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

LiDAR Surveys and Flood Mapping of Lumintao River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños
Department of Science and Technology

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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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]
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
UPB	University of the Philippines Baguio
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 LUMINTAO RIVER

Dr. Chelo Pascua and Enrico C. Paringit, Dr. Eng., Dante Gideon K. Vergara

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Banos (UPLB). UPLB 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 45 river basins in the MIMAROPA Region. The university is located at Los Banos, Laguna.

1.2 Overview of the Lumintao River Basin

Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

Lumintao River Basin is a 3,710-hectare watershed located in Occidental Mindoro. It covers the barangays of San Agustin, San Francisco, San Nicolas, San Vicente, Lagnas, Malisbong, Batong Buhay, Buenavista, Burgos, Ligaya, Poblacion, Santa Lucia, Santo Niño, Tagumpay, Victoria, Tusban, Gen. Emilio Aguinaldo, Claudio Salgado, Ibud, Invita, Paetan and Pag-asa in the Municipality of Sablayan; Adela, Aguas, Magsikap, Malawaan, Manoot, Pitogo, Rizal, Rumbang, Salvacion, San Pedro and Santo Niño in Rizal; and Concepcion, Iriron, Malpalon, New Dagupan, Poblacion, Poypoy and Tanyag in Calintaan. The basin area has ten geological classifications with Oligocene (Sedimentary and Metamorphic) as the most dominant while the rest are Basement Complex, Cretaceous-Paleogene, Oligocene-Miocene, Paleoecene-Eocene, Pliocene-Pleistocene, Recent and Upper Miocene-Pliocene. The river basin is typically characterized by >50% slope and elevation of 0-250 meters above mean sea level. The soil types in the river basin are Maranlig gravelly sandy clay loam, Quingua clay loam, Bantog clay, Faraon clay/river wash, Umingan loam, San Manuel sandy loam, and Bantog clay. Other areas are still unclassified (rough mountainous land) and has beach sand. Cultivated area mixed with brushland/grassland is predominant in the area followed by arable land (crops mainly cereals and sugar), closed canopy (mature trees covering >50%), crop land mixed with coconut plantation, grassland (grass covering >70%), open canopy (mature trees covering <50%) and riverbeds.

Lumintao River passes through Tuban in Sablayan municipality; Rizal, Magsikap and Malwaan in Rizal; Malpalon, Poypoy and Poblacion in Calintaan. Poblacion in Calintaan and Malwaan in Rizal are the most populated barangay based on the 2010 NSO Census of Population and Housing.

Based on the studies conducted by the Mines and Geosciences Bureau, in terms of flood susceptibility, all municipalities covered by the river basin has low to high susceptibilities to landslides. The field surveys conducted by the PHIL-LiDAR 1 validation team showed that there were several notable weather disturbances that caused flooding in 2004 (Yoyong), 2009 (Ondoy), 2013 (Yolanda), 2014 (Glenda) and 2016 (Butchoy). The heavy rains brought by southwest monsoon also caused flooding in 2013 and 2015 affecting Malawaan and Rizal, respectively.

Lumintao River Basin is located in the Municipality of Calintaan and Rizal in the province of Occidental Mindoro. The DENR River Basin Control Office (RCBO) states that the Lumintao River Basin has a drainage area of 334 km^2 with the estimated annual run-off of 534 million cubic meter (MCM).

Its main stem, Lumintao River, traverses the barangays Poypoy and Tanyag in Calintaan Municipality; and barangays Rizal, Masikap and Malawan in Rizal Municipality. According to the Philippine Statistics Authority Census, a total of 24,835 locals are residing in the said barangays as of 2010. Its water is used mainly for domestic and agricultural activities. The greatest flooding event recorded for the Municipality of Rizal is brought by Typhoon Rosing in August 1972 wherein Lumintao River over flowed. The flood greatly affected Bario Magui (Sitio Lumintao) and destroyed many houses and transformed the wide agricultural land into riverbed. There are no recent significant flooding events recorded for Lumintao River.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LUMINTAO FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Lumintao floodplain in Occidental Mindoro. These missions were planned for fifteen (15) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1 and Table 2Error! Reference source not found.. Figure 1 and Figure 2 show the flight plans and base stations for Lumintao floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29 A	600	30	36	50	40	130	5
BLK29 B	550	30	36	50	40	130	5
BLK29 C	650	30	36	50	40	130	5
BLK29 D	600/650	30	36	50	40	130	5
BLK 29F	600	30	36	50	40	130	5
BLK 29G	650	30	36	50	40	130	5
BLK 29K	550	30	36	50	40	130	5
BLK 29P	600	30	36	50	40	130	5

Table 2. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29 K	1100	30	50	200	30	130	5
BLK29 L	1100	30	50	200	30	130	5
BLK29 M	1100	30	50	200	30	130	5
BLK19 N	850	30	50	250	32	130	5
BLK29 O	1100	30	50	200	30	130	5
BLK29 Q	850	30	50	250	32	130	5
BLK29 R	850	30	50	250	32	130	5
BLK29 S	850	30	50	250	32	130	5

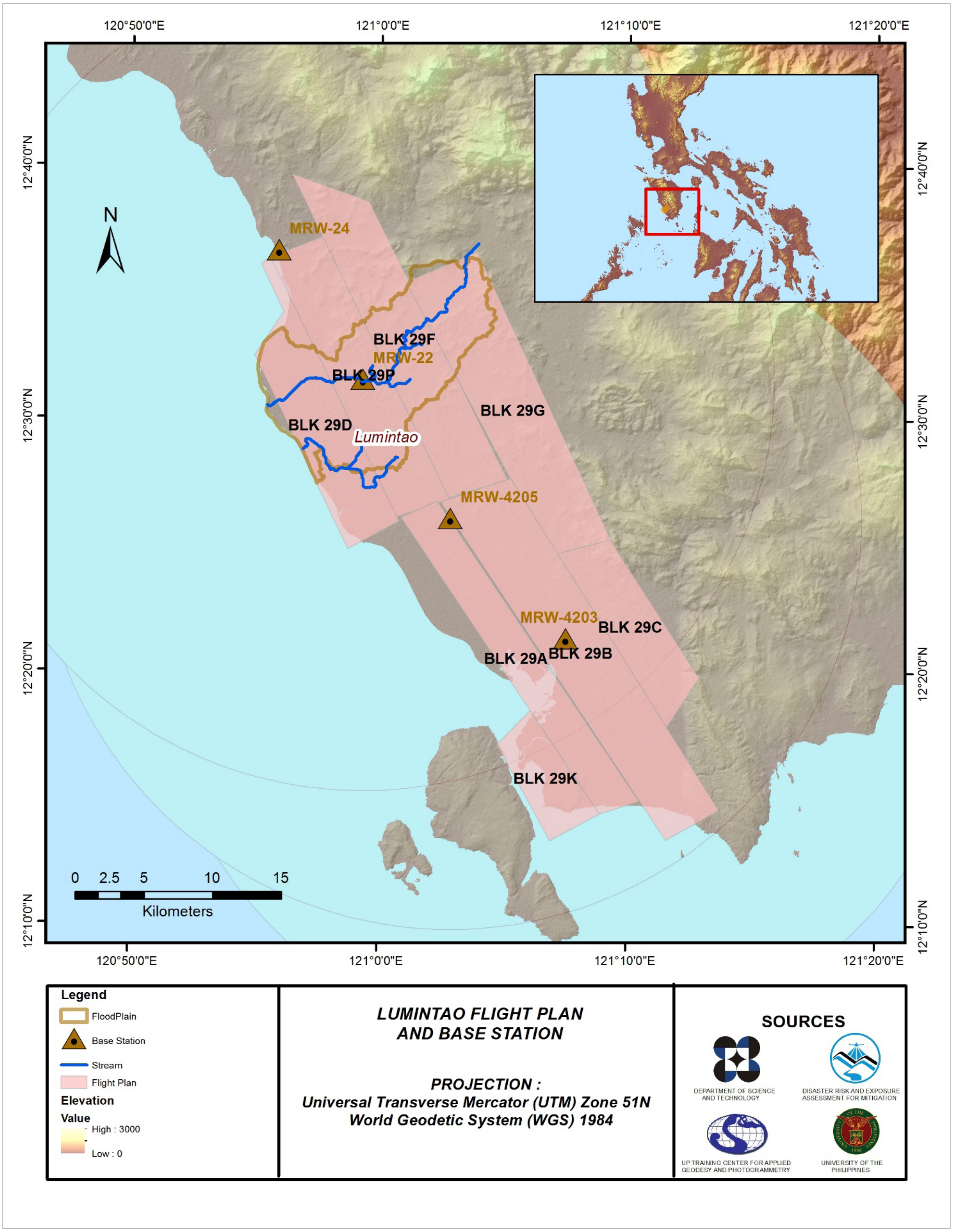

Figure 1. Flight plans used for Lumintao floodplain using Aquarius Sensor.

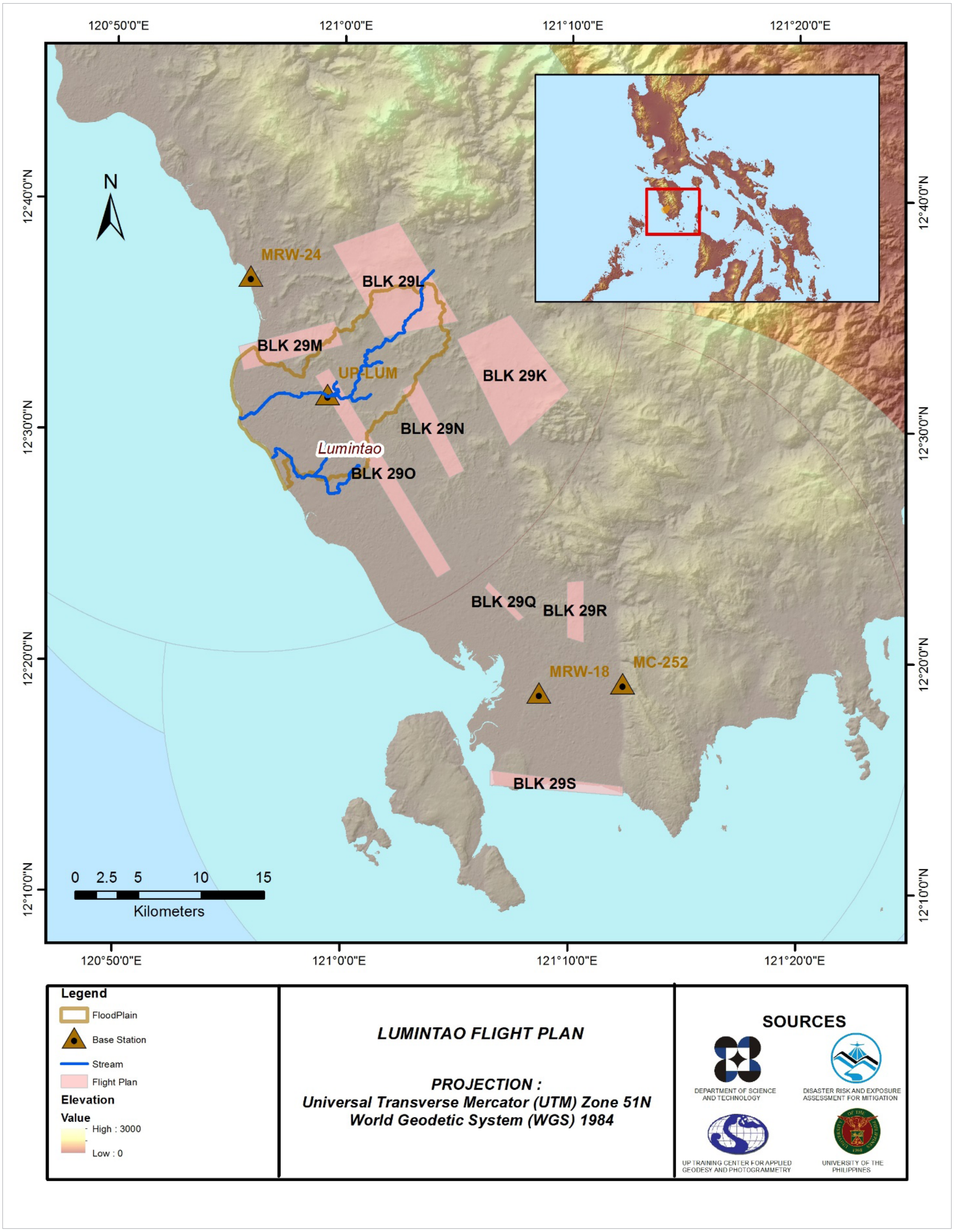

Figure 2. Flight plans used for Lumintao Floodplain using Pegasus Sensor.

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA horizontal ground control points: MRW-18, MRW-22, and MRW-24 which are all of second (2nd) order accuracy. The project team also re-processed coordinates of two (2) ground control points: MRW-4203 and MRW-4205. The team also established one ground control point (UP-LUM) with 2nd order accuracy. One (1) NAMRIA benchmark (MC-252) was recovered. This benchmark was used as a vertical reference point and was also established as a ground control point. The certification for the NAMRIA reference points and benchmark are found in ANNEX 2 while the baseline processing reports for re-processed control points are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (February 25 to March 3, 2014, and December 10-11, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, TRIMBLE SPS 985 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Lumintao floodplain are shown in Figures 1 and 2.

Figure 3 and Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 9 show the details about the following NAMRIA control stations and established points, while Table 10 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

Table 3. Details of the recovered NAMRIA horizontal control point MRW-18 used as base station for the LiDAR acquisition.

Station Name	MRW-18	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°18'45.39463" North 121°8'36.92441" East 21.29500 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	515618.524 m 1361517.851 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 18' 40.53383" North 121° 8' 42.01469" East 71.37500 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	298113.89 m 1361734.74 m

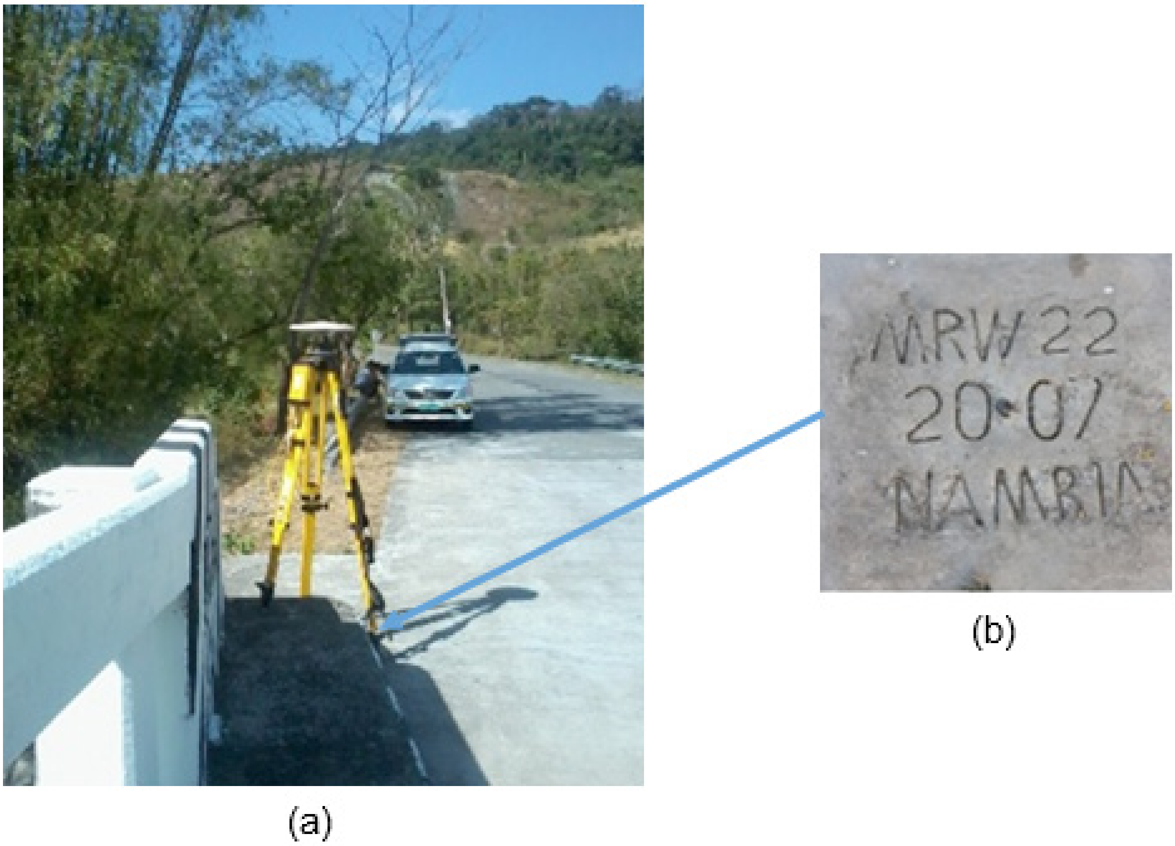

Figure 3. a) GPS set-up over MRW-22 located at Lumintao Bridge in Brgy. Tanyag, Municipality of Calintaan, Occidental Mindoro. b) NAMRIA reference point MRW-22 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRW-22 used as base station for the LiDAR acquisition.

Station Name	MRW-22	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31’36.76881” North 120°59’13.46492” East 35.12700 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	498595.125 m 1385214.96 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 31’31.84278” North 120° 59’ 18.53734” East 84.27100 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	281265.62 m 1385563.72 m

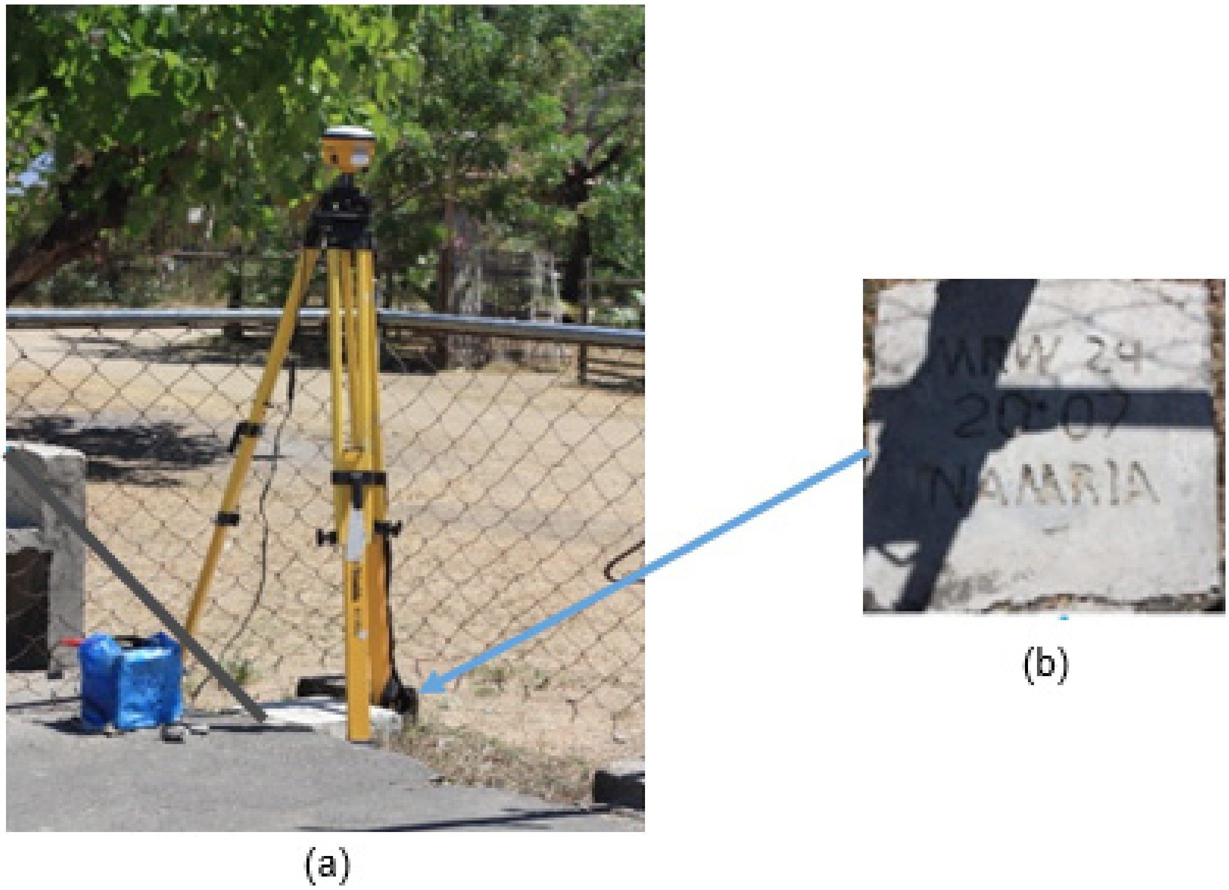

Figure 4. a) GPS set-up over MRW-24 located at the basketball court in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro b) NAMRIA reference point MRW-24 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRW-24 used as base station for the LiDAR acquisition.

Station Name	MRW-24	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°36'42.98691" North 120°55'49.01762" East 5.69500 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	492425.435 m 1394624.897 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 36'38.03549" North 120° 55' 54.08296" East 54.47900 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	275166.05 m 1395022.71 m

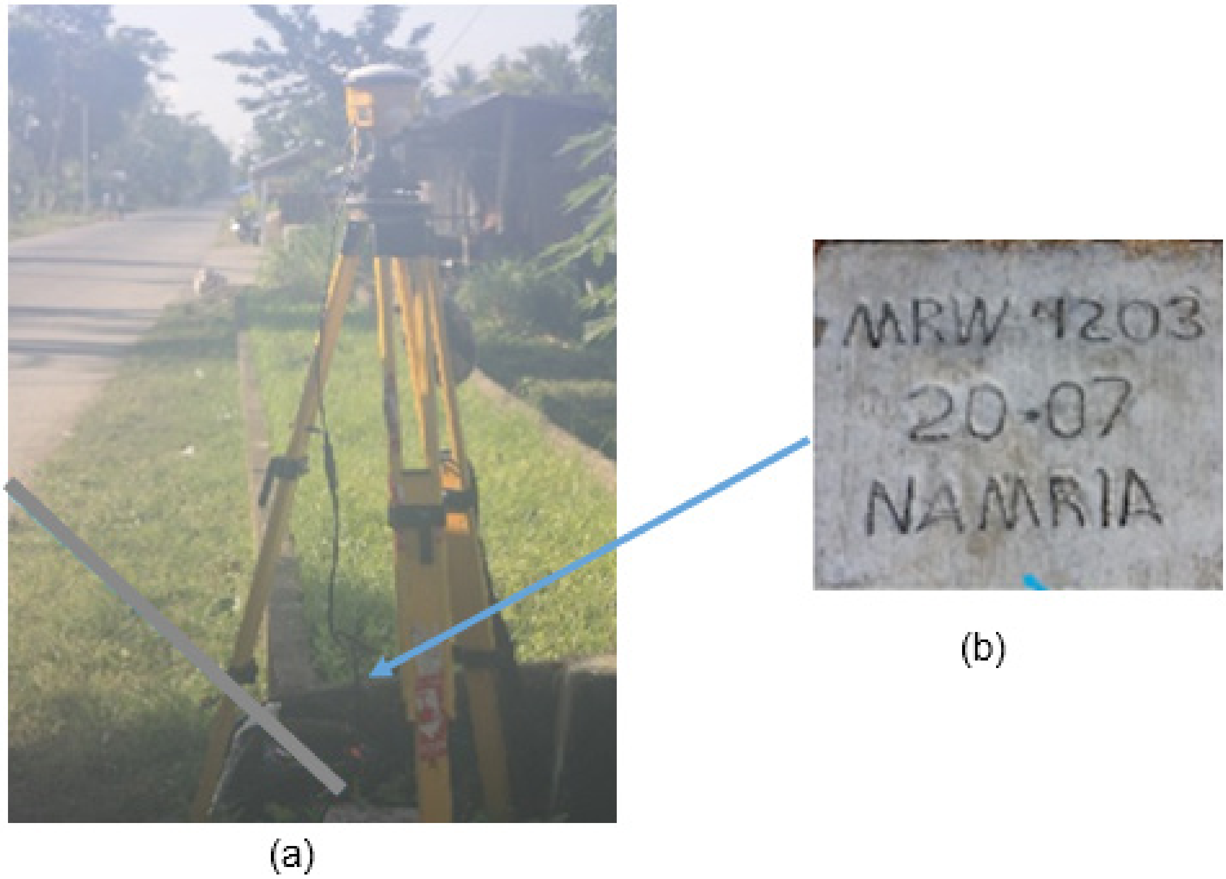

Figure 5. a) GPS set-up over MRW-4203 located in front of the barangay hall of Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro b) NAMRIA reference point MRW-4203 as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point MRW-4203 used as base station for the LiDAR acquisition.

Station Name	**MRW-4203**	
Order of Accuracy	**2^{nd}**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 21’ 24.45021” North 121° 07’ 26.92622” East 7.414 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 21’ 19.57700” North 121° 07’ 32.01274” East 57.334 m
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting Northing	296032.858 m 1366637.239 m

Table 7. Details of the recovered NAMRIA horizontal control point MRW-4205 used as base station for the LiDAR acquisition.

Station Name	MRW-4203	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 26' 08.33883" North 121° 02' 46.62885" East 12.555 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 26' 03.43990" North 121° 02' 51.70890" East 62.080 m
Grid Coordinates, Philippine Transverse Mercator Zone 50 (UTM Zone 50 WGS84)	Easting Northing	287627.814 m 1375422.160 m

Table 8. Details of the recovered NAMRIA reference point MC-252 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	MC-252	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 19' 05.80624" North 121° 12' 22.14215" East 126.454 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 19' 10.66357" North 121° 12' 17.05287" East 76.241 m
Grid Coordinates, Philippine Transverse Mercator Zone 50 (UTM Zone 50 WGS84)	Easting Northing	304770.876 m 1362466.0012 m

Table 9. Details of the established control point UP-LUM used as base station for the LiDAR acquisition.

Station Name	UP-LUM	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 31' 36.65200" North 121° 59' 13.78049" East 35.151 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 31' 31.72599" North 121° 59' 18.85291" East 84.296 m
Grid Coordinates, Philippine Transverse Mercator Zone 50 (UTM Zone 50 WGS84)	Easting Northing	281275.130 m 1385560.055 m

Table 10. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
03-29-14	7156GC	2BLK19E088A	ABY-9, LPH-01
03-30-14	7158GC	2BLK19ES089A & 2BLK19G089A	ABY-9, LPH-01
03-31-14	7160GC	2BLK19I90A	ABY-9, LPH-01
03-31-14	7161GC	2BLK19IS090B	ABY-9, LPH-01
04-03-14	7167GC	2BLK19K093A & 2BLK10IS093A	ABY-9, LPH-01
04-04-14	7168GC	2BLK19L094A	ABY-9, LPH-01
04-05-14	7171GC	2BLK19M095A	ABY-92, LPH-01
04-06-14	7172GC	2BLK19CS096A & 2BLK19D096A	ABY-92, LPH-01
04-07-14	7174GC	2BLK19F097A	ABY-92, AL-298
04-07-14	7175GC	2BLK19H097B	ABY-92, LPH-01
04-08-14	7176GC	2BLK19HS098A	ABY-9, ABY-92
04-12-14	7184GC	2BLK19J102A	ABY-92
04-20-14	7200GC	2BLK19JS110A & 2BLK19N110A	ABY-8, ABY-92
04-22-14	7204GC	2BLK19A112A	ABY-8, ABY-92
04-26-14	7212GC	2BLK19P116A & 2BLK190116A	ABY-8, ABY-9, ABY-92
04-26-14	7213GC	2BLK19OS116B & VOIDS	ABY-8, ABY-9, ABY-92
04-28-14	7216GC	2BLK19AS118A & VOIDS	ABY-8, ABY-9
02-28-16	3825G	2BLK19JFS059B	ABY-82
02-29-16	3829G	2BLK19FS060B	ABY8, ABY-9, ABY-82
03-04-16	3843G	2BLK19DS064A	ABY-93, AL-191

2.3 Flight Missions

Nine (9) missions were conducted to complete LiDAR data acquisition in Lumintao floodplain, for a total of thirty six hours and twenty one minutes of flying time for RP-C9022 and RP-C9122. All missions were acquired using Aquarius and Pegasus LiDAR systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in Lumintao floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within the Floodplain (km²)	Area Surveyed outside the Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 23, 2014	1142A	101.12	110.31	44.75	65.56	126	3	59
February 27, 2014	1152A	195.45	89.81	39.78	50.03	1077	4	23
February 27, 2014	1154A	73.45	78.53	41.35	37.18	616	3	53
February 28, 2014	1156A	104.78	114.55	31.71	82.84	1310	4	29
March 1, 2014	1160A	181.94	107.85	0	107.85	201	4	35
March 1, 2014	1162A	148.92	85.76	0	87.17	594	3	41
March 3, 2014	1168A	381.12	68.39	0	68.39	0	4	29
December 10, 2015	3074P	137.02	190.47	45.02	145.45	454	4	05
December 11, 2015	3078P	30.05	60.69	2.64	58.05	211	2	47
TOTAL		**2597.19**	**1691.18**	**269.23**	**1421.95**	**2795**	**36**	**21**

Table 12. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1142A	600	30	36	50	40	130	5
1152A	650	30	30	50	40	130	5
1154A	600	30	36	50	40	130	5
1156A	600	30	36	50	40	130	5
1160A	650	30	36	50	40	130	5
1162A	600	30	36	50	40	130	5
1168A	550	30	36	50	40	130	5
3074P	1100	30	50	200	30	130	5
3078P	850	30	50	250	32	130	5

2.4 Survey Coverage

Lumintao floodplain is situated within municipalities of Rizal and Calintaan in the province of Occidental Mindoro. These municipalities are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Lumintao Floodplain is presented in Figure 6.

Table 13. List of municipalities and cities surveyed during Lumintao floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Pangasinan	Rizal	184.98	180.82	97.75%
	Calintaan	282.31	149.39	52.92%
	Magsaysay	256.56	106.63	41.56%
	San Jose	449.82	185.64	41.27%
	Sablayan	2350.46	28.94	1.23%
Total		**3524.13**	**651.43**	**46.95%**

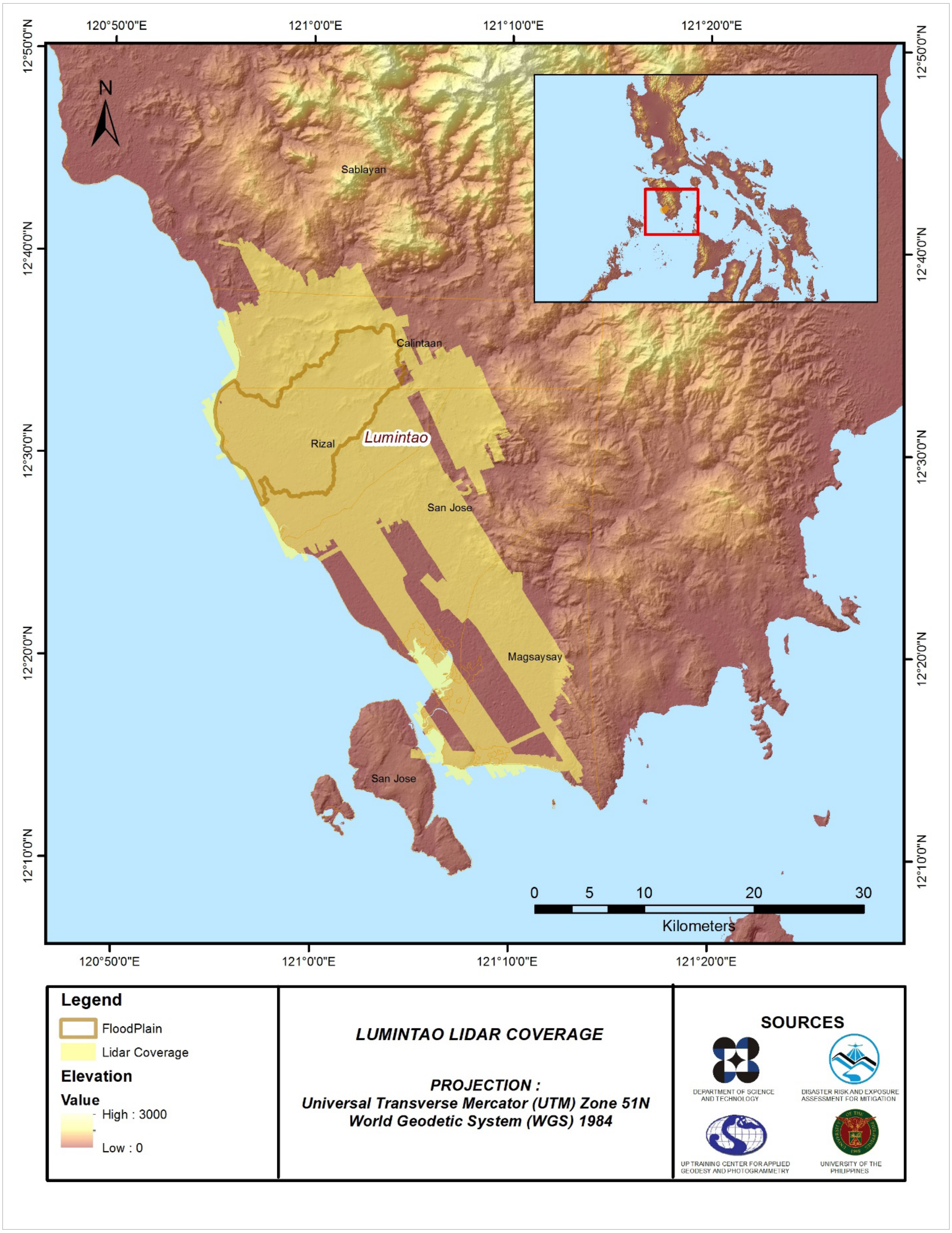

Figure 6. Actual LiDAR survey coverage for Lumintao floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LUMINTAO FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

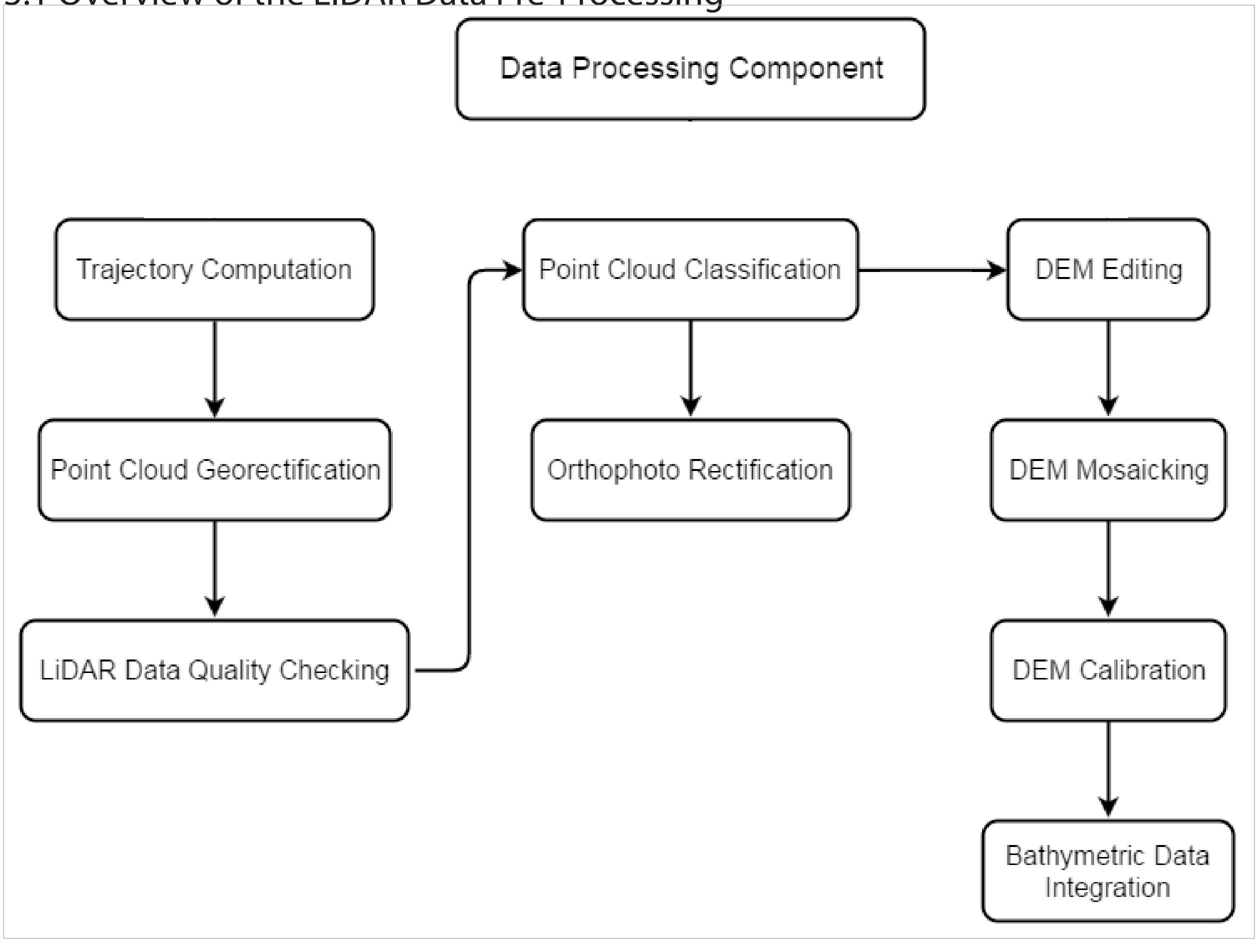

Figure 7. Schematic Diagram for Data Pre-Processing Component.

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

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

These processes are summarized in the flowchart shown in Figure 7.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Lumintao floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on January 2016 were flown using the Pegasus system over Rizal, Occidental Mindoro. The Data Acquisition Component (DAC) transferred a total of 146.64 Gigabytes of Range data, 1.90 Gigabytes of POS data, 128.52 Megabytes of GPS base station data, and 356 Gigabytes of raw image data to the data server on March 19, 2014 for the first survey and January 13, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Lumintao was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for Lumintao floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1142A, one of the Lumintao flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 24, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

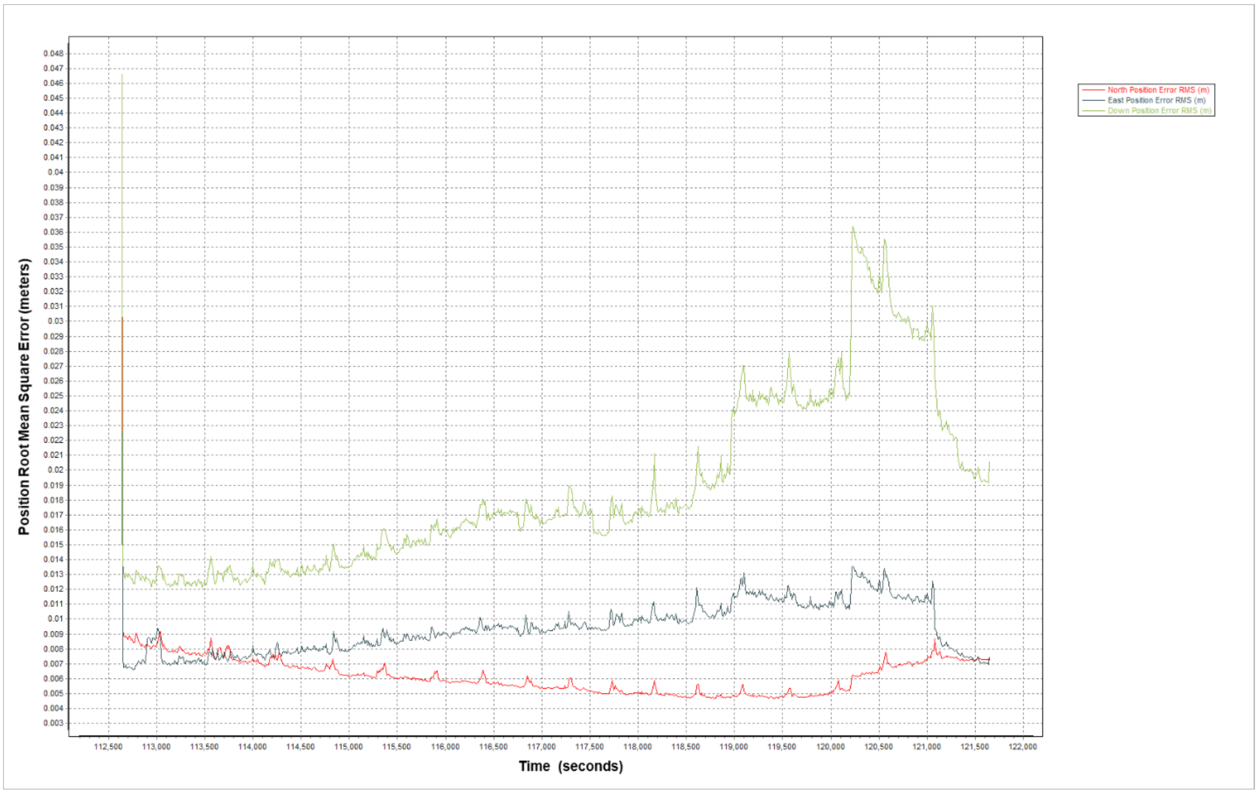

Figure 8. Smoothed Performance Metric Parameters of a Lumintao Flight 1142A.

The time of flight was from 112500 seconds to 121500 seconds, which corresponds to afternoon of February 24, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 0.90 centimeters, the East position RMSE peaks at 1. 40 centimeters, and the Down position RMSE peaks at 3.60 centimeters, which are within the prescribed accuracies described in the methodology.

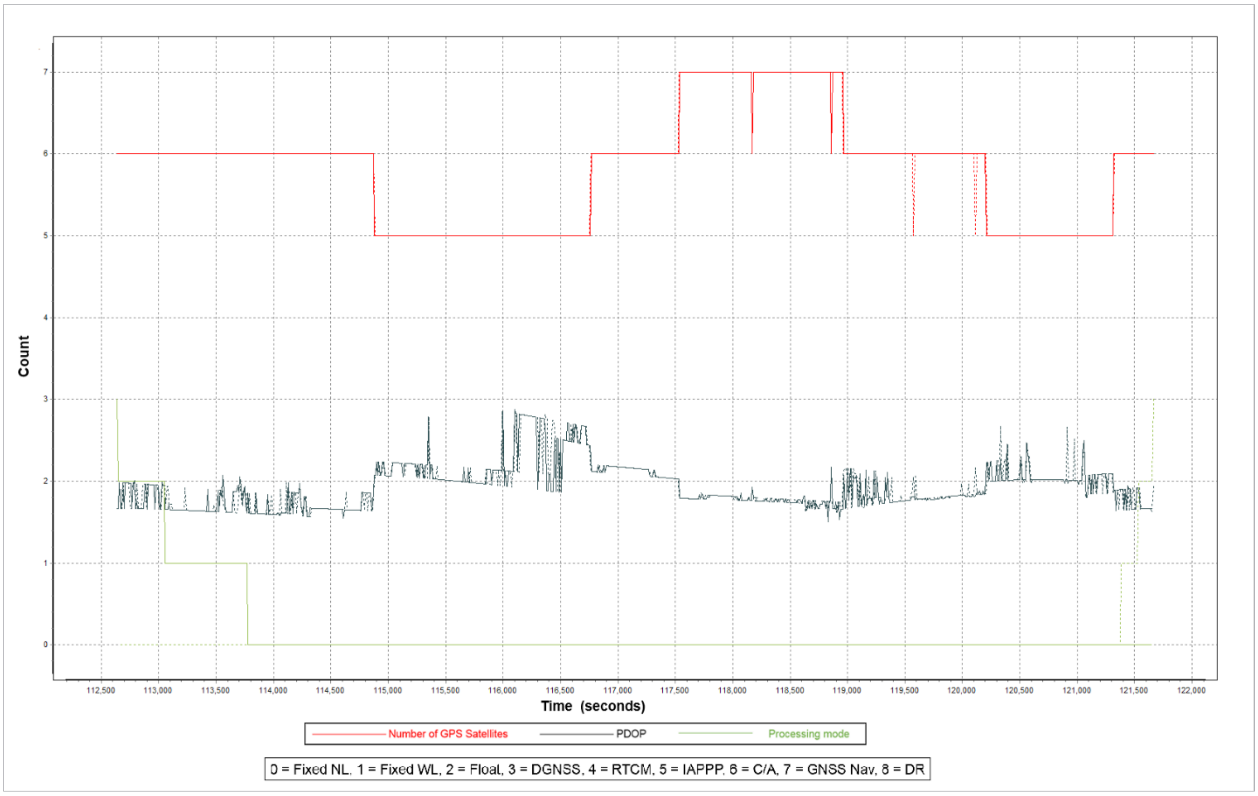

Figure 9. Solution Status Parameters of Lumintao Flight 1142A.

The Solution Status parameters of flight 1142A, one of the Lumintao flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 5 and 7. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Lumintao flights is shown in Figure 10.

