator
I. Roxas
Signature over Printed Name

Figure A-6.3. Flight Log for 1BLK69F313A Mission

Flight Log for 1BLK76NO051A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: Jun Almalvez	2 ALTM Model: Pegasus	3 Mission Name: 1BLK76NO051A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC 9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/20/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 8:30	14 Engine Off: 13:05	15 Total Engine Time: 4+35	16 Take off: 8:35	17 Landing: 13:00	18 Total Flight Time: 4+25
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
	LEE JAY PUNZALAN	C. ALFONSO III	Jonathan Almalvez	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for1BLK76NO051A Mission

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

MISAMIS OCCIDENTAL
(October 28 to November 9, 2014 and February 20, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2133P	BLK 69E; BLK 69F	1BLK69FE301A	J Alviar	October 28, 2014	Surveyed BLK 69E and BLK 69F; Cloudy
2135P	BLK 69F	1BLK69F301B	I Roxas	October 28, 2014	Surveyed BLK 69F; LAS output not saved in LAS folder
2181P	BLK 69F	1BLK69F313A	I Roxas	November 9, 2014	Filled gaps in BLK 69F
23116P	BLK 76N; BLK 76O	1BLK76NO051A	J Almalvez	February 20, 2016	Encountered lost Channel A; Completed voids over Oroquieta and Ozamis City

SWATH OF LIDAR BOUNDARIES PER FLIGHT

Flight No.: 2133P
Area: BLK 69E; BLK 69F
Mission Name: 1BLK69FE301A
Parameters: Altitude: 800 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS

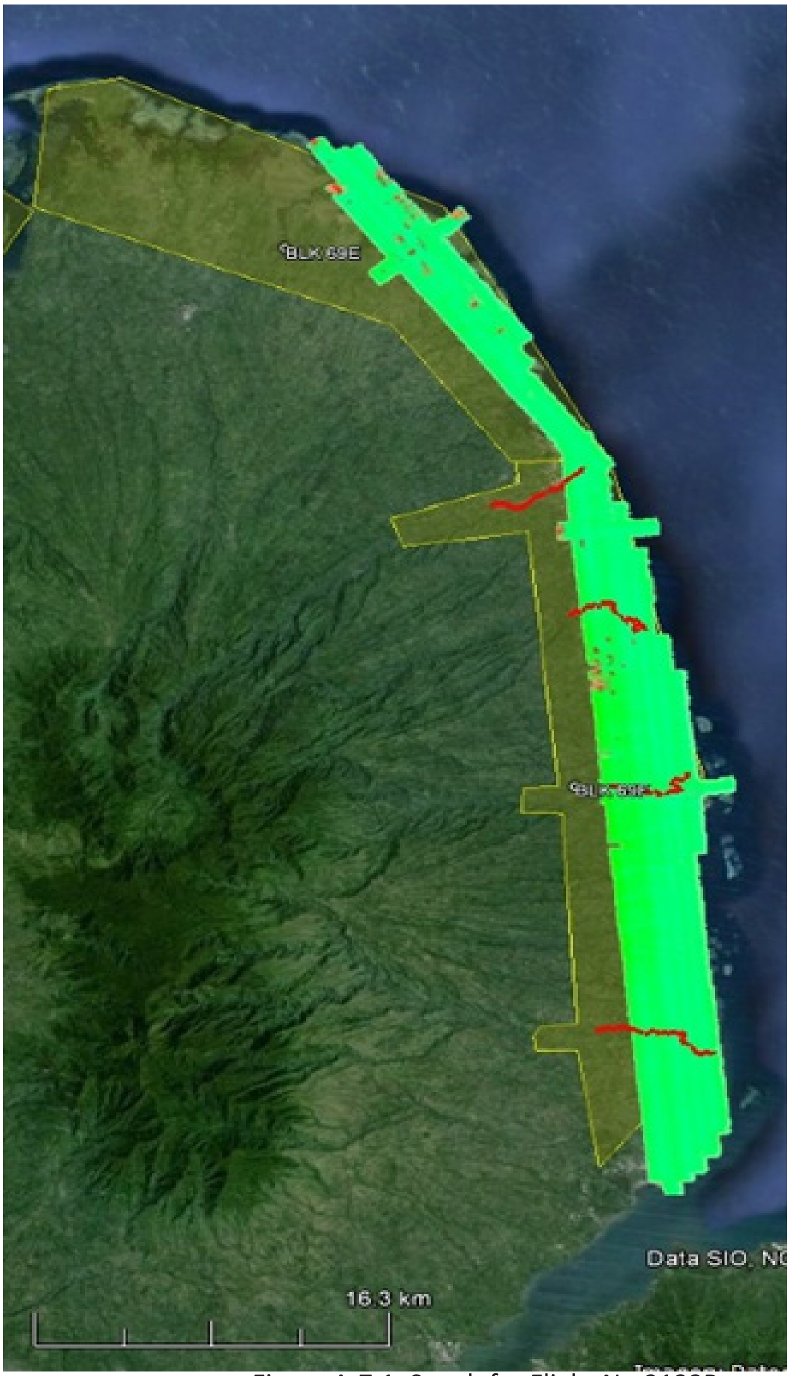


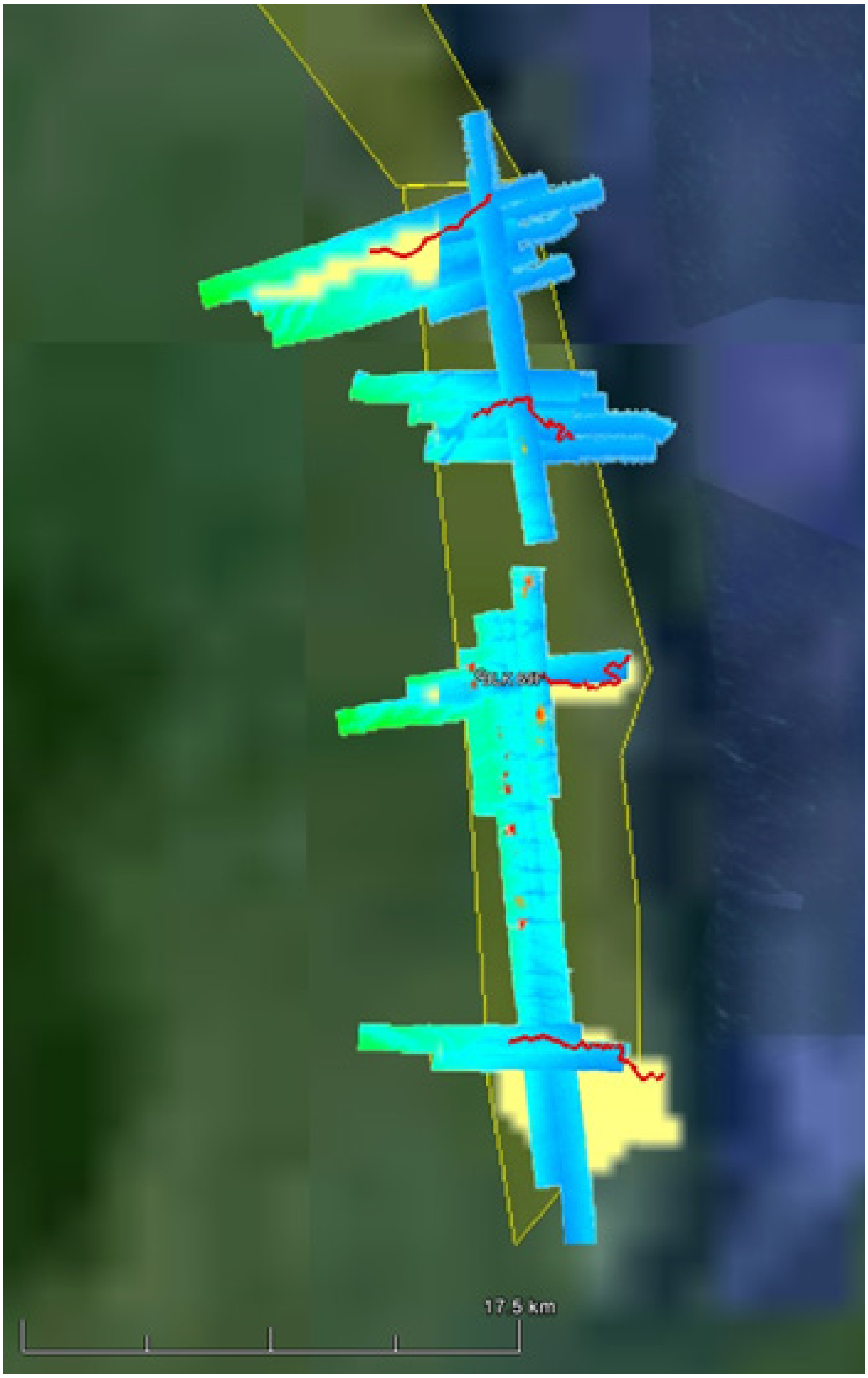
Figure A-7.1. Swath for Flight No.2133P

Flight No.: 2135P
Area: BLK 69F
Mission Name: 1BLK69F301B
Parameters: Altitude: 1000 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS

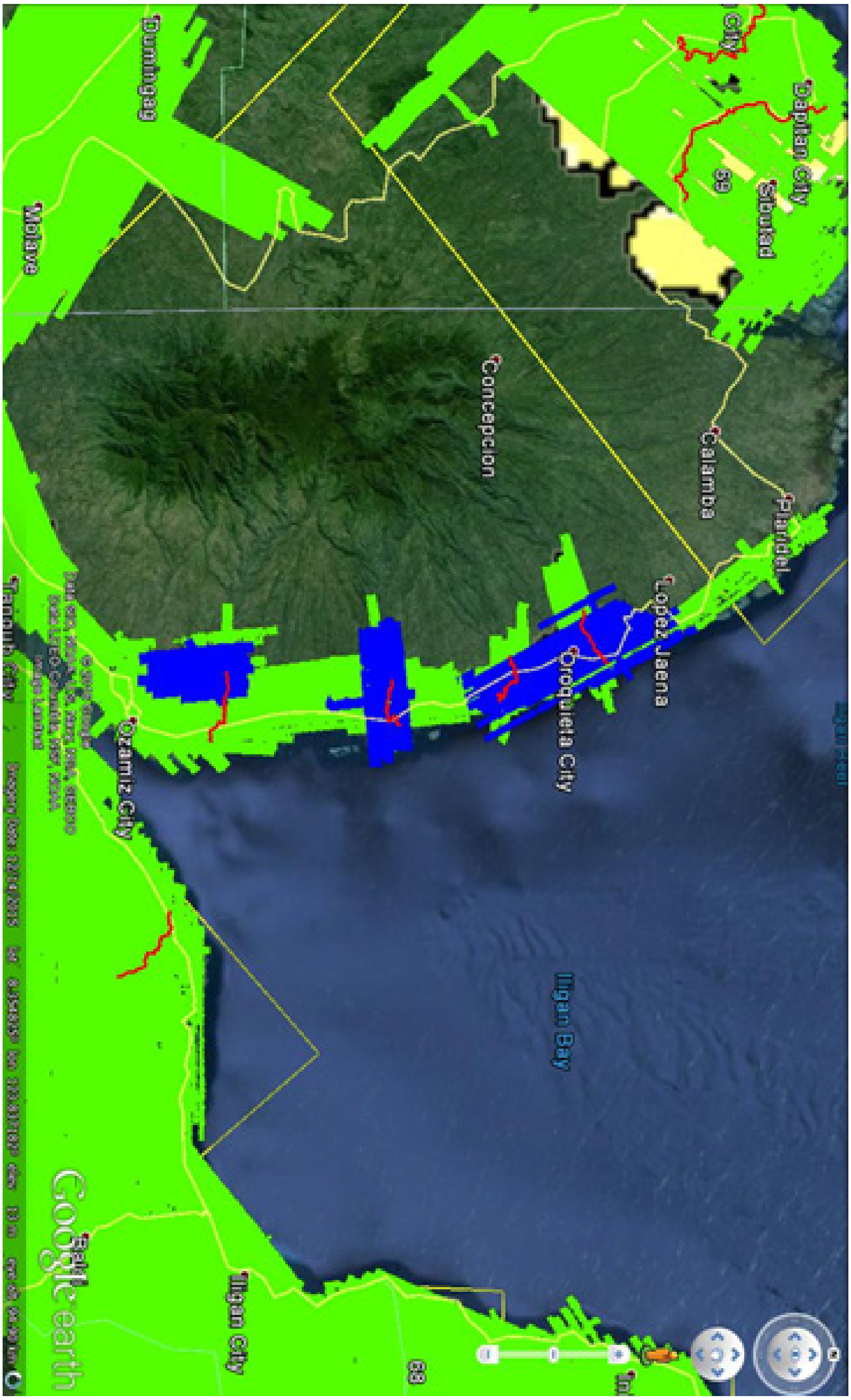
Flight No.: 2181P
Area: BLK 69F
Mission Name: 1BLK69F313A
Parameters: Altitude: 1000 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



