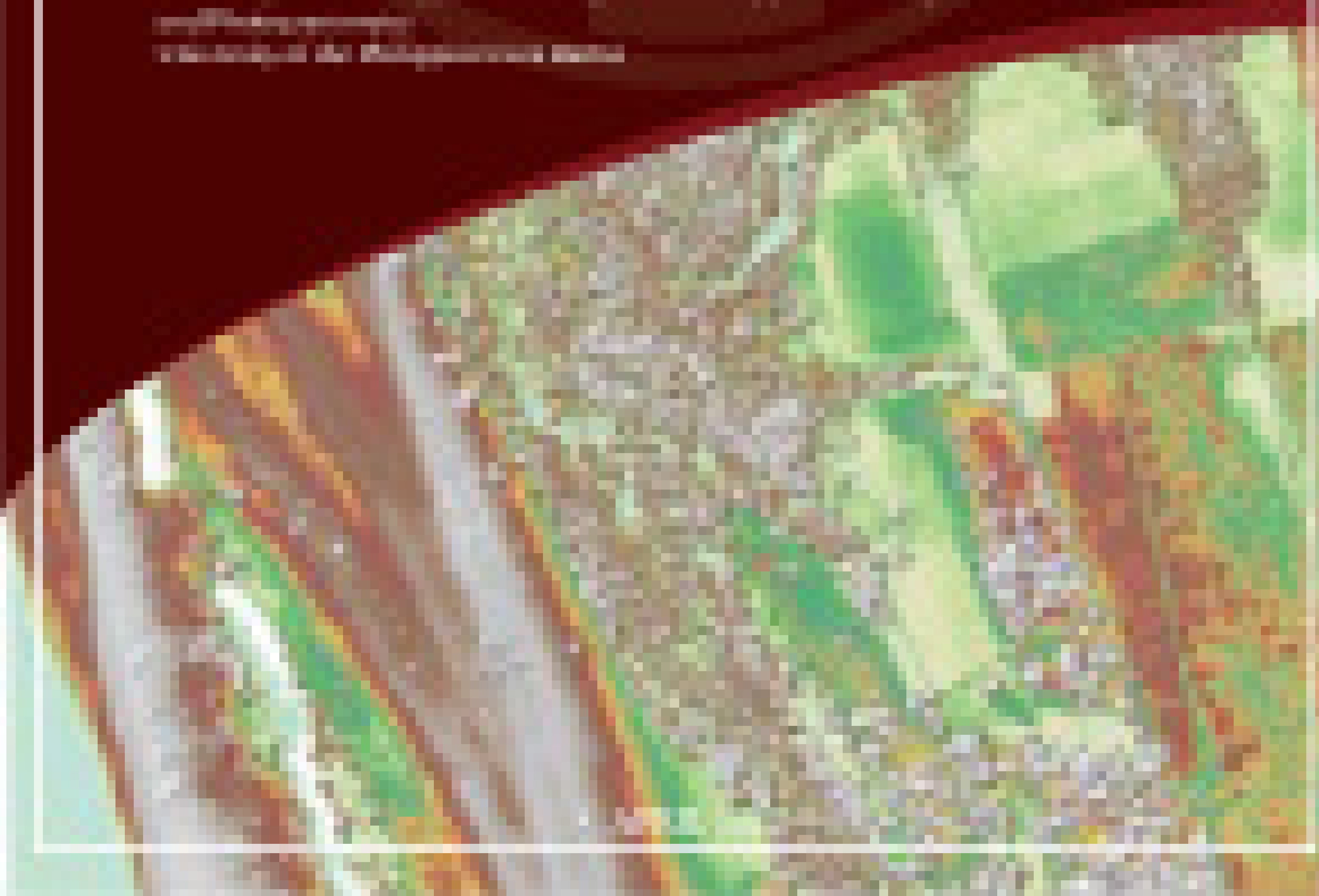
LiDAR Surveys and Flood Mapping of Pola River



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
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
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UPLB	University of the Philippines Los Baños
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND POLA RIVER

Enrico C. Paringit, Dr. Eng. and Asst. Prof. Edwin R. Abucay

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Phiippines 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 forty-five (45) river basins in the Southern Luzon region. The university is located in the municipality of Los Baños in the province of Laguna.

1.2 Overview of the Pola River Basin

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

The DENR River Basin Control Office (RCBO) identified the Pola river basin as one of the 421 river basins in the Philippines, having a drainage area of 288 sq. km and an estimated 461 million cubic meter (MCM) annual run-off.

Its main stem, Pola River stream network ,traverses the Barangay Poblacion I and small portion of Barangay Casague, both in Municipality of Sta. Cruz. There is a total of 4,511 people residing within the two barangays along the river according to the 2010 to Philippine Statistics Authority Census. The most recent flooding event of the river was on September 2013 due to Southwest Monsoon.

Pola River is a 14,100-ha watershed located in Occidental Mindoro partially covering the barangays of Poblacion 1 and 2, Casague, Lumangbayan, Kurtinganan and San Vicente.In terms of geology, the extent of Pola river basin in the Municipality of Sta. Cruz are mainly classified into Basement Complex (Pre-Jurrasic), Recent, and Paleocene-Eocene (Sedimentary and Metamorphic Rocks). The slope of the areas covered by Pola river basin are mainly partitioned into steep (30-50%) and very steep (>50%). The elevation of the areas covered by Pola river basin primarily ranges from 10 to above 300 meters above sea level (masl). Soils in the area include Quiangua silt loam, Alaminos silty clay loam, San Manuel sandy loam, Banto clay loam, Faraon clay/river wash, and Banto clay loam. However, large areas are still unclassified (rough mountainous land) and beach sand. The most dominant land cover type in the area is other land (natural grassland) and other wooded land mainly shrubs.

Pola river basin discloses barangay Poblacion 2, Kurtinganan and San Vicente attributable to extent of its main stream network ended in barangay Casague. Based on the 2010 NSO Census of Population and Housing, Casague is the most populated barangay in the area.

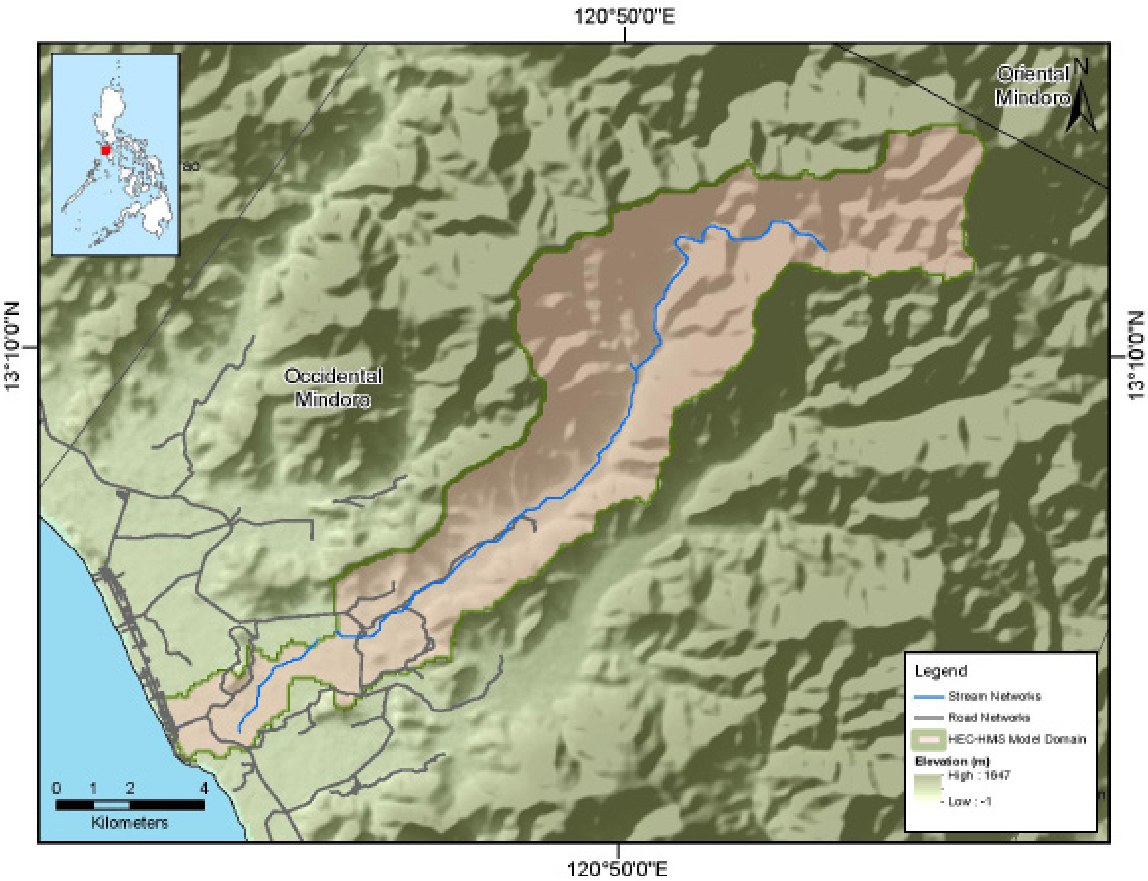

Figure 1. Map of Pola River Basin (in brown)

Based on the studies conducted by the Mines and Geosciences Bureau, all the barangays have low to high susceptibilities to flood and landslides, respectively. Poblacion 1 in Sta. Cruz has high susceptibilities to flooding. The field surveys conducted by the PHIL-LiDAR 1 validation team showed severalweather disturbances thatcaused flooding: 1998 (Loleng), 2006 (Reming), 2009 (Reming), 2011 (Pedring), 2012 (Pablo),2013 (Yolanda), 2014 (Glenda), 2015 (Nona) and 2016 (Karen and Nina).

CHAPTER 2: LIDAR ACQUISITION IN POLA FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, and Engr. Gerome Hipolito

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 PolaFloodplain in Occidental Mindoro. These missions were planned for 20 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 and Table 2. Figure 2shows the flight plan for Pola Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK29H	600	30	36	50	40	130	5
BLK29I	600	30	36	50	40	130	5
BLK29O	600	30	40, 36	50	40	110	5

Table 2. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK29A	1400	30	40	150	30	115	5
BLK29B	1100	30	50	200	30	130	5
BLK29C	1200	30	50	200	30	115	5
BLK29D	1400	30	40	150	30	115	5
BLK29E	1400	30	40	150	30	115	5
BLK29I	1100	30	50	200	30	130	5

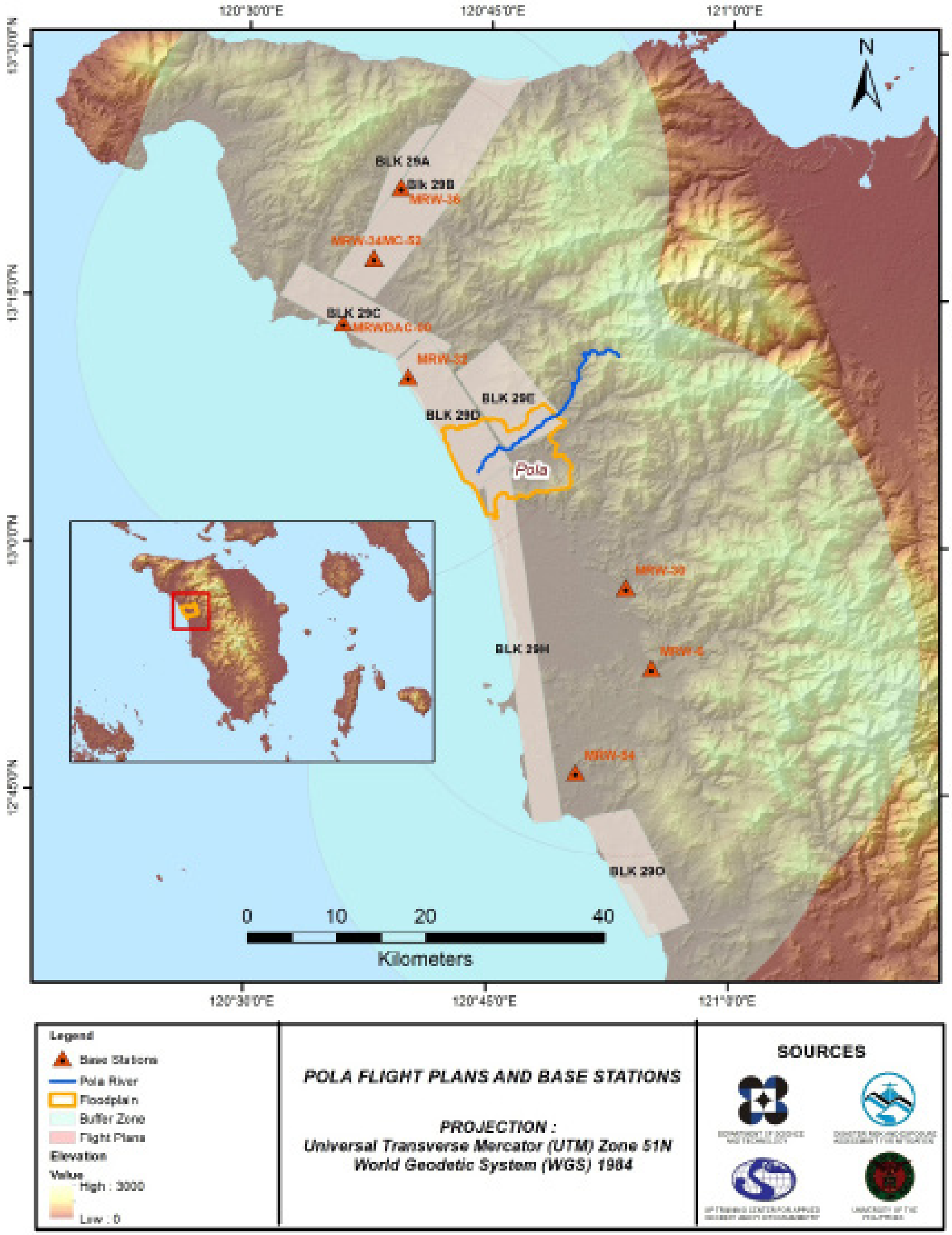

Figure 2. Flight plans and base stations used for Pola Floodplain

2.2 Ground Base Station

The project team was able to recover four(4) NAMRIA ground control points: MRW-30, MRW-32, MRW-34 and MRW-36which areof second (2nd) order accuracy.One (1) NAMRIA bench mark: MC-52 was recovered. This benchmark was used as vertical reference point and was also established as ground control point. The project team also establishedone (1) ground control point, MRWDAC-00.The certifications for the NAMRIA reference points are found in Annex 2, while the baseline processing reports for the NAMRIA benchmark and established point are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 19 - 23, 2014; December 6-8, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in PolaFloodplain are shown in Figure 2.

Figure 3to Figure 7show the recovered NAMRIA reference points within the area, in addition Table 3 to Table 10show the details about the following NAMRIA control stations and established points, Table 11shows the list of all ground control points occupied during the acquisition together with the dates they wereutilized during the survey.

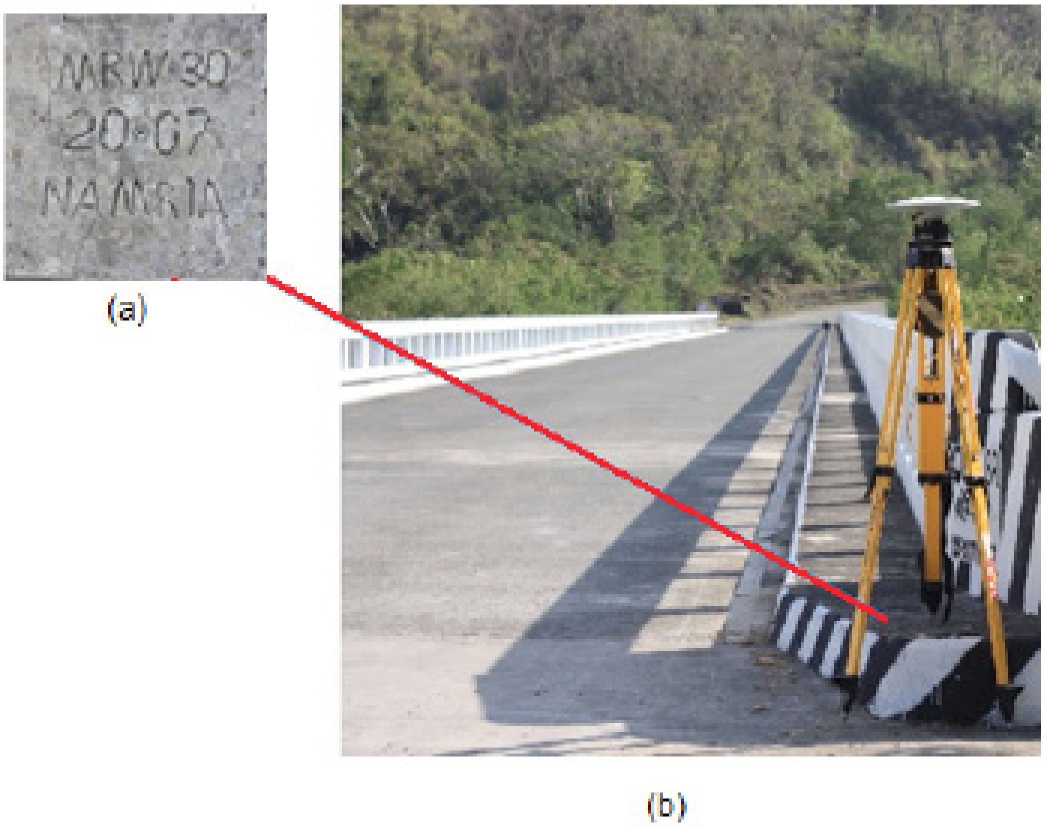

Figure 3. GPS set-up over MRW-30as recovered in Amnay Bridge in Brgy. Pinagturilan, municipality of Sta. Cruz, Occidental Mindoro (a) and NAMRIA reference point MRW-30 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point MRW-30 used as base station for the LiDAR acquisition

Station Name	MRW-30	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°57’32.22950” North 120°53’28.50896” East 42.01300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	488201.05 meters 1433011.7 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°57’27.19115” North 120°53’33.54442” East 89.79300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	271237.33 meters 1433451.97 meters

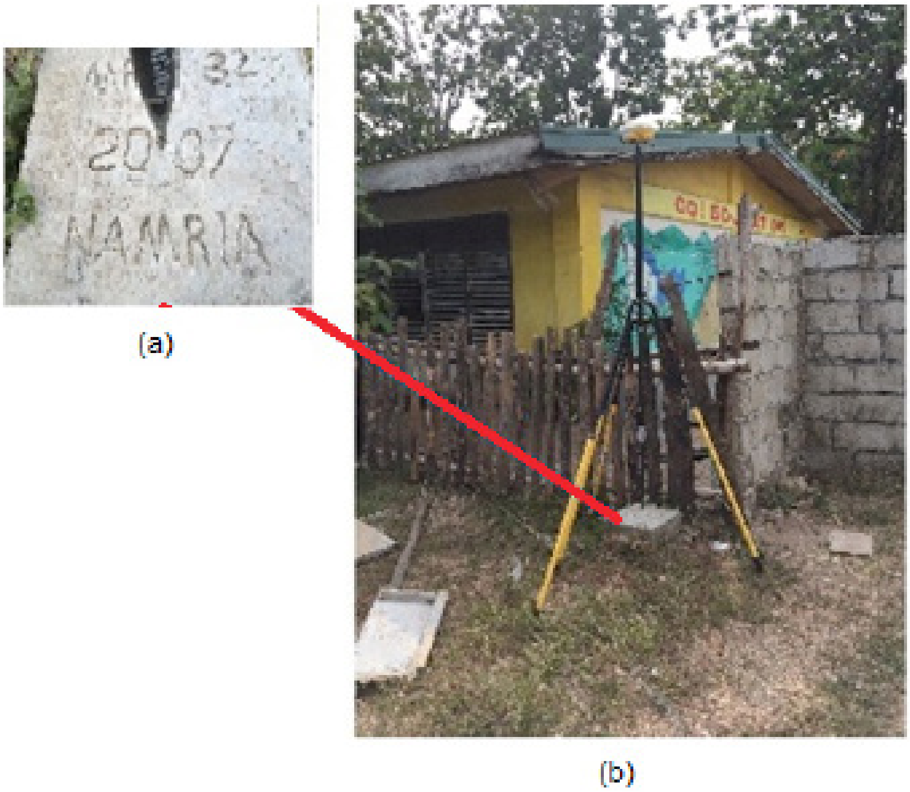

Figure 4. GPS set-up over MRW-32 as recovered in the corner of a day care center in Brgy. Fatima, municipality of Mamburao, Occidental Mindoro (a) and NAMRIA reference point MRW-32 (b) as recovered by the field

Table 4. Details of the recovered NAMRIA horizontal control point MRW-32 used as base station for the LiDAR acquisition

Station Name	MRW-32	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°10’14.92094” North 120°39’52.29557” East 1.47400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	463632.46 meters 1456469.064 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°10’9.81293” North 120°39’57.31386” East 48.13600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	246845.90 meters 1457111.12 meters

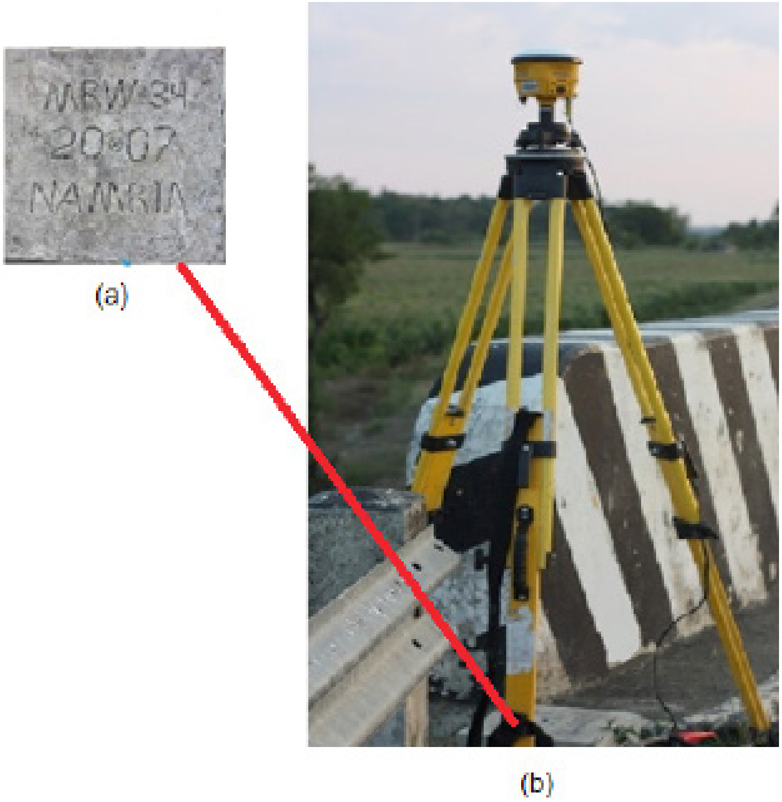

Figure 5. 5GPS set-up over MRW-34 as recovered in Balibago Bridge in Brgy. Armado, municipality of Abrade Ilog, Occidental Mindoro (a) and NAMRIA reference point MRW-34 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point MRW-34 used as base station for the LiDAR acquisition

Station Name	MRW-34	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°17'25.00981" North 120°37'41.53630" East 8.01600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	459714.493 meters 1469690.588 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°17'19.87026" North 120°37' 46.54446" East 54.26900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	243032.08 meters 1470369.33 meters

Figure 6. GPS set-up over MRW-36as recovered in Baclaran Bridge in Brgy. Cabacao, municipality of Abra de Ilog, Occidental Mindoro (a) and NAMRIA reference point MRW-36 (b) as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point MRW-36 used as base station for the LiDAR acquisition

Station Name	MRW-36	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°21'44.07349" North 120°39'20.54160" East 31.49300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	462705.446 meters 1477646.985 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°21'38.91908" North 120°39'25.54340" East 77.62100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	246088.34 meters 1478304.87 meters

Figure 7. GPS set-up over MC-52as recovered in Balibago Bridge in Brgy. Armado, municipality of Abra de Ilog, Occidental Mindoro (a) and NAMRIA bench mark MC-52 (b) as recovered by the field team

Table 7. Details of the recovered NAMRIA Benchmark MC-52with processed coordinates used as base station for the LiDAR acquisition

Station Name	MC-52	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude	13° 17’ 25.66996” North 120° 37’ 41.97783” East
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 17’ 20.53041” North 120° 37’ 46.98588” East 54.352 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	243198.172 meters 1470321.018 meters

Table 8. Details of the recovered NAMRIA horizontal control point MRW-6 used as base station for the LiDAR acquisition

Station Name	MRW-6	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1 in 20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°52'40.22762" North 120°55'6.44586" East 80.63530 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	491149.868 meters 1424038.201 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°52'35.21155" North 120°55'11.48810" East 128.69600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	274116.83 meters 1424453.14 meters

Table 9. Details of the recovered NAMRIA horizontal control point MRW-54 used as base station for the LiDAR acquisition

Station Name	MRW-54	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°46'18.56204" North 120°50'27.44152" East 28.20700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	482731.146 meters 1412314.677 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°46'13.56455" North 120°50'32.49343" East 76.35500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	265604.90 meters 1412791.69 meters

Table 10. Details of the established horizontal control point MRWDAC-00 used as base station for the LiDAR acquisition.

Station Name	MRWDAC-00	
Order of Accuracy (benchmark)	2nd	
Elevation (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°13'23.10541" 120°35'55.10583" 11.60100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	239755.834 meters 1462963.518 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°13'17.97945" North 120°36'00.11991" East 57.96100 meters

Table 11. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
20-Feb-14	1124A	3BLK29OS51A	MRW-32 & MRW-34, MRW-36& MC-52
22-Feb-14	1132A	3BLK29IS53A	MRW-30, MRW-6, MRW-34, MRW-32
23-Feb-14	1136A	3BLK29HB54A	MRW-54, MRW-6
6-Dec-15	3060P	1BLK29DE340B	MRW-34 & MC-52
7-Dec-15	3062P	1BLK29BCS341A	MRW-34 & MC-52
8-Dec-15	3066P	1BLK29ACDF342A	MRW-30& MRWDAC-00

2.3 Flight Missions

Five(5) missions were conducted to complete the LiDAR Data Acquisition in PolaFloodplain, for a total of twenty four hours and seventeen minutes (24+17)of flying time for RP-C9122. All missions were acquired using the Aquarius and Pegasus LiDAR systems. Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for LiDAR data acquisition in Pola 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
19-Feb-14	1122A	92.68	116.73	10.70	106.03	300	2	17
20-Feb-14	1124A	92.68	91.21	34.81	56.40	1107	4	35
22-Feb-14	1132A	248.63	120.42	10.82	109.60	610	4	41
23-Feb-14	1136A	131.25	69.06	22.31	46.75	1241	4	29
6-Dec-15	3060P	104.62	44.88	26.38	18.50	96	2	5
7-Dec-15	3062P	171.52	174.85	8.84	166.01	391	3	23
8-Dec-15	3066P	207.9	115.28	22.31	92.97	245	2	47
TOTAL		1049.28	732.43	136.17	596.26	3990	24	17

Table 13. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1122A	700, 600	30	30/40	50	40	110	5
1124A	600	30	36	50	40	110	5
1132A	600	30	36	50	40	130	5
1136A	600	30	36	50	40	130	5
3060P	1100	30	50	150	30	110	5
3062P	1400	30	40	150	30	115	5
3066P	1100, 1400	30	50/40	200/150	30	115	5

2.4 Survey Coverage

Pola Floodplain is located in the province of Occidental Mindoro, with majority of the floodplain situated within the municipalityof Santa Cruz.The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Pola Floodplain is presented in Figure 8.

Table 14. List of municipalities and cities surveyed in Pola Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Occidental Mindoro	Mamburao	344.99	179.29	52%
	Santa Cruz	709.53	171.36	24%
	Abra de Ilog	523.87	106.14	20%
	Sablayan	2350.46	131.09	6%
	Calintaan	282.31	14.04	5%
	Paluan	557.78	4.42	1%
TOTAL		4,768.94	606.34	12.71%

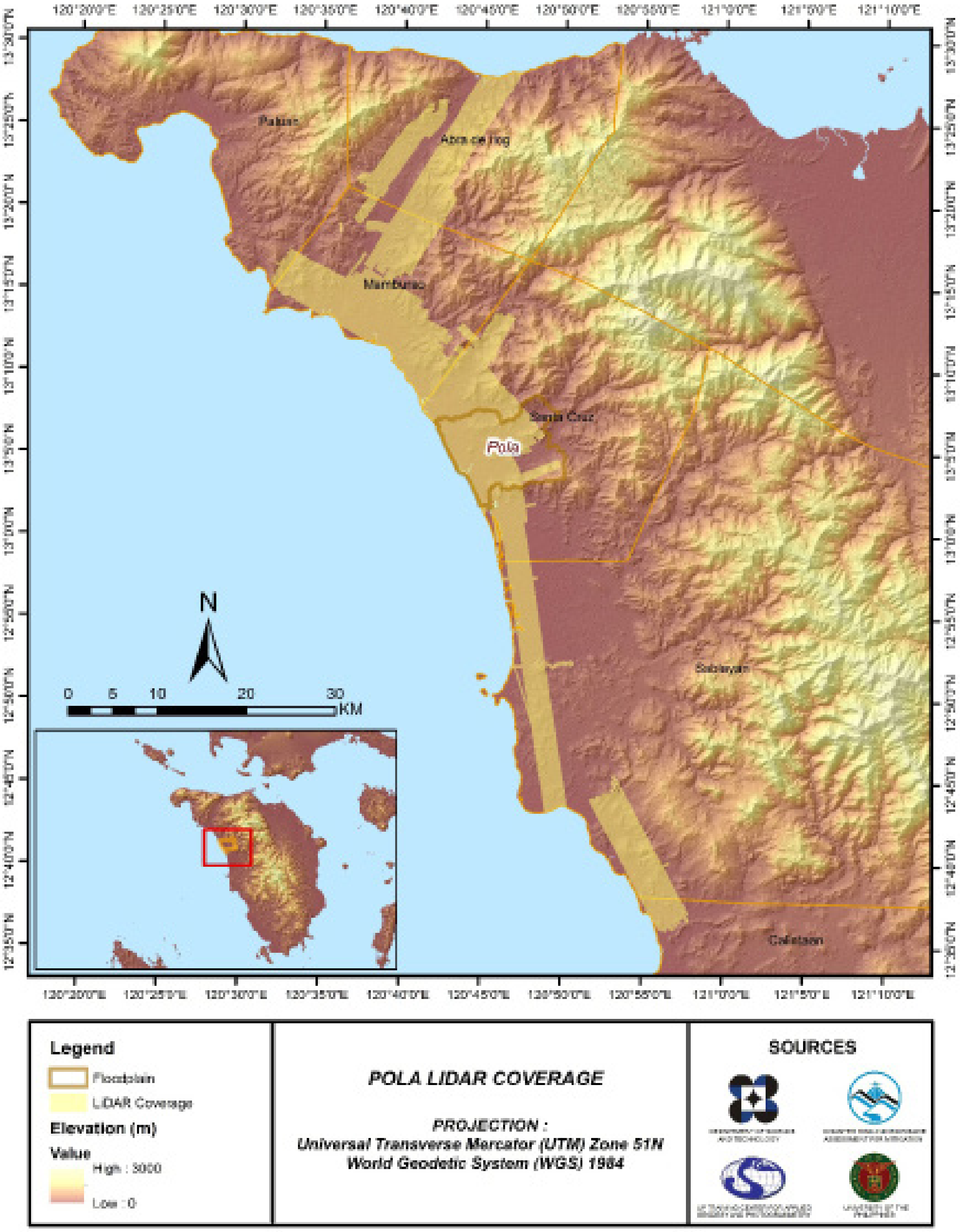

Figure 8. Actual LiDAR data acquisition for Pola Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR POLA FLOODPLAIN

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

3.1 Overview of LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model. Using the elevation of points gathered in the field, the LiDAR-derived digital models were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flow chart shown in Figure 9.

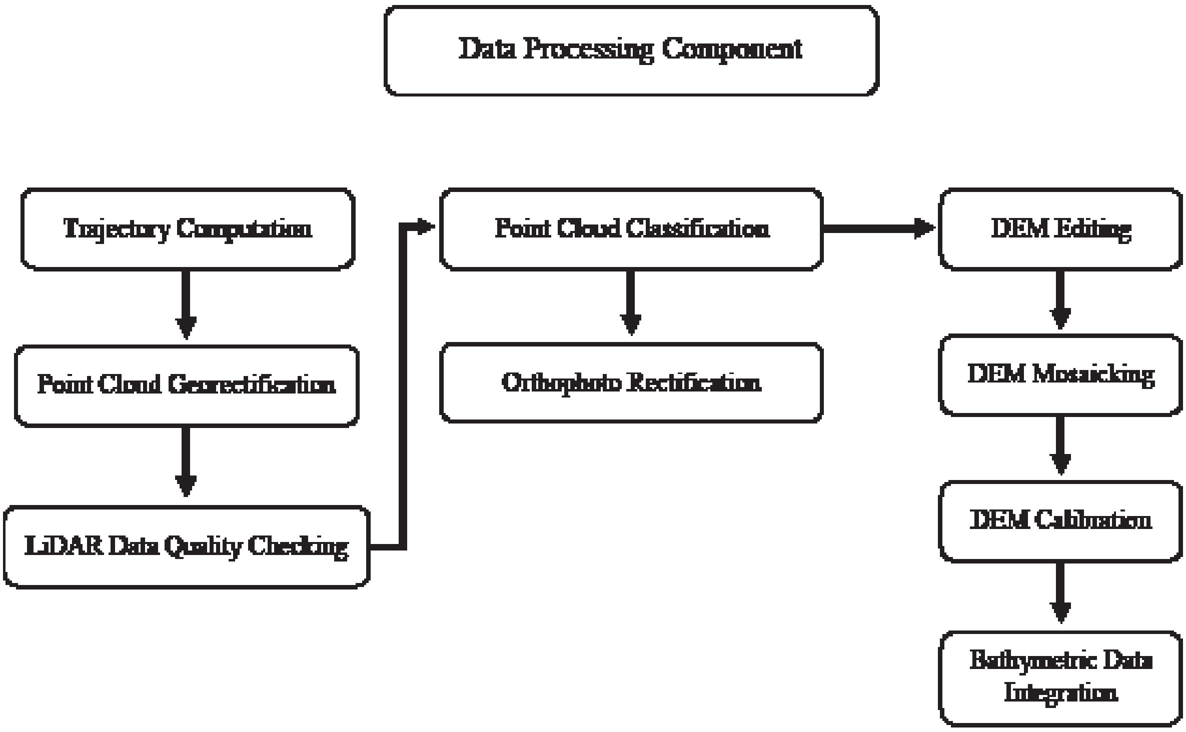


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pola 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 while missions acquired during the second survey on December 2016 were flown using the Pegasus system over Sta. Cruz, Occidental Mindoro. The Data Acquisition Component (DAC) transferred a total of 61.42 Gigabytes of Range data, 1.12 Gigabytes of POS data, 87.31 Megabytes of GPS base station data, and 176.49 Gigabytes of raw image data to the data server on February 2, 2014 for the first survey and December 6, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pola was fully transferred on January 5, 2016 as indicated on the Data Transfer Sheets for Pola Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3060P, one of the Pola flights, which is the North, East, and Down position RMSE values are shown in Figure 10. 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 December 6, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

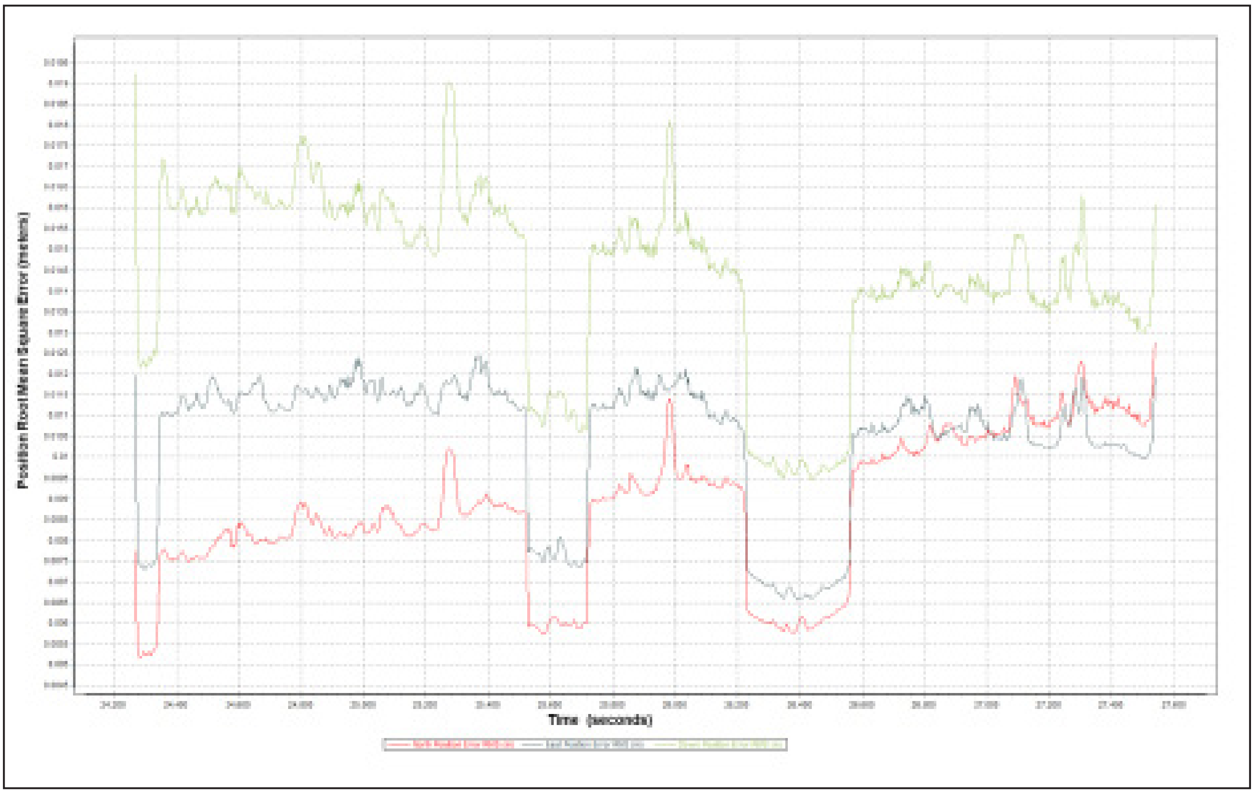


Figure 10. Smoothed Performance Metrics of a Pola Flight 3060P

The time of flight was from 24200 seconds to 27600 seconds, which corresponds to afternoon of December 6, 2015. 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 started 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 10 shows that the North position RMSE peaked at 1.25 centimeters, the East position RMSE peaked at 1.25centimeters, and the Down position RMSE peaked at 1.90centimeters, which are within the prescribed accuracies described in the methodology.

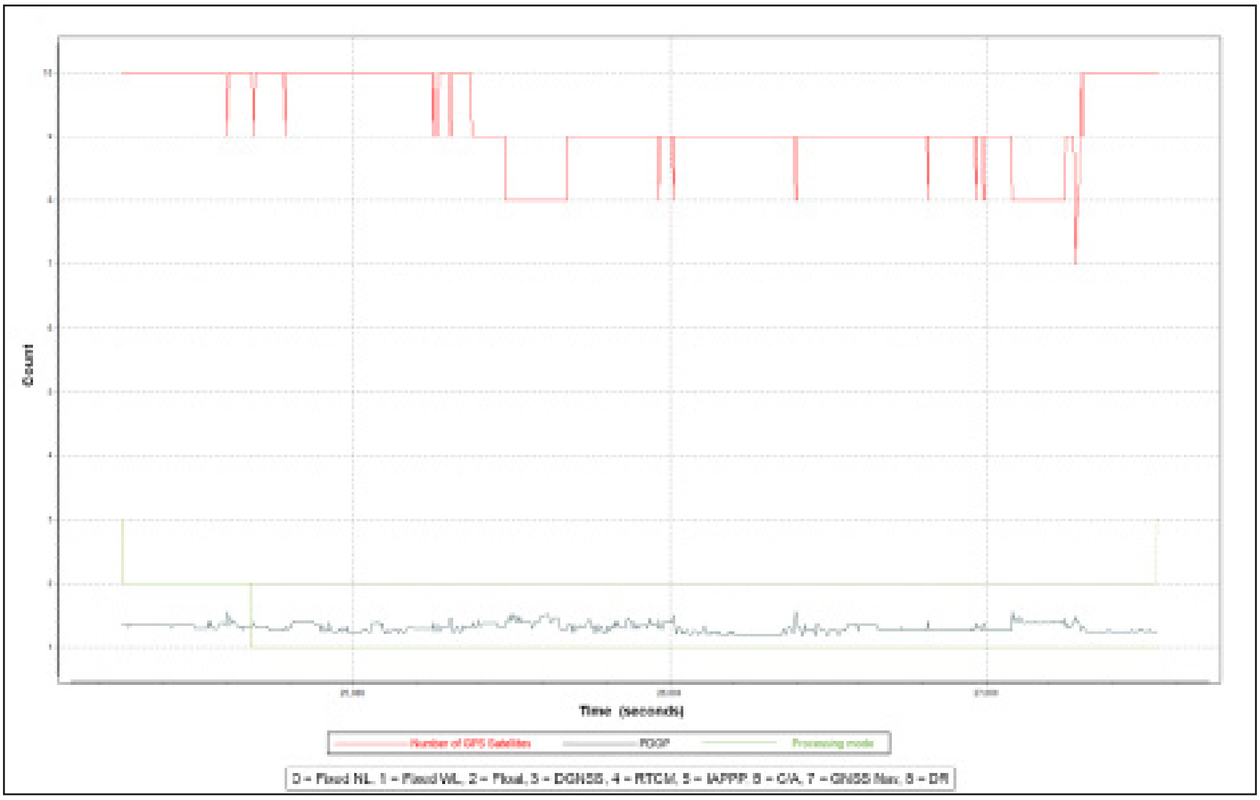


Figure 11. Solution Status Parameters of Pola Flight 3060P.

The Solution Statusparameters of flight 3060P,one of the Pola flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 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 Pola flights is shown in Figure 12.

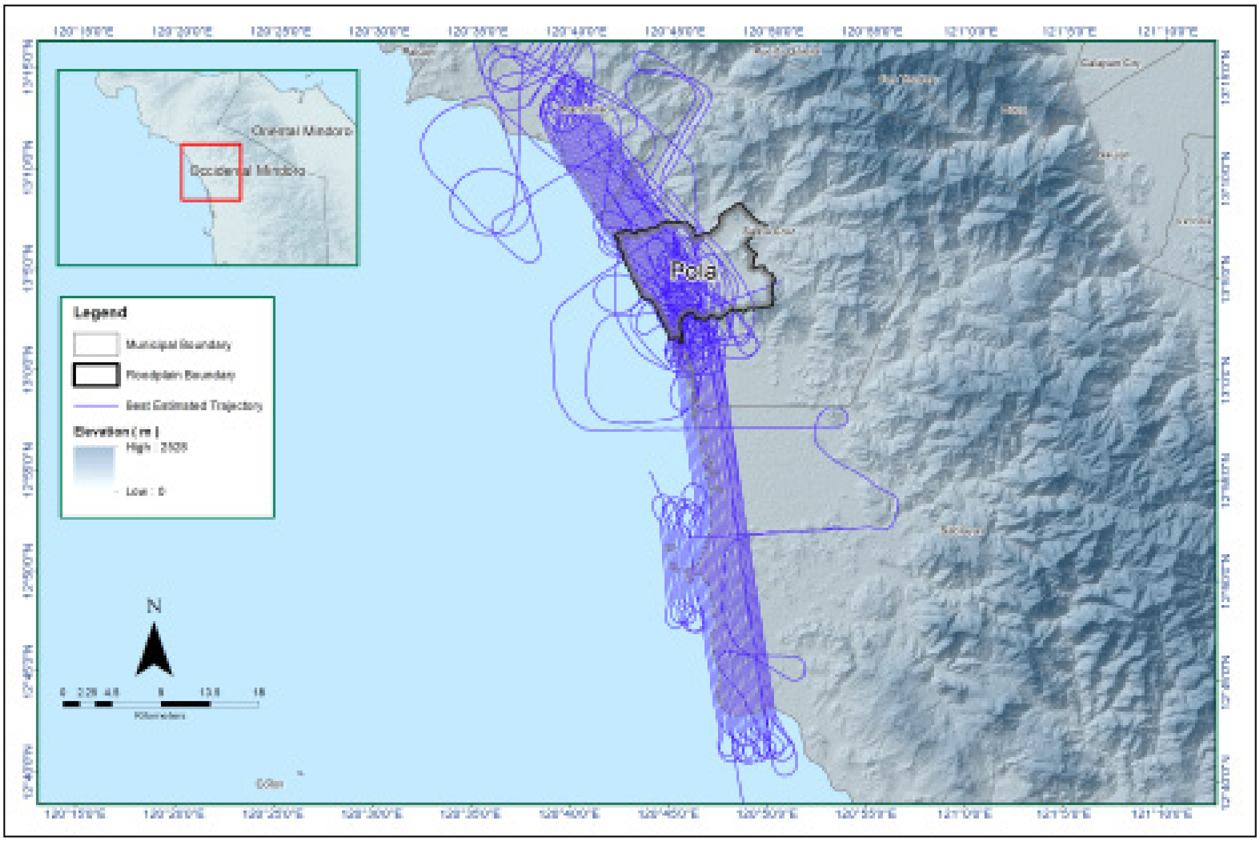


Figure 12. Best Estimated Trajectory for Pola Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 78 flight lines, with each flight line containing one channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Pola Floodplain are given in Table 15.

