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

LiDAR Surveys and Flood Mapping of Layawan 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
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MCM	million cubic meters
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 LAYAWAN RIVER

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

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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 river 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 Layawan River Basin

The Layawan (also known as Oroquieta) river basin is located in the province of Misamis Occidental under Region , Philippines. The main river used in delineating the basin is Layawan River which traverses within Oroquieta City, the capital city of the province of Misamis Occidental. Oroquieta City has a very moderate but changing climatic condition where rainfall is at appropriate level to suffice the much needed water for farmers to cultivate farms and grow crops. The topography of Oroquieta consists mostly of lowland plains and wide coastal on its eastern side and rolling to wide highlands and mountains on its western side. It has a number of waterways, the main being the other rivers, small creeks and streams also traverse the area, more common of these are the Tipan, Plinis and Domogo Rivers and Dagalan Creek.

The basin is bounded on the North by the municipality of Lopez Jaena, on the East is the open wide bay of Iligan City, down to the south is its sister town Aloran, facing to the southeast is the municipality of Conception, and then to the northwest is Sapang Dalaga. 26 out of 47 barangays in Oroquieta City are found within the river basin. These barangays are Apil, Bolibol, Buenavista, Buntawan, Canubay, Dolipos Bajo, Lamac Lower, Lamac Upper, Langcangan Lower, Langcangan Proper, Langacangan Upper, Layawan, Loboc Lower, Loboc Upper, Mobod, Pines, Poblacion I, Poblacion II, San Vicente Alto, San Vicente Bajo, Taboc Norte, Taboc Sur, Talairon, Talic, Toliyok and Villaflor. All of these barangays are found within the river basin and are accessible by barangay, city and national roads from the barangay Poblacion 1 and Poblacion 2. The outlet of the basin, where flow measurements were obtained, is located at the barangay Langcangan Upper, Oroquieta City, Misamis Occidental.

The Layawan river basin has an estimated area of 114.2 square kilometres and the floodplain area delineated within the basin has an area of 34.47 square kilometres, which is 30.2% of the whole area of the river basin. A total of 18,275 buildings, 24 bridges, 36 water bodies and 131.59 km road-length were extracted within the floodplain which belongs to the barangays of Oroquieta City flood prone area. The Layawan River Basin covers majority of Municipality of Don Victoriano Chiongbian and Layawan City, and small portion of Municipalities of Aloran, Jimenez and Concepcion in Misamis Occidental. According to DENR RBCO, the basin has catchment area of approximately 108 km2 and an estimated annual runoff of 81 MCM.

The basin's main stem, Layawan River is among the 16 rivers covered by the Mindanao State University - Iligan Institute of Technology in Mindanao. There is a total of 25,085 people living within the immediate vicinity of the river according to the 2015 census conducted by NSO. Its water is used mainly for domestic and agricultural activities. Layawan River was assessed to overflow and contribute in flooding. Thus, the identified barangays along the river namely: Dolipos Bajo, Langcangan Lower, Langcangan Upper, Layawan, Poblacion I, Poblacion II, Taboc Norte, Talairon, Talic, and Villaflor, are listed to be highly susceptible to flooding whenever there are heavy rains and typhoons because of its proximity to the river. (http://www.mgb10.com/geohazard/geobulletin/flood%20and%20landslide.html, 2008). On January 2017, low lying barangays in Layawan City were flooded due to continuous rainfall brought by Low Pressure Area (http://www.ndbcnews.com.ph/news/update-floods-hit-cdo-commercial-district-submerge-cars, 2017).

Typhoon Sendong in year 2011 flooded and caused a lot of casualties in a number of cities and municipalities in Misamis Oriental specifically in Cagayan de Oro and Iigan City. But its neighboring provinces did not escape its rage. Typhoon Sendong inflicted millions of damages in Oroquieta City, Misamis Occidental especially in one of its source of livelihood, fishing. Fishermen of Oroquieta City could not help but restrain themselves from fishing as many dead human bodies were found in the shores of Oroquieta.

A year after Sendong, a much bigger and deadlier typhoon came on the 4th of December. It wrecked and caused havoc on many cities and municipalities in Mindanao including General Santos City, Cagayan de Oro City, Iligan City and Davao (Rappler). Though close to none were reported about Oroquieta City during typhoon Pablo, a number of people residing near the Layawan River also suffered. Residents from barangays Taboc Norte, Taboc Sur, Layawan, Upper Langcangan, Talic and Poblacion II were affected by the said typhoon. Residents near the river especially those who were near the river mouth decided to voluntarily evacuate after they noticed the abrupt rise of the water level. No deaths were reported but there were damages inflicted.

The latest flood incident happened on the 16th of January 2017. The flooding was caused by continuous heavy rainfall. The torrential rain lasted for hours causing the Layawan River to overflow. Due to this, Oroquieta City was declared to be under the state of calamity by Hon. Jason Almonte, Mayor of Oroquieta City. A number of barangays were affected during the rainfall especially the barangays near the Layawan River. Barangay San Vicente Alto was mostly affected by the mentioned flooding as some highways and a bridge connecting San Vicente Alto and Talairon were impassable. Sixteen (16) individuals including a one (1) month old baby were rescued by the Barangay Disaster Risk Reduction Management Council (BDRRMC) of the said barangay. The city being under the State of Calamity was lifted on January 18th of the same year as the rainfall has already subsided and roads were cleaned and passable again (ABS-CBN News).

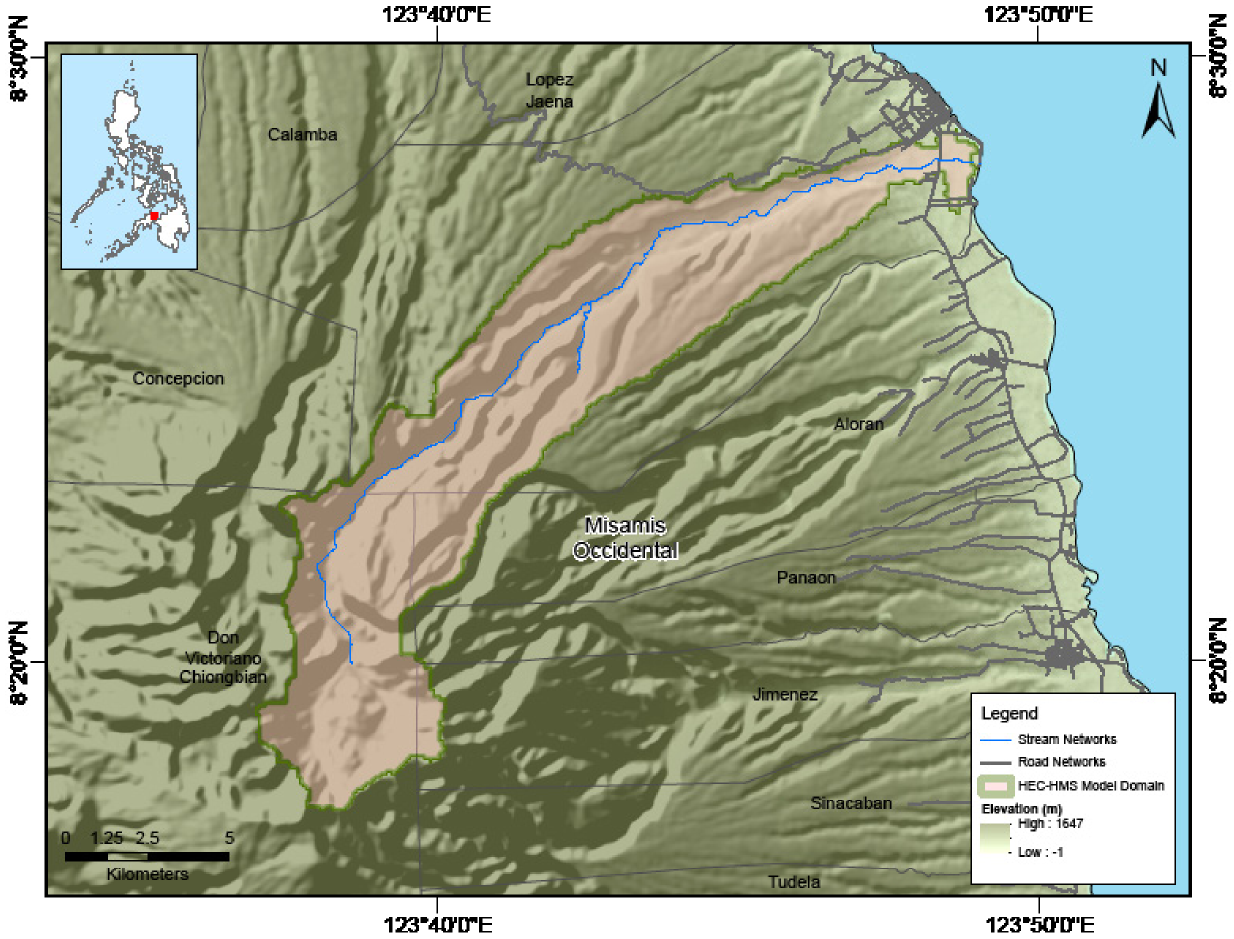

Figure 1. Map of the Layawan (also known as Oroquieta) River Basin

CHAPTER 2: LIDAR ACQUISITION IN LAYAWAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, and 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

Plans were made to acquire LiDAR data within the delineated priority area for Layawan Floodplain in Northern Mindanao. The mission was planned for 16 lines and ran for at most four (4) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plans and base stations for Layawan Floodplain.

Table 1. Flight planning parameters for 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)
BLK76P	1000	30	50	200	30	130	5
BLK76P additional	1000	30	50	200	30	130	5
BLK76O	1000	30	50	200	30	130	5
BLK69E	1000	30	50	200	30	130	5
BLK69F	1100	30	50	200	30	130	5

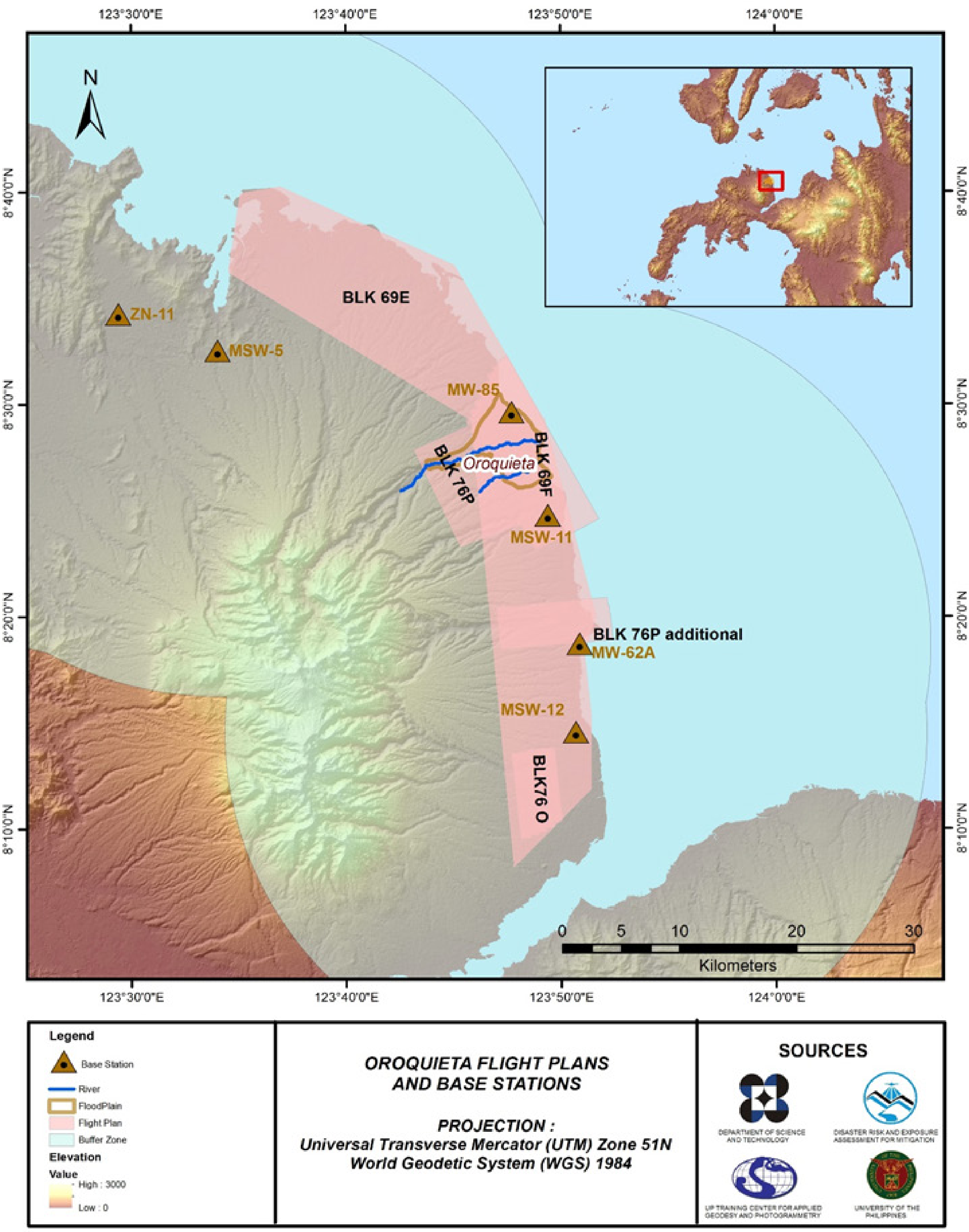

Figure 2. Flight plans and base stations used to cover Layawan (also known as Oroquieta) Floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: MSW-11, MSW-12, and MSW-5 which are of second (2nd) order accuracy. Three (3) NAMRIA benchmarks were recovered: MW-62A, MW-85, and ZN-11. These benchmarks were used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2, while the processing reports for the NAMRIA benchmarks are found in Annex 3. These were used as base stations during the flight operation for the entire duration of the survey (February 4 – March 4, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Layawan floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to 7 show the details about the NAMRIA control points and benchmarks while Table 8 shows the list of all ground control points occupied during the acquisition together with corresponding dates of utilization.

(A)

(B)

Figure 3. GPS set-up over MSW-12 at Brgy. Poblacion, Municipality of Tudela, Misamis Occidenal (a) and NAMRIA reference point MSW-12 (b) as recovered by the field team.

Table 2. 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 in 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 5.69800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	593,072.214 meters 911, 485.567 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 14' 30.02425" North 123° 50' 46.54658" East 71.79800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	593,039.64 meters 911,166.53 meters

(A)

(B)

Figure 4. GPS set-up over MSW-5 at Brgy. Poblacion, Municipality of Sapang Dalaga, Misamis Occidental (a) and NAMRIA reference point MSW-5 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MSW-5 used as base station for the LiDAR Acquisition.

Station Name	**MSW-5**	
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° 32’ 35.68185” North 123° 33’ 56.01853” East 113.481 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	5,622,620.537 meters 9,446,710.948 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 32’ 31.98501” North 123° 34’ 1.42685” East 178.274 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	562,240.75 meters 944,341.30 meters

(A)

(B)

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

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

Station Name	MW-62A	
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°18’43.11445” North 123°50’51.87475” East 73.395 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°18’43.11445” North 123°50’51.87475” East 73.395 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	593351.478 meters 918887.412 meters

(A)

(B)

Figure 6. GPS set-up over ZN-11 at Potungan Bridge, Dapitan, Zamboanga del Norte (a) reference point ZN-11 (b) as established by the field team.

Table 5. Details of the recovered NAMRIA vertical control point ZN- 11 used as base station for the LiDAR Acquisition.on.

Station Name	**ZN-11**	
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°32’19.31150” North 123°29’19.41683” East 21.953 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°32’15.60892” North 123°29’24.82623” East 86.565 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	553,785.501 meters 943,827.025 meters

Table 6. 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	**2rd**	
Relative Error (horizontal positioning)	**1 in 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 4 (PTM Zone 4 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

Table 7. Details of the recovered NAMRIA Benchmark MW-85 used as base station for the LiDAR Acquisition.

Station Name	**MW-85**	
Order of Accuracy (benchmark)	**2nd**	
Elevation (horizontal positioning)	**1:50,000**	
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
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 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	587,366.444 meters 939,034.768 meters

Table 8. . Ground Control points using LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
October 28, 2014	2133P	1BLK69F301A	MSW-11, MW-85
November 9, 2014	2181P	1BLK69F313A	MSW-11, MW-85
February 20, 2016	23116P	1BLK76NO051A	MSW-12, MW-62A
November 22, 2016	23566P	1BLK69E327A	MSW-5, ZN-11

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR Data Acquisition in Layawan Floodplain, for a total of sixteen hours and twelve minutes (16+12) of flying time for RP-C9122. The mission was acquired using the Pegasus LiDAR system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight Missions for LiDAR Data Acquisition in Layawan 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
October 28, 2014	2133P	531.26	137.65	9.41	128.24	826	3	53
November 9, 2014	2181P	201.46	123.05	23.20	99.86	361	3	11
February 20, 2016	23116P	201.46	120.07	27.43	92.65	NA	4	35
November 22, 2016	23566P	138.75	100.26	12.84	87.42	NA	4	29
TOTAL		340.20	220.34	40.27	180.07	1187	16	12

Table 9. Actual Parameters used during LiDAR Data Acquisition

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	110-130	5
2181P	1000	30	50	200	30	110-130	5
23116P	600	30	50	200	30	110-130	5
23566P	800	30	50	200	30	110-130	5

2.4 Survey Coverage

Layawan floodplain is located in the province of Misamis Occidental covering parts of Layawan City and Aloran. The list of municipalities/cities surveyed in these provinces during the LiDAR acquisition is shown in Table 11. In Figure 7, the actual coverage of the LiDAR acquisition for Layawan floodplain is shown.

Table 11. List of municipalities and cities surveyed during Layawan Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Misamis Occidental	Aloran	105.66	57.88	55%
	Layawan City	195.63	75.72	39%
	Jimenez	78.48	25.12	32%
	Clarin	113.99	18.37	16%
	Ozamis City	149.44	13.49	9%
	Sinacaban	70.99	6.11	9%
	Lopez Jaena	90.54	7.34	8%
	Tudela	108.93	3.43	3%
	Panaon	52.52	1	2%
TOTAL		966.18	208.46	21.58%

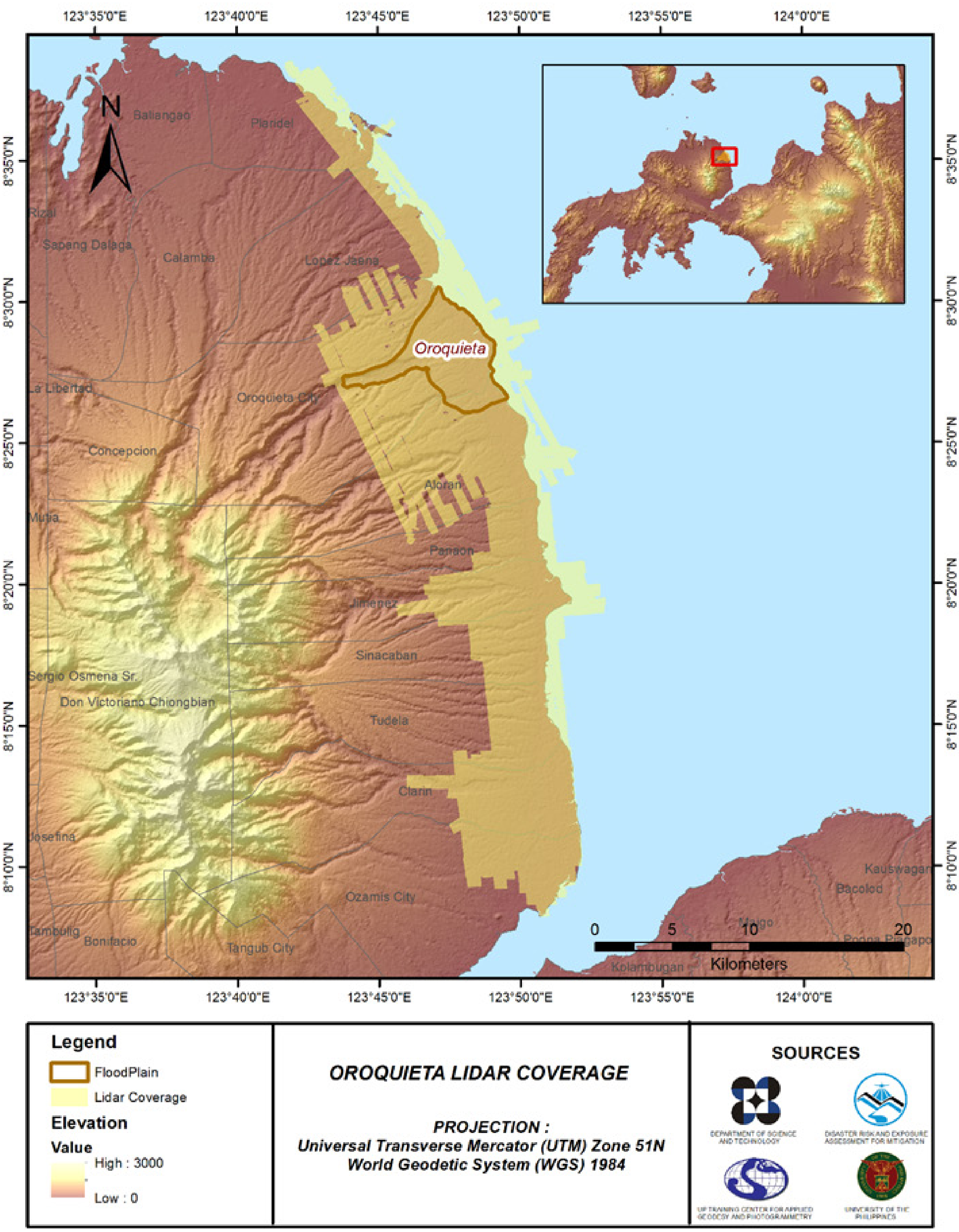

Figure 7. Actual LiDAR data acquisition for Layawan (also known as Oroquieta) Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR LAYAWAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

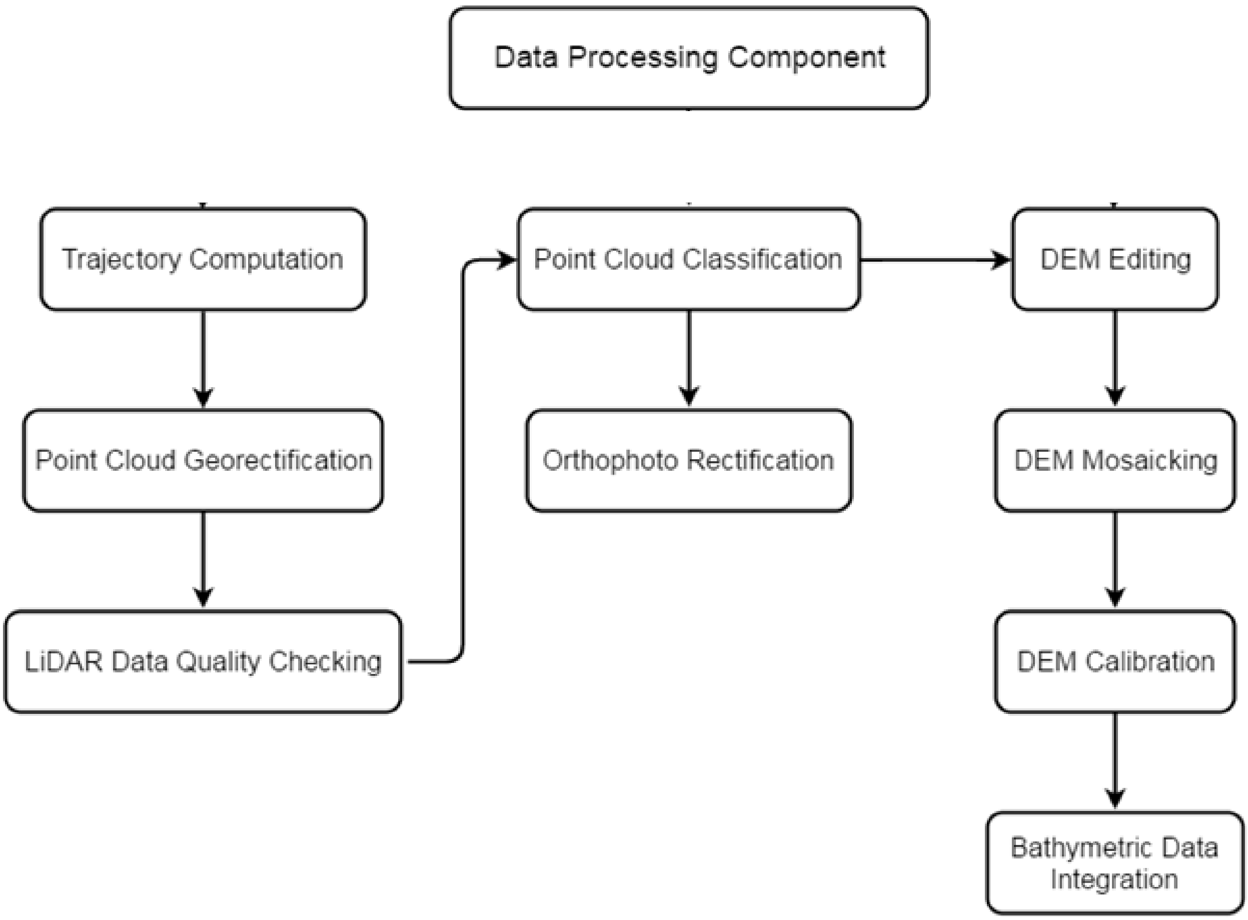

Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Layawan floodplain can be found in Annex 5. Missions flown during the first survey conducted on October 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the following surveys on February and November 2016 were also flown using the Pegasus system over Dipolog and Pagadian. The Data Acquisition Component (DAC) transferred a total of 63 Gigabytes of Range data, 1.06 Gigabytes of POS data, 343.4 Megabytes of GPS base station data, and 79.8 Gigabytes of raw image data to the data server on November 9, 2014 for the first survey. The next two surveys were transferred on February 20 and November 22, 2016, respectively. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Layawan was fully transferred on December 6, 2016, as indicated on the Data Transfer Sheets for Layawan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2181P, one of the Layawan flights, which was the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on November 9, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

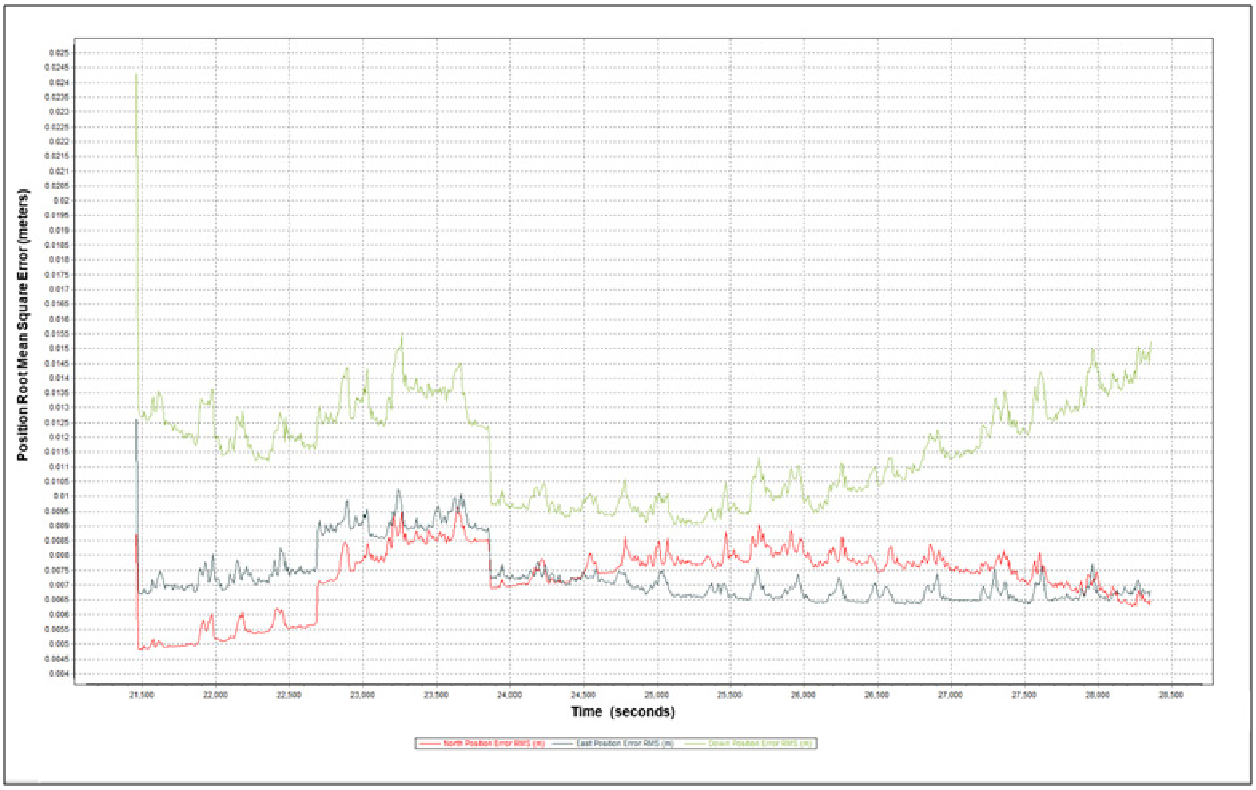

Figure 9. Smoothed Performance Metrics of Layawan Flight 2181P.

The time of flight was from 21500 seconds to 28400 seconds, which corresponds to morning of November 9, 2014. The initial spike that was seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 0.85 centimeters, the East position RMSE peaks at 1.25 centimeters, and the Down position RMSE peaks at 2.43 centimeters, which were within the prescribed accuracies described in the methodology.

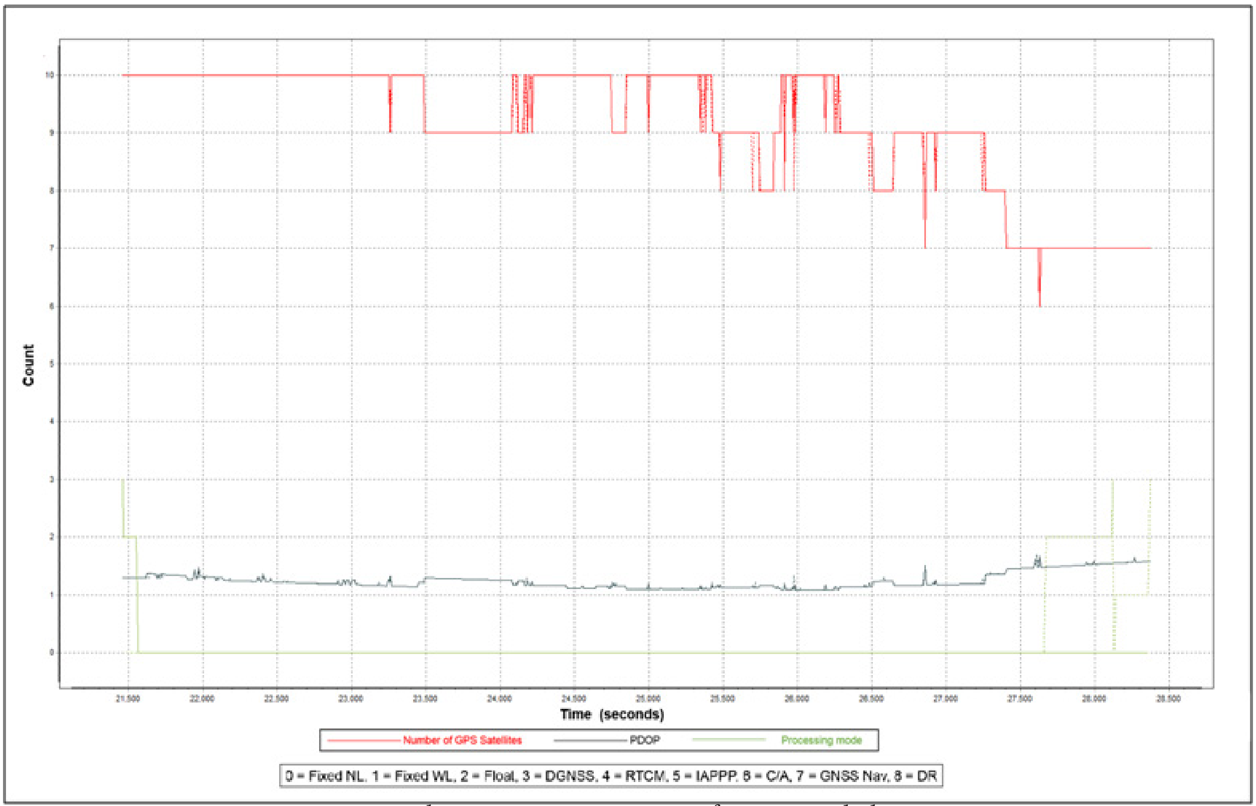

Figure 10. Solution Status Parameters of Layawan Flight 2181P.

The Solution Status parameters of flight 2181P, one of the Layawan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 3 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Layawan flights is shown in Figure 11.

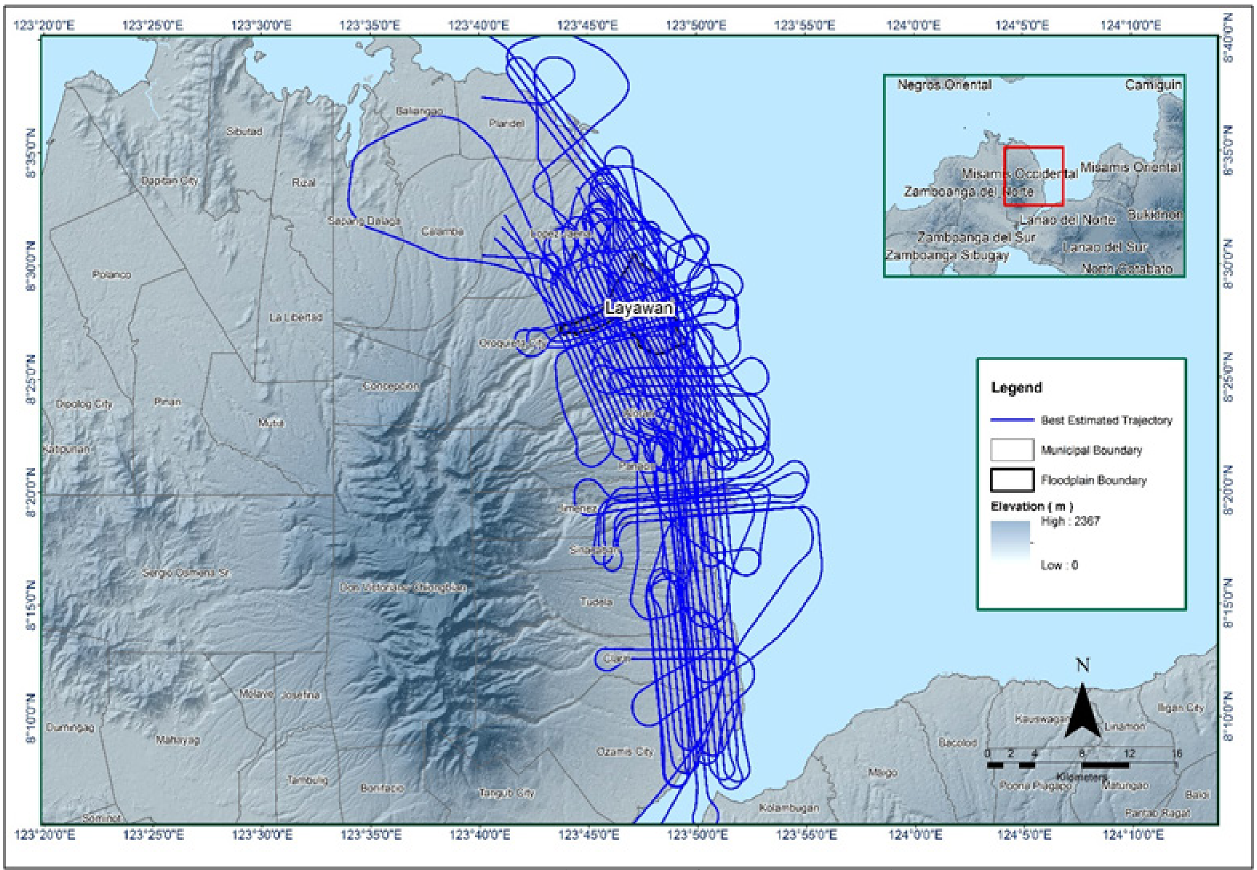

Figure 11. Best Estimated Trajectory for Layawan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 61 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Layawan floodplain are given in Table 12.

Table 12. Self-Calibration Results values for Layawan flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000253
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000977
GPS Position Z-correction stdev	(<0.01meters)	0.0053

The optimum accuracy was obtained for all Layawan flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in Annex 8. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

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

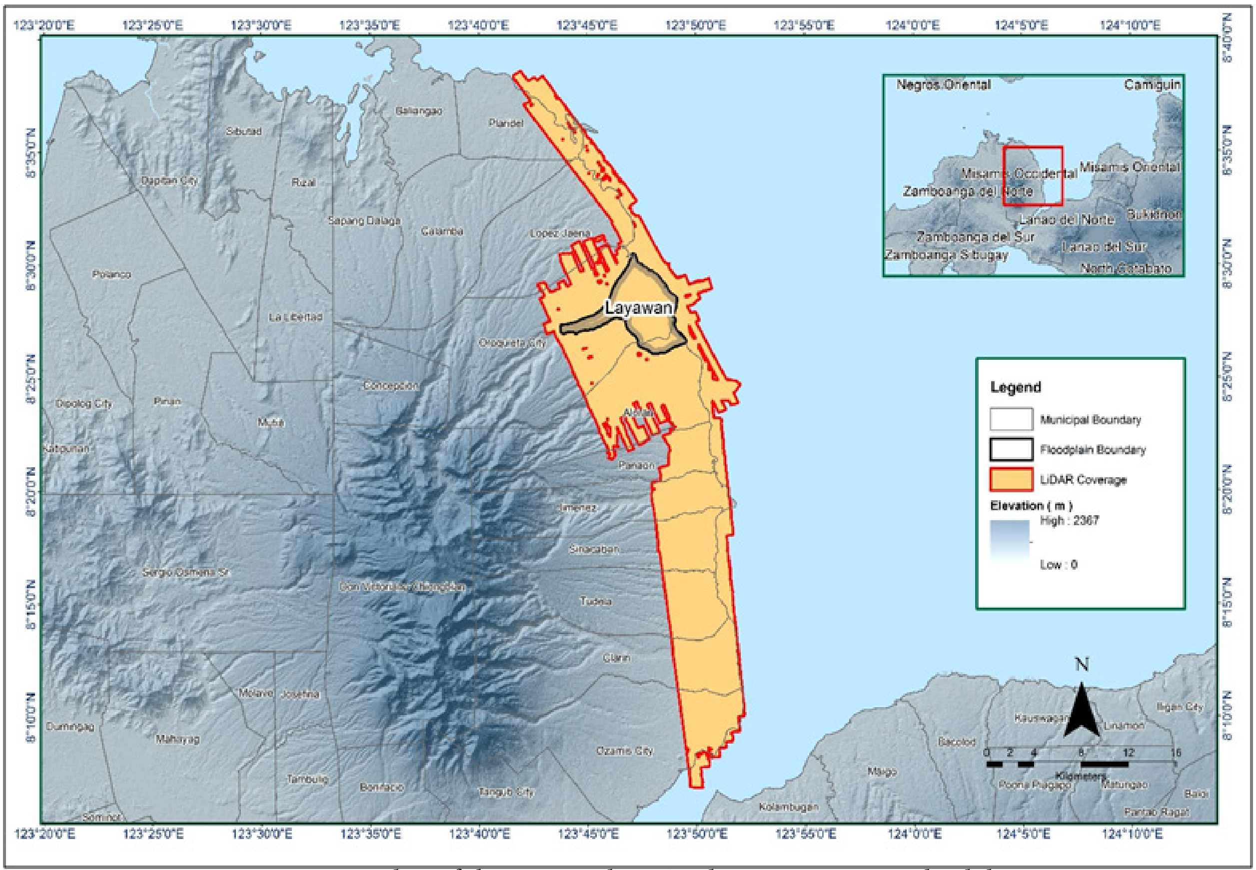

Figure 12. Boundary of the processed LiDAR data over Layawan Floodplain.

The total area covered by the Layawan missions is 460.83 sq.km that is comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 13.

Table 13. . List of LiDAR blocks for Layawan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dipolog_Blk69E	2133P	47.02
Dipolog_Blk69F	2133P	232.40
	2135P	
	2181P	
Pagadian_Blk76P	23116P	80.45
Dipolog_relfights_Blk76P	23566P	100.96
TOTAL		**460.83 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there was limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

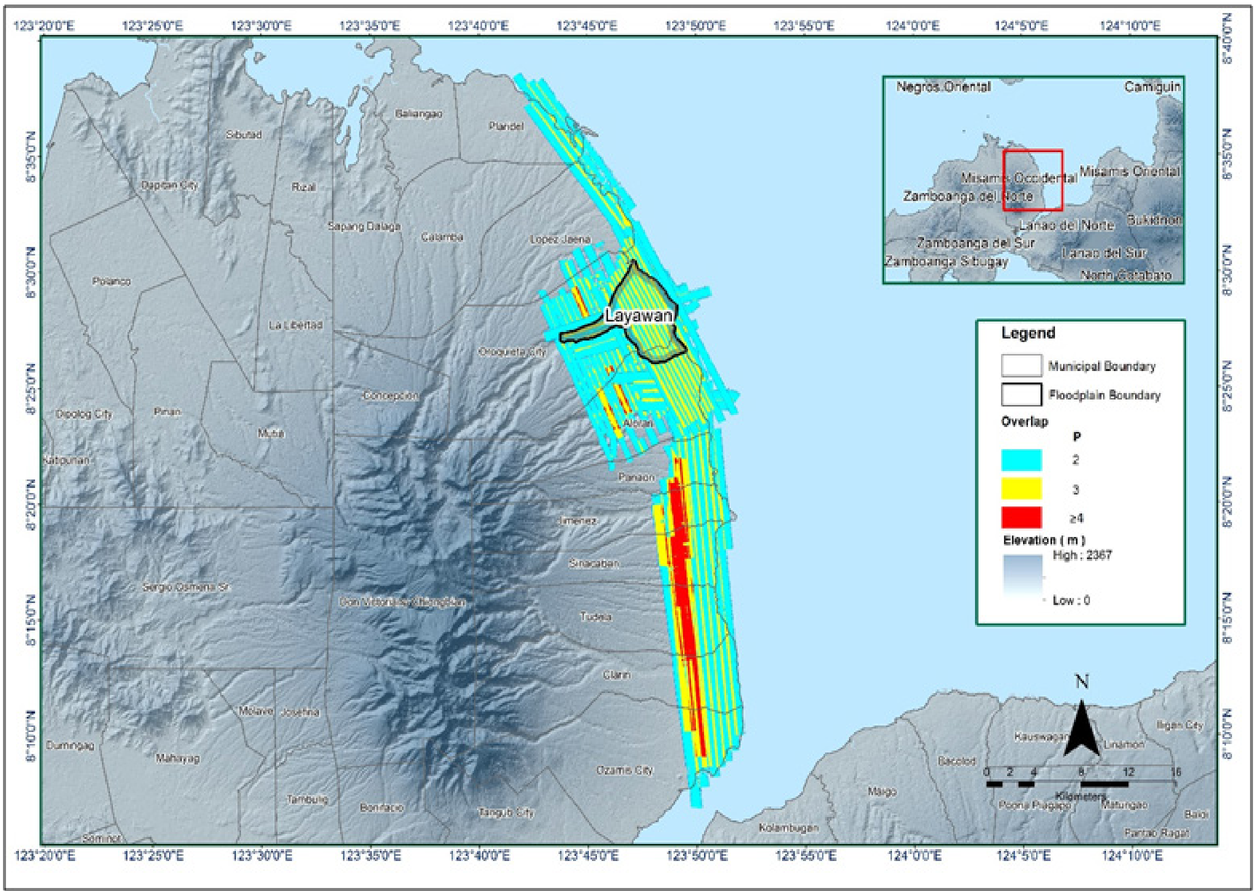

Figure 13. Image of data overlap for Layawan Floodplain.

The overlap statistics per block for the Layawan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 28.40% and 46.32% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Layawan floodplain satisfy the point density requirement, and the average density for the entire survey area was 4.61 points per square meter.

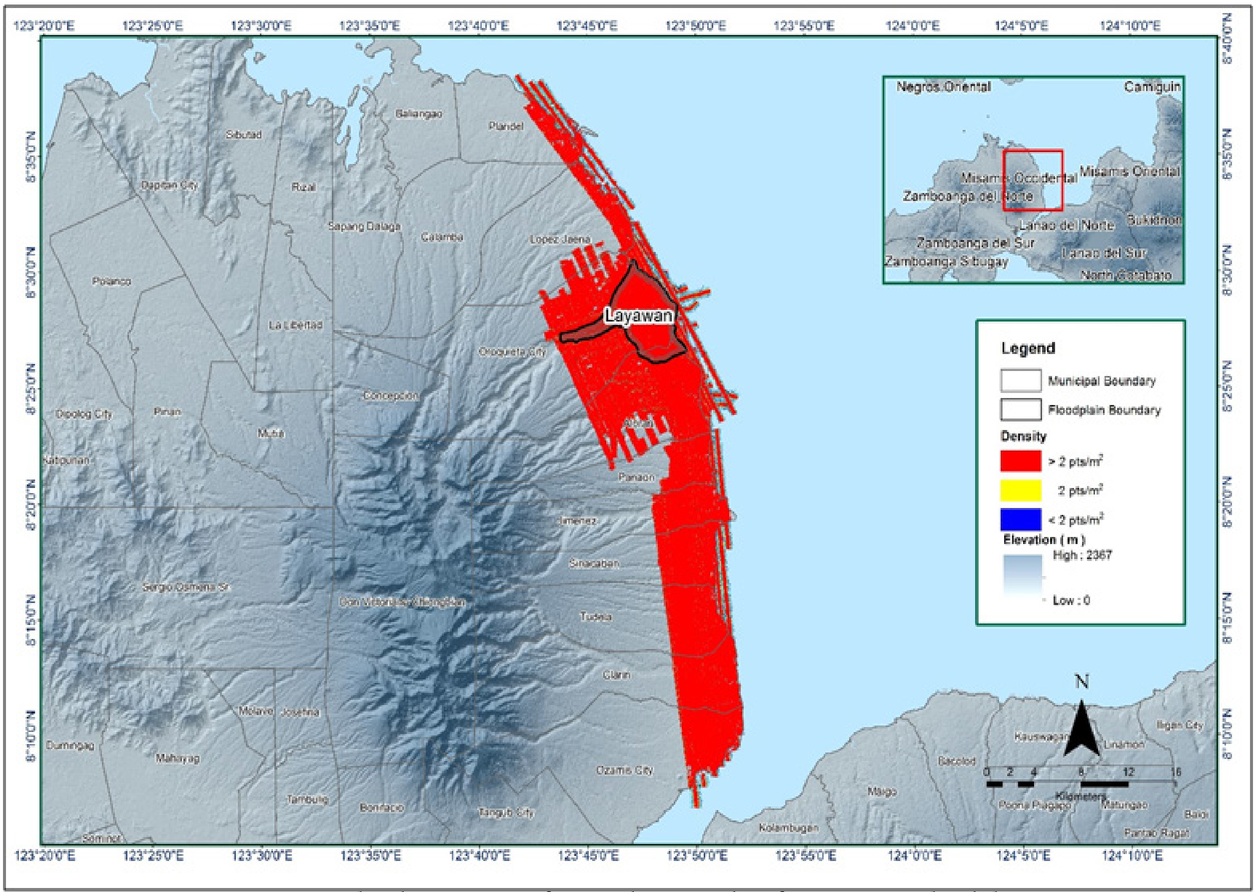

Figure 14. Pulse density map of merged LiDAR data for Layawan Floodplain.

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

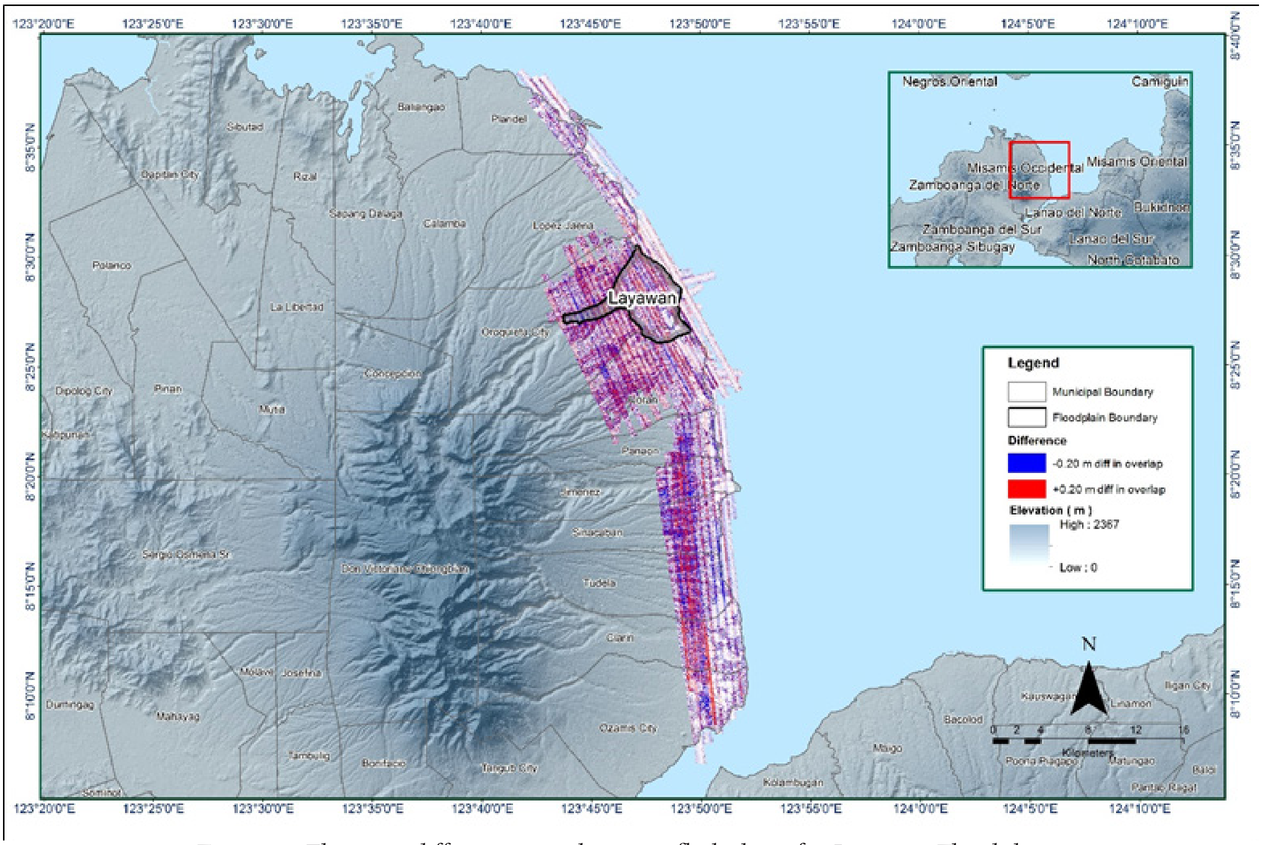

Figure 15. Elevation difference map between flight lines for Layawan Floodplain.

A screen capture of the processed LAS data from a Layawan flight 2181P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

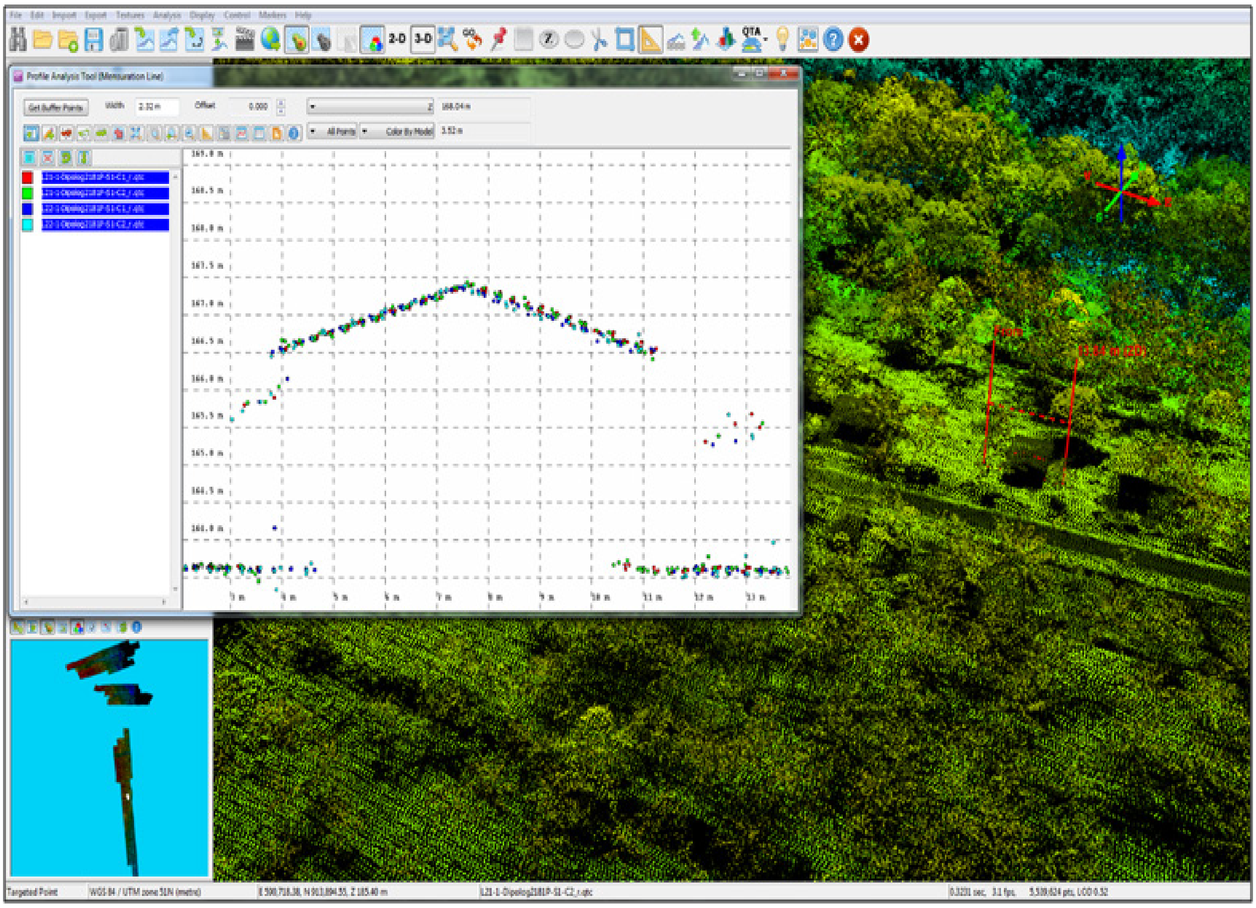

Figure 16. Quality checking for Layawan flight 2181P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Layawan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	544,113,965
Low Vegetation	523,659,573
Medium Vegetation	630,796,141
High Vegetation	1,494,616,570
Building	64,074,190

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Layawan floodplain is shown in Figure 17. A total of 658 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 726.77 meters and 53.91 meters respectively.

