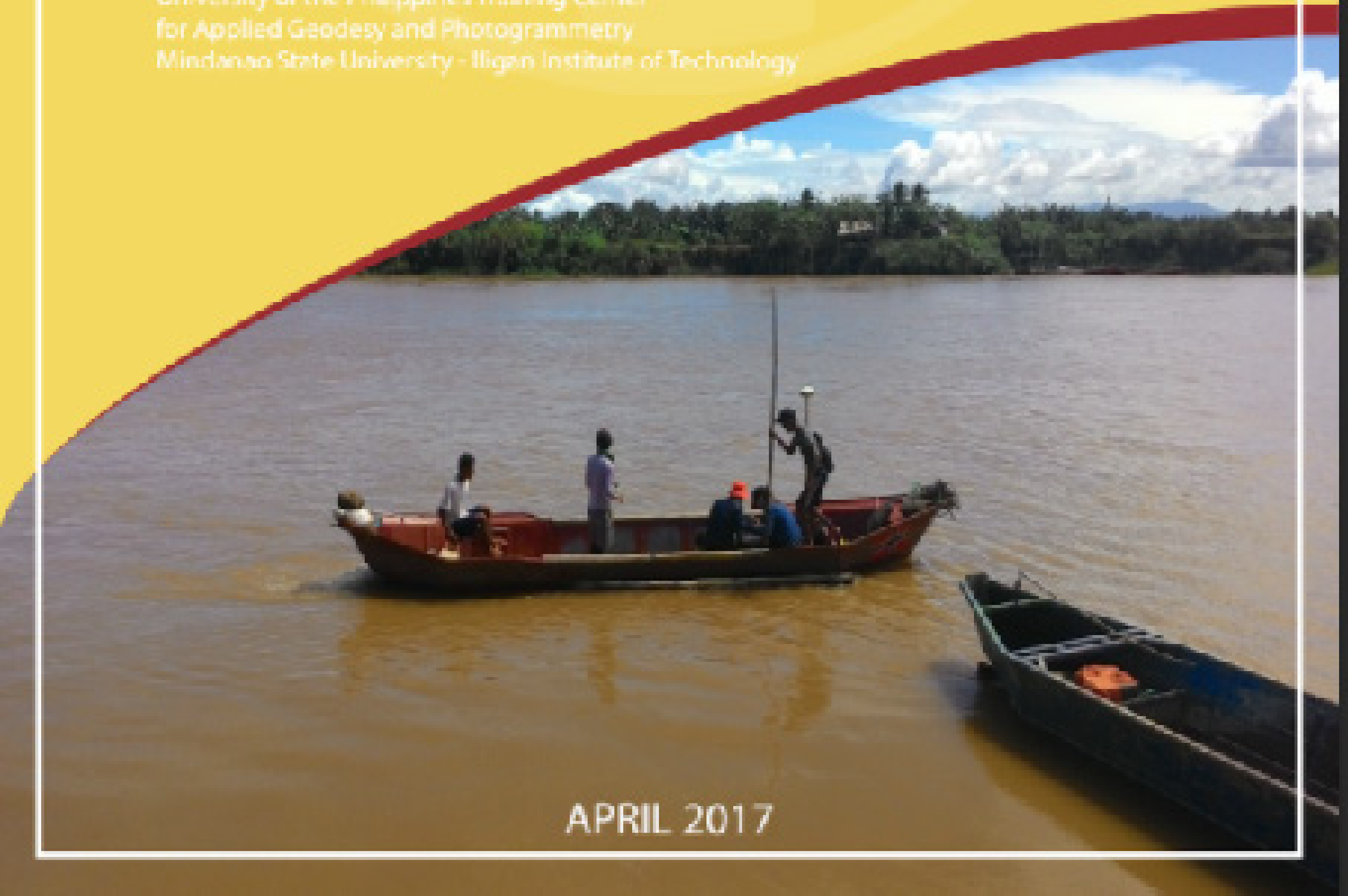
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Labo River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LABO RIVER

Enrico C. Paringit, Dr. Eng., Allan E. Milano

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at a 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the 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 sixteen (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 Labo River Basin

The Labo River Basin is located in the province of Misamis Occidental in Northern Mindanao, covering the Municipalities of Clarin, Don Victoriano, and Calabayan City. The basin is bounded in the north by the Mindanao Sea; in the east by Iligan Bay and Panguil Bay, which separates Calabayan City from its twin city Cagayan de Oro City; in the south by Tangub City; and in the west by the Municipality of Don Victoriano.

The basin's main stem, the Labo River (also known as the Calabayan River), is among the sixteen (16) river systems in Northern Mindanao. The main river starts in the uplands of Calabayan City, which boasts of natural scenic views. These include the Labo River Canyon, the Tipan Ridge and Waterfalls, the Guimad, and the Gala Heights (greedypeg.org, N.D.).

The river basin has an estimated area of 226.395 square kilometers, and a floodplain area of 23.63 square kilometers. The PHIL-LIDAR 1 Flood Modeling Component (FMC) has determined the drainage area of the Labo River Basin to be 81.81 square kilometers.

The floodplain of the Labo River Basin, which is Calabayan City, is nestled at the passageway of the rich Panguil Bay. It has an estimated land area of 16,407 hectares. The area is characterized by its low flat elevation in the urban areas, rising in gentle slopes towards the west, approaching the interior of the territory. Behind the floodplain stands Mt. Malindang, which soars up to 7,956 feet high and approximately 2,411 meters above sea level - serving as a protective barrier against typhoons and strong winds. The weather in the area is relatively uniform, with rainfall fairly distributed throughout the year.

Ozamiz City comprises a total of fifty-one (51) barangays, wherein twenty-three (23) are classified as urban, and twenty-eight (28) are classified as rural (Ozamizcity.com, N.D.). The barangays in Calabayan City that are encompassed in the floodplain include Aguada, Bañadero, Calabayan, Carangan, Doña Consuelo, Gango, Lam-an, Maningcol, Molicay, and San Antonio. In the LiDAR surveys, there were approximately 36,645 building features extracted from the floodplain. Flow measurements were gathered from the Labo-Embargo Steel Bridge, at 8°19’45.40”N and 123°50’5.88”E.

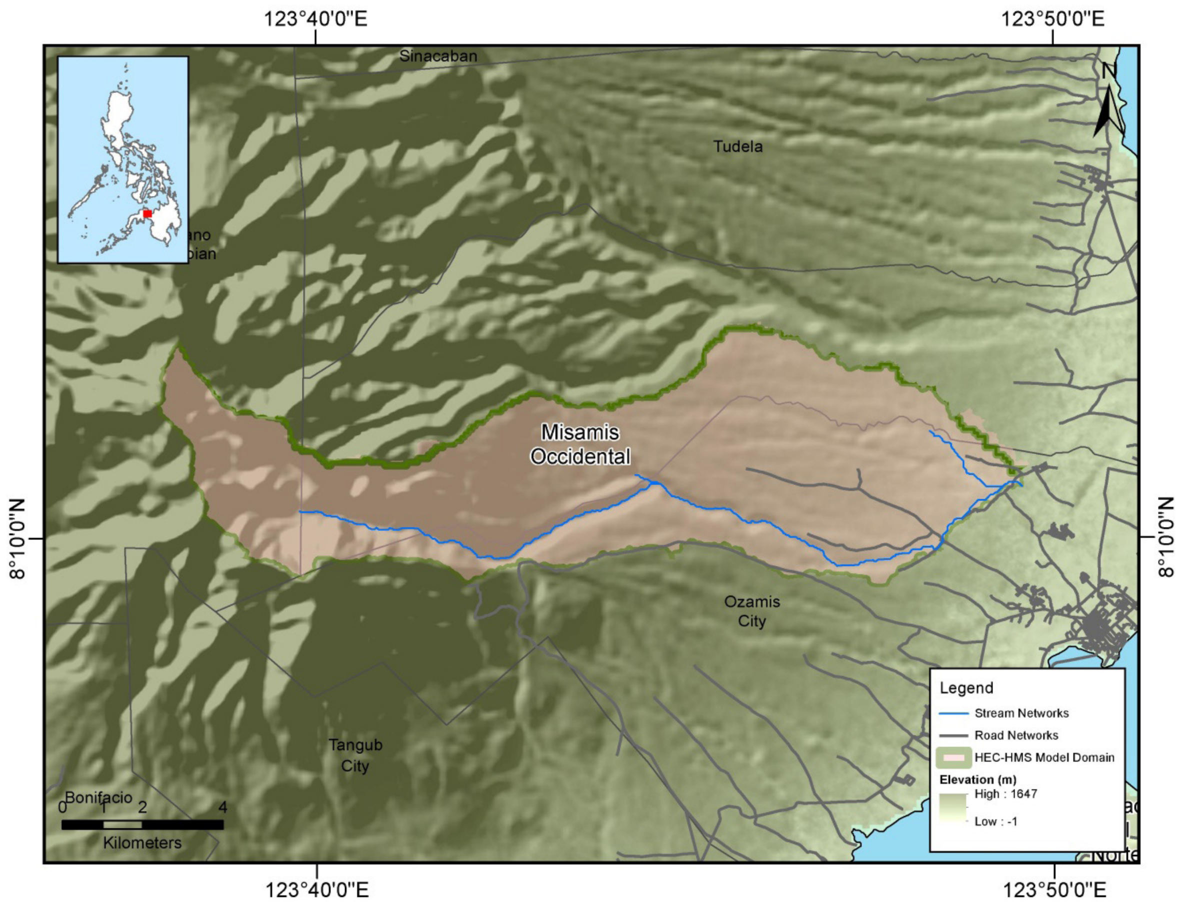

Figure 1. Location map of the Labo River Basin (in brown)

According to the 2015 national census of the Philippine Statistics Authority (PSA), the total population of residents within the immediate vicinity of the Labo River is 25,113, distributed among Barangays Lapasan, Gata Diot, Gata Daku, and Kinangay Sur in the Municipality of Clarin; and among barangays Labo, Embargo, Molicay, Gotokan Diot, Mentering, Liposong, Pantaon, Kinuman Sur, Dalapang, Stimson Abordo, Trigos, Guimad, and Guingona in the City of Calabayan.

Agriculture is the primary industry in the province of Misamis Occidental, which has 805,174 hectares of agricultural lands. Coconut, sugarcane, banana, pineapple, and cassava are some of the top agricultural products of the country that are produced in the region (National Economic and Development Authority Region X, 2015).

Aside from being an agricultural zone, Calabayan City in particular has the potential to become a commercial center in Northern Mindanao, considering its strategic location and its peaceful atmosphere (Calabayancity.com, N.D.). The city enjoys an excellent harbor location, with its local port as the principal outlet of mineral deposits and agricultural and forest products of the rich provinces of Lanao del Norte and Misamis Occidental.

Misamis Occidental has endured some severe flooding events in the recent years. In December 2011, continuous heavy rainfall brought about by Tropical Storm Sendong battered several provinces in Regions VI, VII, IX, X, XI, XIII, and the ARMM. In Misamis Occidental in Region X, the Municipality of Clarin and the City of Calabayan were affected (National Disaster Risk Reduction and Management Council, 2012).

Ten (10) hours of sustained heavy rains that began in the evening of February 9, 2012 inundated several areas in Misamis Occidental, causing residents to flee to higher ground as floodwaters swamped their homes. Mayor Estela Obut of the Municipality of Tudela reported that two hundred and forty-one (241) families were rescued from neck-deep waters that submerged eleven (11) barangays (newsinfo.inquirer.net, N.D.).

On January 30, 2013, relentless rains prompted the local government of Calabayan City to suspend classes. The entire urban section and outlying suburban villages were submerged in knee-deep waters. Fortunately, no fatalities were reported (newsinfo.inquirer.net, N.D.).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LABO FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Labo floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Misamis Occidental. Each flight mission had an average of ten (10) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Pegasus LiDAR system was utilized for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 illustrates the flight plans for the Labo floodplain survey.

Table 1. Flight planning parameters for the LiDAR Pegasus system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK71ext	1000/1100	30	50	200	30	130	5
BLK69F	800/1000	30	50	200	30	130	5
BLK76O	800/900/1000	30	50	200	30	130	5

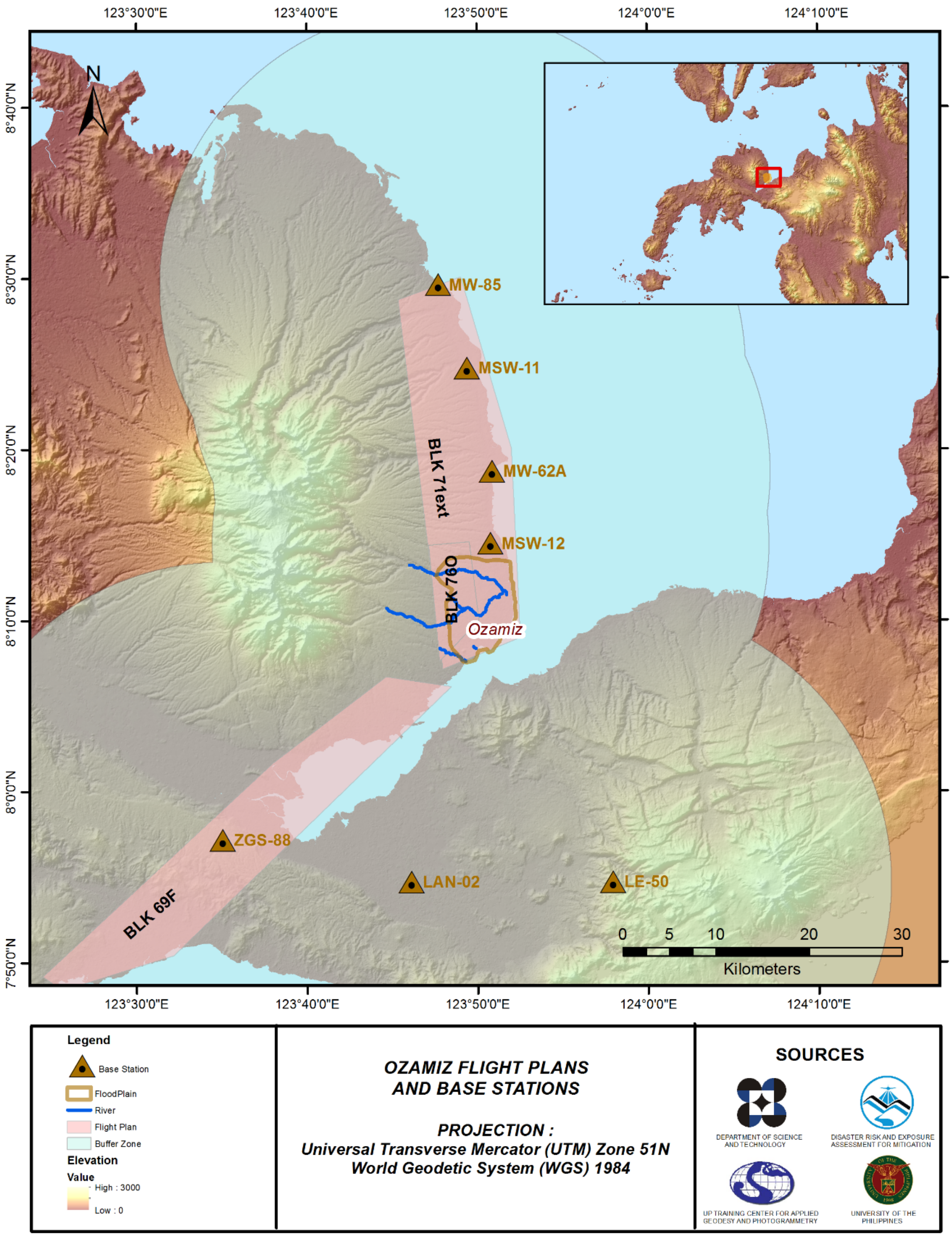


Figure 2. Flight plans and base stations used to cover the Labo floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover four (4) NAMRIA ground control points: (i.) LAN-2, which is of first (1st) order accuracy; and (ii.) ZGS-88, (iii.) MSW-11, and (iv.) MSW-12, which are of second (2nd) order accuracy. Three (3) NAMRIA benchmarks were recovered: LE-50, MW-85, and MW-62A, which are of second (2nd) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certifications for the NAMRIA reference points 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 operations for the entire duration of the survey, held on May 22 - July 10, 2014; on October 8 - November 11, 2014; and on February 4 - March 4, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852, and SPS 985, and TOPCON GR5. The flight plans and the locations of base stations used during the aerial LiDAR acquisition in the Labo floodplain are shown in Figure 2. The composition of the full project team is given in Annex 4.

Figure 3 to Figure 8 exhibit the recovered NAMRIA control stations within the area. Table 2 to Table 8 provide the details about the NAMRIA control stations and established points. Table 9 lists all of the ground control points occupied during the acquisition, together with the dates of utilization.

(a) (b)

Figure 3. (a) GPS set-up over LAN-02 on top of a concrete irrigation canal water gate in Barangay Pinoyak, Lala, Lanao del Norte; and (b) NAMRIA reference point LAN-02, as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point LAN-02, used as a base station for the LiDAR acquisition

Station Name	LAN-2	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7°54'46.07859" North
	Longitude	123°46'0.85333" East
	Ellipsoidal Height	17.35400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	364025.74 meters
	Northing	875110.149 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7°54'42.56546" North
	Longitude	123°46'6.31720" East
	Ellipsoidal Height	83.92120 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	584533.45 meters
	Northing	874680.35 meters

(a) (b)

Figure 4. (a) GPS set-up over ZGS-88 on a center island in Puroy Saray, Aurora, Zamboanga del Sur; and (b) NAMRIA reference point ZGS-88, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-88, used as a base station for the LiDAR acquisition

Station Name	ZGS-88	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7°57’13.25316” North
	Longitude	123°34’56.50093” East
	Ellipsoidal Height	258.34500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	564207.26 meters
	Northing	879474.685 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7°57’9.71271” North
	Longitude	123°35’1.96243” East
	Ellipsoidal Height	324.37300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	564184.79 meters
	Northing	879166.85 meters

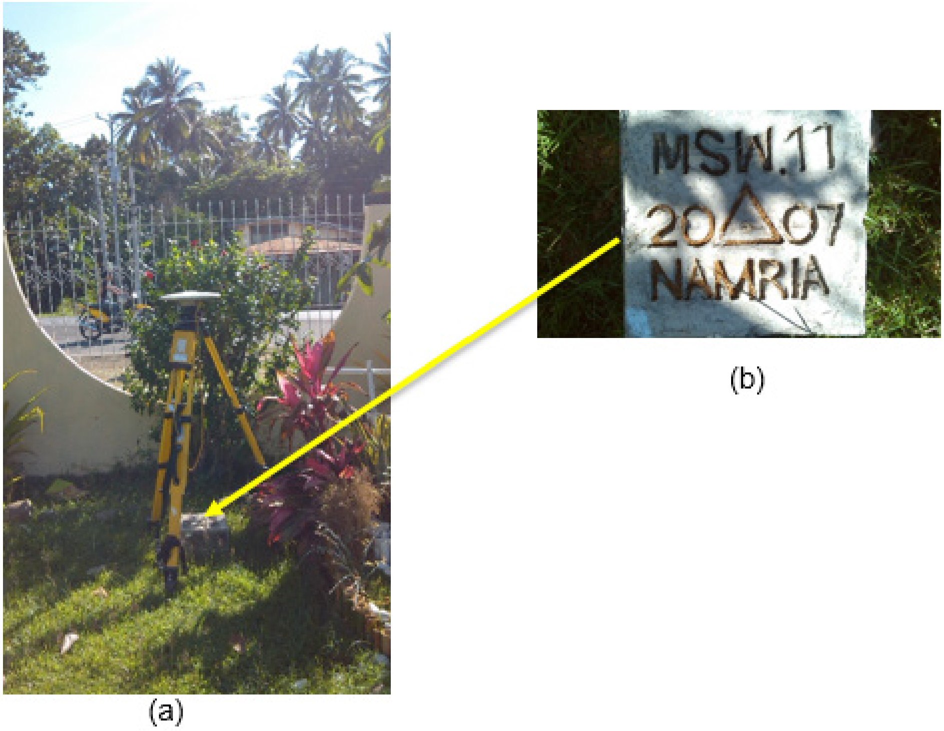


Figure 5. (a) GPS set-up over MSW-11 in Barangay Ospital, Aloran, Misamis Occidental; and (b) NAMRIA reference point MSW-11, as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point MSW-11, used as a base station for the LiDAR acquisition

Station Name	MSW-11	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 24’ 49.21851” North
	Longitude	123° 49’ 18.84776” East
	Ellipsoidal Height	4.399 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	590515.033 meters
	Northing	930392.306 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°24’ 45.57851” North
	Longitude	123° 49’ 24.26581” East
	Ellipsoidal Height	70.095 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	590483.35 meters
	Northing	930066.65 meters

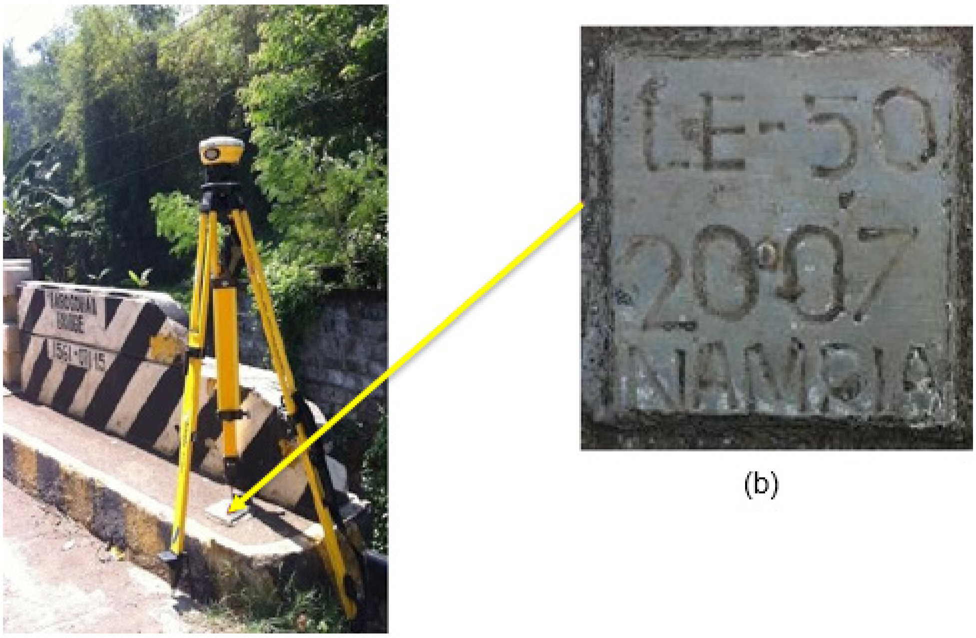
(a)

(b)

Figure 6. (a) GPS set-up over MSW-12 in Barangay Poblacion, Tudadela, Misamis Occidental; and (b) NAMRIA reference point MSW-12, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point MSW-12, used as a base station for the LiDAR acquisition

Station Name	MSW-12	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 14’ 33.61728” North
	Longitude	123° 50’ 41.11353” East
	Ellipsoidal Height	5.698 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	911485.567 meters
	Northing	593072.214 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 14’ 30.02425” North
	Longitude	123° 50’ 46.54685” East
	Ellipsoidal Height	71.798 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	911166.576 meters
	Northing	593039.64 meters



(a) (b)

Figure 7. (a) GPS set-up over LE-50 on the Barogohan Bridge in Maigo, Lanao del Norte; and (b) NAMRIA bench mark point LE-50, as recovered by the field team

Table 6. Details of the recovered NAMRIA Benchmark LE-50 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	LE-50	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8°9’54.972” North
	Longitude	123°57’50.357” East
	Ellipsoidal Height	6.91 m meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	385831.49 meters
	Northing	902974.41 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°09’51.11024” North
	Longitude	123°57’55.36634” East
	Ellipsoidal Height	73.452 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	606345.902 meters
	Northing	902577.426 meters

(a)

(b)

Figure 8. (a) GPS set-up over MW-62A in Brgy, Sinonoc, Sinacaban, Misamis Occidental; and (b) NAMRIA benchmark point MW-62A, as recovered by the field team

Table 7. Details of the recovered NAMRIA Benchmark MW-62A with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	MW-62A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8°18'46.72583" North
	Longitude	123°50'46.44781" East
	Ellipsoidal Height	(b)7.578 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	593186.315 meters
	Northing	918939.972 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°18'43.11445" North
	Longitude	123°50'51.87475" East
	Ellipsoidal Height	73.593 meters

Table 8. Details of the recovered NAMRIA horizontal control point MW-85, used as a base station for the LiDAR acquisition

Station Name	MW-85	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8°29'41.44871" North
	Longitude	123°47'37.52758" East
	Ellipsoidal Height	4.320 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	587366.444 meters
	Northing	939034.768 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8°29'37.78490"North
	Longitude	123°47'42.93851" East
	Ellipsoidal Height	69.779 meters

Table 9. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 3, 2014	1665P	1BLK71ES184A	LAN-02 and LE-50
July 5, 2014	1673P	1BLK71ES186A	ZGS-88 and LAN-02
July 6, 2014	1677P	1BLK71S187A	ZGS-88 and LAN-02
October 28, 2014	2133P	1BLK69FE301A	MWS-11 and MW-85
October 28, 2014	2135P	1BLK69F301B	MWS-11 and MW-85
November 9, 2014	2181P	1BLK69F313A	MWS-11 and MW-85
February 15, 2016	23096P	1BLK76NO46A	MSW-12 and MW-62A
February 20, 2106	23116P	1BLK76NO51A	MSW-12 and MW-62A

2.3 Flight Missions

A total of eight (8) flight missions were conducted to complete the LiDAR data acquisition in the Labo floodplain, for a total of twenty-four hours and thirty-six minutes (24+36) of flying time for RP-C9022. All missions were acquired using the Pegasus system. The flight logs for the missions are provided in Annex 6. Table 10 indicates the total area of actual coverage and the corresponding flying hours per mission; while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for the LiDAR data acquisition in the Labo floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
July 3, 2014	1665P	324.36	42.73	22.1	20.63	NA	2	59
July 5, 2014	1673P	225	125.28	18.03	107.25	330	2	55
July 5, 2014	1677P	324.36	90.14	17	73.14	170	2	35
October 28, 2014	2133P	322.28	184.23	32.81	151.42	826	3	53
October 28, 2014	2135P	322.28	49.01	19.52	29.5	NA	1	47
November 9, 2014	2181P	322.282	137.57	20.44	117.13	361	3	11
February 15, 2016	23096P	47.79	53.53	30.32	23.21	196	2	41
February 20, 2016	23116P	71	157.2	28.23	128.97	NA	4	35
TOTAL		1959.35	839.69	188.45	651.25	1883	24	36

Table 11. Actual parameters used during the LiDAR data acquisition

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1665P	1100	30	50	200	30	130	5
1673P	1000	30	50	200	30	130	5
1677P	1000	30	50	200	30	130	5
2133P	800	30	50	200	30	130	5
2135P	1000	30	50	200	30	130	5
2181P	1000	30	50	200	30	130	5
23096P	1100	30	50	200	30	130	5
23116P	1000	30	50	200	30	130	5

2.4 Survey Coverage

The Labo floodplain is located in the province of Misamis Occidental, covering the Municipalities of Aloran, Bonifacio, Calabayan, Jimenez, Lopez Jaena, Oroquieta City, Calabayan City, Panaon, Plaridel, Sinacaban, Tangub City, and Tudela. The municipalities and cities surveyed during the LiDAR acquisition are listed in Table 12. Figure 9 presents the actual coverage of the LiDAR acquisition for the Labo floodplain. See Annex 7 for the flight status reports.

Table 12. List of municipalities/cities surveyed in the Labo floodplain

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Lanao del Norte	Lala	125.18	12.38	10%
	Baroy	62.08	5.19	8%
	Tubod	121.95	4.13	4%
	Kapatagan	184.77	5.94	3%
Misamis Occidental	Calabayan City	149.44	64.16	43%
	Jimenez	78.48	27.84	36%
	Calabayan	114	40.22	35%
	Sinacaban	70.99	23.22	33%
	Aloran	105.66	33.79	32%
	Tangub City	141.82	44.51	31%
	Panaon	52.52	15.22	29%
	Tudela	108.93	29.84	27%
	Oroquieta City	195.63	45.96	24%
	Plaridel	56.35	11.08	20%
	Lopez Jaena	90.54	10.91	12%
	Bonifacio	103.87	1.78	2%
Zamboanga del Sur	Aurora	162.23	15.28	9%
	Tukuran	119.01	10.12	9%
	Tambulig	142.93	8.32	6%
	Labangan	176.44	1.02	1%
Total		2362.82	410.91	17.39%

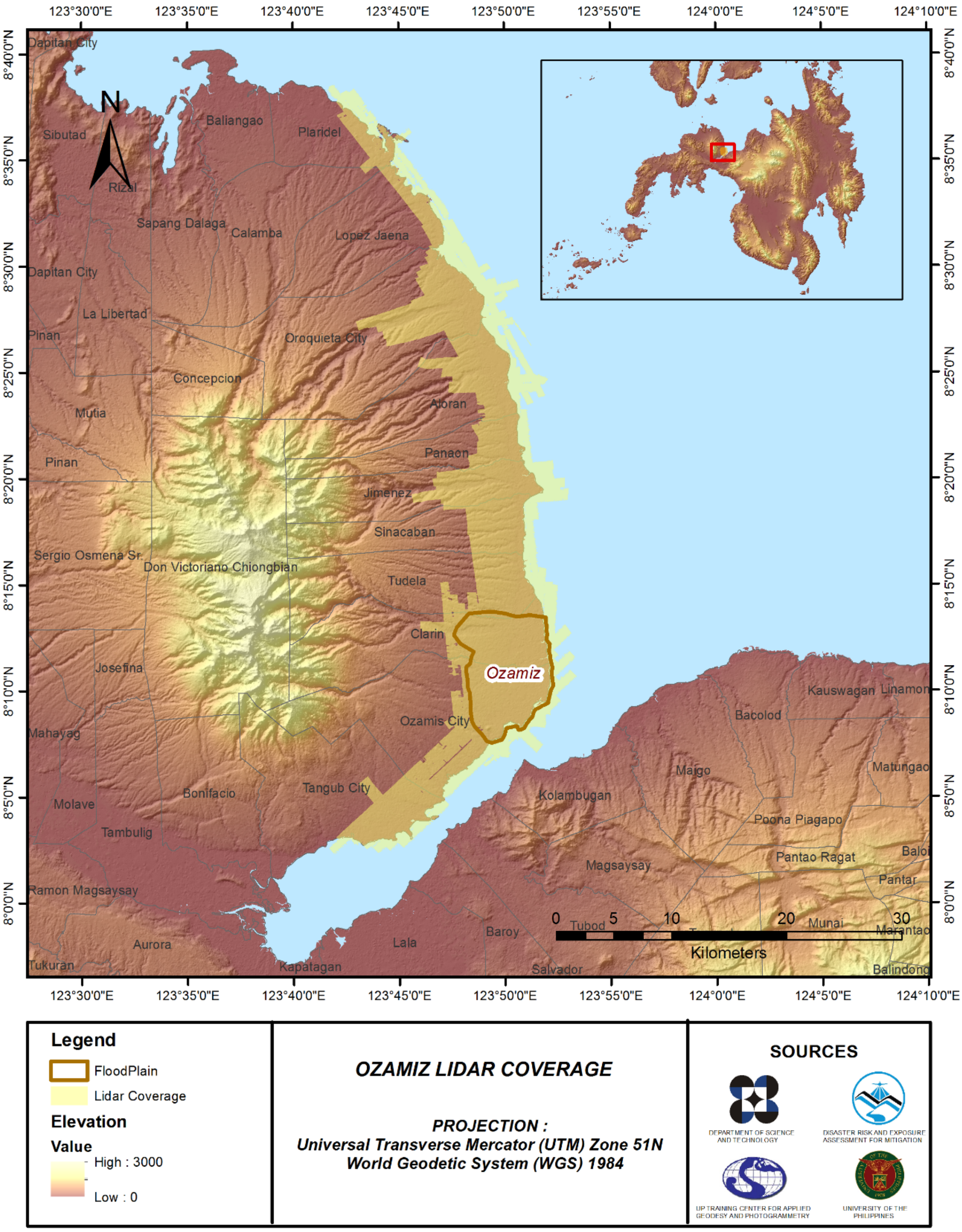


Figure 9. Actual LiDAR survey coverage of the Labo floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE LABO FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the DAC 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 the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and the vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

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 (DVBC). 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 attained through the help of the georectified point clouds, and the metadata containing the time that the image was captured.

These processes are summarized in the diagram in Figure 10.

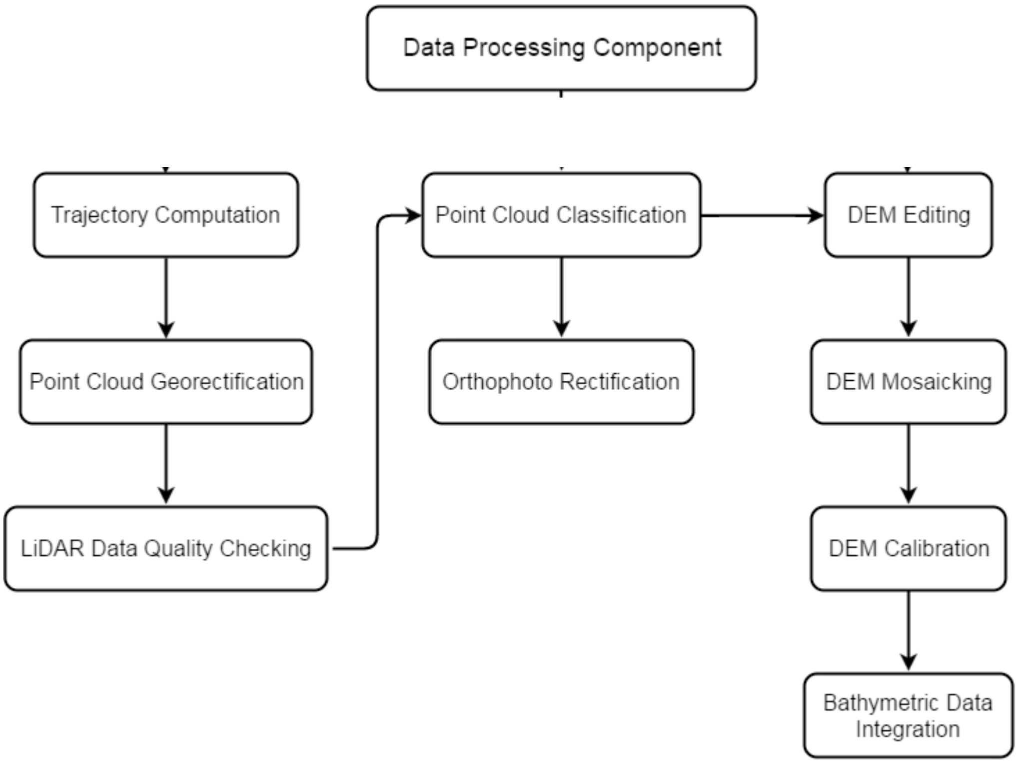


Figure 10. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Labo floodplain can be found in Annex 5. Missions flown over Northern Mindanao during the first survey conducted in July 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The DAC transferred a total of 73.13 Gigabytes of Range data, 1.46 Gigabytes of POS data, and 262.69 Megabytes of GPS base station data to the data server on August 6, 2014 for the first survey, and on July 1, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Labo survey was fully transferred on November 19, 2016, as indicated on the data transfer sheets for the Labo floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 2135P, one of the Labo flights, which are the North, East, and Down position RMSE values, are exhibited in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on October 28, 2014 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

Figure 11. Smoothed Performance Metric Parameters of Labo Flight 2135P

The time of flight was from 201300 seconds to 204000 seconds, which corresponds to the afternoon of October 28, 2014. The initial spike reflected on the data signifies the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values indicates the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaked at 1.16 centimeters, the East position RMSE peaked at 1.04 centimeters, and the Down position RMSE peaked at 1.85 centimeters, which are within the prescribed accuracies described in the methodology.

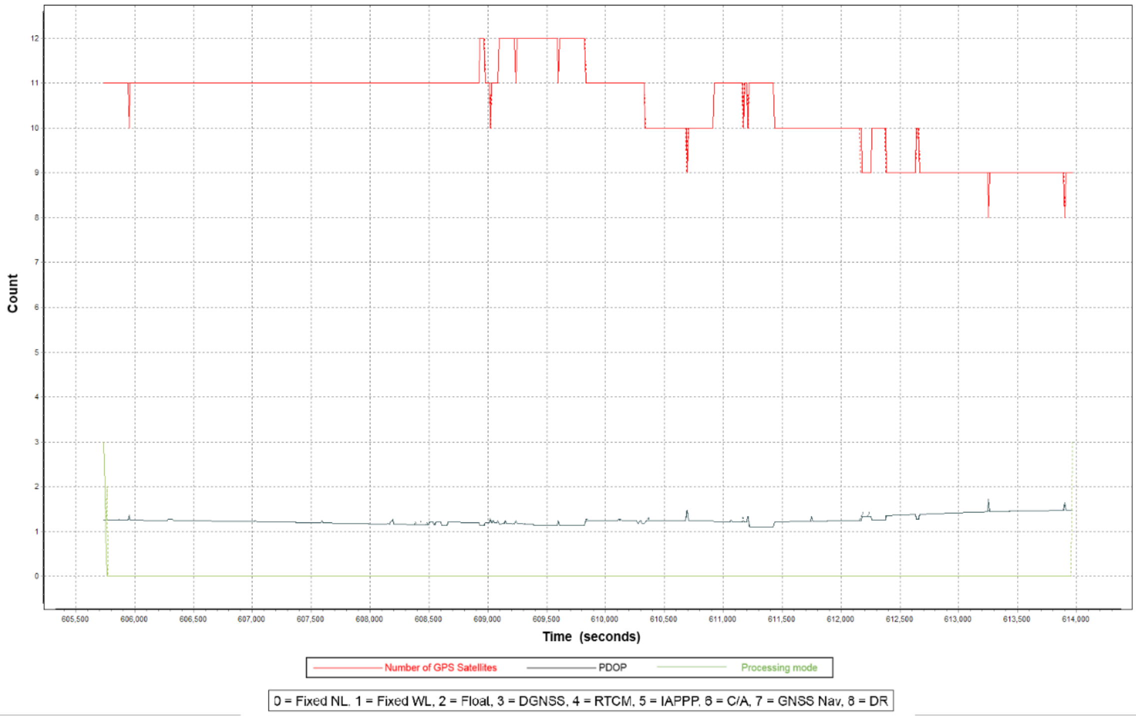


Figure 12. Solution Status Parameters of Labo Flight 2135P

The Solution Status parameters of Flight 2135P - one of the Labo flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used - are illustrated in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 7. Majority of the time, the number of satellites tracked was between 7 and 8. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some peaks to up to 1, attributed to the turns performed by the aircraft. The value of 0 signifies a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Labo flights is depicted in Figure 13.

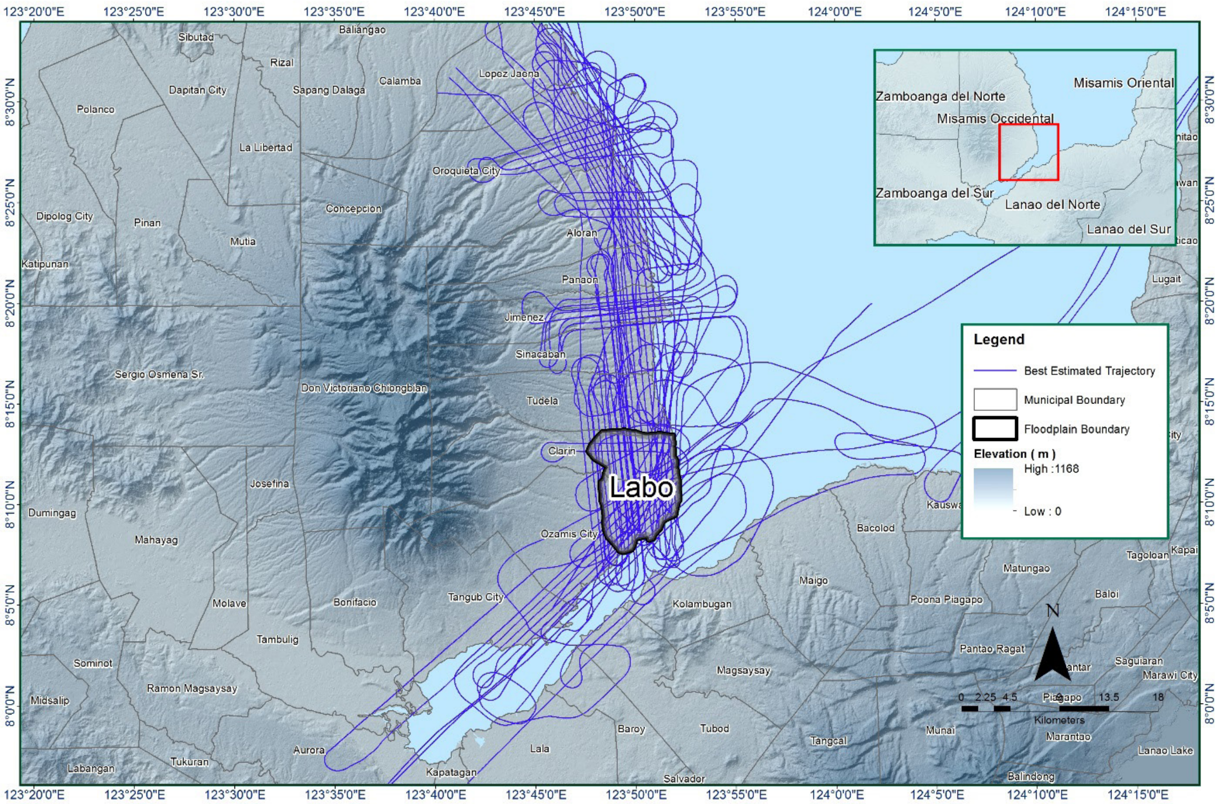


Figure 13. The best estimated trajectory conducted over the Labo floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains fifty-six (56) flight lines, with each flight line containing two (2) channels, since the Pegasus system contains two (2) channels. The summary of the self-calibration results for all flights over the Labo floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 13.

Table 13. Self-calibration results for the Labo flights

Parameter	Accepted Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000253
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.001628
GPS Position Z-correction stdev	(<0.01meters)	0.0059

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Labo floodplain are represented in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

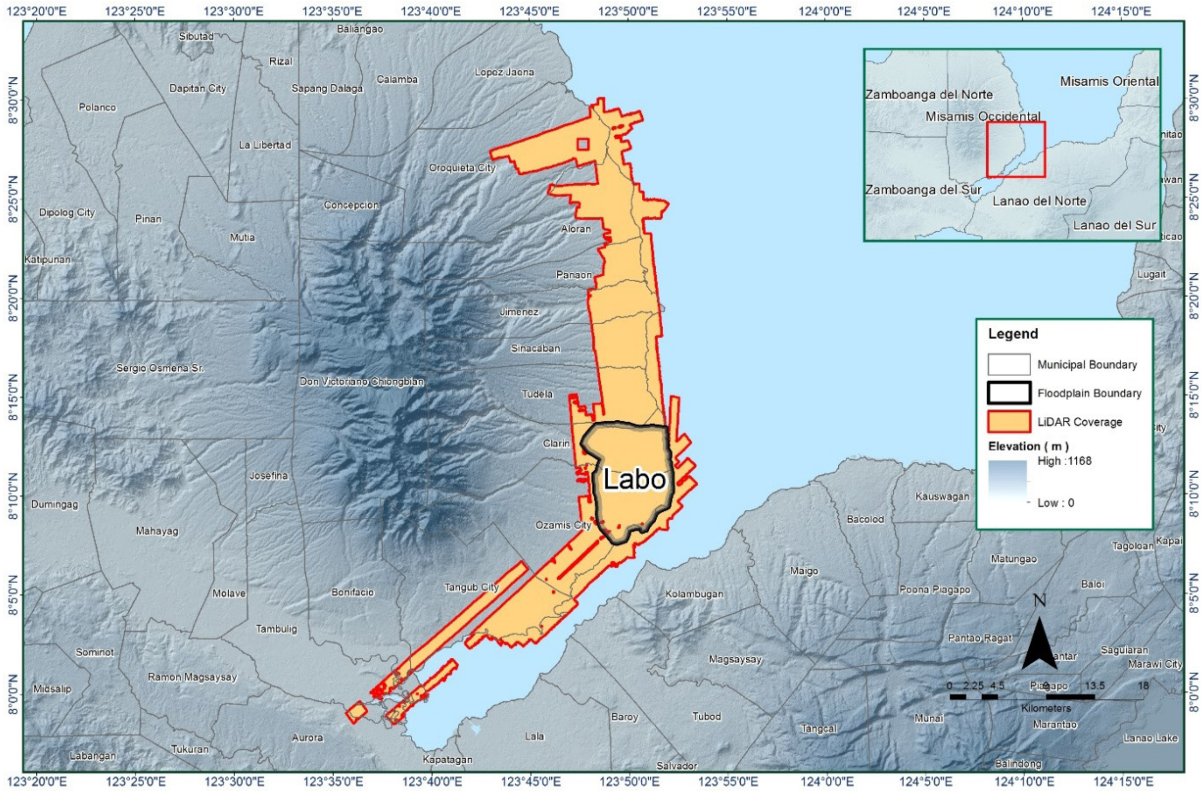


Figure 14. Boundaries of the processed LiDAR data over the Labo floodplain

The total area covered by the Labo missions is 455.84 square kilometers, comprised of eight (8) flight acquisitions that were grouped and merged into four (4) blocks, as outlined in Table 14.

Table 14. List of LiDAR blocks for the Labo floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dipolog_Blk69F	2133P	51.12
	2135P	
	2181P	
NorthernMindanao_Blk71_extension	1665P	34.02
	1673P	
	1677P	
Pagadian_Blk76O	23096P	232.40
Pagadian_Blk76O_supplement	23116P	138.30
TOTAL		455.84 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is depicted in Figure 15. Since the Pegasus system employs two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

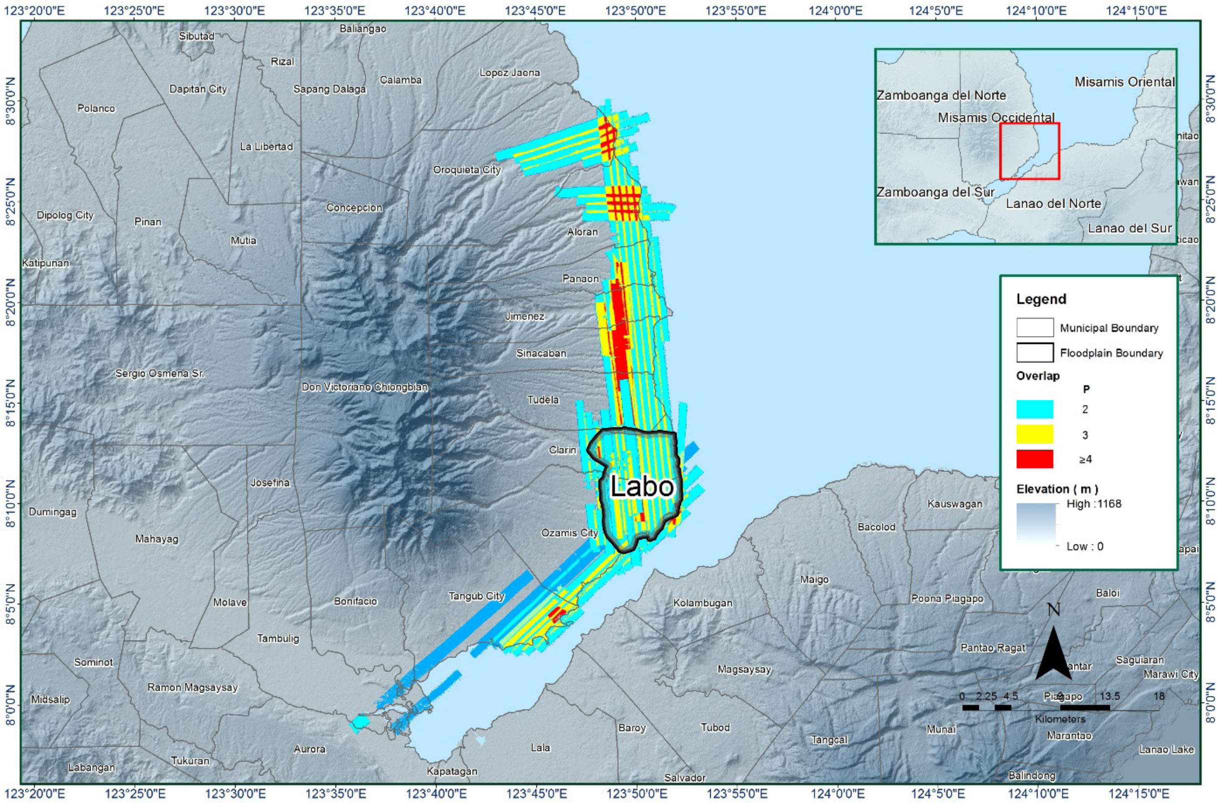


Figure 15. Image of data overlap for the Labo floodplain

The overlap statistics per block for the Labo floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 27.83% and 46.32%, respectively, which satisfied the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is presented in Figure 16. It was determined that all LiDAR data for the Labo floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.89 points per square meter.

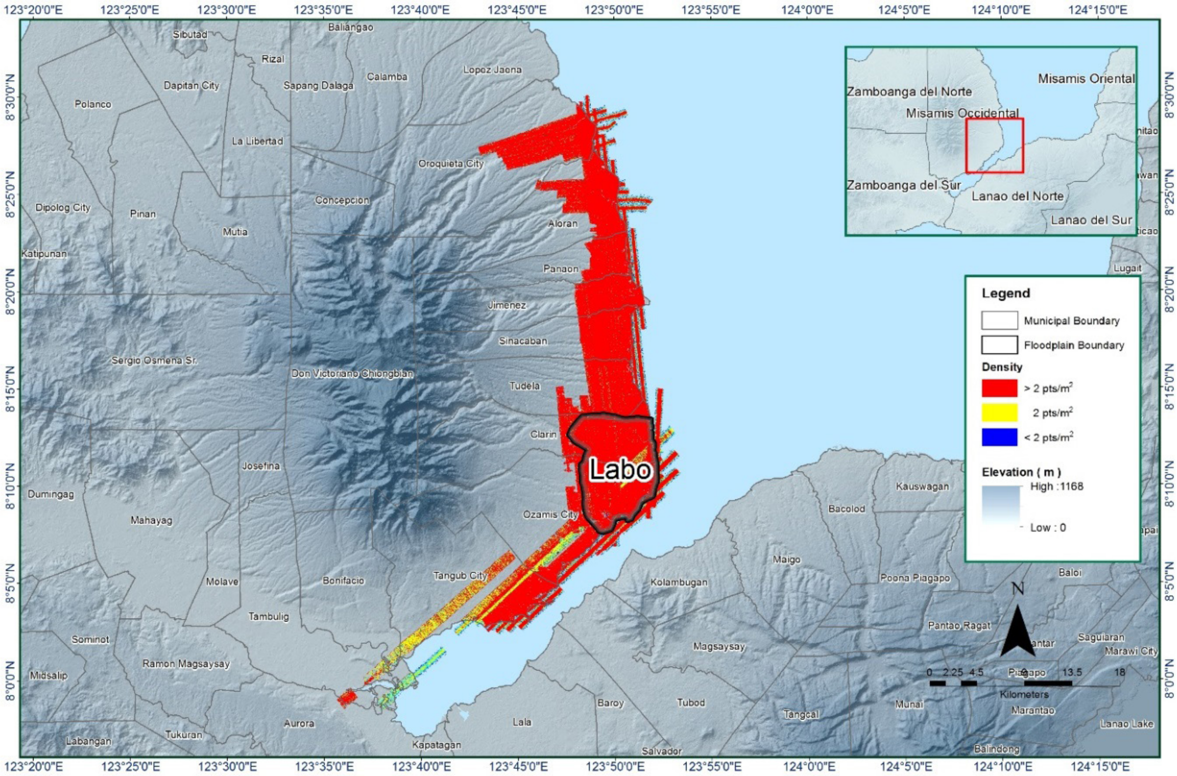


Figure 16. Pulse density map of merged LiDAR data for the Labo floodplain

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

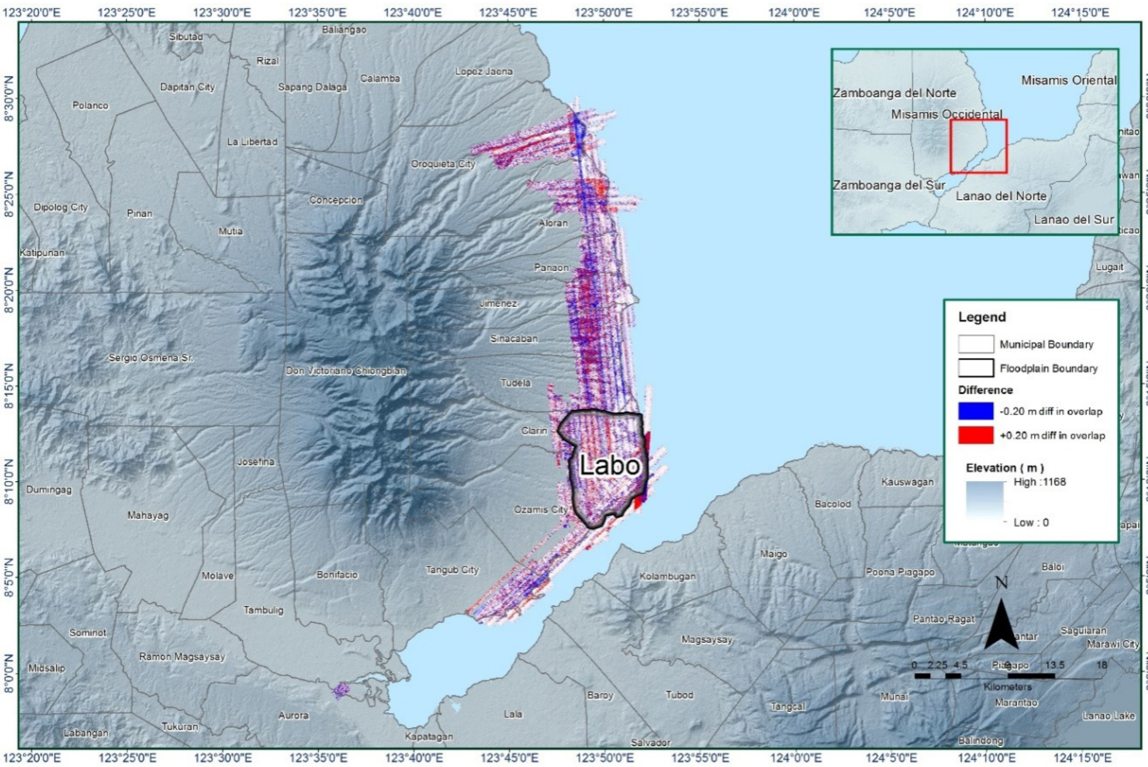


Figure 17. Elevation difference map between flight lines for the Labo floodplain

A screen capture of the processed LAS data from Labo Flight 2135P loaded in the QT Modeler is provided in Figure 18. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis represents the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

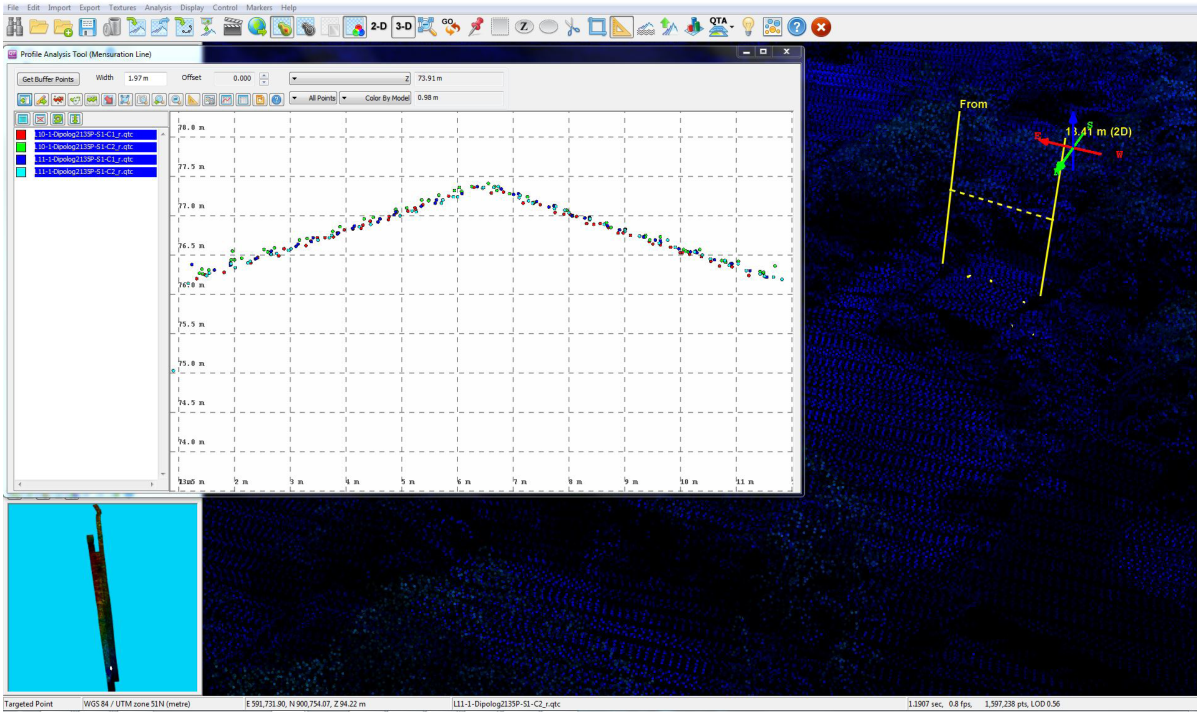


Figure 18. Quality checking for Labo Flight 2135P, using the Profile Tool of the QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Labo classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,068,616,309
Low Vegetation	865,948,051
Medium Vegetation	1,697,976,068
High Vegetation	4,392,288,327
Building	84,714,554

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Labo floodplain, are presented in Figure 19. A total of 1,769 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 15. The point cloud had a maximum and minimum height of 840.48 meters and 9.63 meters, respectively.

