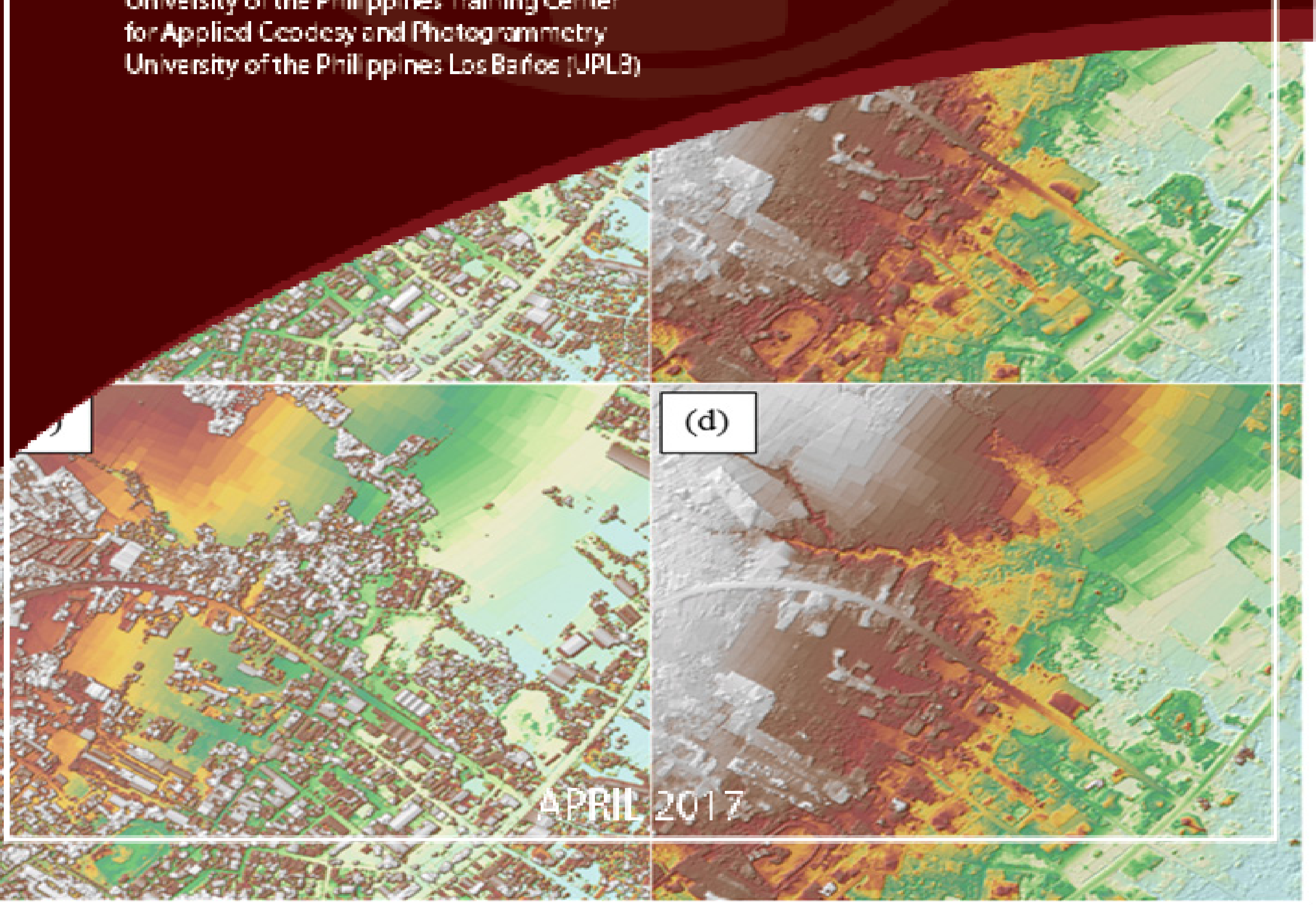
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Ocayan River

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



APRIL 2017

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

LIDAR SURVEYS AND FLOOD MAPPING OF OCAYAN RIVER

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

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND OCAYAN

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

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

1.2 Overview of the Ocayan 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 Ocayan River Basin covers one (1) municipality in Palawan; namely, the municipality of Bataraza. The DENR River Basin Control Office (RBCO) states that the Ocayan River Basin has a drainage are of 58 km² and an estimated 93 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Ocayan River, is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner HEI, University of the Philippines Los Baños. According to the 2015 national census of PSA, a total of 16,577 persons are residing in Brgy. Rio Tuba in the Municipality of Bataraza, which is within the immediate vicinity of the river. The economy of the province of Palawan is primarily agriculture-based; particularly fishing, tourism, trade, commerce, and mineral extraction (Source: pkp.pcsd.gov.ph/images/ppcprofile/Economic%20Profile.pdf). On November 17, 2016, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Ocayan River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area

Ocayan River Basin is a 26.980-hectare watershed located in Palawan. It covers the barangays of Ocayan, Rio Tuba and Sandoval in Bataraza municipality. The river basin is generally has 8-18% slope. Bolinao clay soil type and rough mountainous land (unclassified) can be found in the area. The river basin area is typically arable land (crops mainly cereals and sugar). Other land cover include cultivated area mixed with brushland/grassland, mossy forest, coconut plantations, mangrove vegetation and crop land mixed with coconut plantation.

Ocayan River passes through Ocayan, Rio Tuba and Sandoval in Bataraza municipality. Rio Tuba is the most populated barangay in the Bataraza based on the 2010 NSO Census of Population and Housing records.

Based on the studies conducted by the Mines and Geosciences Bureau, the landslide susceptibility condition of the barangays within the river basin is low risk. On the other hand, it has high risk to flooding. The field surveys conducted by the PHIL-LiDAR 1 validation team found that heavy rainfall caused flooding in 2014 (January), 2015 (October) and 2016 (June and December).

affecting Southern Luzon, Visayas and Mindanao as per NDRRMC report (Source: http://www.ndrrmc.gov.ph/attachments/article/3/General_ Flood_Advisories_as_of_17NOV

CHAPTER 2: LIDAR DATA ACQUISITION OF THE OCAYAN FLOODPLAIN

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

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).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Ocayan floodplain in Palawan province. These missions were planned for 17 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the Pegasus and Gemini LiDAR systems used are found in Table 1 and Table 2, respectively. Figure 1 shows the flight plan for Ocayan floodplain. Annex 1 shows the technical specifications of the Pegasus and Gemini LiDAR systems and aerial camera.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK42Q	1000	30	50	200	30	130	5
BLK42R	1200	30	50	200	30	130	5
BLK42T	1000	30	50	200	30	130	5

Table 2. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK42eT	1000	30	26	100	50	119	5
BLK42Q	850	30	40	125	50	120	5
BLK42R	1000	30	26	100	50	120	5
BLK42Tv	1000	30	26	100	50	120	5
BLK42eU	700	30	40	125	40	114	5
BLK42eS	850	30	40	125	40	117	5
BLK42eN	1000	30	26	100	50	120	5

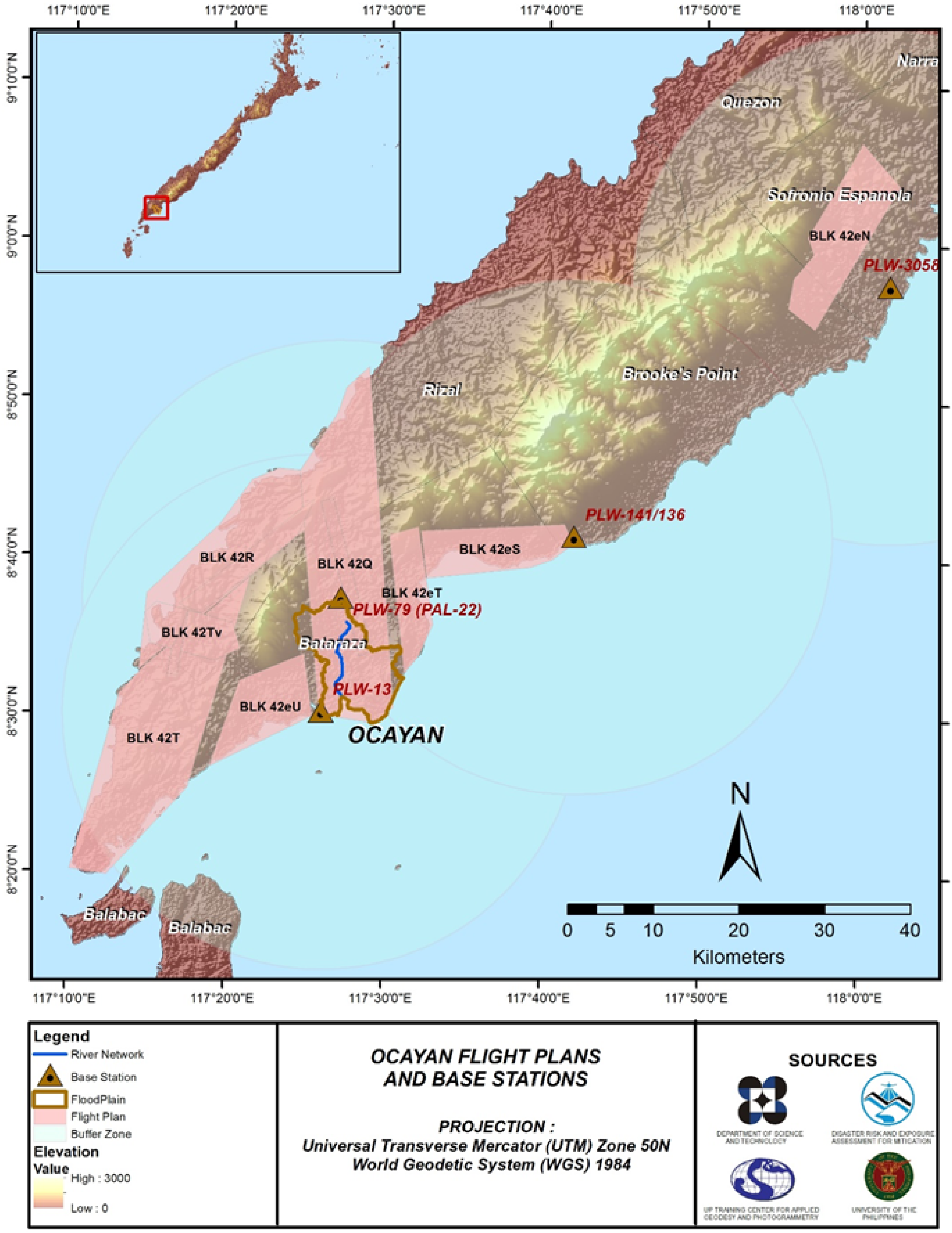


Figure 1. Flight plans used for Ocayan floodplain.

2.2 Ground Base Stations

Three (3) NAMRIA ground control points (GCP): PLW-13, PLW-141 (PLW-136), and PLW-79 which are all of second (2nd) order accuracy were recovered for use as base station during the survey. Upon reconnaissance of PLW-141's location based on its description from NAMRIA, it was found out however that “PLW-136” was inscribed in the cement landmark instead of “PLW-141”, though the original PLW-136 based on NAMRIA description should be in Balabac Island south of Palawan. This was reported to NAMRIA and they issued a GCP certificate for PLW-141 with title indicating “PLW-141/136”. Also, PLW-3058 which is a fourth (4th) order GCP was used and re-processed as 2nd order control point for the project's accuracy. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports are found in Annex 3. These were used as base stations or reference points during flight operations for the entire duration of the survey (June 28 to July 8, 2015 and December 4 to December 10, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ocayan floodplain are shown in Figure 1.

Figure 2 to Figure 5 show the recovered NAMRIA reference points within the area, while Table 2 to Table 5 show the corresponding details about the following NAMRIA control stations and established points. In addition, Table 6 shows the list of all ground control points occupied in line with their respective mission names and flight numbers, together with the dates of acquisition.

(a) (b)

Figure 2. a) GPS set-up over PLW-13 on a boulder in a barangay ukay-ukay market near Rio Tuba Nickel mining site and pier. b) NAMRIA reference point PLW-13 as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point PLW-13 used as base station for the LiDAR data acquisition.

Station Name	PLW-13	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 30’ 17.42901” 117° 25’ 55.42672” -0.25567 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting Northing	382,414.126 meters 940,540.844 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 30 ’13.19373” 117° 26’ 0.86501” 49.35 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N WGS 1984)	Easting Northing	547,553.57 meters 940,076.76 meters

(a)

(b)

Figure 3. a) GPS set-up over PLW-141/136 in Malis Elementary School, Brooke’s Point Palawan. b) NAMRIA reference point PLW-136 as recovered by the field team.

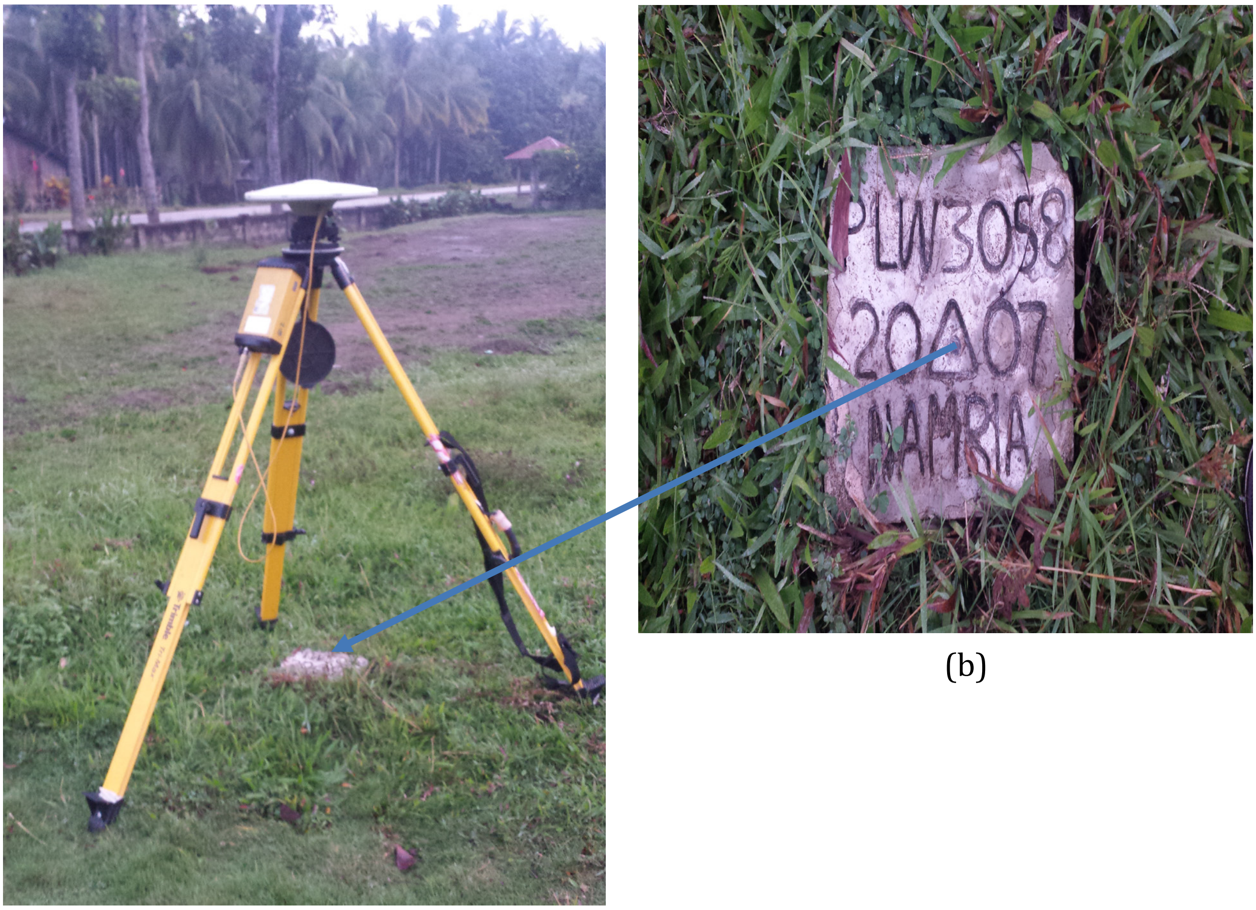
Table 4. Details of the recovered NAMRIA horizontal control point PLW-141/136 used as base station for the LiDAR data acquisition.

Station Name	PLW-141/136	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 41’ 32.51585” 117° 41’ 48.08062” -2.493 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting Northing	411,596.8 meters 961,210.738 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 41’ 28.25671” 117° 41’ 53.50178” 47.391 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N WGS 1984)	Easting Northing	576,642.18 meters 960,851.09 meters

Figure 4. GPS set-up over PLW-79 (PAL-22) along the barangay road of Brgy. Sandoval near the house of Tribal Chieftain Acat in the Municipality of Bataraza.

Table 5. Details of the recovered NAMRIA horizontal control point PLW-79 (PAL-22) used as base station for the LiDAR data acquisition.

Station Name	PLW-79 (PAL-22)	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 37' 30.44877" 117° 27' 5.39859" 25.88011 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting Northing	384,591.01 meters 953,839.48 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 37' 26.18482" 117° 27' 10.82604" 75.29 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N WGS 1984)	Easting Northing	549,677.23 meters 953,376.65 meters



(a) (b)

Figure 5. a) GPS set-up over PLW-3058 on the ground inside Caranasan Elementary School, Espanola, Palawan. b) NAMRIA reference point PLW-3058 as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point PLW-3058 used as base station for the LiDAR data acquisition.

Station Name	PLW-3058	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°30'17.42900" N 117°25'55.42676" E -0.256 m
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting Northing	-113,741.490 m 944,471.057 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°30'13.19373" N 117°26'00.86501" E 49.350 m

Table 7. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
June 28, 2015	3105P	1BLK42QR179A	PLW-13 & PLW-79
June 29, 2015	3109P	1BLK42QR180A	PLW-13 & PLW-79
July 7, 2015	3141P	1BLK42QRT188A	PLW-13 & PLW-79
July 8, 2015	3145P	1BLK42QRT189A	PLW-13 & PLW-79
December 4, 2015	3571G	2BLK42Tv338A	PLW-13
December 8, 2015	3585G	2BLK42Nv342A	PLW-13 & PLW-3058
December 10, 2015	3593G	2BLK42TReT344A	PLW-13 & PLW-141/136
December 10, 2015	3595G	2BLK42UeS344B	PLW-13 & PLW-141/136

2.3 Flight Missions

Eight (8) missions were conducted to complete LiDAR data acquisition in Ocayan Floodplain, for a total of twenty-six hours and four minutes (26+4) of flying time for RP-C9022. All missions were acquired using Pegasus and Gemini LiDAR systems. The team line-up is shown in Annex 4. The aerial camera (D-8900) was experiencing technical malfunctions during the Pegasus flights and was completely not functioning during the Gemini flights, though the camera problem was reported to and coordinated with the service provider during the time of survey. A LiDAR technician was sent by Optech after the field work to fix the problem. Table 8 shows the total area of actual coverage and number of images; and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition. The data transfer sheet, flight logs and flight status reports of each mission are shown in Annex 5, 6 and 7 respectively.

Table 8. Flight missions for LiDAR data acquisition in Ocayan 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
June 28, 2015	3105P	659.433	287.716	22.062	265.654	566	3	31
June 29, 2015	3109P	311.869	156.722	49.867	106.855	NA	2	25
July 7, 2015	3141P	759.434	333.896	31.036	302.86	34	4	15
July 8, 2015	3145P	168.864	103.271	0	103.271	3	2	15
December 4, 2015	3571G	81.897	92.442	11.058	81.384	NA	3	5
December 8, 2015	3585G	114.959	119.527	2.971	116.556	NA	3	53
December 10, 2015	3593G	147.208	126.082	0	126.082	NA	3	59
December 10, 2015	3595G	160.863	107.577	0.017	107.56	NA	2	41
TOTAL		2404.53	1327.233	117.011	1210.222	603	26	4

Table 9. Actual parameters used during LiDAR data acquisition.

Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3105P	1000	30	50	200	30	130	5
3109P	1000	30	50	200	30	130	5
3141P	1200	30	50	200	30	130	5
3145P	800	30	50	200	30	120	5
3571G	850/1000	30	40	125/100	50	120	5
3585G	1000/700	30	30/50	100/125	50/40	120	5
3593G	1000	30	26	100	50	120	5
3595G	1000/700	30	40	125	40	120	5

2.4 Survey Coverage

Ocayan floodplain is located in the province of Palawan situated within the municipality of Bataraza. LiDAR swath coverage for these flights also covers parts of Rizal, Brooke's Point, and Sofronio Española municipalities. The list of municipalities and/or cities surveyed, with at least one (1) square kilometer coverage is shown in Table 10. The actual coverage of the LiDAR acquisition for Ocayan Floodplain is presented in Figure 6.

Table 10. List of municipalities and/or cities surveyed during Ocayan floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveye
Palawan	Bataraza	810.536	587.292	72%
Palawan	Rizal	971.980	264.313	27%
Palawan	Brooke's Point	886.345	27.277	3%
Palawan	Sofronio Española	474.096	87.750	18%
TOTAL		3142.96	966.63	30.76%

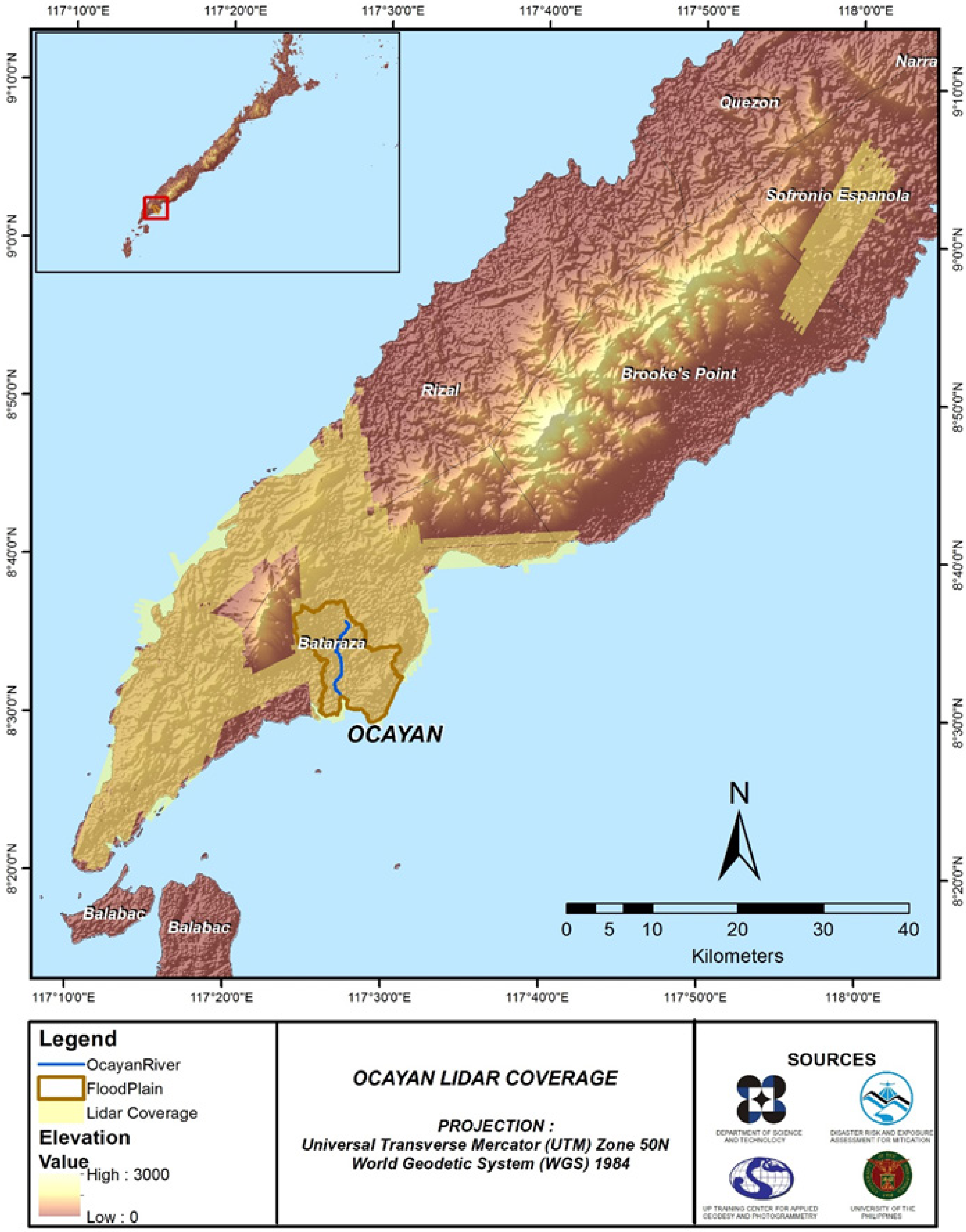


Figure 6. Actual LiDAR survey coverage for Ocayan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE OCAYAN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos, Engr. Angelo Carlo B. Bongat, Engr. Ma. Ailyn L. Olanda, Engr. Justine Y. Francisco, Marie Denise V. Bueno, Engr. Regis R. Guhiting, Engr. Merven Matthew D. Natino, Gillian Katherine L. Inciong, Gemmalyn E. Magnaye, Leendel Jane D. Punzalan, Sarah Joy A. Acepcion, Ivan Marc H. Escamos, Allen Roy C. Roberto, Jan Martin C. Magcale

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

3.1 Overview of the LIDAR Data Pre-Processing

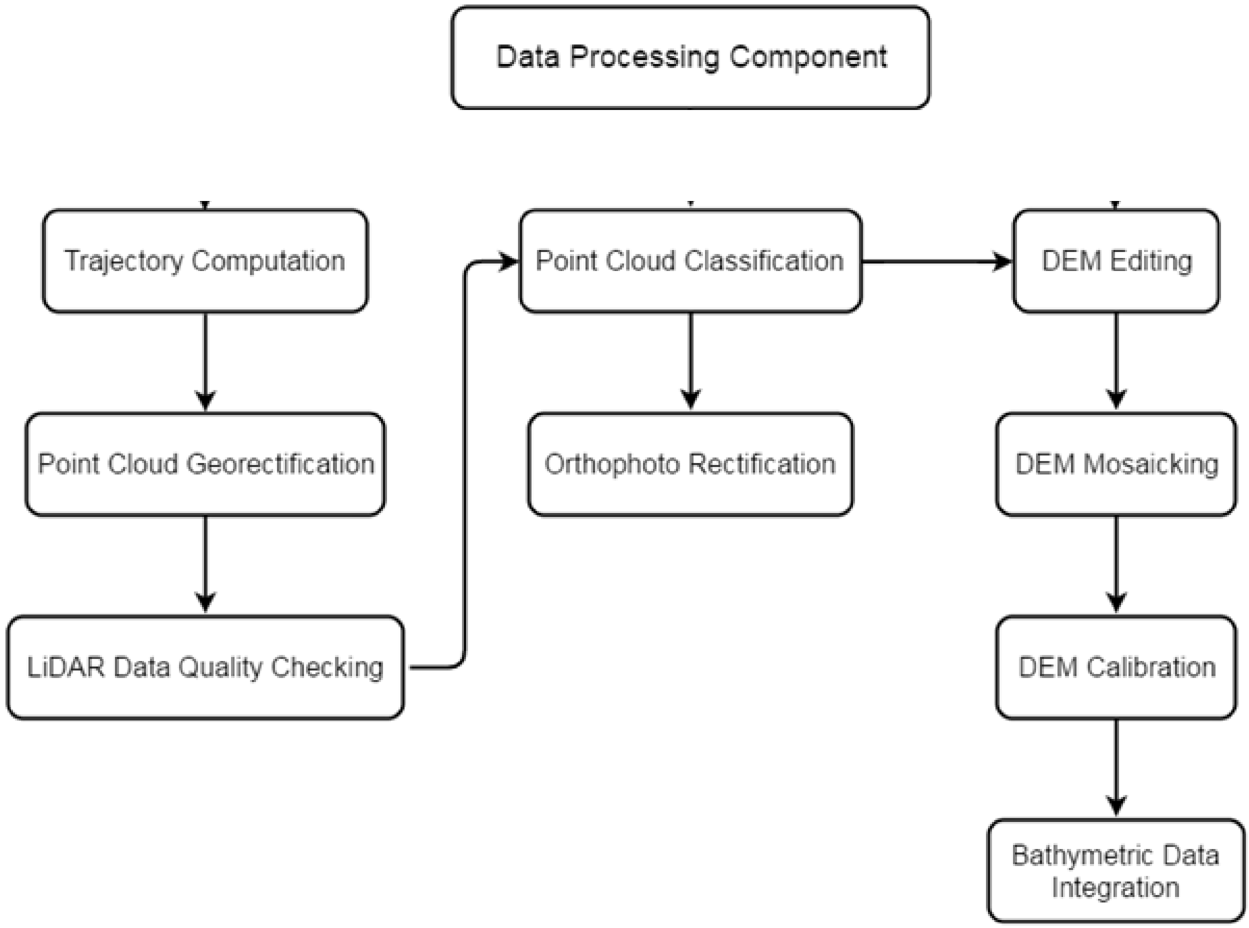


Figure 7. Schematic Diagram for Data Pre-Processing Component.

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

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

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ocayan floodplain can be found in Annex 5. Missions flown during the first survey conducted on July 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on November 2015 were flown using the Gemini system over Bataraza, Palawan. The Data Acquisition Component (DAC) transferred a total of 173.90 Gigabytes of Range data, 1.52 Gigabytes of POS data, 704.38 Megabytes of GPS base station data, and 223.01 Gigabytes of raw image data to the data server on July 7, 2015 for the first survey and November 21, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ocayan was fully transferred on January 5, 2016, as indicated on the Data Transfer Sheets for Ocayan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3141P, one of the Ocayan flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on July 7, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

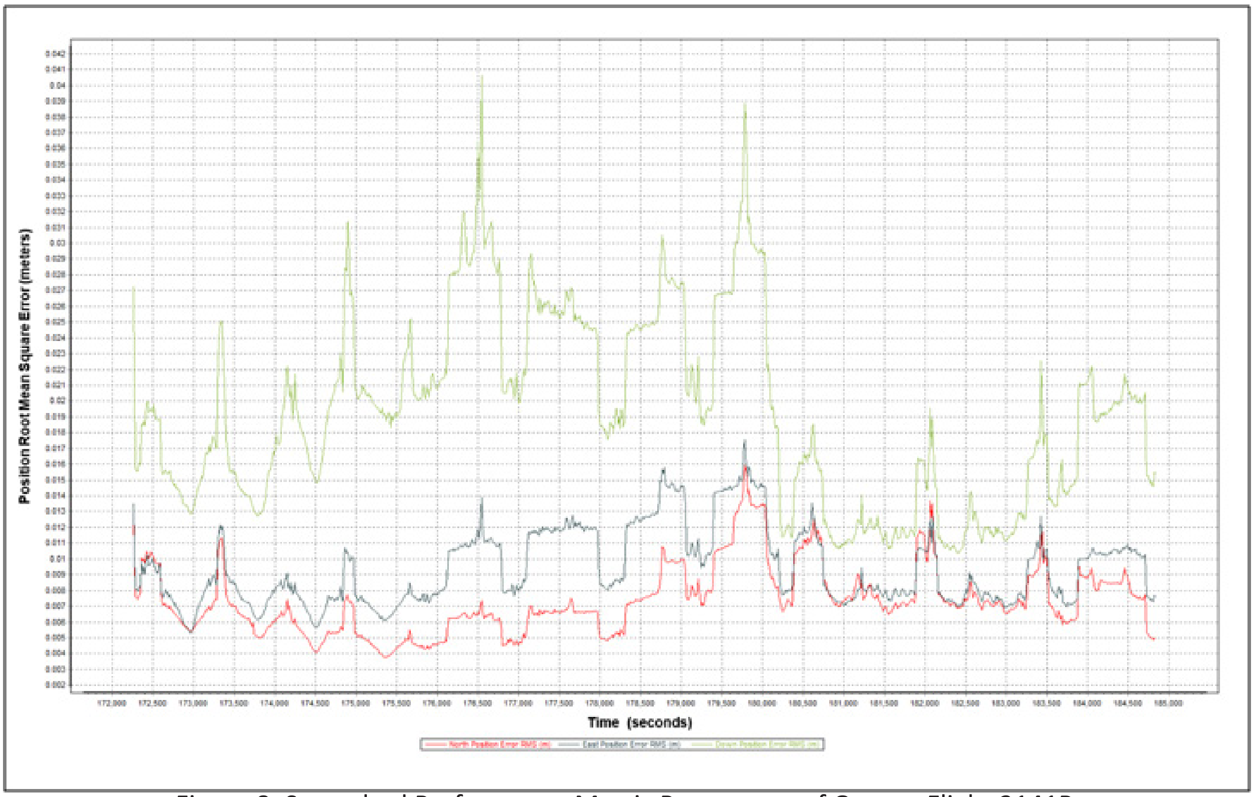


Figure 8. Smoothed Performance Metric Parameters of Ocayan Flight 3141P.

The time of flight was from 172000 seconds to 185000 seconds, which corresponds to morning of July 7, 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 starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.60 centimeters, the East position RMSE peaks at 1.80 centimeters, and the Down position RMSE peaks at 4.10 centimeters, which are within the prescribed accuracies described in the methodology.

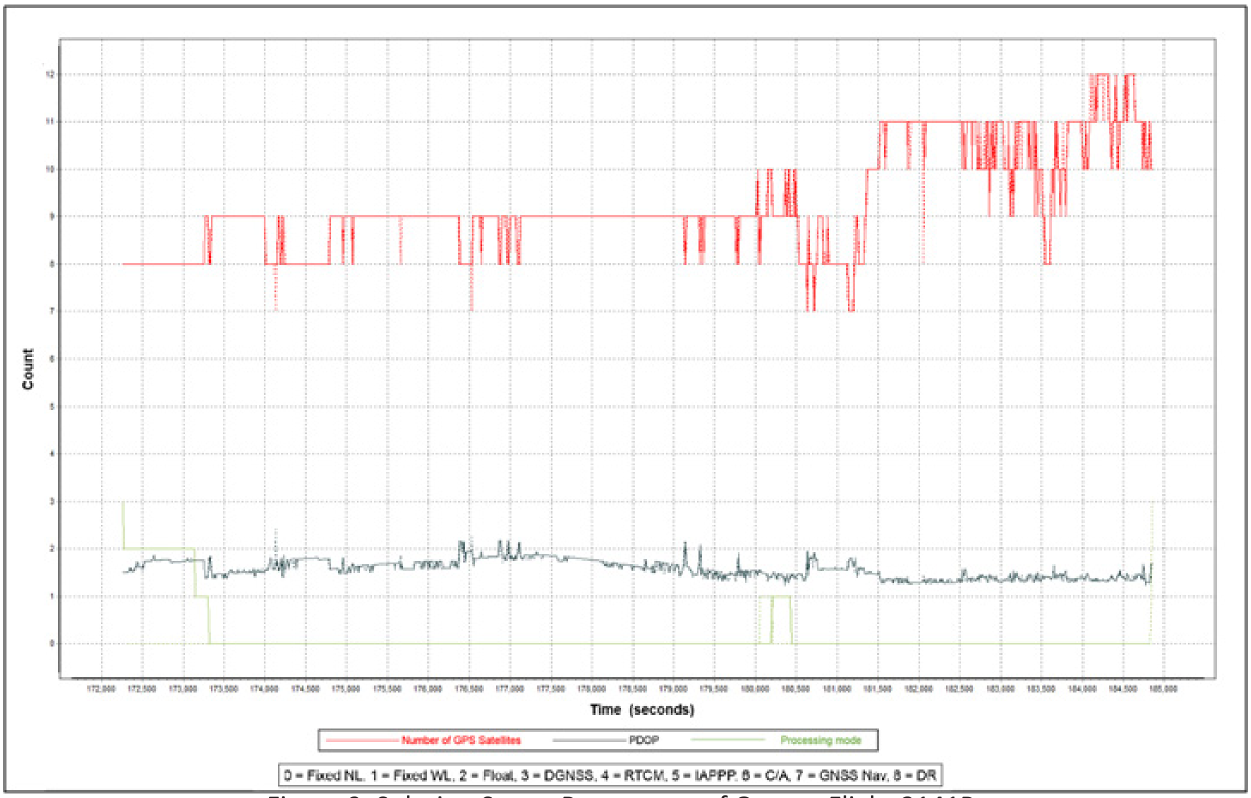


Figure 9. Solution Status Parameters of Ocayan Flight 3141P.

The Solution Status parameters of flight 3141P, one of the Ocayan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 12. 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 2 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 Ocayan flights is shown in Figure 10.

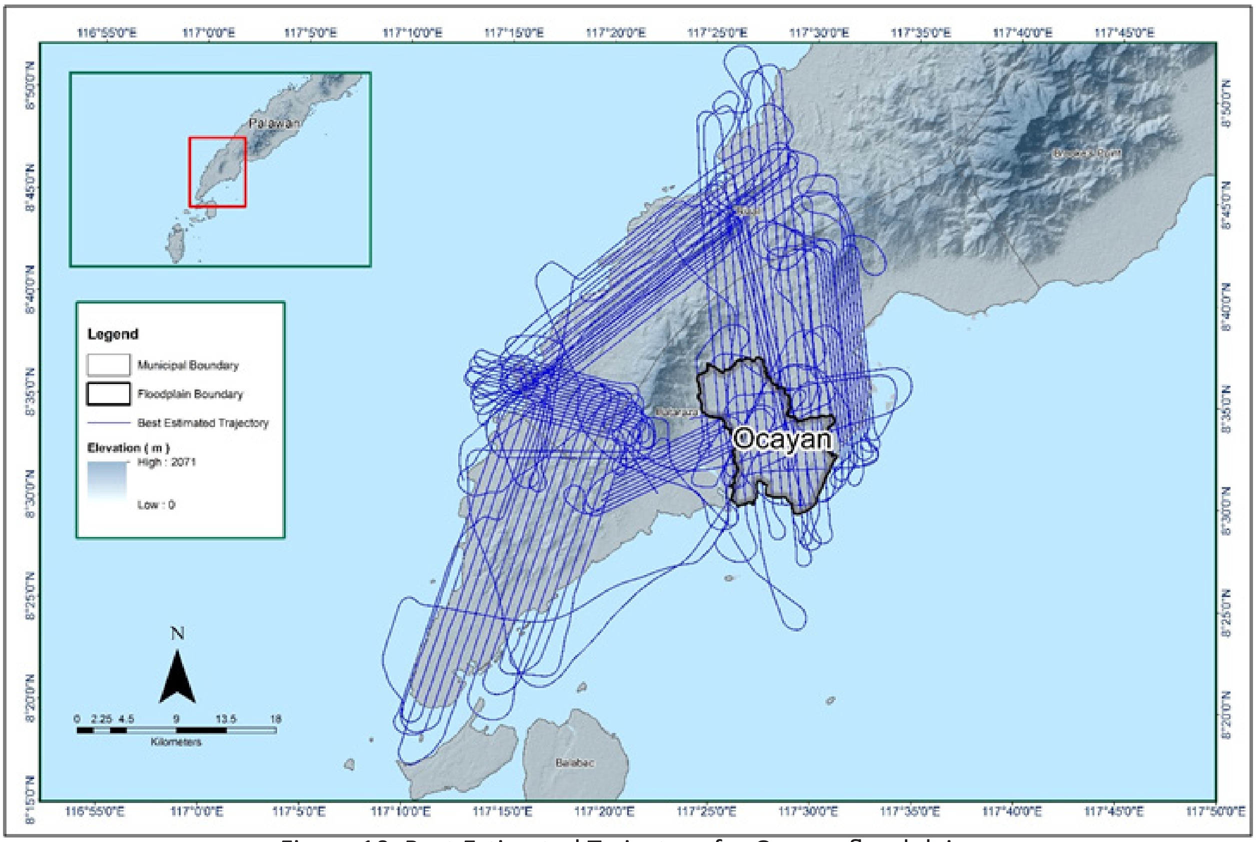


Figure 10. Best Estimated Trajectory for Ocayan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 108 flight lines, with each flight line containing one channel for the Gemini system since it contains only one channel and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ocayan floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Ocayan flights.

Parameter		Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000201
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000705
GPS Position Z-correction stdev	(<0.01meters)	0.0016

The optimum accuracy is obtained for all Ocayan 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 Quality Checking

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

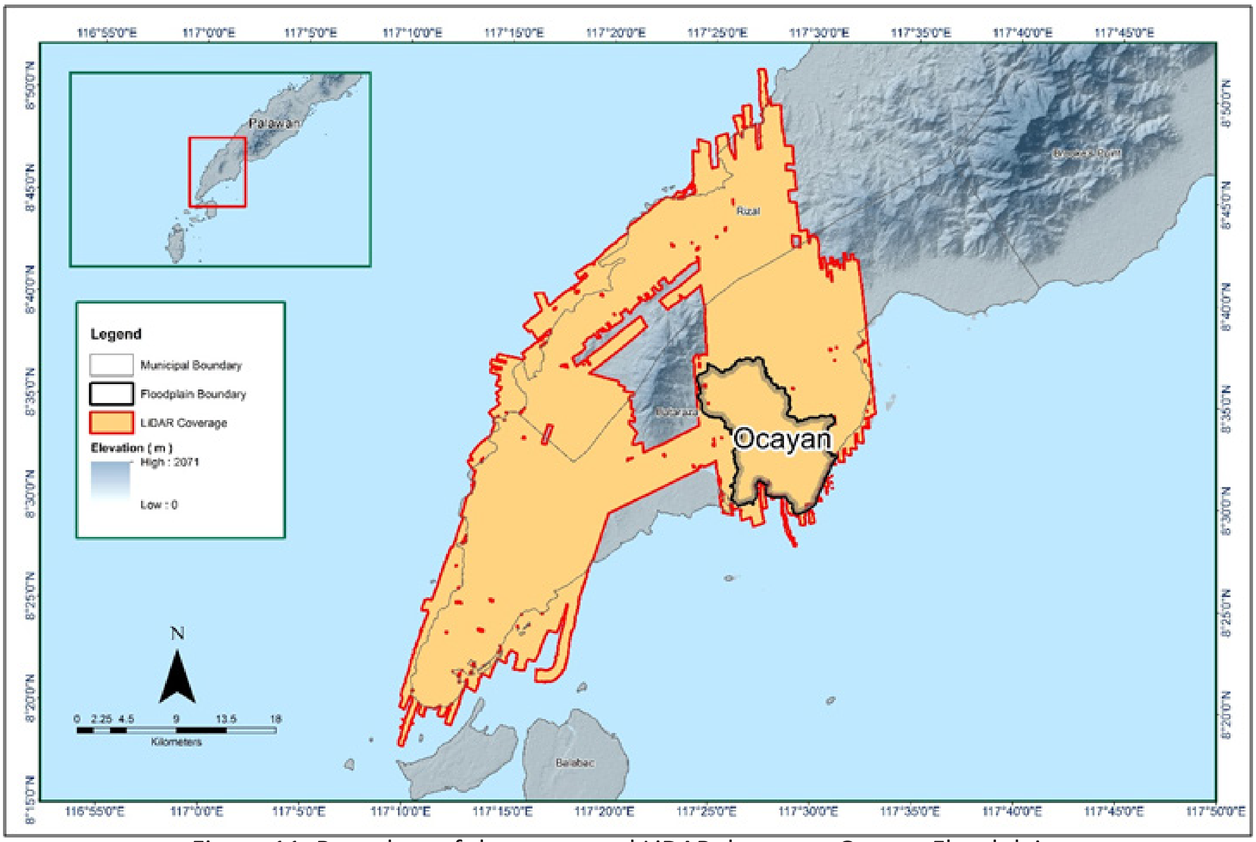


Figure 11. Boundary of the processed LiDAR data over Ocayan Floodplain.

The total area covered by the Ocayan missions is 1063.08 sq.km that is comprised of eight (8) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Ocayan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan Blk42Q	3109P	231.80
	3105P	
Palawan Blk42Q_additional	3141P	126.29
Palawan Blk42R	3105P	174.43
	3141P	
	3145P	
Palawan Blk42T	3105P	324.66
	3141P	
Palawan_reflights_Blk42Q	3571G	37.71
Palawan_reflights_Blk42Q_ additional	3571G	9.98
	3585G	
Palawan_reflights_Blk42T	3593G	59.81
Palawan_reflights_Blk42U	3595G	39.73
Palawan_reflights_Blk42eT	3593G	58.67
	3571G	
TOTAL		**1,063.08 sq.km**

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

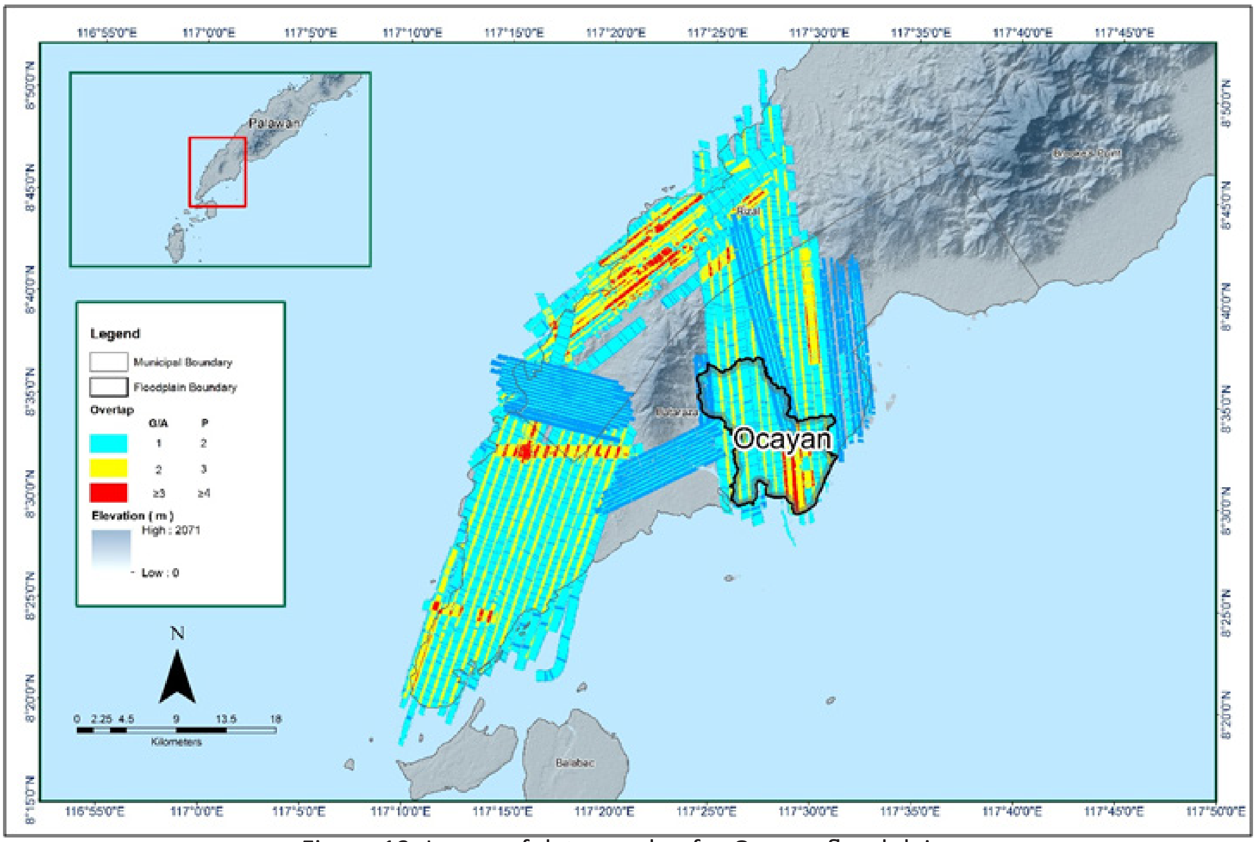


Figure 12. Image of data overlap for Ocayan floodplain.

The overlap statistics per block for the Ocayan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.85% and 43.57% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Ocayan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.45 points per square meter.

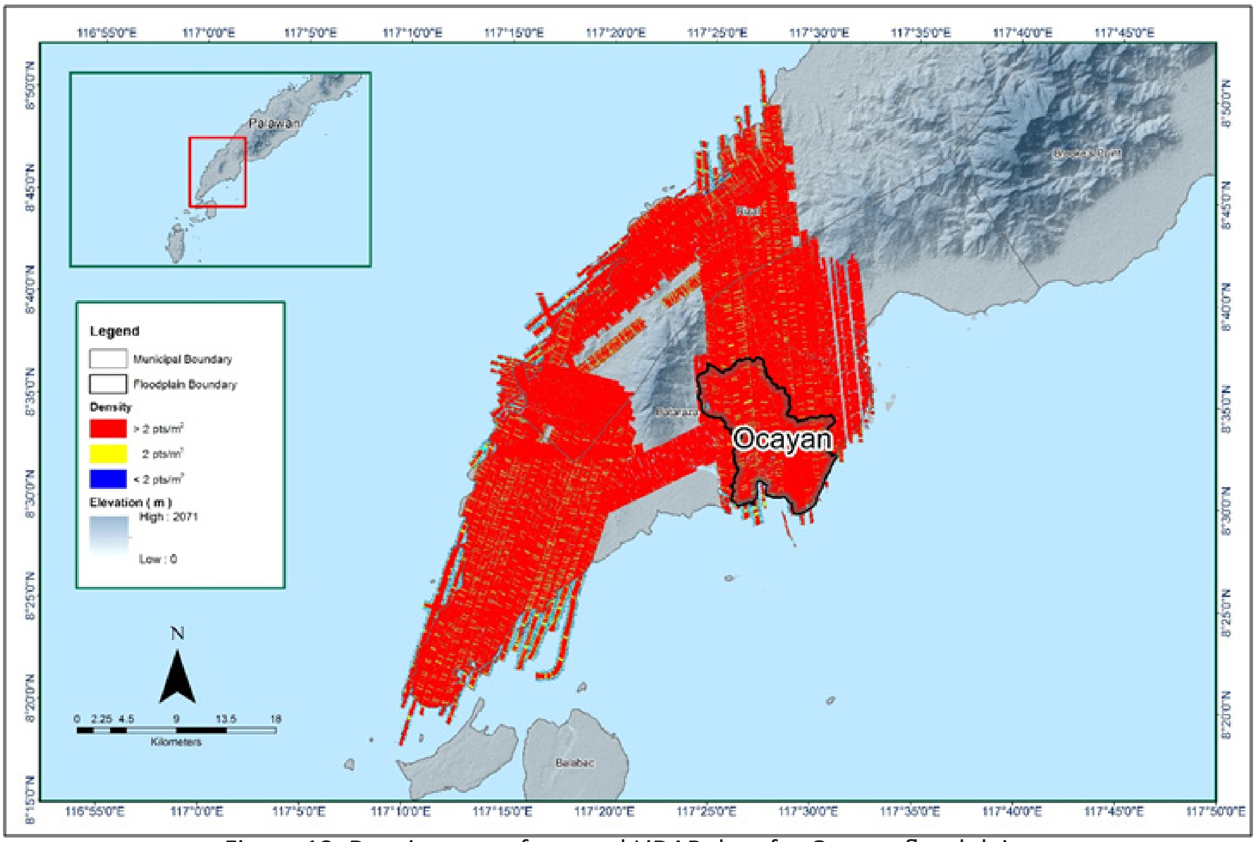


Figure 13. Density map of merged LiDAR data for Ocayan floodplain.

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

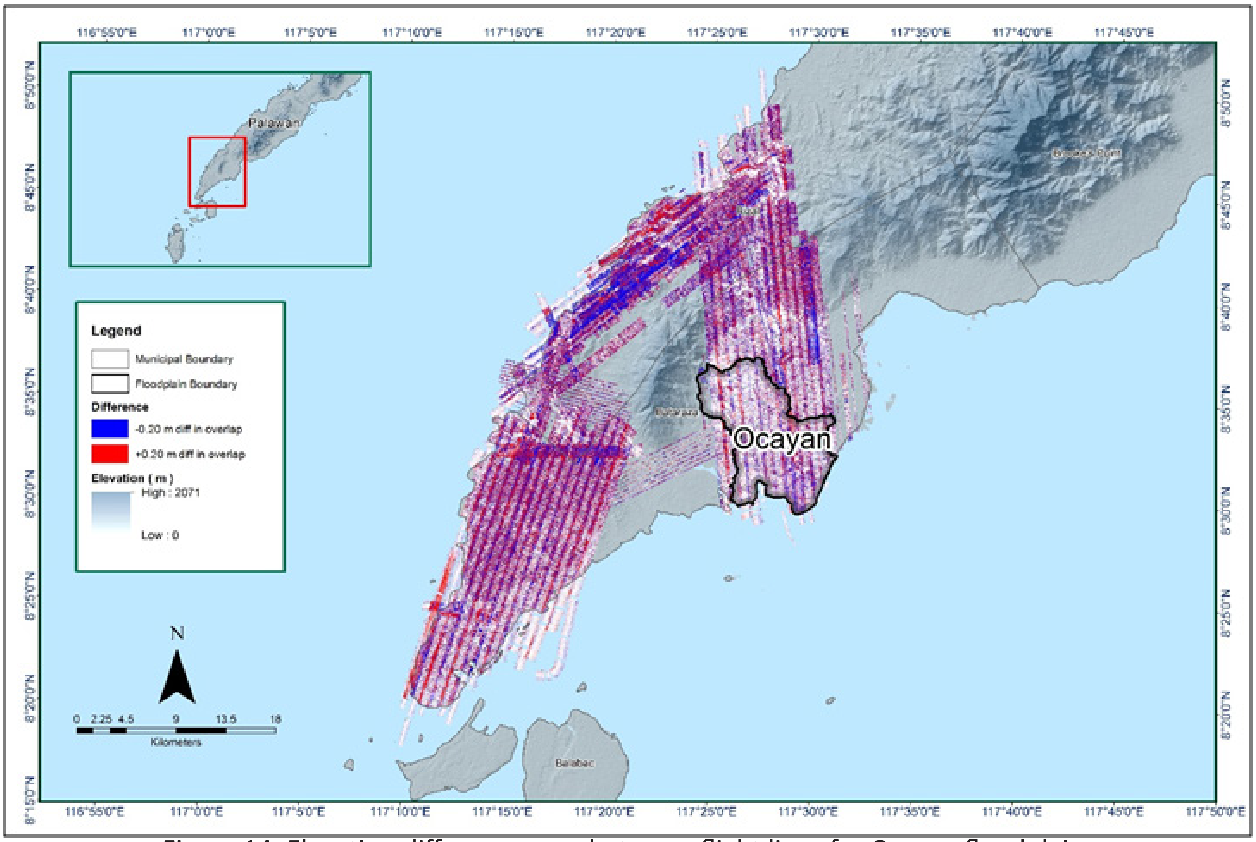


Figure 14. Elevation difference map between flight lines for Ocayan floodplain.

A screen capture of the processed LAS data from Ocayan flight 3141P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

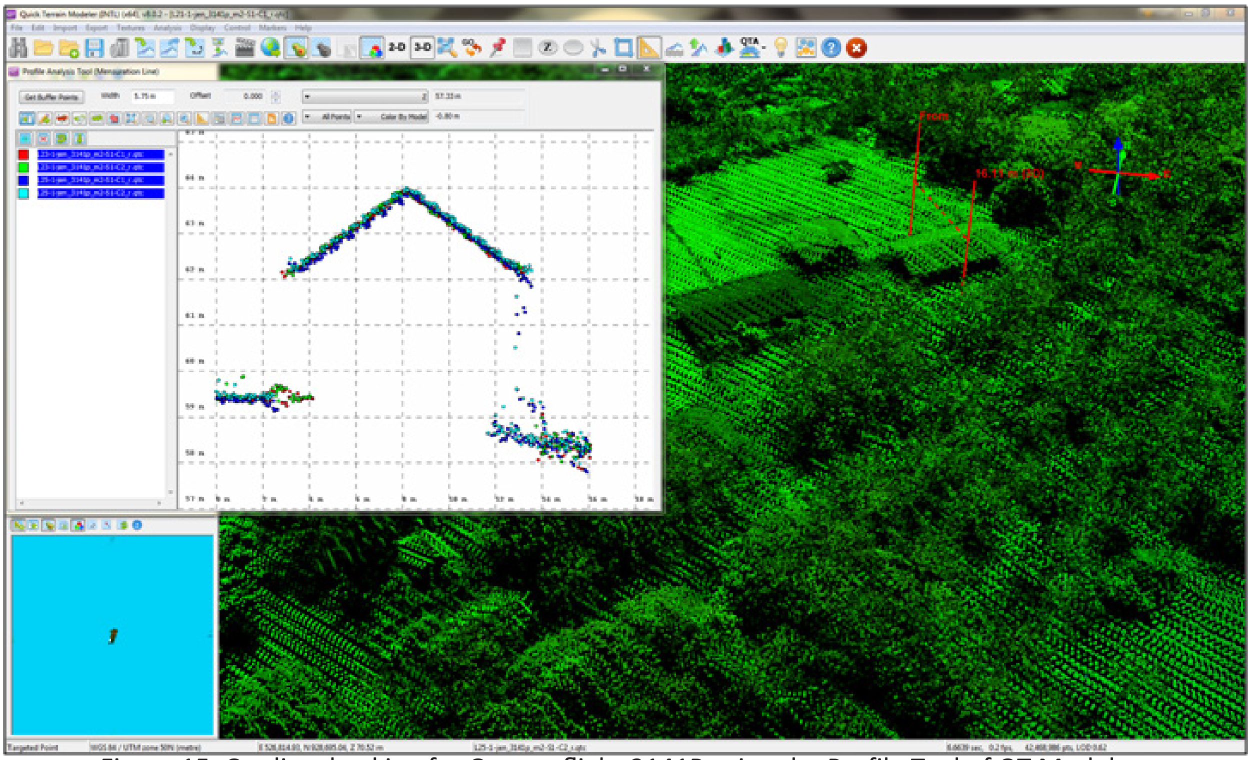


Figure 15. Quality checking for Ocayan flight 3141P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Ocayan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	847,934,467
Low Vegetation	501,964,459
Medium Vegetation	1,449,176,978
High Vegetation	2,548,733,041
Building	32,455,673

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ocayan floodplain is shown in Figure 16. A total of 1,522 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 755.63 meters and 9.35 meters respectively.

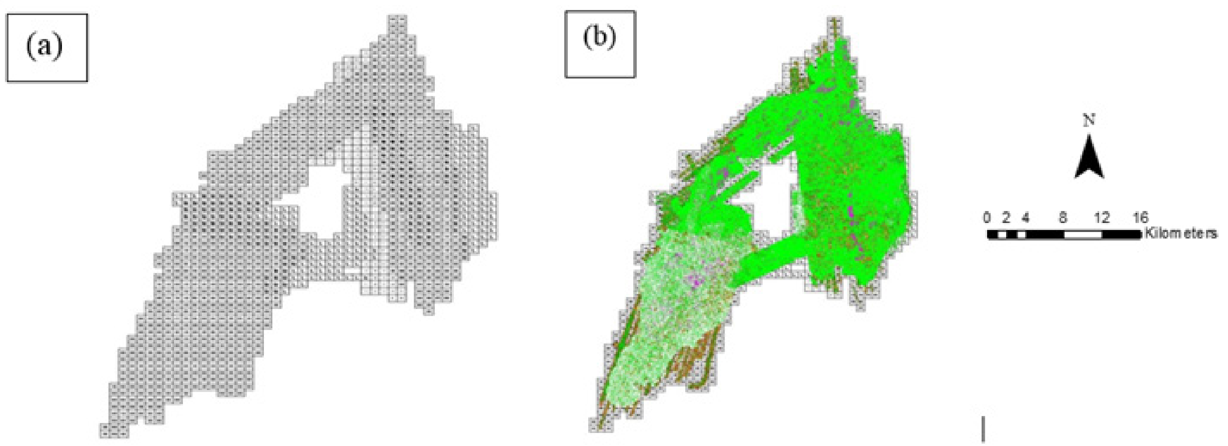


Figure 16. Tiles for Ocayan floodplain (a) and classification results (b) in TerraScan.