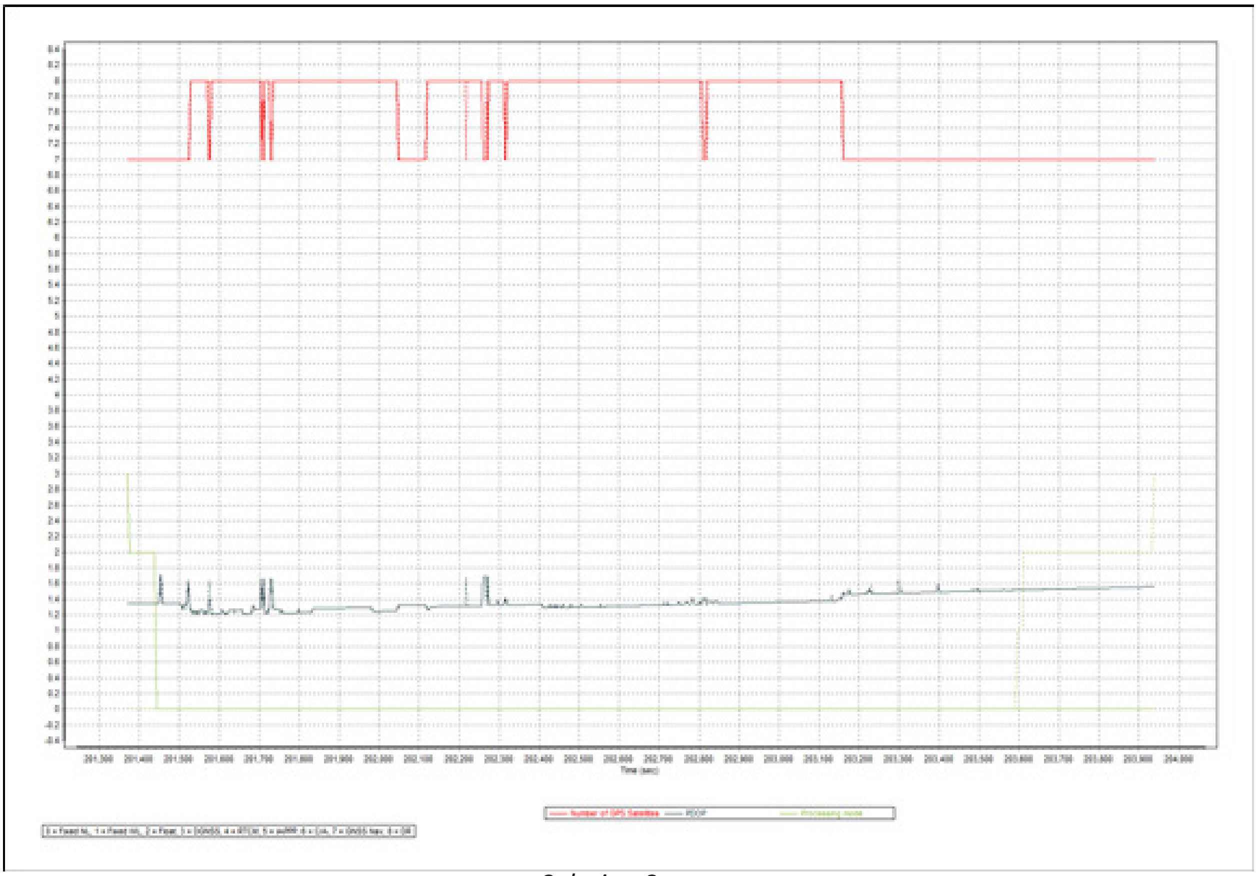
Flight No.: 23116P
Area: BLK 76N, BLK 76O
Mission Name: 1BLK76NO051A
Parameters: Altitude: 1000 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS

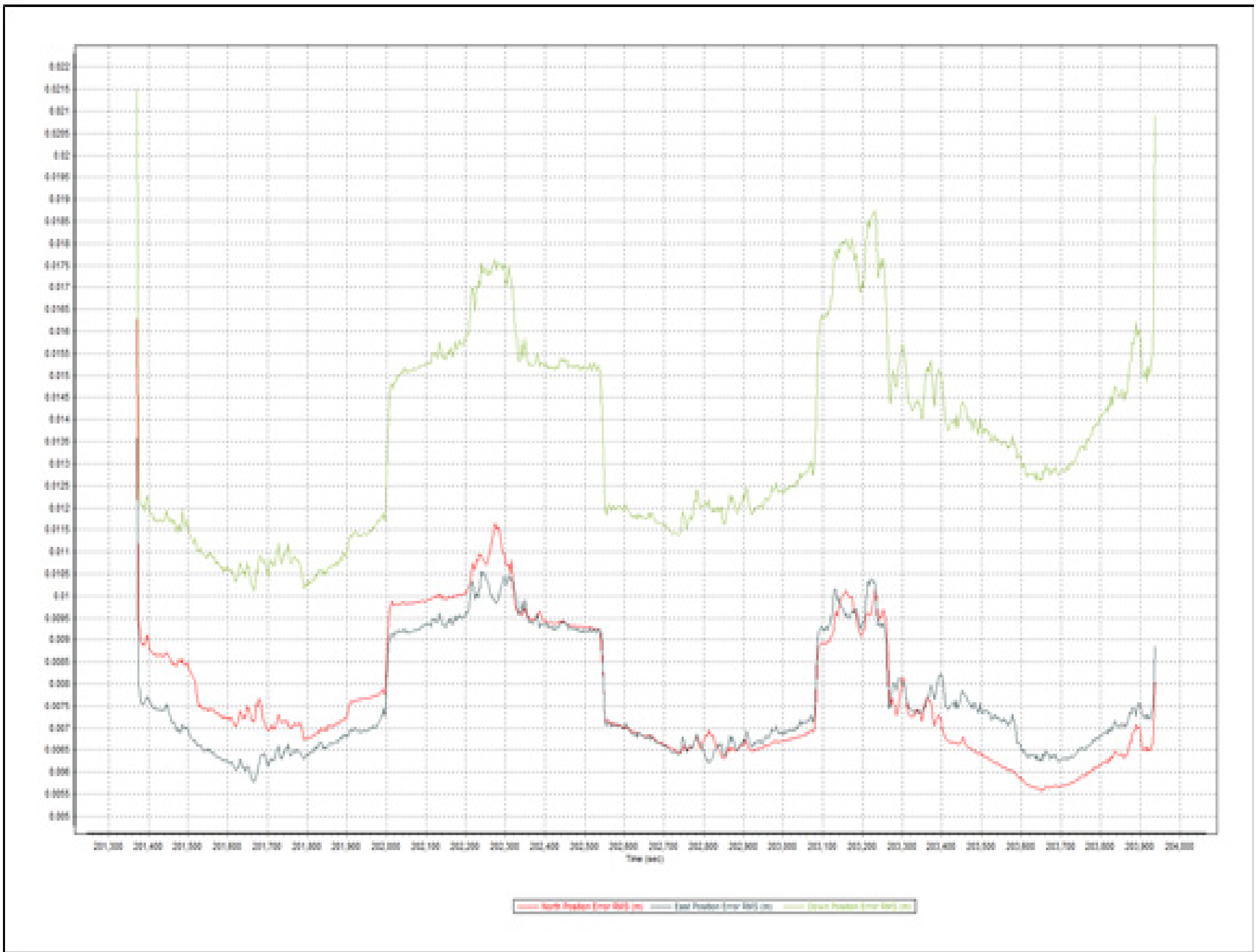


Annex 8.

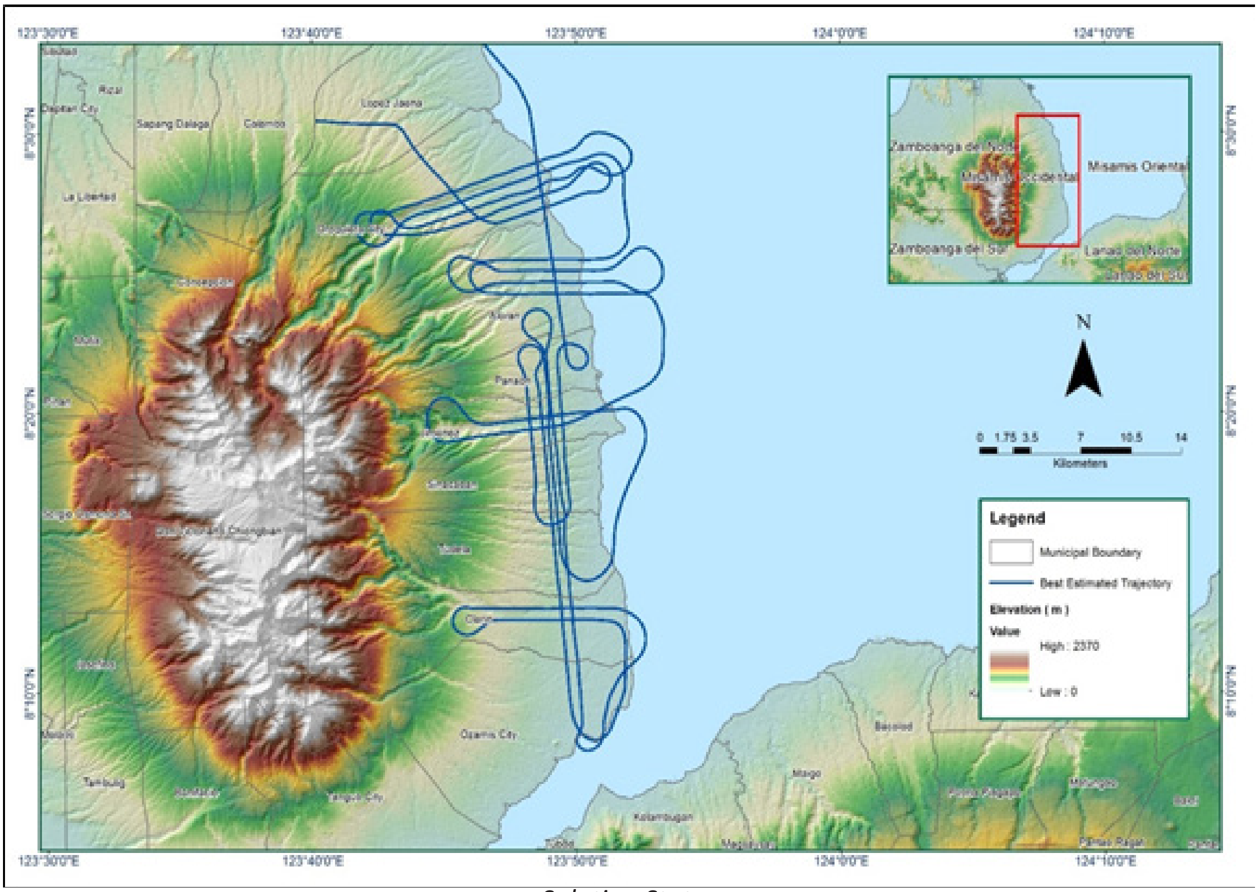
Flight Area	Dipolog
Mission Name	Blk69F
Inclusive Flights	2133P,2135P,2181P
Range data size	43.4 GB
POS	501.6 MB
Image	79.8 GB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.04
RMSE for Down Position (<8.0 cm)	1.85
Boresight correction stdev (<0.001deg)	0.000253
IMU attitude correction stdev (<0.001deg)	0.001628
GPS position stdev (<0.01m)	0.0059
Minimum % overlap (>25)	46.32%
Ave point cloud density per sq.m. (>2.0)	4.58
Number of 1km x 1km blocks	308
Maximum Height	420.83 m
Minimum Height	53.91 m
Classification (# of points)	
Ground	252,809,434
Low vegetation	288,314,909
Medium vegetation	302,935,924
High vegetation	361,519,536
Building	32,102,903
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Tox Salvacion, Engr. Jovy Narisma