Table 15. Self-Calibration Results values for Pola flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000442
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.004259
GPS Position Z-correction stdev	(<0.01meters)	0.0174

The optimum accuracy is obtained for all Pola 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 Pola Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

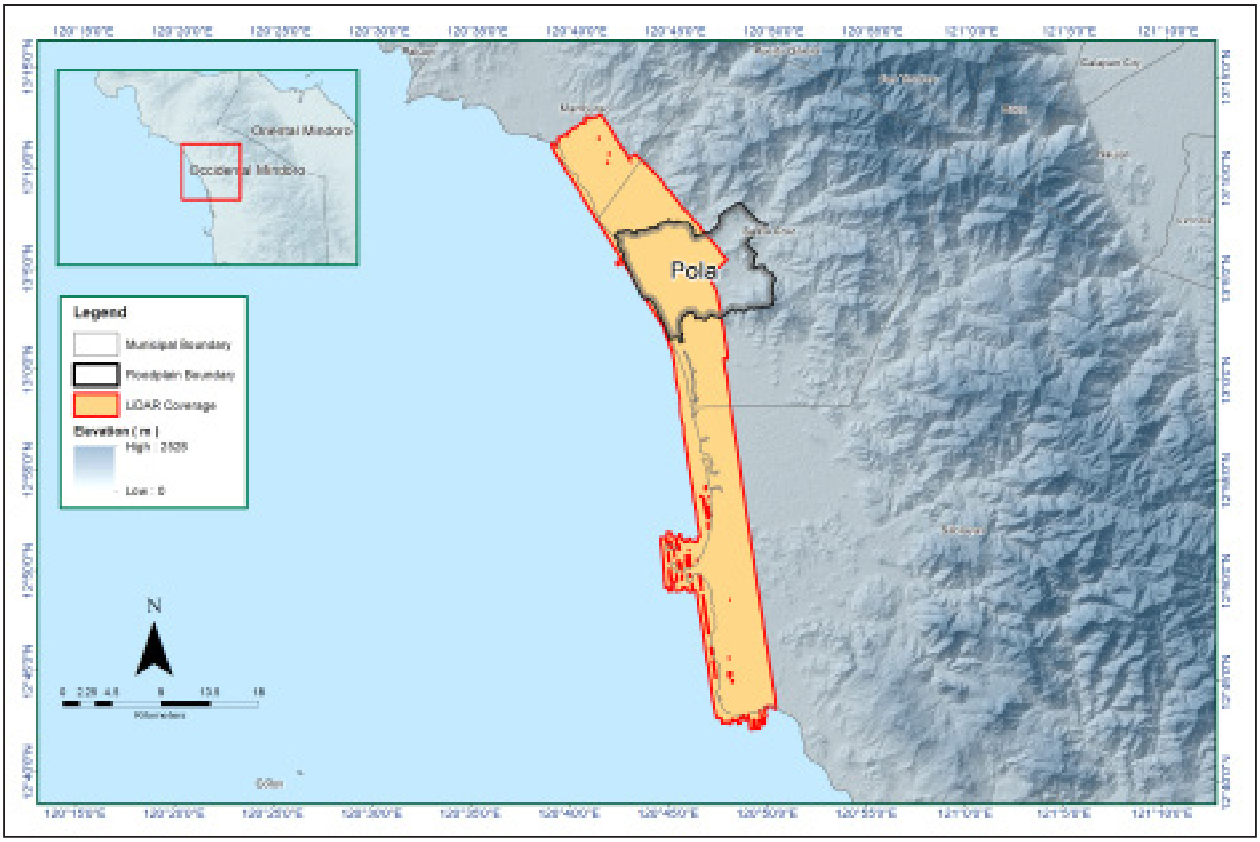


Figure 13. Boundary of the processed LiDAR data over Pola Floodplain

The total area covered by the Pola missions is 316.74 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into four (4) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Pola Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk290	1122A	103.39
	1124A	
OccidentalMindoro_Blk29H	1136A	102.41
OccidentalMindoro_Blk29HI_Supplement	1132A	48.73
OccidentalMindoro_reflights_Blk29O	3060P	62.21
	3062P	
TOTAL		500.69 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 14. Since the Pegasus and Aquarius systems employ two and one channels respectively, an average value of 1 (blue) for Aquarius and 2 for Pegasus is expected for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for Aquarius and 3 for Pegasus for areas with three or more overlapping flight lines.

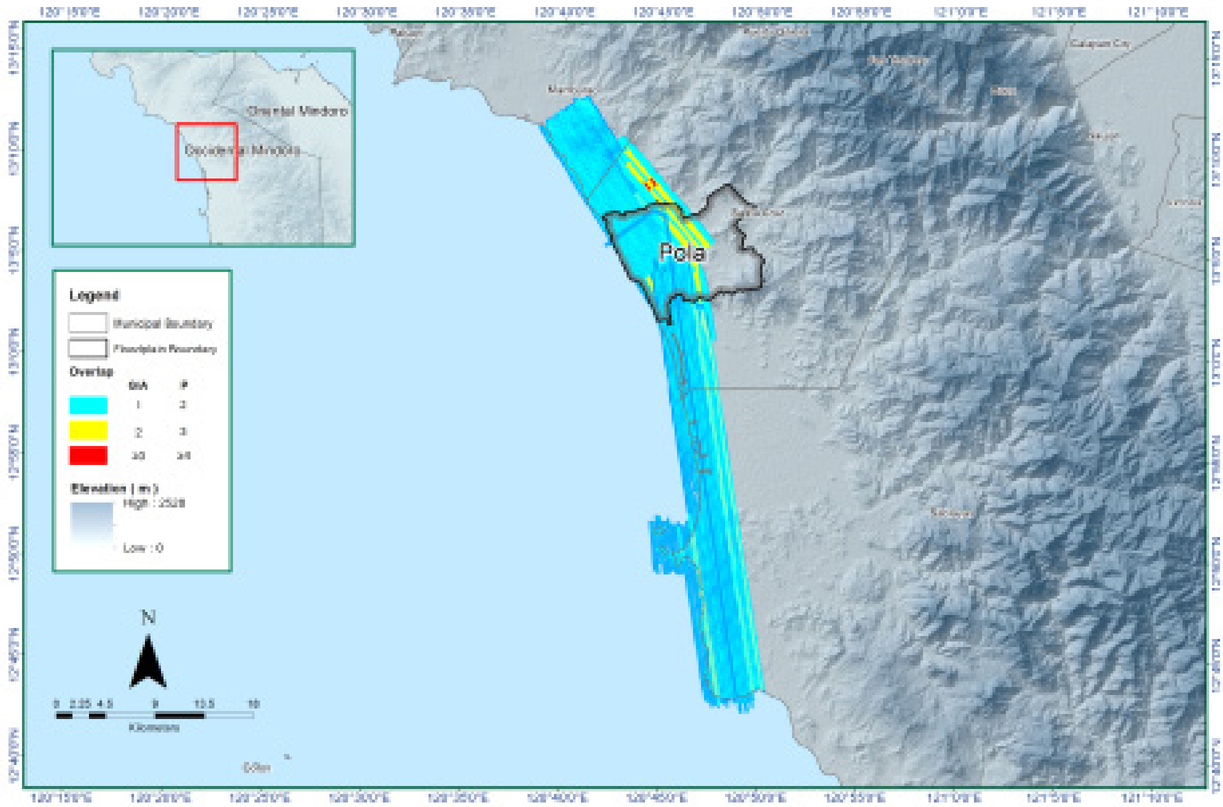


Figure 14. Image of data overlap for Pola Floodplain.

The overlap statistics per block for the Pola floodplain can be found in Annex. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 30.09% and 68.31% 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 15. It was determined that all LiDAR data for Pola Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.12 points per square meter.

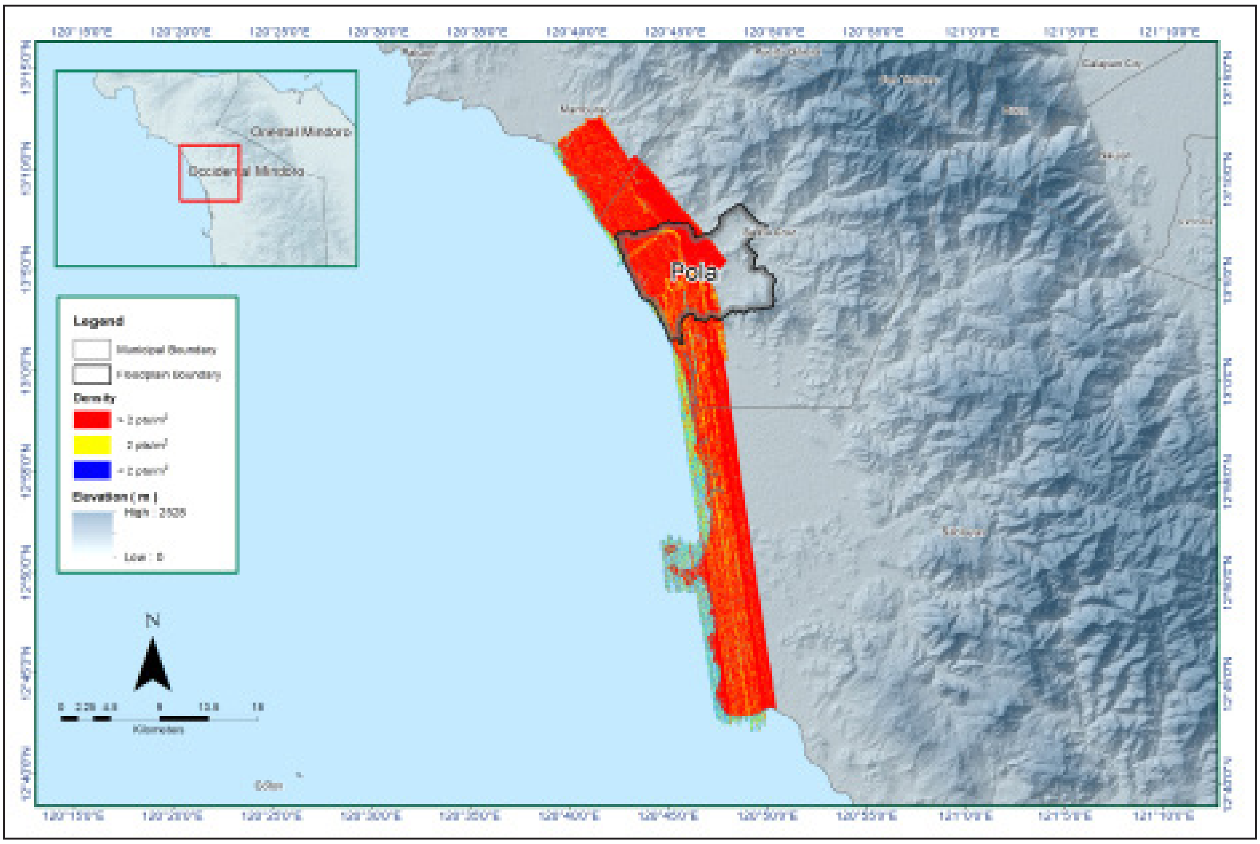


Figure 15. Density map of merged LiDAR data for Pola Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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 0.20 m 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 0.20 m 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.

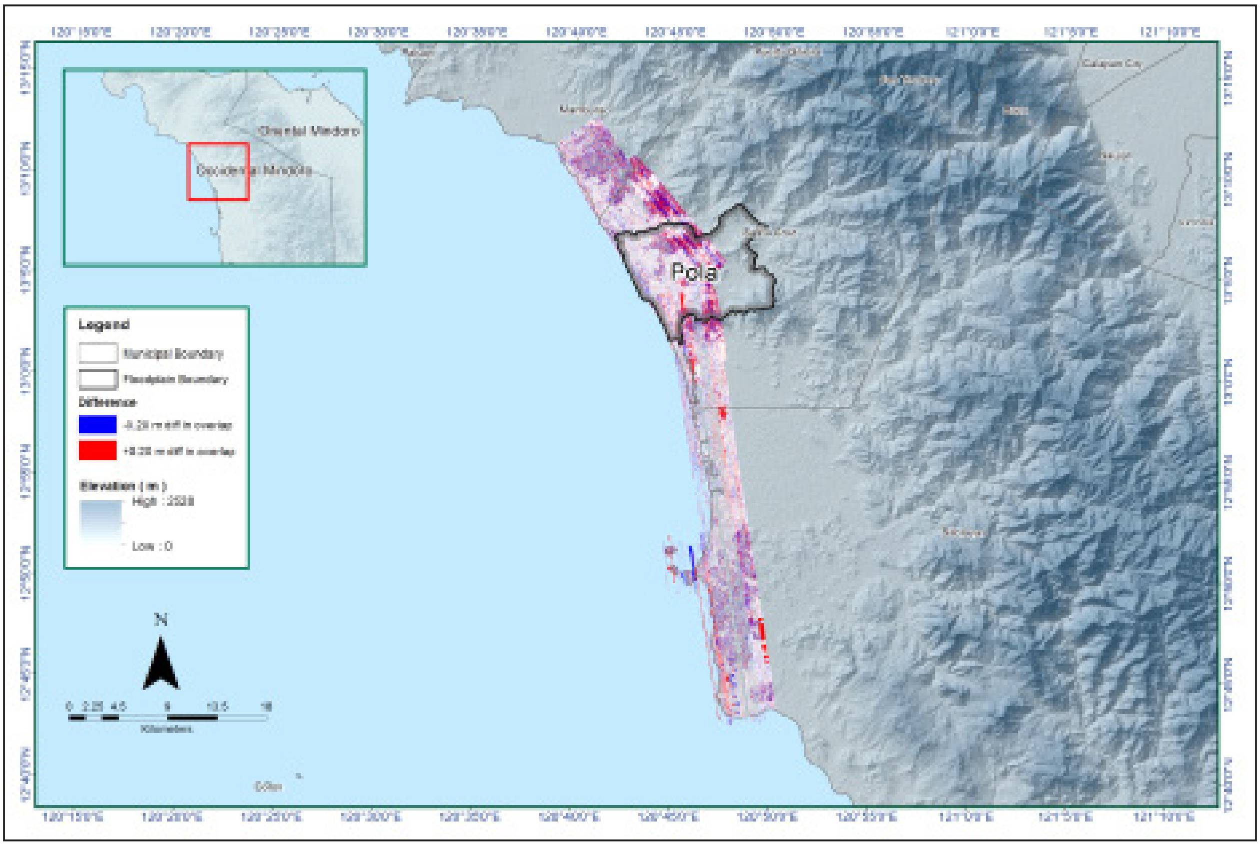


Figure 16. Elevation difference map between flight lines for Pola Floodplain.

A screen capture of the processed LAS data from a Pola flight 3060P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow 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 researcher was satisfied with the quality of the LiDAR data. No reprocessing was done for this LiDAR dataset.

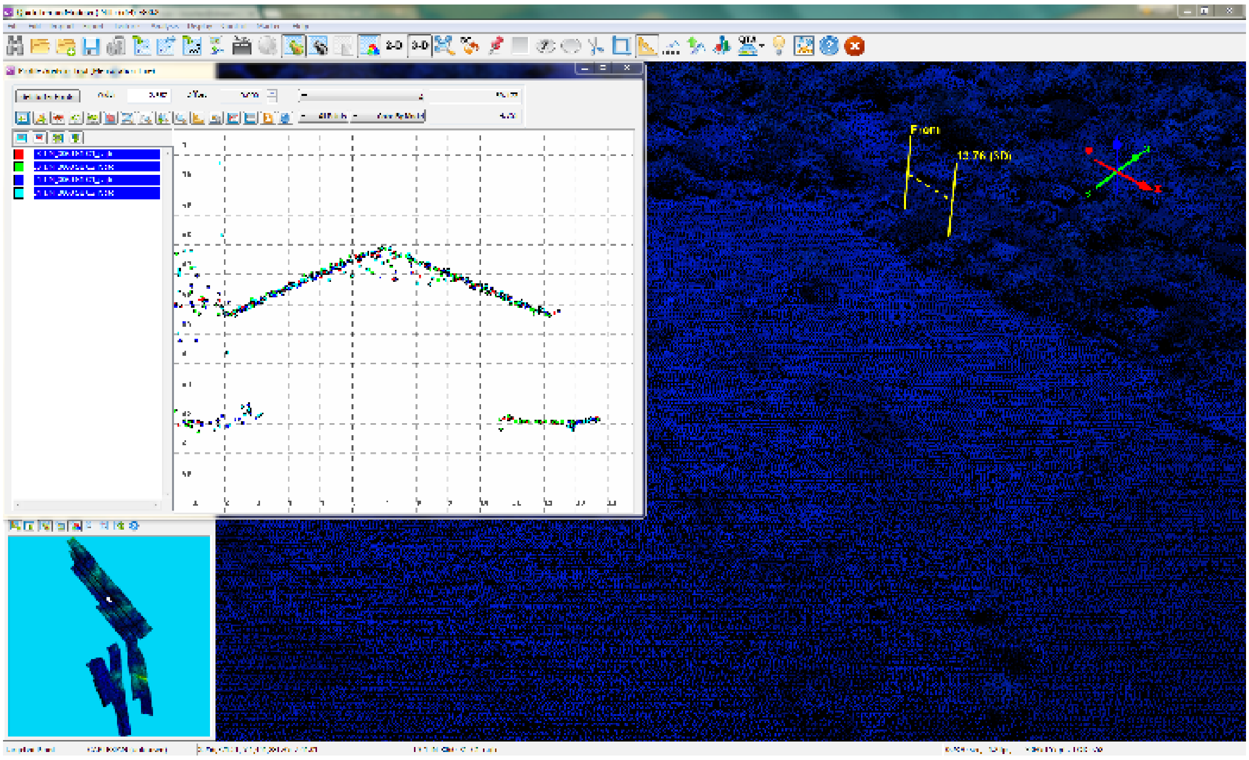


Figure 17. Quality checking for Pola flight 1166A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Pola classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	255,924,862
Low Vegetation	293,223,480
Medium Vegetation	347,172,570
High Vegetation	253,147,290
Building	8,421,873

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pola Floodplain is shown in Figure 18. A total of 602 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 562.67 meters and 32.75 meters respectively.

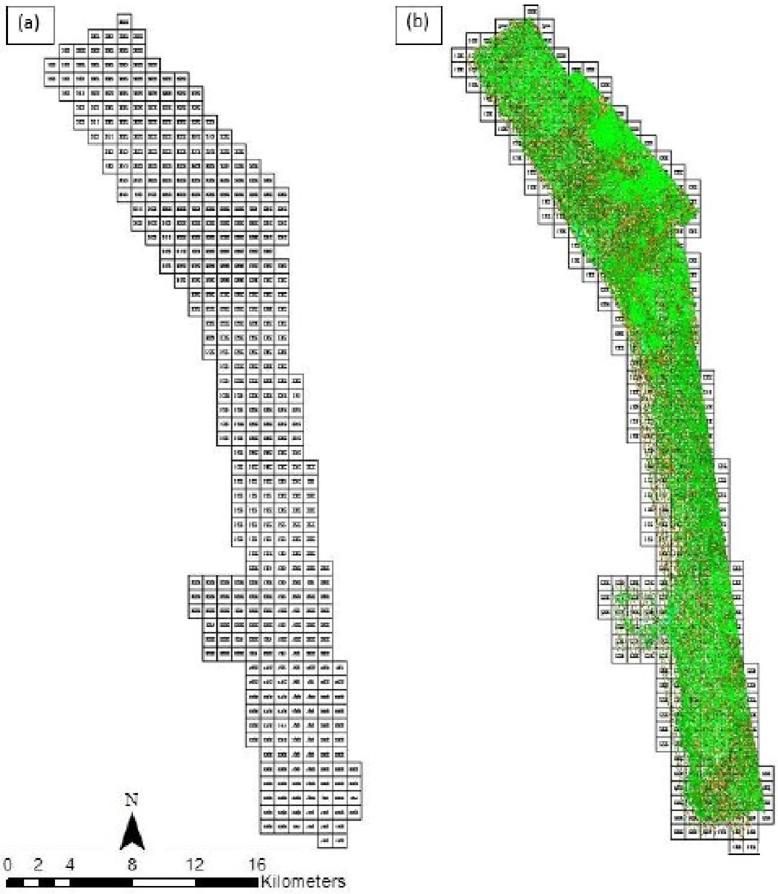


Figure 18. Tiles for Pola Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

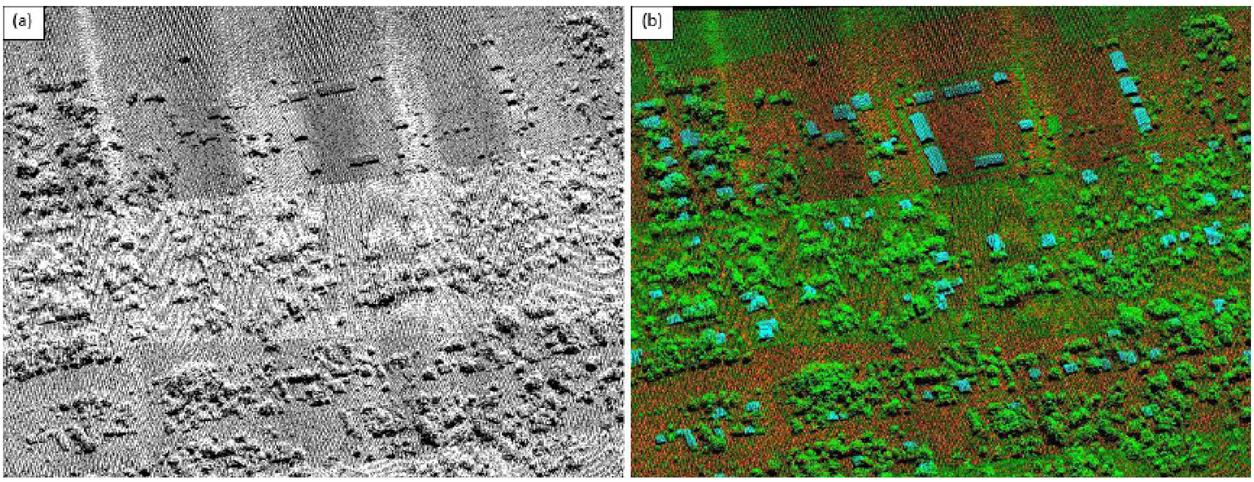


Figure 19. Point cloud before (a) and after (b) classification.

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 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

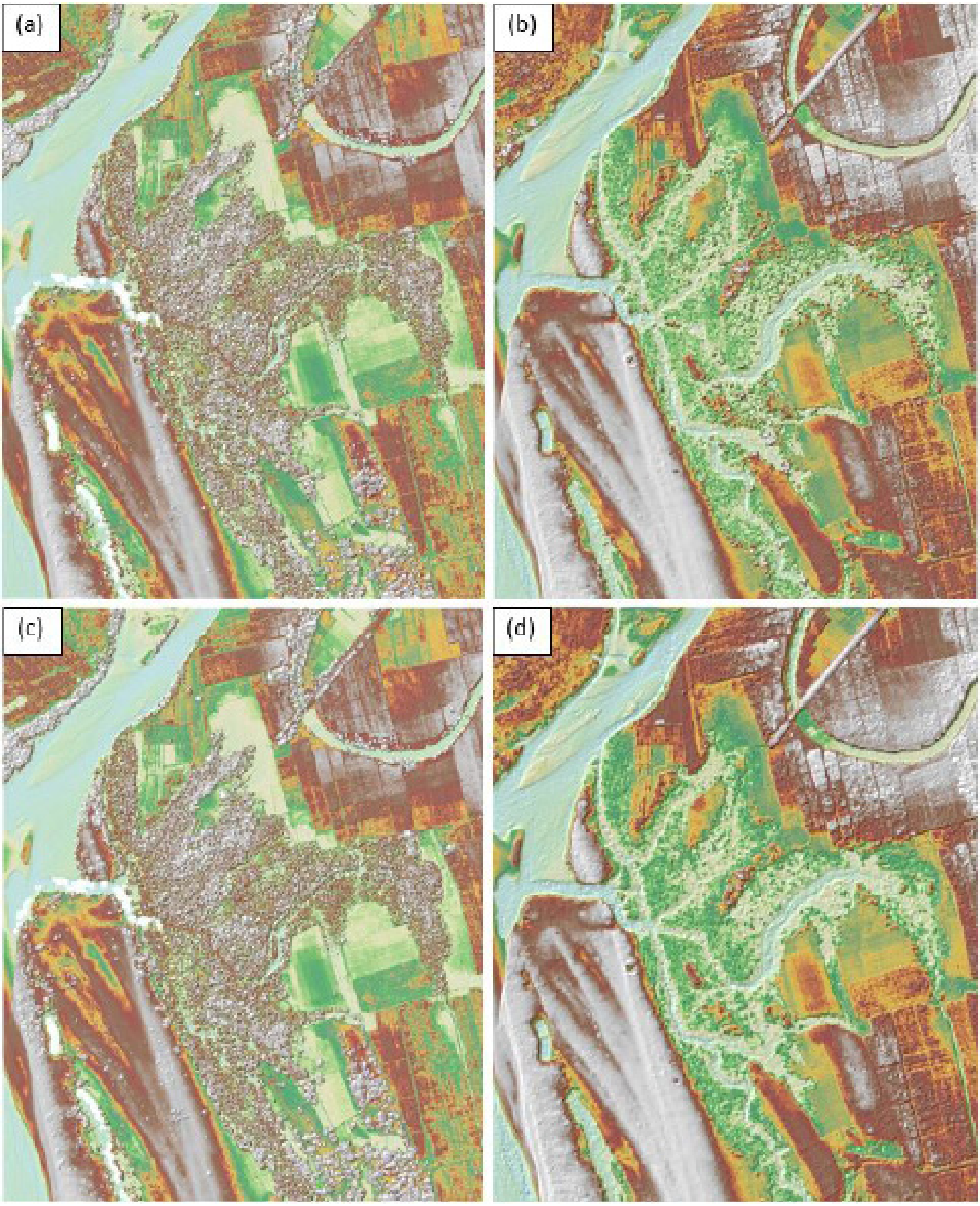


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pola Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 380 1km by 1km tiles area covered by Pola floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Pola Floodplain has a total of 241.46 sq.km orthophotograph coverage comprised of 2,680 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

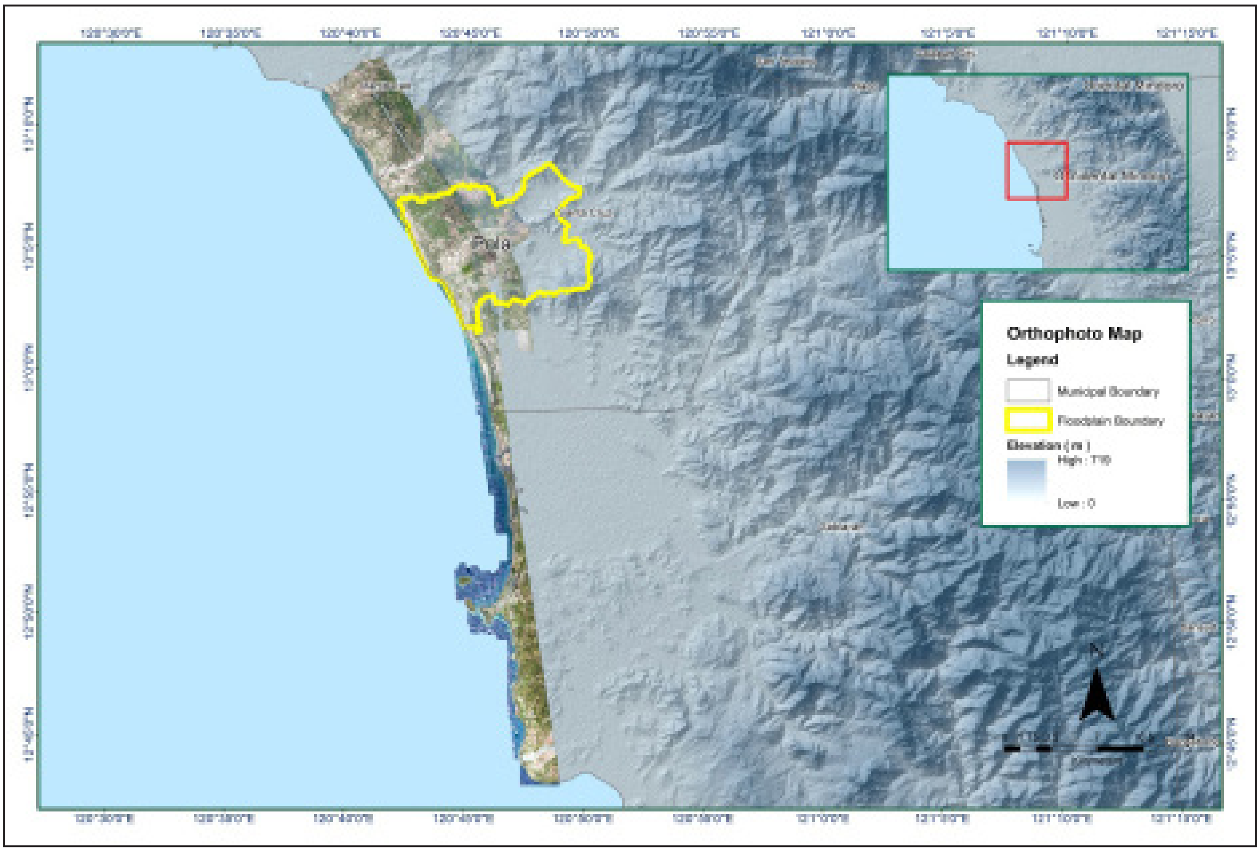


Figure 21. Pola floodplain with available orthophotographs

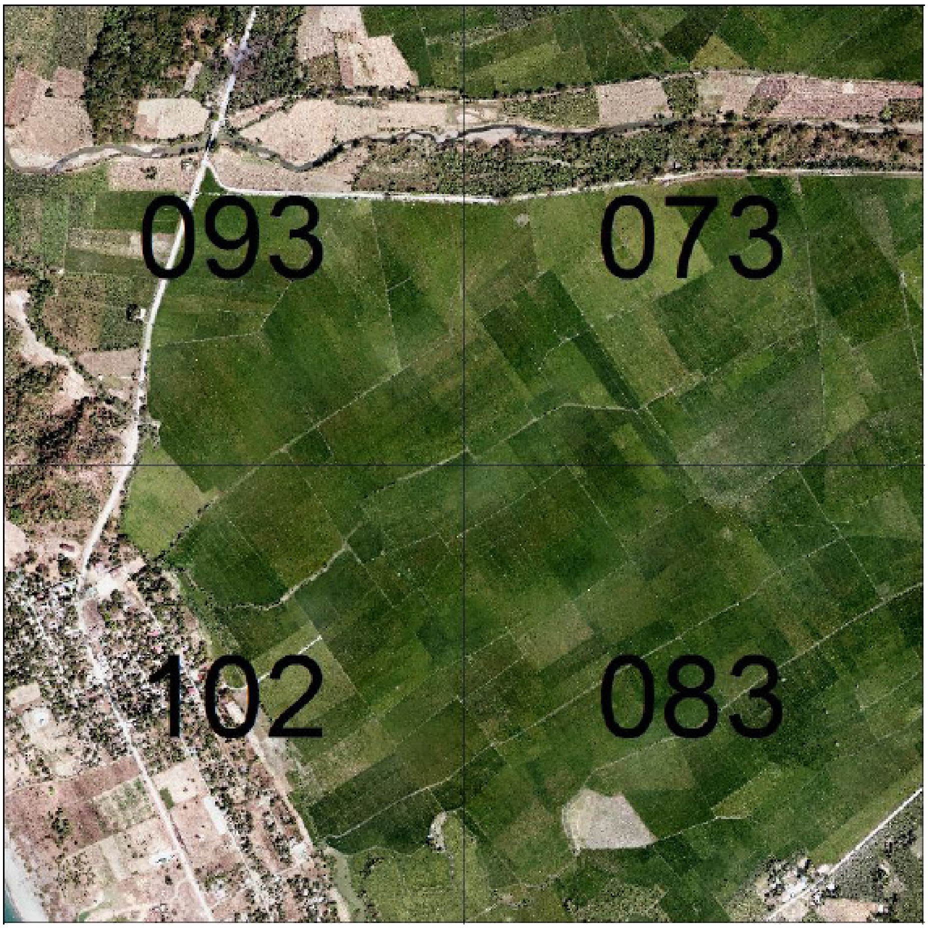


Figure 22. Sample orthophotograph tiles for Pola Floodplain

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Pola Floodplain. These blocks are composed of Occidental Mindoro and Occidental Mindoro_reflights blocks with a total area of 316.74 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
OccidentalMindoro_Blk29O	103.39
OccidentalMindoro_Blk29H	102.41
OccidentalMindoro_Blk29HI_supplement	48.73
OccidentalMindoro_reflights_Blk29O	62.21
TOTAL	316.74 sq.km

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) was considered to be an impedance to the flow of water along the river and had to be removed (Figure 23b) in order to hydrologically correct the river. The paddy field (Figure 23c) was misclassified and removed during classification process and had to be retrieved to complete the surface (23d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 23e) and had to be removed through manual editing (Figure 23f).

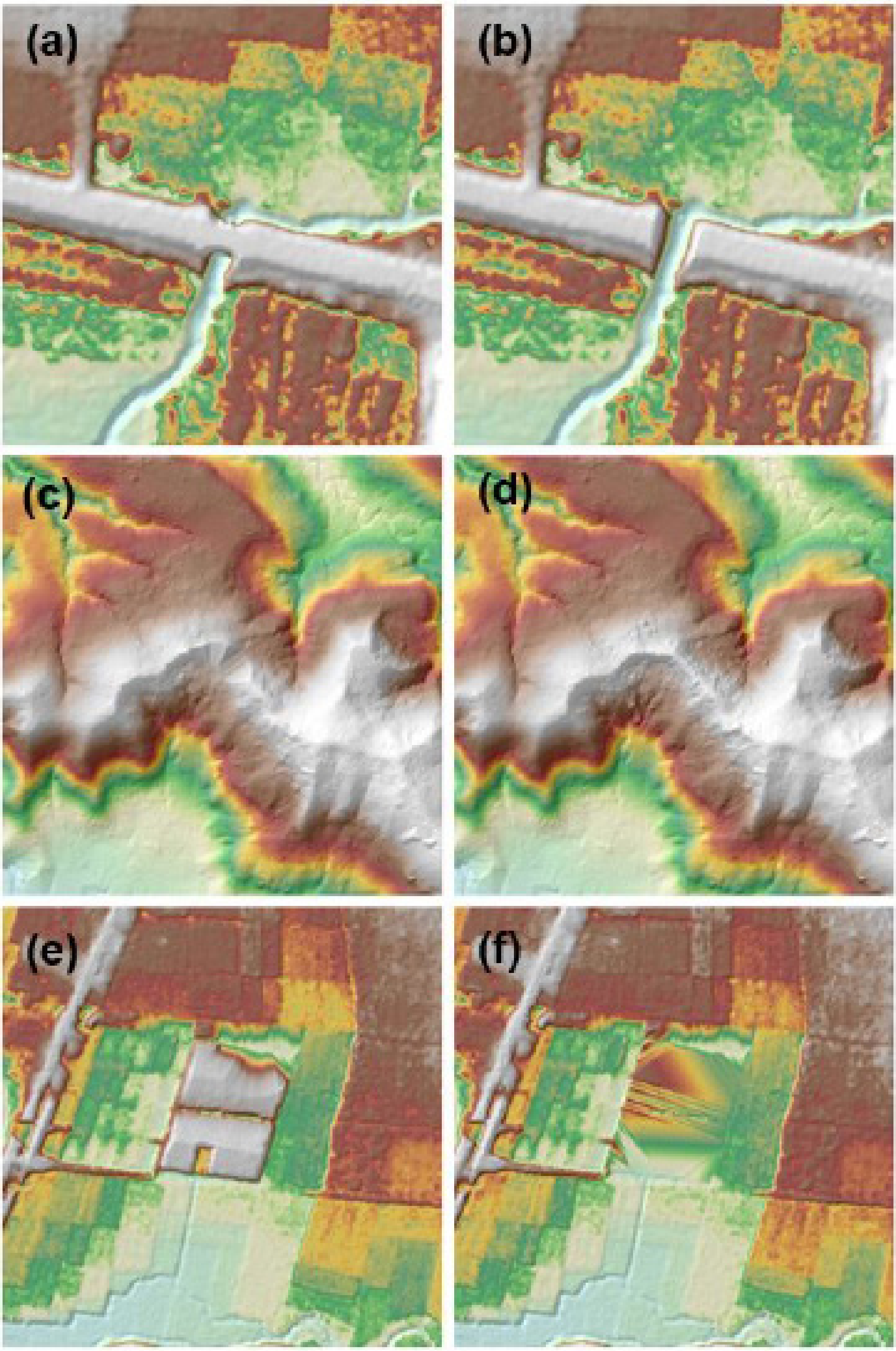


Figure 23. Portions in the DTM of Pola Floodplain – a bridge before (a) and after (b) manual editing; a mountain before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing

3.9 Mosaicking of Blocks

Mindoro_Blk29M was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 19 shows the shift values applied to each LiDAR block during mosaicking

Mosaicked LiDAR DTM for Pola Floodplain is shown in Figure 24. It can be seen that the entire Pola Floodplain is 47.51% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 19. Shift Values of each LiDAR Block of Pola Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29O	0.00	0.00	-0.28
OccidentalMindoro_Blk29H	0.00	0.00	-0.83
OccidentalMindoro_Blk29HI_supplement	0.00	0.00	-0.88
OccidentalMindoro_Reflight_Blk29O (Upper)	-31.01	-1.01	-1.16
OccidentalMindoro_Reflight_Blk29O (Left)	0.00	0.00	-1.16
OccidentalMindoro_Reflight_Blk29O (Right)	0.00	0.00	-1.16

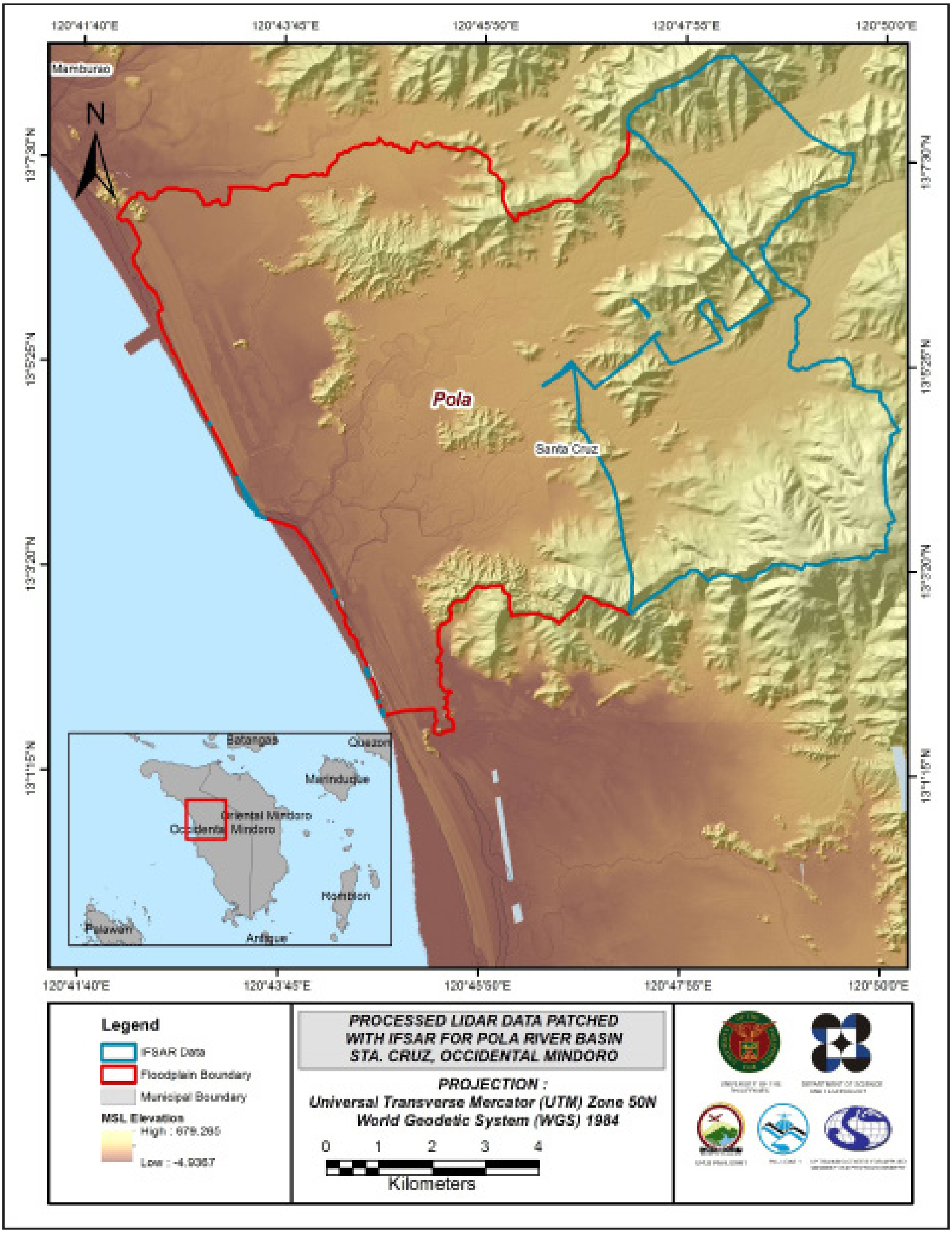


Figure 24. Map of Processed LiDAR Data for Pola Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Pola to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 28,494 survey points were gathered for all the flood plains within Occidental Mindoro wherein the Pola floodplain is located. Random selection of 80% of the survey points, resulting to 22,795 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Pola LiDAR data was done by adding the height difference value, 0.23 meters, to Pola mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

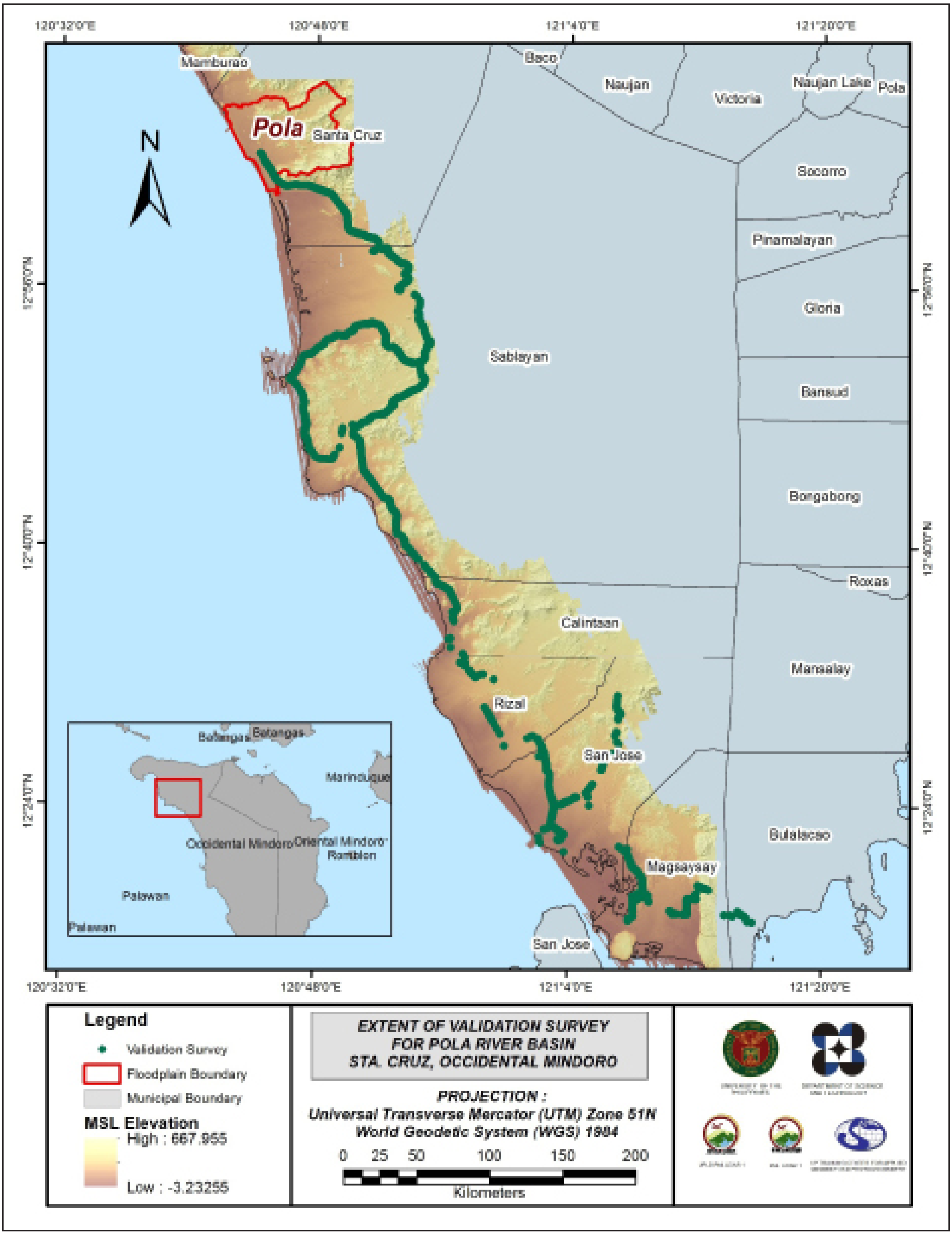


Figure 25. Map of Pola Flood Plain with validation survey points in green.

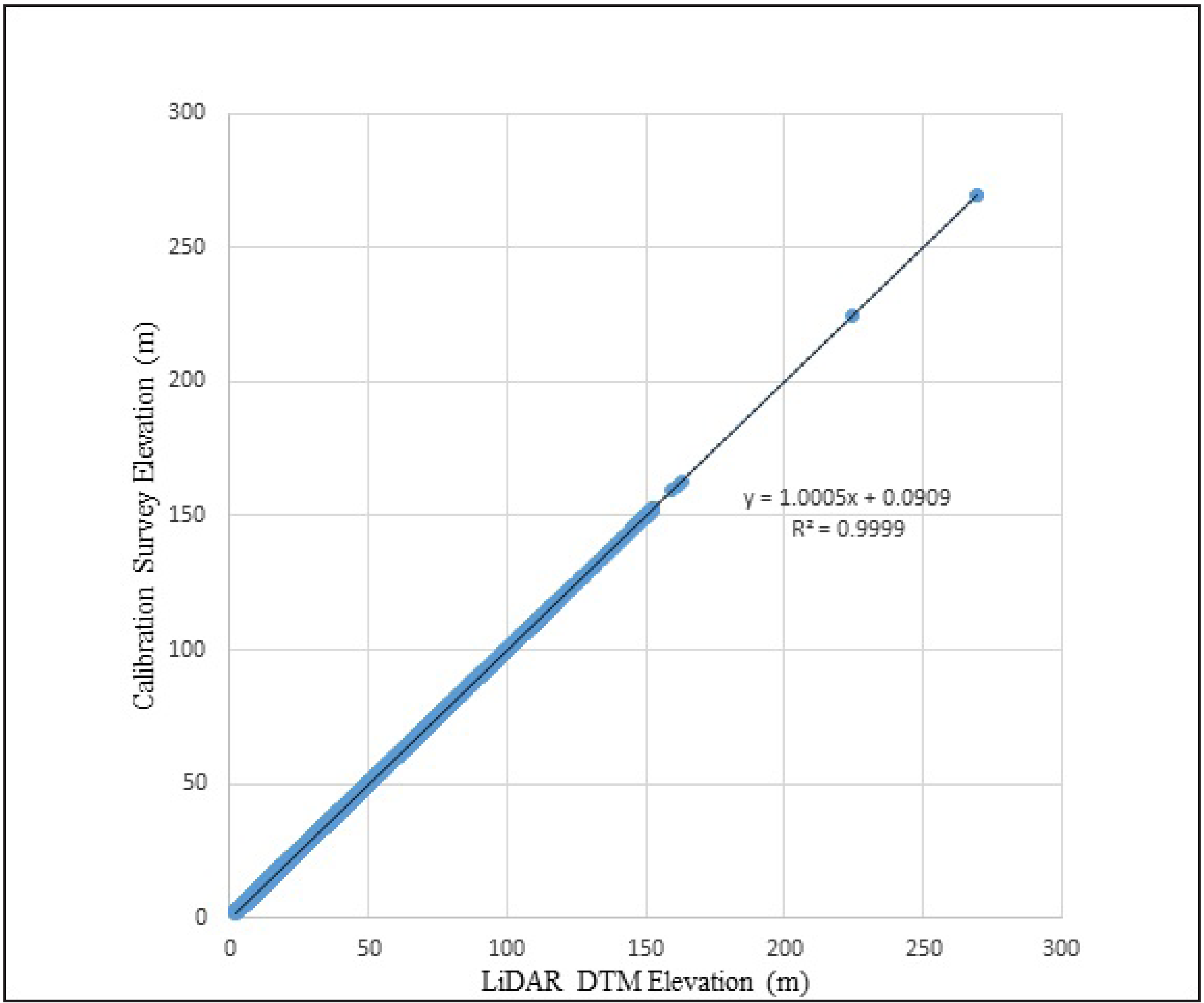


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 20. Calibration Statistical Measures.