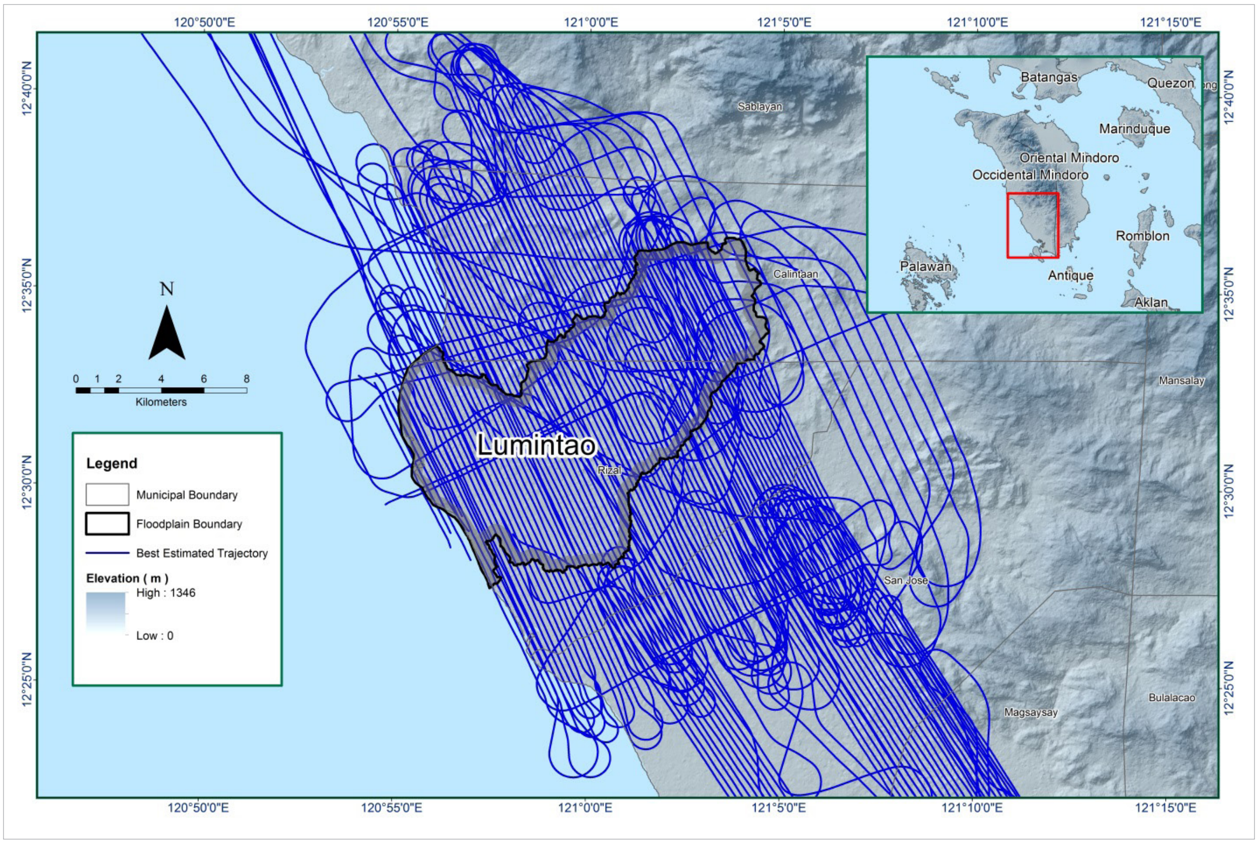

Figure 10. Best Estimated Trajectory for Lumintao floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 240 flight lines, with each flight line containing one or two channels, since the Aquarius system contains one channel only and the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Lumintao floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Lumintao flights.

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000355
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.001037
GPS Position Z-correction stdev	(<0.01meters)	0.0017

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

3.5 LiDAR Data Quality Checking

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

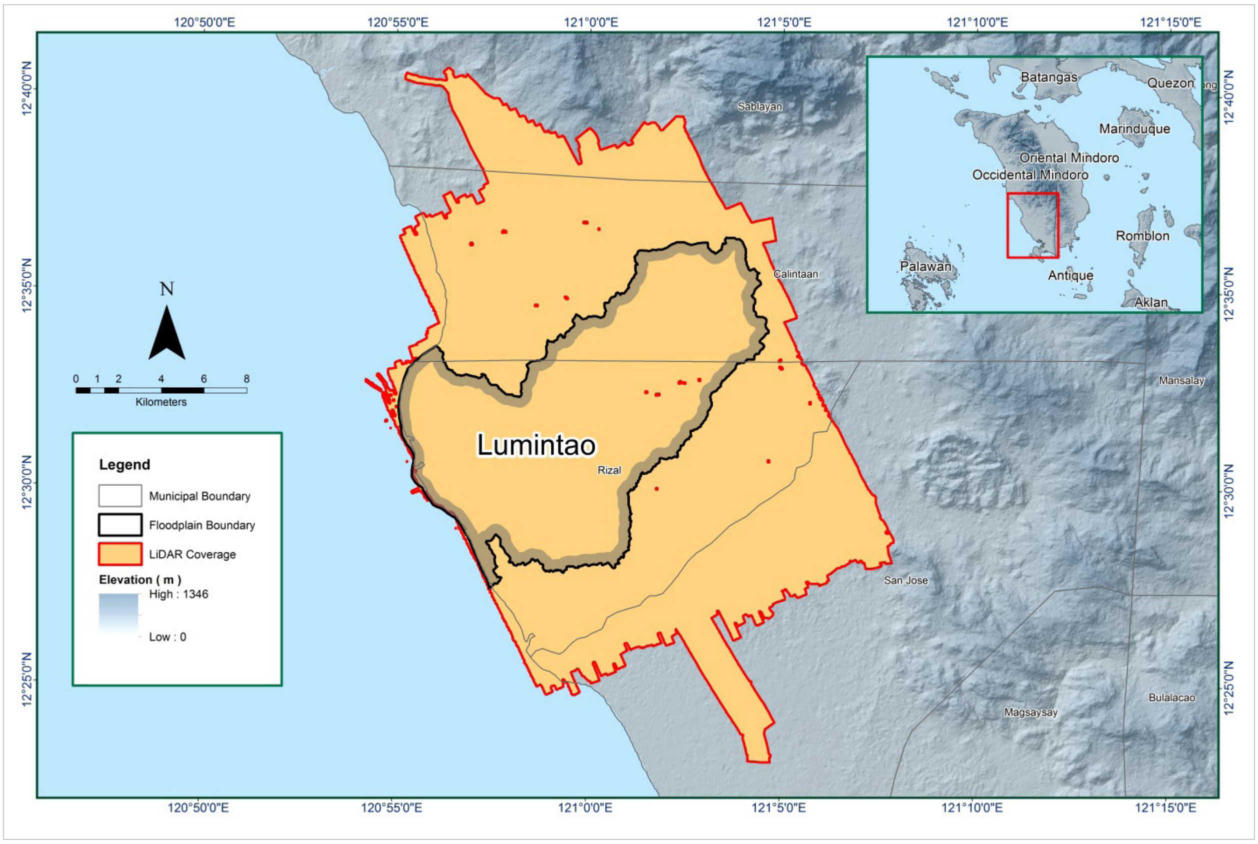

Figure 11. Boundary of the processed LiDAR data over Lumintao Floodplain.

The total area covered by the Lumintao missions is 569.71 sq.km that is comprised of Twelve (12) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Lumintao floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29C_supplement	1168A	6.45
OccidentalMindoro_Blk29D	1154A	89.07
	1152A	
	1162A	
OccidentalMindoro_Blk29D_additional	1152A	11.05
	1168A	
OccidentalMindoro_Blk29F	1156A	112.31
OccidentalMindoro_Blk29G	1152A	65.98
OccidentalMindoro_Blk29G_supplement	1160A	30.22
OccidentalMindoro_Blk29P	1142A	106.52
OccidentalMindoro_reflights_Blk29G_additional	3074P	123.54
OccidentalMindoro_reflights_Blk29F	3078P	24.57
TOTAL		**569.71 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

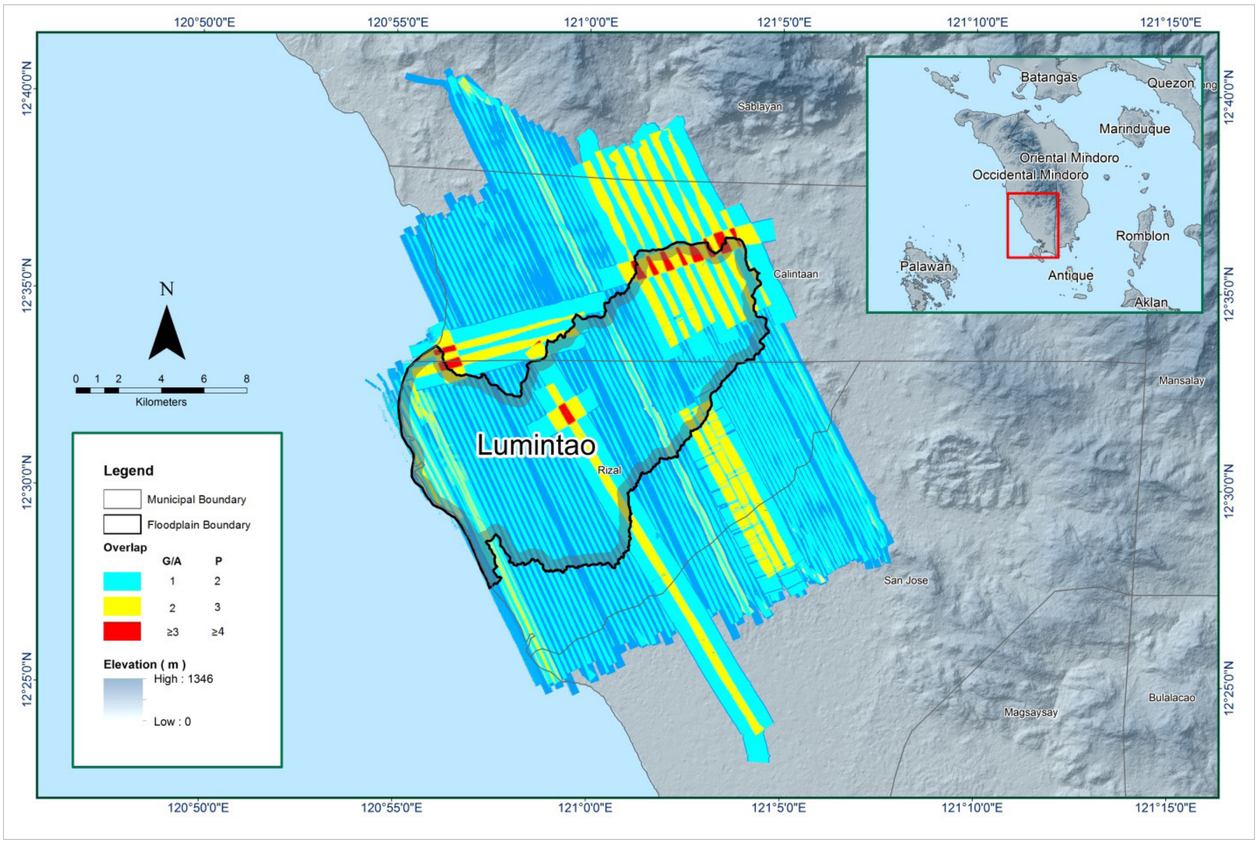

Figure 12. Image of data overlap for Lumintao Floodplain.

The overlap statistics per block for the Lumintao floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 39.69% and 60.10% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Lumintao floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.23 points per square meter.

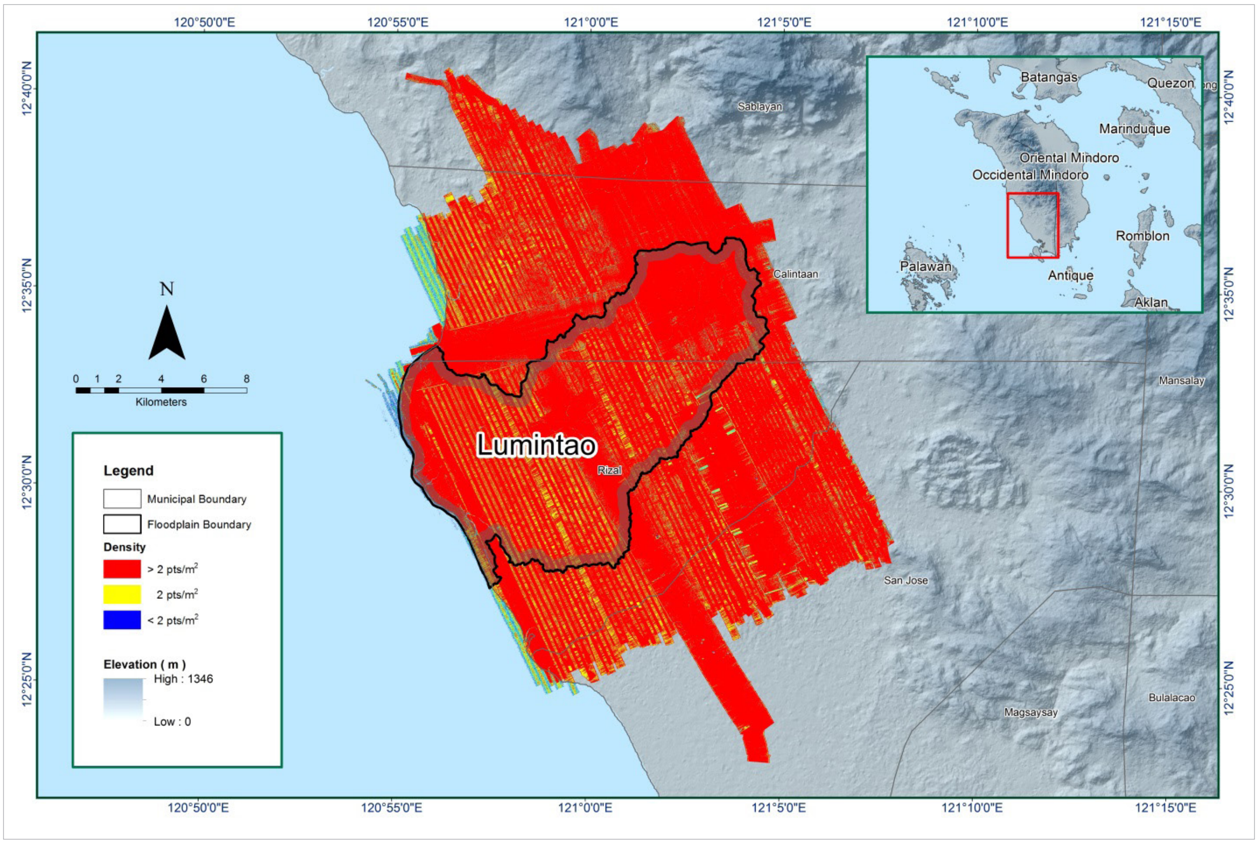

Figure 13. Pulse density map of merged LiDAR data for Lumintao Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

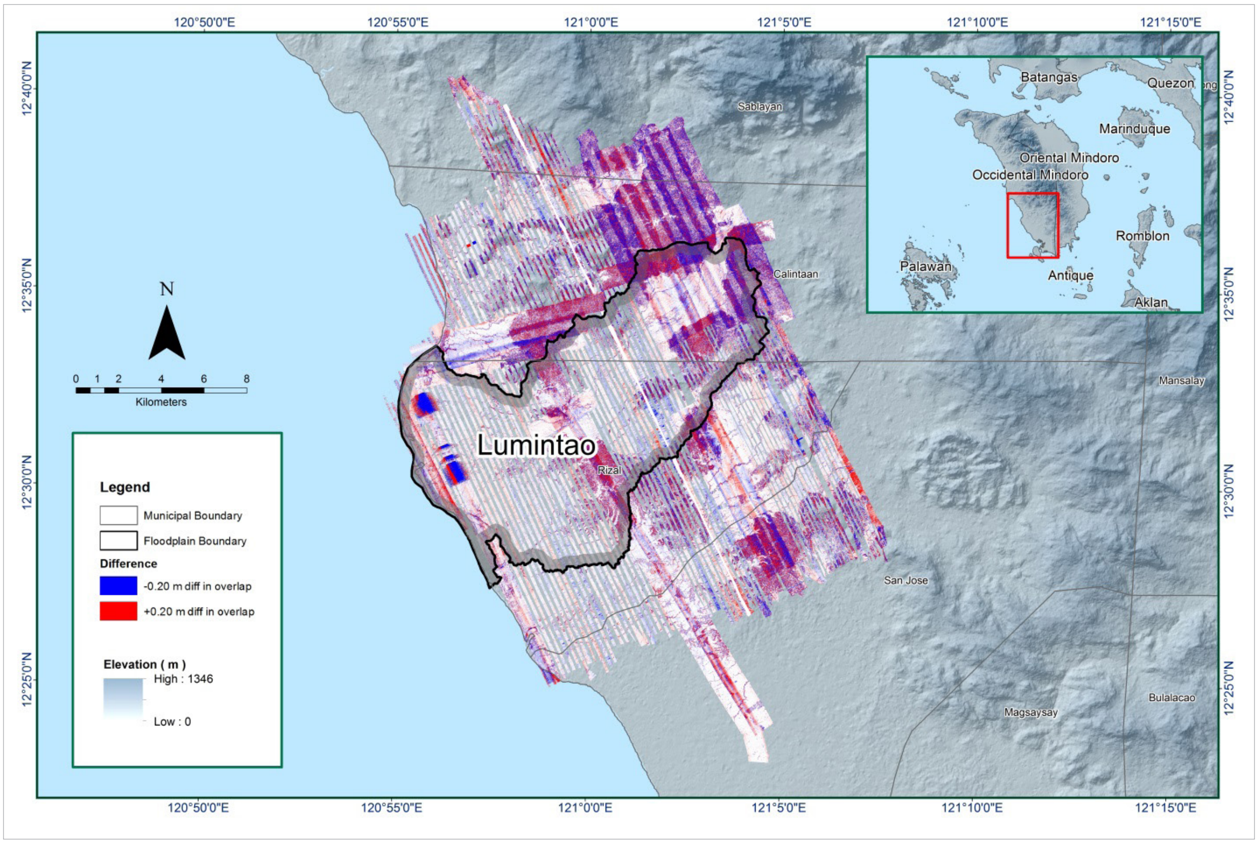

Figure 14. Elevation difference map between flight lines for Lumintao floodplain.

A screen capture of the processed LAS data from a Lumintao flight 1142A loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

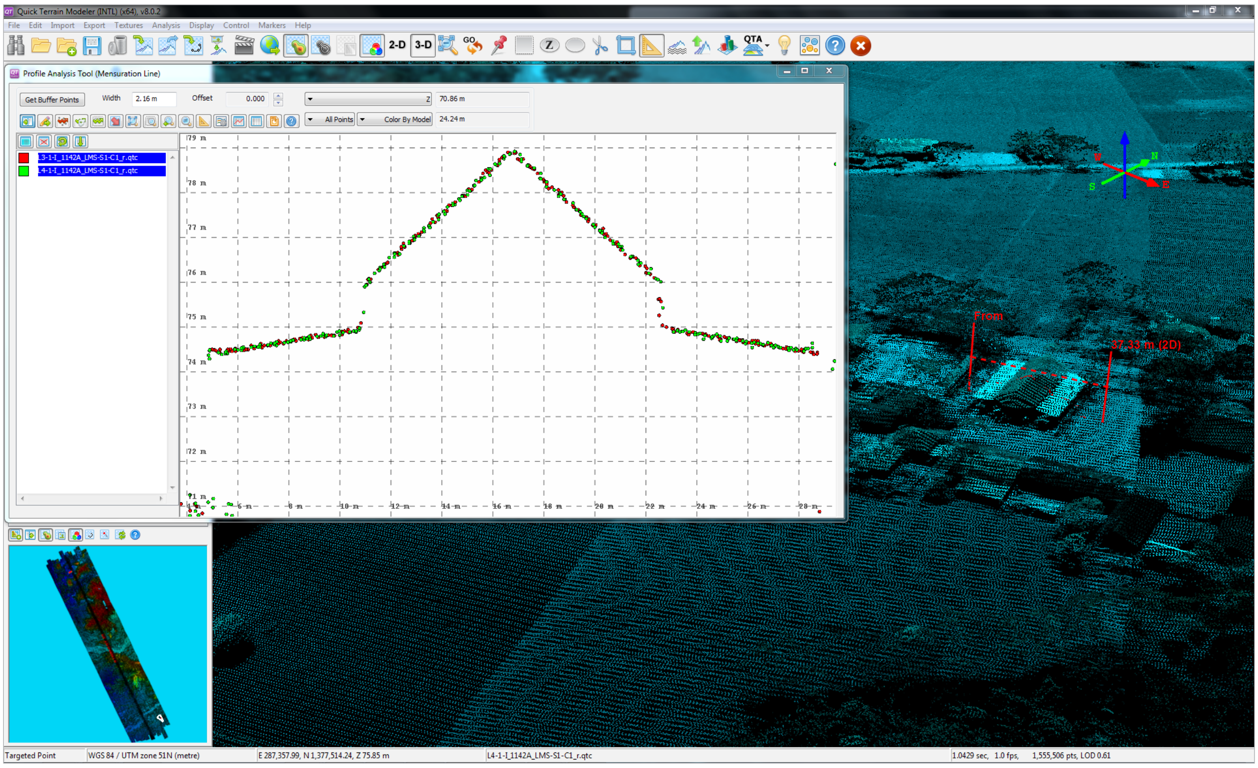

Figure 15. Quality checking for a Lumintao flight 1142AA using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Lumintao classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	482,948,569
Low Vegetation	536,784,423
Medium Vegetation	459,476,714
High Vegetation	756,298,627
Building	18,283,192

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Lumintao floodplain is shown in Figure 16. A total of 897 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 541.38 meters and 44.17 meters respectively.

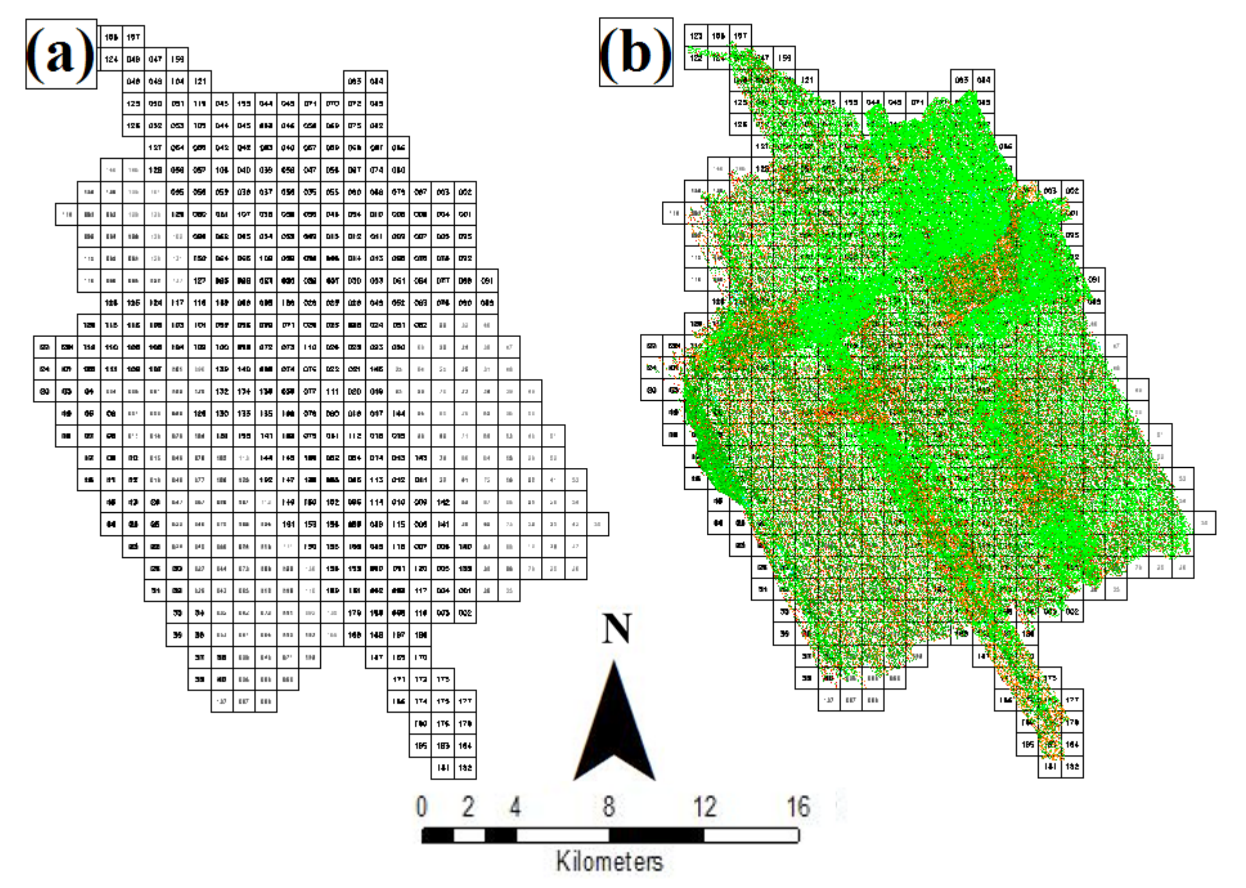

Figure 16. Tiles for Lumintao floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

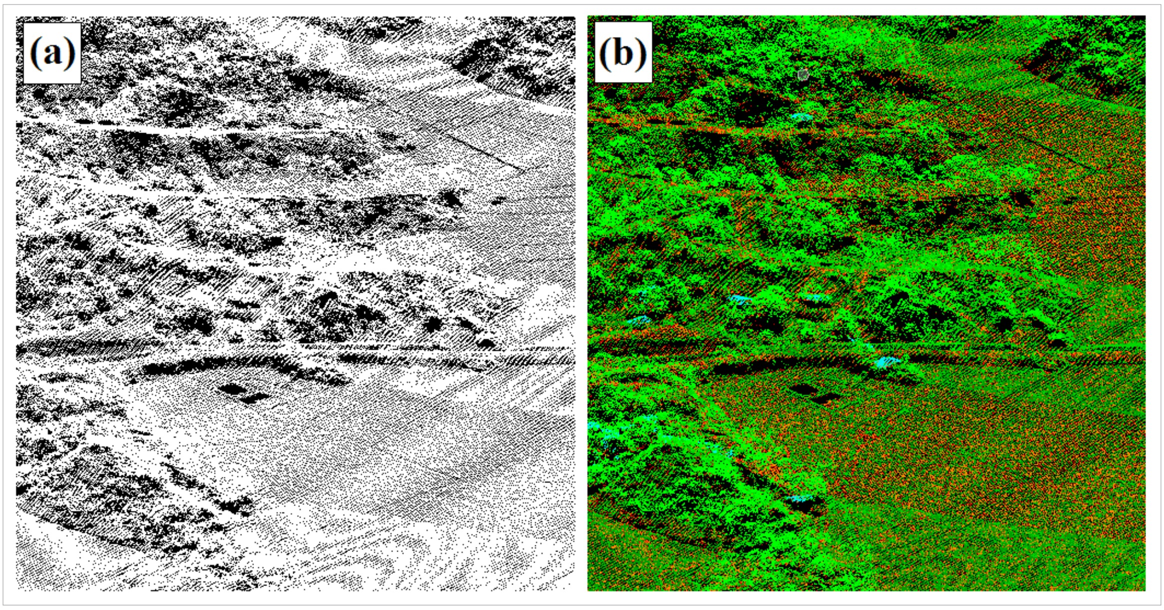

Figure 17. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 18. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

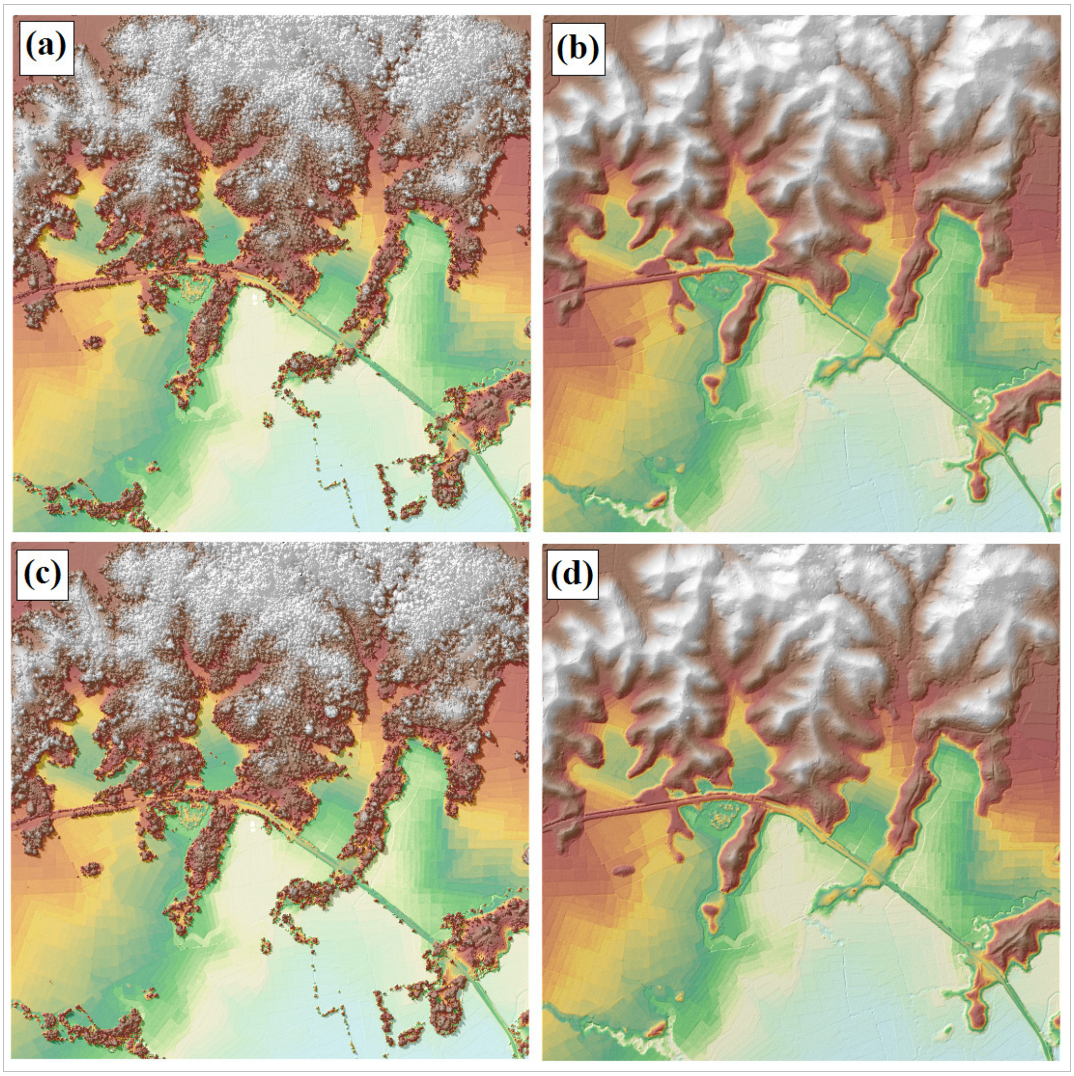

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Lumintao floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 750 1km by 1km tiles area covered by Lumintao floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Lumintao floodplain has a total of 391.53 sq.km orthophotogaph coverage comprised of 4,038 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

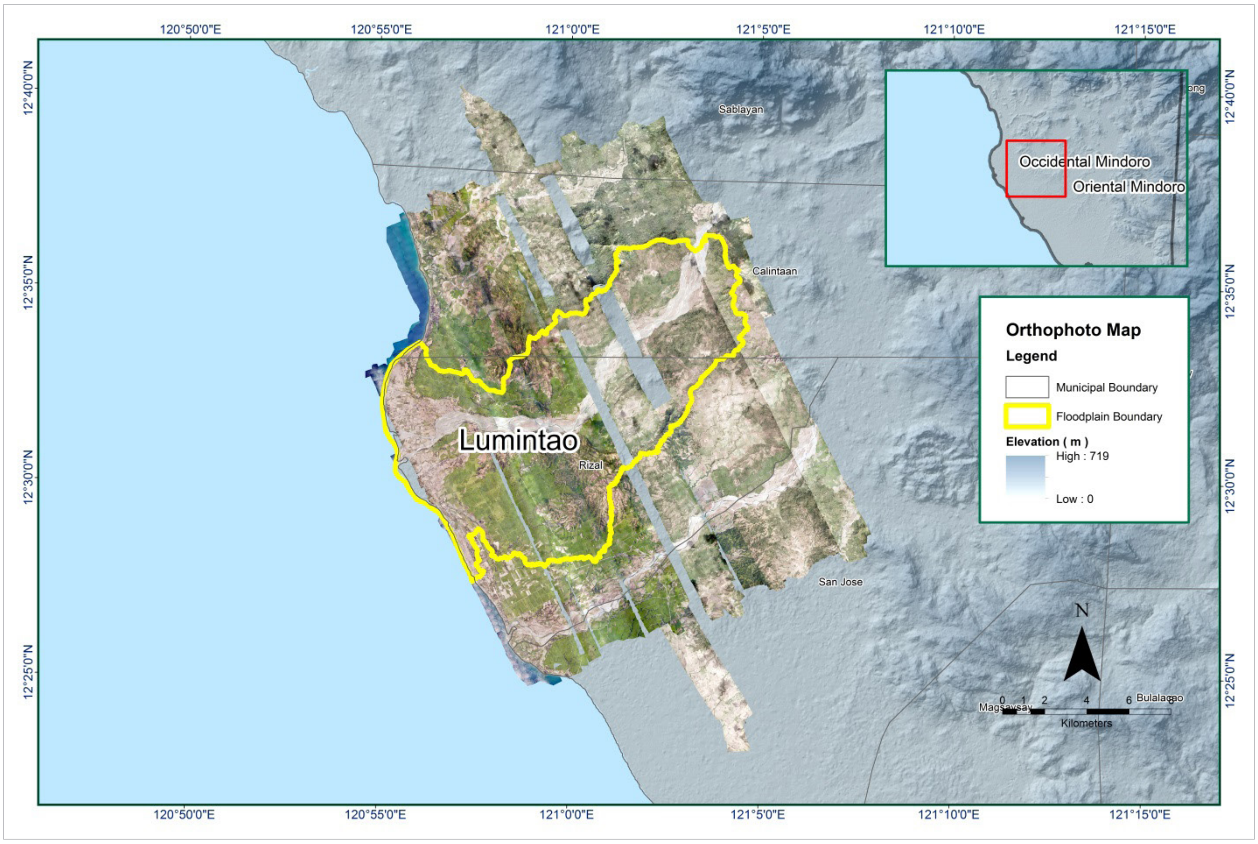

Figure 19. Lumintao floodplain with available orthophotographs.

Figure 20. Sample orthophotograph tiles for Lumintao Floodplain.

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Lumintao flood plain. These blocks are composed of OccidentalMindoro and OccidentalMindoro_reflights blocks with a total area of 569.71 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
OccidentalMindoro_Blk29C_supplement	6.45
OccidentalMindoro_Blk29D	89.07
OccidentalMindoro_Blk29D_additional	11.05
OccidentalMindoro_Blk29F	112.31
OccidentalMindoro_Blk29G	65.98
OccidentalMindoro_Blk29G_supplement	30.22
OccidentalMindoro_Blk29P	106.52
OccidentalMindoro_reflights_Blk29G_additional	123.54
OccidentalMindoro_reflights_Blk29F	24.57
TOTAL	**569.71 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The mountain (Figure 21c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water. Pit appeared on the terrain (Figure 21e) due to error in classification and has to be interpolated (Figure 21f) to complete the surface.

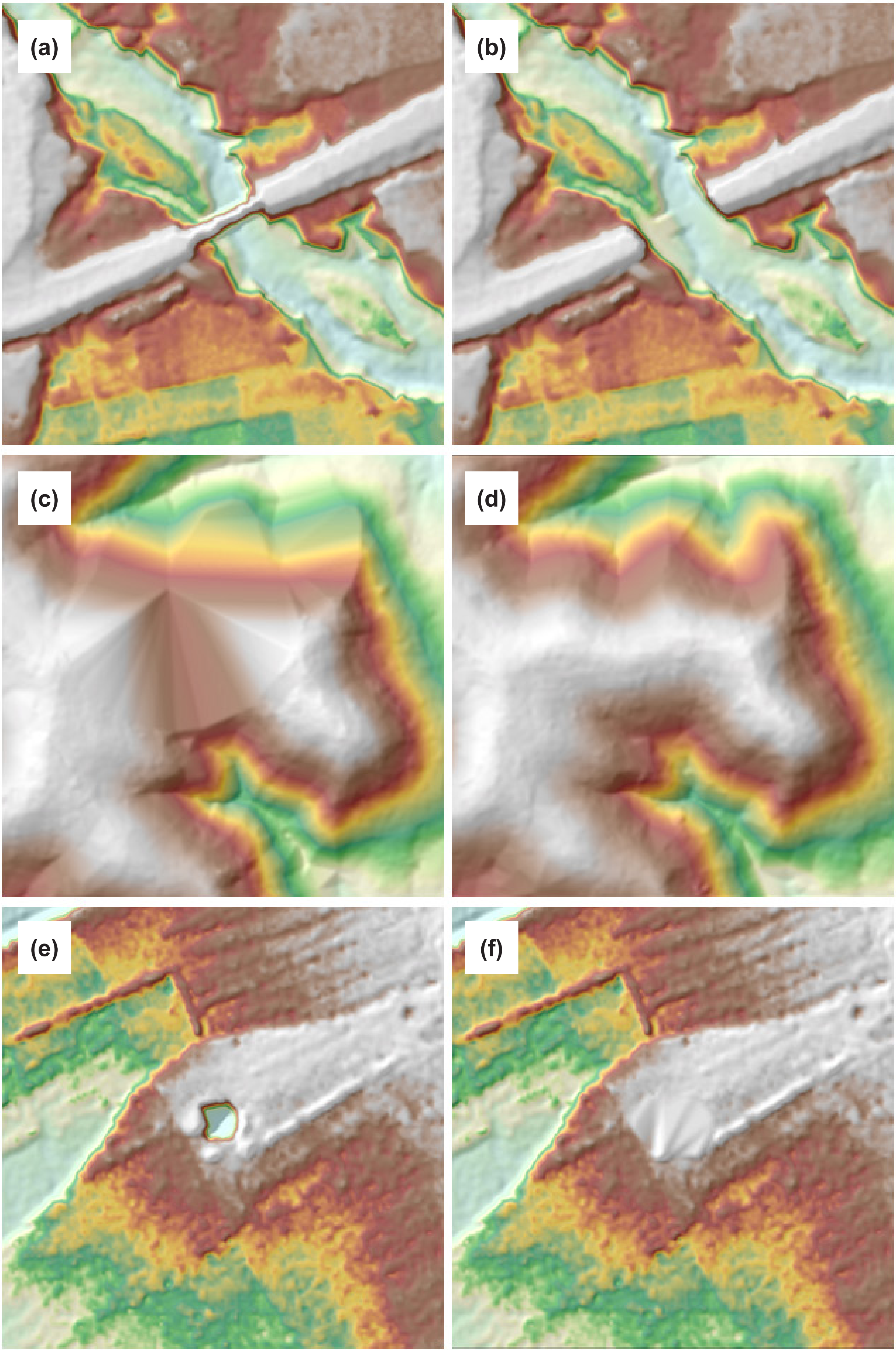

Figure 21. Portions in the DTM of Lumintao floodplain – a bridge before (a) and after (b) manual editing; a mountain before (c) and after (d) data retrieval; a pit before (e) and after (f) interpolation.

3.9 Mosaicking of Blocks

OccidentalMindoro_Blk29M was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table B-5 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Lumintao floodplain is shown in Figure 22. It can be seen that the entire Lumintao floodplain is 98.62% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Lumintao floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29C_supplement	0.00	0.00	-0.88
OccidentalMindoro_Blk29D	0.00	0.00	-0.76
OccidentalMindoro_Blk29D_additional	-0.04	0.00	-0.68
OccidentalMindoro_Blk29F	0.00	0.00	-0.55
OccidentalMindoro_Blk29G	0.00	0.00	-0.40
OccidentalMindoro_Blk29G_supplement	0.00	0.00	-0.76
OccidentalMindoro_Blk29P	0.00	0.00	-0.65
OccidentalMindoro_reflights_Blk29G_additional	0.00	0.00	-1.51
OccidentalMindoro_reflights_Blk29F	0.00	0.00	-1.41

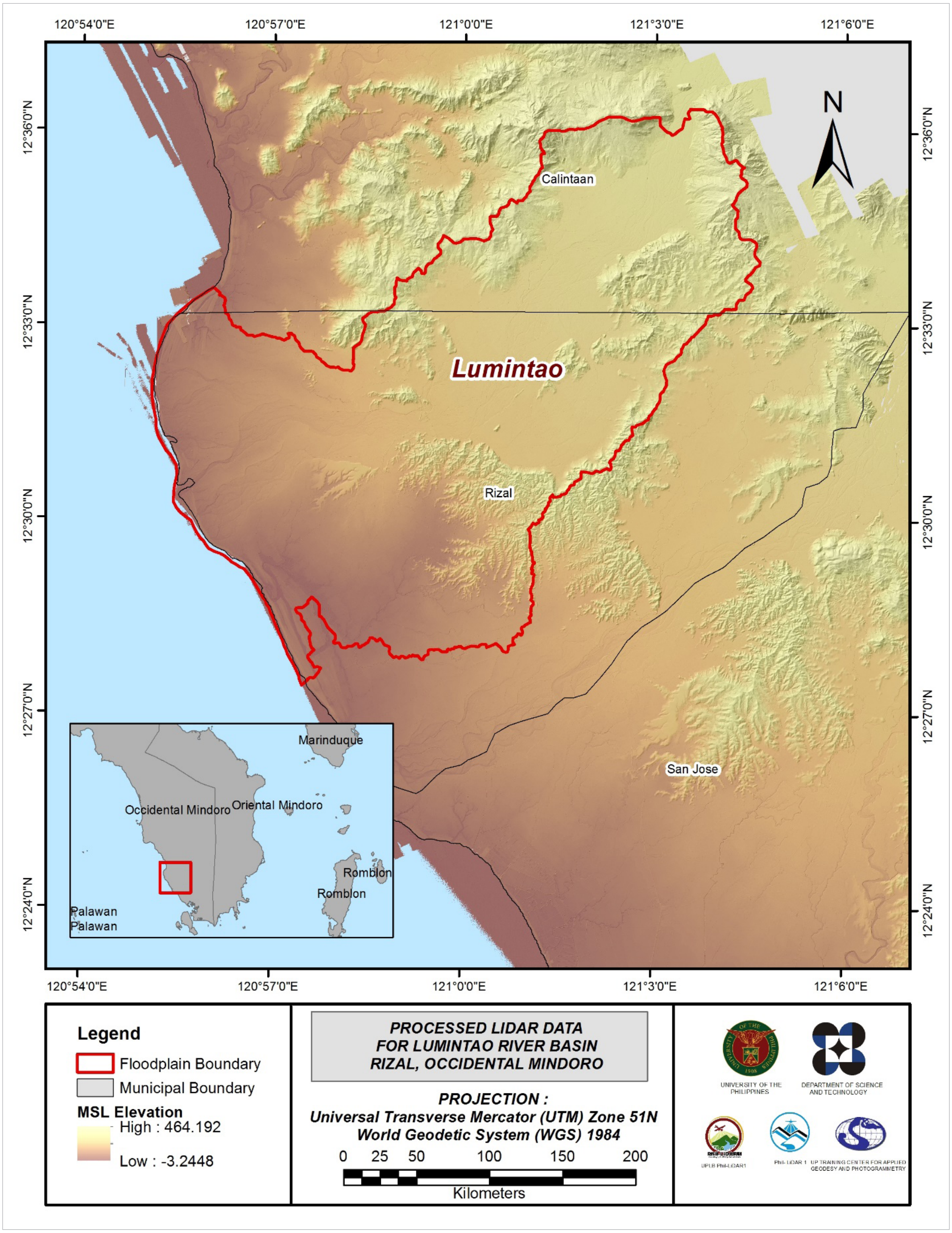

Figure 22. Map of Processed LiDAR Data for Lumintao Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Lumintao to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 28,494 survey points were used for calibration and validation of Lumintao LiDAR data. Random selection of 80% of the survey points, resulting to 22,795 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Lumintao LiDAR data was done by adding the height difference value, 0.23 meters, to Lumintao mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

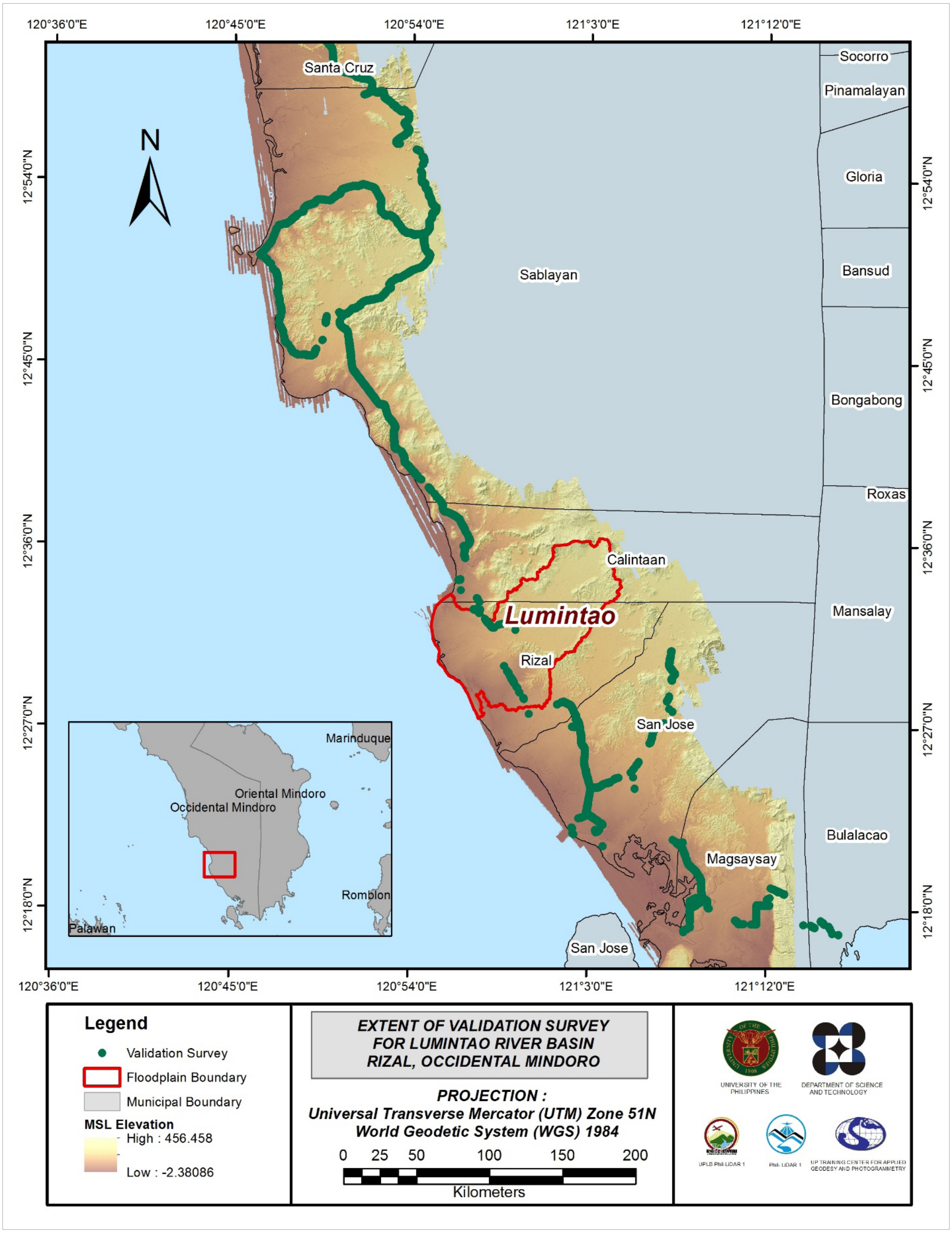

Figure 23. Map of Lumintao Flood Plain with validation survey points in green.

