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

LiDAR Surveys and Flood Mapping of Bansud River

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

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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPLB	University of the Philippines Los Baños
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 BANSUD RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin Abucay, and Ms. Miyah D. Queliste

1.1 Background of the Phil-LIDAR 1 Program

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

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

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

1.2 Overview of the Bansud River Basin

Bansud River Basin is a 8,470-hectare watershed located in Oriental Mindoro. It covers the barangays of Manguyang and Conrazon in Gloria municipality; Pag-asa, Poblacion, Alcadesma, Proper Bansud, Proper Tiguisan, Salcedo, Rosacara, Manihala, Malo, Tawas, Bato, and Sumagui in Bansud; and, Banus, Sigange, Carmundo, Libertad and Labasan in Bongabong. The basin area has seven geological classifications with Upper-Miocene-Pliocene rocks as the most dominant type while the remaining include Cretaceous-Paleogene and Oligocene-Miocene. In terms of topography, the river basin has 0-50% slope and elevation between 0-250 meters above mean sea level. Sandy clay loam, loam and clay loam are the types of soil that can be found in the area. Three land cover types dominant the river basin including cultivated land (perennial crops), open forests and grasslands.

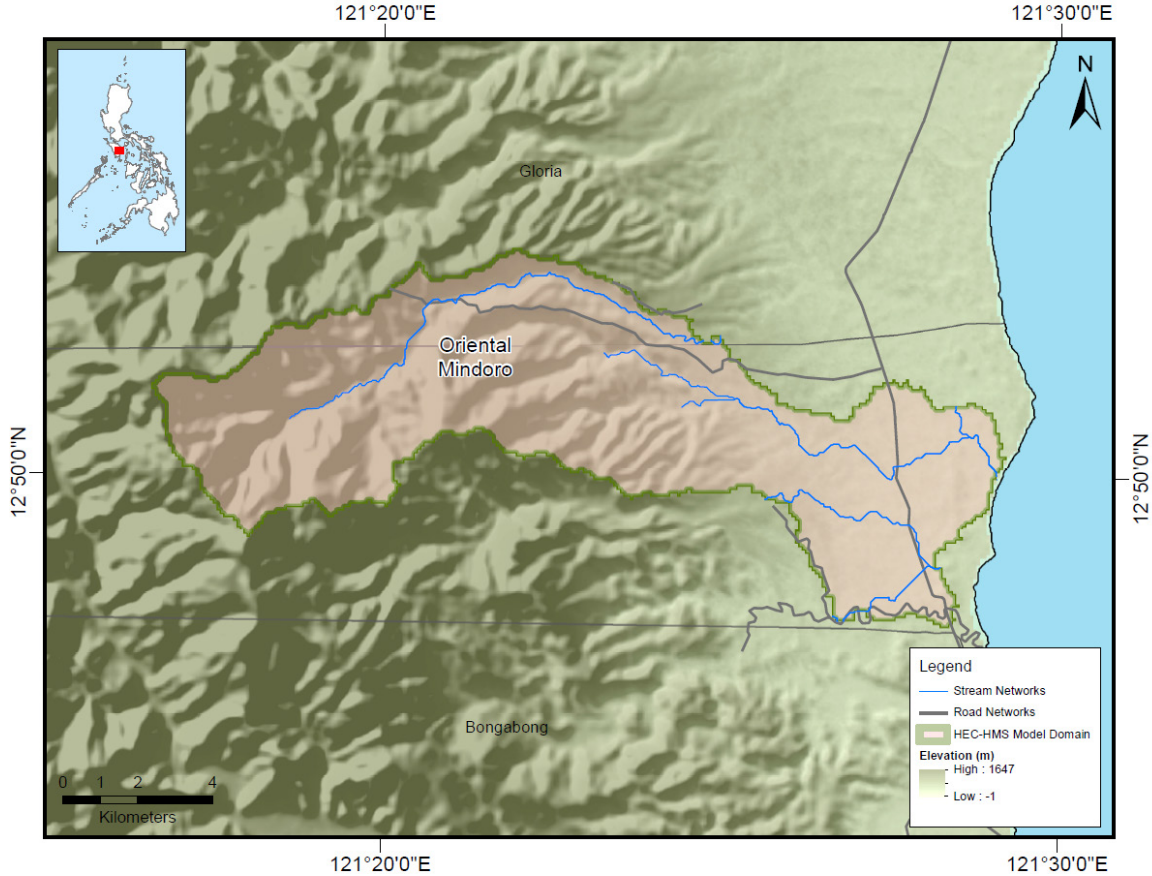


Figure 1. Map of Bansud River Basin (in brown).

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.

Bansud River passes through Manguyan and Conrazon in Gloria; Pagasa, Poblacion, Alcadesma, Proper Bansud, Proper Tiguisan, Salcedo, Rosacara, Manihala, Malo, Tawas, Bato and Sumagui in Bansud; and, Banus, Sigange, Carmundo, Libertad and Labasan in Bongabong. The 2010 NSO Census of Population and Housing records showed that, Banus in Gloria; Poblacion in Bansud and Labasan in Bongabong are the most populated barangays located within the river basin.

According to the Mines and Geosciences Bureau, barangays Manguyang and Banus of Gloria; Rosacara, Manihala and Malo of Bansud; and, Tawas and Sigange of Bongabong have high risks to landslide the remaining barangays within the river basin have low risks. The field surveys conducted by the PHIL-LiDAR 1 validation team, showed that there were seven notable weather disturbance that caused flooding in 2006 (Caloy), 2008 (Frank), 2012 (Ofel), 2013 (Yolanda), 2015 (Nona), and 2016 (Lando).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BANSUD FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, and Mr. Merlin A. Fernando

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

To initiate the LiDAR acquisition survey of the Bansud floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Bansud Floodplain in Oriental Mindoro. These flight missions were planned for 21 lines and ran for at most four and a half hours (4.5) including take-off, landing and turning time using two sensors – the Aquarius and Gemini (see Annex 1 for sensor specifications). The flight planning parameters for the LiDAR systems are outlined in Table 1 and Table 2. Figure 2, on the other hand, shows the flight plan and base stations for Bansud floodplain survey.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	600	30	36	50	45	130	5
BLK28B	600	30	36	50	45	130	5
BLK28C	600	30	36	50	45	130	5
BLK28D	600	30	36	50	45	130	5
BLK28E	600	30	36	50	45	130	5
BLK28F	600	30	36	50	45	130	5
BLK28G	600	30	36	50	45	130	5
BLK 28H	600	30	36	50	45	130	5
BLK28I	600, 1000	30	36	50	45	130	5
BLK28J	600	30	36	50	45	130	5

Table 2. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Fre-quency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28E	1200	30	30	100	50	130	5
BLK28F	1000	30	40	100	50	130	5
BLK28H	1200	30	30	100	50	130	5
BLK28I	1200	30	30	100	50	130	5

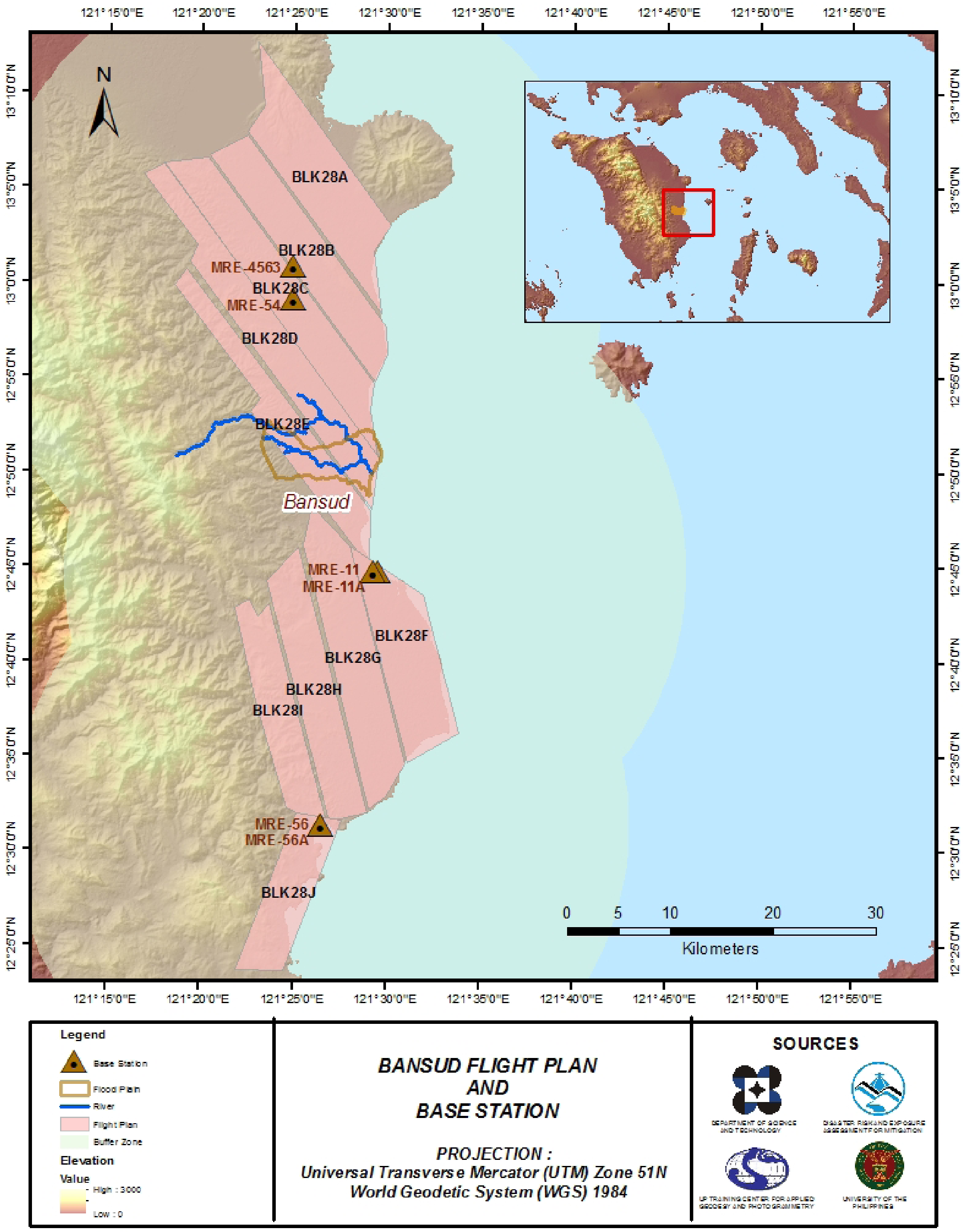


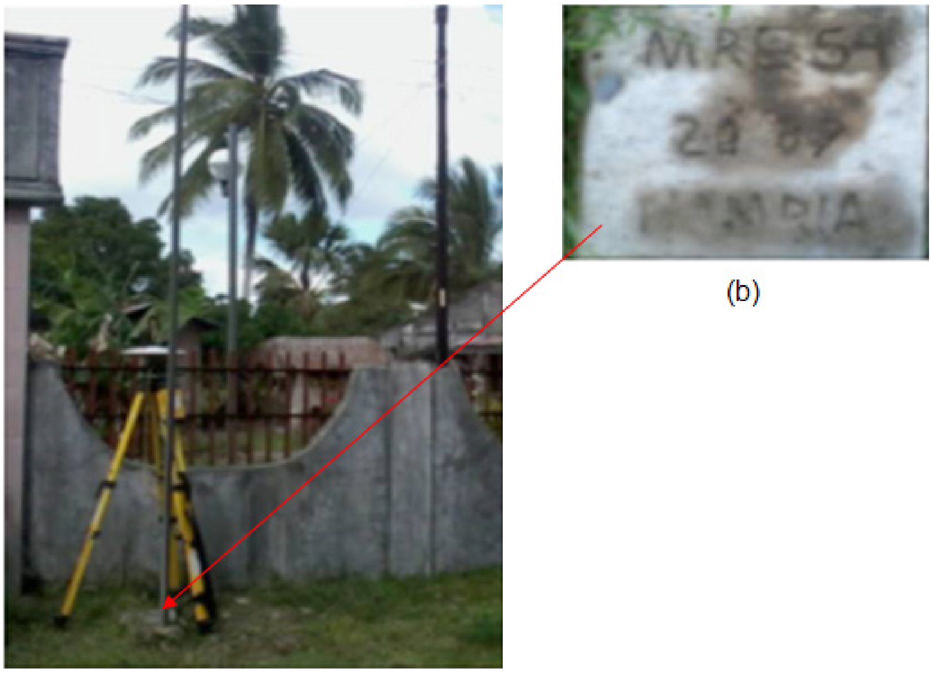
Figure 2. Flight plans and base stations used for Bansud floodplain.

2.2 Ground Base Stations

The project team was able to recover four (4) NAMRIA ground control points: MRE-54 and MRE-56 which are of second (2^{nd}) order accuracy, MRE-11 which is of third (3^{rd}) order accuracy, and MRE-4563 which is of fourth (4^{th}) order accuracy. The project team also established two (2) ground control points, MRE-11A and MRE 56A.

The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from February 3-12, 2014; October 23-26, 2015. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Bansud floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Bansud Floodplain LiDAR Survey. Figure 3 and Figure 4 show the recovered NAMRIA reference points within the area of the floodplain, while Table 3 to Table 8 show the details about the following NAMRIA control stations and established points. Table 9, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(b)

(a)

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

Table 3. Details of the recovered NAMRIA horizontal control point MRE-54 used as base station for the LiDAR Acquisition.

Station Name	MRE-54	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12°59'12.43671'' North
	Longitude	121°24'46.52637'' East
	Ellipsoidal Height	42.40800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	544797.009 meters
	Northing	1436124.562 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	12°59'7.43505'' North
	Longitude	122°41'8.09853'' East
	Ellipsoidal Height	91.39500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	327864.09 meters
	Northing	1436121.49 meters

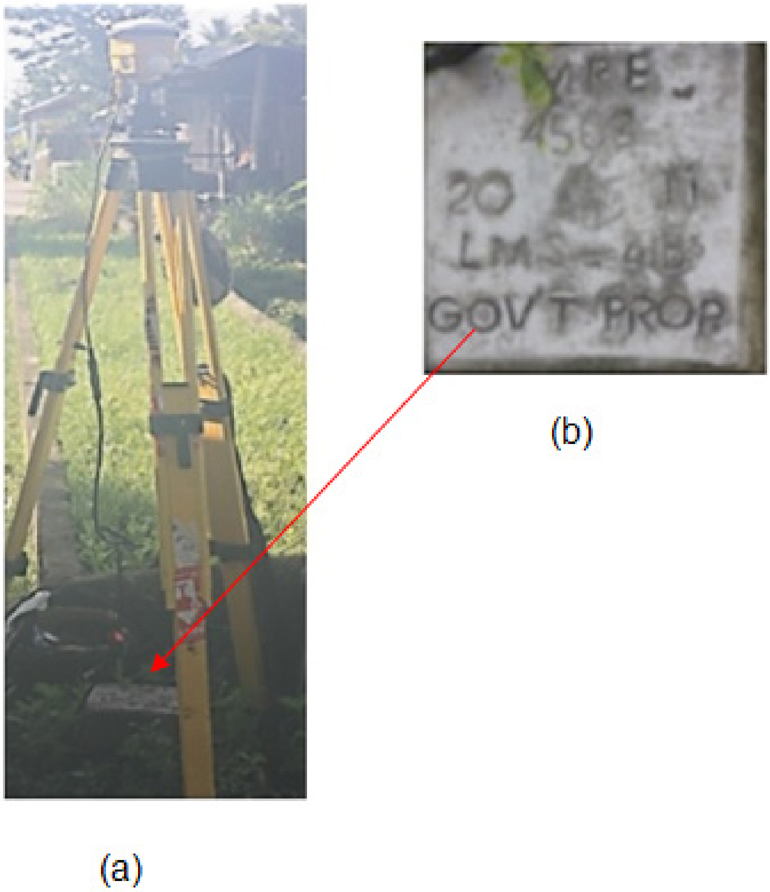


Figure 4. GPS set-up over MRE-4563 (a) just outside the compound of the barangay hall of Brgy. Pagala-gala, municipality of Pinamalayan, Oriental Mindoro; and NAMRIA reference point MRE-4563 (b) as recovered by the field team.

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

Station Name	MRE-4563	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1:50,000	
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13°00’53.01692’’ North
	Longitude	121°24’51.45337’’ East
	Ellipsoidal Height	73.715m meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	328034.015 meters
	Northing	1439300.319 meters

Table 5. Details of the recovered NAMRIA horizontal control point MRE-11 used as base station for the LiDAR Acquisition.

Station Name	MRE-11	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12°44'50.41380'' North
	Longitude	121°29'7.80130'' East
	Ellipsoidal Height	5.11500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	552720.766 meters
	Northing	1409650.153 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12°44'45.47630'' North
	Longitude	121°29'12.85191'' East
	Ellipsoidal Height	54.91100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	335581.55 meters
	Northing	1409587.05 meters

Table 6. Details of the recovered established horizontal control point MRE-11A used as base station for the LiDAR Acquisition.

Station Name	MRE-11A	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12°44'45.50783'' North
	Longitude	121°29'29.79714'' East
	Ellipsoidal Height	55.558 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	338880.152 meters
	Northing	1409583.946 meters

Table 7. Details of the recovered NAMRIA horizontal control point MRE-56 used as base station for the LiDAR Acquisition.

Station Name	MRE-56	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12°31'25.76362'' North
	Longitude	121°26'25.21109'' East
	Ellipsoidal Height	7.87000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	547,857.861 meters
	Northing	1,384,916.657 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12°31'20.87629'' North
	Longitude	121°26'30.28143'' East
	Ellipsoidal Height	58.13600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	330,530.08 meters
	Northing	1,384,892.31 meters

Table 8. Details of the recovered established horizontal control point MRE-56A used as base station for the LiDAR Acquisition.

<table>
<tr><th>Station Name</th><th colspan="2">MRE-56A</th></tr>
<tr><td>Order of Accuracy</td><td colspan="2">2nd</td></tr>
<tr><td>Relative Error (horizontal positioning)</td><td colspan="2">1:50,000</td></tr>
<tr><td rowspan="3">Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)</td><td>Latitude</td><td>12°31’20.59653’’ North</td></tr>
<tr><td>Longitude</td><td>121°26’30.40791’’ East</td></tr>
<tr><td>Ellipsoidal Height</td><td>57.601 meters</td></tr>
<tr><td rowspan="2">Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)</td><td>Easting</td><td>330,688.179 meters</td></tr>
<tr><td>Northing</td><td>1,384,818.639 meters</td></tr>
</table>

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
3-Feb-14	1056A	3BLK28C034A	MRE-54
5-feb-14	1066A	3BLK28DS036A	MRE-54, MRE-4563
6-Feb-14	1070A	3BLK28DSE037A	MRE-54, MRE-4563
12-Feb-14	1092A	3BLK28ABES043A	MRE-54, MRE-4563
23-Oct-15	8302G	2BLK28ASEHI296A	MRE-54, MRE-11
24-Oct-15	8304G	2BLK28FHS297A	MRE-54, MRE-11
25-Oct-15	8306G	2CALIBBLK28FSGS298A	MRE-11, MRE11A
26-oct-15	8308G	2BLK28J299A	MRE-56,MRE-56A

2.3 Flight Missions

A total of eight (8) missions were conducted to complete the LiDAR Data Acquisition in Bansud Floodplain, for a total of thirty hours and thirty-nine minutes (30+39) of flying time for RP-C9122 and RP-C9322 (See Annex 6). All missions were acquired using the Aquarius and Gemini LiDAR system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 10, while the actual parameters used during the LiDAR data acquisition are presented in Table 11.

Table 10. Flight missions for LiDAR data acquisition in Bansud floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	**Min**
3-Feb-14	1056A	153.08	89.97	3.56	86.41	1111	3	41
5-Feb-14	1066A	132.98	95.19	11.56	83.63	1088	3	35
6-Feb-14	1070A	243.37	134.14	21.28	112.86	1517	4	29
12-Feb-14	1092A	314.3	99.90	7.50	92.4	1176	4	5
23-Oct-15	8302G	434.44	117.20	5.23	111.97	443	3	47
24-Oct-15	8304G	220.17	110.37	0.51	109.86	368	3	30
25-Oct-15	8306G	112.27	70.58	4.31	66.27	N/A	3	41
26-Oct-15	8308G	99.08	103.41	4.23	99.18	N/A	3	51
TOTAL		1709.59	820.76	58.18	762.58	5703	30	39

Table 11. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (kHz)	Scan Frequency (Hz)	Average Speed (Kts)	Average Turn Time (Minutes)
1056A	600	30	36	50	40	130	5
1066A	600	30	36	50	40	115	5
1070A	600	30	36	50	40	130	5
1092A	600	30	36	50	40	130	5
8302G	1200, 800	30	30,40	100	50	130	5
8304G	1200, 900	35	30, 36	100	50	130	5
8306G	1200, 900	35	30, 40	100	50	130	5
8308G	1100	35	36	100	50	120	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Bansud floodplain (See Annex 7). It is situated within the municipality of Bansud, Oriental Mindoro. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 12. Figure 5, on the other hand, shows the actual coverage of the LiDAR acquisition for the Bansud floodplain.

Table 12. List of municipalities and cities surveyed during Bansud floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Oriental Mindoro	Bansud	197.00	90.95	46%
	Bongabong	493.74	114.20	23%
	Bulalacao	365.58	83.73	23%
	Gloria	327.28	132.19	40%
	Mansalay	477.24	34.36	7%
	Naujan	431.57	3.69	1%
	Pinamalayan	206.87	55.33	27%
	Pola	127.04	38.21	30%
	Roxas	90.14	9.17	10%
	Socorro	206.05	63.49	31%
	Victoria	216.22	8.86	4%
TOTAL		3138.73	634.18	20.20%

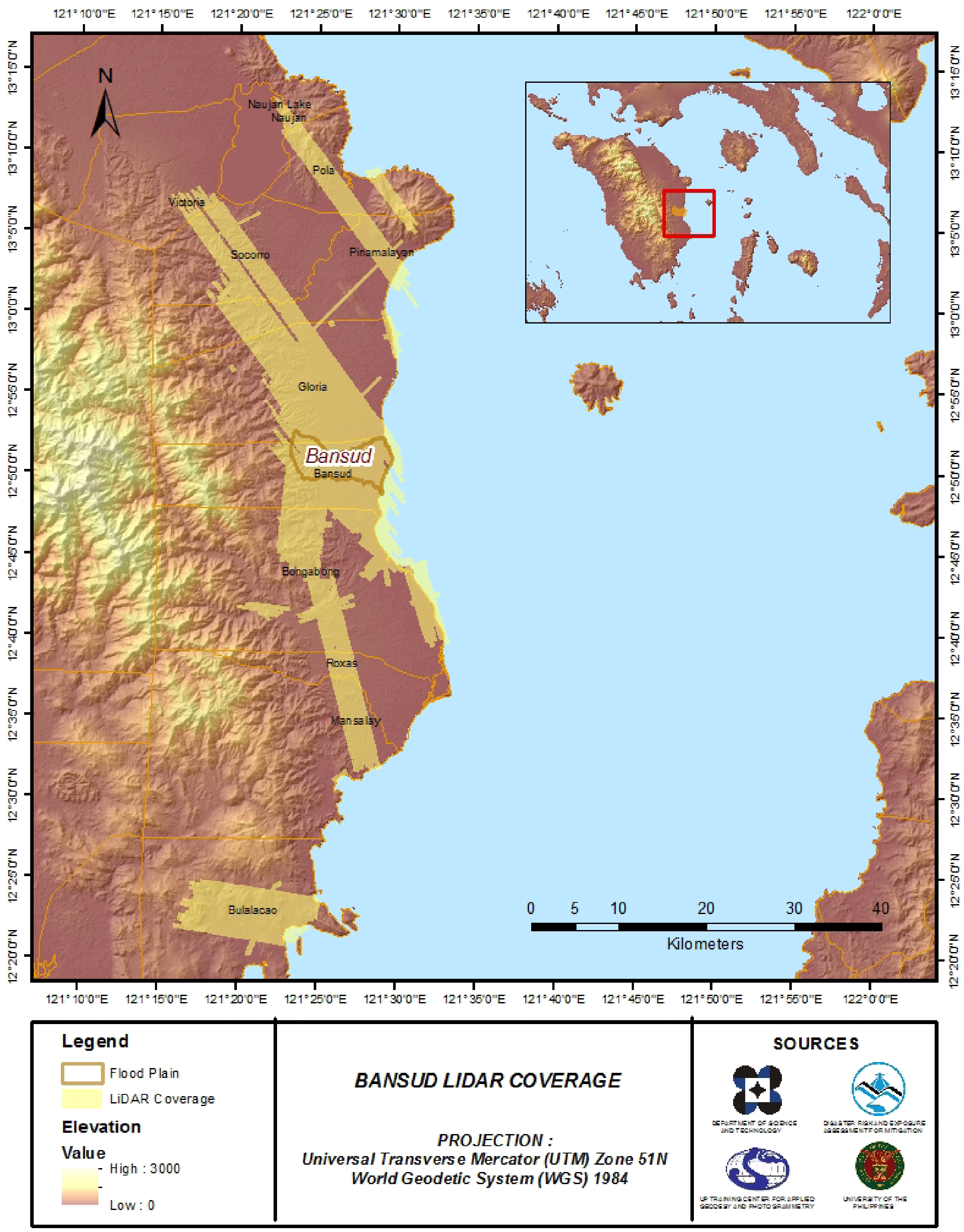


Figure 5. Actual LiDAR survey coverage for Bansud floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BANSUD FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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 6.

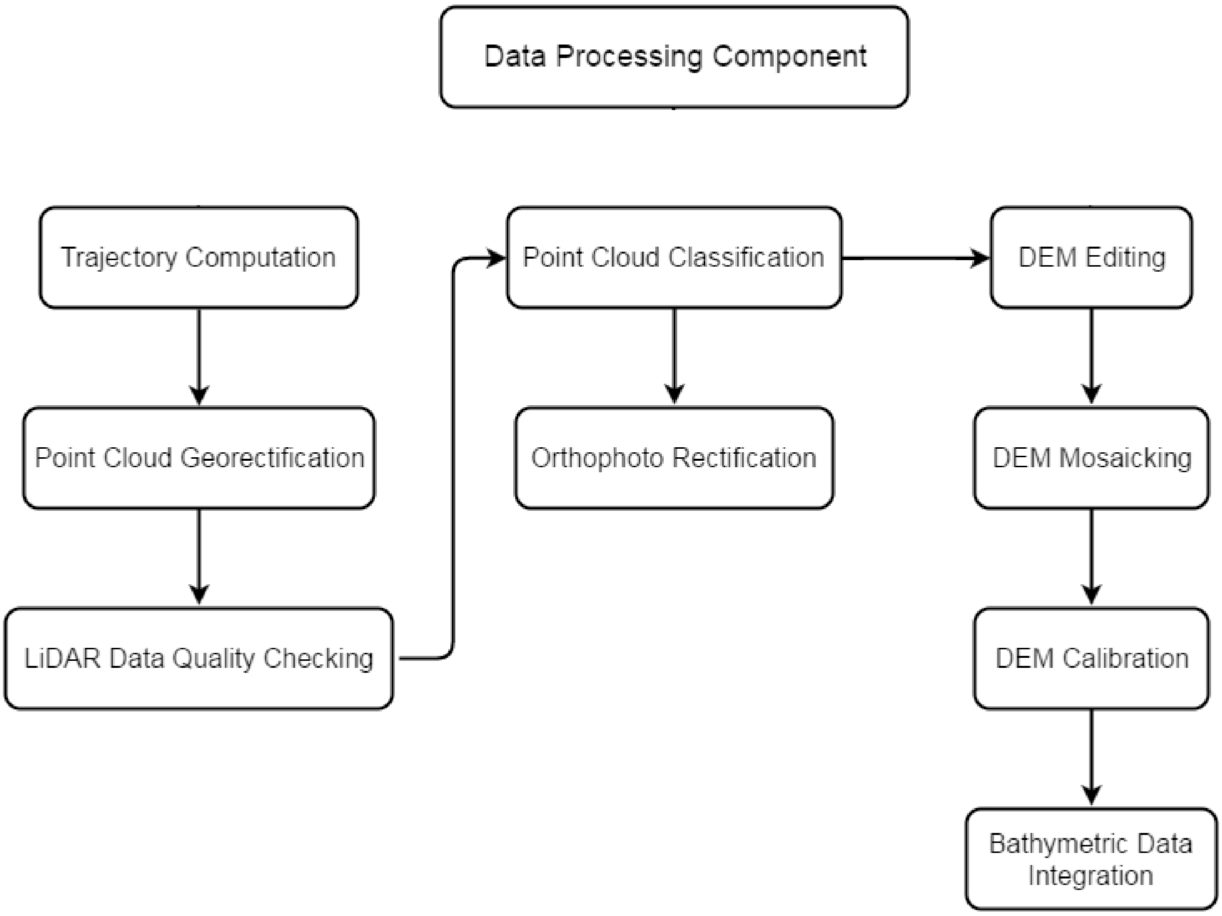


Figure 6. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Bansud floodplain can be found in Annex 5. Missions flown over Bansud, Oriental Mindoro during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on October 2015 were flown using the Gemini system.

The Data Acquisition Component (DAC) transferred a total of 105.90 Gigabytes of Range data, 1.82 Gigabytes of POS data, 88.18 Megabytes of GPS base station data, and 331.8 Gigabytes of raw image data to the data server on February 21, 2014 for the first survey and October 10, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Bansud was fully transferred on October 10, 2015, as indicated on the Data Transfer Sheets for Bansud floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1070A, one of the Bansud flights, which is the North, East, and Down position RMSE values are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 6, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

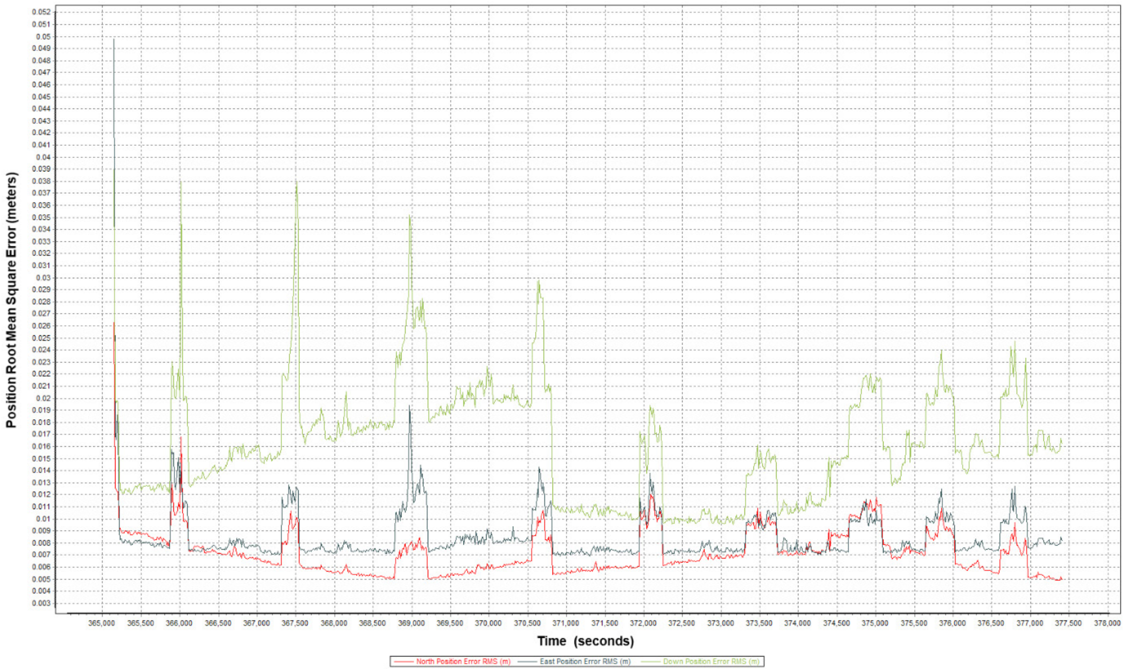


Figure 7. Smoothed Performance Metrics of a Bansud Flight 1070A.

The time of flight was from 365,000 seconds to 377,500 seconds, which corresponds to afternoon of February 6, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.70 centimeters, the East position RMSE peaks at 1. 95 centimeters, and the Down position RMSE peaks at 3.80 centimeters, which are within the prescribed accuracies described in the methodology.

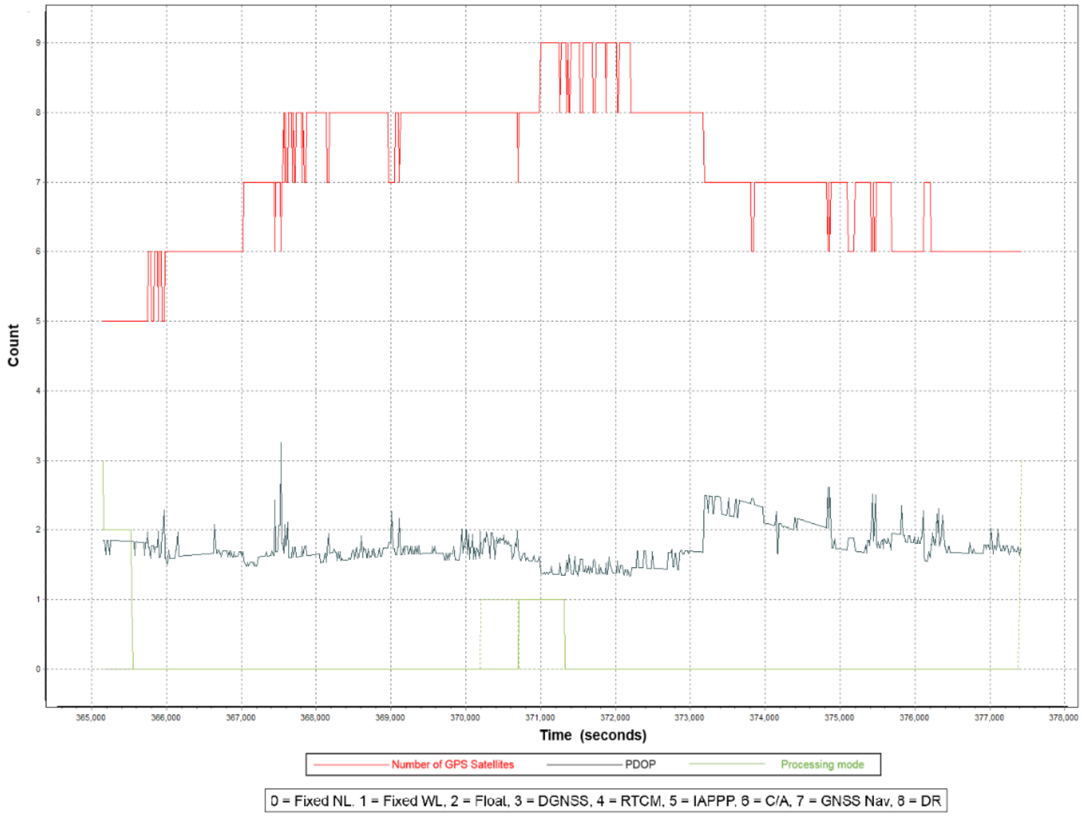


Figure 8. Solution Status Parameters of Bansud Flight 1070A

The Solution Status parameters of flight 1070A, one of the Bansud flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 5 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Bansud flights is shown in Figure 9.

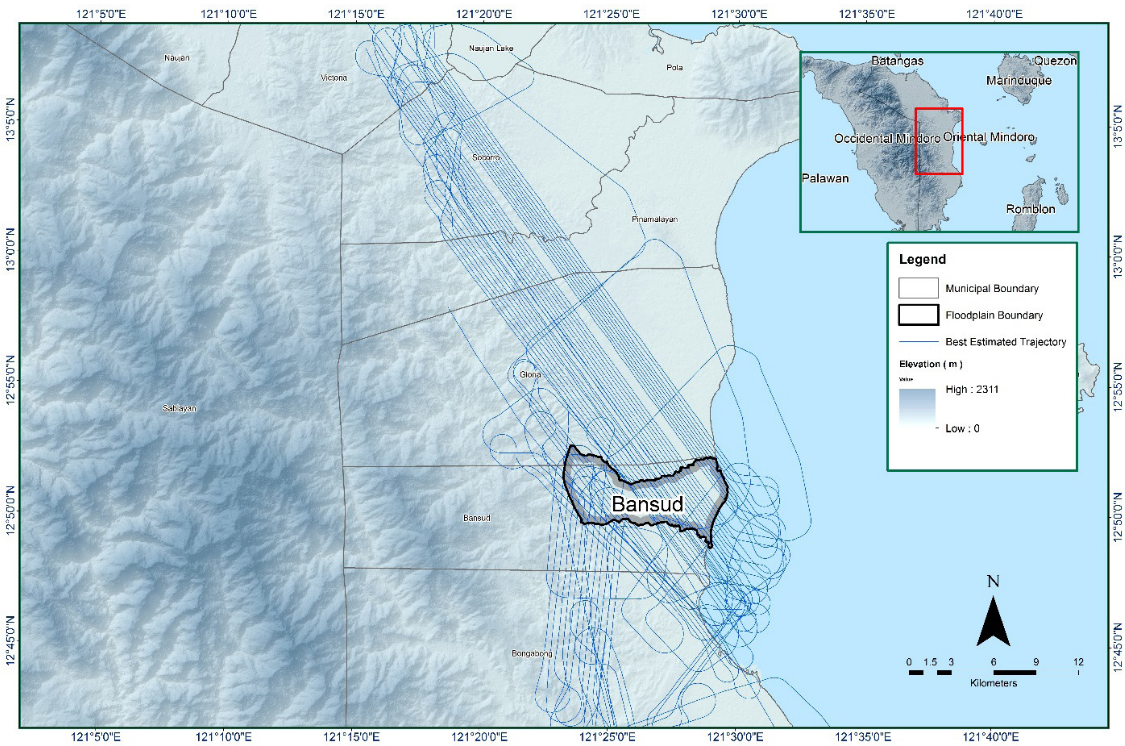


Figure 9. Best Estimated Trajectory of the LiDAR missions conducted over the Bansud Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 140 flight lines, with each flight line containing one channel, since the Aquarius and Gemini system both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Bansud floodplain are given in Table 13.

Table 13. Self-calibration Results values for Bansud flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000346
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000905
GPS Position Z-correction stdev)	<0.01meters	0.0087

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

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Bansud Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

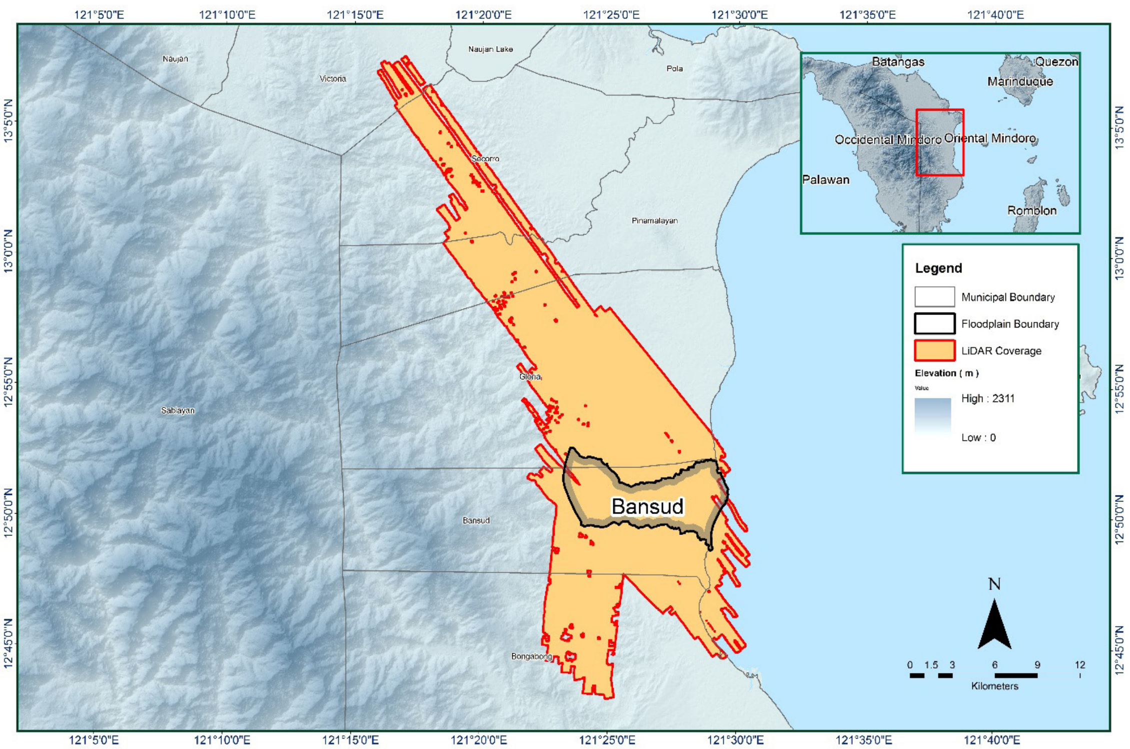


Figure 10. Boundaries of the processed LiDAR data over the Bansud Floodplain.

The total area covered by the Bansud missions is 494.87 square kilometers (sq. kms.) that is comprised of nine (9) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for the Bansud floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km.)
OrientalMindoro_Blk28C	1056A	29.34
OrientalMindoro_Blk28C_supplement	1056A	87.46
OrientalMindoro_Blk28D_supplement	1066A	89.76
OrientalMindoro_Blk28E	1070A	125.45
OrientalMindoro_Blk28E_supplement	1092A	29.61
OrientalMindoro_reflights_Blk28C	8302G	49.04
OrientalMindoro_reflights_Blk28E	8306G	30.83
	8308G	
OrientalMindoro_reflights_Blk28H_supplement	8304G	53.38
	8306G	
	TOTAL	**494.87 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 11. Since the Aquarius and Gemini system both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

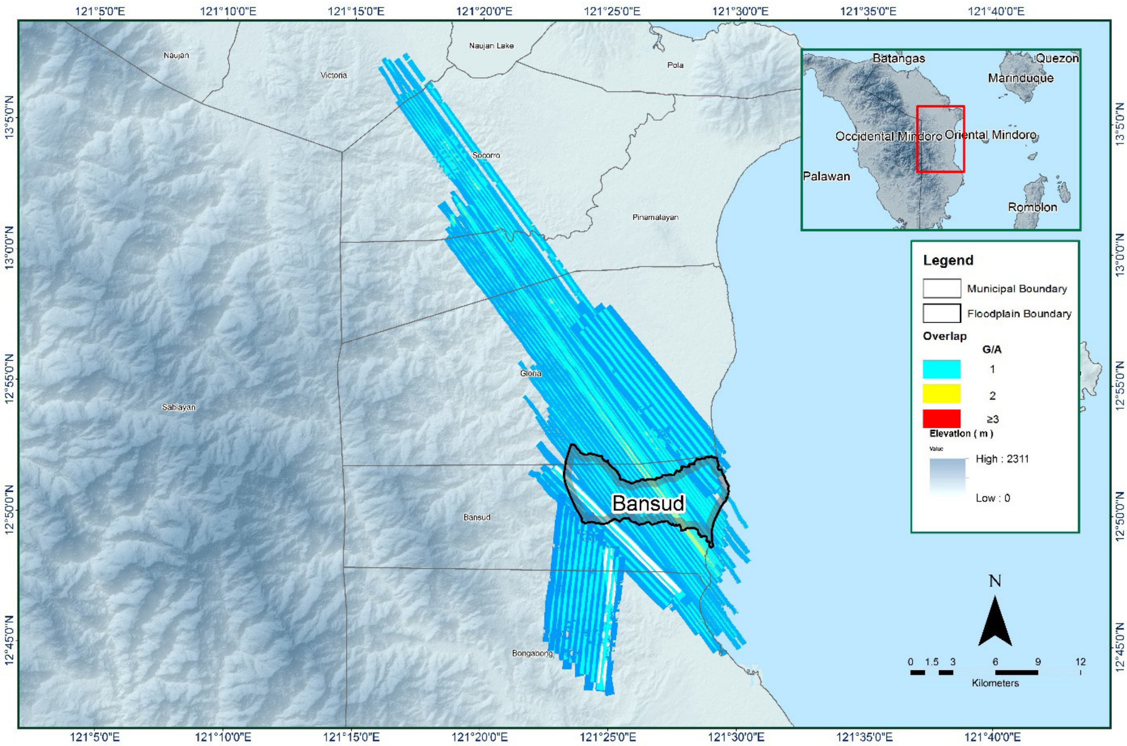


Figure 11. Image of data overlap for Bansud floodplain.

The overlap statistics per block for the Bansud floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.89% and 65.39% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 12. It was determined that all LiDAR data for the Bansud floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.64 points per square meter.

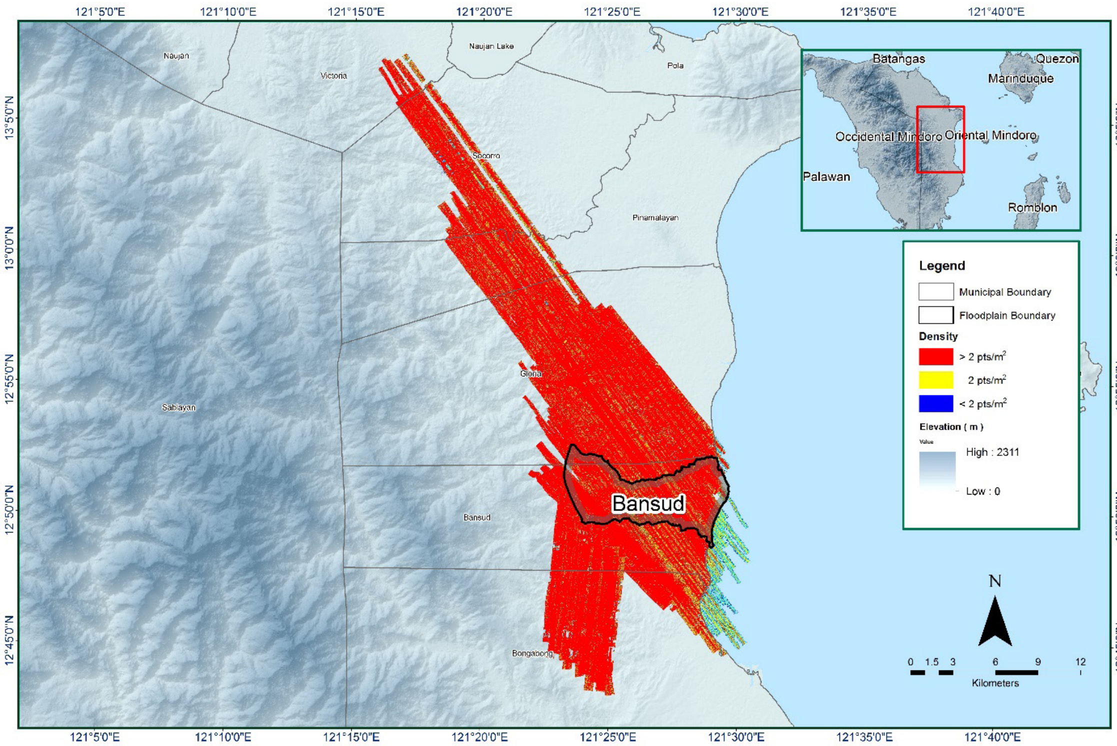


Figure 12. Pulse density map of the merged LiDAR data for Bansud floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in . 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.