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

A total of 833 survey points lie within Pola Floodplain and were used for the validation of the calibrated Pola 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.15 meters with a standard deviation of 0.15 meters, as shown in Table 21.

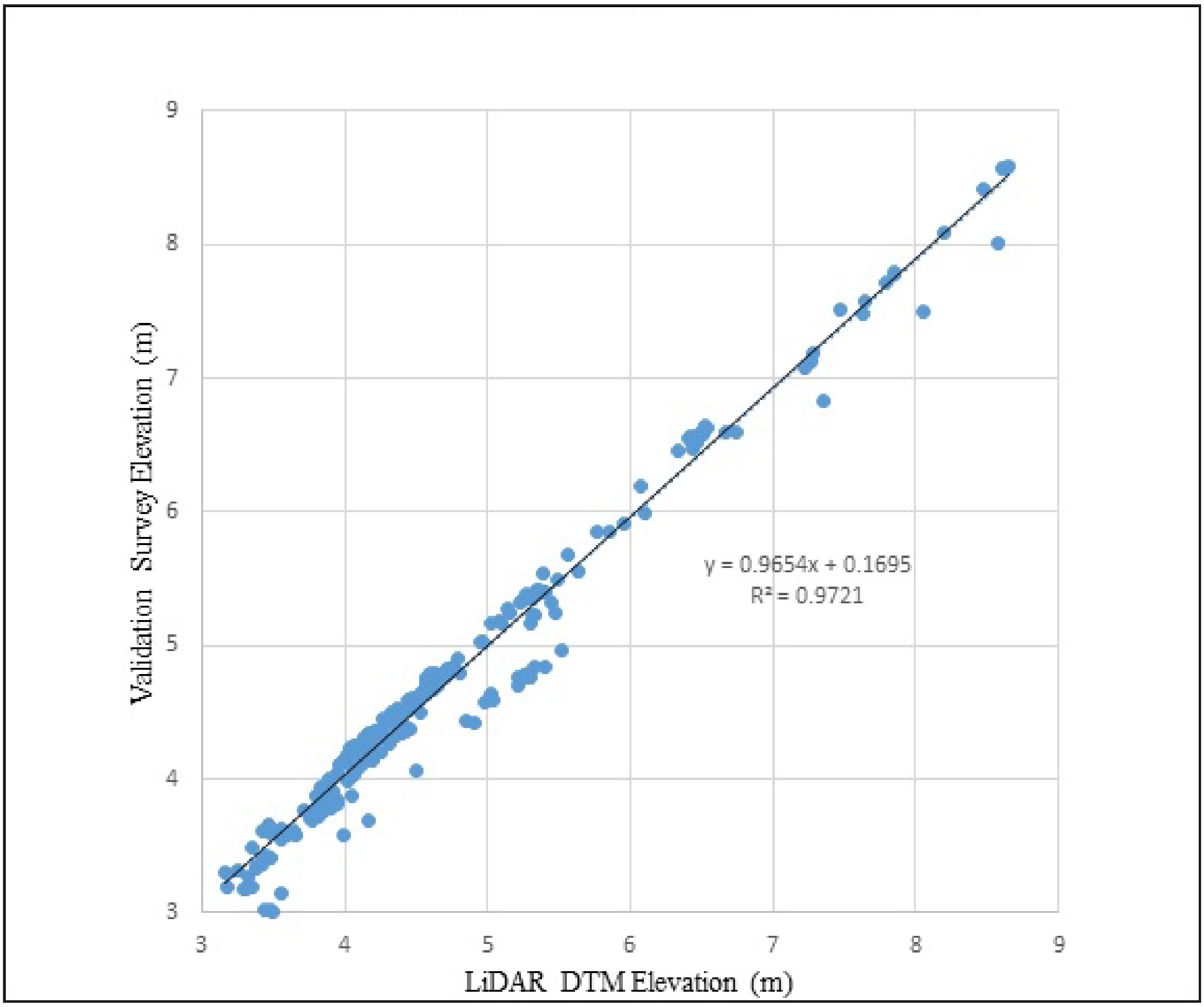


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 21. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.18
Average	0.01
Minimum	-0.56
Maximum	0.20

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathymetric data integration, 2,496 points were used. The resulting raster surface produced was done by Kernel Interpolation with Barrier method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.27 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Pola integrated with the processed LiDAR DEM is shown in Figure 20.

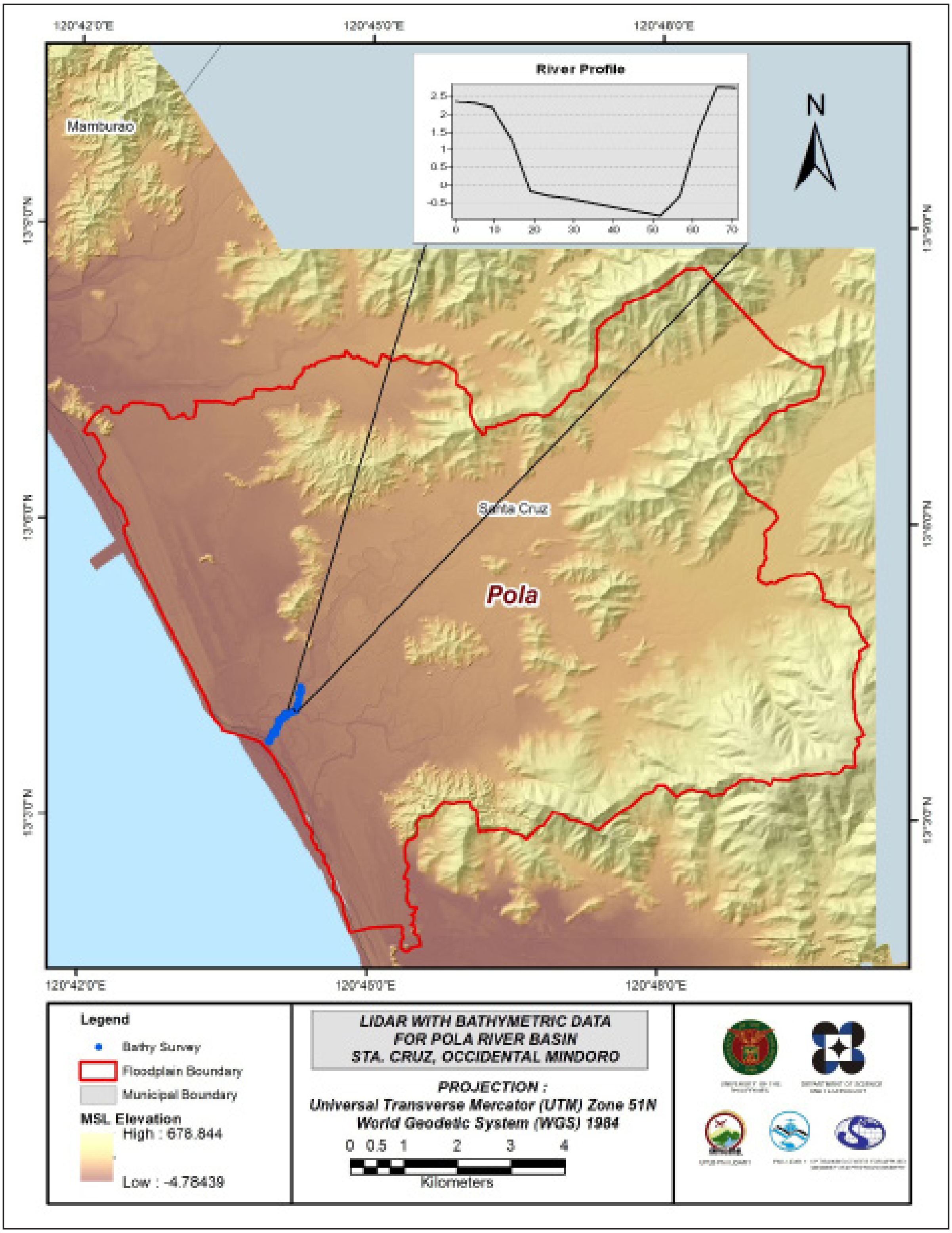


Figure 28. Map of Pola Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE POLA RIVER BASIN

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted survey in Pola River on November 3-24, 2015 with the following scope of work: cross-section, bridge as-built and water level marking in MSL of Pola Bridge; validation points acquisition in the province of Occidental Mindoro which covers Pola River Basin; and bathymetry survey from the mouth of the river in Brgy. Poblacion II to part of Brgy. Casague in the Municipality of Sta. Cruz by feet using Trimble® GNSS PPK survey technique. (See Figure 29)

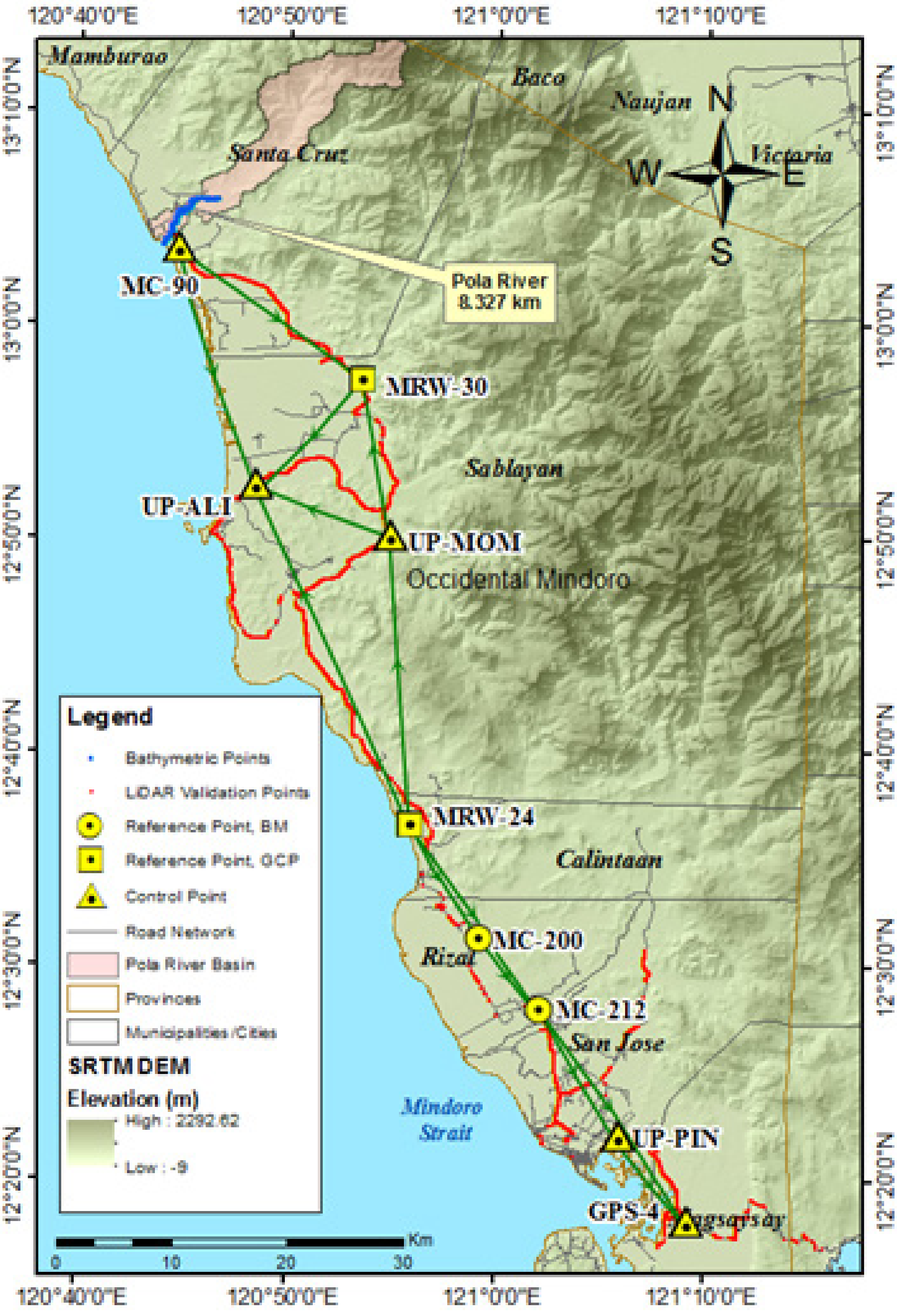


Figure 29. Pola River Survey Extent

4.2 Control Survey

The GNSS network used for Pola River Basin is composed of eight (8) loops established on November 5, 15 and 17, 2015 occupying the following reference points: MRW-24, a second order GCP in Brgy. Iriron, Municipality of Calintaan; MRW-30, a second order GCP in Bry. Pinagturilan, Municipality of Sta. Cruz; MC-200, a first order BMin Brgy. Magsikap, Municipality of Rizal; and MC-212, also a first order BM in Brgy. Sto. Niño in Rizal.

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

The summary of reference and control points and its location is summarized in Table 22 while the GNSS network established is illustrated in Figure 30.

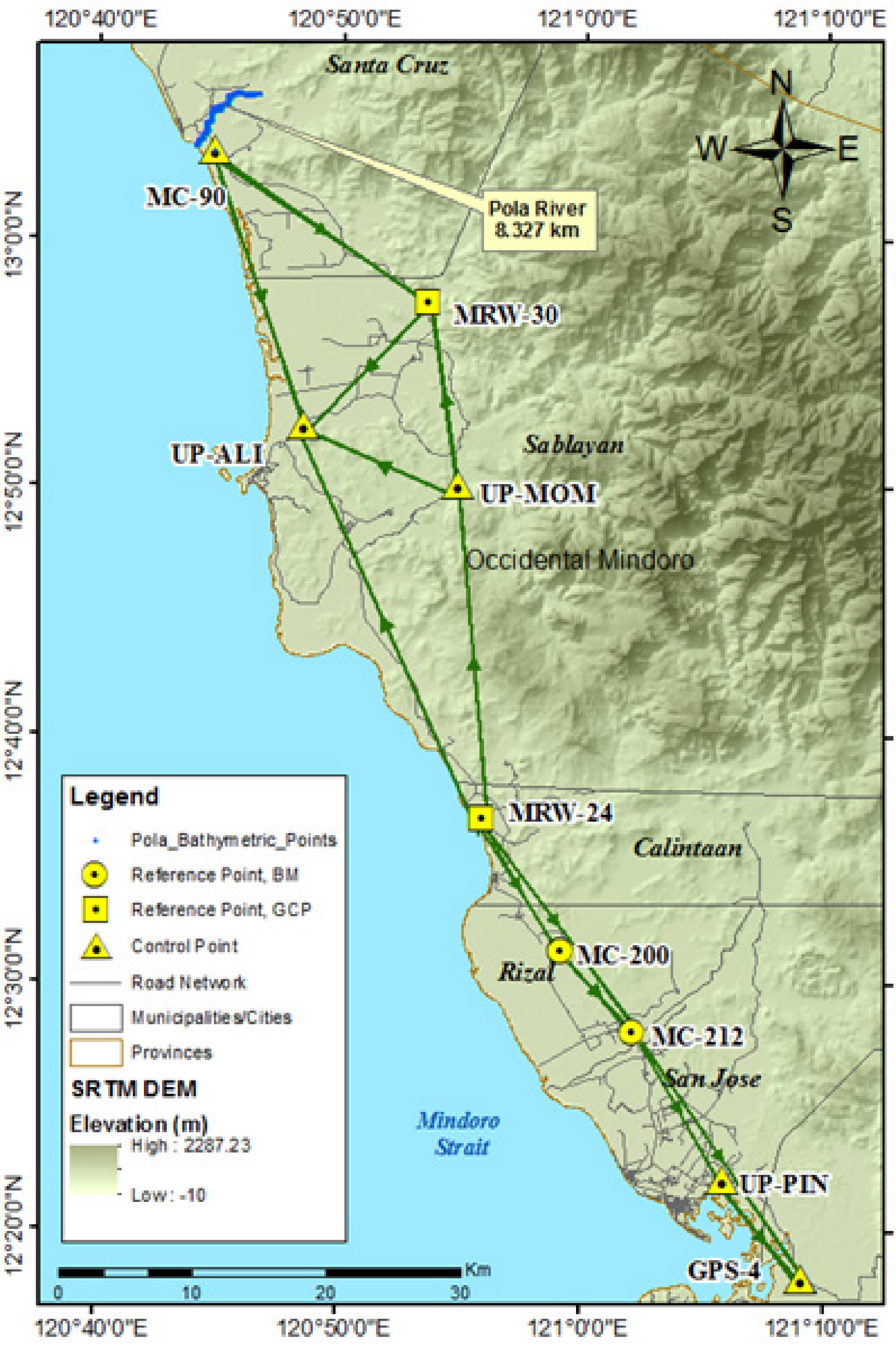


Figure 30. GNSS Network of Occidental Mindoro Field Survey

Table 22. List of reference and control points used during the survey in Pola River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MC-200	1st order, BM	-	-	83.225	-	2007
MC-212	1st order, BM	-	-	74.473	-	2007
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	4.746	2007
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	41.752	2007
MC-90	UP Established	-	-	-	-	2007
UP-ALI	UP Established	-	-	-	-	2015
UP-MOM	UP Established	-	-	-	-	2015
UP-PIN	UP Established	-	-	-	-	2015
GPS-4	DPWH Established	-	-	-	-	2013

The GNSS set-up in reference points and established control points in Occidental Mindoro survey are shown in Figures 31 to 39.

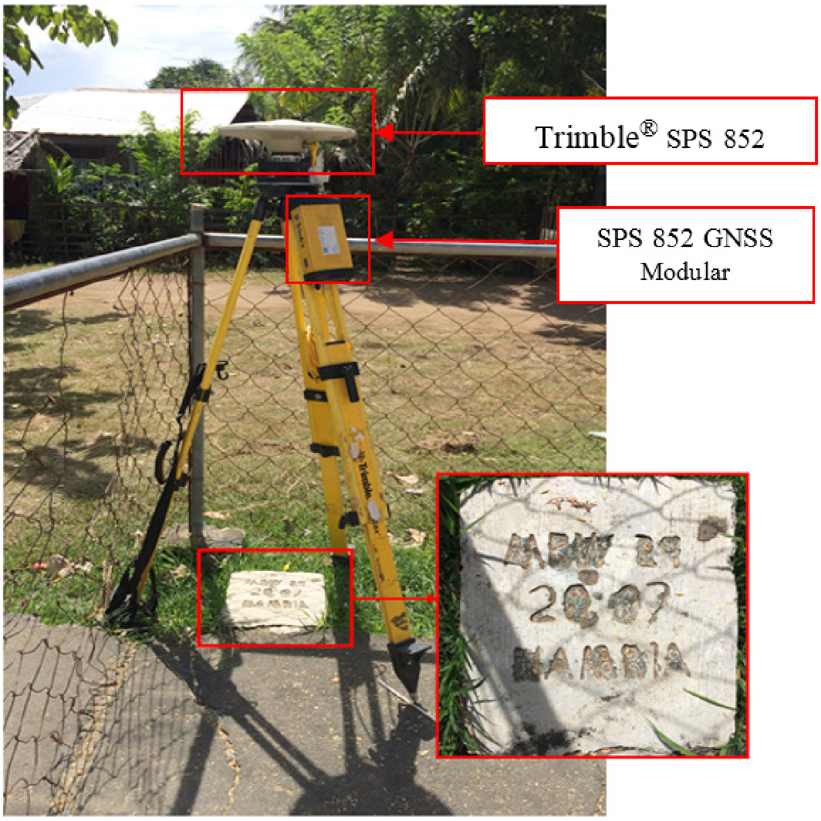


Figure 31. GNSS base set-up, Trimble® SPS 882, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

Figure 32. GNSS receiver set-up, Trimble® SPS 882, at MRW- 30 Amnay Bridge approach in Sitio Kabangkalan, Brgy. Pinagturilan, Municipality of Santa Cruz, Occidental Mindoro

Figure 33. GNSS receiver set-up, Trimble® SPS 882, at MC-200, Lumintao Bridge approach in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

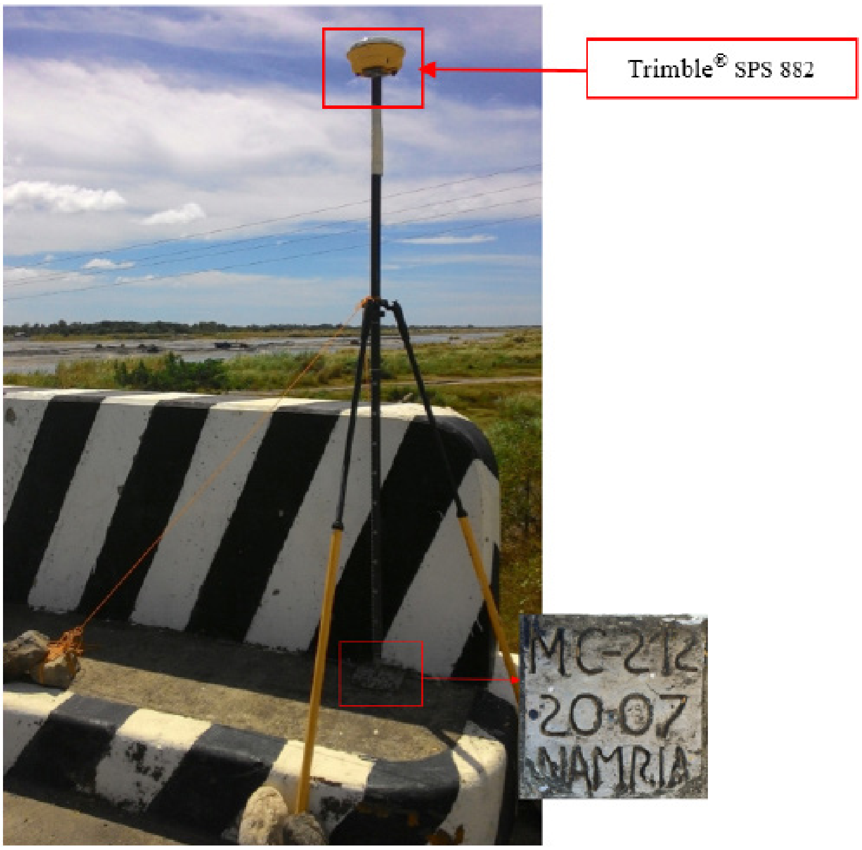


Figure 34. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

Figure 35. GNSS base, Trimble® SPS 852, at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

Figure 36. GNSS receiver, Trimble® SPS 882, at GPS-4 on right side of the road abutment after Caguray Bridge going to Bulalacao in Brgy. Poblacion, Municipality of Magsaysay, Occidental Mindoro

Figure 37. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 38. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro

Figure 39. GNSS receiver set-up, Trimble® SPS 882, at UP-ALI, Alipid Bridge approach in Brgy. Sto. Niño, Municipality of Sablayan, Occidental Mindoro

4.3 Baseline Processing

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

Baseline processing result of control points in Pola River Basin is summarized in Table 23 generated TBC software.

Table 23. Baseline Processing Report for Pola River Static Survey
(Source: NAMRIA, UP-TCAGP)

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

4.4 Network Adjustment

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

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

Where:

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

The nine (9) control points, MRW-24, MRW-30, MC-200, MC-212, MC-90, GPS-4, UP-PIN, UP-MOM, and UP-ALI were occupied and observed simultaneously to form a GNSS loop. All 14 baselines acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively as shown in Table C-2Table 24.

Table 24. Control Point Constraints

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

Table 25. Adjusted Grid Coordinates

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

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

GPS-4			
	Horizontal accuracy	=	$\sqrt{((3.9)^2 + (3.2)^2}$
		=	$\sqrt{(15.21 + 10.24)}$
		=	5.0 cm < 20 cm
	Vertical accuracy	=	6.8 cm < 10 cm
MC-200			
	Horizontal accuracy	=	$\sqrt{((2.2)^2 + (1.6)^2}$
		=	$\sqrt{(4.84 + 2.56)}$
		=	7.4 cm < 20 cm
	Vertical accuracy	=	Fixed
MC-212			
	Horizontal accuracy	=	$\sqrt{((2.8)^2 + (2.2)^2}$
		=	$\sqrt{(7.84+ 4.84)}$
		=	3.6 cm < 20 cm
	Vertical accuracy	=	Fixed
MC-90			
	Horizontal accuracy	=	$\sqrt{((3.9)^2 + (2.3)^2}$
		=	$\sqrt{(15.21 + 5.29)}$
		=	4.5 cm < 20 cm
	Vertical accuracy	=	9.5 cm < 10 cm
MRW-24			
	Horizontal accuracy	=	Fixed
	Vertical accuracy	=	4.5 cm < 10 cm
MRW-30			
	Horizontal accuracy	=	Fixed
	Vertical accuracy	=	9.1 cm < 10 cm
UP-ALI			
	Horizontal accuracy	=	$\sqrt{((2.0)^2 + (1.5)^2}$
		=	$\sqrt{(4.0 + 2.25)}$
		=	2.5 cm < 20 cm
	Vertical accuracy	=	7.1 cm < 10 cm
UP-MOM			
	Horizontal accuracy	=	$\sqrt{((1.5)^2 + (1.2)^2}$
		=	$\sqrt{(2.25 + 1.44)}$
		=	1.9 cm < 20 cm
	Vertical accuracy	=	5.5 cm < 10 cm
UP-PIN			
	Horizontal accuracy	=	$\sqrt{((3.1)^2 + (2.4)^2}$
		=	$\sqrt{(9.61 + 5.76)}$
		=	3.9 cm < 20 cm
	Vertical accuracy	=	4.5 cm < 10 cm

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

Table 26. Adjusted Geodetic Coordinates

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

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 27. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

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

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

Cross-section and as-built survey were conducted on November 18 and 21, 2015 along the downstream side of Salagan Bridge located in Brgy. Sta. Lucia, Municipality of Sablayan using Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 40.

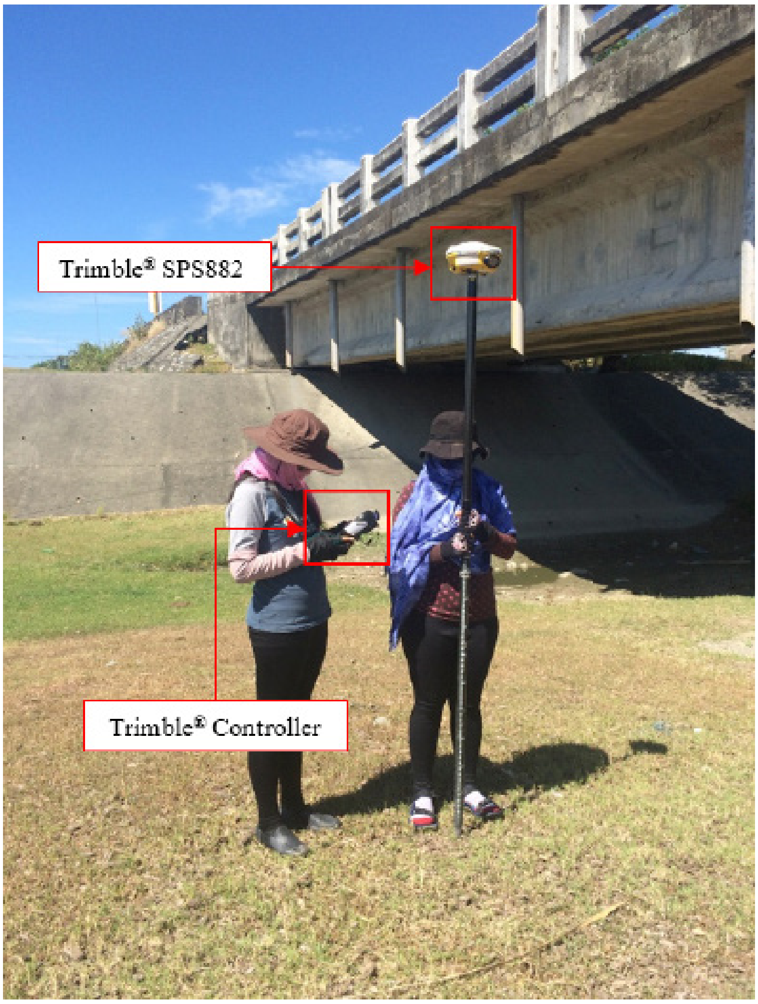


Figure 40. As-built survey at Pola Bridge, Brgy. Poblacion, Municipality of Magsaysay

A total of four hundred and forty-two (442) points with corresponding length of 276 meters were gathered from the survey of the Bridge using the control point MC-90 as base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 41 to Figure 43 respectively.

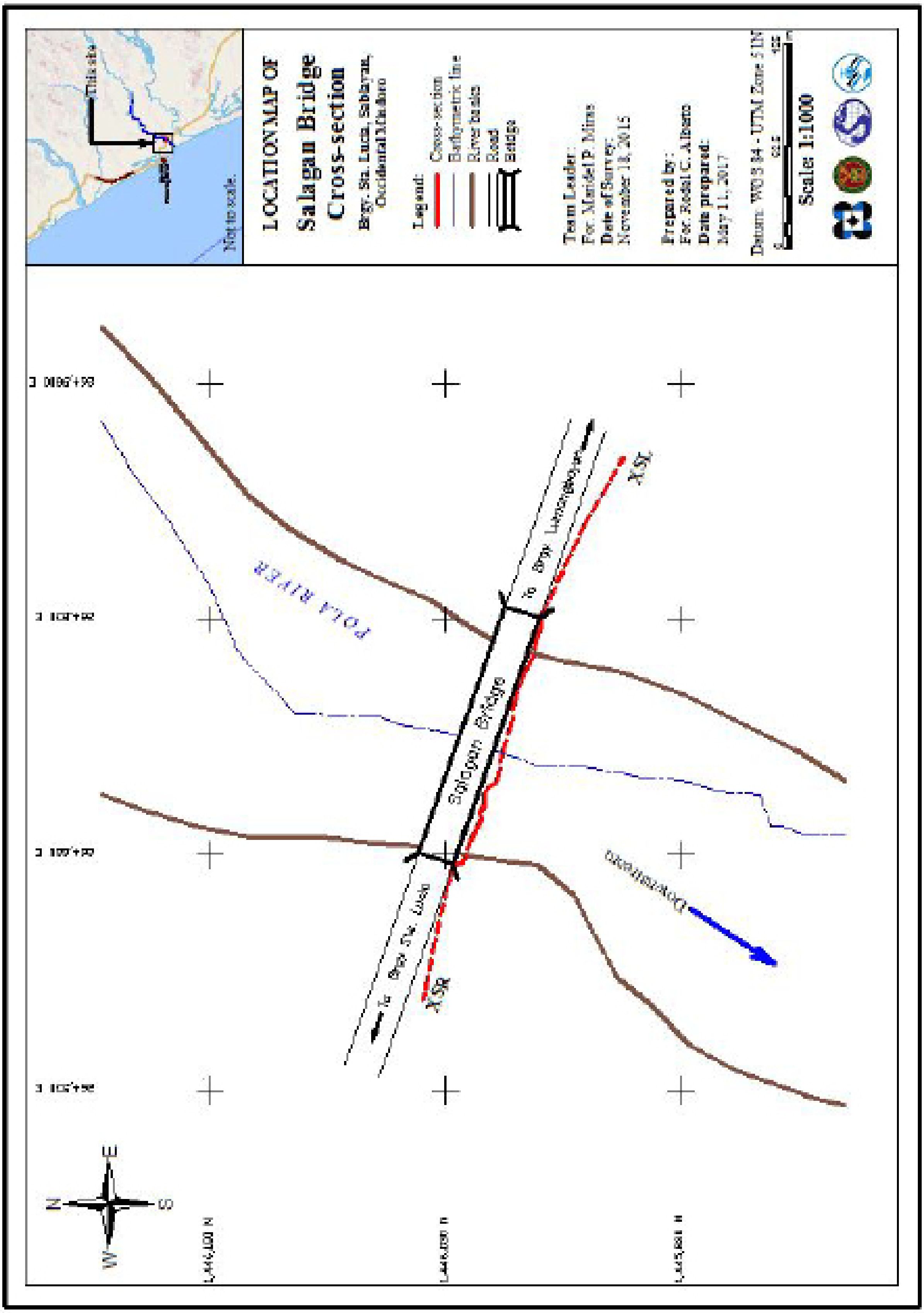


Figure 41. Salagan Bridge cross-section diagram

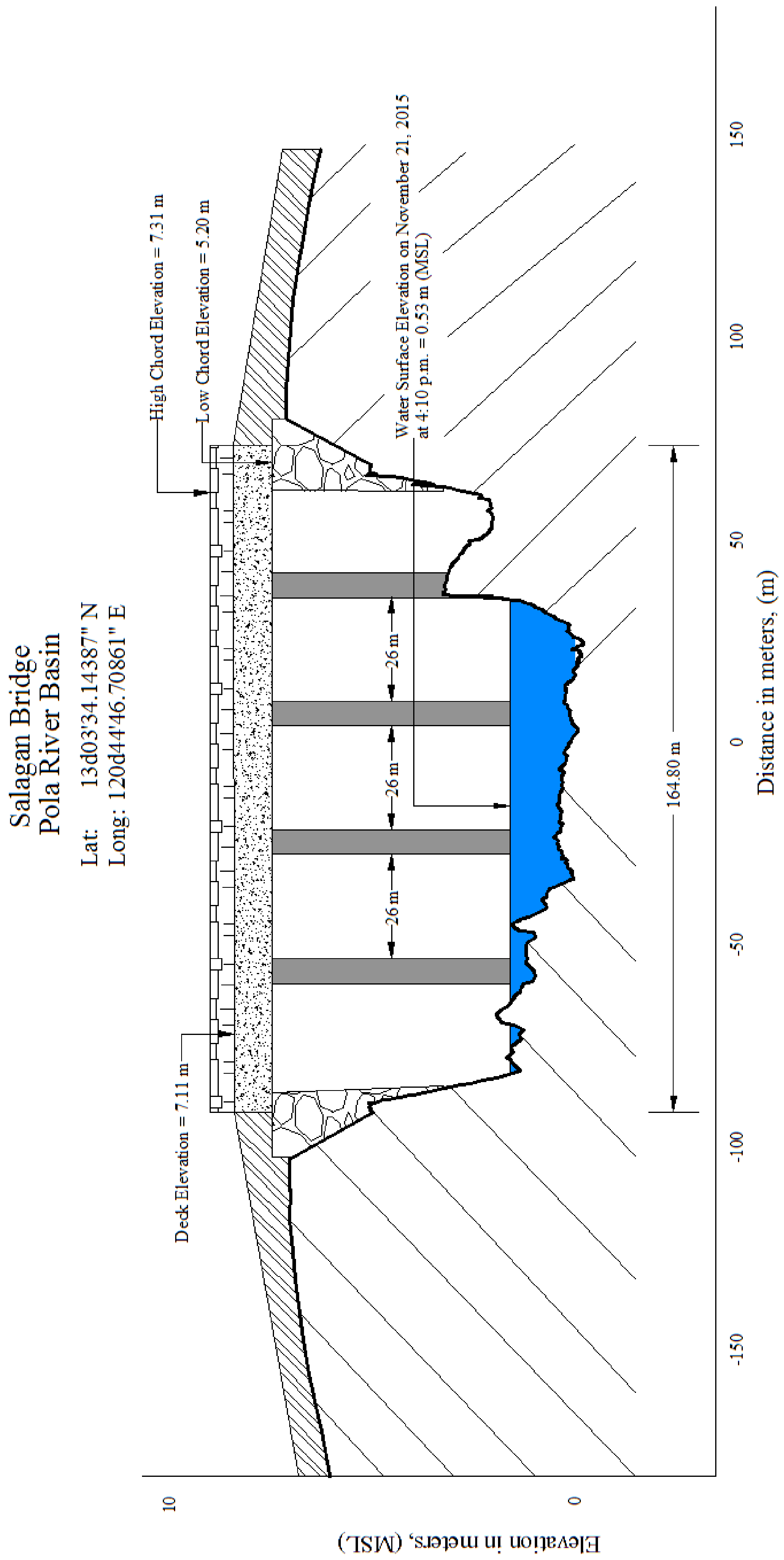


Figure 42. Salagan Bridge cross-section location map

Bridge Data Form

Bridge Name: Salagan Bridge **Date: November 18, 2015**

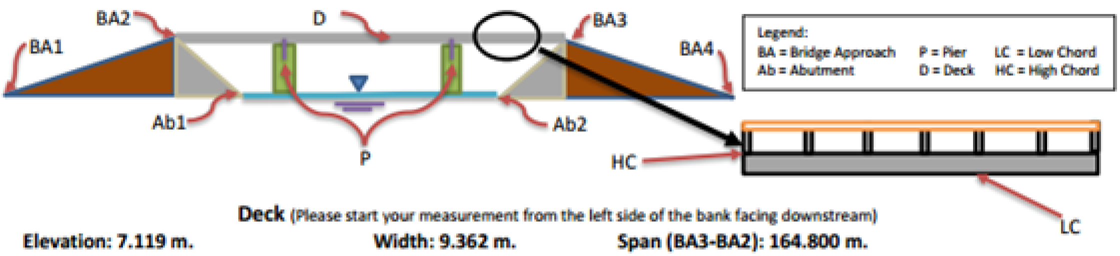
River Name: Pola River **Time: 12:30 PM**

Location: Brgy. Sta. Lucia, Municipality of Sablayan, Occidental Mindoro

Survey Team: Kristine Ailene Borromeo, Maridel Miras, Precious Annie Lopez, Dona Rina Patricia Tajora, Kim Patrick Tort, Rodel Alberto, Caren Joy Ordoña

Flow condition: low ✓ normal high **Weather Condition:** ✓ fair rainy

Latitude: 13°04'11.97480"N **Longitude: 120°44'20.54829"E**



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

Elevation: 7.119 m. **Width: 9.362 m.** **Span (BA3-BA2): 164.800 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	Station 1	7.315	5.208
2			
3			

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	5.226	BA3	280.760	7.345
BA2	115.985	7.323	BA4	368.403	5.877

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

	Station (Distance from BA1)	Elevation
Ab1	NA	NA
Ab2	269.315	2.175

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

Shape: Flattened Cylinder Number of Piers: 4 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	150.933	7.319	approx. 0.9 m.
Pier 2	182.703	7.324	approx. 0.9 m.
Pier 3	214.483	7.350	approx. 0.9 m.
Pier 4	246.137	7.346	approx. 0.9 m.

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

Figure 43. Salagan Bridge Data Form

The water surface elevation of Pola River was also acquired using Trimble® 882 GNSS PPK survey technique on November 21, 2015 at 4:10 p.m. The resulting water surface elevation at Salagan Bridge is 0.53 m above MSL. The water level marking for Salagan Bridge, shown in Figure 44, has an EGMOrtho value of 2.61 meters which was then translated into a marking on the bridge's pier using a digital level. This value shall be updated by UPLB PHIL-LiDAR 1 to its respective MSL value of 1.566 m to serve as reference for their flow data gathering and depth gauge deployment.

Figure 44. Water level marking at Salagan Bridge, Brgy. Casague, Municipality of Sta. Cruz

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 6, 7, 8 14, 17, 18, and 21, 2015 using a survey-grade GNSS Rover, Trimble® SPS 882, receiver mounted on a pole which was attached either to the front or side of vehicle as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.460 and 1.91 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with MC-212, GPS-4, MC-90 and MRW-30 occupied as the GNSS base stations all throughout the conduct of the survey.

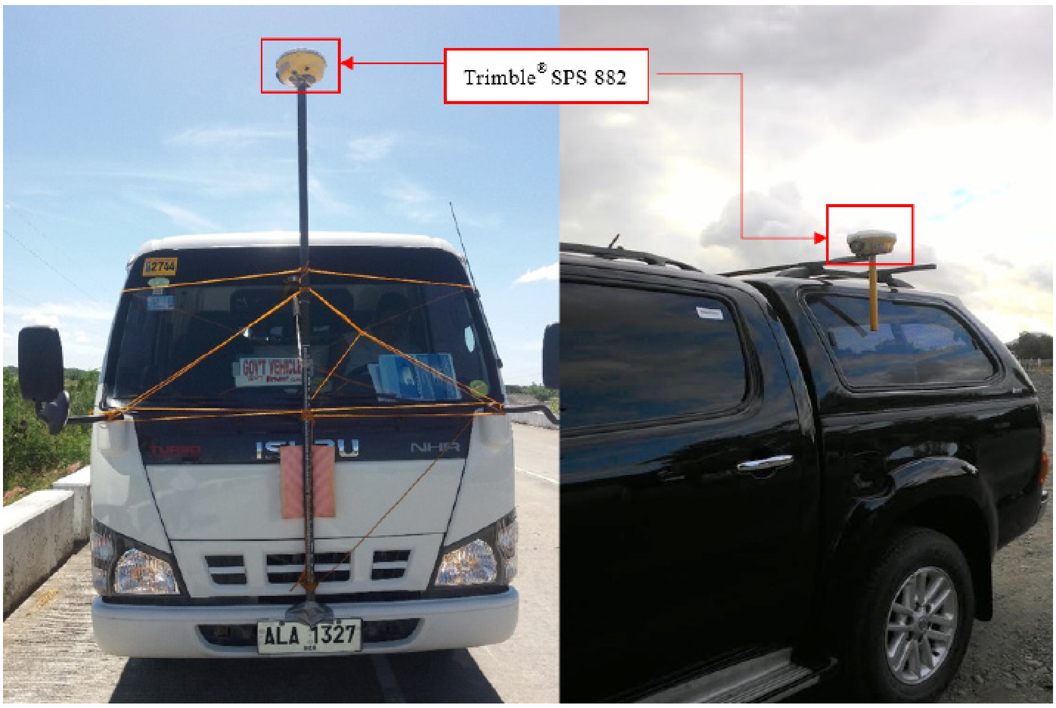


Figure 45. Validation points acquisition survey set-up

The validation point acquisition survey for the Pola River Basin traversed the municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay. The survey perpendicularly traversed the LiDAR flight strips in the survey area. A total of 26,449 points with an approximate length of 191 km was acquired for the validation point acquisition survey as shown in the map in Figure 46.

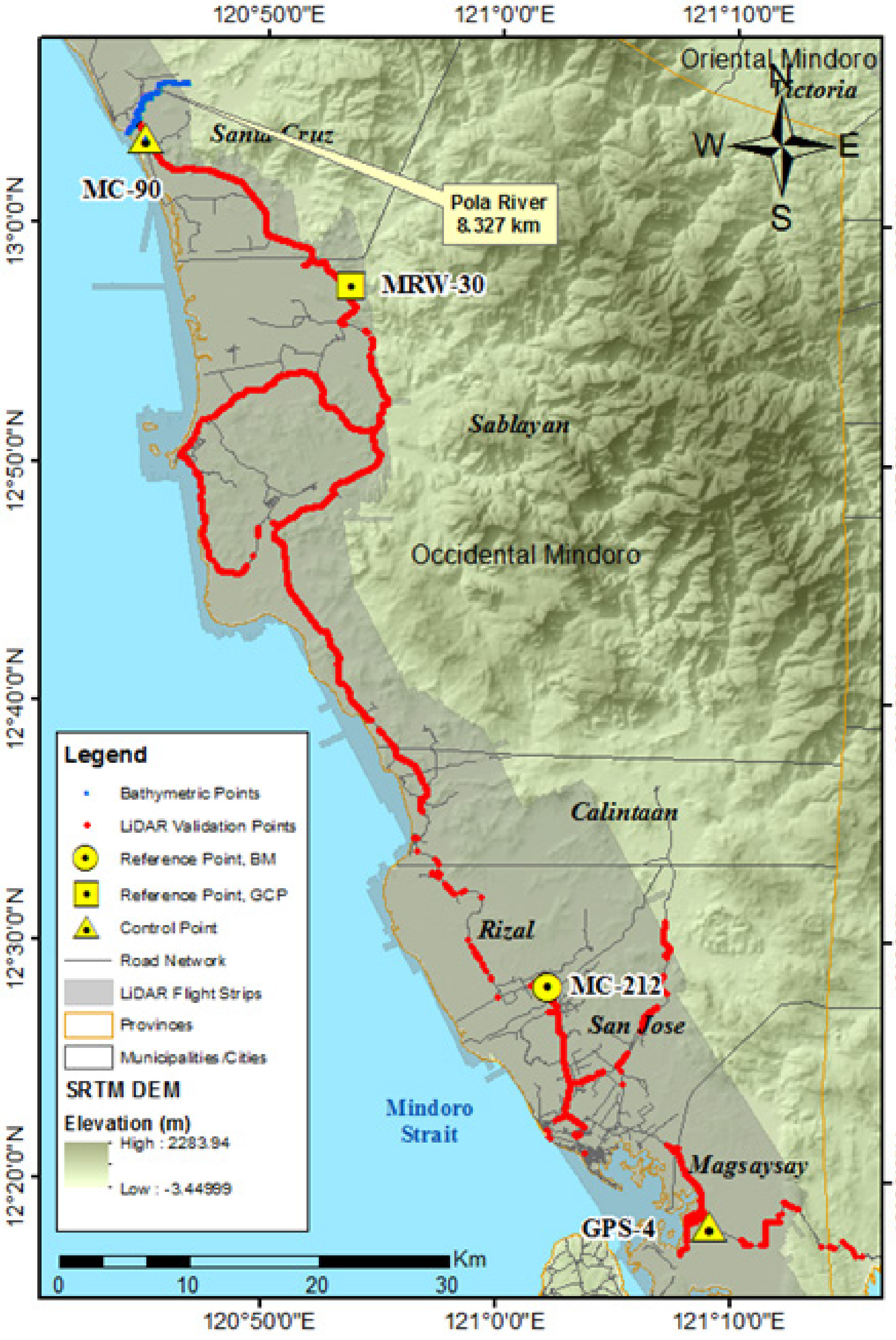


Figure 46. Validation Point Acquisition Survey for the Pola River Survey Area

4.3.2 Bathymetric Survey

Manual bathymetric survey was conducted on November 18, 2015 using a Trimble® SPS 882 GNSS PPK survey technique with MC-90 as the GNSS base station. The survey began at the upstream portion of the river in Brgy. Casague with coordinates 13°05'52.75484" 120°46'35.34598", traversed the river by foot, and ended at the mouth of the river in Brgy.Poblacion II with coordinates 13d03'44.63856"120d43'58.36175", both of which is in the Municipality of Sta. Cruz. The set-up of manual bathymetry is shown on Figure 47.

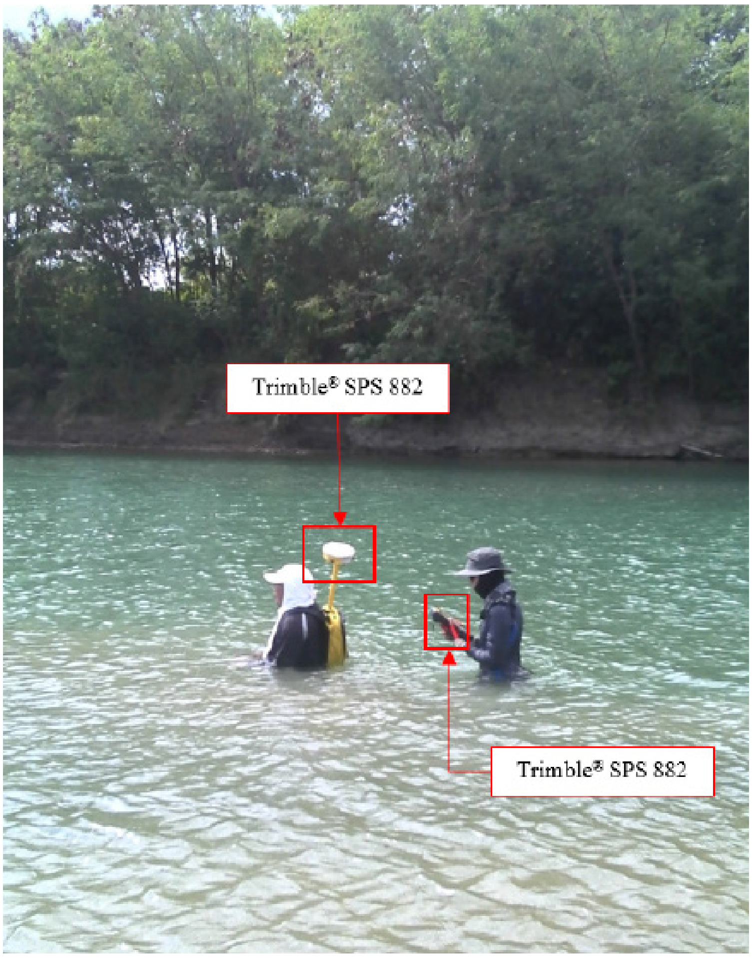


Figure 47. Manual Bathymetry set-up and execution for Pola River survey.

