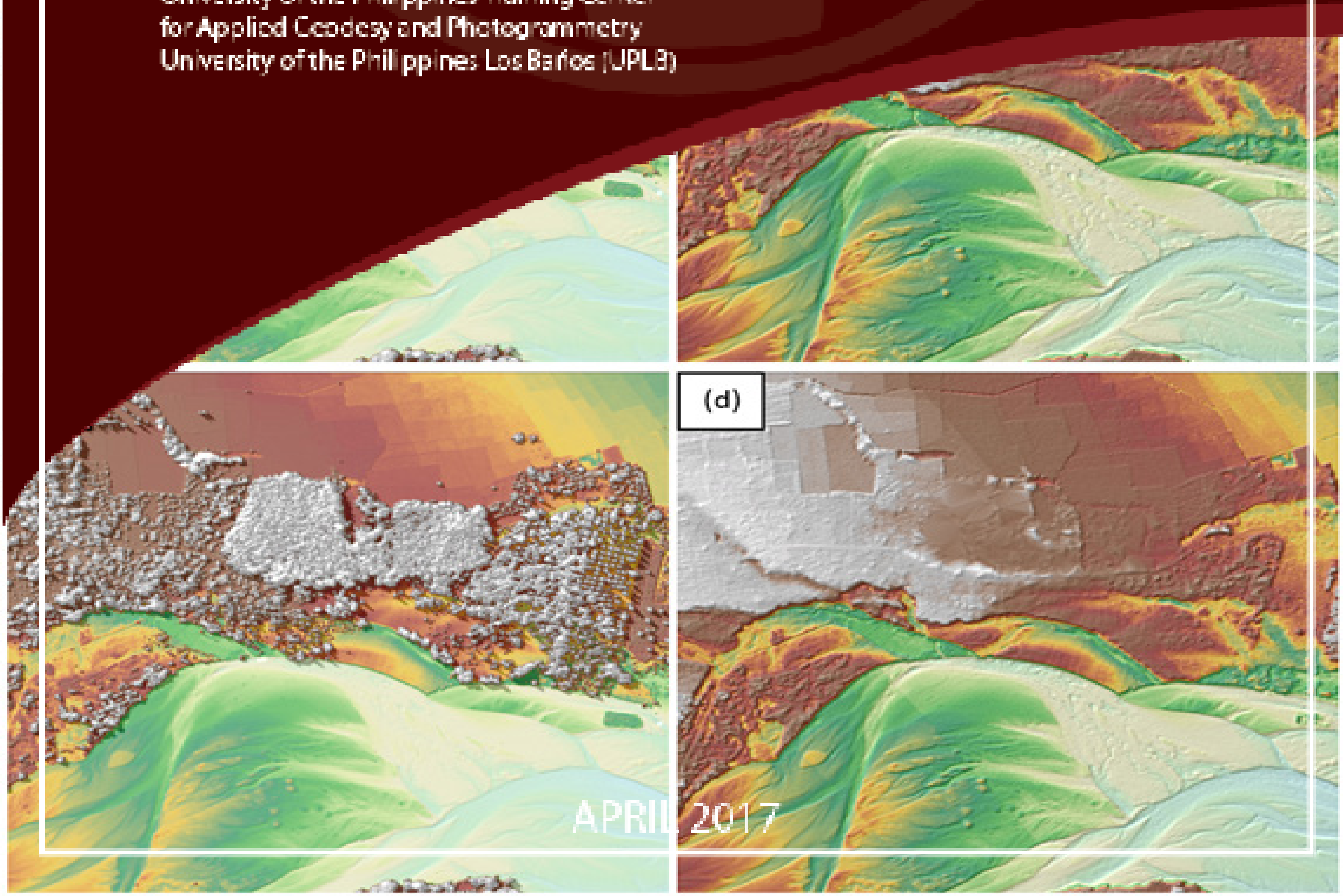
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Butas River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños (UPLB)



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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BUTASRIVER

Enrico C. Paringit, Dr. Eng.,and Prof. Edwin R. Abucay, Joan Pauline P. Talubo

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 implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 45 river basins in the MIMAROPA Region. The university is located in Los Baños in the province of Laguna.

1.2 OVERVIEW OF THE BUTAS RIVER BASIN

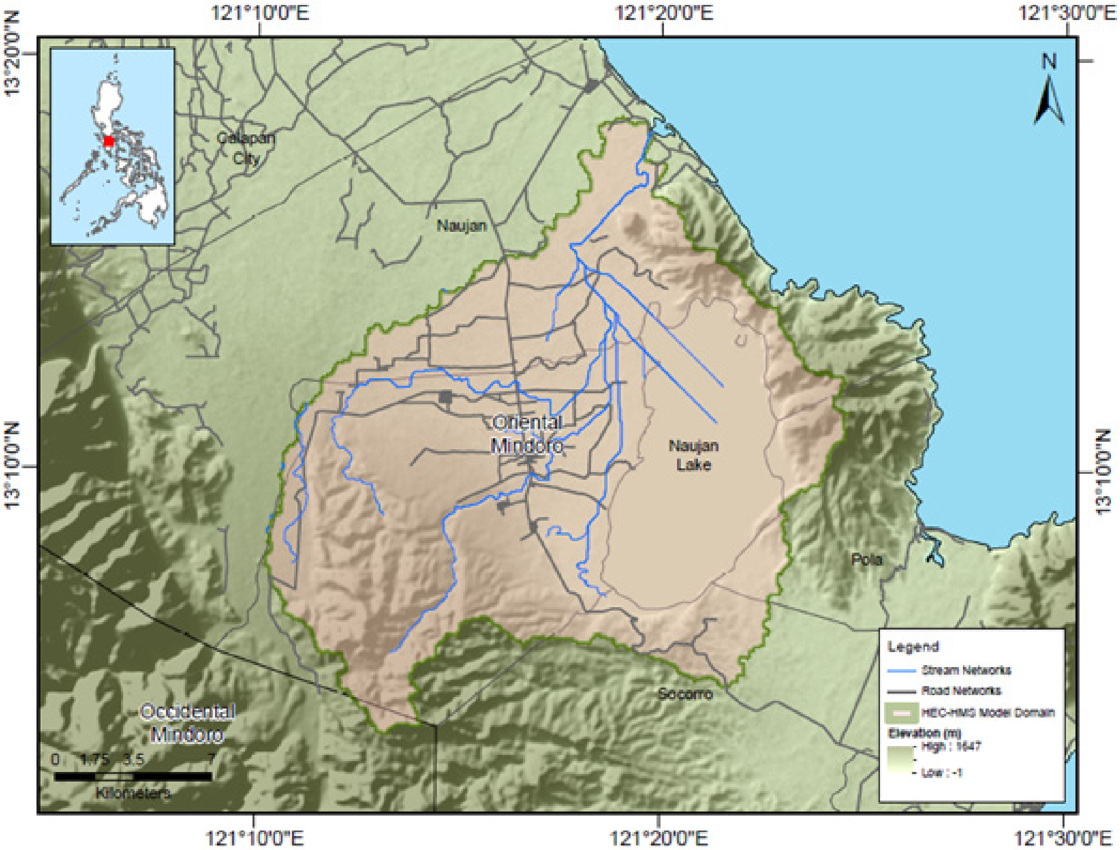

Figure 1. Map of Butas River Basin in brown

Butas River Basin is a 3,800-hectare watershed located in Oriental Mindoro covering majority of the Municipality of Victoria and Naujan, and minor portions of the Municipality of Socorro and Pola, respectively. It covers the barangays of Adrialuna, An polo Bagong Buhay, Bancuro, Concepcion, Dao, Laguna, Mabini, Malaya, Malinao, Melgar A and B, Montelago, Montemayor, Pagkakaisa, Pinagsabangan I, San Agus n I and II, San Carlos, San Isidro, San Jose, San Pedro and Santa Isabel in Naujan municipality; Tagbakin in Pola, Batong Dalig, Mabuhay I and II, Pasi I and II, Santo Domingo and Subaan in Socorro; and, Alcate, Babangonan, Bambanin, Bethel, Canaan, Duongan, Jose Leido, Loyal, Macatoc, Malabo, Matungao, Merit, Ordovilla, Pakyas, Poblcaion I to IV, Sampaguita, San Antonio, San Cristobal, San Gabriel, San Gelacio, San Juan, San Narciso, Urdaneta and Villa Cerveza in Victoria. The DENR River Control Basin Office estimated that the river basin discharges an annual runoff of 570 million cubic meters (River Basin Control Office, 2017).

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

The basin area has eight geological classifications with Recent as the most dominant while the remaining include Basement Complex, Cretaceous-Paleogene, Lake, Neogene, Pliocene- Pleistocene, Pliocene-Quaternary and Upper Miocene-Pliocene. The area is generally characterized by 30- 50% slope and eleva on of 10-50 meters above mean sea level. About 10 soil types can be found in the area including Luisiana clay loam, Buguay loamy sand, Bulacan clay loam, Calumpang clay, San Manuel clay loam, San Manuel loam, San Manuel sandy loam, San Manuel silt, Silt loam and San Miguel silt loam. Beach sand, hydrosol and rough mountain land (unclassi ed) can be also be found in the area. The dominant land cover in the basin area is arable land (crops mainly cereals and sugar). Other land cover include built-up area, cropland mixed with coconut planta on, cul vated area mixed with brushland/grassland, shpond derived from mangrove, lake and riverbeds.

Butas River extends to an approximate length of 10.18 km, derived from the 2012 flood susceptibility and hazard map of Socorro, Oriental Mindoro. It passes through Antipolo, Bagong Buhay, Bancuro, Bayani, Concepcion, Dao, Mabini, Malinao, Melgar A, Pagkakaisa, Pinagsabangan I, San Agus n I and II, San Carlos, San Isidro and San Jose in Naujan municipality. Based on the 2010 NSO Census of Population and Housing, among the barangays in Naujan municipality, Pinagsabangan I is the most populated. Moreover, according to the 2015 National Census there is a total of 8,504 people residing within the immediate vicinity of the river distributed among three Barangays Matungao and Sto. Domingo in Municipality of Socorro, and Brgy. Matulatula in Municipality of Pola (Philippine Statistics Authority, 2016).

The flood maps indicate that the vicinities along Butas River reflects moderate to high susceptibility. Based on the studies conducted by the Mines and Geosciences Bureau, of the barangays in Naujan municipality, Bancuro and Bayani have moderate to high risk; Antipolo, Bagong Buhay, Dao, Mabini, Malinao, Pagkakaisa, Pinagsabangan I, San Agus n I and II, San Carlos and San Isidro are under low to moderate risk; and, Bayani, Concepcion, Melgar A and San Jose have no flood hazard at all in terms of ood suscep bility. The field surveys conducted by the PHIL-LiDAR 1 validation team showed that three notable weather disturbances caused flooding in 1995 (Rosing), 2015 (Nona), and 2016 (Nina). For landslide susceptibility, under moderate to high risk are Bayani, Concepcion, Melgar A and B, Montelago and Montemayor in Naujan, Pahilahan, Panikihan, Pu ng Cacao and Tagbakin in Pola, Happy Valley and Ma. Concepcion in Socorro, Alcate, Concepcion, Loyal, San Antonio, San Cristobal and Villa Cerveza in Victora; low to moderate to low includes Adrialuna, An polo, Apitong, Bagong Buhay, Bancuro, Dao, Laguna, Mabini, Malaya, Malinao, Pagkakaisa, Pinagsabangan I, San Agus n I and II, San Isidro, San Jose, San Pedro, Santa Isabel and Santa Maria in Naujan, Matulatula in Pola, Batong Dalig, Mabuhay I and II, Matungao, Pasi I and II, Santo Domingo, Subaan in Socorro, and Babangonan, Bagong Buhay, Bambanin, Bethel, Canaan, Duongan, Jose Leido Jr., Mabini, Macatoc, Malabo, Merit, Ordovilla, Pakyas, Poblacion I to IV, Sampaguita, San Gabriel, San Gelacio, San Isidro, San Juan, San Narciso and Urdaneta in Victoria.

On the other hand, the river has a great contribution to nearby communities. Inhabitants are thinly spread along the stretch of the river while dense volume of forest lands and rice paddies exist (Socorro LGU, 2014).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BUTAS FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Butas Floodplain in Oriental Mindoro. These missions were planned for 17 lines that run 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 Butas Floodplain.

Table 1. Parameters used in Aquarius LiDAR System during Flight Acquisition

Block Name	Flying Height (m AGL)	Overlap (%)	Max. Field of View (θ)	Pulse Rate Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	750	30	36	125	45	130	5
BLK28B	600	30	36	125	45	130	5
BLK28C	600	30	36	125	45	130	5
BLK28D	600	30	36	125	45	130	5
BLK28E	600	30	36	125	45	130	5
BLK28J	600	30	36	125	45	130	5
BLK28I	600	30	36	125	45	130	5

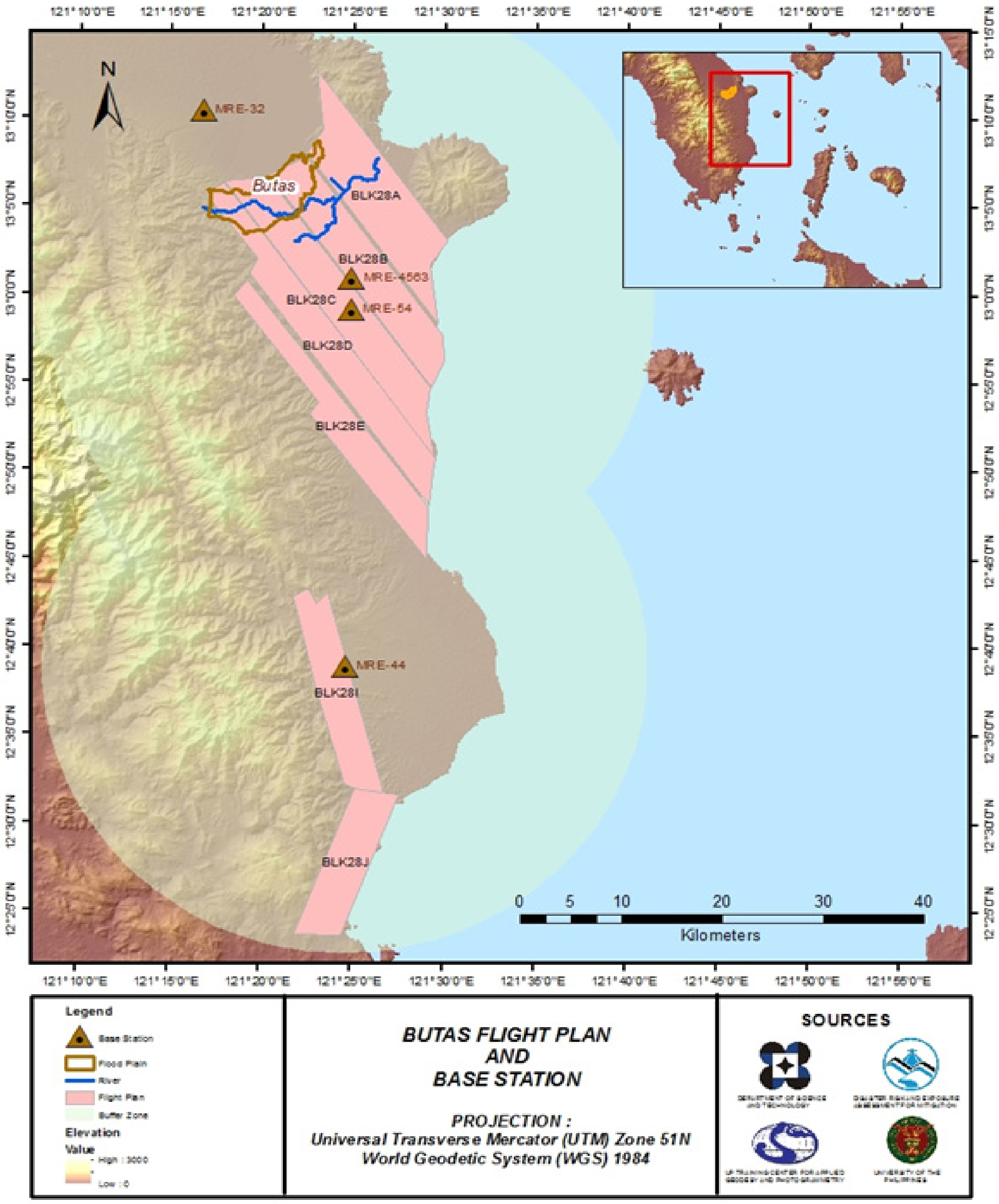


Figure 2. Flight plans and base stations used for Butas Floodplain survey

2.2 Ground Base Stations

The project team was able to recover four (4) NAMRIA ground control points: MRE-54, MRE-44, and MRE-32 which are of second (2nd) order accuracy, and MRE-4563 which is of fourth (4th) order accuracy. 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 (February 2-15, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Butas floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area, in addition Table 2 to Table 5 show the details about the following NAMRIA control stations, Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

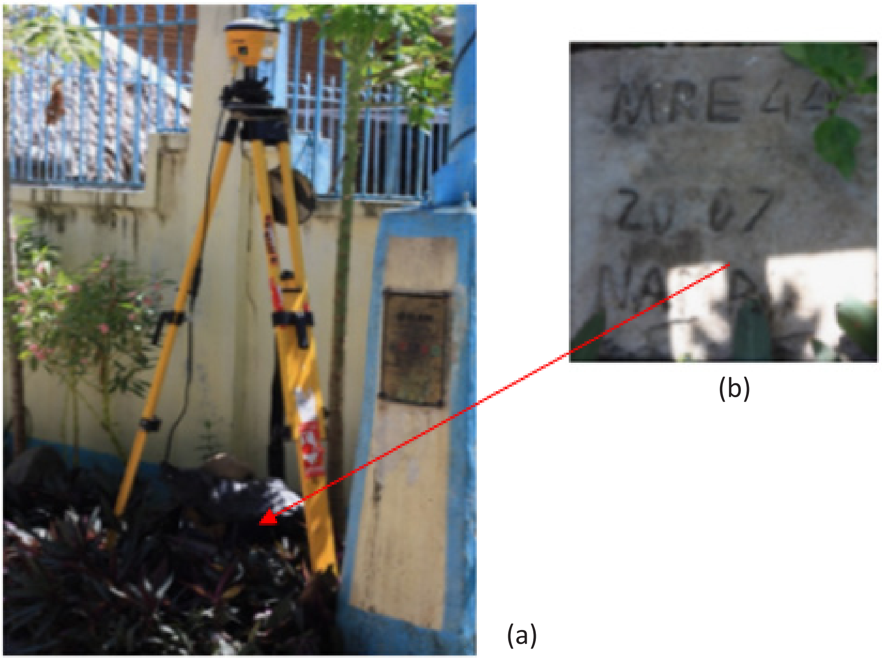
(b)

(a)

Figure 3. GPS set-up over MRE-54 as recovered inside the compound of the barangay hall of Maliangcog, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-54 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MRE-54 used as base station for the LiDAR Acquisition.

Station Name	MRE-54	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12°59'12.43671'' North
	Longitude	121°24'46.52637'' East
	Ellipsoidal Height	42.40800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	544797.009 meters
	Northing	1436124.562 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	12°59'7.43505'' North
	Longitude	122°41'8.09853'' East
	Ellipsoidal Height	91.39500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	327864.09 meters
	Northing	1436121.49 meters



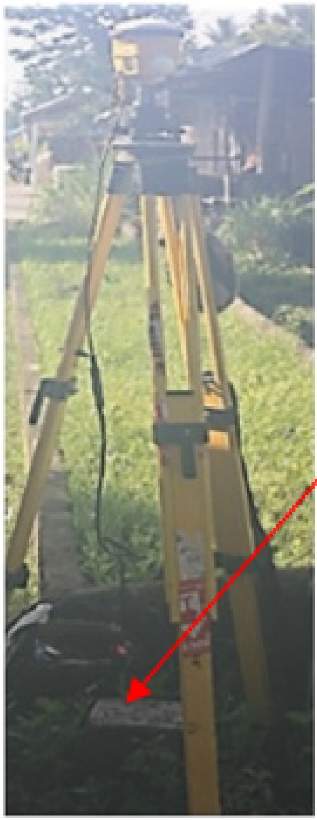
(b)

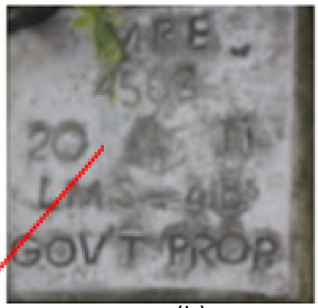
(a)

Figure 4. GPS set-up over MRE-44 as recovered just outside the compound of the barangay hall of Happy Valley, municipality of Roxas, Oriental Mindoro (a) and NAMRIA reference point MRE-44 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MRE-44 used as base station for the LiDAR Acquisition.

Station Name	MRE-54	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12°38'59.03778" North
	Longitude	121°24'32.60444" East
	Ellipsoidal Height	87.94200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	544436.519 meters
	Northing	1398838.995 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	12°38'54.11733" North
	Longitude	121°24'37.66392" East
	Ellipsoidal Height	137.80400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	327214.81 meters
	Northing	1398840.08 meters





(b)

(a)

Figure 5. GPS set-up over MRE-4563 as recovered, just outside the compound of the barangay hall of Brgy. Pagala-gala, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-4563 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRE-4563 used as base station for the LiDAR Acquisition.

Station Name	MRE-4563	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13°00'53.01692'' North
	Longitude	121°24'51.45337'' East
	Ellipsoidal Height	73.715 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	328034.015 meters
	Northing	1439300.319 meters

Table 5. Details of the recovered NAMRIA horizontal control point MRE-32 used as base station for the LiDAR Acquisition.

Station Nam	MRE-32	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13°10'28.85064'' North
	Longitude	121°16'38.44761'' East
	Ellipsoidal Height	19.49300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	530065.679 meters
	Northing	1456889.419 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13°10'23.79251'' North
	Longitude	121°16'43.46244'' East
	Ellipsoidal Height	67.64700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	313296.85 meters
	Northing	1457002.75 meters

Table 6. Ground Control Points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
2-Feb-14	1052A	3BLK28A033A	MRE-54
2-Feb-14	1054A	3BLK28B033B	MRE-54
3-Feb-14	1056A	3BLK28C034A	MRE-54
3-Feb-14	1058A	3BLK28CD034B	MRE-54
5-Feb-14	1066A	3BLK28DS036A	MRE-54, MRE-4563
12-Feb-14	1094A	3BLK28BS043B	MRE-54, MRE-4563
13-Feb-14	1098A	3BLK28JSI044B	MRE-44, MRE-32

2.3 Flight Missions

Seven (7) missions were conducted to complete the LiDAR Data Acquisition in Butas Floodplain, for a total of twenty-four hours and thirty-five minutes (24+35) of flying time for RP-C9122. All missions were acquired using the Aquarius LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight Missions for LiDAR Data Acquisition in Butas Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
2-Feb-14	1052A	117.89	115.70	2.17	113.53	769	3	47
2-Feb-14	1054A	103.26	91.32	10.21	81.11	1094	3	41
3-Feb-14	1056A	118.79	89.97	11.43	78.54	1111	3	41
3-Feb-14	1058A	236.00	100.05	14.78	85.27	1016	3	23
5-Feb-14	1066A	204.55	95.19	7.94	87.25	1088	3	35
12-Feb-14	1094A	308.50	51.18	7.39	43.79	500	2	29
13-Feb-14	1098A	144.96	76.86	1.74	75.12	909	3	59
TOTAL		1233.95	620.27	55.66	564.61	6487	24	35

Table 8. 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)
1052A	800	30	30, 40, 36	70, 50	40, 50	130	5
1054A	1000, 600	30	36	70, 50	50	130	5
1056A	600	30	40, 36	50	50	130	5
1058A	600	30	36	50	50, 40	130	5
1066A	600	30	36	50	40	130	5
1094A	600	30	36	50	40	130	5
1098A	600, 700	30	36	50	40, 50	130	5

2.4 Survey Coverage

Butas floodplain is located in the provinces of Oriental Mindoro with majority of the floodplain situated within the municipality of Socorro. Municipalities of Socorro, Pinamalayan and Gloria are mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Butas floodplain is presented in Figure 6.

Table 9. List of municipalities and cities surveyed during Butas Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Oriental Mindoro	Bansud	197.00	19.07	10%
	Bongabong	493.74	19.61	4%
	Bulalacao	365.58	5.42	1%
	Gloria	327.28	135.50	41%
	Mansalay	477.24	30.10	6%
	Naujan	431.57	6.70	2%
	Pinamalayan	206.87	98.90	47%
	Pola	127.04	37.73	30%
	Roxas	90.14	9.16	10%
	Socorro	206.05	142.23	69%
	Victoria	216.22	10.26	5%
TOTAL		3138.73	514.68	16.40%

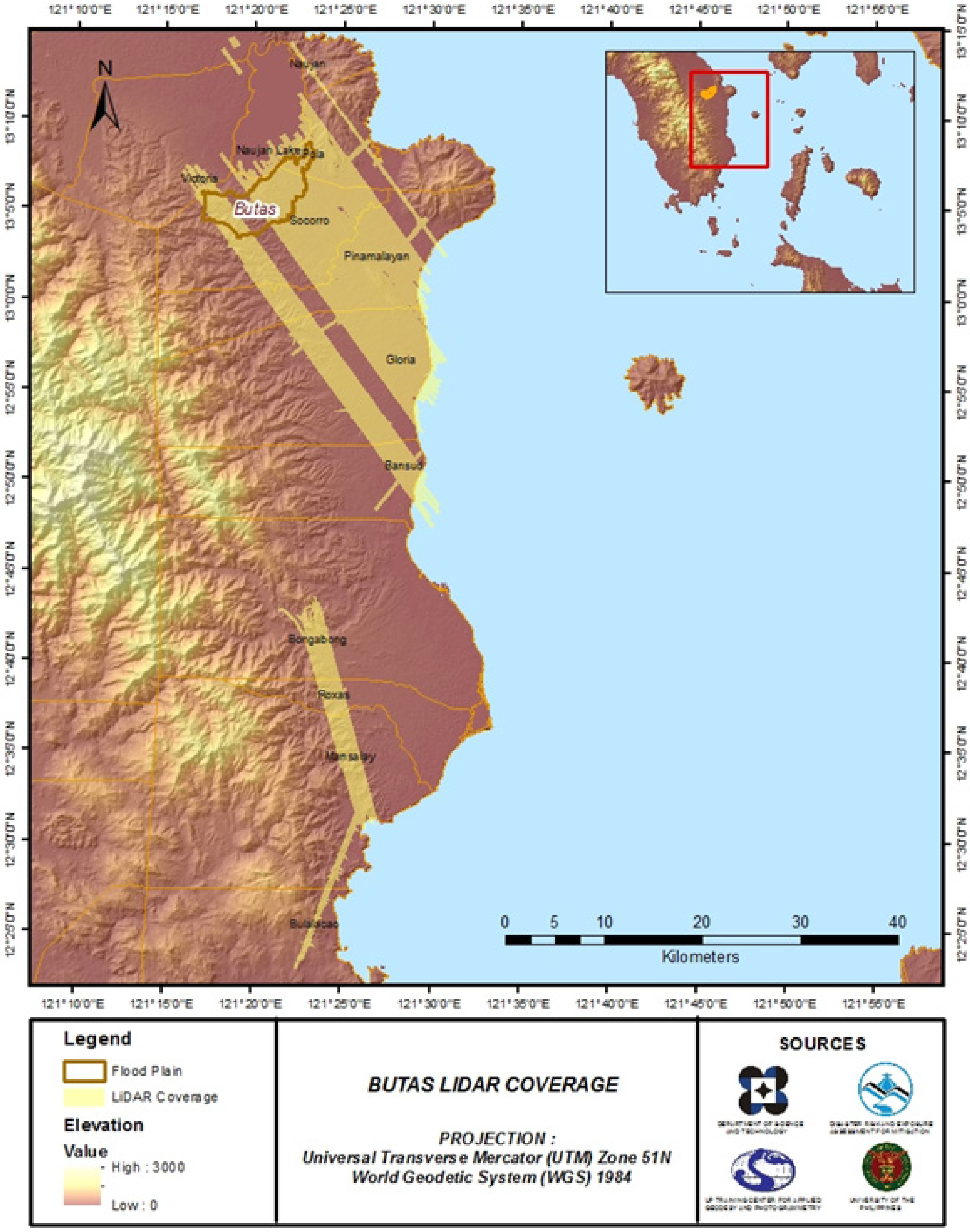


Figure 6. Actual LiDAR survey coverage for Butas floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR BUTAS FLOODPLAIN

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

3.1 LiDAR Data Processing for Butas 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 7.

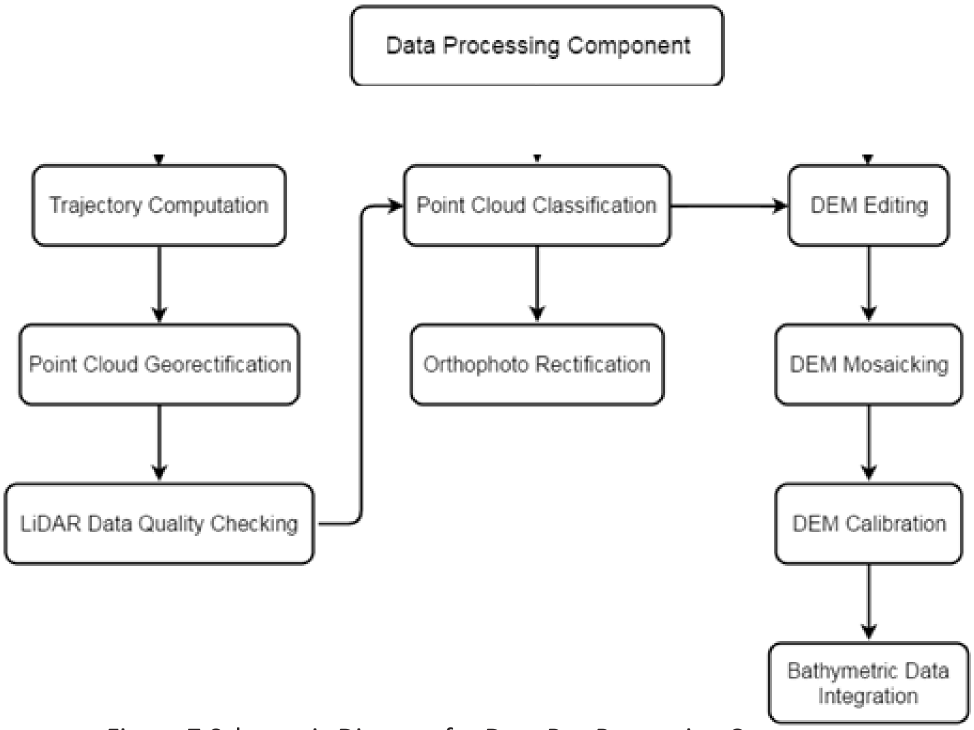

Figure 7.Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Butas floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Socorro, Oriental Mindoro. The Data Acquisition Component (DAC) transferred a total of 64.05 Gigabytes of Range data, 1.18 Gigabytes of POS data, 61.9 Megabytes of GPS base station data, and 342.96 Gigabytes of raw image data to the data server on February 21, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Butas was fully transferred on February 21, 2014, as indicated on the Data Transfer Sheets for Butas floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1058A, one of the Butas flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 3, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

Figure 8. Smoothed Performance Metric Parameters of a Butas Flight 1058A

The time of flight was from 171750 seconds to 176750 seconds, which corresponds to afternoon of February 3, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 2.10 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 3.70 centimeters, which are within the prescribed accuracies described in the methodology.

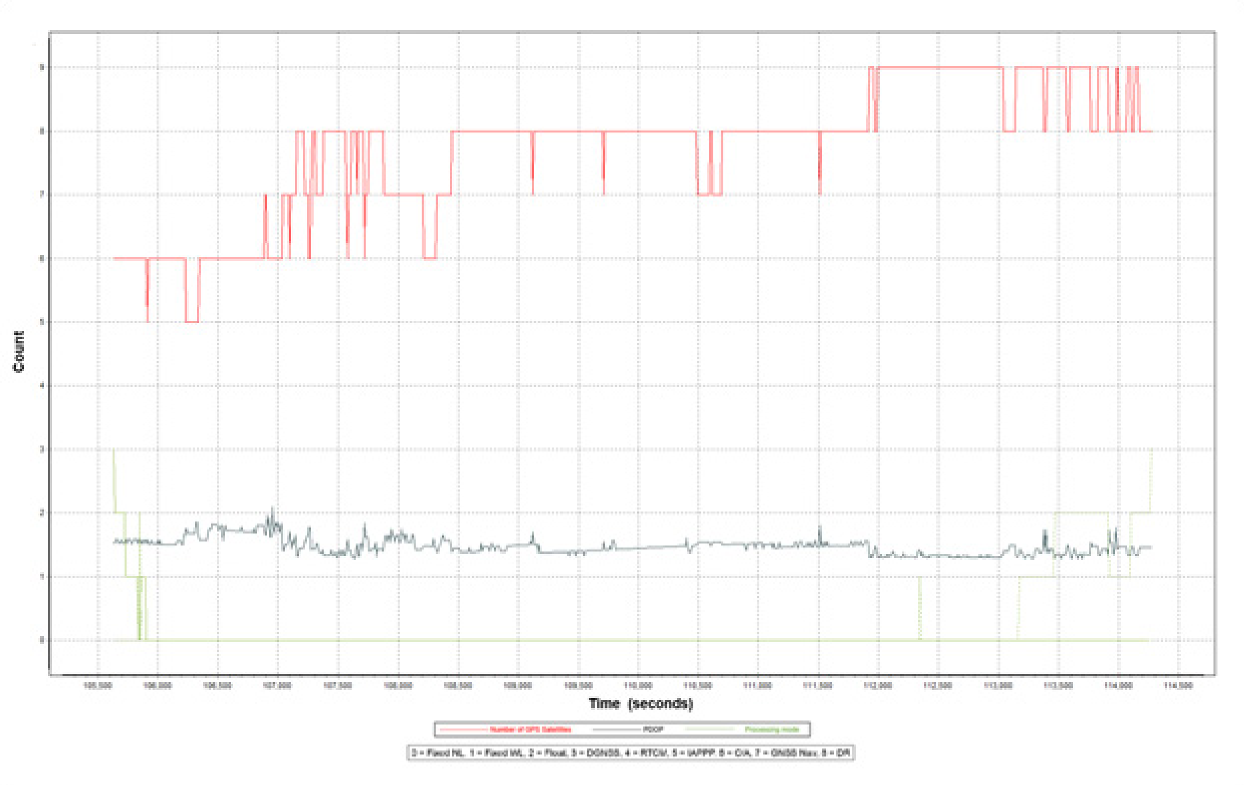

Figure 9. Solution Status Parameters of Butas Flight 1058A

The Solution Status parameters of flight 1058A, one of the Butas flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 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 Butas flights is shown in Figure 10.

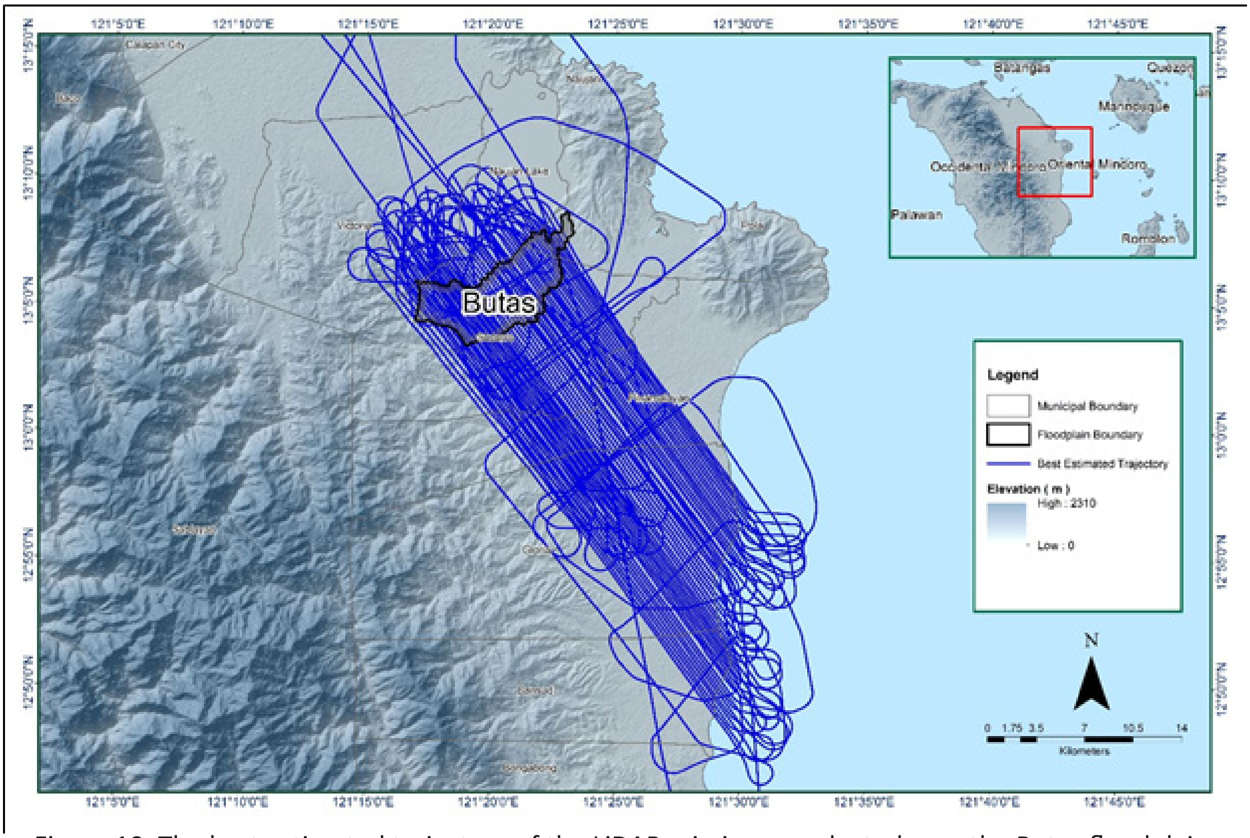

Figure 10. The best estimated trajectory of the LiDAR missions conducted over the Butas floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 149 flight lines, with each flight line containing one channel, since the Gemini system contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Butas floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Butas flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000367
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000906
GPS Position Z-correction stdev (<0.01meters)	0.0025

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

3.5 LiDAR Data Quality Checking

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

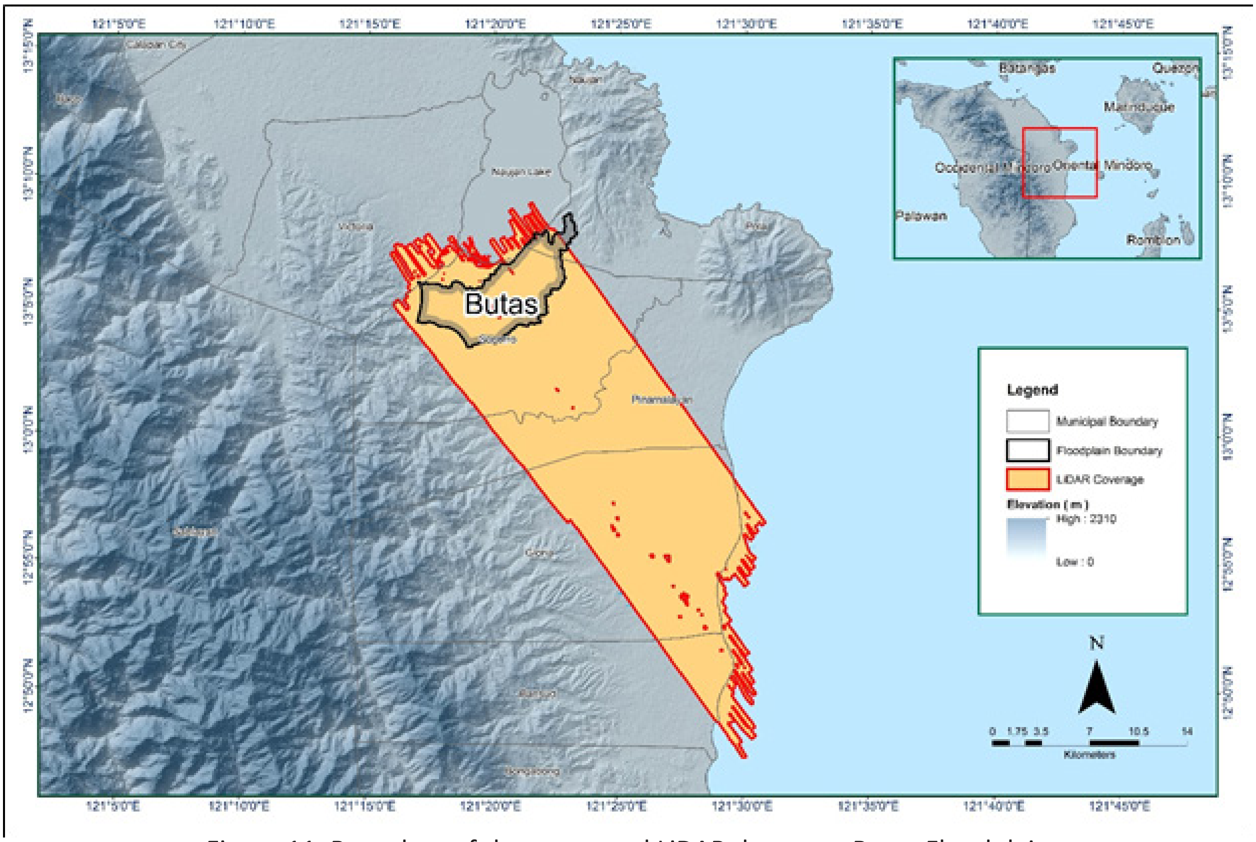

Figure 11. Boundary of the processed LiDAR data over Butas Floodplain

The total area covered by the Butas missions is 593.94 sq.km that is comprised of eight (8) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Butas floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
OrientalMindoro_Blk28B	1054A	75.67
OrientalMindoro_Blk28B_supplement	1094A	48.08
OrientalMindoro_Blk28Bs_additional	1098A	11.67
OrientalMindoro_Blk28C	1056A	29.66
OrientalMindoro_Blk28C_supplement	1056A	87.46
OrientalMindoro_Blk28D	1058A	68.56
OrientalMindoro_Blk28D_supplement	1066A	90.30
OrientalMindoro_reflights_Blk28B	8300G	73.59
	8301G	
OrientalMindoro_reflights_Blk28D	**8301G**	**108.95**
	TOTAL	**593.94 sq.km**

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

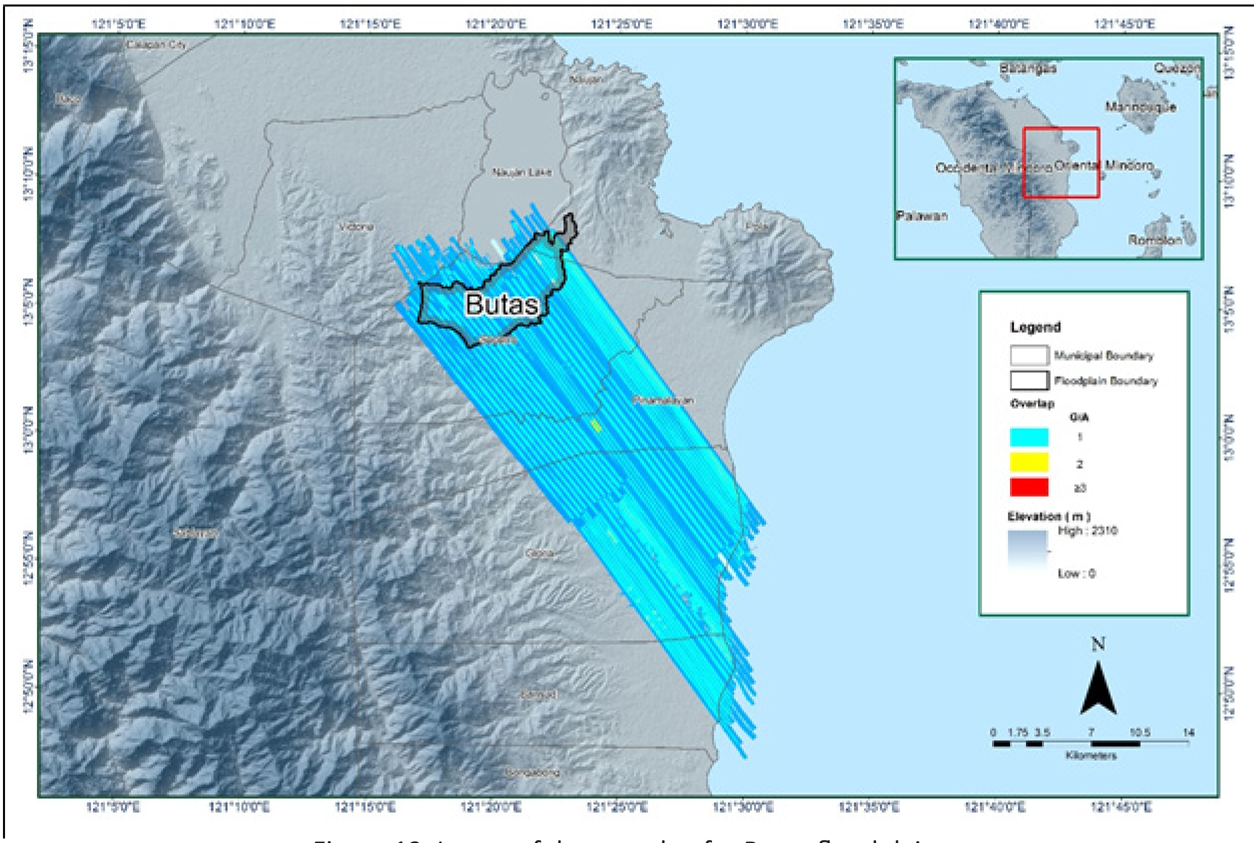

Figure 12. Image of data overlap for Butas floodplain.

