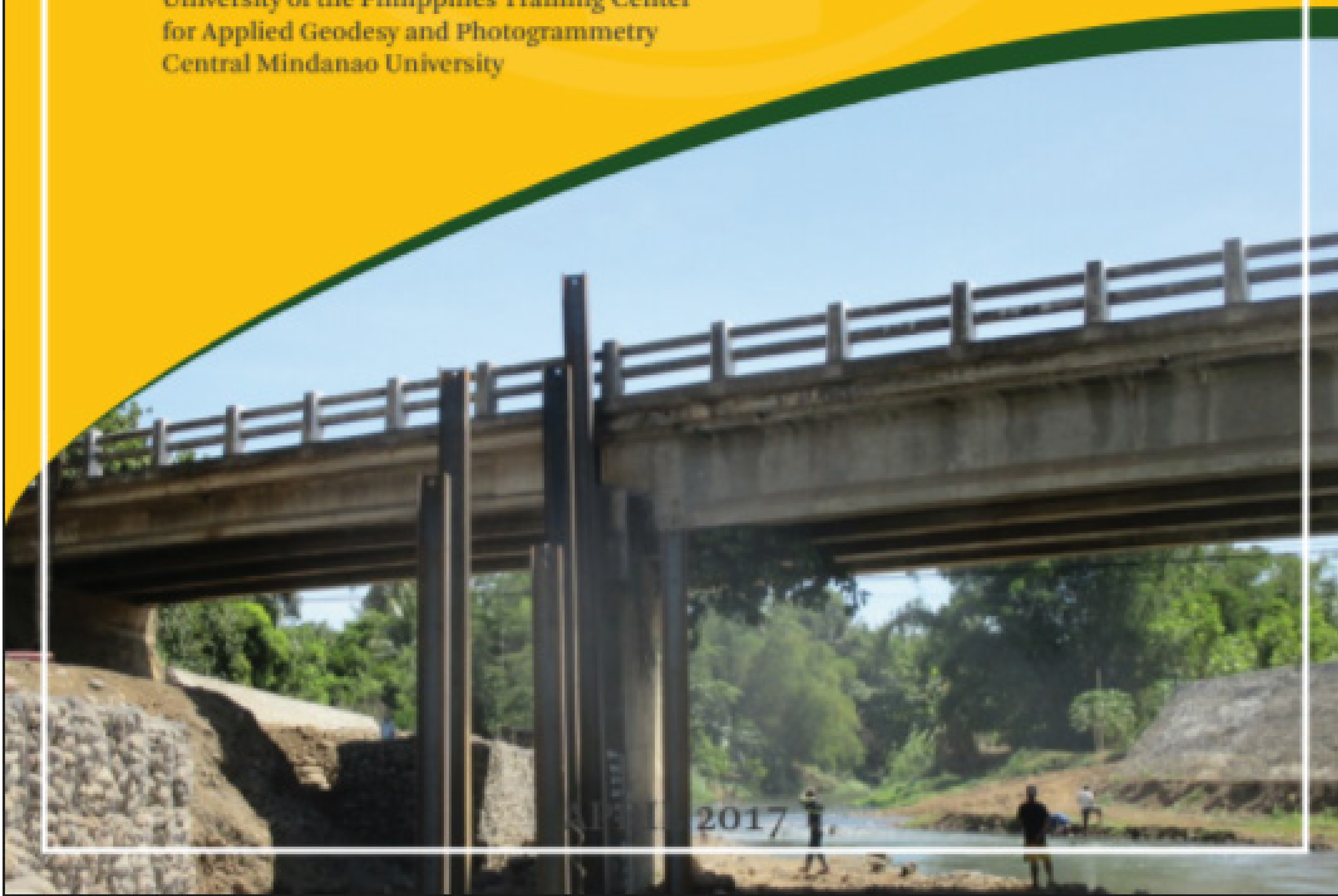
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Manupali River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Central Mindanao University



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CMU	Central Mindanao University
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
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System
ADZU	Ateneo de Zamboanga University

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MANUPALI RIVER

Enrico C. Paringit, Dr. Eng., and Dr. George R. Puno

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) 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).

The implementing partner university for the Phil-LiDAR 1 Program is the Central Mindanao University (CMU). CMU 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 13 river basins in the Central Mindanao Region. The university is located in Maramag in the province of Bukidnon.

1.2 Overview of the Manupali River Basin

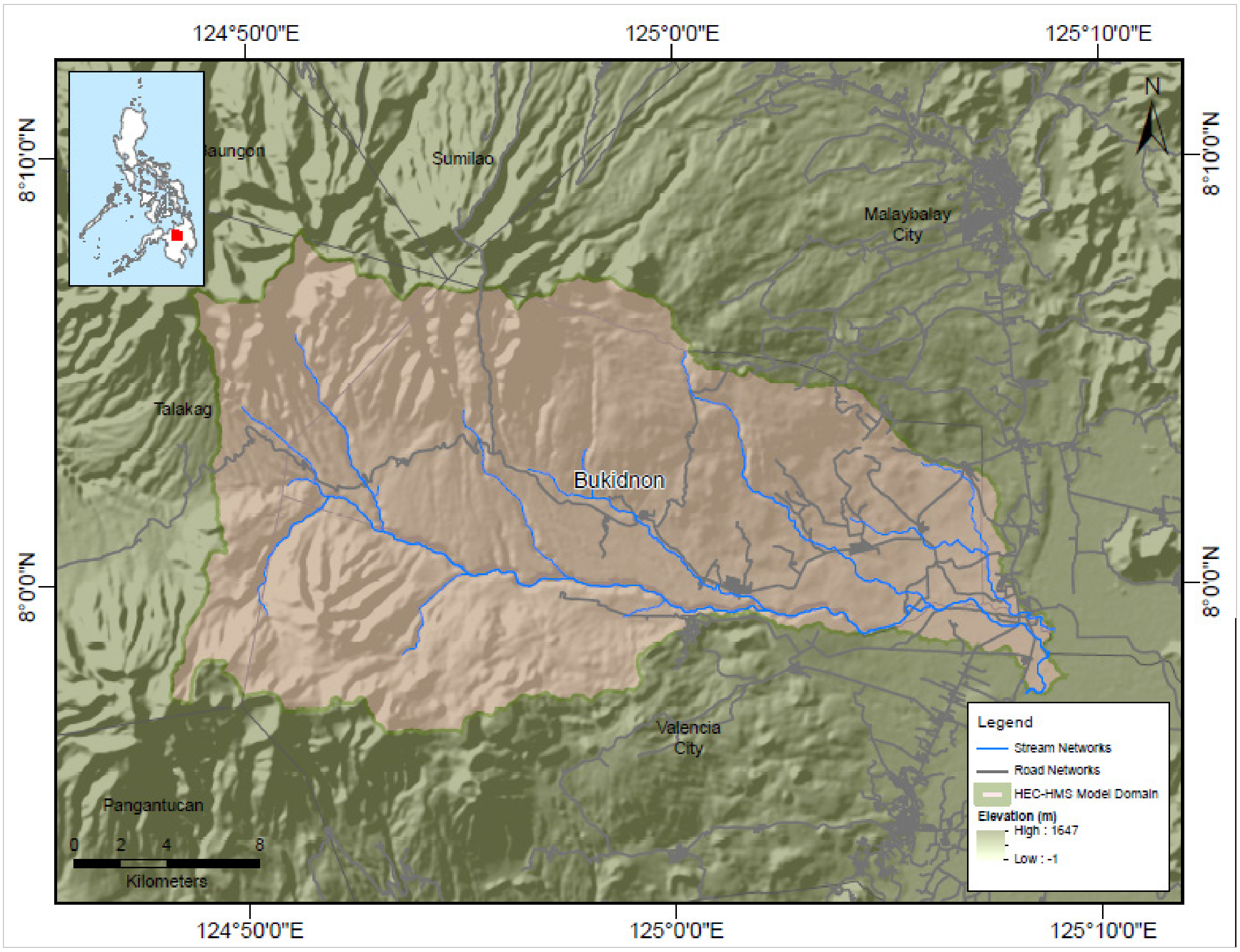


Figure 1. Map of the Manupali River Basin in brown

The 50,553-hectare Manupali river basin largely covers the Municipality of Lantapan, some parts of Talakag and few portions of Valencia City and Malaybalay City in the province of Bukidnon. It geographically lies between 7°58’38.93” to 8°13’50.16” north latitudes and 124°55’7.81” to 125°14’26.85” east longitudes. The Manupali River is a tributary of a relatively bigger Pulangi watershed. Its headwaters emanates from Kalatungan and Kitanglad mountain ranges, both declared as protected areas and belonged to the ancestral domain of the Talaandig tribe. It consists of four major tributaries namely Tugasan, Maagnao, Alanib and Kulasihan.

The Manupali River Basin also traverses the barangays of Mailag, Colonia, San Carlos, Lurogan and Mt. Nebo in the City of Valencia, barangays Lantapan, Kulasihan, Bantuanon and Poblacion in the Municipality of Lantapan and Sto. Niño and Bangcud in the City of Malaybalay, Bukidnon. The DENR River Basin Control Office (RBCO) states that the Sawaga River Basin has a drainage area of 1,047 km² with an estimated annual run-off of 1.216 cubic meter (MCM) (RBCO, 2015).

Downstream portions of the watershed are utilized for large-scale plantations of corn, banana, pineapple and sugarcane serving as a core agri-based center in the province. Moreover, the river irrigates vast rice fields in Valencia City. The river water however is evidently degrading in quantity and quality. Increasing population and land use conversions increased runoff and flood hazards in the communities along the river channels and floodplains. The floodplains of Manupali river namely Barangays Bangcud, Colonia, Aglayan of Malaybalay City, among others are greatly affected by flooding in the past years. Recent flood incidents include the August and December 2007 events, Typhoon Pablo on December 2012, on October and September of 2012, and October of 2013.

According to the 2015 national census of PSA, a total of 52,350 persons are residing in the barangays in the City of Lantapan, Malaybalay and Valencia that are within the immediate vicinity of the river. The economy of the province of Bukidnon largely rests on agriculture particularly farming, fishing, trade, and commerce. The province is a major producer of rice, corn, sugar, coffee and cassava (Province of Bukidnon Brief Information, 2014). On January 19, 2017, the tail-end of a cold front triggered floods in parts of Mindanao, including eight (8) barangays in the City of Valencia in the Province of Bukidnon. (Lagsa, 2017).

Manupali river is among the 13 rivers assigned to Central Mindanao University CMU under the Phil-LiDAR 1 Program generated with up-to-date, detailed, and high-resolution three-dimensional (3D) flood hazard maps using Light Detection and Ranging (LiDAR) technology. These maps were generated through flood modelinginvolving two simulations, the hydrologic and hydraulic simulations performed using standalone softwares of Hydrologic Engineering Centre's – Hydrologic Modeling System (HEC-HMS) and Hydrologic Engineering Centre's – Hydrologic River Analysis System (HEC-RAS).HMS models the upstream and simulates the complete hydrologic processes of dendritic watershed systems while RAS models the flood plain to perform one-dimensional (1D) unsteady flow river hydraulics calculations.

The model was generated through delineation of the basin using Synthetic Aperture Radar (SAR) 10m Digital Elevation Model (DEM) with default threshold area of 500 hectares. The model consists of twenty-six (26) sub-basins, thirteen (13) reaches and fourteen (14) junctions and was calibrated using an event on May23-34, 2016. Statistical efficiency tests revealed a satisfactory model performance.

Using the calibrated model, hypothetical discharge scenarios were simulated using Rainfall Intensity Duration Frequency (RIDF) data of Philippines Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) based on a 31-year historical data of Malaybalay rain gauge. Flood hydraulic simulation was performed using LiDAR Digital Terrain Model (DTM) consequently showing flood extent and depth information. Flood generated project the flood scenarios for the 5-, 25-, and 100-year return periods.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MANUPALI FLOODPLAIN

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 Manupali floodplain in Bukidnon. These missions were planned for 12 lines that 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 is found in Table 1. Figure 2 shows the flight plan for Manupali floodplain.

Table 1. 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)
RX_BLKE	900	30	50	200	30	130	5
BLK 64A	900	30	50	200	30	130	5
BLK 64B	900	30	50	200	30	130	5
BLK 64C	900	30	50	200	30	130	5
BLK 64D	900	30	50	200	30	130	5
BLK 64E	900	30	50	200	30	130	5

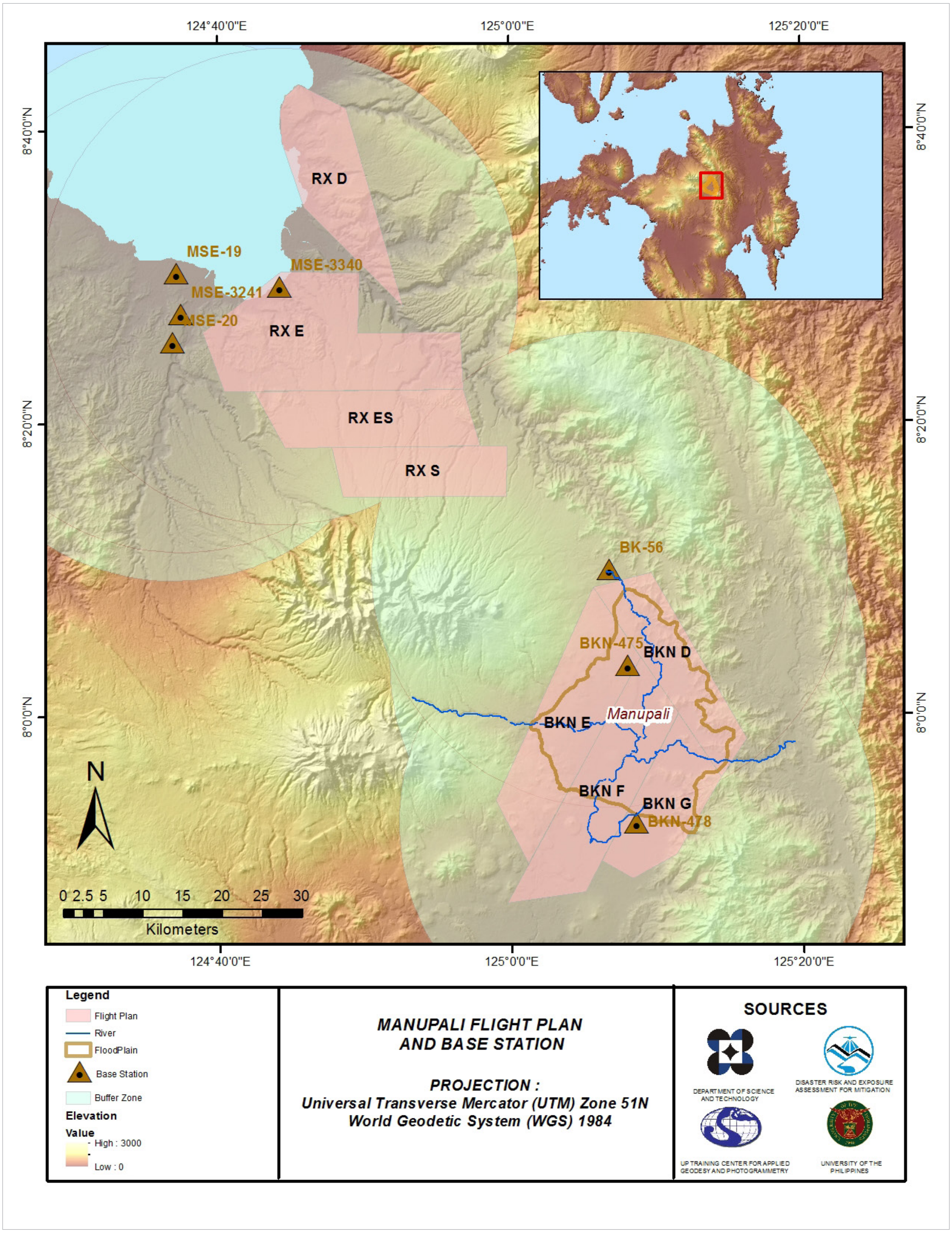


Figure 2. Flight plans and base stations for Manupali floodplain

2.2 Ground Base Stations

The project team was able to recover six (6) NAMRIA ground control points: MSE-19, MSE-20, BKN-475 and BKN-478 which are of second (2nd) order accuracy; and MSE-3241, MSE-3340 which are of third (3rd) order accuracy. The team was also able to recover one (1) NAMRIA benchmark: BK-56 which is of first (1st) order vertical accuracy. The benchmark was used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference points are found in ANNEX 2. These were used as base stations during flight operations for the entire duration of the survey (May 27 – July 10, 2014 and October 23 – November 14, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Manupali floodplain are shown in Figure 2.

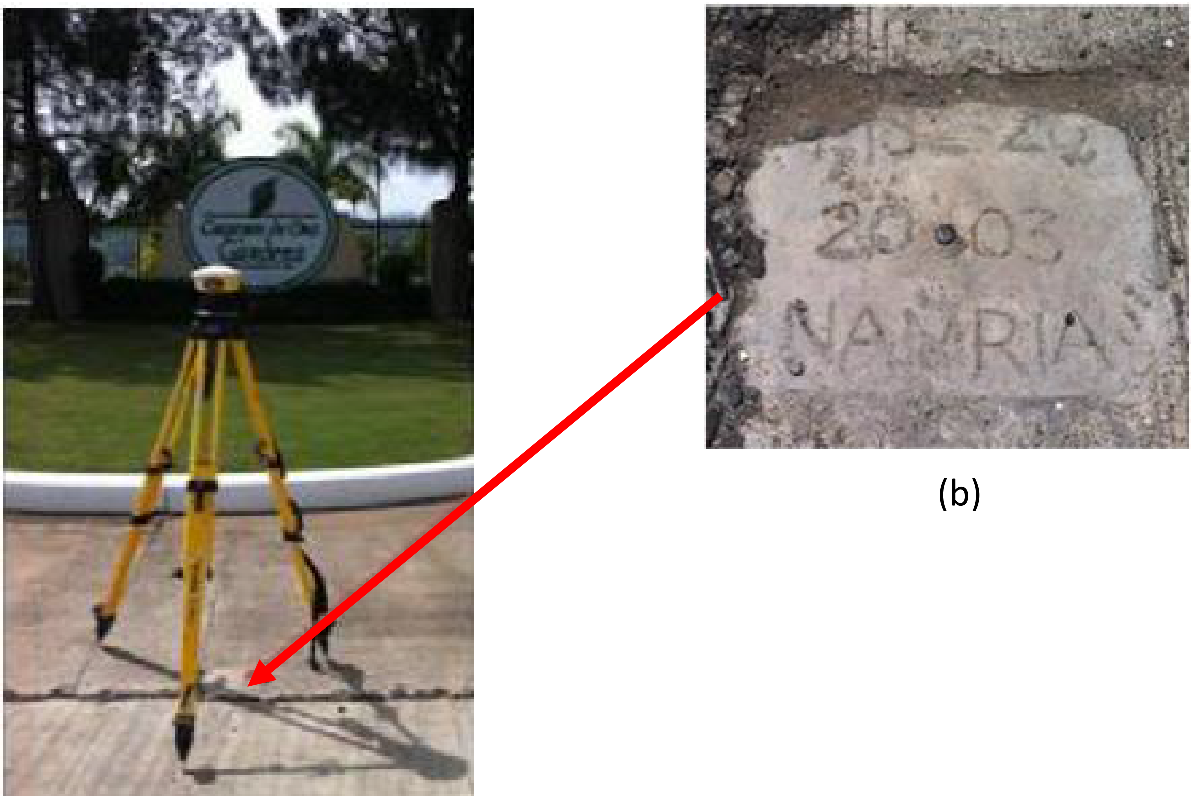
Figure 3 to Figure 9 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 8 show the details about the following NAMRIA control stations, while Table 9 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a) (b)

Figure 3. GPS set-up over MSE-19 at the center island located at the road intersections going to Cagayan de Oro, Butuan City and Iligan City (a) and NAMRIA reference point MSE-19 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MSE-19 used as base station for the LiDAR acquisition.

Station Name	**MSE-19**	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 30’ 19.11464” North 124° 37’ 6.46518” East 11.24200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	457,992.786 meters 940,451.853 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 30’ 15.52234” North 124° 37’ 11.86795” East 78.72200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	678,151.65 meters 940,474.22 meters



(a) (b)

Figure 4. GPS set-up over MSE-20 in front of Cagayan de Oro Gardens Memorial Park, located at Barangay Lumbia, Cagayan de Oro City (a) and NAMRIA reference point MSE-20 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MSE-20 used as base station for the LiDAR acquisition.

Station Name	MSE-20	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 25' 34.65372" North 124° 36' 50.02579" East 182.812 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	457481.339 meters 931713.993 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 25' 31.08192" North 124° 36' 55.43561" East 250.444 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	677685.12 meters 931773.67 meters

(a) (b)

Figure 5. GPS set-up over MSE-3241 on a center island near a gasoline station beside SM Cagayan de Oro (a) and NAMRIA reference point MSE-3241 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MSE-3241used as base station for the LiDAR acquisition.

Station Name	MSE-3241	
Order of Accuracy	3rd order	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 27' 31.07607" North 124° 37' 23.18891" East 109.46700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	458499.251 meters 935289.375 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 27' 27.49608" North 124° 37' 28.59587" East 177.055 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	678684.71 meters 935314.30 meters

(a)

(b)

Figure 6. GPS set-up over MSE-3340 inside Agusan Barangay Plaza (a) and NAMRIA reference point MSE-3340 (b) as recovered by the field team.

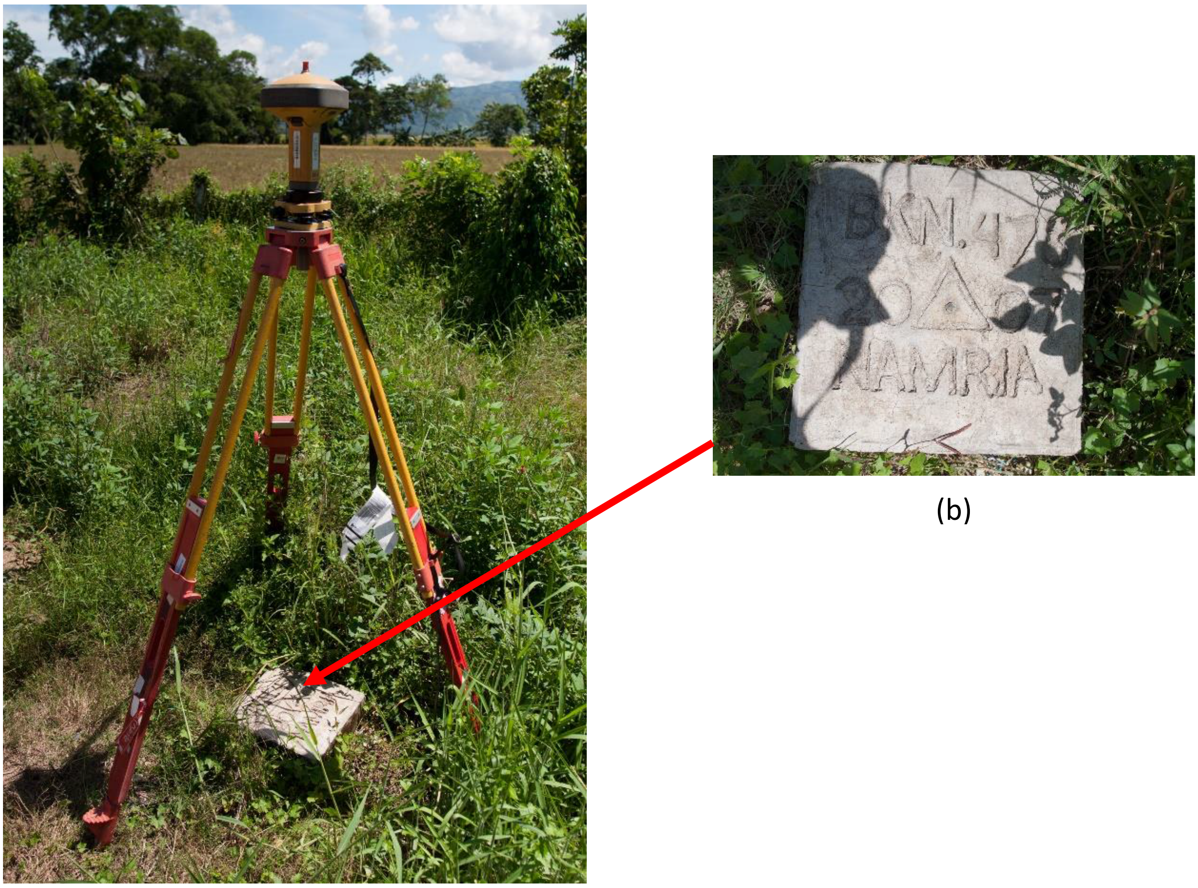
Table 5. Details of the recovered NAMRIA horizontal control point MSE-3340 used as base station for the LiDAR acquisition.

Station Name	MSE-3340	
Order of Accuracy	3rd order	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 29’ 23.43073” North 124° 44’ 11.52934” East 5.996 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	470991.591 meters 983730.493 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 29’ 19.85261” North 124° 44’ 16.93252” East 73.801 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	691159.9 meters 938819.85 meters

Figure 7. GPS set-up over NAMRIA reference point BKN-475 inside Agusan Barangay Plaza

Table 6. Details of the recovered NAMRIA horizontal control point BKN-475 used as base station for the LiDAR acquisition.

Station Name	BKN-475	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 3’ 25.94887” North 125° 7’ 58.6868” East 404.314 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	890880.244 meters 514656.29 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 3’ 22.52096” North 125° 8’ 4.12506” East 473.98 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	891179.54 meters 735073.78 meters



(a) (b)

Figure 8. GPS set-up over BKN-478 beside the basketball court of Purok 6, Brgy. Sinayawan, Valencia City (a) and NAMRIA reference point BKN-475 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point BKN-478 used as base station for the LiDAR acquisition.

Station Name	BKN-478	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 52' 39.32095" North 125° 8' 33.26511" East 302.837 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	871017.702 meters 515721.851 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 52' 35.94157" North 125° 8' 38.71964" East 372.885 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	871315.75 meters 736235.86 meters

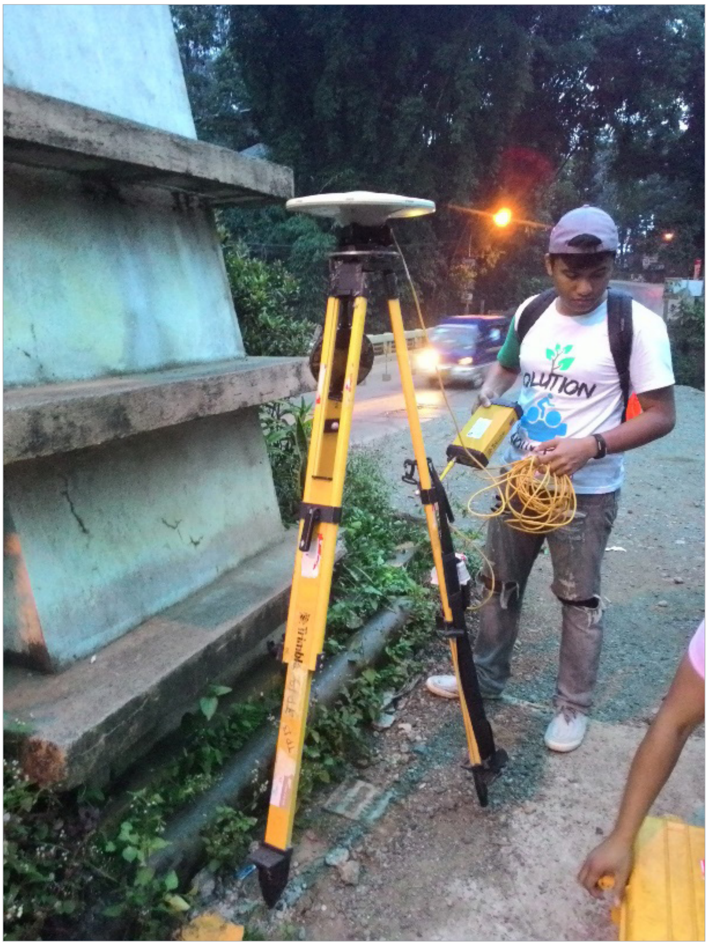


Figure 9. GPS set-up over NAMRIA benchmark BK-56 inside Agusan Barangay Plaza

Table 8. Details of the recovered NAMRIA benchmark BK-56 used as base station for the LiDAR acquisition with processed coordinates.

Station Name	**BK-56**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 9' 56.15912" North 125° 6' 49.1855" East 657.991 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 9' 52.70089" North 125° 8' 4.12506" East 473.98 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	732882.695 meters 903158.564 meters
Elevation (mean sea level)	10.9546 meters	

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 27,2014	1517P	1RXE147A	MSE-19 & MSE-3241
June 9, 2014	1569P	1BLKRXE160A	MSE-19 & MSE-3241
June 16, 2014	1597P	1BLKRXE167A	MSE-19 & MSE-3241
June 24,2014	1629P	1BLKRXES175A	MSE-20 & MSE-3340
July 10, 2014	1693P	1RXES191A	MSE-20 & MSE-3340
October 23, 2016	23486P	1BKND297A	BKN-478 & BK-56
October 24, 2016	23488P	1BKNDE298A	BKN-478 & BK-56
October 25, 2016	23492P	1BKNDE299A	BKN-475 & BK-56
November 6, 2016	23516P	1BKNF311A	BKN-475 & BK-56
November 6, 2016	23518P	1BKNF311B	BKN-475 & BK-56
November 7, 2016	23520P	1BKNF312A	BKN-475 & BK-56
November 8, 2016	23524P	1BKND313A	BKN-475 & BK-56
November 10, 2016	23534P	1BKNG315A	BKN-475 & BK-56
November 11, 2016	23536P	1BKNDE316A	BKN-475 & BK-56
November 12, 2016	23540P	1BKNE317A	BKN-475 & BK-56
November 13, 2016	23544P	1BKNE318A	BKN-475 & BK-56
November 13, 2016	23546P	1BKNE319A	BKN-475 & BK-56
November 14, 2016	23548P	1BLK64A320A	BKN-475 & BK-56

2.3 Flight Missions

Two (2) missions under DREAM program covered around three hundred fourteen (314) square kilometers (Table 10) within Manupali river basin. Eighteen (18) missions were conducted to complete the LiDAR data acquisition in Manupali floodplain, for a total of seventy four hours and seven minutes (74+07) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. 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 10. Flight missions under DREAM program which covers part of Manupali river basin.

Flight Number	Mission Name	Area Surveyed within the Floodplain (km^2)
388G	2TAGWA224A	158.77
396G	2TAGWD226A	155.32
TOTAL		**314.09**

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

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 27, 2014	1517P	522.19	164.99	0	164.99	NA	4	23
June 9, 2014	1569P	340.82	289.86	0	289.86	NA	4	18
June 16, 2014	1597P	522.19	155.21	0	155.21	NA	4	0
June 24, 2014	1629P	182.55	223.66	0	223.66	527	3	47
July 10, 2014	1693P	522.19	196.80	0	196.80	NA	3	11
October 23, 2016	23486P	182.55	86.52	0	86.52	NA	3	41
October 24, 2016	23488P	133.31	155.98	0	155.98	NA	4	29
October 25, 2016	23492P	242.43	207.05	84.49	122.56	NA	4	23
November 6, 2016	23516P	235.81	177.38	96.66	80.72	NA	5	16
November 6, 2016	23518P	235.81	94.78	50.45	44.33	NA	2	29
November 7, 2016	23520P	381.09	252.33	132.96	119.37	NA	4	11
November 8, 2016	23524P	164.60	124.87	101.04	23.83	NA	4	29
November 10, 2016	23534P	145.29	50.15	11.36	38.79	NA	4	05
November 11, 2016	23536P	164.60	105.80	35.01	70.79	NA	4	23
November 12, 2016	23540P	242.43	96.13	20.24	75.89	NA	4	11
November 13, 2016	23544P	242.43	189.41	110.73	78.68	NA	4	11
November 13, 2016	23546P	145.29	136.72	101.20	35.52	NA	4	11
November 14, 2016	23548P	235.81	197.42	99.44	97.98	NA	4	29
TOTAL		**4841.39**	**2905.06**	**843.58**	**2061.48**	**527**	**74**	**07**

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)
1517P	900	30	50	200	30	130	5
1569P	1000	30	50	200	30	130	5
1597P	800	30	50	200	30	130	5
1629P	1200	30	50	200	30	130	5
1693P	1100	30	50	200	30	130	5
23486P	800	30	50	200	30	130	5
23488P	800	30	50	200	30	130	5
23492P	1000	30	50	200	30	130	5
23516P	1000	30	50	200	30	130	5
23518P	1000	30	50	200	30	130	5
23520P	1200	30	50	200	30	130	5
23524P	1200	30	50	200	30	130	5
23534P	1200	30	50	200	30	130	5
23536P	1200	30	50	200	30	130	5
23540P	1200	30	50	200	30	130	5
23544P	1200	30	50	200	30	130	5
23546P	1200	30	50	200	30	130	5
23548P	1200	30	50	200	30	130	5

2.4 Survey Coverage

Manupali floodplain is located in the province of Bukidnon with majority of the floodplain situated within the City of Valencia and Malaybalay. Municipality of Manolo Fortich is 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 Manupali floodplain is presented in Figure 10.

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

Province	Municipality/City	Area of Municipality/City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Bukidnon	Manolo Fortich	350.15	249.97	71.39%
	Libona	282.23	182.47	64.63%
	Valencia City	726.07	393.05	54.13%
	Sumilao	259.26	119.07	45.935
	Maramag	323.88	91.75	28.32%
	Lantapan	290.82	80.20	27.58%
	Malaybalay City	1,115.98	281.10	25.19%
	Malitbog	359.59	38.81	10.79%
	Quezon	641.25	38.25	5.97%
	Impasug-Ong	854.63	29.11	3.41%
	Baungon	331.88	3.97	1.20%
Misamis Oriental	Villanueva	46.05	32.51	70.60%
	Jasaan	68.33	44.11	64.56%
	Tagoloan	55.72	19.10	34.27%
	Cagayan de Oro City	440.17	147.73	33.56%
	Claveria	768.95	28.33	3.68%
	Balingasag	125.59	1.37	1.09
TOTAL		**7,040.55**	**1,780.9**	**31.54%**

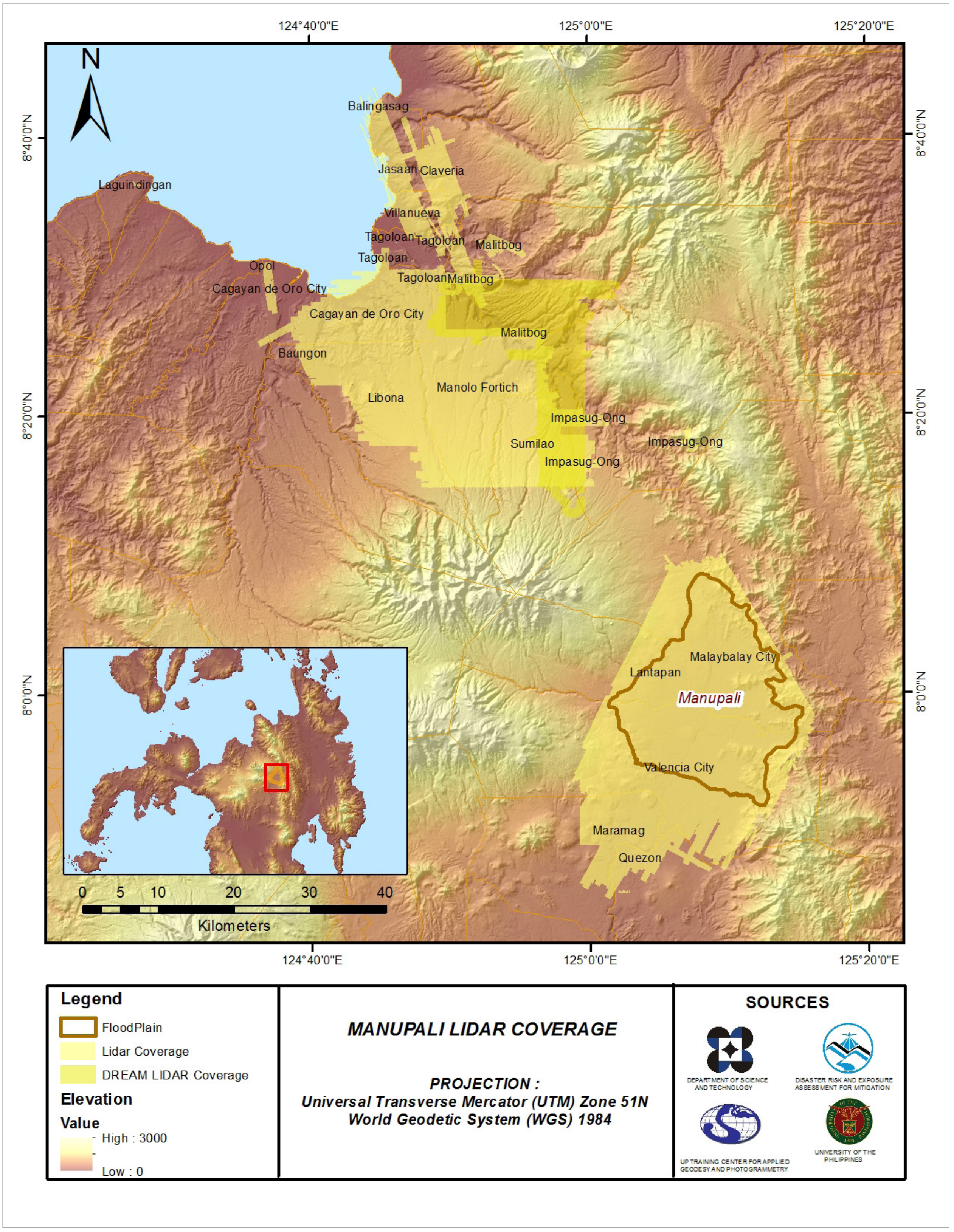


Figure 10. Actual LiDAR survey coverage for Manupali floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR MANUPALI FLOODPLAIN

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 LiDAR Data Processing for Manupali Floodplain

3.1.1 Overview of the LiDAR Date Pre-Processing

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

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

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

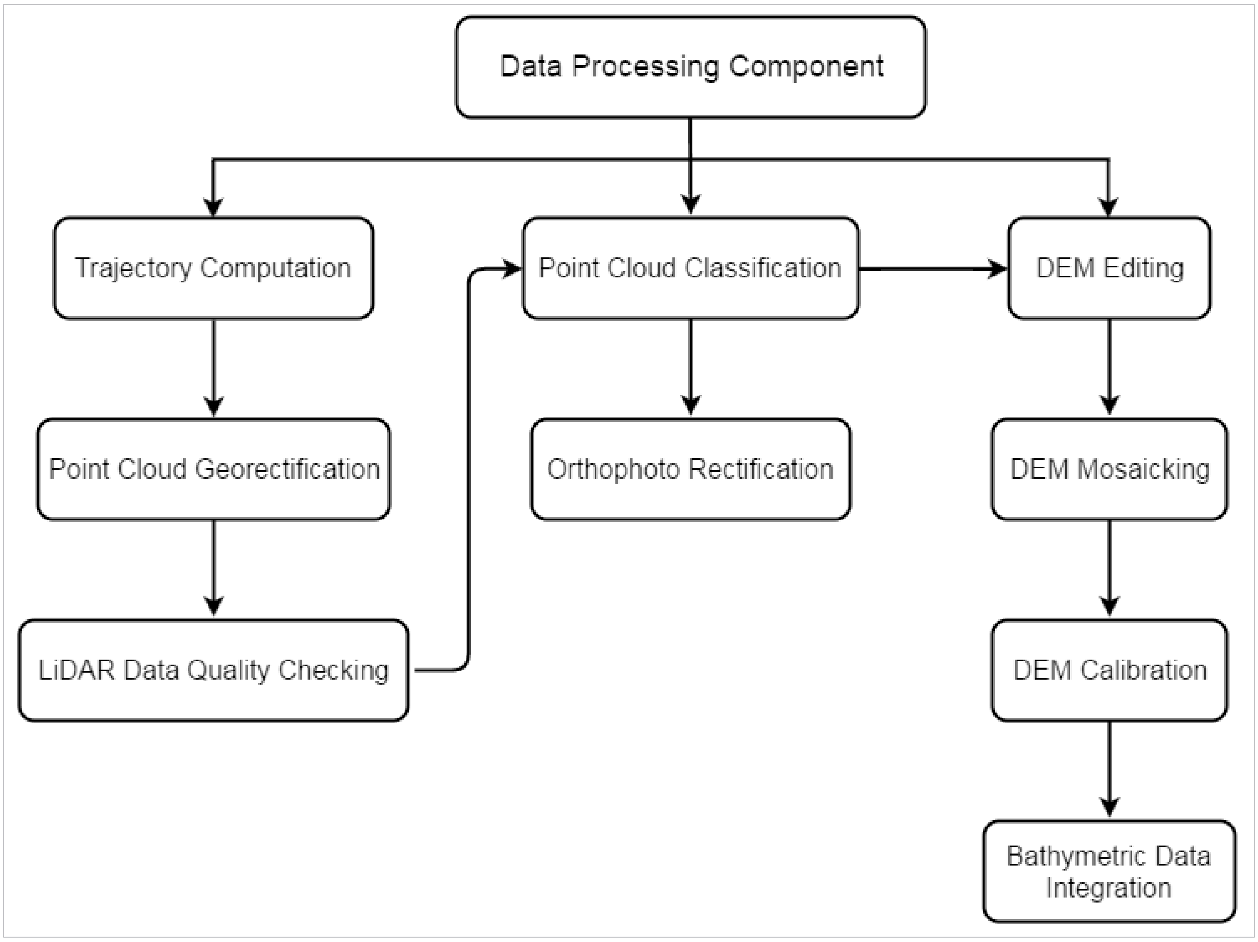


Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Manupali floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on August 2013 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the last survey on November 2016 were flown using the Pegasus system over Bukidnon, Northern Mindanao. The Data Acquisition Component (DAC) transferred a total of 418.63 Gigabytes of Range data, 4.96 Gigabytes of POS data, 2827.02 Megabytes of GPS base station data, and 79.66 Gigabytes of raw image data to the data server on August 12, 2013 for the first survey and November 14, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Manupali was fully transferred on November 24, 2016, as indicated on the Data Transfer Sheets for Manupali floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metric* parameters of the computed trajectory for flight 23534P, one of the Manupali flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on November 10, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

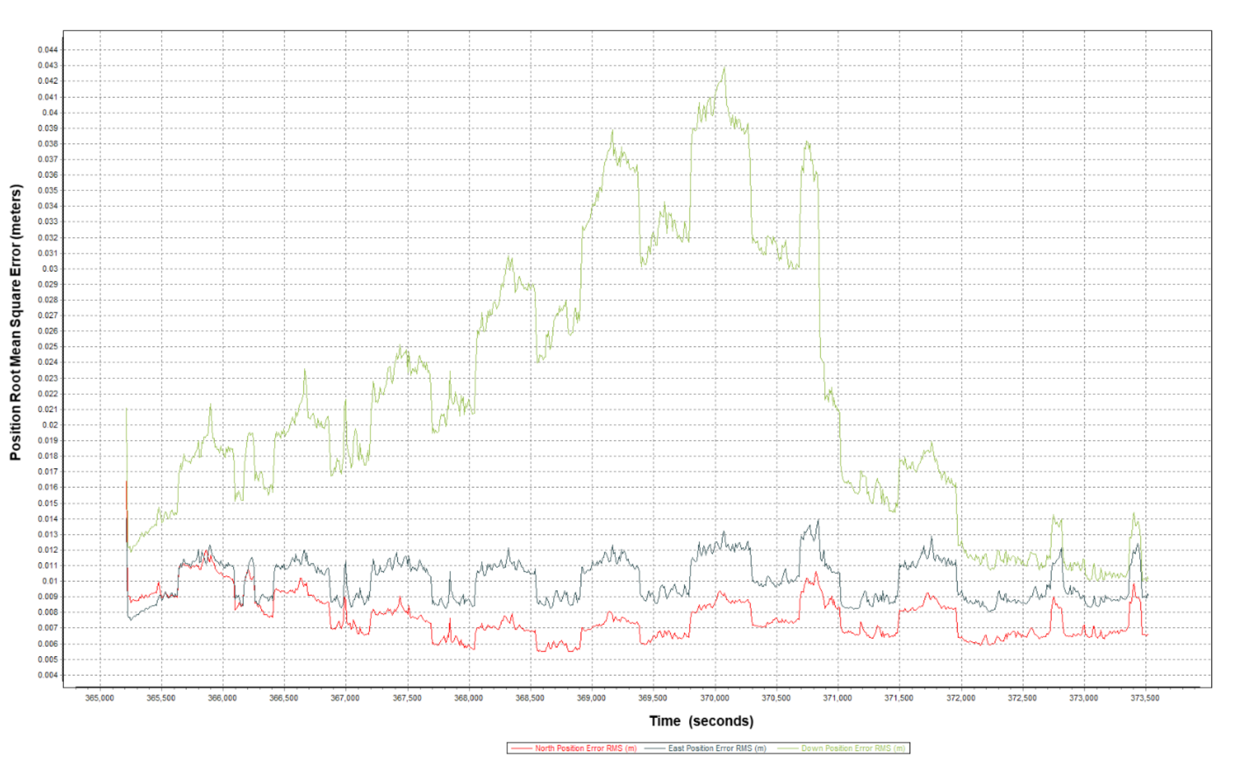


Figure 12. Smoothed Performance Metric Parameters of a Manupali Flight 23534P.

The time of flight was from 365000 seconds to 373500 seconds, which corresponds to morning of November 10, 2016. 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 12 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.40 centimeters, and the Down position RMSE peaks at 4.30 centimeters, which are within the prescribed accuracies described in the methodology.

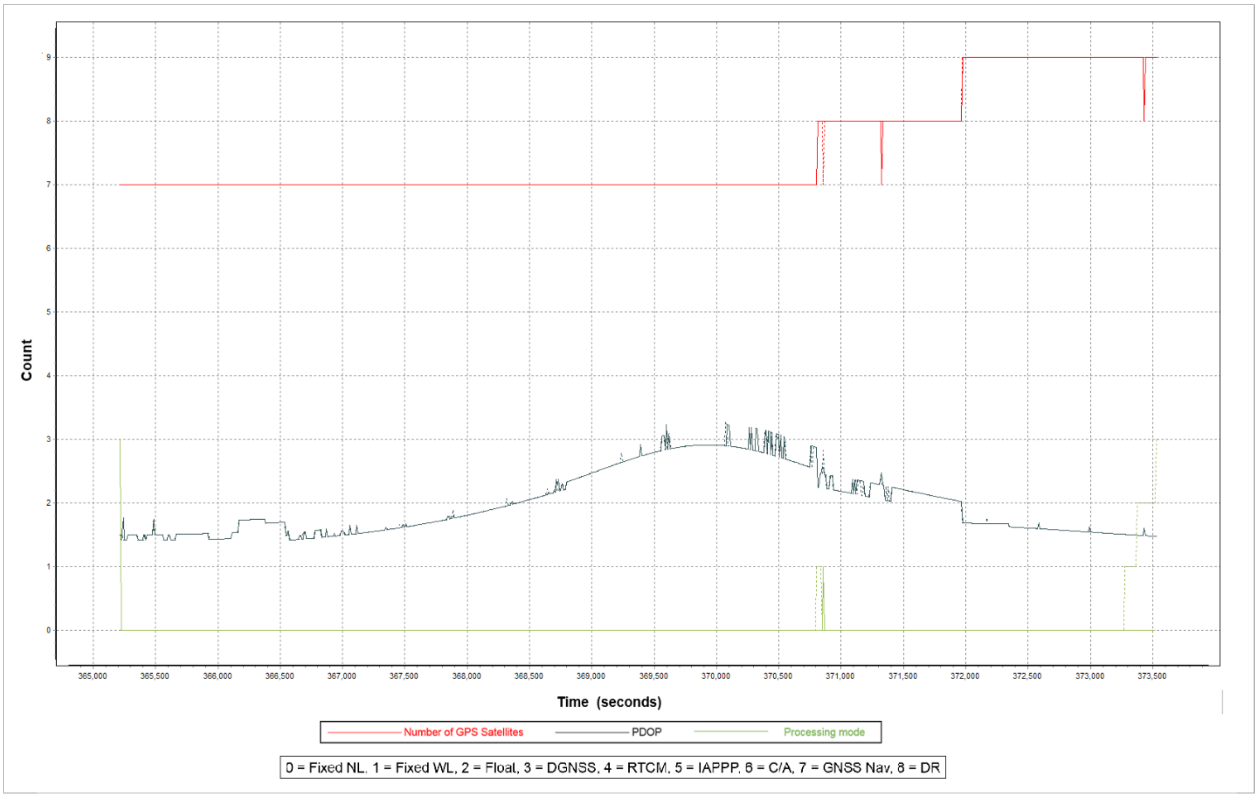


Figure 13. Solution Status Parameters of Manupali Flight 23534P.

The *Solution Status* parameters of flight 23534P, one of the Manupali flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 9. 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 Manupali flights is shown in Figure 14.

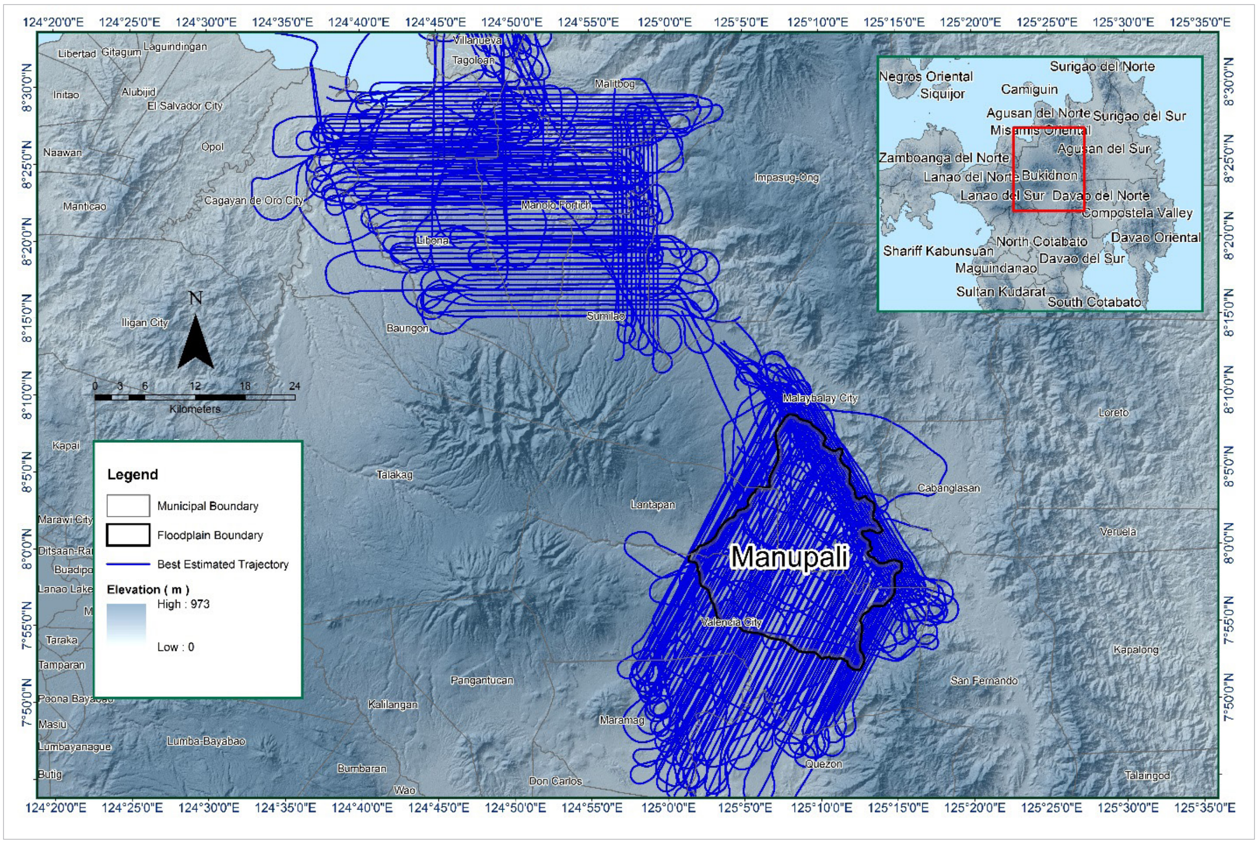


Figure 14. The best estimated trajectory of the LiDAR missions conducted over the Manupali floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 276 flight lines, with each Gemini flight line containing one channel, and each Pegasus flight line containing two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Manupali floodplain are given in Table 14.

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

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000090
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000888
GPS Position Z-correction stdev	(<0.01meters)	0.0066

The optimum accuracy values for all Manupali flights were calculated 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 Manupali Floodplain is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

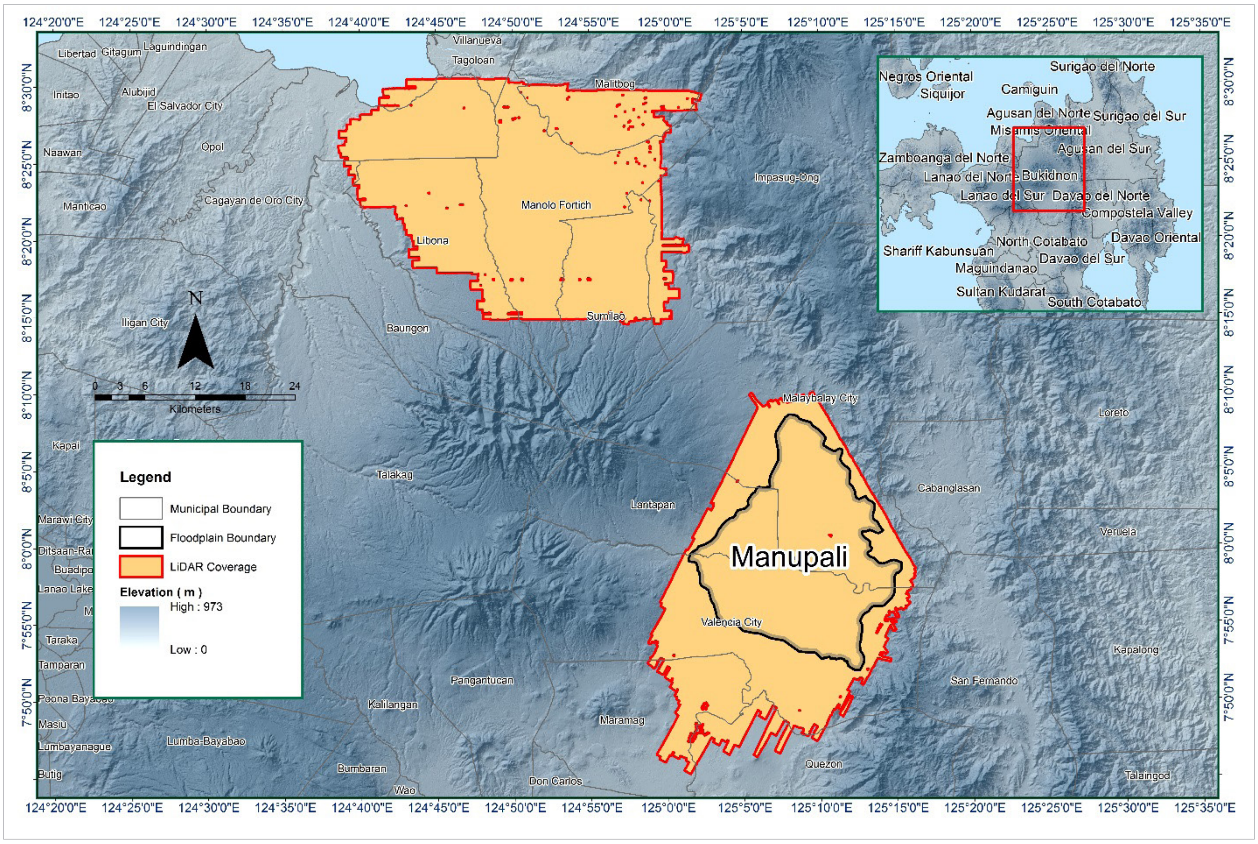


Figure 15. Boundary of the processed LiDAR data over Manupali Floodplain

The total area covered by the Manupali missions is 2,772.84 km² that is comprised of nineteen (19) flight acquisitions grouped and merged into nineteen (19) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Manupali floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Tagoloan_396G	396G	142.86
Tagoloan_388G	388G	150.69
NorthernMindanao_RX_BlkE_additional	1569P 1597P 1629P 1693P	429.95
NorthernMindanao_RX_BlkE	1517P	91.47
NorthernMindanao_RX_BlkE_additional2	1569P 1597P 1629P 1693P	226.25
Bukidnon_Blk64A	23492P	227.37
Bukidnon_Blk64A_additional	23534P	21.72
Bukidnon_Blk64A_supplement	23536P	80.87
Bukidnon_Blk64B_supplement2	23540P 23544P	263.4
Bukidnon_Blk64B	23516P 23518P 23520P	244.68
Bukidnon_Blk64B_supplement	23548P	172.64
Bukidnon_Blk64C	23520P 23516P	159.70
Bukidnon_Blk64C_additional	23534P	55.92
Bukidnon_Blk64C_supplement	23546P	119.87
Bukidnon_Blk64D	23524P	80.72
Bukidnon_Blk64D_additional	23524P	75.71
Bukidnon_Blk64D_supplement	23536P	23.74
Bukidnon_Blk64E	23488P	156.01
Bukidnon_Blk64E_supplement	23486P	49.27
TOTAL		**2,772.84 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 16. Since the Gemini 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.

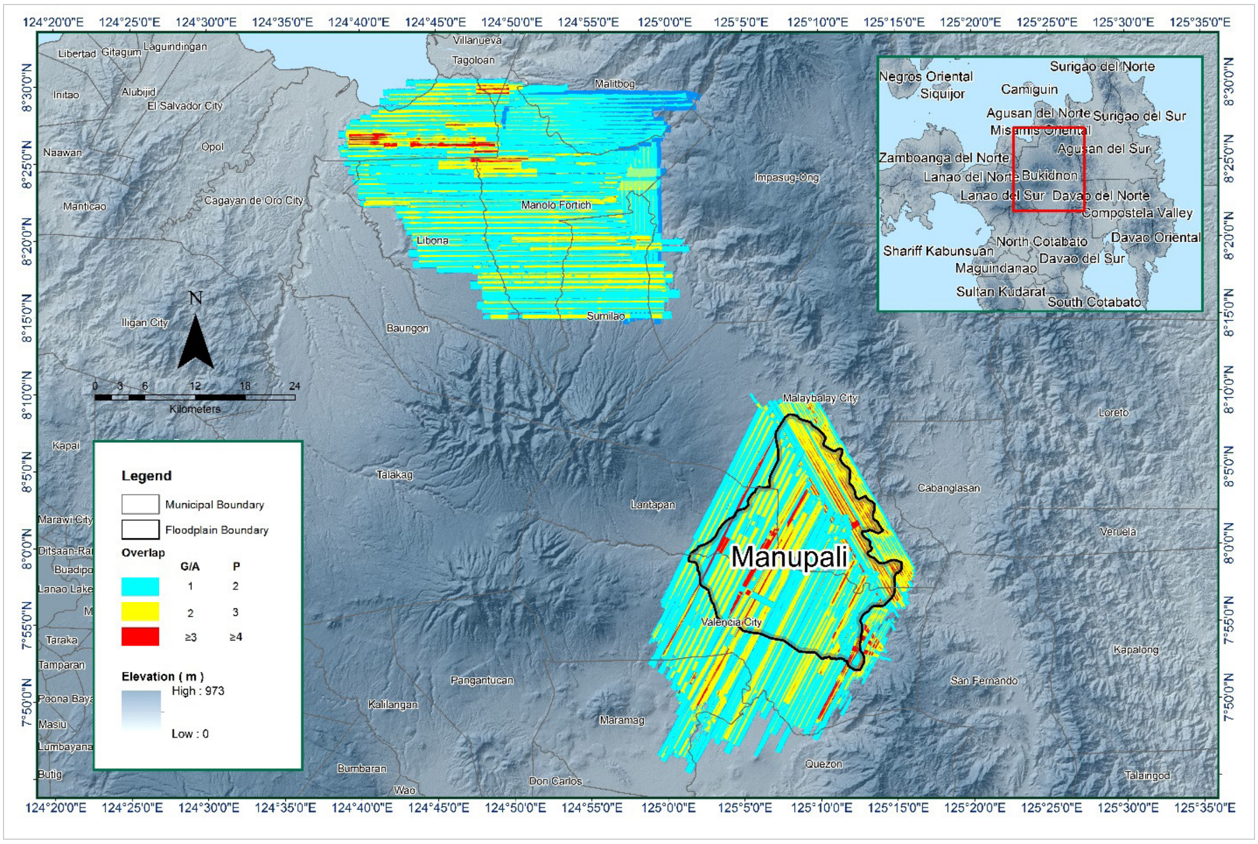


Figure 16. Image of data overlap for Manupali floodplain.

The overlap statistics per block for the Manupali 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 27.70% and 72.40% 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 17. It was determined that all LiDAR data for Manupali floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.23 points per square meter.

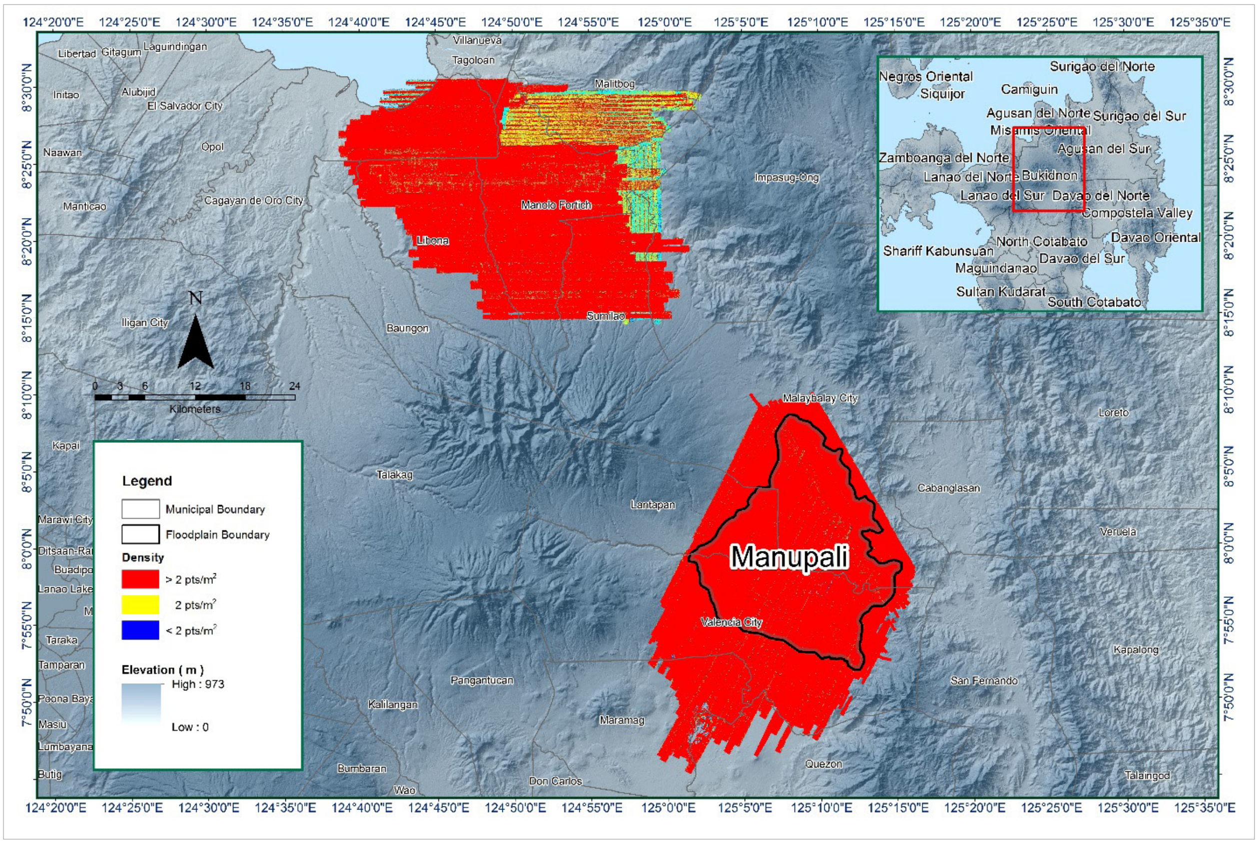


Figure 17. Density map of merged LiDAR data for Manupali floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

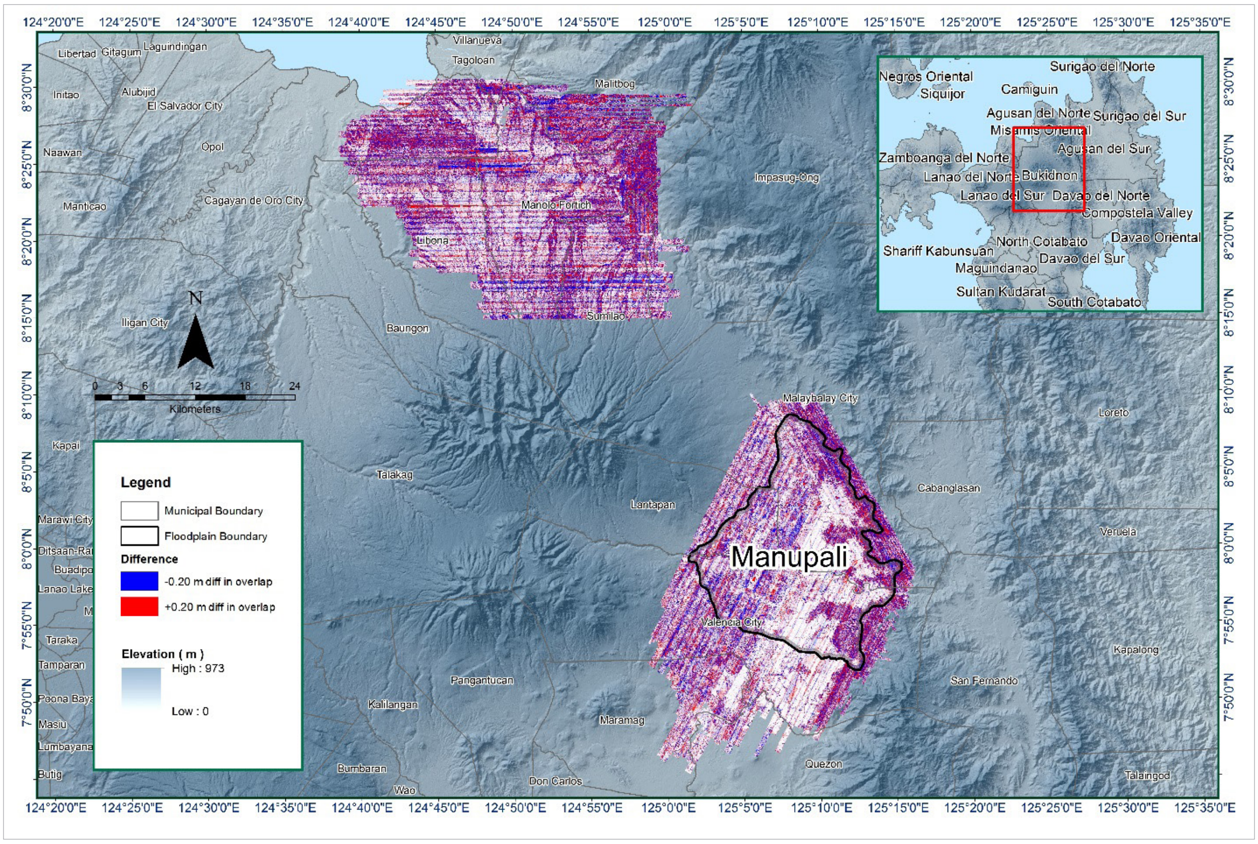


Figure 18. Elevation difference map between flight lines for Manupali floodplain.