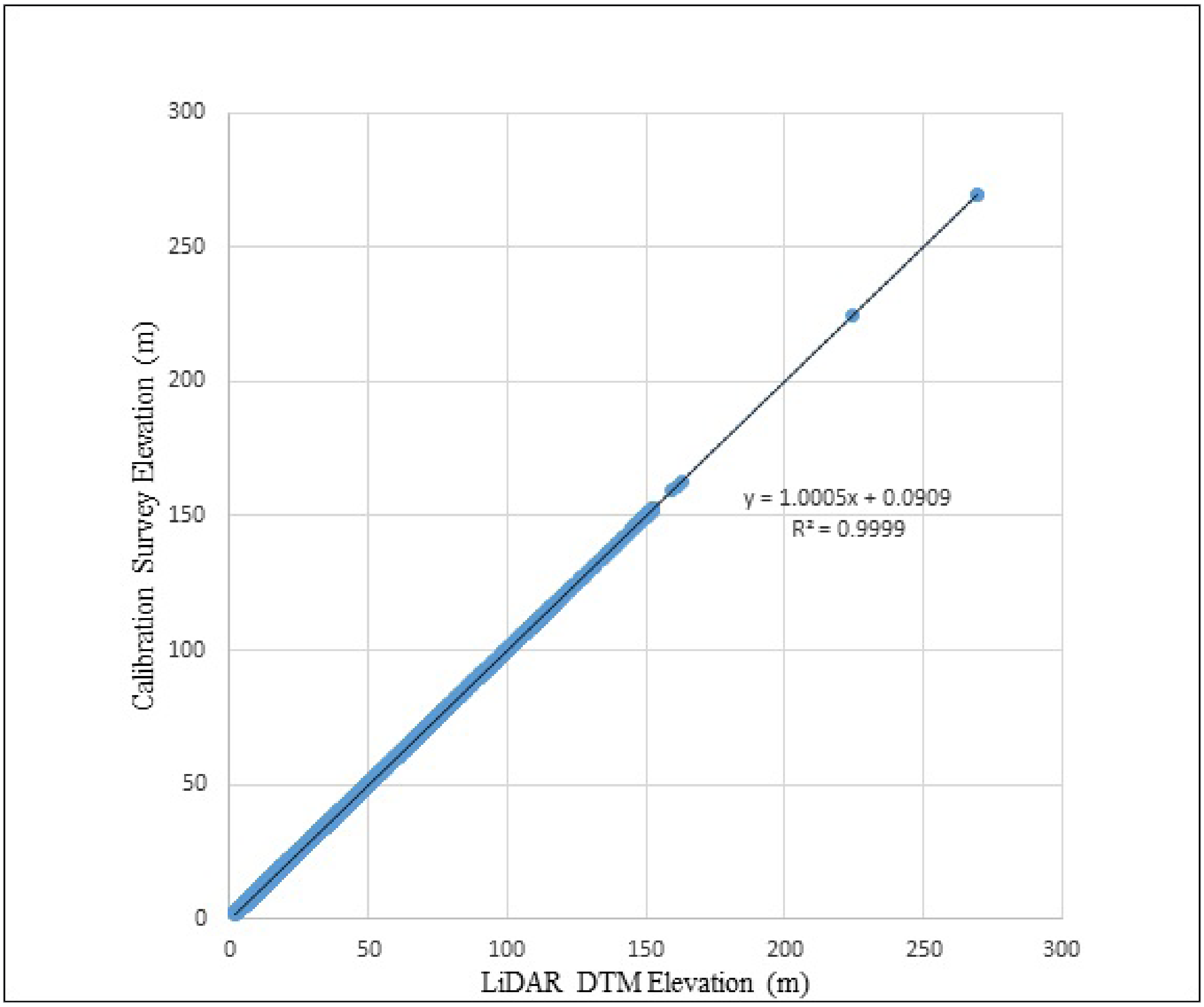

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.23
Standard Deviation	0.20
Average	0.10
Minimum	-0.33
Maximum	0.53

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 26 points. These were used for the validation of calibrated Lumintao DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.06 meters, as shown in Table 20.

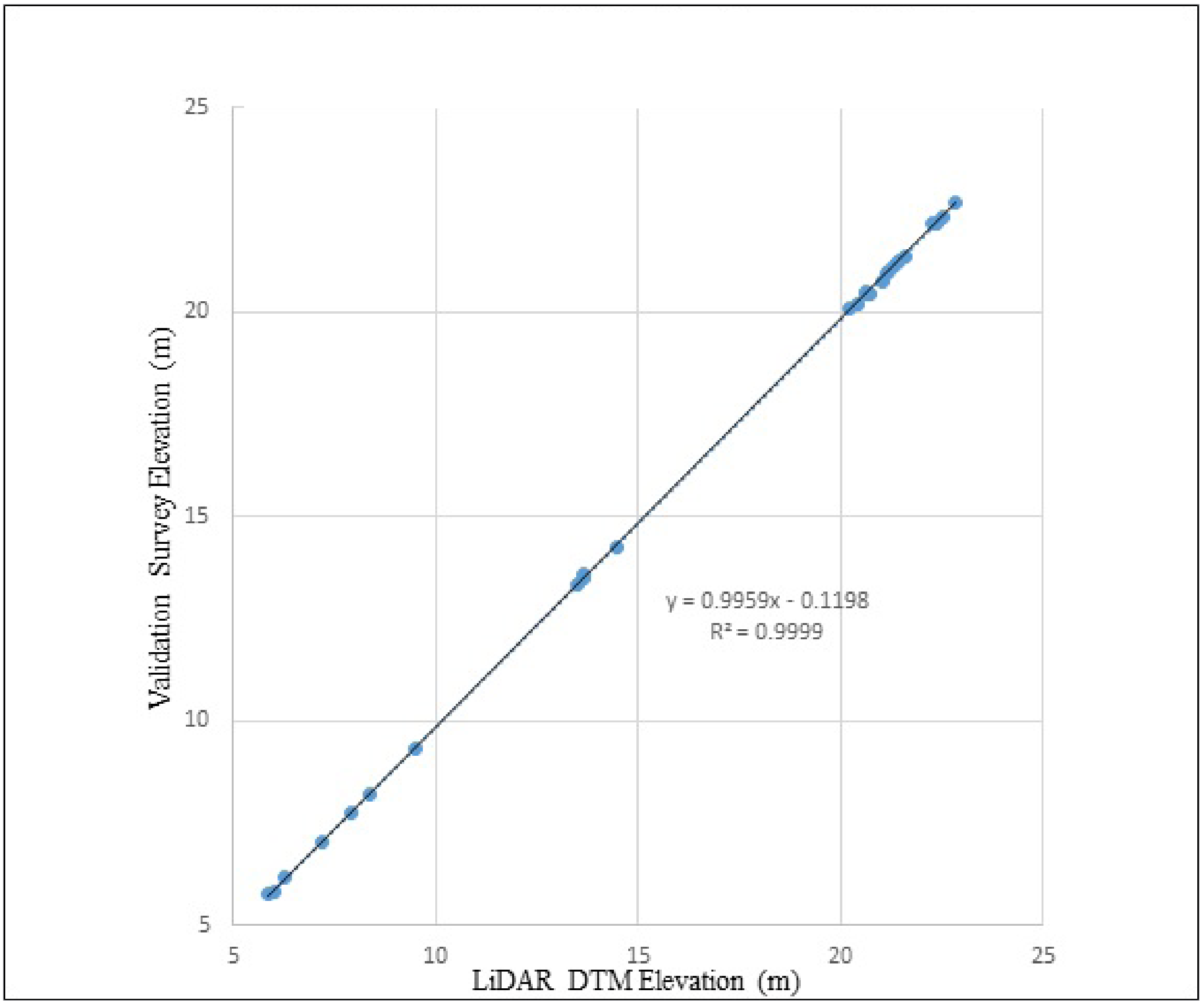

Figure 25. Correlation plot between validation survey points and LiDAR data

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.06
Average	-0.19
Minimum	-0.31
Maximum	-0.10

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Lumintao with 28,933 and 5,968 bathymetric survey points, respectively. However, no bathy integration was performed because the geometry of the river is best represented by the acquired LiDAR data. This is applicable for areas flown during dry season where the wetted perimeter of the river corresponds to only 10% of its width. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Lumintao integrated with the processed LiDAR DEM is shown in Figure 26.

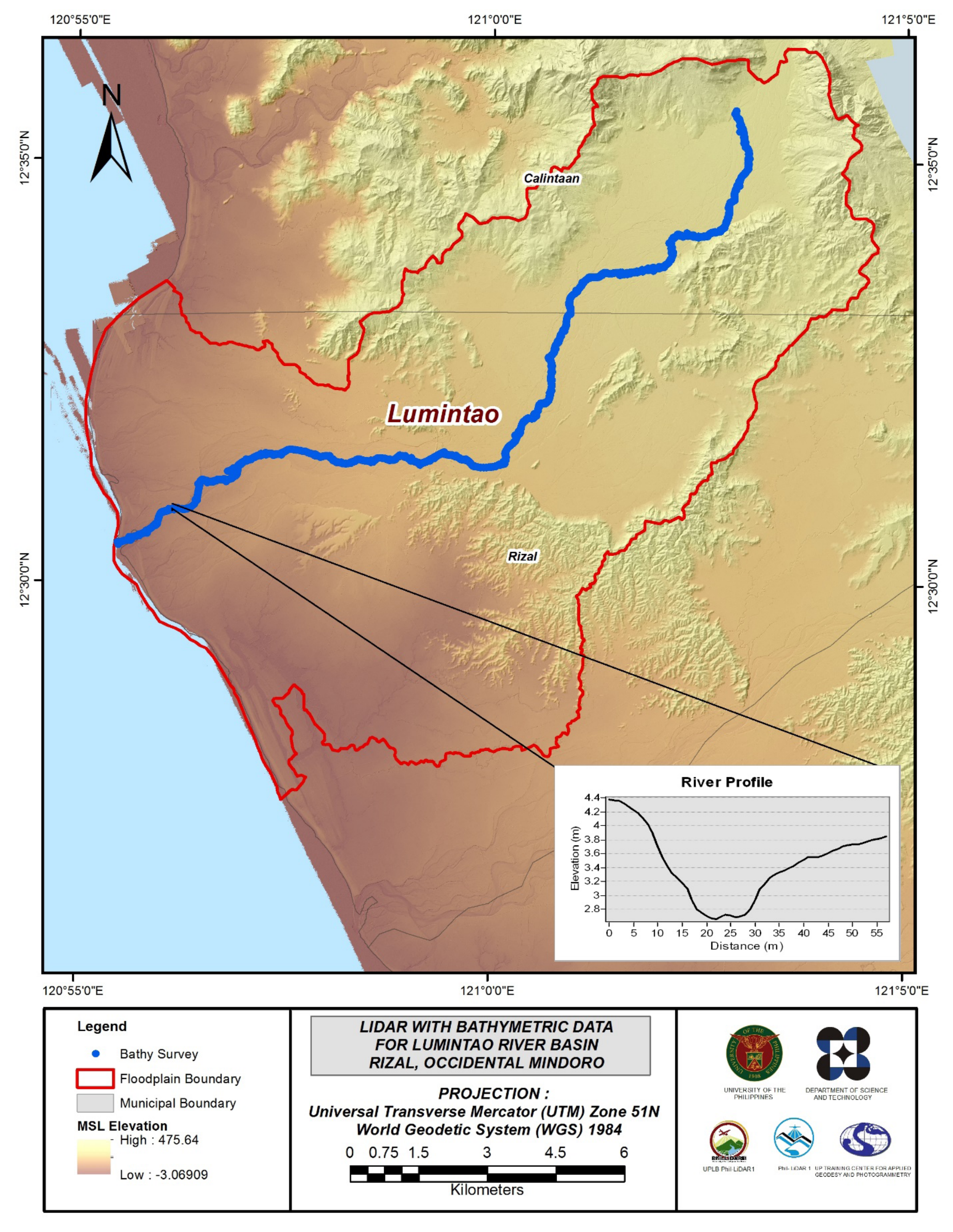

Figure 26. Map of Lumintao Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Lumintao River on November 3-24, 2015 with the following scope of work: reconnaissance to determine the viability of traversing the planned routes for bathymetric survey; courtesy call with UPLB, Rizal and Calintaan LGUs and MDRRMC; control survey; cross-section survey, bridge as-built features determination and water level marking at Lumintao Bridge in Brgy. Magsikap, Municipality of Rizal; ground validation survey along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate distance of 191 km. Lastly, bathymetric survey from Brgy. Poypoy down to the mouth of the river in Brgy. Malawaan, with an approximate length of 16.01 km using GNSS PPK survey technique.

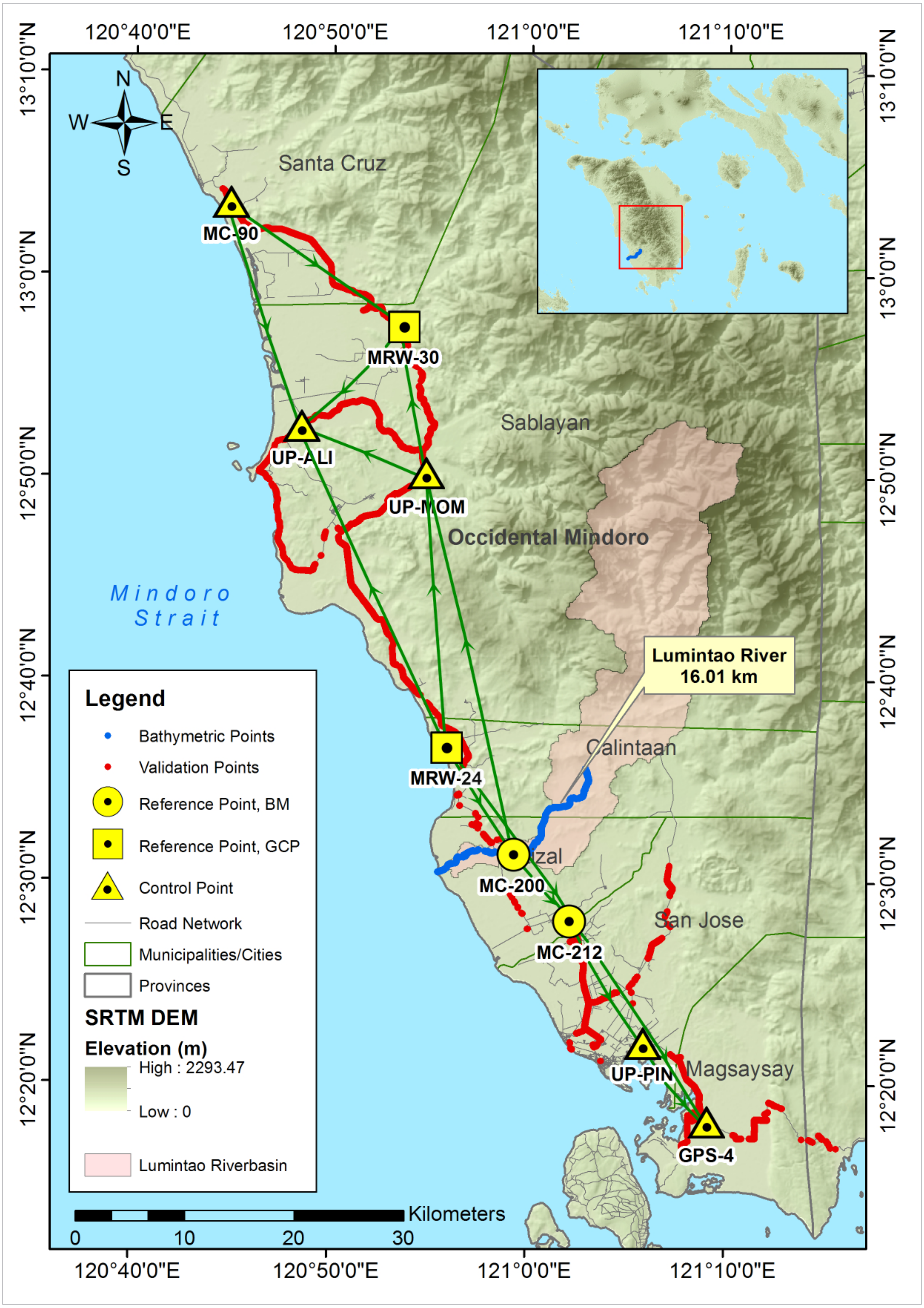


Figure 27. Lumintao River survey extent.

4.2 Control Survey

The GNSS network used for Lumitao River Basin is composed of five (5) loops established on November 5, 15 and 17, 2015 occupying the following reference points: MRW-24, a second order GCP in Brgy. Iriron, Municipality of Calintaan; MRW-30, a second order GCP in Bry. Pinagturilan, Municipality of Sta. Cruz; MC-200, a first order BM in Brgy. Magsikap, Municipality of Rizal; and MC-212, also a first order BM in Brgy. Sto. Niño in Rizal.

Three (3) control points were established along the approach of bridges, namely: UP-PIN at Pinamanaan Bridge in Brgy. Mapaya, Municipality of San Jose; UP-ALI at Alipid Bridge in Brgy. Sto. Niño, Municipality of Sablayan; and UP-MOM at Mompong Bridge in Brgy. Lumang Bato, also in Sablayan. The control point established by DPWH, namely GPS-4, in Brgy. Poblacion, Municipality of Magsaysay; and MC-90, established by NAMRIA, in Brgy. Barahan, Municipality of Sta. Cruz were also occupied to use as a marker for the network.

The summary of reference and control points and its location is summarized in Error! Reference source not found. while the GNSS network established is illustrated in Error! Reference source not found.8.

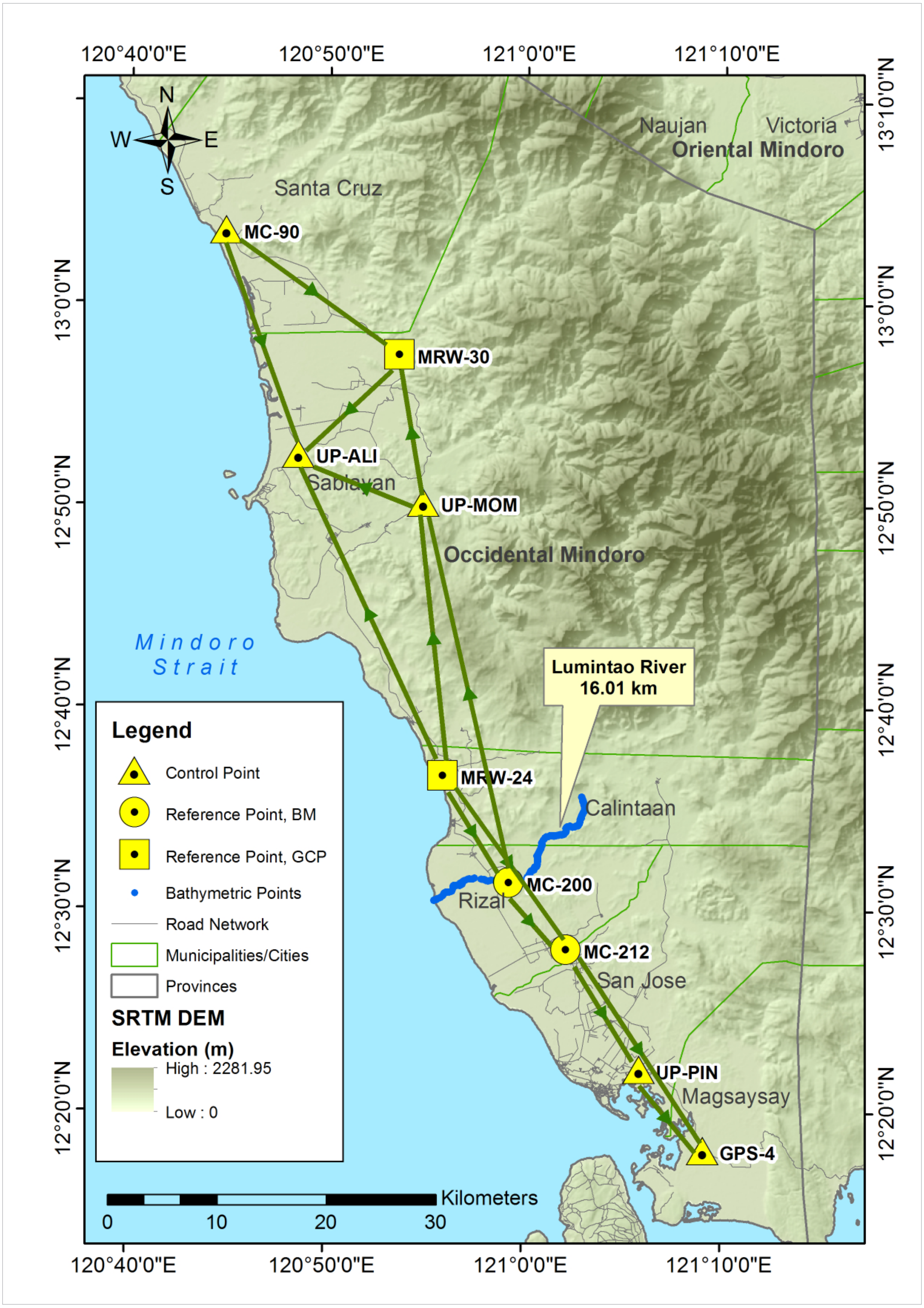


Figure 28. GNSS Network covering Lumintao River

Table 21. List of reference and control points occupied for Lumintao River Survey (Source: NAMRIA and UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
MC-200	1st order, BM	-	-	83.225	-	2007
MC-212	1st order, BM	-	-	74.473	-	2007
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	4.746	2007
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	41.752	2007
MC-90	UP Established	-	-	-	-	2007
UP-ALI	UP Established	-	-	-	-	2015
UP-MOM	UP Established	-	-	-	-	2015
UP-PIN	UP Established	-	-	-	-	2015
GPS-4	DPWH Established	-	-	-	-	2013

The GNSS set up in reference points and established control points in Occidental Mindoro survey are shown in Error! Reference source not found. to 37.

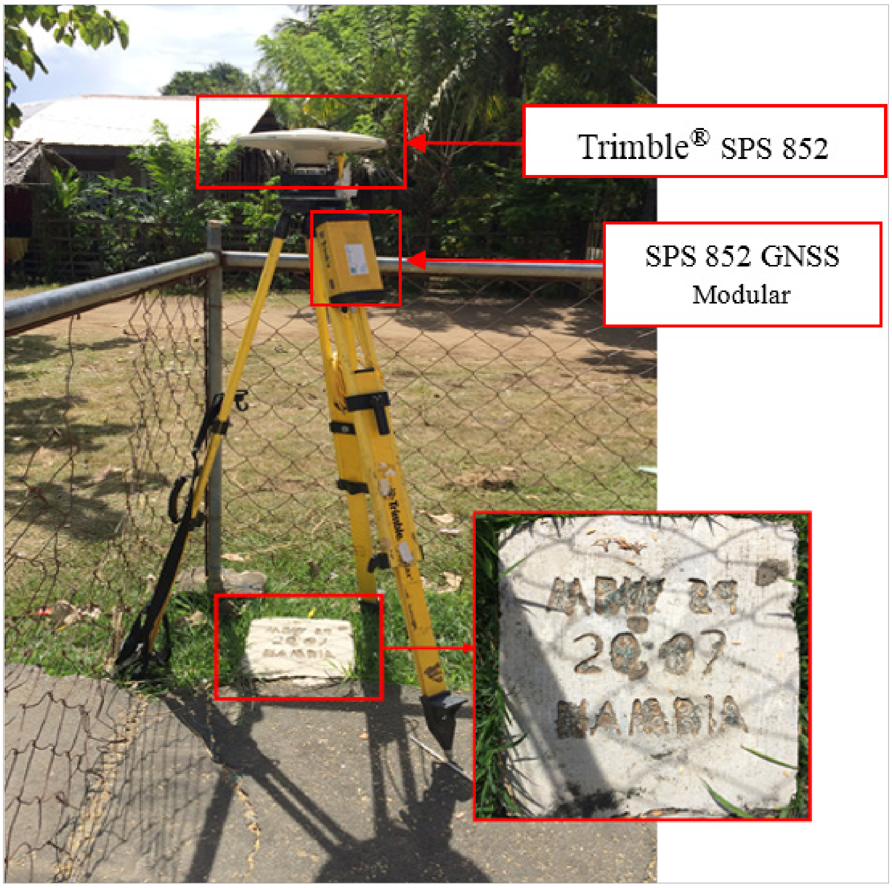


Figure 29. GNSS base set-up, Trimble® SPS 882, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro.

Figure 30. GNSS receiver setup, Trimble® SPS 882, at MRW- 30 Amnay Bridge approach in Sitio Kabangkalan, Brgy. Pinagturilan, Municipality of Santa Cruz, Occidental Mindoro.

Figure 31. GNSS receiver set-up, Trimble® SPS 882, at MC-200, Lumintao Bridge approach in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro.

Figure 32. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro.

Figure 33. GNSS base, Trimble® SPS 852, at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

Figure 34. GNSS receiver, Trimble® SPS 882, at GPS-4 on right side of the road abutment after Caguray Bridge going to Bulalacao in Brgy. Poblacion, Municipality of Magsaysay, Occidental Mindoro.

Figure 35. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 36. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro.

Figure 37. GNSS receiver set up, Trimble® SPS 882, at UP-ALI, Alipid Bridge approach in Brgy. Sto. Niño, Municipality of Sablayan, Occidental Mindoro

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Lumintao River Basin is summarized in Error! Reference source not found. generated in TBC software.

Table 22. Baseline Processing Report for Lumintao River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
MC-212 --- GPS-4	11-05-2015	Fixed	0.003	0.015	145°21'06"	22241.566	-11.807
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.011	0.017	170°24'13"	13704.513	55.240
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.003	0.023	170°24'12"	13704.541	55.249
MRW-30 --- MC-90	11-17-2015	Fixed	0.010	0.018	305°24'12"	19473.086	-35.515
UP-PIN --- MC-212	11-05-2015	Fixed	0.003	0.007	328°11'40"	12856.399	14.631
UP-PIN --- GPS-4	11-05-2015	Fixed	0.003	0.006	141°30'11"	9422.221	2.872
MC-200 --- UP-PIN	11-05-2015	Fixed	0.003	0.022	144°37'57"	20841.368	-23.356
MC-200 --- UP-MOM	11-05-2015	Fixed	0.009	0.014	346°57'26"	35544.301	60.755
MC-200 --- UP-MOM	11-05-2015	Fixed	0.004	0.014	346°57'27"	35544.309	60.692
MC-200 --- MC-212	11-05-2015	Fixed	0.003	0.006	138°58'31"	8048.668	-8.741
UP-ALI --- UP-MOM	11-15-2015	Fixed	0.008	0.013	110°57'37"	12258.370	88.024
UP-MOM --- UP-ALI	11-15-2015	Fixed	0.004	0.036	110°57'37"	12258.373	88.139
UP-ALI --- MRW-30	11-17-2015	Fixed	0.009	0.012	45°05'52"	12929.488	32.865
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.017	45°05'52"	12929.476	32.850
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.007	45°05'51"	12929.529	32.747
MC-90 --- UP-ALI	11-17-2015	Fixed	0.004	0.008	341°46'30"	21480.592	-2.784
MRW-24 --- UP-PIN	11-05-2015	Fixed	0.003	0.006	145°50'52"	32317.096	6.413
MRW-24 --- MC-200	11-05-2015	Fixed	0.005	0.007	148°04'31"	11489.166	29.777
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.009	0.015	355°30'36"	24950.818	90.611
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.003	0.006	355°30'36"	24950.824	90.574
MRW-24 --- UP-ALI	11-15-2015	Fixed	0.006	0.007	335°24'00"	32186.124	2.579

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

The nine (9) control points, MRW-24, MRW-30, MC-200, MC-212, MC-90, GPS-4, UP-PIN, UP-MOM, and UP-ALI were occupied and observed simultaneously to form a GNSS loop. All 14 baselines acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively as shown in Error! Reference source not found.

Table 23. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
MC-200	Grid				Fixed
MC-212	Grid				Fixed
MRW-24	Global	Fixed	Fixed		
MRW-30	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

Table 24. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
GPS-4	299069.894	0.039	1360649.962	0.032	12.062	0.068	
MC-200	281320.527	0.022	1385155.121	0.016	34.024	?	e
MC-212	286558.124	0.028	1379041.958	0.022	24.884	?	e
MC-90	255607.924	0.039	1444800.407	0.023	8.195	0.095	
MRW-24	275320.607	?	1394955.913	?	4.746	0.045	LL
MRW-30	271390.777	?	1433384.691	?	41.752	0.091	LL
UP-ALI	262152.459	0.020	1424334.041	0.015	9.503	0.071	
UP-MOM	273564.872	0.015	1419850.456	0.012	96.192	0.055	
UP-PIN	293256.669	0.031	1368066.413	0.024	9.659	0.045	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown inError! Reference source not found.Error! Reference source not found..Using the equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20\ cm$ for horizontal and $z_e < 10\ cm$ for the vertical; below is the computation for accuracy that passed the required precision:

a. GPS-4

Horizontal accuracy = $\sqrt{((3.9)^2 + (3.2)^2}$
= $\sqrt{(15.21 + 10.24)}$
= 5.0 cm < 20 cm
Vertical accuracy = 6.8 cm < 10 cm

b. MC-200

Horizontal accuracy = $\sqrt{((2.2)^2 + (1.6)^2}$
= $\sqrt{(4.84 + 2.56)}$
= 7.4 cm < 20 cm
Vertical accuracy = Fixed

c. MC-212

Horizontal accuracy = $\sqrt{((2.8)^2 + (2.2)^2}$
= $\sqrt{(7.84+ 4.84)}$
= 3.6 cm < 20 cm
Vertical accuracy = Fixed

d. MC-90

Horizontal accuracy = $\sqrt{((3.9)^2 + (2.3)^2}$
= $\sqrt{(15.21 + 5.29)}$
= 4.5 cm < 20 cm
Vertical accuracy = 9.5 cm < 10 cm

e. MRW-24

Horizontal accuracy = Fixed
Vertical accuracy = 4.5 cm < 10 cm

f. MRW-30

Horizontal accuracy = Fixed
Vertical accuracy = 9.1 cm < 10 cm

g. UP-ALI

Horizontal accuracy = $\sqrt{((2.0)^2 + (1.5)^2}$
= $\sqrt{(4.0 + 2.25)}$
= 2.5 cm < 20 cm
Vertical accuracy = 7.1 cm < 10 cm

h. UP-MOM

Horizontal accuracy = $\sqrt{((1.5)^2 + (1.2)^2}$
= $\sqrt{(2.25 + 1.44)}$
= 1.9 cm < 20 cm
Vertical accuracy = 5.5 cm < 10 cm

i. UP-PIN

Horizontal accuracy = $\sqrt{((3.1)^2 + (2.4)^2}$
= $\sqrt{(9.61 + 5.76)}$
= 3.9 cm < 20 cm
Vertical accuracy = 4.5 cm < 10 cm

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

Table 25. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
GPS-4	N12°18'07.55698"	E121°09'08.74194"	62.705	0.068	
MC-200	N12°31'20.68884"	E120°59'15.31613"	83.225	?	e
MC-212	N12°28'03.07503"	E121°02'10.26310"	74.473	?	e
MC-90	N13°03'34.14427"	E120°44'46.70844"	53.232	0.095	
MRW-24	N12°36'38.03549"	E120°55'54.08296"	53.435	0.045	LL
MRW-30	N12°57'27.19115"	E120°53'33.54442"	88.823	0.091	LL
UP-ALI	N12°52'30.24359"	E120°48'29.69149"	55.998	0.071	
UP-MOM	N12°50'07.47193"	E120°54'49.30855"	144.013	0.055	
UP-PIN	N12°22'07.54999"	E121°05'54.64323"	59.843	0.045	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Error! Reference source not found.. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Error! Reference source not found..

Table 26. References and Control Points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MC-200	1st order, BM	12°31'20.68883"	120°59'15.31614"	83.225	1385155.121	281320.527	34.024
MC-212	1st order, BM	12°28'03.07504"	121°02'10.26310"	74.473	1379041.958	286558.124	24.884
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MC-90	UP Established	13°03'34.14426"	120°44'46.70845"	53.232	1444800.407	255607.924	8.195
UP-ALI	UP Established	12°52'30.24358"	120°48'29.69148"	55.998	1424334.041	262152.459	9.503
UP-MOM	UP Established	12°50'07.47192"	120°54'49.30854"	144.013	1419850.456	273564.872	96.192
UP-PIN	UP Established	12°22'07.55000"	121°05'54.64323"	59.843	1368066.413	293256.669	9.659
GPS-4	DPWH Established	12°18'07.55700"	121°09'08.74194"	62.706	1360649.962	299069.894	12.062

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

Bridge cross-section and as-built survey were conducted on November 5 and 8, 2015 at the downstream side of Lumintao Bridge across Lumintao River in Brgy. Magsikap, Municipality of Rizal using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Error! Reference source not found..

Figure 38. Bridge as-built and cross-section survey at the downstream side of Lumintao Bridge, Brgy. Magsikap, Municipality of Rizal

The cross-sectional line length in Lumintao is about 609.99 meters with 181 cross-sectional points using MRW-24 and MC-212 as the GNSS base stations. The cross section diagram, location map, and the bridge data form are shown in Error! Reference source not found. to Error! Reference source not found., respectively.

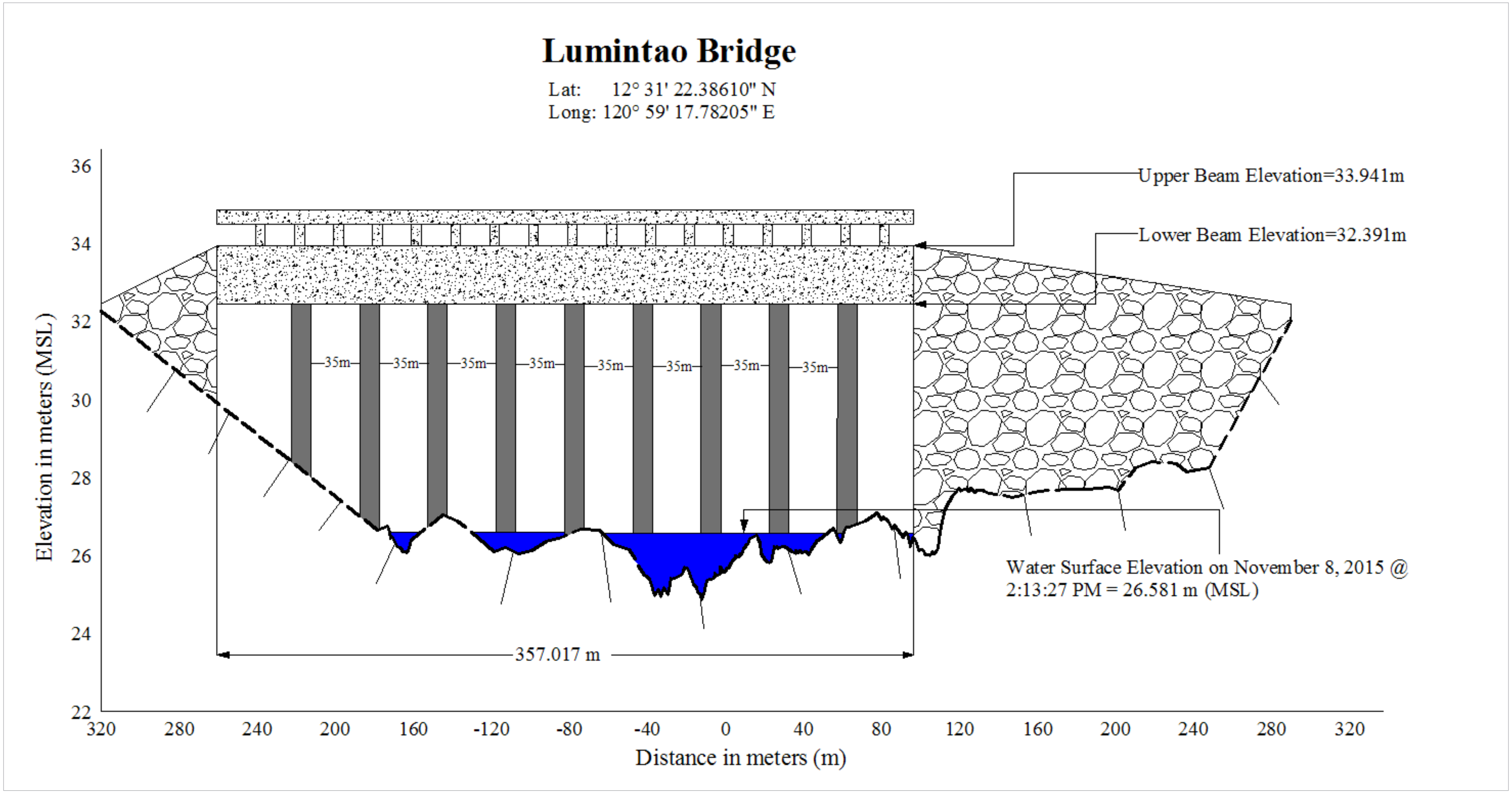


Figure 39. Lumintao Bridge cross-section diagram.

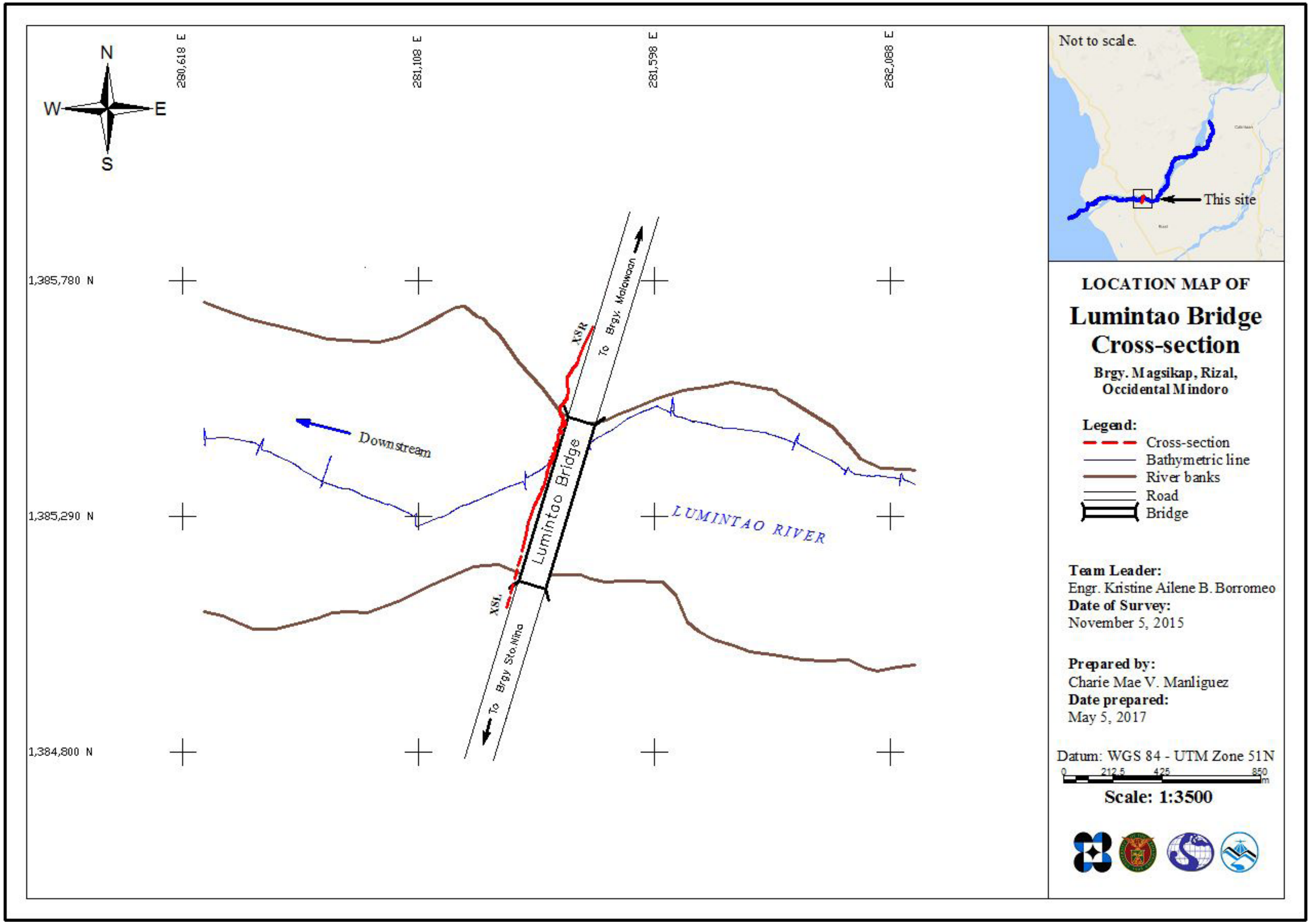


Figure 40. Lumintao bridge cross-section location map.

Bridge Data Form

Bridge Name: Lumintao Bridge **Date:** November 8, 2015

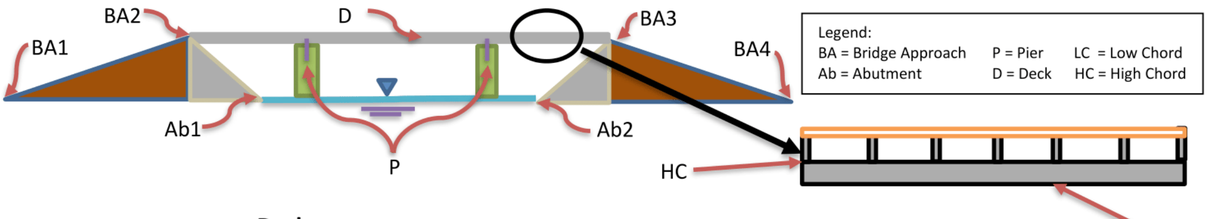
River Name: Lumintao River **Time:** 2:13:27 PM

Location (Brgy, City, Region): Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

Survey Team: Occidental Mindoro Team

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

Latitude: 12d28'03.07520" N **Longitude:** 121d02'10.26303" E



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

Elevation 24.892 m MSL **Width:** ______ **Span (BA3-BA2):** 357.017 m

	Station	High Chord Elevation	Low Chord Elevation
1		33.941	32.391
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	32.247	**BA3**	416.2112925	33.996
BA2	59.19440917	34.070	**BA4**	609.9939846	32.013

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: CYLINDRICAL **Number of Piers:** 9 **Height of column footing:** ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	97.35519645	33.941	
Pier 2	132.427011	33.923	
Pier 3	167.1761027	34.062	
Pier 4	202.2619963	34.051	
Pier 5	237.5454212	33.939	
Pier 6	272.4557671	33.942	
Pier 7	307.3713705	34.009	
Pier 8	342.3571279	34.026	
Pier 9	377.2996365	34.068	

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

Figure 41. Lumintao Bridge Data Form.

The water surface elevation of 27.625 in EGMOrtho (26.581 m in MSL) Lumintao River was determined using a Trimble® SPS 882 in PPK mode technique on November 8, 2015 at 2:13:27 PM. This was translated onto marking the bridge's pier using a digital level. The value of 27.863 m in Error! Reference source not found. is in EGMOrtho and will be updated by UP Los Baños to reflect its corresponding MSL value of 26.581 m. The marked pier will serve as their reference for flow data gathering and depth gauge deployment for Lumintao River.

Figure 42. Water level marking at Lumintao Bridge's pier in Brgy. Magsikap, Municipality of Rizal

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 6, 7, 8 14, 17, 18, and 21, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached either to the front or side of vehicle as shown in Error! Reference source not found.. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.460 and 1.91 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with MC-212, GPS-4, MC-90 and MRW-30 occupied as the GNSS base stations in the conduct of the survey.