The bathymetric survey coverage for Pola river is 8.327 illustrated in the map in Figure 48. Approximately 1.5 km of the delineated target bathymetric line was not covered due to absence of community in the upstream portion of the river.

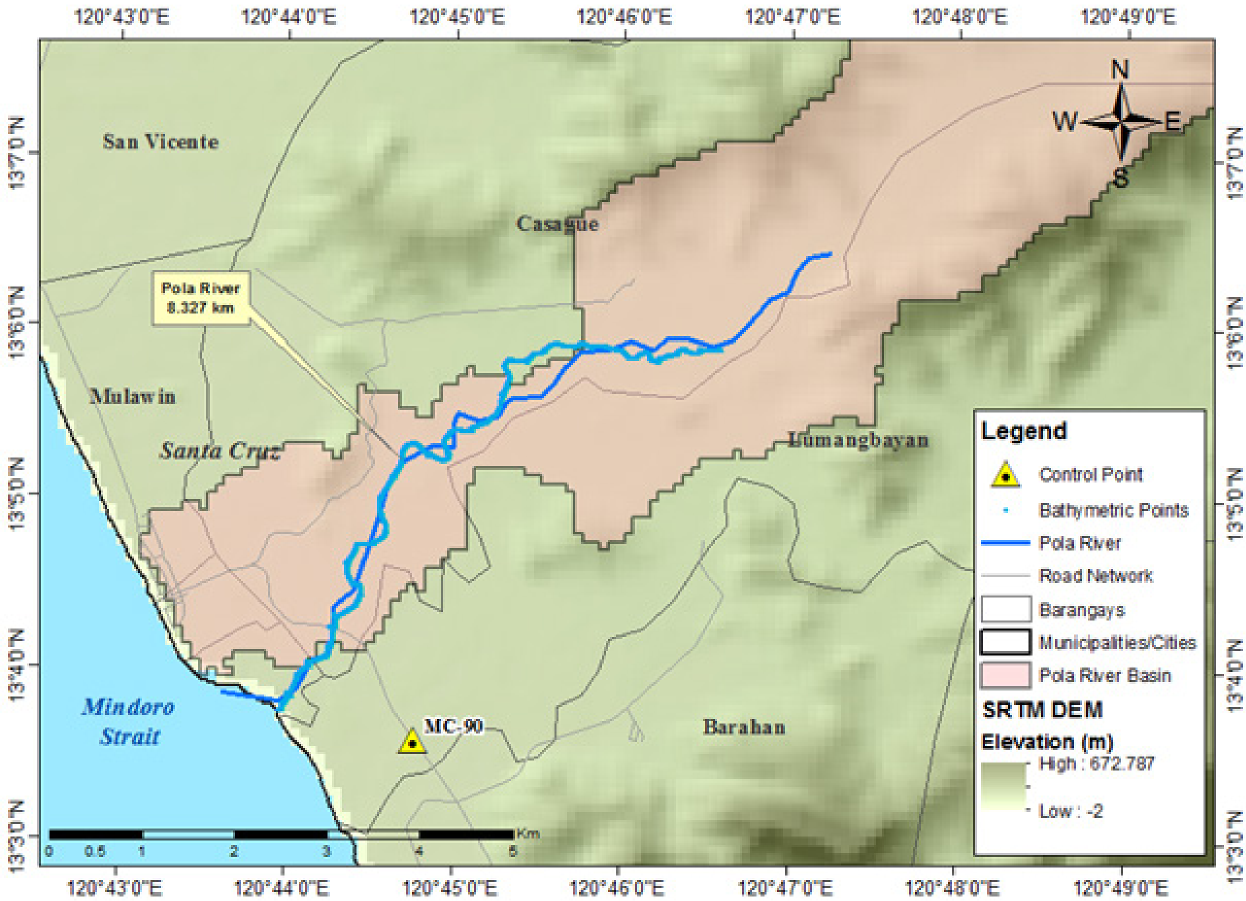


Figure 48. Bathymetric points gathered from Pola River

A CAD drawing was also produced to illustrate the Pola riverbed centerline profile as shown inFigure 49. There is about a 15-m change in elevation observed within the 8.327-km bathymetric data from its upstream in Brgy. Casague down to the mouth of the river in Brgy. Poblacion in Sta. Cruz, Occidental Mindoro.

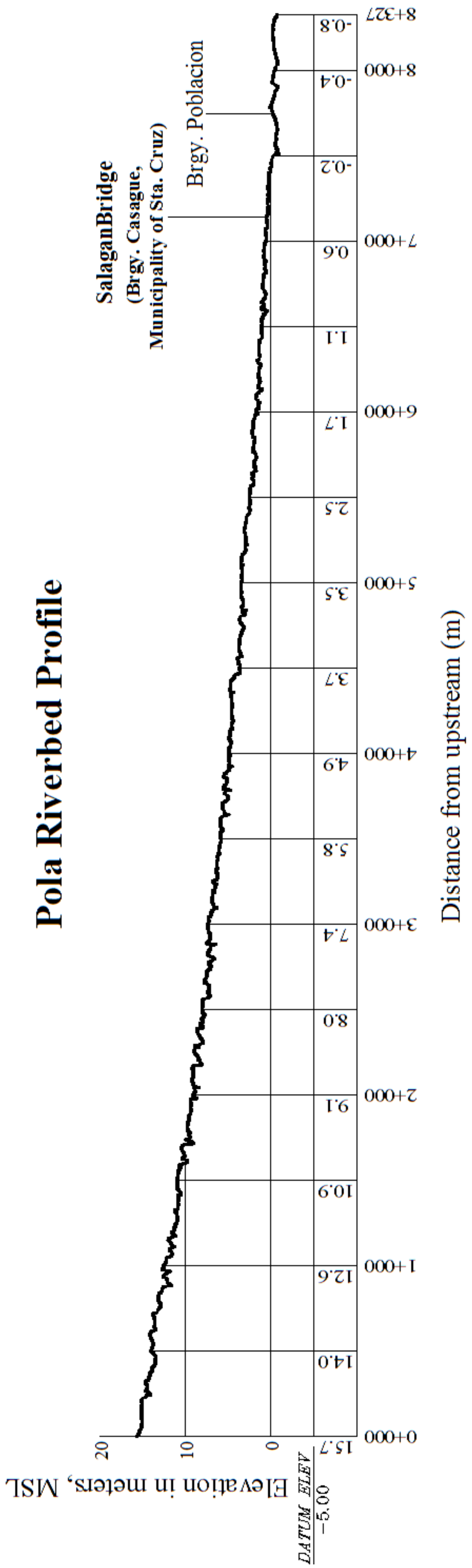


Figure 49. Pola centerline riverbed profile (Upstream)

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data used

No gathered rainfall data for Pola river basin. The HMS model was not calibrated. The values generated HMS model were by default.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Pola Rain Gauge (Figure 52). The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time (Figure 53). This station chosen based on its proximity to the Pola watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 28. RIDF values for Ambulong 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	22.7	35.5	36.3	50.2	68.2	80.1	104.1	125.7	150.8
5	27.9	45.5	53.8	74.2	103.4	122.5	159.7	192.9	226.7
10	34.2	52.1	65.4	90.1	126.7	150.6	196.5	237.3	276.9
15	37.8	57.4	71.9	99	139.8	166.4	217.3	262.4	305.3
20	40.3	61	76.5	105.3	149	177.5	231.9	280	325.1
25	42.2	63.9	80	110.1	156.1	186	243.1	293.5	340.4
50	48.1	72.6	90.9	125	178	212.3	277.6	335.2	387.5
100	54	81.2	101.6	139.8	199.7	238.4	311.8	376.6	434.3

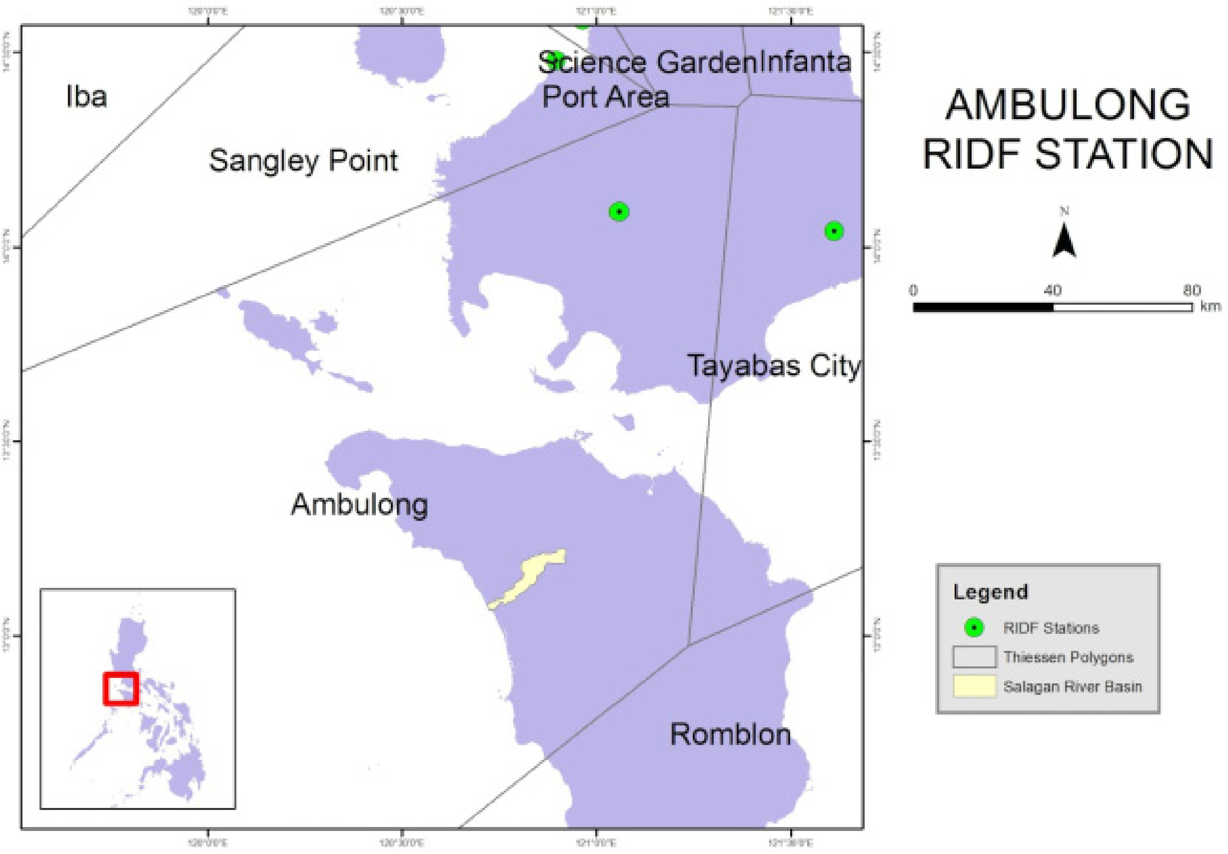


Figure 50. Location of Ambulong RIDF station relative to Pola River Basin

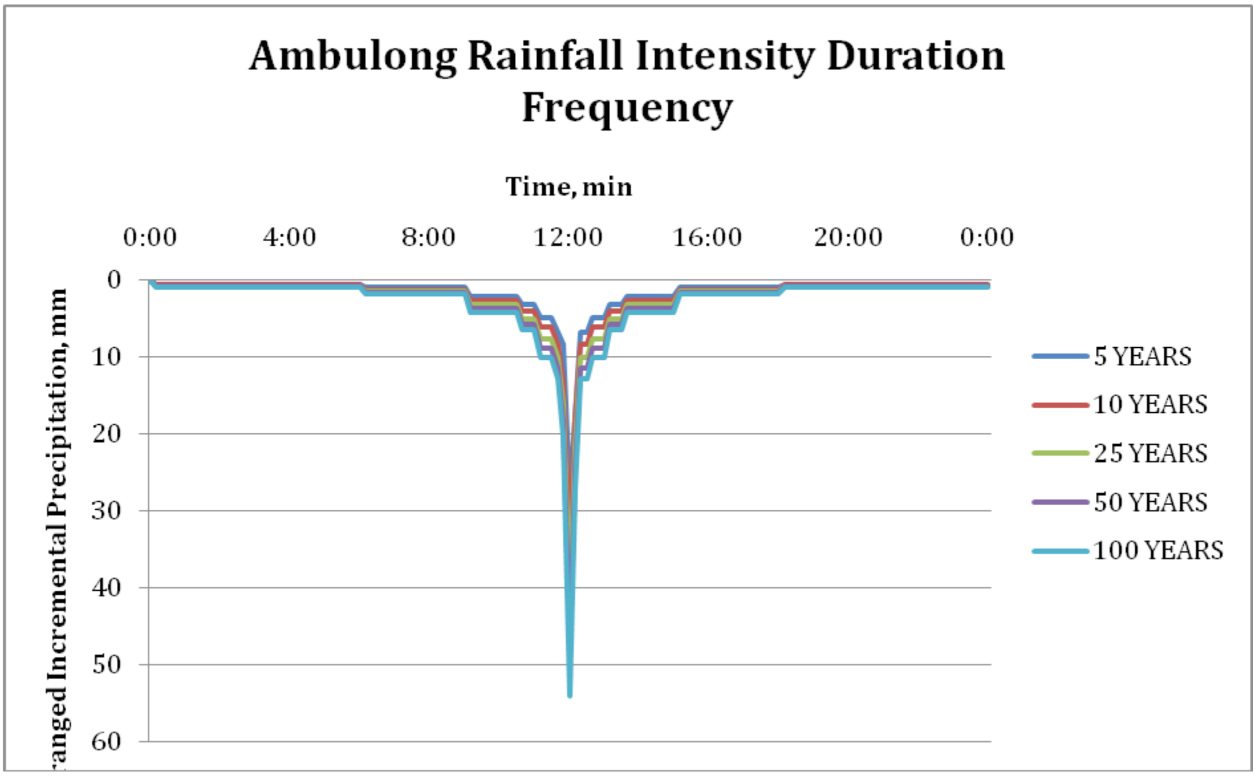


Figure 51. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA).

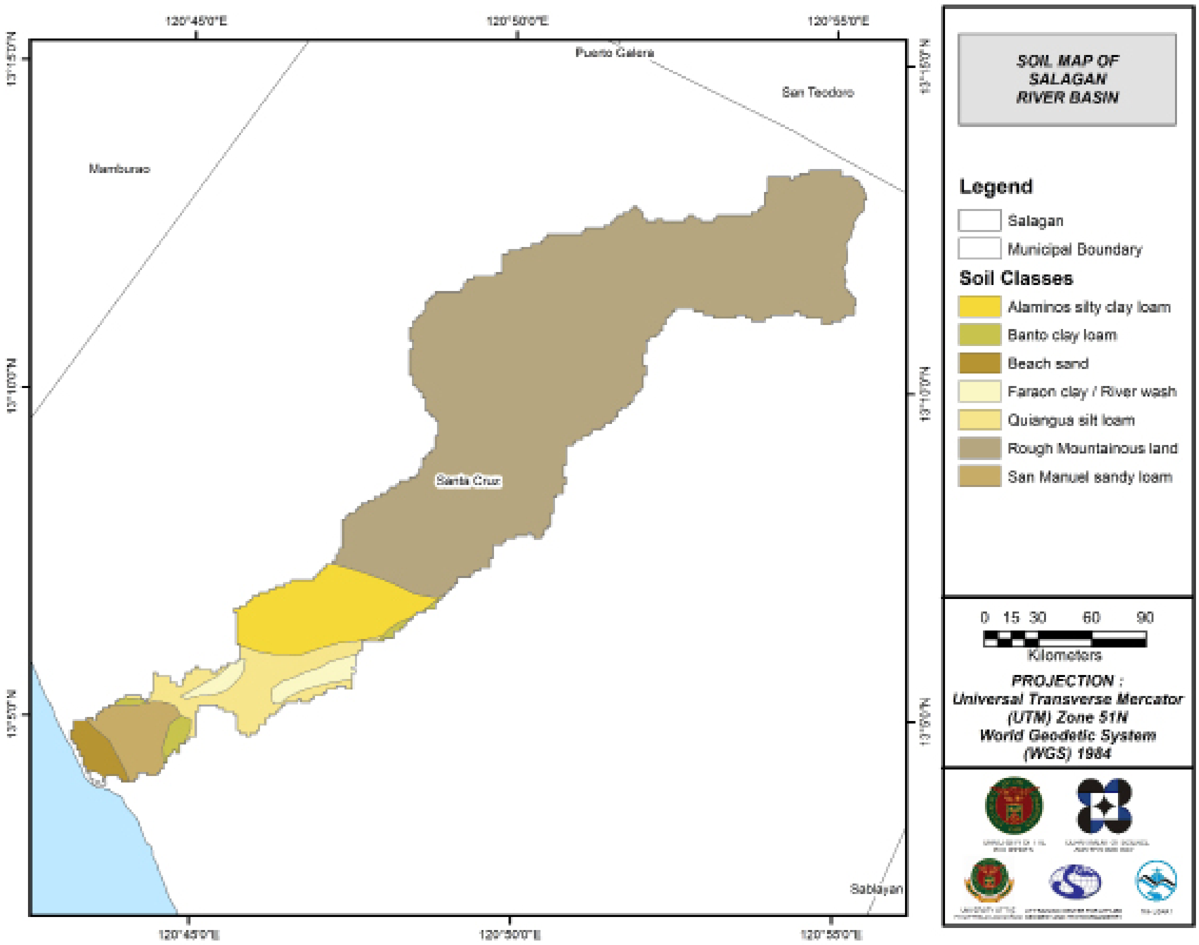


Figure 52. The soil map of the Pola River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

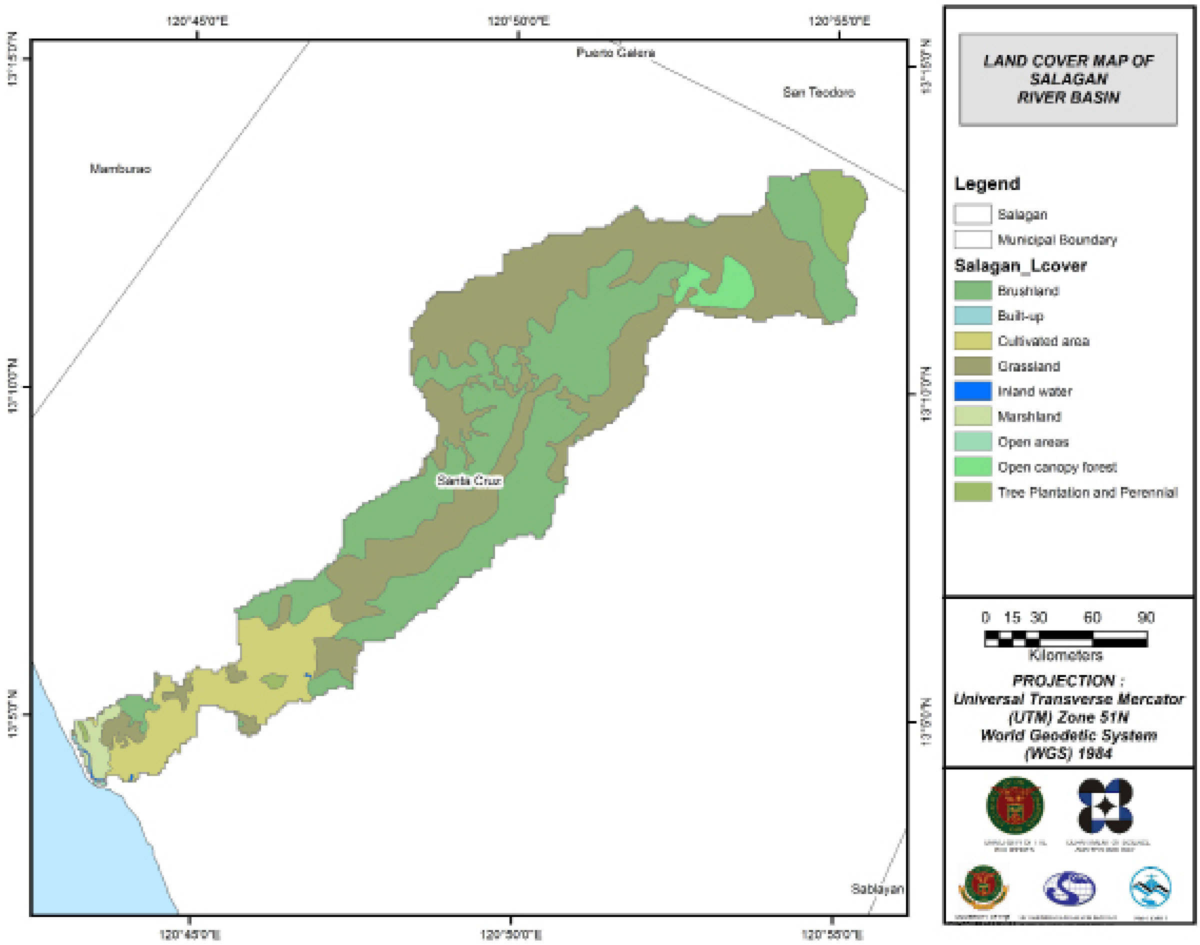


Figure 53. The land cover map of the Pola River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

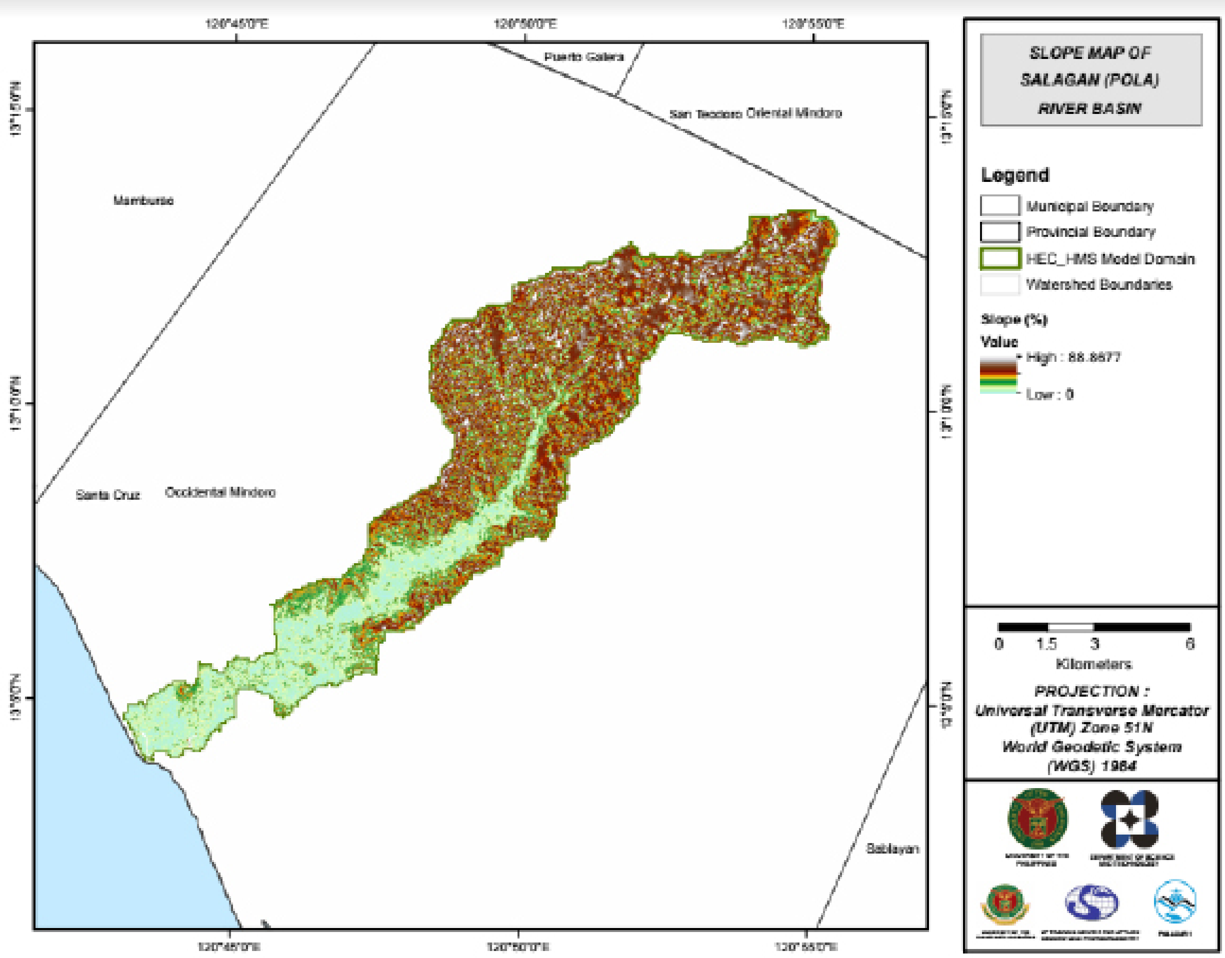


Figure 54. Slope Map of the Pola River Basin

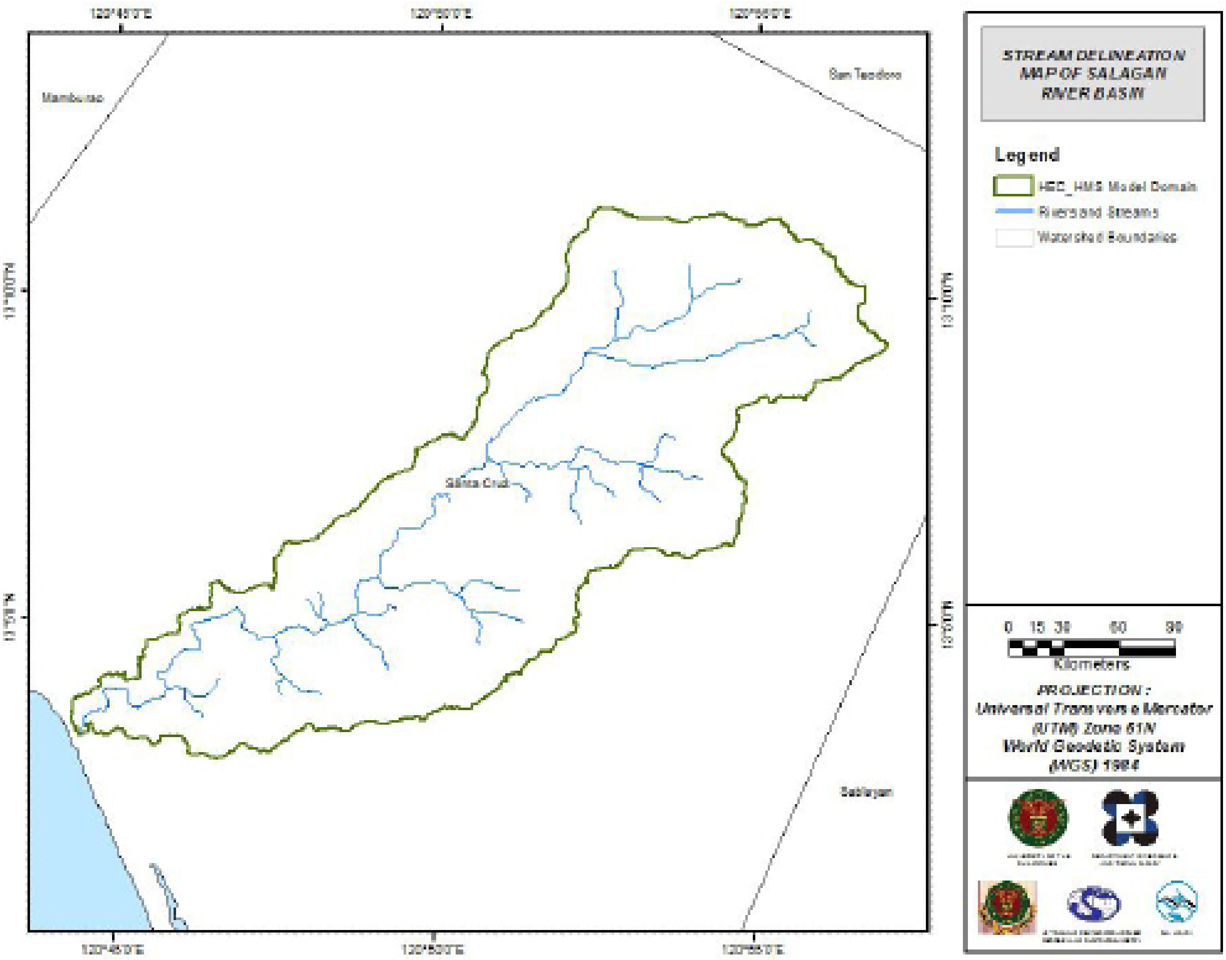


Figure 55. Stream Delineation Map of the Pola River Basin

Using SAR-based DEM, the Pola basin was delineated and further subdivided into subbasins. The model consists of 50 sub basins, 24 reaches, and 23 junctions. The main outlet is labelled as Pola_outlet. This basin model is illustrated in Figure 56.

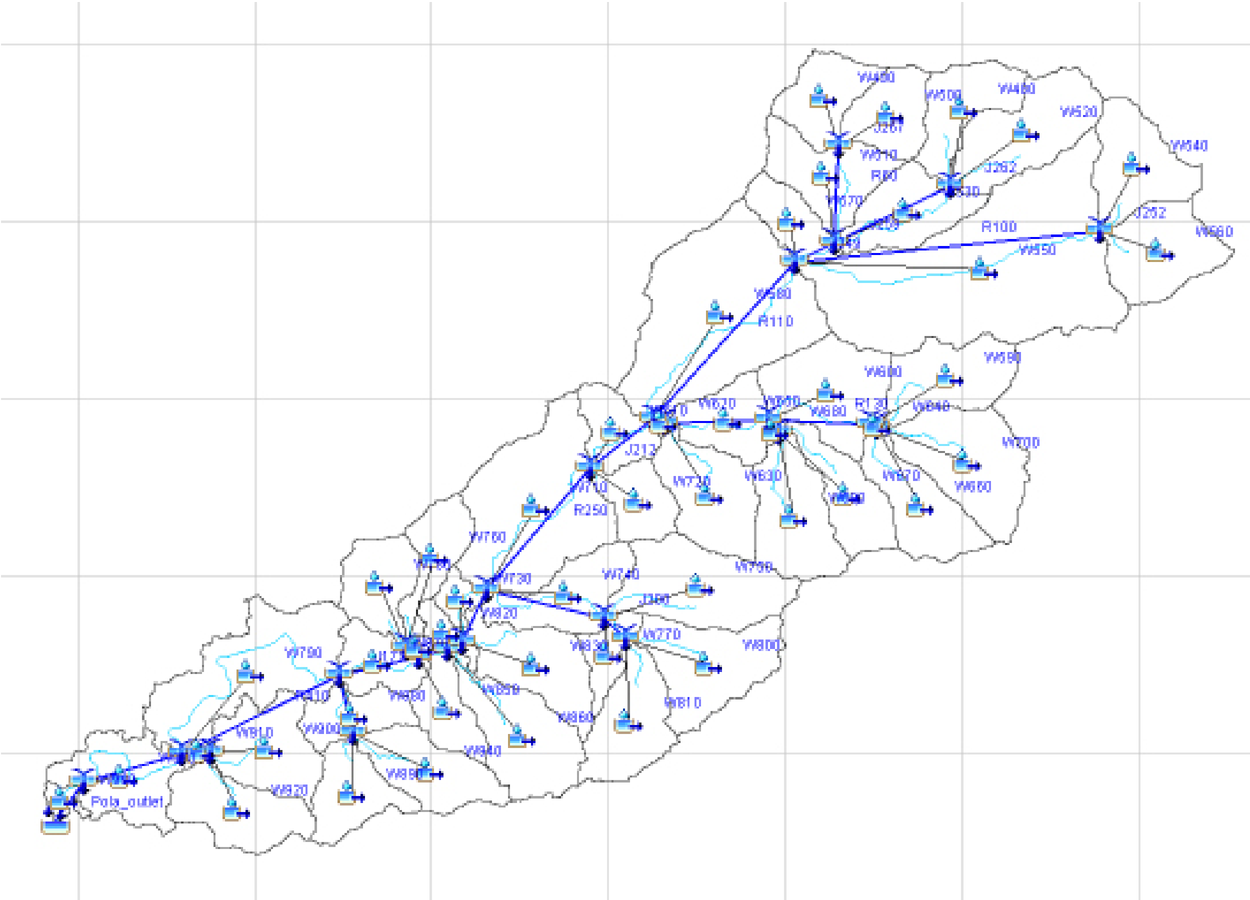


Figure 56. The Pola river basin model generated using HEC-HMS

5.4 Cross-section Data

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

5.5 Flo 2D Model

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

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

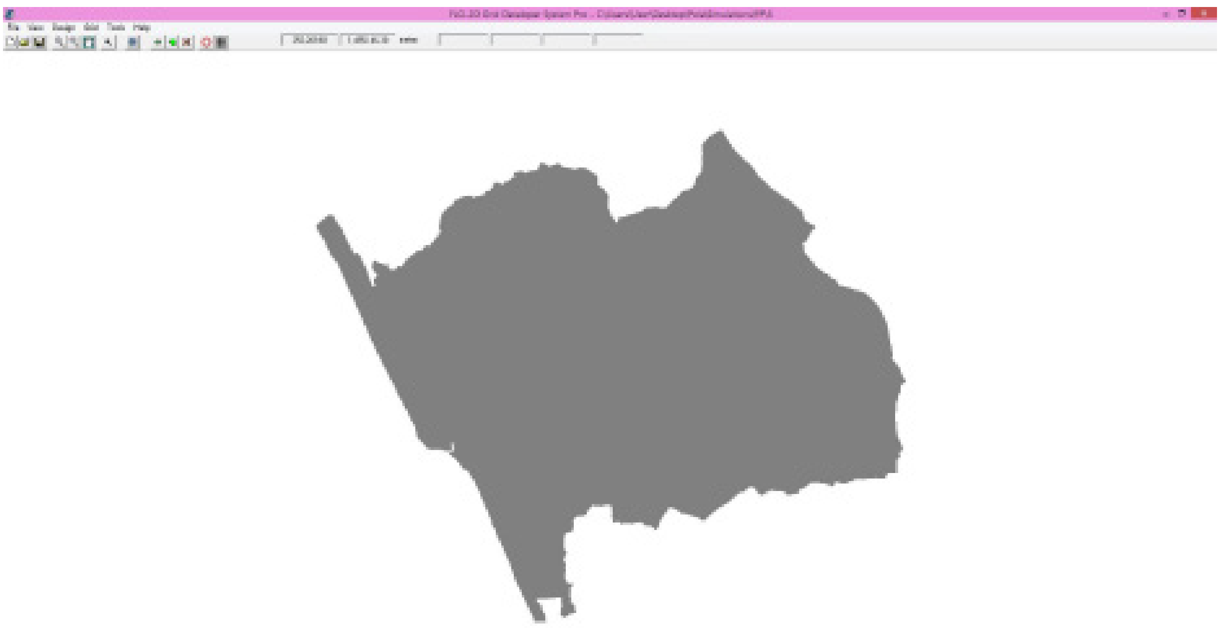


Figure 57. Screenshot of sub-catchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 79.65125 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 93356256.00 m2.

There is a total of 71915265.36 m3 of water entering the model. Of this amount, 35063556.99 m3 is due to rainfall while 36851708.37 m3 is inflow from other areas outside the model. 13284148.00 m3 of this water is lost to infiltration and interception, while 12228291.23 m3 is stored by the flood plain. The rest, amounting up to 46402719.62 m3, is outflow.

5.6 HEC-HMS Model Values (Uncalibrated)

Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Values for Pola River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3 - 14
			Curve Number	48 - 80
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 3
			Storage Coefficient (hr)	0.5 - 5

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 3 to 14mm means that there is 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 48 to 80 for curve number is slightly lower than the advisable range for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 hours to 5 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

5.7 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Pola River using the calibrated HMS base flow is shown in Figure 58.

Figure 58. Sample output of Pola RAS Model

5.8 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Pola Floodplain are shown in Figure 59 to 64. The floodplain, with an area of 94.45 sq. km., covers the municipality of Sta. Cruz. Table 30 shows the percentage of area affected by flooding per municipality.

Table 30. Municipalities affected in Pola Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Santa Cruz	709.53	94.22	13.28%

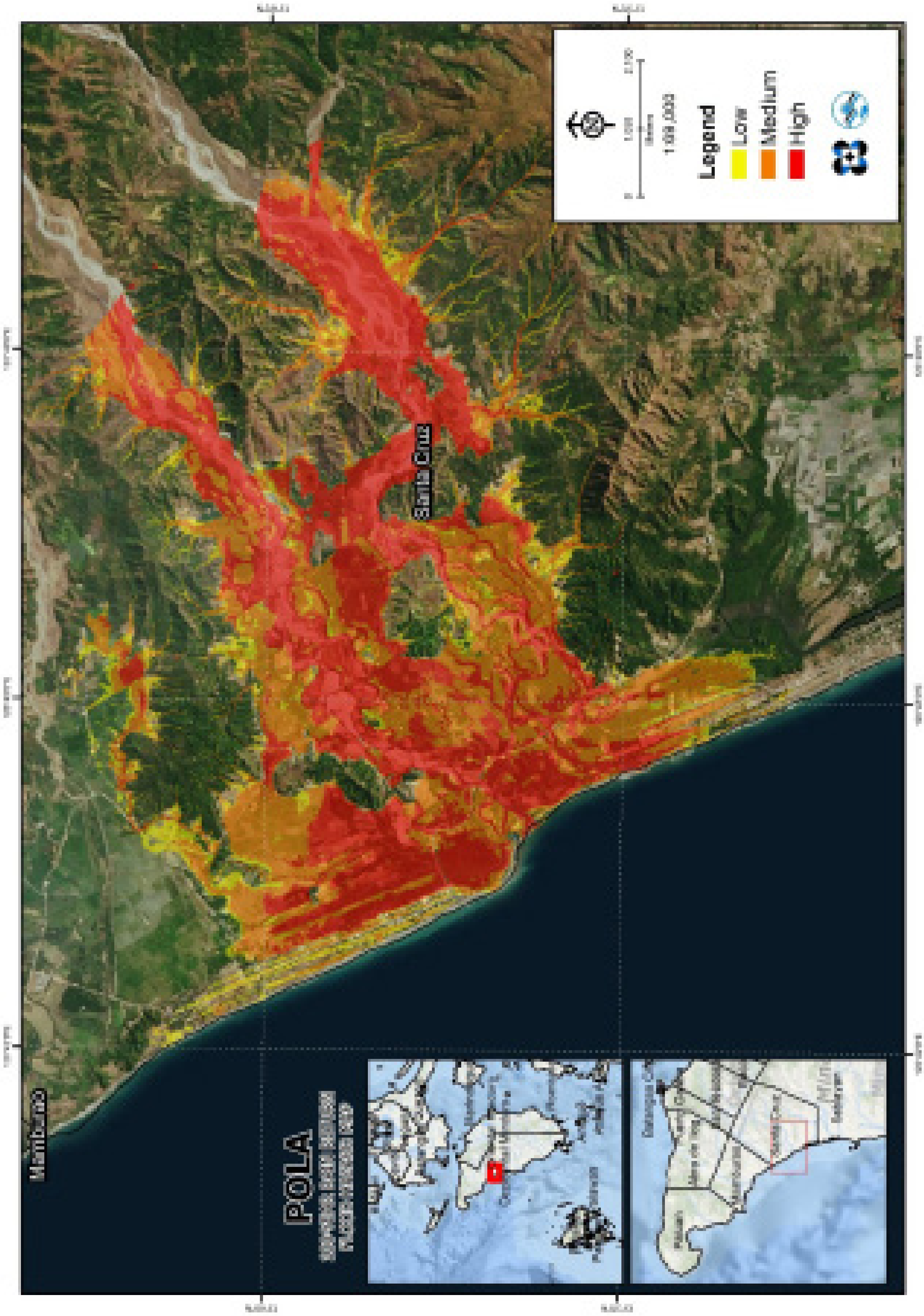


Figure 59. 100-year Flood Hazard Map for Pola Floodplain overlaid in Google Earth imagery

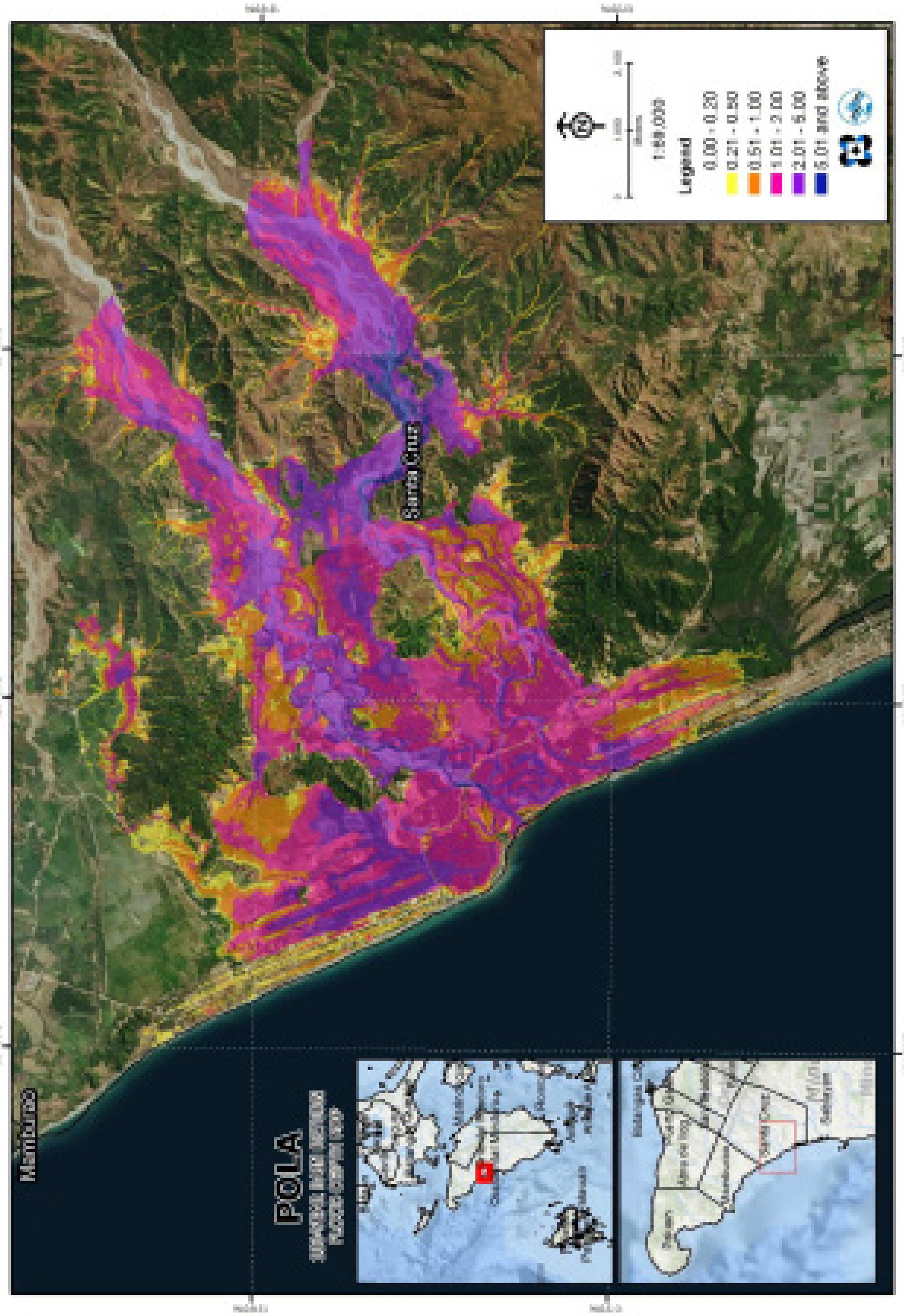


Figure 60. 100-year Flow Depth Map for Pola Floodplain overlaid in Google Earth imagery

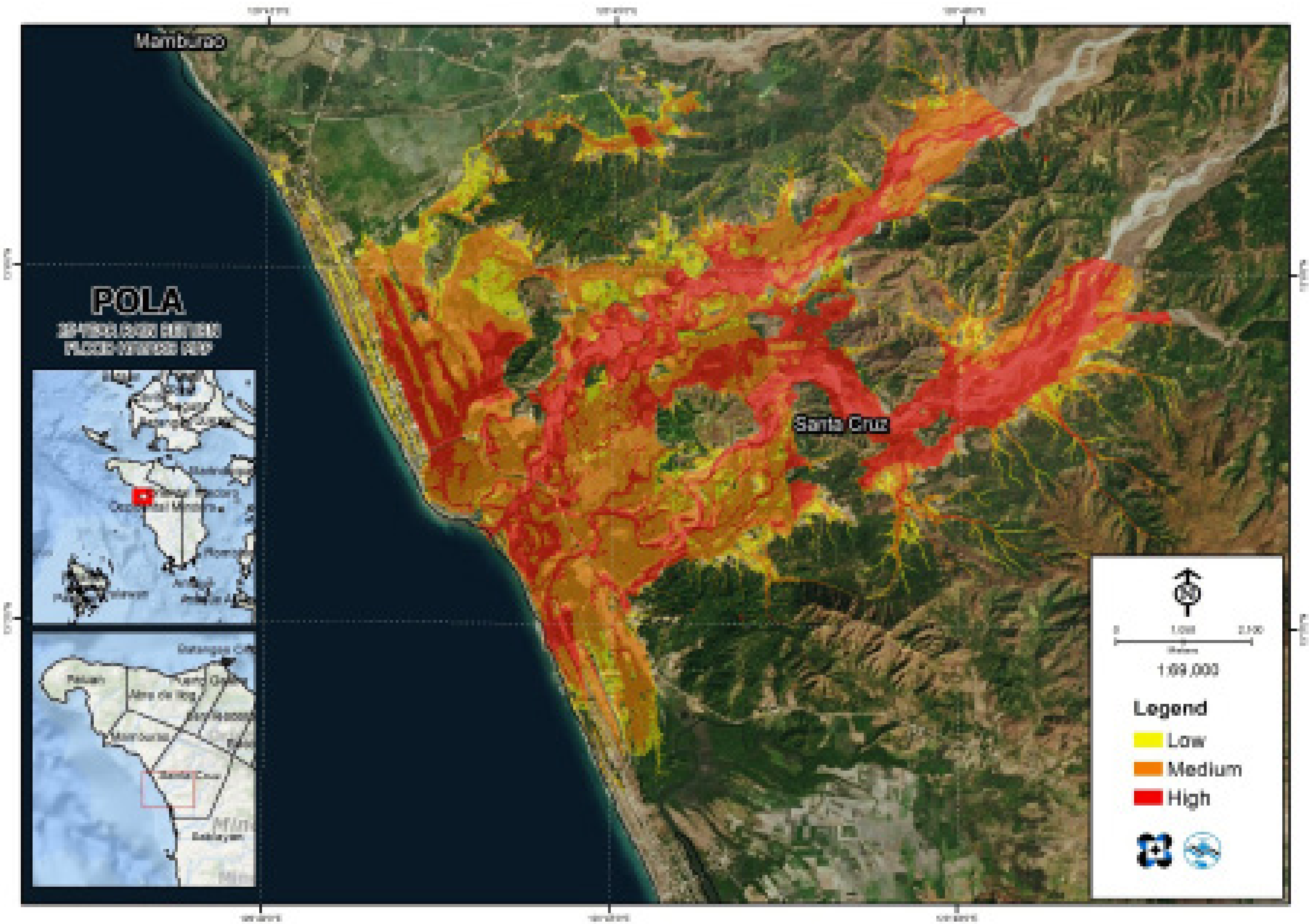


Figure 61. 25-year Flood Hazard Map for Pola Floodplain overlaid in Google Earth imagery