A screen capture of the processed LAS data from a Manupali flight 23534P loaded in QT Modeler is shown in Figure 19. 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.

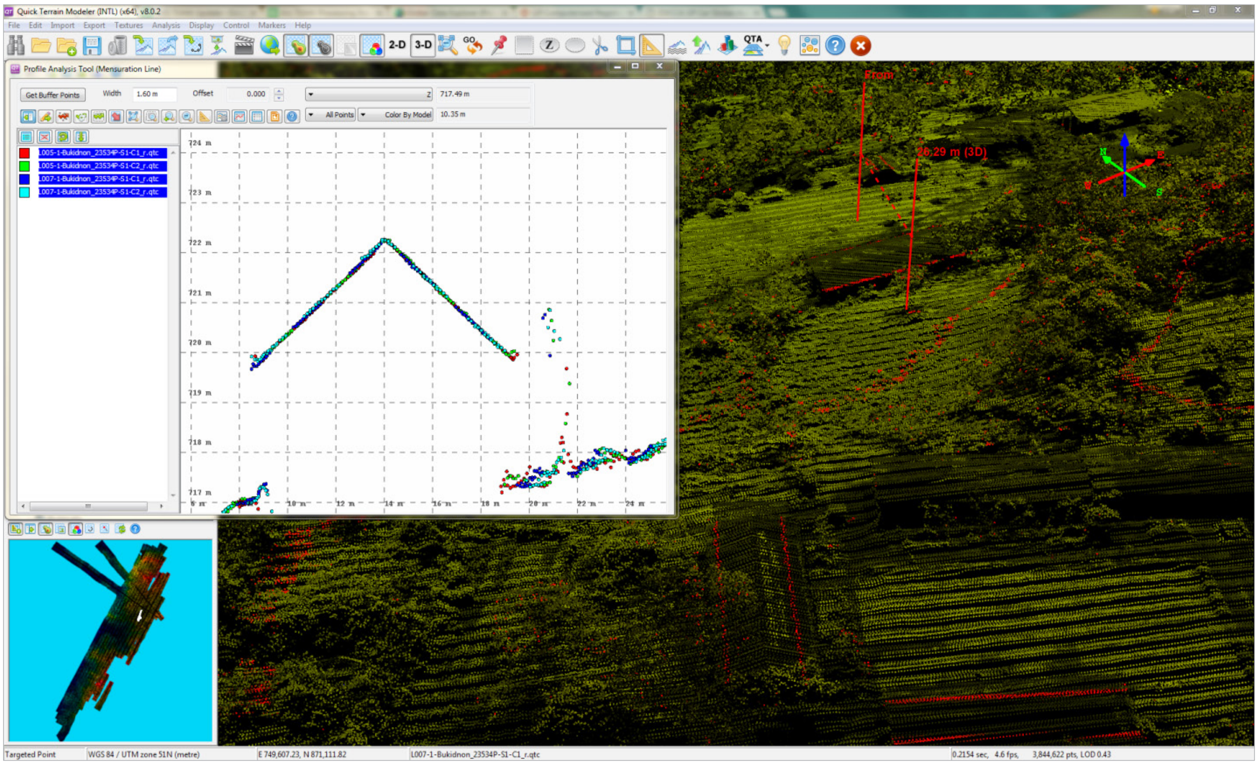


Figure 19. Quality checking for a Manupali flight 23534P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Manupali classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	3,857,468,123
Low Vegetation	2,850,039,233
Medium Vegetation	5,472,064,570
High Vegetation	5,504,381,780
Building	381,576,586

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Manupali floodplain is shown in Figure 20. A total of 3,754 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 1,590.61 meters and 65.84 meters respectively.

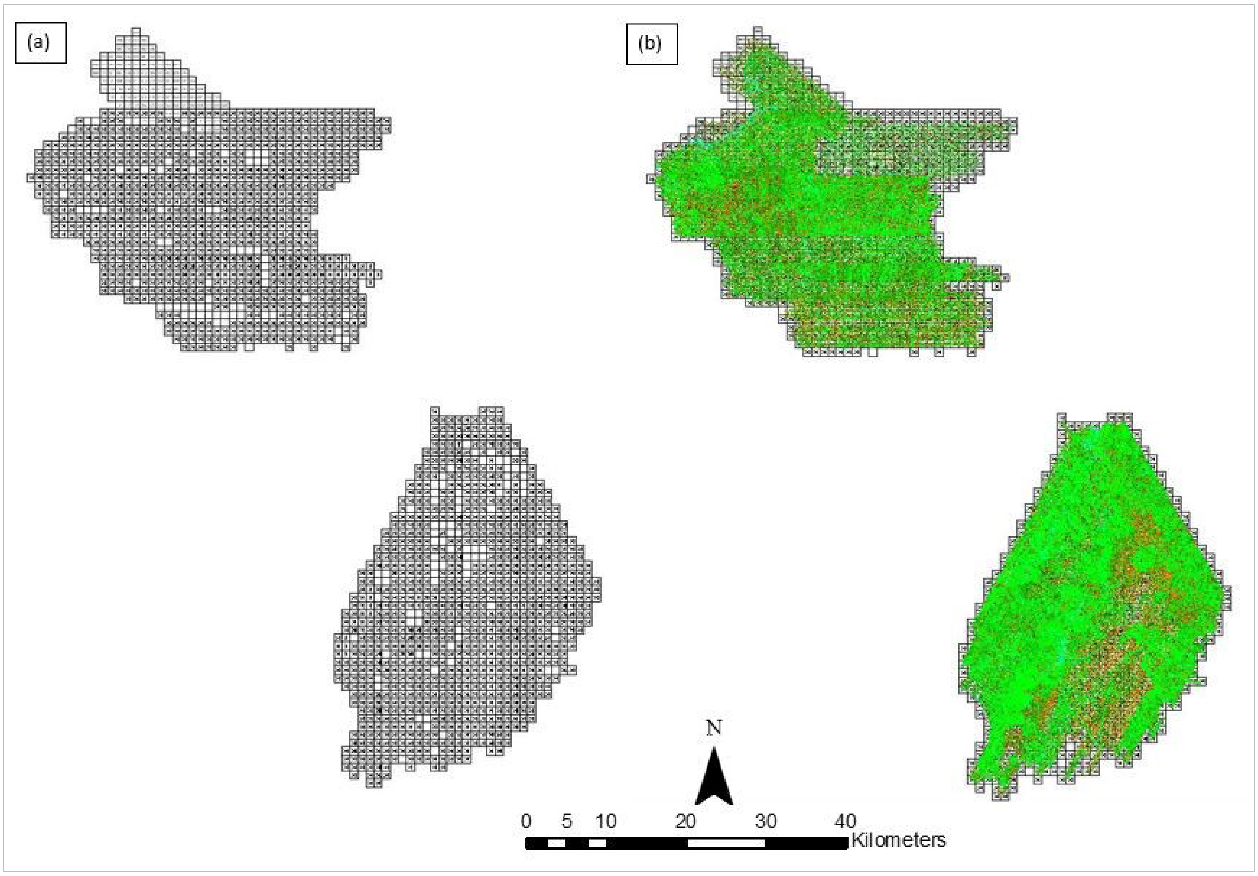


Figure 20. Tiles for Manupali floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

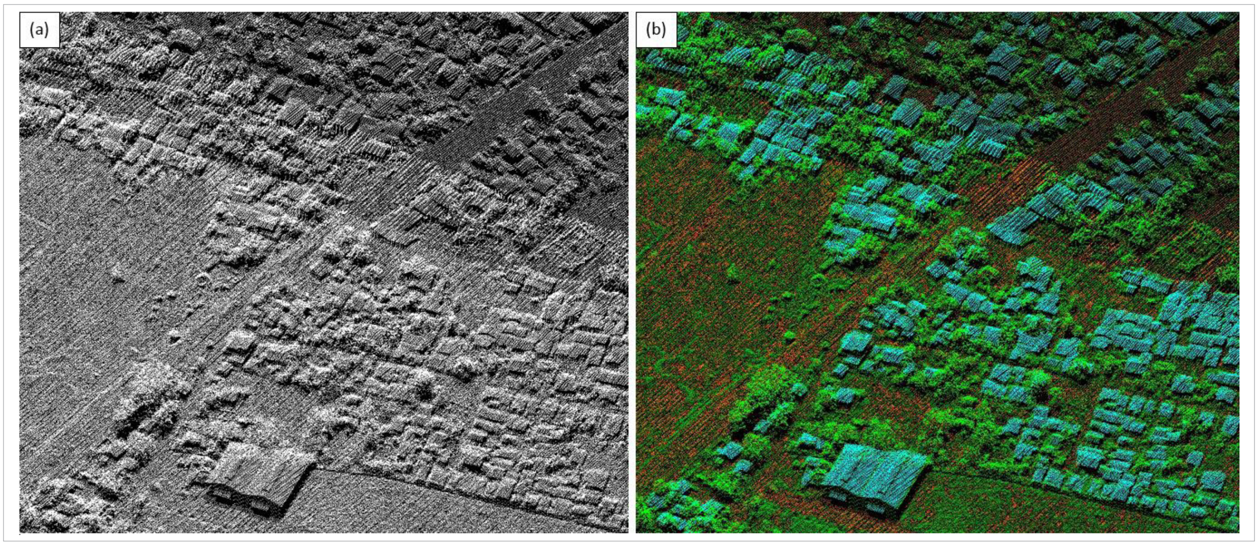


Figure 21. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 22. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

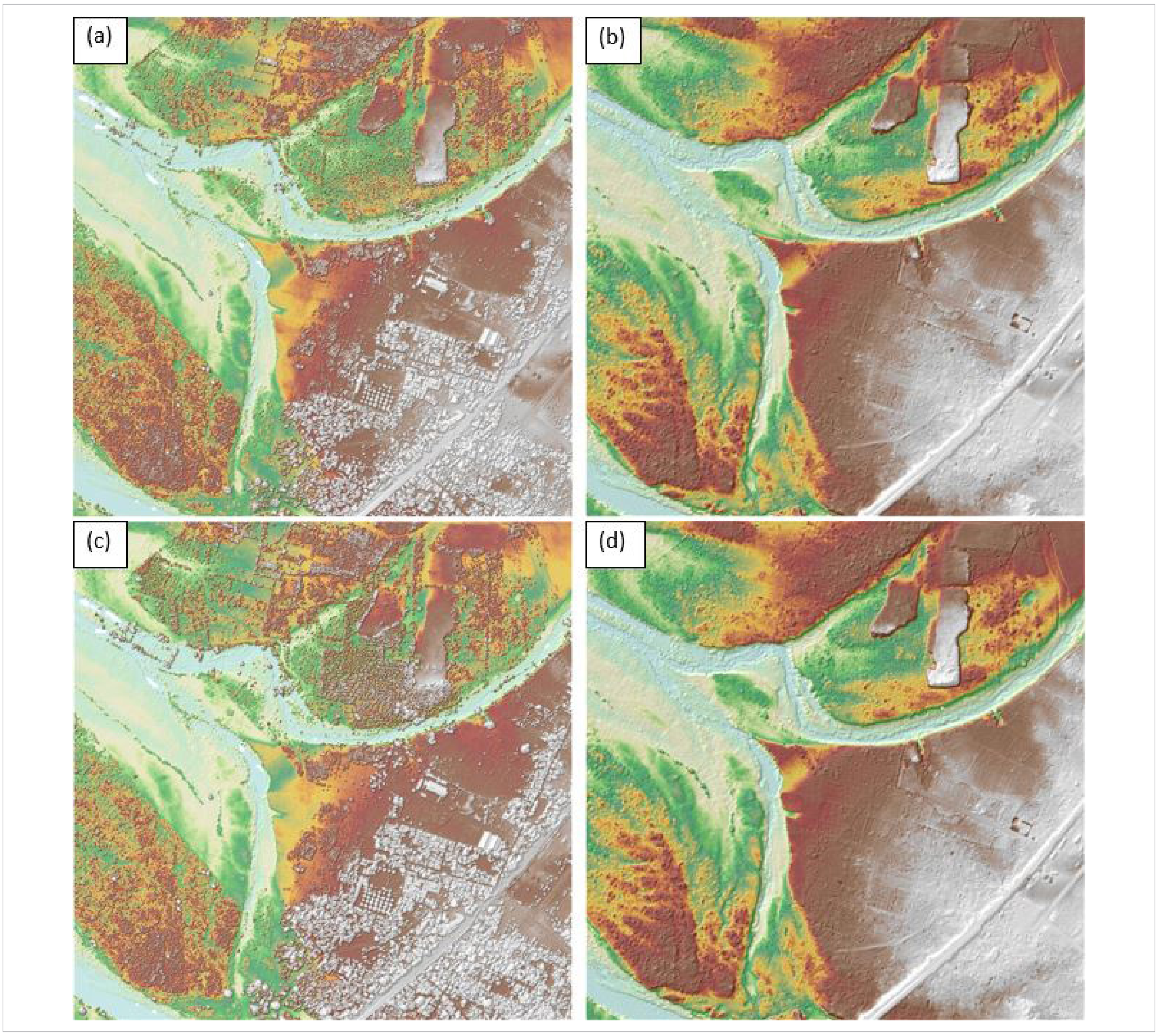


Figure 22. The production of the last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Manupali floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 301 1km by 1km tiles of the block covering the Manupali floodplain is shown in Figure 23. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Manupali floodplain survey attained a total of 240.922 km^2 in orthophotogaph coverage, comprised of 642 images. However, the block does not have a complete set of orthophotographs and no orthophotographs cover the area of the Manupali floodplain. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

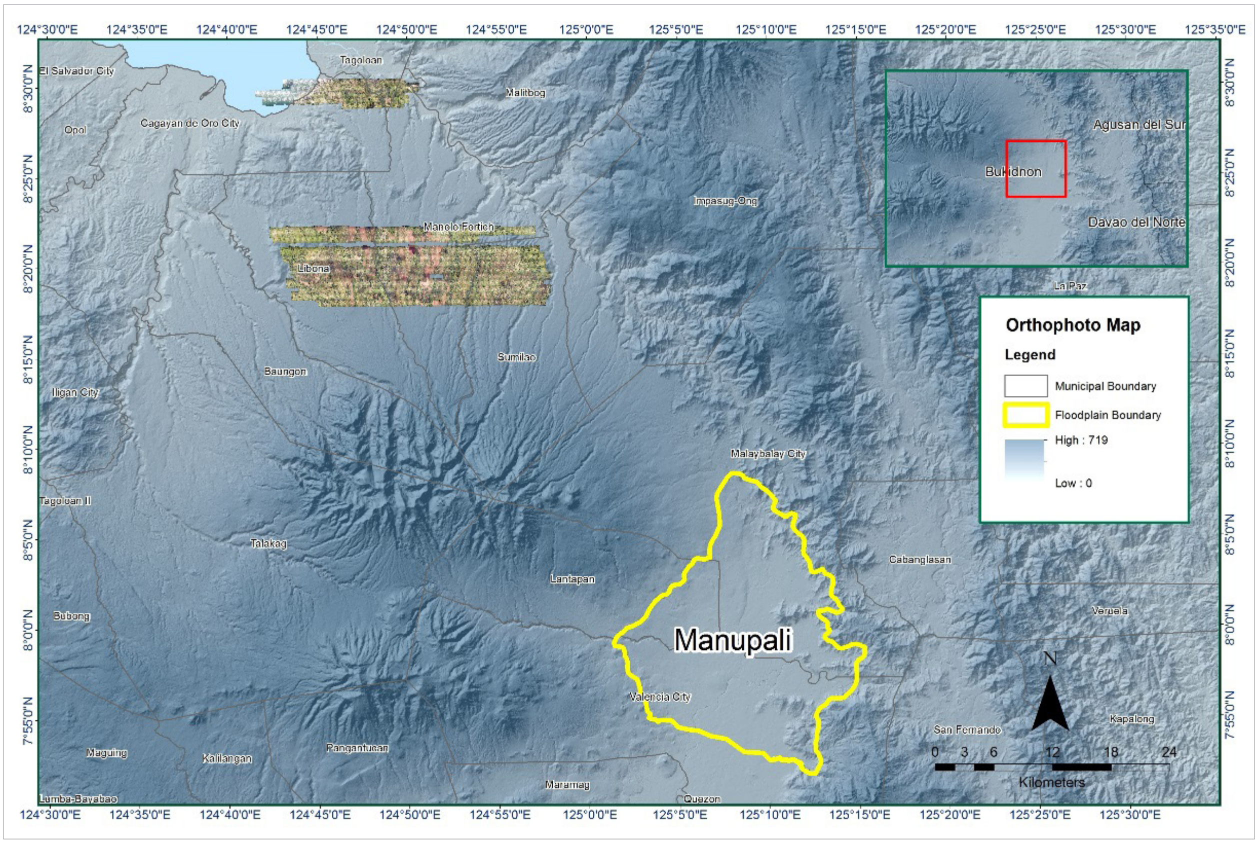


Figure 23. Available orthophotographs near Manupali floodplain.

Figure 24. Sample orthophotograph tiles near Manupali floodplain.

3.8 DEM Editing and Hydro-Correction

Nineteen (17) mission blocks were processed for Manupali flood plain. These blocks are composed of Bukidnon, Tagoloan and NorthernMindanao missions with a total area of 2,772.84 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)
NorthernMindanao_RX_BlkE_additional	429.95
NorthernMindanao_RX_BlkE	91.47
NorthernMindanao_RX_BlkE_additional2	226.25
Bukidnon_Blk64A	227.37
Bukidnon_Blk64A_additional	21.72
Bukidnon_Blk64A_supplement	80.87
Bukidnon_Blk64B_supplement2	263.4
Bukidnon_Blk64B	244.68
Bukidnon_Blk64B_supplement	172.64
Bukidnon_Blk64C	159.70
Bukidnon_Blk64C_additional	55.92
Bukidnon_Blk64C_supplement	119.87
Bukidnon_Blk64D	80.72
Bukidnon_Blk64D_additional	75.71
Bukidnon_Blk64D_supplement	23.74
Bukidnon_Blk64E	156.01
Bukidnon_Blk64E_supplement	49.27
TOTAL	**2,772.84 sq.km**

Portions of DTM before and after manual editing are shown in Figure 25. The bridge (Figure 25a) and abrupt elevation change through presence of high portions along the tributaries (Figure 25c) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 25b and Figure 25d) in order to hydrologically correct the river. This was done through interpolation process wherein a specific polygon determines the upstream and downstream elevation values to generate an interpolated portion of a river and eventually remove the bridge footprint. On the other hand, object retrieval was done in areas which have been removed (Figure 25e) during classification process and have to be retrieved to complete the surface (Figure 25f).

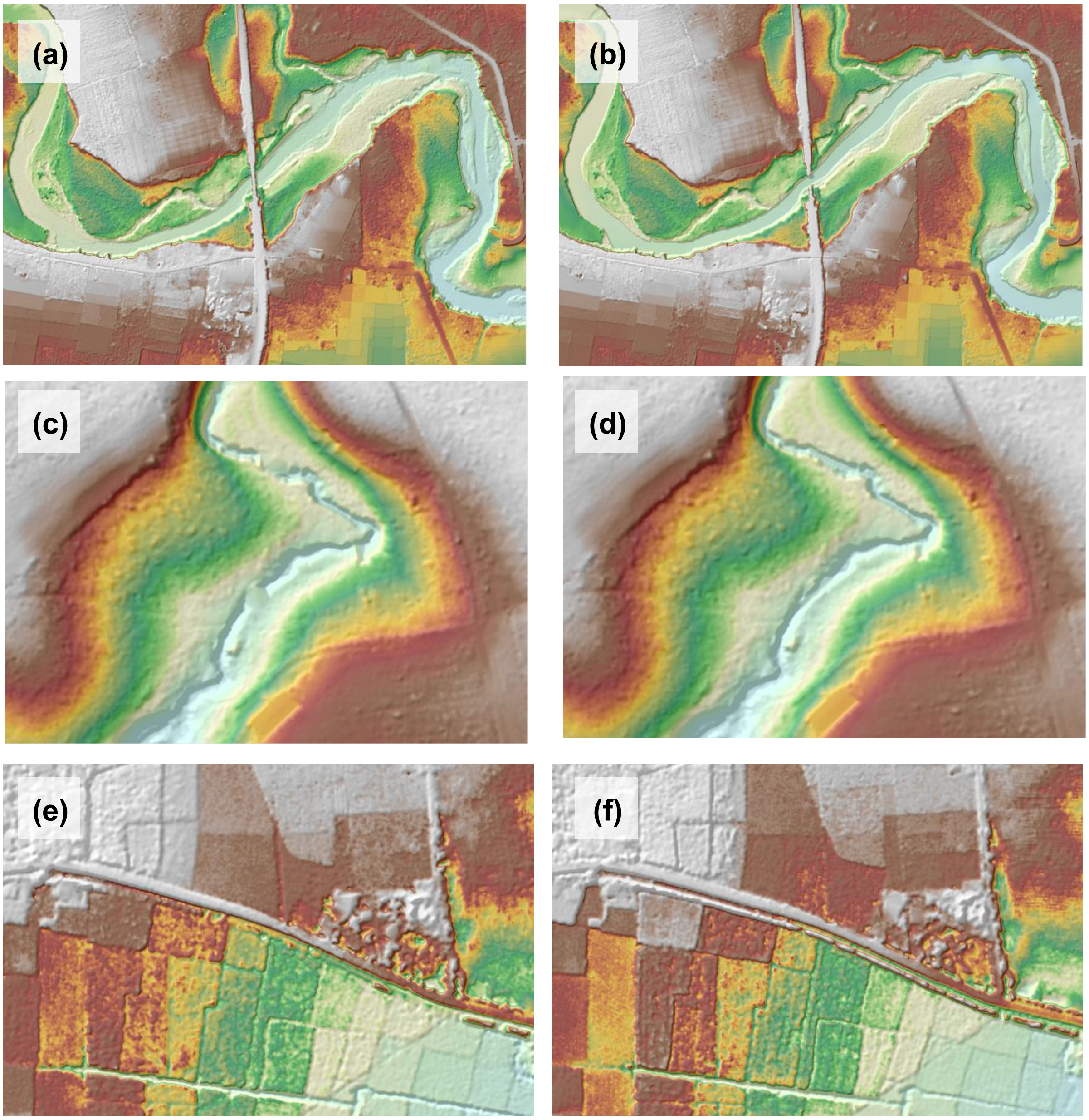


Figure 25. Portions in the DTM of Manupali floodplain – a bridge before (a) and after (b) manual editing; a point of high elevation before (c) and after (d) manual editing; and a paddy field before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

The Bukidnon_Blk64C was used as the reference block for mosaicking of Bukidnon blocks while Northern Mindanao blocks used NorthernMindanao_RX_BlkE as reference. Table 18 shows the area of each LiDAR blocks and the shift values applied during mosaicking. Shifting values were derived from the height difference of the calibrated block and the overlapping adjacent block.

Mosaicked LiDAR DTM for Manupali floodplain is shown in Figure 26. It can be seen that the entire Manupali floodplain is 100% covered by LiDAR data.

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

Mission Blocks	Shift Values (meters)		
	x	y	z
Blocks in Bukidnon			
Bukidnon_Blk64A	0.00	0.00	-0.01
Bukidnon_Blk64A-supplement	0.00	0.00	0.03
Bukidnon_Blk64A_additional	0.00	0.00	-0.08
Bukidnon_Blk64B	0.00	0.00	-0.16
Bukidnon_Blk64B_supplement	0.00	0.00	-0.16
Bukidnon_Blk64B_supplement2	0.00	0.00	-0.03
Bukidnon_Blk64C	0.00	0.00	0.00
Bukidnon_Blk64C_supplement	0.00	0.00	0.08
Bukidnon_Blk64C_additional	0.00	0.00	0.17
Bukidnon_Blk64D	0.00	0.00	0.02
Bukidnon_Blk64D_supplement	0.00	0.00	-0.11
Bukidnon_Blk64D_additional	0.00	0.00	-0.04
Blocks in Northern Mindanao			
Bukidnon_Blk64E	0.00	0.00	0.63
Bukidnon_Blk64E_supplement	0.00	0.00	-0.37
NorthernMindanao_RX_BlkE	0.00	0.00	0.00
NorthernMindanao_RX_BlkE_additional	0.00	0.00	-0.37
NorthernMindanao_RX_BlkE_additional2	0.00	0.00	-0.48

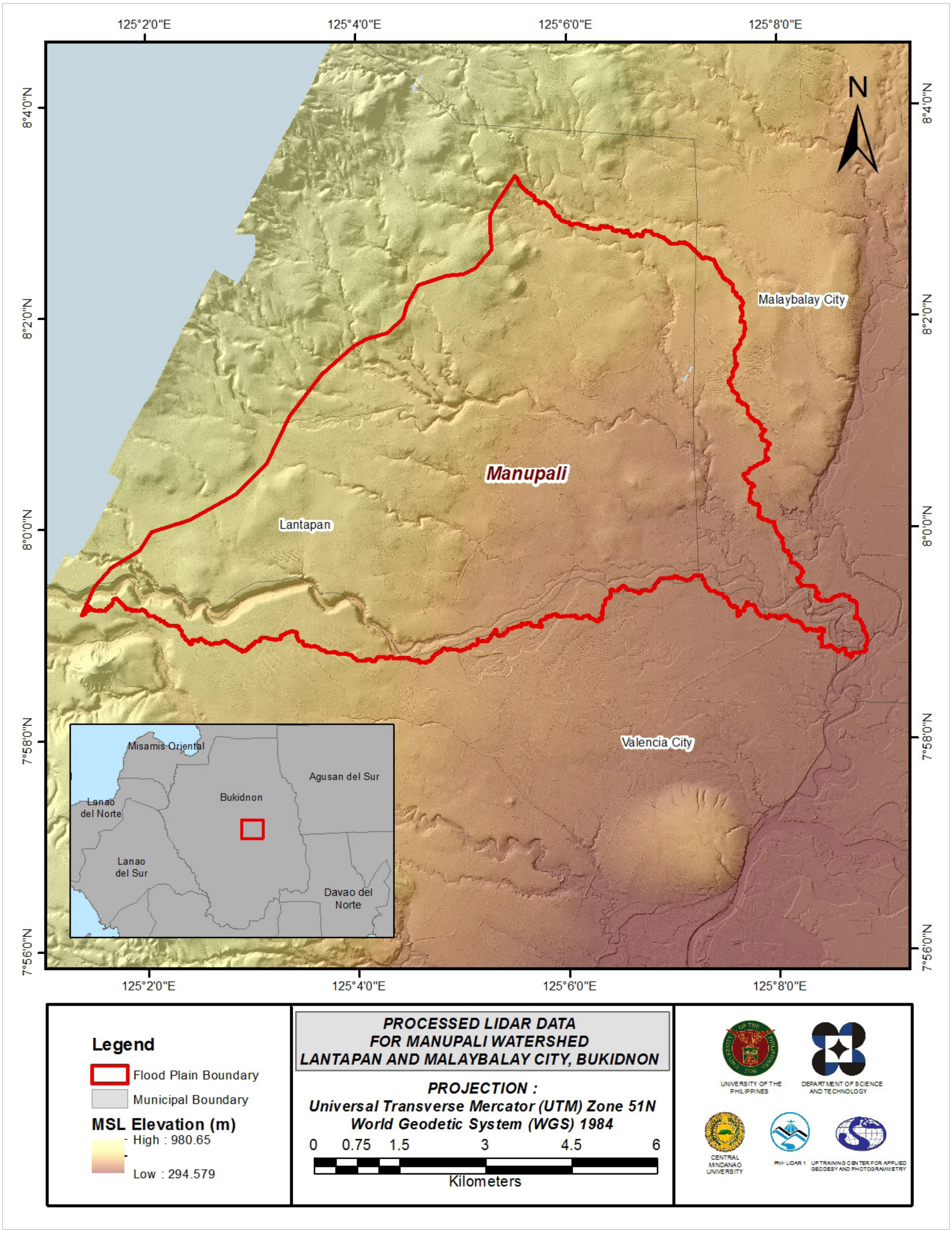


Figure 26. Map of Processed LiDAR Data for Manupali Flood Plain.

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 Manupali to collect points with which the LiDAR dataset is validated is shown in Figure 27. A total of 7,734 survey points were used for calibration and validation of Manupali LiDAR data. Random selection of 80% of the survey points, resulting to 4,512 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 28. 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 0.38 meters with a standard deviation of 0.08 meters. Calibration of Manupali LiDAR data was done by adding the height difference value, 0.38 meters, to Manupali mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

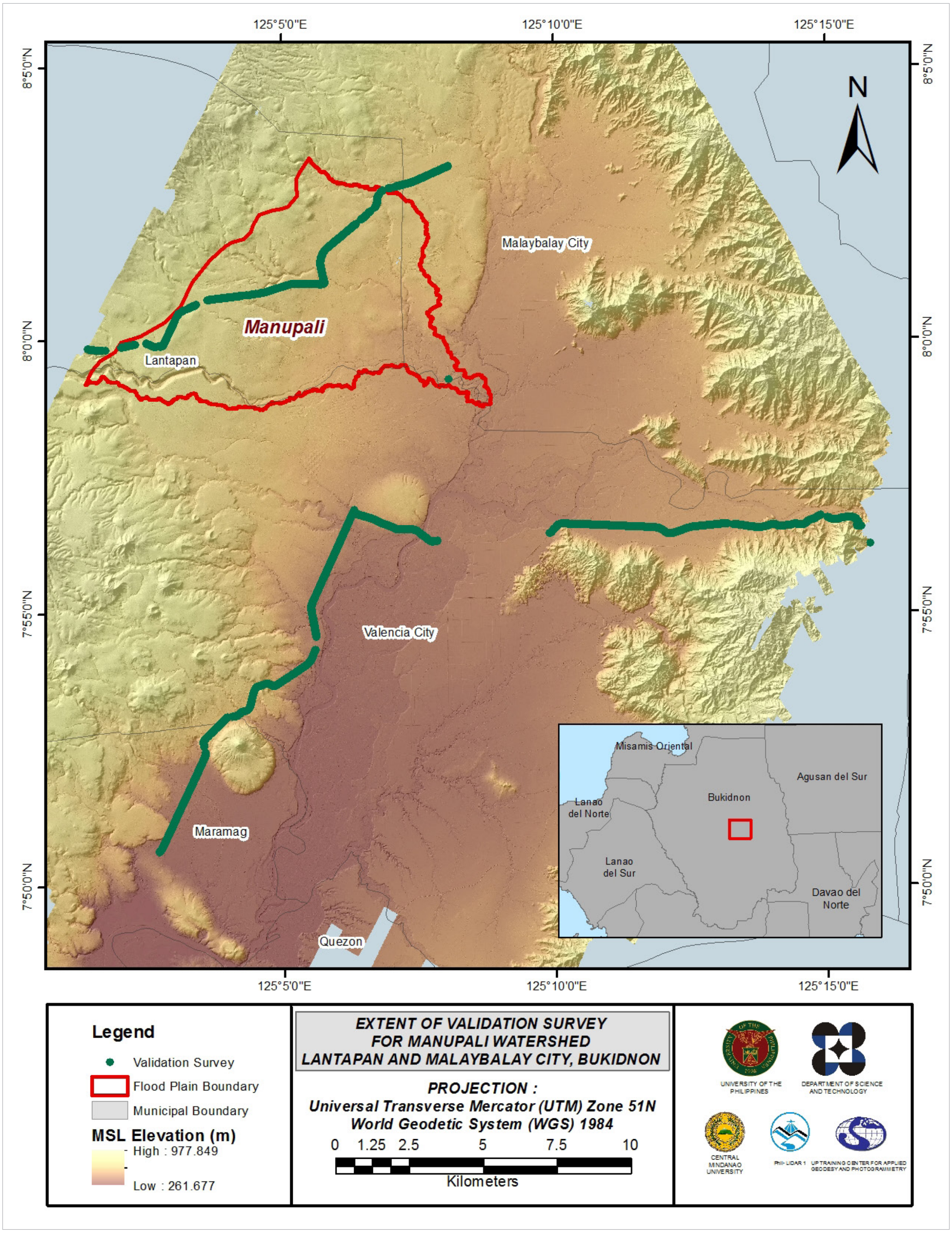


Figure 27. Map of Manupali Flood Plain with validation survey points in green.

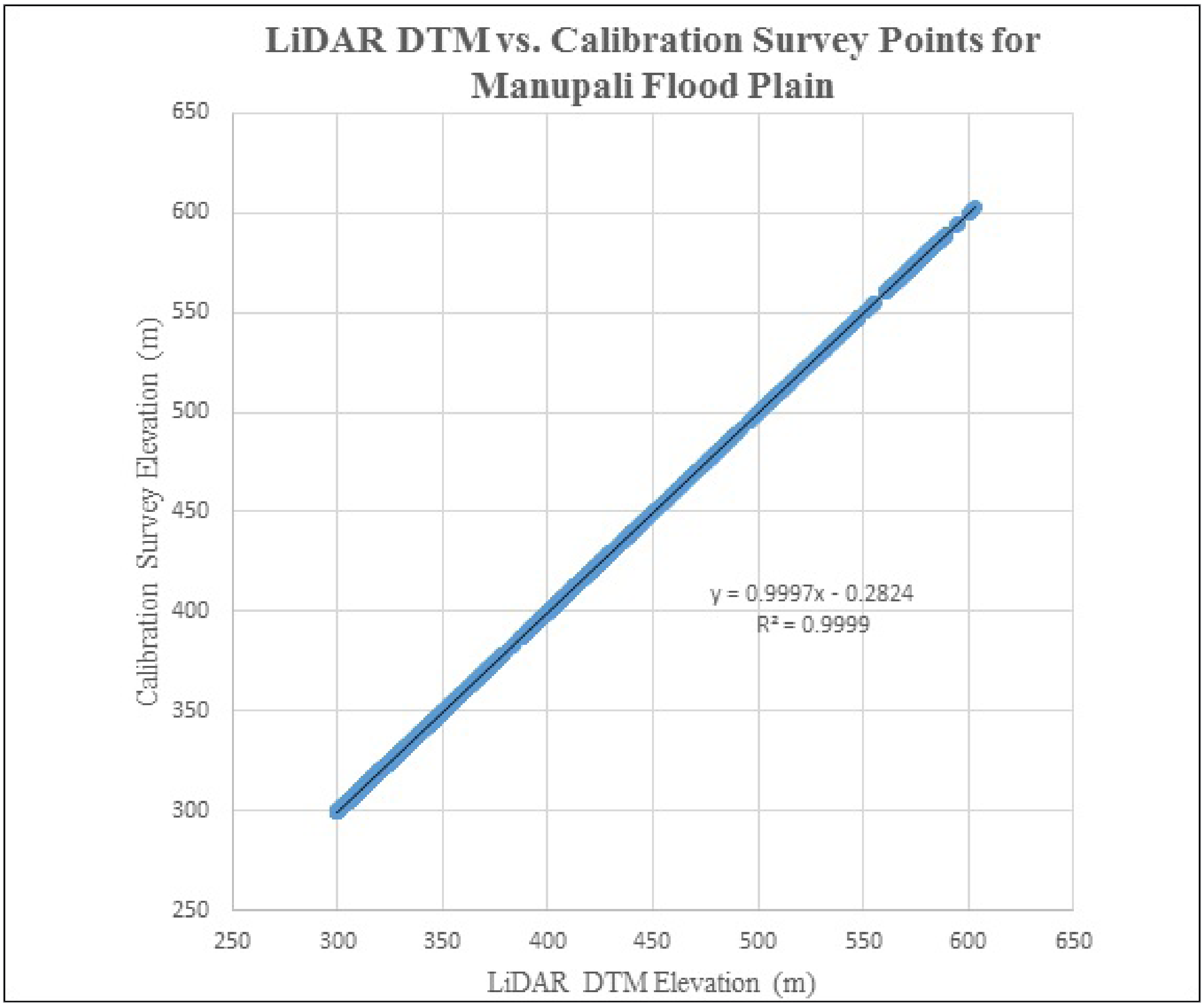


Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.38
Standard Deviation	0.08
Average	-0.38
Minimum	-0.64
Maximum	0.56

The remaining 20% of the total survey points, resulting to 825 points, were used for the validation of calibrated Manupali 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 29. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19 meters with a standard deviation of 0.19 meters, as shown in Table 20.

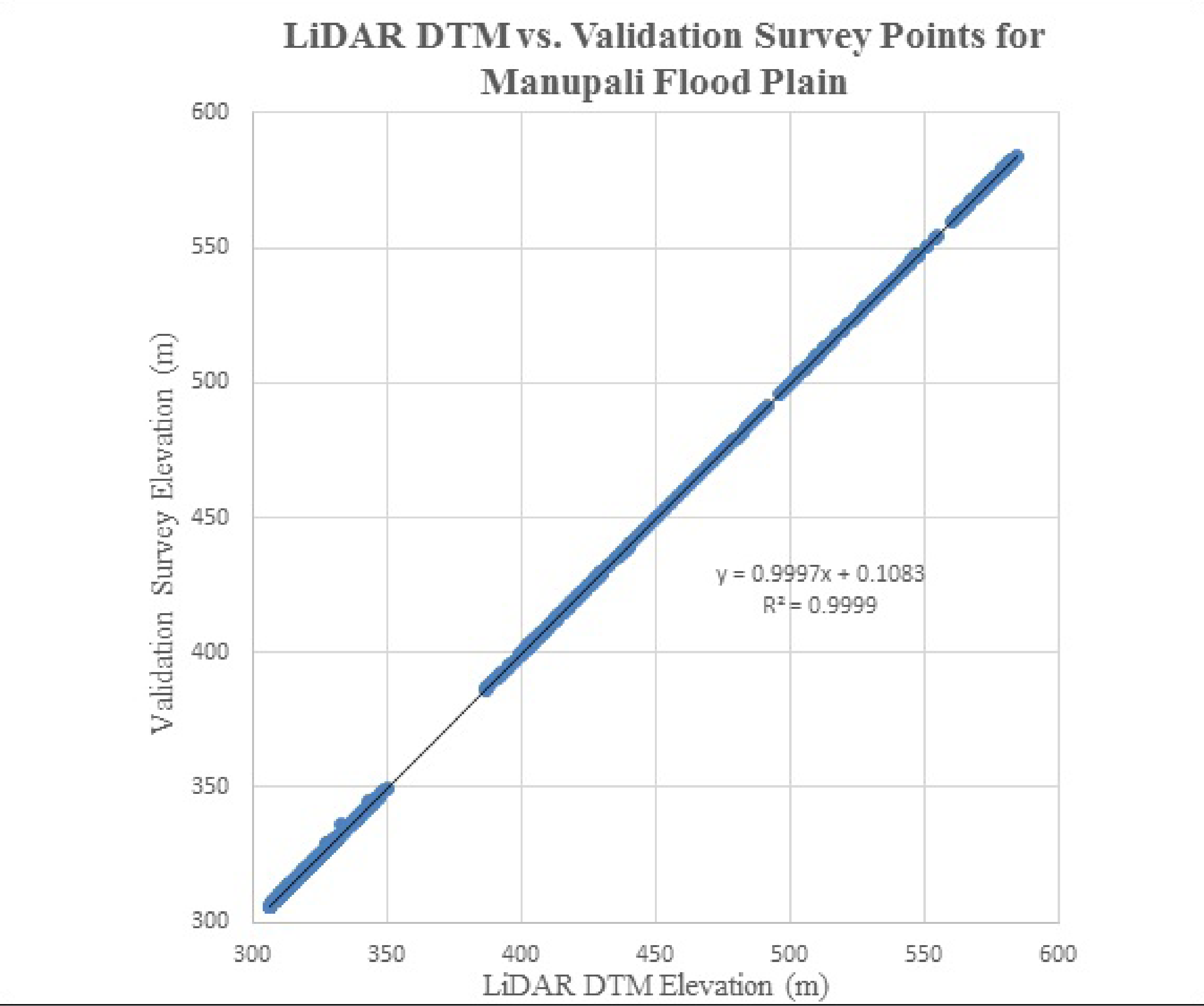


Figure 29. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.19
Average	0.00
Minimum	-0.38
Maximum	0.40

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross section data was available for Manupali with 3,076 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.49 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Manupali integrated with the processed LiDAR DEM is shown in Figure 30.

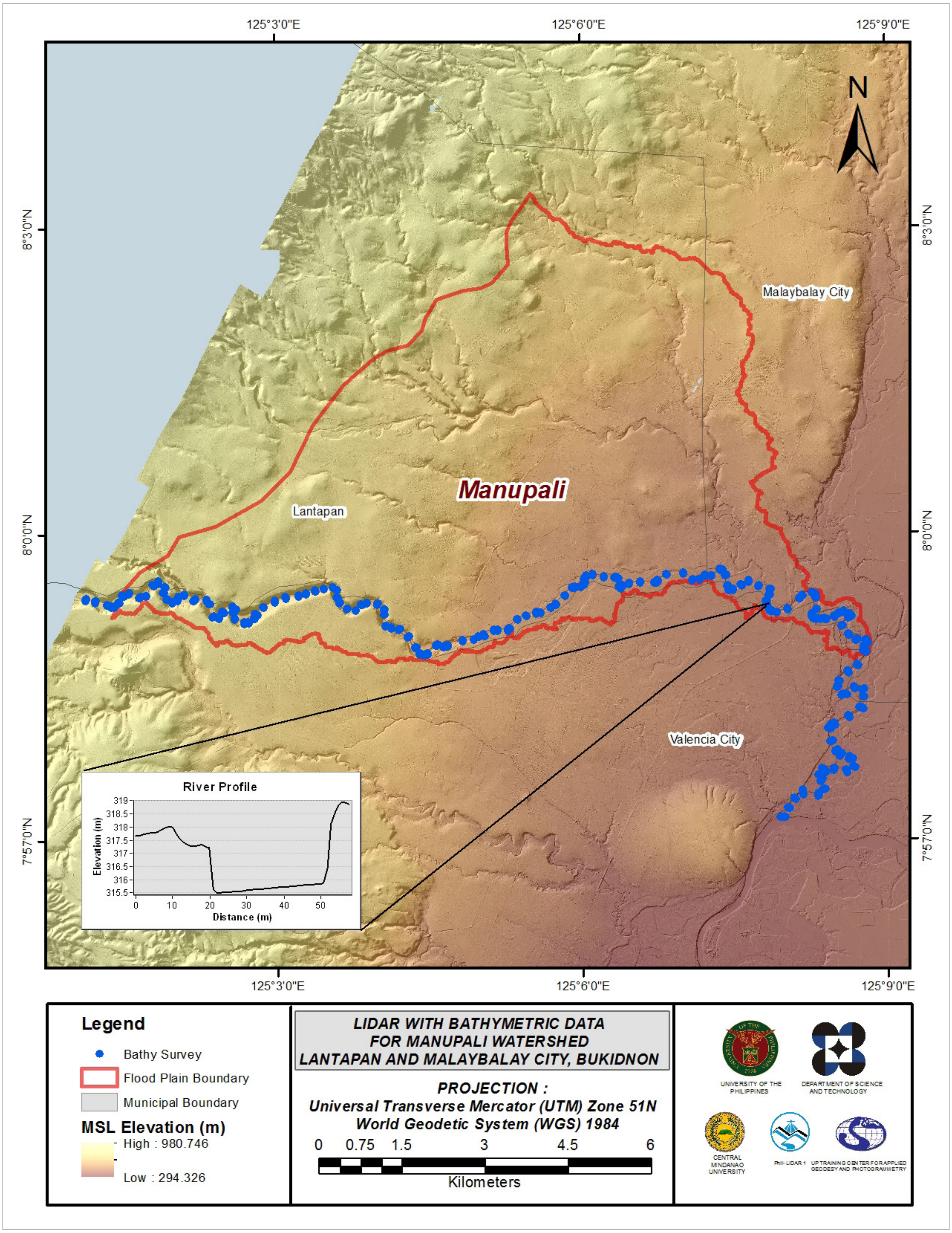


Figure 30. Map of Manupali Flood Plain with bathymetric survey points shown in blue.

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.

3.12.1 Quality Checking of Digitized Features' Boundary

Manupali floodplain, including its 200 m buffer, has a total area of 438.79 sq km. For this area, a total of 14.00 sq km, corresponding to a total of 3372 building features, are considered for QC. Figure 31 shows the QC blocks for Manupali floodplain.

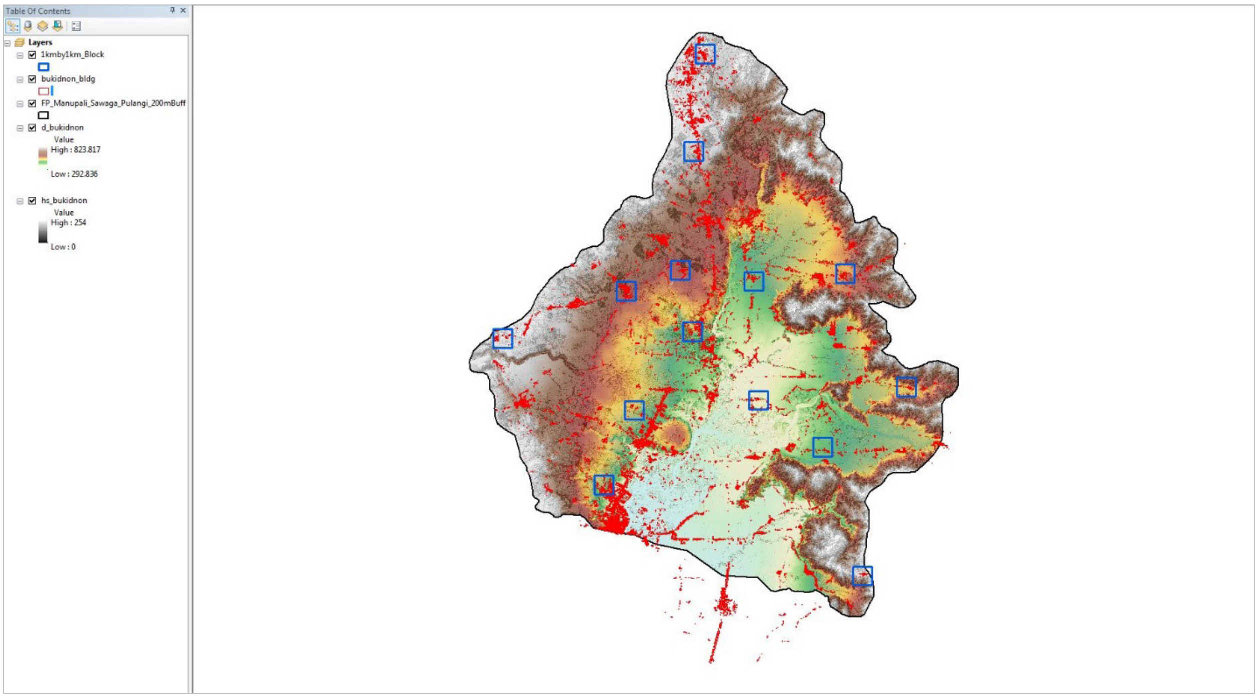


Figure 31. Blocks (in blue) of the Manupali building features that were subjected to QC

Quality checking of Manupali building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Manupali Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Manupali	99.47	99.76	89.09	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,831 building features in Manupali floodplain. Of these building features, none was filtered out after height extraction, resulting to 4,831 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.45 m.

3.12.3 Feature Attribution

Field data collection for the attribution process was done through Geotagging (point to a specific feature and shoot method) using a handheld GPS with a built-in camera. The x,y,z and the viewing direction of the GPS in 0-359 degrees during the photo capture were the essential information in the process. Using Arcmap's tool "Geotagged Photos to Points", the symbology of the imported point shapefile was set as "Airfield" and the viewing angle was set as "Direction". The "Path" is automatically created in the points' attribute table wherein the photo's directory is linked every after the "Identify" button is clicked to a specific point.

Table 22 summarizes the number of building features per type. From the total features identified, approximately 4, 470 of it are residential establishments while the commercial establishments and schools are the most common in non-residential features. On the other hand, Table 23 shows the total length of each road type. Table 24 shows the number of water features extracted per type.

Table 22. Building Features Extracted for Manupali Floodplain.

Facility Type	No. of Features
Residential	4,470
School	109
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	0
Barangay Hall	5
Military Institution	0
Sports Center/Gymnasium/Covered Court	3
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	37
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	26
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	11
Other Commercial Establishments	168
Total	**4,831**

Total Length of Extracted Roads for Manupali Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Manupali	106.47		0	15.38	0	**121.85**

Table 23. Number of Extracted Water Bodies for Manupali Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Manupali	4	0	0	0	0	4

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 32 shows the Digital Surface Model (DSM) of Manupali floodplain overlaid with its ground features.

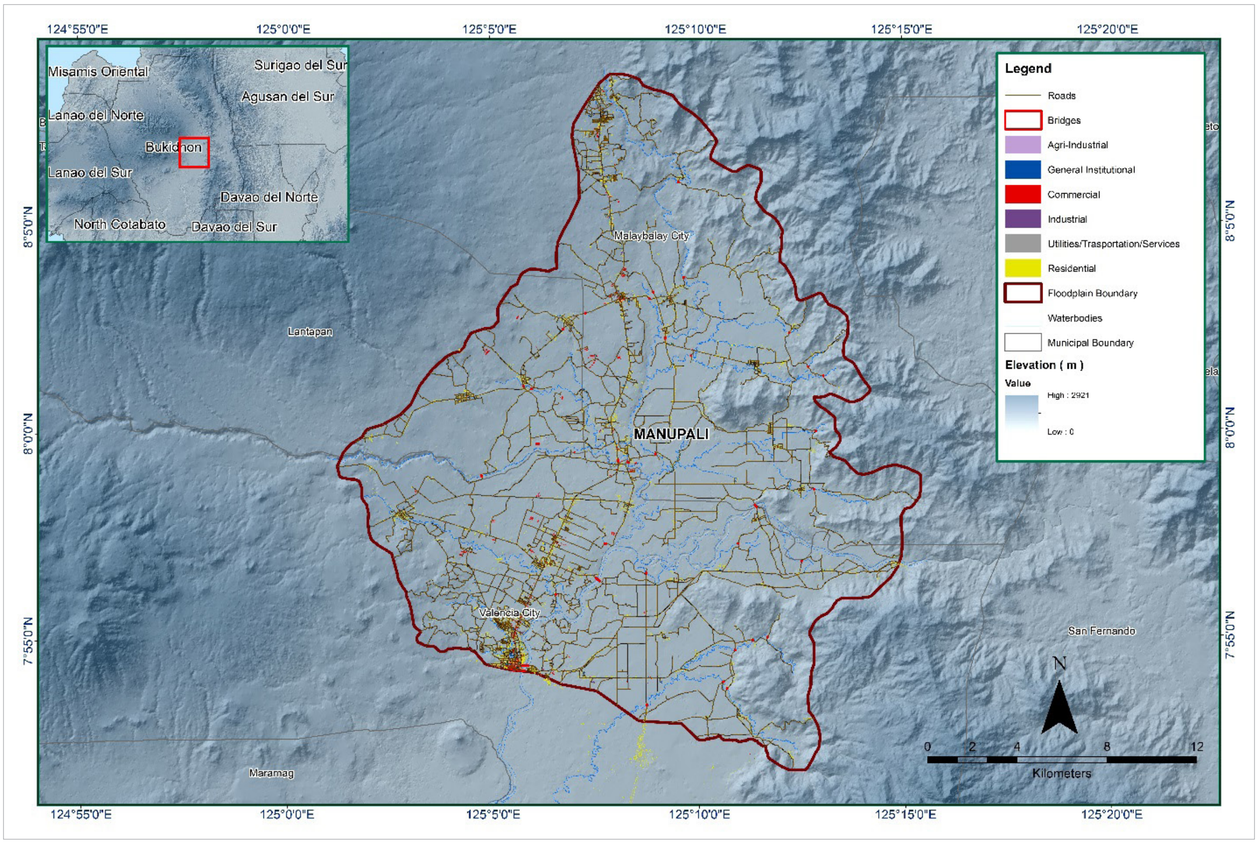


Figure 32. Extracted features for Manupali floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE MANUPALI 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 project team conducted a field survey in Manupali River on February 10, 2015, April 7, 11, 12, 15, 16, 18, 19 to 23 and 27, 2016, and May 8 to 10 and 16, 2016 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Manupali Bridge in Brgy. Colonia, City of Valencia, Bukidnon. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on August 11, 2016 using a Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Manupali River Basin area. The entire survey extent is illustrated in Figure 33.

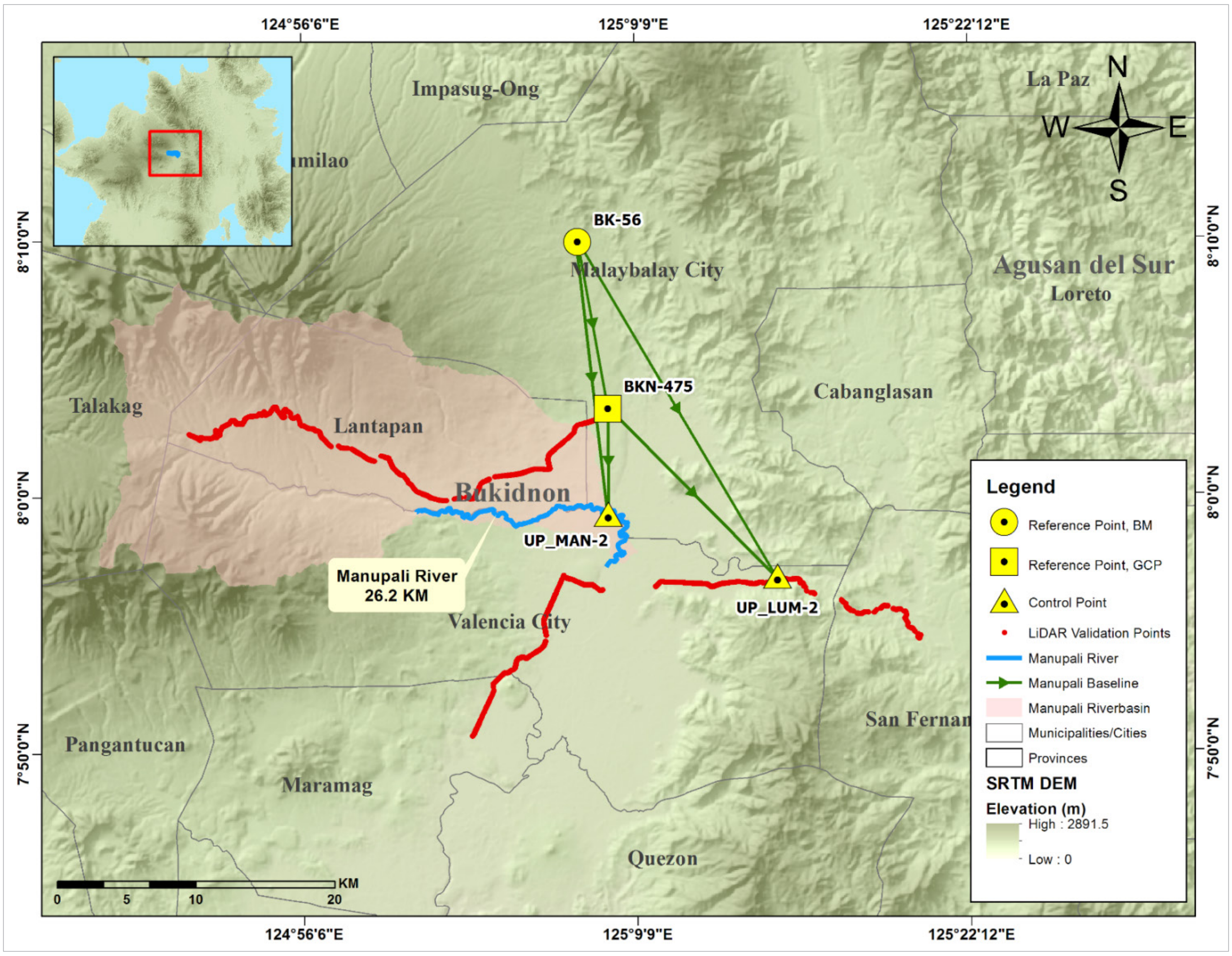


Figure 33. Extent of the bathymetric survey (blue line) in Manupali River and the LiDAR data validation survey (red)

4.2 Control Survey

The GNSS network used for Manupali River is composed of two (2) loops established on August 10, 2016 occupying the following reference points: BK-56, a first-order BM, in Brgy. Sumpong, Malaybalay City, Bukidnon; and BKN-475 a second-order GCP, in Brgy. Linabo, Malaybalay City, Bukidnon.

Two (2) control points established in the area by ABSD were also occupied: UP_MAN-2 located near the approach of Manupali Bridge in Brgy. Bangcud, Malaybalay City, Province of Bukidnon, and UP_LUM-2 located near the Pulangui Diversion Dam in Brgy. Lumbayao, Valencia City, Province of Bukidnon.

The summary of reference and control points and its location is summarized in Table 25 while GNSS network established is illustrated in Figure 34.

Table 24. List of reference and control points used during the survey in Manupali River (Source: NAMRIA, 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
BK-56	1st order, BM	8° 9' 52.69903"N	125° 6' 54.60334"E	727.714	656.645	2008
BKN-475	2nd order, GCP	8° 3' 22.52096"N	125° 8' 4.12506"E	473.980	403.169	2007
UP_MAN-2	Established	7° 59'16.34151"N	125° 8' 3.89549"E	394.653	322.44	02-10-15
UP_LUM2	Established	7°56' 49.14628"N	125° 9' 40.23913"E	411.207	339.432	04-19-2016

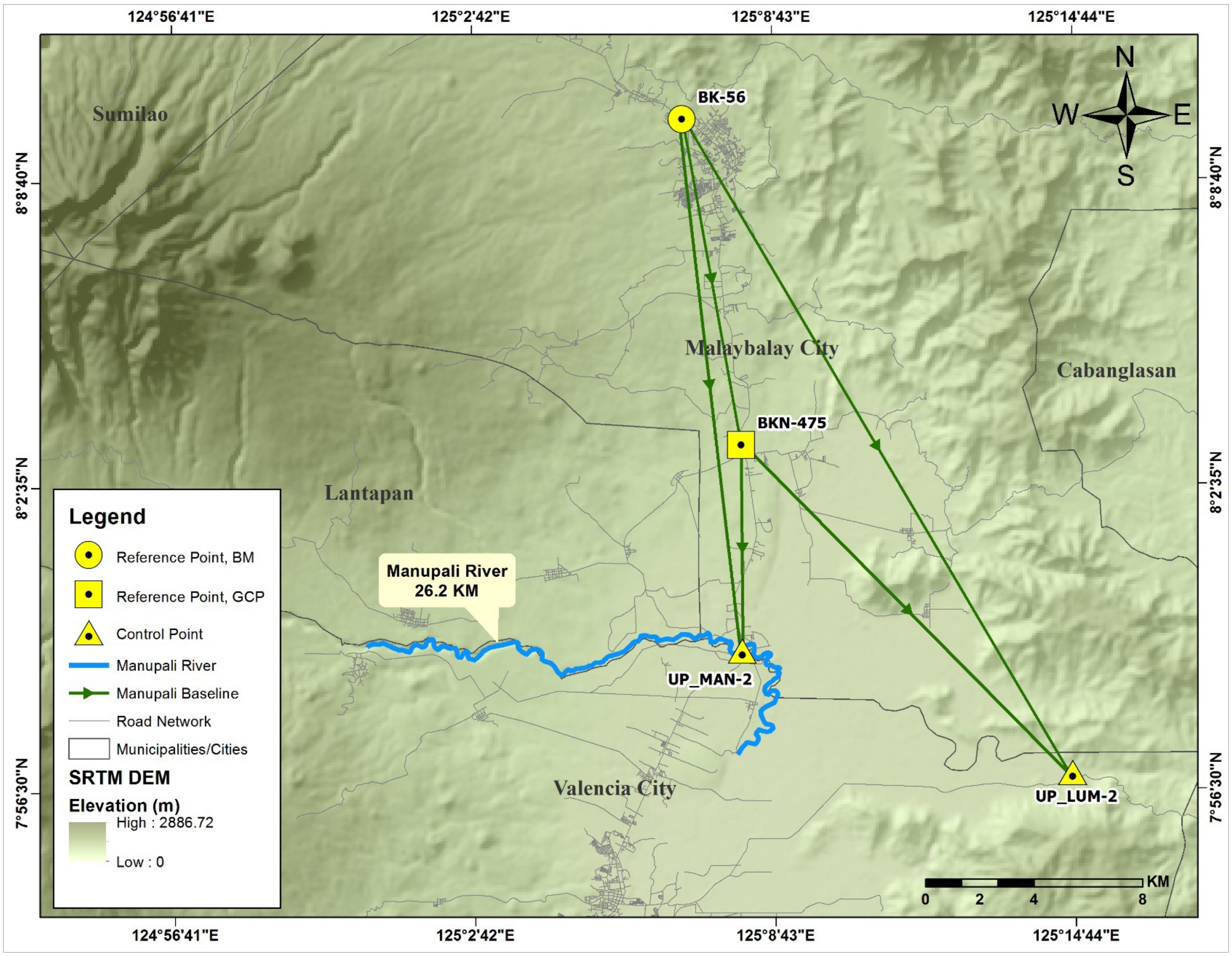


Figure 34. Manupali River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Manupali River are shown from Figure 35 to Figure 38.