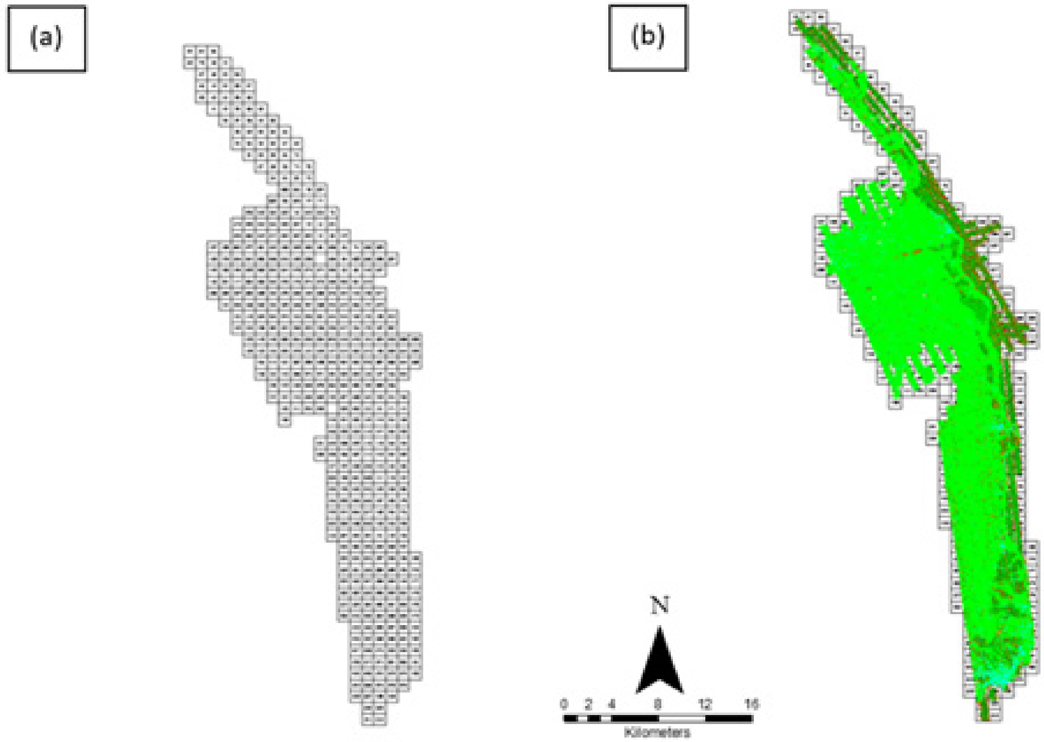

Figure 17. Tiles for Layawan Floodplain (a) and classification results (b) in TerraScan.

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

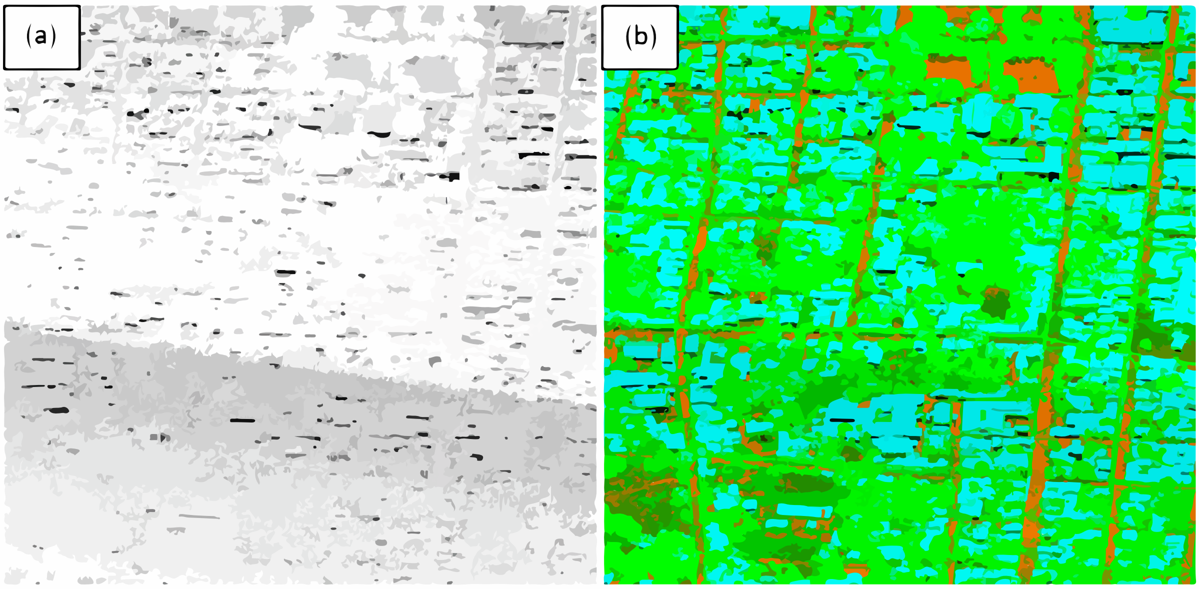

Figure 18. Point cloud before (a) and after (b) classification.

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

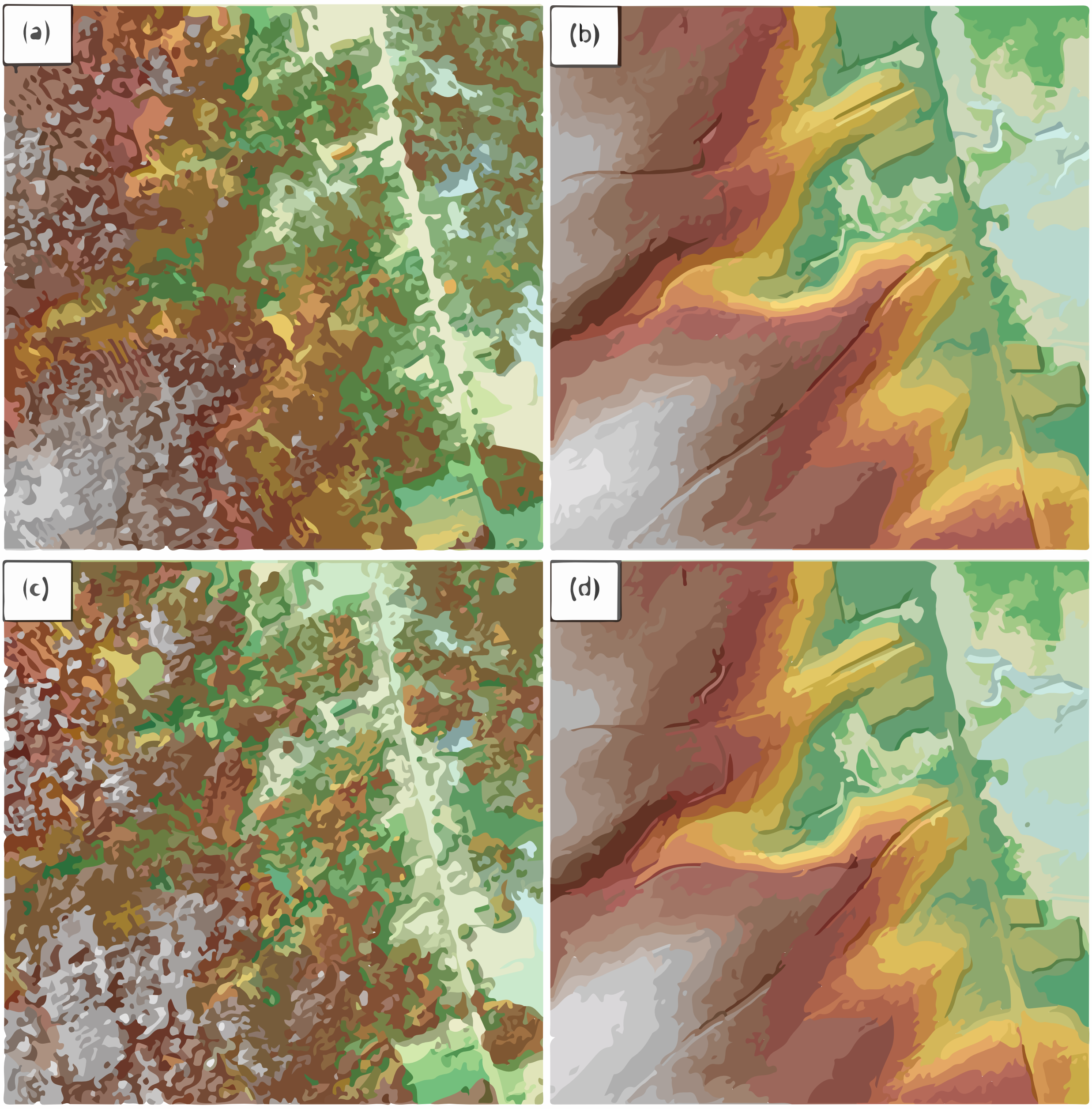

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Layawan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 372 1km by 1km tiles area covered by Layawan floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Layawan floodplain has a total of 265.14 sq.km orthophotogaph coverage comprised of 1,035 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

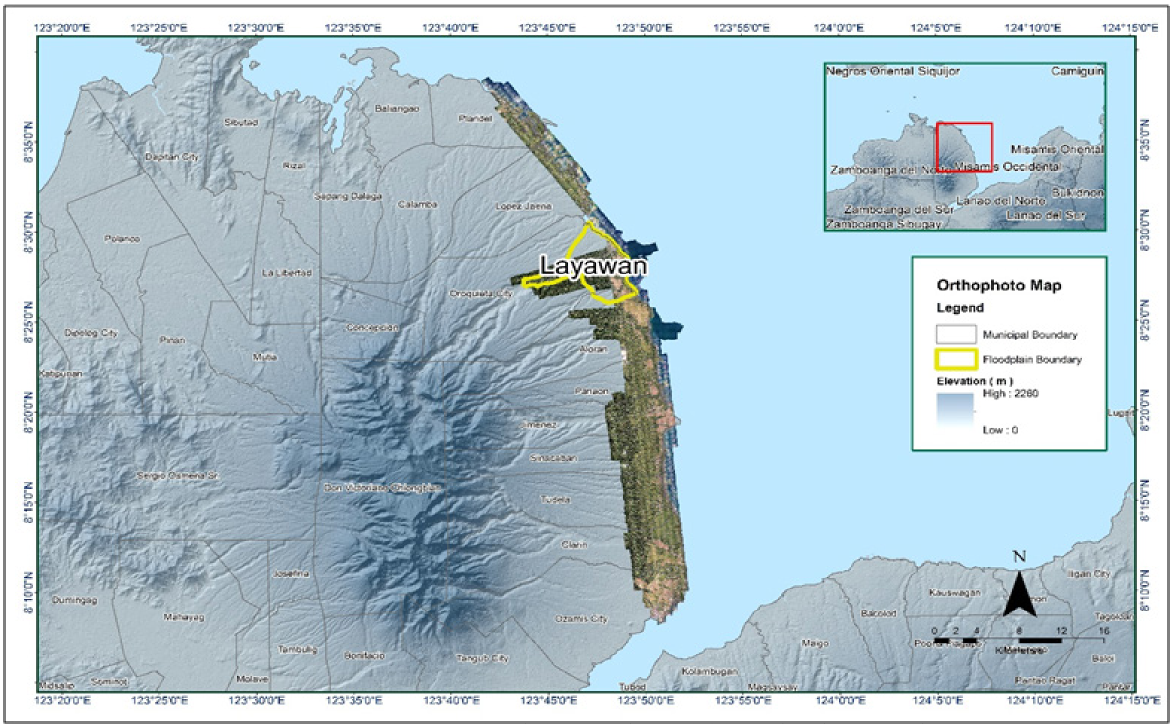

Figure 20. Layawan Floodplain with available orthophotographs.

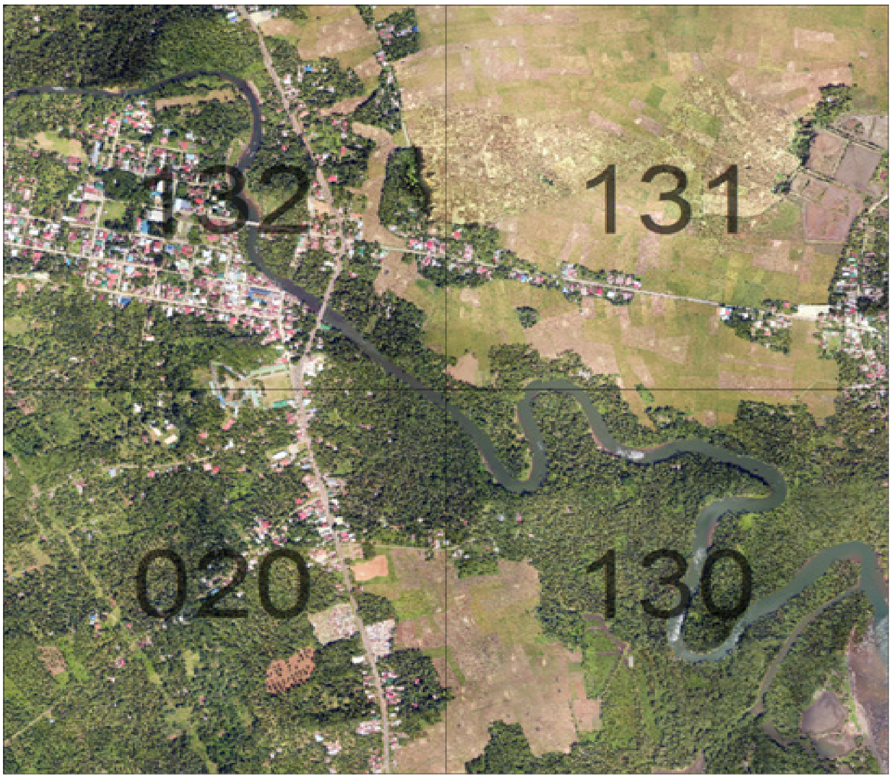

Figure 21. Sample orthophotograph tiles for Layawan Floodplain.

3.8 DEMs Editing and Hydro-Correction

Four (4) mission blocks were processed for Layawan floodplain. These blocks are composed of Dipolog and Pagadian blocks with a total area of 460.83 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Dipolog_Blk69E	47.02
Dipolog_Blk69F	232.40
Pagadian_Blk76P	80.45
Dipolog_reflight_Blk76P	100.961
TOTAL	**460.831 sq.km**

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

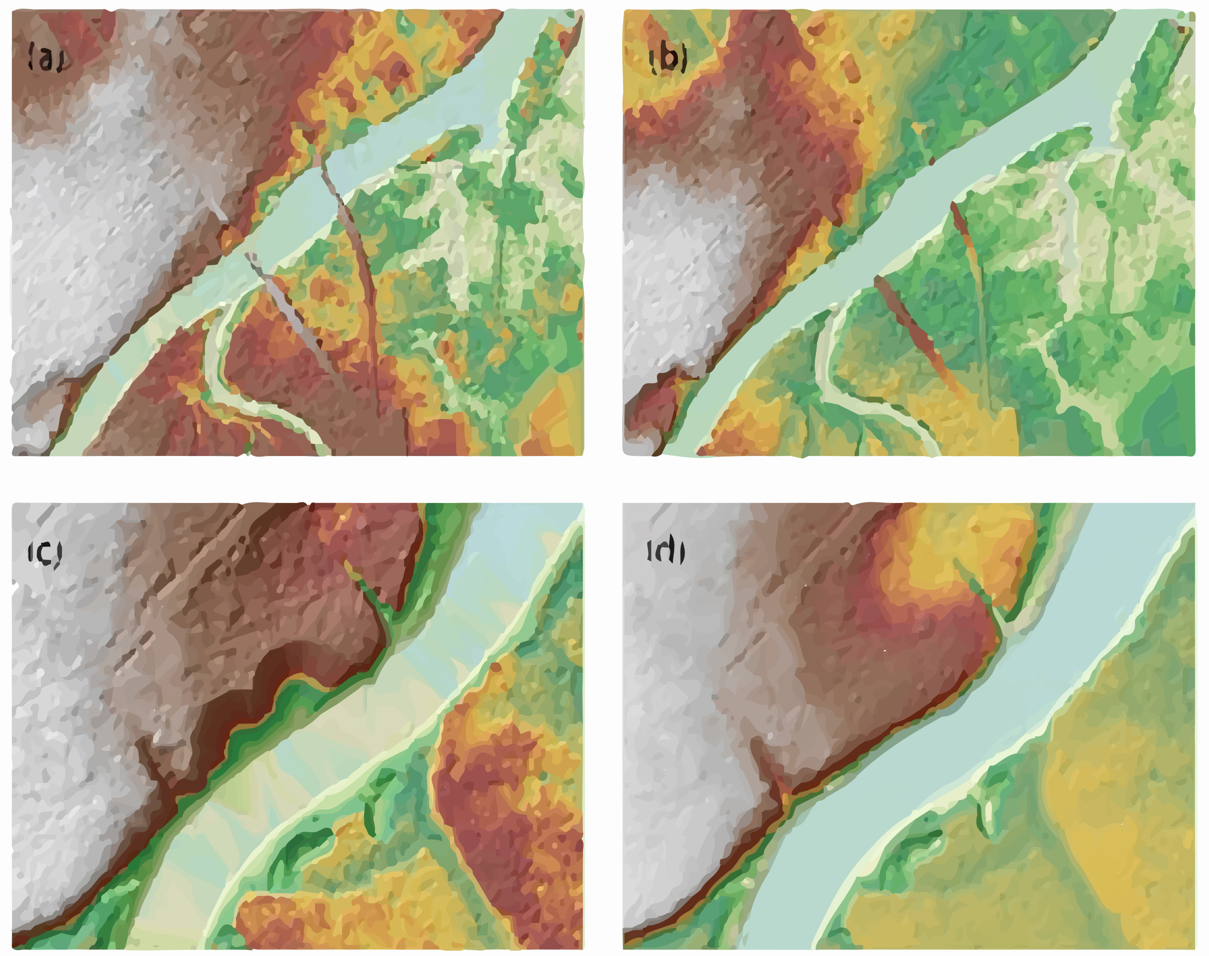

Figure 22. Portions in the DTM of Layawan Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

NorthernMindanao_Blk71_Extension was used as the reference block at the start of mosaicking because it was already vertically calibrated to MSL and it overlapped Dipolog_Blk69F which was the largest DTM of Layawan river basin. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

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

Table 16. Shift Values of each LiDAR Block of Layawan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dipolog_Blk69E	-0.15	0.21	-2.32
Dipolog_Blk69F	-0.15	0.21	-2.32
Pagadian_Blk76P	0.20	-0.10	-2.34
Dipolog_reflights_Blk76P	0.10	0.60	-3.01

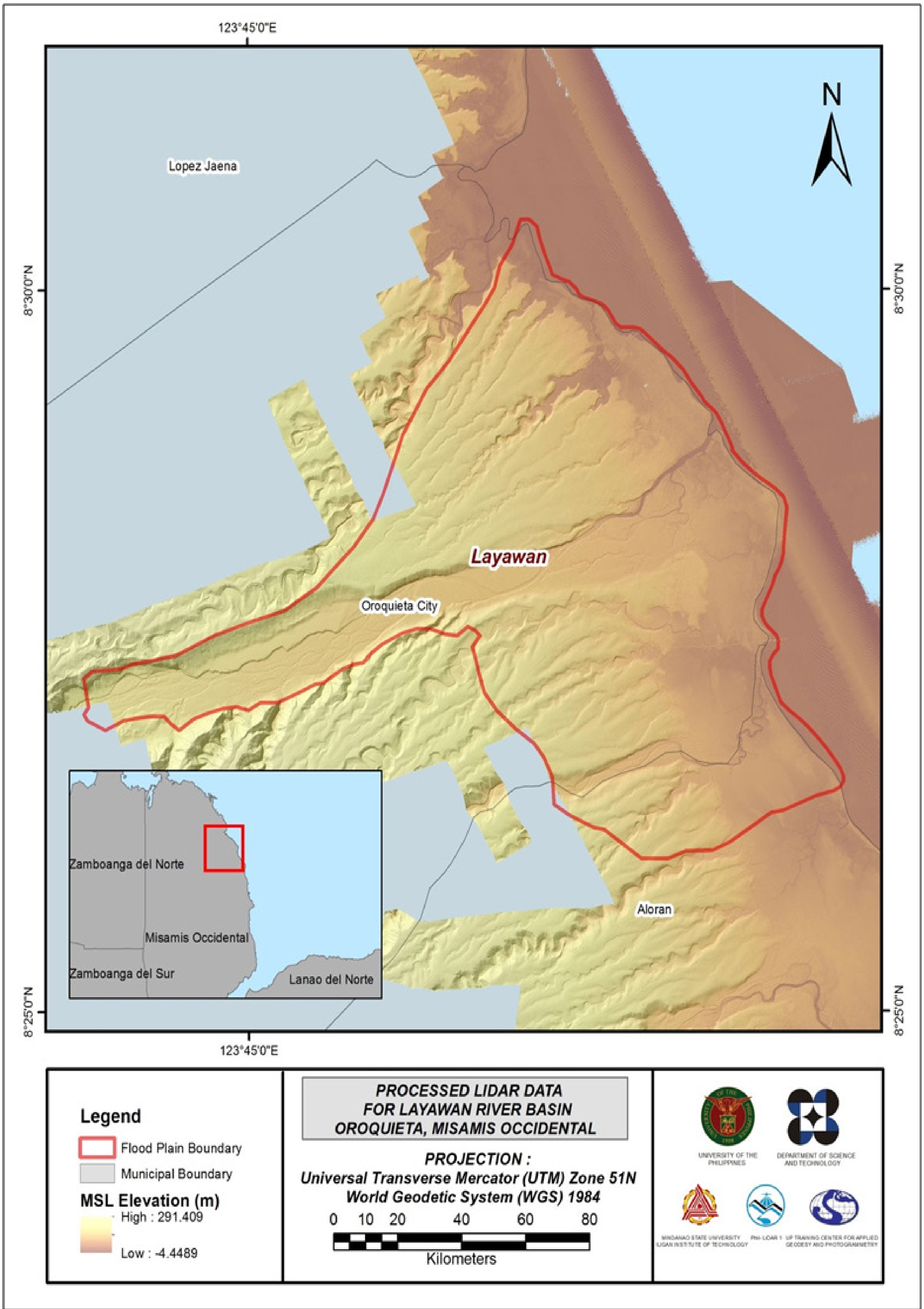

Figure 23. Map of Processed LiDAR Data for Layawan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Layawan to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 2,003 survey points were used for calibration and validation of Layawan LiDAR data. Random selection of 80% of the survey points, resulting to 1,602 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.27 meters with a standard deviation of 0.08 meters. Calibration of Layawan LiDAR data was done by adding the height difference value, 2.27 meters, to Layawan mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

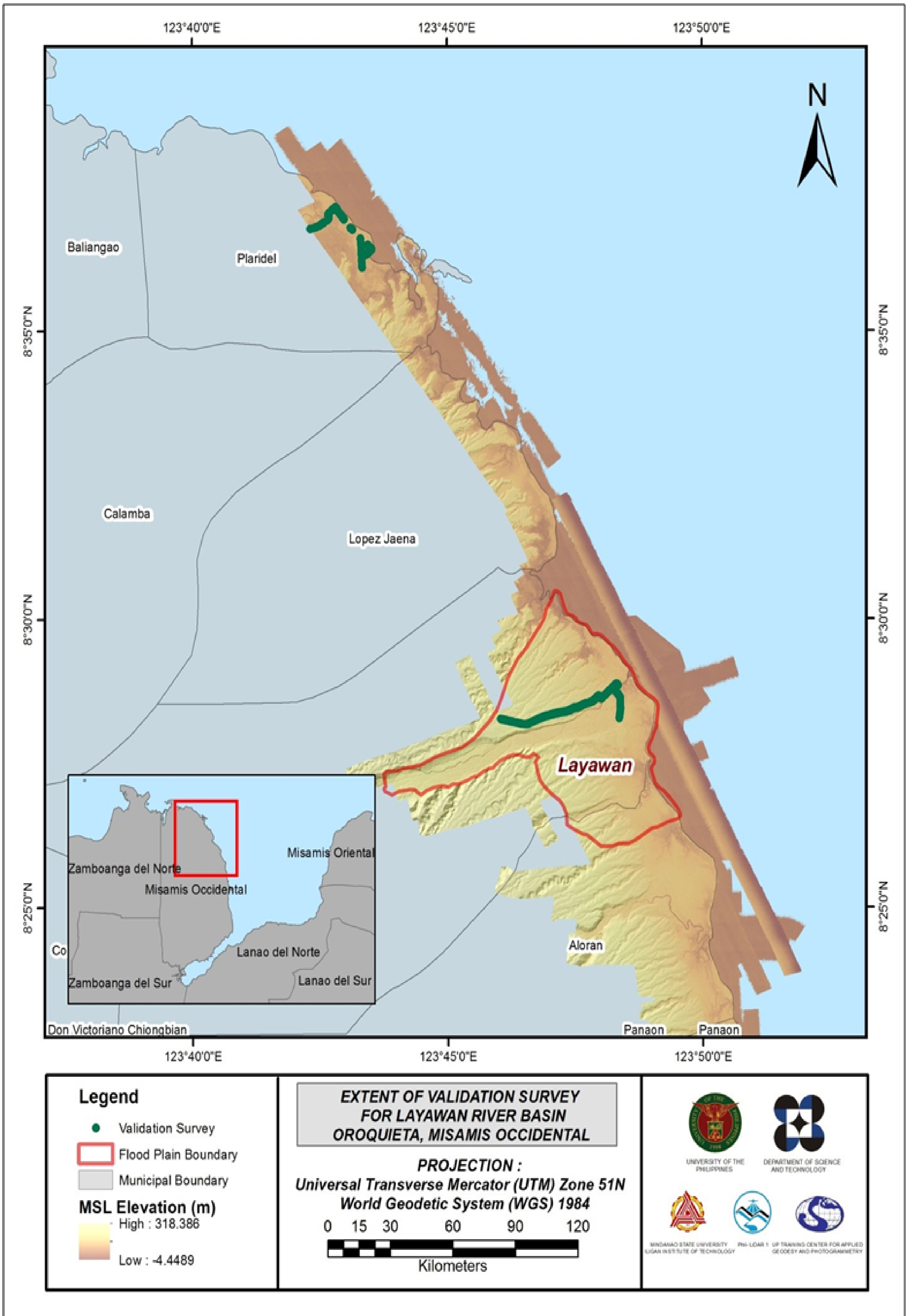

Figure 24. Map of Layawan Floodplain with validation survey points in green.

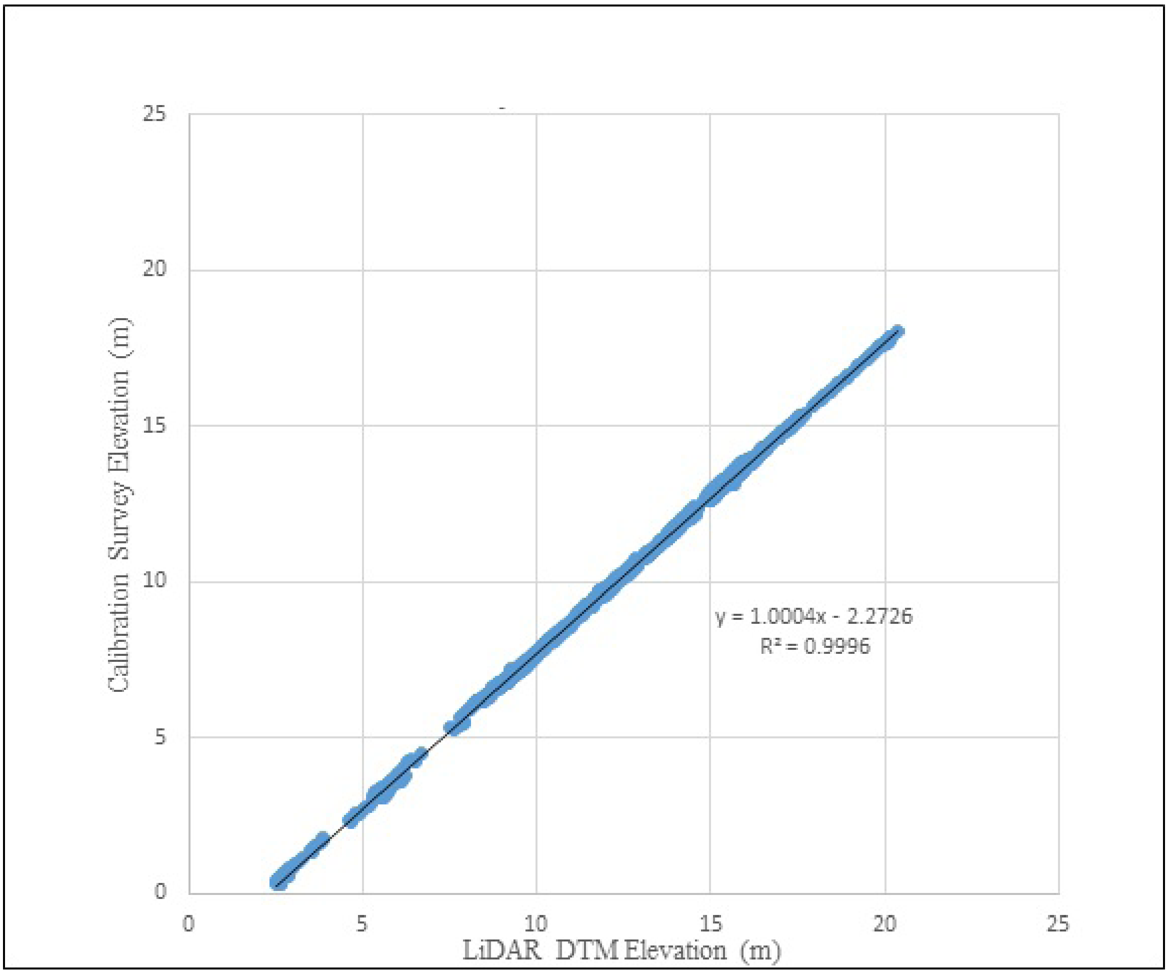

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures.

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 933 survey points were collected by DVBC for the Layawan river basin. Random selection of 20% of the total survey points, resulting to 187 points, were used for the validation of calibrated Layawan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.13 meters with a standard deviation of 0.13 meters, as shown in Table 18.

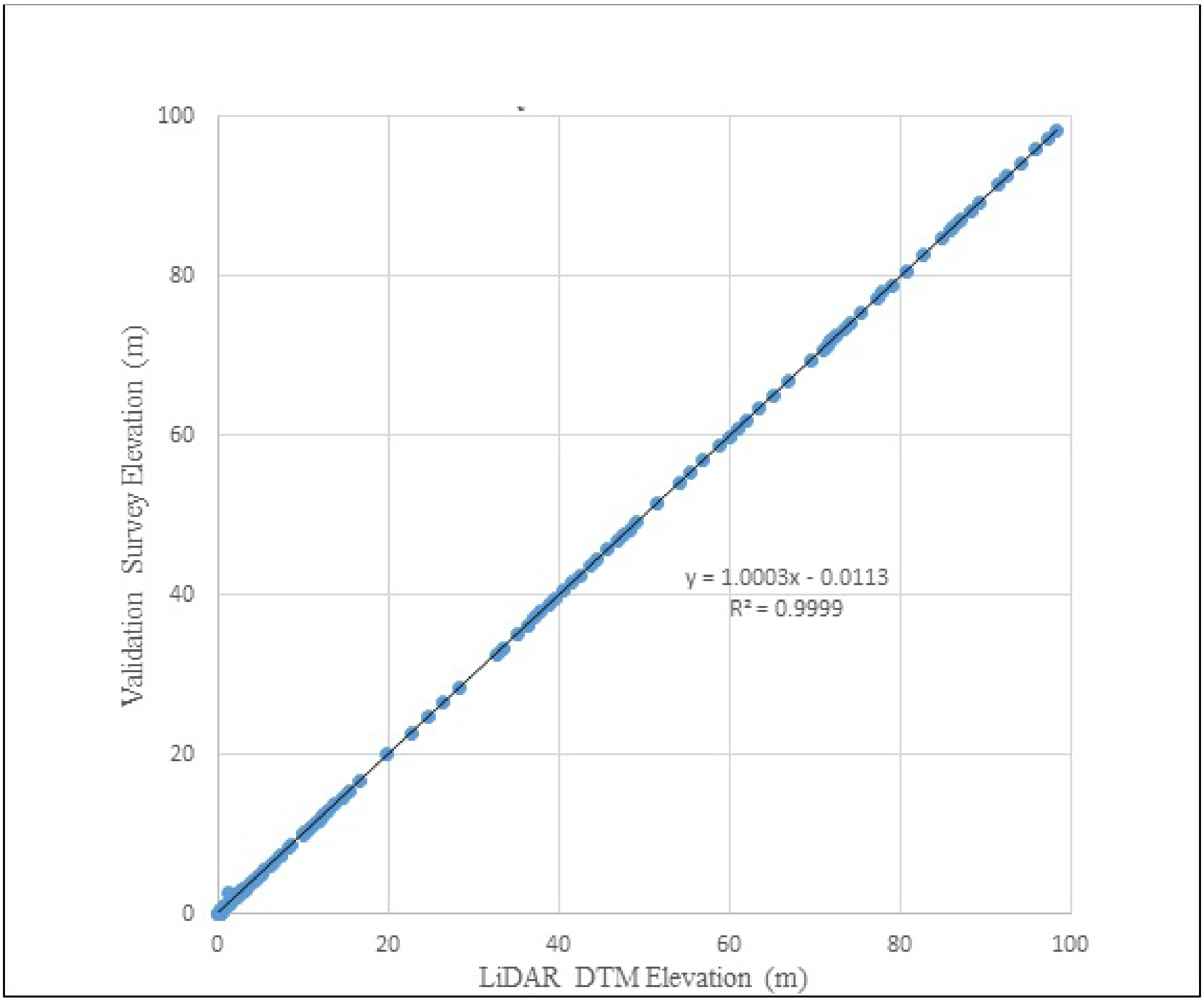

Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.13
Average	0.01
Minimum	-1.52
Maximum	0.17

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Layawan with 5,043 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface was represented by the computed RMSE value of 0.33 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Layawan integrated with the processed LiDAR DEM is shown in Figure 27.

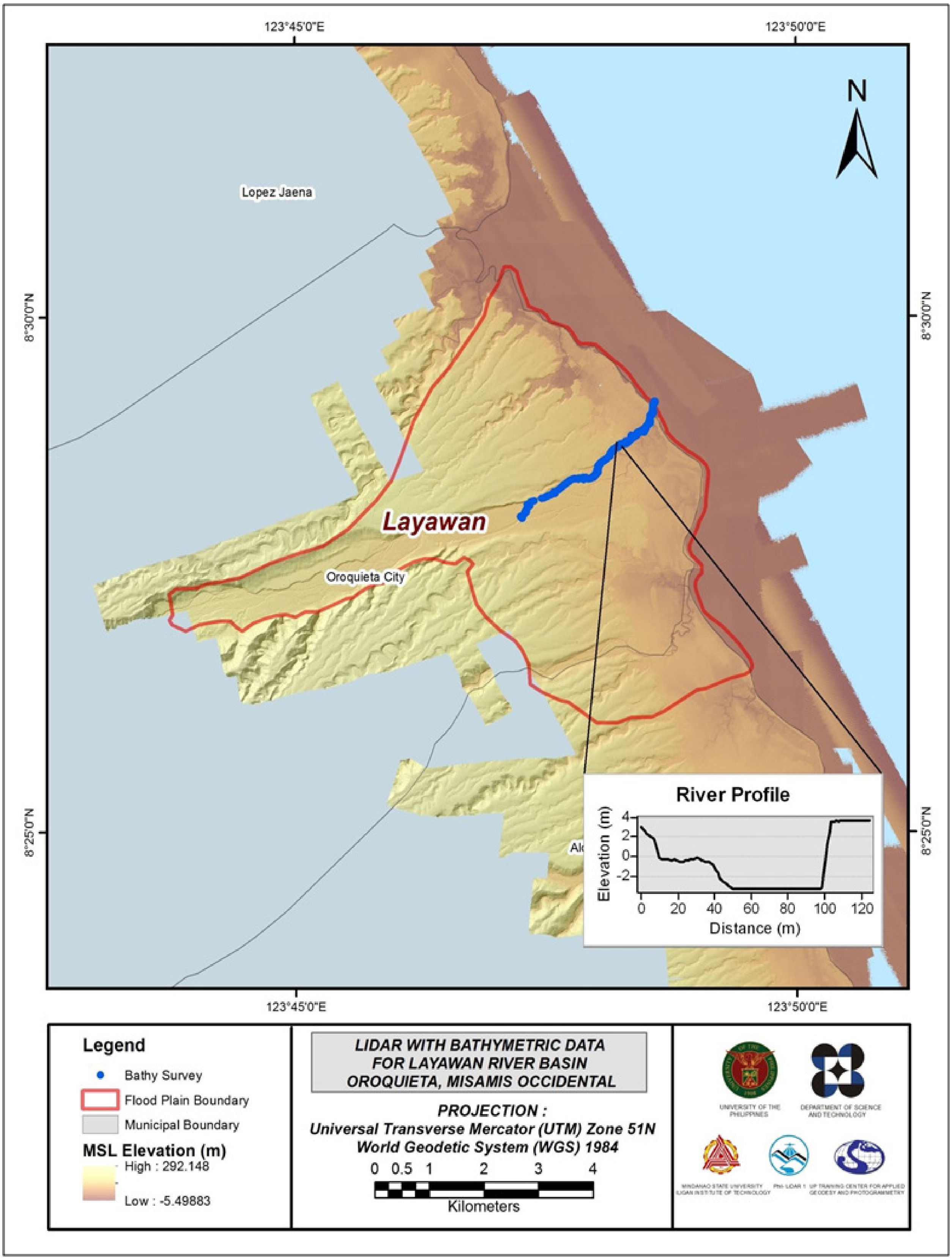

Figure 27. Map of Layawan Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Layawan floodplain, including its 200 m buffer, has a total area of 41.06 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 3,170 building features, are considered for QC. Figure 28 shows the QC blocks for Layawan floodplain.

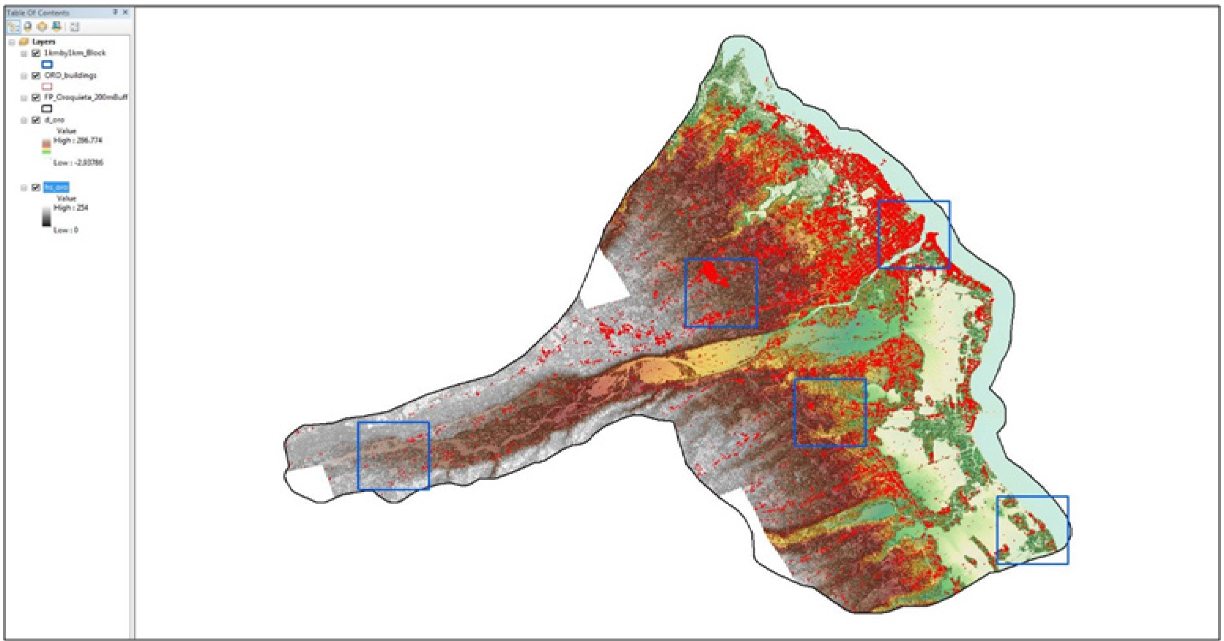

Figure 28. QC blocks for Layawan building features.

Quality checking of Layawan building features resulted in the ratings shown in Table 19.

Table 19. Quality Checking Ratings for Layawan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Layawan	99.34	99.37	84.29	PASSED

3.12.2 Height Extraction

Height extraction was done for 18,731 building features in Layawan floodplain. Of these building features, 456 was filtered out after height extraction, resulting to 18,275 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 10.91 m.

3.12.3 Feature Attribution

Layawan floodplain has one (1) municipality named Oroquieta city. The building attribution on the city of Oroquieta was done with the Google Earth approach. In Google Earth approach, aid from Purok representatives were sought for participatory mapping over the Google Earth software. The attributions of road, bridge and water body features were done using NAMRIA maps, municipal and city records, and participatory mapping of municipals and cities.

Table 20 summarizes the number of building features per type. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Building Features Extracted for Layawan Floodplain.

Facility Type	No. of Features
Residential	17,223
School	238
Market	5
Agricultural/Agro-Industrial Facilities	51
Medical Institutions	38
Barangay Hall	31
Military Institution	0
Sports Center/Gymnasium/Covered Court	14
Telecommunication Facilities	9
Transport Terminal	1
Warehouse	58
Power Plant/Substation	0
NGO/CSO Offices	3
Police Station	1
Water Supply/Sewerage	14
Religious Institutions	110
Bank	10
Factory	1
Gas Station	11
Fire Station	0
Other Government Offices	87
Other Commercial Establishments	370
Total	**18,275**

Table 21. . Total Length of Extracted Roads for Layawan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Layawan	99.62	0.00	0.00	0.00	31.97	131.59

Table 22. Number of Extracted Water Bodies for Layawan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Layawan	27	0	0	0	9	36

A total of 24 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

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

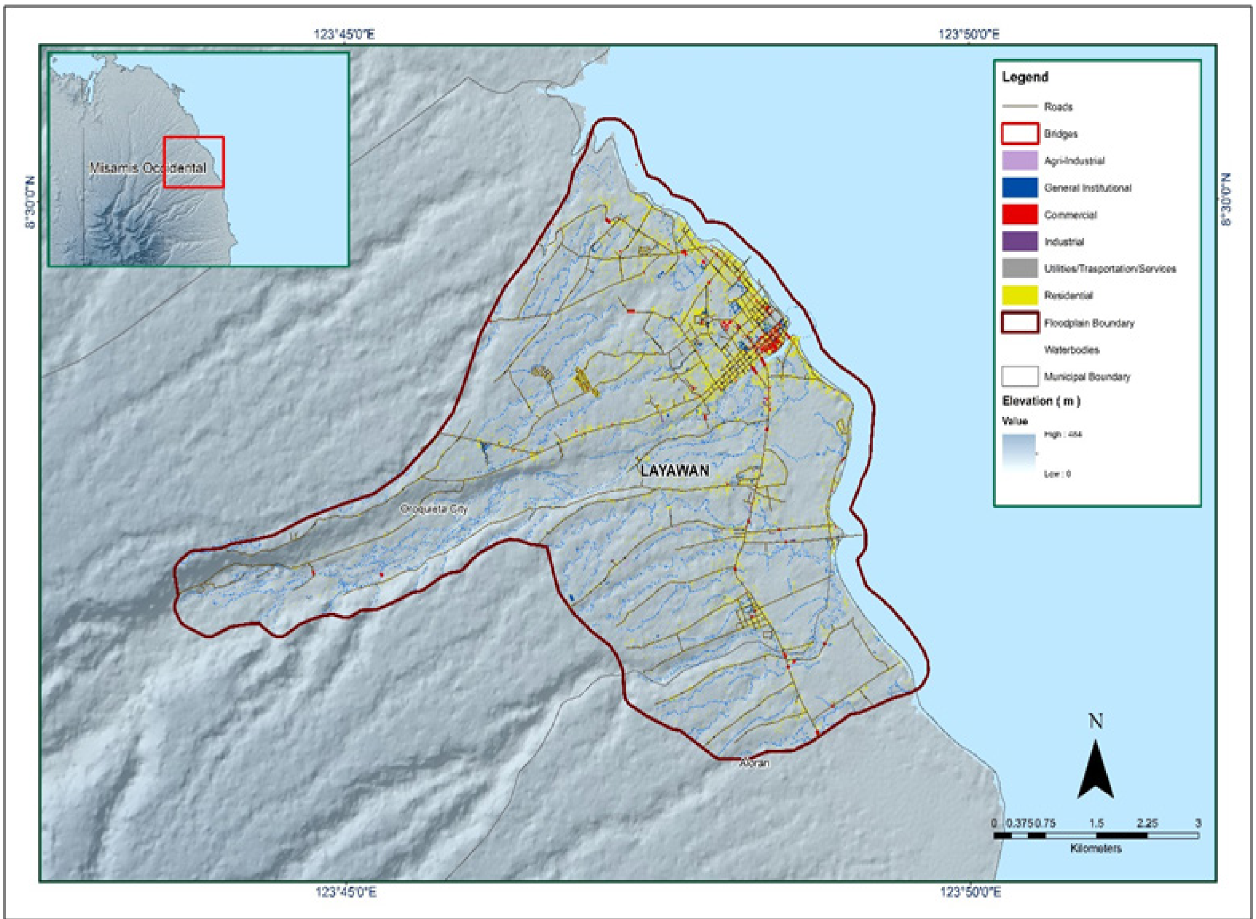

Figure 29. Extracted features for Layawan Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE LAYAWAN 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, Engr. Jovelle Anjeanette S. Canlas, Engr. James Kevin M. Dimaculangan , Engr. Jommer M. Medina, and 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

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Layawan River on October 8 to 19, 2015 with the following scope of work: reconnaissance to locate NAMRIA points and to determine the viability of traversing the planned routes for bathymetric survey; courtesy call with MSU-IIT, Oroquieta LGU's and MDRRMC; control survey for the establishment of control points for GNSS surveys; cross-section survey, bridge-as-built features determination and water level marking at Langcangan Hanging Bridge in Brgy. Upper Langcangan, Oroquieta City; ground validation acquisition survey for LiDAR data with estimated distance of 18.401 km; and bathymetric survey of Layawan River starting from Brgy. Talairon down to Brgy. Taboc Norte with approximate length of 3.466 km utilizing GNSS PPK survey technique. Survey extent is illustrated in Figure 30.

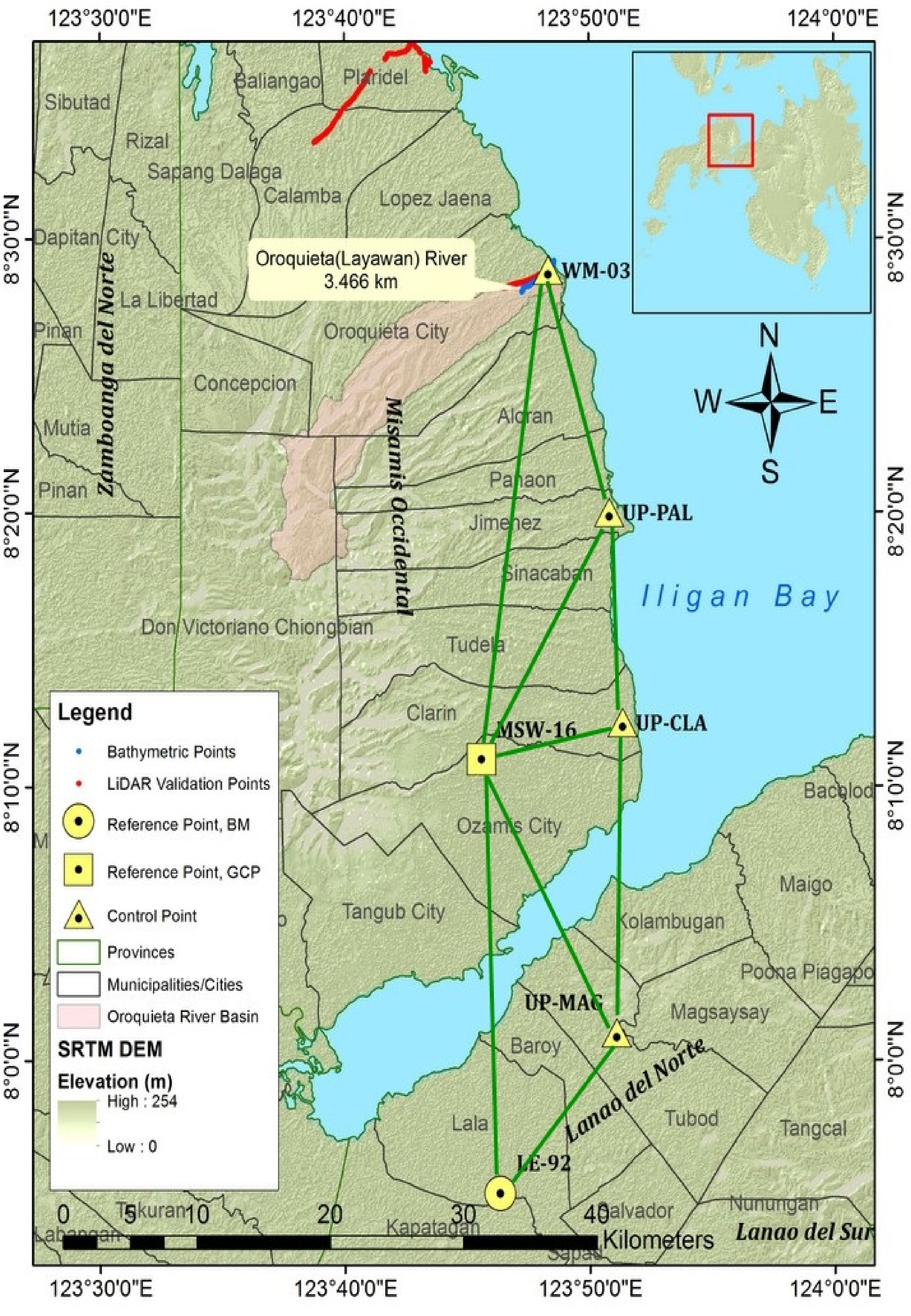

Figure 30. Layawan River survey extent

4.2 Control Survey

The GNSS network used for Layawan River was 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 Bridge 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.

The list of control points used in the survey is summarized in Table 23 while the GNSS network established is illustrated in Figure 31.