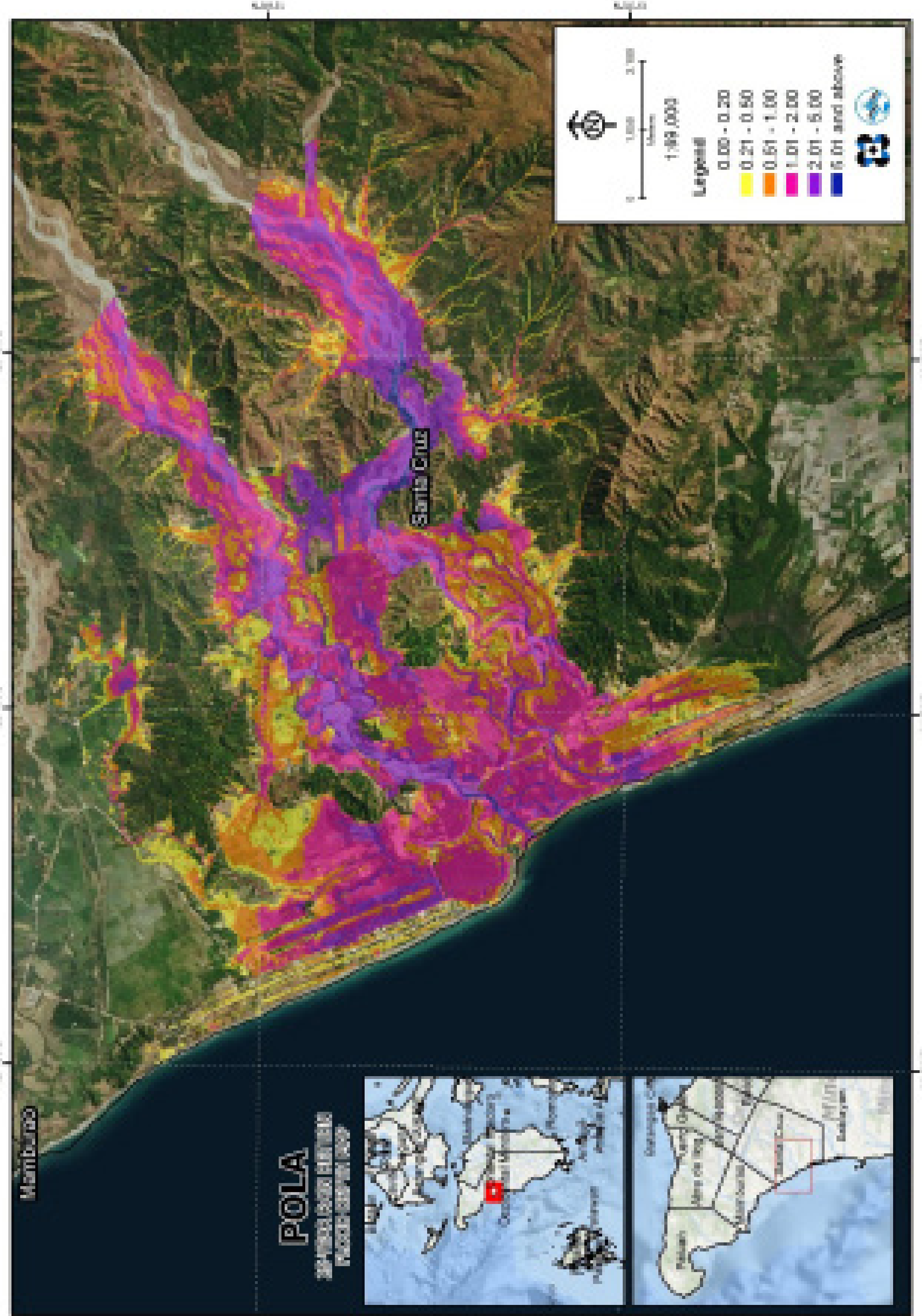


Figure 62. 25-year Flow Depth Map for Pola Floodplain overlaid in Google Earth imagery

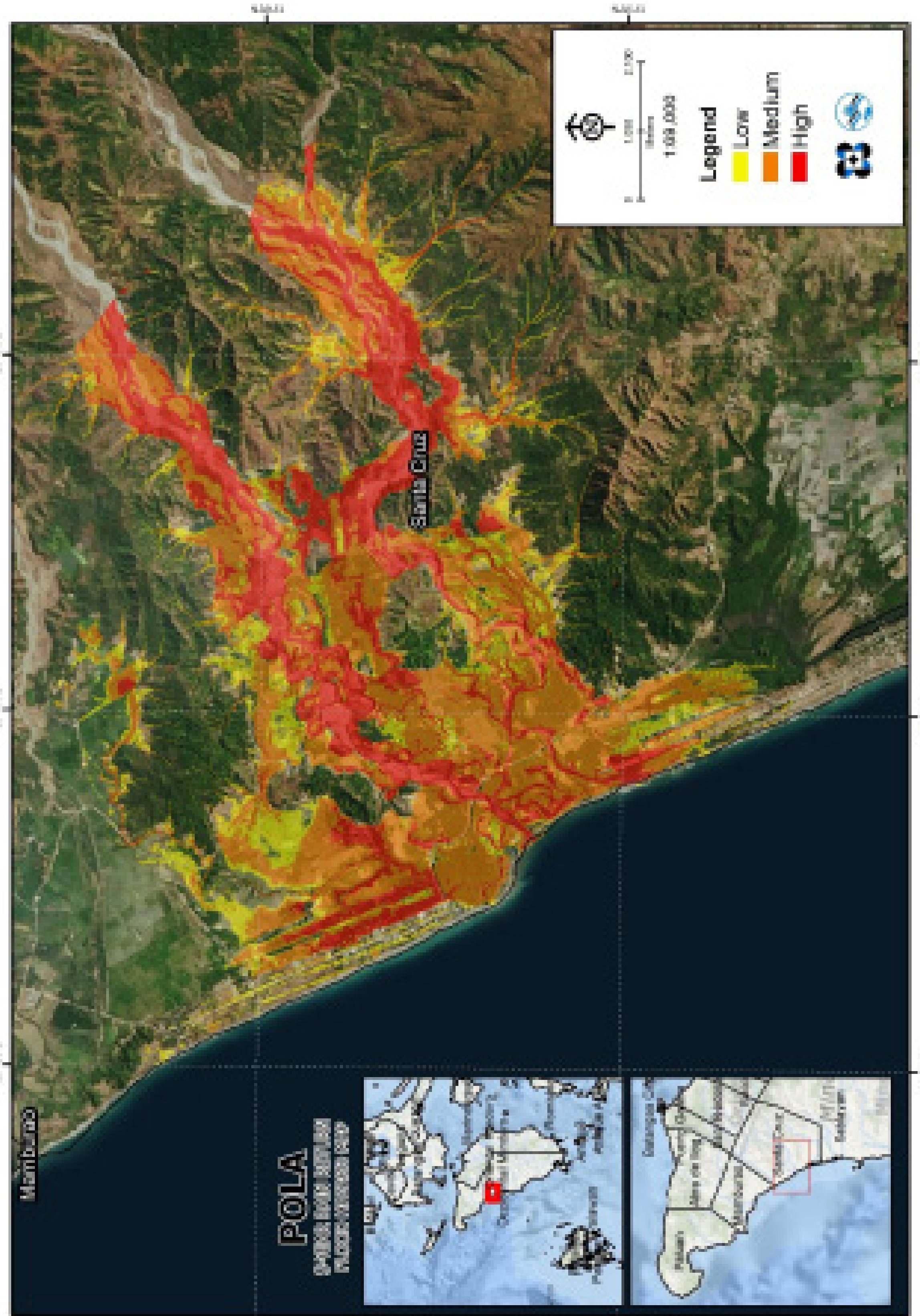


Figure 63. 5-year Flood Hazard Map for Pola Floodplain overlaid in Google Earth imagery

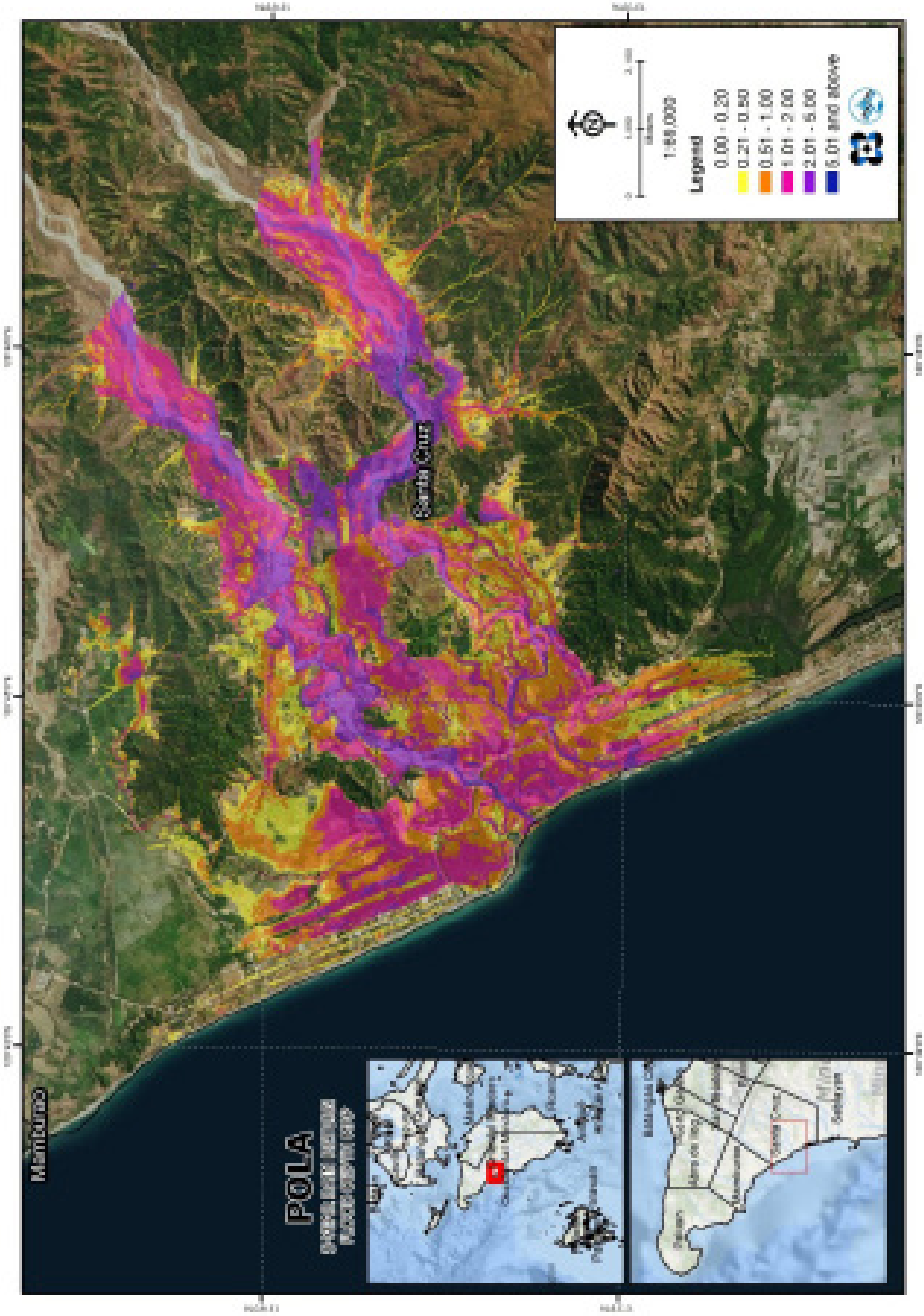


Figure 64. 5-year Flow Depth Map for Pola Floodplain overlaid in Google Earth imagery

5.9 Inventory of Areas Exposed to Flooding

Affected barangays in Pola river basin, grouped by municipality, are listed below. For the said basin, only one municipality consisting of eight (8) barangays is expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 6.96% of the municipality of Santa Cruz with an area of 709.53 sq. km. will experience flood levels of less than 0.20 meters. 1.24% of the area will experience flood levels of 0.21 to 0.50 meters while 1.73%, 2.26%, 1.06%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 31 are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km)							
	Barahan	Casague	Dayap	Lumang-bayan	Mulawin	Pobla-cion I	Pobla-cion II	San Vicente
0.03-0.20	9.91	14.43	8.16	13.12	2.2	0.12	0.12	1.3
0.21-0.50	1.98	3.08	0.33	2	0.91	0.05	0.11	0.32
0.51-1.00	2.53	4.18	0.1	4.23	0.72	0.15	0.28	0.065
1.01-2.00	1.71	5.49	0.048	7.15	0.98	0.42	0.25	0.017
2.01-5.00	0.6	2.78	0.0004	3.94	0.13	0.013	0.084	0.0061
> 5.00	0.034	0.037	0	0.13	0	0	0.0014	0

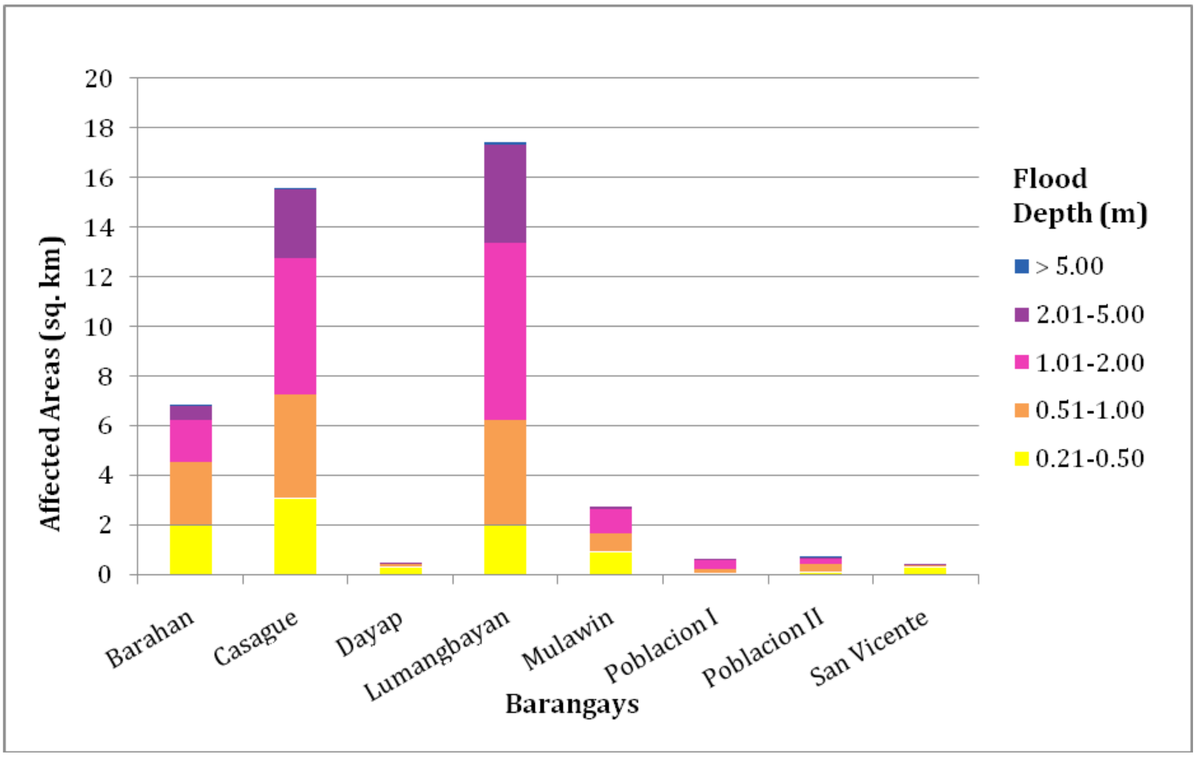


Figure 65. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

For the city of Pola, with an area of 184.42 sq. km., 42.60% will experience flood levels of less 0.20 meters. 4.22% of the area will experience flood levels of 0.21 to 0.50 meters while 1.84%, 1.03%, 0.78%, and 0.16% 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.

For the 25-year return period, 6.58% of the municipality of Santa Cruz with an area of 709.53 sq. km. will experience flood levels of less than 0.20 meters. 1.09% of the area will experience flood levels of 0.21 to 0.50 meters while 1.59%, 2.55%, 1.41%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km)							
	Barahan	Casague	Dayap	Lumang-bayan	Mulawin	Pobla-cion I	Pobla-cion II	San Vicente
0.03-0.20	9.29	13.77	8.05	12.54	1.73	0.1	0.099	1.13
0.21-0.50	1.59	2.85	0.39	1.55	0.84	0.03	0.058	0.44
0.51-1.00	2.52	4.09	0.13	3.25	0.86	0.079	0.21	0.11
1.01-2.00	2.28	6.23	0.068	7.68	0.95	0.5	0.36	0.022
2.01-5.00	1.01	2.99	0.0022	5.24	0.56	0.057	0.12	0.0076
> 5.00	0.053	0.059	0	0.31	0	0	0.0023	0

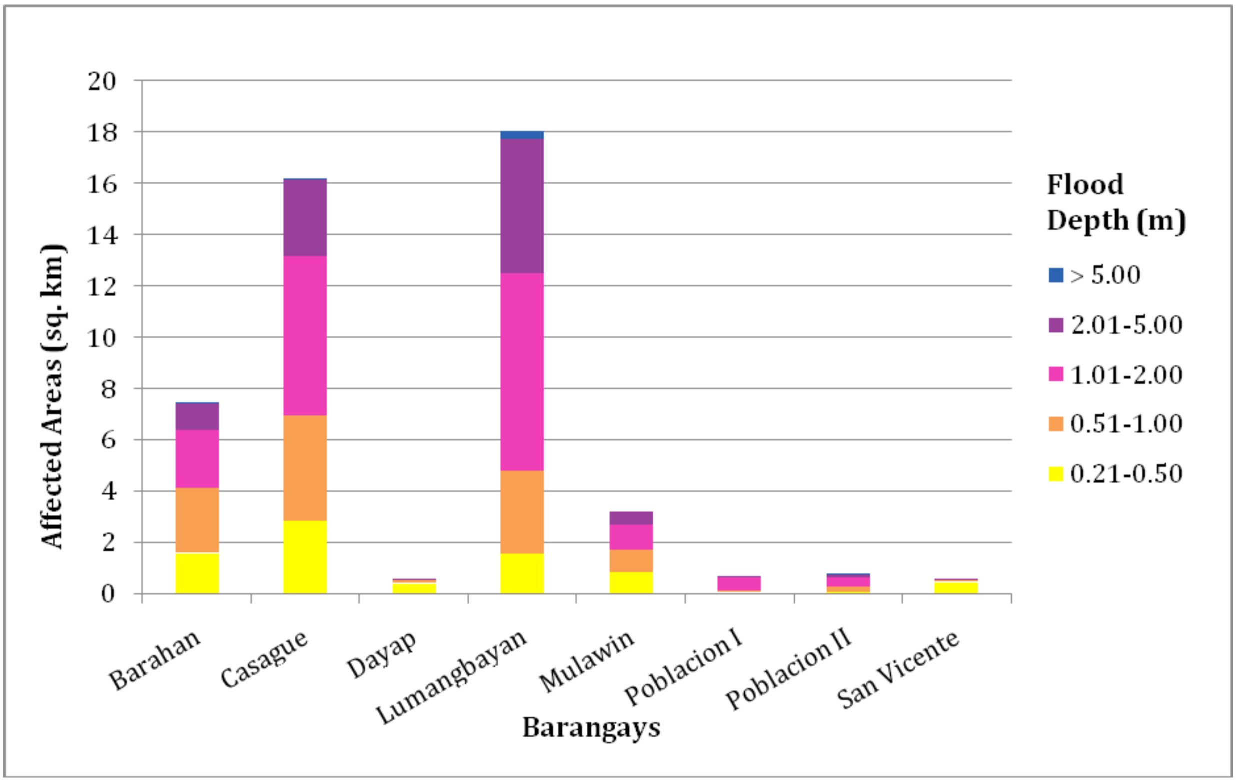


Figure 66. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

For the city of Pola, with an area of 184.42 sq. km., 38.26% will experience flood levels of less 0.20 meters. 5.35% of the area will experience flood levels of 0.21 to 0.50 meters while 3.27%, 1.83%, 1.43%, and 0.49% 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.

For the 100-year return period, 6.25% of the municipality of Santa Cruz with an area of 709.53 sq. km. will experience flood levels of less than 0.20 meters. 0.86% of the area will experience flood levels of 0.21 to 0.50 meters while 1.28%, 2.73%, 2.01%, and 0.13% 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 kilometers by flood depth per barangay.

Table 33. Affected Areas in Santa Cruz, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km)							
	Barahan	Casague	Dayap	Lumang-bayan	Mulawin	Pobla-cion I	Pobla-cion II	San Vicente
0.03-0.20	8.88	13.01	7.94	12.09	1.31	0.073	0.08	0.99
0.21-0.50	1.32	1.83	0.44	1.24	0.76	0.029	0.031	0.48
0.51-1.00	2.28	3.33	0.17	2.18	0.76	0.048	0.14	0.2
1.01-2.00	2.78	7.1	0.087	7.39	1.19	0.37	0.42	0.031
2.01-5.00	1.34	4.62	0.011	6.98	0.92	0.24	0.17	0.0086
> 5.00	0.15	0.11	0	0.69	0	0	0.0057	0

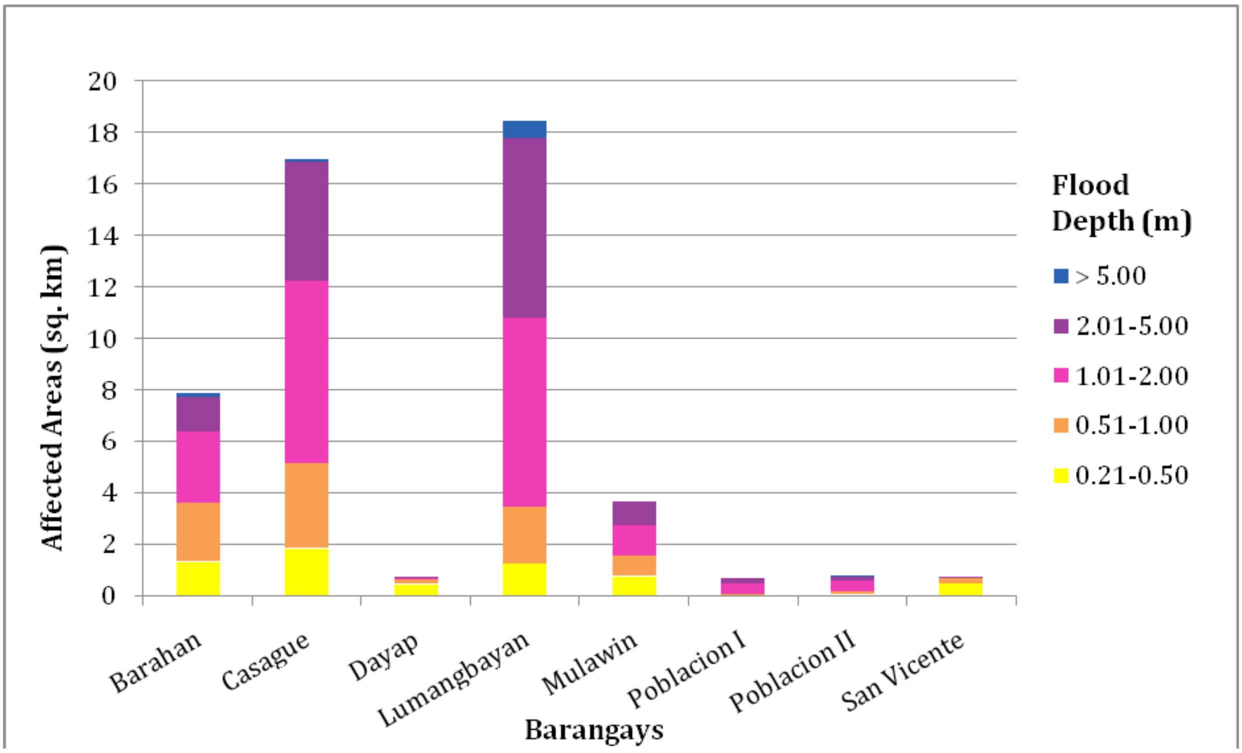


Figure 67. Affected Areas in Santa Cruz, Occidental Mindoro during 100-Year Rainfall Return Period

For the city of Pola, with an area of 184.42 sq. km., 35.76% will experience flood levels of less 0.20 meters. 5.62% of the area will experience flood levels of 0.21 to 0.50 meters while 4.18%, 2.34%, 1.84%, and 0.88% 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.

Among the barangays in the municipality of Santa Cruz in Occidental Mindoro, Lumangbayan is projected to have the highest percentage of area that will experience flood levels at 4.31%. Meanwhile, Casague posted the second highest percentage of area that may be affected by flood depths at 4.23%.

5.10 Flood Validation

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

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios are 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 or interview some residents with knowledge of or have had experienced flooding in a particular area.

After which, 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 points in the flood map versus its corresponding validation depths are shown in Figure 68.

The flood validation consists of 128 points randomly selected all over the Pola Floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.56m. Table 34 shows a contingency matrix of the comparison.

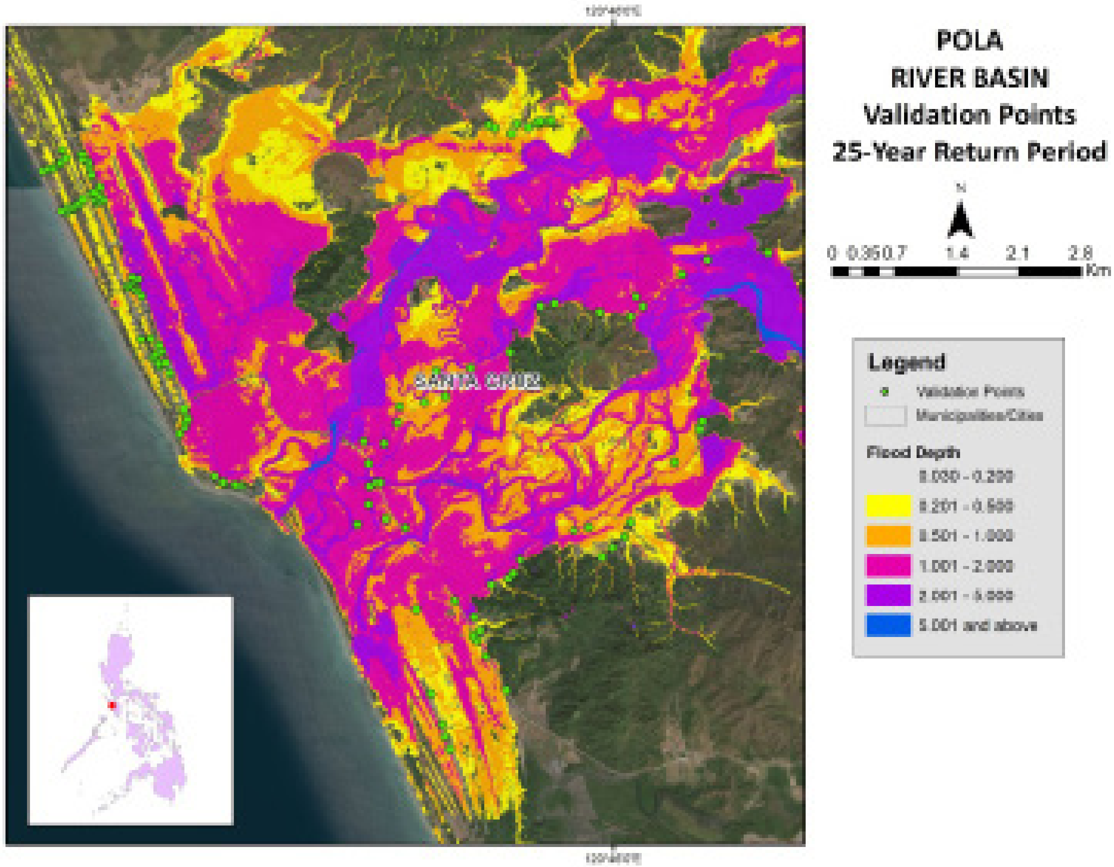


Figure 68. Validation points for 25-year Flood Depth Map of Pola Floodplain

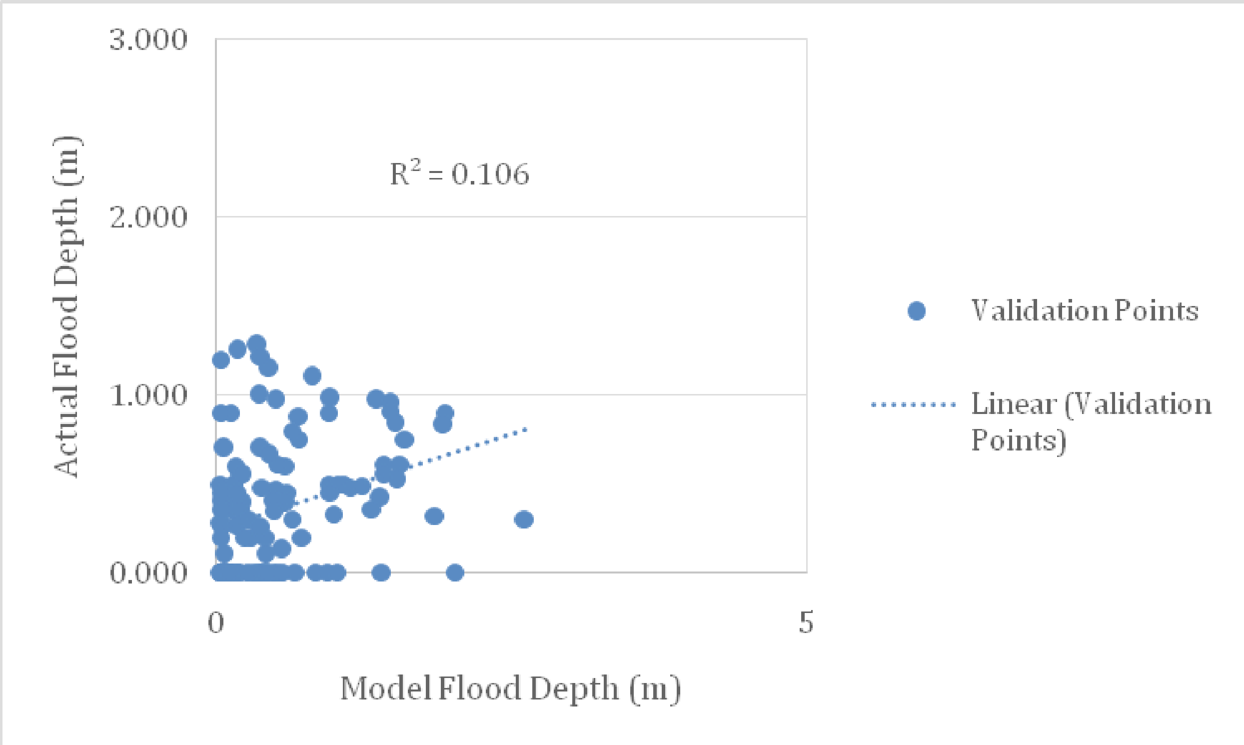


Figure 69. Flood map depth vs actual flood depth

Table 34. Actual Flood Depth vs Simulated Flood Depth in Pola

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	33	12	7	2	1	0	55
0.21-0.50	16	9	6	7	1	0	39
0.51-1.00	5	5	7	11	0	0	28
1.01-2.00	2	3	1	0	0	0	6
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	56	29	21	20	2	0	128

The overall accuracy generated by the flood model is estimated at 38.28% with 49 points correctly matching the actual flood depths. In addition, there were 46 points estimated one level above and below the correct flood depths while there were 22 points and 6 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 32 points were underestimated in the modelled flood depths of Pola. Table 35 depicts the summary of the Accuracy Assessment in the Pola River Basin Survey.

Table 35. Summary of Accuracy Assessment in Pola River Basin Survey

	No. of Points	%
Correct	49	38.28
Overestimated	47	36.72
Underestimated	32	25.00
Total	128	100.00

REFERENCES

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

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

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

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

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

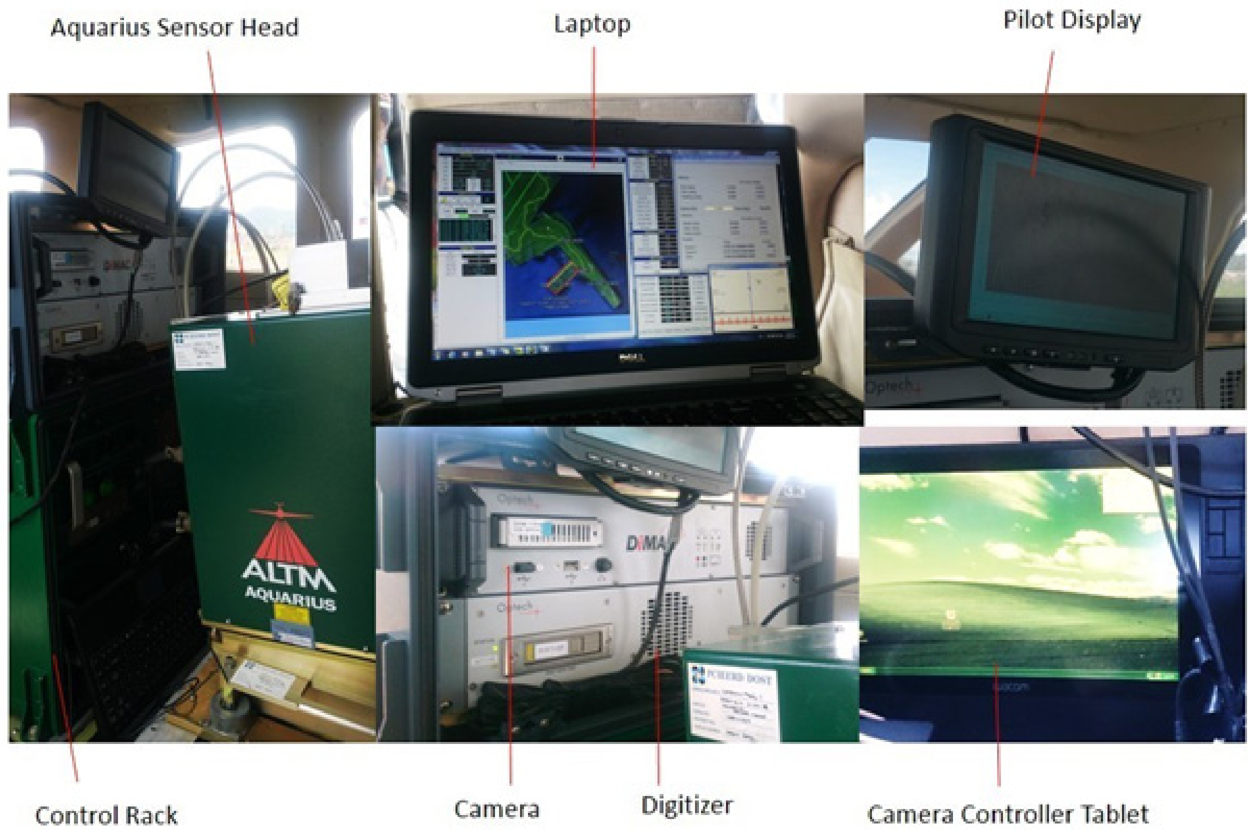
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

Annex 1. Optech Technical Specification of the Sensor

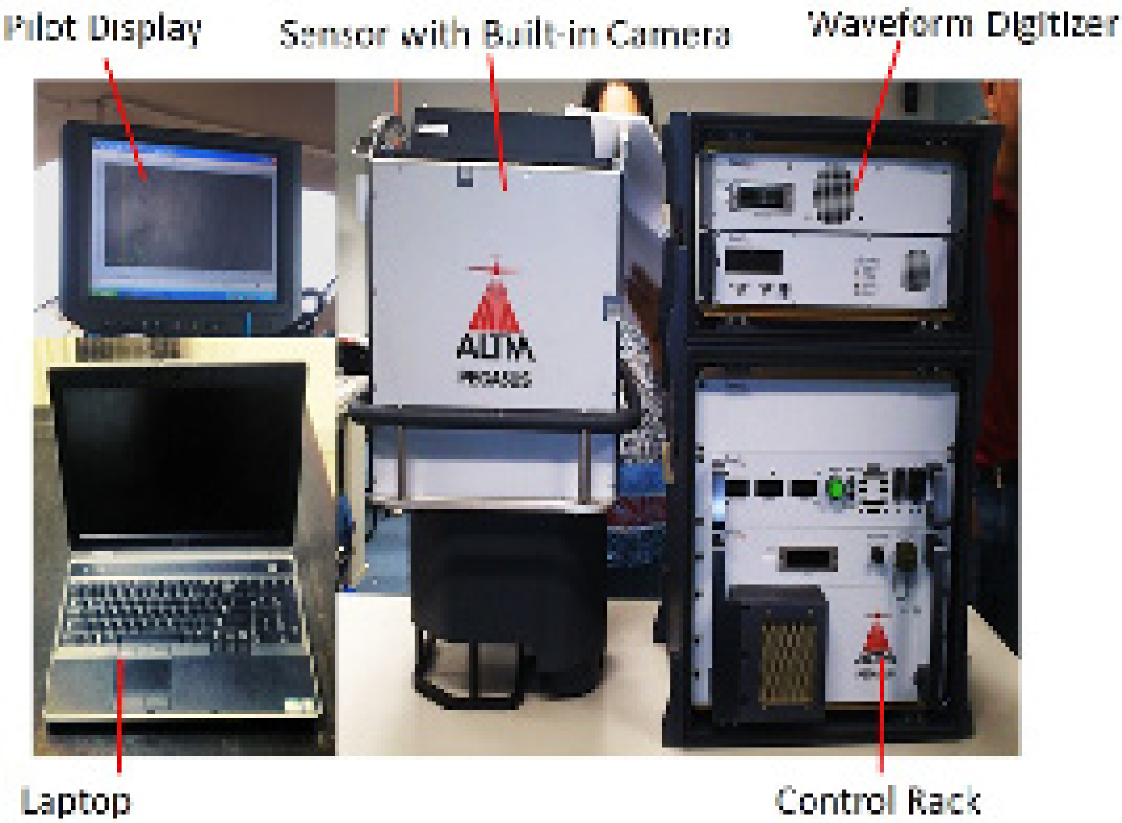
1. AQUARIUS SENSOR



2. PARAMETERS AND SPECIFICATIONS OF THE 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

3. PEGASUS SENSOR



4. PARAMETERS AND SPECIFICATIONS OF THE PEGASUS SENSOR

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

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. MRW-30

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

February 13, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-30**
Order: 2nd

Island: **LUZON** Municipality: **SANTA CRUZ**		Barangay: **PINAGTURILAN (SAN PEDRO)**
	PRS92 Coordinates	
Latitude: 12° 57' 32.22950"	Longitude: 120° 53' 28.50896"	Ellipsoidal Hgt: **42.01300 m.**
	WGS84 Coordinates	
Latitude: 12° 57' 27.19116"	Longitude: 120° 53' 33.54442"	Ellipsoidal Hgt: **90.79300 m.**
	PTM Coordinates	
Northing: **1433911.7 m.**	Easting: **488201.05 m.**	Zone: **3**
	UTM Coordinates	
Northing: 1,433,491.97	Easting: 271,227.23	Zone: **51**

Location Description

MRW-30

From the Sabiayan Astrodome, travel N along the Nat'l Road approx. 35 Km. up to Amay bridge, the Station is permanently marked and located at the SE end of the catwalk of Amnay bridge, and about 7 m SE of Km. post 356. Station is located in Brgy. Pinagturilan, Sitio Kabangkalan, Occ. Mindoro. Mark is the head of 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-30, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8795394 A**
T.N.: **2014-356**

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

NAMRIA OFFICES:
www.namria.gov.ph

2. MRW-32

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-32**
Order: **2nd**

Island: **LUZON**
Municipality: **MAMBURAO (CAPITAL)**
Barangay: **FATIMA (TII)**

PRS92 Coordinates

Latitude: **13° 10' 14.92094"**	Longitude: **120° 39' 52.29557"**	Ellipsoidal Hgt: **1.47400 m.**

WGS84 Coordinates

Latitude: **13° 10' 9.81293"**	Longitude: **120° 39' 57.31386"**	Ellipsoidal Hgt: **48.13600 m.**

PTM Coordinates

Northing: **1456469.064 m.**	Easting: **463632.46 m.**	Zone: **3**

UTM Coordinates

Northing: **1,457,111.12**	Easting: **246,845.90**	Zone: **51**

Location Description

MRW-32
From Abra de Ilog to San Jose, along Nat'l Road, approx. 11.4 Km. from Mamburao Town Proper, 400 m from Km. post 396, 12.6 Km. before Sta. Cruz Town Proper, right side of road located brgy. hall of Fatima, Mamburao, Occ. Mindoro, beside Fatima Elem. School. Station is located in corner fence of Day Care Center. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-32, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-397**

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

9902262014143552

CP/4701/12/09/014

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

3. MRW-34

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: OCCIDENTAL MINDORO
Station Name: MRW-34
Order: 2nd

Island: LUZON Municipality: ABRA DE ILOG		Barangay: ARMADO
	PRS92 Coordinates	
Latitude: 13° 17' 25.00981"	Longitude: 120° 37' 41.53630"	Ellipsoidal Hgt: 8.01600 m.
	WGS84 Coordinates	
Latitude: 13° 17' 19.87026"	Longitude: 120° 37' 46.54446"	Ellipsoidal Hgt: 54.26900 m.
	PTM Coordinates	
Northing: 1469690.588 m.	Easting: 459714.493 m.	Zone: 3
	UTM Coordinates	
Northing: 1,470,369.33	Easting: 243,032.08	Zone: 51

Location Description

MRW-34

From Abra de Ilog to San Jose, along Nat'l Road approx. 20.3 Km. from Abra de Ilog Town Proper, 300 m from Km. post 418, 9.7 Km. before Mamburao Proper, located Balibago Bridge at Brgy. Armado, Sitio Balibago, Abra de Ilog, Occ. Mindoro. Station is located near footpath of Balibago Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-34, 2007, NAMRIA".

Requesting Party: UP DREAM
Pupose: Reference
OR Number: 8795440 A
T.N.: 2014-396

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

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

4. MRW-36

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-36**
Order: **2nd**

Island: **LUZON**		Barangay: **CABACAO**
Municipality: **ABRA DE ILOG**		
	PRS92 Coordinates	
Latitude: **13° 21' 44.07349"**	Longitude: **120° 39' 20.54160"**	Ellipsoidal Hgt: **31.49300 m.**
	WGS84 Coordinates	
Latitude: **13° 21' 38.91908"**	Longitude: **120° 39' 25.54340"**	Ellipsoidal Hgt: **77.62100 m.**
	PTM Coordinates	
Northing: **1477646.985 m.**	Easting: **462705.446 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,478,304.87**	Easting: **246,088.34**	Zone: **51**

Location Description

MRW-36

From Abra de Ilog to Mamburao, along Nat'l Road, approx. 12.6 Km. from Abra de Ilog Town Proper, 600 m from Km. post 427, 400 m before Km. post 426, located Baclaran Bridge at Brgy. Cabacao, Abra de Ilog, Occ., Mindoro. Station is located near footpath of Baclaran Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, MRW-36, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-395**

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

99022620141435 13

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

5. MRW- 6

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: OCCIDENTAL MINDORO
Station Name: MRW-6 (PCP-2992A)
Order: 3rd

Island: LUZON Municipality: SABLAYAN		Barangay: YAPANG
	PRS92 Coordinates	
Latitude: 12° 52' 40.22762"	Longitude: 120° 55' 6.44586"	Ellipsoidal Hgt: 80.63530 m.
	WGS84 Coordinates	
Latitude: 12° 52' 35.21155"	Longitude: 120° 55' 11.48810"	Ellipsoidal Hgt: 128.69600 m.
	PTM Coordinates	
Northing: 1424038.201 m.	Easting: 491149.858 m.	Zone: 3
	UTM Coordinates	
Northing: 1,424,453.14	Easting: 274,116.83	Zone: 51

Location Description

MRW-6 (PCP-2992)
From the Depeartment of Agrarian Reform Office in Yapang, travel north along the national road for about 5 Kms. up to Patrick bridge. The point is permanently marked and located at the NW end of the catwalk of Patrick bridge and about 15 meters southwest of Km. Post 344. Mark is a 4" copper nail drilled in a hole and cement flush to the catwalk with inscription "MRW-6, 1993, NAMRIA".

Requesting Party: UP DREAM
Pupose: Reference
OR Number: 8795394 A
T.N.: 2014-357

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

9902192014141007

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

CF/4Q01/12/01/014

6. MRW-54

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: OCCIDENTAL MINDORO
Station Name: MRW-54
Order: 2nd

Island: LUZON Municipality: SABLAYAN		Barangay: MALISBONG
	PRS92 Coordinates	
Latitude: 12° 46' 18.56204"	Longitude: 120° 50' 27.44152"	Ellipsoidal Hgt: 28.20700 m.
	WGS84 Coordinates	
Latitude: 12° 46' 13.56455"	Longitude: 120° 50' 32.49343"	Ellipsoidal Hgt: 76.35500 m.
	PTM Coordinates	
Northing: 1412314.677 m.	Easting: 482731.146 m.	Zone: 3
	UTM Coordinates	
Northing: 1,412,791.69	Easting: 265,604.90	Zone: 51

Location Description

MRW-54

From Abra de Ilog to San Jose, along Nat'l Road, turn right to Brgy. Road, approx. 1.1 Km. travel, right side of Brgy. Road located brgy. hall boundary of Malisbong, Sablayan, Occ., Mindoro. Station is located at the back of goal post of basketball court. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-54, 2007, NAMRIA".