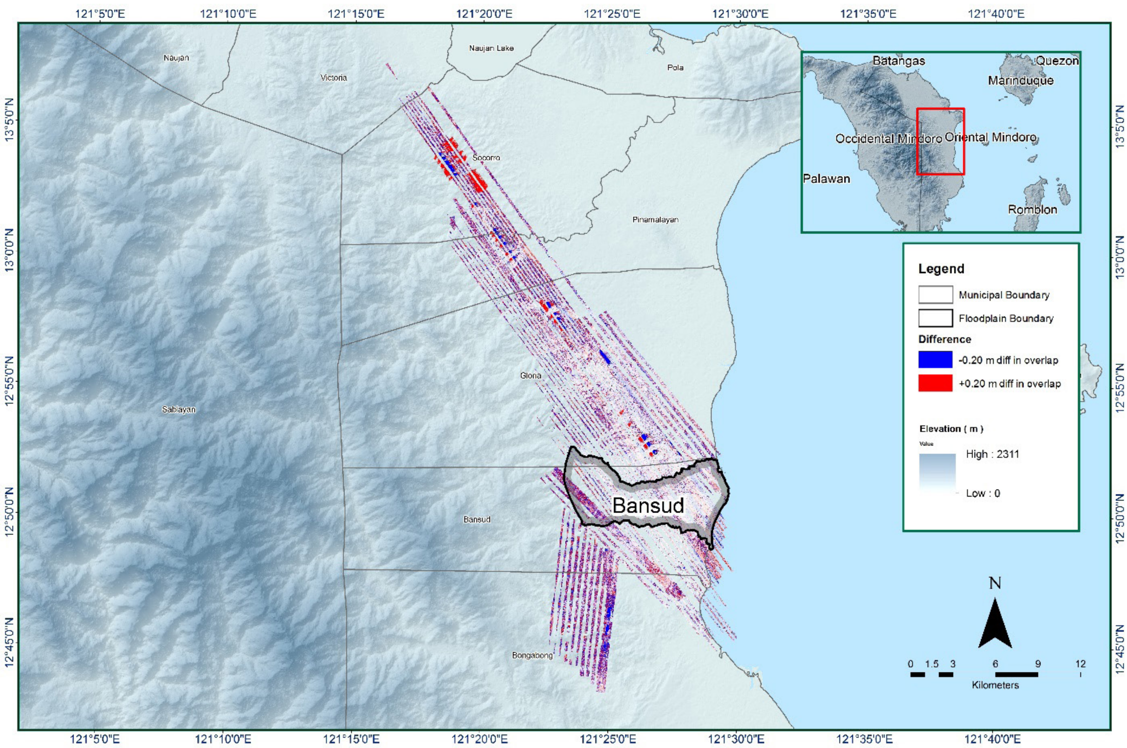


Figure 13. Elevation difference Map between flight lines for the Bansud Floodplain Survey

A screen capture of the processed LAS data from a Bansud flight 1070A loaded in QT Modeler is shown in Figure 14. 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.

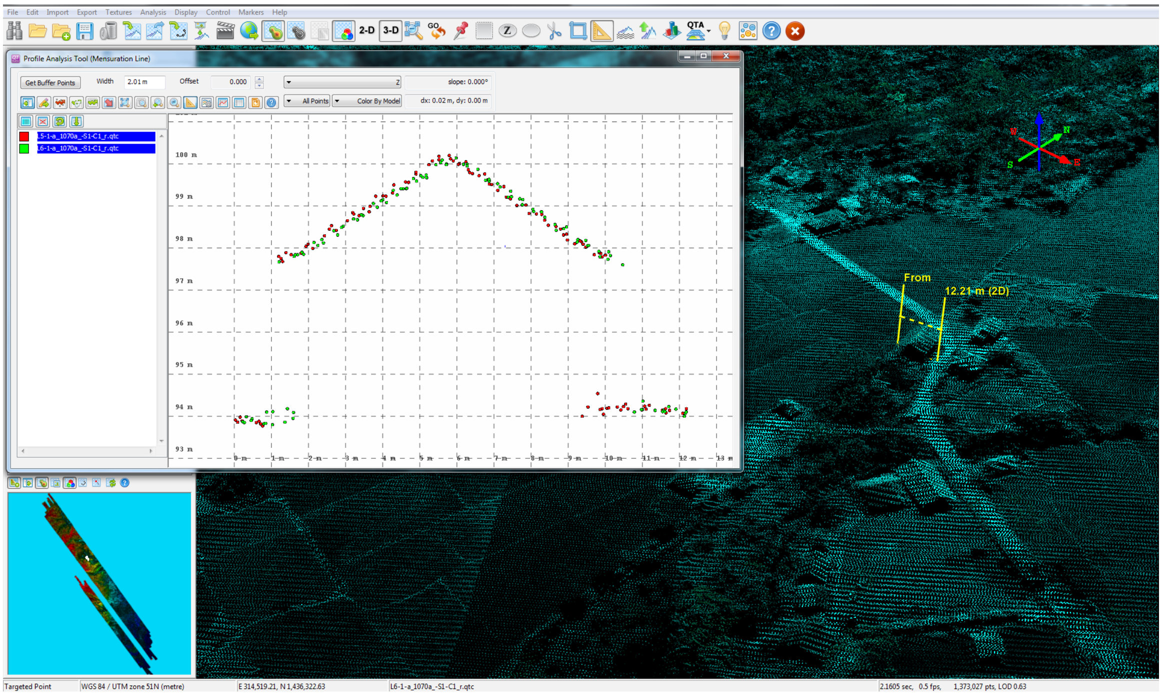


Figure 14. Quality checking for Bansud flight 1070A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Bansud classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	302,650,127
Low Vegetation	333,953,871
Medium Vegetation	403,701,743
High Vegetation	558,457,257
Building	16,210,324

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Bansud floodplain is shown in Figure 15. A total of 900 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 437.09 meters and 48.61 meters, respectively.

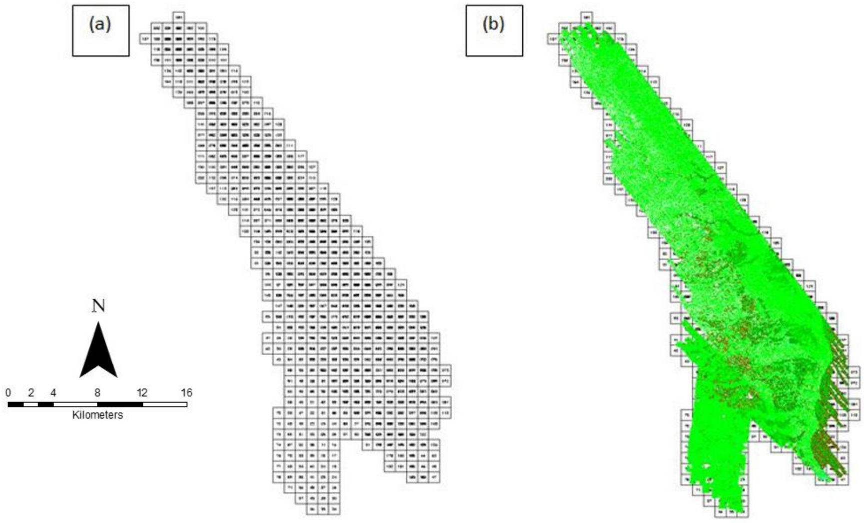


Figure 15. Tiles for Bansud floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 16. The ground points are in orange, while 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 the canopy are classified correctly, due to the density of the LiDAR data.

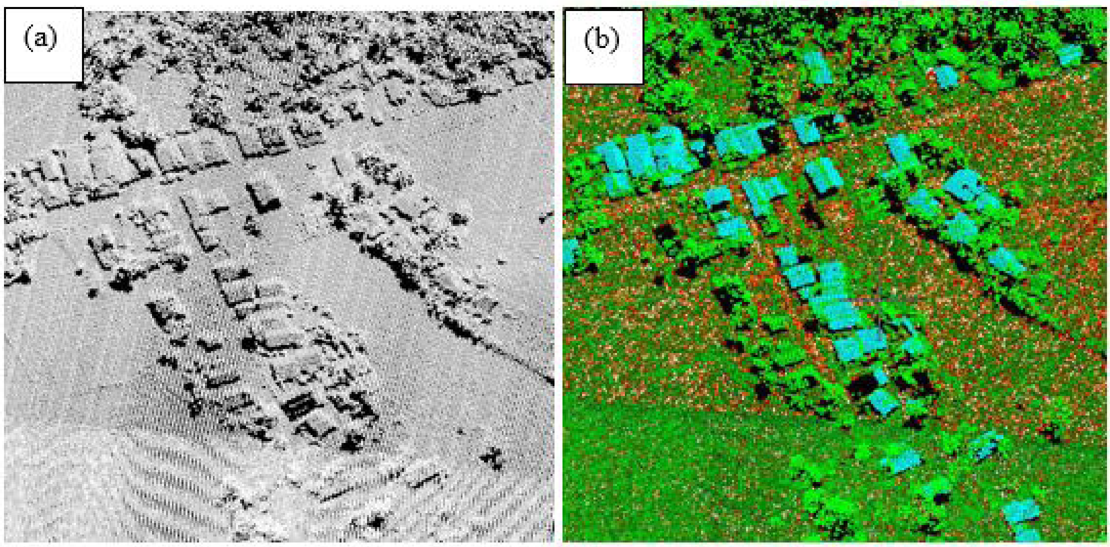


Figure 16. Point cloud before (a) and after (b) classification.

The production of the 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 show in Figure 17. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

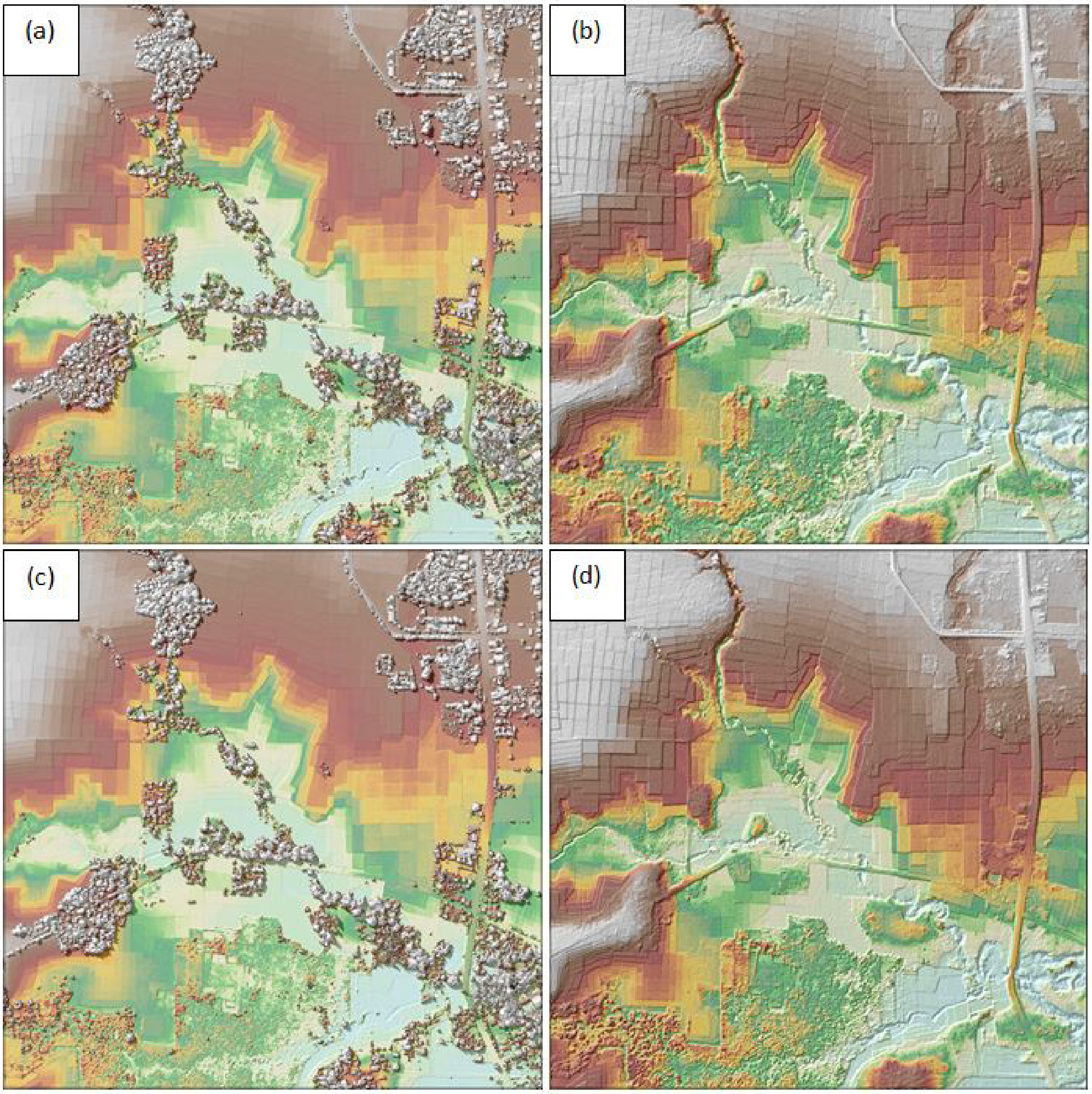


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Bansud floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 499 1km by 1km tiles area covered by Bansud floodplain is shown in Figure 18. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Bansud floodplain has a total of 270.55 sq.km orthophotogaph coverage comprised of 2,583 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

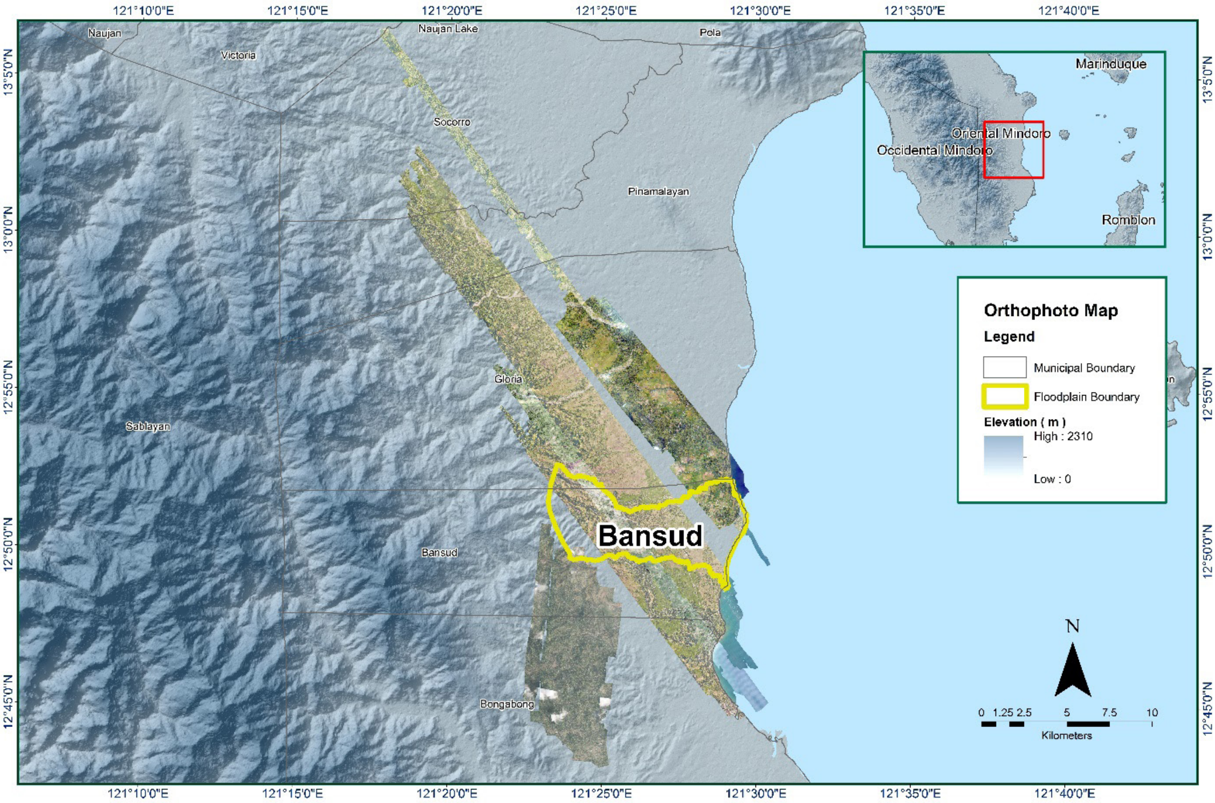


Figure 18. Bansud floodplain with available orthophotographs.

Figure 19. Sample orthophotograph tiles for Bansud floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Bansud flood plain. These blocks are composed of OrientalMindoro and OrientalMindoro_reflights blocks with a total area of 494.87 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq. km.)
OrientalMindoro_Blk28C	29.34
OrientalMindoro_Blk28C_supplement	87.46
OrientalMindoro_Blk28D_supplement	89.76
OrientalMindoro_Blk28E	125.45
OrientalMindoro_Blk28E_supplement	29.61
OrientalMindoro_reflights_Blk28C	49.04
OrientalMindoro_reflights_Blk28E	30.83
OrientalMindoro_reflights_Blk28H_supplement	53.38
TOTAL	**494.87**

Figure 20 shows portions of a DTM before and after manual editing. As evident in the figure, a bridge (Figure 20a) has obstructed the flow of water along the river. To correct the river hydrologically, it was removed through manual editing (Figure 20b). The mountain ridge (Figure 20c) has been misclassified. Object retrieval was performed to retain the correct terrain (Figure 20d).

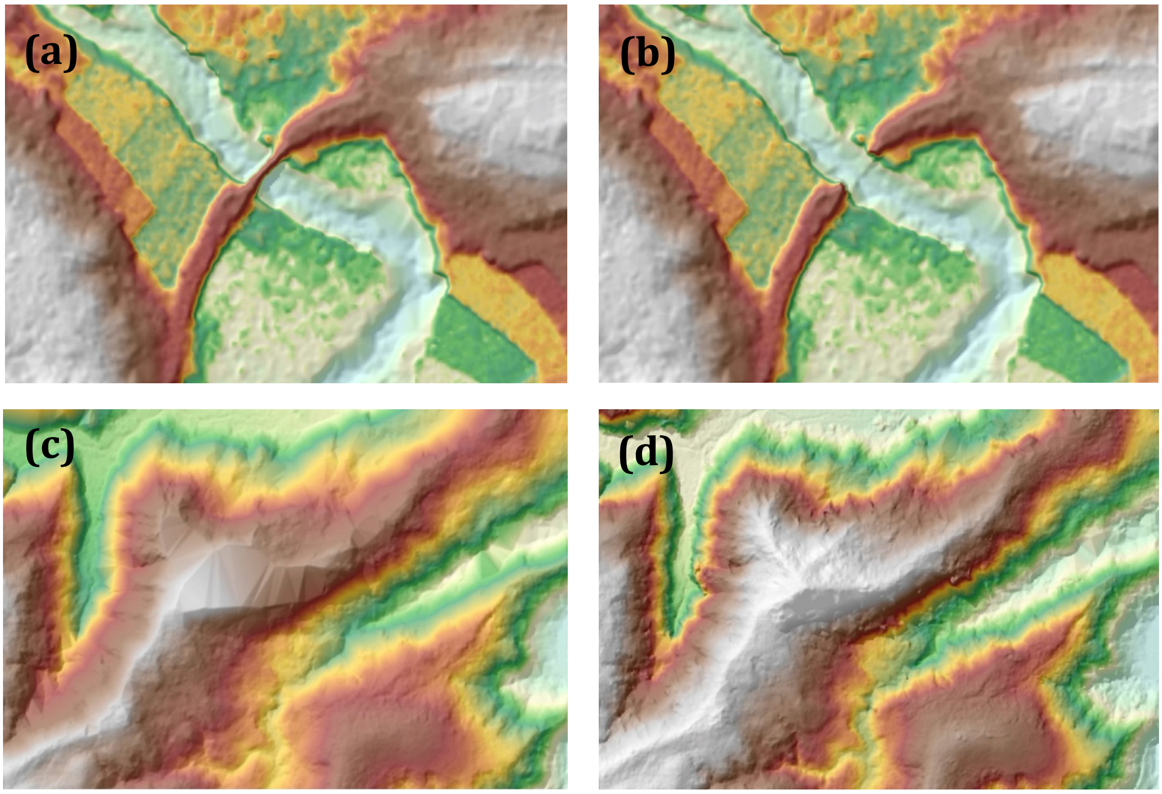


Figure 20. Portions in the DTM of the Bansud Floodplain – a bridge before (a) and after (b) manual editing; and a mountain ridge before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

OrientalMindoro_Blk29N was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 17 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Bansud floodplain is shown in Figure 21. It can be seen that the entire Bansud floodplain is 99.8% covered by LiDAR data.

Table 17. Shift values of each LiDAR block of Bansud Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OrientalMindoro_Blk28C	0.00	0.00	0.68
OrientalMindoro_Blk28C_supplement	-0.17	0.00	0.68
OrientalMindoro_Blk28D_supplement	0.00	0.00	0.92
OrientalMindoro_Blk28E	0.00	0.00	0.69
OrientalMindoro_Blk28E_supplement	0.00	0.00	0.78
OrientalMindoro_reflights_Blk28C	0.00	0.00	0.20
OrientalMindoro_reflights_Blk28E	0.00	0.00	-0.14
OrientalMindoro_reflights_Blk28H_supplement	0.00	0.00	49.56

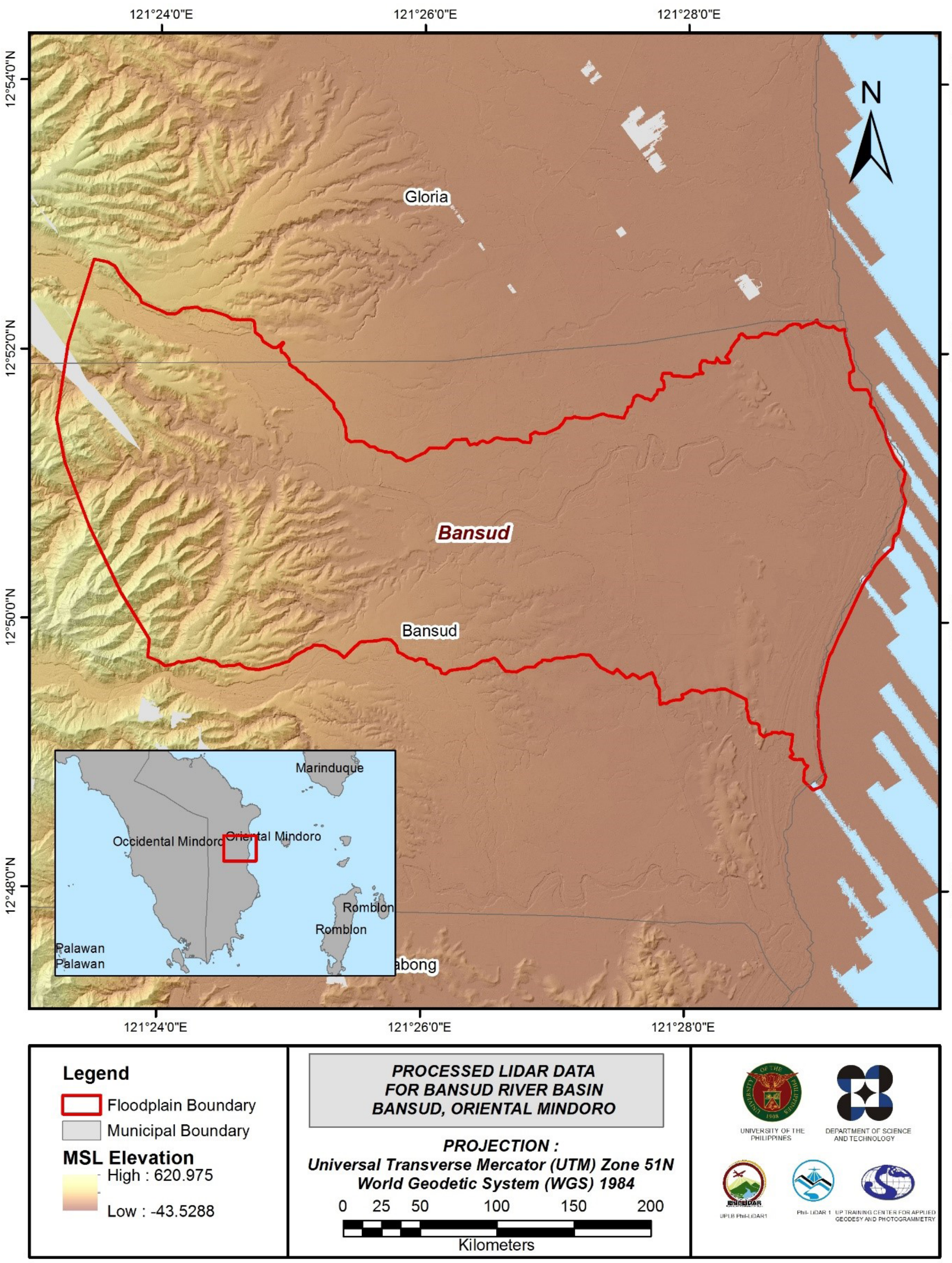


Figure 21. Map of processed LiDAR data for the Bansud Floodplain.

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 Bansud to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 19,114 survey points were gathered for all the flood plains within Oriental Mindoro wherein the Bansud floodplain is located. Random selection of 80% of the survey points, resulting to 15,291 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.60 meters with a standard deviation of 0.17 meters. Calibration of Bansud LiDAR data was done by subtracting the height difference value, 2.60 meters, to Bansud mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

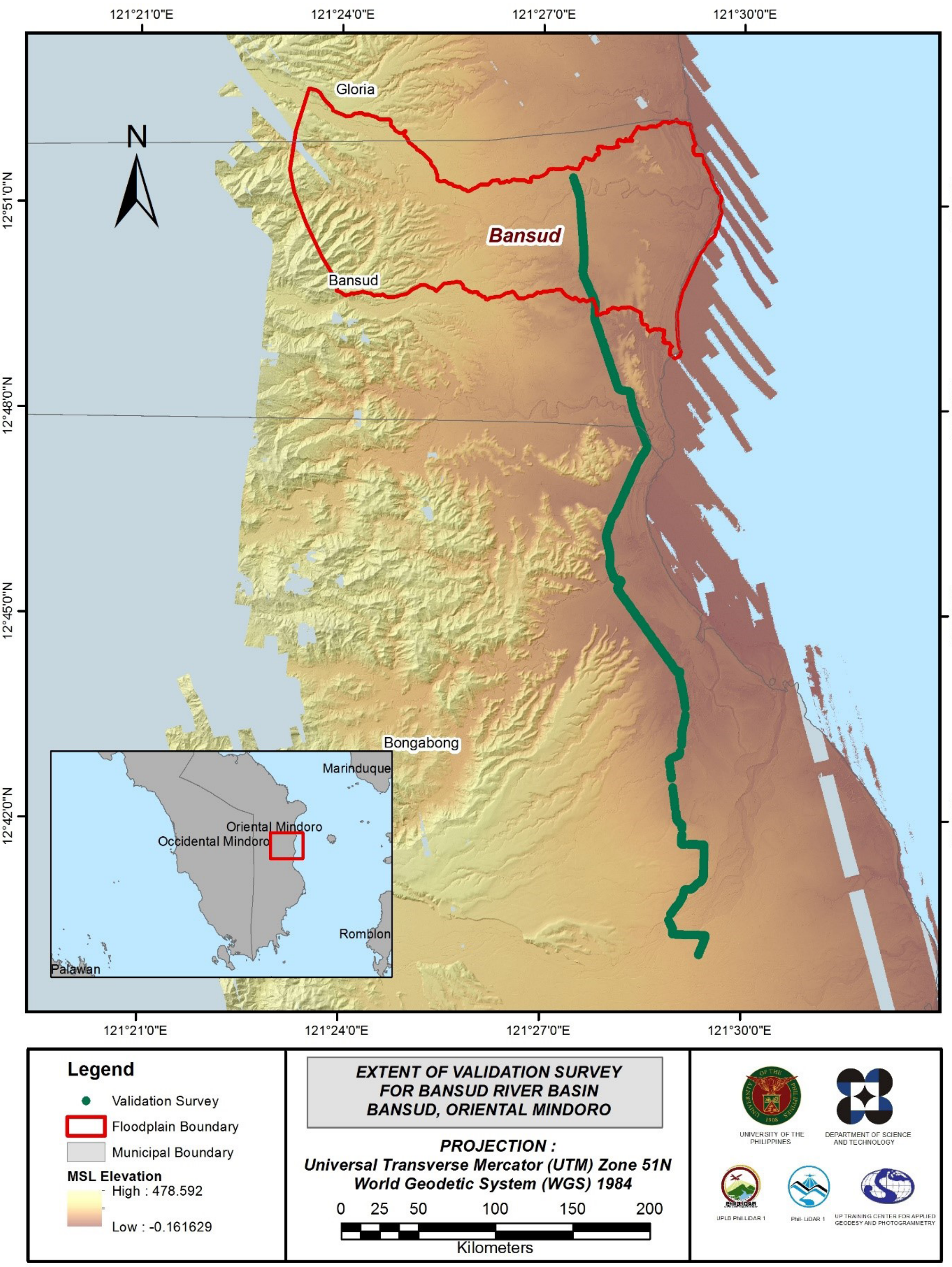


Figure 22. Map of Bansud Floodplain with validation survey points in green.

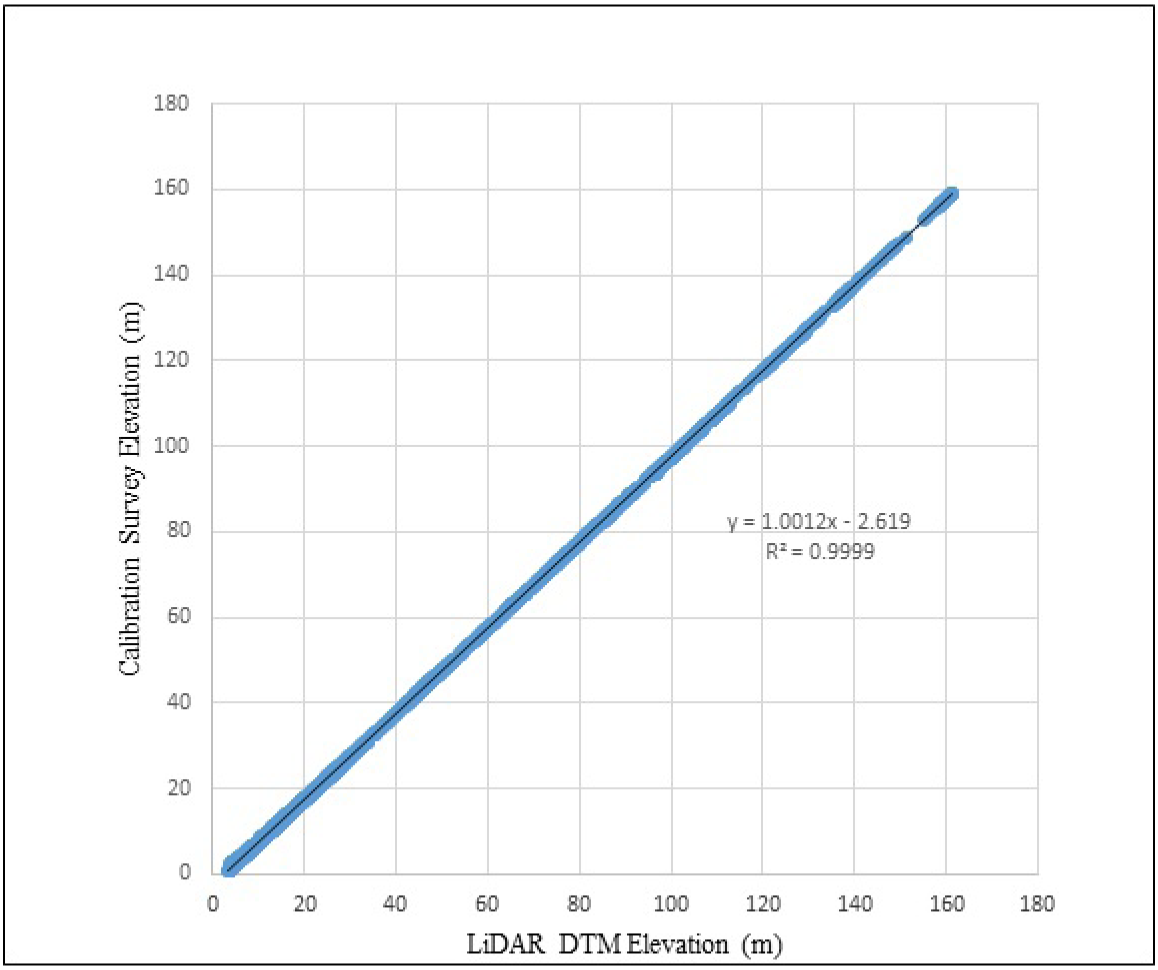


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.60
Standard Deviation	0.17
Average	-2.59
Minimum	-3.03
Maximum	-1.70

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 69 points. These were used for the validation of calibrated Bansud 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 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.08 meters, as shown in Table 19.

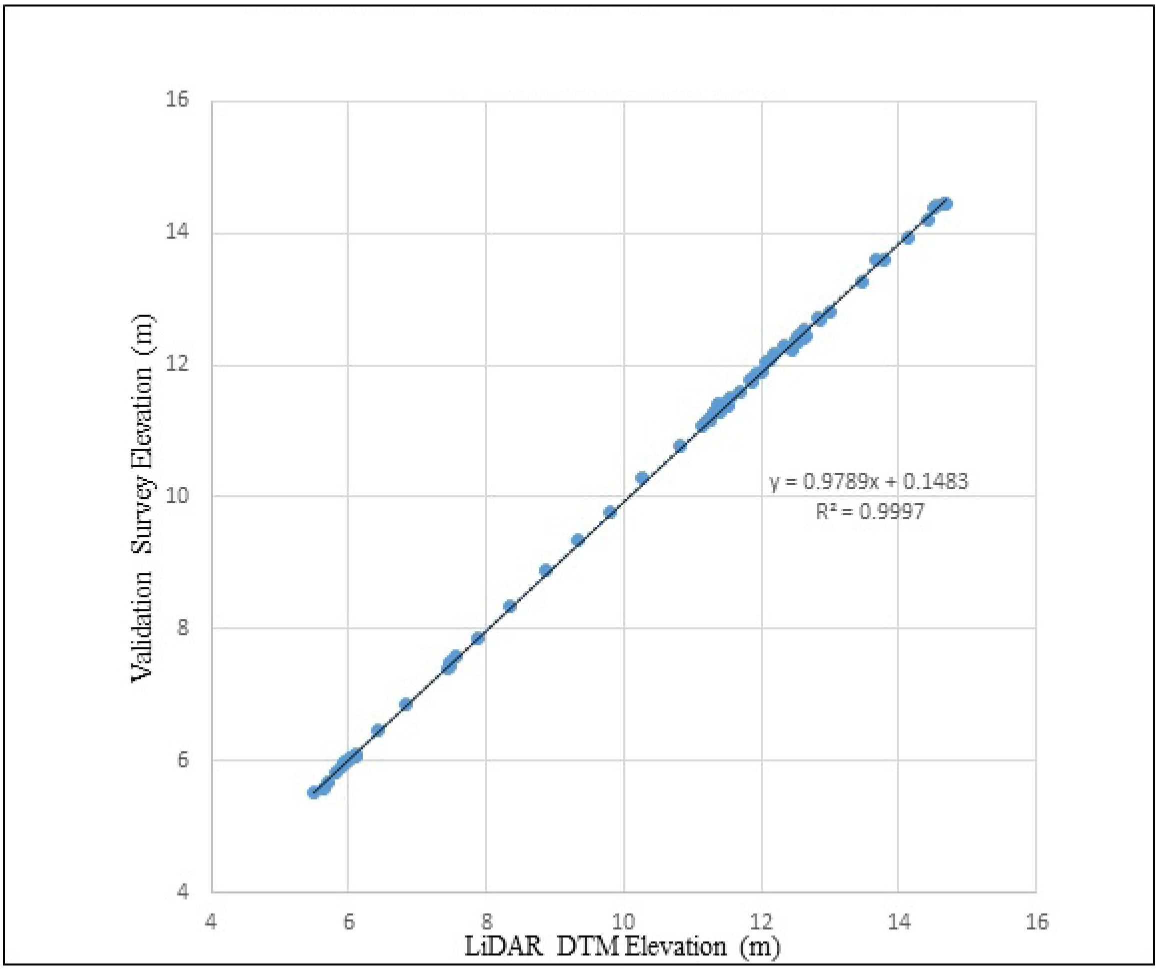


Figure 24. Correlation plot between the validation survey points and the LiDAR data.

Table 19. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.08
Average	-0.07
Minimum	-0.24
Maximum	0.04

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Bansud with 180 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.05 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bansud integrated with the processed LiDAR DEM is shown in Figure 25.

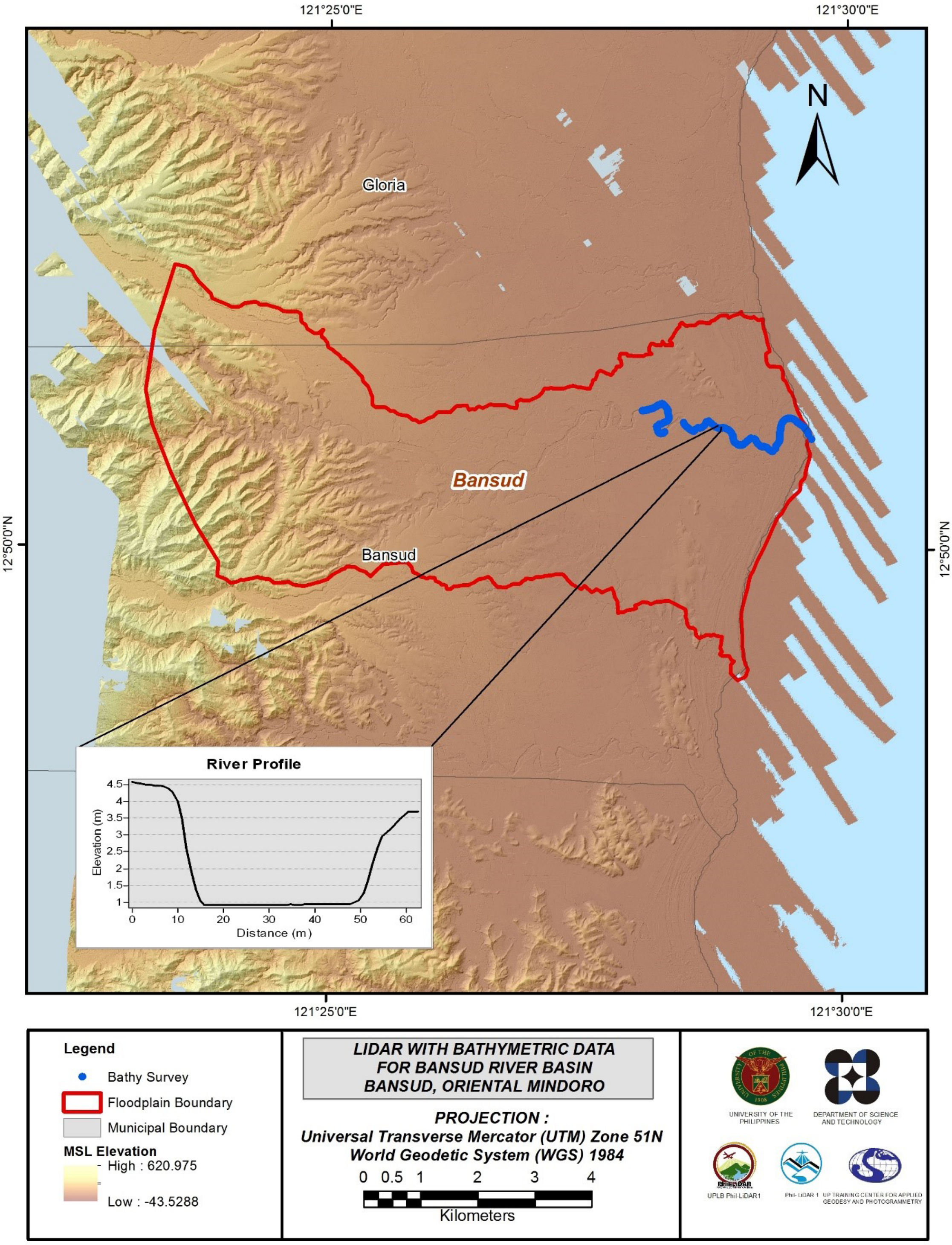


Figure 25. Map of Bansud floodplain with bathymetric survey points in blue.

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 a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Bansud floodplain, including its 200 m buffer, has a total area of 776.76 sq km. For this area, a total of 24.0 sq km, corresponding to a total of 5,893 building features, are considered for QC. Figure 26 shows the QC blocks for Bansud floodplain.

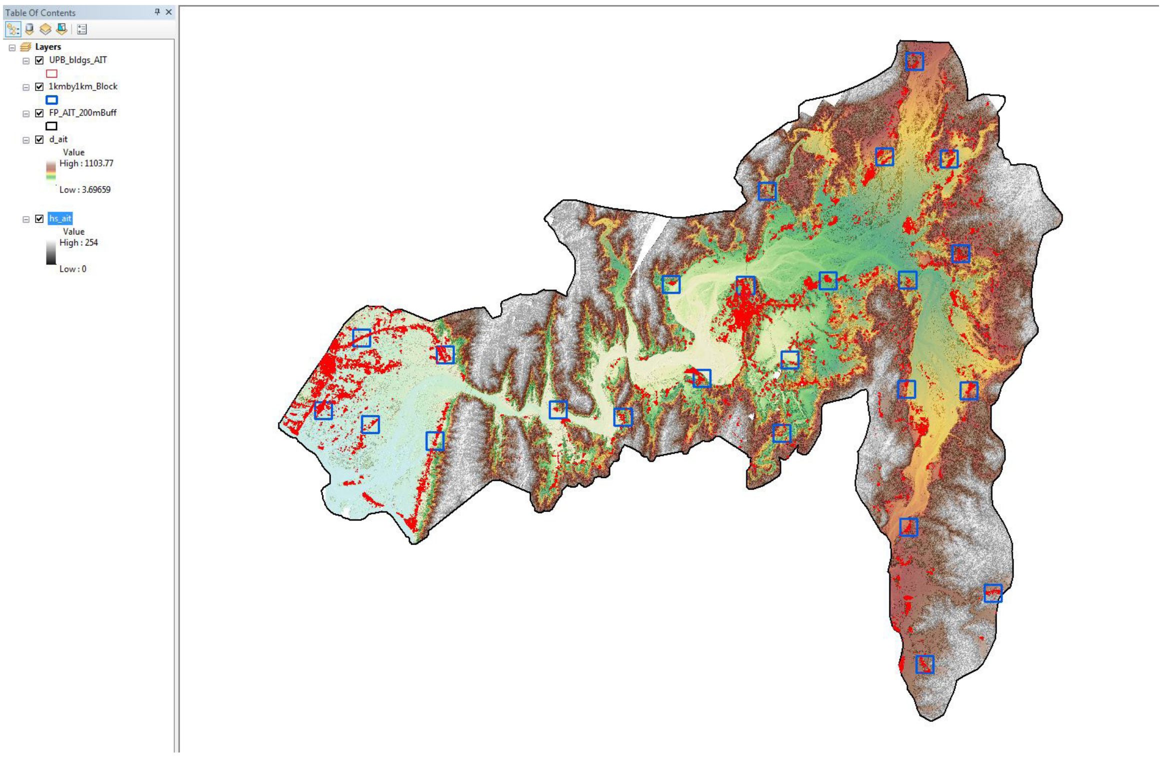


Figure 26. Blocks (in blue) of Bansud building features that was subjected to QC.

Quality checking of Bansud building features resulted in the ratings shown in Table 20.

Table 20. Details of the quality checking ratings for the building features extracted for the Bansud River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Bansud	99.44	99.98	97.30	PASSED

3.12.2 Height Extraction

Height extraction was done for 51,234 building features in Bansud floodplain. Of these building features, 843 were filtered out after height extraction, resulting to 50,391 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 14.87 meters.

3.12.3 Feature Attribution

Data collected from various sources which includes OpenStreetMap and Google Maps/Earth were used in the attribution of building features. Areas where there is no available data were subjected for field attribution using ESRI's Collector App. The app can be accessed offline and data collected can be synced to ArcGIS Online when WiFi or mobile data is available.

Table 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building features extracted for Bansud Floodplain.

Facility Type	No. of Features
Residential	49,140
School	749
Market	37
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	38
Barangay Hall	6
Military Institution	0
Sports Center/Gymnasium/Covered Court	11
Telecommunication Facilities	2
Transport Terminal	16
Warehouse	3
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	3
Water Supply/Sewerage	0
Religious Institutions	56
Bank	10
Factory	32
Gas Station	23
Fire Station	2
Other Government Offices	51
Other Commercial Establishments	207
Total	**50,391**

Table 22. Total length of extracted roads for Bansud Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Bansud	382.5	225.68	12.17	100.03	0.00	**720.38**

Table 23. Number of extracted water bodies for Bansud Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Bansud	147	164	0	0	0	**311**

A total of 25 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 27 shows the completed Digital Surface Model (DSM) of the Bansud floodplain overlaid with its ground features.

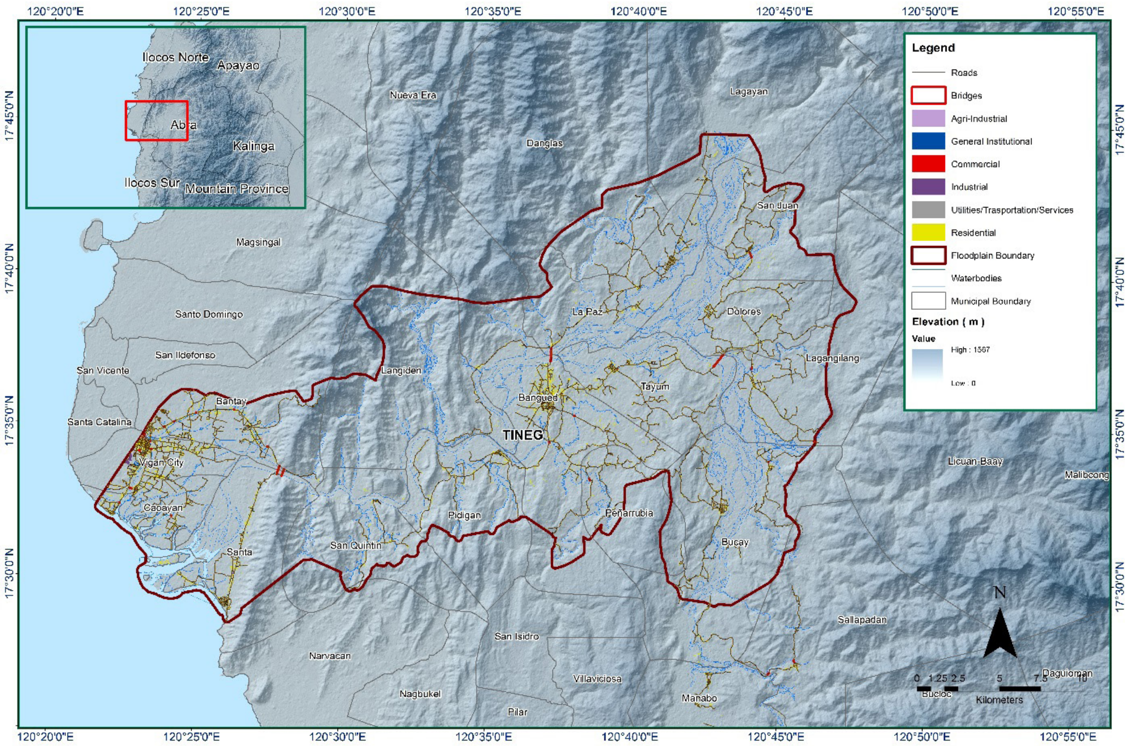


Figure 27. Extracted features of the Bansud Floodplain.