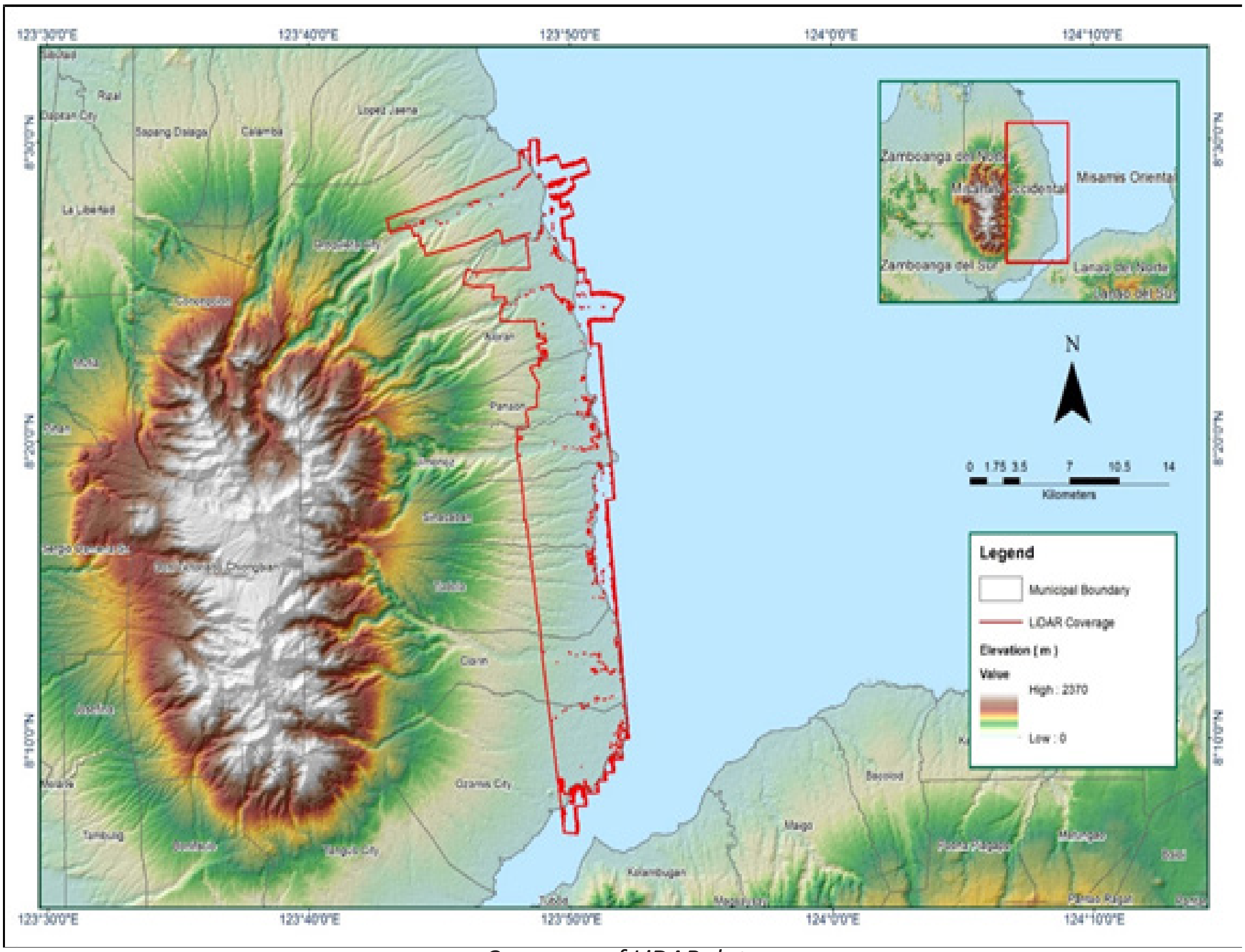
Solution Status



Smoothed Performance Metric Parameters



Solution Status



Coverage of LiDAR data

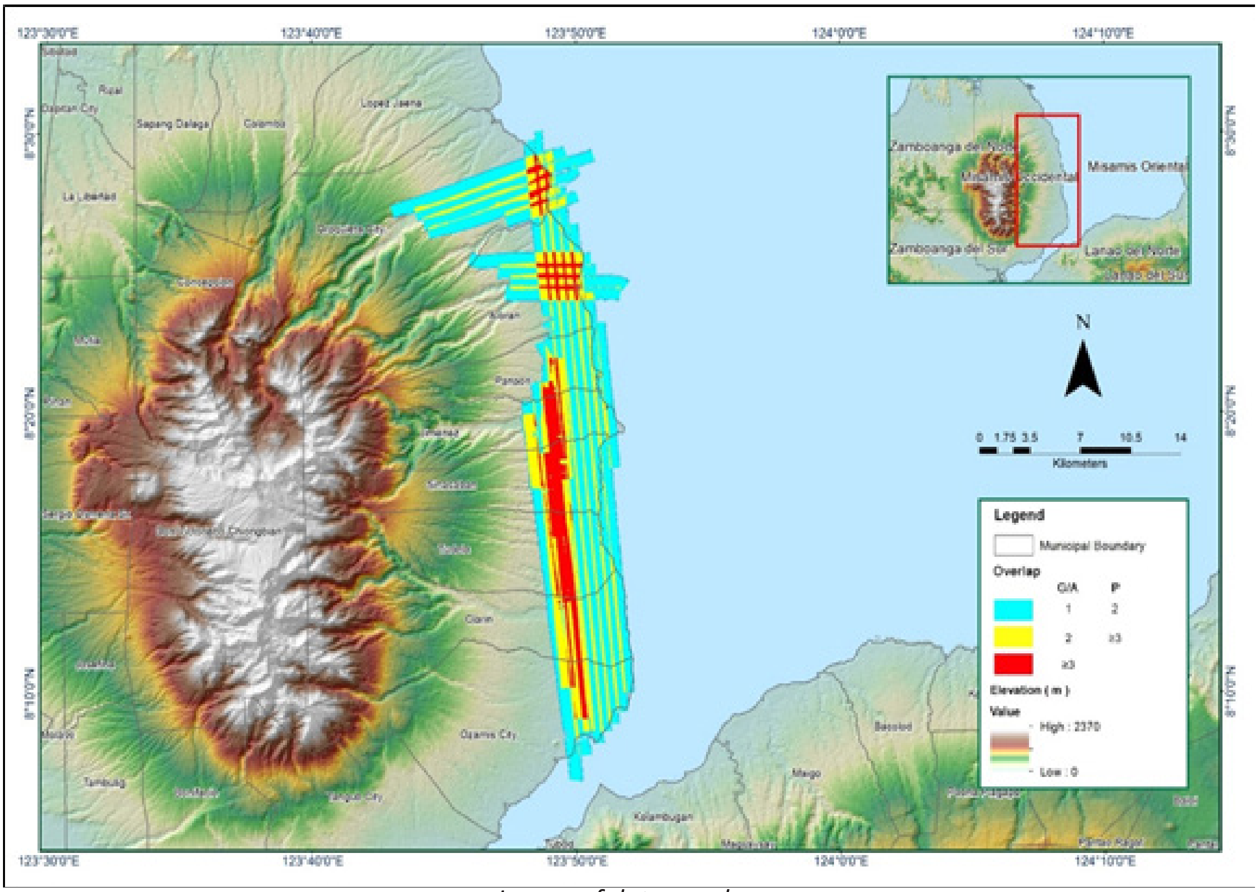
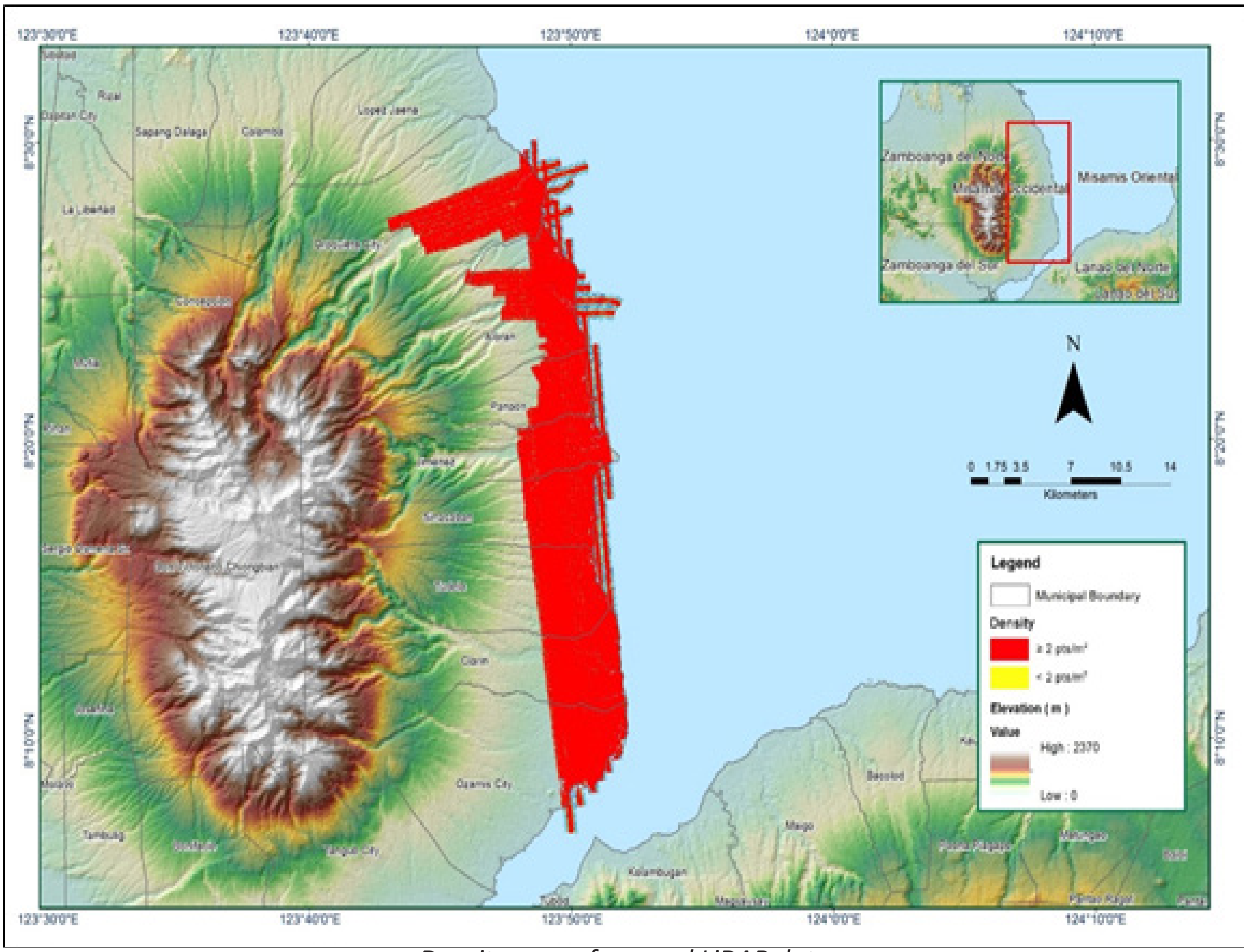
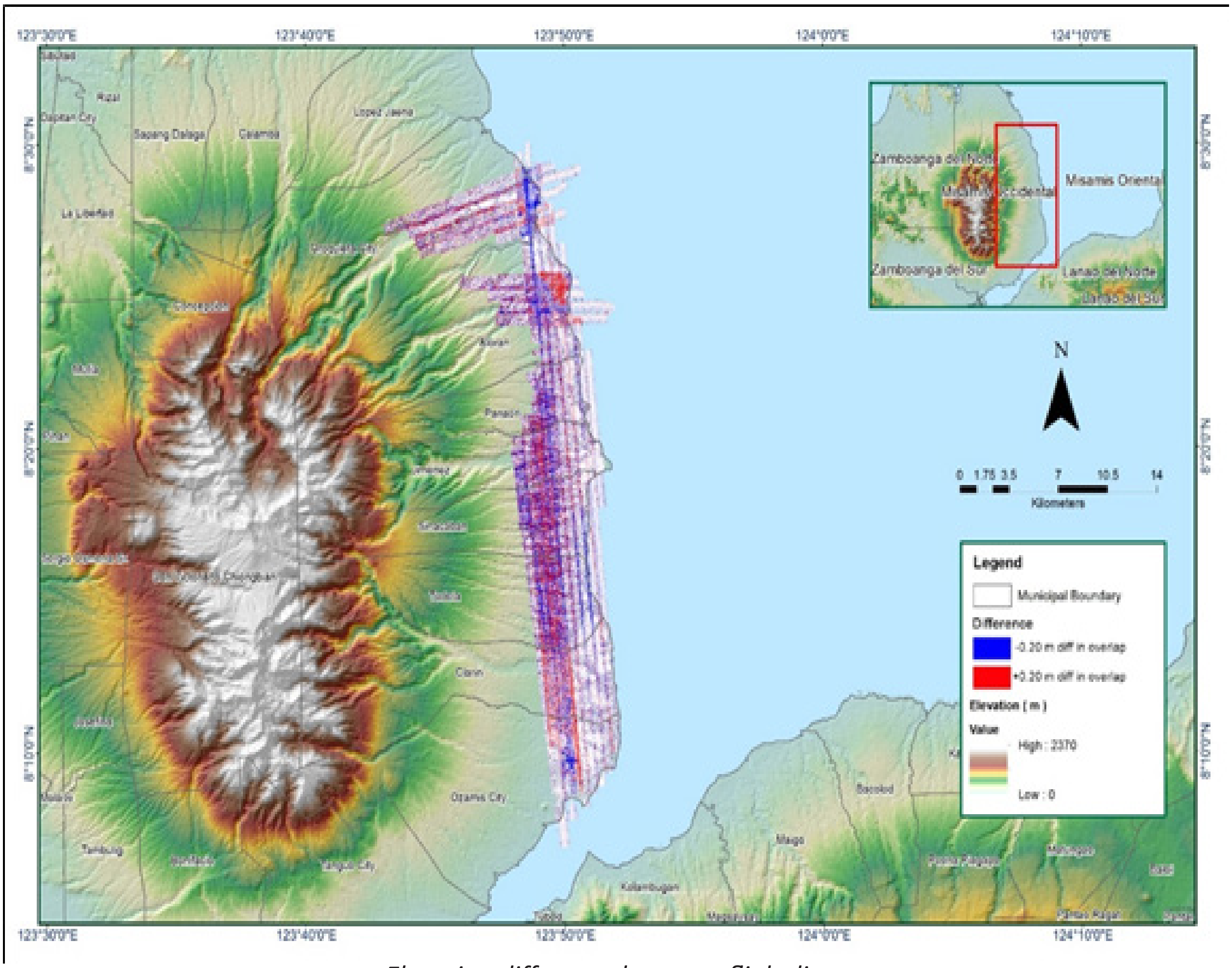