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

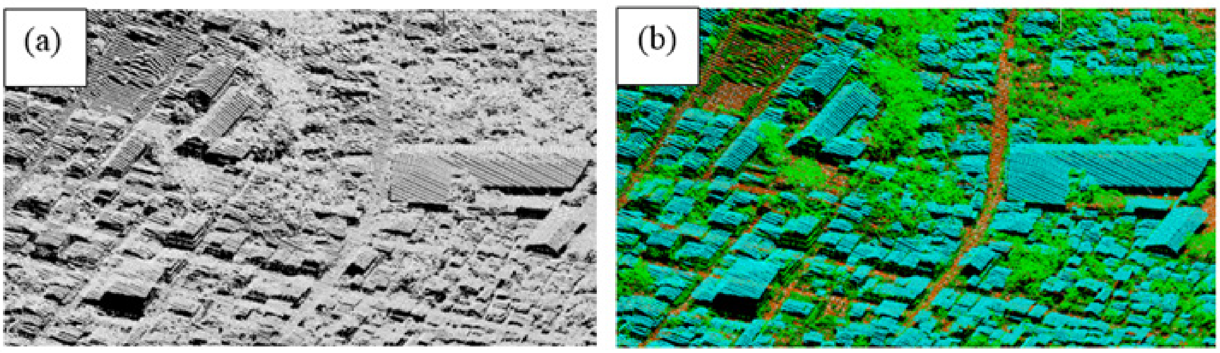


Figure 17. Point cloud before (a) and after (b) classification.

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

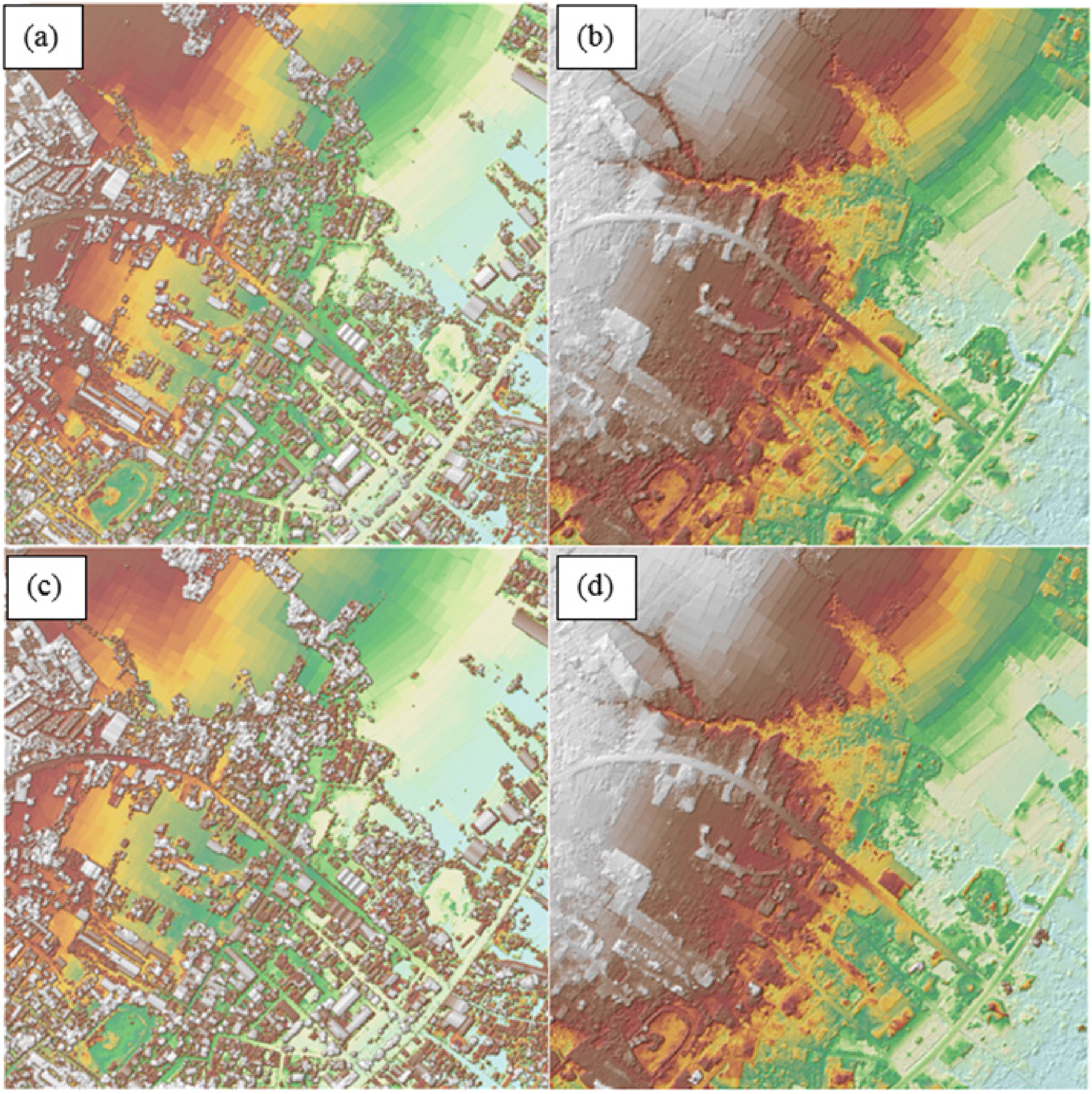


Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ocayan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 564 1km by 1km tiles area covered by Ocayan floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Ocayan floodplain has a total of 322.37 sq.km orthophotograph coverage comprised of 981 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

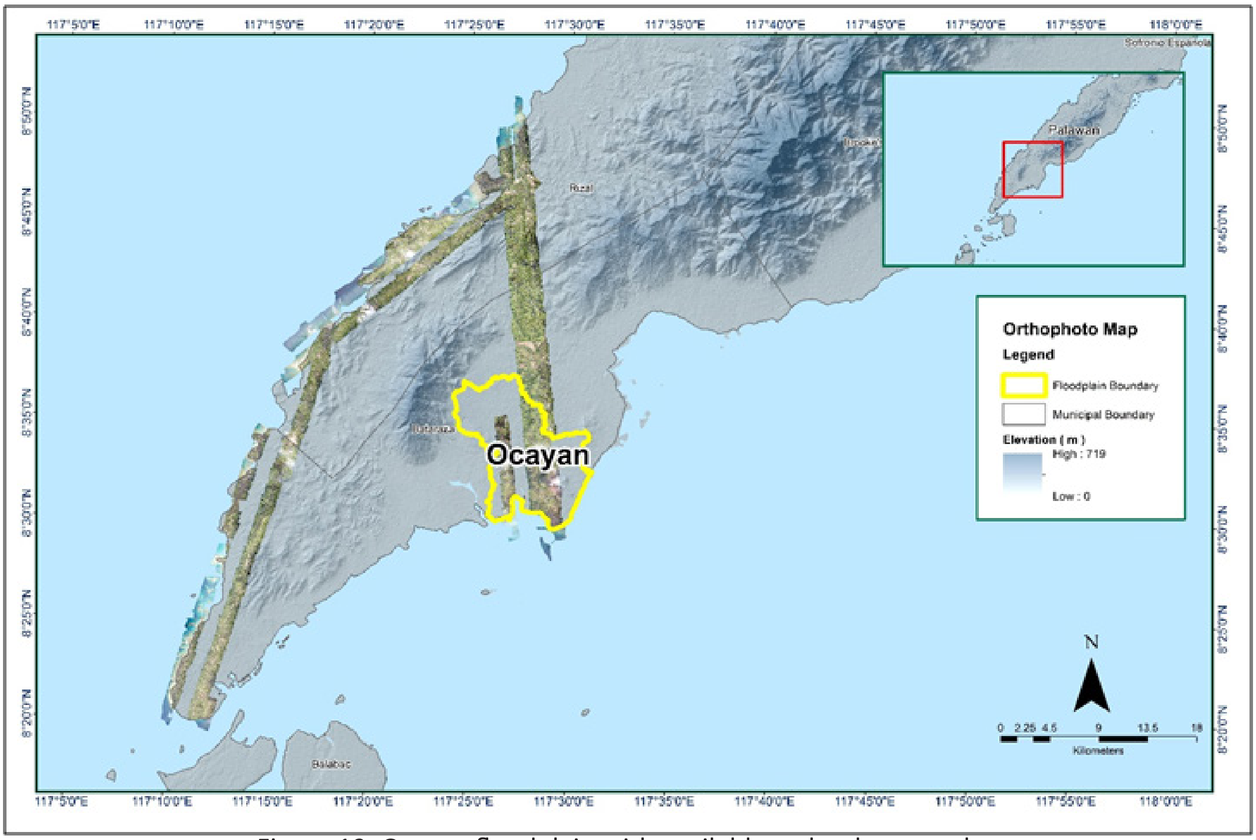


Figure 19. Ocayan floodplain with available orthophotographs.

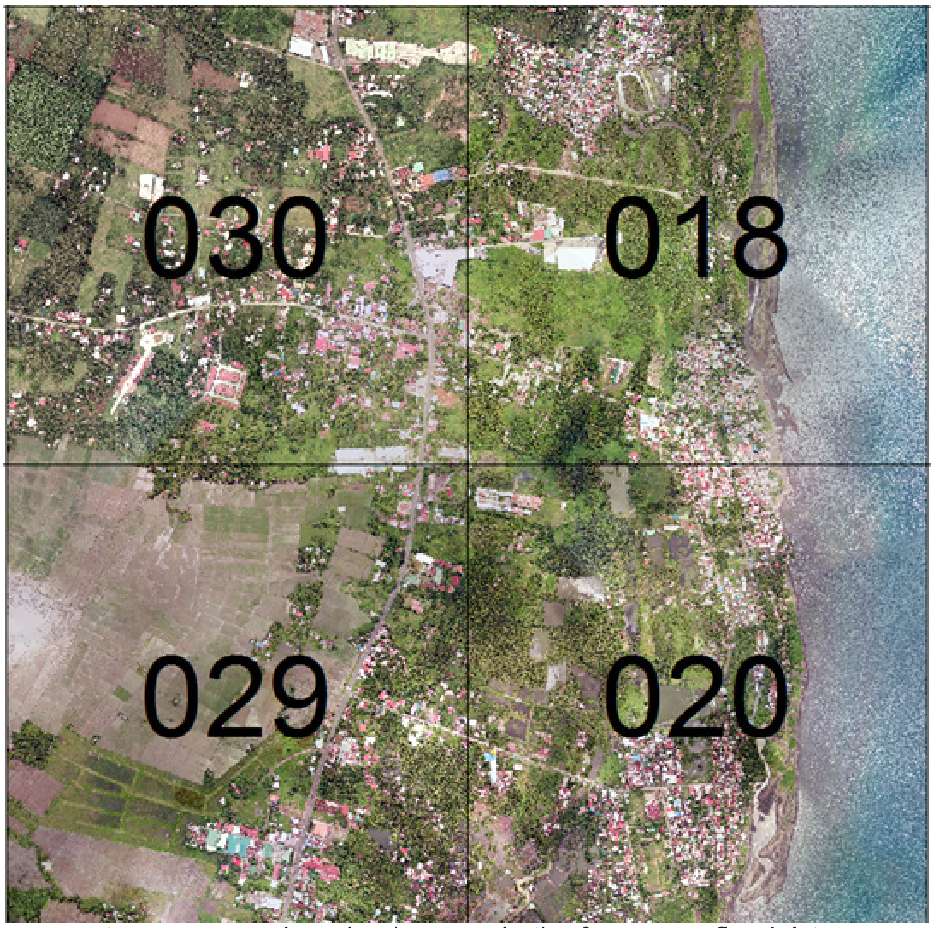


Figure 20. Sample orthophotograph tiles for Ocayan floodplain.

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Ocayan flood plain. These blocks are composed of Palawan and Palawan_Reflight blocks with a total area of 1,063.08 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42Q	231.80
Palawan_Blk42Q_additional	126.29
Palawan_Blk42R	174.43
Palawan_Blk42T	324.66
Palawan_Reflights_Blk42Q	37.71
Palawan_Reflights_Blk42Q_additional	9.98
Palawan_Reflights_Blk42T	59.81
Palawan_Reflights_Blk42U	39.73
Palawan_Reflights_Blk42eT	58.67
TOTAL	**1,063.08 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The terrain (Figure 21c) was deformed and has the feature has be retrieved (Figure 21d) from the T-ascii in order to correct the surface.

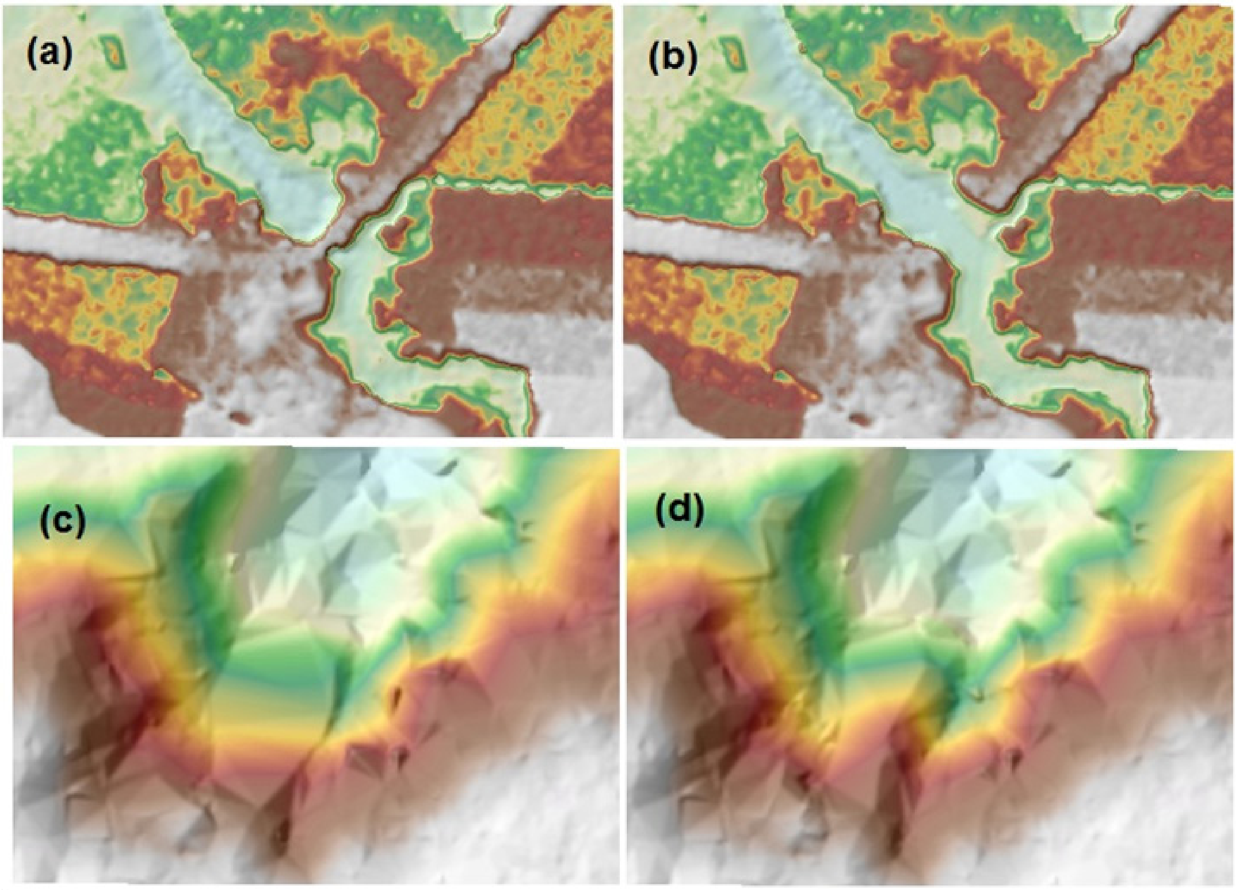


Figure 21. Portions in the DTM of Ocayan floodplain – a bridge before (a) and after (b) manual editing; and a flattened surface before (c) and after (d) object retrieval.

3.9 Mosaicking of Blocks

Palawan_Blk42Aa was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. Upon inspection of the blocks mosaicked for the Ocayan floodplain, it was concluded that the elevation of the DTM for all of the blocks needed adjustment before merging. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Ocayan floodplain is shown in Figure 22. The entire Ocayan flood plain is 97.36% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 15. Shift Values of each LiDAR Block of Ocayan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42Q	0.00	0.00	6.20
Palawan_Blk42Q_additional	0.00	0.00	6.02
Palawan_Blk42R	0.00	0.00	6.10
Palawan_Blk42T	0.00	0.00	6.22
Palawan_Reflights_Blk42Q	0.00	0.00	7.09
Palawan_Reflights_Blk42Q_additional	0.00	0.00	5.65
Palawan_Reflights_Blk42T	0.00	0.00	5.86
Palawan_Reflights_Blk42U	0.00	0.00	6.36
Palawan_Reflights_Blk42eT	0.00	0.00	5.86

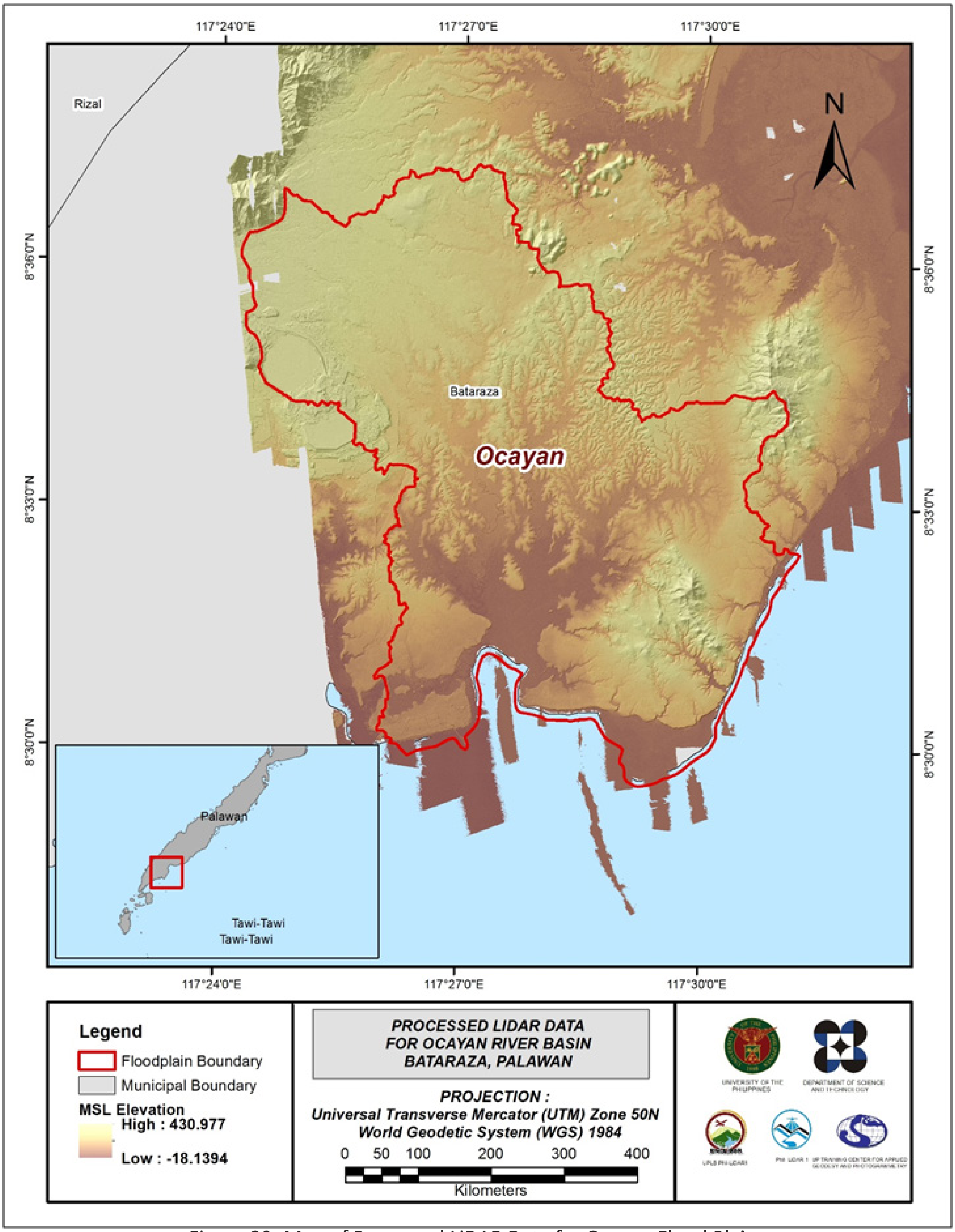


Figure 22. Map of Processed LiDAR Data for Ocayan Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ocayan to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 1,083 survey points were used for calibration and validation of Ocayan LiDAR data. Random selection of 80% of the survey points, resulting to 869 points, was used for calibration. A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 17.06 meters with a standard deviation of 0.20 meters. Calibration of Ocayan LiDAR data was done by adding the height difference value, 17.06 meters, to Ocayan mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data.

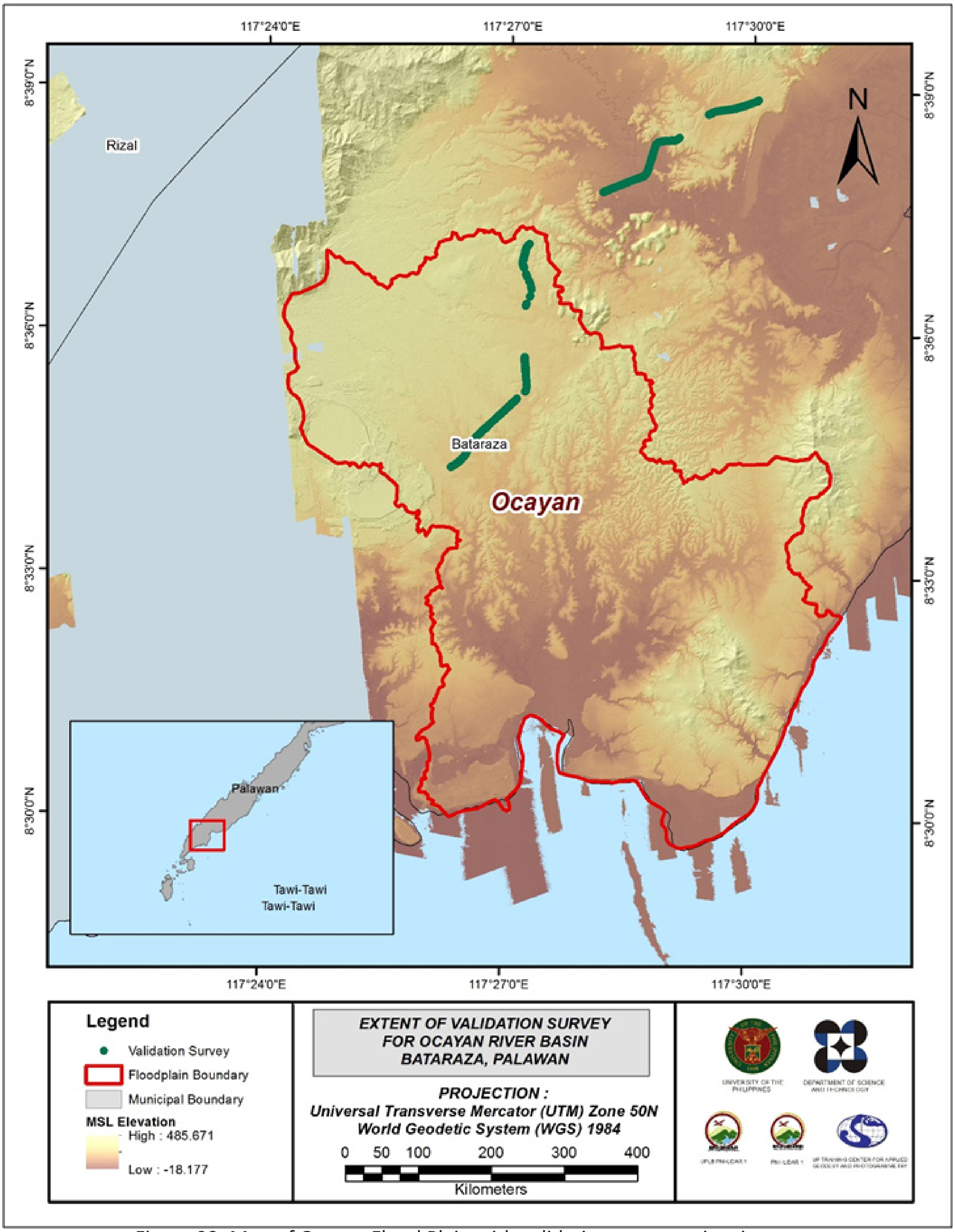


Figure 23. Map of Ocayan Flood Plain with validation survey points in green.

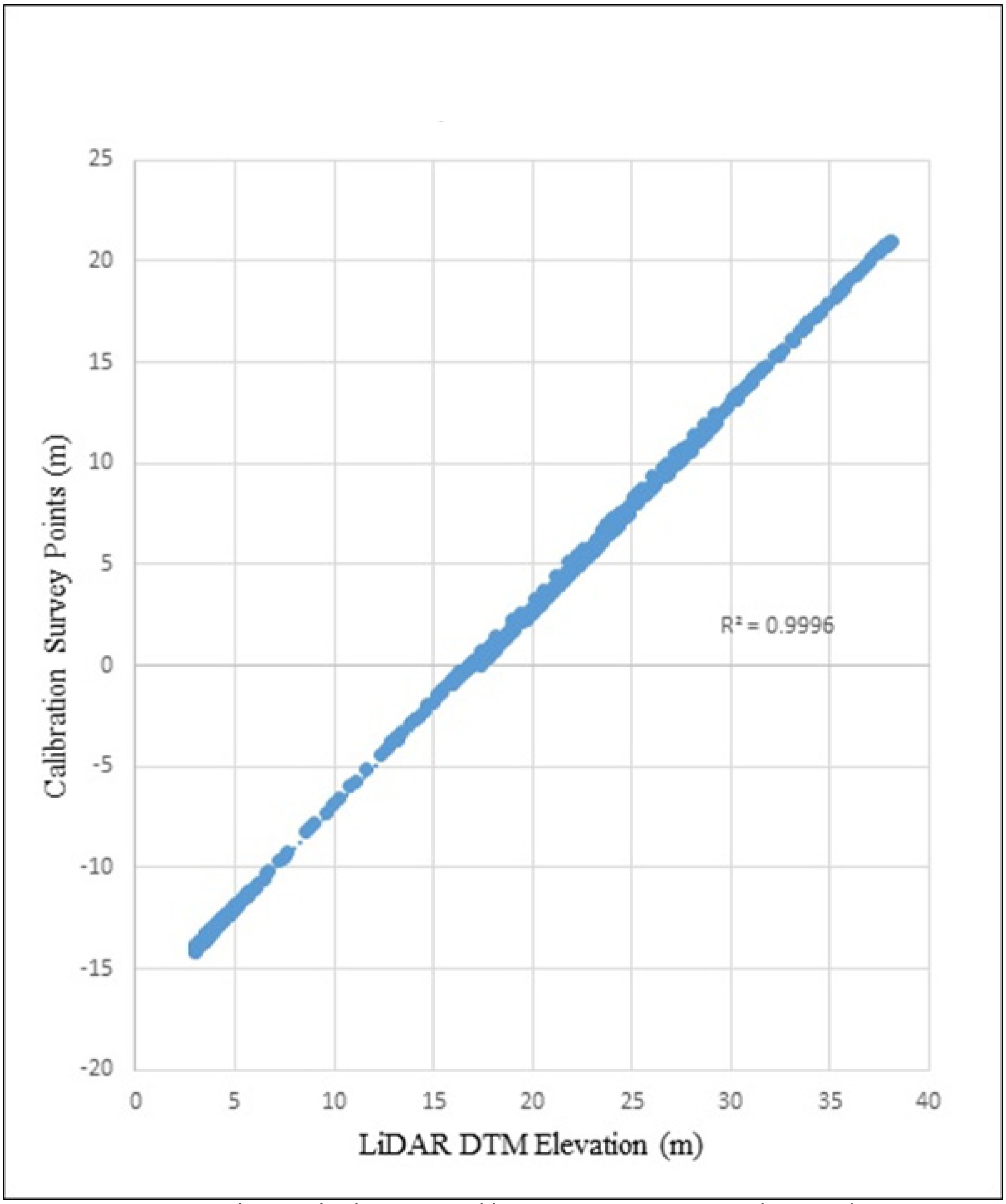


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	17.06
Standard Deviation	0.20
Average	17.06
Minimum	16.66
Maximum	17.46

The remaining 20% of the total survey points, resulting to 214, were used for the validation of calibrated Ocayan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.20 meters, as shown in Table 17.

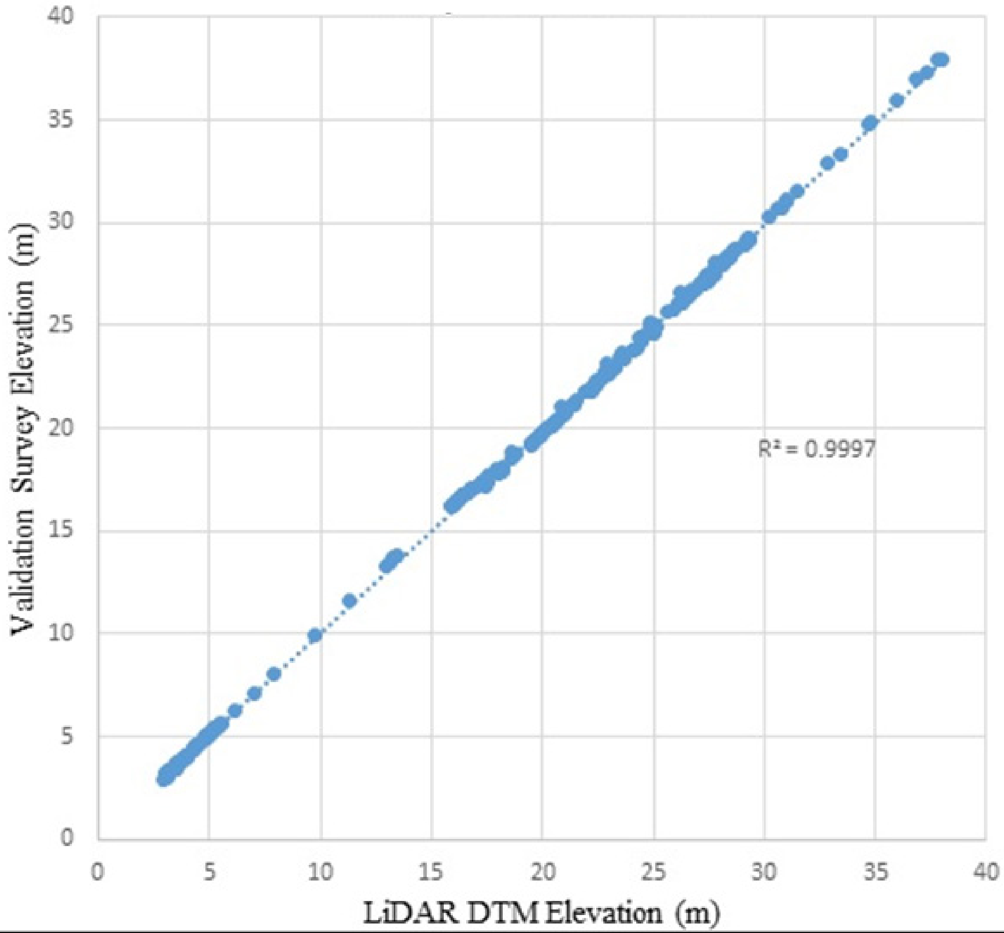


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.20
Average	0.001
Minimum	-0.39
Maximum	0.41

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, zigzag and centerline was available for Ocayan with of 2,830 bathymetric survey points. 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 0.46 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ocayan integrated with the processed LiDAR DEM is shown in Figure 26.

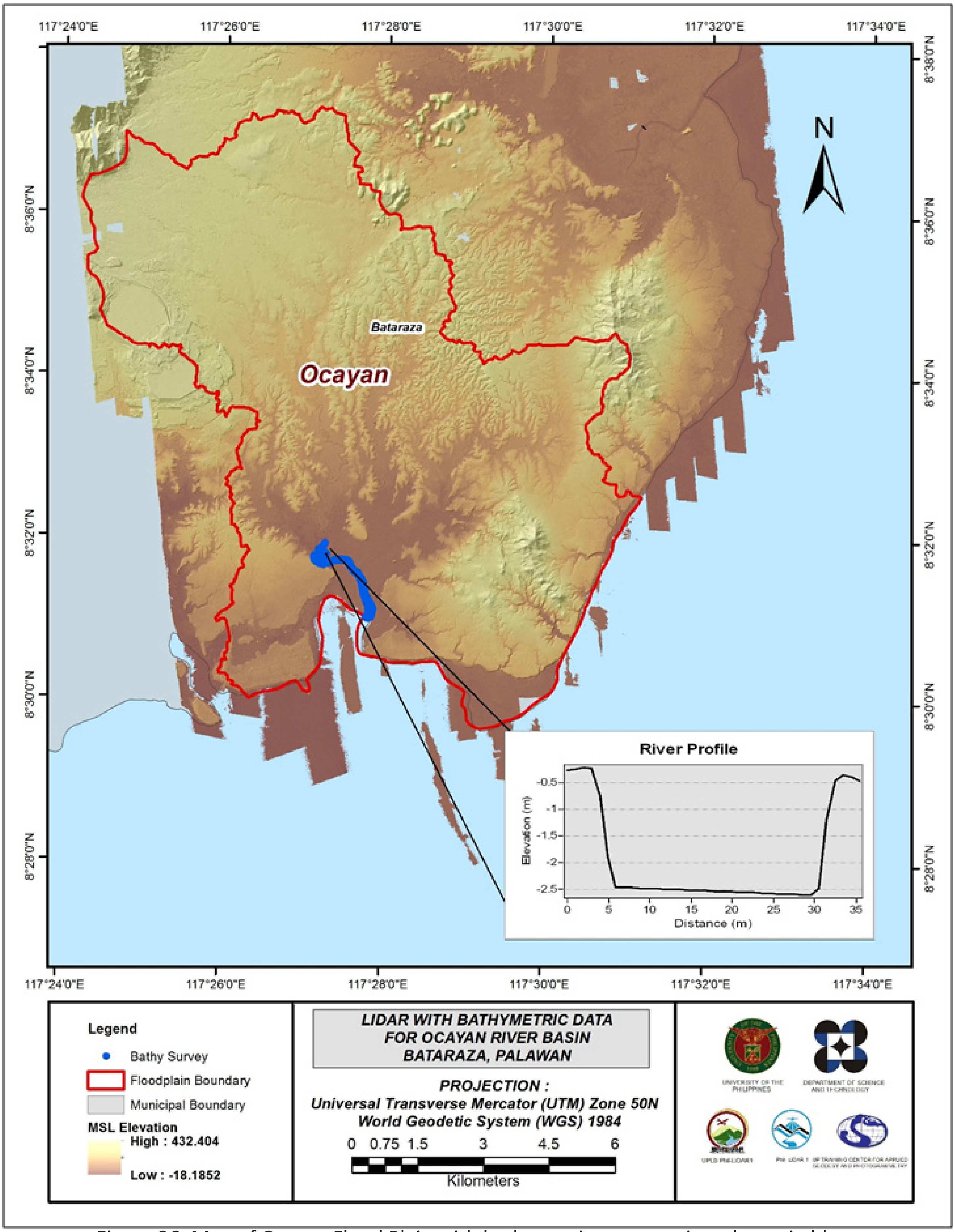


Figure 26. Map of Ocayan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

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

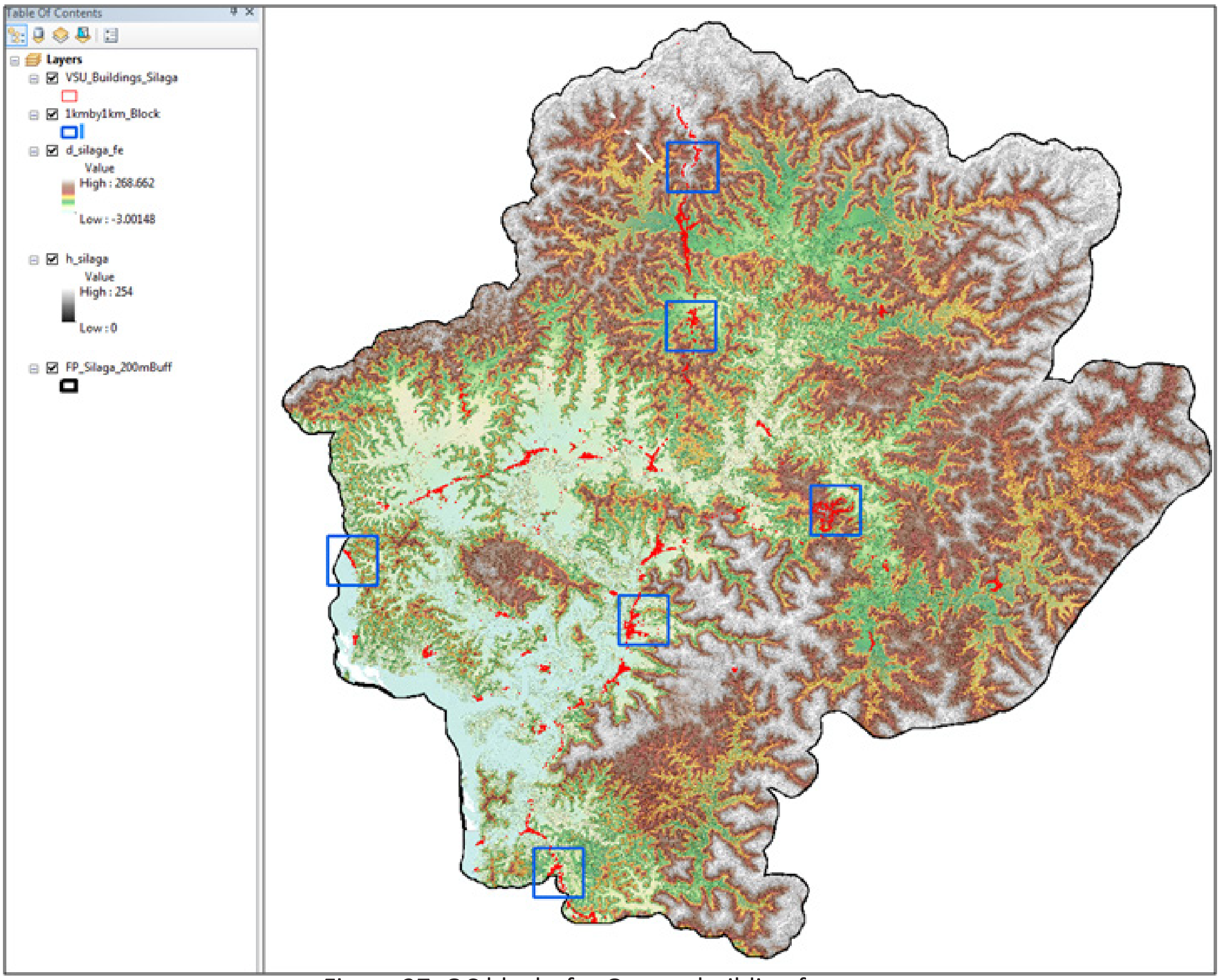


Figure 27. QC blocks for Ocayan building features.

Quality checking of Ocayan building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Ocayan Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Ocayan	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

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

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building Features Extracted for Ocayan Floodplain.

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

Table 20. Total Length of Extracted Roads for Ocayan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Ocayan	22.95	13.63	0.00	19.77	0.00	56.35

Table 21. Number of Extracted Water Bodies for Ocayan Floodplain.

Floodplain	Road Network Length (km)					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Ocayan	157	49	0	0	0	206

A total of 44 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 28 shows the Digital Surface Model (DSM) of Ocayan floodplain overlaid with its ground features.

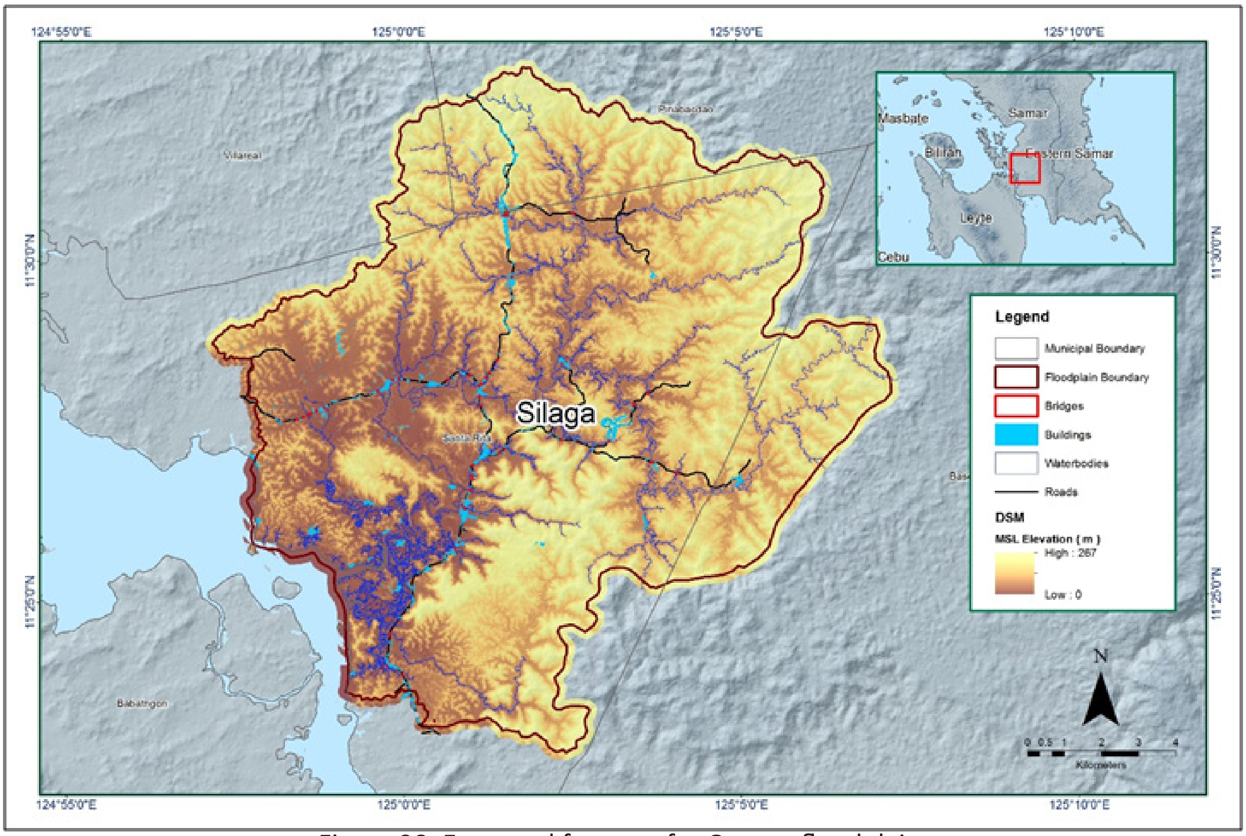


Figure 28. Extracted features for Ocayan floodplain

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

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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).

4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted a field survey in Ocayan River on December 1, December 11, and December 15, 2015 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Ocayan Bridge in Brgy. Ocayan, Municipality of Bataraza, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVC on August 16-28, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Ocayan River Basin area. The entire survey extent is illustrated in Figure 29.

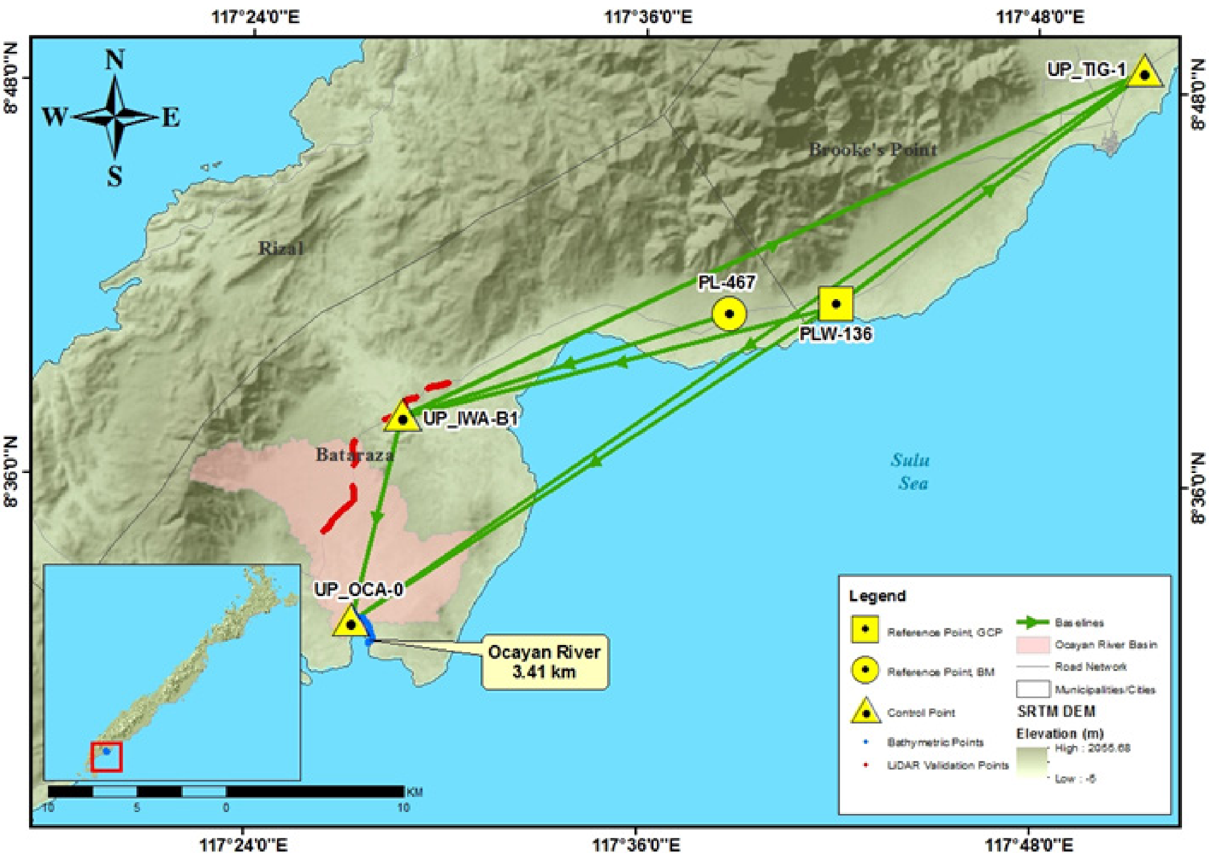

Figure 29. Ocayan River Survey Extent.

4.2 Control Survey

The GNSS network used for Ocayan River is composed of three (3) loops established on December 11 and 15, 2015 occupying the following reference point: PLW-136, a second-order GCP, in Brgy. Malis, Brookes Point, Palawan.

Three (3) control points were established in the area by ABSD were also occupied: UP_IWAS_B-1 near Iwahig Brookes River in Brgy. Iwahig, Bataraza, Palawan, UP_OCA-0 near Ocayan River in Brgy. Rio Tuba, Bataraza, Palawan; and UP_TIG-1 near Tigaplan River in Brgy. Barong-Barong, Brooke's Point, Palawan.

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

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
PLW-136	2nd order, GCP	8°41'28.25671"N	117°41'53.50178"E	47.391	-2.115	2007
UP_IWA_B-1	Established	8°37'56.73695"N	117°28'38.14147"E	47.522	-0.457	December 2015
UP_OCA-0	Established	8°31'39.42064"N	117°27'09.07545"E	50.661	2.778	December 2015
UP_TIG-1	Established	8°48'46.72614"N	117 51'10.83936"E	54.024	4.178	December 2015

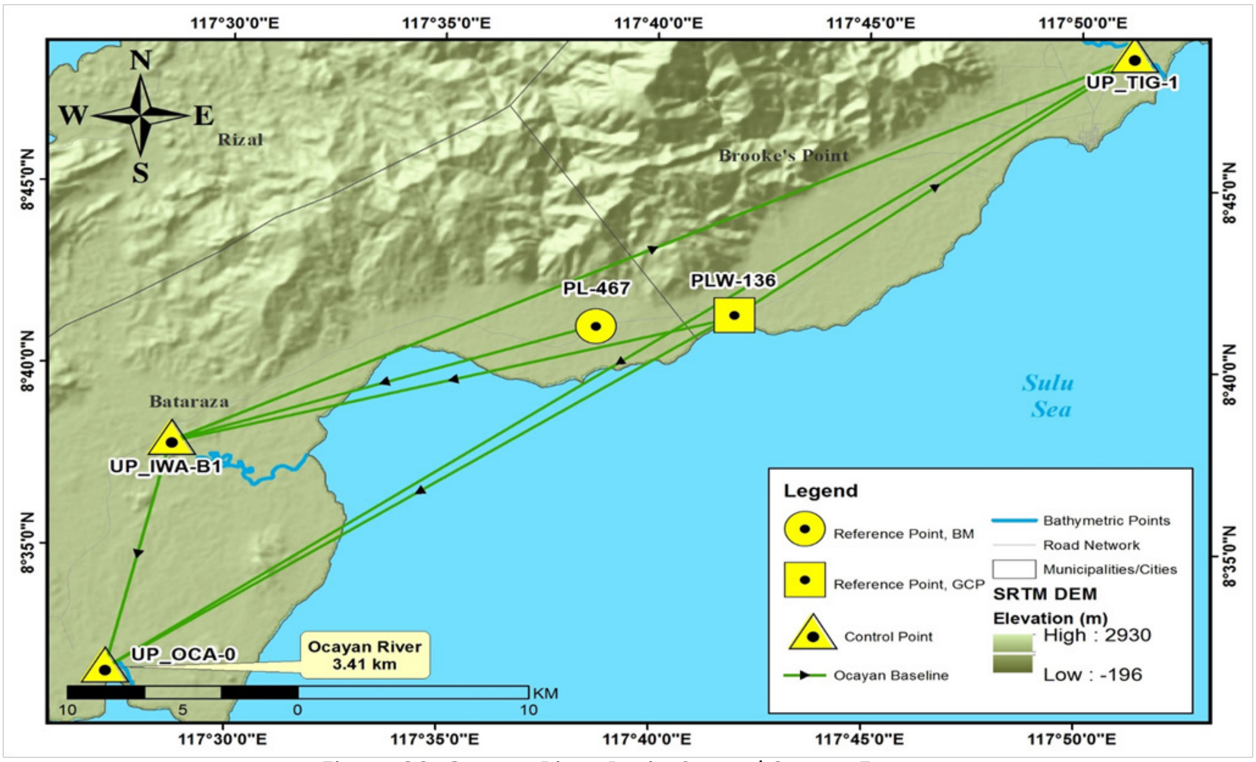

Figure 30. Ocayan River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Ocayan River are shown from Figure 31 to 34.

Figure 31. GNSS receiver set up, Trimble® SPS 882, at PLW-136, located at the Malis Elementary School compound, Brgy. Malis, Brooke's Point, Province of Palawan

Figure 32. GNSS receiver set up, Trimble® SPS 985, at UP_IWA-1, located at the approach of Iwahig Bridge in Brgy. Iwahig, Bataraza, Province of Palawan.

Figure 33. GNSS base set up, Trimble® SPS 882, at UP_OCA-0, located about 23 m from Elementary School near Ocayan River in Brgy. Rio Tuba, Bataraza, Province of Palawan.

Figure 34. GNSS receiver set up, Trimble® SPS 985, at UP_PAN-1, located on the approach of Tigaplan Bridge in Brgy. Barong-Barong, Brooke's Point, Province of Palawan.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Ocayan River Basin is summarized in Table 23 generated by TBC software.

Table 23. Baseline Processing Report for Ocayan River Static Survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_IWA_B-1 --- UP_OCA-0	8-21-2016	Fixed	0.016	0.053	193°13'25"	11907.513	3.115
PLW-136 --- UP_OCA-0	8-21-2016	Fixed	0.010	0.035	236°14'14"	32535.077	3.274
PLW-136 --- UP_IWA_B-1	8-21-2016	Fixed	0.006	0.030	255°03'15"	25168.863	0.136
UP_TIG-1 --- UP_OCA-0	8-21-2016	Fixed	0.030	0.070	234°25'32"	54210.634	-3.402
PLW-136 --- UP_TIG-1	8-21-2016	Fixed	0.009	0.033	51°39'07"	21717.287	6.663
UP_IWA_B-1--- UP_TIG-1	8-21-2016	Fixed	0.008	0.052	64°11'35"	45917.125	6.496

As shown Table 23 a total of six (6) baselines were processed with coordinate and ellipsoidal height values of PLW-136 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown from Table 24 to Table C-26 for the complete details. Refer to Annex 1 for the computation for the accuracy of ABSD. The five (5) control points, PLW-137, PL-689, UP-IWA-1, UP_PAN-1, and UP-IRA-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of PLW-137 were held fixed during the processing of the control points as presented in Table 24. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 24. Control Point Constraints.

Point ID	**Type**	**East σ (Meter**	**North σ (Meter)**	**Height σ (Meter)**	**Elevation σ (Meter)**
PLW-136	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Table 25. Adjusted Grid Coordinated.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Cons traint
PLW-136	576807.192	?	960781.167	?	-2.115	?	LLh
UP_ IWA_B-1	552510.181	0.007	954247.549	0.008	-0.457	0.053	
UP_OCA-0	549801.726	0.014	942656.632	0.010	2.778	0.062	
UP_TIG-1	593808.816	0.009	974282.807	0.007	4.178	0.057	

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

PLW-136
horizontal accuracy = Fixed
vertical accuracy = Fixed

UP_IWA_B-1
horizontal accuracy = $\surd((0.7)^2 + (0.8)^2$
= $\surd (0.49 + 0.64)$
= 1.06< 20 cm
vertical accuracy = 5.3 < 10 cm

UP_OCA-0
horizontal accuracy = $\surd((1.4)^2 + (1.0)^2$
= $\surd (1.96 + 1.0)$
= 1.4 < 20 cm
vertical accuracy = 6.2 < 10 cm

UP_TIG-1
horizontal accuracy = $\surd((0.9)^2 + (0.7)^2$
= $\surd (0.81 + 0.49)$
= 1.14 < 20 cm
vertical accuracy = 6.2 < 10 cm

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

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
PLW-136	N8°41'28.25671"	E117°41'53.50178"	47.391	?	LLh
UP_IWA_B-1	N8°37'56.73695"	E117°28'38.14147"	47.522	0.053	
UP_OCA-0	N8°31'39.42064"	E117°27'09.07545"	50.661	0.062	
UP_TIG-1	N8°48'46.72614"	E117°51'10.83936"	54.024	0.057	

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 equation is satisfied; hence, the required accuracy for the program was met.
The summary of reference 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)	Ellipsoidal Height (m)	Easting (m)	MSL Elevation (m)
PLW-136	2nd order, GCP	8°41'28.25671"N	117°41'53.50178"E	47.391	960781.167	576807.192	-2.115
UP_IWA_B-1	Established	8°37'56.73695"N	117°28'38.14147"E	47.522	954247.549	552510.181	-0.457
UP_OCA-0	Established	8°31'39.42064"N	117°27'09.07545"E	50.661	942656.632	549801.726	2.778
UP_TIG-1	Established	8°48'46.72614"N	117°51'10.83936"E	52.045	974282.807	593808.816	4.178

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

Cross-section and as-built surveys were conducted on December 1, 2015 at the upstream side of Ocayan Bridge in Brgy. Ocayan, Municipality of Bataraza as shown in Figure 35. A total station was utilized for this survey as shown in Figure 36.

Figure 35. Ocayan Bridge facing downstream

Figure 36. As-built survey of Ocayan Bridge.

The cross-sectional line of Ocayan Bridge is about 107.33 m with thirty-six (36) cross-sectional points using the control points UP_OCA-1 and UP_OCA-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure 37 to Figure 39.

Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 22, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole. Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.938 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.324 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

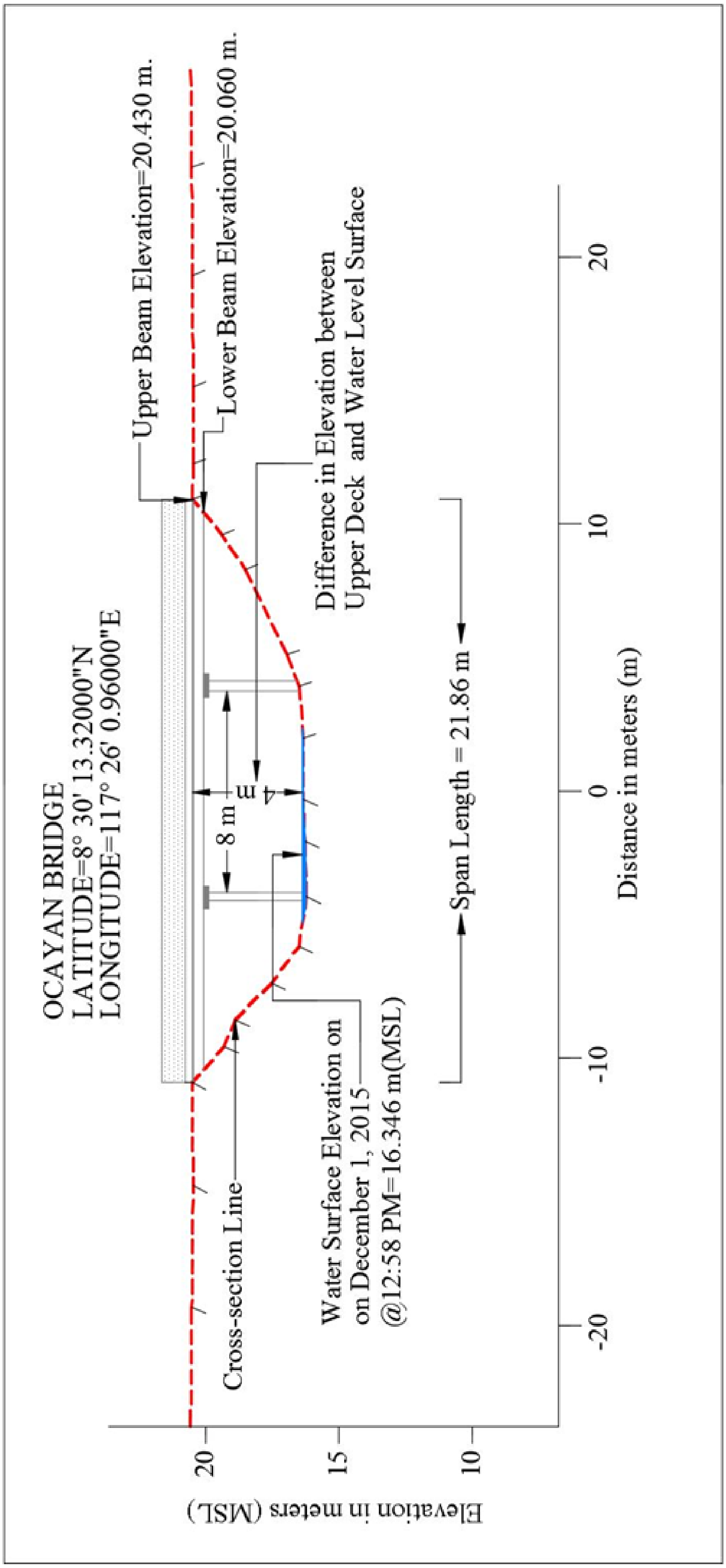

Figure 37. Ocayan Bridge Cross-section Diagram

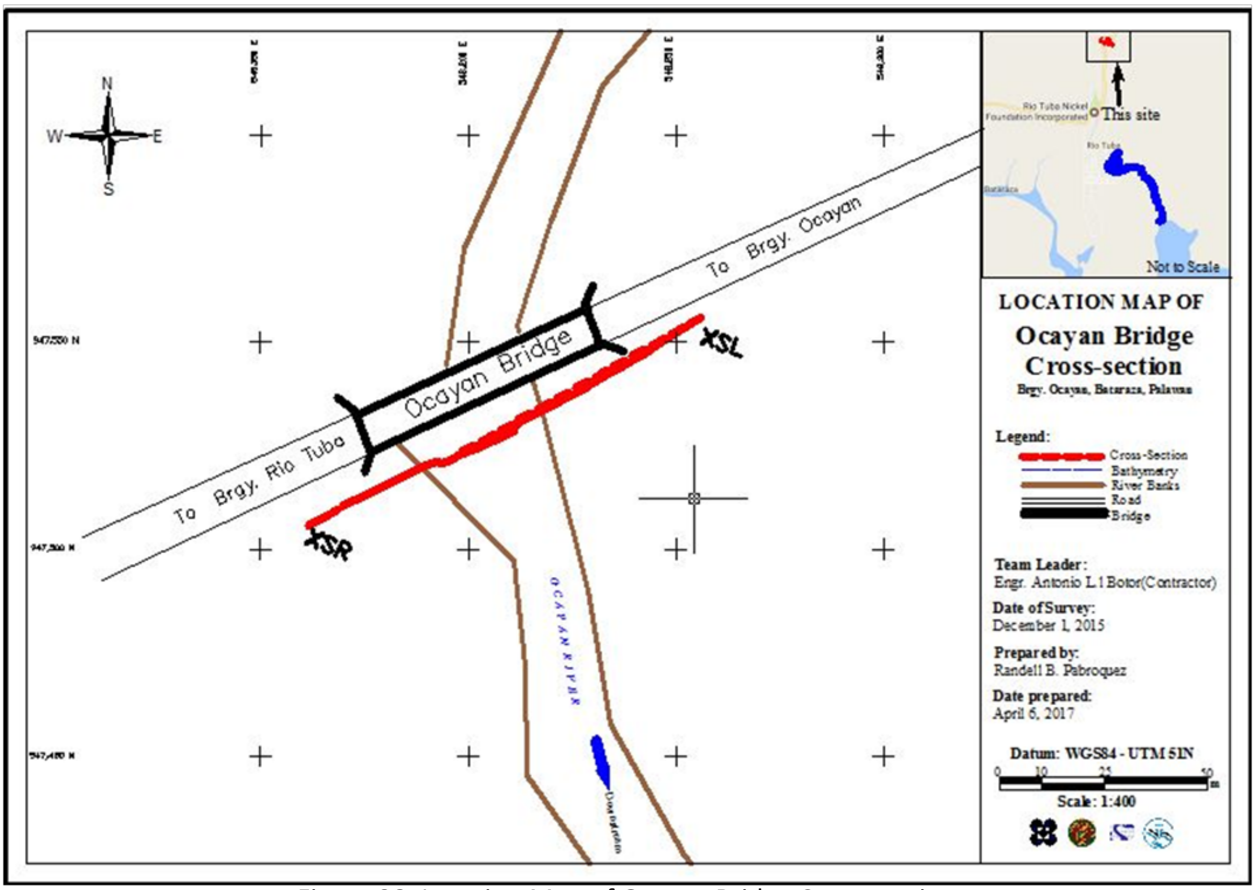

Figure 38. Location Map of Ocayan Bridge Cross-section

Bridge Data Form

Bridge Name: OCAYAN BRIDGE

River Name: OCAYAN RIVER
Location (Brgy, City, Region): Brgy. Ocayan, Bataraza, Palawan

Survey Team: Nilo Alpas, Bernard Burcia
Date and Time: December 1, 2015, 12:58 PM

Flow Condition: low ✔ normal high

Weather Condition: ✔ fair rainy

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

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	2.48 m	
2. BA2-BA3	21.86 m	
3. BA3-BA4	2.51 m	
4. BA1-Ab1	3.95 m	
5. Ab2-BA4	3.95 m	
6. Deck/beam thickness	0.37 m	
7. Deck elevation	20.474 m	

Note: Observer should be facing downstream

Figure 39. Ocayan Bridge Data Sheet.

Water surface elevation of Ocayan River was determined by a Horizon® Total Station on December 1, 2015 at 12:58 PM at Ocayan Bridge area with a value of 16.346 m in MSL as shown in Figure 40. This was translated into marking on the bridge's pier as shown in Figure 40. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Ocayan River, the University of the Philippines Los Baños.

Figure 40. Water-level markings on Ocayan Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 16-28, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 41.It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.361 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with PLW-136 occupied as the GNSS base station in the conduct of the survey.

Figure 41. Validation points acquisition survey set-up for Ocayan River.

The survey started from Brgy. Tarusan, Municipality of Quezon, Palawan going southwest along the national high way covering three (3) barangays in the Municipality of Bataraza, and ended in Brgy. Ocayan, Municipality of Bataraza, Palawan. The survey gathered a total of 2,690 points with approximate length of 29.98 km using UP_OCA-0 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 42.

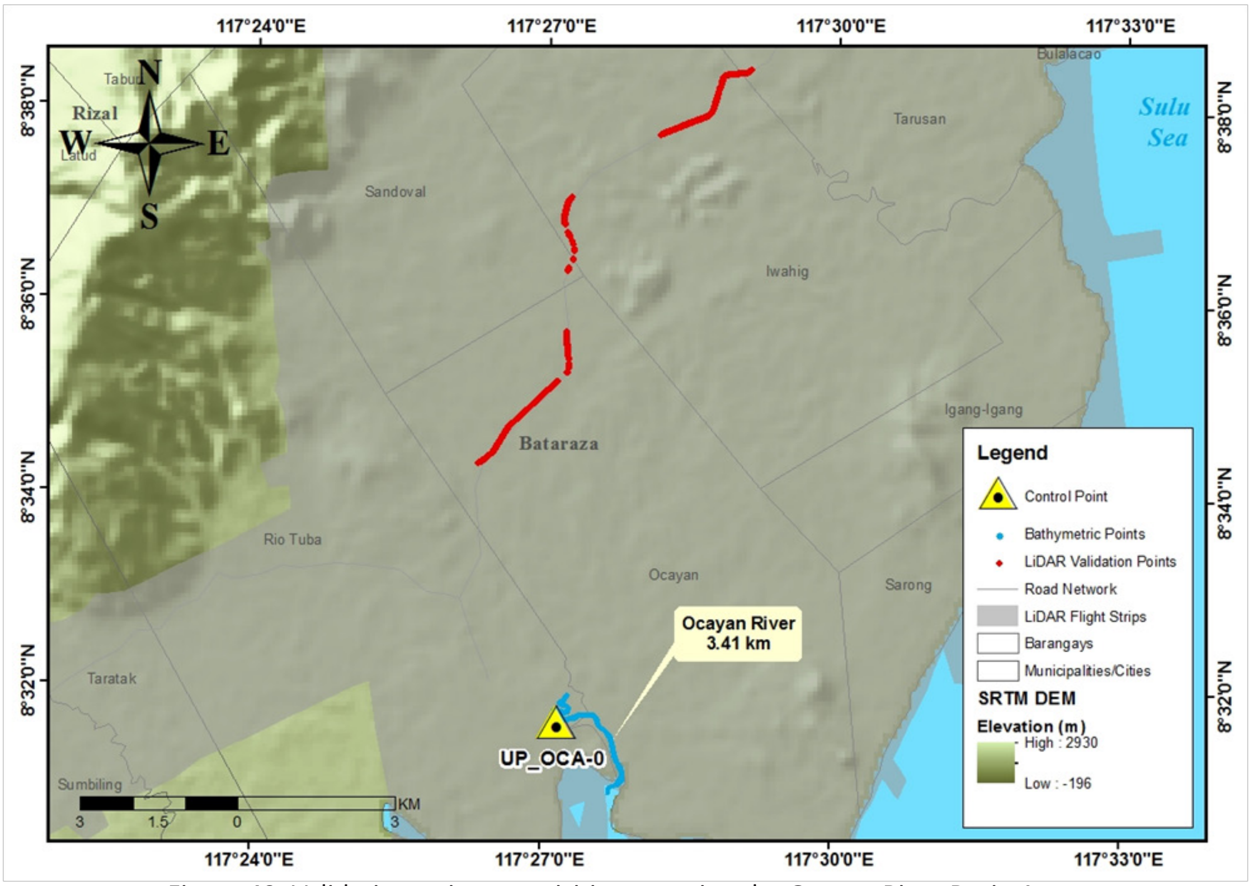

Figure 42. Validation points acquisition covering the Ocayan River Basin Area.

4.7 Bathymetric Survey

Bathymetric survey was executed on December 11, 2015 using a Hi-Target™ Echo Sounder as illustrated in Figure 43. The survey started in Brgy. Rio Tuba, Municipality of Bataraza, Palawan with coordinates 8° 31’ 55.19257”N, 117° 27’ 16.71516”E and ended at the mouth of the river in Brgy. Ocayan, Municipality of Bataraza as well, with coordinates 8° 31’ 53.24574”N, 117° 27’ 15.07500”E. The control point UP_OCA-0 was used as GNSS base station all throughout the entire survey.

Gathering of random points for the checking of ABSD’s bathymetric data was performed by DVC on August 22, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique, see Figure 44. A map showing the DVC bathymetric checking points is shown in Figure 46.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets. The computed R2 values of 0.540 and 0.550 for centerline and zigzag line bathymetry, respectively, did not meet the required range for R2 which is 0.85 to 1. However, these points have very small differences in elevations and do not exceed the maximum difference in elevation of 0.5 m so the values were deemed acceptable. Additionally, an RMSE value of 0.214 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

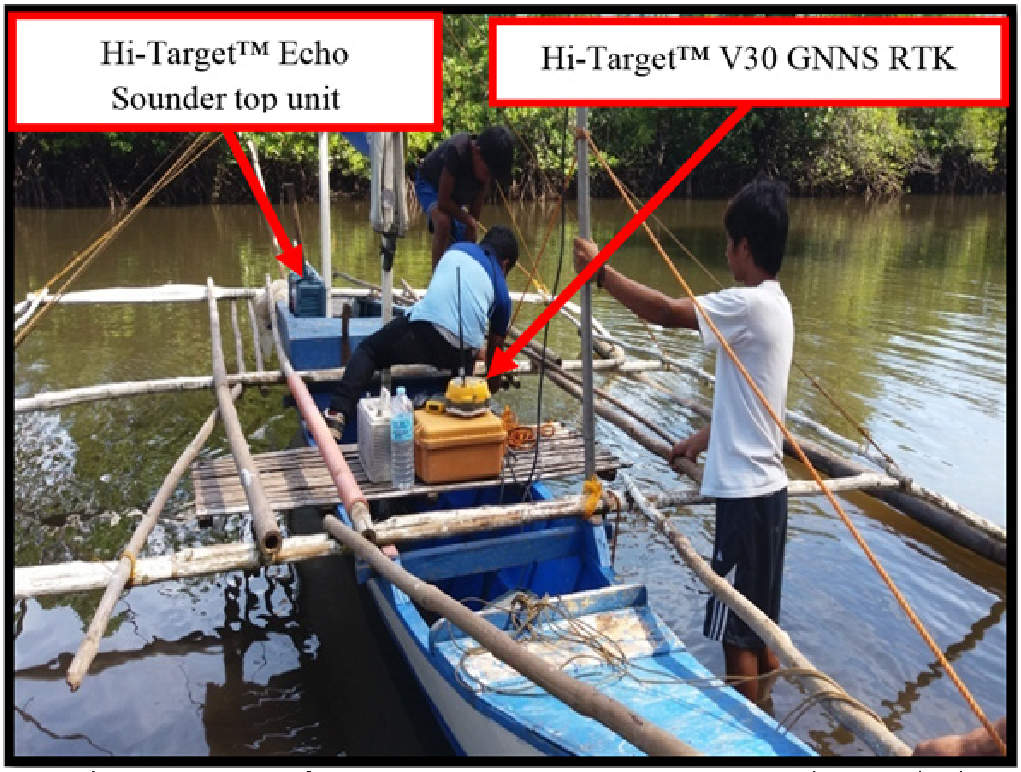

Figure 43. Bathymetric survey of ABSD at Ocayan River using Hi-Target™ Echo Sounder (upstream).

Figure 44. Gathering of random bathymetric points along Ocayan River.

The bathymetric survey for Ocayan River gathered a total of 2,856 points covering 3.4 km of the river traversing Brgy. Ocayan in the Municipality of Bataraza. A CAD drawing was also produced to illustrate the riverbed profile of Ocayan River. As shown in Figure 46, the highest and lowest elevation has a 5-m difference. The highest elevation observed was -0.303 m below MSL while the lowest was -6.986 m below MSL located in Brgy. Maasin, Municipality of Quezon.

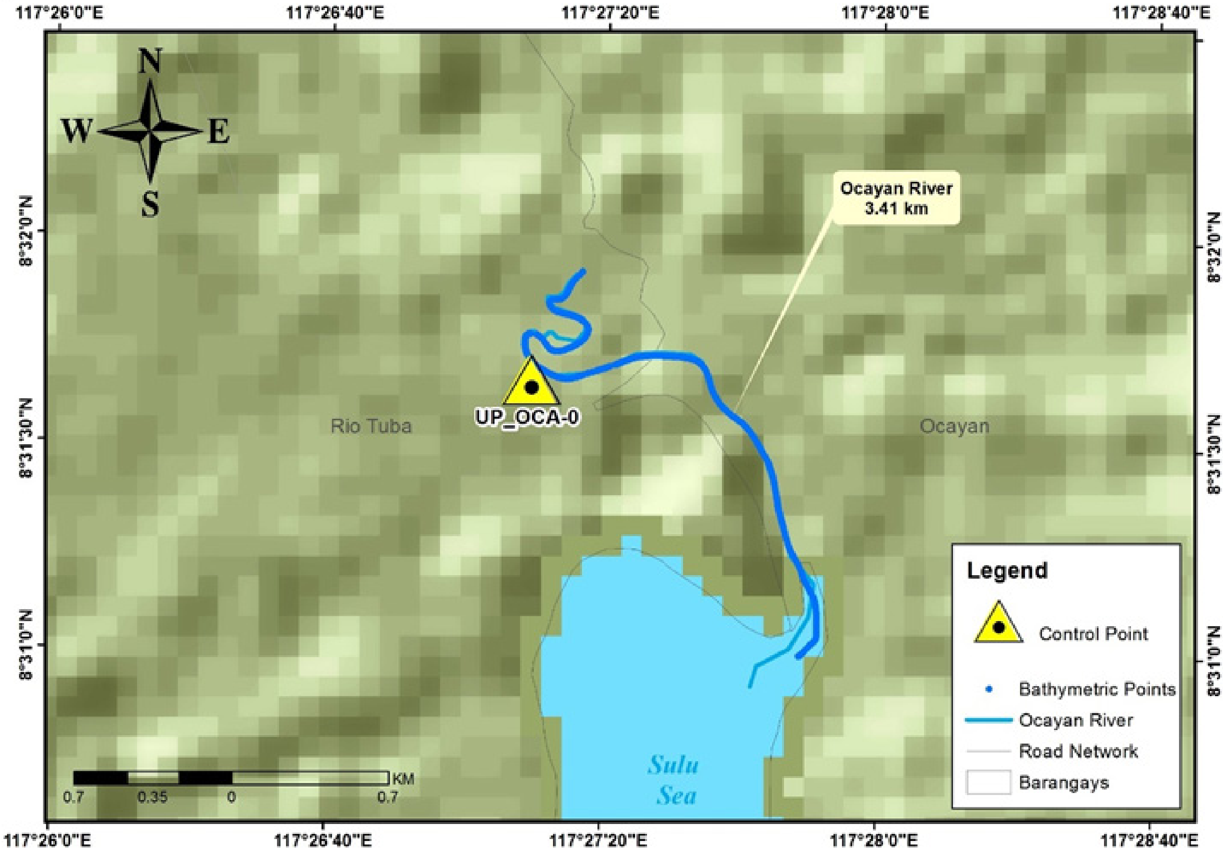

Figure 45. Bathymetric survey of Ocayan River.

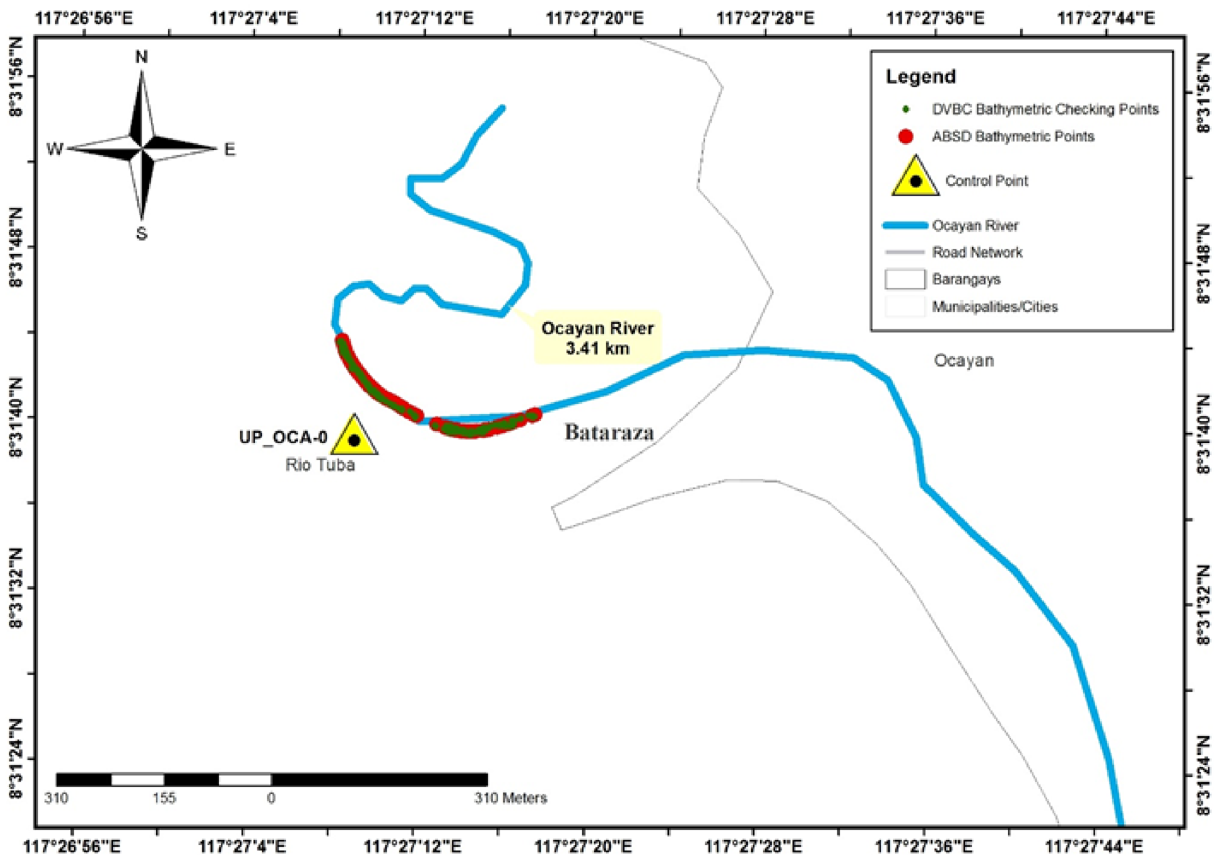

Figure 46. Quality checking points gathered along Ocayan River by DVBC.

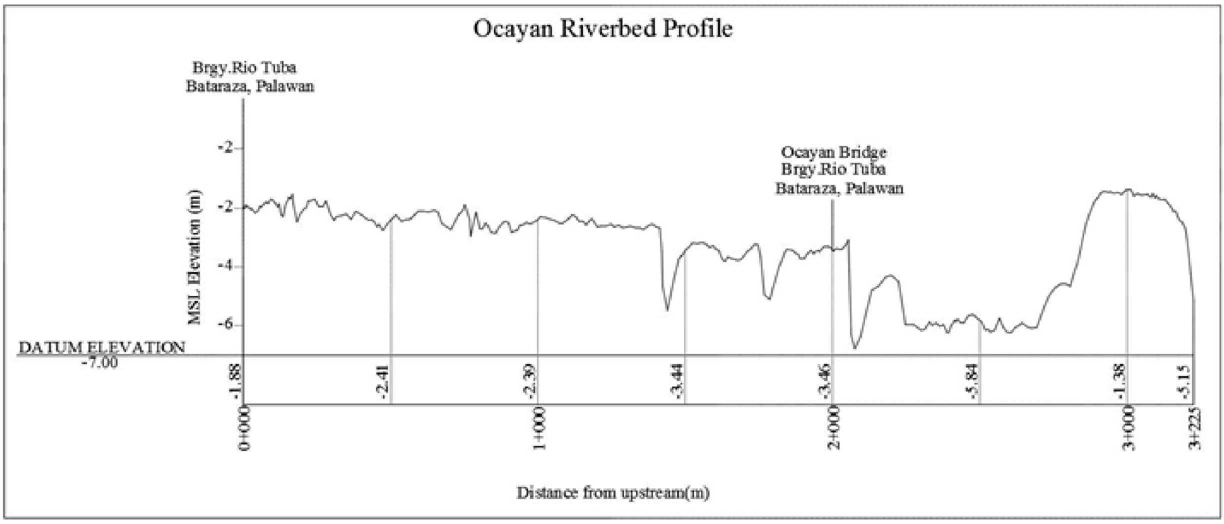

Figure 47. Ocayan Riverbed Profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from a portable rain collector deployed on a strategic location within the riverbasin (8.619800° N, 117.455101° E). The location of the rain gauge is seen in Figure 48.

The total precipitation for this event is 32.20 mm. It has a peak rainfall of 4.20 mm on February 24, 2017 at 6:30 am. The lag time between the peak rainfall and discharge is 2 hour and 40 minutes, as seen in Figure 50.

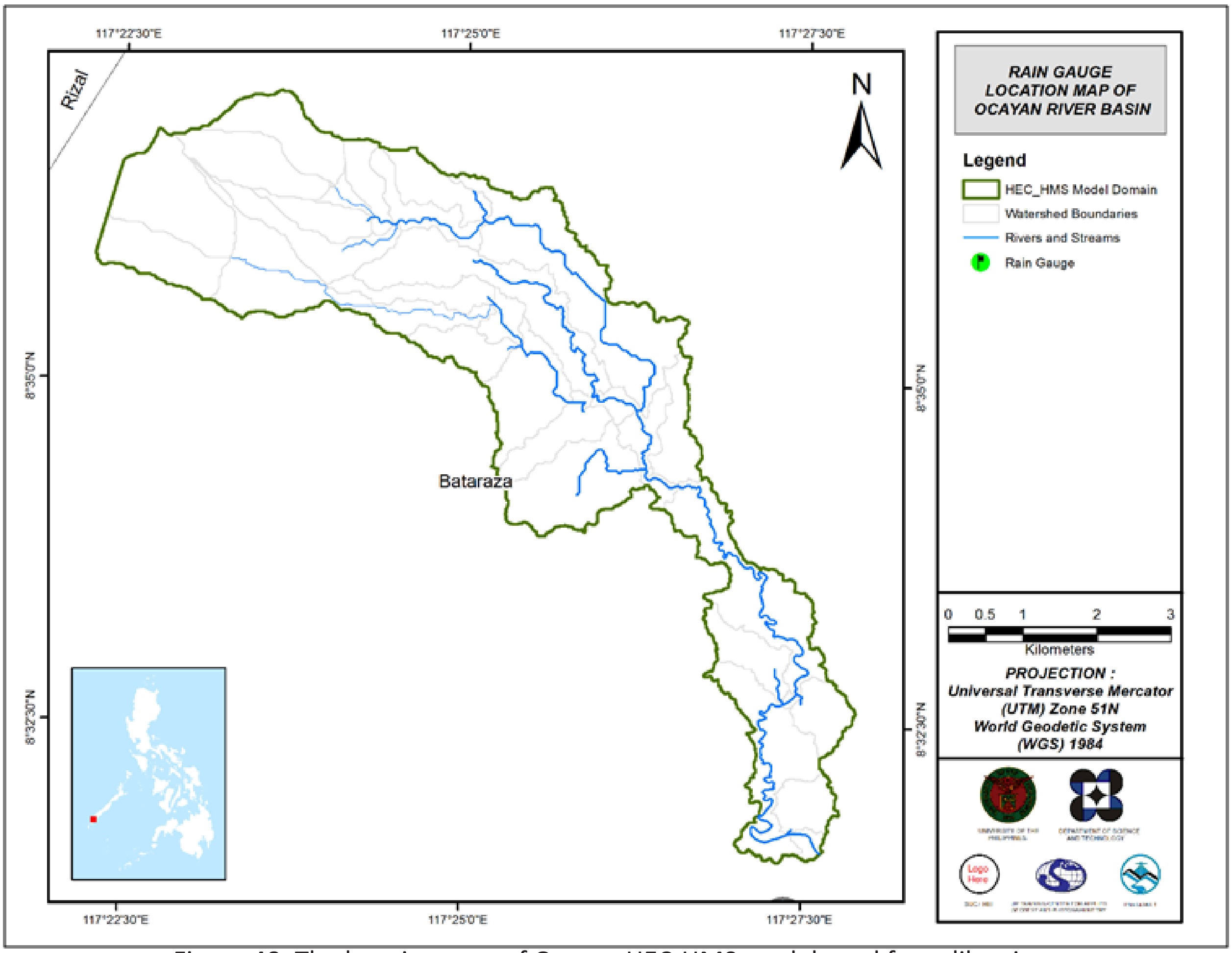

Figure 48. The location map of Ocayan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Ocayan Bridge, Bataraza, Palawan (8.572172° N, 117.438831° E). It gives the relationship between the observed water levels from the Ocayan Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Ocayan Bridge, the rating curve is expressed as Q = 408.34x -6644.30 as shown in Figure 50.

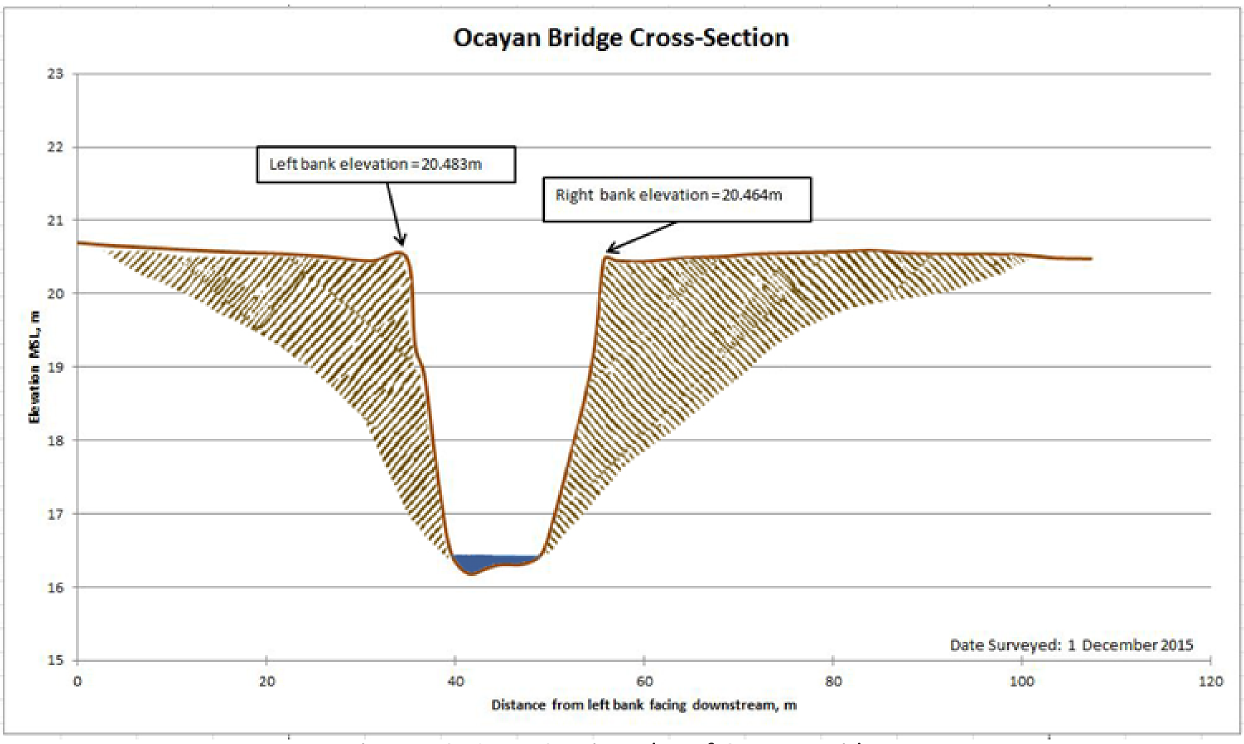

Figure 49. Cross Section Plot of Ocayan Bridge.

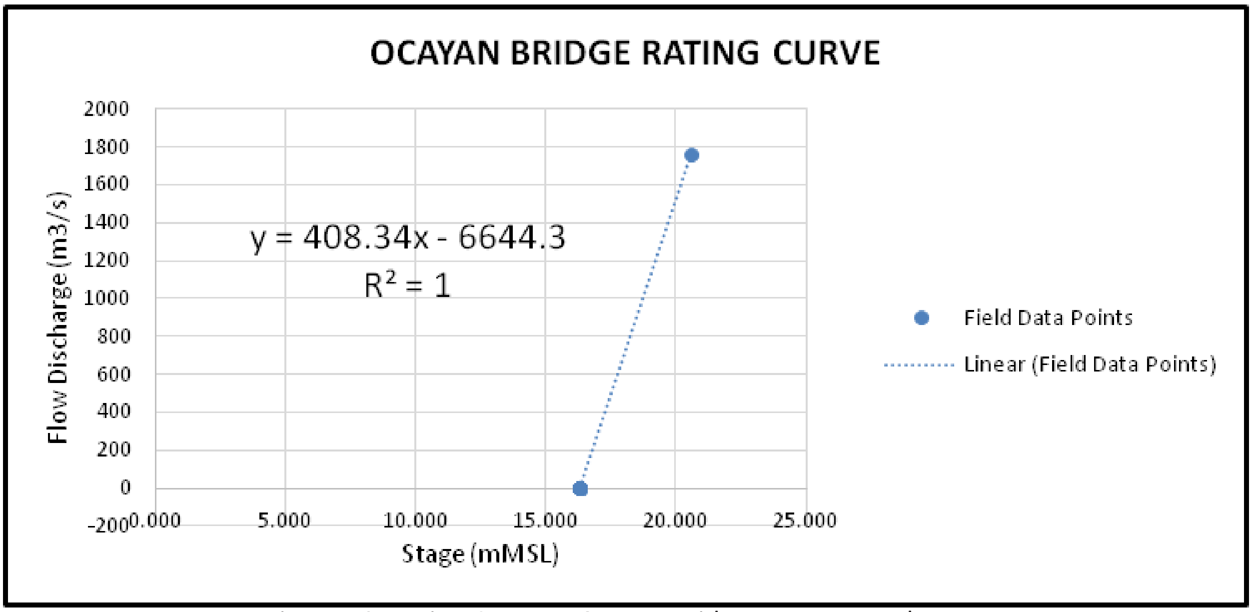

Figure 50. Rating Curve at Ocayan Bridge, Bataraza, Palawan.

For the calibration of the HEC-HMS model, shown in Figure 50, actual flow discharge during a rainfall event was collected in the Ocayan bridge. Peak discharge is 65.14 cu. m/s on February 24, 2017 at 9:10 am.

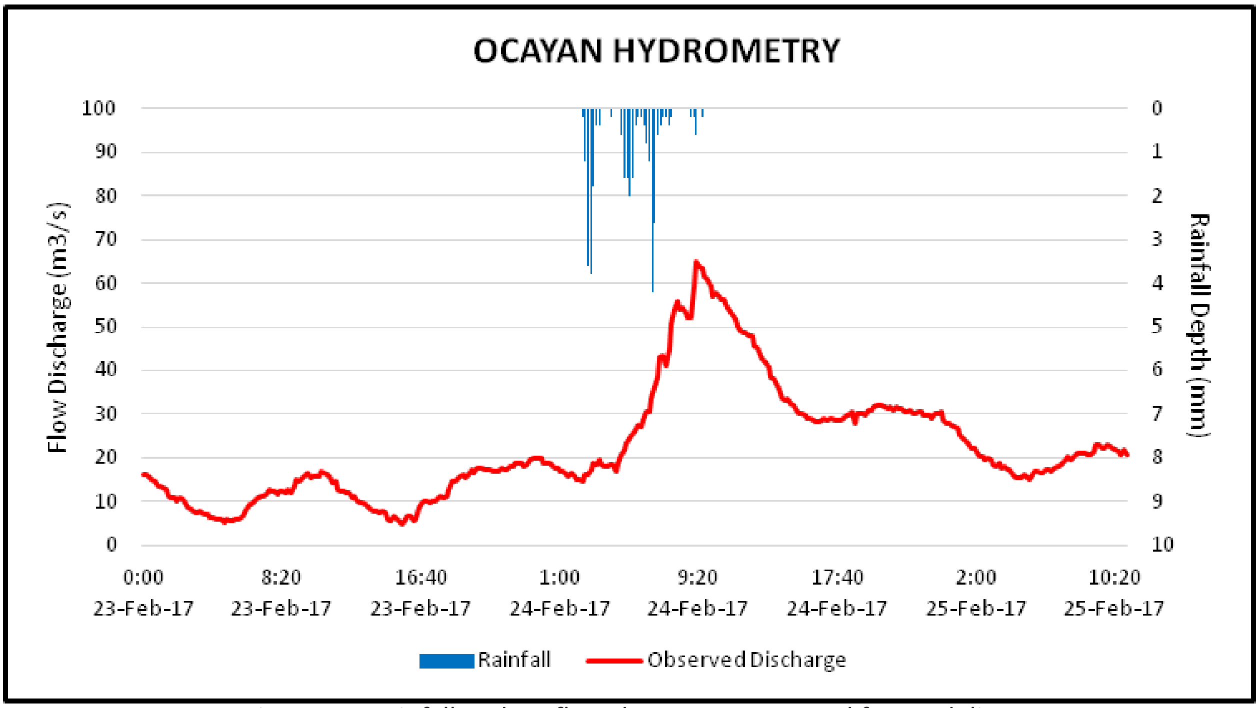

Figure 51. Rainfall and outflow data at Ocayan used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Ocayan watershed. The extreme values for this watershed were computed based on a 58-year record.

Table 28. RIDF values for Puerto Princesa 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	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

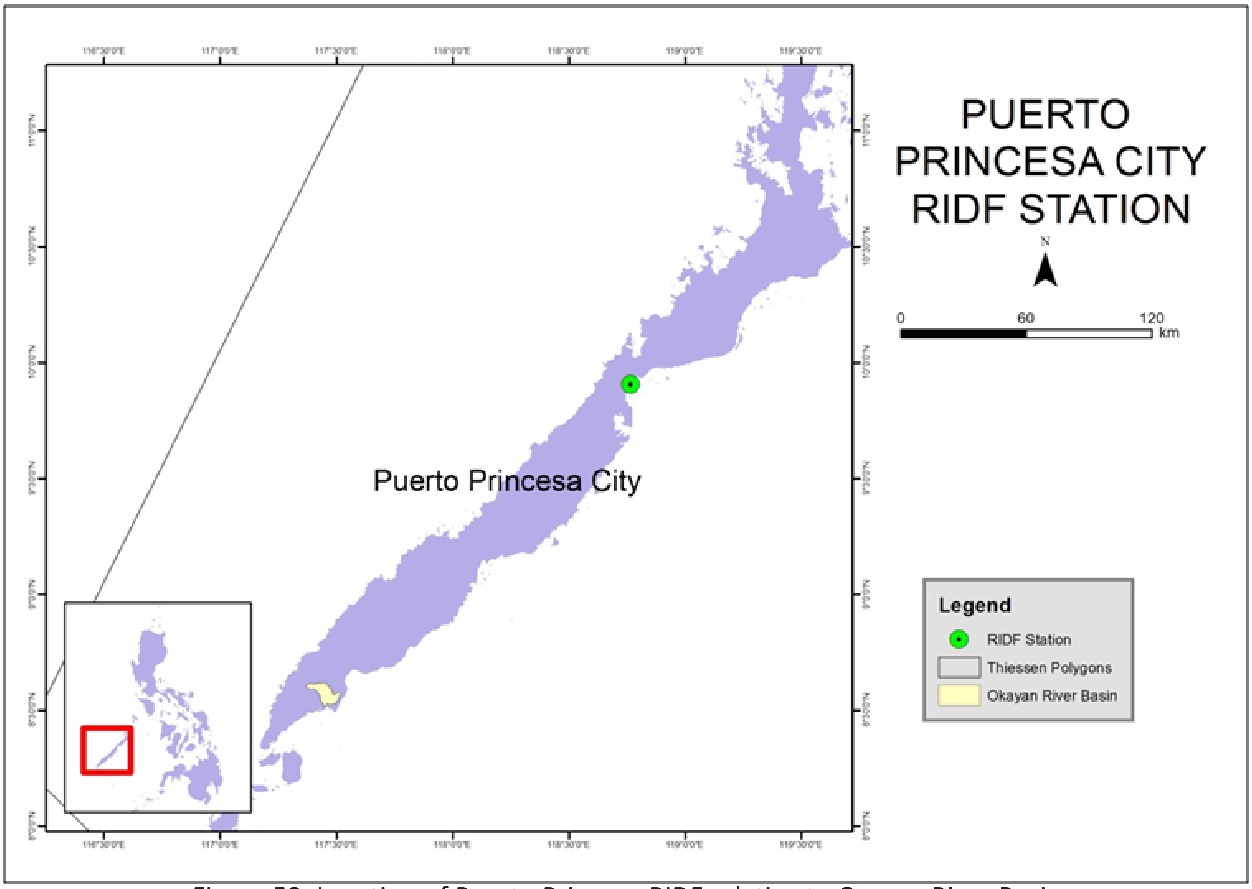

Figure 52. Location of Puerto Princesa RIDF relative to Ocayan River Basin

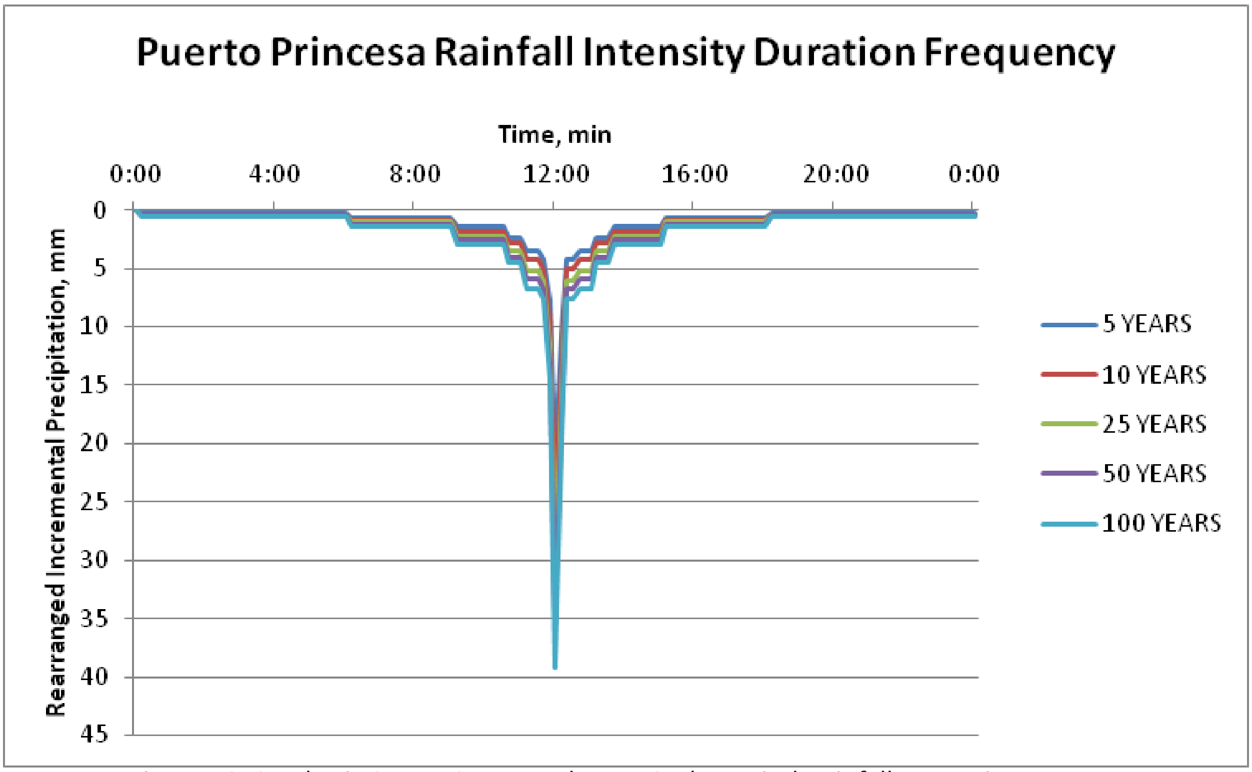

Figure 53. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return

5.3 HMS Model

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

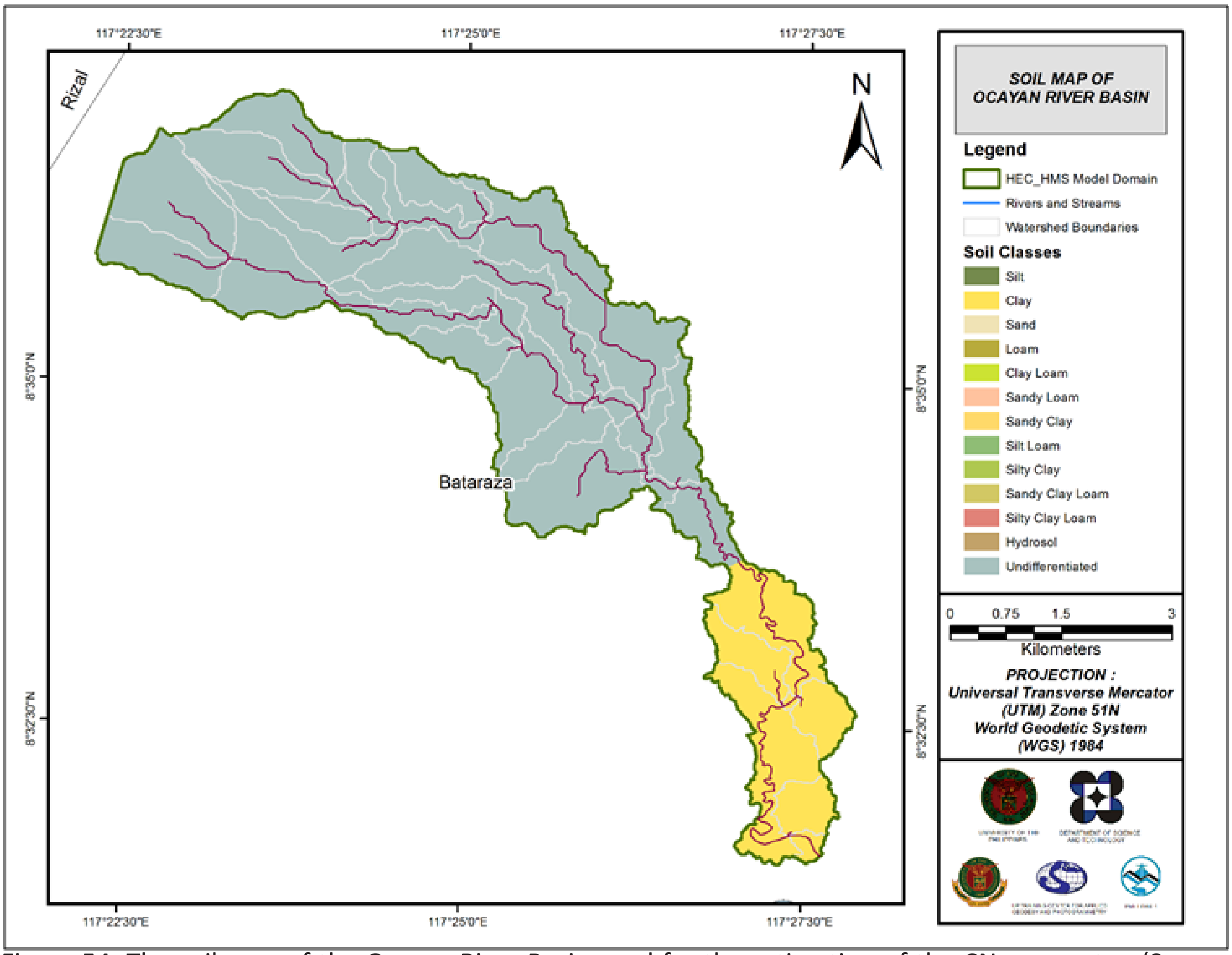

Figure 54. The soil map of the Ocayan River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture).

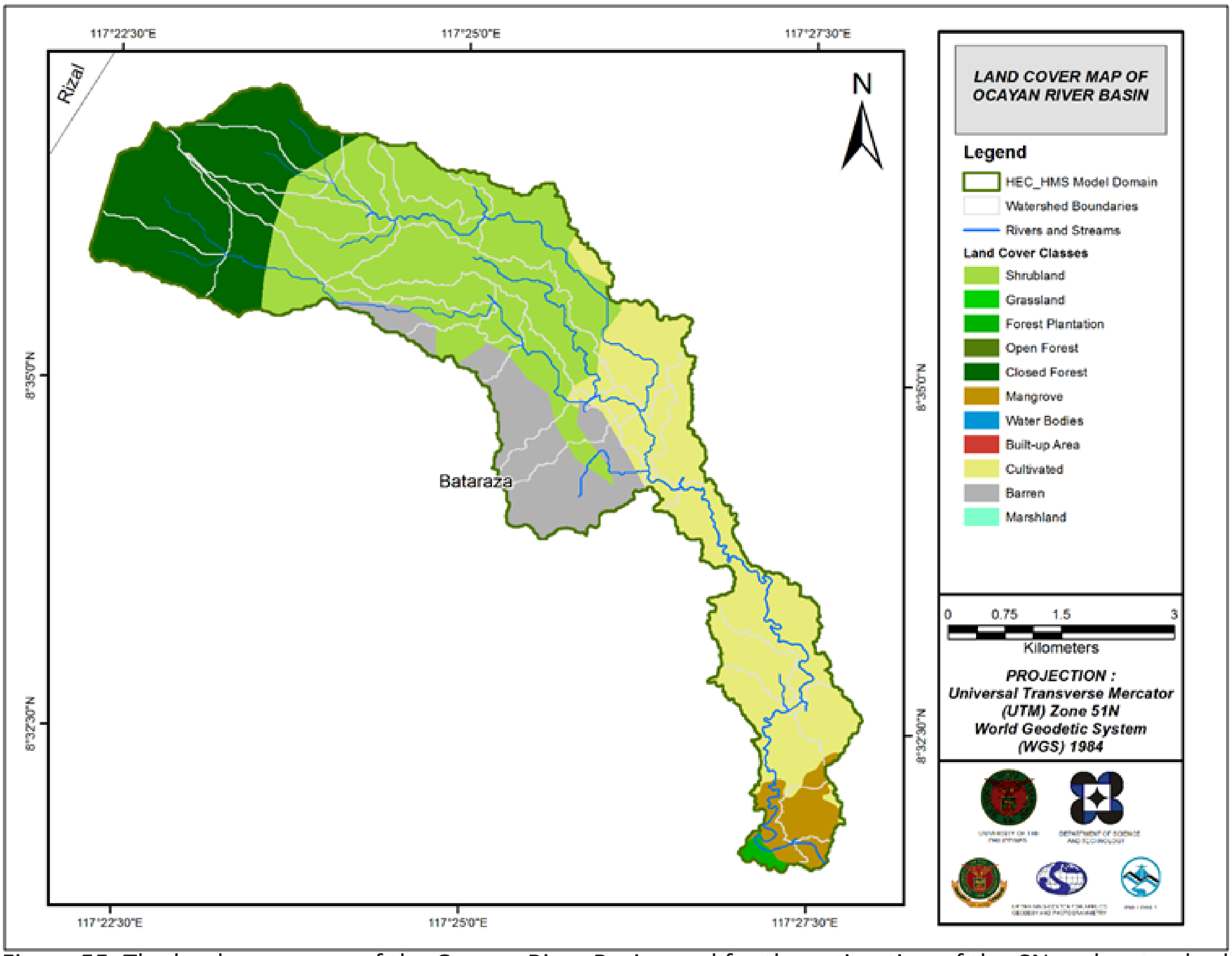

Figure 55. The land cover map of the Ocayan River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

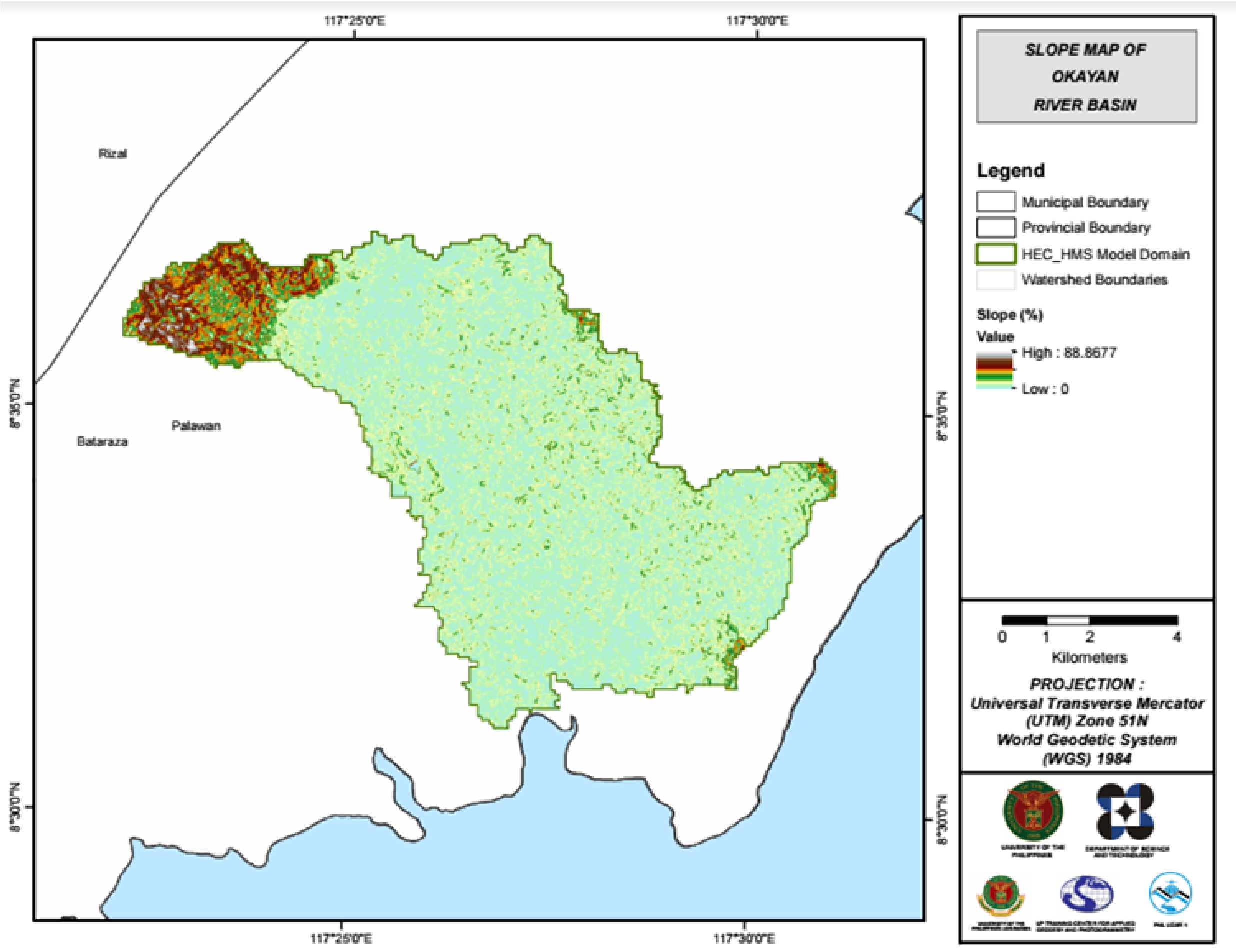

Figure 56. Slope Map of the Ocayan River Basin.

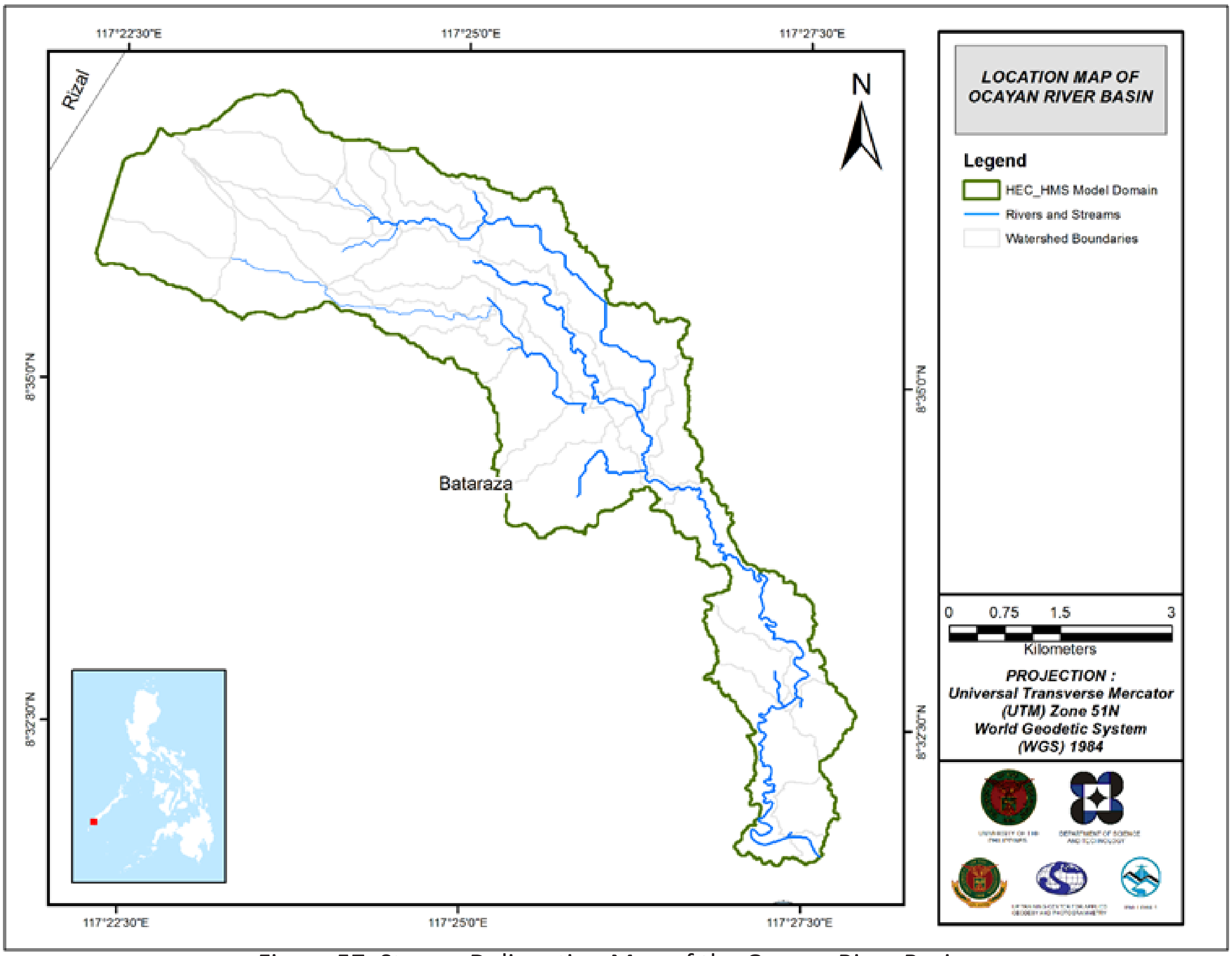

Figure 57. Stream Delineation Map of the Ocayan River Basin.

Using SAR-based DEM, the Ocayan basin was delineated and further subdivided into subbasins. The model consists of 32 sub basins, 16 reaches, and 16 junctions. The main outlet is at Ocayan Bridge.