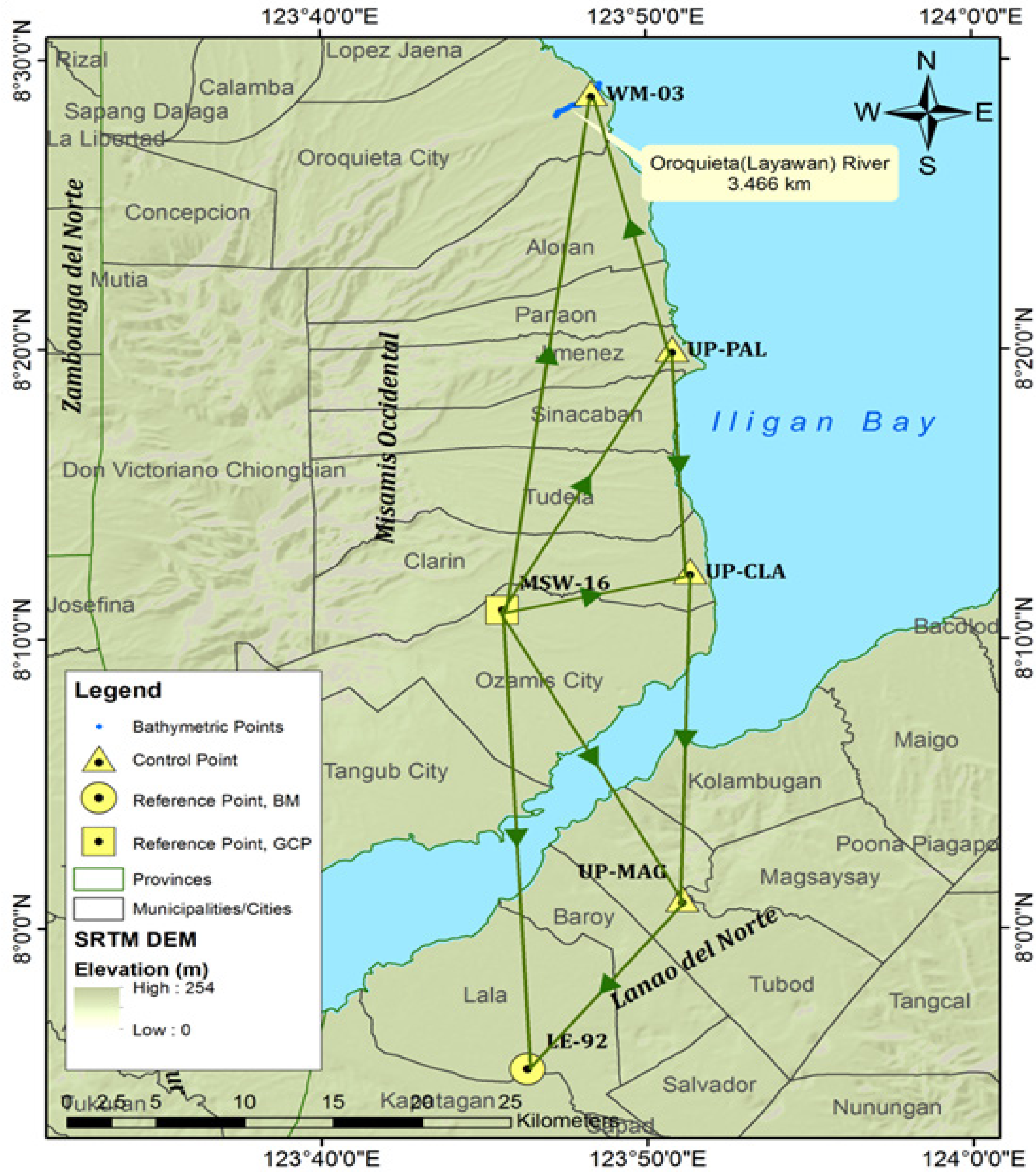

Figure 31. GNSS network covering Layawan (Layawan) River

Table 23. List of References and Control Points used in Dipolog 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	8°11'00.29164"N	123°45'35.16284"E	360.45	-	2007
LE-92	1st Order GCP	7°55'08.47442"N	123°46'19.89121"E	89.406	18.440	2007
WM-03	UP 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

The GNSS set up on the recovered reference and control points are shown in Figure 32 to Figure 37

Figure 32. Trimble® SPS 852 setup at MSW-16 beside the fence of the basketball court in Brgy. Stimson Abordo, Ozamiz City, Misamis Occidental

Figure 33. Trimble® SPS 882 setup at LE-92 on the southwest end of Maranding Bridge foot walk in Brgy. Maranding, Mun. of Lala, Lanao del Norte

Figure 34. Trimble® SPS 882 setup at WM-03, G. Pelaez Bridge approach in Brgy. Lower Langcangan, Oroquieta City, Misamis Occidental

Figure 35. Trimble® SPS 985 setup at UP-CLA, Clarin Bridge approach in Brgy. Poblacion IV, Mun. of Clarin, Misamis Occidental

Figure 36. Trimble® SPS 852 setup at UP-MAG, Magsaysay Bridge approach in Brgy. Baguiguicon, Mun. of Magsaysay, Lanao del Norte

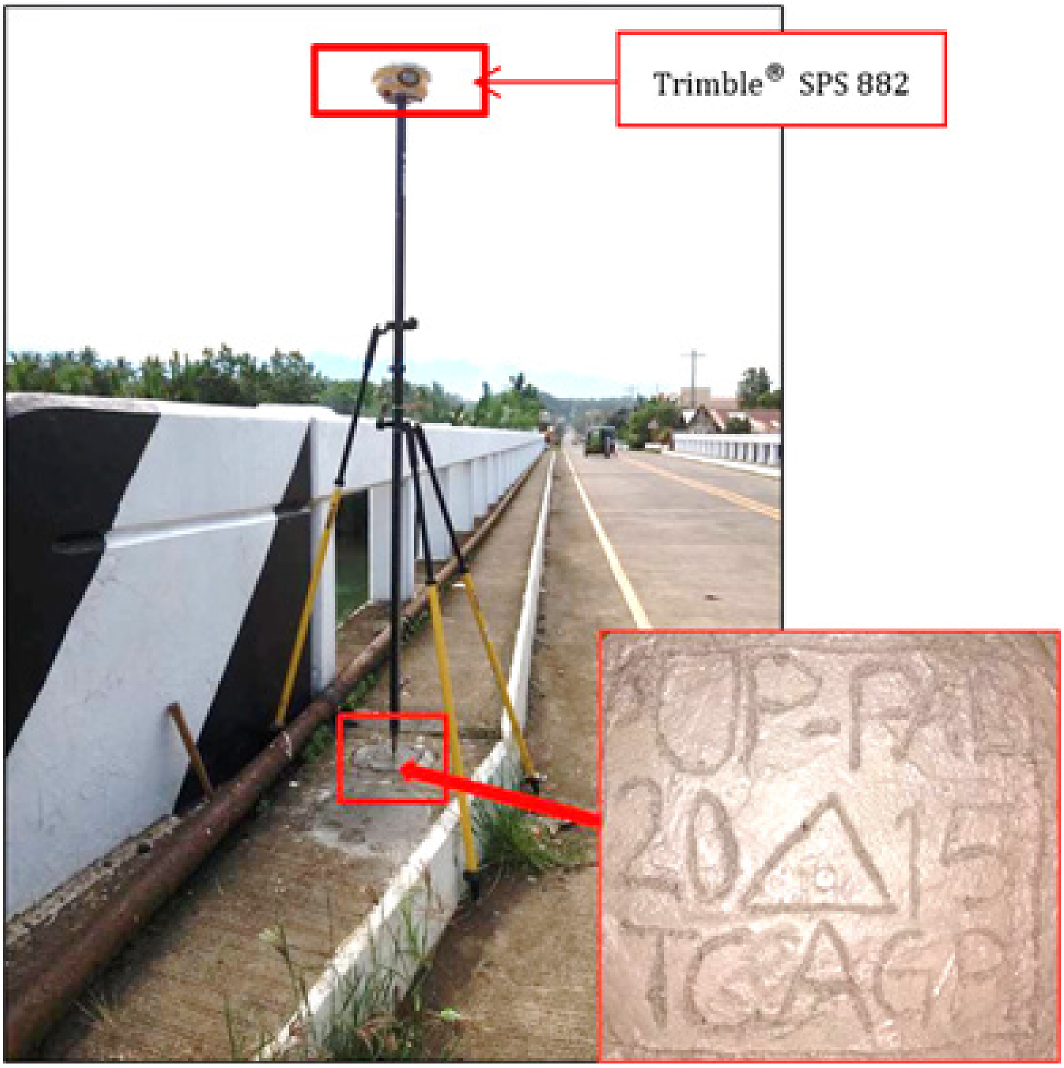

Figure 37. Trimble® SPS 882 setup at UP-PAL, Palilan Bridge approach in Brgy. Rizal, Jimenez, Misamis Occidental.

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 done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points used in Layawan River Basin survey is summarized in Table 24 as generated by TBC software.

Table 24. Baseline processing report for Layawan River control survey.

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

As shown in Table 24, a total of ten (10) baselines were processed with reference points MSW-16 fixed for coordinates values, and LE-91 fixed for elevation value. All of them passed the accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 25 to Table 27 for the complete details.

Table 25. Control Point Constraints

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

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 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Adjusted Geodetic Coordinates

Point ID	Easting(Meter)	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 network is fixed at a NAMRIA reference point MSW-16 and LE-92 for grid and elevation, respectively. With the mentioned equation, $\sqrt{(x_e)^2+(y_e)^2}<20cm$ for horizontal and $z_e<10$ cm for the vertical; the horizontal and vertical accuracy computation 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 accuracy of the program.

Table 28. Adjusted Geodetic Coordinates

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	

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 27. Based on the result of the computation, the accuracy condition is satisfied hence the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 27. 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	Easting	MSL Elevation (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	Used as Establish	8°12'20.32560"	123°51'20.80389"	72.796	907132.927	594261.657	4.138
UP-MAG	Used as Establish	8°01'00.58291"	123°51'05.06713"	102.053	886255.504	593823.908	33.073
UP-PAL	Used as Establish	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

Cross-section survey was conducted on October 15, 2015 at the upstream side of Langcangan Hanging Bridge in Brgy. Upper Langcanga, Oroquieta City, Misamis Occidental using a prismless Trimble® Total Station through open traverse method as shown in Figure 38. Two known points were obtained using Trimble® SPS 882 in GNSS PPK survey technique to serve as reference points derived from UP-CLA.

Figure 38. Cross-section survey along Lawayan River in the upstream side of Langcangan Hanging Bridge

The cross-sectional line length of Langcangan Hanging Bridge is about 74.17 meters with 27 cross-sectional points. The location map and summary of gathered cross-section data in a diagram are shown in Figure 39 and Figure 40.

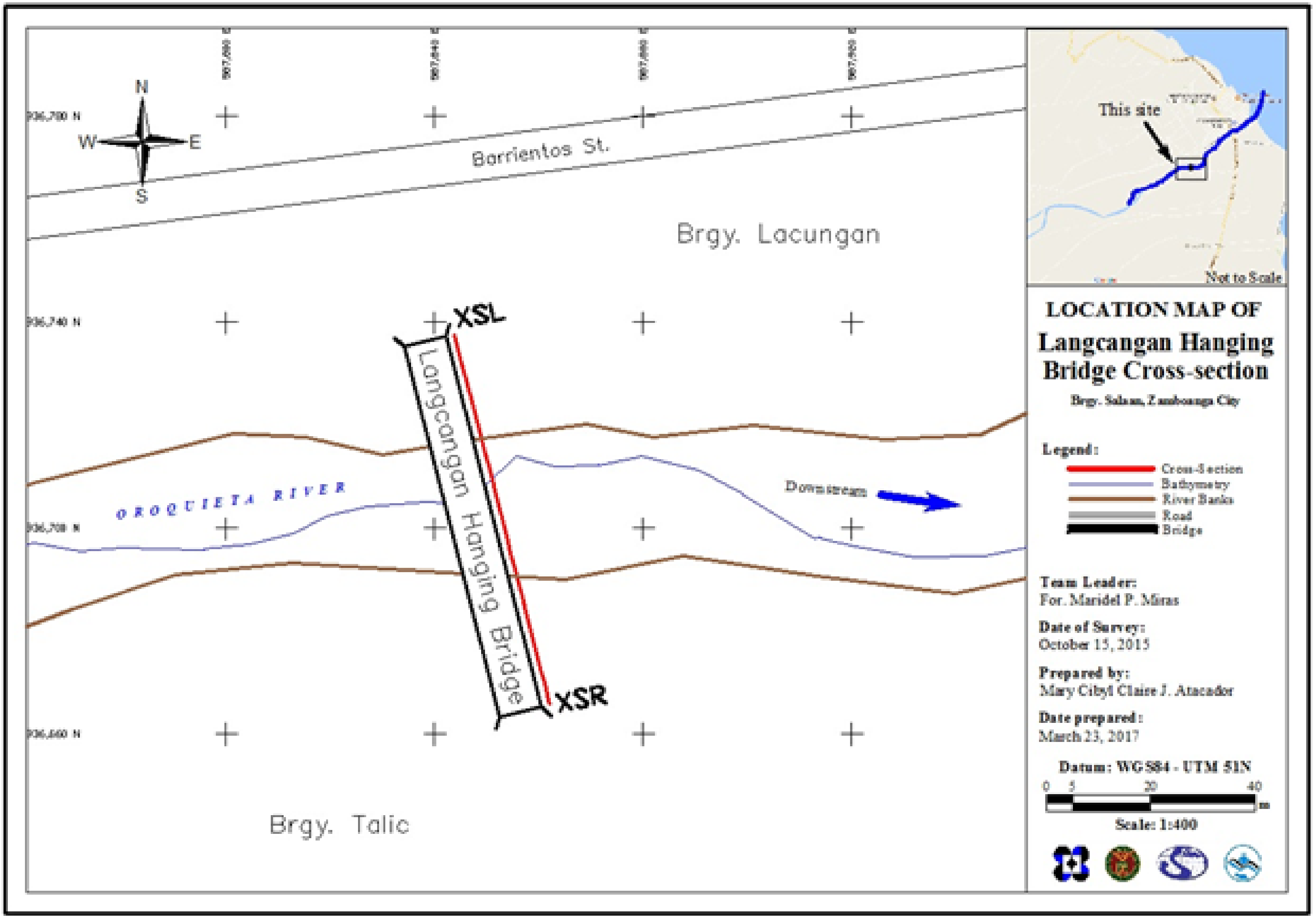

Figure 39. Langcangan hanging bridge cross-section location map.

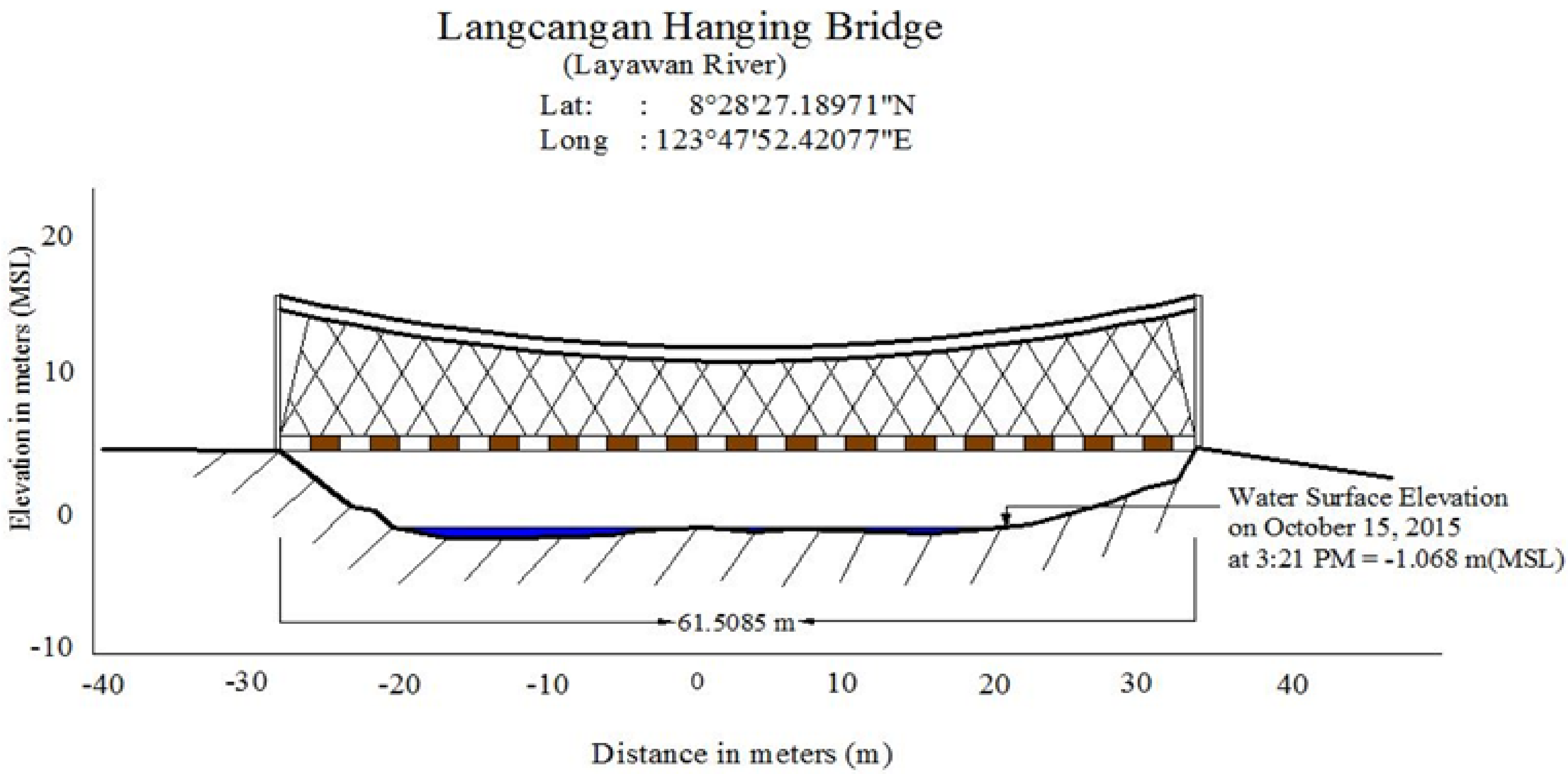

Figure 40. Langcangan Hanging Bridge cross-sectional diagram.

Figure 41. Water level markings on the dike of near Langcangan Hanging Bridge

Water surface elevation in MSL of Layawan River was determined using a Trimble® total station on October 15, 2015 at 3:21 P.M with a value of -1.068 m in MSL. This was translated onto marking on the dike near Langcangan Hanging Bridge. The value 102.716 m was still an assumed elevation and yet to be changed to the computed 2.827 m in MSL by MSU-IIT. They shall update the marked post in Figure 41 to reflect its corresponding MSL values. The marking will serve as their reference for flow data gathering and depth gauge deployment for Layawan River.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 12, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 42. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 1.975 from the ground up to the bottom of notch of the GNSS Rover receiver.

Figure 42. Trimble® SPS 985 set-up for validation points acquisition survey of Layawan (Layawan) River

The survey was conducted using PPK technique on a continuous topography mode using MW-03 as GNSS base station. The survey is composed of two routes: one started in Brgy. Eastern Looc, Mun. of Plaridel traversing seven more barangays in the municipality and three barangays in Mun. of Calamba which ended in Brgy. Solinog; and started in Brgy. Talic, Oroquieta City traversing four more barangays and ended in Brgy. Villaflor, Oroquieta City, Misamis Occidental. It covered an estimated total of 18.401 km with 1,521 validation points. The gaps in the validation line as shown in Figure 43 were due to difficulties in acquiring satellites with the presence of obstruction such as dense canopy cover of trees along the roads. Additionally, portions of the national highway are currently under construction.

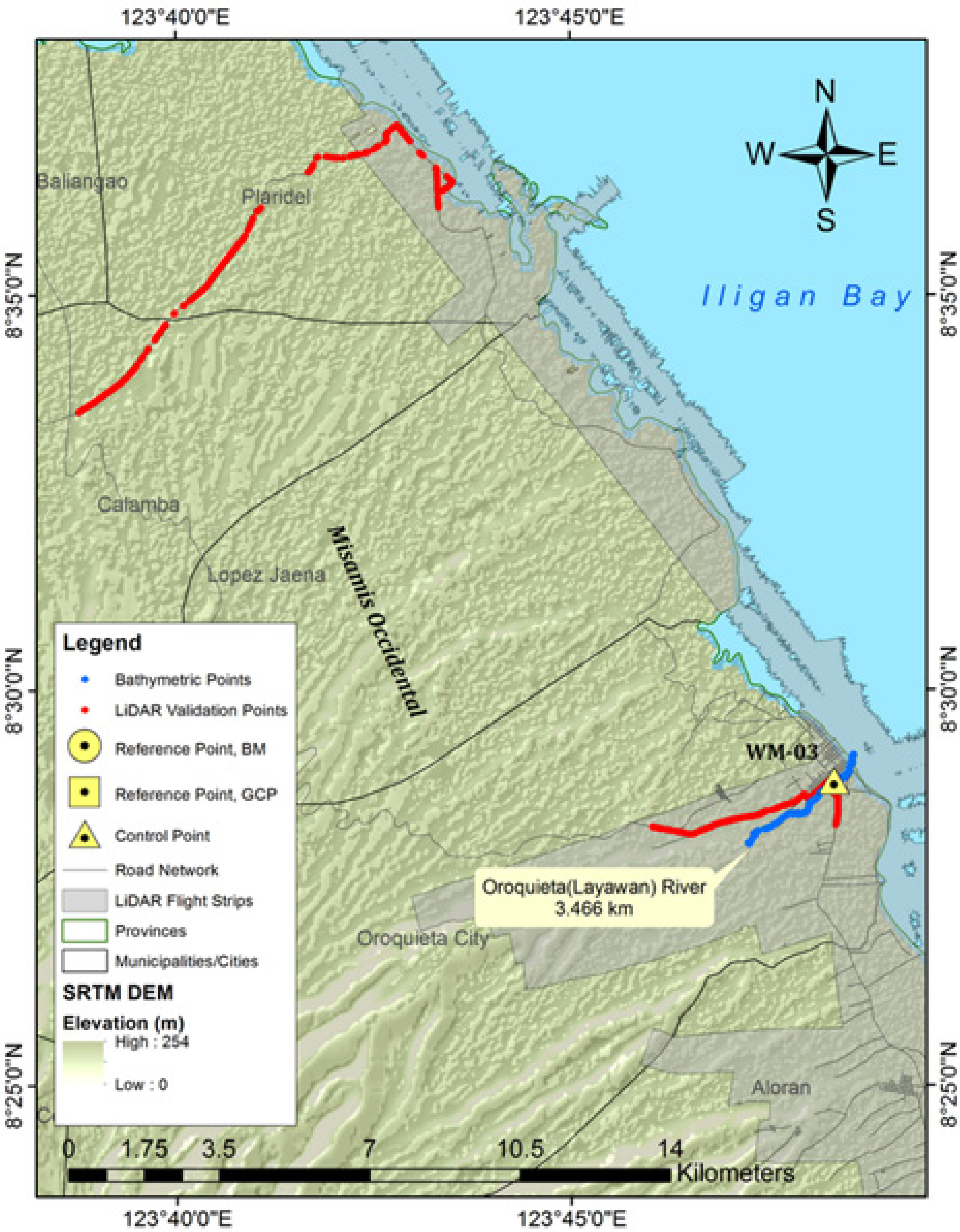

Figure 43. LiDAR ground validation survey coverage for Layawan River Basin

4.7 Bathymetric Survey

Bathymetric survey was executed on June 9 and 10, 2015 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ Single Beam Echo Sounder mounted to a boat as shown in Figure 45. The survey began in Brgy. Villahermosa, Municipality of Polanco with coordinates 8°32'24.43863" 123°22'41.20246", down to the mouth of the river in Brgy. Barra, Dipolog City with coordinates 8°35'26.35898" 123°20'03.55581".

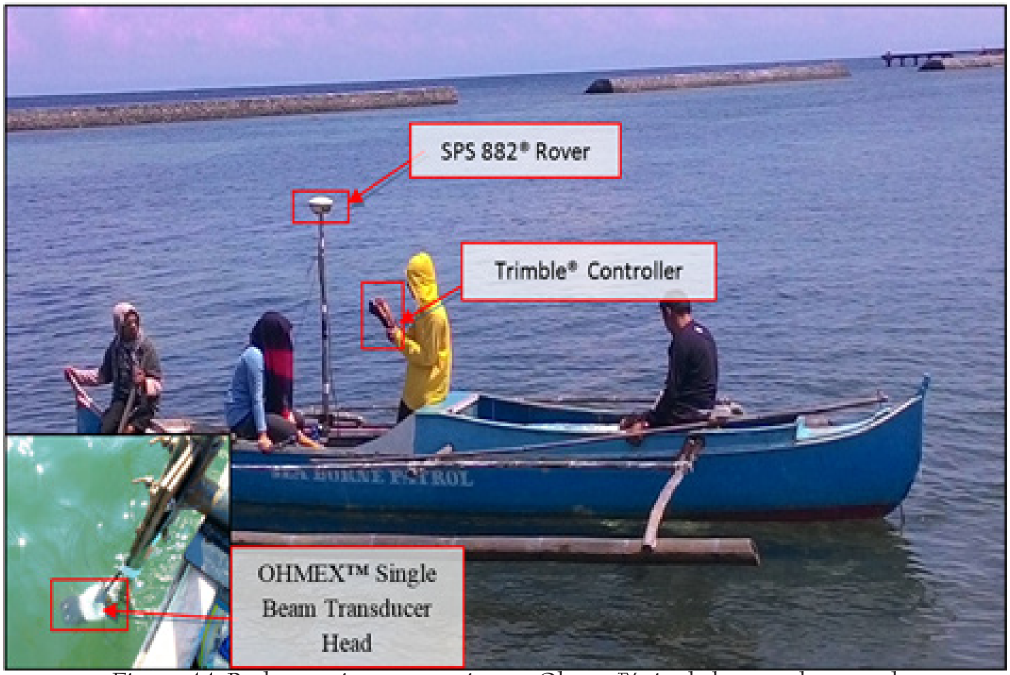

Figure 44. Bathymetric survey using an Ohmex™ single beam echo sounder.

Figure 45. Manual bathymetric survey along Layawan (Layawan) River from the upstream shallow part in Brgy. Talairon down to Brgy. Talic

Manual bathymetric survey on the other hand was conducted on October 10 and 12, 2015 using Trimble® SPS882 in GNSS PPK survey technique as shown in Figure 45. The survey started in the upstream part of the river in Brgy. Talairon, Oroquieta City with coordinates 8°28'04.13887"N, 123°47'16.60489"E, walked down the river by foot and ended at the starting point of bathymetric survey using boat. The control point WM-03 was used as GNSS base station all throughout the bathymetric survey.

The entire bathymetric survey gathered a total of 5,120 points covering a total of 3.466 km of the river traversing seven (7) barangays of Oroquieta City namely: Lower Langcangan, Upper Langcangan, Poblacion II, Taboc Norte, Talairon, Talic and Villaflor as shown in Figure 47. A CAD drawing was also produced to illustrate the riverbed profile of Layawan River. As shown in Figure 47, the highest and lowest elevation has 17-meter difference. The highest elevation observed was 11.502 m in MSL located at the upstream part of the river in Brgy. Talairon, while the lowest elevation value was -6.014 m below MSL located in the downstream part of the river in Brgy. Taboc Norte. The gaps in the bathymetric surveyed were due to difficulties in acquiring satellite caused by the presence of obstructions such as dense canopy cover of trees.

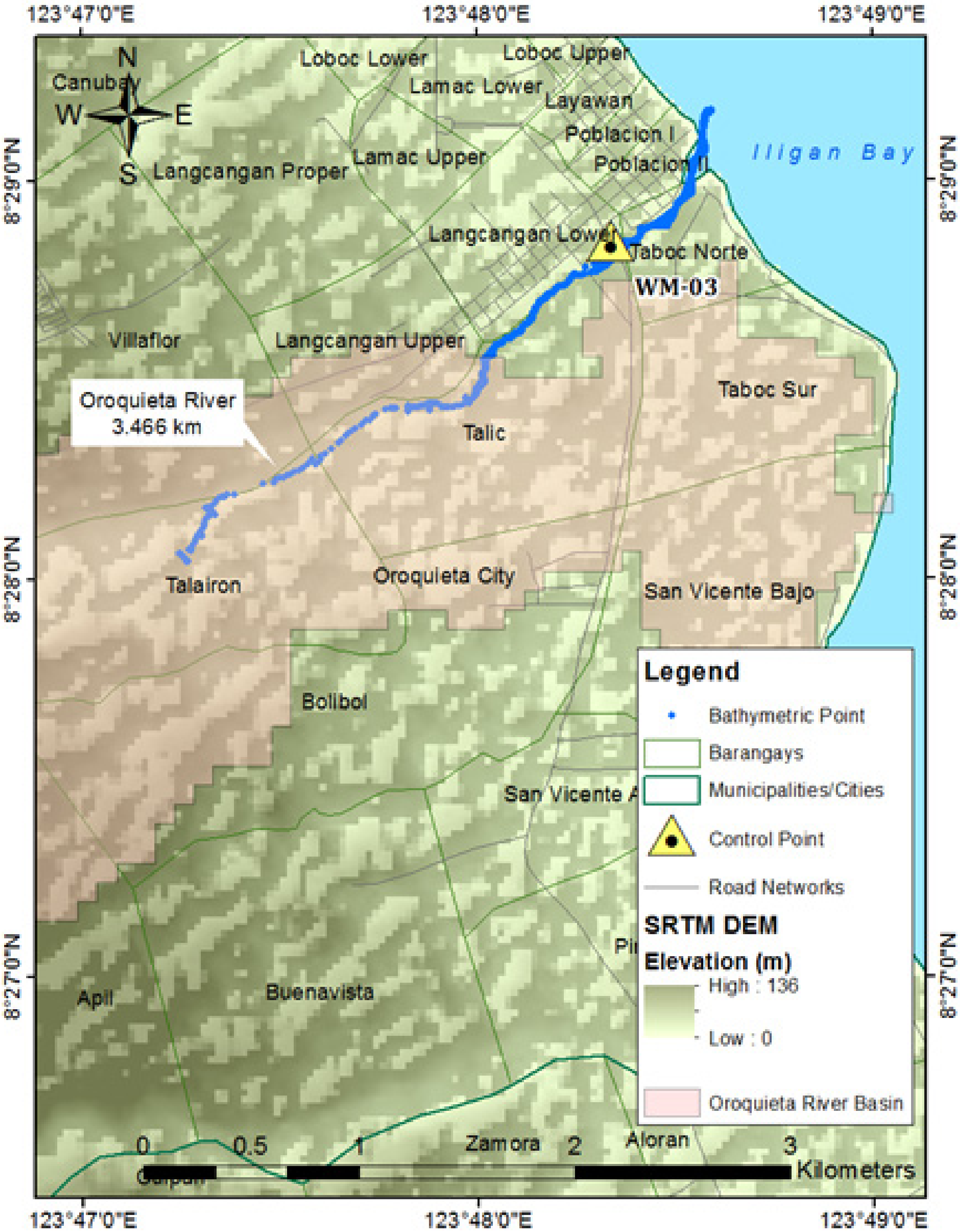

Figure 46. Bathymetric survey of Layawan River

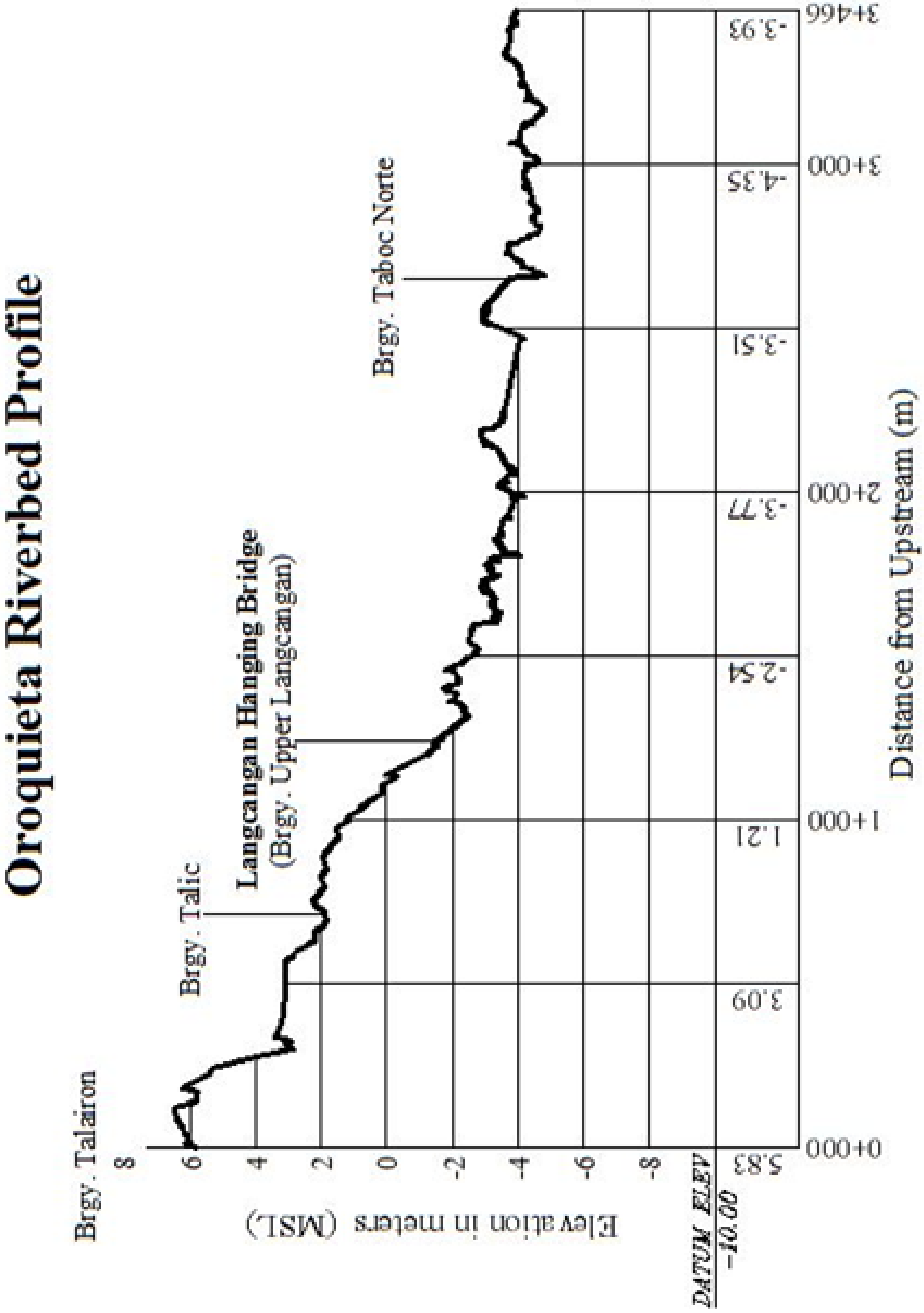

Figure 47. Riverbed profile of Layawan (also known as Oroquieta) River.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1.2 Precipitation

Precipitation data was taken from the Portable Automatic Rain Gauge (ARG) installed upstream by the DOST. The ARG was specifically installed in the municipality of Layawan with coordinates 8°27'35.70" N Latitude and 123°44'36.10"E Longitude. The location of the rain gauge is shown in Figure 48 below.

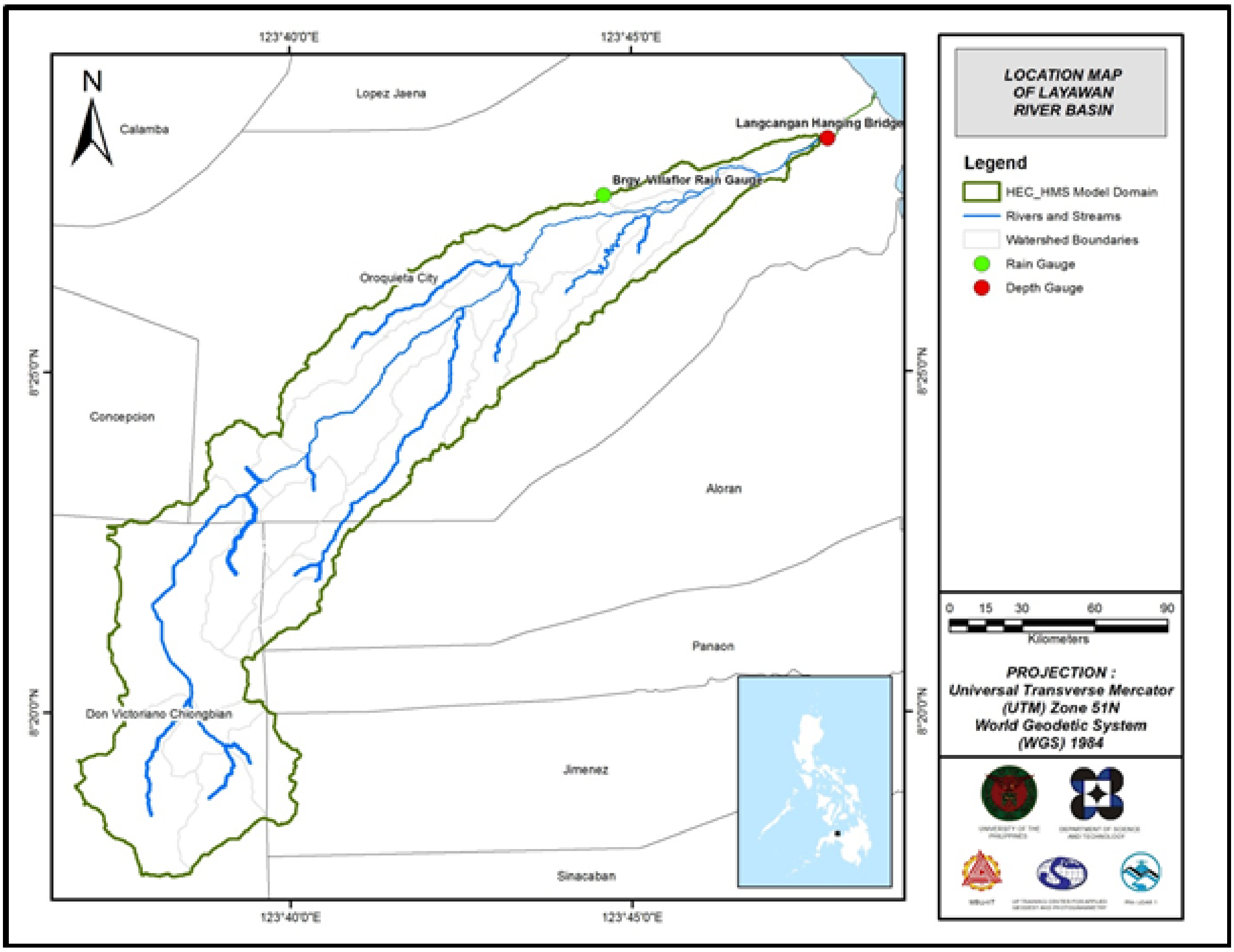

Figure 48. The location map of Layawan HEC-HMS model used for calibration.

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 50 shows the highest R-Squared value of 0.9969 compared to the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

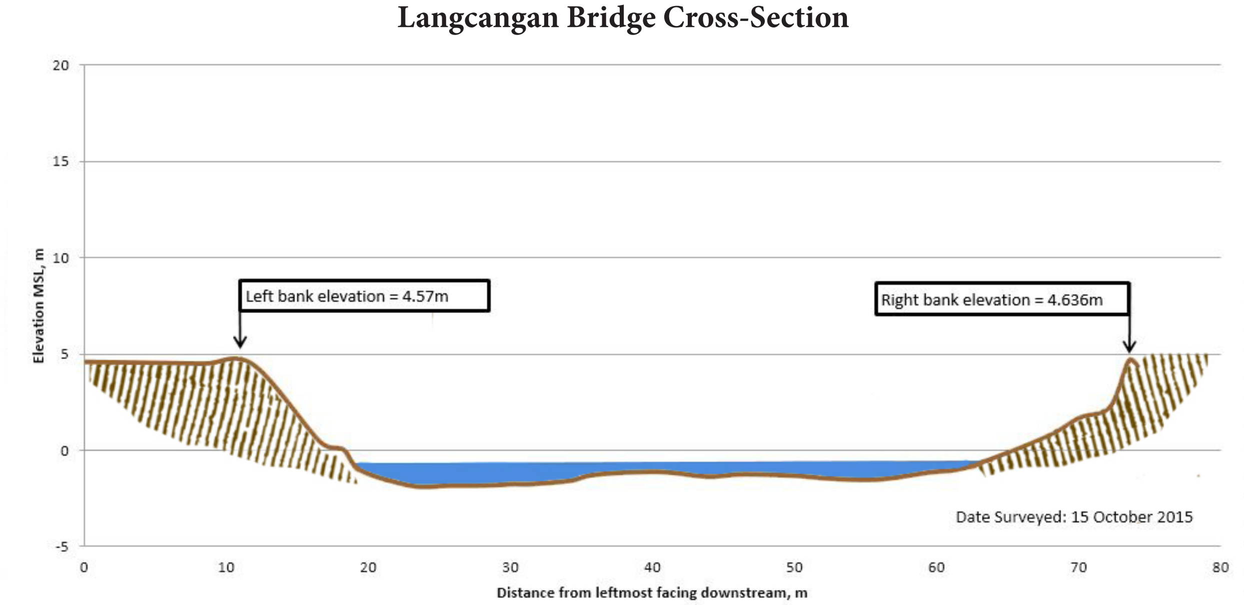

Figure 49. Cross-Section Plot of Upper Lagcangan Bridge.

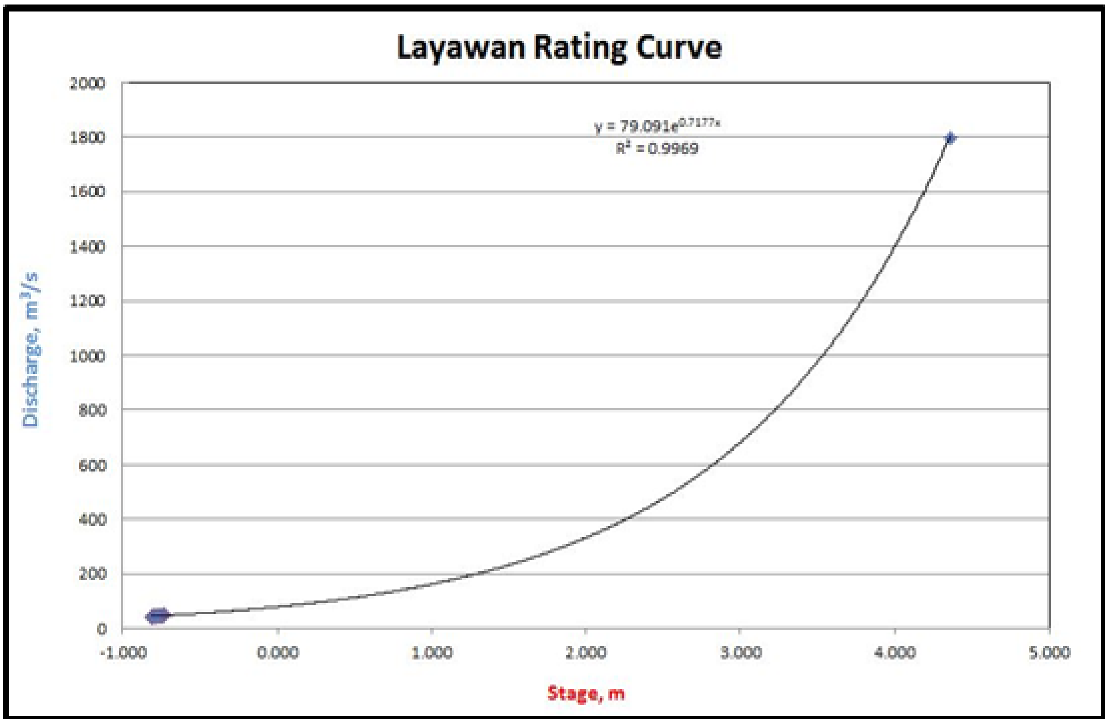

Figure 50. Rating Curve at Upper Langcangan Bridge

This rating curve equation was used to compute the river outflow at Upper Langcangan Bridge for the calibration of the HEC-HMS model.

Total rainfall taken from the ARG at Villaflor Layawan was 59.99 mm. It peaked to 13.52 mm on 18 June 2016, 21:00. The lag time between the peak rainfall and discharge is 1 hour and 50 minutes, as shown in the figure below.

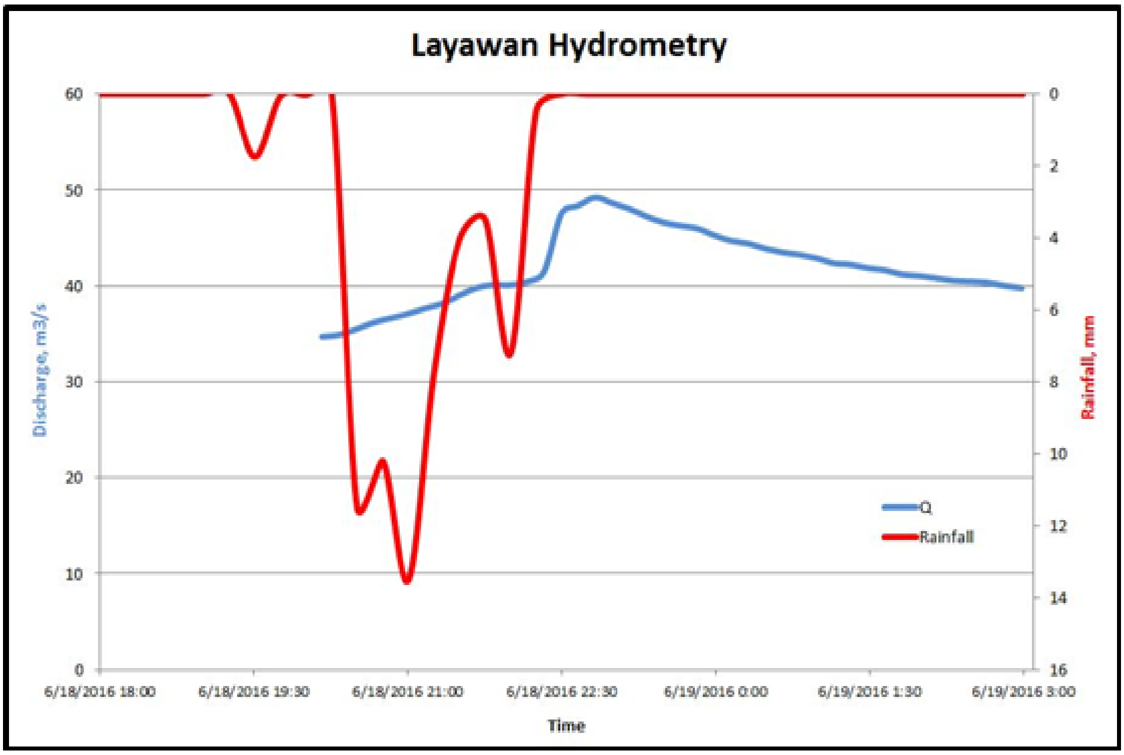

Figure 51. Rainfall and outflow data at Upper Langcangan Bridge used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Dipolog Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Layawan watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 29. 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

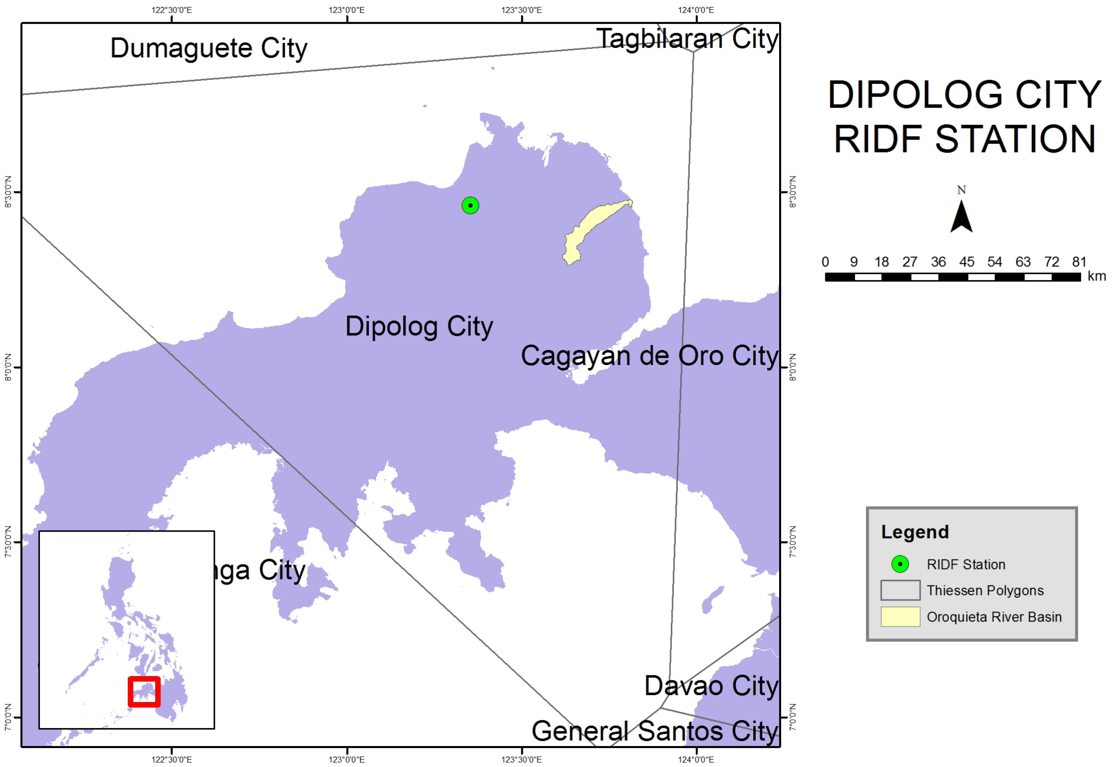

Figure 52. Location of Dipolog RIDF station relative to Layawan (Oroquieta) River Basin.

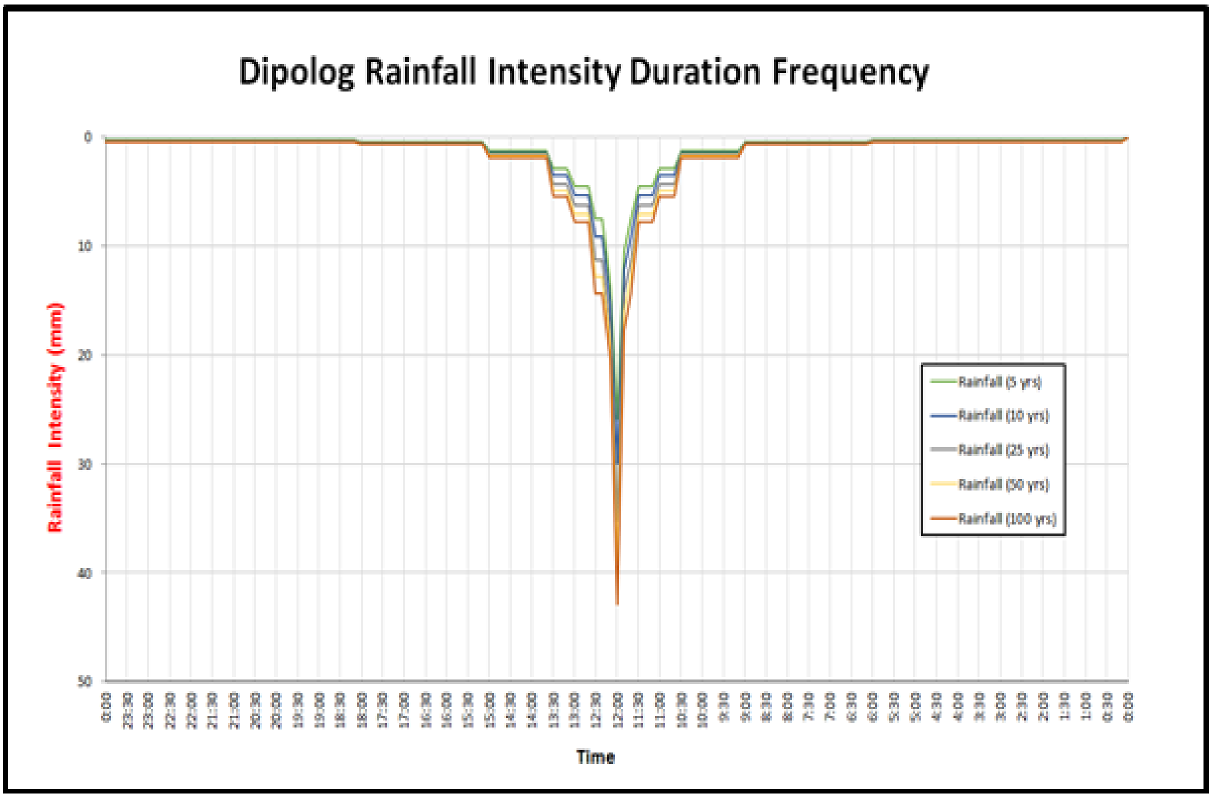

Figure 53. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil texture dataset was generated in 2004 from the Bureau of Soils and Water Management (BSWM); this is under the Department of Agriculture. The soil texture map (Figure 54) of the Layawan River basin was used as one of the factors for the estimation of the CN parameter.