Image of data overlap

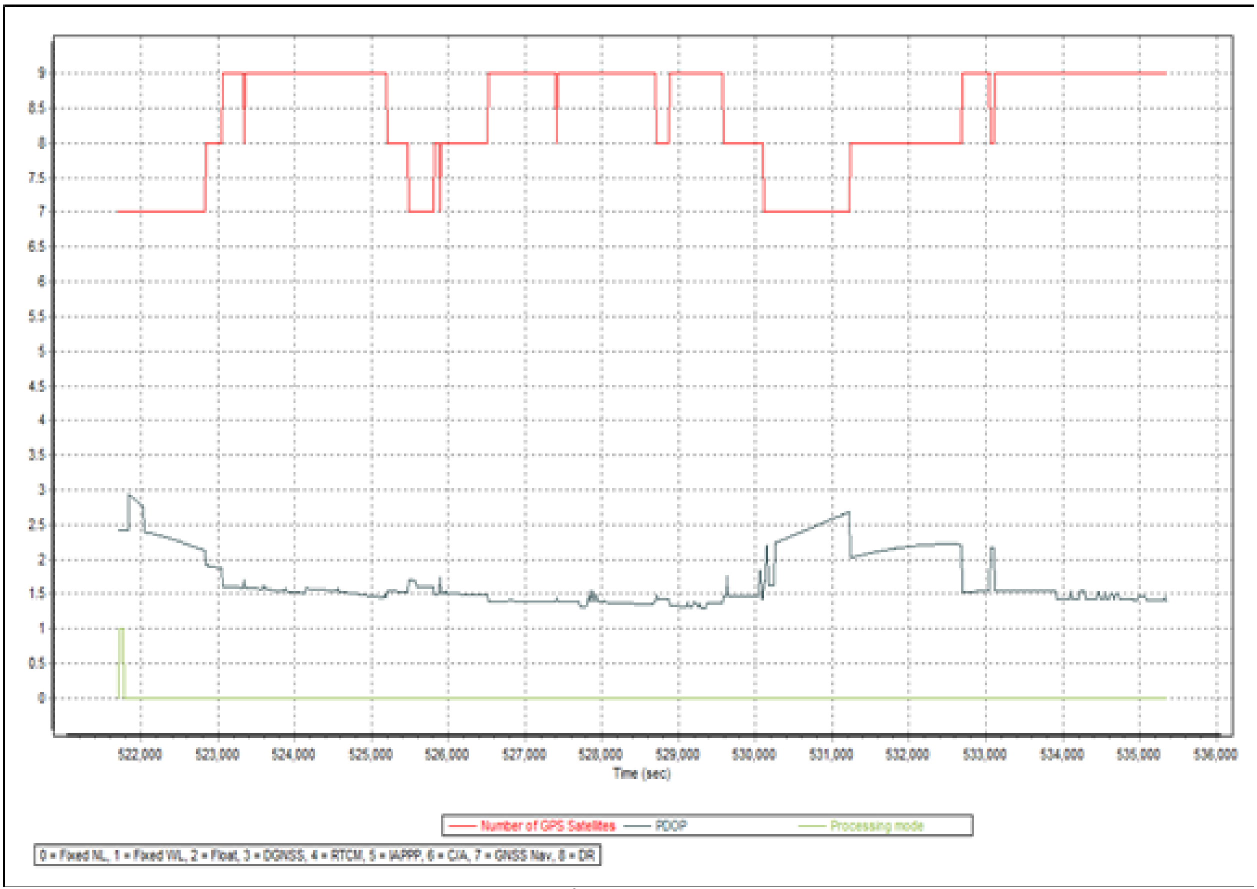


Density map of merged LiDAR data

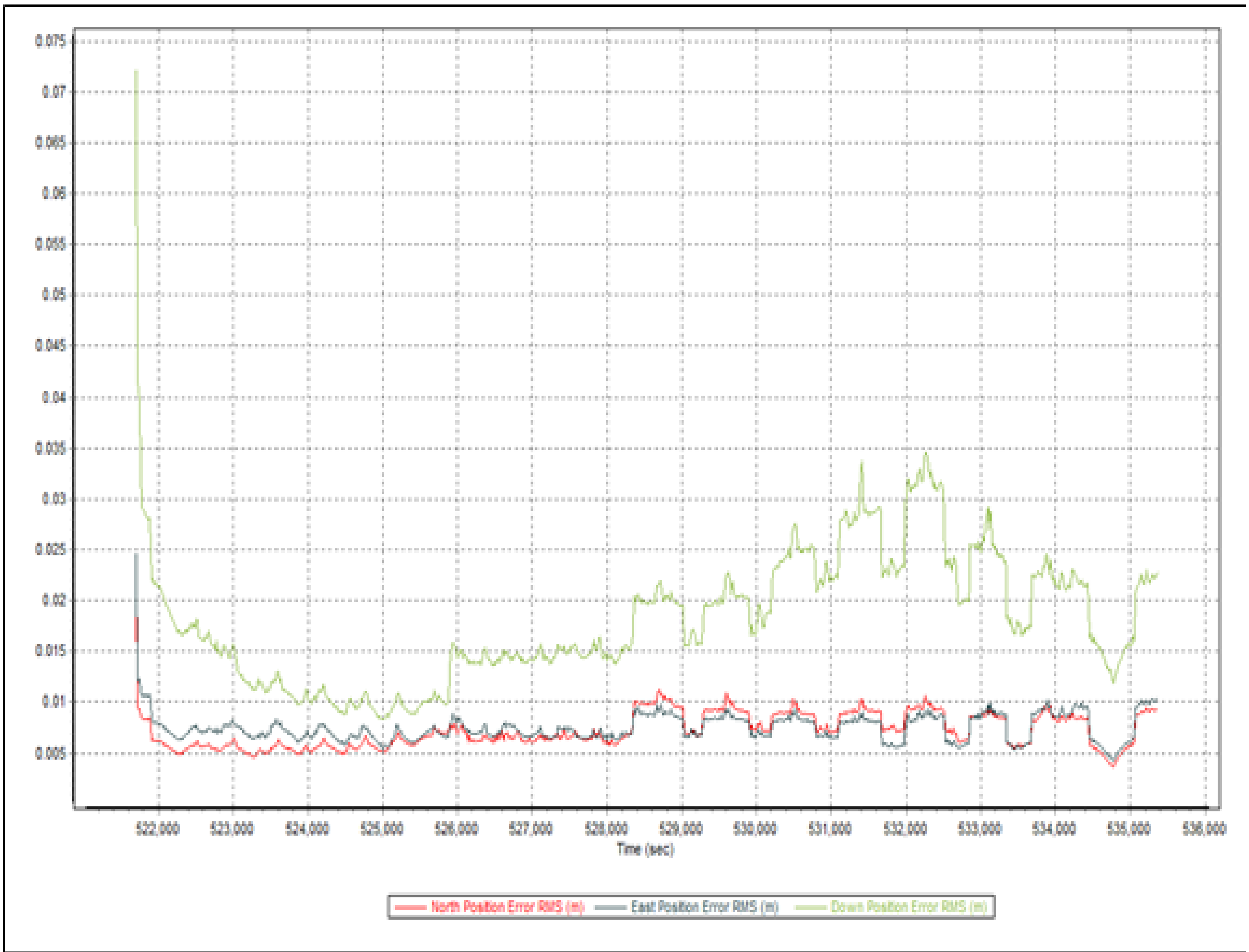


Elevation difference between flight lines

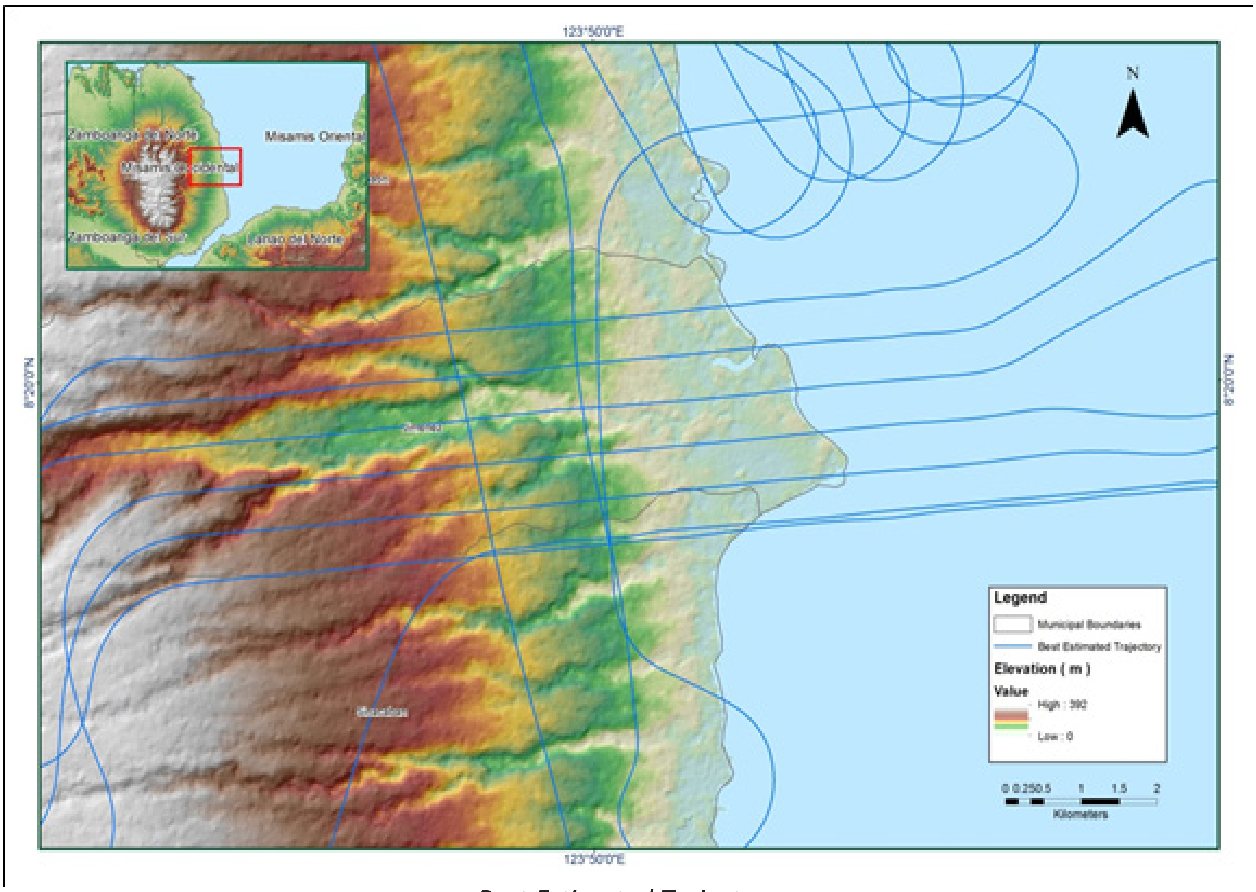
Flight Area	Dipolog
Mission Name	**76P_Additional**
Inclusive Flights	23116P
Range data size	24.4
POS data size	294
Base data size	63.8
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000323
IMU attitude correction stdev (<0.001deg)	0.000306
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	38.20
Ave point cloud density per sq.m. (>2.0)	4.16
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	367.21 m
Minimum Height	59.70 m
Classification (# of points)	
Ground	50,436,324
Low vegetation	41,279,846
Medium vegetation	43,785,029
High vegetation	144,399,584
Building	4,149,832
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Merven Natino, Engr. Denise Bueno



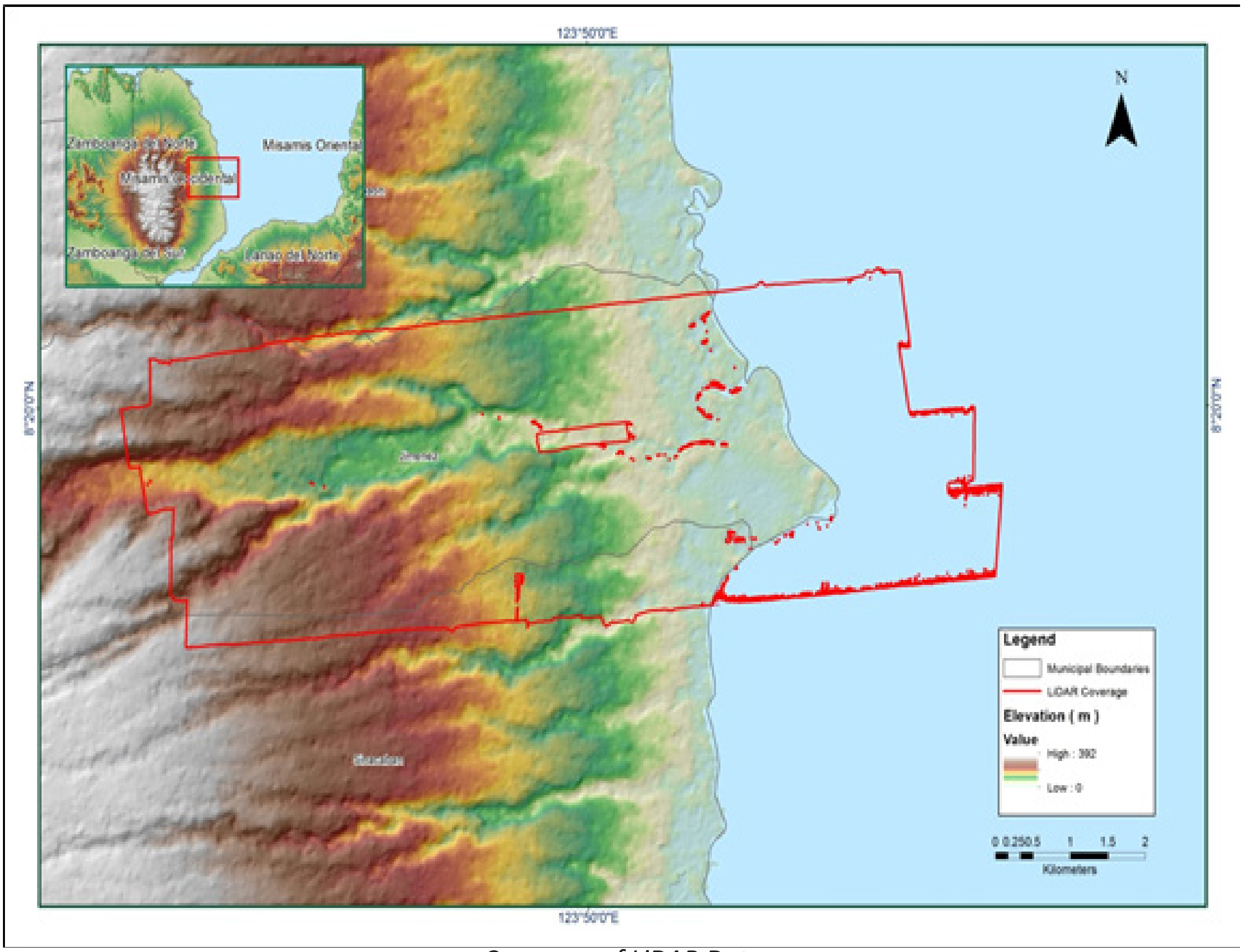
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR Data