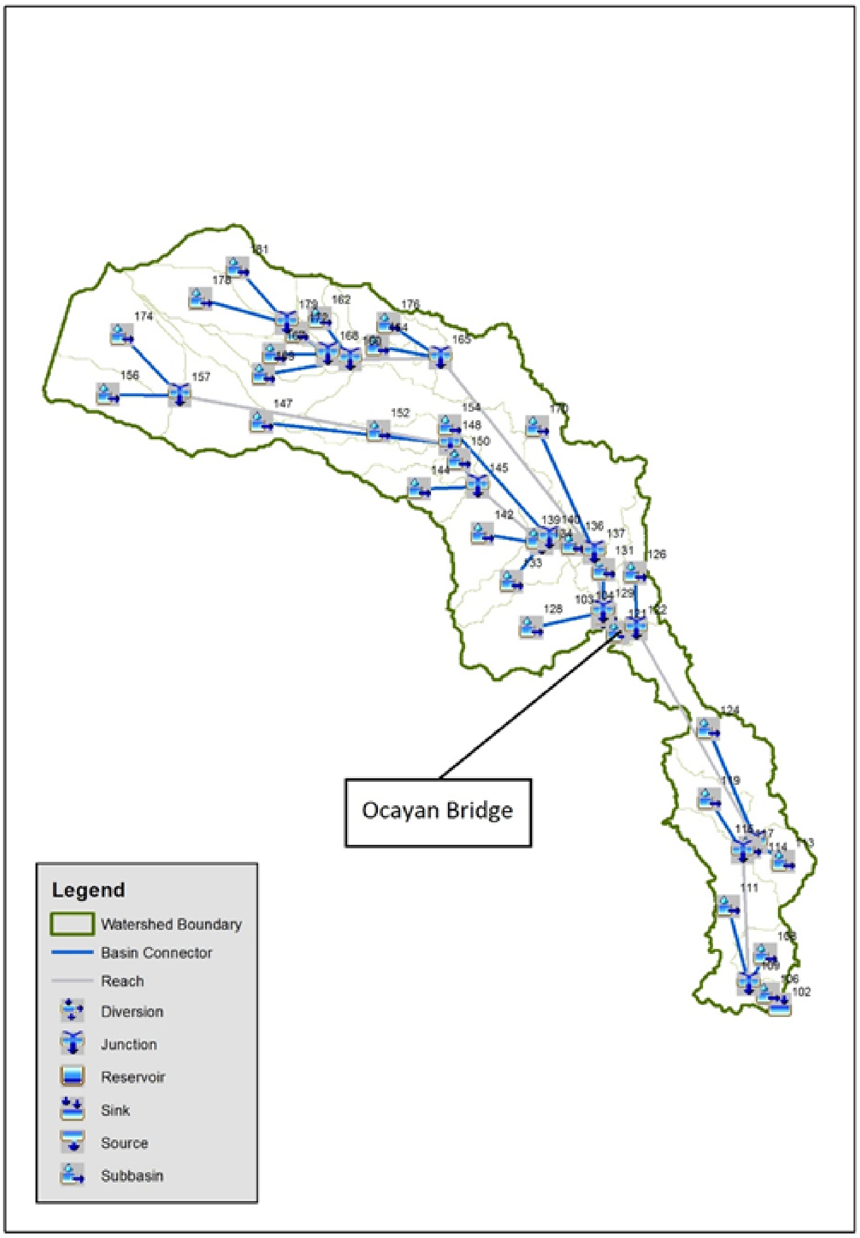

Figure 58. The Ocayan river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

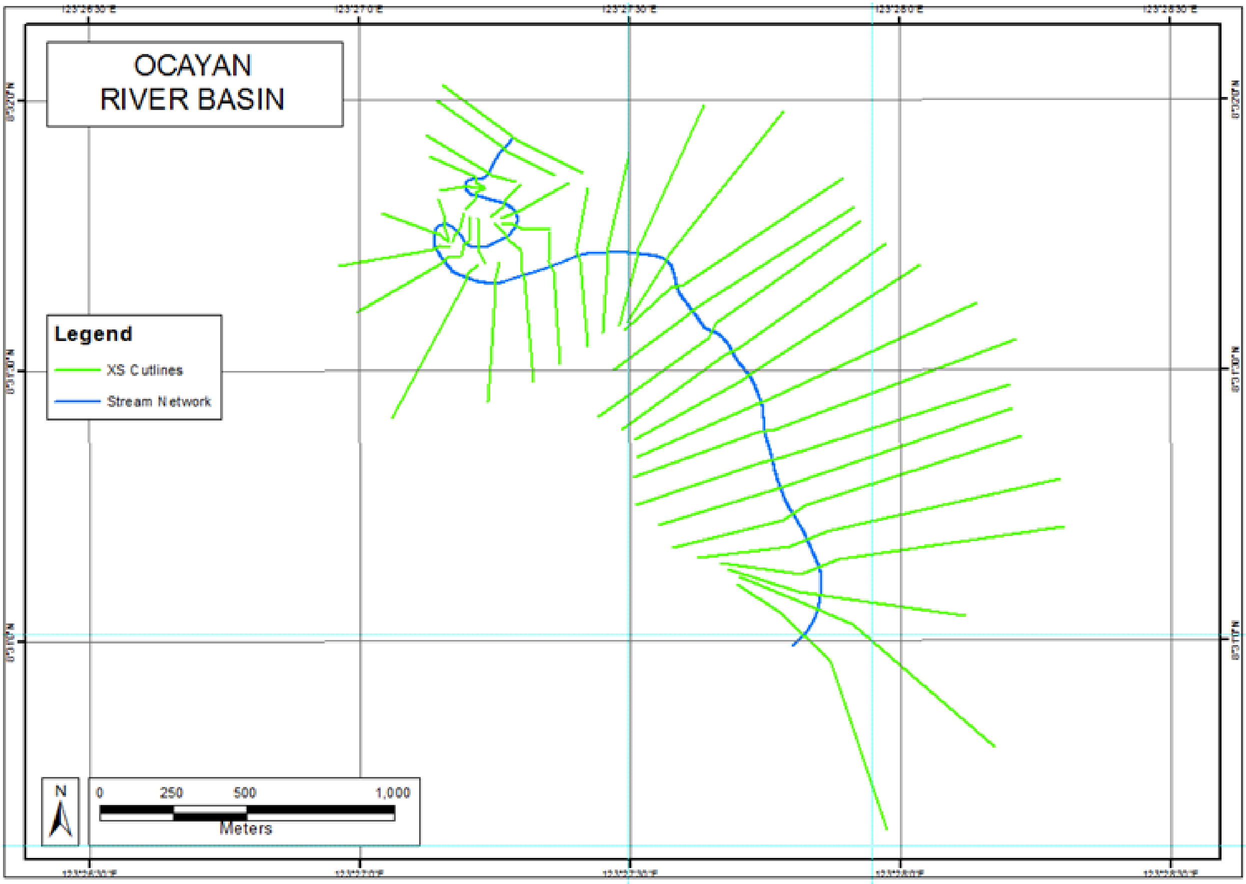

Figure 59. River cross-section of Ocayan River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

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

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

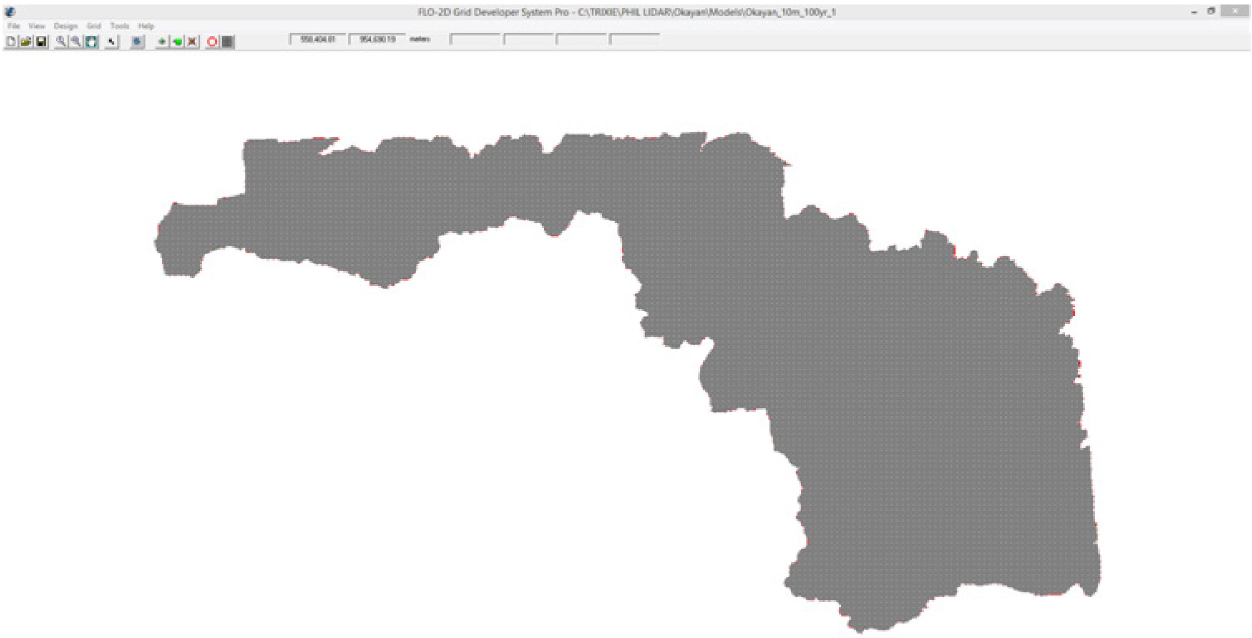

Figure 60. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 39.55225 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 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 34 336 700.00 m2.

There is a total of 9 410 191.64 m3 of water entering the model due to rainfall. 2 388 571.25 m3 of this water is lost to infiltration and interception, while 2 032 019.38 m3 is stored by the flood plain. The rest, amounting up to 4 989 600.44 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Ocayan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data.

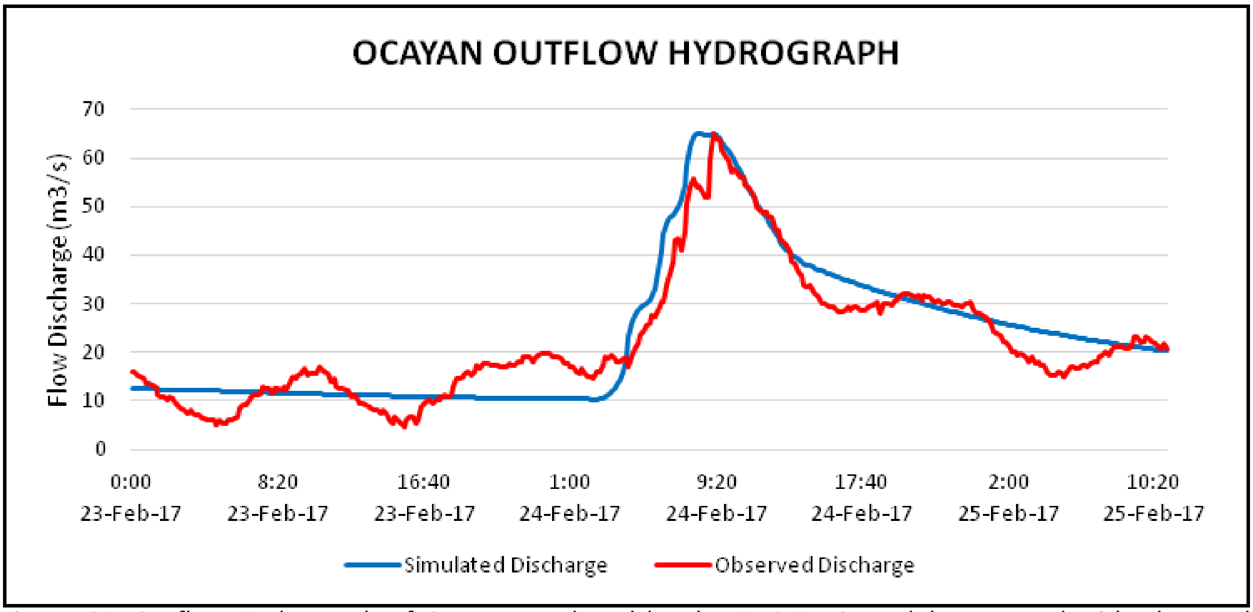

Figure 61. Outflow Hydrograph of Ocayan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for Ocayan.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	0.006 - 4
			Curve Number	78 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.1 - 8
			Storage Coefficient (hr)	0.03 - 7
	Baseflow	Recession	Recession Constant	0.2 - 1
			Ratio to Peak	0.2 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04 – 0.6

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.006 to 4mm 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 78 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.03 hours to 8 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. The characteristics of this watershed relating to the recession constant and ratio to peak differs per reach.

Manning's roughness coefficient of 0.04 to 6 corresponds to the higher range compared to the common roughness of watersheds (Brunner, 2010).

Table 30. Summary of the Efficiency Test of Ocayan HMS Model

Root Mean Square Error (RMSE)	12.25847
Pearson Correlation Coefficient (r2)	0.7697
Nash-Sutcliffe (E)	0.614193
Percent Bias (PBIAS)	0.621134
Observation Standard Deviation Ratio (RSR)	0.402172

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 4.979.
The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.945.
The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.920.
A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -4.152.
The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.376.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 62) shows the Ocayan outflow using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

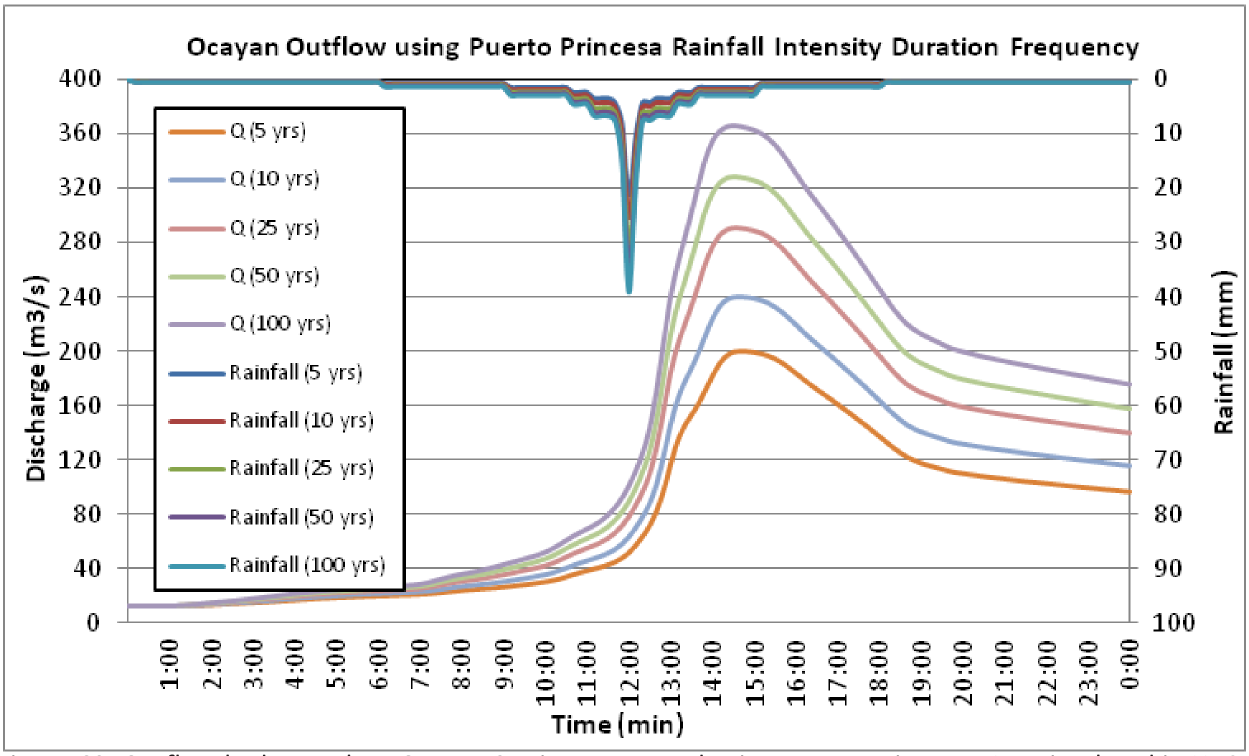

Figure 62. Outflow hydrograph at Ocayan Station generated using Puerto Princesa RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Ocayan discharge using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Ocayan HECHMS Model outflow using the Puerto Princesa RIDF.

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (m3/s)	Time to Peak
5-year RIDF	156.40	21.30	199.705	2 hours 40 minutes
10-year RIDF	191.10	25.60	239.997	2 hours 40 minutes
25-year RIDF	234.90	31.10	290.845	2 hours 30 minutes
50-year RIDF	267.30	35.20	328.804	2 hours 30 minutes
100-year RIDF	299.60	39.20	366.216	2 hours 30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Ocayan River using the HMS base flow is shown on Figure 63 below.

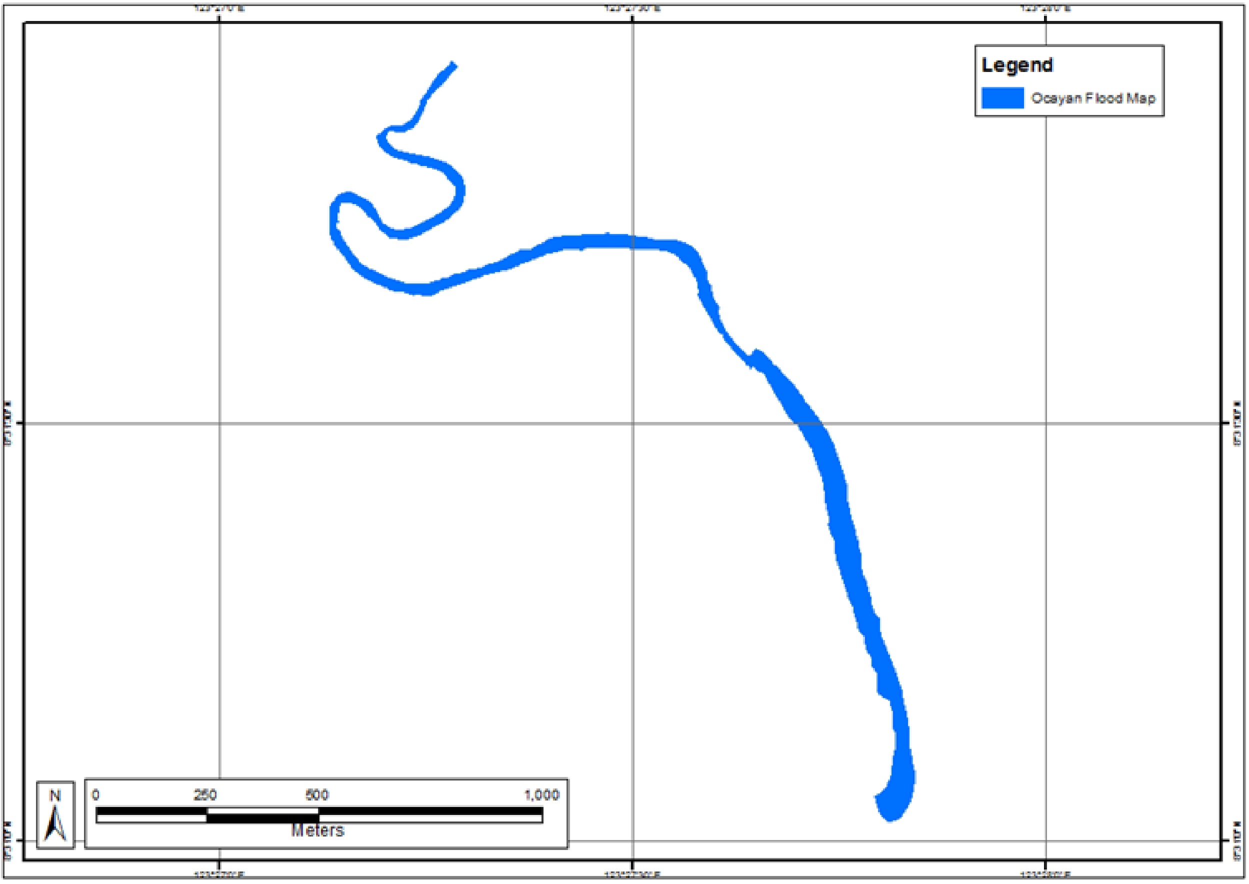

Figure 63. Ocayan HEC-RAS Output.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Ocayan floodplain are shown in Figure 64 to 69. The floodplain, with an area of 147.16 sq. km., covers one municipality namely Bataraza. Table shown the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Ocayan floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Bataraza	818.11	147.15	17.99

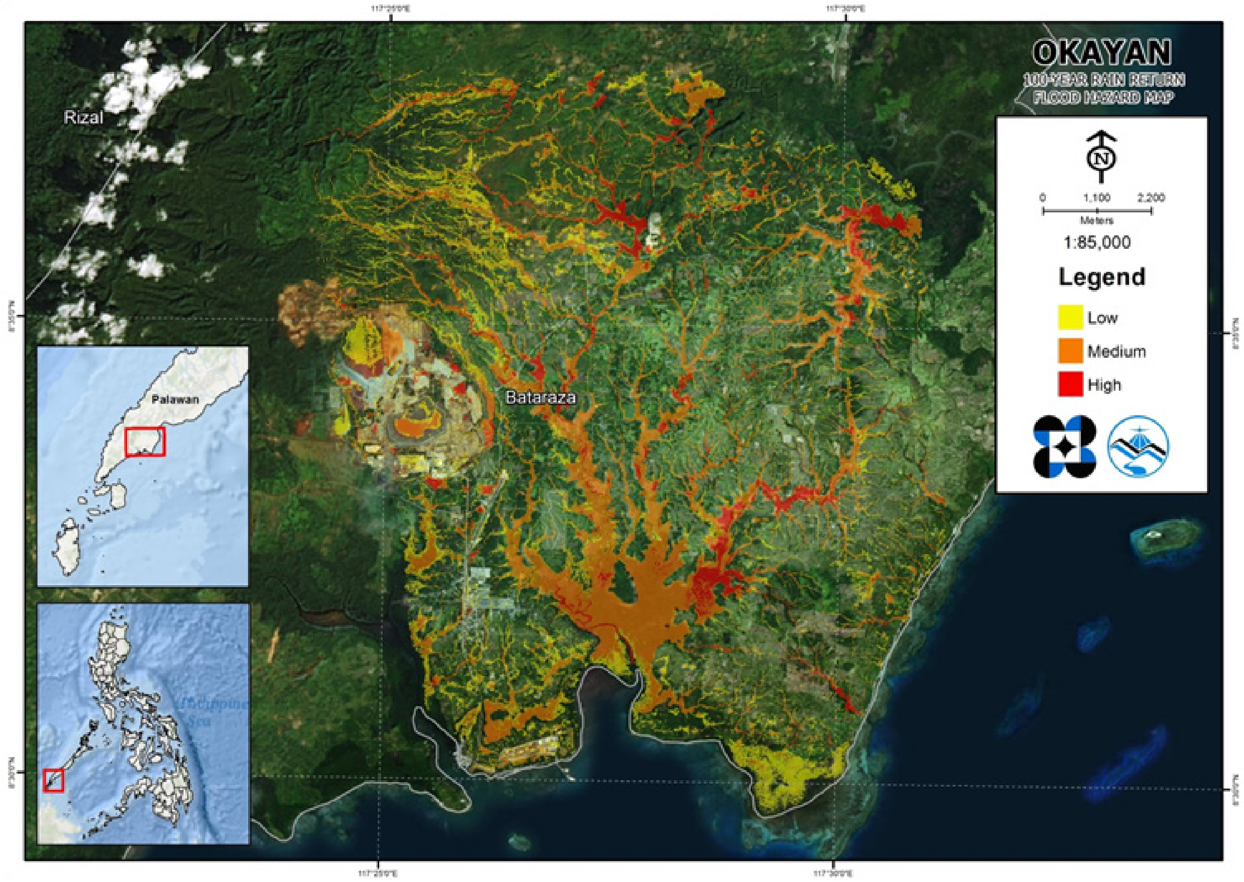

Figure 64. 100-year Flood Hazard Map for Ocayan Floodplain

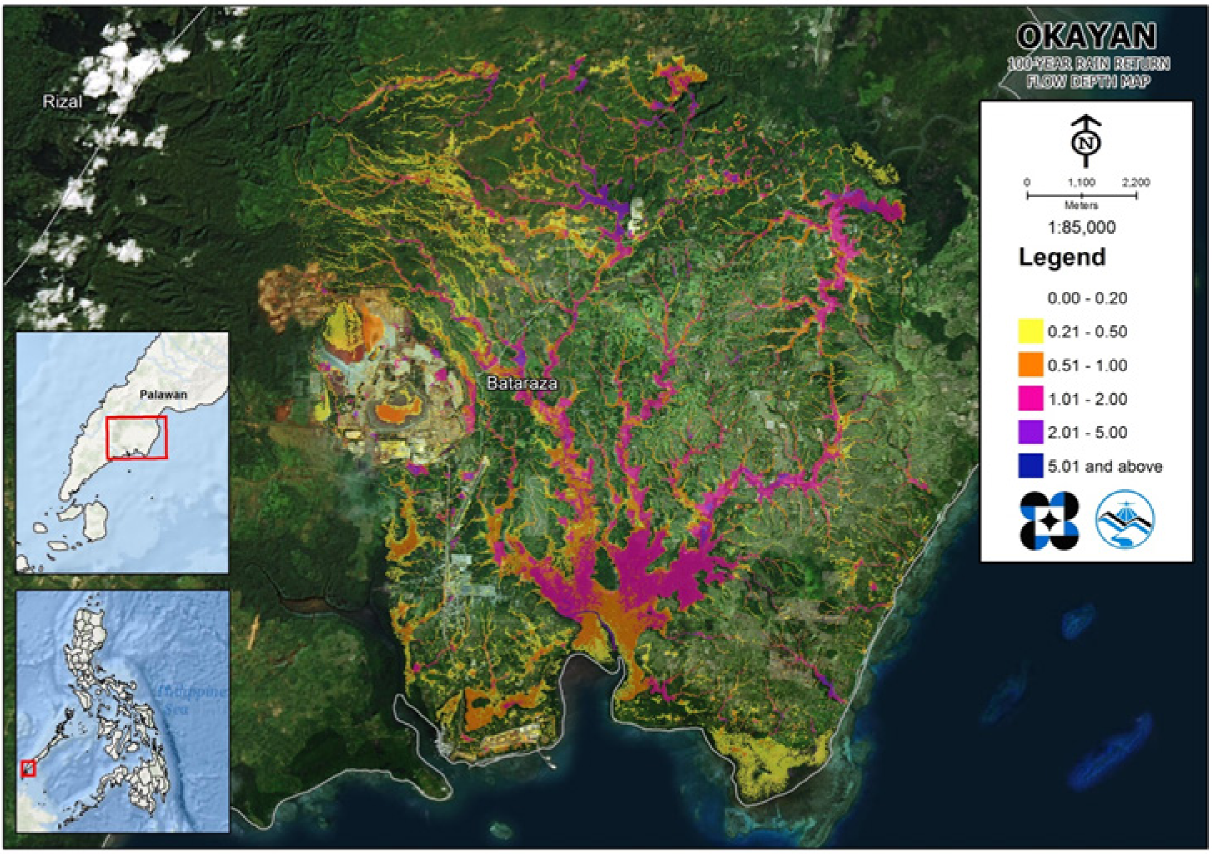

Figure 65. 100-year Flow Depth Map for Ocayan Floodplain.

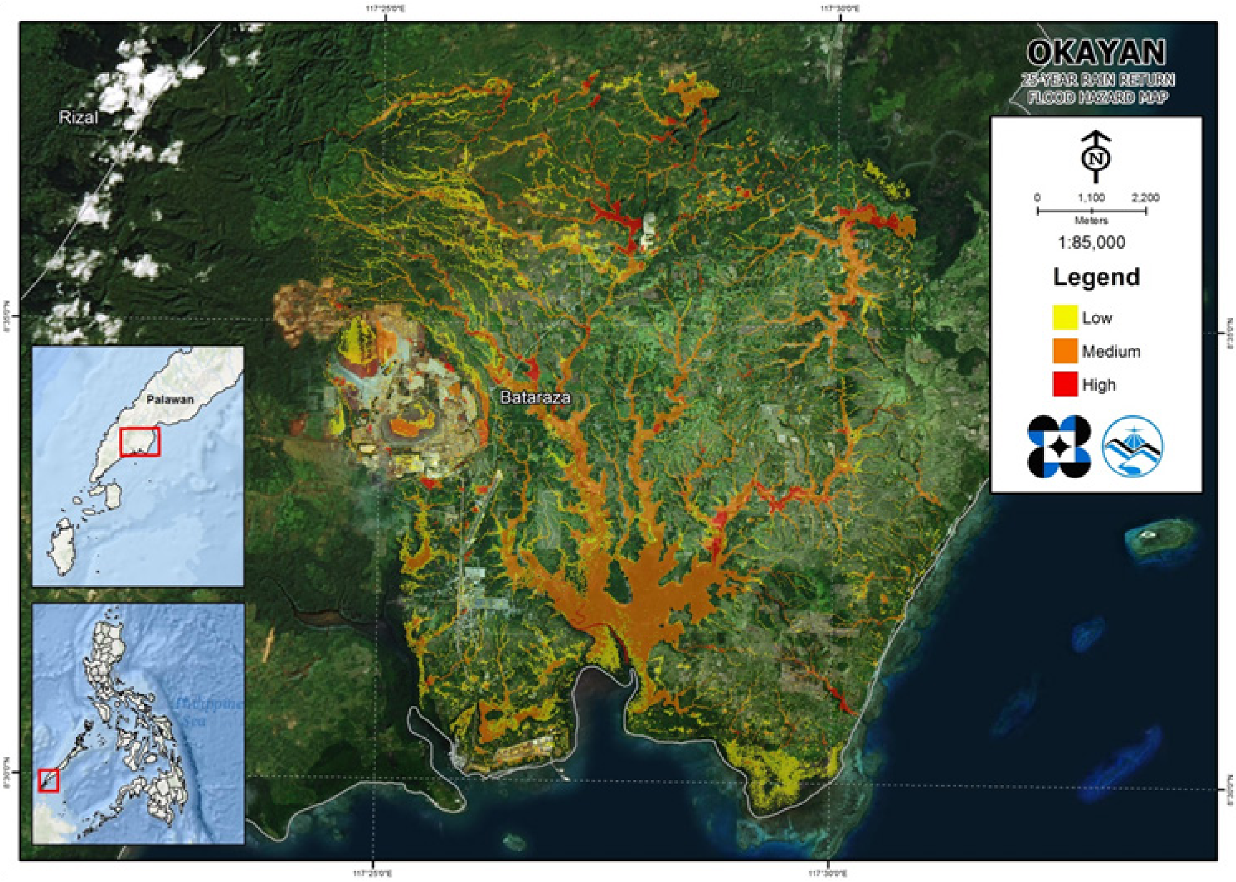

Figure 66. 25-year Flood Hazard Map for Ocayan Floodplain.

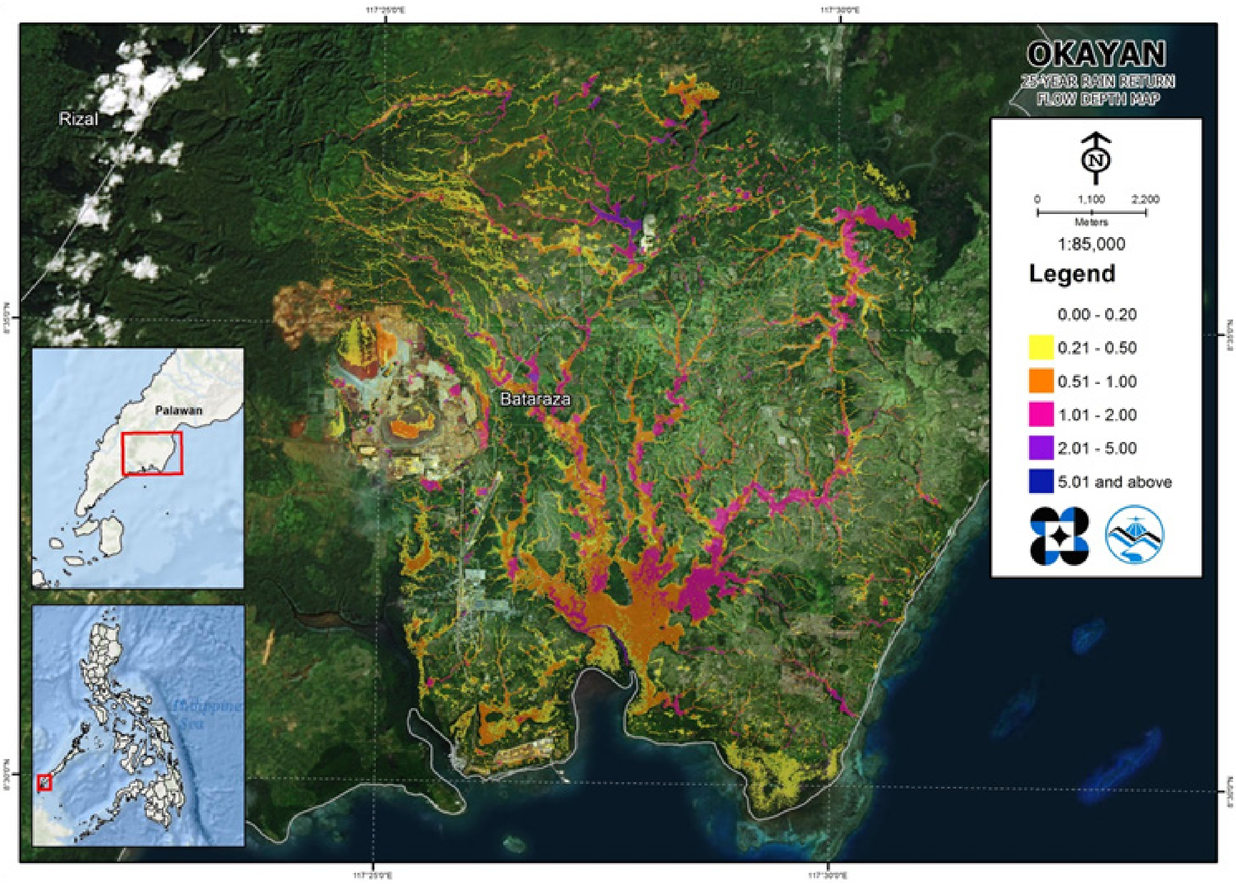

Figure 67. 25-year Flow Depth Map for Ocayan Floodplain.

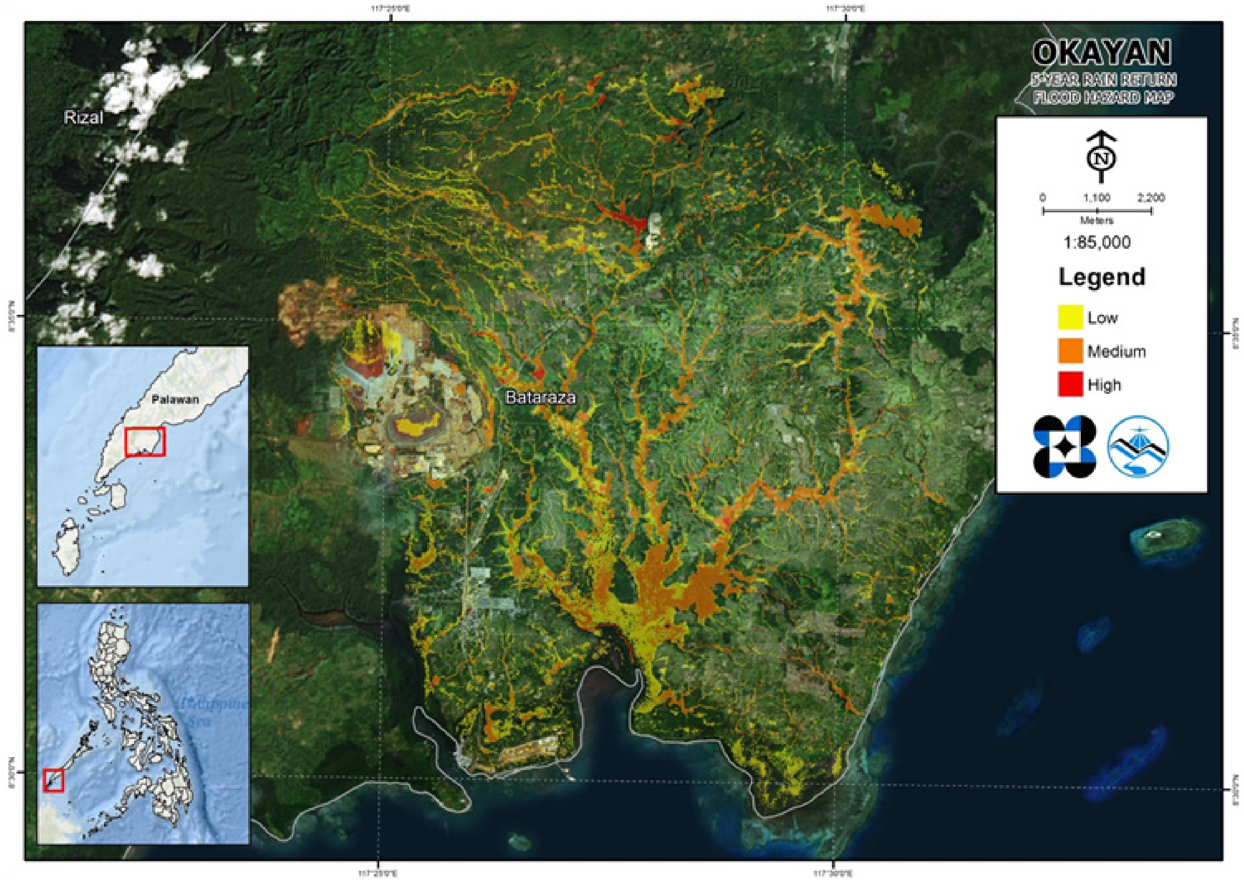

Figure 68. 5-year Flood Hazard Map for Ocayan Floodplain.

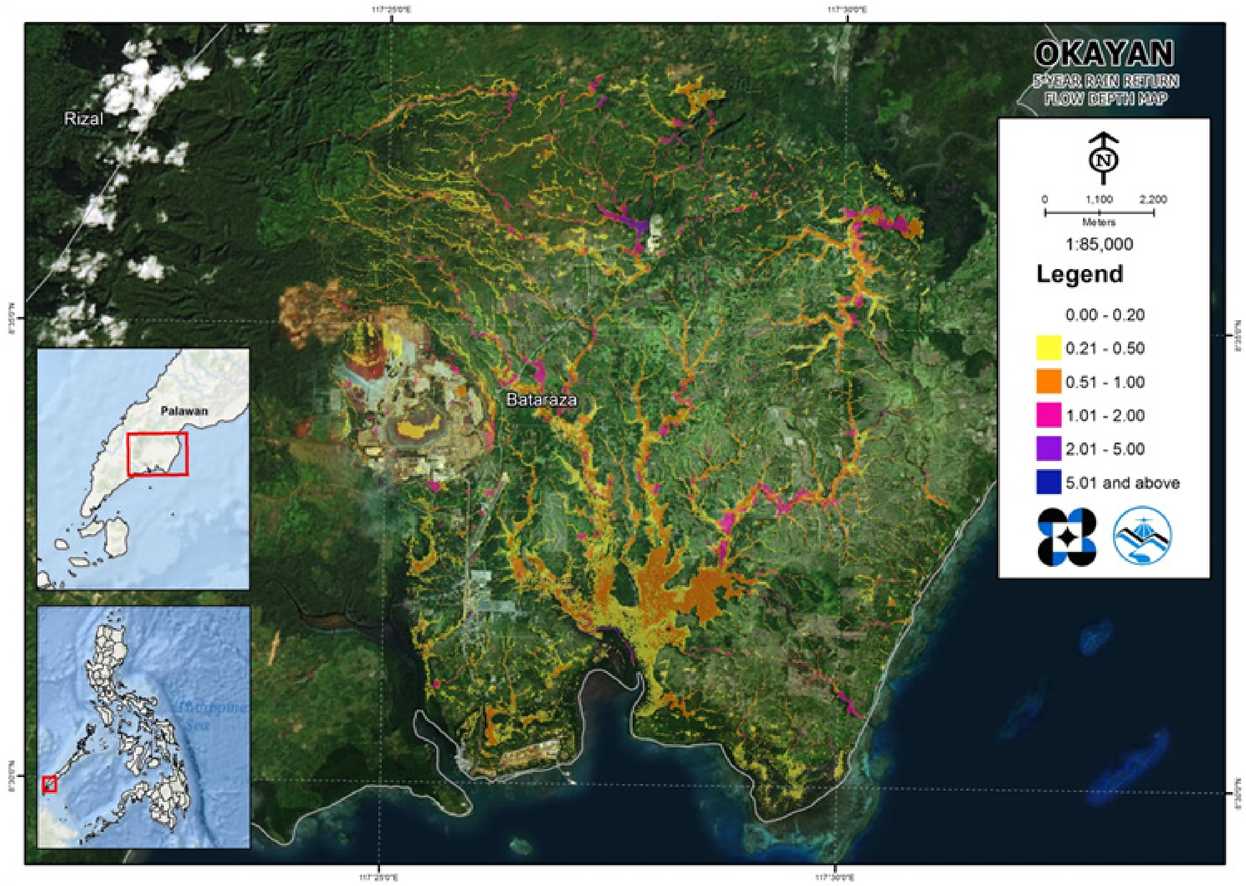

Figure 69. 5-year Flow Depth Map for Ocayan Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Ocayan river basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 7 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 14.59% of the municipality of Bataraza with an area of 818.11 sq. km. will experience flood levels of less 0.20 meters. 1.80% of the area will experience flood levels of 0.21 to 0.50 meters while 1.25%, 0.32%, 0.03%, and 0.0002% 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 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Bataraza, Palawan during 5-Year Rainfall Return Period.

OCAYAN BASIN		Affected Barangays in Bataraza						
		Igang-Igang	Iwahig	Ocayan	Rio Tuba	Sandoval	Sarong	Tarusan
ffected Area (km2)	0.03-0.20	5.499397	25.02584	41.64118	25.60654	15.55958	6.011662	0.00487
	0.21-0.50	0.341774	2.030206	6.389925	3.908438	1.703222	0.348333	0
	0.51-1.00	0.279487	2.054306	5.573463	1.377944	0.683326	0.234587	0
	1.01-2.00	0.065045	0.777596	1.209638	0.255803	0.255651	0.074413	0
	2.01-5.00	0.003107	0.122493	0.052079	0.035526	0.017667	0.0053	0
	> 5.00	0	0.0016	0	0	0	0	0

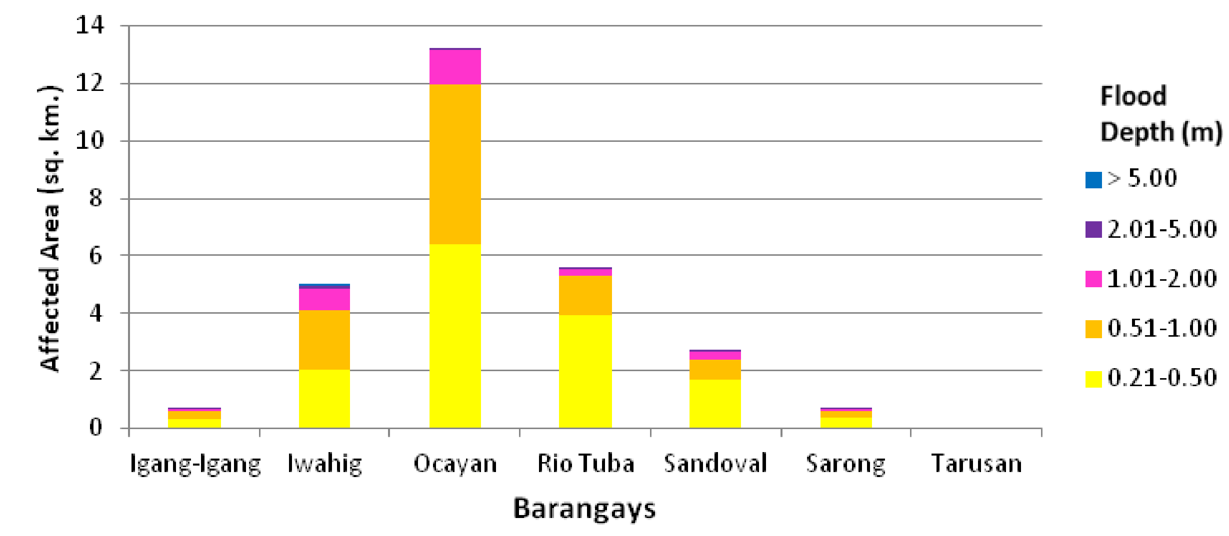

Figure 70. Affected Areas in Bataraza, Palawan during 5-Year Rainfall Return Period.

For the 25-year return period, 13.66% of the municipality of Bataraza with an area of 818.11 sq. km. will experience flood levels of less 0.20 meters. 1.75% of the area will experience flood levels of 0.21 to 0.50 meters while 1.67%, 0.83%, 0.08%, and 0.0005% 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 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Bataraza, Palawan during 25-Year Rainfall Return Period

OCAYAN BASIN		Affected Barangays in Bataraza						
		Igang-Igang	Iwahig	Ocayan	Rio Tuba	Sandoval	Sarong	Tarusan
ffected Area (km2)	0.03-0.20	5.348433	23.97468	38.74302	23.2855	14.57078	5.83251	0.00487
	0.21-0.50	0.351802	1.908656	5.153229	4.255431	2.234835	0.42679	0
	0.51-1.00	0.332524	2.234011	6.937786	2.917169	0.968751	0.26202	0
	1.01-2.00	0.147844	1.581319	3.859478	0.633124	0.393783	0.143177	0
	2.01-5.00	0.008207	0.310574	0.172229	0.092403	0.051286	0.0098	0
	> 5.00	0	0.0028	0.000545	0.000626	0	0	0

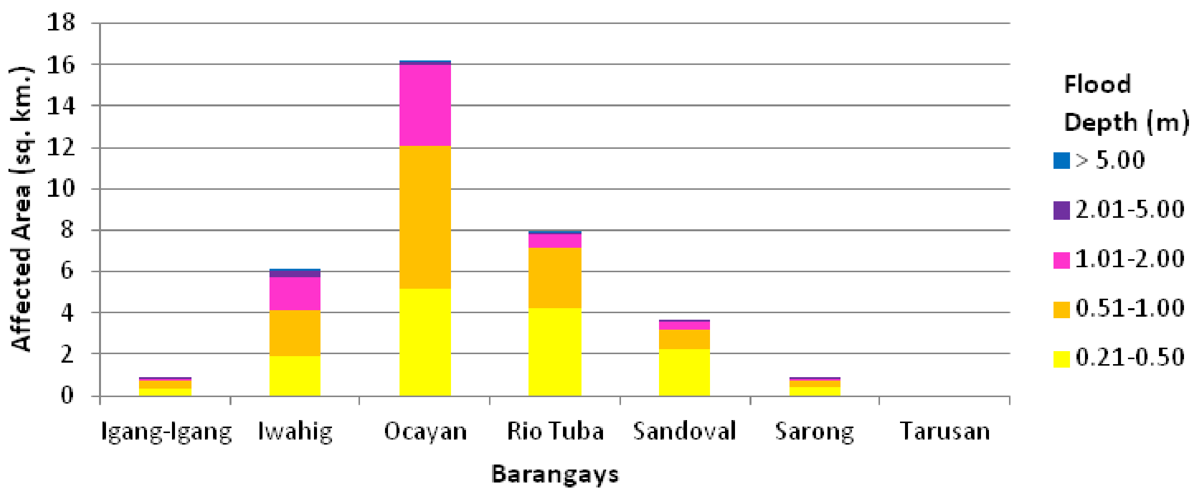

Figure 71. Affected Areas in Bataraza, Palawan during 25-Year Rainfall Return Period.

For the 100-year return period, 13.13% of the municipality of Bataraza with an area of 818.11 sq. km. will experience flood levels of less 0.20 meters. 1.79% of the area will experience flood levels of 0.21 to 0.50 meters while 1.61%, 1.30%, 0.15%, and 0.001% 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 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Bataraza, Palawan during 100-Year Rainfall Return Period.

OCAYAN BASIN		Affected Barangays in Bataraza						
		Igang-Igang	Iwahig	Ocayan	Rio Tuba	Sandoval	Sarong	Tarusan
ffected Area (km2)	0.03-0.20	5.24327	23.3576	37.22629	22.04283	13.85716	5.711691	0.004762
	0.21-0.50	0.368077	1.927025	4.988381	4.330807	2.563687	0.481817	0.000108
	0.51-1.00	0.337199	2.135255	5.781762	3.43095	1.20785	0.275193	0
	1.01-2.00	0.227858	2.035218	6.409083	1.234865	0.510881	0.191912	0
	2.01-5.00	0.012407	0.552346	0.455725	0.143572	0.079865	0.013684	0
	> 5.00	0	0.0046	0.00504	0.001231	0	0	0

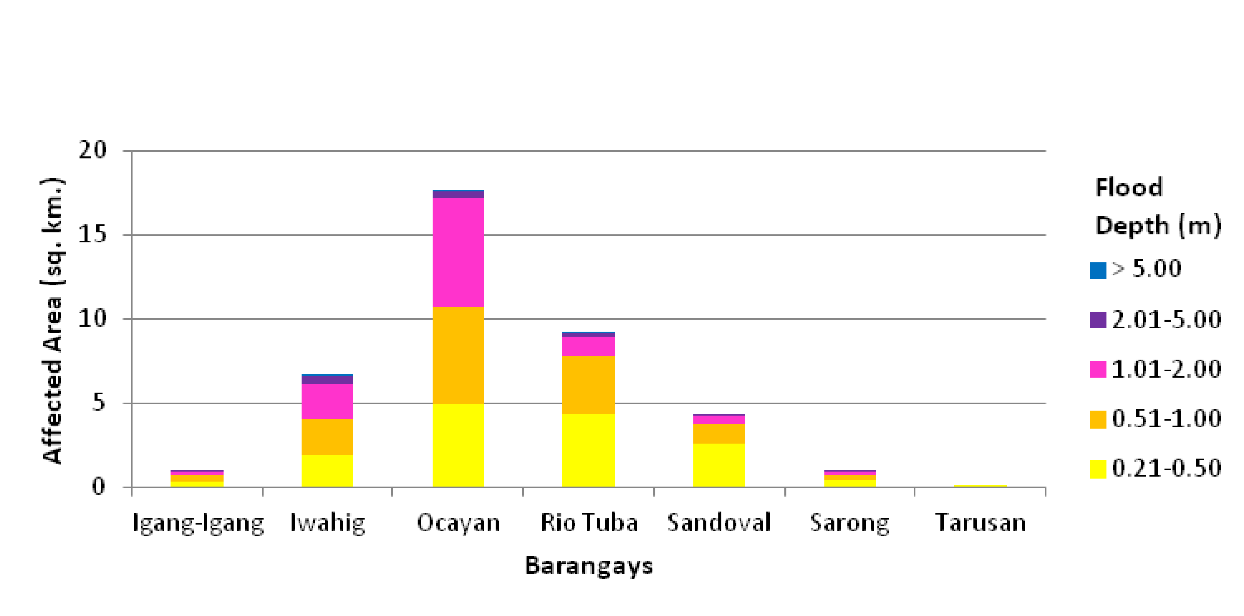

Figure 72. Affected Areas in Bataraza, Palawan during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Bataraza, Ocayan is projected to have the highest percentage of area that will experience flood levels at 6.71%. Meanwhile, Rio Tuba posted the second highest percentage of area that may be affected by flood depths at 3.81%.

5.11 Field Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 74.
The flood validation consists of 103 points randomly selected all over the Ocayan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.27m. Table ___ shows a contingency matrix of the comparison.

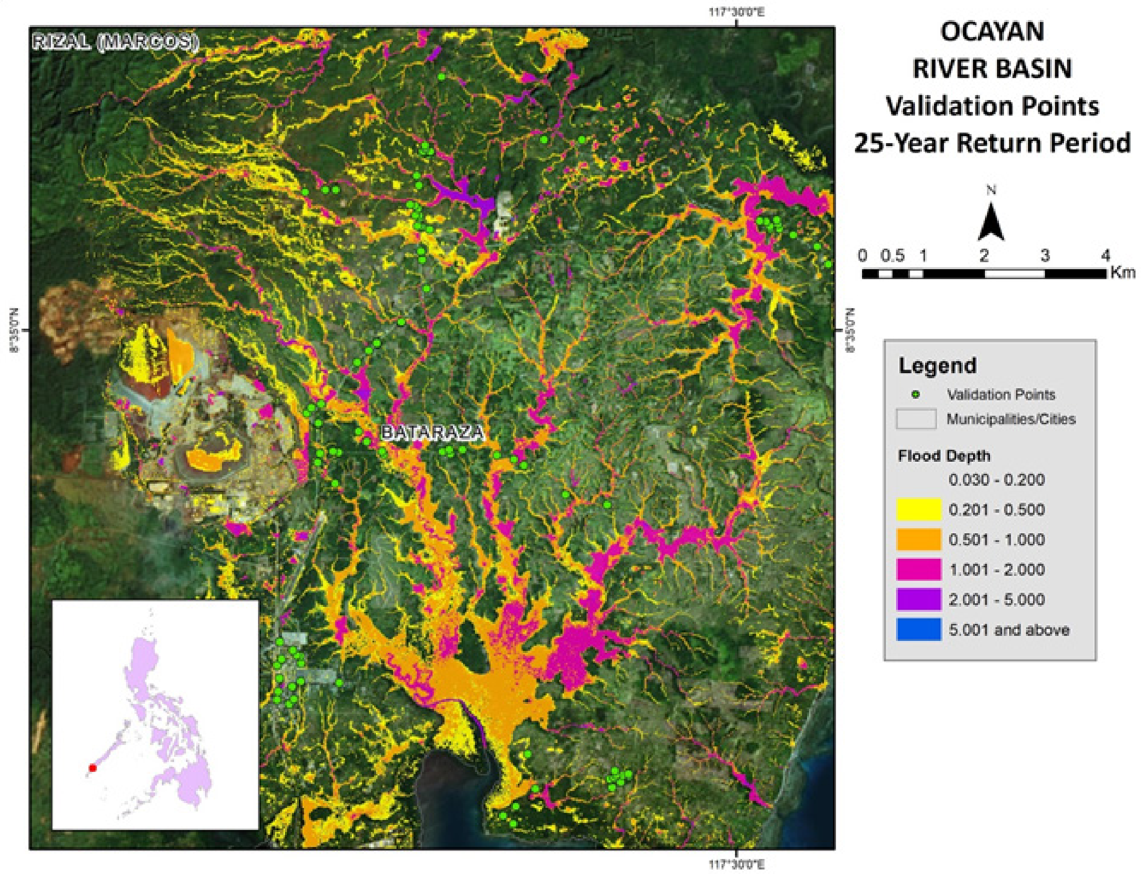

Figure 73. Validation points for 25-year Flood Depth Map of Ocayan Floodplain.

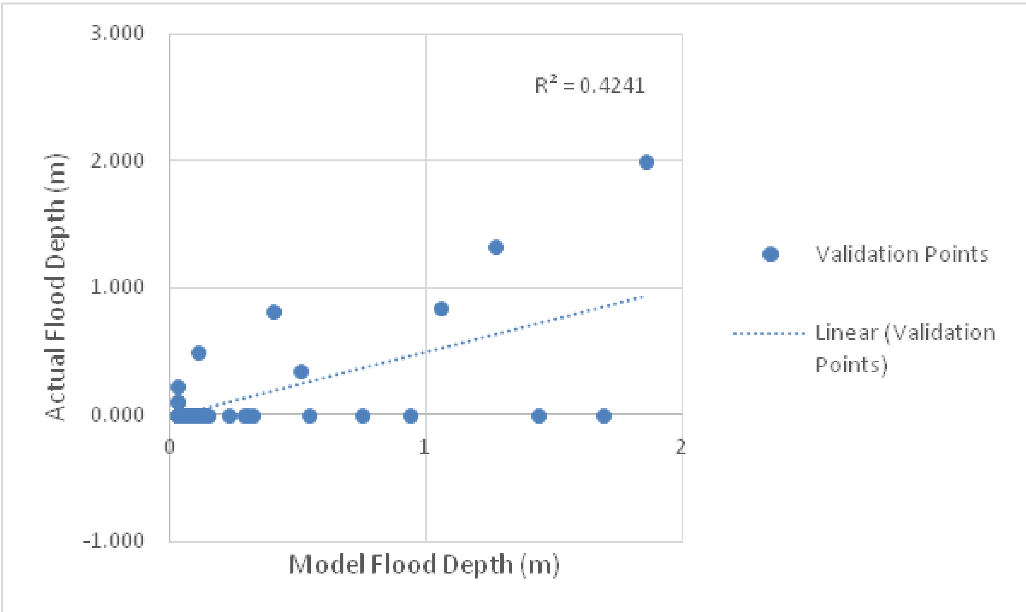

Figure 74. Flood map depth vs actual flood depth.

Table 36. Actual Flood Depth vs Simulated Flood Depth at different levels in the Ocayan River Basin.

OCAYAN BASIN		**Modeled Flood Depth (m)**						
		0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
Actual Flood Depth (m)	0-0.20	87	4	3	2	0	0	96
	0.21-0.50	2	0	1	0	0	0	3
	0.51-1.00	0	1	0	1	0	0	2
	1.01-2.00	0	0	0	2	0	0	2
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	**89**	5	4	5	0	0	103

The overall accuracy generated by the flood model is estimated at 86.41% with 89 points correctly matching the actual flood depths. In addition, there were 8 points estimated one level above and below the correct flood depths while there were 3 points and 2 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 3 points were underestimated in the modelled flood depths of Ocayan. Table 37 depicts the summary of the Accuracy Assessment in the Ocayan River Basin Survey.

Table 37. Summary of Accuracy Assessment in the Ocayan River Basin Survey.

	No. of Points	%
Correct	45	55.56
Overestimated	31	38.27
Underestimated	5	6.17
Total	81	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 GEMINI AND PEGASUS SENSORS

GEMINI

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
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)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

PEGASUS

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

D-8900 AERIAL CAMERA

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6μm x 6 μm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Fire wire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

ANNEX 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. PLW-13

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

July 21, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **PALAWAN**	
	Station Name: **PLW-13**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **RIO TUBA**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 30' 17.42901"**	Longitude: **117° 25' 55.42672"**	Ellipsoidal Hgt: **-0.25567 m.**
	WGS84 Coordinates	
Latitude: **8° 30' 13.19373"**	Longitude: **117° 26' 0.86501"**	Ellipsoidal Hgt: **49.35000 m.**
	PTM / PRS92 Coordinates	
Northing: **940540.844 m.**	Easting: **382414.126 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **940,076.76**	Easting: **547,553.57**	Zone: **50**

Location Description

PLW-13
From Puerto Princesa travel along the National Highway for 249.2 ikilometers, about 4 hours and 15 minutes drive to Rio Tuba Nickel iMining Corporation. Thence travel south direction for 4.7 ikilometers or 5 minutes drive, then turn right going West idirection for 300 meters up to barangay Rio Tuba. The station is ilocated on a big boulder in the pier site; 70 meters North of ibarangay captain's house. Station mark is a cross cut of 0.15 m x i0.01 m in diameter brass rod, set in a drill hole centered in a i30 cm x 30 cm cement patty on big boulder. Inscribed on top with ithe station name. All reference mark numbers 1,2,3 and 4 are icross cut on top of brass rods, set in a drill hole on big iboulder, centered in a 25 cm x 25 cm cement patty, and inscribed iwith the station name and arrows pointing to the station.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8086767 I**
T.N.: **2015-1694**

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

9907212013170424

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. PLW-141/136

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **PALAWAN**	
	Station Name: **PLW-141/136**	
	Order: **2nd**	
Island: **Luzon**	Barangay: **MALIS**	
Municipality: **BROOKE'S POINT**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 41' 32.51585"**	Longitude: **117° 41' 48.08062"**	Ellipsoidal Hgt: **-2.49300 m.**
	WGS84 Coordinates	
Latitude: **8° 41' 28.25671"**	Longitude: **117° 41' 53.50178"**	Ellipsoidal Hgt: **47.39100 m.**
	PTM / PRS92 Coordinates	
Northing: **961210.738 m.**	Easting: **411596.8 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **960,851.09**	Easting: **576,642.18**	Zone: **50**

Location Description

From Brooke's Point Poblacion, travel South bound along Nat'l highway towards the town of Batarazan for approx. 20kms up to Brgy. Malis, then turn SE direction on Malis junction going to Aplaya, and travel for approx. 120m. The station is situated inside Malis Elem. School compd.

Mark is the head of a 4" copper nail flushed in a cement block (30cmx30cmx120cm) embedded 1m in the ground with inscriptions "PLW 136 2007, NAMRIA". The monument is made 20 cm above ground surface with ref. mark 1,2&3.