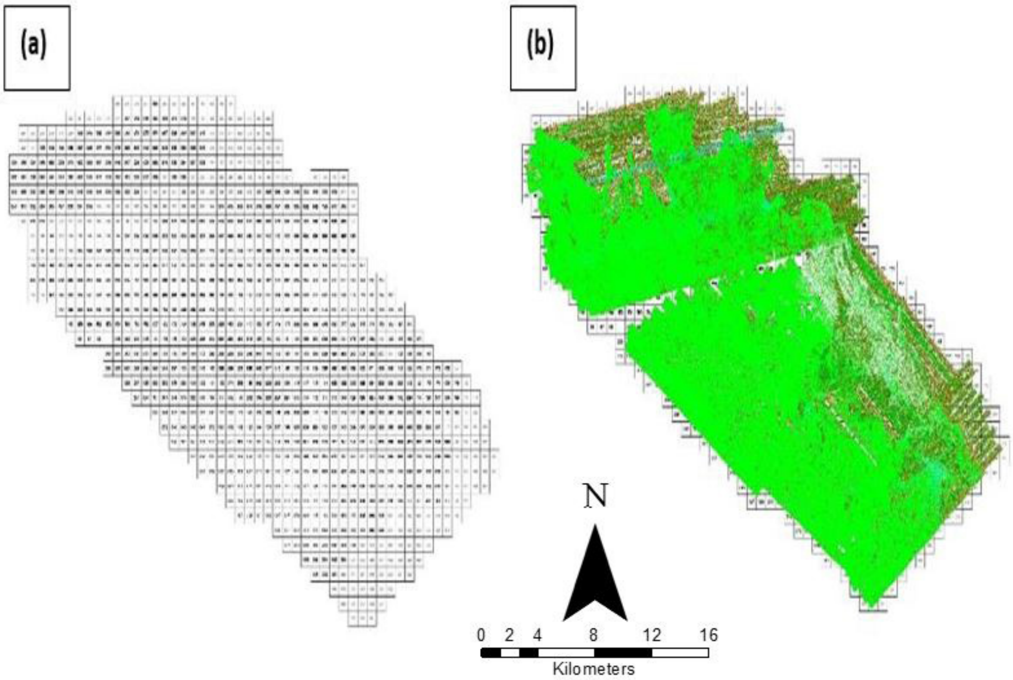


Figure 19. (a) Tiles for the Labo floodplain, and (b) classification results in TerraScan

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

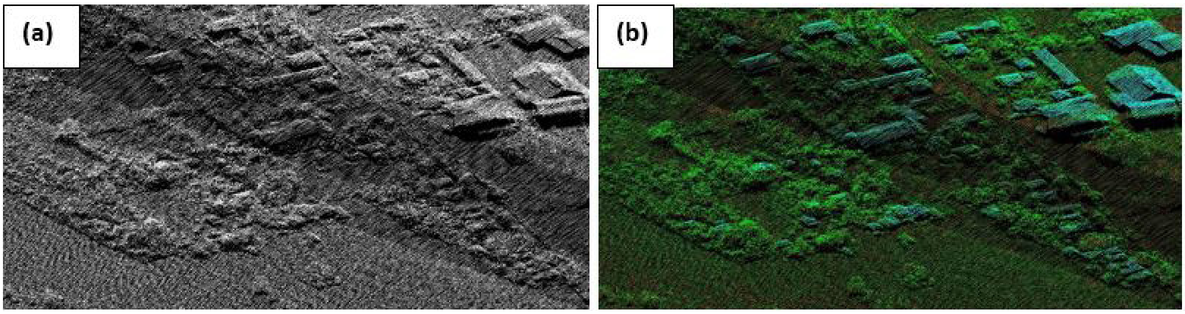


Figure 20. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 21, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

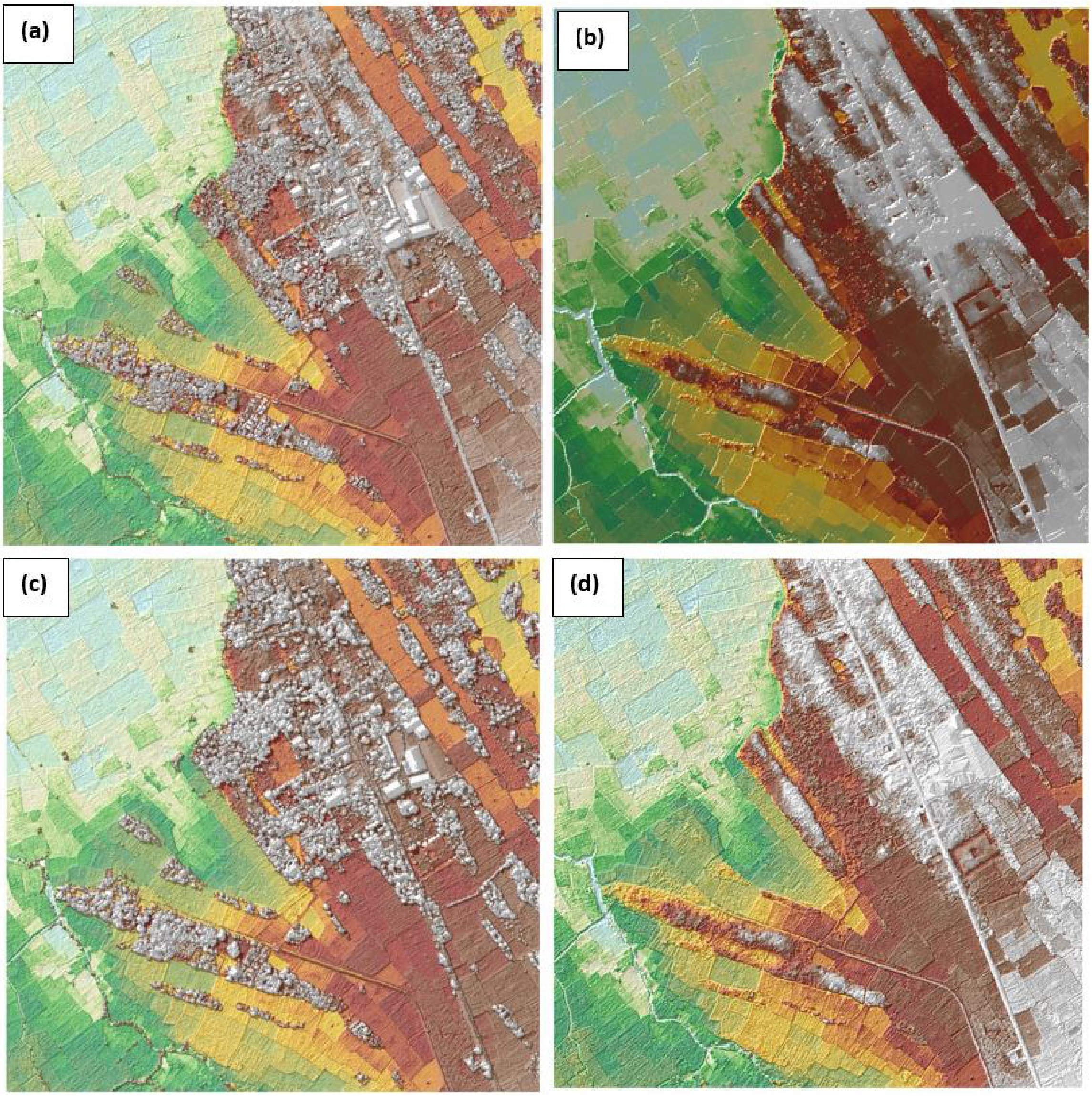


Figure 21. (a) The production of last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of the Labo floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 558 1km by 1km tiles area covered by the Labo floodplain is displayed in Figure 22. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Labo floodplain survey attained a total of 339.87 square kilometers in orthophotographic coverage, comprised of 1,391 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 23.

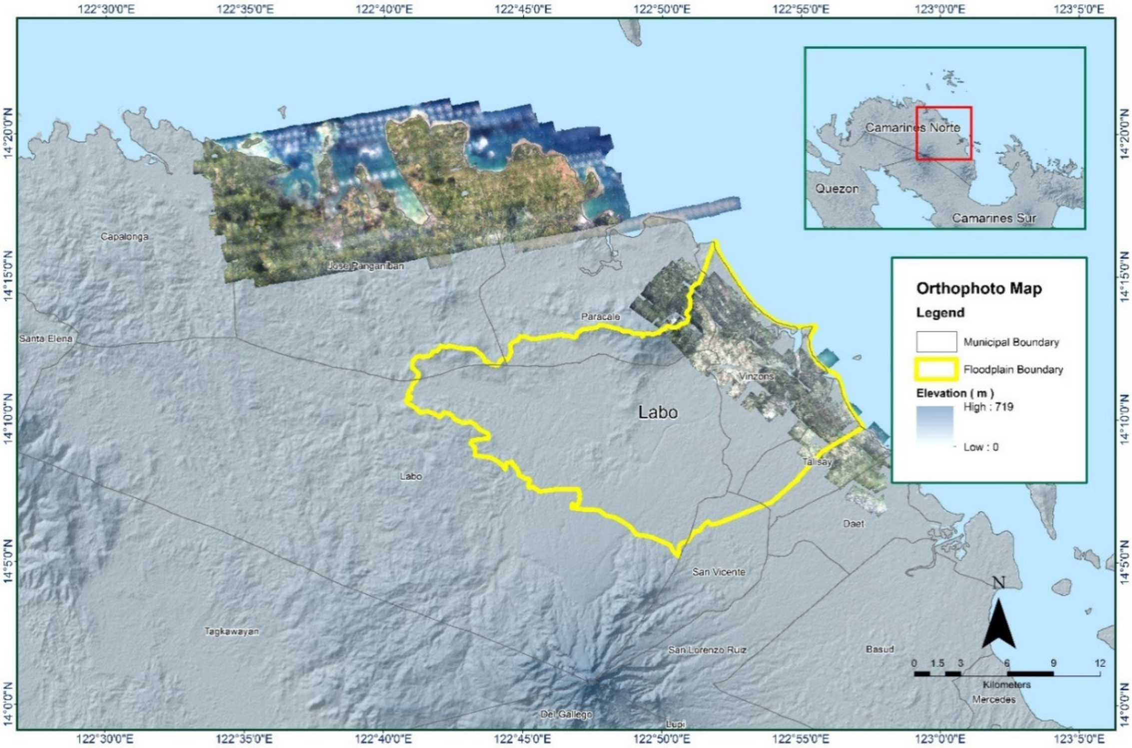


Figure 22. The Labo floodplain with available orthophotographs

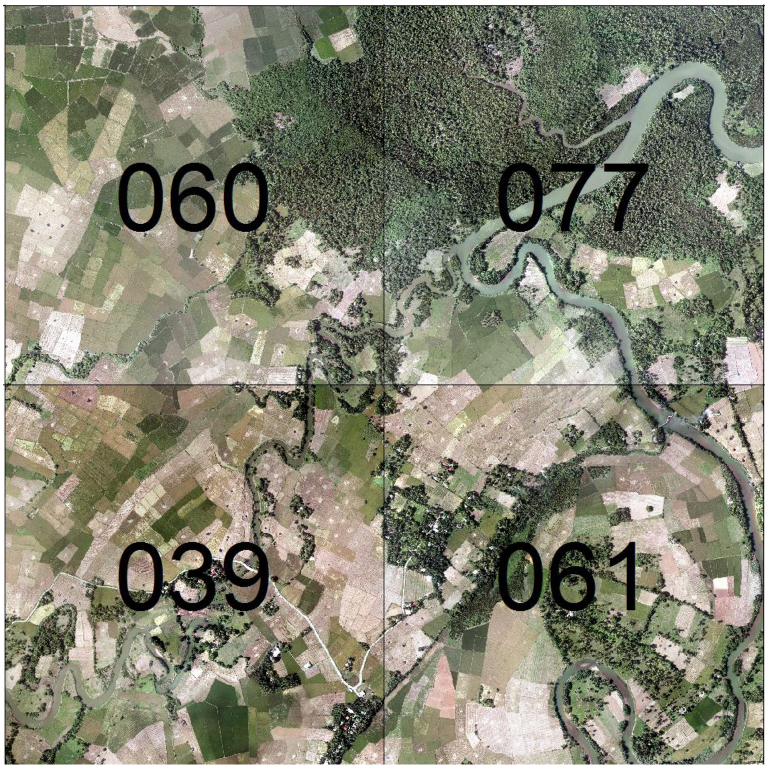


Figure 23. Sample orthophotograph tiles for the Labo floodplain

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for the Labo floodplain. These blocks are composed of Pagadian, Dipolog, and NorthernMindanao blocks, with a total area of 455.84 square kilometers. Table 16 lists the names and corresponding areas of the blocks, in square kilometers.

Table 16. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Pagadian_Blk76O	51.12
Pagadian_Blk76O_supplement	34.02
Dipolog_Blk69F	232.4
NorthernMindanao_Blk71_extension	138.3
TOTAL	455.84 sq.km

Portions of the DTM before and after manual editing are exhibited in Figure 24. The bridge (Figure 24a) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 24b) in order to hydrologically correct the river. The river embankment (Figure 24c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 24d) to allow for the correct flow of water.

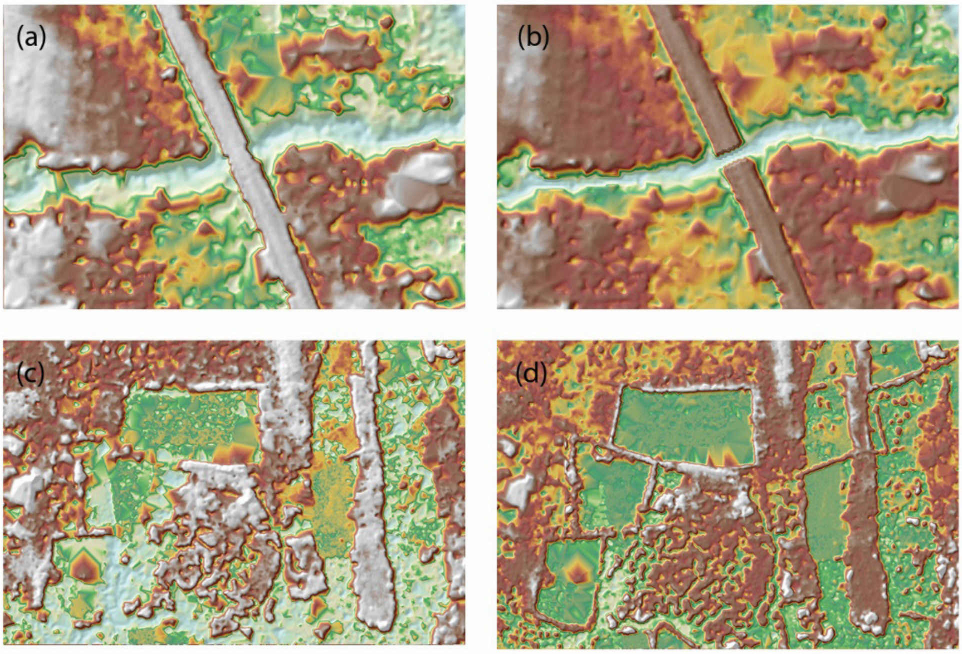


Figure 24. Portions in the DTM of the Labo floodplain – a bridge (a) before and (b) after manual editing; a paddy field (c) before and (d) after data retrieval

3.9 Mosaicking of Blocks

The NorthernMindanao_Blk71_Extension block was used as the reference block at the start of mosaicking, as it was already vertically calibrated to MSL; and it overlaps with the Dipolog_Blk69F block, which is the largest DTM of the Labo River Basin. Table 17 summarizes the shift values applied to each LiDAR block during the mosaicking process.

The mosaicked LiDAR DTM for the Labo floodplain is presented in Figure 25. It demonstrates that the Labo floodplain was 99.44% covered by the LiDAR data.

Table 17. Shift values of each LiDAR block of the Labo floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Pagadian_Blk76O	0.00	0.00	0.00
Pagadian_Blk76O_supplement	0.00	0.00	0.00
Dipolog_Blk69F	-0.15	0.21	0.00
NorthernMindanao_Blk71_extension	0.00	0.00	0.00

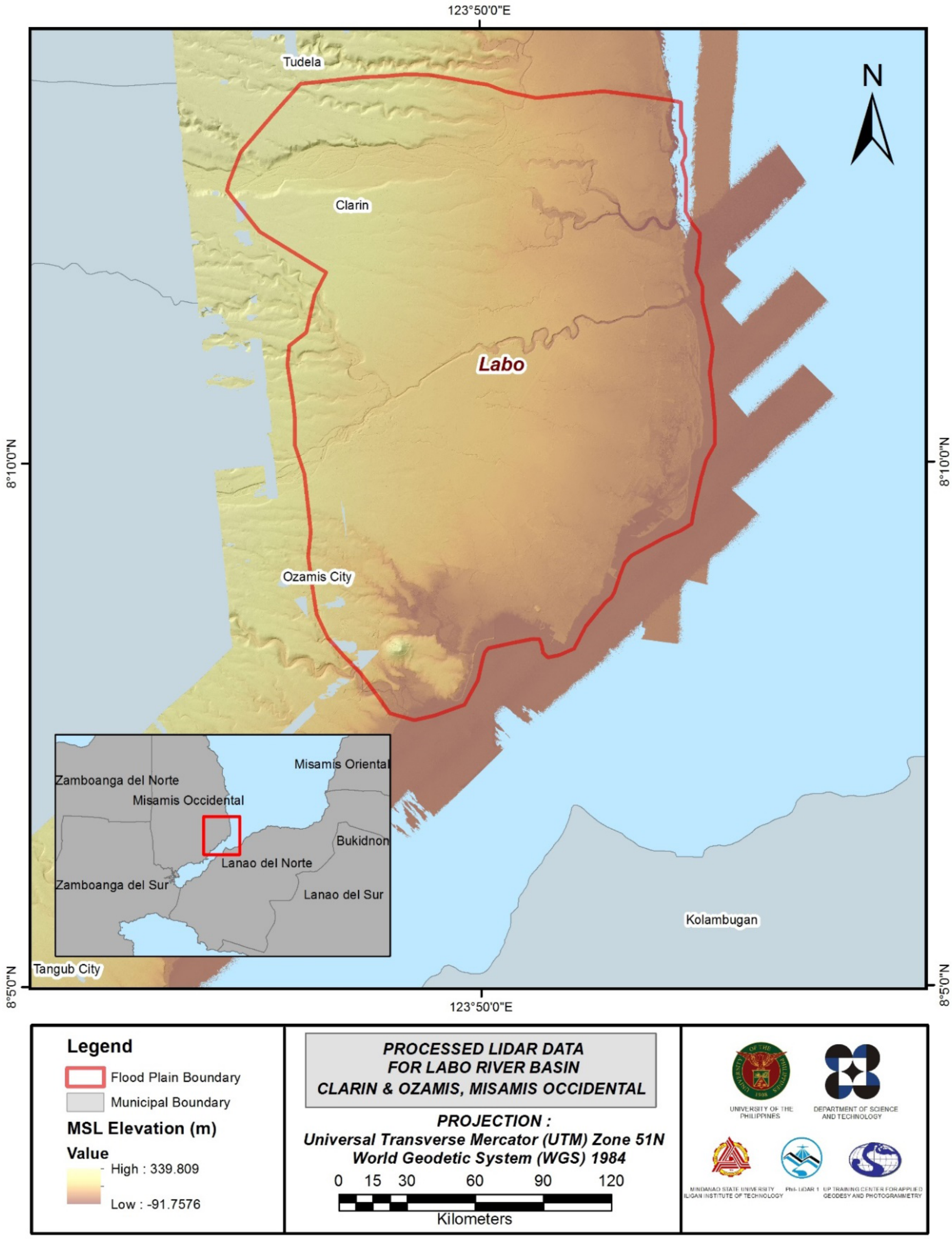


Figure 25. Map of processed LiDAR data for the Labo floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Labo floodplain. The extent of the validation survey done in Labo to collect points with which the LiDAR dataset was validated is illustrated in Figure 26, with the validation survey points highlighted in green.

The Labo LiDAR data were calibrated with NorthernMindanao_Blk71_Extension as the reference block. A total of 2,003 survey points from the Maranding floodplain were used for the calibration of the Labo DTM. Random selection of 80% of the survey points resulted in 1,602 points, which were used for the calibration of the Labo DTM. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 27. Statistical values were computed from the extracted LiDAR values using the selected points, to assess the quality of data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 2.27 meters, with a standard deviation of 0.08 meters. Calibration of the Labo LiDAR data was performed by subtracting the height difference value, 2.27 meters, from the Labo mosaicked LiDAR data. Table 18 specifies the statistical measurements of the compared elevation values between the LiDAR data and the calibration data.

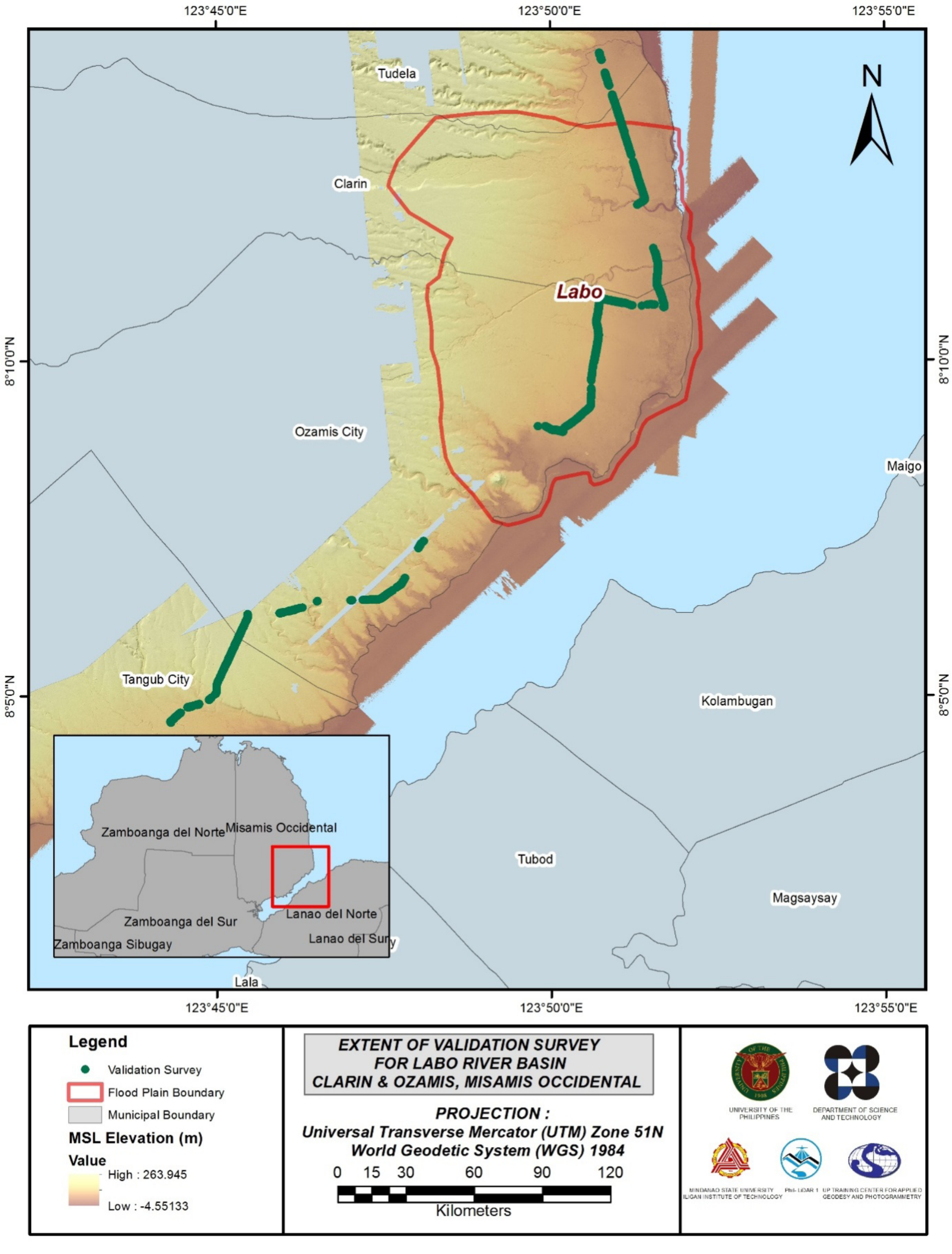


Figure 26. Map of the Labo floodplain, with the validation survey points in green

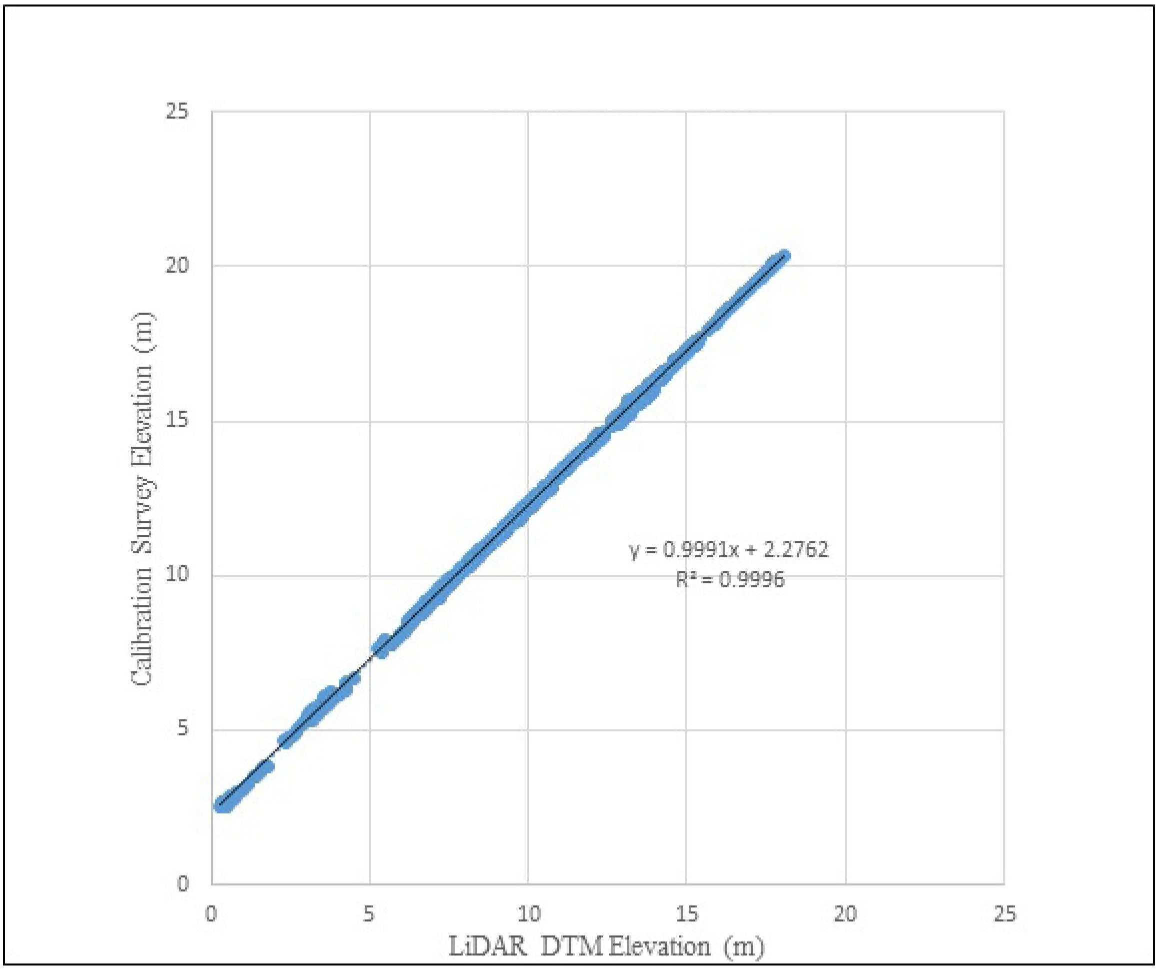


Figure 27. Correlation plot between the calibration survey points and the LiDAR data

Table 18. 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 2,288 survey points were collected by the DVBC for the Labo River Basin. Random selection of 20% of the total survey points resulted in 458 points, which were used for the validation of the calibrated Labo 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 demonstrated in Figure 28. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.18 meters, with a standard deviation of 0.18 meters, as shown in Table 19.

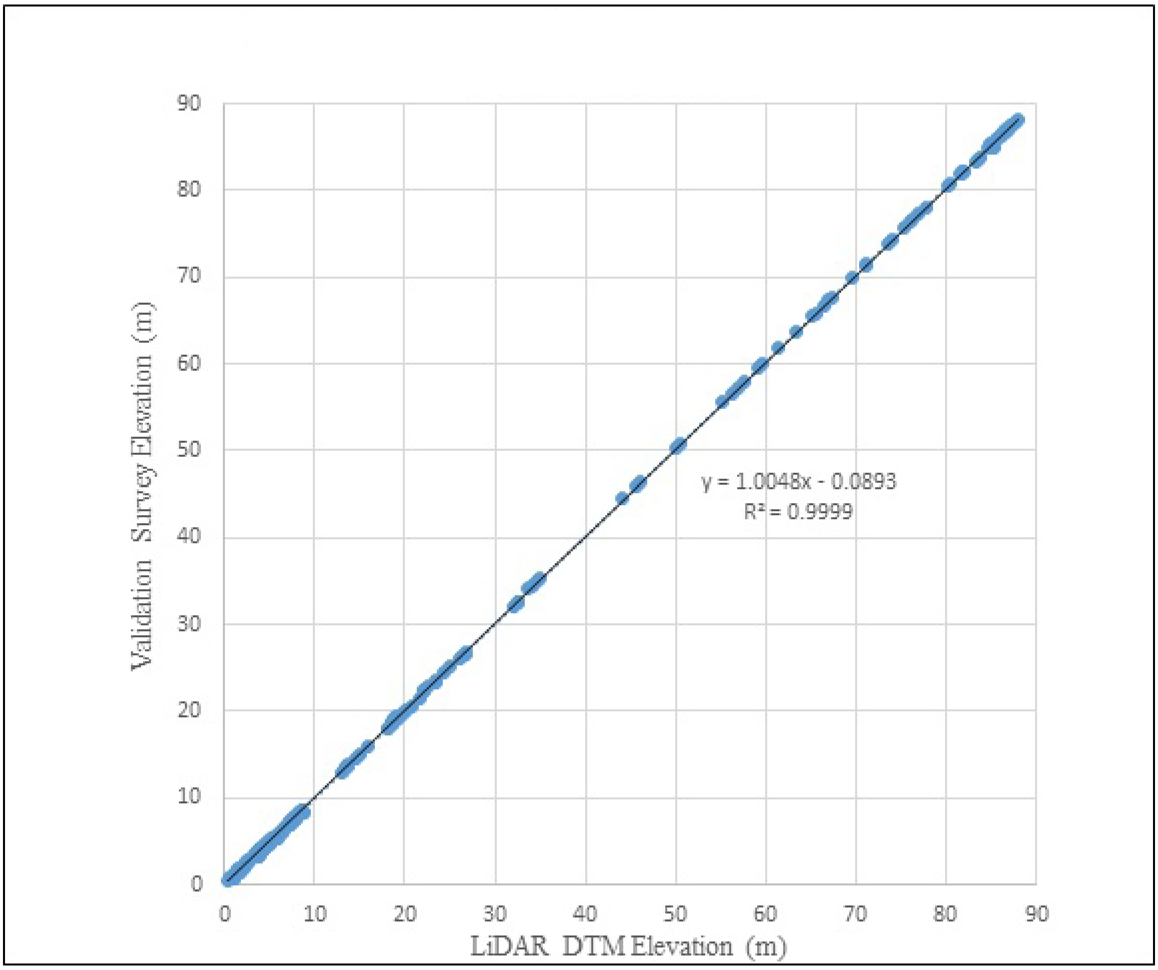


Figure 28. Correlation plot between the validation survey points and the LiDAR data

Table 19. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.18
Average	-0.01
Minimum	-0.45
Maximum	0.41

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline, zigzag line, and cross-section data were available for Labo, with 3,350 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.53 meters. The extent of the bathymetric survey done by the DVBC in the Labo River, integrated with the processed LiDAR DEM, is depicted in Figure 29.

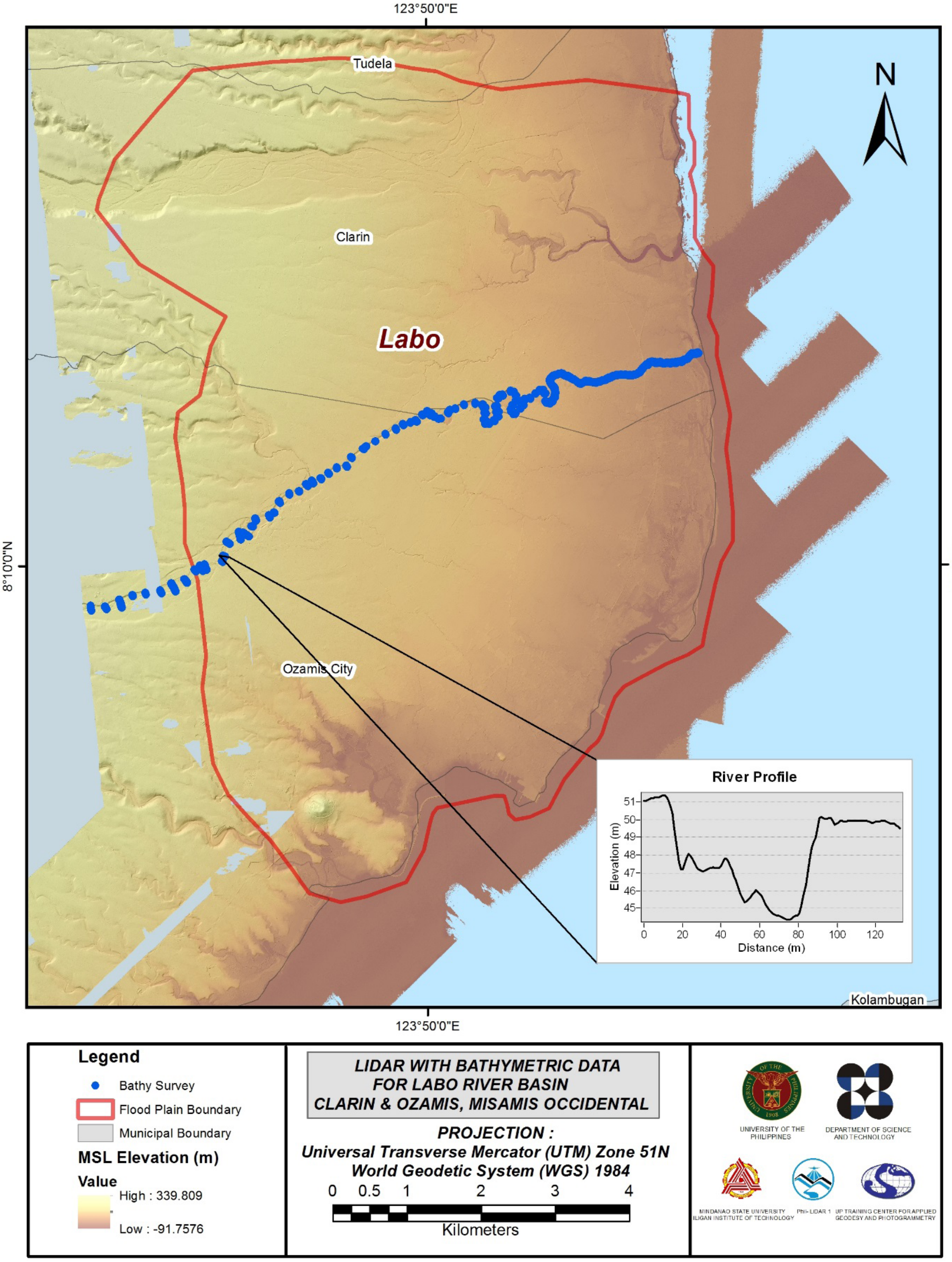


Figure 29. Map of the Labo floodplain, with bathymetric survey points shown in blue

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 a 200-meter buffer zone. Mosaicked LiDAR DEM with a 1-meter 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 – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Labo floodplain, including its 200-meter buffer zone, has a total area of 77.05 square kilometers. Of this area, a total of 5.00 square kilometers, corresponding to a total of 2,399 building features, were considered for quality checking (QC). Figure 30 presents the QC blocks for the Labo floodplain.

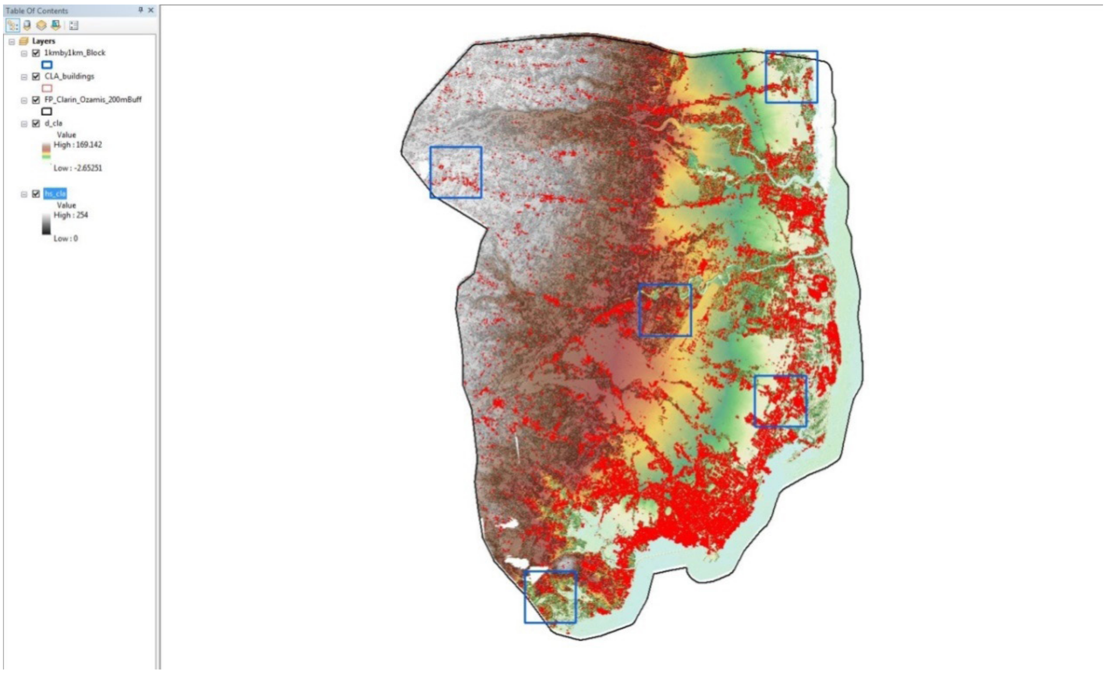


Figure 30. Blocks (in blue) of Labo building features that were subjected to QC

Quality checking of the Labo building features resulted in the ratings given in Table 20.

Table 20. Quality checking ratings for the Labo building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Labo	98.01	96.42	82.20	PASSED

3.12.2 Height Extraction

Height extraction was done for 37,938 building features in the Labo floodplain. Of these building features, 1,293 were filtered out after height extraction, resulting in 36,645 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 16.32 meters.

3.12.3 Feature Attribution

The Labo floodplain is shared by the Municipality of Clarin and the City of Ozamis. The building attribution in the floodplain was executed through the Google Earth approach, where assistance from purok (barangay zone) representatives were sought for participatory mapping over the Google Earth software. The attributions of road, bridge, and water body features were conducted using NAMRIA maps, municipal and city records, and participatory mapping of municipals and cities.

Table 21 summarizes the number of building features per type. Table 22 indicates the total length of each road type, and Table 23 specifies the number of water features extracted per type.

Table 21. Building features extracted for the Labo floodplain

Facility Type	No. of Features
Residential	34,760
School	364
Market	9
Agricultural/Agro-Industrial Facilities	161
Medical Institutions	75
Barangay Hall	42
Military Institution	3
Sports Center/Gymnasium/Covered Court	38
Telecommunication Facilities	11
Transport Terminal	18
Warehouse	103
Power Plant/Substation	3
NGO/CSO Offices	3
Police Station	7
Water Supply/Sewerage	6
Religious Institutions	120
Bank	20
Factory	70
Gas Station	27
Fire Station	2
Other Government Offices	177
Other Commercial Establishments	579
Total	**36,645**

Table 22. Total length of extracted roads for the Labo floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Labo	130.69	82.50	22.73	15.80	2.21	**253.93**

Table 23. Number of extracted water bodies for the Labo floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Labo	21	0	0	0	1	**22**

A total of eighty-seven (87) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

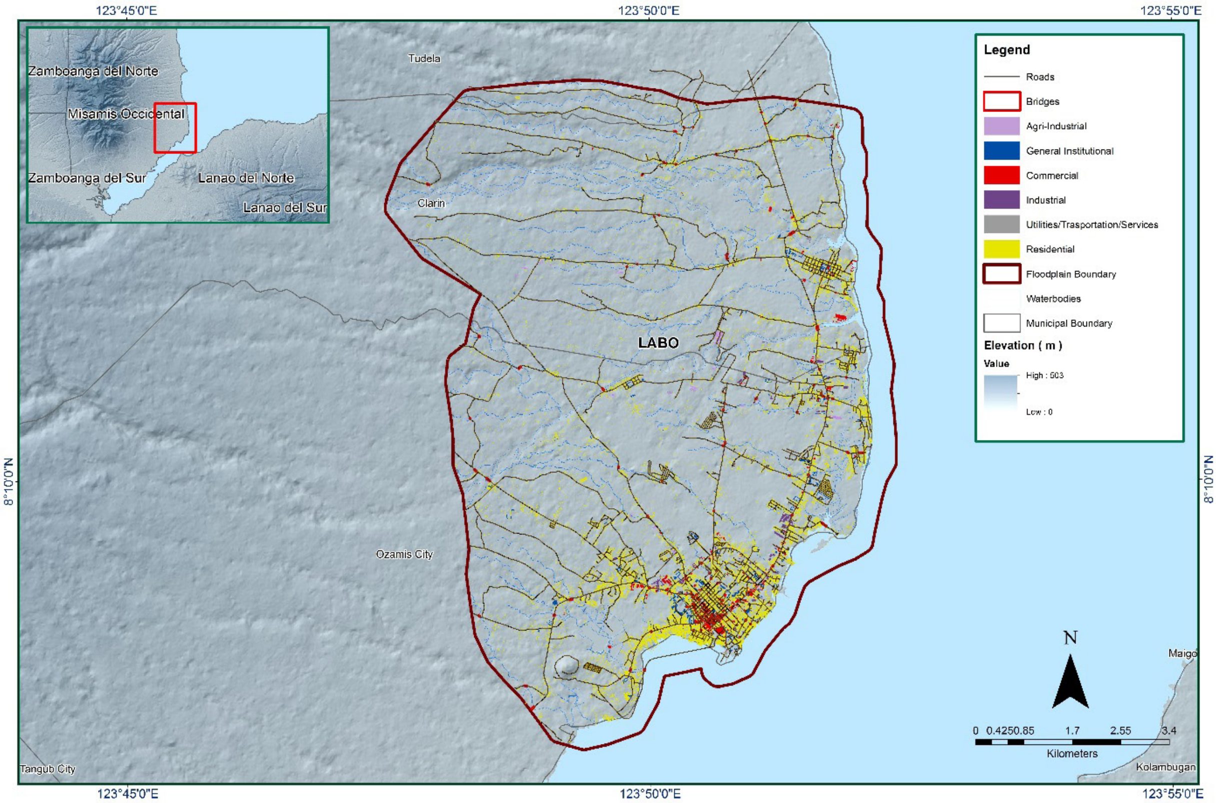


Figure 31. Extracted features for the Labo floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto

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

4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted field surveys in the Labo River on April 1, 2016 and on May 1-9, 2016. The scope of work was comprised of: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built survey at the Calabayan Bridge in Barangay Mentering, Calabayan City, Misamis Occidental; and (iv.) bathymetric survey from the river's upstream in Barangay Guingona, Calabayan City, to the mouth of the river located in Barangay Lapasan, Clarin, with an approximate length of 16.9 kilometers, using a Hi-Target™ Echo Sounder and a Nikon® Total Station. Random checking points for the contractor's cross-section and bathymetry data were gathered by the DVBC on August 16-25, 2016 and on October 24, 2016, using a survey-grade GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique. In addition to this, a validation points acquisition survey was conducted covering the Labo River Basin area. The entire survey extent is illustrated in Figure 32.

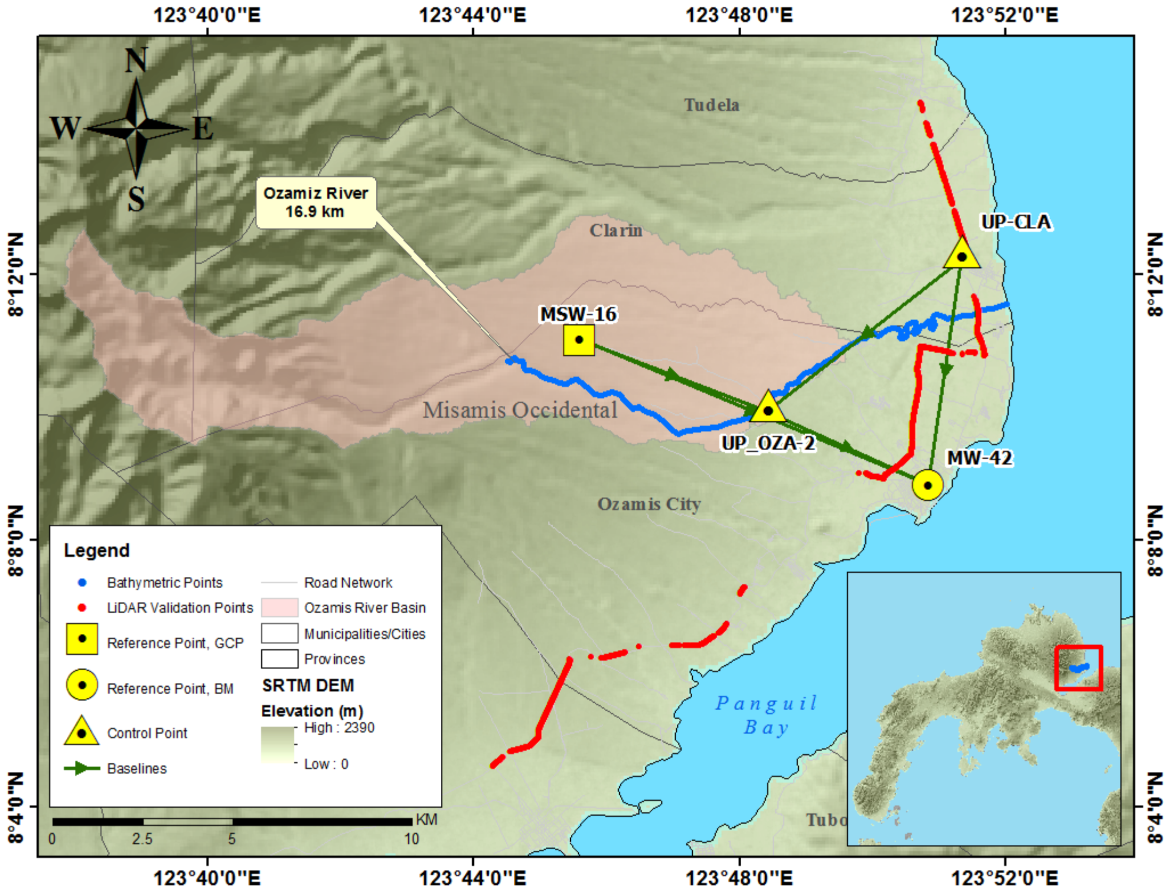


Figure 32. Extent of the bathymetric survey (in blue line) in the Labo River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Labo River is composed of two (2) loops established on October 24, 2016, occupying the following reference points: (i.) UP - CLA, a control point established by the DREAM-DVC team on October 8-19, 2015 for the survey of the Clarin River, in Barangay Poblacion IV, Clarin, Misamis Occidental; and (ii.) MSW-16, a second-order GCP, in Barangay Capupao, Calabayan City, Misamis Occidental.

One NAMRIA-established (1) control point in the area was also occupied: MW-42, a first-order BM, in Barangay Carmen, Calabayan City, Misamis Occidental.

One (1) control point established in the area by the ABSD was also occupied: UP - OZA-2, located beside the railings near the Ozamiz Bridge in Barangay Mentering, Calabayan City, Misamis Occidental.

The summary of reference and control points and their corresponding locations is given in Table 24; while the established GNSS network is illustrated in Figure 33.

Table 24. Reference and control points used during the survey in the Labo River (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellip-soid Height (m)	Elevation (MSL) (m)	Date of Estab-lish-ment
UP-CLA	Established	8°12’20.32560”N	123°51’20.80387”E	72.796	4.138	10-9-2015
MSW-16	2nd order, GCP	8°11’00.29163”N	123°45’35.16283”E	358.160	289.316	2007
MW-42	Used as marker	8°08’49.75314”N	123°50’50.12216”E	69.691	0.922	2008
UP_OZA-2	Established	8°10’01.18254”N	123°48’26.31494”E	124.346	55.604	5-1-2016

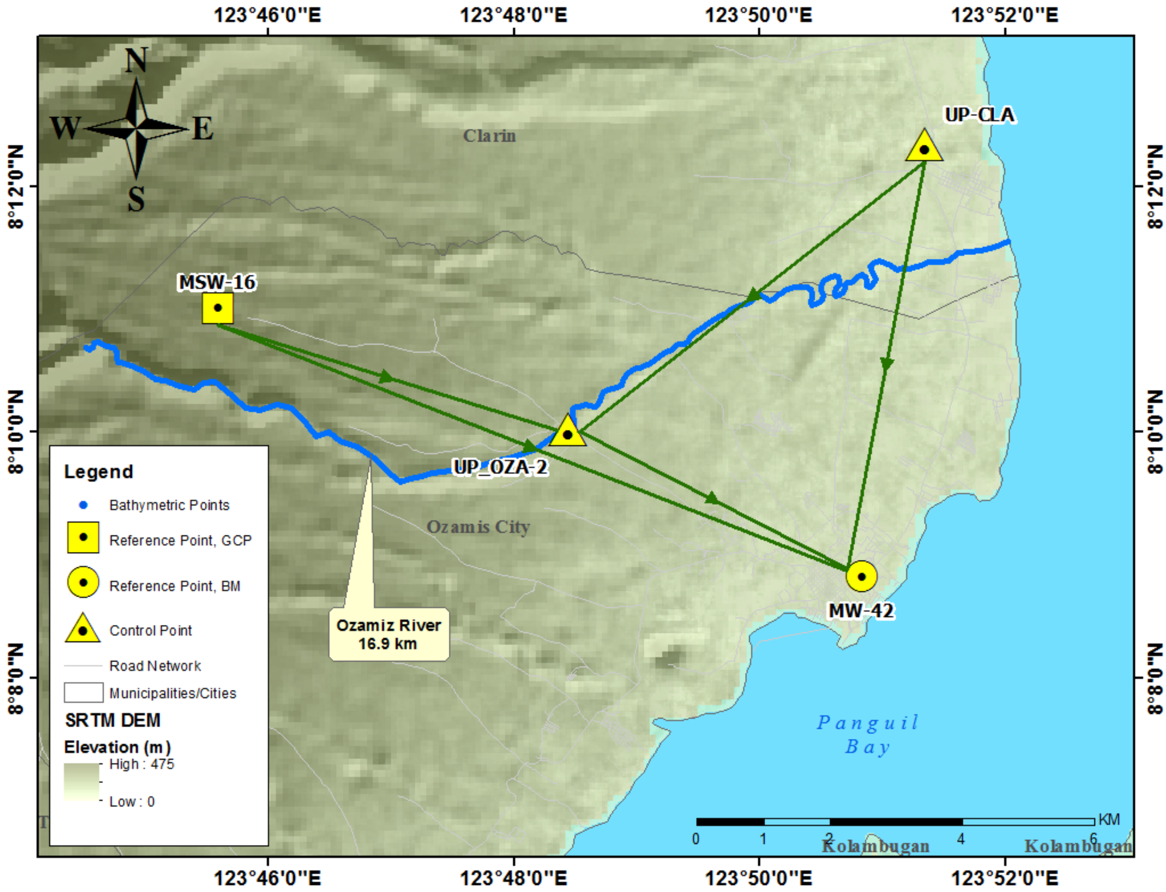


Figure 33. Extent of the Labo River Basin control survey

The GNSS set-ups on the recovered reference points and established control points in the Labo River are exhibited in Figure 34 to Figure 37.

Figure 34. GNSS base set-up, Trimble® SPS 985 at UP-CLA, located at the approach of the Clarin Bridge in Barangay Poblacion IV, Clarin, Misamis Occidental

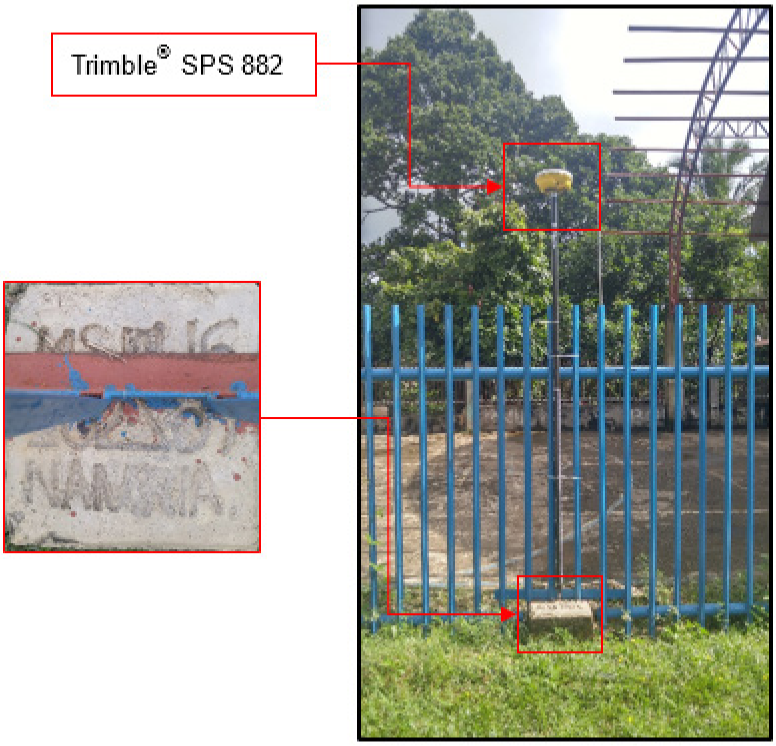


Figure 35. GNSS receiver set-up, Trimble® SPS 882 at MSW-16, located along the fence beside a basketball court in Barangay Cpucao P. Ozamiz City, Misamis Occidental

Figure 36. GNSS receiver set-up, Trimble® SPS 852 at MW-42, located at the approach of the center island across Citi Hardware in Barangay Carmen, Calabayan City, Misamis Occidental

Figure 37. GNSS receiver set-up, Trimble® SPS 882 at UP_OZA-2, located beside the railings near the Ozamiz Bridge in Barangay Mentering, Calabayan City, 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 the +/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of control points in the Labo River Basin, generated by the TBC software, are summarized in Table 25.

Table 25. Baseline Processing Report for Labo River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
MSW-16 --- UP_OZA-2	10-24-2016	Fixed	0.008	0.034	109°06’50”	5544.745	-233.898
UP_OZA-2--- MW-42	10-24-2016	Fixed	0.012	0.052	116°29’34”	4918.751	-54.700
UP-CLA --- UP_OZA-2	10-24-2016	Fixed	0.009	0.051	231°19’52”	6840.944	51.696
MSW-16 --- MW-42	10-24-2016	Fixed	0.008	0.034	112°34’45”	10441.939	-288.518
UP-CLA --- MW-42	10-24-2016	Fixed	0.010	0.052	188°15’40”	6536.884	-2.957

As reflected in Table 25, a total of five (5) baselines were processed, with the coordinates and elevation values of UP-CLA and MSW-16 held fixed. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the squares of x and y must be less than 20 centimeters, and z less than 10 centimeters, or in equation form:

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

Where:

is the Easting Error,

is the Northing Error, and

is the Elevation Error

for each control point. See the Network Adjustment Report presented in Table 26 to Table 28 for the complete details.

The four (4) control points – UP-CLA, MSW-16, MW-42, and UP - OZA-2 – were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation values of UP-CLA and MSW-16 were held fixed during the processing of the control points, as demonstrated in Table 26. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 26. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MSW-16	Grid	Fixed	Fixed		Fixed
UP-CLA	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 27. All fixed control points did not yield values for grid errors and elevation errors.