The overlap statistics per block for the Butas 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 31.26% and 65.39% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Butas floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.73 points per square meter.

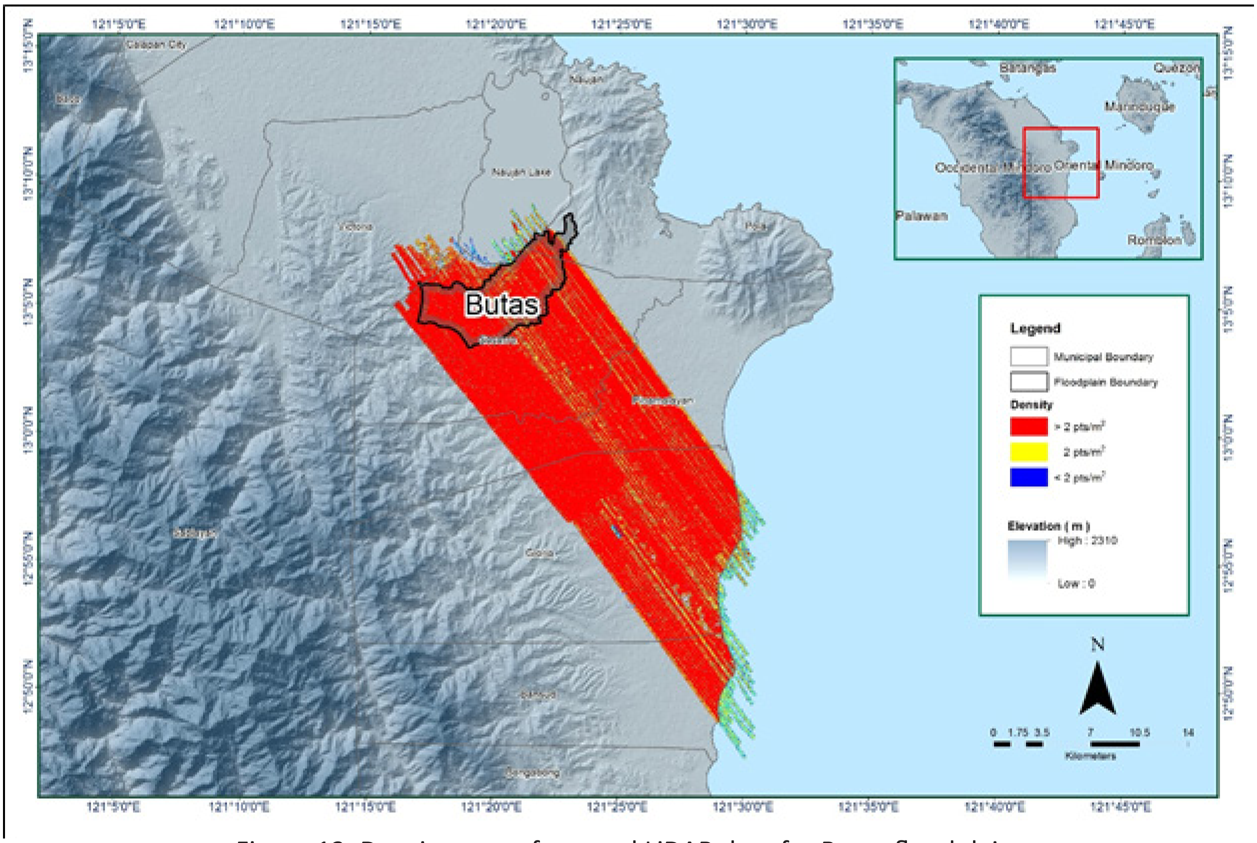

Figure 13. Density map of merged LiDAR data for Butas floodplain.

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

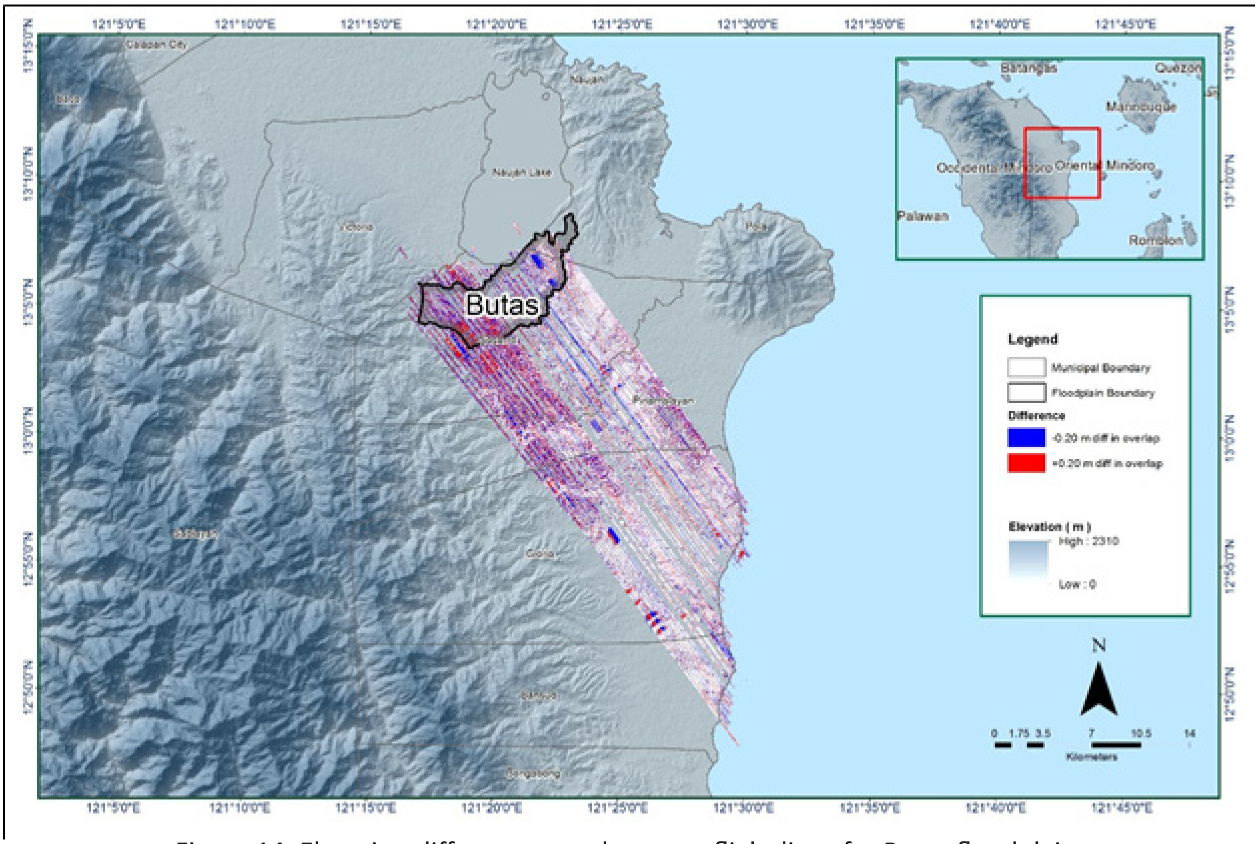

Figure 14. Elevation difference map between flight lines for Butas floodplain.

A screen capture of the processed LAS data from a Butas flight 1058A loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

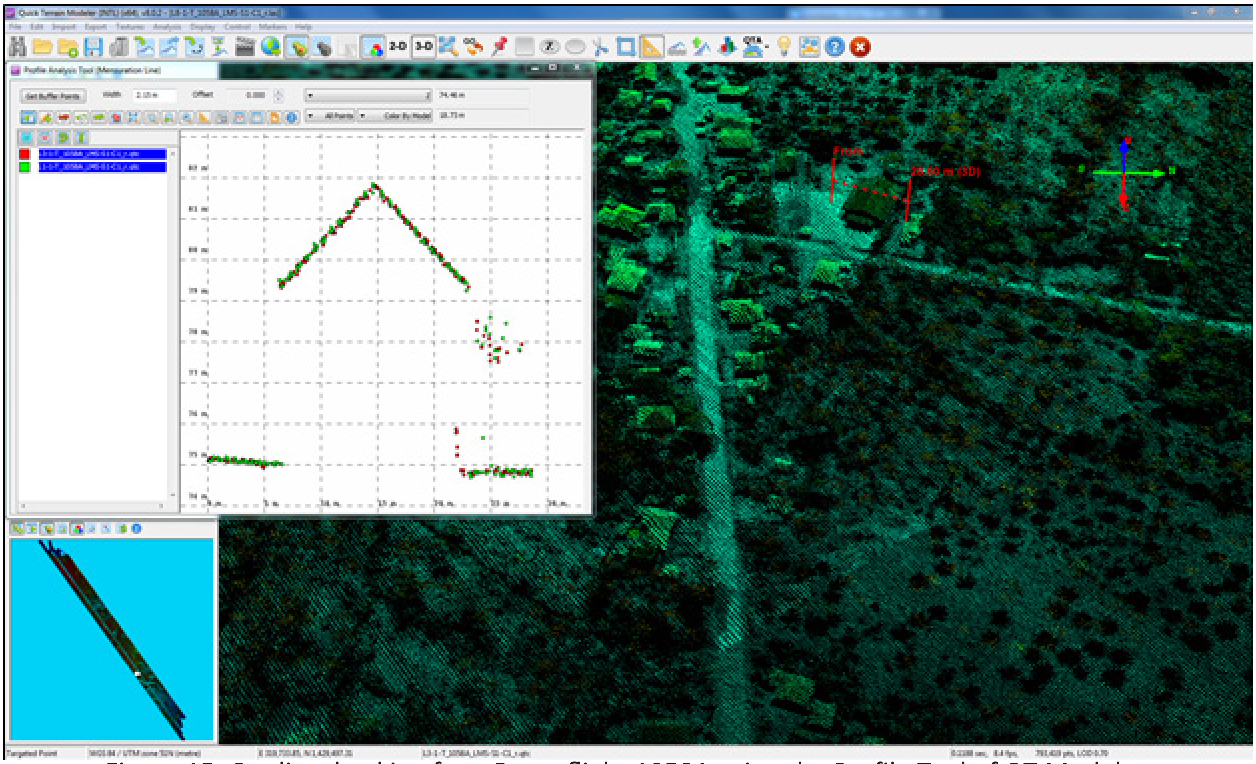

Figure 15. Quality checking for a Butas flight 1058A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Butas classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	364,960,187
Low Vegetation	437,993,166
Medium Vegetation	485,384,553
High Vegetation	737,852,906
Building	17,172,873

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Butas floodplain is shown in Figure 16. A total of 1, 243 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 385.39 meters and 8.45 meters respectively.

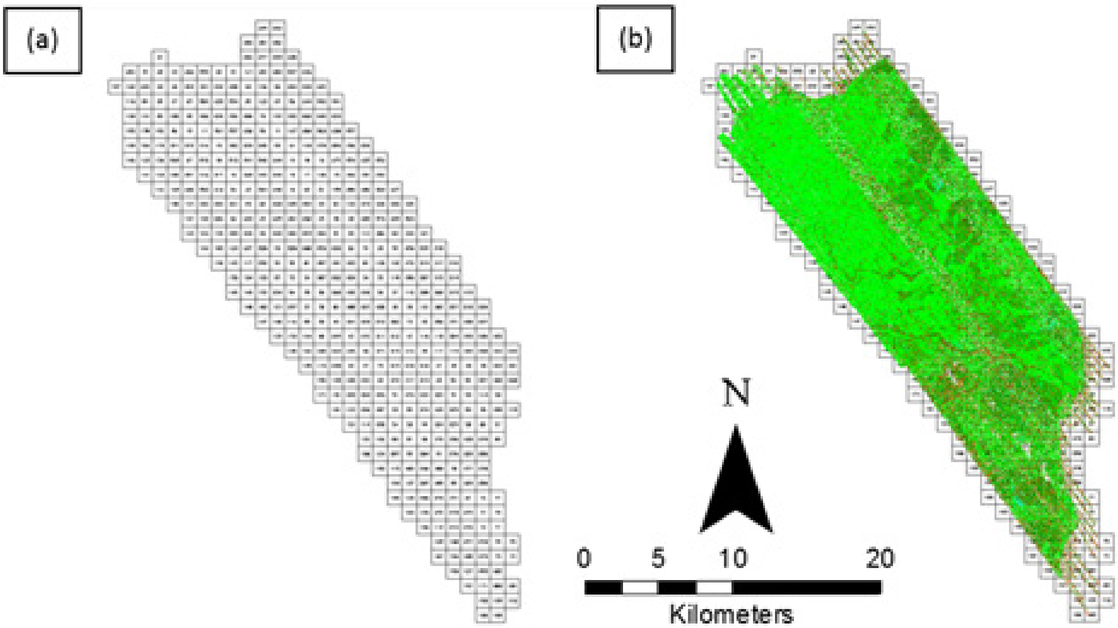

Figure 16. Tiles for Butas floodplain (a) and classification results (b) in TerraScan.

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

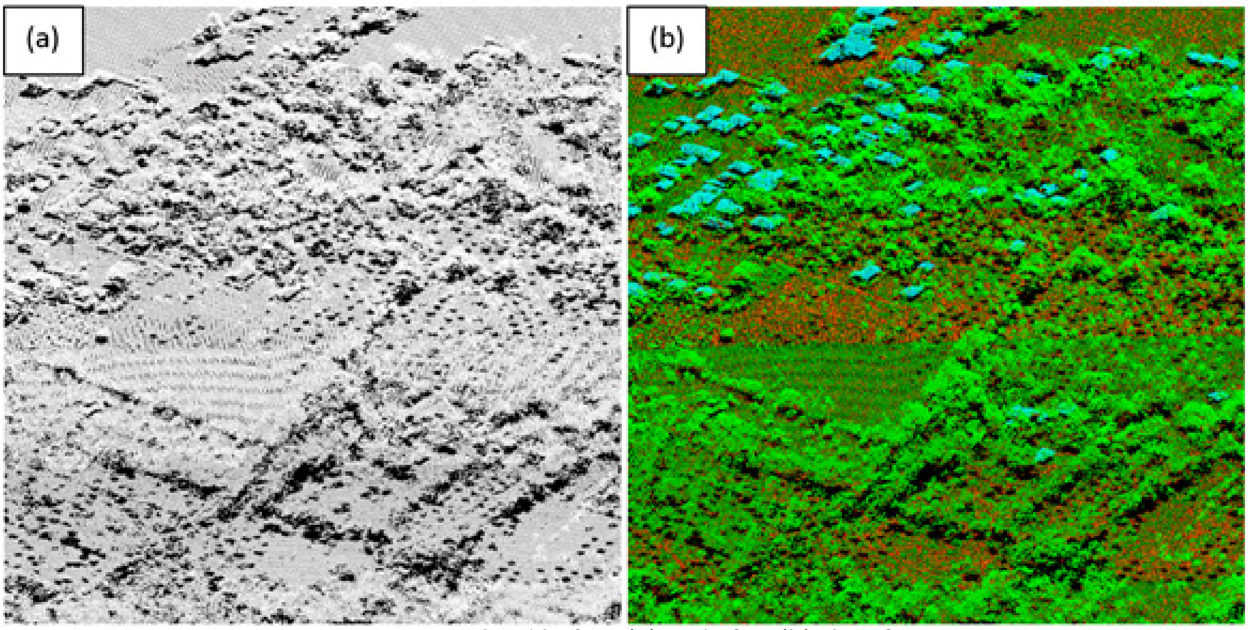

Figure 17. Point cloud before (a) and after (b) classification

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

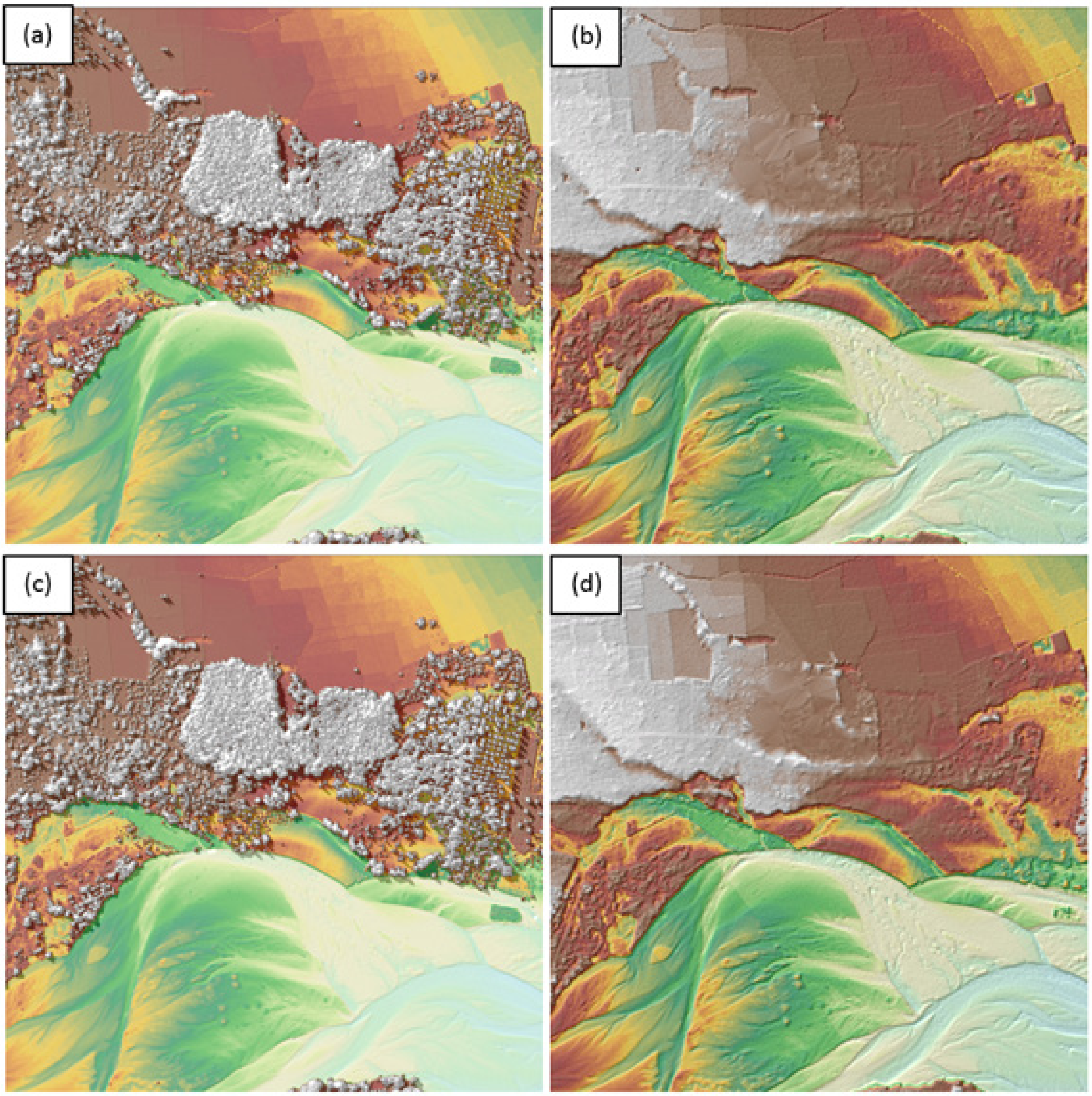

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Butas floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 614 1km by 1km tiles area covered by Butas floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Butas floodplain survey attained a total of 259.05 km2 in orthophotogaph coverage, comprised of 2,514 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

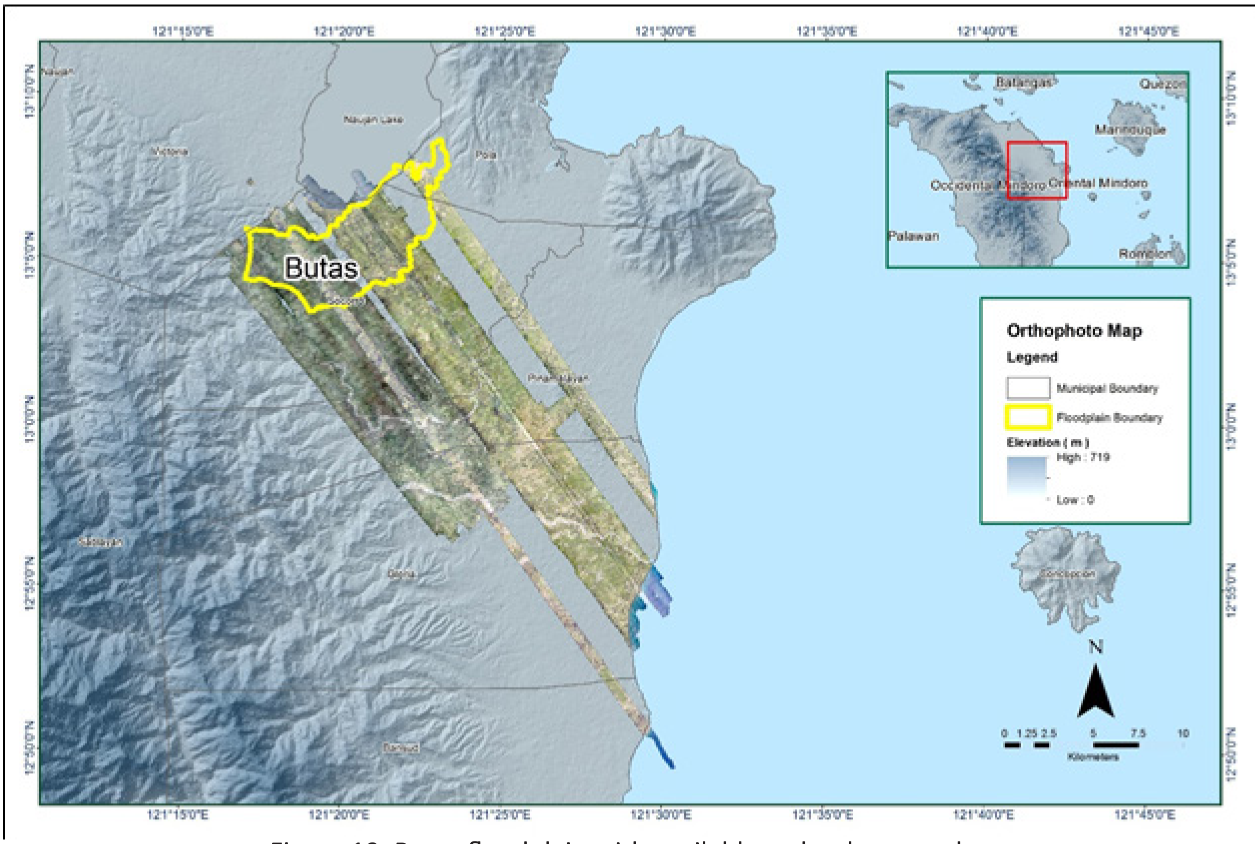

Figure 19. Butas floodplain with available orthophotographs.

Figure 20. Sample orthophotograph tiles for Butas floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Butas flood plain. These blocks are only composed of Mindoro blocks with a total area of 593.94 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
OrientalMindoro_Blk28B	75.67
OrientalMindoro_Blk28B_supplement	48.08
OrientalMindoro_Blk28Bs_additional	11.67
OrientalMindoro_Blk28C	29.66
OrientalMindoro_Blk28C_supplement	87.46
OrientalMindoro_Blk28D	68.56
OrientalMindoro_Blk28D_supplement	90.30
OrientalMindoro_reflights_Blk28B	73.59
OrientalMindoro_reflights_Blk28D	108.95
TOTAL	**593.94 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The paddy field (Figure 21c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 21e) and has to be removed through manual editing (Figure 21f).

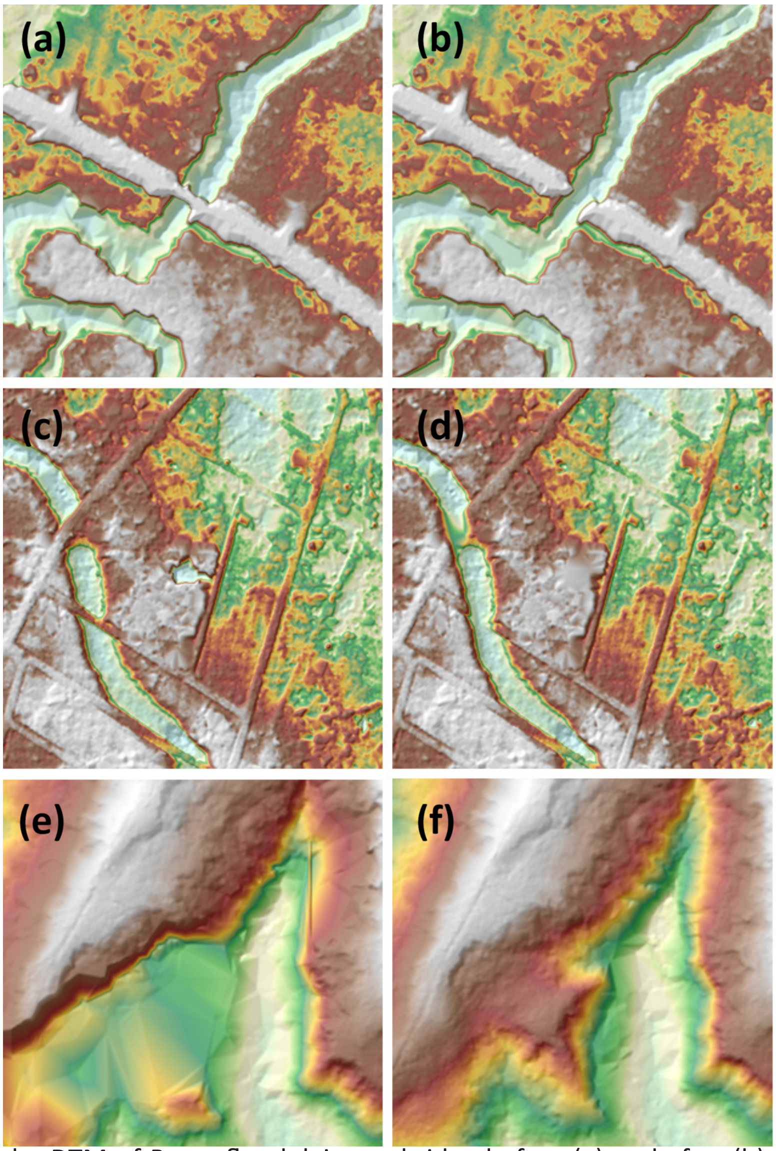

Figure 21. Portions in the DTM of Butas floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

eferred to a base station with an acceptable order of accuracy. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Butas floodplain is shown in Figure 22. It can be seen that the entire Butas floodplain is 85.18% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Butas floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
OrientalMindoro_Blk28B	0.00	0.00	0.90
OrientalMindoro_Blk28B_supplement	0.00	0.00	0.68
OrientalMindoro_Blk28Bs_additional	0.00	0.00	0.68
OrientalMindoro_Blk28C	0.00	0.00	0.68
OrientalMindoro_Blk28C_supplement	-0.17	0.00	0.68
OrientalMindoro_Blk28D	0.00	0.00	0.75
OrientalMindoro_Blk28D_supplement	0.00	0.00	0.92
OrientalMindoro_reflights_Blk28B	0.00	0.00	0.00
OrientalMindoro_reflights_Blk28D	0.00	0.00	-0.12

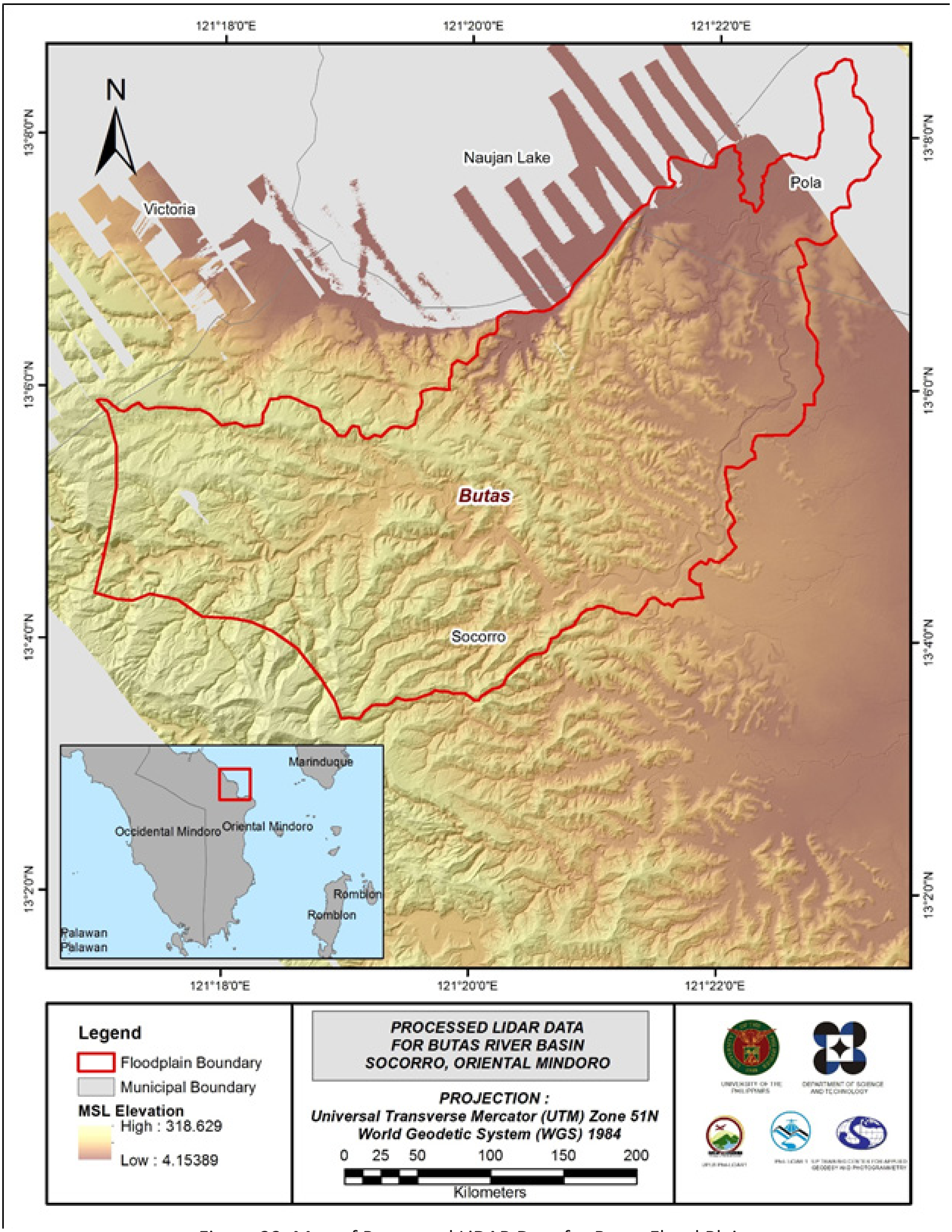

Figure 22. Map of Processed LiDAR Data for Butas Flood Plain.

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 Butas to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 1,540 survey points were used for calibration and validation of Butas LiDAR data. Random selection of 80% of the survey points, resulting to 1,219 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.60 meters with a standard deviation of 0.09 meters. Calibration of Butas LiDAR data was done by adding the height difference value, 0.67 meters, to Butas mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

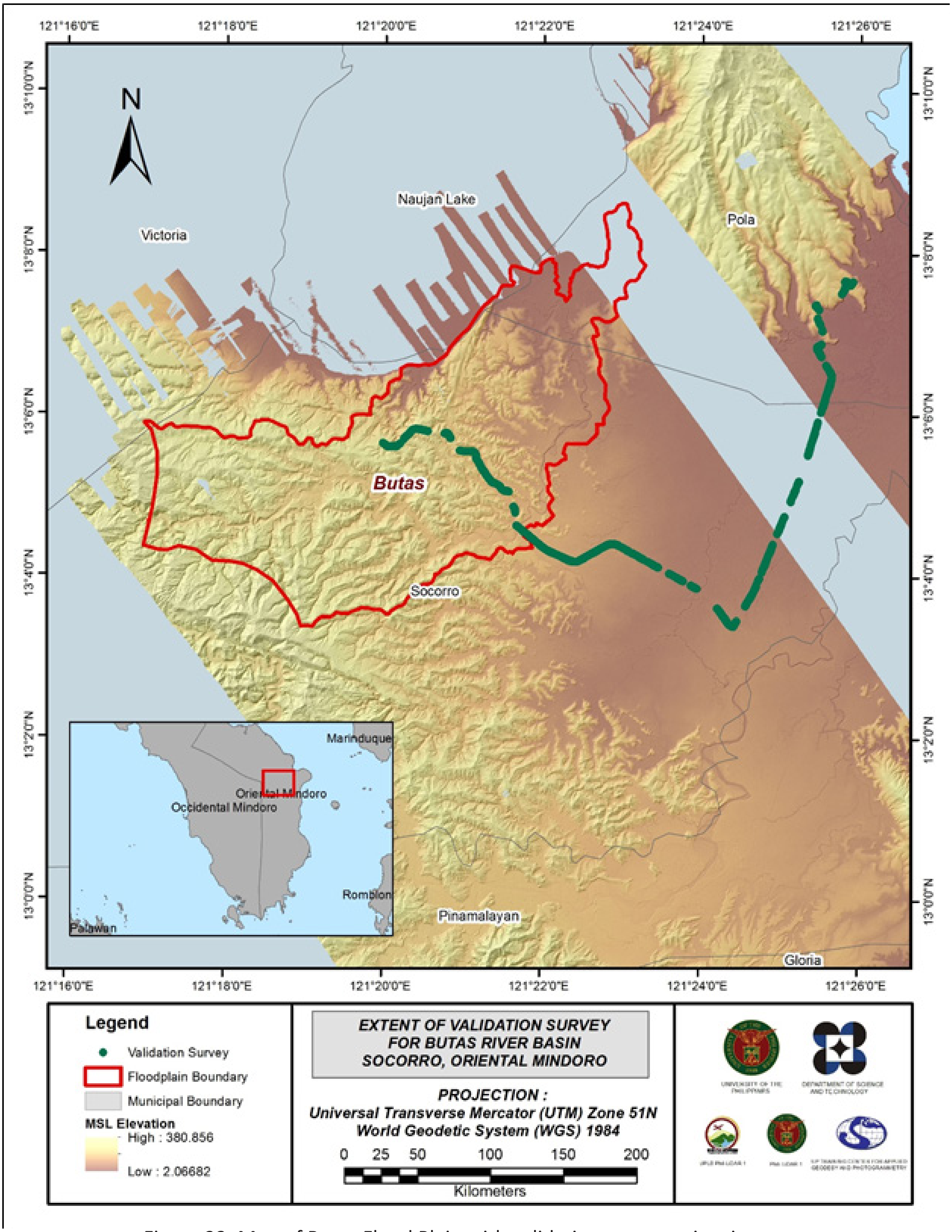

Figure 23. Map of Butas Flood Plain with validation survey points in green.

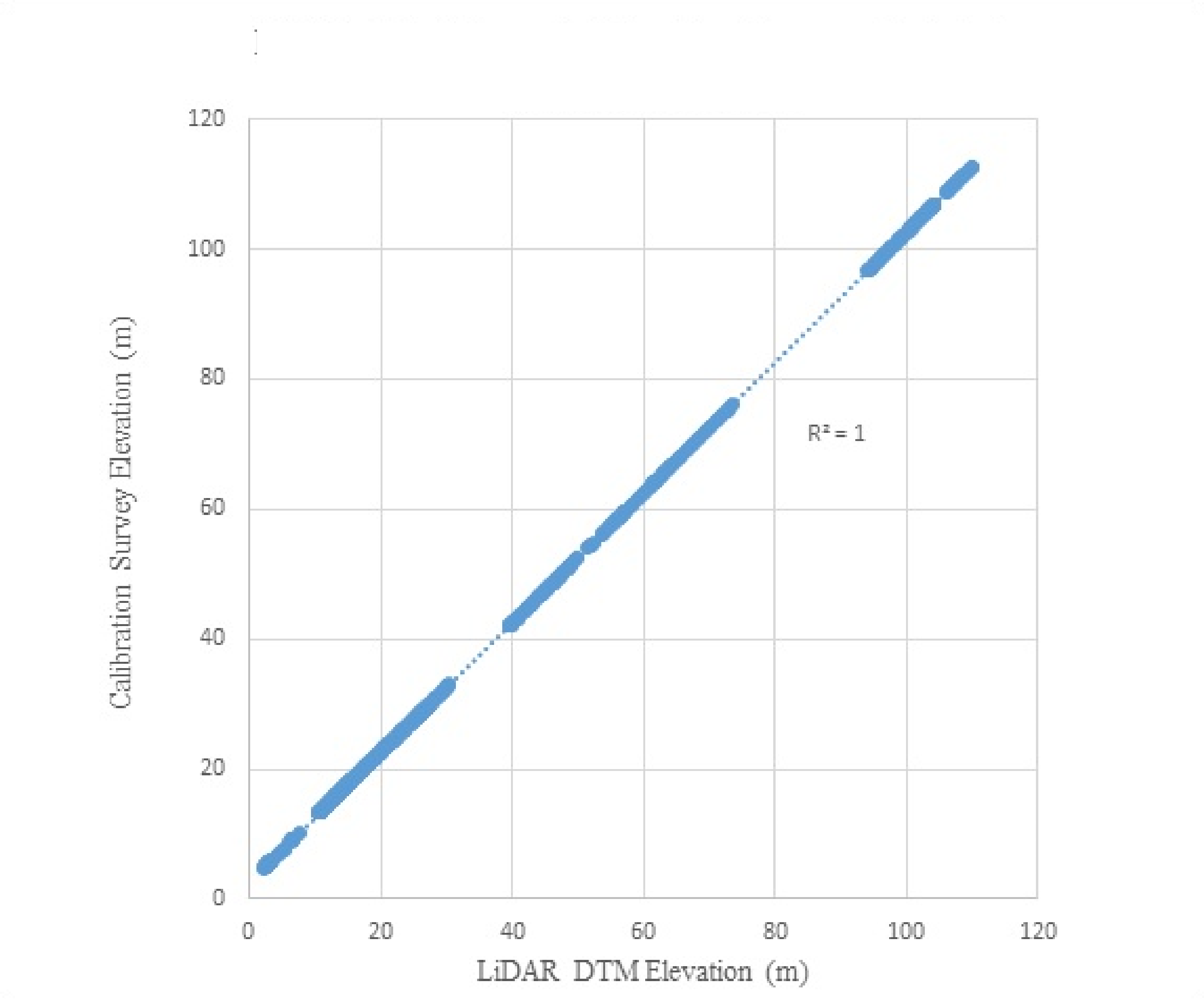

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.60
Standard Deviation	0.09
Average	-2.60
Minimum	-2.79
Maximum	-2.41

The remaining 20% of the total survey points, resulting to 321 points, were used for the validation of calibrated Butas DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.12 meters with a standard deviation of 0.12 meters, as shown in Table 16.