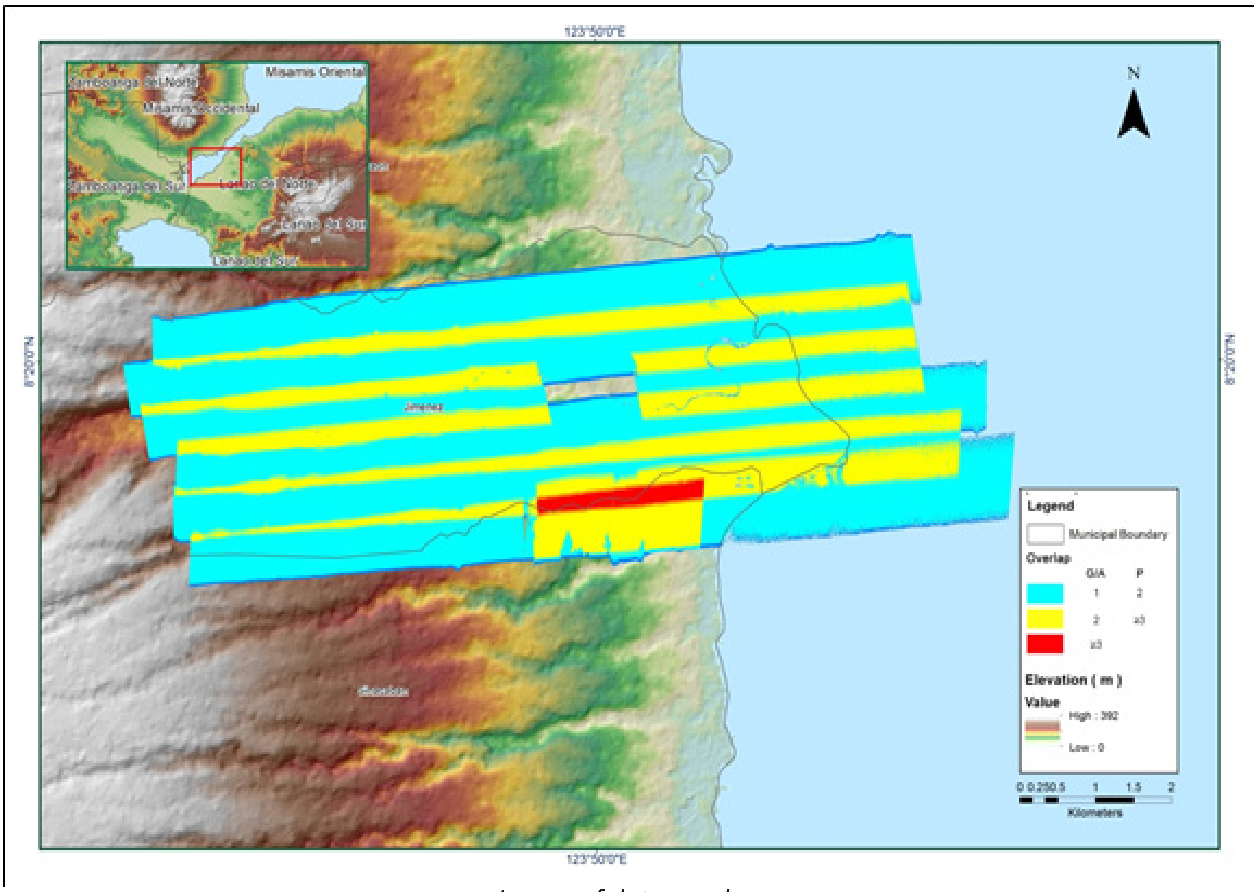
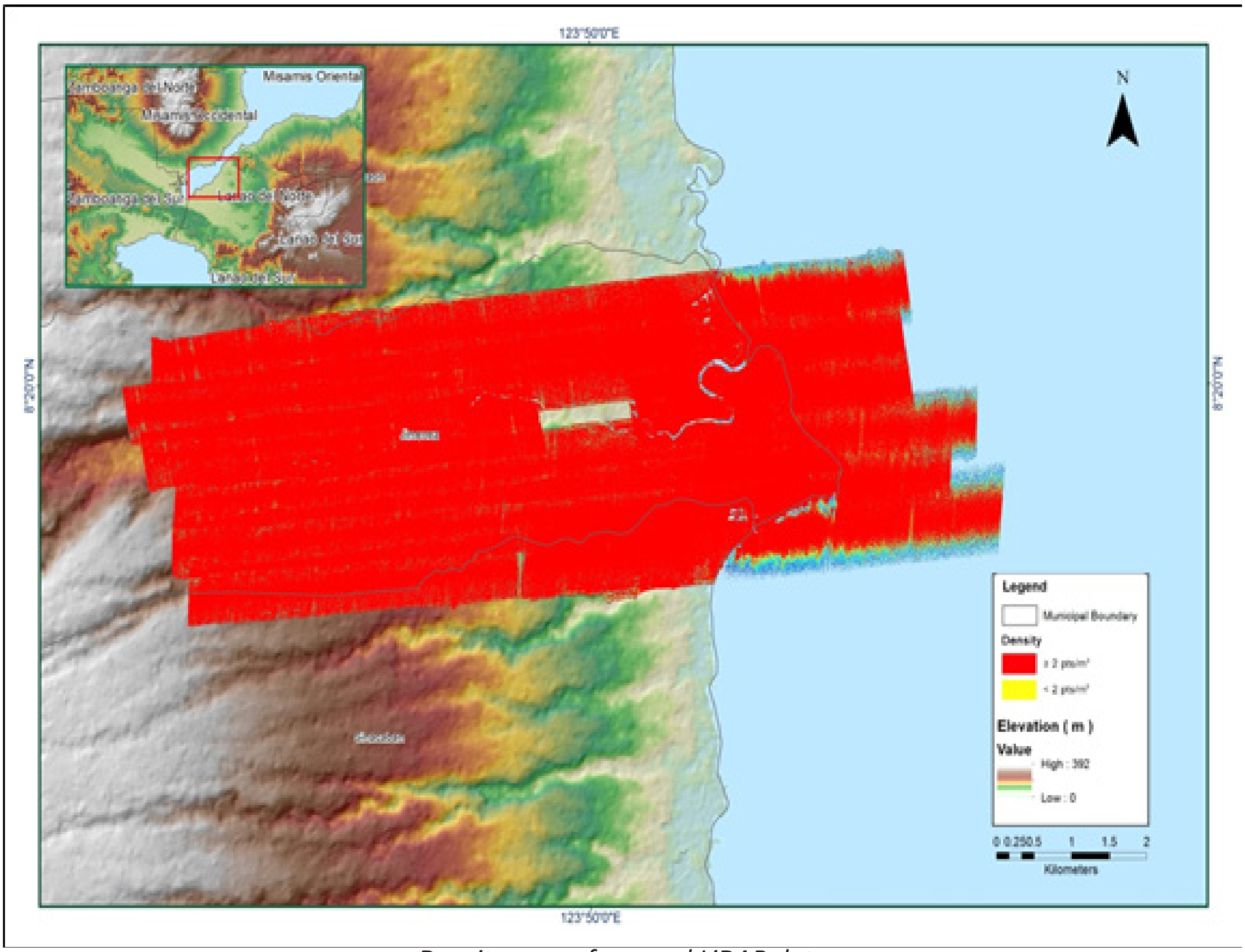
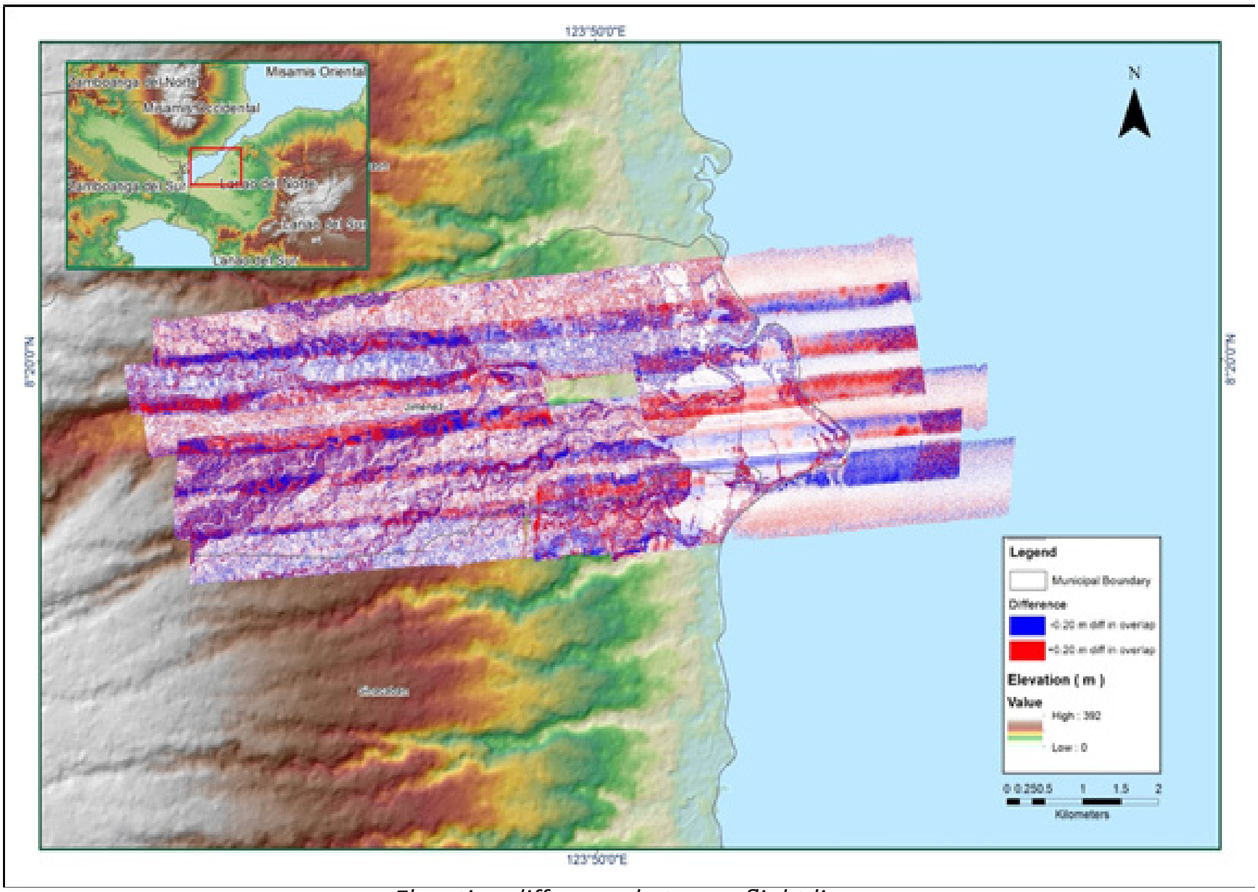


Image of data overlap



Density map of merged LiDAR data



Elevation difference between flight lines

Annex 9. Palilan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W360	74.477	58.888	0.0	0.219528	1.8294	Discharge	0.18261	1	Ratio to Peak	0.5
W370	105.8087959	50.205	0.0	0.33860	2.8216	Discharge	0.36205	1	Ratio to Peak	0.5
W390	74.493	58.8828125	0.0	0.243162	2.0263	Discharge	0.26621	1	Ratio to Peak	0.5
W400	79.381	57.336	0.0	0.35244	2.937	Discharge	0.55883	1	Ratio to Peak	0.5
W410	29.045	78.600	0.0	0.80975	4.5087	Discharge	0.55538	1	Ratio to Peak	0.5
W420	28.9347666	78.664	0.0	0.80726	3.0173	Discharge	0.16329	1	Ratio to Peak	0.5
W430	102.5703236	50.982	0.0	0.23562	1.9635	Discharge	0.14813	1	Ratio to Peak	0.5
W440	22.217	82.764	0.0	0.40649	3.4788	Discharge	0.20853	1	Ratio to Peak	0.5
W450	70.7149482	60.137	0.0	0.32393	2.6994	Discharge	0.24014	1	Ratio to Peak	0.5
W460	96.679	52.459	0.0	0.35612	3.1117	Discharge	0.37705	1	Ratio to Peak	0.5
W480	28.175	79.107	0.0	0.205848	3.0454	Discharge	0.48035	1	Ratio to Peak	0.5
W500	39.489	72.984	0.0	0.247221	2.3609	Discharge	0.19822	1	Ratio to Peak	0.5
W510	35.792	74.878	0.0	0.369054	3.2446	Discharge	0.30788	1	Ratio to Peak	0.5
W520	32.413	76.697	0.0	0.34803	3.1145	Discharge	0.45491	1	Ratio to Peak	0.5
W530	39.403	73.027	0.0	0.247311	3.8378	Discharge	0.23857	1	Ratio to Peak	0.5
W540	92.465	53.569	0.0	0.282114	2.3510	Discharge	0.23035	1	Ratio to Peak	0.5
W560	46.429	69.676	0.0	0.261423	1.5768	Discharge	0.22485	1	Ratio to Peak	0.5
W580	38.348	73.558	0.0	0.195633	4.0452	Discharge	0.16057	1	Ratio to Peak	0.5
W590	39.433	73.012	0.0	0.149643	4.1153	Discharge	0.24178	1	Ratio to Peak	0.5
W600	87.552	54.924	0.0	0.235764	1.9647	Discharge	0.17616	1	Ratio to Peak	0.5
W610	84.144	55.905	0.0	0.291024	2.4252	Discharge	0.21333	1	Ratio to Peak	0.5
W620	75.819	58.455	0.0	0.60408	5.0340	Discharge	1.0441	1	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W630	79.300	57.361	0.0	0.26145	2.1787	Discharge	0.30747	1	Ratio to Peak	0.5
W640	53.939	66.418	0.0	0.163413	1.3618	Discharge	0.11125	1	Ratio to Peak	0.5
W650	96.226	52.576	0.0	0.252684	2.1057	Discharge	0.23071	1	Ratio to Peak	0.5
W660	39.4569863	73	0.0	0.237267	3.6969	Discharge	0.20275	1	Ratio to Peak	0.5
W670	39.734	72.862	0.0	0.138051	3.0703	Discharge	0.17883	1	Ratio to Peak	0.5
W690	80.926	56.864	0.0	0.165798	1.3817	Discharge	0.15661	1	Ratio to Peak	0.5
W700	71.942	59.724	0.0	0.137736	1.1478	Discharge	0.15333	1	Ratio to Peak	0.5

Annex 10. Palilan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	4502.3	0.0192172	0.035	Trapezoid	24.376	1
R110	Automatic Fixed Interval	481.42	0.0415817	0.035	Trapezoid	19.2	1
R120	Automatic Fixed Interval	2999.4	0.0177763	0.035	Trapezoid	11.678	1
R140	Automatic Fixed Interval	3141.8	0.0527399	0.035	Trapezoid	13.24	1
R150	Automatic Fixed Interval	1885.1	0.0230866	0.035	Trapezoid	13.028	1
R160	Automatic Fixed Interval	526.98	0.0372396	0.035	Trapezoid	11.958	1
R170	Automatic Fixed Interval	1230.2	0.0442936	0.035	Trapezoid	5.716	1
R20	Automatic Fixed Interval	604.26	0.0949947	0.035	Trapezoid	7.35	1
R200	Automatic Fixed Interval	1150.8	0.0825369	0.035	Trapezoid	12.354	1
R230	Automatic Fixed Interval	1123.3	0.0408834	0.035	Trapezoid	11.66	1
R260	Automatic Fixed Interval	1646.1	0.0747873	0.035	Trapezoid	8.406	1
R270	Automatic Fixed Interval	6278.3	0.0415769	0.035	Trapezoid	9.514	1
R290	Automatic Fixed Interval	933.26	0.13163	0.035	Trapezoid	9.75	1
R350	Automatic Fixed Interval	8462.8	0.0805179	0.035	Trapezoid	10.58	1
R60	Automatic Fixed Interval	3655.3	0.0682570	0.035	Trapezoid	8.97	1
R70	Automatic Fixed Interval	1831.8	0.21043	0.035	Trapezoid	19.172	1
R80	Automatic Fixed Interval	1616.8	0.0101332	0.035	Trapezoid	25.72	1