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Bansud River on May 30 to June 11, 2014. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point at the approach of Subaan Bridge occupied as a base station for GNSS surveys; (iii) the cross section survey and bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Bansud Bridge; (iv) validation points acquisition; and (v) manual bathymetric survey from the upstream from Brgy. Pag-asa down to Bansud Proper with an approximate length of 7.2 km. A follow up survey commenced on October 27 to November 3, 2014 with the following activities: courtesy call with LGU of Bansud and UPLB; and bridge as-built and water level marking of Bansud Bridge with coordinates Lat 12d51’17.70562” N and Long 121d27’28.70961” E; and LiDAR acquired validation survey with an estimated distance of 19.76 km. Figure 28 illustrates the extent of the entire survey in Bansud River.

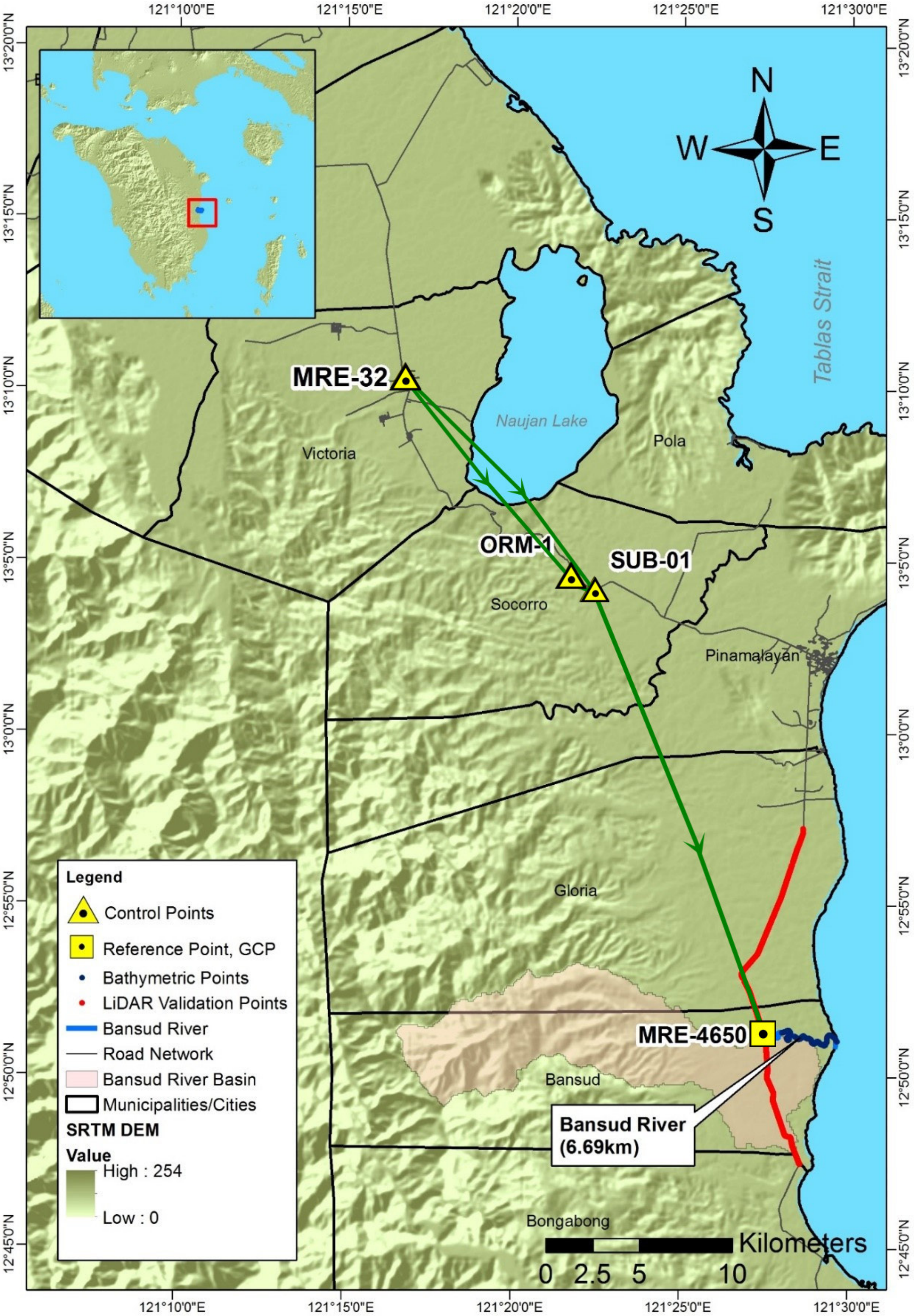


Figure 28. Bansud River Survey Extent.

4.2 Control Survey

The GNSS network utilized for the Bansud River Basin is composed of two (2) loops established on May 30 and May 31, 2014, which occupied the following reference point: MRE-32, a second-order GCP fixed from the previous field survey in Mindoro Oriental for Mag Asawang Tubig river.

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

Three (3) control points were established in the area namely: MOR-10, located at the approach of Cawa-cat Bridge in Brgy. Campaasan, Municipality of Bulalacao; ORM-1, located in Subaan Bridge in Barangay Subaan, Municipality of Socorro; and SUB-01, located within the Maramot Residence in Brgy. Subaan, Municipality of Socorro. An LMS-established control point namely MRE-4650, located at Bansud Bridge, Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro was also occupied to use as marker in the survey.

Table 24 depicts the summary of reference and control points utilized, with their corresponding locations while the GNSS network established is illustrated in Figure 29.

Table 24. List of reference and control points used during the survey in Bansud River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date of Establishment
MRE-32	2nd order, GCP	13°10’23.79251”	121°16’43.46244”	65.638	17.175	2007
MOR-10	UP Established	-	-	-	-	5-31-2014
MRE-4650	Used as marker	-		-	-	2011
ORM-1	UP Established	-	-	-	-	5-31-2014
SUB-01	UP Established	-	-	-	-	5-31-2014

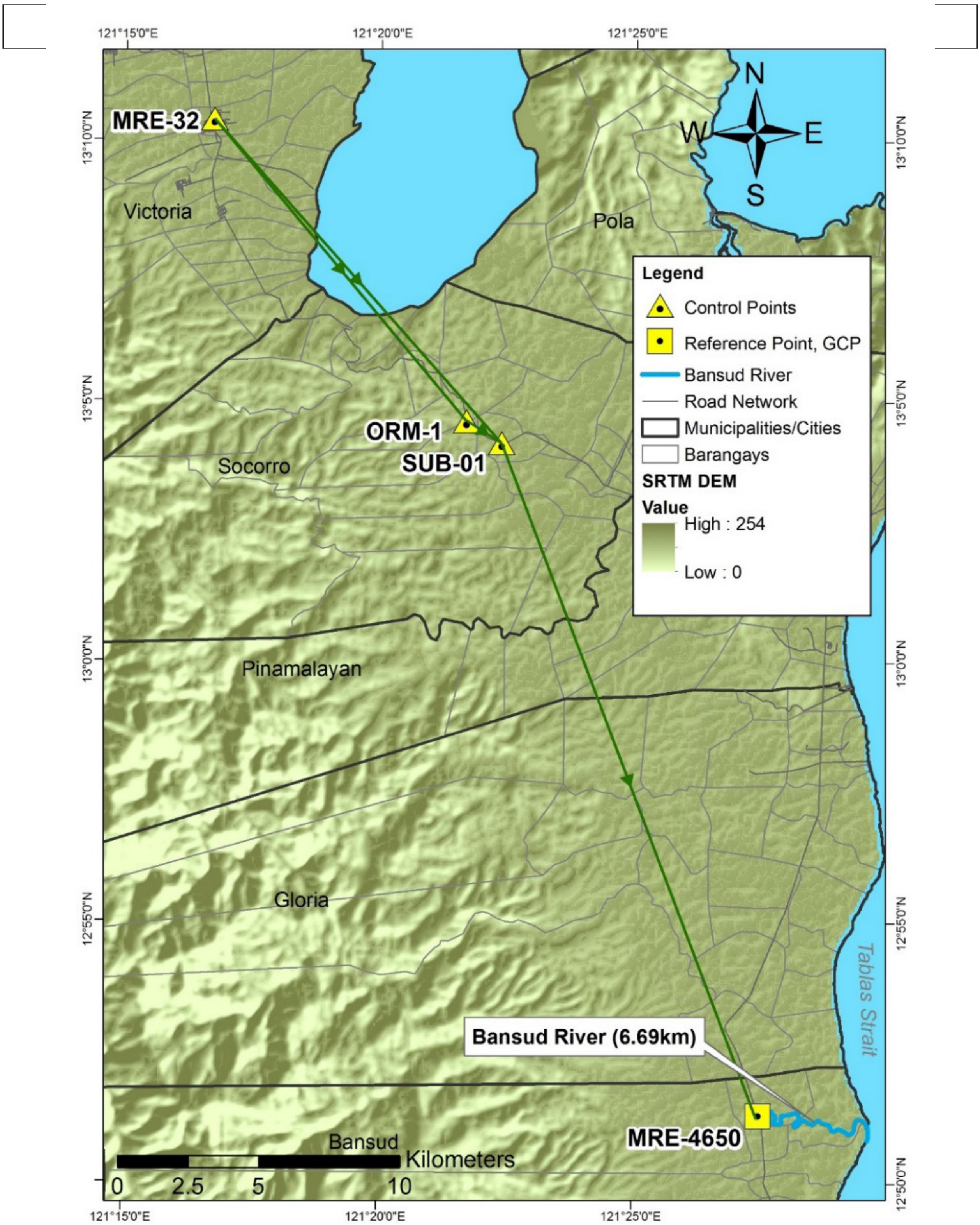


Figure 29. GNSS network of Bansud River field survey.

Figure 30 to Figure 34 depict the setup of the GNSS on recovered reference points and established control points in the Bansud River.

Figure 30. GPS setup of Trimble® SPS 882 at MRE-32, located at the Municipal Park of Victoria, in Brgy. Poblacion 1, Oriental Mindoro.

Figure 31. GPS setup of Trimble® SPS 852 at MOR-10, located in the approach of the Cawacat Bridge, in Bry. Campasaan, Municipality of Bulalacao, Oriental Mindoro.

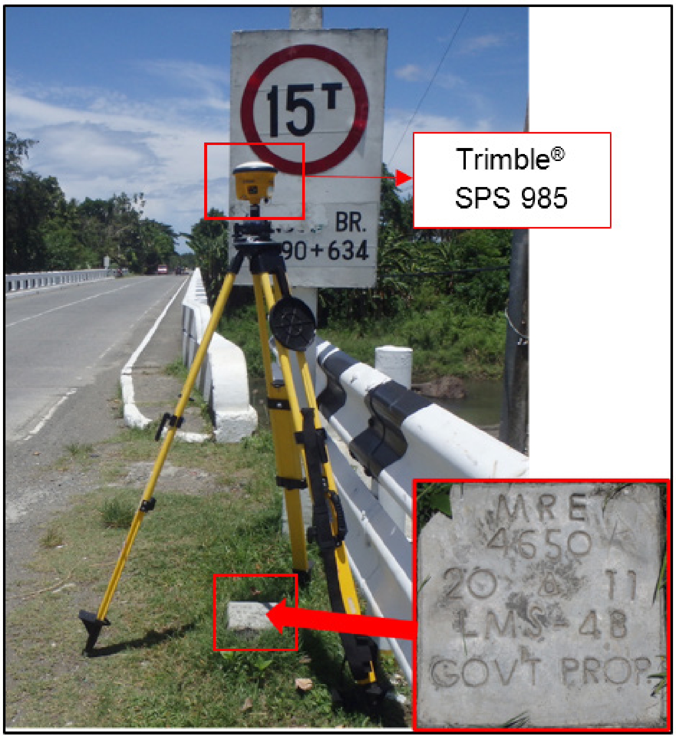


Figure 32. GPS setup of Trimble® SPS 985 at MRE-4650, an LMS control point located at the approach of Bansud Bridge, in Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro.

Figure 33. GPS setup of Trimble® SPS 852 at ORM-1, located on Subaan Bridge, Brgy. Subaan, Municipality of Socorro, Oriental Mindoro.

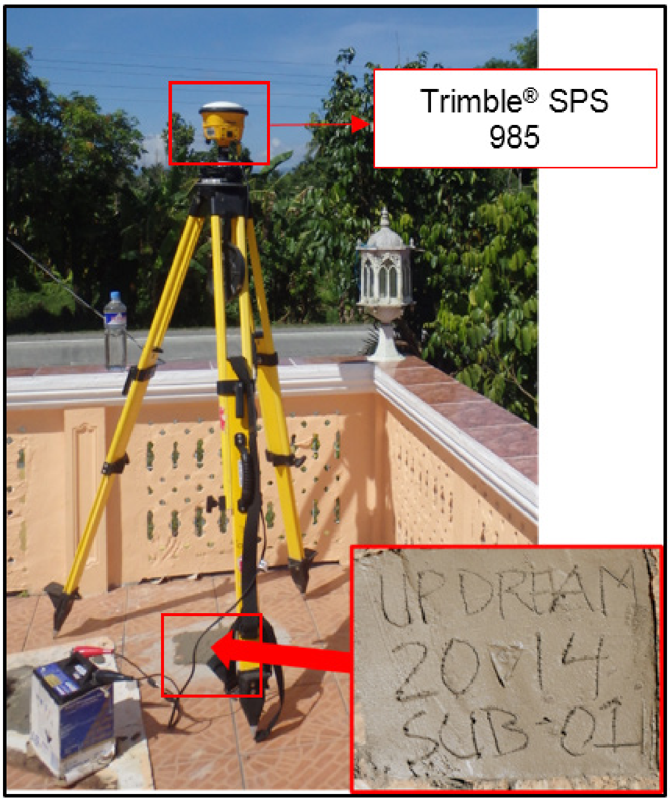


Figure 34. GPS setup of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro.

4.3 Baseline Processing

The 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 cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 25 presents the baseline processing results of control points in the Bansud River Basin, as generated by the TBC software.

Table 25. The Baseline processing report for the Bansud River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H.Prec (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
ORM-1 --- SUB-01	05-30-2014	Fixed	0.004	0.006	301°40'27"	1466.251
SUB-01 --- MRE-32	05-30-2014	Fixed	0.010	0.031	318°11'52"	15342.18
SUB-01 ---MOR-10	05-31-2014	Fixed	0.014	0.044	182°47'52"	80162.62
SUB-01 --- MRE-4650	05-31-2014	Fixed	0.006	0.038	158°49'08"	25506.78
ORM-1 --- MRE 32	05-30-2014	Fixed	0.01	0.032	319°54'33"	13942.72
MOR-10 ---MRE 4650	05-31-2014	Fixed	0.012	0.051	13°07'21"	57794.34

As shown in Table 25, a total of six (6) baselines were processed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 26 to Table 29.

The five (5) control points, MRE-32, ORM-1, MOR-10, MRE-4650 and SUB-01 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MRE-32 were held fixed during the processing of the control points as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Constraints applied to the adjustment of the control points.

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

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 27.

Table 27. Adjusted grid coordinates for the control points used in the Bansud River flood plain survey.

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

The results of the computation for accuracy are as follows:

a. **MRE-32**
Horizontal accuracy = Fixed
Vertical accuracy = Fixed

b. **MOR-10**
Horizontal accuracy = √ ((1.0) ^{2} + (1.0) ^{2}
= √(1.0 + 1.0)
= 1.1 cm < 20 cm
Vertical accuracy = 1.4 cm< 10 cm

c. **MRE-4650**
Horizontal accuracy = √ ((0.8) ^{2} + (0.6) ^{2}
= √(0.64 + 0.36)

	=	1.0 cm < 20 cm
Vertical accuracy	=	4.9 cm < 10 cm

d. **ORM-1**

Horizontal accuracy	=	√ ((0.7) ² + (0.3) ²
	=	√(0.49 + 0.90)
	=	1.2 cm < 20 cm
Vertical accuracy	=	2.8 cm < 10 cm

e. **SUB-01**

Horizontal accuracy	=	√ ((0.7) ² + (0.3) ²
	=	√(0.49 + 0.90)
	=	1.2 cm < 20 cm
Vertical accuracy	=	2.8 cm < 10 cm

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

Table 28. Adjusted geodetic coordinates for control points used in the Bansud River Flood Plain validation.

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

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Bansud River GNSS Static Survey are seen in Table 29.

Table 29. The reference and control points utilized in the Bansud River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ell Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MRE-32	2nd order, GCP	13°10'23.79251"	121°16'43.46244"	65.368	1456936.499	313449.201	17.175
MOR-10	UP Established	12°20'46.18547"	121°20'13.54772"	58.186	1365393.240	319188.891	6.868
MRE-4650	Used as marker	12°51'17.70515"	121°27'28.71020"	64.693	1421592.819	332665.789	14.627

ORM-1	UP Estab-lished	13°04'36.74731"	121°21'41.63863"	79.500	1446211.774	322358.982	30.565
SUB-01	UP Estab-lished	13°04'11.69491"	121°22'23.06063"	74.676	1445433.872	323601.847	25.687

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

The GNSS receiver Trimble® SPS 882 in PPK survey technique was applied to acquire the cross section of the river (Figure 35) on May 31, 2014 along the downstream side of Bansud Bridge in Barangay Pag-asa, Oriental Mindoro using MRE-465 as a base station. Bridge as-built features determination was performed on October 30, 2014 to get the distance of piers and abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high cord and meter tapes to get its low cord elevation.

Figure 35. Cross-section survey for Bansud Bridge, Brgy. Pagasa, Oriental Mindoro.

The length of the cross-sectional line surveyed at Bansud Bridge is about 132.85 m with 25 cross-sectional points.. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 36 to Figure 38. Water surface elevation of Bansud River was not determined during the survey on October 30, 2015 because the river is already silted which made it too shallow or dry during dry season.

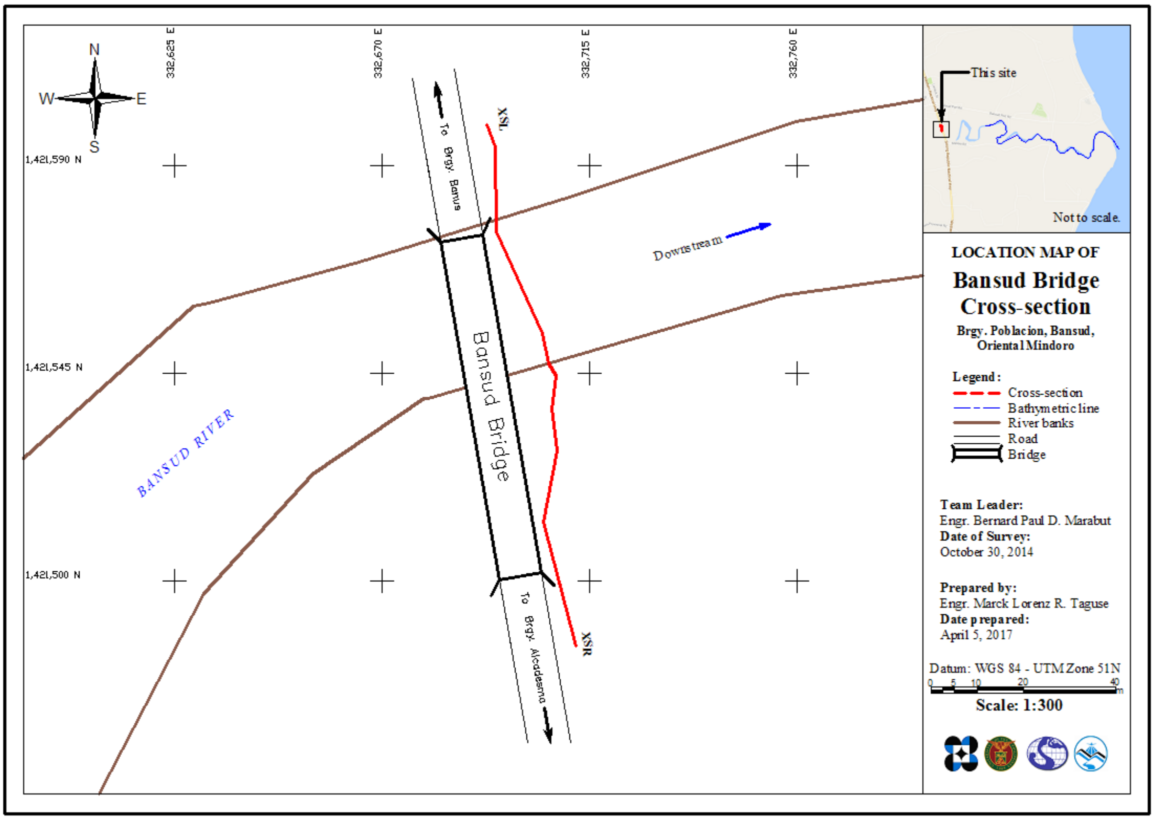


Figure 36. Location map of the Bansud Bridge Cross Section.

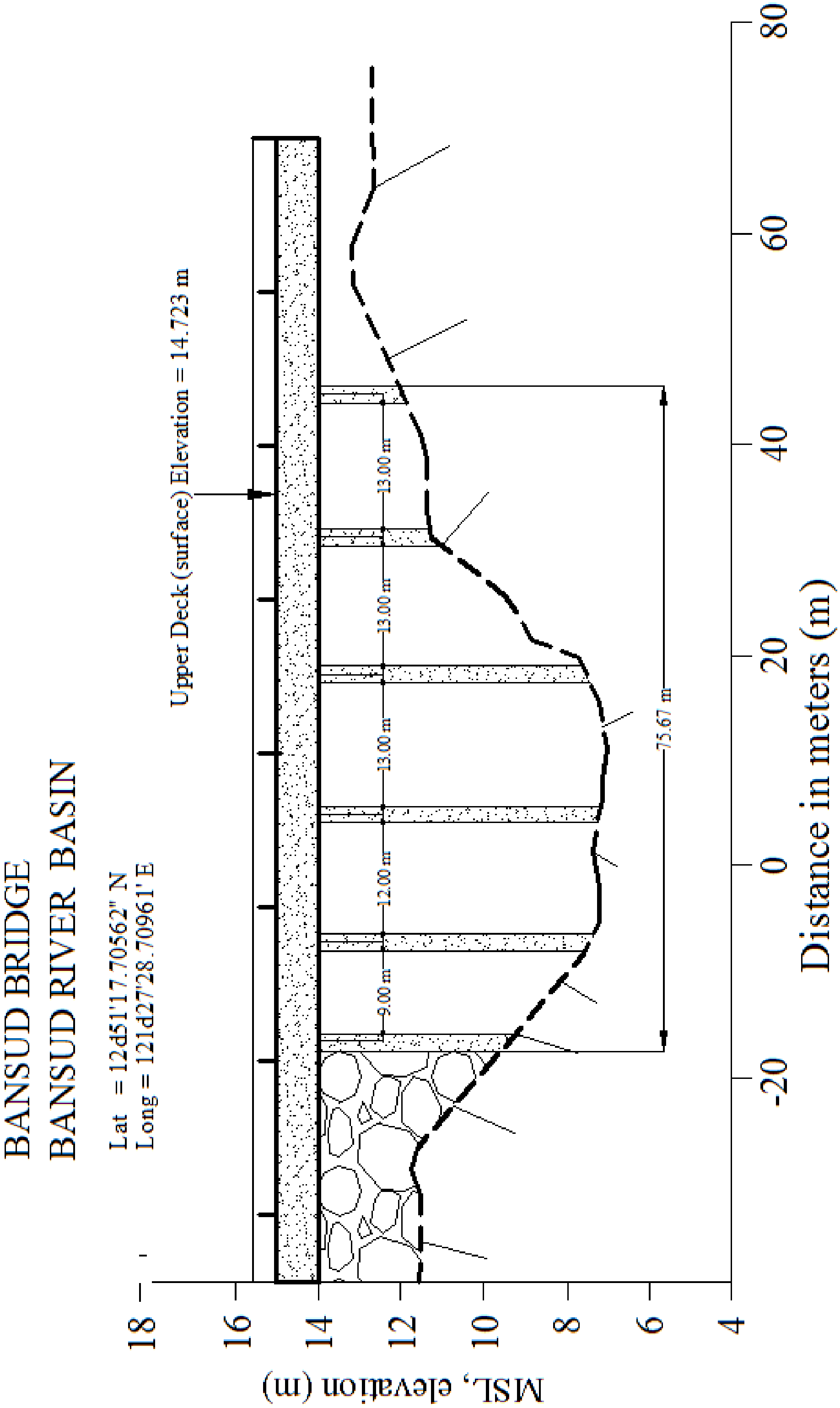


Figure 37. The Bansud Bridge cross-section survey drawn to scale.

Bridge Data Form

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

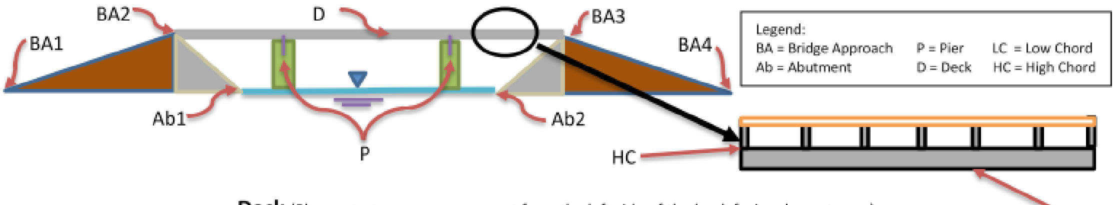
River Name: BANSUD RIVER **Time:** 4:05 PM

Location (Brgy, City, Region): Brgy. Poblacion, Municipality of Bansud, Oriental Mindoro

Survey Team: Team Bernard

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

Latitude: 12d51'17.70562"N **Longitude:** 121d27'28.70961"E



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

Elevation 14.7532 m **Width:** 8.886 m **Span (BA3-BA2):** ______

	Station	High Chord Elevation	Low Chord Elevation
1		16.883	15.2958
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	**0**	13.624 m	**BA3**	149.1084	14.655 m
BA2	73.34018	14.747 m	**BA4**	214.8332	13.815 m

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

	Station (Distance from BA1)	Elevation
Ab1	78.83028	11.296 m
Ab2	145.0054	12.488 m

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

Shape: Cylindrical **Number of Piers:** 6 **Height of column footing:** ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	76.16856	14.723 m	
Pier 2	90.1124	14.783 m	
Pier 3	104.2335	14.781 m	
Pier 4	118.1511	14.765 m	
Pier 5	132.2078	14.784 m	
Pier 6	146.0386	14.852 m	

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

Figure 38. The Bansud Bridge as-built survey data.

For the purpose of flow data gathering and depth gauge deployment of the accompanying SUC, water level value was translated onto marking on one of the bridge's pier using a Digital Level as shown in Figure 36. This was translated into marking on the bridge's pier using the same technique as shown in Figure 39

Figure 39. Water level markings on the post of Bansud Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by DVBC on November 3, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached on the side of a vehicle as shown in Figure 40. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 1.498 m from the ground up to the bottom of the notch of the GNSS Rover receiver.

Figure 40. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The survey started from Municipality of Mansalay to the Municipality of Gloria, covering an approximate distance of 19.76 km. The survey was conducted using Post Process Kinematic technique on a continuous topography mode. The survey gathered a total of 2019 points using MRE-4650 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 41.

Figure 41. The extent of the LiDAR ground validation survey (in red) for Bansud River Basin.

4.7 River Bathymetric Survey

A bathymetric survey was performed on June 7, 2014 using Trimble® SPS 882 in GNSS RTK technique, as illustrated in Figure 42. The survey started from Bansud Bridge in Brgy. Pagasa, Municipality of Basud with coordinates 12°51'17.70562" 121°27'28.70961", traversed down by foot and ended at the mouth of the river in Brgy. Proper Bansud, also in Municipality of Bansud with coordinates 12°51'02.45153" 121°29'40.60157". The control point MRE-4650 was used as the GNSS base station all throughout the survey.

Figure 42. Set up of the bathymetric survey at Bansud River: upstream (a) and downstream (b).

The bathymetric line surveyed has an approximate length of 10.18 km with a total of 3,658 bathymetric points acquired covering at least three (3) barangay boundaries: Brgy. Poblacion, Pag-asa and Bansud Proper, Municipality of Bansud, Oriental Mindoro as shown in Figure 43.

To further illustrate this, a CAD drawing of the riverbed profile of the Bansud River was produced. As seen in Figure 44, an elevation drop of 6.0 m was observed within the approximate distance of 7.2 km. The highest value observed was 4.447 m in MSL located at the upstream part of the river in Brgy. Pag-asa, while the lowest value observed was -1.429 m below MSL located in Brgy. Bansud Proper, both in Municipality of Bansud.

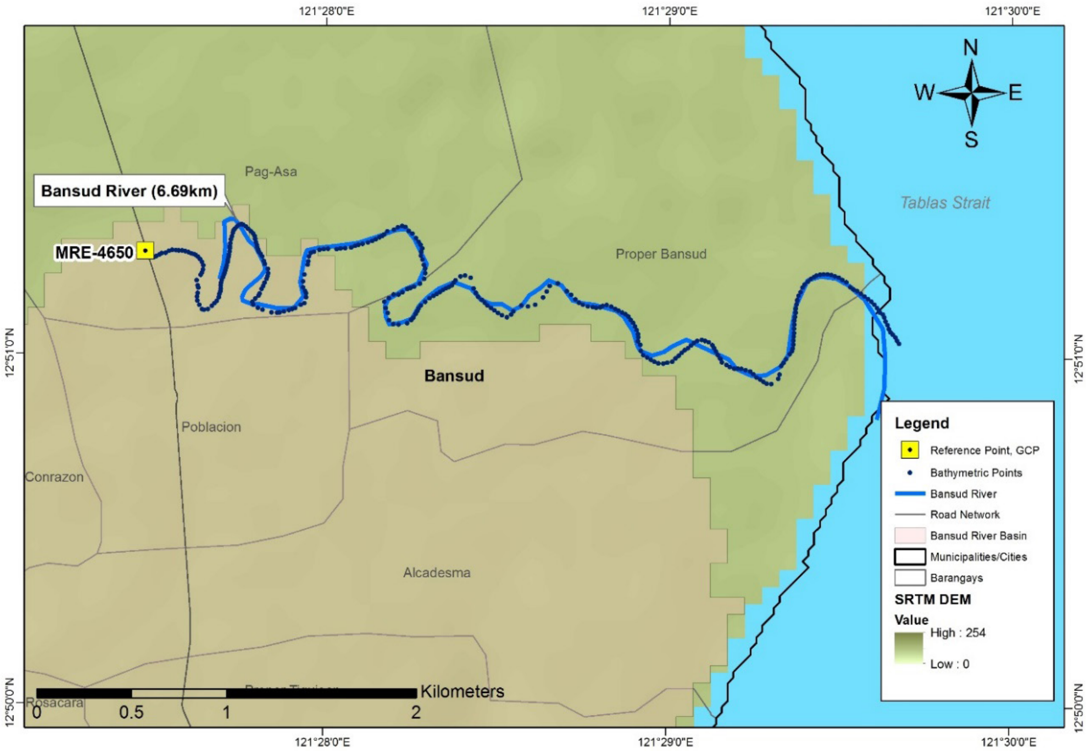


Figure 43. The extent of the Bansud River Bathymetry Survey.

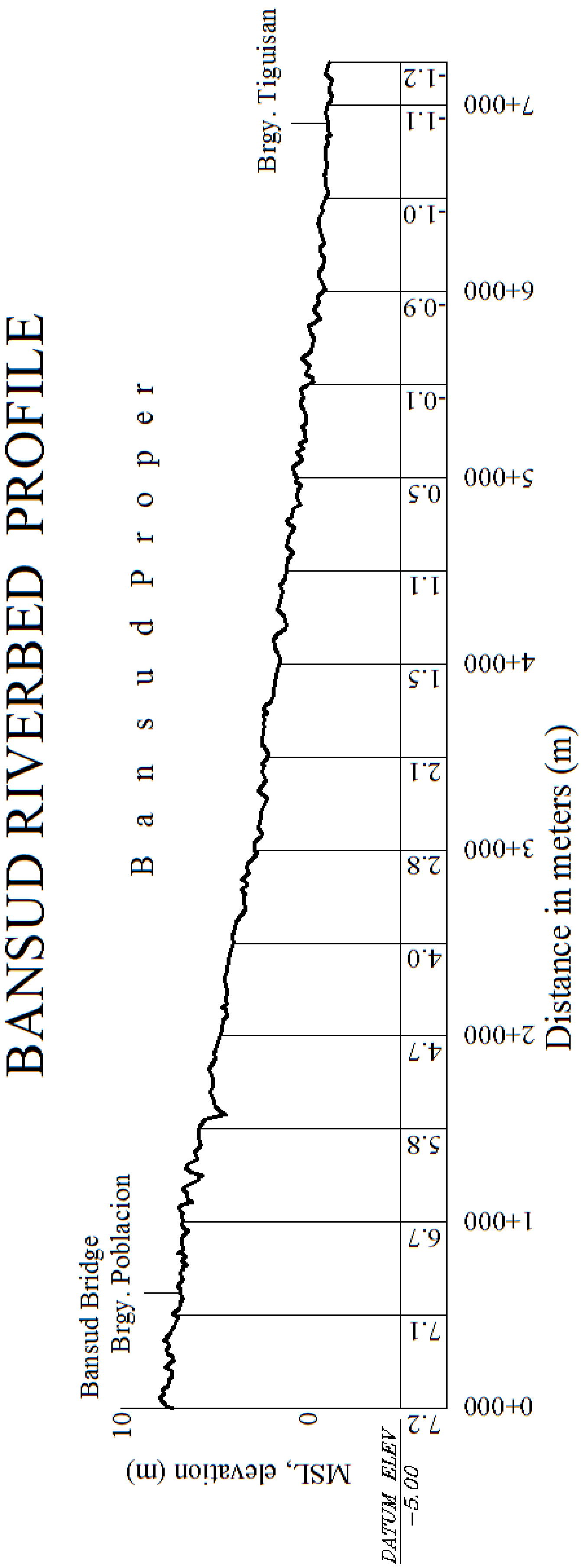


Figure 44. The Bansud Riverbed Profile.

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, and 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

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

5.1.2 Precipitation

Precipitation data was taken from HOBO rain gauges installed by DVBC-UPLB on a significantly high point in the basin area. The location of the rain gauges is illustrated in Figure 45.

The total precipitation for this event was 106 mm. It has a peak rainfall of 48.0 mm on November 9, 2015 at 1:00 pm. The lag time between the peak rainfall and discharge is 3 hours and 55 minutes.

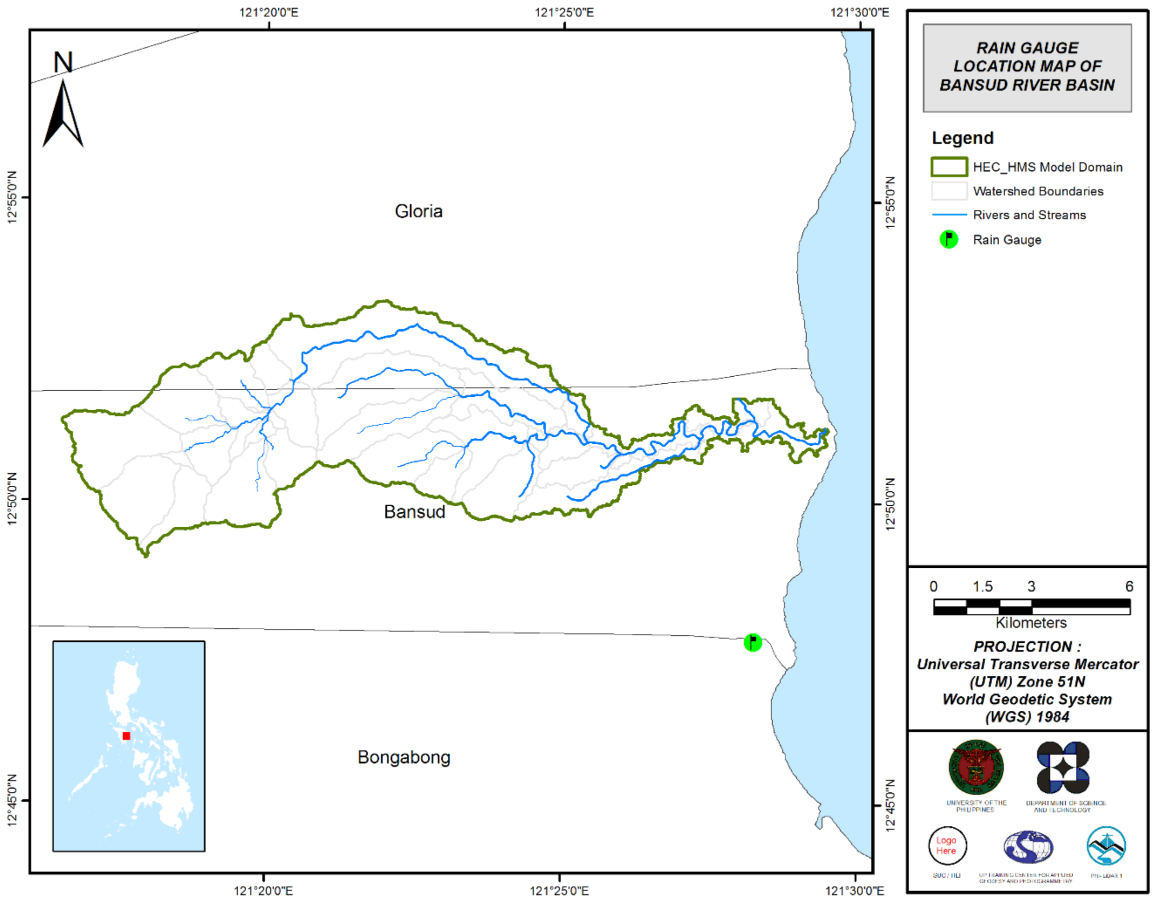


Figure 45. Location Map of the Bansud HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed at Bansud Bridge, Oriental Mindoro (12.854606° N, 121.458303°E) using Manning's Bankfull Method to establish the relationship between the observed water levels (H) from Bansud Bridge and the outflow (Q) of the watershed at this location.

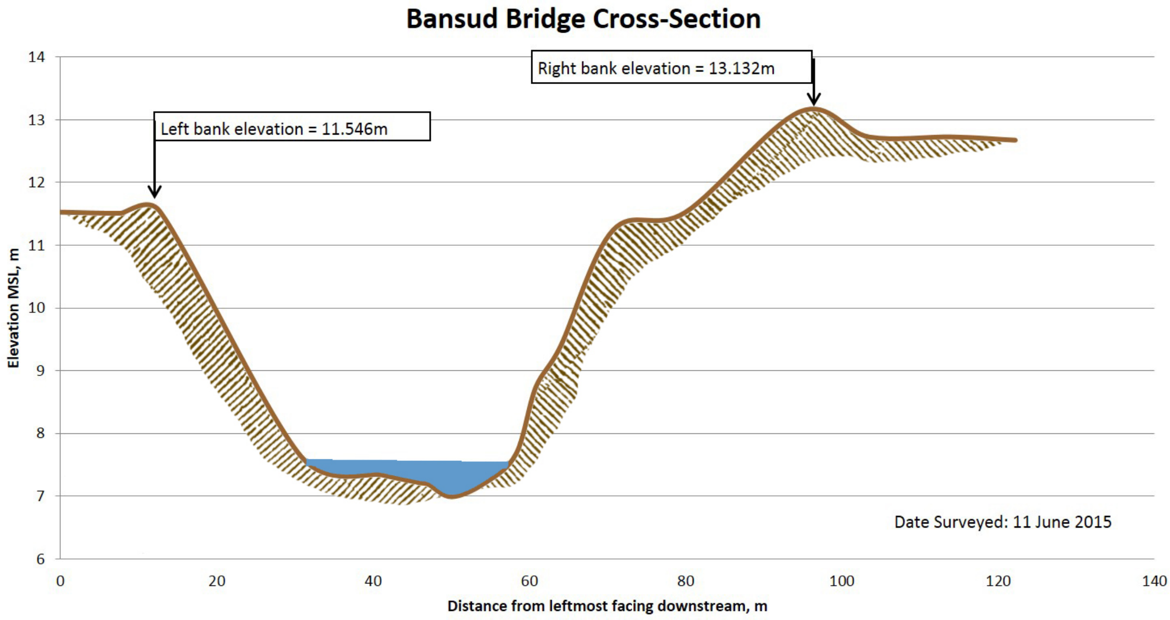


Figure 46. Cross-Section Plot of Bansud Bridge.

For Bansud Bridge, the rating curve is expressed as $Q = 5E\text{-}09e^{2.1145x}$ as shown in Figure 47.

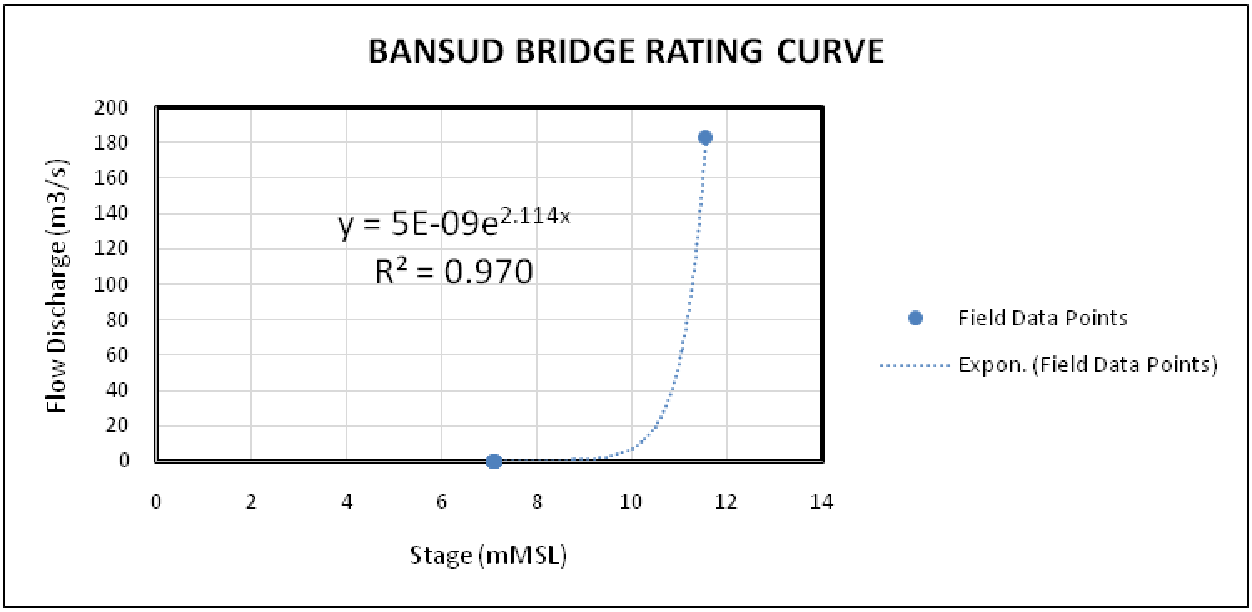


Figure 47. The rating curve at Bansud Bridge.

For the calibration of the HEC-HMS model, however, this rating curve equation was not used to compute the river outflow at Bansud Bridge. Instead, flow velocity readings using Acoustic Doppler Current Profiler (ADCP) and water level change data using water level logger were used for the calibration of the HEC-HMS model shown in Figure 48. The peak discharge is 414.680 cu.m/s on November 9, 2015 at 4:55 PM.

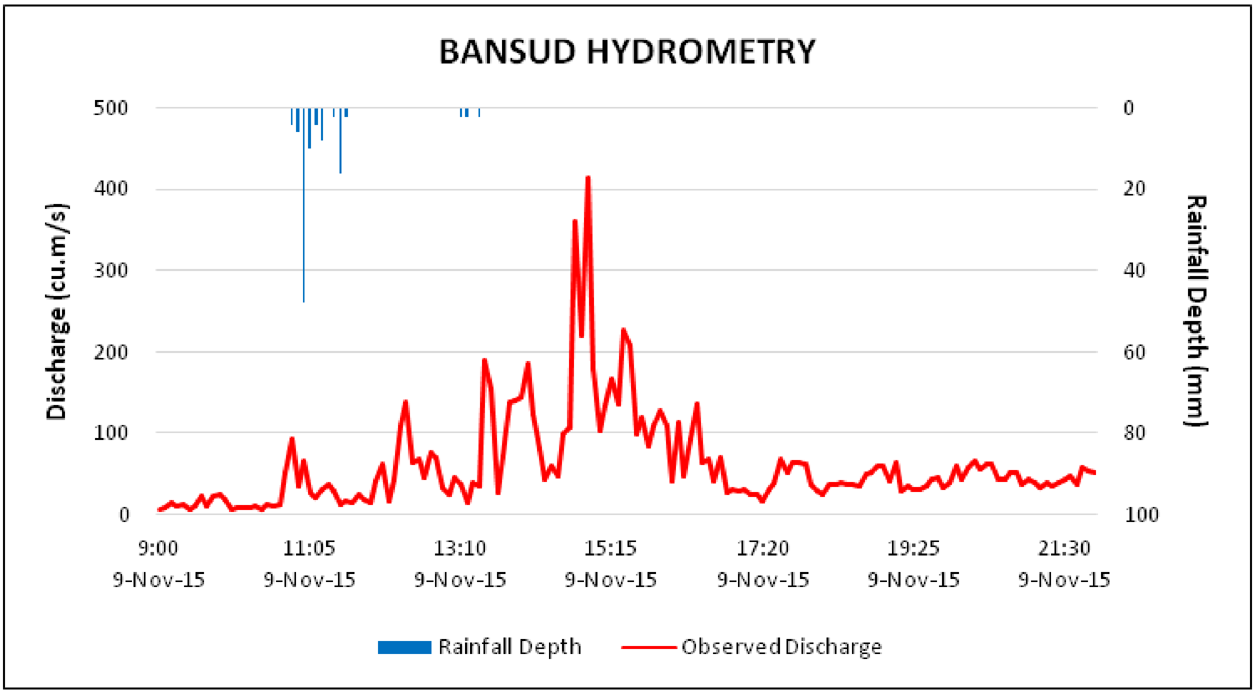


Figure 48. Rainfall and outflow data at Bansud Bridge, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Romblon Rain Gauge (Table 30). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 48). This station was selected based on its proximity to the Bansud watershed. The extreme values for this watershed were computed based on a 48-year record.