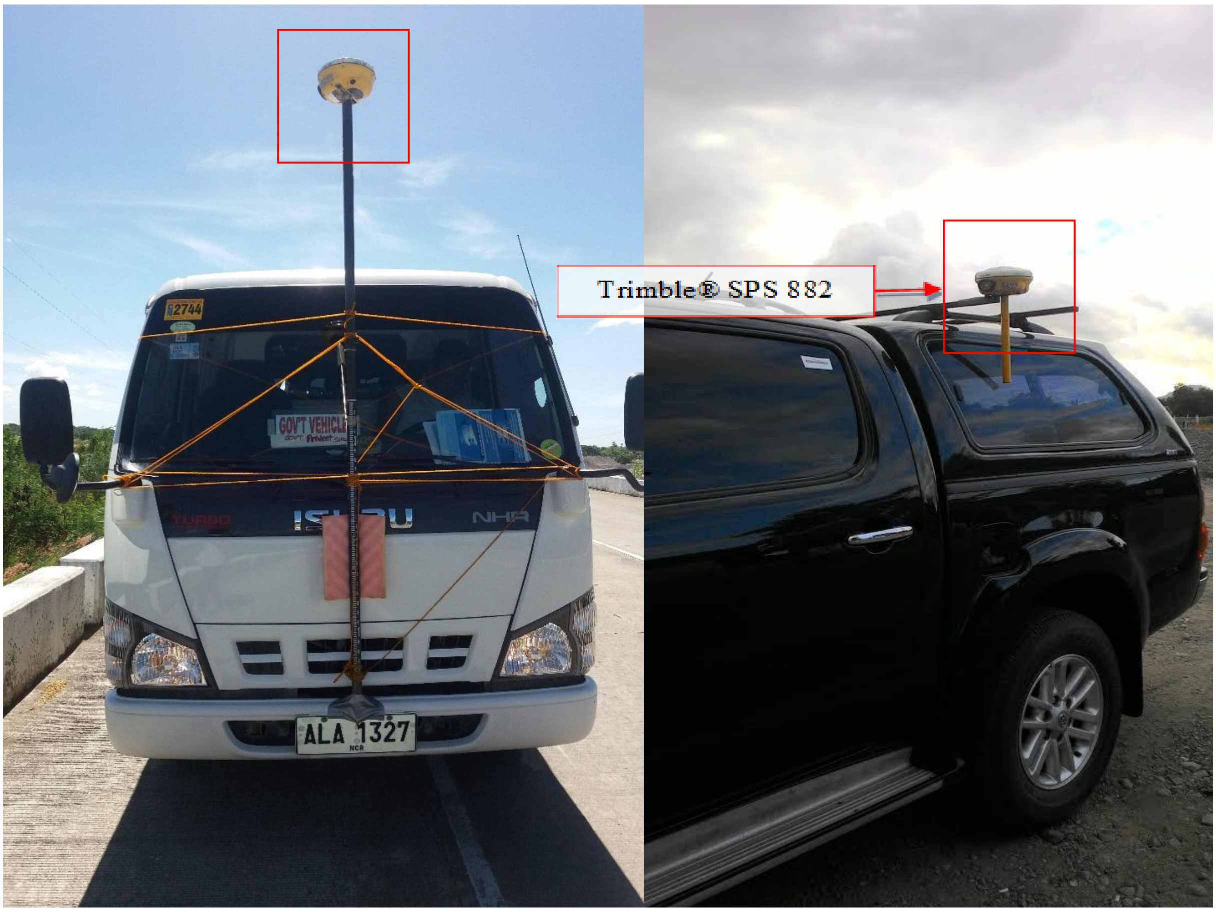


Figure 43. Validation points acquisition survey set-up.

The survey was along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate length of 191 km with 26,449 validation points gathered. The gaps in the validation line as shown in Error! Reference source not found. were due to road contractions and difficulties in receiving satellite signals because of the presence of obstructions such as dense canopy cover of trees along the roads.

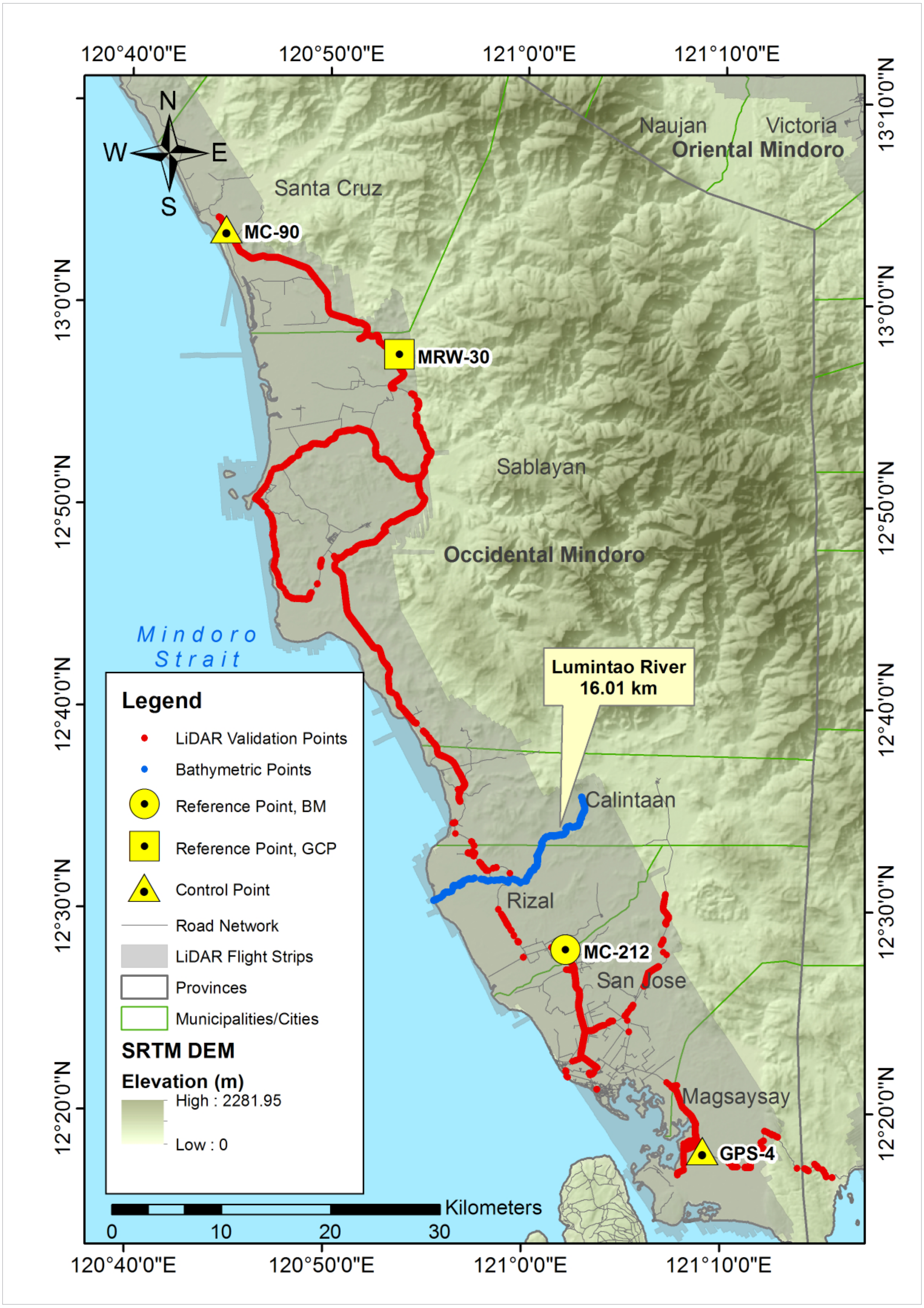


Figure 44. Validation point acquisition survey for Lumintao River Basin.

4.7 River Bathymetric Survey

Bathymetric survey was conducted on November 10, 11 and 12, 2015 using Trimble® SPS 882 using the control point MC-200 as base station. The survey started at the upstream portion of the river in Brgy. Poypoy, Municipality of Calintaan with coordinates 12°35’37.16210” 121°02’55.08124” down to Brgy. Magsikap, Municipality of Rizal and ended at the mouth of the river in Brgy. Malawaan also in Rizal with coordinates 12°30’28.04622” 120°55’33.36736”. The set-up of manual bathymetry is shown on Error! Reference source not found..

Figure 45. Manual Bathymetry along Lumintao River.

The entire bathymetric data coverage for Lumintao River is illustrated in the map in Error! Reference source not found.46. The gaps in the bathymetric survey was due to difficulties in acquiring satellite caused by obstructions such as dense canopy of trees and presence of rapids along the river.

A CAD diagram was also produced to illustrate the Lumintao riverbed profile as shown in Error! Reference source not found.47. An elevation drop of 55.4 meters in MSL was observed within the approximate distance of 16.01 km with a total of 34, 931 bathymetric points gathered. Gradual change in elevation can also be seen in the illustration with an average change elevation of about 1.8m for every 500-meter interval.

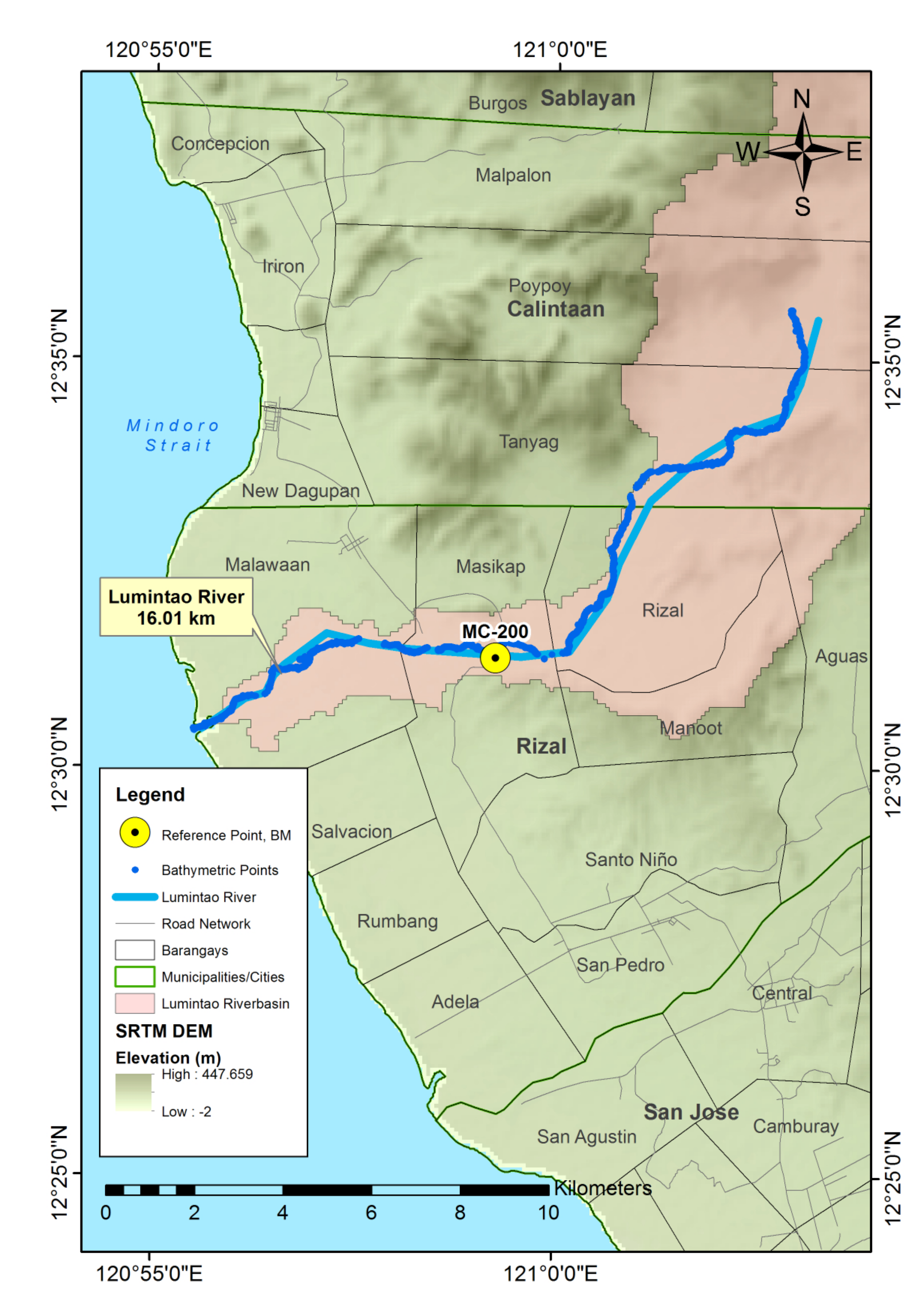


Figure 46. Bathymetric survey of Lumintao River.

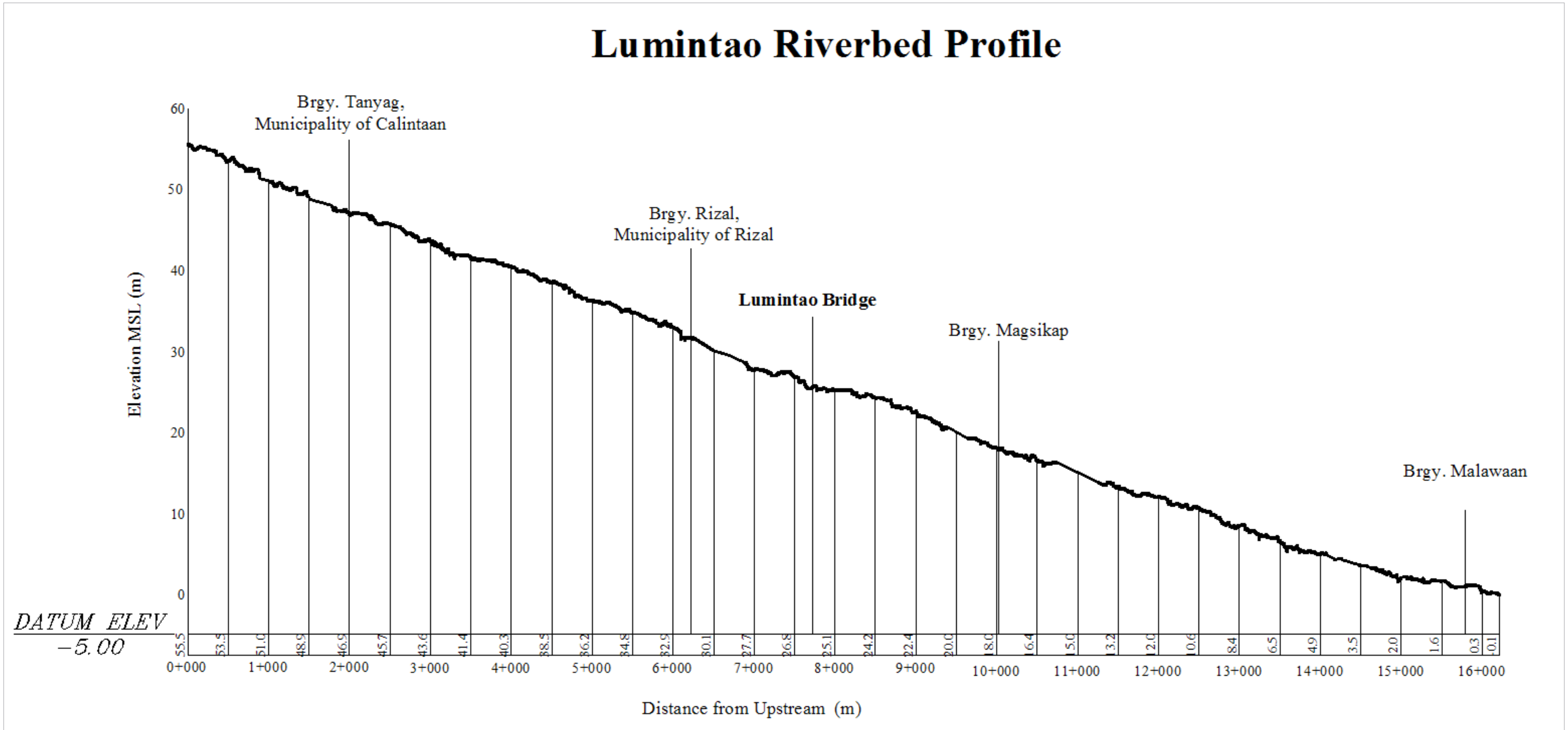


Figure 47. Riverbed profile of Lumintao River.

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Kevin M. Manalo

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

5.1 Data used in Hydrologic Modeling

No gathered rainfall data for Lumintao river basin. The HMS model is not calibrated. The values generated HMS model are by default.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Romblon Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Lumintao watershed. The extreme values for this watershed were computed based on a 48-year record.

Table 27. RIDF values for Romblon 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	18.2	27	33.5	44.3	59.5	70.4	89.5	107	119.8
5	26	37.7	46.5	60.7	82.2	97.6	125.5	152.9	171.6
10	31.1	44.8	55	71.5	97.3	115.7	149.3	183.4	205.9
15	34	48.8	59.9	77.7	105.8	125.8	162.8	200.5	225.2
20	36	51.6	63.3	82	111.8	133	172.2	212.6	238.8
25	37.6	53.8	65.9	85.3	116.4	138.4	179.4	221.8	249.2
50	42.4	60.4	74	95.4	130.5	155.3	201.8	250.3	281.4
100	47.2	67	81.9	105.5	144.5	172.1	223.9	278.6	313.3

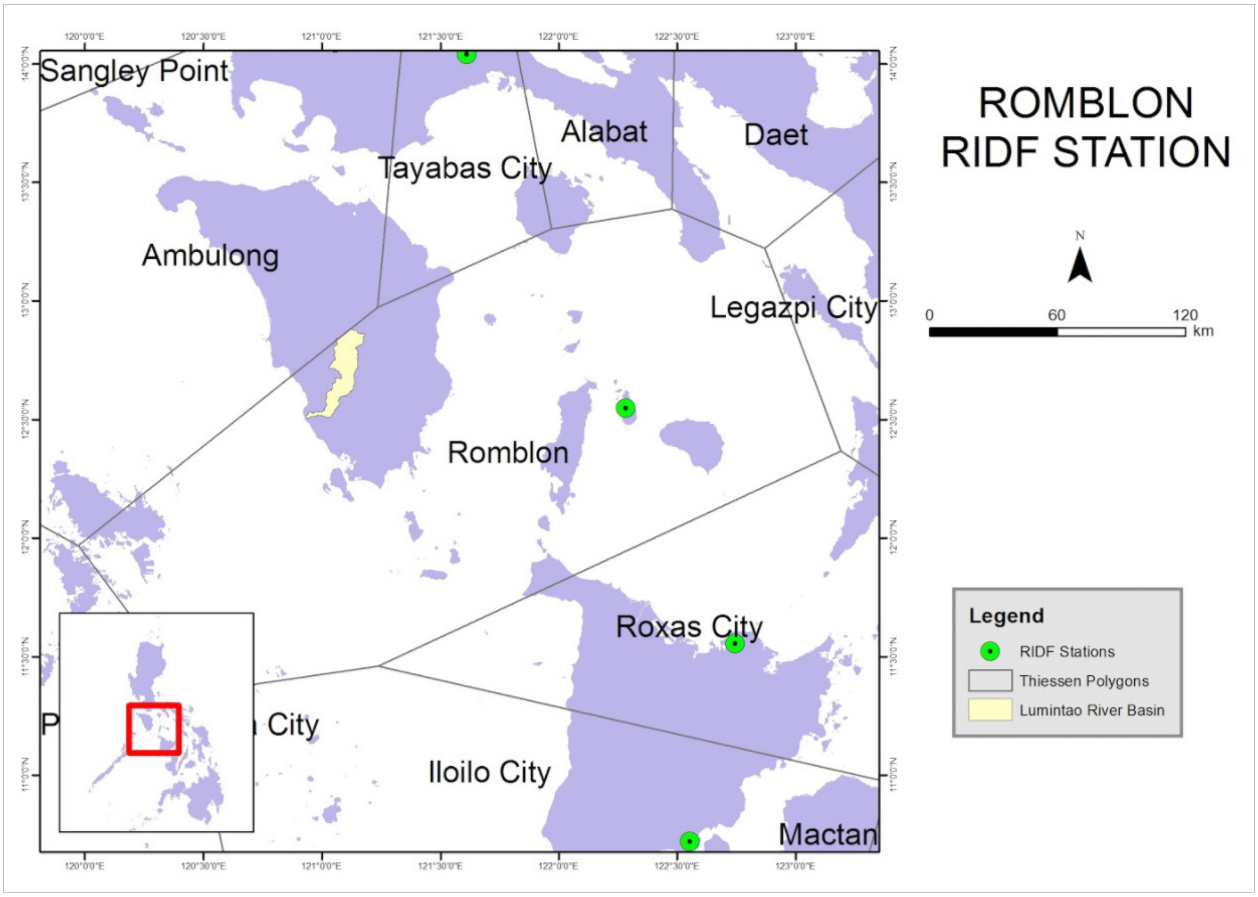


Figure 48. Location of Puerto Princesa RIDF relative to Lumintao River Basin.

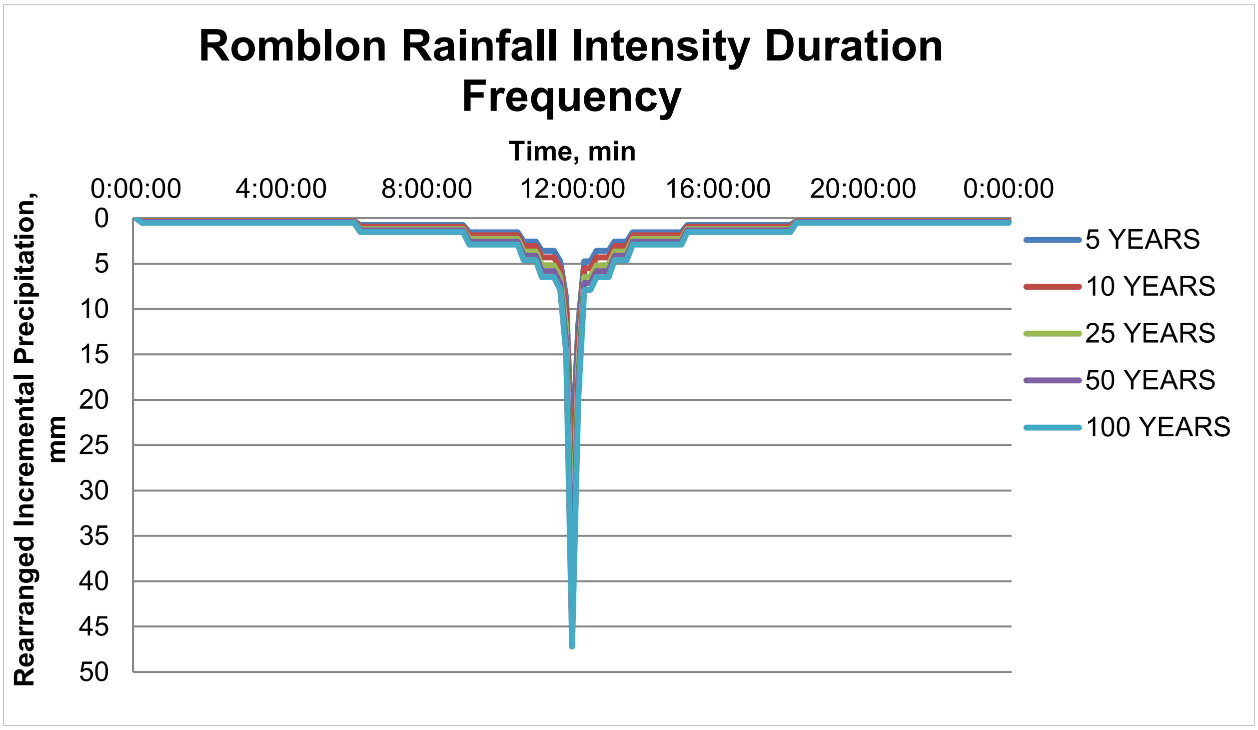


Figure 49. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil shape file was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA).

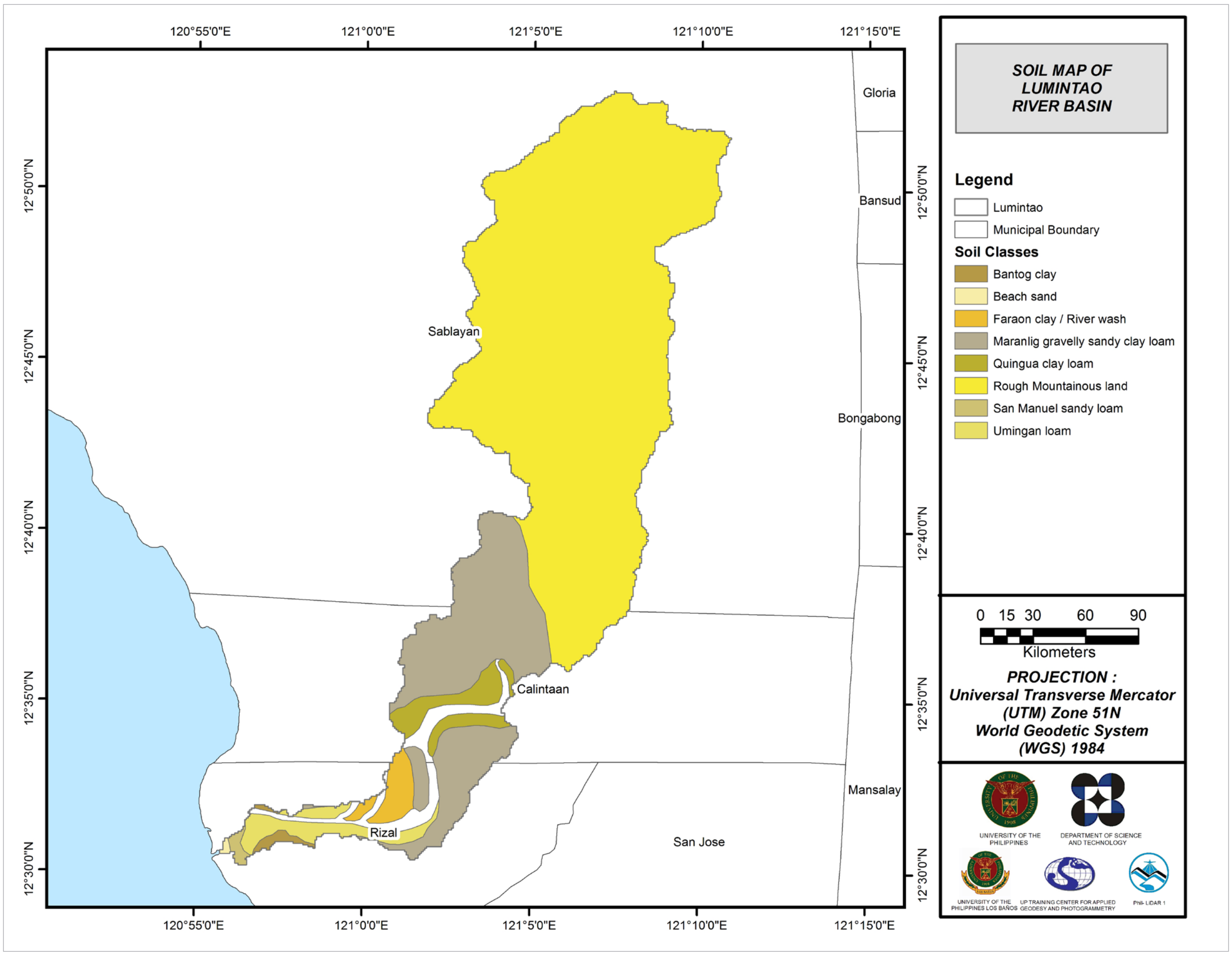


Figure 50. The soil map of the Lumintao River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture).

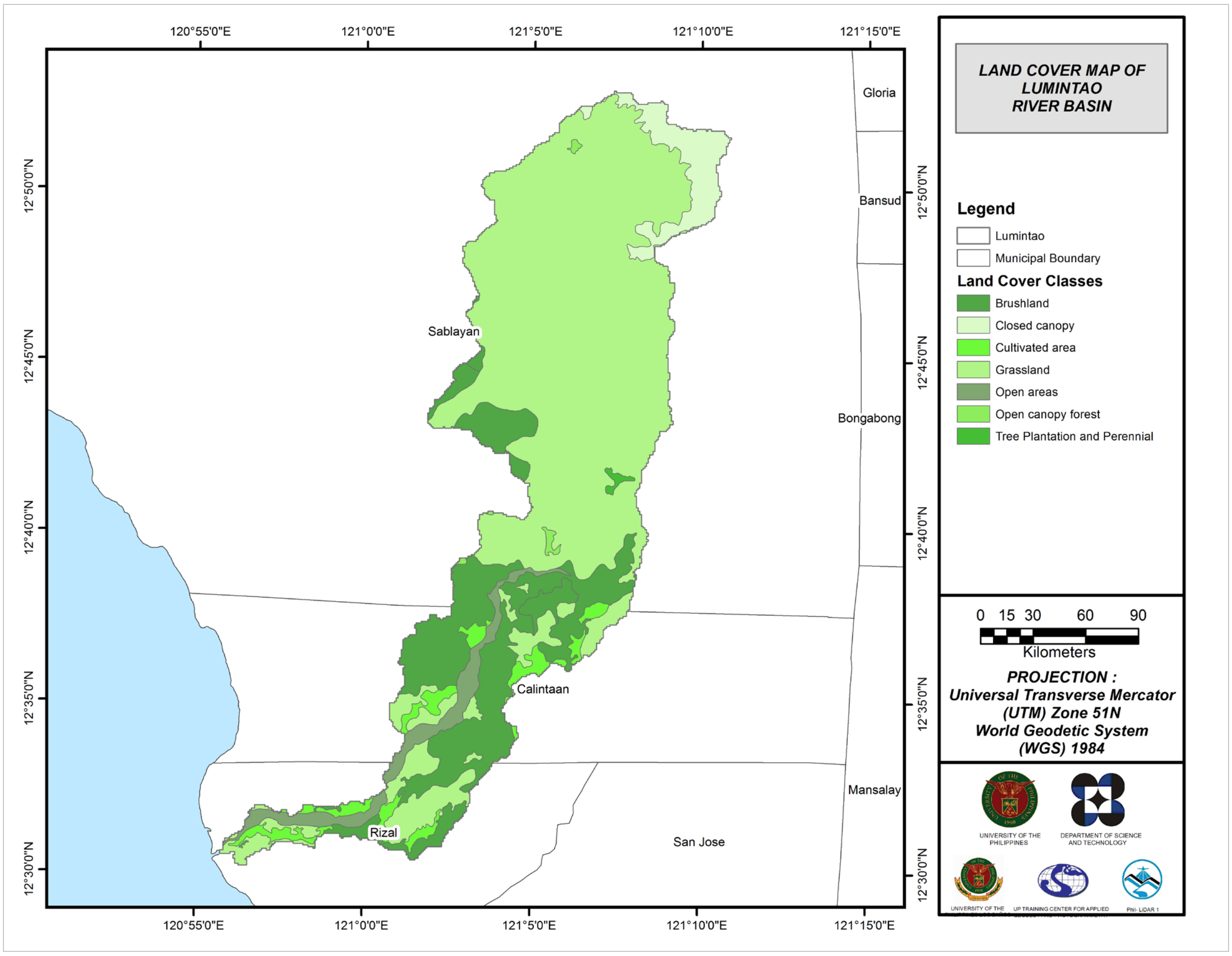


Figure 51. The land cover map of the Lumintao River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture).

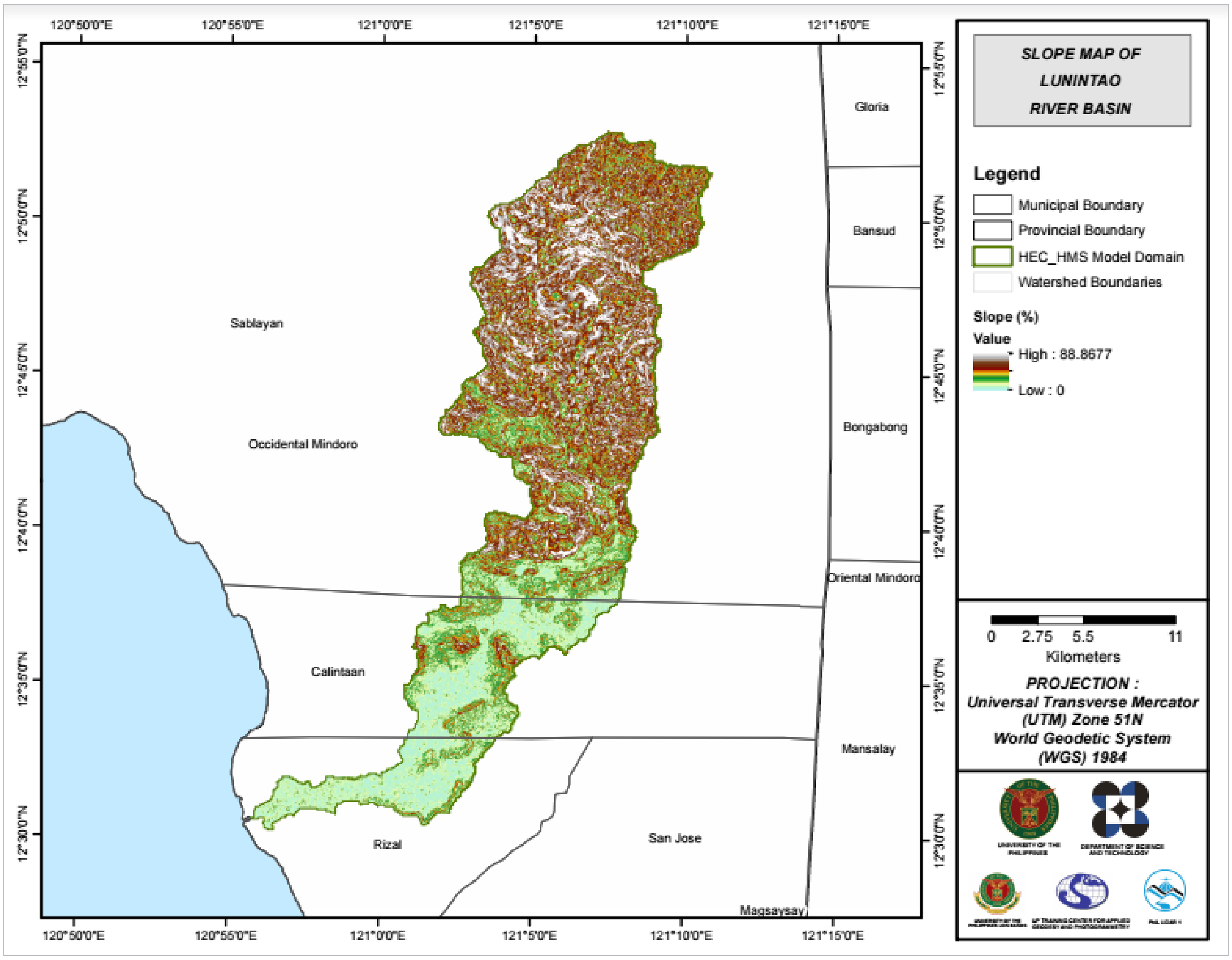


Figure 52. Slope Map of the Lumintao River Basin

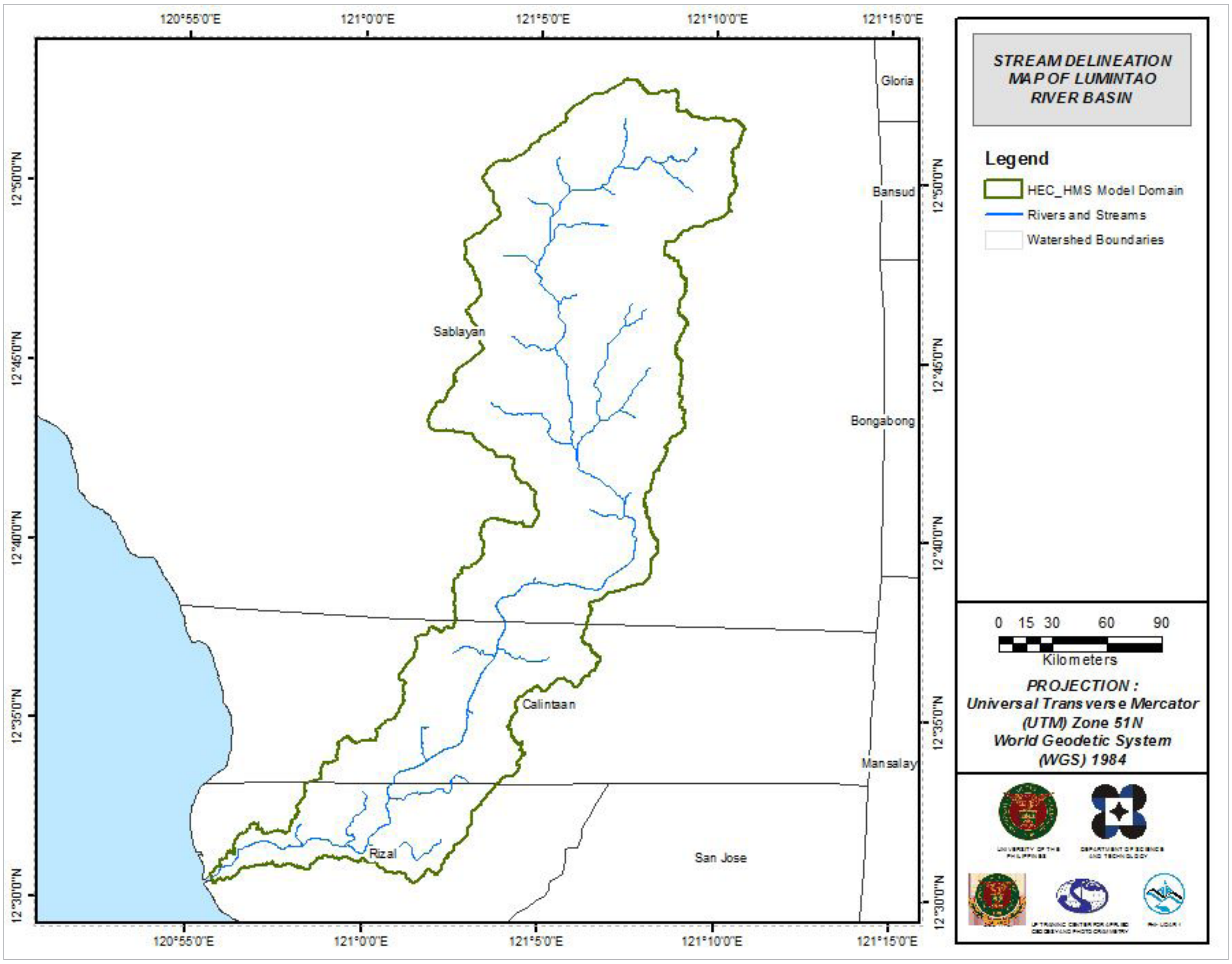


Figure 53. Stream Delineation Map of the Lumintao River Basin

Using SAR-based DEM, the Lumintao basin was delineated and further subdivided into subbasins. The model consists of 54 sub basins, 26 reaches, and 25 junctions. The main outlet is labelled as Lumintao_outlet. This basin model is illustrated in Figure 54. The basins were identified based on soil and land cover characteristics of the area.

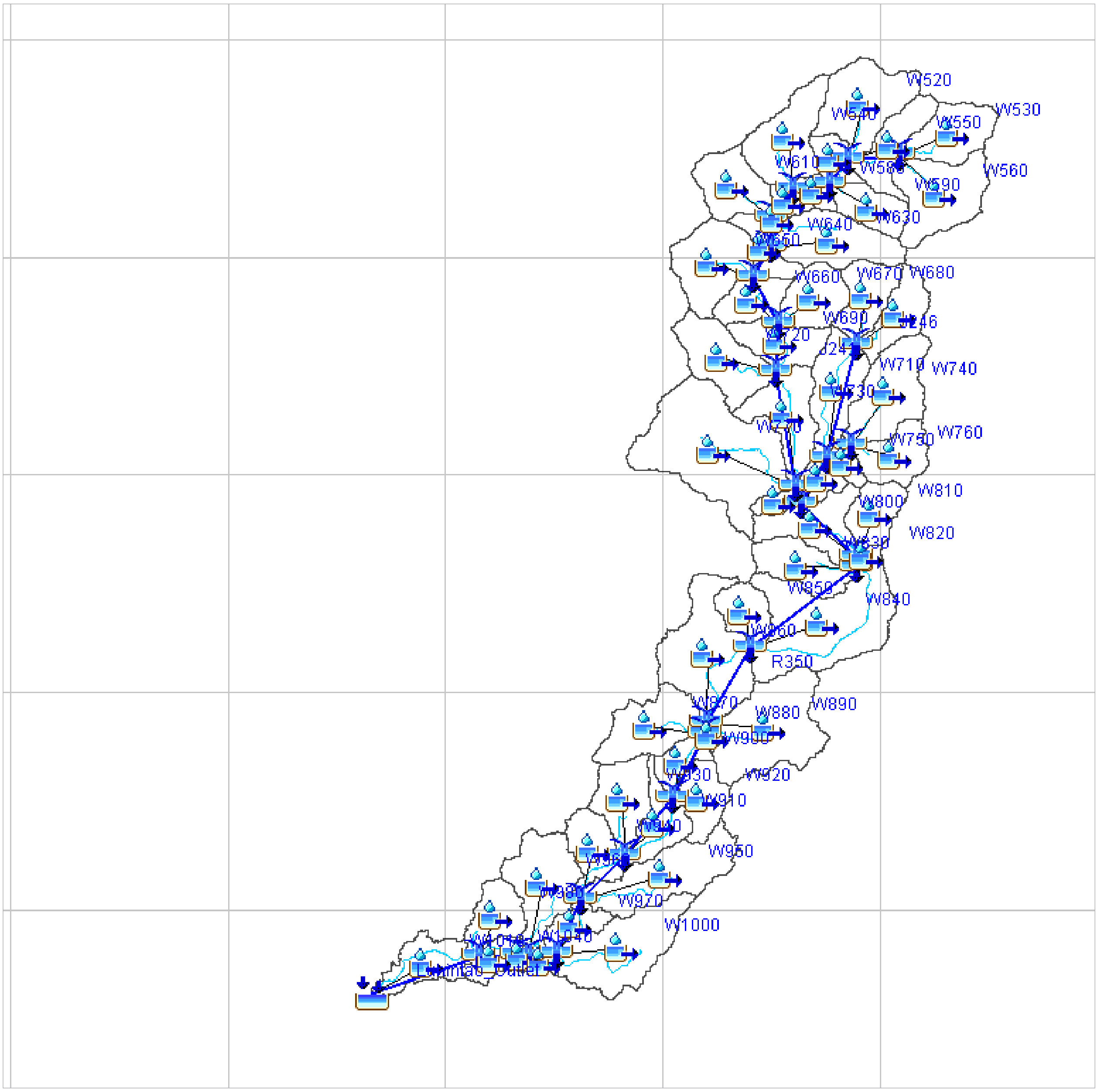


Figure 54. The Lumintao river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

5.5 Flo 2D Model

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

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

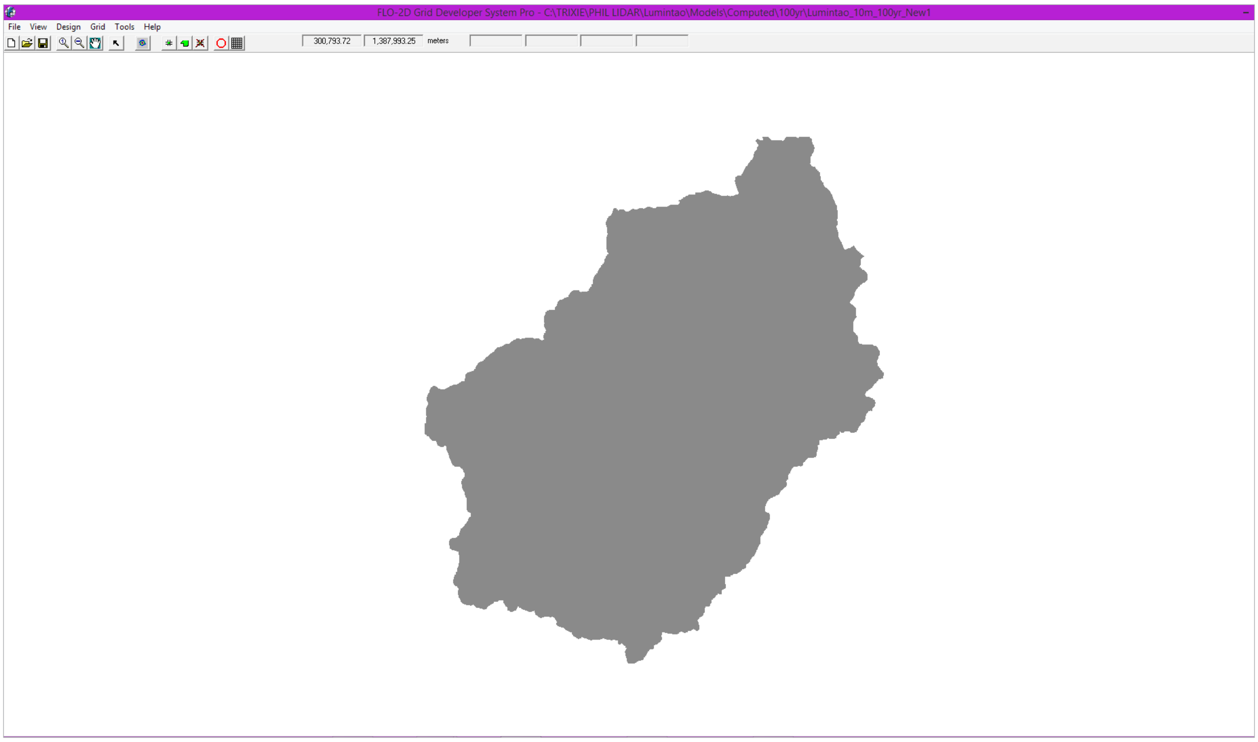


Figure 55. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 39.55225 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 73 373 376.00m^2.