Requesting Party: UP-DREAM
Pupose: Reference
OR Number: 8795470 A
T.N.: 2014-445

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

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

Annex 3. Baseline Processing Report of Reference Points Used

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRWDAC-00 --- MRW-30 (B1)	MRW-30	MRWDAC-00	Fixed	0.003	0.011	312°40'19"	43136.391	-30.412
MRWDAC-00 --- MRW-30 (B2)	MRW-30	MRWDAC-00	Fixed	0.006	0.016	312°40'19"	43136.383	-30.384

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

MRWDAC-00 - MRW-30 (7:22:03 AM-9:48:26 AM) (S1)

Baseline observation:	MRWDAC-00 --- MRW-30 (B1)
Processed:	12/15/2015 5:32:10 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.011 m
RMS:	0.004 m
Maximum PDOP:	2.308
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/8/2015 7:22:11 AM (Local: UTC+8hr)
Processing stop time:	12/8/2015 9:48:26 AM (Local: UTC+8hr)
Processing duration:	02:26:15
Processing interval:	1 second

1

Vector Components (Mark to Mark)

From:	MRW-30				
Grid		Local		Global	
Easting	271237.336 m	Latitude	N12°57'32.22851"	Latitude	N12°57'27.19115"
Northing	1433451.975 m	Longitude	E120°53'28.50896"	Longitude	E120°53'33.54442"
Elevation	42.722 m	Height	42.013 m	Height	89.793 m

To:	MRWDAC-00				
Grid		Local		Global	
Easting	239755.834 m	Latitude	N13°13'23.10541"	Latitude	N13°13'17.97945"
Northing	1462963.518 m	Longitude	E120°35'55.10583"	Longitude	E120°36'00.11991"
Elevation	15.198 m	Height	11.601 m	Height	57.961 m

Vector					
ΔEasting	-31481.502 m	NS Fwd Azimuth	312°40'19"	ΔX	30671.804 m
ΔNorthing	29511.543 m	Ellipsoid Dist.	43138.391 m	ΔY	10509.502 m
ΔElevation	-27.524 m	ΔHeight	-30.412 m	ΔZ	28452.486 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000093026		
Y	-0.0000128686	0.0000223985	
Z	-0.0000041460	0.0000065394	0.0000035059

2

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)
mrw36 --- mc-52 (B1)	mrw36	mc-52	Fixed	0.003	0.013	200°29'07"	8478.543	-23.269

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

mrw36 - mc-52 (1:29:26 PM-6:02:58 PM) (S1)

Baseline observation:	mrw36 --- mc-52 (B1)
Processed:	2/27/2014 11:00:00 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.013 m
RMS:	0.002 m
Maximum PDOP:	2.232
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	2/20/2014 1:29:29 PM (Local: UTC+8hr)
Processing stop time:	2/20/2014 6:02:58 PM (Local: UTC+8hr)
Processing duration:	04:33:29
Processing interval:	1 second

1

Vector Components (Mark to Mark)

From:	mrw36				
Grid		Local		Global	
Easting	246240.672 m	Latitude	N13°21'38.91908"	Latitude	N13°21'38.91908"
Northing	1478236.407 m	Longitude	E120°39'25.54340"	Longitude	E120°39'25.54340"
Elevation	33.839 m	Height	77.821 m	Height	77.821 m

To:	mc-52				
Grid		Local		Global	
Easting	243198.172 m	Latitude	N13°17'20.53041"	Latitude	N13°17'20.53041"
Northing	1470321.018 m	Longitude	E120°37'46.98588"	Longitude	E120°37'46.98588"
Elevation	11.004 m	Height	54.352 m	Height	54.352 m

Vector					
ΔEasting	-3042.500 m	NS Fwd Azimuth	200°29'07"	ΔX	1630.653 m
ΔNorthing	-7915.388 m	Ellipsoid Dist.	8478.543 m	ΔY	3066.891 m
ΔElevation	-22.835 m	ΔHeight	-23.269 m	ΔZ	-7732.333 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000108465		
Y	-0.0000168791	0.0000331814	
Z	-0.0000050625	0.0000092050	0.0000035632

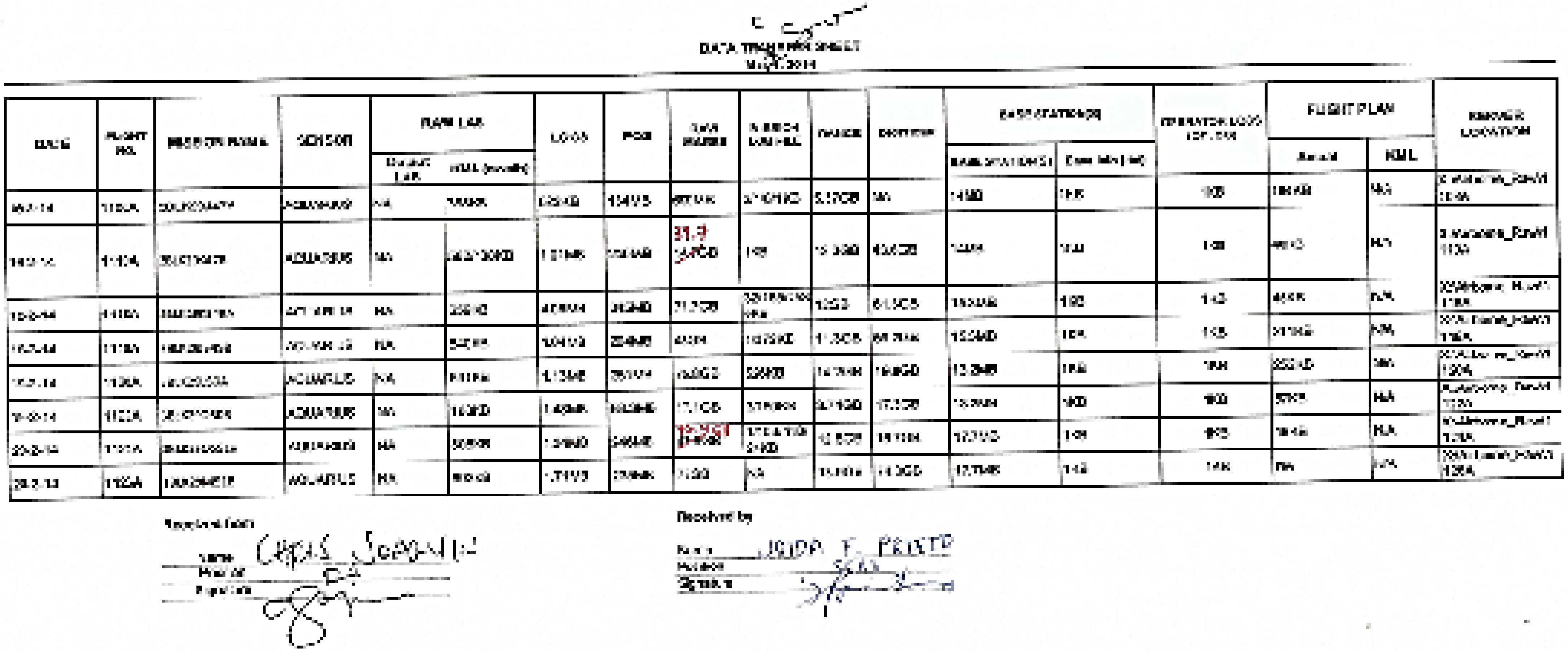
Annex 4. The LiDAR Survey Team Composition

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
	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist	PAULINE JOANNE ARCEO	UP-TACGP
	Research Associate (RA)	PATRICIA YSABEL ALCANTARA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	ENGR. MILLIE SHANE REYES	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. FRANK NICOLAS ILEJAY	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. JOHN ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJAMIN CARBOLLEDO	PAF
	Pilot	CAPT. JEFFREY JEREMY ALAAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC
		CAPT. SHERWIN ALFONSO III	AAC
			AAC

Annex 5. Data Transfer Sheet For Pola Floodplain



DATA TRANSFER SHEET

[illegible]

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	
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	31.7 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]
[illegible]	[illegible]	[illegible]	AQUARIUS	NA	[illegible]	[illegible]	[illegible]	[illegible]	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA	NA	[illegible]

Received from

Name: CHRIS JOSON III

Position:

Signature:

Received by

Name: JOIDA F. PRIETO

Position:

Signature:

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6-Dec-15	3058P	1BLK29C340A	pegasus	752	189	5.69	120	9.79	74	7.56	na	15.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	460	108	3.43	115	6.09	48	4.79	na	15.4	1KB	1KB	394/344/58	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.45	430	9.18	206	25.6	192	14.4	na	7.51	1KB	1KB	100/89/95	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDI342A	pegasus	982	276	7.18	177	17	121	9.79	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	0	67	2.7	114	4.63	37	2.77	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	953	217	5.7	143	14.3	na	9.37	na	5.96	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.09	212	9.12	225	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	259	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/318/296/ 313/146/156	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	561	171	6.23	167	12.9	105	6.2	na	7.02	1KB	1KB	47/394/344/3 13/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	932	206	6.85	174	13.1	95	9.22	na	7.81	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from

Name [illegible]
Position
Signature

Received by

Name AC Bongat
Position SSRA
Signature 1/15/16

Annex 6. Flight Logs

1. Flight Log for 3BLK29O50B Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1122

1 LiDAR Operator: PJ Arceo	2 ALTM Model:	3 Mission Name: 3BLK29O50B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: JR Jacinto	9 Route:			
10 Date: 2/19/14	12 Airport of Departure (Airport, City/Province): Masbate		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1513	14 Engine Off: 1730	15 Total Engine Time: 2+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 5 lines in area O					

21 Problems and Solutions:

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

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

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

2. Flight Log for3BLK29OS51A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1124

1 LiDAR Operator: PY Alcantara	2 ALTM Model: AQUA	3 Mission Name: 3BLK29OS51A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: V Alcajar	9 Route:			
10 Date: 2/20/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province): Mamburao		
13 Engine On: 809	14 Engine Off: 1244	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	[signature]	[signature]	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for3BLK29IS+H53A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1132

1 LiDAR Operator: LK Paragas	2 ALTM Model: Aqua	3 Mission Name: 3BLK29IS/H53A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 7/12/14		12 Airport of Departure (Airport, City/Province): Mambusao		12 Airport of Arrival (Airport, City/Province): Mambusao	
13 Engine On: 0804	14 Engine Off: 1245	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission I completed. 8 lines in area M

21 Problems and Solutions:

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

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

Pilot-in-Command — [illegible] — Signature over Printed Name

Lidar Operator — LK Paragas — Signature over Printed Name

4. Flight Log for3BLK29HS54A/3BLK29HB54A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1138

1 LiDAR Operator:	2 ALTM Model: Aquarius	3 Mission Name: 3BLK29HS54A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Alajar	8 Co-Pilot: J. Javier	9 Route:			
10 Date: 2/23/14	12 Airport of Departure (Airport, City/Province): Mambucal		12 Airport of Arrival (Airport, City/Province): Mambucal		
13 Engine On: 0909	14 Engine Off: 1338	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

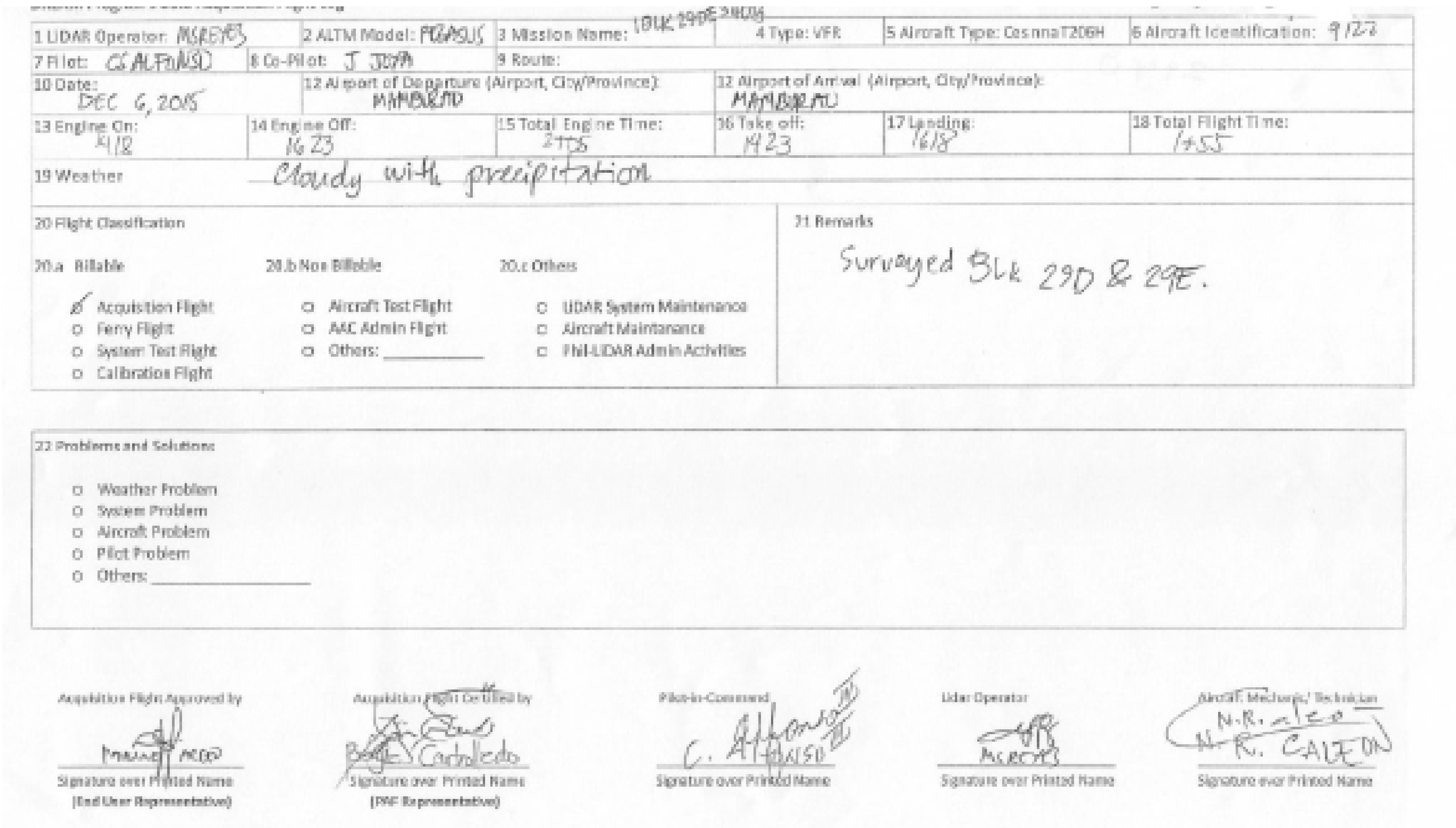
20 Remarks:

Completed lines in area E

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot in Command	Lidar Operator
	EC CABANAGON	JEFFREY ALAJAR	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight Log for1BLK29DE340B Mission



1 LIDAR Operator: MS REYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29DE340B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C. ALFONSO	8 Co-Pilot: J. JOYA	9 Route:			
10 Date: DEC 6, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 1418	14 Engine Off: 1623	15 Total Engine Time: 2+05	16 Take off: 1423	17 Landing: 1618	18 Total Flight Time: 1+55
19 Weather	Cloudy with precipitation				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29D & 29E.

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

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

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

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

Lidar Operator — M. REYES — Signature over Printed Name

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

6. Flight Log for1BLK29BCS341A Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2942

1 LiDAR Operator: MSREYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29BCS341A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOSE	9 Route: Mamburao			
10 Date: DEC 7, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0725	14 Engine Off: 1048	15 Total Engine Time: 3+23	16 Take off: 0730	17 Landing: 1043	18 Total Flight Time: 3+13
19 Weather: windy with passing clouds					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29B & C

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
PAULINO MARGES	[illegible] Cortabledo	C. ALFONSO III	MS REYES	N.R. GALEON
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

7. Flight Log for1BLK29ACDF342A Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2946

1 LIDAR Operator: G SINADJAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29A CDF342A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: CG ALFONSO	8 Co-Pilot: J JOTA	9 Route:			
10 Date: DEC 8, 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0708	14 Engine Off: 0955	15 Total Engine Time: 02+47	16 Take off: 0713	17 Landing: 0950	18 Total Flight Time: 2+37
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful flight. Surveyed BLK 29A,C,D,I

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	C. Alfonso Signature over Printed Name	Signature over Printed Name	N. R. GALEON Signature over Printed Name

Annex 7. Flight Status

FLIGHT STATUS REPORT
POLA FLOODPLAIN
February 19- 23, 2014; December 6-8, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1122A	BLK29O	3BLK29O50B	PY ALCANTARA	19-Feb-14	Completed 5 lines of Area O. Computer hanged after covering the tie line.
1124A	BLK29O	3BLK29OS51A	PY ALCANTARA	20-Feb-14	Completed 20 lines of Area O. Range missing in line 6.Restarted the system thrice.
1132A	BLK29I & BLK29H	3BLK29IS+H53A	LK PARAGAS	22-Feb-14	Completed area I and 8 lines in area H.
1136A	BLK29H	3BLK29HS54A	PY ALCANTARA	23-Feb-14	Mission completed.
3060P	BLK29D, E	1BLK29DE340B	MS REYES	6-Dec-15	Surveyed BLK29D & E
3062P	BLK29BCS	1BLK29BCS341A	MS REYES	7-Dec-15	Surveyed BLK29B & C
3066P	BLK29ACDI	1BLK29ACDF342A	G SINADJAN	8-Dec-15	Surveyed BLK29A, C, D & I

FLIGHT NO. 1122A
AREA: BLK29O
MISSION NAME: 3BLK29O50B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

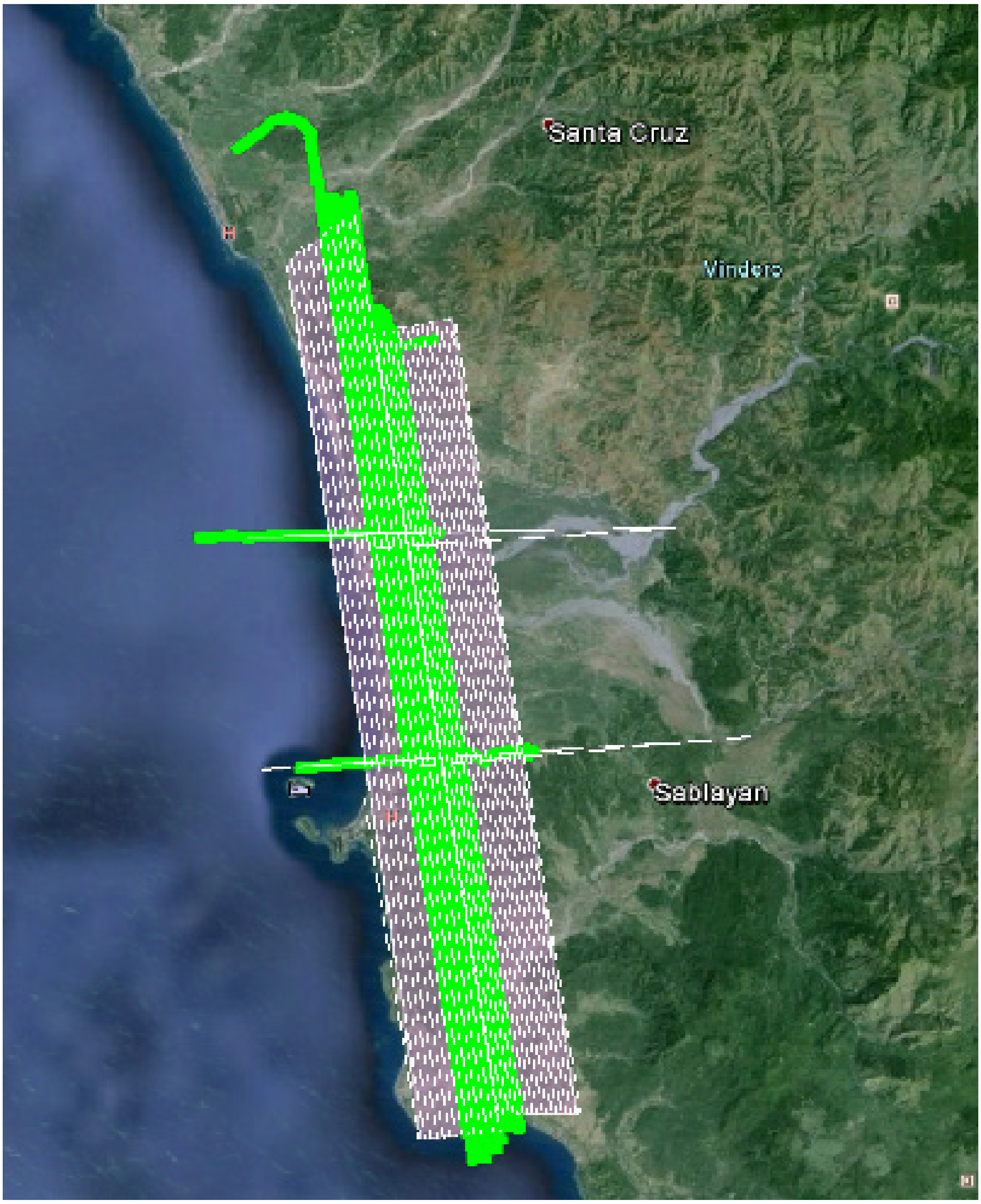
SURVEY COVERAGE:

FLIGHT NO. 1124A
AREA: BLK29O
MISSION NAME: 3BLK29OS51A
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

FLIGHT NO. 1132A
AREA: BLK29I AND BLK29H
MISSION NAME: 3BLK29IS+H53A
PARAMETERS: Alt: 600 S can Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

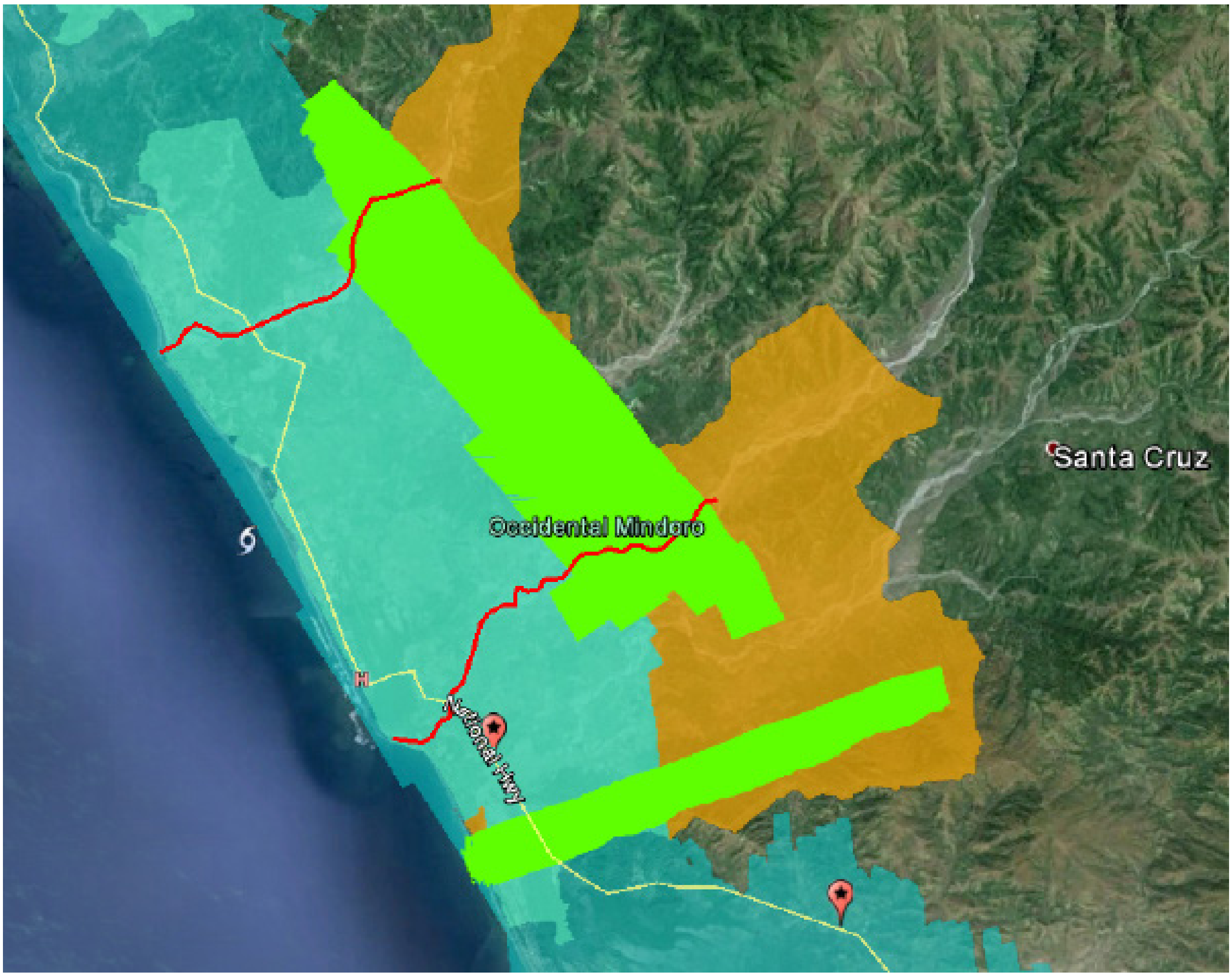


FLIGHT NO.	1136A		
AREA:	BLK29H		
MISSION NAME:	3BLK29HS54A		
PARAMETERS	Alt: 600	Scan Freq: 40 kHz	Scan Angle: 18 deg

SURVEY COVERAGE:

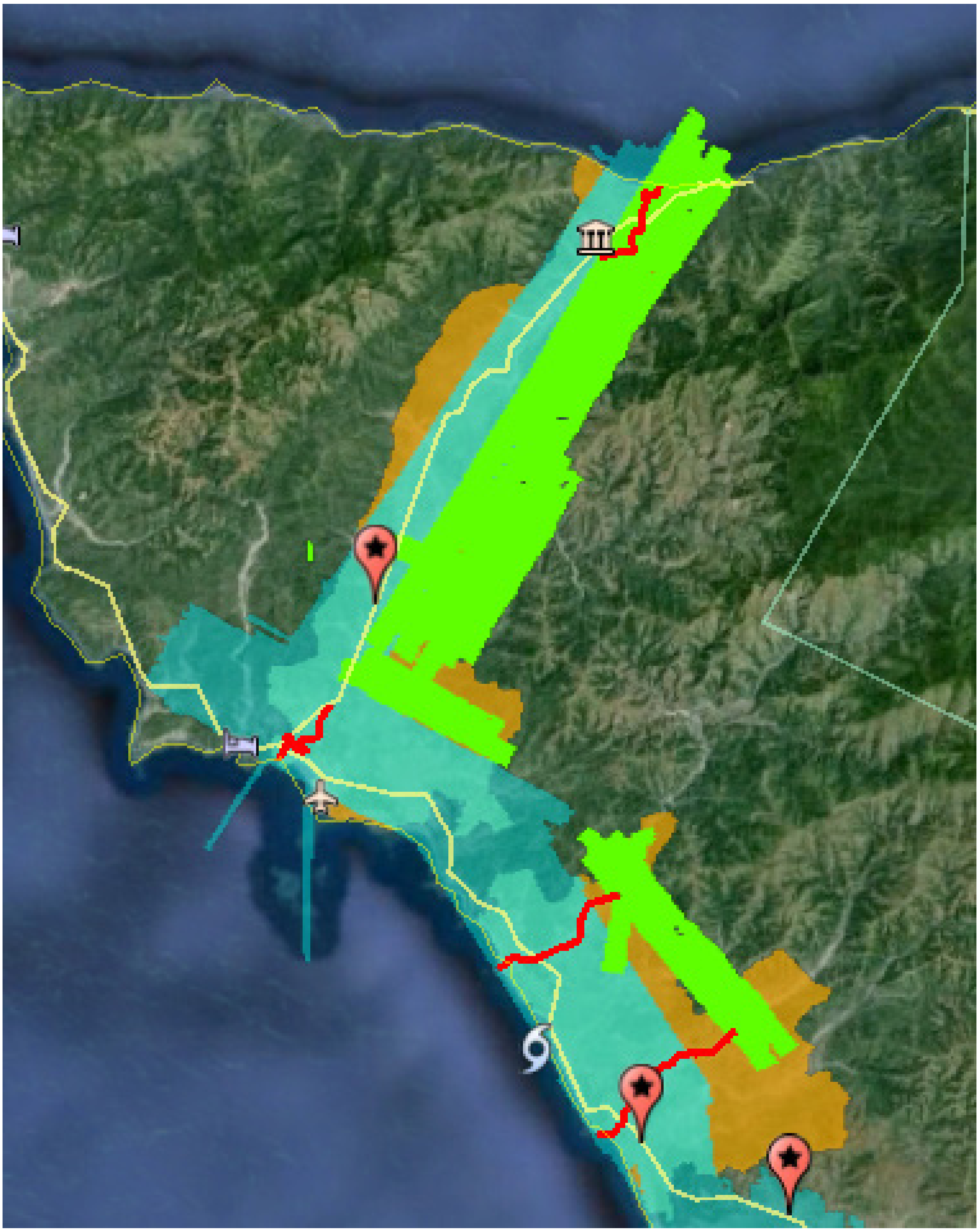
FLIGHT NO.	3060P		
AREA:	BLK29D & E		
MISSION NAME:	1BLK29DE340B		
PARAMETERS:	Alt: 1100 m	Scan Freq: 30 kHz	Scan Angle: 25deg

SURVEY COVERAGE:



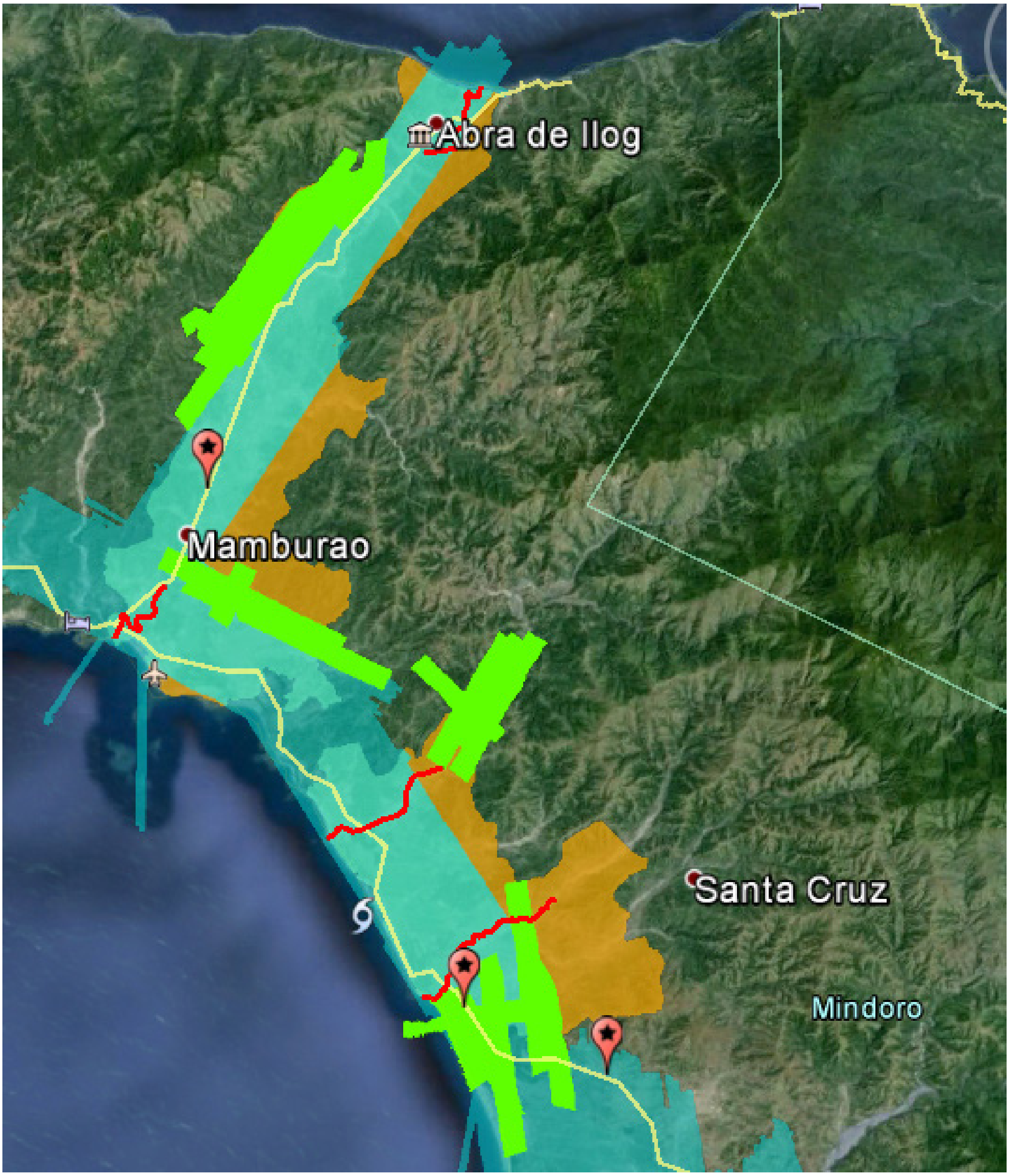
FLIGHT NO. 3062P
AREA: BLK29B & C
MISSION NAME: 1BLK29BCS341A
PARAMETERS: Alt: 1100 m Scan Freq: 30 kHz Scan Angle: 25deg

SURVEY COVERAGE:



FLIGHT NO. 3066P
AREA: BLK29A, C, D & I
MISSION NAME: 1BLK29ACDI342A
PARAMETERS: Alt: 1100 m Scan Freq: 30 kHz Scan Angle: 25 deg

SURVEY COVERAGE:



Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk29O

Flight Area	Occidental Mindoro
Mission Name	Blk29O
Inclusive Flights	1122A, 1124A
Range data size	16.34 GB
POS	344.3 MB
Image	92.5 GB
Transfer date	03/07/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	68.31%
Ave point cloud density per sq.m. (>2.0)	3.68
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	140
Maximum Height	392.65 m
Minimum Height	39.47 m
Classification (# of points)	
Ground	77,532,897
Low vegetation	93,964,891
Medium vegetation	81,470,250
High vegetation	61,944,922
Building	2,711,988
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, CelinaRosete, Ryan Nicholai Dizon