Table 30. RIDF values for the Romblon Rain Gauge, as computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	18.2	27	33.5	44.3	59.5	70.4	89.5	107	119.8
5	26	37.7	46.5	60.7	82.2	97.6	125.5	152.9	171.6
10	31.1	44.8	55	71.5	97.3	115.7	149.3	183.4	205.9
15	34	48.8	59.9	77.7	105.8	125.8	162.8	200.5	225.2
20	36	51.6	63.3	82	111.8	133	172.2	212.6	238.8
25	37.6	53.8	65.9	85.3	116.4	138.4	179.4	221.8	249.2
50	42.4	60.4	74	95.4	130.5	155.3	201.8	250.3	281.4
100	47.2	67	81.9	105.5	144.5	172.1	223.9	278.6	313.3

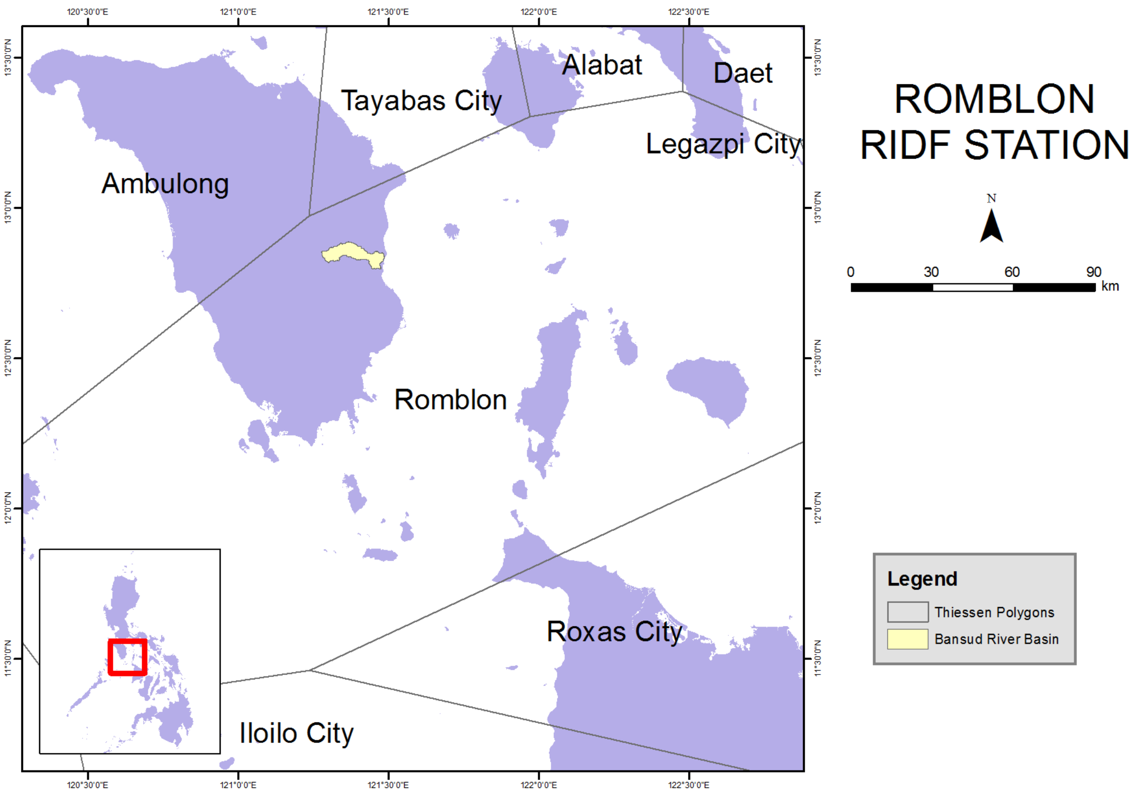


Figure 49. Location of Romblon RIDF Station relative to Bansud River Basin.

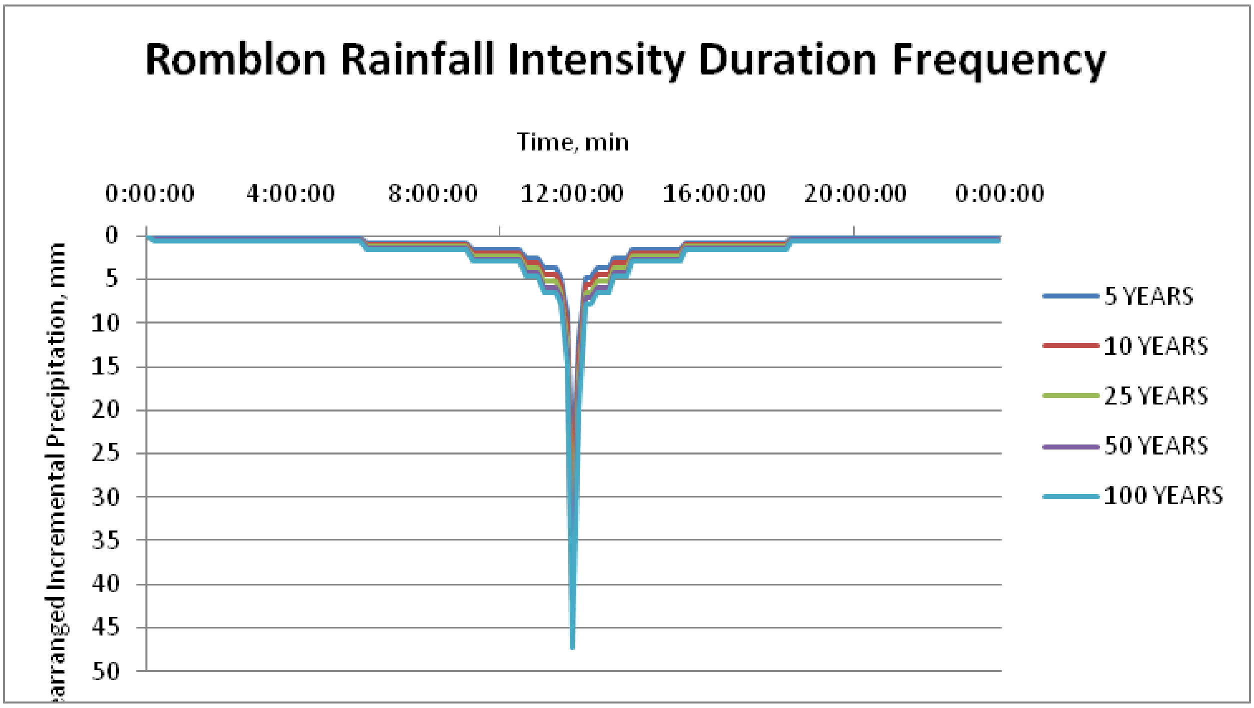


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils under the Department of Environment and Natural Resources Management. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Bansud River Basin are shown in Figure 51 and Figure 52, respectively.

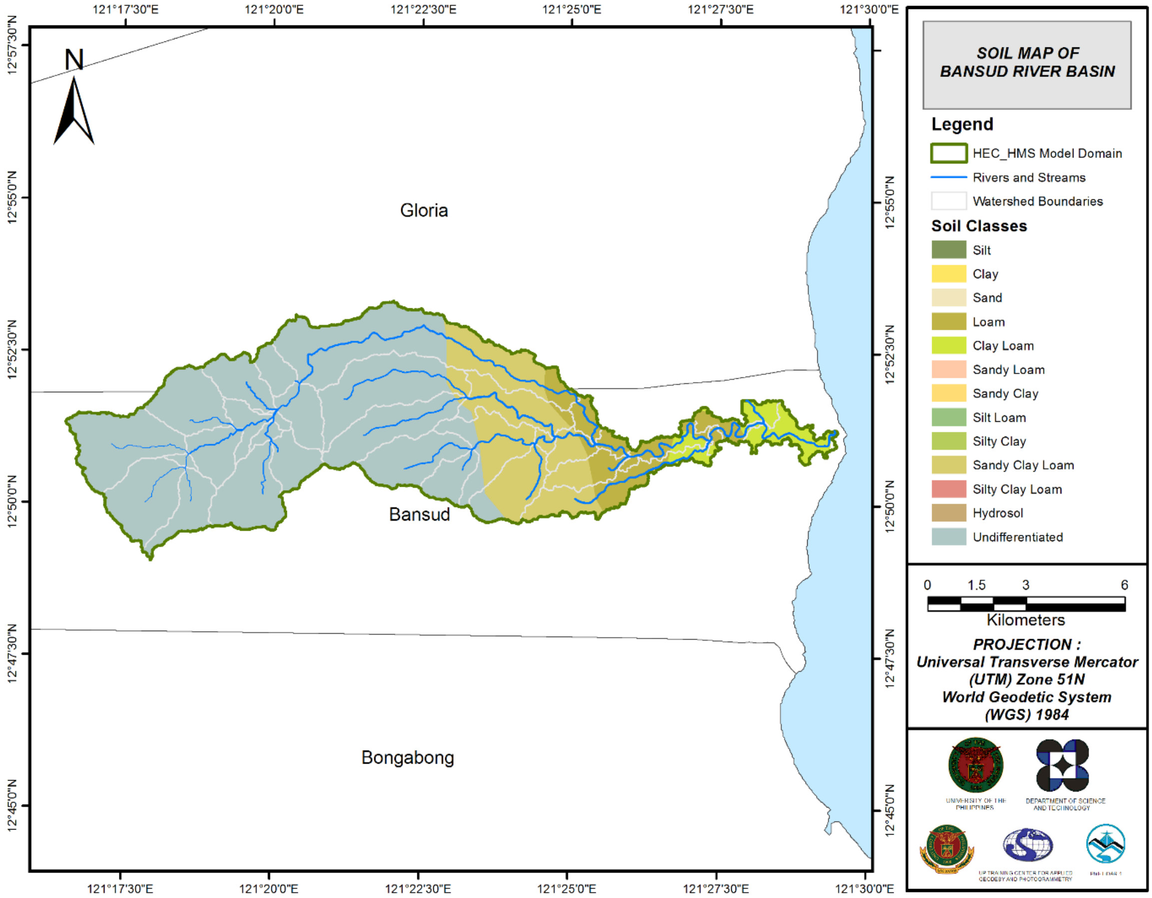


Figure 51. Soil Map of Bansud River Basin.

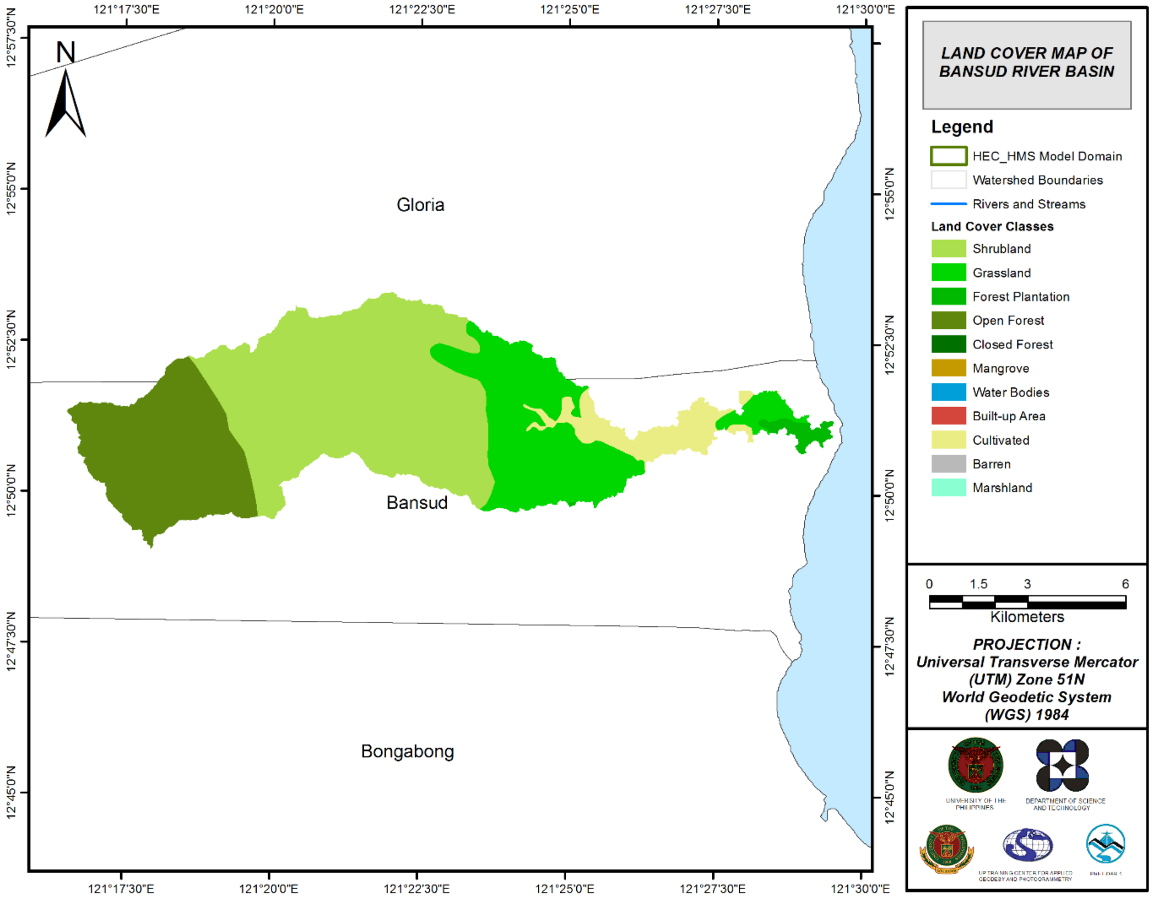


Figure 52. Land Cover Map of Bansud River Basin.

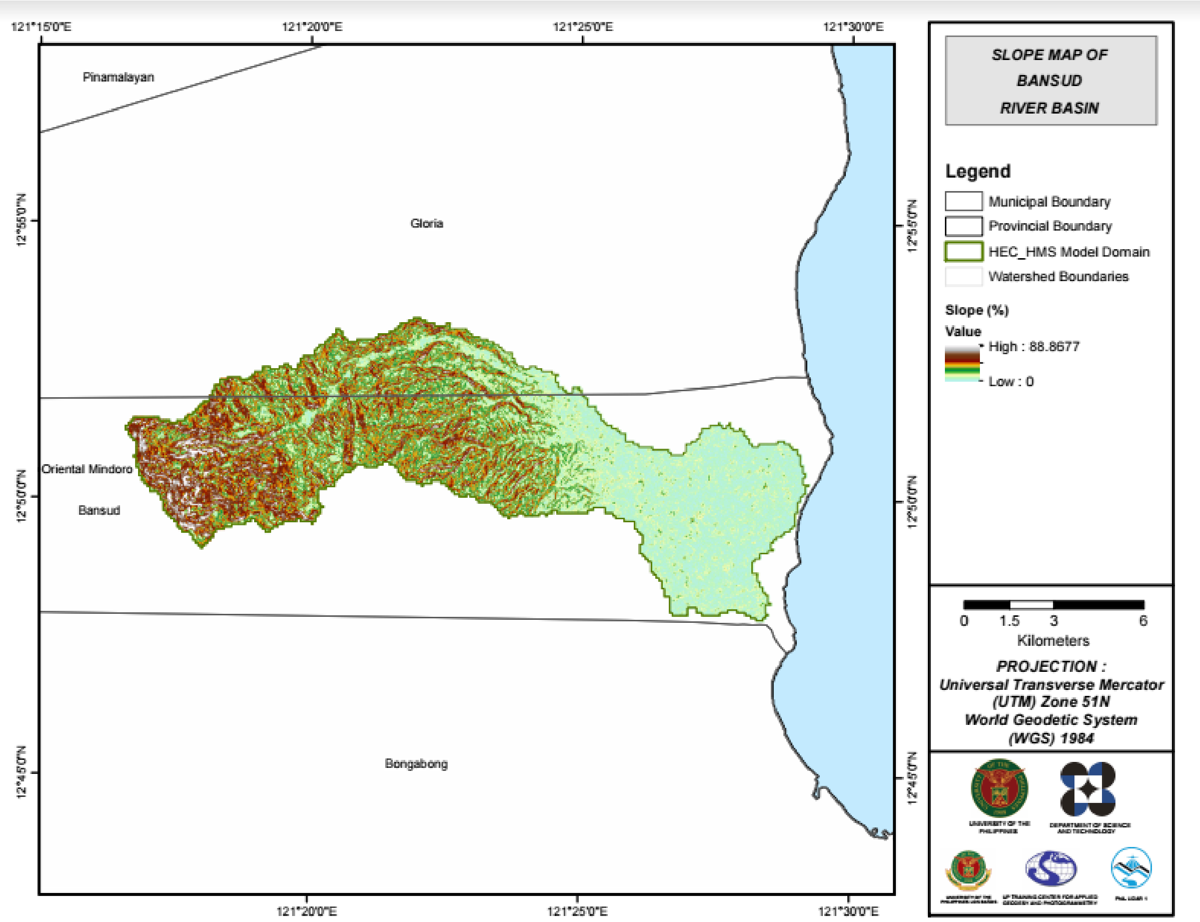


Figure 53. Slope Map of the Bansud River Basin.

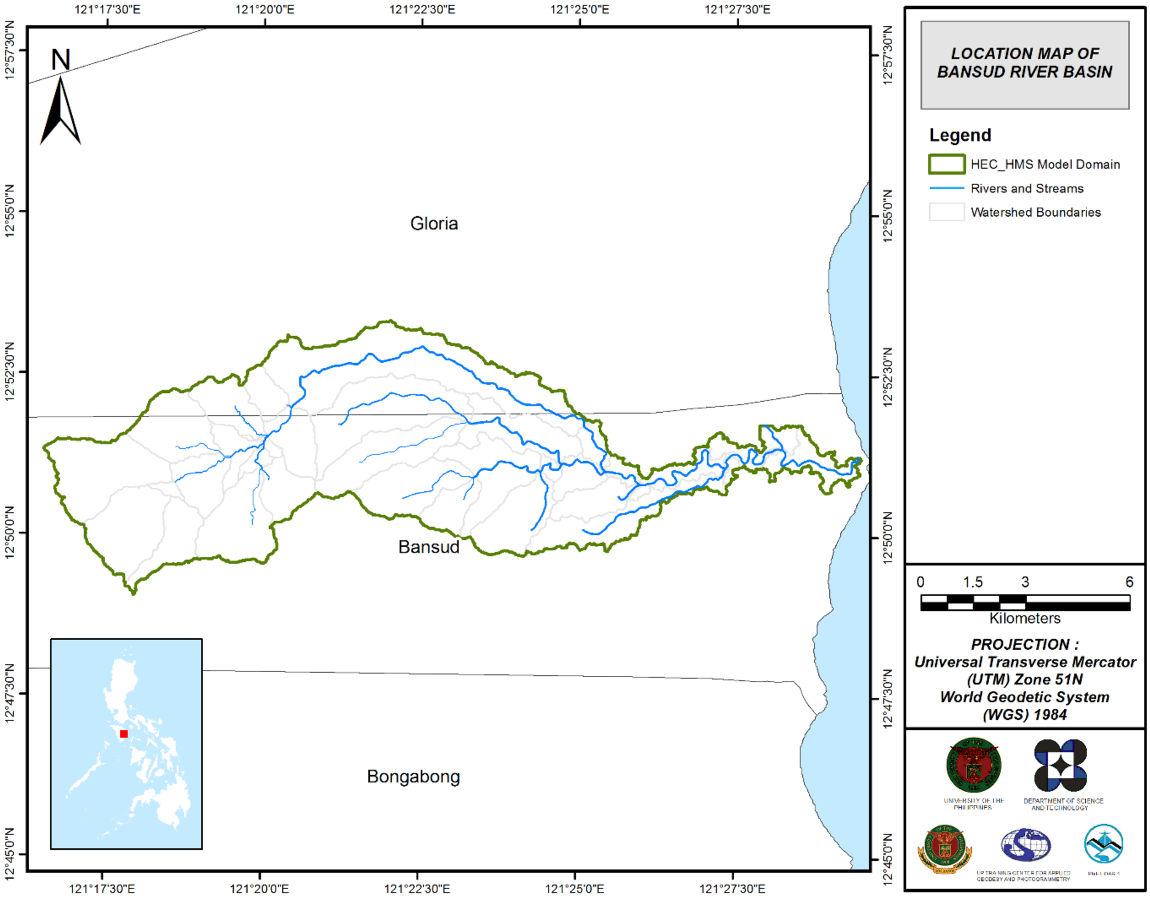


Figure 54. Stream Delineation Map of Bansud River Basin

Using the SAR-based DEM, the Bansud basin was delineated and further subdivided into subbasins. The model consists of 32 sub basins, 16 reaches, and 16 junctions as shown in Figure 55 (See Annex 10). The main outlet is at 108. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from rain gauges set up by the Data Validation team of UPLB (DVC-UPLB) on strategic points within the river basin. Finally, it was calibrated using the flow data collected from the Bansud Bridge.

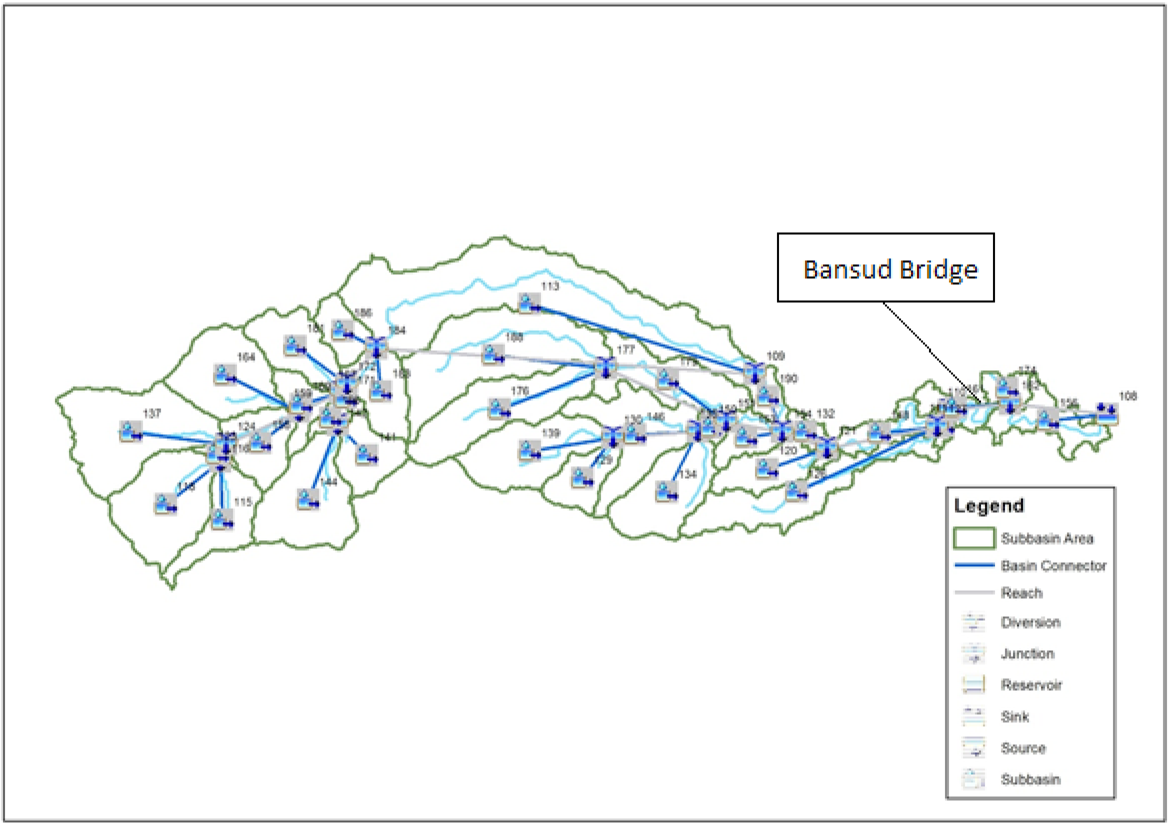


Figure 55. Bansud river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 56).

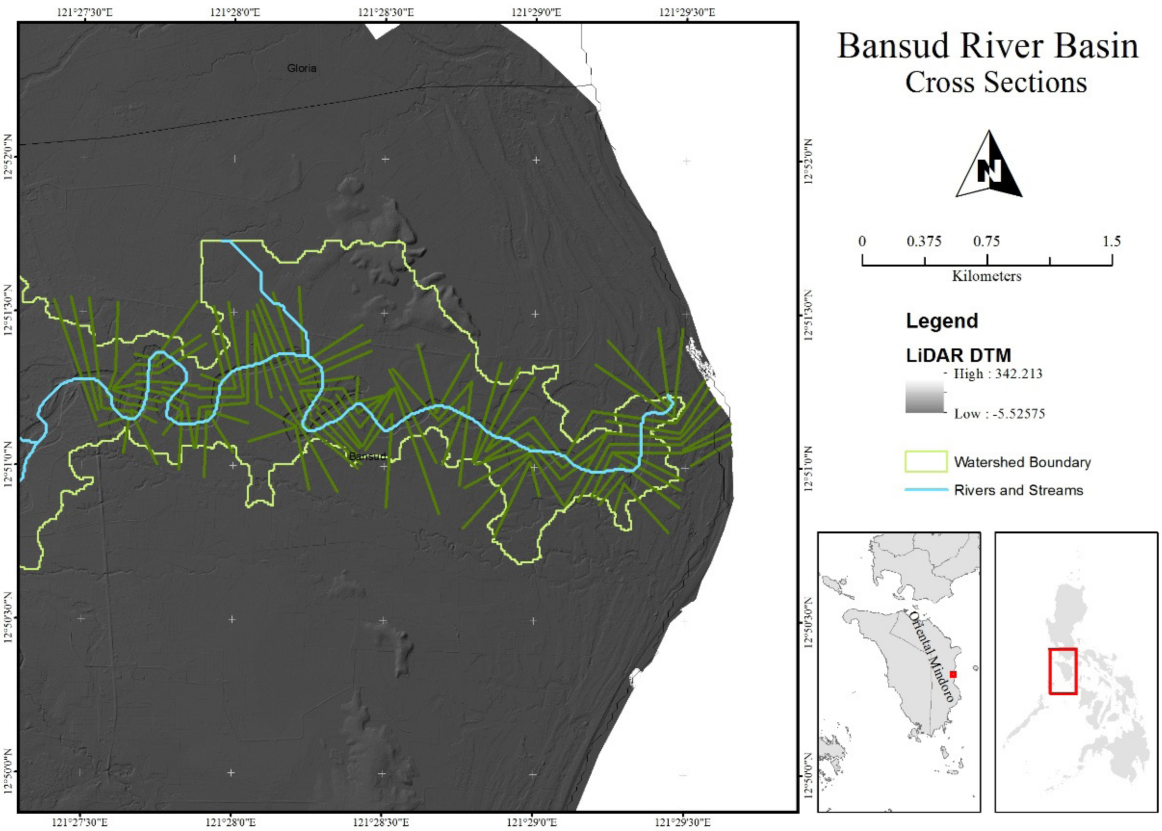


Figure 56. River cross-section of the Bansud River through the ArcMap HEC GeoRas tool.

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 south of the model to the north, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

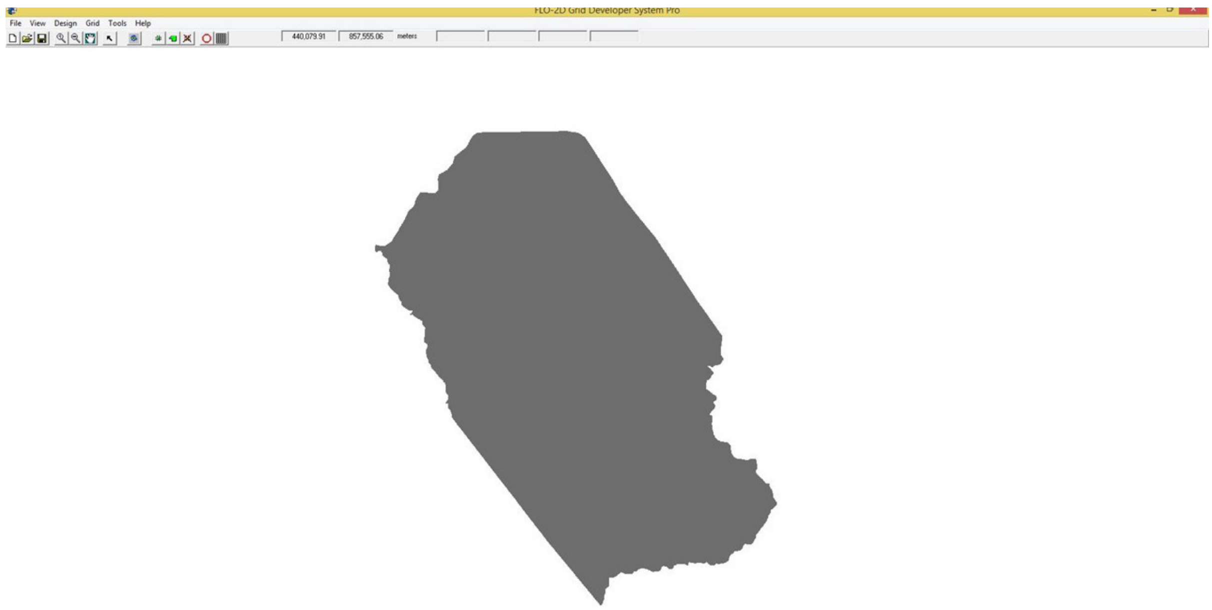


Figure 57. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 100.06329 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s. The generated hazard maps for Bansud are in Figure 62, 64, and 66.

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 63 792 800.00 m^2. The generated flood depth maps for Bansud are in Figure 63, 65, and 67.

There is a total of 465 228 177.98 m^3 of water entering the model. Of this amount, 25 253 779.51 m^3 is due to rainfall while 439 974 398.47 m^3 is inflow from other areas outside the model. 11 329 565.00 m^3 of this water is lost to infiltration and interception, while 24 641 579.81 m^3 is stored by the flood plain. The rest, amounting up to 429 257 024.59 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Bansud HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 58 shows the comparison between the two discharge data.

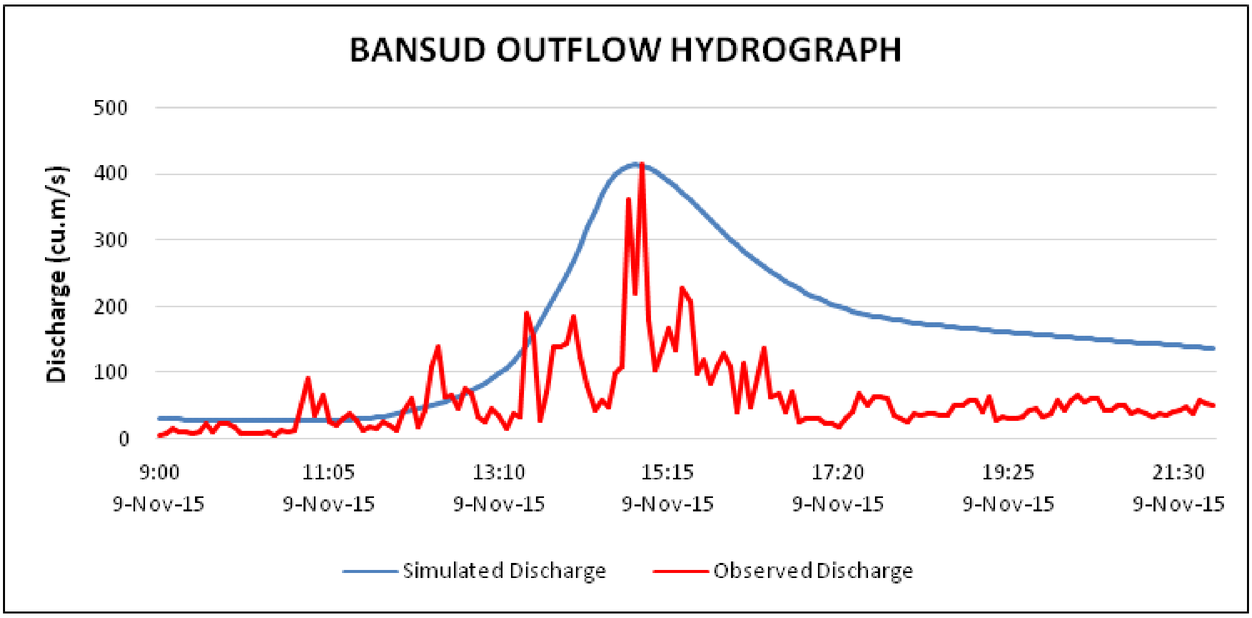


Figure 58. Outflow Hydrograph of Bansud produced by the HEC-HMS model compared with observed outflow.

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

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

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1 - 11
			Curve Number	56 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2 - 4
			Storage Coefficient (hr)	0.6 - 11
	Baseflow	Recession	Recession Constant	0.2 - 1
			Ratio to Peak	0.2 – 0.7
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.04 – 0.5

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 1 to 11 mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 56 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (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 0.2 hours to 11 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.2 to 1 and ratio to peak of 0.04 to 0.5 indicates a diverse characteristic per subbasin.

Manning's roughness coefficient of 0.04 to 5 is relatively average to high compared to the common roughness of watersheds (Brunner, 2010).

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

Accuracy measure	Value
RMSE	3.793
r^2	0.763
NSE	0.989
PBIAS	-92.007
RSR	0.105

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 3.793 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.763.

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 0.989.

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 -92.007.

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 0.105.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 59) shows the Bansud outflow using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

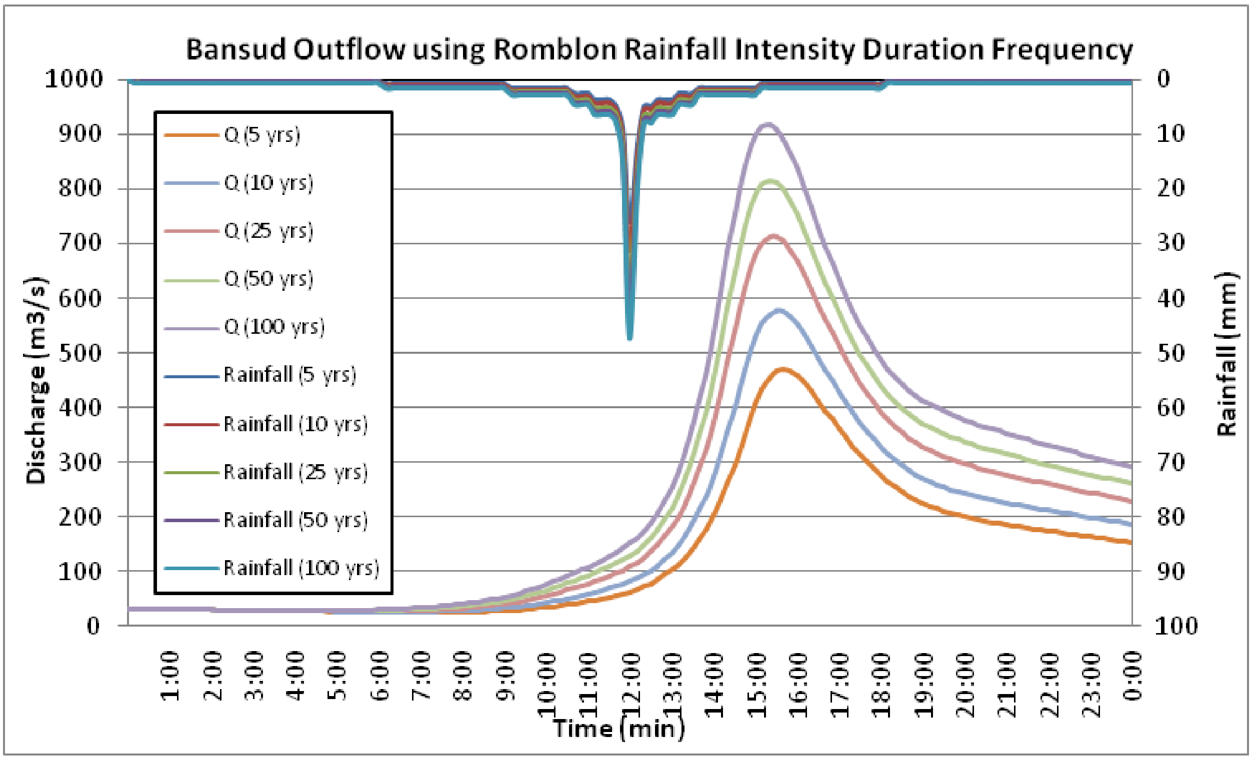


Figure 59. The Outflow hydrograph at the Bansud Station, generated using the Romblon RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Bansud discharge using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. The peak values of the Bansud HEC-HMS Model outflow using the Maasin RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-yr	171.60	26	469.357	15 hours 40 minutes
10-yr	205.90	31.1	577.386	15 hours 30 minutes
25-yr	249.20	37.6	713.340	15 hours 30 minutes
50-yr	281.40	42.4	815.763	15 hours 20 minutes
100-yr	313.30	47.2	918.448	15 hours 20 minutes

5.7.2 Discharge Data Using Dr. Horritt's Recommended Hydrologic Method.

The river discharge values for the three rivers entering the floodplain are shown in Figure 60 to Figure 62 and the peak values are summarized in Table 34 To Table 36.

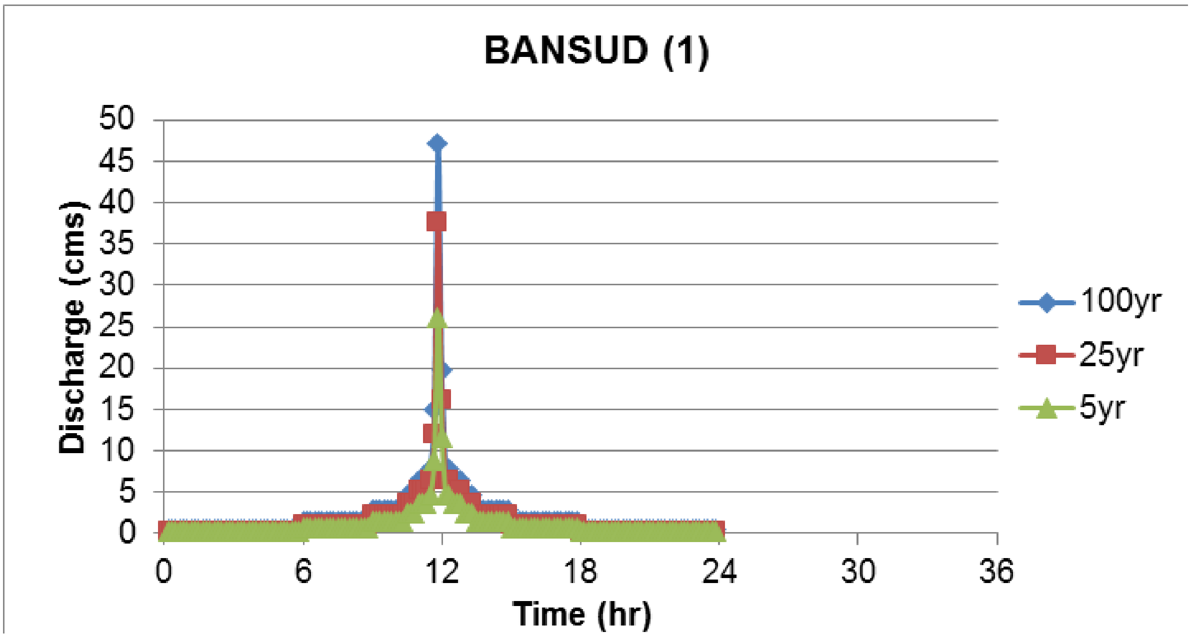


Figure 60. Bansud river (1) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

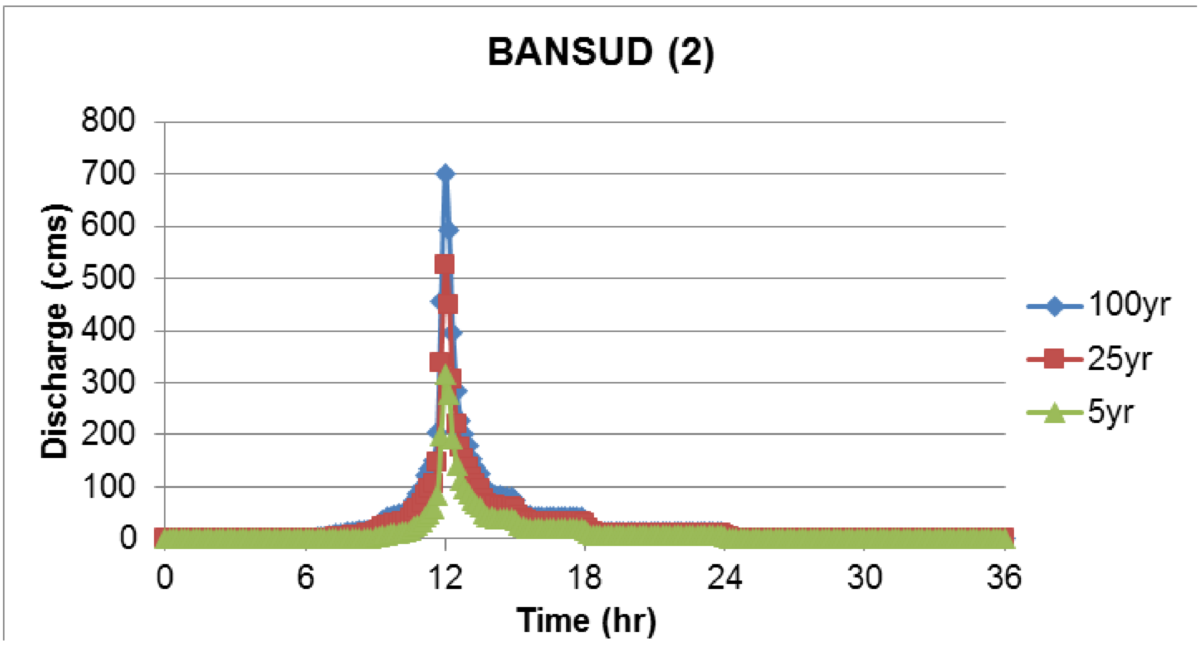


Figure 61. Bansud river (2) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

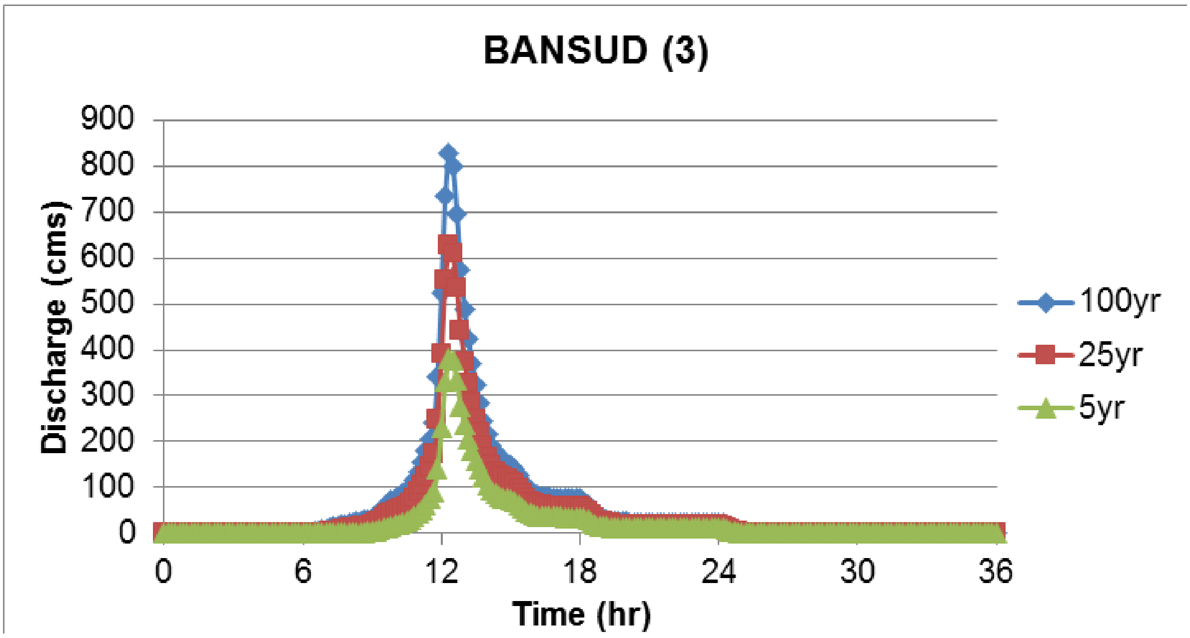


Figure 62. Bansud river (3) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 34. Summary of Bansud river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	696.0	12 hours, 40 minutes
25-Year	525.2	12 hours, 40 minutes
5-Year	317.9	12 hours, 40 minutes

Table 35. Summary of Bansud river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	701.5	12 hours
25-Year	526.2	12 hours
5-Year	314.6	12 hours

Table 36. Summary of Bansud river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	827.4	12 hours, 20 minutes
25-Year	626.3	12 hours, 20 minutes
5-Year	381.6	12 hours, 20 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 37.

Table 37. Validation of river discharge estimates.

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Dis-charge	Specific Dis-charge
Bansud (1)	279.752	199.436	304.698	Pass	Pass
Bansud (2)	276.848	409.365	196.601	Pass	Pass
Bansud (3)	335.808	487.239	294.873	Pass	Pass

All three values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

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

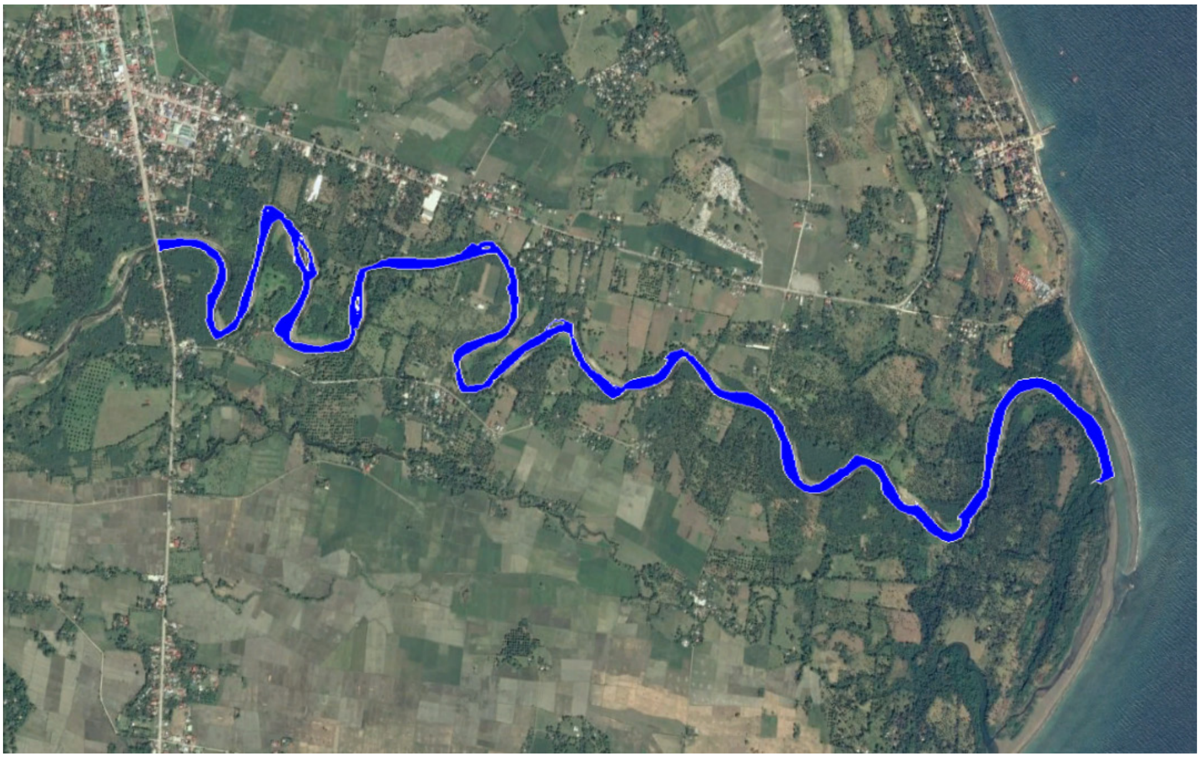


Figure 63. Sample output map of the Bansud RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 64 to Figure 69 show the 5-, 25-, and 100-year rain return scenarios of the Bansud floodplain. The floodplain, with an area of 43.67 sq. km., covers two municipalities, namely Bansud and Gloria. Table 38 shows the percentage of area affected by flooding per municipality.