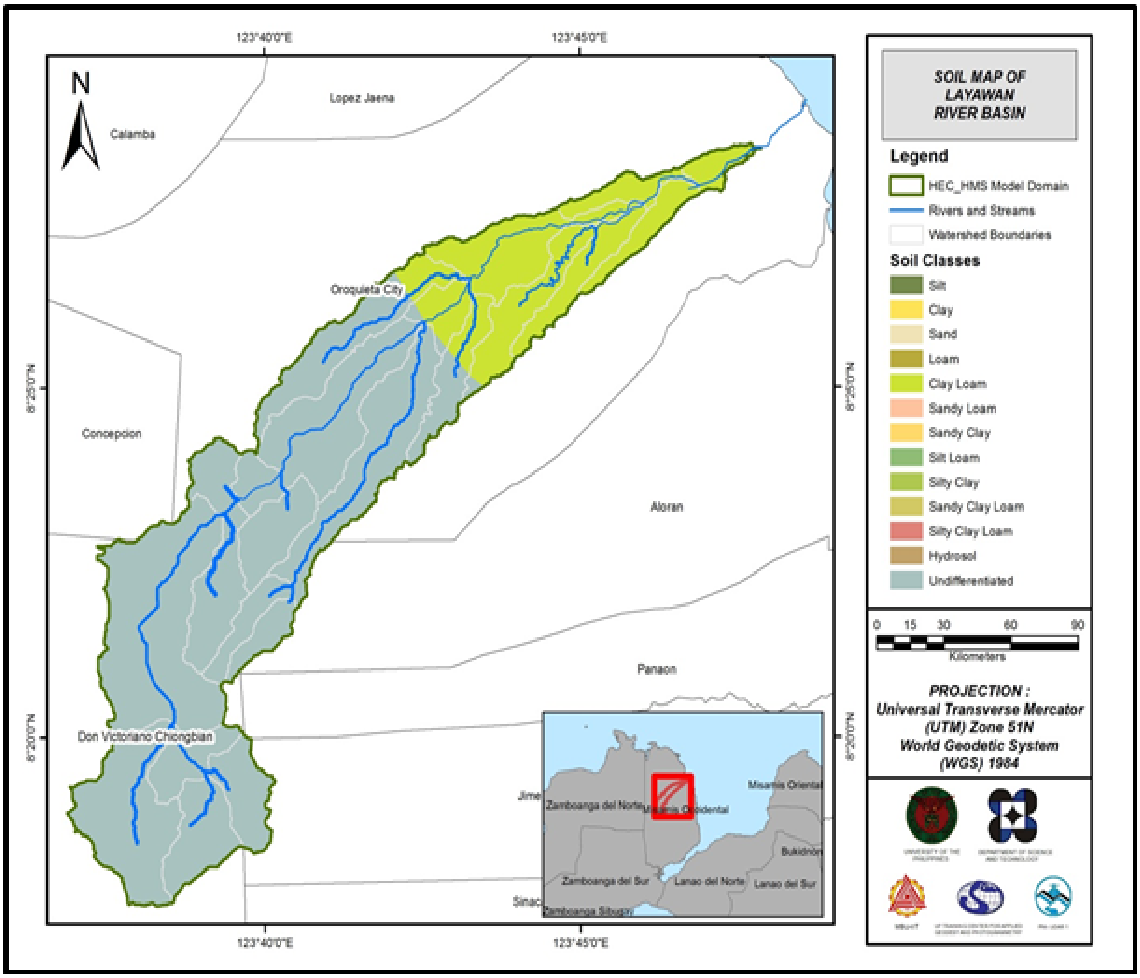

Figure 54. Soil Map of Layawan River Basin

The land cover dataset was generated before 2004 from the National Mapping and Resource information Authority (NAMRIA). Figure 55 shows the land cover of the Layawan River Basin. The land cover map of Layawan River Basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

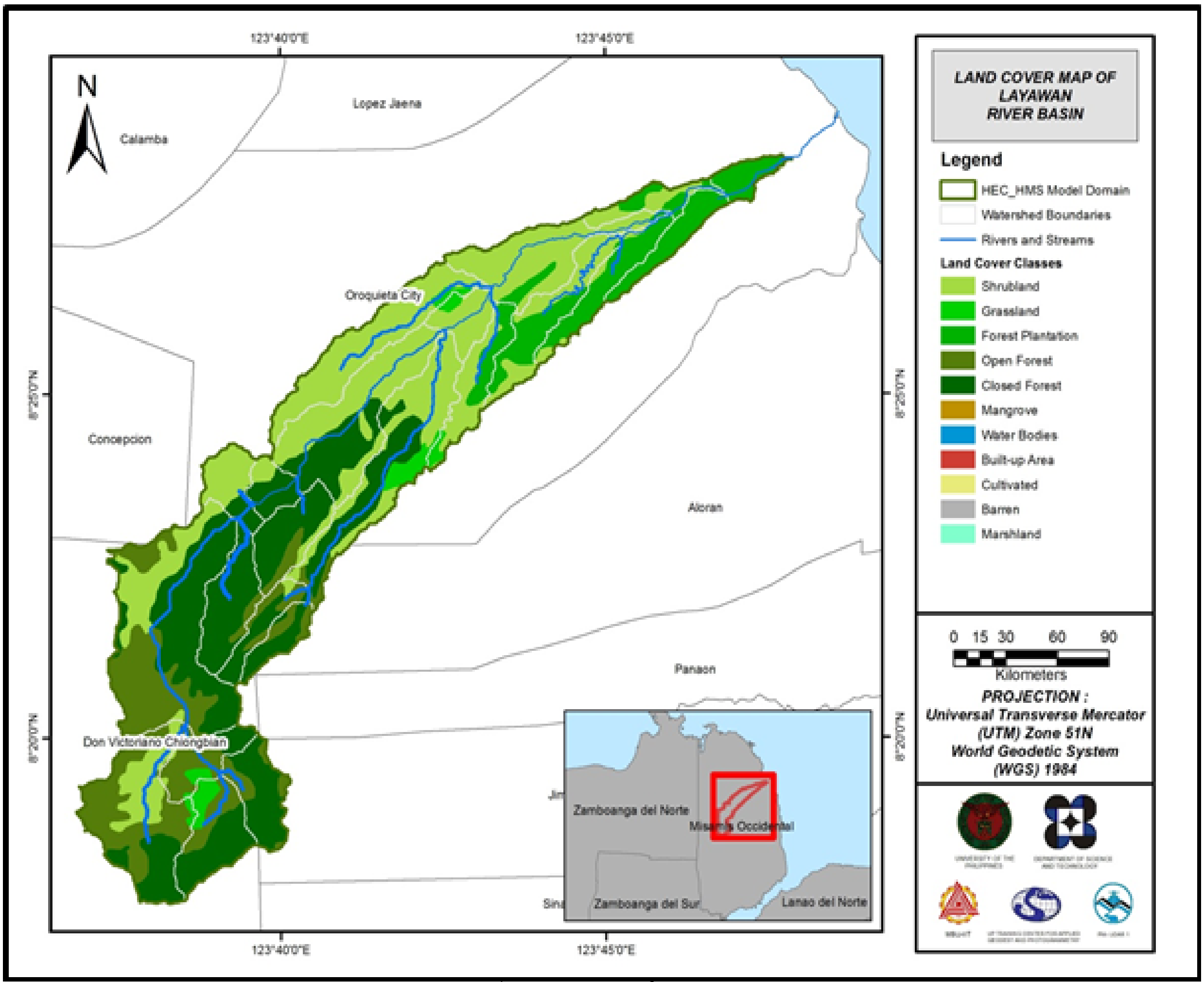

Figure 55. Land Cover Map of Layawan River Basin

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

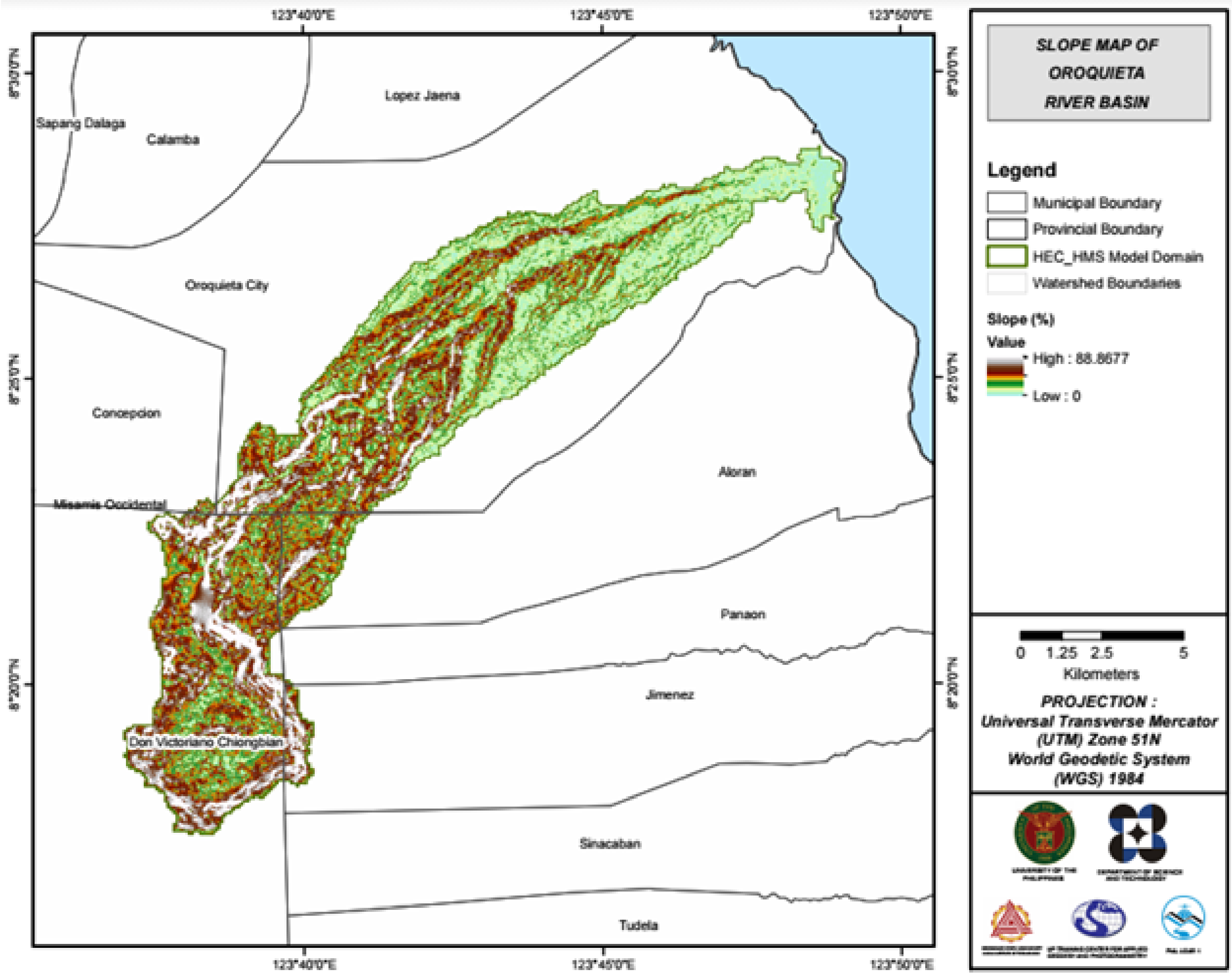

Figure 56. Soil Map of Layawan (also known as Oroquieta)

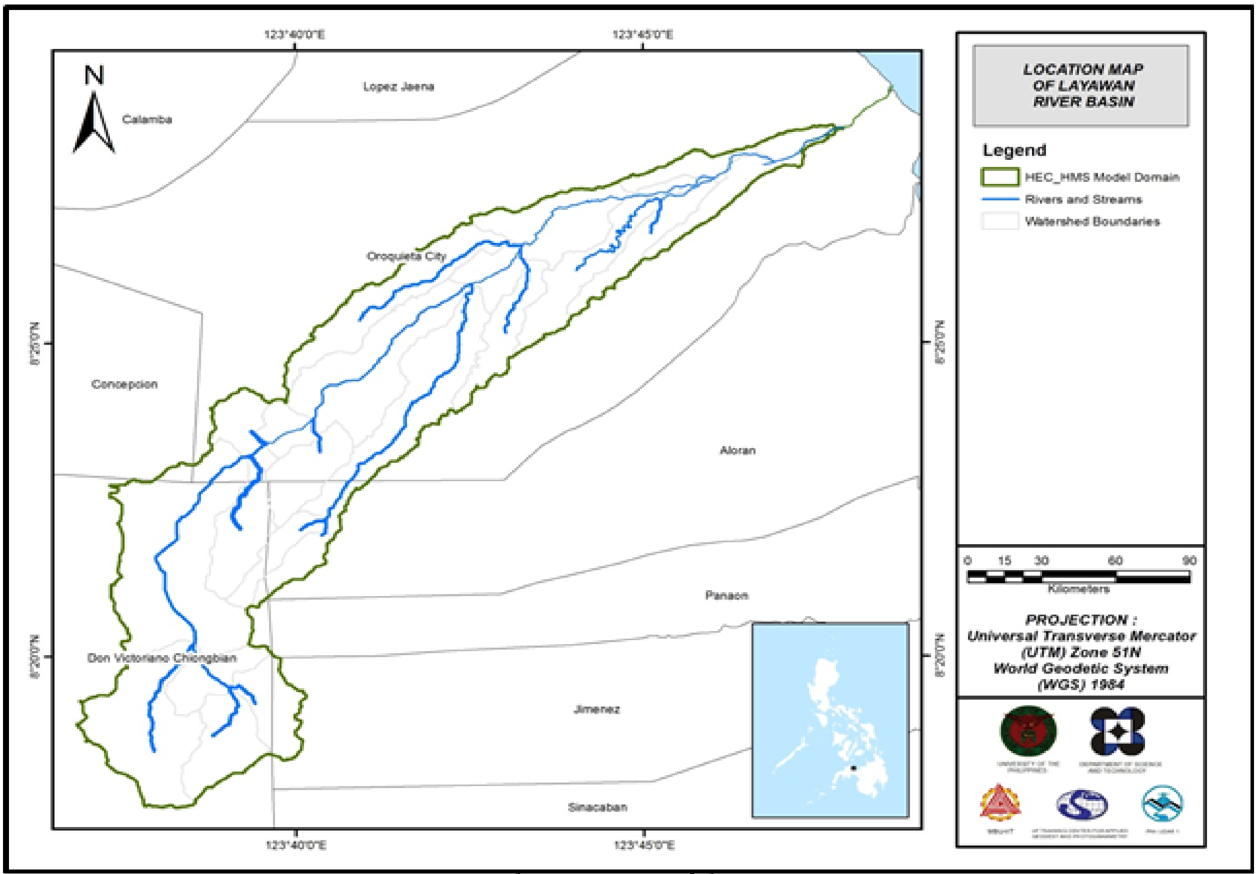

Figure 57. Stream Delineation Map of the Layawan River Basin

Using the SAR-based DEM, the Layawan 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 Upper Langcangan Bridge, Oroquieta City. This basin model is illustrated in Figure 58. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Upper Langcangan Hanging Bridge.

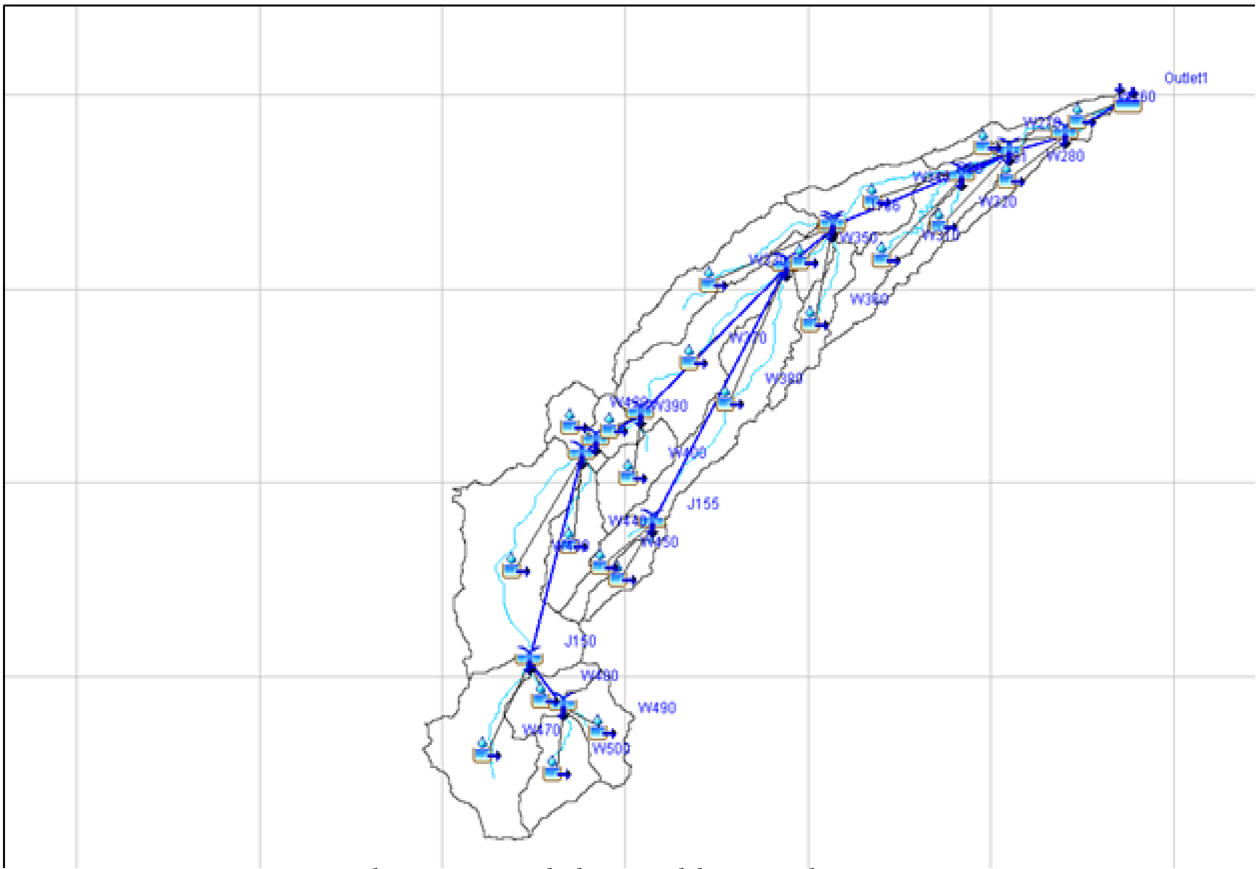

Figure 58. The Layawan Hydrologic Model generated in HEC-GeoHMS

5.4 Cross-section Data

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

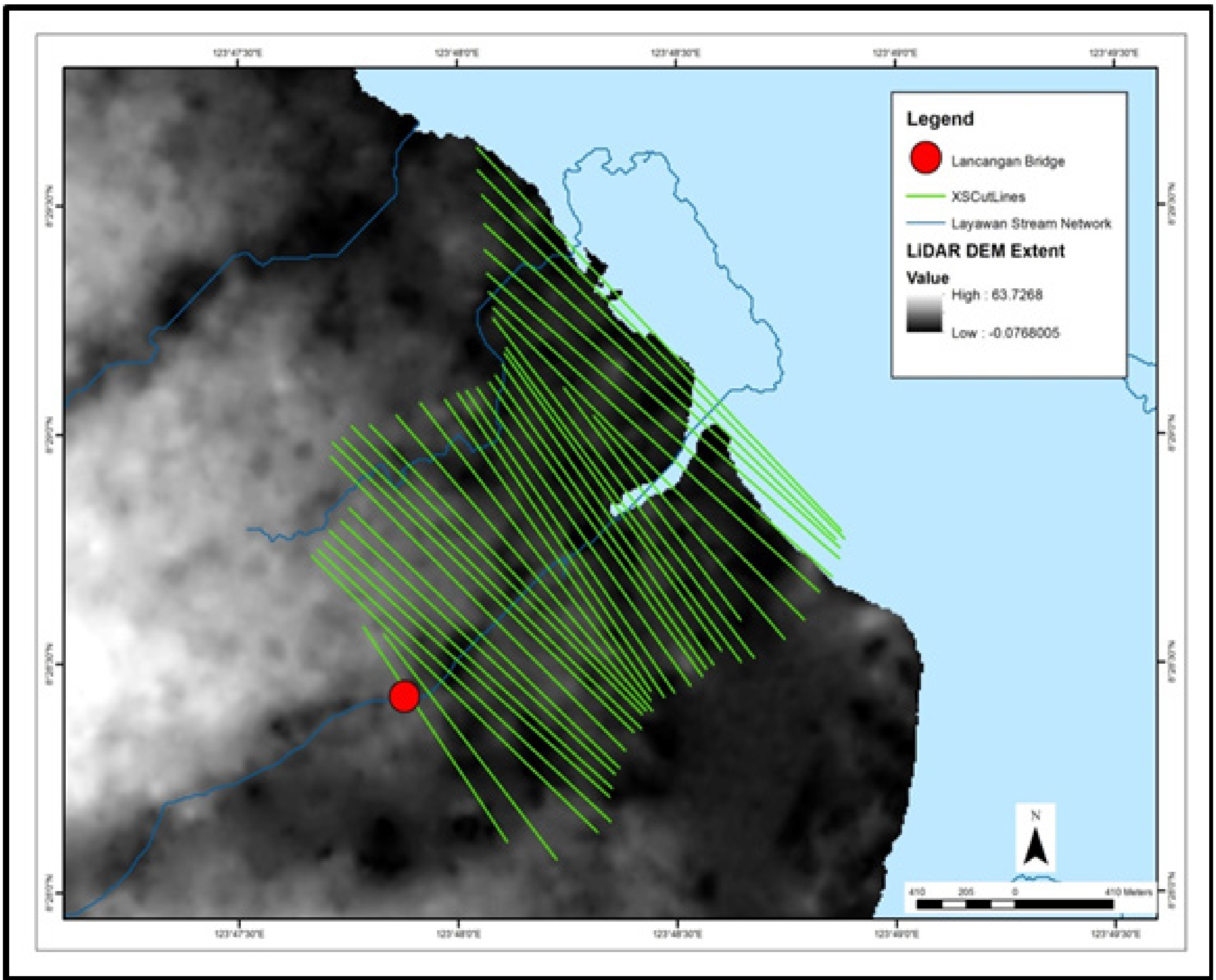

Figure 59. River cross-section of Layawan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 60. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS PRO)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 13.46463 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Dipolog are in Figures 64, 66, and 68.

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 26971900.00 m2. The generated flood depth maps for Dipolog are in Figures 65, 67, and 69.

There is a total of 21585080.45 m3 of water entering the model. Of this amount, 6409927.96 m3 is due to rainfall while 15175152.49 m3 is inflow from other areas outside the model 2251281.00 m3 of this water is lost to infiltration and interception, while 1215681.69 m3 is stored by the flood plain. The rest, amounting up to 18118118.86 m3, is outflow.

5.6 Results of HMS Calibration

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

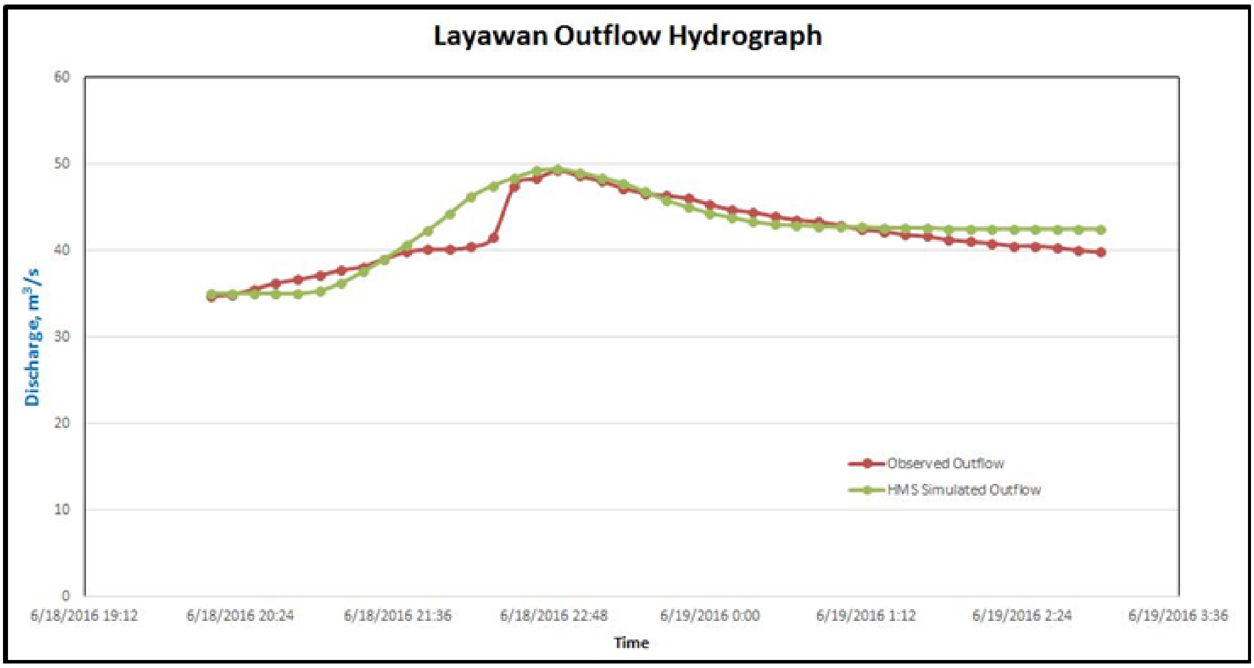

Figure 61. Outflow Hydrograph of Layawan Bridge generated in HEC-HMS model compared with observed outflow

Enumerated in Table 30 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of Calibrated Values for Layawan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	28 - 140
			Curve Number	49 - 83
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.25 - 1
			Storage Coefficient (hr)	0.25 - 1
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

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 28mm to 140mm 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 49 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 0.25 to 1 hour 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 0.04 corresponds to the common roughness in Layawan watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 31. Summary of the Efficiency Test of Layawan HMS Model

Accuracy Measure	Value
RMSE	1.86
r2	0.83
NSE	0.77
PBIAS	-1.53
RSR	0.48

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.86 (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 0.83.

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 0.77.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -1.53.

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 0.48.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 62) shows the Layawan 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.

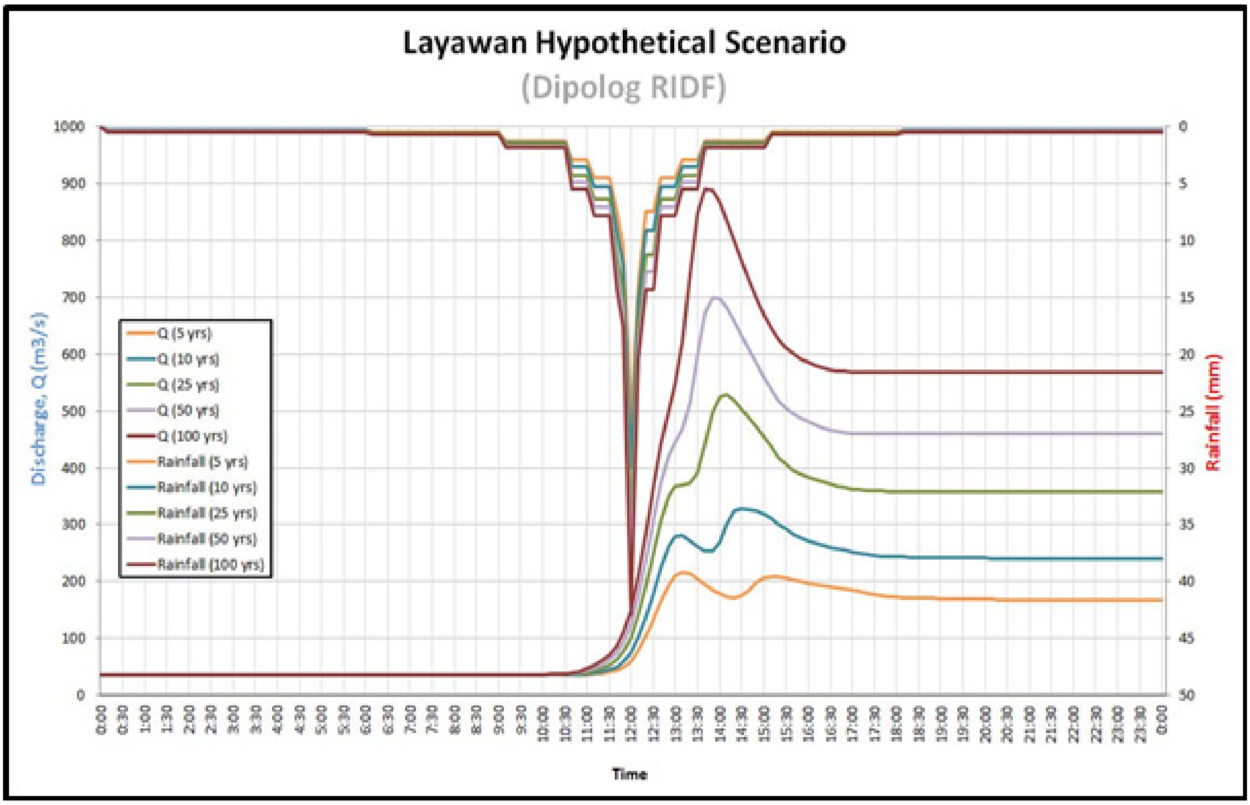

Figure 62. Outflow hydrograph at Layawan Station generated using Dipolog RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Layawan discharge using the Dipolog Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 32.

Table 32. Peak values of the Dipolog HEC-HMS Model outflow using Dipolog RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	178.32	25.9	216.7	3 hours 10 mins
10-Year	206.37	30	329	4 hours 30 mins
25-Year	241.91	35.2	528.5	4 hours 10 mins
50-Year	268.14	39	699.7	3 hours 50 mins
100-Year	294.55	42.9	891.1	3 hours 40 mins

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Layawan River using the calibrated HMS base flow is shown in Figure 63.

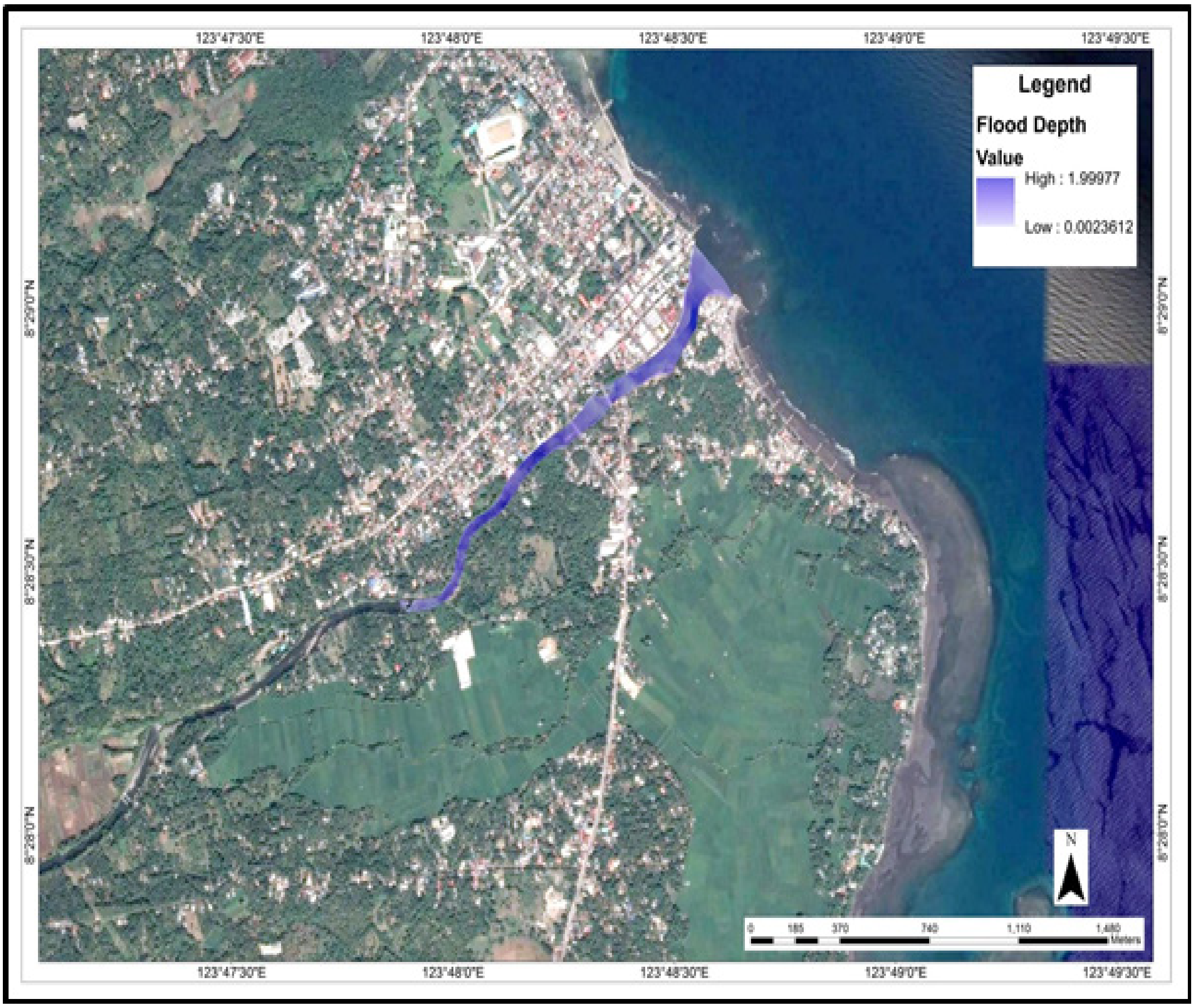

Figure 63. Sample output of Layawan RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 64 to Figure 69 shows the 5-, 25-, and 100-year rain return scenarios of the Layawan floodplain. The floodplain, with an area of 118.81 sq. km., covers Oroquieta City and five municipalities namely Aloran, Concepcion, Don Victoriano Chiongbian, Jimenez, and Panaon. Table 33 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Layawan Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Aloran	105.66	5.61	5%
Concepcion	63.46	0.05	0.1%
Don Victoriano Chiongbian	307.71	35.26	11%
Jimenez	78.47	1.80	2%
Oroquieta City	195.63	75.93	39%
Panaon	52.52	0.01	0.01%

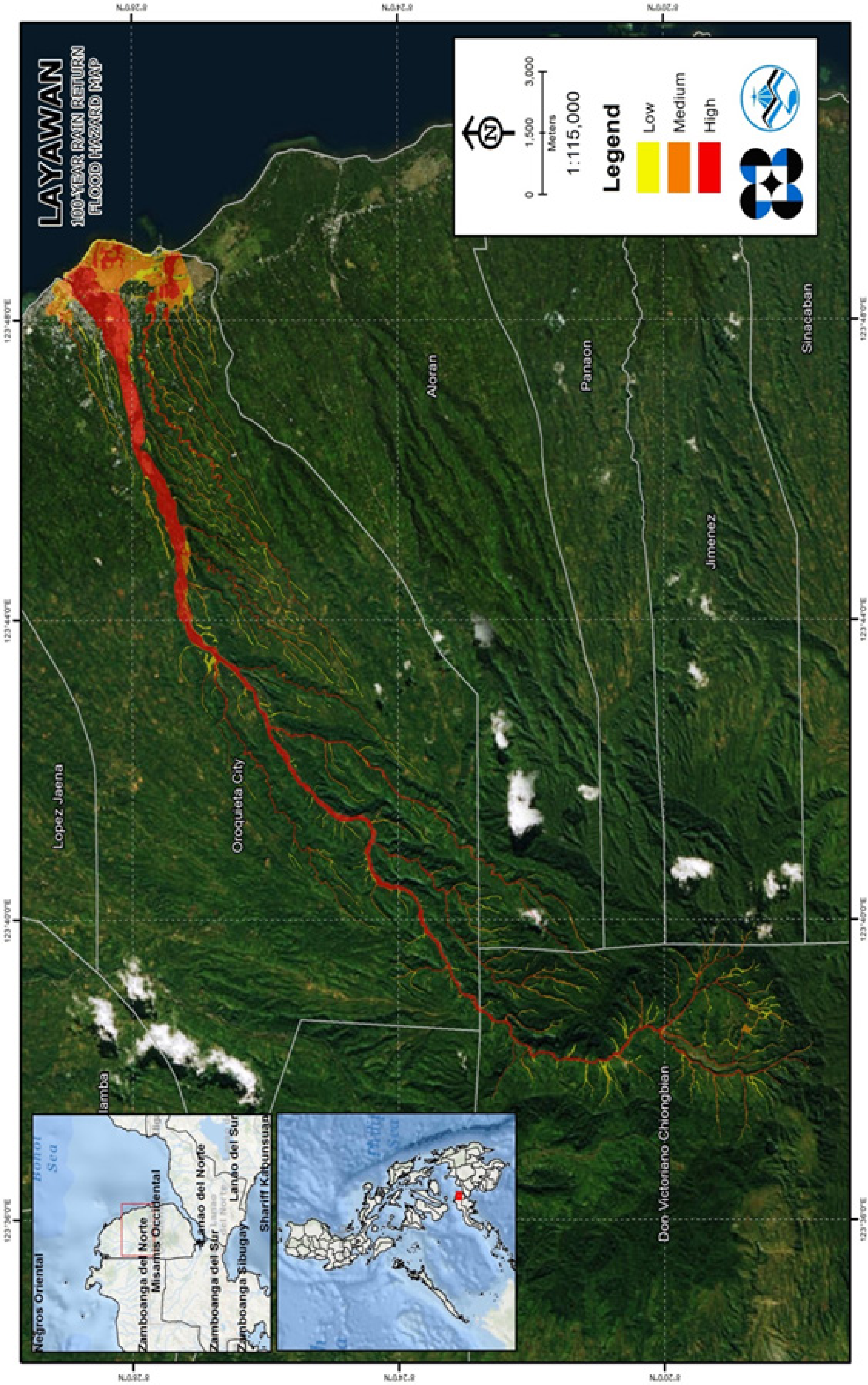

Figure 64. 100-year Hazard Map for Layawan Floodplain overlaid on Google Earth imagery

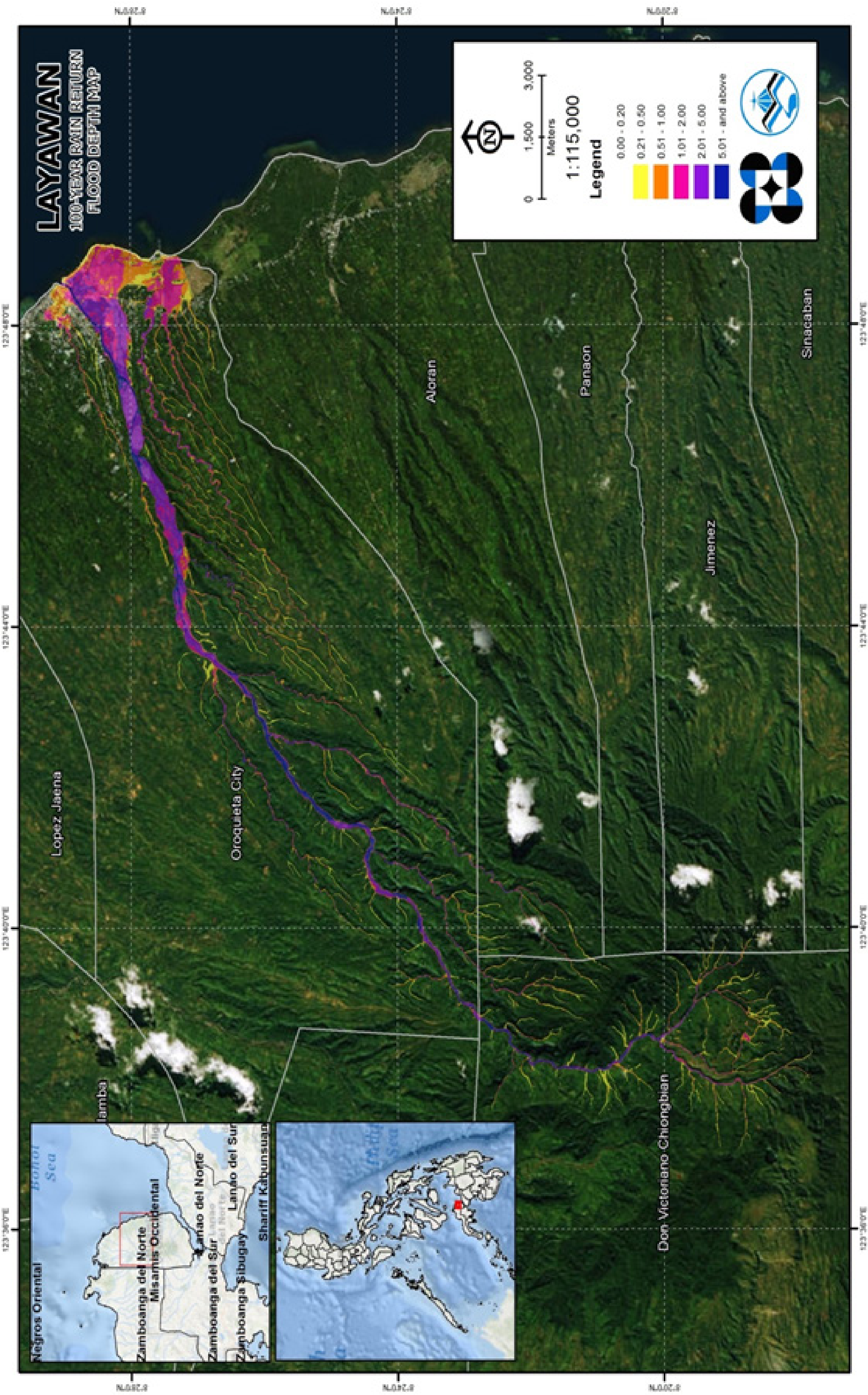

Figure 65. 100-year Flow Depth Map for Layawan Floodplain overlaid on Google Earth imagery

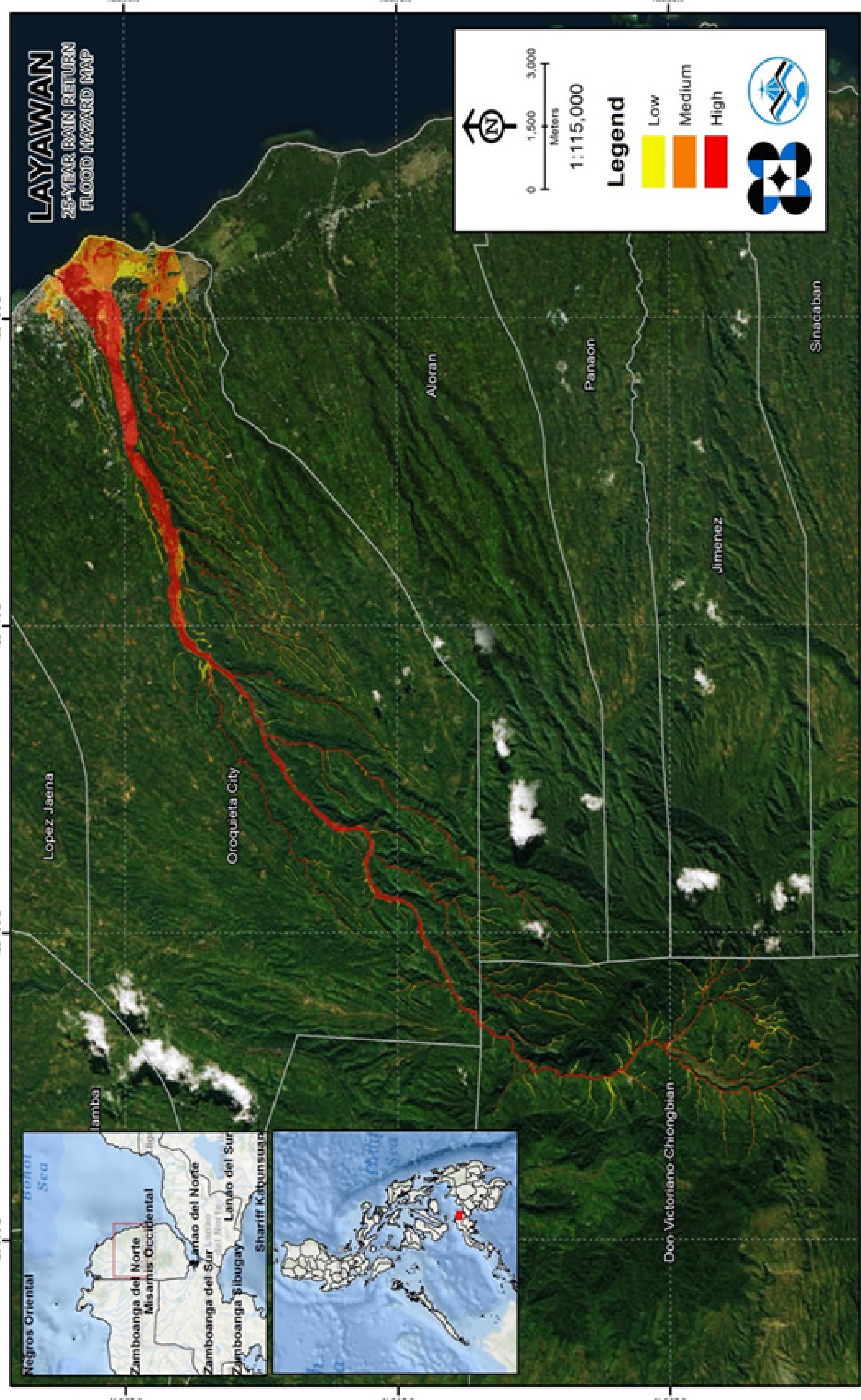

Figure 66. 25-year Hazard Map for Layawan Floodplain overlaid on Google Earth imagery

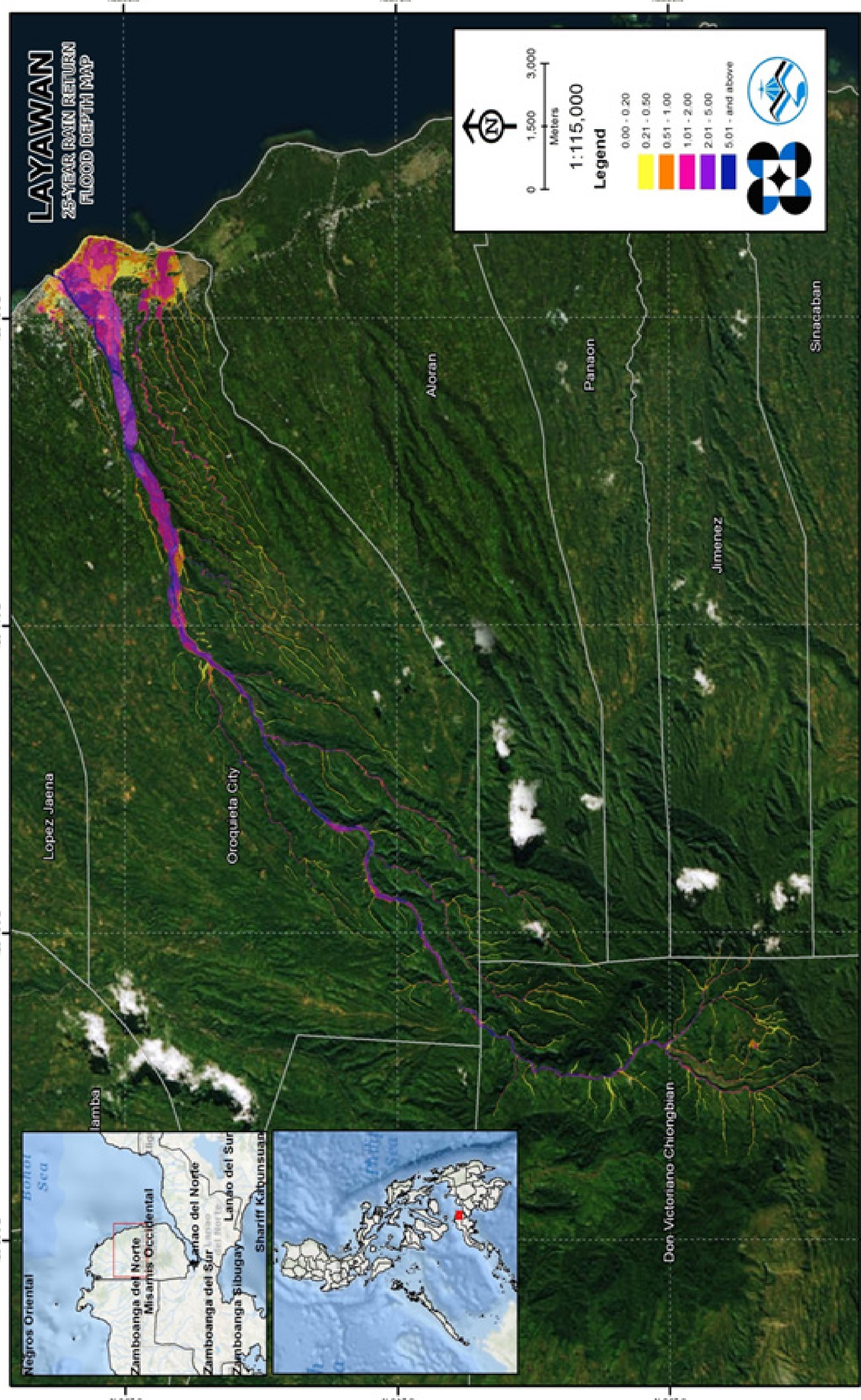

Figure 67. 25-year Flow Depth Map for Layawan Floodplain overlaid on Google Earth imagery

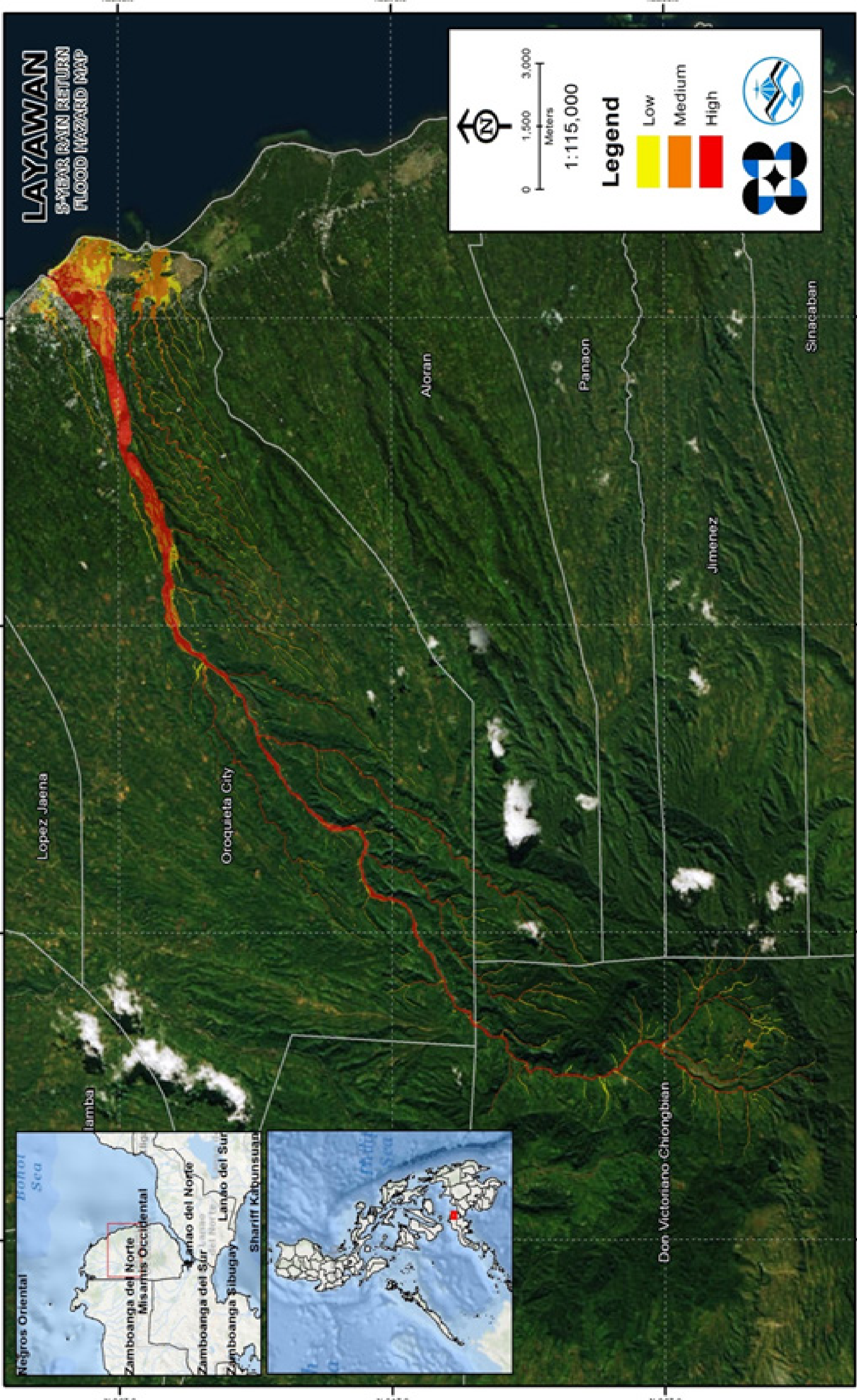

Figure 68. 5-year Hazard Map for Layawan Floodplain overlaid on Google Earth imagery

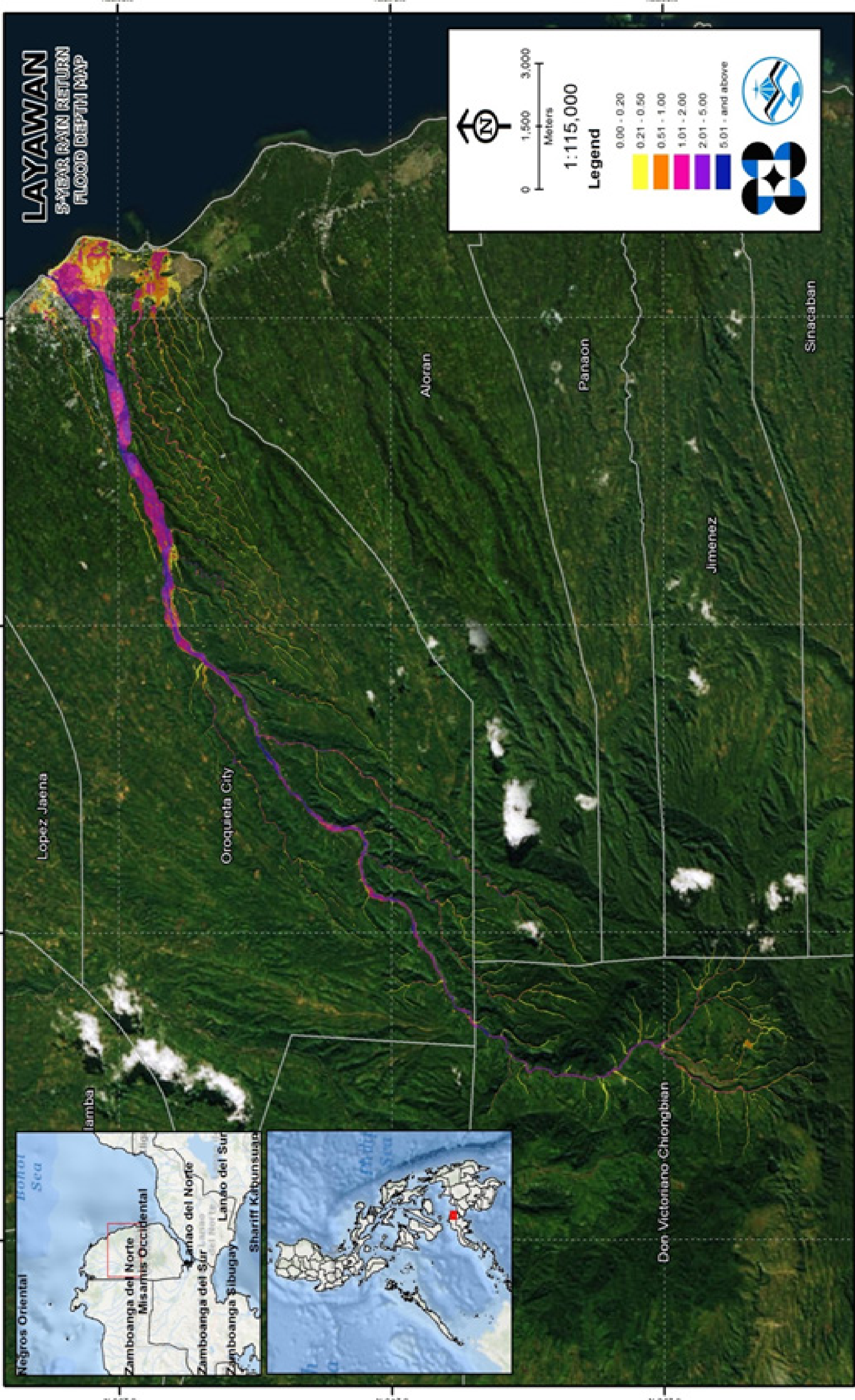

Figure 69. 5-year Flow Depth Map for Layawan Floodplain overlaid on Google Earth imager

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Layawan river basin, grouped by municipality, are listed below. For the said basin, six municipalities consisting of 42 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 5.10% of the municipality of Aloran with an area of 105.66 sq. km. will experience flood levels of less 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.03%, 0.02%, 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 34 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Aloran, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Aloran				
	Conat	Roxas	San Pedro	Sinampongan	Tugaya
0.03-0.20	0.024	2.22	0.84	2.02	0.3
0.21-0.50	0.0077	0.028	0.018	0.041	0.0073
0.51-1.00	0.0073	0.025	0.014	0.01	0.00046
1.01-2.00	0.00095	0.024	0.0015	0.0094	0
2.01-5.00	0	0.002	0	0.016	0
> 5.00	0	0	0	0.0016	0

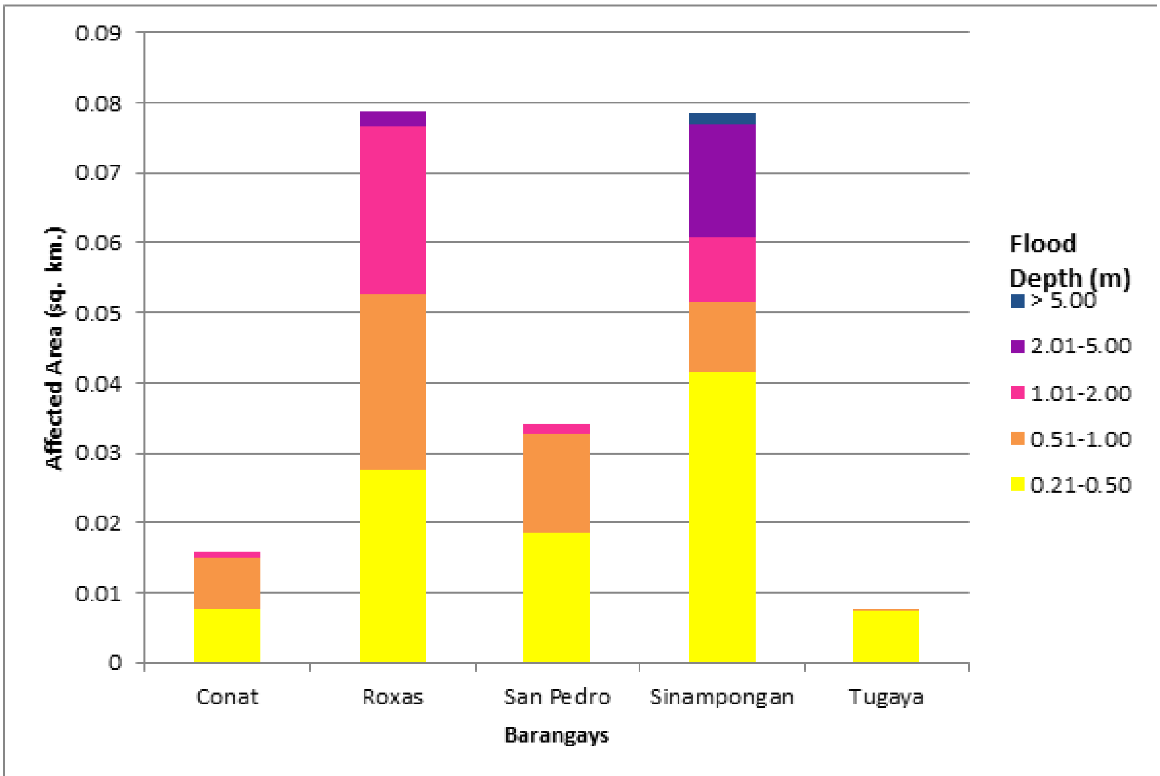

Figure 70. Affected Areas in Aloran, Misamis Occidental during 5-Year Rainfall Return Period

For the municipality of Concepcion, with an area of 63.46 sq. km., only the barangay of Upper Dioyo will experience flooding at 0.08%. Only flood level of less 0.20 meters is projected.