There is a total of 106 772 761.46 m^3 of water entering the model. Of this amount, 25 477 086.04 m^3 is due to rainfall while 81 295 675.42 m^3 is inflow from other areas outside the model. 11 002 991.00 m^3 of this water is lost to infiltration and interception, while 4 204 850.85 m^3 is stored by the flood plain. The rest, amounting up to 91 564 926.27 m^3, is outflow.

5.6 HEC-HMC Model Values (Uncalibrated)

Enumerated in Table 28 are the range of values of the parameters in the model.

Table 28. Range of Values for Lumintao.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.2 – 1
			Curve Number	59 – 94
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.03 – 0.07
			Storage Coefficient (hr)	0.03 – 0.6

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.2 to 1mm means that there is no to minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 59 to 94 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.03 hours to 0.6 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Discharge data using Dr. Horritt's recommended hydrologic method

The river discharge values for the five rivers entering the floodplain are shown in Error! Reference source not found. to 60 and the peak values are summarized in Error! Reference source not found.29 to Table 34.

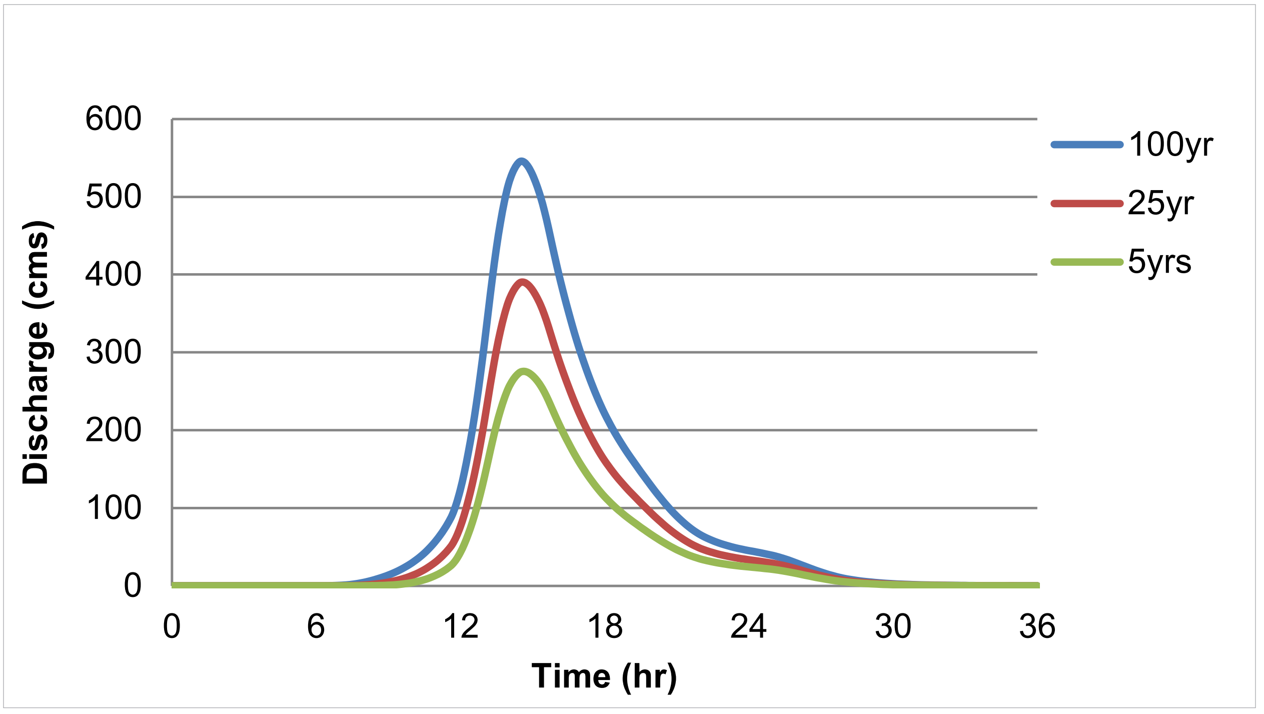


Figure 56. Lumintao river (1) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

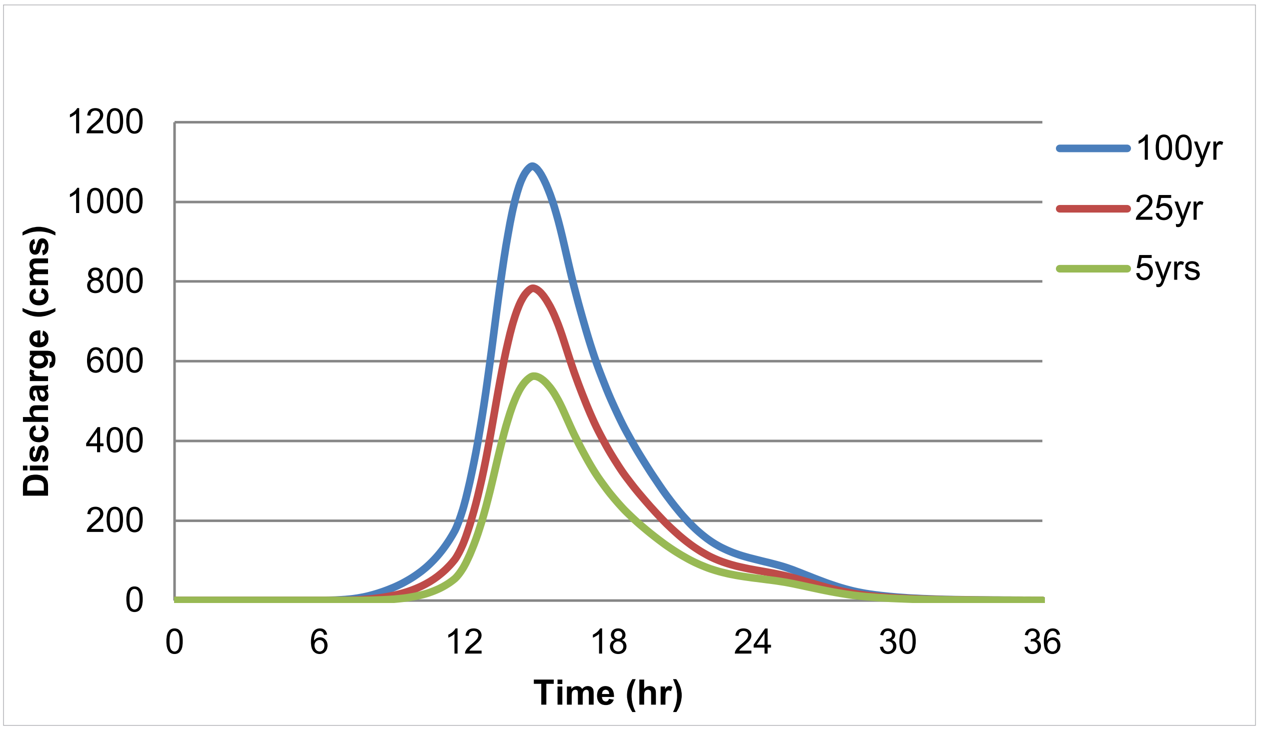


Figure 57. Lumintao river (2) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

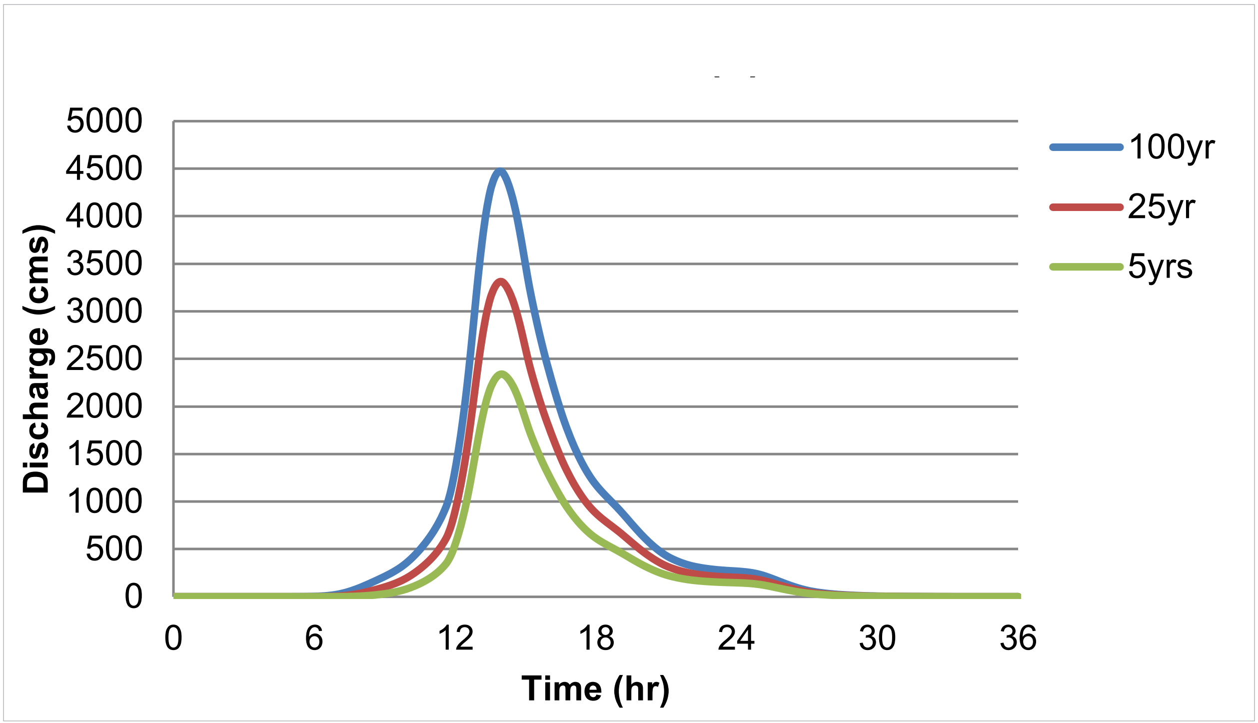


Figure 58. Lumintao river (3) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

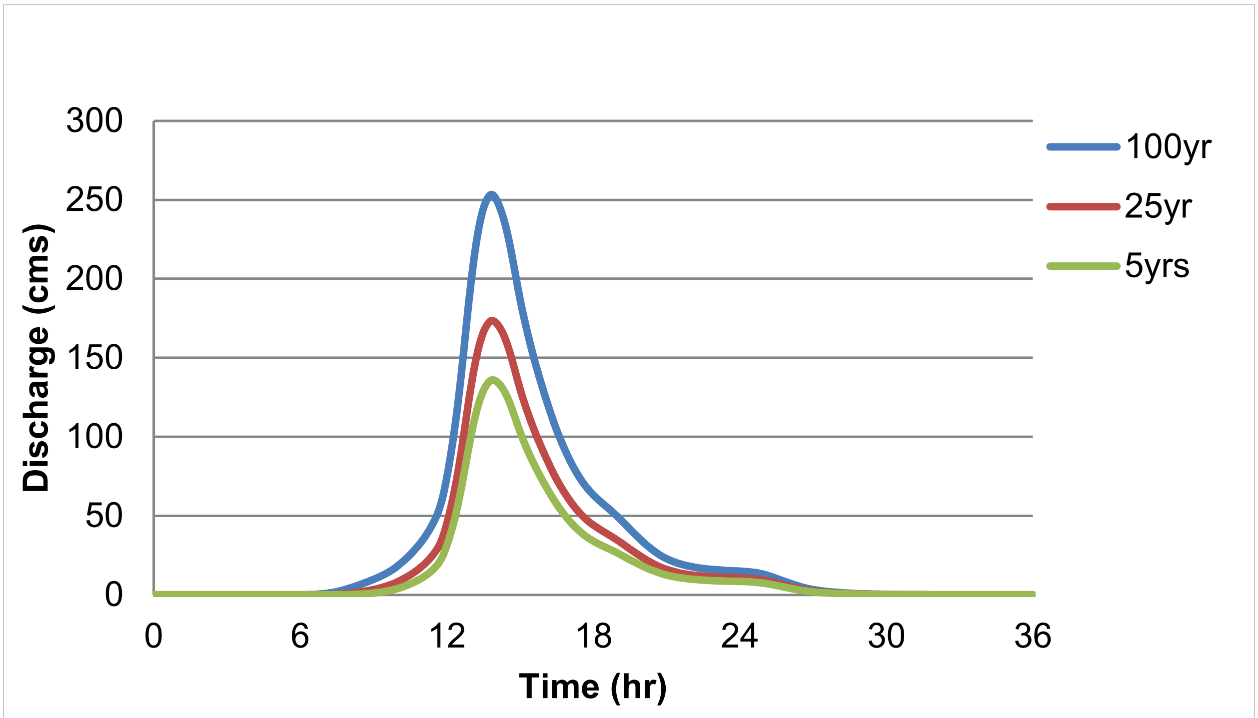


Figure 59. Lumintao river (4) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

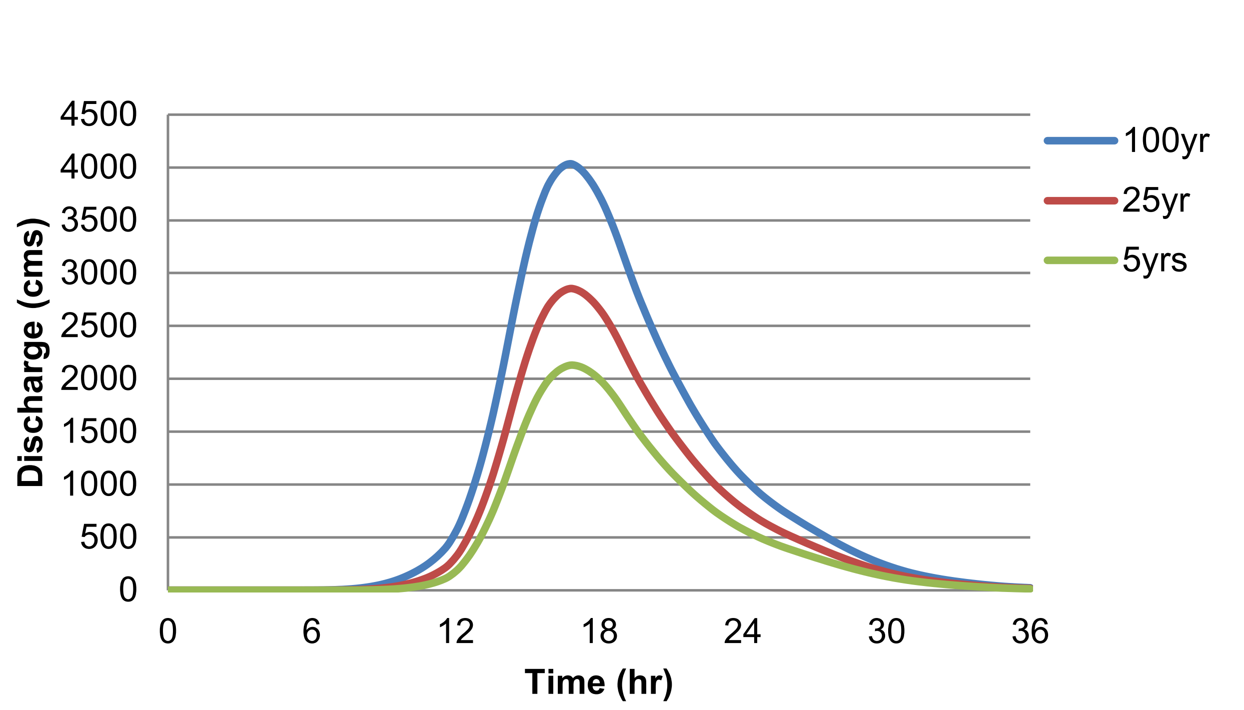


Figure 60. Lumintao river (5) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 29. Summary of Lumintao river (1) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	545.6	151.58 minutes
25-Year	389.9	151.58 minutes
5-Year	275.6	151.58 minutes

Table 30. Summary of Lumintao river (2) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	4466.2	118.53 minutes
25-Year	3310.6	118.53 minutes
5-Year	2339.9	118.53 minutes

Table 31. Summary of Lumintao river (3) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	4466.2	118.53 minutes
25-Year	3310.6	118.53 minutes
5-Year	2339.9	118.53 minutes

Table 32. Summary of Lumintao river (4) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	253.4	113.22 minutes
25-Year	173.6	113.22 minutes
5-Year	135.9	113.22 minutes

Table 33. Summary of Lumintao river (5) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	4034.2	274.17 minutes
25-Year	2854.5	274.17 minutes
5-Year	2129.6	274.17 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Error! Reference source not found.5.

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Lumintao (1)	242.528	287.515	361.192	Pass	Pass
Lumintao (2)	494.648	78.948	582.262	Fail	Pass
Lumintao (3)	2059.112	1575.407	1159.329	Pass	Fail
Lumintao (4)	119.592	93.052	184.985	Pass	Pass
Lumintao (5)	1874.048	1872.851	1497.352	Pass	Pass

Three out of five of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using both the bankful and specific discharge methods. Two did not pass and will need further recalculation. The passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for 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 real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Lumintao floodplain are shown in Figure 61 to 66. The floodplain, with an area of 284.04 sq. km., covers three municipalities namely Calintaan, Rizal, San Jose. Table shown the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Lumintao floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Calintaan	282.31	95.25	33.74%
Rizal	184.98	167.27	90.43%
San Jose	449.82	21.32	4.74%

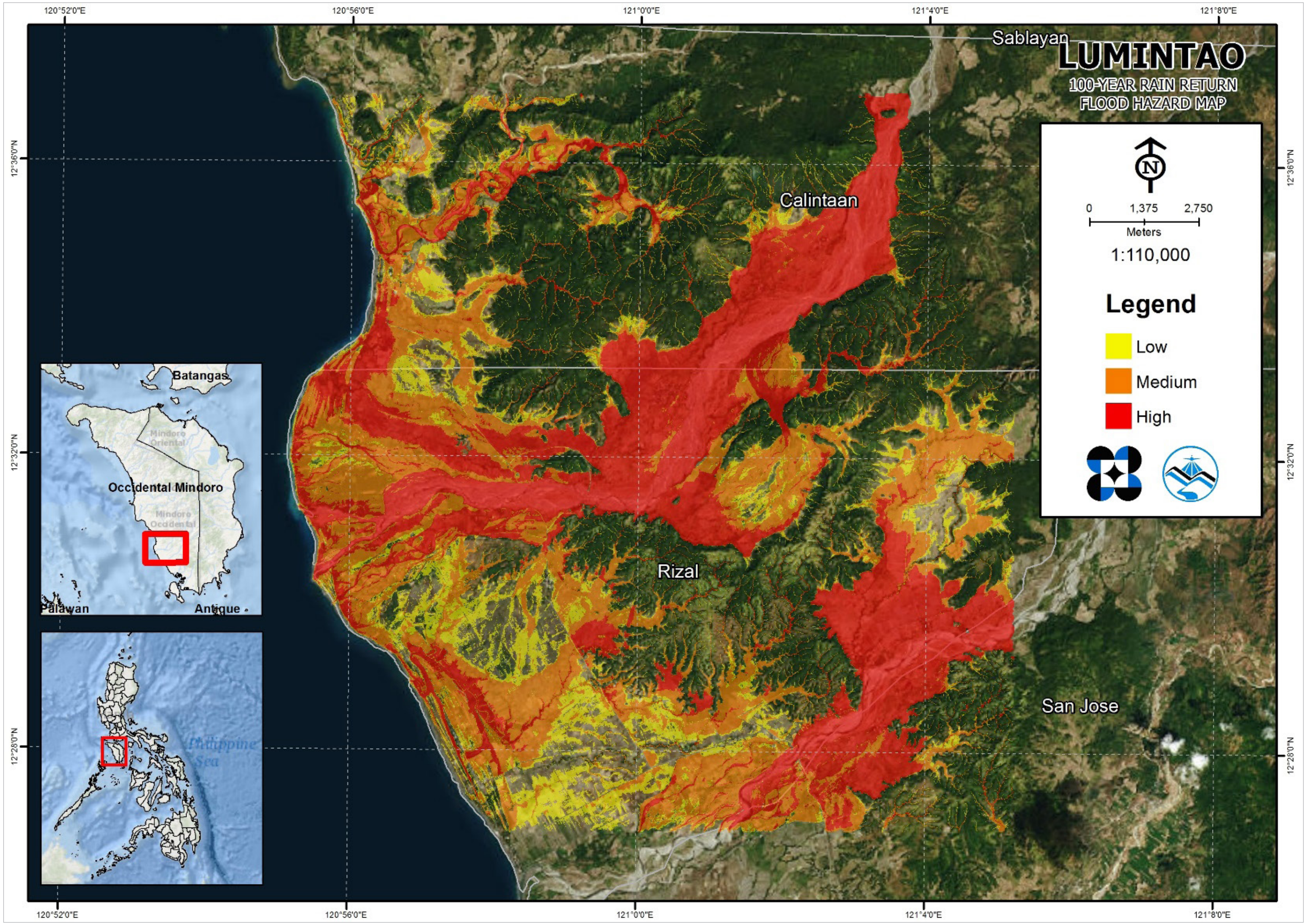


Figure 61. 100-year Flood Hazard Map for Lumintao Floodplain

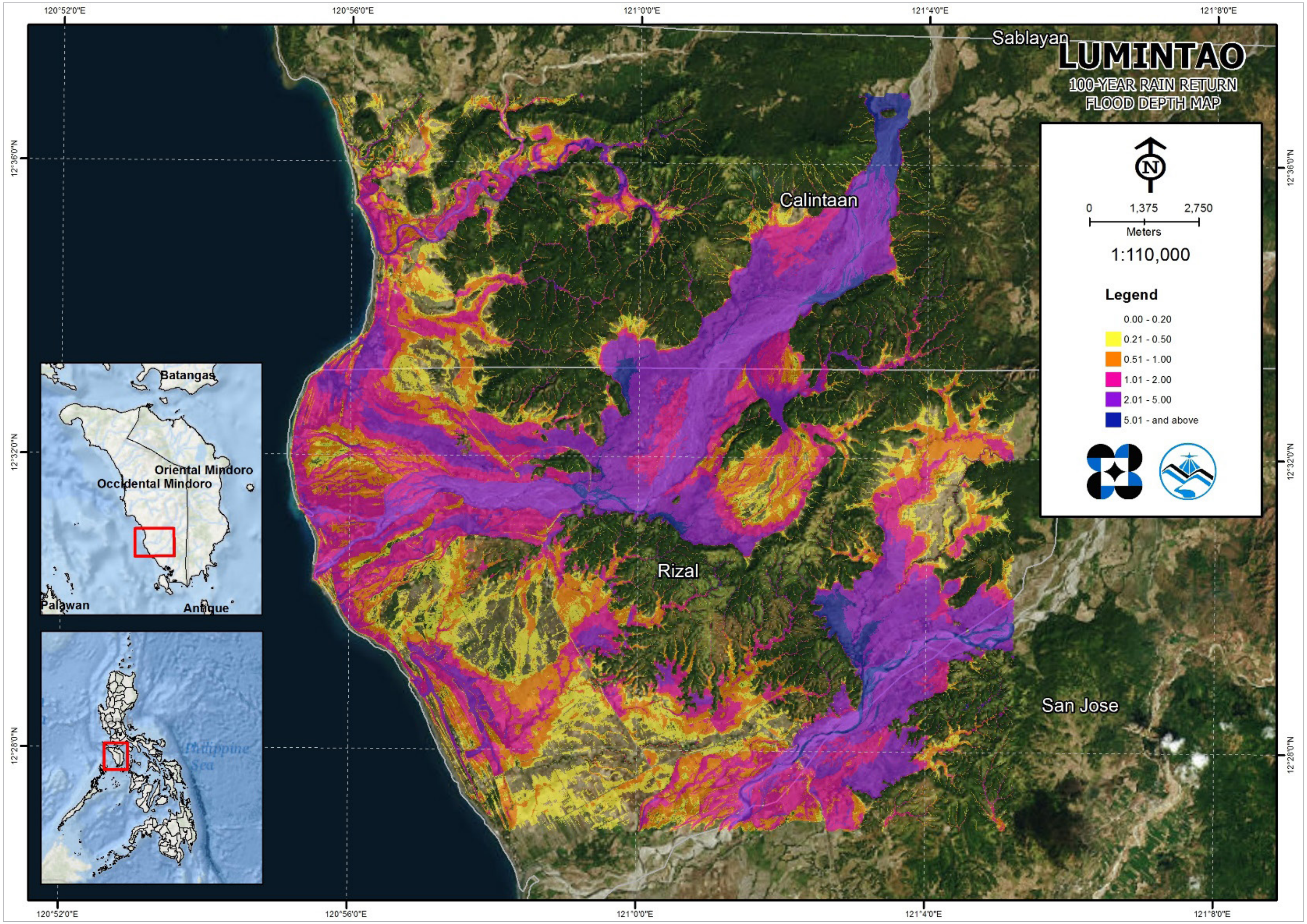


Figure 62. 100-year Flow Depth Map for Lumintao Floodplain.

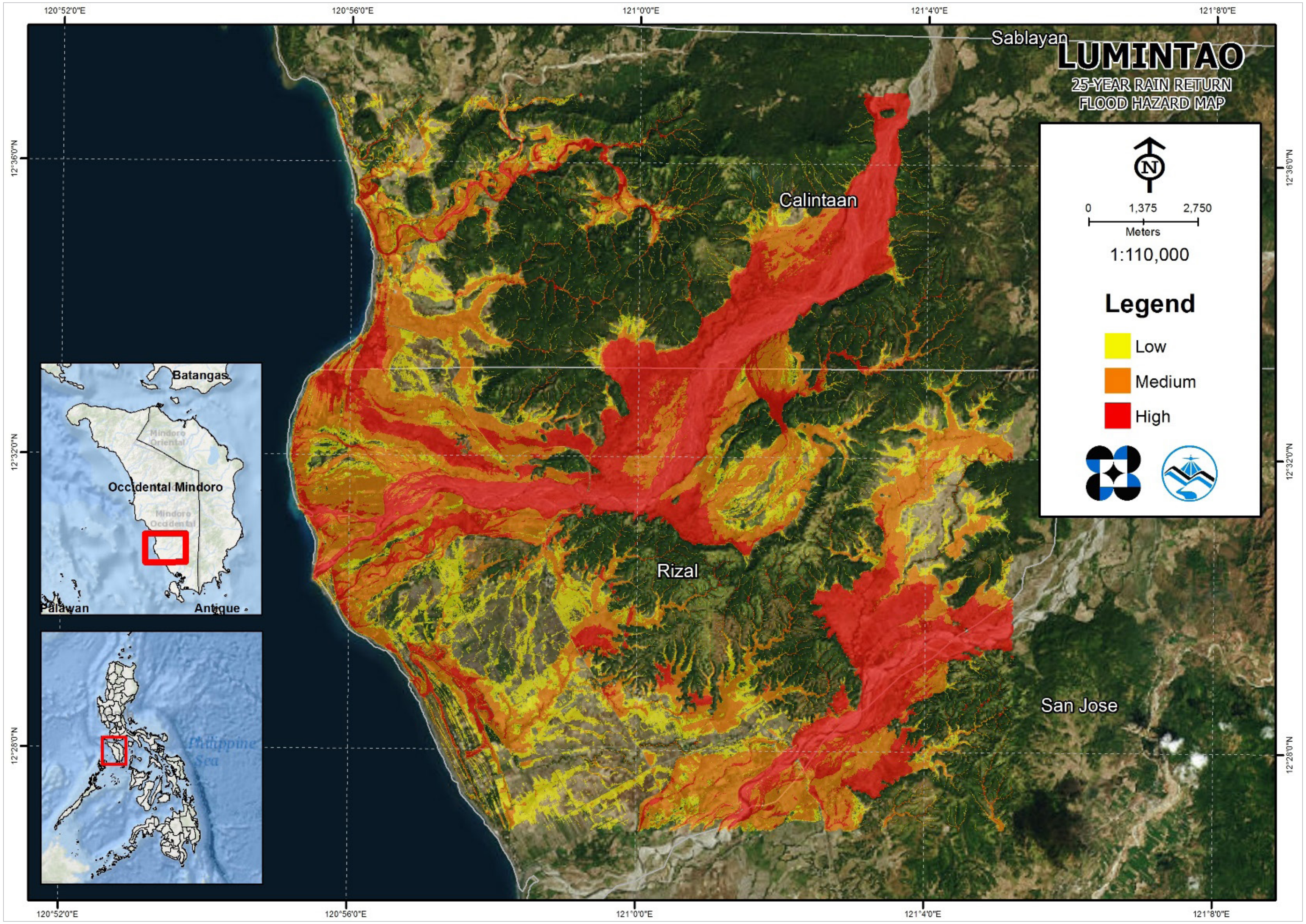


Figure 63. 25-year Flood Hazard Map for Lumintao Floodplain.

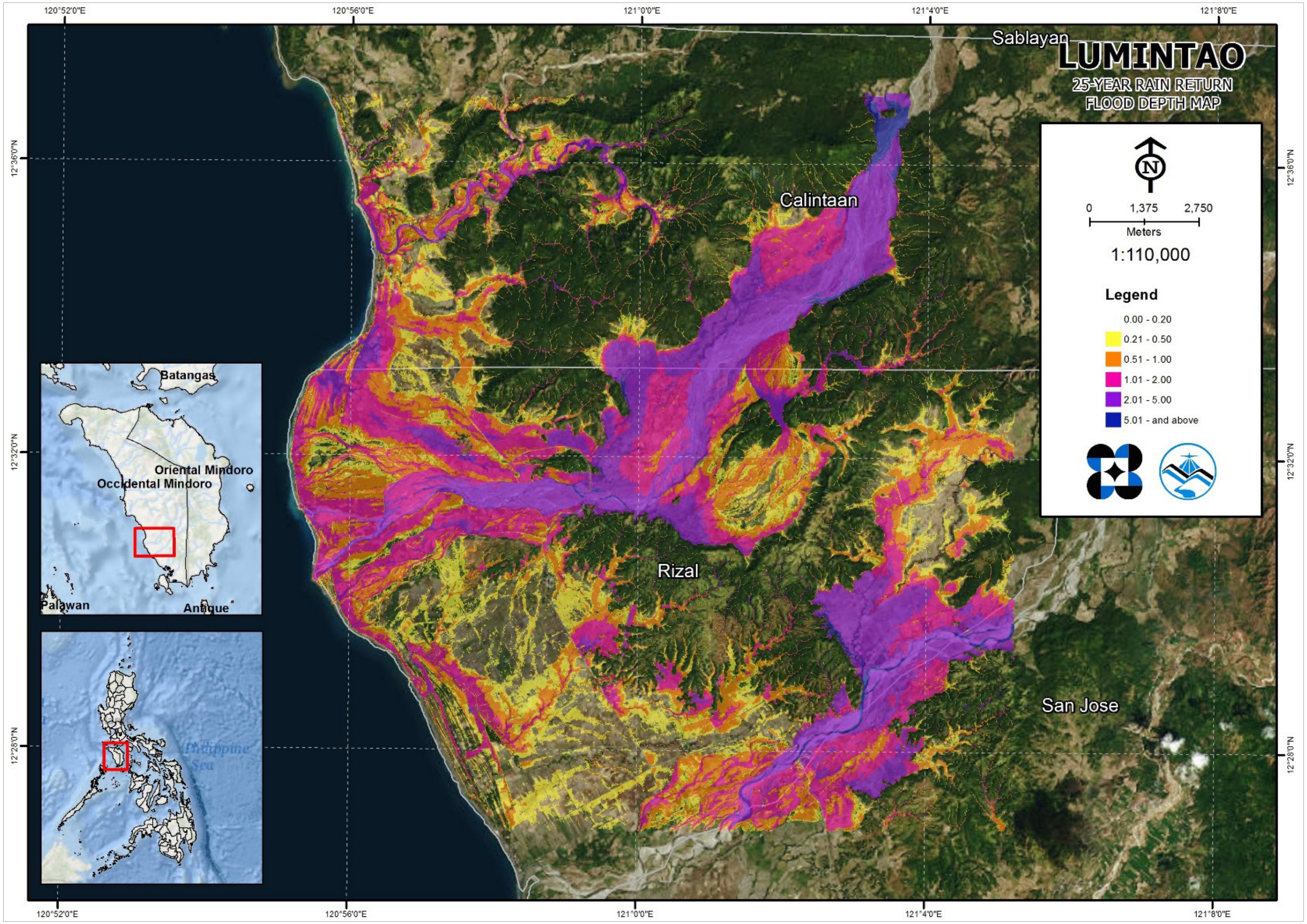


Figure 64. 25-year Flow Depth Map for Lumintao Floodplain

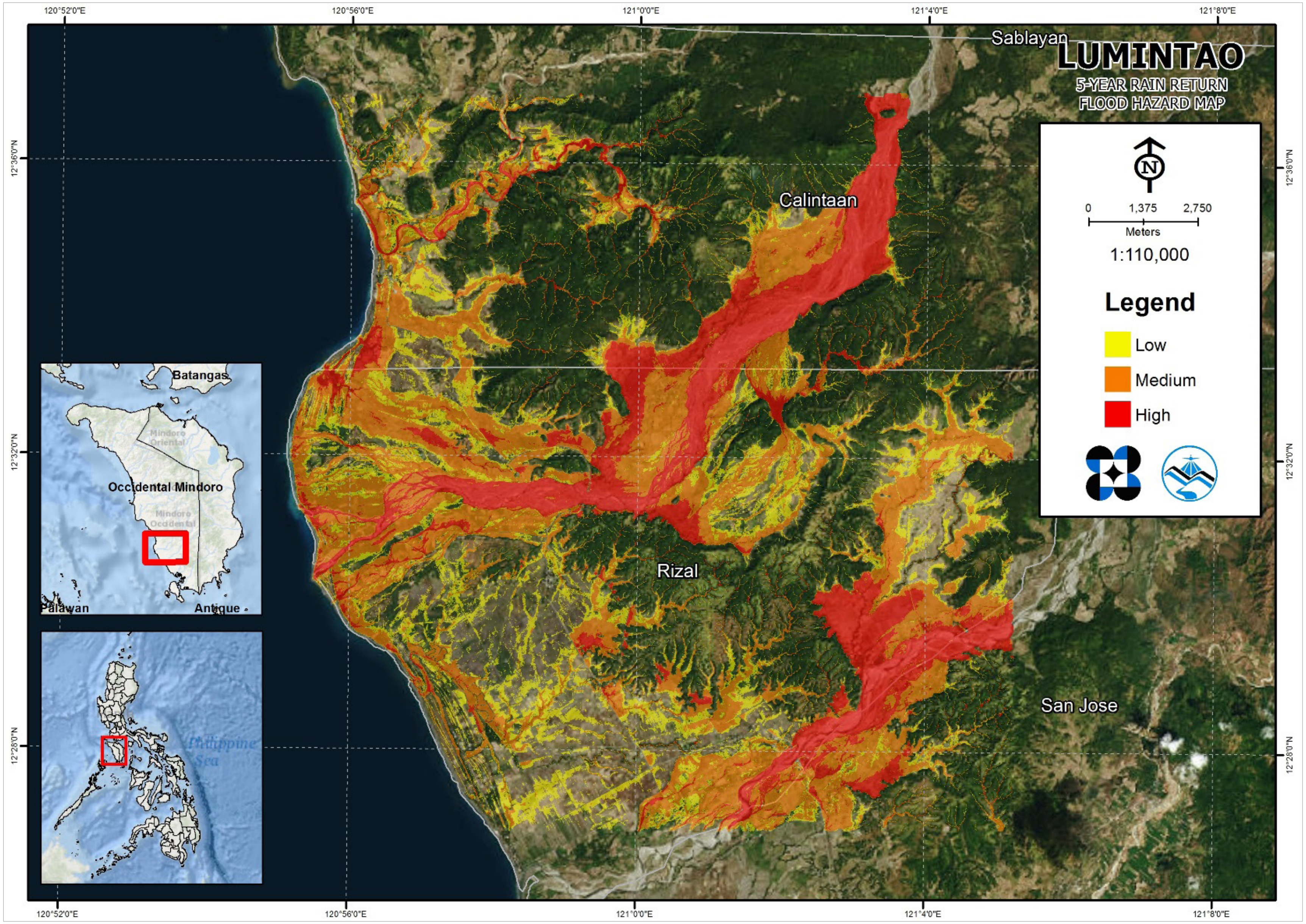


Figure 65. 5-year Flood Hazard Map for Lumintao Floodplain

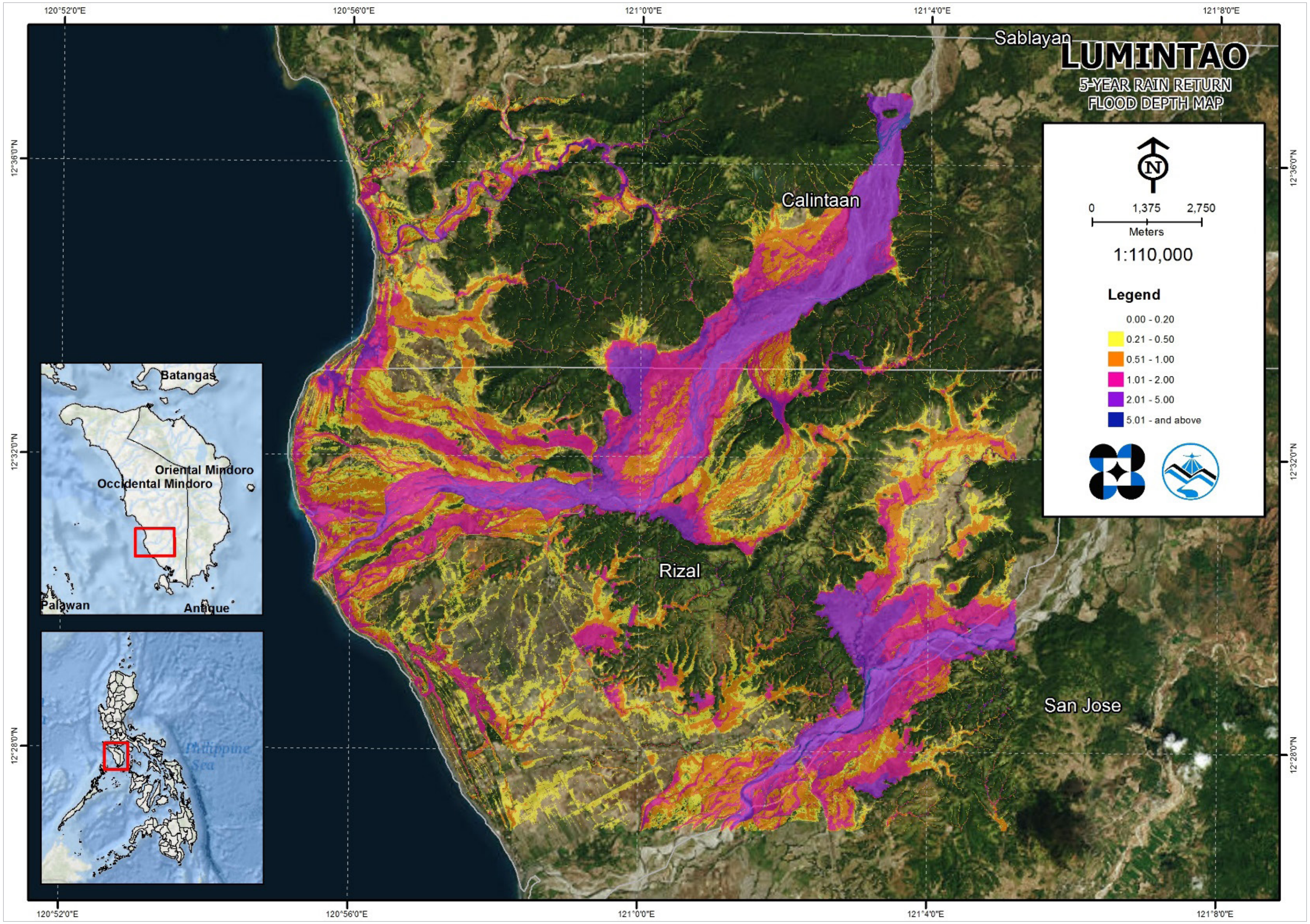


Figure 66. 5-year Flow Depth Map for Lumintao Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Lumintao River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 22 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 23% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters, while 2.72% of the area will experience flood levels of 0.21 to 0.50 meters; 2.88%, 2.5%, 3.53%, and 0.11% 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. Table 37 depicts the areas affected in Calintaan in square kilometers by flood depth per barangay.

Table 35. Affected areas in Calintaan, Occidental Mindoro during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)					
	Iriron	Malpalon	New Dagupan	Poblacion	Poypoy	Tanyag
0.03-0.20	4.67	2.52	1.9	1.08	24.79	27.14
0.21-0.50	0.9	0.24	1.09	0.82	2.5	2.13
0.51-1.00	0.49	0.16	1.37	0.67	2.55	2.88
1.01-2.00	0.33	0.08	0.81	0.31	1.7	3.82
2.01-5.00	0.037	0.62	0.29	0.2	3.28	5.54
> 5.00	0	0.11	0	0	0.16	0.035

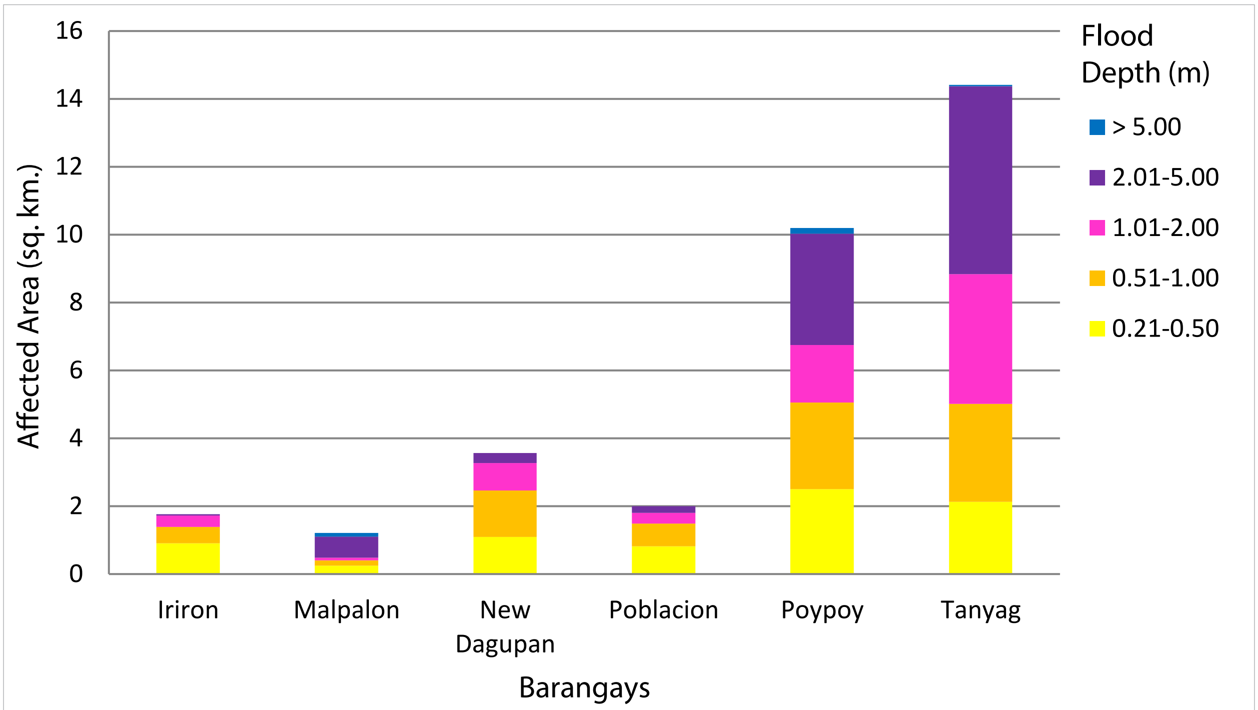


Figure 67. Affected areas in Calintaan, Occidental Mindoro during a 5-Year Rainfall Return Period

For the municipality of Rizal, with an area of 184.98 sq. km., 43.48% will experience flood levels of less 0.20 meters. 13.53% of the area will experience flood leves of 0.21 to 0.50 meters while 13.83%, 12.92%, 6.58%, and 0.1% 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. Error! Reference source not found.8 depicts the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected areas in Rizal, Occidental Mindoro during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)										
	Adela	Aguas	Magsikap	Malawaan	Manoot	Pitogo	Rizal	Rumbang	Salvacion	San Pedro	Santo Niño
0.03-0.20	4.06	10.33	11.79	7.42	10.07	4.19	4.56	4.81	4.84	3.92	14.44
0.21-0.50	1.52	2.73	2.32	5.33	1.09	1.1	2.6	1.96	1.6	1.9	2.87
0.51-1.00	0.15	3.04	2.37	7.83	0.93	0.91	3.78	0.74	0.56	3.04	2.24
1.01-2.00	0.018	3.1	2.72	7.67	0.47	0.58	4.83	0.62	0.6	1.82	1.47
2.01-5.00	0.000078	3.39	3.09	1.46	0.19	0.095	1.81	0.0003	0.013	1.24	0.89
> 5.00	0	0.12	0.02	0	0.003	0.00094	0	0	0	0.036	0.0006

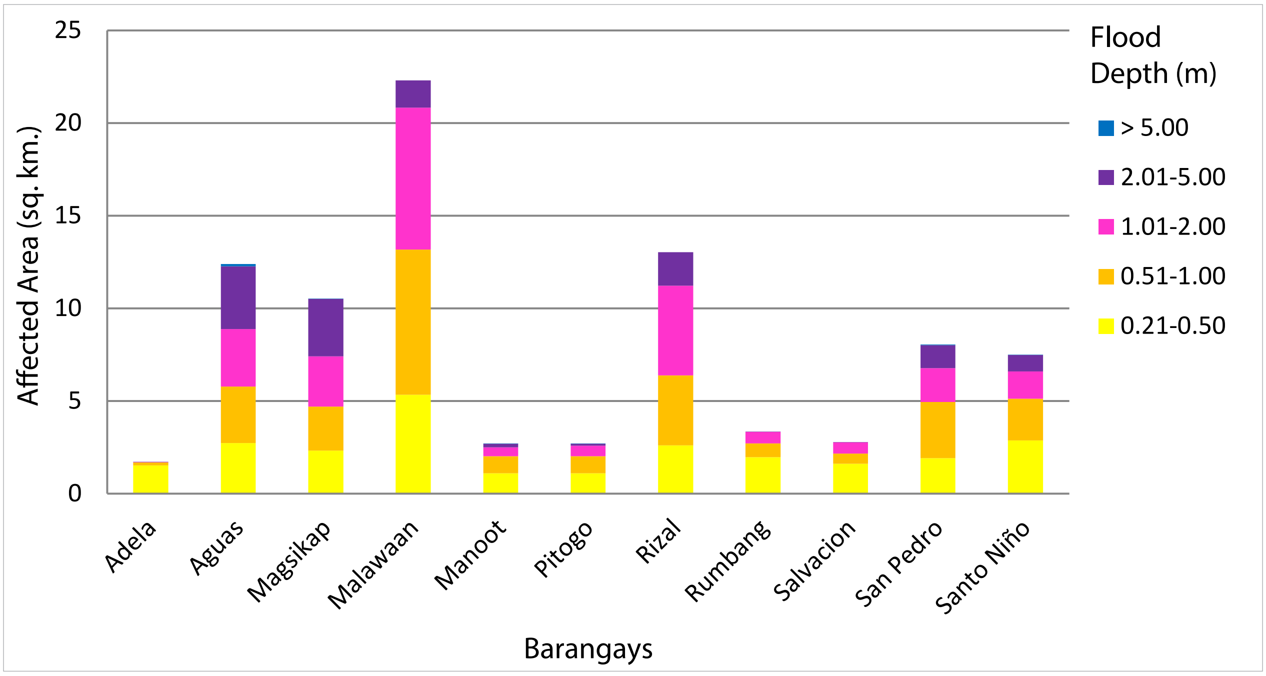


Figure 68. Affected areas in Rizal, Occidental Mindoro during a 5-Year Rainfall Return Period

For the municipality of San Jose, with an area of 449.82 sq. km., 2.33% will experience flood levels of less 0.20 meters. 0.31% of the area will experience flood levels of 0.21 to 0.50 meters while 0.69%, 0.9%, 0.5%, and 0.02% 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. Table 39 depicts the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in San Jose, Occidental Mindoro during a 5-Year Rainfall Return Period...