Table 38. Municipalities affected in Bansud floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Oriental Mindoro	Bansud	197	41.02	20.82
Oriental Mindoro	Gloria	327.28	2.58	0.79

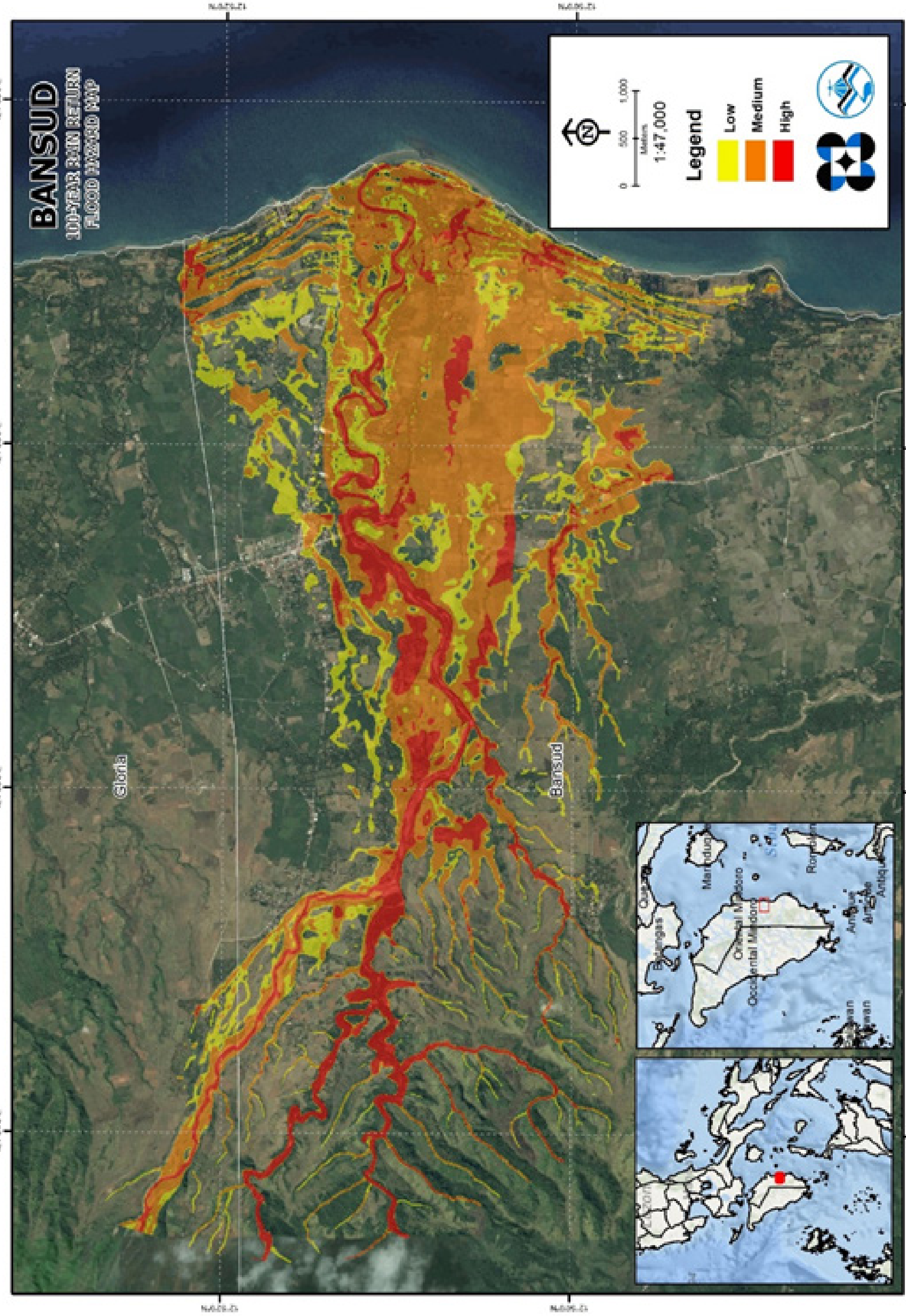


Figure 64. A 100-year Flood Hazard Map for Bansud Floodplain overlaid on Google Earth imagery.

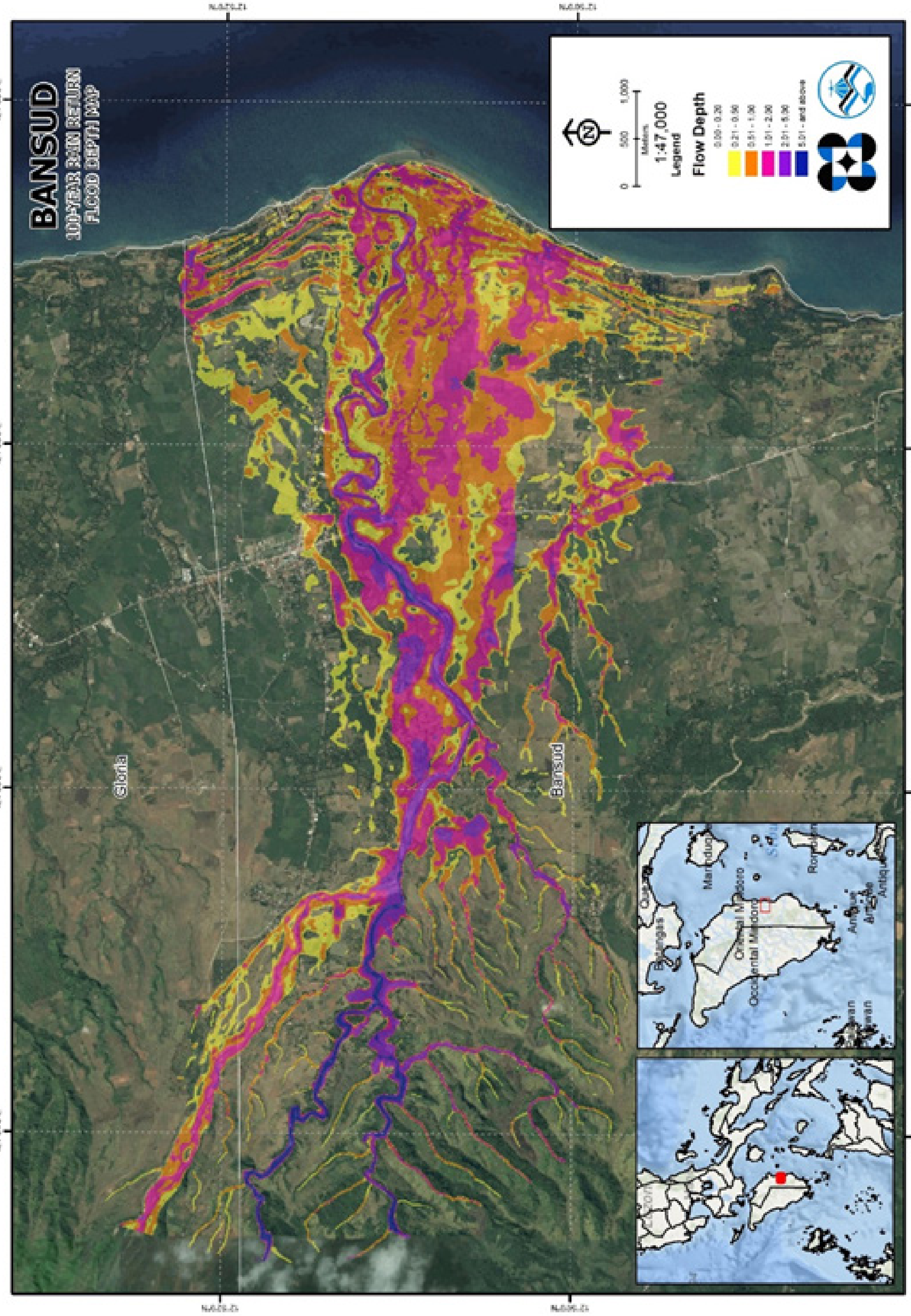


Figure 65. A 100-year Flow Depth Map for Bansud Floodplain overlaid on Google Earth imagery.

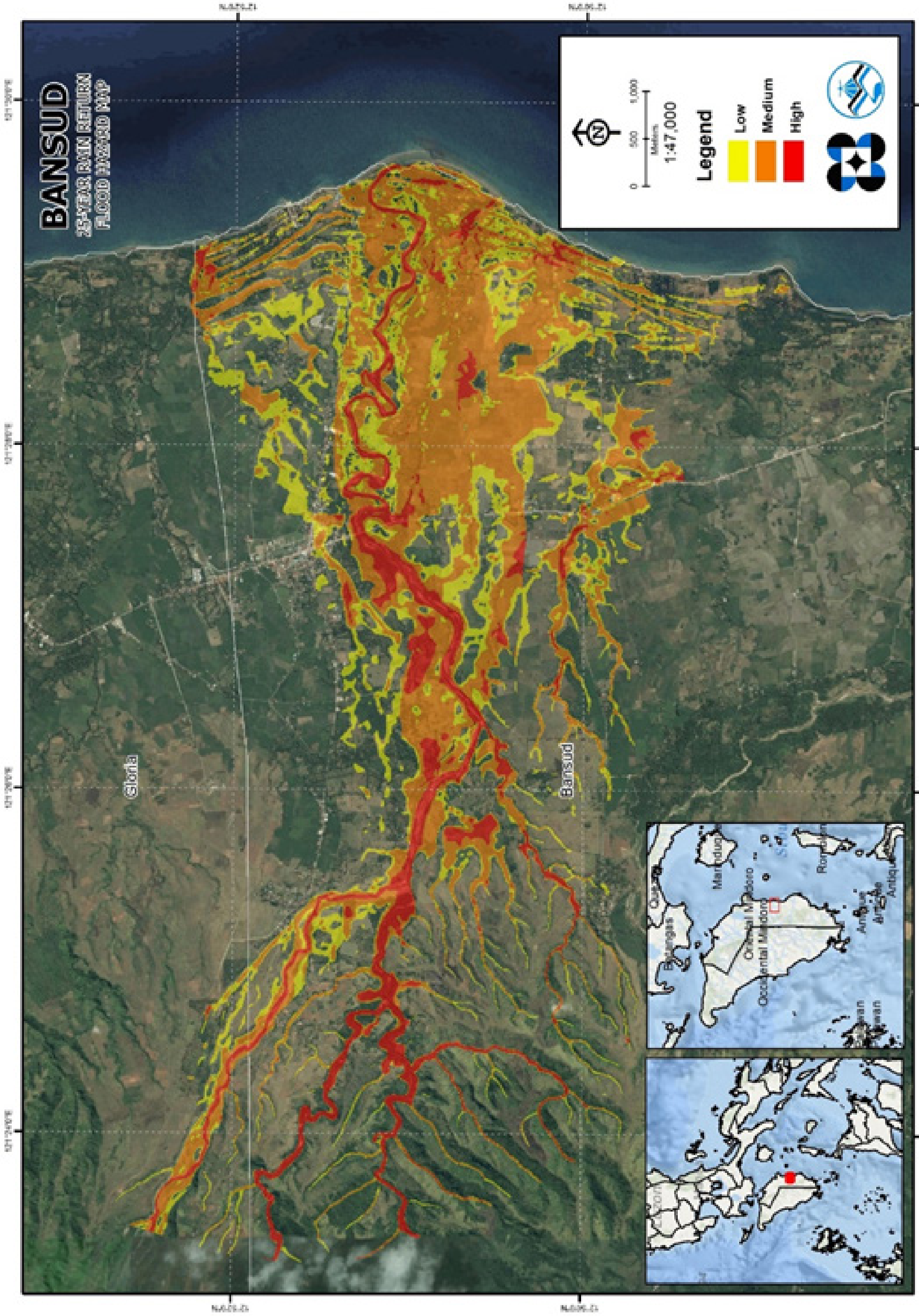


Figure 66. A 25-year Flood Hazard Map for Bansud Floodplain overlaid on Google Earth imagery.

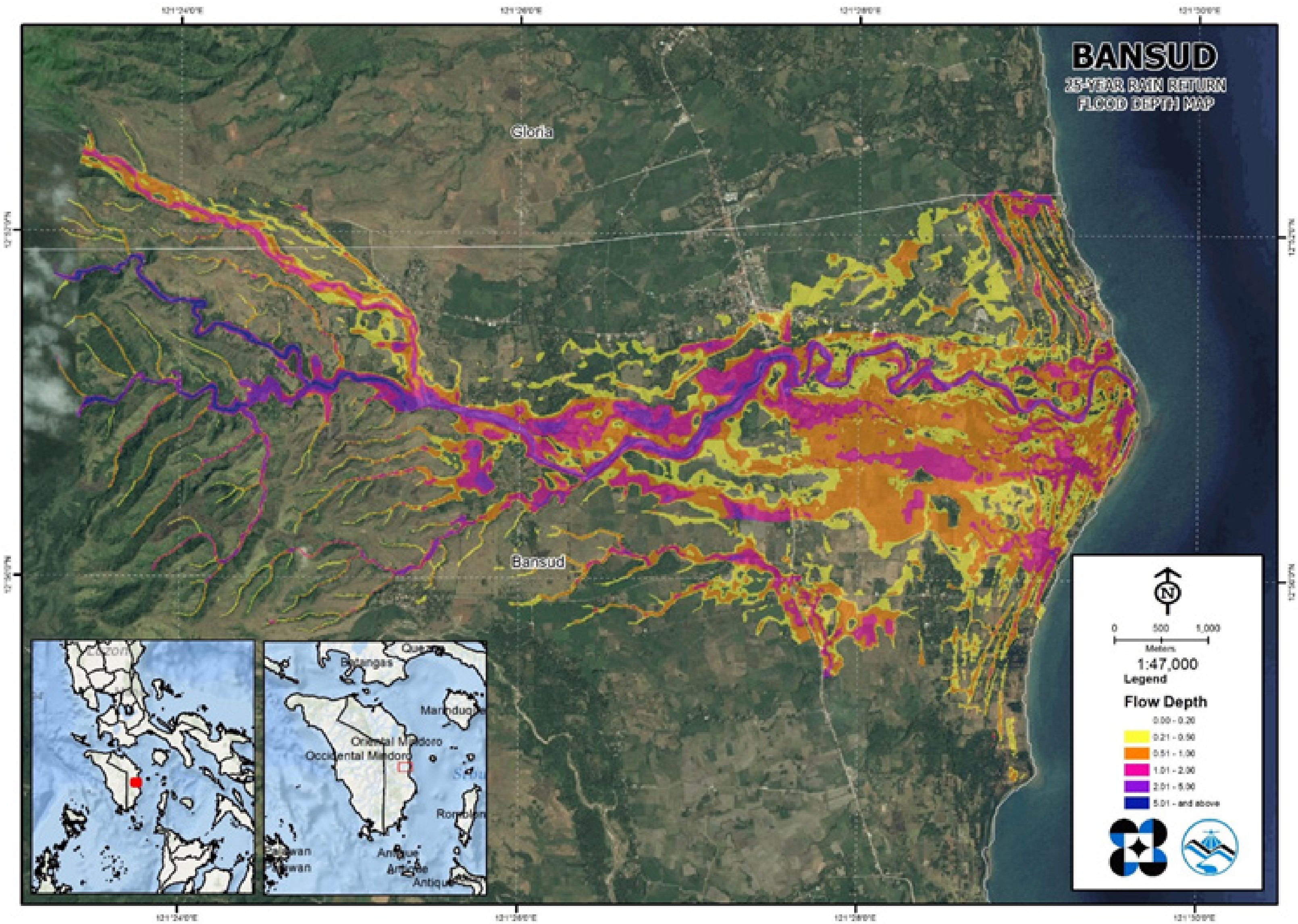


Figure 67. A 25-year Flow Depth Map for Bansud Floodplain overlaid on Google Earth imagery.

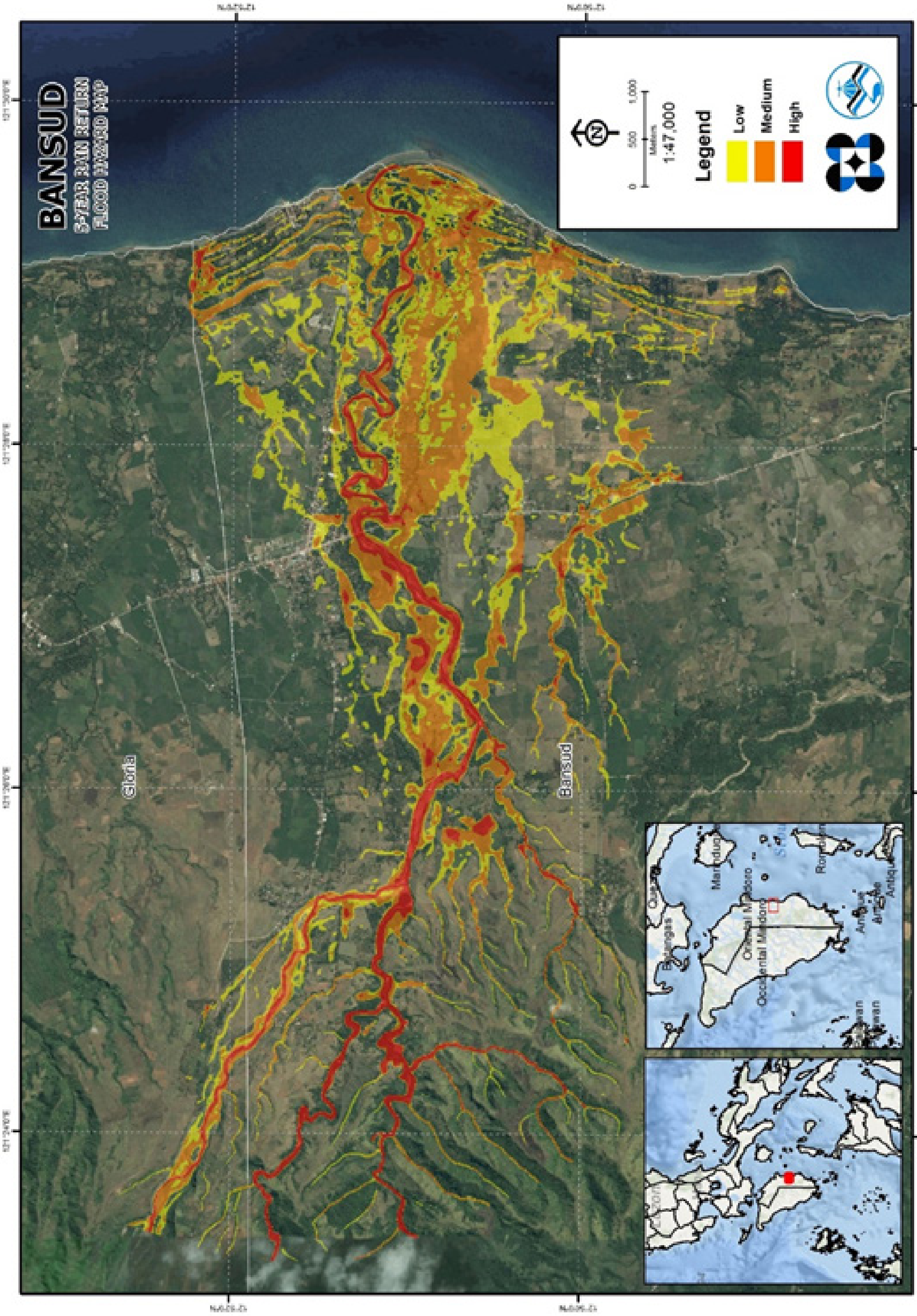


Figure 68. A 5-year Flood Hazard Map for Bansud Floodplain overlaid on Google Earth imagery.

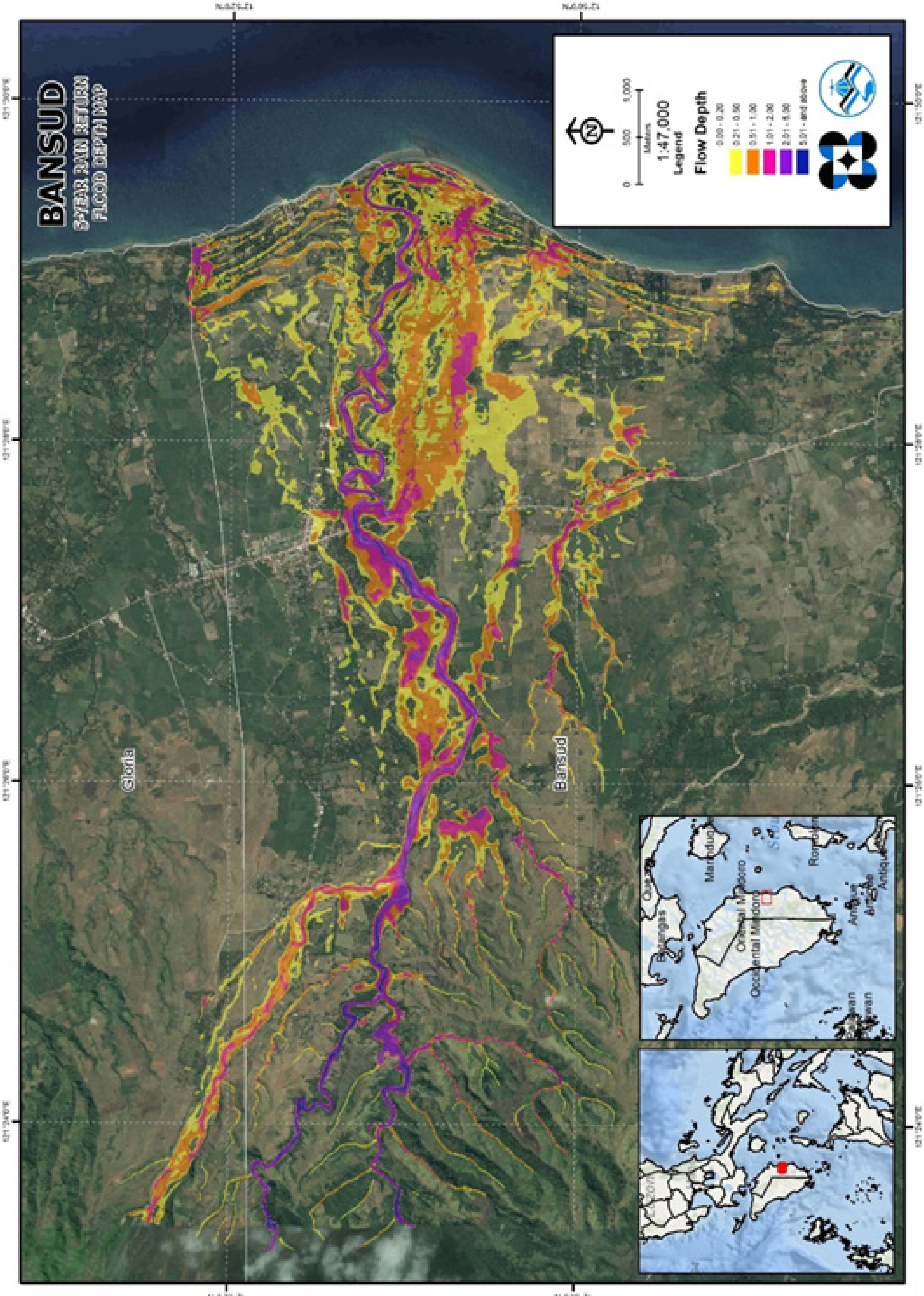


Figure 69. A 5-year Flood Depth Map for Bansud Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Bansud River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 10 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 8.15% of the municipality of Bansud with an area of 345.37 sq. km. will experience flood levels of less 0.20 meters. 1.67% of the area will experience flood levels of 0.21 to 0.50 meters while 1.23%, 0.54%, 0.29%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 39 depicts areas affected in Bansud in square kilometres by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding, respectively.

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Table 39. Affected areas in Bansud, Oriental Mindoro during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bansud (in sq. km.)							
	Alcadesma	Conrazon	Pag-Asa	Poblacion	Proper Bansud	Proper Tiguisan	Rosacara	Salcedo
0.03-0.20	2.05	13.91	1.86	0.8	2.39	2.05	4.42	0.68
0.21-0.50	1.25	1.45	0.64	0.31	1.24	0.43	0.3	0.15
0.51-1.00	0.85	1.25	0.3	0.41	0.99	0.21	0.16	0.071
1.01-2.00	0.33	0.84	0.21	0.1	0.21	0.05	0.068	0.037
2.01-5.00	0.01	0.64	0.18	0.023	0.13	0.0002	0.011	0
> 5.00	0	0.096	0.01	0.0042	0	0	0	0

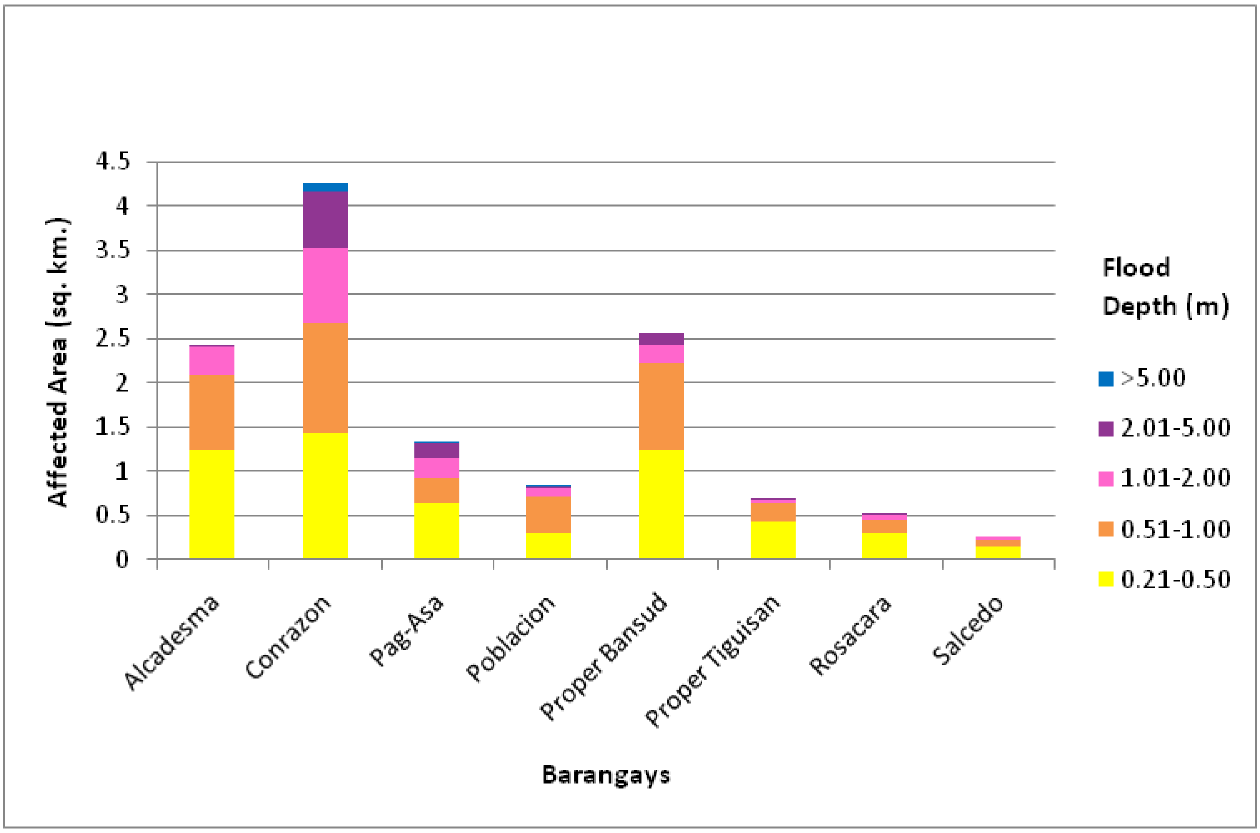


Figure 70. Affected areas in Bansud, Oriental Mindoro during a 5-Year Rainfall Return Period.

For the municipality of Gloria, with an area of 256.1 sq. km., 0.8% will experience flood levels of less 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.03%, and 0.0004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 40 depicts the areas affected in Gloria, Oriental Mindoro in square kilometers by flood depth per barangay.

Table 40. Affected areas in Gloria, Oriental Mindoro during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq. km.)	
	Agsalin	Manguyang
0.03-0.20	0.0053	2.04
0.21-0.50	0.0034	0.24
0.51-1.00	0.0054	0.21
1.01-2.00	0.0054	0.071
2.01-5.00	0.00027	0.0002
> 5.00	0	0

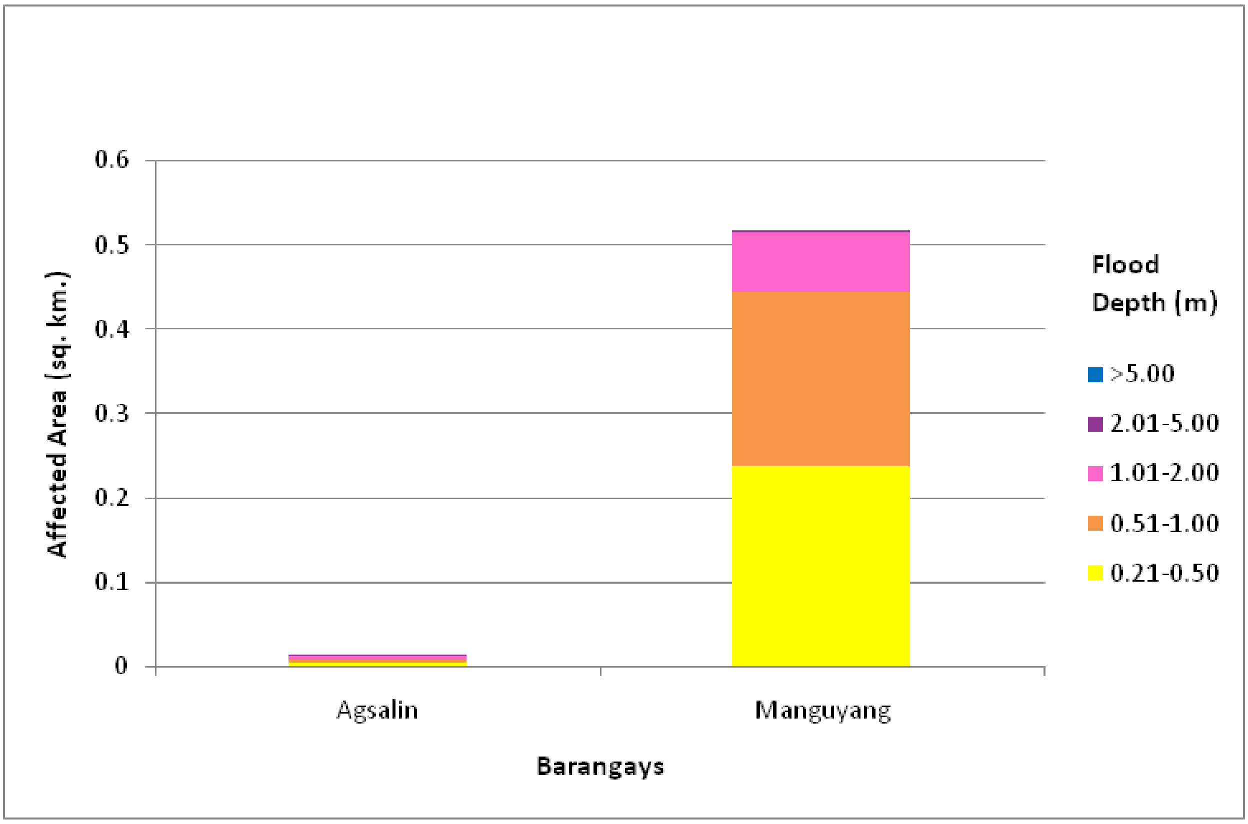


Figure 71. Affected areas in Gloria, Oriental Mindoro during a 5-Year Rainfall Return Period.

For the 25-year return period, 6.83% of the municipality of Bansud with an area of 345.37 sq. km. will experience flood levels of less 0.20 meters. 1.67% of the area will experience flood levels of 0.21 to 0.50 meters while 1.9%, 1.04%, 0.4%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 41 depicts areas affected in Bansud in square kilometres by flood depth per barangay.

Table 41. Affected areas in Bansud, Oriental Mindoro during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bansud (in sq. km.)							
	Alcadesma	Conrazon	Pag-Asa	Poblacion	Proper Bansud	Proper Tiguisan	Rosacara	Salcedo
0.03-0.20	1.07	12.58	1.4	0.38	1.63	1.68	4.28	0.57
0.21-0.50	0.83	1.55	0.85	0.34	1.16	0.55	0.32	0.15
0.51-1.00	1.76	1.5	0.42	0.63	1.51	0.37	0.22	0.15
1.01-2.00	0.8	1.41	0.3	0.26	0.53	0.14	0.095	0.066
2.01-5.00	0.033	0.94	0.21	0.031	0.15	0.0008	0.03	0.004
> 5.00	0	0.22	0.016	0.0068	0.0002	0	0	0

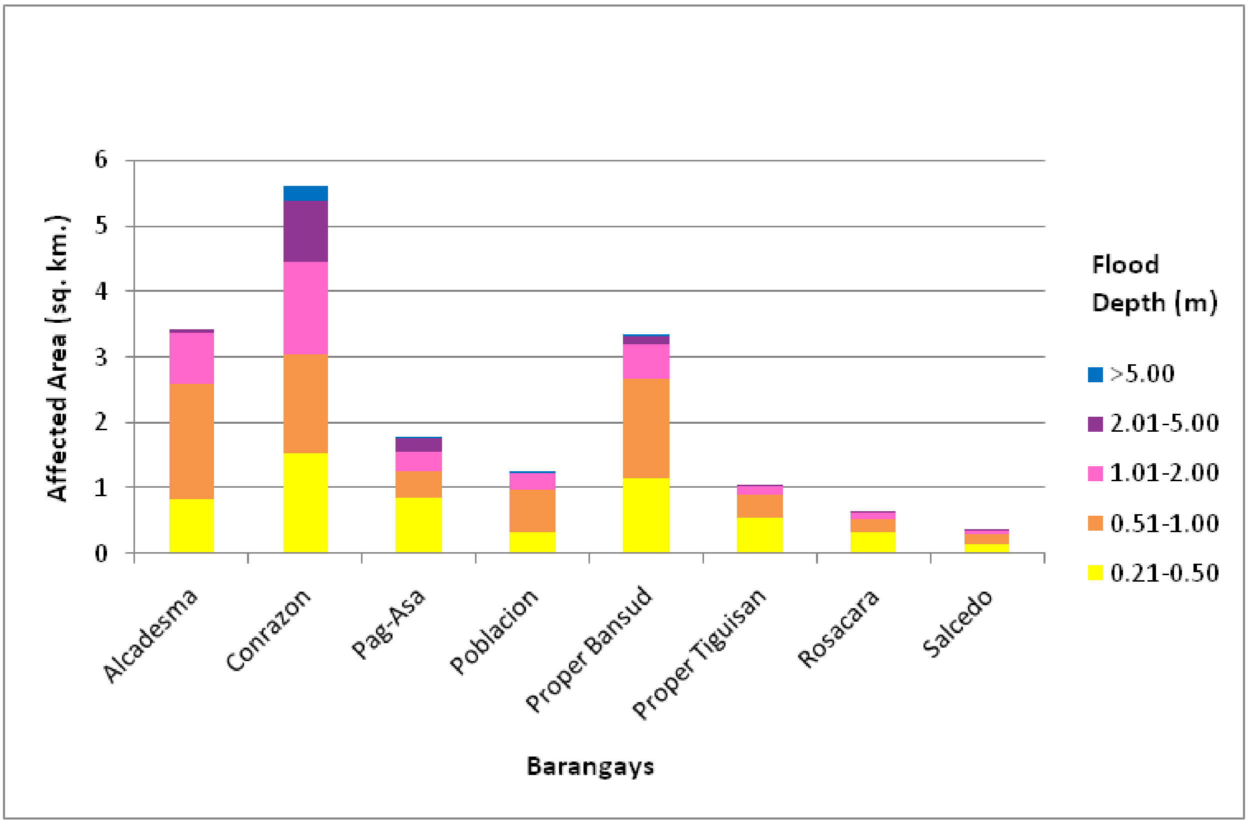


Figure 72. Affected areas in Bansud, Oriental Mindoro during a 25-Year Rainfall Return Period.

For the municipality of Gloria, with an area of 256.1 sq. km., 0.75% will experience flood levels of less 0.20 meters. 0.1% of the area will experience flood levels of 0.21 to 0.50 meters while 0.1%, 0.06%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 42 depicts the areas affected in Gloria, Oriental Mindoro in square kilometers by flood depth per barangay.

Table 42. Affected areas in Gloria, Oriental Mindoro during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq. km.)	
	Agsalin	Manguyang
0.03-0.20	0.0029	1.93
0.21-0.50	0.003	0.24
0.51-1.00	0.0053	0.24
1.01-2.00	0.0074	0.14
2.01-5.00	0.001	0.0036
> 5.00	0	0

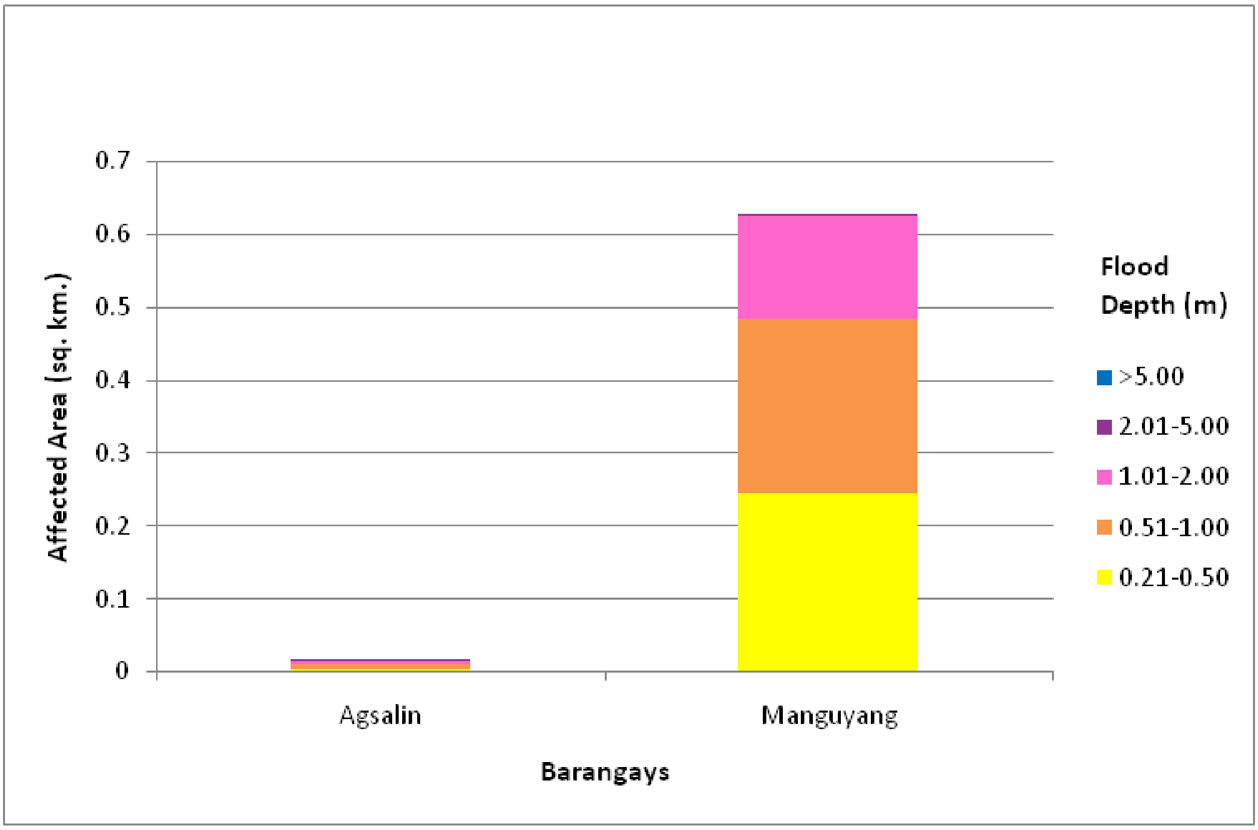


Figure 73. Affected areas in Gloria, Oriental Mindoro during a 25-Year Rainfall Return Period.

For the 100-year return period, 6.24% of the municipality of Bansud with an area of 345.37 sq. km. will experience flood levels of less 0.20 meters. 1.54% of the area will experience flood levels of 0.21 to 0.50 meters while 1.96%, 1.56%, 0.52%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 43 depicts areas affected in Bansud in square kilometres by flood depth per barangay.

Table 43. Affected areas in Bansud, Oriental Mindoro during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bansud (in sq. km.)							
	Alcadesma	Conrazon	Pag-Asa	Poblacion	Proper Bansud	Proper Tiguisan	Rosacara	Salcedo
0.03-0.20	0.81	11.87	1.25	0.14	1.35	1.4	4.19	0.53
0.21-0.50	0.55	1.48	0.85	0.28	1.06	0.64	0.34	0.14
0.51-1.00	1.58	1.57	0.52	0.64	1.57	0.48	0.26	0.17
1.01-2.00	1.46	1.79	0.32	0.54	0.84	0.23	0.12	0.091
2.01-5.00	0.081	1.2	0.24	0.041	0.17	0.0037	0.044	0.012
> 5.00	0	0.22	0.016	0.0068	0.0002	0	0	0

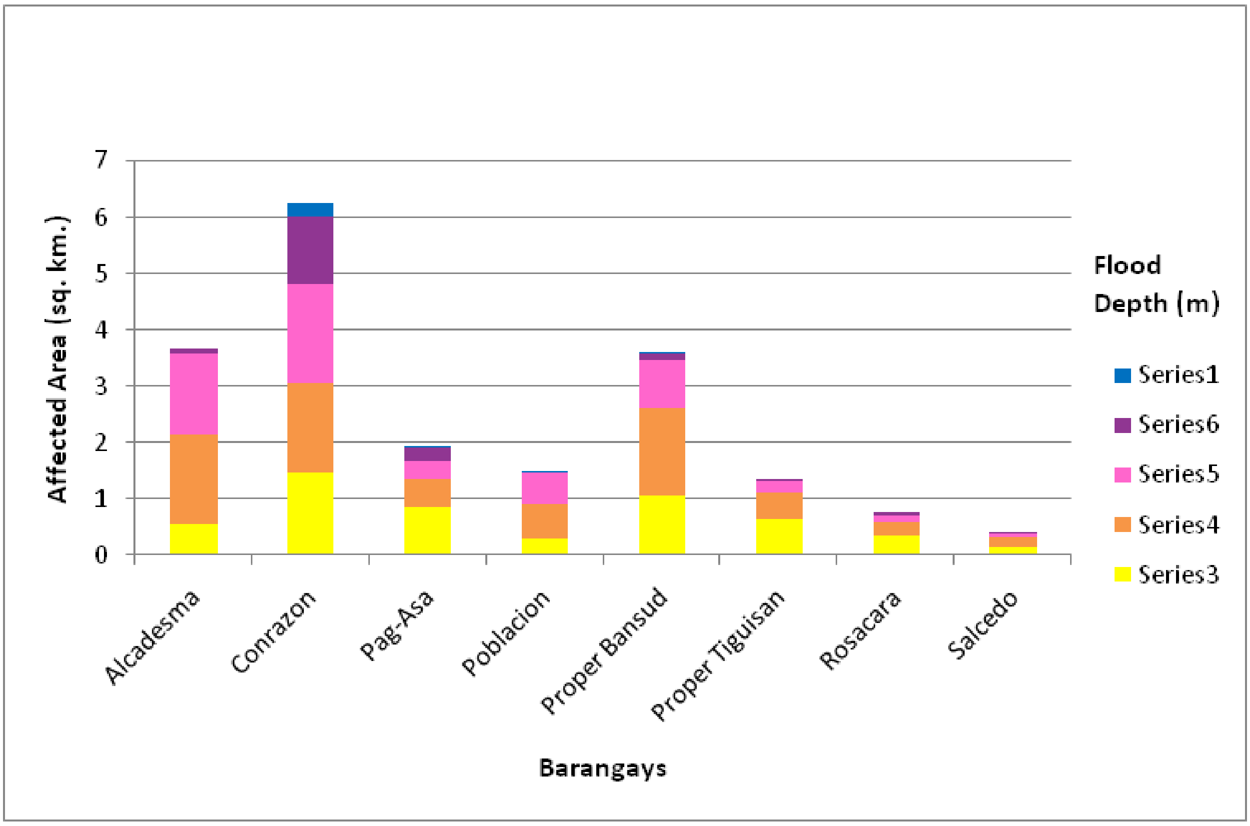


Figure 74. Affected areas in Bansud, Oriental Mindoro during a 100-Year Rainfall Return Period.

For the municipality of Gloria, with an area of 256.1 sq. km., 0.72% will experience flood levels of less 0.20 meters. 0.1% of the area will experience flood levels of 0.21 to 0.50 meters while 0.1%, 0.09%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 44 depicts the areas affected in Gloria, Oriental Mindoro in square kilometers by flood depth per barangay.

Table 44. Affected areas in Gloria, Oriental Mindoro during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq. km.)	
	Agsalin	Manguyang
0.03-0.20	0.00089	1.8
0.21-0.50	0.0036	0.26
0.51-1.00	0.0048	0.24
1.01-2.00	0.0088	0.21
2.01-5.00	0.0016	0.0098
> 5.00	0	0

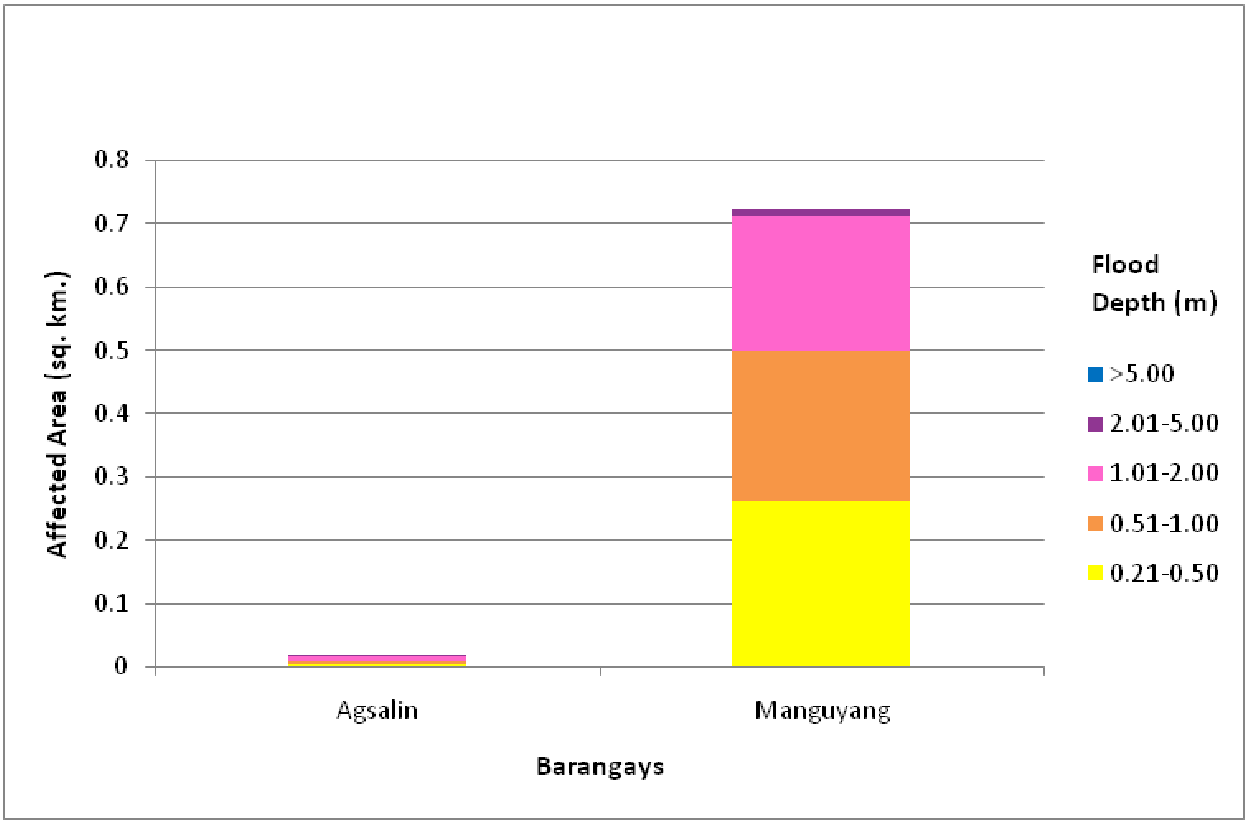


Figure 75. Affected areas in Gloria, Oriental Mindoro during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Bansud, Conrazon is projected to have the highest percentage of area that will experience flood levels at 5.27%. Meanwhile, Proper Bansud posted the second highest percentage of area that may be affected by flood depths at 1.44%.