Table 27. Adjusted grid coordinates for the control points used in the Labo floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MSW-16	583690.278	?	904653.668	?	289.316	?	ENe
MW-42	593336.441	0.021	900663.777	0.022	0.922	0.099	
UP-CLA	594261.657	?	907132.927	?	4.138	?	ENe
UP - OZA-2	588931.138	0.017	902848.507	0.013	55.604	0.098	

With the mentioned equation, for horizontal accuracy and for vertical accuracy, the computations for accuracy are as follows:

a. **MSW-16**

Horizontal Accuracy = Fixed

Vertical Accuracy = Fixed

b. **MW-42**

Horizontal Accuracy = $\sqrt{((2.1)^2 + (2.2)^2}$

= $\sqrt{(4.41+ 4.84)}$

= 3.04 < 20 cm

Vertical Accuracy = 9.9 < 10 cm

c. **UP-CLA**

Horizontal Accuracy = Fixed

Vertical Accuracy = Fixed

d. **UP - OZA-2**

Horizontal Accuracy = $\sqrt{((1.7)^2 + (1.3)^2}$

= $\sqrt{(2.89+ 1.69)}$

= 2.14 < 20 cm

Vertical Accuracy = 9.8 < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two (2) occupied control points are within the required precision.

Table 28. Adjusted geodetic coordinates for control points used in the Labo River floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
MSW-16	N8°11'00.29163"	E123°45'35.16283"	358.160	?	ENe
MW-42	N8°08'49.75314"	E123°50'50.12216	69.691	0.099	
UP-CLA	N8°12'20.32560"	E123°51'20.80387	72.796	?	ENe
UP_OZA-2	N8°10'01.18254"	E123°48'26.31494	124.346	0.098	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 28. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Labo River GNSS Static Survey are indicated in Table 29.

Table 29. Reference and control points used in the Labo River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM Zone 51N		
		Latitude	Longitude	Ellipsoidal Height (Meter)	Northing (m)	Easting (m)	BM Ortho (m)
UP-CLA	Established	8°12'20.32560"N	123°51'20.80387"E	72.796	907132.927	594261.657	4.138
MSW-16	2nd order, GCP	8°11'00.29163"N	123°45'35.16283"E	358.160	904653.668	583690.278	289.316
MW-42	Used as marker	8°08'49.75314"N	123°50'50.12216"E	69.691	900663.777	593336.441	0.922
UP - OZA-2	Established	8°10'01.18254"N	123°48'26.31494"E	124.346	902848.507	588931.138	55.604

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

The cross-section and bridge as-built surveys were conducted on May 4, 2016 at the downstream side of the Calabayan Bridge in Barangay Mentering, Misamis Occidental, as depicted in Figure 38. A Nikon® Total Station was utilized for this survey, as demonstrated in Figure 39.

Figure 38. Calabayan Bridge facing upstream

Figure 39. As-built survey of the Calabayan Bridge

The length of the cross-sectional line surveyed in the Calabayan Bridge is about 149 meters with one hundred twenty-one (121) cross-sectional points, using the control points UP - OZA-2 and UP - OZA-3 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 41 to Figure 43. The DVBC gathered random points for the purpose of checking ABSD's bridge cross-section and bridge points data on August 22, 2016, using a survey-grade GNSS Rover receiver attached to a 2-meter pole, as seen in Figure 40.

Figure 40. Gathering of random cross-section points along the Calabayan Bridge

Linear square correlation (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range was determined to ensure that the submitted data of the contractor were within the accuracy standards of the project, which are ±20 centimeters and ±10 centimeters for horizontal and vertical accuracies, respectively. The R^2 value must be within 0.85 to 1. An R^2 approaching 1 signifies a strong correlation between the vertical elevation values of the two (2) datasets. A computed R^2 value of 0.98 was obtained by comparing the data of the contractor and that of DVBC, signifying a strong correlation between the two (2) datasets.

The Root Mean Square (RMSE) analysis was also performed in order to assess the difference in elevation between the DVBC checking points and that of the contractor's. The RMSE value should only have a maximum radial distance of 5 meters; and the difference in elevation within the radius of 5 meters should not go beyond 0.50 meters. For the bridge cross-section data, a computed value of 0.107 was acquired. Therefore, the computed R^2 and RMSE values are within the accuracy requirements of the program.

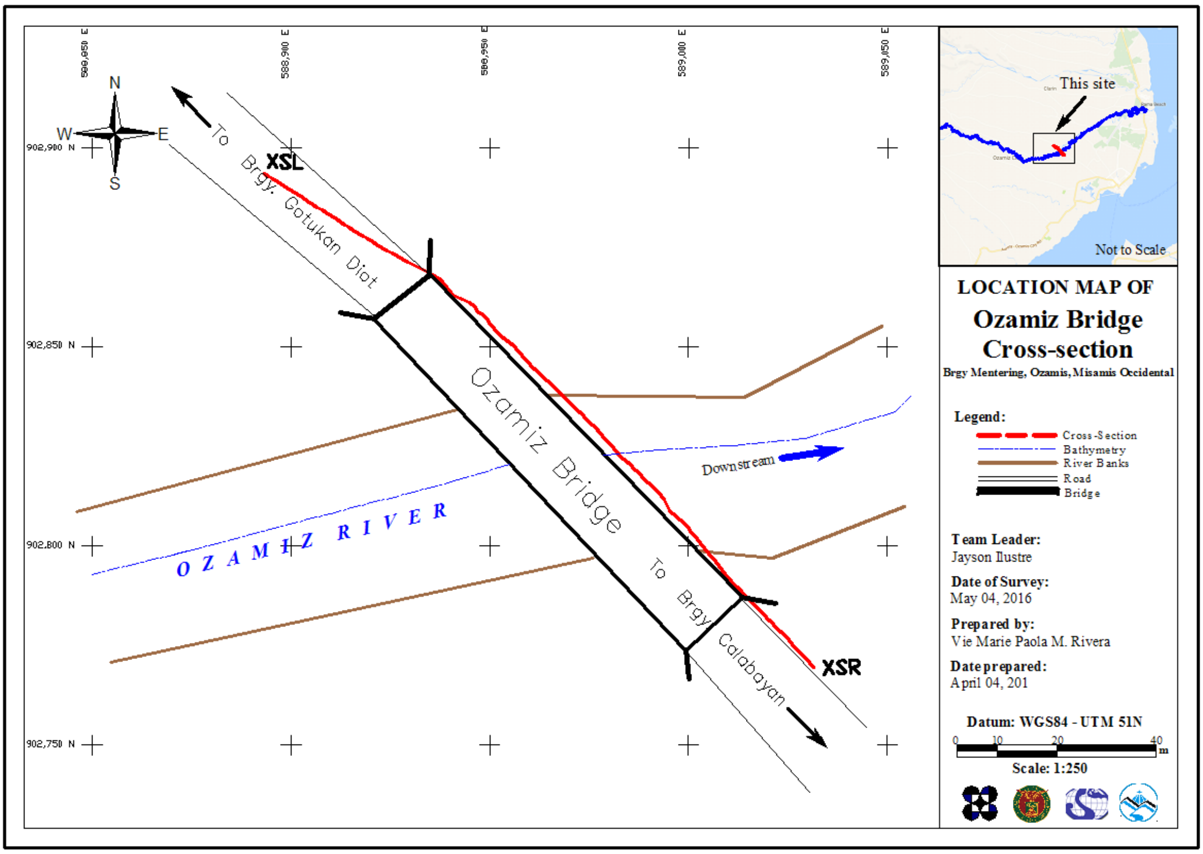


Figure 41. Location map of the Calabayan Bridge cross-section

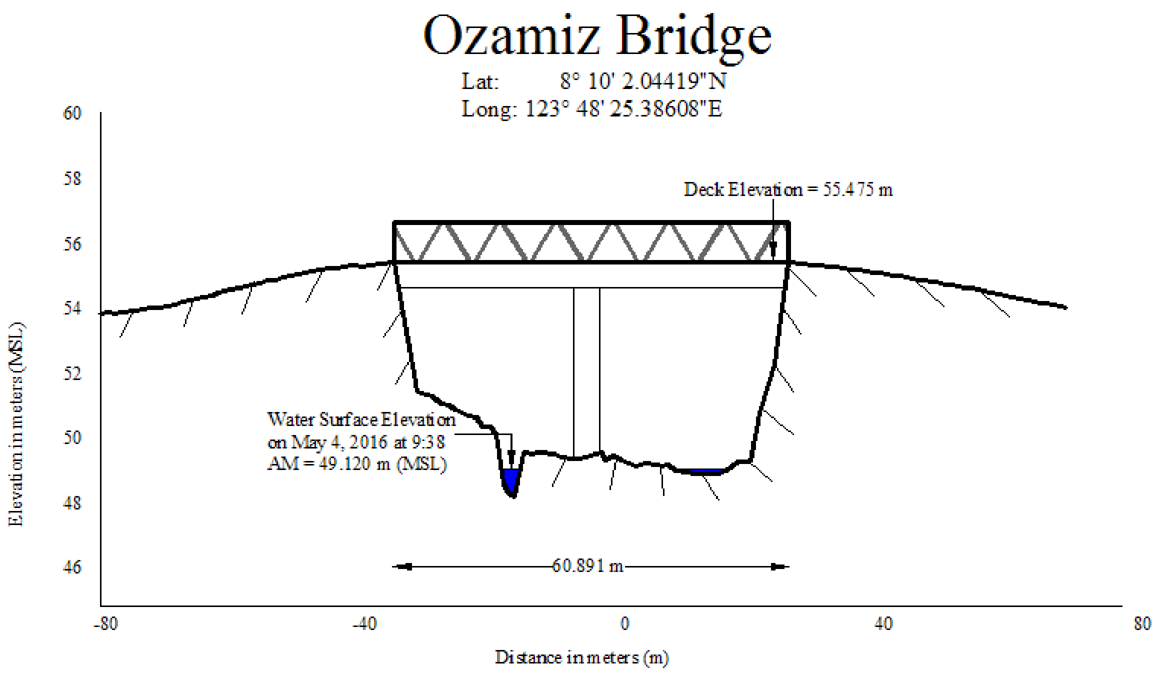


Figure 42. Calabayan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Ozamiz Bridge

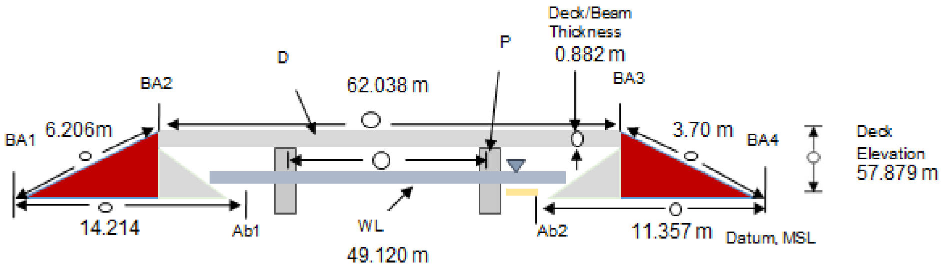
River Name: Ozamiz River
Location (Brgy, City, Region): Brgy. Mentering, Ozamiz City, Misamis Occidental

Survey Team: Jayson Illustre, Ryan Antonio
Date and Time: May 4, 2016, 9:38 A.M.

Flow Condition: low ✔ normal high

Weather Condition: ✔ fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	6.206 m	
2. BA2-BA3	62.038 m	
3. BA3-BA4	3.70 m	
4. BA1-Ab1	14.214 m	
5. Ab2-BA4	11.357 m	
6. Deck/beam thickness	0.882 m	
7. Deck elevation	57.879 m	

Note: Observer should be facing downstream

Figure 43. Calabayan Bridge data sheet

The water surface elevation of the Labo River was determined using a Nikon® Total Station on May 4, 2016 at 09:38 hrs. at the Calabayan Bridge area. An elevation value of 49.120 meters in MSL was obtained, as reflected in Figure 42. This was translated into markings on the bridge's pier, as displayed in Figure 44. The markings served as a reference for flow data gathering and depth gauge deployment of the MSU-IIT Phil-LiDAR 1 Team.

Figure 44. Water-level markings on the Calabayan Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by the DVBC on August 21 - 22, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882. The receiver was mounted on a range pole that was attached at the side of a vehicle, as demonstrated in Figure 45. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.4 meters, measured from the ground up to the bottom of the antenna mount of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with UP-CLA occupied as the GNSS base station.

Figure 45. Validation points acquisition survey set-up for the Labo River

The survey started in Barangay Taguima in the Municipality of Tudela, Misamis Occidental. It headed southwest along the national highway, traversing one (1) barangay in the Municipality of Tudela, five (5) barangays in the Municipality of Clarin, and five (5) barangays in Calabayan City, before ending in Barangay Banadero in Calabayan City, Misamis Occidental. The survey continued in Barangay Dimaluna in Calabayan City; and traveled southwest along the national highway, traversing three (3) barangays in Calabayan City and two (2) barangays in Tangub City, before ending in Barangay Prenza in Tangub City, Misamis Occidental. The survey gathered a total of 3,091 points with an approximate length of 24.45 kilometers, using UP-CLA as the GNSS base station for the entire extent of validation points acquisition survey, as illustrated in the map in Figure 46.

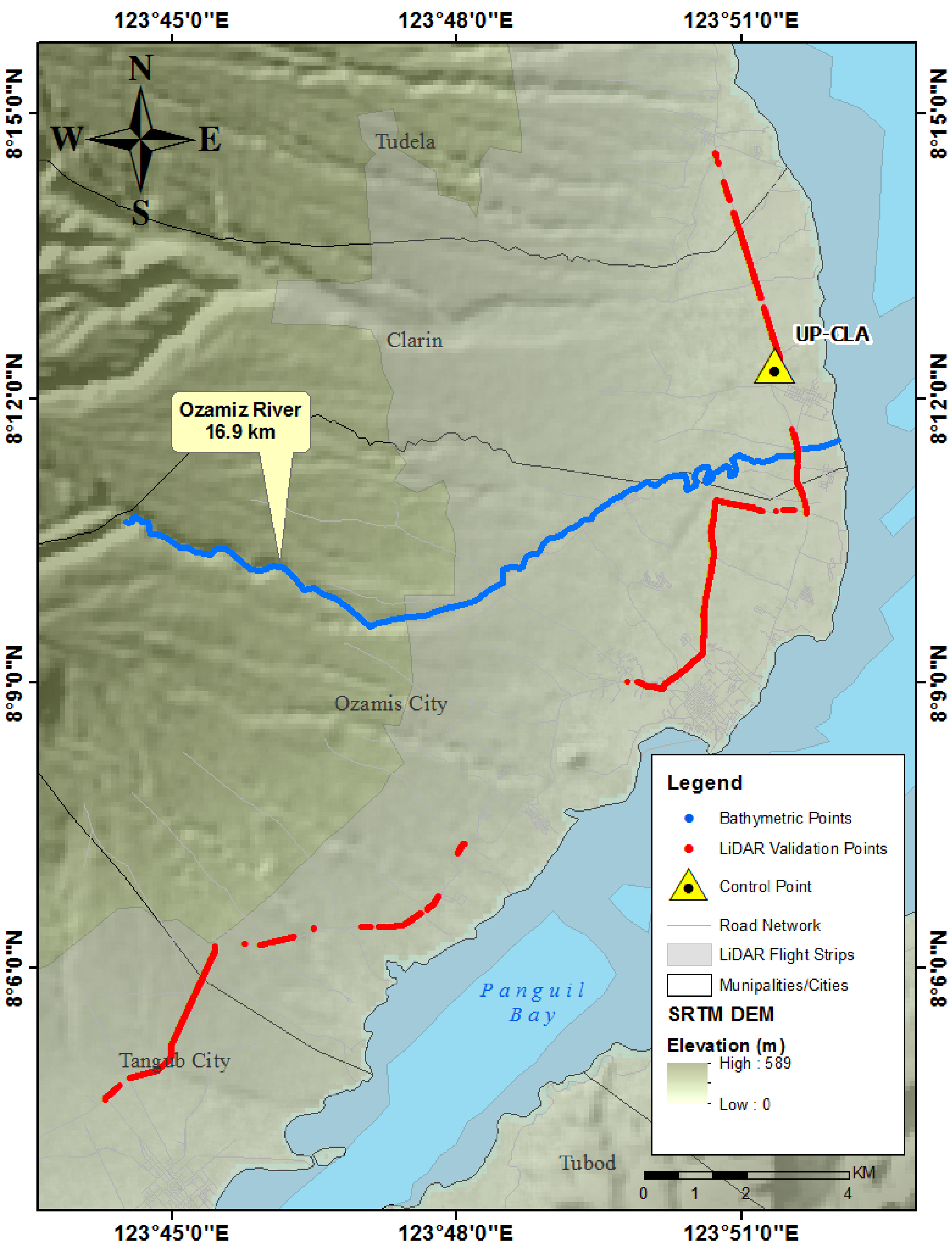


Figure 46. Extent of the LiDAR ground validation survey of the Labo River Basin

4.7 Bathymetric Survey

A bathymetric survey was executed by the ABSD on April 1, 2016 using a Hi-Target™ Echo Sounder, as seen in Figure 47. The survey started in Barangay Gata Diot in the Municipality of Clarin, Misamis Occidental, with coordinates 8° 11' 11.58508"N, 123° 50' 54.68784"E; and ended at the mouth of the river in Barangay Lapasan in the Municipality of Clarin, Misamis Occidental, with coordinates 8° 11' 32.87041"N, 123° 52' 0.04728"E.

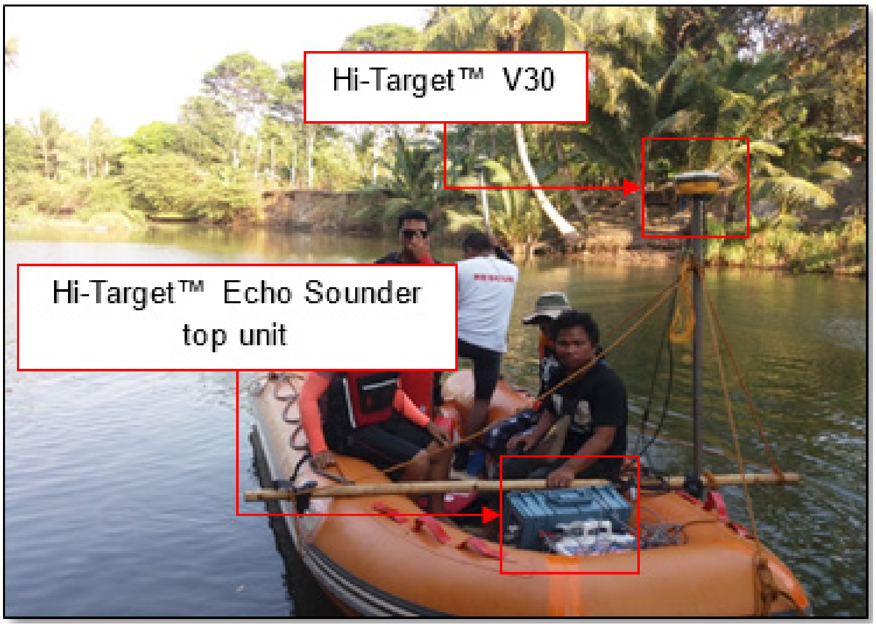


Figure 47. Bathymetric survey of the ABSD at the Labo River, using Hi-Target™ Echo Sounder

A manual bathymetric survey was executed on May 1-3, 2016, on May 5, 2016, and on May 7-9, 2016, using a Nikon® Total Station, as depicted in Figure 48. The survey started in Barangay Guingona in Calabayan City, Misamis Occidental, with coordinates 8° 10' 39.48772"N, 123° 44' 28.49806"E; and ended at the starting point of the bathymetric survey by boat. The control points UP - OZA-0, UP- OZA-1, and UP - OZA-2 served as the GNSS base stations all throughout the survey.

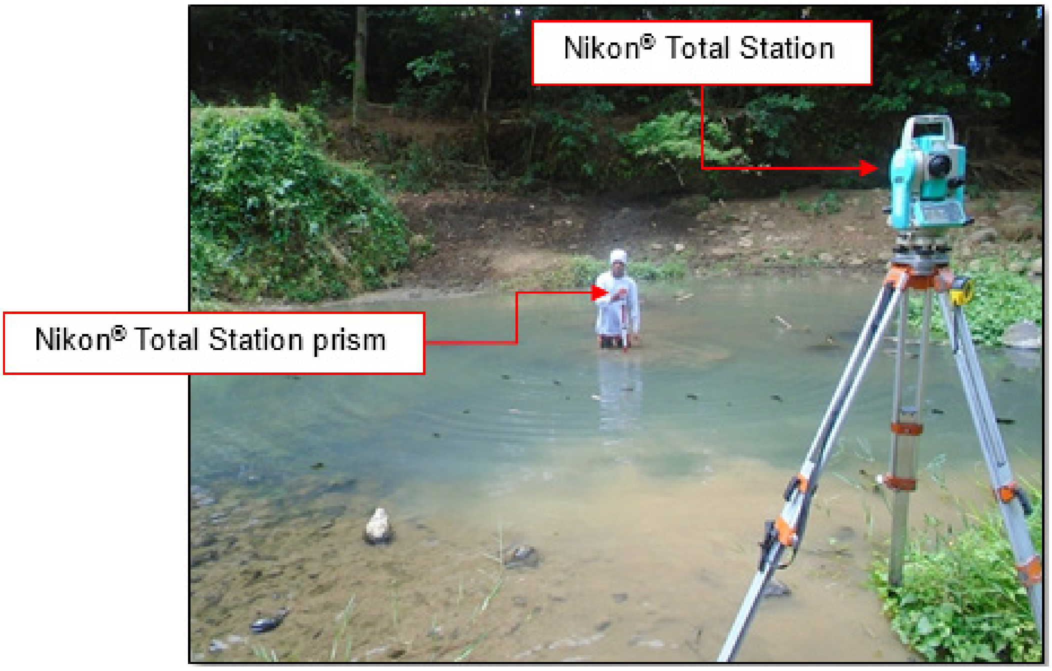


Figure 48. Manual bathymetric survey of the ABSD at the Labo River, using Nikon® Total Station

The DVBC gathered random points to validate ABSD's bathymetric data on August 21, 2016, using a GNSS Rover receiver, Trimble® SPS 882, attached to a 2-meter pole, as illustrated in Figure 49. A map showing the DVBC's bathymetric checking points is displayed in Figure 51.

Figure 49. Gathering of random bathymetric points of DVBC along the Labo River

Linear square correlation (R^2) and RMSE analysis were also performed on the two (2) datasets. The computed R^2 value of 0.998 is within the required range, which is from 0.85 to 1. Additionally, an RMSE value of 0.183 was obtained. Both the computed R^2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for the Labo River gathered a total of 5,217 points covering 16.99 kilometers of the river, traversing the following barangays: Lapasan, Gata Diot, Gata Daku, and Kinangay Sur in the Municipality of Clarin; and barangays Labo, Embargo, Molicay, Gotokan Diot, Mentering, Liposong, Pantaon, Kinuman Sur, Dalapang, Stimson Abordo, Trigos, Guimad, and Guingona in the City of Calabayan (Figure 50). A CAD drawing was also produced to illustrate the riverbed profile of Labo River, presented in Figure 52. The profile demonstrates that the highest and lowest elevation had a 274-meter difference. The highest elevation observed was 266.939 meters above MSL, located in Barangay Guingona in Calabayan City; while the lowest was -6.824 meters below MSL, located in Barangay Lapasan in Clarin.

Figure 50. Extent of the bathymetric survey of the Labo River

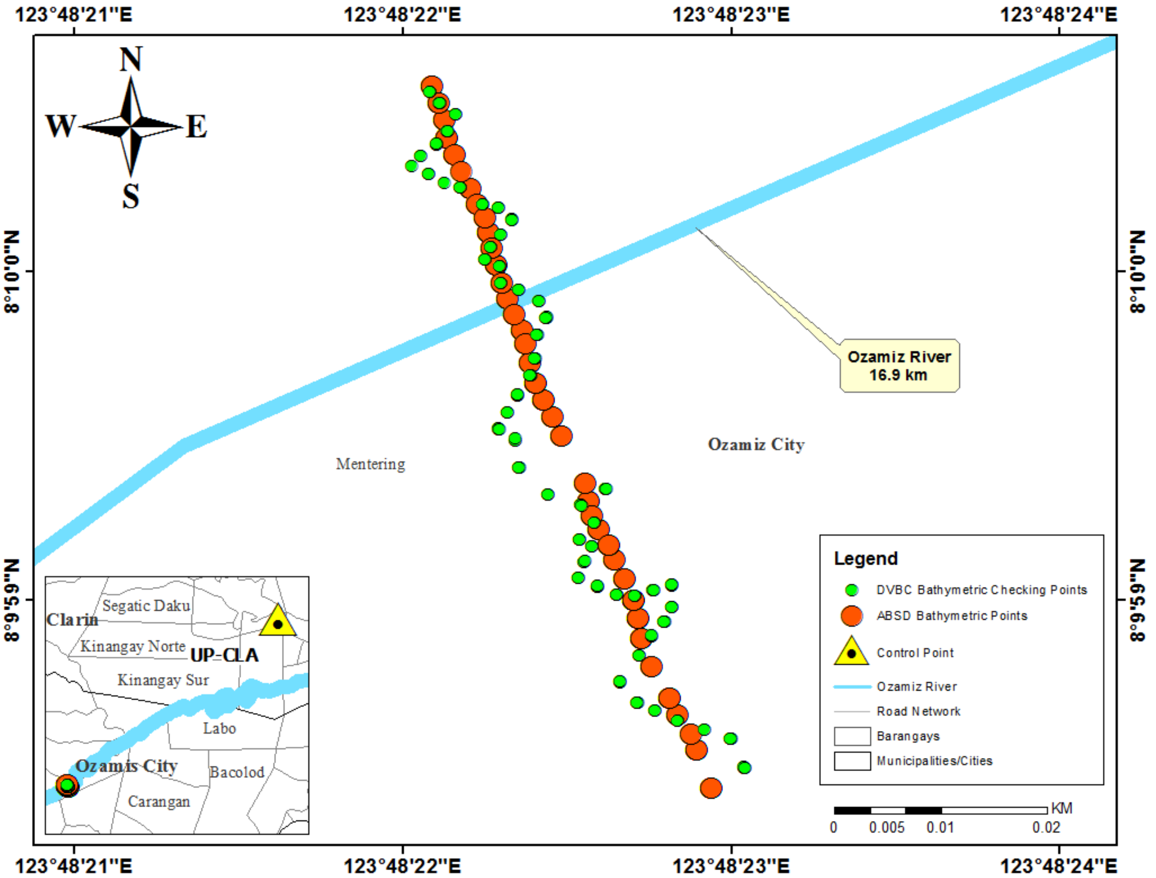


Figure 51. Quality checking points gathered along the Labo River by DVBC

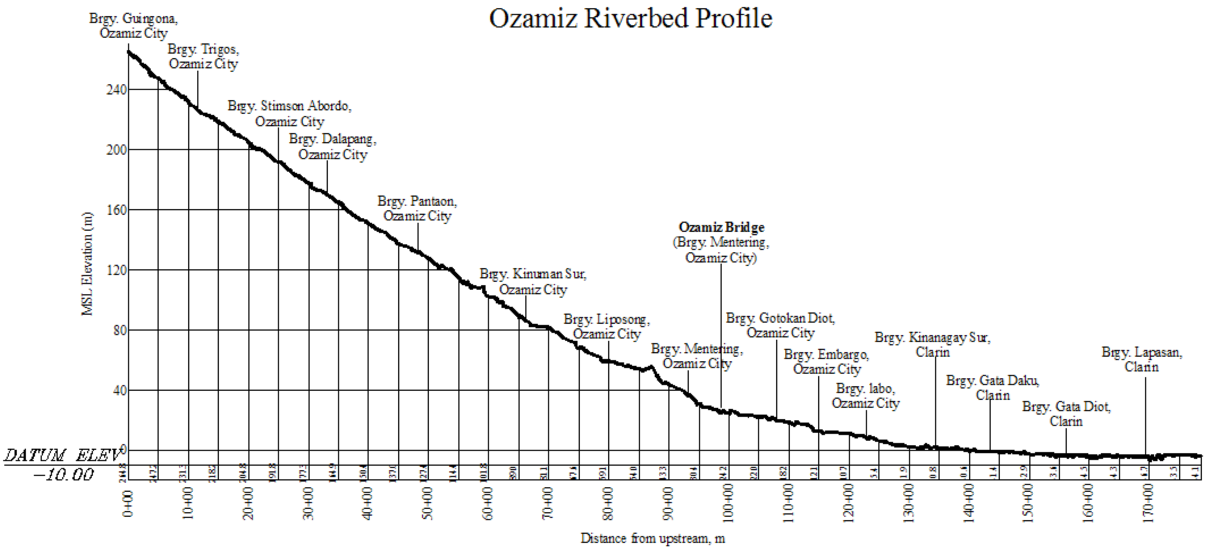


Figure 52. Labo riverbed profile

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the Automatic Rain Gauge (ARG) installed upstream by the DOST. The ARG was specifically installed in the City of Labo, with coordinates 8°11'45.96"N Latitude and 123°47'41.71"E Longitude. The location of the rain gauge is shown in Figure 53.

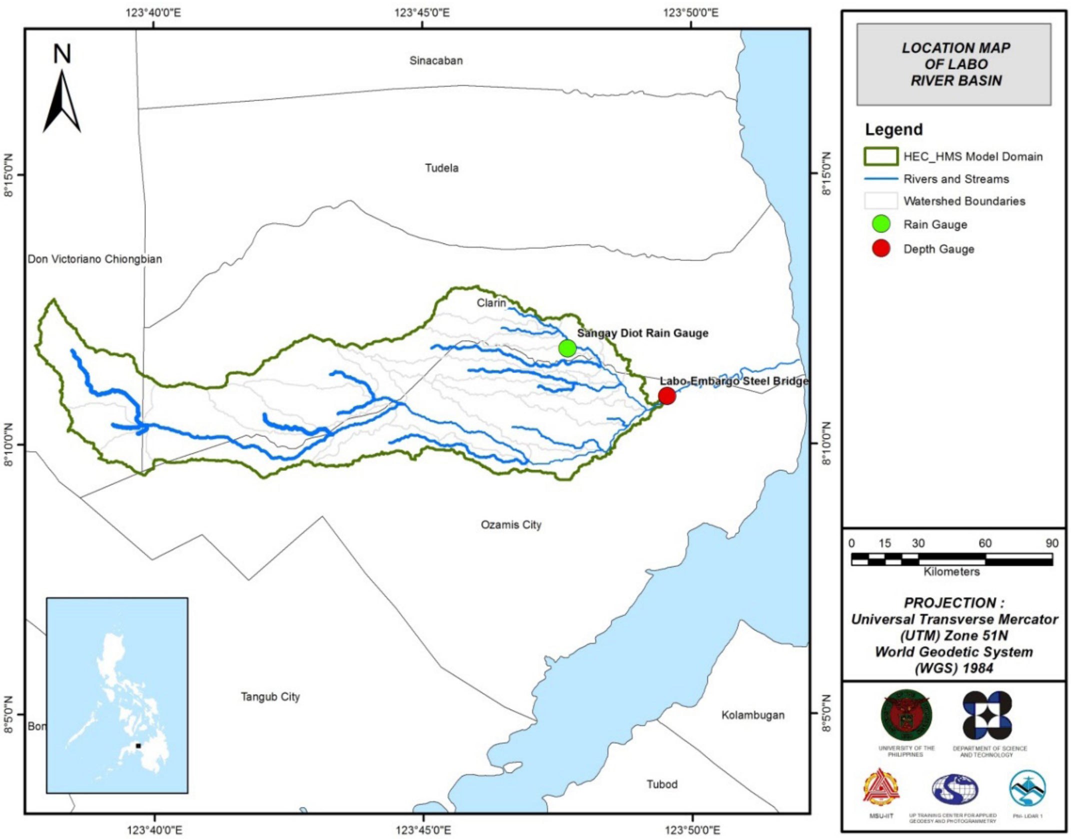


Figure 53. The location map of Labo HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 54) at the Labo-Embargo Steel Bridge to establish the relationship between the observed water levels (H) and outflow (Q) of the watershed at this location. The HQ curve analysis is important in determining the equation to be used in establishing the Q values that will yield R-Squared values closer to 1, which gives a more accurate trend line. For Labo, the base flow hydrometry was used.

Figure 55 illustrates the highest R-Squared value of 0.9488, compared with the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

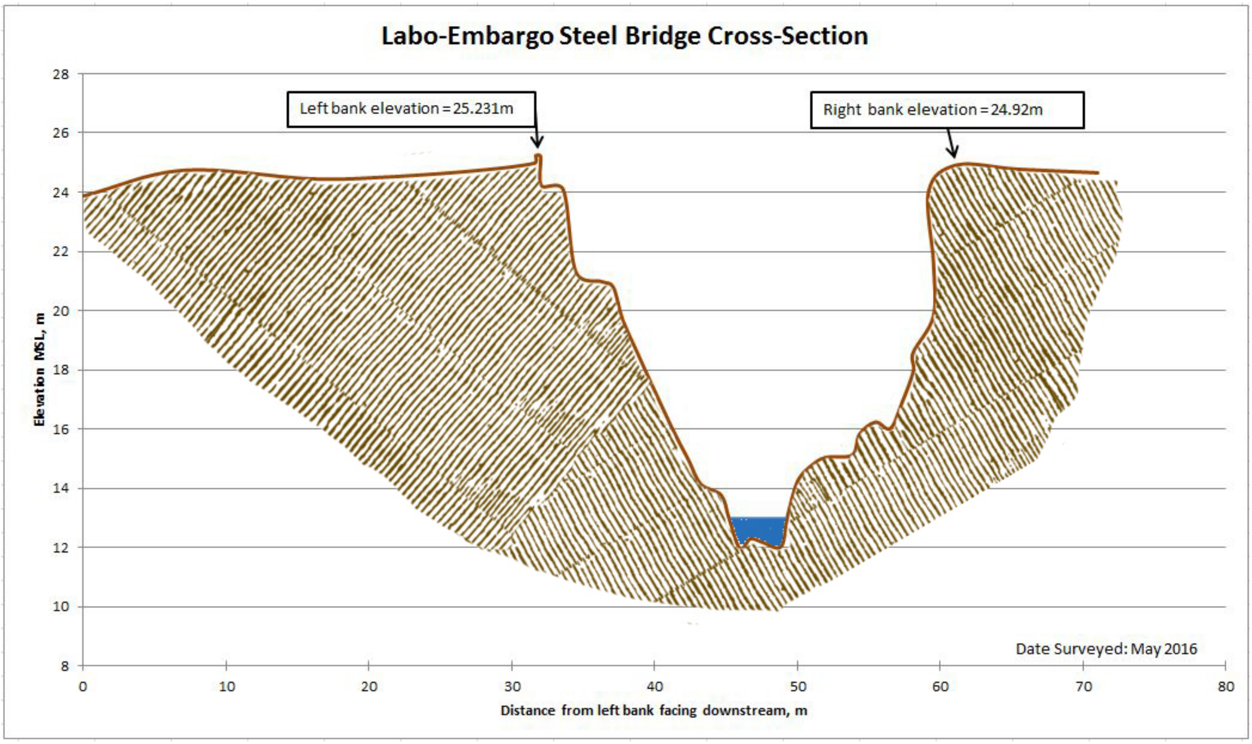


Figure 54. Cross-section plot of the Labo-Embargo Steel Bridge

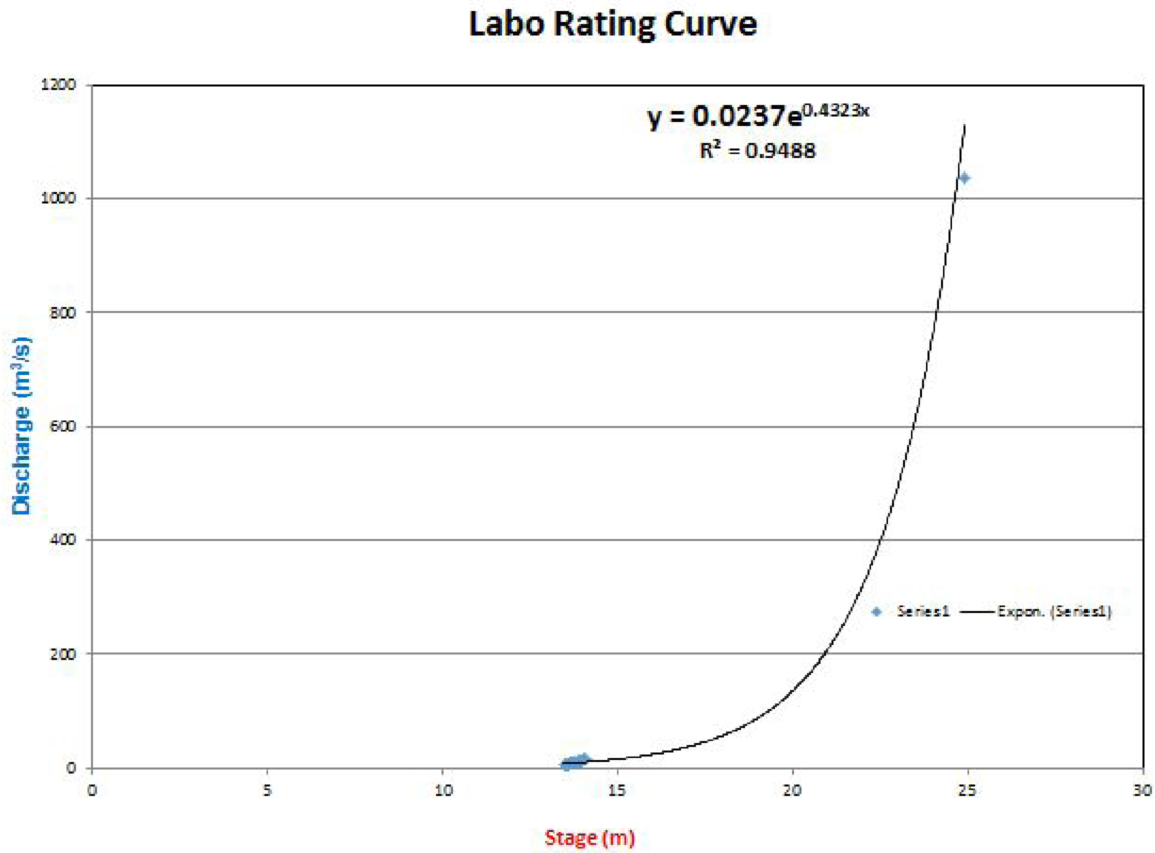


Figure 55. Rating curve at the Labo-Embargo Steel Bridge

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

The total rainfall taken from the ARG at Sangay Diot, Calabayan City was 93.2 millimeters. It peaked at 16.4 millimeters on October 11, 2016 at 15:20 hrs. The lag time between the peak rainfall and discharge was four (4) hours and twenty (20) minutes.

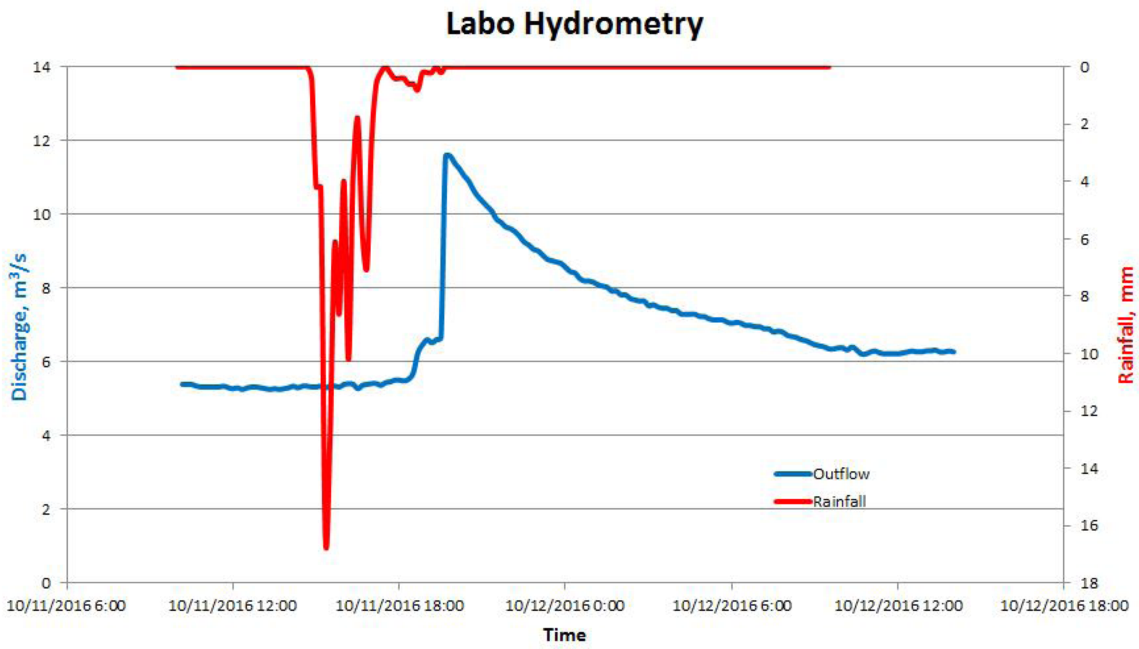


Figure 56. Rainfall and outflow data at the Labo-Embargo Steel Bridge, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Dipolog Rain Gauge (Table 30). This station was selected based on its proximity to the Labo watershed (Figure 57). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 51-year record.

Table 30. RIDF values for the 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

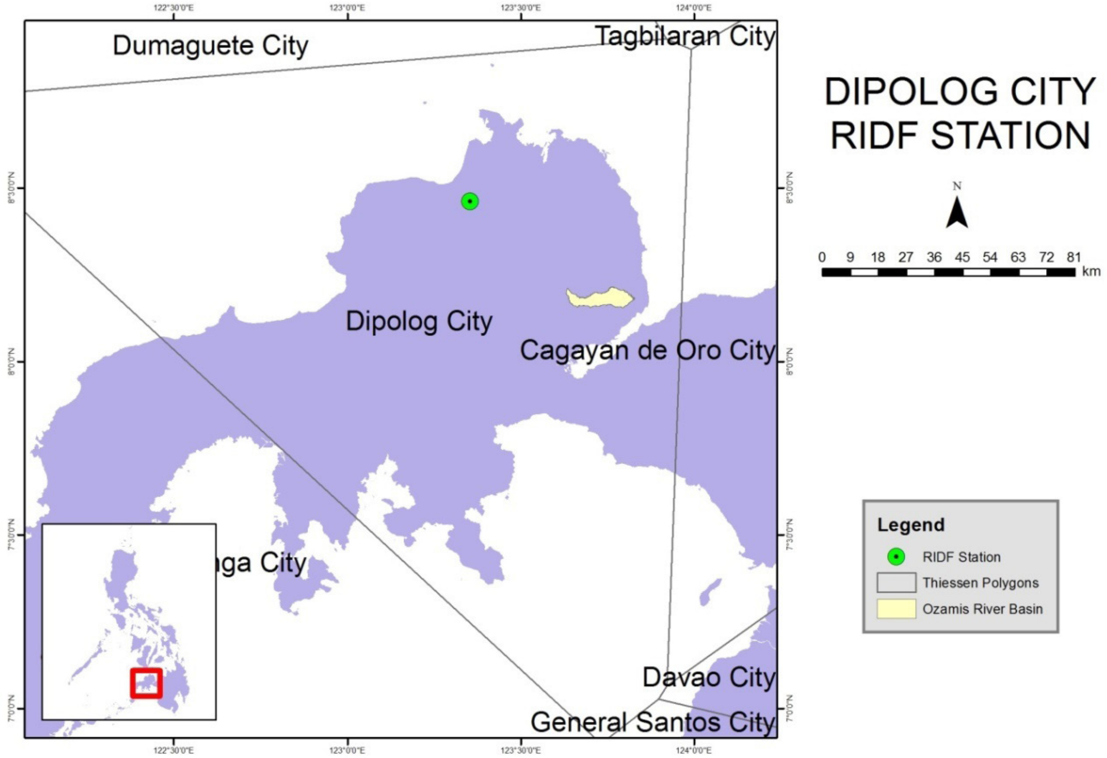


Figure 57. Location of the Dipolog RIDF station relative to the Labo (Calabayan) River Basin

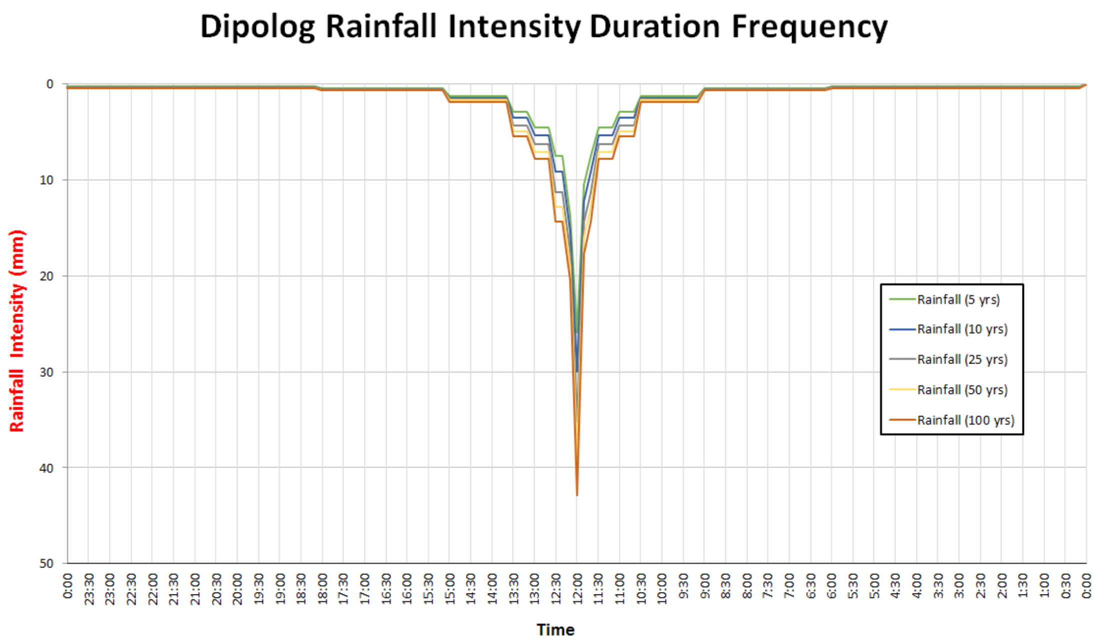


Figure 58. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil texture shape file was generated in 2004 from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The soil texture map (Figure 59) of the Labo River Basin was used as one of the factors for the estimation of the CN parameter.

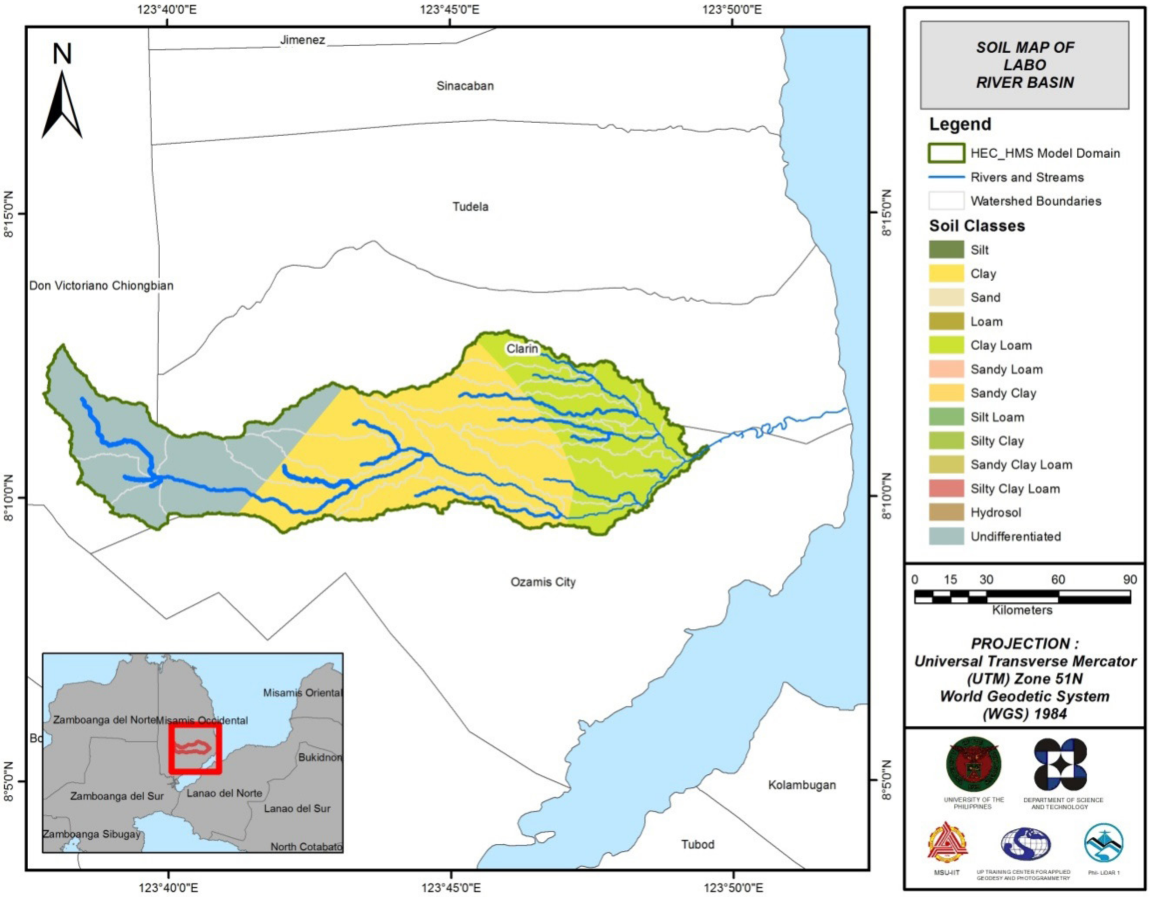


Figure 59. Soil map of the Labo River Basin (Source: DA)

The land cover data was generated in 2003 from the National Mapping and Resource Information Authority (NAMRIA), DENR. Figure 60 presents the land cover inside the Labo River Basin. The land cover map of the Labo River Basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

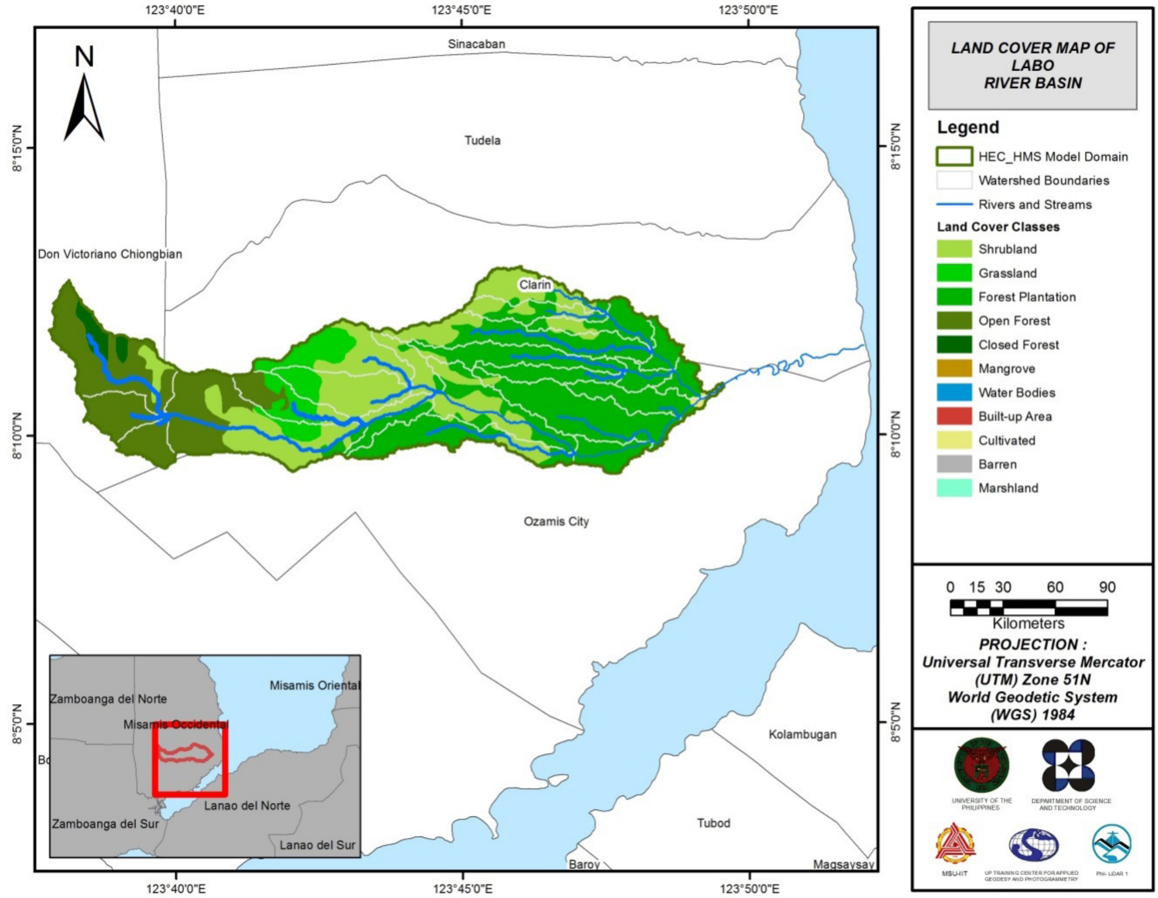


Figure 60. Land cover map of the Labo River Basin (Source: NAMRIA)

The soil classes identified in the Labo River Basin were clay loam, clay, and undifferentiated soil. The land cover types identified were shrub lands, grasslands, forest plantations, open forests, and closed forests.