Table 35. Affected Areas in Concepcion, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Concepcion
	Upper Dioyo
0.03-0.20	0.049
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

For the municipality of Don Victoriano Chiongbian, with an area of 307.71 sq. km., 10.92% will experience flood levels of less 0.20 meters. 0.28% of the area will experience flood levels of 0.21 to 0.50 meters while 0.11%, 0.07%, 0.08%, and 0.008% 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 kilometres by flood depth per barangay.

Table 36. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.)	Affected Barangays in Don Victoriano Chiongbian				
	Gandawan	Lake Duminagat	Lalud	Liboron	Napangan
0.03-0.20	0.02	17	0.075	9	7.5
0.21-0.50	0	0.45	0	0.19	0.22
0.51-1.00	0	0.18	0	0.07	0.1
1.01-2.00	0	0.13	0	0.048	0.021
2.01-5.00	0	0.13	0	0.1	0.0005
> 5.00	0	0.0042	0	0.021	0

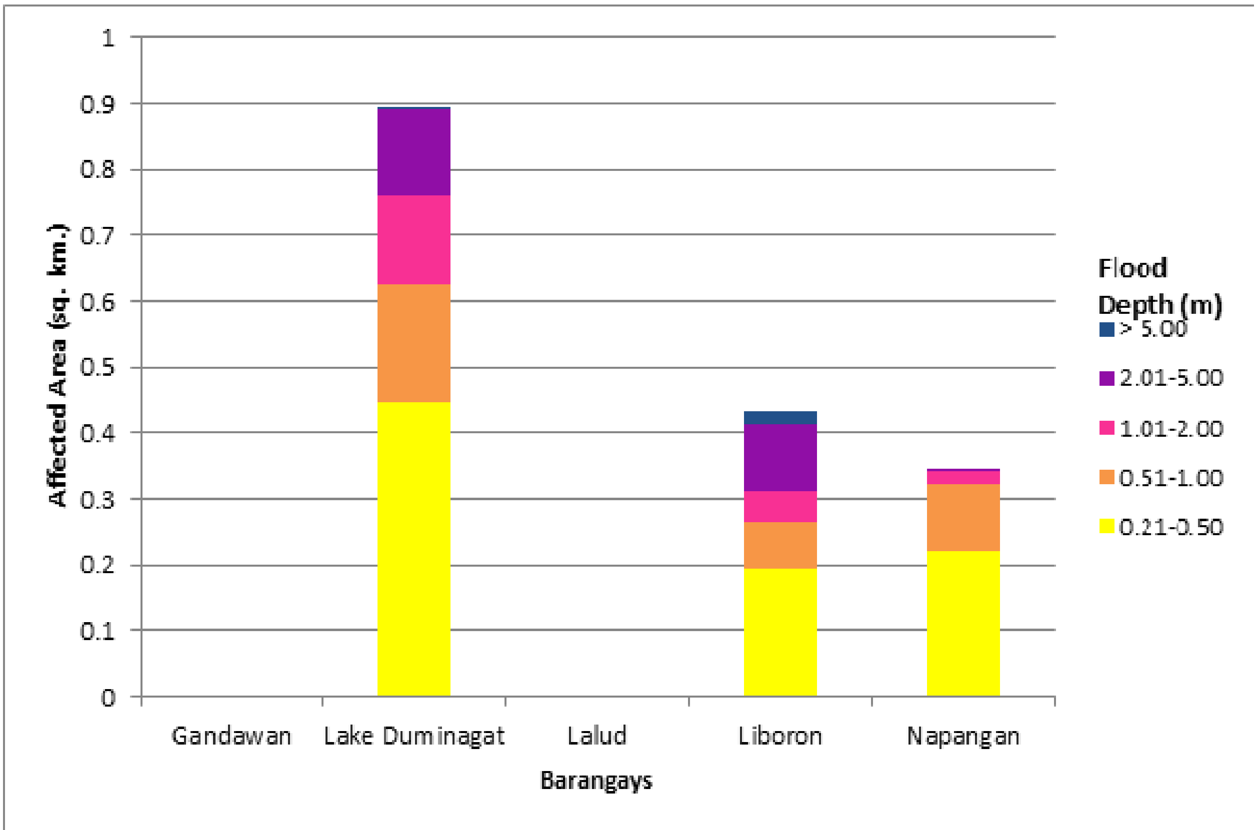

Figure 71. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 5-Year Rainfall Return Period

For the municipality of Jimenez, with an area of 78.48 sq. km., 2.27% will experience flood levels of less 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.005%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Jimenez, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Jimenez
	Guintomoyan
0.03-0.20	1.78
0.21-0.50	0.018
0.51-1.00	0.004
1.01-2.00	0.001
2.01-5.00	0
> 5.00	0

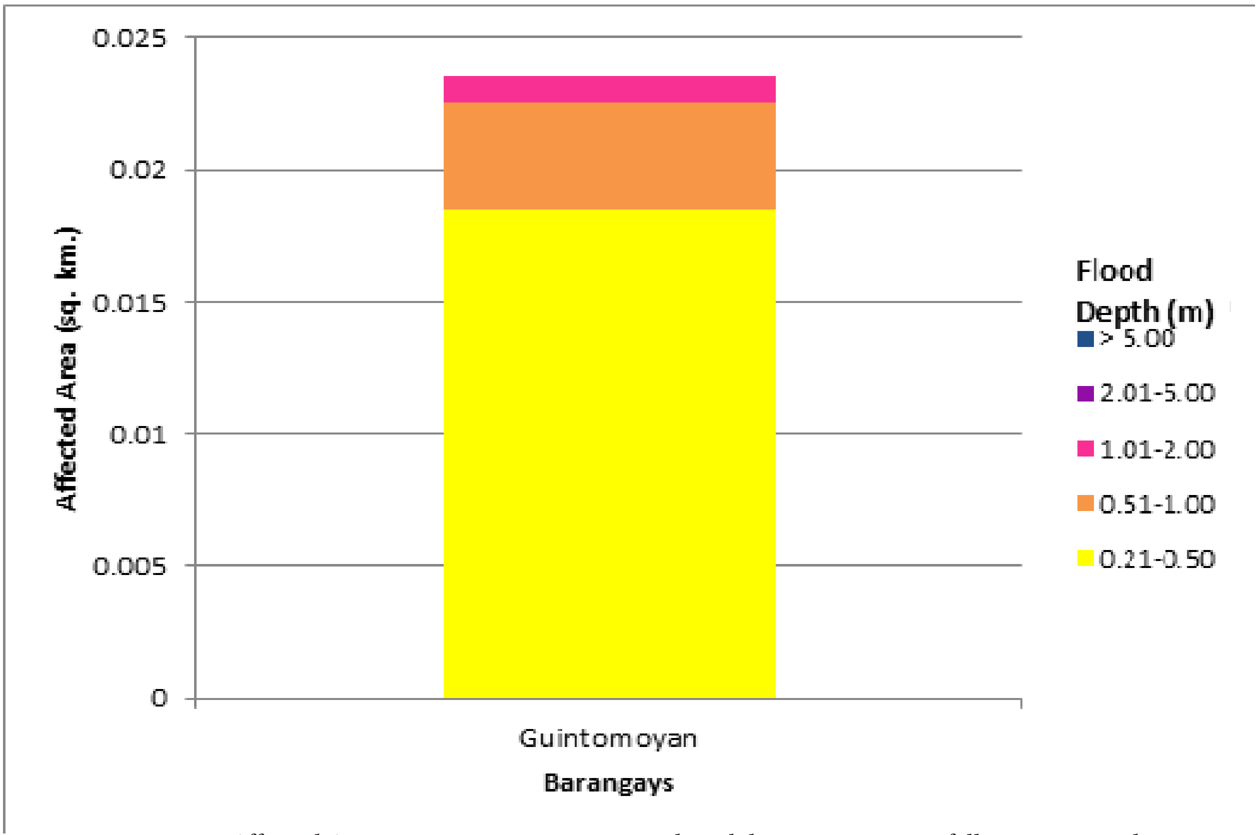

Figure 72. Affected Areas in Jimenez, Misamis Occidental during 5-Year Rainfall Return Period

For the city of Oroquieta, with an area of 195.627 sq. km., 33.04% will experience flood levels of less 0.20 meters. 1.40% of the area will experience flood levels of 0.21 to 0.50 meters while 1.27%, 1.81%, 1.15%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Oroquieta City, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Oroquieta City													
	Apil	Bolibol	Buenavista	Buntawan	Dolipos Alto	Dolipos Bajo	Dullan Norte	Dullan Sur	Lamac Lower	Lamac Upper	Langcan-gan Lower	Langcan-gan Proper	Langcan-gan Upper	Layawan
0.03-0.20	2.64	1.87	1.59	2.4	3.28	3.83	2.76	1.61	0.069	0.16	0.36	0.27	0.52	0.019
0.21-0.50	0.12	0.073	0.089	0.16	0.093	0.12	0.091	0.067	0.012	0.0079	0.072	0.0047	0.023	0.03
0.51-1.00	0.1	0.087	0.075	0.13	0.051	0.088	0.018	0.047	0.043	0.0065	0.048	0.011	0.003	0.012
1.01-2.00	0.05	0.16	0.02	0.18	0.034	0.2	0.011	0.0089	0.0058	0.009	0.032	0.0032	0.013	0
2.01-5.00	0.0078	0.024	0.00044	0.21	0.024	0.31	0.0012	0.0002	0	0	0.016	0	0.0037	0
> 5.00	0	0	0	0.013	0.0038	0.026	0	0	0	0	0.0048	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Oroquieta City													
	Mialen	Pines	Poblacion I	Poblacion II	San Vicente Alto	San Vicente Bajo	Sebucal	Taboc Norte	Taboc Sur	Talairon	Talic	Toliyok	Victoria	Villaflor
0.03-0.20	29.61	0.42	0.048	0.045	0.46	0.78	1.19	0.011	0.054	0.71	0.029	1.83	5.27	2.77
0.21-0.50	0.45	0.17	0.035	0.046	0.14	0.25	0.056	0.03	0.26	0.024	0.025	0.066	0.11	0.12
0.51-1.00	0.27	0.11	0.0025	0.028	0.31	0.2	0.031	0.036	0.37	0.026	0.14	0.081	0.081	0.079
1.01-2.00	0.39	0.09	0	0.00053	0.13	0.098	0.015	0.21	0.2	0.32	0.77	0.2	0.079	0.31
2.01-5.00	0.51	0	0	0.000001	0	0.00033	0.0003	0.038	0.0013	0.36	0.19	0.21	0.15	0.18
> 5.00	0.12	0	0	0	0	0	0	0.0031	0	0.047	0.063	0.025	0.01	0.01

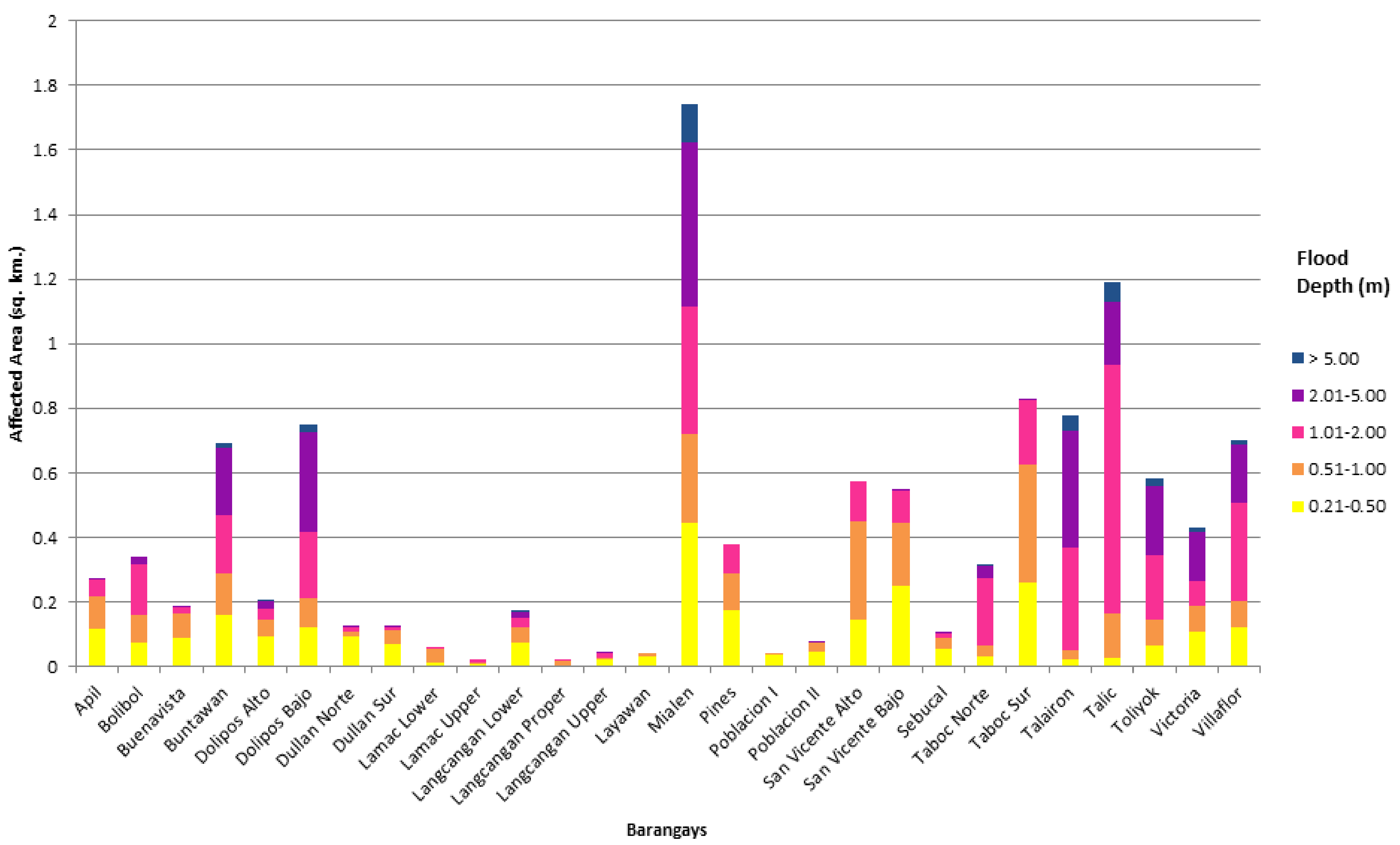

Figure 73. Affected Areas in Oroquieta City, Misamis Occidental during 5-Year Rainfall Return Period

For the municipality of Panaon, with an area of 52.52 sq. km., only the barangay of Bangko will experience flooding at 0.01%. Only flood level of less 0.20 meters is projected.

Table 39. Affected Areas in Panaon, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Panaon
	Bangko
0.03-0.20	0.007
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

For the 25-year return period, 5.04% of the municipality of Aloran with an area of 105.66 sq. km. will experience flood levels of less 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.05%, 0.02%, and 0.005% 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 kilometres by flood depth per barangay.

Table 40. Affected Areas in Aloran, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)				
	Conat	Roxas	San Pe-dro	Sinampongan	Tugaya
0.03-0.20	0.014	2.2	0.83	1.99	0.3
0.21-0.50	0.0088	0.025	0.018	0.062	0.0082
0.51-1.00	0.012	0.026	0.015	0.012	0.0024
1.01-2.00	0.0048	0.032	0.0073	0.0099	0
2.01-5.00	0	0.0073	0	0.018	0
> 5.00	0	0	0	0.0052	0

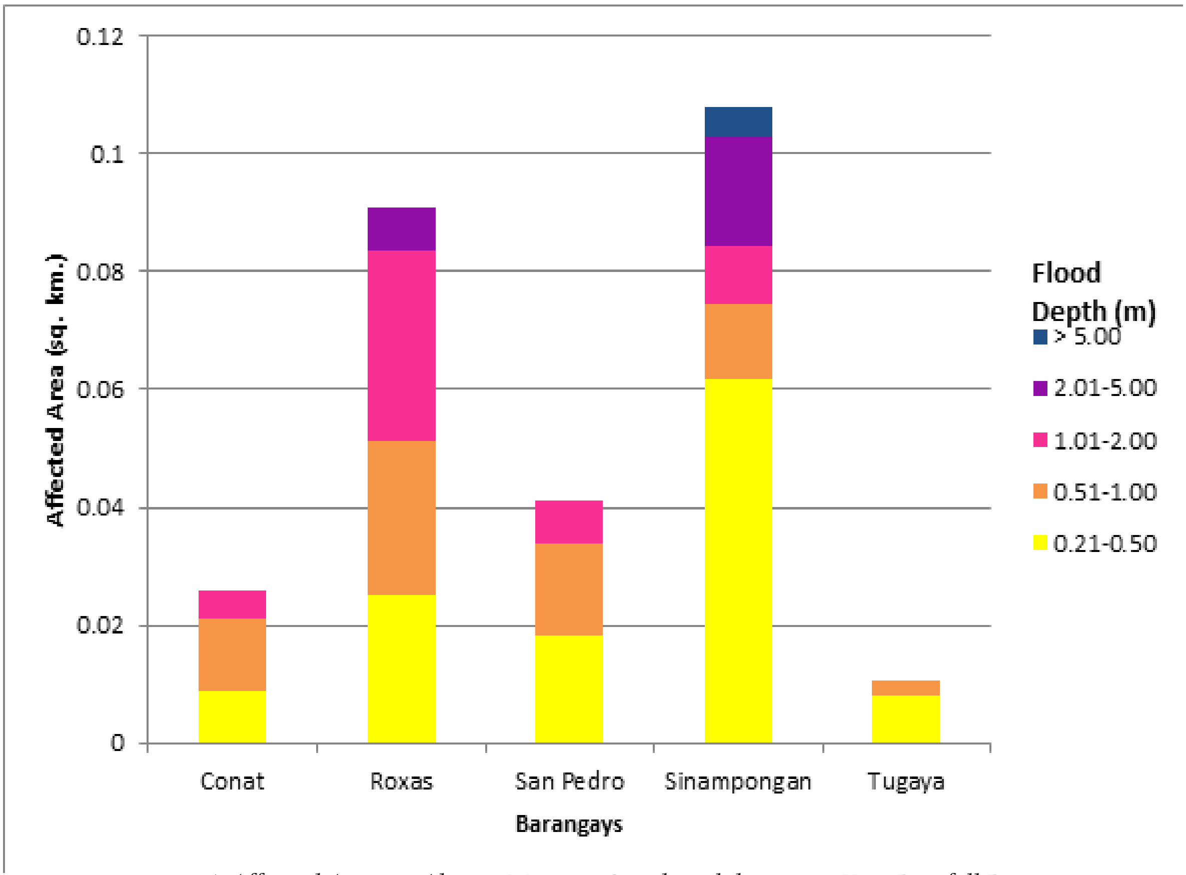

Figure 74. Affected Areas in Aloran, Misamis Occidental during 25-Year Rainfall Return

For the municipality of Concepcion, with an area of 63.46 sq. km., only the barangay of Upper Dioyo will experience flooding at 0.08%. Only flood level of less 0.20 meters is projected.

Table 41. Affected Areas in Concepcion, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Concepcion
	Upper Dioyo
0.03-0.20	0.049
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

For the municipality of Don Victoriano Chiongbian, with an area of 307.71 sq. km., 10.76% will experience flood levels of less 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.09%, 0.09%, and 0.03% 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 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)				
	Gandawan	Lake Dumi-nagat	Lalud	Liboron	Napangan
0.03-0.20	0.02	16.73	0.075	8.89	7.39
0.21-0.50	0	0.55	0	0.22	0.26
0.51-1.00	0	0.23	0	0.1	0.13
1.01-2.00	0	0.16	0	0.058	0.048
2.01-5.00	0	0.19	0	0.099	0.0034
> 5.00	0	0.032	0	0.06	0

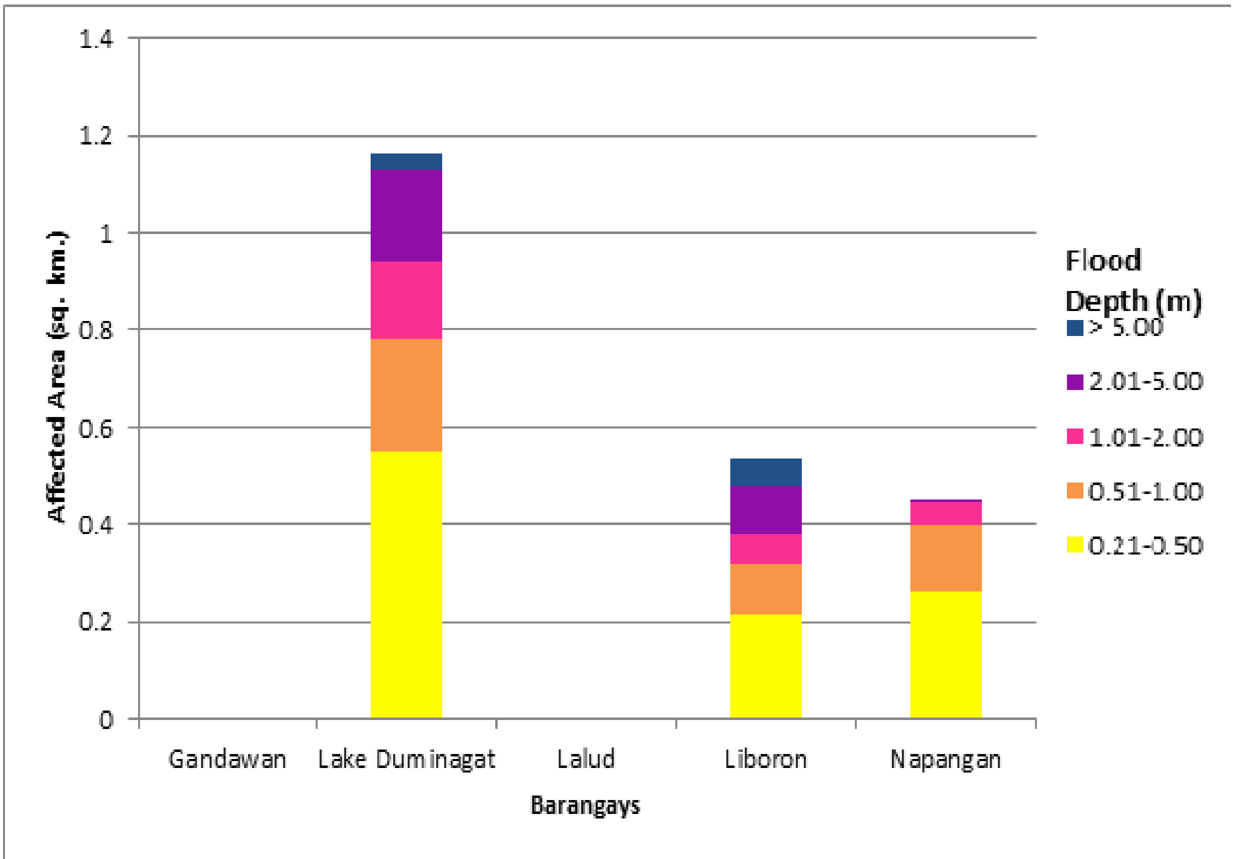

Figure 75. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 25-Year Rainfall Return Period

For the municipality of Jimenez, with an area of 78.48 sq. km., 2.26% will experience flood levels of less 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Jimenez, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Jimenez
	Guintomoyan
0.03-0.20	1.77
0.21-0.50	0.025
0.51-1.00	0.008
1.01-2.00	0.0016
2.01-5.00	0
> 5.00	0

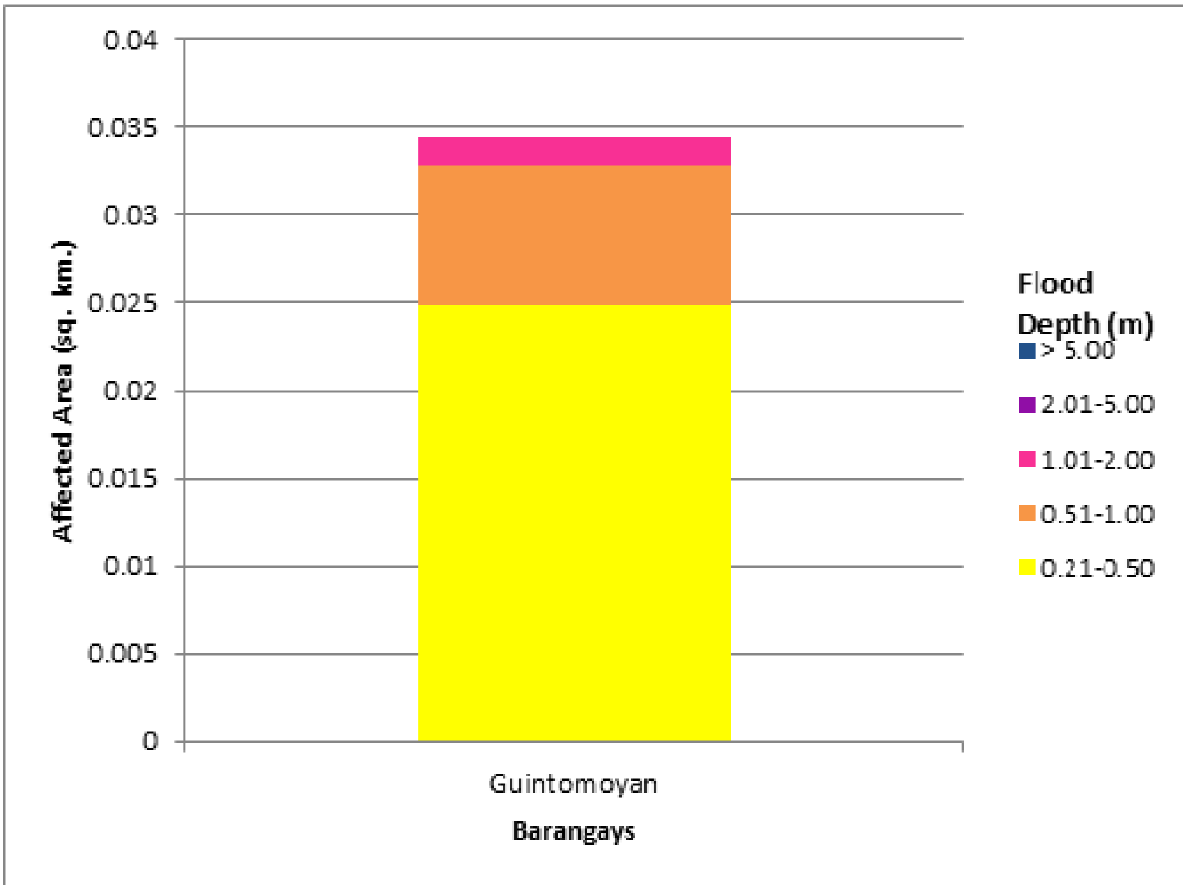

Figure 76. Affected Areas in Jimenez, Misamis Occidental during 25-Year Rainfall Return Period

For the city of Oroquieta, with an area of 195.627 sq. km., 31.98% will experience flood levels of less 0.20 meters. 1.38% of the area will experience flood levels of 0.21 to 0.50 meters while 1.38%, 2.03%, 1.72%, and 0.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected Areas in Oroquieta City, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Oroquieta City													
	Apil	Bolibol	Bue-navista	Bun-tawan	Dolipos Alto	Dolipos Bajo	Dullan Norte	Dullan Sur	Lamac Lower	Lamac Upper	Lang-cangan Lower	Lang-can-gan Proper	Lang-can-gan Upper	Lay-awan
0.03-0.20	2.58	1.8	1.55	2.27	3.22	3.77	2.71	1.57	0.063	0.16	0.32	0.26	0.5	0.0056
0.21-0.50	0.11	0.075	0.08	0.13	0.12	0.12	0.11	0.082	0.0072	0.0094	0.071	0.0055	0.039	0.02
0.51-1.00	0.11	0.082	0.089	0.17	0.064	0.11	0.037	0.058	0.031	0.006	0.075	0.0074	0.0056	0.036
1.01-2.00	0.091	0.15	0.05	0.2	0.043	0.12	0.013	0.027	0.028	0.013	0.049	0.012	0.0091	0.0001
2.01-5.00	0.03	0.11	0.0023	0.27	0.037	0.41	0.0047	0.0016	0	0	0.014	0.0001	0.0098	0
> 5.00	0	0	0	0.033	0.0089	0.044	0	0	0	0	0.0096	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Oroquieta City													
	Mialen	Pines	Pobla-cion I	Pobla-cion II	San Vicente Alto	San Vi-cente Bajo	Sebu-cal	Taboc Norte	Taboc Sur	Talai-ron	Talic	Toliy-ok	Victo-ria	Villaflor
0.03-0.20	29.16	0.3	0.014	0.017	0.39	0.36	1.17	0.0052	0.012	0.67	0.02	1.78	5.18	2.7
0.21-0.50	0.58	0.15	0.034	0.028	0.086	0.33	0.053	0.013	0.032	0.032	0.0052	0.092	0.13	0.14
0.51-1.00	0.3	0.17	0.037	0.063	0.19	0.38	0.039	0.035	0.32	0.029	0.034	0.041	0.085	0.097
1.01-2.00	0.37	0.18	0.00066	0.012	0.36	0.25	0.03	0.15	0.49	0.12	0.64	0.21	0.091	0.24
2.01-5.00	0.63	0.0016	0	0.000001	0.0018	0.012	0.0048	0.11	0.022	0.57	0.46	0.24	0.16	0.27
> 5.00	0.31	0	0	0	0	0	0	0.01	0	0.075	0.068	0.041	0.055	0.016

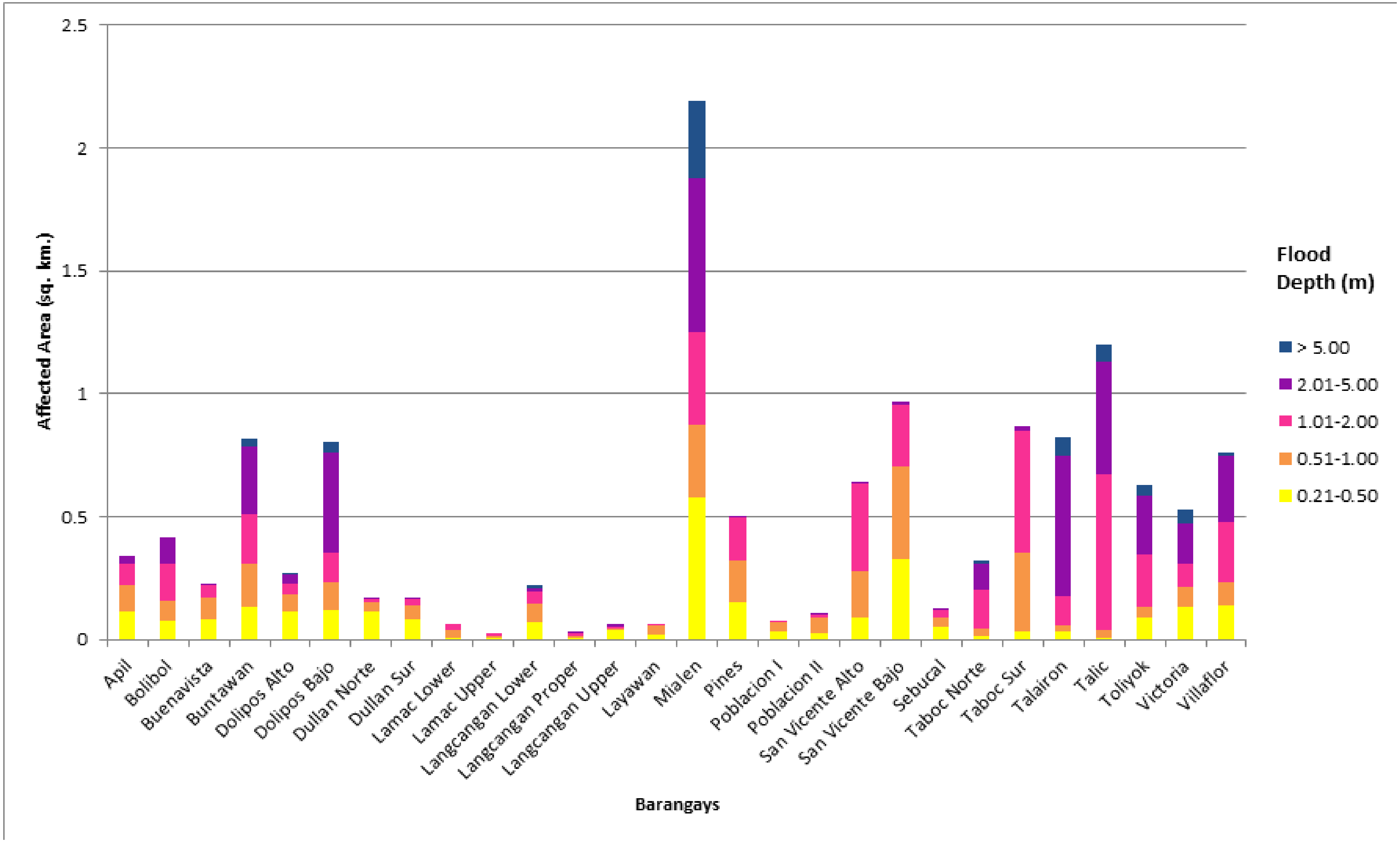

Figure 77. Affected Areas in Oroquieta City, Misamis Occidental during 25-Year Rainfall Return Period

For the municipality of Panaon, with an area of 52.52 sq. km., only the barangay of Bangko will experience flooding at 0.01%. Only flood level of less 0.20 meters is projected.

Table 45. Affected Areas in Panaon, Misamis Occidental during 25-Year Rainfall Return

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Panaon
	Bangko
0.03-0.20	0.007
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

For the 100-year return period, 5.01% of the municipality of Aloran with an area of 105.66 sq. km. will experience flood levels of less 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.06%, 0.06%, and 0.04% 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 46 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Aloran, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Aloran				
	Conat	Roxas	San Pedro	Sinampon-gan	Tugaya
0.03-0.20	0.0056	2.2	0.82	1.97	0.3
0.21-0.50	0.012	0.025	0.02	0.074	0.009
0.51-1.00	0.013	0.025	0.015	0.014	0.0034
1.01-2.00	0.0085	0.031	0.011	0.011	0
2.01-5.00	0.0001	0.017	0.0005	0.02	0
> 5.00	0	0	0	0.0071	0

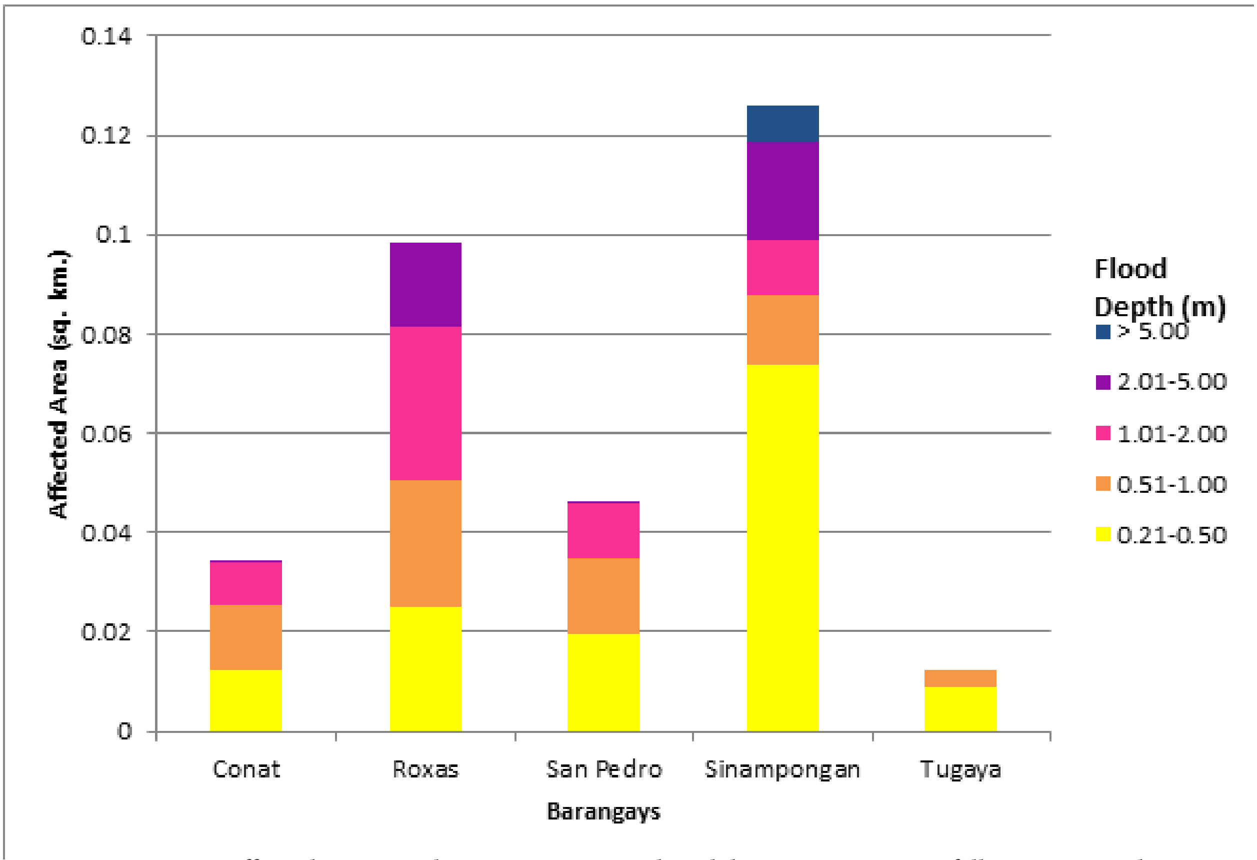

Figure 78. Affected Areas in Aloran, Misamis Occidental during 100-Year Rainfall Return Period

For the municipality of Concepcion, with an area of 63.46 sq. km., only the barangay of Upper Dioyo will experience flooding at 0.08%. Only flood level of less 0.20 meters is projected.

Table 47. Affected Areas in Concepcion, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Concepcion
	Upper Dioyo
0.03-0.20	0.049
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

For the municipality of Don Victoriano Chiongbian, with an area of 307.71 sq. km., 10.66% will experience flood levels of less 0.20 meters. 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.18%, 0.10%, 0.10%, 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 48 are the affected areas in square kilometres by flood depth per barangay.

Table 48. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Don Victoriano Chiongbian				
	Gandawan	Lake Duminagat	Lalud	Liboron	Napangan
0.03-0.20	0.02	16.57	0.075	8.83	7.32
0.21-0.50	0	0.61	0	0.23	0.29
0.51-1.00	0	0.27	0	0.13	0.15
1.01-2.00	0	0.17	0	0.064	0.07
2.01-5.00	0	0.21	0	0.093	0.01
> 5.00	0	0.064	0	0.093	0

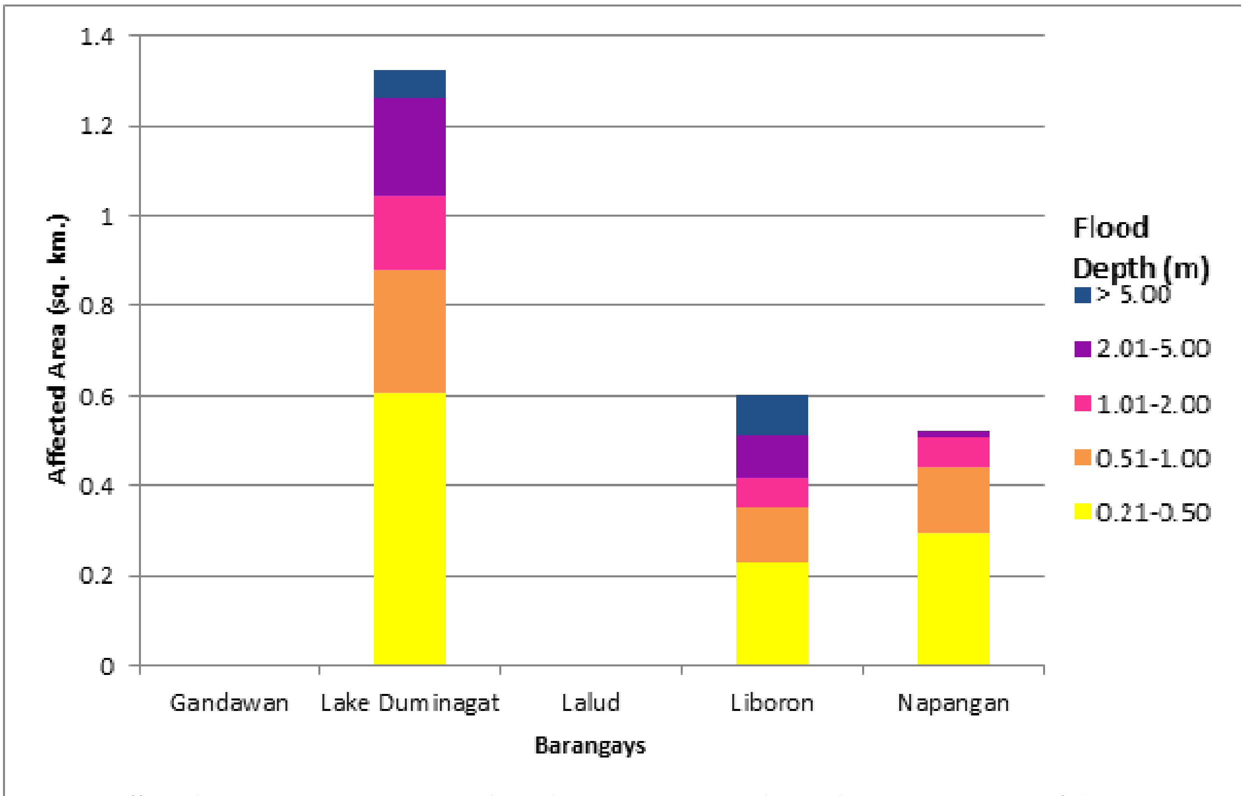

Figure 79. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 100-Year Rainfall Return Period

For the municipality of Jimenez, with an area of 78.48 sq. km., 2.24% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.003%, and 0.0001% 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 49 are the affected areas in square kilometres by flood depth per barangay.

Table 49. Affected Areas in Don Victoriano Chiongbian, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Jimenez
	Guintomoyan
0.03-0.20	1.76
0.21-0.50	0.031
0.51-1.00	0.011
1.01-2.00	0.002
2.01-5.00	0.0001
> 5.00	0

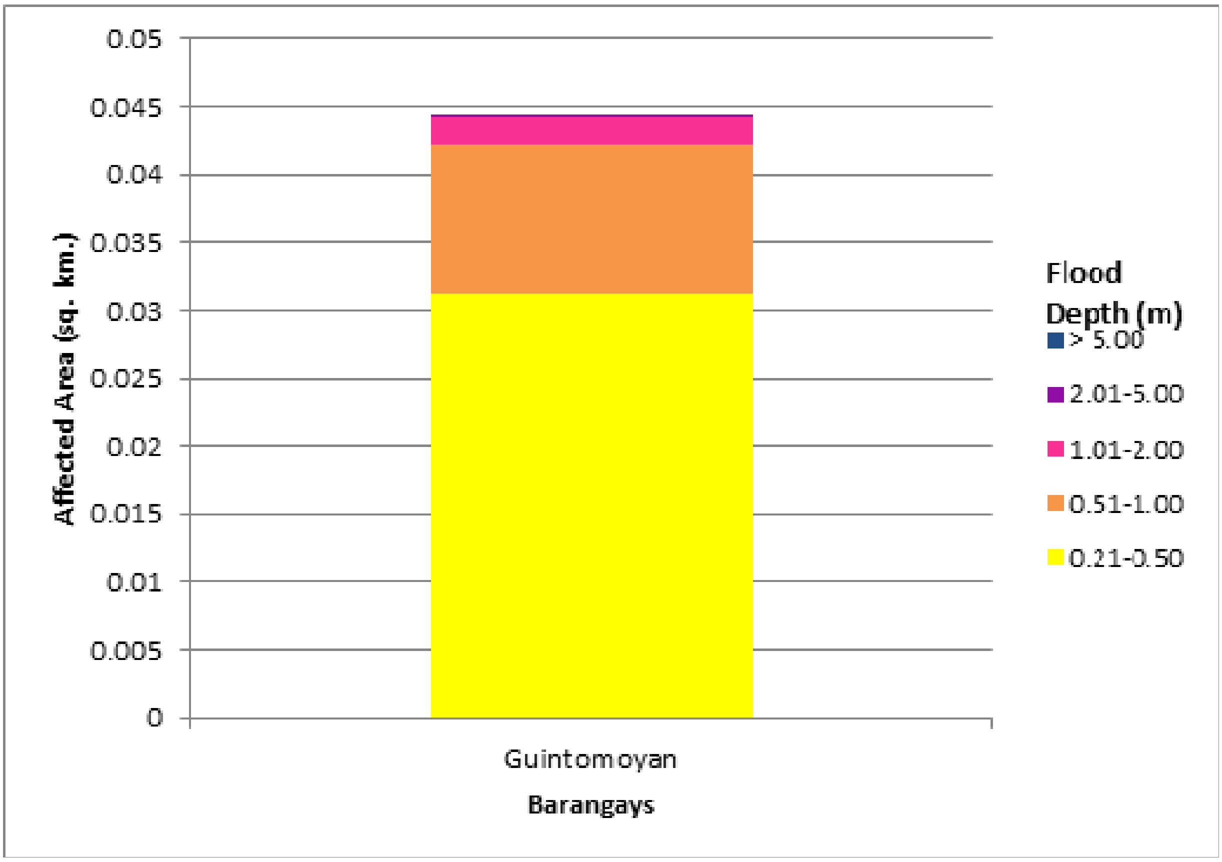

Figure 80. Affected Areas in Jimenez, Misamis Occidental during 100-Year Rainfall Return Period

For the city of Oroquieta, with an area of 195.627 sq. km., 31.43% will experience flood levels of less 0.20 meters. 1.36% of the area will experience flood levels of 0.21 to 0.50 meters while 1.34%, 1.99%, 2.18%, and 0.53% 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 50 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected Areas in Oroquieta City, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Oroquieta City													
	Apil	Bolibol	Buenavista	Buntawan	Dolipos Alto	Dolipos Bajo	Dullan Norte	Dullan Sur	Lamac Lower	Lamac Upper	Langcangan Lower	Langcangan Proper	Langcangan Upper	Layawan
0.03-0.20	2.54	1.74	1.53	2.21	3.18	3.74	2.67	1.54	0.06	0.15	0.3	0.26	0.48	0.0015
0.21-0.50	0.1	0.088	0.078	0.14	0.13	0.12	0.13	0.087	0.0062	0.011	0.054	0.0052	0.053	0.012
0.51-1.00	0.11	0.083	0.089	0.13	0.075	0.11	0.058	0.059	0.02	0.0054	0.093	0.006	0.0077	0.043
1.01-2.00	0.1	0.14	0.072	0.22	0.053	0.098	0.014	0.045	0.043	0.015	0.064	0.017	0.0057	0.0048
2.01-5.00	0.057	0.17	0.0049	0.32	0.045	0.44	0.0079	0.003	0.000012	0.0019	0.016	0.0024	0.015	0
> 5.00	0	0.0005	0	0.057	0.014	0.075	0	0	0	0	0.011	0	0	0

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Oroquieta City													
	Mialen	Pines	Poblacion I	Poblacion II	San Vicente Alto	San Vicente Bajo	Sebucal	Taboc Norte	Taboc Sur	Talairon	Talic	Toliyok	Victoria	Villaflor
0.03-0.20	28.84	0.25	0.0079	0.012	0.34	0.3	1.15	0.0042	0.0069	0.63	0.019	1.76	5.09	2.66
0.21-0.50	0.67	0.13	0.021	0.019	0.083	0.19	0.049	0.0083	0.025	0.037	0.0031	0.1	0.16	0.15
0.51-1.00	0.33	0.17	0.055	0.066	0.14	0.45	0.048	0.035	0.15	0.035	0.021	0.039	0.083	0.1
1.01-2.00	0.35	0.23	0.0015	0.022	0.46	0.35	0.036	0.11	0.64	0.062	0.36	0.15	0.097	0.12
2.01-5.00	0.69	0.013	0	0.000001	0.014	0.036	0.009	0.16	0.059	0.6	0.74	0.3	0.16	0.4
> 5.00	0.47	0	0	0	0	0	0	0.012	0	0.12	0.071	0.059	0.12	0.032

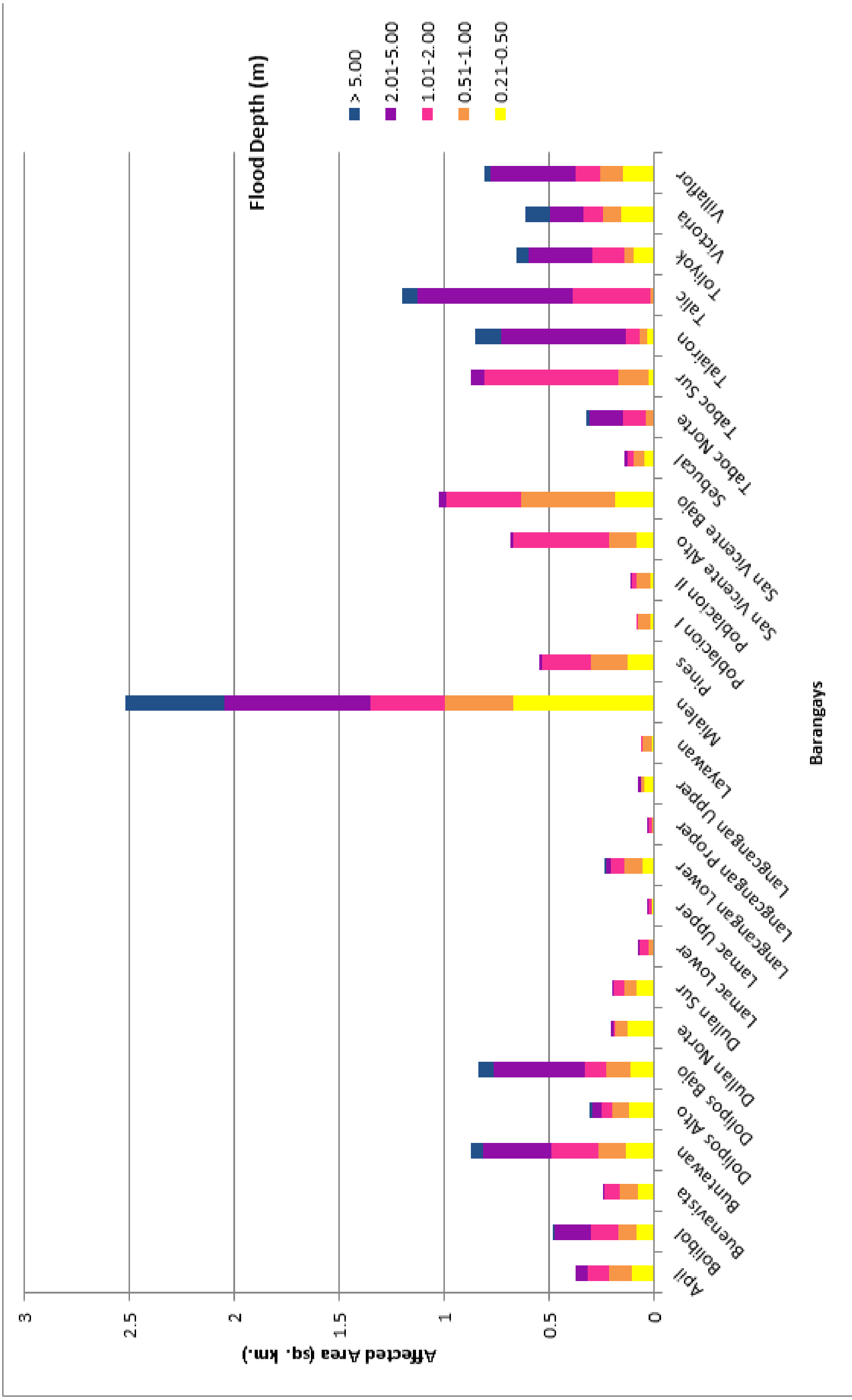

Figure 81. Affected Areas in Oroquieta City, Misamis Occidental during 100-Year Rainfall Return Period

For the municipality of Panaon, with an area of 52.52 sq. km., only the barangay of Bangko will experience flooding at 0.01%. Only flood level of less 0.20 meters is projected.

Table 51. Affected Areas in Panaon, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Affected Barangays in Panaon
	Bangko
0.03-0.20	0.007
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

Among the barangays in the municipality of Aloran, Roxas is projected to have the highest percentage of area that will experience flood levels at 2.17%. Meanwhile, Sinampongan posted the second highest percentage of area that may be affected by flood depths at 1.98%.
Among the barangays in the municipality of Concepcion, only Upper Dioyo is projected to experience flood levels at a percentage of 0.08%.

Among the barangays in the municipality of Don Victoriano Chiongbian, Lake Duminagat is projected to have the highest percentage of area that will experience flood levels at 5.82%. Meanwhile, Napangan posted the second highest percentage of area that may be affected by flood depths at 2.55%.

Among the barangays in the municipality of Jimenez, only Guintomoyan is projected to experience flood levels at a percentage of 2.30%.

Among the barangays in the city of Oroquieta, Mialen is projected to have the highest percentage of area that will experience flood levels at 16.03%. Meanwhile, Victoria posted the second highest percentage of area that may be affected by flood depths at 2.92%.