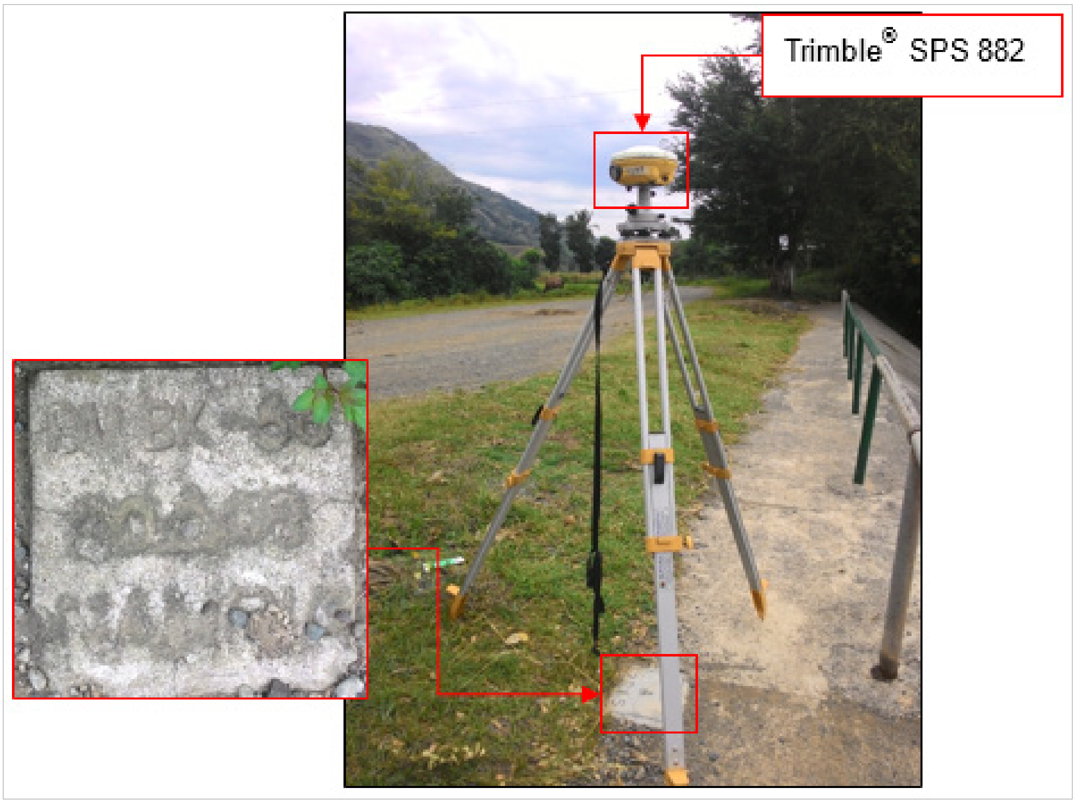


Figure 35. GNSS receiver set up, Trimble® SPS 882, at BK--56, located at the west post of the welcome arc of Malaybalay City in Brgy. Sumpong, Bukidnon

Figure 36. GNSS receiver setup, BKN-475, located within the DPWH Compound in Brgy. Aglayan, Valencia City, Bukidnon.

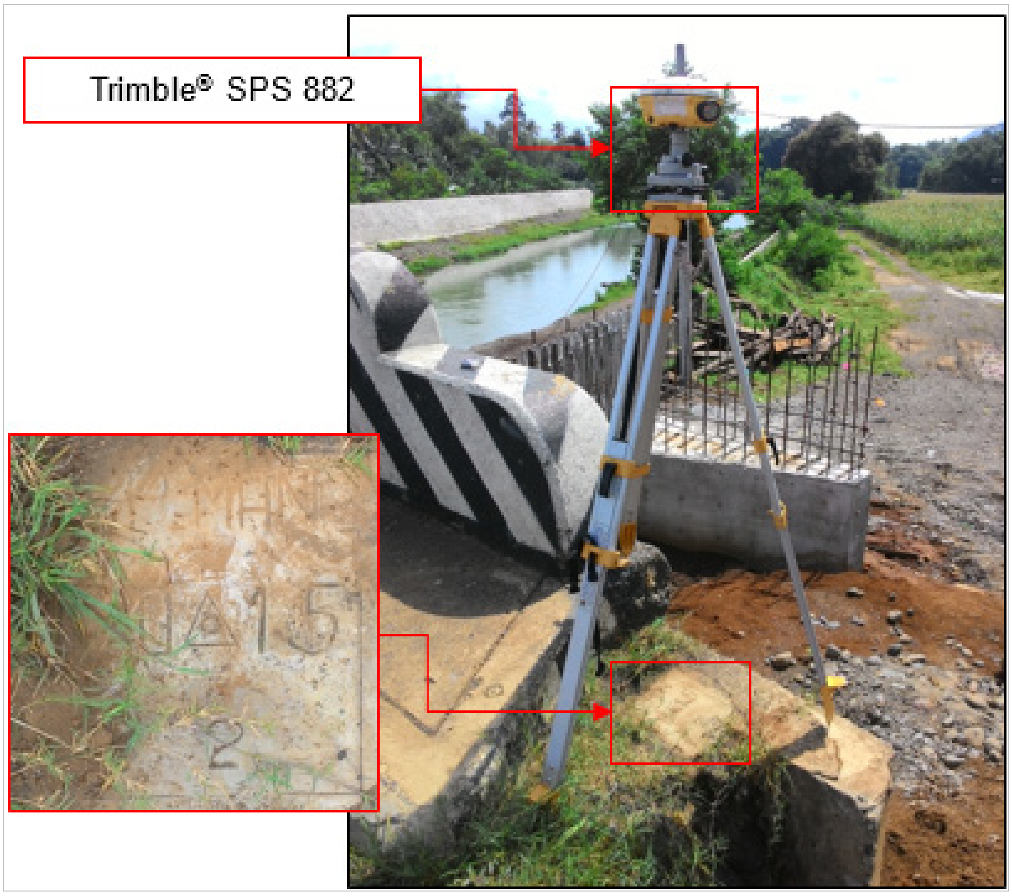


Figure 37. GNSS receiver set up, Trimble® SPS 882, at UP_MAN -2, located near the approach of Manupali Bridge in Brgy. Bangcud, Malaybalay City, Province of Bukidnon

Figure 38. GNSS receiver serup, UP_LUM-2, located near the Pulangui Diversion Dam in Brgy. Lumbayao, Valencia City, Province of Bukidnon.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In 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 Manupali River Basin is summarized in Table 26 generated by TBC software.

Table 25. Baseline Processing Report for Manupali River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
BK-56 --- BKN-475	8-10-2016	Fixed	0.007	0.024	169°55'49"	12174.173	-253.707
BK-56 --- UP_MAN-2	8-10-2016	Fixed	0.004	0.022	173°48'19	19664.461	-334.563
BKN-475 --- UP_MAN-2	8-10-2016	Fixed	0.004	0.015	180°03'12"	7562.993	-80.875
BK-56--- UP_LUM-2	8-10-2016	Fixed	0.006	0.029	149°19'44"	27983.972	-318.479
BKN-475 --- UP_LUM-2	8-10-2016	Fixed	0.004	0.016	134°51'09"	17132.460	-253.707

As shown in Table 26, a total of five (5) baselines were processed with coordinate and ellipsoidal height values of BKN-475 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

for each control point. See the Network Adjustment Report shown from Tables 23 to 25 for the complete details. Refer to ANNEX 11 for the computation for the accuracy of ABSD.

The four (4) control points, BK-56, BKN-475, UP-MAN-2, and UP_LUM-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of BKN-475 were held fixed during the processing of the control points as presented in Table 27. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 26. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
BK-56	Grid				
BKN-475	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BK-56	733046.484	0.009	903110.050	0.007	656.645	?	e
BKN-475	735238.147	?	891131.322	?	403.210	0.057	LLh
UP_MAN-2	735270.463	0.009	883566.236	0.007	322.440	0.061	
UP_LUM-2	747450.236	0.009	879107.389	0.007	338.965	0.067	

With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20\text{ cm}$ for horizontal and $z_e < 10\text{ cm}$ for the vertical; the computation for the accuracy are as follows:

a. BK-56

horizontal accuracy = √((0.9)² + (0.7)²
= √ (0.81 + 0.49)
= 1.3 < 20 cm

vertical accuracy = Fixed

b. BKN-475

horizontal accuracy = Fixed
vertical accuracy = Fixed

c. UP_MAN-2

horizontal accuracy = √((0.9)² + (0.7)²
= √ (0.81 + 0.49)
= 1.3 < 20 cm

vertical accuracy = 6.1 < 10 cm

d. UP_LUM-2

horizontal accuracy = √((0.9)² + (0.7)²
= √ (0.81 + 0.49)
= 1.3 < 20 cm

vertical accuracy = 6.7 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
BK-56	N8°09'52.69746"	E125°06'54.60518"	729.219	?	e
BKN-475	N8°03'22.52096"	E125°08'04.12506"	475.526	0.057	LLh
UP_MAN-2	N7°59'16.33836"	E125°08'03.89549"	394.653	0.061	
UP_LUM-2	N7°56'49.14664"	E125°14'40.69052"	410.740	0.067	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. 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 control points used is indicated in Table 30.

Table 29. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BK-56	1st order, BM	8°9'52.69903"N	125°6'54.60334"E	727.714	903110.046	733046.488	656.645
BKN-475	2nd order, GCP	8°3'22.52096"N	125° 8' 4.12506"E	473.980	891131.322	735238.147	403.175
UP_MAN-2	Established	7°59'16.34151"N	125° 8' 3.89549"E	394.653	883566.236	735270.463	322.44
UP_LUM-2	Established	7°56'49.14628"N	125°9'40.23913"E	411.207	879107.378	747450.247	339.432

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

Cross-section and as-built surveys were conducted on April 27, 2016 at the upstream side of Manupali Bridge in Brgy. Violeta, City of Malaybalay as shown in Figure 39. Nikon® Total Station was utilized for this survey.

Figure 39. Manupali Bridge facing upstream

The cross-sectional line of Manupali Bridge is about 127.002 m with thirty-one (31) cross-sectional points using the established control points by ABSD, UP_MAN-1 and UP_MAN-2 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 40 to Figure 42.

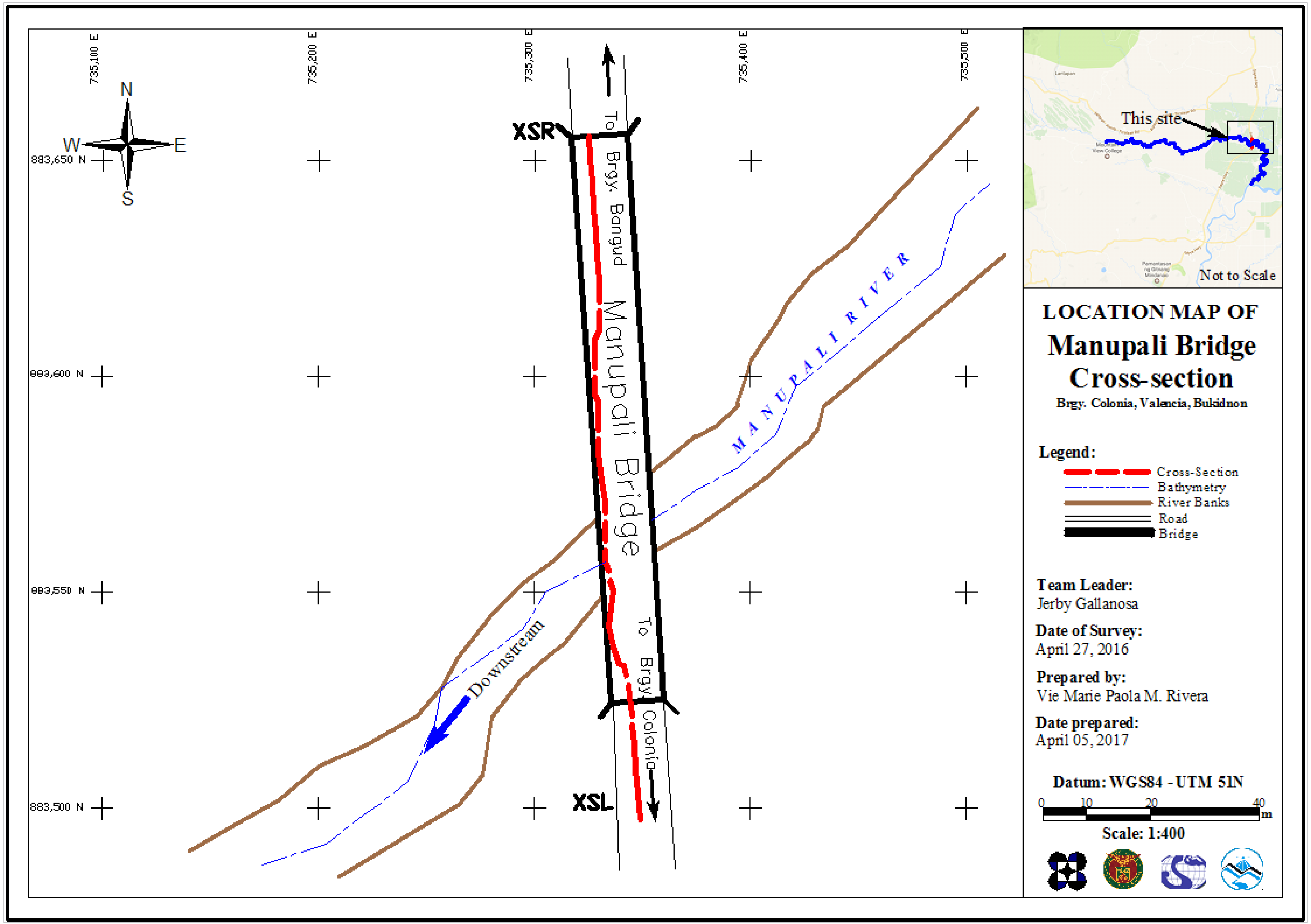


Figure 40. Valencia Bridge Location Map

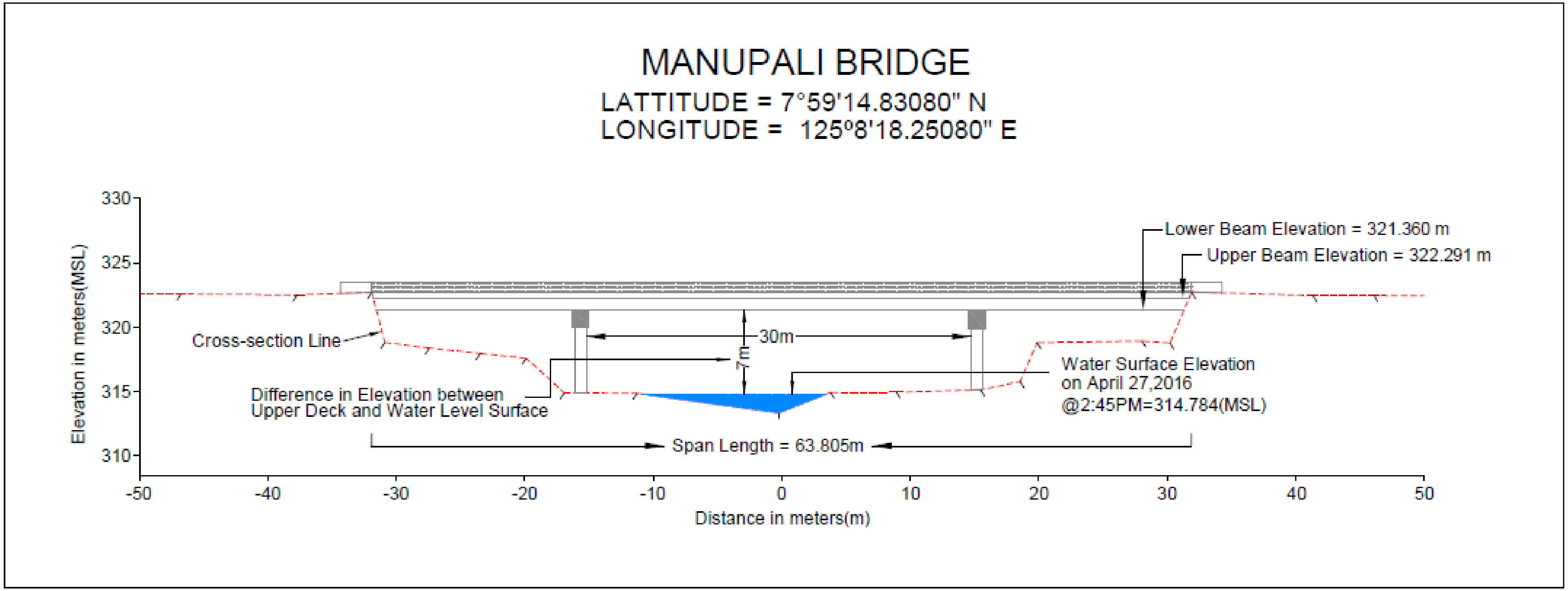


Figure 41. Manupali Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: MANUPALI BRIDGE

River Name: MANUPALI RIVER

Location (Brgy, City, Region): Brgy. Colonia, Valencia City, Bukidnon

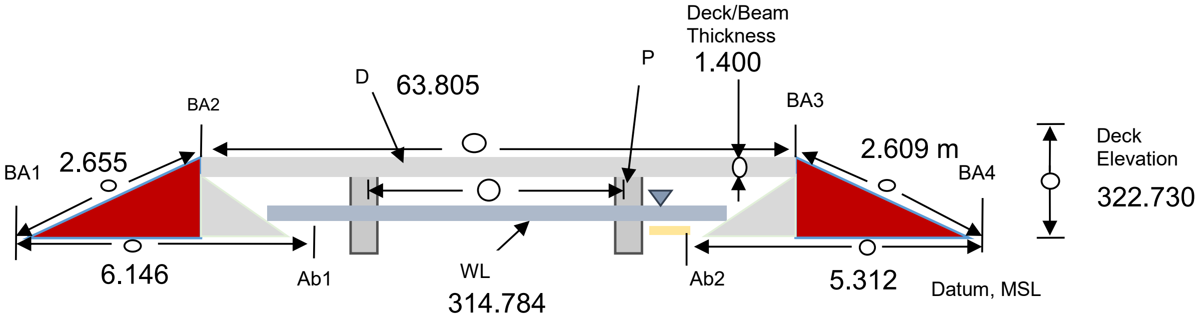
Survey Team: Jerby Gallosa

Date and Time: April 27, 2016; 2:45 P.M.

Flow Condition: low ✔normal high

Weather Condition: ✔fair rainy

Cross-sectional View (not to scale)



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

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	2.655 m	
2. BA2-BA3	63.805 m	
3. BA3-BA4	2.609 m	
4. BA1-Ab1	6.146 m	
5. Ab2-BA4	5.312 m	
6. Deck/beam thickness	1.400 m	
7. Deck elevation	322.730 m	

Note: Observer should be facing downstream

Figure 42. Valencia Bridge Data Sheet

Water surface elevation of Manupali River was determined by a Nikon® Total Station on April 27, 2016 at 2:45 PM at Manupali Bridge area with a value of 314.784 m in MSL as shown in Figure 41. This was translated into marking on the bridge's abutment as shown in 43. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Manupali River, Central Mindanao University.

Figure 43. Water-level markings on Manupali Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 12, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached at the back of the vehicle as shown in Figure 45.It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.235 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with PLW-48 occupied as the GNSS base station in the conduct of the survey.

Figure 44. Validation points acquisition survey set-up for Manupali River

The survey started from Brgy. Basak, Municipality of Lantapan, Bukidnon going southeast along the national highway and ended in Brgy. Dologon, City of Valencia, Bukidnon. A total of 9,668 points were gathered with an approximate length of 54 km using UP_MAN-2 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 46.

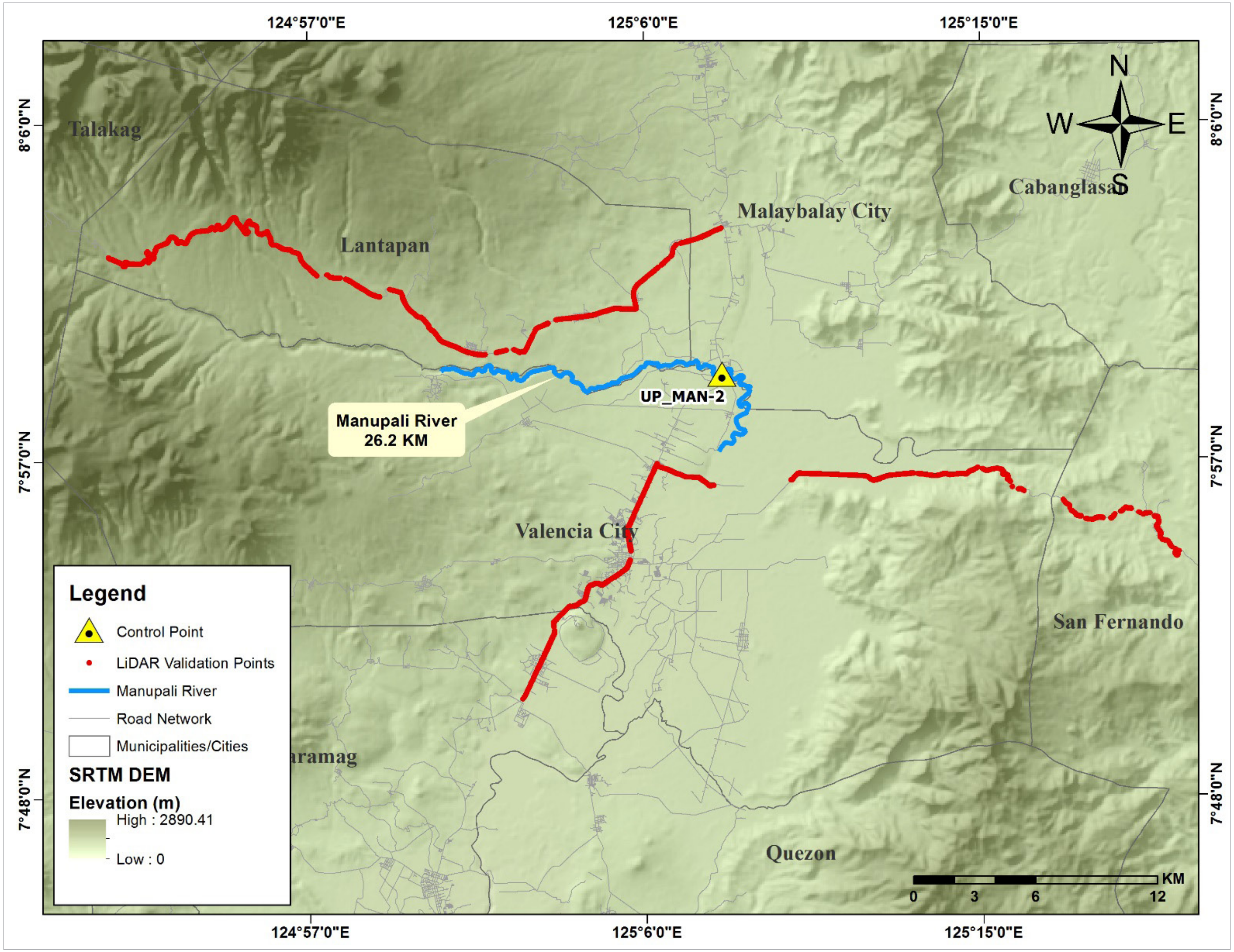


Figure 45. Validation points acquisition covering the Manupali River Basin Area

4.7 River Bathymetric Survey

Manual bathymetric survey was executed on April 11, 15, 16 and 18, 2016 using a NIkon® Total Station as illustrated in Figure 46. The survey started downstream in Brgy. Mt. Nebo, City of Valencia, Bukidnon with coordinates 7°59'26.01012"N, 125° 0' 36.38397"E and ended upstream in Brgy. Mailag, City of Valencia, Bukidnon, with coordinates 7° 57' 12.79718"N, 125° 7' 57.96163"E. The established control points established by ABSD, AB-13M and AB-14M, were used as GNSS base station all throughout the entire survey.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 11, 2016 using a Trimble® SPS 882 GNSS PPK survey technique, see Figure 47. A map showing the DVBC bathymetric checking points is shown in Figure 49.

Linear square correlation (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R^2 value must be within 0.85 to 1. An R^2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R^2 value of 0.898 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bathymetric data, a computed value of 0.162 was acquired. The computed R^2 and RMSE values are within the accuracy requirement of the program.

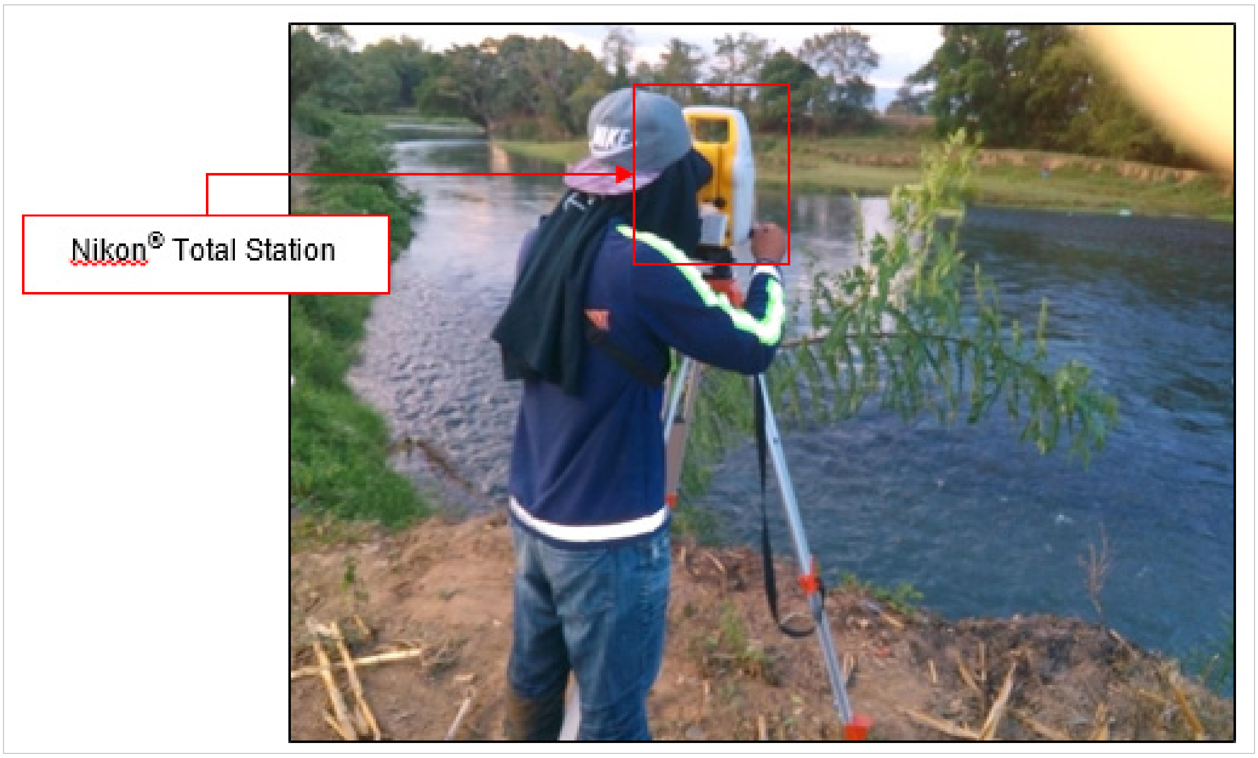


Figure 46. Manual Bathymetric survey of ABSD at Manupali River using Nikon® Total Station

Figure 47. Gathering of random bathymetric points along Upper Pulangui River

The manual bathymetric survey for Manupali River gathered a total of 4,060 points covering an approximate of 26.2 km of the river traversing Brgy. Colonia, San Carlos, Lurogan, Mt. Nebo and Mailag in the City of Valencia, Bukidnon, Brgy. Sto. Nino and Bangcud in the City of Malaybalay, Bukidnon and Brgy. Kulasihan, Bantuaon and Poblacion in the Municipality of Lantapan, Bukidnon. A CAD drawing was also produced to illustrate the riverbed profile of Manupali River. As shown in Figure 50, the highest and lowest elevation has a 255-m difference. The highest elevation observed was 556.638 m above MSL located in Brgy. Mt. Nebo, Valencia City, Bukidnon while the lowest was 306.500 m above MSL located in Brgy. Mailag, Valencia City, Bukidnon.

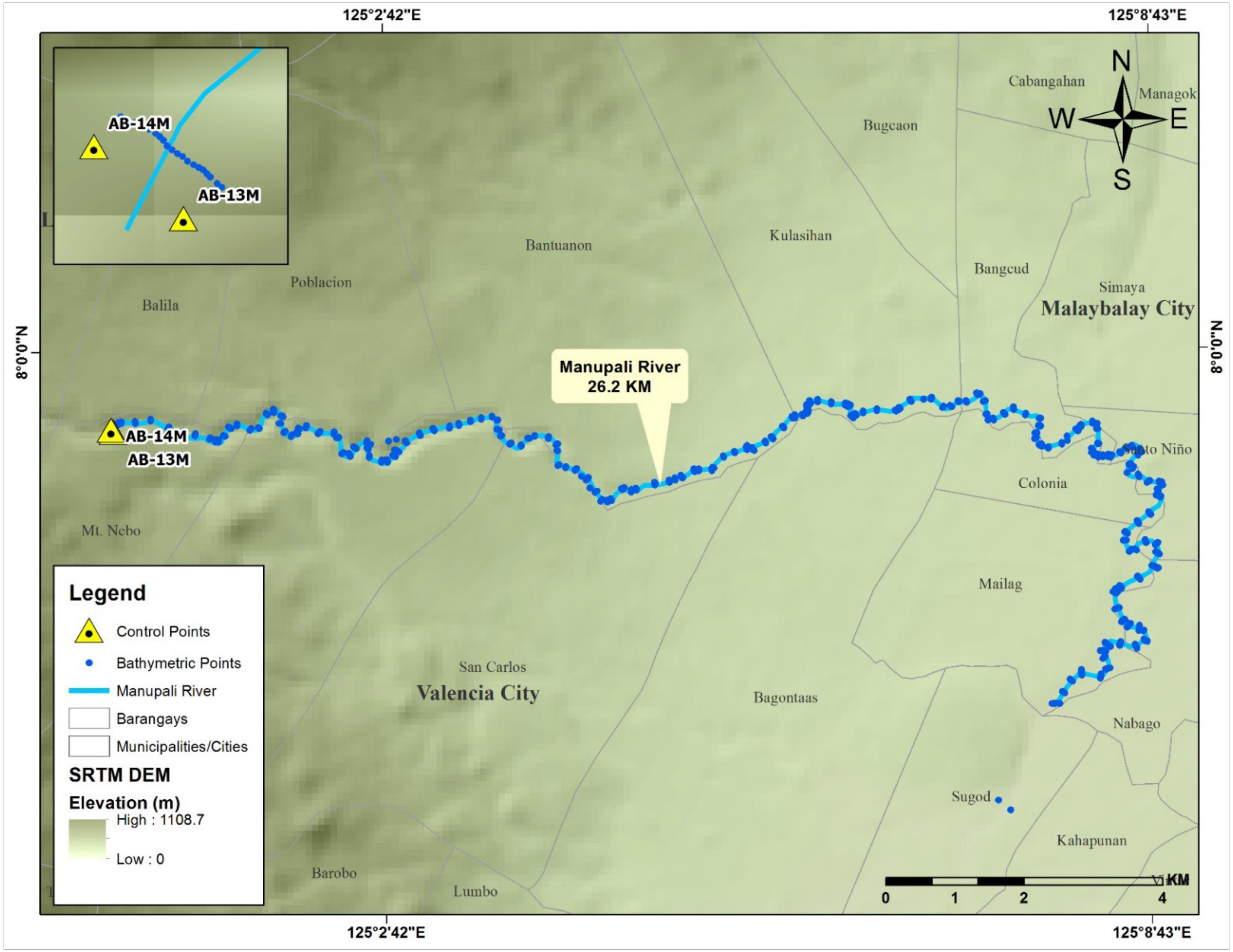


Figure 48. Bathymetric survey of Manupali River

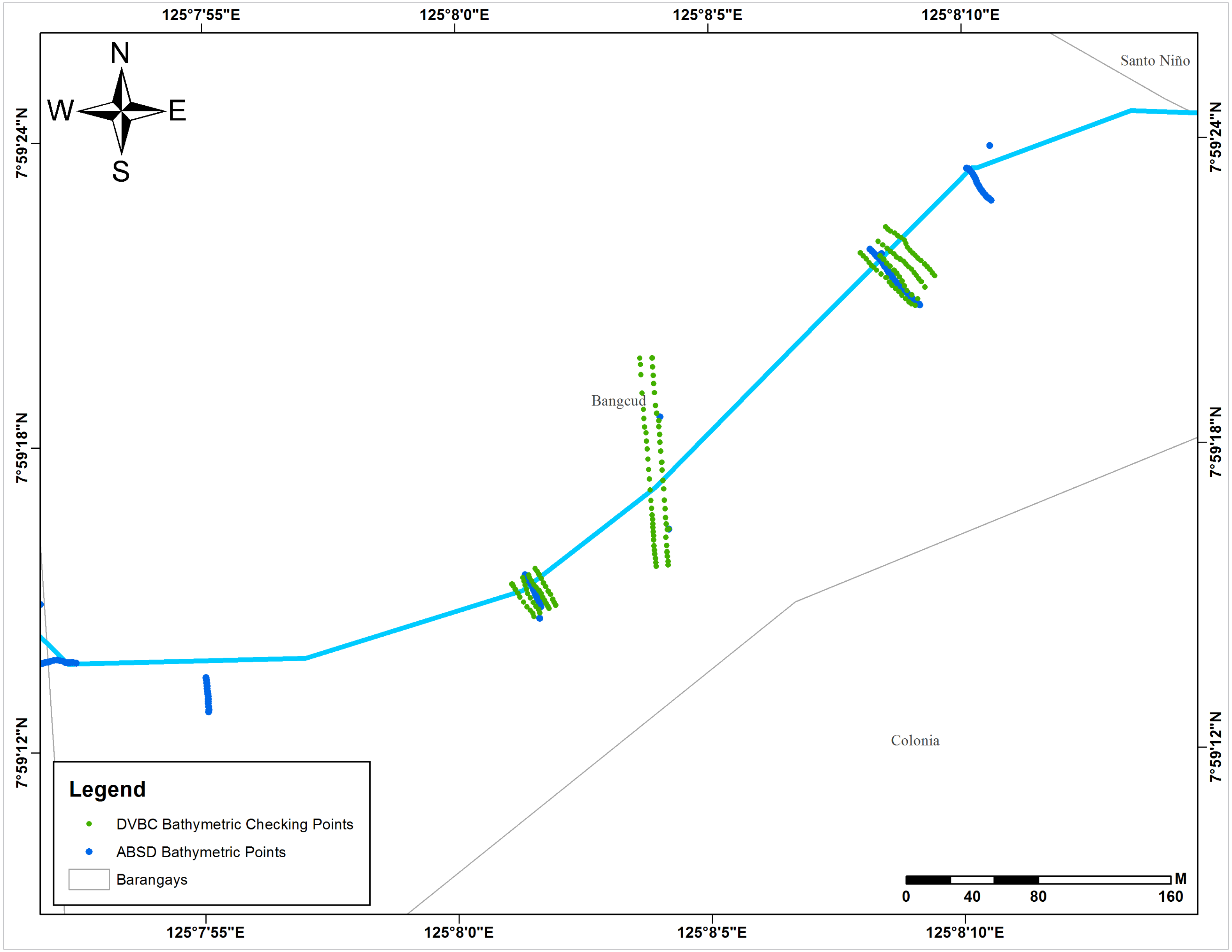


Figure 49. Quality checking points gathered along Manupali River by DVBC

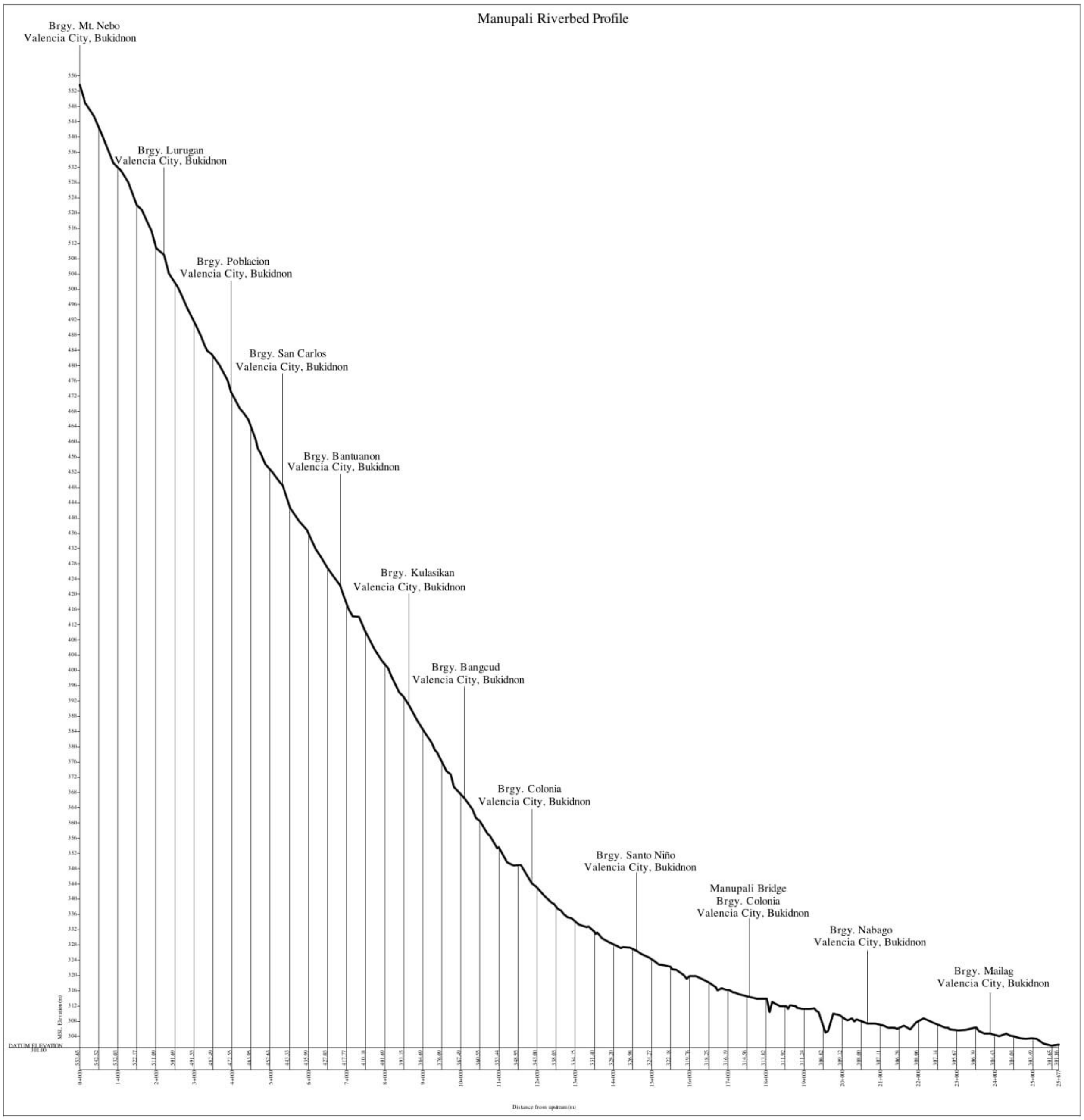


Figure 50. Manupali Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

The 24 hours duration of rainfall data on 23 May 2016 from 1320 hours of 23 May 2016 to 1320 hours of 24 May 2016 was collected from the rain gauges in Lantapan and Mountain View College. CMU Phil-LiDAR 1 initiated to install an automatic rain gauge in Lantapan (8°0'2"N, 125° 1'12"E) considering that Lantapan has contributing factor when it comes to rainfall. On the other hand, Mountain View College (7°58'56"N, 125° 0'35"E) was installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI) Region X.

Total rain for this event in Mountain View College rain gauge is 51.4mm. It peaked to 7.8 mm on 23 May 2016 12:00. For Poblacion, total precipitation for this event is 79.2 mm. Peak rain of 17.6 mm was recorded on 23 May 2016, 12:00. The two rain gauges in the Maupali River Basin are shown in Figure 51.

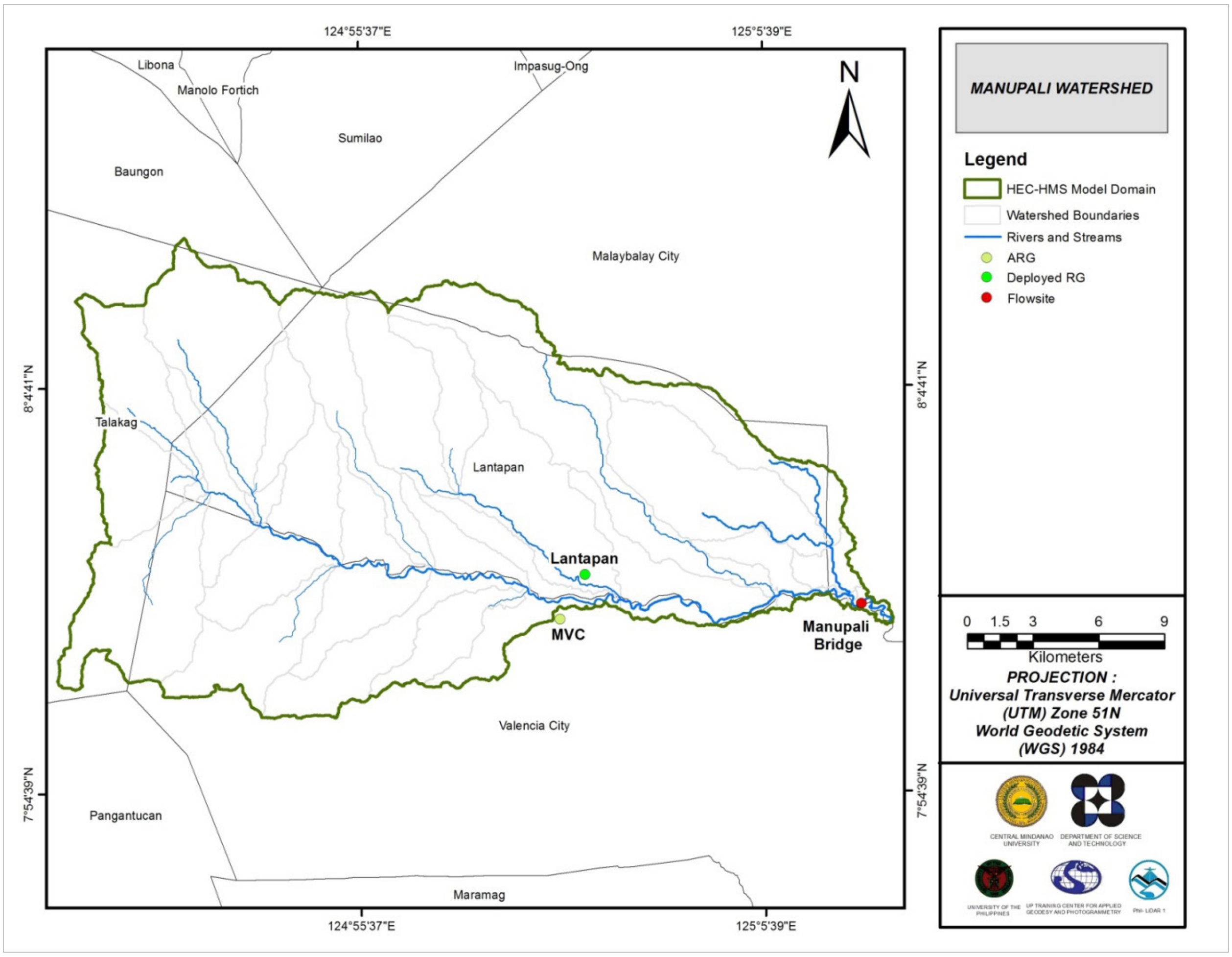


Figure 51. The location map of Manupali HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

The event on 23 May 2016 resulted to a water level rise of 0.74 meter and peak discharge of 11.03 m³/s recorded at 2110 hours taken from Manupali Bridge, National Highway, Brgy. Colonia. Lag time between peak rainfall and peak discharge is 9 hours and 10 minutes (Figure 53). The collected hydrologic data are inputted in HEC-HMS for the basin model calibration.

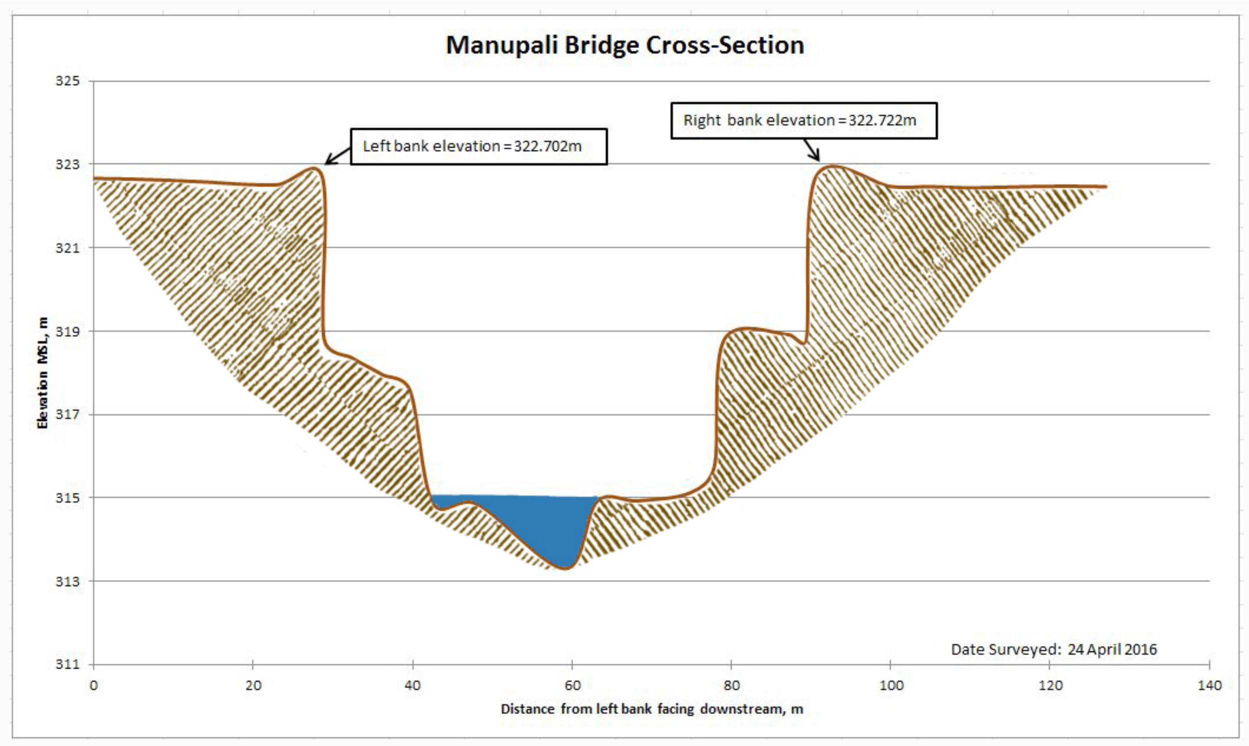


Figure 52. The cross-section plot of the Manupali Bridge

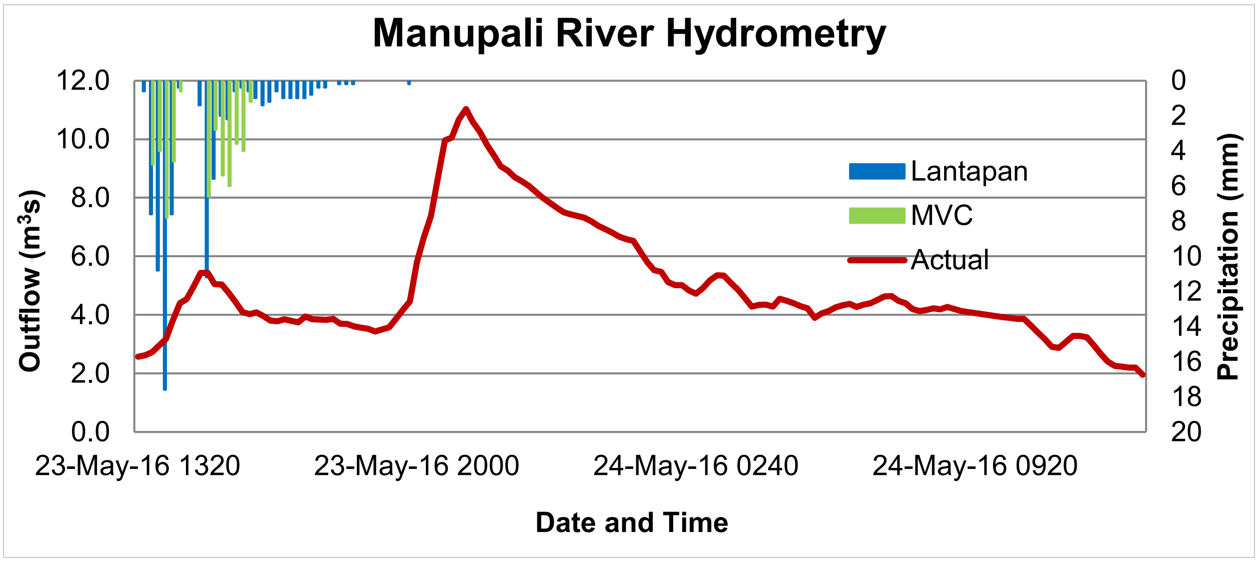


Figure 53. Rainfall and outflow data used for modeling.

A rating curve was generated to illustrate the relationship of the observed flow and water level. It is expressed in the form of the following equation::

$$Q=a^{nh}$$

where,

Q:	Discharge (m³/s),
h:	Gauge height (reading from Riverside staff gauge), and
a and n:	Constants.

The Manupali River Rating Curve measured at Manupali Bridge, National Highway, Brgy. Colonia is expressed as $Q = 0.2546^{0.1316x}$ (Figure 54).

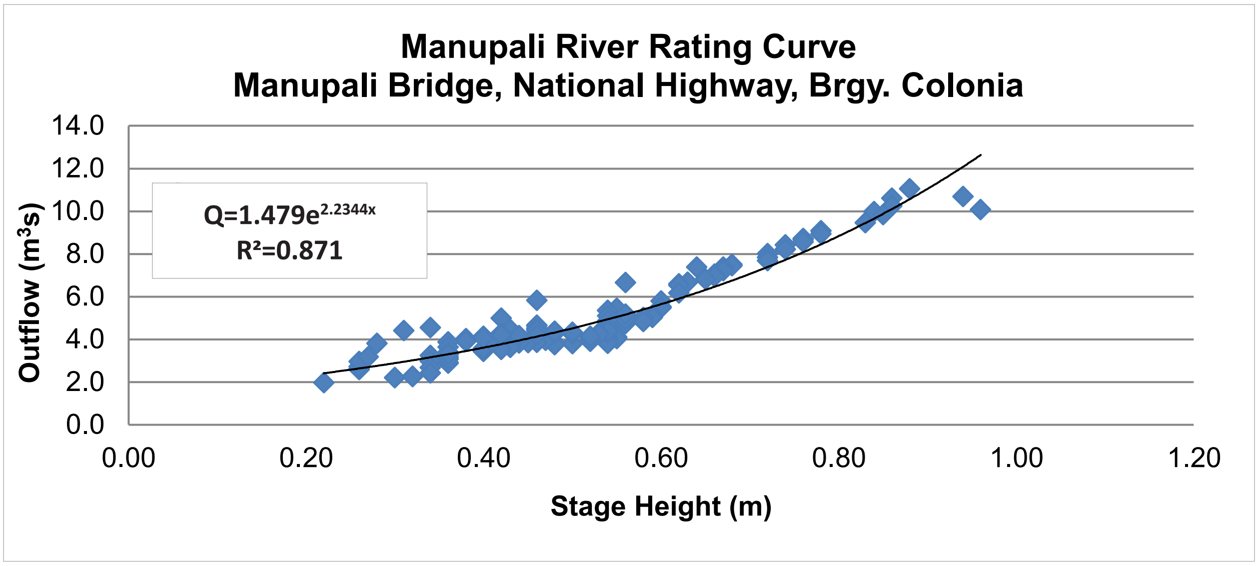


Figure 54. HQ Curve of HEC-HMS model.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Malaybalay 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 is chosen based on its proximity to the Manupali watershed. The extreme values for this watershed were computed based on a 31-year record.

Table 30. RIDF values for Malaybalay 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	17.9	28.5	35.6	47.8	63.7	73.5	90.2	103.4	112.8
5	26.7	45.3	57.9	78.4	100.8	114.3	130.2	143.2	153.6
10	32.5	56.5	72.7	98.6	125.3	141.4	156.7	169.6	180.7
15	35.8	62.8	81	110	139.1	156.6	171.6	184.4	195.9
20	38.1	67.2	86.8	117.9	148.8	167.3	182.1	194.8	206.6
25	39.9	70.6	91.3	124.1	156.3	175.5	190.1	202.8	214.8
50	45.4	81	105.1	143	179.3	200.9	214.9	227.5	240.2
100	50.8	91.4	118.8	161.8	202.2	226	239.5	252	265.3

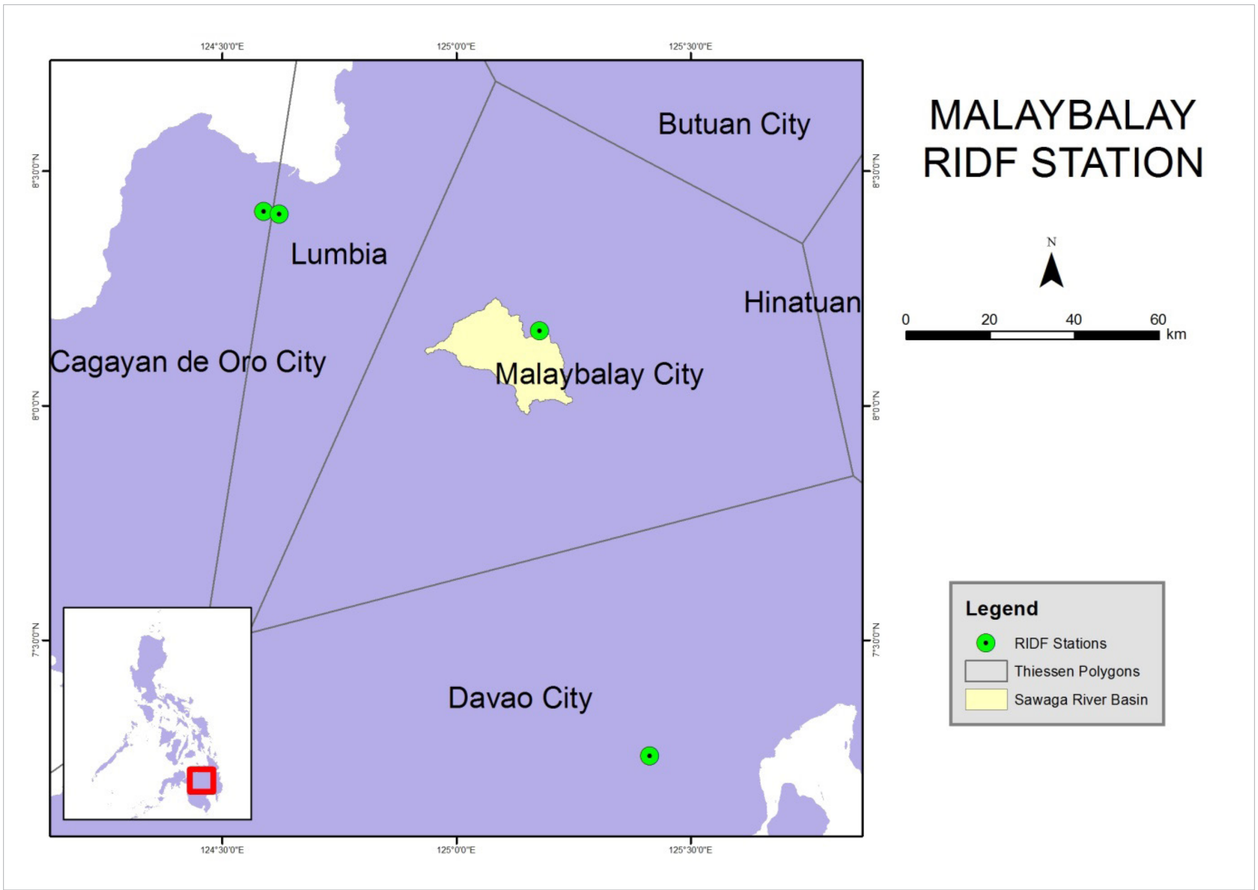


Figure 55. Location of Malaybalay RIDF Station relative to Manupali River Basin

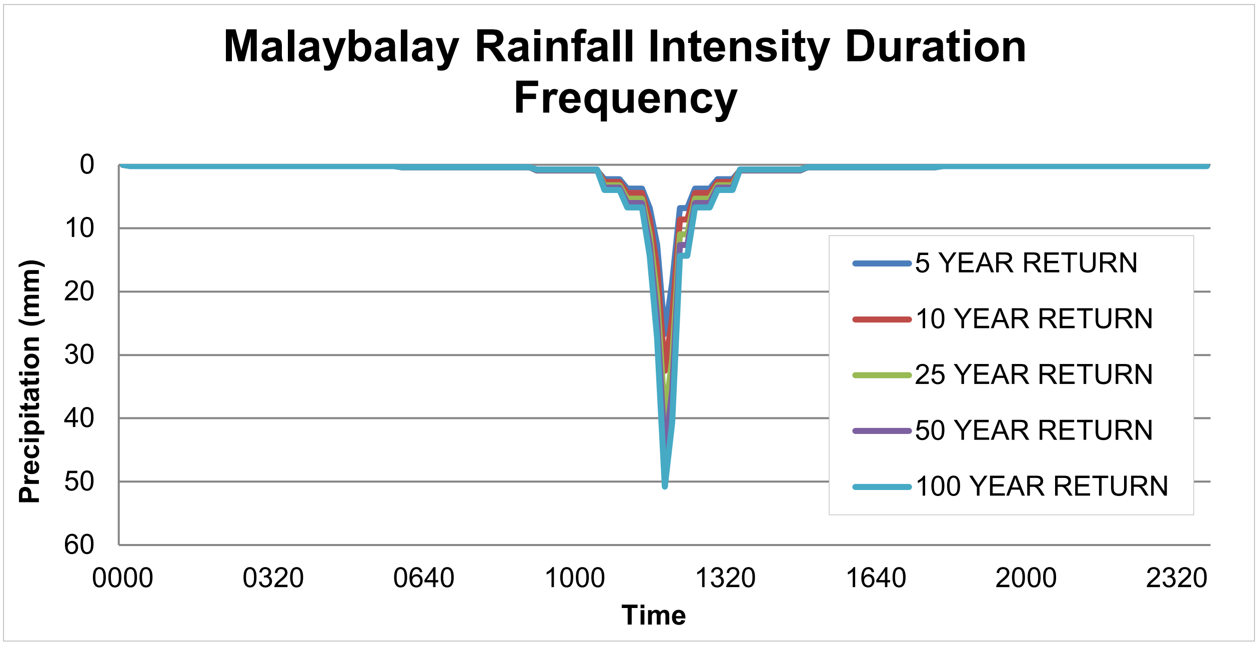


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shapefile (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Manupali River Basin are shown in Figures 57 and 58, respectively.

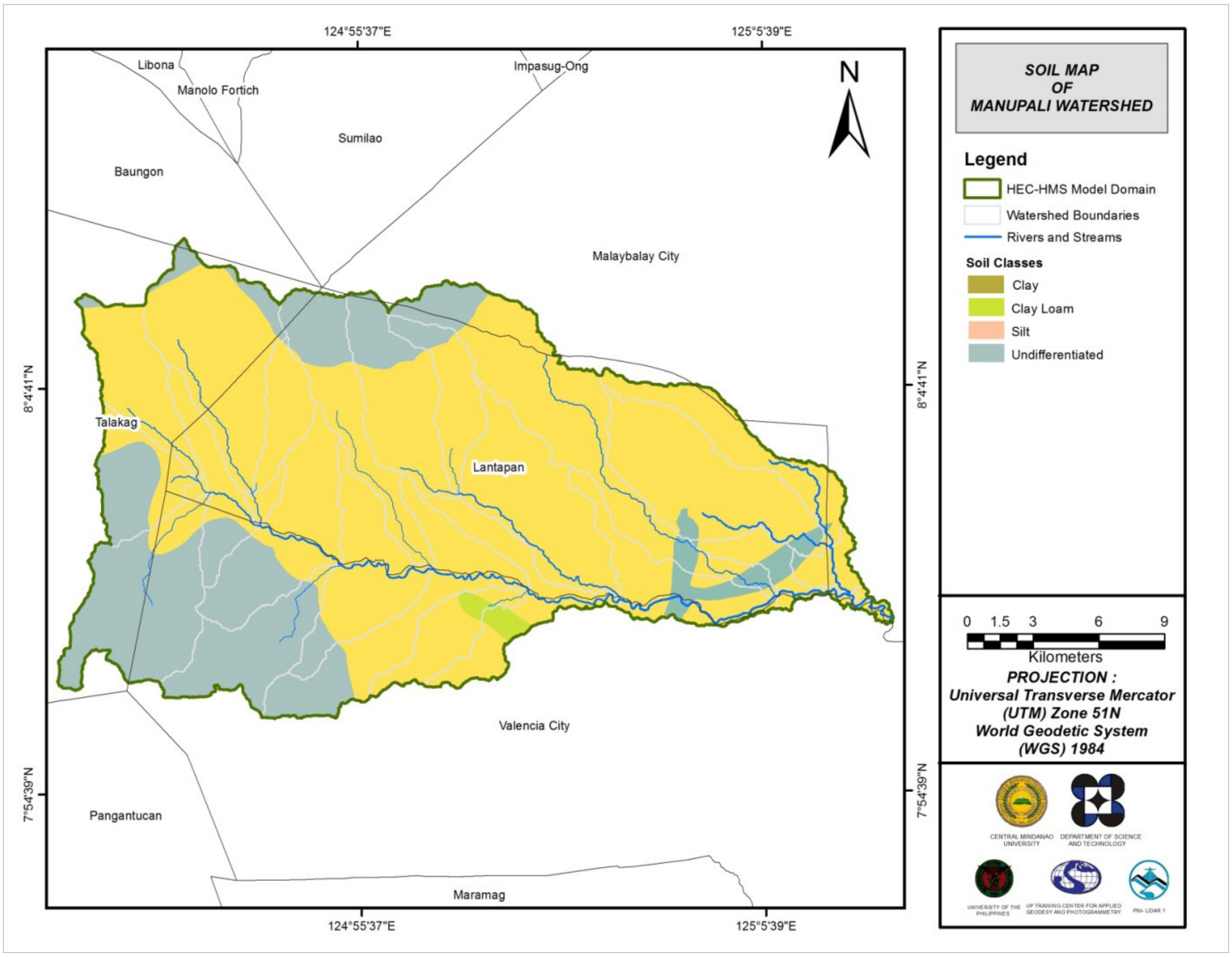


Figure 57. The soil map of the Manupali River Basin (Source: Bureau of Soils and Water Management)

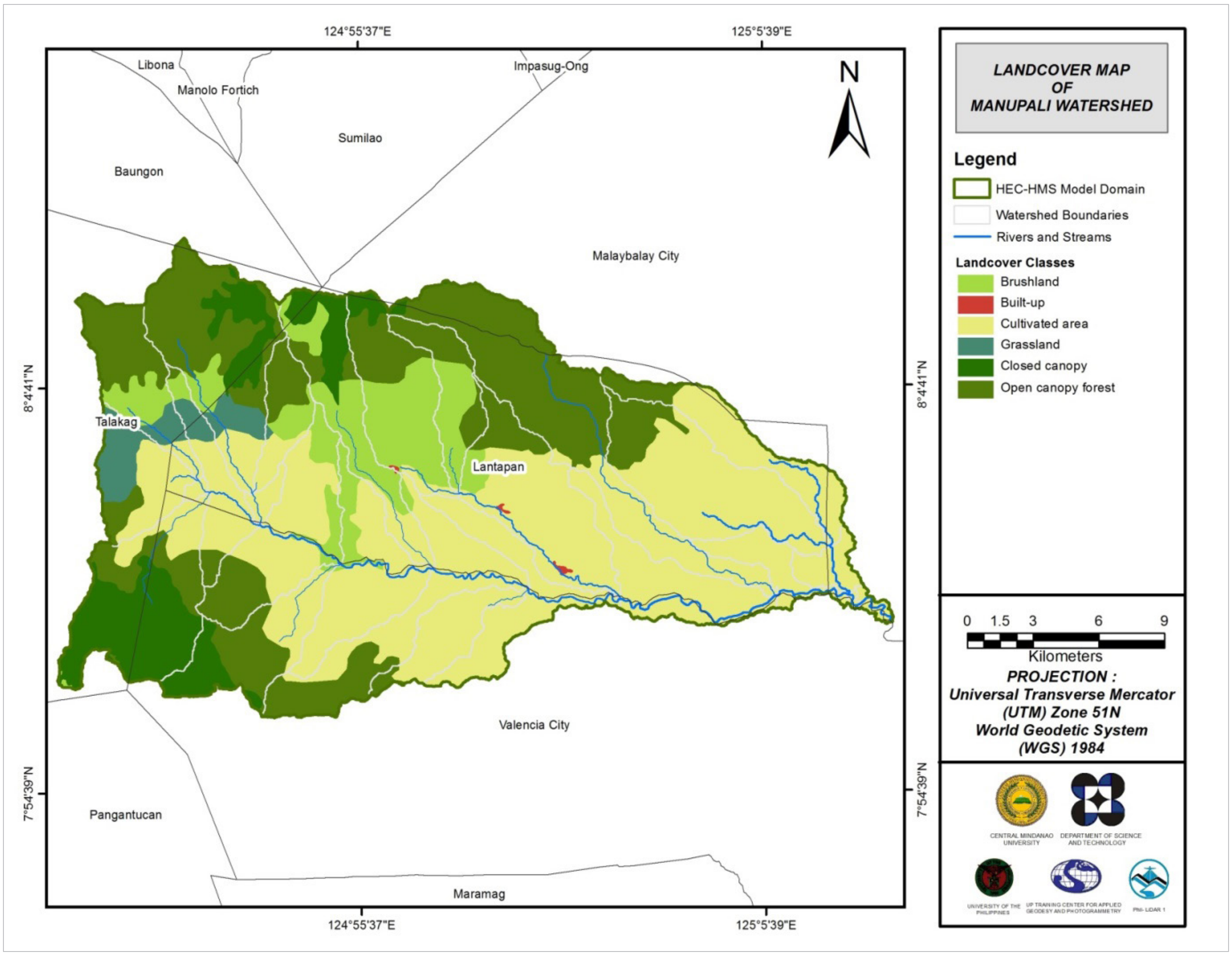


Figure 58. The land cover map of the Manupali River Basin (Source: NAMRIA)

For Manupali, four soil classes were identified. These are clay loam, clay, silt, and undifferentiated soil. Moreover, six land cover classes were identified. These are brushland, built-up, cultivated area, grassland, closed canopy, and open canopy forest.