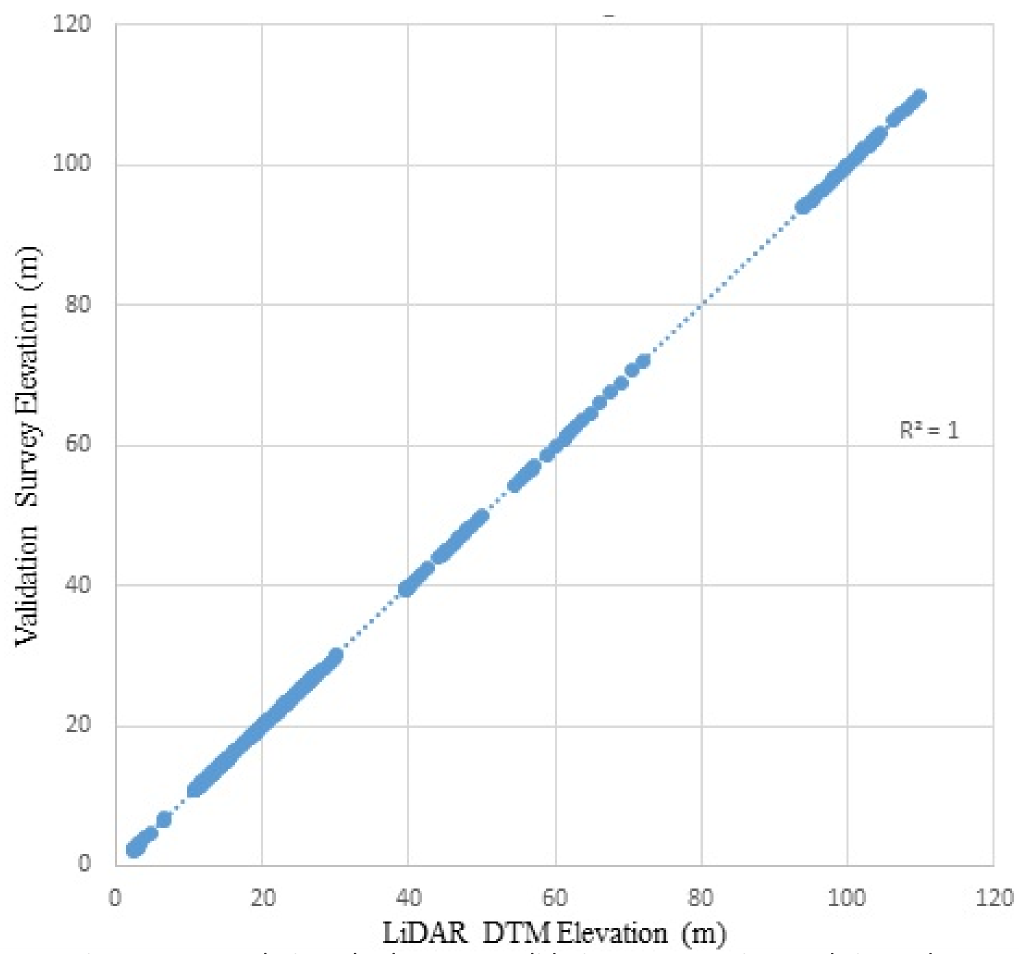

Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 16 . Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.12
Average	0.01
Minimum	-0.21
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Butas with 769 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 0.32 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Butas integrated with the processed LiDAR DEM is shown in Figure 26.

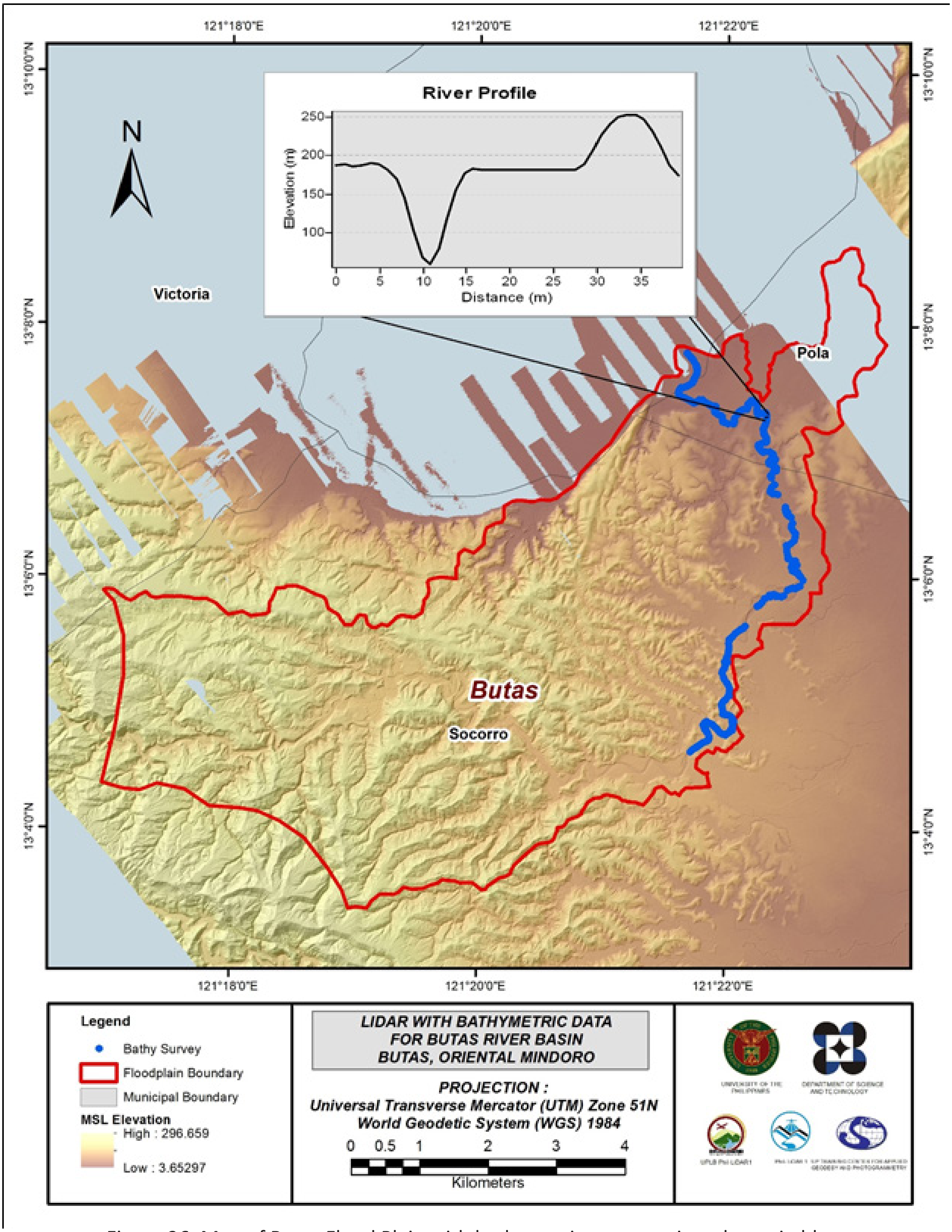

Figure 26. Map of Butas Flood Plain with bathymetric survey points shown in blue.

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

Butas floodplain, including its 200 m buffer, has a total area of 208.01 km2. For this area, a total of 6.0 km2, corresponding to a total of 1031 building features, are considered for QC. Figure 27 shows the QC blocks for Butas floodplain.

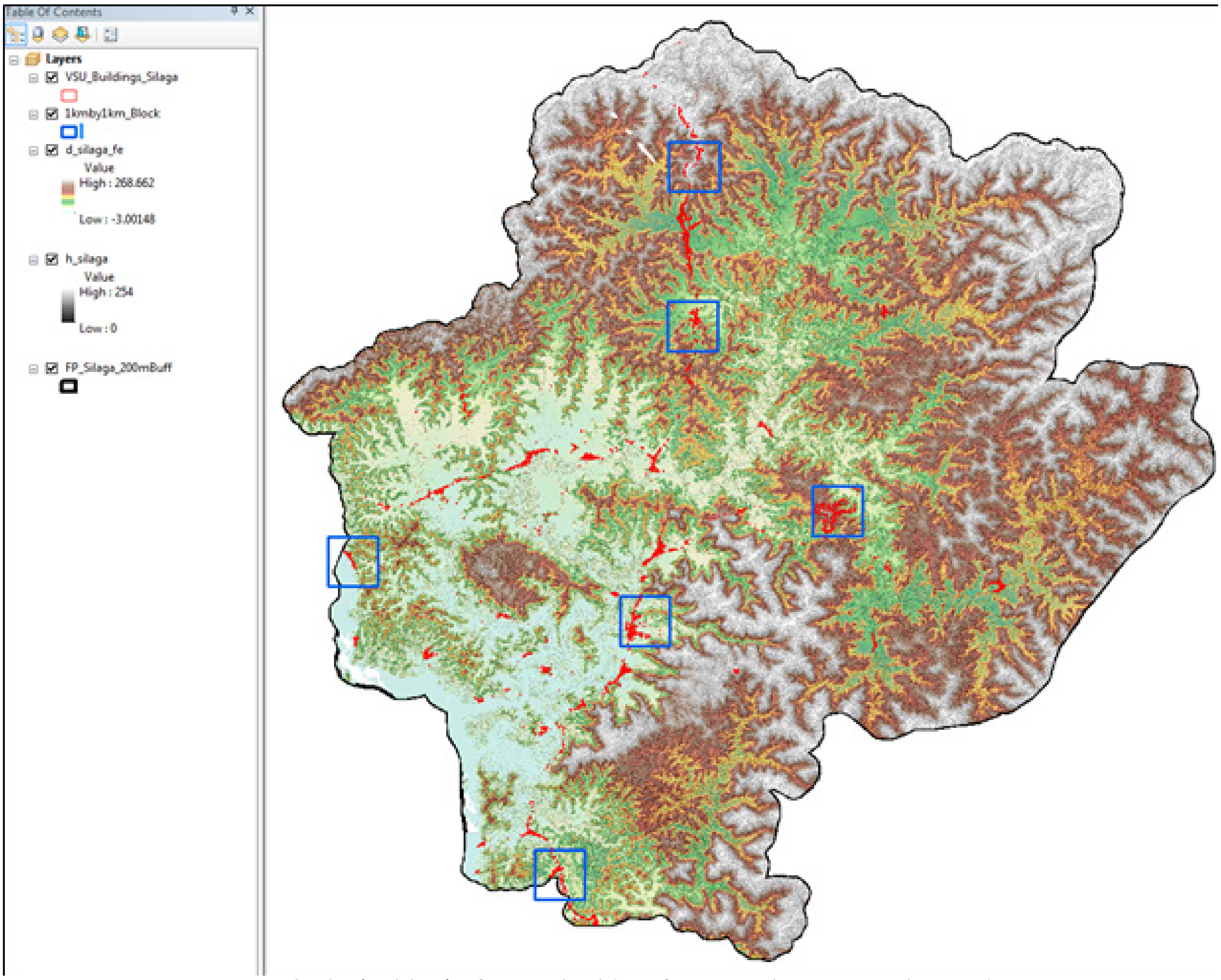

Figure 27. Blocks (in blue) of Butas building features that were subjected to QC

Quality checking of Butas building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Butas Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Butas	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Butas floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

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

Table 18. Building Features Extracted for Butas Floodplain.

Facility Type	No. of Features
Residential	5,486
School	83
Market	1
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	2
Barangay Hall	9
Military Institution	14
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	4
Power Plant/Substation	3
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	18
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	21
Other Commercial Establishments	21
Total	5,690

Table 19. Total Length of Extracted Roads for Butas Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Butas	11,139.38	1,237.66	465.98	524.05	0.00	13,367.07

Table 20. Number of Extracted Water Bodies for Butas Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Butas	1,530	13,793	0	0	0	15,323

A total of 44 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 28 shows the Digital Surface Model (DSM) of Butas floodplain overlaid with its ground features.

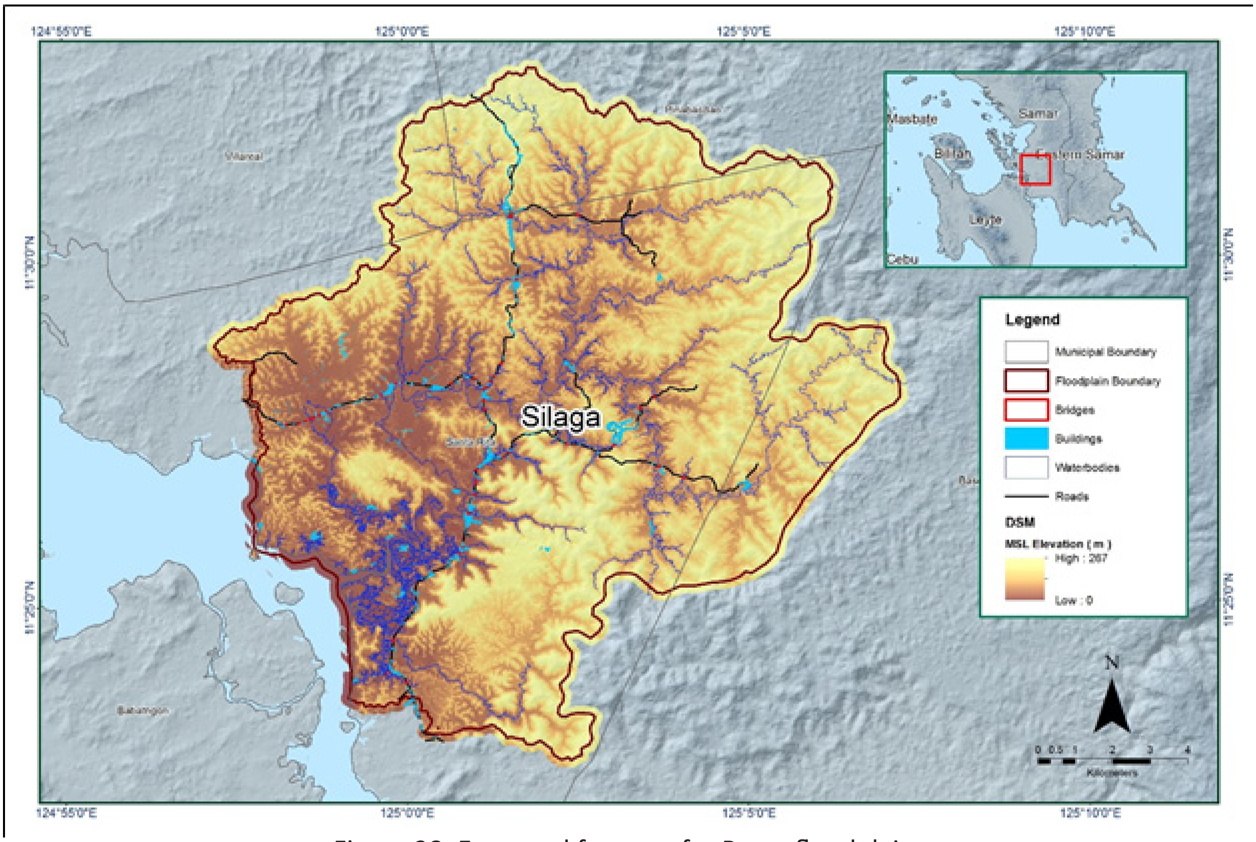

Figure 28. Extracted features for Butas floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BUTAS 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 Butas River from May 30 to June 11, 2014 with the following scope of work: control survey for the establishment of control point at the approach of Subaan Bridge occupied as a base station for GNSS surveys and bridge cross-section. A follow up survey commenced from October 27 to November 3, 2014 with the following activities: courtesy call to the LGU of Socorro and University of the Philippines Los Baños as partner SUC assigned in Butas River; bridge as-built and water level marking of Subaan Bridge with coordinates Lat 13d04'36.74728"N and Long 121d21'41.63816"E; LiDAR ground validation with an estimated length of 30 km, and; manual bathymetric survey of Butas River starting at the upstream in Brgy. Subaan down to Naujan Lake with an approximate distance of 10.18 km.

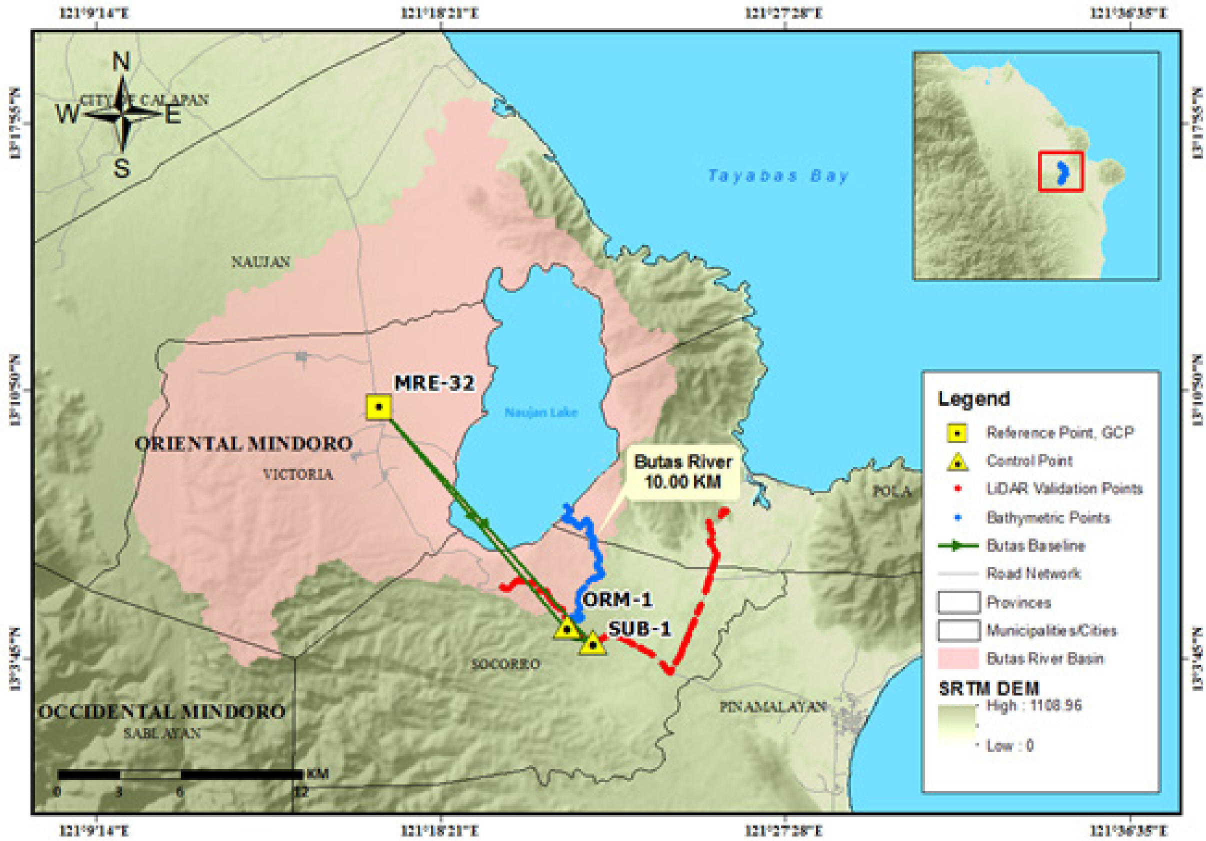


Figure 29. Extent of the bathymetric survey (in blue line) in Butas River Basin and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS network was established for previous PHIL-LiDAR fieldwork in Mindoro on February 28 – March 11, 2013 occupying MR-178, a first-order BM located at the approach of Panggalaan Bridge in Brgy. Bucayao, Calapan City, Oriental Mindoro; and MRE-32, a second order GCP in Brgy. Poblacion 1, Mun. of Victoria, Oriental Mindoro.

The GNSS network used for Butas River Basin is composed of two (2) loops and four (4) baselines established on May 30 and May 31, 2014 occupying the reference point MRE-32, a second-order GCP fixed from the previous field survey in Mindoro Oriental.

Seven (7) control points were established namely: BAR-1 located at the approach of Baroc Bridge in Brgy. San Isidro, Municipality of Mansalay; BONG-01 located near Bongabong Bridge in Brgy. San Isidro, Municipality of Luna; MOR-10, located at the approach of Cawacat Bridge in Brgy. Campaasan, Municipality of Bulalacao; ORM-1, located in Subaan Bridge in Barangay Subaan, Municipality of Socorro; ORM-3 located in Balete bridge in Brgy. Balete, Municipality of Gloria; ORM-4 in Pola Bridge, Brgy. Casiligan, Municipality of Pola; and SUB-01, located within the Maramot Residence in Brgy. Subaan, Municipality of Socorro. An LMS-established control point namely MRE-4650, located at Bansud Bridge, Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro was also occupied to use as marker in the survey.

The summary of references and control points and its location is summarized in Table 21 while the GNSS network established is illustrated in Figure 30.

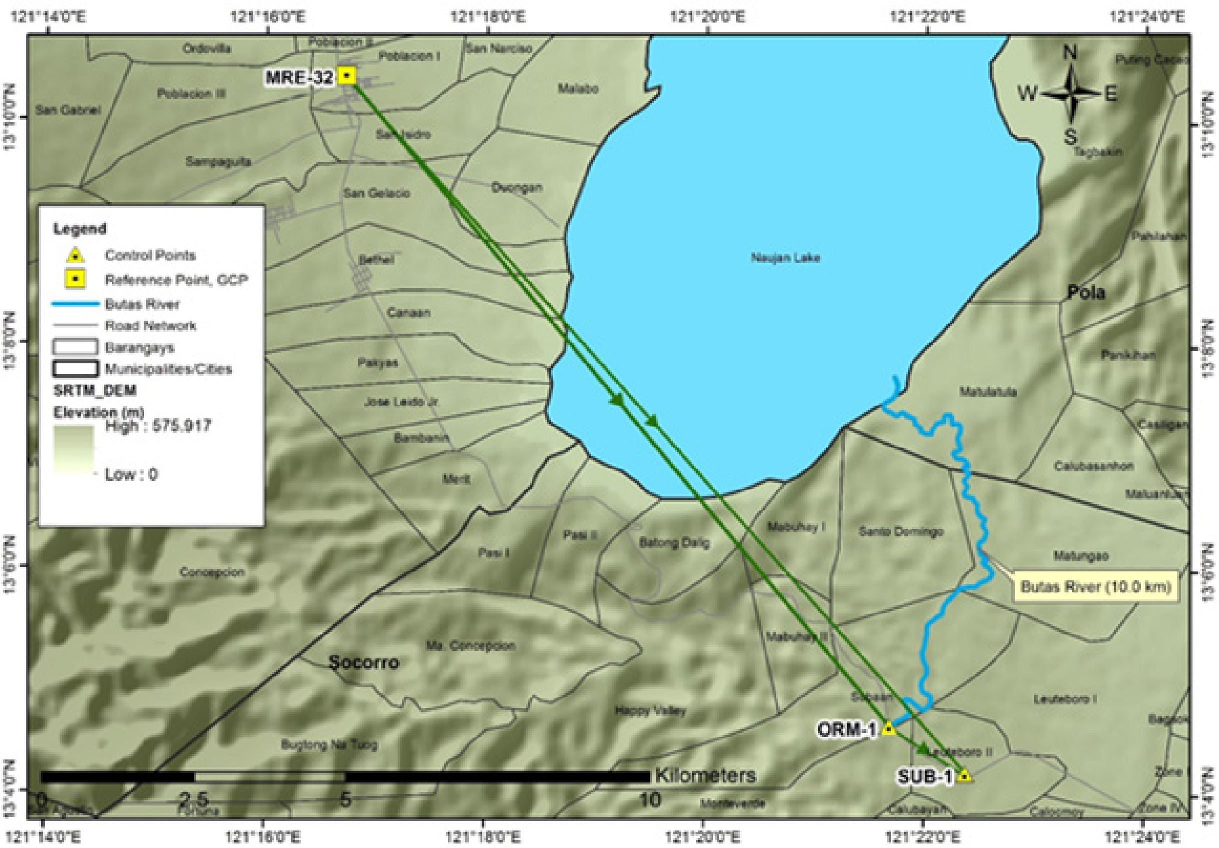


Figure 30. GNSS network of Butas River field survey

Table 21. List of Reference and Control points occupied during Butas river survey (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid height (Meter)	Elevation in MSL (m)	Date Established
MRE-32	2nd order, GCP	13°10'23.79251"	121°16'43.46244"	65.638	17.175	2007
MRE-4650	Used as marker	-		-	-	2011
BAR-1	UP Established	-	-	-	-	6-1-20014
BONG-01	UP Established	-	-	-	-	6-1-2014
MOR-10	UP Established	-	-	-	-	5-31-2014
ORM-1	UP Established	-	-	-	-	5-30-2014
ORM-3	UP Established	-	-	-	-	5-31-2014
ORM-4	UP Established	-	-	-	-	5-31-2014
SUB-01	UP Established	-	-	-	-	5-31-2014

The GNSS set ups made in the location of the reference and control points are exhibited in Figures 31 to 39.

Figure 31. GPS setup of Trimble® SPS 882 at MRE-32, located at the Municipal Park of Victoria, in Brgy. Poblacion 1, Oriental Mindoro

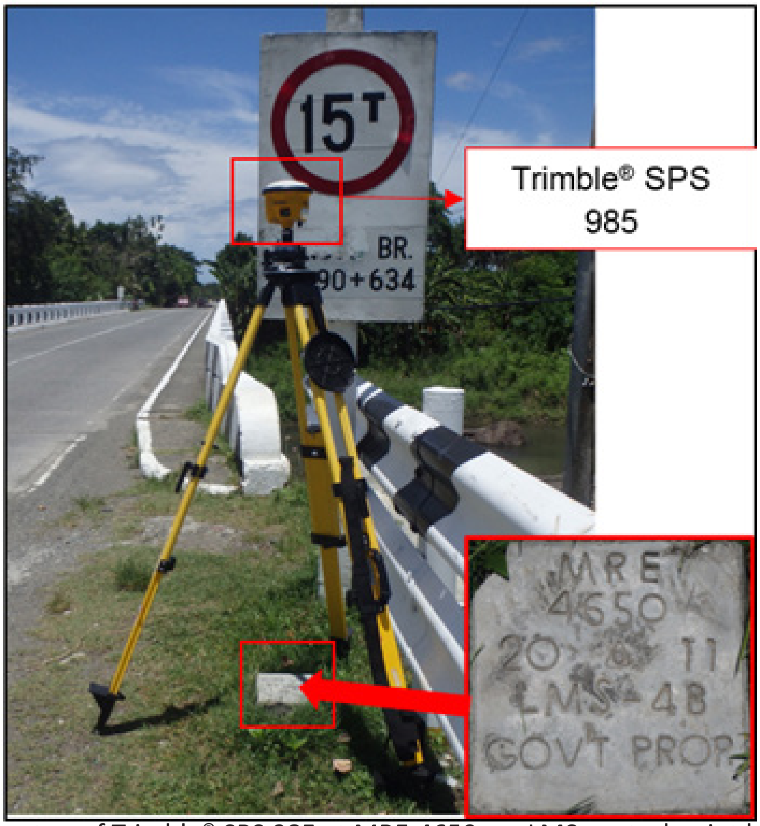


Figure 32. The GPS setup of Trimble® SPS 985 at MRE-4650, an LMS control point located at the approach of Bansud Bridge, in Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro

Figure 33. GPS setup of Trimble® SPS 882 at BAR-1, an established control point located in Baroc Bridge, Brgy. San Isidro, Mansalay, Oriental Mindoro

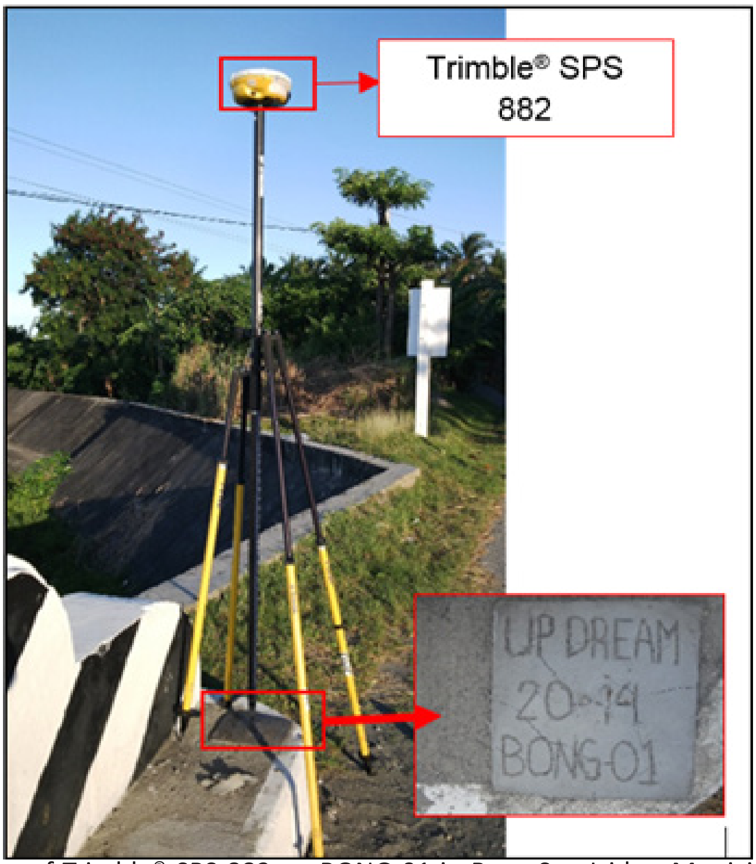


Figure 34. GNSS setup of Trimble® SPS 882 on BONG-01 in Brgy. San Isidro, Municipality of Bongabong, Oriental Mindoro

Figure 35. GPS setup of Trimble® SPS 852 at MOR-10, located in the approach of the Cawacat Bridge, in Bry. Campasaan, Municipality of Bulalacao, Oriental Mindoro

Figure 36. GPS setup of Trimble® SPS 852 at ORM-1, located on Subaan Bridge, Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

Figure 37. Trimble® SPS 985 setup at ORM-3 located at the approach of Balete Bridge, Brgy. Balete, Municipality of Gloria, Oriental Mindoro

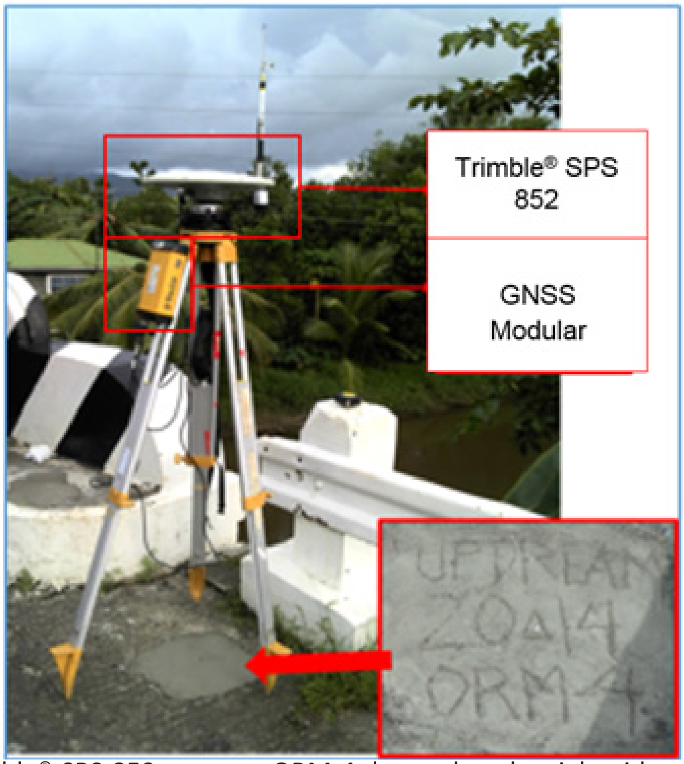


Figure 38. GNSS receiver Trimble® SPS 852 setup at ORM-4, located at the right side of the approach of Pola Bridge in Barangay Casiligan, Municipality of Pola, Oriental Mindoro

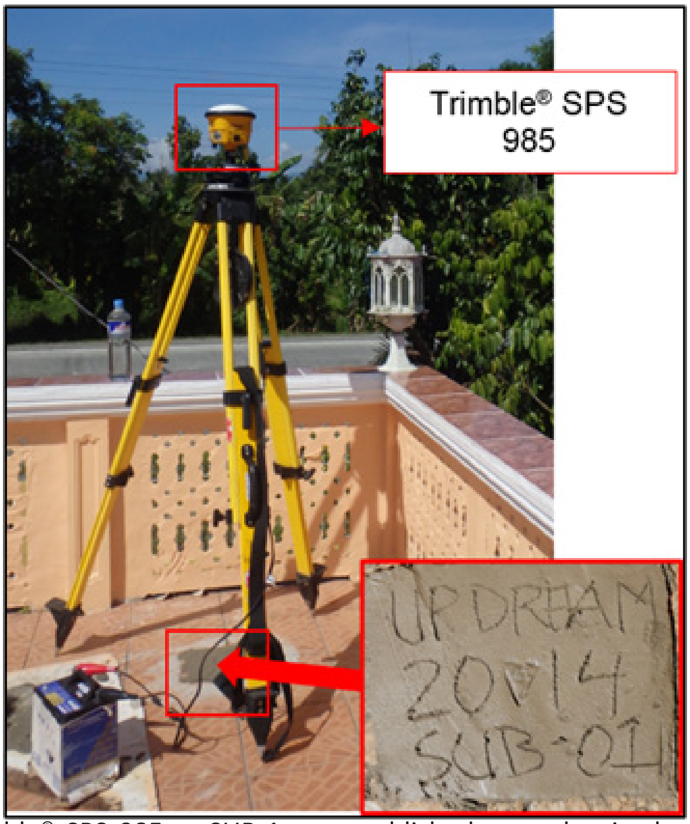


Figure 39. GPS setup of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

4.3 Baseline Processing

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

Table 22. Baseline Processing Report for Butas River Static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter
ORM-1 --- SUB-01	05-30-2014	Fixed	0.004	0.006	301°40'27"	1466.251	4.823
SUB-01 --- MRE-32	05-30-2014	Fixed	0.010	0.031	318°11'52"	15342.18	-9.283
SUB-01 --- MOR-10	05-31-2014	Fixed	0.014	0.044	182°47'52"	80162.62	-16.502
SUB-01 --- MRE-4650	05-31-2014	Fixed	0.006	0.038	158°49'08"	25506.78	-9.971
SUB-01 --- ORM-3	5-31-2014	Fixed	0.007	0.028	141°48'05"	17755.532	-12.886
SUB-01 --- ORM-4	6-1-2014	Fixed	0.003	0.022	48°43'17"	7475.934	-19.149
SUB-01 --- BAR-1	6-1-2014	Fixed	0.024	0.107	167°15'17"	57308.832	-16.370
SUB-01 --- BONG-01	6-1-2014	Fixed	0.021	0.035	164°45'51"	45313.95	0.212
ORM-1 --- MRE 32	05-30-2014	Fixed	0.010	0.032	319°54'33"	13942.72	-14.146
MOR-10 --- MRE 4650	05-31-2014	Fixed	0.012	0.051	13°07'21"	57794.34	6.484

As shown in Table 22, a total of ten (10) baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

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

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

Where:

xe is the Easting Error,
ye is the Northing Error, and
ze is the Elevation Error

The five (5) control points, MRE-32, ORM-1, MOR-10, MRE-4650 and SUB-01 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MRE-32 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MRE-32	Grid	Fixed	Fixed	Fixed	Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. All fixed control points have no values for grid and elevation errors.

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MOR-10	319188.891	0.010	1365393.240	0.010	6.868	0.052	
MRE-32	313449.201	?	1456936.499	?	17.175	?	ENe
MRE-4650	332665.789	0.008	1421592.819	0.006	14.627	0.049	
ORM-1	322358.982	0.007	1446211.774	0.003	30.565	0.028	
SUB-01	323601.847	0.007	1445433.872	0.003	25.687	0.028	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 25.Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10$ cm for the vertical; below is the computation for accuracy that passed the required precision:

a. MRE-32

Horizontal accuracy = Fixed

Vertical accuracy = Fixed

b. MOR-10

Horizontal accuracy = $\sqrt{((1.0)^2 + (1.0)^2}$

= $\sqrt{(1.0 + 1.0)}$

= 1.1 cm < 20 cm

Vertical accuracy = 1.4 cm< 10 cm

c. MRE-4650

Horizontal accuracy = $\sqrt{((0.8)^2 + (0.6)^2}$

= $\sqrt{(0.64 + 0.36)}$

= 1.0 cm < 20 cm

Vertical accuracy = 4.9 cm < 10 cm

d. ORM-1

Horizontal accuracy = $\sqrt{((0.7)^2 + (0.3)^2}$

= $\sqrt{(0.49 + 0.90)}$

= 1.2 cm < 20 cm

Vertical accuracy = 2.8 cm < 10 cm

e. SUB-01

Horizontal accuracy = $\sqrt{((0.7)^2 + (0.3)^2}$

= $\sqrt{(0.49 + 0.90)}$

= 1.2 cm < 20 cm

Vertical accuracy = 2.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required accuracy of the project.

Table 25. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
MOR-10	N12°20'46.18547"	E121°20'13.54772"	58.186	0.052	
MRE-32	N13°10'23.79251"	E121°16'43.46244"	65.368	?	ENe
MRE-4650	N12°51'17.70515"	E121°27'28.71020"	64.693	0.049	
ORM-1	N13°04'36.74731"	E121°21'41.63863"	79.500	0.028	
SUB-01	N13°04'11.69491"	E121°22'23.06063"	74.676	0.028	

Table 26. List of references and control points used in Butas River Survey

Control Point	Order	Geographic Coordinates (WGS 84)			UTM Zone N51		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Elevation in MSL
MRE-32	2nd Order, GCP	13°10'23.79251"	121°16'43.46244"	65.368	1456936.499	313449.201	17.175
MRE-4650	Used as Marker	12°51'17.70515"	121°27'28.71020"	64.693	1421592.819	332665.789	14.627
BAR-1	UP Established	12°33'52.65149"	121°29'21.90040"	58.344	1389460.775	335892.131	6.953
BONG-01	UP Established	12°40'28.89755"	121°28'57.71173"	74.917	1401640.553	335232.485	23.974
MOR-10	UP Established	12°20'46.18547"	121°20'13.54772"	58.186	1365393.24	319188.891	6.868
ORM-1	UP Established	13°04'36.74731"	121°21'41.63863"	79.5	1446211.774	322358.982	30.565
ORM-3	UP Established	12°56'37.56304"	121°28'27.33712"	61.799	1431410.893	334491.821	12.031
ORM-4	UP Established	13°06'52.16736"	121°25'29.58456"	55.523	1450329.531	329251.554	6.585
SUB-01	UP Established	13°04'11.69491"	121°22'23.06063"	74.676	1445433.872	323601.847	25.687

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

Cross-section survey was conducted on June 8, 2014 along the downstream portion of Subaan Bridge in Brgy. Subaan, Oriental Mindoro using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 40. Bridge as-built features determination was performed on October 28 and 30, 2014 using the same technique to get the distance of piers and abutments from the bridge approach.

Figure 40. Cross-section and bridge as-built survey for Subaan Bridge, Brgy Subaan, Oriental Mindoro

The cross-sectional line for the Butas Bridge is about 84.72 m with 24 cross-sectional points gathered using ORM-1 as GNSS base station. The location map, bridge cross-section diagram, and as-built data for Butas (Subaan) Bridge are displayed in Figure 41 to Figure 43, respectively.