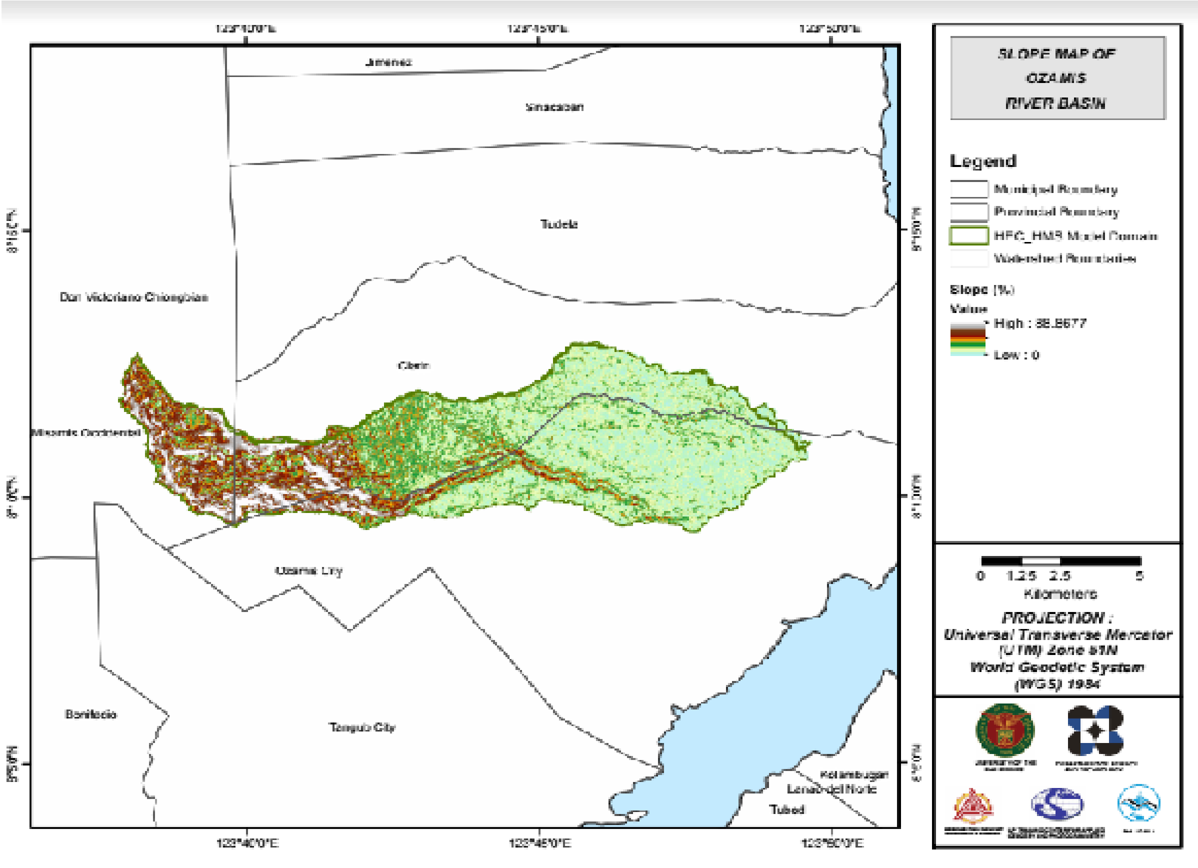


Figure 61. Slope map of the Labo River Basin

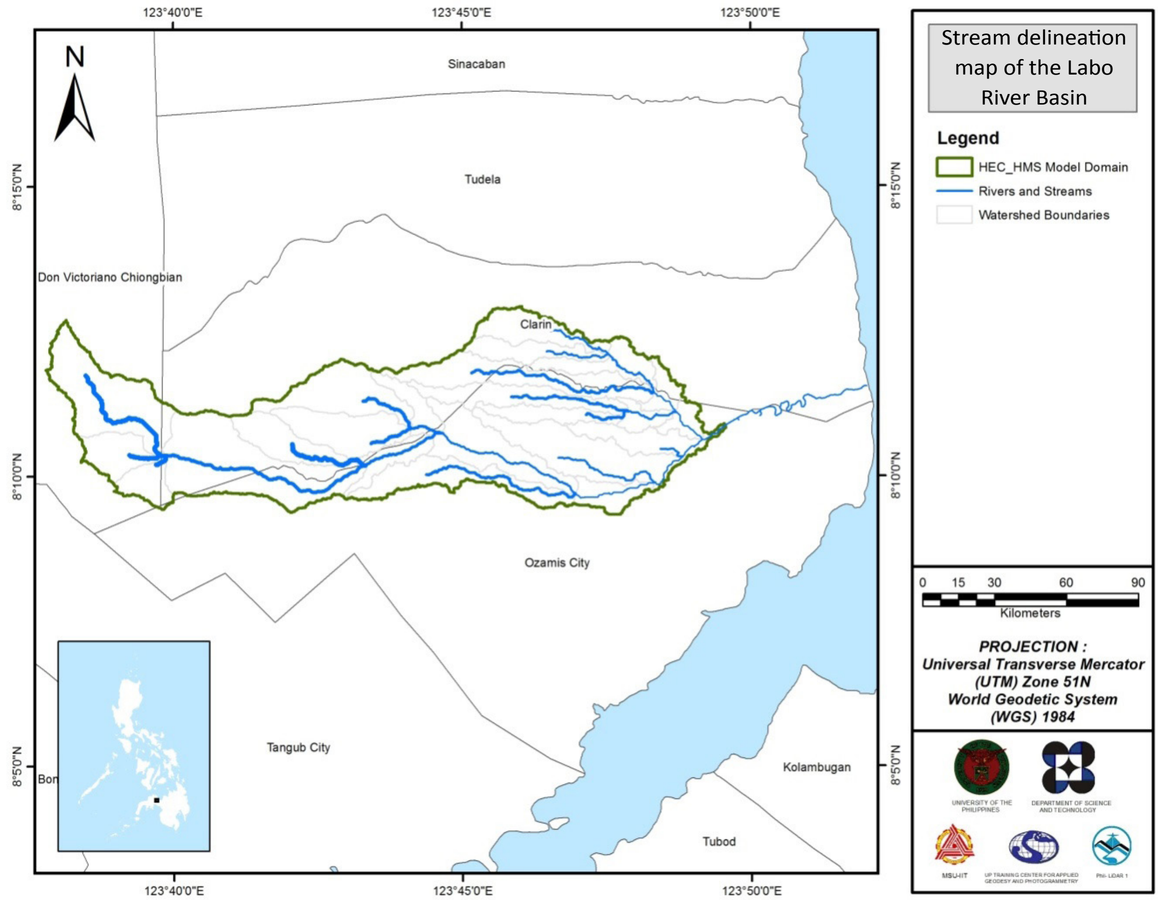


Figure 62. Stream delineation map of the Labo River Basin

Using the SAR-based DEM, the Labo basin was delineated and further subdivided into sub-basins. The model consists of twenty-three (23) sub-basins, thirteen (13) reaches, and thirteen (13) junctions. The main outlet is located at the Labo-Embargo Steel Bridge, Calabayan City. The basin model is illustrated in Figure 63. Finally, the model was calibrated using the hydrological data derived from the depth gauge and flow meter deployed at the Labo-Embargo Bridge. See Annex 10 for the Labo Model Reach Parameters

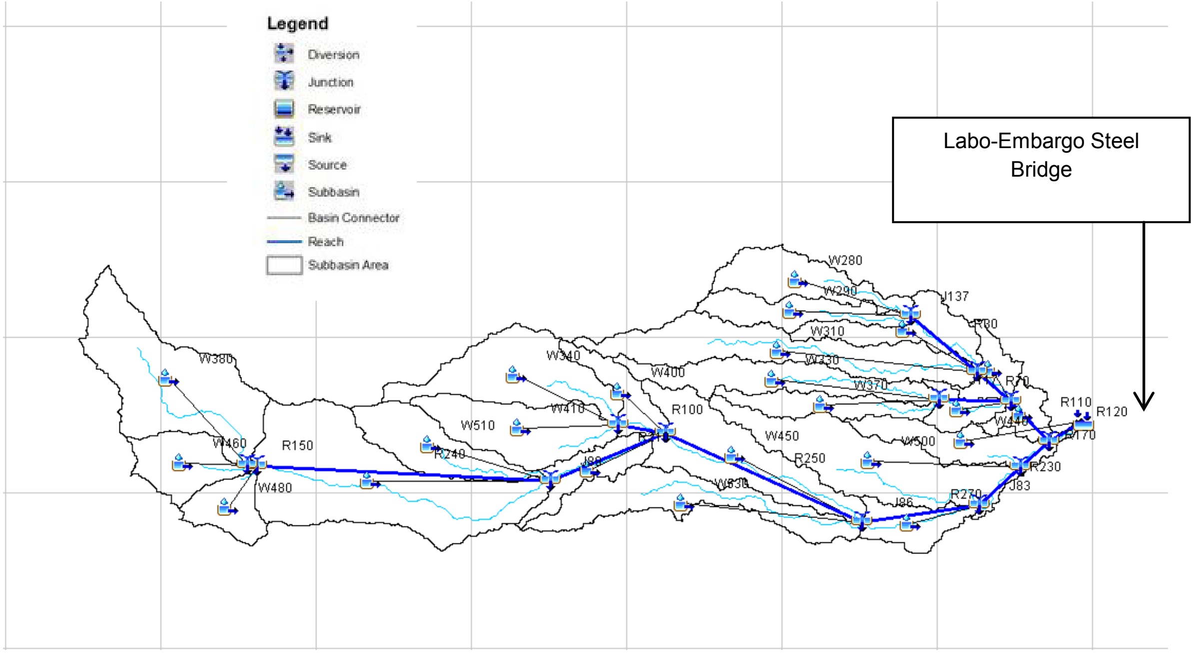


Figure 63. The Labo hydrologic model, generated in HEC-GeoHMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 64).

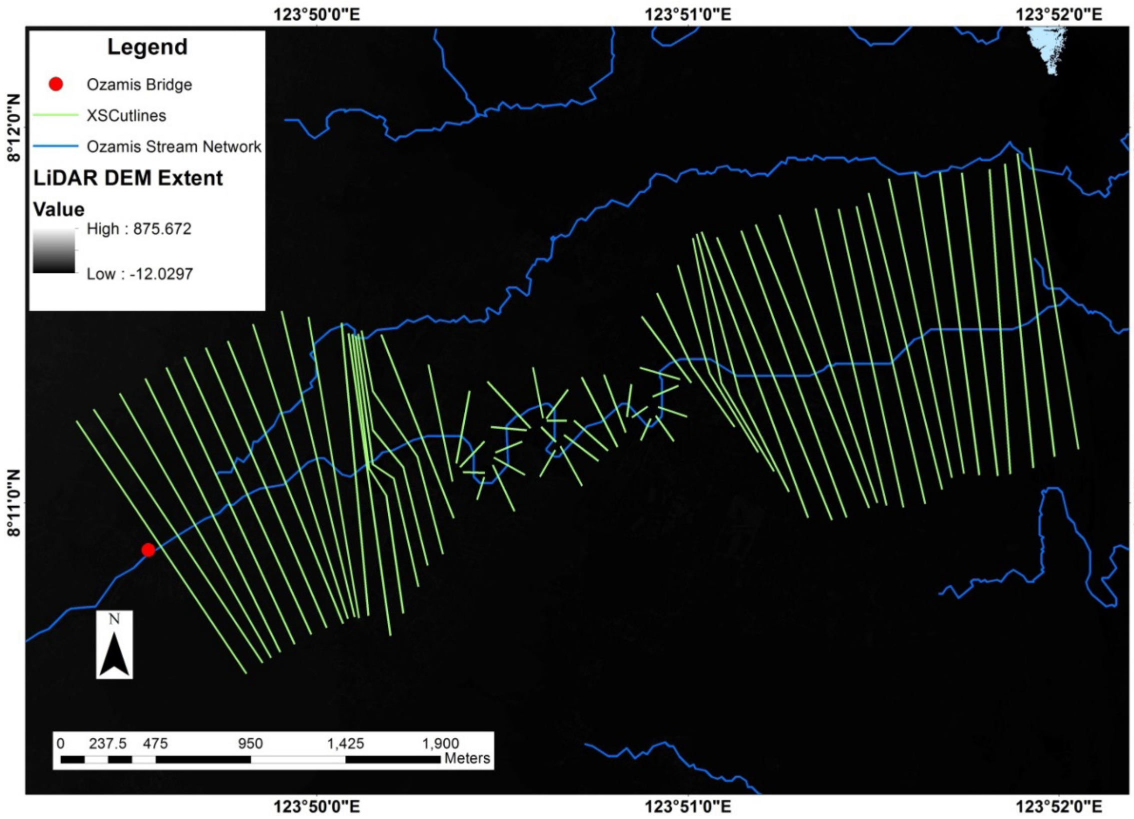


Figure 64. River cross-section of the Labo River, generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

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

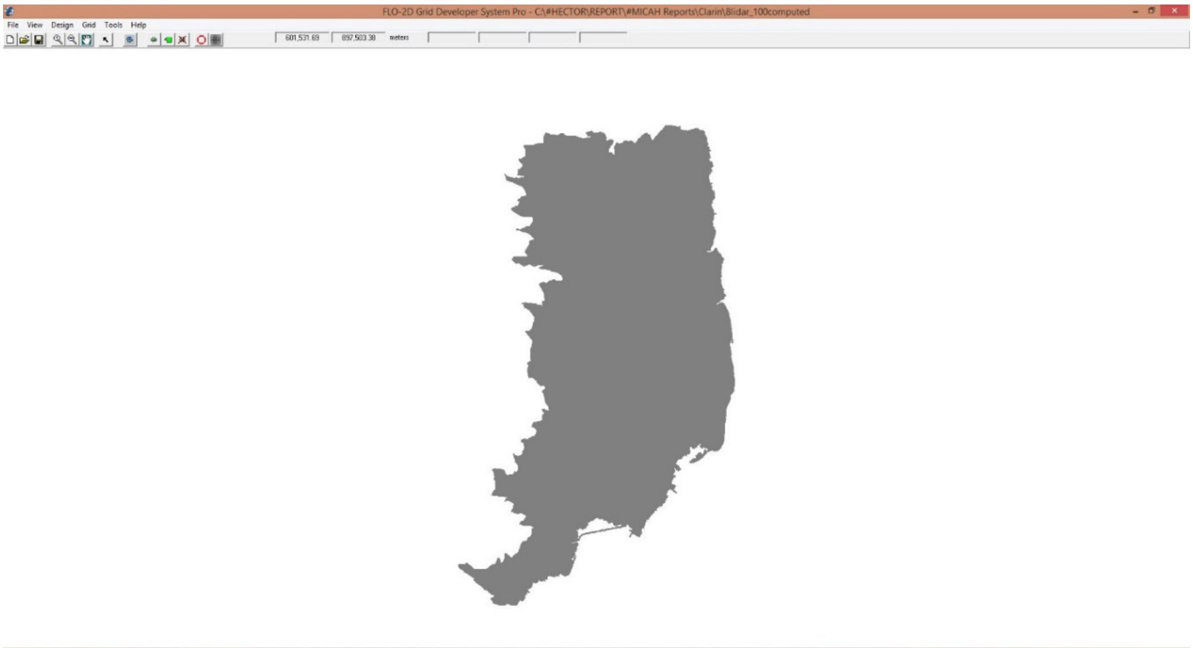


Figure 65. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 44.87689 hours. After the simulation, the FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows the 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 generated the flood hazard map. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (maximum depth) was set at 0.2 meters; while the minimum vh {product of maximum velocity (v) and maximum depth (h)} was set at 0 square meters per second (m^2/s).

The creation of a flood hazard map from the model also automatically generated a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 50 629 200.00 m^2.

There was a total of 56 007 705.64 cubic meters (m^3) of water that entered the model. Of this amount, 12 566 275.37 m^3 was due to rainfall, while 43 441 430.27 m^3 was inflow from areas outside the model. 6 549 024.00 m^3 of this water was lost to infiltration and interception, while 4 008 039.25 m^3 was stored by the floodplain. The rest, amounting to up to 45 450 634.04 m^3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Labo HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 66 depicts the comparison between the two discharge data. The Labo Model Basin Parameters are available in Annex 9.

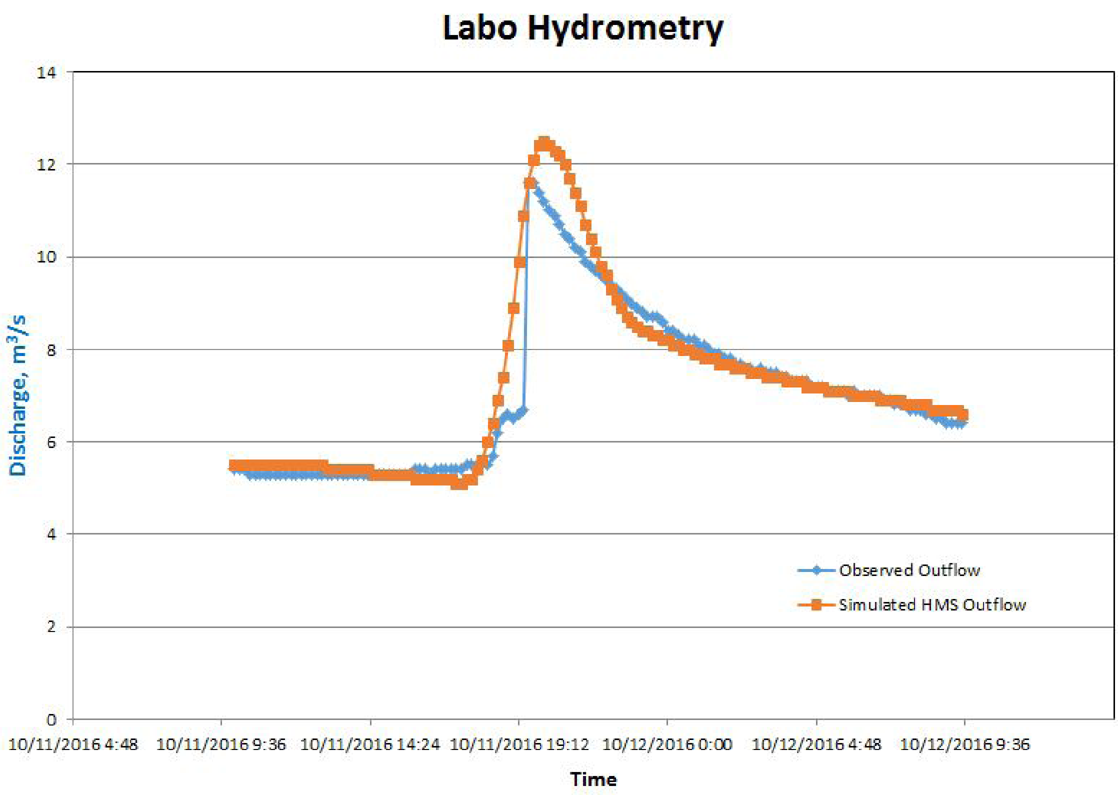


Figure 66. Outflow Hydrograph of the Labo Bridge generated in HEC-HMS model, compared with observed outflow

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

Table 31. Range of calibrated values for the Labo model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.8 - 15
			Curve Number	73 - 80
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.5 – 2.5
			Storage Coefficient (hr)	0.7 - 4
	Baseflow	Recession	Recession Constant	0.7
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. A range of values from 0.8 to 15 millimeters for the initial abstraction signifies a minimal amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 73 to 80 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Labo, the basin mostly consists of shrub lands, grasslands, and forests; and the soil consists of clay and clay loam.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.5 to 4 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.7 indicates that the basin is unlikely to quickly revert to its original discharge, and will be higher instead. A ratio to peak of 0.5 implies that the flow will be relatively stable when it comes to the receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.04 corresponds to the common roughness in the Labo watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 32. Efficiency Test of the Labo HMS Model

RMSE	0.65
r^2	0.90
NSE	0.86
PBIAS	-2.41
RSR	0.38

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.65 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 represents an almost perfect match of the observed discharge and the resulting discharge from the HEC-HMS model. Here, it was measured at 0.90.

The Nash-Sutcliffe (NSE) 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 0.86.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -2.41.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained an RSR value of 0.38.

5.7 Calculated outflow hydrography and Discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph in Figure 67 presents the Labo outflow using the Dipolog RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

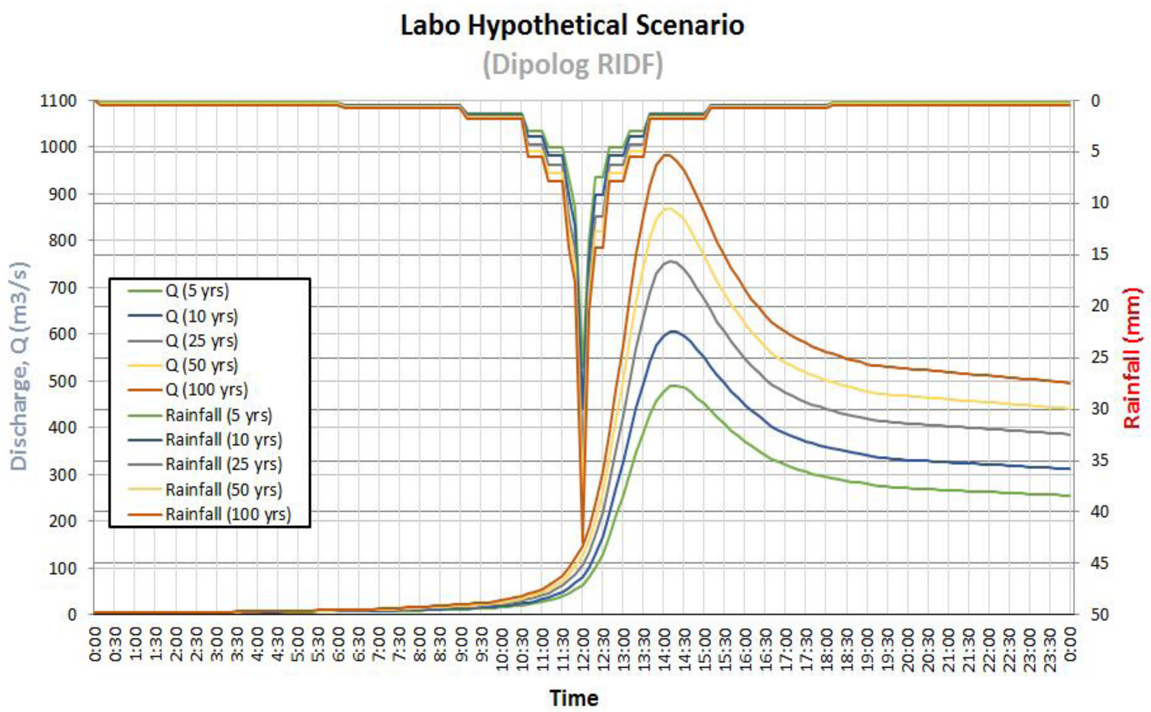


Figure 67. Outflow hydrograph at the Labo Station generated using the Dipolog RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Labo discharge using the Dipolog RIDF curves in five (5) different return periods is given in Table 33.

Table 33. Peak values of the Labo HEC-HMS Model outflow, using the Dipolog RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	178.32	25.9	394.3	15 hours 40 mins
10-Year	206.37	30	494.3	15 hours 30 mins
25-Year	241.91	35.2	583.7	15 hours 40 mins
50-Year	268.14	39	662.7	15 hours 40 mins
100-Year	294.55	42.9	768.1	15 hours 40 mins

5.7.2 Discharge data using Dr. Horritt's prescribed hydrologic method

The river discharges for the two (2) rivers entering the floodplain are illustrated in Figure 68 to Figure 69; and the peak values are summarized in Table 34 to Table 35.

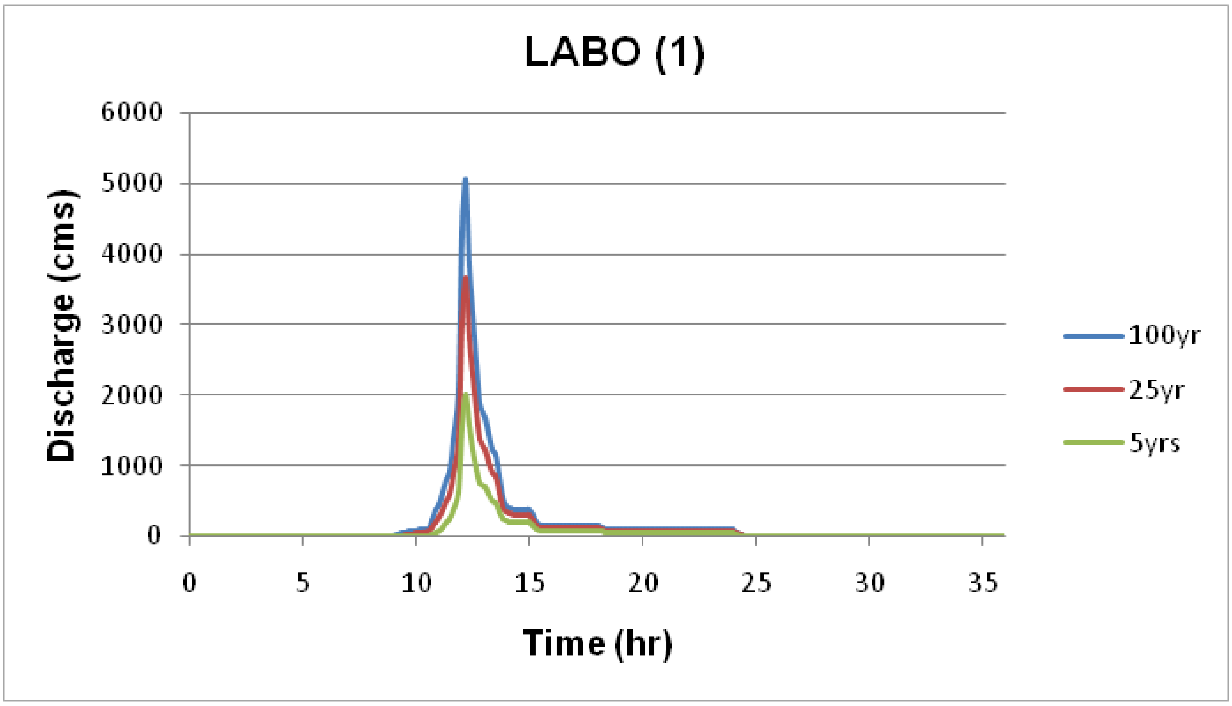


Figure 68. Labo River (1) generated discharge using 5-year, 25-year, and 100-year Dipolog RIDF in HEC-HMS

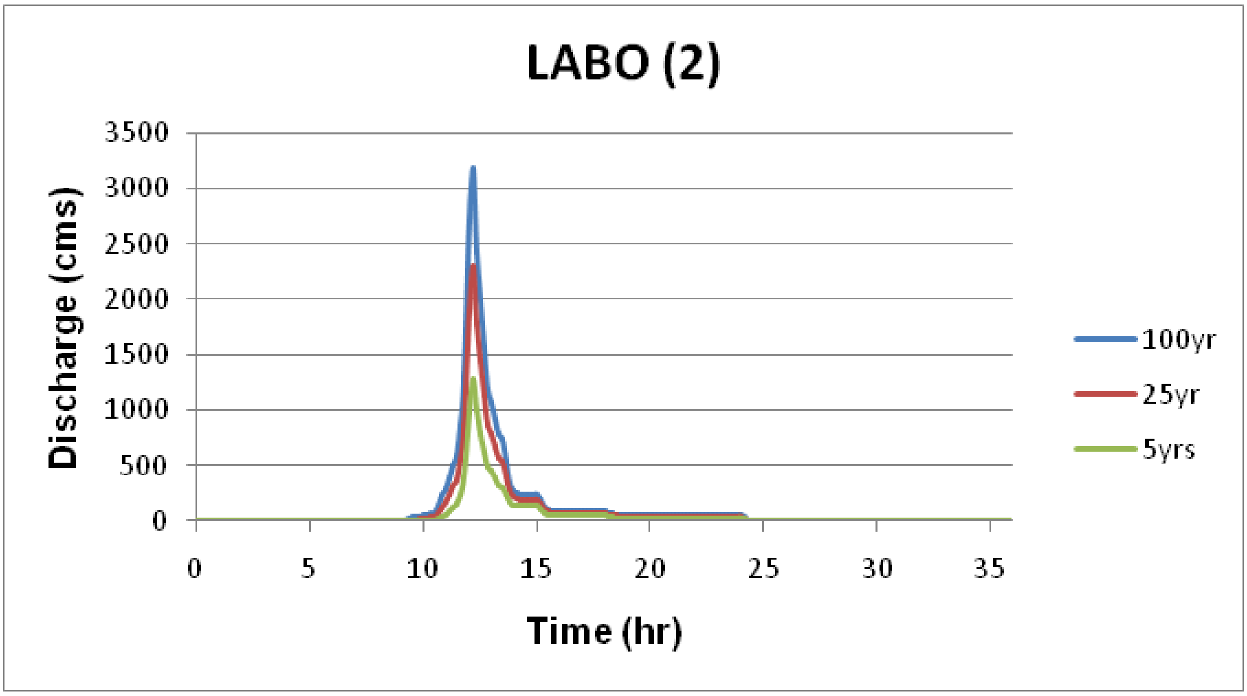


Figure 69. Labo River (2) generated discharge using 5-year, 25-year, and 100-year Dipolog RIDF in HEC-HMS

Table 34. Summary of the Labo River (1) discharge, generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	5046.1	12 hours, 10 minutes
25-Year	3659.1	12 hours, 10 minutes
5-Year	2011.1	12 hours, 10 minutes

Table 35. Summary of the Labo River (2) discharge, generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	3178	12 hours, 10 minutes
25-Year	2304.4	12 hours, 10 minutes
5-Year	1271	12 hours, 10 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is provided in Table 36.

Table 36. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Labo (1)	271.128	224.133	444.630	Pass	Pass
Labo (2)	229.152	189.295	336.073	Pass	Pass

Both values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported by other discharge computation methods; thus, they were appropriate for flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain the actual values of the river discharges to achieve higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. The sample generated map of the Labo River using the calibrated HMS base flow is presented in Figure 70.

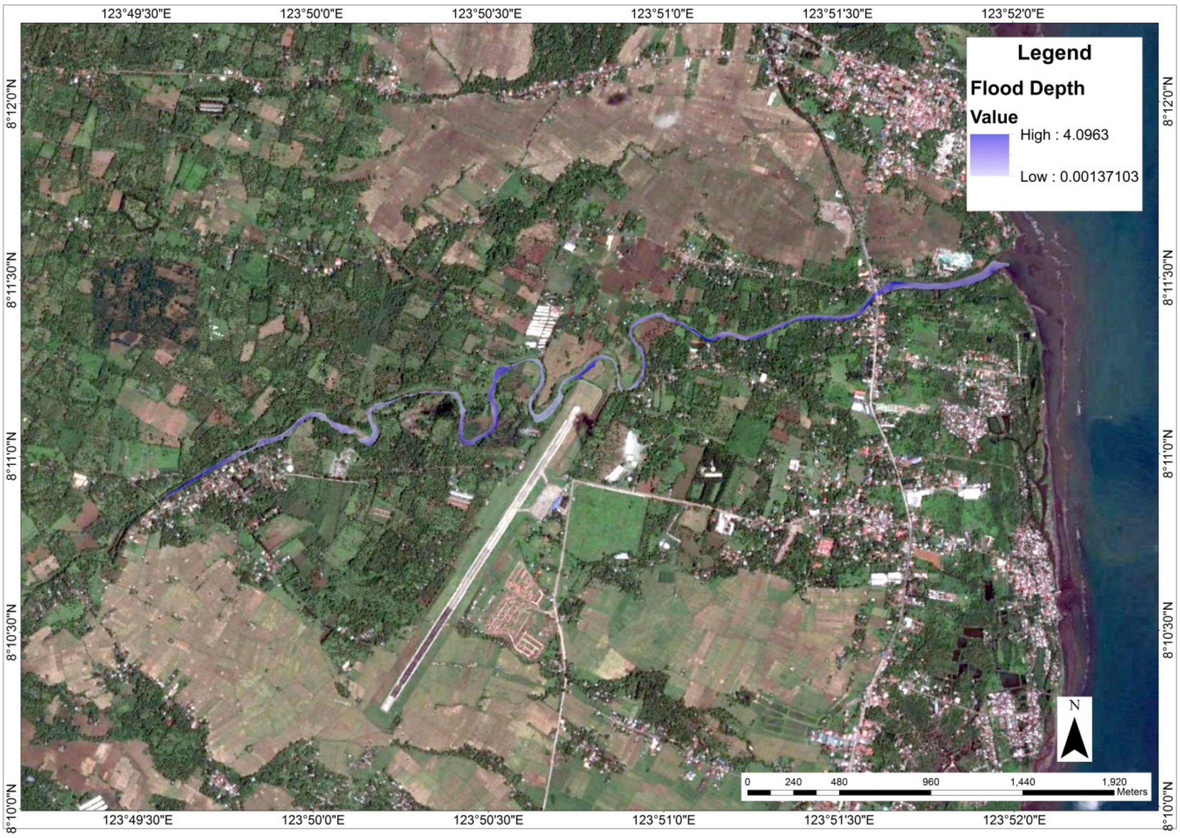


Figure 70. Sample output map of the Labo RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 71 to Figure 76 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Labo floodplain. The floodplain, with an area of 50.22 square kilometers, covers the Municipalities of Clarin, Calabayan City, and Tudela. Table 37 summarizes the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in the Labo floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Clarin	113.99	22.29	20%
Calabayan City	149.437	25.68098	17%
Tudela	108.933	1.983236	2%

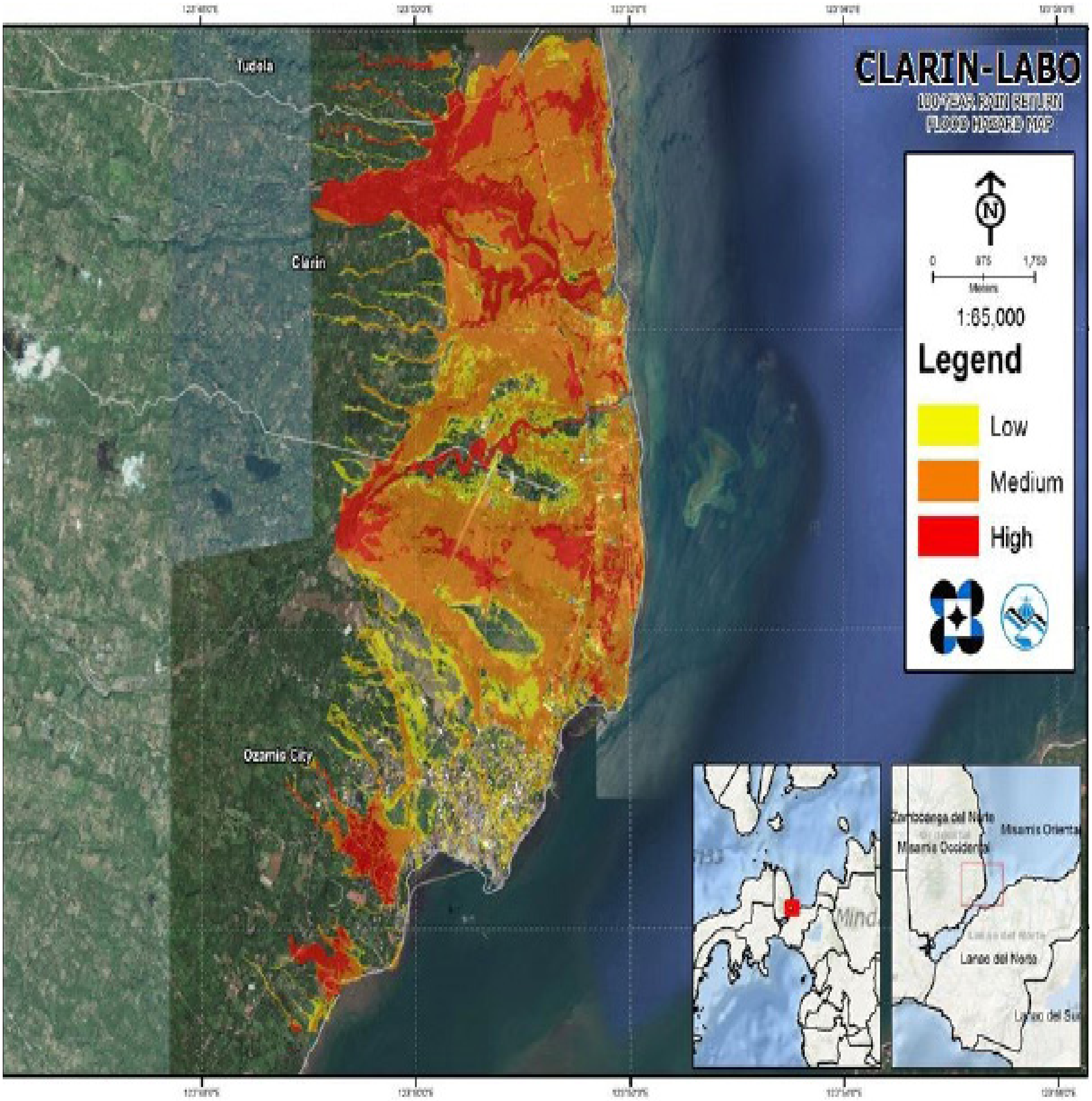


Figure 71. 100-year flood hazard map for the Clarin-Labo floodplain, overlaid on Google Earth imagery

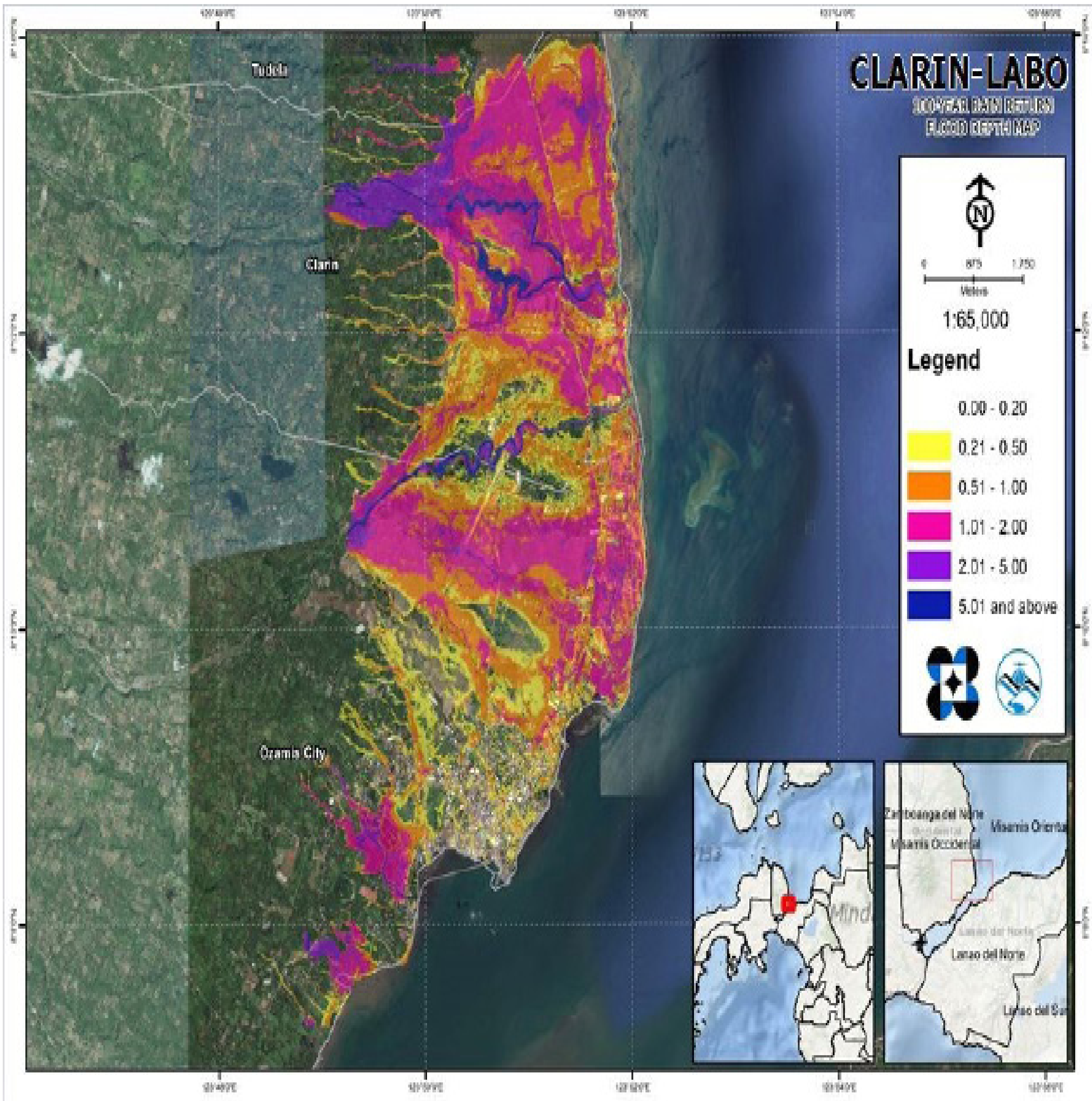


Figure 72. 100-year flow depth map for the Clarin-Labo floodplain, overlaid on Google Earth imagery

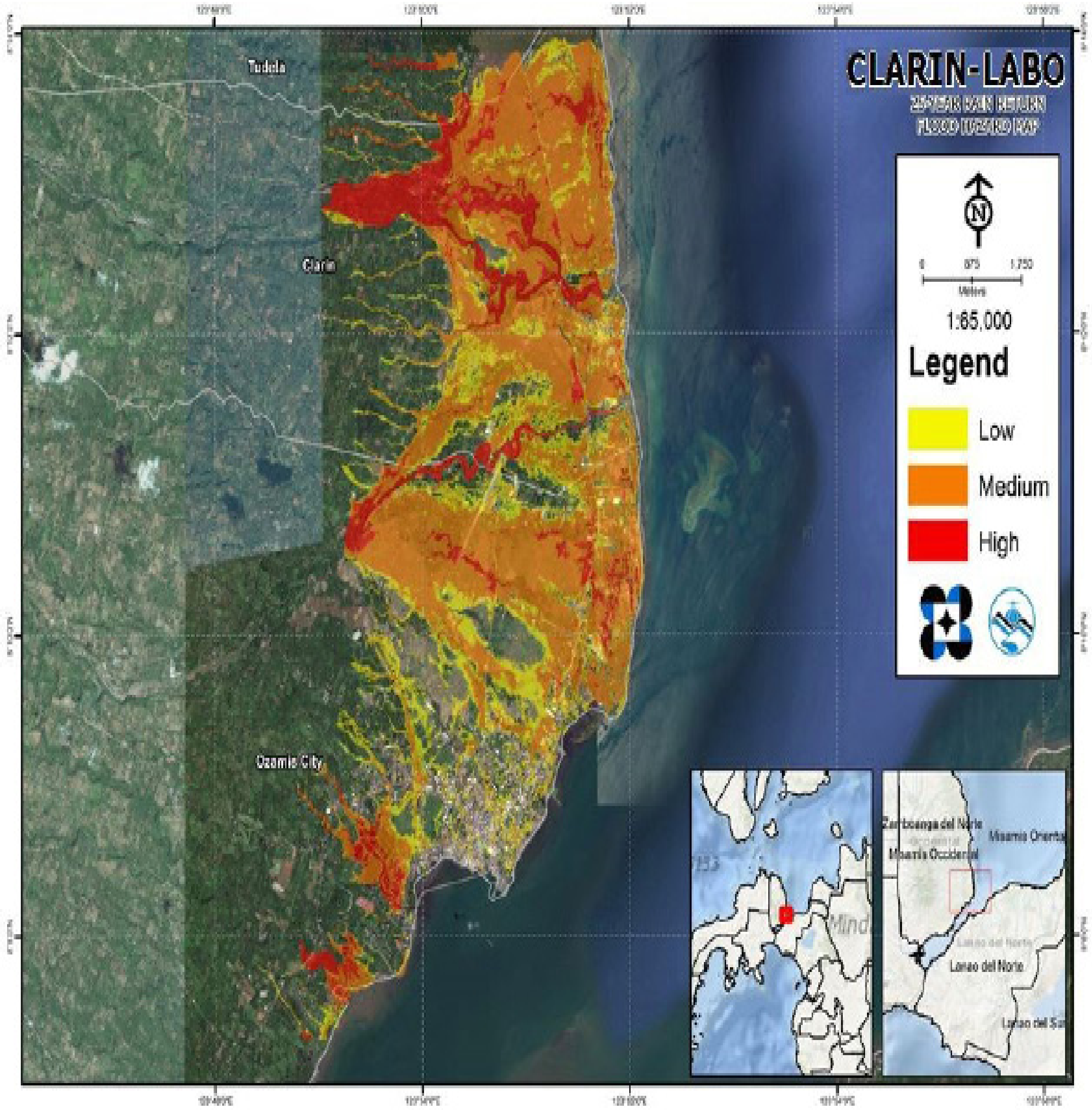


Figure 73. 25-year flood hazard map for the Clarin-Labo floodplain, overlaid on Google Earth imagery

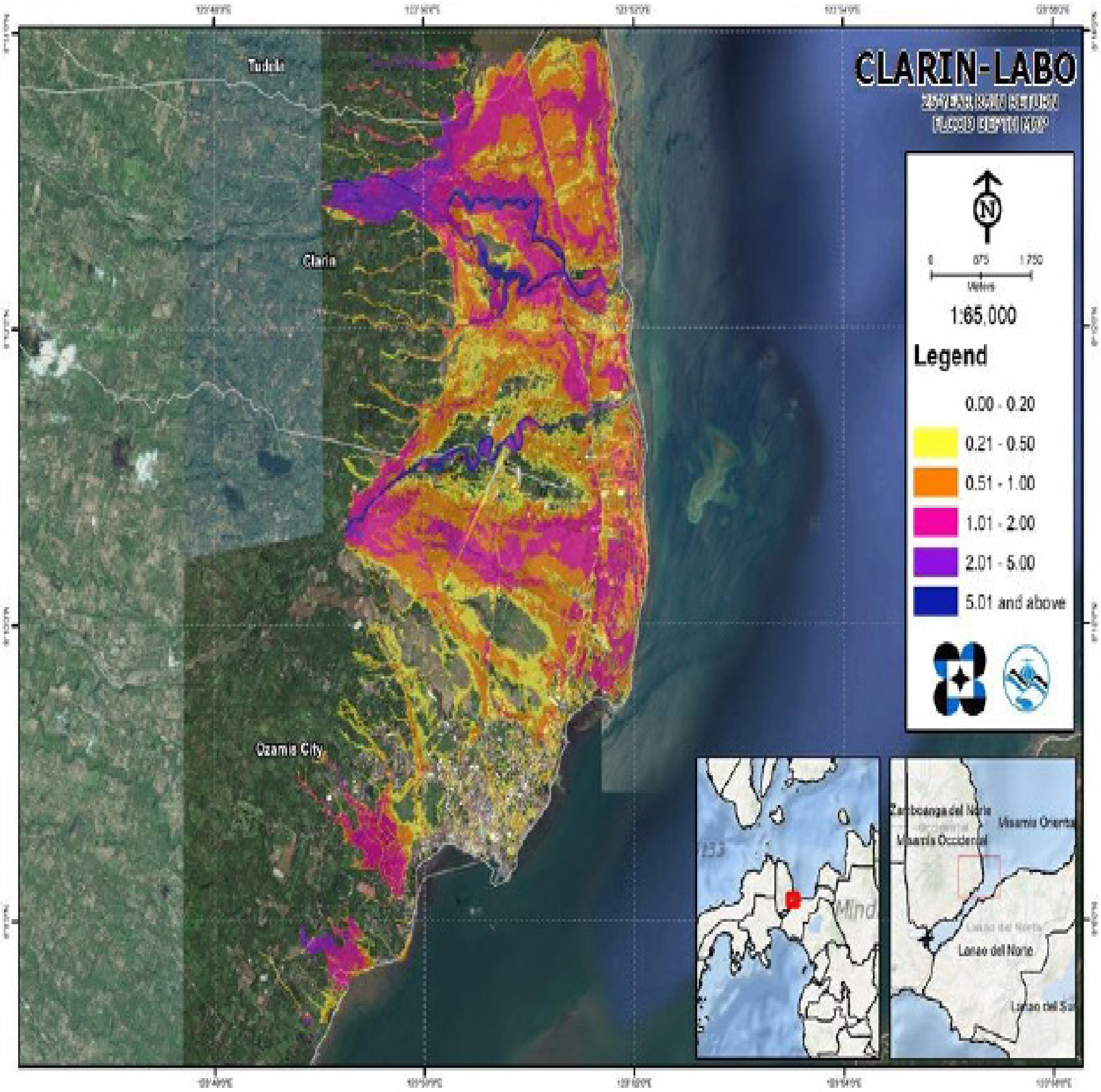


Figure 74. 25-year flow depth map for the Clarin-Labo floodplain, overlaid on Google Earth imagery

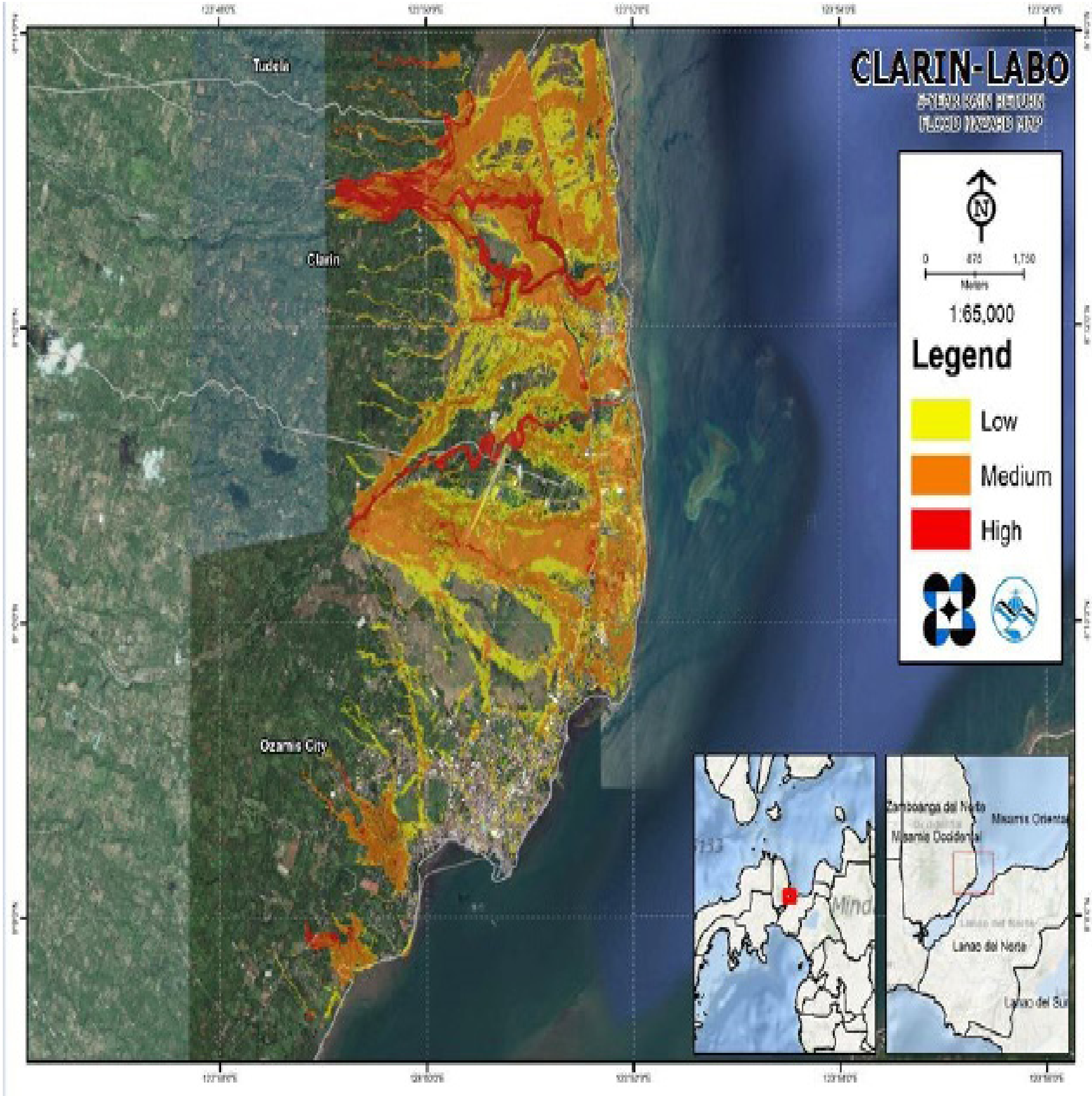


Figure 75. 5-year flood hazard map for the Clarin-Labo floodplain, overlaid on Google Earth imagery

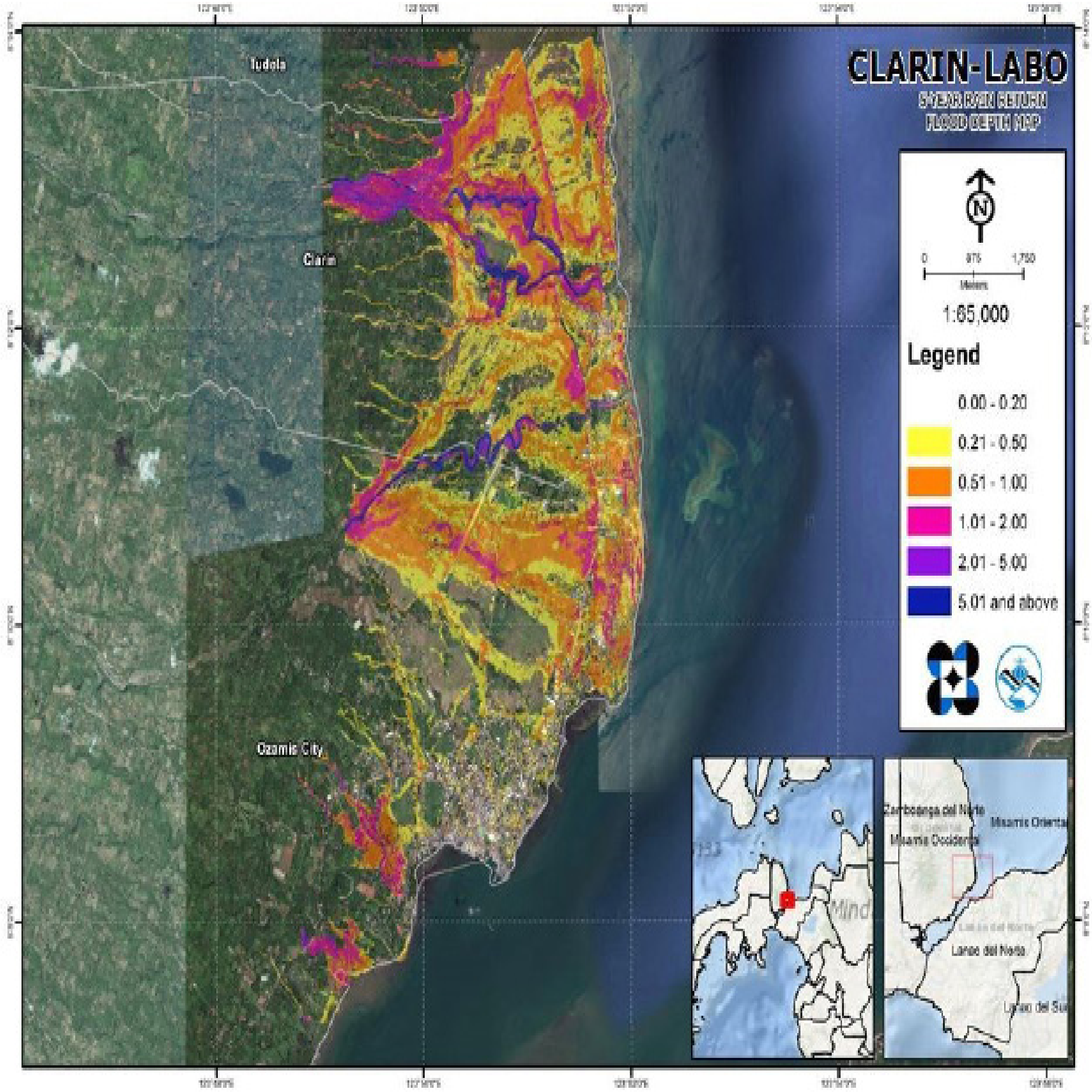


Figure 76. 5-year flow depth map for the Clarin-Labo floodplain overlaid, on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

The affected barangays in the Labo River Basin, grouped by municipality, are listed below. For the said basin, three (3) municipalities consisting of forty-nine (49) barangays are expected to experience flooding when subjected to 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 7.64% of the Municipality of Clarin, with an area of 113.99 square kilometers, will experience flood levels of less than 0.20 meters. 4.35% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.33%, 2.12%, 0.81%, and 0.30% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Clarin, Misamis Occidental during a 5-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Clarin									
		Canibungan Daku	Canipacan	Dela Paz	Dolores	Gata Daku	Gata Diot	Kinangay Norte	Kinangay Sur	Lapasan	Lupagan
Affected Area (sq. km.)	0.03-0.20	0.21	0.24	0.32	0.87	0.42	0.25	1.41	1.93	0.34	0.16
	0.21-0.50	0.008	0.17	0.22	0.054	0.68	0.26	0.4	0.61	0.26	0.36
	0.51-1.00	0.0036	0.17	0.12	0.076	0.49	0.19	0.14	0.35	0.45	0.34
	1.01-2.00	0.0059	0.079	0.013	0.21	0.034	0.024	0.018	0.04	0.14	0.2
	2.01-5.00	0.0012	0.081	0	0.036	0.013	0.036	0.0089	0.047	0.024	0
	> 5.00	0	0.039	0	0.0002	0.012	0.03	0	0.046	0.0059	0

CLARIN-LABO BASIN		Affected Barangays in Clarin									
		Masabud	Mialen	Pan-Ay	Poblacion I	Poblacion II	Poblacion III	Poblacion IV	Segatic Daku	Segatic Diot	Tinacla-An
Affected Area (sq. km.)	0.03-0.20	0.23	0.2	0.25	0.099	0.091	0.2	0.039	1.23	0.085	0.14
	0.21-0.50	0.2	0.54	0.67	0.12	0.066	0.088	0.062	0.055	0.023	0.12
	0.51-1.00	0.41	0.5	1.05	0.091	0.047	0.11	0.17	0.047	0.055	0.11
	1.01-2.00	0.26	0.11	0.53	0.053	0.012	0.083	0.095	0.1	0.37	0.037
	2.01-5.00	0.19	0.00052	0.046	0	0	0.04	0.051	0.066	0.26	0.023
	> 5.00	0.13	0	0.0036	0	0	0.0066	0.057	0	0.017	0.0014

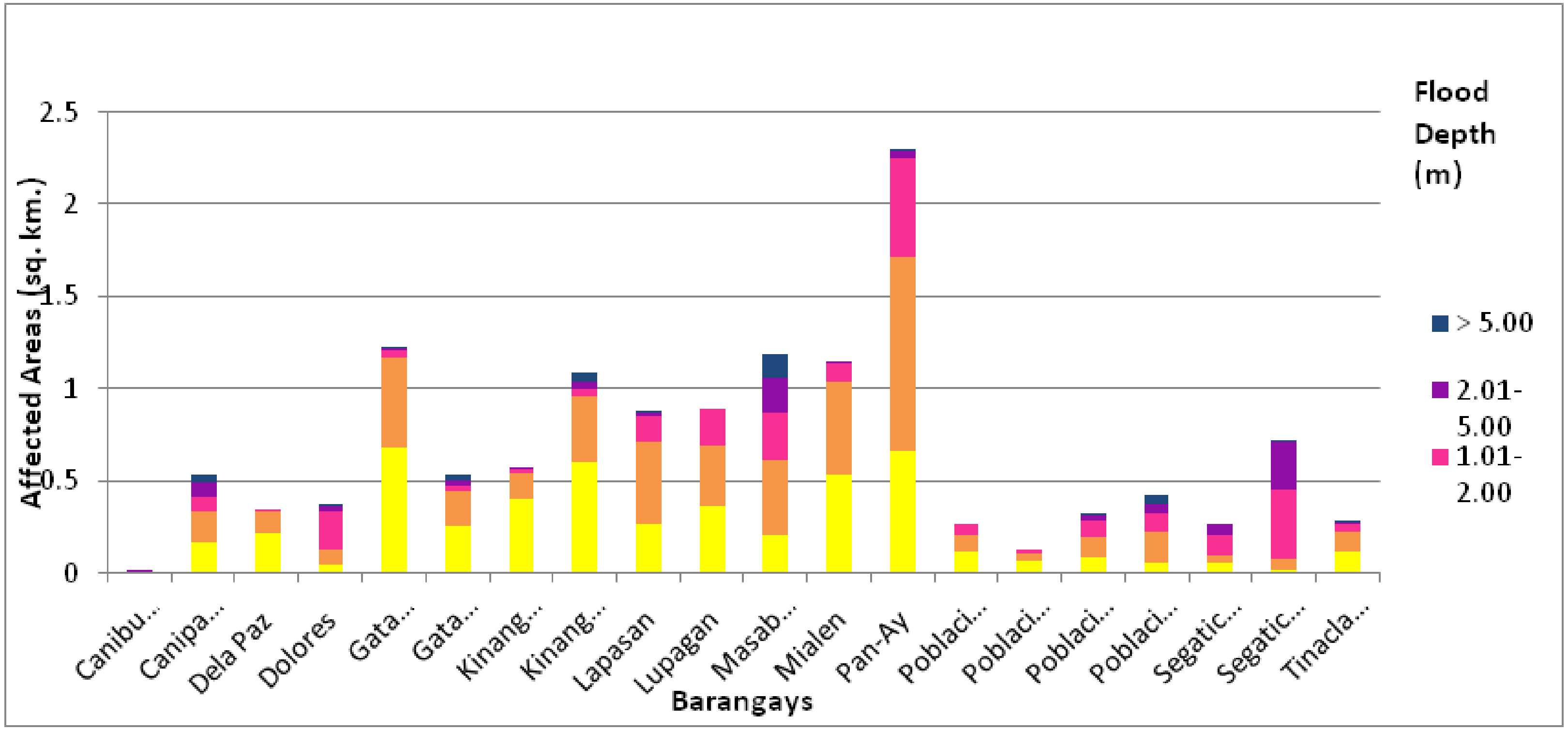


Figure 77. Affected areas in Clarin, Misamis Occidental during a 5-year rainfall return period