Among the barangays in the municipality of Panaon, only Bangko is projected to experience flood levels at a percentage of 0.01%.

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

Table 52. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.01	3.28	3.43
Medium	4.80	4.91	4.85
High	5.65	7.94	9.31
TOTAL	**13.46**	**16.13**	**17.59**

Of the 97 identified Education Institutions in Layawan Flood plain, 16 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 16 schools were assessed to be exposed to Medium level flooding and 3 schools were assessed to be exposed to High level flooding in the same scenario. In the 25 year scenario, 19 schools were assessed to be exposed to the Low level flooding while 25 schools were assessed to be exposed to Medium level flooding and 8 schools were assessed to be exposed to High level flooding in the same scenario. For the 100 year scenario, 14 schools were assessed for Low level flooding and 34 schools for Medium level flooding. In the same scenario, 9 schools were assessed to be exposed to High level flooding. See Annex 12 for a detailed enumeration of schools inside Layawan floodplain.

Of the 32 identified Health Institutions in Layawan Flood plain, 5 were assessed to be exposed to the Low level flooding during a 5 year scenario while 3 were assessed to be exposed to Medium level flooding in the same scenario. In the 25 year scenario, 4 were assessed to be exposed to the Low level flooding while 8 were assessed to be exposed to Medium level flooding. For the 100 year scenario, 2 schools were assessed for Low level flooding and 10 for Medium level flooding. See Annex 13 for a detailed enumeration of heath insitutions inside Layawan floodplain.

5.11 Flood Validation

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

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios were identified for validation.

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 83.

The flood validation data were obtained on January 2017. The flood validation consisted of 151 points randomly selected all over the Layawan floodplain. It has an RMSE value of 0.98.

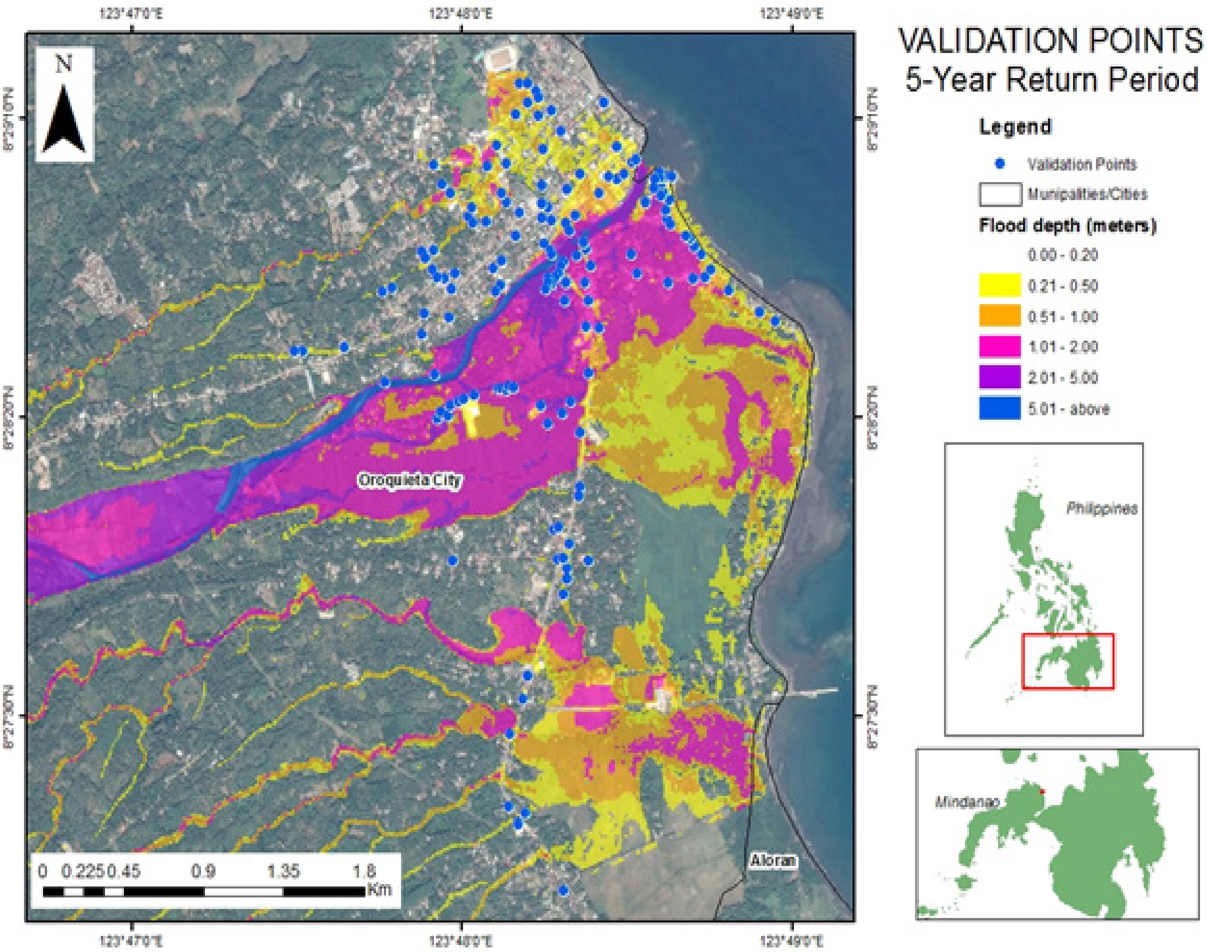

Figure 82. Validation points for 5-year Flood Depth Map of Layawan (also known as Oroquieta) Floodplain

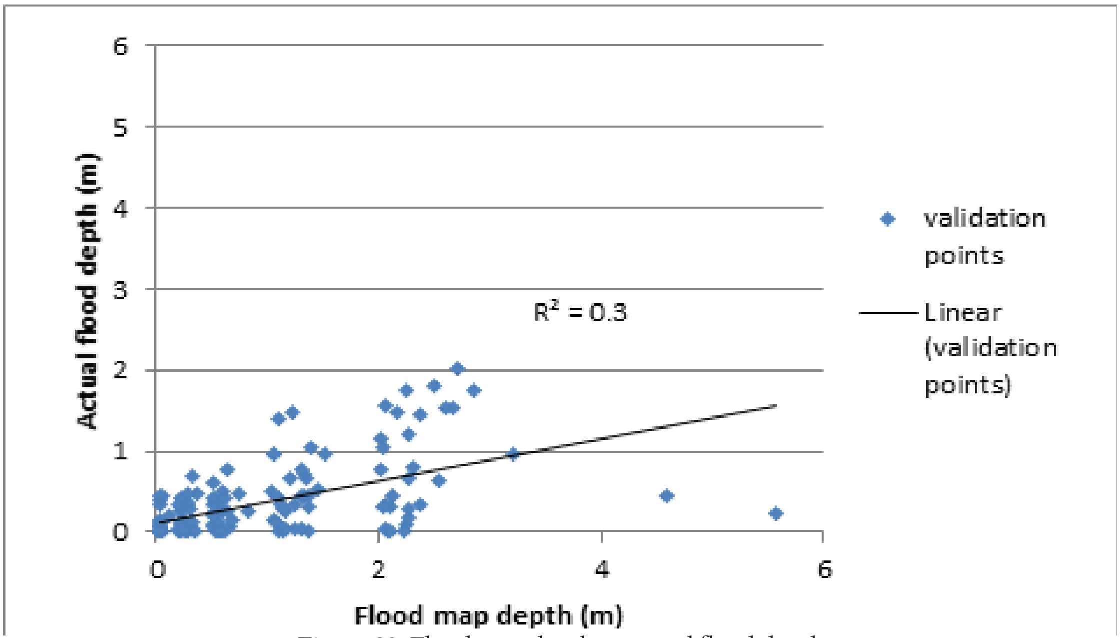

Figure 83. Flood map depth vs actual flood depth

Table 53. Actual Flood Depth vs Simulated Flood Depth in Layawan

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	26	18	13	9	6	0	72
0.21-0.50	4	11	14	10	7	1	47
0.51-1.00	0	1	2	8	5	0	16
1.01-2.00	0	0	0	3	11	0	14
2.01-5.00	0	0	0	0	1	0	1
> 5.00	0	0	0	0	0	0	0
Total	30	30	29	30	30	1	150

The overall accuracy generated by the flood model is estimated at 28.67%, with 43 points correctly matching the actual flood depths. In addition, there were 56 points estimated one level above and below the correct flood depths while there were 28 points and 23 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 102 points were overestimated while a total of 5 points were underestimated in the modelled flood depths of Layawan.

Table 54. Summary of Accuracy Assessment in the Layawan River Basin Survey

	No. of Points	%
Correct	43	28.67
Overestimated	102	68.00
Underestimated	5	3.33
Total	150	100

REFERENCES

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

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

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

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

Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines

Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

Annex 1. Optech Technical Specification of the Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
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)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

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 Certificates of Reference Points Used

1. 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**
Municipality: **TUDELA**
Barangay:
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

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

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-12

2. 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 1 3 3 4 4 9

CIP/4701/12/09/614

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Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 MSW-11

3. MW-85

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

December 09, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MISAMIS OCCIDENTAL**
Station Name: **MW-85**

Island: **Mindanao**	Municipality: **OROQUIETA CITY (CAPITAL)**	Barangay:
Elevation: **8.3932 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

MW-85 is in the Province of Misamis Occidental, City of Oroqueta,Brgy. Lutao, along the Oroqueta city-Dipolog city National road.The station is located east -northeast of Lutao Bridge at KM 1744+185 and about 4 m. southeast of the centerline of the road.

Mark is the head of a 4" copper nail set on drilled hole and cemented flushed on top of 15 cm x 15 cm cement putty with inscription "MW-85,2008,NAMRIA".

Requesting Party:	**Christopher Cruz**
Purpose:	**Reference**
OR Number:	**8077396 I**
T.N.:	**2014-2986**

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

9 9 1 2 0 9 2 0 1 4 1 0 5 7 3 0

CIP/4701/12/09/814

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-2.3 MW-85

4.MSW-5

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

December 01, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **MISAMIS OCCIDENTAL**	
	Station Name: **MSW-5**	
	Order: **2nd**	
Island: **MINDANAO**	Barangay: **POBLACION**	
Municipality: **SAPANG DALAGA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 32' 35.68185"**	Longitude: **123° 33' 56.01853"**	Ellipsoidal Hgt: **113.48100 m.**
	WGS84 Coordinates	
Latitude: **8° 32' 31.98501"**	Longitude: **123° 34' 1.42685"**	Ellipsoidal Hgt: **178.27400 m.**
	PTM / PRS92 Coordinates	
Northing: **944671.948 m.**	Easting: **562262.537 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **944,341.30**	Easting: **562,240.75**	Zone: **51**

Location Description

MSW-5
From Dipolog City, travel along the Nat'l. Highway going to Calamba until reaching Sapang Dalaga Proper. Station is located inside Sapang Dalaga Mun. Hall compound, beside the fence near the basketball court. It is about 50 m. from the DAR office and 100 m. from the mun. hall. Mark is the head of a 4 in. copper nail embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "MSW-5 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **FREE ISSUE**
T.N.: **2016-2168**

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

9 9 1 2 0 1 2 0 1 6 1 6 3 2 5 7

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4 MSW-5

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 Baseline Processing Report - A

2. ZN-11

MSW-5 - ZN-11 (7:25:46 AM-1:19:59 PM) (S1)

Baseline observation:	MSW-5 --- ZN-11 (B1)
Processed:	16/02/2017 1:35:17 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.010 m
Vertical precision:	0.043 m
RMS:	0.027 m
Maximum PDOP:	7.421
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	22/11/2016 7:25:58 AM (Local: UTC+8hr)
Processing stop time:	22/11/2016 1:19:59 PM (Local: UTC+8hr)
Processing duration:	05:54:01
Processing interval:	1 second

From:	MSW-5				
Grid		Local		Global	
Easting	562240.744 m	Latitude	N8°32'35.68185"	Latitude	N8°32'31.98501"
Northing	944341.296 m	Longitude	E123°33'56.01853"	Longitude	E123°34'01.42685"
Elevation	111.479 m	Height	113.481 m	Height	178.274 m

To:	ZN-11				
Grid		Local		Global	
Easting	553785.501 m	Latitude	N8°32'19.31150"	Latitude	N8°32'15.60892"
Northing	943827.025 m	Longitude	E123°29'19.41683"	Longitude	E123°29'24.82623"
Elevation	20.021 m	Height	21.953 m	Height	86.565 m

Vector					
ΔEasting	-8455.244 m	NS Fwd Azimuth	266°36'12"	ΔX	7060.361 m
ΔNorthing	-514.271 m	Ellipsoid Dist.	8473.905 m	ΔY	4659.059 m
ΔElevation	-91.458 m	ΔHeight	-91.528 m	ΔZ	-511.155 m

Figure A-3.2 Baseline Processing Report - B

3. 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-3.3 Baseline Processing Report - C

Annex 4. The LiDAR Survey Team

Table A-4.1 The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		GEROME HIPOLITO	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	SSRS	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	JERIEL PAUL ALAMBAN	UP-TCAGP
	RA	GEF SORIANO	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	IRO ROXAS	UP-TCAGP
	RA	MERLIN FERNANDO	UP-TCAGP
	RA	RENAN PUNTO	UP-TCAGP
	RA	KRISTINE ANDAYA	UP-TCAGP
	Airborne Security	SSG. JAYCO MANZANO	PHILIPPINE AIR FORCE (PAF)
LiDAR Operation	Airborne Security	SSG. GERONIMO BALICAO	PAF
	Pilot	CAPT. F. DE OCAMPO	ASIAN AEROSPACE CORPORATION (AAC)
	Pilot	CAPT. B. DONGUINES	AAC
	Pilot	CAPT. SHERWIN ALFONSO III	AAC
	Pilot	CAPT. JERICHO JECIEL	AAC
	Pilot	CAPT. A. DAYO	AAC
	Pilot	CAPT E. SAYSAY	AAC

Annex 5. Data Transfer Sheet for Layawan Floodplain Flights

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	450	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	73/51/81/59	na	Z:\DAC\RAW DATA
28-Oct	2135P	1BLK69F301B	PEGASUS	268	1701/67	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	450/220	7.37	190	28.3	181	11.2	na	19.4	1KB	1KB	106/93/92/75	na	Z:\DAC\RAW DATA
31-Oct	2145P	1BLK69C304A	PEGASUS	2.30	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 11/19/2014

14-94

Figure A-5.1 Data Transfer Sheet for Layawan 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	580/100/91/82	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	125/108/98/87/78/78	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	84/84/72/76/57	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 Data Transfer Sheet for Layawan Floodplain - B

DATA TRANSFER SHEET
DIPOLOG 12/6/2016

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 20, 2016	23558P	1BLK69BC325A	PEGASUS	249	NA	11.2	274	NA	NA	24.8	NA	175	1KB	1KB	234	NA	Z:\DAC\RAW DATA
November 21, 2016	23562P	1BLK69BD326A	PEGASUS	2.64	NA	12.2	289	NA	NA	29.5	NA	165	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA
November 22, 2016	23566P	1BLK69E327A	PEGASUS	1.65	NA	9.58	267	NA	NA	18	NA	188	1KB	1KB	652	NA	Z:\DAC\RAW DATA
November 24, 2016	23574P	1BLK69AD329A	PEGASUS	1.92	NA	10	264	NA	NA	21.7	NA	126	1KB	1KB	421	NA	Z:\DAC\RAW DATA
November 26, 2016	23582P	1BLK73DE331A	PEGASUS	2.46	NA	11.6	281	25.1	274	25.5	NA	162	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature] 12/6/16

Figure A-5.3 Data Transfer Sheet for Layawan Floodplain - C

Annex 6. Flight Logs

1. Flight Log for 2133P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2133P

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): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for Mission 2133P

2. Flight Log for 2181P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2181

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK60F313A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: B. Dongwines	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: nov. 9, 2014	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 1315	14 Engine Off: 1626	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Alvarez	IRA Mo Cheng	FERDINAND M. 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 Mission 2181P

3. Flight Log for 23116P 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. Jecie | 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
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

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

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

21 Remarks

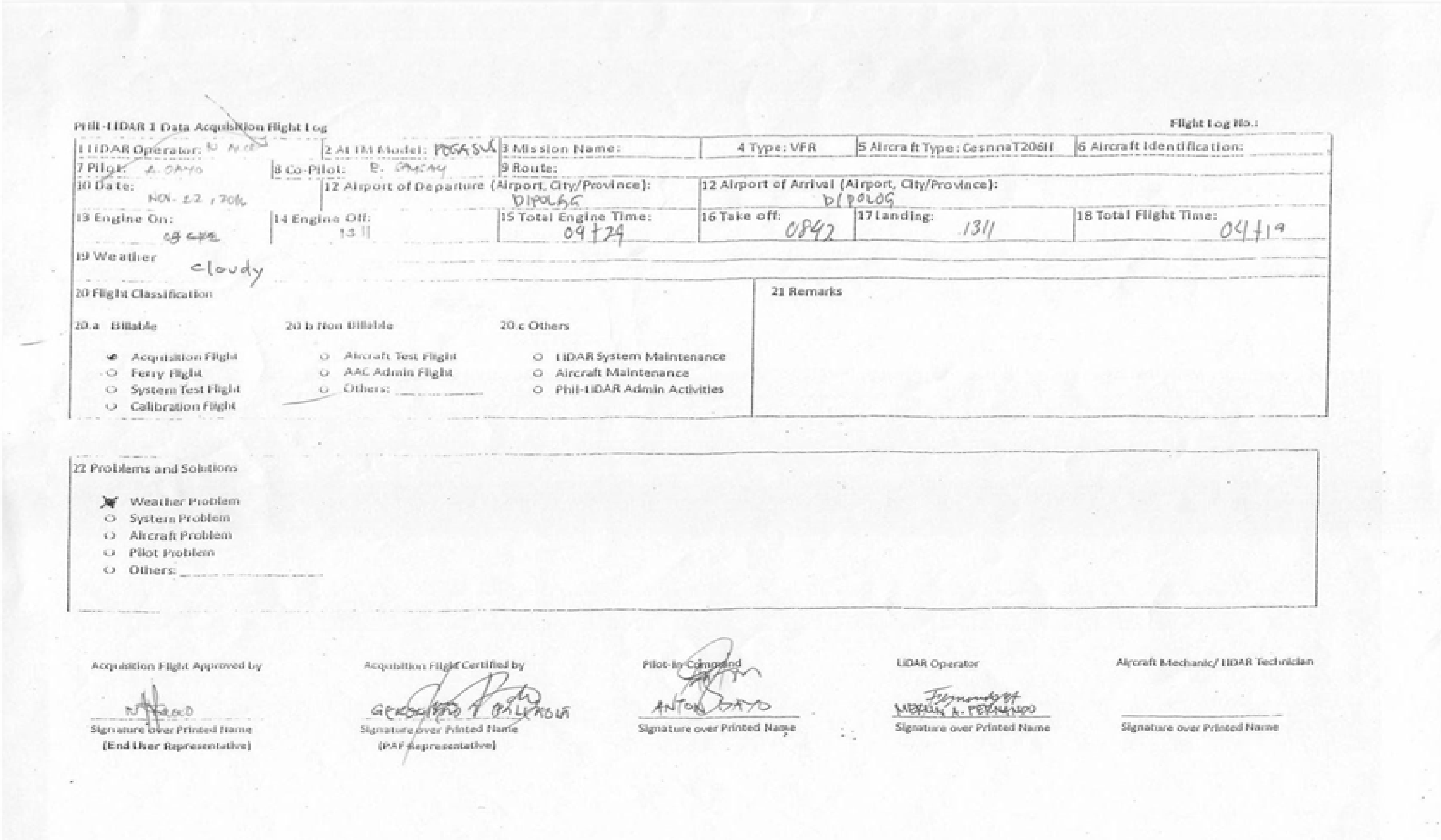
Successful flight

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o 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-6.3 Flight Log for Mission 23116P

4. Flight Log for 23566P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: | 2 ALTM Model: PEGASUS | 3 Mission Name: | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification:

7 Pilot: A. OAYO | 8 Co-Pilot: B. | 9 Route:

10 Date: NOV. 22, 2016 | 12 Airport of Departure (Airport, City/Province): DIPOLOG | 12 Airport of Arrival (Airport, City/Province): DIPOLOG

13 Engine On: | 14 Engine Off: 1311 | 15 Total Engine Time: 04+29 | 16 Take off: 0842 | 17 Landing: 1311 | 18 Total Flight Time: 04+19

19 Weather: cloudy

20 Flight Classification

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

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

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

21 Remarks

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

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

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

Pilot-in-Command: ANTON DAYO. Signature over Printed Name

LiDAR Operator: M. A. FERNANDO. Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: Signature over Printed Name

Figure A-6.4 Flight Log for Mission 23566P

Annex 7. Flight Status Reports

Table A-7.1
FLIGHT STATUS REPORT
DIPOLOG - ZAMBOANGA DEL NORTE
(October 8-November 11, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2133P	BLK 69FE	1BLK69FE301A	J. Alviar	Oct 28	Surveyed BLK 69E and F, cloudy
2181P	BLK 69F	1BLK69F313A	I. Roxas	Nov 9	Filled up gaps in BLK 69F

LAS BOUNDARIES PER FLIGHT

Flight No. : 2133P
Area: BLK 69FE
Mission Name: 1BLKFE301A
Parameters: Altitude: 800m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

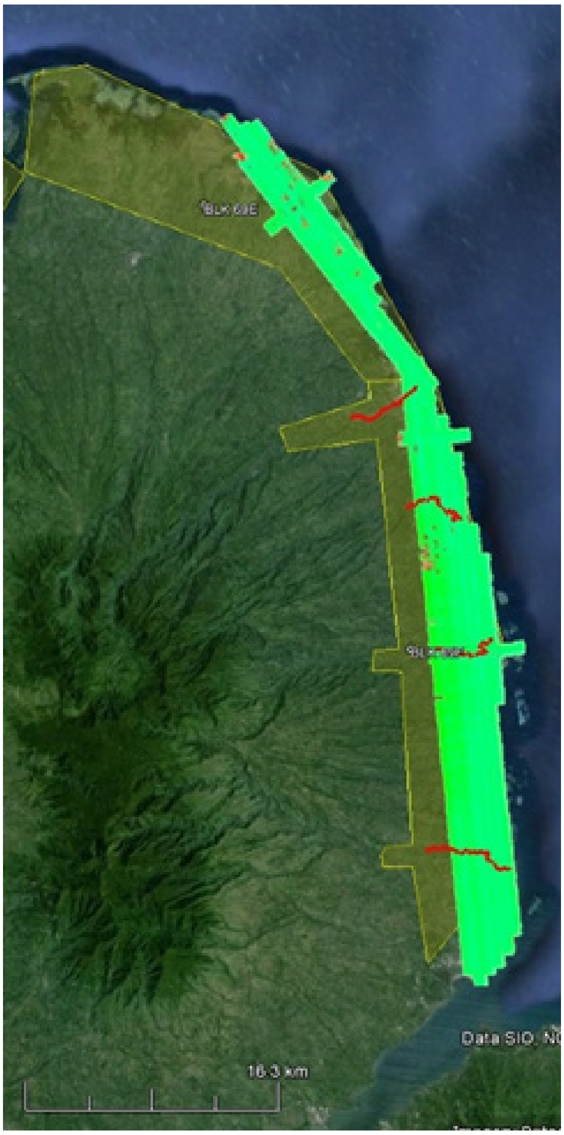


Figure A-7.1 Swath for Flight No. 2133P

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

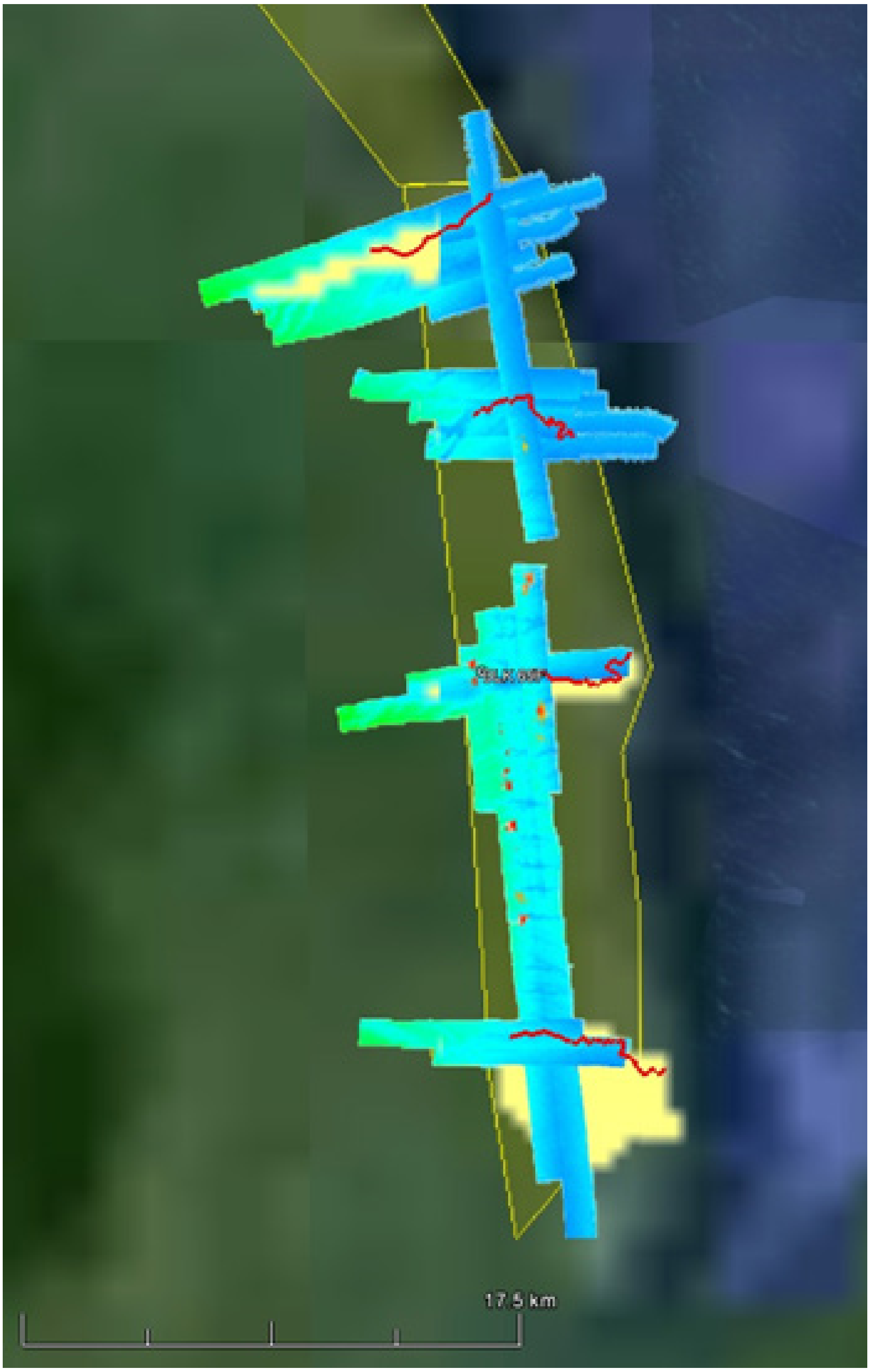


Figure A-7.2 Swath for Flight No. 2181P

Table A-7.2
FLIGHT STATUS REPORT
MISAMIS OCCIDENTAL
(January 20 – February 4, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23116P	BLK 76 N, O	1BLK76NO051A	J ALMALVEZ	FEB 20, 2016	ENCOUNTERED LOST CHANNEL A .COMPLETED VOIDS OVER OROQUIETA AND OZAMIS CITY

LAS BOUNDARIES PER FLIGHT

Flight No. : 2311P
Area: BLK 79NO
Mission Name: 1BLK76NO051A
Parameters: Altitude: 600m; Scan Frequency: 30Hz; Scan Angle: 25deg; Overlap: 30%

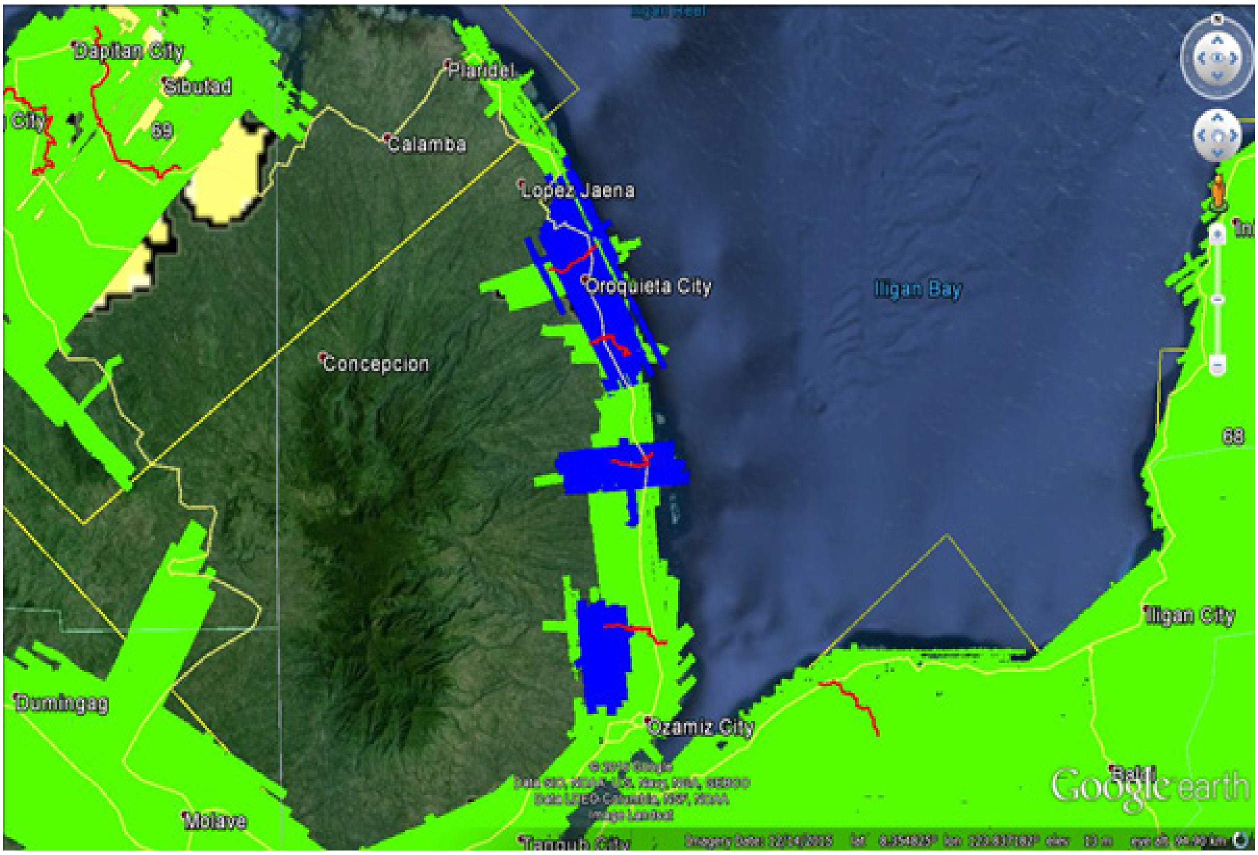


Figure A-7.3 Swath for Flight No. 2311P

Table A-7.3
FLIGHT STATUS REPORT
DIPOLOG FLIGHTS
(NOVEMBER 20 - 26, 2016)

Date	Flight No.	Operator	Mission Name	Area	Remarks
NOVEMBER 22, 2016	23566	PJ ARCEO M FERNANDO	1BLK69E327A	OROQUIETA BLK 69E	SURVEYED VOIDS IN BLK 69E OVER OROQUIETA FLOODPLAIN

LAS BOUNDARIES PER FLIGHT

Flight No. : 23566P
Area: BLK 76NO
Mission Name: 1BLK6E327A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz; Scan Angle: 25deg; Overlap: 30%

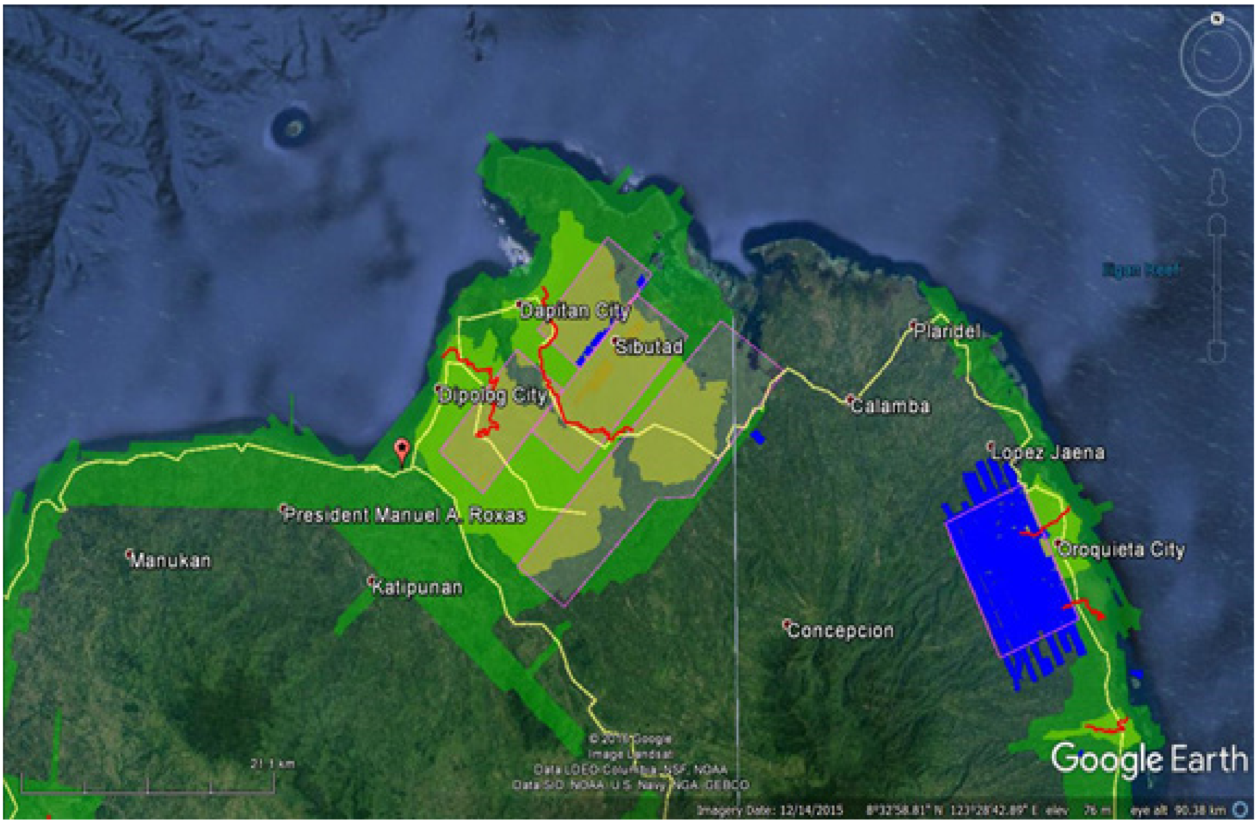


Figure A-7.4 Swath for Flight No. 23566P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for 76P

Flight Area	Pagadian
Mission Name	**76P**
Inclusive Flights	23116P
Range data size	24.4 GB
POS data size	294 MB
Base data size	63.8 MB
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)	0.000180
IMU attitude correction stdev (<0.001deg)	0.051682
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	39.38
Ave point cloud density per sq.m. (>2.0)	5.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	125
Maximum Height	226.71 m
Minimum Height	55.36 m
Classification (# of points)	
Ground	112,013,148
Low vegetation	122,498,412
Medium vegetation	115,753,334
High vegetation	406,275,310
Building	18,265,115
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga Jr., Jovy Narisma

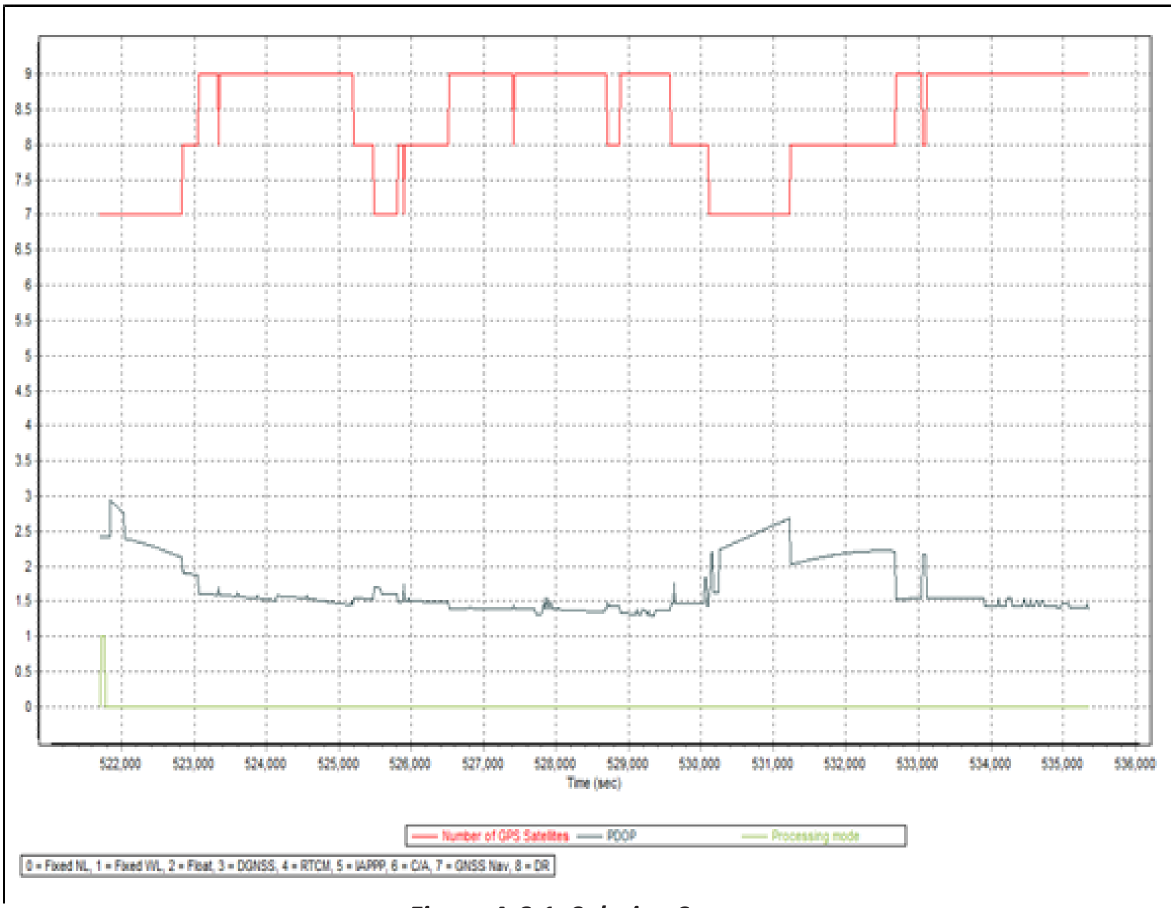


Figure A-8.1. Solution Status

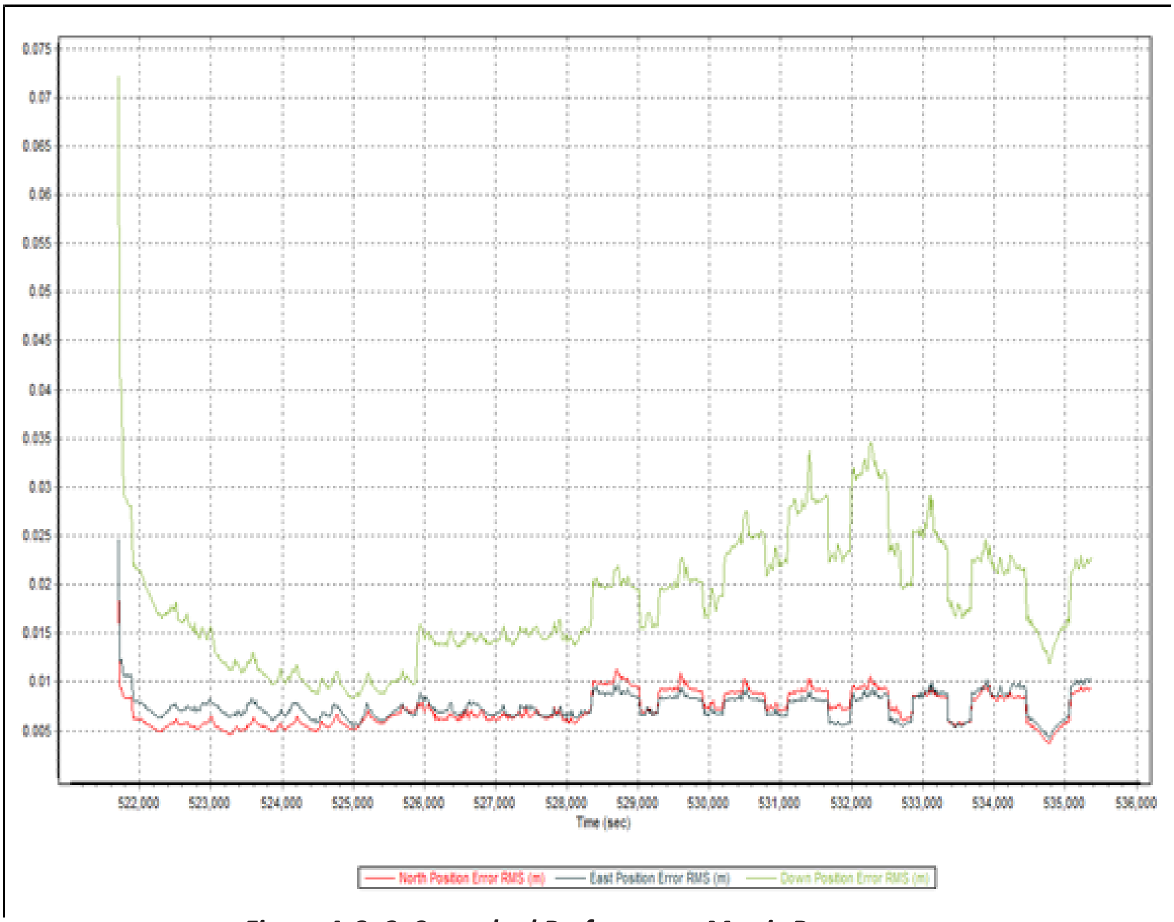


Figure A-8..2. Smoothed Performance Metric Parameters

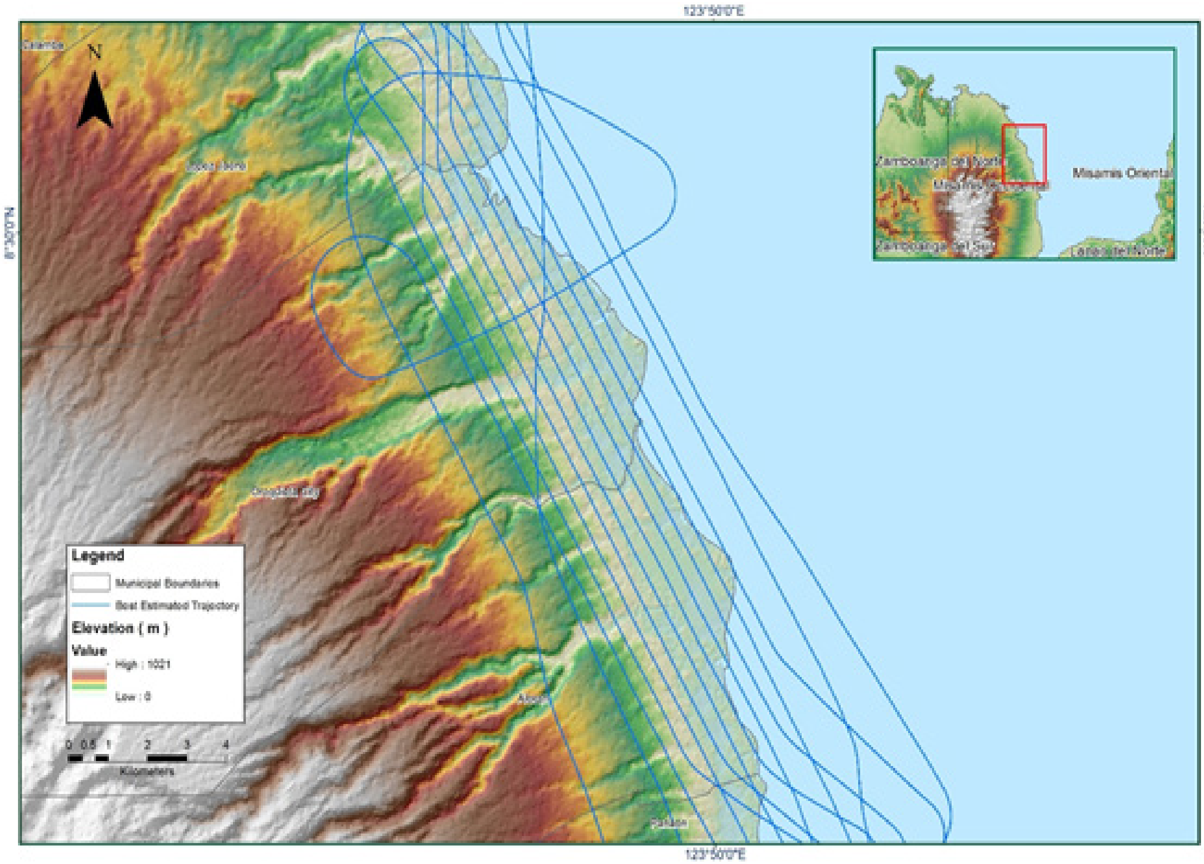


Figure A-8.3. Best Estimated Trajectory

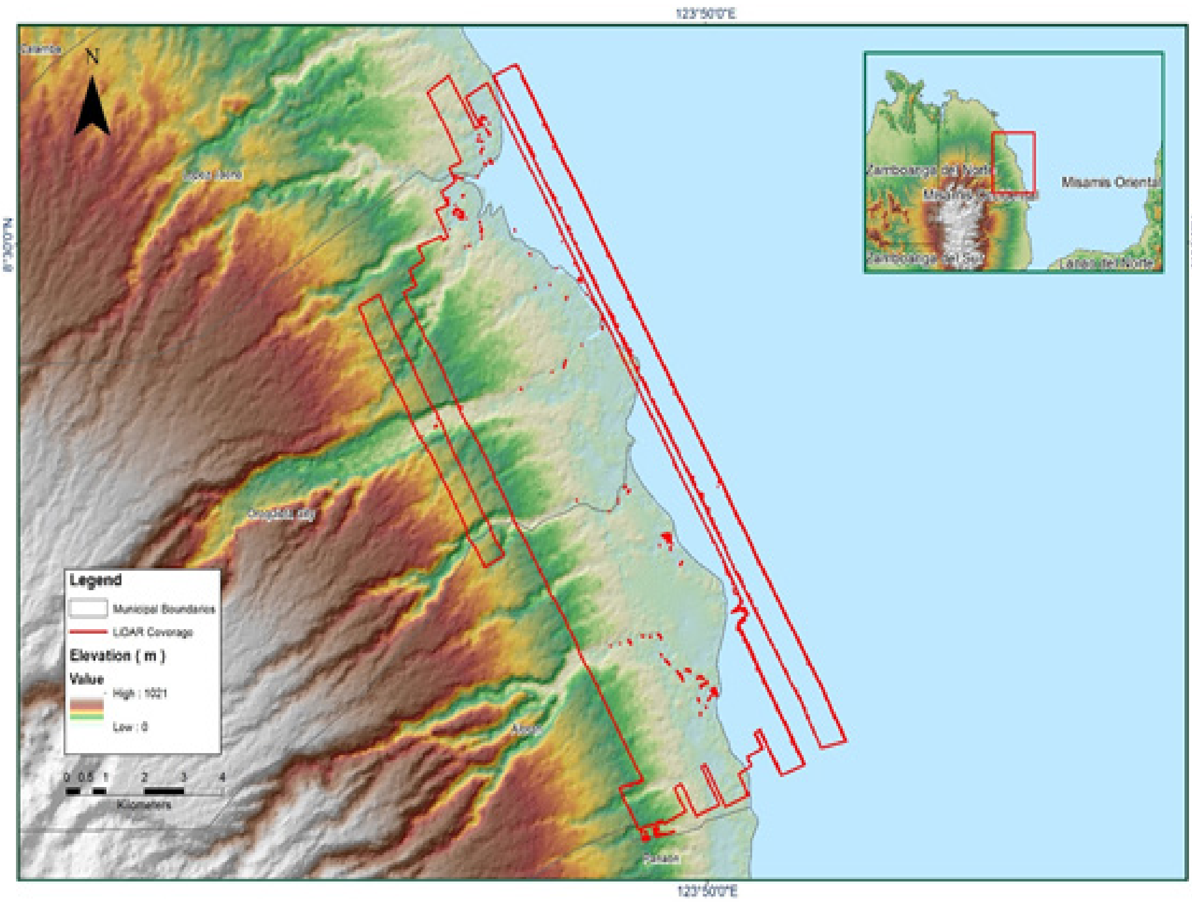


Figure A-8.4. Coverage of LiDAR Data

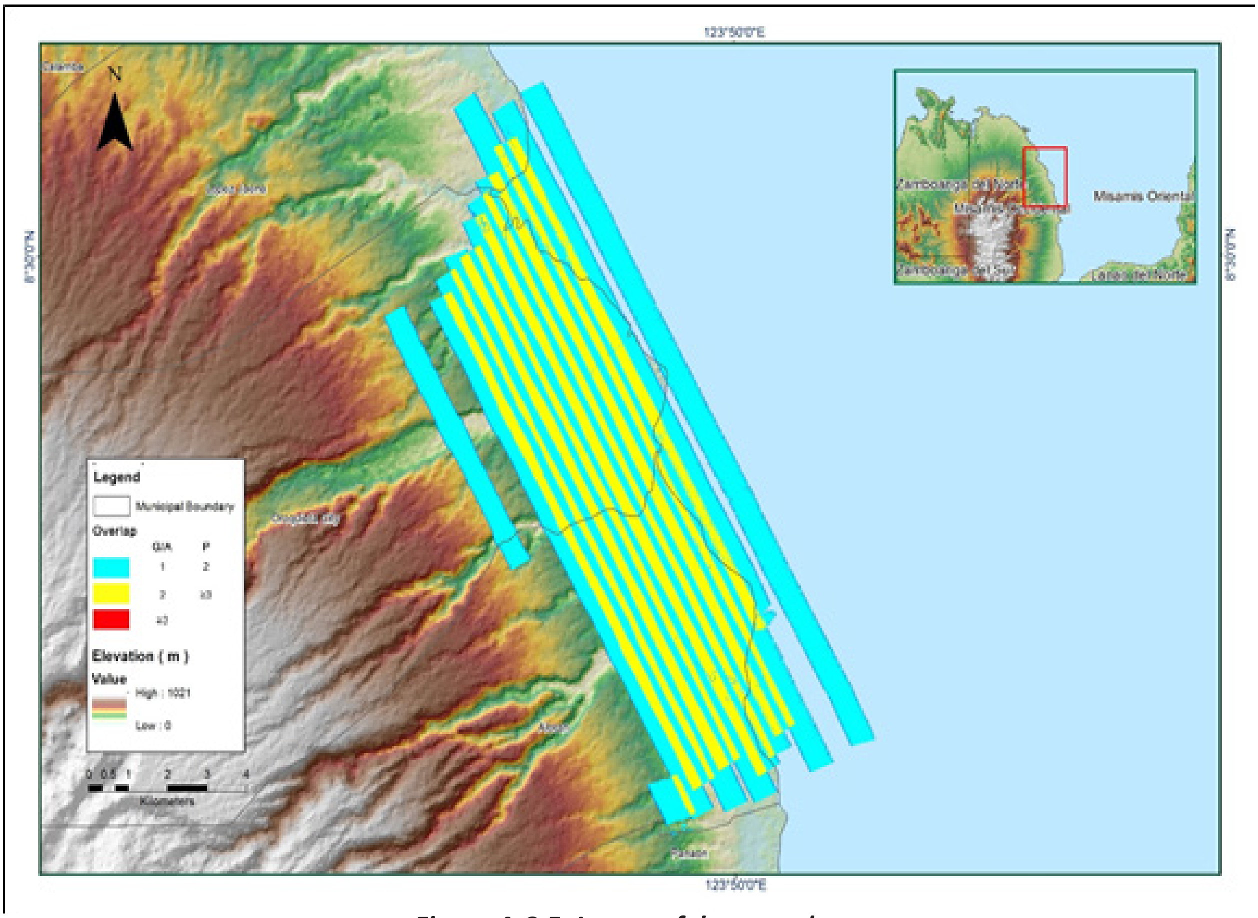


Figure A-8.5. Image of data overlap

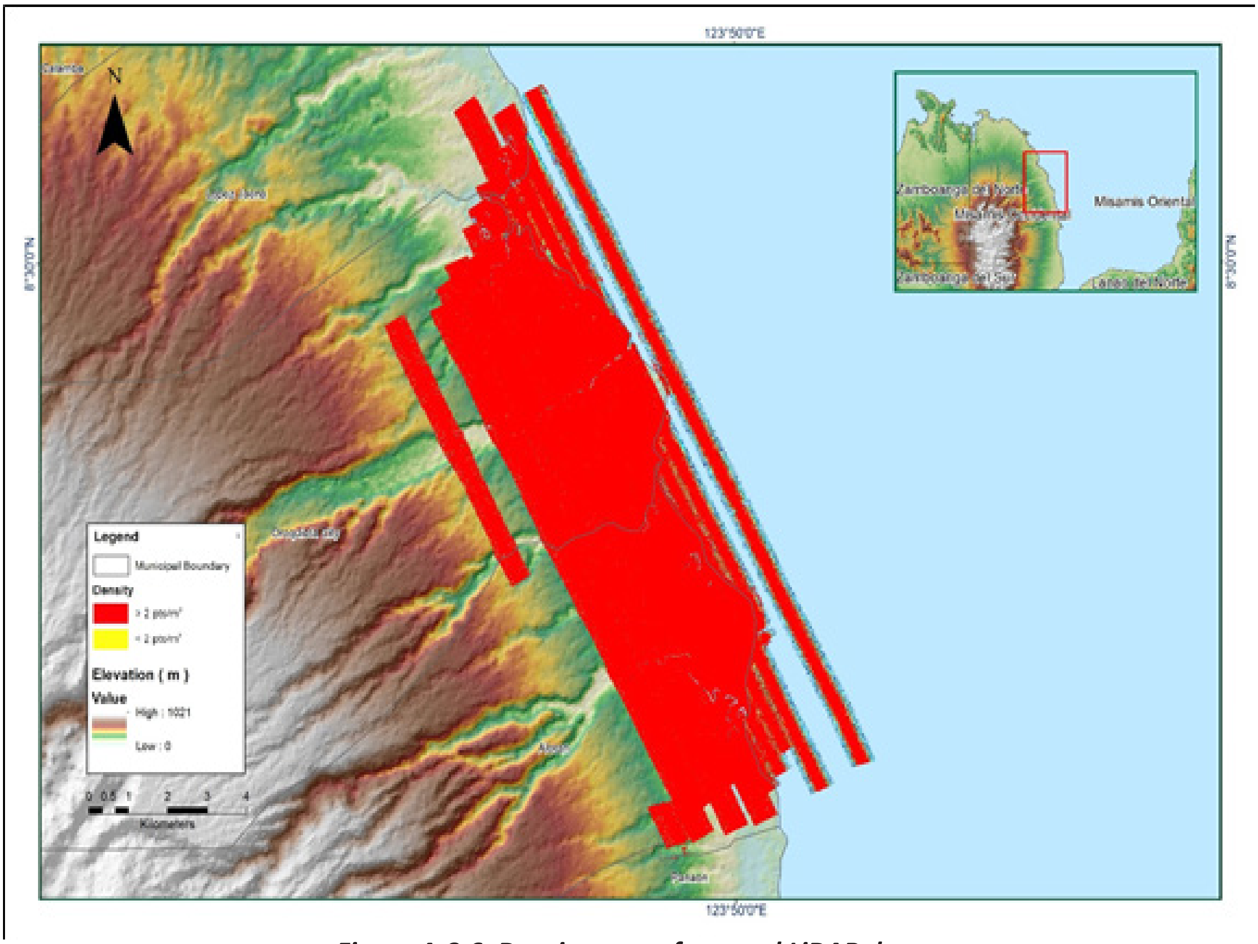


Figure A-8.6. Density map of merged LiDAR data

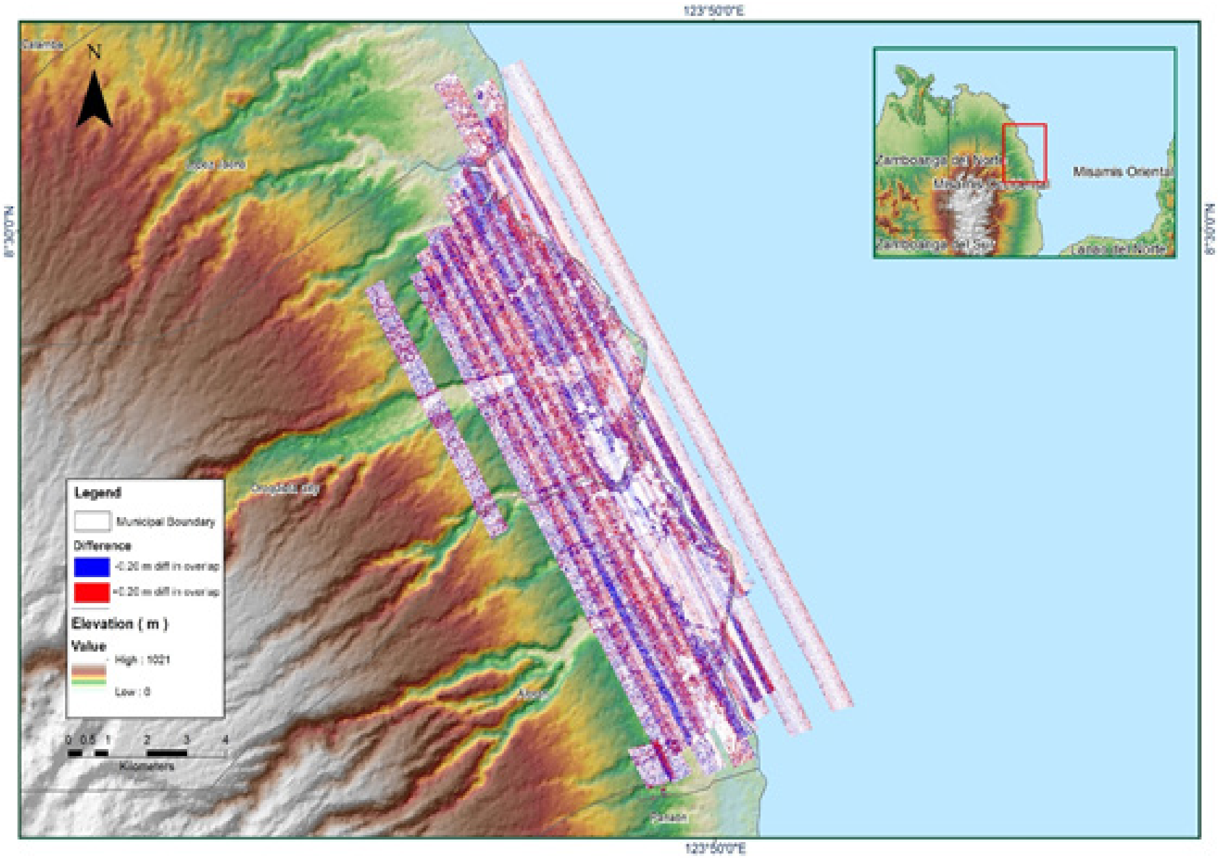


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Blk69E

Flight Area	Dipolog
Mission Name	Blk69E
Inclusive Flights	2133P
Range data size	22.8 GB
POS	225 MB
Base Data	37.3 MB
Image	28.3 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)	1.3
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000314
IMU attitude correction stdev (<0.001deg)	0.000830
GPS position stdev (<0.01m)	0.0108
Minimum % overlap (>25)	15.28%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	82
Maximum Height	128.21 m
Minimum Height	65.18 m
Classification (# of points)	
Ground	35,332,398
Low vegetation	36,813,591
Medium vegetation	28,058,702
High vegetation	34,061,375
Building	3,743,997
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Chelou Prado, Engr. Elainne Lopez