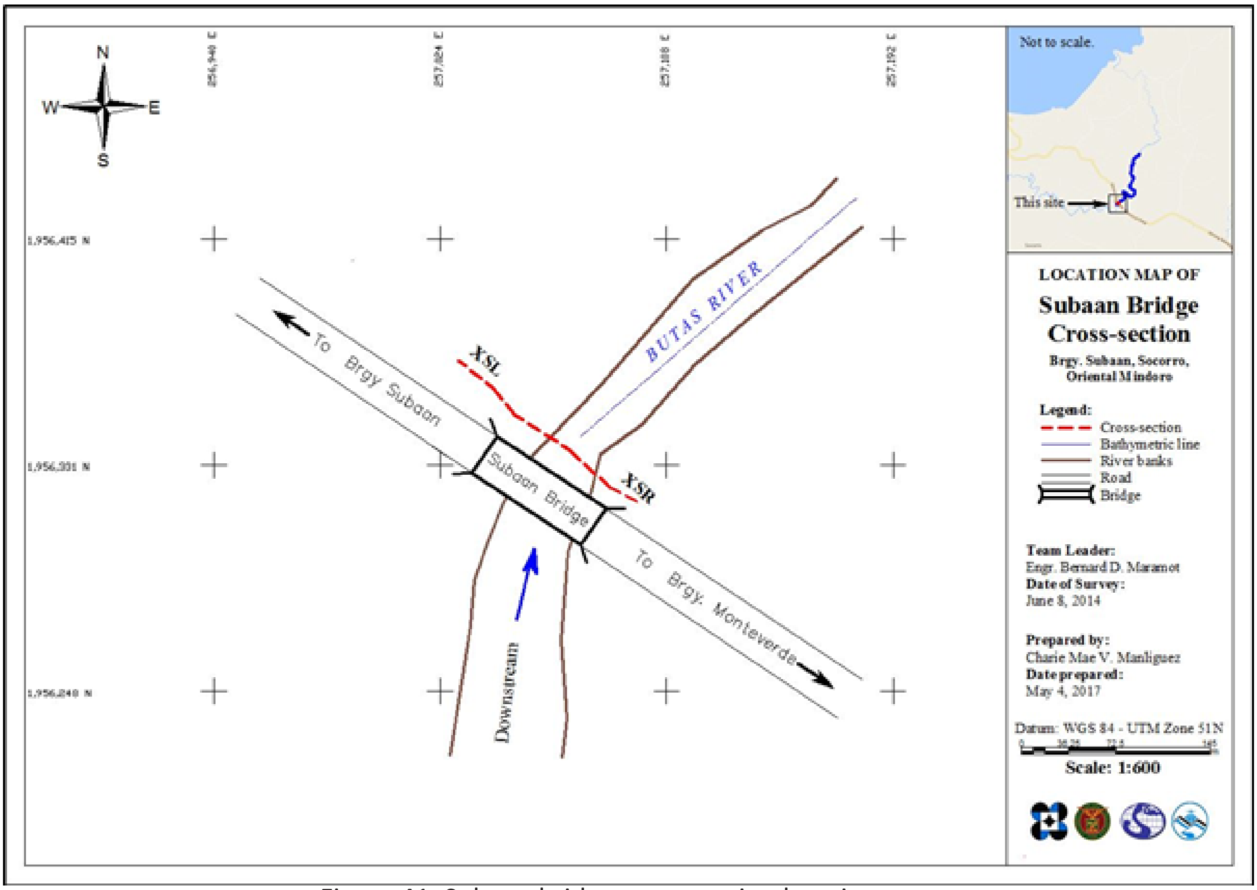


Figure 41. Subaan bridge cross-section location map

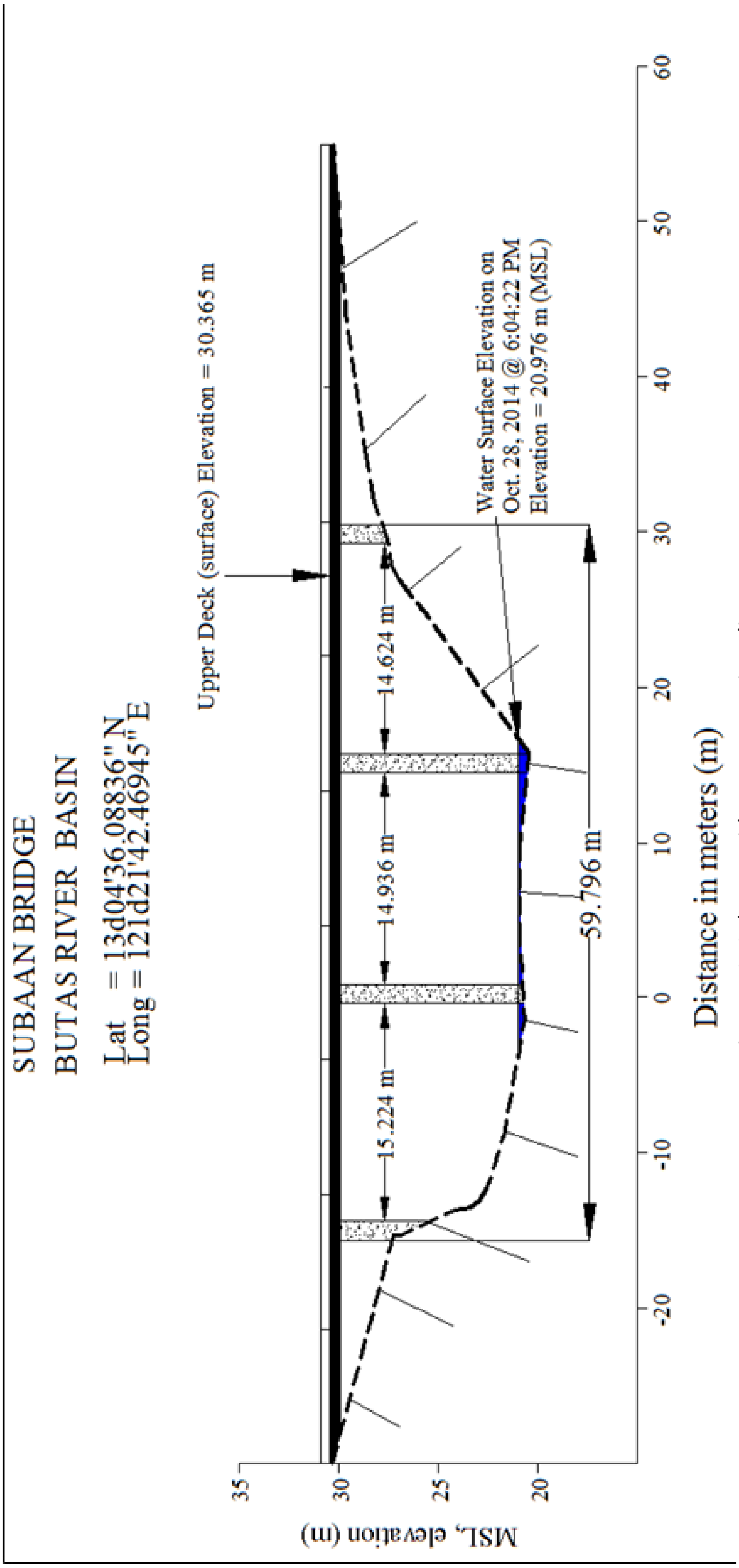


Figure 42. Subaan Bridge cross-section diagram

Bridge Data Form

Bridge Name: SUBAAN BRIDGE **Date:** October 30, 2014

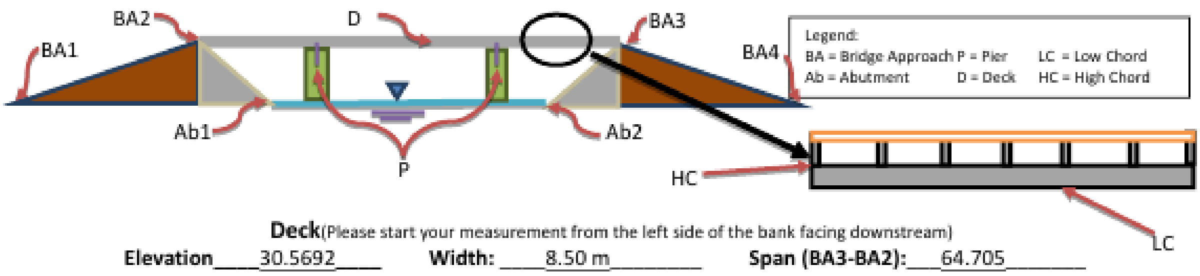
River Name: BUTAS RIVER **Time:** 9:45 am

Location (Brgy, City,Region): Brgy. Subaan, Socorro, Oriental Mindoro,

Survey Team: Team Bernard

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

Latitude: 13d04'36.74728" N **Longitude:** 121d21'41.63816" E



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

Elevation 30.5692 **Width:** 8.50 m **Span (BA3-BA2):** 64.705

	Station	High Chord Elevation	Low Chord Elevation
1		30.511 m	29.191 m
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	29.779 m	**BA3**	115.880	30.606 m
BA2	51.549	30.562 m	**BA4**	212.709	28.999 m

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

	Station(Distance from BA1)	Elevation
Ab1	57.416	28.600 m
Ab2	105.465	24.754 m

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

Shape: CYLINDRICAL **Number of Piers:** 5 **Height of column footing:**

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	53.75738	30.485 m	
Pier 2	68.84019	30.579 m	
Pier 3	83.60432	30.496 m	
Pier 4	98.51772	30.477 m	
Pier 5	113.5543	30.400 m	
Pier 6			
Pier 7			

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

Figure 43. Subaan Bridge Data Form

Figure 44. Water level marking on one of Subaan Bridge's pier

Water surface elevation in MSL of Butas River was determined using Trimble® SPS 882 in PPK mode survey on October 28, 2014 at 6:04 PM. This was translated onto marking the bridge's pier using a Digital Level. The marked pier, as shown in Figure 44 shall serve as reference for flow data gathering and depth gauge deployment by the accompanying SUC, UPLB, who is responsible for Butas River.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 29, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached in front of the vehicle, as shown in Figure 45. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 1.498 m from the ground up to the bottom of the notch of the GNSS Rover receiver.

The survey was conducted using PPK technique on a continuous topography mode which started from Brgy. Happy Valley, Municipality of Socorro to Brgy. Panikihan, Municipality of Pola. The survey gathered 1,900 validation points covering an approximate distance of 30 km. The gaps in the validation line, as shown in Figure 46 were due to some difficulties in acquiring satellite signals due to the presence of obstructions such as dense canopy cover of trees along the roads.

Figure 45. Trimble® SPS 882 setup for validation points acquisition survey for Butas River Basin

Figure 46. Validation points acquisition survey along Butas River Basin

4.7 River Bathymetric Survey

Manual bathymetric survey was conducted on October 28, 2014 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 47. The survey started in the upstream part of the river in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro with coordinates 13°04'36.74728" 121°21'41.63816", traversed down the river by foot and ended at the Naujan Lake with coordinates 13°07'46.30880" 121°21'41.42578". The control point ORM-1 was used as the GNSS base station all throughout the survey.

Figure 47. Bathymetric survey in Butas River: (a) upstream and (b) downstream

The bathymetric line surveyed has an approximate length of 10.18 km with a total of 793 points traversing barangays Matulatula, Sto. Domingo, Matungao and Subaan. A map showing the coverage of the bathymetric survey is shown in Figure 48.

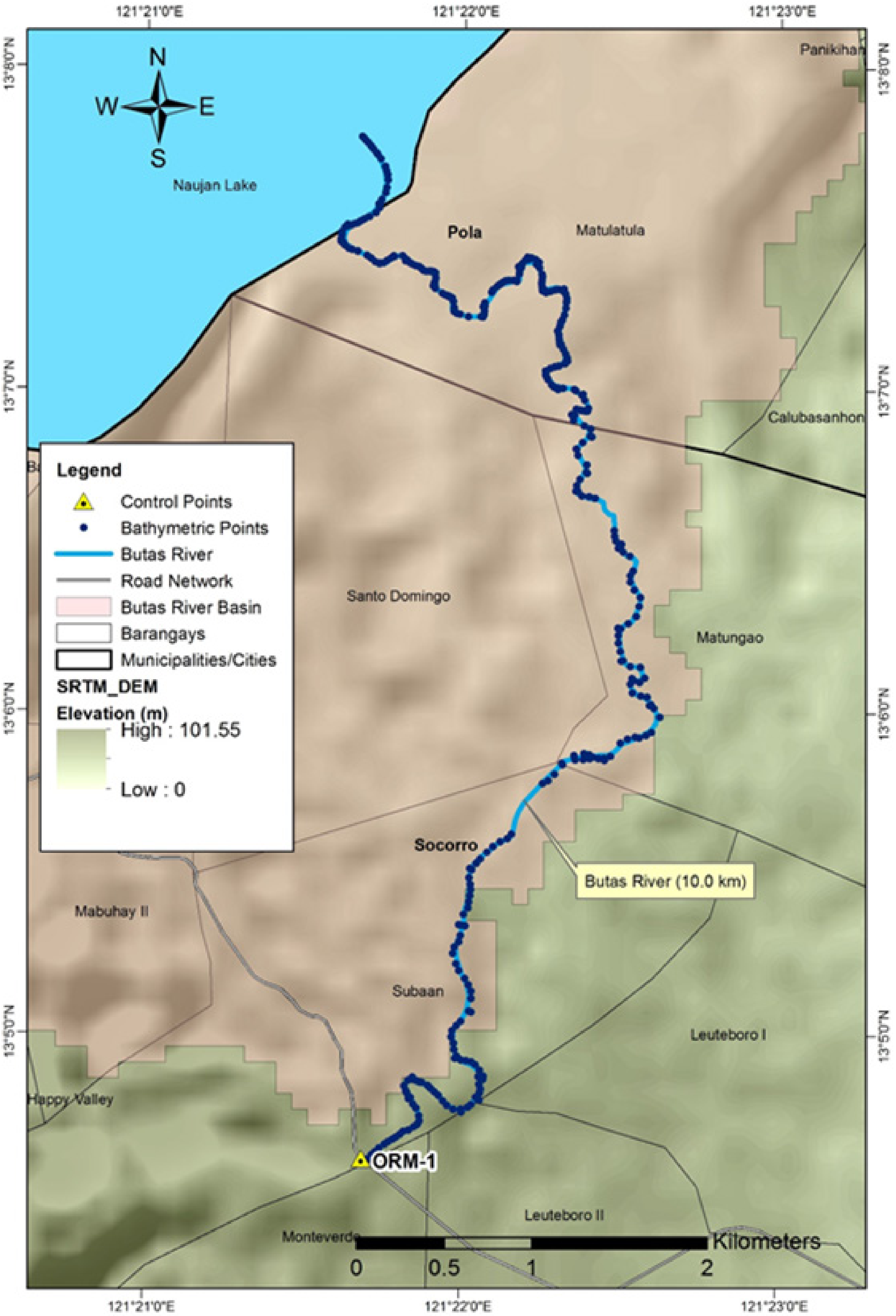


Figure 48. Bathymetric points gathered along Butas River

A CAD drawing was also produced to illustrate the riverbed profile of Butas River. As shown in Figure 49, an elevation drop of 20.0 m was observed from upstream to the downstream. The highest elevation observed was 20.98 m in MSL located in Brgy. Subaan, Socorro, while the lowest elevation observed was 0.513 m below MSL located in Brgy. Matulatula, Municipality of Pola, Oriental Mindoro.

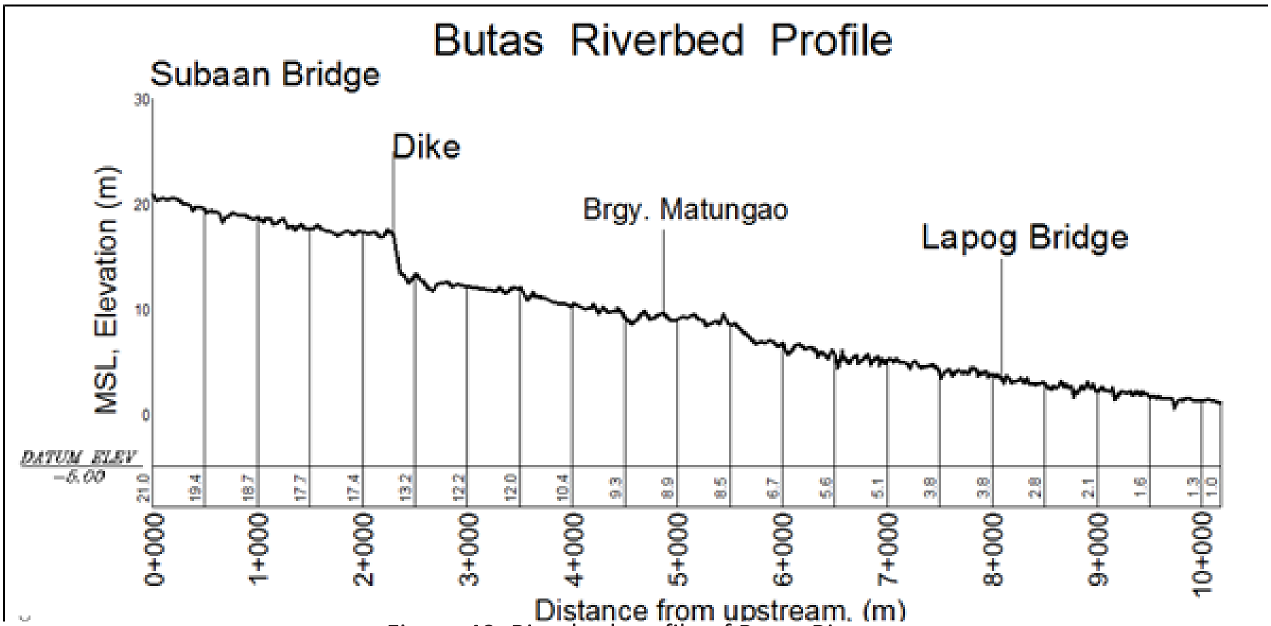


Figure 49. Riverbed profile of Butas River

CHAPTER 5: FLOOD MODELING AND MAPPING

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Angelo Carlo B. Bongat , Engr. Ma. Ailyn L. Olanda, Engr. Erica Erin E. Elazegui, Marie Denise V. Bueno , Engr. Regis R. Guhiting, Engr. Merven Matthew D. Natino, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Kevin M. Manalo

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All data that affect the hydrologic cycle of the 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 Butas River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge (13.072944° N, 121.357189° E) deployed within the riverbasin. The location of the rain gauge is seen in Figure 1.

The total precipitation for this event is 33.40 mm. The peak rainfall is 6.0 mm on March 27, 2017 at 7:10 pm. The lag time between the peak rainfall and discharge is 6 hours and 30 minutes, as seen in Figure 50.

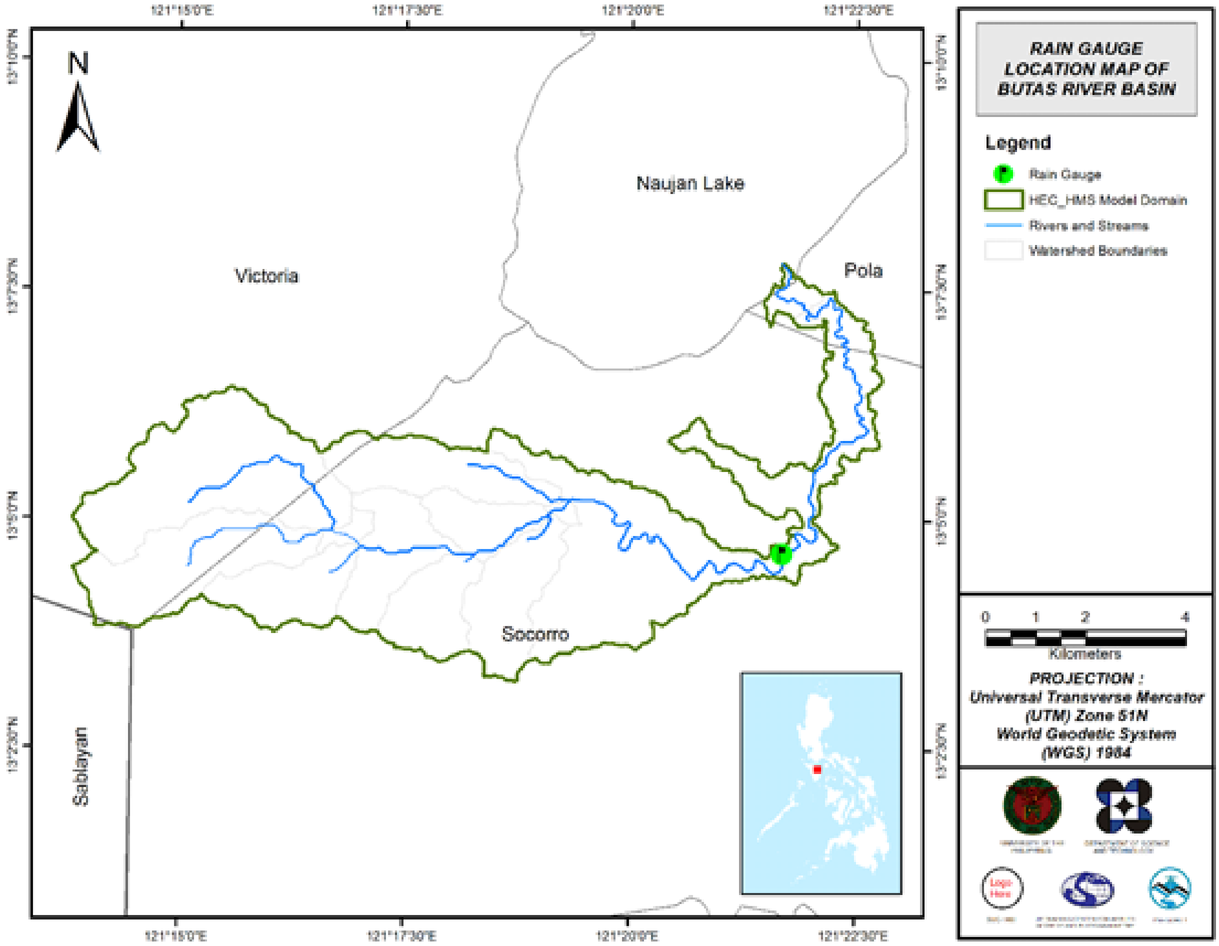


Figure 50. The location map of Butas HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Subaan Bridge, Socorro, Oriental Mindoro (13.076874°N, 121.361566° E). It gives the relationship between the observed water levels from the Subaan Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Subaan Bridge, the rating curve is expressed as Q = 87.852x2 -6327.90x +37455 as shown in Figure 52.

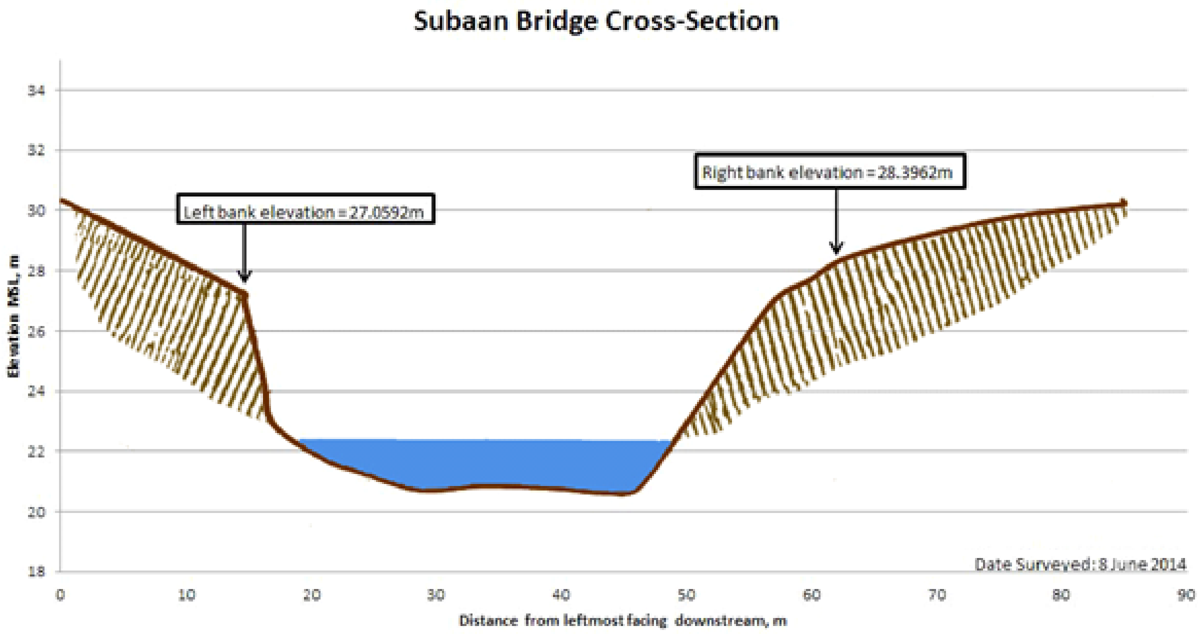


Figure 51. Cross-Section Plot of Subaan Bridge

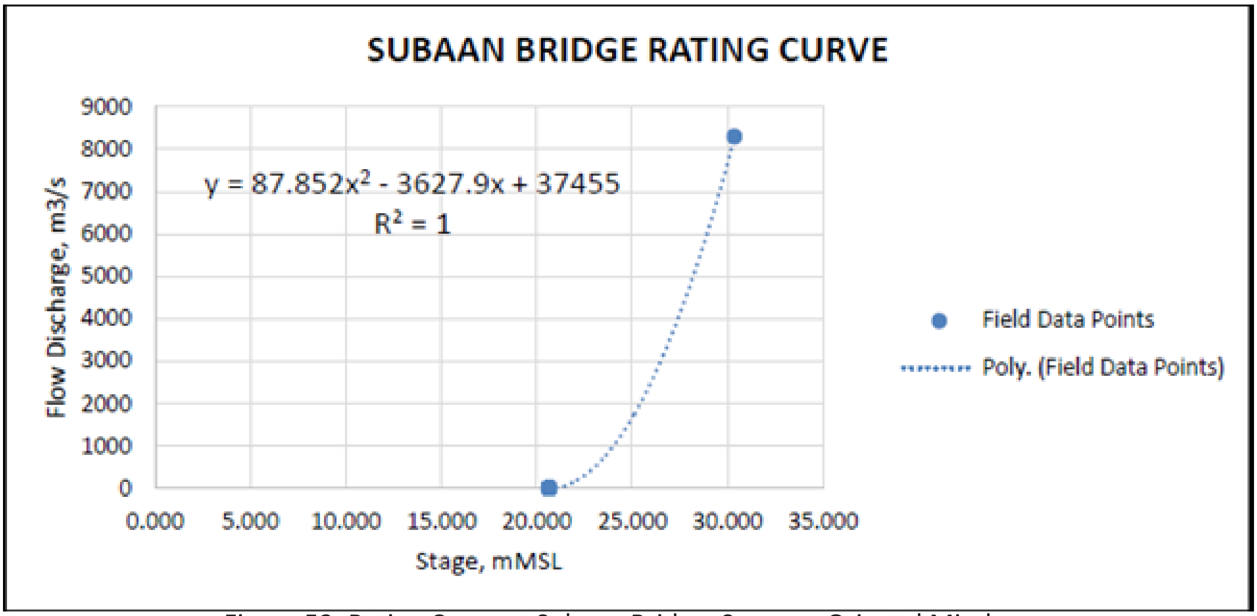


Figure 52. Rating Curve at Subaan Bridge, Socorro, Oriental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 53, actual flow discharge during a rainfall event was collected in the Subaan Bridge. Peak discharge is 20.20 cu.m/s on March 28, 2017 at 1:30 am.

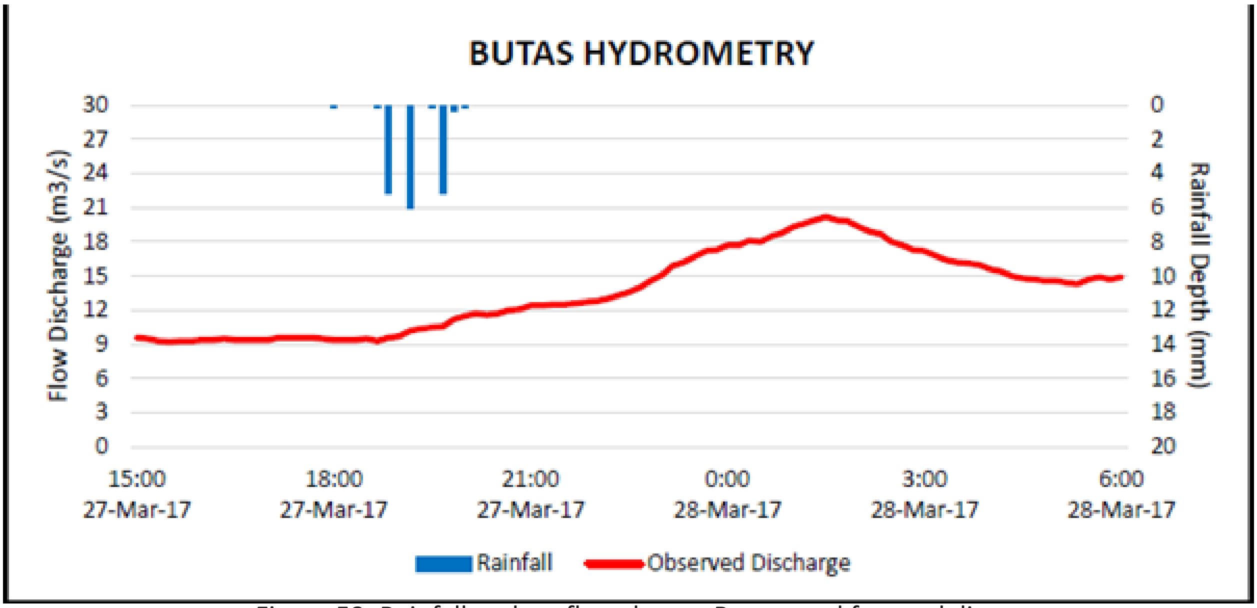


Figure 53. Rainfall and outflow data at Butas used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Tayabas Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Butas watershed. The extreme values for this watershed were computed based on a 41-year record.

Table 27. RIDF values for Tayabas 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	21	32.7	42	59.3	83	99.9	128.2	161.5	195.9
5	29.6	42.1	52.5	77.3	116.1	143	192.6	232.3	279.5
10	35.4	48.3	59.4	89.2	138	171.5	235.2	279.3	334.9
15	38.6	51.8	63.3	96	150.3	187.6	259.3	305.7	366.1
20	40.9	54.3	66.1	100.7	159	198.9	276.1	324.3	388
25	42.6	56.2	68.2	104.3	165.7	207.5	289.1	338.5	404.8
50	48	62	74.7	115.5	186.2	234.3	329.1	382.5	456.7
100	53.4	67.8	81.1	126.6	206.6	260.8	368.8	426.2	508.3

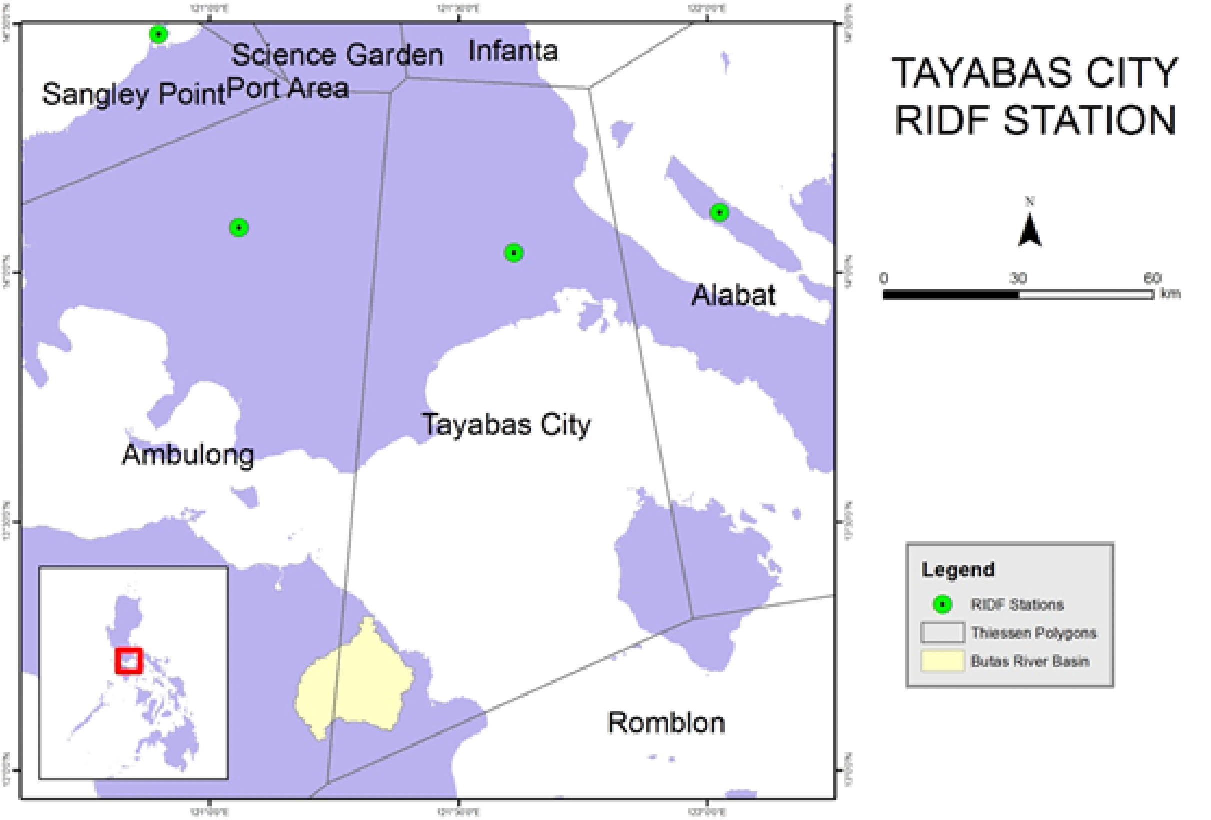


Figure 54. Location of Tayabas RIDF relative to Butas River Basin

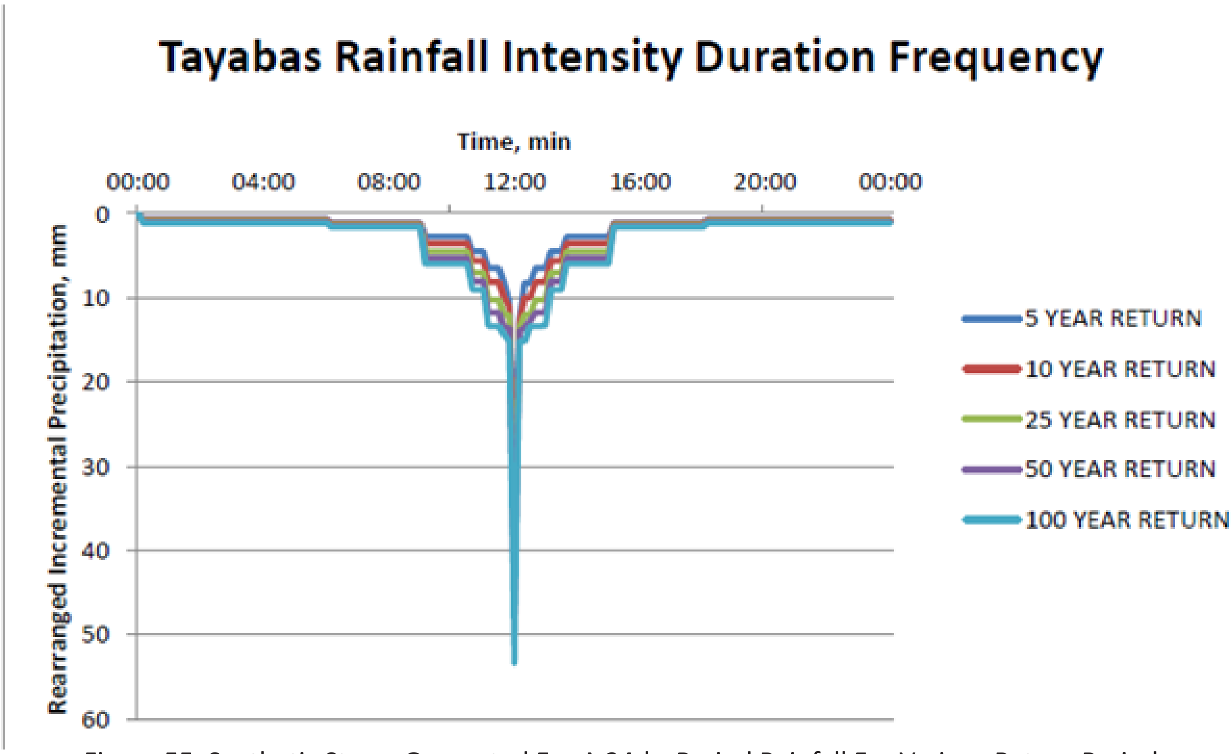


Figure 55. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil shape file (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Butas River Basin are shown in Figure 56, and Figure 57, respectively.