Among the barangays in the municipality of Gloria, Manguyang is projected to have the highest percentage of area that will experience flood levels at 1%. Meanwhile, Agsalin posted the second highest percentage of area that may be affected by flood depths at 0.01%.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 76.

The flood validation consists of 82 points randomly selected all over the Bansud floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.62m. Table 43 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

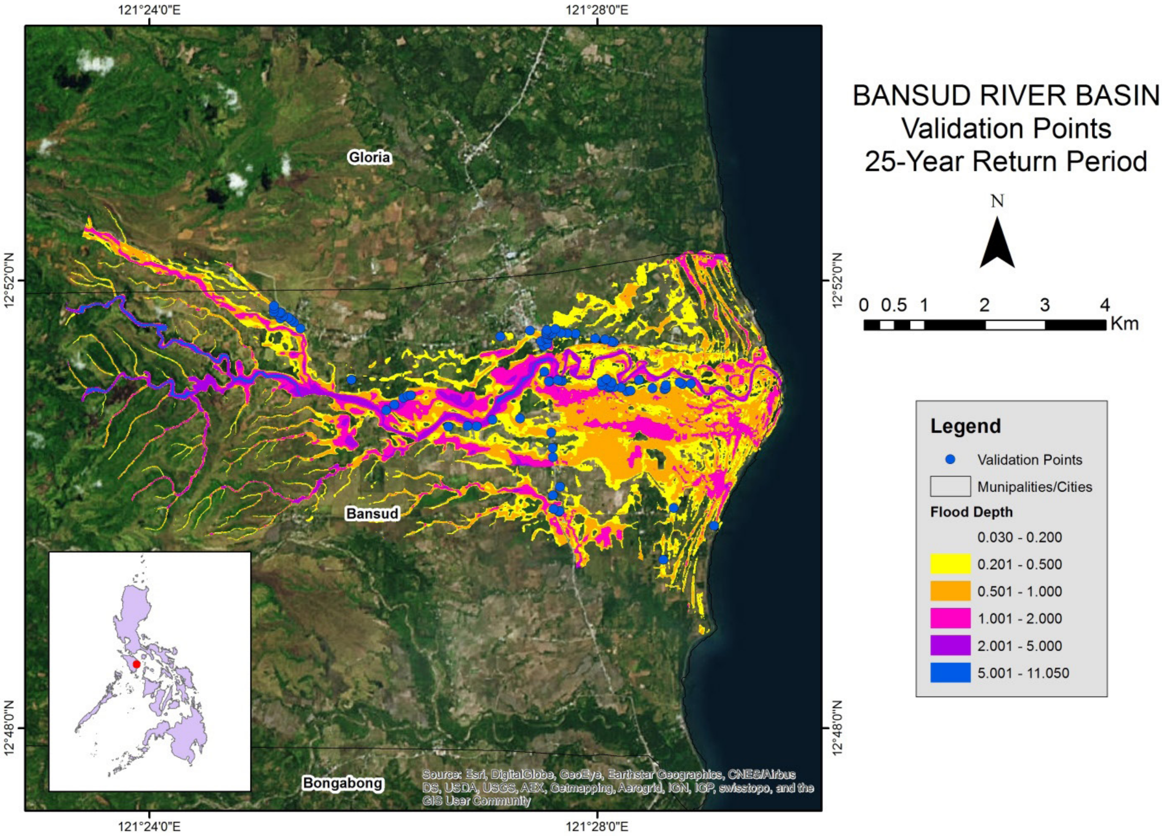


Figure 76. Validation Points for a 25-year Flood Depth Map of the Bansud Floodplain.

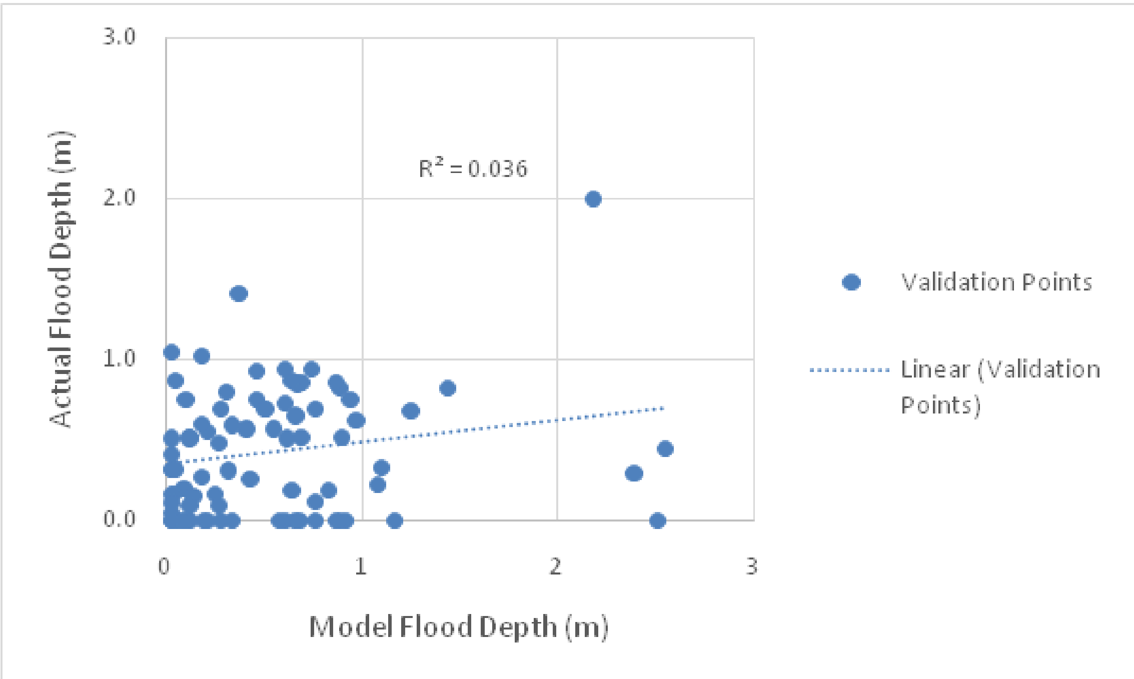


Figure 77. Flood depth map vs actual flood depth.

Table 45. Actual Flood Depth versus Simulated Flood Depth at different levels in the Bansud River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	14	5	11	1	1	0	32
0.21-0.50	8	3	1	2	2	0	16
0.51-1.00	4	8	16	2	0	0	30
1.01-2.00	2	1	0	0	1	0	4
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	28	17	28	5	4	0	82

On the whole, the overall accuracy generated by the flood model is estimated at 40.24% with 33 points correctly matching the actual flood depths. In addition, there were 17 points estimated one level above and below the correct flood depths while there were 18 points and 6 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 23 points were underestimated in the modelled flood depths of Bansud.

Table 46 depicts the summary of the Accuracy Assessment in the Bansud River Basin Flood Depth Map.

Table 46. Summary of the Accuracy Assessment in the Bansud River Basin Survey.

	No. of Points	%
Correct	33	40.24
Overestimated	26	31.71
Underestimated	23	28.05
Total	82	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Bansud Floodplain Survey

1. GEMINI SENSOR

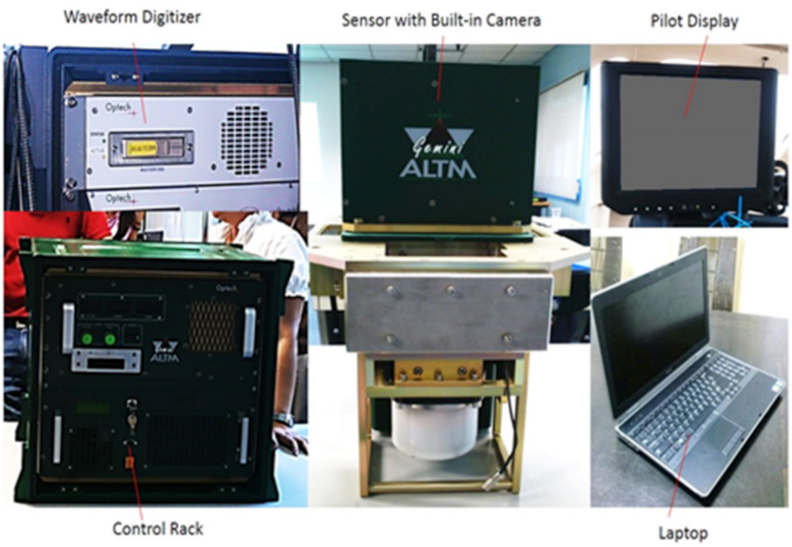


Figure A-1.1 Gemini Sensor

Table A-1.1 Parameters and Specifications of Gemini Sensor

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

2. AQUARIUS SENSOR

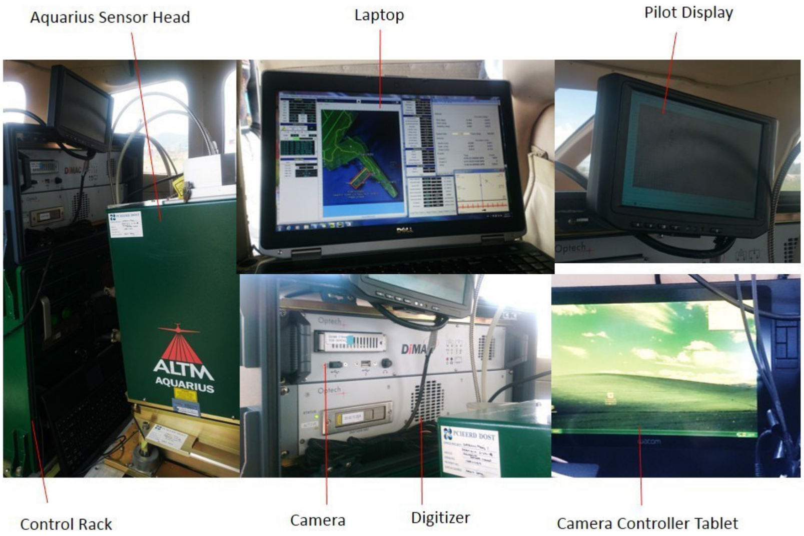


Figure A-1.2 Aquarius Sensor

Table A-1.2 Parameters and Specifications of Aquarius Sensor

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

Annex 2. NAMRIA certification of reference points used in the LiDAR survey

1. MRE-54

Figure A-2.1. MRE-54

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

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

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

Location Description

MRE-54

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

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

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

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

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

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

2. MRE-11

Figure A-2.2. MRE-11

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

October 28, 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: **ORIENTAL MINDORO**	
	Station Name: **MRE-11**	
	Order: **3rd**	
Island: **LUZON**	Barangay:	
Municipality: **BONGABONG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 44' 50.41380"**	Longitude: **121° 29' 7.80130"**	Ellipsoidal Hgt: **5.11500 m.**
	WGS84 Coordinates	
Latitude: **12° 44' 45.47630"**	Longitude: **121° 29' 12.85191"**	Ellipsoidal Hgt: **54.91100 m.**
	PTM / PRS92 Coordinates	
Northing: **1409650.153 m.**	Easting: **552720.766 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,409,587.05**	Easting: **335,581.55**	Zone: **51**

Location Description

MRE-11
To reach the station from Calapan town proper, travel SE to S ìalong the nat'l. road for about 120 kms. leading to the town of ìBongabong, passing by the towns of Victoria, Pinamalayan and ìBansud. Station is located inside the school compound of ìMagdalena Umali Suyon Elem. School on the SE corner of the ìfooting of a concrete landmark bearing the school name. It is ìabout 20 m. W of the main gate along Gov. Umali St. Mark is the ìhead of a 4 in. copper nail embedded and centered on a 0.15 m. x ì0.15 m. cement putty, with inscriptions "MRE-11 1997 NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3525**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 9 1 1

CIP/4701/12/01/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. MRE-56

Figure A-2.3. MRE-56

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

October 28, 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: **ORIENTAL MINDORO**
Station Name: **MRE-56**
Order: **2nd**

Island: **LUZON**	Barangay:	
Municipality: **MANSALAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 31' 25.76362"**	Longitude: **121° 26' 25.21109"**	Ellipsoidal Hgt: **7.87000 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 20.87629"**	Longitude: **121° 26' 30.28143"**	Ellipsoidal Hgt: **58.13600 m.**
	PTM / PRS92 Coordinates	
Northing: **1384916.657 m.**	Easting: **547857.861 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,384,892.31**	Easting: **330,530.08**	Zone: **51**

Location Description

MRE-56

From Calapan City to Bulalacao, along Nat'l Road approx. 4 Km. from Roxas Proper is an intersection of Roxas, Mansalay, Bongabong Road, turn left, approx. 14 Km. travel, right side of Nat'l Road located Mun. Hall of Mansalay, Oriental Mindoro, in front of Mansalay Hospital. Station is located in corner wall of Mun. Park in front of Mun. Hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscritions, "MRE-56, 2007, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3523**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 8 1 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

CIP/4701/12/01/814

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

1. MRE-4563

Table A-3.1. MRE-4563

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

Baseline Processing Report

Processing Summary

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

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

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

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

2. MRE-11A

Table A-3.2. MRE-11A

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE11 -25 --- MRE11A - 25 (B1)	MRE11 - 25	MRE11A - 25	Fixed	0.001	0.002	1.673	0.540	1.035	302°48'16"	2.032	0.515

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

1

MRE11 -25 - MRE11A - 25 (7:49:43 AM-10:53:15 AM) (S1)

Baseline observation:	MRE11 -25 --- MRE11A - 25 (B1)
Processed:	11/5/2015 4:59:57 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.001 m
Maximum PDOP:	3.139
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/25/2015 7:49:43 AM (Local: UTC+8hr)
Processing stop time:	10/25/2015 10:53:15 AM (Local: UTC+8hr)
Processing duration:	03:03:32
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE11 -25				
Grid		**Local**		**Global**	
Easting	0.310 m	**Latitude**	N12°44'45.47200"	**Latitude**	N12°44'45.47200"
Northing	-4.205 m	**Longitude**	E121°29'12.85377"	**Longitude**	E121°29'12.85377"
Elevation	55.043 m	**Height**	55.043 m	**Height**	55.043 m

To:	MRE11A - 25				
Grid		**Local**		**Global**	
Easting	-1.398 m	**Latitude**	N12°44'45.50783"	**Latitude**	N12°44'45.50783"
Northing	-3.104 m	**Longitude**	E121°29'12.79714"	**Longitude**	E121°29'12.79714"
Elevation	55.558 m	**Height**	55.558 m	**Height**	55.558 m

Vector					
ΔEasting	-1.708 m	**NS Fwd Azimuth**	302°48'16"	**ΔX**	1.321 m
ΔNorthing	1.101 m	**Ellipsoid Dist.**	2.032 m	**ΔY**	1.114 m
ΔElevation	0.515 m	**ΔHeight**	0.515 m	**ΔZ**	1.188 m

11/5/2015 5:01:03 PM		Business Center - HCE

2

1.

3. MRE-11 AM1

Table A-3.3. MRE-11 AM1

MRE54 - 22 - MRE11 AM1 -22 (7:40:13 AM-8:58:26 AM) (S3)

Baseline observation:	MRE54 - 22 --- MRE11 AM1 -22 (B3)
Processed:	11/5/2015 4:50:09 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.035 m
RMS:	0.005 m
Maximum PDOP:	3.705
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/22/2015 7:40:33 AM (Local: UTC+8hr)
Processing stop time:	10/22/2015 8:58:26 AM (Local: UTC+8hr)
Processing duration:	01:17:53
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE54 - 22				
Grid		**Local**		**Global**	
Easting	328016.924 m	**Latitude**	N12°59'07.43505"	**Latitude**	N12°59'07.43505"
Northing	1436055.870 m	**Longitude**	E121°24'51.55668"	**Longitude**	E121°24'51.55668"
Elevation	43.116 m	**Height**	91.395 m	**Height**	91.395 m

To:	MRE11 AM1 -22				
Grid		**Local**		**Global**	
Easting	335735.169 m	**Latitude**	N12°44'45.47242"	**Latitude**	N12°44'45.47242"
Northing	1409521.797 m	**Longitude**	E121°29'12.85426"	**Longitude**	E121°29'12.85426"
Elevation	5.611 m	**Height**	54.990 m	**Height**	54.990 m

Vector					
ΔEasting	7718.245 m	**NS Fwd Azimuth**	163°25'41"	**ΔX**	-9779.902 m
ΔNorthing	-26534.073 m	**Ellipsoid Dist.**	27635.215 m	**ΔY**	890.711 m
ΔElevation	-37.505 m	**ΔHeight**	-36.405 m	**ΔZ**	-25831.822 m

2

4. MRE-11 PM2

Table A-3.4. MRE-11 PM2

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE54 - 22 --- MRE11 AM1 -22 (B3)	MRE54 - 22	MRE11 AM1 -22	Fixed	0.006	0.035	-9779.846	890.616	-25831.853	163°25'41"	27635.215	-36.405
MRE54 - 22 --- MRE11 PM2 - 22 (B2)	MRE54 - 22	MRE11 PM2 - 22	Fixed	0.004	0.023	-9779.877	890.724	-25831.856	163°25'41"	27635.232	-36.300

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

1

MRE54 - 22 - MRE11 PM2 - 22 (1:23:53 PM-4:46:28 PM) (S2)

Baseline observation:	MRE54 - 22 --- MRE11 PM2 - 22 (B2)
Processed:	11/5/2015 4:50:38 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.023 m
RMS:	0.006 m
Maximum PDOP:	8.263
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/22/2015 1:23:53 PM (Local: UTC+8hr)
Processing stop time:	10/22/2015 4:46:28 PM (Local: UTC+8hr)
Processing duration:	03:22:35
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE54 - 22				
Grid		Local		Global	
Easting	328016.924 m	Latitude	N12°59'07.43505"	Latitude	N12°59'07.43505"
Northing	1436055.870 m	Longitude	E121°24'51.55668"	Longitude	E121°24'51.55668"
Elevation	43.116 m	Height	91.395 m	Height	91.395 m

To:	MRE11 PM2 - 22				
Grid		Local		Global	
Easting	335735.139 m	Latitude	N12°44'45.47157"	Latitude	N12°44'45.47157"
Northing	1409521.771 m	Longitude	E121°29'12.85328"	Longitude	E121°29'12.85328"
Elevation	5.716 m	Height	55.095 m	Height	55.095 m

Vector					
ΔEasting	7718.215 m	NS Fwd Azimuth	163°25'41"	ΔX	-9779.933 m
ΔNorthing	-26534.099 m	Ellipsoid Dist.	27635.232 m	ΔY	890.818 m
ΔElevation	-37.400 m	ΔHeight	-36.300 m	ΔZ	-25831.824 m

11/5/2015 4:52:33 PM		Business Center - HCE

3

5. MRE-56A

Table A-3.5. MRE-56A

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE56 - 26 --- MRE56a - 26 (B1)	MRE56 - 26	MRE56a - 26	Fixed	0.001	0.002	-3.920	-0.909	-8.525	156°03'00"	9.407	-0.535

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

1

MRE56 - 26 - MRE56a - 26 (6:52:03 AM-10:24:32 AM) (S1)

Baseline observation:	MRE56 - 26 --- MRE56a - 26 (B1)
Processed:	11/5/2015 5:05:12 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	12.356
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/26/2015 6:52:03 AM (Local: UTC+8hr)
Processing stop time:	10/26/2015 10:24:32 AM (Local: UTC+8hr)
Processing duration:	03:32:29
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE56 - 26				
Grid		**Local**		**Global**	
Easting	330684.411 m	**Latitude**	N12°31'20.87629"	**Latitude**	N12°31'20.87629"
Northing	1384827.258 m	**Longitude**	E121°26'30.28143"	**Longitude**	E121°26'30.28143"
Elevation	7.925 m	**Height**	58.136 m	**Height**	58.136 m

To:	MRE56a - 26				
Grid		**Local**		**Global**	
Easting	330688.179 m	**Latitude**	N12°31'20.59653"	**Latitude**	N12°31'20.59653"
Northing	1384818.639 m	**Longitude**	E121°26'30.40791"	**Longitude**	E121°26'30.40791"
Elevation	7.390 m	**Height**	57.601 m	**Height**	57.601 m

Vector					
ΔEasting	3.768 m	**NS Fwd Azimuth**	156°03'00"	**ΔX**	-3.958 m
ΔNorthing	-8.619 m	**Ellipsoid Dist.**	9.407 m	**ΔY**	-0.847 m
ΔElevation	-0.535 m	**ΔHeight**	-0.535 m	**ΔZ**	-8.509 m

11/5/2015 5:06:23 PM		Business Center - HCE

2

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE BALIGUAS	UP-TCAGP
	RA	ENGR. MILLIE SHANE REYES	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
	RA	ENGR. GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC

Annex 5. Data Transfer Sheet for Bansud Floodplain

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

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

Received from
Name Faith Sible
Position KA
Signature

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

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

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

DATA TRANSFER SHEET

Feb 18, 2014

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

Received from

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

Received by

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

Verified by

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

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

DATA TRANSFER SHEET
Feb 21, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
2/11/2014	1088A	3BLK28HS042A	AQUARIUS	N/A	781	1.23MB	269	80.7GB ~~25.4~~	565	14	N/A	14.7	143	506	6	12	\\FREENAS\geostorage3\Airborne_Raw\1088A
2/11/2014	1090A	3BLK28J042B	AQUARIUS	N/A	215	822KB	156	19.4	162	4.96	N/A	14.7	143	267	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1090A
2/12/2014	1092A	3BLK28ABES043A	AQUARIUS	N/A	1657	1.70MB	242	23.7	601	12.7	N/A	15.4	123	364	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1092A
2/12/2014	1094A	3BLK28BS043B	AQUARIUS	N/A	332	2.27MB	128	28.4GB ~~22.1~~	186	6.05	N/A	15.4	123	334	8	N/A	\\FREENAS\geostorage3\Airborne_Raw\1094A
2/13/2014	1096A	3BLK28NAJ044A	AQUARIUS	N/A	449	772KB	207	36.6	291	7.46	N/A	13.3	175	411	6	N/A	\\FREENAS\geostorage3\Airborne_Raw\1096A
2/13/2014	1098A	3BLK28JSI044B	AQUARIUS	N/A	582	954KB	235	23.9	291	11	N/A	13.3	175	725	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1098A
2/15/2014	1104A	3BLK28JSI046A	AQUARIUS	N/A	787	1.08MB	276	56.2	288KB&170KB	10.3	N/A	9.85	134	325	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1104A

Received from

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

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

Verified by

Name JOIDA F. PRIETO
Position SSRS
Signature

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

DATA TRANSFER SHEET
Calapan 11/9/15

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	
Oct. 22, 2015	8300	2BLK28ABC295A	Gemini	na	400	675	236	28.5	214	18.2	247	15.6	1KB	1KB	24	na	Z:\DAC\RAW DATA
Oct. 22, 2015	8301	2BLK28CSD295B	Gemini	na	587	947	249	39.1/10.5	307/87	22.7	na	15.6	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 23, 2015	8302	2BLK28ASEHI296A	Gemini	na	343	593	228	28.2	223	14.5	na	11.5	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 24, 2015	8304	2BLK28FHS297A	Gemini	na	315	519	214	24.8	187	14.2	221	8.92	1KB	1KB	5/11/24/14/13	na	Z:\DAC\RAW DATA
Oct. 25, 2015	8306	2CALIBBLK28FSGS298A	Gemini	na	136	366	220	na	na	10.7	4.29	8.28	1KB	1KB	28/27	na	Z:\DAC\RAW DATA
Oct. 26, 2015	8308	2BLK28J299A	Gemini	na	312	356	235	na	na	14	153	8.39	1KB	1KB	7/5/2	na	Z:\DAC\RAW DATA
Oct. 28, 2015	8312	2BLK28JKLS301A	Gemini	na	40	292	215	na	na	11	427	7.5	1KB	1KB	7	270	Z:\DAC\RAW DATA

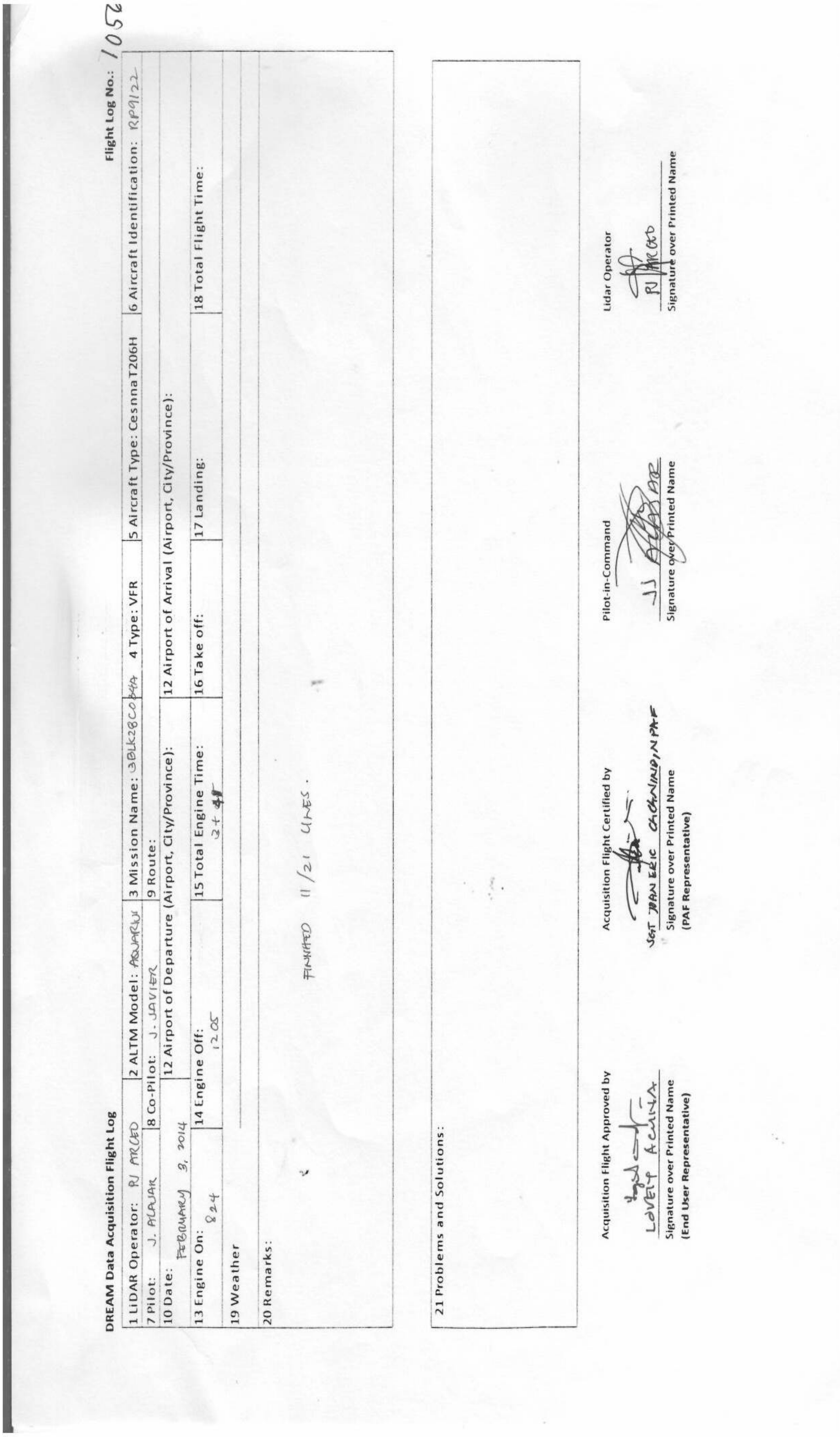
Received from
Name C. Joaquin
Position RA
Signature

Received by
Name AC Bongat
Position SSRS
Signature 11/12/15

Figure A-5.4. Transfer Sheet for Bansud Floodplain - D

Annex 6. Flight logs for the flight missions

1. Flight Log for 1056A



DREAM Data Acquisition Flight Log

Flight Log No.: 1052

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28CO34A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEBRUARY 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 824	14 Engine Off: 1205	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 11/21 LINES.					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	SGT JAN ERIC OCHININO, PAF	JJ ALAJAR	RJ ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1056A

2. Flight Log for 1066A

DREAM Data Acquisition Flight Log — Flight Log No.: 1066

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

21 Problems and Solutions:

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

Figure A-6.2. Flight Log for Mission 1066A

3. Flight Log for 1070A

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1070

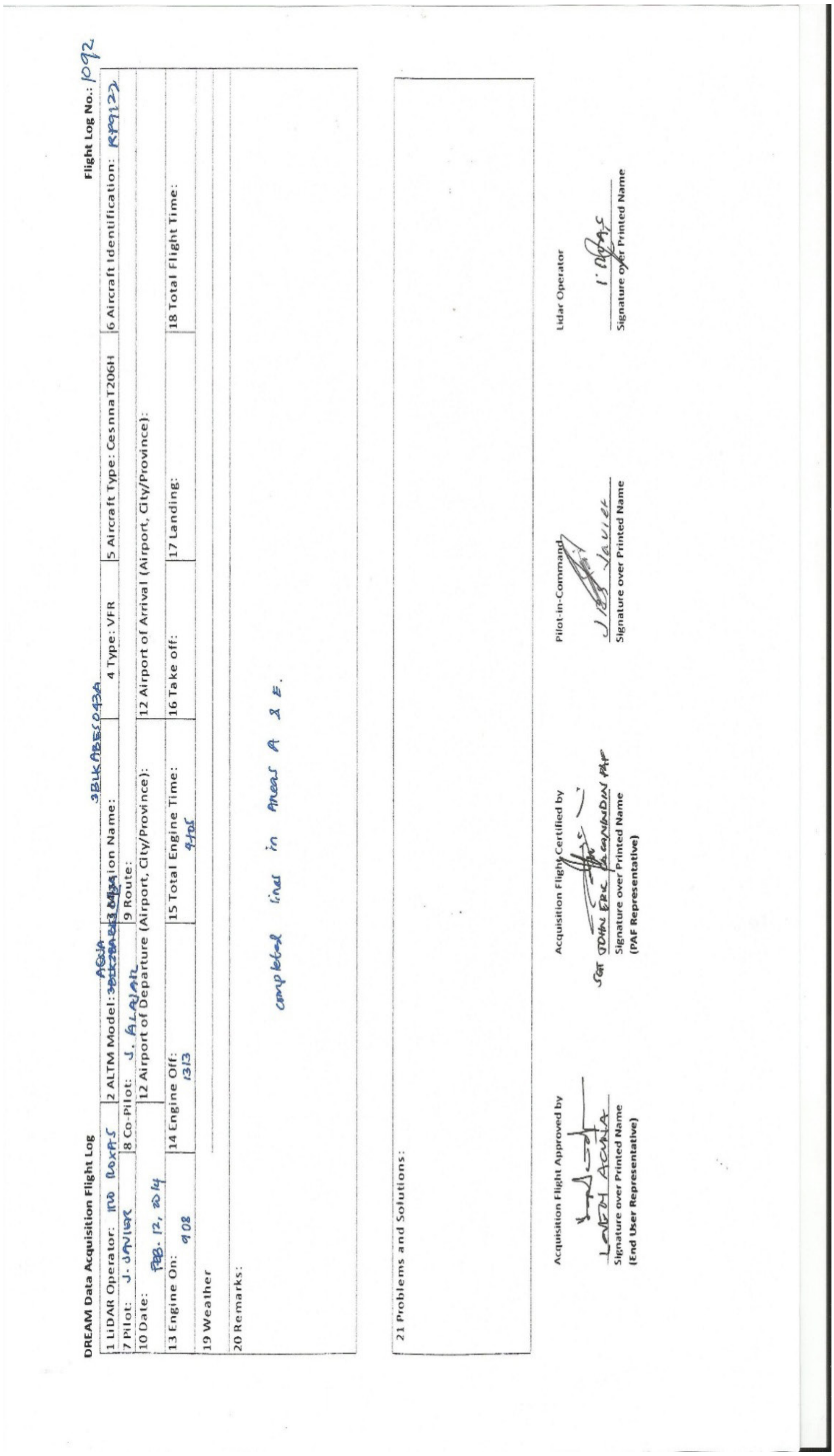
1 LiDAR Operator: I RO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK28DSE034A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J ALAJAR	8 Co-Pilot: J JAVIER	9 Route:			
10 Date: Feb 4, 14	12 Airport of Departure (Airport, City/Province): Collapan		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1723	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 3BLK 29 D					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN ERIC CAGANDAHAN PAF	J J ALAJAR	I ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1070A

4. Flight Log for 1092A



DREAM Data Acquisition Flight Log — Flight Log No.: 1092

1 LiDAR Operator: I. Roxas	2 ALTM Model: Aqua	3 Mission Name: 3BLKABESO43A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. Javier	8 Co-Pilot: J. Alajar	9 Route:			
10 Date: Feb. 12, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 908	14 Engine Off: 1313	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

completed lines in areas A & E.

21 Problems and Solutions:

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

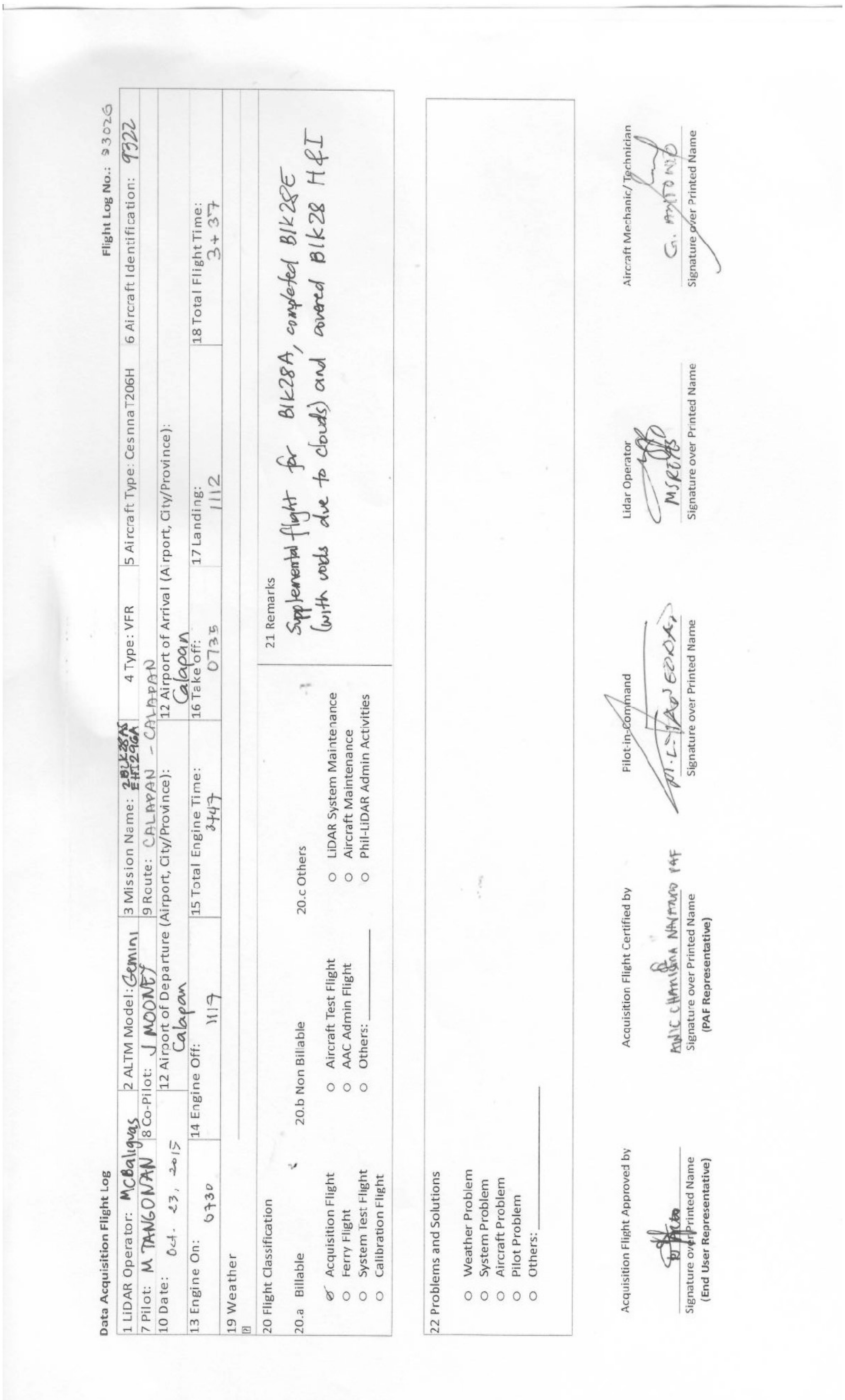
Acquisition Flight Certified by: SGT John Eric Bacanindin PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: I. Roxas — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1092A

5. Flight Log for 8302G


Data Acquisition Flight Log — Flight Log No.: 8302G

1 LiDAR Operator: MCBalguas	2 ALTM Model: Gemini	3 Mission Name: 2BLK28AS EHI296A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct. 23, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0730	14 Engine Off: 1117	15 Total Engine Time: 3+47	16 Take off: 0735	17 Landing: 1112	18 Total Flight Time: 3+37
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

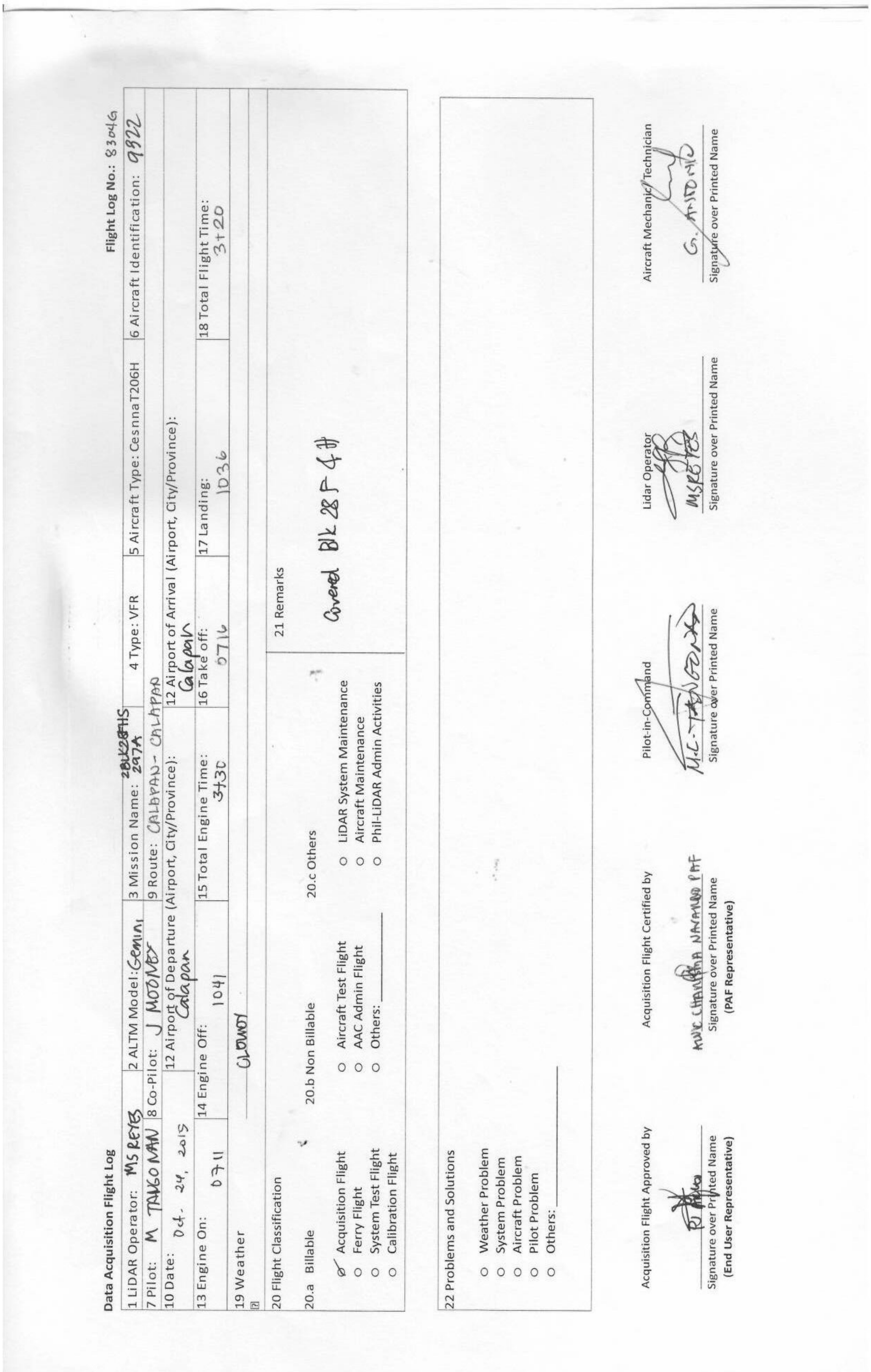
Supplemental flight for BLK28A, completed BLK28E (with voids due to clouds) and covered BLK28 H&I

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

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

Figure A-6.5. Flight Log for Mission 8302G

6. Flight Log for 8304G



Data Acquisition Flight Log

Flight Log No.: 8304G

1 LiDAR Operator: MS REYES	2 ALTM Model: Gemini	3 Mission Name: 2BLK28FHS 297A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct. 24, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0711	14 Engine Off: 1041	15 Total Engine Time: 3+30	16 Take off: 0716	17 Landing: 1036	18 Total Flight Time: 3+20
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

Covered BLK 28F 4H

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
RJ Abuyo	MAJ CHANDRA NAVARRO PAF	M.C. TANGONAN	MS REYES	G. ARISTOTELES
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.6. Flight Log for Mission 8304G

7. Flight Log for 8306G

Data Acquisition Flight Log

Flight Log No.: 8306G

1 LiDAR Operator: MCE BALIGUAS / PJ ARCEO	2 ALTM Model: Gemini	3 Mission Name: 2CALIBBLK28FSGS298A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: Calapan - Calapan			
10 Date: Oct. 25, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0746	14 Engine Off: 1127	15 Total Engine Time: 3+41	16 Take off: 0751	17 Landing: 1122	18 Total Flight Time: 3+31
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

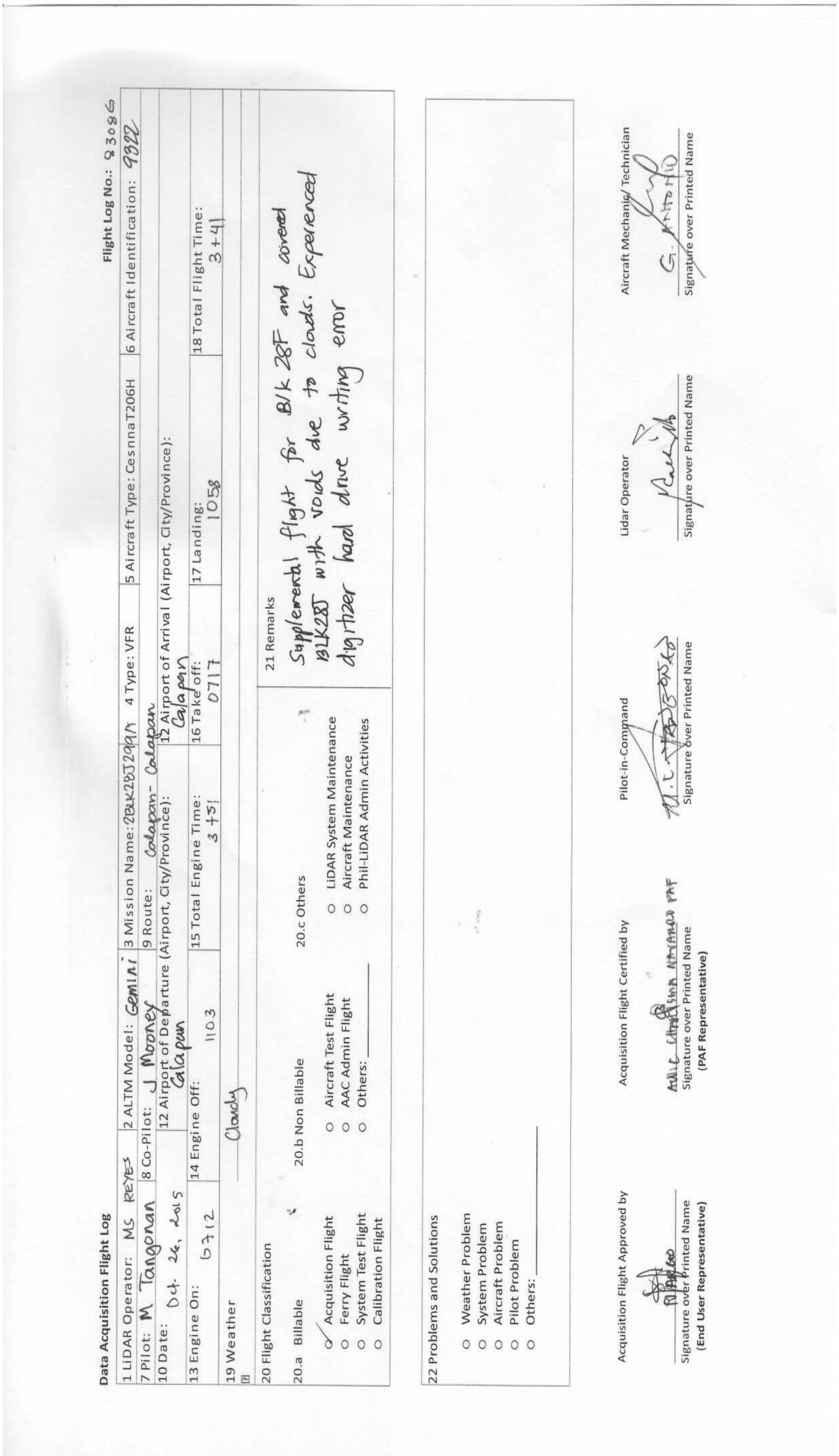
LMS Calib over Piramalayan. Completed BlK28F and covered 3 lines of BlK28G

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
PJ ARCEO	ANNIE CHRISTINA NAVARRO PAF	M. L. TANGONAN		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

Figure A-6.7. Flight Log for Mission 8306G

8. Flight Log for 8308G


Data Acquisition Flight Log

Flight Log No.: 8308G

1 LiDAR Operator: MS Reyes	2 ALTM Model: Gemini	3 Mission Name: 2BLK28J299A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: M Tangonan	8 Co-Pilot: J Mooney	9 Route: Calapan-Calapan			
10 Date: Oct. 26, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0712	14 Engine Off: 1103	15 Total Engine Time: 3+51	16 Take off: 0717	17 Landing: 1058	18 Total Flight Time: 3+41
19 Weather	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

Supplemental flight for Blk 28F and covered BLK28J with voids due to clouds. Experienced digitizer hard drive writing error

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

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

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

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: G. [illegible] Signature over Printed Name

Figure A-6.8. Flight Log for Mission 8308G

Annex 7. Flight status reports

BANSUD FLOODPLAIN

February 2-15, 2014; October 23-26, 2014

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1056A	BLK28C	3BLK28C034A	PAULINE ARCEO	FEB 3, 2014	Finished lower half of BLK28C
1066A	BLOCK 28D	3BLK28DS036A	PAULINE ARCEO	FEB 5, 2014	Survey 8 lines BLK28D
1070A	BLOCK 28D & 28E	3BLK28DSE037A	IRO ROXAS	FEB 6, 2014	Finished Block 28D and some lines of Block 28E
1092A	BLK 28A,B,E	3BLK28ABES043A	IRO ROXAS	FEB 12, 2014	Mission Complete
8302G	BLK28EHI	2BLK28ASEHI296A	CATH BALIGUAS	OCT 23, 2014	Supplemental flight for BLK 28A, completed BLK28E and covered BLK 28 H&I
8304G	BLK28FH	2BLK28FHS297A	CATH BALIGUAS, SHANE REYES	OCT 24, 2014	Covered BLK 28 F&H
8306G	BLK28F	2CALIBBLK28FSGS298A	PAU ARCEO, CATH BALIGUAS	OCT 25, 2014	LMS Calib over Pinamalayan; completed BLK 28F and covered BLK 28G
8308G	BLK28J	2BLK28J299A	MS Reyes	OCT 26, 2014	Supplemental flight for BLK28F and covered BLK28J with voids due to clouds. Experienced Digitizer hard drive writing error.