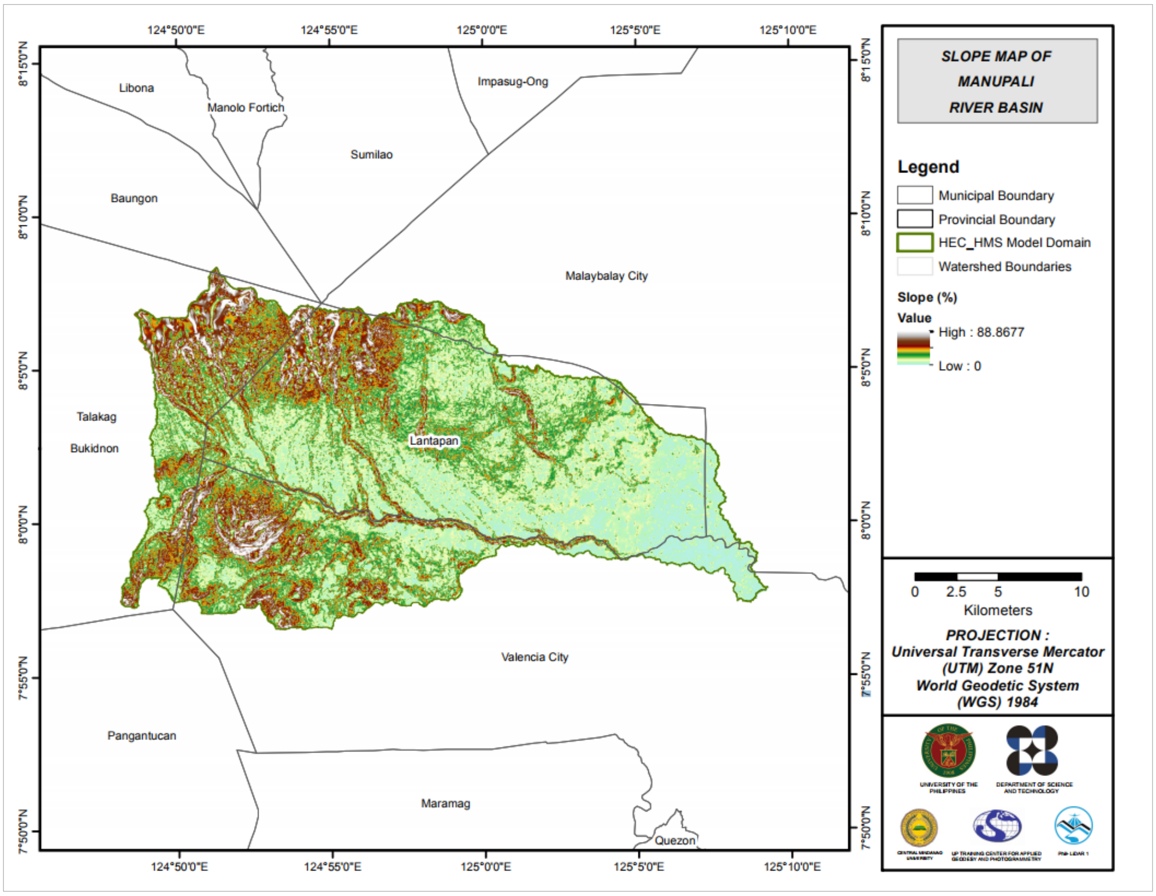


Figure 59. Slope Map of Manupali River Basin

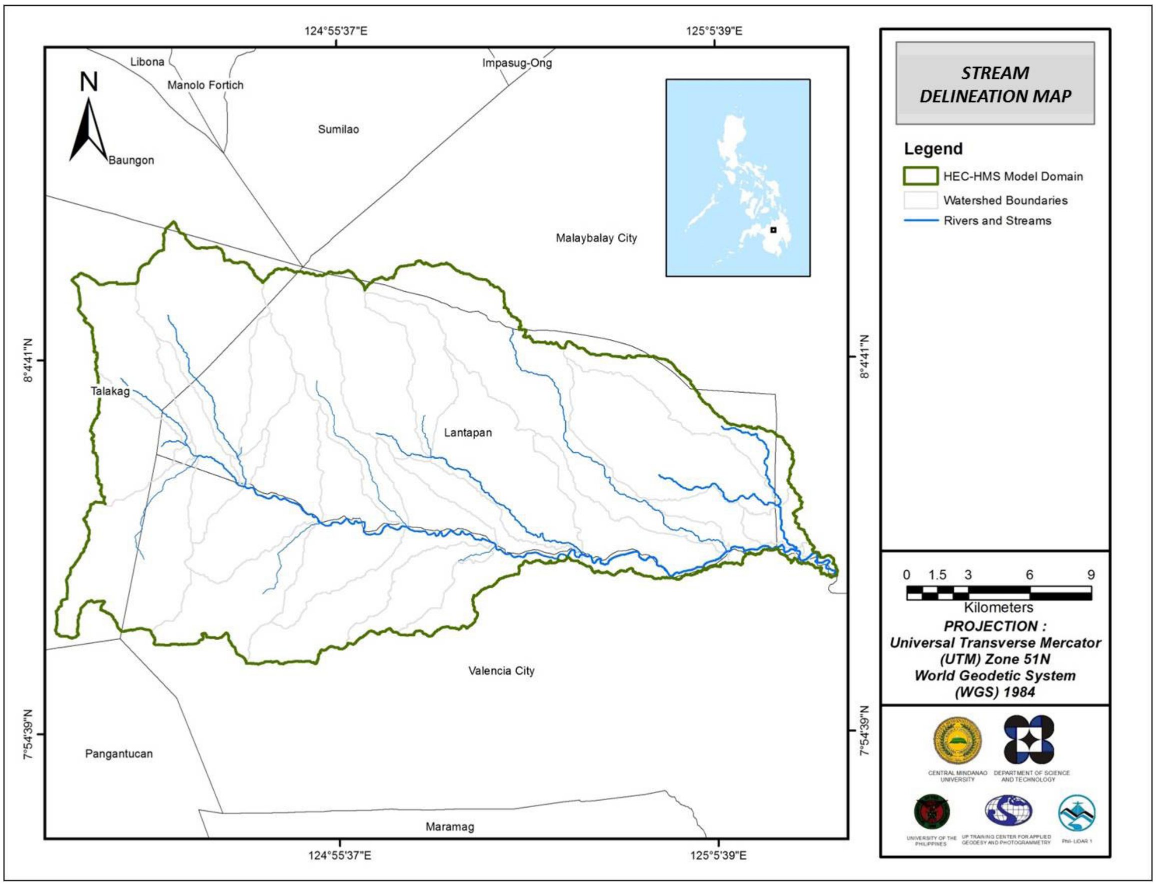


Figure 60. Stream delineation map of Manupali river basin

Using ArcMap 10.1 with HEC-GeoHMS version 10.1 extension, the drainage system of Silway river was delineated using the river's centreline and SAR-DEM 10m resolution as primary input data. Delineated drainage system includes the basin boundary, subbasin and the stream networks. The river centreline was digitized starting from upstream towards downstream in Google Earth (2014).

Using the 10m SAR-DEM with default threshold area of 500 hectares, the delineated drainage system of Manupali Watershed generated twenty-six (26) sub-basins, thirteen (13) reaches and fourteen (14) junctions including the main outlet of the watershed (Figure 61).

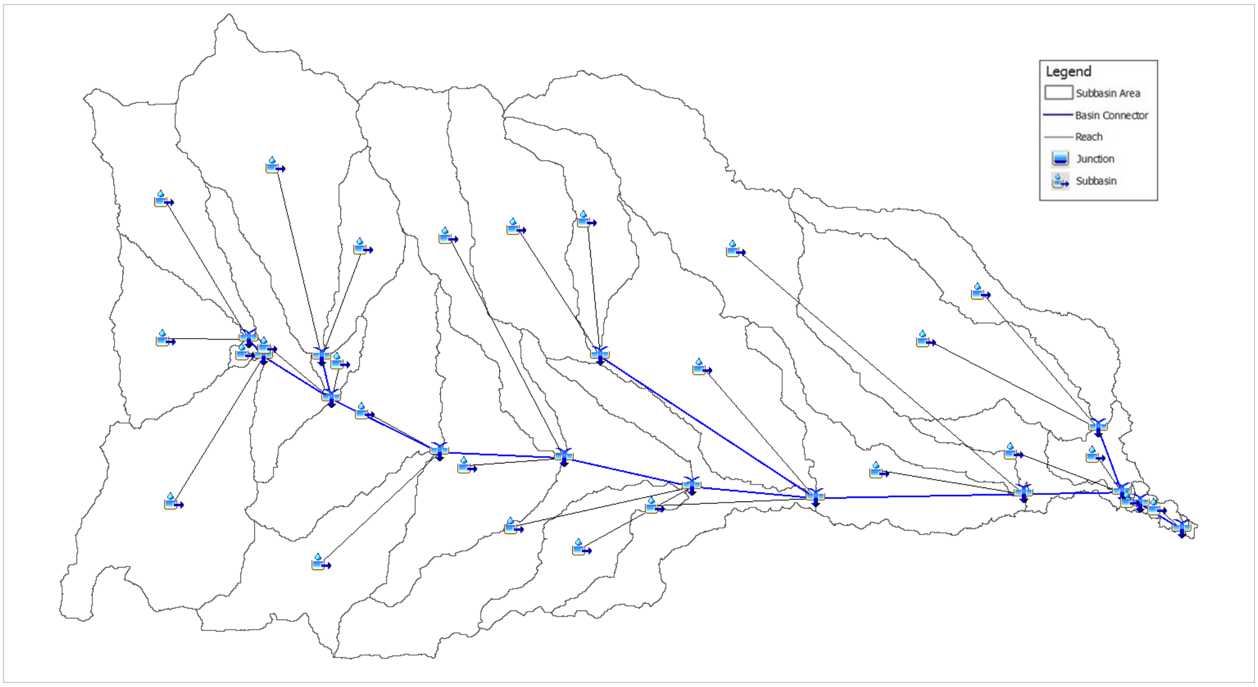


Figure 61. HEC-HMS generated Manupali River Basin Model.

5.4 Cross-section Data

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

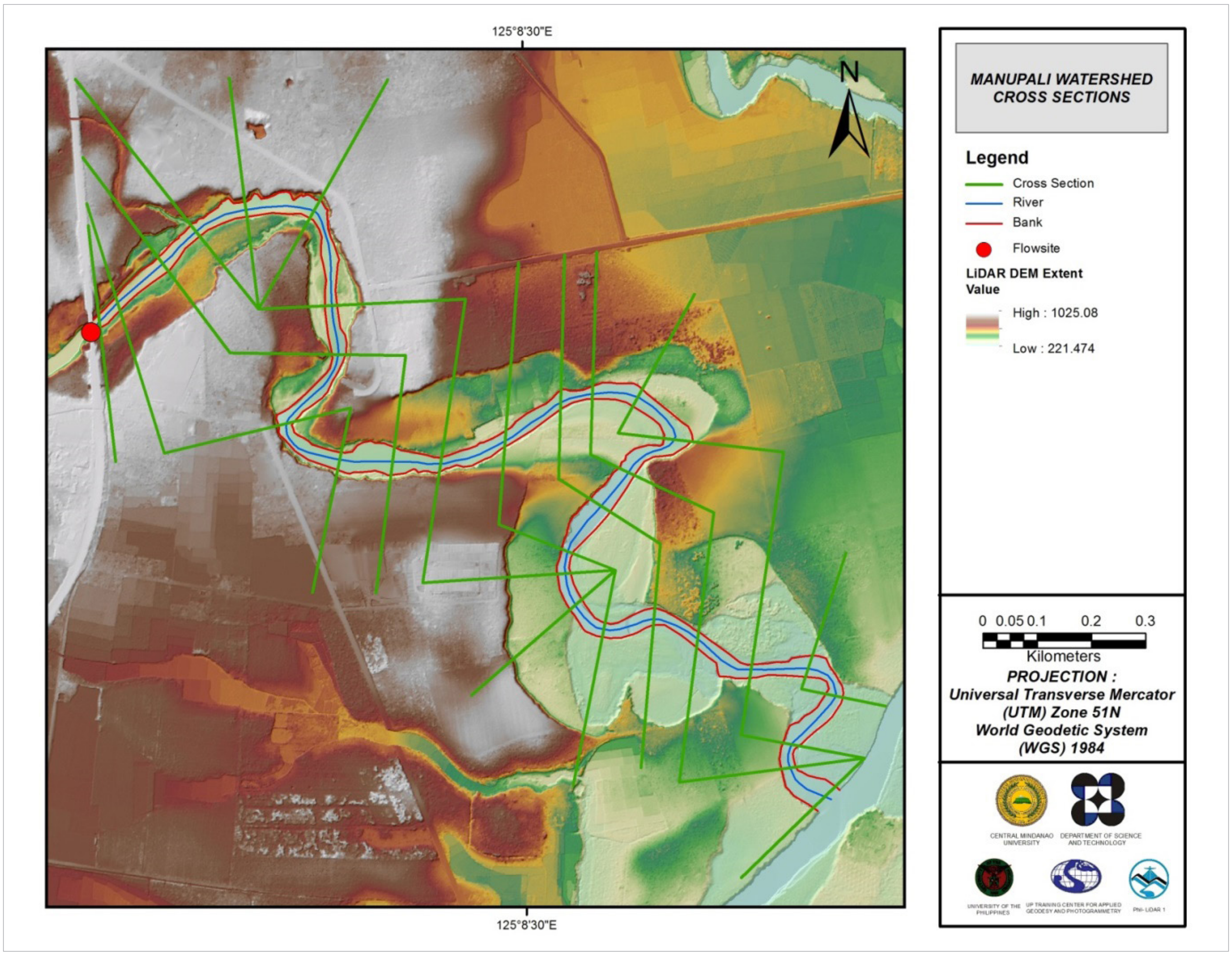


Figure 62. Manupali River Cross-section generated using HEC GeoRAS tool.

5.5 Flo 2D Model

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

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

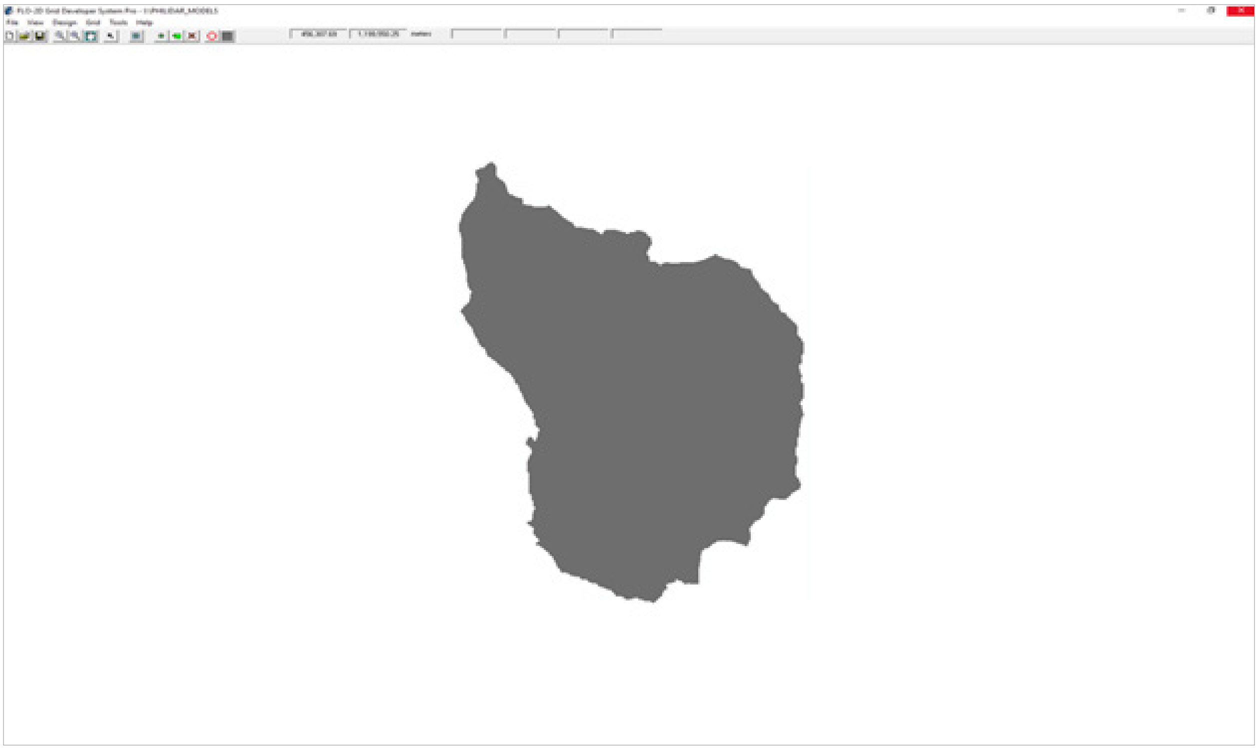


Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 28.32373 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 **m²**/s.

The 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 30 871 500.00 **m²**.

There is a total of 208 903 237.15 m³ of water entering the model. Of this amount, 11 957 813.56 m³ is due to rainfall while 196 945 423.58 m³ is inflow from other areas outside the model. 3 829 085.00 m³ of this water is lost to infiltration and interception, while 2 099 733.22 m³ is stored by the flood plain. The rest, amounting up to 202 974 422.96 m³, is outflow.

5.6 Results of HMS Calibration

After calibrating the Manupali HEC-HMS river basin model, its accuracy was measured against the observed values (see ANNEX 9: Manupali Model Basin Parameters). Figure 63 shows the comparison between the two discharge data.

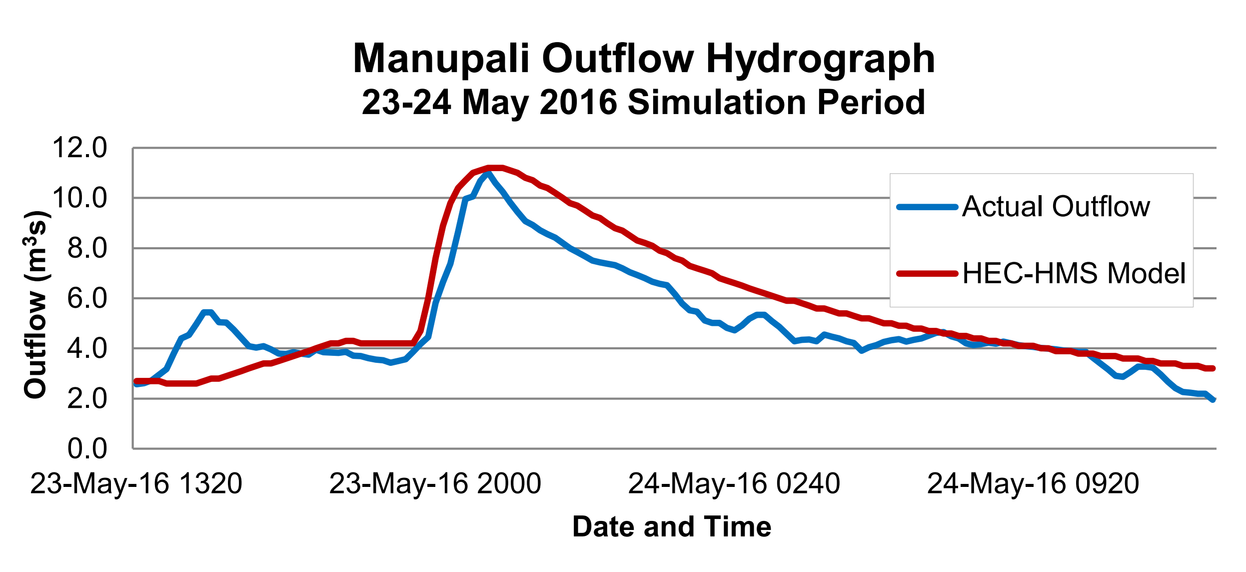


Figure 64. Outflow Hydrograph of Manupali produced by the HEC-HMS model compared with observed outflow.

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

Table 31. Range of calibrated values for the Manupali River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 - 95
			Curve Number	34 - 40
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 0.92
			Storage Coefficient (hr)	0.02 – 0.92
	Baseflow	Recession	Recession Constant	0.00001
			Ratio to Peak	0.00001
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.5

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 5mm to 95mm signifies that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 34 to 40 for curve number is less than the advisable range for Philippine watersheds (70 to 80) depending on the soil and land cover of the area (Horritt, personal communication, 2012). For Manupali, the basin mostly consists of cultivated area and open canopy forest; the soil consists mostly of clay and undifferentiated soil.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 0.92 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.00001 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.00001 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.5 is higher than the Manning's value (0.04) corresponding to the land cover of Manupali watershed which is determined to be cultivated with mature field crops (Brunner, 2010)

Table 32. Summary the Efficiency Test of the Manupali HMS Model

Accuracy measure	Value
RMSE	1.2
r^2	0.86
NSE	0.65
PBIAS	18.96
RSR	0.59

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.2 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.86.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.65.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 18.96.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.59.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 64) shows the Manupali River outflow using the Malaybalay Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

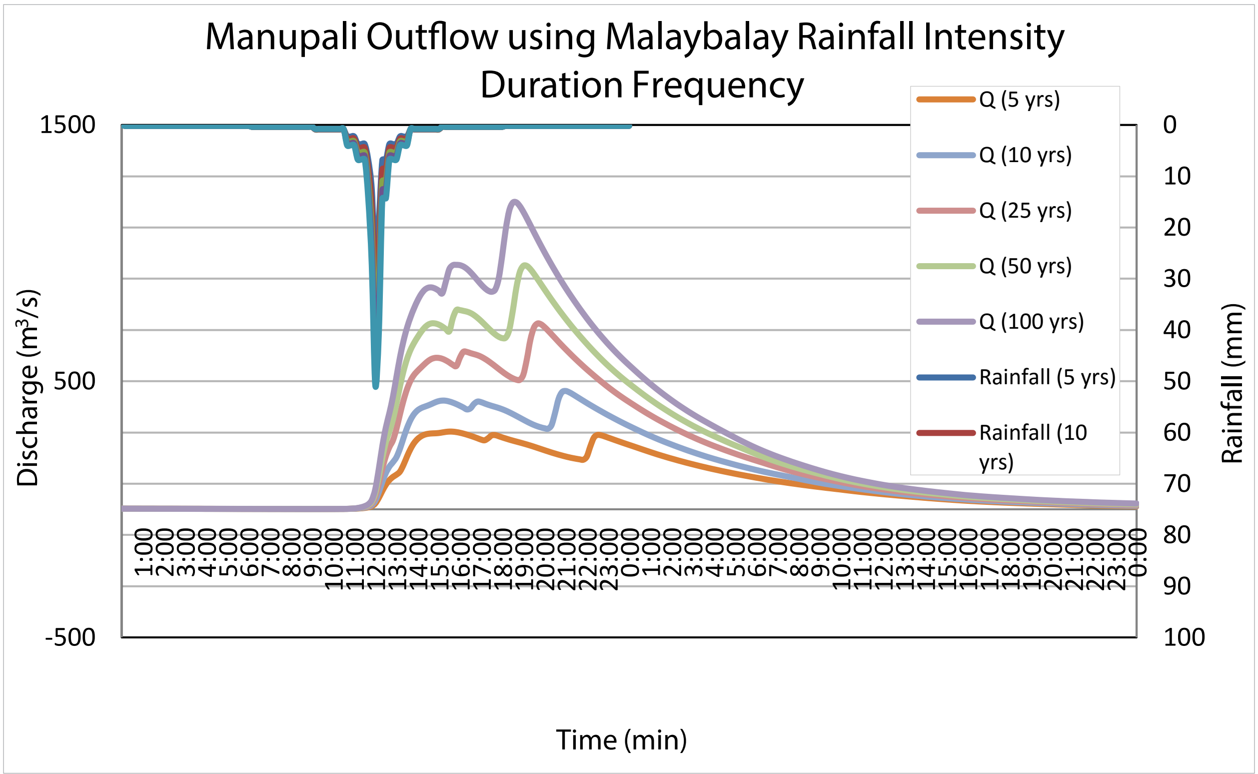


Figure 65. Outflow hydrograph at Manupali Station generated using Malaybalay RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Manupali discharge using the Malaybalay Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 33. Peak values of the Manupali HEC-HMS Model outflow using the Malaybalay RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-yr	153.6	26.7	258.7	5 hours and 10 minutes
10-yr	180.7	32.5	458.6	3 hours and 20 minutes
25-yr	214.8	39.9	657	2 hours
50-yr	240.2	45.4	870.1	1 hour and 20 minutes
100-yr	265.3	50.8	1101.9	50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Manupali River using the calibrated HMS base flow is shown in Figure 65.

Figure 66. Sample output of Manupali RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 5-, 25-, and 100-year rain return scenarios of the Manupali-Sawaga-Upper Pulangi floodplain. The floodplain, with an area of 732.86 sq. km., covers the municipalities of Lantapan, Maramag, Quezon, and San Fernando and the cities of Malaybalay and Valencia. Table 35 shows the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Manupali-Upper Pulangi-Upper Pulangi floodplain

Municipality	Total Area	Area Flooded	% Flooded
Lantapan	355.91	81.26	22.83%
Malaybalay City	1004.67	259.22	25.80%
Maramag	320.61	10.19	3.18%
Quezon	647.63	6.02	0.93%
San Fernando	605.87	0.49	0.08%
Valencia City	668.14	375.69	56.23%

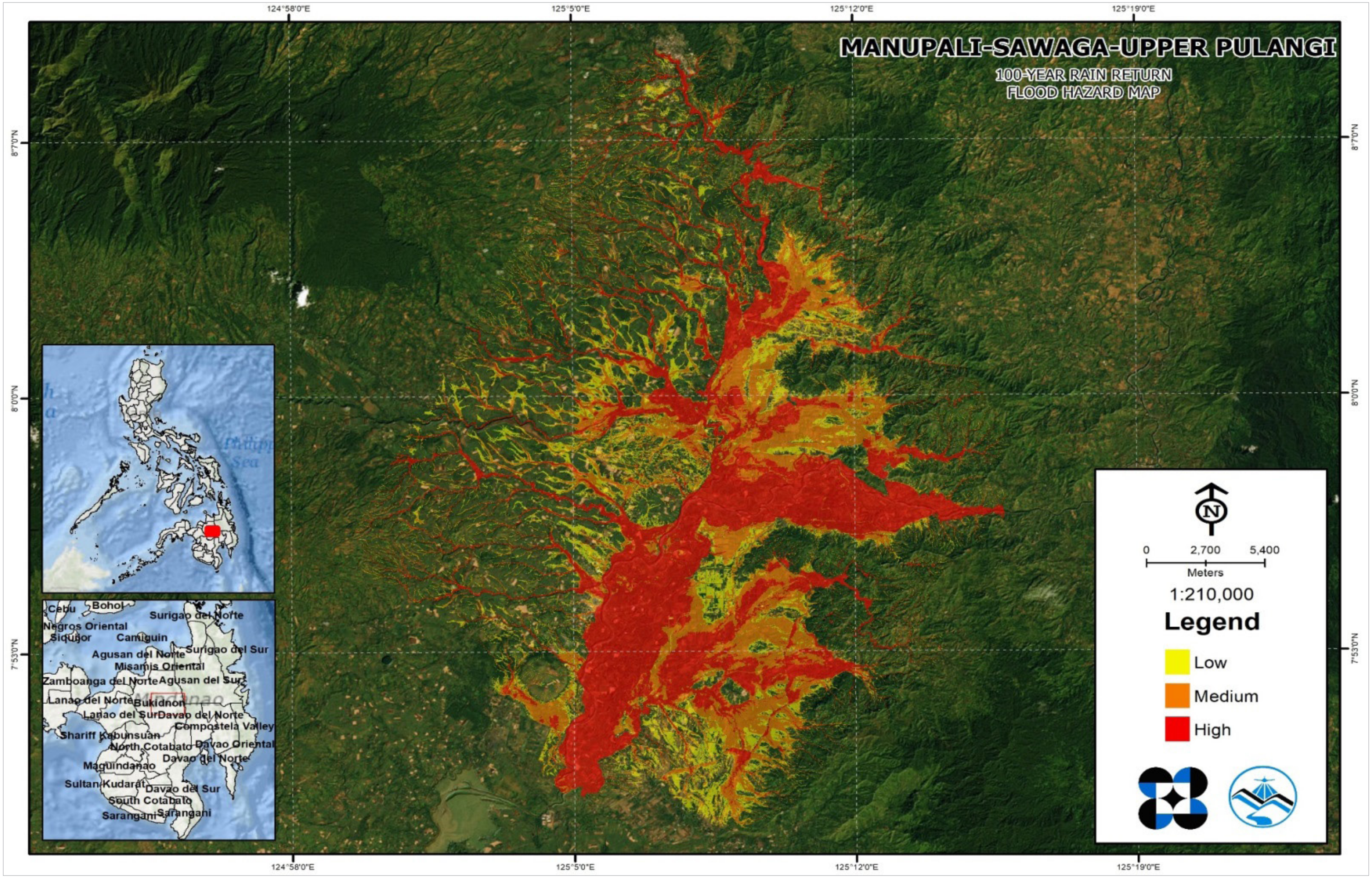


Figure 67. 100-year Flood Hazard Map for Manupali-Sawaga-Upper Pulangi Floodplain

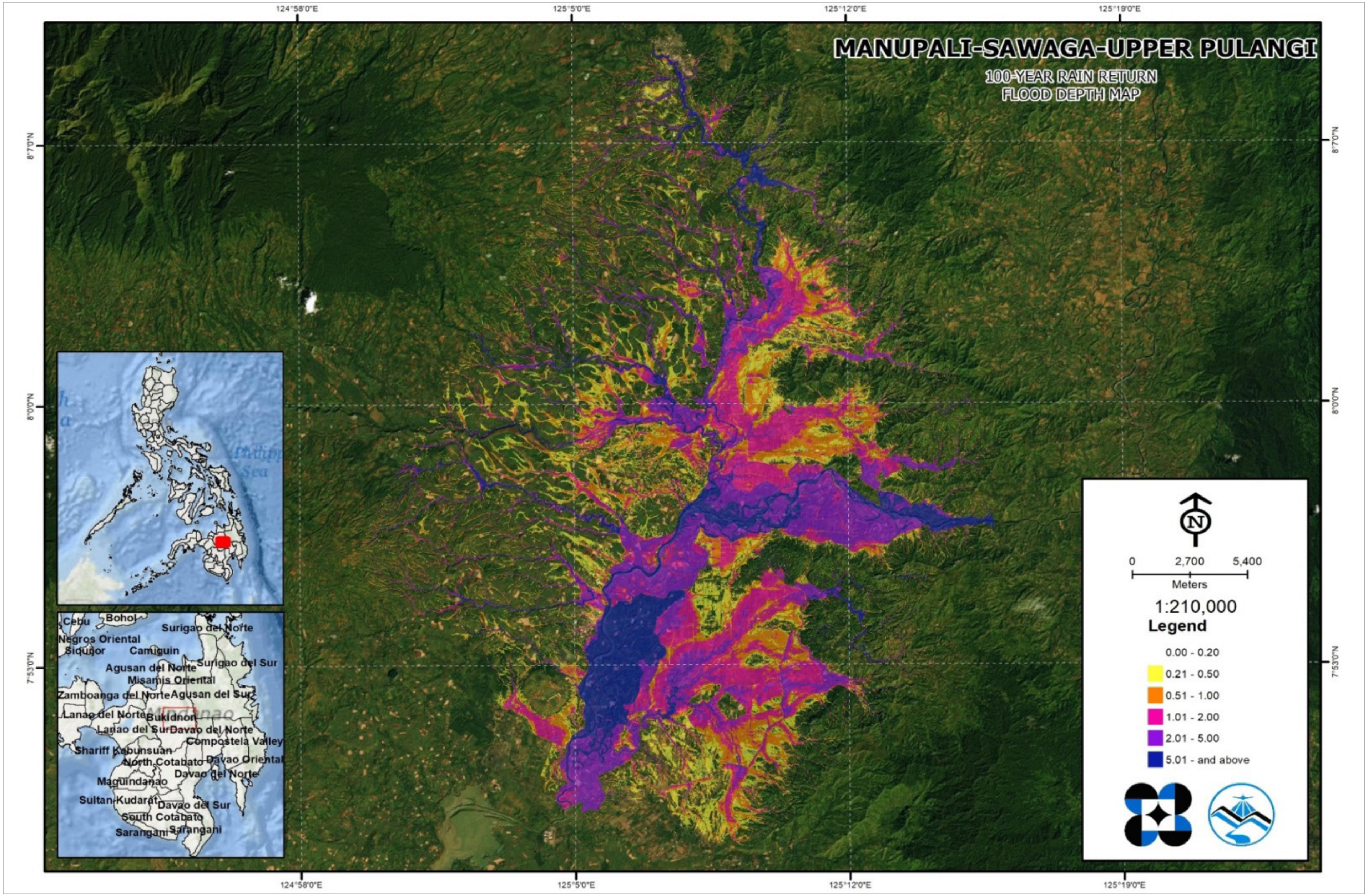


Figure 68. 100-year Flood Depth Map for Manupali-Sawaga-Upper Pulangi Floodplain

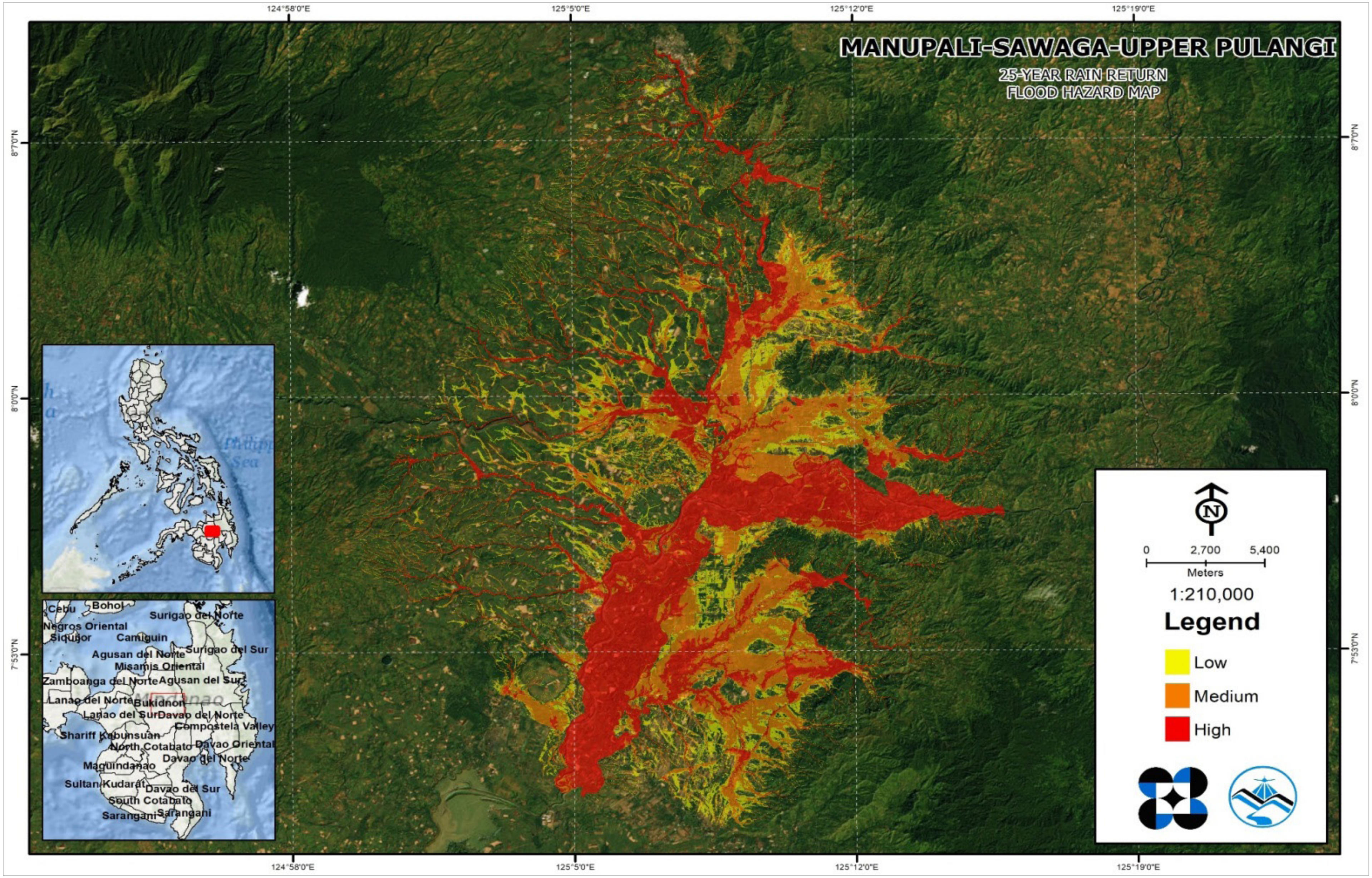


Figure 69. 25-year Flood Hazard Map for Manupali-Sawaga-Upper Pulangi Floodplain

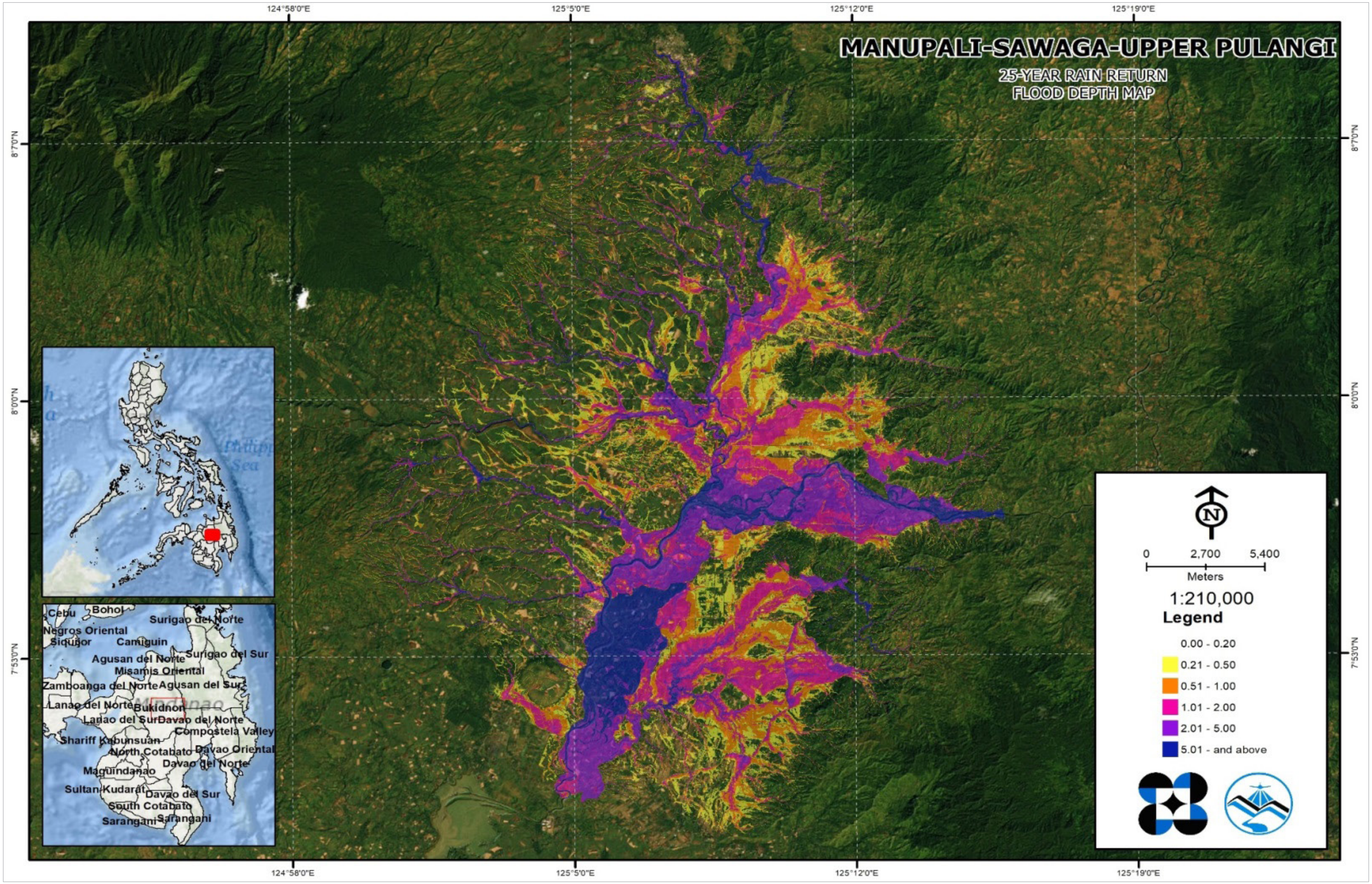


Figure 70. 25-year Flood Depth Map for Manupali-Sawaga-Upper Pulangi Floodplain

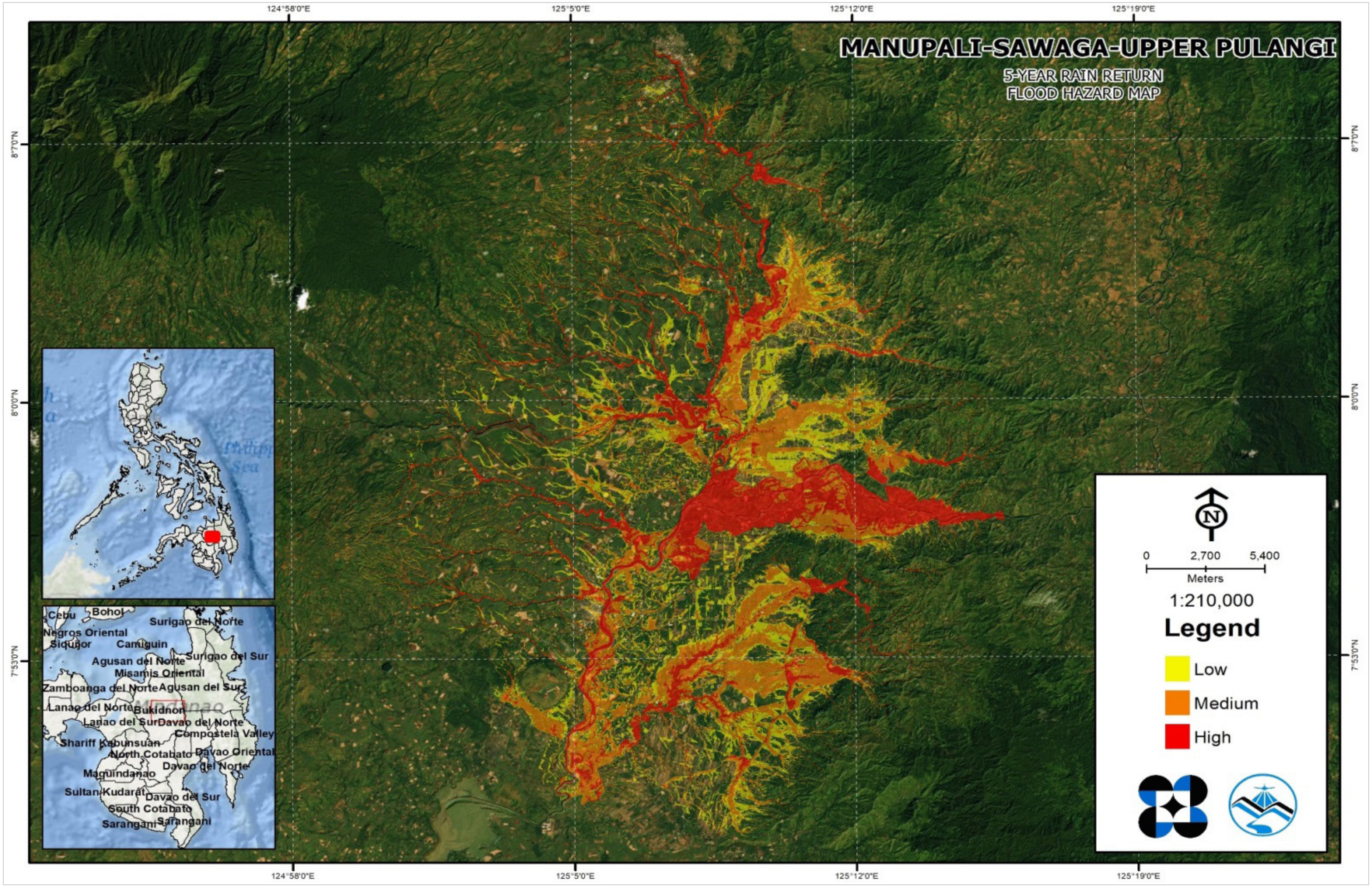


Figure 71. 5-year Flood Hazard Map for Manupali-Sawaga-Upper Pulangi Floodplain

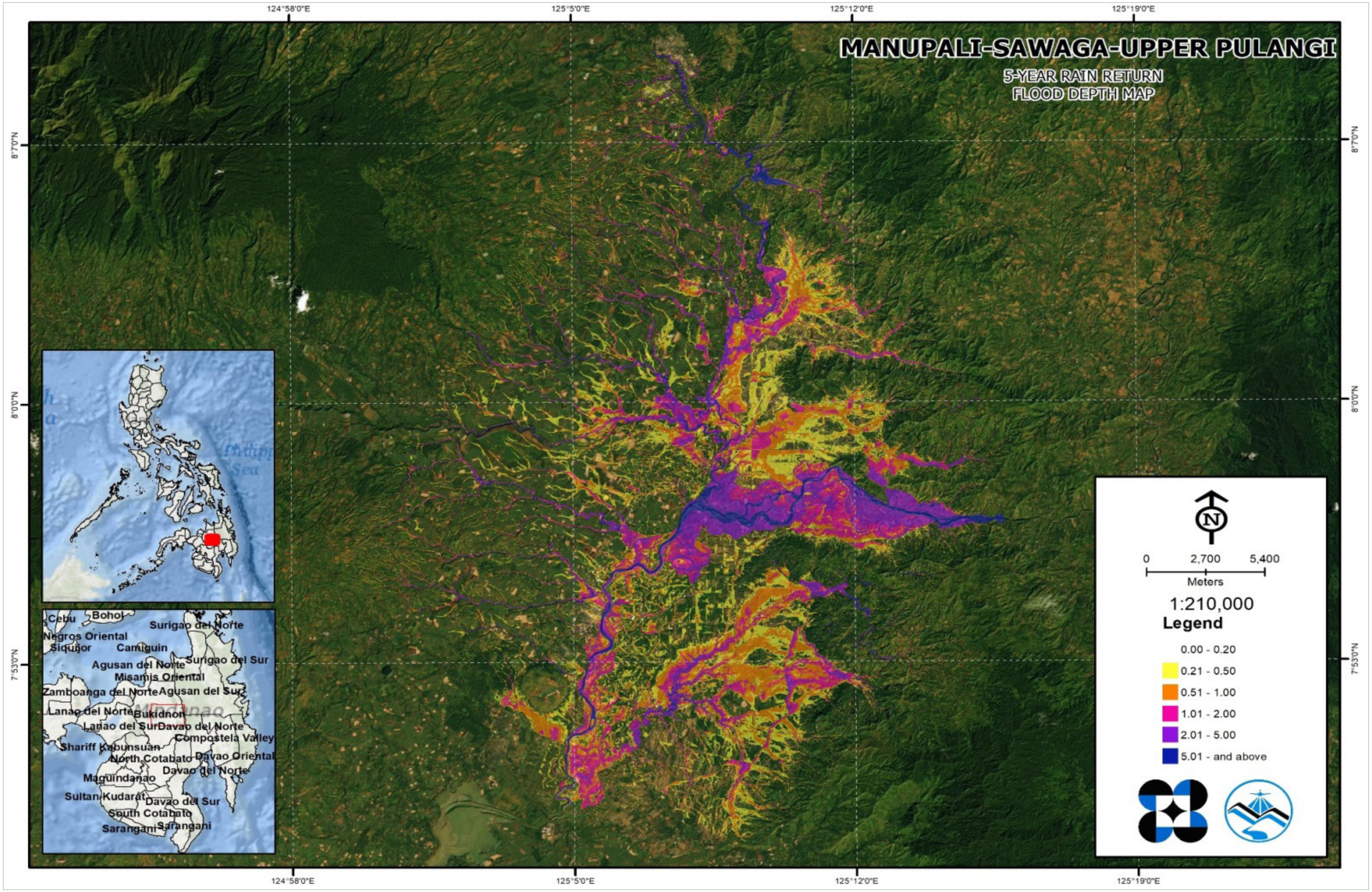


Figure 72. 5-year Flood Depth Map for Manupali-Sawaga-Upper Pulangi Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Manupali-Sawaga-Upper Pulangi Floodplain, grouped by municipality, are listed below. For the said floodplain, five municipalities consisting of 66 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 22.41% of the municipality of Lantapan with an area of 290.82 sq. km. will experience flood levels of less than 0.20 meters. 2.04% of the area will experience flood levels of 0.21 to 0.50 meters while 1.03%, 0.77%, 0.60%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Lantapan, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lantapan (in sq. km)					
	Balila	Bantuanon	Bugcaon	Capitan Juan	Kulasihan	Poblacion
0.03-0.20	0.064	24.75	12.6	6.14	13.03	8.58
0.21-0.50	0	2.3	0.9	0.33	1.84	0.56
0.51-1.00	0	1.28	0.38	0.2	0.85	0.29
1.01-2.00	0	0.78	0.49	0.056	0.8	0.12
2.01-5.00	0	0.71	0.51	0.0047	0.49	0.018
> 5.00	0	0.046	0.062	0.0041	0.1	0

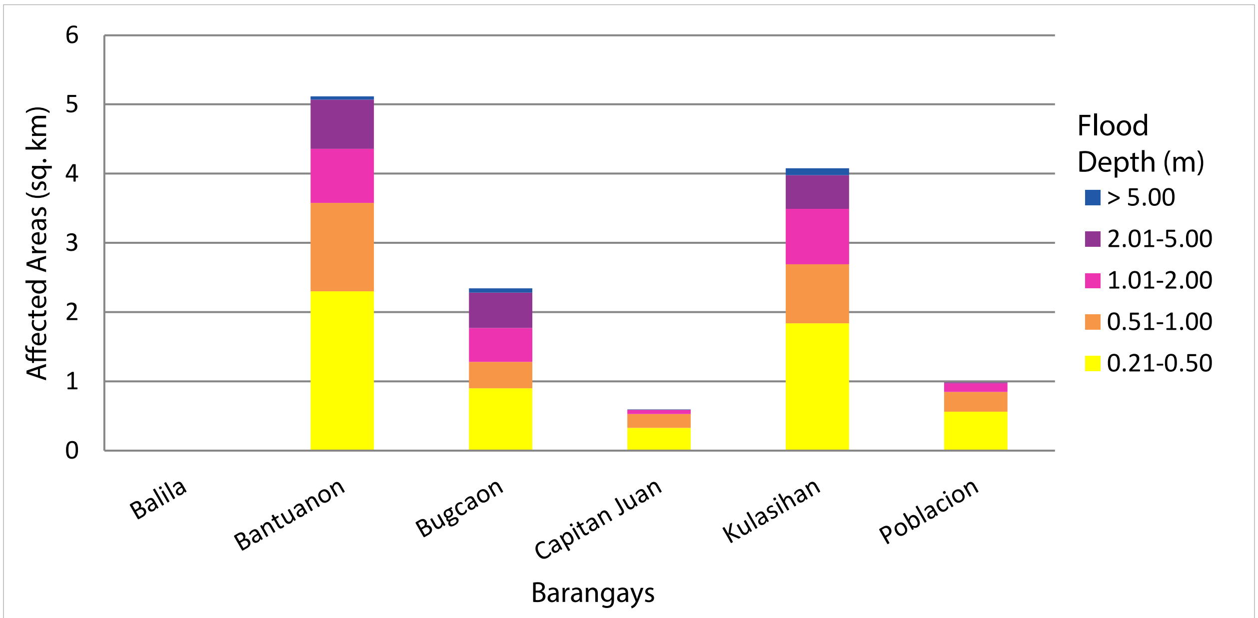


Figure 73. Affected Areas in Lantapan, Bukidnon during 5-Year Rainfall Return Period

For the 5-year return period, 17.48% of the municipality of Malaybalay City with an area of 1115.98 sq. km. will experience flood levels of less than 0.20 meters. 2.17% of the area will experience flood levels of 0.21 to 0.50 meters while 1.80%, 1.26%, 0.95%, and 0.29% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Lantapan, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malaybalay City (in sq. km)									
	Aglayan	Apo Macote	Bangcud	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7
0.03-0.20	11.63	4.77	3.45	2.25	0.48	0.28	0.33	0.34	3.06	0.68
0.21-0.50	0.56	0.16	0.78	0.071	0.022	0.014	0.018	0.013	0.077	0.058
0.51-1.00	0.39	0.084	0.32	0.055	0.0068	0.012	0.011	0.0059	0.049	0.012
1.01-2.00	0.35	0.068	0.72	0.058	0.014	0.0081	0.01	0.011	0.041	0.0077
2.01-5.00	0.16	0.087	1.1	0.076	0.058	0.0049	0.028	0.032	0.041	0.02
> 5.00	0.01	0.0079	0.21	0.031	0.061	0	0.005	0.02	0.04	0.0025

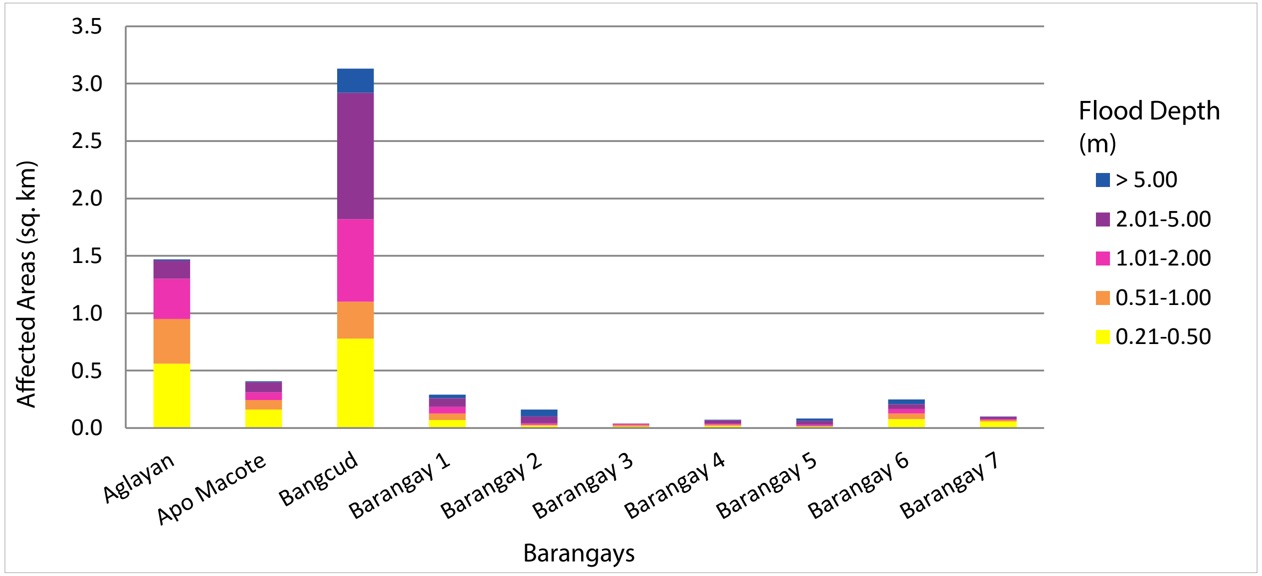


Figure 74. Affected Areas in Malaybalay City, Bukidnon during 5-Year Rainfall Return Period

Table 37. Affected Areas in Malaybalay City, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malaybalay City (in sq. km)									
	Barangay 8	Barangay 9	Barangay 10	Barangay 11	Cabangahan	Canayan	Casisang	Laguitas	Linabo	Magsaysay
0.03-0.20	0.33	4.2	6.64	0.45	4.43	1.06	27.29	25.1	5.29	2
0.21-0.50	0.016	0.2	0.43	0.012	0.72	0.024	1.26	1.15	0.45	0.11
0.51-1.00	0.01	0.18	0.18	0.0081	0.37	0.018	0.86	0.73	0.22	0.055
1.01-2.00	0.0079	0.17	0.19	0.0029	0.23	0.012	0.89	0.73	0.27	0.021
2.01-5.00	0.01	0.058	0.1	0.000021	0.18	0.01	0.69	0.62	0.31	0.0043
> 5.00	0.028	0.066	0.0081	0	0.0011	0.0012	0.63	0.31	0.083	0

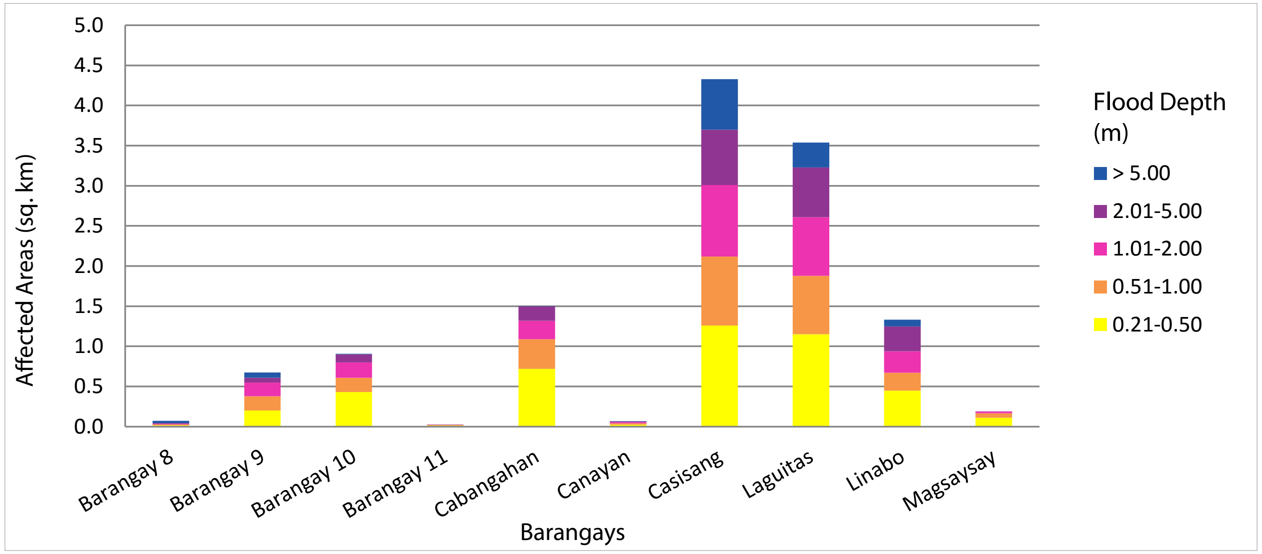


Figure 75. Affected Areas in Malaybalay City, Bukidnon during 5-Year Rainfall Return Period

Table 38. Affected Areas in Malaybalay City, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malaybalay City (in sq. km)									
	Maligaya	Managok	Miglamin	San Jose	San Martin	Santo Niño	Simaya	Sinanglanan	Sumpong	Violeta
0.03-0.20	11.93	13.94	1.44	12.92	21.39	5.89	12.46	6.02	0.36	4.66
0.21-0.50	0.43	3.7	0.022	0.71	0.77	4.42	5.6	0.67	0.011	1.73
0.51-1.00	0.32	3.62	0.012	0.37	0.49	3.68	5.14	1.12	0.0051	1.72
1.01-2.00	0.36	2.9	0.01	0.24	0.38	2.19	2.08	1.11	0.0085	0.99
2.01-5.00	0.15	1.92	0.0093	0.2	0.23	2.47	0.98	0.39	0.01	0.68
> 5.00	0.0011	0.17	0.0002	0.66	0.0084	0.57	0.17	0	0.021	0.17

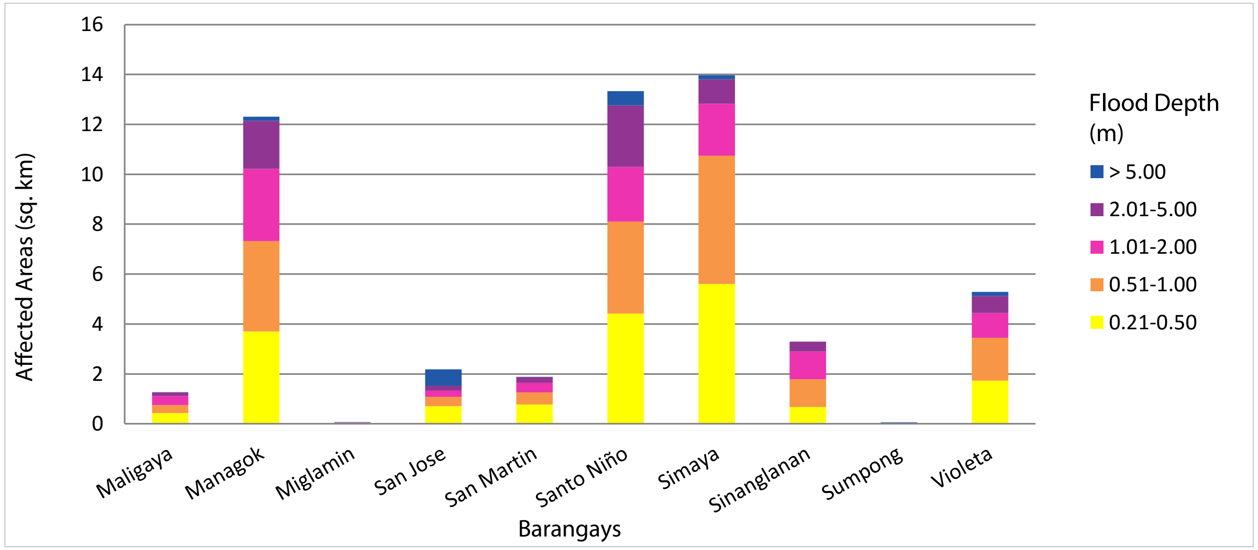


Figure 76. Affected Areas in Malaybalay City, Bukidnon during 5-Year Rainfall Return Period

For the 5-year return period, 3.20% of the municipality of Maramag with an area of 323.88 sq. km. will experience flood levels of less than 0.20 meters. 0.67% of the area will experience flood levels of 0.21 to 0.50 meters while 0.67%, 0.34%, 0.07%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Maramag, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maramag (in sq. km)
	Dologon
0.03-0.20	10.38
0.21-0.50	2.18
0.51-1.00	2.18
1.01-2.00	1.09
2.01-5.00	0.23
> 5.00	0.18