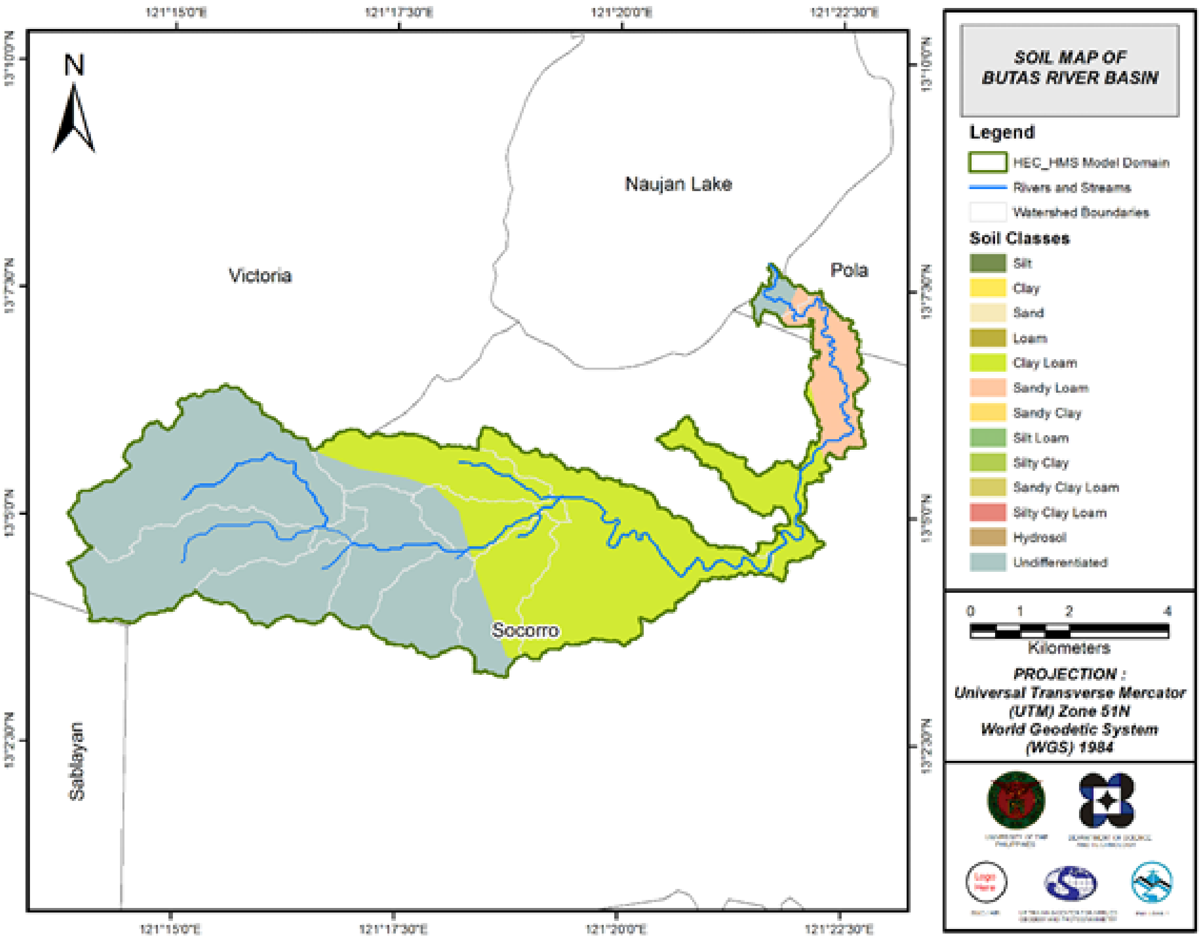


Figure 56. The soil map of the Butas River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

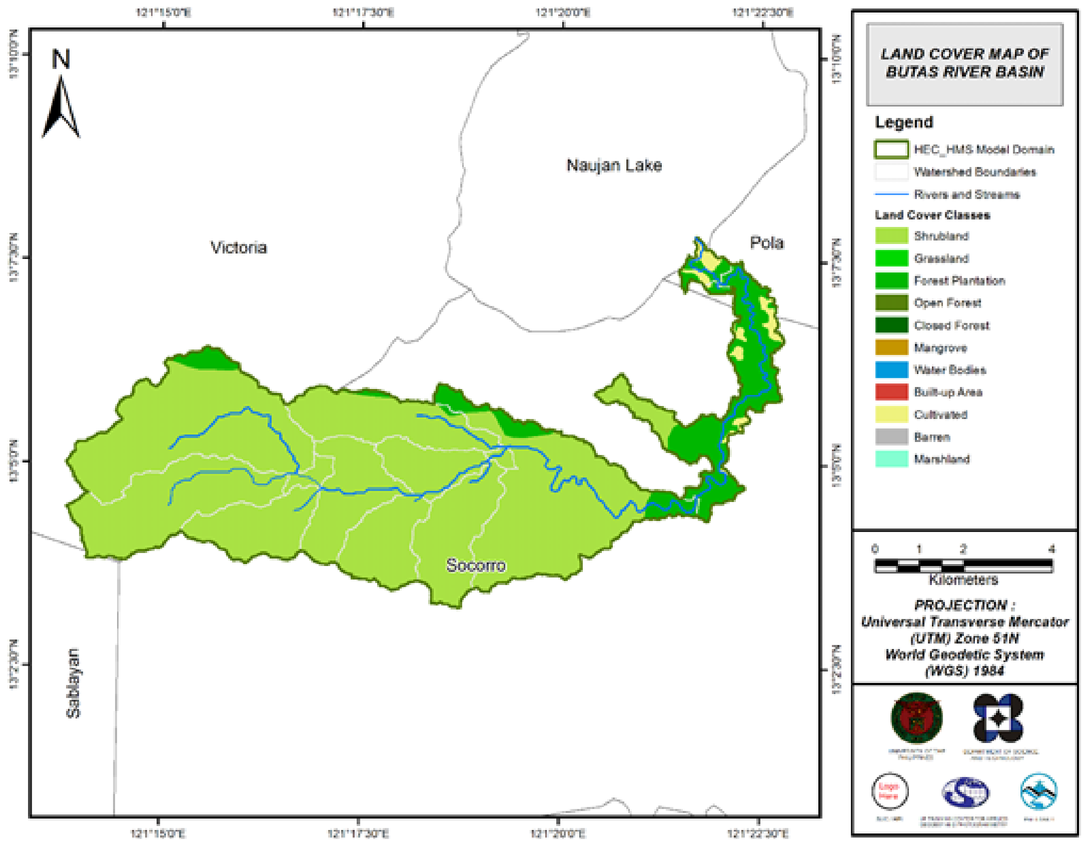


Figure 57. The land cover map of the Butas River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

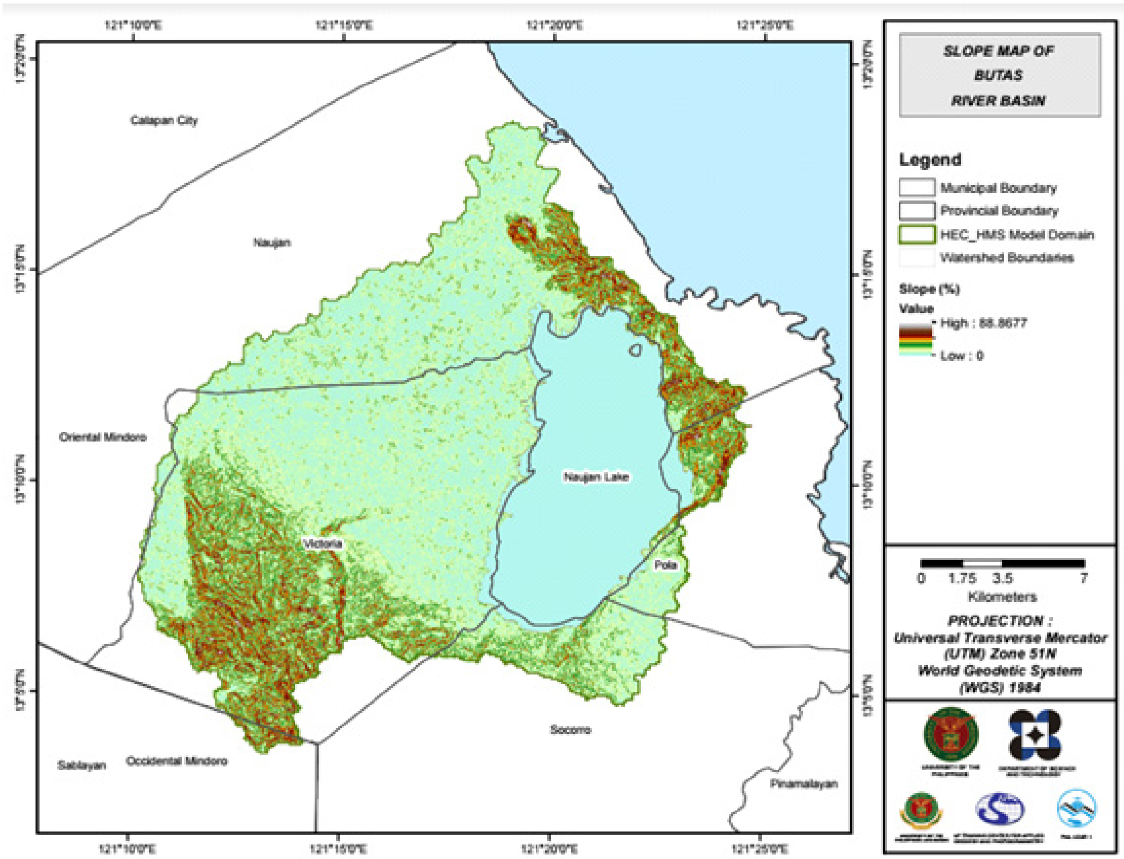


Figure 58. Slope Map of the Butas River Basin

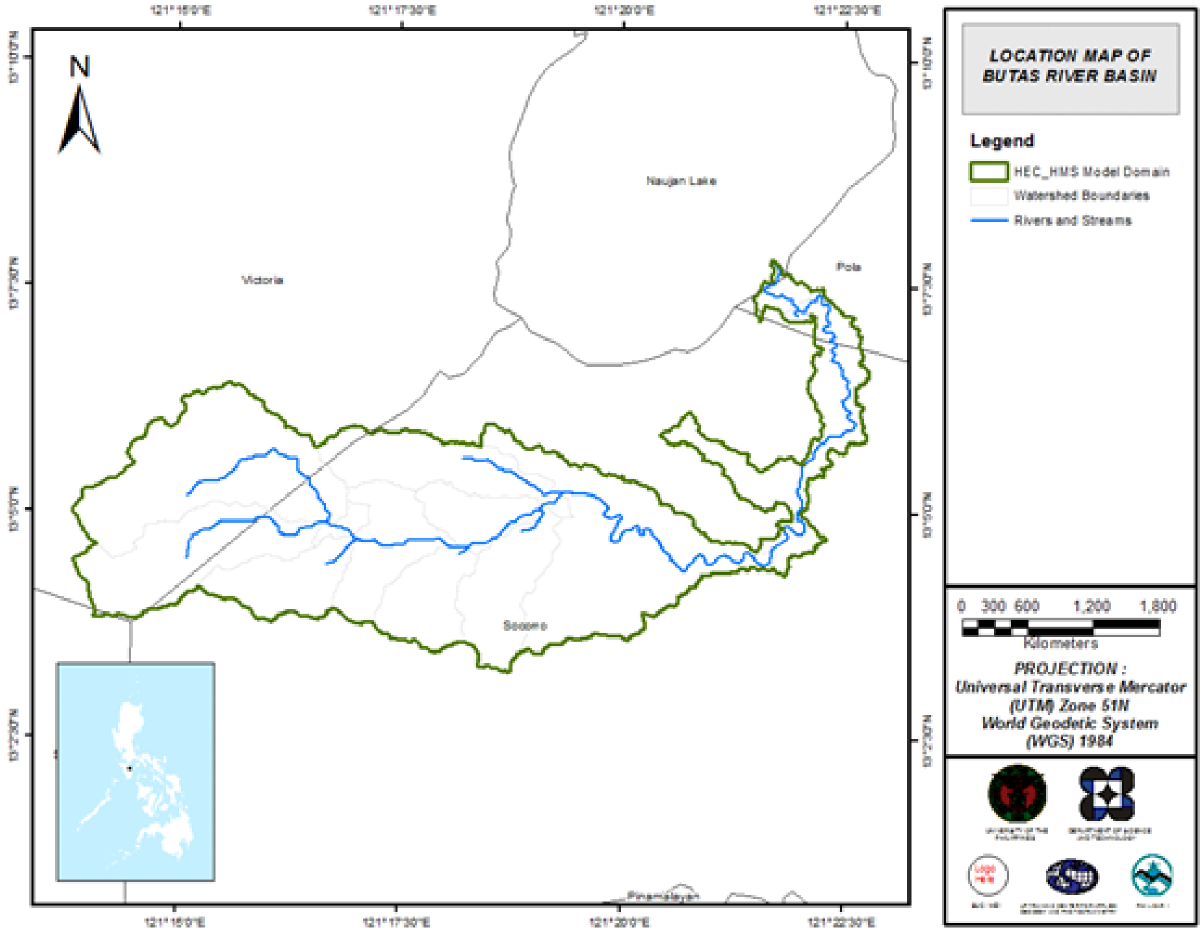


Figure 59. Stream Delineation Map of the Butas River Basin

Using SAR-based DEM, the Butas basin was delineated and further subdivided into subbasins. The model consists of 14 sub basins, 14 reaches, and 7 junctions. The main outlet is is Subaan Bridge, labelled as 47.

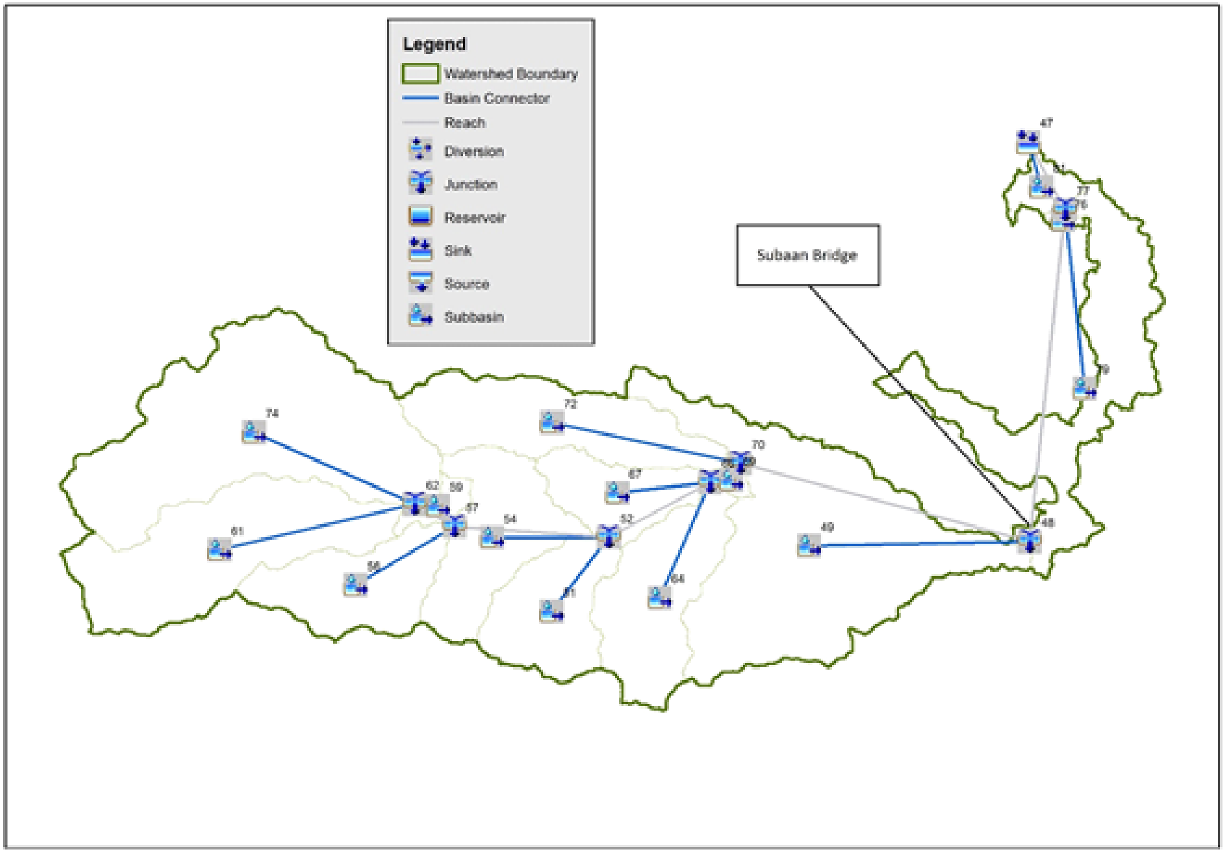


Figure 60. The Butas river basin model generated using HEC-HMS

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 from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

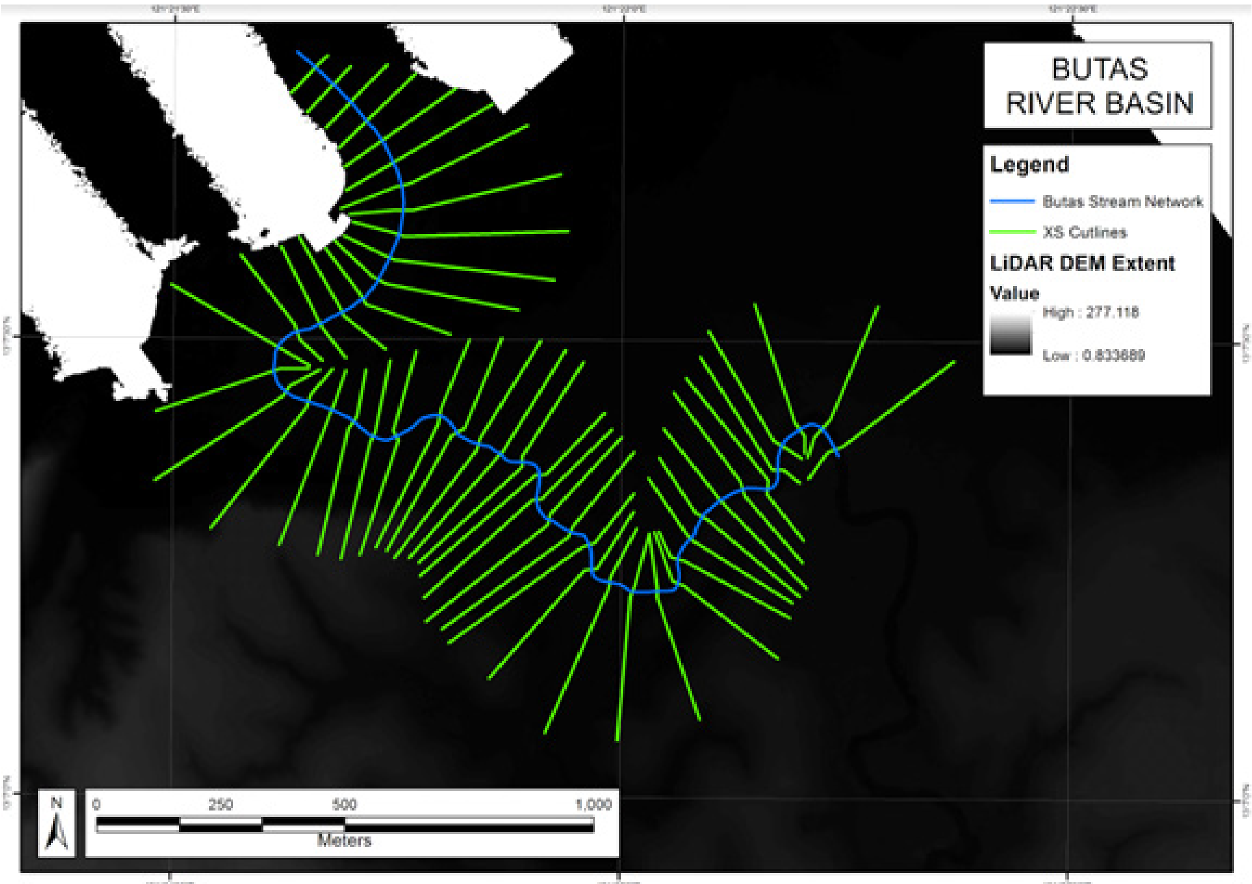


Figure 61. River cross-section of Butas River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

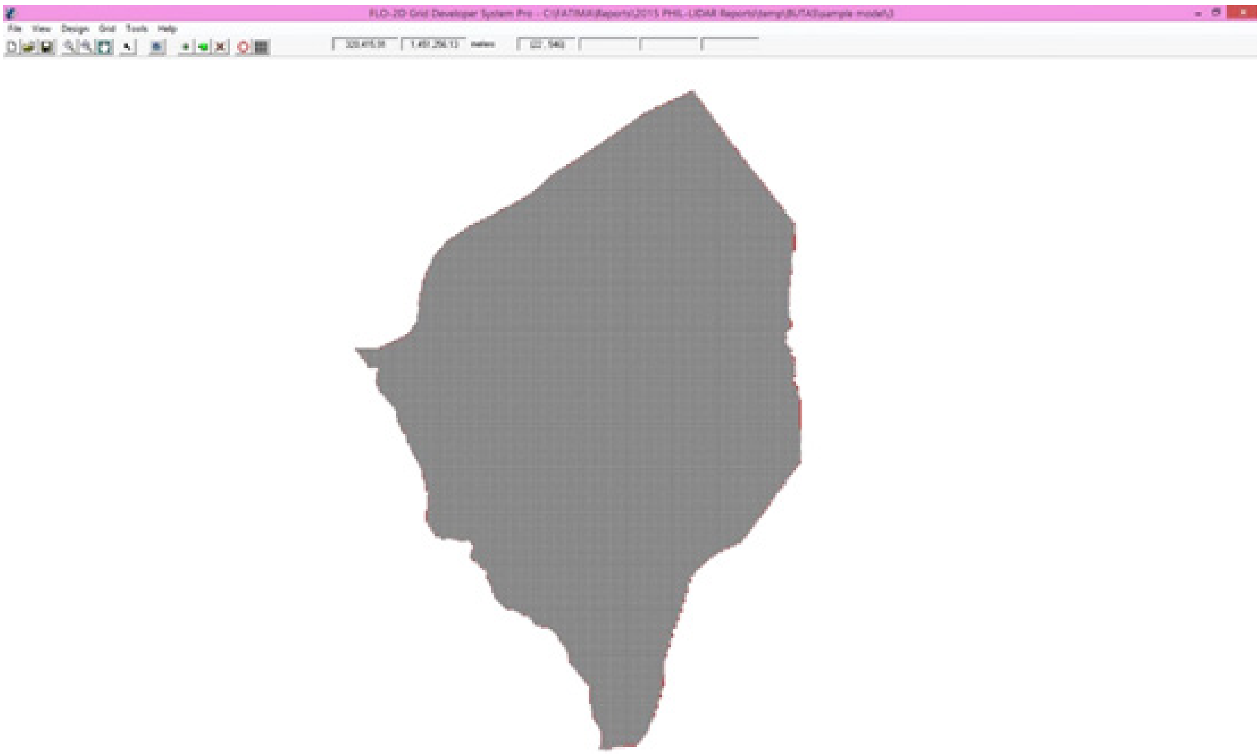


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

5.6 Results of HMS Calibration

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

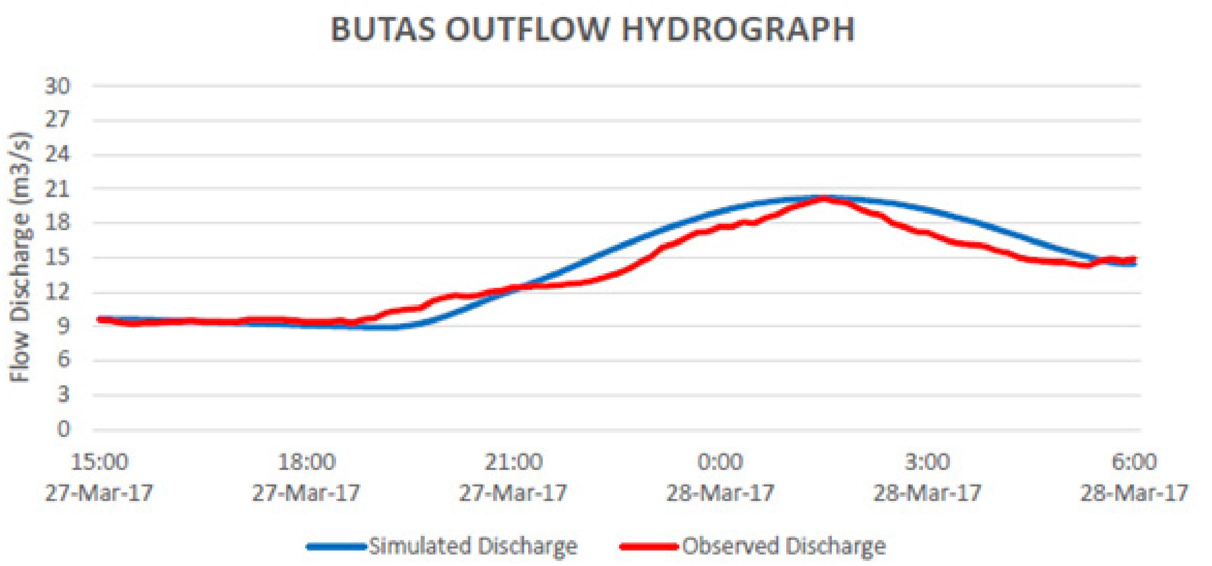


Figure 63. Outflow Hydrograph of Butas produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of Calibrated Values for Butas

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.2 - 10
			Curve Number	56 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 20
			Storage Coefficient (hr)	0.3 - 6
	Baseflow	Recession	Recession Constant	0.5 – 0.6
			Ratio to Peak	0.1 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.007 – 0.04

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.2mm to 10mm means that the basin has a minimal amount of infiltration or rainfall interception by vegetation.
Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 56 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area. For Butas, the soil cover mostly consists of clay loam, and sandy loam while land cover consists of grassland, and forest plantation.
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 0.3 to 20 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.
Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.5 to 0.6 indicates that the

hydrograph will most likely go back to its original baseflow while ratio to peak from 0.1 to 0.5 indicates a steeper to normal receding limb of the outflow hydrograph.
Manning's roughness coefficient from 0.007 is low compared to the the common roughness of Philippine watersheds, which is 0.04. This means that the riverbed is relatively smooth and water will most likely flow faster.

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

Root Mean Square Error (RMSE)	1.237
Pearson Correlation Coefficient (r2)	0.978
Nash-Sutcliffe (E)	0.876
Percent Bias (PBIAS)	-4.215
Observation Standard Deviation Ratio (RSR)	0.353

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 1.237.
The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.978.
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 0.876.
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 -4.215
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 0.353.

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 Butas outflow using the Tayabas Rainfail 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 (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

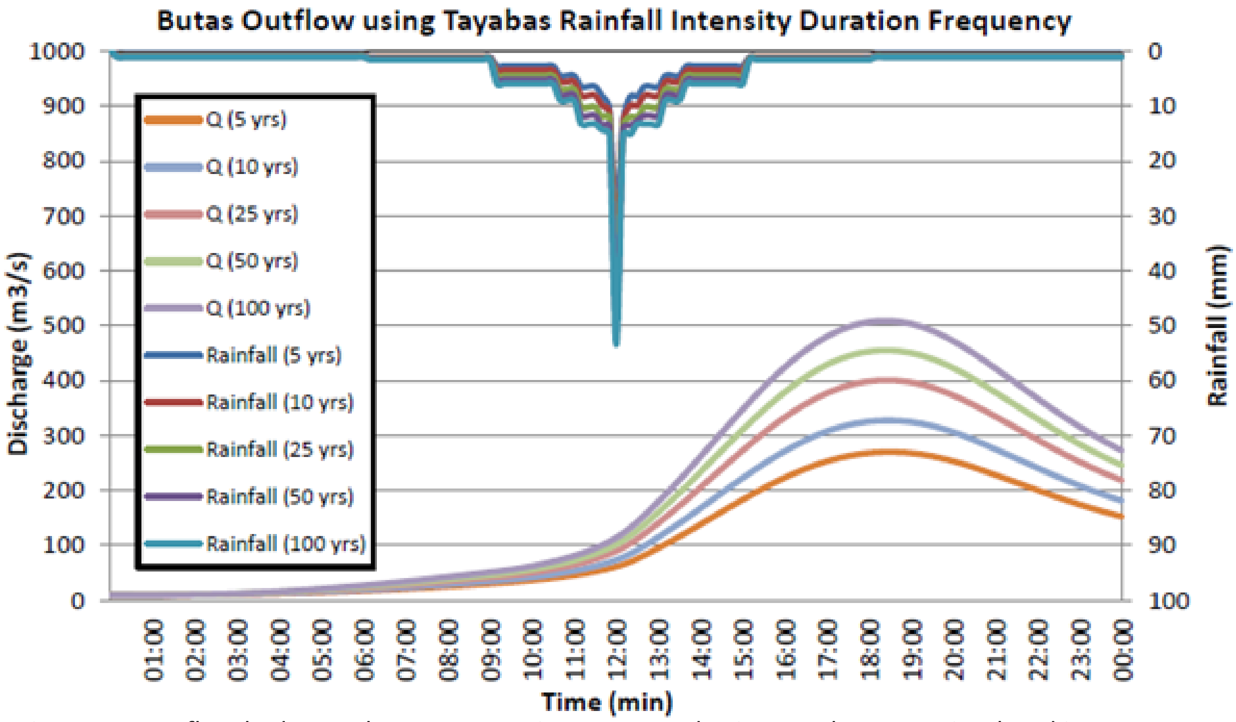


Figure 64. Outflow hydrograph at Butas Station generated using Tayabas RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Butas HECHMS Model outflow using the Tayabas RIDF

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak
5-yr	279.50	29.60	270.0	6 hours 30 minutes
10-yr	334.90	35.40	327.50	6 hours 30 minutes
25-yr	404.80	42.60	400.60	6 hours 20 minutes
50-yr	456.70	48.0	455.0	6 hours 20 minutes
100-yr	508.30	53.40	508.80	6 hours 20 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. The sample map of Butas River using the HMS base flow is shown on Figure 65 below.

Figure 65. Butas HEC-RAS Output

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Butas floodplain are shown in Figure 66 to 71. The floodplain, with an area of 46.47 sq. km., covers four municipalities namely Naujan Lake, Pola, Socorro, and Victoria. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Butas floodplain

Municipality	Total Area	Area Flooded	% Flooded
Naujan Lake	76.1061	0.08393	0.11028
Pola	127.036	3.579796	2.817938
Socorro	206.055	42.35064	20.55308
Victoria	216.221	0.454948	0.210409

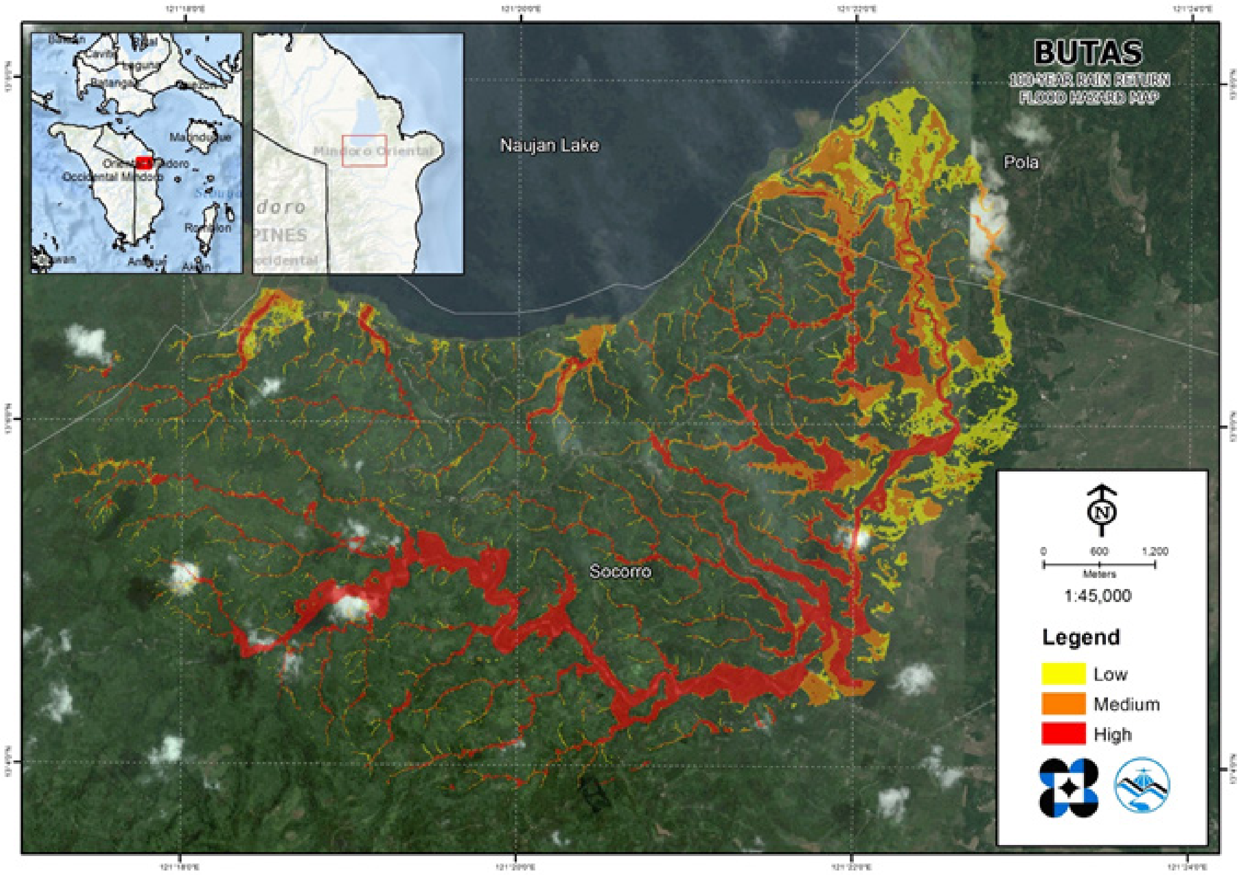


Figure 66. 100-year Flood Hazard Map for Butas Floodplain

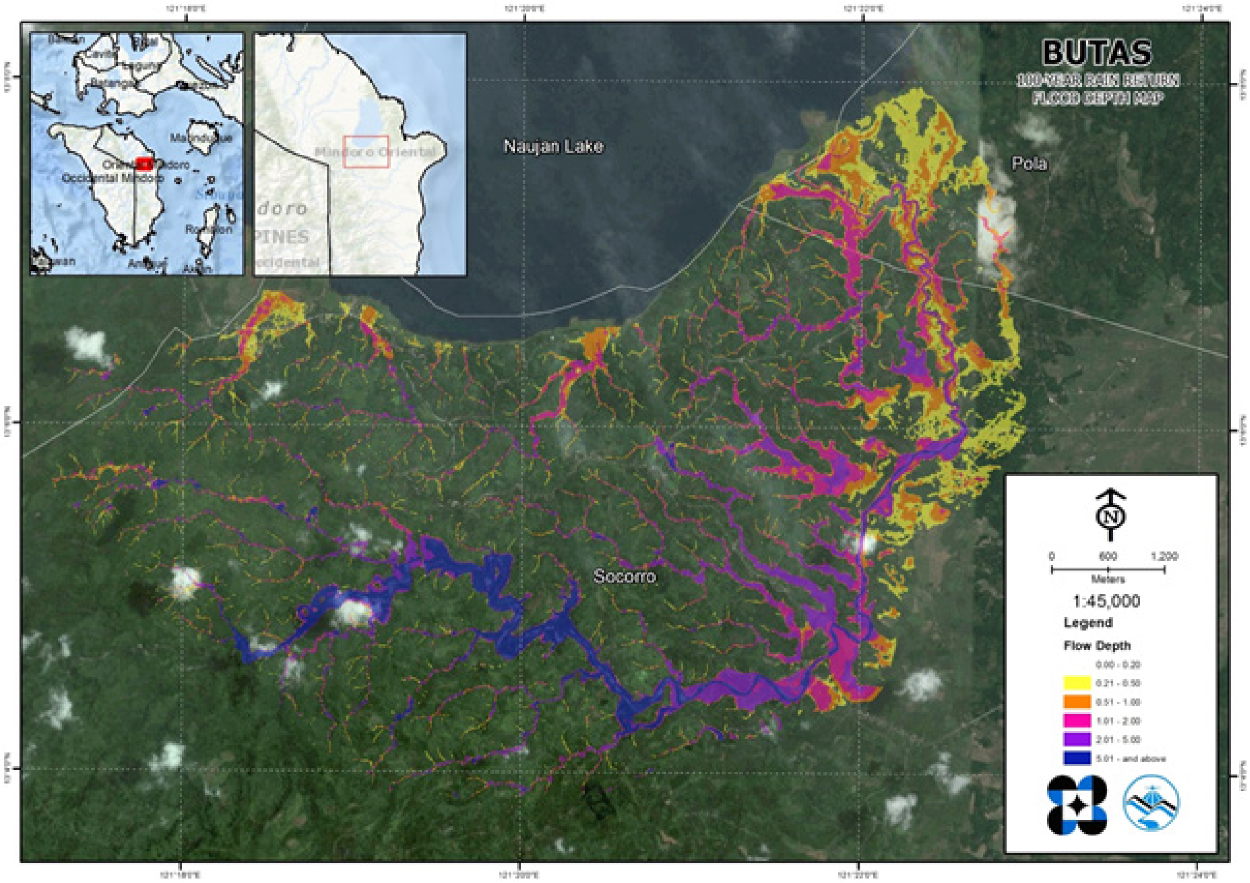


Figure 67. 100-year Flow Depth Map for Butas Floodplain

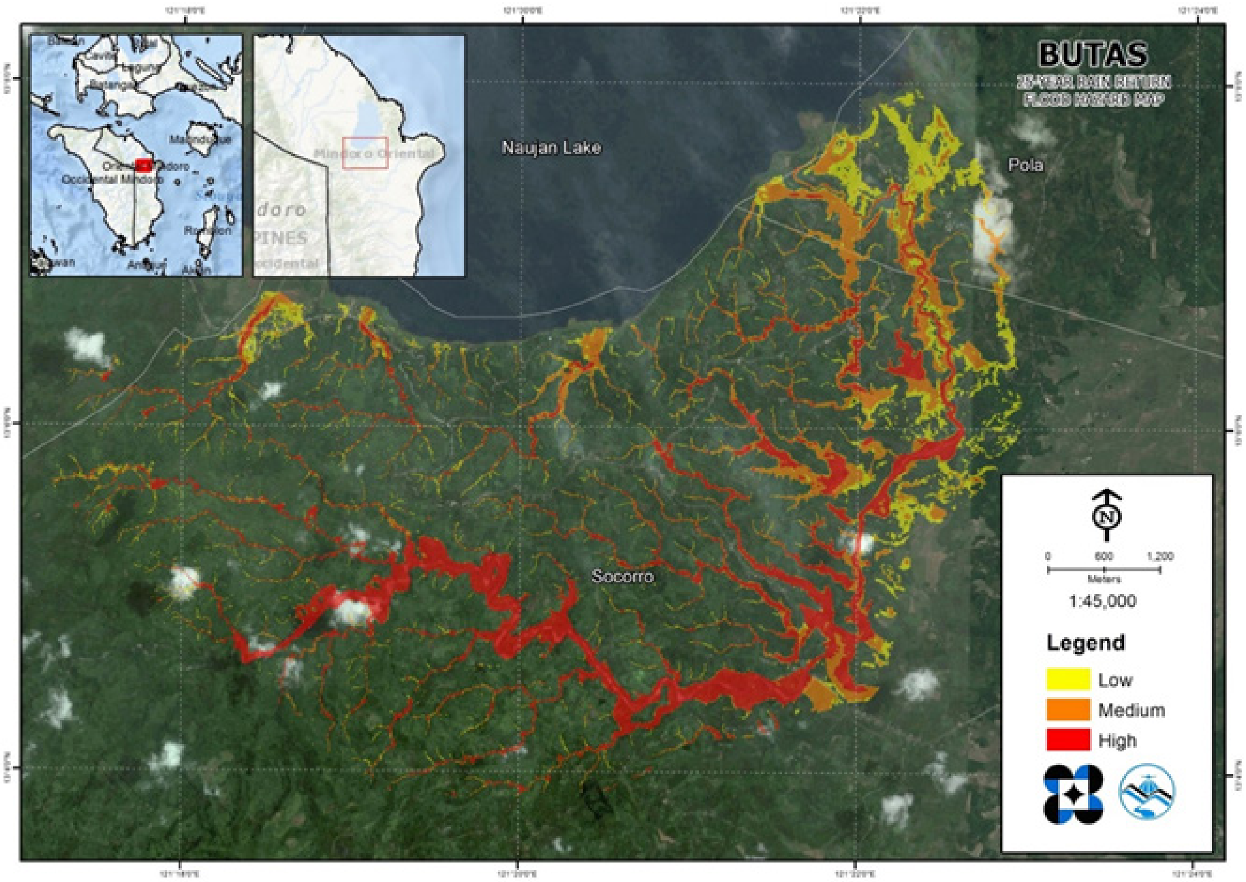


Figure 68. 25-year Flood Hazard Map for Butas Floodplain

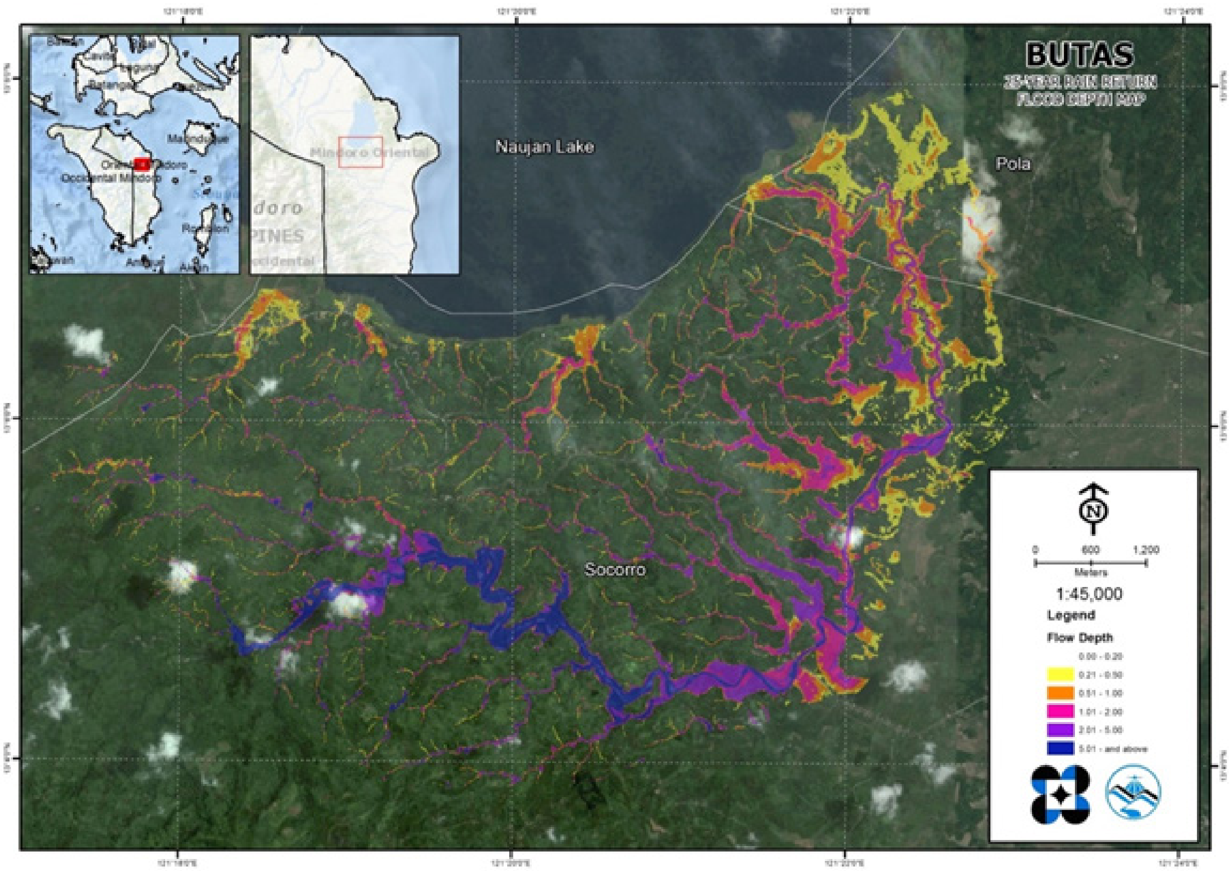


Figure 69. 25-year Flow Depth Map for Butas Floodplain

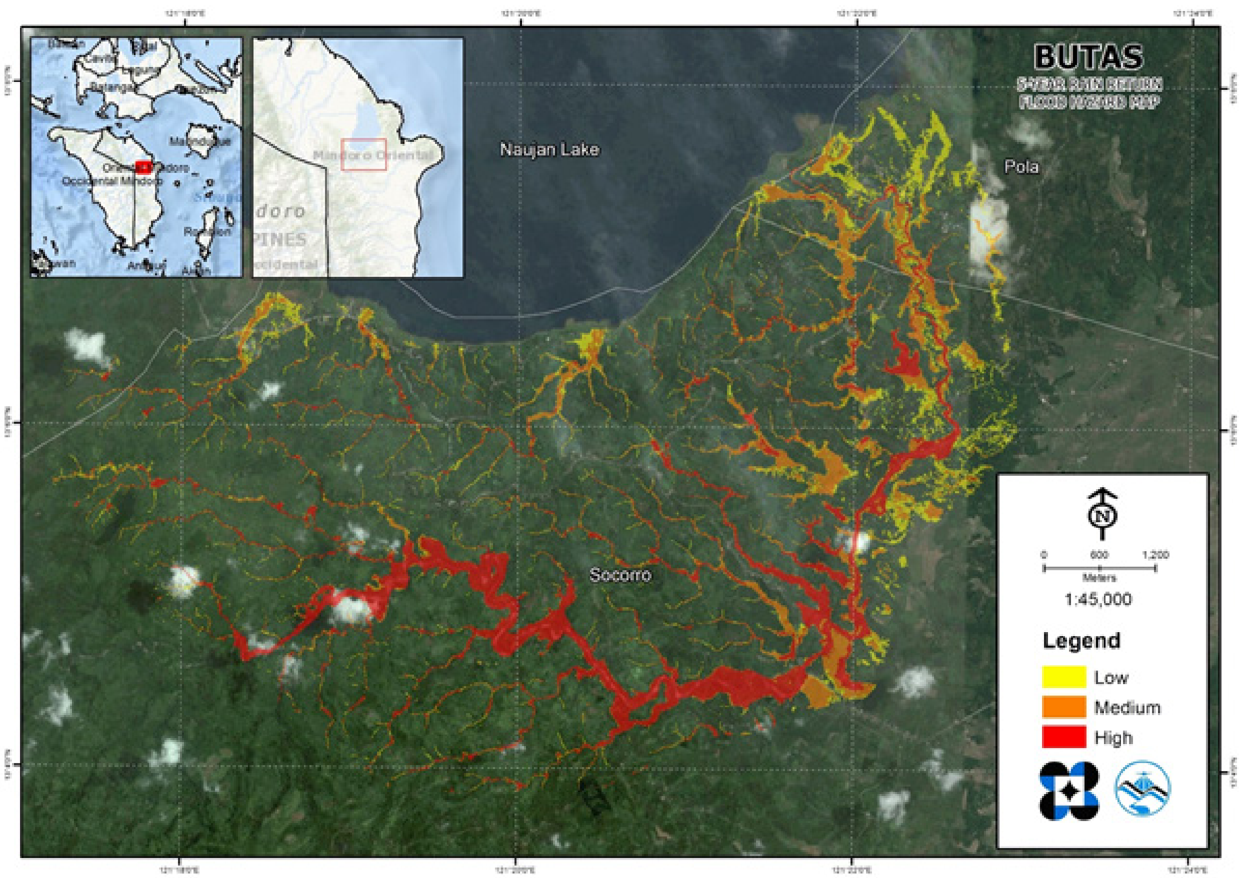


Figure 70. 5-year Flood Hazard Map for Butas Floodplain

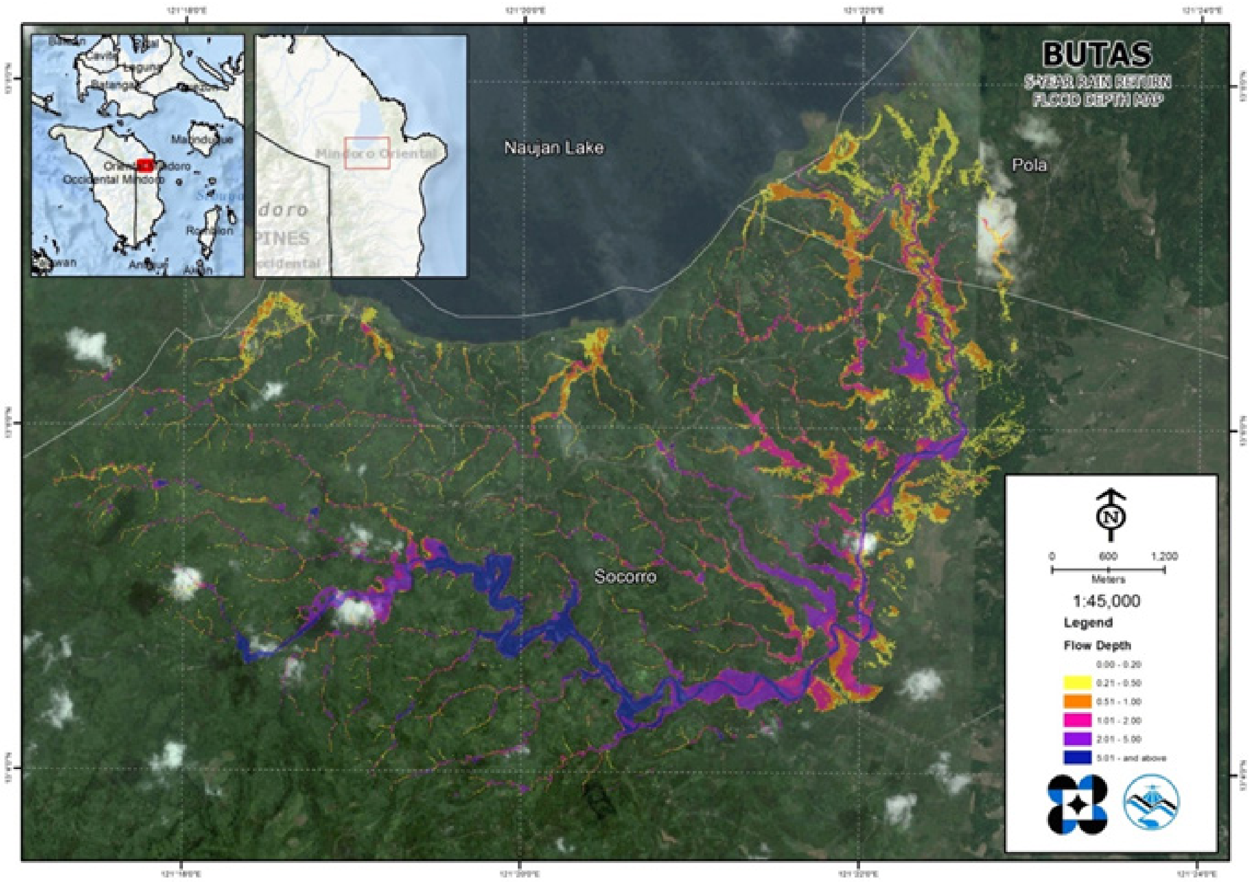


Figure 71. 5-year Flow Depth Map for Butas Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Butas river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 19 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 0.09% of the municipality of Naujan Lake with an area of 76.11 sq. km. will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.001%, and 0.0009% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 32 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Naujan Lake, Oriental Mindoro during 5-Year Rainfall Return Period