For the City of Calabayan, with an area of 149.44 square kilometers, 9.58% will experience flood levels of less than 0.20 meters. 3.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.25%, 1.07%, 0.10%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Calabayan City, Misamis Occidental during a 5-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Calabayan City												
		50th District	Aguada	Bacolod	Bagakay	Banadero	Baybay San Roque	Baybay Santa Cruz	Baybay Triunfo	Bong-bong	Carangan	Carmen	Catadman-Mana-bay	Doña Consuelo
Affected Area (sq. km.)	0.03-0.20	0.15	0.12	2.6	0.58	1	0.53	0.19	0.17	0.000002	2.13	0.28	0.22	0.19
	0.21-0.50	0.018	0.024	0.9	0.026	0.11	0.047	0.023	0.028	0.000025	0.37	0.056	0.048	0.11
	0.51-1.00	0.0022	0.00022	0.65	0.026	0.012	0.0023	0.002	0.00092	0	0.074	0.0085	0.0066	0.19
	1.01-2.00	0	0	0.089	0.043	0.0015	0	0	0	0.0001	0.0052	0.0005	0.0001	0.045
	2.01-5.00	0	0	0.0038	0.014	0	0	0	0	0.0002	0.00042	0	0	0
	> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

CLARIN-LABO BASIN		Affected Barangays in Calabayan City											
		Embargo	Gango	Gotokan Diot	Labo	Lam-An	Malaubang	Maning-col	Menter-ing	Molicay	Pulot	San Antonio	Tinago
Affected Area (sq. km.)	0.03-0.20	0.29	0.28	0.00013	0.99	0.37	1.27	0.7	0.00015	0.61	0.86	0.18	0.61
	0.21-0.50	0.078	0.37	0.0002	0.7	0.06	0.11	0.46	0.00088	0.52	0.084	0.26	0.23
	0.51-1.00	0.11	0.6	0.000041	1.09	0.0097	0.24	0.45	0.000013	0.6	0.08	0.47	0.22
	1.01-2.00	0.17	0.2	0	0.13	0.0001	0.21	0.062	0	0.12	0.075	0.28	0.16
	2.01-5.00	0.042	0	0	0.051	0	0.014	0.0005	0	0.0015	0.028	0	0
	> 5.00	0.035	0	0	0.084	0	0	0	0	0	0.00056	0	0

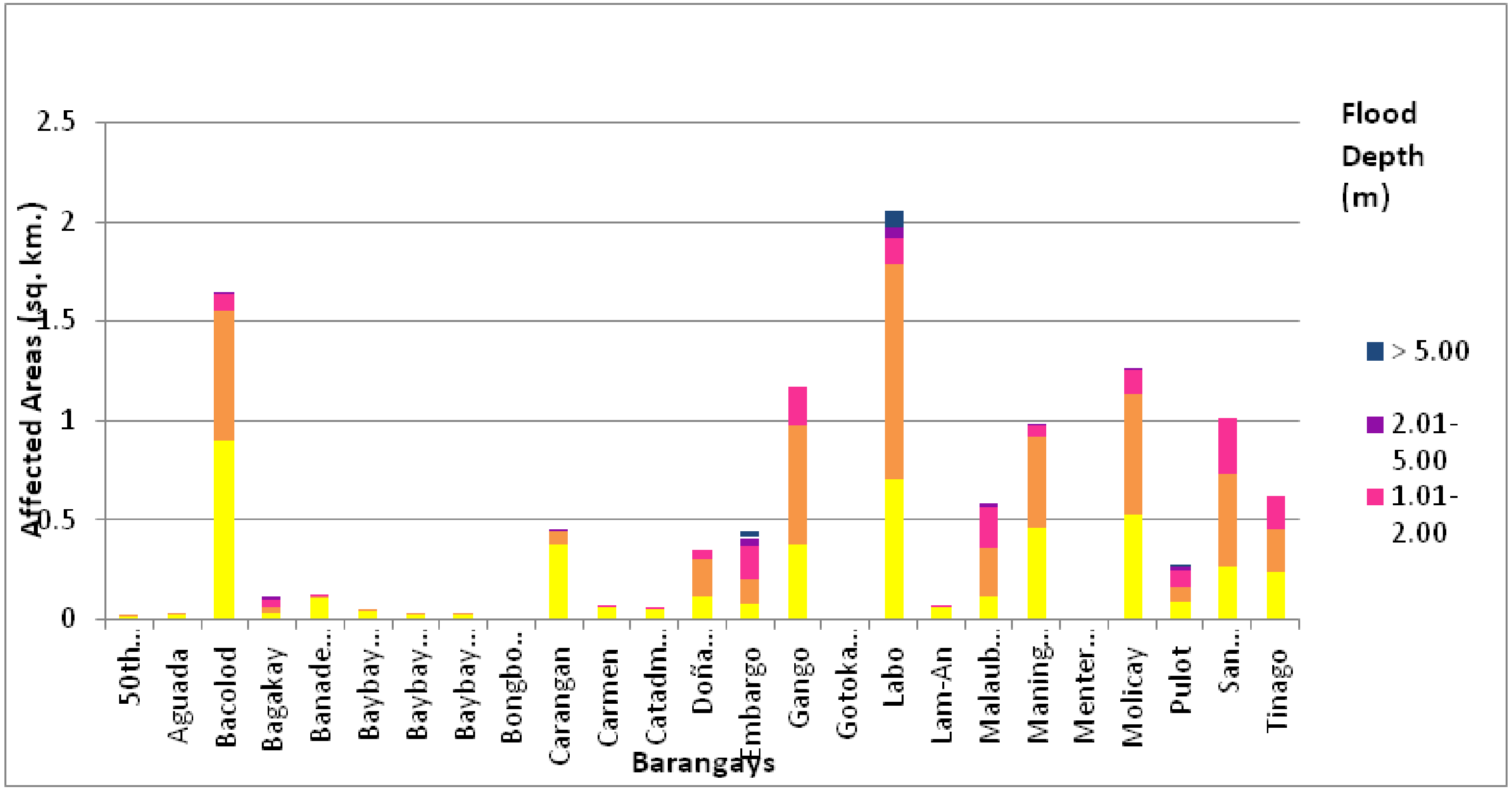


Figure 78. Affected areas in Calabayan City, Misamis Occidental during a 5-year rainfall return period

For the Municipality of Tudela, with an area of 108.933 square kilometers, 1.35% will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.21%, 0.12%, and 0.03% 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 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Tudela, Misamis Occidental during a 5-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Tudela			
		Canibungan Proper	Locso-On	Pan-Ay Diot	Yahong
Affected Area (sq. km.)	0.03-0.20	0.084	0.49	0.11	0.78
	0.21-0.50	0.00069	0.03	0.077	0.024
	0.51-1.00	0.0018	0.078	0.11	0.04
	1.01-2.00	0.0022	0.076	0.02	0.034
	2.01-5.00	0	0.023	0	0.0054
	> 5.00	0	0	0	0

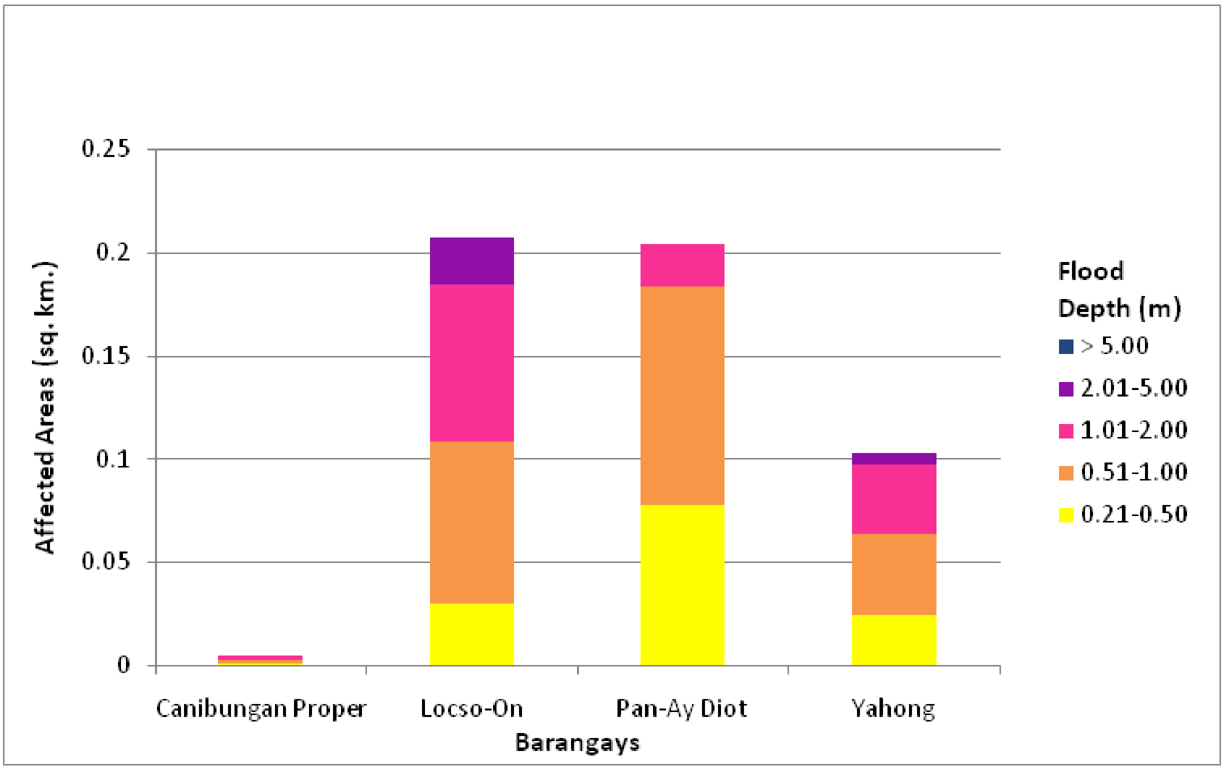


Figure 79. Affected areas in Tudela, Misamis Occidental during a 5-year rainfall return period

For the 25-year return period, 5.58% of the Municipality of Clarin, with an area of 113.99 square kilometers, will experience flood levels of less than 0.20 meters. 2.79% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.44%, 3.96%, 1.41%, and 0.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Clarin, Misamis Occidental during a 25-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Clarin									
		Canibungan Daku	Canipacan	Dela Paz	Dolores	Gata Daku	Gata Diot	Kinangay Norte	Kinangay Sur	Lapasan	Lupagan
Affected Area (sq. km.)	0.03-0.20	0.2	0.14	0.075	0.82	0.17	0.22	1.24	1.6	0.25	0.014
	0.21-0.50	0.011	0.1	0.19	0.055	0.47	0.26	0.36	0.54	0.23	0.089
	0.51-1.00	0.0028	0.22	0.3	0.049	0.74	0.22	0.31	0.68	0.47	0.46
	1.01-2.00	0.0063	0.17	0.099	0.16	0.25	0.025	0.06	0.11	0.24	0.48
	2.01-5.00	0.0028	0.083	0	0.16	0.014	0.036	0.011	0.049	0.027	0.022
	> 5.00	0	0.06	0	0.0006	0.013	0.03	0.0001	0.048	0.0067	0

CLARIN-LABO BASIN		Affected Barangays in Clarin									
		Masabud	Mialen	Pan-Ay	Poblacion I	Poblacion II	Poblacion III	Poblacion IV	Segatic Daku	Segatic Diot	Tinacla-An
Affected Area (sq. km.)	0.03-0.20	0.088	0.035	0.015	0.016	0.015	0.11	0.022	1.18	0.048	0.1
	0.21-0.50	0.099	0.19	0.18	0.079	0.05	0.086	0.016	0.066	0.03	0.067
	0.51-1.00	0.33	0.78	0.95	0.15	0.11	0.13	0.092	0.05	0.02	0.15
	1.01-2.00	0.53	0.33	1.28	0.12	0.04	0.14	0.21	0.065	0.12	0.082
	2.01-5.00	0.23	0.006	0.12	0	0	0.053	0.067	0.14	0.56	0.032
	> 5.00	0.15	0	0.0054	0	0	0.0079	0	0	0	0

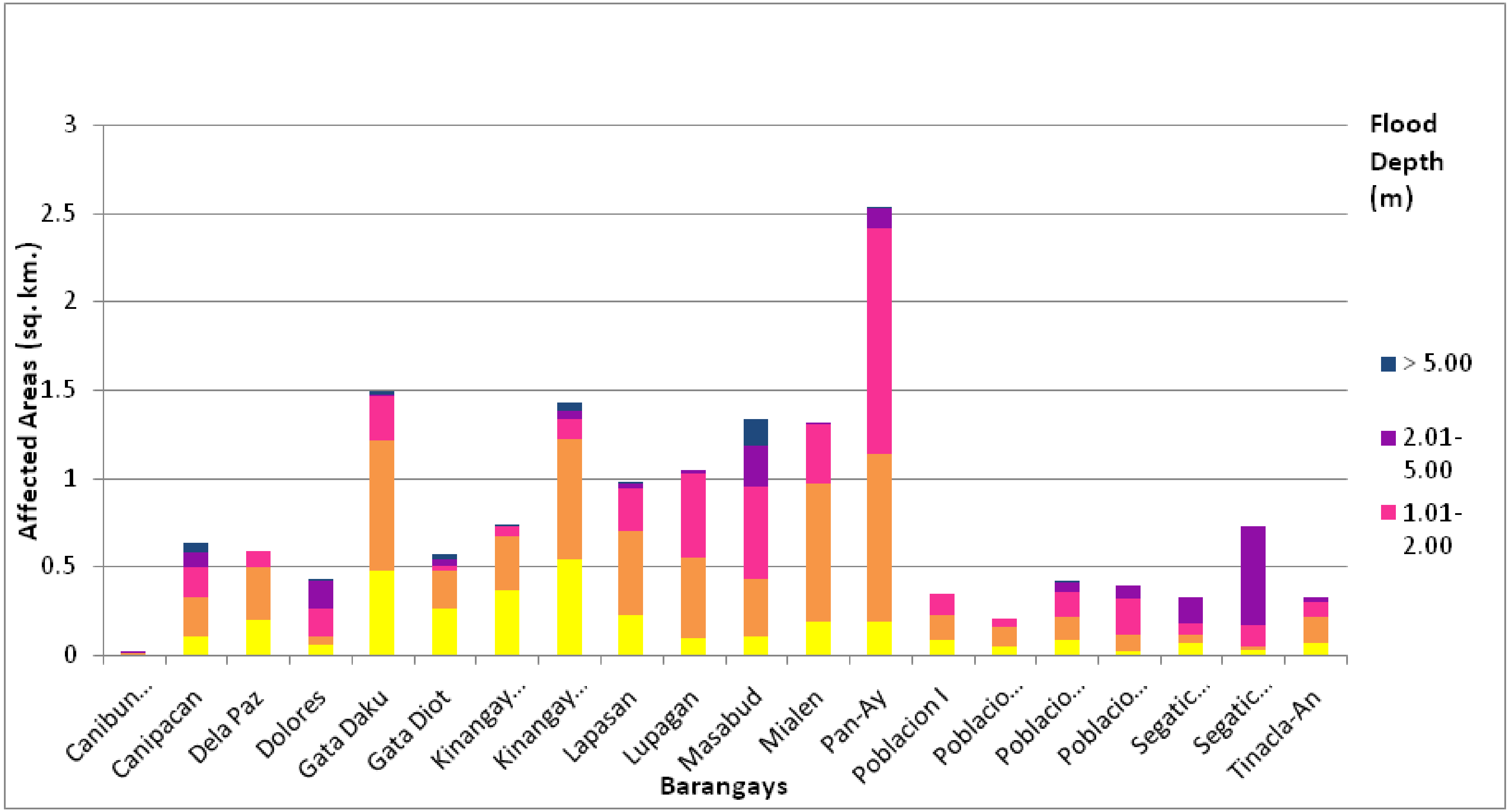


Figure 80. Affected areas in Clarin, Misamis Occidental during a 25-year rainfall return period

For the City of Calabayan, with an area of 149.44 square kilometers, 7.36% will experience flood levels of less than 0.20 meters. 3.00% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.64%, 2.88%, and 0.22% 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 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in Calabayan City, Misamis Occidental during a 25-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Calabayan City												
		50th District	Aguada	Bacolod	Bagakay	Banadero	Baybay San Roque	Baybay Santa Cruz	Baybay Triunfo	Bongbong	Carangan	Carmen	Catad-man-Manabay	Doña Con-suelo
Affected Area (sq. km.)	0.03-0.20	0.14	0.099	1.82	0.56	0.94	0.47	0.18	0.15	0	1.78	0.21	0.18	0.11
	0.21-0.50	0.025	0.042	0.96	0.031	0.14	0.1	0.035	0.049	0	0.62	0.11	0.079	0.081
	0.51-1.00	0.0044	0.0026	0.99	0.025	0.034	0.0054	0.0039	0.0029	0.000025	0.17	0.018	0.021	0.15
	1.01-2.00	0.0001	0	0.46	0.039	0.0036	0.0001	0	0	0.000002	0.014	0.0011	0.0007	0.2
	2.01-5.00	0	0	0.0096	0.032	0.00027	0	0	0	0.00031	0.00042	0	0	0
	> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

CLARIN-LABO BASIN		Affected Barangays in Calabayan City											
		Embargo	Gango	Gotokan Diot	Labo	Lam-An	Malau-bang	Maning-col	Menter-ing	Molicay	Pulot	San Anto-nio	Tinago
Affected Area (sq. km.)	0.03-0.20	0.23	0.12	0	0.6	0.33	1.2	0.29	0	0.32	0.8	0.062	0.42
	0.21-0.50	0.078	0.23	0	0.49	0.086	0.078	0.51	0.000003	0.3	0.1	0.095	0.22
	0.51-1.00	0.072	0.6	0.00013	1.05	0.018	0.15	0.64	0.00015	0.77	0.055	0.41	0.24
	1.01-2.00	0.25	0.49	0.00024	0.74	0.00051	0.35	0.23	0.00089	0.46	0.12	0.6	0.34
	2.01-5.00	0.068	0.0004	0	0.065	0	0.069	0.002	0	0.016	0.05	0.015	0.0022
	> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

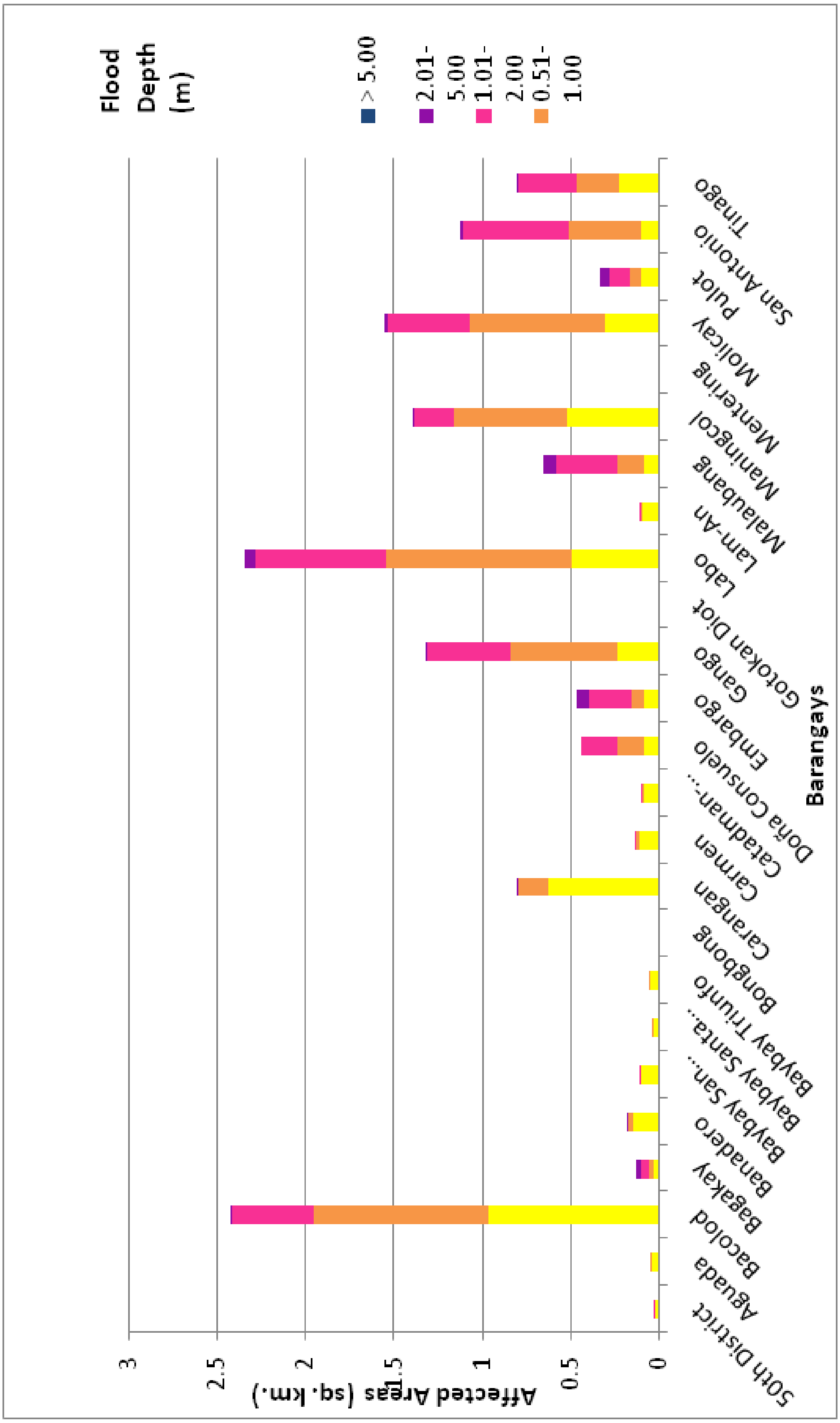


Figure 81. Affected areas in Calabayan City, Misamis Occidental during a 25-year rainfall return period

For the Municipality of Tudela, with an area of 108.933 square kilometers, 1.25% will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.19%, 0.20%, and 0.06% 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 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Tudela, Misamis Occidental during a 25-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Tudela			
		Canibungan Proper	Locso-On	Pan-Ay Diot	Yahong
Affected Area (sq. km.)	0.03-0.20	0.084	0.47	0.044	0.77
	0.21-0.50	0.0009	0.029	0.065	0.029
	0.51-1.00	0.0013	0.048	0.12	0.032
	1.01-2.00	0.0032	0.089	0.081	0.049
	2.01-5.00	0	0.059	0	0.012
	> 5.00	0	0	0	0

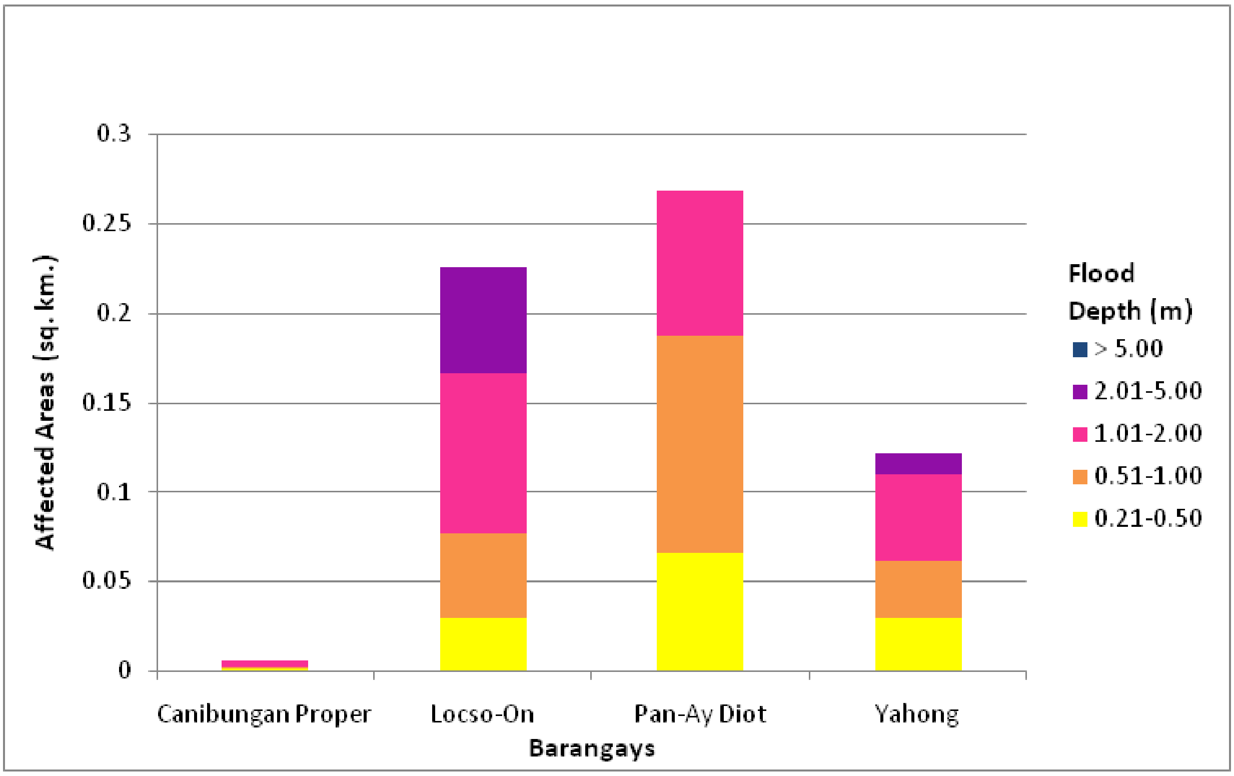


Figure 82. Affected areas in Tudela, Misamis Occidental during a 25-year rainfall return period

For the 100-Year return period, 5.04% of the Municipality of Clarin, with an area of 113.99 square kilometers, will experience flood levels of less than 0.20 meters. 2.02% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.67%, 5.42%, 1.95%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Clarin, Misamis Occidental during a 100-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Clarin									
		Canibungan Daku	Canipacan	Dela Paz	Dolores	Gata Daku	Gata Diot	Kinangay Norte	Kinangay Sur	Lapasan	Lupagan
Affected Area (sq. km.)	0.03-0.20	0.2	0.091	0.033	0.79	0.12	0.23	1.18	1.47	0.23	0.0056
	0.21-0.50	0.012	0.051	0.11	0.058	0.35	0.26	0.28	0.51	0.21	0.027
	0.51-1.00	0.0027	0.17	0.31	0.039	0.67	0.21	0.38	0.75	0.43	0.28
	1.01-2.00	0.006	0.29	0.2	0.12	0.48	0.024	0.12	0.19	0.31	0.63
	2.01-5.00	0.0045	0.094	0.0047	0.24	0.014	0.036	0.013	0.051	0.031	0.12
	> 5.00	0	0.077	0	0.002	0.013	0.03	0.0002	0.048	0	0

CLARIN-LABO BASIN		Affected Barangays in Clarin									
		Masabud	Mialen	Pan-Ay	Poblacion I	Poblacion II	Poblacion III	Poblacion IV	Segatic Daku	Segatic Diot	Tinacla-An
Affected Area (sq. km.)	0.03-0.20	0.027	0.017	0.0042	0.0042	0.0073	0.056	0.009	1.14	0.04	0.083
	0.21-0.50	0.036	0.072	0.039	0.032	0.021	0.097	0.017	0.059	0.0024	0.042
	0.51-1.00	0.22	0.66	0.55	0.15	0.11	0.12	0.047	0.063	0.032	0.12
	1.01-2.00	0.68	0.58	1.63	0.17	0.074	0.18	0.25	0.064	0.035	0.14
	2.01-5.00	0.29	0.017	0.32	0.0012	0.0002	0.069	0.084	0.17	0.63	0.042
	> 5.00	0	0	0	0	0	0	0	0	0	0

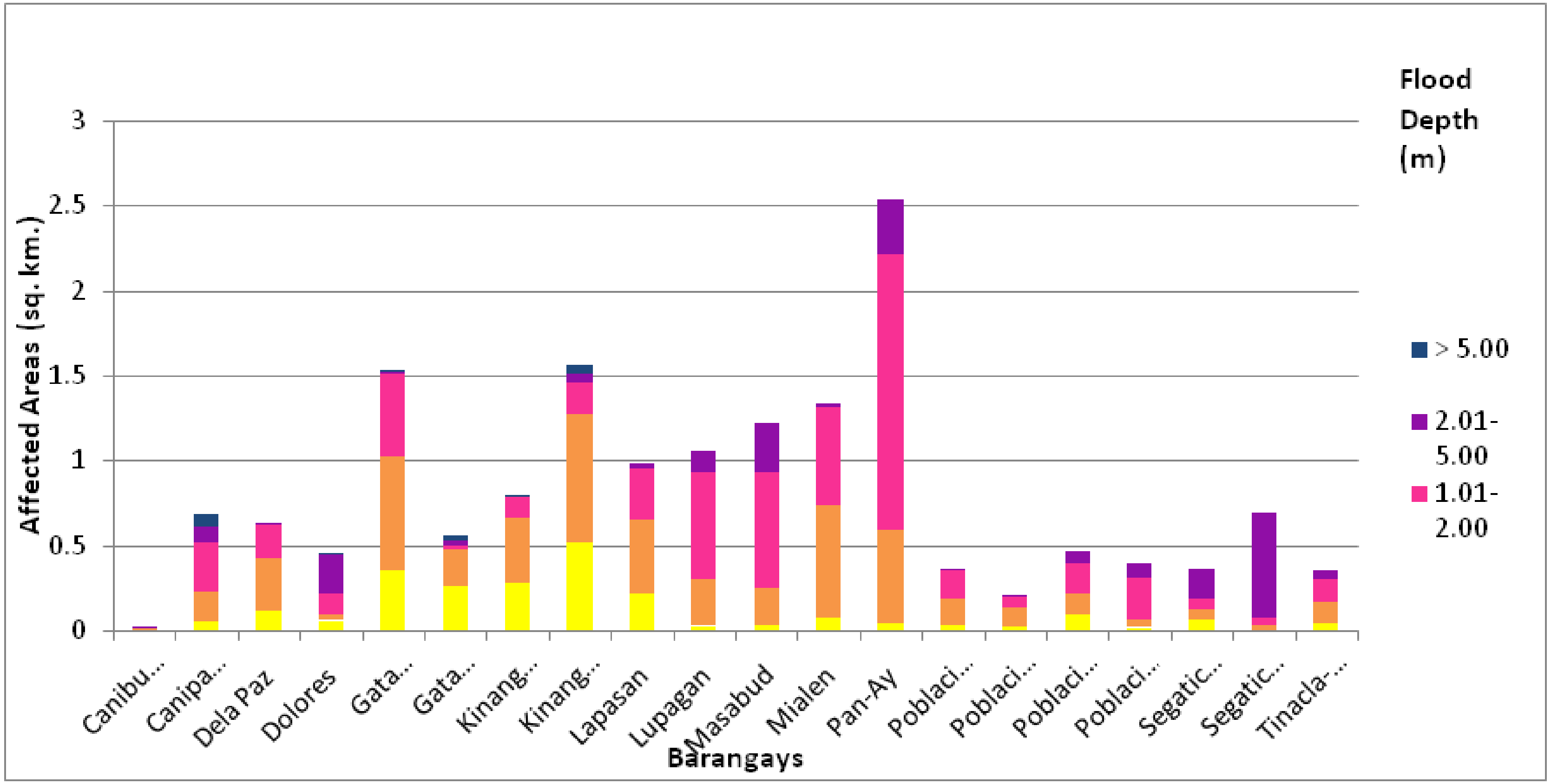


Figure 83. Affected areas in Clarin, Misamis Occidental during a 100-year rainfall return period

For the City of Calabayan, with an area of 149.44 square kilometers, 6.20% will experience flood levels of less than 0.20 meters. 2.92% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.44%, 4.03%, and 0.50% 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 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Calabayan City, Misamis Occidental during a 100-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Calabayan City												
		50th District	Aguada	Bacolod	Bagakay	Banadero	Baybay San Roque	Baybay Santa Cruz	Baybay Triunfo	Bongbong	Carangan	Carmen	Catad-man-Manabay	Doña Consuelo
Affected Area (sq. km.)	0.03-0.20	0.14	0.086	1.38	0.55	0.9	0.4	0.17	0.13	0	1.49	0.18	0.14	0.063
	0.21-0.50	0.03	0.051	0.91	0.035	0.16	0.16	0.044	0.061	0	0.83	0.14	0.097	0.078
	0.51-1.00	0.0063	0.0063	1.2	0.025	0.053	0.012	0.0054	0.0069	0	0.24	0.028	0.04	0.12
	1.01-2.00	0.0001	0	0.73	0.039	0.0056	0.00029	0	0	0.000027	0.024	0.0016	0.0012	0.28
	2.01-5.00	0	0	0.019	0.041	0.00047	0	0	0	0.00031	0.00052	0	0	0.0028
	> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

CLARIN-LABO BASIN		Affected Barangays in Calabayan City											
		Embargo	Gango	Gotokan Diot	Labo	Lam-An	Malaubang	Maningcol	Mentering	Molicay	Pulot	San Antonio	Tinago
Affected Area (sq. km.)	0.03-0.20	0.21	0.075	0	0.44	0.31	1.17	0.12	0	0.19	0.77	0.029	0.35
	0.21-0.50	0.077	0.17	0	0.41	0.11	0.07	0.41	0	0.19	0.11	0.062	0.16
	0.51-1.00	0.061	0.54	0	0.79	0.023	0.11	0.68	0.000003	0.62	0.061	0.26	0.25
	1.01-2.00	0.22	0.65	0.00033	1.22	0.0012	0.35	0.46	0.001	0.8	0.11	0.74	0.38
	2.01-5.00	0.13	0.0083	0.000041	0.087	0	0.15	0.0071	0.000013	0.06	0.077	0.089	0.084
	> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

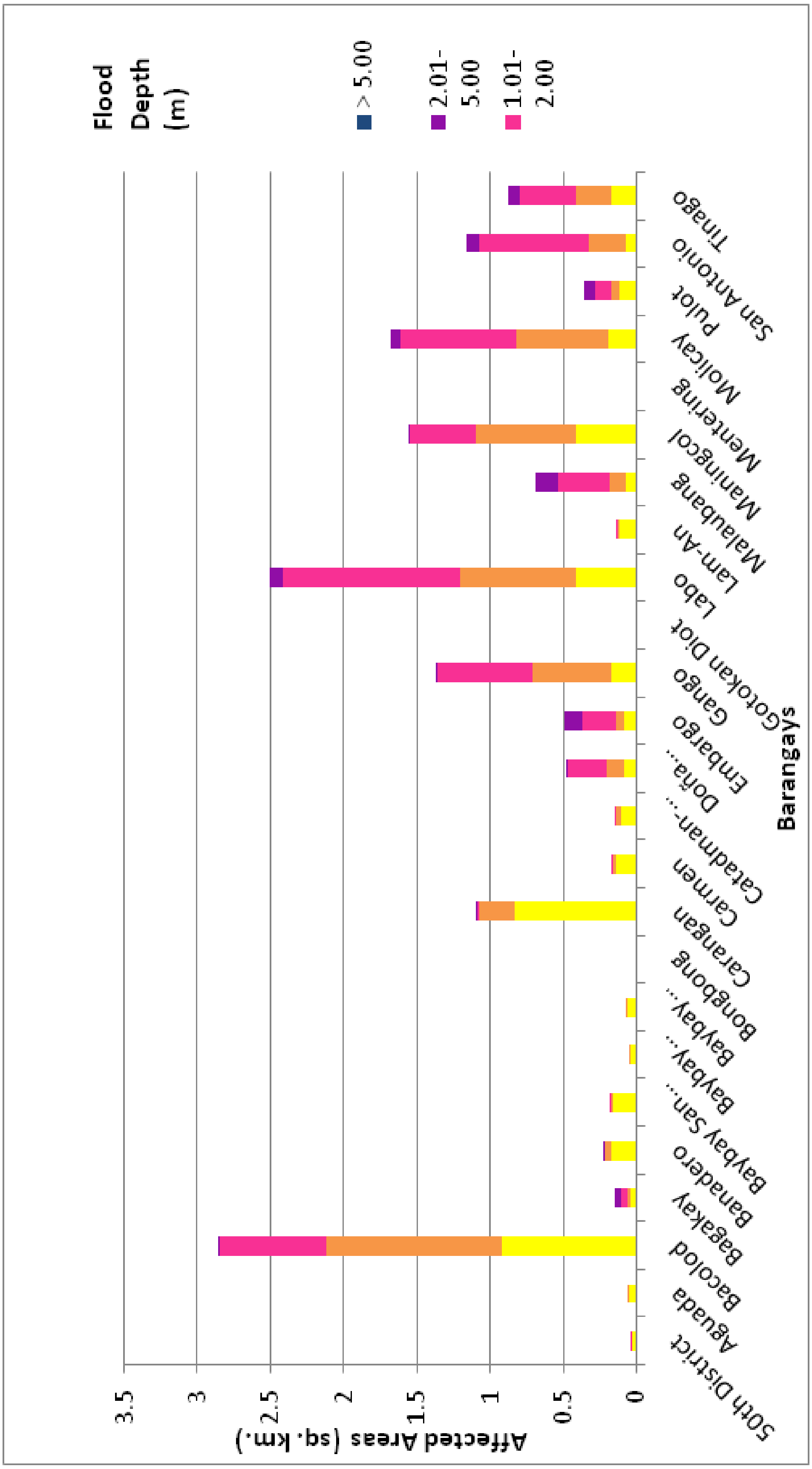


Figure 84. Affected areas in Calabayan City, Misamis Occidental during a 100-year rainfall return period

For the Municipality of Tudela, with an area of 108.933 square kilometers, 1.21% will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.15%, 0.28%, and 0.08% 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 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Tudela, Misamis Occidental during a 100-year rainfall return period

CLARIN-LABO BASIN		Affected Barangays in Tudela			
		Canibungan Proper	Locso-On	Pan-Ay Diot	Yahong
Affected Area (sq. km.)	0.03-0.20	0.083	0.46	0.025	0.75
	0.21-0.50	0.0011	0.029	0.047	0.03
	0.51-1.00	0.0012	0.034	0.096	0.031
	1.01-2.00	0.0038	0.098	0.14	0.057
	2.01-5.00	0	0.069	0.0001	0.017
	> 5.00	0	0	0	0

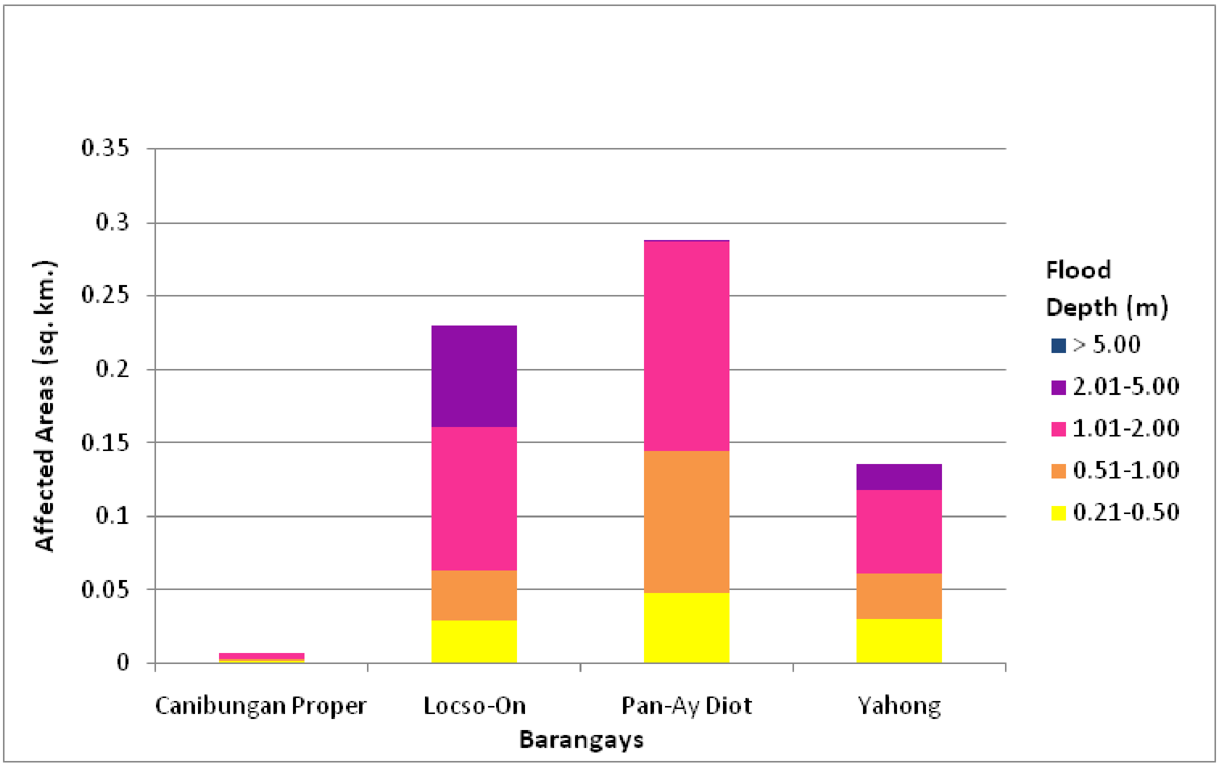


Figure 85. Affected areas in Tudela, Misamis Occidental during a 100-year rainfall return period

Among the barangays in the Municipality of Clarin, Kinangay Sur is projected to have the highest percentage of area that will experience flood levels, at 2.65%. Meanwhile, Pan-ay posted the second highest percentage of area that may be affected by flood depths, at 2.23%.

Among the barangays in the City of Calabayan, Bacolod is projected to have the highest percentage of area that will experience flood levels, at 2.84%. Meanwhile, Labo posted the second highest percentage of area that may be affected by flood depths, at 1.97%.

Among the barangays in the Municipality of Tudela, Yahong is projected to have the highest percentage of area that will experience flood levels, at 0.81%. Meanwhile, Locso-on posted the percentage of area that may be affected by flood depths, at 0.63%.

The generated flood hazard maps for the Labo floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood hazard maps – "Low", "Medium", and "High" – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year).

Table 47. 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	9.76	7.80	6.80
Medium	13.22	18.48	19.04
High	2.58	5.05	7.91

Of the one hundred and fourteen (114) identified educational institutions in the Labo floodplain, twenty-one (21) were assessed to be exposed to Low-level flooding during a 5-year rainfall scenario. Meanwhile, thirty (30) schools were assessed to be exposed to Medium-level flooding, and two (2) schools were found to be exposed to High-level flooding in the same scenario. In the 25-year scenario, twenty (20) schools were discovered to be exposed to Low-level flooding, forty-one (41) to Medium-level flooding, and four (4) to High-level flooding. For the 100-year scenario, twenty-two (22) schools were assessed to be exposed to Low-level flooding, while (43) schools were projected to be exposed to Medium-level flooding. In the same scenario, eight (8) schools were expected to be subjected to High-level flooding. See Annex 12 for a detailed enumeration of schools within the Labo floodplain.

Of the fifty-four (54) identified medical institutions in the Labo floodplain, twelve (12) were assessed to be exposed to Low-level flooding during a 5-year scenario; while nine (9) were assessed to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, ten (10) health centers were found to be exposed to Low-level flooding, fifteen (15) to Medium-level flooding, and one (1) to High-level flooding. For the 100-year scenario, eighteen (18) institutions were discovered to be exposed to Low-level flooding, and sixteen (16) to Medium-level flooding. In the same scenario, one (1) center was projected to experience High-level flooding. See Annex 13 for a detailed enumeration of the medical institutions within the Labo floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in the different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in a river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 87.

The flood validation consists of one hundred and forty-three (143) points, randomly selected all over the Labo floodplain. Comparing the validation with the flood depth map of the nearest storm event, the map attained an RMSE value of 0.68 meters. Table 48 presents a contingency matrix of the comparison. The validation points are found in Annex 11.

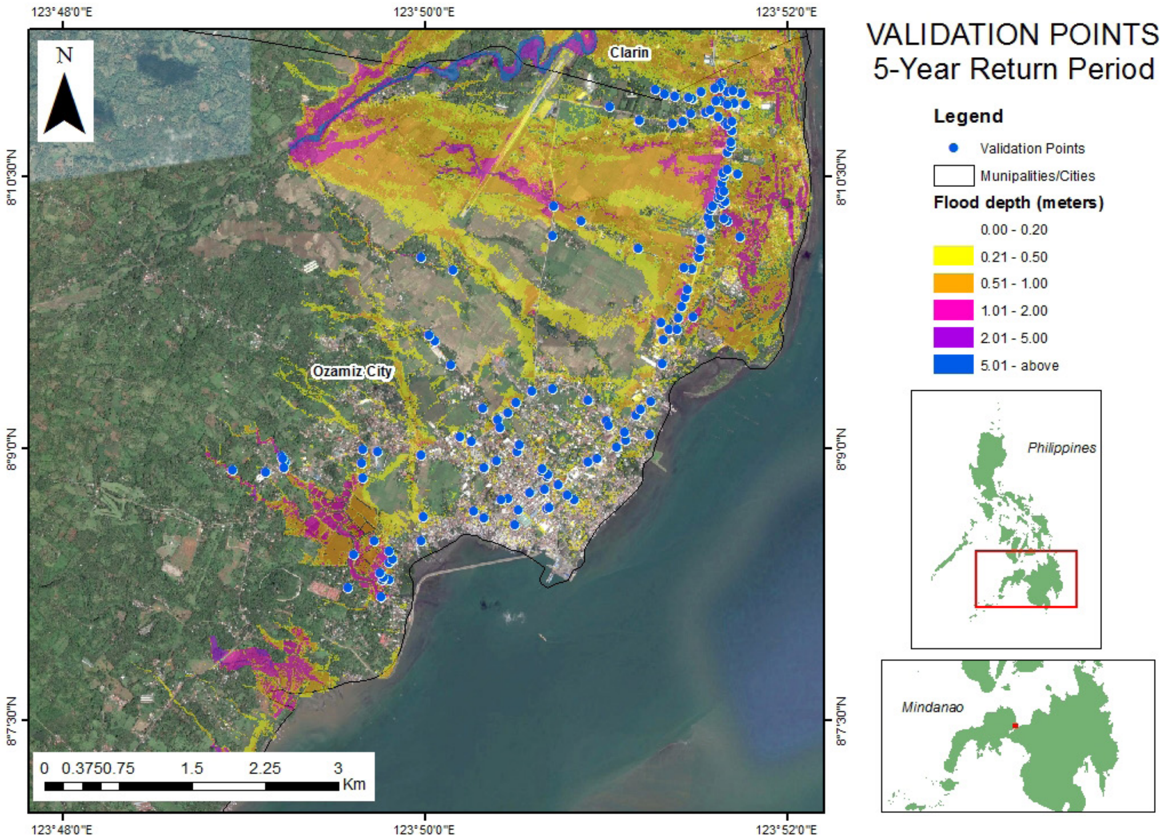


Figure 86. Validation points for the 5-year flood depth map of the Labo floodplain

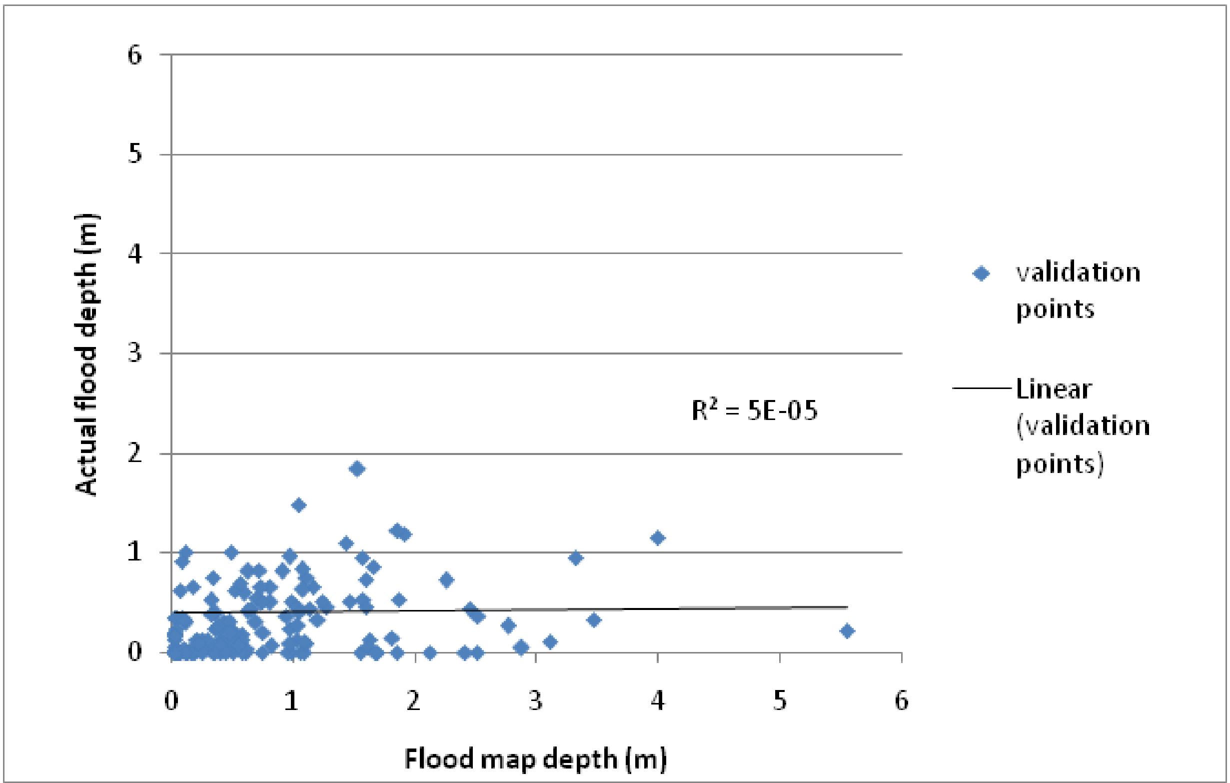


Figure 87. Flood map depth vs. actual flood depth

Table 48. Actual flood depth vs. simulated flood depth in the Labo River Basin

LABO BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	34	16	14	12	5	0	81
	0.21-0.50	6	7	8	7	4	1	33
	0.51-1.00	3	3	12	11	2	0	31
	1.01-2.00	1	0	0	5	1	0	7
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	1	0	0	0	0	0	1
	Total	45	26	34	35	12	1	153

The overall accuracy generated by the flood model is estimated at 37.91%, with fifty-eight (58) points correctly matching the actual flood depths. In addition, there were forty-five (45) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were twenty-six (26) points and twenty-four (24) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of eighty-one (81) points were overestimated, while a total of fourteen (14) points were underestimated in the modeled flood depths of Labo.

The validation data were obtained on August 2016

Table 49. Summary of Accuracy Assessment in the Labo River Basin

	No. of Points	%
Correct	58	37.91
Overestimated	81	52.94
Underestimated	14	9.15
Total	153	100

REFERENCES

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

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

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

ANNEXES

Annex 1. Technical Specifications of the Pegasus LiDAR Sensor used in the Labo Floodplain Survey

Table A-1.1. Technical 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

Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. LAN-02

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

June 24, 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: **LANAO DEL NORTE**	
	Station Name: **LAN-2**	
Island: **MINDANAO**	Order: **1st**	Barangay: **PINOYAK**
Municipality: **LALA**		
	PRS92 Coordinates	
Latitude: **7° 54' 46.07859"**	Longitude: **123° 46' 0.85333"**	Ellipsoidal Hgt: **17.35400 m.**
	WGS84 Coordinates	
Latitude: **7° 54' 42.56546"**	Longitude: **123° 46' 6.31720"**	Ellipsoidal Hgt: **83.92120 m.**
	PTM Coordinates	
Northing: **875110.149 m.**	Easting: **364025.74 m.**	Zone: **5**
	UTM Coordinates	
Northing: **874,680.35**	Easting: **584,533.45**	Zone: **51**

Location Description

LAN-2
From Iligan City, travel southwest along the National highway for 74.5 kilometers to the municipality of Lala. Travel farther along the national highway for 1.4 kilometers up to Maranding junction. Thence from the junction travel southeast along the national highway for another 1.3 kilometers to a dirt road going to Pinoyak barangay proper. Turn right on the dirt road and national highway intersection and continue travelling westward for 400 meters up to the irrigation canal. Station is located on top of the concrete irrigation canal water gate. Station mark is 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in a drill hole on top of the concrete irrigation canal water gate; centered in cement patty and inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in drill holes on top of the concrete irrigation canal water gate; centered in cement patty and inscribed with the reference mark numbers and arrow pointing to the station.

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1441**

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

9 9 0 6 2 4 2 0 1 4 1 1 1 6 5 8

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. LAN-02

2. ZGS-88

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

July 11, 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: **ZAMBOANGA DEL SUR**	
	Station Name: **ZGS-88**	
Island: **MINDANAO**	Order: **2nd**	Barangay: **SAN JOSE**
Municipality: **AURORA**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **7° 57' 13.25316"**	Longitude: **123° 34' 56.50093"**	Ellipsoidal Hgt: **258.34500 m.**
	WGS84 Coordinates	
Latitude: **7° 57' 9.71271"**	Longitude: **123° 35' 1.96243"**	Ellipsoidal Hgt: **324.37300 m.**
	PTM / PRS92 Coordinates	
Northing: **879474.685 m.**	Easting: **564207.26 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **879,166.85**	Easting: **564,184.79**	Zone: **51**

Location Description

ZGS-88
Is located on the S end of the W wedge-shaped island in Purok Saray, Brgy. San Jose, Aurora. It is about 500 m. N of the municipal hall, 30 m. W of the Seaoil Gasoline Station and 5 m. E of the W side of the road. Mark is the head of a 3 in. copper nail embedded and centered on a 27 cm. x 26 cm. x cement putty, with inscriptions "ZGS-88 2005 NAMRIA LEP IX".

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1601**

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

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

CERTIFICATION INTERNATIONAL ISO 9001 : 2008
CIP/4701/13/09/814

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-2.2. ZGS-88

3. 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**	Barangay: **OSPITAL (POB.)**	
Municipality: **ALORAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 24' 49.21851"**	Longitude: **123° 49' 18.84776"**	Ellipsoidal Hgt: **4.39900 m.**
	WGS84 Coordinates	
Latitude: **8° 24' 45.57851"**	Longitude: **123° 49' 24.26581"**	Ellipsoidal Hgt: **70.09500 m.**
	PTM / PRS92 Coordinates	
Northing: **930392.306 m.**	Easting: **590515.033 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **930,066.65**	Easting: **590,483.35**	Zone: **51**

Location Description

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

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

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 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
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. MSW-11

4. 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

CERTIFICATION INTERNATIONAL ISO 9001:2008 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-2.4. MSW-12

5. LE-50

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

July 25, 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: **LANAO DEL NORTE** Station Name: LE-50	
Island: **Mindanao**	Municipality: **MAIGO**	Barangay: **CLARO M. RECTO**
Elevation: **5.3895 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LE-50 is in the Province of Lanao Del Norte, Town of Maigo, Brgy. C.M. Recto, along the Butuan - Zamboanga National Road, and about 50 meters North East of the Covenant Baptist Church. The station is located at the South West end of the Barogohan Bridge footwalk and about 70 meters South West of KM post 1561.

A brass rod is set on a drilled hole and cemented flushed on top of a 15cm x 15cm cement putty with inscription "LE-50, 2007, NAMRIA".