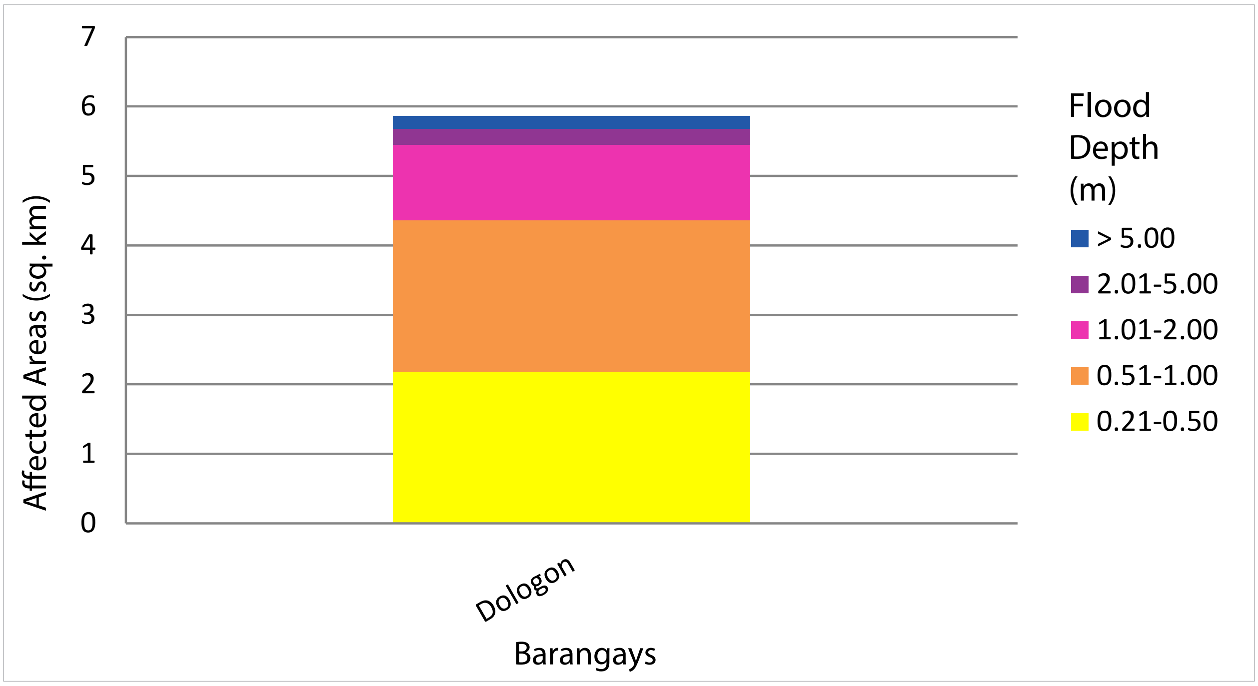


Figure 77. Affected Areas in Lantapan, Bukidnon during 5-Year Rainfall Return Period

For the 5-year return period, 0.60% of the municipality of Quezon with an area of 641.25 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.12%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Quezon, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Quezon (in sq. km)
	Paitan
0.03-0.20	3.84
0.21-0.50	0.4
0.51-1.00	0.52
1.01-2.00	0.77
2.01-5.00	0.072
> 5.00	0

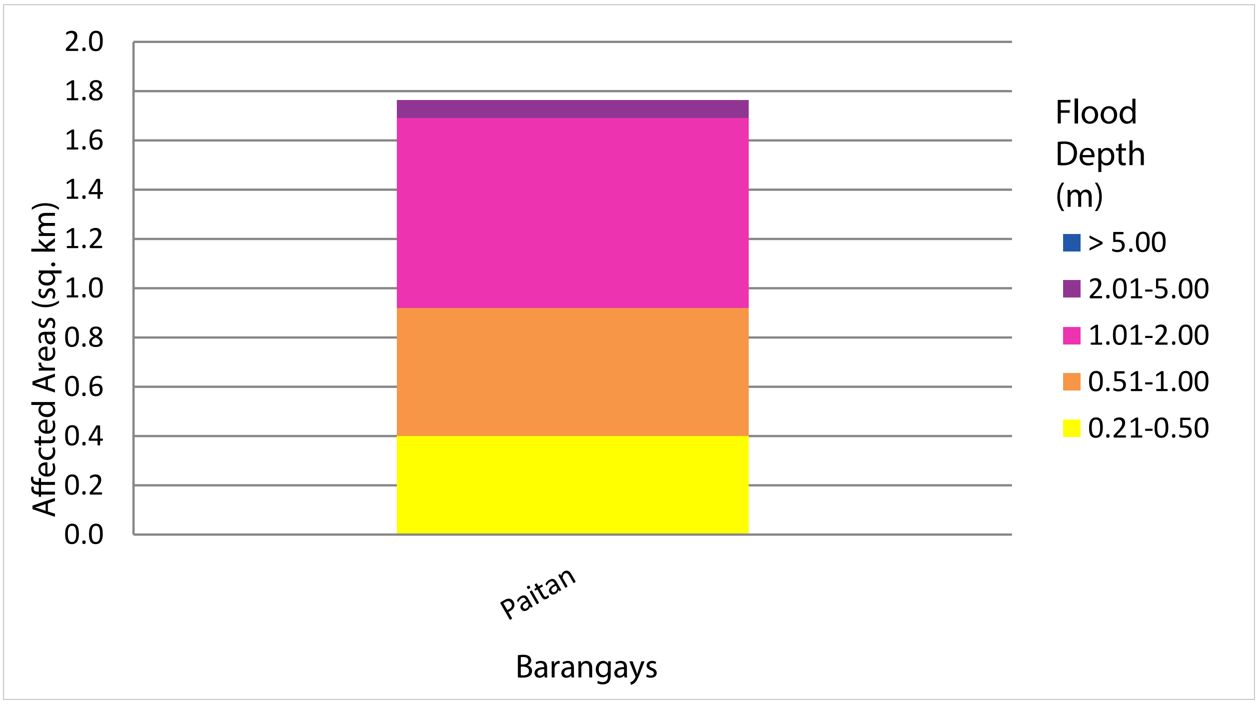


Figure 78. Affected Areas in Quezon, Bukidnon during 5-Year Rainfall Return Period

For the 5-year return period, 32.07% of the municipality of Valencia City with an area of 726.07 sq. km. will experience flood levels of less than 0.20 meters. 5.30% of the area will experience flood levels of 0.21 to 0.50 meters while 4.69%, 3.81%, 3.45%, and 1.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Valencia City, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)									
	Bagontaas	Banlag	Barobo	Batangan	Catumbalon	Colonia	Concepcion	Dagat-Kidavao	Kahapunan	Laligan
0.03-0.20	20.71	14.12	12.48	5.92	2.96	0.85	10.22	21.25	1.28	5.34
0.21-0.50	3.59	3.09	0.46	1.94	1.55	0.67	0.28	4.94	0.2	2.82
0.51-1.00	1.92	3.09	0.37	0.94	2.36	0.59	0.18	2.47	0.34	5.9
1.01-2.00	1.28	1.5	0.33	0.43	3.22	0.5	0.15	0.93	1.03	2.38
2.01-5.00	1.21	0.34	0.21	0.24	0.5	0.31	0.19	0.2	1.72	0.71
> 5.00	0.19	0.0019	0.009	0.03	0.34	0.056	0.14	0.0003	0.023	0.018

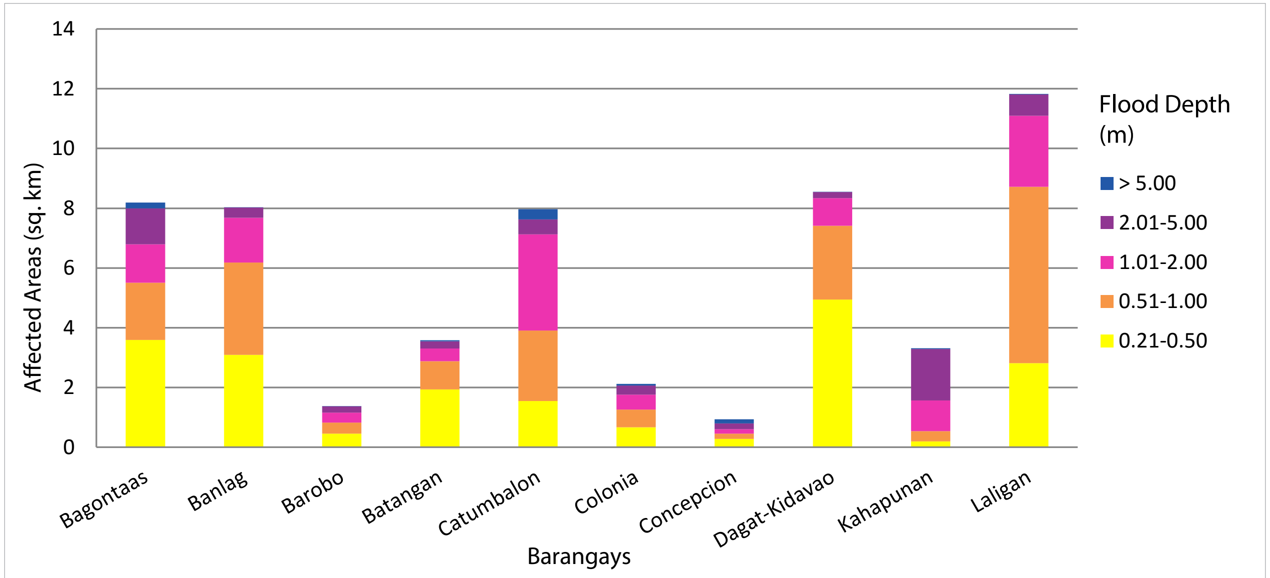


Figure 79. Affected Areas in Valencia City, Bukidnon during 5-Year Rainfall Return Period

Table 42. Affected Areas in Valencia City, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)								
	Lumbayao	Lumbo	Lurogan	Maapag	Mabuhay	Mailag	Mt. Nebo	Nabago	Pinatilan
0.03-0.20	3.84	24.07	20.83	3.12	8.01	5.41	3.43	0.99	3.58
0.21-0.50	0.14	1.54	0.85	1.48	1.17	1.47	0.17	1.11	1.22
0.51-1.00	0.099	1.03	0.46	1.34	0.51	0.87	0.086	1.02	1.01
1.01-2.00	0.069	1.08	0.4	0.8	0.44	0.46	0.039	1.53	0.77
2.01-5.00	0.19	0.67	0.35	0.5	0.53	0.5	0.0064	4.42	0.12
> 5.00	0.55	0.31	0.02	0.13	0.12	0.44	0	1.58	0.18

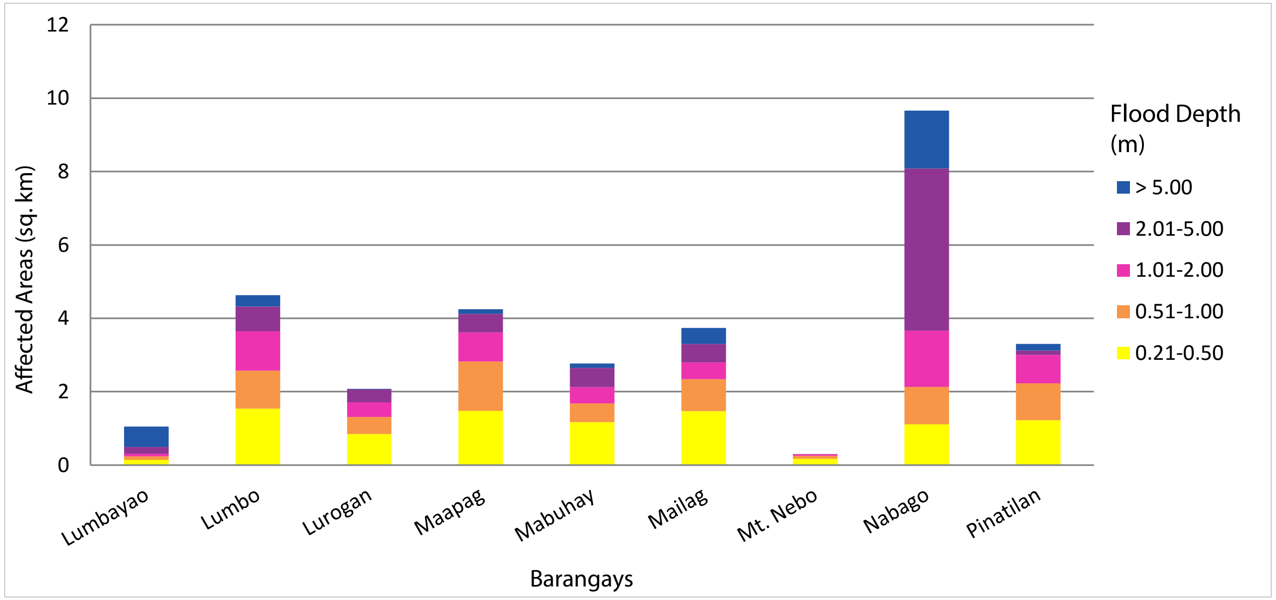


Figure 80. Affected Areas in Valencia City, Bukidnon during 5-Year Rainfall Return Period

Table 43. Affected Areas in Valencia City, Bukidnon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)								
	Poblacion	San Carlos	San Isidro	Sinabuagan	Sinayawan	Sugod	Tongantongan	Tugaya	Vintar
0.03-0.20	0.24	20.79	0.057	13.67	3.09	3.56	11.29	1.99	9.78
0.21-0.50	0.12	1.53	0.11	1.03	1.77	0.57	2.97	0.1	1.56
0.51-1.00	0.2	0.63	0.41	0.91	2.42	0.75	2.75	0.059	1.35
1.01-2.00	0.31	0.42	2.24	1.6	1.6	1.2	0.96	0.014	1.95
2.01-5.00	0.23	0.43	2.62	3.55	1.2	1.55	0.9	0.0001	1.66
> 5.00	0.15	0.091	0.37	0.93	0.12	0.7	0.11	0	0.66

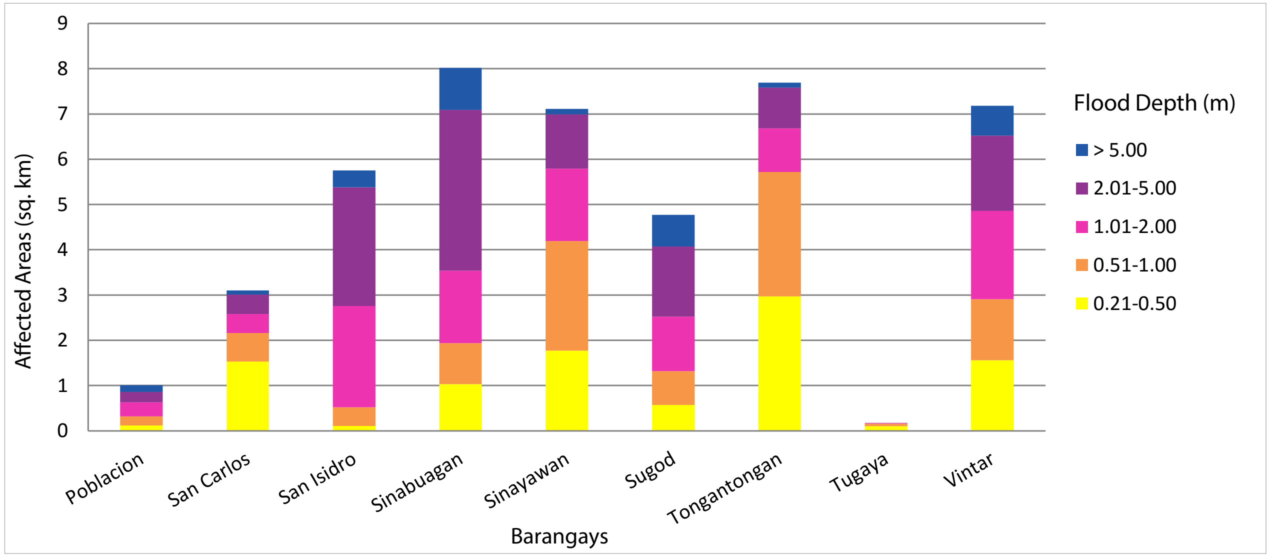


Figure 81. Affected Areas in Valencia City, Bukidnon during 5-Year Rainfall Return Period

For the 25-year return period, 20.82% of the municipality of Lantapan with an area of 290.82 sq. km. will experience flood levels of less than 0.20 meters. 2.47% of the area will experience flood levels of 0.21 to 0.50 meters while 1.42%, 0.99%, 1.01%, and 0.23% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Lantapan, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lantapan (in sq. km)					
	Balila	Bantuanon	Bugcaon	Capitan Juan	Kulasihan	Poblacion
0.03-0.20	0.064	23.12	11.67	6	11.53	8.16
0.21-0.50	0	2.69	1.19	0.34	2.17	0.78
0.51-1.00	0	1.67	0.53	0.25	1.32	0.35
1.01-2.00	0	1.15	0.52	0.12	0.87	0.23
2.01-5.00	0	1.02	0.84	0.022	0.99	0.054
> 5.00	0	0.23	0.2	0.0041	0.24	0.00063

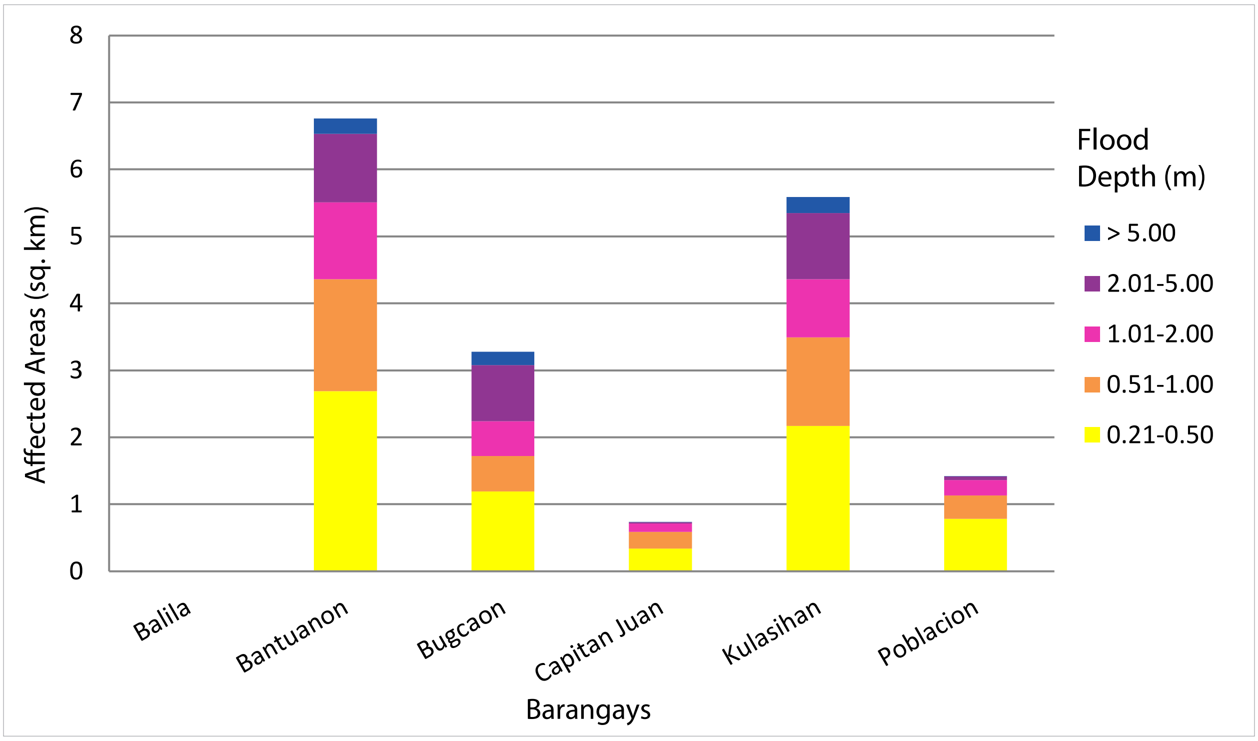


Figure 82. Affected Areas in Lantapan, Bukidnon during 25-Year Rainfall Return Period

For the 25-year return period, 3.37% of the municipality of Malaybalay City with an area of 1115.98 sq. km. will experience flood levels of less than 0.20 meters. 0.42% of the area will experience flood levels of 0.21 to 0.50 meters while 0.36%, 0.35%, 0.69%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Malaybalay City, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malaybalay City (in sq. km)												
	Aglayan	Apo Macote	Bangcud	Cabangahan	Casisang	Laguitas	Linabo	Magsaysay	San Jose	San Martin	Santo Niño	Simaya	Sinanglanan
0.03-0.20	10.37	4.65	1.97	1.76	2.05	0.9	0.0028	1.96	1.75	0.8	3.59	0.1	5.69
0.21-0.50	0.64	0.21	0.73	0.38	0.13	0.079	0	0.12	0.1	0.033	1.58	0.0071	0.52
0.51-1.00	0.4	0.11	0.28	0.17	0.09	0.045	0	0.07	0.079	0.017	1.9	0.0046	0.73
1.01-2.00	0.36	0.073	0.18	0.078	0.068	0.044	0	0.033	0.056	0.014	1.5	0.0098	1.47
2.01-5.00	0.26	0.1	1.01	0.12	0.02	0.035	0.31	0.0098	0.0055	0.011	2.29	0.0058	0.87
> 5.00	0.031	0.043	0.33	0.018	0.63	0.0027	0.083	0	0.00000031	0.0084	0.7	0.17	0.0059

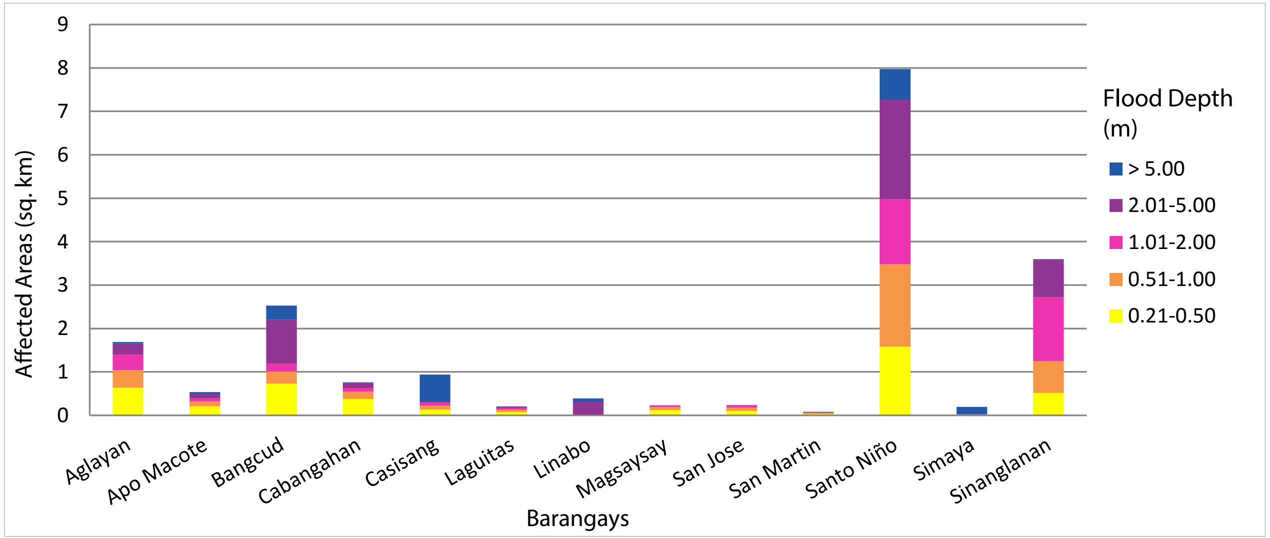


Figure 83. Affected Areas in Malaybalay City, Bukidnon during 25-Year Rainfall Return Period

For the 25-year return period, 2.61% of the municipality of Maramag with an area of 323.88 sq. km. will experience flood levels of less than 0.20 meters. 0.59% of the area will experience flood levels of 0.21 to 0.50 meters while 0.54%, 0.64%, 0.42%, and 0.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Maramag, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maramag (in sq. km)
	Dologon
0.03-0.20	8.45
0.21-0.50	1.92
0.51-1.00	1.75
1.01-2.00	2.06
2.01-5.00	1.35
> 5.00	0.71

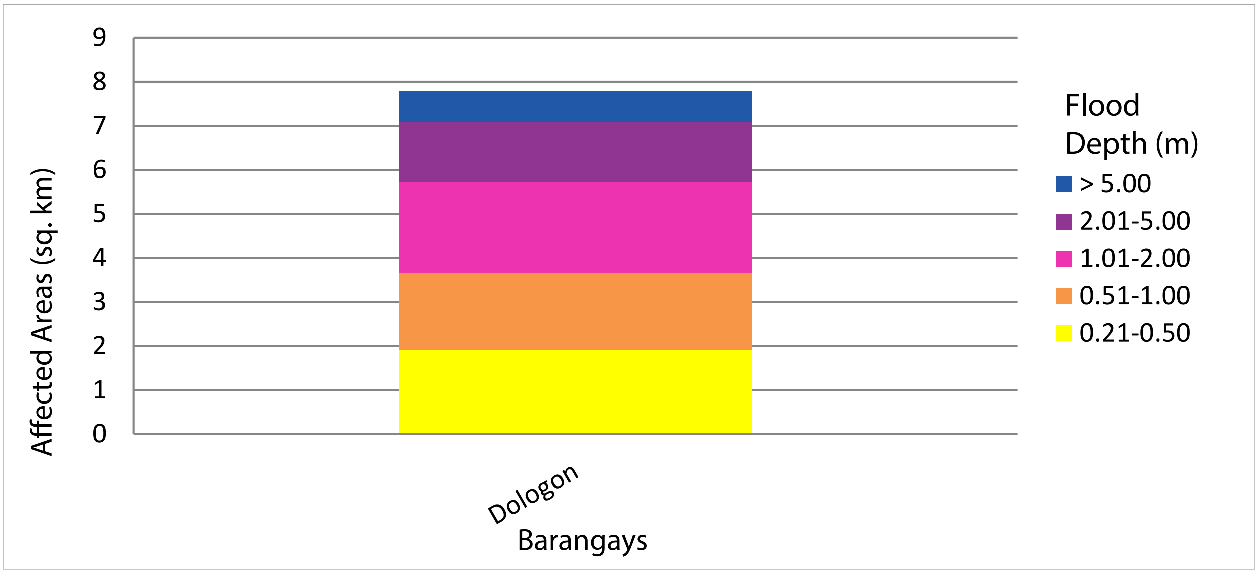


Figure 84. Affected Areas in Lantapan, Bukidnon during 25-Year Rainfall Return Period

For the 25-year return period, 0.53% of the municipality of Quezon with an area of 641.25 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.05%, 0.20%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Quezon, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Quezon (in sq. km)
	Paitan
0.03-0.20	3.39
0.21-0.50	0.38
0.51-1.00	0.17
1.01-2.00	0.35
2.01-5.00	1.27
> 5.00	0.037

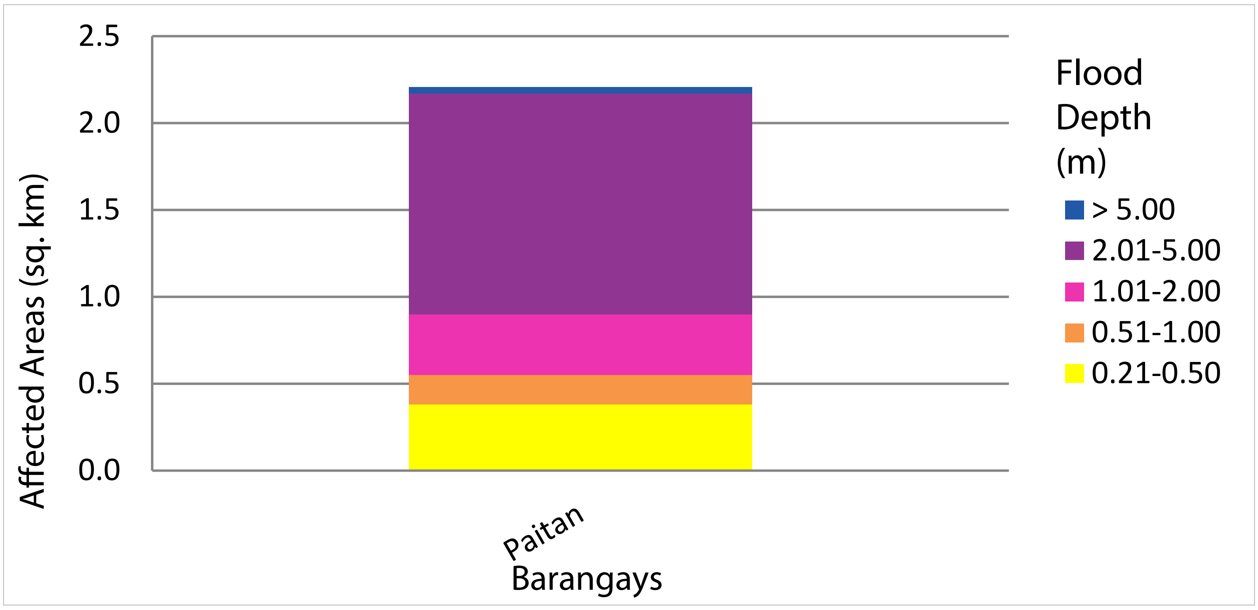


Figure 85. Affected Areas in Quezon, Bukidnon during 25-Year Rainfall Return Period

For the 25-year return period, 26.33% of the municipality of Valencia City with an area of 726.07 sq. km. will experience flood levels of less than 0.20 meters. 4.59% of the area will experience flood levels of 0.21 to 0.50 meters while 4.29%, 5.25%, 5.86%, and 3.85% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)									
	Bagontaas	Banlag	Barobo	Batangan	Catumbalon	Colonia	Concepcion	Dagat-Kidavao	Kahapunan	Laligan
0.03-0.20	17.5	12.64	12.13	0.37	0.34	0.27	9.99	17.54	0.53	4.1
0.21-0.50	4.57	2.24	0.49	0.44	0.18	0.22	0.32	6.12	0.44	1.71
0.51-1.00	2.48	3.3	0.38	0.7	0.22	0.49	0.21	4.05	0.34	4.12
1.01-2.00	1.78	3.26	0.4	2.14	0.22	0.72	0.18	1.66	0.93	5.95
2.01-5.00	1.97	0.7	0.4	3.03	5.12	0.27	0.22	0.41	2.25	1.24
> 5.00	0.59	0.0051	0.059	2.81	4.84	0.021	0.24	0.0005	0.11	0.033

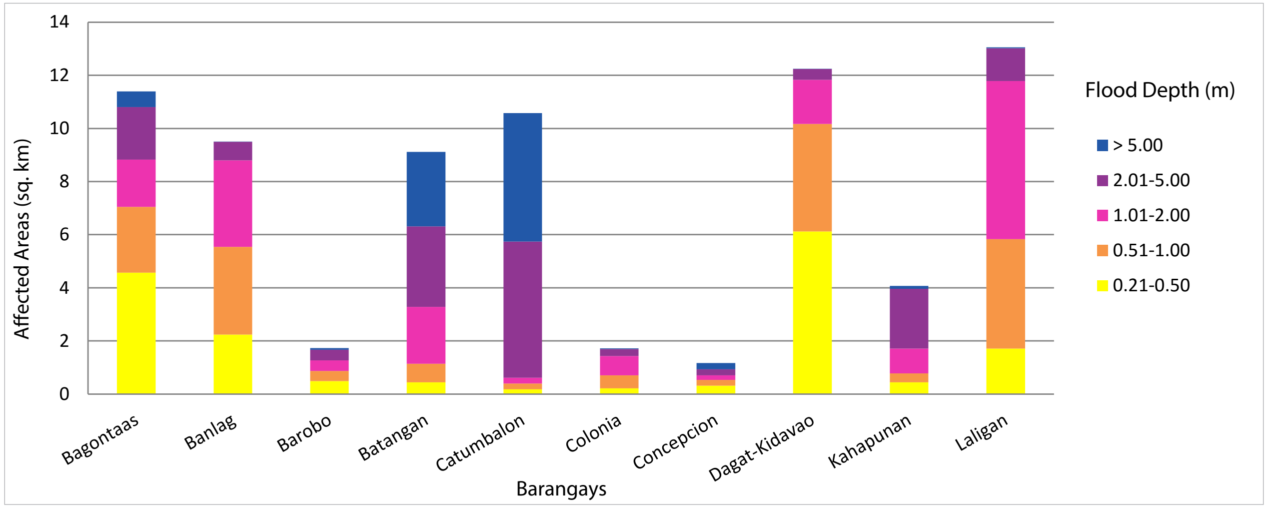


Figure 86. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Table 49. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)								
	Lumbayao	Lumbo	Lurogan	Maapag	Mabuhay	Mailag	Mt. Nebo	Nabago	Pinatilan
0.03-0.20	3.7	22.7	19.95	0.49	6	3.93	3.19	0.011	0.0012
0.21-0.50	0.15	1.77	1.12	0.5	2.01	1.64	0.2	0.076	0.0078
0.51-1.00	0.12	1.08	0.52	1.07	1.15	1.27	0.11	0.93	0.12
1.01-2.00	0.081	0.67	0.44	2.42	0.77	1.09	0.11	2.13	0.25
2.01-5.00	0.13	0.75	0.64	1.46	0.68	0.66	0.13	5.01	0.38
> 5.00	0.72	1.73	0.23	1.45	0.18	0.58	0.0001	2.51	6.12

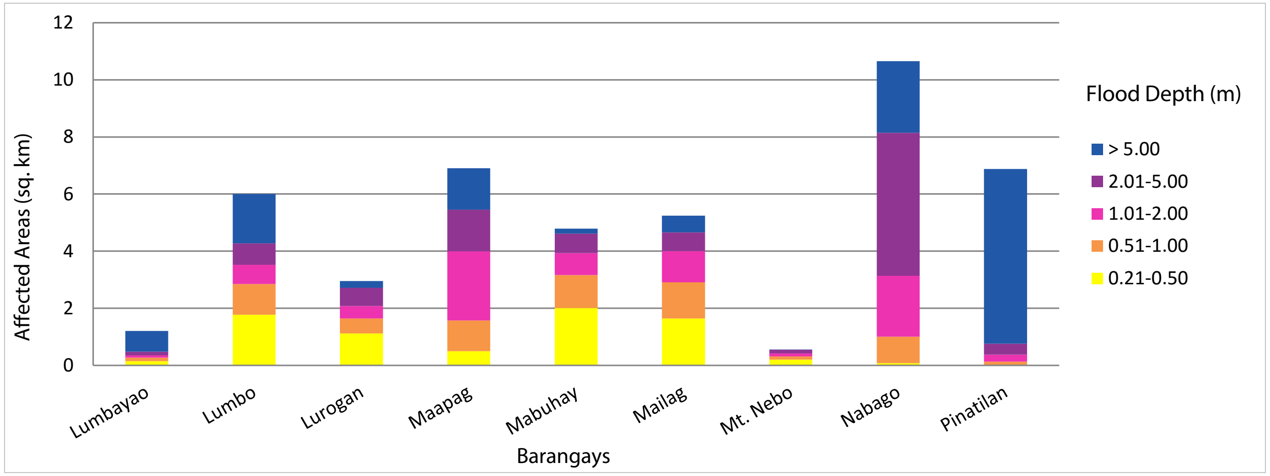


Figure 87. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Table 50. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)								
	Poblacion	San Carlos	San Isidro	Sinabuagan	Sinayawan	Sugod	Tongantongan	Tugaya	Vintar
0.03-0.20	0.092	19.37	0.019	13	1.27	2.65	9.5	1.92	7.97
0.21-0.50	0.068	2.1	0.024	1.04	0.8	0.31	3.05	0.097	1.65
0.51-1.00	0.087	0.93	0.1	0.73	1.99	0.35	2.51	0.078	1.74
1.01-2.00	0.22	0.6	0.93	1.2	3.93	1.33	2.57	0.049	2.12
2.01-5.00	0.22	0.53	4.14	3.88	1.99	2.78	1.13	0.014	2.45
> 5.00	0.56	0.36	0.58	1.85	0.23	0.91	0.22	0	1.02

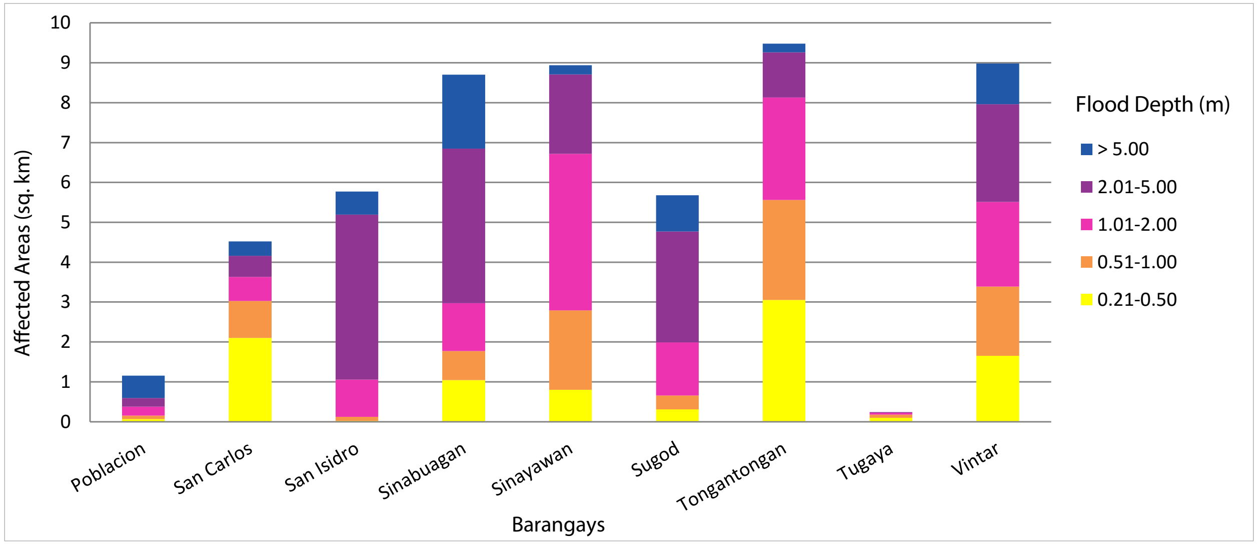


Figure 88. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

For the 100-year return period, 0.02% of the municipality of Lantapan with an area of 290.82 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected Areas in Lantapan, Bukidnon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lantapan (in sq. km)
	Bantuanon
0.03-0.20	0.056
0.21-0.50	0.001
0.51-1.00	0.001
1.01-2.00	0.002
2.01-5.00	0.0053
> 5.00	0.012

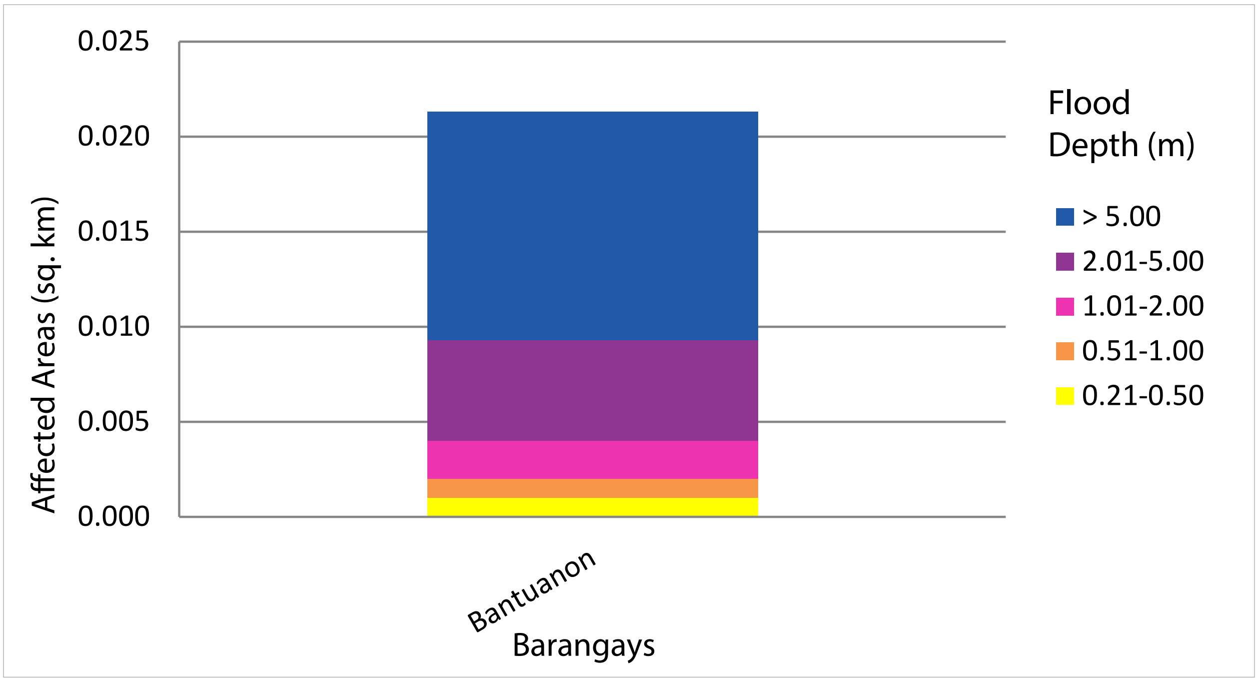


Figure 89. Affected Areas in Lantapan, Bukidnon during 100-Year Rainfall Return Period

For the 100-year return period, 0.15% of the municipality of Malaybalay City with an area of 1115.98 sq. km. will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.20%, 0.15%, 0.13%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Malaybalay City, Bukidnon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malaybalay City (in sq. km)	
	Apo Macote	Santo Niño
0.03-0.20	0	1.71
0.21-0.50	0	1.1
0.51-1.00	0	2.18
1.01-2.00	0	1.67
2.01-5.00	0	1.48
> 5.00	0.0011	0.69

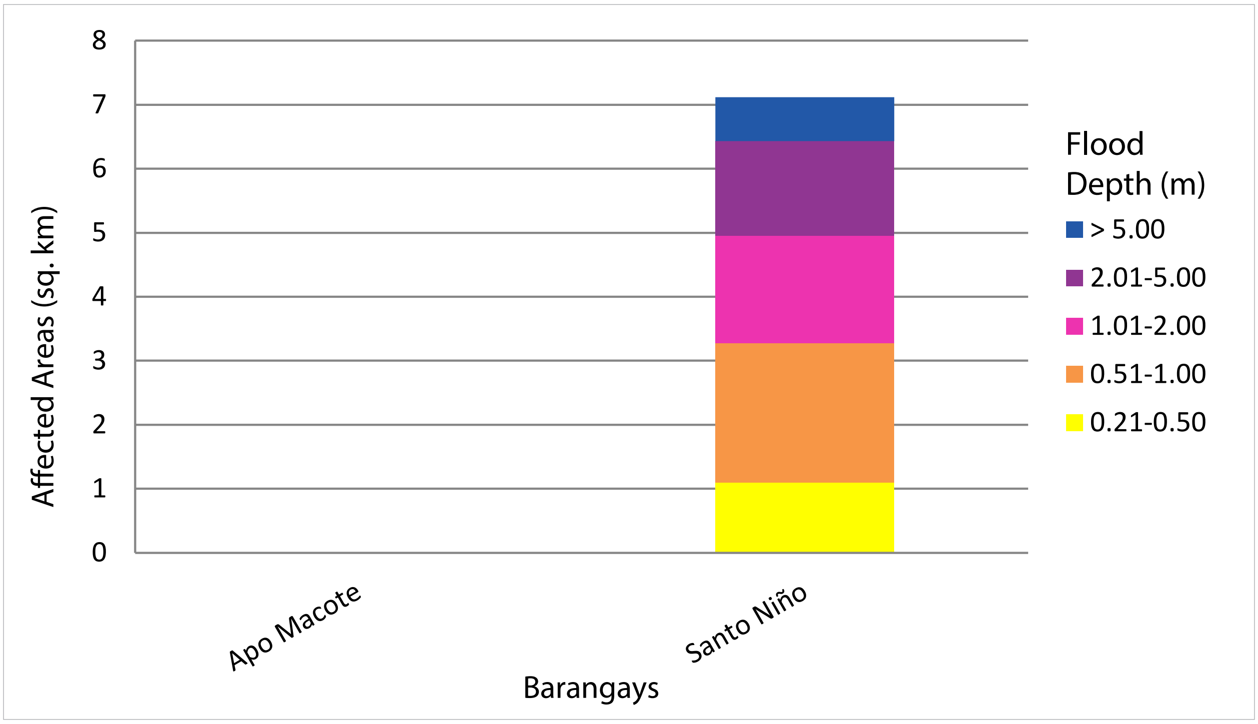


Figure 90. Affected Areas in Lantapan, Bukidnon during 25-Year Rainfall Return Period

For the 100-year return period, 2.38% of the municipality of Maramag with an area of 323.88 sq. km. will experience flood levels of less than 0.20 meters. 0.61% of the area will experience flood levels of 0.21 to 0.50 meters while 0.53%, 0.78%, 0.43%, and 0.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Maramag, Bukidnon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maramag (in sq. km)
	Dologon
0.03-0.20	7.71
0.21-0.50	1.97
0.51-1.00	1.73
1.01-2.00	2.53
2.01-5.00	1.38
> 5.00	0.92

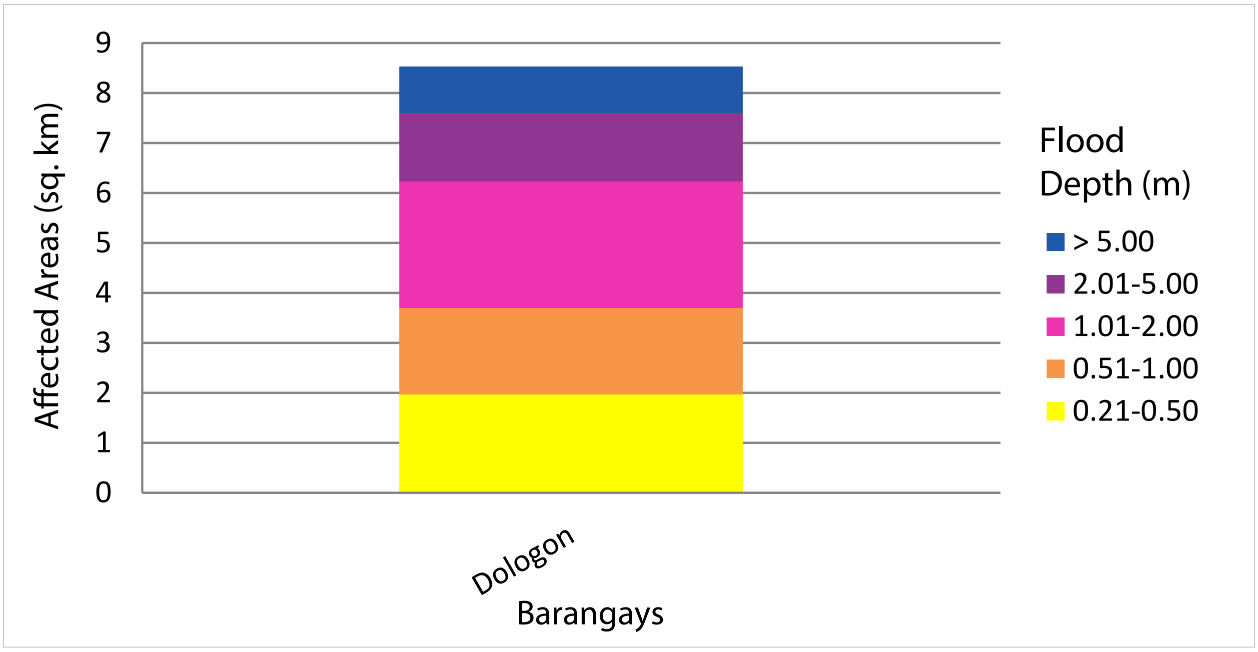


Figure 91. Affected Areas in Maramag, Bukidnon during 100-Year Rainfall Return Period

For the 100-year return period, 0.49% of the municipality of Quezon with an area of 641.25 sq. km. will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.05%, 0.22%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected Areas in Quezon, Bukidnon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Quezon (in sq. km)
	Paitan
0.03-0.20	3.17
0.21-0.50	0.54
0.51-1.00	0.16
1.01-2.00	0.29
2.01-5.00	1.4
> 5.00	0.038

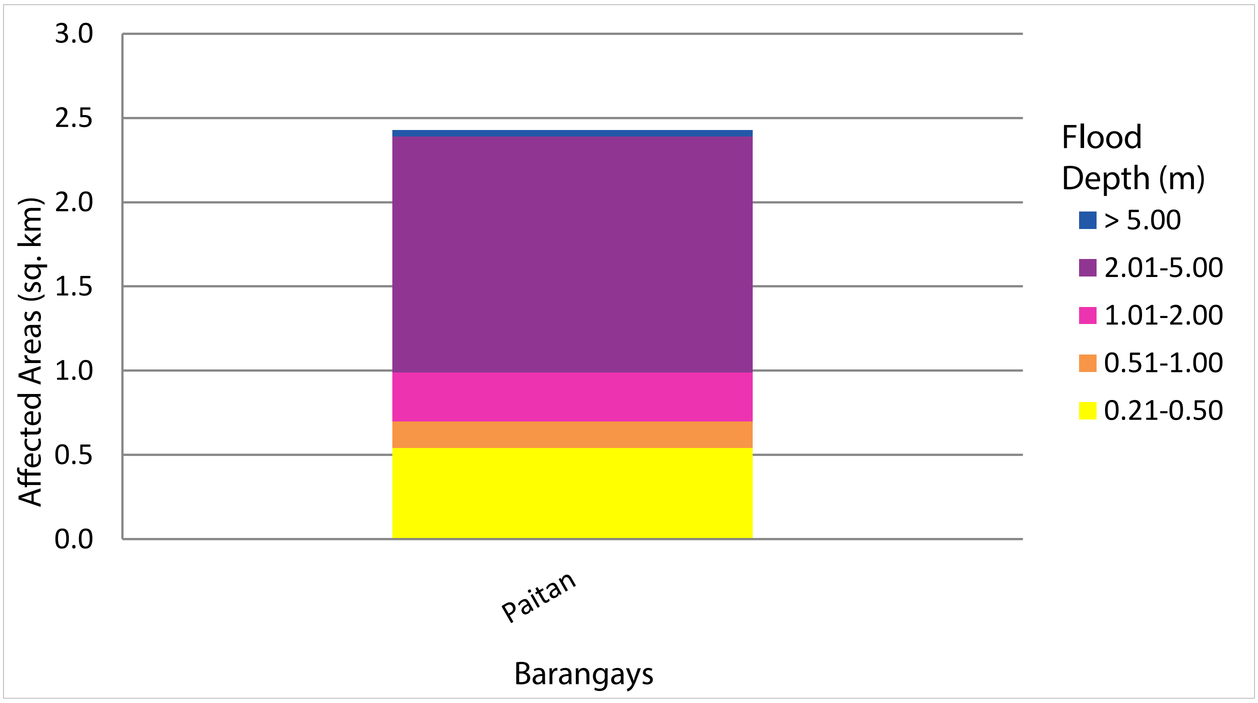


Figure 92. Affected Areas in Quezon, Bukidnon during 100-Year Rainfall Return Period

For the 100-year return period, 23.11% of the municipality of Valencia City with an area of 726.07 sq. km. will experience flood levels of less than 0.20 meters. 4.54% of the area will experience flood levels of 0.21 to 0.50 meters while 3.78%, 5.55%, 6.57%, and 4.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected Areas in Valencia City, Bukidnon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)												
	Bagontaas	Banlag	Barobo	Batangan	Catumbalon	Colonia	Concepcion	Dagat-Kidavao	Kahapunan	Laligan	Santo Niño	Simaya	Sinanglanan
0.03-0.20	14.56	11.91	11.9	0.26	0.21	0.22	9.83	15.26	0.23	3.53	3.59	0.1	5.69
0.21-0.50	4.64	1.97	0.53	0.36	0.12	0.085	0.36	6.81	0.3	1.3	1.58	0.0071	0.52
0.51-1.00	2.19	2.85	0.4	0.24	0.25	0.15	0.22	4.7	0.59	3.06	1.9	0.0046	0.73
1.01-2.00	1.65	3.87	0.43	1.75	0.25	0.16	0.19	2.42	0.86	7.04	1.5	0.0098	1.47
2.01-5.00	2.1	1.53	0.5	4.05	4.1	0.046	0.25	0.59	2.41	2.17	2.29	0.0058	0.87
> 5.00	0.83	0.013	0.12	2.84	5.98	0.021	0.31	0.0013	0.22	0.05	0.7	0.17	0.0059

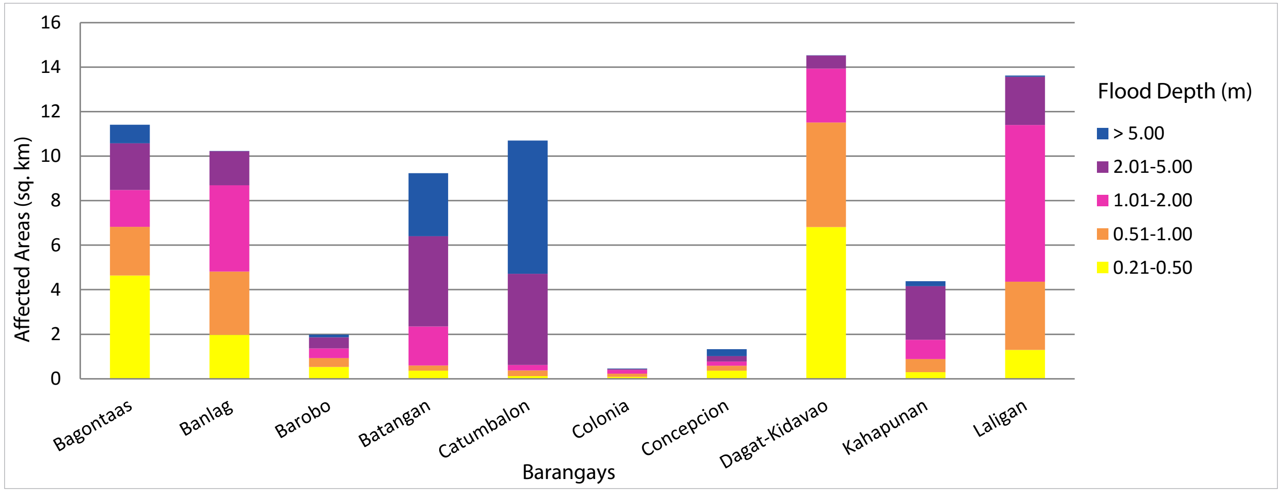


Figure 93. Affected Areas in Valencia City, Bukidnon during 100-Year Rainfall Return Period

Table 56. Affected Areas in Valencia City, Bukidnon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)								
	Lumbayao	Lumbo	Lurogan	Maapag	Mabuhay	Mailag	Mt. Nebo	Nabago	Pinatilan
0.03-0.20	0.59	21.92	16.13	0.15	4.55	3.74	2.13	0.0038	0
0.21-0.50	0.013	2	1.04	0.19	2.61	1.9	0.15	0.0089	0.00037
0.51-1.00	0.0044	1.21	0.55	0.74	1.29	1.45	0.09	0.27	0.0021
1.01-2.00	0.0016	0.82	0.4	2.62	1.27	0.85	0.082	2.68	0.28
2.01-5.00	0.0035	0.91	0.52	1.96	0.82	0.56	0.13	4.62	0.25
> 5.00	0.0009	1.85	0.3	1.72	0.22	0.61	0.0038	3.08	6.35

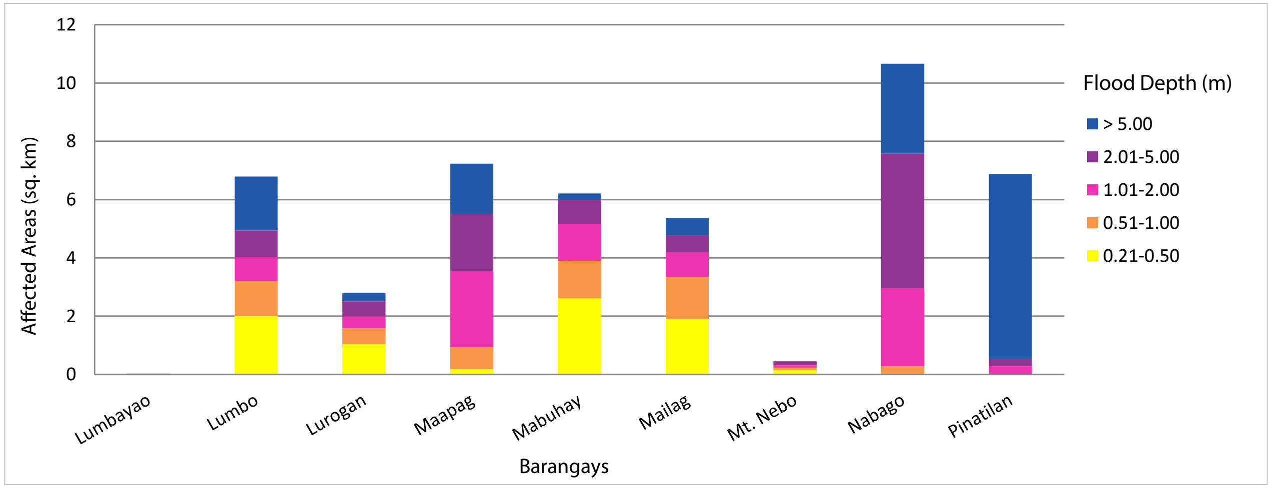


Figure 94. Affected Areas in Valencia City, Bukidnon during 100-Year Rainfall Return Period

Table 57. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valencia City (in sq. km)								
	Poblacion	San Carlos	San Isidro	Sinabuagan	Sinayawan	Sugod	Tongantongan	Tugaya	Vintar
0.03-0.20	0.059	17.5	0.01	11.93	0.79	2.47	8.73	1.9	7.3
0.21-0.50	0.04	2.3	0.013	1.02	0.48	0.4	2.82	0.096	1.39
0.51-1.00	0.086	1.07	0.043	0.72	0.88	0.22	2.54	0.083	1.55
1.01-2.00	0.19	0.7	0.43	0.77	4.25	1.11	3.25	0.061	1.94
2.01-5.00	0.3	0.61	4.46	3.46	3.49	3.12	1.28	0.026	3.46
> 5.00	0.57	0.44	0.77	1.33	0.31	1.01	0.37	0.0001	1.31

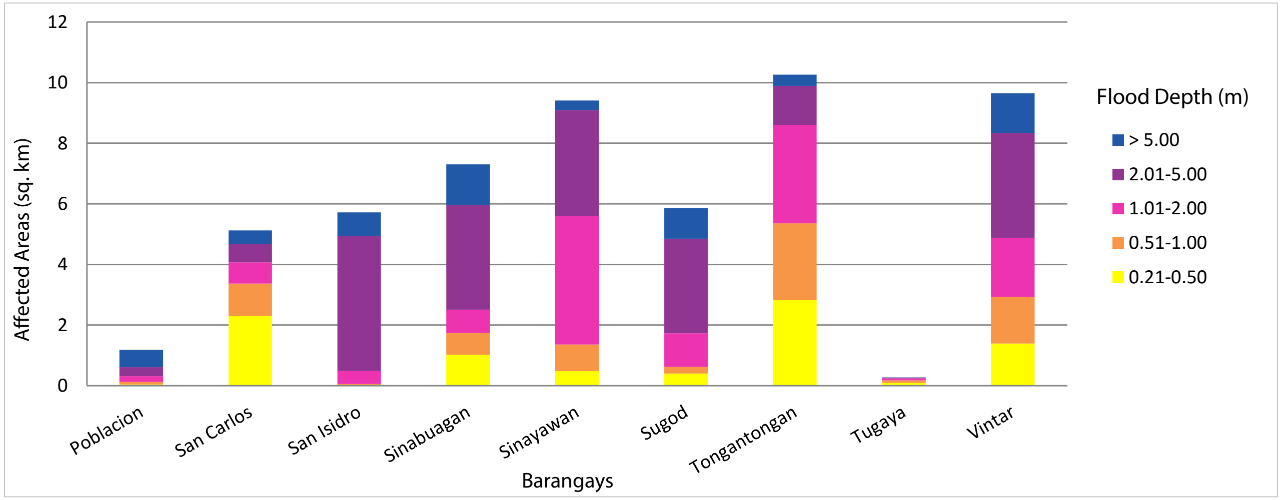


Figure 95. Affected Areas in Valencia City, Bukidnon during 25-Year Rainfall Return Period

Among the barangays in the municipality of Lantapan in Bukidnon, Bantuanon is projected to have the highest percentage of area that will experience flood levels at 10.27%. Meanwhile, Kulasihan posted the second highest percentage of area that may be affected by flood depths at 5.88%.

Among the barangays in the municipality of Malaybalay City in Bukidnon, Casisang is projected to have the highest percentage of area that will experience flood levels at 10.87%. Meanwhile, Laguitas posted the second highest percentage of area that may be affected by flood depths at 9.85%.

Brgy. Dologon is the only barangay affected in the municipality of Maramag in Bukidnon. The barangay is projected to experience flood in 5.58% of the municipality.

Brgy. Paitan is the only barangay affected in the municipality of Quezon in Bukidnon. The barangay is projected to experience flood in 1.93% of the municipality.

Among the barangays in the municipality of Valencia City in Bukidnon, Dagat-Kidavao is projected to have the highest percentage of area that will experience flood levels at 10.24%. Meanwhile, Bagontaas posted the second highest percentage of area that may be affected by flood depths at 9.94%.

Moreover, the generated flood hazard maps for the Manupali-Sawaga-Upper Pulangi Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps ("Low", "Medium", and "High"), the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-year, 25-year, and 10-year).

Table 58. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	72.25	67.13	68.35
Medium	87.85	98.40	97.07
High	68.99	126.61	152.82
TOTAL	229.09	292.14	318.24

Of the 115 identified Education Institute in Manupali-Sawaga-Upper Pulangi Flood plain, 20 schools were discovered exposed to Low-level flooding during a 5-year scenario, while 25 schools were found exposed to Medium-level flooding and 12 schools were discovered exposed to High-level flooding in the same scenario.

In the 25-year scenario, 23 schools were found exposed to Low-level flooding, while 28 schools were discovered exposed to Medium-level flooding. In the same scenario, 24 schools were found exposed to High-level flooding.

For the 100-year scenario, 19 schools were discovered exposed to Low-level flooding, while 26 schools were exposed to Medium-level flooding. In the same scenario, 33 schools were found exposed to High-level flooding. See Appendix D for a detailed enumeration of affected education institutes in the Manupali-Sawaga-Upper Pulangi floodplain.

Apart from this, 34 Medical Institutions were identified in the Manupali-Sawaga-Upper Pulangi Floodplain. Five (5) of these medical institutions were found exposed to Low-level flooding during a 5-year scenario, while 10 were discovered exposed to Medium-level flooding. In the same scenario, two (2) hospitals were found exposed to High-level flooding.

In the 25-year scenario, seven (7) medical institutions were discovered exposed to Low-level flooding, while 10 were found exposed to Medium-level flooding. In the same scenario, seven (7) hospitals were discovered exposed to High-level flooding.

For the 100-year scenario, eight (8) medical institutions were found exposed to Low-level flooding, while 10 were discovered exposed to Medium-level flooding. In the same scenario, eight (8) hospitals were found exposed to High-level flooding. See Appendix E for a detailed enumeration of the affected medical institutions in the Manupali-Sawaga-Upper Pulangi floodplain.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 404 points randomly selected all over the Manupali-Sawaga-Upper Pulangi flood plain. It has an RMSE value of 1.69.