BUTAS BASIN		**Affected Barangays in Naujan Lake**
		Naujan Lake
Affected Area (sq. km.)	**0.03-0.20**	0.071
	0.21-0.50	0.0074
	0.51-1.00	0.0042
	1.01-2.00	0.001
	2.01-5.00	0.0007
	> 5.00	0

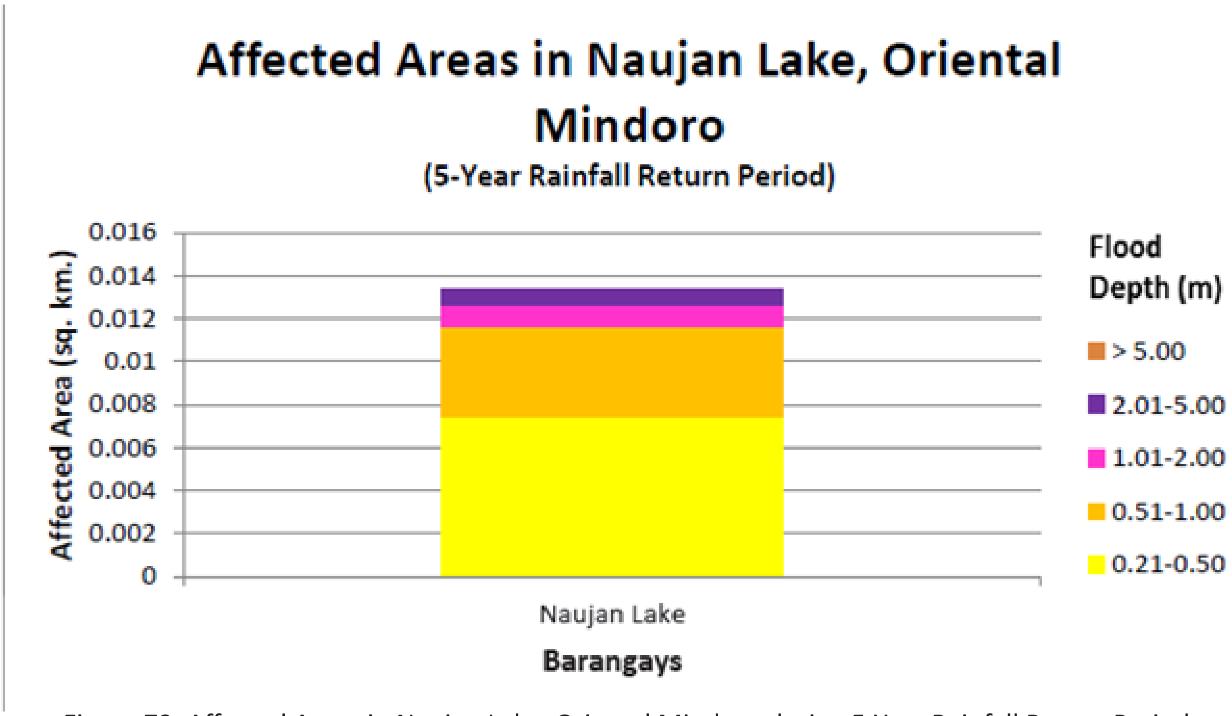


Figure 72. Affected Areas in Naujan Lake, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Pola, with an area of 127.04 sq. km., 2.05% will experience flood levels of less 0.20 meters. 0.44% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.05%, 0.03%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 33 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Pola, Oriental Mindoro during 5-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Pola	
		Calubasanhon	Matulatula
Affected Area (sq. km.)	0.03-0.20	0.013	2.59
	0.21-0.50	0.0025	0.56
	0.51-1.00	0.00058	0.3
	1.01-2.00	0.0002	0.069
	2.01-5.00	0	0.042
	> 5.00	0	0.0022

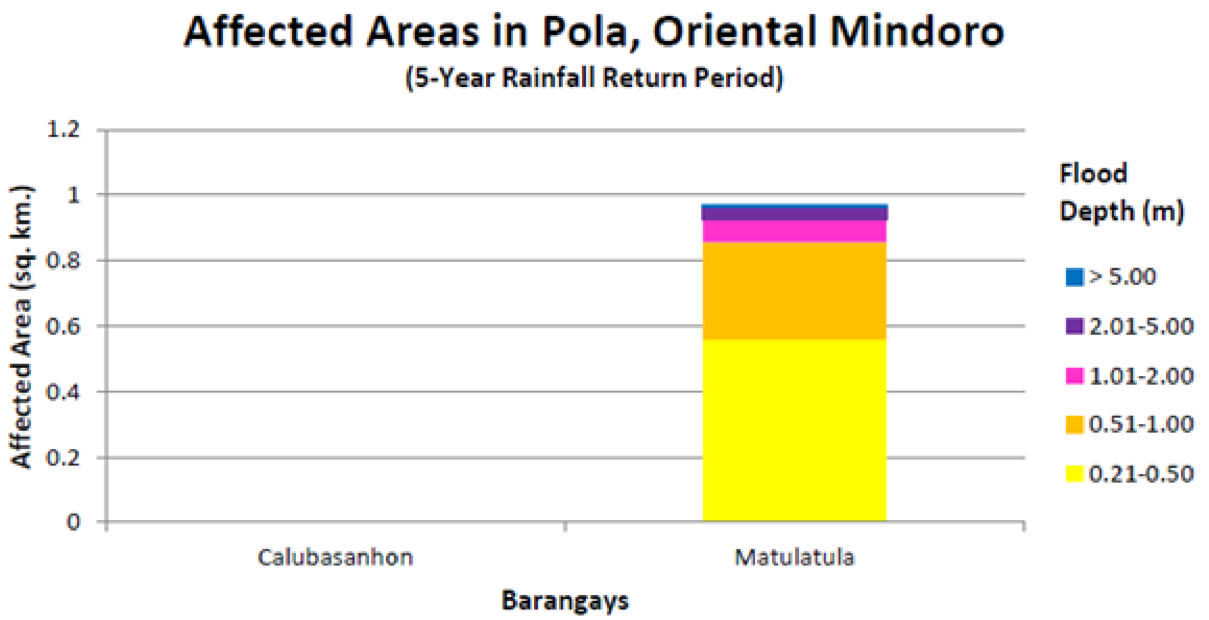


Figure 73. Affected Areas in Pola, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Socorro, with an area of 206.06 sq. km., 17.13% will experience flood levels of less 0.20 meters. 0.82% of the area will experience flood levels of 0.21 to 0.50 meters while 0.70%, 0.69%, 0.75%, and 0.47% 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 Tables 34-35 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Socorro, Oriental Mindoro during 5-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Socorro						
		Batong Dalig	Bugtong Na Tuog	Happy Valley	Leuteboro I	Leuteboro II	Ma. Concepcion	Mabuhay I
Affected Area (sq. km.)	2.28	0.077	7.28	0.032	0.15	4.33	2.33	2.326409
	0.12	0.0014	0.14	0.0031	0.045	0.1	0.059	0.059344
	0.11	0.00099	0.12	0.0024	0.038	0.08	0.058	0.057845
	0.046	0.0008	0.17	0.0026	0.064	0.1	0.029	0.02906
	0.018	0.00089	0.33	0.0011	0.0068	0.13	0.012	0.012025
	0	0.00044	0.59	0.000057	0.0004	0.03	0.00043	0.000425

Table 35. Affected Areas in Socorro, Oriental Mindoro during 5-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Socorro						
		Mabuhay II	Matungao	Monteverde	Pasi I	Pasi II	Santo Domingo	Subaan
Affected Area (sq. km.)	0.03-0.20	1.92	1.43	1.35	2.32	1.89	4.34	5.58
	0.21-0.50	0.04	0.31	0.042	0.16	0.087	0.26	0.33
	0.51-1.00	0.042	0.17	0.076	0.074	0.048	0.3	0.31
	1.01-2.00	0.064	0.1	0.11	0.025	0.028	0.3	0.38
	2.01-5.00	0.05	0.099	0.12	0.013	0.016	0.11	0.64
	> 5.00	0.0024	0.03	0.027	0.0016	0.0006	0.0006	0.27

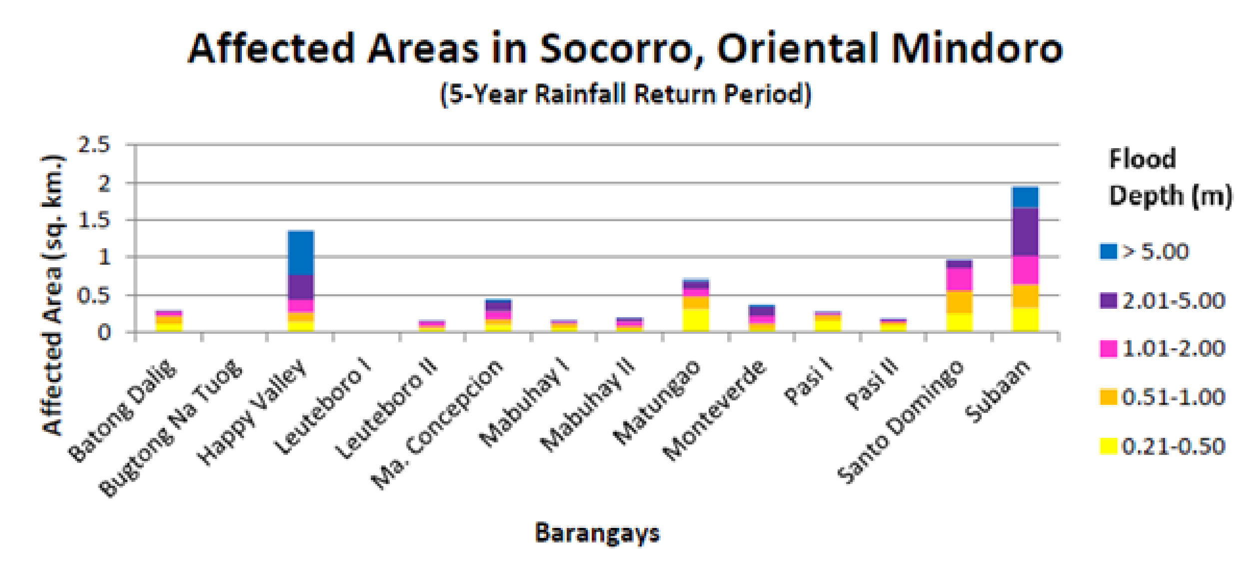


Figure 74. Affected Areas in Socorro, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Victoria, with an area of 216.22 sq. km., 0.20% will experience flood levels of less 0.20 meters. 0.004% of the area will experience flood levels of 0.21 to 0.50 meters while 0.003%, 0.003%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Victoria, Oriental Mindoro during 5-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Victoria	
		Concepcion	Merit
Affected Area (sq. km.)	0.03-0.20	0.17	0.26
	0.21-0.50	0.0032	0.0047
	0.51-1.00	0.0026	0.0039
	1.01-2.00	0.0024	0.0045
	2.01-5.00	0.0011	0.0039
	> 5.00	0	0

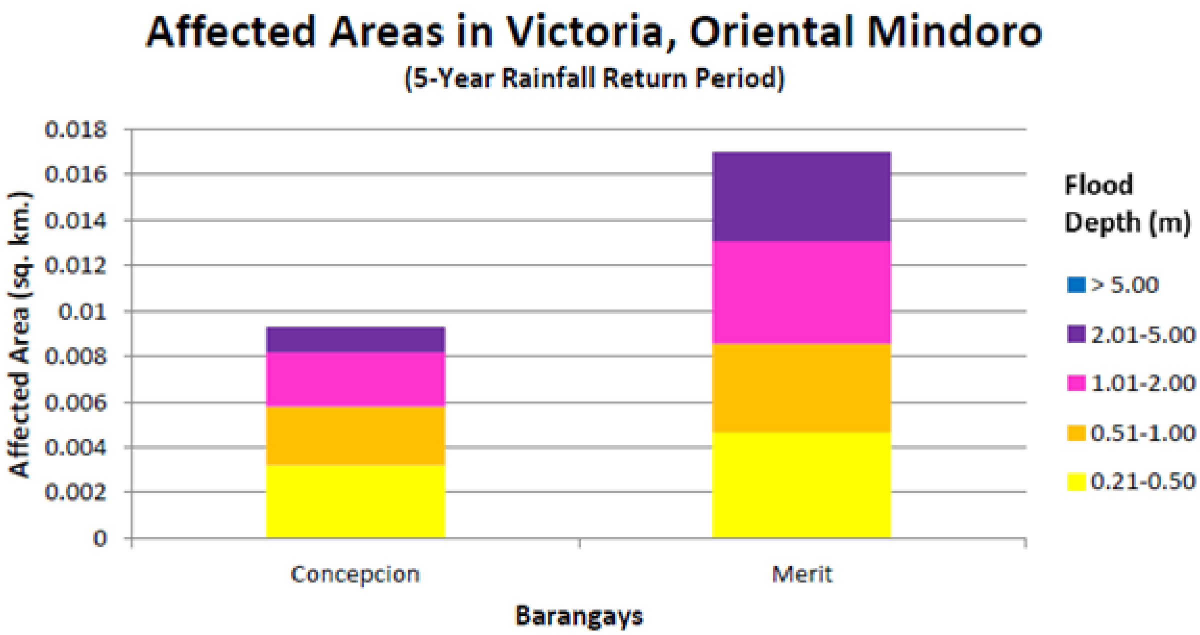


Figure 75. Affected Areas in Victoria, Oriental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 0.08% of the municipality of Naujan Lake with an area of 76.11 sq. km. will experience flood levels of less 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, and more than 1 meter, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Naujan Lake, Oriental Mindoro during 25-Year Rainfall Return

BUTAS BASIN		Affected Barangays in Naujan Lake
		Naujan Lake
Affected Area (sq. km.)	0.03-0.20	0.063
	0.21-0.50	0.013
	0.51-1.00	0.0072
	1.01-2.00	0.00075
	2.01-5.00	0
	> 5.00	0

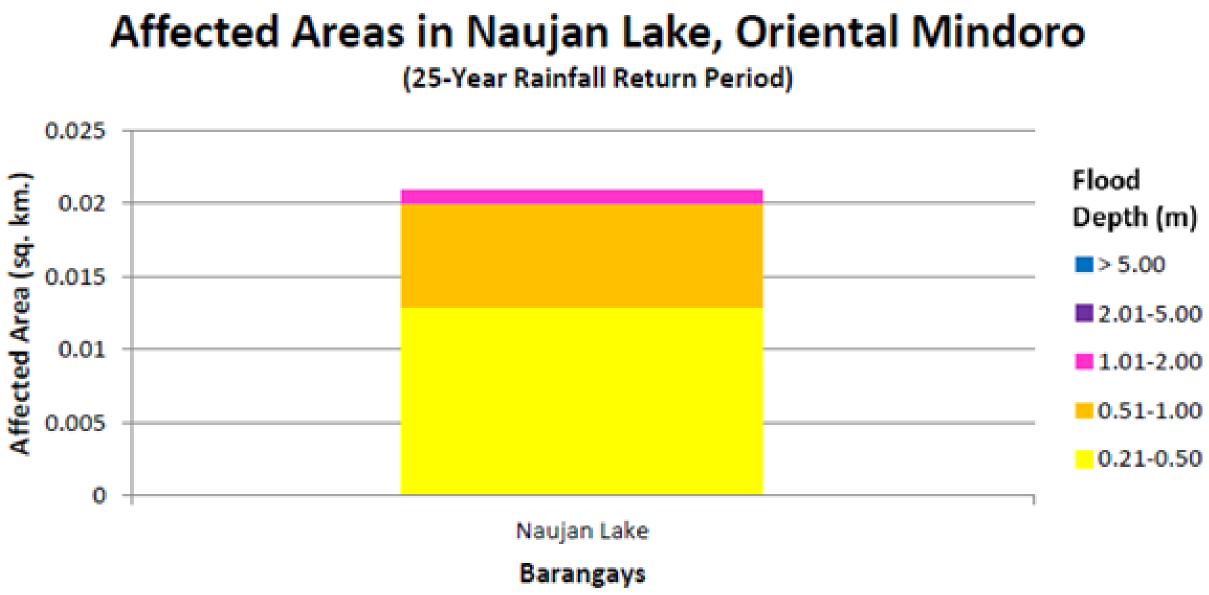


Figure 76. Affected Areas in Naujan Lake, Oriental Mindoro during 25-Year Rainfall Return Period

For the municipality of Pola, with an area of 127.04 sq. km., 1.74% will experience flood levels of less 0.20 meters. 0.59% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.15%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Pola, Oriental Mindoro during 25-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Pola	
		Calubasanhon	Matulatula
Affected Area (sq. km.)	0.03-0.20	0.012	2.19
	0.21-0.50	0.0016	0.75
	0.51-1.00	0.0032	0.39
	1.01-2.00	0.0001	0.19
	2.01-5.00	0	0.036
	> 5.00	0	0

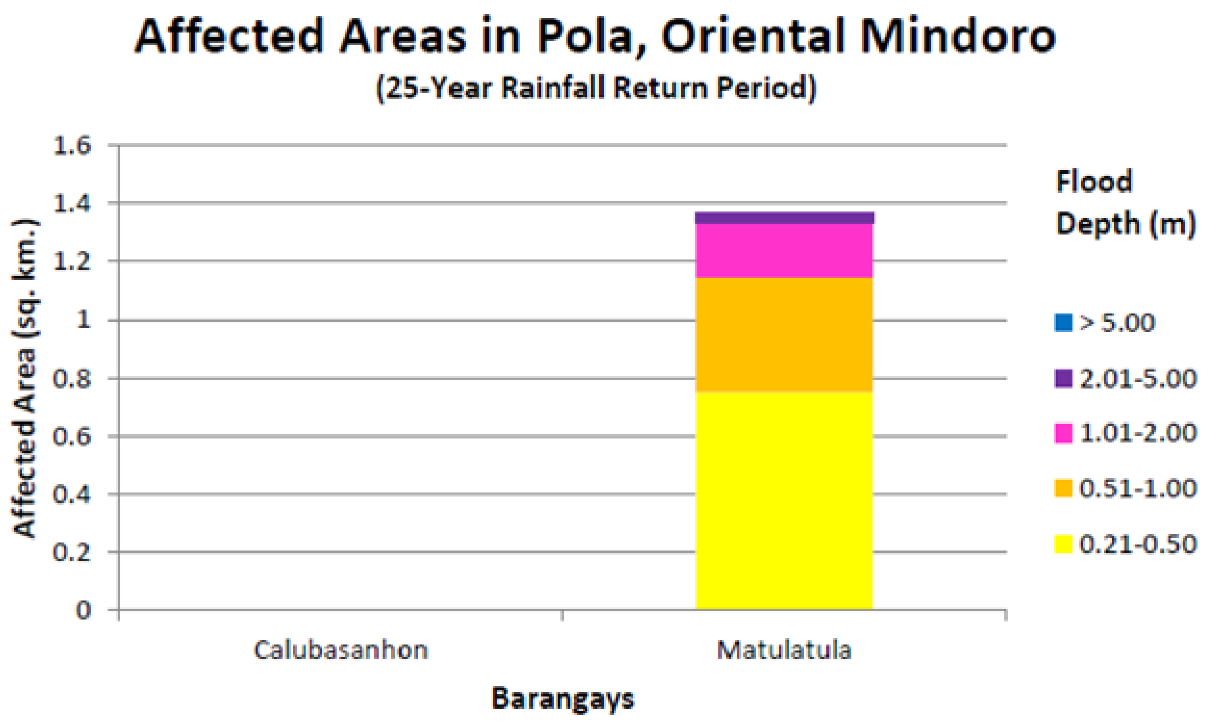


Figure 77. Affected Areas in Pola, Oriental Mindoro during 25-Year Rainfall Return Period

For the municipality of Socorro, with an area of 206.06 sq. km., 16.63% will experience flood levels of less 0.20 meters. 0.86% of the area will experience flood levels of 0.21 to 0.50 meters while 0.76%, 0.86%, 0.90%, and 0.55% 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 Tables 39-40 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Socorro						
		Batong Dalig	Bugtong Na Tuog	Happy Valley	Leuteboro I	Leuteboro II	Ma. Concepcion	Mabuhay I
Affected Area (sq. km.)	0.03-0.20	2.23	0.077	7.15	0.032	0.14	4.23	2.28
	0.21-0.50	0.092	0.0011	0.15	0.0017	0.038	0.11	0.072
	0.51-1.00	0.14	0.00098	0.12	0.0035	0.042	0.084	0.07
	1.01-2.00	0.081	0.0012	0.16	0.0022	0.061	0.098	0.052
	2.01-5.00	0.028	0.00099	0.35	0.0018	0.019	0.16	0.015
	> 5.00	0.0002	0.00054	0.71	0.00011	0.0005	0.083	0.00048

Table 40. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Socorro						
		Mabuhay II	Matungao	Monteverde	Pasi I	Pasi II	Santo Domingo	Subaan
Affected Area (sq. km.)	0.03-0.20	1.88	1.3	1.32	2.22	1.85	4.09	5.46
	0.21-0.50	0.039	0.35	0.043	0.18	0.096	0.25	0.35
	0.51-1.00	0.041	0.22	0.071	0.13	0.067	0.32	0.26
	1.01-2.00	0.066	0.13	0.13	0.046	0.038	0.45	0.46
	2.01-5.00	0.084	0.12	0.13	0.018	0.022	0.19	0.72
	> 5.00	0.0069	0.019	0.032	0.0039	0.0013	0	0.27

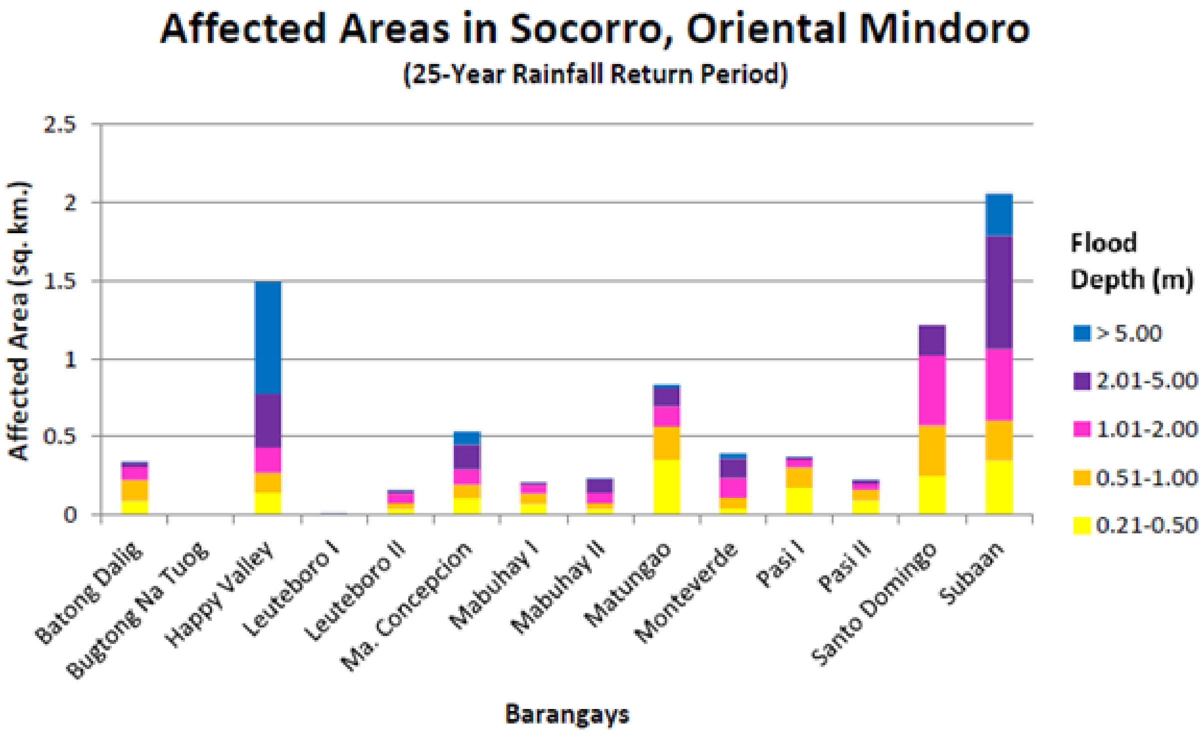


Figure 78. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

For the municipality of Victoria, with an area of 216.22 sq. km., 0.20% will experience flood levels of less 0.20 meters. 0.004% of the area will experience flood levels of 0.21 to 0.50 meters while 0.004%, 0.004%, 0.003%, and 0.0001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Victoria, Oriental Mindoro during 25-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Victoria	
		Concepcion	Merit
Affected Area (sq. km.)	0.03-0.20	0.17	0.26
	0.21-0.50	0.0042	0.0045
	0.51-1.00	0.0024	0.0053
	1.01-2.00	0.0034	0.0043
	2.01-5.00	0.0012	0.0051
	> 5.00	0	0.0001

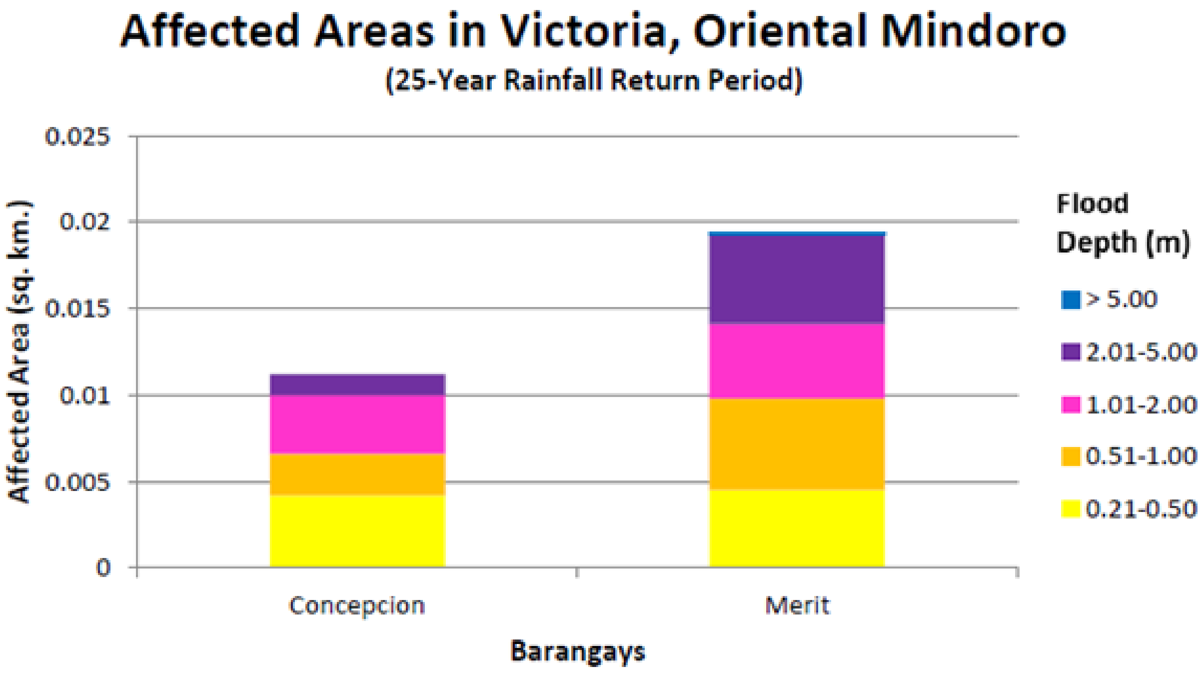


Figure 79. Affected Areas in Victoria, Oriental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 0.07% of the municipality of Naujan Lake with an area of 76.11 sq. km. will experience flood levels of less 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.002%, and 0.00006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Naujan Lake, Oriental Mindoro during 100-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Naujan Lake
		Naujan Lake
Affected Area (sq. km.)	0.03-0.20	0.051
	0.21-0.50	0.02
	0.51-1.00	0.012
	1.01-2.00	0.0012
	2.01-5.00	0.000042
	> 5.00	0

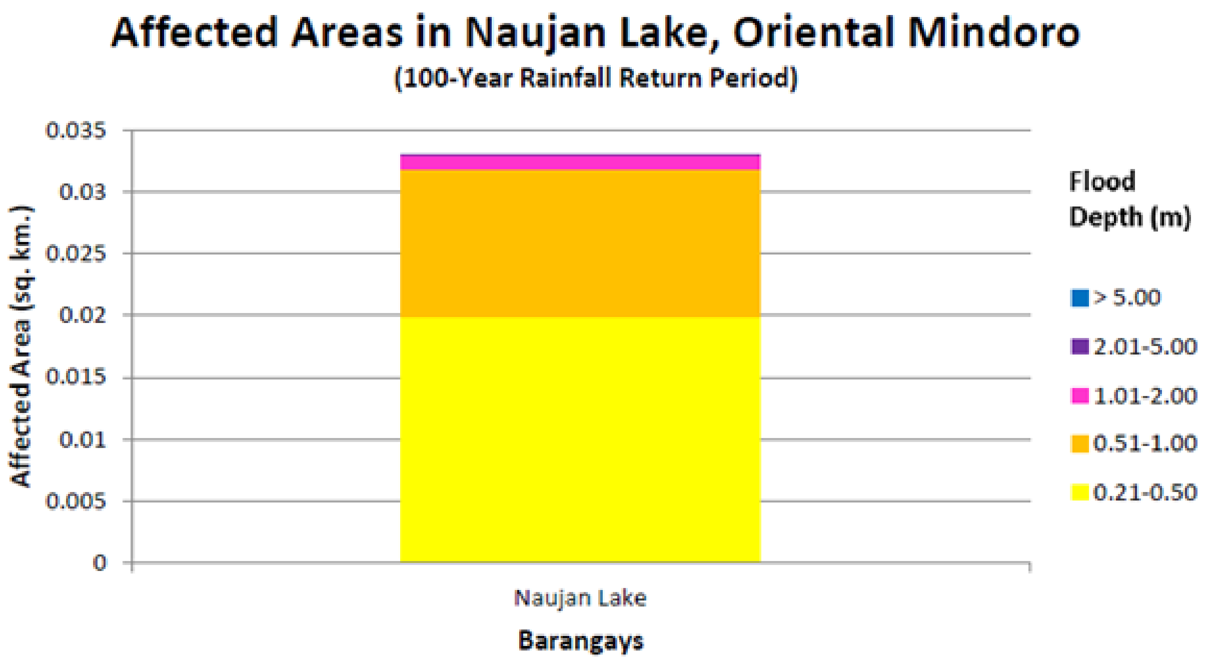


Figure 80. Affected Areas in Naujan Lake, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Pola, with an area of 127.04 sq. km., 1.43% will experience flood levels of less 0.20 meters. 0.67% of the area will experience flood levels of 0.21 to 0.50 meters while 0.46%, 0.22%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Pola, Oriental Mindoro during 100-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Pola	
		Calubasanhon	Matulatula
Affected Area (sq. km.)	0.03-0.20	0.011	1.81
	0.21-0.50	0.0017	0.85
	0.51-1.00	0.0027	0.59
	1.01-2.00	0.0013	0.28
	2.01-5.00	0	0.039
	> 5.00	0	0

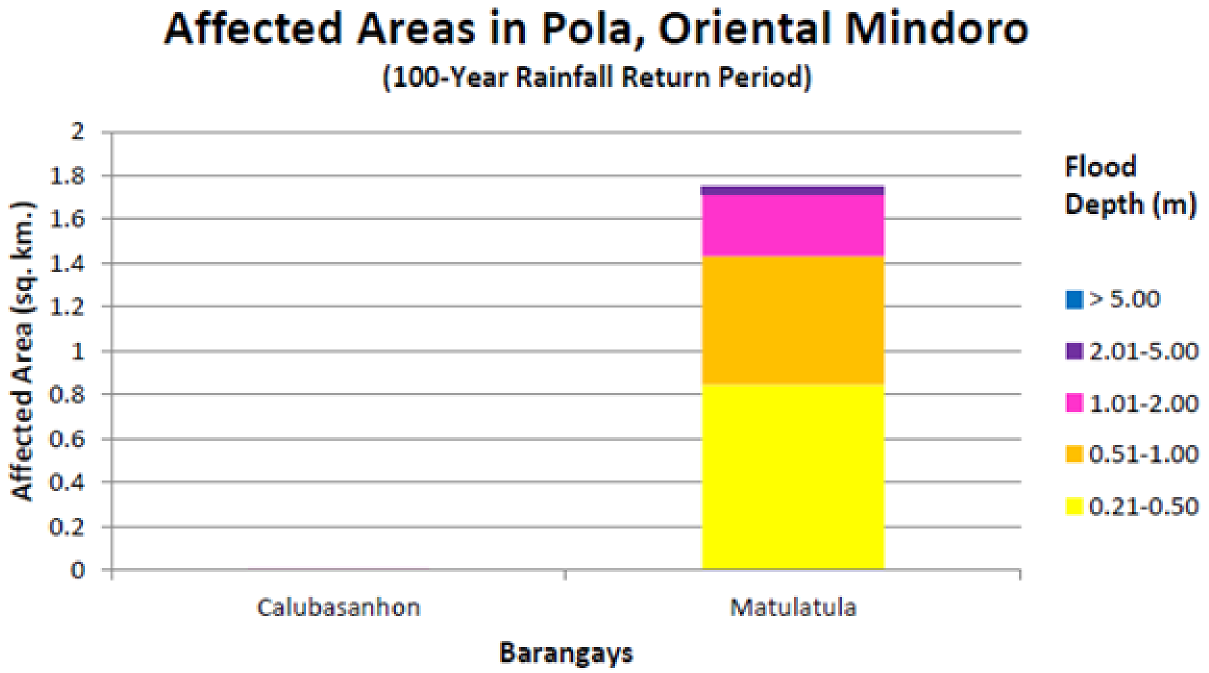


Figure 81. Affected Areas in Pola, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Socorro, with an area of 206.06 sq. km., 16.10% will experience flood levels of less 0.20 meters. 1.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.81%, 0.92%, 1.03%, and 0.66% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 44-45 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Socorro						
		Batong Dalig	Bugtong Na Tuog	Happy Valley	Leuteboro I	Leuteboro II	Ma. Concepcion	Mabuhay I
Affected Area (sq. km.)	0.03-0.20	2.2	0.076	7.03	0.029	0.12	4.18	2.24
	0.21-0.50	0.084	0.0014	0.16	0.0035	0.028	0.12	0.083
	0.51-1.00	0.14	0.0011	0.12	0.0042	0.056	0.09	0.075
	1.01-2.00	0.1	0.0012	0.17	0.0026	0.056	0.096	0.071
	2.01-5.00	0.042	0.0012	0.3	0.002	0.038	0.18	0.021
	> 5.00	0.0011	0.00064	0.86	0.00011	0.0005	0.11	0.00058

Table 40. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Socorro						
		Mabuhay II	Matungao	Monteverde	Pasi I	Pasi II	Santo Domingo	Subaan
Affected Area (sq. km.)	0.03-0.20	1.86	1.02	1.3	2.18	1.82	3.93	5.2
	0.21-0.50	0.039	0.57	0.046	0.18	0.099	0.28	0.44
	0.51-1.00	0.042	0.26	0.06	0.14	0.076	0.3	0.31
	1.01-2.00	0.06	0.15	0.14	0.075	0.049	0.49	0.44
	2.01-5.00	0.11	0.12	0.14	0.02	0.027	0.3	0.81
	> 5.00	0.0099	0.02	0.037	0.0054	0.0017	0.0001	0.31

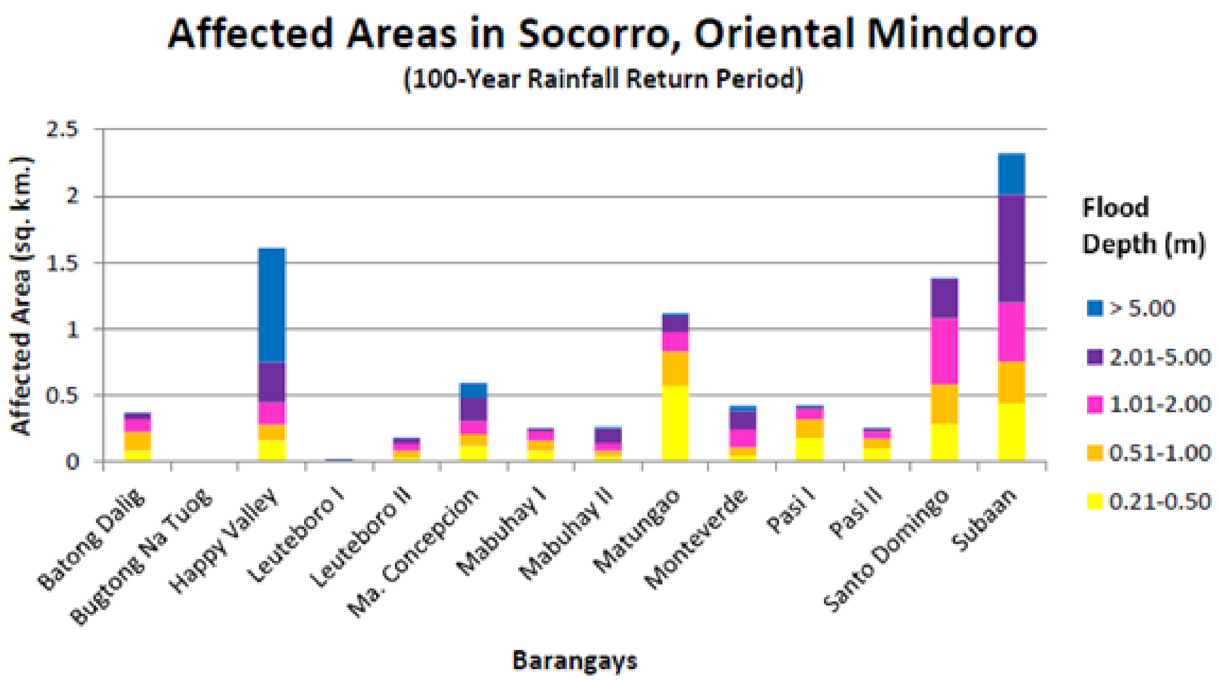


Figure 82. Affected Areas in Socorro, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Victoria, with an area of 216.22 sq. km., 0.19% will experience flood levels of less 0.20 meters. 0.004% of the area will experience flood levels of 0.21 to 0.50 meters while 0.004%, 0.004%, 0.004%, and 0.00005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Victoria, Oriental Mindoro during 100-Year Rainfall Return Period

BUTAS BASIN		Affected Barangays in Victoria	
		Concepcion	Merit
Affected Area (sq. km.)	0.03-0.20	0.17	0.25
	0.21-0.50	0.0047	0.0047
	0.51-1.00	0.0025	0.0063
	1.01-2.00	0.0035	0.0047
	2.01-5.00	0.0012	0.0058
	> 5.00	0	0.0001

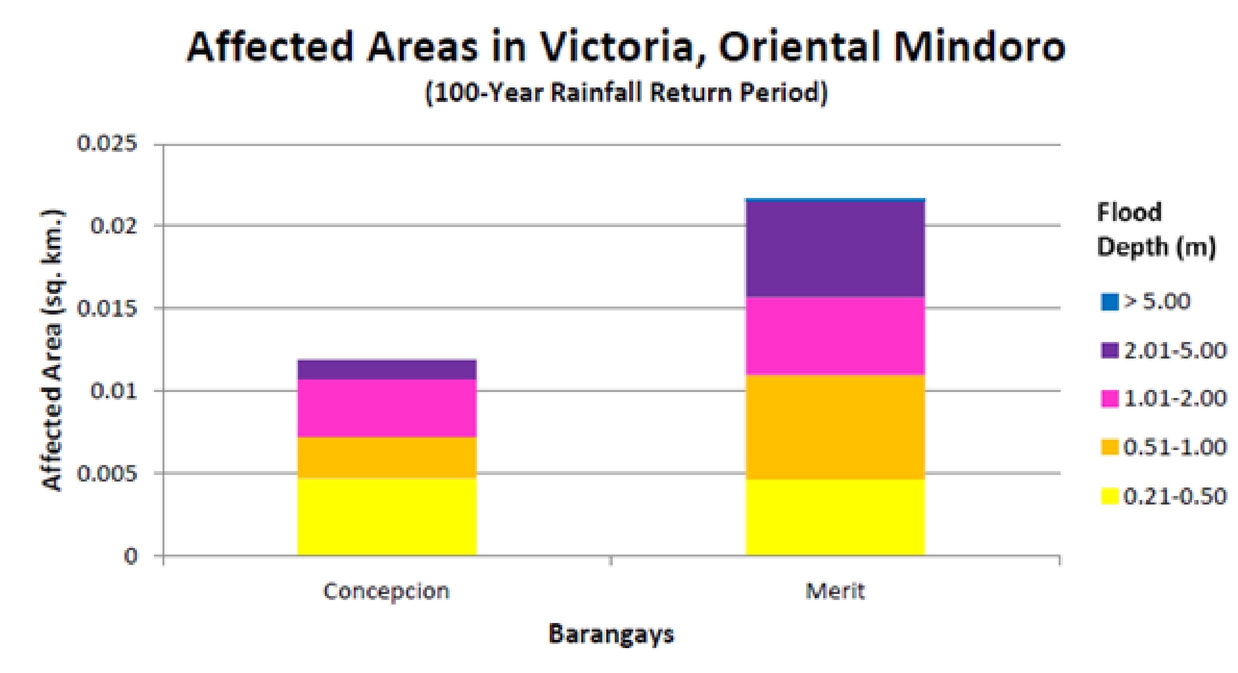


Figure 83. Affected Areas in Victoria, Oriental Mindoro during 100-Year Rainfall Return Period

Among the barangays in the municipality of Naujan Lake, Naujan Lake is projected to have the highest percentage of area that will experience flood levels at 0.11%.
Among the barangays in the municipality of Pola, Matulatula is projected to have the highest percentage of area that will experience flood levels at 2.80%. Meanwhile, Calubasanhon posted the second highest percentage of area that may be affected by flood depths at 0.01%.
Among the barangays in the municipality of Socorro, Happy Valley is projected to have the highest percentage of area that will experience flood levels at 4.19%. Meanwhile, Subaan posted the second highest percentage of area that may be affected by flood depths at 3.65%.
Among the barangays in the municipality of Victoria, Merit is projected to have the highest percentage of area that will experience flood levels at 0.13%. Meanwhile, Concepcion posted the second highest percentage of area that may be affected by flood depths at 0.08%.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and through interviews of 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 76 points randomly selected all over the Butas flood plain. It has an RMSE value of 1.268.