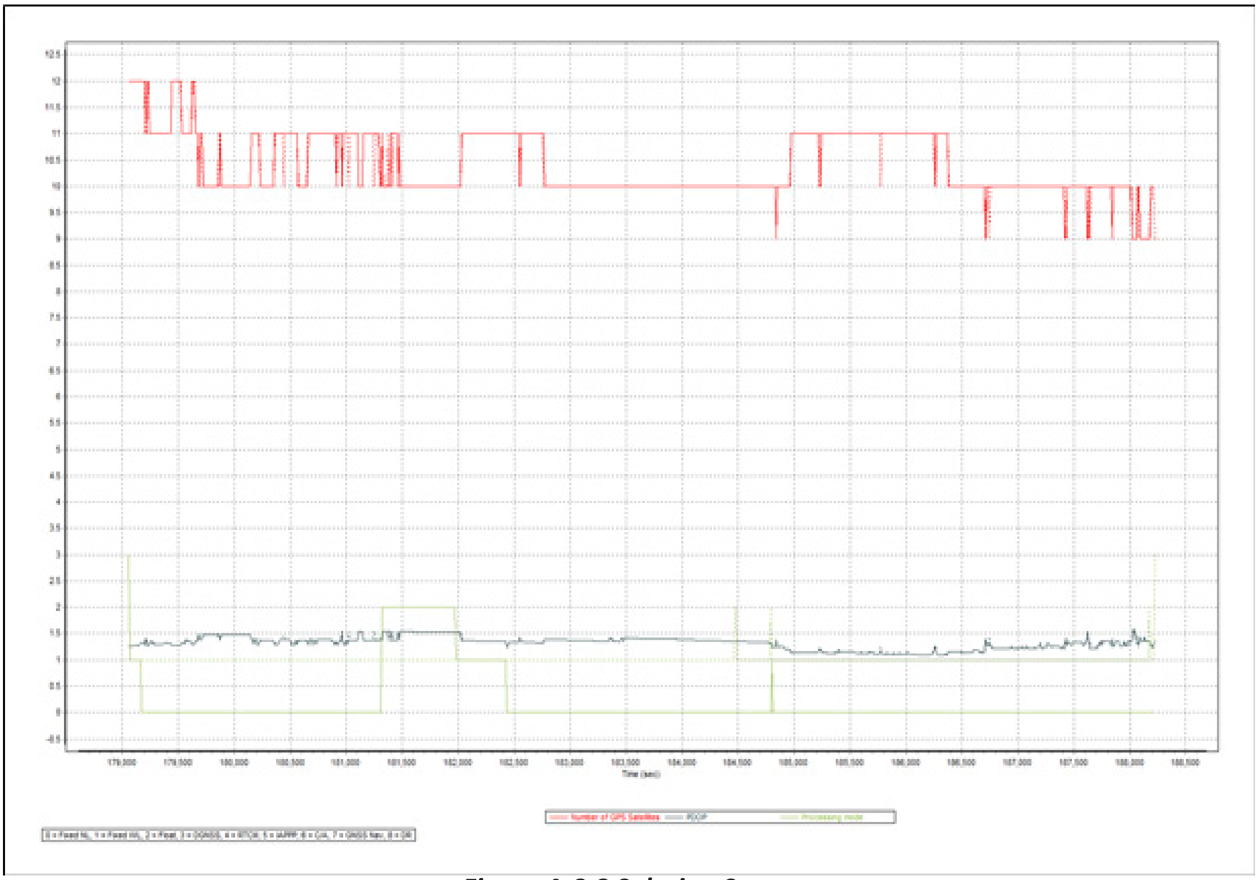


Figure A-8.8 Solution Status

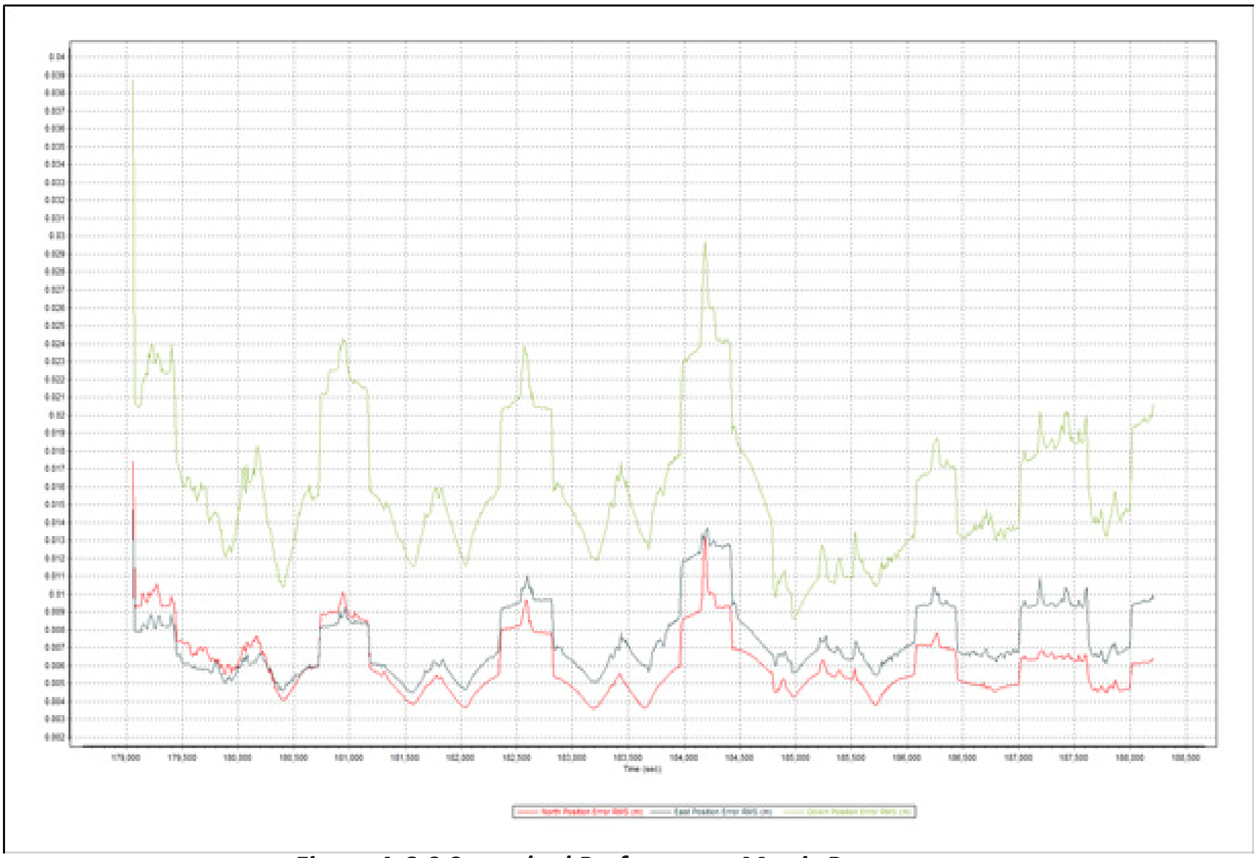


Figure A-8.9 Smoothed Performance Metric Parameters

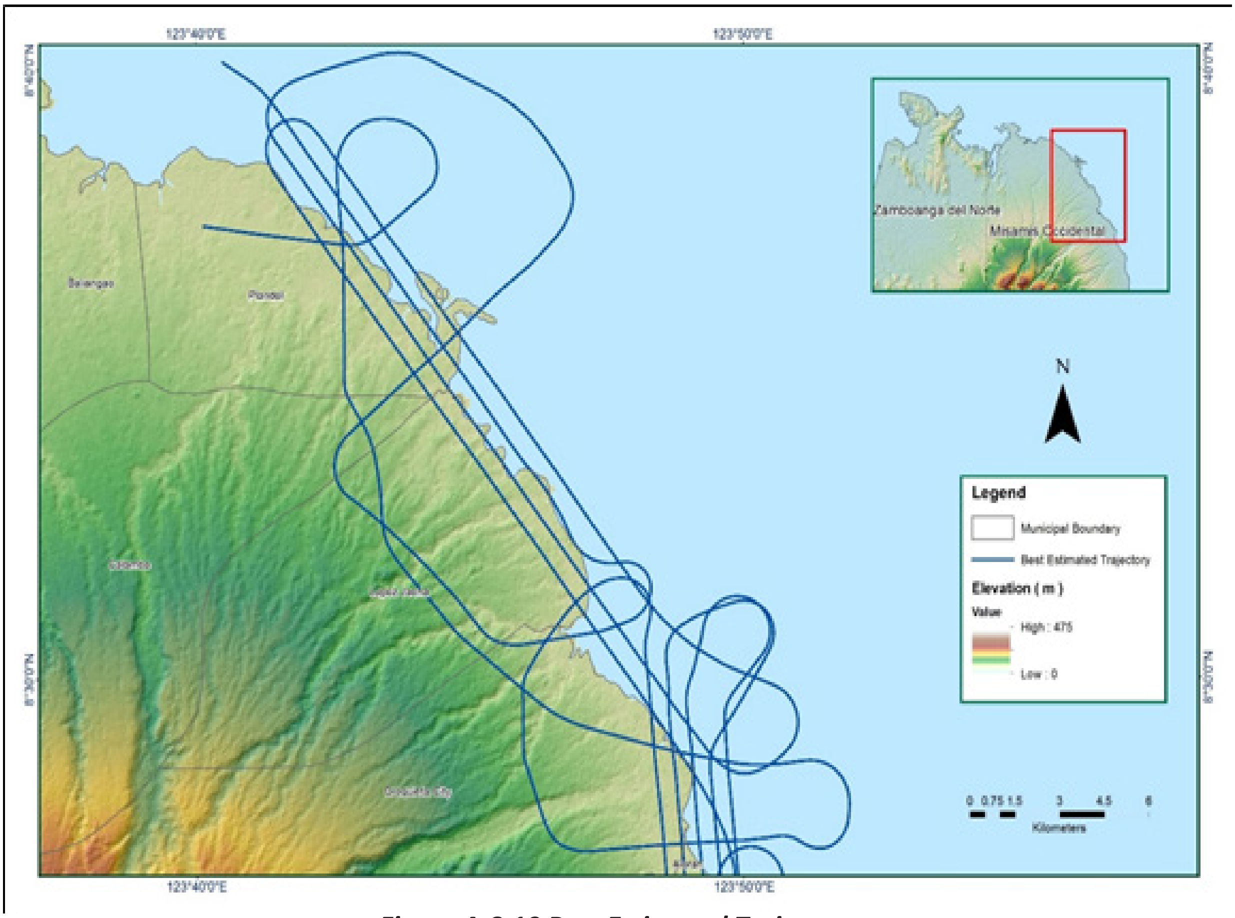


Figure A-8.10 Best Estimated Trajectory

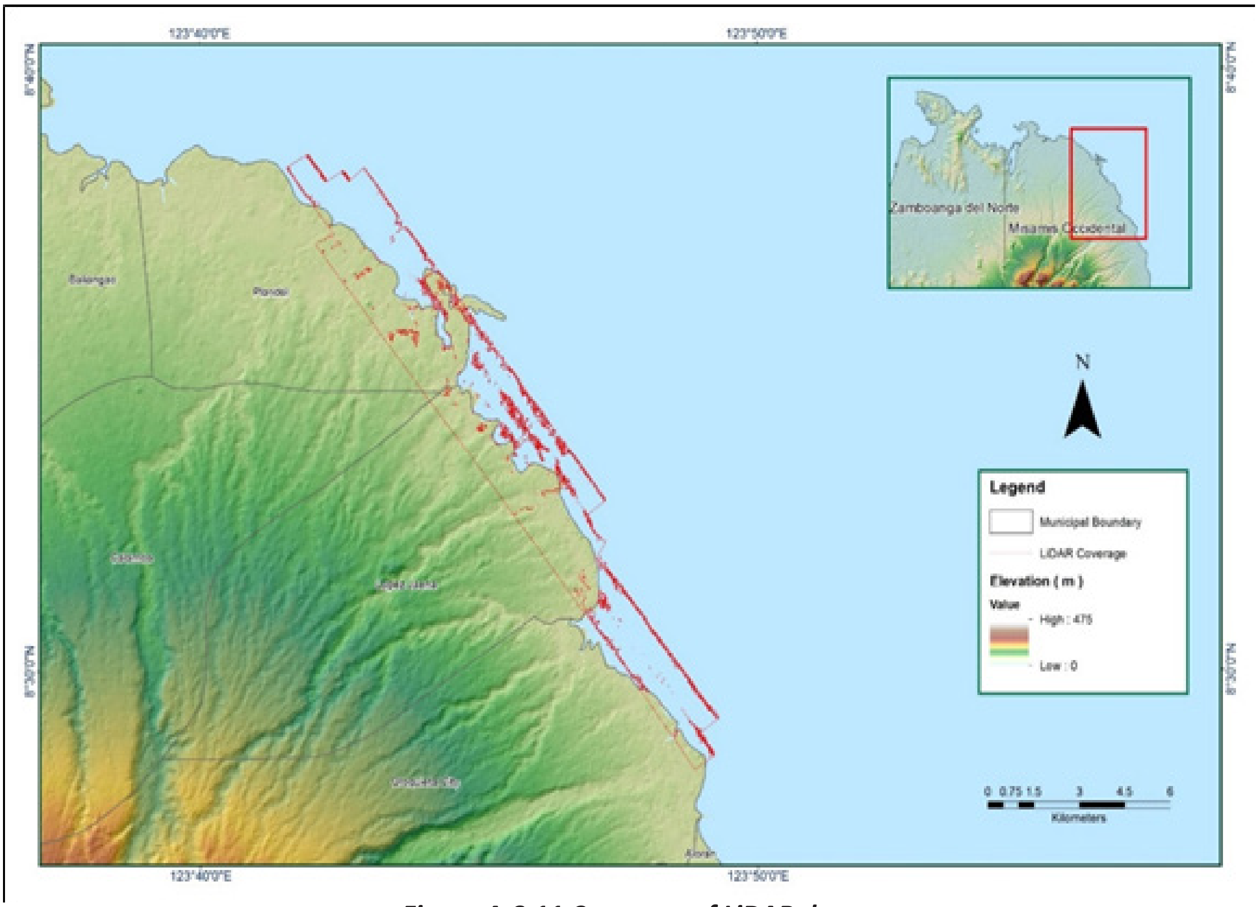


Figure A-8.11 Coverage of LiDAR data

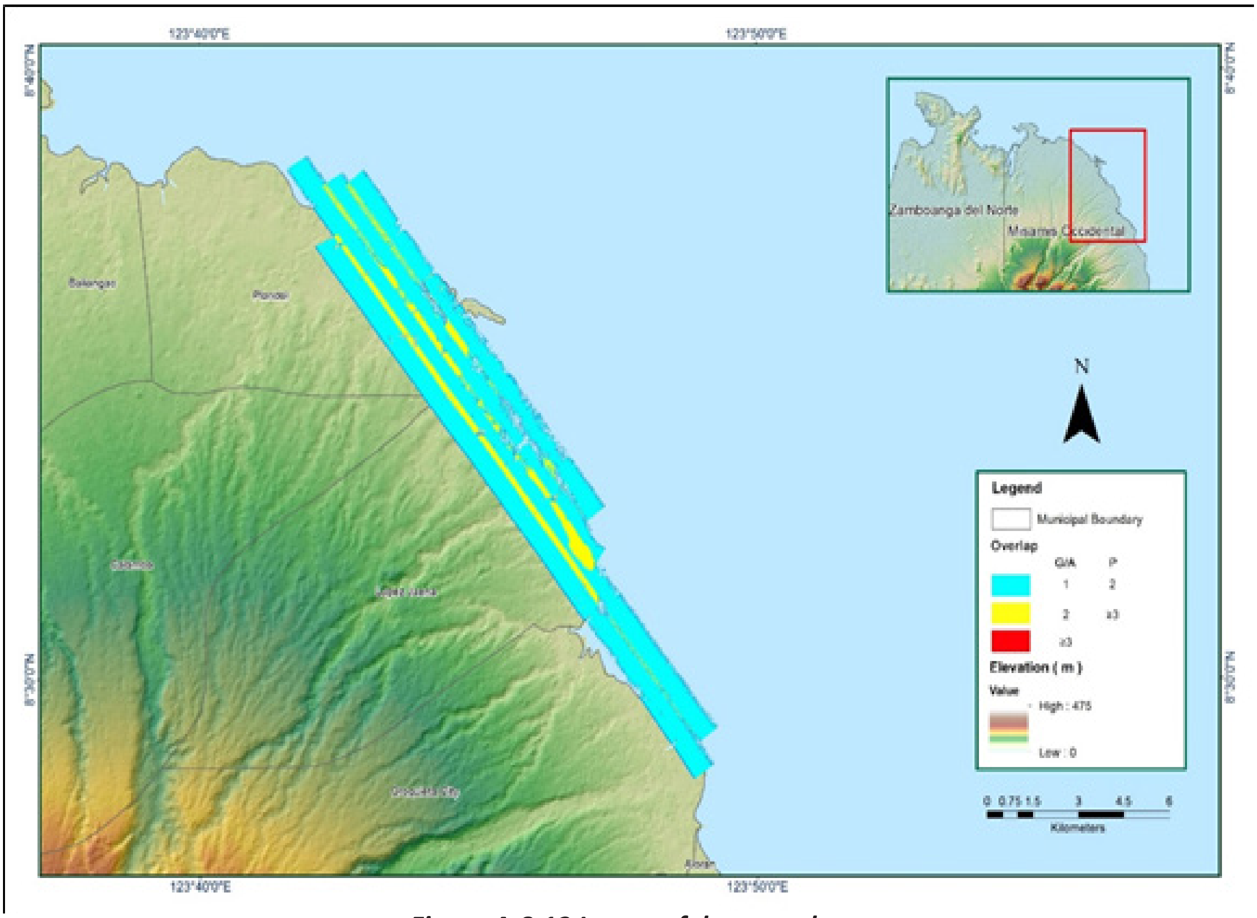


Figure A-8.12 Image of data overlap

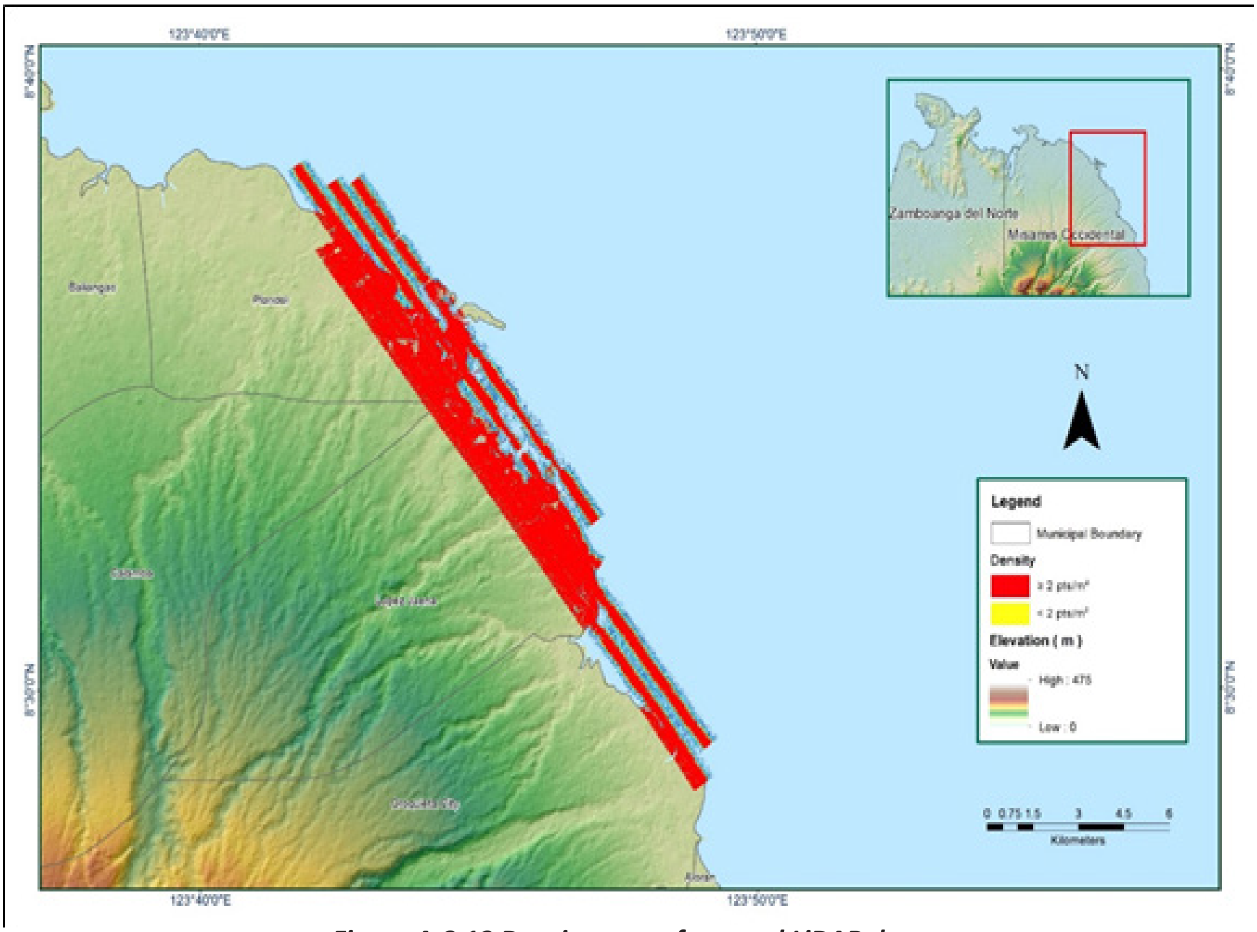


Figure A-8.13 Density map of merged LiDAR data

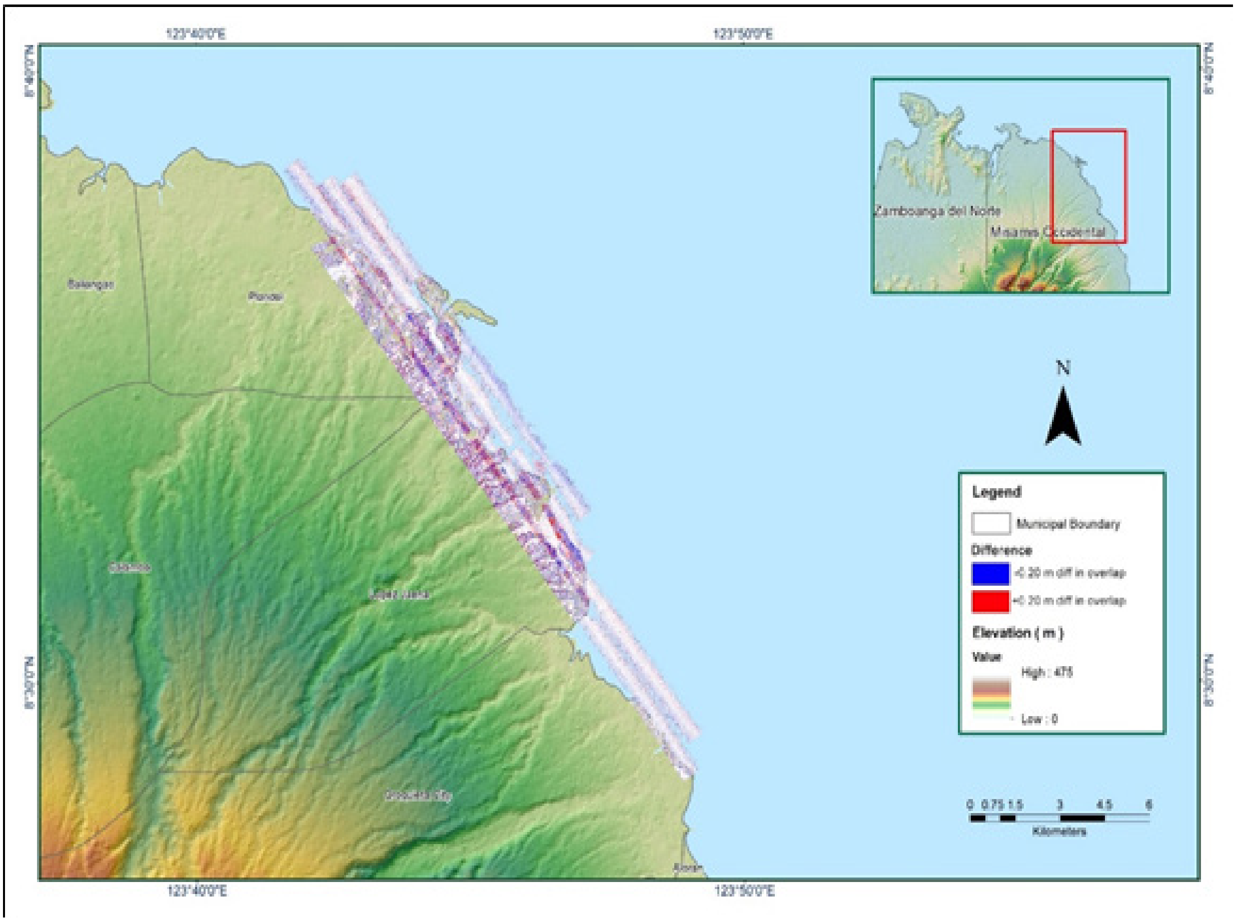


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Blk69F

Flight Area	Dipolog
Mission Name	Blk69F
Inclusive Flights	2133P,2135P,2181P
Range data size	43.4 GB
POS	501.6 MB
Base Data	91.6 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
Elevation difference between strips (<0.20 m)	Yes
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. Mark Joshua Salvacion, Jovy Narisma

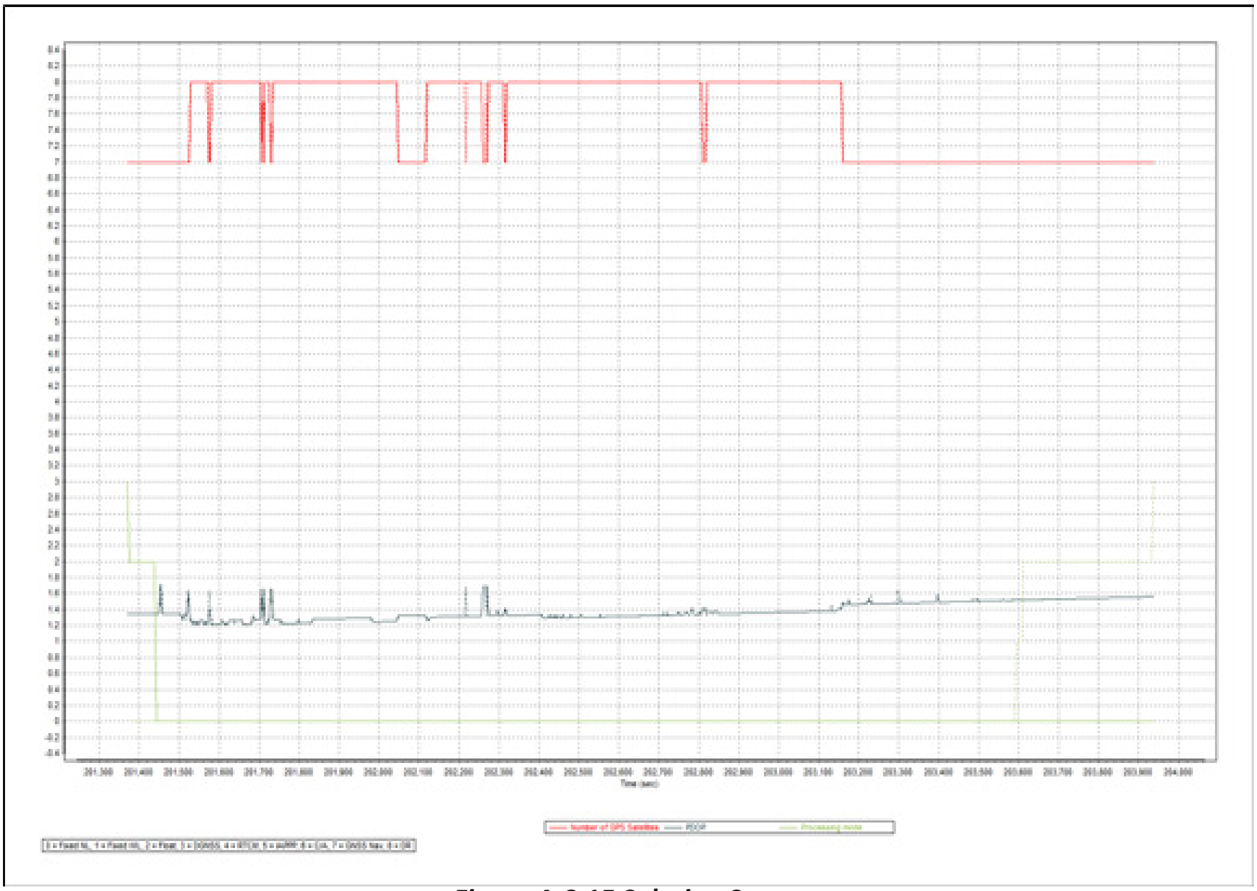


Figure A-8.15 Solution Status

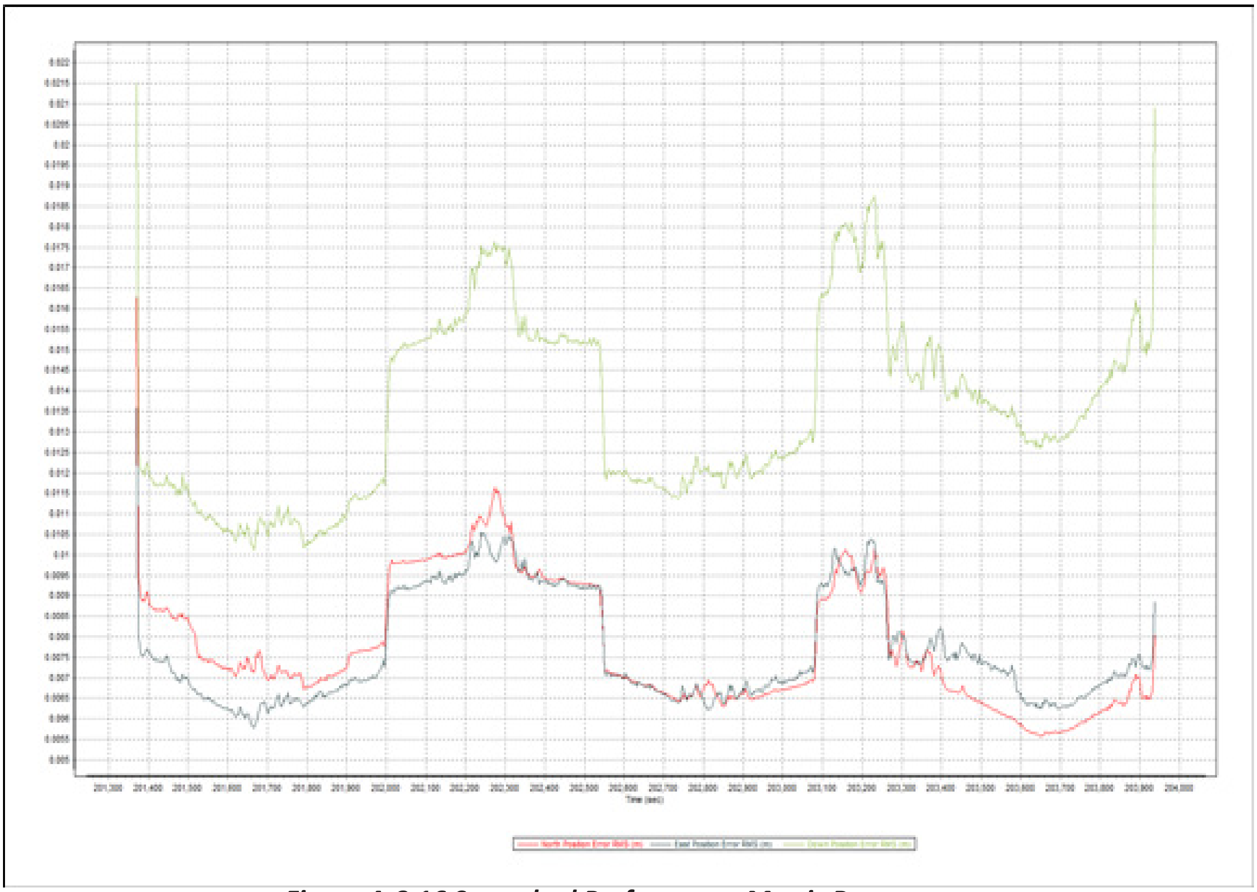


Figure A-8.16 Smoothed Performance Metric Parameters

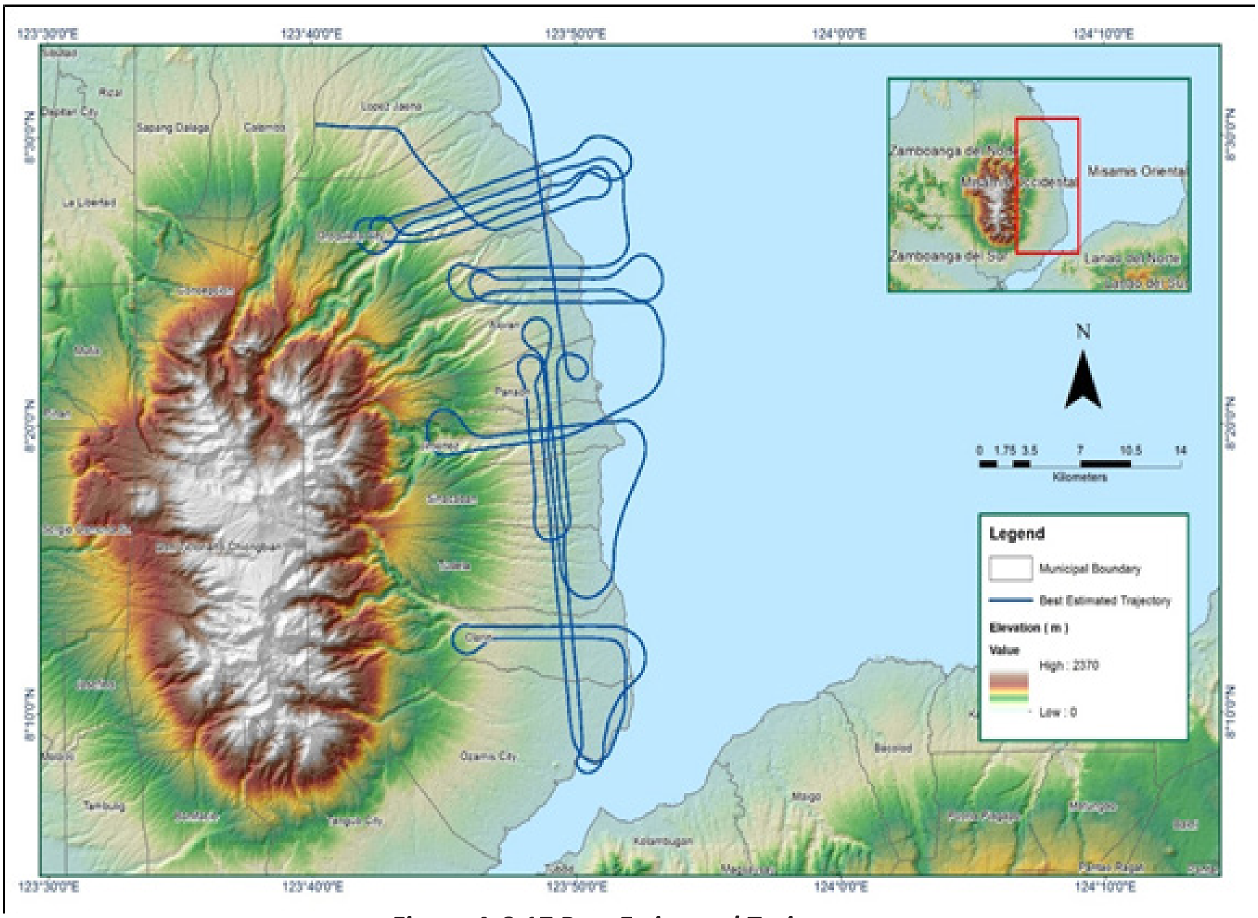


Figure A-8.17 Best Estimated Trajectory

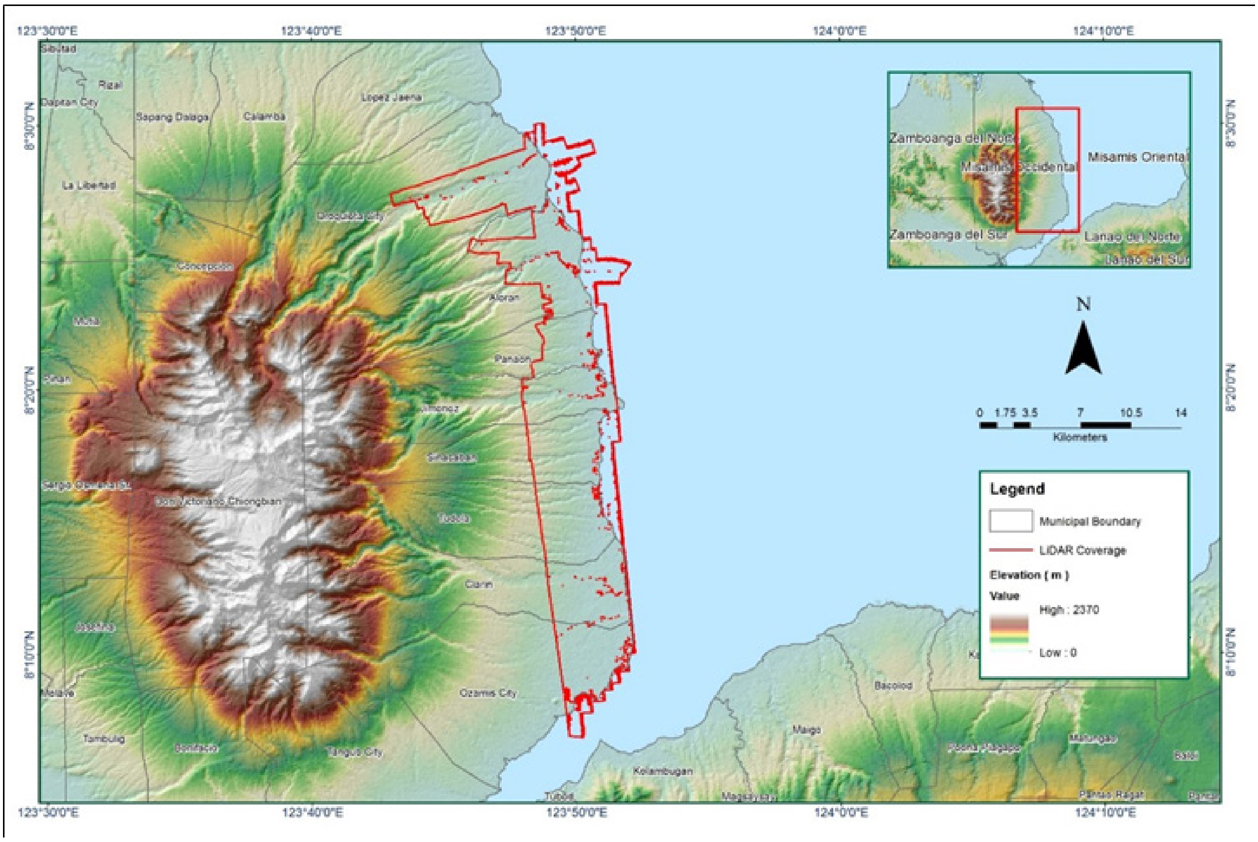


Figure A-8.18 Coverage of LiDAR data

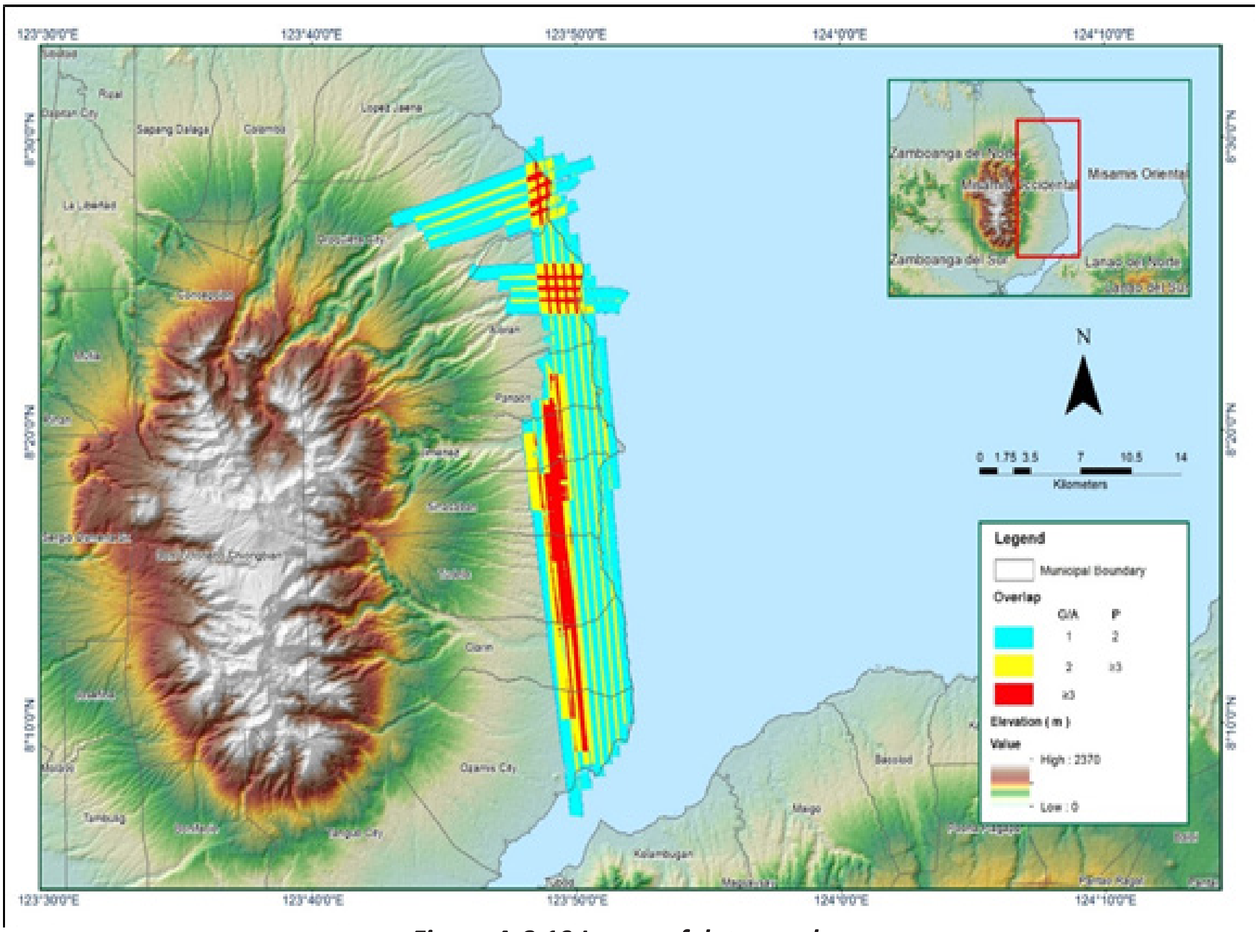


Figure A-8.19 Image of data overlap

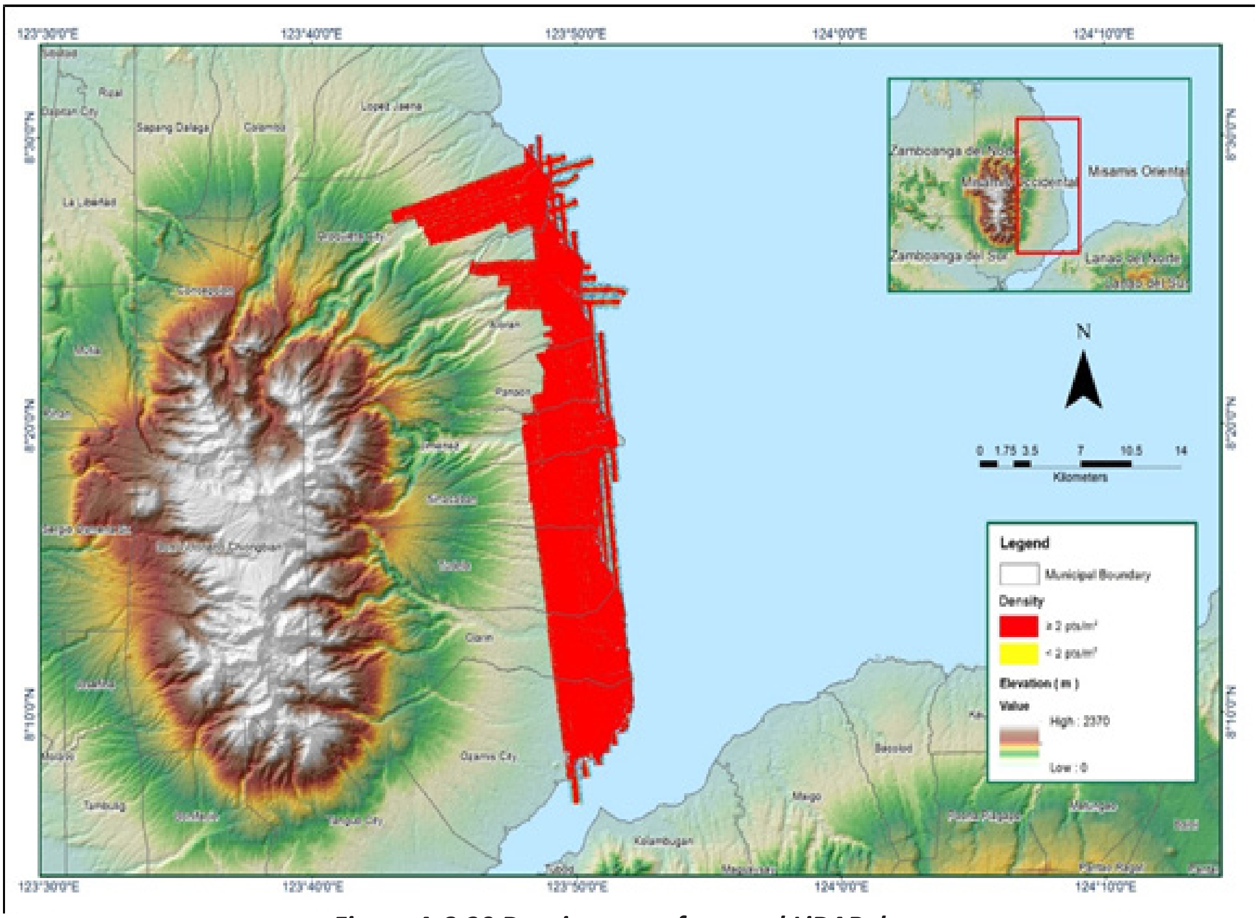


Figure A-8.20 Density map of merged LiDAR data

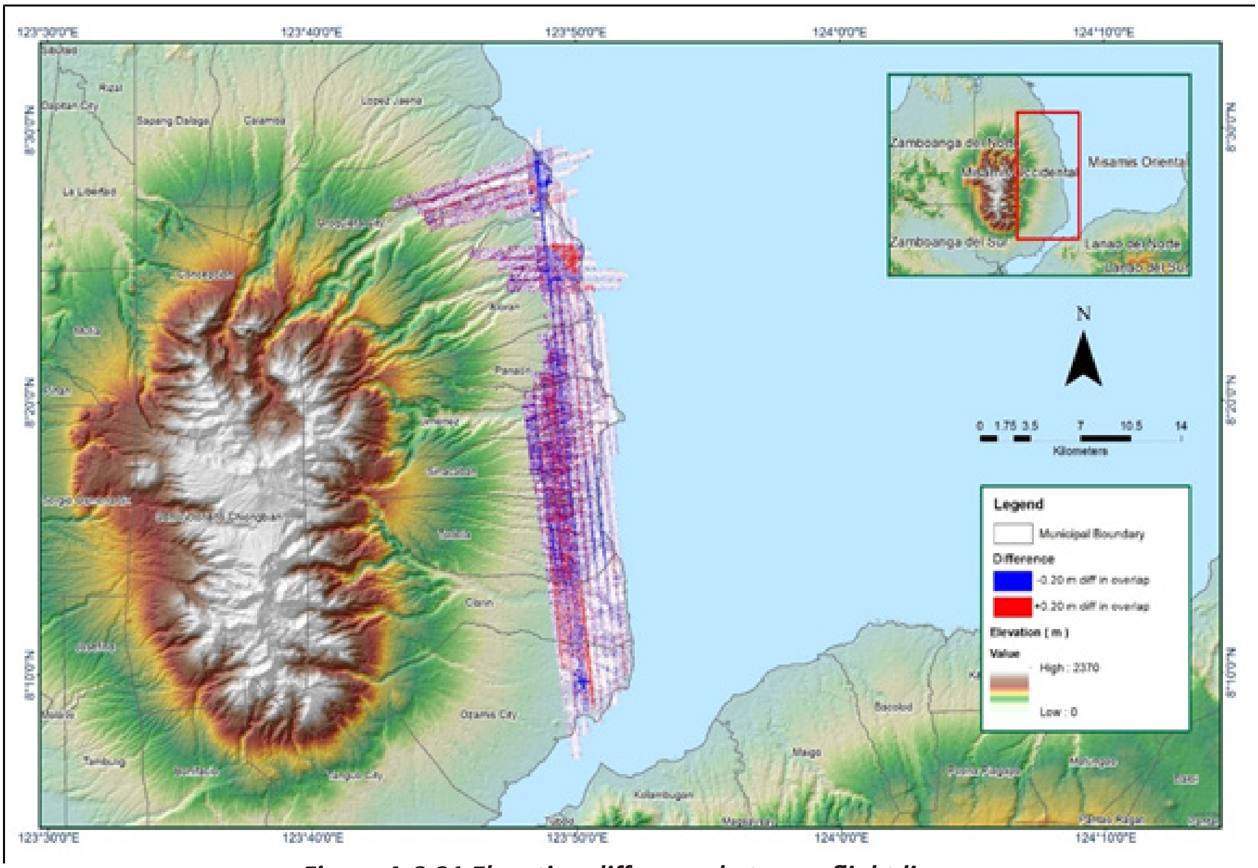


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Blk76P

Flight Area	Dipolog
Mission Name	Blk76P
Inclusive Flights	23566P
Range data size	18 GB
POS data size	267 MB
Base data size	188 MB
Image	n/a
Transfer date	December 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.495
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	3.418
Boresight correction stdev (<0.001deg)	0.000165
IMU attitude correction stdev (<0.001deg)	0.001616
GPS position stdev (<0.01m)	0.0083
Minimum % overlap (>25)	28.40 %
Ave point cloud density per sq.m. (>2.0)	5.72
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	143
Maximum Height	726.77
Minimum Height	66.72
Classification (# of points)	
Ground	143,958,985
Low vegetation	76,032,661
Medium vegetation	184,048,181
High vegetation	692,760,349
Building	9,962,175
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga Jr., Engr. Monalyne Rabino