SWATH PER FLIGHT MISSION

FLIGHT LOG NO.	1056A	Scan Freq: 45 kHz
AREA:	BLOCK 28C	Scan Angle: 18 deg
MISSION NAME:	3BLK28C034A	Alt: 600 m

Figure A-7.1. Swath for Flight No. 1056A

FLIGHT LOG NO.	1066A	Scan Freq: 45 kHz
AREA:	BLOCK 28D	Scan Angle: 18 deg
MISSION NAME:	3BLK28DS036A	Alt: 600 m

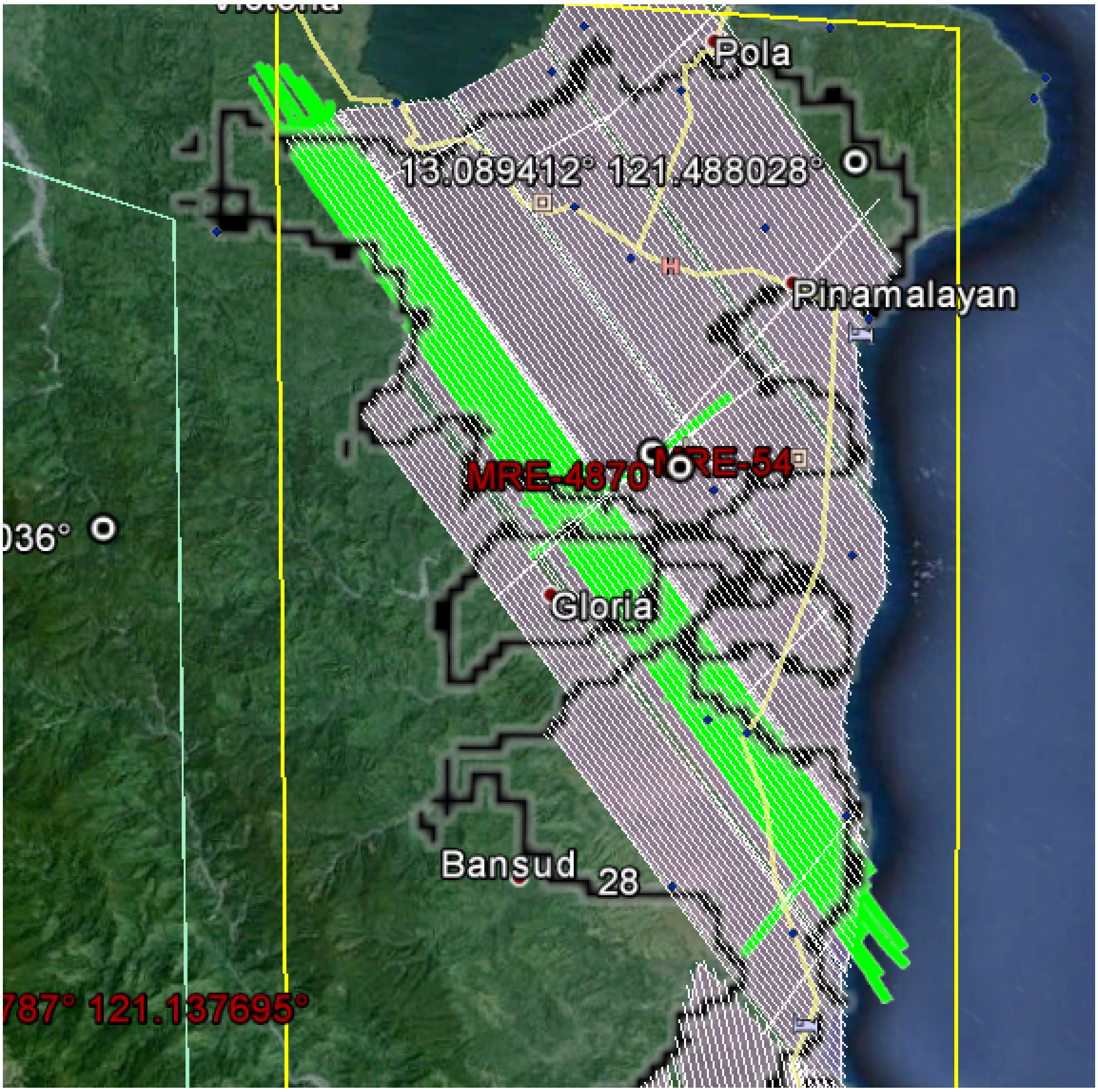


Figure A-7.2. Swath for Flight No. 1066A

FLIGHT LOG NO.	1070A	Scan Freq: 45 kHz
AREA:	BLOCK 28D & BLOCK 28E	Scan Angle: 18 deg
MISSION NAME:	3BLK28DSE037A	Alt: 600 m

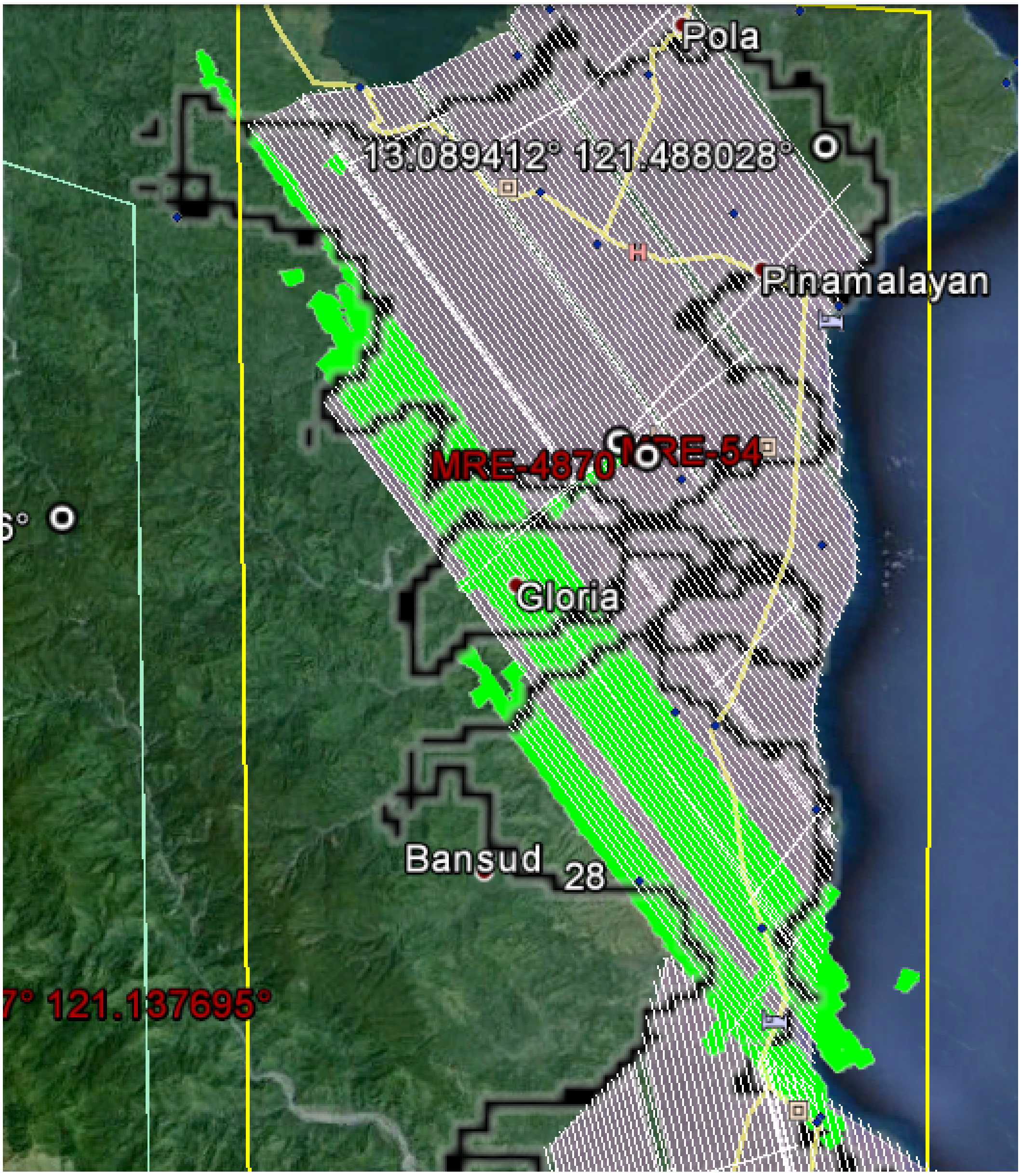


Figure A-7.3. Swath for Flight No. 1070A

FLIGHT LOG NO.	1092A	Scan Freq: 45 kHz
AREA:	BLOCK 28A, B, E	Scan Angle: 18 deg
MISSION NAME:	3BLK28ABES43A	Alt: 600 m

Figure A-7.4. Swath for Flight No. 1092A

FLIGHT LOG NO.	8302G	Scan Freq: 50 kHz
AREA:	BLOCK 28A, 28E, 28H & 28I	Scan Angle: 15 deg
MISSION NAME:	2BLK28ASEHI296A	Alt: 1200 m

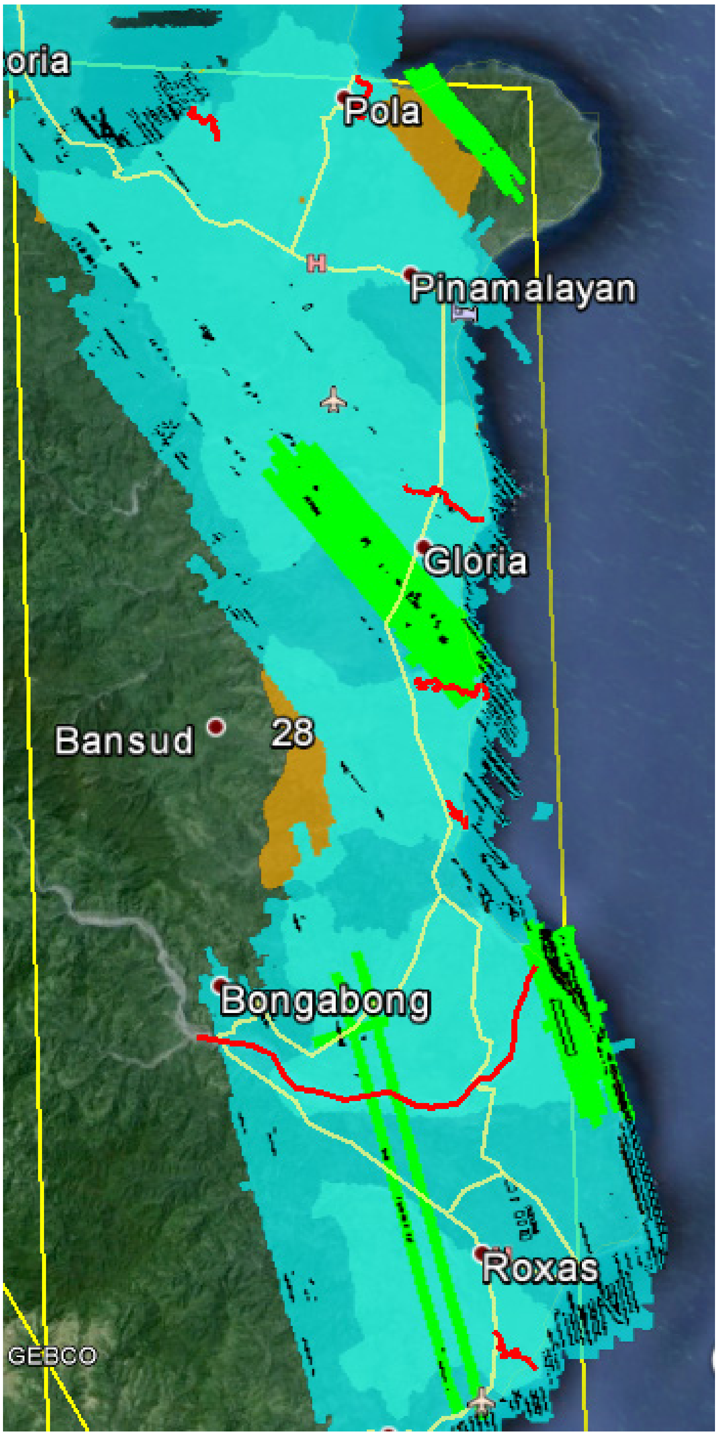


Figure A-7.5. Swath for Flight No. 8302G

FLIGHT LOG NO.	8304G	Scan Freq: 50 kHz
AREA:	BLOCK 28F & 28H	Scan Angle: 15 deg
MISSION NAME:	2BLK28FHS297A	Alt: 1200 m

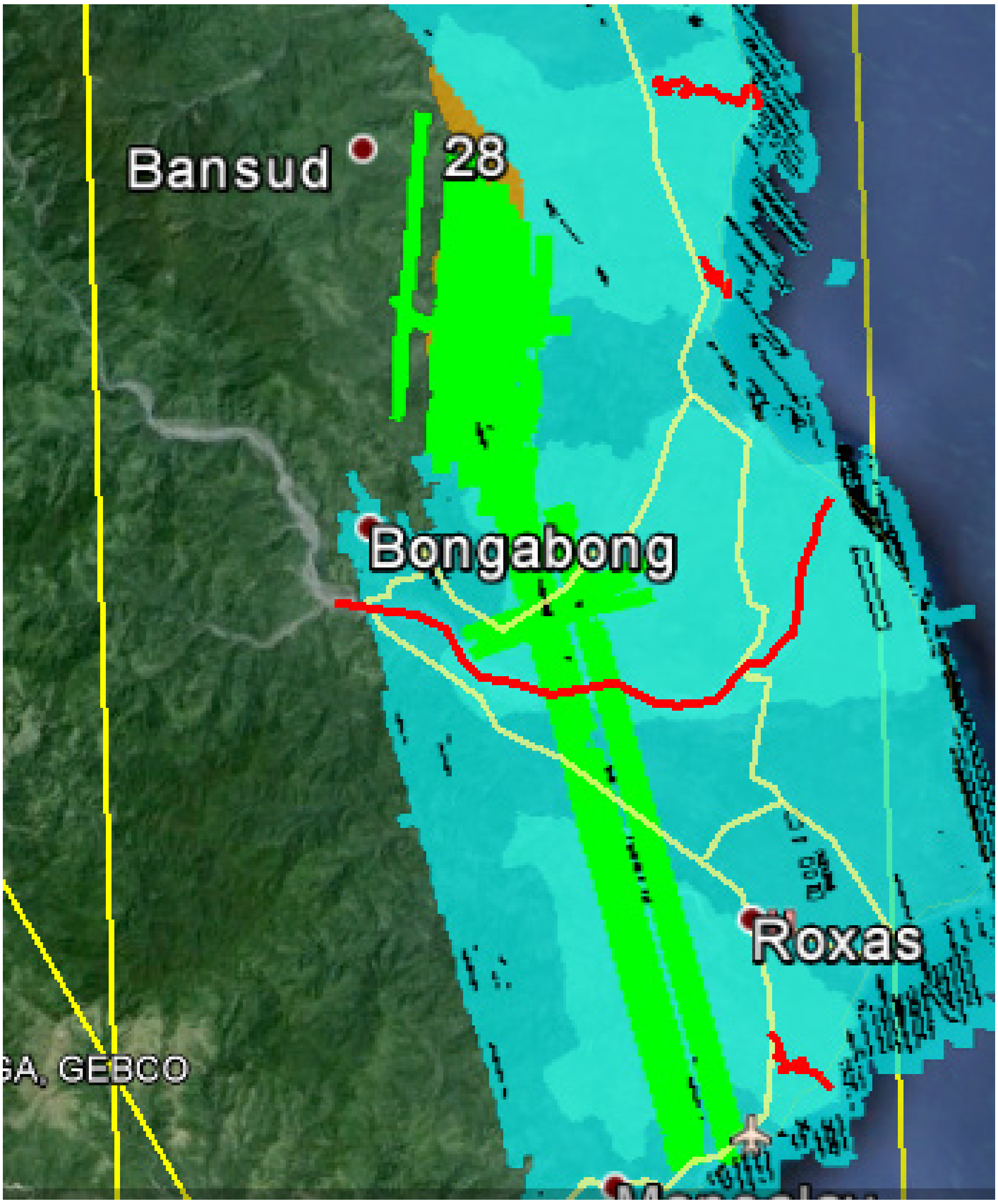


Figure A-7.6. Swath for Flight No. 8304G

FLIGHT LOG NO.	8306G	Scan Freq: 50 kHz
AREA:	BLOCK 28F & 28G	Scan Angle: 20 deg
MISSION NAME:	2CALIBBLK28FSGS298A	Alt: 1000 m

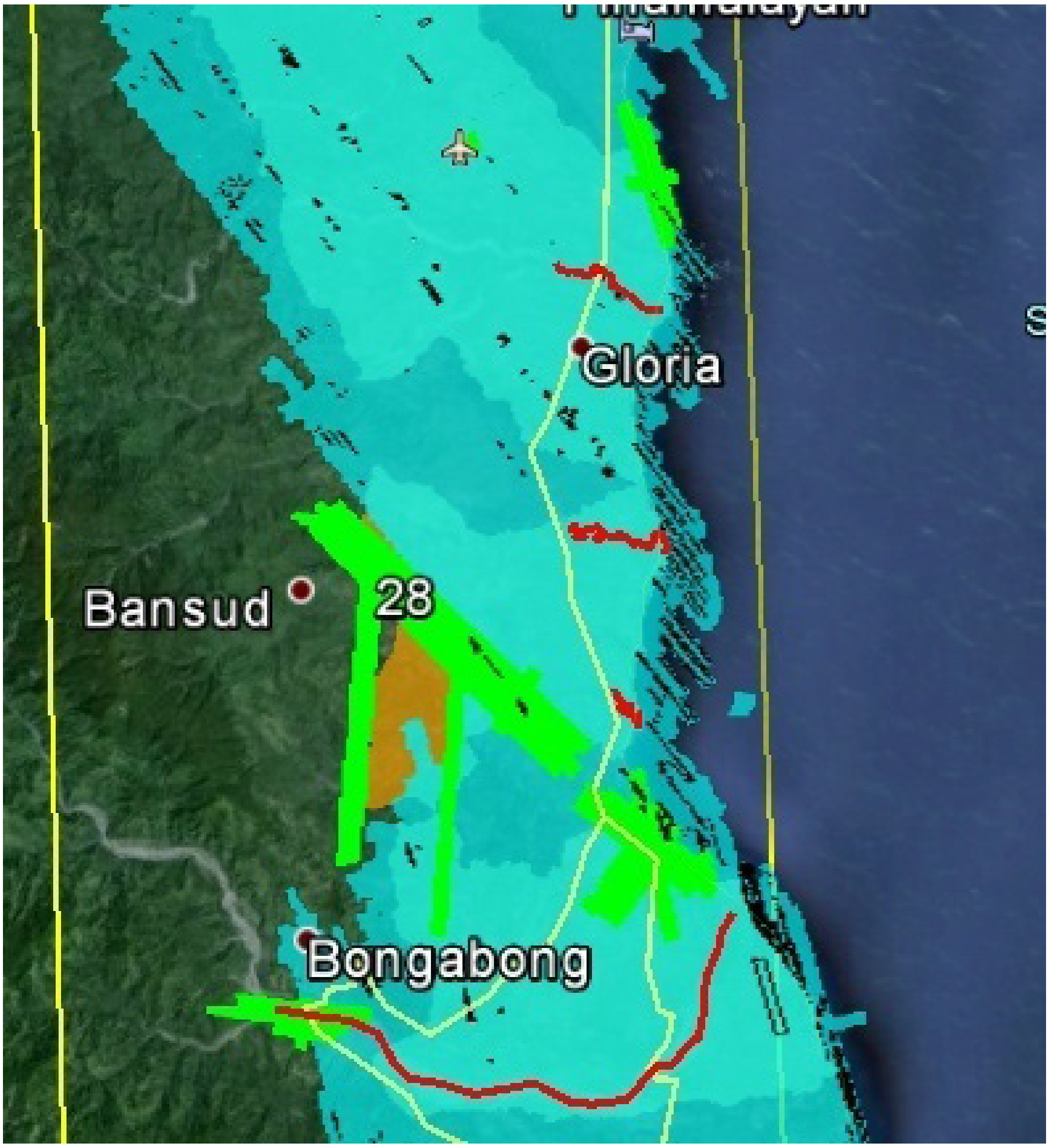


Figure A-7.7. Swath for Flight No. 8306G

FLIGHT NO.:	8308G	
AREA:	Oriental Mindoro	
MISSION NAME:	2BLK28J299A	
ALT: 1000 m	SCAN FREQ: 50	SCAN ANGLE: 18

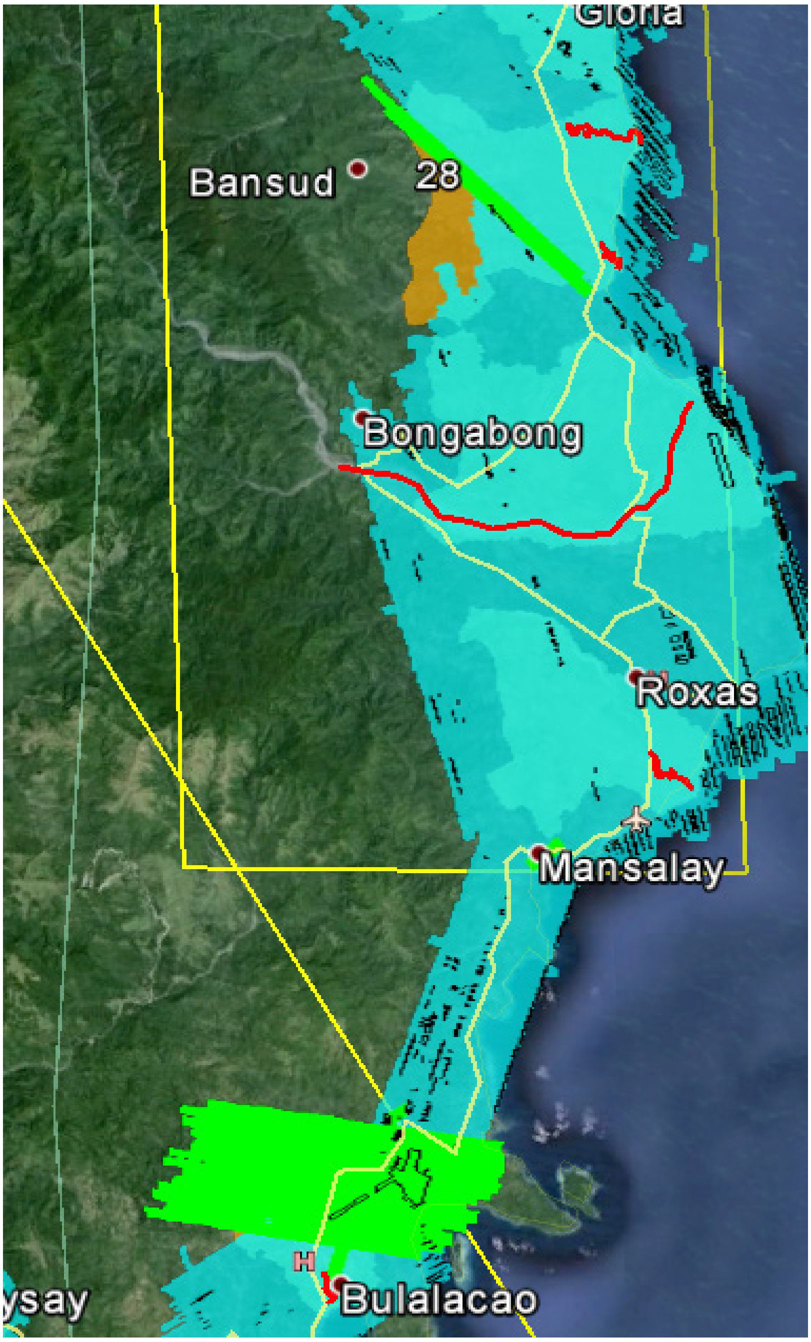


Figure A-7.8. Swath for Flight No. 8308G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk28C

Flight Area	Oriental Mindoro
Mission Name	**Blk 28C**
Inclusive Flights	1056A
Range data size	12.2 GB
POS	210 MB
Image	77.2 GB
Base data size	6.29 MB
Transfer date	February 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000367
IMU attitude correction stdev (<0.001deg)	0.011964
GPS position stdev (<0.01m)	0.0209
Minimum % overlap (>25)	65.39%
Ave point cloud density per sq.m. (>2.0)	2.77
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	257
Maximum Height	254.22 m
Minimum Height	48.61 m
Classification (# of points)	
Ground	60,654,258
Low vegetation	70,685,819
Medium vegetation	65,858,614
High vegetation	99,720,386
Building	2,215,401
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Jeffrey Delica

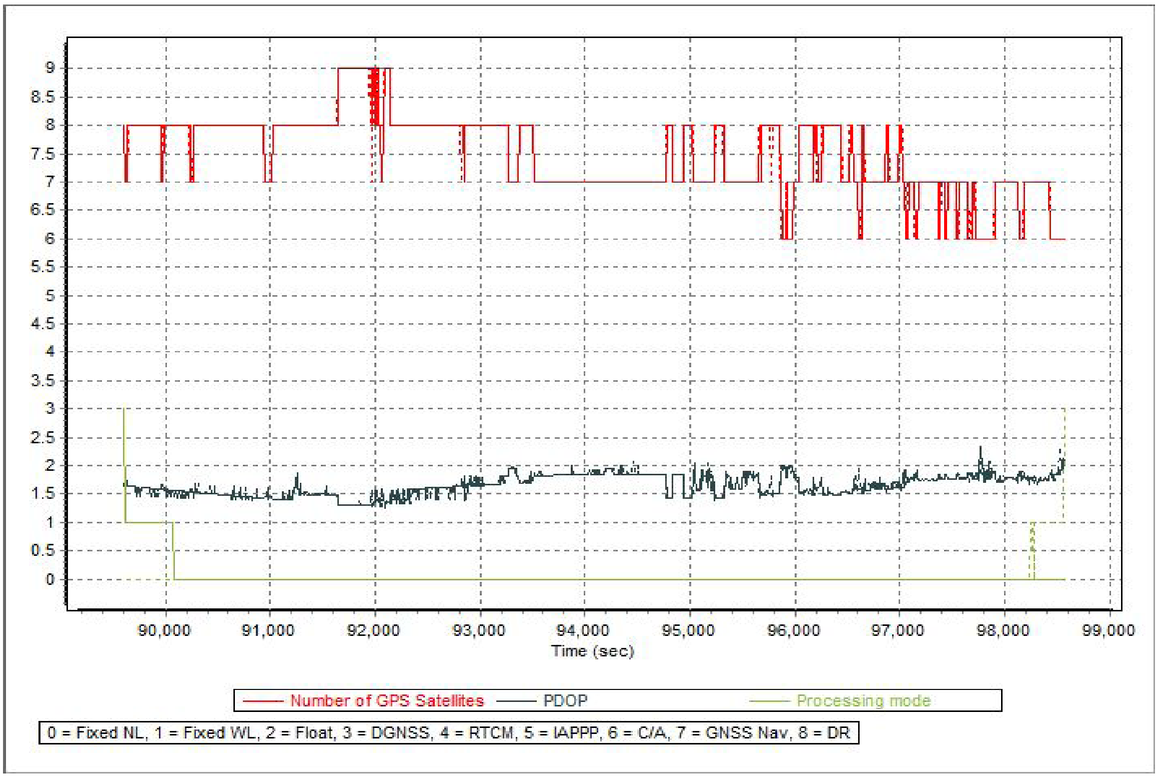


Figure A-8.1. Solution Status

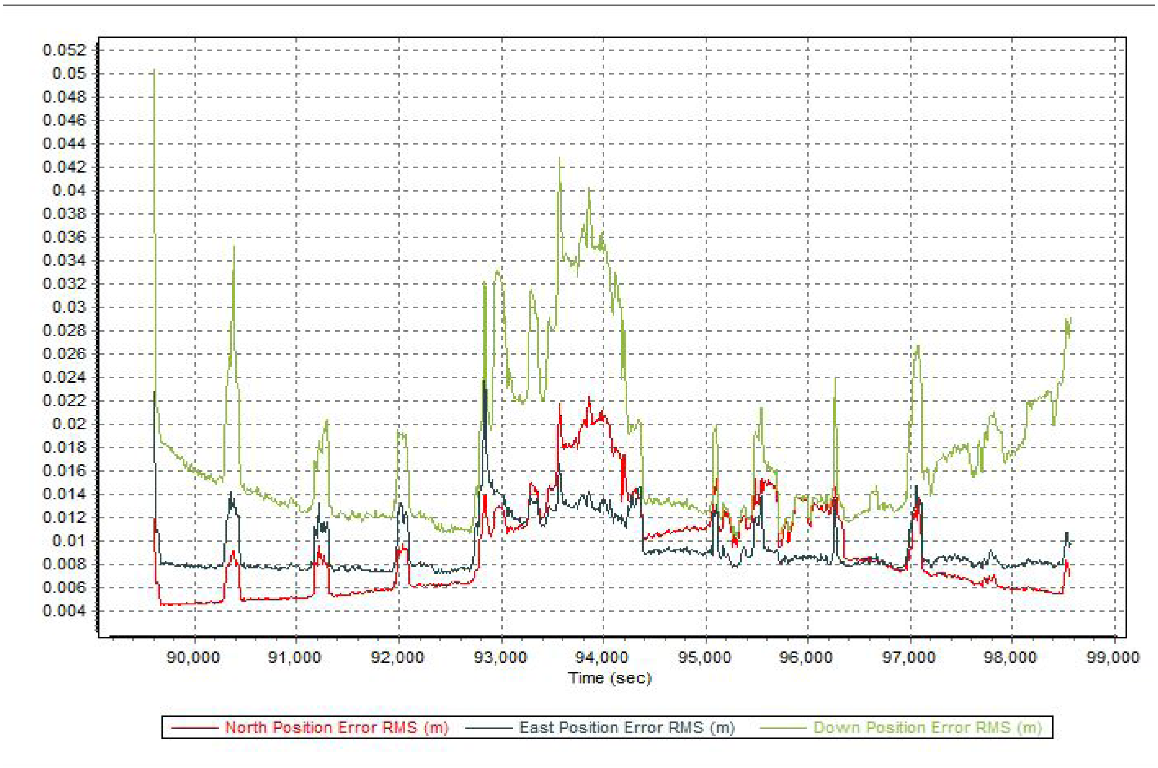


Figure A-8.2. Smoothed Performance Metrics Parameters

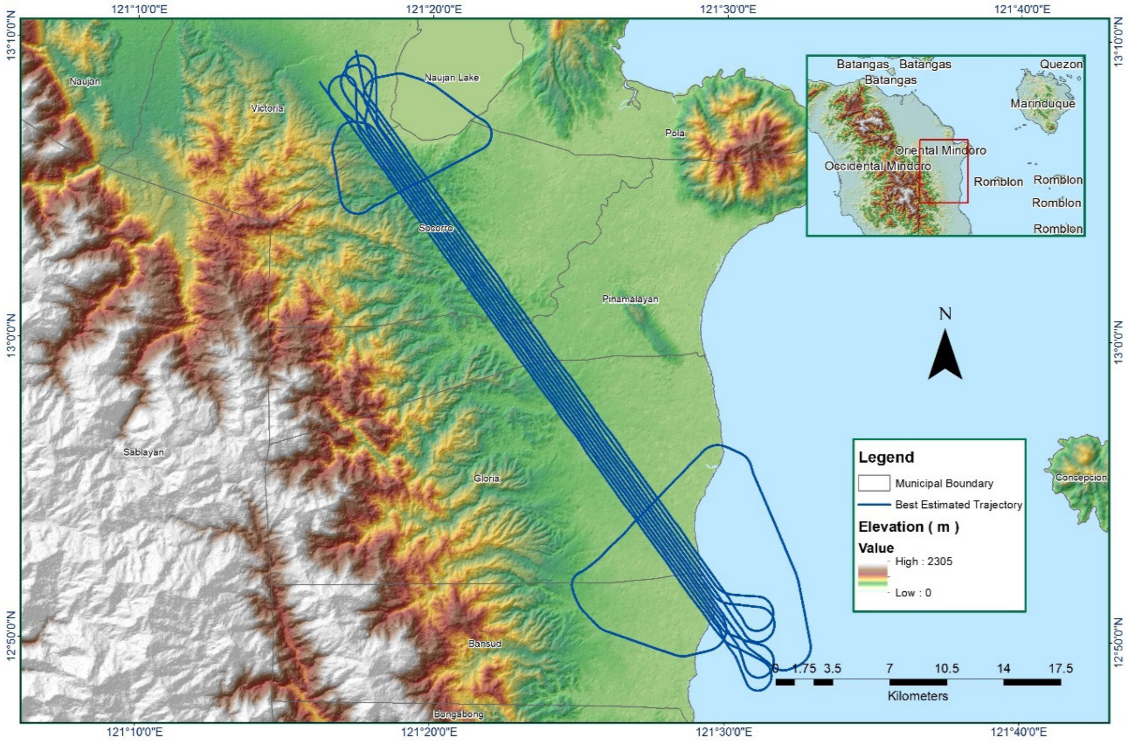


Figure A-8.3. Best Estimated Trajectory

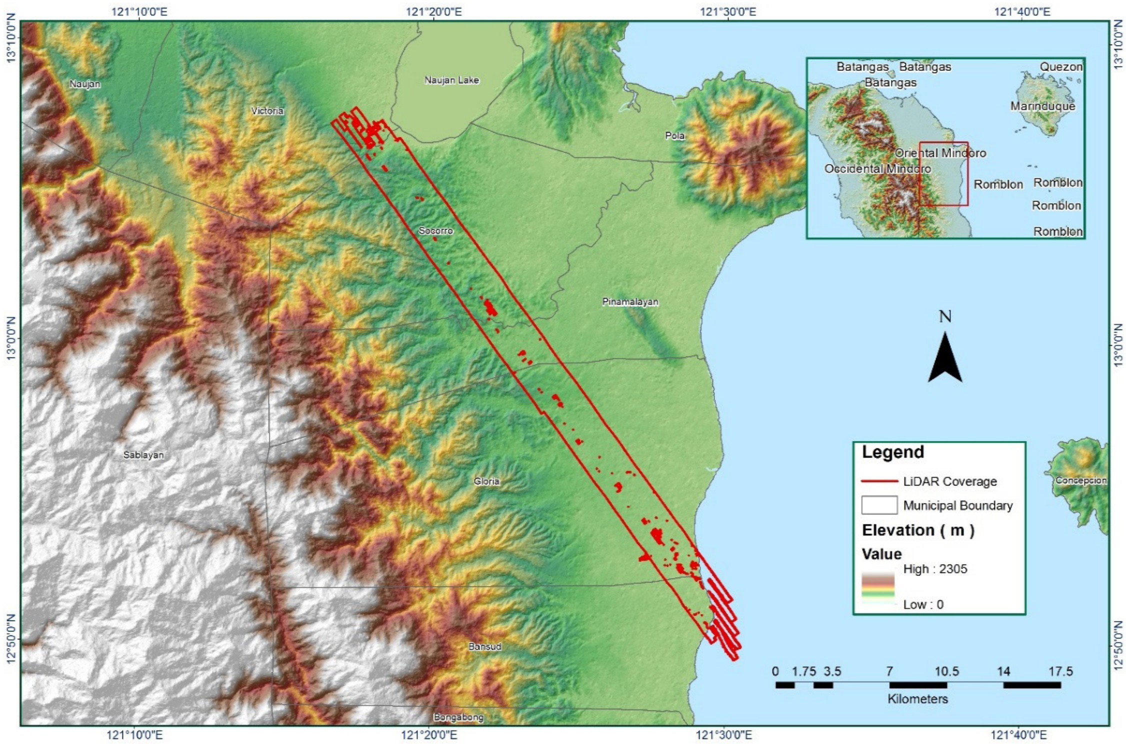


Figure A-8.4 Coverage of LiDAR data

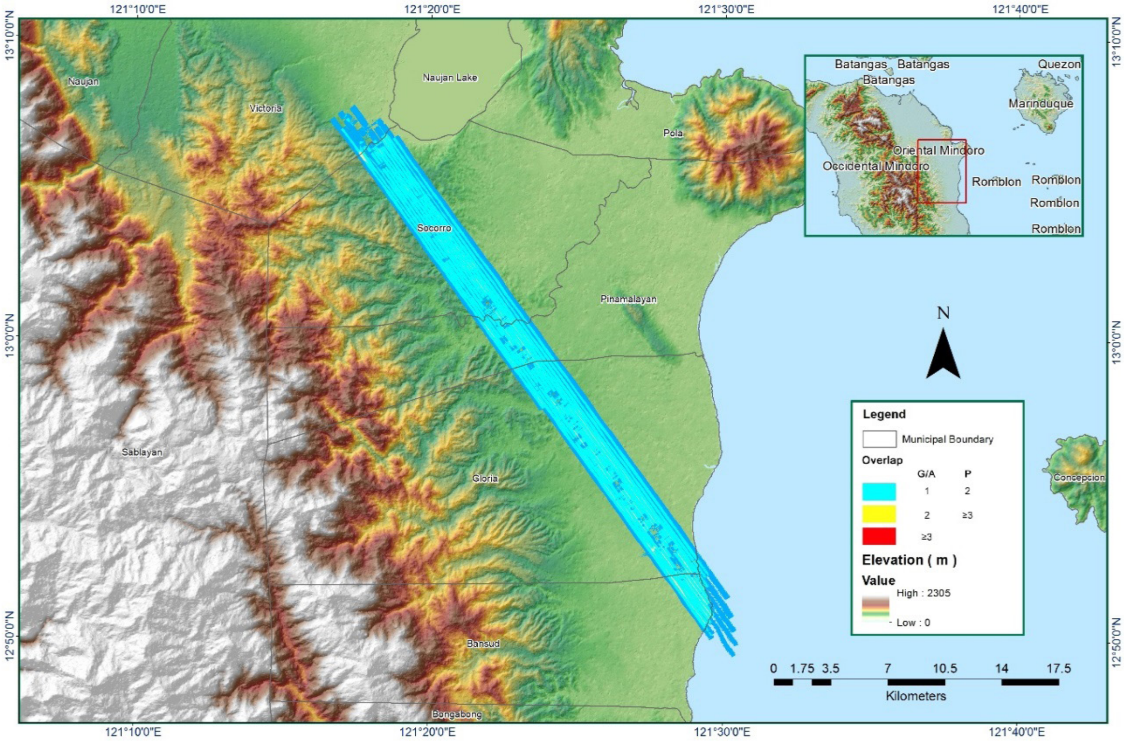


Figure A-8.5. Image of data overlap

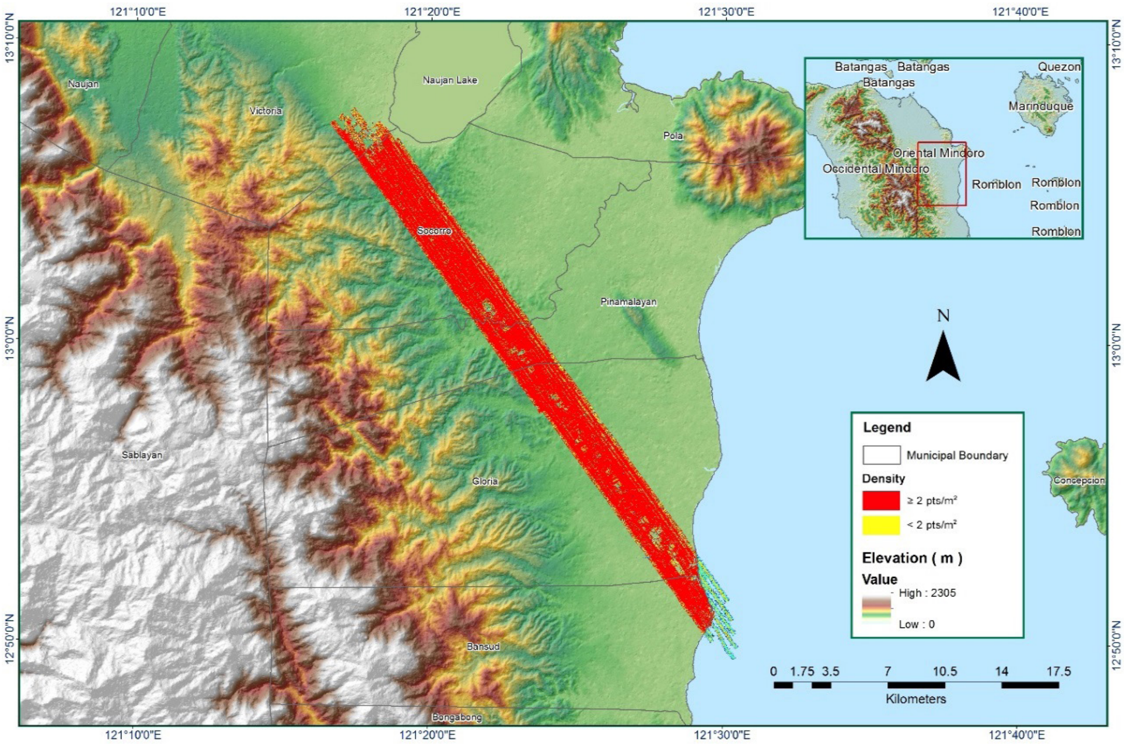


Figure A-8.6. Density map of merged LiDAR data

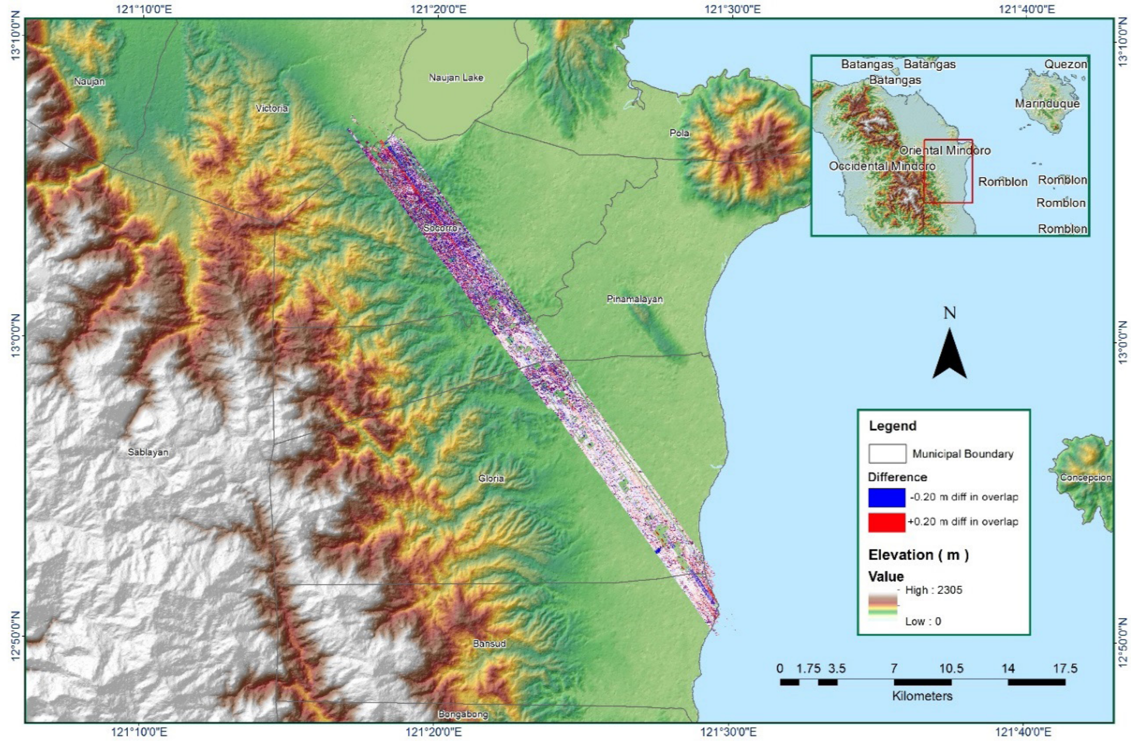


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk28C_supplement

Flight Area	Oriental Mindoro
Mission Name	**Blk28C_supplement**
Inclusive Flights	1056A
Range data size	12.2 GB
Base data size	6.29 MB
POS	210 MB
Image	77.2 GB
Transfer date	February 6,2014
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)	2.2
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000367
IMU attitude correction stdev (<0.001deg)	0.011964
GPS position stdev (<0.01m)	0.0209
Minimum % overlap (>25)	52.68%
Ave point cloud density per sq.m. (>2.0)	3.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	161
Maximum Height	236.75 m
Minimum Height	48.61 m
Classification (# of points)	
Ground	46,847,528
Low vegetation	57,381,551
Medium vegetation	53,054,311
High vegetation	75,091,227
Building	1,786,653
Ortophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Gladys Mae Apat