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)				
	Batasan	Central	Murtha	San Agustin	San Isidro
0.03-0.20	0.0003	1.76	3.36	0.0025	5.36
0.21-0.50	0.00094	0.72	0.12	0.0078	0.54
0.51-1.00	0.018	2.27	0.13	0.017	0.66
1.01-2.00	0.16	3.12	0.064	0.017	0.67
2.01-5.00	0.053	1.1	0.014	0.0035	1.06
> 5.00	0	0.035	0.0001	0	0.048

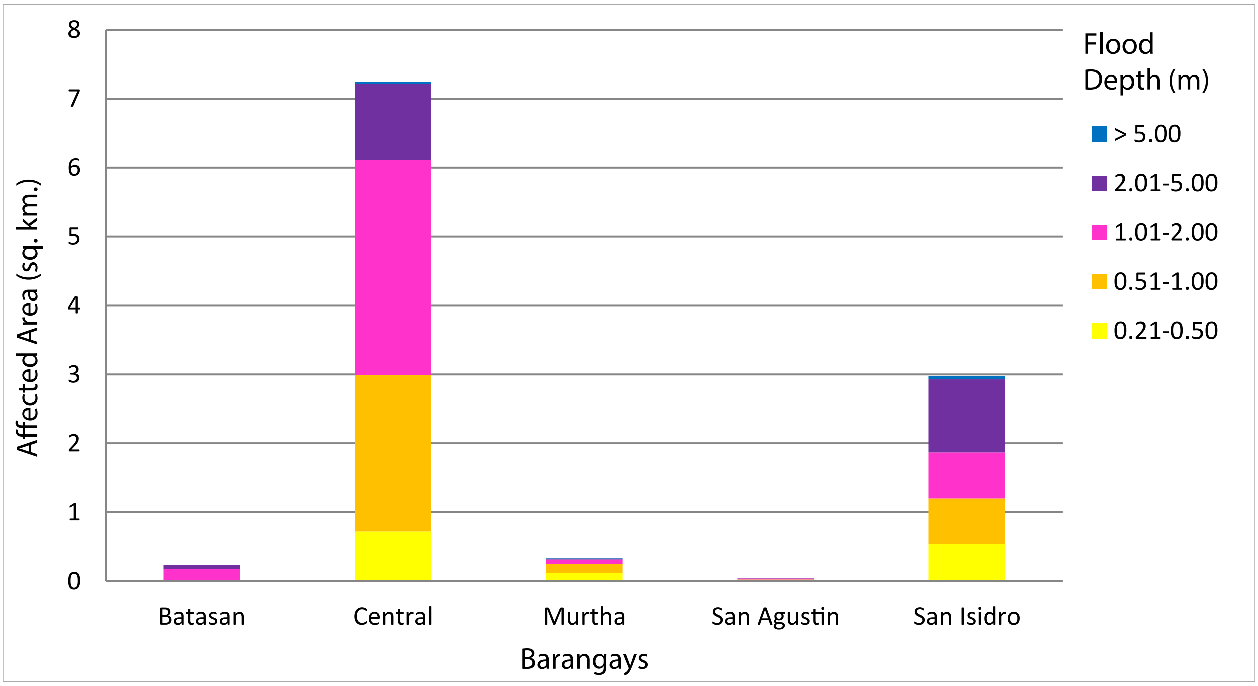


Figure 69. Affected areas in San Jose, Occidental Mindoro during a 5-Year Rainfall Return Period.

For the 25-year return period, 21.14% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters, while 2.59% of the area will experience flood levels of 0.21 to 0.50 meters; 2.51%, 2.77%, 4.34%, and 0.39% 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. Table 40 depicts the areas affected in Calintaan in square kilometers by flood depth per barangay.

Table 38. Affected areas in Calintaan, Occidental Mindoro during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)					
	Iriron	Malpalon	New Dagupan	Poblacion	Poypoy	Tanyag
0.03-0.20	4.37	2.45	1.43	0.87	24.02	26.53
0.21-0.50	1.01	0.25	1.03	0.71	2.33	1.99
0.51-1.00	0.57	0.17	1.4	0.78	2.22	1.95
1.01-2.00	0.42	0.066	1.1	0.51	2.58	3.14
2.01-5.00	0.061	0.32	0.52	0.22	3.34	7.78
> 5.00	0	0.46	0	0	0.48	0.17

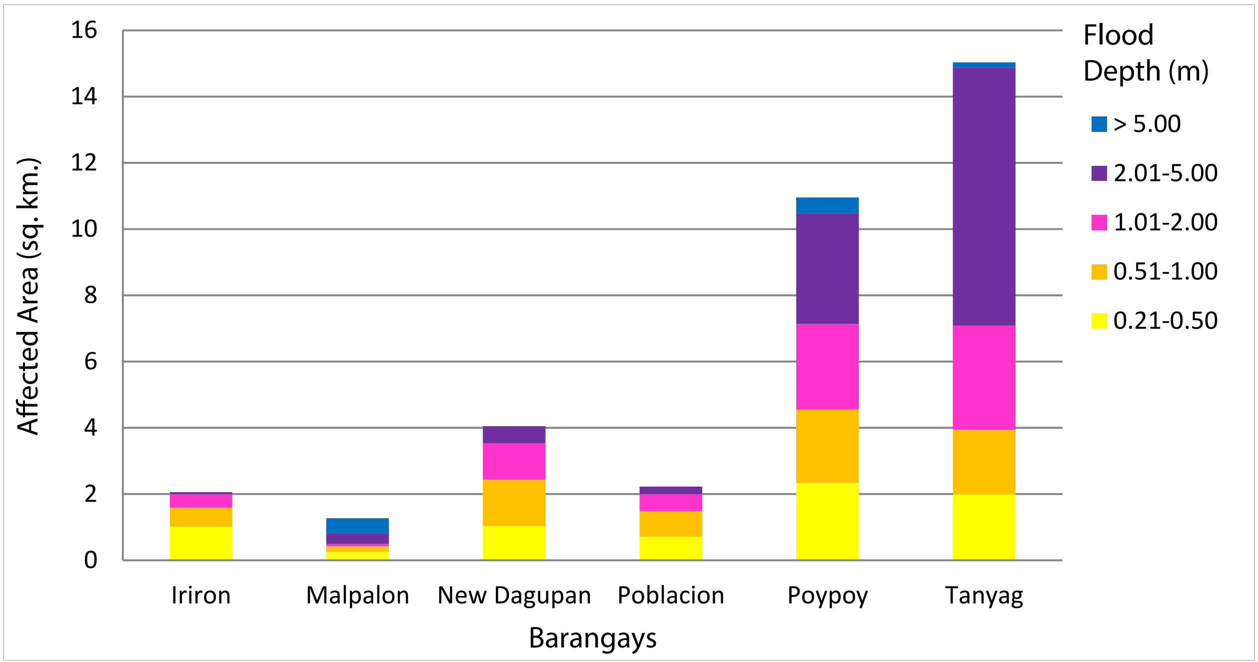


Figure 70. Affected areas in Calintaan, Occidental Mindoro during a 25-Year Rainfall Return Period.

For the municipality of Merida, with an area of 184.98 sq. km., 37.89% will experience flood levels of less 0.20 meters. 12.35% of the area will experience flood leves of 0.21 to 0.50 meters while 13.53%, 15.61%, 10.75%, and 0.3% 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. Error! Reference source not found. depicts the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Rizal, Occidental Mindoro during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)										
	Adela	Aguas	Magsikap	Malawaan	Manoot	Pitogo	Rizal	Rumbang	Salvacion	San Pedro	Santo Niño
0.03-0.20	3.71	9.61	10.25	4.8	9.75	4	3.34	3.52	3.98	3.44	13.69
0.21-0.50	1.8	2.44	2.39	3.79	0.89	0.97	1.72	2.2	1.98	1.85	2.82
0.51-1.00	0.22	2.7	2.11	7.17	1	0.97	3.19	1.35	0.77	3.05	2.49
1.01-2.00	0.021	2.91	2.83	10.75	0.75	0.62	5.16	1.02	0.81	2.21	1.8
2.01-5.00	0.00068	4.79	4.57	3.19	0.36	0.32	4.17	0.035	0.084	1.33	1.03
> 5.00	0	0.26	0.16	0.0002	0.004	0.0017	0.0056	0	0	0.049	0.069

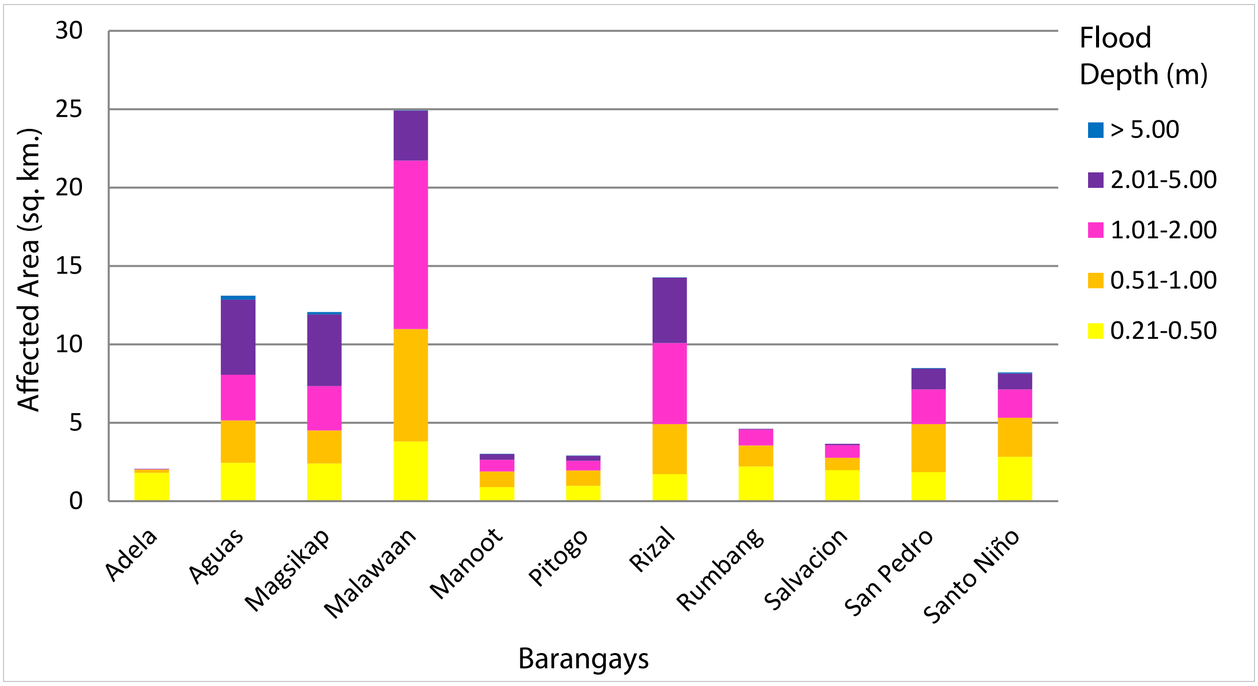


Figure 71. Affected areas in Rizal, Occidental Mindoro during a 5-Year Rainfall Return Period

For the municipality of San Jose, with an area of 449.82 sq. km., 2.26% will experience flood levels of less 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.47%, 0.96%, 0.79%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 42 depicts the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in San Jose, Occidental Mindoro during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)				
	Batasan	Central	Murtha	San Agustin	San Isidro
0.03-0.20	0	1.56	3.34	0.002	5.27
0.21-0.50	0.0003	0.37	0.12	0.0064	0.49
0.51-1.00	0.0027	1.45	0.14	0.019	0.49
1.01-2.00	0.1	3.33	0.07	0.018	0.79
2.01-5.00	0.13	2.24	0.018	0.0039	1.18
> 5.00	0	0.053	0.0001	0	0.13

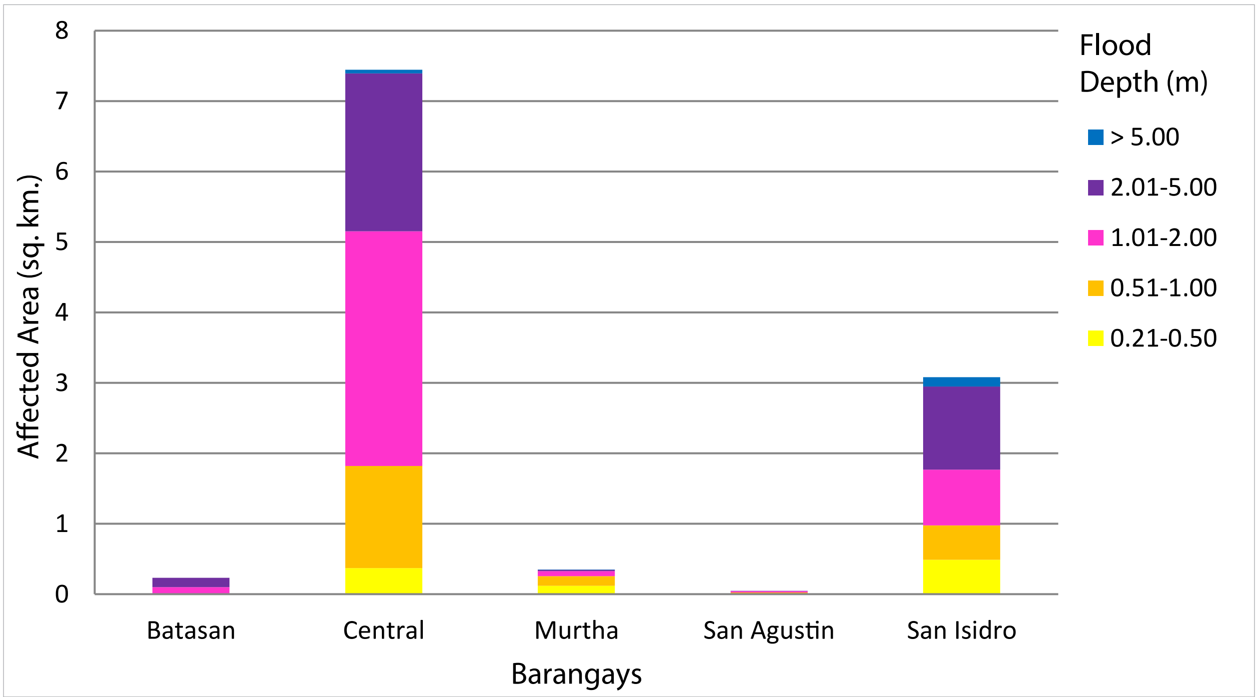


Figure 72. Affected areas in San Jose, Occidental Mindoro during a 5-Year Rainfall Return Period.

For the 100-year return period, 20.12% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters, while 2.47% of the area will experience flood levels of 0.21 to 0.50 meters; 2.39%, 3.07%, 4.82%, and 0.87% 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. Table 43 depicts the areas affected in Calintaan in square kilometers by flood depth per barangay.

Table 41. Affected areas in Calintaan, Occidental Mindoro during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)					
	Iriron	Malpalon	New Dagupan	Poblacion	Poypoy	Tanyag
0.03-0.20	3.94	2.34	1.08	0.69	23.01	25.74
0.21-0.50	1.1	0.28	0.87	0.52	2.24	1.97
0.51-1.00	0.73	0.2	1.24	0.79	2.06	1.73
1.01-2.00	0.55	0.1	1.53	0.85	3.05	2.59
2.01-5.00	0.12	0.068	0.75	0.25	3.54	8.88
> 5.00	0	0.73	0	0	1.08	0.64

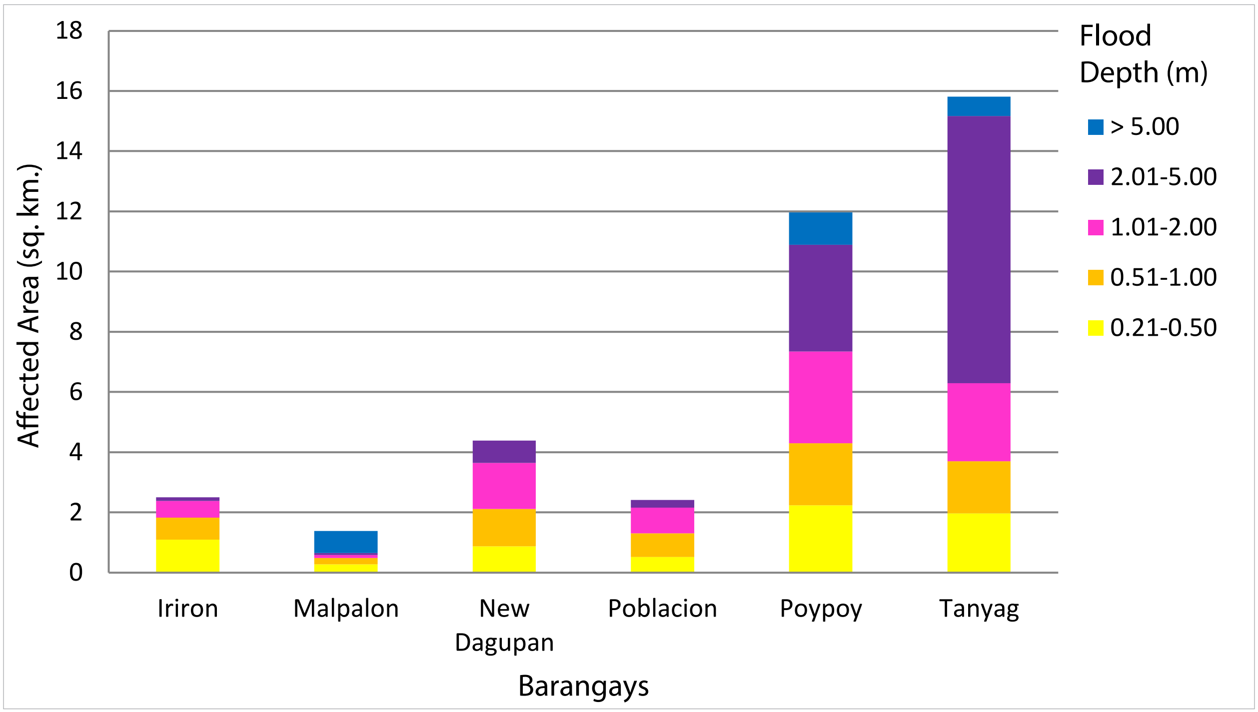


Figure 73. Affected areas in Calintaan, Occidental Mindoro during a 25-Year Rainfall Return Period.

For the municipality of Merida, with an area of 184.98 sq. km., 31.81% will experience flood levels of less 0.20 meters. 10.59% of the area will experience flood leves of 0.21 to 0.50 meters while 13.2%, 17.45%, 15.99%, and 1.39% 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. Error! Reference source not found.44 depicts the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Rizal, Occidental Mindoro during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)										
	Adela	Aguas	Magsikap	Malawaan	Manoot	Pitogo	Rizal	Rumbang	Salvacion	San Pedro	Santo Niño
0.03-0.20	2.82	8.6	9.07	3.52	9.45	3.64	2.84	1.54	2.6	2.63	12.14
0.21-0.50	2.41	1.88	1.79	2.71	0.63	0.85	1.02	1.26	2.43	1.8	2.81
0.51-1.00	0.48	2.57	2.52	5.58	0.84	1.01	2.34	2.31	1.05	2.89	2.83
1.01-2.00	0.049	2.57	2.98	12.07	1.05	0.68	4.16	2.25	1.01	3.04	2.42
2.01-5.00	0.0022	6.02	5.31	5.82	0.74	0.7	7.06	0.76	0.53	1.49	1.15
> 5.00	0	1.08	0.64	0.0027	0.049	0.0021	0.16	0	0	0.09	0.55

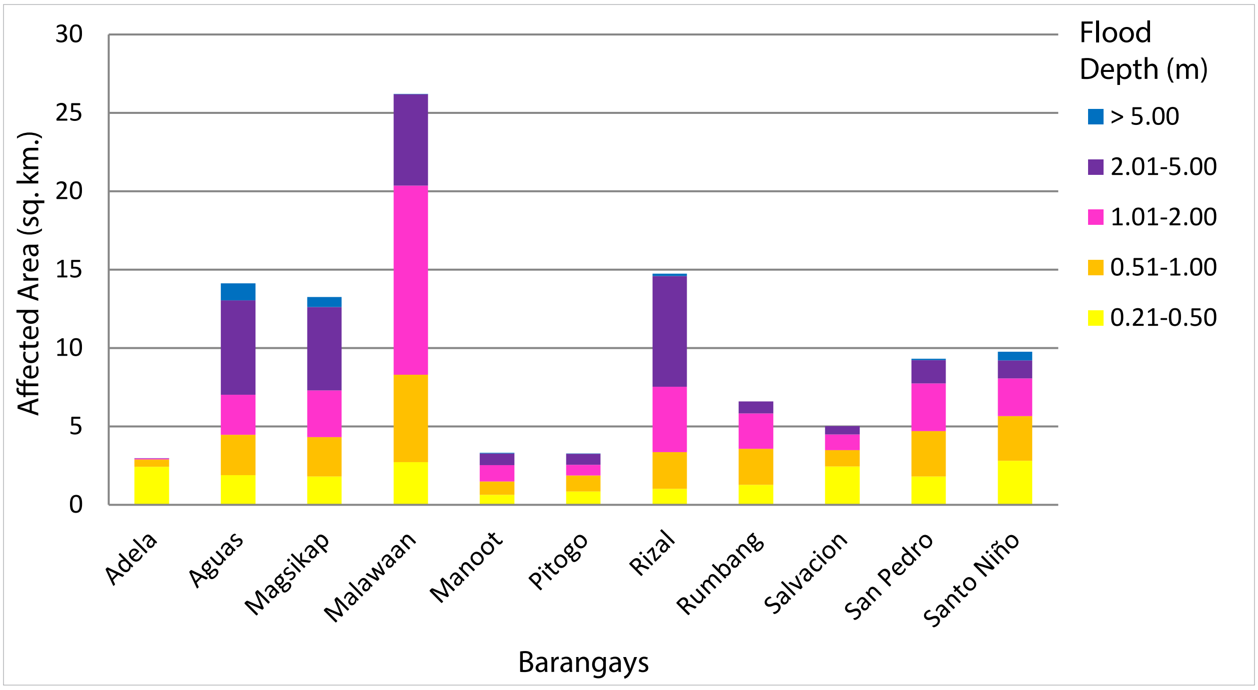


Figure 74. Affected areas in Rizal, Occidental Mindoro during a 100-Year Rainfall Return Period.

For the municipality of San Jose, with an area of 449.82 sq. km., 2.19% will experience flood levels of less 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.29%, 0.81%, 1.19%, and 0.1% 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. Table 45 depicts the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in San Jose, Occidental Mindoro during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)				
	Batasan	Central	Murtha	San Agustin	San Isidro
0.03-0.20	0	1.44	3.3	0.0017	5.1
0.21-0.50	0	0.17	0.13	0.0052	0.41
0.51-1.00	0.0001	0.7	0.12	0.018	0.48
1.01-2.00	0.016	2.93	0.11	0.019	0.57
2.01-5.00	0.22	3.65	0.031	0.0049	1.44
> 5.00	0.0025	0.11	0.0001	0	0.34

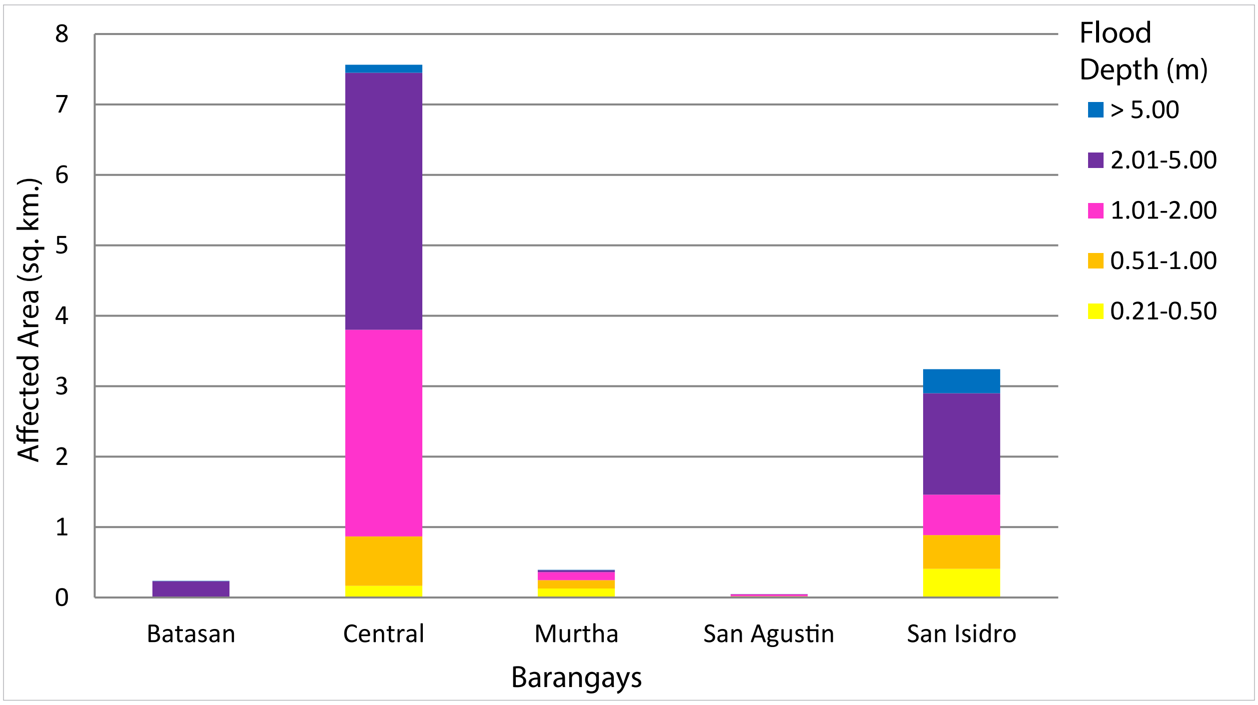


Figure 75. Affected areas in San Jose, Occidental Mindoro during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Calintaan, Tanyag is projected to have the highest percentage of area that will experience flood levels of at 14.72%. On the other hand, Poypoy posted the percentage of area that may be affected by flood depths of at 12.39%.

Among the barangays in the municipality of Rizal, Malawaan is projected to have the highest percentage of area that will experience flood levels of at 16.06%. On the other hand, Aguas posted the percentage of area that may be affected by flood depths of at 12.28%.

Among the barangays in the municipality of San Jose, Central is projected to have the highest percentage of area that will experience flood levels of at 2.002%. On the other hand, San Isidro posted the percentage of area that may be affected by flood depths of at 1.85%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 76.

The flood validation consists of 125 points randomly selected all over the Lumintao flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.65m. Error! Reference source not found.6 shows a contingency matrix of the comparison.

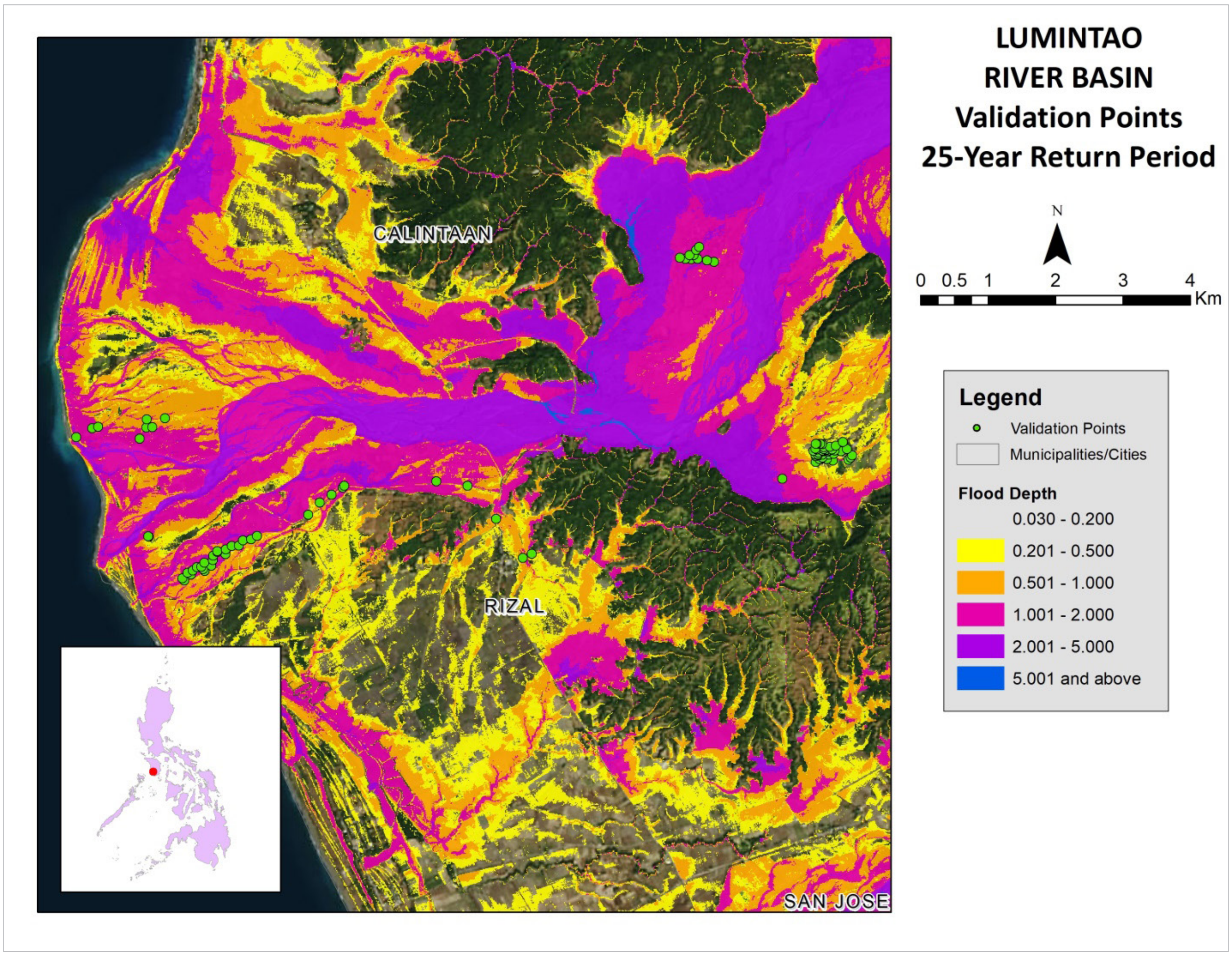


Figure 76. Validation points for 25-year Flood Depth Map of Lumintao Floodplain.

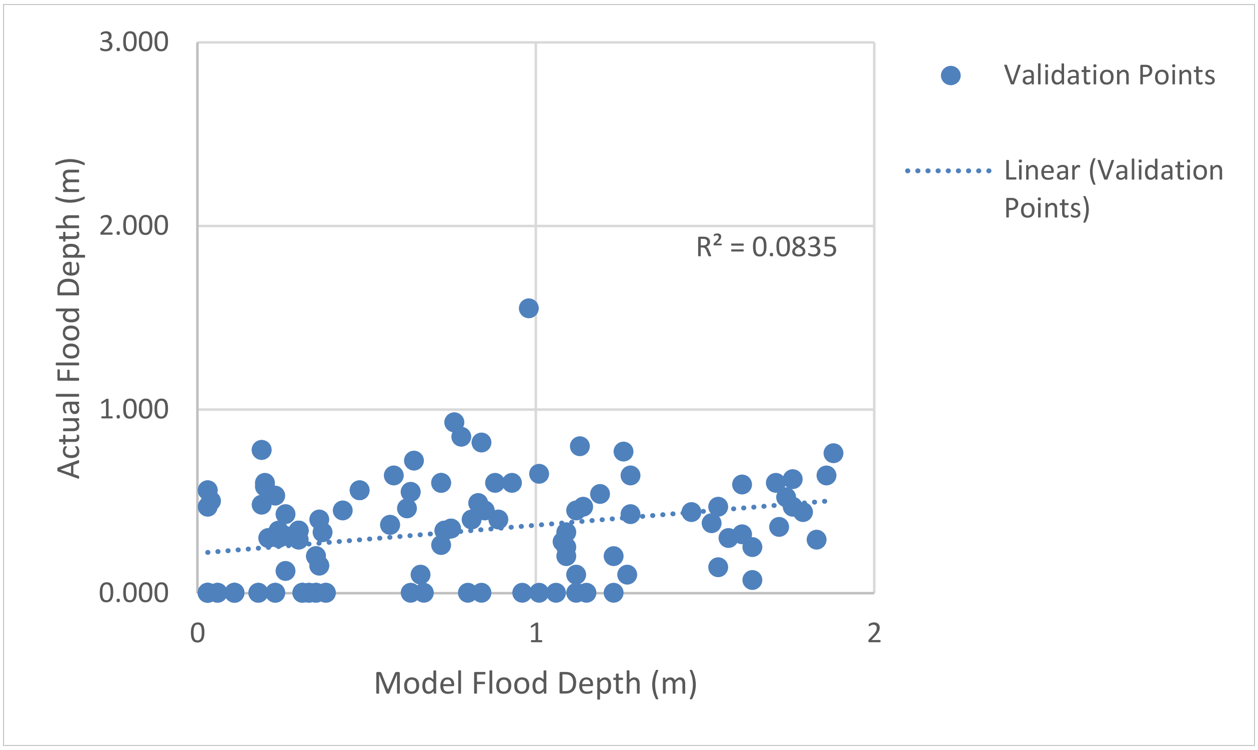


Figure 77. Flood map depth vs actual flood depth.

Table 44. Actual Flood Depth vs Simulated Flood Depth at different levels in the Lumintao River Basin.

LUMINTAO 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	15	16	6	11	0	0	**48**
	0.21-0.50	3	13	12	16	0	0	**44**
	0.51-1.00	6	3	12	11	0	0	**32**
	1.01-2.00	0	0	1	0	0	0	**1**
	2.01-5.00	0	0	0	0	0	0	**0**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**24**	**32**	**31**	**38**	**0**	**0**	**125**

The overall accuracy generated by the flood model is estimated at 32.00% with 40 points correctly matching the actual flood depths. In addition, there were 43 points estimated one level above and below the correct flood depths while there were 28 points and 11 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 13 points were underestimated in the modelled flood depths of Lumintao. Error! Reference source not found.7 depicts the summary of the Accuracy Assessment in the Lumintao River Basin Survey.

Table 45. Summary of Accuracy Assessment in the Lumintao River Basin Survey

	No. of Points	%
Correct	40	32.00
Overestimated	72	57.60
Underestimated	13	10.40
Total	**125**	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

ANNEX 1. Technical Specification of the LiDAR Sensors used in the

Table A-1.1 Technical Specifications of the LiDAR Sensors used in the Lumintao Floodplain Survey

The Gemini Sensor

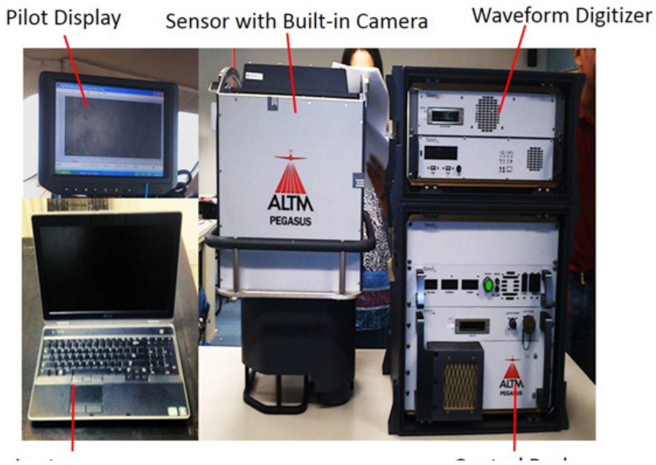


Figure A-1.1 Pegasus Sensor

1. Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

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

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

2. Aquarius Sensor

Table A-1.2 Parameters and Specifications of the Pegasus Sensor

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

ANNEX 2. NAMRIA Certification of Reference Points Used in the LiDAR Survey

Table A-2.1. NAMRIA Certification of Reference Points used in the LiDAR Survey

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

December 11, 2015

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: **OCCIDENTAL MINDORO**	
	Station Name: **MRW-18**	
	Order: **2nd**	
Island: **LUZON**	Barangay:	
Municipality: **MAGSAYSAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 18' 45.39463"**	Longitude: **121° 8' 36.92441"**	Ellipsoidal Hgt: **21.29500 m.**
	WGS84 Coordinates	
Latitude: **12° 18' 40.53383"**	Longitude: **121° 8' 42.01469"**	Ellipsoidal Hgt: **71.37500 m.**
	PTM / PRS92 Coordinates	
Northing: **1361517.851 m.**	Easting: **515618.524 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,361,734.74**	Easting: **298,113.89**	Zone: **51**

Location Description

MRW-18

From Municipality of Magsaysay, located in front of statue of President Ramon Magsaysay, inside the Municipal Compound, about 40 m SE of Municipal Bldg. of Magsaysay. Station is located in Municipality of Magsaysay, Occ. Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-18, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088861 I**
T.N.: **2015-4114**

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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CIP/4701/12/07/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MRW-18

1. MRW-18

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-22**
Order: **2nd**

Island: **LUZON**		Barangay: **TANYAG**
Municipality: **CALINTAAN**		
	PRS92 Coordinates	
Latitude: **12° 31' 36.76881"**	Longitude: **120° 59' 13.46492"**	Ellipsoidal Hgt: **35.12700 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 31.84278"**	Longitude: **120° 59' 18.53734"**	Ellipsoidal Hgt: **84.27100 m.**
	PTM Coordinates	
Northing: **1385214.96 m.**	Easting: **498595.125 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,385,563.72**	Easting: **281,265.62**	Zone: **51**

Location Description

MRW-22

From Abra de Ilog to San Jose, along Nat'l Road, approx. 9 Km. from Calintaan Town Proper, located Lumintao Bridge at Brgy. Tanyag, Sitio Marilao, Calintaan, Occ. Mindoro. Station is located at the N end of the catwalk of Lumintao Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-22, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-446**

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

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Figure A-2.2 MRW-22

2. MRW-22

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-24**
Order: **2nd**

Island: **LUZON**
Municipality: **CALINTAAN**
Barangay: **IRIRON**

PRS92 Coordinates

Latitude:	**12º 36' 42.98691"**	Longitude:	**120º 55' 49.01762"**	Ellipsoidal Hgt:	**5.69500 m.**

WGS84 Coordinates

Latitude:	**12º 36' 38.03549"**	Longitude:	**120º 55' 54.08296"**	Ellipsoidal Hgt:	**54.47900 m.**

PTM Coordinates

Northing:	**1394624.897 m.**	Easting:	**492425.435 m.**	Zone:	**3**

UTM Coordinates

Northing:	**1,395,022.71**	Easting:	**275,166.05**	Zone:	**51**

Location Description

MRW-24

From San Jose to Abra de Ilog, along Nat'l Road, approx. 9.2 Km. from Calintaan Proper, right side of the road located Evelyn's Welding Shop, left turn to Brgy. Road leading to Brgy. Iriron, approx. 1.9 Km. travel to reach Brgy. Plaza, in front of Iriron Elem. School located at Brgy. Iriron, Calintaan, Occ. Mindoro.Station is in NE corner of basketball court, about 10 m N of Goal. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-24, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-447**

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

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Figure A-2.3 MRW-24

3. MRW-24

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

March 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-4203**
Order: **3rd**

Island: **LUZON**		Barangay: **MAPAYA**
Municipality: **SAN JOSE**		
	PRS92 Coordinates	
Latitude: **12° 21' 24.45294"**	Longitude: **121° 7' 26.92407"**	Ellipsoidal Hgt: **7.40100 m.**
	WGS84 Coordinates	
Latitude: **12° 21' 19.57973"**	Longitude: **121° 7' 32.01059"**	Ellipsoidal Hgt: **57.32000 m.**
	PTM Coordinates	
Northing: **1366404.003 m.**	Easting: **513501.246 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,366,637.32**	Easting: **296,032.79**	Zone: **51**

Location Description

MRW-4203

From San Jose Town Proper to Brgy. Mapaya, approx. 7.8 Km. travel to reach brgy. hall. The station is located inside the compound of brgy. plaza, beside the gate post, left side fronting brgy. hall about 40 m NE of brgy. hall, 200 m NW of post Km. post 228, along Nat'l Road, 7 Km. to San Jose. Station is located in Brgy. Mapaya, San Jose, Occ., Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4203, 2007, NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795829 A**
T.N.:	**2014-643**

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

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CIP/4701/12/09/814

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Figure A-2.4 MRW-4203

4. MRW-4203

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-4205**
Order: **3rd**

Island: **LUZON**
Municipality: **SAN JOSE**
Barangay: **CENTRAL**

	PRS92 Coordinates	
Latitude: **12º 26' 8.33964"**	Longitude: **121º 2' 46.62783"**	Ellipsoidal Hgt: **12.56900 m.**
	WGS84 Coordinates	
Latitude: **12º 26' 3.44072"**	Longitude: **121º 2' 51.70789"**	Ellipsoidal Hgt: **62.09500 m.**
	PTM Coordinates	
Northing: **1375124 m.**	Easting: **505032.188 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,375,422.19**	Easting: **287,627.78**	Zone: **51**

Location Description

MRW-4205

From Abra de Ilog to San Jose, along Nat'l Road, approx. 10 Km. travel from San Jose Town Proper, 70 m E of Km. post 247 located Mabuhay Home Based ECCD Center for Health and Nutrition Bldg. located at Brgy. Central, Sitio Mabuhay, San Jose, Occ., Mindoro. Station is located beside fence, 2.0 m SW of Sitio Mabuhay Home Based ECCD Center of Health and Nutrition Post, 40 m NE of Nat'l Road, 70 m E of Km. post 247. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4205, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-448**

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

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Figure A-2.5 MRW-4205

5. MRW-4205

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

December 11, 2015

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: **OCCIDENTAL MINDORO**
Station Name: **MC-252**

Island: **Luzon**	Municipality: **MAGSAYSAY**	Barangay: **NICOLAS (BULO)**
Elevation: **73.9140 +/- 0.11 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

Mark is the head of a 4" copper nail flushed in a cement block embedded in the groun with inscriptions "MC-252 2008 NAMRIA"

The station is situated beside KM post 211, 26 KM to Bulalacao, 11 KM from Magsaysay 2 KM from Nicolas Brgy. Hall. From Magsaysay located along National road beside KM post 211, Magsaysay Occidental Mindoro.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088861 I**
T.N.: **2015-4115**

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

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CIP/4701/12/09/814

Figure A-2.6 MC-252

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

Table A-3.1. Baseline Processing Reports of Control Points used in the LiDAR Survey

1. MRW-4203

Vector Components (Mark to Mark)

From:	MRW-22				
Grid		Local		Global	
Easting	281265.629 m	Latitude	N12°31'36.76881"	Latitude	N12°31'31.84278"
Northing	1385563.717 m	Longitude	E120°59'13.46492"	Longitude	E120°59'18.53734"
Elevation	35.076 m	Height	35.127 m	Height	84.271 m

To:	MRW-4203				
Grid		Local		Global	
Easting	296032.858 m	Latitude	N12°21'24.45021"	Latitude	N12°21'19.57700"
Northing	1366637.239 m	Longitude	E121°07'26.92622"	Longitude	E121°07'32.01274"
Elevation	6.991 m	Height	7.414 m	Height	57.334 m