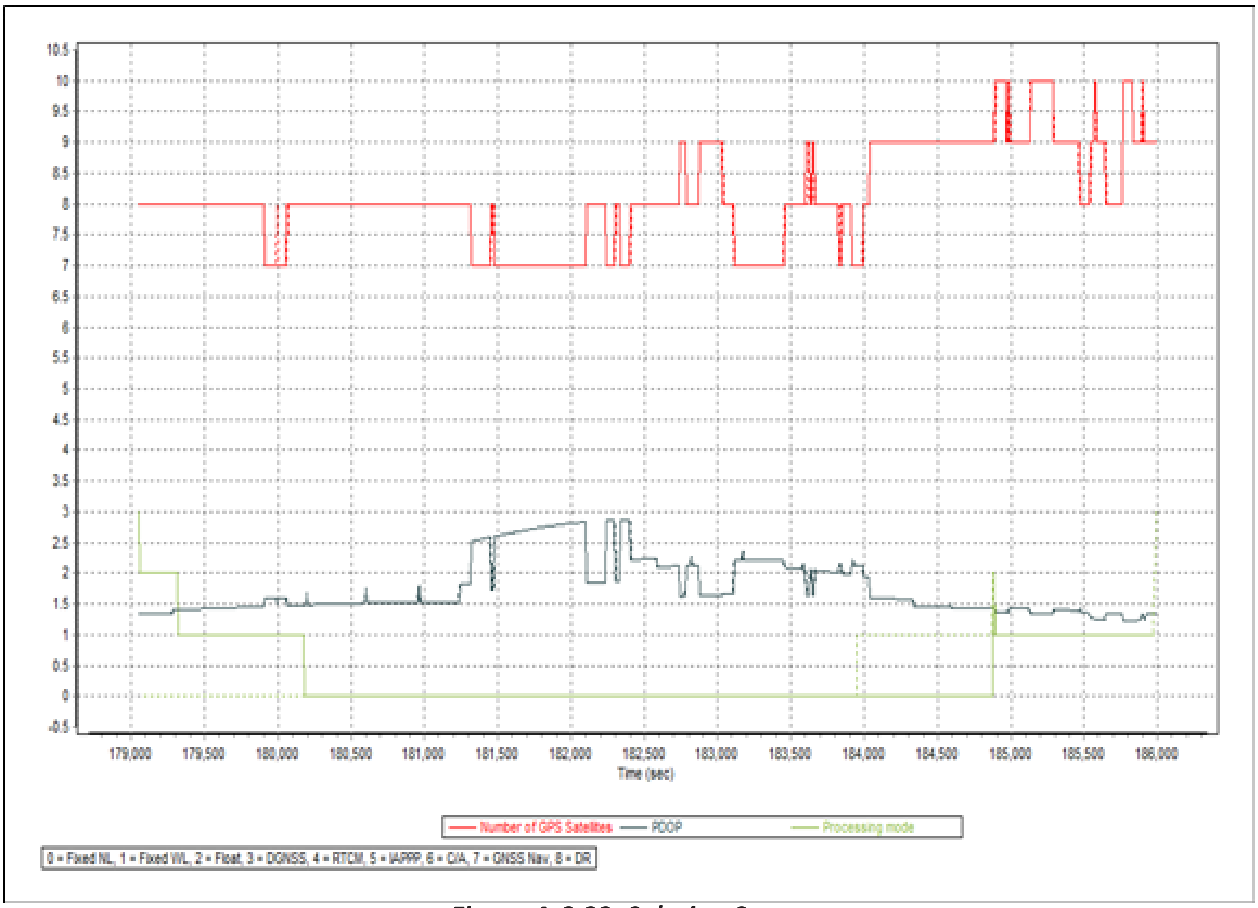


Figure A-8.22. Solution Status

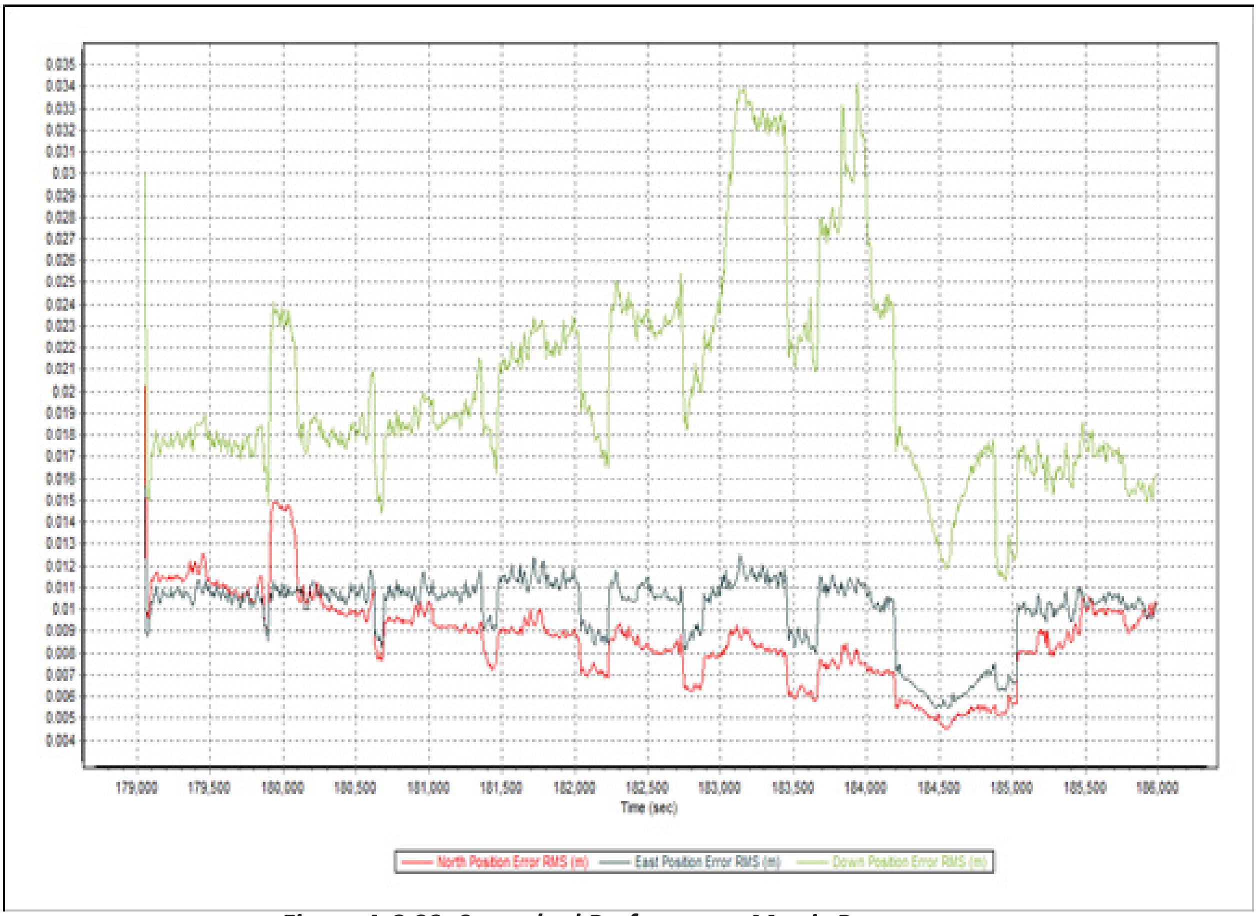


Figure A-8.23. Smoothed Performance Metric Parameters

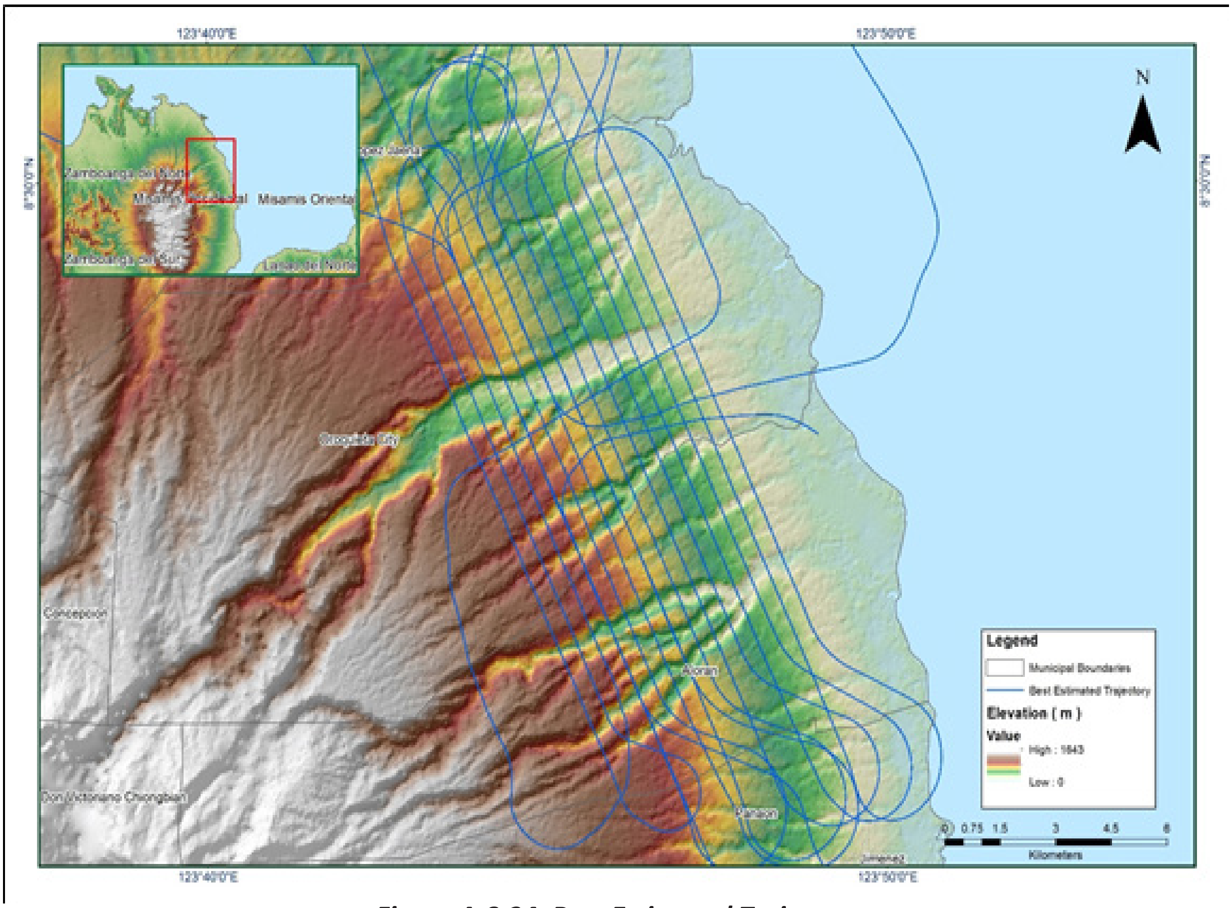


Figure A-8.24. Best Estimated Trajectory

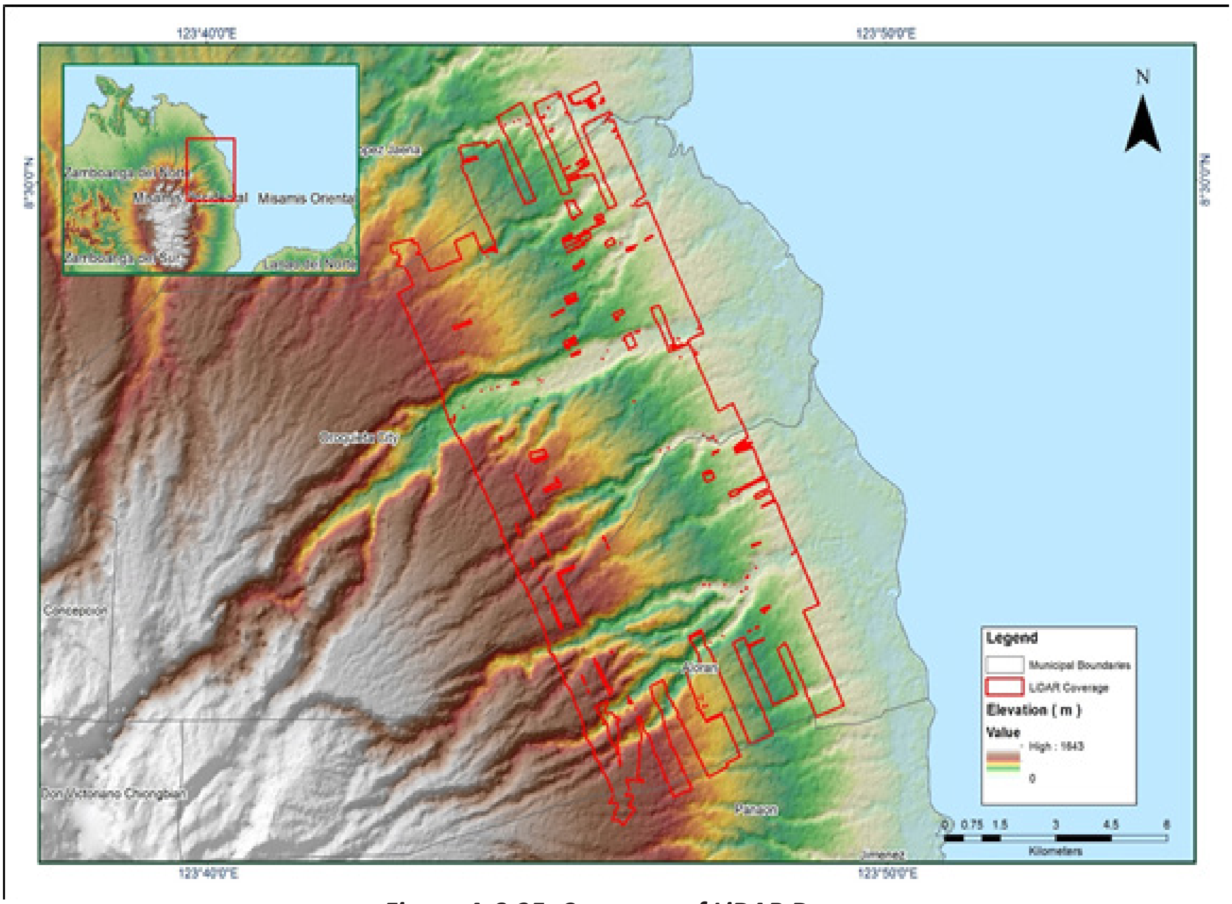


Figure A-8.25. Coverage of LiDAR Data

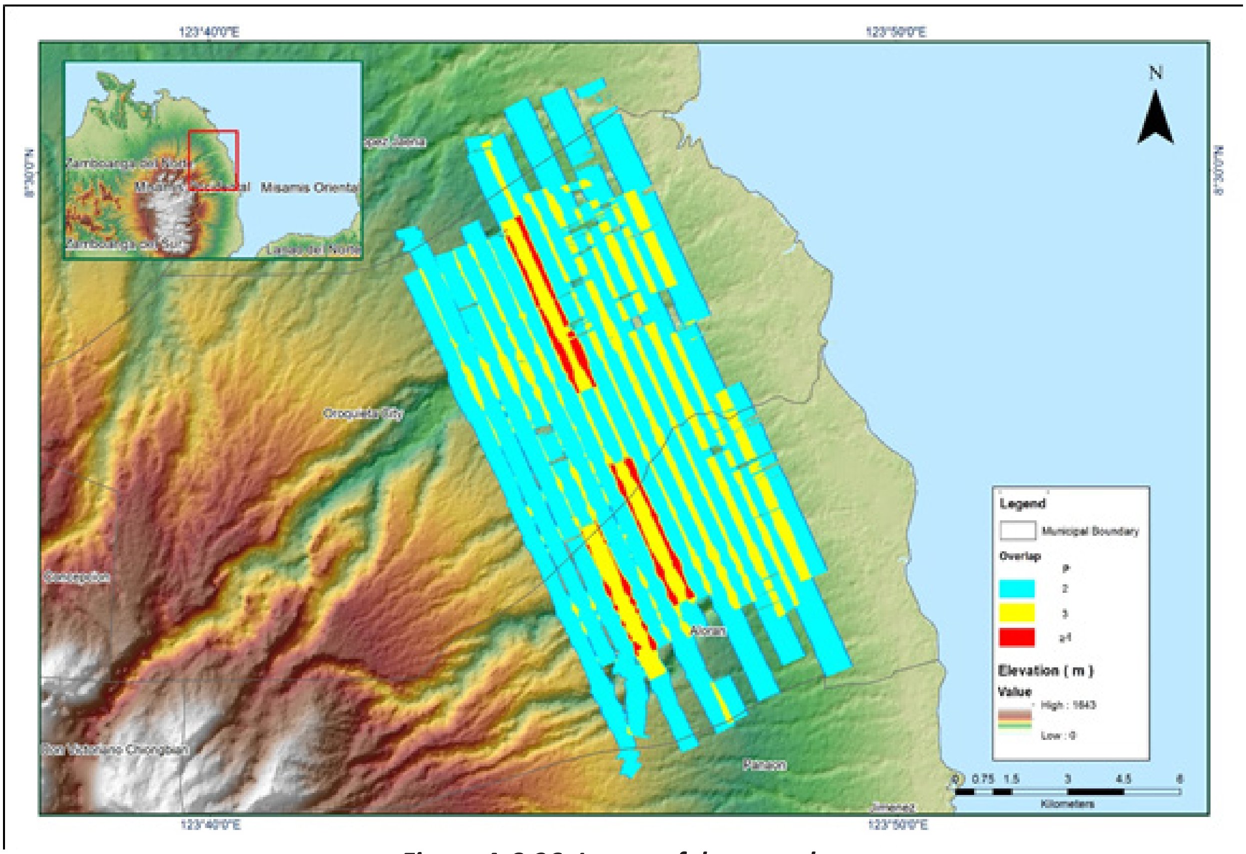


Figure A-8.26. Image of data overlap

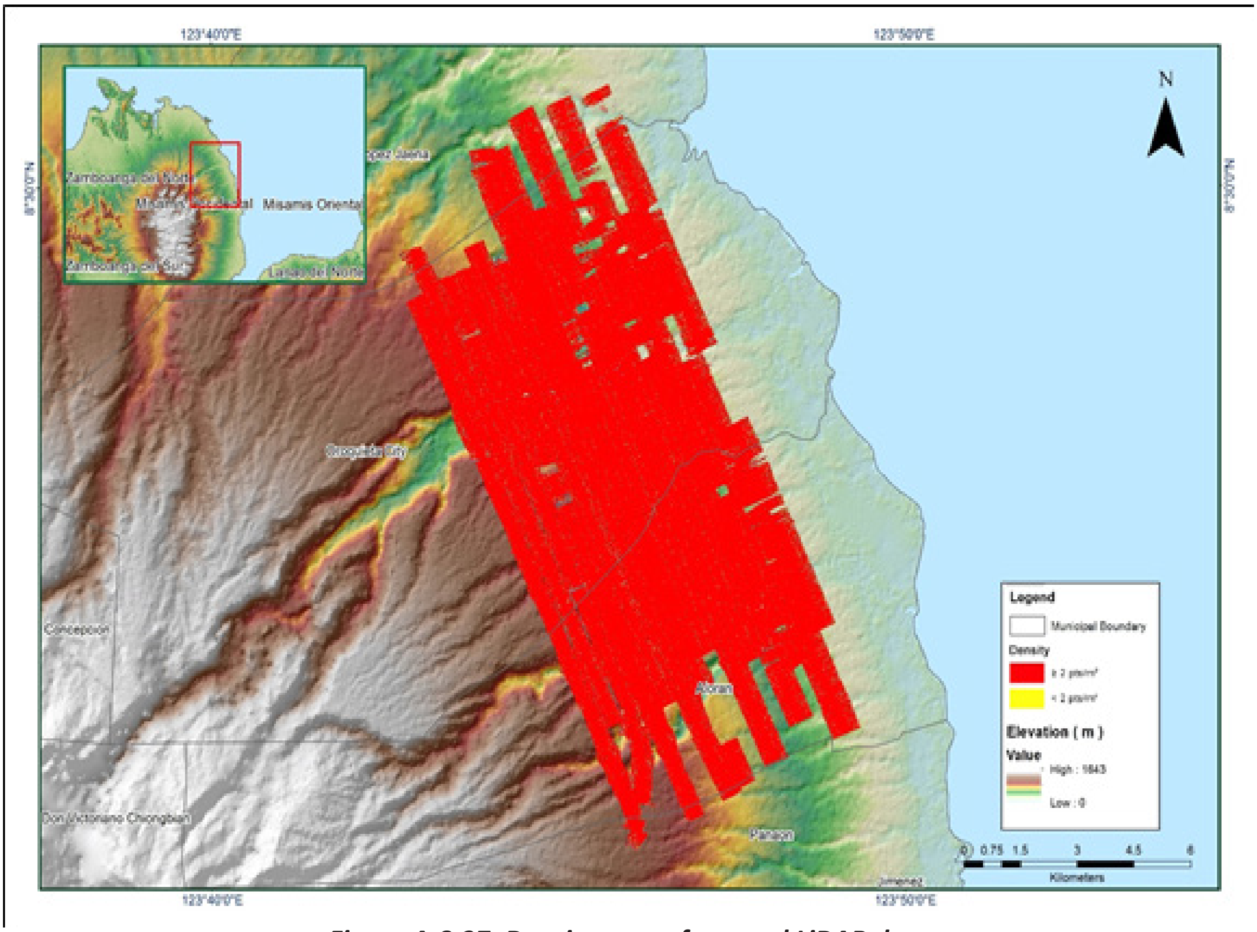


Figure A-8.27. Density map of merged LiDAR data

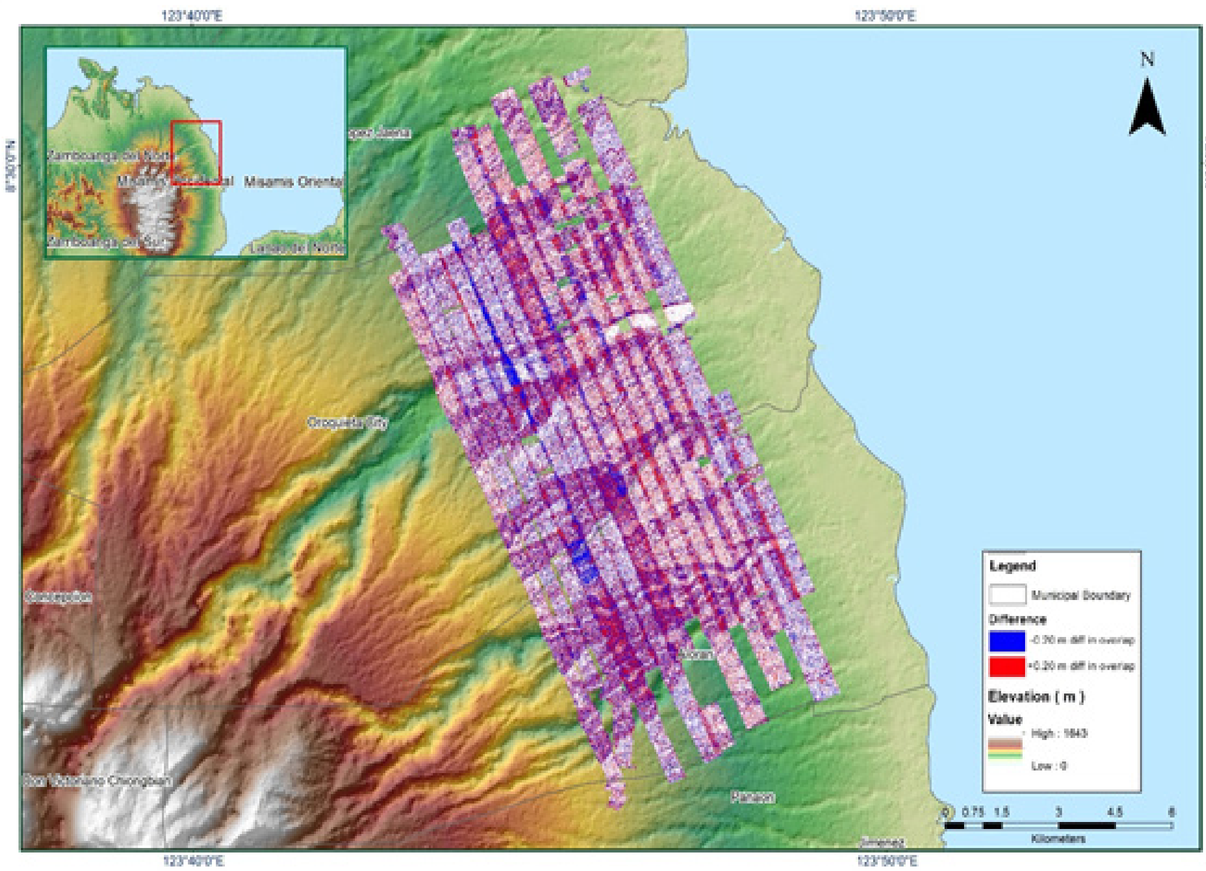


Figure A-8.28. Elevation difference between flight lines

Annex 9. Layawan Model Basin Parameters

Table A-9.1. Layawan Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW				
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Con-centration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (CU.M/S)	Recession Constant	Threshold Type	Ratio to Peak
W260	27.885	83	0	0.34482	0.34482	Discharge	0.482	1	Ratio to Peak	0.5
W270	33.345	80.326	0	0.49378	0.49378	Discharge	0.66405	1	Ratio to Peak	0.5
W280	29.73153	82.076	0	0.505904	0.505904	Discharge	0.76439	1	Ratio to Peak	0.5
W310	40.790	76.946	0	0.712488	0.712488	Discharge	1.5694	1	Ratio to Peak	0.5
W320	37.527	78.392	0	0.577696	0.577696	Discharge	1.0916	1	Ratio to Peak	0.5
W330	116.8083243	53.822	0	1.197084	1.197084	Discharge	2.2628	1	Ratio to Peak	0.5
W340	46.159	74.68	0	0.810852	0.810852	Discharge	2.1066	1	Ratio to Peak	0.5
W350	55.535	71.027	0	0.254408	0.254408	Discharge	0.734	1	Ratio to Peak	0.5
W360	92.259	59.607	0	0.733908	0.733908	Discharge	1.1801	1	Ratio to Peak	0.5
W370	136.3510963	49.962	0	1.226596	1.226596	Discharge	3.0993	1	Ratio to Peak	0.5
W380	127.3588161	51.667	0	1.150408	1.150408	Discharge	3.1979	1	Ratio to Peak	0.5
W390	129.0888073	51.33	0	0.2626792	0.2626792	Discharge	0.584	1	Ratio to Peak	0.5

W400	110.583075	55.18	0	0.442988	0.442988	Discharge	1.2779	1	Ratio to Peak	0.5
W420	140.284905	49.251	0	0.2975	0.2975	Discharge	0.83695	1	Ratio to Peak	0.5
W430	109.7186792	55.374	0	0.868784	0.868784	Discharge	5.5972	1	Ratio to Peak	0.5
W440	111.3905455	55	0	0.469336	0.469336	Discharge	1.4113	1	Ratio to Peak	0.5
W450	104.605779	56.55	0	0.387996	0.387996	Discharge	0.71576	1	Ratio to Peak	0.5
W460	103.0114096	56.927	0	0.34328	0.34328	Discharge	0.60192	1	Ratio to Peak	0.5
W470	103.9392349	56.707	0	0.522956	0.522956	Discharge	3.2511	1	Ratio to Peak	0.5
W480	106.5282755	56.102	0	0.355376	0.355376	Discharge	0.96415	1	Ratio to Peak	0.5
W490	105.7693587	56.278	0	0.303856	0.303856	Discharge	1.1807	1	Ratio to Peak	0.5
W500	100.7146788	57.479	0	0.3801	0.3801	Discharge	1.4717	1	Ratio to Peak	0.5

Annex 10. Layawan Model Reach Parameters

Table A-10.1. Layawan Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	2275.4	0.0056279	0.04	Trapezoid	40.1	1
R120	Automatic Fixed Interval	6591.2	0.0332842	0.04	Trapezoid	26.53	1
R140	Automatic Fixed Interval	1587.2	0.0083046	0.04	Trapezoid	26.866	1
R160	Automatic Fixed Interval	566.69	0.0540286	0.04	Trapezoid	29.982	1
R170	Automatic Fixed Interval	9230.5	0.0660546	0.04	Trapezoid	21.9475	1
R210	Automatic Fixed Interval	7343.4	0.0534904	0.04	Trapezoid	21.32	1
R220	Automatic Fixed Interval	1766.5	0.0569767	0.04	Trapezoid	30	1
R30	Automatic Fixed Interval	2396.6	0.0059104	0.04	Trapezoid	41.58	1
R40	Automatic Fixed Interval	1775.8	0.0087585	0.04	Trapezoid	16.898	1
R60	Automatic Fixed Interval	6912.8	0.0135253	0.04	Trapezoid	56.994	1
R70	Automatic Fixed Interval	116.57	0.0181186	0.04	Trapezoid	20.5208	1
R90	Automatic Fixed Interval	1875.5	0.0131245	0.04	Trapezoid	22.346	1

Annex 11. Layawan Field Validation

Table A-11.1. Layawan Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/Scenario
	Latitude	Longitude					
1	8.483892	123.798549	0.22	0.00	0.22	LPA / Jan. 10-11, 2014	5 -Year
2	8.482614	123.799351	1.37	0.30	1.07	LPA / Jan. 10-11, 2014	5 -Year
3	8.482985	123.798974	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
4	8.483874	123.801223	1.16	0.25	0.91	LPA / Jan. 10-11, 2014	5 -Year
5	8.484793	123.801705	1.09	0.41	0.68	LPA / Jan. 10-11, 2014	5 -Year
6	8.482164	123.802210	1.06	0.97	0.09	LPA / Jan. 10-11, 2014	5 -Year
7	8.482615	123.801980	1.39	1.04	0.35	LPA / Jan. 10-11, 2014	5 -Year
8	8.481509	123.800305	0.74	0.48	0.26	LPA / Jan. 10-11, 2014	5 -Year
9	8.481227	123.800542	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
10	8.479968	123.798542	0.42	0.35	-0.07	LPA / Jan. 10-11, 2014	5 -Year
11	8.478652	123.799051	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
12	8.478840	123.799635	0.23	0.13	-0.10	LPA / Jan. 10-11, 2014	5 -Year
13	8.479104	123.801538	0.06	0.00	0.06	LPA / Jan. 10-11, 2014	5 -Year
14	8.479485	123.801980	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
15	8.480598	123.802664	0.73	0.38	-0.35	LPA / Jan. 10-11, 2014	5 -Year
16	8.481933	123.804281	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
17	8.481915	123.800456	0.39	0.33	-0.06	LPA / Jan. 10-11, 2014	5 -Year
18	8.484004	123.802218	0.54	0.36	0.18	LPA / Jan. 10-11, 2014	5 -Year
19	8.482957	123.804010	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
20	8.481696	123.802893	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
21	8.482126	123.804024	0.23	0.13	0.10	LPA / Jan. 10-11, 2014	5 -Year

22	8.481258	123.801201	0.61	0.48	-0.12	LPA / Jan. 10-11, 2014	5 -Year
23	8.481424	123.804018	0.21	0.00	0.21	LPA / Jan. 10-11, 2014	5 -Year
24	8.479895	123.797937	0.44	0.33	-0.11	LPA / Jan. 10-11, 2014	5 -Year
25	8.478047	123.795965	0.22	0.10	0.12	LPA / Jan. 10-11, 2014	5 -Year
26	8.478232	123.796439	0.25	0.05	0.21	LPA / Jan. 10-11, 2014	5 -Year
27	8.479561	123.798145	0.59	0.25	0.34	LPA / Jan. 10-11, 2014	5 -Year
28	8.479051	123.798492	0.22	0.00	0.22	LPA / Jan. 10-11, 2014	5 -Year
29	8.475456	123.794025	0.28	0.04	0.24	LPA / Jan. 10-11, 2014	5 -Year
30	8.478705	123.798717	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
31	8.476978	123.798048	0.84	0.45	-0.39	LPA / Jan. 10-11, 2014	5 -Year
32	8.476845	123.799321	0.05	0.02	0.03	LPA / Jan. 10-11, 2014	5 -Year
33	8.474178	123.798620	4.58	0.45	4.13	LPA / Jan. 10-11, 2014	5 -Year
34	8.476053	123.797919	0.03	0.01	0.02	LPA / Jan. 10-11, 2014	5 -Year
35	8.478164	123.799432	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
36	8.481318	123.804468	0.27	0.15	-0.12	LPA / Jan. 10-11, 2014	5 -Year
37	8.478311	123.801876	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
38	8.478021	123.801637	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
39	8.480263	123.804131	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
40	8.481180	123.805233	1.06	0.97	0.09	LPA / Jan. 10-11, 2014	5 -Year
41	8.480847	123.805413	1.52	0.97	0.55	LPA / Jan. 10-11, 2014	5 -Year
42	8.453816	123.803181	0.27	0.02	0.25	LPA / Jan. 10-11, 2014	5 -Year
43	8.454108	123.802350	0.63	0.33	-0.30	LPA / Jan. 10-11, 2014	5 -Year
44	8.453392	123.802803	0.82	0.25	0.57	LPA / Jan. 10-11, 2014	5 -Year
45	8.453257	123.802800	0.28	0.10	0.18	LPA / Jan. 10-11, 2014	5 -Year
46	8.450186	123.805065	0.28	0.00	0.28	LPA / Jan. 10-11, 2014	5 -Year
47	8.487718	123.802878	0.54	0.00	0.54	LPA / Jan. 10-11, 2014	5 -Year
48	8.484637	123.804071	0.60	0.51	0.09	LPA / Jan. 10-11, 2014	5 -Year
49	8.486211	123.803824	0.53	0.38	0.15	LPA / Jan. 10-11, 2014	5 -Year

50	8.487677	123.803311	0.57	0.38	0.19	LPA / Jan. 10-11, 2014	5 -Year
51	8.487328	123.803722	0.59	0.00	0.59	LPA / Jan. 10-11, 2014	5 -Year
52	8.487011	123.803842	0.57	0.00	0.57	LPA / Jan. 10-11, 2014	5 -Year
53	8.485472	123.804954	0.12	0.08	-0.05	LPA / Jan. 10-11, 2014	5 -Year
54	8.486799	123.807114	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
55	8.486440	123.804479	0.52	0.10	0.42	LPA / Jan. 10-11, 2014	5 -Year
56	8.486797	123.803300	0.58	0.03	0.55	LPA / Jan. 10-11, 2014	5 -Year
57	8.486281	123.802664	0.54	0.25	0.29	LPA / Jan. 10-11, 2014	5 -Year
58	8.484029	123.808562	0.88	0.76	-0.12	LPA / Jan. 10-11, 2014	5 -Year
59	8.484166	123.808727	0.88	0.46	-0.43	LPA / Jan. 10-11, 2014	5 -Year
60	8.482620	123.806895	1.08	0.13	0.95	LPA / Jan. 10-11, 2014	5 -Year
61	8.483246	123.807792	0.54	0.23	0.31	LPA / Jan. 10-11, 2014	5 -Year
62	8.483509	123.808176	0.51	0.22	0.29	LPA / Jan. 10-11, 2014	5 -Year
63	8.482788	123.805278	0.17	0.10	-0.07	LPA / Jan. 10-11, 2014	5 -Year
64	8.483357	123.807399	0.57	0.01	0.56	LPA / Jan. 10-11, 2014	5 -Year
65	8.483498	123.805957	0.51	0.08	0.43	LPA / Jan. 10-11, 2014	5 -Year
66	8.481552	123.805683	1.06	0.14	0.92	LPA / Jan. 10-11, 2014	5 -Year
67	8.484753	123.807817	0.12	0.08	-0.05	LPA / Jan. 10-11, 2014	5 -Year
68	8.460193	123.803272	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
69	8.459080	123.803043	0.30	0.29	0.01	LPA / Jan. 10-11, 2014	5 -Year
70	8.457452	123.802375	1.20	0.65	0.55	LPA / Jan. 10-11, 2014	5 -Year
71	8.479787	123.808492	1.38	0.02	1.36	LPA / Jan. 10-11, 2014	5 -Year
72	8.478894	123.808845	1.34	0.66	0.68	LPA / Jan. 10-11, 2014	5 -Year
73	8.478616	123.811614	1.09	0.03	1.07	LPA / Jan. 10-11, 2014	5 -Year
74	8.479068	123.812524	0.56	0.04	0.52	LPA / Jan. 10-11, 2014	5 -Year
75	8.479750	123.812044	0.62	0.01	0.61	LPA / Jan. 10-11, 2014	5 -Year
76	8.480139	123.811709	1.04	0.49	0.55	LPA / Jan. 10-11, 2014	5 -Year
77	8.480461	123.811433	1.25	0.33	0.92	LPA / Jan. 10-11, 2014	5 -Year

78	8.480618	123.811260	1.07	0.13	0.95	LPA / Jan. 10-11, 2014	5 -Year
79	8.482301	123.810414	0.51	0.33	0.18	LPA / Jan. 10-11, 2014	5 -Year
80	8.482633	123.810110	0.65	0.06	0.59	LPA / Jan. 10-11, 2014	5 -Year
81	8.481368	123.810320	2.02	0.77	1.25	LPA / Jan. 10-11, 2014	5 -Year
82	8.481798	123.810260	2.07	0.05	2.02	LPA / Jan. 10-11, 2014	5 -Year
83	8.483092	123.810075	0.68	0.14	0.54	LPA / Jan. 10-11, 2014	5 -Year
84	8.483311	123.810171	1.06	0.69	-0.37	LPA / Jan. 10-11, 2014	5 -Year
85	8.483368	123.810339	0.44	0.36	-0.08	LPA / Jan. 10-11, 2014	5 -Year
86	8.483390	123.810542	0.41	0.32	-0.09	LPA / Jan. 10-11, 2014	5 -Year
87	8.483527	123.809936	0.24	0.16	0.08	LPA / Jan. 10-11, 2014	5 -Year
88	8.478684	123.812218	1.12	0.34	0.78	LPA / Jan. 10-11, 2014	5 -Year
89	8.483284	123.809982	0.34	0.02	0.32	LPA / Jan. 10-11, 2014	5 -Year
90	8.483257	123.809741	0.33	0.12	0.21	LPA / Jan. 10-11, 2014	5 -Year
91	8.482814	123.809633	0.69	0.61	-0.09	LPA / Jan. 10-11, 2014	5 -Year
92	8.482199	123.809232	0.55	0.00	0.55	LPA / Jan. 10-11, 2014	5 -Year
93	8.481138	123.810526	2.07	1.57	0.51	LPA / Jan. 10-11, 2014	5 -Year
94	8.482494	123.809997	1.33	0.71	0.62	LPA / Jan. 10-11, 2014	5 -Year
95	8.478062	123.813453	0.55	0.12	0.43	LPA / Jan. 10-11, 2014	5 -Year
96	8.478471	123.810396	1.71	1.47	-0.24	LPA / Jan. 10-11, 2014	5 -Year
97	8.477052	123.814976	0.52	0.21	0.31	LPA / Jan. 10-11, 2014	5 -Year
98	8.476662	123.815794	0.51	0.42	0.09	LPA / Jan. 10-11, 2014	5 -Year
99	8.465528	123.806352	0.21	0.05	0.16	LPA / Jan. 10-11, 2014	5 -Year
100	8.468939	123.805904	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
101	8.466331	123.805392	0.35	0.01	0.34	LPA / Jan. 10-11, 2014	5 -Year
102	8.465177	123.805265	0.67	0.48	-0.19	LPA / Jan. 10-11, 2014	5 -Year
103	8.464690	123.805286	0.30	0.26	-0.04	LPA / Jan. 10-11, 2014	5 -Year
104	8.463943	123.805062	0.62	0.43	0.19	LPA / Jan. 10-11, 2014	5 -Year
105	8.465600	123.804778	0.59	0.41	-0.18	LPA / Jan. 10-11, 2014	5 -Year

106	8.466995	123.804591	0.27	0.00	0.27	LPA / Jan. 10-11, 2014	5 -Year
107	8.467105	123.804852	0.27	0.19	-0.08	LPA / Jan. 10-11, 2014	5 -Year
108	8.465660	123.805089	0.63	0.26	0.37	LPA / Jan. 10-11, 2014	5 -Year
109	8.468531	123.805854	0.22	0.01	0.21	LPA / Jan. 10-11, 2014	5 -Year
110	8.465544	123.799502	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
111	8.472161	123.798749	2.09	0.02	2.07	LPA / Jan. 10-11, 2014	5 -Year
112	8.472432	123.798887	2.37	0.34	2.03	LPA / Jan. 10-11, 2014	5 -Year
113	8.472254	123.799233	2.10	0.30	1.80	LPA / Jan. 10-11, 2014	5 -Year
114	8.472729	123.799381	2.24	1.74	0.50	LPA / Jan. 10-11, 2014	5 -Year
115	8.472889	123.799773	2.61	1.52	1.09	LPA / Jan. 10-11, 2014	5 -Year
116	8.473026	123.800049	2.27	1.21	1.06	LPA / Jan. 10-11, 2014	5 -Year
117	8.473233	123.800562	2.01	1.16	0.85	LPA / Jan. 10-11, 2014	5 -Year
118	8.473825	123.796101	5.57	0.24	5.33	LPA / Jan. 10-11, 2014	5 -Year
119	8.479998	123.806216	1.33	0.45	0.88	LPA / Jan. 10-11, 2014	5 -Year
120	8.479215	123.806501	1.24	0.04	1.20	LPA / Jan. 10-11, 2014	5 -Year
121	8.480301	123.806135	2.07	0.34	1.73	LPA / Jan. 10-11, 2014	5 -Year
122	8.479967	123.804447	1.38	0.45	0.93	LPA / Jan. 10-11, 2014	5 -Year
123	8.479691	123.805752	2.11	0.02	2.09	LPA / Jan. 10-11, 2014	5 -Year
124	8.479405	123.805097	2.67	1.52	1.15	LPA / Jan. 10-11, 2014	5 -Year
125	8.479221	123.804960	0.03	0.00	0.03	LPA / Jan. 10-11, 2014	5 -Year
126	8.478446	123.806199	1.31	0.76	0.55	LPA / Jan. 10-11, 2014	5 -Year
127	8.477608	123.806326	1.70	1.40	-0.31	LPA / Jan. 10-11, 2014	5 -Year
128	8.478853	123.804838	2.25	0.10	2.15	LPA / Jan. 10-11, 2014	5 -Year
129	8.478697	123.804640	2.49	1.80	0.69	LPA / Jan. 10-11, 2014	5 -Year
130	8.478694	123.804285	3.22	0.97	2.25	LPA / Jan. 10-11, 2014	5 -Year
131	8.478361	123.804478	2.22	0.00	2.22	LPA / Jan. 10-11, 2014	5 -Year
132	8.478441	123.804283	2.32	0.79	1.53	LPA / Jan. 10-11, 2014	5 -Year
133	8.478434	123.805237	2.55	0.64	1.92	LPA / Jan. 10-11, 2014	5 -Year

134	8.477610	123.805129	2.27	0.65	1.62	LPA / Jan. 10-11, 2014	5 -Year
135	8.476430	123.806233	1.15	0.00	1.15	LPA / Jan. 10-11, 2014	5 -Year
136	8.476337	123.806917	1.31	0.05	1.26	LPA / Jan. 10-11, 2014	5 -Year
137	8.474266	123.806351	1.15	0.29	0.86	LPA / Jan. 10-11, 2014	5 -Year
138	8.471469	123.805952	1.46	0.53	0.93	LPA / Jan. 10-11, 2014	5 -Year
139	8.471901	123.804317	1.30	0.44	0.86	LPA / Jan. 10-11, 2014	5 -Year
140	8.472739	123.803950	2.38	1.44	0.94	LPA / Jan. 10-11, 2014	5 -Year
141	8.472369	123.805038	2.05	1.03	1.02	LPA / Jan. 10-11, 2014	5 -Year
142	8.472895	123.805431	2.04	0.31	1.73	LPA / Jan. 10-11, 2014	5 -Year
143	8.473500	123.801796	2.26	0.18	2.08	LPA / Jan. 10-11, 2014	5 -Year
144	8.473519	123.801939	2.27	0.29	1.98	LPA / Jan. 10-11, 2014	5 -Year
145	8.473427	123.802201	1.17	0.05	1.12	LPA / Jan. 10-11, 2014	5 -Year
146	8.473660	123.802317	2.85	1.76	1.09	LPA / Jan. 10-11, 2014	5 -Year
147	8.473585	123.802561	2.70	2.01	0.69	LPA / Jan. 10-11, 2014	5 -Year
148	8.478168	123.804182	2.16	1.47	0.69	LPA / Jan. 10-11, 2014	5 -Year
149	8.479790	123.804497	2.12	0.45	1.67	LPA / Jan. 10-11, 2014	5 -Year
150	8.475261	123.791918	0.24	0.03	0.21	LPA / Jan. 10-11, 2014	5 -Year
151	8.475247	123.791479	0.45	0.33	-0.12	LPA / Jan. 10-11, 2014	5 -Year

Annex 12. Educational Institutions Affected by Flooding in Layawan Floodplain

Table A-12.1 Educational institutions in Aloran, Misamis Occidental affected by flooding in Layawan Floodplain

MISAMIS OCCIDENTAL				
ALORAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
San Vicente Bajo Elementary School	Conat		Low	Medium

Table A-12.2 Educational institutions in Oroquieta City, Misamis Occidental affected by flooding in Layawan Floodplain

MISAMIS OCCIDENTAL				
OROQUIETA CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bolibol Elementary School	Apil			
Talairon Central Elementary School	Bolibol			
Day Care Center	Bolibol			
San Vicente Alto Elementary School	Bolibol			
School Waiting Shed	Bolibol			
SDA Church School Bldg. 2	Bolibol			
Seventh Day Adventist School	Bolibol			
Talairon Central Elementary School	Bolibol			
Talairon Central Elementary School	Bolibol			
Talairon Central Elementary School Building 12	Bolibol			
Talairon Central Elementary School Building 2	Bolibol			
Talairon Central Elementary School Building 4	Bolibol			
Talairon Central Elementary School Building 5	Bolibol			
Talairon Central Elementary School Building 6	Bolibol			
Talairon National 3 School Main	Bolibol			Low
Buenavista Elementary School	Buenavista			
Dullan Norte Elementary School	Buntawan			Low
MONHS Bldg 1	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 10	Lamac Lower	Low	Medium	Medium
MONHS Bldg 2	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 3	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 4	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 5	Lamac Lower	Medium	Medium	Medium

MONHS Bldg 6	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 7	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 8	Lamac Lower	Medium	Medium	Medium
MONHS Bldg 9	Lamac Lower	Medium	Medium	Medium
SDA Kinder School Bldg 1	Lamac Lower			
SDA Kinder School Bldg 1	Lamac Upper			
Center Day Care	Langcangan Lower	Medium	Medium	Medium
Day Care Center	Langcangan Lower			
Layawan Elementary School	Langcangan Lower		Medium	Medium
1er Langcangan Elementary School	Langcangan Lower			
1er Langcangan Elementary School Bldg 2	Langcangan Lower			Low
1er Langcangan Elementary School Bldg 3	Langcangan Lower			
1er Langcangan Elementary School Gate	Langcangan Lower			
MU Bldg 3	Langcangan Lower		Low	Medium
MU Bldg 4	Langcangan Lower		Low	Medium
MU Library	Langcangan Lower		Low	Medium
OVS	Langcangan Lower	Low	Medium	Medium
School Covered Court	Langcangan Lower			
Zion Academy Bldg 1	Langcangan Lower			
Zion Academy Bldg 2	Langcangan Lower			
School H.E. Building	Langcangan Proper			
Proper Langcangan Elem. School	Langcangan Upper			
Solomon Molina College Bldg. 2	Langcangan Upper	Low	Low	Low
Day Care Center	Pines		Low	Low
Misamis Occidental Science and Technology School	Pines		Low	Low
Pines Central Elementary School	Pines			
San Vicente Bajo Elementary School	Pines	Low	Medium	Medium
Misamis Occidental Technical Institute	Poblacion I		Low	Medium
Misamis University Main Bldg	Poblacion I		Low	Medium
MU Bldg 3	Poblacion I			
MU Bldg 5	Poblacion I		Low	Medium

Quanset Hall	Poblacion I	Low	Medium	Medium
SMC Bldg 1	Poblacion I	Low	Medium	Medium
SMC Bldg 10	Poblacion I		Low	Low
SMC Bldg 3	Poblacion I	Low	Low	Medium
SMC Bldg 5	Poblacion I		Medium	Medium
SMC Bldg 6	Poblacion I		Low	Medium
SMC Bldg 7	Poblacion I			Low
SMC Bldg 8	Poblacion I			
SMC Bldg 9	Poblacion I		Low	Low
SMC Chapel	Poblacion I		Low	Low
SMC Home Economics Bldg	Poblacion I	Low	Medium	Medium
MU Bldg 4	Poblacion II		Low	Medium
MU Bldg 5	Poblacion II		Low	Medium
Poblacion 2 Elem School	Poblacion II	Low	Medium	Medium
School C.R.	Poblacion II	Low	Medium	Medium
SMC Bldg 1	Poblacion II			
SMC Bldg 2	Poblacion II			
SMC Bldg 3	Poblacion II	Low	Medium	Medium
SMC Bldg 4	Poblacion II		Low	Low
Southern Capital College	Poblacion II	Low	Medium	Medium
Southern Capitol College	Poblacion II	Low	Medium	Medium
Day Care Center	San Vicente Alto			
San Vicente Bajo Elementary School	San Vicente Alto	Low	Medium	Medium
NC Pueblos School	San Vicente Bajo			Low
Vicente Flores Memorial Elementary School	Taboc Norte	High	High	High
Day Care Center	Talairon			
Dolipos Bajo Elementary School	Talairon			
Talic Elementary School Abandoned Building	Talic	Medium	High	High
Enhakkore Learning Center	Talic	High	High	High
Talic Elementary School Building 1	Talic	Medium	High	High
Talic Elementary School Building 2	Talic	Medium	High	High
Talic Elementary School Building 3	Talic	Medium	High	High
Talic Elementary School Canteen	Talic	Medium	High	High
Talic Elementary School Comfort Rooms	Talic	Medium	Medium	High
Talic Elementary School Stage Building	Talic	High	High	High
Agro-Industrial School	Villaflor			
Agro-Industrial School Welding/Automotive Build*	Villaflor			
Agro-Industrial School	Villaflor			
Oroquieta City National 3 School	Villaflor			
Solomon Molina College Bldg. 1	Villaflor	Low	Low	Low
Solomon Molina College Bldg. 2	Villaflor			
Solomon Molina College Bldg. 3	Villaflor	Low	Low	Low

Annex 13. Health Institutions Affected by Flooding in Layawan Floodplain

Table A-13.1 Health Institutions in Oroquieta City, Misamis Occidental affected by flooding in Layawan Floodplain

MISAMIS OCCIDENTAL				
OROQUIETA CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Abuton Clinic	Langcangan Lower	Medium	Medium	Medium
Almonte Clinic	Langcangan Lower	Low	Medium	Medium
Calapini Clinic	Langcangan Lower			
Dignum Hospital	Langcangan Lower			
Dr. Go Clinic	Langcangan Lower		Medium	Medium
On-going Bldg Construction	Langcangan Lower			
Pharmacy	Langcangan Lower			
Provincial Hospital	Langcangan Lower			
Provincial Hospital Bldg 1	Langcangan Lower			
Provincial Hospital Bldg 10	Langcangan Lower			
Provincial Hospital Bldg 11	Langcangan Lower			
Provincial Hospital Bldg 12	Langcangan Lower			
Provincial Hospital Bldg 2	Langcangan Lower			
Provincial Hospital Bldg 3	Langcangan Lower			
Provincial Hospital Bldg 4	Langcangan Lower			
Provincial Hospital Bldg 5	Langcangan Lower			
Provincial Hospital Bldg 6	Langcangan Lower			
Provincial Hospital Bldg 7	Langcangan Lower			
Provincial Hospital Bldg 8	Langcangan Lower			
Provincial Hospital Bldg 9	Langcangan Lower		Low	Low
Provincial Hospital Gate	Langcangan Lower			
St. Theresa Pharmacy	Langcangan Lower	Low	Low	Medium
St. Therese Hospital	Langcangan Lower			
GSK Botika	Poblacion I		Low	Low
City Health Office	Poblacion II	Low	Medium	Medium
Mercury Drug Store	Poblacion II	Low	Medium	Medium
Pausanos Optical Clinic	Poblacion II	Medium	Medium	Medium
Pharmacia Jessica	Poblacion II		Low	Medium
Rose Pharmacy	Poblacion II	Low	Medium	Medium
Brgy. Health Center	San Vicente Alto			
Health Center	Taboc Norte	Medium	Medium	Medium
Villaflor Health Center	Villaflor			