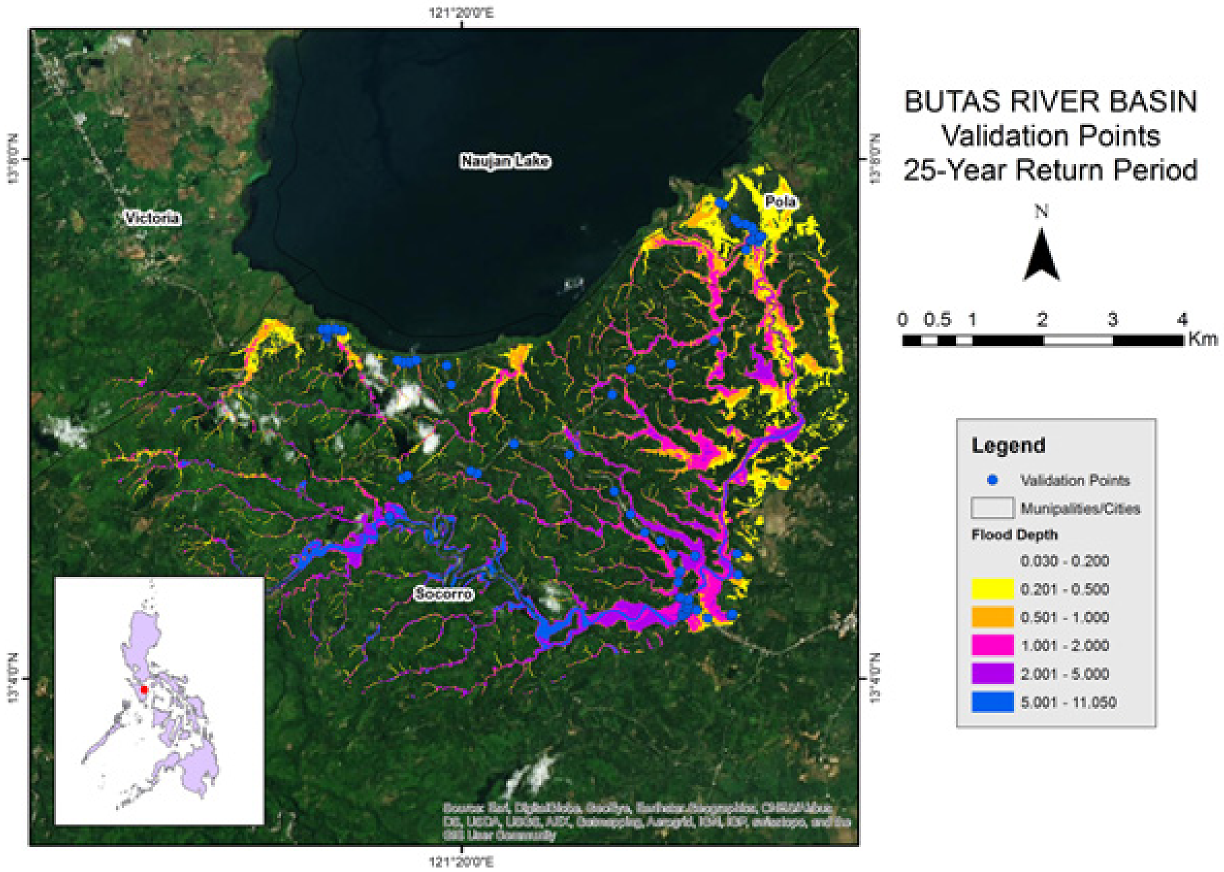


Figure 84. Validation points for 5-year Flood Depth Map of Butas Floodplain

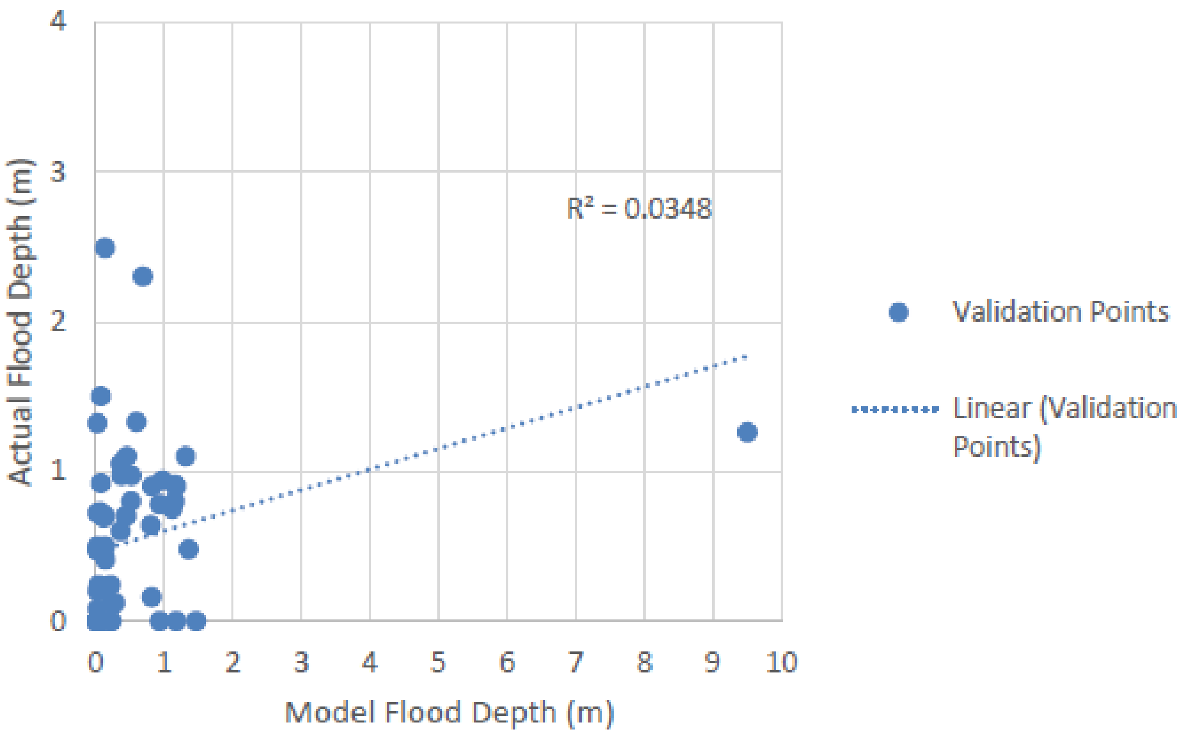


Figure 85. Flood map depth vs actual flood depth

Table 47. Actual Flood Depth vs Simulated Flood Depth in Butas

BUTAS 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	25	1	1	2	0	0	29
	0.21-0.50	2	0	0	0	0	0	2
	0.51-1.00	2	0	3	1	0	0	6
	1.01-2.00	1	1	1	1	0	1	5
	2.01-5.00	1	0	1	0	0	0	2
	> 5.00	0	0	1	0	0	0	1
	Total	31	2	7	4	0	1	45

The overall accuracy generated by the flood model is estimated at 64.44%, with 29 points correctly matching the actual flood depths. In addition, there were 5 points estimated one level above and below the correct flood depths while there were 6 points and 5 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 6 points were overestimated while a total of 10 points were underestimated in the modelled flood depths of Butas.

Table 48. Summary of Accuracy Assessment in Butas

	No. of Points	%
Correct	29	64.44
Overestimated	6	13.33
Underestimated	10	22.22
Total	45	100

REFERENCES

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River Basin Control Office. (2017). Retrieved from www.rbco.denr.gov.ph/: http://rbco.denr.gov.ph/

Socorro LGU. (2014). Socorro Local Government Unit.

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

ANNEXES

Annex 1.Technical Specifications of the LIDAR Sensors used in the Butas Flood-plain Survey

1.AQUARIUS SENSOR

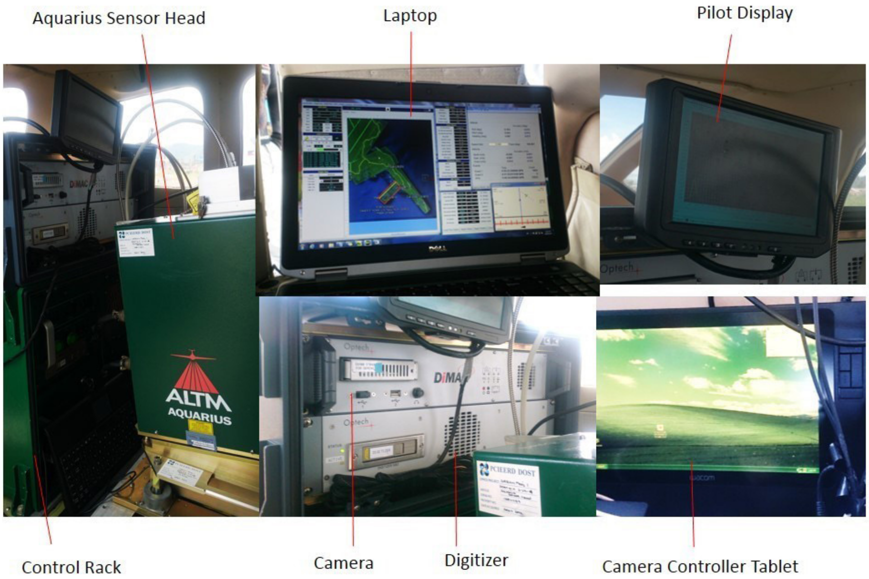


Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specification of Aquarius Sensor

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

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

1. MRE-54

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-54**
Order: **2nd**

Island: **LUZON**		Barangay: **MALIANGCOG**
Municipality: **PINAMALAYAN**		
	PRS92 Coordinates	
Latitude: **12° 59' 12.43671"**	Longitude: **121° 24' 46.52637"**	Ellipsoidal Hgt: **42.40800 m.**
	WGS84 Coordinates	
Latitude: **12° 59' 7.43505"**	Longitude: **121° 24' 51.55668"**	Ellipsoidal Hgt: **91.39500 m.**
	PTM Coordinates	
Northing: **1436124.562 m.**	Easting: **544797.009 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,436,121.49**	Easting: **327,864.09**	Zone: **51**

Location Description

MRE-54

From Calapan City to Roxas, along Nat'l Road, approx. 100 m from Pula Bridge, along Brgy. Sto. Niño, right turn to Brgy. Road leading to Gloria Airport, passing through Brgy. Sto. Niño, Brgy. Sta. Maria, Brgy. Pambigan Malaki, all in Mun. of Pinamalayan. approx. 7.8 Km. from Nat'l Road, 1.1 Km. from Brgy. Chapel, 600 m from Maliangkog Elem. School, left side of road located Brgy. Hall of Maliangkog, Pinamalayan, Oriental Mindoro. Station is located beside of flagpole near gate of brgy. hall. Mark is the head of a 4 in, copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-54, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-196**

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814

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

Figure A-2.1. MRE-54

2. MRE-44

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-44**
Order: **2nd**

Island: **LUZON**
Municipality: **ROXAS**
Barangay: **HAPPY VALLEY**

PRS92 Coordinates

Latitude: **12° 38' 59.03778"** Longitude: **121° 24' 32.60444"** Ellipsoidal Hgt: **87.94200 m.**

WGS84 Coordinates

Latitude: **12° 38' 54.11733"** Longitude: **121° 24' 37.66392"** Ellipsoidal Hgt: **137.80400 m.**

PTM Coordinates

Northing: **1398838.995 m.** Easting: **544436.519 m.** Zone: **3**

UTM Coordinates

Northing: **1,398,840.08** Easting: **327,214.81** Zone: **51**

Location Description

MRE-44

From Calapan City to Bulalacao, approx. 4 Km. from Roxas Town Proper, along Nat'l Road is an intersection going to Roxas Proper, Mansalay, and Bongabong, Oriental Mindoro. Turn right to road leading to Bongabong Town Proper, approx. 6.9 Km., passing through Brgy. San Aquilino, Brgy. Libertad, Brgy. Little Tanauan, and Brgy. San Mariano, all in Mun. of Roxas. Along Brgy. San Rafael, left side of road located Km. post 130 about 50 m after RCBCulvert, turn left to Brgy. Road leading to Sitio Amawan, approx. 800 m passing through San Rafael Elem. School, and GK Village, left side of road located Brgy. Hall of Happy Valley, Roxas, Oriental Mindoro. Station is located beside of streetlight outside wall of brgy. hall. Mark is the head of a 4 in. copper nial flushed in a cement block embedded in the ground with inscriptions, "MRE-44, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-198**

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814

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

Figure A-2.2. MRE-44

3. MRE-32

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

April 05, 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: **ORIENTAL MINDORO**
Station Name: **MRE-32**
Order: **2nd**

Island: **LUZON**
Municipality: **VICTORIA**
Barangay:

			PRS92 Coordinates		
Latitude:	**13° 10' 28.85064"**	Longitude:	**121° 16' 38.44761"**	Ellipsoidal Hgt:	**19.49300 m.**
			WGS84 Coordinates		
Latitude:	**13° 10' 23.79251"**	Longitude:	**121° 16' 43.46244"**	Ellipsoidal Hgt:	**67.64700 m.**
			PTM Coordinates		
Northing:	**1456889.419 m.**	Easting:	**530065.679 m.**	Zone:	**3**
			UTM Coordinates		
Northing:	**1,457,002.75**	Easting:	**313,296.85**	Zone:	**51**

Location Description

MRE-32

From Calapan City to Roxas, along Nat'l. Road approx. 34 Km. travel to Victoria Town Proper, 10 Km. from intersection of Naujan, left turn to Shell Gasoline Station, approx. 150 m, right side of road located Mun. Hall of Victoria, Oriental Mindoro. Station is located in Mun. Park in front of Former Mayor Statue, along corner of pathwalk. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-32, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943485 B**
T.N.: **2013-0270**

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

9904052013155257

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814

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

Figure A-2.3. MRE-32

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

Table A-3.1. Baseline Processing Report

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE-4563 --- MRE-54 (B1)	MRE-54	MRE-4563	Fixed	0.005	0.015	359°56'42"	3244.605	-17.680

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

MRE-4563 - MRE-54 (7:57:34 AM-5:20:54 PM) (S1)

Baseline observation:	MRE-4563 --- MRE-54 (B1)
Processed:	2/11/2014 3:05:00 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.015 m
RMS:	0.001 m
Maximum PDOP:	6.448
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	2/6/2014 7:57:51 AM (Local: UTC+8hr)
Processing stop time:	2/6/2014 5:20:54 PM (Local: UTC+8hr)
Processing duration:	09:23:03
Processing interval:	1 second

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	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	PAULINE JOANNE ARCEO	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC

Annex 5. Data Transfer Sheet for Butas Floodplain

DATA TRANSFER SHEET
~~Jan~~ Feb 6, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Feb 1, 2014	1052A	3BLK28A033A	AQUARIUS	N/A	528KB	920KB	222MB	52.9GB	385KB	14.8GB	46.3GB	6.12MB	19B	626B	888KB	N/A	X:\Airborne_Raw\1052A
Feb 1, 2014	1054A	3BLK28B033B	AQUARIUS	N/A	672KB	1.70MB	206MB	73.7GB	385KB	11.8GB	N/A	6.12MB	19B	625B	314KB	N/A	X:\Airborne_Raw\1054A
Feb 3, 2014	1056A	3BLK28C034A	AQUARIUS	N/A	700KB	1.06MB	210MB	77.2GB	558KB	12.2GB	172GB	6.29MB	19B	651B	239KB	N/A	X:\Airborne_Raw\1056A
Feb 3,2014	1058A	3BLK28CD034B	AQUARIUS	N/A	646KB	1.82MB	201MB	65.8GB	491KB	11.3GB	N/A	6.29MB	19B	328B	9.10KB	N/A	X:\Airborne_Raw\1058A

Received from

Name Feyth Sible
Position
Signature

Received by

Name JOIDA F. PRIETO 02/06/14
Position SSRS
Signature

Verified by

Name JOIDA F. PRIETO 02/06/14
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Butas Floodplain - A

DATA TRANSFER SHEET
Feb 18, 2014

DATE of Operation	FLIGHT NO.	SENSOR	MISSION NAME	RAW LAS (MB)	LOGS (KB)	POS (MB)	RAW IMAGES	MISSION LOG FILE	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S) (MB)	OPERATOR COMMENTS (DPC LOGS) (Bytes)	FLIGHT PLAN (KB)	SERVER LOCATION
2/7/2014	1072A	Aquarius	3BLK28F038A	703KB	1.16MB	256	81.4GB	563KB	12.5	174	14.1	767	13	\\FREENAS\geostorage3\Airborne_Raw\1072A
2/7/2014	1074A	Aquarius	3BLK28G038B	134 KB	968 KB	174	33.7GB	274KB	6.4	60.9	14.1	258	11 (28F)&12(28G)	\\FREENAS\geostorage3\Airborne_Raw\1074A
2/8/2014	1076A	Aquarius	3BLK28GS039A	643KB	1.21MB	233	76.8	308KB&218KB	11.5	101	14.3	357	12	\\FREENAS\geostorage3\Airborne_Raw\1076A
2/5/2014	1066A	Aquarius	3BLK28DS036A	360KB	1.38MB	203	73.9	311KB	11.7	N/A	14.5	414	11	\\FREENAS\geostorage3\Airborne_Raw\1066A
2/6/2014	1070A	Aquarius	3BLK28DSE037A	932KB	1.46MB	270	104	764KB	15.9	249	14.9	300	12	\\FREENAS\geostorage3\Airborne_Raw\1070A
2/8/2014	1078A	Aquarius	3BLK28GSH039B	530KB	892KB	197	56.8	442KB	9.71	N/A	14.3	738	12 (28G) & 12 (28H)	\\FREENAS\geostorage3\Airborne_Raw\1078A

Received from
Name/Signature: Lovely Acuña
Position: Supervising SRS
Date: 02/19/2014

Received by
Name/Signature: JOIDA PRIETO
Position: SSRS
Date: 02/20/2014

Verified by
Name/Signature: JOIDA PRIETO
Position: SSRS
Date: 02/20/14

Figure A-5.2. Transfer Sheet for Butas Floodplain - B

DATA TRANSFER SHEET

Feb 21, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2/11/2014	1088A	3BLK28HS042A	AQUARIUS	N/A	781	1.23MB	269	~~25.4~~ 80.9GB	565	14	N/A	14.7	143	506	6	12	\\FREENAS\geostorage3\Airborne_Raw\1088A
2/11/2014	1090A	3BLK28J042B	AQUARIUS	N/A	215	822KB	156	19.4	162	4.96	N/A	14.7	143	267	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1090A
2/12/2014	1092A	3BLK28ABES043A	AQUARIUS	N/A	1657	1.70MB	242	23.7	601	12.7	N/A	15.4	123	364	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1092A
2/12/2014	1094A	3BLK28BS043B	AQUARIUS	N/A	332	2.27MB	128	~~22.1~~ 28.4GB	186	6.05	N/A	15.4	123	334	8	N/A	\\FREENAS\geostorage3\Airborne_Raw\1094A
2/13/2014	1096A	3BLK28NAJ044A	AQUARIUS	N/A	449	772KB	207	36.6	291	7.46	N/A	13.3	175	411	6	N/A	\\FREENAS\geostorage3\Airborne_Raw\1096A
2/13/2014	1098A	3BLK28JSI044B	AQUARIUS	N/A	582	954KB	235	23.9	291	11	N/A	13.3	175	725	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1098A
2/15/2014	1104A	3BLK28JSI046A	AQUARIUS	N/A	787	1.08MB	276	56.2	288KB&170KB	10.3	N/A	9.85	134	325	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1104A

Received from

Name: Lovely Acuña / [signature]
Position: Supervising SRS
Signature: [signature] 02/21/2014

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature]

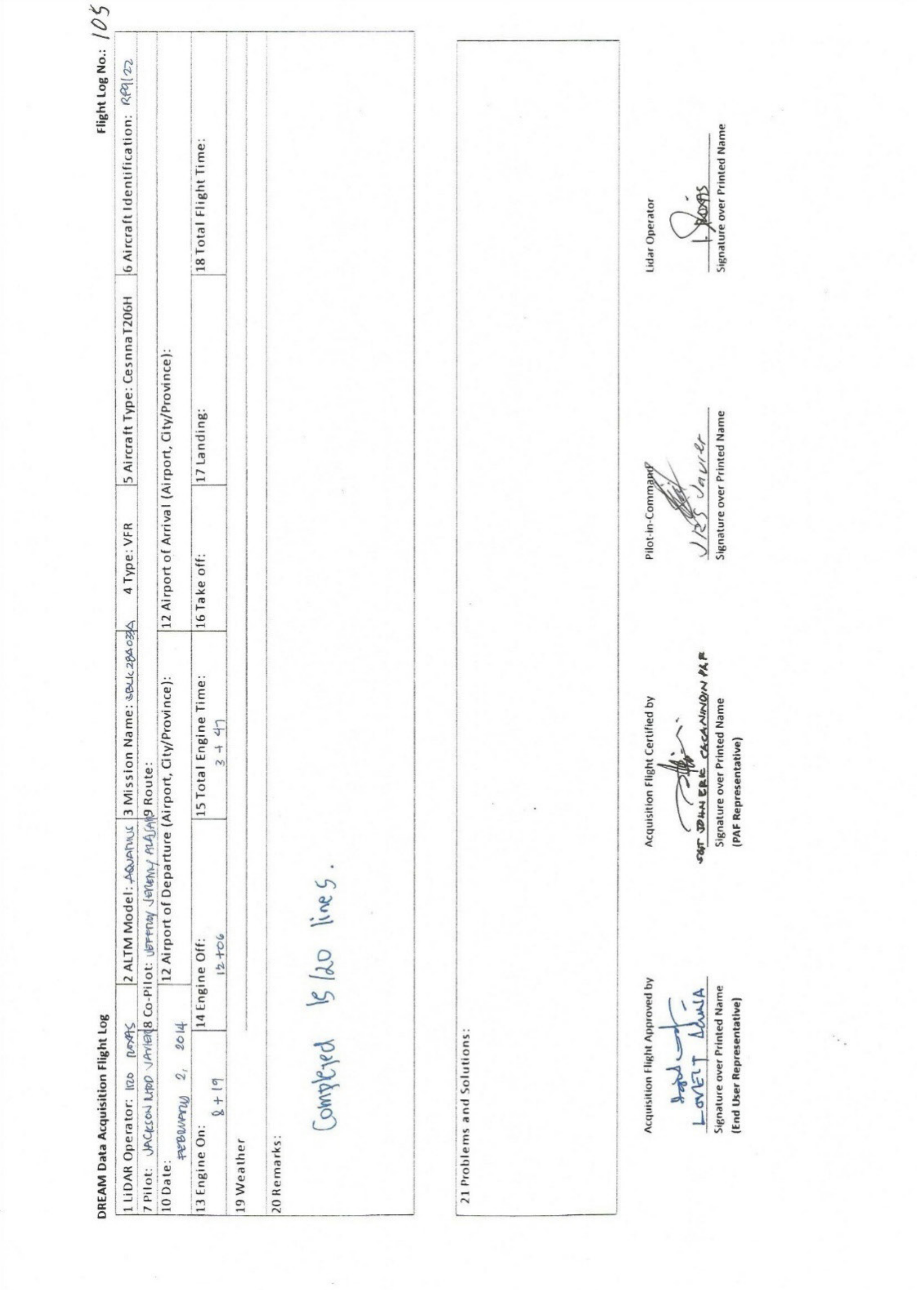
Verified by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature]

Figure A-5.3. Transfer Sheet for Butas Floodplain - C

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 3BLK28A033A



DREAM Data Acquisition Flight Log — Flight Log No.: 105

1 LiDAR Operator: I. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK28A033A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: Jackson Reid Javier	8 Co-Pilot: Jeffrey Jeremy Alajar	9 Route:			
10 Date: February 2, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8+19	14 Engine Off: 12+06	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 15/120 lines.					
21 Problems and Solutions:					

Acquisition Flight Approved by: Lovely T. Alvia — Signature over Printed Name (End User Representative)

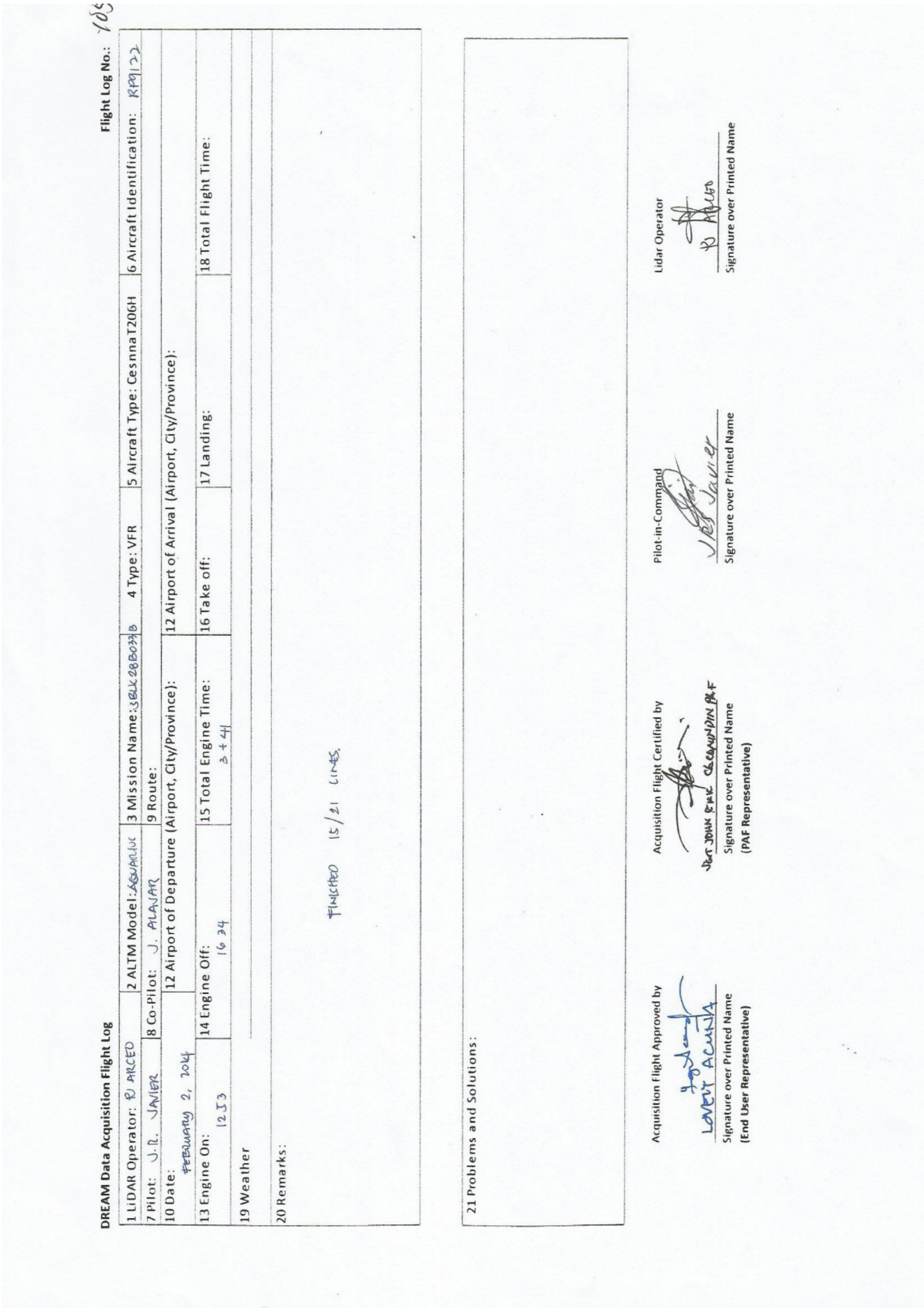
Acquisition Flight Certified by: SSGT John Eric Cacanindin PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: I. Roxas — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 3BLK28A033A

2. Flight Log for Mission 3BLK28B033B



DREAM Data Acquisition Flight Log

Flight Log No.: 105

1 LIDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28B033B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J.R. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEBRUARY 2, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1253	14 Engine Off: 1634	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 15/21 LINES					

21 Problems and Solutions:

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

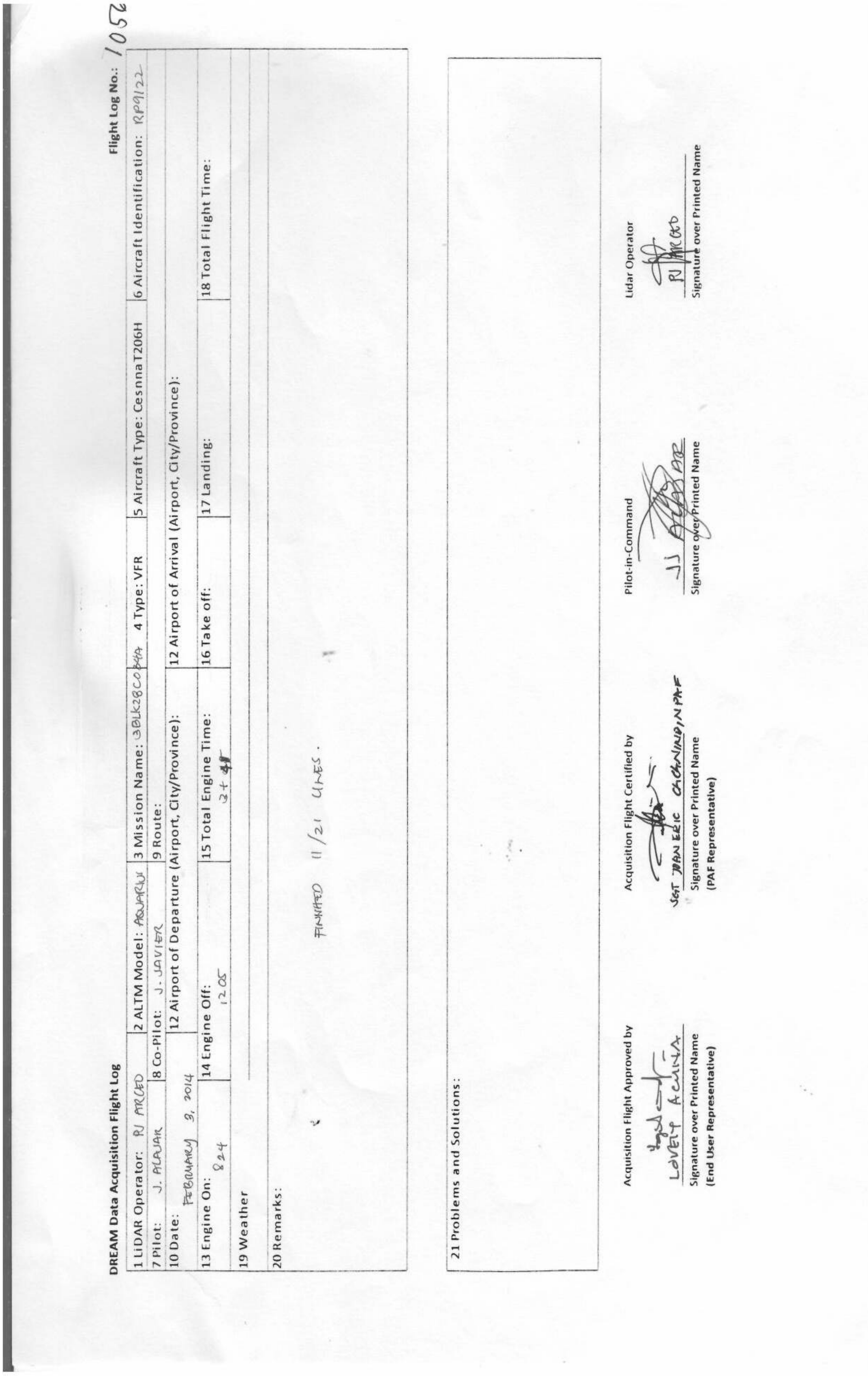
Acquisition Flight Certified by — SGT JOHN ERIC CLEMENDIN PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator — RJ Arceo — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 3BLK28B033B

3. Flight Log for Mission 3BLK28C034A



DREAM Data Acquisition Flight Log — Flight Log No.: 1052

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28C034A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEBRUARY 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 824	14 Engine Off: 1205	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 11/21 LINES.					

21 Problems and Solutions:

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

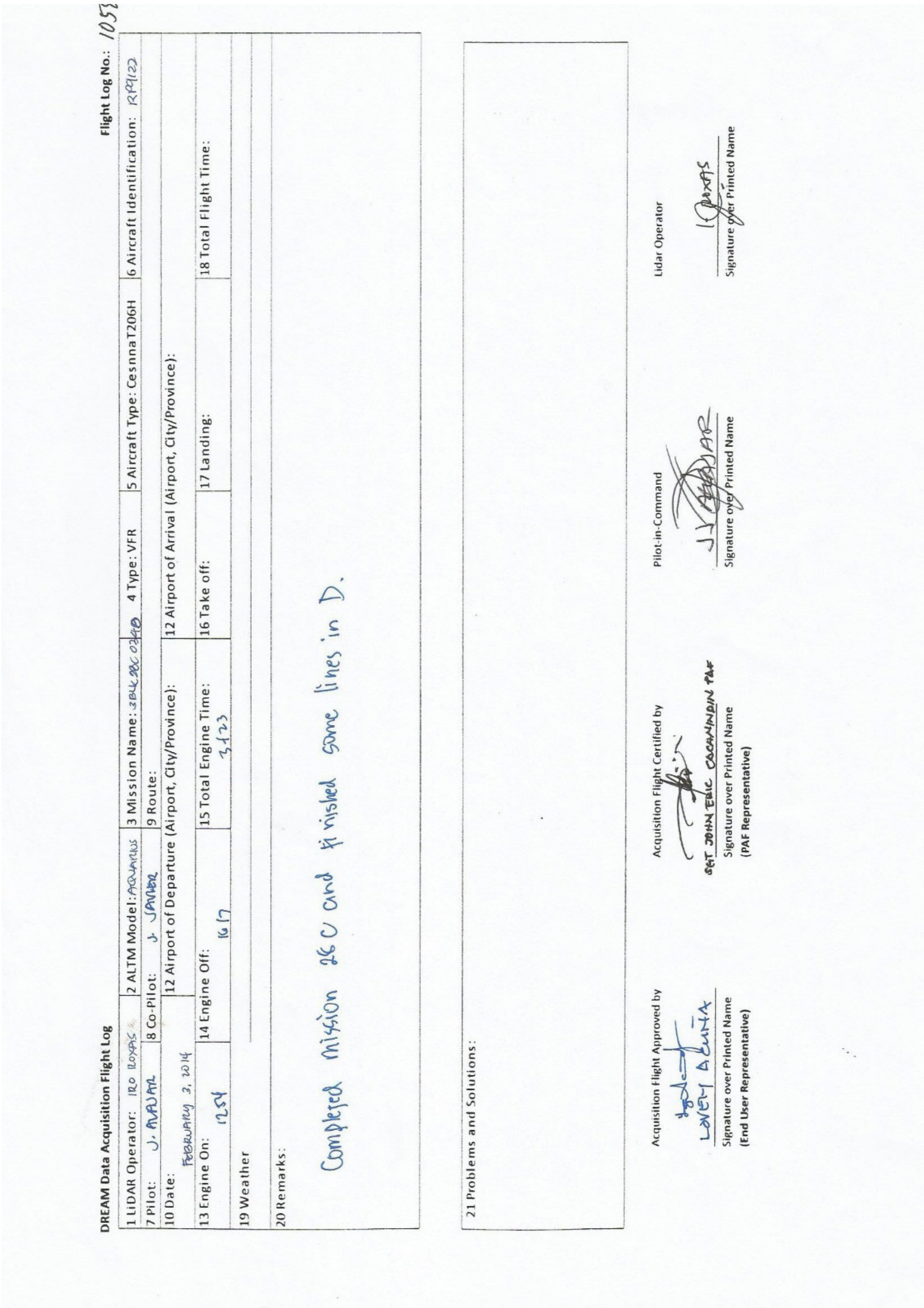
Acquisition Flight Certified by — SGT JOHN ERIC CACANINDIN PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command — JJ ALAJAR PAF — Signature over Printed Name

Lidar Operator — RJ ARCEO — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 3BLK28C034A

4. Flight Log for Mission 3BLK28CD034B



DREAM Data Acquisition Flight Log — Flight Log No.: 1053

1 LIDAR Operator: I.R.O. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK28CD034B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. Alburo	8 Co-Pilot: J. Javier	9 Route:			
10 Date: February 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1617	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission 28C and finished some lines in D.					
21 Problems and Solutions:					

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

Acquisition Flight Certified by: SGT John Eric Escamindin PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: I. Roxas — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 3BLK28CD034B

5.