Requesting Party:	**UP-TCAGP / Engr. Christopher Cruz**
Pupose:	**Reference**
OR Number:	**8799582 A**
T.N.:	**2014-1723**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.5. LE-50

6. 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

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CERTIFICATION INTERNATIONAL ISO 9001:2008 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-2.6. MW-85

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

1. MW-62A

Table A-3.1. MW-62A

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MSW-12 --- MW-62A (B1)	MSW-12	MW-62A	Fixed	0.004	0.019	1°12'09"	7777.102	1.880

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

MSW-12 - MW-62A (8:37:03 AM-12:38:09 PM) (S1)

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

2. MW-85

Table A-3.2. MW-85

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\MSW 11 - MW 85.vce	Name:	UTM
		Datum:	PRS 92
Size:	394 KB	Zone:	51 North (123E)
Modified:	12/10/2014 6:31:21 PM (UTC:8)	Geoid:	EGMPH
Time zone:	Taipei Standard Time	Vertical datum:	
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MSW 11 --- MW 85 AM (B1)	MSW 11	MW 85 AM	Fixed	0.004	0.022	340°57'21"	9497.194	-0.079
MSW 11 --- MW 85 PM (B2)	MSW 11	MW 85 PM	Fixed	0.005	0.028	340°57'21"	9497.202	-0.087

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

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

3. LE-50

Table A-3.3. LE-50

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Processing Start Time	Processing Stop Time	Satellite Available
LE50 --- LAN2 (B1)	LAN2	LE50	6/20/2014 10:05:34 AM	6/20/2014 2:59:59 PM	Fixed	0.012	0.024	-15846.890	-15348.670	27636.104	37°51'51"	35361.439	-10.469	6/20/2014 10:05:34 AM	6/20/2014 2:59:59 PM	GPS: 15 GLONASS: 13 Galileo: 0 QZSS: 0

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	LAN2				
Grid		Local		Global	
Easting	584699.973 m	Latitude	N7°54'42.56546"	Latitude	N7°54'42.56546"
Northing	874628.035 m	Longitude	E123°46'06.31720"	Longitude	E123°46'06.31720"
Elevation	15.242 m	Height	83.921 m	Height	83.921 m

To:	LE50				
Grid		Local		Global	
Easting	606345.902 m	Latitude	N8°09'51.11024"	Latitude	N8°09'51.11024"
Northing	902577.426 m	Longitude	E123°57'55.36634"	Longitude	E123°57'55.36634"
Elevation	4.394 m	Height	73.452 m	Height	73.452 m

Vector					
ΔEasting	21645.929 m	NS Fwd Azimuth	37°51'51"	ΔX	-15847.070 m
ΔNorthing	27949.392 m	Ellipsoid Dist.	35361.439 m	ΔY	-15348.392 m
ΔElevation	-10.847 m	ΔHeight	-10.469 m	ΔZ	27636.144 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI S. SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUNA	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
LiDAR Operation	Research Associate (RA)	ENGR. RENAN PUNTO	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	ENGR. GEF SORIANO	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey	RA	JASMIN DOMINGO	UP-TCAGP
	RA	LANCE CINCO	
LiDAR Operation	Airborne Security	JAYCO MANZANO	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Airborne Security	LEE JAY PUNZALAN	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. SHERWIN CESAR ALFONSO	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Pilot	CAPT. JOSEPH LIM	AAC
LiDAR Operation	Pilot	CAPT. BRIAN DONGUINES	(AAC)
LiDAR Operation	Pilot	CAPT. FERDINAND DE OCAMPO	AAC
LiDAR Operation	Pilot	CAPT. JERICO JECIEL	AAC

Annex 5. Data Transfer Sheets for the Labo Floodplain Flights

DATA TRANSFER SHEET
08/05/2014(Northern Mindanao - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	SHP	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	
7/3/2014	1665P	1BLK71ES184A	Pegasus	606	93	4.69	94.5	169	NA	NA	6.77	NA	6.94	1KB	1KB	35	NA	Z:\Airborne_Raw
7/5/2014	1673P	1BLK71ES186A	Pegasus	1.05	379	7.58	335	190	22.4	167	12.5	27.8	5.09	1KB	1KB	92/84	NA	Z:\Airborne_Raw
7/6/2014	1677P	1BLK71S187A	Pegasus	695	68	5.33	188	141	11.2	86	7.79	NA	4.94	1KB	1KB	130	NA	Z:\Airborne_Raw
7/8/2014	1685P	1BLK71S189A	Pegasus	2.31	515	11	578	242	37	288	22.4	47.4	4.39	1KB	1KB	184	NA	Z:\Airborne_Raw
7/8/2014	1687P	1BLK71S189B	Pegasus	749	79	4.81	176	136	NA	NA	7.47	NA	4.39	1KB	1KB	NA	NA	Z:\Airborne_Raw
7/9/2014	1689P	1BLK71S190A	Pegasus	2.56	156	12.6	740	257	NA	NA	27.1	NA	3.68	1KB	1KB	196/207	NA	Z:\Airborne_Raw
7/10/2014	1693P	1RXES191A	Pegasus	1.78	551	8.11	448	175	NA	NA	16.9	NA	4.08	1KB	1KB	53	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
8/6/14

Figure A-5.1. Data Transfer Sheet for Labo Floodplain – A

DATA TRANSFER SHEET
11/17/2014(dpsing)

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	4.06	1KB	1KB	47/23	na	Z:\DAC\RAW DATA
20-Oct	2111P	1BLK69B296A	PEGASUS	2.01	459	12.4	230	29.5	292	22.2	na	7.99	1KB	1KB	28/24/668	na	Z:\DAC\RAW DATA
20-Oct	2113P	1BLK69B296A	PEGASUS	1.62	394	16	215	30.4	280	18.4	na	15.1	1KB	1KB	48/51/44/87	na	Z:\DAC\RAW DATA
23-Oct	2115P	1BLK6970A296B	PEGASUS	794	171	6.26	185	13.6	115	8.18	na	15.1	1KB	1KB	48/51/25	na	Z:\DAC\RAW DATA
24-Oct	2117P	1BLK69B297A	PEGASUS	1.24	237	6.75	115	18.8	164	12.4	na	7.64	1KB	1KB	48/51/50	na	Z:\DAC\RAW DATA
26-Oct	2125P	1BLK69C299A	PEGASUS	1.8	267	8.41	211	32	239	15.4	na	37.4	1KB	1KB	48/51/50/41/ 55/49/33	na	Z:\DAC\RAW DATA
28-Oct	2127P	1BLK6970A299B	PEGASUS	2.54	na	5.91	114	16	1	12.8	na	37.4	1KB	1KB	27/1	na	Z:\DAC\RAW DATA
28-Oct	2133P	1BLK69FE301A	PEGASUS	2.06	29/4/64	10.2	225	37.9	343	na	na	37.3	1KB	1KB	73/51/01/38	na	Z:\DAC\RAW DATA
28-Oct	2135P	1BLK69F301B	PEGASUS	288	170/167	3.43	60.8	na	58	8.4	na	37.3	1KB	1KB	82	na	Z:\DAC\RAW DATA
29-Oct	2137P	1BLK70D302A	PEGASUS	1.06	453/230	7.37	190	28.3	181	11.2	na	19.4	1KB	1KB	108/10/82/75	na	Z:\DAC\RAW DATA
31-Oct	2145P	1BLK69C304A	PEGASUS	2.33	1118/634	9.11	182	49.6	342	22.6	na	8.52	1KB	1KB	74	na	Z:\DAC\RAW DATA
1-Nov	2149P	1BLK70B305A	PEGASUS	1.79	328	7.28	182	32.1	227	20.3	na	20.2	1KB	1KB	54/73	na	Z:\DAC\RAW DATA
3-Nov	2157P	1BLK70C307A	PEGASUS	2.28	108	11.3	340	40.6	256	28.1	na	20.3	1KB	1KB	30	na	Z:\DAC\RAW DATA
6-Nov	2169P	1BLK73AS310A	PEGASUS	3.01	833	12.1	246	62.8	na	26.9	na	21.3	1KB	1KB	80	na	Z:\DAC\RAW DATA
8-Nov	2177P	1BLK70C312A	PEGASUS	1.75	327	8.89	198	28.1	na	17.6	na	17.9	1KB	1KB	60/60/57	na	Z:\DAC\RAW DATA
9-Nov	2181P	1BLK69F313A	PEGASUS	1.48	291	8.11	192	22.4	182	18.2	na	17	1KB	1KB	65/68/51	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

Figure A-5.2. Data Transfer Sheet for Labo Floodplain – B

DATA TRANSFER SHEET
PAGADIAN 2/29/16

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	
2016-02-17	23104P	1BLK76DLM48A	Pegasus	1.81 GB	NA	10.09 MB	287.01 MB	25.87 GB	193.97 KB	18.3 GB	0 B	116.78 MB	133 B	1.08 KB	0 B	NA	Z:\DAC\RAW DATA\23104P
2016-02-16	23100P	1BLK76G047A	Pegasus	2.83 GB	NA	12.33 MB	285.96 MB	38 GB	297.52 KB	27.31 GB	0 B	103.23 MB	132 B	341B	0 B	NA	Z:\DAC\RAW DATA\23100P
2016-02-15	23096P	1BLK76NO46A	Pegasus	665.91 MB	NA	4.64 MB	164.2 MB	9.7 GB	82.64 KB	7.07 GB	0 B	90.32 MB	133 B	603 B	0 B	NA	Z:\DAC\RAW DATA\23096P
2016-02-14	23092P	1BLK76IG045A	Pegasus	2.19 GB	NA	10.66 MB	203.46 MB	28.87 GB	230.75 KB	22.33 GB	0 B	110.72 MB	132 B	279 B	0 B	NA	Z:\DAC\RAW DATA\23092P
2016-02-13	23088P	1BLK76ILM044A	Pegasus	2.48 GB	NA	11.64 MB	283.62 MB	35.45 GB	263.38 KB	24.65 GB	0 B	101.29 MB	133 B	889 B	0 B	NA	Z:\DAC\RAW DATA\23088P
2016-02-12	23084P	1BLK76KJLM043A	Pegasus	3.01 GB	NA	13.36 MB	276.9 MB	44.56 GB	332.83 KB	29.36 GB	0 B	129.73 MB	133 B	362 B	0 B	NA	Z:\DAC\RAW DATA\23084P

Received from

Name R. PUNTO
Position RA
Signature [signature]

Received by

Name AC Borgat
Position SSRS
Signature [signature] 3/1/16

16-14

Figure A-5.3. Data Transfer Sheet for Labo Floodplain – C

DATA TRANSFER SHEET
PAGADIAN 3/7/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/8 2	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/8 7/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/5 7	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

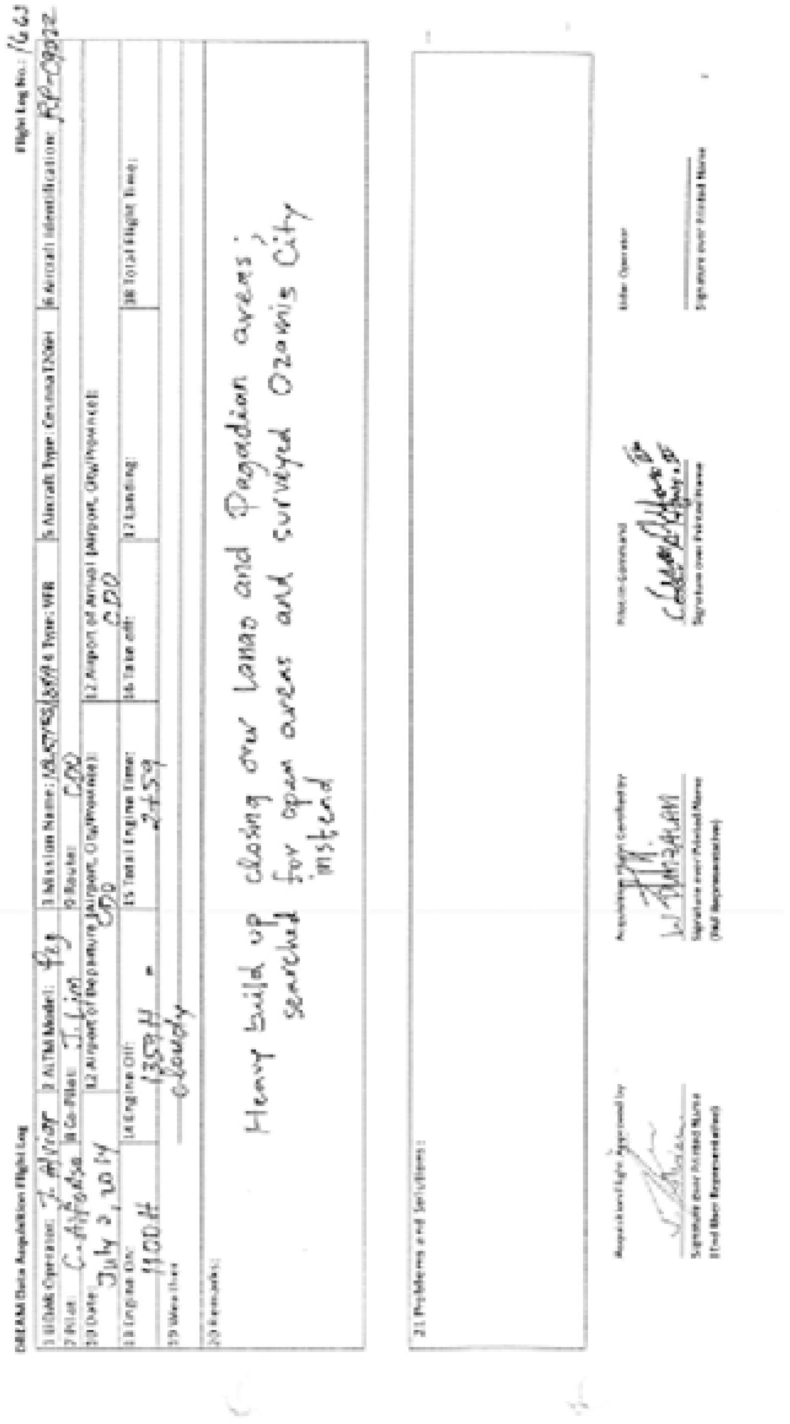
Name AC Bongat
Position SSRS
Signature 3/10/16

16-17

Figure A-5.4. Data Transfer Sheet for Labo Floodplain – D

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1665P Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1663

1 LiDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 2, 2014	12 Airport of Departure (Airport, City/Province): CDO	12 Airport of Arrival (Airport, City/Province): CDO			
13 Engine On: 1100H	14 Engine Off: 1359H	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Heavy build up closing over Lanao and Pagadian areas; searched for open areas and surveyed Ozamis City instead

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.1. Fight Log for Mission 1665P

2. Flight Log for 1673P Mission

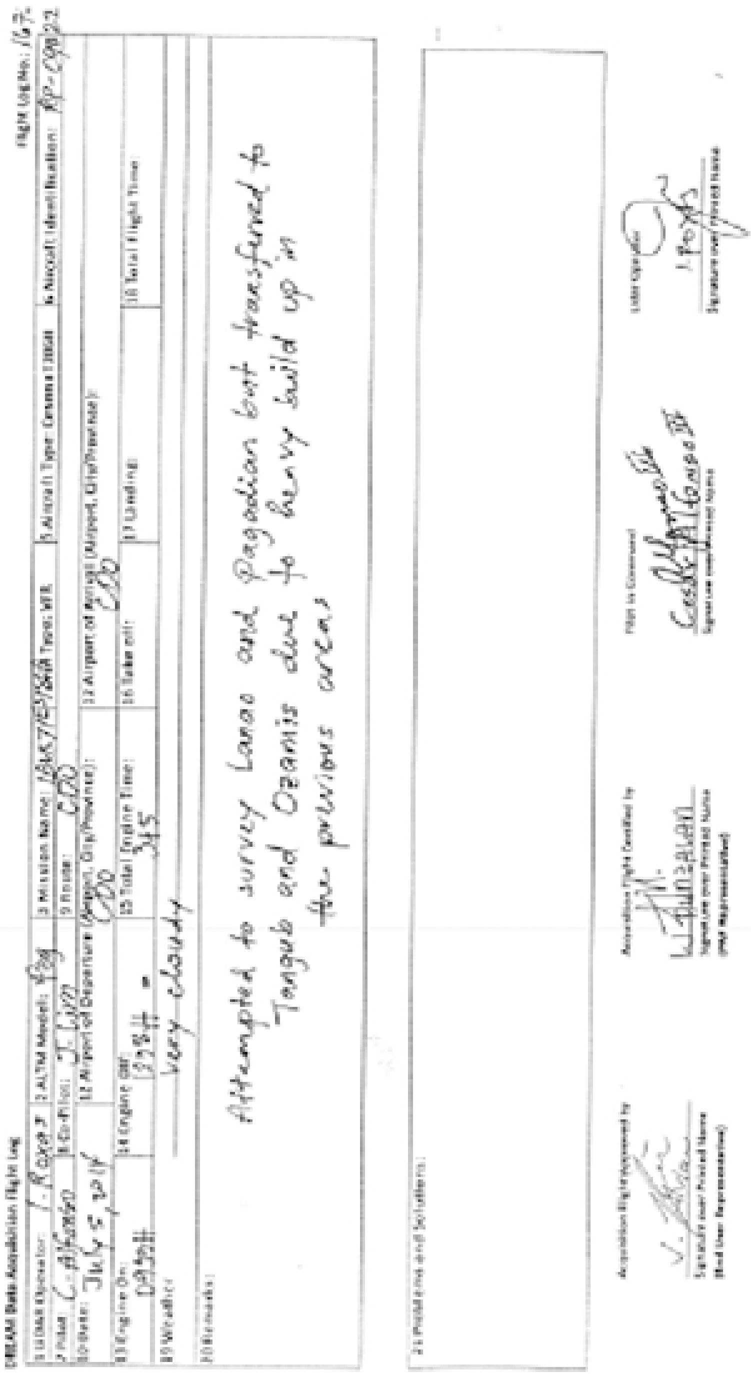
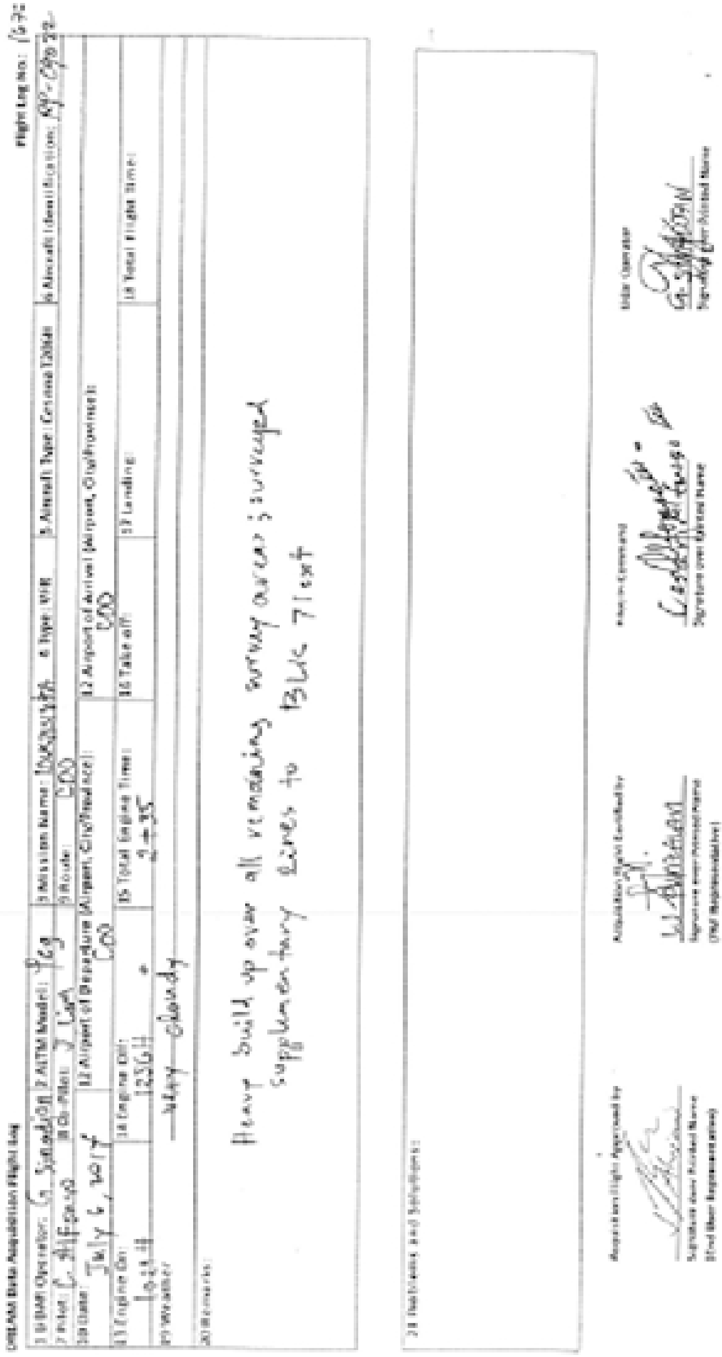


Figure A-6.2. Fight Log for Mission 1673P

3. Flight Log for 1677P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1677

1 LiDAR Operator: G. Sinadjan
2 ALTM Model: Peg
3 Mission Name:
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: RP-C9022

7 Pilot: C. Alfonso
8 Co-Pilot: J. Lim
9 Route: CDO

10 Date: July 6, 2017
12 Airport of Departure (Airport, City/Province): CDO
12 Airport of Arrival (Airport, City/Province): CDO

13 Engine On: 1023H
14 Engine Off: 1236H
15 Total Engine Time: 2+35
16 Take off:
17 Landing:
18 Total Flight Time:

19 Weather: very cloudy

20 Remarks:

Heavy build up over all remaining survey areas; surveyed supplementary lines to BLK 71ext

21 Problems and Solutions:

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

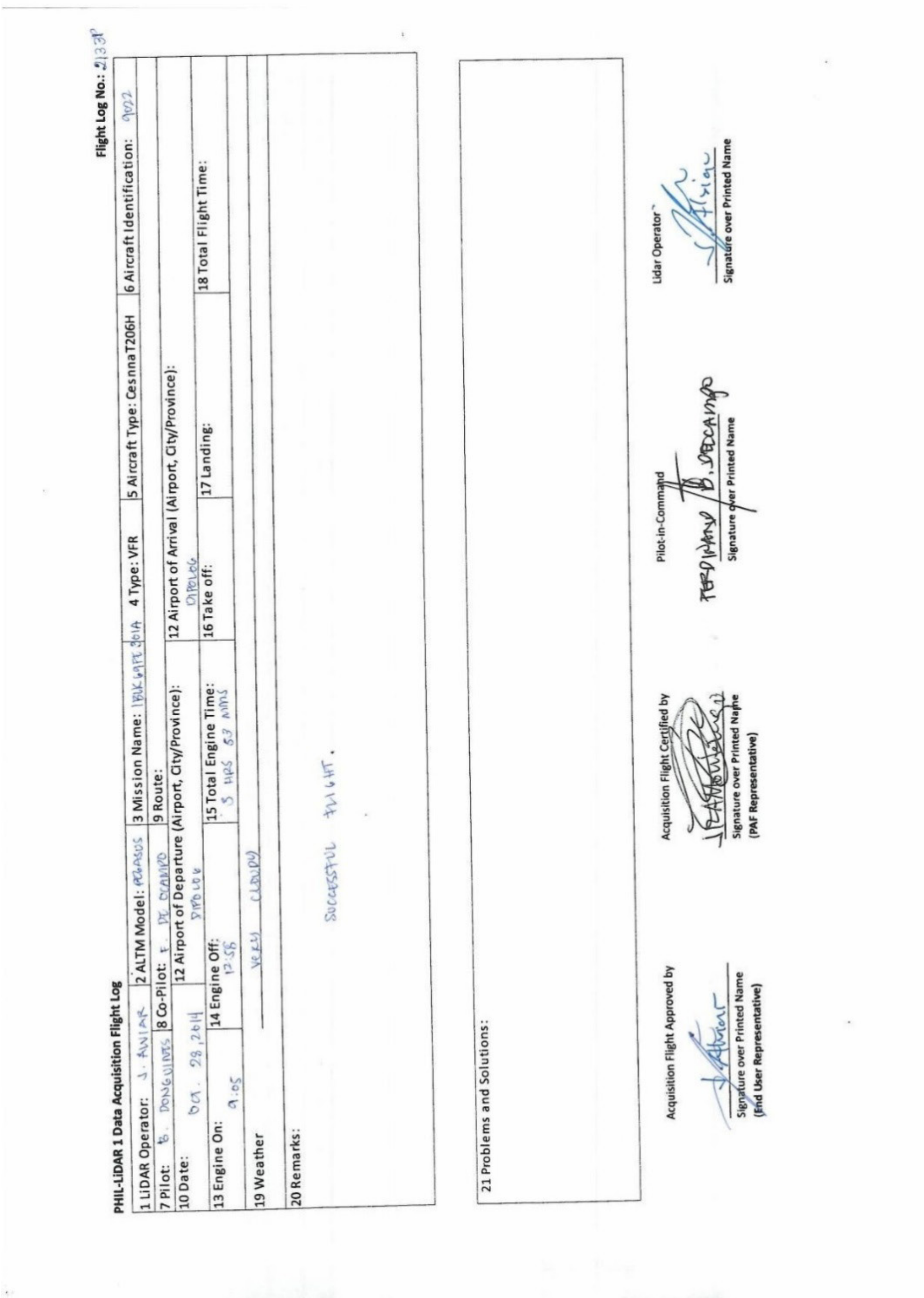
Acquisition Flight Certified by — W. Almarez — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — G. Sinadjan — Signature over Printed Name

Figure A-6.3. Fight Log for Mission 1677P

4. 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: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: OCT. 28, 2014	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 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 — Signature over Printed Name (End User Representative)

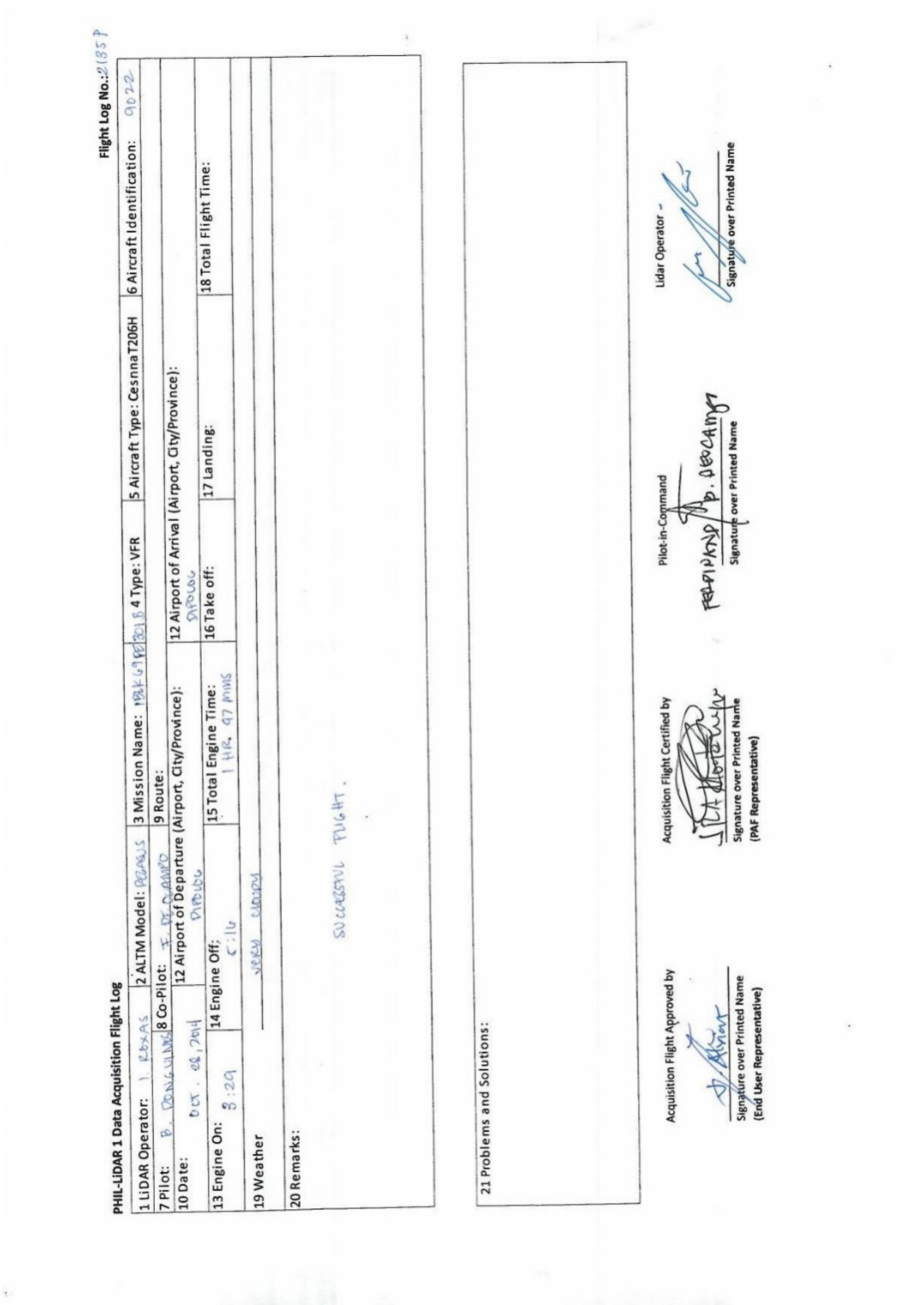
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — FERDINAND B. DOCAMPO — Signature over Printed Name

Lidar Operator — J. ALVIAR — Signature over Printed Name

Figure A-6.4. Fight Log for Mission 2133P

5. Flight Log for 2135P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2135P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK69FE301B	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: 8:29	14 Engine Off: 10:16	15 Total Engine Time: 1 HR. 47 MINS	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Very Cloudy					
20 Remarks: Successful flight.					

21 Problems and Solutions:

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

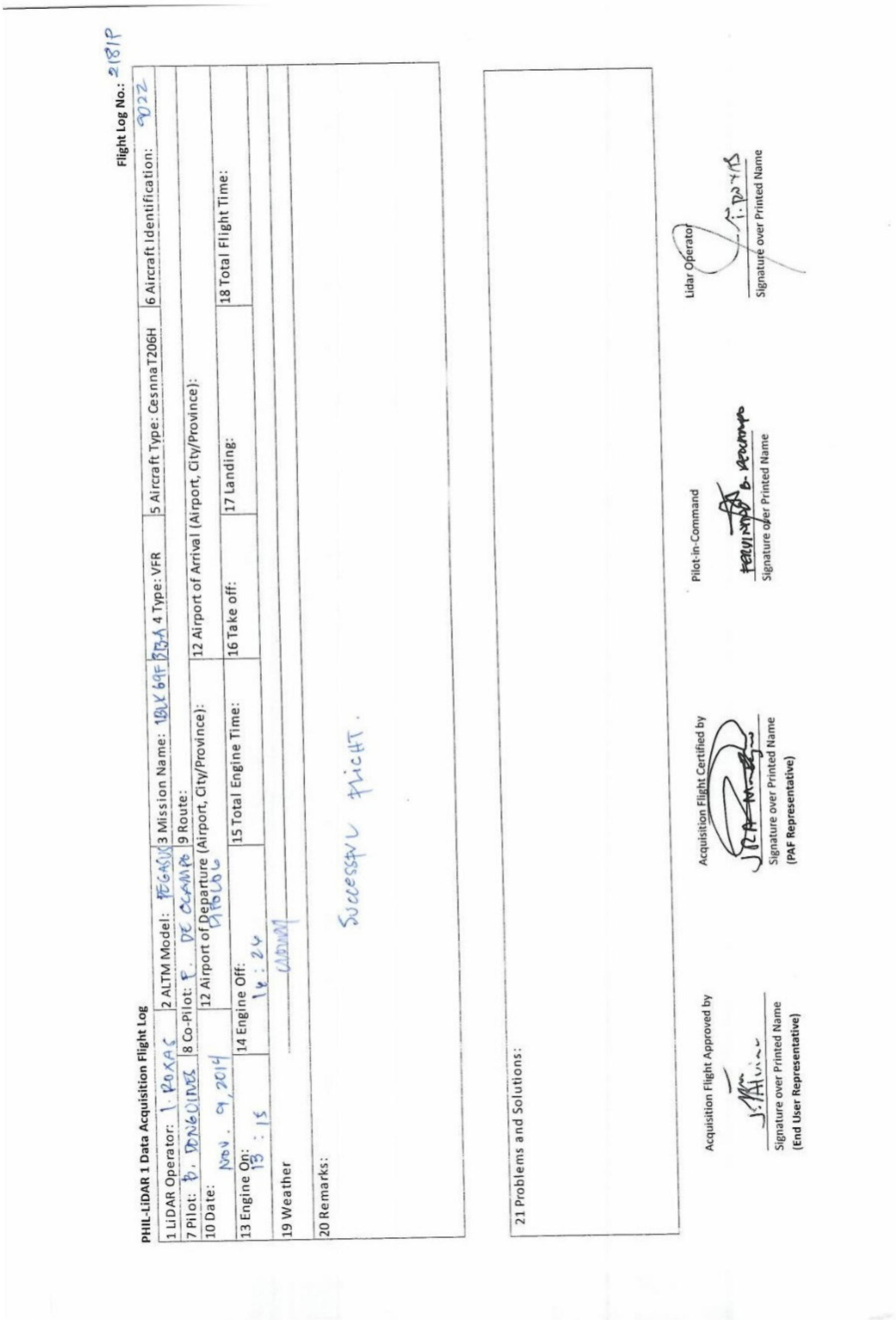
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.5. Fight Log for Mission 2135P

6. Flight Log for 2181P Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2181P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK69F313A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: B. Donguines	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: Nov. 9, 2014	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 13:15	14 Engine Off: 16:24	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Successful flight.					

21 Problems and Solutions:

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

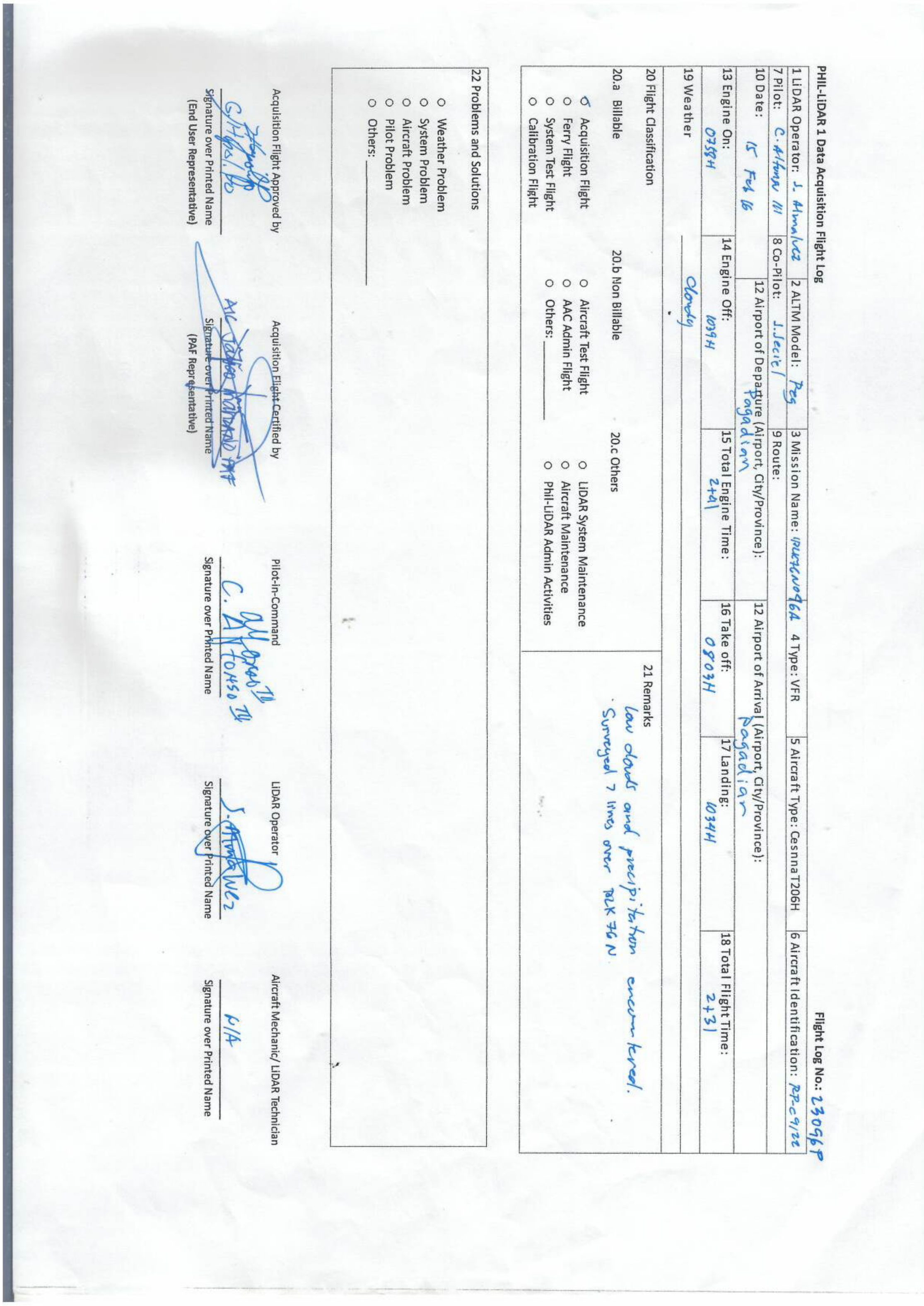
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — I. Roxas — Signature over Printed Name

Figure A-6.6. Fight Log for Mission 2181P

7. Flight Log for 23096P Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23096P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: 1PLK76N046A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecie!	9 Route:			
10 Date: 15 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0758H	14 Engine Off: 1039H	15 Total Engine Time: 2+41	16 Take off: 0803H	17 Landing: 1034H	18 Total Flight Time: 2+31
19 Weather	cloudy				

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

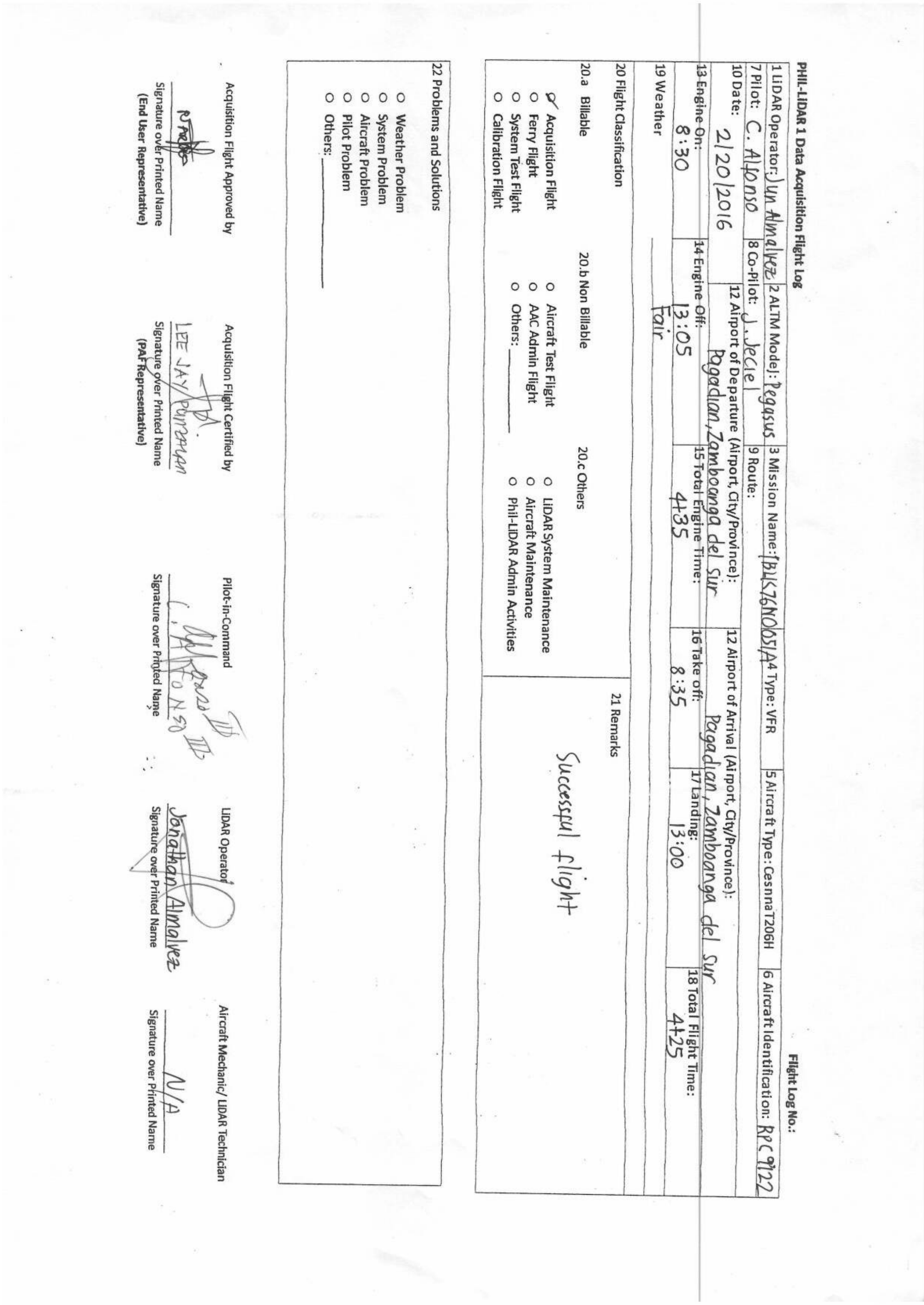
low clouds and precipitation encountered.
· Surveyed 7 lines over BLK 76 N.

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
[signature]	[signature] A1C [illegible] PAF	[signature] C. Alfonso III	[signature] J. 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-6.7. Fight Log for Mission 23096P

8. 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. Jeciel	9 Route:			
10 Date: 2/20/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 8:30	14 Engine Off: 13:05	15 Total Engine Time: 4+35	16 Take off: 8:35	17 Landing: 13:00	18 Total Flight Time: 4+25
19 Weather	Fair				

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- 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: Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: LEE JAY PUNZALAN, Signature over Printed Name (PAF Representative)

Pilot-in-Command: C. ALFONSO III, Signature over Printed Name

LiDAR Operator: Jonathan Almalvez, Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A, Signature over Printed Name

Figure A-6.8. Fight Log for Mission 23116P

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
Northern Mindanao; Dipolog; Pagadian
July 3, 5 and 6 ,2104; October 28 and November 9, 2014; February 15 and 20, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1665P	BLK 71 ext	1BLK71ES184A	J ALVIAR	JUL 3, 2014	HEAVY BUILD UP CLOSING IS OVER LANAO AND PAGADIAN AREAS; SEARCHED FOR OPEN AREAS AND SURVEYED Calabayan CITY INSTEAD
1673P	BLK 71 ext	1BLK71ES186A	I ROXAS	JUL 5, 2014	ATTEMPTED TO SURVEY LANAO AND PAGADIAN BUT TRANSFERRED TO TANGUB AND OZAMIS DUE TO HEAVY BUILD UP IN THE PREVIOUS AREAS
1677P	BLK 71 ext	1BLK71S187A	G SINADJAN	JUL 6, 2014	HEAVY BUILD UP OVER ALL REMAINING SURVEY AREAS; SURVEYED SUPPLEMENTARY LINES TO BLK71ext
2133P	BLK 69FE	1BLK69FE301A	J ALVIAR	OCT 28, 2014	SURVEYED BLK 69E AND F, CLOUDY
2135P	BLK 69F	1BLK69F301B	I ROXAS	OCT 28, 2014	SURVEYED BLK 69F; LAS OUTPUT NOT SAVED IN LAS FOLDER
2181P	BLK 69F	1BLK69F313A	I ROXAS	NOV 9, 2014	FILLED GAPS IN BLK 69F
23096	BLK N,O	1BLK76N046A	JM ALMALVEZ	FEB 15, 2016	VERY CLOUDY IN THE SURVEY AREA
23116P	BLK 76 N, O	1BLK76NO051A	J ALMALVEZ	FEB 20, 2016	ENCOUNTERED LOST CHANNEL A .COMPLETED VOIDS OVER OROQUIETA AND Calabayan CITY

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	1665P		
Area:	BLK 71E		
Mission Name:	1BLK71ES184A		
Parameters:	Altitude:	1100m;	Scan Frequency: 30Hz;
	Scan Angle:	25deg;	Overlap: 30%

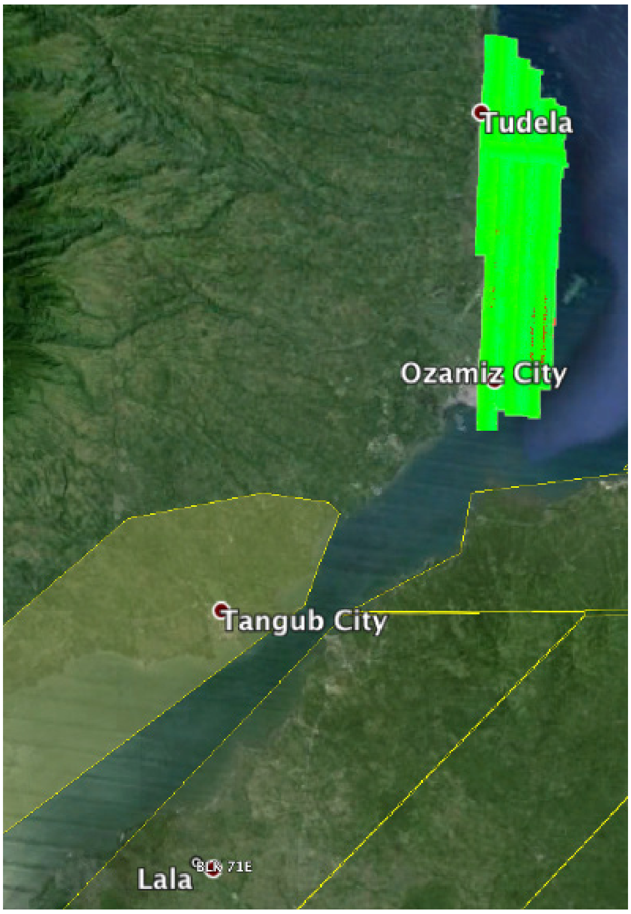


Figure A-7.1. Swath for Flight No. 1665P

Flight No. :	1673P		
Area:	BLK 71 ext		
Mission Name:	1BLK71ES186A		
Parameters:	Altitude:	1000m;	Scan Frequency: 30Hz;
	Scan Angle:	25deg;	Overlap: 30%

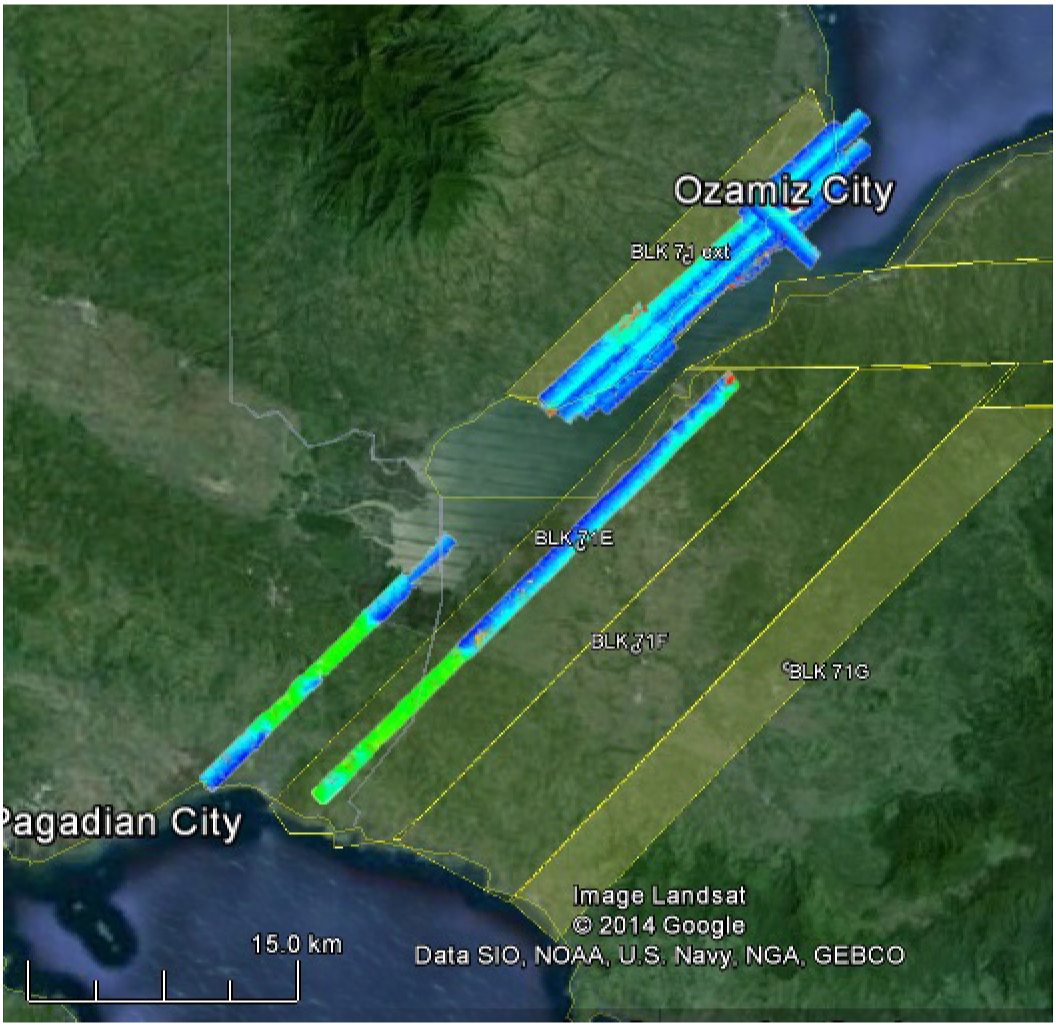


Figure A-7.2. Swath for Flight No. 1673P

Flight No. :	1677P		
Area:	BLK 71 ext		
Mission Name:	1BLK71S187A		
Parameters:	Altitude:	1000m;	Scan Frequency: 30Hz;
	Scan Angle:	25deg;	Overlap: 30%

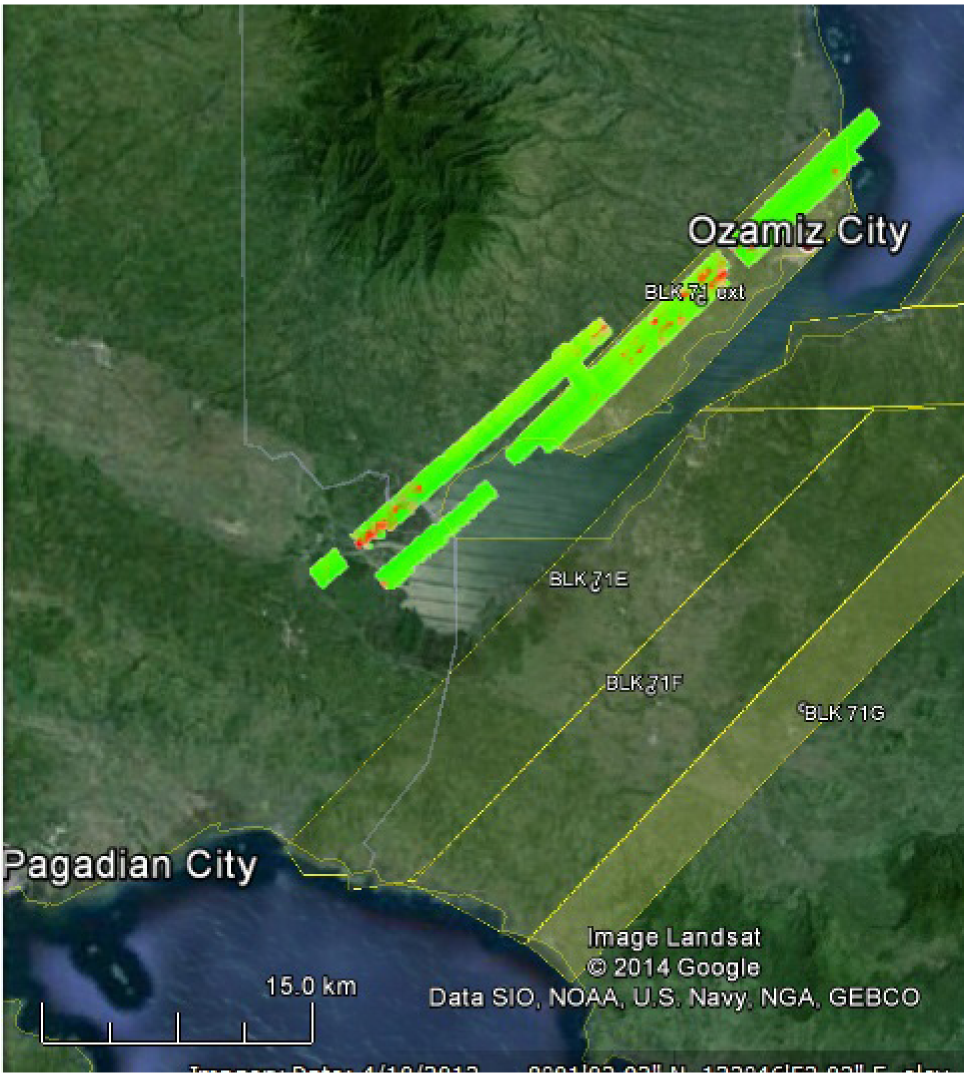


Figure A-7.3. Swath for Flight No. 1677P

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

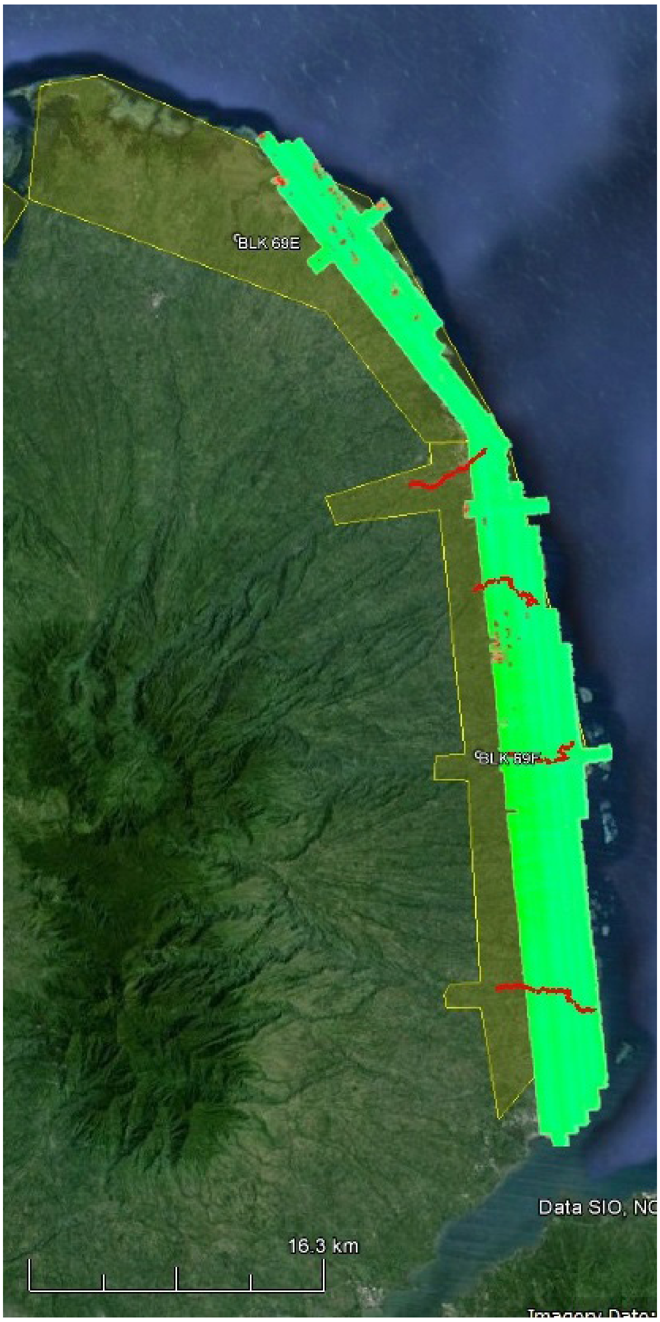


Figure A-7.4. Swath for Flight No. 2133P

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

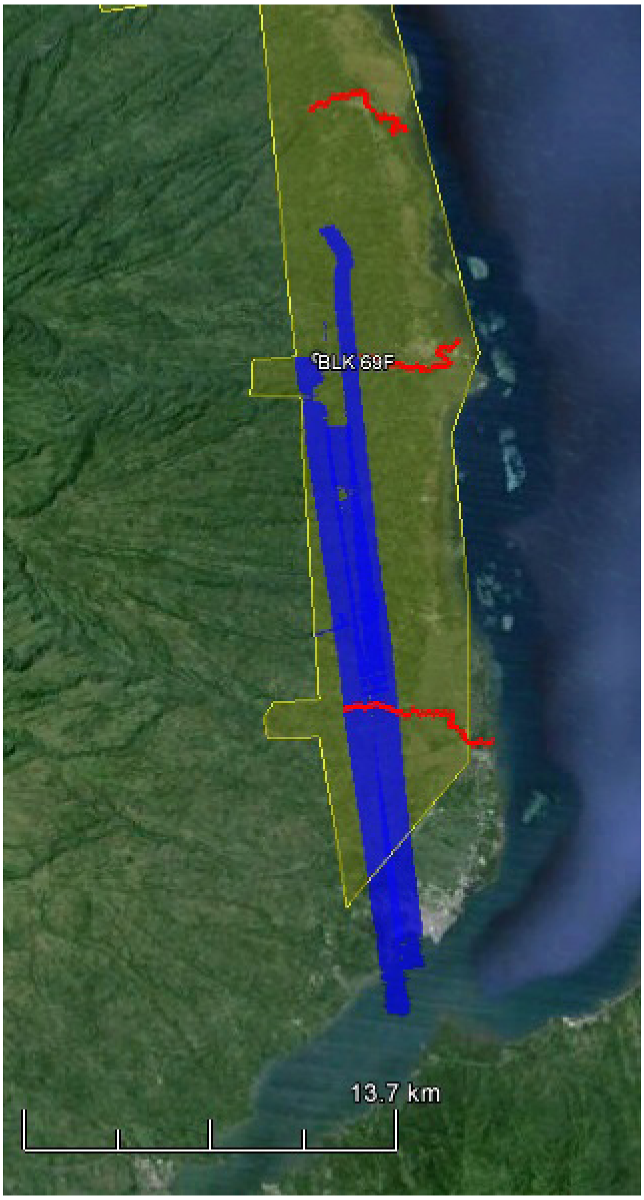


Figure A-7.5. Swath for Flight No. 2135P

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

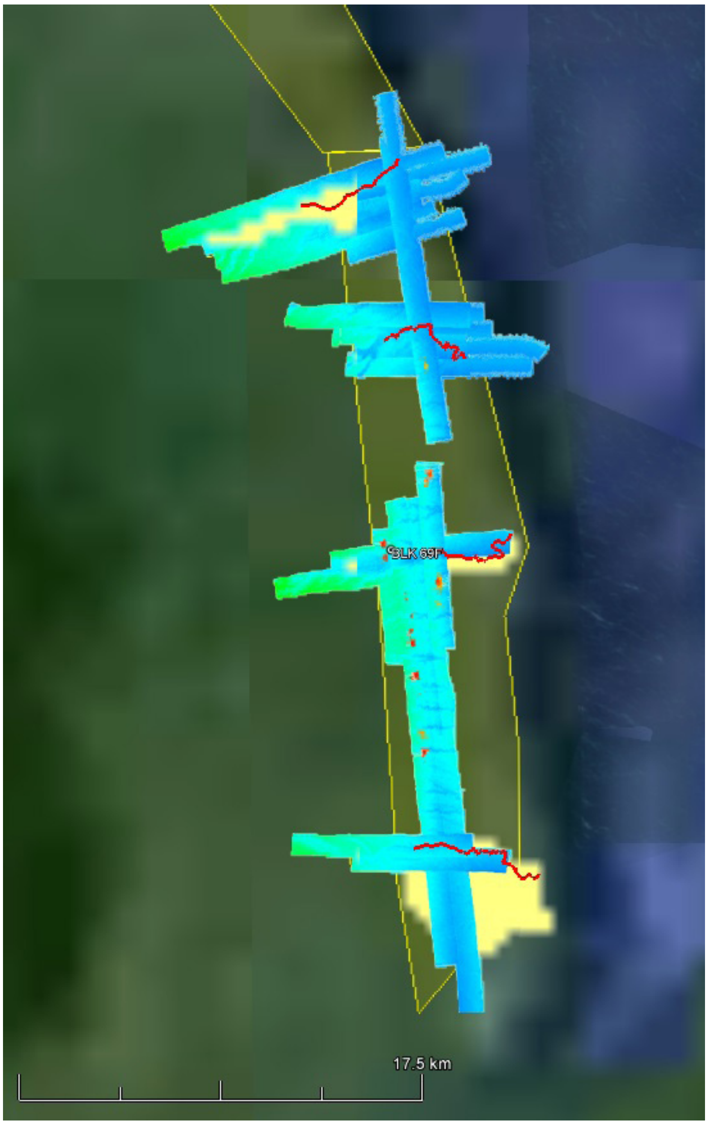


Figure A-7.6. Swath for Flight No. 2181P

Flight No. :	23096P		
Area:	BLK N,O		
Mission Name:	1BLK76N046A		
Parameters:	Altitude:	1100m;	Scan Frequency: 30Hz;
	Scan Angle:	25deg;	Overlap: 30%