Annex 11. Palilan Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	8.337105	123.8235697	0.03	0	-0.03		5-Year
2	8.337646	123.8212737	0.23	0.2	-0.03	2016	5-Year
3	8.337576	123.8204926	0.26	0.37	0.11	1991	5-Year
4	8.336807	123.824153	0.03	0	-0.03		5-Year
5	8.336648	123.8249354	0.03	0	-0.03		5-Year
6	8.336287	123.8247875	0.03	0	-0.03		5-Year
7	8.336855	123.8224973	0.06	0	-0.06		5-Year
8	8.336096	123.8247514	0.03	0	-0.03		5-Year
9	8.336613	123.8272199	0.03	0	-0.03		5-Year
10	8.335916	123.8324204	0.27	0.34	0.07	2016	5-Year
11	8.337521	123.8258363	0.05	0	-0.05		5-Year
12	8.33555	123.831733	0.24	0	-0.24		5-Year
13	8.336292	123.8323229	0.05	0	-0.05		5-Year
14	8.336294	123.8275246	0.2	0	-0.2		5-Year
15	8.336586	123.8255099	0.03	0	-0.03		5-Year
16	8.336327	123.8254851	0.03	0.23	0.2	2016	5-Year
17	8.336413	123.8262345	0.03	0	-0.03		5-Year
18	8.33641	123.8268216	0.03	0	-0.03		5-Year
19	8.335873	123.8270168	0.03	0	-0.03		5-Year
20	8.336531	123.8256614	0.05	0	-0.05		5-Year
21	8.33598	123.825311	0.09	0.18	0.09	2008	5-Year
22	8.336246	123.8273116	0.12	0	-0.12		5-Year
23	8.335866	123.8287518	0.03	0	-0.03		5-Year
24	8.335145	123.8342811	0.03	0	-0.03		5-Year
25	8.338812	123.8418151	0.03	0	-0.03		5-Year
26	8.335943	123.8385515	0.03	0	-0.03		5-Year
27	8.339297	123.8403125	0.06	0	-0.06		5-Year
28	8.337537	123.8410588	0.08	0	-0.08		5-Year
29	8.335898	123.8416872	0.12	0	-0.12		5-Year
30	8.337427	123.839126	0.03	0	-0.03		5-Year
31	8.335775	123.8397764	0.22	0	-0.22		5-Year
32	8.335993	123.839814	0.23	0	-0.23		5-Year
33	8.339142	123.8399414	0.28	0.2	-0.08		5-Year
34	8.337714	123.8380803	0.23	0	-0.23		5-Year
35	8.338627	123.8388147	0.26	1.34	1.08	Sendong / December 2011	5-Year
36	8.338151	123.8380911	0.26	0.15	-0.11	Sendong / December 2011	5-Year
37	8.337484	123.8418655	0.23	0	-0.23		5-Year
38	8.335005	123.8424042	0.25	0.68	0.43		5-Year
39	8.338729	123.8421176	0.32	0	-0.32		5-Year
40	8.336301	123.8423516	0.03	0	-0.03		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	8.335262	123.8416481	0.16	0	-0.16		5-Year
42	8.336613	123.8406911	0.2	0.1	-0.1	Jun-16	5-Year
43	8.337394	123.8456509	1.87	0	-1.87		5-Year
44	8.337994	123.8452803	1.92	0	-1.92		5-Year
45	8.335123	123.8447057	2.53	0	-2.53		5-Year
46	8.335178	123.845183	2.87	0	-2.87		5-Year
47	8.339012	123.839631	0.58	0.75	0.17		5-Year
48	8.339514	123.8402298	0.59	0	-0.59		5-Year
49	8.338048	123.8383913	0.55	0	-0.55		5-Year
50	8.338722	123.8390837	0.59	0.46	-0.13	1995	5-Year
51	8.33813	123.8389789	0.87	0.54	-0.33	2009	5-Year
52	8.336084	123.843067	0.66	0	-0.66		5-Year
53	8.339522	123.8415063	0.03	0.92	0.89	2014	5-Year
54	8.33572	123.8422284	0.03	0	-0.03		5-Year
55	8.338439	123.8421044	0.03	0	-0.03		5-Year
56	8.336566	123.8427426	0.03	0	-0.03		5-Year
57	8.33509	123.8418359	0.09	0	-0.09		5-Year
58	8.336606	123.8433761	2.44	0	-2.44		5-Year
59	8.333767	123.824902	0.03	0	-0.03		5-Year
60	8.332581	123.8239283	8.98	0	-8.98		5-Year
61	8.332413	123.8234146	11	0	-11		5-Year
62	8.329247	123.8163337	15.1	0	-15.1		5-Year
63	8.330124	123.8169605	15.6	0.69	-14.91	Eliang / December 18, 1985	5-Year
64	8.329449	123.8163975	15.7	0.69	-15.01	Eliang / December 18, 1985	5-Year
65	8.329283	123.815695	15.7	0.9	-14.8	Eliang / December 18, 1985	5-Year
66	8.329337	123.81526	16.1	0	-16.1		5-Year
67	8.329587	123.8148769	16.7	0	-16.7		5-Year
68	8.327914	123.8150682	12.5	0.5	-12	1996	5-Year
69	8.327926	123.8154258	12.6	0.5	-12.1	1996	5-Year
70	8.328129	123.8156631	13.2	0.5	-12.7	1996	5-Year
71	8.328291	123.8161456	13.9	0.5	-13.4	1996	5-Year
72	8.328283	123.8164527	14.2	0.5	-13.7	1996	5-Year
73	8.332546	123.8335022	0.03	0	-0.03		5-Year
74	8.332109	123.8344204	0.03	0	-0.03		5-Year
75	8.332204	123.8365039	0.06	0	-0.06		5-Year
76	8.332672	123.8312753	0.07	0	-0.07		5-Year
77	8.333741	123.8300122	0.3	0.21	-0.09		5-Year
78	8.333752	123.8304661	0.35	0	-0.35		5-Year
79	8.332502	123.8369984	0.21	0	-0.21		5-Year
80	8.332466	123.836219	0.21	0.18	-0.03		5-Year
81	8.332838	123.8366014	0.22	1.02	0.8	2009	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	8.333202	123.835779	0.25	1.1	0.85	2010	5-Year
83	8.332099	123.8374069	0.22	0	-0.22		5-Year
84	8.332001	123.8348158	0.03	0	-0.03		5-Year
85	8.332756	123.8375834	0.11	0	-0.11		5-Year
86	8.333816	123.8317617	0.17	0.2	0.03		5-Year
87	8.332964	123.8356091	0.55	0.44	-0.11	2010	5-Year
88	8.332897	123.8366272	0.6	0.82	0.22	2009	5-Year
89	8.33136	123.8359539	0.7	0	-0.7		5-Year
90	8.331857	123.8338921	0.03	0	-0.03		5-Year
91	8.332005	123.835304	0.03	0	-0.03		5-Year
92	8.332133	123.8372941	0.04	0	-0.04		5-Year
93	8.332033	123.8367223	0.05	0	-0.05		5-Year
94	8.333719	123.8303226	0.43	0	-0.43		5-Year
95	8.333957	123.8317593	0.38	0	-0.38		5-Year
96	8.333337	123.8339573	0.45	0	-0.45		5-Year
97	8.33125	123.8357496	1.26	0	-1.26		5-Year
98	8.33186	123.8342985	0.03	0	-0.03		5-Year
99	8.333973	123.8278225	0.03	0	-0.03		5-Year
100	8.333682	123.8266937	0.05	0	-0.05		5-Year
101	8.33124	123.8364156	5.05	0.25	-4.8		5-Year
102	8.331022	123.8361742	5.55	0.27	-5.28	December 2015	5-Year
103	8.330898	123.8365396	6.16	0.27	-5.89	December 2015	5-Year
104	8.330778	123.8359996	6.25	0	-6.25		5-Year
105	8.330228	123.8359196	7.04	0	-7.04		5-Year
106			7.78	0	-7.78		5-Year
107	8.334448	123.8363015	0.04	0	-0.04		5-Year
108	8.332932	123.8435584	0.31	0	-0.31		5-Year
109	8.33265	123.8435584	0.39	0	-0.39		5-Year
110	8.333647	123.8414998	0.03	0	-0.03		5-Year
111	8.333099	123.8435316	0.7	0	-0.7		5-Year
112	8.333304	123.8423038	0.77	0	-0.77		5-Year
113	8.333357	123.8431345	0.92	0	-0.92		5-Year
114	8.332863	123.8428075	1.18	0.55	-0.63	1981	5-Year
115	8.333569	123.8441145	2.8	0	-2.8		5-Year
116	8.333403	123.8452186	3.21	0	-3.21		5-Year
117	8.33361	123.8447642	3.22	0	-3.22		5-Year
118	8.333218	123.8446684	3.49	0	-3.49		5-Year
119	8.333891	123.8425999	0.77	0.15	-0.62		5-Year
120	8.332963	123.8439965	0.94	0	-0.94		5-Year
121	8.332318	123.8424648	1	0	-1		5-Year
122	8.333404	123.8414824	0.08	0	-0.08		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
123	8.333512	123.843618	1.1	0	-1.1		5-Year
124	8.332664	123.8432992	1.2	0	-1.2		5-Year
125	8.332761	123.8427896	1.3	0.55	-0.75	1981	5-Year
126	8.332972	123.8440444	1.86	0	-1.86		5-Year
127	8.332644	123.8438732	1.9	0	-1.9		5-Year
128	8.333688	123.8441046	2.81	0	-2.81		5-Year
129	8.333375	123.8416761	0.03	0	-0.03		5-Year
130	8.332848	123.8422004	0.52	0	-0.52		5-Year
131	8.332701	123.8439287	1.79	0	-1.79		5-Year
132	8.333323	123.8452855	3.43	0	-3.43		5-Year
133	8.332766	123.8447698	3.64	0	-3.64		5-Year
134	8.331985	123.8445296	4.85	0	-4.85		5-Year
135	8.332164	123.8429567	2.25	0	-2.25		5-Year
136	8.334181	123.8462818	3.92	0	-3.92		5-Year
137	8.334705	123.8409732	0.03	0	-0.03		5-Year
138	8.334493	123.8382269	0.09	0	-0.09		5-Year