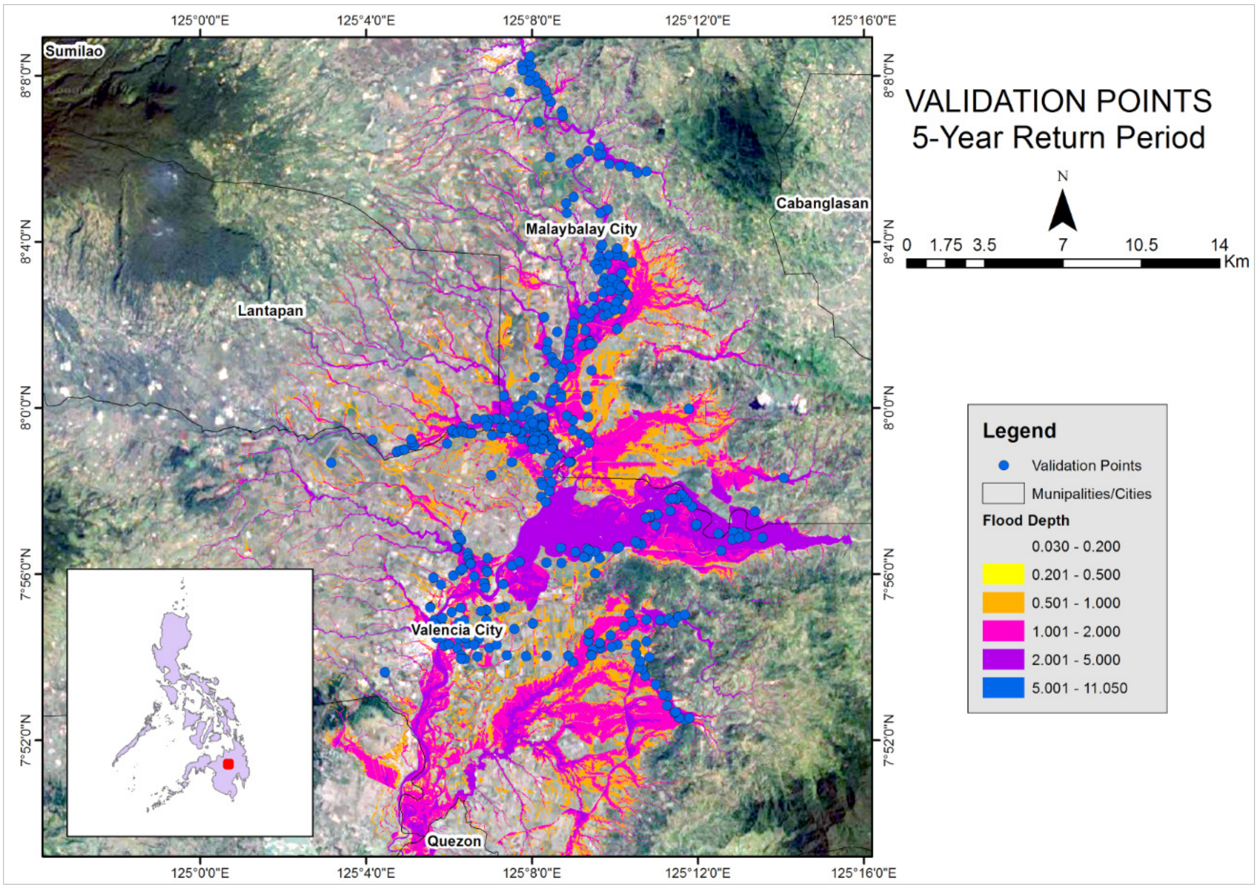


Figure 96. The Validation Points for a 5-year Flood Depth Map of the Manupali-Sawaga-Upper Pulangi Floodplain

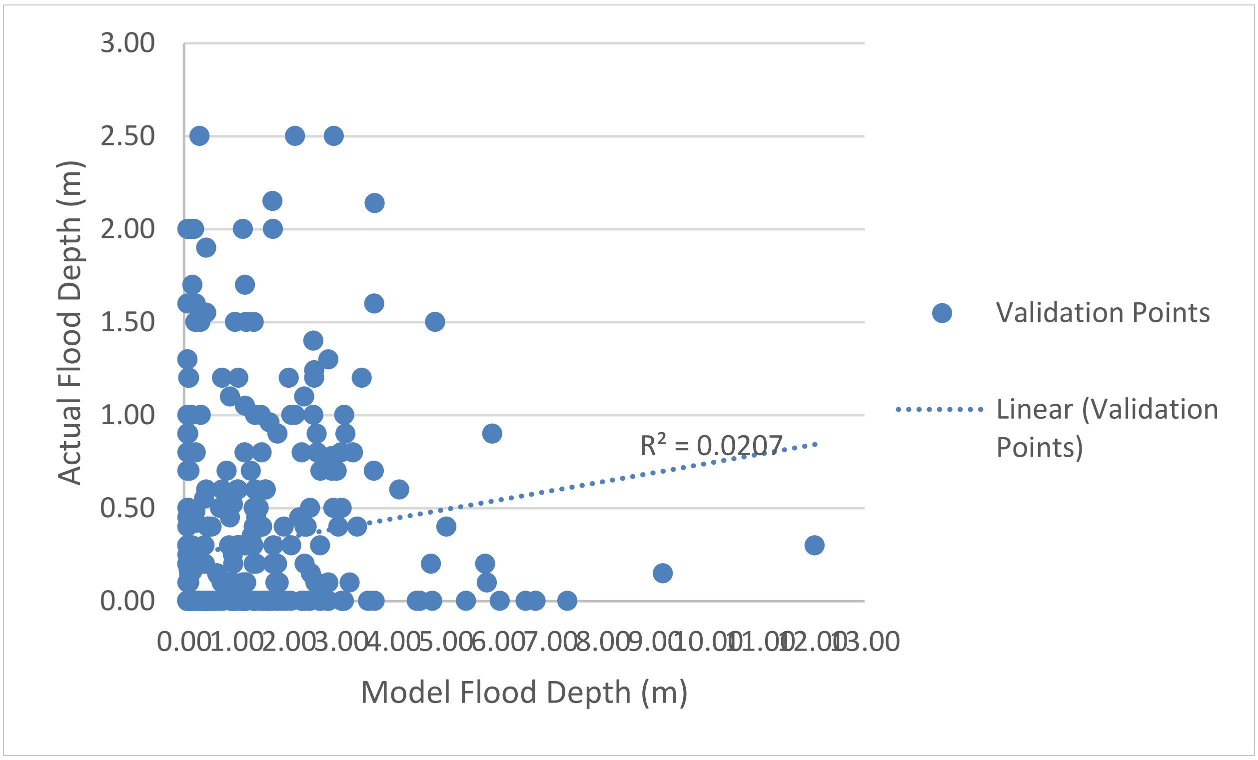


Figure 97. Flood map depth vs actual flood depth

Table 59. Actual flood vs simulated flood depth at differnent levels in the Manupali-Sawaga-Manupali River Basin.

Manupali 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	141	27	22	46	30	8	**274**
	0.21-0.50	10	5	5	15	10	2	**47**
	0.51-1.00	9	4	3	12	16	1	**45**
	1.01-2.00	9	5	3	7	9	0	**33**
	2.01-5.00	0	1	0	1	3	0	**5**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**169**	**42**	**33**	**81**	**68**	**11**	**404**

On the whole, the overall accuracy generated by the flood model is estimated at 39.36% with 159 points correctly matching the actual flood depths. In addition, there were 67 points estimated one level above and below the correct flood depths while there were 67 points and 107 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 42 points were underestimated in the modelled flood depths of Manupali-Manupali-Manupali. Table 43 depicts the summary of the Accuracy Assessment in the Manupali-Manupali-Manupali River Basin Survey.

Table 60. The summary of the Accuracy Assessment in the Manupali-Manupali-Manupali River Basin Survey

	No. of Points	%
Correct	159	39.36
Overestimated	203	50.25
Underestimated	42	10.40
Total	**404**	**100.00**

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

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

ANNEX

ANNEX 1. Technical Specifications of the LIDAR Sensors used in the Manupali Floodplain Survey

Table A-1.1 Parameters and Specification of Pegasus Sensor

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

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

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

1. MSE-19

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

June 24, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MISAMIS ORIENTAL**
Station Name: **MSE-19**
Order: **2nd**

Island: **MINDANAO**
Municipality: **CAGAYAN DE ORO**
Barangay: **BULUA**

PRS92 Coordinates

Latitude:	8° 30' 19.11464"	Longitude:	124° 37' 6.46518"	Ellipsoidal Hgt:	11.24200 m.

WGS84 Coordinates

Latitude:	8° 30' 15.52234"	Longitude:	124° 37' 11.86795"	Ellipsoidal Hgt:	78.72200 m.

PTM Coordinates

Northing:	940451.853 m.	Easting:	457992.786 m.	Zone:	5

UTM Coordinates

Northing:	940,474.22	Easting:	678,151.65	Zone:	51

Location Description

MSE-19
The station is located at the intersection of roads going to Cagayan de Oro City, Butuan City and Iligan City. It is situated on the center island between two triangular islands, about 14.5 m E of Bulua marker, about 21m W of black-tiled peace marker, about 10m S of road centerline, and about 3.5m S of the N end of the arc-shaped curb of the island. Statio mark is the head of a 4" copper nail set on the center of a 30cm. x 30 cm. x 60cm. concrete monument protruding by about 12cm. above the ground, with inscriptions, MSE-19, 2003 NAMRIA.

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1437**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MSE-19

2. MSE-20

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

July 11, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MISAMIS ORIENTAL**
Station Name: **MSE-20**
Order: **2nd**

Island: **MINDANAO**
Municipality: **CAGAYAN DE ORO**
Barangay: **LUMBIA**
MSL Elevation:

PRS92 Coordinates

Latitude:	**8° 25' 34.65372"**	Longitude:	**124° 36' 50.02579"**	Ellipsoidal Hgt:	**182.81200 m.**

WGS84 Coordinates

Latitude:	**8° 25' 31.08192"**	Longitude:	**124° 36' 55.43561"**	Ellipsoidal Hgt:	**250.44400 m.**

PTM / PRS92 Coordinates

Northing:	**931713.993 m.**	Easting:	**457481.339 m.**	Zone:	**5**

UTM / PRS92 Coordinates

Northing:	**931,733.67**	Easting:	**677,685.12**	Zone:	**51**

Location Description

MSE-20
The station is located at barangay Lumbia, Cagayan de Oro City. It is situated about 17m S of Km Post 1447, 10 Km. drive from Cagayan de Oro towards Talakag, and about 7 min. drive from SM mall. The station is in front of Oro Gardens Memorial Park, about 2.3m WNW of center curb, about 9m ESE of road centerline, and about 14m NW of S gate. Station mark is the head of a 4" copper nail, set on the center of a 9cm x 8cm cement putty, with inscriptions, MSE-20, 2003 NAMRIA.

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1597**

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

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Figure A-2.2 MSE-20

3. MSE-3241

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

April 18, 2013

CERTIFICATION

To whom it may concern:

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

Province: **MISAMIS ORIENTAL**
Station Name: **MSE-3241**
Order: **3rd**

Island: **MINDANAO**
Municipality: **CAGAYAN DE ORO CITY (CAPITAL)**
Barangay: **BARANGAY 10 (POB.)**

PRS92 Coordinates

Latitude:	**8° 27' 31.07607"**	Longitude:	**124° 37' 23.18891"**	Ellipsoidal Hgt:	**109.46700 m.**

WGS84 Coordinates

Latitude:	**8° 27' 27.49608"**	Longitude:	**124° 37' 28.59587"**	Ellipsoidal Hgt:	**177.05500 m.**

PTM Coordinates

Northing:	**935289.375 m.**	Easting:	**458499.251 m.**	Zone:	**5**

UTM Coordinates

Northing:	**935,314.30**	Easting:	**678,684.71**	Zone:	**51**

Location Description

MSE-3241
Is located at the center island along Macapagal Rd., Brgy. 10 (Pob.), Cagayan de Oro City. It is situated between Sungcle Bldg. and Super Mart Mall, about 20 m. facing the mall entrance. Mark is the head of a 4 in. copper nail embedded on a 25 cm. x 25 cm. concrete block, with inscriptions "MSE-3241 2007 NAMRIA".

Requesting Party:	**UP DREAM/ Melchor Nery**
Pupose:	**Reference**
OR Number:	**3943540 B**
T.N.:	**2013-0311**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/13/09/864

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Figure A-2.3 MSE-3241

4. MSE-3340

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

July 11, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MISAMIS ORIENTAL**
Station Name: **MSE-3340**
Order: **3rd**

Island: **MINDANAO**		Barangay: **AGUSAN**
Municipality: **CAGAYAN DE ORO CITY (CAPITAL)**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **8° 29' 23.43073"**	Longitude: **124° 44' 11.52934"**	Ellipsoidal Hgt: **5.99600 m.**
	WGS84 Coordinates	
Latitude: **8° 29' 19.85261"**	Longitude: **124° 44' 16.93252"**	Ellipsoidal Hgt: **73.80100 m.**
	PTM / PRS92 Coordinates	
Northing: **938730.493 m.**	Easting: **470991.591 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **938,819.85**	Easting: **691,159.90**	Zone: **51**

Location Description

MSE-3340
MSE 3340 is located inside the Agusan Barangay Plaza, Agusan, Cagayan de Oro City. Mark is the rubber engraved with bronze nail at the center of a concrete monuments with inscription " MSE 3340, 2008 LMS 10 " on top.

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1598**

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

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Figure A-2.4 MSE-3340

5. BKN-475

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

February 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: **BUKIDNON**
Station Name: **BKN-475**
Order: **2nd**

Island: **MINDANAO**
Municipality: **CITY OF MALAYBALAY (CAPITAL)**
Barangay: **AGLAYAN**
MSL Elevation:

PRS92 Coordinates

Latitude:	**8° 3' 25.94887"**	Longitude:	**125° 7' 58.68680"**	Ellipsoidal Hgt:	**404.31400 m.**

WGS84 Coordinates

Latitude:	**8° 3' 22.52096"**	Longitude:	**125° 8' 4.12506"**	Ellipsoidal Hgt:	**473.98000 m.**

PTM / PRS92 Coordinates

Northing:	**890880.244 m.**	Easting:	**514656.29 m.**	Zone:	**5**

UTM / PRS92 Coordinates

Northing:	**891,179.54**	Easting:	**735,073.78**	Zone:	**51**

Location Description

BKN-475
From Malaybalay City Proper, travel along the Nat'l. Road going to Valencia City until reaching Brgy. Aglayan. Station is located inside the DPWH compound. Mark is the head of a 4 in. copper nail embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "BKN-475 2007 NAMRIA".

Requesting Party: **AB Surveying & Dev't.**
Purpose: **Reference**
OR Number: **8077642 I**
T.N.: **2015-0286**

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

9902112015140124

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Figure A-2.5 BKN-475

6. BKN-478

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

November 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: **BUKIDNON**
Station Name: **BKN-478**
Order: **2nd**

Island: **MINDANAO**
Municipality: **CITY OF VALENCIA**
Barangay: **SINAYAWAN**
MSL Elevation:

	PRS92 Coordinates	
Latitude: **7° 52' 39.32095"**	Longitude: **125° 8' 33.26511"**	Ellipsoidal Hgt: **302.83700 m.**
	WGS84 Coordinates	
Latitude: **7° 52' 35.94157"**	Longitude: **125° 8' 38.71964"**	Ellipsoidal Hgt: **372.88500 m.**
	PTM / PRS92 Coordinates	
Northing: **871017.702 m.**	Easting: **515721.851 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **871,315.75**	Easting: **736,235.86**	Zone: **51**

Location Description

BKN-478
Is located beside the basketball court of Purok 6, Brgy. Sinayawan. Mark is the head of a 4 in. copper nail embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "BKN-478 2007 NAMRIA".

Requesting Party: **Phil Lidar 1**
Purpose: **Reference**
OR Number: **FREE ISSUE**
T.N.: **2016-2056**

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

99111420161444632

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Figure A-2.6 BKN-478

7. BK-56

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

February 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: **BUKIDNON**
Station Name: **BK-56**

Island: **Mindanao**	Municipality: **MALAYBALAY**	Barangay: **KALASUNGAY**
Elevation: **656.6448 +/- 0.00**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

BK-56
Station is located at the west post of the welcome arc of Malaybalay, and about 7m. from the centerline of the highway. Mark is the head of 4" copper nail set on a drilled hole and cemented on top of a 15x15 cm. cement ptty with the inscription " BMBK-56, 2008, NAMRIA".

Requesting Party: **AB Surveying & Dev't.**
Purpose: **Reference**
OR Number: **8077642 I**
T.N.: **2015-0285**

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

9902112015135941

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Figure A-2.7 BK-56

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

Table A-3.1 [ ]

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	
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	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		PAULINE ARCEO	
	Research Associate (RA)	GRACE SINADJAN	
		ENGR. IRO NIEL ROXAS	
		REGINA FELISMINO	
		NICHOLAS ILEJAY	
Ground Survey, Data Download and Transfer	RA	LANCE KERWIN CINCO	
		BRYLLE DE CASTRO	
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR ALFONSO III	
		CAPT. ANTON DAYO	
		CAPT. ERNESTO SAYSAY JR.	

ANNEX 5. Data Transfer Sheet for Manupali Floodplain

DATA TRANSFER SHEET
06/10/2014(Northern Mindanao) Outgoing

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	
5/22/2014	1497P	1BLK67B142A	PEGASUS	1.8	1342	8.61	201	31.8	221	19.1	NA	5.19	1KB	1KB	49	NA	Z:\Airborne_Raw\1497P
5/23/2014	1501P	1BLK67C143A	PEGASUS	3	1221	14.1	271	77.3	539	29.5	NA	7.61	1KB	1KB	59/56	NA	Z:\Airborne_Raw\1501P
5/24/2014	1505P	1BLK67BC144A	PEGASUS	2.25	759	10	212	46.7	340	21.8	NA	7.68	1KB	1KB	97	NA	Z:\Airborne_Raw\1505P
5/25/2014	1509P	1RDXE145A	PEGASUS	2.4	338	11.2	254	~~NA~~ 31.622	~~31.6/22~~ NA	26.2	NA	4.96	1KB	1KB	50/43	NA	Z:\Airborne_Raw\1509P
5/27/2014	1517P	1RXE147A	PEGASUS	2.74	1497	12	235	NA	NA	27.7	NA	9.7	1KB	1KB	78/72	NA	Z:\Airborne_Raw\1517P
5/28/2014	1521P	1RXC148A	PEGASUS	2.39	490	12	252	NA	NA	28	NA	5.54	1KB	1KB	52	NA	Z:\Airborne_Raw\1521P

Received from

Name C. Joaquin
Position
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 6/10/2014

Figure A-5.1 Transfer Sheet for Manupali Floodplain - A

DATA TRANSFER SHEET
07/28/2014(Northern Mindanao - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6/8/2014	1565P	1BLK71B159A	Pegasus	NA	16	6.93	168	NA	NA	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw
6/9/2014	1569P	1BLKRXE160A	Pegasus	4.16	832	16.5	290	8.86	62	38.5	NA	10	1KB	1KB	85	NA	Z:\Airborne_Raw
6/16/2014	1597P	1BLKRXE167A	Pegasus	2.18	332	10.5	237	NA	NA	21.3	NA	7.52	1KB	1KB	68	NA	Z:\Airborne_Raw
6/19/2014	1609P	1RXS170A	Pegasus	2.16	526	11.2	259	45.3	309	22.1	NA	7.07	1KB	1KB	77/76	NA	Z:\Airborne_Raw
6/20/2014	1613P	1BLK71G171A	Pegasus	3.44	177	13.7	258	67.3	437	33.2	NA	5.92	1KB	1KB	46	NA	Z:\Airborne_Raw
6/23/2014	1625P	1BLK67BC174A	Pegasus	3.09	1112	11.7	212	60.3	415	29.4	86.6	4.97	1KB	1KB	52/56	NA	Z:\Airborne_Raw
6/24/2014	1629P	1BLKRXES175A	Pegasus	2.79	370	10.7	187	36.3	268	26.1	NA	4.45	1KB	1KB	73	NA	Z:\Airborne_Raw
6/27/2014	1641P	1BLK68A178A	Pegasus	2.94	1995	12.6	268	57.4	398	28.9	57.2	7.7	1KB	1KB	65/65/60/58	NA	Z:\Airborne_Raw
6/27/2014	1643P	1BLK67ABS178B	Pegasus	532	95	4.33	119	NA	NA	5.65	NA	7.7	1KB	1KB	48	NA	Z:\Airborne_Raw
6/28/2014	1645P	1BLK71C179A	Pegasus	2.84	NA	11.4	242	51.8	375	27.4	NA	6.25	1KB	1KB	59/68	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 7/28/14

Figure A-5.2 Transfer Sheet for Manupali Floodplain - B

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

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

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

8/6/14

Figure A-5.3 Transfer Sheet for Manupali Floodplain - C

DATA TRANSFER SHEET

BUKIDNON 11/14/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
October 23, 2016	23486P	1BKND297A	PEGASUS	1.53	215	8.14	208	NA	NA	13.2	NA	210	1KB	1KB	1.29	NA	Z:\DAC\RAW DATA
October 24, 2016	23488P	1BKNDE298A	PEGASUS	2.11	363	11.4	255	NA	NA	21	NA	272	1KB	1KB	457	NA	Z:\DAC\RAW DATA

Received from

Name [illegible]
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 11/16/16

Figure A-5.4 Transfer Sheet for Manupali Floodplain - D

DATA TRANSFER SHEET
BUKIDNON (11/07/2016)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
October 25, 2016	23492P	1BKNDE299A	PEGASUS	2.2 GB	290KB	9.91 MB	230 MB	NA	NA	20.9 GB	NA	217 MB	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 11/16/16

Figure A-5.5 Transfer Sheet for Manupali Floodplain - E

DATA TRANSFER SHEET
BUKIDNON 11/14/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 06, 2016	23516P	1BKNF311A	PEGASUS	2.41	NA	11.9	269	NA	NA	22.5	NA	283	1KB	1KB	715	NA	Z:\DAC\RAW DATA
November 06, 2016	23518P	1BKNF311B	PEGASUS	973	NA	4.98	105	NA	NA	8.86	NA	283	1KB	1KB	857	NA	Z:\DAC\RAW DATA
November 07, 2016	23520P	1BKNF312A	PEGASUS	2.83	NA	13.1	274	NA	NA	24.5	NA	158	1KB	1KB	595	59.8	Z:\DAC\RAW DATA
November 08, 2016	2352[illegible]P	1BKNF313A	PEGASUS	2.91	NA	12.1	237	NA	NA	27	NA	141	1KB	1KB	595	12.8	Z:\DAC\RAW DATA

23524P

Received from

Name R. Punto
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 11/14/16

Figure A-5.6 Transfer Sheet for Manupali Floodplain - F

DATA TRANSFER SHEET
BUKIDNON 11/21/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 10, 2016	23534P	1BKNG315A	PEGASUS	1.61	NA	8	255	NA	NA	16.6	NA	136	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
November 11, 2016	23536P	1BKNDE316A	PEGASUS	2.45	NA	10.6	236	NA	NA	22.9	NA	146	1KB	1KB	595	5KB	Z:\DAC\RAW DATA
November 12, 2016	23540P	1BKNE317A	PEGASUS	2.3	NA	9.76	263	NA	NA	21.4	NA	131	1KB	1KB	646	NA	Z:\DAC\RAW DATA
November 13, 2016	23544P	1BKNE318A	PEGASUS	2.61	NA	10.8	230	NA	NA	24.3	NA	299	1KB	1KB	595	NA	Z:\DAC\RAW DATA
November 13, 2016	23546P	1BKNG318B	PEGASUS	1.95	NA	9.55	262	NA	NA	18.1	NA	299	1KB	1KB	554	NA	Z:\DAC\RAW DATA
November 14, 2016	23548P	1BKNEF319A	PEGASUS	2.86	NA	12	268	NA	NA	26.7	NA	208	1KB	1KB	554	NA	Z:\DAC\RAW DATA
November 15, 2016	23552P	1BLK64A320A	PEGASUS	2.1	NA	10.5	261	NA	NA	20.6	NA	131	1KB	1KB	174	NA	Z:\DAC\RAW DATA

Received from

Name: R. PUNTO
Position: RA
Signature: [signature]

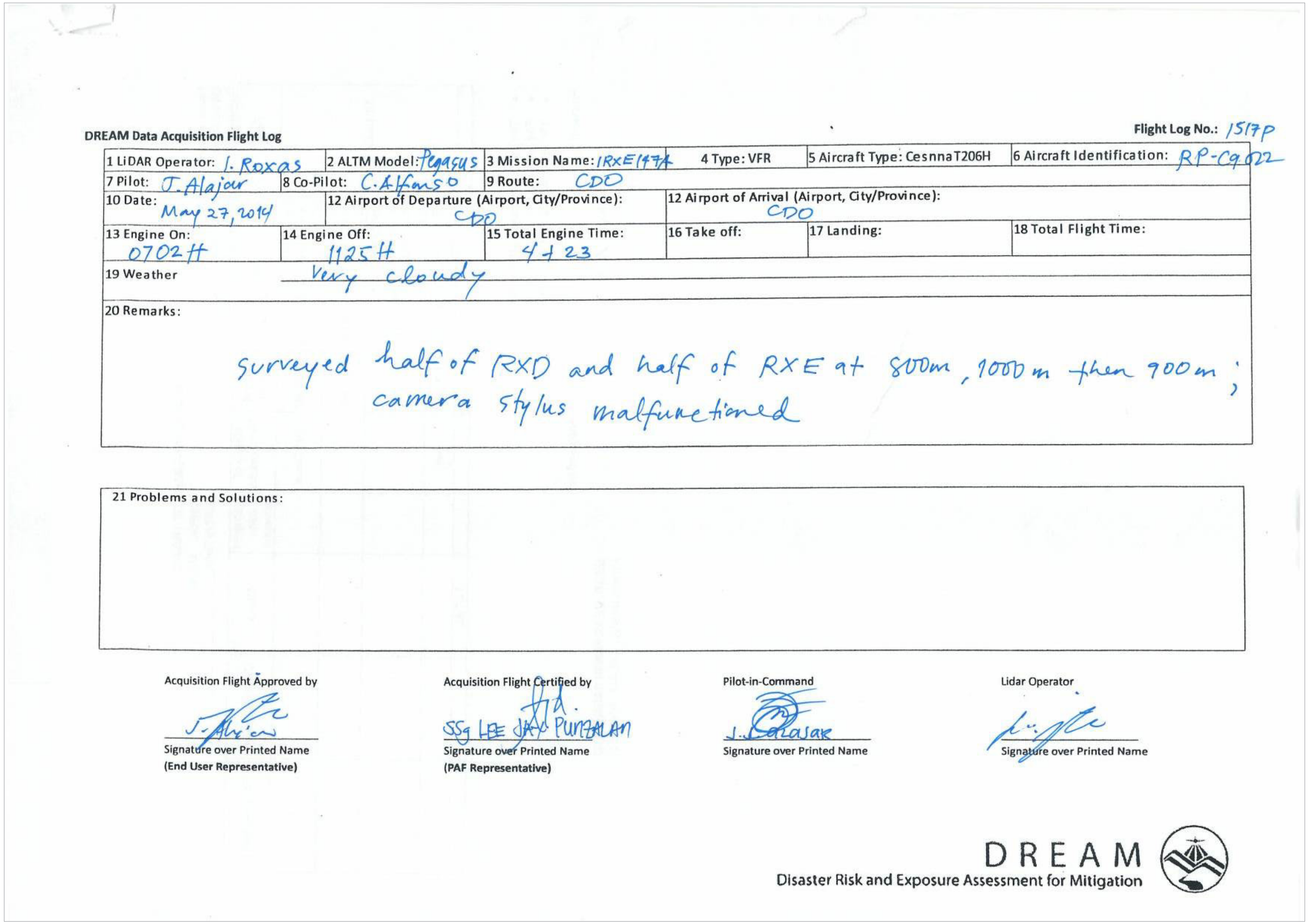
Received by

Name: AC Bongat
Position: SSRS
Signature: [signature] 11/24/2016

Figure A-5.7 Transfer Sheet for Manupali Floodplain - G

ANNEX 6. Flight logs for the flight missions

1. Flight Log for Mission 1517P



DREAM Data Acquisition Flight Log

Flight Log No.: 1517P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1RXE147A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: C. Alfonso	9 Route: CDO			
10 Date: May 27, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0702H	14 Engine Off: 1125H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Very cloudy				

20 Remarks:

surveyed half of RXD and half of RXE at 800m, 1000m then 900m; camera stylus malfunctioned

21 Problems and Solutions:

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

Acquisition Flight Certified by: SSg Lee Jay Punzalan — Signature over Printed Name (PAF Representative)

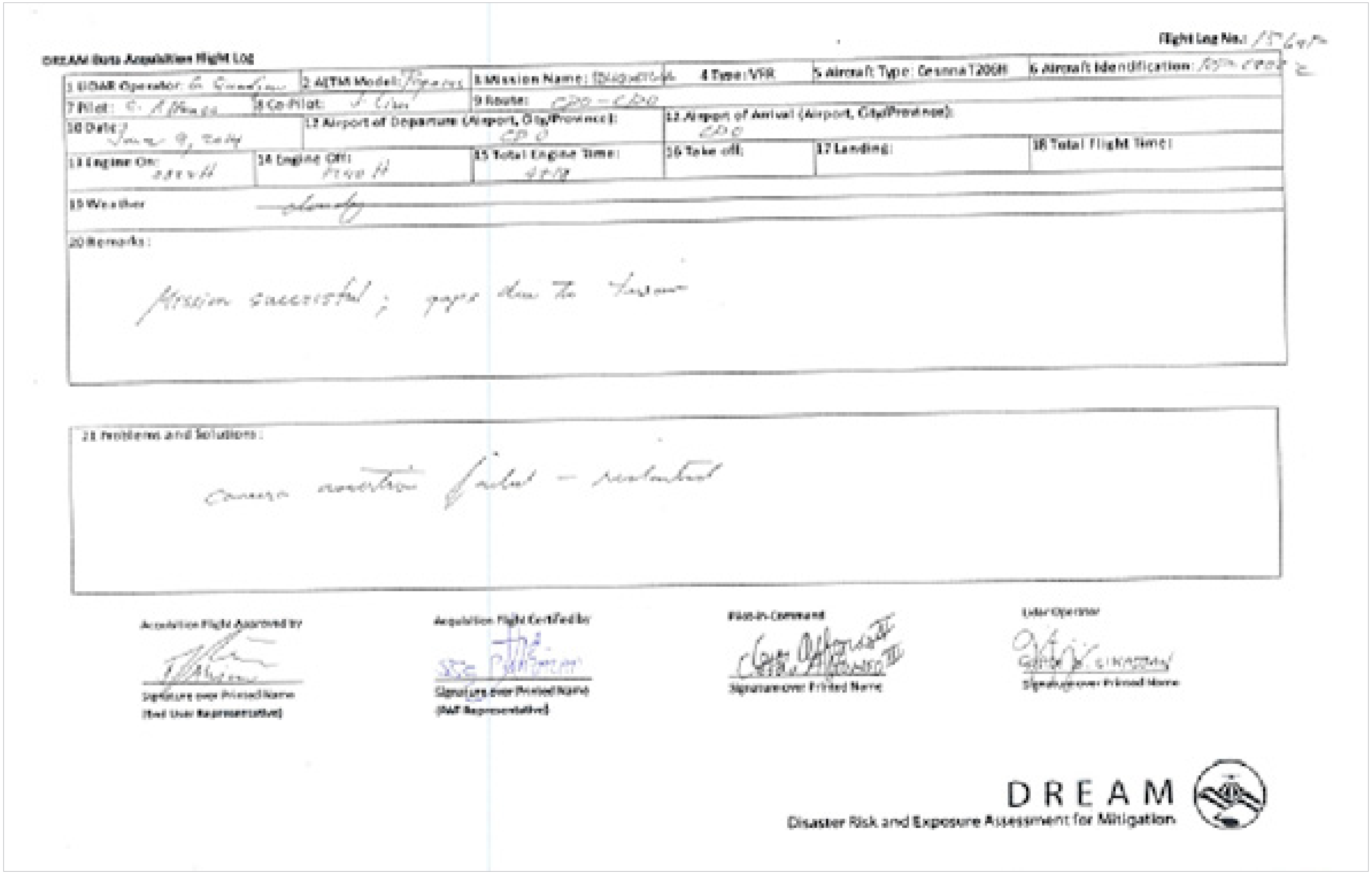
Pilot-in-Command: J. Calasag — Signature over Printed Name

Lidar Operator: Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1 Flight Log for Mission 1517P

2. Flight Log for Mission 1569P



Flight Log No.: 1569P

DREAM Data Acquisition Flight Log

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Chan	9 Route: CDO - CDO			
10 Date: June 9, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Mission successful; ...

21 Problems and Solutions:

camera ... failed - restarted

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

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

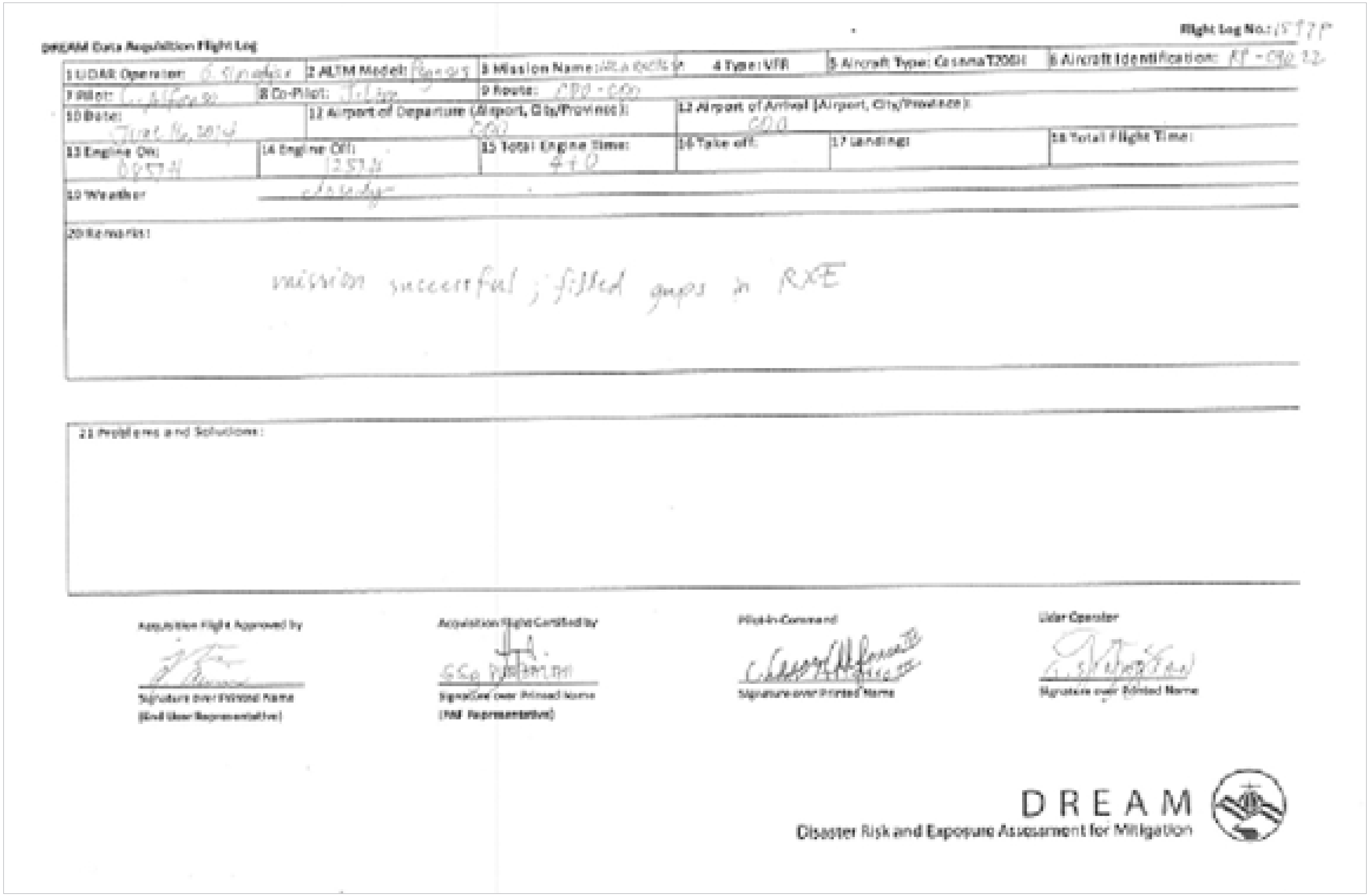
Pilot-in-Command — C. Alfonso III — Signature over Printed Name

Lidar Operator — G. Sinadjan — Signature over Printed Name

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2 Flight Log for Mission 1569P

3. Flight Log for Mission 1597P



Flight Log No.: 1597P

DREAM Data Acquisition Flight Log

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

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

10 Date: June 16, 2014
12 Airport of Departure (Airport, City/Province): CDO
12 Airport of Arrival (Airport, City/Province): CDO

13 Engine On: 0853H
14 Engine Off: 1253H
15 Total Engine Time: 4+0
16 Take off:
17 Landing:
18 Total Flight Time:

19 Weather: cloudy

20 Remarks:

mission successful; filled gaps in RXE

21 Problems and Solutions:

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3 Flight Log for Mission 1597P

4. Flight Log for Mission 1629P

DREAM Data Acquisition Flight Log

Flight Log No.: [illegible]

1 LIDAR Operator: [illegible]	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: [illegible]
7 Pilot: [illegible]	8 Co-Pilot: [illegible]	9 Route: [illegible]			
10 Date: [illegible]	11 Airport of Departure (Airport, City/Province): [illegible]		12 Airport of Arrival (Airport, City/Province): [illegible]		
13 Engine On: [illegible]	14 Engine Off: [illegible]	15 Total Engine Time: [illegible]	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Mission successful at 1500 AGL

21 Problems and Solutions:

Left magneto problem before flight

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

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

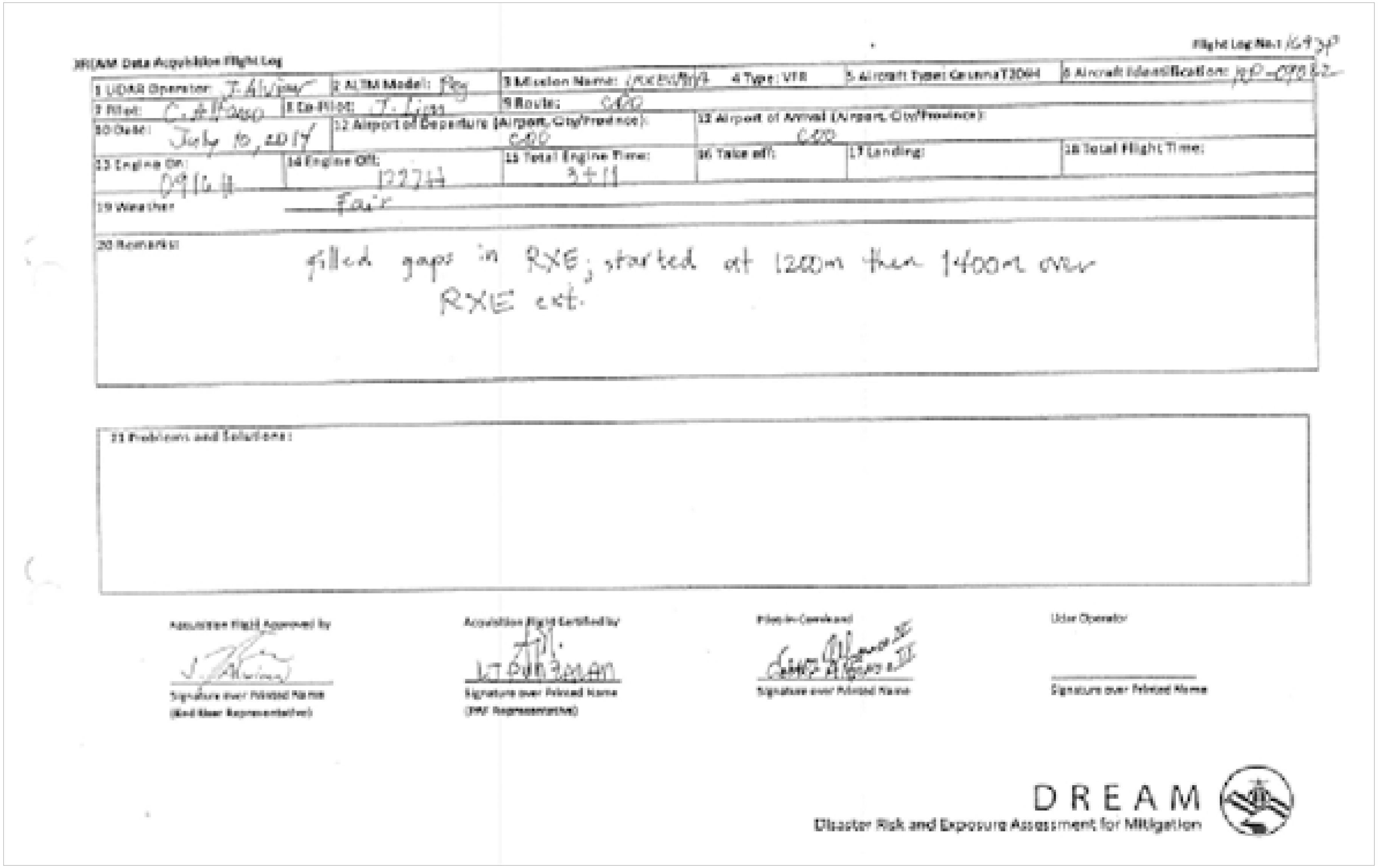
Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4 Flight Log for Mission 1629P

5. Flight Log for Mission 1693P



Flight Log No.: 1693P

DREAM Data Acquisition Flight Log

1 LIDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1RXE193A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CGO			
10 Date: July 10, 2014	12 Airport of Departure (Airport, City/Province): CGO		12 Airport of Arrival (Airport, City/Province): CGO		
13 Engine On: 0916H	14 Engine Off: 1227H	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Remarks:

filled gaps in RXE; started at 1200m then 1400m over RXE ext.

21 Problems and Solutions:

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

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

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

Lidar Operator: Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.5 Flight Log for Mission 1693P

6. Flight Log for Mission 23486P

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23486P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BKNS297A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. Dayo	8 Co-Pilot: K. Chi	9 Route: Laguindingan - Laguindingan			
10 Date: Oct 23, 2014	12 Airport of Departure (Airport, City/Province): Laguindingan		12 Airport of Arrival (Airport, City/Province): Laguindingan		
13 Engine On: 1155H	14 Engine Off: 1534H	15 Total Engine Time: 3+41	16 Take off: 1200H	17 Landing: 1531H	18 Total Flight Time: 3+31
19 Weather	heavy build up w/ ppt				

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

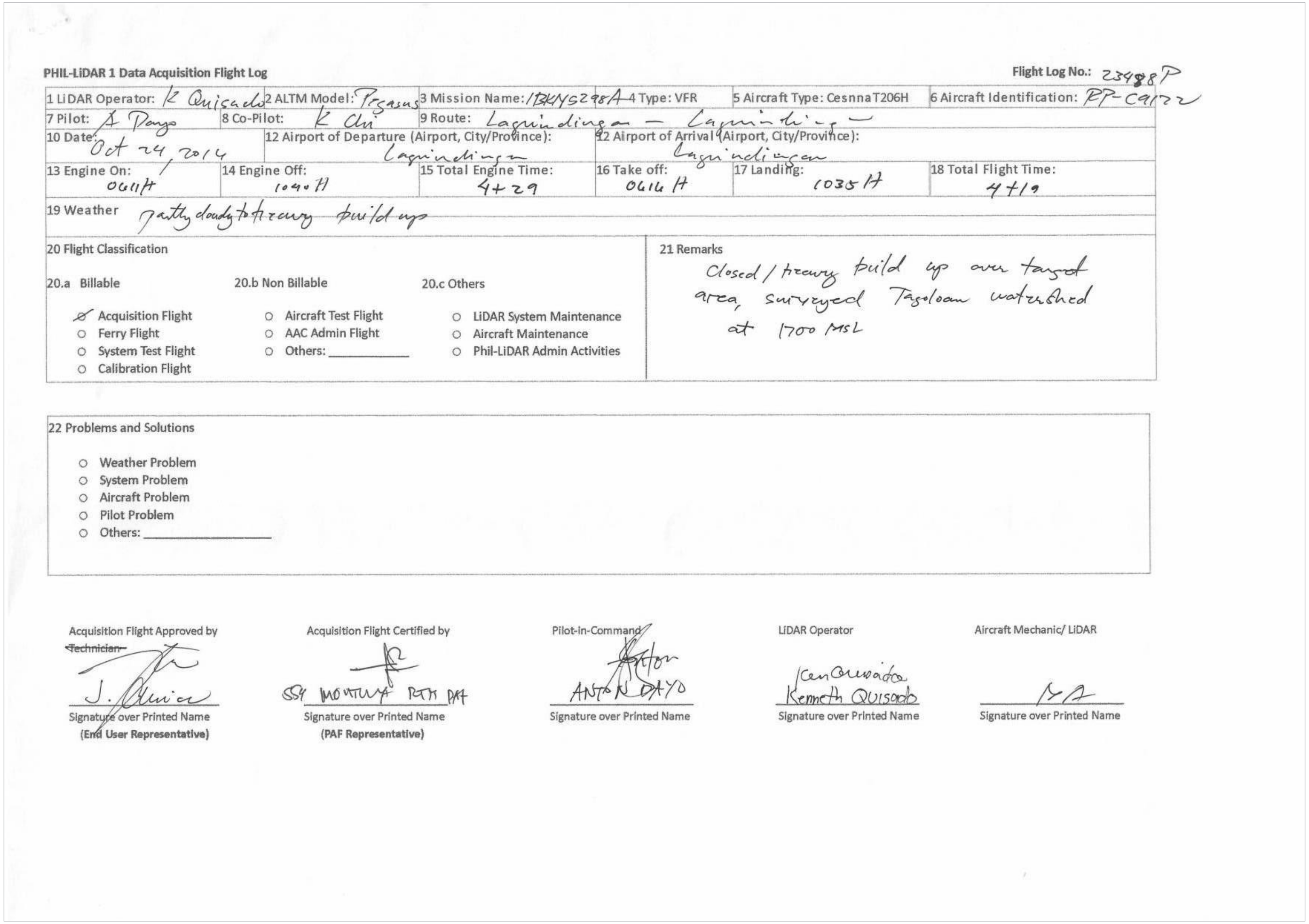
visual closing in target areas; transferred to Manolo Fortich (Tagoloan VVS); surveyed few at 1300m MSL

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR ~~Technician~~
J. Alviar	SSG [illegible] PAF	Anton Dayo	J. Alviar	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.6 Flight Log for Mission 23486P

7. Flight Log for Mission 23488P


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23488P

1 LiDAR Operator: K Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK52 98A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: A Dayo	8 Co-Pilot: K Chi	9 Route: Laguindingan – Laguindingan			
10 Date: Oct 24, 2014	12 Airport of Departure (Airport, City/Province): Laguindingan		12 Airport of Arrival (Airport, City/Province): Laguindingan		
13 Engine On: 0611H	14 Engine Off: 1040H	15 Total Engine Time: 4+29	16 Take off: 0616H	17 Landing: 1035H	18 Total Flight Time: 4+19
19 Weather: partly cloudy to heavy build ups					

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

Closed / heavy build up over target area, surveyed Tagoloan watershed at 1700 MSL

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

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

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

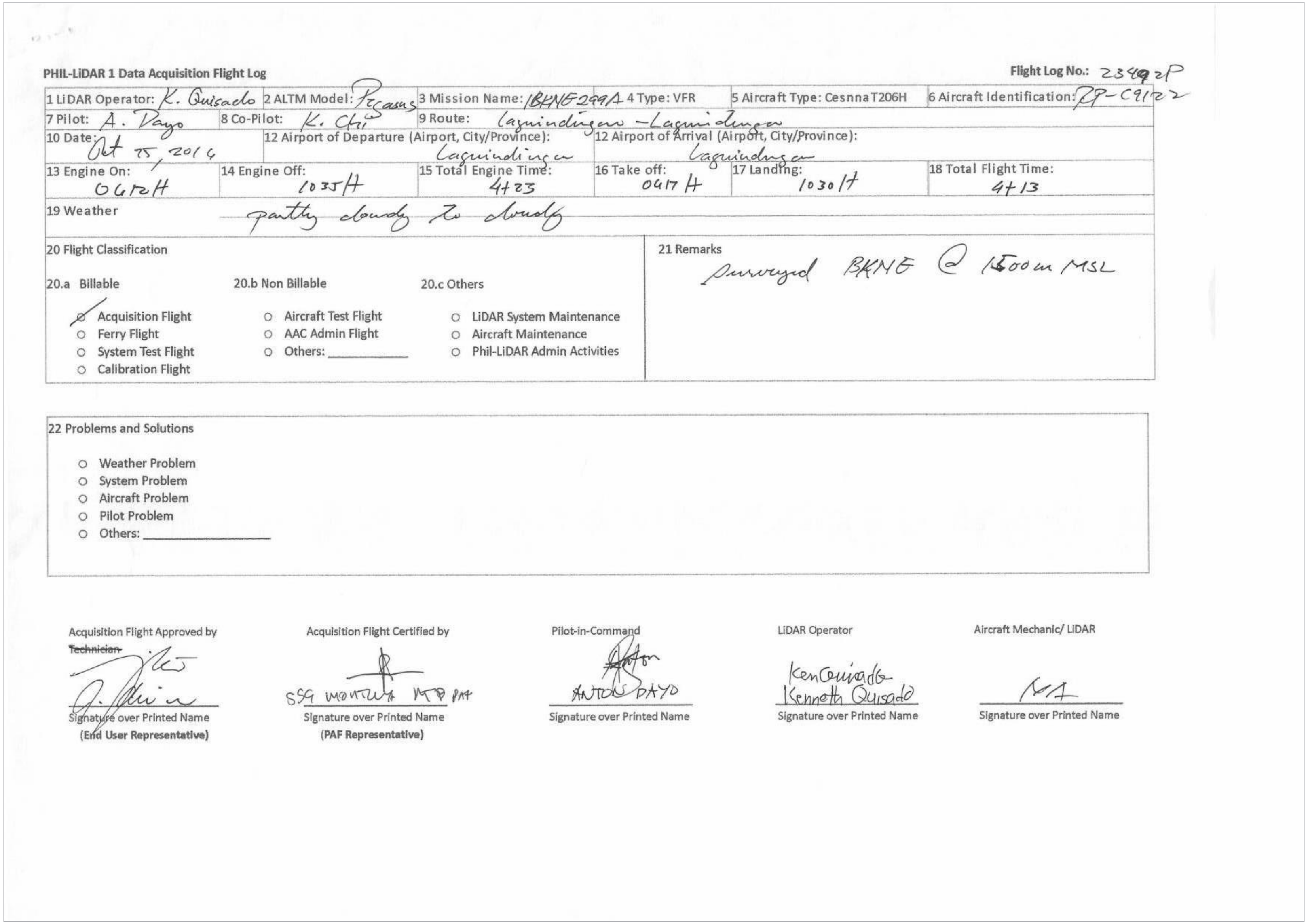
Pilot-in-Command: Anton Dayo — Signature over Printed Name

LiDAR Operator: Kenneth Quisado — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.7 Flight Log for Mission 23488P

8. Flight Log for Mission 23492P



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23492P

1 LiDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BKNE 299A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. Dayo	8 Co-Pilot: K. Chi	9 Route: Laguindingan – Laguindingan			
10 Date: Oct 25, 2014	12 Airport of Departure (Airport, City/Province): Laguindingan		12 Airport of Arrival (Airport, City/Province): Laguindingan		
13 Engine On: 0612H	14 Engine Off: 1035H	15 Total Engine Time: 4+23	16 Take off: 0617H	17 Landing: 1030H	18 Total Flight Time: 4+13
19 Weather: partly cloudy to 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

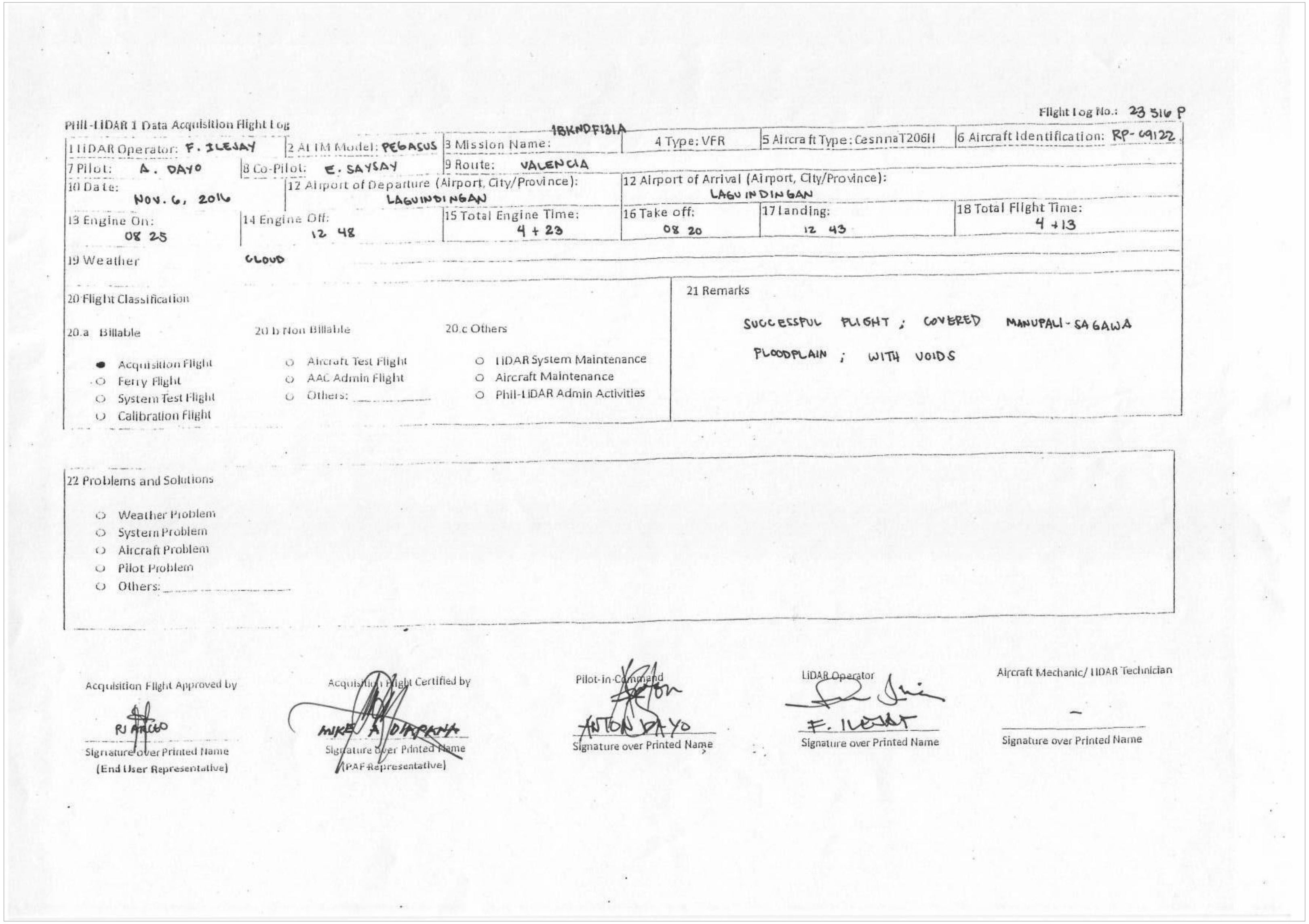
Surveyed BKNE @ 1500 m MSL

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name (End User Representative)	SSG Montilla [illegible] PAF Signature over Printed Name (PAF Representative)	Anton Dayo Signature over Printed Name	Kenneth Quisado Signature over Printed Name	Signature over Printed Name

Figure A-6.8 Flight Log for Mission 23492P

9. Flight Log for Mission 23516P



Flight Log No.: 23516P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: F. ILEJAY	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNDF131A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 6, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 08 25	14 Engine Off: 12 48	15 Total Engine Time: 4 + 23	16 Take off: 08 20	17 Landing: 12 43	18 Total Flight Time: 4 + 13
19 Weather: CLOUD					

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 ; COVERED MANUPALI-SAGAWA FLOODPLAIN ; WITH VOIDS

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

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

Acquisition Flight Certified by: MIKE A DIAPANA — Signature over Printed Name (PAF Representative)

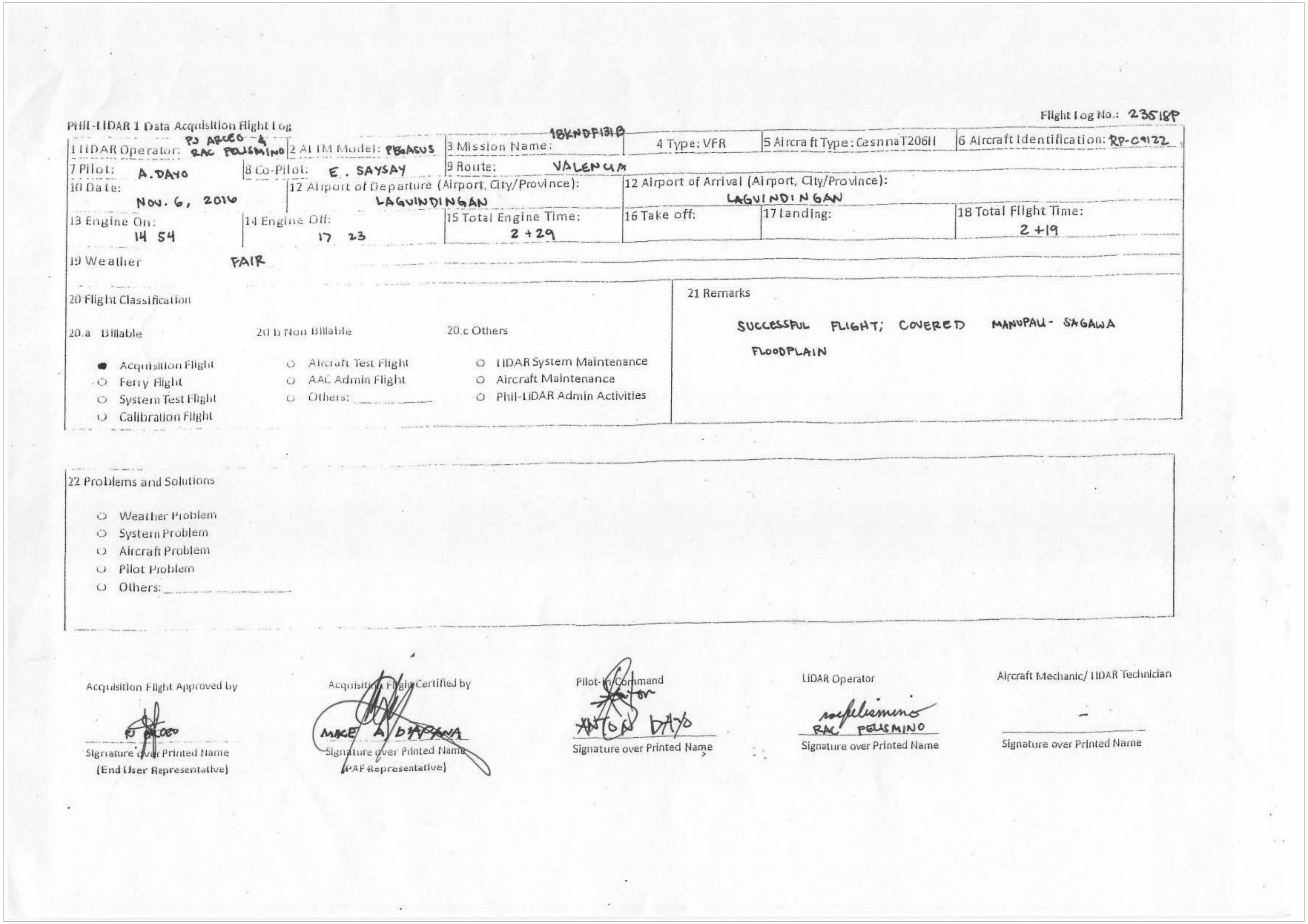
Pilot-in-Command: ANTON DAYO — Signature over Printed Name

LIDAR Operator: F. ILEJAY — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

Figure A-6.9 Flight Log for Mission 23516P

10. Flight Log for Mission 23518P



Flight Log No.: 23518P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: PJ ARCEO - RAC FELISMINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNDF131B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 6, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 14 54	14 Engine Off: 17 23	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time: 2+19
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

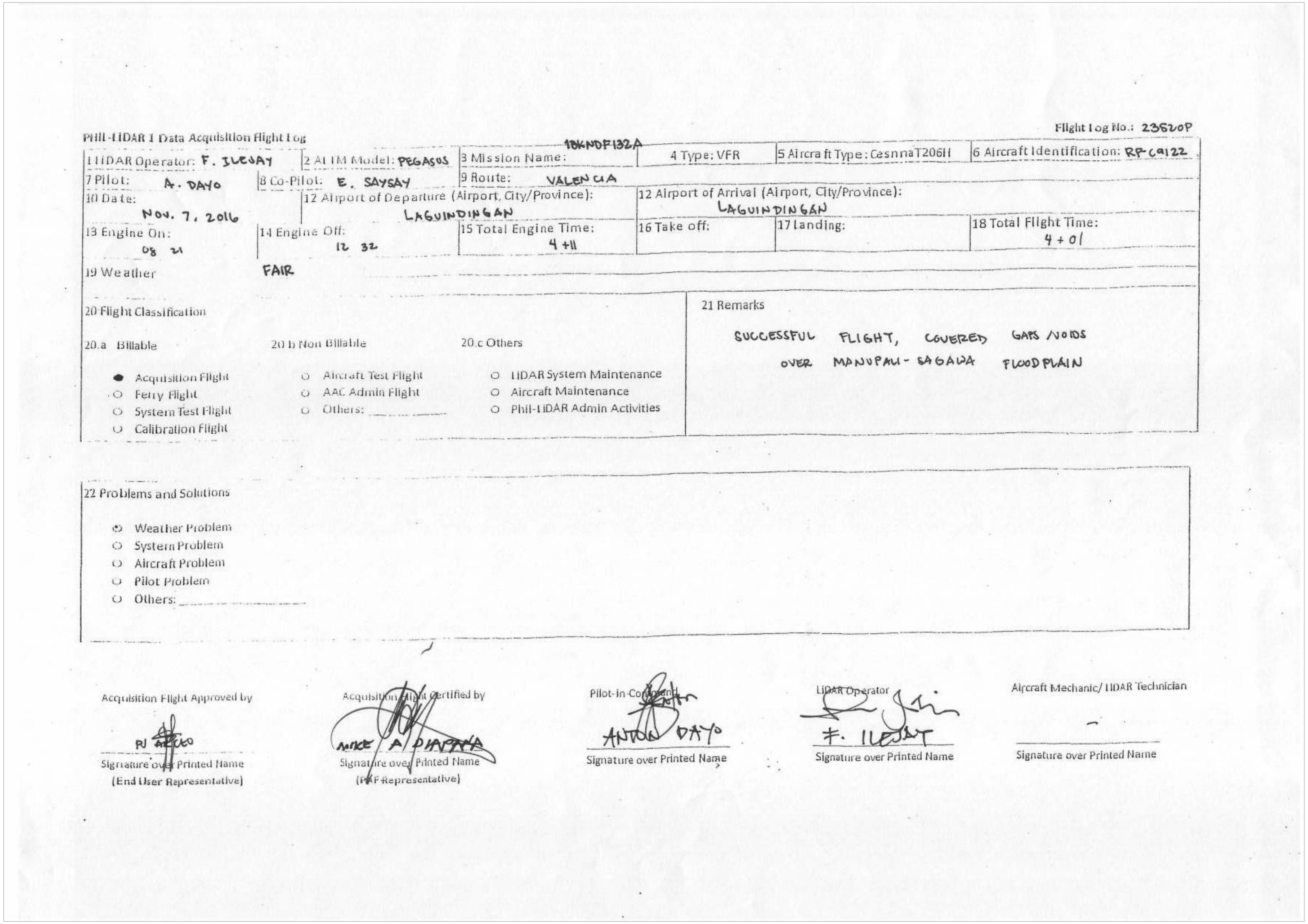
SUCCESSFUL FLIGHT; COVERED MANUPALI - SAGAWA FLOODPLAIN

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
PJ ARCEO Signature over Printed Name (End User Representative)	MIKE A. DIAPANA Signature over Printed Name (PAF Representative)	ANTON DAYO Signature over Printed Name	RAC FELISMINO Signature over Printed Name	Signature over Printed Name

Figure A-6.10 Flight Log for Mission 23518P

11. Flight Log for Mission 23520P



Flight Log No.: 23520P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: F. ILEJAY	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNDF132A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 7, 2016		12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN	
13 Engine On: 08 21	14 Engine Off: 12 32	15 Total Engine Time: 4 +11	16 Take off:	17 Landing:	18 Total Flight Time: 4 + 01
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, COVERED GAPS/VOIDS OVER MANUPALI - SAGADA FLOODPLAIN

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

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

Acquisition Flight Certified by: MIKE A DIAPANA — Signature over Printed Name (PAF Representative)