RM1=120m SE of road centerline
RM2=25m E of school gate
RM3=60m N of school buildings

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number:
T.N.:

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

9 9 0 2 1 0 2 0 1 6 1 2 4 9 5 7

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. PLW-79

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

July 21, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **PALAWAN**	
	Station Name: **PLW-79 (PAL-22)**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **SANDOVAL**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 37' 30.44877"**	Longitude: **117° 27' 5.39859"**	Ellipsoidal Hgt: **25.88011 m.**
	WGS84 Coordinates	
Latitude: **8° 37' 26.18482"**	Longitude: **117° 27' 10.82604"**	Ellipsoidal Hgt: **75.29000 m.**
	PTM / PRS92 Coordinates	
Northing: **953839.48 m.**	Easting: **384591.01 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **953,376.65**	Easting: **549,677.23**	Zone: **50**

Location Description

PLW-79 (PAL-22)
From Puerto Princesa City travel south bound of the road by a shuttle van going to Brgy Rio Tuba, Bataraza passing through brooks points for almost 2 to 3 hours. The station is located along the brgy. road at Brgy. Sandoval near the house of Tribal Chieftain Acat. Mark is a 4" copper nail centered on top of a 30 x 30 x 100 cm concrete monument 20 cm projection above the ground and 80 cm set on the ground. Station is along the brgy. road at Brgy. Sandoval with inscription PAL-22 2006 NCIP.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8086767 I**
T.N.: **2015-1695**

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

9 9 0 7 2 1 2 0 1 5 1 7 0 5 0 3

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ANNEX 3. BASELINE PROCESSING REPORT

1. PLW-3058

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)
PLW-3058 --- PLW-13 (B1)	PLW-13	PLW-3058	Fixed	0.007	0.024	52°27'10"	82603.650	-2.724
PLW-3058 --- PLW-13 (B2)	PLW-13	PLW-3058	Fixed	0.007	0.019	52°27'10"	82603.646	-2.673

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

PLW-3058 - PLW-13 (7:29:44 AM-1:02:54 PM) (S1)

Baseline observation:	PLW-3058 --- PLW-13 (B1)
Processed:	1/4/2016 1:53:45 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.007 m
Vertical precision:	0.024 m
RMS:	0.005 m
Maximum PDOP:	2.036
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/7/2015 7:30:04 AM (Local: UTC+8hr)
Processing stop time:	12/7/2015 1:02:54 PM (Local: UTC+8hr)
Processing duration:	05:32:50
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	PLW-13				
Grid		Local		Global	
Easting	-113741.490 m	Latitude	N8°30'17.42900"	Latitude	N8°30'13.19373"
Northing	944471.057 m	Longitude	E117°25'55.42676"	Longitude	E117°26'00.86501"
Elevation	1.573 m	Height	-0.256 m	Height	49.350 m

To:	PLW-3058				
Grid		Local		Global	
Easting	-47262.005 m	Latitude	N8°57'34.41144"	Latitude	N8°57'30.11418"
Northing	994023.989 m	Longitude	E118°01'39.35193"	Longitude	E118°01'44.74872"
Elevation	-3.162 m	Height	-2.979 m	Height	47.176 m

Vector					
ΔEasting	66479.484 m	NS Fwd Azimuth	52°27'10"	ΔX	-54449.894 m
ΔNorthing	49552.932 m	Ellipsoid Dist.	82603.650 m	ΔY	-37251.571 m
ΔElevation	-4.735 m	ΔHeight	-2.724 m	ΔZ	49706.928 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.011 m
σ ΔElevation	0.012 m	σ ΔHeight	0.012 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000356543		
Y	-0.0000566784	0.0001191653	
Z	-0.0000106477	0.0000187894	0.0000078497

ANNEX 4. THE SURVEY TEAM

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	Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	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, Data Download and Transfer	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2015	ENGR. GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA 2015	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA 2015	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey	RA	JERIEL PAUL ALAMBAN	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
LiDAR Operation	Airborne Security	SSG ARIS TORNO	PHILIPPINE AIR FORCE (PAF)
		A2C JUMAR PARANGUE	PAF
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. ALBERT PAUL LIM	AAC
		CAPT. JUSTIN JOYA	AAC
		CAPT. RANDY LAGCO	AAC

ANNEX 5. DATA TRANSFER SHEET FOR OCAYAN FLOODPLAIN FLIGHTS

1. 3105P, 3109P

15-19

DATA TRANSFER SHEET
7/9/2015(Palawan)

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	
18-Jun	3065P	1BLK42Ac169A	pegasus	1.09	na	7.83	187	37.7	266	20.6	60.1	3.9	1kb	na	96/15	na	Z:\DAC\RAW DATA
28-Jun	3105P	1BLK42QR179A	pegasus	1.45	na	9.25	213	36.9	40	29.4	59.3	9.17	1KB	na	108	na	Z:\DAC\RAW DATA
29-Jun	3109P	1BLK42QR180A	pegasus	988	na	6	147	na	na	18.3	16.3	6.79	1KB	na	108/117	6	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 7/10/15

2. 3141P, 3145P

DATA TRANSFER SHEET
8/3/2015(palawan)

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	
14-Jun-15	3049P	1BLK42S165A	Pegasus	969	na	7	162	31	252	18.3	29.3	16.3	1KB	1KB	70/67	na	Z:\DAC\RAW DATA
20-Jun-15	3073P	1BLK42S171A	Pegasus	361	na	3.65	107	12.3	88	7.1	NA	4.15	1KB	1KB	92	na	Z:\DAC\RAW DATA
7-Jul	3141P	1BLK42QRT188A	Pegasus	1.84	na	11.6	256	2.11	15/20/9/1	35.5	108	8.43	1KB	1KB	95	na	Z:\DAC\RAW DATA
8-Jul	3145P	1BLK42QRT189A	Pegasus	752	na	5.41	124	184	101	14.8	NA	11.9	1KB	1KB	176/95	na	Z:\DAC\RAW DATA
11-Jul	3157P	1BLK42PO192A	Pegasus	2.29	na	13	279	35.2	369	43.3	113	20.6	1KB	1KB	206	na	Z:\DAC\RAW DATA
11-Jul	3159P	1BLK42PO192B	Pegasus	1.11	na	8.95	199	55.5	1	21.6	25.9	20.6	1KB	1KB	NA	na	Z:\DAC\RAW DATA
12-Jul	3161P	1BLK42LM193A	Pegasus	1.51	427/407	9.62	214	41.7	359	28.8	67.6	4.29	1KB	1KB	215	na	Z:\DAC\RAW DATA
13-Jul	3165P	1BLK42LM194A	Pegasus	1.5	na	10.5	255	36.4	295	28.9	na	11.5	1KB	1KB	na	na	Z:\DAC\RAW DATA
13-Jul	3167P	1BLK42JS194B	Pegasus	329	na	3.65	106	4.93	2	7.36	11	11.5	1KB	1KB	106/123	NA	Z:\DAC\RAW DATA
15-Jul	3173P	1BLK42KS196A	Pegasus	160	96/28	2.73	63.2	na	na	3.33	7.6	1.19	1KB	1KB	11	NA	Z:\DAC\RAW DATA

Received from

Name [illegible]
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 8/5/2015

15-22

3. 3571G, 3585G, 3593G, 3595G

DATA TRANSFER SHEET
PALAWAN 12/17/15

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	
20-Nov-15	3565	2BLK42PQR337A	GEMINI	NA	92	535	202	na	na	25.4	na	6.96	1KB	1KB	22/24/22/48/51	NA	Z:\DAC\RAW DATA
21-Nov-15	3571	2BLK42Tv338A	GEMINI	NA	171	370	160	na	na	14.6	na	640	1KB	1KB	22/24/22/48/51	NA	Z:\DAC\RAW DATA
26-Nov-15	3573	2BLK42Ov339A	GEMINI	NA	484	1	227	na	na	19.7	na	12.1	1KB	1KB	24/22/48/53/51/30	NA	Z:\DAC\RAW DATA
27-Nov-15	3575	2BLK42OQ339B	GEMINI	NA	734	530	218	na	na	22.3	na	12.1	1KB	1KB	24/22/30/53/50/48/51	NA	Z:\DAC\RAW DATA
28-Nov-15	3581	2BLK42NPQ341A	GEMINI	NA	872	484	232	na	na	21.2	na	8.55	1KB	NA	24/22/21/27/30/53/50/48/51	NA	Z:\DAC\RAW DATA
30-Nov-15	3585	2BLK42Nv342A	GEMINI	NA	1080	558	234	na	na	23	na	5.29	1KB	1KB	24/22/21/28/27/30/53/50/48/51	NA	Z:\DAC\RAW DATA
30-Nov-15	3593	2BLK42TwEwF344A	GEMINI	NA	1343	523	227	na	na	20.9	na	11.4	1KB	1KB	53/50/48/17	NA	Z:\DAC\RAW DATA
1-Dec-15	3595	2BLK42US344B	GEMINI	NA	253	387	156	na	na	17.4	na	11.4	1KB	1KB	17/16	NA	Z:\DAC\RAW DATA

transferred twice

Received from

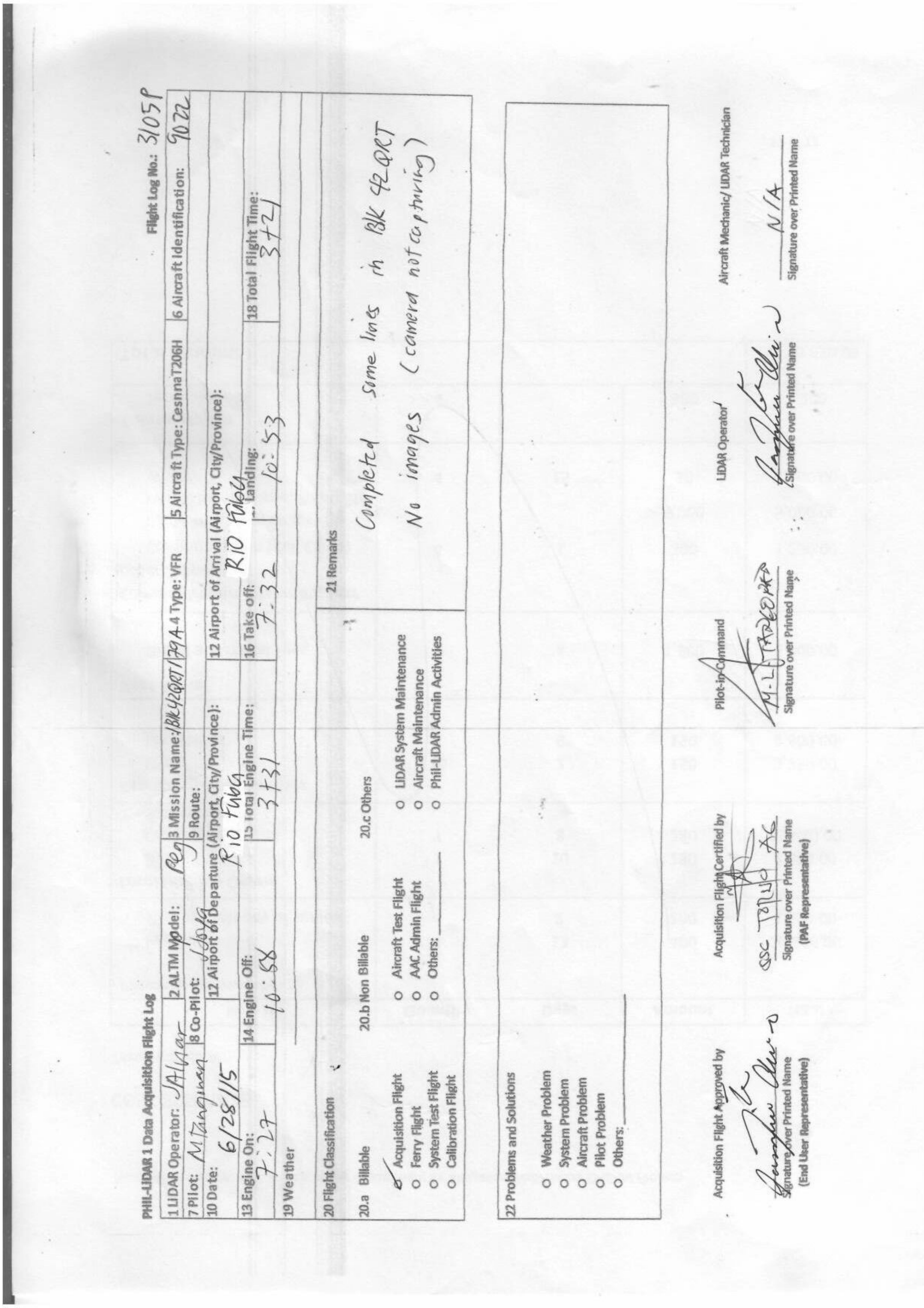
Name C. Joaquin
Position
Signature

Received by

Name AC Bongat
Position SSRS
Signature 1/5/2016

ANNEX 6. FLIGHT LOGS

1. Flight Log for 3105P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3105P

1 LiDAR Operator: J Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK42QRT179A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: [illegible]	9 Route:			
10 Date: 6/28/15	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 7:27	14 Engine Off: 10:58	15 Total Engine Time: 3+31	16 Take off: 7:32	17 Landing: 10:53	18 Total Flight Time: 3+21
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Completed some lines in BLK 42QRT

No images (camera not capturing)

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

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

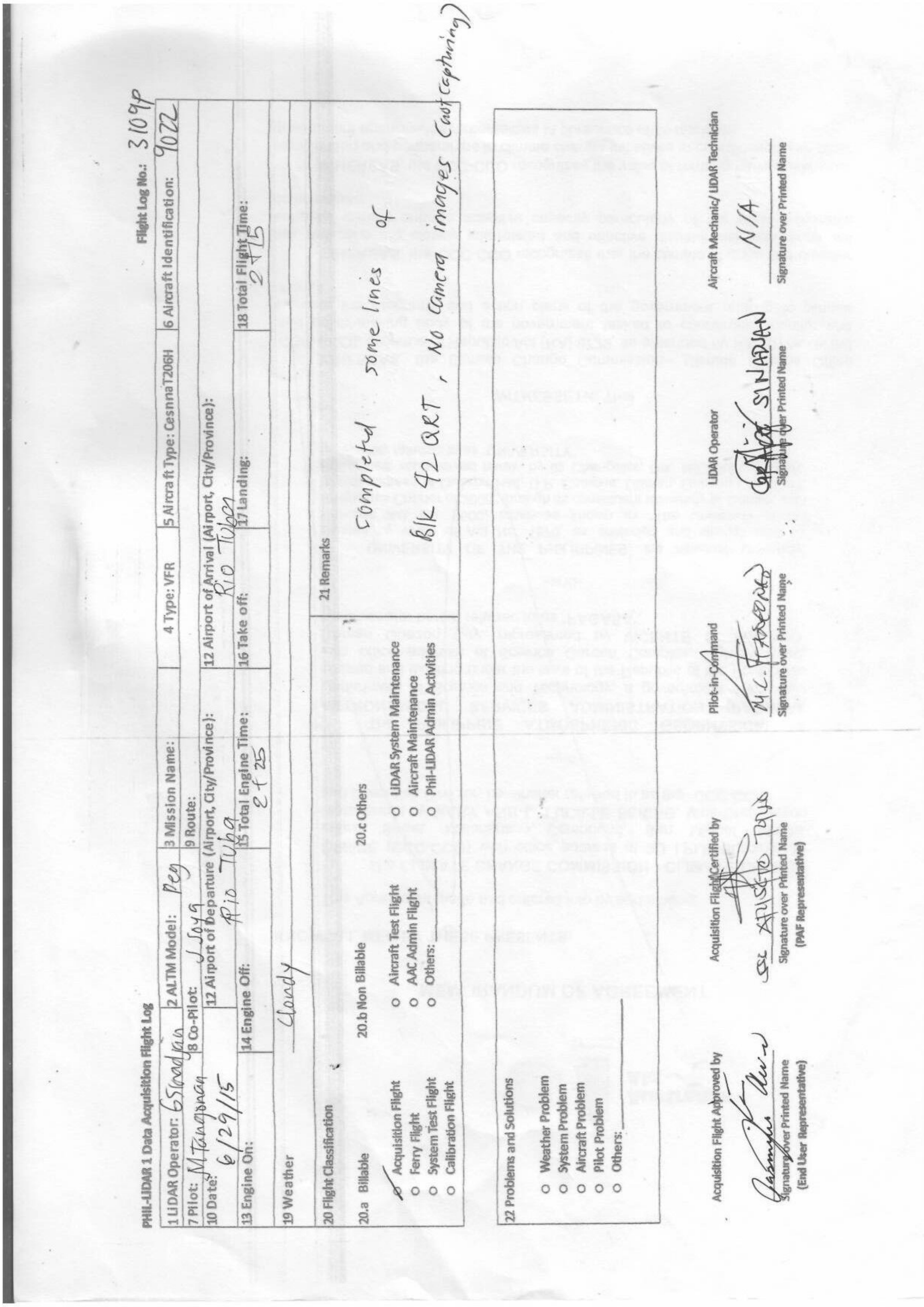
Acquisition Flight Certified by — SSC Tolu AC — Signature over Printed Name (PAF Representative)

Pilot-in-Command — M.L. Tangonan — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — N/A — Signature over Printed Name

2. Flight Log for 3109P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3109P

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Soya	9 Route:			
10 Date: 6/29/15	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 2+25	16 Take off:	17 Landing:	18 Total Flight Time: 2+15
19 Weather: Cloudy					

20 Flight Classification

20.a Billable
- Acquisition Flight (checked)
- 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

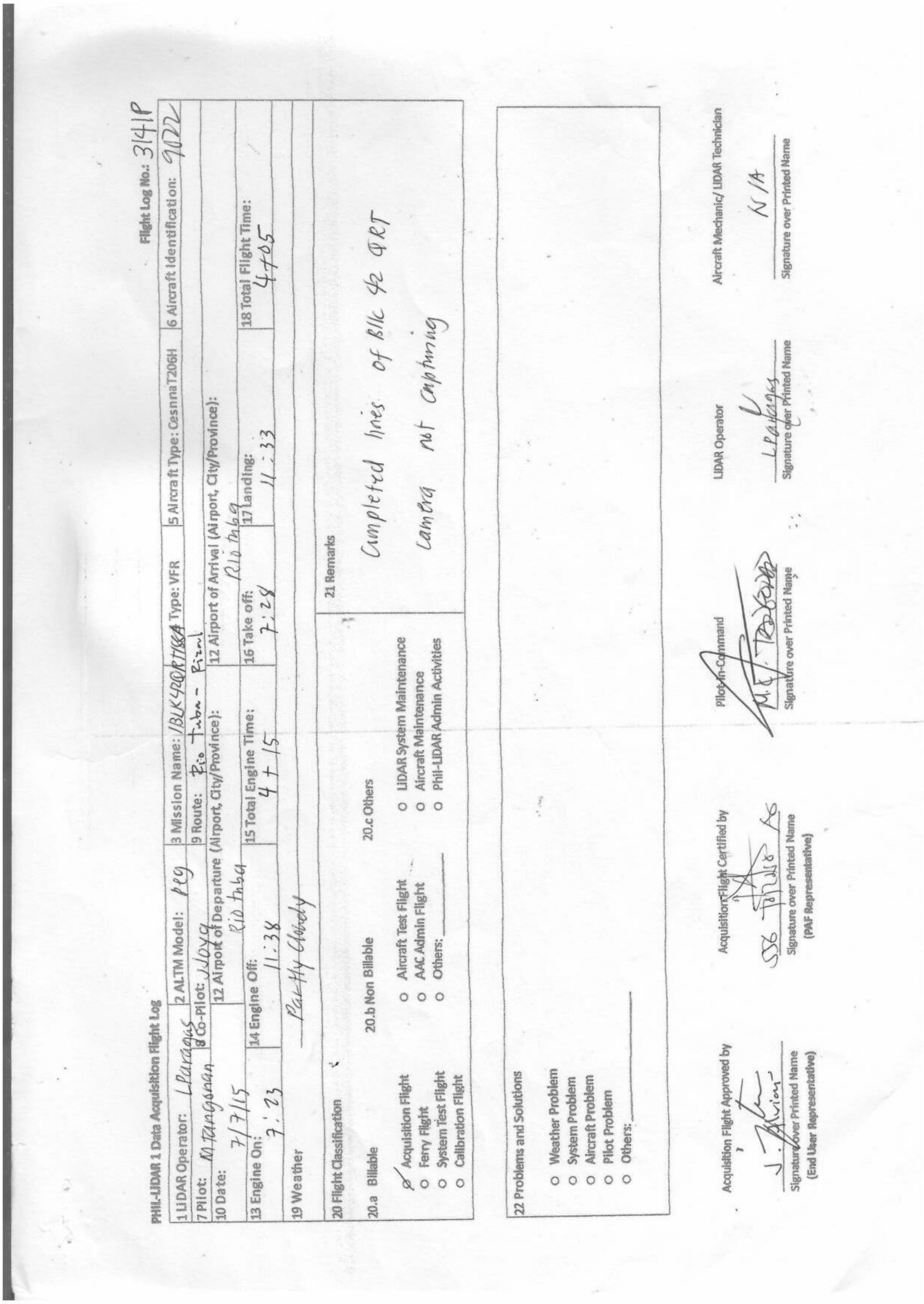
21 Remarks

Completed some lines of Blk 42QRT, No camera images (not capturing)

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Jasmin Alvarez (signature)	SSL Aljuseto Tayao (signature)	M.L. Fajardo (signature)	G Sinadjan (signature)	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 3141P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3141P

1 LiDAR Operator: LParagas	2 ALTM Model: Peg	3 Mission Name: 1BLK42QRT188A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba - Rizal			
10 Date: 7/7/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 7:23	14 Engine Off: 11:38	15 Total Engine Time: 4+15	16 Take off: 7:28	17 Landing: 11:33	18 Total Flight Time: 4+05
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Completed lines of Blk 42 QRT
camera not capturing

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

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

4. Flight Log for 3145P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3145P

1 LIDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42QRT189A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba – Rizal			
10 Date: 7/8/15	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 9:56	14 Engine Off: 12:11	15 Total Engine Time: 2+15	16 Take off: 10:01	17 Landing: 12:06	18 Total Flight Time: 2+05
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Completed some lines of BLK42QRT
no camera captures

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Alviar	SSgt Toledo	M. C. Tangonan	Grace Sinadjan	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

5. Flight Log for 3571G Mission

Data Acquisition Flight Log — Flight Log No. 3571G

1 LiDAR Operator: J ALMALVEZ	2 ALTM Model: LEM	3 Mission Name: 2BLK42TV338A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: A. LAGCO	9 Route: RTN - RTN			
10 Date: Dec. 4, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 1341	14 Engine Off: 1646	15 Total Engine Time: 03+05	16 Take off: 1346H	17 Landing: 1641H	18 Total Flight Time: 2+55
19 Weather: heavy buildups					

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

Error code 10 was experienced during transit.
Surveyed BLK42T and voids from previous flight.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
G. Hipolito	A2C MAGNAYE PAF	A. Lim	J. Almalvez	G. Antonio
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

6. Flight Log for 3585G Mission

Data Acquisition Flight Log

Flight Log No.: 3585G

1 LiDAR Operator: J ALMALVEZ	2 ALTM Model: GEM	3 Mission Name: 2BLK42N342A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: R. LAGCO	9 Route: Rio Tuba - Rio Tuba			
10 Date: Dec. 8, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 0700	14 Engine Off: 1053	15 Total Engine Time: 3+53	16 Take off: 0707H	17 Landing: 1049H	18 Total Flight Time: 3+42
19 Weather: Cloudy					

20 Flight Classification

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

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

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

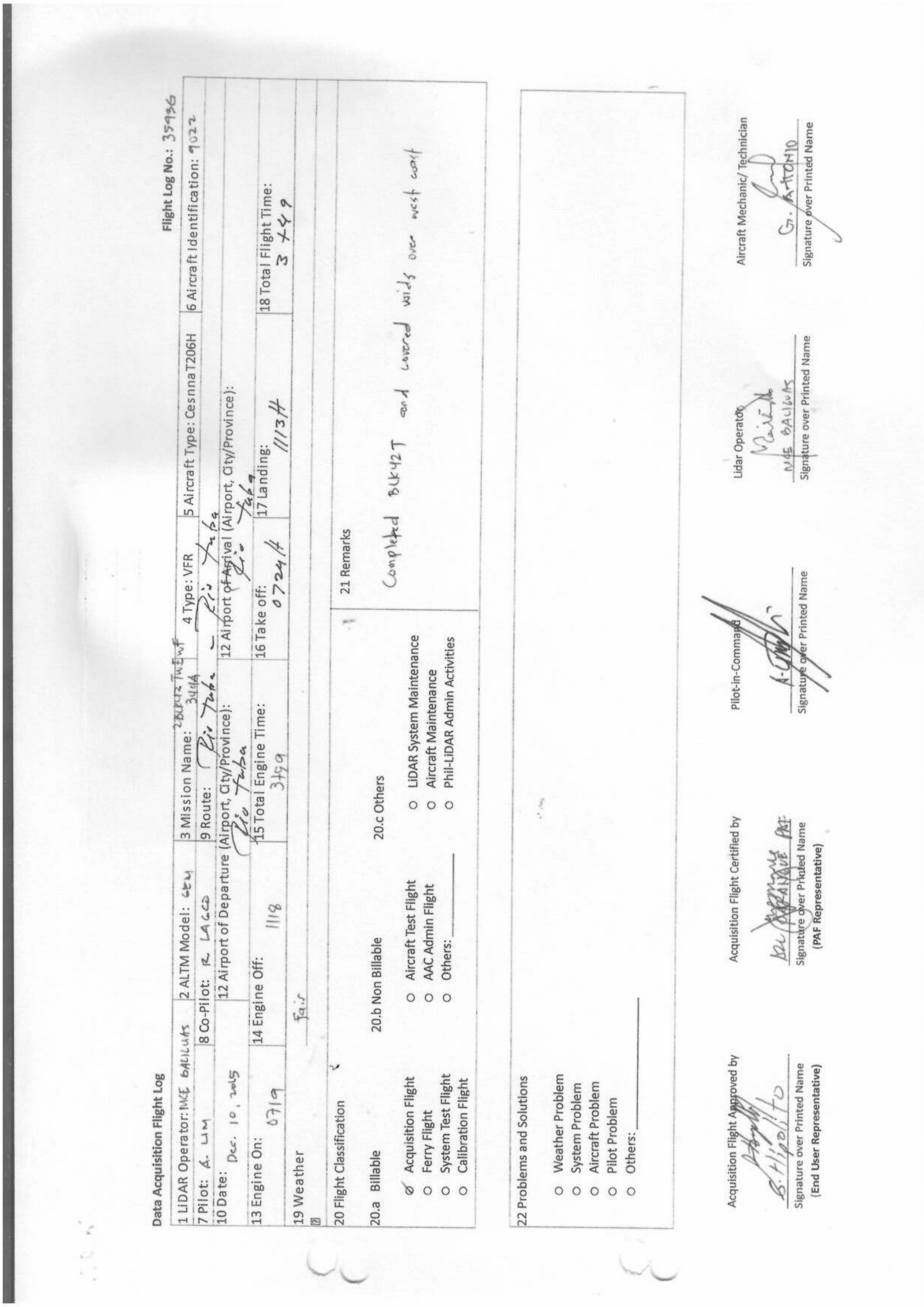
21 Remarks

Completed BLK42N with voids due to clouds

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
S. LIPDA (?)	A2C [illegible] PAF	[illegible]	J. ALMALVEZ	G. ANTONIO
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 for 3593G Mission



Data Acquisition Flight Log

Flight Log No.: 3593G

1 LiDAR Operator: MCE BALILUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK42TWEWF 344A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: R. LAGCO	9 Route: Rio Tuba – Rio Tuba			
10 Date: Dec. 10, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 0719	14 Engine Off: 1118	15 Total Engine Time: 3+59	16 Take off: 0724H	17 Landing: 1113H	18 Total Flight Time: 3+49
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed BLK42T and covered voids over west coast

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
S. Hipolito	[illegible] PARANAQUE PAF	A. LIM	MCE BALILUAS	G. ANTONIO
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

8. Flight Log for 3595G Mission

Data Acquisition Flight Log

Flight Log No.: 3595G

1 LiDAR Operator: J. Almalvez	2 ALTM Model: GEM	3 Mission Name: 2BLK42US349B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lacco	9 Route: Rio Tuba – Rio Tuba			
10 Date: Dec. 10, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 1433	14 Engine Off: 1714	15 Total Engine Time: 2+41	16 Take off: 1438H	17 Landing: 1709H	18 Total Flight Time: 2+31
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed 7 lines of BLK42S and 9 lines of BLK42U

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
G. Hipolito	[illegible] PAF	A. Lim	J. Almalvez	G. Antonio
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

ANNEX 7. FLIGHT STATUS REPORT

FLIGHT STATUS REPORT
RIO TUBA
June 28 to July 8, 2015 and December 4 to 10, 2015

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3105P	BLK 42QRT	1BLK42QR179A	J. Alviar	June 28	SURVEYED SOME LINE IN BLK 42Q, BLK 42R, BLK 42T. TOO CLOUDY. CAM ERROR: EMPTY STATUS STRING, NO CAPTURES MID FLIGHT DIGI: SOFTWARE STOPPED MID FLIGHT 288.38 SQ.KM.
3109P	BLK 42Q	1BLK42QR180A	G. Sinadjan	June 29	CLOUDY. CAM ERROR. 153.41 SQ.KM
3141P	BLK 42QRT	1BLK42QRT188A	L. Paragas	July 7	SURVEYED BLK 42Q, BLK 42T AND BLK 42R AT 1200M 318.93 SQ.KM
3145P	BLK 42R	1BLK42QRT189A	G. Sinadjan	July 8	SURVEYED BLK 42R BUT WITH GAPS DUE TO CLOUDS 108.39 SQ.KM.
3571G	BLK42 eT; 42Q voids	2BLK42Tv338A	JM Almalvez	04-Dec-15	Surveyed BLK42eT and voids/ gaps over Rio Tuba RBs
3585G	BLK42 eN; 42Q voids	2BLK42Nv342A	JM Almalvez	08-Dec-15	Completed BLK42eN with voids due to clouds; Covered voids over Rio Tuba
3593G	BLK42 eT; 42R,T voids	2BLK42TwEwF344A	MCE Baliguas	10-Dec-15	Completed BLK42eT and covered voids/gaps over west coast (42R,T)
3595G	BLK42 U,eS	2BLK42US344B	JM Almalvez	10-Dec-15	Surveyed 7 lines of BLK42eS and 9 lines of BLK42U; added a line to morning flight to completely cover Canipan RB

SWATH PER FLIGHT MISSION

Flight No. : 3105P

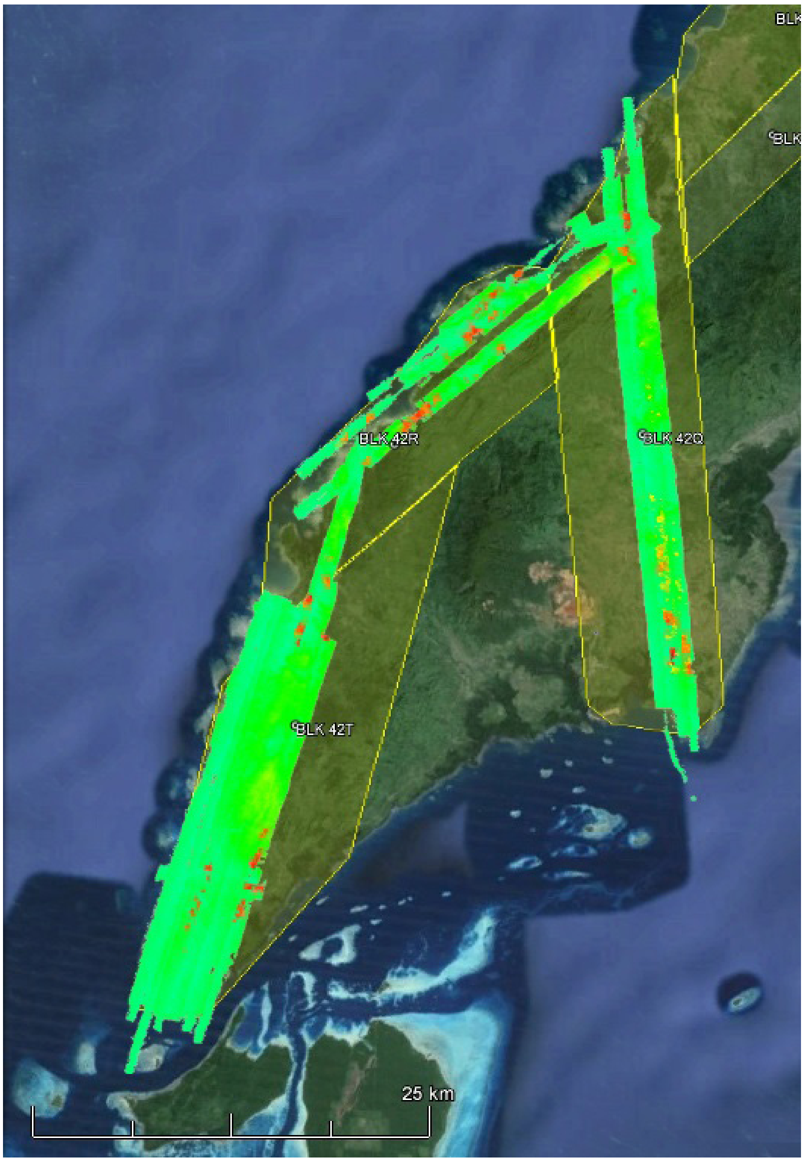
Area: BLK 42QRT

Mission Name: 1BLK42QR179A

Parameters: PRF 200 SF 30 FOV 50

Area Surveyed: 288.38 sq.km.

LAS



Flight No. : 3109P

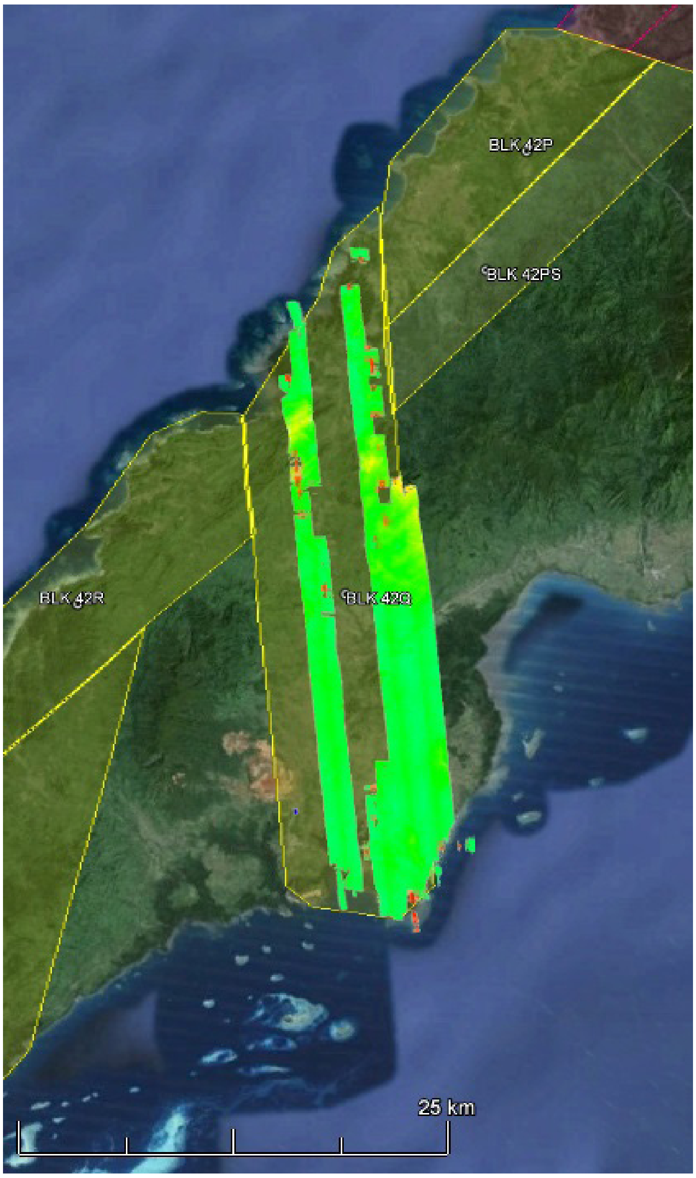
Area: BLK 42Q

Mission Name: 1BLK42QR180A

Parameters: PRF 200 SF 30 FOV 50

Area Surveyed: 153.41 sq.km.

LAS



Flight No. : 3141P

Area: BLK 42QRT

Mission Name: 1BLK42QRT188A

Parameters: PRF 200 SF 30 FOV 50

Area Surveyed: 318.93 sq.km.

LAS

Flight No. : 3145P

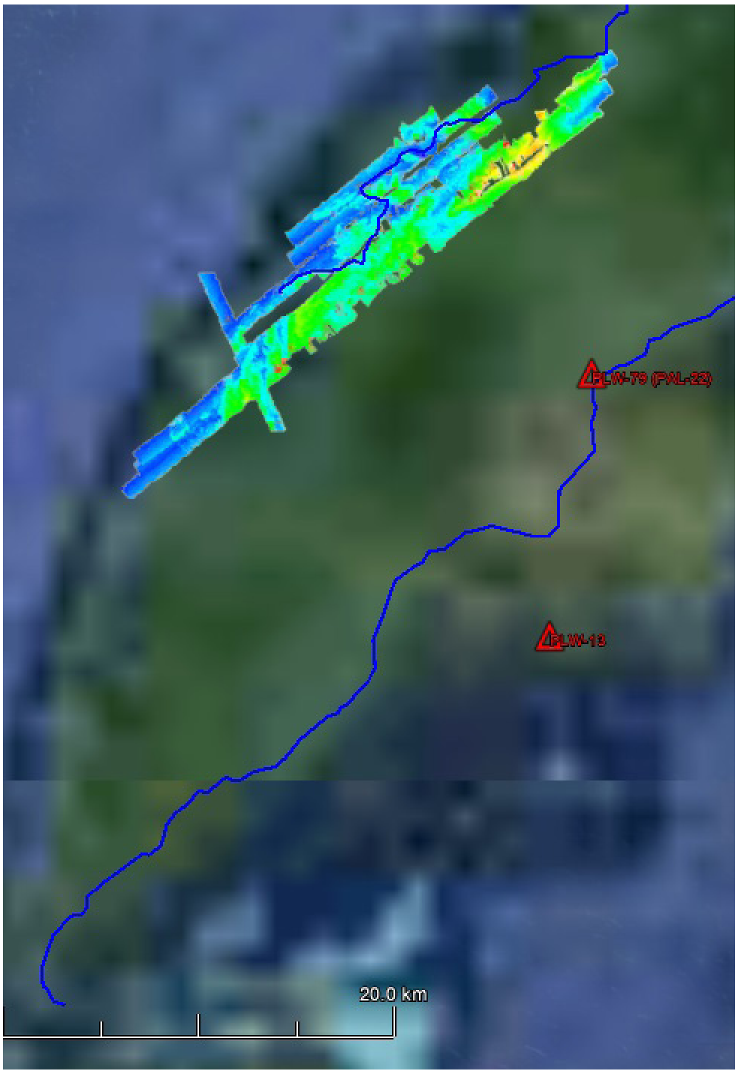
Area: BLK 42R

Mission Name: 1BLK42QRT189A

Parameters: PRF 200 SF 30 FOV 50

Area Surveyed: 108.39 sq.km.

LAS

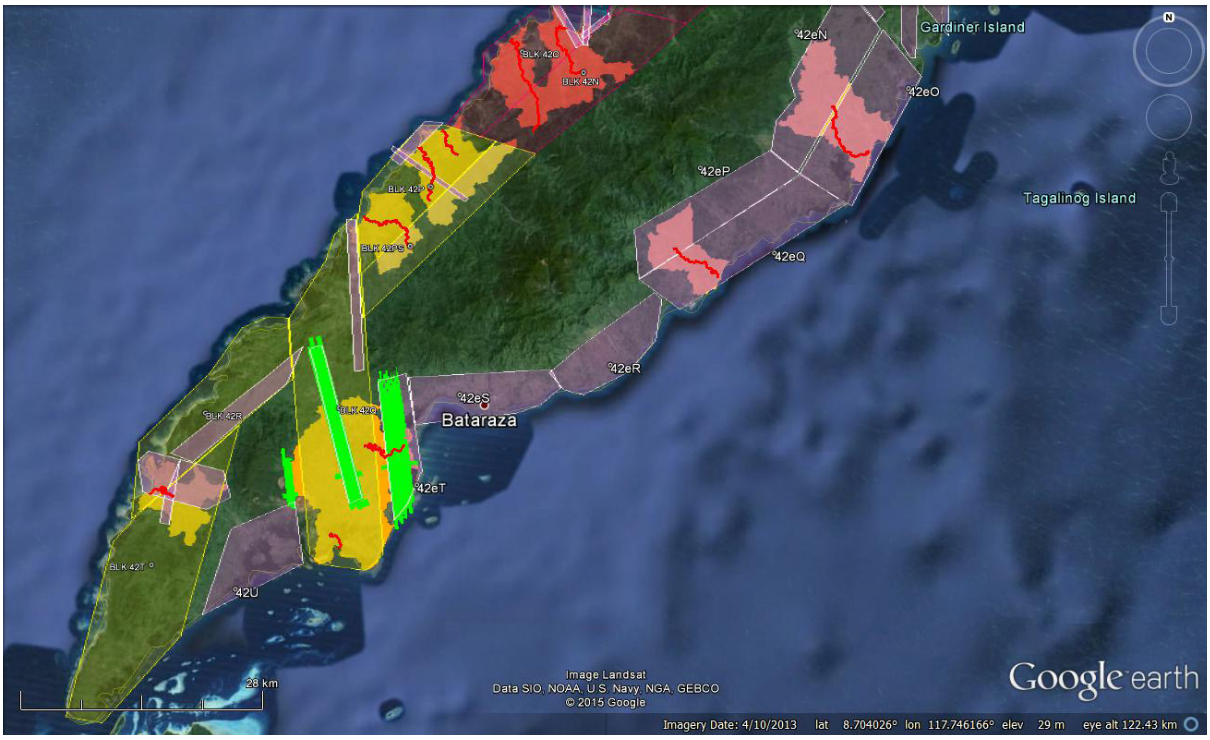


Flight No. : 3571G

Area: BLK 42 eT, 42Q voids/gaps

Mission Name: 2BLK42Tv338A

Area Surveyed: 92.441 sq.km.

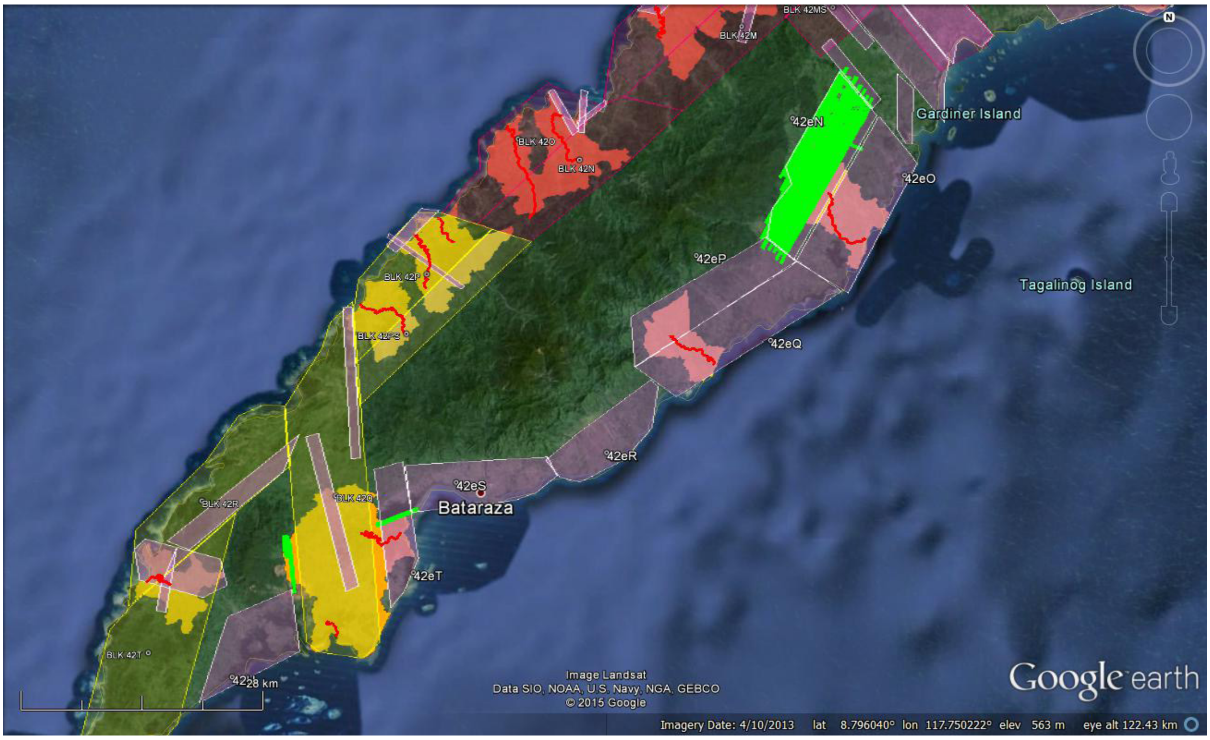


Flight No. : 3585G

Area: BLK 42 eN, 42Q voids/gaps

Mission Name: 2BLK42Nv342A

Area Surveyed: 119.527 sq.km.

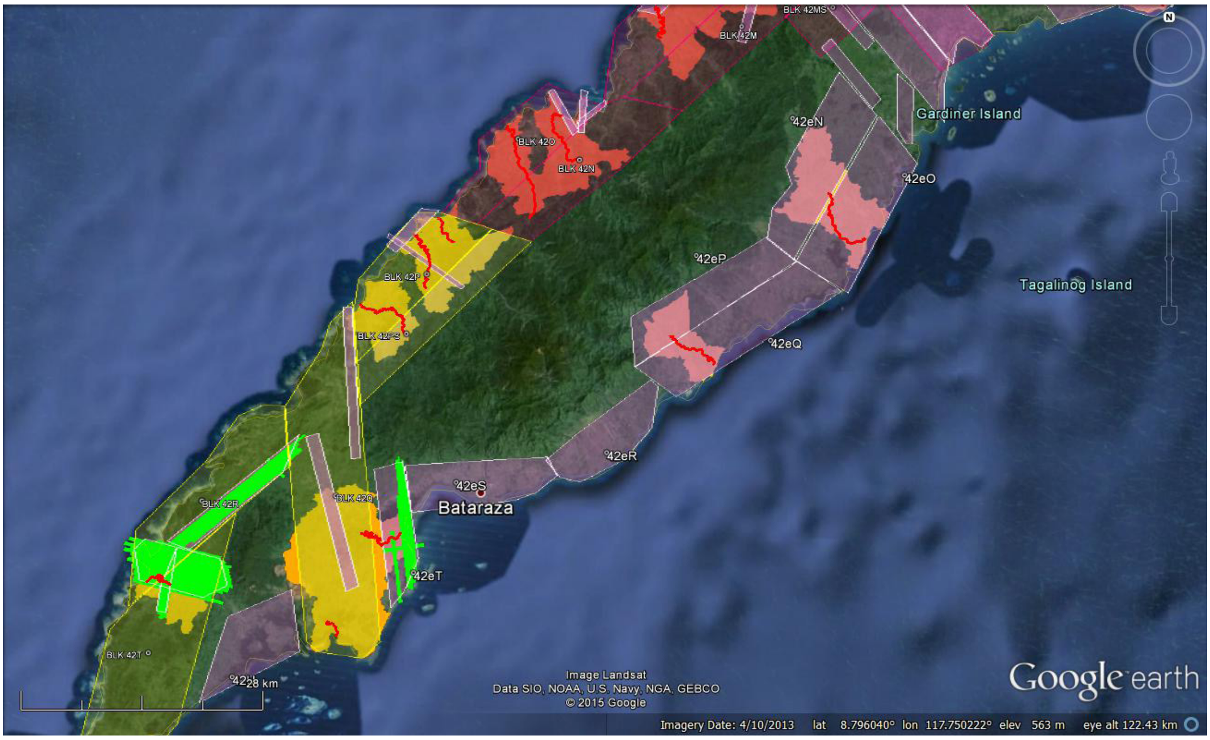


Flight No. : 3593G

Area: BLK 42 eT, 42R, 42Tv

Mission Name: 2BLK42TveT344A

Area Surveyed: 126.082 sq.km.

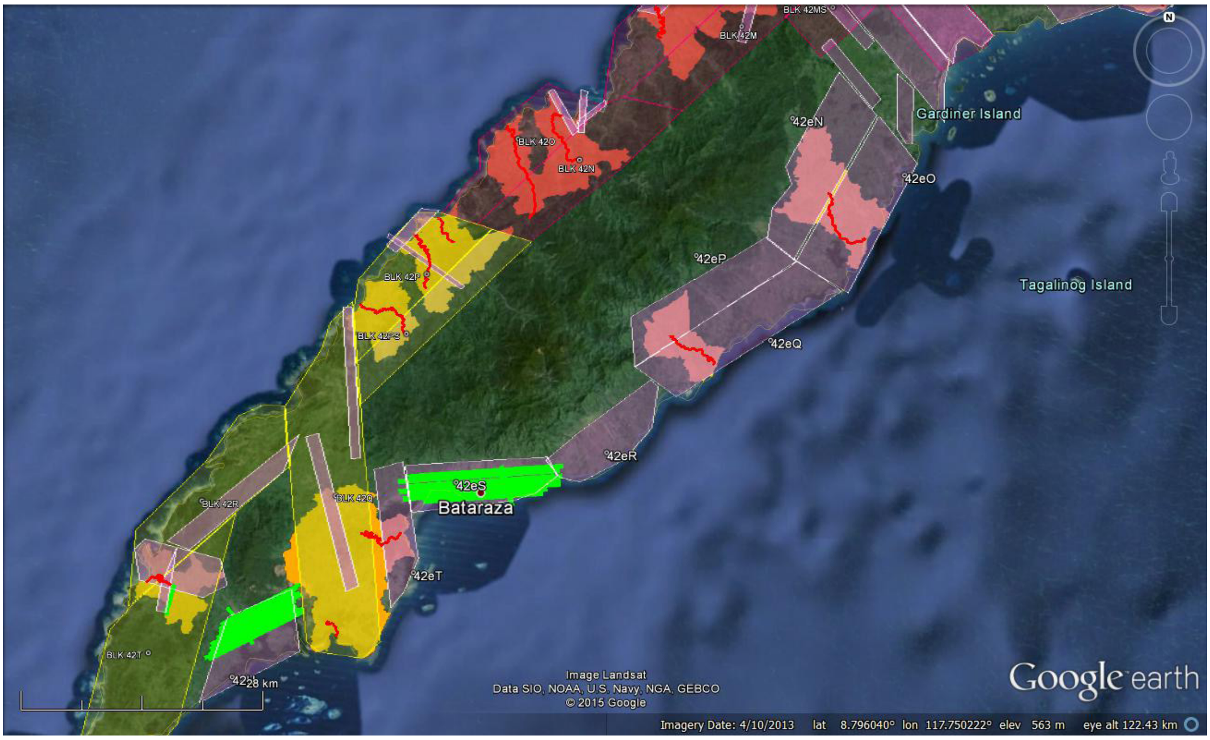


Flight No. : 3595G

Area: BLK 42 eS, eU

Mission Name: 2BLK42US344B

Area Surveyed: 107.577 sq.km.



ANNEX 8. MISSION SUMMARY REPORT

ANNEX G. MISSION SUMMARY REPORT

Flight Area	**Palawan**
Mission Name	**Block 42Q**
Inclusive Flights	3105P and 3109P
Range data size	47.70 GB
POS	360 MB
Image	36.90 GB
Transfer date	July 13, 2015
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)	2.30
RMSE for East Position (<4.0 cm)	2.40
RMSE for Down Position (<8.0 cm)	7.40
Boresight correction stdev (<0.001deg)	0.000201
IMU attitude correction stdev (<0.001deg)	0.000705
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	34.21
Ave point cloud density per sq.m. (>2.0)	3.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	307
Maximum Height	629.73
Minimum Height	41.42
Classification (# of points)	
Ground	191878544
Low vegetation	158669367
Medium vegetation	309684770
High vegetation	290534732
Building	3125298
Orthophoto	Yes
Processed by	Engr. Sheila Maye Santillan, Engr. Merven Matthew Natino, Alex John Escobido