139	8.332512	123.8433286	1.01	0	-1.01		5-Year
140	8.334209	123.8447549	3.57	0.29	-3.28	2016	5-Year
141	8.3385	123.8385914	0.19	0	-0.19		5-Year
142	8.338428	123.8390488	0.93	0.4	-0.53		5-Year
143	8.337859	123.8385048	1.13	1.7	0.57	1985	5-Year
144	8.339835	123.8403641	1.49	0.1	-1.39	2010	5-Year
145	8.336404	123.8434645	1.56	0	-1.56		5-Year
146	8.335064	123.8429028	1.68	0	-1.68		5-Year
147	8.336677	123.8425939	0.03	0	-0.03		5-Year
148	8.335466	123.8419176	0.18	0	-0.18		5-Year
149	8.335703	123.8431932	1.07	0	-1.07		5-Year
150	8.336278	123.8432027	1.86	0	-1.86		5-Year
151	8.335245	123.8433411	2.04	0	-2.04		5-Year
152	8.338669	123.838687	0.03	0	-0.03		5-Year
153	8.338729	123.8380763	0.03	0	-0.03		5-Year
154	8.337745	123.8389259	0.04	0	-0.04		5-Year
155	8.33852	123.8411872	0.03	0	-0.03		5-Year
156	8.336855	123.8406349	0.04	0	-0.04		5-Year
157	8.338052	123.8460167	2.64	0.7	-1.94	Sendong / December 2011	5-Year
158	8.342078	123.840898	0.03	0	-0.03		5-Year
159	8.340204	123.8396729	0.03	0	-0.03		5-Year
160	8.339557	123.8387971	0.03	0	-0.03		5-Year
161	8.340964	123.8378072	0.03	0	-0.03		5-Year
162	8.340125	123.8378281	0.06	0	-0.06		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
164	8.341151	123.8408331	0.22	0	-0.22		5-Year
165	8.340853	123.8397317	0.23	0	-0.23		5-Year
166	8.342152	123.8400935	0.29	0	-0.29		5-Year
167	8.343487	123.8407266	0.26	10	9.74	Sendong / December 2011	5-Year
168	8.3407	123.843494	0.3	0	-0.3		5-Year
169	8.34173	123.8427123	0.03	0	-0.03		5-Year
170	8.336913	123.8439148	2.01	0	-2.01		5-Year
171	8.336154	123.8450495	2.09	0	-2.09		5-Year
172	8.336488	123.8532993	0.3	0	-0.3		5-Year
173	8.337425	123.8540723	0.45	0	-0.45		5-Year
174	8.337132	123.8542264	0.8	0	-0.8		5-Year
175	8.336871	123.8546611	0.96	0.35	-0.61	December 2015	5-Year
176	8.336963	123.8544813	1.15	0.15	-1	December 2015	5-Year
177	8.337173	123.8548471	1.04	0.47	-0.57	December 2015	5-Year
178	8.335577	123.8565333	1.08	0	-1.08		5-Year
179	8.336725	123.854907	1.13	0	-1.13		5-Year
180	8.326148	123.8228898	0.03	0	-0.03		5-Year
181	8.324917	123.8186489	0.03	0	-0.03		5-Year
182	8.327211	123.8241243	0.54	0	-0.54		5-Year
183	8.324742	123.8260521	0.03	0	-0.03		5-Year
184	8.327576	123.8263676	0.03	0	-0.03		5-Year
185	8.325159	123.8287414	0.03	0	-0.03		5-Year
186	8.330938	123.8400545	1.34	0	-1.34		5-Year
187	8.332944	123.8393359	0.05	0	-0.05		5-Year
188	8.333929	123.8487319	2.34	0	-2.34		5-Year
189	8.332637	123.8495927	2.56	0	-2.56		5-Year
190	8.33323	123.8500869	2.82	0	-2.82		5-Year
191	8.330651	123.8399514	5.17	0	-5.17		5-Year
192	8.3303	123.8411564	5.18	0	-5.18		5-Year
193	8.33089	123.8392742	5.21	0	-5.21		5-Year
194	8.330941	123.8426051	5.46	0	-5.46		5-Year
195	8.330081	123.8409412	5.54	0	-5.54		5-Year
196	8.326964	123.8390331	5.41	0.15	-5.26	2007	5-Year
197	8.332204	123.8408914	0.95	0	-0.95		5-Year
198	8.330584	123.8406192	2.82	0	-2.82		5-Year
199	8.333533	123.8470696	3.39	0	-3.39		5-Year
200	8.333339	123.8486097	3.47	0	-3.47		5-Year
201	8.334929	123.8482164	3.7	0.75	-2.95	December 2014	5-Year
202	8.330907	123.8423886	4.32	0	-4.32		5-Year
203	8.328495	123.8430799	4.33	0	-4.33		5-Year
204	8.331213	123.8383938	6.95	0.3	-6.65	October 2006	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
205	8.326109	123.8442324	3.78	0	-3.78		5-Year
206	8.32719	123.8436884	4	0	-4		5-Year
207	8.325503	123.8429775	4.19	0	-4.19		5-Year
208	8.327309	123.8388726	5.21	0	-5.21		5-Year
209	8.326355	123.8326104	0.03	0	-0.03		5-Year
210	8.328228	123.8296165	0.05	0	-0.05		5-Year
211	8.328358	123.8347811	7.64	1	-6.64	March 2004	5-Year
212	8.332576	123.8386386	0.37	0	-0.37		5-Year
213	8.333197	123.838922	0.05	0	-0.05		5-Year
214	8.33328	123.8404199	0.03	0	-0.03		5-Year
215	8.330983	123.8405245	0.51	0	-0.51		5-Year
216	8.332585	123.8400831	0.72	0.3	-0.42	December 2010	5-Year
217	8.333129	123.8392017	0.03	0	-0.03		5-Year
218	8.333175	123.8406373	0.03	0	-0.03		5-Year
219	8.336609	123.8449359	2.12	0	-2.12		5-Year
220	8.336697	123.8445196	2.14	0	-2.14		5-Year
221	8.336014	123.8456454	2.25	0	-2.25		5-Year
222	8.33575	123.8450658	2.25	0	-2.25		5-Year
223	8.335573	123.8447526	3.16	0.6	-2.56	Sendong / December 2011	5-Year
224	8.343906	123.843067	0.81	0.6	-0.21	Sendong / December 2011	5-Year
225	8.336195	123.8470059	0.84	0	-0.84		5-Year
226	8.343199	123.8404161	0.87	0	-0.87		5-Year
227	8.337675	123.8444737	0.87	0	-0.87		5-Year
228	8.340039	123.8437969	0.96	0	-0.96		5-Year
229	8.341184	123.8409781	0.1	0	-0.1		5-Year
230	8.34192	123.8421973	0.24	0	-0.24		5-Year
231	8.335889	123.8441887	2.75	0.25	-2.5	October 2016	5-Year
232	8.335523	123.844674	2.78	0.15	-2.63	September 2016	5-Year
233	8.335759	123.843965	2.81	0	-2.81		5-Year
234	8.335365	123.8442941	3.07	0.17	-2.9	September 2016	5-Year
235	8.341292	123.8430366	1.02	0.4	-0.62	Sendong / December 2011	5-Year
236	8.344252	123.8426213	1.07	0.55	-0.52	Sendong / December 2011	5-Year
237	8.343372	123.8403785	1.7	0.2	-1.5	November 2006	5-Year
238	8.341806	123.8410809	1.11	0	-1.11		5-Year
239	8.336978	123.8438868	1.93	0	-1.93		5-Year
240	8.335665	123.8438677	2.76	0	-2.76		5-Year
241	8.335405	123.847092	3.5	0.42	-3.08	Sendong / December 2011	5-Year
242	8.337303	123.8540326	0.5	0.4	-0.1	December 2015	5-Year
243	8.336577	123.8536482	0.68	0	-0.68		5-Year
244	8.336329	123.8530446	0.84	0	-0.84		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
246	8.336169	123.8537945	1.3	0	-1.3		5-Year
247	8.336321	123.8545458	1.43	0	-1.43		5-Year
248	8.336006	123.8546381	0.93	0	-0.93		5-Year
249	8.331993	123.8568639	0.69	0	-0.69		5-Year
250	8.33478	123.8531387	0.8	0.95	0.15	December 2007	5-Year
251	8.327795	123.858498	0.95	0.95	0	December 2007	5-Year
252	8.330463	123.8574366	0.97	0	-0.97		5-Year
253	8.333192	123.8526422	0.98	0	-0.98		5-Year
254	8.332574	123.8559039	0.99	0	-0.99		5-Year
255	8.328987	123.85807	1	0	-1		5-Year
256	8.333655	123.8567602	1.04	0.45	-0.59	October 2016	5-Year
257	8.334809	123.8566	1.07	0	-1.07		5-Year
258	8.332489	123.8535994	1.06	0	-1.06		5-Year
259	8.332381	123.856577	1.29	0	-1.29		5-Year
260	8.333119	123.8508175	1.61	0	-1.61		5-Year
261	8.330488	123.8563502	1.95	0.5	-1.45	December 2015	5-Year
262	8.332206	123.8550051	1.63	0	-1.63		5-Year
263	8.330075	123.8568256	2.06	0	-2.06		5-Year
264	8.323209	123.8507224	3.45	0.8	-2.65	December 2014	5-Year
265	8.32909	123.8575564	1.24	0	-1.24		5-Year
266	8.330266	123.8569924	1.94	0	-1.94		5-Year
267	8.33023	123.850757	2.21	0	-2.21		5-Year
268	8.326095	123.8504835	2.89	0	-2.89		5-Year
269	8.339591	123.8356182	0.03	0	-0.03		5-Year
270	8.339651	123.8341389	0.05	0	-0.05		5-Year
271	8.336702	123.8364554	0.17	0.3	0.13	October 2016	5-Year
272	8.340561	123.8408245	0.03	0	-0.03		5-Year
273	8.341887	123.838943	0.03	0	-0.03		5-Year