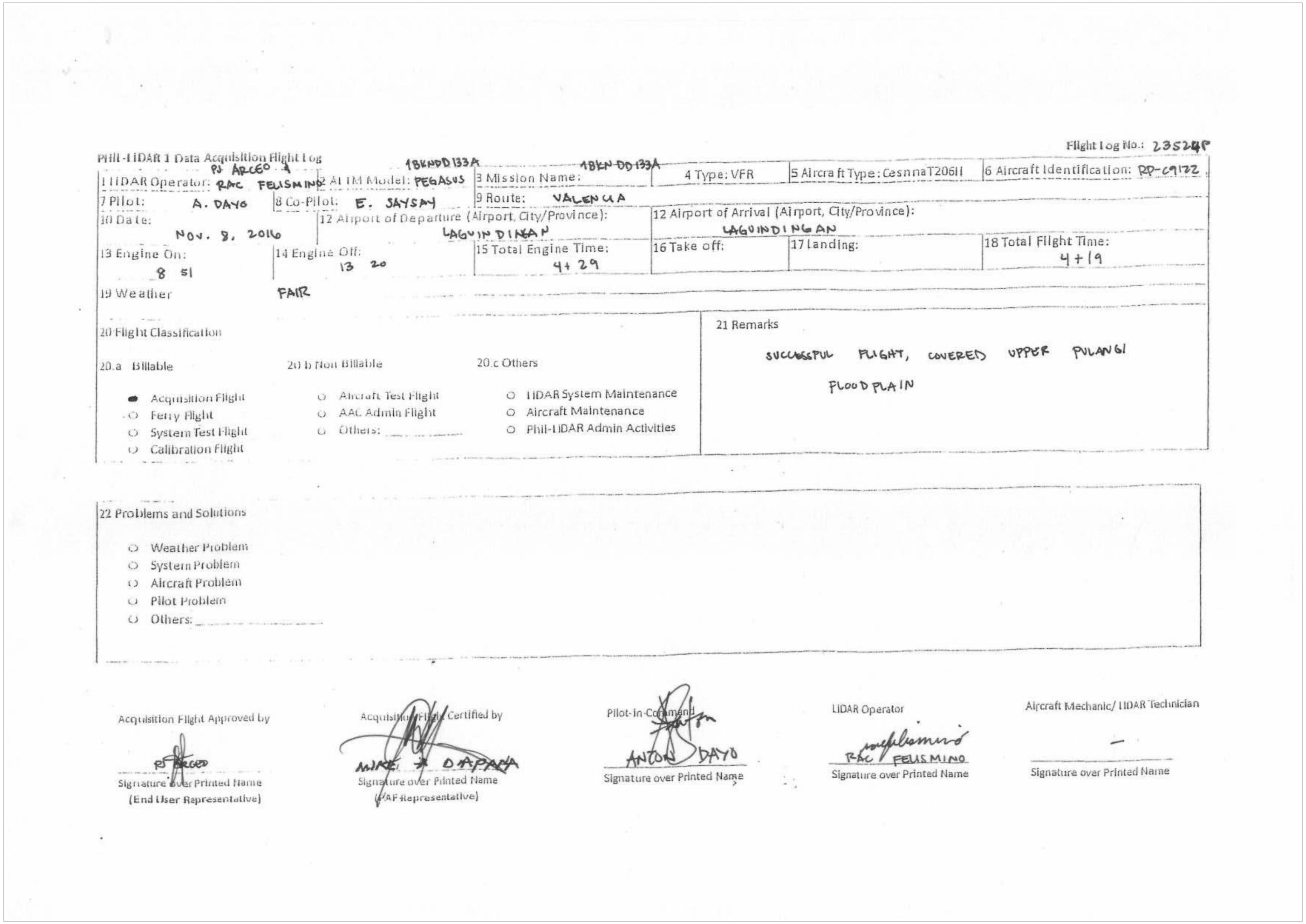
Pilot-in-Command: ANTON DAYO — Signature over Printed Name

LIDAR Operator: F. ILEJAY — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

Figure A-6.11 Flight Log for Mission 23520P

12. Flight Log for Mission 23524P



Flight Log No.: 23524P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: RAC FELISMINO / PJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNDD133A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 8, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 8 51	14 Engine Off: 13 20	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time: 4+19
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

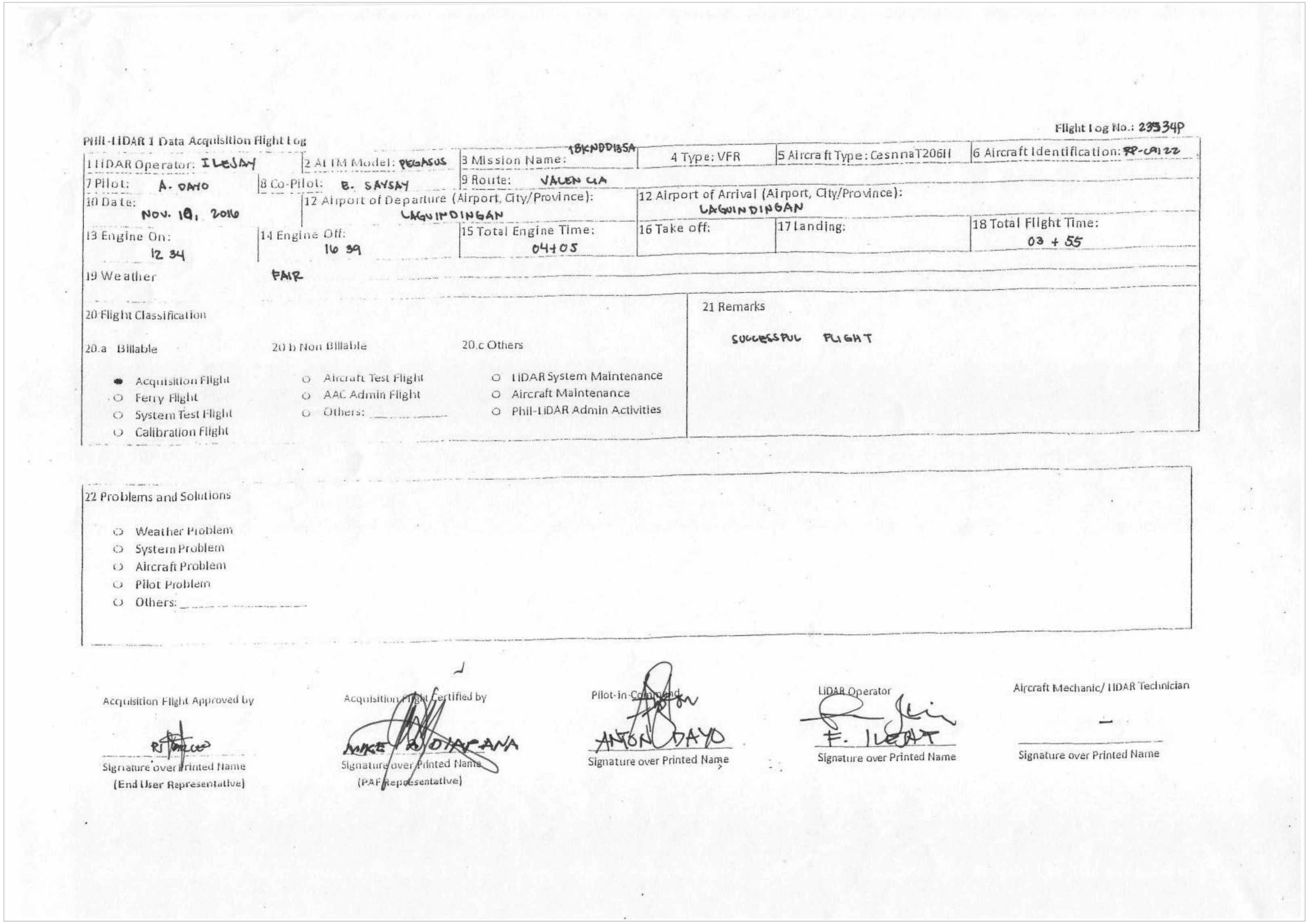
SUCCESSFUL FLIGHT, COVERED UPPER PULANGI FLOOD PLAIN

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
PJ ARCEO	MIKE ? DAPAPA	ANTON DAYO	RAC FELISMINO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.12 Flight Log for Mission 23524P

13. Flight Log for Mission 23534P



Flight Log No.: 23534P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: I. LEJAY	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNDD185A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: B. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 19, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 12 34	14 Engine Off: 16 39	15 Total Engine Time: 04+05	16 Take off:	17 Landing:	18 Total Flight Time: 03 + 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

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

Acquisition Flight Approved by: RJ [signature] — Signature over Printed Name (End User Representative)

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

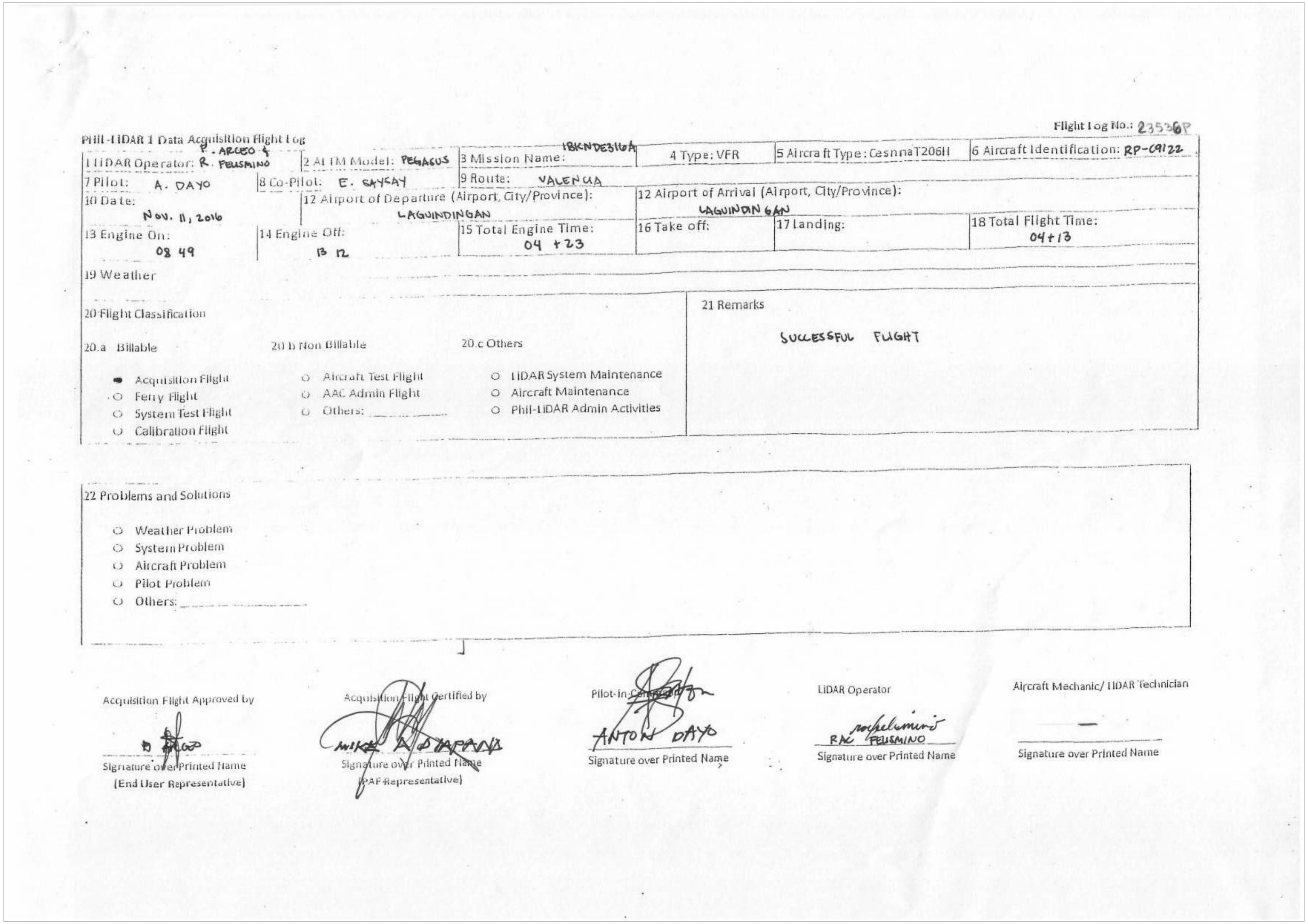
Pilot-in-Command: ANTON DAYO — Signature over Printed Name

LIDAR Operator: F. ILEJAY — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

Figure A-6.13 Flight Log for Mission 23534P

14. Flight Log for Mission 23536P



Flight Log No.: 23536P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: P. ARCEO & R. FELISMINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNDE316A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 11, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 08 49	14 Engine Off: 13 12	15 Total Engine Time: 04 + 23	16 Take off:	17 Landing:	18 Total Flight Time: 04+13
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

SUCCESSFUL FLIGHT

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name (End User Representative)	MIKE A. DAPANA Signature over Printed Name (PAF Representative)	ANTON DAYO Signature over Printed Name	RAC FELISMINO Signature over Printed Name	Signature over Printed Name

Figure A-6.14 Flight Log for Mission 23536P

15. Flight Log for Mission 23540P

Flight Log No.: 23540P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: F. ILEJAY	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNE317A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 12, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 10 19	14 Engine Off: 14 30	15 Total Engine Time: 04 +11	16 Take off:	17 Landing:	18 Total Flight Time: 04 + 01
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

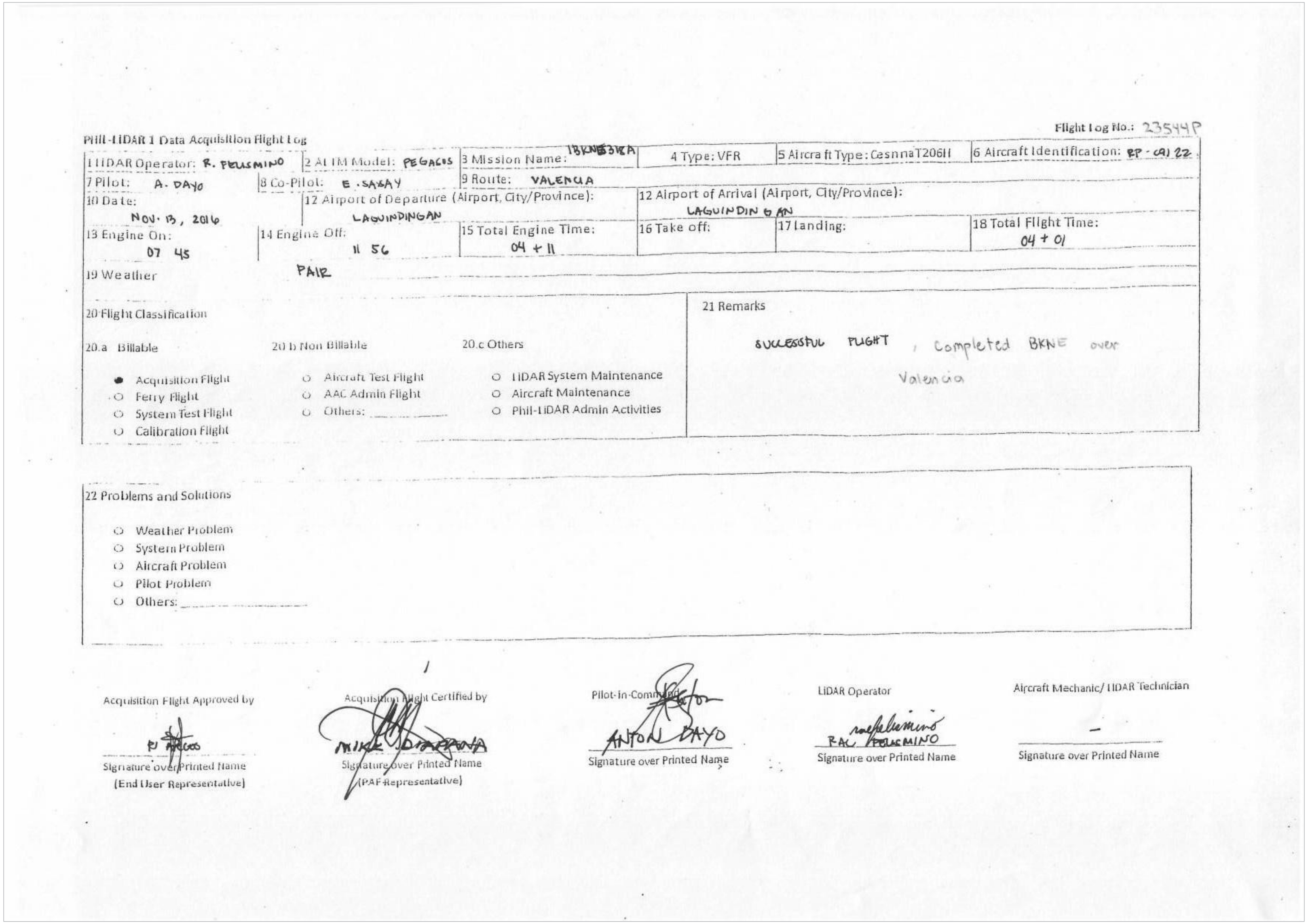
SUCCESSFUL FLIGHT, Surveyed gaps over BKNE

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
RJ [illegible]	MIKE [illegible]	ANTON DAYO	F. ILEJAY	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.15 Flight Log for Mission 23540P

16. Flight Log for Mission 23544P



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23544P

1 LIDAR Operator: R. PELISMINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNE318A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAGAY	9 Route: VALENCIA			
10 Date: NOV. 13, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 07 45	14 Engine Off: 11 56	15 Total Engine Time: 04 + 11	16 Take off:	17 Landing:	18 Total Flight Time: 04 + 01
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, Completed BKNE over Valencia

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

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

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

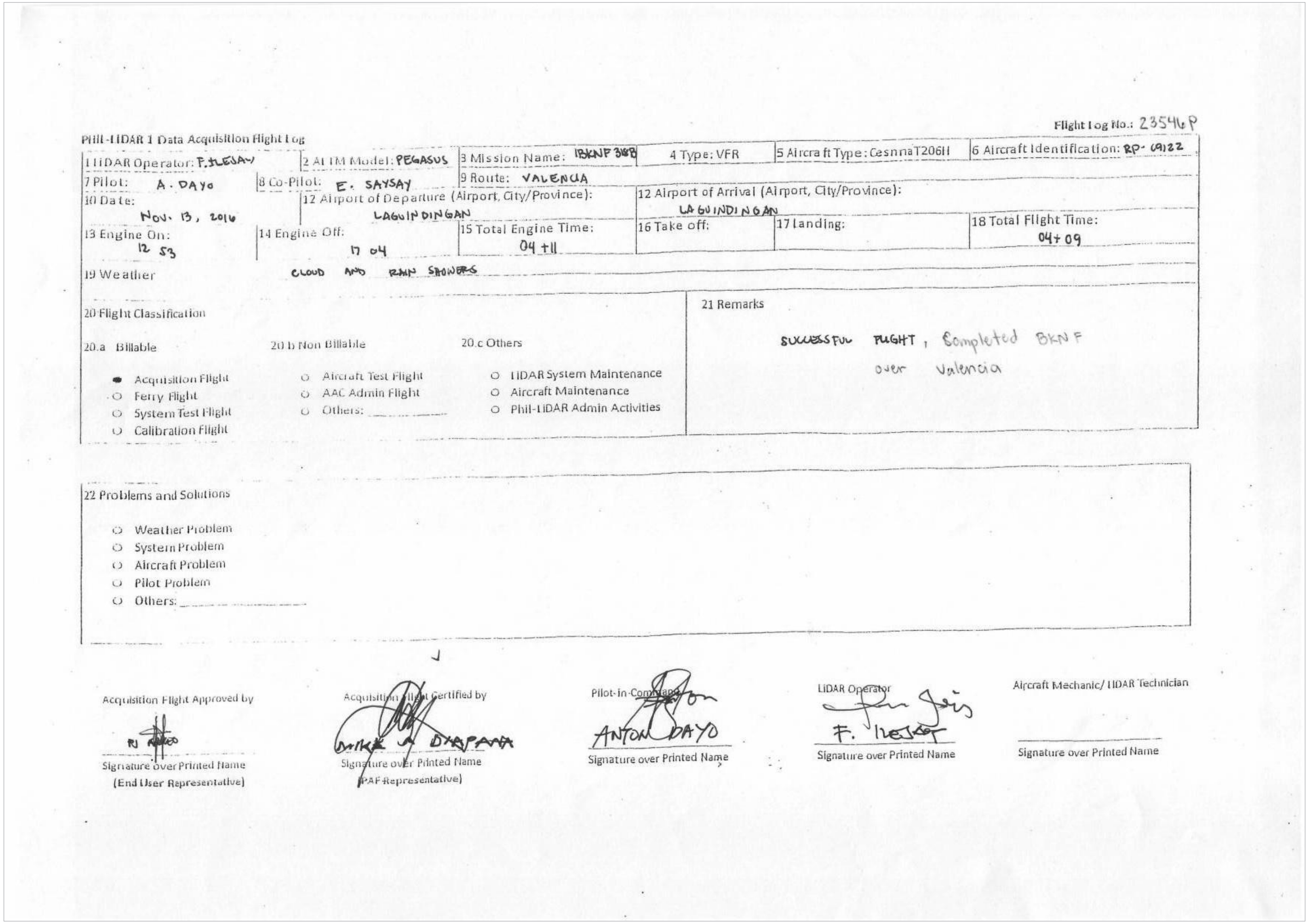
Pilot-in-Command: ANTON DAYO — Signature over Printed Name

LIDAR Operator: RAL PELISMINO — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

Figure A-6.16 Flight Log for Mission 23544P

17. Flight Log for Mission 23546P



Flight Log No.: 23546P

Phil-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: F. ILEJAY	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNF 318B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 13, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 12 53	14 Engine Off: 17 04	15 Total Engine Time: 04+11	16 Take off:	17 Landing:	18 Total Flight Time: 04+09
19 Weather: CLOUD AND RAIN SHOWERS					

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, Completed BKNF over Valencia

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

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

Acquisition Flight Certified by: MIKE A DIAPANA — Signature over Printed Name (PAF Representative)

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

LIDAR Operator: F. ILEJAY — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.17 Flight Log for Mission 23546P

18. Flight Log for Mission 23548P

Flight Log No.: 23548P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: F. ILESAY	2 ALTM Model: PEGASUS	3 Mission Name: 1BKNEF3HA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP- C9122
7 Pilot: A. DAYO	8 Co-Pilot: E. SAYSAY	9 Route: VALENCIA			
10 Date: NOV. 14, 2016	12 Airport of Departure (Airport, City/Province): LAGUINDINGAN		12 Airport of Arrival (Airport, City/Province): LAGUINDINGAN		
13 Engine On: 08 19	14 Engine Off: 12 48	15 Total Engine Time: 04+29	16 Take off:	17 Landing:	18 Total Flight Time: 04 + 19
19 Weather: CLOUD					

20 Flight Classification

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

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

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

21 Remarks

SUCCESSFUL FLIGHT

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name (End User Representative)	MIKEY A. DIAPANA Signature over Printed Name (PAF Representative)	ANTON DAYO Signature over Printed Name	F. ILESAY Signature over Printed Name	Signature over Printed Name

Figure A-6.18 Flight Log for Mission 23548P

ANNEX 7. Flight Status Reports

NORTHERN MINDANAO
(May 27 – July 10, 2014 and October 23 – November 14, 2016)

Table A-7.1 Flight Status Report

Flight No	Area	Mission	Operator	Date Flown	Remarks
1517P	RX BLK D,E	1RXE147A	I. Roxas	May 27, 2014	Surveyed half of RX D and half of RX E at 800m, 1000m then 900m; cam stylus malfunctioned
1569P	RX BLK E	1BLKRXE160A	G.Sinadjan	June 9, 2014	Mission successful; gaps due to high terrain; camera assertion failed
1597P	RX BLK D,E	1BLKRXE167A	G.Sinadjan	June 16, 2014	Mission successful; filled gaps in RX E
1629P	RX BLK E	1BLKRXES175A	G.Sinadjan	June 24, 2014	Mission successful at 1400 AGL
1693P	RX BLK ES	1RXES191A	J. Alviar	July 10, 2014	Filled in gaps in RX E
23486P	MANOLO FORTICH BKN S2	1BKND297A	J Alviar	October 23,2014	Surveyed Manolo Fortich at 1300m MSL; heavy build up and precipitation in bukidnon
23488P	MANOLO FORTICH BKN S1	1BKNDE298A	K. Quisado	October 24,2014	Closed visual over target areas; surveyed Tagoloan watershed in Manolo Fortich at 1700m MSL
23492P	BKN E	1BKNDE299A	K Quisado	October 25,2014	Surveyed BKN E at 1500m MSL
23516P	VALENCIA BNK F	1BKNF311A	FN Ilejay	November6,2016	Surveyed Manupali-Manupali floodplain with voids due to build up and strong winds
23518P	VALENCIA BNK F	1BKNF311B	PJ Arceo RA Felismino	November6,2016	Surveyed only 4 lines over Manupali-Manupali floodplain due to time constraint
23520P	VALENCIA BKN F	1BKNF312A	FN Ilejay	November7,2016	Surveyed gaps over Manupali-Manupali floodplain
23524P	VALENCIA BKN D	1BKND313A	PJ Arceo RA Felismino	November8,2016	Surveyed Manupali-Manupali-Manupali floodplain

23534P	VALENCIA BNK G	1BKNGS315A	FN Ilejay	November 10, 2016	Surveyed Manupali-Manupali floodplain with voids due to build up and strong winds
23536P	VALENCIA BKN E	1BKNE317A	PJ Arceo, RA Felismino	November 11,2016	Surveyed gaps over Manupali-Manupali floodplain
23540P	VALENCIA BKN E	1BKNE317A	FN Ilejay	November 12, 2016	Surveyed gaps over Manupali-Manupali floodplain
23544P	VALENCIA BKN E	1BKNE318A	RA Felismino	November 13, 2016	Completed BKN E over Valencia
23546P	VALENCIA BKN G	1BKNG318B	FN Ilejay	November 13, 2016	COMPLETED BKN G OVER VALENCIA
23548P	VALENCIA BKN E,F	1BKNEF319A	FN Ilejay	November 14, 2016	Fill up gaps and voids over Malaybalay and Valencia

LAS BOUNDARIES PER FLIGHT

Flight No. : 1517P

Area: RX D, RX E

Mission Name: 1RXE147A

Parameters:

Altitude: 900m;

Scan Frequency: 30Hz;

Scan Angle: 25deg;

Overlap: 30%

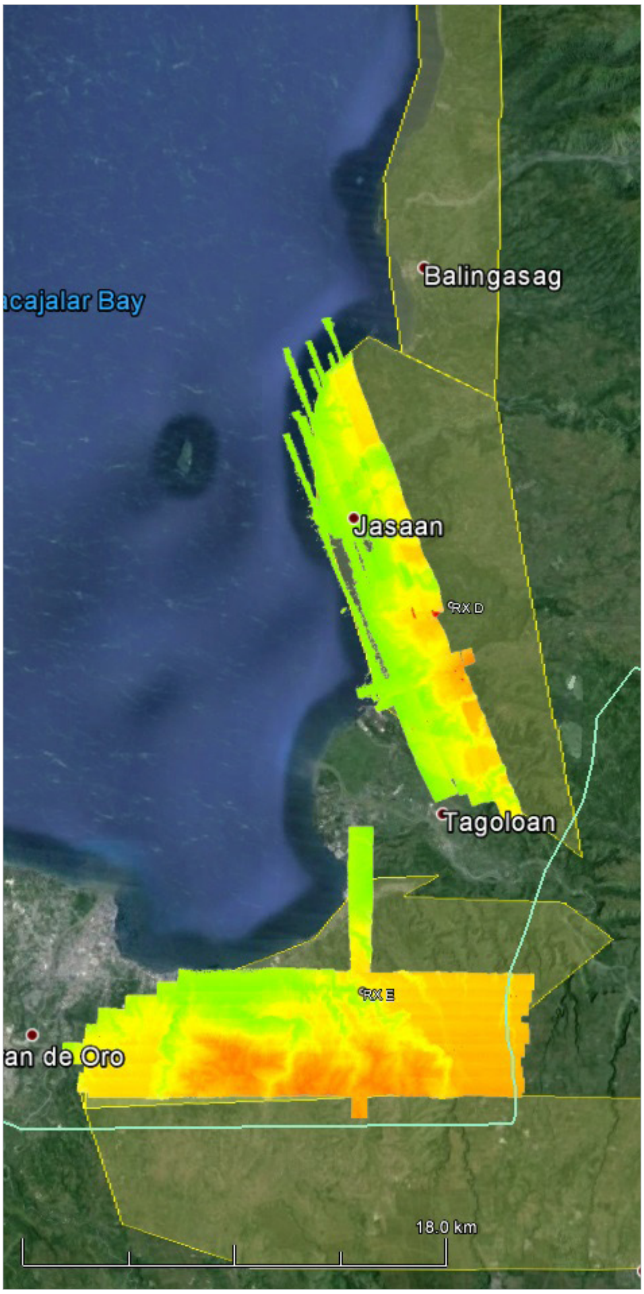


Figure A-7.1 Swath for Flight No. 1517P

Flight No. : **1569P**
Area: RX D
Mission Name: 1BLKRXE160A
Parameters:
Altitude: 1000 m;
Scan Frequency: 30Hz;
Scan Angle: 25deg;
Overlap: 30%

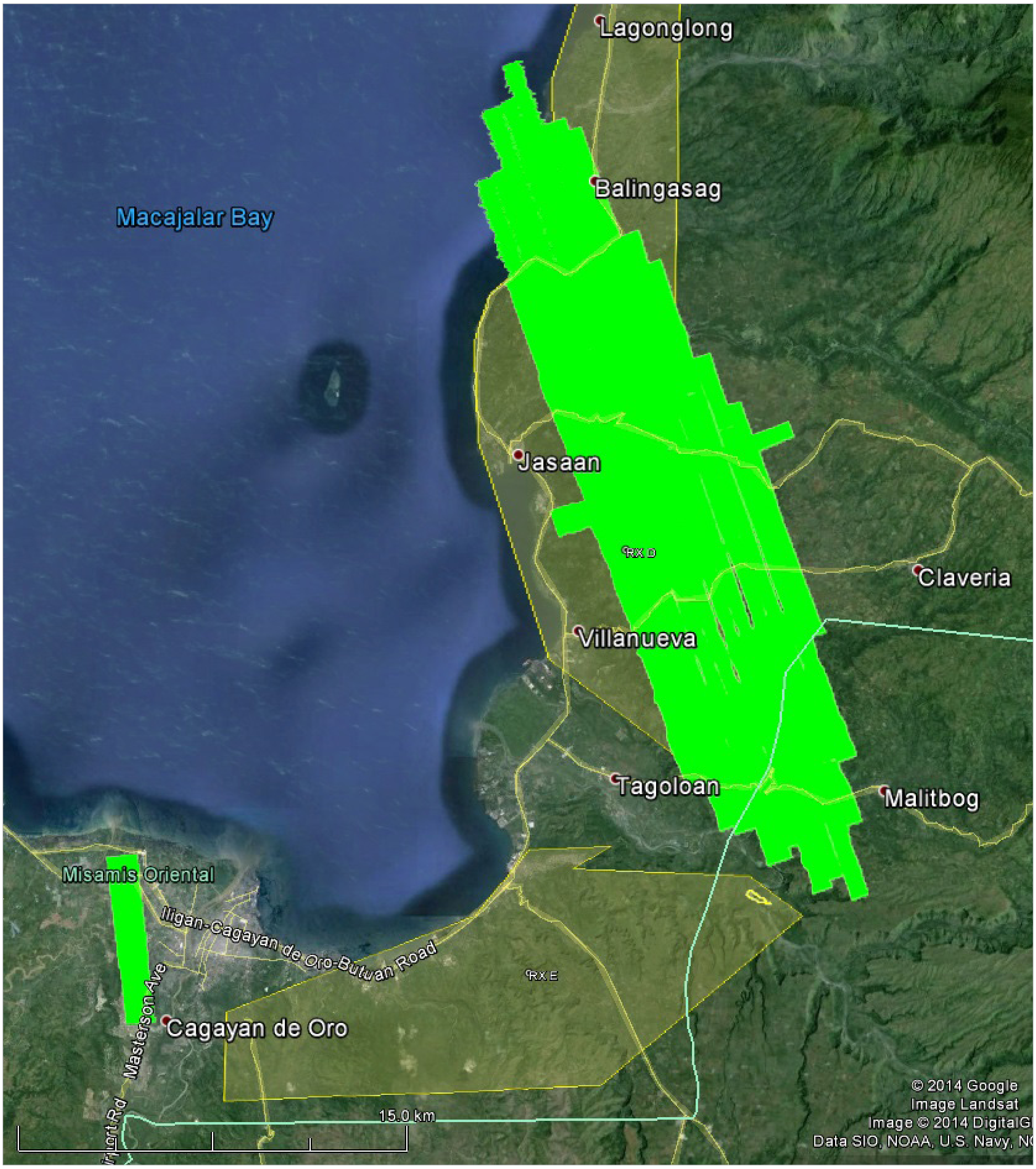


Figure A-7.2 Swath for Flight No. 1569P

Flight No. : **1597P**
Area: RX D, RX E
Mission Name: 1BLKRXE167A
Parameters:
Altitude: 800m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

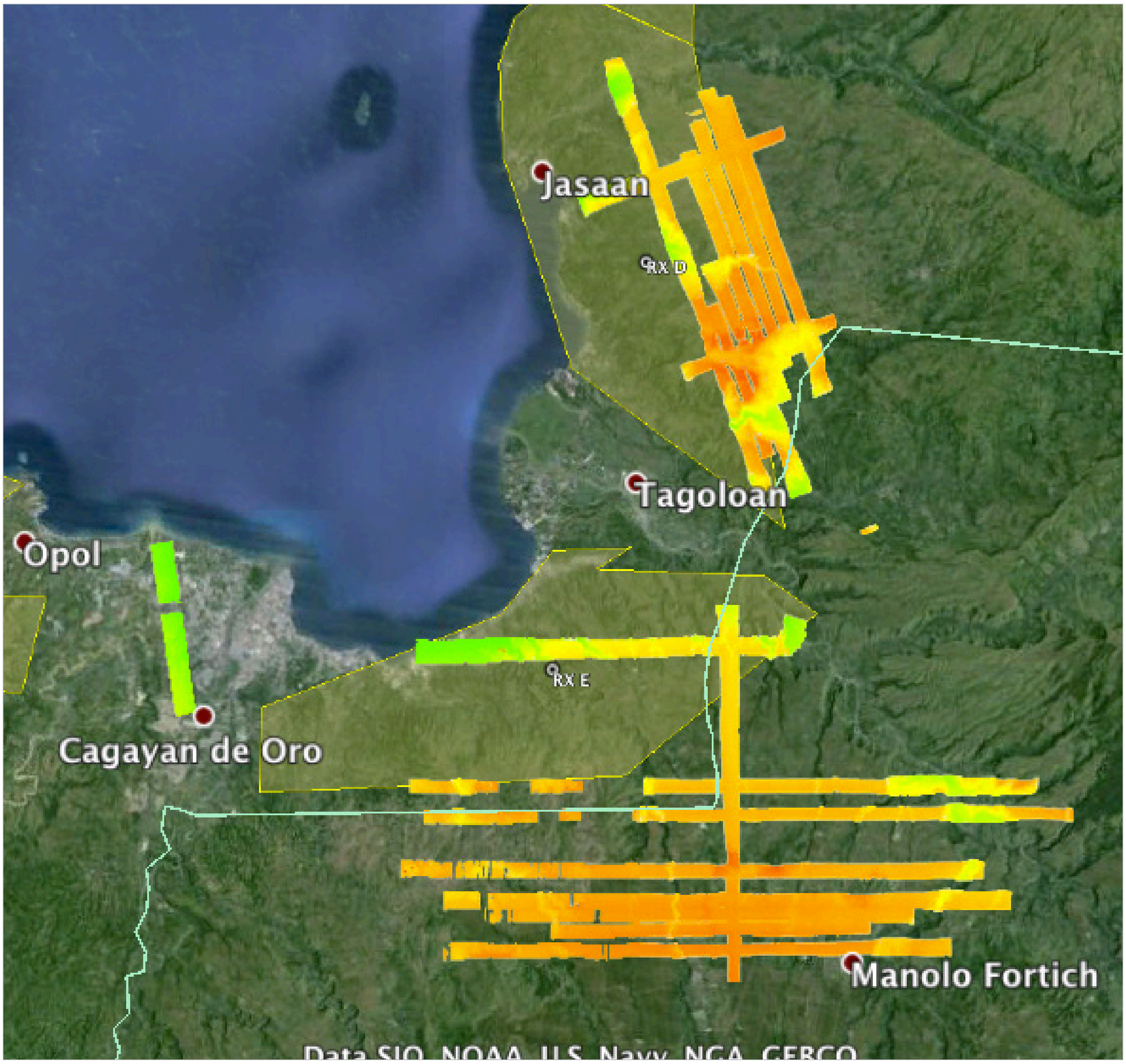


Figure A-7.3 Swath for Flight No. 1597P

Flight No. : **1629P**
Area: RX E
Mission Name: 1BLKRXE175A
Parameters:
Altitude: 1400m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

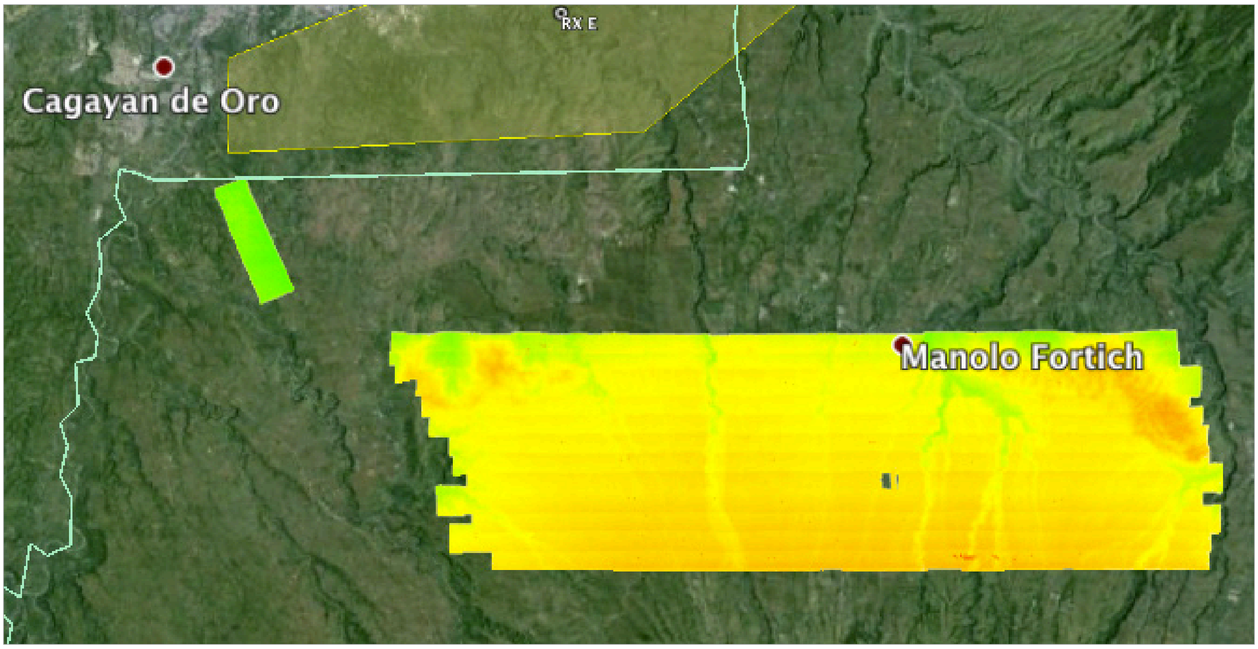


Figure A-7.4 Swath for Flight No. 1629P

Flight No. : **1693P**
Area: RX ES
Mission Name: 1RXES191A
Parameters:
Altitude: 1200m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

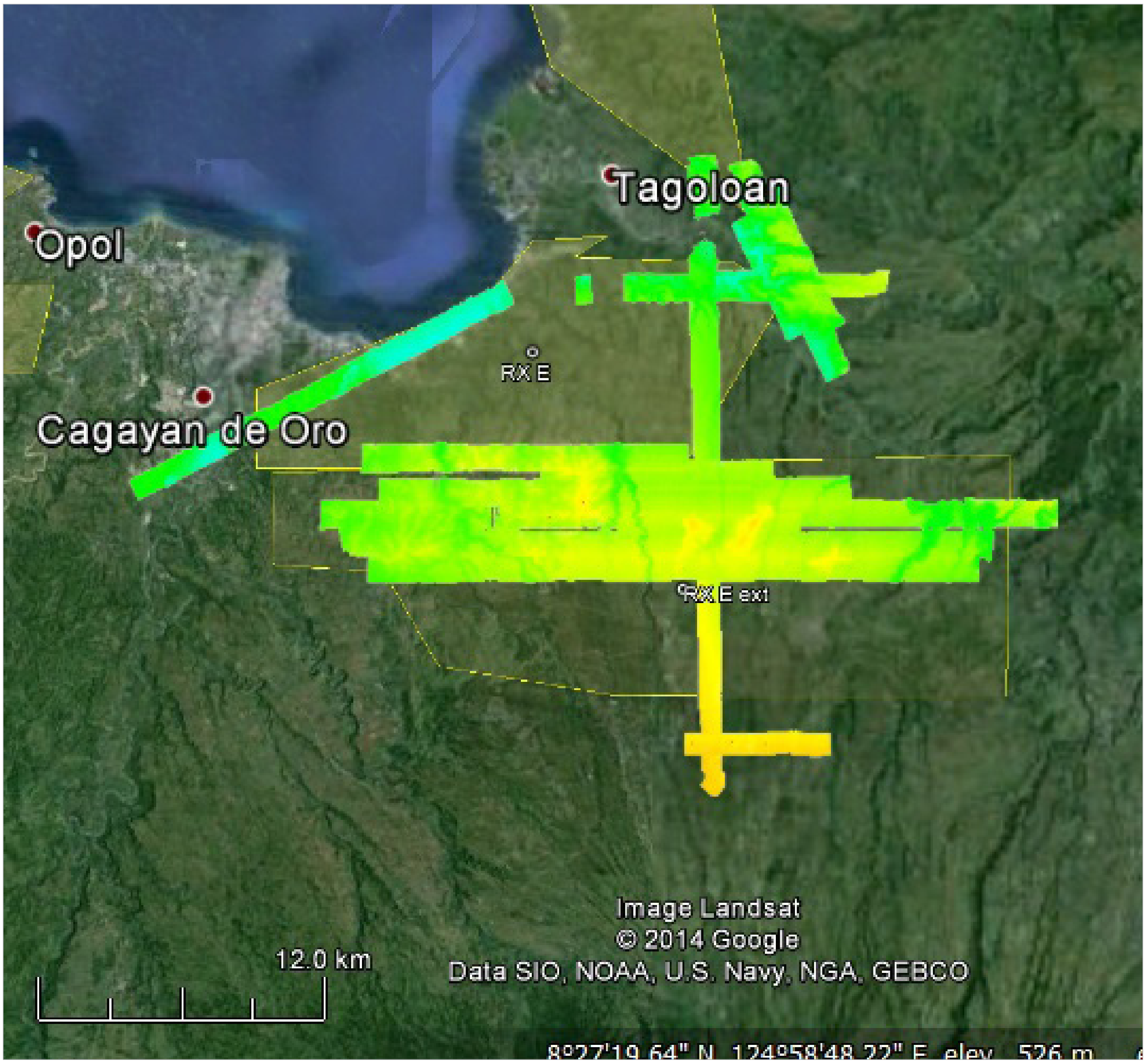


Figure A-7.5 Swath for Flight No. 1693P

Flight No. : **23486P**
Area: BKN S2
Mission Name: 1BKND297A
Parameters:
- Altitude: 1300m;
- Scan Frequency: 30Hz;
- Scan Angle: 25 deg;
- Overlap: 30%

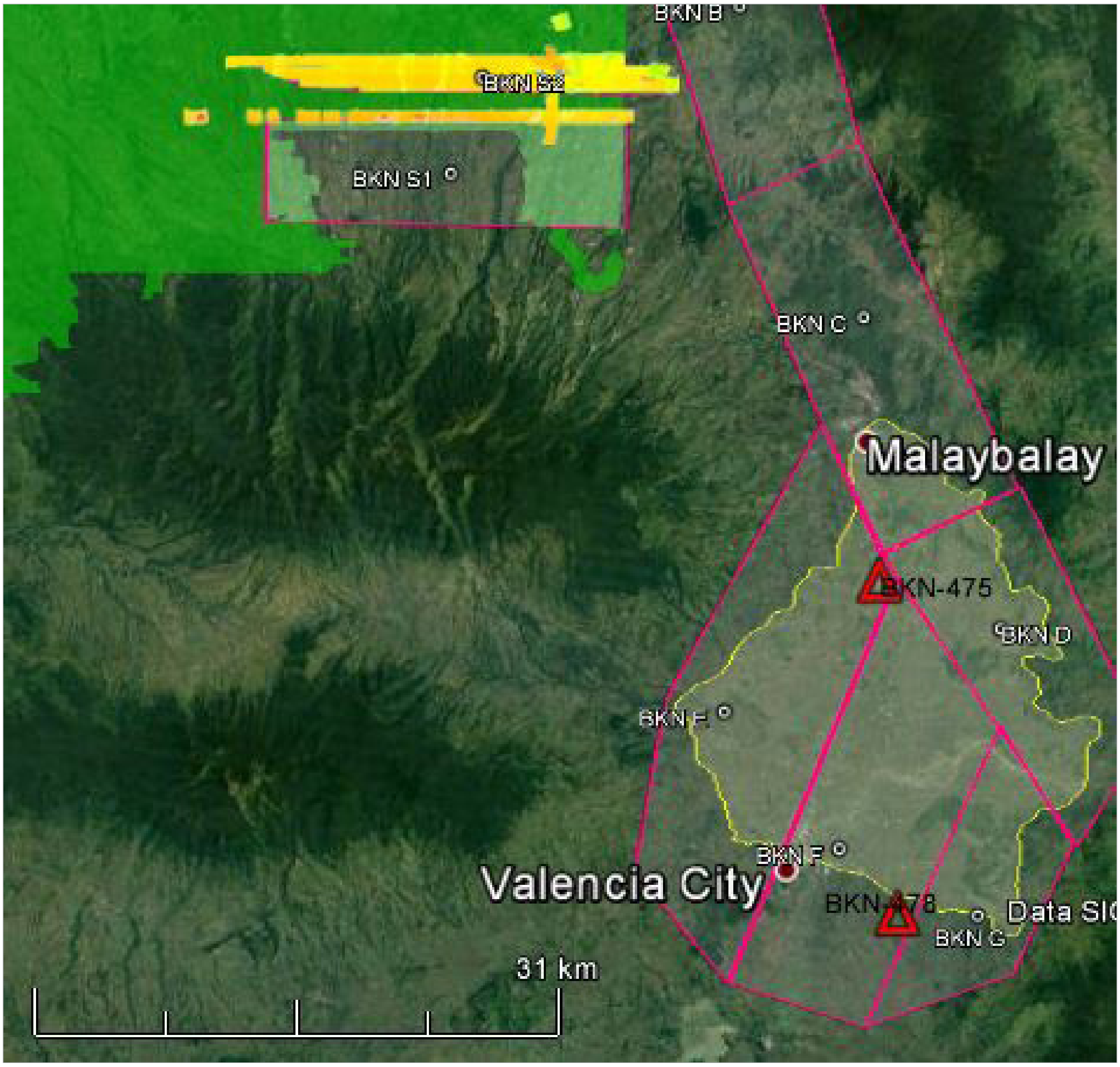


Figure A-7.6 Swath for Flight No. 23486P

Flight No. : **23488P**
Area: BKN S1
Mission Name: 1BKNDE298A
Parameters:
Altitude: 1700m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

Figure A-7.7 Swath for Flight No. 23488P

Flight No. : **23492P**
Area: BKN E
Mission Name: 1BKNDE299A
Parameters:
Altitude: 1500m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

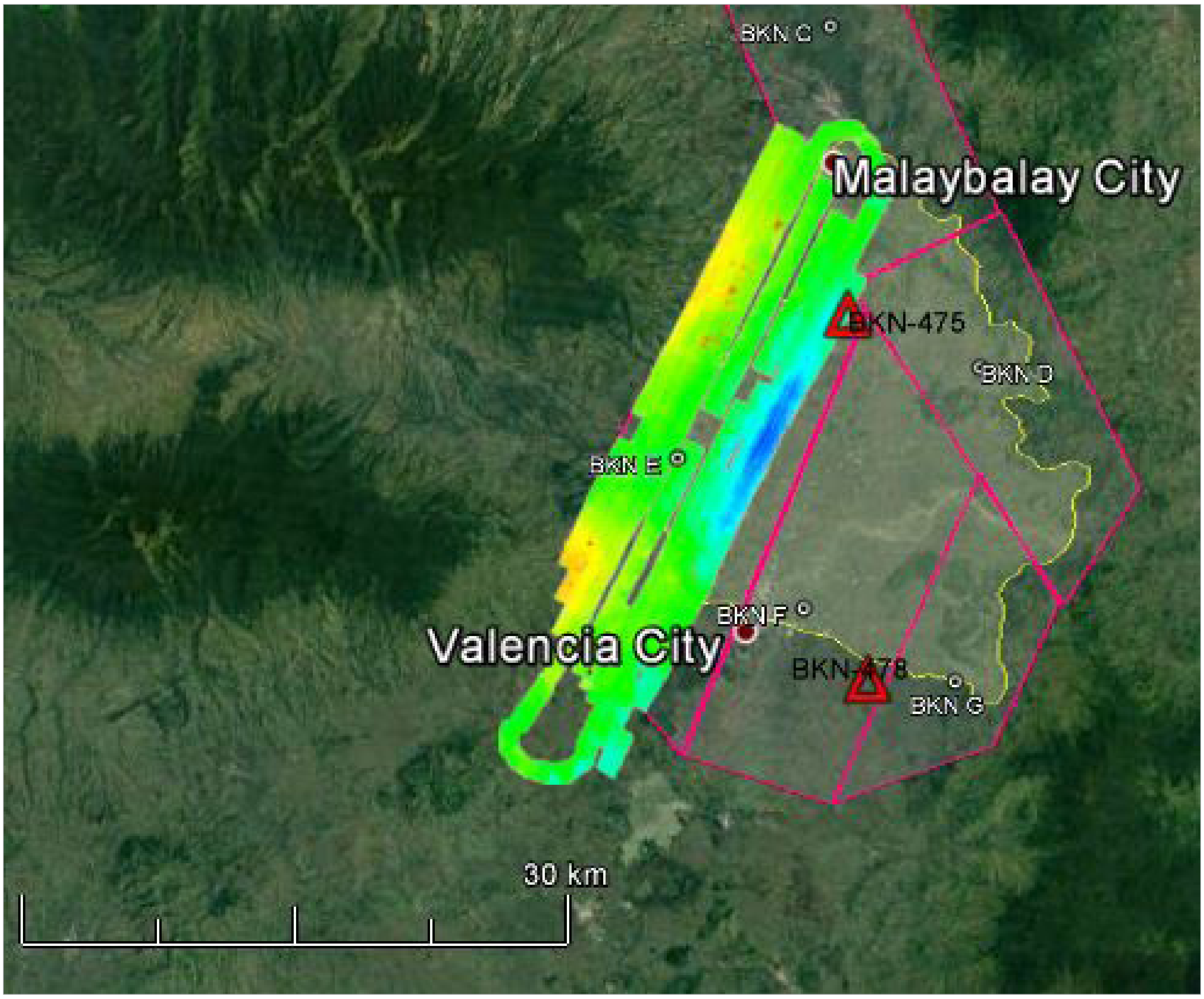


Figure A-7.8 Swath for Flight No. 23492P

Flight No. : **23516P**
Area: VALENCIA BKN F
Mission Name: 1BKNF311A
Parameters:
- Altitude: 1000m;
- Scan Frequency: 30Hz;
- Scan Angle: 25 deg;
- Overlap: 30%

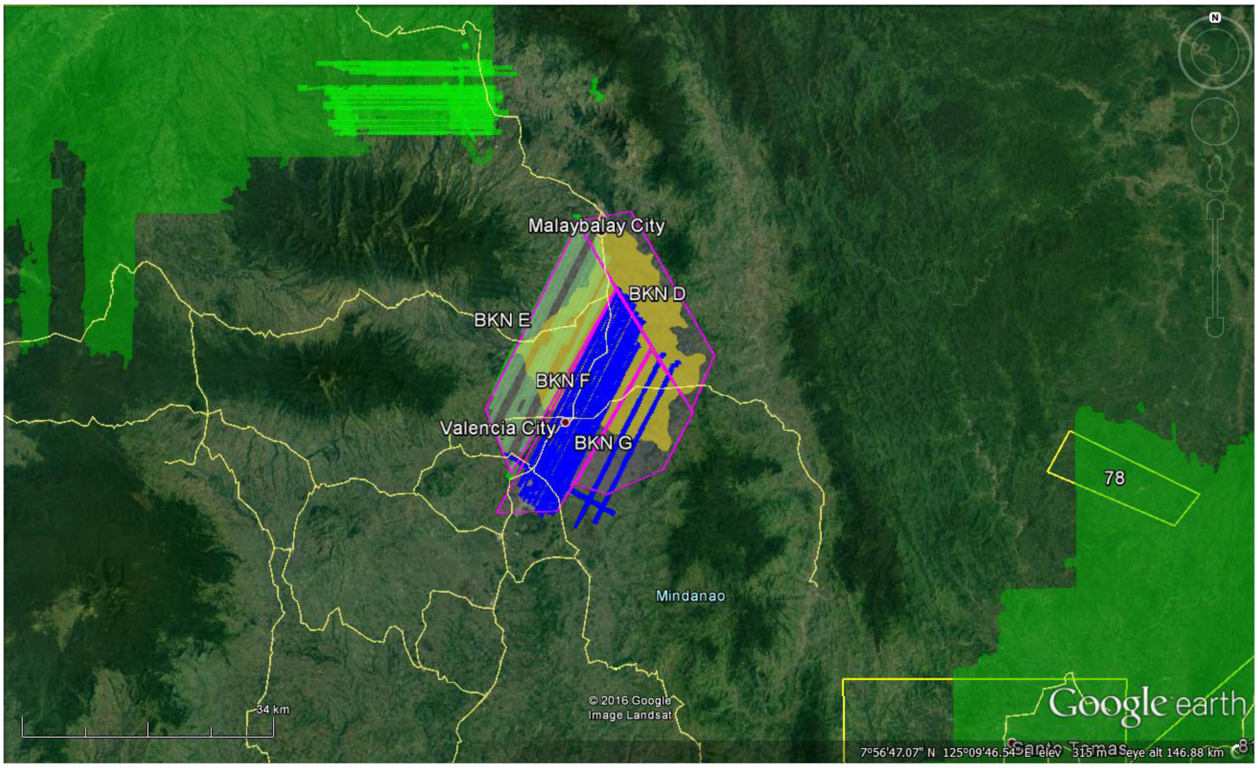


Figure A-7.9 Swath for Flight No. 23516P

Flight No. : **23518P**
Area: BKN F
Mission Name: 1BKNF311B
Parameters:
Altitude: 1000m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

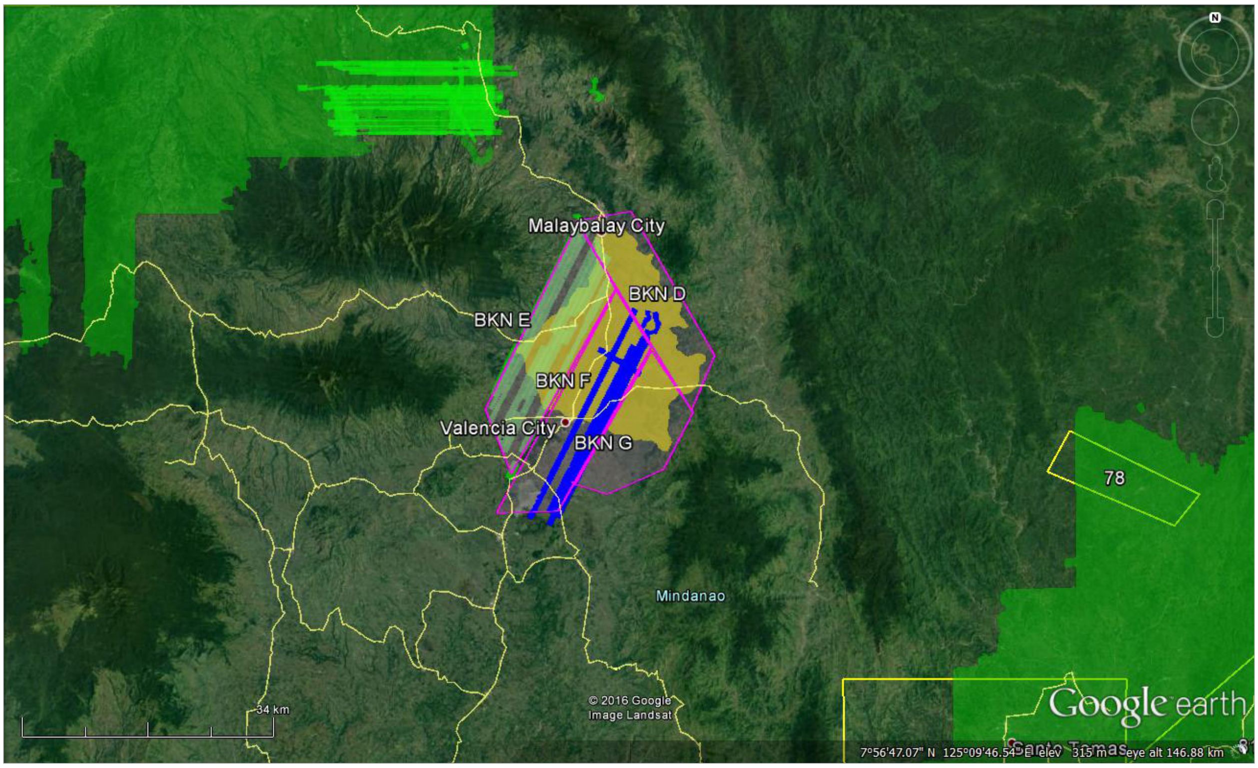


Figure A-7.10 Swath for Flight No. 23518P

Flight No. : **23520P**
Area: BKN F
Mission Name: 1BKNF312A
Parameters:
Altitude: 1200m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

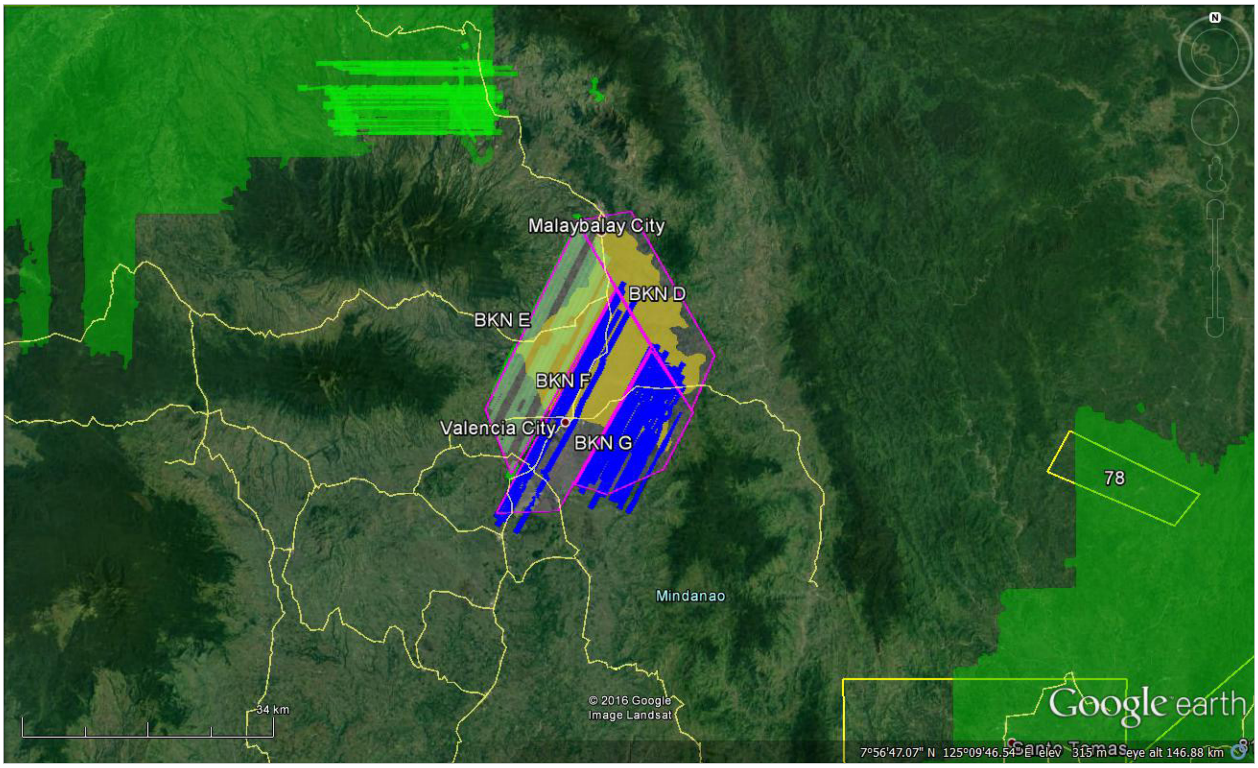


Figure A-7.11 Swath for Flight No. 23520P

Flight No. : **23524P**
Area: BKN D
Mission Name: 1BKND313A
Parameters:
Altitude: 1200m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

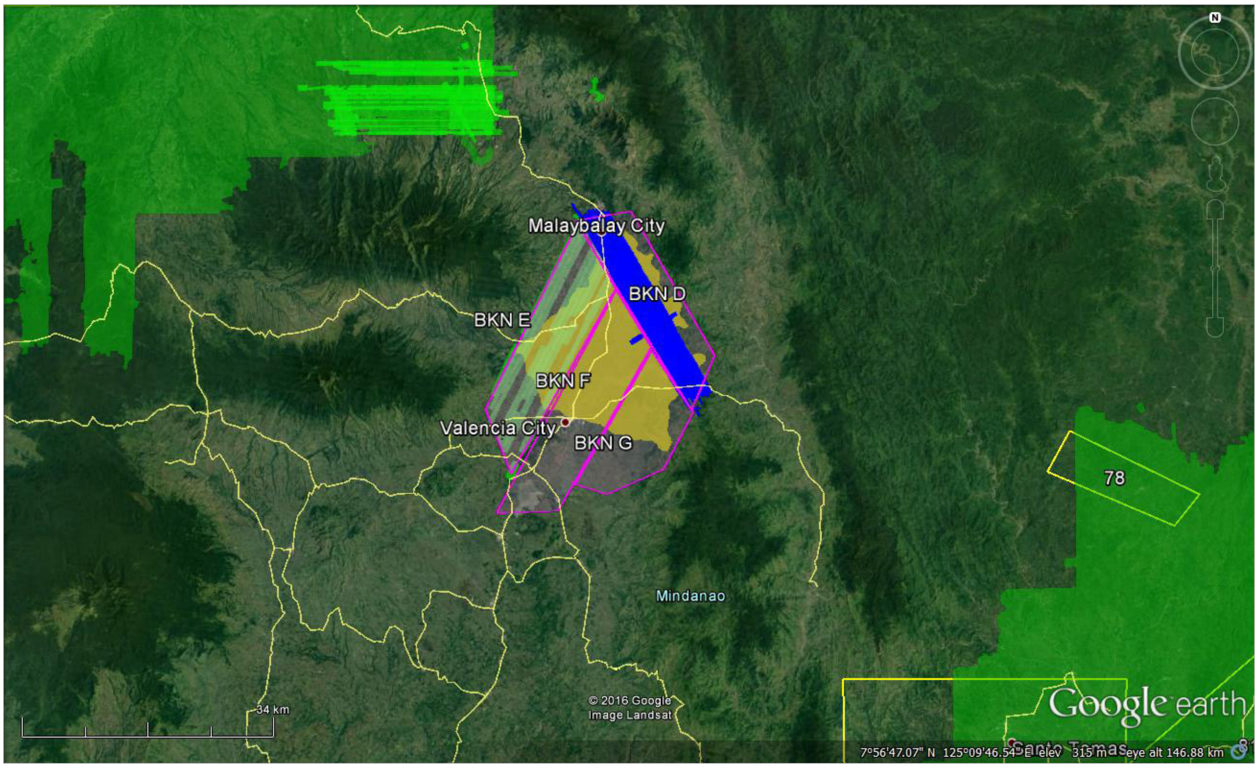


Figure A-7.12 Swath for Flight No. 23524P

Flight No. : **23534P**
Area: BKN G
Mission Name: 1BKNG315A
Parameters:
Altitude: 1200m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