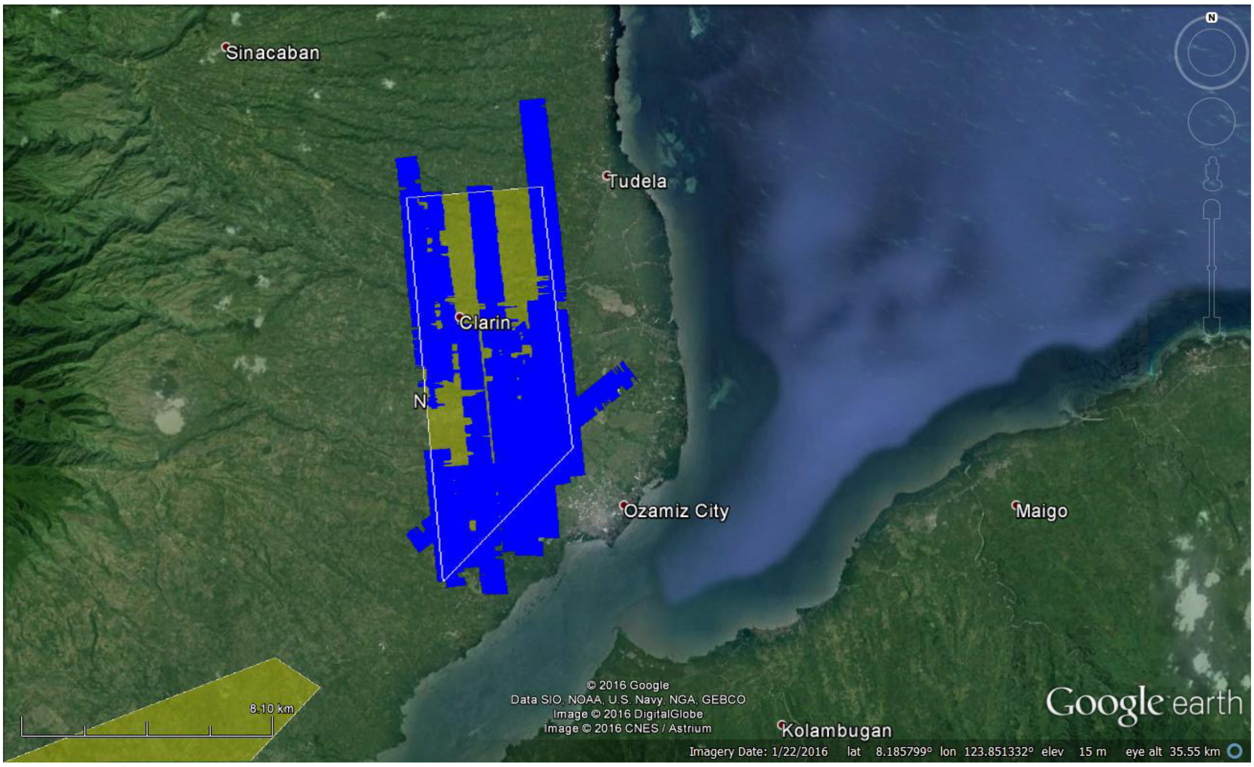


Figure A-7.7. Swath for Flight No. 23096P

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

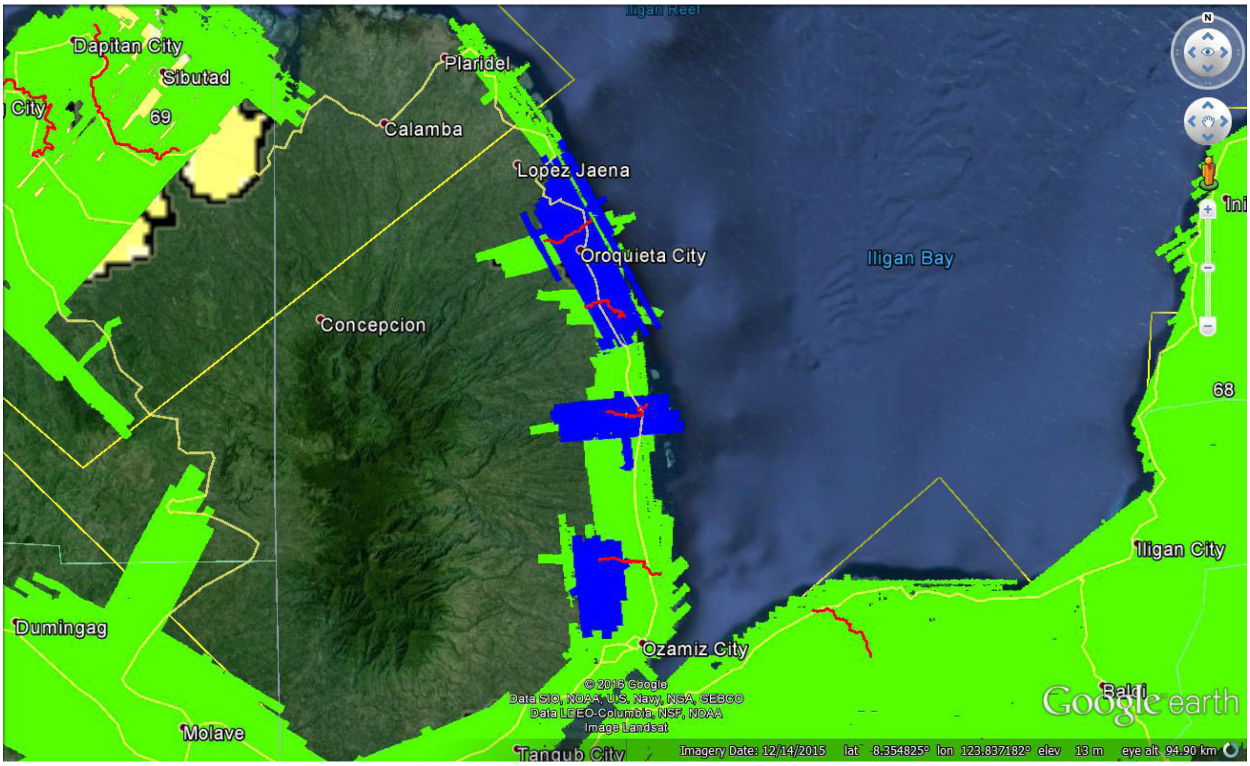


Figure A-7.8. Swath for Flight No. 23116P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk69F

Flight Area	Dipolog
Mission Name	Blk69F
Inclusive Flights	2133P,2135P,2181P
Range data size	43.4 GB
POS	501.6 MB
Image	79.8 GB
Transfer date	November 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.04
RMSE for Down Position (<8.0 cm)	1.85
Boresight correction stdev (<0.001deg)	0.000253
IMU attitude correction stdev (<0.001deg)	0.001628
GPS position stdev (<0.01m)	0.0059
Minimum % overlap (>25)	46.32%
Ave point cloud density per sq.m. (>2.0)	4.58
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

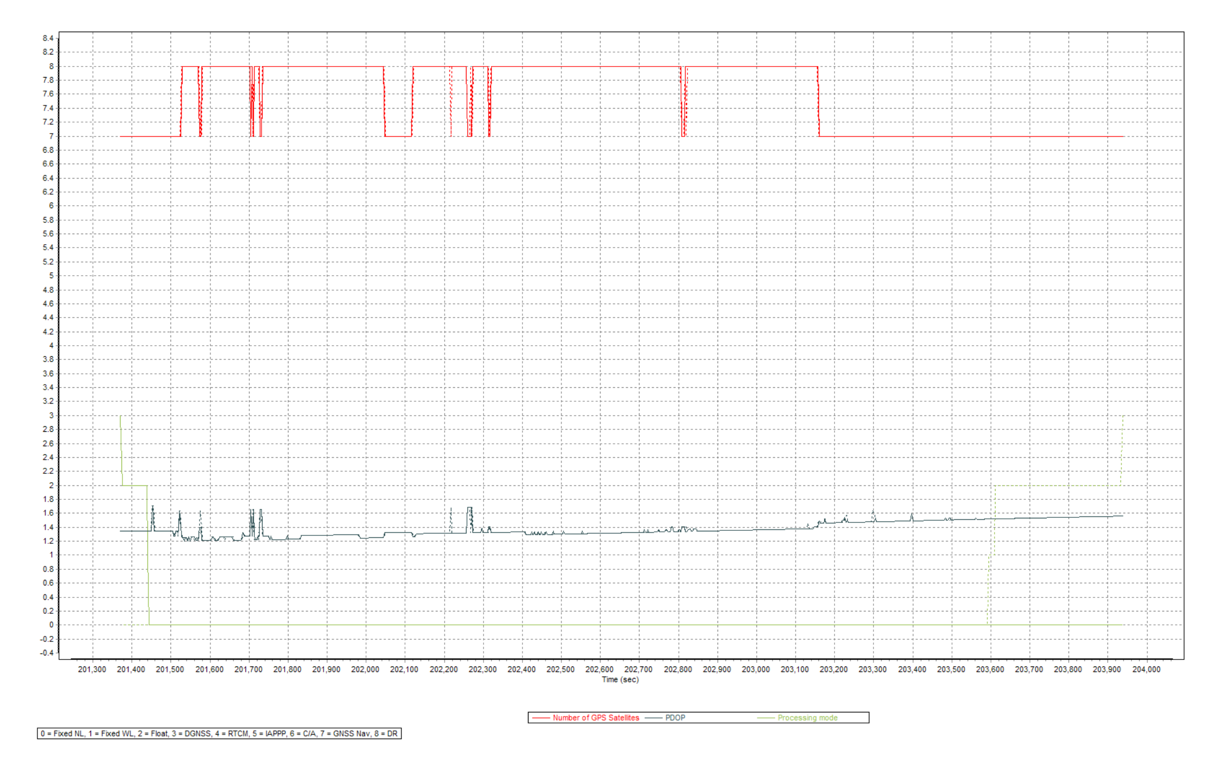


Figure A-8.1. Solution Status

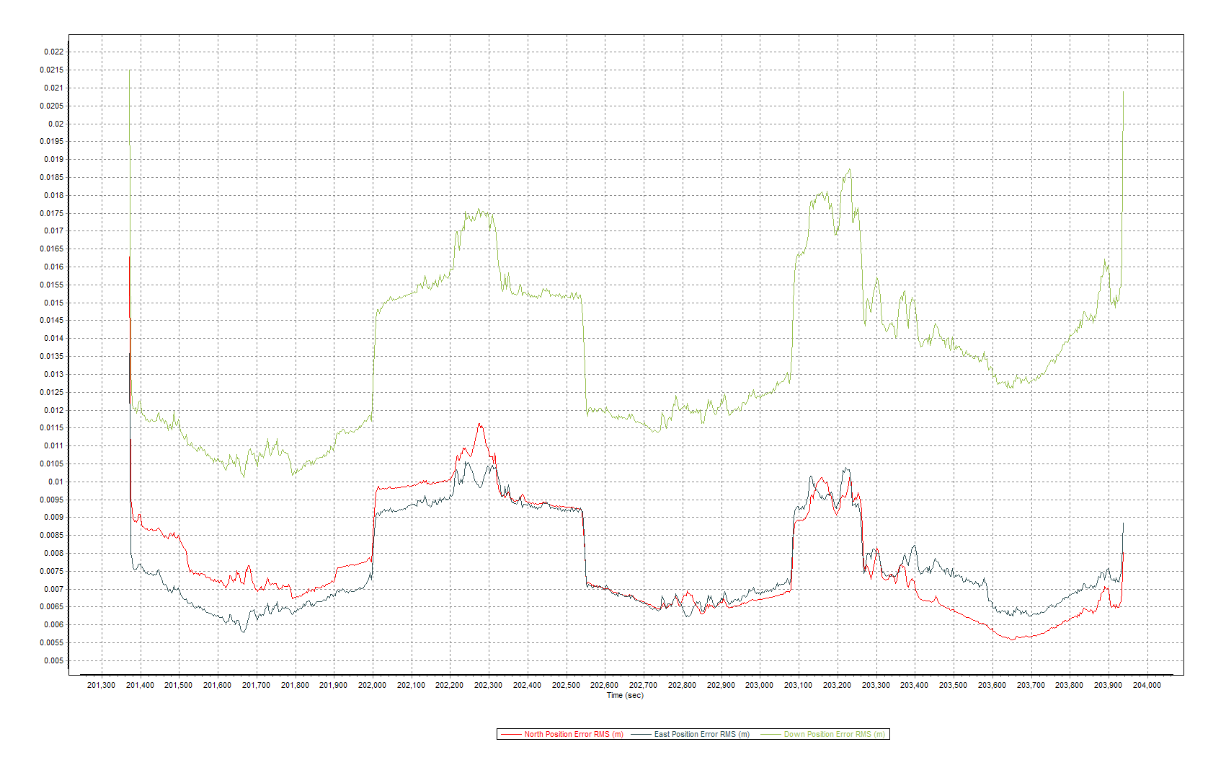


Figure A-8.2. Smoothed Performance Metric Parameters

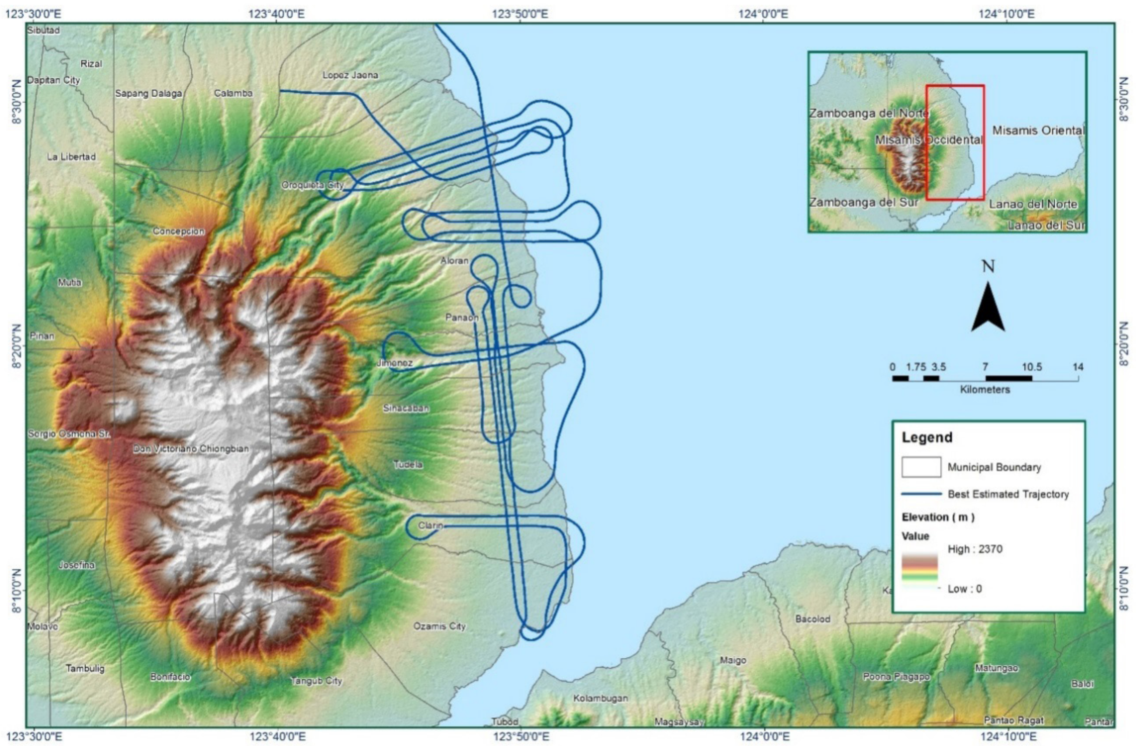


Figure A-8.3. Best Estimated Trajectory

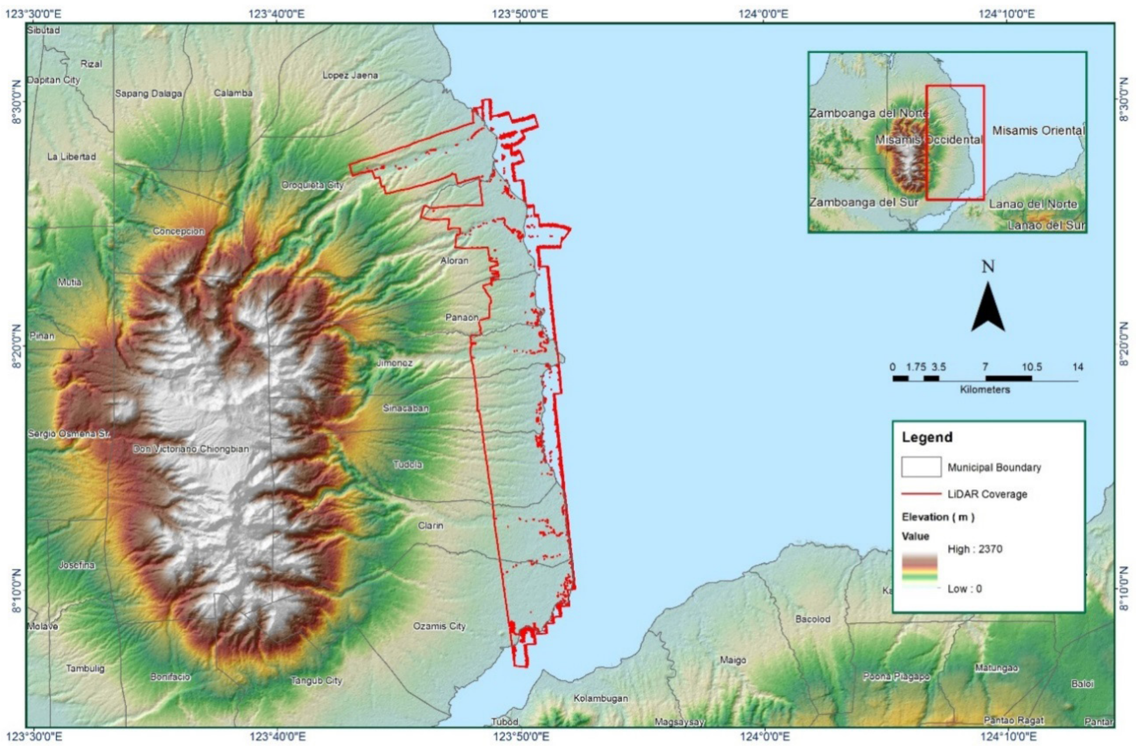


Figure A-8.4. Coverage of LiDAR data

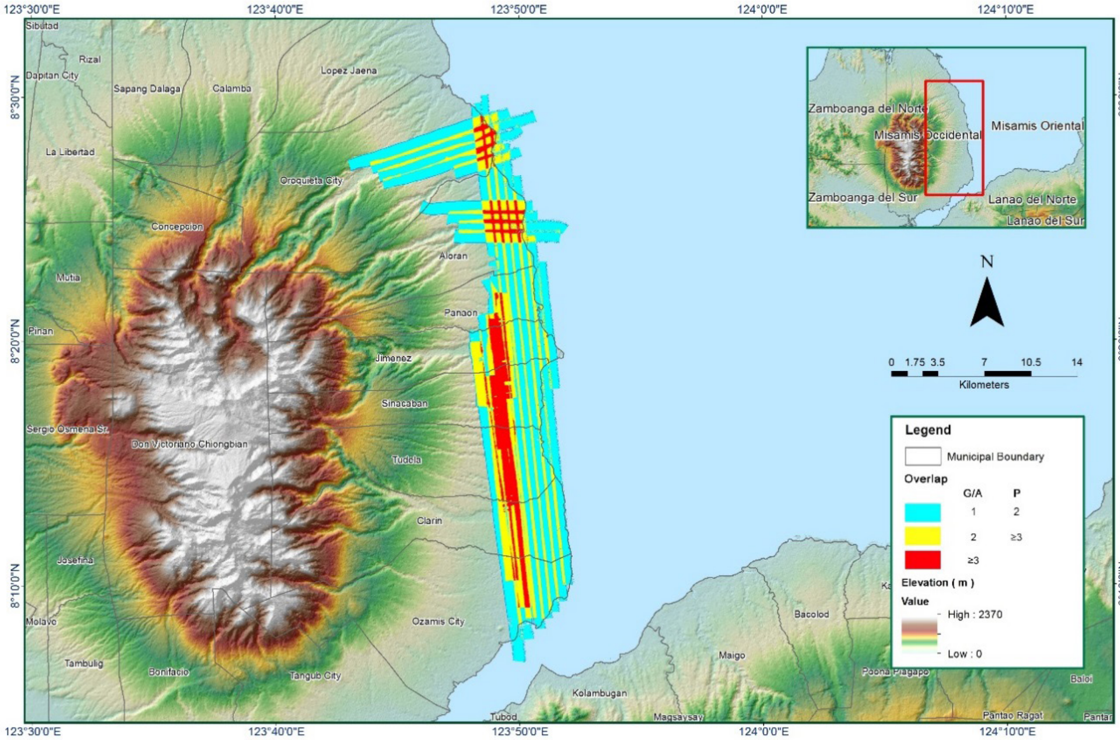


Figure A-8.5. Image of data overlap

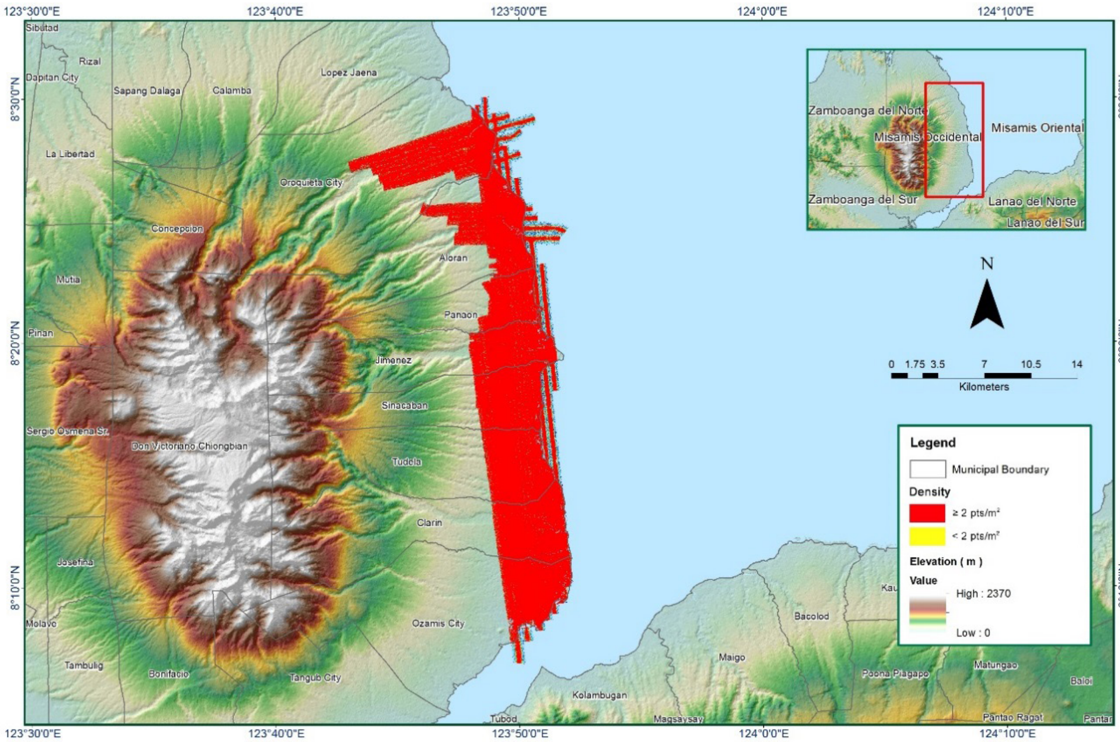


Figure A-8.6. Density map of merged LiDAR data

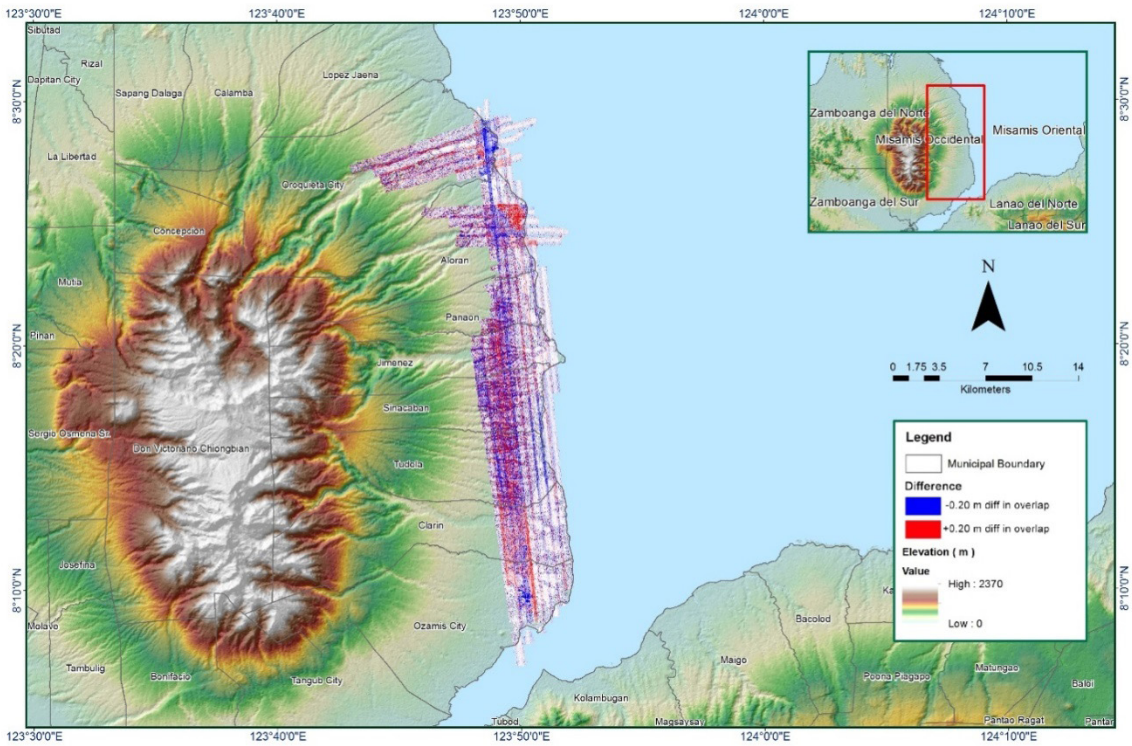


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk71Extension

Flight Area	**Northern Mindanao**
Mission Name	**Blk71Extension**
Inclusive Flights	1665P, 1673P, 1677P
Range data size	27.06 GB
POS	500 MB
Image	33.6 GB
Transfer date	August 6, 2014
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)	3.0
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000243
IMU attitude correction stdev (<0.001deg)	0.001298
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	27.83%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	868.76 m
Minimum Height	63.2 m
Classification (# of points)	
Ground	107,907,148
Low vegetation	96,229,157
Medium vegetation	96,176,102
High vegetation	80,601,347
Building	17,253,174
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

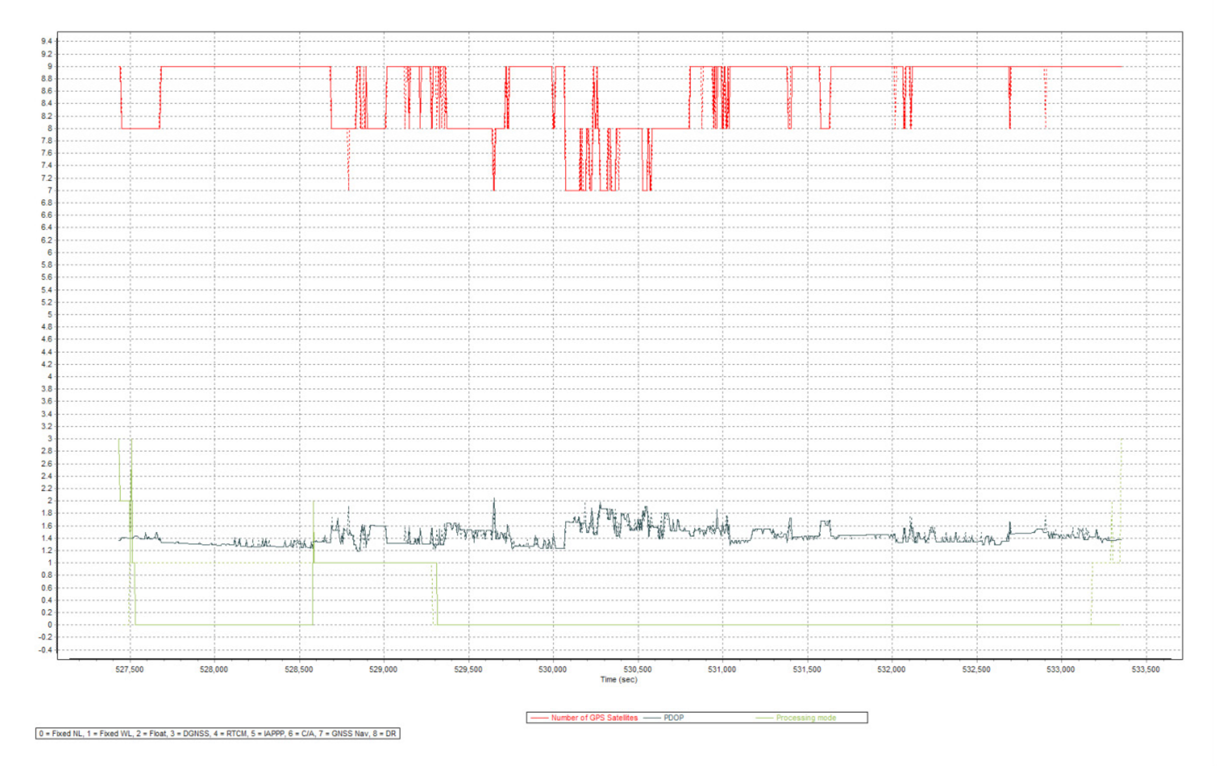


Figure A-8.8. Solution Status

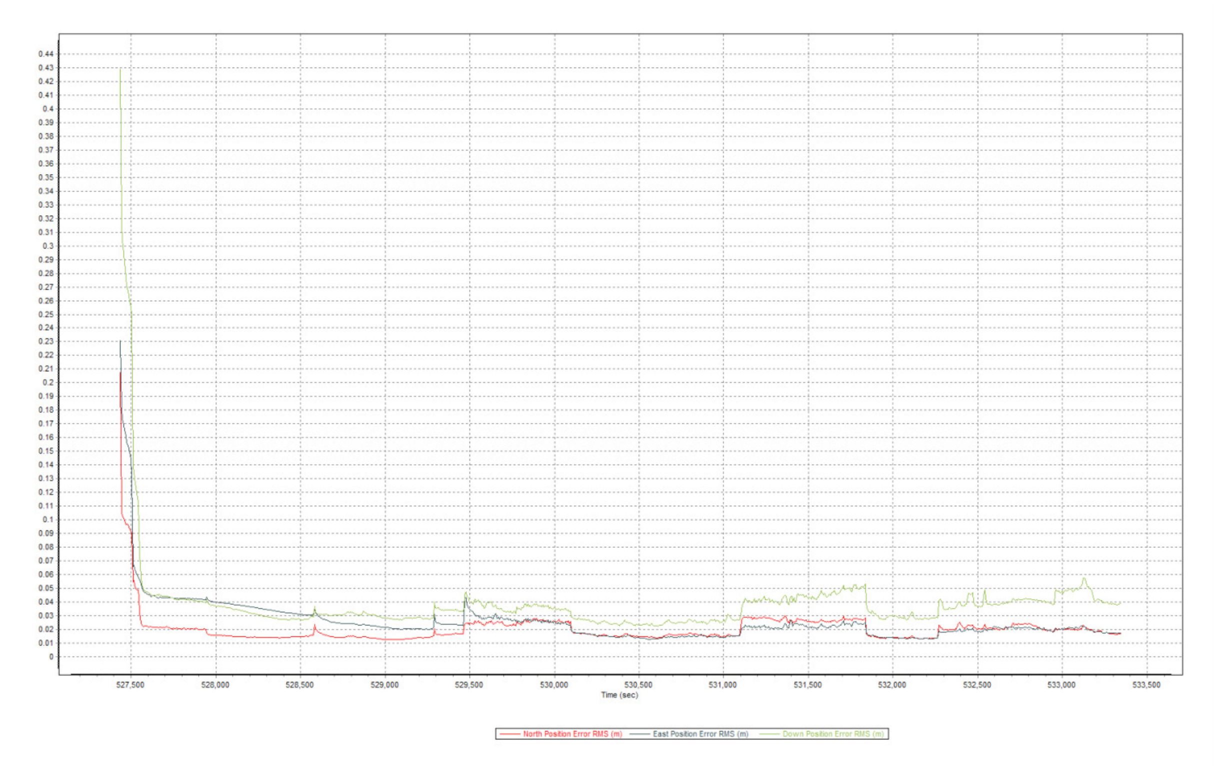


Figure A-8.9. Smoothed Performance Metric Parameters

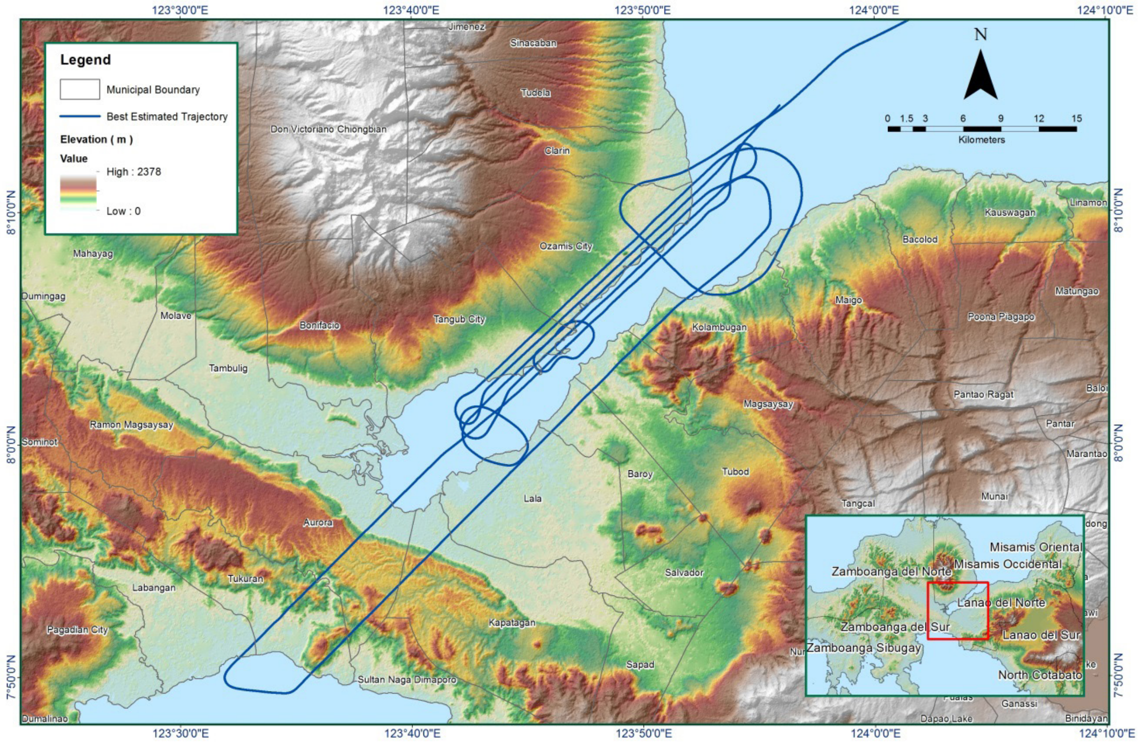


Figure A-8.10. Best Estimated Trajectory

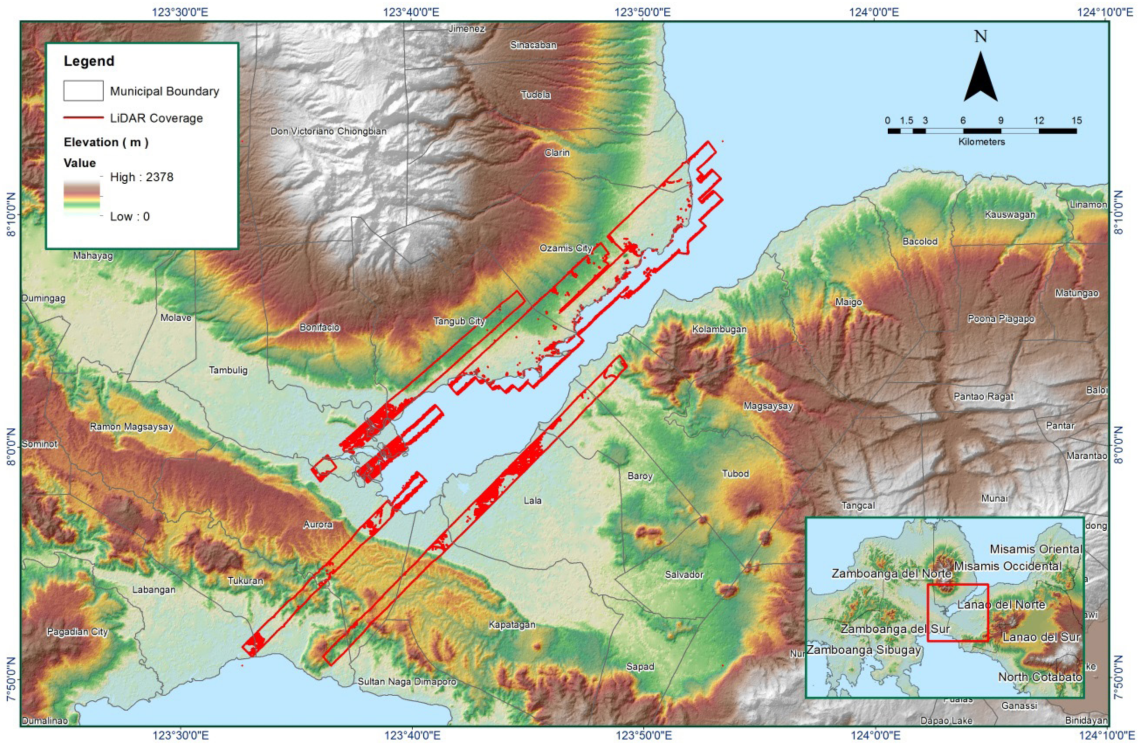


Figure A-8.11. Coverage of LiDAR data

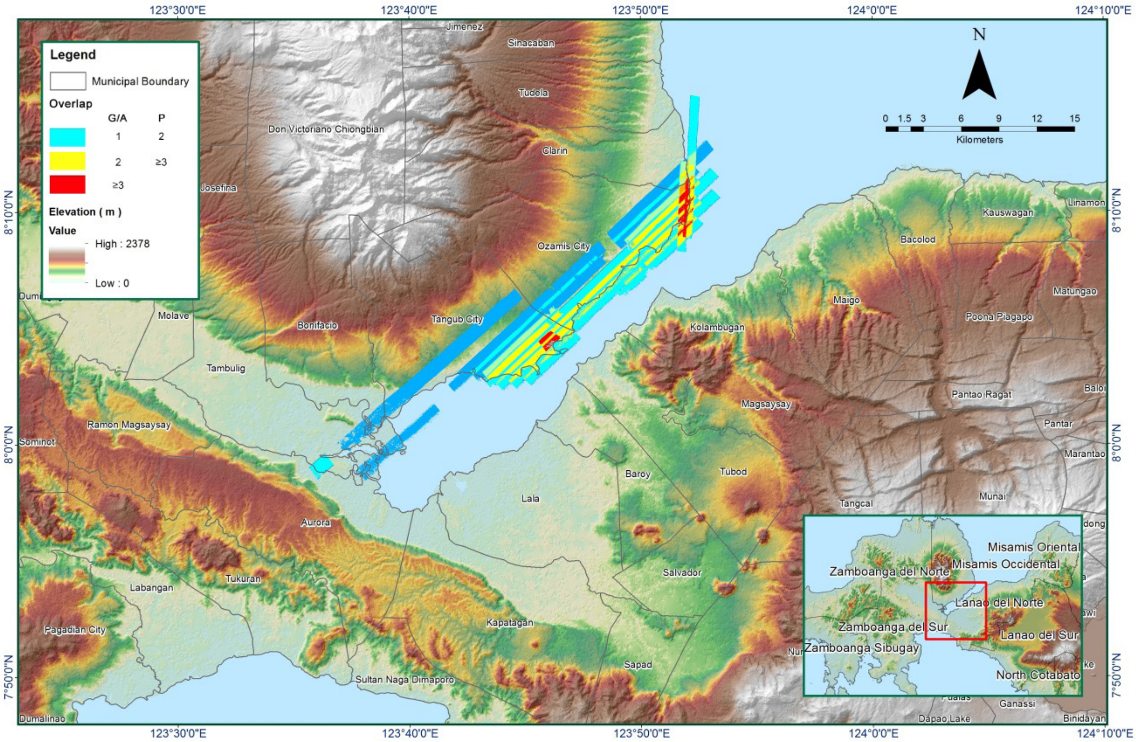


Figure A-8.12. Image of data overlap

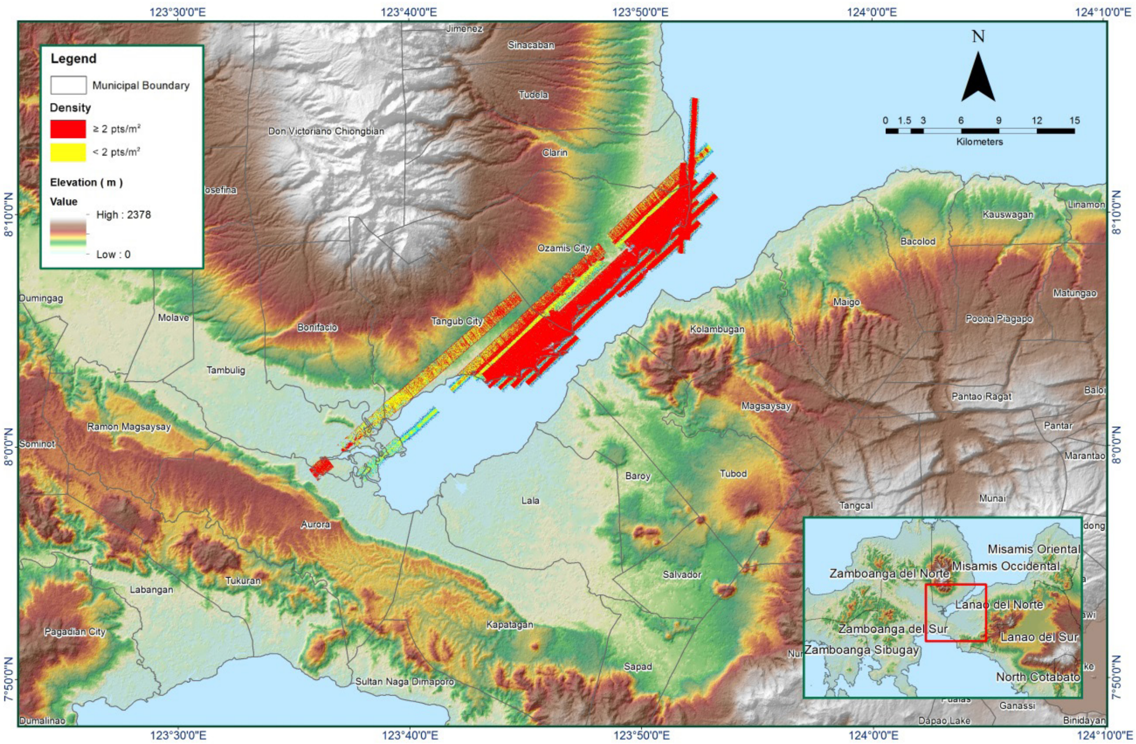


Figure A-8.13. Density map of merged LiDAR data

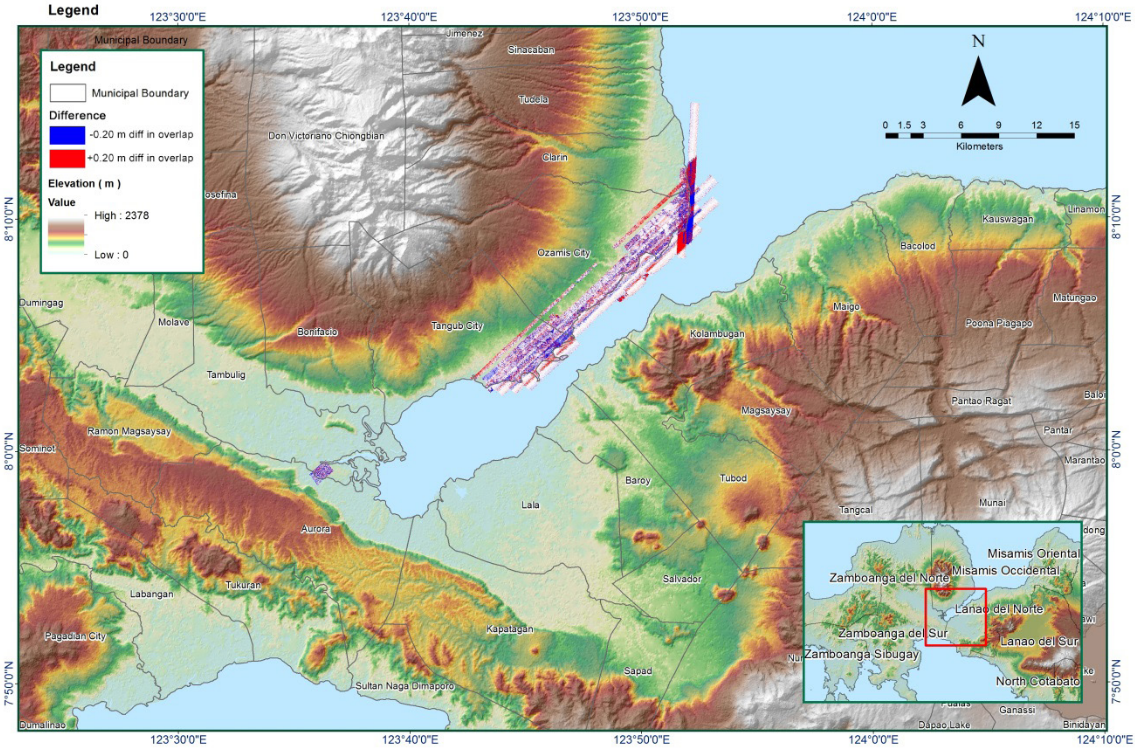


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission 76O

Flight Area	Pagadian
Mission Name	**76O**
Inclusive Flights	23096P
Range data size	7.07
POS data size	164.2
Base data size	90.32
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000290
IMU attitude correction stdev (<0.001deg)	0.002830
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	21.83
Ave point cloud density per sq.m. (>2.0)	4.05
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	87
Maximum Height	355.86 m
Minimum Height	67.90 m
Classification (# of points)	
Ground	58,381,992
Low vegetation	43,493,419
Medium vegetation	47,030,745
High vegetation	157,370,432
Building	4,864,208
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Merven Matthew Natino, Engr. Melissa Fernandez