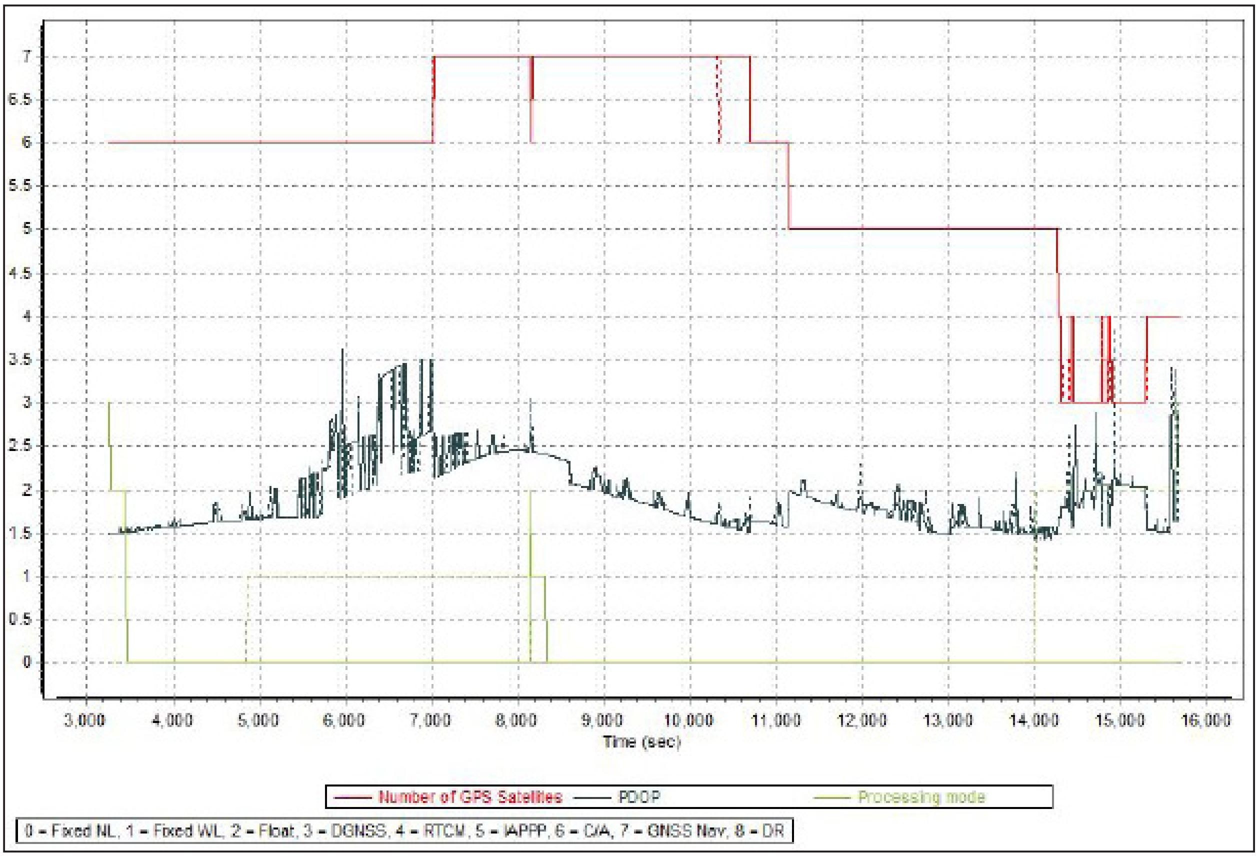


Figure A-8.1. Solution Status

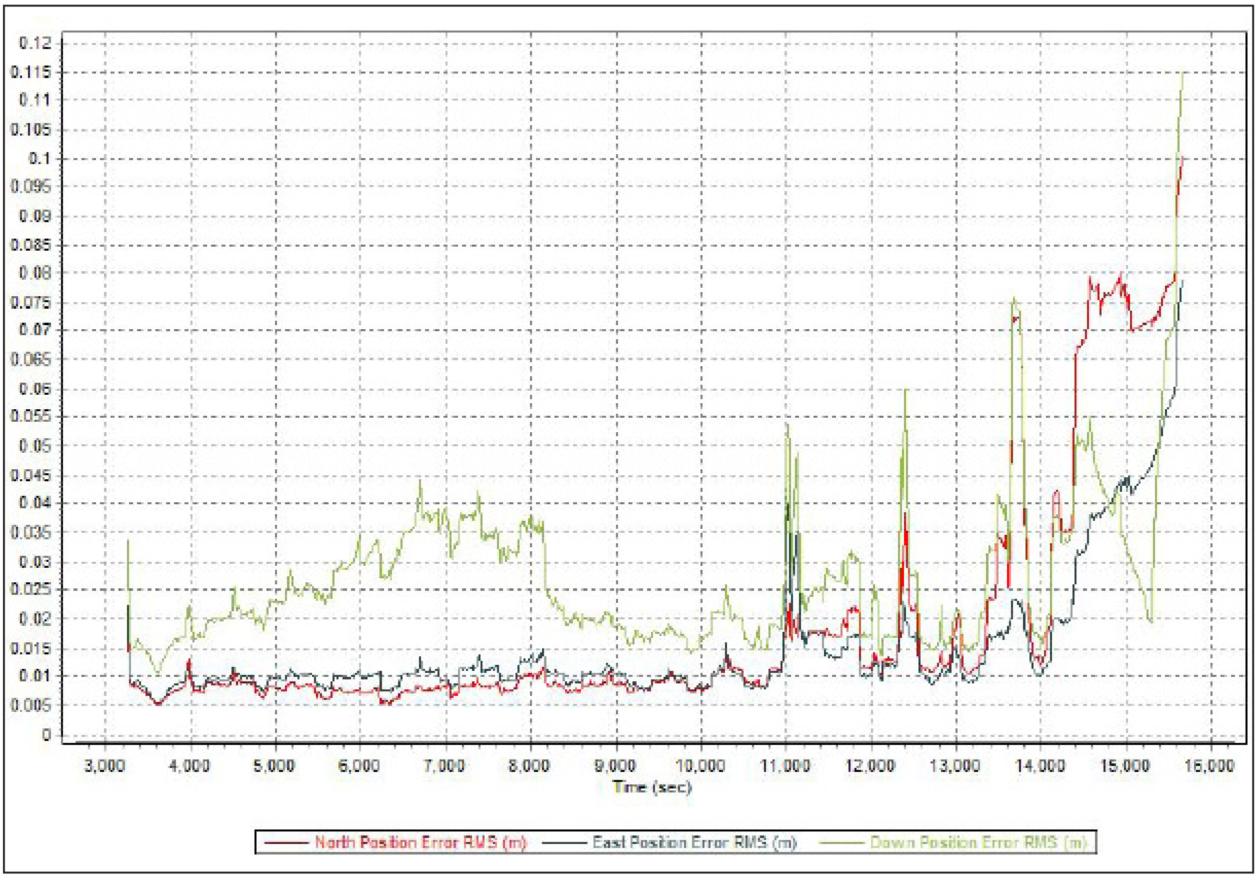


Figure A-8.2. Smoothed Performance Metric Parameters

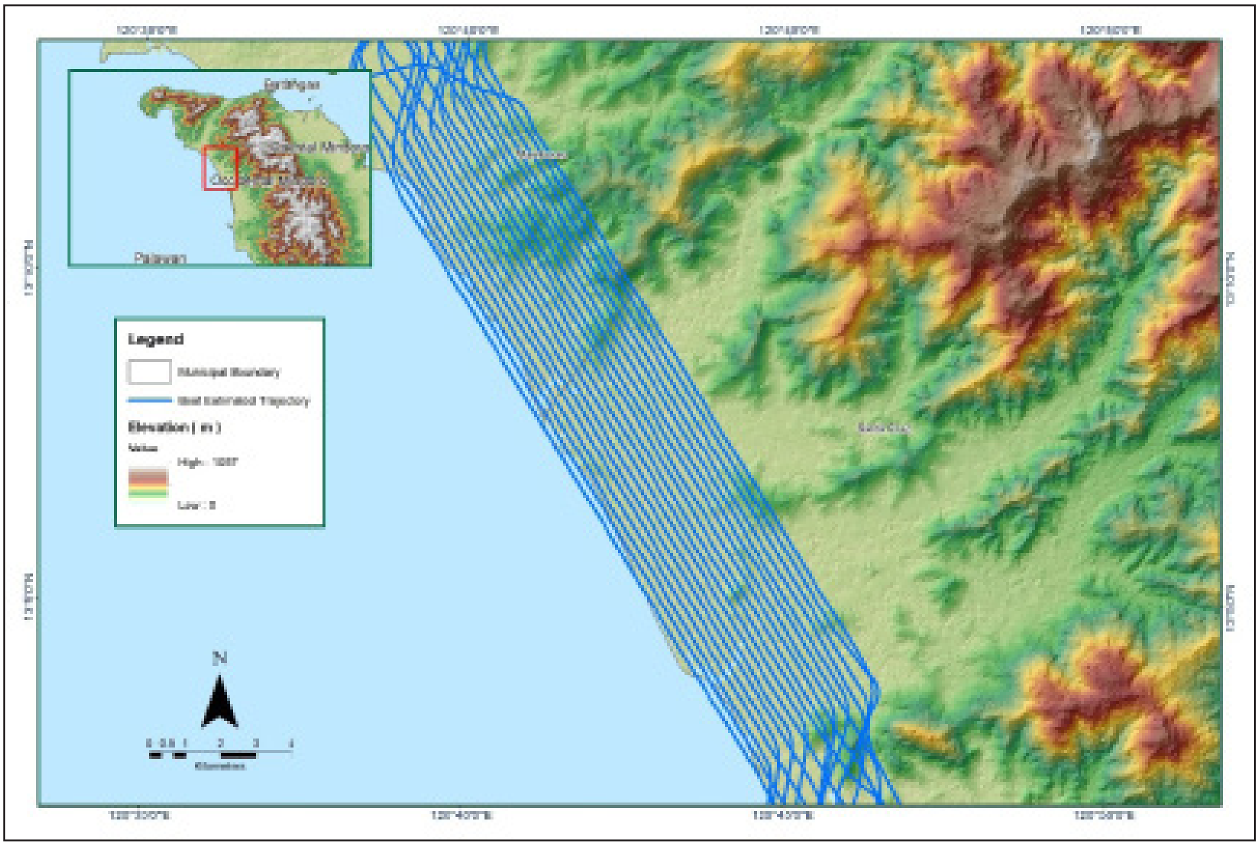


Figure A-8.3. Best Estimated Trajectory

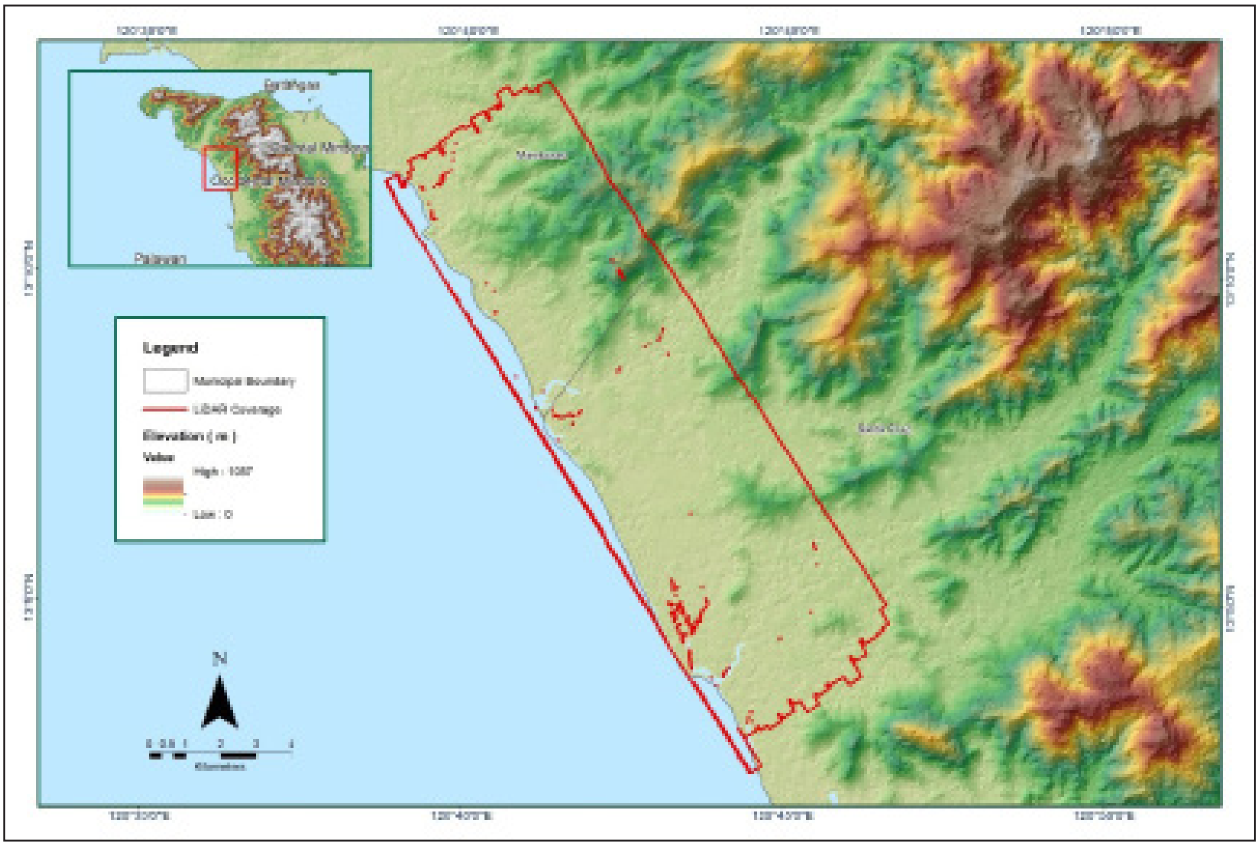


Figure A-8.4. Coverage of LiDAR data

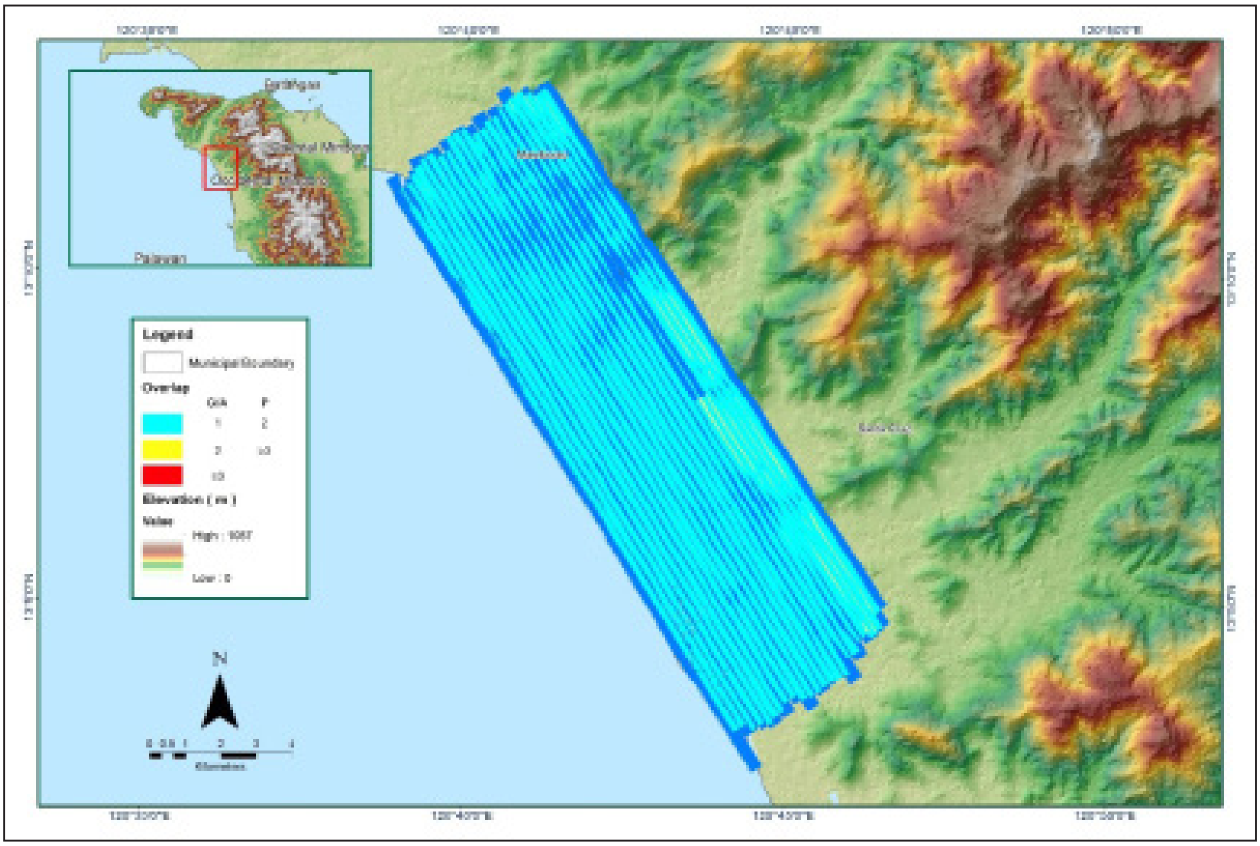


Figure A-8.5. Image of data overlap

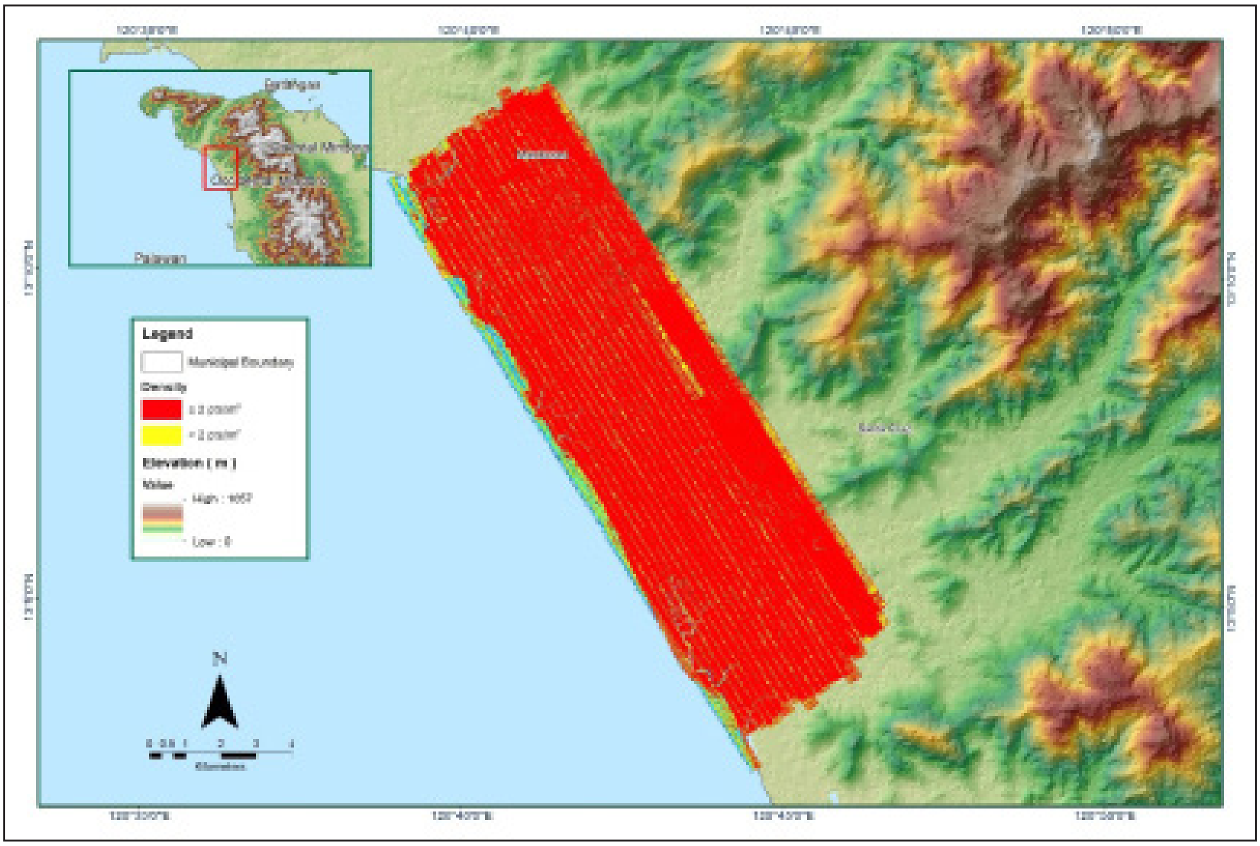


Figure A-8.6. Density map of merged LiDAR data

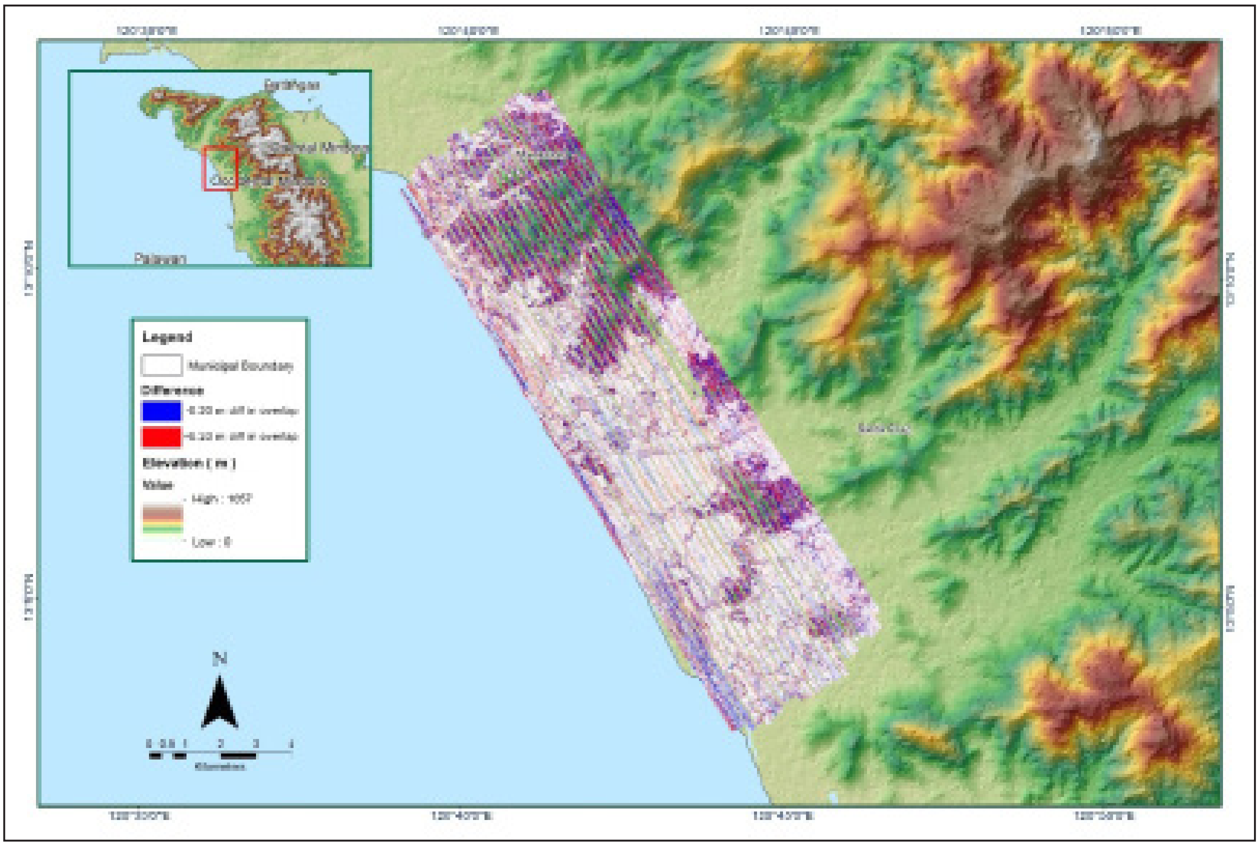


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk29H

Flight Area	Occidental Mindoro
Mission Name	Blk29H
Inclusive Flights	1136A
Range data size	15 GB
POS	256 MB
Image	86.5 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000355
IMU attitude correction stdev (<0.001deg)	0.074523
GPS position stdev (<0.01m)	0.0409
Minimum % overlap (>25)	37.19%
Ave point cloud density per sq.m. (>2.0)	2.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	174
Maximum Height	613.49 m
Minimum Height	39.16 m
Classification (# of points)	
Ground	53,263,528
Low vegetation	57,288,707
Medium vegetation	68,165,762
High vegetation	30,718,677
Building	1,782,193
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, CelinaRosete, JovyNarisma

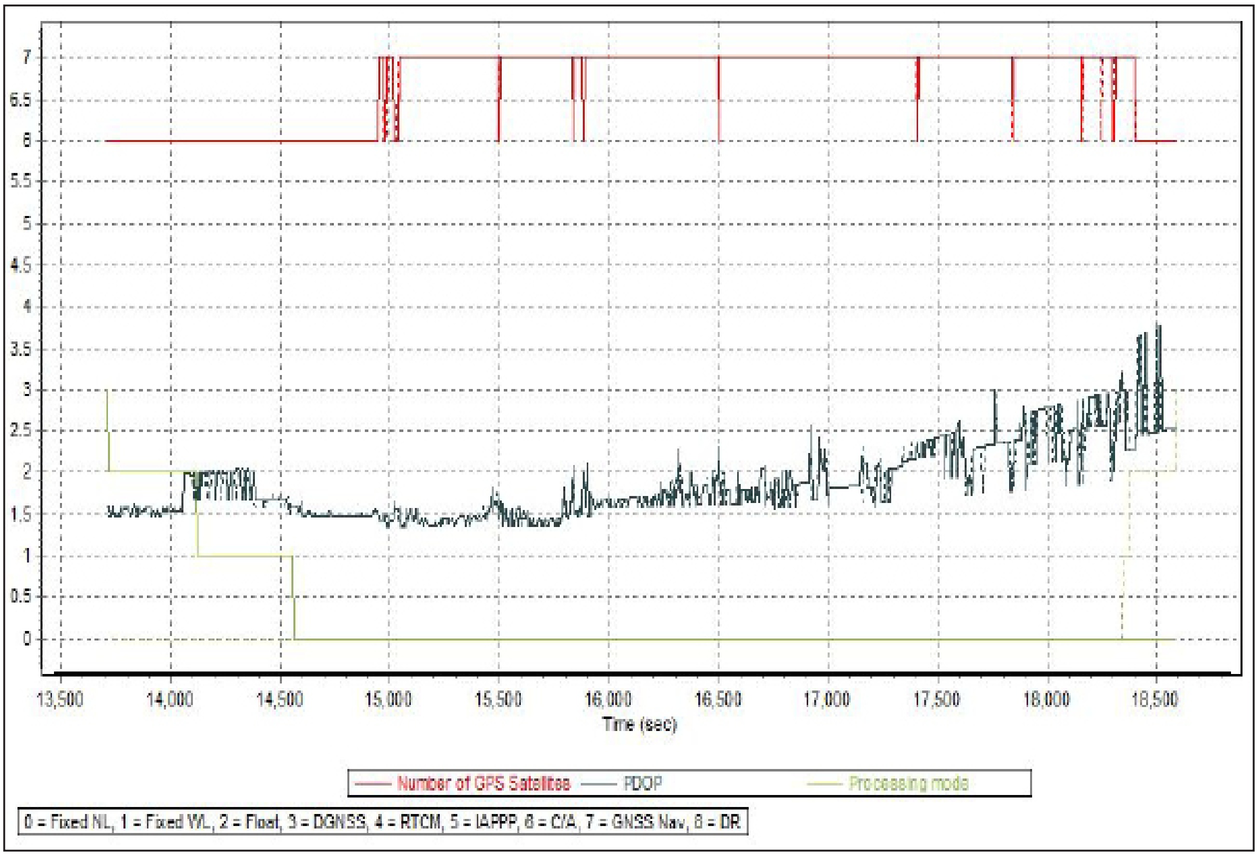


Figure A-8.8. Solution Status

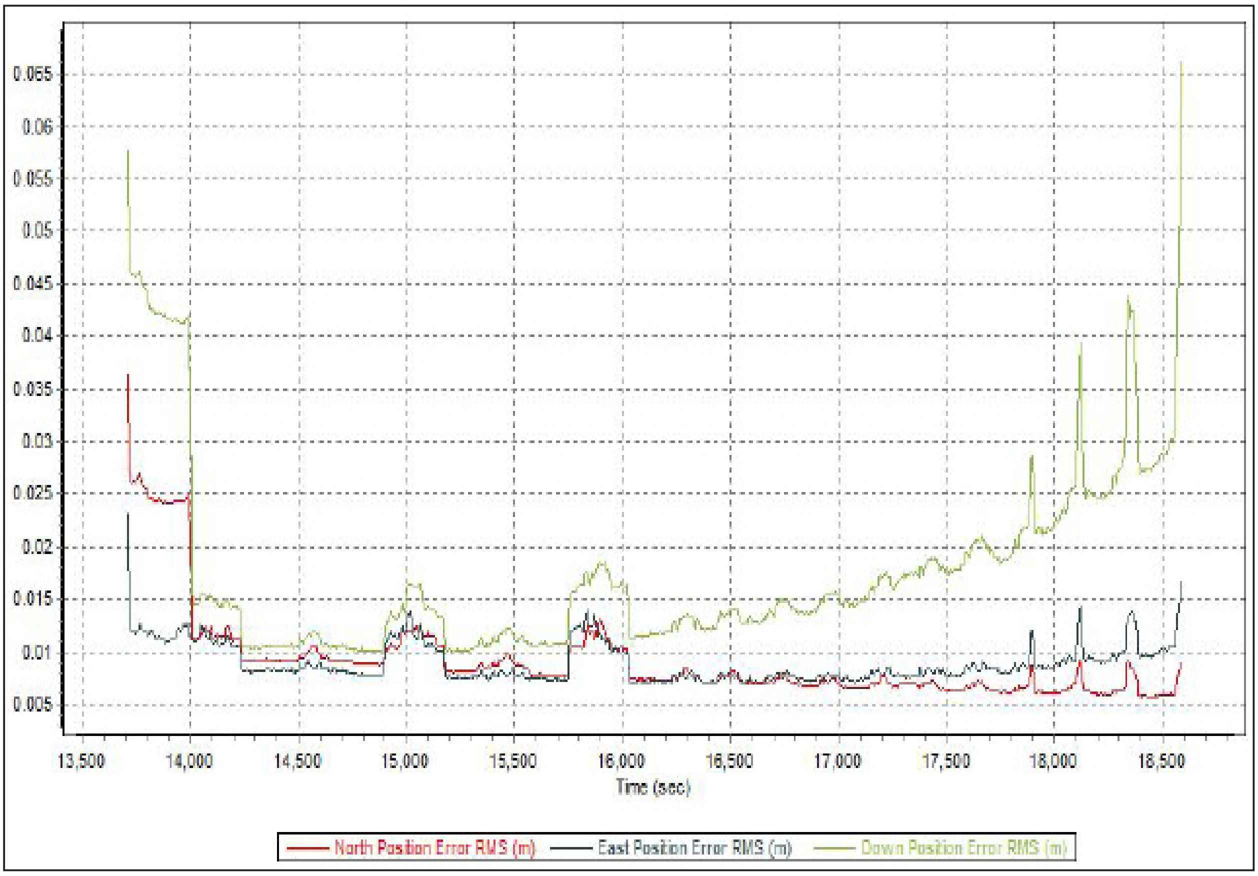


Figure A-8.9. Smoothed Performance Metric Parameters

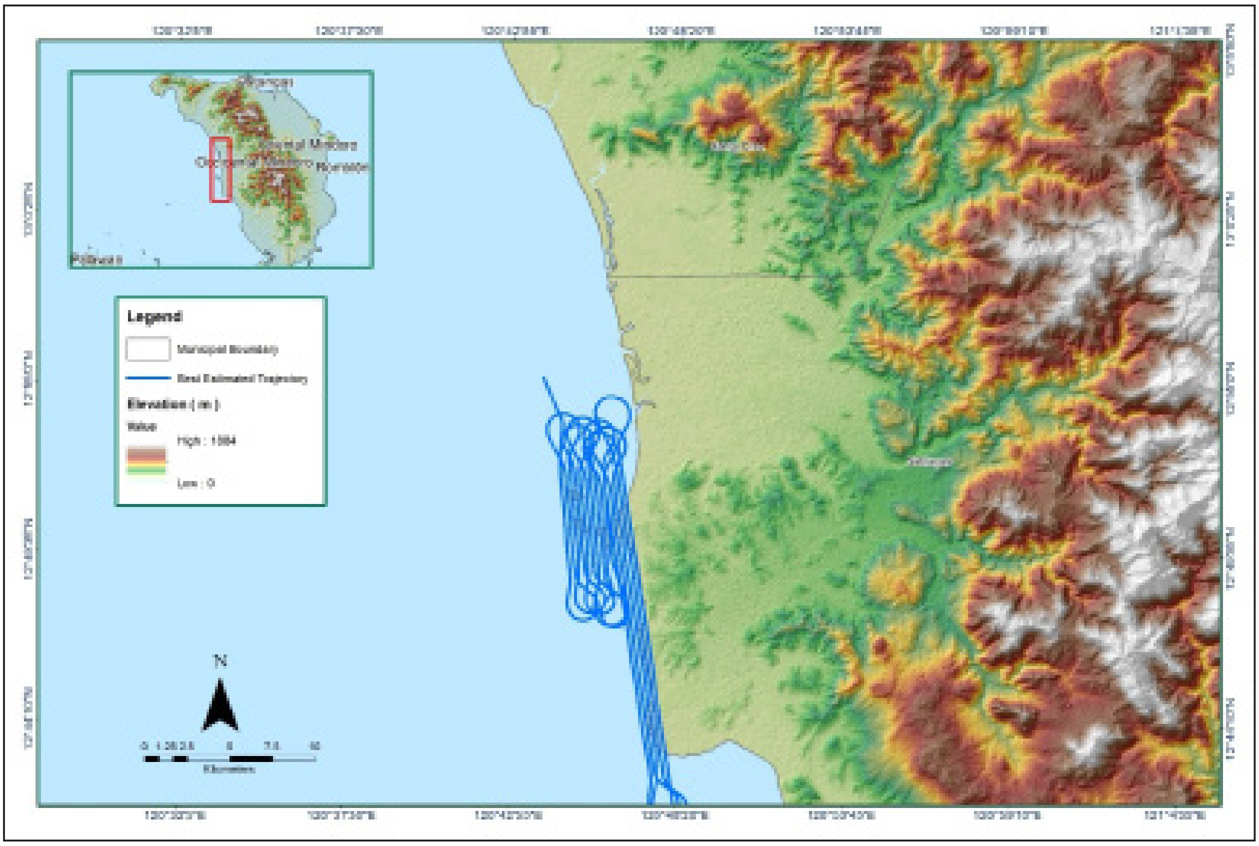


Figure A-8.10. Best Estimated Trajectory

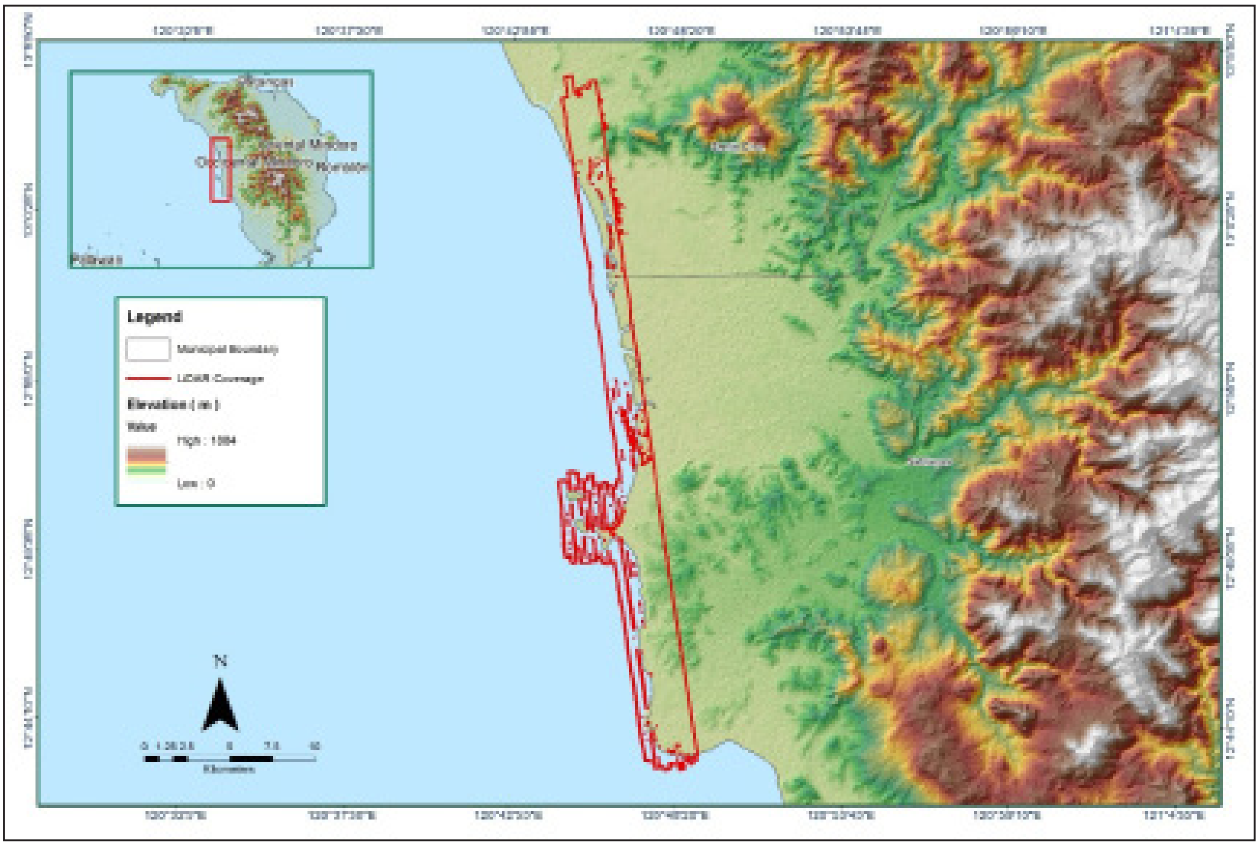


Figure A-8.11. Coverage of LiDAR data

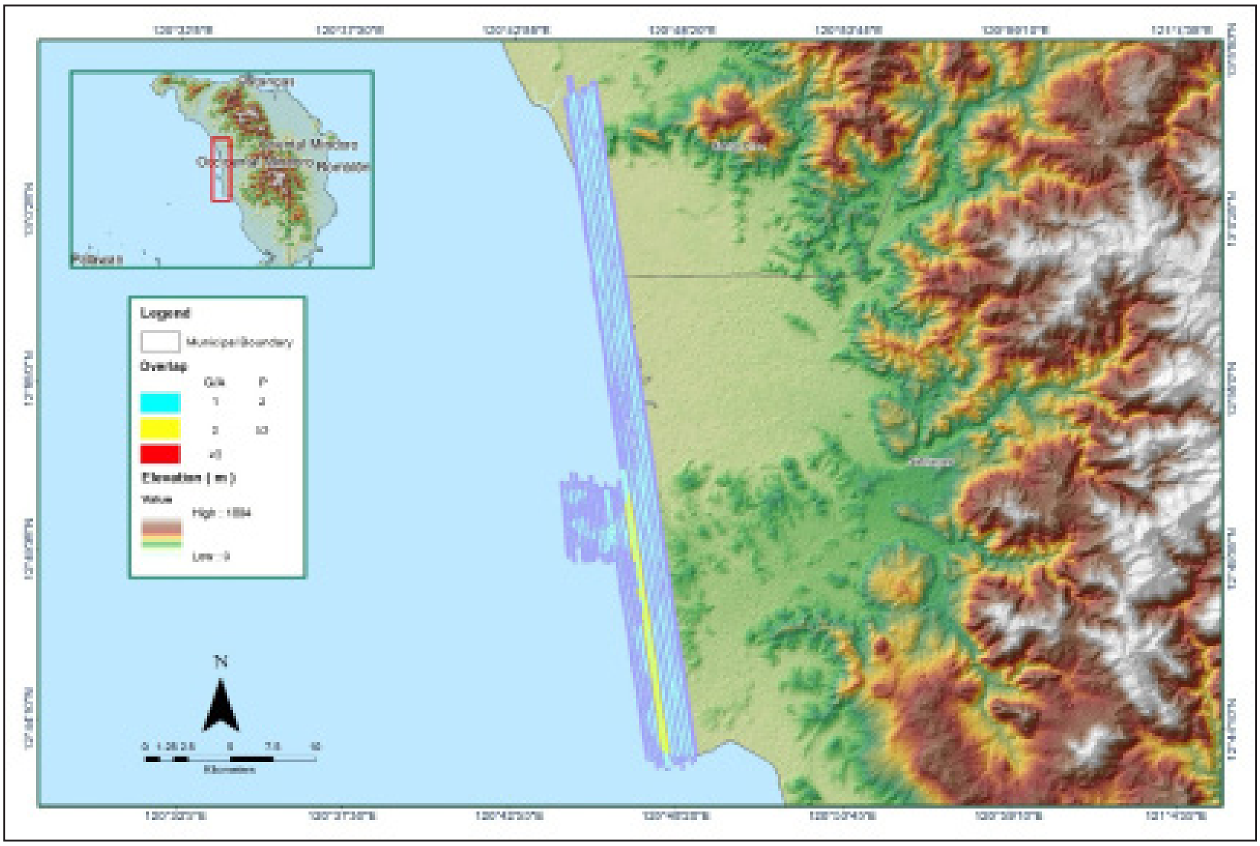


Figure A-8.12. Image of data overlap

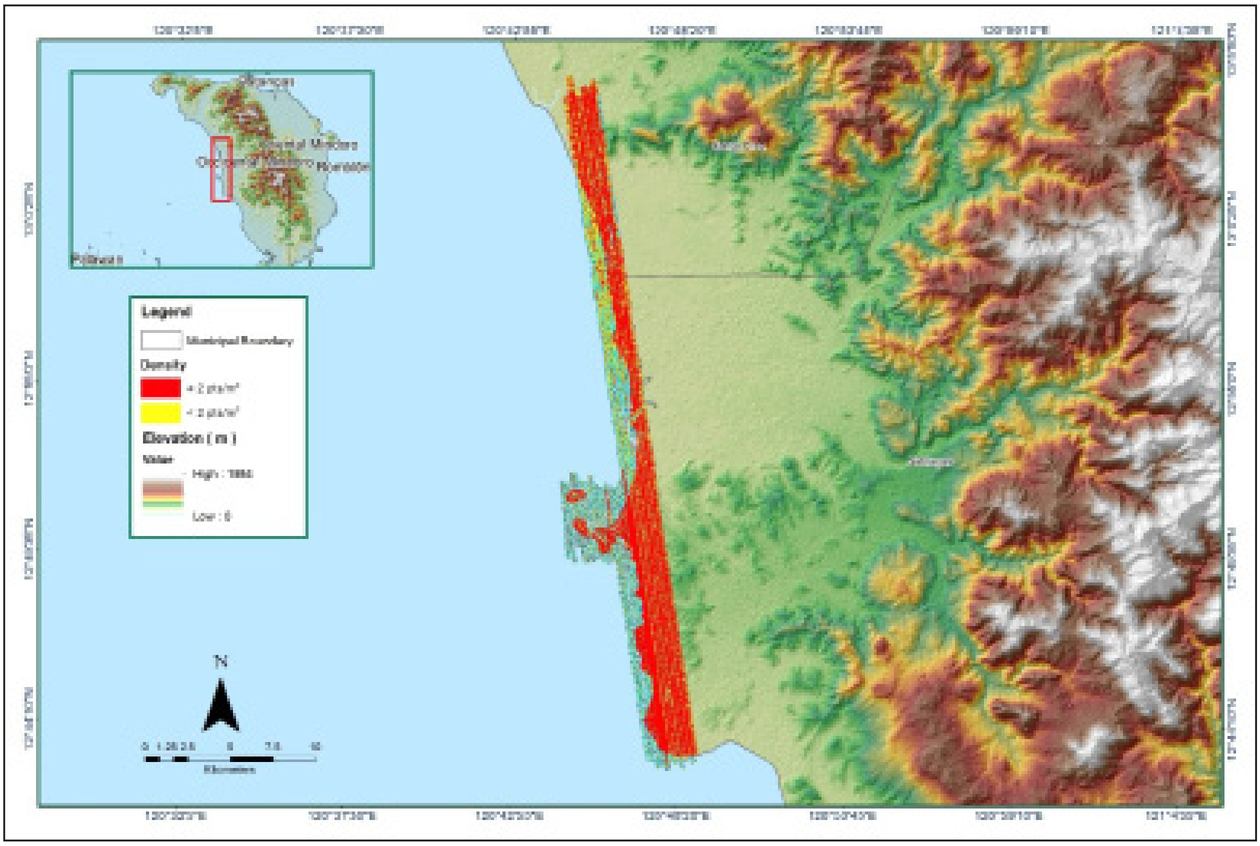


Figure A-8.13. Density map of merged LiDAR data

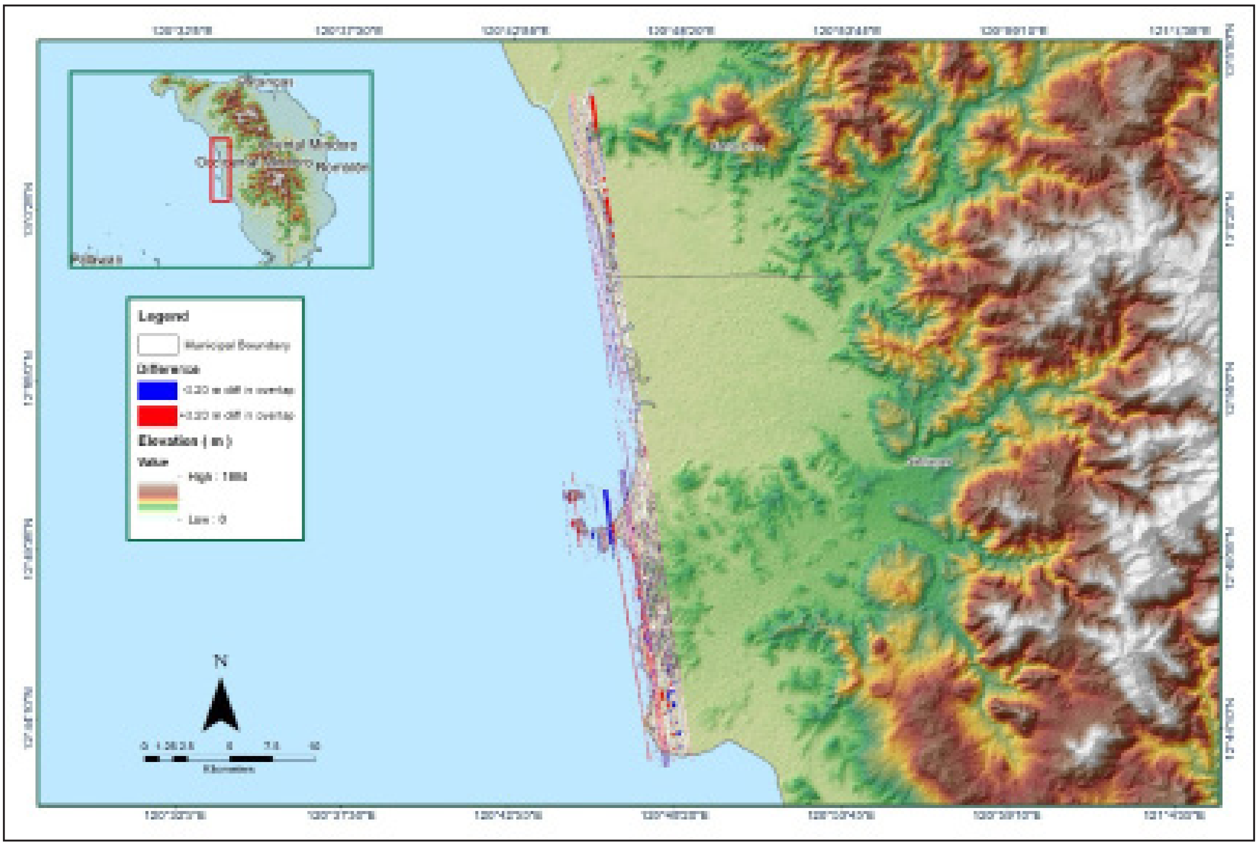


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk29HI_supplement

Flight Area	Occidental Mindoro
Mission Name	Blk29HI_supplement
Inclusive Flights	1132A
Range data size	16.1 GB
POS	276 MB
Image	34.3 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000400
IMU attitude correction stdev (<0.001deg)	0.005740
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	55.11%
Ave point cloud density per sq.m. (>2.0)	3.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	175
Maximum Height	308.28 m
Minimum Height	43.14 m
Classification (# of points)	
Ground	75,373,003
Low vegetation	106,983,904
Medium vegetation	125,916,220
High vegetation	46,925,200
Building	1,788,962
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. ChristyLubiano, Engr. Jeffrey Delica