Vector					
ΔEasting	14767.230 m	NS Fwd Azimuth	141°36'12"	ΔX	-14844.540 m
ΔNorthing	-18926.478 m	Ellipsoid Dist.	24002.218 m	ΔY	-4238.929 m
ΔElevation	-28.085 m	ΔHeight	-27.712 m	ΔZ	-18378.800 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Figure A-3.1 Baseline Processing Report for MRW-4203

2. MRW-4205

Vector Components (Mark to Mark)

From:	MRW-22				
Grid		Local		Global	
Easting	281265.629 m	Latitude	N12°31'36.76881"	Latitude	N12°31'31.84278"
Northing	1385563.717 m	Longitude	E120°59'13.46492"	Longitude	E120°59'18.53734"
Elevation	35.076 m	Height	35.127 m	Height	84.271 m

To:	MRW-4205				
Grid		Local		Global	
Easting	287627.814 m	Latitude	N12°26'08.33883"	Latitude	N12°26'03.43990"
Northing	1375422.160 m	Longitude	E121°02'46.62885"	Longitude	E121°02'51.70890"
Elevation	12.319 m	Height	12.555 m	Height	62.080 m

Vector					
ΔEasting	6362.185 m	NS Fwd Azimuth	147°27'47"	ΔX	-6629.191 m
ΔNorthing	-10141.557 m	Ellipsoid Dist.	11969.898 m	ΔY	-1466.672 m
ΔElevation	-22.757 m	ΔHeight	-22.572 m	ΔZ	-9858.113 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Figure A-3.2 Baseline Processing Report for MRW-4205

3. MC-252

Vector Components (Mark to Mark)

From:	MRW-18				
Grid		Local		Global	
Easting	298113.895 m	Latitude	N12°18'45.39463"	Latitude	N12°18'40.53383"
Northing	1361734.745 m	Longitude	E121°08'36.92444"	Longitude	E121°08'42.01469"
Elevation	20.797 m	Height	21.295 m	Height	71.375 m

To:	MC-252				
Grid		Local		Global	
Easting	304770.876 m	Latitude	N12°19'10.66357"	Latitude	N12°19'05.80624"
Northing	1362466.012 m	Longitude	E121°12'17.05287"	Longitude	E121°12'22.14215"
Elevation	75.616 m	Height	76.241 m	Height	126.454 m

Vector					
ΔEasting	6656.981 m	NS Fwd Azimuth	83°20'06"	ΔX	-5632.860 m
ΔNorthing	731.267 m	Ellipsoid Dist.	6696.437 m	ΔY	-3538.801 m
ΔElevation	54.818 m	ΔHeight	54.946 m	ΔZ	770.489 m

Standard Errors

Vector errors:					
σ ΔEasting	0.005 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.011 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.005 m	σ ΔY	0.019 m
σ ΔElevation	0.021 m	σ ΔHeight	0.021 m	σ ΔZ	0.005 m

Figure A-3.3 Baseline Processing Report for MC-252

4. UP-LUM

Vector Components (Mark to Mark)

From:	MRW-24				
Grid		Local		Global	
Easting	275166.053 m	Latitude	N12°36'42.98690"	Latitude	N12°36'38.03549"
Northing	1395022.712 m	Longitude	E120°55'49.01761"	Longitude	E120°55'54.08296"
Elevation	5.790 m	Height	5.694 m	Height	54.479 m

To:	UP-LUM_2015_TCAGP				
Grid		Local		Global	
Easting	281275.130 m	Latitude	N12°31'36.65200"	Latitude	N12°31'31.72599"
Northing	1385560.055 m	Longitude	E120°59'13.78049"	Longitude	E120°59'18.85291"
Elevation	35.101 m	Height	35.151 m	Height	84.296 m

Vector					
ΔEasting	6109.077 m	NS Fwd Azimuth	146°42'11"	ΔX	-6369.234 m
ΔNorthing	-9462.657 m	Ellipsoid Dist.	11260.986 m	ΔY	-1398.516 m
ΔElevation	29.311 m	ΔHeight	29.457 m	ΔZ	-9180.860 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Figure A-3.4 Baseline Processing Report for UP-LUM

ANNEX 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Supervising SRS	LOVELYN ASUNCION	UP-TCAGP
	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	
		PATRICIA YSABEL ALCANTARA	
		ENGR. MILLIE SHANE REYES	
LiDAR Operation/ Ground Survey, Data Download and Transfer	RA	ENGR. GRACE B. SINADJAN	
Ground Survey	RA	ENGR. FRANK NICOLAS ILEJAY	
LiDAR Operation	Airborne Security	SSG. JOHN ERIC CACANINDIN	Philippine Air Force (PAF)
		SSG. BENJIE CARBOLLEDO	
	Pilot	CAPT. JEFFREY ALAJAR	Asian Aerospace Corporation (AAC)
		CAPT. JACKSON JAVIER	
		CAPT. SHERWIN ALFONSO	
		CAPT. JUSTIN JOYA	

ANNEX 5. Data Transfer Sheet For Lumintao Floodplain

Table A-5.1. Data Transfer Sheet for the Lumintao Floodplain

DATA TRANSFER SHEET
Mar 19, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Jan 15, 2014	989P	1PAMS015A	PEGASUS	1.02MB	NA	5.85MB	168MB	NA	NA	9.2GB	N/A	11MB	1KB	1KB	NA	N/A	X:\Airborne_Raw\989P
Jan 21, 2014	1004A	3PNG1AB021A	AQUARIUS	NA	NA	620KB	209MB	23.4GB	194KB	10.6GB	47.7GB	8.24MB	1KB	2KB	7/114/114KB	389/16KN	X:\Airborne_Raw\1004A
Jan 21, 2014	1006A	3PNG1ABS021B	AQUARIS	NA	NA	214KB	128MB	6.78GB	65KB	4.08GB	15.5GB	8.24MB	1KB	1KB	16/46/7KB	124KB	X:\Airborne_Raw\1006A
Jan 22, 2014	1008A	3PNG1AS022A	AQUARIUS	NA	NA	482KB	204MB	26.3GB	209KB	8.14GB	33.1GB	10.6MB	1KB	1KB	1/7/101KB	281KB	X:\Airborne_Raw\1008A
Feb 21, 2014	1128A	3BLK29I52A	AQUARIUS	NA	NA	1.34MB	269MB	6.32GB	1.672KB	16.1GB	NA	12.3MB	1KB	1KB	6/303KB	854KB	X:\Airborne_Raw\1128A
Feb 22, 2014	1132A	3BLK29IS53A/3BLK29H53A	AQUARIUS	NA	NA	1.62MB	276MB	34.3GB	251/1/326KB	16.1GB	83.7GB	13.4MB	1KB	1KB	432KB	383/506/320/384KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1132A
Feb 22, 2014	1134A	3BLK29MS53B/3BLK29MR53B	AQUARIUS	NA	NA	1.08MB	144MB	27.8GB	105/28/1/30.55/44KB	4.99GB	12.6GB	13.4MB	1KB	1KB	102KB	131KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1134A
Feb 23, 2014	1136A	3BLK29HS54A/3BLK29HB54A	AQUARIUS	NA	NA	1.37MB	256MB	86.5GB	227/337/61KB	15GB	NA	15.8MB	1KB	1KB	268KB	265/265/520/36KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1136A
Feb 23, 2014	1138A	3BLK29E54B	AQUARIUS	NA	NA	833KB	196MB	50.4GB	408KB	8.89GB	42.6GB	15.8MB	1KB	1KB	172KB	500KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1138A
Feb 24, 2014	1140A	3BLK29ES55A/3BLK29G55A	AQUARIUS	NA	NA	961KB	241MB	53.3GB	401KB	9.99GB	40.8GB	12.1MB	1KB	1KB	367KB	244/264KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1140A
Feb 24, 2014	1142A	3BLK29P55B	AQUARIUS	NA	NA	2.04MB	228MB	61.7GB	56/490KB	12.4GB	64.2GB	12.1MB	1KB	1KB	709KB	247KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1142A

TRANSFERRED IN FREENAS.

Received from

Name CHRIS JOAQUIN

Position RA

Signature

Received by

Name JONIDA PRIETO

Position SSRS

Signature

Figure A-5.1 Data Transfer Sheet for Lumintao Floodplain - A

DATA TRANSFER SHEET
3/19/2014(OCCMIIN)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Feb 27, 2014	1152A	3BLK29GSD58A	AQUARIUS	NA	NA	1.12MB	255MB	73GB	544KB	12.6GB	53.8GB	15.9MB	1KB	1KB	339KB	135/556KB	Z:\Airborne_Raw\1152A
Feb 27, 2014	1154A\	3BLK29DS58B	AQUARIUS	NA	NA	NA	214MB	39.9GB	283/29KB	44.5GB	9.42GB	15.9MB	1KB	2KB	687KB	NA	Z:\Airborne_Raw\1154A
Feb 28, 2014	1156A	3BLK29F59A	AQUARIUS	NA	NA	1.72MB	268MB	89.5GB	NA	14.3GB	69.8GB	17.1MB	1KB	1KB	352KB	813KB	Z:\Airborne_Raw\1156A
Feb 28, 2014	1158A	3BLK29A59B	AQUARIUS	NA	NA	683 KB	210 MB	38GB	95/199KB	8.14GB	13.7GB	17.1MB	1KB	1KB	6/144KB	424KB	Z:\Airborne_Raw\1158A
Mar 1, 2014	1160A	3BLK29C60A	AQUARIUS	NA	NA	1.03MB	268MB	13.5GB	10/50/40KB	14.1GB	57GB	17.8MB	1KB	1KB	519KB	399/16KB	Z:\Airborne_Raw\1160A
Mar 1, 2014	1162A	3BLK29AS60B	AQUARIUS	NA	NA	759KB	199MB	34.6GB	147/88KB	9.54GB	87.2GB	17.8MB	1KB	1KB	11/176KB	445KB	Z:\Airborne_Raw\1162A
Mar 2, 2014	1164A	3BLK29N61A	AQUARIUS	NA	NA	878KB	293MB	22.5GB	147KB	13.6GB	73.8GB	18.4MB	1KB	1KB	237KB	76/44KB	Z:\Airborne_Raw\1164A
Mar 2, 2014	1166A	3BLK29B61B	AQUARIUS	NA	NA	1.16MB	230MB	NA	NA	12.5GB	144GB	18.4MB	1KB	1KB	9/242KB	714/714KB	Z:\Airborne_Raw\1166A
Mar 3, 2014	1168A	3BLK29BS62A	AQUARIUS	NA	NA	2.37MB	268MB	NA	NA	12.3GB	15.7GB	10.8MB	1KB	1KB	184KB	300/666/670KB	Z:\Airborne_Raw\1168A

Received from

Name Chris Joaquin

Position RA

Signature 04/21/14

Received by

Name JOIDA F. PRIETO

Position SSRS

Signature 4/23/14

Figure A-5.2 Data Transfer Sheet for Lumintao Floodplain - B

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

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	
6-Dec-15	3058P	1BLK29C340A	pegasus	752	189	5.69	120	9.79	74	7.56	na	15.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	460	108	3.43	115	6.09	48	4.79	na	15.4	1KB	1KB	394/344/58	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.45	430	9.18	206	26.6	192	14.4	na	7.51	1KB	1KB	100/89/95	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDI342A	pegasus	982	276	7.18	177	17	121	9.79	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	0	67	2.7	114	4.63	37	2.77	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	953	217	5.7	143	14.3	na	9.37	na	5.96	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.09	212	9.12	225	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	259	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/318/295/313/146/156	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	551	171	5.23	167	12.9	105	6.2	na	7.02	1KB	1KB	47/394/344/313/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	932	206	6.85	174	13.1	95	9.22	na	7.61	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from

Name
Position
Signature

Received by

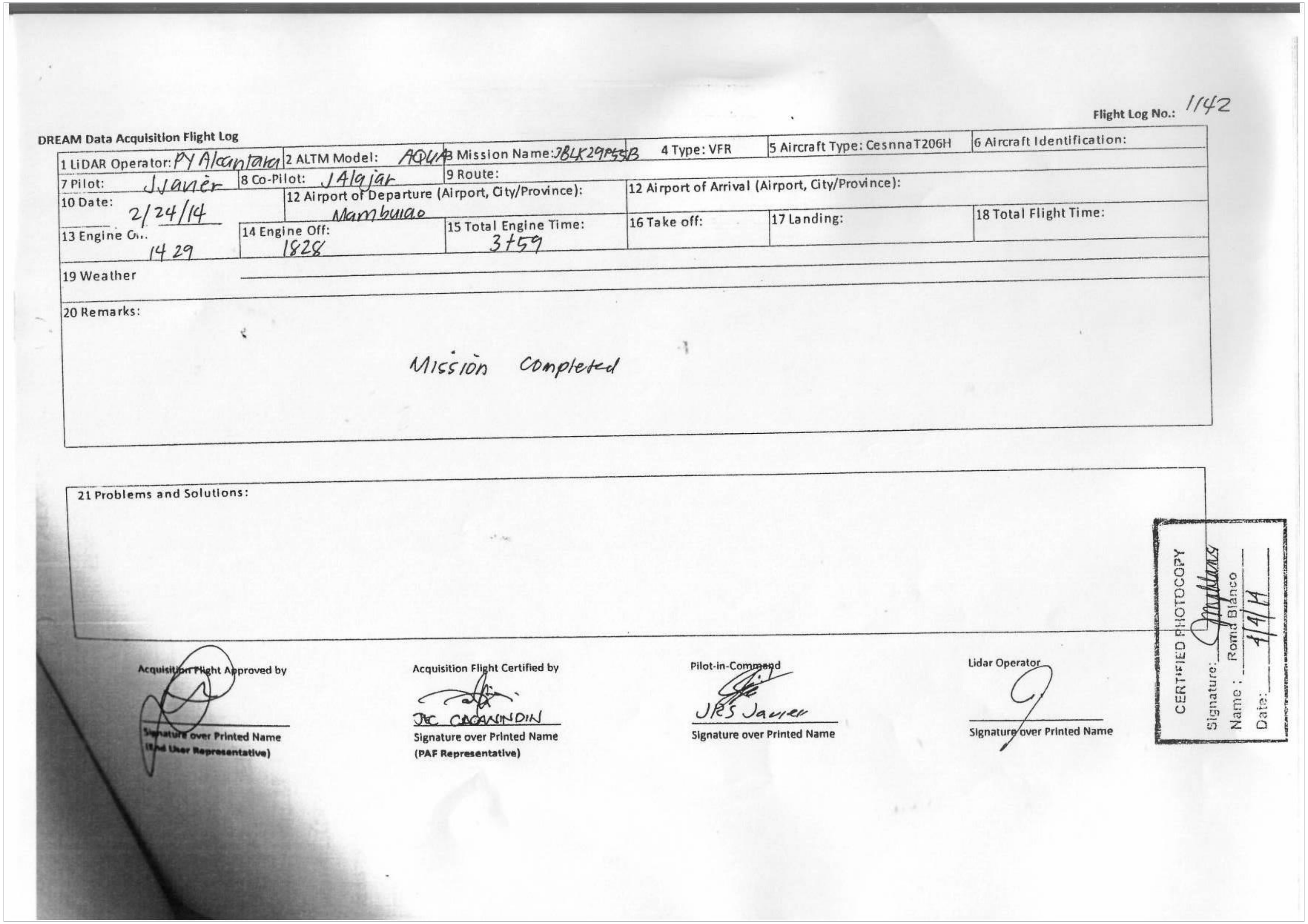
Name
Position
Signature

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

ANNEX 6. Flight Logs for the Flight Missions

1. Flight log for 1142A Mission

Table A-6.1. Flight Logs for the Flight Missions



Flight Log No.: 1142

DREAM Data Acquisition Flight Log

1 LiDAR Operator: PY Alcantara	2 ALTM Model: AQUA	3 Mission Name: 3BLK29PS5B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/24/14	12 Airport of Departure (Airport, City/Province): Mambulao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1429	14 Engine Off: 1828	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed

21 Problems and Solutions:

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

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

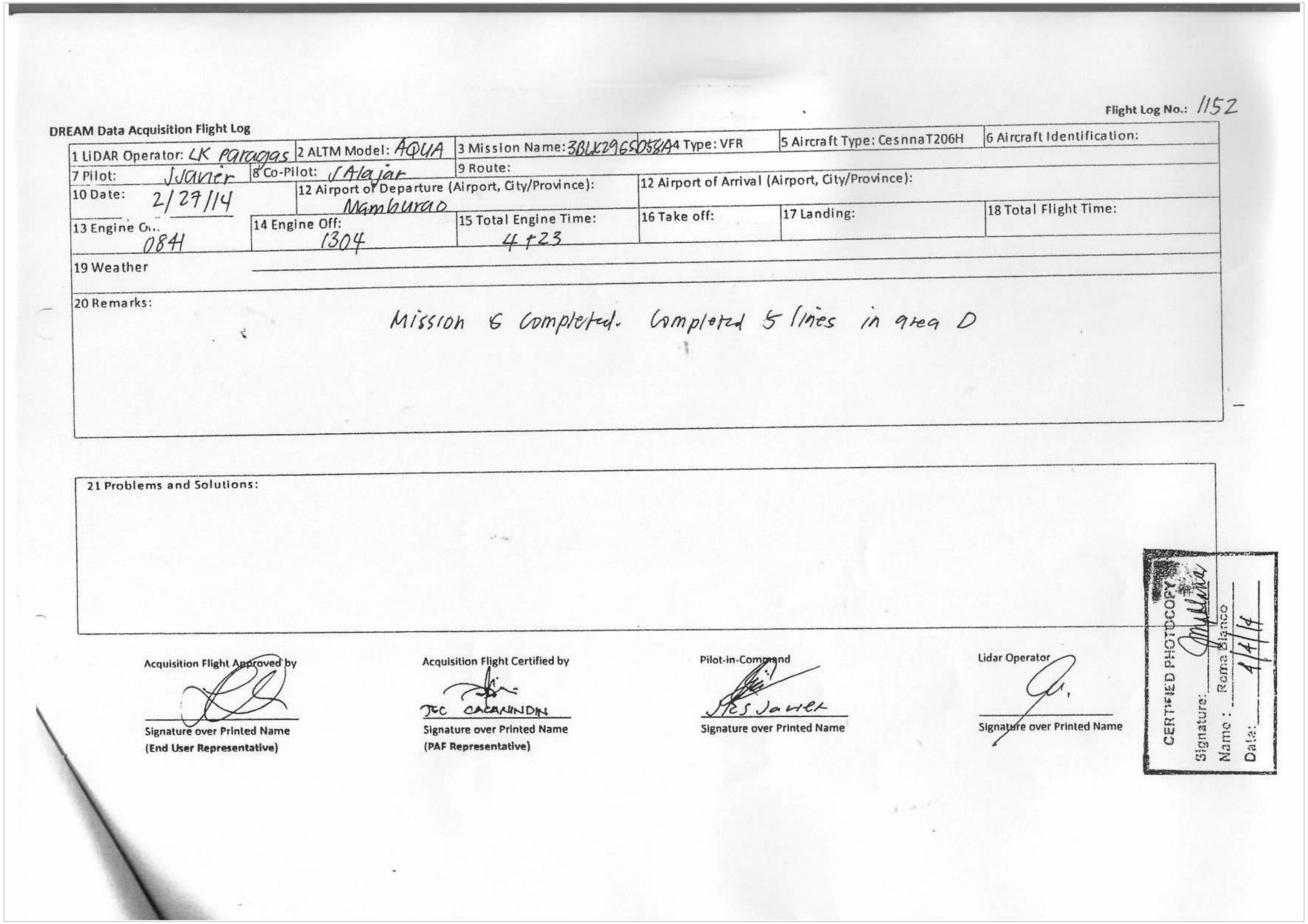
Pilot-in-Command — JRS Javier — Signature over Printed Name

Lidar Operator — Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature: ____
Name: Romd Blanco
Date: 4/4/14

Figure A-6.1 Flight log for 1142A Mission

2. Flight log for 1152A Mission


Flight Log No.: 1152

DREAM Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas
2 ALTM Model: AQUA
3 Mission Name: 3BLK29G5058A
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification:
7 Pilot: J Javier
8 Co-Pilot: J Alajar
9 Route:
10 Date: 2/27/14
12 Airport of Departure (Airport, City/Province): Mamburao
12 Airport of Arrival (Airport, City/Province):
13 Engine On: 0841
14 Engine Off: 1304
15 Total Engine Time: 4+23
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather
20 Remarks: Mission is completed. Completed 5 lines in area D

21 Problems and Solutions:

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

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

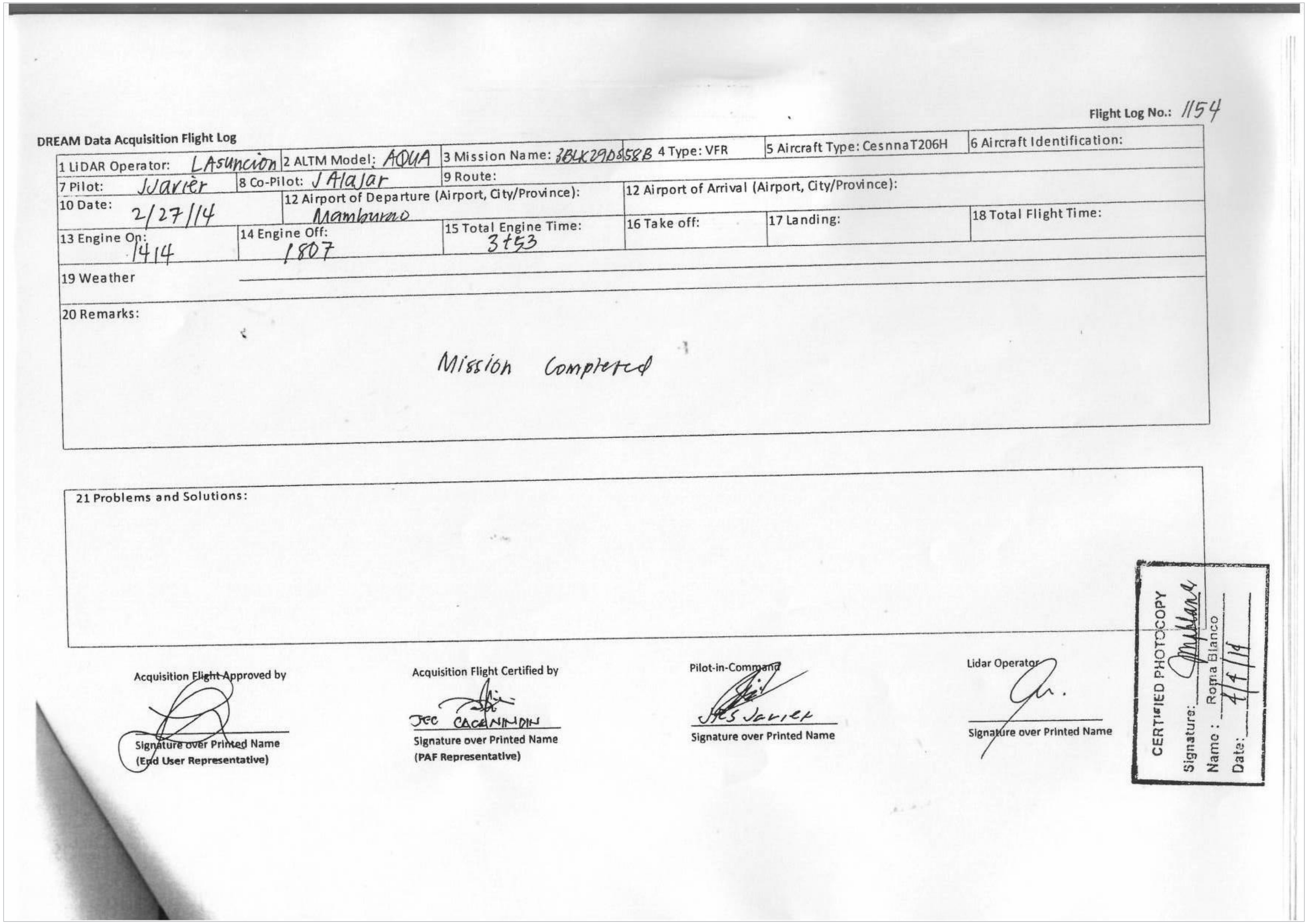
Pilot-in-Command
JCS Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Roma Blanco
Date: 4/4/14

Figure A-6.2 Flight log for 1152A Mission

3. Flight log for 1154A Mission



Flight Log No.: 1154

DREAM Data Acquisition Flight Log

1 LiDAR Operator: LAsuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29DS58B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: JJavier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/27/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1414	14 Engine Off: 1807	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					
21 Problems and Solutions:					

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

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

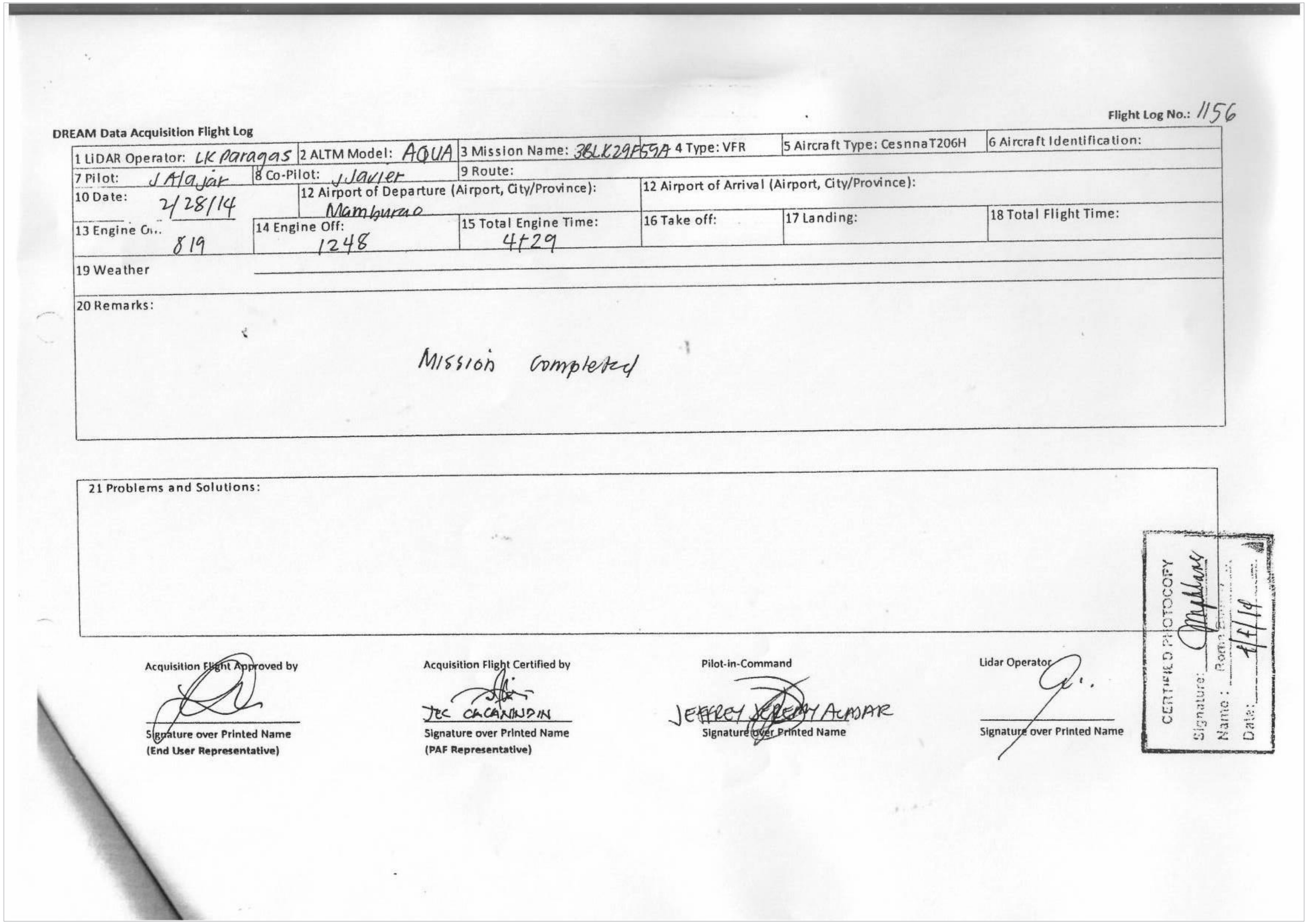
Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Roma Blanco
Date: 4/4/14

Figure A-6.3 Flight log for 1154A Mission

4. Flight log for 1156A Mission



Flight Log No.: 1156

DREAM Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29F59A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/28/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 819	14 Engine Off: 1248	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					
21 Problems and Solutions:					

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

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

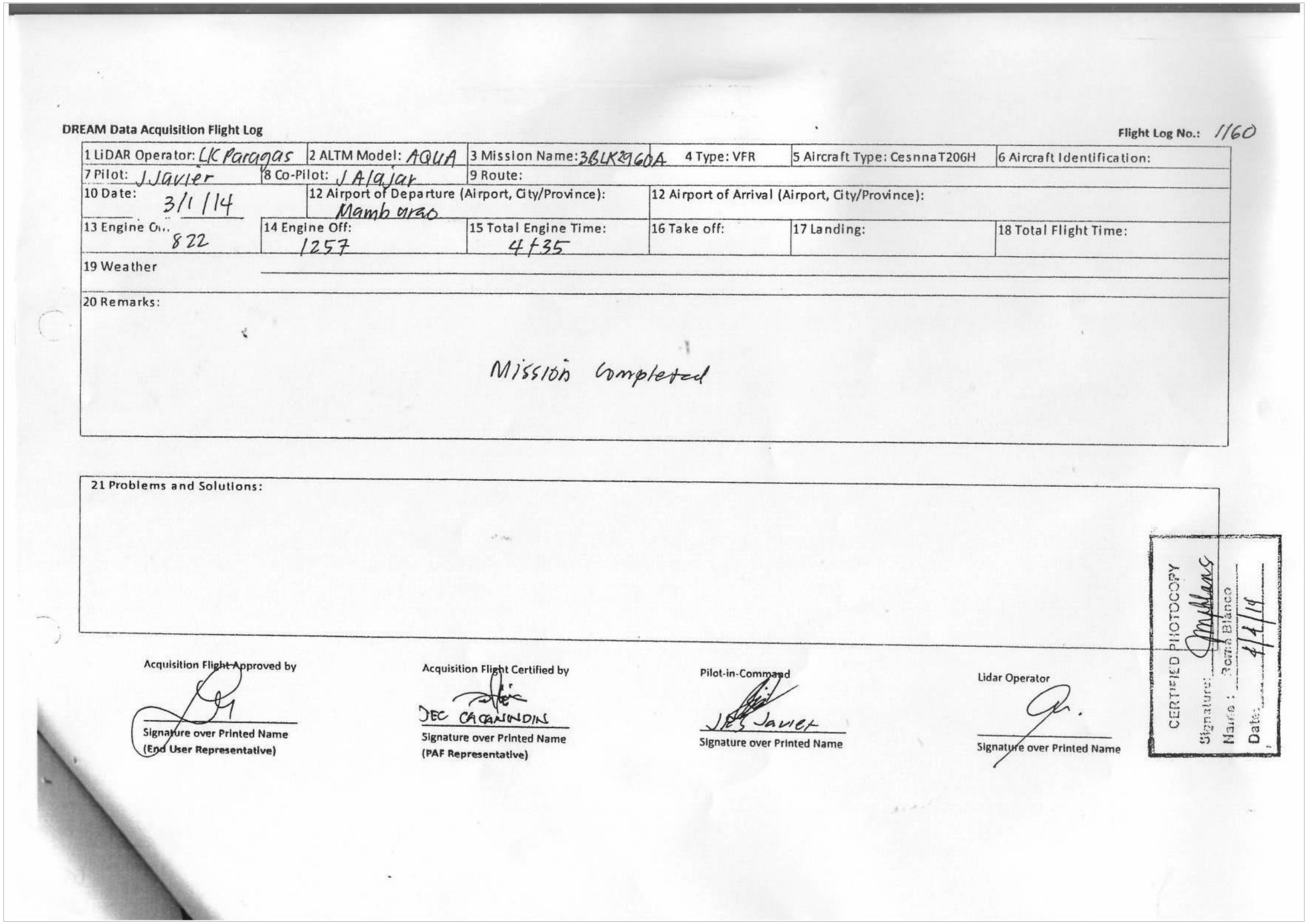
Pilot-in-Command
JEFFREY JEREMY ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name:
Date: 4/4/14

Figure A-6.4 Flight log for 1156A Mission

5. Flight log for 1160A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1160

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29160A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J. Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 822	14 Engine Off: 1257	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

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

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

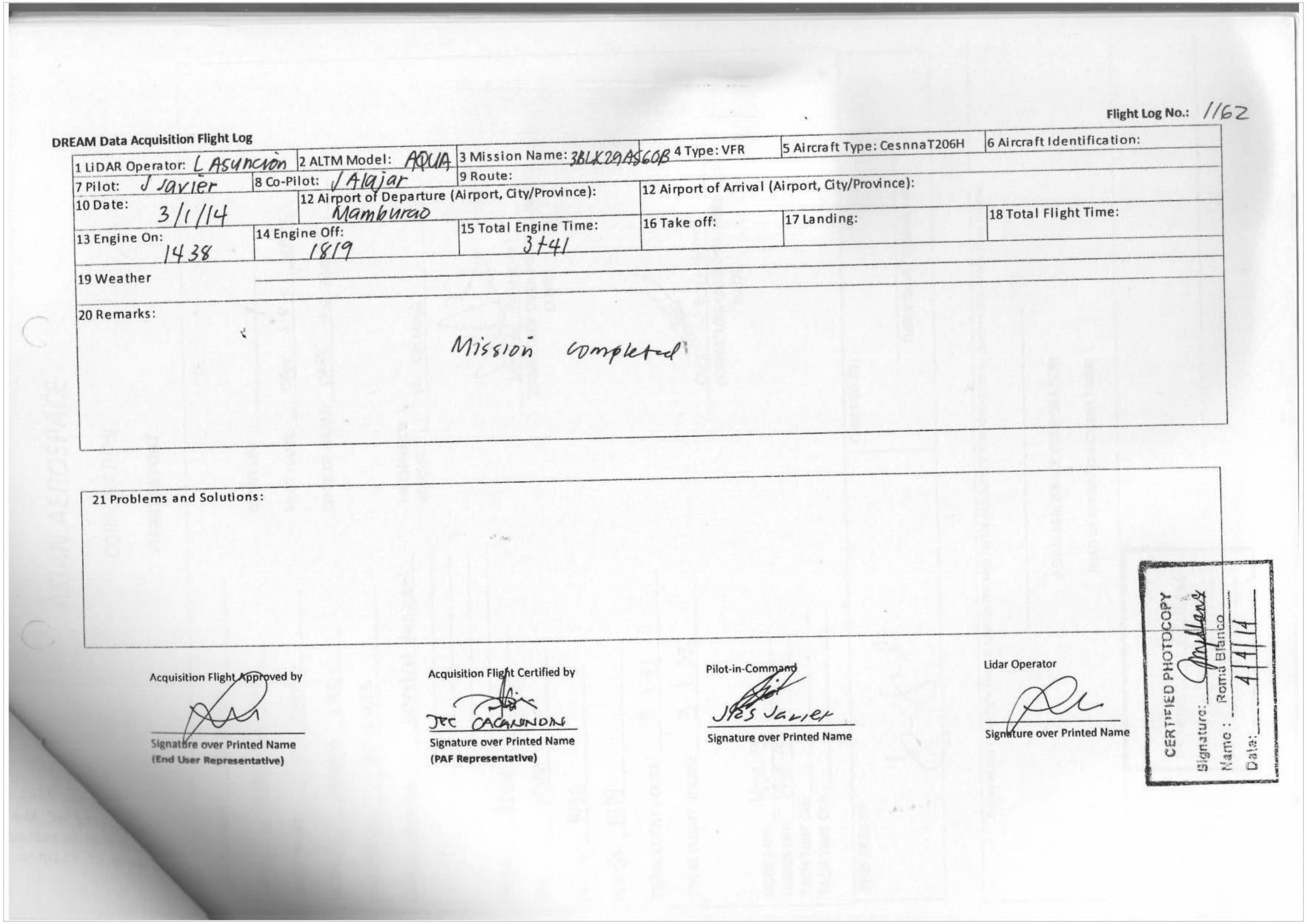
Pilot-in-Command — J. Javier — Signature over Printed Name

Lidar Operator — Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Romé Blanco
Date: 4/2/14

Figure A-6.5 Flight log for 1160A Mission

6. Flight log for 1162A Mission



Flight Log No.: 1162

DREAM Data Acquisition Flight Log

1 LiDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29AS60B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1438	14 Engine Off: 1819	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed

21 Problems and Solutions:

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

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

Pilot-in-Command
JPES Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Roma Blanco
Date: 4/4/14

Figure A-6.6 Flight log for 1162A Mission

7. Flight log for 1168A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1168

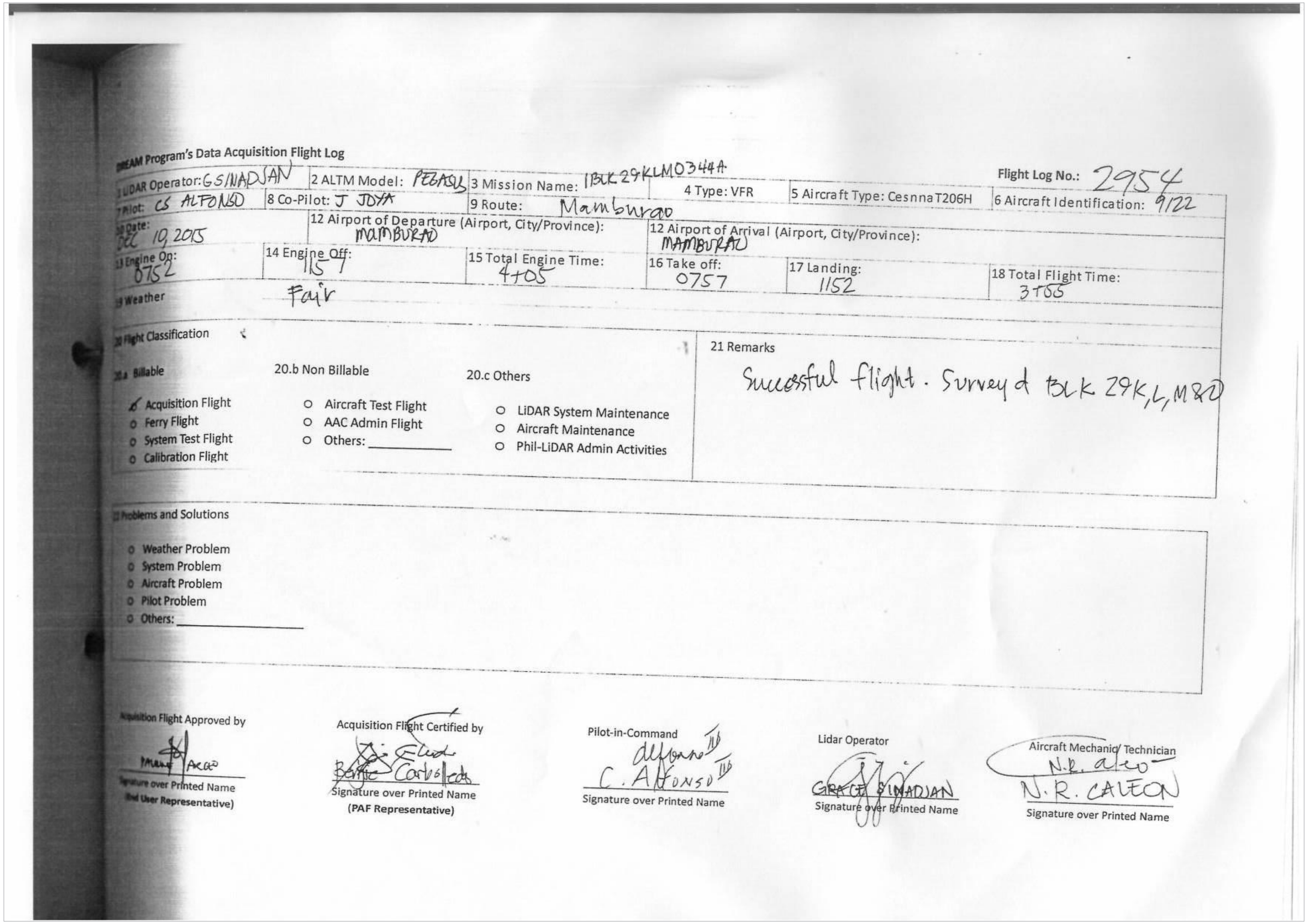
1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29B562A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/3/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0813	14 Engine Off: 1242	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					
21 Problems and Solutions:					

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

CERTIFIED PHOTOCOPY
Signature: ____
Name: Roma Blanco
Date: 4/4/14

Figure A-6.7 Flight log for 1168A Mission

8. Flight log for 3074P Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2954

1 LiDAR Operator: G SINADJAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29KLM0344A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao			
10 Date: DEC 10, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0752	14 Engine Off: 1157	15 Total Engine Time: 4+05	16 Take off: 0757	17 Landing: 1152	18 Total Flight Time: 3+55
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Successful flight. Surveyed BLK 29K,L,M&O

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

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

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

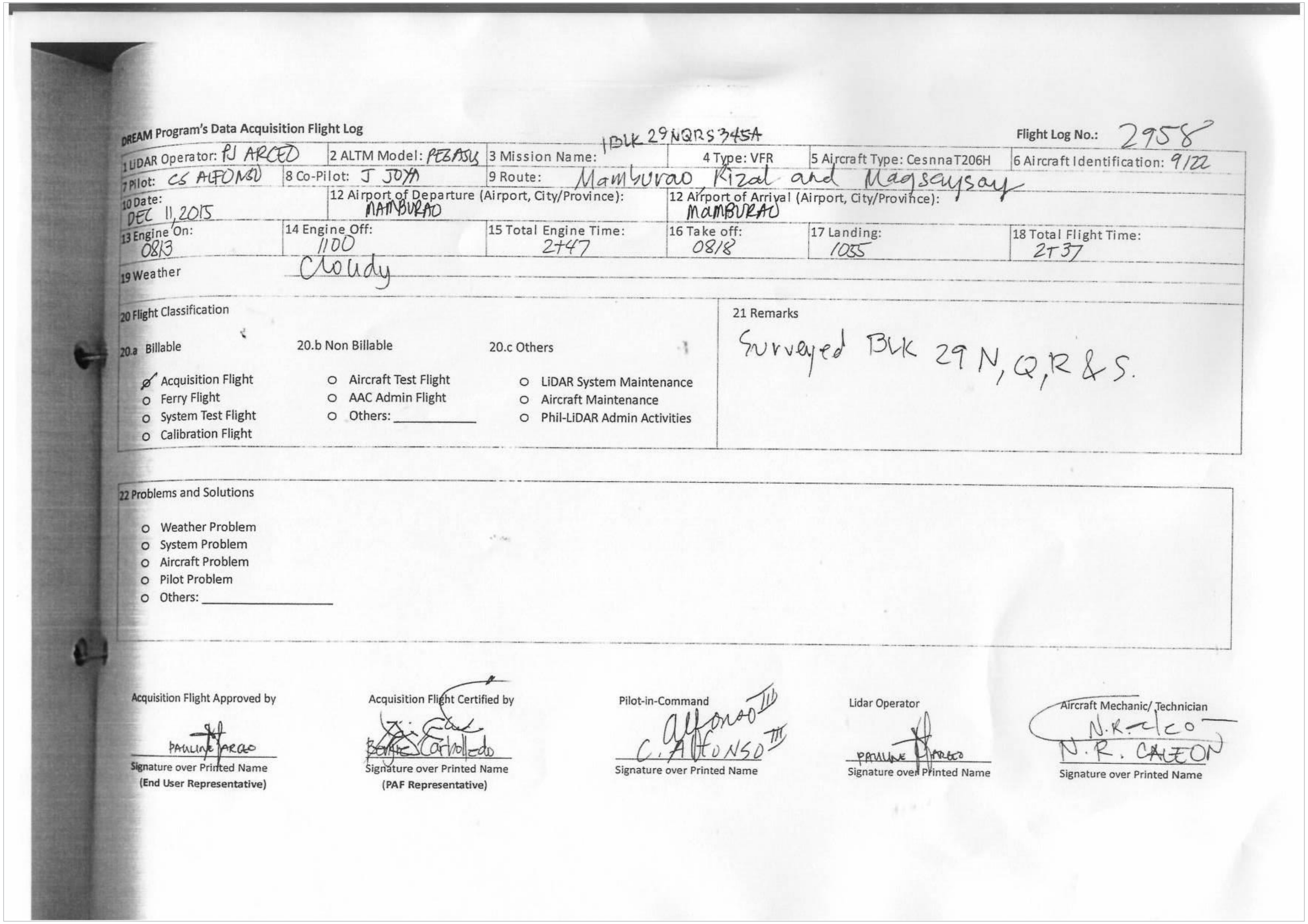
Pilot-in-Command: C. ALFONSO — Signature over Printed Name

Lidar Operator: GRACE SINADJAN — Signature over Printed Name

Aircraft Mechanic/ Technician: N.R. CALEON — Signature over Printed Name

Figure A-6.8 Flight log for 3074P Mission

9. Flight log for 3078P Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2958

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29NQRS345A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao, Rizal and Magsaysay			
10 Date: DEC 11, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0813	14 Engine Off: 1100	15 Total Engine Time: 2+47	16 Take off: 0818	17 Landing: 1055	18 Total Flight Time: 2+37
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29 N, Q, R & S.