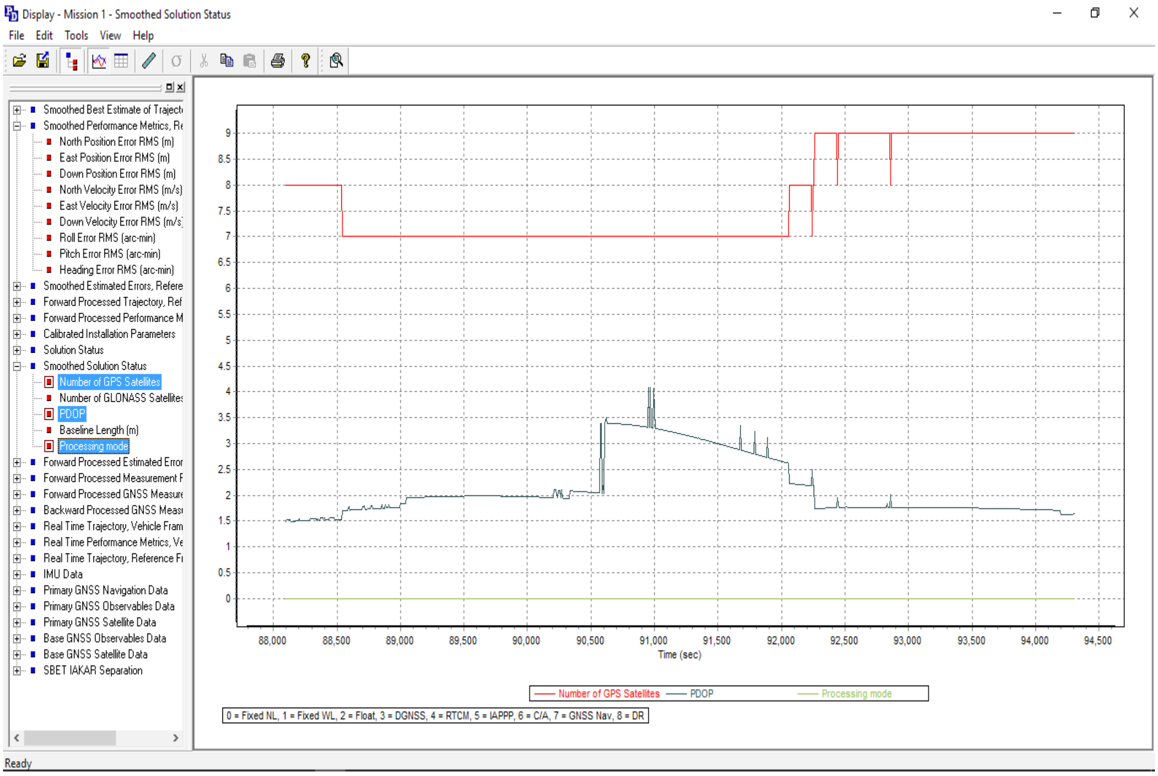


Figure A-8.15. Solution Status

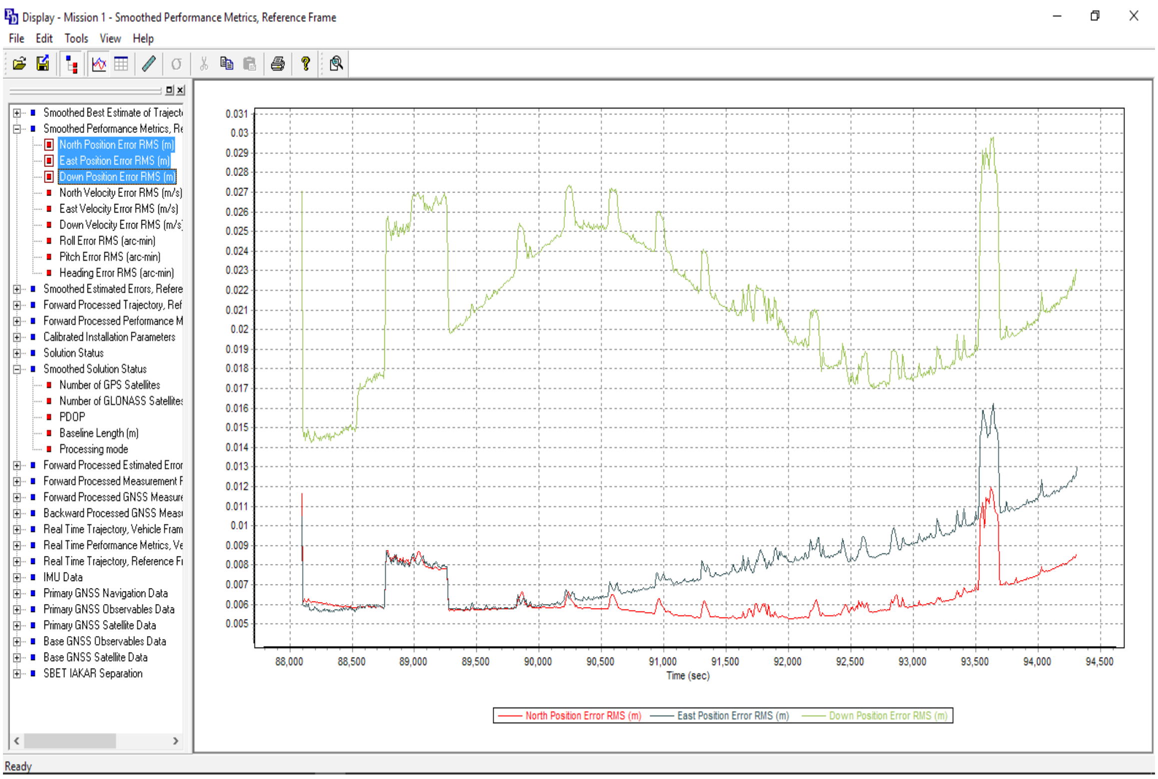


Figure A-8.16. Smoothed Performance Metric Parameters

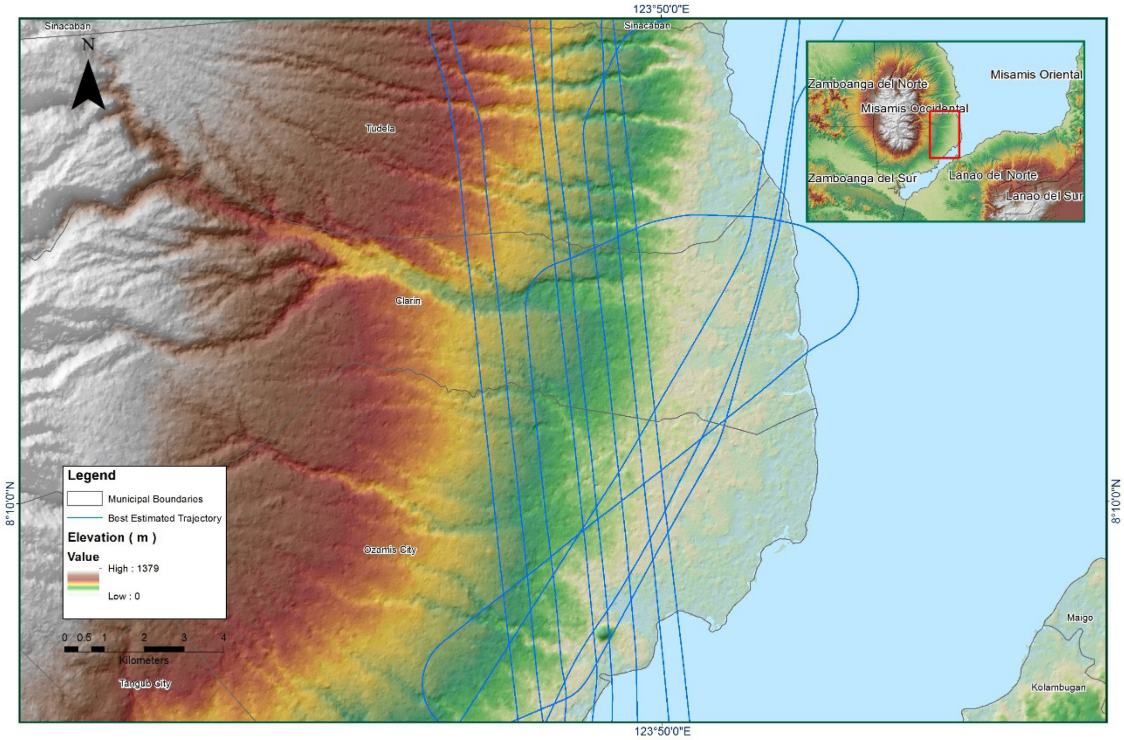


Figure A-8.17. Best Estimated Trajectory

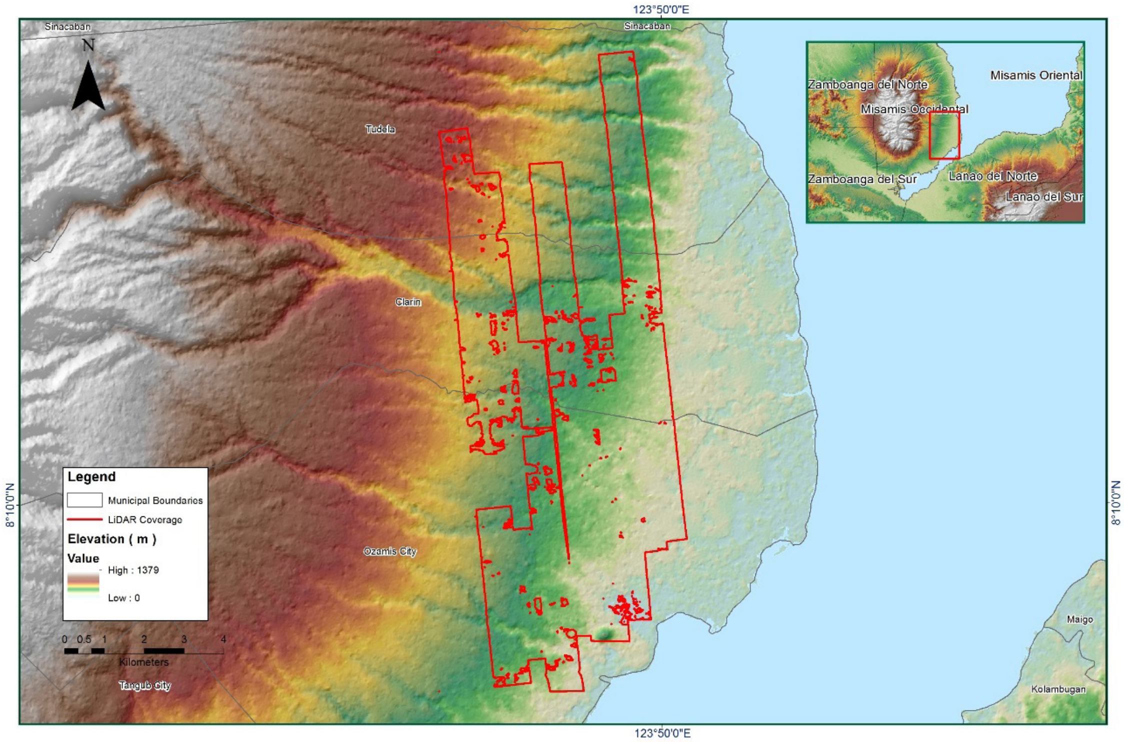


Figure A-8.18. Coverage of LiDAR Data

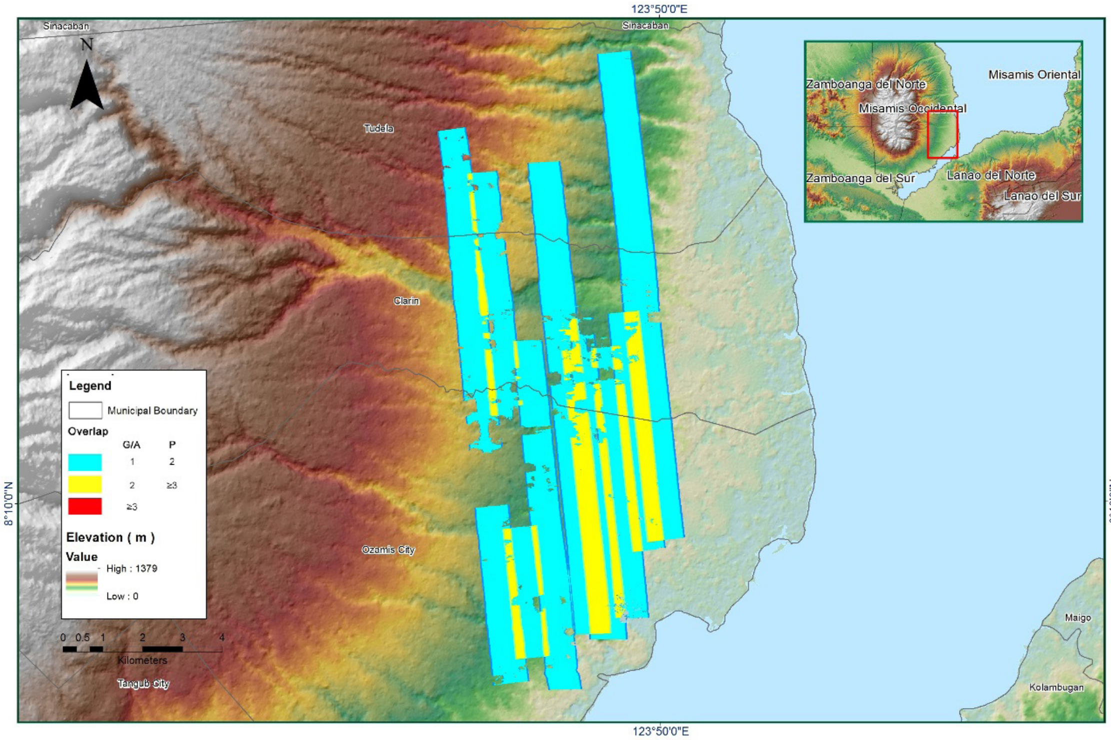


Figure A-8.19. Image of data overlap

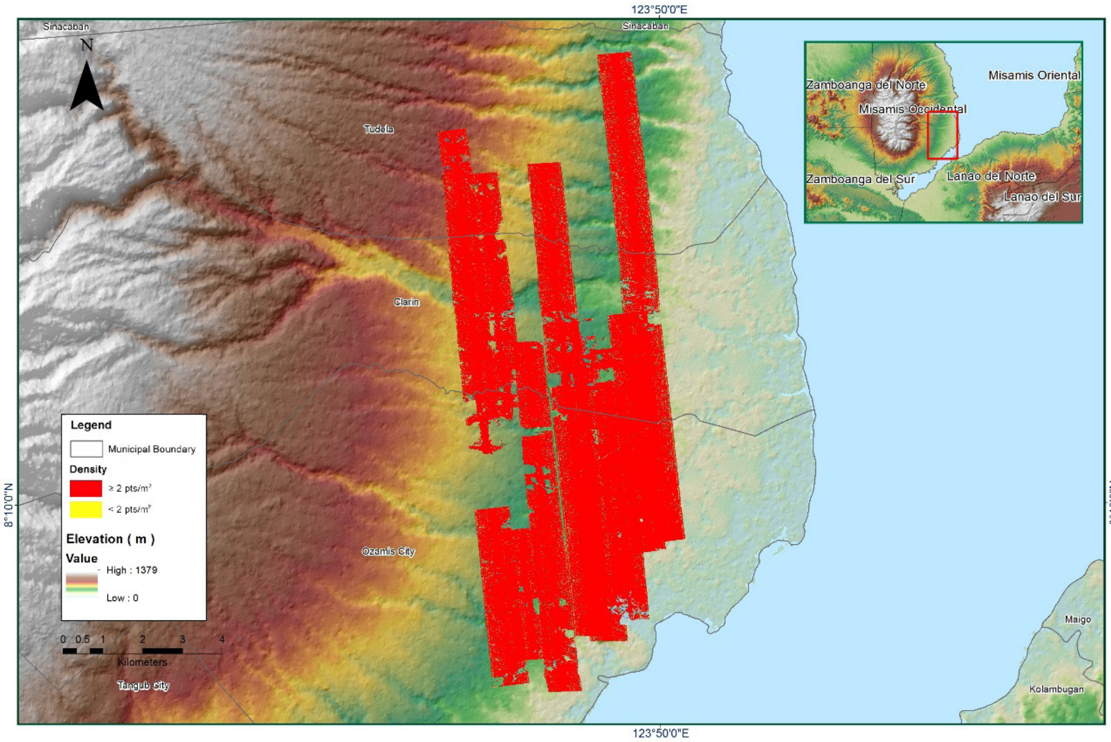


Figure A-8.20. Density map of merged LiDAR data

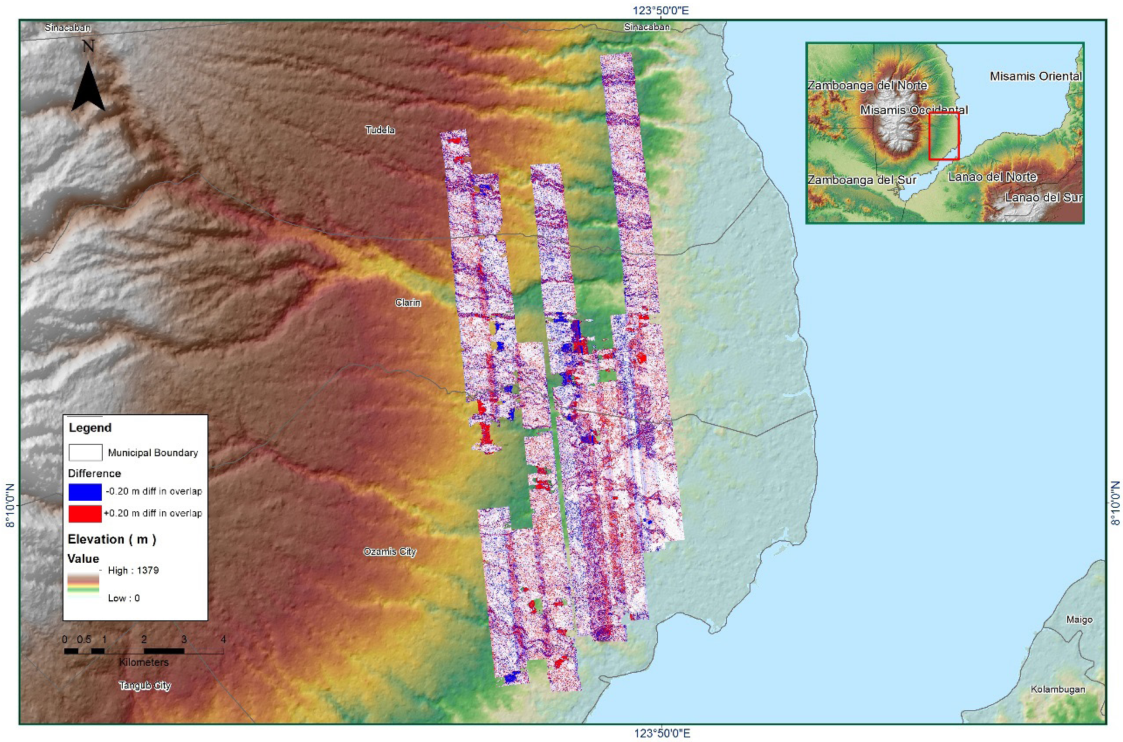


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission 76O_Supplement

Flight Area	Pagadian
Mission Name	**76O_Supplement**
Inclusive Flights	23116P
Range data size	24.4
POS data size	294
Base data size	63.8
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000269
IMU attitude correction stdev (<0.001deg)	0.000354
GPS position stdev (<0.01m)	0.0009
Minimum % overlap (>25)	40.81
Ave point cloud density per sq.m. (>2.0)	4.53
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	50
Maximum Height	285.79 m
Minimum Height	73.96 m
Classification (# of points)	
Ground	50,283,577
Low vegetation	45,189,706
Medium vegetation	43,272,105
High vegetation	148,620,455
Building	3,336,066
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Aljon Rei Araneta, Marie Denise Bueno

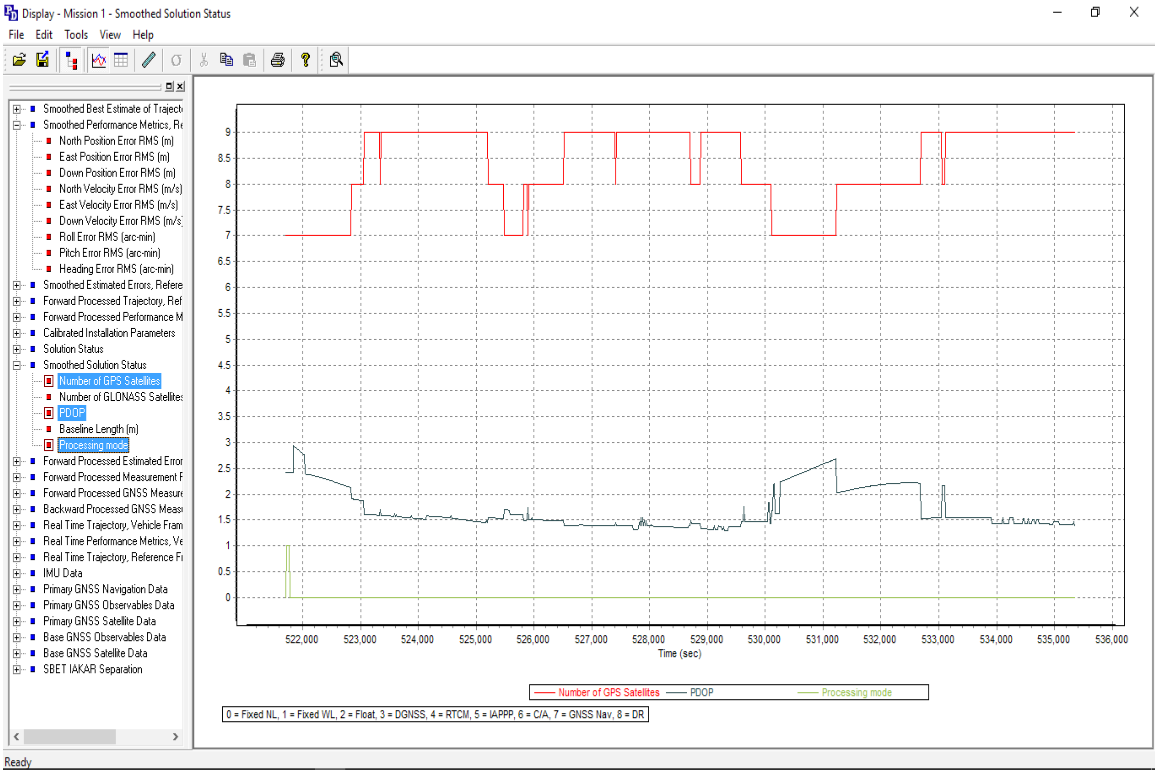


Figure A-8.22. Solution Status

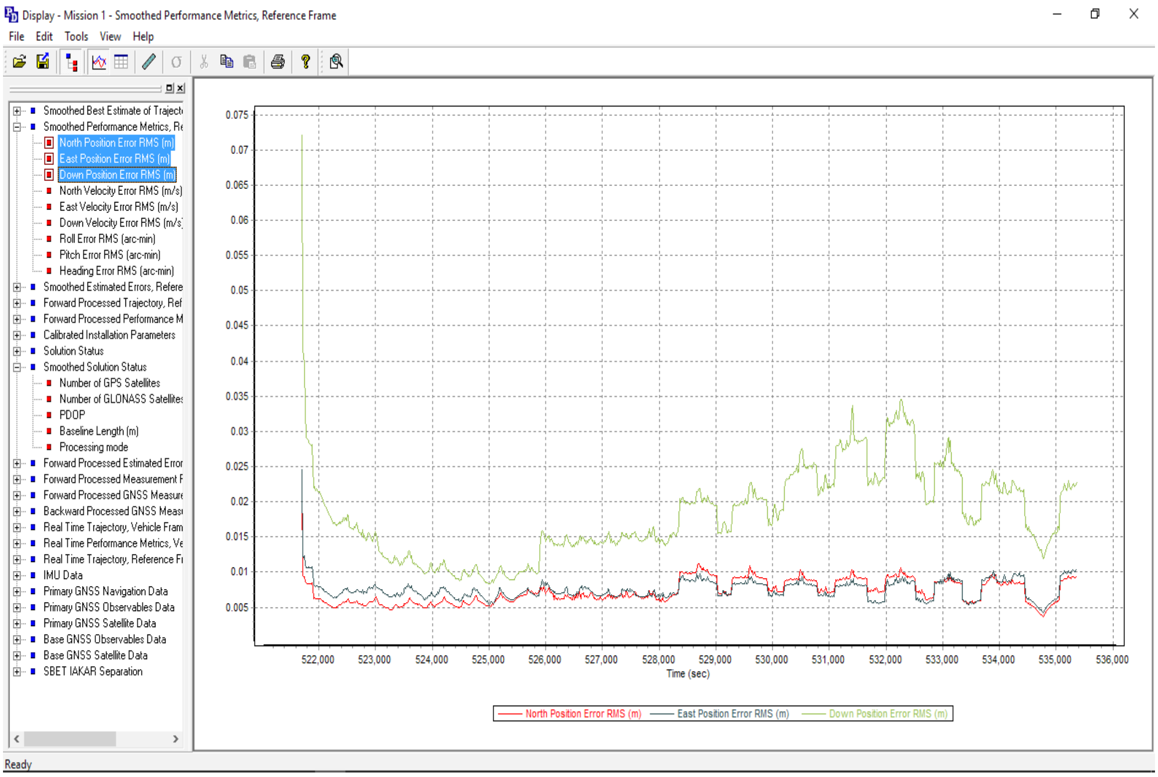


Figure A-8.23. Smoothed Performance Metric Parameters

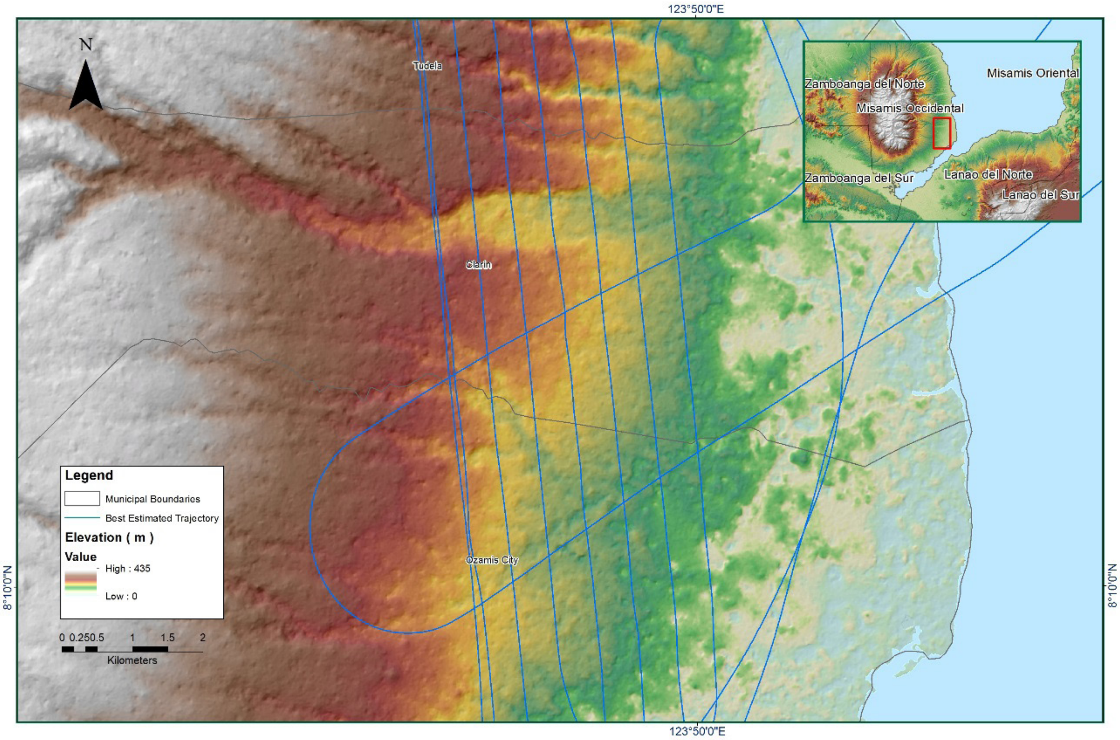


Figure A-8.24. Best Estimated Trajectory

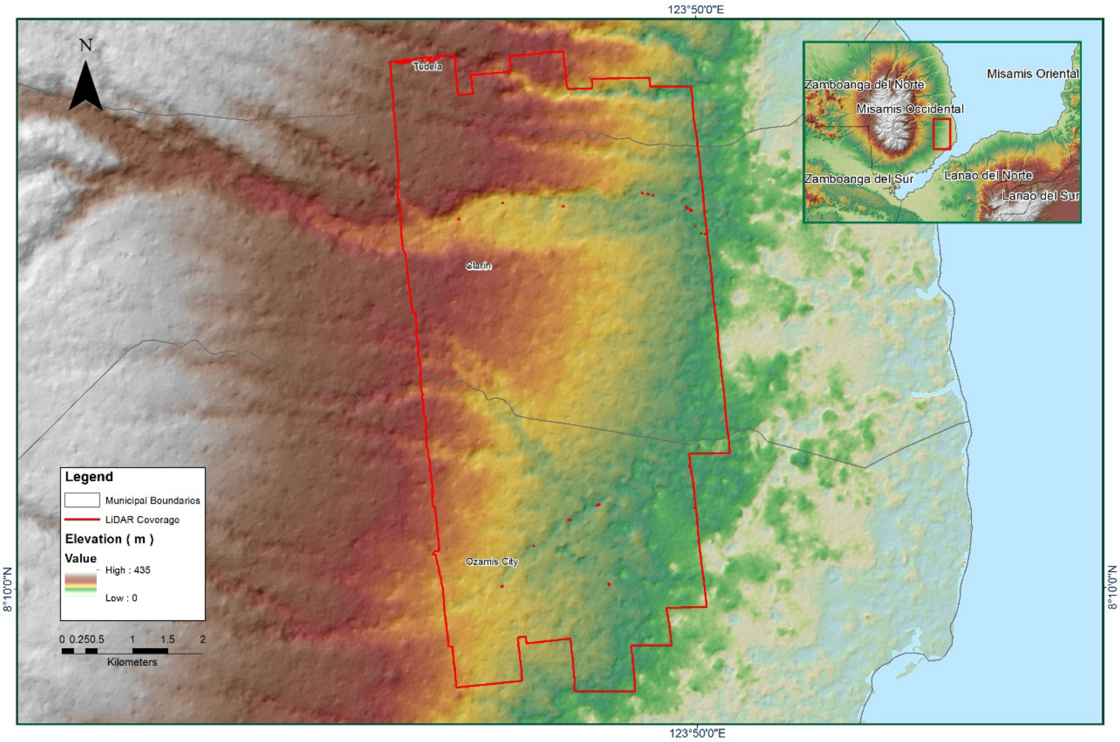


Figure A-8.25. Coverage of LiDAR Data

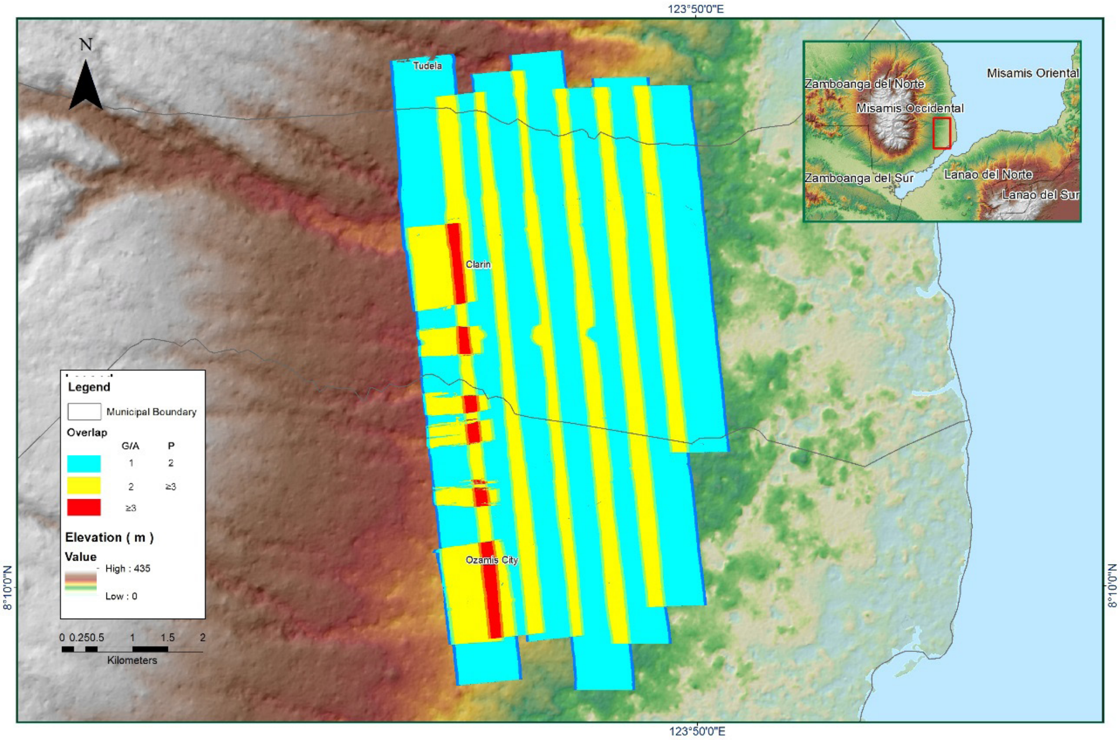


Figure A-8.26. Image of data overlap

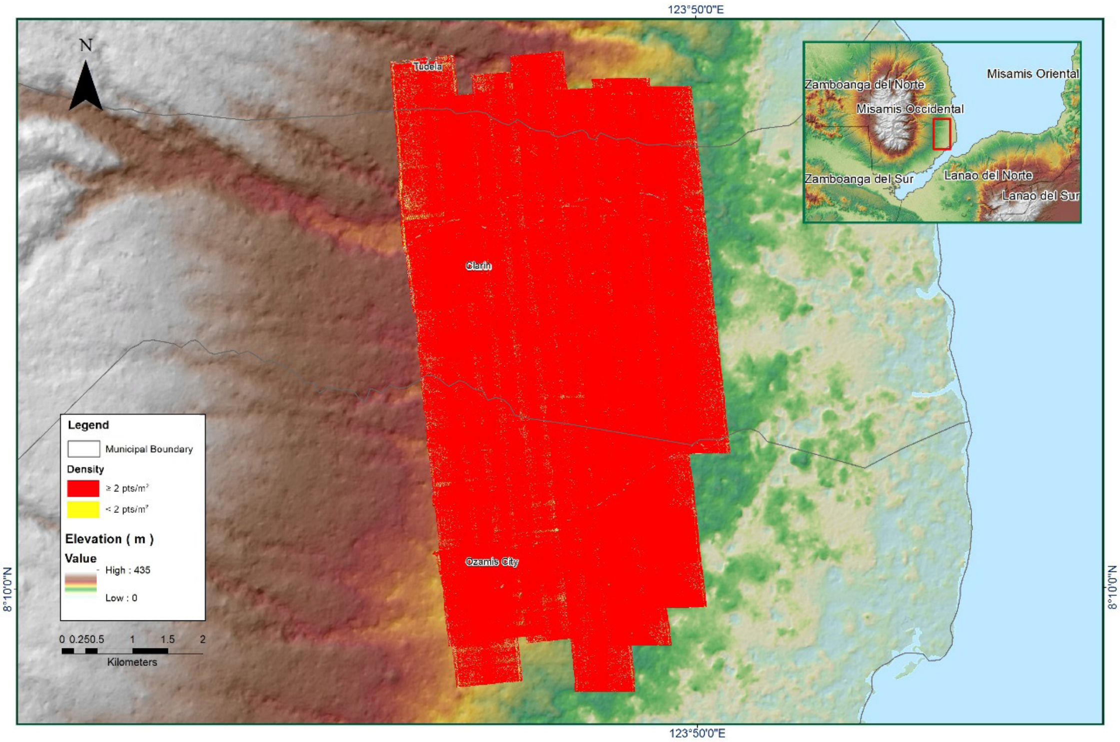


Figure A-8.27. Density map of merged LiDAR data

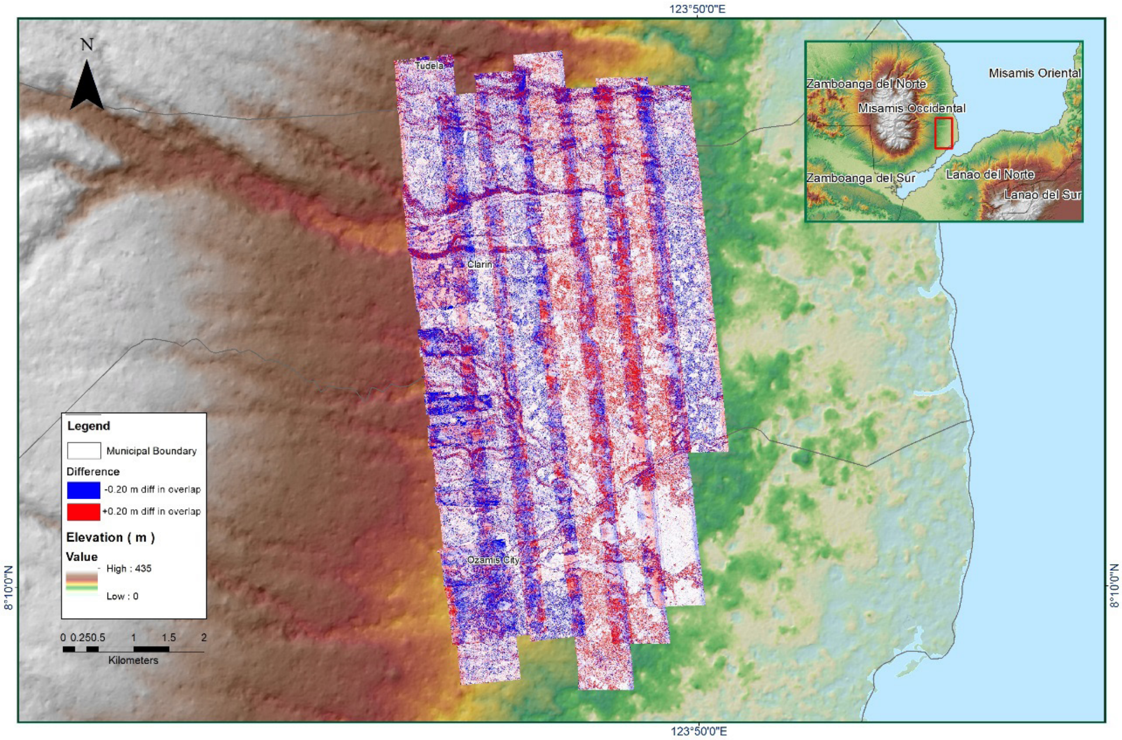


Figure A-8.28. Elevation difference between flight lines

Annex 9. Labo Model Basin Parameters

Table A-9.1. Labo Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W280	7.2917625	75.6687	0	1.4642	3.52749	Discharge	0.20204	0.7	Ratio to Peak	0.5
W290	6.8833875	76.77948	0	1.3797	3.324006	Discharge	0.15405	0.7	Ratio to Peak	0.5
W300	0.96892	80.68812	0	1.2683	1.146597	Discharge	0.16569	0.7	Ratio to Peak	0.5
W310	1.1102	80.08122	0	1.8703	1.909383	Discharge	0.4	0.7	Ratio to Peak	0.5
W320	1.2717375	76.194	0	0.68506	0.7269438	Discharge	0.0802214	0.7	Ratio to Peak	0.5
W330	1.3129875	75.50652	0	1.4479	1.029231	Discharge	0.24516	0.7	Ratio to Peak	0.5
W340	9.932175	78.97656	0	1.1343	2.732619	Discharge	0.33423	0.7	Ratio to Peak	0.5
W350	1.2717375	76.194	0	0.59533	0.9076149	Discharge	0.0728647	0.7	Ratio to Peak	0.5
W360	1.2717375	76.194	0	0.60122	0.96275	Discharge	0.0736348	0.7	Ratio to Peak	0.5
W370	0.84781	76.194	0	1.2146	0.8565765	Discharge	0.12899	0.7	Ratio to Peak	0.5
W380	15.2043375	79.7997	0	1.4101	3.397104	Discharge	0.52096	0.7	Ratio to Peak	0.5
W400	7.5169875	75.07098	0	0.78395	1.8887	Discharge	0.10582	0.7	Ratio to Peak	0.5
W410	8.267325	73.14318	0	0.88664	2.136024	Discharge	0.28795	0.7	Ratio to Peak	0.5
W420	7.234425	75.82272	0	0.98419	2.371128	Discharge	0.12303	0.7	Ratio to Peak	0.5
W440	1.2659625	76.25316	0	1.4367	3.272577	Discharge	0.18323	0.7	Ratio to Peak	0.5
W450	1.1833	78.96534	0	1.3566	1.452567	Discharge	0.3581	0.7	Ratio to Peak	0.5
W460	14.02995	80.46678	0	0.58367	1.501485	Discharge	0.1646245	0.7	Ratio to Peak	0.5
W480	13.9701375	76.20624	0	0.46311	1.115628	Discharge	0.11846	0.7	Ratio to Peak	0.5
W500	0.83948	76.06038	0	2.528	1.791459	Discharge	0.44613	0.7	Ratio to Peak	0.5
W510	10.36695	78.30132	0	0.94388	2.2739523	Discharge	0.21593	0.7	Ratio to Peak	0.5
W520	12.148125	74.62422	0	1.6176	3.896979	Discharge	0.71331	0.7	Ratio to Peak	0.5
W530	1.4860725	80.33928	0	0.96709	1.546125	Discharge	0.3123	0.7	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W540	1.2463	76.194	0	1.2168702	0.8432961	Discharge	0.12068	0.7	Ratio to Peak	0.5

Annex 10. Labo Model Reach Parameters

Table A-10.1. Labo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	1148.4	0.0480172	0.04	Trapezoid	7.742	45
R110	Automatic Fixed Interval	1344.4	0.0144267	0.04	Trapezoid	5.888	45
R120	Automatic Fixed Interval	944.83	0.0092485	0.04	Trapezoid	11.092	45
R150	Automatic Fixed Interval	208.28	0.11556	0.04	Trapezoid	30	45
R170	Automatic Fixed Interval	932.96	0.0118861	0.04	Trapezoid	11.738	45
R210	Automatic Fixed Interval	2973.9	0.0395873	0.04	Trapezoid	8.742	45
R230	Automatic Fixed Interval	1524.4	0.0182775	0.04	Trapezoid	26.526	45
R240	Automatic Fixed Interval	7449.3	0.0671749	0.04	Trapezoid	8.746	45
R250	Automatic Fixed Interval	5245.0	0.0273412	0.04	Trapezoid	15.388	45
R270	Automatic Fixed Interval	2887.5	0.0183577	0.04	Trapezoid	57.984	45
R30	Automatic Fixed Interval	2344.5	0.0297524	0.04	Trapezoid	30	45
R60	Automatic Fixed Interval	1104.0	0.0159183	0.04	Trapezoid	7.0167	45
R70	Automatic Fixed Interval	1838.5	0.0293970	0.04	Trapezoid	30	45

Annex 11. Labo Field Validation Points

Table A-11.1. Labo Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	8.181691	123.862742	0.03	0.00	0.031	December 13, 2013	5 - Year
2	8.181792	123.861759	0.13	0.34	-0.215	December 13, 2013	5 - Year
3	8.182718	123.862323	0.49	0.31	0.183	December 13, 2013	5 - Year
4	8.182843	123.861117	0.52	0.00	0.518	December 13, 2013	5 - Year
5	8.182911	123.861645	0.22	0.00	0.223	December 13, 2013	5 - Year
6	8.151028	123.836492	0.30	0.64	-0.344	December 13, 2013	5 - Year
7	8.150611	123.837538	0.36	0.00	0.357	December 13, 2013	5 - Year
8	8.152691	123.839953	0.03	0.00	0.03	December 13, 2013	5 - Year
9	8.153739	123.838639	0.17	0.41	-0.241	December 13, 2013	5 - Year
10	8.153317	123.840884	0.72	0.55	0.166	December 13, 2013	5 - Year
11	8.154232	123.841615	0.33	0.08	0.249	December 13, 2013	5 - Year
12	8.157700	123.835613	0.03	0.00	0.03	December 13, 2013	5 - Year
13	8.155279	123.843131	0.03	0.00	0.03	December 13, 2013	5 - Year
14	8.159870	123.834179	0.37	0.07	0.299	December 13, 2013	5 - Year
15	8.160466	123.833620	0.80	0.00	0.796	December 13, 2013	5 - Year
16	8.166419	123.835899	2.56	0.21	2.348	December 13, 2013	5 - Year
17	8.167562	123.832945	1.71	0.67	1.037	December 13, 2013	5 - Year
18	8.172263	123.845156	1.59	0.81	0.776	December 13, 2013	5 - Year
19	8.153110	123.852720	0.31	0.64	-0.327	December 13, 2013	5 - Year
20	8.153596	123.853125	0.45	0.61	-0.159	December 13, 2013	5 - Year
21	8.160033	123.855243	0.69	0.00	0.685	December 13, 2013	5 - Year
22	8.161001	123.855706	1.65	0.53	1.121	December 13, 2013	5 - Year
23	8.161544	123.855039	1.76	0.98	0.778	December 13, 2013	5 - Year
24	8.163053	123.856888	0.54	0.57	-0.032	December 13, 2013	5 - Year
25	8.163898	123.857256	0.61	0.39	0.224	December 13, 2013	5 - Year
26	8.164614	123.857432	0.35	0.44	-0.089	December 13, 2013	5 - Year
27	8.166488	123.857792	0.77	0.31	0.461	December 13, 2013	5 - Year
28	8.166660	123.857138	0.03	0.38	-0.349	December 13, 2013	5 - Year
29	8.168421	123.852931	0.57	0.26	0.308	December 13, 2013	5 - Year
30	8.170916	123.847650	0.03	0.00	0.03	December 13, 2013	5 - Year
31	8.169576	123.844975	0.03	0.40	-0.37	December 13, 2013	5 - Year
32	8.167778	123.858368	1.03	0.51	0.522	December 13, 2013	5 - Year
33	8.167577	123.858466	0.77	0.00	0.768	December 13, 2013	5 - Year
34	8.168271	123.858552	0.51	0.18	0.33	December 13, 2013	5 - Year
35	8.169273	123.858708	0.03	0.00	0.03	December 13, 2013	5 - Year
36	8.171266	123.859343	1.10	0.46	0.637	December 13, 2013	5 - Year
37	8.172003	123.859543	0.93	0.05	0.883	December 13, 2013	5 - Year
38	8.172325	123.859710	1.19	0.15	1.035	December 13, 2013	5 - Year
39	8.173823	123.860316	1.57	0.72	0.847	December 13, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
40	8.174359	123.860551	1.40	0.85	0.554	December 13, 2013	5 - Year
41	8.175037	123.860795	1.29	0.81	0.477	December 13, 2013	5 - Year
42	8.175351	123.860704	1.15	0.54	0.613	December 13, 2013	5 - Year
43	8.175637	123.861079	1.30	0.53	0.766	December 13, 2013	5 - Year
44	8.177293	123.861134	0.83	0.28	0.545	December 13, 2013	5 - Year
45	8.177819	123.861412	1.04	0.75	0.289	December 13, 2013	5 - Year
46	8.178227	123.861456	1.44	0.46	0.975	December 13, 2013	5 - Year
47	8.179259	123.861515	1.27	0.51	0.761	December 13, 2013	5 - Year
48	8.179929	123.860888	1.06	0.45	0.606	December 13, 2013	5 - Year
49	8.179754	123.861083	1.10	0.00	1.099	December 13, 2013	5 - Year
50	8.180114	123.857034	0.03	0.12	-0.09	December 13, 2013	5 - Year
51	8.179902	123.856012	0.03	0.00	0.03	December 13, 2013	5 - Year
52	8.180233	123.853042	0.03	0.00	0.03	December 13, 2013	5 - Year
53	8.183675	123.860541	0.85	0.00	0.849	December 13, 2013	5 - Year
54	8.183457	123.860380	1.10	0.76	0.338	December 13, 2013	5 - Year
55	8.183196	123.860377	1.12	0.38	0.741	December 13, 2013	5 - Year
56	8.181970	123.860438	0.71	0.00	0.708	December 13, 2013	5 - Year
57	8.183087	123.859952	0.73	0.36	0.369	December 13, 2013	5 - Year
58	8.181658	123.861107	1.07	0.61	0.456	December 13, 2013	5 - Year
59	8.180027	123.861561	0.64	0.89	-0.249	December 13, 2013	5 - Year
60	8.180476	123.860299	0.58	0.05	0.532	December 13, 2013	5 - Year
61	8.181965	123.860039	0.67	0.46	0.214	December 13, 2013	5 - Year
62	8.180793	123.857728	0.39	0.51	-0.118	December 13, 2013	5 - Year
63	8.182176	123.857874	0.30	0.54	-0.244	December 13, 2013	5 - Year
64	8.182286	123.857557	0.14	0.18	-0.036	December 13, 2013	5 - Year
65	8.180936	123.859088	0.03	0.00	0.03	December 13, 2013	5 - Year
66	8.181078	123.859508	0.53	0.43	0.098	December 13, 2013	5 - Year
67	8.182355	123.856226	0.07	0.18	-0.115	December 13, 2013	5 - Year
68	8.182848	123.858696	0.45	0.35	0.097	December 13, 2013	5 - Year
69	8.182597	123.855262	0.06	0.52	-0.464	December 13, 2013	5 - Year
70	8.183011	123.854525	0.03	0.28	-0.25	December 13, 2013	5 - Year
71	8.181447	123.850258	0.11	0.63	-0.522	December 13, 2013	5 - Year
72	8.150770	123.851729	0.09	0.10	-0.013	December 13, 2013	5 - Year
73	8.151291	123.853969	0.26	0.74	-0.483	December 13, 2013	5 - Year
74	8.150123	123.850861	0.37	0.11	0.264	December 13, 2013	5 - Year
75	8.170588	123.859511	0.03	0.00	0.03	December 13, 2013	5 - Year
76	8.169448	123.862199	1.51	0.23	1.282	December 13, 2013	5 - Year
77	8.172495	123.860703	0.89	0.00	0.891	December 13, 2013	5 - Year
78	8.173014	123.860305	1.20	0.51	0.687	December 13, 2013	5 - Year
79	8.172732	123.860836	1.17	0.53	0.644	December 13, 2013	5 - Year
80	8.175252	123.862020	0.42	0.05	0.367	December 13, 2013	5 - Year
81	8.170914	123.861080	1.58	0.81	0.77	December 13, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	8.171188	123.860791	1.51	0.83	0.677	December 13, 2013	5 - Year
83	8.173230	123.860514	1.27	0.48	0.785	December 13, 2013	5 - Year
84	8.173650	123.860738	1.07	0.83	0.237	December 13, 2013	5 - Year
85	8.154299	123.854037	0.46	0.23	0.225	December 13, 2013	5 - Year
86	8.157817	123.855106	0.03	0.10	-0.07	December 13, 2013	5 - Year
87	8.161978	123.856573	0.03	0.33	-0.3	December 13, 2013	5 - Year
88	8.160989	123.856426	0.91	0.85	0.063	December 13, 2013	5 - Year
89	8.162060	123.857939	1.74	1.41	0.334	December 13, 2013	5 - Year
90	8.148849	123.839840	0.20	0.53	-0.328	December 13, 2013	5 - Year
91	8.145893	123.842948	0.03	0.00	0.03	December 13, 2013	5 - Year
92	8.146214	123.844256	0.21	0.12	0.091	December 13, 2013	5 - Year
93	8.149732	123.841752	0.27	0.31	-0.04	December 13, 2013	5 - Year
94	8.147377	123.844454	0.39	0.06	0.328	December 13, 2013	5 - Year
95	8.147933	123.843936	0.21	0.46	-0.247	December 13, 2013	5 - Year
96	8.151914	123.840202	0.27	0.31	-0.043	December 13, 2013	5 - Year
97	8.150299	123.842005	0.41	0.47	-0.056	December 13, 2013	5 - Year
98	8.146614	123.845504	0.23	0.21	0.015	December 13, 2013	5 - Year
99	8.147635	123.844595	0.73	0.00	0.729	December 13, 2013	5 - Year
100	8.148163	123.844090	0.28	0.75	-0.47	December 13, 2013	5 - Year
101	8.149072	123.849077	0.03	0.00	0.03	December 13, 2013	5 - Year
102	8.148784	123.848228	0.43	0.20	0.227	December 13, 2013	5 - Year
103	8.151549	123.851674	0.03	0.33	-0.3	December 13, 2013	5 - Year
104	8.152538	123.849907	0.36	0.35	0.009	December 13, 2013	5 - Year
105	8.152162	123.850133	0.45	0.37	0.075	December 13, 2013	5 - Year
106	8.155532	123.845057	0.22	0.06	0.156	December 13, 2013	5 - Year
107	8.154430	123.848312	0.03	0.00	0.03	December 13, 2013	5 - Year
108	8.145452	123.840903	0.59	0.17	0.422	December 13, 2013	5 - Year
109	8.148276	123.838740	0.44	0.32	0.117	December 13, 2013	5 - Year
110	8.145267	123.840312	0.36	0.33	0.026	December 13, 2013	5 - Year
111	8.144239	123.837811	0.30	0.23	0.07	December 13, 2013	5 - Year
112	8.143757	123.833172	0.58	0.72	-0.144	December 13, 2013	5 - Year
113	8.137904	123.829975	1.05	1.18	-0.126	December 13, 2013	5 - Year
114	8.137910	123.829309	1.26	1.01	0.252	December 13, 2013	5 - Year
115	8.138155	123.829515	1.22	0.96	0.262	December 13, 2013	5 - Year
116	8.139492	123.829974	1.24	0.90	0.344	December 13, 2013	5 - Year
117	8.139866	123.830337	1.23	0.94	0.285	December 13, 2013	5 - Year
118	8.138607	123.829167	0.43	0.83	-0.401	December 13, 2013	5 - Year
119	8.149670	123.828907	0.06	0.00	0.062	December 13, 2013	5 - Year
120	8.149350	123.832887	1.22	0.51	0.709	December 13, 2013	5 - Year
121	8.147247	123.827558	0.80	0.53	0.269	December 13, 2013	5 - Year
122	8.140564	123.829966	0.85	0.80	0.045	December 13, 2013	5 - Year
123	8.141495	123.828658	1.33	1.18	0.147	December 13, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
124	8.148634	123.827498	0.48	0.18	0.304	December 13, 2013	5 - Year
125	8.149966	123.827568	0.74	0.18	0.561	December 13, 2013	5 - Year
126	8.148805	123.820300	2.57	0.00	2.572	December 13, 2013	5 - Year
127	8.148754	123.820456	1.05	0.00	1.05	December 13, 2013	5 - Year
128	8.149318	123.820082	2.15	0.00	2.145	December 13, 2013	5 - Year
129	8.145300	123.846968	0.05	0.36	-0.307	December 13, 2013	5 - Year
130	8.145763	123.846335	0.03	0.00	0.03	December 13, 2013	5 - Year
131	8.144409	123.844492	0.21	0.11	0.096	December 13, 2013	5 - Year
132	8.144574	123.844748	0.30	0.51	-0.213	December 13, 2013	5 - Year
133	8.144377	123.841895	0.48	0.00	0.478	December 13, 2013	5 - Year
134	8.143009	123.841518	0.55	0.13	0.416	December 13, 2013	5 - Year
135	8.143610	123.838716	0.03	0.00	0.03	December 13, 2013	5 - Year
136	8.141560	123.832916	0.03	0.00	0.03	December 13, 2013	5 - Year
137	8.148037	123.815561	2.06	0.00	2.057	December 13, 2013	5 - Year
138	8.149052	123.820180	2.85	0.00	2.848	December 13, 2013	5 - Year
139	8.147800	123.818602	0.31	0.00	0.311	December 13, 2013	5 - Year
140	8.148283	123.820302	3.45	1.16	2.291	December 13, 2013	5 - Year
141	8.140245	123.826765	1.37	1.21	0.159	December 13, 2013	5 - Year
142	8.137173	123.826253	0.03	0.00	0.03	December 13, 2013	5 - Year
143	8.136403	123.829233	1.29	0.59	0.701	December 13, 2013	5 - Year

Annex 12. Educational Institutions Affected by Flooding in Labo Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Labo Floodplain – Clarin, Misamis Occidental

MISAMIS OCCIDENTAL				
CLARIN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Dolores Elementary School	Canibungan Daku			
Masabud Elementary School	Canipacan	Medium	Medium	High
Dolores Elementary School	Dolores			
Clarin Elementary School	Gata Daku	Medium	Medium	Medium
Clarin National High School	Gata Daku	Medium	Medium	Medium
Day Care Center	Gata Daku			
Gata Daku Elementary School	Gata Daku		Low	Low
Day Care Center	Gata Diot	Medium	Medium	Medium
Day Care Center	Kinangay Norte	High	High	High
Kinangay Norte Elementary School	Kinangay Norte			
Segatic Daku Elementary School	Kinangay Norte			
Tinacla-an Elementary School	Kinangay Norte	Medium	Medium	High
Segatic Elementary School	Kinangay Norte			
Kinangay Sur Elementary School	Kinangay Sur			
Purok High Reading Center	Kinangay Sur	Low	Low	Low
Day Care Center	Lapasan	Medium	Medium	Medium
ECCD Day Care Center	Lapasan	Medium	Medium	Medium
Lapasan Elementary School	Lapasan	Medium	Medium	Medium
San Roque Elementary School	Lapasan	Medium	Medium	Medium
St. Anne School of Clarin	Lapasan	Medium	Medium	Medium
Day Care Center	Lupagan	Low	Medium	Medium
International Greece Bible Institute	Lupagan	Low	Medium	Medium
Lupagan Elementary School	Lupagan	Low	Medium	Medium
Purok High Reading Center	Masabud	Medium	High	High
Emmanuel Christian Academy	Mialen	Low	Medium	Medium
Mialen Barra Day Care Center	Mialen	Medium	Medium	Medium
Mialen Central School	Mialen	Low	Medium	Medium
Clarin National High School Annex	Pan-Ay	Medium	Medium	Medium
Day Care Center	Pan-Ay	Medium	High	High
ECCD Day Care Center	Pan-Ay	High	High	High
Pan-ay Elementary School	Pan-Ay	Medium	Medium	High
Clarin Elementary School	Poblacion I	Low	Medium	Medium
GDMPC Learning Center	Poblacion I	Low	Medium	Medium
Holy Child Elementary School	Poblacion I		Low	Medium
Holy Child High School	Poblacion I	Low	Medium	Medium
San Roque Elementary School	Poblacion II	Medium	Medium	High
Anteru	Poblacion III		Low	Low
Day Care Center	Poblacion III	Medium	Medium	Medium

MISAMIS OCCIDENTAL				
CLARIN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Holy Child Elementary School	Poblacion III		Low	Medium
Clarin National High School	Poblacion IV	Medium	Medium	Medium
Canicapan Elementary School	Segatic Daku			Low
Day Care Center	Segatic Daku			

Table A-12.2. Educational Institutions Affected by Flooding in the Labo Floodplain – Calabayan City, Misamis Occidental

MISAMIS OCCIDENTAL				
Calabayan CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Landon Academy	50th District			
Calabayan City Central School	50th District			
PSALMS Christian Academy	50th District			
FMC MA School	Aguada			
ADC Elementary School	Bacolod		Low	Low
Anrea D. Costonera Elementary School	Bacolod	Low	Low	Low
Bacolod Elementary School	Bacolod			
Brgy. Aguada Day Care Literacy Center	Bacolod			
DEPED	Bacolod			
Firm Foundation Christian Academy	Bacolod			
Golden Horizon Pension House	Bacolod			
LSU College Building	Bacolod	Low	Low	Medium
LSU College Building Medium	Bacolod	Low	Low	Low
LSU High School Building	Bacolod			Low
LSU Integrated School	Bacolod			
Montessori Center-Kindergarten	Bacolod			
Our Lady of the Angels School	Bacolod			
Calabayan City Technical and Vocational School	Bacolod			
Tutorial Center	Bacolod			
Sancho Capa Elementary School	Bagakay			
Misamis Institute of Technology	Banadero			
Misamis Instiute of Technology	Banadero			
Basakan Day Care Center	Baybay San Roque	Low	Low	Medium
City Library	Baybay San Roque			
Day Care Center	Baybay San Roque			
Calabayan City Central School	Baybay San Roque			
Calabayan City Christian School	Baybay San Roque			Low
Calabayan City National High School	Baybay San Roque			Low
Sta. Cruz Elementary School	Baybay Santa Cruz			
Day Care Center	Baybay Santa Cruz			
Baybay Central School	Baybay Triunfo			Low

MISAMIS OCCIDENTAL				
Calabayan CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Day Care Center	Baybay Triunfo			
IHL	Baybay Triunfo			
WMST	Baybay Triunfo			
ALS Bldg.	Baybay Triunfo			Low
Faustino C. Decena Elementary School	Carangan			
Saint John Paul College Seminary	Carangan			Low
Day Care Center	Carangan			
Faustino C. Decena Elementary School	Carangan	Low	Low	Low
LSU College Building	Carmen	Low	Low	Medium
LSU Guard House - Entrance	Carmen	Low	Low	Low
LSU High School Building	Carmen		Low	Low
LSU Lobby	Carmen		Low	Low
LSU Registrar's Office	Carmen			
Misamis Annex Integrated School	Carmen			
Catadman Elementary School	Catadman-Manabay	Low	Low	Medium
Labo Day Care Center	Embargo	Medium	Medium	Medium
Gango Elementary School	Gango	Medium	Medium	Medium
San Antonio Elementary School	Gango	Medium	Medium	Medium
San Antonio Elementary School	Gango	Medium	Medium	Medium
San Antonio National High School	Gango	Low	Medium	Medium
Labo Central School	Labo	Medium	Medium	Medium
Labo Central School Stage	Labo		Medium	Medium
Labo National High School	Labo	Medium	Medium	Medium
Labo Central School Gym	Labo	Low	Medium	Medium
Misamis Union High School	Lam-An			
Misamis University	Lam-An			
MU Ma. Mercado Building	Lam-An			Low
MU Main Library	Lam-An		Low	Low
Calabayan City Christian School	Lam-An		Low	Low
Sanctuary Christian Academy	Lam-An			
Day Care Center	Malaubang			
Malaubang Integrated School	Malaubang		Low	Low
Maningcol Elementary School	Maningcol	Medium	Medium	Medium
Medina College	Maningcol	Medium	Medium	Medium
Medina Medical College	Maningcol	Medium	Medium	Medium
OCSAT	Maningcol	Medium	Medium	Medium
Domingo A. Barloa Elementary School	Molicay	Low	Medium	Medium
Doña Consuelo Elementary School	San Antonio	Low	Medium	Medium
Malanoy Day Care Center	San Antonio	Medium	Medium	Medium
San Antonio Day Care Center	San Antonio	Medium	Medium	Medium
Basakan Day Care Center	Tinago		Low	Low

Annex 13. Medical Institutions Affected by Flooding in Labo Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Labo Floodplain – Clarin, Misamis Occidental

MISAMIS OCCIDENTAL				
CLARIN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Canipacan	Medium	Medium	Medium
Health Center	Dolores			Low
Health Center	Gata Daku	Low	Medium	Medium
Health Center	Gata Diot	Medium	Medium	Medium
Health Center	Kinangay Norte			
Health Center	Lapasan	Medium	Medium	Medium
Botika ng Bayan	Lupagan	Low	Medium	Medium
Health Center	Lupagan	Low	Medium	Medium
Health Center	Masabud	Medium	Medium	Medium
Health Center	Pan-Ay	Medium	Medium	Medium
Municipal Health Office	Poblacion I		Medium	Medium
Municipal Health Office	Poblacion II		Low	Low
Brgy. Poblacion Medium Health Center	Poblacion III	Medium	Medium	Medium
Olegario General Hospital	Poblacion IV	Low	Medium	Medium
Health Center	Segatic Daku			

Table A-13.2. Medical Institutions Affected by Flooding in the Labo Floodplain – Calabayan City, Misamis Occidental

MISAMIS OCCIDENTAL				
Calabayan CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Lourdes Pharmacy	50th District	Low	Medium	Medium
Metro Lab Center	50th District			
Calabayan Mercury Drug Main	50th District			
St. Joseph General Hospital	50th District			
St. Joseph General Hospital	Aguada			
Health Center	Bacolod			Low
St. Cecile Diagnostics	Bacolod			
MU Medical Center	Bagakay			
Birthing Place	Baybay San Roque			
Community Hospital	Baybay San Roque			
Health Center	Baybay San Roque			Low
Dra. Juat Optical Clinic	Baybay Santa Cruz	Low	Low	Low
Love Mae Pharmacy	Baybay Santa Cruz			Low
Rose Pharmacy	Baybay Santa Cruz	Low	Low	Low
St. Joseph General Hospital	Baybay Santa Cruz			
Acebedo Optical Clinic	Baybay Triunfo			
Brgy Carmen Health Center	Baybay Triunfo			Low

MISAMIS OCCIDENTAL				
Calabayan CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Clinic	Baybay Triunfo		Low	Low
De Guzman Clinic	Baybay Triunfo			
Dr. Villaseran Clinic	Baybay Triunfo			Low
Dr. Ybañez Clinic	Baybay Triunfo			
Proposed Birthing Clinic	Baybay Triunfo			
Health Center	Carangan	Low	Low	Low
Family General Hospital	Carmen			Low
Medina Hospital	Carmen			Low
SM Lao Memorial General Hospital	Catadman-Manabay	Low	Low	Medium
Maningcol Sub Health Center	Doña Consuelo			Low
Health Center	Gango	Medium	High	High
Labo Health Center	Labo	Low	Medium	Medium
Animal Aide Clinic	Lam-An			
Faith Hospital Bldg. Low	Lam-An			
Faith Hospital Bldg. Medium	Lam-An	Low	Low	Low
Faith Hospital Bldg. High	Lam-An		Low	Low
Faith Hospital Guard House	Lam-An	Low	Low	Low
Zion Drugmart	Lam-An			
Gems Lying-in	Maningcol	Medium	Medium	Medium
SM Lao Memorial General Hospital	Maningcol		Low	Low
Brgy Health Center and BNS Office	San Antonio	Medium	Medium	Medium
MHARS TTH	San Antonio			