Figure A-8.15. Solution Status

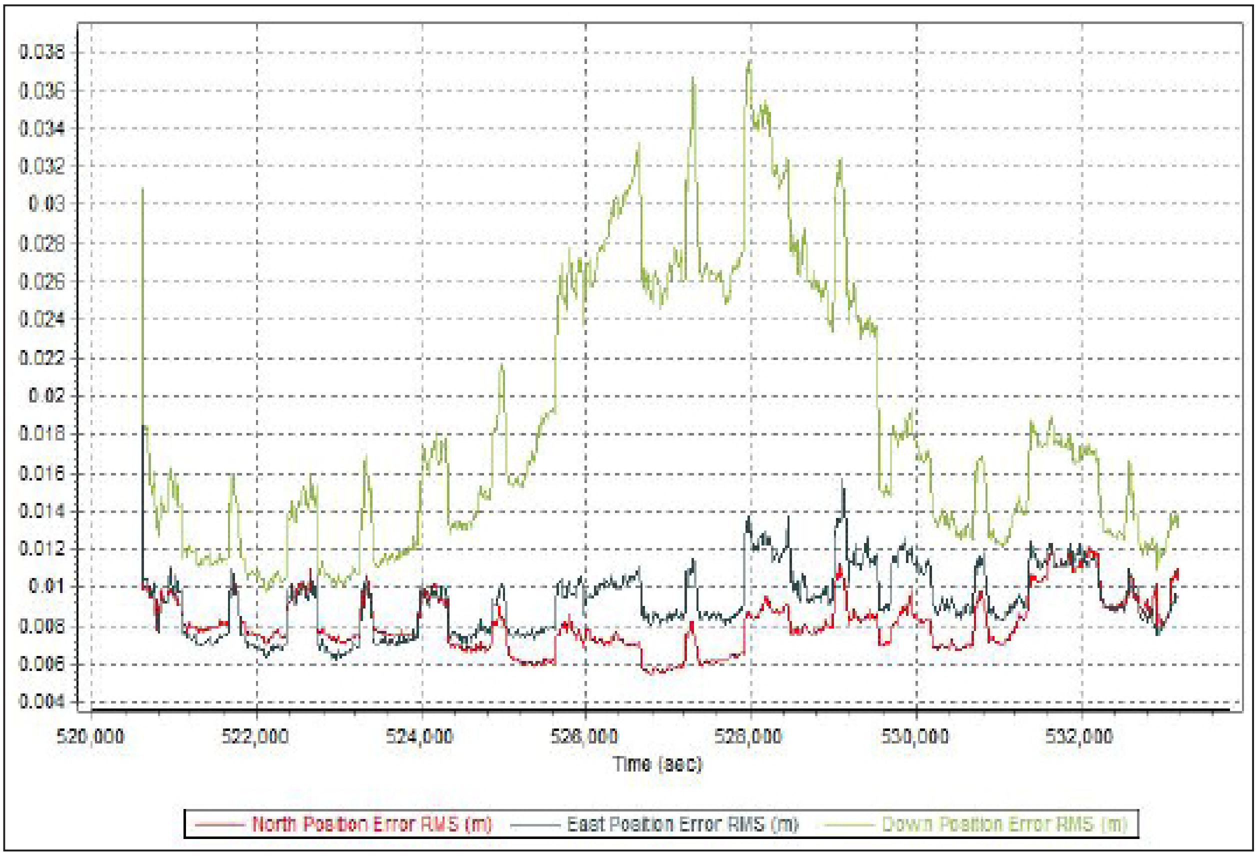


Figure A-8.16. Smoothed Performance Metric Parameters

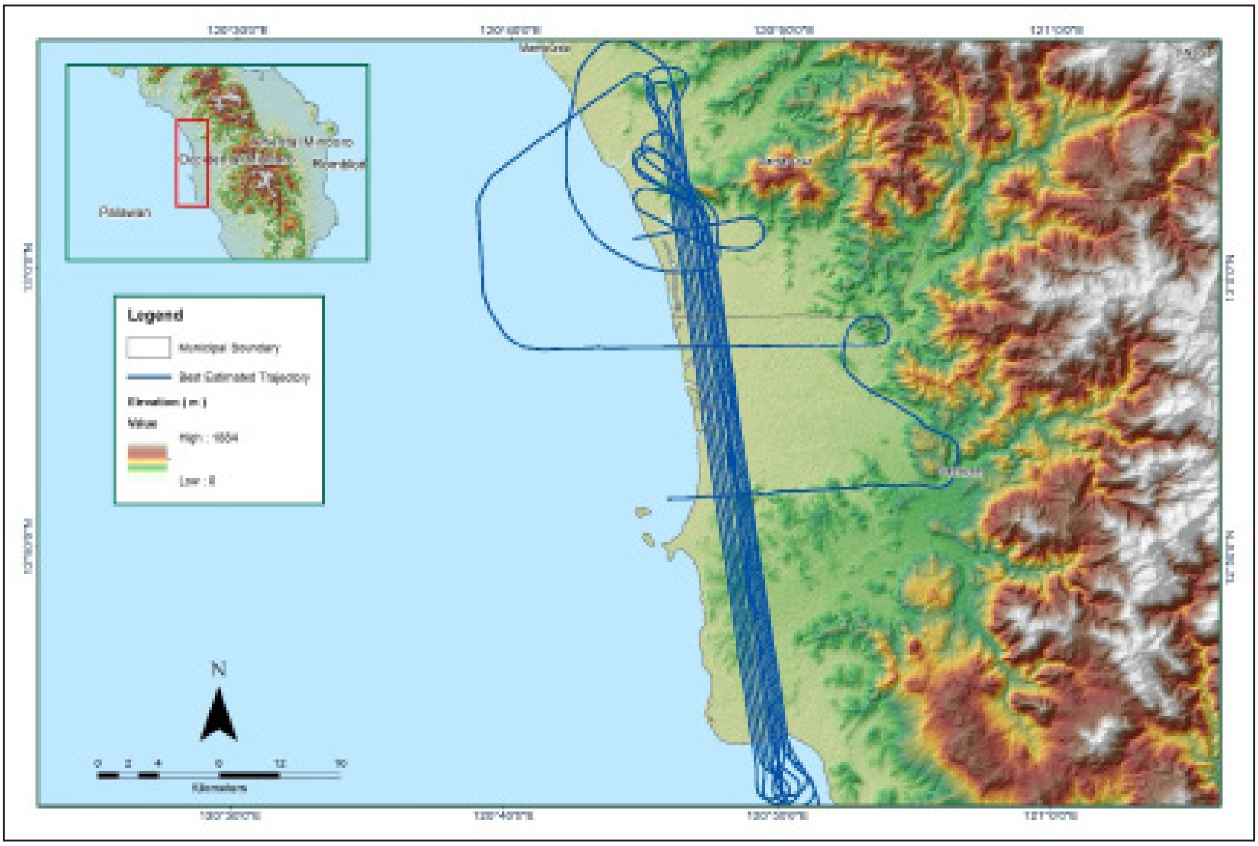


Figure A-8.17. Best Estimated Trajectory

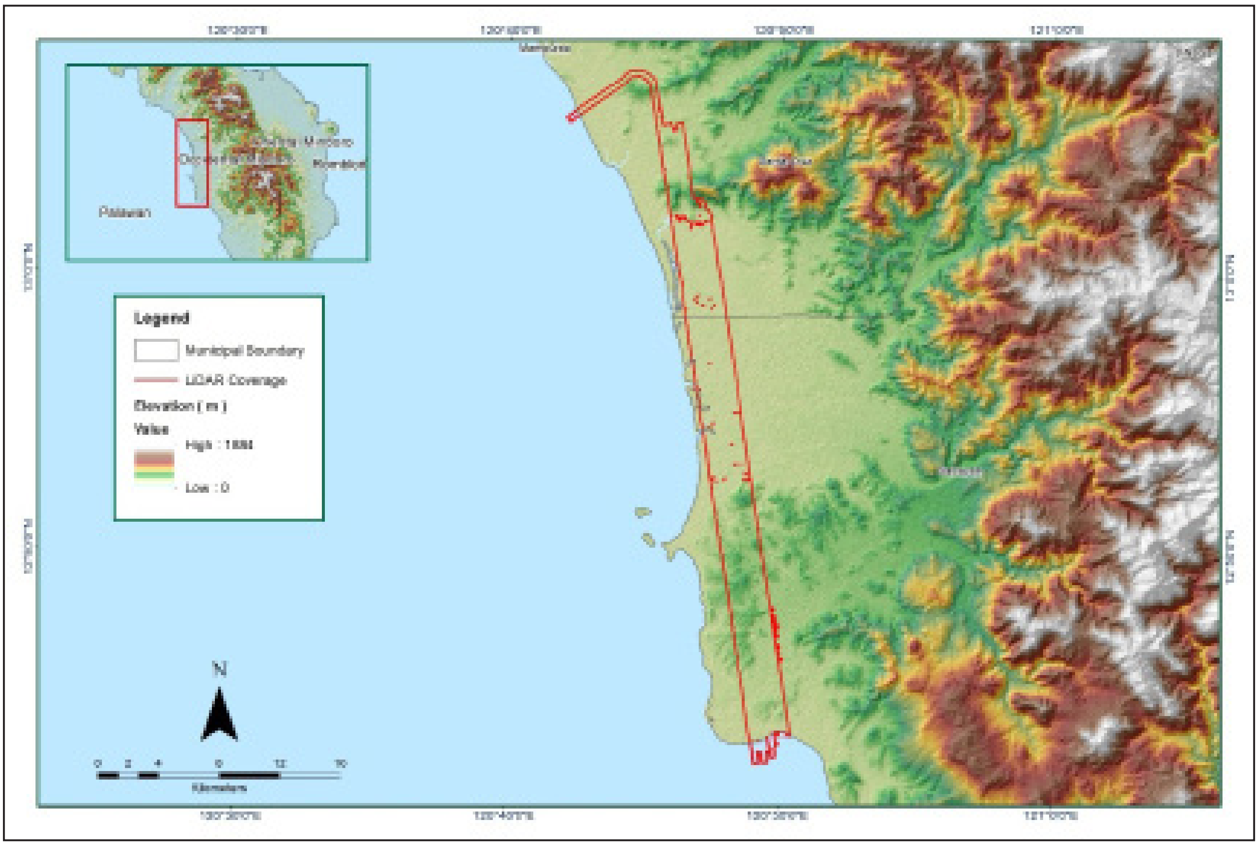


Figure A-8.18. Coverage of LiDAR data

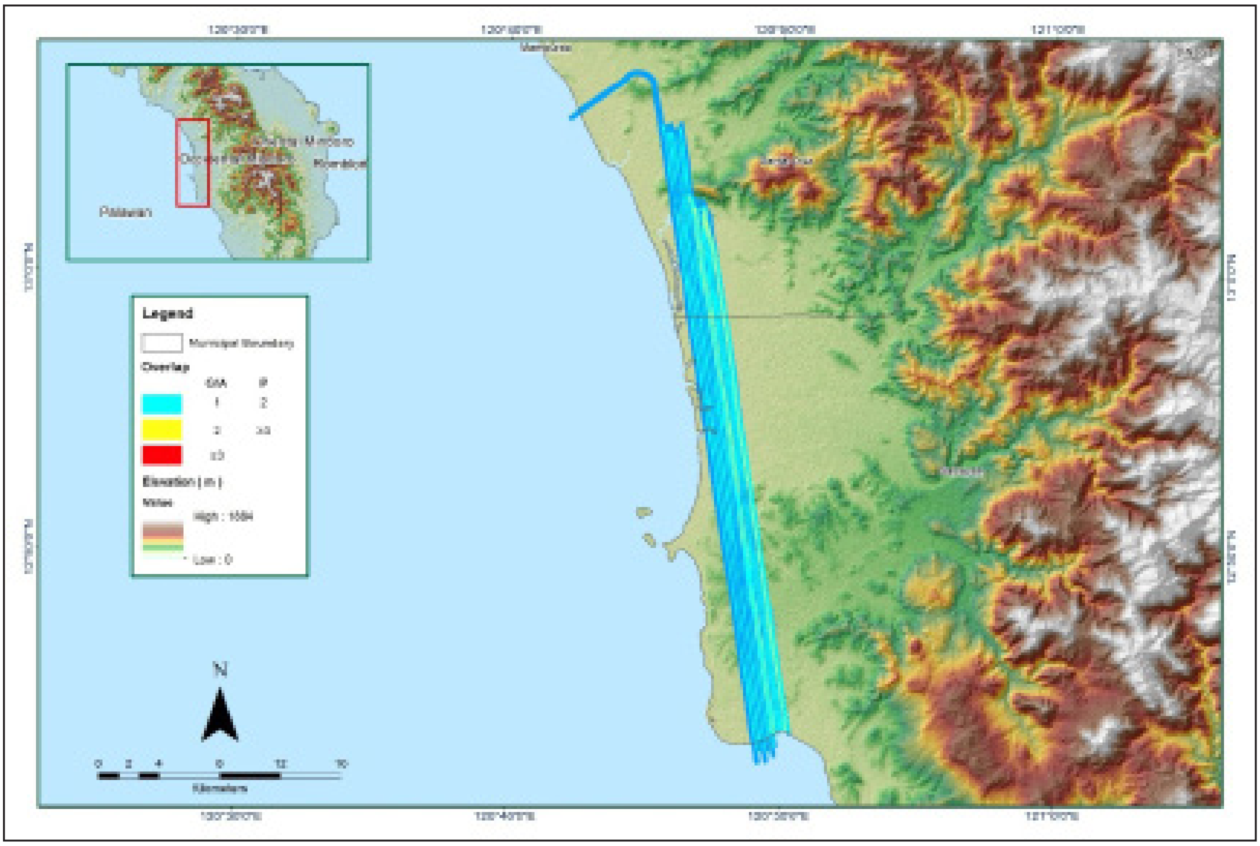


Figure A-8.19. Image of data overlap

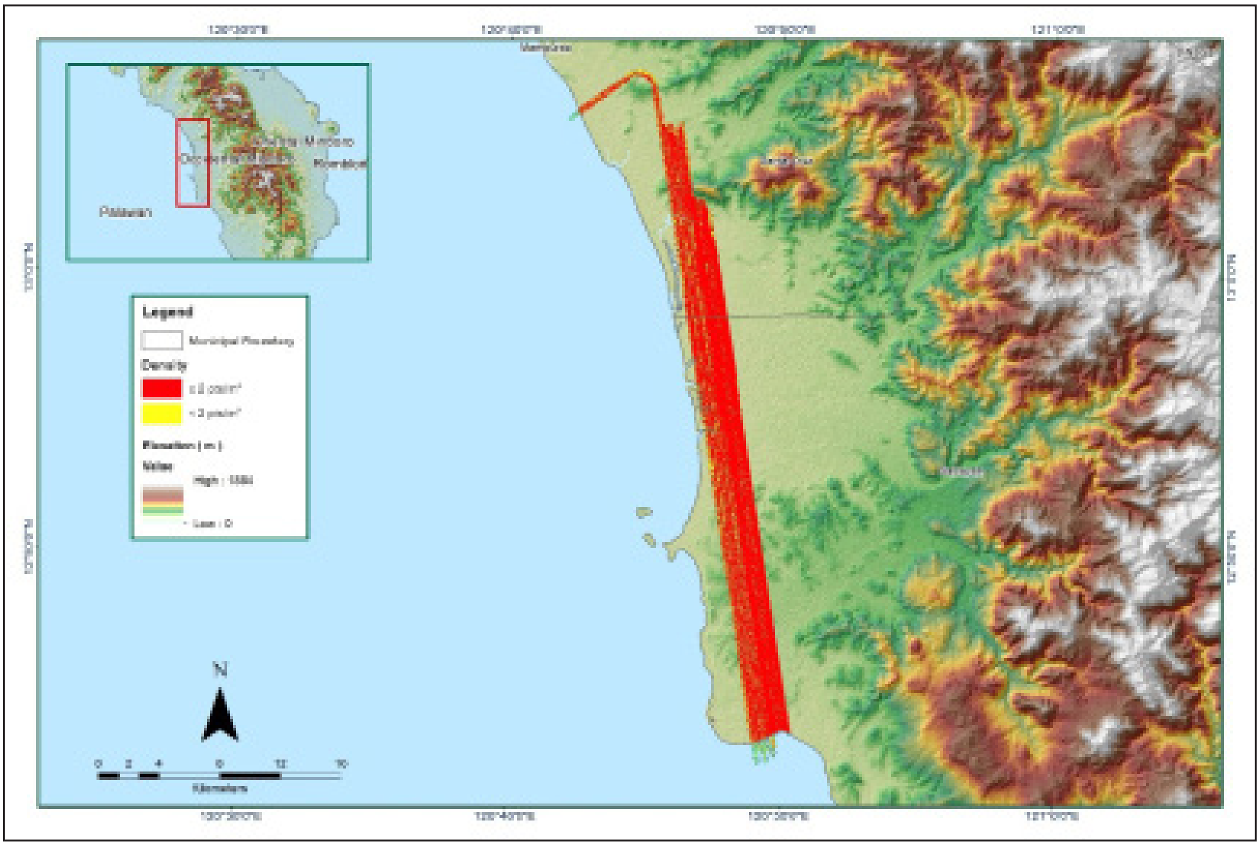


Figure A-8.20. Density map of merged LiDAR data

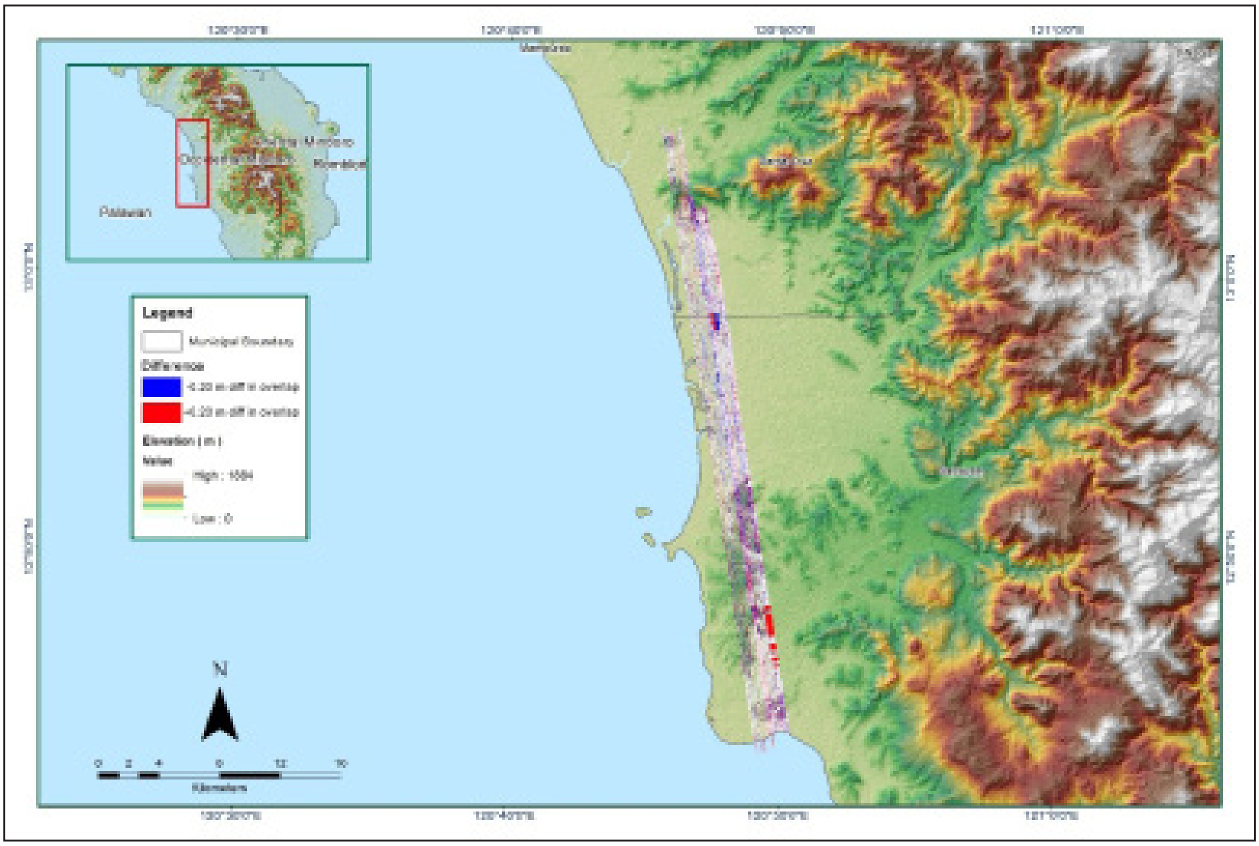


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk29O

Flight Area	Occidental Mindoro Reflights
Mission Name	Blk29O
Inclusive Flights	3066P, 3060P, 3062P
Range data size	28.98GB
POS	498MB
Image	49.69MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.11
RMSE for East Position (<4.0 cm)	1.13
RMSE for Down Position (<8.0 cm)	2.17
Boresight correction stdev (<0.001deg)	0.000442
IMU attitude correction stdev (<0.001deg)	0.004259
GPS position stdev (<0.01m)	0.0174
Minimum % overlap (>25)	30.09
Ave point cloud density per sq.m. (>2.0)	1.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	110
Maximum Height	562.67 m
Minimum Height	46.30 m
Classification (# of points)	
Ground	49,733,362
Low vegetation	34,970,589
Medium vegetation	71,641,806
High vegetation	114,102,370
Building	2,166,793
Orthophoto	Yes
Processed by	Engr. AnalynNaldo, Engr. Justine Francisco, Marie Denise Bueno

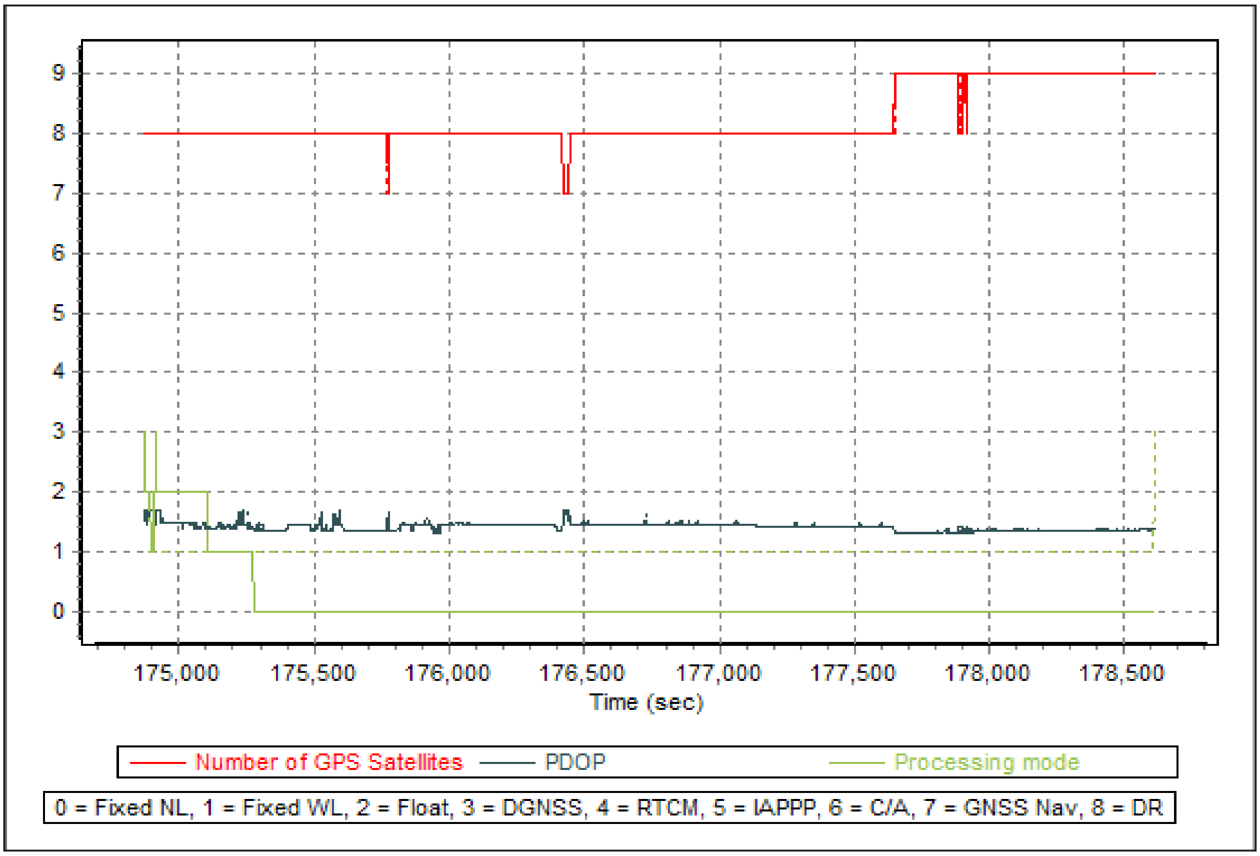


Figure A-8.22. Solution Status

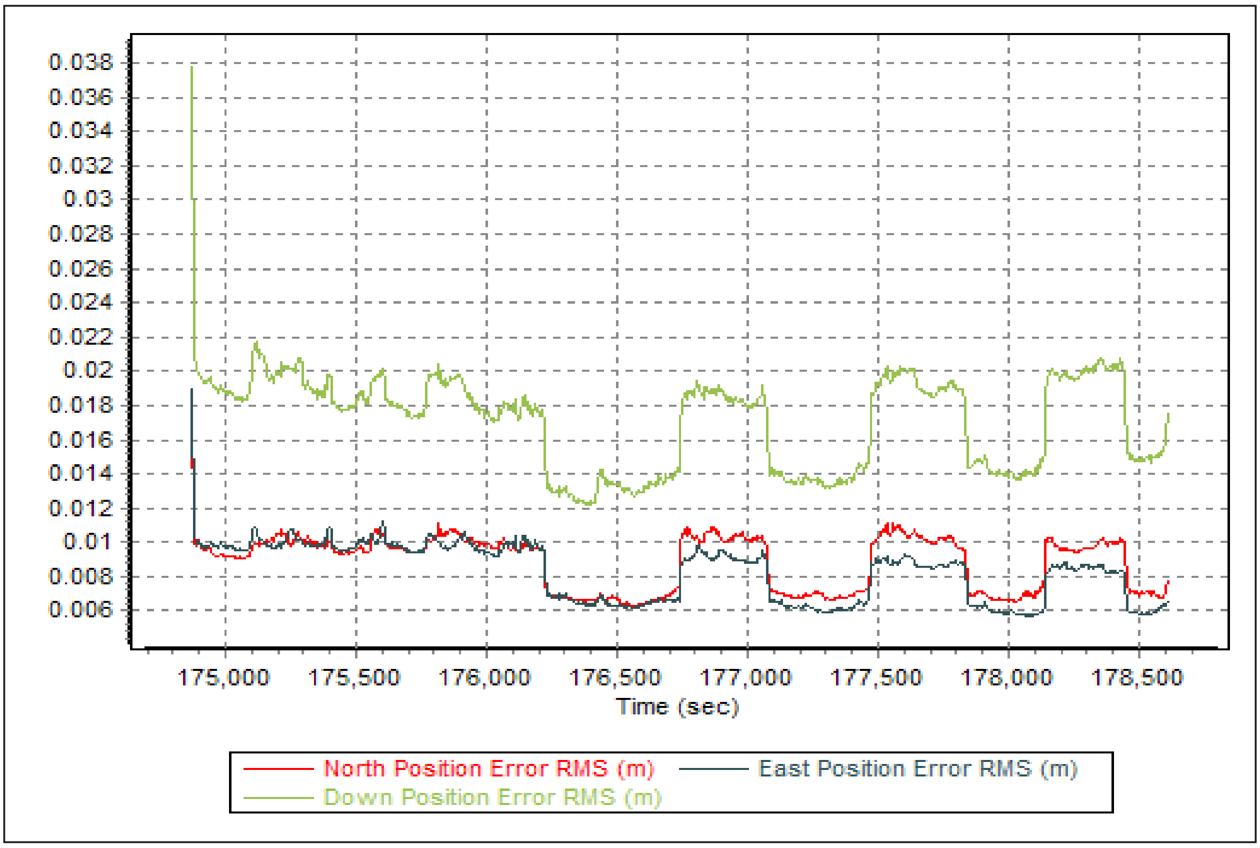


Figure A-8.23. Smoothed Performance Metric Parameters

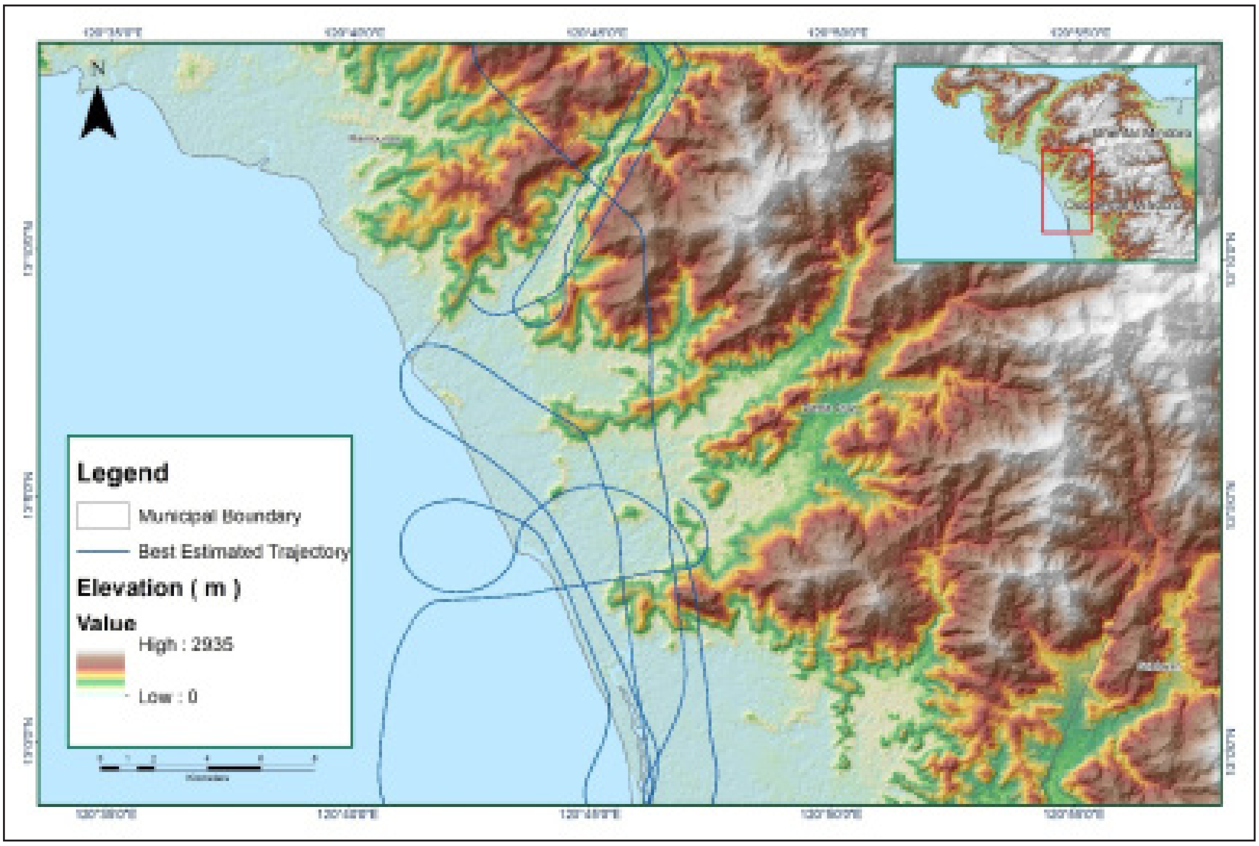


Figure A-8.24. Best Estimated Trajectory

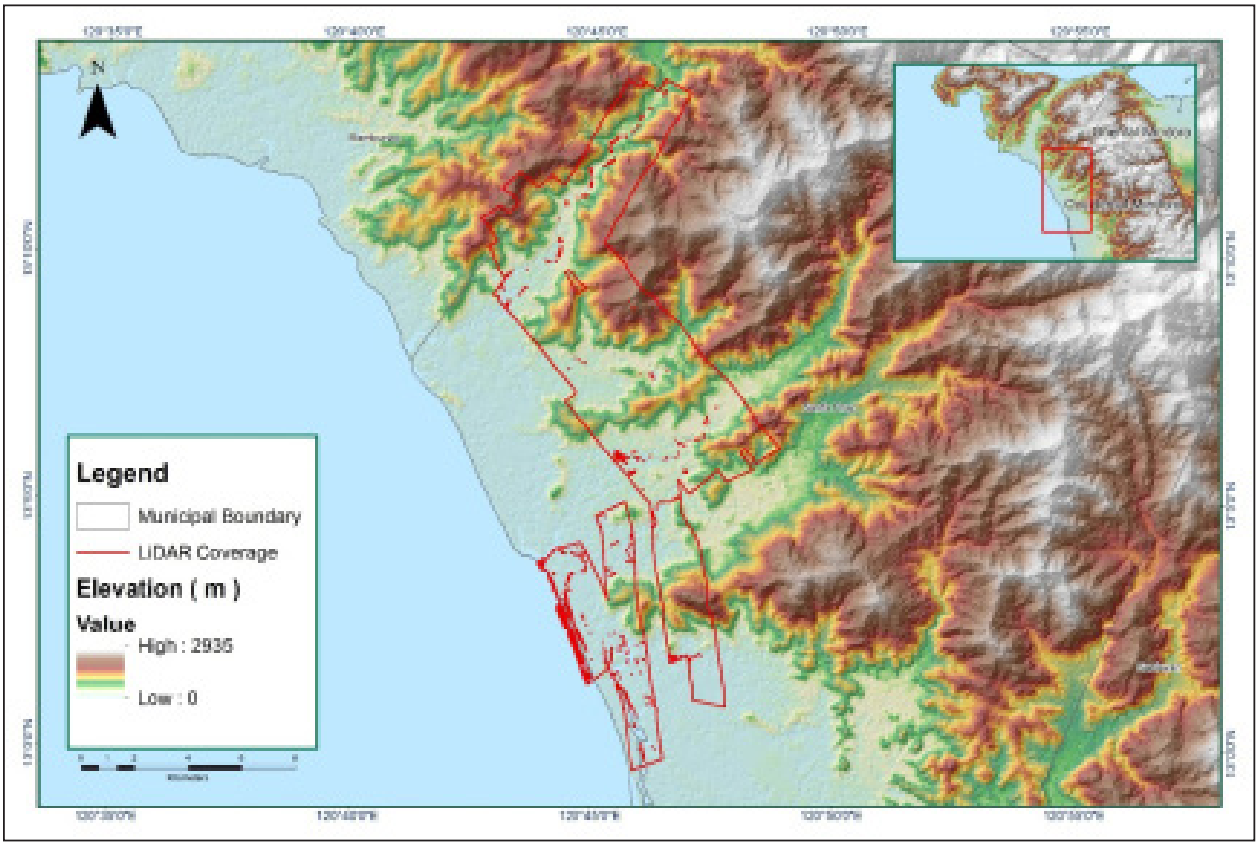


Figure A-8.25. Coverage of LiDAR data

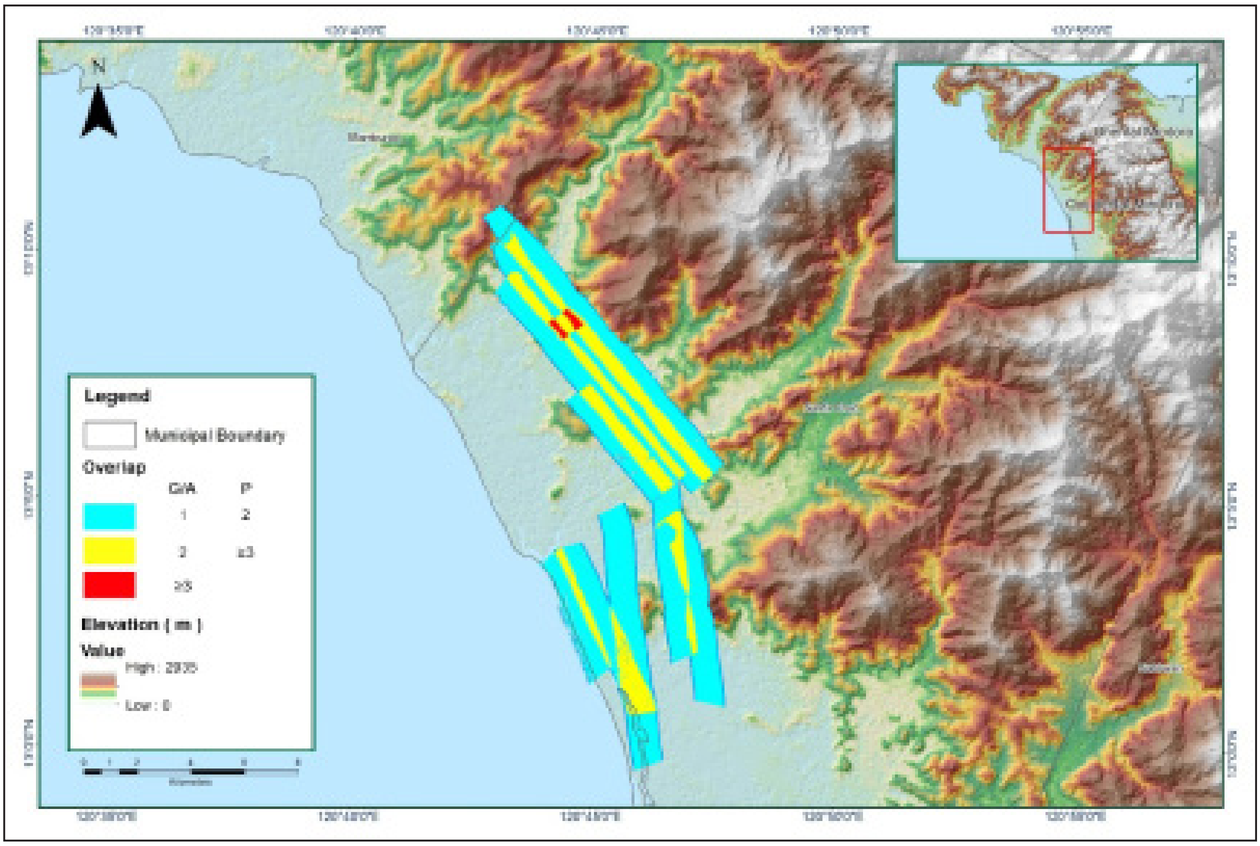


Figure A-8.26. Image of data overlap

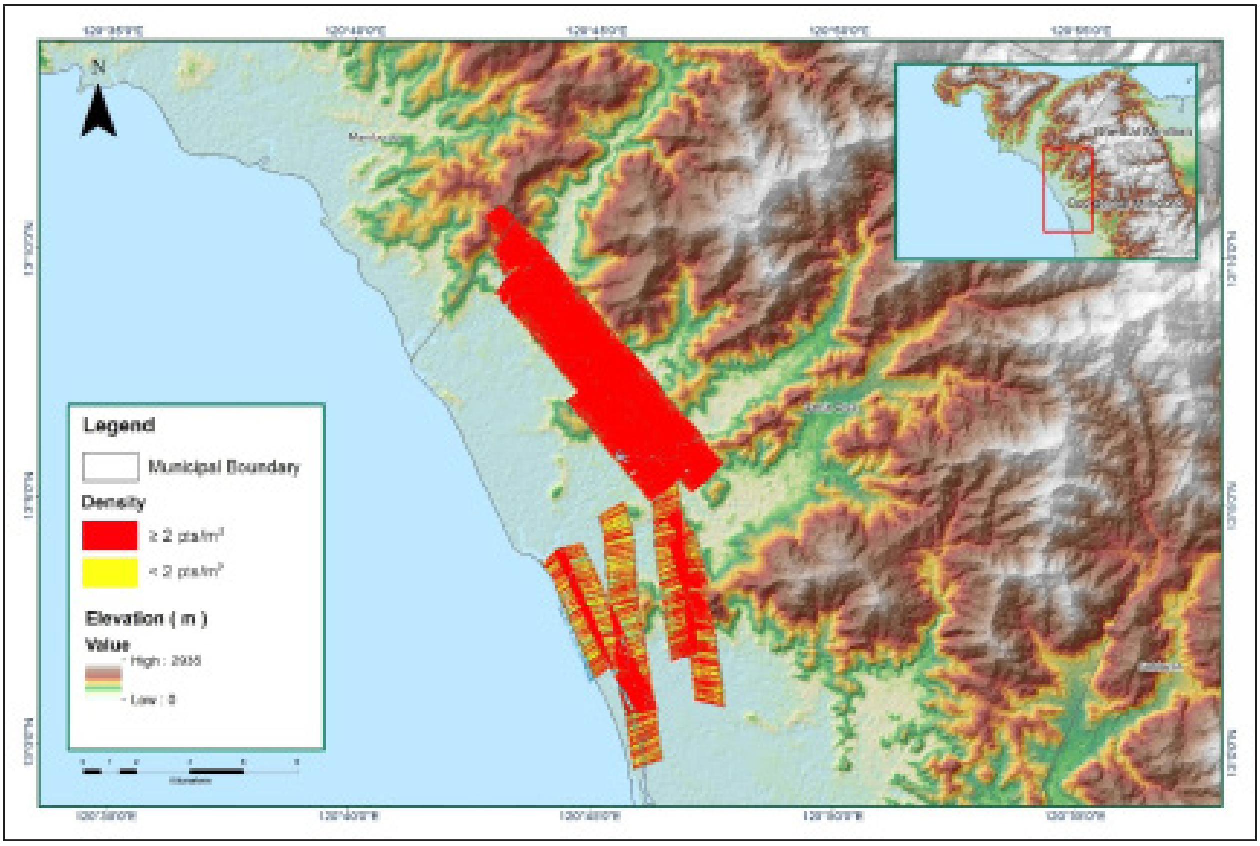


Figure A-8.27. Density map of merged LiDAR data

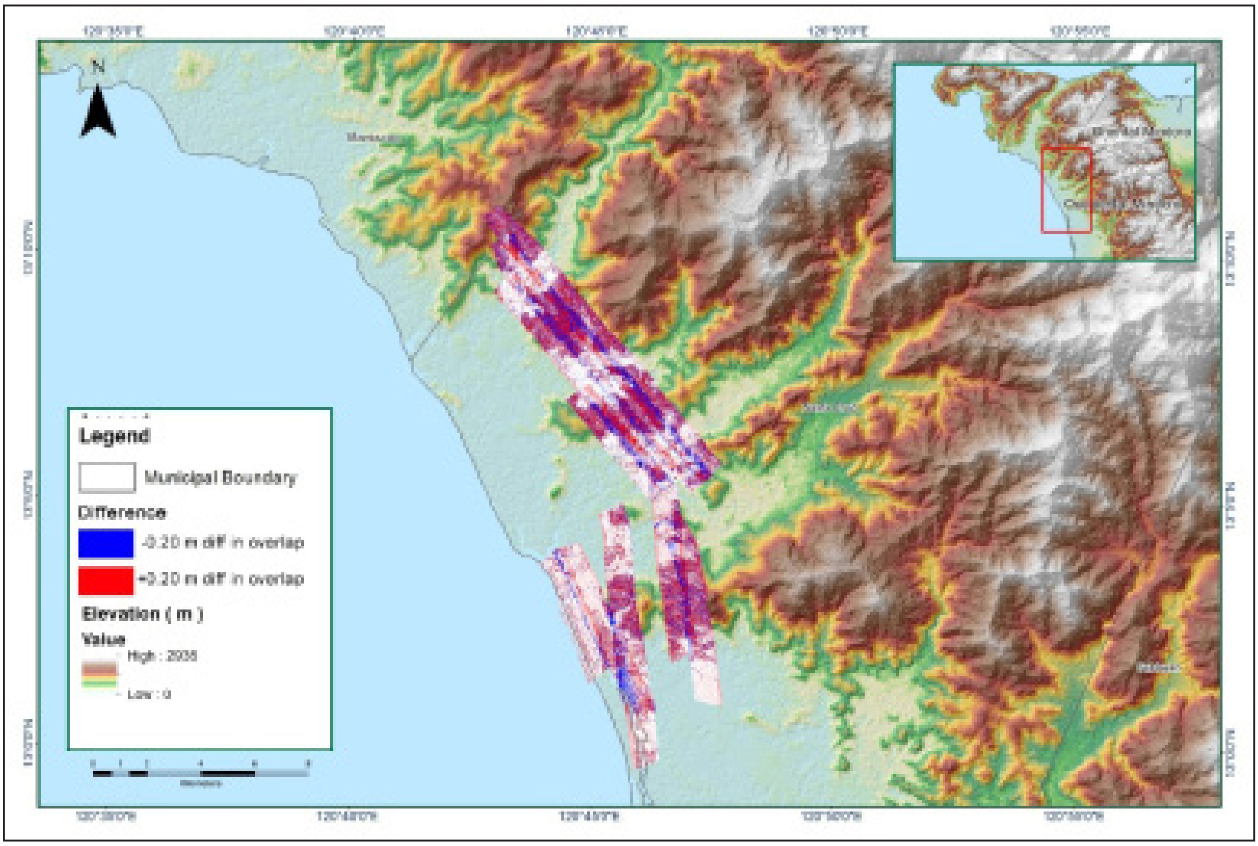


Figure A-8.28. Elevation difference between flight lines

Annex 9. Pola Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W480	9.093	58.275	0	1.1366	1.8549
W490	9.2621	57.827	0	0.77841	1.2704
W500	9.5431	57.096	0	0.88711	1.4478
W510	10.586	54.538	0	1.2143	1.9817
W520	9.5857	56.987	0	1.2829	2.0937
W530	10.719	54.23	0	1.4169	2.3123
W540	11.823	51.789	0	1.1157	1.8208
W550	11.82	51.794	0	3.1509	5.1422
W560	13.344	48.764	0	1.0998	1.7949
W570	10.903	53.808	0	0.79317	1.2944
W580	11.979	51.462	0	2.8691	4.6824
W590	11.416	52.662	0	1.5501	2.5297
W600	12.319	50.762	0	1.9843	3.2385
W610	11.686	52.08	0	1.5823	2.5823
W620	9.3533	57.588	0	0.46204	0.75406
W630	13.099	49.226	0	2.0327	3.3173
W640	13.75	48	0	0.3956	0.64562
W650	12.13	51.149	0	1.6367	2.6712
W660	11.824	51.787	0	1.4318	2.3368
W670	11.612	52.238	0	1.6939	2.7644
W680	9.9372	56.102	0	0.50668	0.8269
W690	13.352	48.749	0	1.8062	2.9476
W700	11.474	52.536	0	1.5316	2.4995
W710	10.646	54.4	0	3.1989	5.2206
W720	12.719	49.963	0	1.6656	2.7182
W730	3.9823	76.129	0	0.59692	0.97417
W740	9.8437	56.335	0	2.1557	3.518
W750	13.581	48.323	0	2.2409	3.6571
W760	4.4998	73.838	0	1.288	2.1019
W770	13.325	48.798	0	1.1701	1.9095
W780	4.1971	75.161	0	1.0313	1.6831
W790	3.2023	79.863	0	2.7726	4.5249
W800	11.408	52.681	0	1.817	2.9654
W810	12.773	49.857	0	1.8358	2.996
W820	3.8949	76.529	0	0.88519	1.4446
W830	10.482	54.783	0	1.8704	3.0525
W840	3.55	78	0	0.33833	0.55216
W850	6.1114	67.512	0	0.90827	1.4823
W860	13.057	49.306	0	2.0213	3.2988

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W870	4.3924	74.302	0	2.0289	3.3112
W880	4.1698	75.282	0	0.98323	1.6046
W890	4.6256	73.302	0	0.80005	1.3057
W900	4.65	73	0	1.4473	2.362
W920	3.8257	76.85	0	0.86943	1.4189
W940	6.9595	64.6	0	1.2739	3.9472
W960	6.25	67	0	2.4186	2.0791
W970	3.4389	78.692	0	1.5827	2.583

Annex 10. Pola Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing			
	Length (M)	Slope(M/M)	Shape	Side Slope (xH:1V)
R100	6605.2	0.05748	Trapezoid	1
R110	5110.1	0.022194	Trapezoid	1
R120	253.14	0.022194	Trapezoid	1
R130	2552.1	0.034267	Trapezoid	1
R150	130.71	0.010056	Trapezoid	1
R160	2371.4	0.012892	Trapezoid	1
R170	476.98	0.022571	Trapezoid	1
R190	2085.8	0.010832	Trapezoid	1
R250	3839.5	0.006884	Trapezoid	1
R270	2880.4	0.009581	Trapezoid	1
R280	701.84	0.018991	Trapezoid	1
R290	1506.7	0.007551	Trapezoid	1
R330	353.85	0.007551	Trapezoid	1
R350	353.85	0.008256	Trapezoid	1
R360	646.27	0.014136	Trapezoid	1
R370	1932.4	0.001642	Trapezoid	1
R400	1516.8	0.004037	Trapezoid	1
R410	6338.1	0.003873	Trapezoid	1
R420	613.85	0.0188	Trapezoid	1
R470	1072	1.88E-02	Trapezoid	1
R60	2159.2	0.11455	Trapezoid	1
R70	3155.3	0.12319	Trapezoid	1
R90	930.83	0.006432	Trapezoid	1
R990	3344.2	0.0188	Trapezoid	1

Annex 11. Pola Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
1	13.03851	120.75	0.19	0.55	0.36		Nov. 2015	25-Year
2	13.0398	120.7495	0.18	0.41	0.23		May, 2014	25-Year
3	13.04094	120.7493	0.17	1.25	1.08	Ondoy	Sept. 2009	25-Year
4	13.04416	120.7481	0.5	0.97	0.47	Pablo	Dec. 2012	25-Year
5	13.04452	120.7558	0.03	1.2	1.17		Aug. 2016	25-Year
6	13.04791	120.7537	0.04	0.5	0.46	Ondoy	Sept. 2009	25-Year
7	13.04958	120.7528	0.08	0.4	0.32	Loleng	Oct. 1998	25-Year
8	13.05001	120.7525	0.03	0.36	0.33		Dec. 2016	25-Year
9	13.05053	120.7531	0.07	0	-0.07			25-Year
10	13.05191	120.7526	1.36	0.97	-0.39	Ondoy	Sept. 2009	25-Year
11	13.05263	120.7467	0.69	0.75	0.06		2014	25-Year
12	13.05353	120.7505	0.07	0.7	0.63	Ondoy	Sept. 2009	25-Year
13	13.05524	120.7543	0.97	0.98	0.01	Karen	2016	25-Year
14	13.05587	120.756	0.12	0	-0.12			25-Year
15	13.05638	120.7565	1.85	0.32	-1.53	Ondoy	Sept. 2009	25-Year
16	13.05774	120.7572	1.07	0.5	-0.57		2010	25-Year
17	13.058	120.7656	0.03	0	-0.03			25-Year
18	13.0589	120.7666	0.1	0	-0.1			25-Year
19	13.06	120.7678	0.51	0	-0.51			25-Year
20	13.06068	120.7627	0.95	0.5	-0.45		2012	25-Year
21	13.06108	120.7642	0.64	0.3	-0.34		Aug. 2016	25-Year
22	13.06104	120.7456	1.51	0.84	-0.67	Yolanda	Nov. 2013	25-Year
23	13.06134	120.7407	1.41	0.61	-0.8		May, 2006	25-Year
24	13.06161	120.7684	0.34	0	-0.34			25-Year
25	13.06188	120.7436	0.83	0	-0.83			25-Year
26	13.06337	120.7418	1.47	0.95	-0.52	Pedring	2011	25-Year
27	13.06516	120.7419	1.39	0.42	-0.97	Karen	2016	25-Year
28	13.06516	120.7289	0.03	0	-0.03			25-Year
29	13.06523	120.7286	0.03	0	-0.03			25-Year
30	13.06531	120.7283	0.03	0.45	0.42	Glenda	14-Jul	25-Year
31	13.06549	120.7426	1.04	0.5	-0.54	Ondoy	Sept. 2009	25-Year
32	13.06555	120.743	1.13	0.48	-0.65	Karen	2016	25-Year
33	13.06559	120.727	0.15	0	-0.15			25-Year
34	13.06559	120.727	0.15	0.5	0.35	Ondoy	Sept. 2009	25-Year
35	13.06617	120.7262	0.19	0	-0.19			25-Year
36	13.06767	120.7729	0.7	0.88	0.18	Yolanda	Nov. 2013	25-Year
37	13.06752	120.7418	1.56	0.61	-0.95	Loleng	Oct. 1998	25-Year
38	13.06954	120.7434	1.52	0.52	-1		2011	25-Year
39	13.06973	120.7413	1.6	0.75	-0.85	Yolanda	Nov. 2013	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
40	13.07097	120.7754	0.03	0	-0.03			25-Year
41	13.07051	120.7227	0.35	1.28	0.93		2006	25-Year
42	13.07122	120.7232	0.81	1.1	0.29			25-Year
43	13.07179	120.7757	0.03	0	-0.03			25-Year
44	13.0716	120.7447	1.41	0.55	-0.86	Yolanda	Nov. 2013	25-Year
45	13.0716	120.7233	0.64	0.8	0.16	Ondoy	Sept. 2009	25-Year
46	13.07196	120.7235	0.6	0.45	-0.15	Ondoy	Sept. 2009	25-Year
47	13.07265	120.7232	0.12	0.9	0.78	Reming	Nov. 2006	25-Year
48	13.073	120.7232	0.03	0	-0.03			25-Year
49	13.07327	120.745	0.56	0.13	-0.43	Reming	2006	25-Year
50	13.07366	120.7475	0.49	0	-0.49			25-Year
51	13.07436	120.7496	0.48	0.4	-0.08		2011	25-Year
52	13.07685	120.7487	0.67	0	-0.67			25-Year
53	13.07667	120.7216	0.03	0	-0.03			25-Year
54	13.07718	120.7522	1.93	0.9	-1.03	Loleng	Oct. 1998	25-Year
55	13.0773	120.7206	0.41	0	-0.41			25-Year
56	13.07763	120.7208	0.59	0.6	0.01	Reming	Nov. 2006	25-Year
57	13.07764	120.7205	0.38	0.7	0.32	Reming	Nov. 2006	25-Year
58	13.07771	120.7212	0.03	0.4	0.37	Yolanda	Nov. 2013	25-Year
59	13.07828	120.72	0.03	0	-0.03			25-Year
60	13.07872	120.7561	0.55	0	-0.55			25-Year
61	13.07851	120.7202	0.16	0.6	0.44	Nina	Dec. 2016	25-Year
62	13.07886	120.7208	0.03	0	-0.03	Yolanda	Nov. 2013	25-Year
63	13.07941	120.7206	0.03	0	-0.03			25-Year
64	13.0801	120.7187	0.32	0	-0.32			25-Year
65	13.08016	120.7197	0.37	0	-0.37			25-Year
66	13.08239	120.7684	0.99	0.33	-0.66	Loleng	Oct. 1998	25-Year
67	13.08285	120.7653	0.93	0	-0.93			25-Year
68	13.0834	120.7697	1.23	0.49	-0.74		2011	25-Year
69	13.08343	120.7593	1.4	0	-1.4			25-Year
70	13.08371	120.7607	1.92	0.83	-1.09		2011	25-Year
71	13.08438	120.769	1.32	0.36	-0.96		2011	25-Year
72	13.08444	120.7188	0.39	0	-0.39			25-Year
73	13.08505	120.7183	0.03	0.9	0.87			25-Year
74	13.08531	120.7179	0.45	1.15	0.7	Yolanda	Nov. 2013	25-Year
75	13.08536	120.7174	0.22	0.39	0.17			25-Year
76	13.08561	120.7177	0.95	0.9	-0.05	Yolanda	Nov. 2013	25-Year
77	13.08568	120.7182	0.06	0.1	0.04	Ondoy		25-Year
78	13.08582	120.7181	0.09	0	-0.09			25-Year
79	13.08609	120.7182	1.02	0	-1.02			25-Year
80	13.0867	120.7736	0.59	0.39	-0.2		2011	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
81	13.08623	120.7185	2.61	0.3	-2.31	Nina		25-Year
82	13.08641	120.7179	0.97	0.45	-0.52	Yolanda	Nov. 2013	25-Year
83	13.08816	120.7762	1.47	0.91	-0.56		Sept. 2011	25-Year
84	13.08886	120.7824	2.01	0	-2.01			25-Year
85	13.09294	120.7112	0.12	0.43	0.31	Nina		25-Year
86	13.0931	120.7107	0.03	0	-0.03			25-Year
87	13.09329	120.7119	0.04	0.28	0.24	Habagat		25-Year
88	13.09341	120.7114	0.5	0.47	-0.03	Nona		25-Year
89	13.09349	120.7119	0.03	0.26	0.23	Nina		25-Year
90	13.09365	120.7125	0.08	0	-0.08			25-Year
91	13.09366	120.7122	0.14	0.36	0.22	Nona		25-Year
92	13.09389	120.7125	0.05	0.26	0.21	Nina		25-Year
93	13.09397	120.7143	0.49	0.4	-0.09	Nina		25-Year
94	13.09414	120.7146	0.16	0	-0.16			25-Year
95	13.09425	120.7149	0.03	0	-0.03			25-Year
96	13.09429	120.7129	0.18	0.26	0.08	Nina		25-Year
97	13.0944	120.7141	0.29	0.2	-0.09	Nina		25-Year
98	13.09461	120.7144	0.03	0	-0.03			25-Year
99	13.09488	120.7137	0.39	0.48	0.09	Nina		25-Year
100	13.09497	120.7141	0.19	0	-0.19			25-Year
101	13.09552	120.7146	0.03	0	-0.03			25-Year
102	13.09671	120.7137	0.03	0	-0.03			25-Year
103	13.09711	120.7088	0.04	0	-0.04			25-Year
104	13.09733	120.7094	0.05	0.46	0.41	Nina		25-Year
105	13.09742	120.7098	0.22	0.55	0.33	Nina		25-Year
106	13.09756	120.7135	0.03	0	-0.03			25-Year
107	13.0977	120.7103	0.05	0.36	0.31		16-Jun	25-Year
108	13.09787	120.7104	0.08	0	-0.08		2016	25-Year
109	13.0979	120.7106	0.21	0.36	0.15	Caren		25-Year
110	13.09803	120.7134	0.03	0	-0.03			25-Year
111	13.09828	120.7131	0.03	0	-0.03			25-Year
112	13.09836	120.7111	0.26	0	-0.26			25-Year
113	13.09839	120.7128	0.1	0	-0.1			25-Year
114	13.09885	120.7127	0.1	0	-0.1			25-Year
115	13.09928	120.7108	0.03	0.2	0.17	Nina		25-Year
116	13.10093	120.7563	0.51	0.61	0.1	Reming	Nov. 2006	25-Year
117	13.10153	120.7546	0.36	1	0.64	Reming	Nov. 2006	25-Year
118	13.10156	120.7581	0.25	0.2	-0.05	Yolanda	Nov. 2013	25-Year
119	13.10179	120.754	0.73	0.2	-0.53	Nina	Dec. 2016	25-Year
120	13.10188	120.7591	0.42	0.2	-0.22	Nina	Dec. 2016	25-Year
121	13.10192	120.7569	0.18	0.45	0.27	Nina	Dec. 2016	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
122	13.10208	120.7595	0.43	0	-0.43			25-Year
123	13.10207	120.7589	0.38	1.22	0.84	Yolanda	Nov. 2013	25-Year
124	13.10209	120.7604	0.41	0.1	-0.31	Nina	Dec. 2016	25-Year
125	13.10216	120.7599	0.28	0.3	0.02	Nina	Dec. 2016	25-Year
126	13.10221	120.7601	0.38	0.25	-0.13	Nina	Dec. 2016	25-Year
127	13.10222	120.7593	0.44	0.66	0.22	Yolanda	Nov. 2013	25-Year
128	13.1023	120.7603	0.48	0.35	-0.13	Nina	Dec. 2016	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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Information Systems Analyst
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