Annex 12. Educational Institutions Affected in Palilan Flood Plain

MISAMIS OCCIDENTAL				
JIMENEZ				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Butuay Elem. School Bu	Butuay		Low	Low
Butuay Elem. School	Butuay			Low
Butuay Elem. School Bui	Butuay	Low	Low	Low
Butuay Elem. School Pri	Butuay			Low
Day Care Center	Butuay			
Mialem Elementary Scho	Carmen	Low	Low	Low
Mialem Elementary Schoo	Carmen			
Nacional Victorious Chri	Dicoloc			
Nacional Christian Minda	Nacional	Low	Low	Low
Nacional The School of S	Nacional			
Nacional UEL Christian A	Nacional	Low	Low	Low
Naga Day Care Center	Naga		Low	
Naga Jimenez Bethel Inst	Naga	Low	Low	Low
Naga Jimenez Bethel Inst	Palilan			
Industrial Arts Building	Rizal			
Kindergarten/Library Pal	Rizal			
Multi-Purpose Bldg Palil	Rizal			
Palilan Day Care Center	Rizal			
Palilan Elem School	Rizal			
Palilan Home Economic Bl	Rizal			
Palilan Petron School	Rizal			
Palilan Principal's Offi	Rizal			
2-storey National Compr	San Isidro			Low
Naga Jimenez Bethel Inst	Santa Cruz		Low	Low
Rizal Day Care Center	Santa Cruz	Low	Low	Medium
Sinara Bajo Day Care Ce	Seti		Low	Low
Sinara Bajo Elem. Schoo	Seti	Low	Low	Low
Carino Gata Elem. Schoo	Sibaroc		Low	Medium
Day Care Center	Sibaroc	Low	Low	Medium
Gata Elem. School HE Bl	Sibaroc			
Gata Elem. School Multi	Sibaroc			
Marcos Type Gata Elem.	Sibaroc			
Type 2 Gata Elem. Schoo	Sibaroc			
Taboo Integrated School	Tabo-O			
Naga Day Care Center	Taraka			
Taraka Day Care Center	Taraka		Low	Low

MISAMIS OCCIDENTAL				
SINACABAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Macabayao Elementary Sch	Cagay-Anon			
Tabo-o Anex Elem. School	Cagay-Anon	High	High	High
Macabayao Elementary Sch	San Vicente			

Annex 13. Medical Institutions Affected in Palilan Flood Plain

MISAMIS OCCIDENTAL				
JIMENEZ				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Mialem Health Center	Carmen	High	High	High
Adianez Pharmacy	Nacional			Medium
Farmacia de los Santos	Nacional			High
Maternity Care Package	Nacional			Low
Uy Medical Clinic	Nacional			Medium
Nacional Jimenez Medicar	Nacional			
Naga Francisca Apao Uy M	Naga	Medium	High	High
Goodlife Pharmacy	Santa Cruz	High	High	High
M.G. Ruano Pharmacy	Santa Cruz	High	High	High
Naga Francisca Apao Uy M	Santa Cruz	Medium	High	High
Rizal Quimbo Dental Clin	Santa Cruz	High	High	High
Rizal Sullano Dental Cli	Santa Cruz	High	High	High
Sinara Bajo Drug Center	Seti			