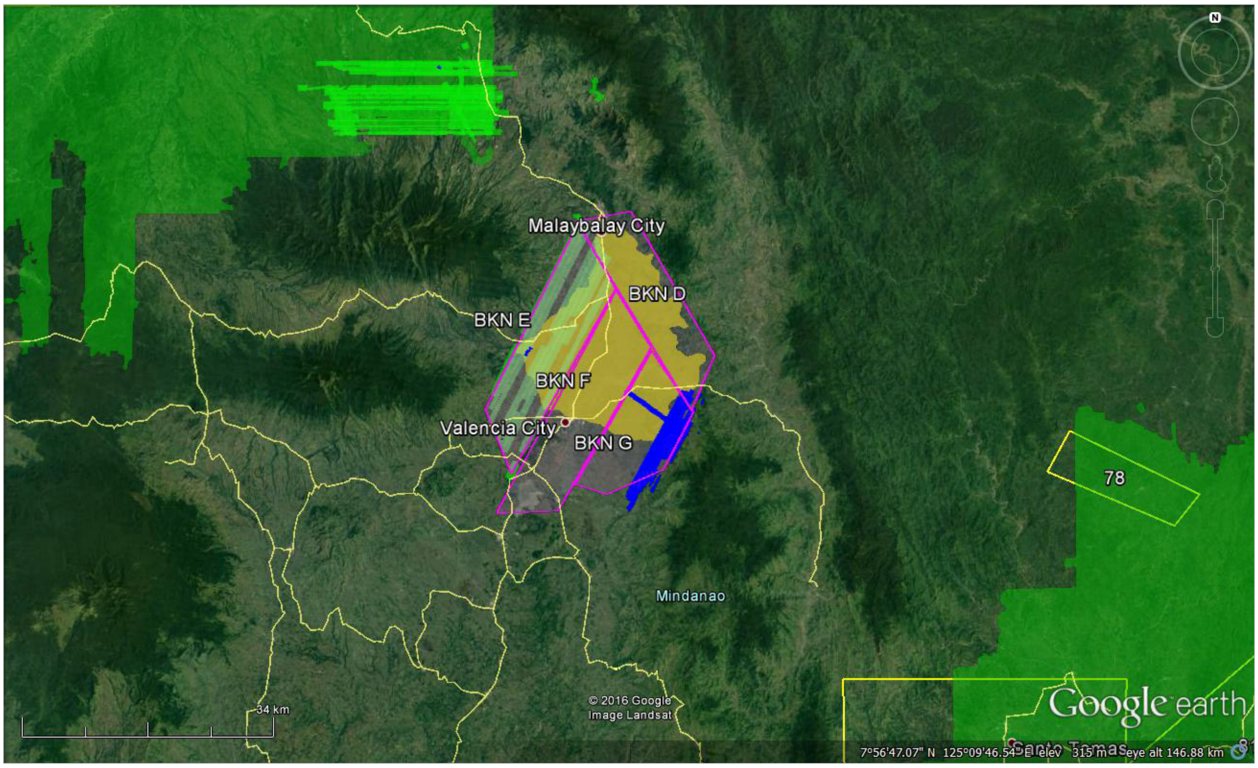


Figure A-7.13 Swath for Flight No. 23534P

Flight No. : **23536P**
Area: BKN E
Mission Name: 1BKNE316A
Parameters:
Altitude: 1300m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

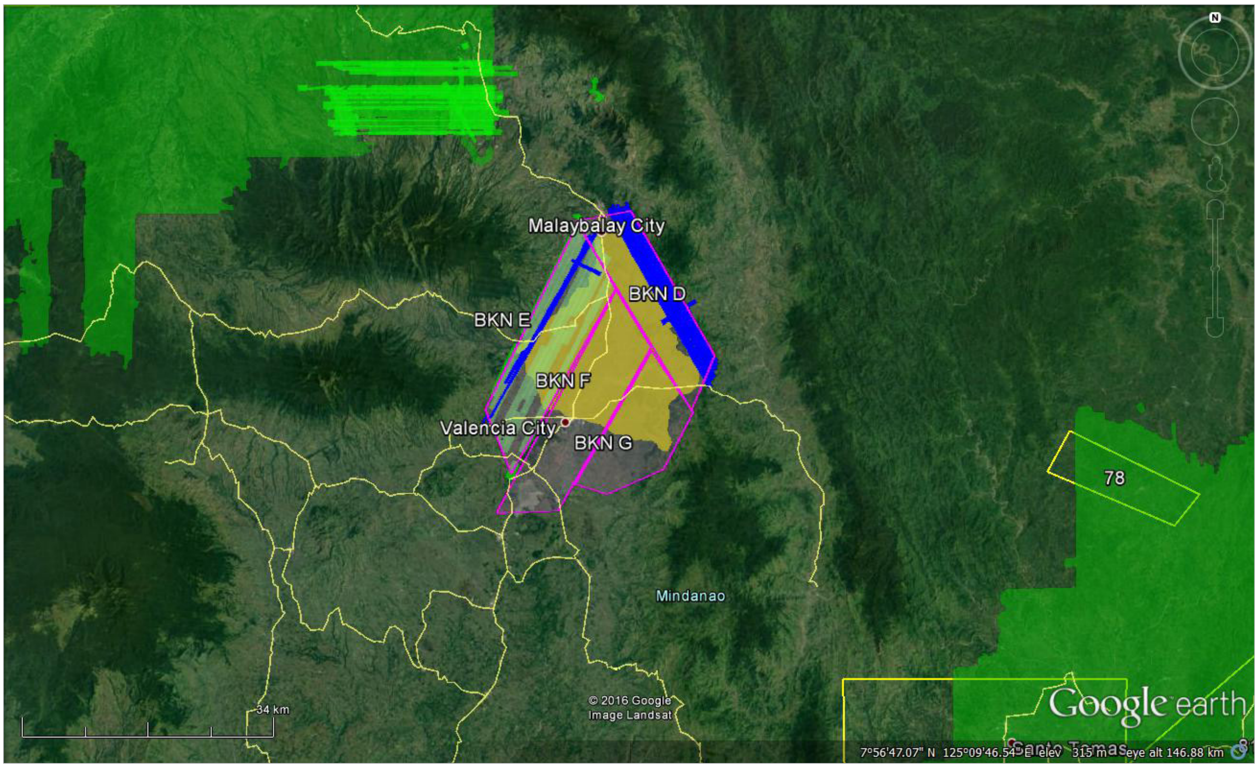


Figure A-7.14 Swath for Flight No. 23536P

Flight No. : **23540P**
Area: BKN E
Mission Name: 1BKNE317A
Parameters:
Altitude: 1300m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

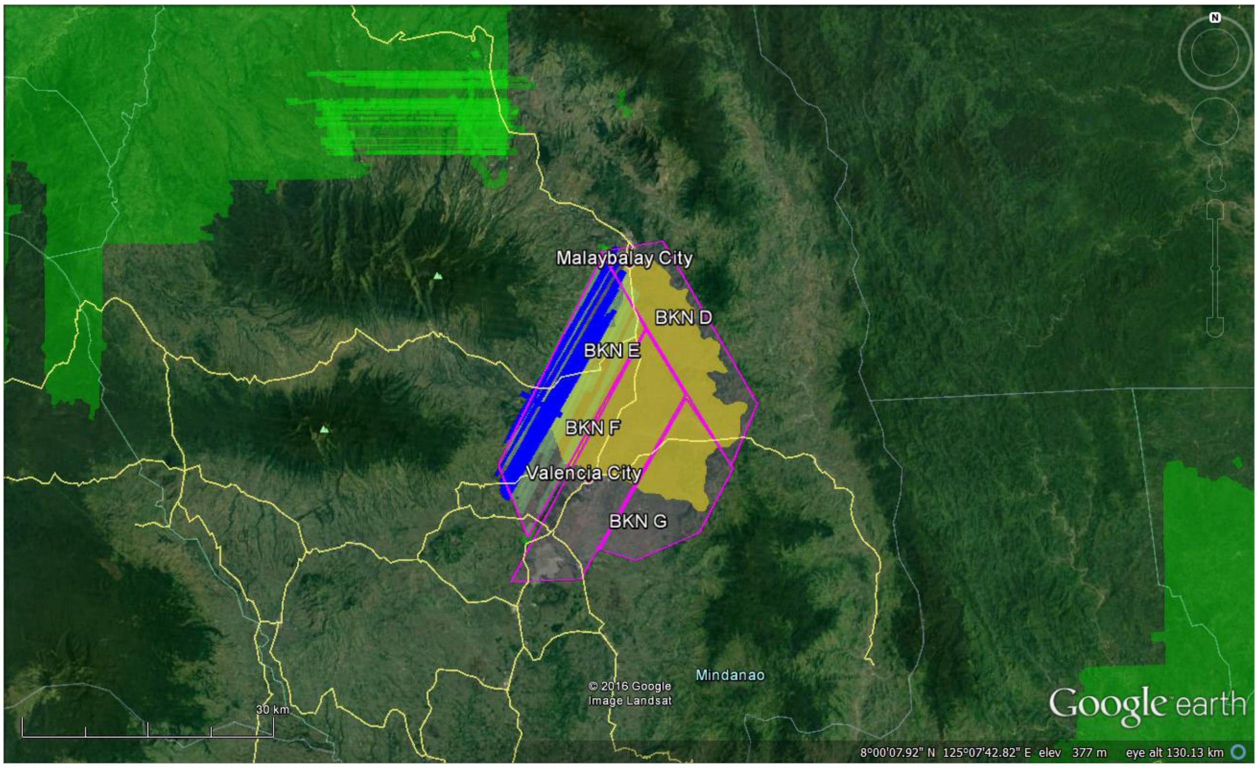


Figure A-7.15 Swath for Flight No. 23540P

Flight No. : **23544P**
Area: BKN E
Mission Name: 1BKNE318A
Parameters:
Altitude: 1300m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

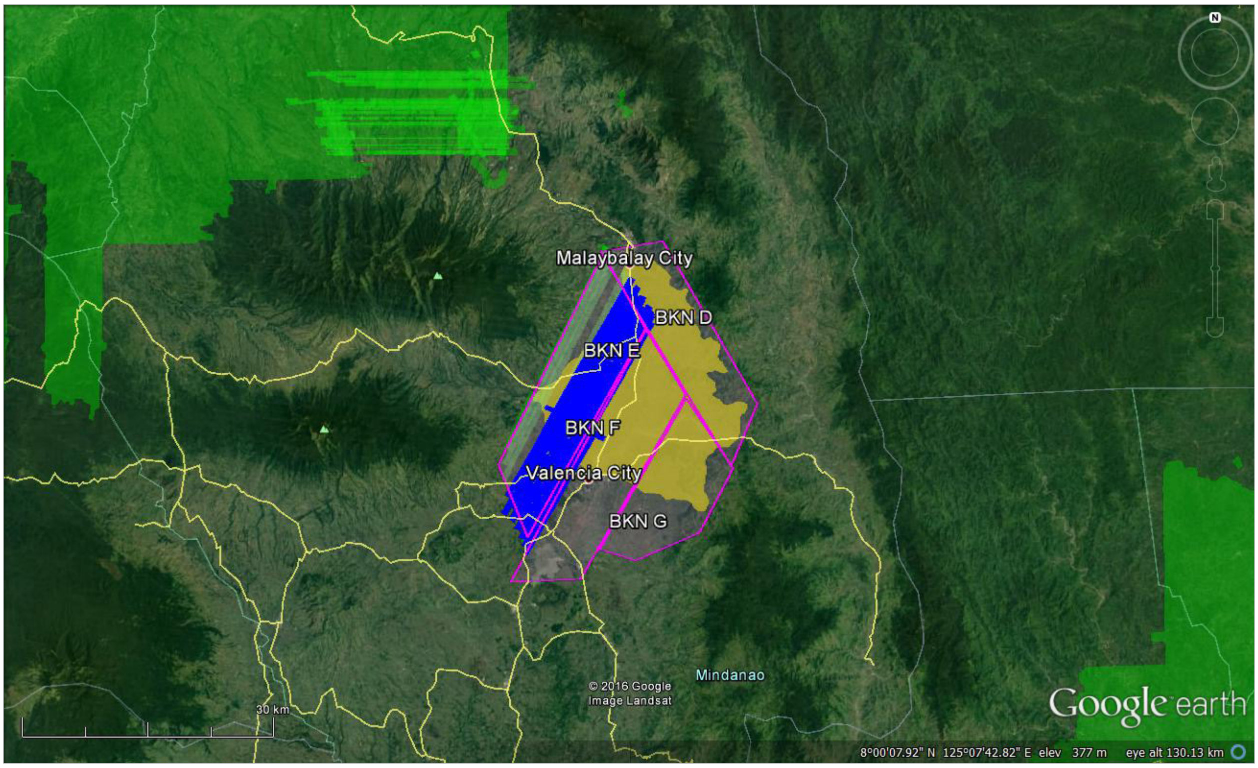


Figure A-7.16 Swath for Flight No. 23544P

Flight No. : **23546P**
Area: BKN E
Mission Name: 1BKNG318B
Parameters:
Altitude: 1300m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

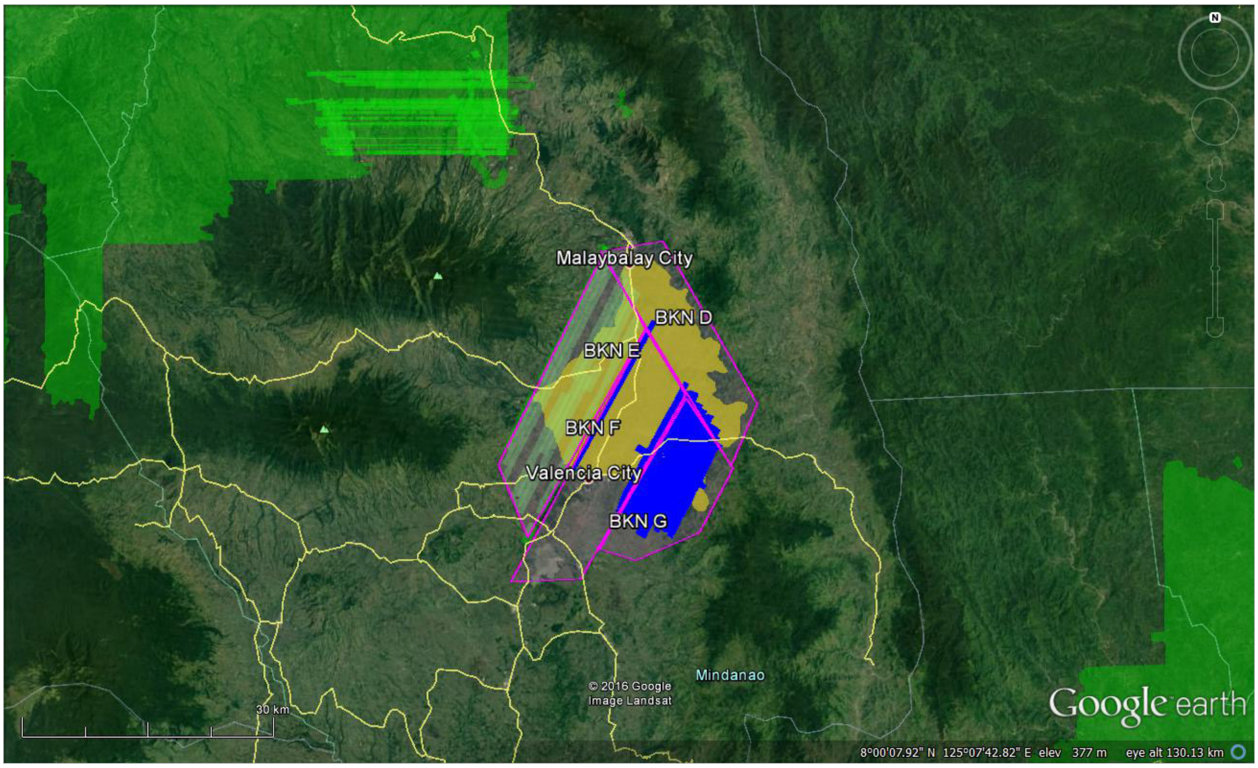


Figure A-7.17 Swath for Flight No. 23546P

Flight No. : **23548P**
Area: BKN E, F
Mission Name: 1BKNEF319A
Parameters:
Altitude: 1300m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg;
Overlap: 30%

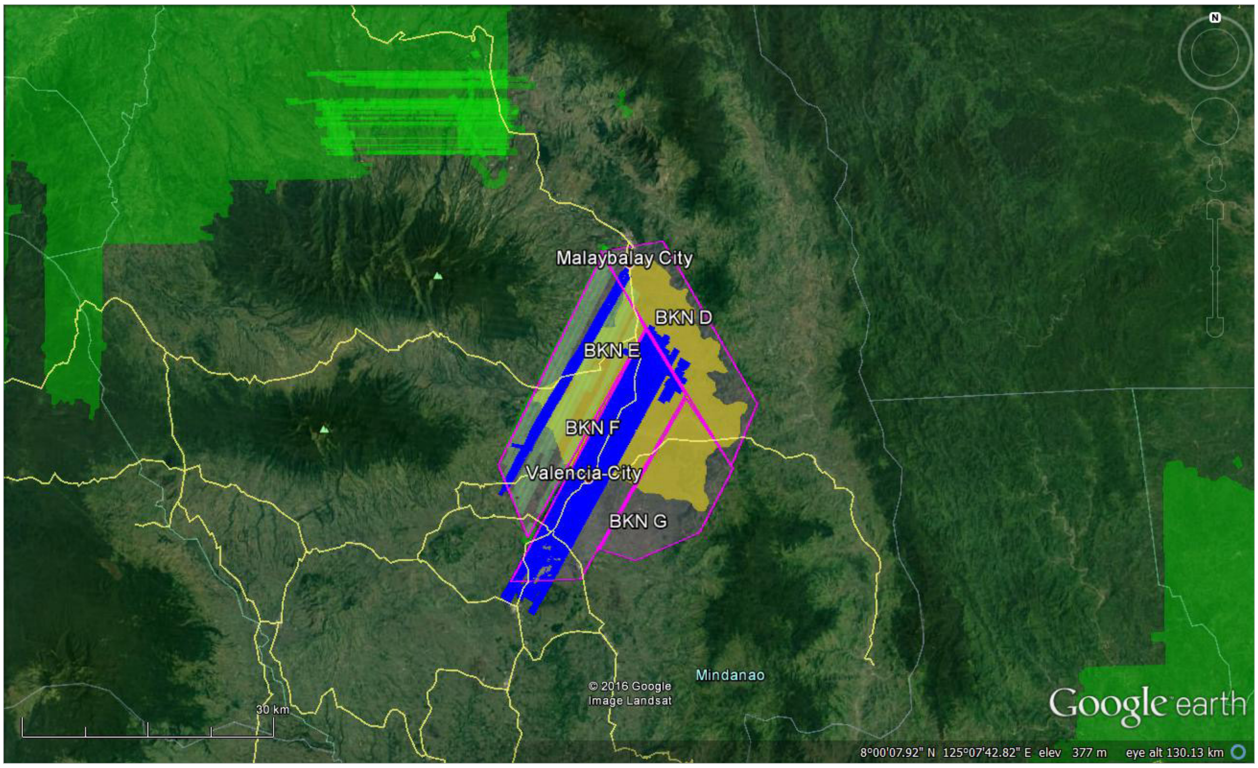


Figure A-7.18 Swath for Flight No. 23548P

ANNEX 8. Mission Summary Reports

ANNEX 9. Manupali Model Basin Parameters

Table A-9.1 Manupali Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform			Recession Baseflow			
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M³/S)	Recession Constant	Threshold Type	Ratio to Peak
W3490	16.14125	40.455	0	0.19072	5.2722	Discharge	0.007	0.00001	Ratio to Peak	0.00001
W3500	7.1065	40.455	0	0.4677121	1.8918	Discharge	0.004	0.00001	Ratio to Peak	0.00001
W2770	16.74125	40.093	0	0.40353	4.1547	Discharge	0.028	0.00001	Ratio to Peak	0.00001
W2750	21.061	75	0	0.91939	6.3174	Discharge	0.042	0.00001	Ratio to Peak	0.00001
W2650	12.098125	76	0	0.20052	5.486	Discharge	0.196	0.2	Ratio to Peak	0.5
W2470	4.876875	83	0	0.0489566	5.9985	Discharge	0.095	0.2	Ratio to Peak	0.00001
W2800	10.483	39.443	0	0.45896	6.0445	Discharge	0.100	0.2	Ratio to Peak	0.00001
W2360	17.23375	36.891	0	0.0676382	7.4468	Discharge	0.253	0.2	Ratio to Peak	0.00001
W2780	13.255	40.455	0	0.59764	5.0332	Discharge	0.097	0.00001	Ratio to Peak	0.00001
W2590	15.86625	39.347	0	0.3545	5.1428	Discharge	0.172	0.00001	Ratio to Peak	0.00001
W2540	25.865	34.48	0	0.19987	4.115	Discharge	0.137	0.00001	Ratio to Peak	0.00001
W2440	34.38125	34.535	0	0.2963	3.5601	Discharge	0.071	0.00001	Ratio to Peak	0.00001
W2760	34.646	40.11	0	0.35419	3.2821	Discharge	0.065	0.00001	Ratio to Peak	0.00001
W2730	48.4	38.852	0	0.431	5.3404	Discharge	0.154	0.00001	Ratio to Peak	0.00001
W2720	94.98	39.254	0	0.1901	3.7066	Discharge	0.132	0.00001	Ratio to Peak	0.00001
W2390	64.57875	35.073	0	0.0180215	4.9992	Discharge	0.127	0.00001	Ratio to Peak	0.00001
W2710	130.6221855	37.051	0	0.52712	3.6147	Discharge	0.112	0.00001	Ratio to Peak	0.00001
W2640	75.35125	38.012	0	0.16072	3.3347	Discharge	0.157	0.00001	Ratio to Peak	0.00001
W2580	47.59625	40.455	0	0.59606	1.808	Discharge	0.012	0.00001	Ratio to Peak	0.00001
W2550	17.99625	38.536	0	0.21267	3.54	Discharge	0.069	0.00001	Ratio to Peak	0.00001

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform			Recession Baseflow			
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M^3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2530	78.4275	36.403	0	0.0798007	2.3725	Discharge	0.055	0.0001	Ratio to Peak	0.00001
W2340	22.45375	35.946	0	0.10487	4.0619	Discharge	0.209	0.0001	Ratio to Peak	0.00001
W2560	72.524	36.028	0	0.12004	3.6599	Discharge	0.194	0.0001	Ratio to Peak	0.00001
W2500	22.60625	40.455	0	0.0582673	0.77056	Discharge	0.002	0.0001	Ratio to Peak	0.00001
W2490	20.13	37.864	0	0.13219	3.1522196	Discharge	0.089	0.0001	Ratio to Peak	0.00001
W2420	30.4475	35.525	0	0.0481973	3.7916	Discharge	0.103	0.0001	Ratio to Peak	0.00001

ANNEX 10. Manupali Model Reach Parameters

Table A-10.1 Manupali Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R980	Automatic Fixed Interval	2826.3	0.0046885	0.46	Trapezoid	60.8	1
R1010	Automatic Fixed Interval	10859	0.0360771	0.46	Trapezoid	60.8	1
R810	Automatic Fixed Interval	1676.8	0.0467289	0.42	Trapezoid	60.8	1
R690	Automatic Fixed Interval	874.6	0.0387764	0.4	Trapezoid	60.8	1
R830	Automatic Fixed Interval	3359.5	0.0372368	0.4	Trapezoid	60.8	1
R930	Automatic Fixed Interval	5059.4	0.0197589	0.4	Trapezoid	60.8	1
R960	Automatic Fixed Interval	6522.7	0.0182329	0.6	Trapezoid	60.8	1
R970	Automatic Fixed Interval	6243.1	0.0177787	0.7	Trapezoid	60.8	1
R1020	Automatic Fixed Interval	5953.7	0.0175149	0.7	Trapezoid	60.8	1
R1110	Automatic Fixed Interval	10702	0.0156574	0.001	Trapezoid	60.8	1
R1000	Automatic Fixed Interval	4726.5	0.0041291	0.001	Trapezoid	60.8	1
R3510	Automatic Fixed Interval	1237.2	0.0026627	0.0001	Trapezoid	60.8	1
R1090	Automatic Fixed Interval	3291.4	0.0019054	0.0001	Trapezoid	60.8	1

ANNEX 11. Manupali Field Validation Points

Table A-11.1 Manupali Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
1	8.11910	125.14531	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
2	8.11722	125.14577	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
3	8.12302	125.14084	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
4	8.12510	125.13943	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
5	8.12740	125.13881	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
6	8.13035	125.13678	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
7	8.13090	125.13519	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
8	8.13319	125.13446	0.23	0.00	-0.23	Pablo/4Dec2012	5YR
9	8.13437	125.13259	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
10	8.13739	125.13276	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
11	8.13914	125.13172	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
12	8.14126	125.13241	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
13	8.13748	125.12915	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
14	8.13560	125.12939	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
15	8.13131	125.13211	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
16	8.12689	125.12446	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
17	8.11489	125.13581	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
18	8.10075	125.14046	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
19	8.09839	125.14884	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
20	8.10009	125.15165	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
21	8.10318	125.15587	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
22	8.10182	125.16125	6.72	0.00	-6.72	Pablo/4Dec2012	5YR
23	8.10478	125.16039	4.50	0.00	-4.50	Pablo/4Dec2012	5YR
24	8.10193	125.15997	6.53	0.00	-6.53	Pablo/4Dec2012	5YR
25	8.09804	125.16442	12.05	0.30	-11.75	Pablo/4Dec2012	5YR
26	8.09711	125.16862	2.82	0.78	-2.04	Pablo/4Dec2012	5YR
27	8.09681	125.17267	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
28	8.09448	125.17560	1.48	0.80	-0.68	Pablo/4Dec2012	5YR
29	8.09497	125.17931	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
30	8.07839	125.14722	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
31	8.08218	125.14704	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
32	8.07978	125.16353	4.74	0.00	-4.74	Pablo/4Dec2012	5YR
33	8.07838	125.16082	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
34	8.08481	125.14996	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
35	8.03645	125.13822	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
36	8.02659	125.13947	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
37	8.02327	125.13928	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
38	8.02040	125.14146	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
39	8.01833	125.14197	0.06	0.00	-0.06	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
40	8.01795	125.14304	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
41	8.03065	125.14343	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
42	7.99650	125.15581	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
43	7.99528	125.14968	0.68	0.00	-0.68	Pablo/4Dec2012	5YR
44	7.99719	125.14723	0.89	0.00	-0.89	Pablo/4Dec2012	5YR
45	7.99126	125.14976	0.90	0.00	-0.90	Pablo/4Dec2012	5YR
46	7.98980	125.15284	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
47	7.98838	125.15510	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
48	7.98625	125.15622	0.31	0.00	-0.31	Pablo/4Dec2012	5YR
49	7.98136	125.14365	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
50	7.98018	125.14217	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
51	7.97815	125.14064	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
52	7.97404	125.13961	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
53	7.97057	125.13696	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
54	7.97309	125.11676	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
55	7.97843	125.12517	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
56	8.06459	125.16093	6.03	0.00	-6.03	Pablo/4Dec2012	5YR
57	8.06555	125.16147	4.50	0.00	-4.50	Pablo/4Dec2012	5YR
58	8.06092	125.17001	1.13	0.00	-1.13	Pablo/4Dec2012	5YR
59	8.05853	125.17349	0.37	0.20	-0.17	Pablo/4Dec2012	5YR
60	8.06132	125.16734	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
61	8.06265	125.16697	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
62	8.06410	125.16748	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
63	8.06134	125.16413	0.18	0.20	0.02	Pablo/4Dec2012	5YR
64	8.06077	125.16027	1.10	0.00	-1.10	Pablo/4Dec2012	5YR
65	8.05855	125.16120	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
66	8.05776	125.16339	1.49	0.40	-1.09	Pablo/4Dec2012	5YR
67	8.05728	125.16123	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
68	8.05782	125.15857	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
69	8.05577	125.15981	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
70	8.05218	125.16236	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
71	8.05065	125.16176	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
72	8.05001	125.16353	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
73	8.04957	125.16531	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
74	8.05116	125.16782	1.45	0.00	-1.45	Pablo/4Dec2012	5YR
75	8.05398	125.16925	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
76	8.05207	125.16554	9.15	0.15	-9.00	Pablo/4Dec2012	5YR
77	8.04899	125.16901	1.33	0.20	-1.13	Pablo/4Dec2012	5YR
78	8.04692	125.17067	1.19	0.30	-0.89	Pablo/4Dec2012	5YR
79	8.04548	125.17190	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
80	8.03973	125.16919	0.26	0.00	-0.26	Pablo/4Dec2012	5YR
81	8.04359	125.16815	2.30	0.20	-2.10	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
82	8.04239	125.16710	5.01	0.40	-4.61	Pablo/4Dec2012	5YR
83	8.04746	125.16826	2.43	0.15	-2.28	Pablo/4Dec2012	5YR
84	8.04123	125.16186	2.82	0.70	-2.12	Pablo/4Dec2012	5YR
85	8.03946	125.15835	3.31	0.40	-2.91	Pablo/4Dec2012	5YR
86	8.04065	125.16358	3.52	0.00	-3.52	Pablo/4Dec2012	5YR
87	8.04640	125.16200	0.42	0.00	-0.42	Pablo/4Dec2012	5YR
88	8.04716	125.16484	0.10	0.10	0.00	Pablo/4Dec2012	5YR
89	8.04475	125.15785	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
90	8.03956	125.15366	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
91	8.03639	125.15612	4.11	0.60	-3.51	Pablo/4Dec2012	5YR
92	8.03788	125.15645	5.79	0.10	-5.69	Pablo/4Dec2012	5YR
93	8.03708	125.16221	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
94	8.03793	125.16407	0.19	0.00	-0.19	Pablo/4Dec2012	5YR
95	8.03936	125.16648	0.55	0.00	-0.55	Pablo/4Dec2012	5YR
96	8.03181	125.16753	0.63	0.00	-0.63	Pablo/4Dec2012	5YR
97	8.03557	125.15395	0.74	0.00	-0.74	Pablo/4Dec2012	5YR
98	8.03406	125.14994	2.54	0.80	-1.74	Pablo/4Dec2012	5YR
99	8.03105	125.14989	3.00	0.80	-2.20	Pablo/4Dec2012	5YR
100	8.02995	125.14937	1.75	0.10	-1.65	Pablo/4Dec2012	5YR
101	8.02668	125.14816	1.19	0.00	-1.19	Pablo/4Dec2012	5YR
102	8.02300	125.14802	2.26	0.00	-2.26	Pablo/4Dec2012	5YR
103	8.02125	125.14812	3.17	0.10	-3.07	Pablo/4Dec2012	5YR
104	8.03125	125.15454	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
105	8.02699	125.15628	1.35	0.00	-1.35	Pablo/4Dec2012	5YR
106	8.02527	125.15412	1.78	0.10	-1.68	Pablo/4Dec2012	5YR
107	8.02517	125.15372	1.78	0.20	-1.58	Pablo/4Dec2012	5YR
108	8.02689	125.15657	0.81	0.10	-0.71	Pablo/4Dec2012	5YR
109	8.02570	125.15757	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
110	8.01648	125.14895	0.63	0.15	-0.48	Pablo/4Dec2012	5YR
111	8.01515	125.14595	1.02	0.60	-0.42	Pablo/4Dec2012	5YR
112	8.01591	125.14540	1.16	0.80	-0.36	Pablo/4Dec2012	5YR
113	8.01387	125.14555	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
114	8.01250	125.14459	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
115	8.00819	125.14260	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
116	8.00702	125.14186	0.06	0.10	0.04	Pablo/4Dec2012	5YR
117	8.00252	125.14074	1.79	0.10	-1.69	Pablo/4Dec2012	5YR
118	8.00567	125.14499	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
119	8.00427	125.14496	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
120	8.00483	125.15544	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
121	8.01515	125.15725	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
122	7.99258	125.12672	2.25	0.80	-1.45	Pablo/4Dec2012	5YR
123	7.99308	125.12504	0.47	0.40	-0.07	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
124	7.99294	125.12406	0.72	0.10	-0.62	Pablo/4Dec2012	5YR
125	7.99421	125.12166	1.64	0.96	-0.68	Pablo/4Dec2012	5YR
126	7.99581	125.12059	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
127	7.99590	125.11872	0.45	0.00	-0.45	Pablo/4Dec2012	5YR
128	7.99557	125.11600	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
129	7.99418	125.11554	0.59	0.00	-0.59	Pablo/4Dec2012	5YR
130	7.99558	125.11392	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
131	7.99586	125.11067	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
132	8.01231	125.13431	1.03	0.60	-0.43	Pablo/4Dec2012	5YR
133	8.00498	125.13331	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
134	8.00311	125.13001	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
135	8.00090	125.12741	0.09	0.17	0.08	Pablo/4Dec2012	5YR
136	7.99677	125.12931	2.49	1.24	-1.25	Pablo/4Dec2012	5YR
137	7.99687	125.12585	1.90	0.40	-1.50	Pablo/4Dec2012	5YR
138	8.00485	125.12197	5.76	0.20	-5.56	Pablo/4Dec2012	5YR
139	7.99875	125.13212	0.10	0.10	0.00	Pablo/4Dec2012	5YR
140	7.99578	125.13598	2.25	0.00	-2.25	Pablo/4Dec2012	5YR
141	7.99643	125.13770	0.93	0.00	-0.93	Pablo/4Dec2012	5YR
142	7.99252	125.13393	2.30	0.40	-1.90	Pablo/4Dec2012	5YR
143	7.99201	125.13215	1.56	0.60	-0.96	Pablo/4Dec2012	5YR
144	7.99292	125.13200	1.55	0.60	-0.95	Pablo/4Dec2012	5YR
145	7.99135	125.13454	3.64	2.14	-1.50	Pablo/4Dec2012	5YR
146	7.98912	125.13417	1.04	1.20	0.16	Pablo/4Dec2012	5YR
147	7.98544	125.13453	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
148	7.98383	125.13382	1.16	0.00	-1.16	Pablo/4Dec2012	5YR
149	7.96449	125.13688	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
150	7.96247	125.13878	2.92	0.70	-2.22	Pablo/4Dec2012	5YR
151	7.96688	125.14028	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
152	7.97043	125.14114	0.73	0.60	-0.13	Pablo/4Dec2012	5YR
153	7.98372	125.13671	0.18	0.00	-0.18	Pablo/4Dec2012	5YR
154	7.98643	125.14190	3.64	1.60	-2.04	Pablo/4Dec2012	5YR
155	7.98416	125.14119	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
156	7.98734	125.13901	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
157	7.98799	125.13904	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
158	7.98777	125.13914	0.06	0.20	0.14	Pablo/4Dec2012	5YR
159	7.98730	125.14025	0.06	1.60	1.54	Pablo/4Dec2012	5YR
160	7.98744	125.14081	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
161	7.98785	125.14010	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
162	7.98882	125.13994	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
163	7.98856	125.13893	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
164	7.98974	125.13871	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
165	7.99427	125.13838	1.59	0.00	-1.59	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
166	7.99361	125.13824	1.38	0.00	-1.38	Pablo/4Dec2012	5YR
167	7.99089	125.13784	0.52	0.00	-0.52	Pablo/4Dec2012	5YR
168	7.99070	125.13777	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
169	7.99272	125.13776	1.17	0.00	-1.17	Pablo/4Dec2012	5YR
170	7.99149	125.13666	1.12	0.00	-1.12	Pablo/4Dec2012	5YR
171	7.99229	125.13537	1.65	0.00	-1.65	Pablo/4Dec2012	5YR
172	7.99301	125.13614	1.88	0.00	-1.88	Pablo/4Dec2012	5YR
173	7.99307	125.13721	1.79	0.00	-1.79	Pablo/4Dec2012	5YR
174	7.99358	125.13397	1.34	0.00	-1.34	Pablo/4Dec2012	5YR
175	7.99549	125.13279	2.76	0.00	-2.76	Pablo/4Dec2012	5YR
176	7.99429	125.13361	1.28	0.70	-0.58	Pablo/4Dec2012	5YR
177	7.98243	125.07909	3.54	0.00	-3.54	Pablo/4Dec2012	5YR
178	7.98262	125.07904	0.08	1.20	1.12	Pablo/4Dec2012	5YR
179	7.98315	125.08058	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
180	7.98351	125.08204	0.08	0.00	-0.08	Pablo/4Dec2012	5YR
181	7.98518	125.08515	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
182	7.98514	125.08594	0.10	0.10	0.00	Pablo/4Dec2012	5YR
183	7.98639	125.08502	0.65	0.14	-0.51	Pablo/4Dec2012	5YR
184	7.98771	125.08479	0.10	0.15	0.05	Pablo/4Dec2012	5YR
185	7.97813	125.05257	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
186	7.89410	125.07421	0.10	0.00	-0.10	Pablo/4Dec2012	5YR
187	7.99016	125.10144	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
188	7.99107	125.10119	1.96	0.00	-1.96	Pablo/4Dec2012	5YR
189	7.99135	125.10132	1.83	0.00	-1.83	Pablo/4Dec2012	5YR
190	7.99045	125.10335	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
191	7.99264	125.10537	3.02	0.00	-3.02	Pablo/4Dec2012	5YR
192	7.99107	125.10503	1.16	0.00	-1.16	Pablo/4Dec2012	5YR
193	7.99049	125.10595	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
194	7.99012	125.10722	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
195	7.99006	125.10900	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
196	7.98922	125.11728	0.09	0.00	-0.09	Pablo/4Dec2012	5YR
197	7.99282	125.11523	1.78	0.00	-1.78	Pablo/4Dec2012	5YR
198	7.99010	125.12104	0.39	0.00	-0.39	Pablo/4Dec2012	5YR
199	7.99219	125.12092	0.13	0.00	-0.13	Pablo/4Dec2012	5YR
200	7.99215	125.12229	1.62	0.00	-1.62	Pablo/4Dec2012	5YR
201	7.99208	125.12299	2.33	0.00	-2.33	Pablo/4Dec2012	5YR
202	7.98781	125.12911	1.05	0.00	-1.05	Pablo/4Dec2012	5YR
203	7.98893	125.13548	7.32	0.00	-7.32	Pablo/4Dec2012	5YR
204	7.99056	125.12930	2.76	0.10	-2.66	Pablo/4Dec2012	5YR
205	7.99028	125.12858	2.51	0.10	-2.41	Pablo/4Dec2012	5YR
206	7.99079	125.12677	0.98	0.00	-0.98	Pablo/4Dec2012	5YR
207	7.98736	125.06920	0.06	0.00	-0.06	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
208	7.99132	125.12676	3.06	0.00	-3.06	Pablo/4Dec2012	5YR
209	7.99132	125.12676	3.06	0.00	-3.06	Pablo/4Dec2012	5YR
210	7.98691	125.13239	1.63	0.00	-1.63	Pablo/4Dec2012	5YR
211	7.98669	125.13340	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
212	7.98668	125.13341	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
213	7.98677	125.13480	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
214	7.98730	125.13740	2.26	0.00	-2.26	Pablo/4Dec2012	5YR
215	7.98769	125.13789	2.59	0.00	-2.59	Pablo/4Dec2012	5YR
216	7.98646	125.13727	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
217	7.98547	125.13774	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
218	7.87500	125.19466	0.93	0.52	-0.41	Pablo/4Dec2012	5YR
219	7.87577	125.19654	5.89	0.90	-4.99	Pablo/4Dec2012	5YR
220	7.87584	125.19230	2.12	1.00	-1.12	Pablo/4Dec2012	5YR
221	7.87586	125.19238	2.62	0.00	-2.62	Pablo/4Dec2012	5YR
222	7.87784	125.19069	3.63	0.70	-2.93	Pablo/4Dec2012	5YR
223	7.87817	125.19091	5.39	0.00	-5.39	Pablo/4Dec2012	5YR
224	7.88078	125.18753	1.19	0.10	-1.09	Pablo/4Dec2012	5YR
225	7.88459	125.18764	1.70	0.20	-1.50	Pablo/4Dec2012	5YR
226	7.88499	125.18607	2.41	0.50	-1.91	Pablo/4Dec2012	5YR
227	7.88922	125.18310	2.04	0.00	-2.04	Pablo/4Dec2012	5YR
228	7.89267	125.17876	0.68	0.50	-0.18	Pablo/4Dec2012	5YR
229	7.90059	125.13093	0.39	0.20	-0.19	Pablo/4Dec2012	5YR
230	7.90086	125.12312	0.13	0.00	-0.13	Pablo/4Dec2012	5YR
231	7.90084	125.12313	0.15	0.30	0.15	Pablo/4Dec2012	5YR
232	7.93285	125.10162	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
233	7.93204	125.09364	0.26	0.20	-0.06	Pablo/4Dec2012	5YR
234	7.92029	125.09243	0.19	2.00	1.81	Pablo/4Dec2012	5YR
235	7.89537	125.17766	0.23	0.80	0.57	Pablo/4Dec2012	5YR
236	7.89589	125.17616	0.10	0.70	0.60	Pablo/4Dec2012	5YR
237	7.89853	125.17667	1.17	1.05	-0.12	Pablo/4Dec2012	5YR
238	7.90170	125.17512	0.06	0.80	0.74	Pablo/4Dec2012	5YR
239	7.90018	125.18051	0.21	0.00	-0.21	Pablo/4Dec2012	5YR
240	7.90643	125.17934	0.38	0.00	-0.38	Pablo/4Dec2012	5YR
241	7.90523	125.17504	0.13	0.00	-0.13	Pablo/4Dec2012	5YR
242	7.90523	125.16772	0.23	0.42	0.19	Pablo/4Dec2012	5YR
243	7.90431	125.16518	0.87	0.45	-0.42	Pablo/4Dec2012	5YR
244	7.90359	125.16083	0.81	0.70	-0.11	Pablo/4Dec2012	5YR
245	7.90405	125.16003	0.06	0.30	0.24	Pablo/4Dec2012	5YR
246	7.90314	125.15760	0.21	0.48	0.27	Pablo/4Dec2012	5YR
247	7.90098	125.15694	0.45	0.40	-0.05	Pablo/4Dec2012	5YR
248	7.90093	125.15725	0.72	1.20	0.48	Pablo/4Dec2012	5YR
249	7.89833	125.14976	0.06	0.20	0.14	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
250	7.90073	125.14791	0.39	0.30	-0.09	Pablo/4Dec2012	5YR
251	7.90071	125.13925	0.06	0.00	-0.06	Pablo/4Dec2012	5YR
252	7.90662	125.15590	0.72	0.00	-0.72	Pablo/4Dec2012	5YR
253	7.90953	125.15612	0.86	0.30	-0.56	Pablo/4Dec2012	5YR
254	7.90978	125.15620	1.53	0.00	-1.53	Pablo/4Dec2012	5YR
255	7.90577	125.16048	0.38	0.55	0.17	Pablo/4Dec2012	5YR
256	7.90590	125.16044	0.31	0.00	-0.31	Pablo/4Dec2012	5YR
257	7.90891	125.16487	0.08	0.80	0.72	Pablo/4Dec2012	5YR
258	7.91271	125.17042	0.52	0.40	-0.12	Pablo/4Dec2012	5YR
259	7.91750	125.17247	0.16	0.16	0.00	Pablo/4Dec2012	5YR
260	7.91454	125.17368	0.52	0.00	-0.52	Pablo/4Dec2012	5YR
261	7.91528	125.17915	0.45	0.00	-0.45	Pablo/4Dec2012	5YR
262	7.91510	125.18481	0.97	0.00	-0.97	Pablo/4Dec2012	5YR
263	7.91557	125.18819	2.40	0.00	-2.40	Pablo/4Dec2012	5YR
264	7.91373	125.18992	0.40	0	-0.40	Pablo/4Dec2012	5YR
265	7.91645	125.19196	2.95	0.4	-2.55	Pablo/4Dec2012	5YR
266	7.91633	125.19207	2.47	1	-1.47	Pablo/4Dec2012	5YR
267	7.91724	125.19469	1.81	0.1	-1.71	Pablo/4Dec2012	5YR
268	7.94716	125.10493	0.08	0	-0.08	Pablo/4Dec2012	5YR
269	7.92931	125.09663	0.06	0	-0.06	Pablo/4Dec2012	5YR
270	7.92010	125.09236	0.10	0	-0.10	Pablo/4Dec2012	5YR
271	7.94416	125.10332	0.87	1.1	0.23	Pablo/4Dec2012	5YR
272	7.94398	125.10301	4.72	0.2	-4.52	Pablo/4Dec2012	5YR
273	7.94399	125.10292	4.80	1.5	-3.30	Pablo/4Dec2012	5YR
274	7.94909	125.10347	3.01	0.5	-2.51	Pablo/4Dec2012	5YR
275	7.94785	125.10430	2.48	1.2	-1.28	Pablo/4Dec2012	5YR
276	7.94193	125.10748	1.79	0.9	-0.89	Pablo/4Dec2012	5YR
277	7.94054	125.10749	1.38	0.45	-0.93	Pablo/4Dec2012	5YR
278	7.93916	125.10800	2.34	0.4	-1.94	Pablo/4Dec2012	5YR
279	7.93787	125.10852	1.04	0.3	-0.74	Pablo/4Dec2012	5YR
280	7.93759	125.10868	0.93	0.1	-0.83	Pablo/4Dec2012	5YR
281	7.93256	125.11006	1.07	0.3	-0.77	Pablo/4Dec2012	5YR
282	7.97220	125.23444	1.43	0.5	-0.93	Pablo/4Dec2012	5YR
283	7.95867	125.22288	0.10	0.25	0.15	Pablo/4Dec2012	5YR
284	7.94374	125.15541	3.23	0.8	-2.43	Pablo/4Dec2012	5YR
285	7.94065	125.15563	0.58	0	-0.58	Pablo/4Dec2012	5YR
286	7.96357	125.18858	1.38	0.2	-1.18	Pablo/4Dec2012	5YR
287	7.96468	125.19249	2.29	1.1	-1.19	Pablo/4Dec2012	5YR
288	7.89993	125.10539	0.22	1.6	1.38	Pablo/4Dec2012	5YR
289	7.90787	125.09480	0.41	0	-0.41	Pablo/4Dec2012	5YR
290	7.91003	125.09760	0.21	1.5	1.29	Pablo/4Dec2012	5YR
291	7.91004	125.09765	0.29	2.5	2.21	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
292	7.90783	125.09686	2.86	2.5	-0.36	Pablo/4Dec2012	5YR
293	7.91123	125.09332	1.17	0	-1.17	Pablo/4Dec2012	5YR
294	7.91231	125.09548	0.30	0	-0.30	Pablo/4Dec2012	5YR
295	7.91308	125.09681	0.42	1.9	1.48	Pablo/4Dec2012	5YR
296	7.91307	125.09684	0.42	0.6	0.18	Pablo/4Dec2012	5YR
297	7.91338	125.09642	0.06	0	-0.06	Pablo/4Dec2012	5YR
298	7.91427	125.09606	0.39	0	-0.39	Pablo/4Dec2012	5YR
299	7.91429	125.09611	0.32	1	0.68	Pablo/4Dec2012	5YR
300	7.91525	125.09529	1.35	0.6	-0.75	Pablo/4Dec2012	5YR
301	7.91526	125.09523	1.32	0.3	-1.02	Pablo/4Dec2012	5YR
302	7.91516	125.09413	0.42	0	-0.42	Pablo/4Dec2012	5YR
303	7.91357	125.09396	1.16	0	-1.16	Pablo/4Dec2012	5YR
304	7.98766	125.13781	2.60	0.3	-2.30	Pablo/4Dec2012	5YR
305	7.98747	125.13764	3.09	0.9	-2.19	Pablo/4Dec2012	5YR
306	7.99001	125.10896	0.06	0.3	0.24	Pablo/4Dec2012	5YR
307	7.98587	125.09918	0.06	0.3	0.24	Pablo/4Dec2012	5YR
308	7.99287	125.13769	1.34	0.2	-1.14	Pablo/4Dec2012	5YR
309	7.93698	125.12522	1.13	0.1	-1.03	Pablo/4Dec2012	5YR
310	7.92940	125.12175	1.10	0	-1.10	Pablo/4Dec2012	5YR
311	7.92038	125.12239	0.06	0	-0.06	Pablo/4Dec2012	5YR
312	7.91989	125.12042	0.06	0	-0.06	Pablo/4Dec2012	5YR
313	7.91501	125.11501	0.08	0	-0.08	Pablo/4Dec2012	5YR
314	7.91892	125.11500	0.06	0	-0.06	Pablo/4Dec2012	5YR
315	7.91906	125.11493	0.08	0	-0.08	Pablo/4Dec2012	5YR
316	7.91863	125.11286	0.10	0	-0.10	Pablo/4Dec2012	5YR
317	7.91992	125.10463	0.47	0	-0.47	Pablo/4Dec2012	5YR
318	7.90050	125.11138	0.06	0	-0.06	Pablo/4Dec2012	5YR
319	7.90390	125.11614	0.06	0	-0.06	Pablo/4Dec2012	5YR
320	7.90520	125.11918	0.06	0	-0.06	Pablo/4Dec2012	5YR
321	7.91155	125.12609	0.06	0	-0.06	Pablo/4Dec2012	5YR
322	7.91360	125.13369	0.09	0	-0.09	Pablo/4Dec2012	5YR
323	7.93993	125.16057	0.06	0	-0.06	Pablo/4Dec2012	5YR
324	7.94253	125.15861	4.45	0	-4.45	Pablo/4Dec2012	5YR
325	7.94309	125.15622	2.76	0	-2.76	Pablo/4Dec2012	5YR
326	7.94020	125.15426	0.13	0	-0.13	Pablo/4Dec2012	5YR
327	7.94029	125.15412	0.06	0.2	0.14	Pablo/4Dec2012	5YR
328	7.94238	125.15068	3.01	0	-3.01	Pablo/4Dec2012	5YR
329	7.94408	125.14477	3.64	0	-3.64	Pablo/4Dec2012	5YR
330	7.93382	125.15864	0.06	0	-0.06	Pablo/4Dec2012	5YR
331	7.93795	125.14506	0.10	0	-0.10	Pablo/4Dec2012	5YR
332	7.93811	125.13908	0.06	0	-0.06	Pablo/4Dec2012	5YR
333	7.93856	125.12827	1.62	0	-1.62	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
334	7.93988	125.11536	0.06	0	-0.06	Pablo/4Dec2012	5YR
335	7.93523	125.11494	1.13	0	-1.13	Pablo/4Dec2012	5YR
336	7.93428	125.11530	2.40	0	-2.40	Pablo/4Dec2012	5YR
337	7.92998	125.11416	0.06	0	-0.06	Pablo/4Dec2012	5YR
338	7.93004	125.11399	1.33	0	-1.33	Pablo/4Dec2012	5YR
339	7.92806	125.11451	1.70	0	-1.70	Pablo/4Dec2012	5YR
340	7.93486	125.10440	0.13	0	-0.13	Pablo/4Dec2012	5YR
341	7.93557	125.10533	0.93	0.25	-0.68	Pablo/4Dec2012	5YR
342	7.93560	125.10533	0.93	0	-0.93	Pablo/4Dec2012	5YR
343	7.96926	125.13745	0.39	0	-0.39	Pablo/4Dec2012	5YR
344	7.98717	125.13413	2.85	0.5	-2.35	Pablo/4Dec2012	5YR
345	7.90476	125.09809	2.12	2.5	0.38	Pablo/4Dec2012	5YR
346	7.90532	125.09986	1.69	2.15	0.46	Pablo/4Dec2012	5YR
347	7.90372	125.10327	0.06	0.9	0.84	Pablo/4Dec2012	5YR
348	7.90092	125.10483	0.16	1.7	1.54	Pablo/4Dec2012	5YR
349	7.89938	125.10635	0.13	1	0.87	Pablo/4Dec2012	5YR
350	7.89962	125.10470	0.42	1.55	1.13	Pablo/4Dec2012	5YR
351	7.90551	125.10738	0.06	0.9	0.84	Pablo/4Dec2012	5YR
352	7.90960	125.10865	0.06	0.4	0.34	Pablo/4Dec2012	5YR
353	7.90974	125.10853	0.06	0.2	0.14	Pablo/4Dec2012	5YR
354	7.90976	125.11195	0.06	0.5	0.44	Pablo/4Dec2012	5YR
355	7.90752	125.11193	0.13	0	-0.13	Pablo/4Dec2012	5YR
356	7.90517	125.11005	0.08	0.9	0.82	Pablo/4Dec2012	5YR
357	7.90513	125.11005	0.08	0.5	0.42	Pablo/4Dec2012	5YR
358	7.90741	125.10406	0.06	0.45	0.39	Pablo/4Dec2012	5YR
359	7.90787	125.10638	0.06	0.7	0.64	Pablo/4Dec2012	5YR
360	7.91071	125.10449	0.97	1.5	0.53	Pablo/4Dec2012	5YR
361	7.91387	125.10375	0.06	1.3	1.24	Pablo/4Dec2012	5YR
362	7.91475	125.10603	0.06	1	0.94	Pablo/4Dec2012	5YR
363	7.91819	125.10105	0.10	1.2	1.10	Pablo/4Dec2012	5YR
364	7.91594	125.09727	0.13	2	1.87	Pablo/4Dec2012	5YR
365	8.04938	125.16784	2.74	0	-2.74	Pablo/4Dec2012	5YR
366	8.04864	125.16915	1.71	0.3	-1.41	Pablo/4Dec2012	5YR
367	8.02570	125.15653	1.53	0	-1.53	Pablo/4Dec2012	5YR
368	8.02569	125.15662	1.15	0	-1.15	Pablo/4Dec2012	5YR
369	8.00326	125.15519	0.08	0	-0.08	Pablo/4Dec2012	5YR
370	7.97855	125.14886	1.49	0.4	-1.09	Pablo/4Dec2012	5YR
371	7.97849	125.14868	2.05	1	-1.05	Pablo/4Dec2012	5YR
372	7.97842	125.14835	1.29	0.35	-0.94	Pablo/4Dec2012	5YR
373	7.99980	125.19622	0.40	0.2	-0.20	Pablo/4Dec2012	5YR
374	7.94818	125.22582	1.50	0	-1.50	Pablo/4Dec2012	5YR
375	7.95010	125.21651	2.61	0.7	-1.91	Pablo/4Dec2012	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
376	7.94874	125.21925	3.39	1.2	-2.19	Pablo/4Dec2012	5YR
377	7.95049	125.21418	3.06	1	-2.06	Pablo/4Dec2012	5YR
378	7.94740	125.21376	2.76	1.3	-1.46	Pablo/4Dec2012	5YR
379	7.94797	125.21633	2.53	0.1	-2.43	Pablo/4Dec2012	5YR
380	7.94302	125.20920	1.17	0.3	-0.87	Pablo/4Dec2012	5YR
381	7.94971	125.20814	2.00	1.2	-0.80	Pablo/4Dec2012	5YR
382	7.95289	125.19914	1.19	1.5	0.31	Pablo/4Dec2012	5YR
383	7.95346	125.19940	1.16	1.7	0.54	Pablo/4Dec2012	5YR
384	7.95345	125.19939	1.16	0.1	-1.06	Pablo/4Dec2012	5YR
385	7.96064	125.19750	0.06	1.3	1.24	Pablo/4Dec2012	5YR
386	7.96065	125.19751	0.06	0.25	0.19	Pablo/4Dec2012	5YR
387	7.96274	125.19557	1.13	2	0.87	Pablo/4Dec2012	5YR
388	7.96448	125.19425	0.31	1.5	1.19	Pablo/4Dec2012	5YR
389	7.96554	125.19313	1.02	0.3	-0.72	Pablo/4Dec2012	5YR
390	7.96553	125.19320	0.94	0.2	-0.74	Pablo/4Dec2012	5YR
391	7.96346	125.19146	2.20	0.45	-1.75	Pablo/4Dec2012	5YR
392	7.96378	125.19139	2.53	0.9	-1.63	Pablo/4Dec2012	5YR
393	7.96400	125.18978	1.13	0	-1.13	Pablo/4Dec2012	5YR
394	7.95896	125.18883	1.33	0.4	-0.93	Pablo/4Dec2012	5YR
395	7.95744	125.18357	2.47	1.4	-1.07	Pablo/4Dec2012	5YR
396	7.95635	125.18054	1.33	0.5	-0.83	Pablo/4Dec2012	5YR
397	7.95643	125.18054	1.33	1.5	0.17	Pablo/4Dec2012	5YR
398	7.95602	125.17902	1.47	1	-0.47	Pablo/4Dec2012	5YR
399	7.95299	125.18290	1.36	1	-0.36	Pablo/4Dec2012	5YR
400	7.94553	125.17717	1.02	0	-1.02	Pablo/4Dec2012	5YR
401	7.94574	125.17572	0.93	0	-0.93	Pablo/4Dec2012	5YR
402	7.94649	125.17485	2.05	0.3	-1.75	Pablo/4Dec2012	5YR
403	7.94363	125.16718	0.06	2	1.94	Pablo/4Dec2012	5YR
404	7.94437	125.16824	1.70	2	0.30	Pablo/4Dec2012	5YR

ANNEX 12. Educational Institutions Affected by flooding in Manupali Flood Plain

Table A-12.1 Educational Institutions Affected by flooding in Manupali Flood Plain

Bukidnon				
Lantapan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bantuanon Elementary School	Bantuanon			
Bugcaon Elementary School	Bugcaon			
Bugcaon National High School	Bugcaon		Medium	Medium
Elementary School	Kulasihan			
Valbueco Elementary School	Kulasihan		Low	High
Lantapan Central Elementary School	Poblacion	Low	Low	Medium

Bukidnon				
Malaybalay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Elementary School	Apo Macote			
Bangcud National High School	Bangcud	High	High	High
Tigre Day Care Center	Bangcud		Low	Medium
Casisang Elementary School	Barangay 7			
Natid Asan Elementary School	Barangay 9			
Agricultural Training Institute	Casisang			
Day Care Center	Casisang			
Jan Jose Elementary School	Casisang			
Mabuhay Elementary School	Casisang	Medium	High	High
Private School	Casisang			
Bishop Han Theological Seminary	Laguitas			
Laguitas Elementary School	Laguitas			
Laguitas Naional High School	Laguitas			
Aglayan Central School	Linabo	Medium	Medium	Medium
Aglayan National High School	Linabo			Low
Linabo Central Elementary School	Linabo			
Linabo Community Learning Center	Linabo			
Saint Micheal High Schoo	Linabo			

Day Carem Center	Managok	High	High	High
Managok Elementary School	Managok	Low	Low	Low
Managok National High School	Managok			
Manupali Elementary school	Managok	High	High	High
Day Care Center	San Jose	High	High	High
Mabuhay Elementary School	San Jose	High	High	High
Malaybalay CIty National High School	San Jose	Low	Low	Low
Nalapgap Day Care Center	San Martin	Low	Low	Low
Padernal Elementary School	Santo Niño		Low	Low
Bangcud Central School	Simaya	Medium	High	High
Binalbagan Day Care Center	Simaya		Low	Low
Binalbagan Elementary School	Simaya		Low	Low
Bukidnon Fundamental Baptist Seminary	Simaya			
Child Friendly Day Care Center	Simaya		Low	Low
Elementary School	Simaya			
Nalapgap Elementary School	Simaya	Medium	Medium	Medium
San Martin Agro-industrial High School	Simaya			
San Martin Day Care Center	Simaya	Medium	Medium	Medium
San Martin Elementary School	Simaya	Medium	Medium	Medium
Simaya Elementary School	Simaya			
Sinanglanan Day Care Center	Simaya		Low	Low
Soso-on Day Care Center	Simaya	Medium	Medium	Medium
St. Isidore Academy	Simaya		Low	Low
SunBeam Christian Academy of Bangcud	Simaya	Low	Medium	Medium
Apo Macote Day Care Center	Sinanglanan	Low	Medium	Medium
Apo Macote Elementary School	Sinanglanan	Low	Medium	Medium
Elementary School	Sinanglanan			
Sunshine Day Care Center	Violeta	Medium	High	High

Bukidnon				
Valencia City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ACLC	Bagontaas	High	High	High
Bagontaas Adventist Elementary School	Bagontaas			
Bagontaas Central Elementary School	Bagontaas			Low
Casiphia Baptist Christian Academ Inc.	Bagontaas	Low	Low	Low
Central Mindanao Theological School	Bagontaas	Medium	High	High
College	Bagontaas	Medium	High	High
Day Care Center	Bagontaas			
First Fruit Christian Academy	Bagontaas			
Mountain View College ANNEX	Bagontaas	Low	Low	Low
School	Bagontaas			Low
Valencia Colleges	Bagontaas			
Batangan Central School	Batangan		Medium	High
DayCare Center	Batangan		Medium	Medium
Jupiter Day Care Center	Batangan		Medium	High
Colonia elementary School	Colonia	Low	Medium	Medium
Day Care Center	Colonia	Low	Medium	Medium
Padernal Elementary School	Colonia			Low
Day Care Center	Kahapunan	High	High	High
Christian Learning Center	Laligan	Low	Medium	Medium
Gold Day Care Center	Laligan	Medium	Medium	Medium
Laligan Central School	Laligan	Medium	Medium	Medium
Saint Joseph High School	Laligan	Medium	High	High
Tongantongan National High School	Laligan	Medium	Medium	High
Day Care Center	Lumbayao	High	High	High
Lumbayao Elementary School	Lumbayao	High	High	High
High School	Lumbo			
I.B.A College of Mindanao	Lumbo			
San Agustin Institute of Technology	Lumbo	Low	Low	Low
San Agustin Institute of Technology ANNEX	Lumbo	Low	Low	Medium
TESDA School	Lumbo	Low	Low	Medium

Valencia National High School	Lumbo	Medium	Medium	Medium
Lurugan Elementary School	Lurogan			
Dabongdabong Elementary School	Mailag		Low	Low
Good Counsel High School	Mailag		Low	Low
Mailag Elementary School	Mailag		Low	
Seventh Day Adventist School	Mailag			
Nabag.O Elementary School	Nabago	Medium	Medium	High
Faith Christian School	Poblacion	Medium	Medium	High
High School	Poblacion	High	High	High
Review Center	Poblacion	Medium	High	High
STI	Poblacion		Medium	Medium
Valencia Baptist Christian Academy	Poblacion	Low	Low	Medium
Valencia City Adventist Elementary School	Poblacion	High	High	High
Valencia City Central School	Poblacion	Medium	High	High
Valencia National High School	Poblacion	Low	Medium	High
Lurugan Day Care Center	San Carlos			
Lurugan Elementary School	San Carlos			
Lurugan National High School	San Carlos			
San Carlos Elementary School	San Carlos			
San Isidro Elementary School	San Isidro	Medium	High	High
Valencia City High School	San Isidro	High	High	High
Sinabuagan Elementary School	Sinabuagan	Medium	High	High
Day Care Center	Sugod			
Scorpion Day Care Center	Sugod	Medium	Medium	Medium
Adarna Day Care Center	Tongantongan	Medium	High	High
Araneta Elementary School	Tongantongan			
Fundamental Baptist School	Tongantongan	Medium	Medium	Medium
Mecury Day Care Center	Tongantongan	Low	Low	Low
San Vicente Elementary School	Tongantongan		Low	Medium
Tongantongan Elementary School	Tongantongan	Low	Medium	Medium
Cidrec Cumlat Memorial Institute	Vintar	Medium	High	High
Kahaponan Elementary School	Vintar		Medium	High
Vintar Elementary School	Vintar	Low	Medium	High

ANNEX 13. Health Institutions affected by flooding in Manupali Flood Plain

Table A-13.1 Health Institutions affected by flooding in Malabalay City, Bukidnon in Manupali Flood Plain

Bukidnon				
Malaybalay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Provincial Hospital	Barangay 7	Low	Medium	Medium
Provincial Hospital Establishment	Barangay 7			
Provincial Hospital	Casisang	Low	Low	Low
Provincial Hospital Establishment	Casisang		Low	Low
Barangay Health Station	Linabo	Medium	Medium	Medium
Health Center	Managok			Low
Barangay Health Station	Santo Niño		Low	Low
Barangay Health Center	Simaya		Low	Low
Health Center	Simaya			
Barangay Health Station	Sinanglanan	Low	Medium	Medium

Bukidnon				
Valencia City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Health Station	Bagontaas			
Valencia Polymedic General Hospital	Bagontaas	High	High	High
Health Center	Laligan	Medium	Medium	Medium
Blanco Hospital	Lumbo		Low	Low
Bukidnon Community Health Care Center	Lumbo			
City Health Office Of Valencia City	Lumbo			
Lavicaa General Hospital	Lumbo			
Shiphrah and Puah Maternity Clinic	Lumbo	Medium	Medium	High
Mailag Barangay Health Station	Mailag	Medium	High	Medium
Barangay Health Station	Nabago		Medium	Medium
Abella Midway Hospital	Poblacion	Medium	High	High
Blanco Hospital	Poblacion	Medium	Medium	Medium
Clinic	Poblacion			Low
Lavicaa General Hospital	Poblacion			
Sanitarium Hospital	Poblacion	Low	Medium	High

Urgent Care Clinic	Poblacion	Medium	High	High
Valencia Medical Hospital	Poblacion	Medium	High	High
Yap Building	Poblacion	Low	Low	Medium
DOH MPC	San Carlos			
Baranga Health Center	San Isidro	Medium	High	High
Sinabuagan Health Center	Sinabuagan	High	High	High
Barangay Health Center	Sugod		Low	Low
Barangay Health Center	Tongantongan	Medium	Medium	Medium
Barangay Health Station	Vintar		Medium	Medium

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