6. Flight Log for Mission 3BLK28DS036A

DREAM Data Acquisition Flight Log

Flight Log No.: 1066

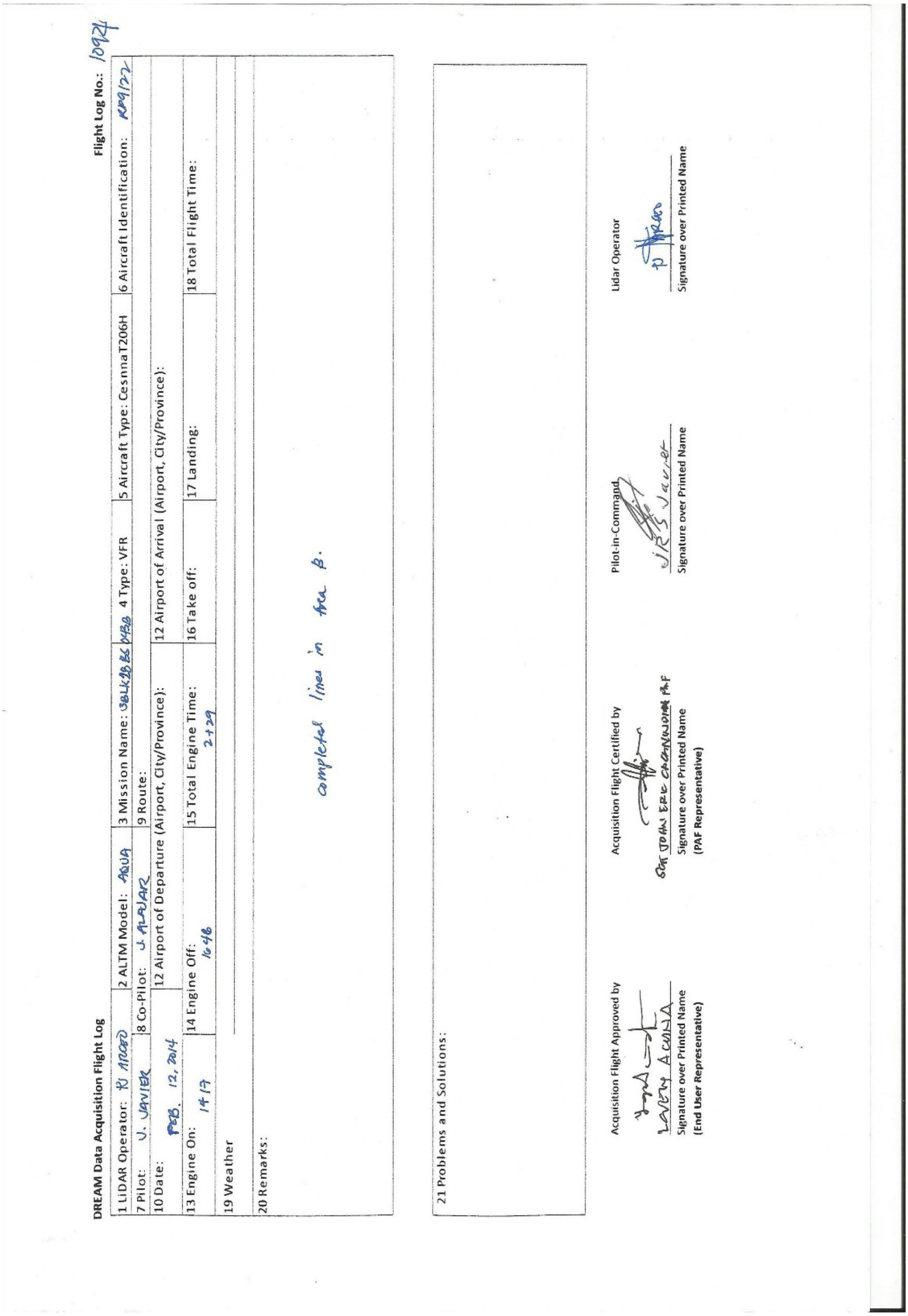
1 LiDAR Operator: PJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28DS036A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 5, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1349	14 Engine Off: 1724	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: COMPLETED 13/19 LINES. MISSION NOT COMPLETED DUE TO TIME CONSTRAINTS.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	SGT JOHN ERIC CASANINO PAF	J. JAVIER	PJ ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3BLK28DS036A

7. Flight Log for Mission 3BLK28BS043B



DREAM Data Acquisition Flight Log — Flight Log No.: 10924

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK28BS043B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 12, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1417	14 Engine Off: 1646	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed lines in Area B.					

21 Problems and Solutions:

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

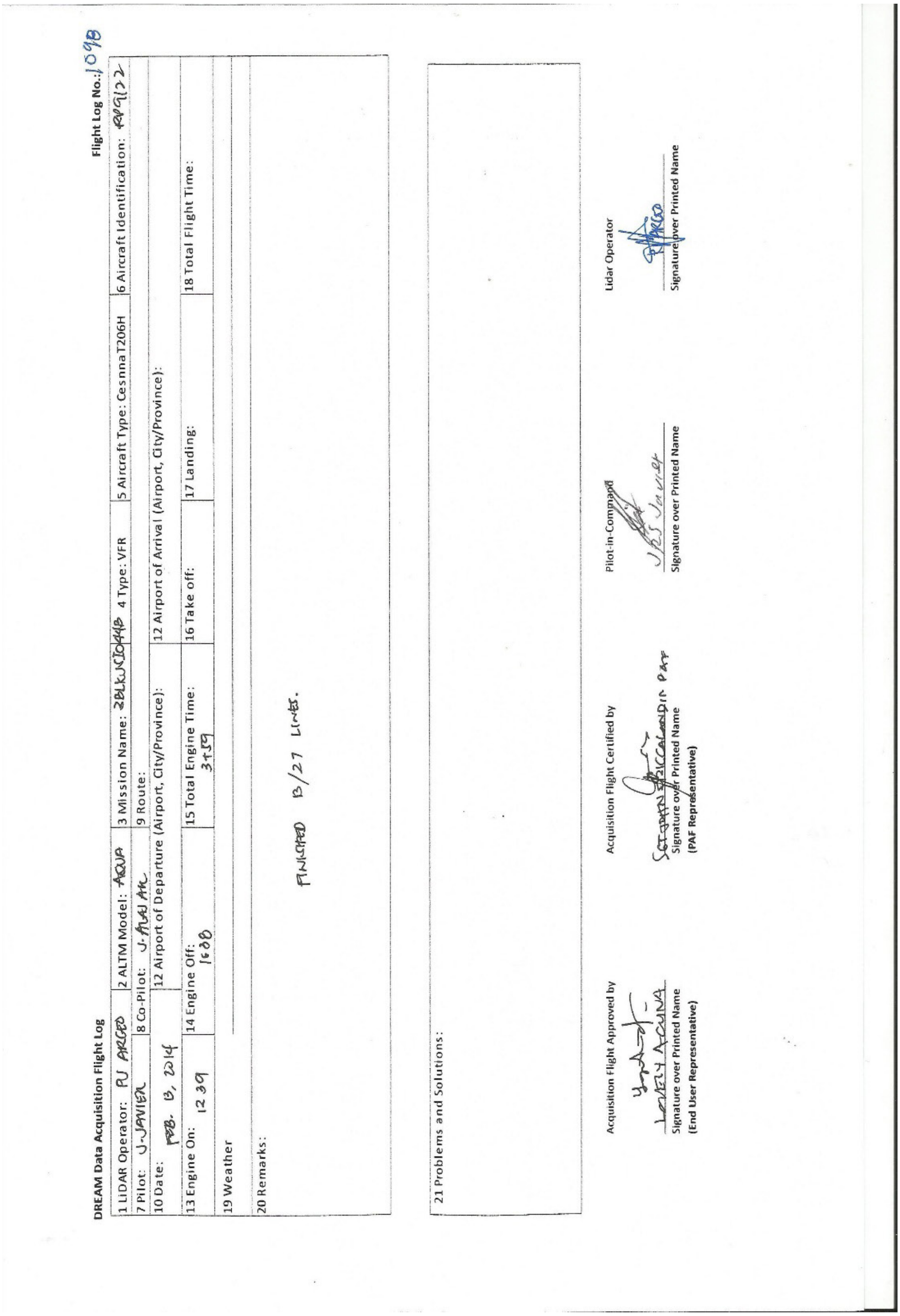
Acquisition Flight Certified by: SGT JOHN ERIC CAGANUJON PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: RJ Arceo — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 3BLK28BS043B

8. Flight Log for Mission 3BLK28JSI044B



DREAM Data Acquisition Flight Log — **Flight Log No.:** 1098

1 LiDAR Operator: PJ ARGEO	2 ALTM Model: AQUA	3 Mission Name: 3BLKJCIO44B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J-JAVIER	8 Co-Pilot: J-ALAJAR	9 Route:			
10 Date: FEB. 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1239	14 Engine Off: 1638	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 13/27 LINES.					

21 Problems and Solutions:

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

Acquisition Flight Certified by: SGT JOHN RICCALANDIR PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: PJ ARGEO — Signature over Printed Name

Figure A-6.7. Flight Log for Mission 3BLK28JSI044B

Annex 7. Flight Status Reports

BUTAS FLOODPLAIN

(February 2-15, 2014)

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1052A	BLOCK 28A	3BLK28A033A	IRO ROXAS	FEB 2, 2014	Finished 15 lines with occasional high dropout or more than 60-80%; not finished
1054A	BLOCK 28B	3BLK28B033B	PAULINE ARCEO	FEB 2, 2014	Change parameters due to high dropouts (600agl, 50pct, 18degrees scan angle), not finished
1056A	BLOCK 28C	3BLK28C034A	PAULINE ARCEO	FEB 3, 2014	Finished lower half of BLK28C
1058A	BLOCK 28CD	3BLK28CD034B	IRO ROXAS	FEB 3, 2014	Finished the rest of BLK28C and some lines of BLK28D
1066A	BLOCK 28D	3BLK28DS036A	PAULINE ARCEO	FEB 5, 2014	Survey 8 lines BLK28D
1094A	BLK 28B	3BLK28BS043B	PAU ARCEO	FEB 12, 2014	Mission Complete
1098A	BLK28J,I	3BLK28JSI044B	PAU ARCEO	FEB 13, 2014	Mission Complete

FLIGHT LOG NO. 1052A | Scan Freq: 45 kHz
AREA: BLOCK 28A | Scan Angle: 18 deg
MISSION NAME: 3BLK28A033A | Alt: 750 m

SURVEY COVERAGE:

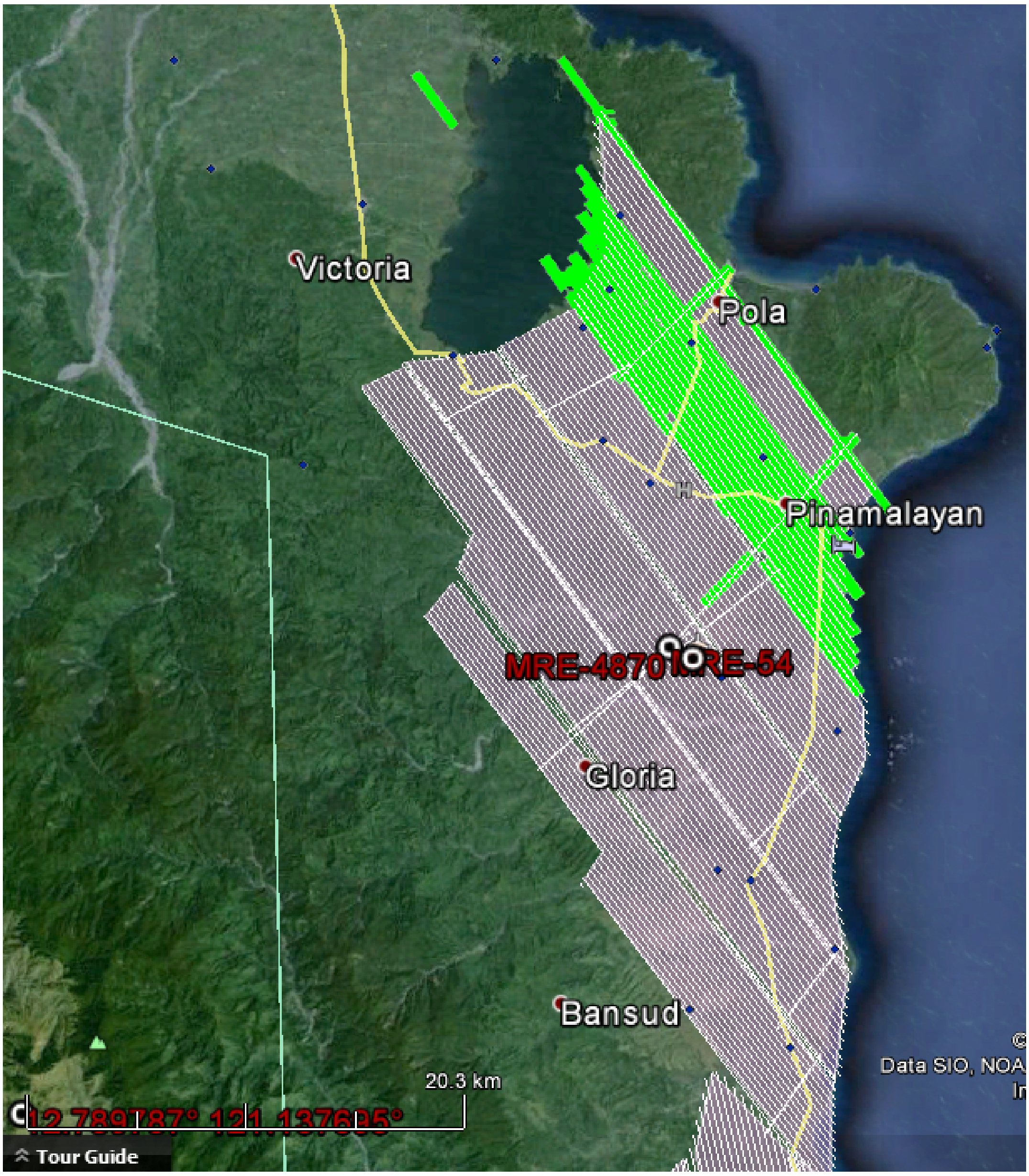


Figure A-7.1. Swath for Flight No. 1052A

FLIGHT LOG NO. 1054A
Scan Freq: 45 kHz
AREA: BLOCK 28B
Scan Angle: 18 deg
MISSION NAME: 3BLK28B033B
Alt: 600m

SURVEY COVERAGE:

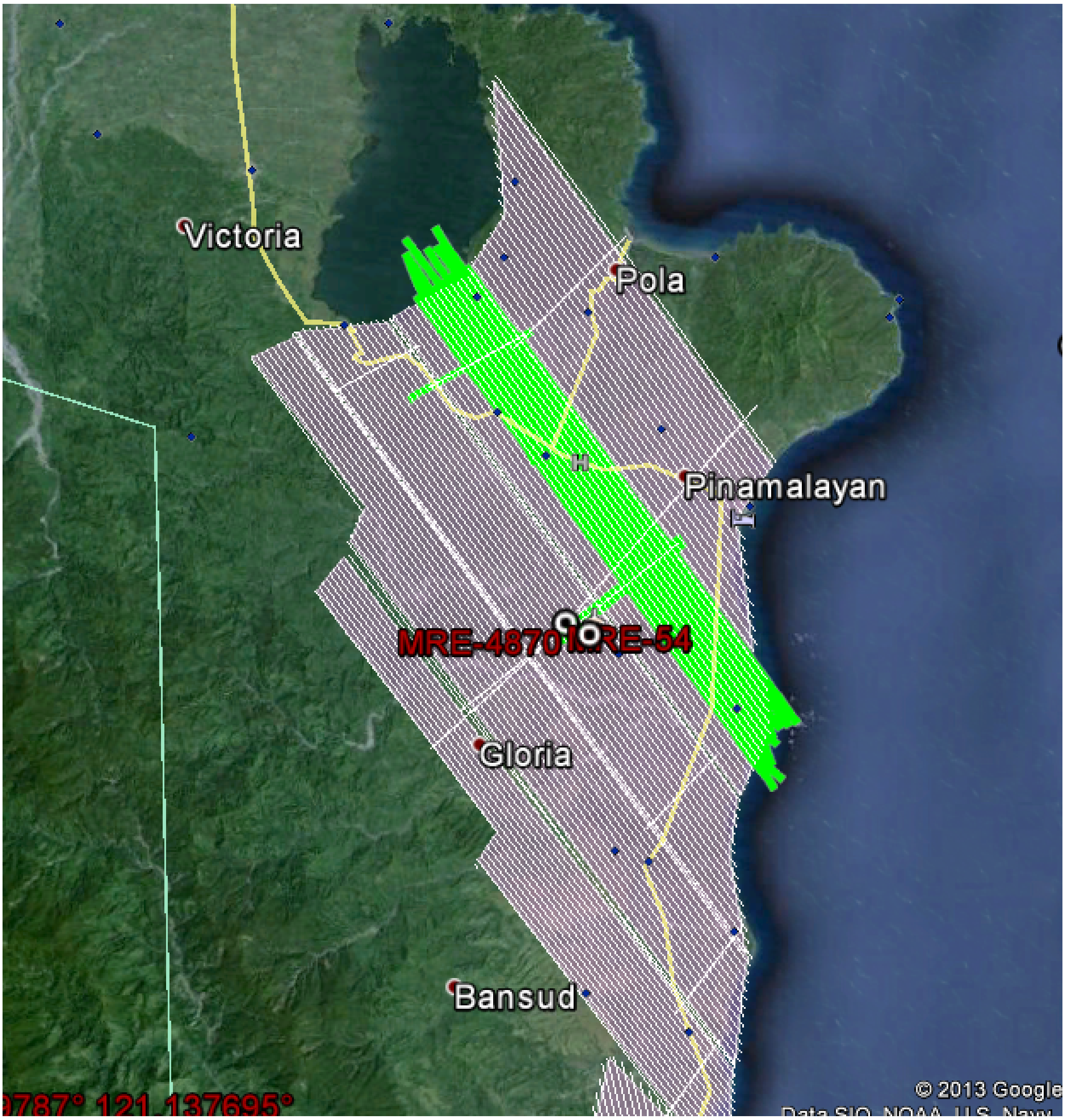


Figure A-7.2. Swath for Flight No. 1054A

FLIGHT LOG NO. 1056A Scan Freq: 45 kHz

AREA: BLOCK 28C Scan Angle: 18 deg

MISSION NAME: 3BLK28C034A Alt: 600 m

SURVEY COVERAGE:

Figure A-7.3. Swath for Flight No. 1056A

FLIGHT LOG NO. 1058A
Scan Freq: 45 kHz
AREA: BLOCK 28CD
Scan Angle: 18 deg
MISSION NAME: 3BLK28CD034B
Alt: 600 m

SURVEY COVERAGE:

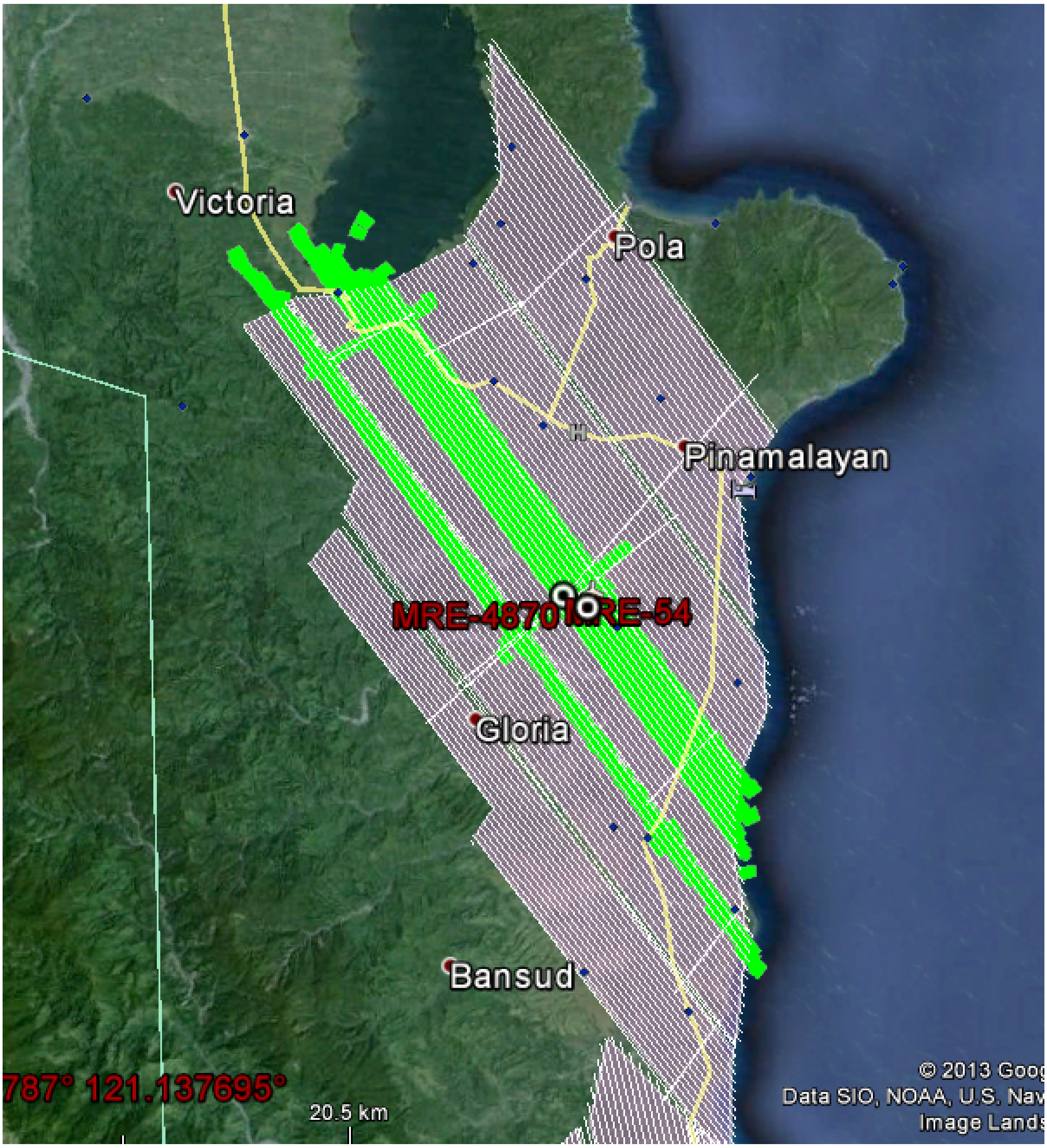


Figure A-7.4. Swath for Flight No. 1058A

FLIGHT LOG NO. 1066A Scan Freq: 45 kHz

AREA: BLOCK 28D Scan Angle: 18 deg

MISSION NAME: 3BLK28DS036A Alt: 600 m

SURVEY COVERAGE:

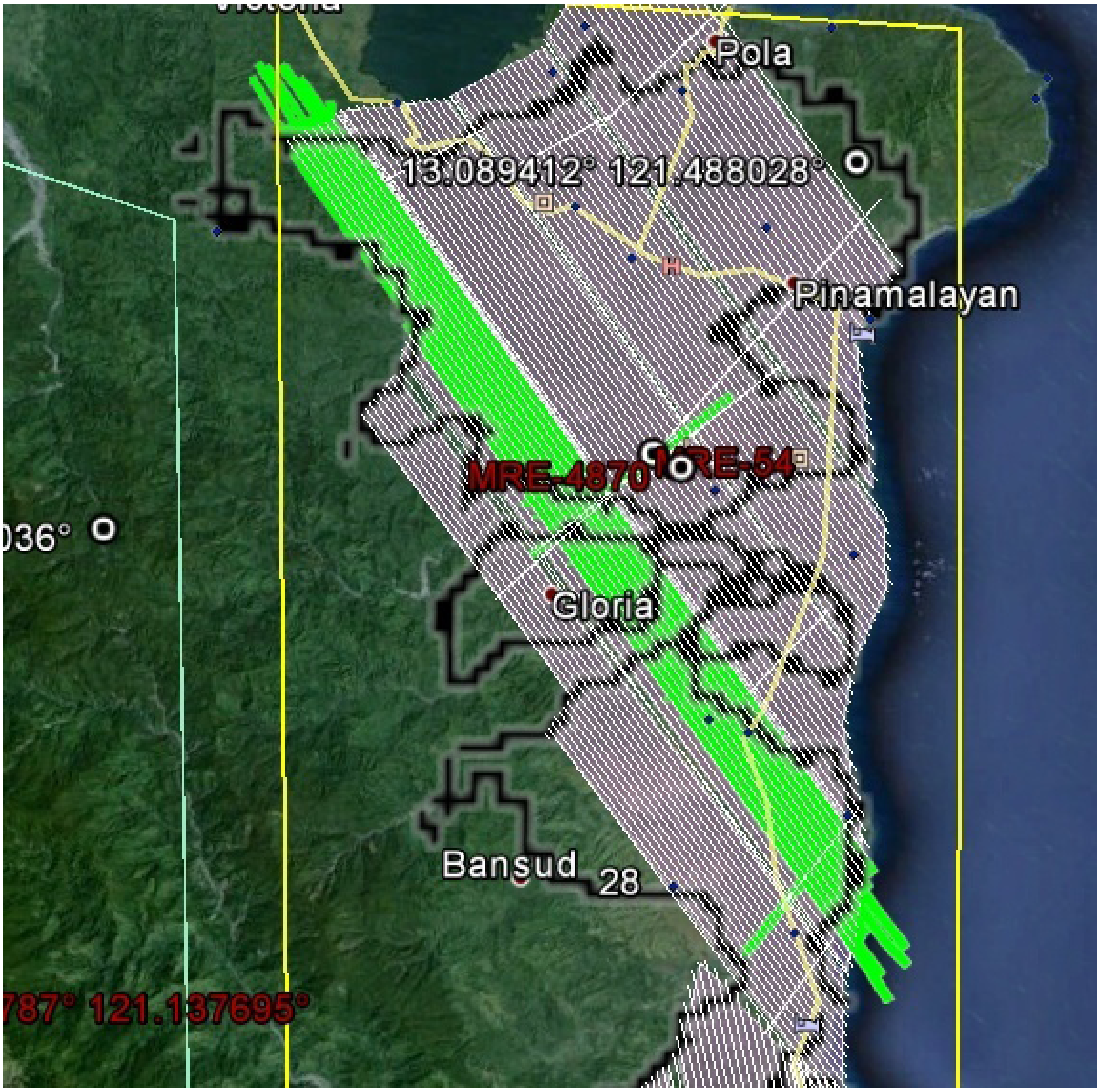


Figure A-7.5. Swath for Flight No. 1066A

FLIGHT LOG NO. 1094A

AREA: BLOCK 28B

MISSION NAME: 3BLK28BS043B

Scan Freq: 45 kHz

Scan Angle: 18 deg

Alt: 600 m

SURVEY COVERAGE:

Figure A-7.6. Swath for Flight No. 1094A

FLIGHT LOG NO. 1098A
Scan Freq: 45 kHz
AREA: BLOCK 28JI
Scan Angle: 18 deg
MISSION NAME: 3BLK28JSI044B
Alt: 600 m

SURVEY COVERAGE:

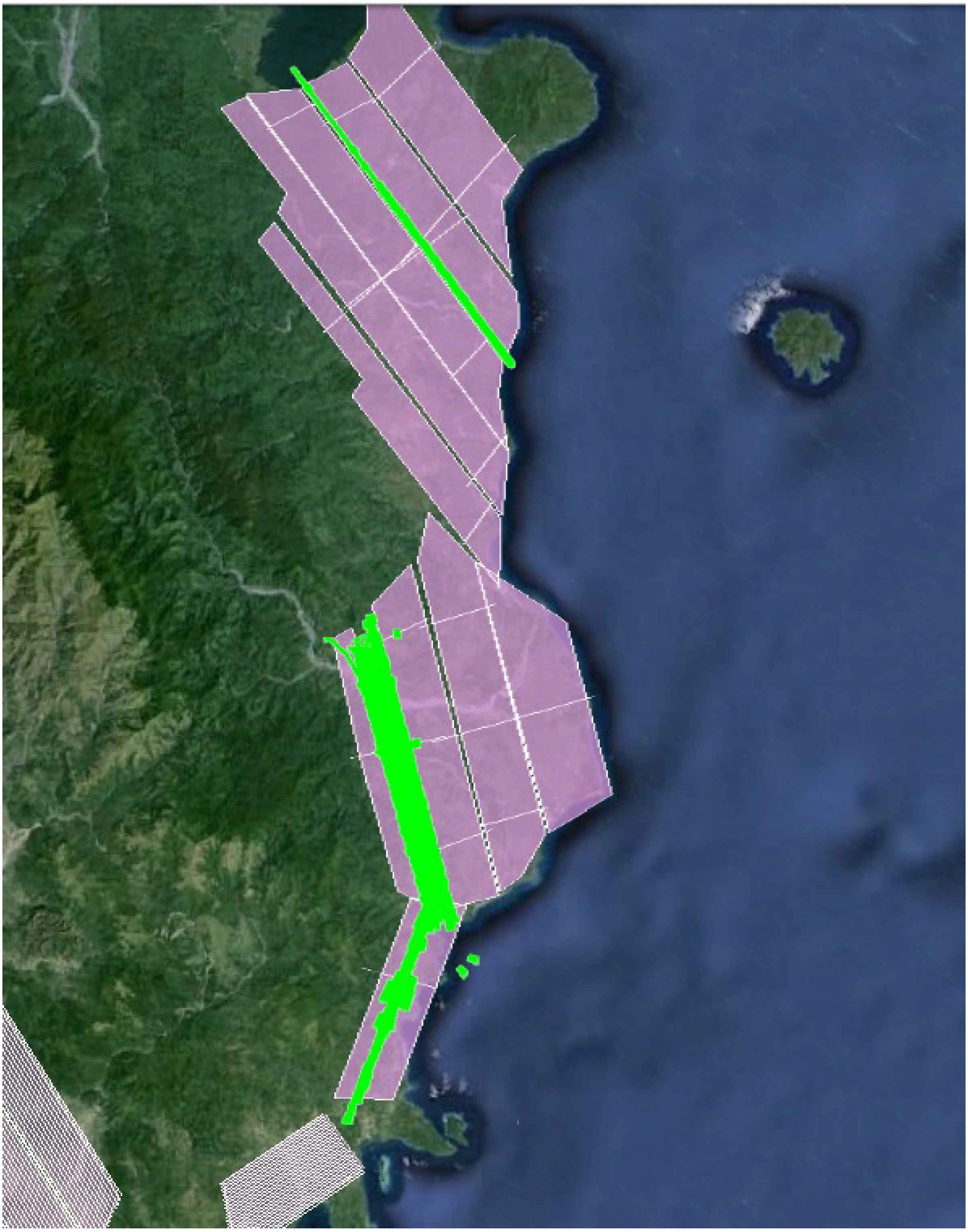


Figure A-7.7. Swath for Flight No. 1098A

Annex 8. Mission Summary Reports

Annex 9. Butas Model Basin Parameters

Table A-9.1. Butas Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W140	7.5477	62.7231	0.0	2.5849	1.4062	0.14049	0.5	0.5
W160	10.0663	55.7843	0.0	1.6139	0.87795	0.0232232	0.5	0.5
W170	0.5218	89.084	0.0	10.045	2.3218	2.0604	0.6	0.125
W180	0.2158	99	0.0	8.6133	1.4632	0.87581	0.59979	0.125
W190	0.27255	99	0.0	1.2664	0.34327	0.0435890	0.54	0.12311
W200	0.2916	99	0.0	7.5586	1.7801	0.42566	0.60297	0.125
W210	0.2855	99	0.0	8.4144	1.9914	0.77287	0.6	0.125
W220	0.55355	85.822	0.0	12.841	2.2513	1.2212	0.6	0.125
W230	0.54251	90.18	0.0	3.2127	1.1291	0.0980601	0.59961	0.12311
W240	0.55275	86.4	0.0	8.4643	1.3372	0.63144	0.6	0.125
W250	0.55275	86.4	0.0	9.6014	2.2262	0.72377	0.6	0.125
W260	0.55265	86.434	0.0	7.3558	1.1494	0.58350	0.6	0.125
W280	6.8586	64.9330	0.0	10.737	5.8411	1.2173	0.5	0.5
W290	0.17467	99.0000	0.0	20.11	4.6411	2.1827	0.6	0.125

Annex 10. Butas Model Reach Parameters

Table A-10.1. Butas Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	1787.0	0.0090663	0.04	Trapezoid	12.454	1
R130	Automatic Fixed Interval	9610.7	0.0017142	0.04	Trapezoid	12.454	1
R300	Automatic Fixed Interval	8183.0	0.0191645	0.0143734	Trapezoid	12.454	1
R40	Automatic Fixed Interval	573.55	0.0288895	0.0318506	Trapezoid	12.454	1
R70	Automatic Fixed Interval	740.12	0.0297723	0.006659	Trapezoid	12.454	1
R80	Automatic Fixed Interval	2478.1	0.0441871	0.0098194	Trapezoid	12.454	1
R90	Automatic Fixed Interval	1886.5	0.0994577	0.0221945	Trapezoid	12.454	1

Annex 11. Butas Field Validation Points

Table A-11.1. Butas Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
1	13.077145	121.361431	0.03	0.00	-0.03	Nona / Dec. 15, 2015	25-Year
2	13.080197	121.361205	0.6	1.33	0.73	Nona / Dec. 15, 2015	25-Year
3	13.080467	121.361412	0.69	2.30	1.61	Nona / Dec. 15, 2015	25-Year
4	13.08245	121.363233	0.03	0.00	-0.03	Nona / Dec. 15, 2015	25-Year
5	13.082607	121.360412	0.03	0.00	-0.03	Nona / Dec. 15, 2015	25-Year
6	13.079069	121.361104	1.16	0.80	-0.36	Nona / Dec. 15, 2015	25-Year
7	13.07706	121.361244	0.03	0.00	-0.03	Nona / Dec. 15, 2015	25-Year
8	13.080025	121.368757	0.82	0.16	-0.66	Nona / Dec. 15, 2015	25-Year
9	13.08271	121.368636	0.03	0.00	-0.03	Nona / Dec. 15, 2015	25-Year
10	13.076873	121.36245	0.53	0.97	0.44	Nona / Dec. 15, 2015	25-Year
11	13.076679	121.36226	0.03	0.72	0.69	Nona / Dec. 15, 2015	25-Year
12	13.076189	121.362372	0.03	0.00	-0.03	Nona / Dec. 15, 2015	25-Year
13	13.075703	121.362296	1.32	1.10	-0.22	Nona / Dec. 15, 2015	25-Year
14	13.075473	121.362299	0.98	0.94	-0.04	Nona / Dec. 15, 2015	25-Year
15	13.075138	121.362092	0.94	0.78	-0.16	Nona / Dec. 15, 2015	25-Year
16	13.074904	121.361764	1.36	0.48	-0.88	Nona / Dec. 15, 2015	25-Year
17	13.074721	121.36166	0.94	0.00	-0.94	Nona / Dec. 15, 2015	25-Year
18	13.074722	121.367846	1.18	0.90	-0.28	Nona / Dec. 15, 2015	25-Year
19	13.074712	121.368	1.16	0.91	-0.25	Nona / Dec. 15, 2015	25-Year
20	13.075025	121.368065	0.81	0.64	-0.17	Nona / Dec. 15, 2015	25-Year
21	13.074855	121.367931	1.12	0.75	-0.37	Nona / Dec. 15, 2015	25-Year
22	13.123448	121.37186	0.37	0.60	0.23	Nona / Dec. 2015	25-Year
23	13.122894	121.37039	0.03	0.50	0.47	Nona / Dec. 2015	25-Year
24	13.121724	121.36979	0.03	0.08	0.05	Nona / Dec. 2015	25-Year
25	13.122916	121.37057	0.03	1.32	1.29	Nona / Dec. 2015	25-Year
26	13.123192	121.37089	0.14	0.70	0.56	Nona / Dec. 2015	25-Year
27	13.123462	121.37158	0.38	0.97	0.59	Nona / Dec. 2015	25-Year
28	13.123448	121.37186	0.37	1.05	0.68	Nona / Dec. 2015	25-Year
29	13.123285	121.37149	0.45	0.70	0.25	Nona / Dec. 15, 2015	25-Year
30	13.123285	121.37149	0.45	0.70	0.25	Nona / Dec. 15, 2015	25-Year
31	13.124223	121.37067	0.07	0.73	0.66	Nona / Dec. 15, 2015	25-Year
32	13.124648	121.37055	0.1	0.71	0.61	Nona / Dec. 15, 2015	25-Year
33	13.125005	121.36974	0.15	0.41	0.26	Nona / Dec. 15, 2015	25-Year
34	13.125087	121.36882	0.03	0.47	0.44	Nona / Dec. 15, 2015	25-Year
35	13.125648	121.36836	0.03	0.20	0.17	Nona / Dec. 15, 2015	25-Year
36	13.12754	121.36693	0.03	0.48	0.45	Nona / Dec. 15, 2015	25-Year
37	13.1227	121.3714	0.52	0.80	0.28	Nona / Dec. 15, 2015	25-Year
38	13.1278	121.3664	0.05	0.24	0.19	Nona / Dec. 15, 2015	25-Year
39	13.111531	121.31722	0.08	1.50	1.42	Rosing / 1993	25-Year

40	13.111304	121.31812	0.83	0.90	0.07	Nina / Dec. 2016	25-Year
41	13.107547	121.32514	0.51	6.00	5.49	Rosing / 1993	25-Year
42	13.107364	121.32573	0.14	2.49	2.35	Nona / Dec. 2015	25-Year
43	13.107341	121.32654	0.06	0.00	-0.06	Nona / Dec. 2015	25-Year
44	13.107153	121.32669	0.04	0.00	-0.04		25-Year
45	13.10714	121.32587	0.06	0.00	-0.06	Nona / Dec. 2015	25-Year
46	13.111445	121.31552	0.29	0.12	-0.17	Nina / Dec. 2016	25-Year
47	13.111486	121.31544	0.12	0.69	0.57	Nina / Dec. 2016	25-Year
48	13.111488	121.31547	0.12	0.45	0.33	Nina / Dec. 2016	25-Year
49	13.111108	121.31619	0.23	0.00	-0.23		25-Year
50	13.111122	121.31621	0.23	0.12	-0.11	Nona / Dec. 2015	25-Year
51	13.111476	121.31608	0.22	0.24	0.02	Nina / Dec. 2016	25-Year
52	13.111557	121.31616	0.08	0.92	0.84	Nina / Dec. 2016	25-Year
53	13.110882	121.31614	0.22	0.00	-0.22	Nina / Dec. 2016	25-Year
54	13.11046	121.31607	0.03	0.00	-0.03	Nona / Dec. 2015	25-Year
55	13.087536	121.32406	1.47	0.00	-1.47	Nona / Dec. 2015	25-Year
56	13.087359	121.32412	1.18	0.00	-1.18	Nona / Dec. 2015	25-Year
57	13.086909	121.3242	9.51	1.26	-8.25	Nona / Dec. 2015	25-Year
58	13.092395	121.32571	0.03	0.00	-0.03		25-Year
59	13.092721	121.32639	0.03	0.00	-0.03		25-Year
60	13.093022	121.33532	0.03	0.00	-0.03		25-Year
61	13.093347	121.33453	0.03	0.00	-0.03		25-Year
62	13.096837	121.34005	0.03	0.00	-0.03		25-Year
63	13.095432	121.34714	0.03	0.00	-0.03		25-Year
64	13.090735	121.35292	0.03	0.00	-0.03		25-Year
65	13.087783	121.35499	0.03	0.00	-0.03		25-Year
66	13.085444	121.35682	0.03	0.00	-0.03		25-Year
67	13.084359	121.35883	0.03	0.00	-0.03		25-Year
68	13.10757	121.3275	0.46	1.10	0.64	Nona / Dec. 2015	25-Year
69	13.106905	121.33143	0.03	0.00	-0.03		25-Year
70	13.104396	121.33201	0.03	0.00	-0.03	Nona / Dec. 2015	25-Year
71	13.103154	121.35264	0.03	0.00	-0.03		25-Year
72	13.106448	121.35507	0.03	0.00	-0.03		25-Year
73	13.107047	121.36018	0.03	0.00	-0.03		25-Year
74	13.110079	121.36574	0.03	0.00	-0.03		25-Year
75	13.074426	121.36484	0.14	0.50	0.36	Nona / Dec. 2015	25-Year
76	13.075493	121.36349	0.1	0.00	-0.1		25-Year

Annex 9. Phil-LiDAR 1 UPLB Team Composition

Project Leader
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