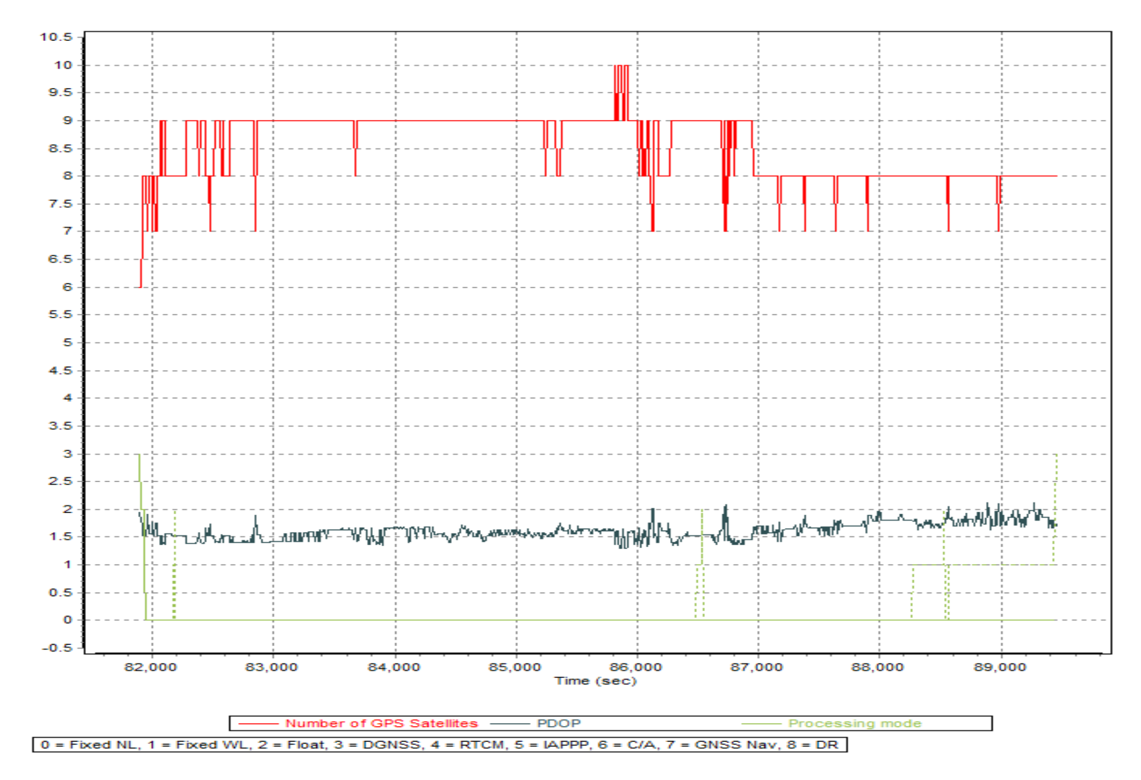


Figure 1.1.1. Solution Status

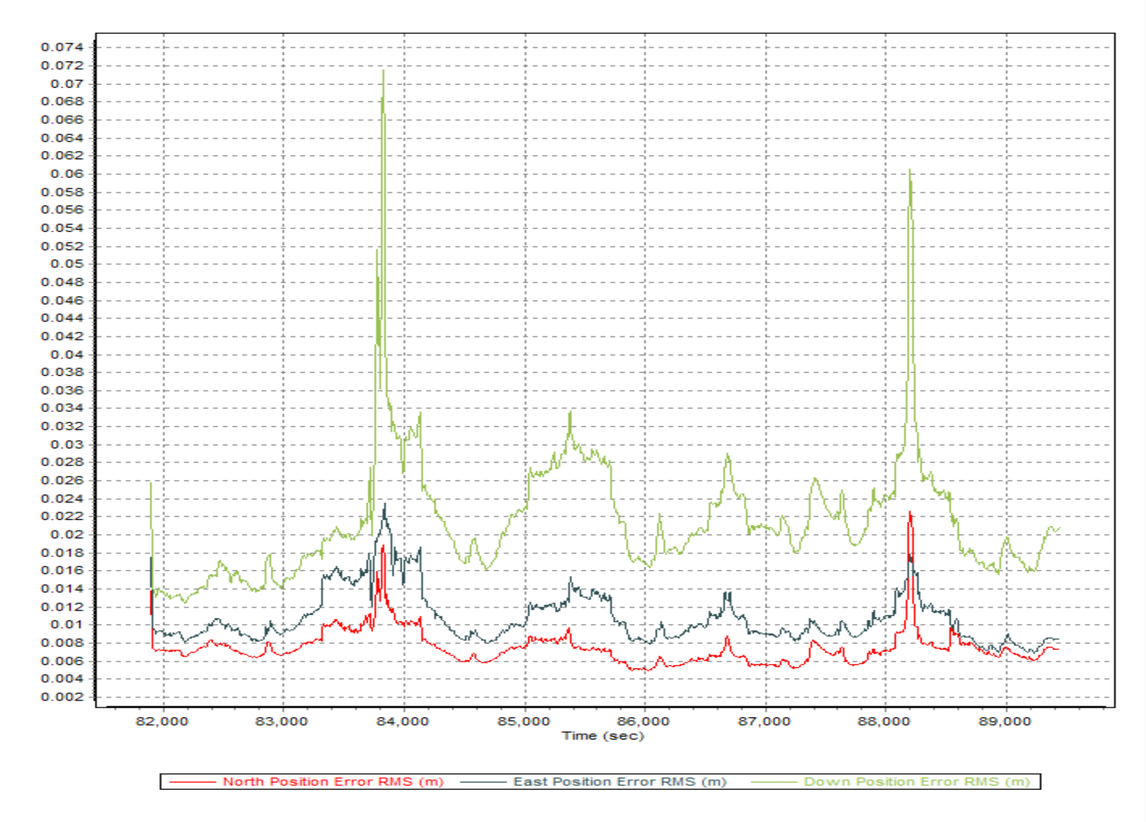


Figure 1.1.2. Smoothed Performance Metric Parameters

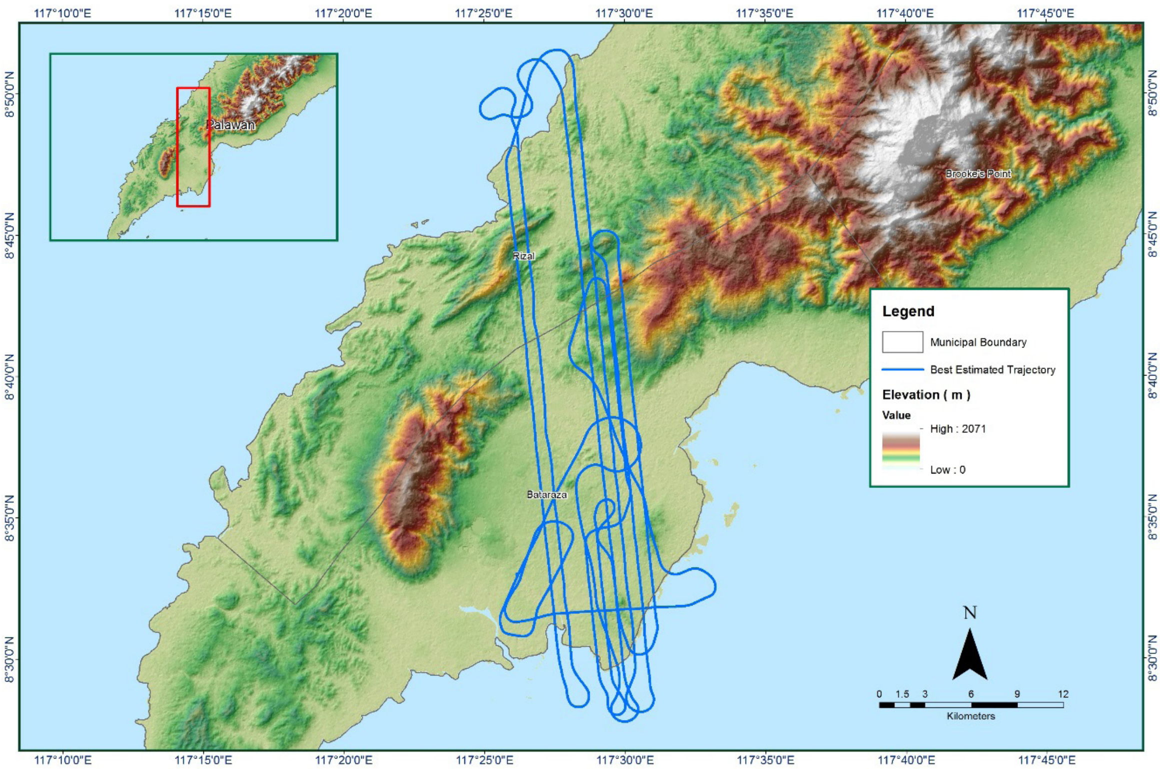


Figure 1.1.3. Best Estimated Trajectory

Figure 1.1.*4*. Coverage of LiDAR data

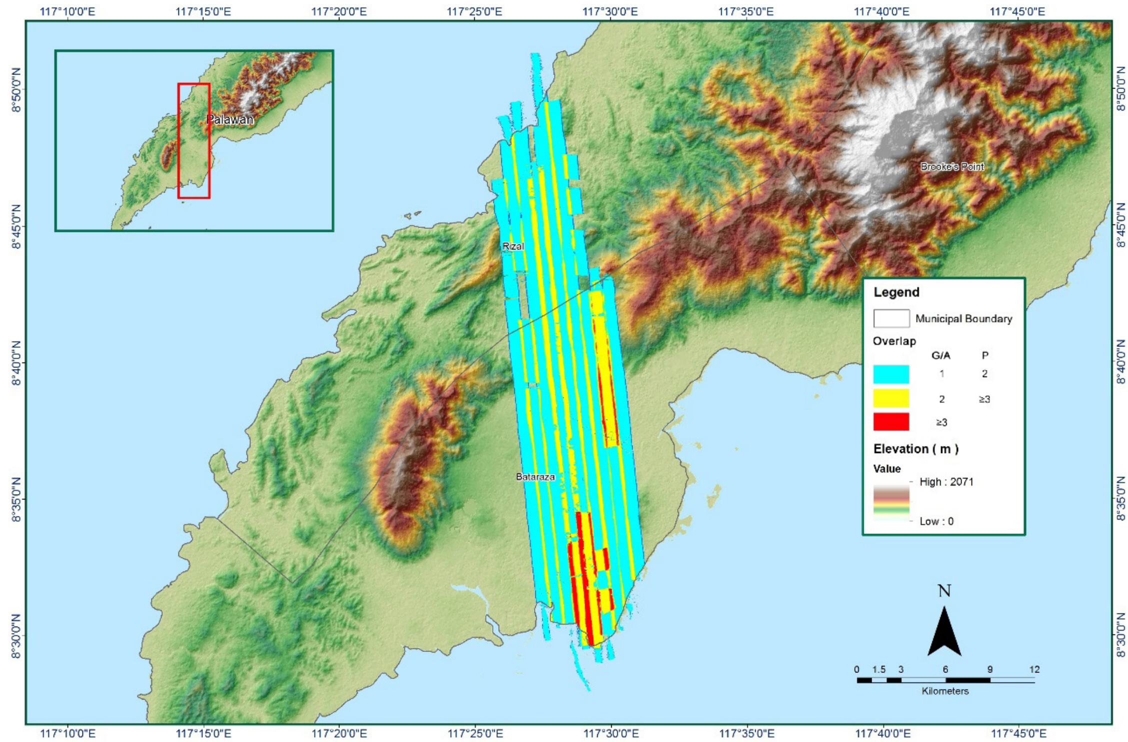


Figure 1.1.*5*. Image of data overlap

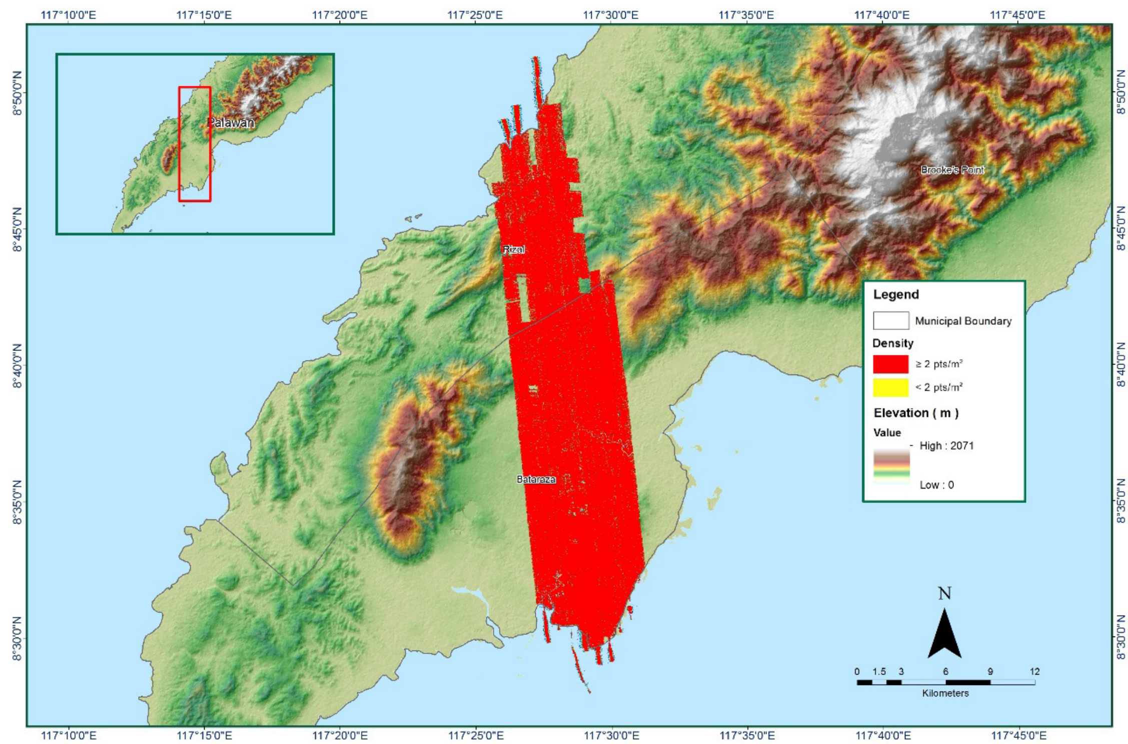


Figure 1.1.6. Density map of merged LiDAR data

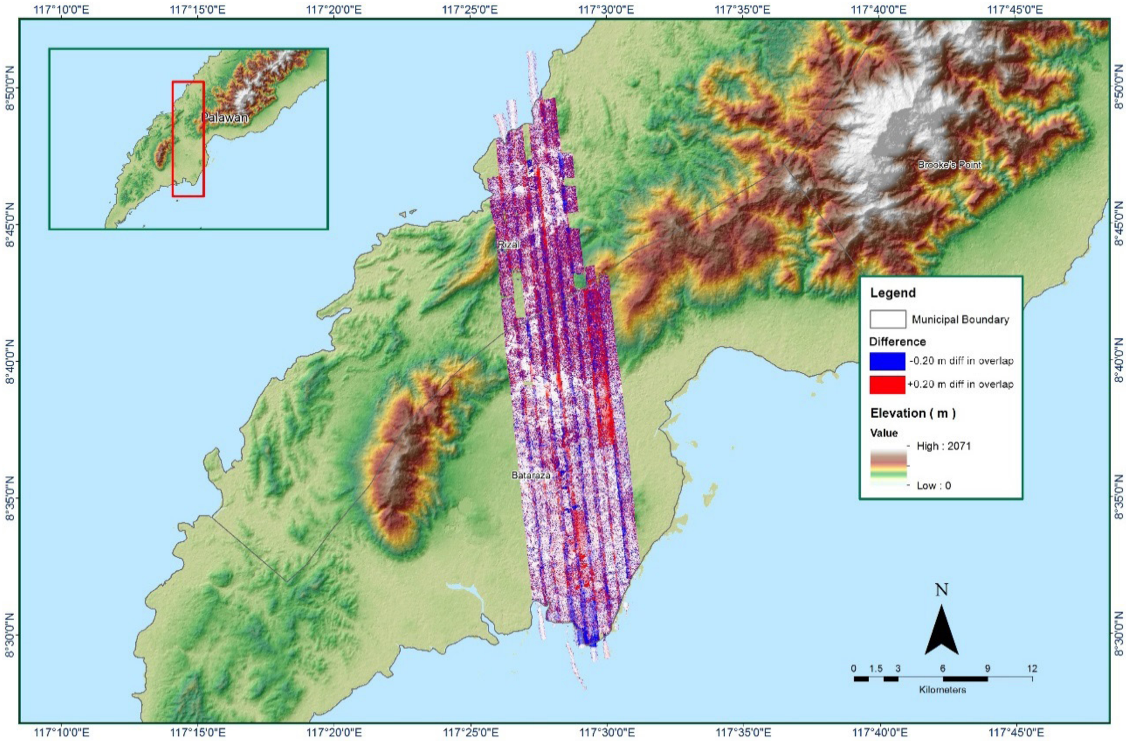


Figure 1.1.7. Elevation difference between flight lines

Flight Area	**Palawan**
Mission Name	**Block 42Q Additional**
Inclusive Flights	3141P
Range data size	35.50 GB
POS	256 MB
Image	2.11 GB
Transfer date	August 5, 2015
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)	1.65
RMSE for East Position (<4.0 cm)	1.80
RMSE for Down Position (<8.0 cm)	4.20
Boresight correction stdev (<0.001deg)	0.000191
IMU attitude correction stdev (<0.001deg)	0.001797
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	23.37
Ave point cloud density per sq.m. (>2.0)	2.56
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	187
Maximum Height	587.16
Minimum Height	40.58
Classification (# of points)	
Ground	126908409
Low vegetation	56499206
Medium vegetation	138672872
High vegetation	296610293
Building	4233860
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Merven Matthew Natino, Alex John Escobido

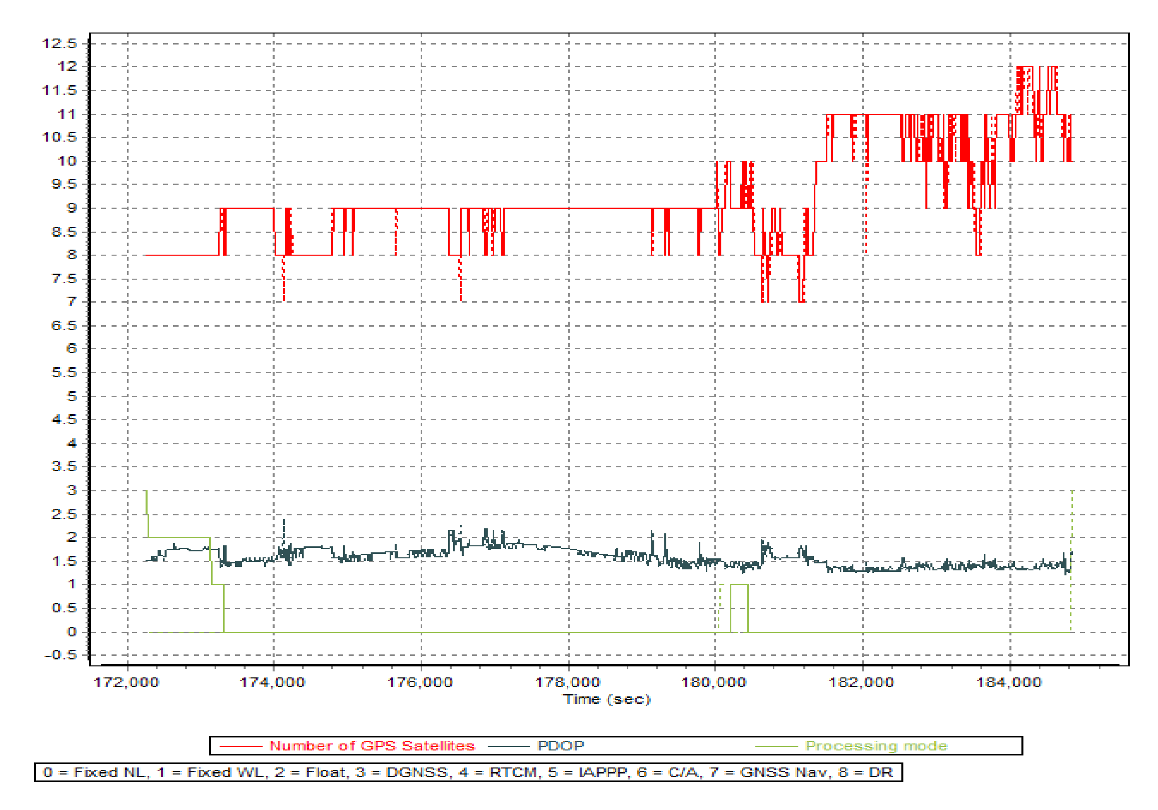


Figure 1.2.1. Solution Status

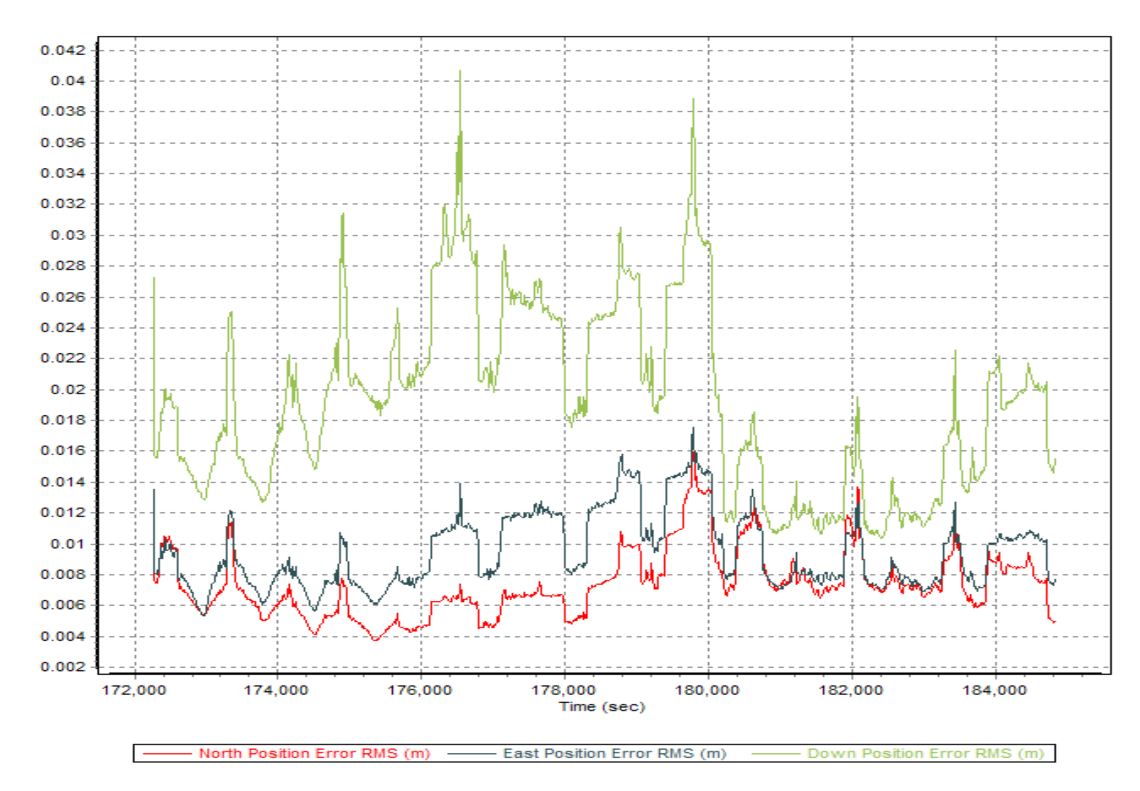


Figure 1.2.2. Smoothed Performance Metric Parameters

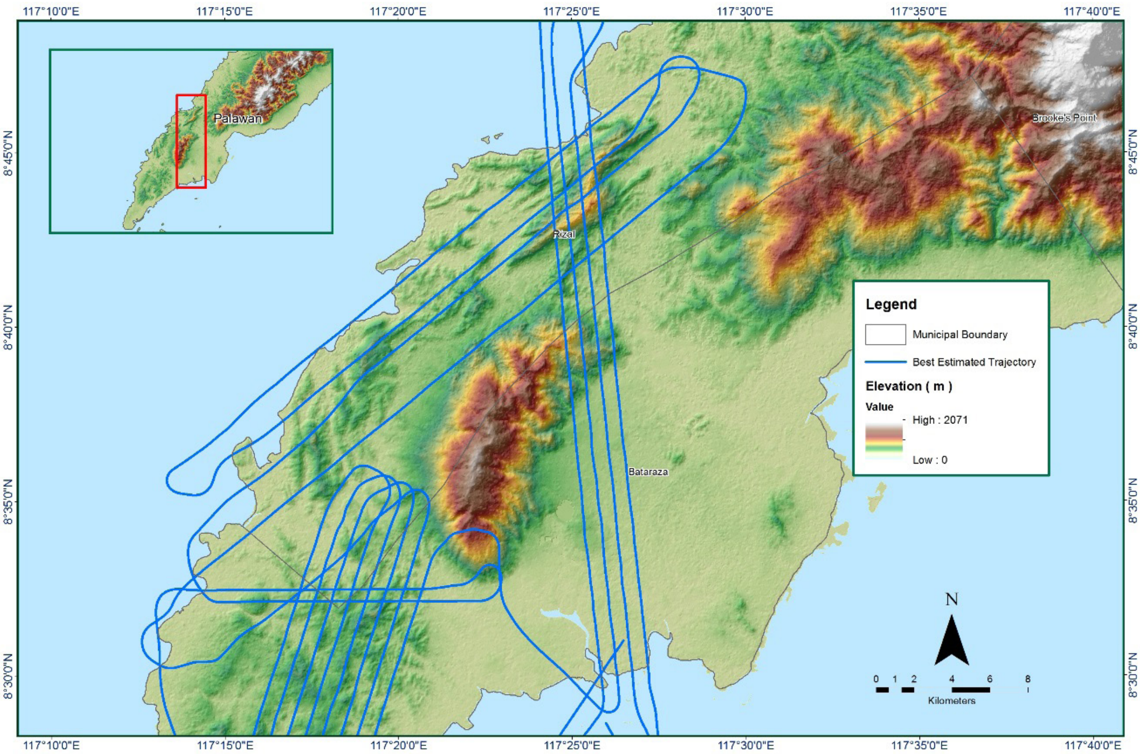


Figure 1.2.3. Best Estimated Trajectory

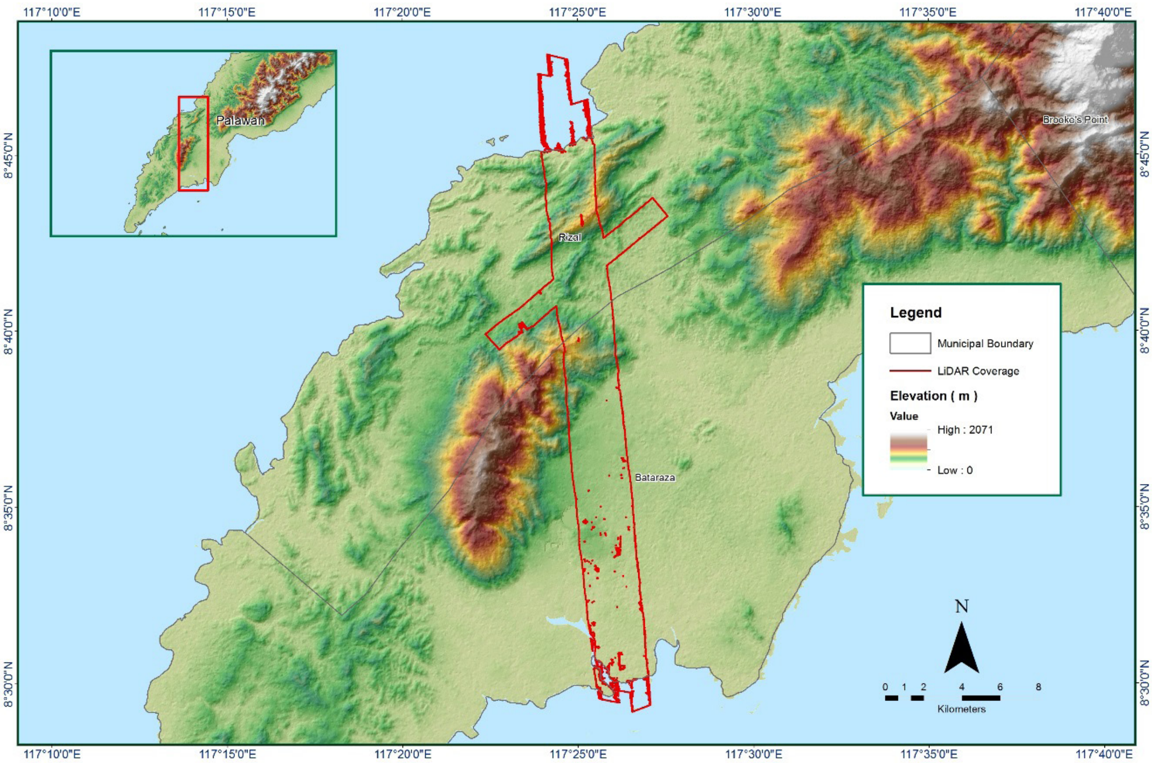


Figure *1.2.4*. Coverage of LiDAR data

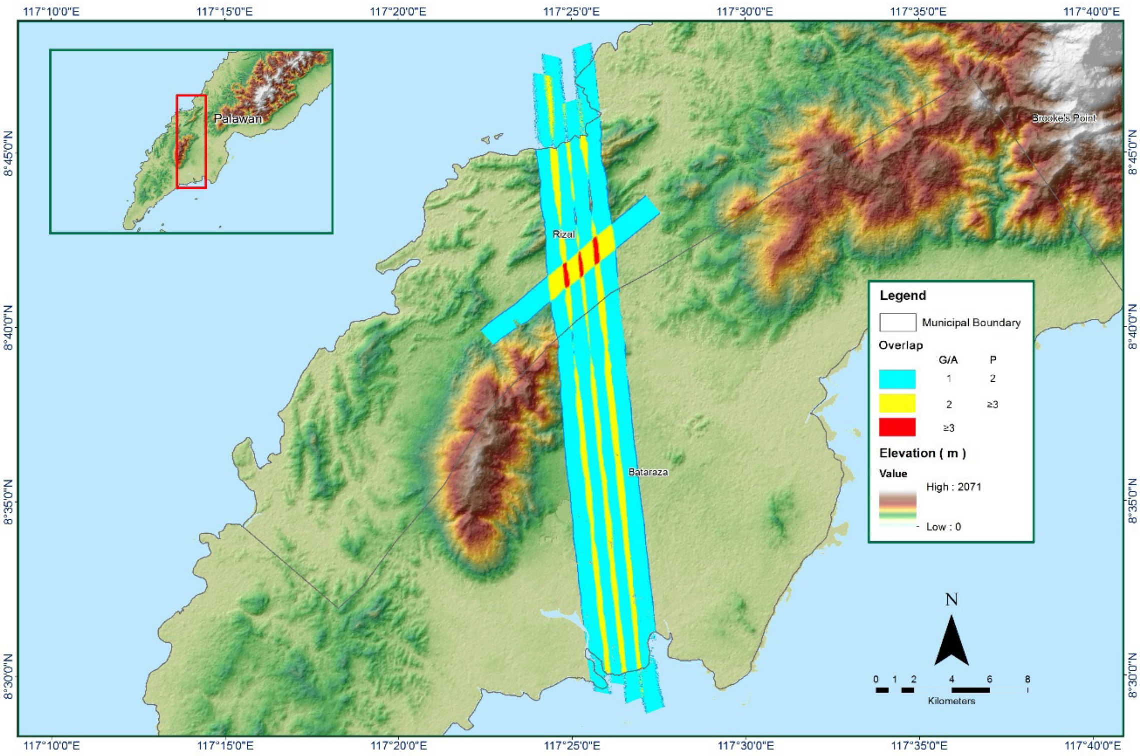


Figure *1.2.5*. Image of data overlap

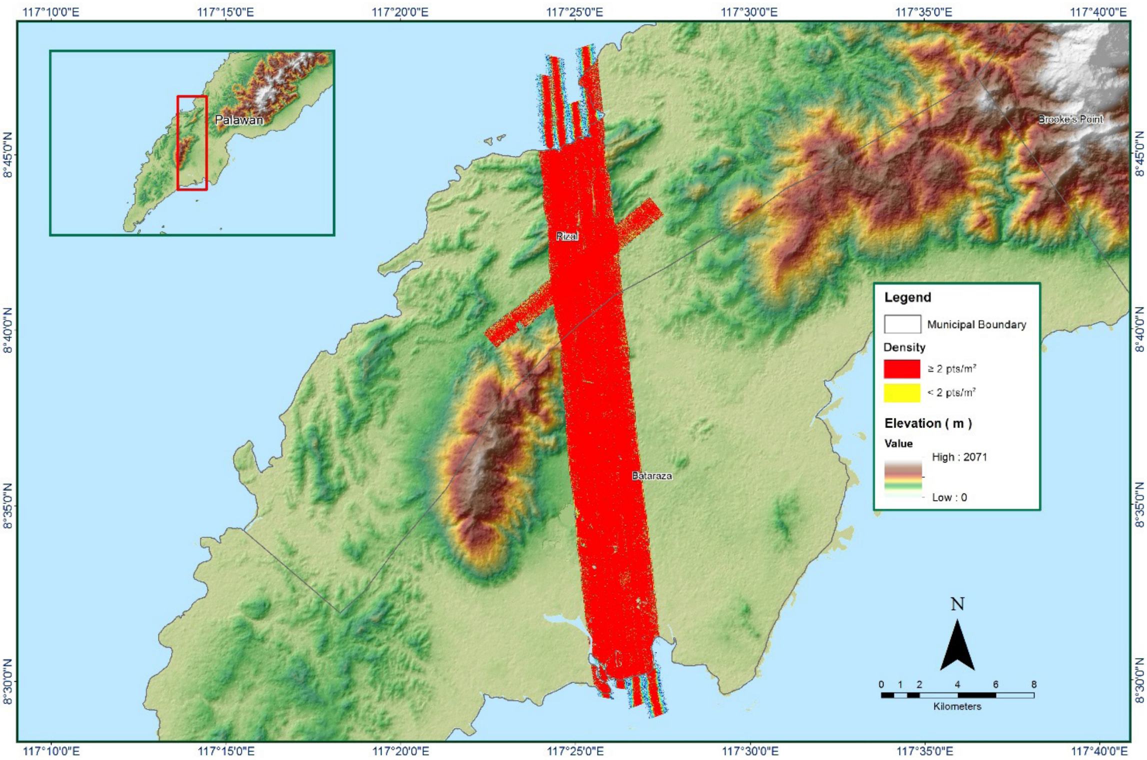


Figure 1.2.6. Density map of merged LiDAR data

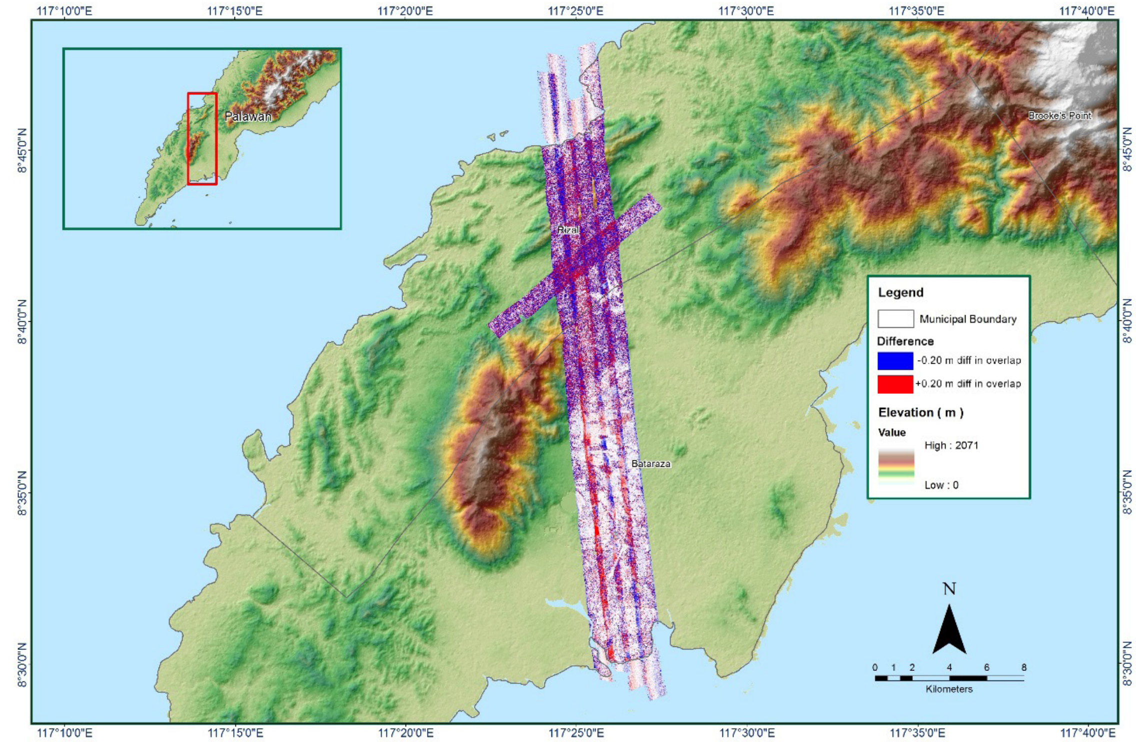


Figure *1.2.*7. Elevation difference between flight lines

Flight Area	**Palawan**
Mission Name	**Block 42R**
Inclusive Flights	3105P, 3141P and 3145P
Range data size	79.34 GB
POS	593 MB
Image	40.85 GB
Transfer date	July 13 and August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.60
RMSE for East Position (<4.0 cm)	1.50
RMSE for Down Position (<8.0 cm)	5.60
Boresight correction stdev (<0.001deg)	0.000191
IMU attitude correction stdev (<0.001deg)	0.001797
GPS position stdev (<0.01m)	0.0056
Minimum % overlap (>25)	43.57
Ave point cloud density per sq.m. (>2.0)	4.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	272
Maximum Height	555.15
Minimum Height	31.86
Classification (# of points)	
Ground	132124722
Low vegetation	108162652
Medium vegetation	313088489
High vegetation	932665830
Building	12880513
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Engr. Mark Sueden Lyle Magtalas

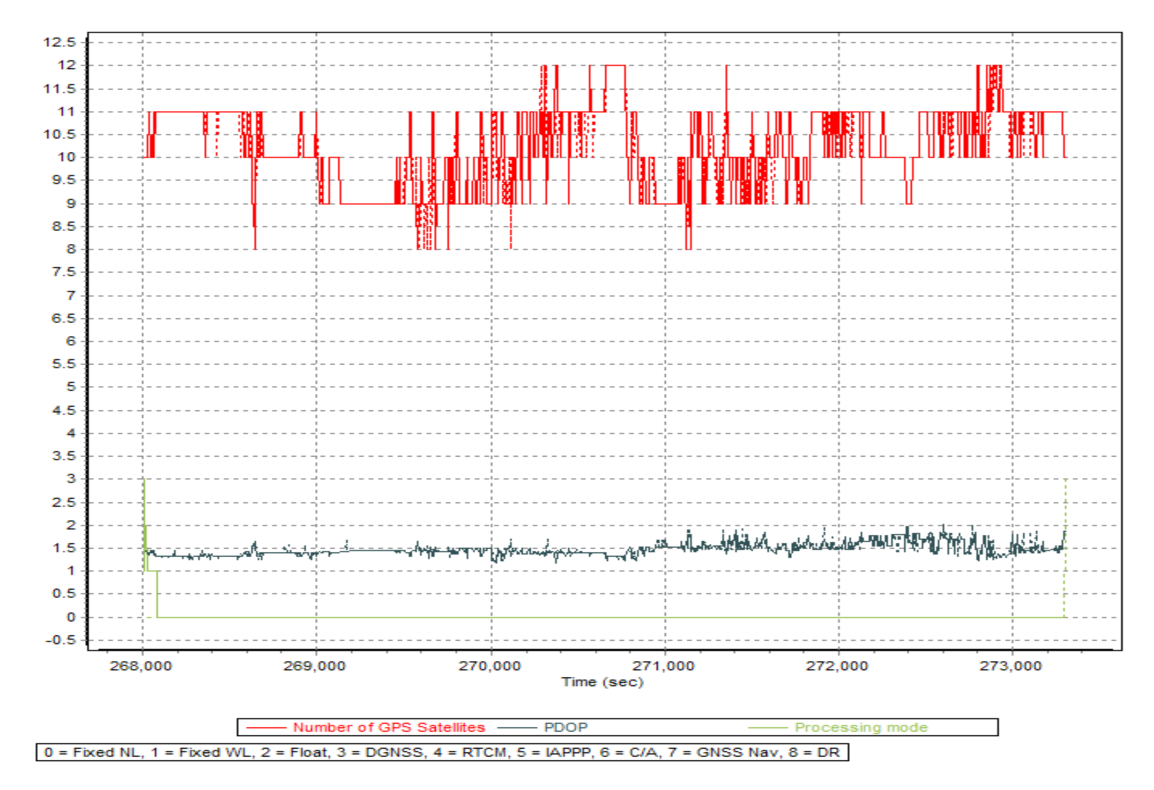


Figure 1.3.1. Solution Status

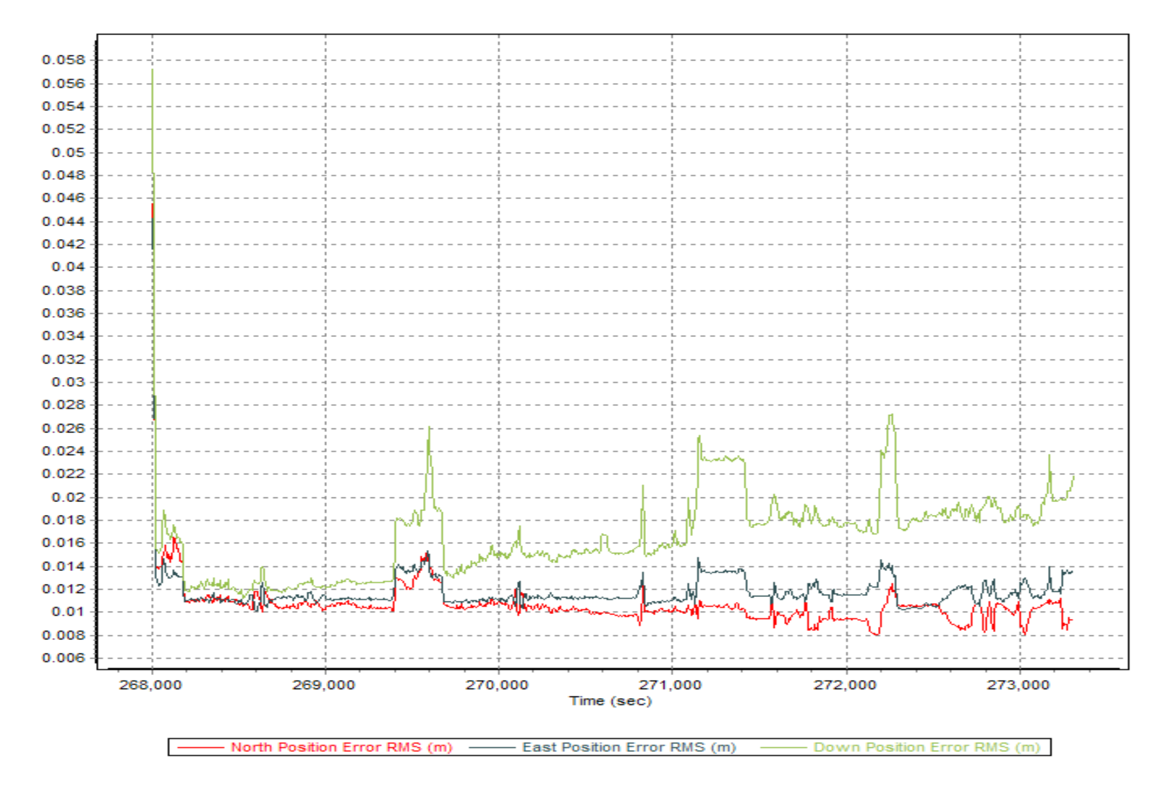


Figure 1.3.2. Smoothed Performance Metric Parameters

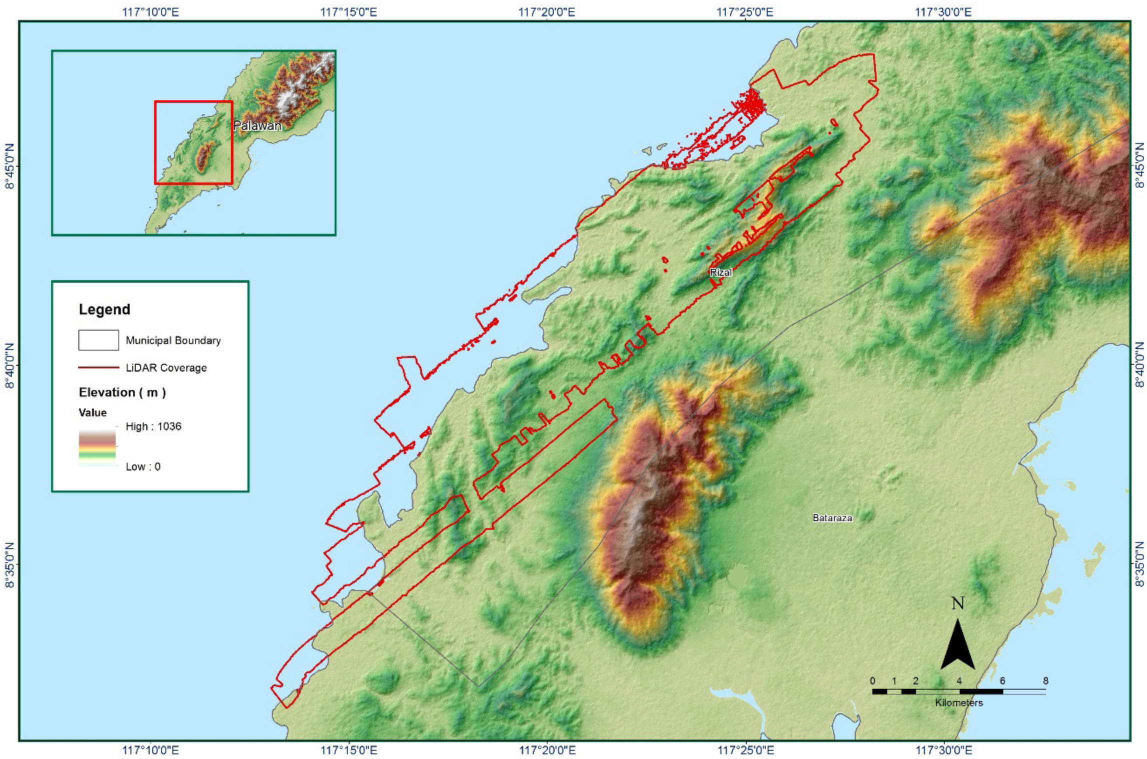
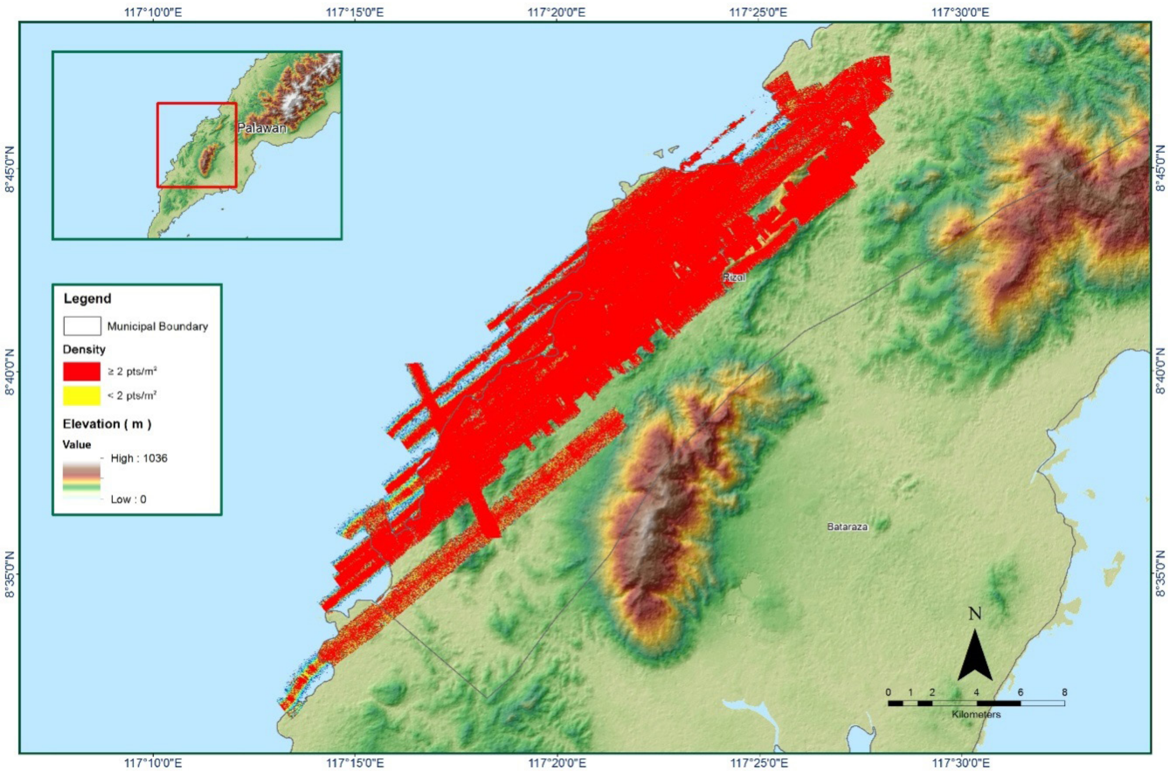


Figure 1.3.3. Best Estimated Trajectory

Figure 1.3.4. Coverage of LiDAR data



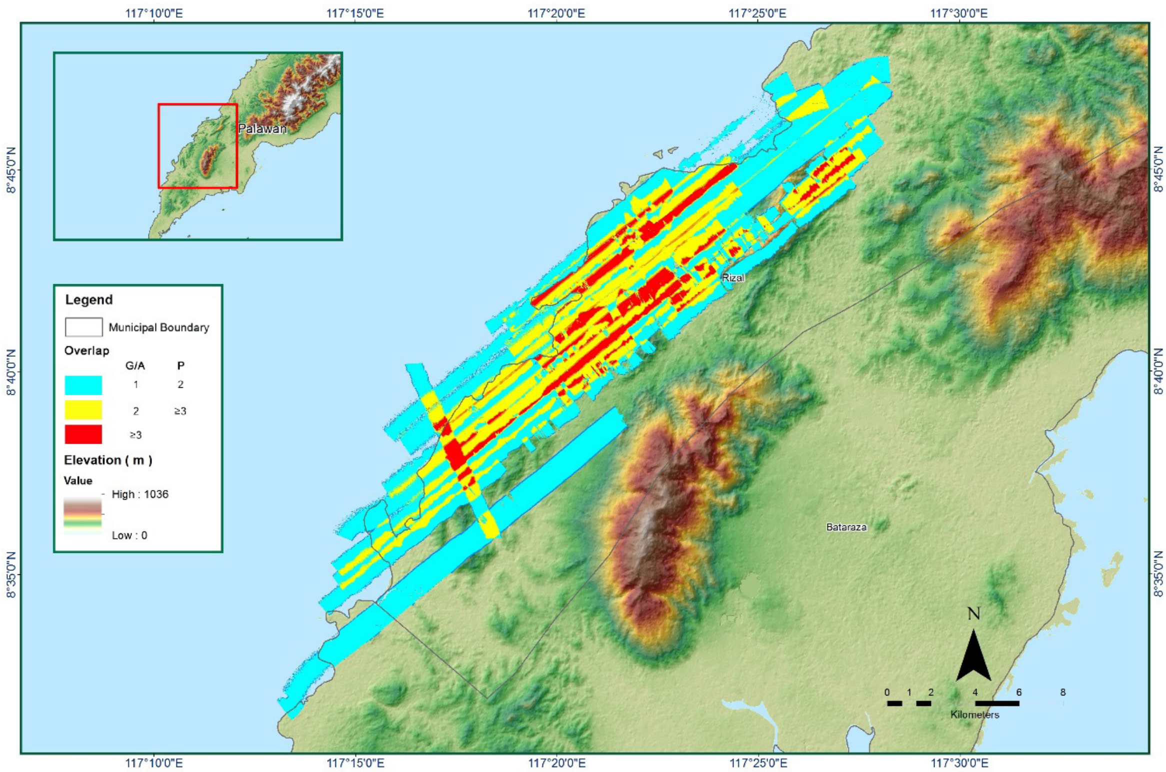


Figure 1.3.5. Image of data overlap

Figure 1.3.6. Density map of merged LiDAR data

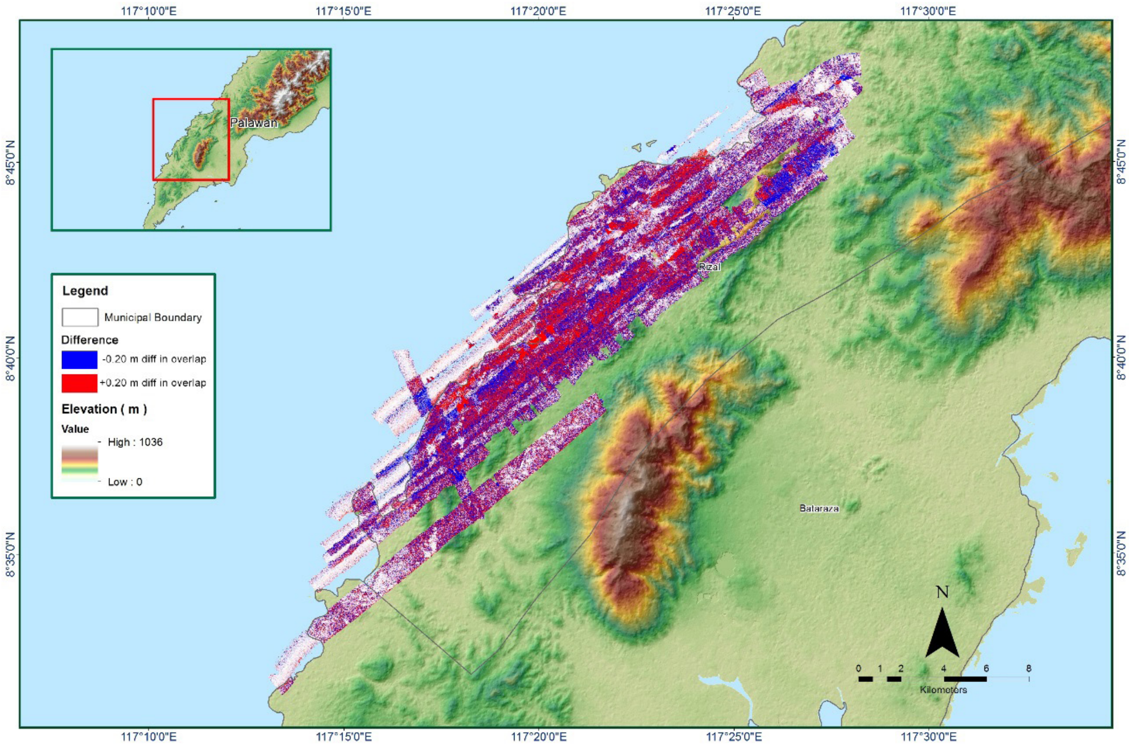
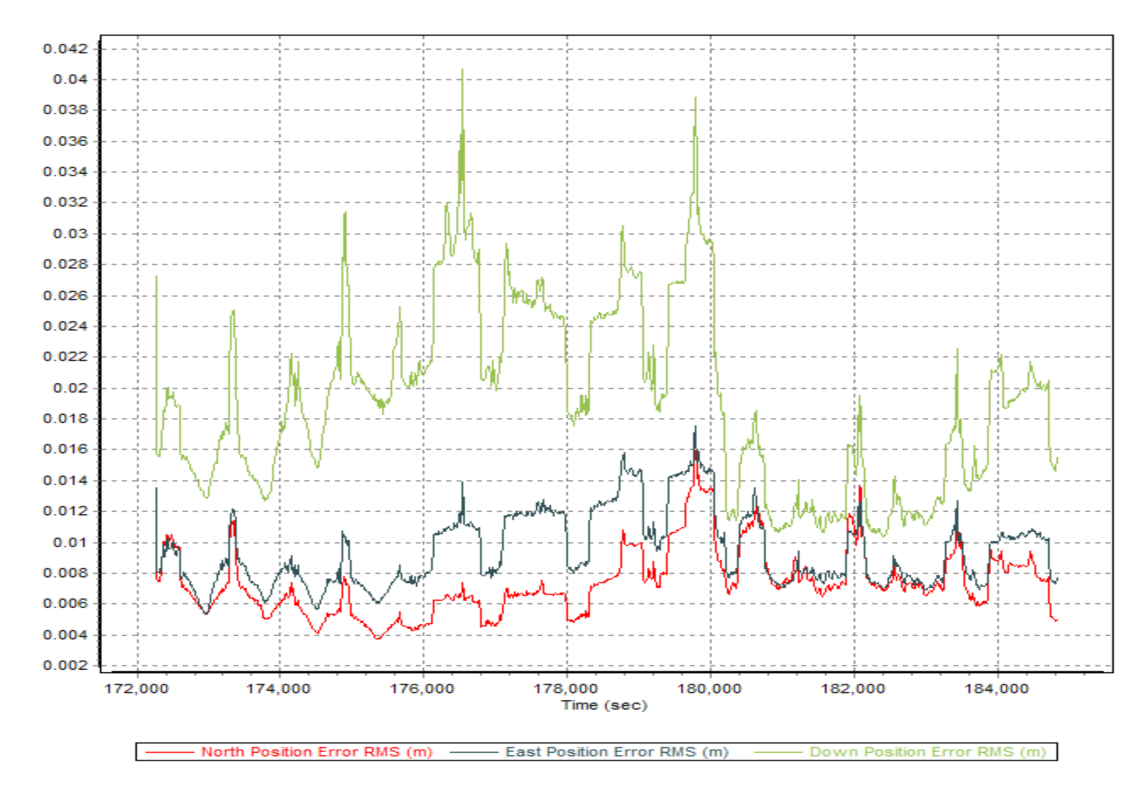


Figure *1.3.*7. Elevation difference between flight lines

Flight Area	**Palawan**
Mission Name	**Block 42T**
Inclusive Flights	3105P & 3141P
Range data size	64.90 GB
POS	469 MB
Image	39.01 GB
Transfer date	July 13 and August 5, 2015
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)	1.65
RMSE for East Position (<4.0 cm)	1.80
RMSE for Down Position (<8.0 cm)	4.20
Boresight correction stdev (<0.001deg)	0.000191
IMU attitude correction stdev (<0.001deg)	0.001797
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	33.95
Ave point cloud density per sq.m. (>2.0)	2.93
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	428
Maximum Height	351.23
Minimum Height	39.96
Classification (# of points)	
Ground	321779256
Low vegetation	103559337
Medium vegetation	271473815
High vegetation	495288353
Building	1826139
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez



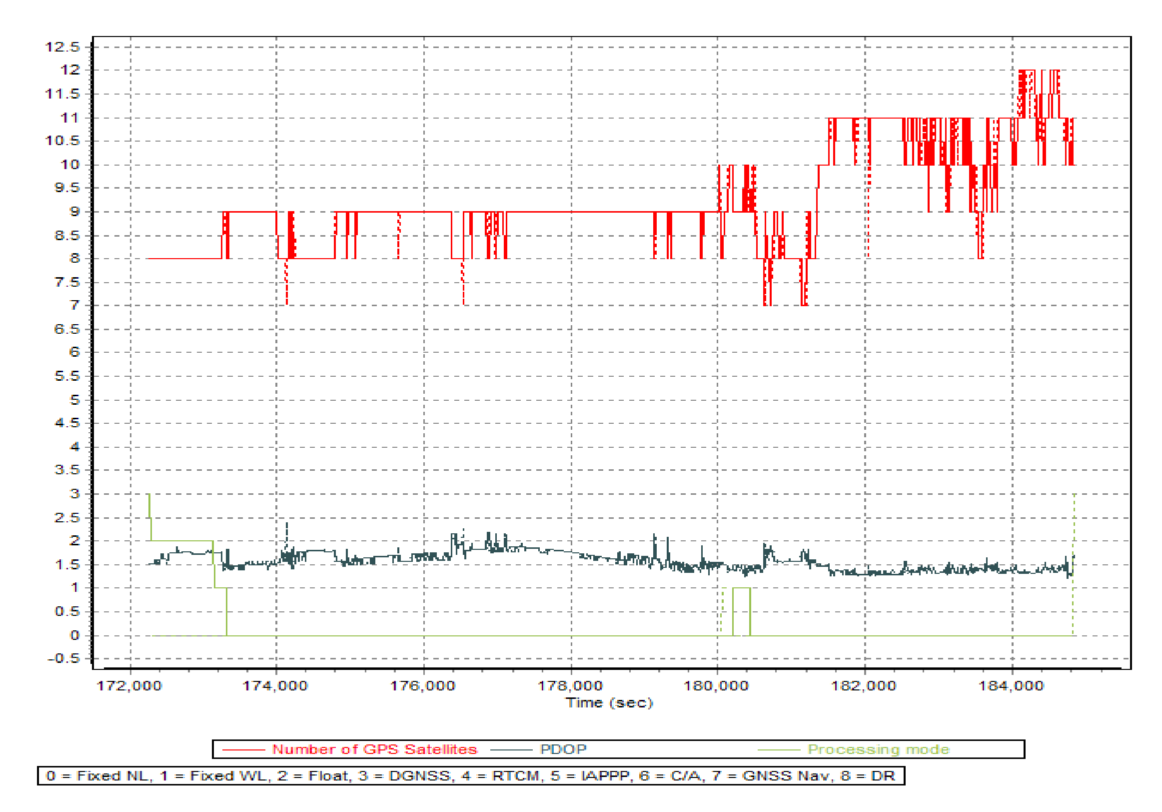


Figure 1.4.1. Solution Status

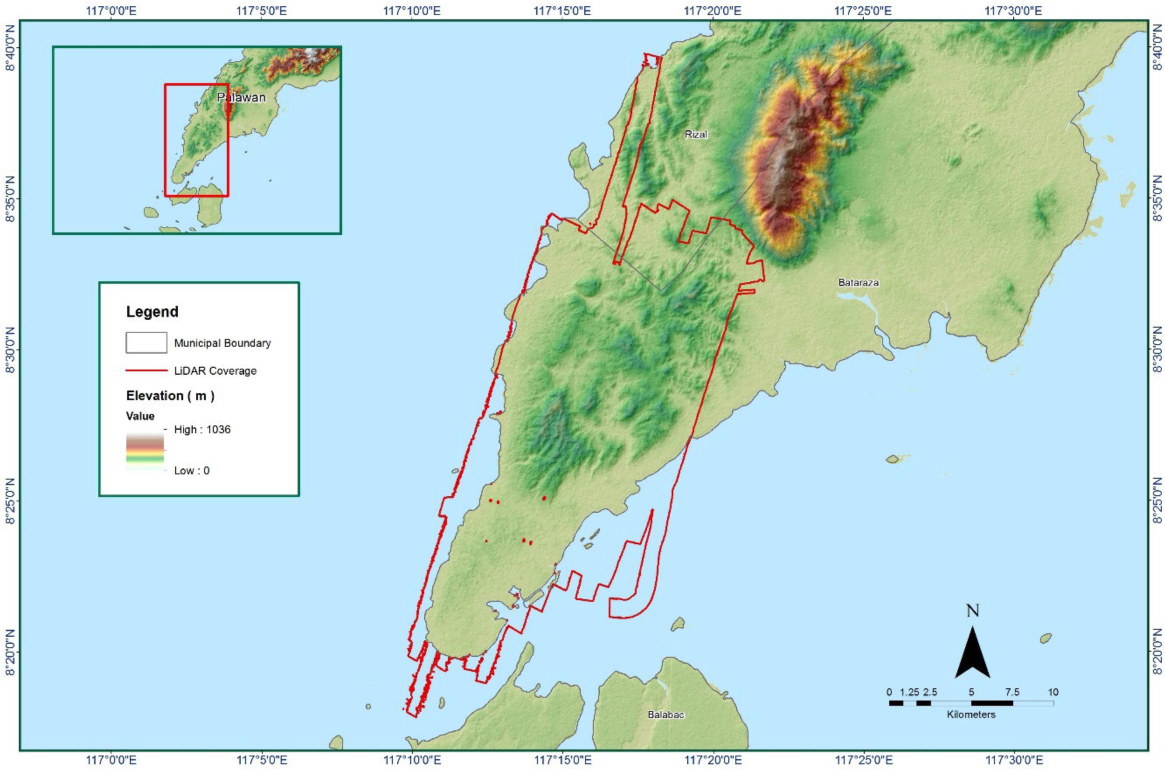


Figure 1.4.2. Smoothed Performance Metric Parameters

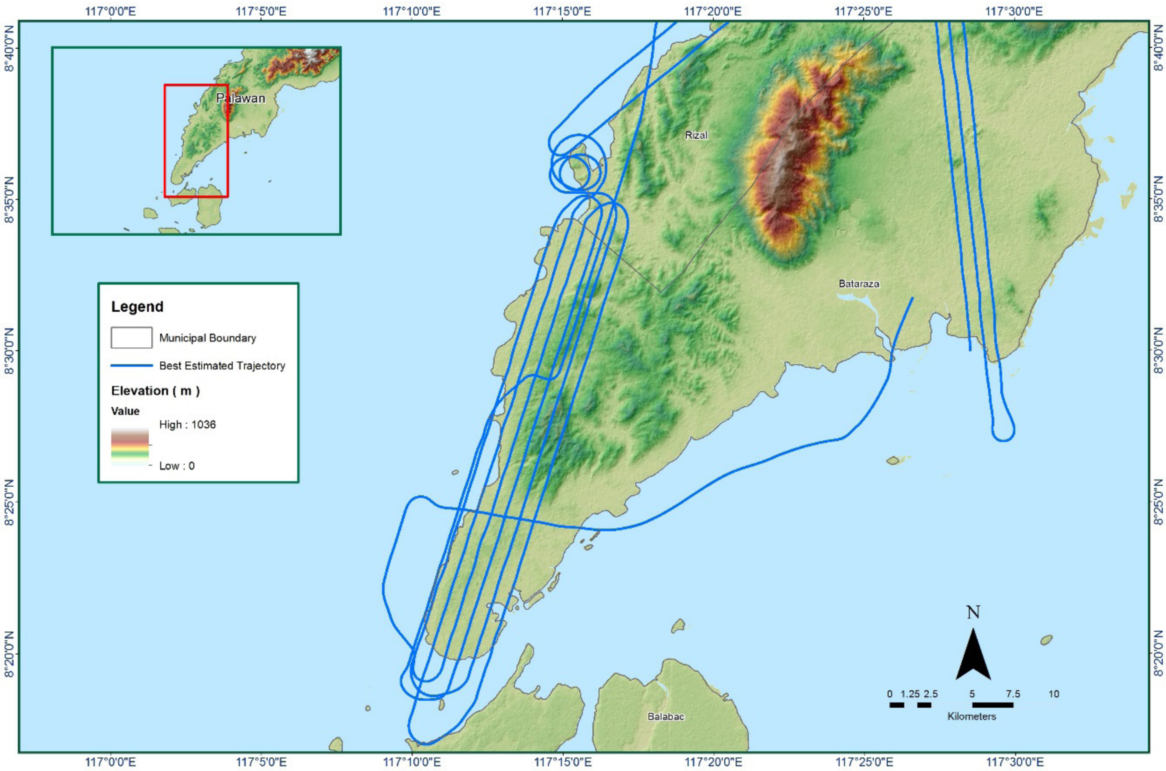


Figure 1.4.3. Best Estimated Trajectory

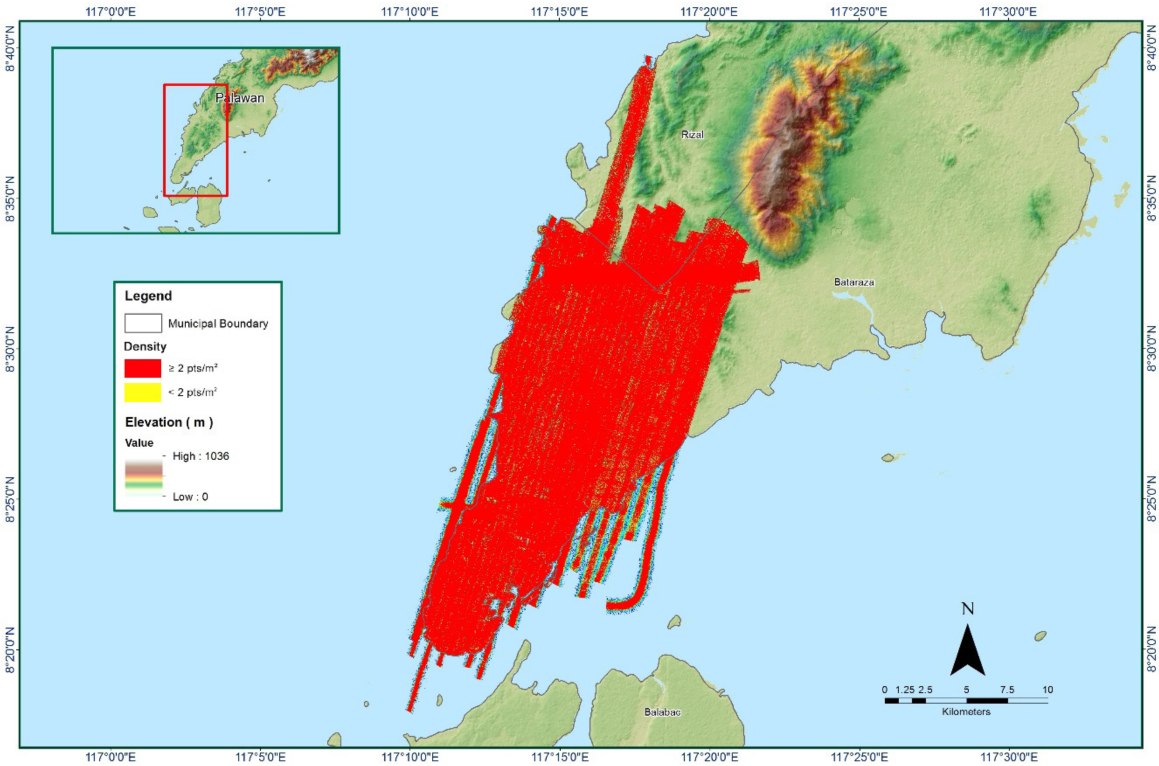


Figure 1.4.4. Coverage of LiDAR data

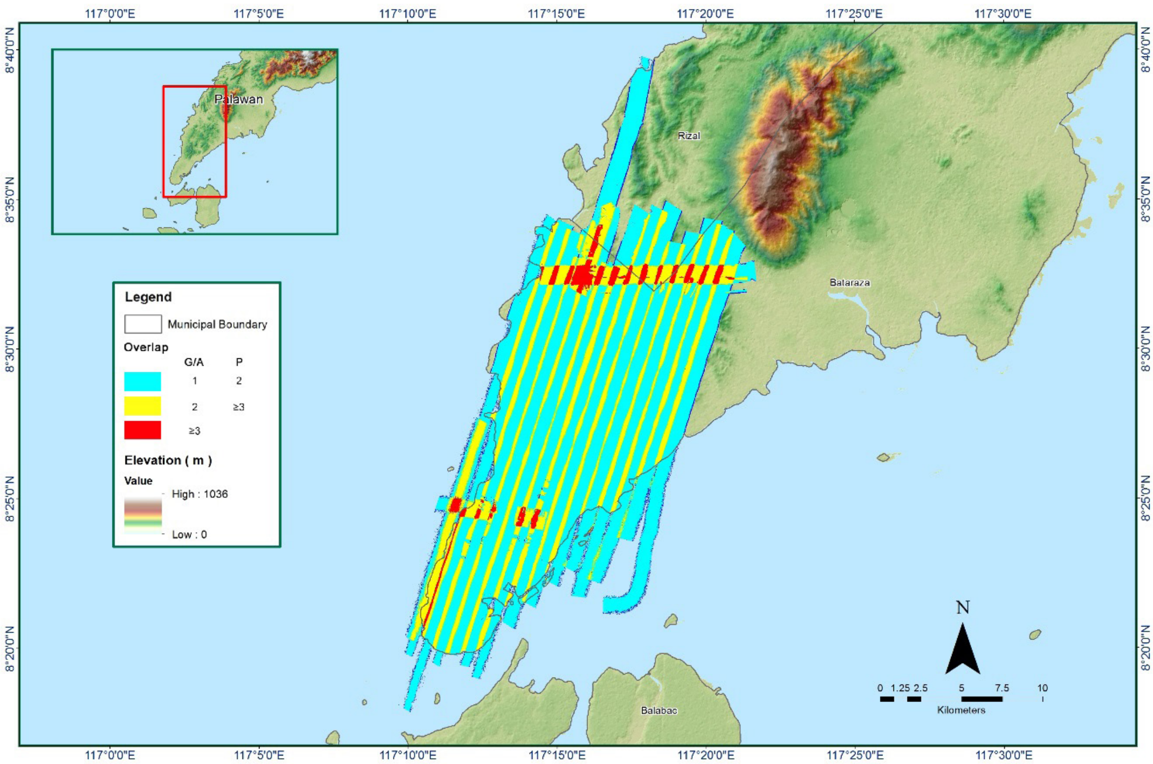


Figure 1.4.5. Image of data overlap

Figure 1.4.6. Density map of merged LiDAR data

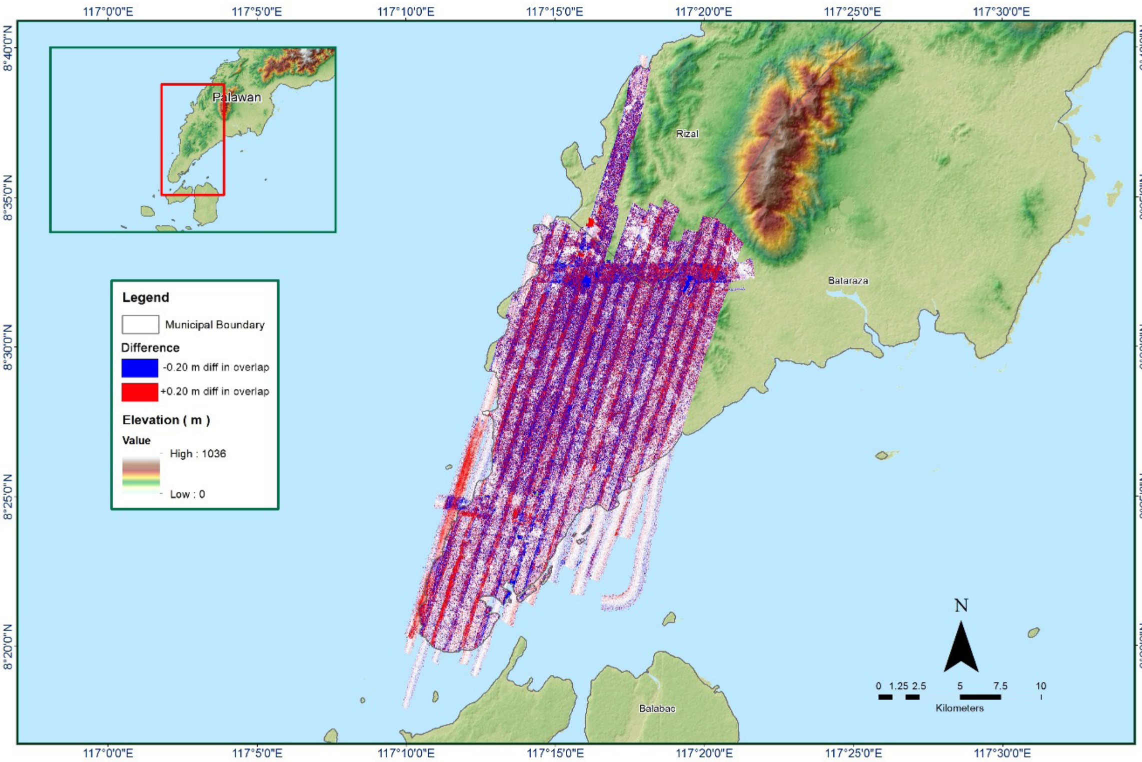


Figure 1.4.7. Elevation difference between flight lines

Flight Area	**Palawan Reflights**
Mission Name	**Blk42Q**
Inclusive Flights	3571G
Range data size	14.6 GB
Base data size	6.4 MB
POS	160 MB
Image	NA
Transfer date	January 5, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.06
RMSE for East Position (<4.0 cm)	2.51
RMSE for Down Position (<8.0 cm)	3.78
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	25.85%
Ave point cloud density per sq.m. (>2.0)	4.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	65
Maximum Height	473.11 m
Minimum Height	41.65 m
Classification (# of points)	
Ground	13,721,106
Low vegetation	11,193,765
Medium vegetation	93,801,252
High vegetation	61,200,015
Building	306,066
Ortophoto	No
Processed by	Engr. Irish Cortez, Engr. Merven Matthew Natino, Engr. Elainne Lopez

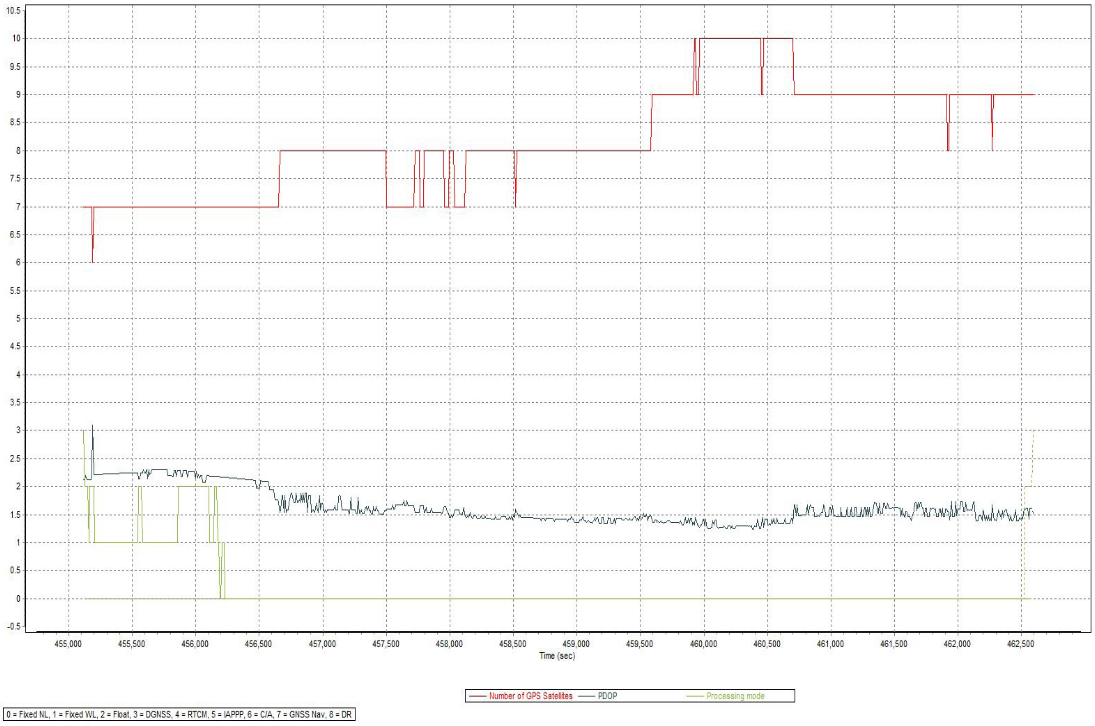


Figure 1.5.1. Solution Status

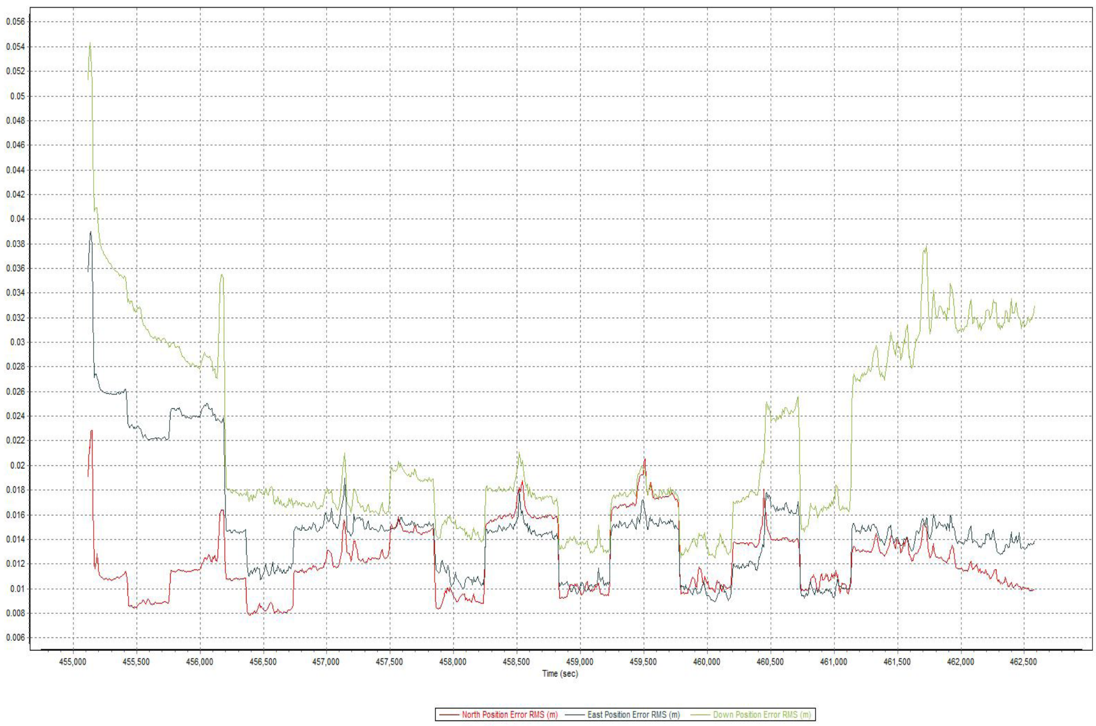


Figure 1.5.2. Smoothed Performance Metric Parameters

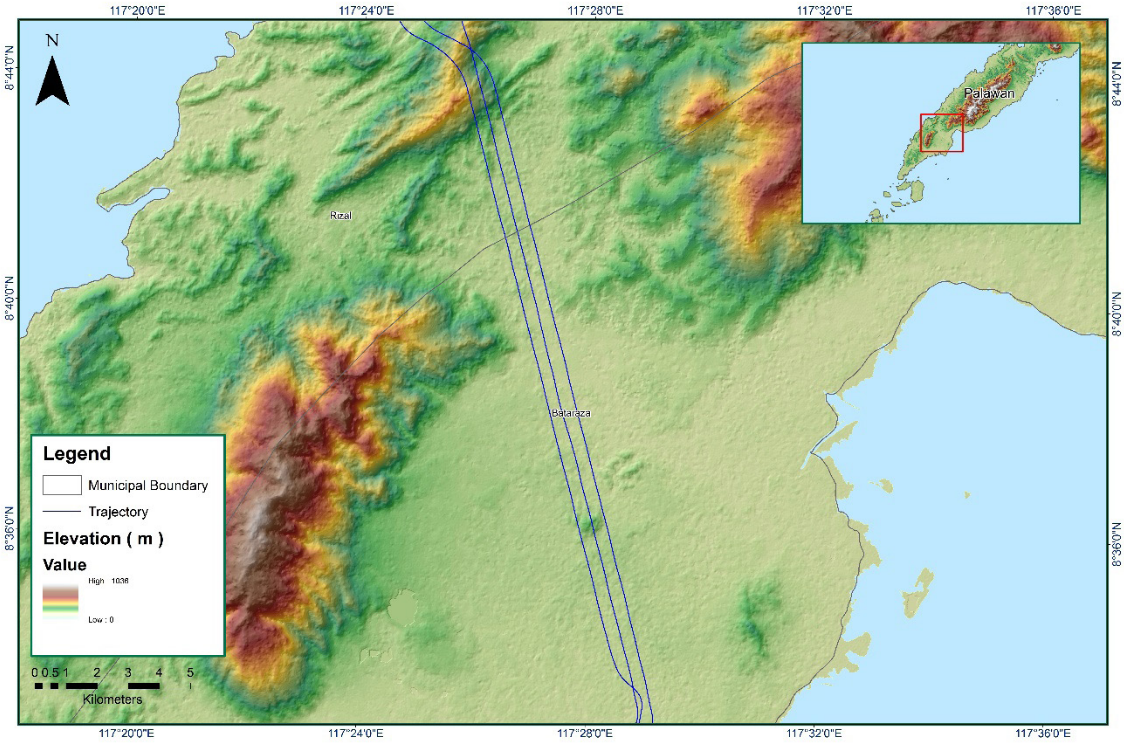


Figure 1.5.3 Best Estimated Trajectory

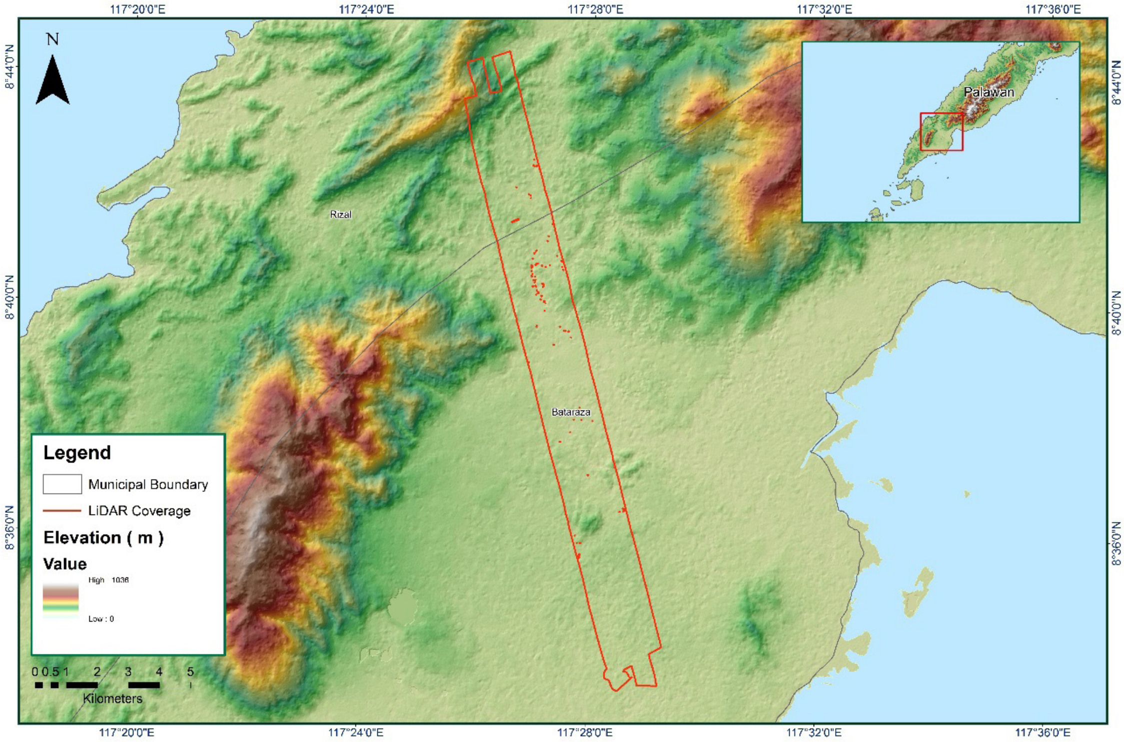


Figure 1.5.4 Coverage of LiDAR data

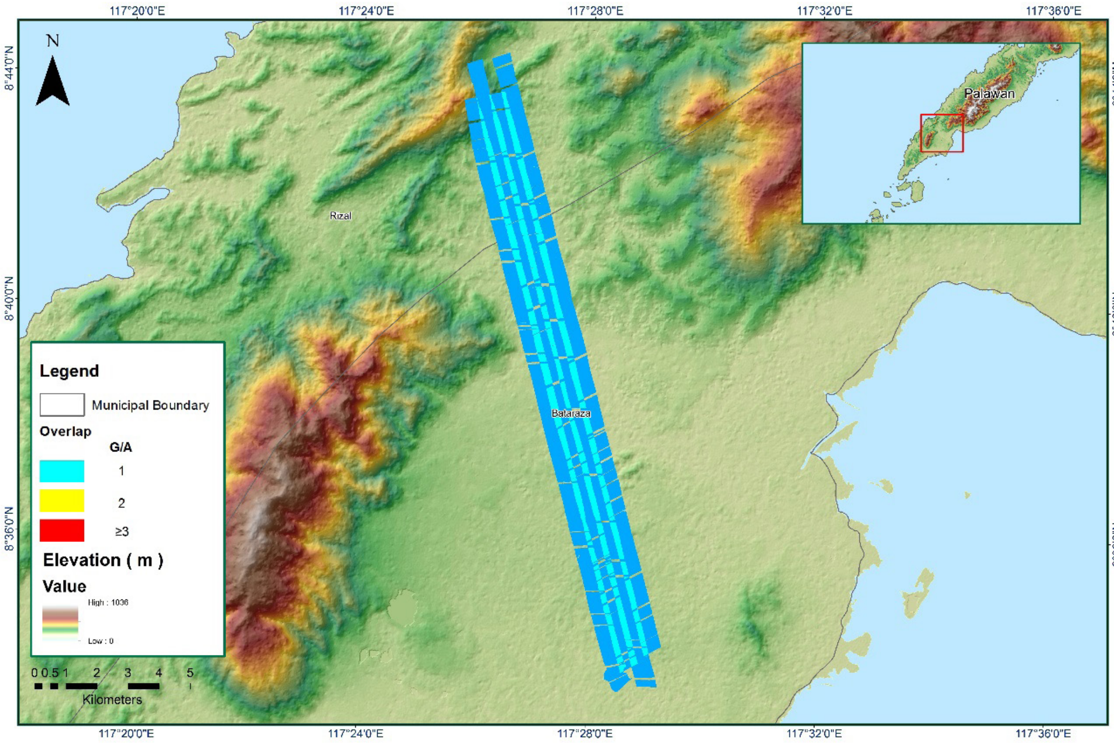


Figure 1.5.5 Image of data overlap

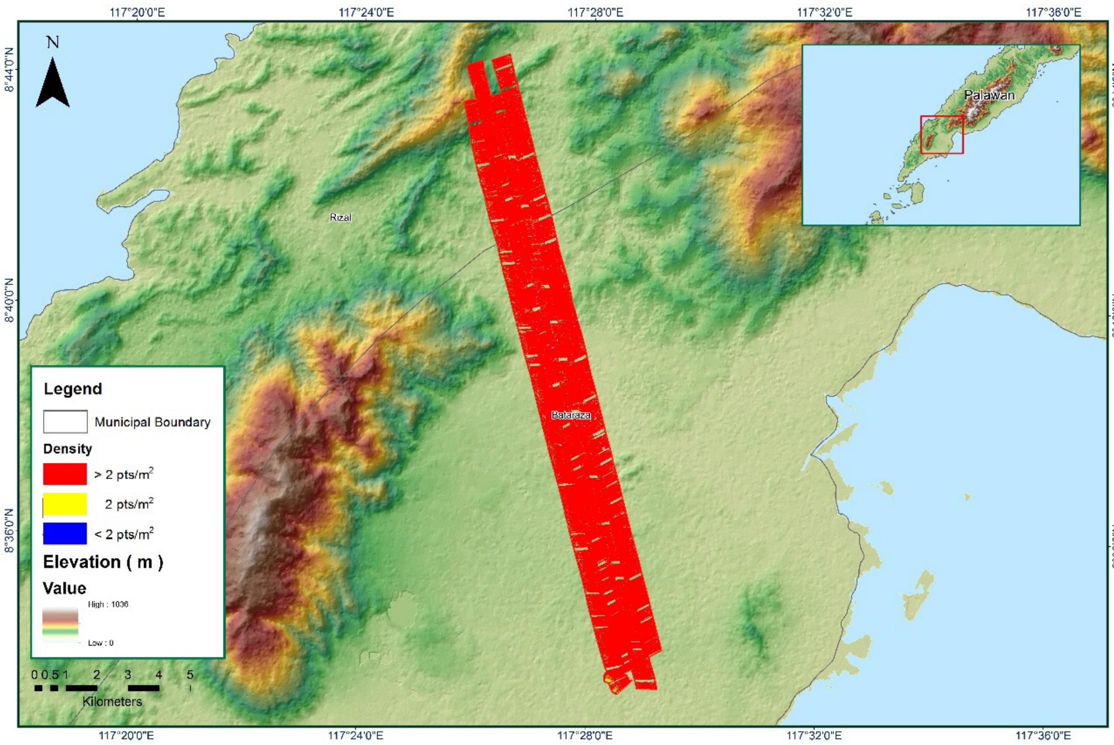


Figure 1.5.6 Density Map of merged LiDAR data

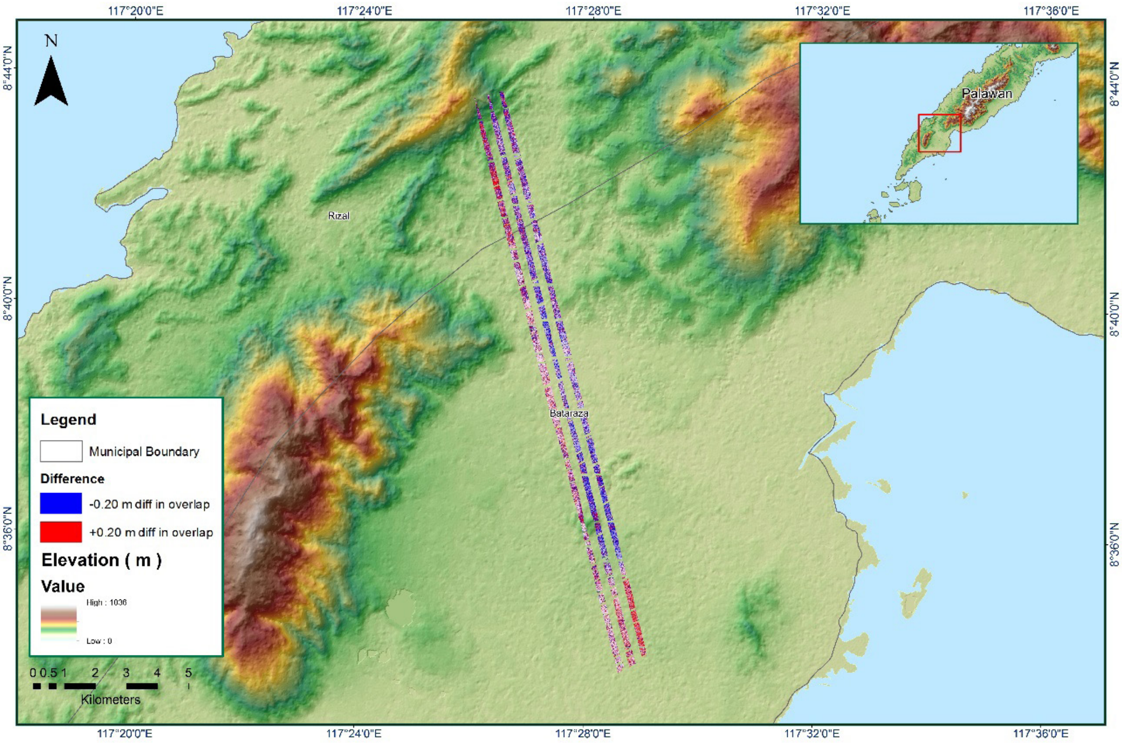


Figure 1.5.7 Elevation Difference Between flight lines

Flight Area	**Palawan Reflights**
Mission Name	**Blk42Q_additional**
Inclusive Flights	3585G
Range data size	23 GB
Base data size	5.29 MB
POS	234 MB
Image	NA
Transfer date	January 5, 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)	1.43
RMSE for East Position (<4.0 cm)	1.46
RMSE for Down Position (<8.0 cm)	5.08
Boresight correction stdev (<0.001deg)	0.571960
IMU attitude correction stdev (<0.001deg)	0.402583
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	14.03%
Ave point cloud density per sq.m. (>2.0)	4.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	21
Maximum Height	527.55 m
Minimum Height	51.58 m
Classification (# of points)	
Ground	3,258,022
Low vegetation	3,401,421
Medium vegetation	23,667,938
High vegetation	23,466,484
Building	263,434
Ortophoto	No
Processed by	Engr. Irish Cortez, Engr. Ma. Joanne Balaga, Marie Denise Bueno

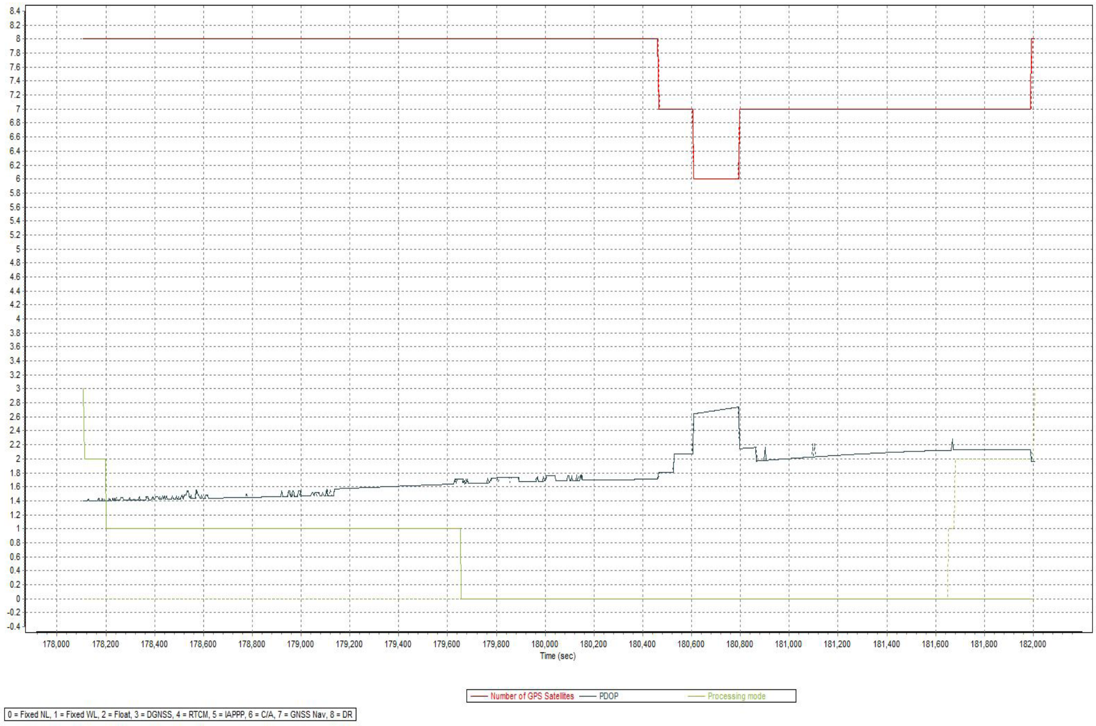


Figure 1.6.1. Solution Status

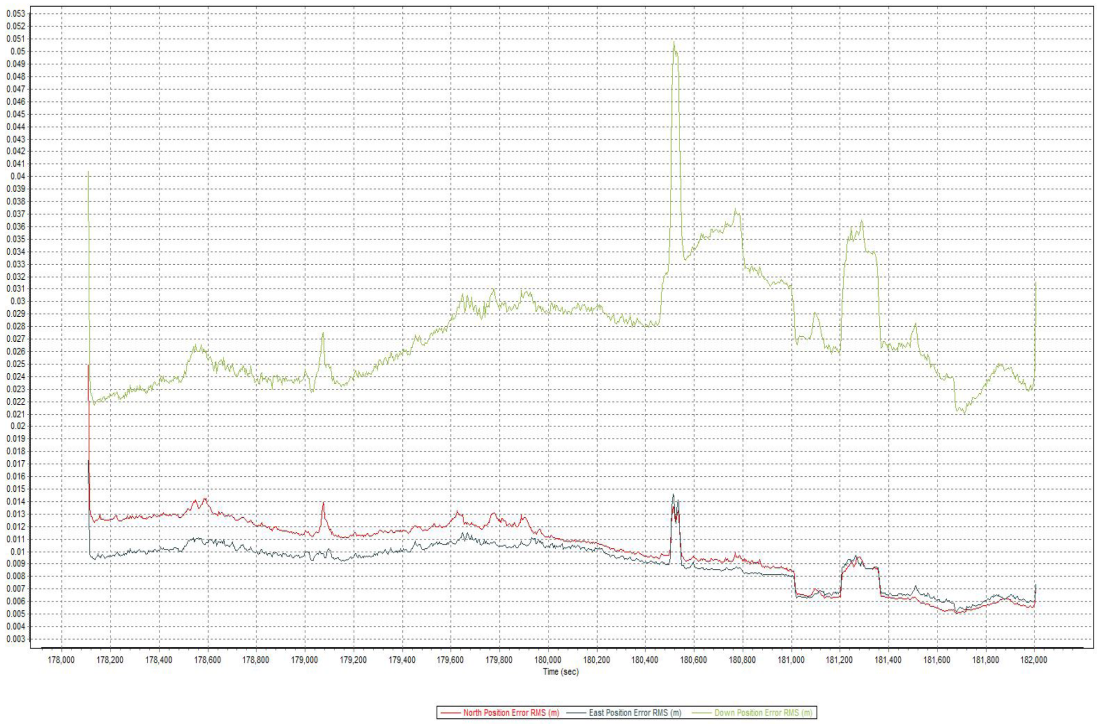


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Figure 1.6.2. Smoothed Performance Metric Parameters

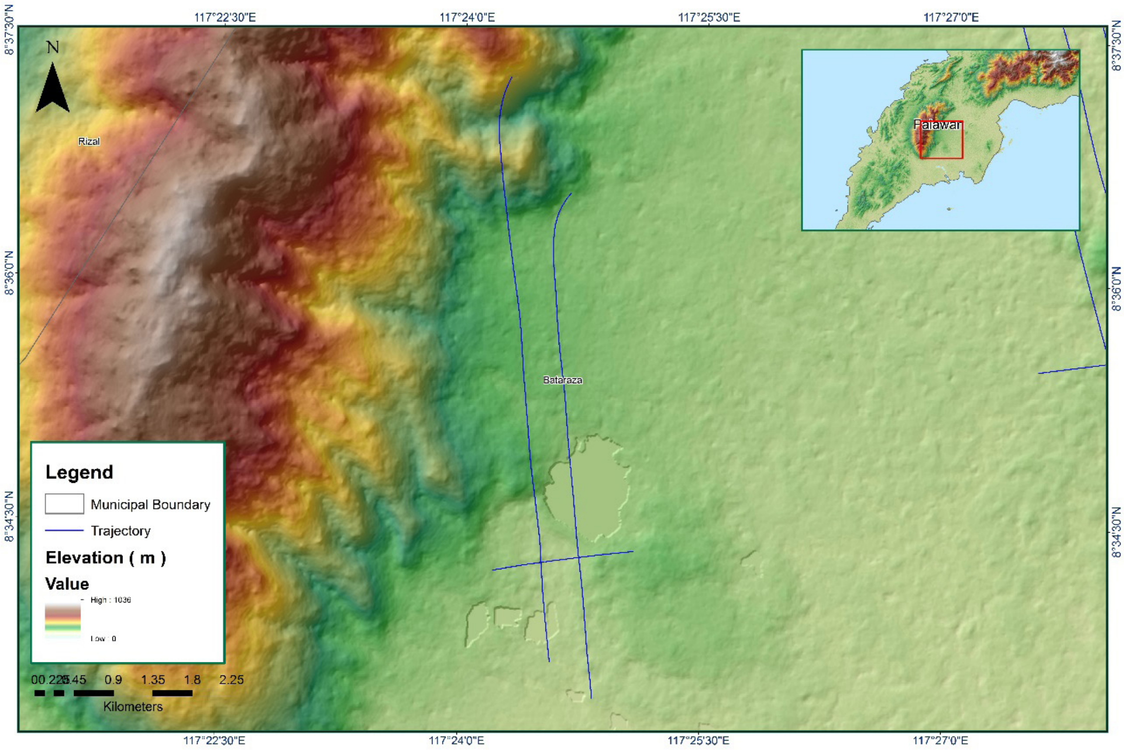

Figure 1.6.3 Best Estimated Trajectory

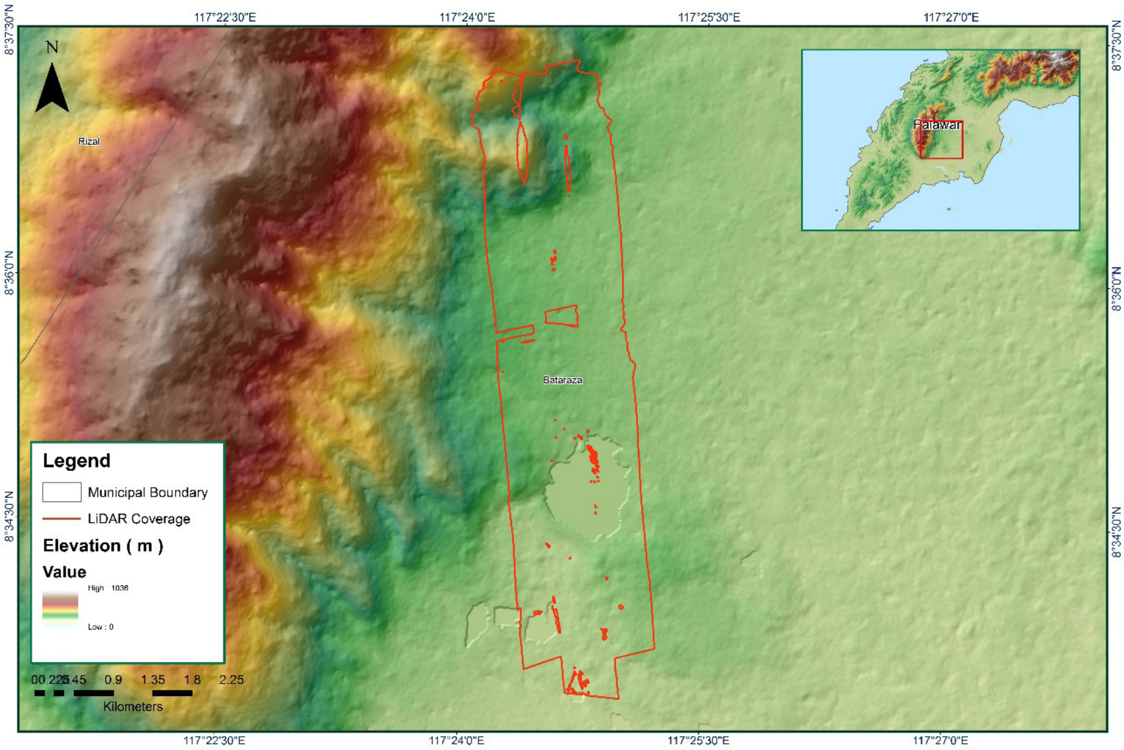

Figure 1.6.4 Coverage of LiDAR data

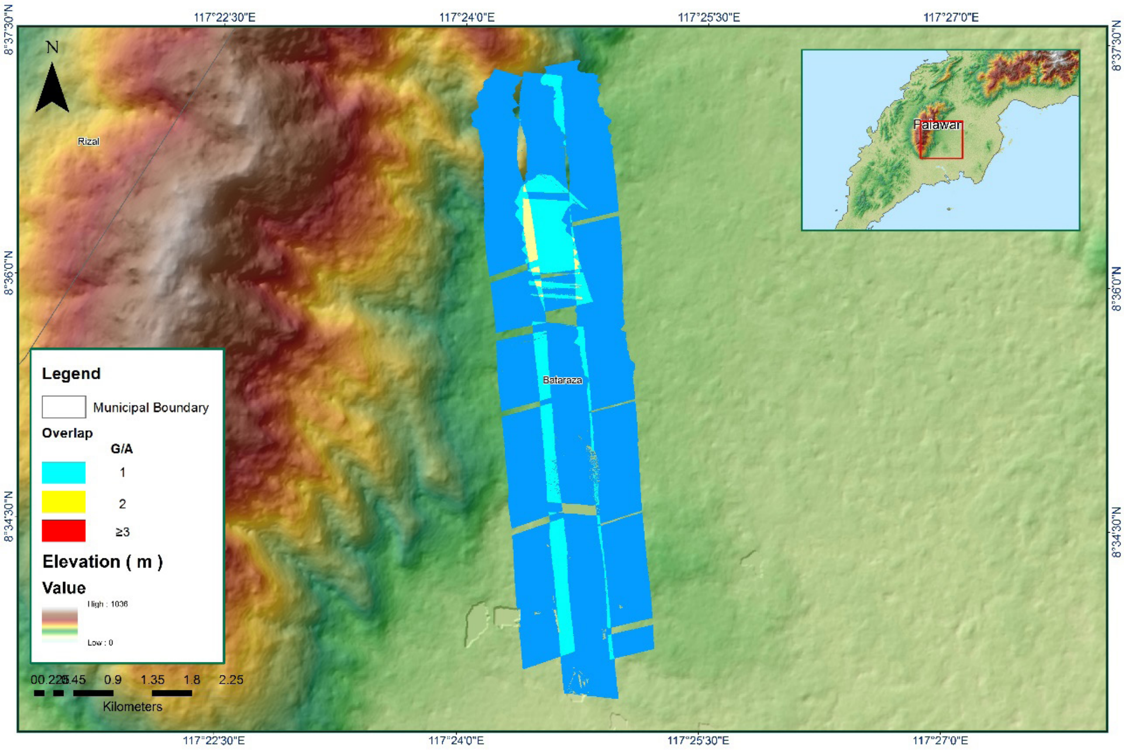

Figure 1.6.5 Image of data overlap

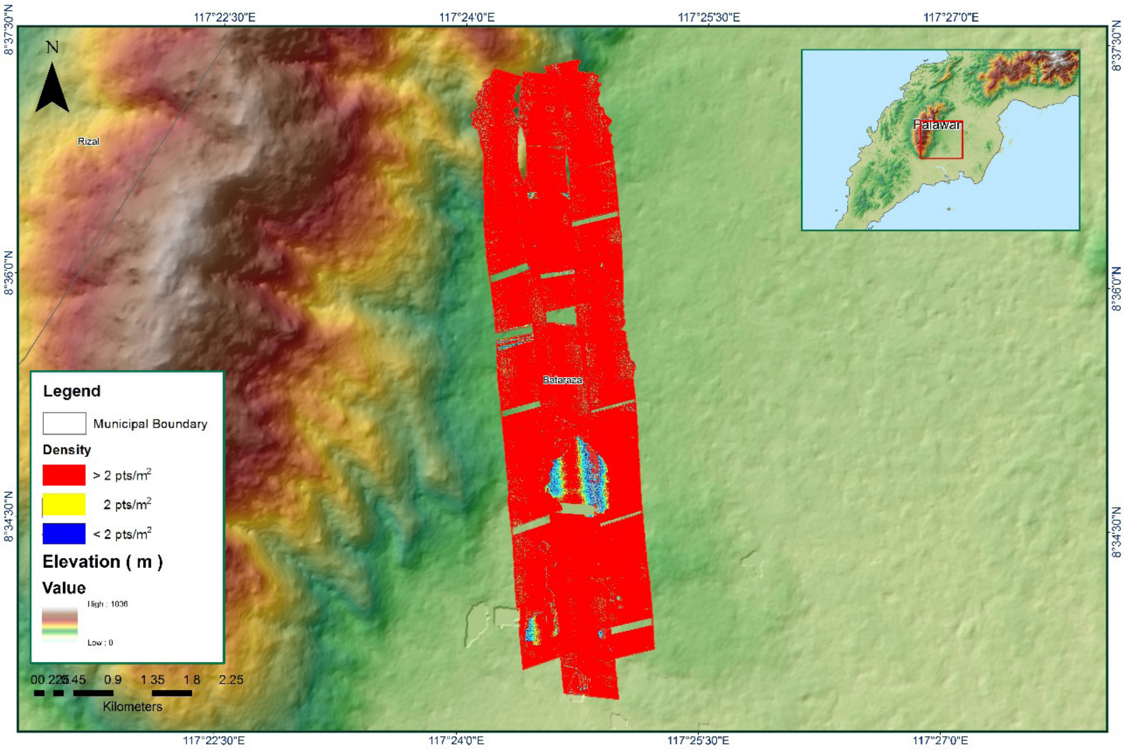

Figure 1.6.6 Density Map of merged LiDAR data

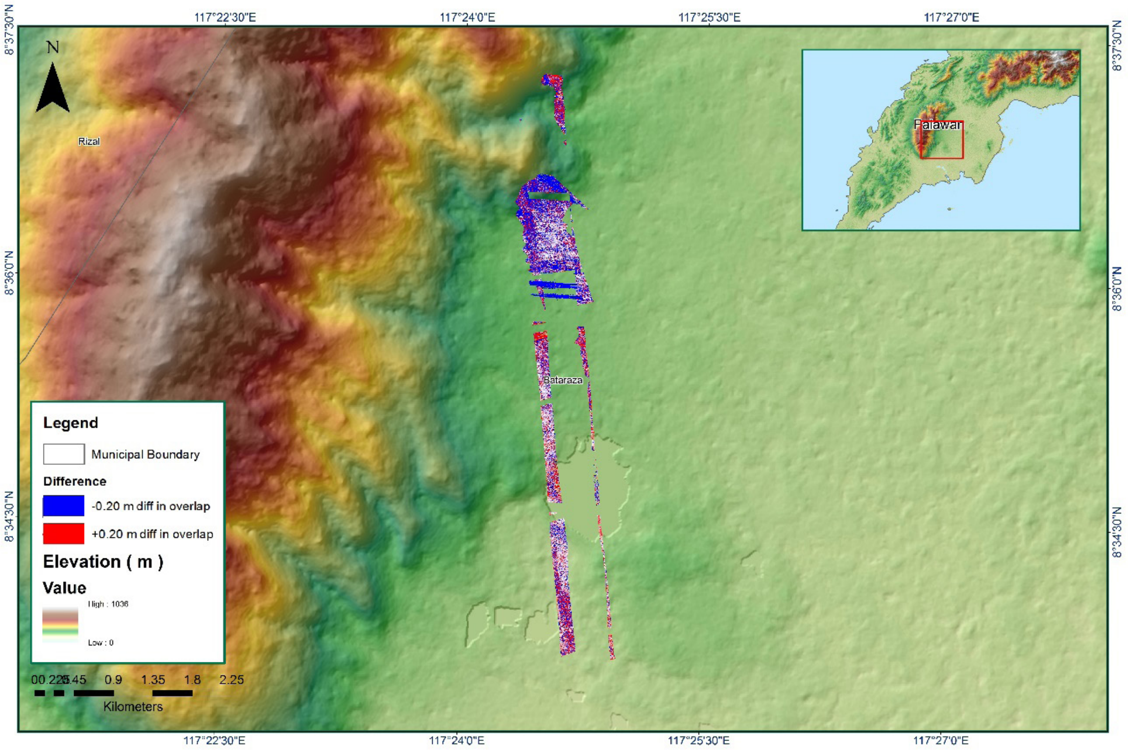

Figure 1.6.7 Elevation Difference Between flight lines

Flight Area	**Palawan Reflights**
Mission Name	**Blk42T**
Inclusive Flights	3593G
Range data size	20.9 GB
Base data size	11.4 MB
POS	227 MB
Image	NA
Transfer date	January 5, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.13
RMSE for East Position (<4.0 cm)	1.02
RMSE for Down Position (<8.0 cm)	2.61
Boresight correction stdev (<0.001deg)	0.018027
IMU attitude correction stdev (<0.001deg)	0.002951
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	26.98%
Ave point cloud density per sq.m. (>2.0)	5.11
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	84
Maximum Height	413.31 m
Minimum Height	38.99 m
Classification (# of points)	
Ground	19,041,183
Low vegetation	15,606,791
Medium vegetation	76,799,121
High vegetation	182,121,974
Building	4,318,128
Ortophoto	No
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Marie Denise Bueno

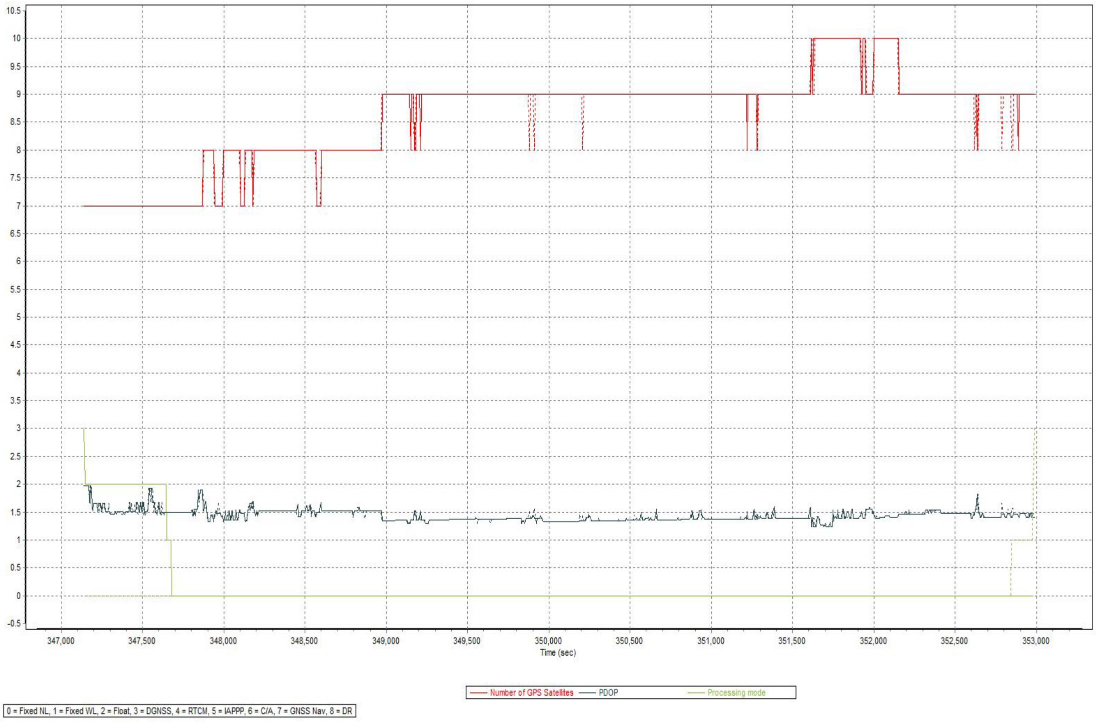

Figure 1.7.1. Solution Status

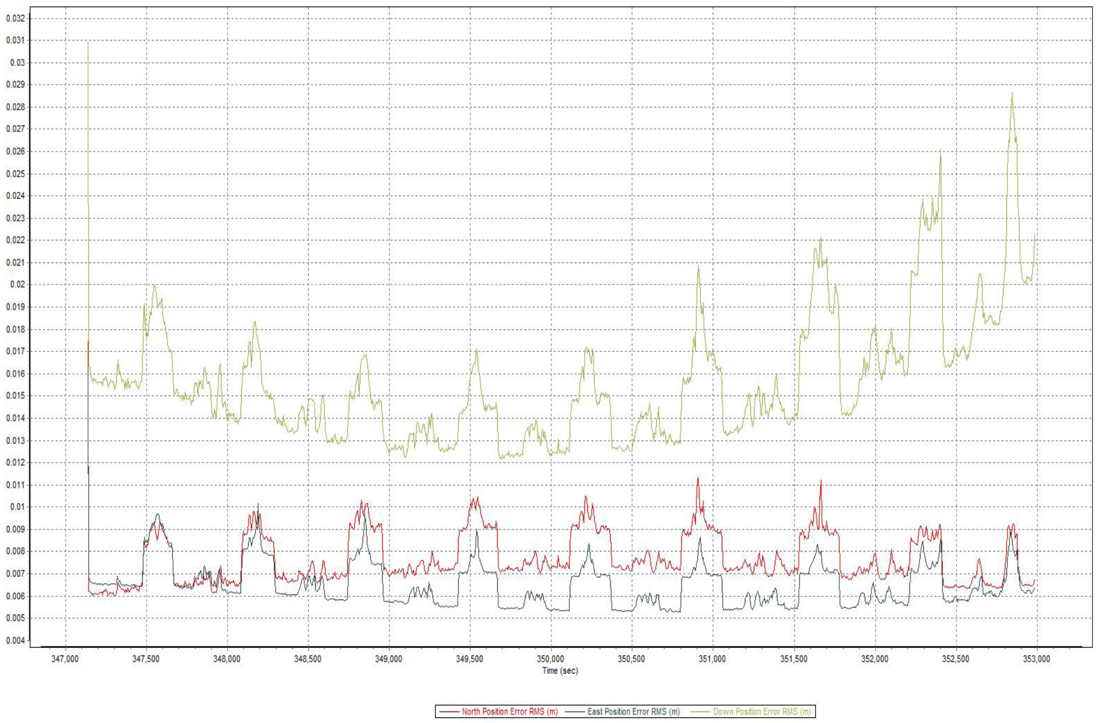

Figure 1.7.2. Smoothed Performance Metric Parameters

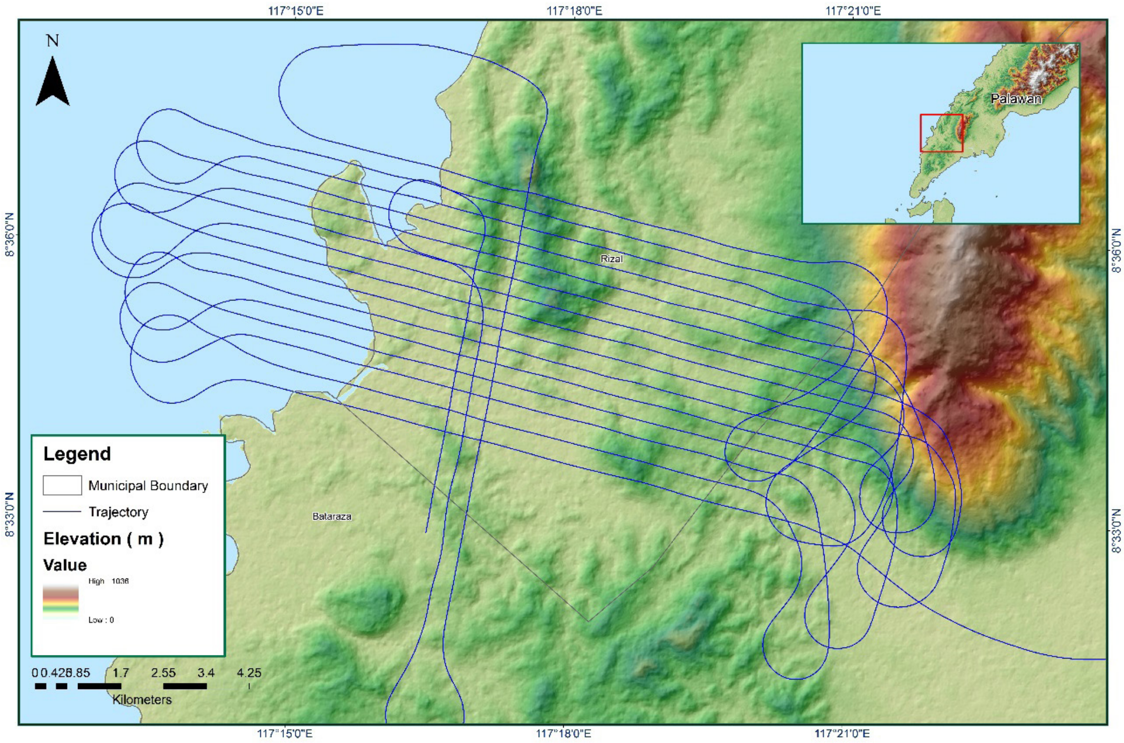

Figure 1.7.3 Best Estimated Trajectory

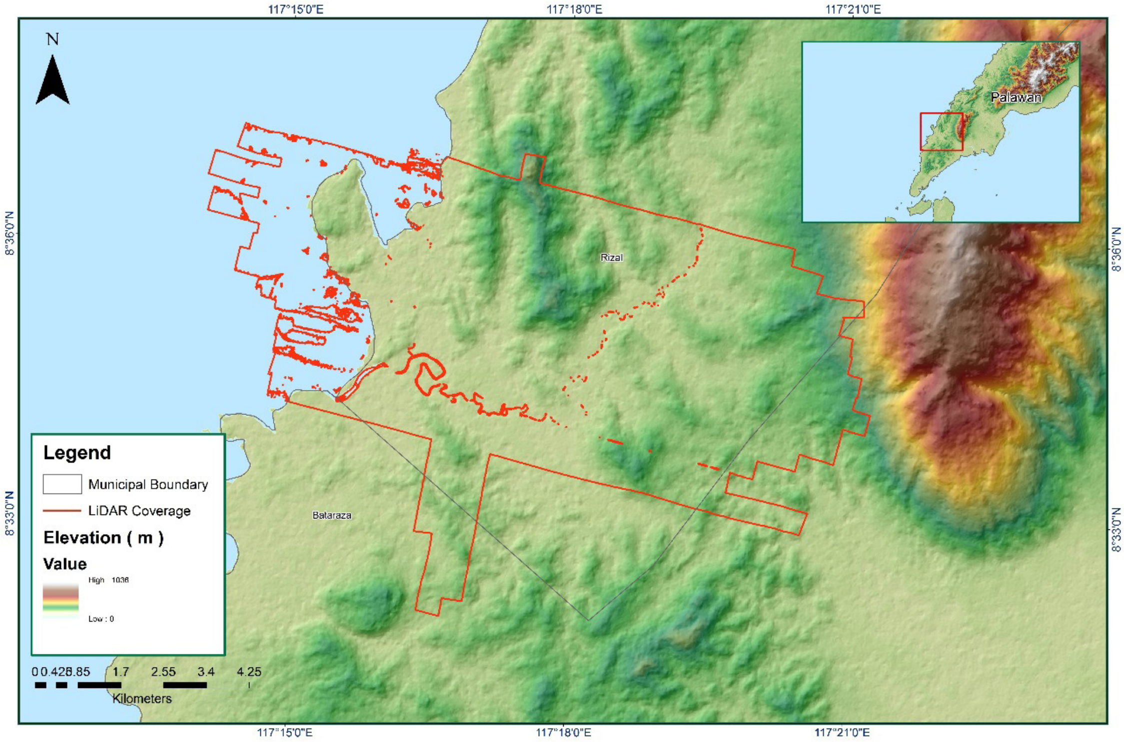

Figure 1.7.4 Coverage of LiDAR data

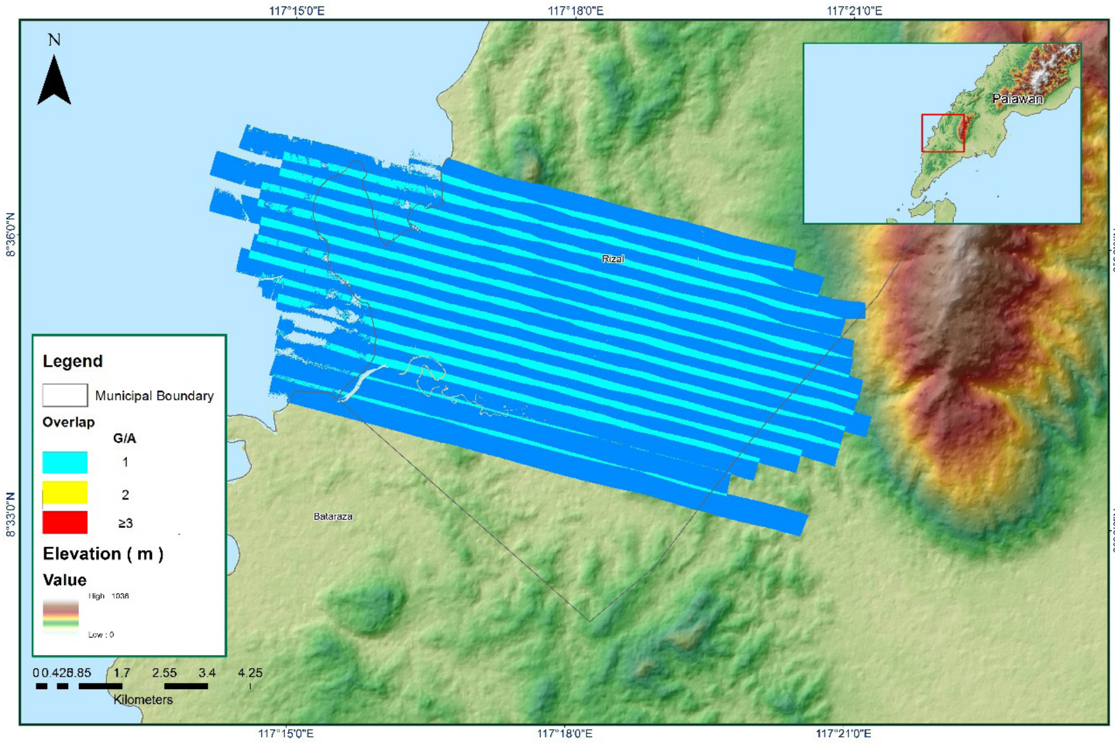

Figure 1.7.5 Image of data overlap

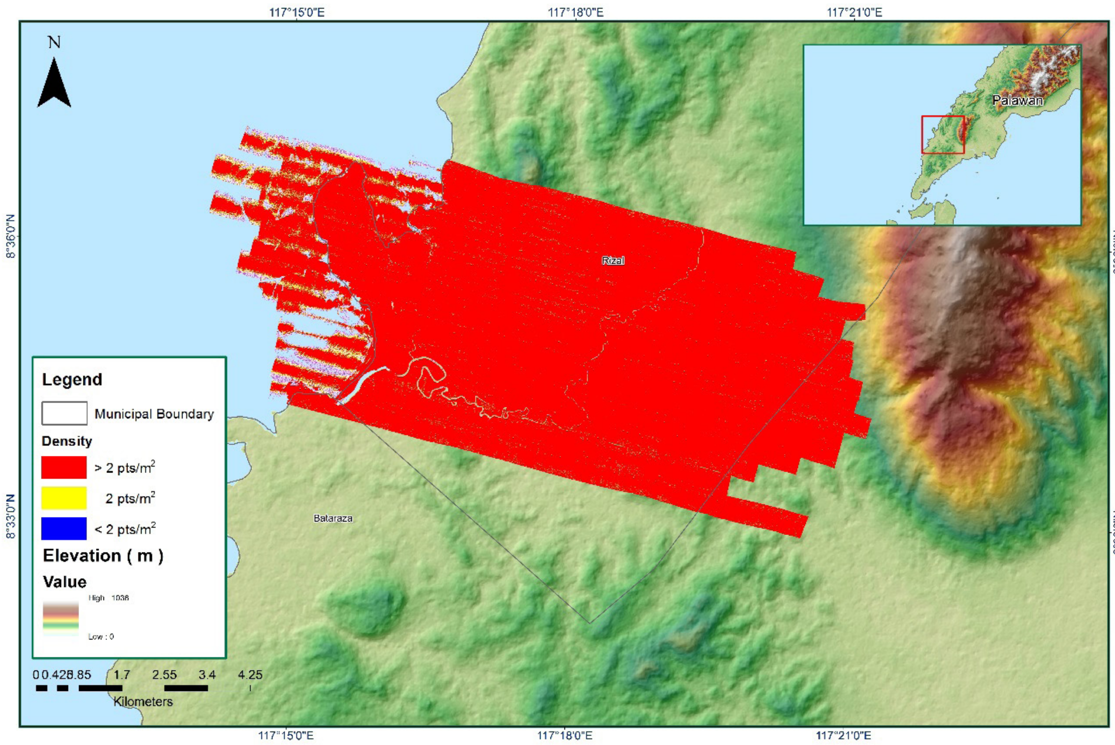

Figure 1.7.6 Density Map of merged LiDAR data

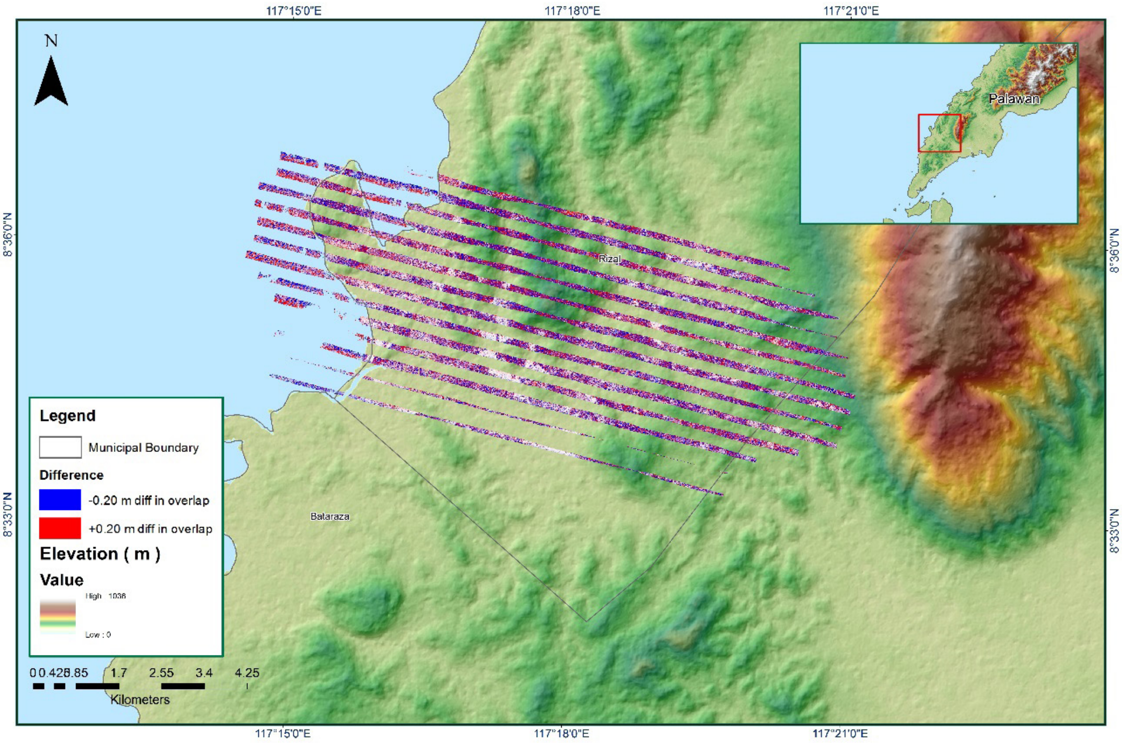

Figure 1.7.7 Elevation Difference Between flight lines

Flight Area	**Palawan Reflights**
Mission Name	**Blk42U**
Inclusive Flights	3595G
Range data size	17.4 GB
Base data size	11.4 MB
POS	156 MB
Image	NA
Transfer date	January 5, 2016
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)	0.73
RMSE for East Position (<4.0 cm)	0.57
RMSE for Down Position (<8.0 cm)	1.67
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	25.89%
Ave point cloud density per sq.m. (>2.0)	5.88
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	64
Maximum Height	257.49 m
Minimum Height	40.58 m
Classification (# of points)	
Ground	13,263,787
Low vegetation	16,868,988
Medium vegetation	115,121,367
High vegetation	122,632,112
Building	4,028,567
Ortophoto	No
Processed by	Engr. Regis Guhiting, Engr. Ma Joanne Balaga, Engr. Melissa Fernandez