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

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

Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

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

Lidar Operator: PAULINE ARCEO — Signature over Printed Name

Aircraft Mechanic/ Technician: N.R. CALZON — Signature over Printed Name

Figure A-6.9 Flight log for 3078P Mission

ANNEX 7. Flight Status Reports

Table A-7.1. Flight Status Reports

MAMBURAO, OCCIDENTAL MINDORO
February 25-March 3, 2014 and December 10-11, 2015

Flight No	Area	Mission	Operator	Date Flown	Remarks
1142A	BLK29P	3BLK29P55B	PY ALCANTARA	February 23, 2014	Mission completed. Camera error in line 16, 100% dropouts in line 15
1152A	BLK29D & BLK29G	3BLK29D+GS58A	L. PARAGAS	February 27, 2014	Completed the rest of BLK29G and 5 lines of BLK29D.
1154A	BLK29D	3BLK29DS58B	L. ASUNCION	February 27, 2014	Completed the rest of BLK29D. Experienced dropouts over water. Camera assertion failed in line 15, restarted the camera. Also, cam error in line 18.
1156A	BLK29F	3BLK29F59A	L. PARAGAS	February 28, 2014	Mission completed. No camera mission logs.
1160A	BLK29C AND BLK29G	3BLK29C+GV60A	L. PARAGAS	March 1, 2014	Mission completed and covered gap in BLK29G. Images manually captured in lines 1, 14 and 16 while no cam images for 2, 3 and 15. Digitizer hanged in line 14. Strong wind near mountainous area.
1162A	BLK29A AND BLK29D	3BLK29AS+DV60B	L. ASUNCION	March 1, 2014	Mission completed. Continuation of BLK29A and covered voids in BLK29D. Restarted the system due to high system temperature. Camera hanged in line 3, no images for half of the line while manually for the rest of the line and entire line 8 while no images for lines 1, 4 and 7.
1168A	BLK29B, A, D, C AND K	3BLK29BS+AB+DB+CV+KV62B	L. PARAGAS	March 3, 2014	Mission completed. Bathy in BLK29A and D but the digitizer hanged in line 2 of area A. Covered voids of BLK29 C and K.
3074P	BLK29K, L, M, O	1BLK29KLMO344A	G. Sinadjan	December 10, 2015	Surveyed BLK29K, L, M, and O
3078P	BLK29N, Q, R, S	1BLK29NQRS345A	PJ. Arceo	December 11, 2015	Surveyed BLK29N, Q, R, and S

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No.: **1142A**
Area: BLK29P
Mission Name: 3BLK29P55B
Parameters:
Altitude: 600
Scan Frequency: 40
Scan Angle: 36
Overlap: 30%

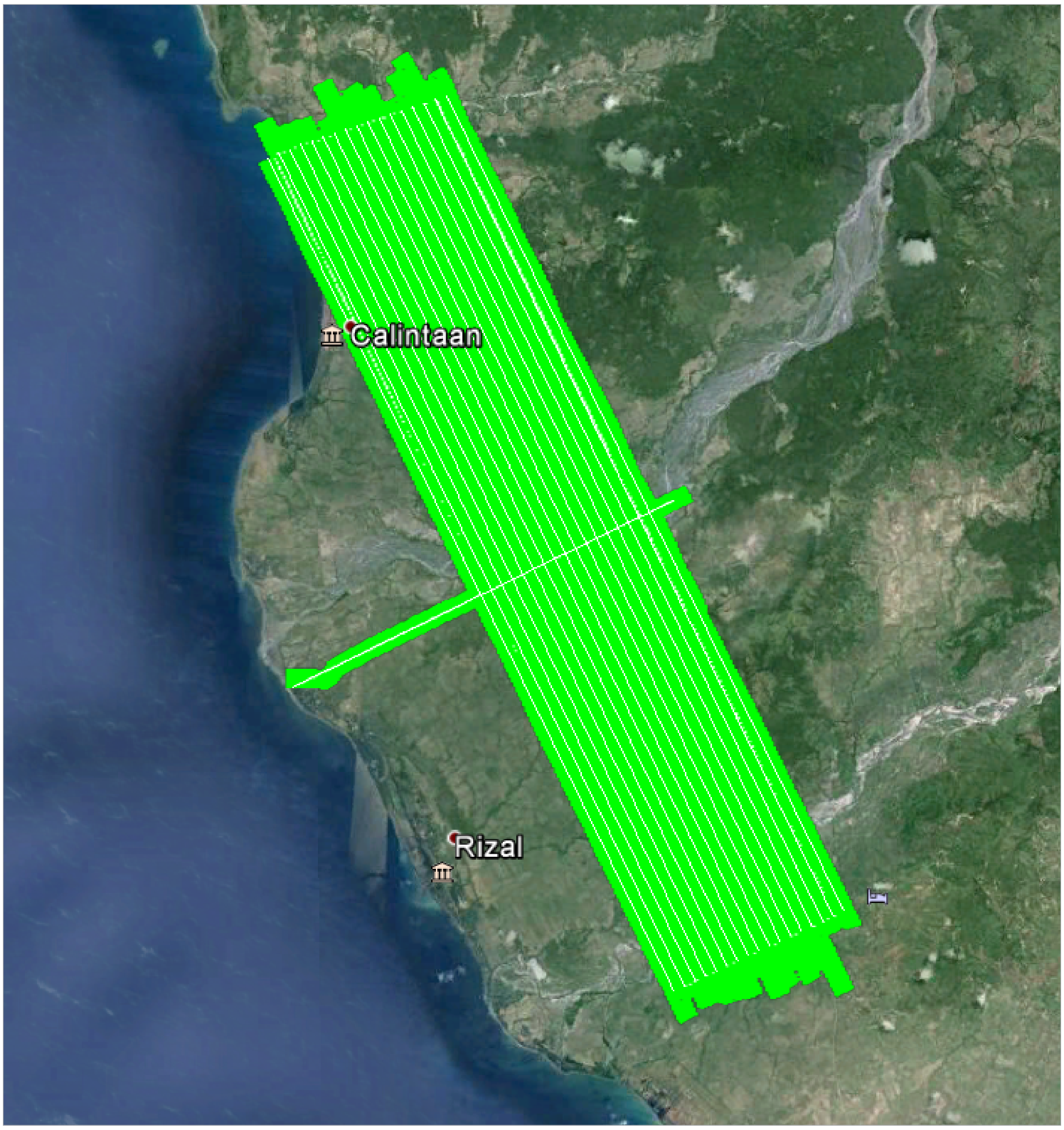


Figure A-7.1 Swath for Flight No. 1142A

Flight No.: **1152A**
Area: BLK29D AND BLK29G
Mission Name: 3BLK29D+GS58A
Parameters:
Altitude: 650
Scan Frequency: 40
Scan Angle: 36
Overlap: 30%

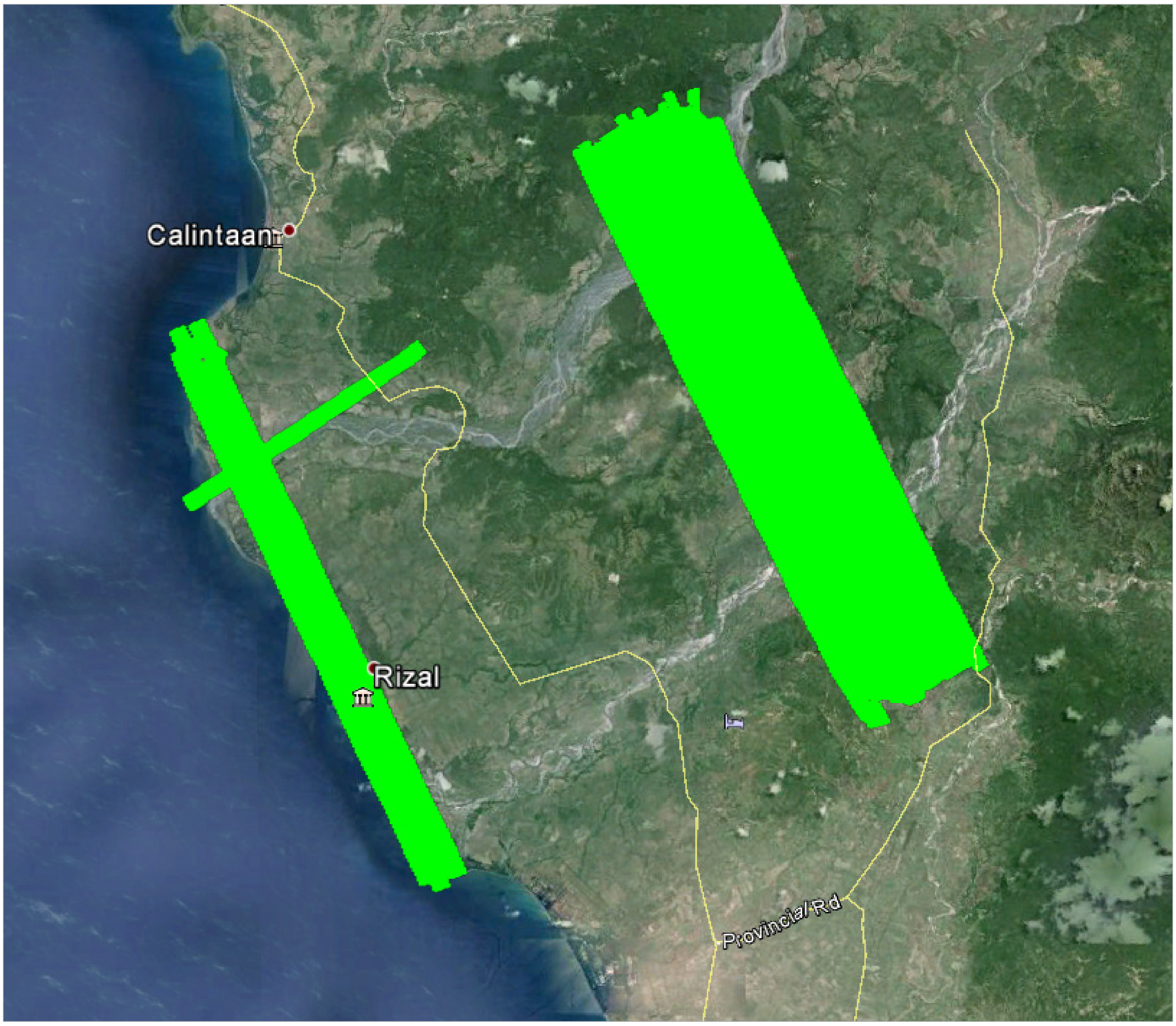


Figure A-7.2 Swath for Flight No. 1152A

Flight No.: **1154A**
Area: BLK29D
Mission Name: 3BLK29DS58B
Parameters:
Altitude: 600
Scan Frequency: 40
Scan Angle: 36
Overlap: 30%

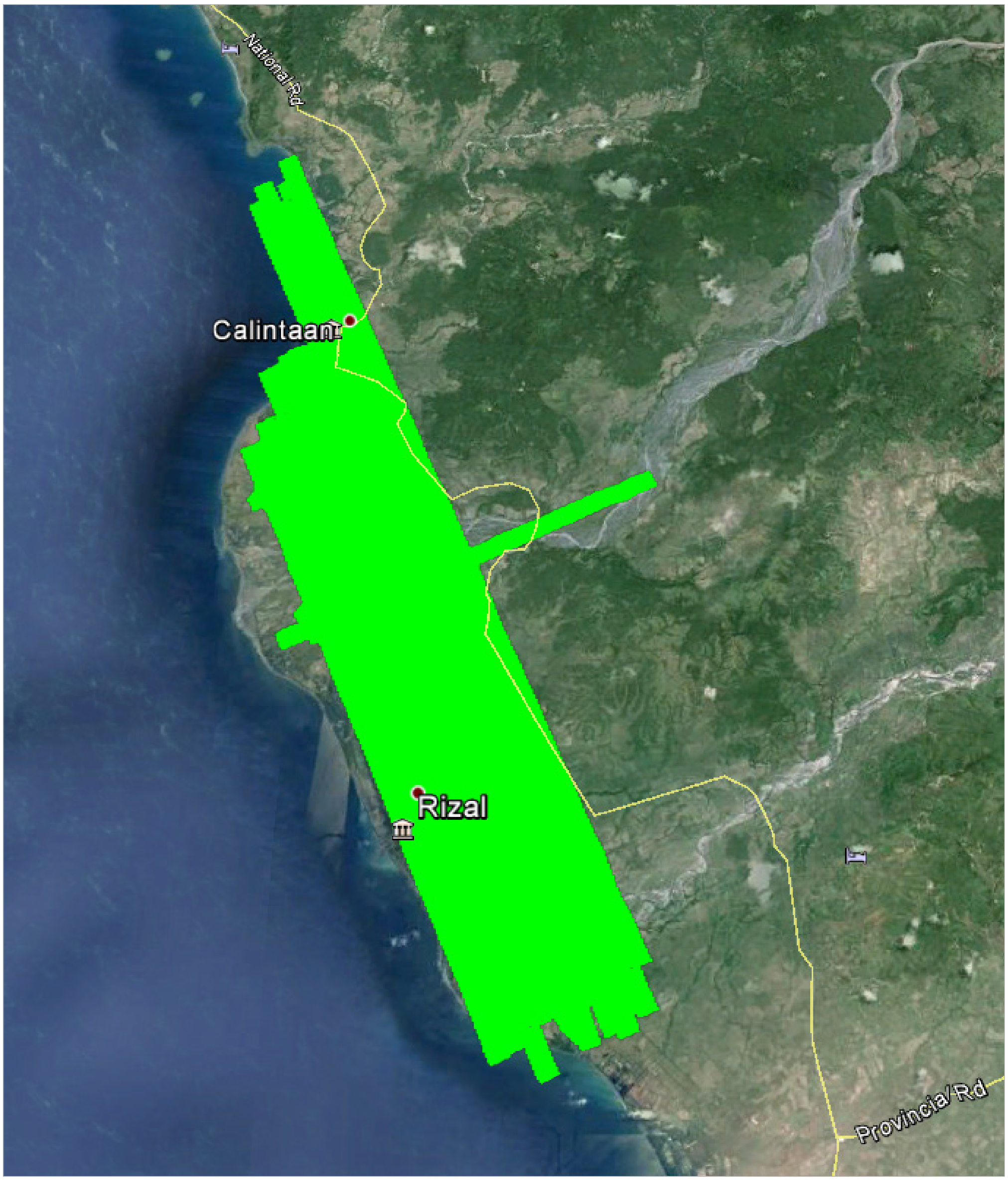


Figure A-7.3 Swath for Flight No. 1154A

Flight No.: 1156A
Area: BLK29F
Mission Name: 3BLK29F59A
Parameters:
- **Altitude:** 600
- **Scan Frequency:** 40
- **Scan Angle:** 36
- **Overlap:** 30%

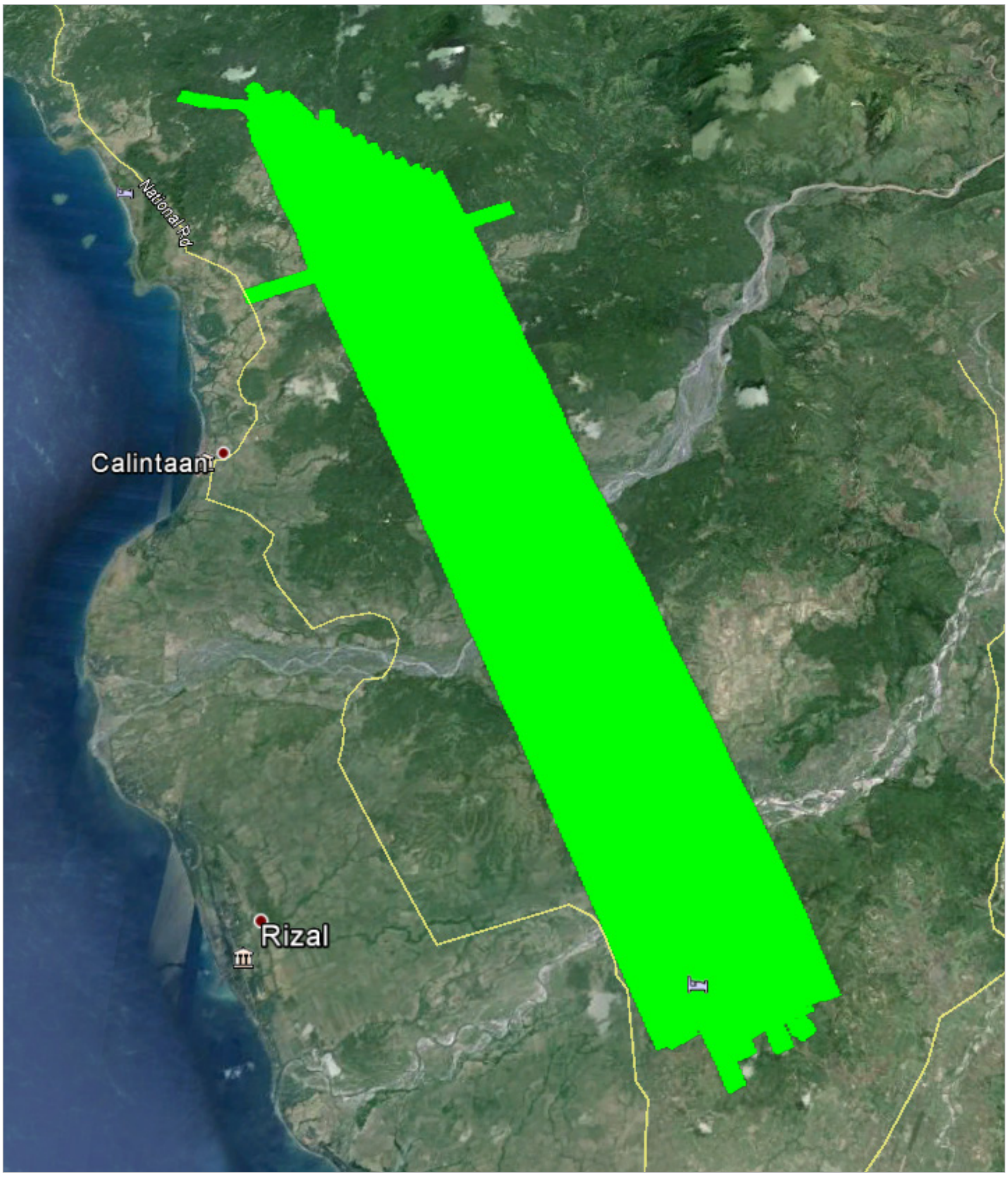


Figure A-7.4 Swath for Flight No. 1156A

Flight No.: **1160A**
Area: BLK29C AND BLK29G
Mission Name: 3BLK29C+GV60A
Parameters:
Altitude: 650
Scan Frequency: 40
Scan Angle: 36
Overlap: 30%

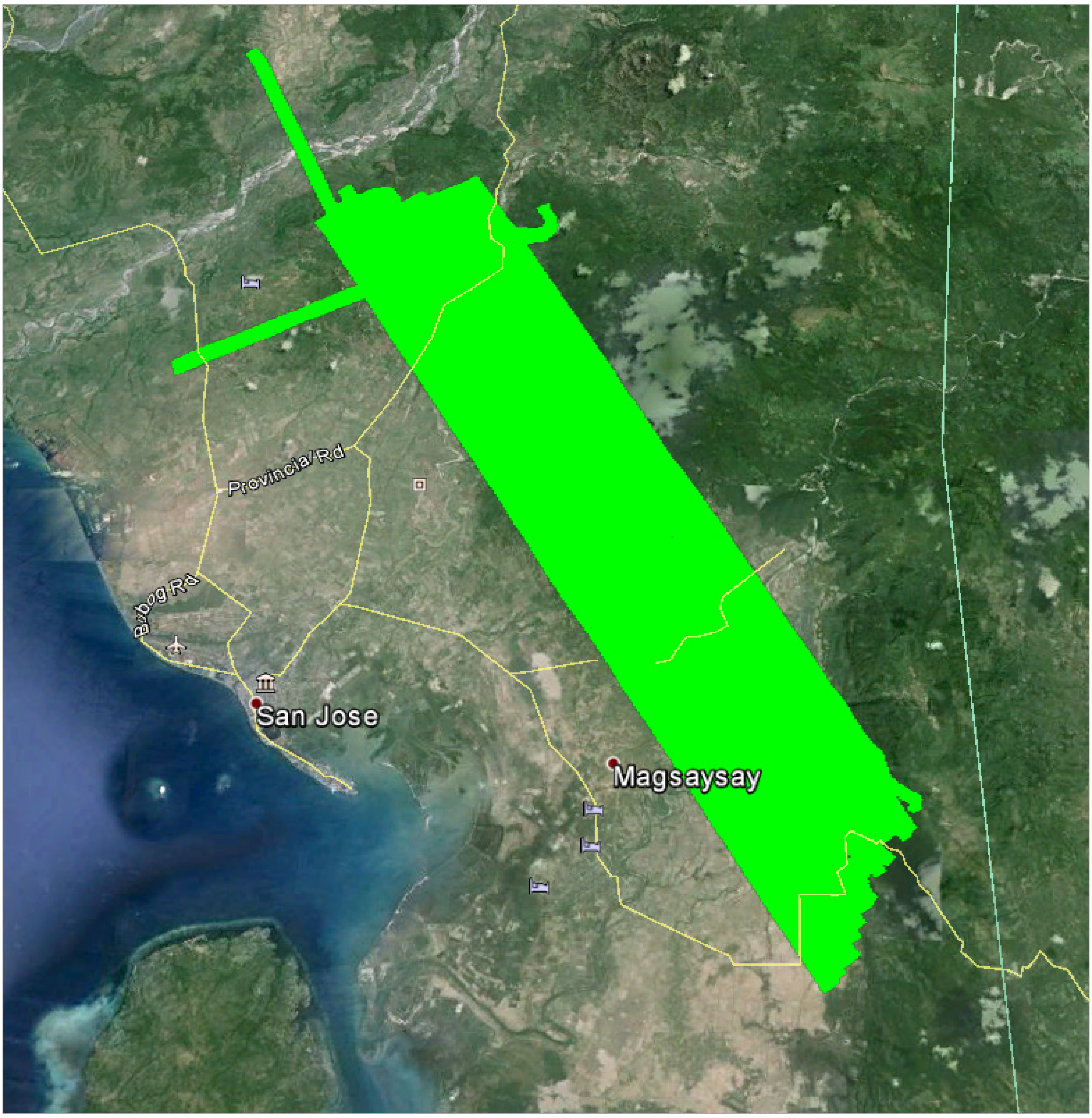


Figure A-7.5 Swath for Flight No. 1160A

Flight No.: **1162A**
Area: BLK29A AND BLK29D
Mission Name: 3BLK29AS+DV60B
Parameters:
Altitude: 600
Scan Frequency: 40
Scan Angle: 36
Overlap: 30%

Figure A-7.6 Swath for Flight No. 1162A

Flight No.: **1168A**
Area: BLK29B, BLK29A, BLK29D, BLK29C AND BLK29K
Mission Name: 3BLK29BS+AB+DB+CV+KV62B
Parameters:
Altitude: 550
Scan Frequency: 40
Scan Angle: 36
Overlap: 30%

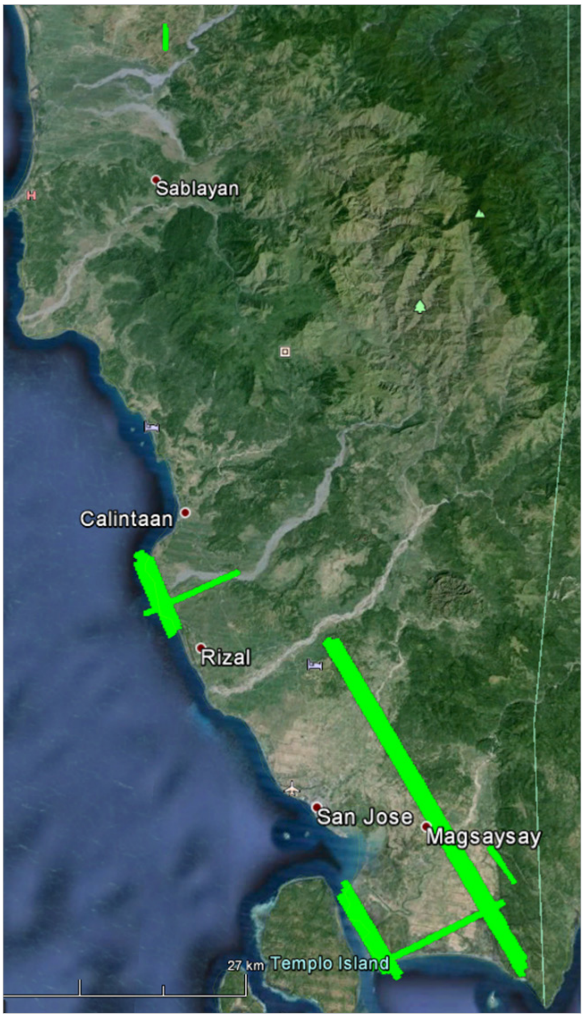


Figure A-7.7 Swath for Flight No. 3585G

Flight No.: **3074P**
Area: BLK29K, L, M, O
Mission Name: 1BLK29KLMO344A
Parameters:
Altitude: 1100
Scan Frequency: 30
Scan Angle: 50
Overlap: 30%

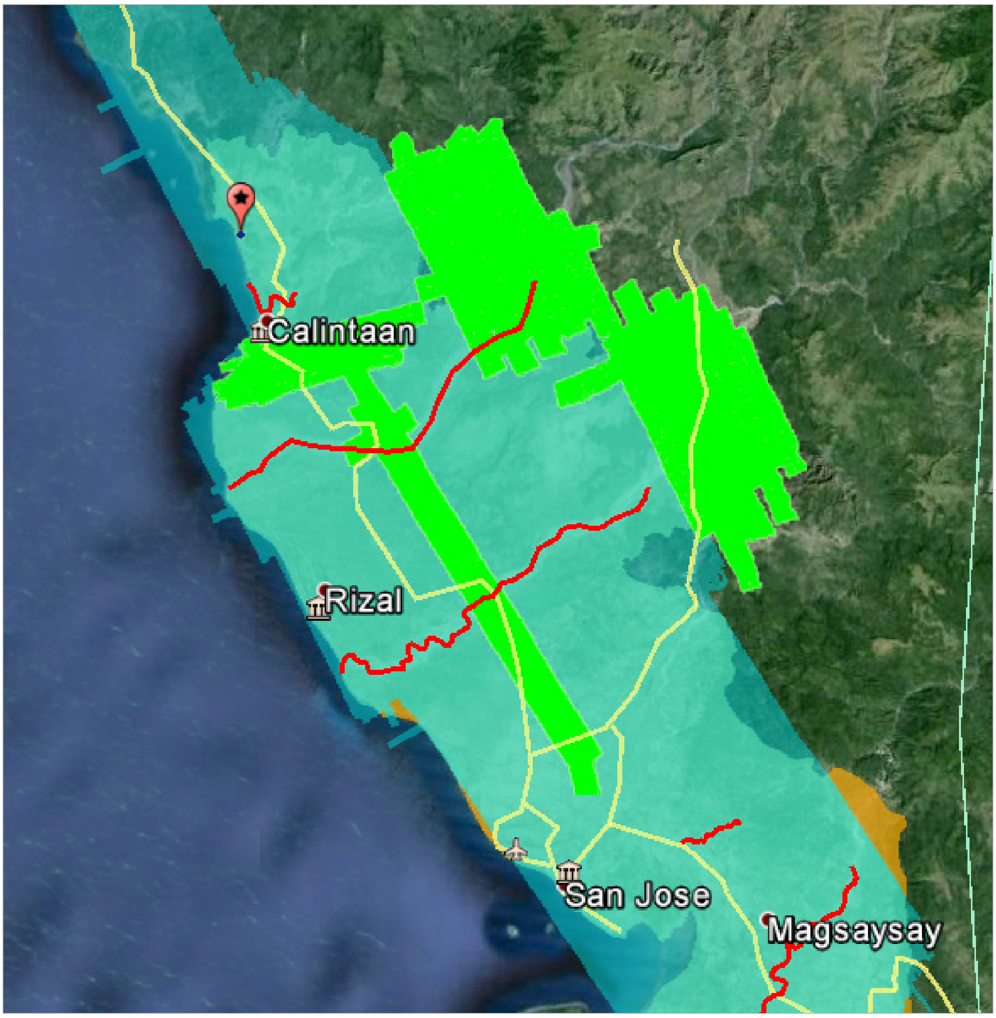


Figure A-7.8 Swath for Flight No. 3074P

Flight No.: **3078P**
Area: BLK29N, Q, R, S
Mission Name: 1BLK29NQRS345A
Parameters:
Altitude: 850
Scan Frequency: 32
Scan Angle: 50
Overlap: 30%

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for

Flight Area	
Mission Name	
Inclusive Flights	
Range data size	
POS	
Image	
Transfer date	
Solution Status	
Number of Satellites (>6)	
PDOP (<3)	
Baseline Length (<30km)	
Processing Mode (<=1)	
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	
RMSE for East Position (<4.0 cm)	
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	
IMU attitude correction stdev (<0.001deg)	
GPS position stdev (<0.01m)	
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	
Maximum Height	
Minimum Height	
Classification (# of points)	
Ground	
Low vegetation	
Medium vegetation	
High vegetation	
Building	
Orthophoto	
Processed by	

ANNEX 9. Lumintao Model Basin Parameters

Table A-9.1. Lumintao Model Basin Parameters

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W1000	0.5173	78.8748	0	0.055552	0.45331
W1010	0.5988	75.4345	0	0.070026	0.57141
W1020	0.5836	76.0521	0	0.033333	0.18301
W1040	0.5559	77.2041	0	0.033333	0.21098
W1050	0.7717	69.0449	0	0.033333	0.069498
W520	0.9493	63.5214	0	0.033333	0.17094
W530	1.0003	62.0922	0	0.033333	0.16892
W540	0.9205	64.3544	0	0.033333	0.17092
W550	0.9463	63.6056	0	0.033333	0.16055
W560	0.9641	63.1004	0	0.033333	0.15193
W570	0.9187	64.4066	0	0.033333	0.075627
W580	0.915	64.38	0	0.033333	0.069373
W590	0.9248	64.2282	0	0.033333	0.10549
W600	0.915	64.38	0	0.033333	0.080527
W610	0.9119	64.6082	0	0.033333	0.13536
W620	0.915	64.38	0	0.033333	0.07641
W630	0.9248	64.2282	0	0.033333	0.18201
W640	0.915	64.38	0	0.033333	0.11259
W650	0.9421	63.727	0	0.033333	0.14148
W660	0.915	64.38	0	0.033333	0.10905
W670	0.915	64.38	0	0.033333	0.095628
W680	0.9224	64.2982	0	0.033333	0.11792
W690	0.915	64.38	0	0.033333	0.12769
W700	0.9216	64.3224	0	0.033333	0.13118
W710	0.915	64.38	0	0.033333	0.19022
W720	0.9578	63.2779	0	0.033333	0.15952
W730	0.915	64.38	0	0.033333	0.20092
W740	0.915	64.38	0	0.033333	0.17682
W750	0.915	64.38	0	0.033333	0.060608
W760	0.915	64.38	0	0.033333	0.12833
W770	1.1294	58.7531	0	0.03773	0.30788
W780	0.915	64.38	0	0.033333	0.12041
W790	0.915	64.38	0	0.033333	0.06949

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W800	0.9308	64.0539	0	0.033333	0.1695
W810	0.8859	65.3871	0	0.033333	0.11685
W820	0.8835	65.462	0	0.033333	0.057901
W830	0.915	64.38	0	0.033333	0.15021
W840	0.974	62.8205	0	0.048382	0.39479
W850	0.6945	71.7572	0	0.033333	0.084905
W860	0.5728	76.4981	0	0.033333	0.22731
W870	0.6431	73.6865	0	0.033333	0.22987
W880	0.366	86.1662	0	0.033333	0.033564
W890	0.7713	69.0602	0	0.040478	0.3303
W900	0.4941	79.91	0	0.033333	0.13256
W910	0.3274	88.248	0	0.033333	0.13645
W920	0.3623	86.3616	0	0.033333	0.092468
W930	0.5264	78.4719	0	0.033333	0.18365
W940	0.3642	86.2629	0	0.033333	0.19001
W950	0.5794	76.2237	0	0.052771	0.43061
W960	0.413	83.7594	0	0.037059	0.3024
W970	0.237	93.5447	0	0.033333	0.123801
W980	0.4654	81.233	0	0.033333	0.19321

ANNEX 10. Lumintao Model Reach Parameters

Table A-10.1 Lumintao Model Reach Parameters

Reach Number	MUSKINGUM CUNGE CHANNEL ROUTING			
	Length (M)	Slope(M/M)	Shape	Side Slope (xH:1V)
R100	1606.9	0.063804	Trapezoid	1
R1060	527.28	0.002214	Trapezoid	1
R110	1371.4	0.063804	Trapezoid	1
R140	1608.2	0.063804	Trapezoid	1
R150	2796.8	0.076689	Trapezoid	1
R190	2580.1	0.023772	Trapezoid	1
R230	5935.4	0.051667	Trapezoid	1
R240	1237.8	0.055378	Trapezoid	1
R260	5593.3	0.023828	Trapezoid	1
R270	885.98	0.008209	Trapezoid	1
R280	2628.7	0.040752	Trapezoid	1
R290	3901.7	0.008763	Trapezoid	1
R30	2776.2	0.081544	Trapezoid	1
R310	527.99	0.040206	Trapezoid	1
R340	9084.7	0.005948	Trapezoid	1
R350	5097	0.004768	Trapezoid	1
R370	519.71	0.004803	Trapezoid	1
R390	3354	0.005323	Trapezoid	1
R40	1537.5	0.078067	Trapezoid	1
R420	3975	0.004278	Trapezoid	1
R430	3404.3	0.003216	Trapezoid	1
R450	3245.3	0.003513	Trapezoid	1
R480	2078.2	0.003466	Trapezoid	1
R490	1695.8	0.005598	Trapezoid	1
R510	6099.3	0.002214	Trapezoid	1
R70	1729.4	0.027031	Trapezoid	1

ANNEX 11. Lumintao Flood Validation Data

Table A-11.1 Lumintao Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
1	12.48681	120.9455	0.66	0.1	-0.56	Habagat	August, 2016	25-Year
2	12.48748	120.9468	0.03	0	-0.03			25-Year
3	12.48825	120.9444	0.83	0.49	-0.34	Yolanda	Nov. 2013	25-Year
4	12.49141	120.9439	0.31	0	-0.31			25-Year
5	12.50307	120.9368	1.08	0.28	-0.8	Yolanda	Nov. 2013	25-Year
6	12.50337	120.9365	1.28	0.43	-0.85	Yolanda	Nov. 2013	25-Year
7	12.50384	120.9377	0.67	0	-0.67			25-Year
8	12.50409	120.9372	1.12	0.45	-0.67	Ondoy	Sept. 2009	25-Year
9	12.50438	120.9395	1.71	0.6	-1.11	Yolanda	Nov. 2013	25-Year
10	12.50441	120.9379	0.96	0	-0.96	Ondoy		25-Year
11	12.50459	120.9393	1.28	0.64	-0.64	Yolanda	Nov. 2013	25-Year
12	12.50485	120.9385	0.88	0.6	-0.28	Ondoy	Sept. 2009	25-Year
13	12.50489	120.939	1.09	0.33	-0.76	Yolanda	Nov. 2013	25-Year
14	12.50507	120.9404	1.12	0	-1.12	Yolanda	Nov. 2013	25-Year
15	12.50544	120.9394	1.01	0	-1.01	Yolanda	Nov. 2013	25-Year
16	12.50608	120.982	1.12	0.1	-1.02	Yolanda	Nov. 2013	25-Year
17	12.5058	120.9406	1.76	0.62	-1.14	Yolanda	Nov. 2013	25-Year
18	12.50663	120.9832	1.26	0.77	-0.49	Yolanda	Nov. 2013	25-Year
19	12.50637	120.9406	1.57	0.3	-1.27	Nona	Dec. 2015	25-Year
20	12.50658	120.9423	1.54	0.47	-1.07	Yolanda	Nov. 2013	25-Year
21	12.50687	120.9412	0.63	0	-0.63	Yolanda	Nov. 2013	25-Year
22	12.507	120.9412	0.89	0.4	-0.49			25-Year
23	12.50722	120.9423	1.46	0.44	-1.02	Habagat	2013	25-Year
24	12.50766	120.9431	1.64	0.07	-1.57	Yolanda		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
25	12.50772	120.9441	0.85	0.45	-0.4	Yolanda	Nov. 2013	25-Year
26	12.50844	120.9446	1.23	0.2	-1.03	Ondoy	Sept. 2009	25-Year
27	12.50857	120.9457	1.06	0	-1.06	Yolanda		25-Year
28	12.50899	120.9465	1.09	0.2	-0.89	Ondoy	Sept. 2009	25-Year
29	12.50893	120.9321	0.84	0.82	-0.02	Yolanda	Nov. 2013	25-Year
30	12.50898	120.932	0.93	0.6	-0.33	Yolanda	Nov. 2013	25-Year
31	12.51128	120.9784	0.8	0	-0.8			25-Year
32	12.51184	120.9533	0.43	0.45	0.02	Yolanda	Nov. 2013	25-Year
33	12.51349	120.9549	0.64	0.72	0.08	Yolanda	Nov. 2013	25-Year
34	12.51451	120.9565	1.09	0.25	-0.84	Yolanda	Nov. 2013	25-Year
35	12.51547	120.958	1.01	0.65	-0.36	Yolanda	Nov. 2013	25-Year
36	12.51573	120.9746	1.23	0	-1.23	Yolanda	Nov. 2013	25-Year
37	12.51569	120.9581	0.84	0	-0.84	Yolanda	Nov. 2013	25-Year
38	12.51631	120.9705	1.27	0.1	-1.17	Yolanda	Nov. 2013	25-Year
39	12.51667	121.0167	1.61	0.32	-1.29	Butchoy	Jul-16	25-Year
40	12.51667	121.0167	1.61	0.59	-1.02	Butchoy	Jul-16	25-Year
41	12.5189	121.0211	0.06	0	-0.06	Glenda	Jul-14	25-Year
42	12.5189	121.0211	0.06	0	-0.06	Glenda	Jul-14	25-Year
43	12.5191	121.0234	0.19	0.78	0.59	Glenda	Jul-14	25-Year
44	12.5191	121.0234	0.19	0.78	0.59	Glenda	Jul-14	25-Year
45	12.5192	121.0255	0.63	0.55	-0.08	Glenda	Jul-14	25-Year
46	12.5192	121.0255	0.63	0.55	-0.08	Glenda	Jul-14	25-Year
47	12.5193	121.0226	0.73	0.34	-0.39		2015	25-Year
48	12.5193	121.0226	0.73	0.34	-0.39		Jul-14	25-Year
49	12.5193	121.0218	0.48	0.56	0.08	Glenda	Jul-14	25-Year
50	12.5193	121.0218	0.48	0.56	0.08	Glenda	Jul-14	25-Year
51	12.5193	121.0216	0.57	0.37	-0.2	Glenda	Jul-14	25-Year
52	12.5193	121.0216	0.57	0.37	-0.2	Glenda	Jul-14	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
53	12.5195	121.0258	0.76	0.93	0.17	Yolanda	Nov. 2014	25-Year
54	12.5195	121.0258	0.76	0.93	0.17	Yolanda	Nov. 2014	25-Year
55	12.5195	121.022	0.75	0.35	-0.4	Glenda	Jul-14	25-Year
56	12.5195	121.022	0.75	0.35	-0.4	Glenda	Jul-14	25-Year
57	12.5197	121.0211	0.31	0	-0.31	Glenda	Jul-14	25-Year
58	12.5197	121.0211	0.31	0	-0.31	Glenda	Jul-14	25-Year
59	12.5198	121.026	0.72	0.6	-0.12	Habagat	2015	25-Year
60	12.5198	121.026	0.72	0.26	-0.46	Yolanda	2014	25-Year
61	12.5198	121.026	0.72	0.6	-0.12	Habagat	2015	25-Year
62	12.5198	121.0215	0.35	0.2	-0.15	Glenda	Jul-14	25-Year
63	12.5198	121.0215	0.35	0.2	-0.15	Glenda	Jul-14	25-Year
64	12.51987	121.0211	0.24	0.34	0.1	Yolanda	Nov. 2013	25-Year
65	12.5199	121.0229	0.03	0	-0.03	Glenda	Jul-14	25-Year
66	12.5199	121.0229	0.03	0	-0.03	Glenda	Jul-14	25-Year
67	12.5199	121.022	0.23	0	-0.23	Glenda	Jul-14	25-Year
68	12.5199	121.022	0.23	0	-0.23	Glenda	Jul-14	25-Year
69	12.5199	121.0214	0.03	0.56	0.53	Glenda	Jul-14	25-Year
70	12.5199	121.0214	0.03	0.56	0.53	Glenda	Jul-14	25-Year
71	12.52	121.0235	0.03	0	-0.03	Glenda	Jul-14	25-Year
72	12.52	121.0235	0.03	0	-0.03	Glenda	Jul-14	25-Year
73	12.5201	121.0215	0.38	0	-0.38	Glenda	Jul-14	25-Year
74	12.5201	121.0215	0.38	0	-0.38	Glenda	Jul-14	25-Year
75	12.52028	121.0227	0.24	0.3	0.06	Glenda	Jul-14	25-Year
76	12.5203	121.0245	0.11	0	-0.11	Glenda	Jul-14	25-Year
77	12.5203	121.0245	0.11	0	-0.11	Glenda	Jul-14	25-Year
78	12.5203	121.0221	0.3	0.34	0.04	Glenda	Jul-14	25-Year
79	12.5203	121.0221	0.3	0.34	0.04	Glenda	Jul-14	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
80	12.52038	121.0208	0.26	0.43	0.17	Yolanda	Nov. 2013	25-Year
81	12.52038	121.0208	0.26	0.12	-0.14	Yoyong	Dec. 2004	25-Year
82	12.5204	121.0228	0.11	0	-0.11	Glenda	Jul-14	25-Year
83	12.5204	121.0228	0.11	0	-0.11	Glenda	Jul-14	25-Year
84	12.5204	121.0224	0.33	0	-0.33	Glenda	Jul-14	25-Year
85	12.5204	121.0224	0.33	0	-0.33	Glenda	Jul-14	25-Year
86	12.5204	121.022	0.36	0.15	-0.21	Glenda	Jul-14	25-Year
87	12.5204	121.022	0.36	0.15	-0.21	Glenda	Jul-14	25-Year
88	12.5204	121.0208	0.23	0.53	0.3	Yolanda	Nov. 2013	25-Year
89	12.52043	121.0236	0.03	0	-0.03	Rainfall		25-Year
90	12.52051	121.0225	0.35	0	-0.35	Yolanda	Nov. 2013	25-Year
91	12.52051	121.0225	0.35	0	-0.35	Glenda	Jul-14	25-Year
92	12.52055	121.0213	0.3	0.29	-0.01	Glenda	Jul-14	25-Year
93	12.5206	121.0253	0.18	0	-0.18	Glenda	Jul-14	25-Year
94	12.5206	121.0253	0.18	0	-0.18	Glenda	Jul-14	25-Year
95	12.5206	121.0233	0.3	0.34	0.04	Yolanda	Nov. 2013	25-Year
96	12.5206	121.0233	0.3	0.34	0.04	Glenda	Jul-14	25-Year
97	12.52062	121.0222	0.62	0.46	-0.16	Yolanda	Nov. 2013	25-Year
98	12.52065	121.0211	0.03	0	-0.03	Rainfall		25-Year
99	12.52085	121.0222	0.04	0.5	0.46	Yolanda	Nov. 2013	25-Year
100	12.5209	121.023	0.36	0.4	0.04	Yolanda	Nov. 2013	25-Year
101	12.52106	121.0238	0.37	0.33	-0.04	Rainfall		25-Year
102	12.52126	121.022	0.21	0.3	0.09	Yolanda	Nov. 2013	25-Year
103	12.52133	121.0217	0.26	0.31	0.05	Yolanda	Nov. 2013	25-Year
104	12.52133	121.0213	0.19	0.48	0.29	Yolanda	Nov. 2013	25-Year
105	12.52133	121.0211	0.2	0.58	0.38	Yolanda	Nov. 2013	25-Year
106	12.52133	121.0211	0.2	0.6	0.4	Glenda	Jul-14	25-Year
107	12.52155	121.0247	0.03	0.47	0.44	Rainfall		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
108	12.52203	120.9308	1.13	0.8	-0.33	Ondoy	Sept. 2009	25-Year
109	12.5222	120.9224	1.15	0	-1.15	Yolanda	Nov. 2013	25-Year
110	12.52338	120.9245	1.14	0.47	-0.67		Aug. 2011	25-Year
111	12.52352	120.9317	0.78	0.85	0.07	Yolanda	Nov. 2013	25-Year
112	12.52353	120.9325	0.81	0.4	-0.41	Ondoy	Sept. 2009	25-Year
113	12.52362	120.9253	0.98	1.55	0.57	Ondoy	Sept. 2009	25-Year
114	12.52458	120.9318	1.19	0.54	-0.65	Ondoy	Sept. 2009	25-Year
115	12.52474	120.9342	0.58	0.64	0.06	Ondoy	Sept. 2009	25-Year
116	12.54563	121.0076	1.52	0.38	-1.14	Ondoy		25-Year
117	12.5458	121.0066	1.79	0.44	-1.35		2012	25-Year
118	12.54594	121.0045	1.86	0.64	-1.22	Yolanda	Nov. 2013	25-Year
119	12.546	121.0037	1.54	0.14	-1.4	Yolanda	Nov. 2013	25-Year
120	12.54602	121.0054	1.64	0.25	-1.39		Oct. 2012	25-Year
121	12.54615	121.003	1.76	0.47	-1.29		Sept. 2014	25-Year
122	12.54648	121.0048	1.83	0.29	-1.54	Yolanda	Nov. 2013	25-Year
123	12.5465	121.0043	1.74	0.52	-1.22	Habagat	August, 2016	25-Year
124	12.54718	121.0052	1.88	0.76	-1.12	Yolanda	Nov. 2013	25-Year
125	12.54759	121.0056	1.72	0.36	-1.36	Glenda	July, 2012	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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