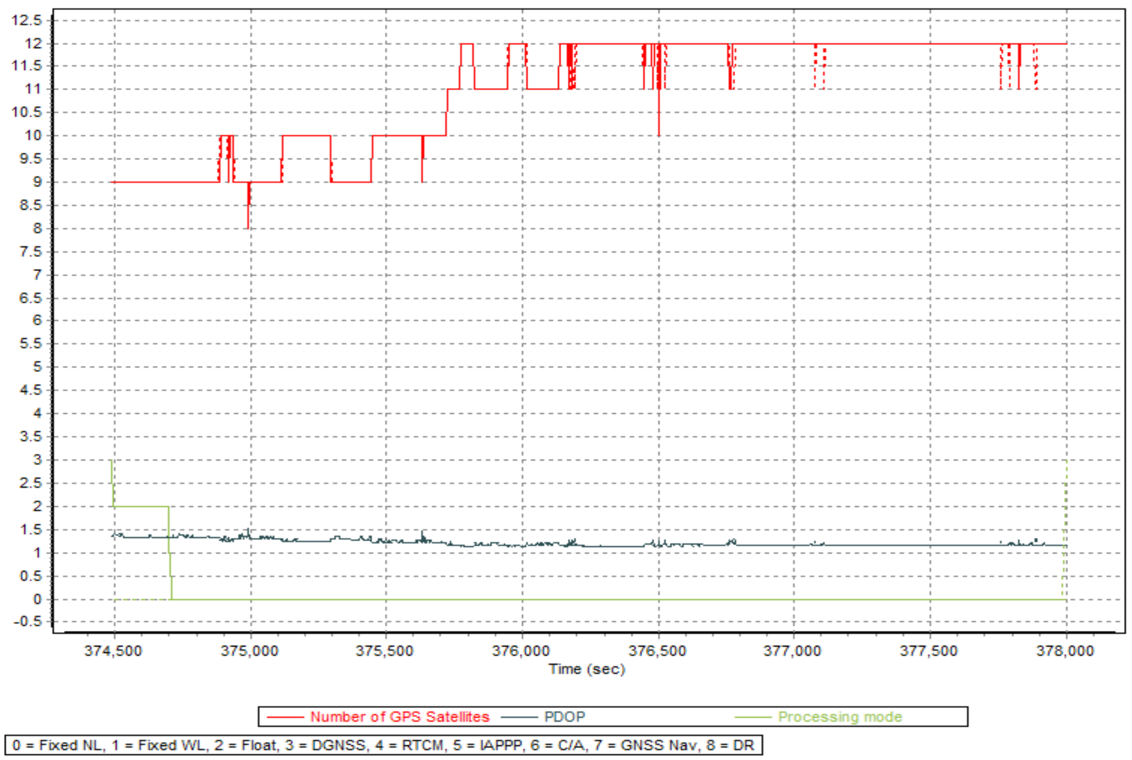

Figure 1.8.1. Solution Status

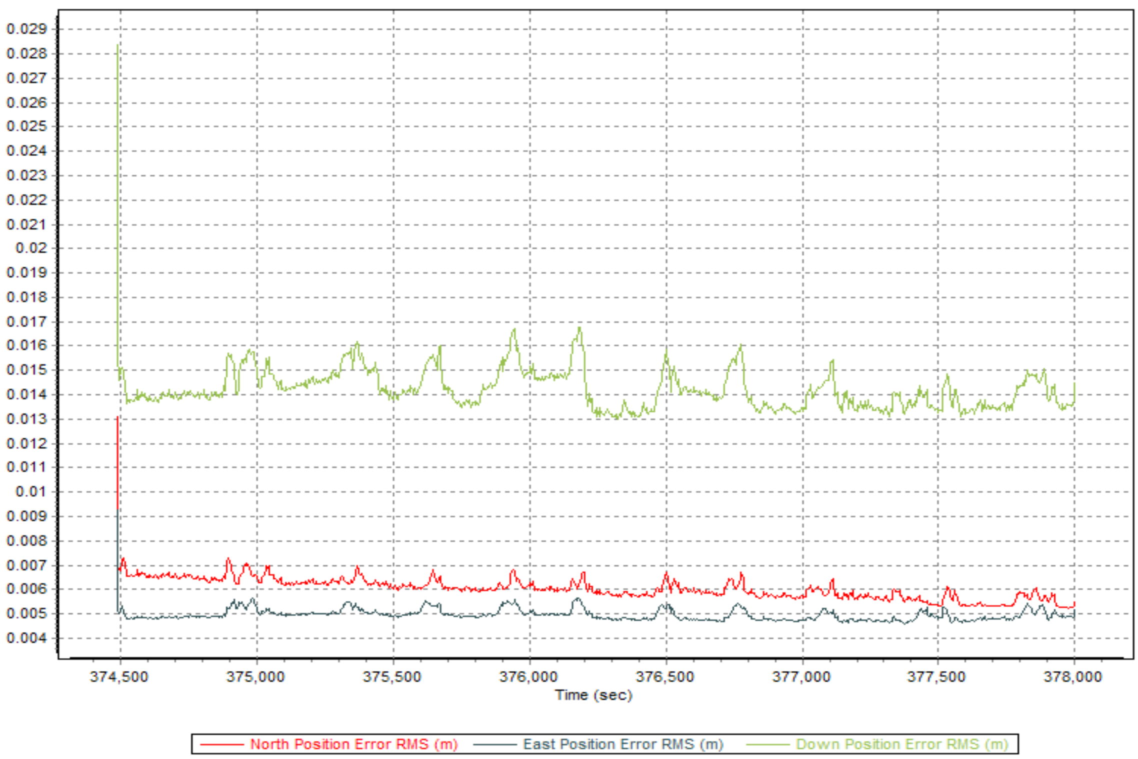

Figure 1.8.2. Smoothed Performance Metric Parameters

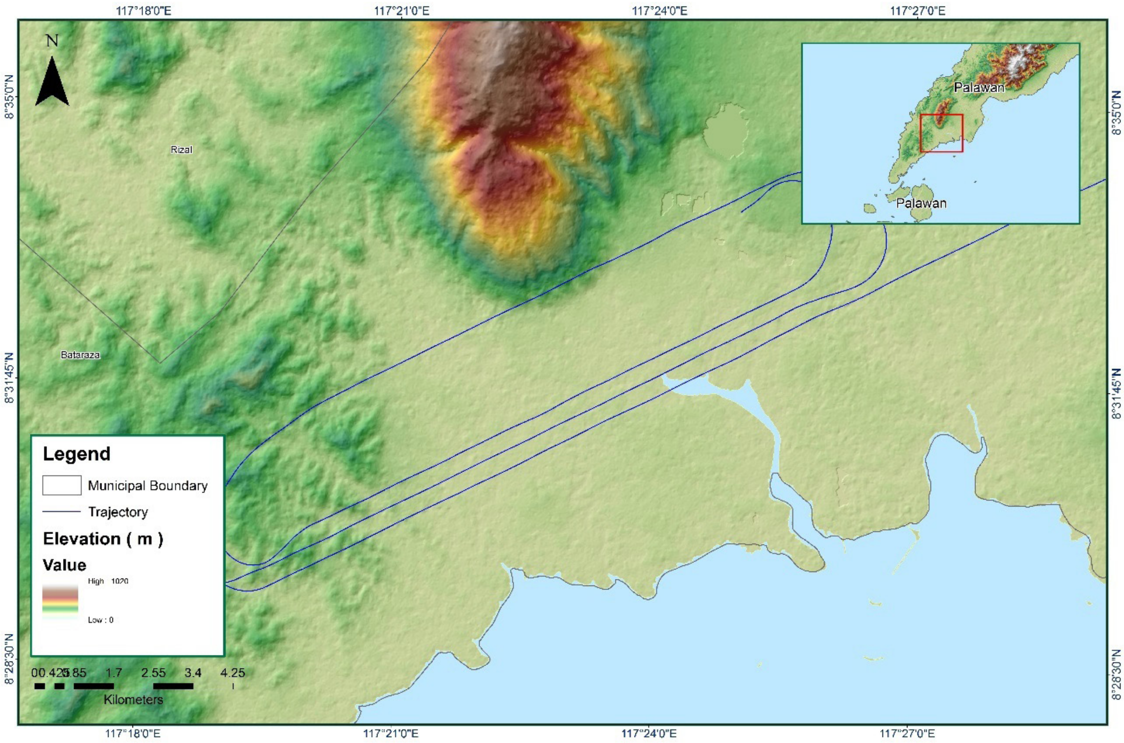

Figure 1.8.3 Best Estimated Trajectory

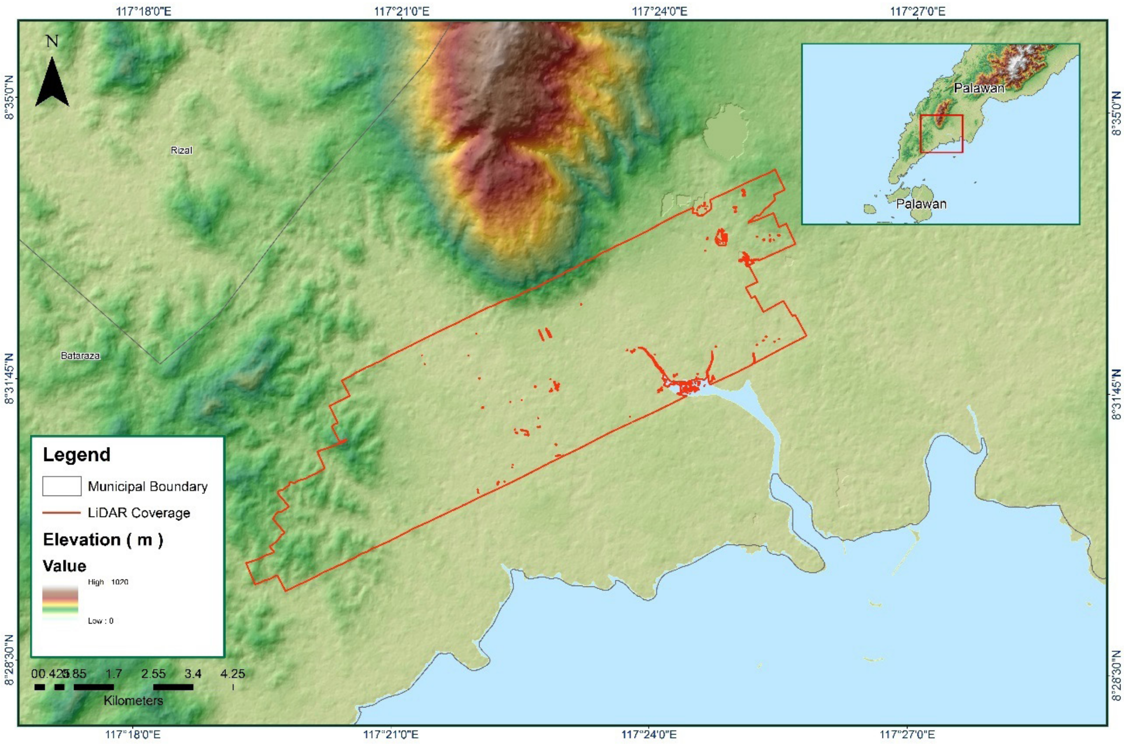

Figure 1.8.4 Coverage of LiDAR data

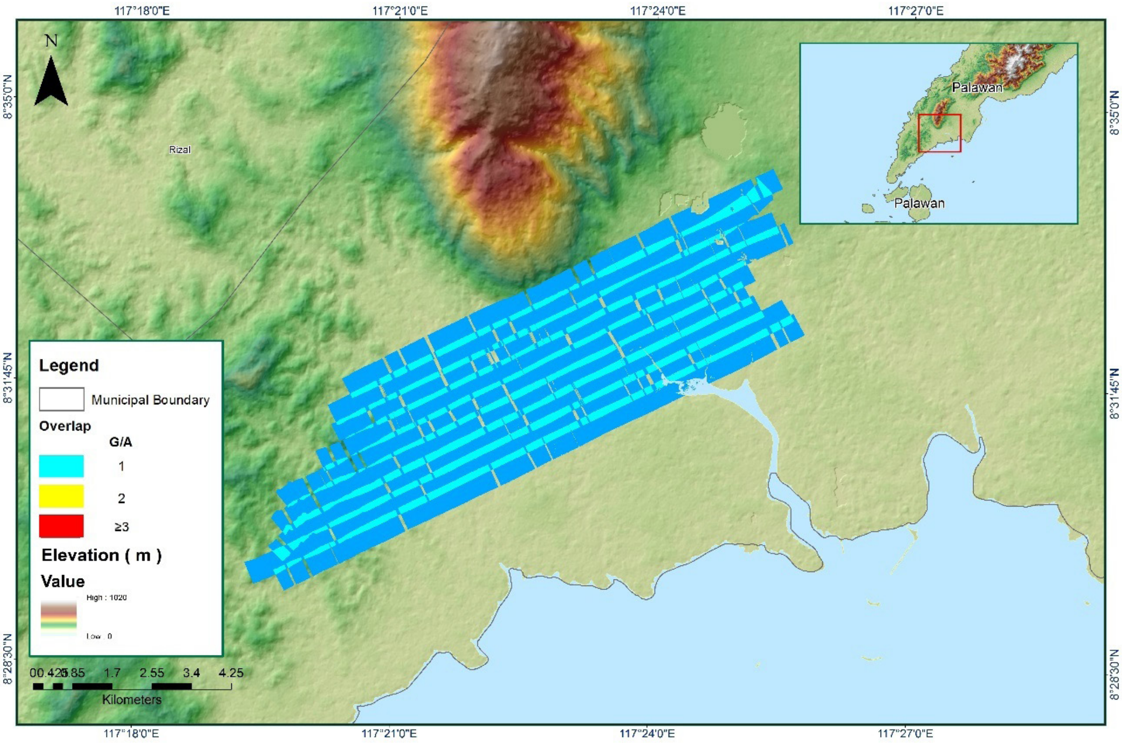

Figure 1.8.5 Image of data overlap

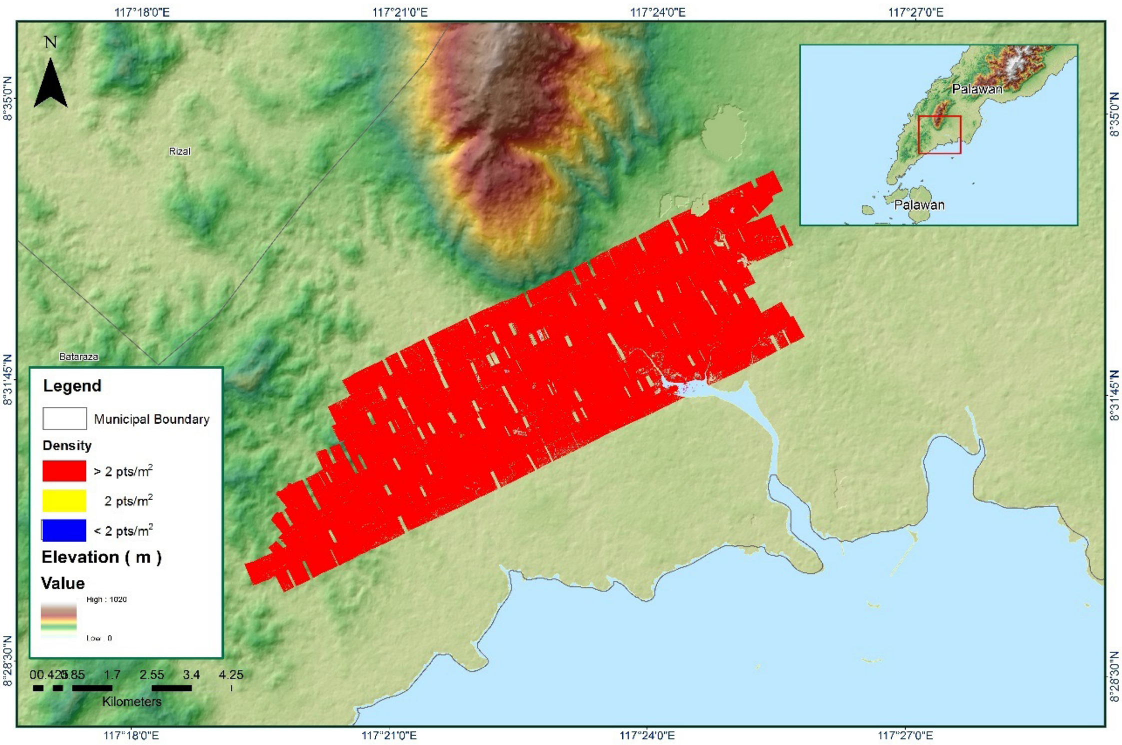

Figure 1.8.6 Density Map of merged LiDAR data

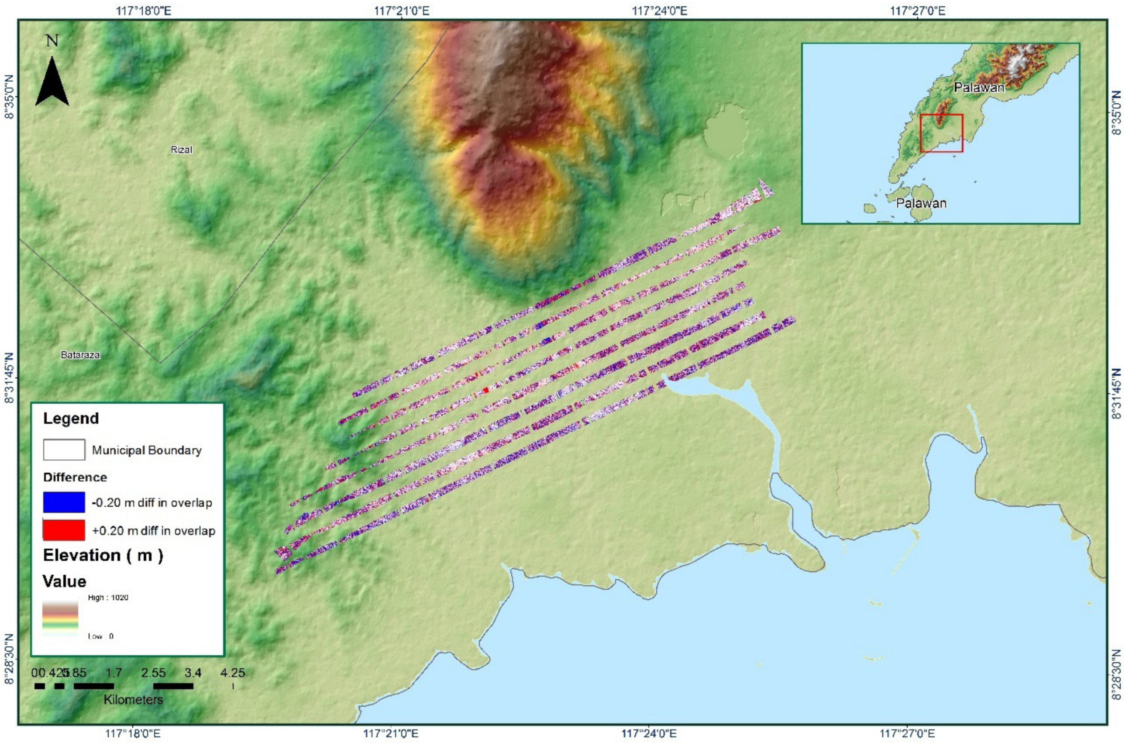

Figure 1.8.7 Elevation Difference Between flight lines

Flight Area	**Palawan Reflights**
Mission Name	**Blk42eT**
Inclusive Flights	3571G, 3593G
Range data size	35.5 GB
Base data size	17.8 MB
POS	387 MB
Image	NA
Transfer date	January 5, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.31
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.21
Boresight correction stdev (<0.001deg)	0.001002
IMU attitude correction stdev (<0.001deg)	0.002183
GPS position stdev (<0.01m)	0.0109
Minimum % overlap (>25)	19.71%
Ave point cloud density per sq.m. (>2.0)	5.03
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	86
Maximum Height	710.24 m
Minimum Height	40.94 m
Classification (# of points)	
Ground	18,993,220
Low vegetation	27,319,279
Medium vegetation	108,976,379
High vegetation	138,214,327
Building	1,719,315
Ortophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Justine Francisco, Maria Tamsyn Malabanan

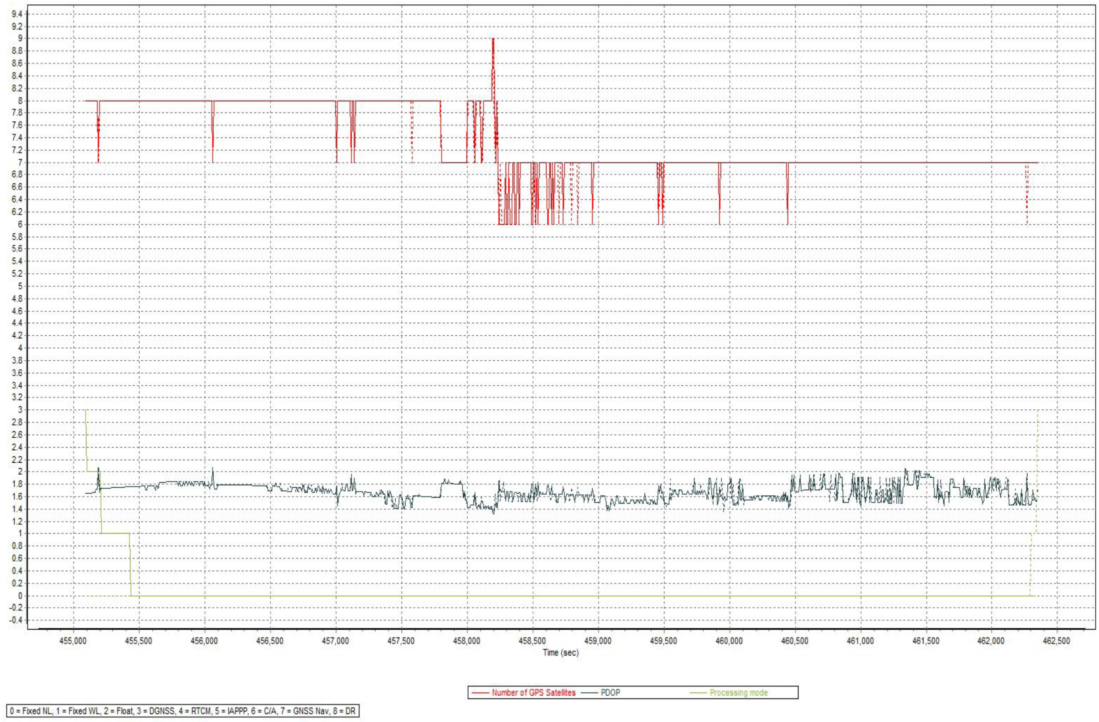

Figure 1.9.1. Solution Status

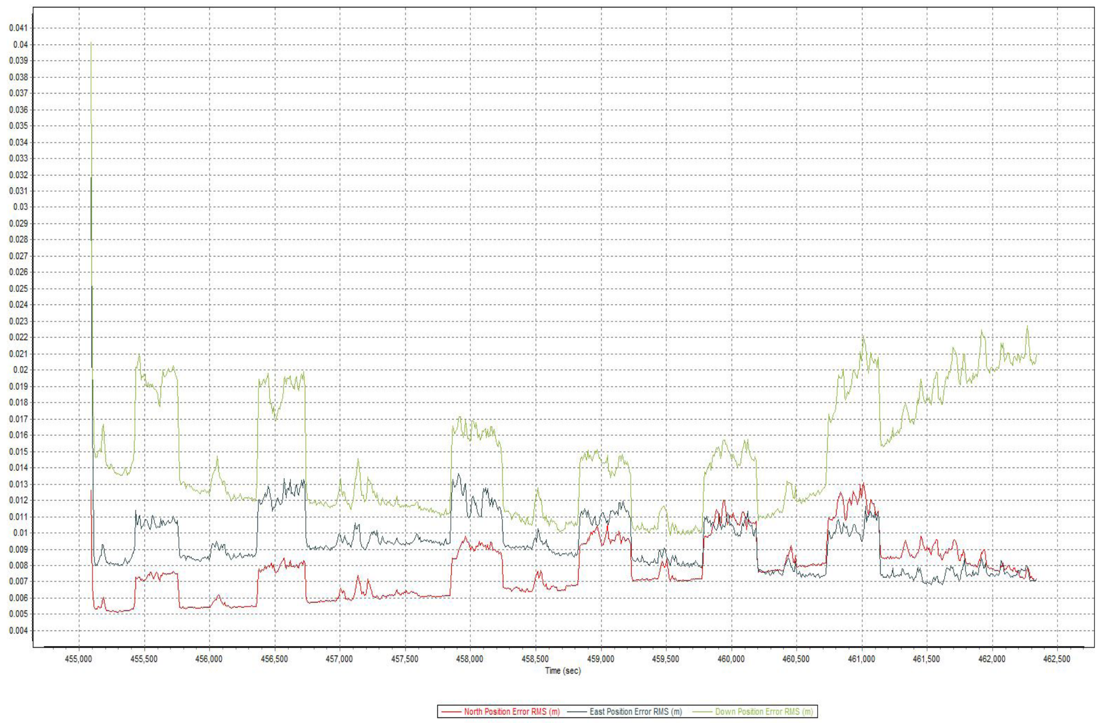

Figure 1.9.2. Smoothed Performance Metric Parameters

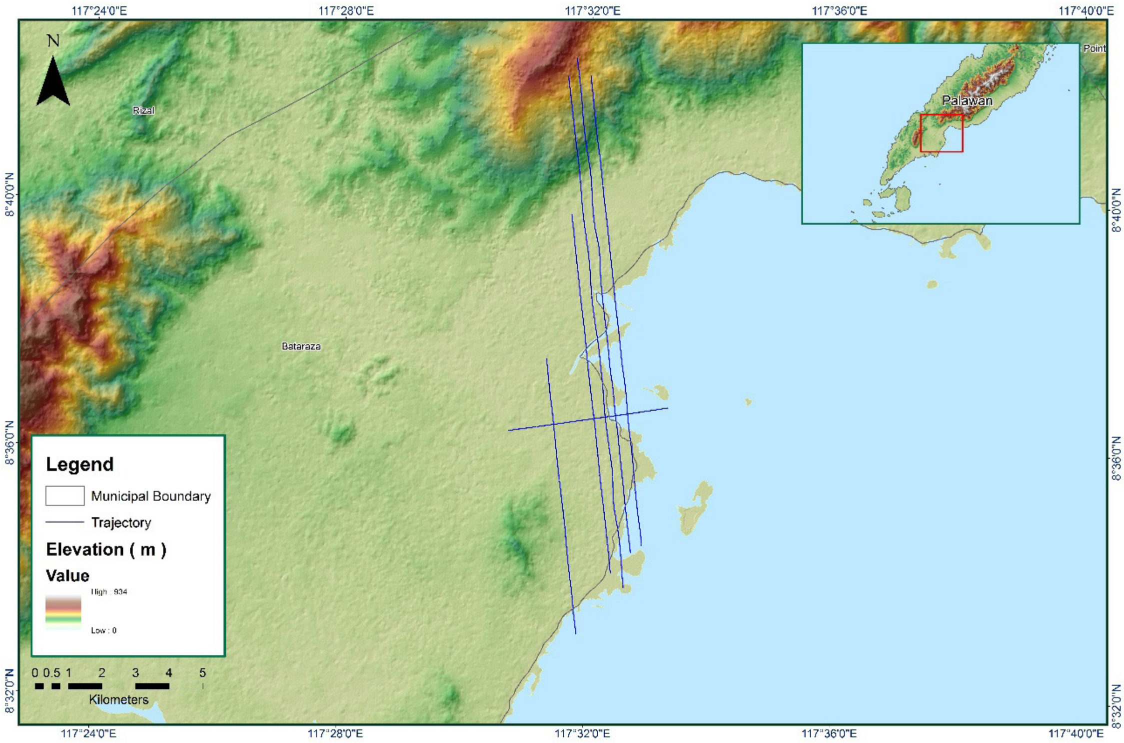

Figure 1.9.3 Best Estimated Trajectory

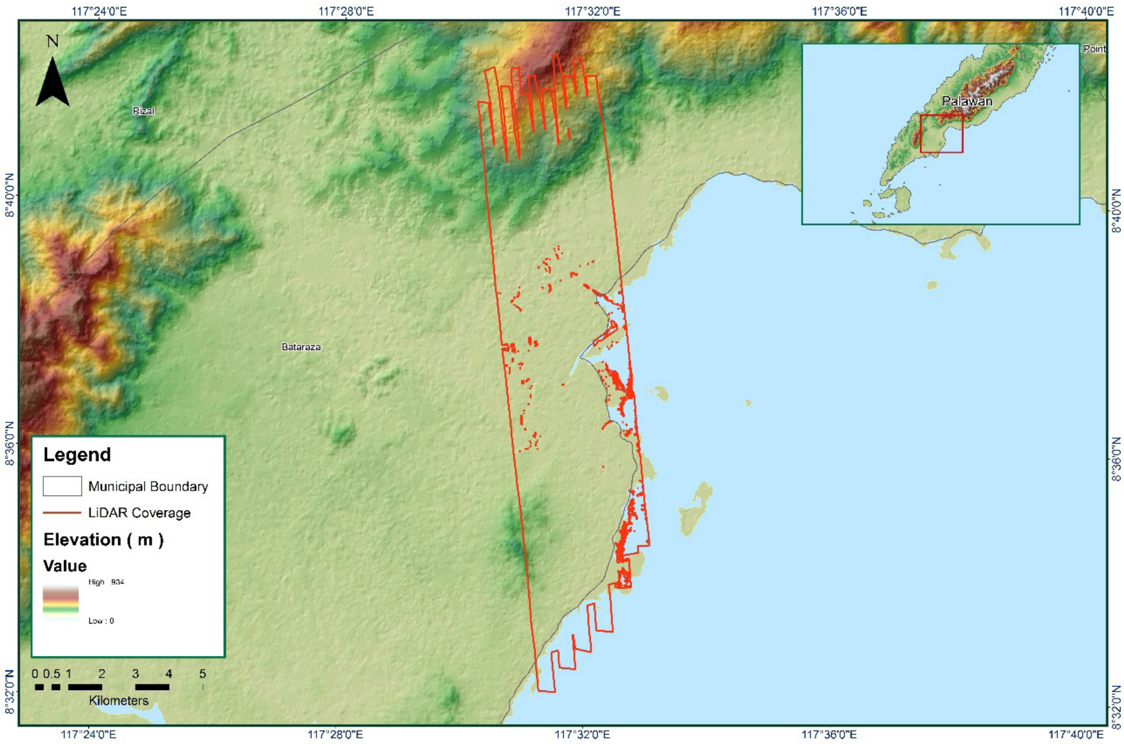

Figure 1.9.4 Coverage of LiDAR data

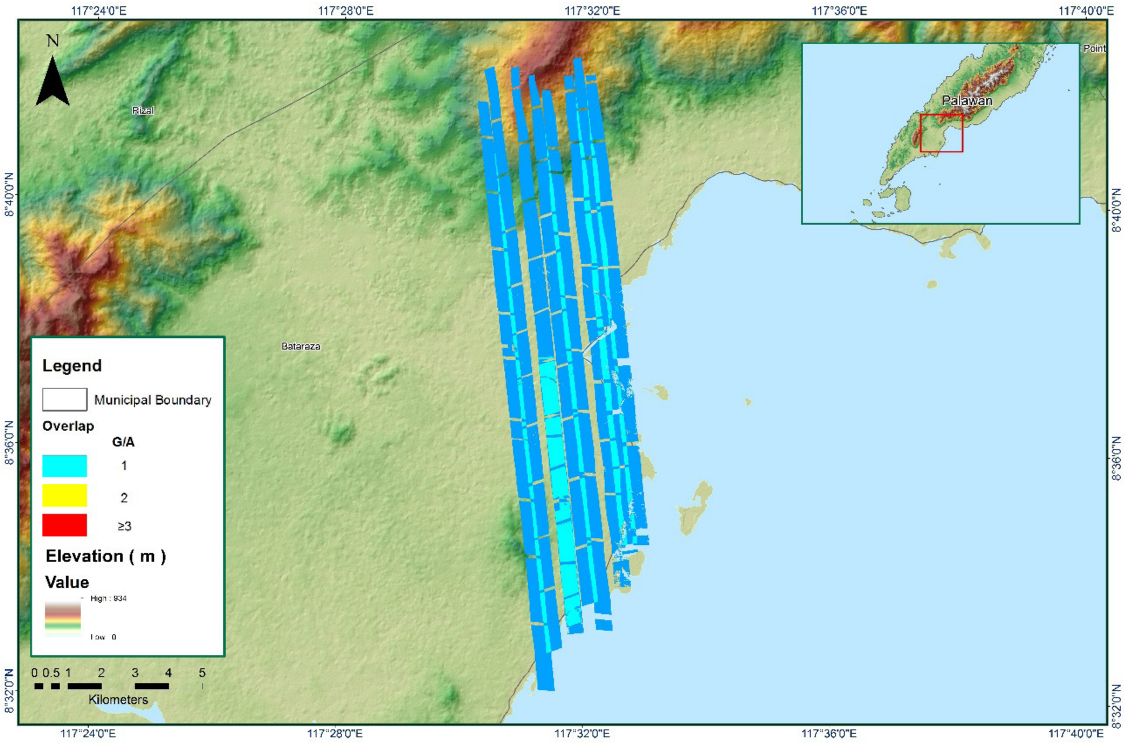

Figure 1.9.5 Image of data overlap

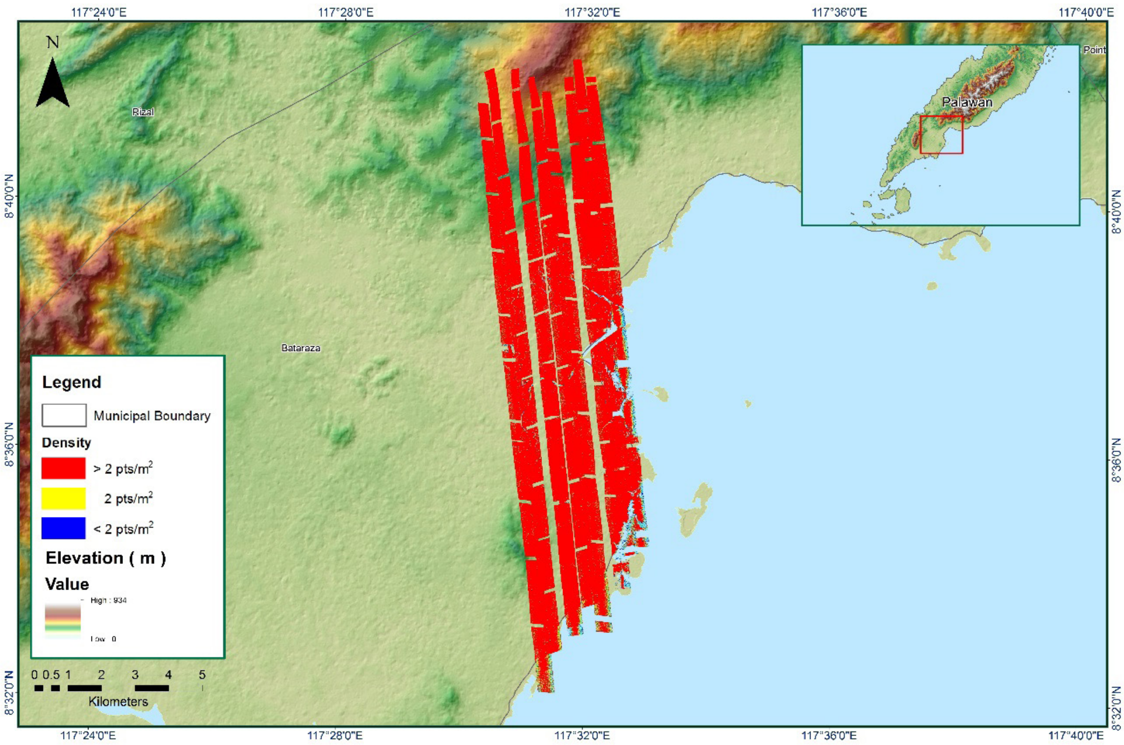

Figure 1.9.6 Density Map of merged LiDAR data

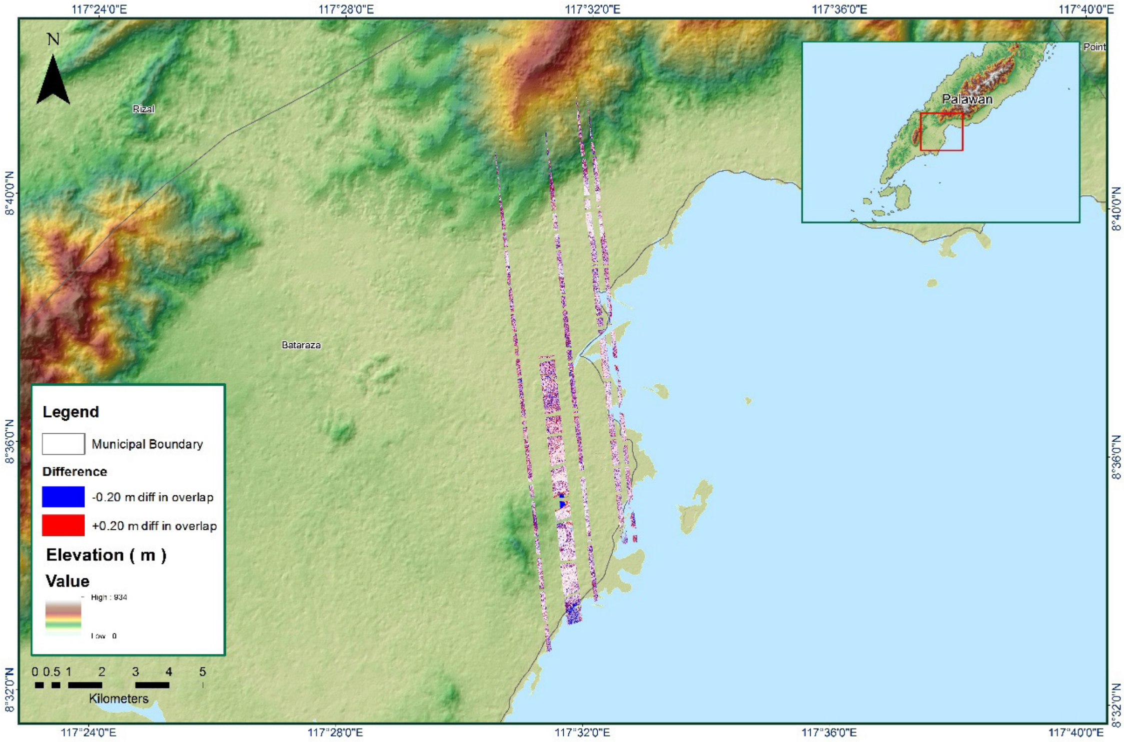

Figure 1.9.7 Elevation Difference Between flight lines

ANNEX 9. OCAYAN MODEL BASIN PARAMETERS

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W320	0.0431	99.0000	0.0	0.1299	0.0333	0.62164	0.2469	0.5554
W330	0.0650	99.0000	0.0	0.2544	0.0333	0.64982	0.3722	0.6062
W340	0.0837	99.0000	0.0	4.7470	0.0413	0.39854	1.0000	0.3864
W350	0.0261	99.0000	0.0	0.2011	0.0333	0.98583	0.2322	0.8812
W360	0.0600	99.0000	0.0	2.3123	0.0358	0.0991752	1.0000	0.3973
W370	0.0174	99.0000	0.0	6.2151	0.0526	1.7564	1.0000	0.3861
W380	0.0377	99.0000	0.0	4.9471	0.0333	0.31724	1.0000	0.3877
W390	0.0848	99.0000	0.0	3.9923	0.0389	0.35537	1.0000	0.2102
W400	0.0503	99.0000	0.0	2.7087	0.0433	0.26259	1.0000	0.2130
W410	0.0520	99.0000	0.0	4.3217	0.0732	0.55704	1.0000	0.3633
W420	0.0261	99.0000	0.0	0.6428	0.0333	0.59902	0.2574	0.9993
W430	0.0236	99.0000	0.0	6.5419	0.0362	1.2324	1.0000	0.3776
W440	0.0550	99.0000	0.0	5.7859	0.0386	0.33305	1.0000	0.3828
W450	0.2930	99.0000	0.0	5.7441	0.0764	0.1739	1.0000	0.2102
W460	0.0997	99.0000	0.0	3.4126	0.0736	1.2279	1.0000	0.3793
W470	0.0269	99.0000	0.0	2.2683	0.0454	0.35745	1.0000	0.2134
W480	0.0172	99.0000	0.0	6.2746	0.0607	0.71726	1.0000	0.2196
W490	0.0104	99.0000	0.0	0.6521	0.0333	0.0226179	0.4515	0.6363
W500	0.0078	99.0000	0.0	4.2994	0.0333	0.10889	1.0000	0.1975
W510	0.0139	99.0000	0.0	4.6831	0.0333	0.39635	1.0000	0.2680
W520	0.0063	99.0000	0.0	4.2263	0.0368	0.23311	1.0000	0.2252
W530	0.0177	99.0000	0.0	7.7196	0.0804	0.97748	1.0000	0.3890
W540	3.5500	78.0000	0.0	1.8542	3.0260	0.3967	1.0000	0.5000
W550	2.2129	85.1610	0.0	4.4362	7.2399	1.203	1.0000	0.5000
W570	1.5500	89.0000	0.0	0.6152	1.0041	0.0762021	1.0000	0.5000
W580	1.5500	89.0000	0.0	1.5736	2.5681	0.37237	1.0000	0.5000
W590	1.5500	89.0000	0.0	0.6449	1.0524	0.0201903	1.0000	0.5000
W600	1.4749	89.5950	0.0	1.8300	2.9865	0.33927	1.0000	0.5000
W610	0.6353	95.2360	0.0	4.0502	6.6099	0.94362	1.0000	0.5000
W620	0.2500	98.0000	0.0	1.0336	1.6869	0.30676	1.0000	0.5000
W640	3.6559	77.6480	0.0	0.5886	0.9606	0.0839585	1.0000	0.5000
W650	0.0133	99.0000	0.0	0.3226	0.0333	0.0088814	0.4386	0.6368

ANNEX 10. OCAYAN MODEL REACH PARAMETERS

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R120	Automatic Fixed Interval	4436.6	0.0635989	0.15125	Trapezoid	10	1
R130	Automatic Fixed Interval	748.41	0.0179619	0.18434	Trapezoid	10	1
R160	Automatic Fixed Interval	1507.1	0.010022	0.12955	Trapezoid	10	1
R170	Automatic Fixed Interval	128.99	0.010022	0.18908	Trapezoid	10	1
R190	Automatic Fixed Interval	791.84	0.0055902	0.0814726	Trapezoid	10	1
R200	Automatic Fixed Interval	4671.6	0.0071624	0.20203	Trapezoid	10	1
R210	Automatic Fixed Interval	1025.7	0.0072524	0.1248	Trapezoid	10	1
R230	Automatic Fixed Interval	565.27	0.0012551	0.04	Trapezoid	10	1
R250	Automatic Fixed Interval	5545.7	0.002072	0.04	Trapezoid	10	1
R280	Automatic Fixed Interval	233.85	0.0090545	0.04	Trapezoid	10	1
R30	Automatic Fixed Interval	764.97	0.0676124	0.62488	Trapezoid	10	1
R300	Automatic Fixed Interval	4118.6	0.0012551	0.04	Trapezoid	10	1
R310	Automatic Fixed Interval	579.56	0.0012551	0.04	Trapezoid	10	1
R60	Automatic Fixed Interval	379.71	0.0193748	0.45581	Trapezoid	10	1
R660	Automatic Fixed Interval	96.569	0.0012551	0.14697	Trapezoid	10	1
R70	Automatic Fixed Interval	1558.5	0.0178403	0.44548	Trapezoid	10	1

ANNEX 11. OCAYAN FIELD VALIDATION

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	8.510242	117.467	0.54	0	-0.54			25-Year
2	8.511402	117.4655	0.03	0	-0.03			25-Year
3	8.512824	117.4674	0.06	0	-0.06			25-Year
4	8.515411	117.4703	1.06	0.85	-0.21		Oct. 2015	25-Year
5	8.515616	117.4816	0.03	0	-0.03			25-Year
6	8.516363	117.4829	0.05	0	-0.05			25-Year
7	8.516738	117.4814	0.03	0	-0.03			25-Year
8	8.516826	117.4813	0.03	0	-0.03			25-Year
9	8.517028	117.4819	0.29	0	-0.29			25-Year
10	8.51731	117.4841	0.09	0	-0.09			25-Year
11	8.517386	117.4832	0.03	0	-0.03			25-Year
12	8.517442	117.4822	0.04	0	-0.04			25-Year
13	8.517629	117.484	0.03	0	-0.03			25-Year
14	8.518076	117.482	0.06	0	-0.06			25-Year
15	8.520565	117.4692	0.03	0	-0.03			25-Year
16	8.527937	117.434	0.08	0	-0.08			25-Year
17	8.528553	117.4322	0.03	0	-0.03			25-Year
18	8.528649	117.4347	0.15	0	-0.15			25-Year
19	8.529794	117.4323	0.09	0	-0.09			25-Year
20	8.530552	117.4344	0.03	0	-0.03			25-Year
21	8.531113	117.4414	0.04	0	-0.04			25-Year
22	8.531312	117.4357	0.1	0	-0.1			25-Year
23	8.531786	117.4325	0.75	0	-0.75			25-Year
24	8.53367	117.4322	0.07	0	-0.07			25-Year
25	8.533983	117.4357	0.11	0	-0.11			25-Year
26	8.53462	117.4328	0.3	0	-0.3			25-Year
27	8.535089	117.4355	0.03	0	-0.03			25-Year
28	8.535182	117.435	0.06	0	-0.06			25-Year
29	8.535904	117.4345	0.03	0	-0.03			25-Year
30	8.537132	117.4326	0.03	0	-0.03			25-Year
31	8.557449	117.4809	0.03	0	-0.03			25-Year
32	8.558927	117.4747	0.03	0	-0.03			25-Year
33	8.560612	117.4407	0.03	0	-0.03			25-Year
34	8.563276	117.4686	0.03	0	-0.03			25-Year
35	8.563673	117.4381	0.03	0	-0.03			25-Year
36	8.564149	117.4672	1.86	2	0.14		Oct. 2015	25-Year
37	8.564784	117.4646	0.94	0	-0.94			25-Year

38	8.565013	117.4577	0.03	0	-0.03			25-Year
39	8.564893	117.4479	0.4	0.81	0.41		Oct. 2015	25-Year
40	8.565029	117.4385	0.03	0	-0.03			25-Year
41	8.565314	117.4566	0.03	0	-0.03			25-Year
42	8.565197	117.4413	0.04	0	-0.04			25-Year
43	8.565343	117.4477	0.32	0	-0.32			25-Year
44	8.565613	117.4595	0.03	0	-0.03			25-Year
45	8.565596	117.4576	0.03	0	-0.03			25-Year
46	8.565365	117.4404	0.03	0	-0.03			25-Year
47	8.566798	117.4454	0.03	0	-0.03			25-Year
48	8.567511	117.4478	0.03	0	-0.03			25-Year
49	8.568294	117.4442	0.03	0	-0.03			25-Year
50	8.569369	117.4382	0.03	0	-0.03			25-Year
51	8.569559	117.4383	0.03	0	-0.03			25-Year
52	8.570997	117.4365	0.05	0	-0.05			25-Year
53	8.571816	117.4372	0.03	0	-0.03			25-Year
54	8.572383	117.4387	1.69	0	-1.69			25-Year
55	8.57855	117.444	0.03	0	-0.03			25-Year
56	8.580283	117.4457	1.44	0	-1.44			25-Year
57	8.581275	117.447	0.03	0	-0.03			25-Year
58	8.581369	117.4469	0.05	0	-0.05			25-Year
59	8.584438	117.4504	0.11	0	-0.11			25-Year
60	8.584493	117.4505	0.03	0	-0.03			25-Year
61	8.589451	117.4542	0.05	0	-0.05			25-Year
62	8.59303	117.5135	0.1	0	-0.1			25-Year
63	8.593702	117.4536	0.07	0	-0.07			25-Year
64	8.594827	117.4536	0.07	0	-0.07			25-Year
65	8.595691	117.5119	0.03	0	-0.03			25-Year

66	8.59497	117.4534	0.08	0	-0.08			25-Year
67	8.597372	117.5083	0.03	0	-0.03			25-Year
68	8.598294	117.5063	0.03	0	-0.03			25-Year
69	8.598288	117.505	0.03	0	-0.03			25-Year
70	8.598683	117.5049	0.03	0	-0.03			25-Year
71	8.598227	117.4547	0.04	0	-0.04			25-Year
72	8.59901	117.5061	0.03	0	-0.03			25-Year
73	8.598546	117.4536	0.04	0	-0.04			25-Year
74	8.598617	117.4532	0.03	0	-0.03			25-Year
75	8.599365	117.5043	0.11	0.5	0.39		2002	25-Year
76	8.599439	117.5034	1.27	1.32	0.05		2002	25-Year
77	8.598726	117.4529	0.14	0	-0.14			25-Year
78	8.599615	117.5059	0.03	0	-0.03			25-Year
79	8.599864	117.4533	0.03	0	-0.03			25-Year
80	8.600242	117.4531	0.05	0	-0.05			25-Year
81	8.600284	117.4526	0.13	0	-0.13			25-Year
82	8.601298	117.4529	0.03	0	-0.03			25-Year
83	8.601721	117.4525	0.23	0	-0.23			25-Year
84	8.601855	117.4518	0.03	0	-0.03			25-Year
85	8.603715	117.4363	0.03	0	-0.03			25-Year
86	8.604071	117.4408	0.03	0	-0.03			25-Year
87	8.60405	117.4393	0.03	0	-0.03			25-Year
88	8.604696	117.4531	0.13	0	-0.13			25-Year
89	8.606166	117.4528	0.51	0.35	-0.16		Jan. 2014	25-Year
90	8.609155	117.4548	0.03	0.22	0.19		Dec. 2016	25-Year
91	8.609238	117.4545	0.03	0	-0.03			25-Year
92	8.609391	117.4536	0.03	0	-0.03			25-Year
93	8.609558	117.454	0.03	0	-0.03			25-Year
94	8.609582	117.4548	0.03	0	-0.03			25-Year
95	8.60962	117.4538	0.03	0	-0.03			25-Year
96	8.609742	117.4548	0.04	0	-0.04			25-Year
97	8.609804	117.4537	0.03	0	-0.03			25-Year
98	8.610248	117.454	0.06	0	-0.06			25-Year
99	8.610651	117.454	0.03	0	-0.03			25-Year
100	8.611483	117.4772	0.03	0	-0.03			25-Year
101	8.611472	117.4716	0.03	0	-0.03			25-Year
102	8.620799	117.4565	0.03	0.1	0.07		June, 2016	25-Year
103	8.620799	117.4565	0.03	0.1	0.07		June, 2016	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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