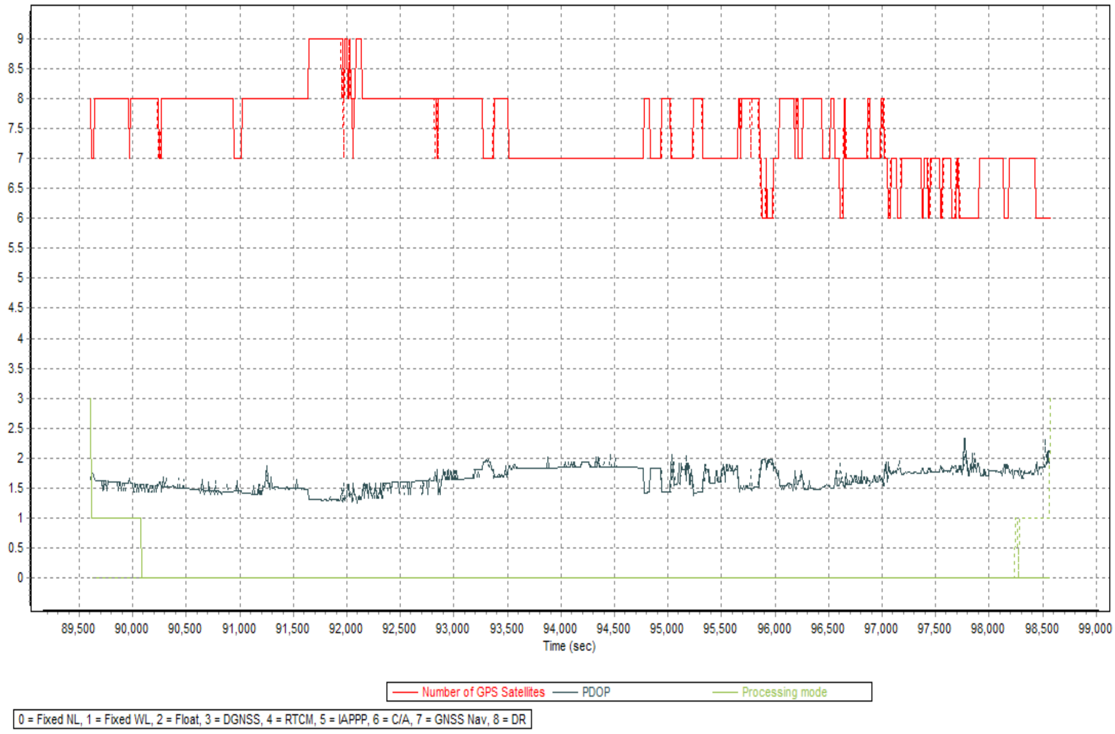


Figure A-8.8. Solution Status

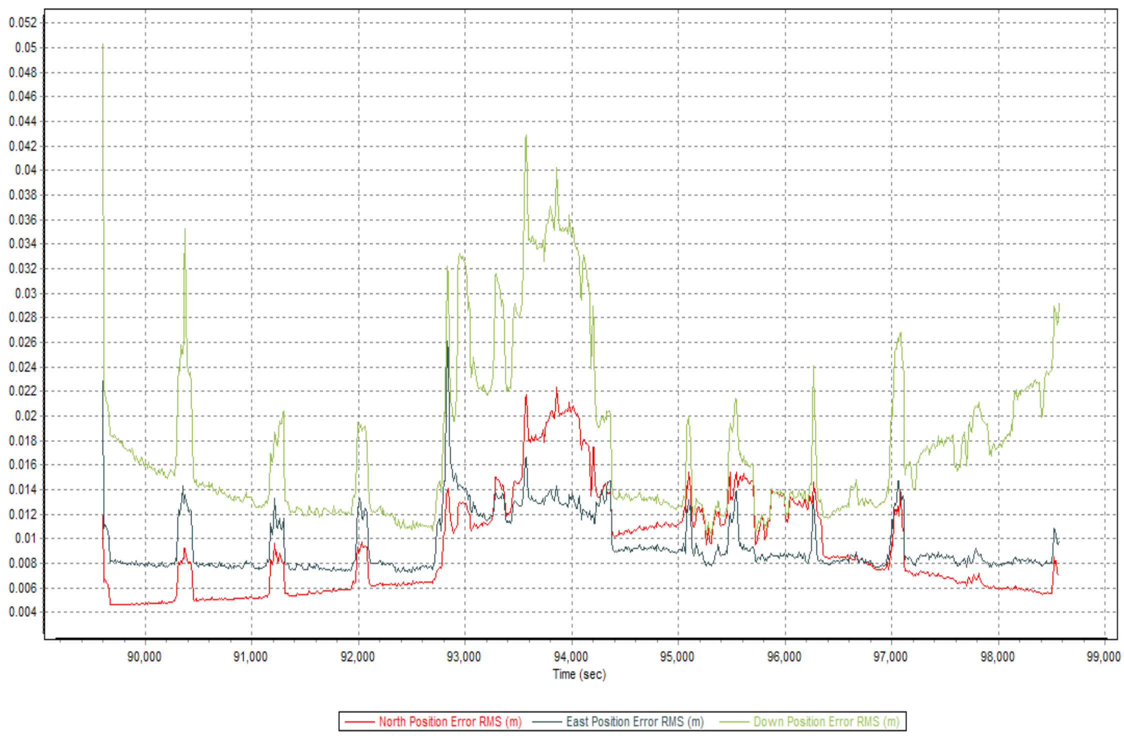


Figure A-8.9. Smoothed Performance Metrics Parameters

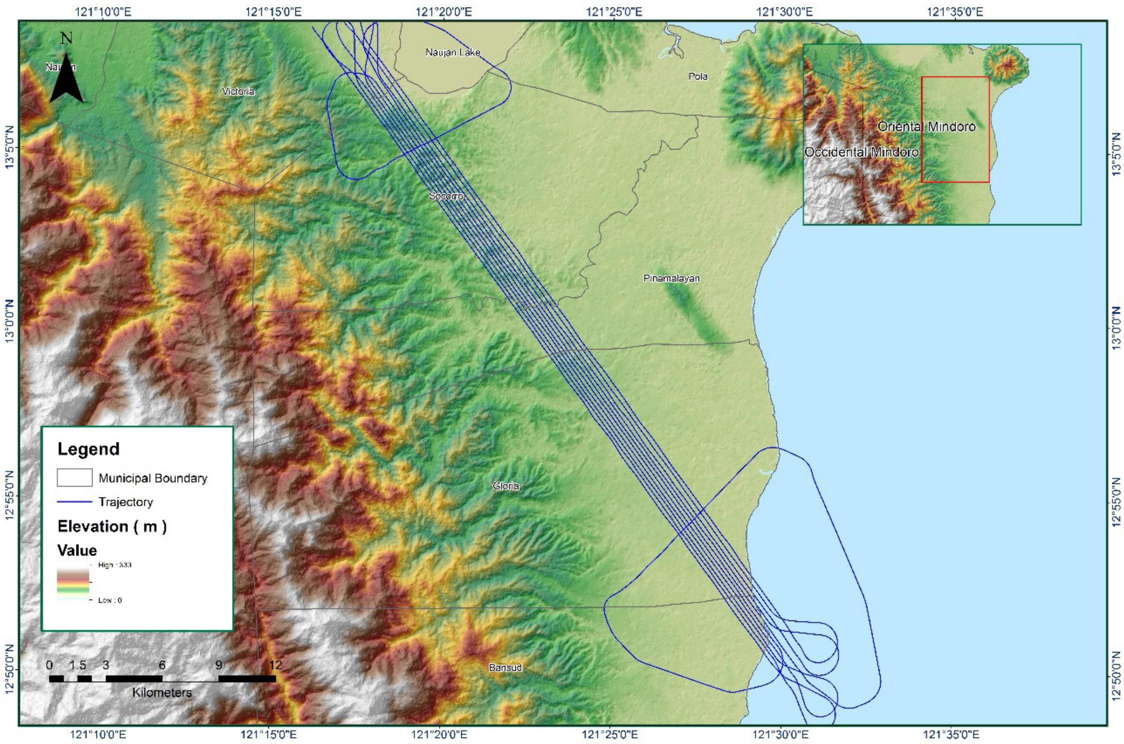


Figure A-8.10. Best Estimated Trajectory

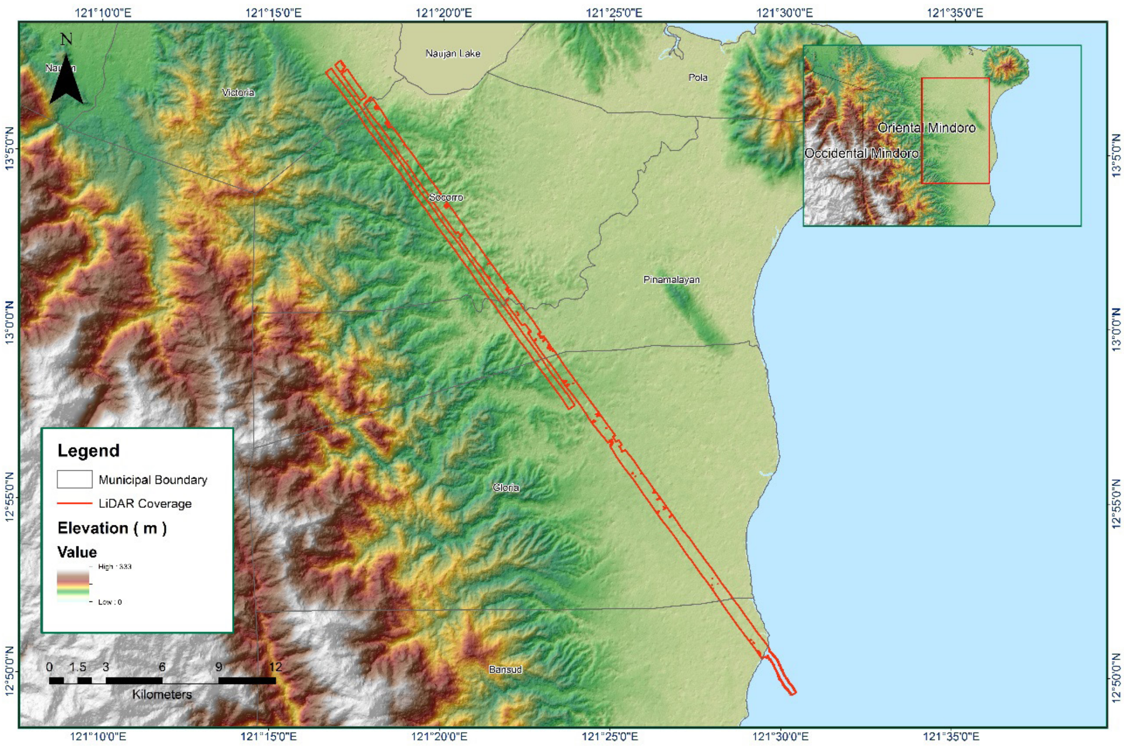


Figure A-8.11. Coverage of LiDAR data

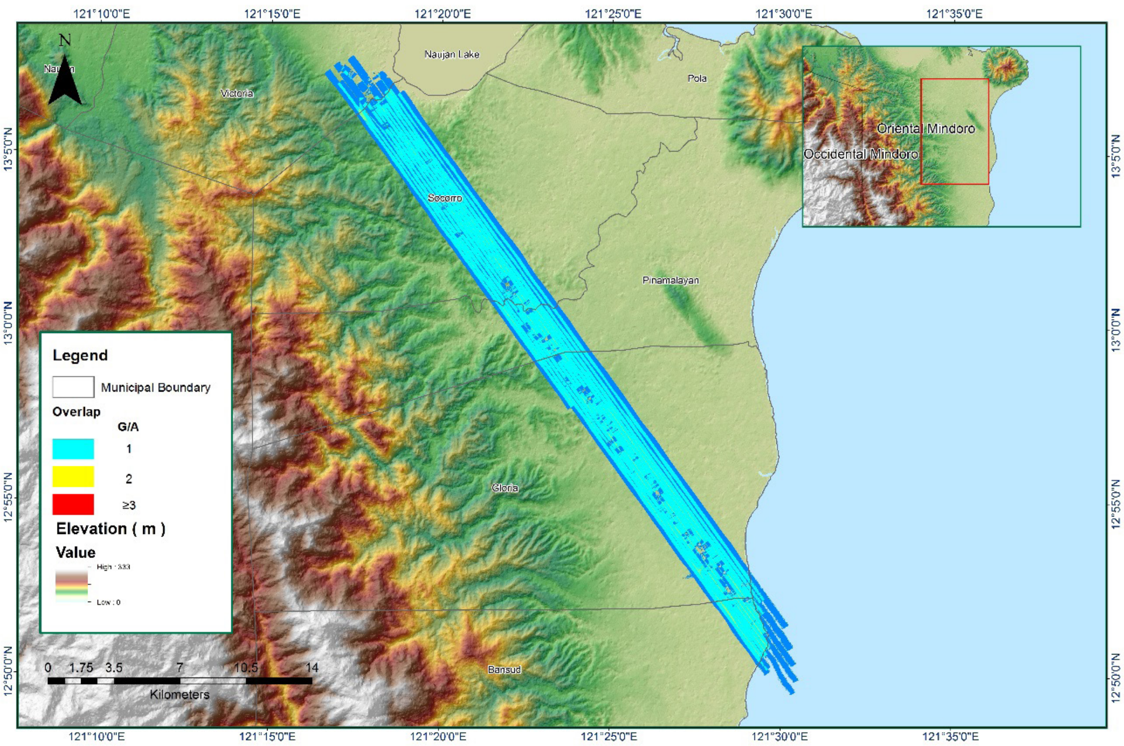


Figure A-8.12. Image of data overlap

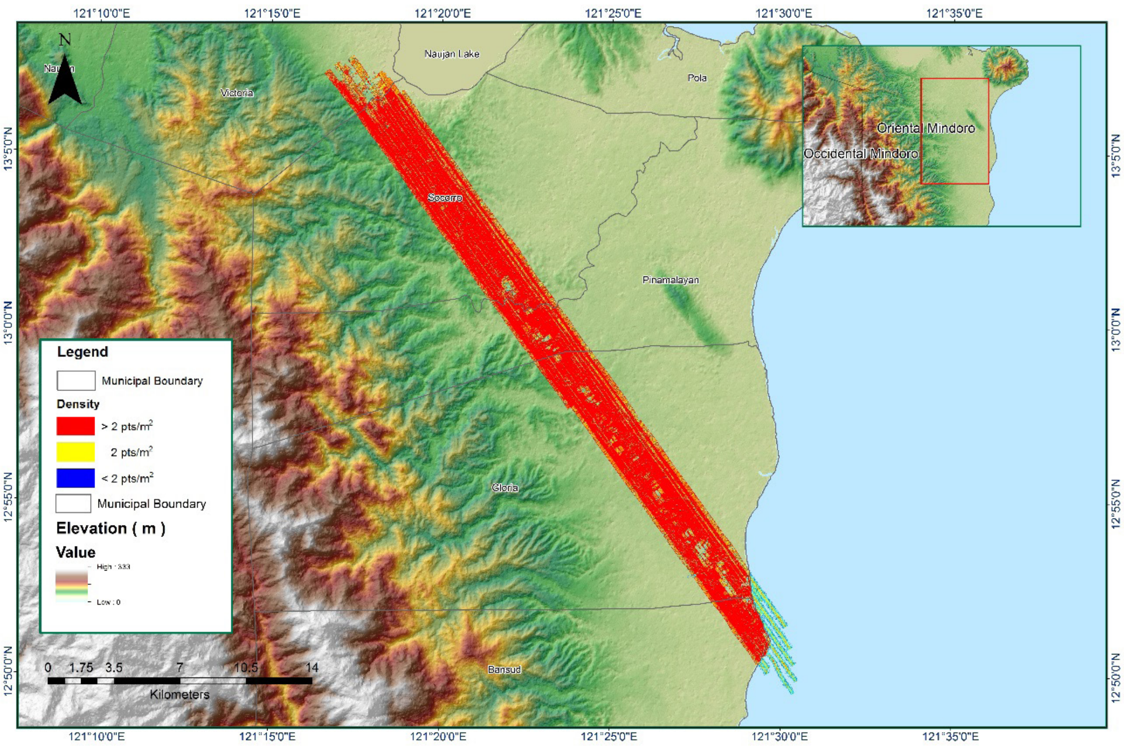


Figure A-8.13. Density map of merged LiDAR data

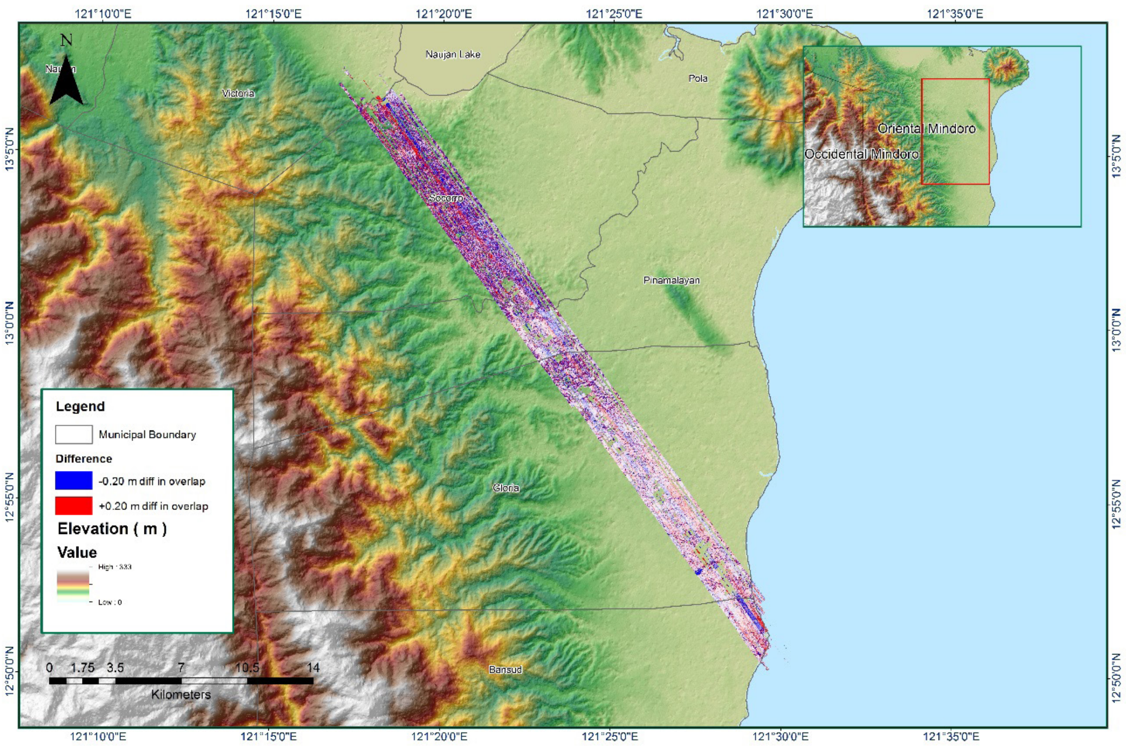


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk28D_supplement

Flight Area	Oriental Mindoro
Mission Name	**Blk28D_supplement**
Inclusive Flights	1066A
Range data size	11.7 GB
POS	203 MB
Image	73.9 GB
Base data size	14.5 MB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000424
IMU attitude correction stdev (<0.001deg)	0.000955
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	49.41%
Ave point cloud density per sq.m. (>2.0)	3.47
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	159
Maximum Height	358.99 m
Minimum Height	47.66 m
Classification (# of points)	
Ground	51,219,472
Low vegetation	61,022,435
Medium vegetation	58,444,262
High vegetation	84,379,495
Building	3,448,633
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Jeffrey Delica

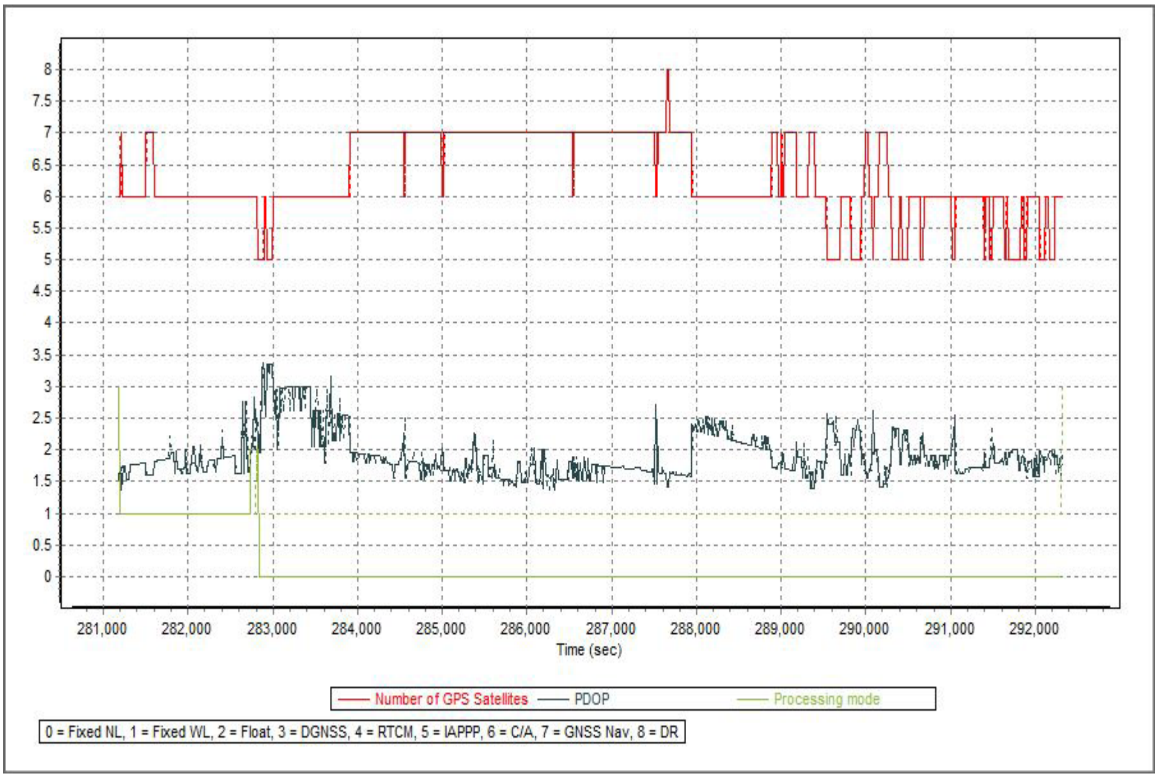


Figure A-8.15. Solution Status

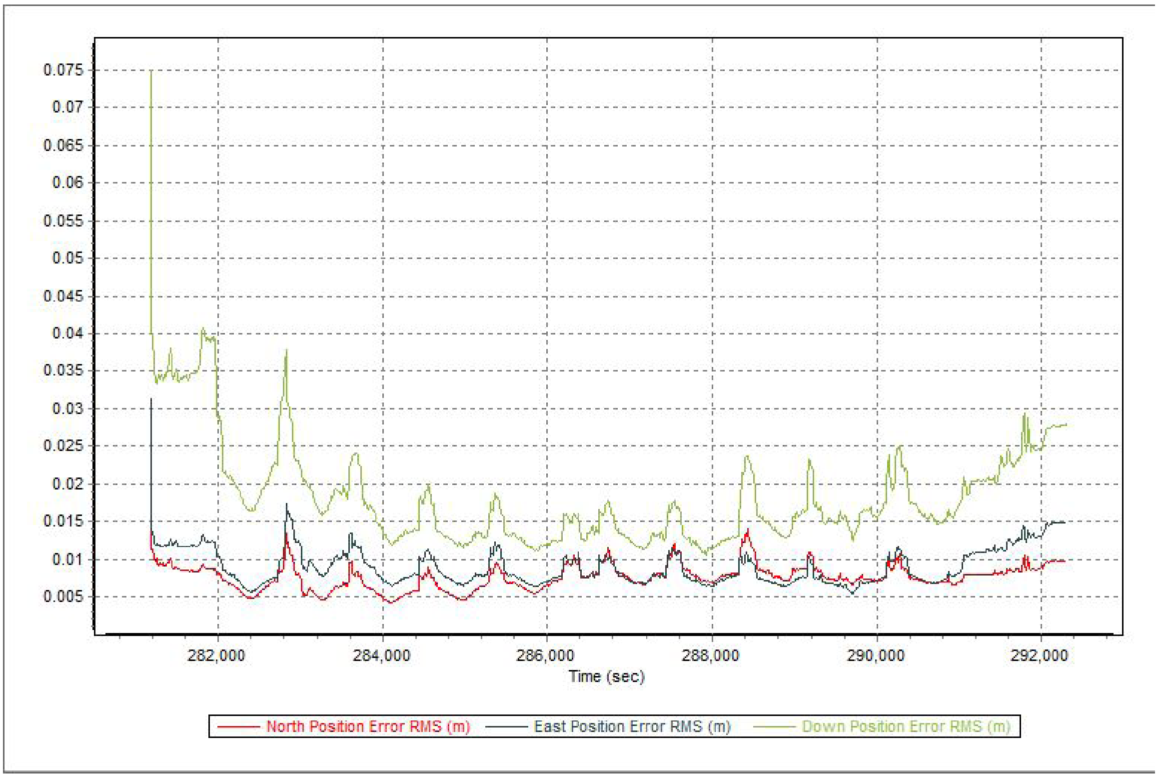


Figure A-8.16. Smoothed Performance Metrics Parameters

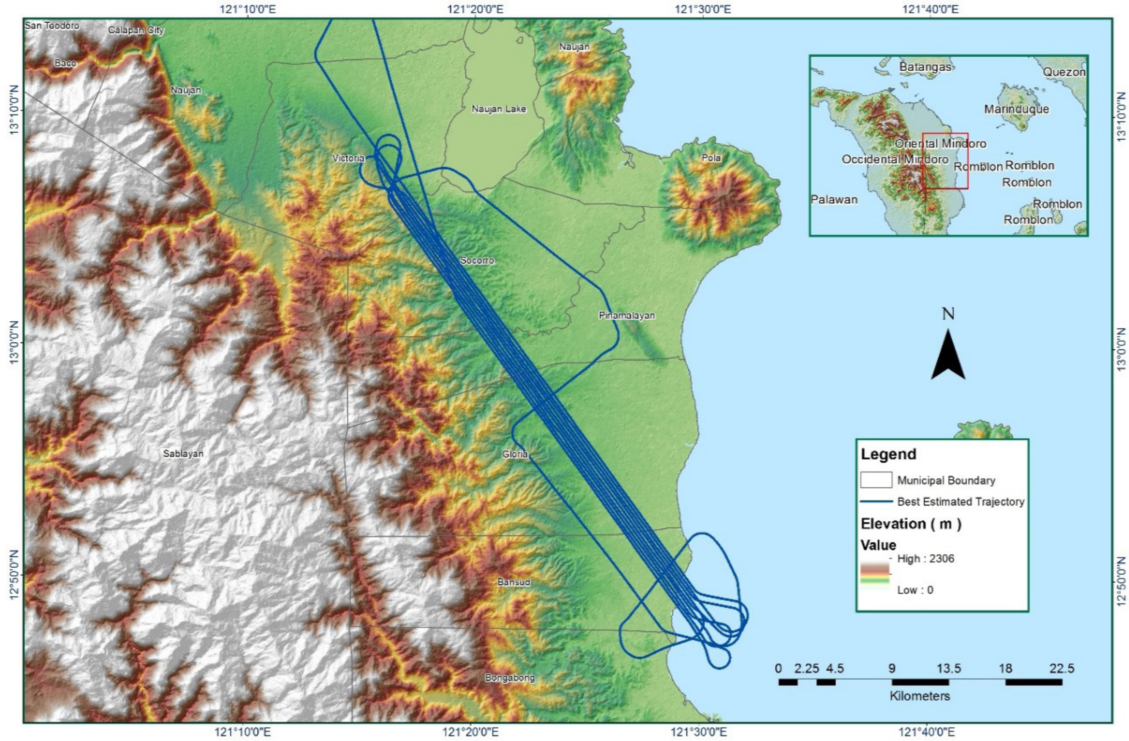


Figure A-8.17. Best Estimated Trajectory

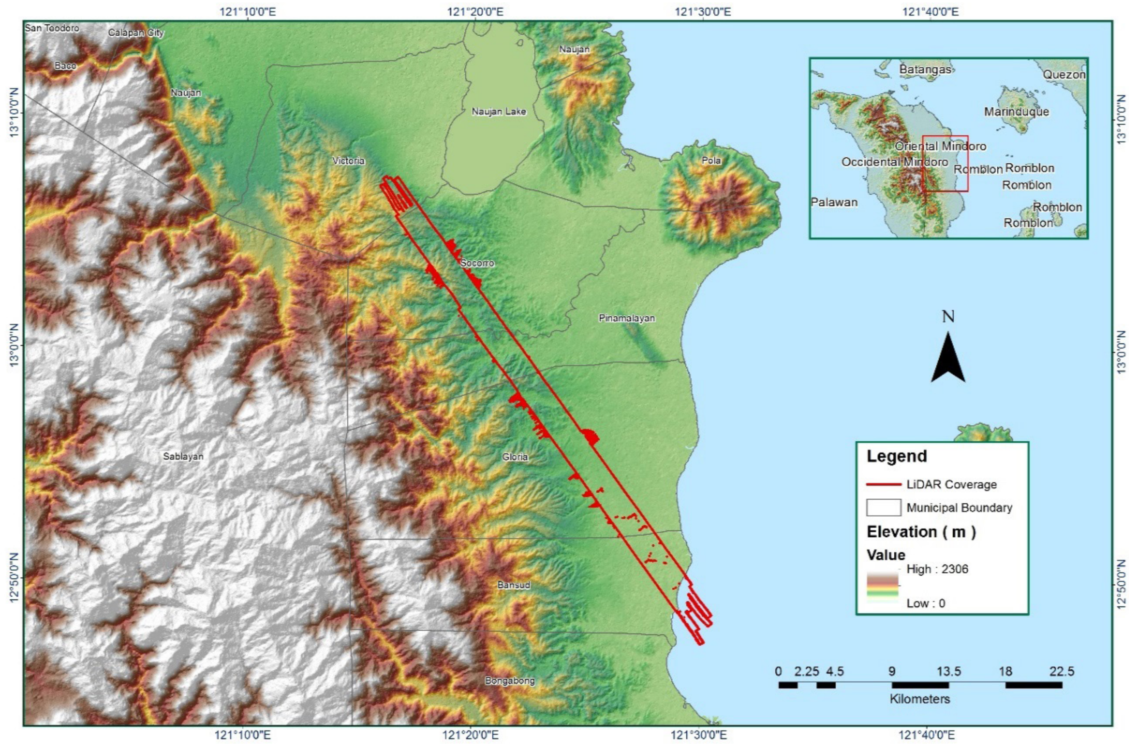


Figure A-8.18. Coverage of LiDAR data

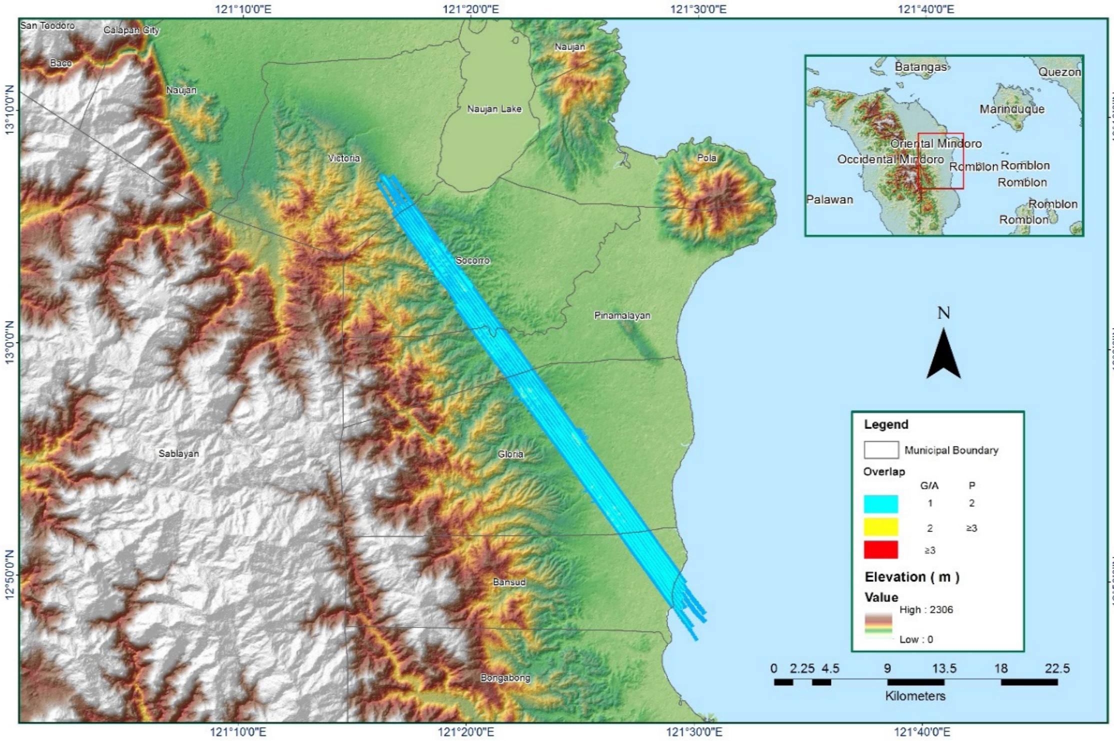


Figure A-8.19. Image of data overlap

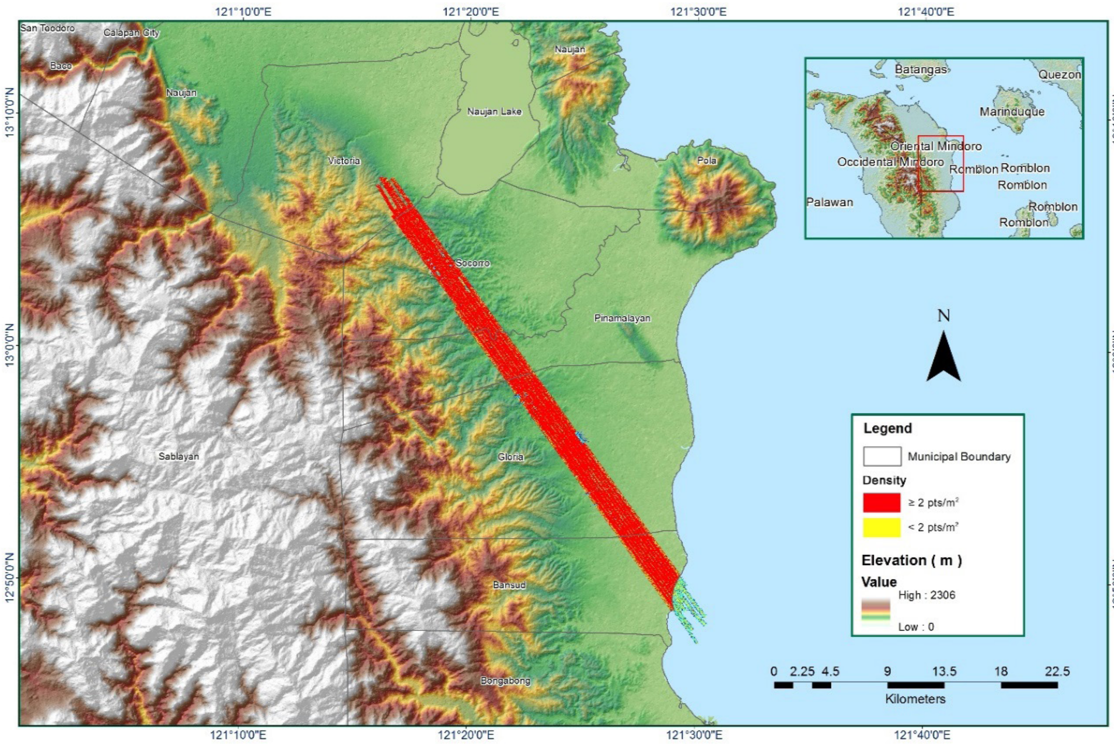


Figure A-8.20. Density map of merged LiDAR data

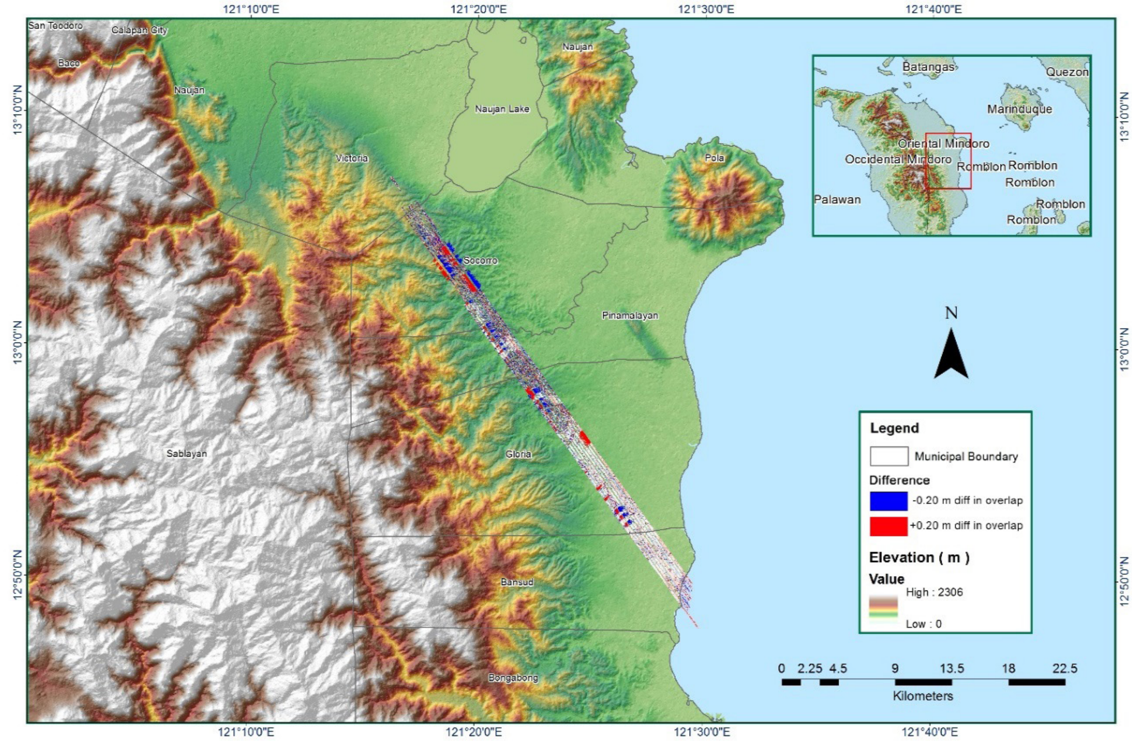


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk28E

Flight Area	Oriental Mindoro
Mission Name	**Blk28E**
Inclusive Flights	1070A
Range data size	15.9 GB
POS	270 MB
Image	104 GB
Base data size	14.9 MB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000346
IMU attitude correction stdev (<0.001deg)	0.0001166
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	38.34%
Ave point cloud density per sq.m. (>2.0)	3.35
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	202
Maximum Height	388.91 m
Minimum Height	48.91 m
Classification (# of points)	
Ground	81,447,001
Low vegetation	92,938,121
Medium vegetation	85,912,374
High vegetation	92,936,807
Building	3,360,220
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Charmaine Cruz, Engr. Elainne Lopez, Engr. John Dill Macapagal

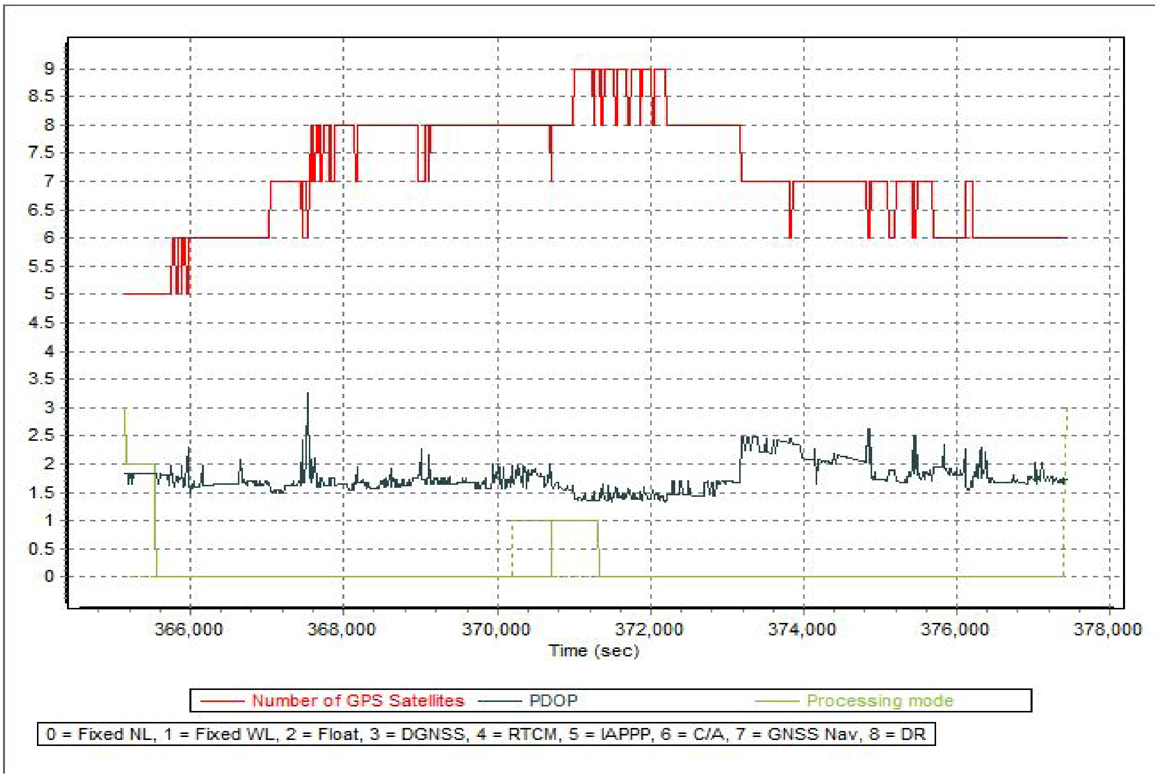


Figure A-8.22. Solution Status

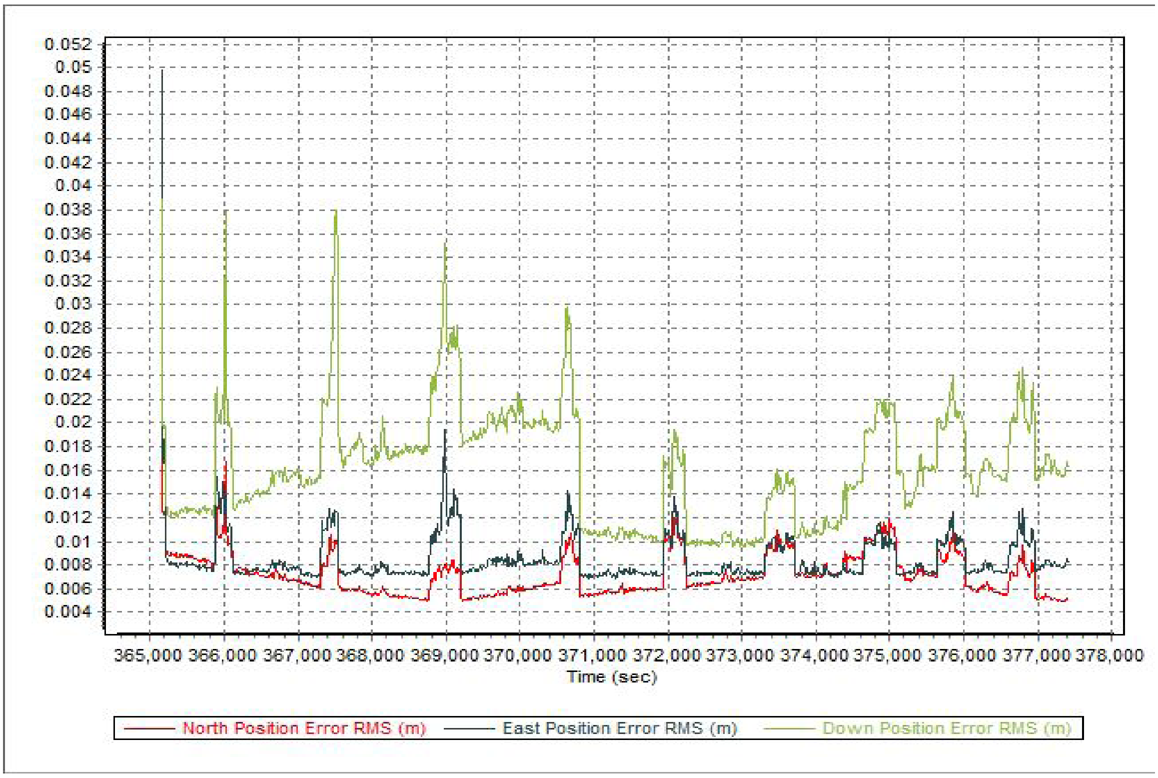


Figure A-8.23. Smoothed Performance Metrics Parameters

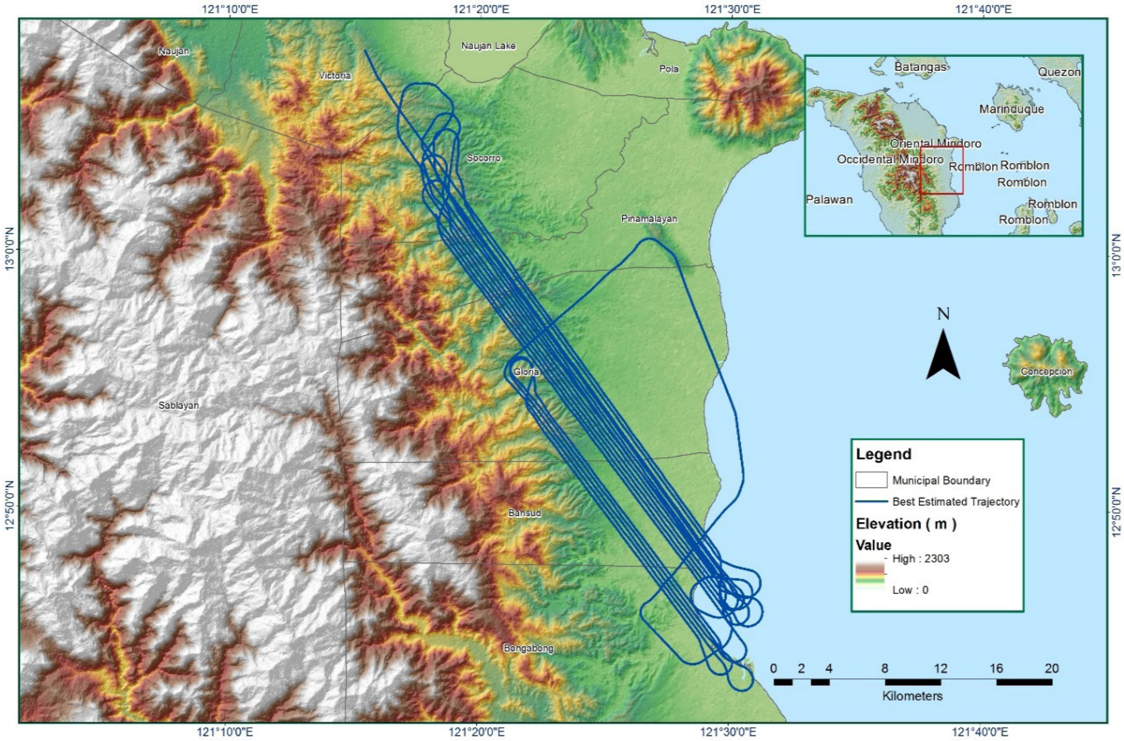


Figure A-8.24. Best Estimated Trajectory

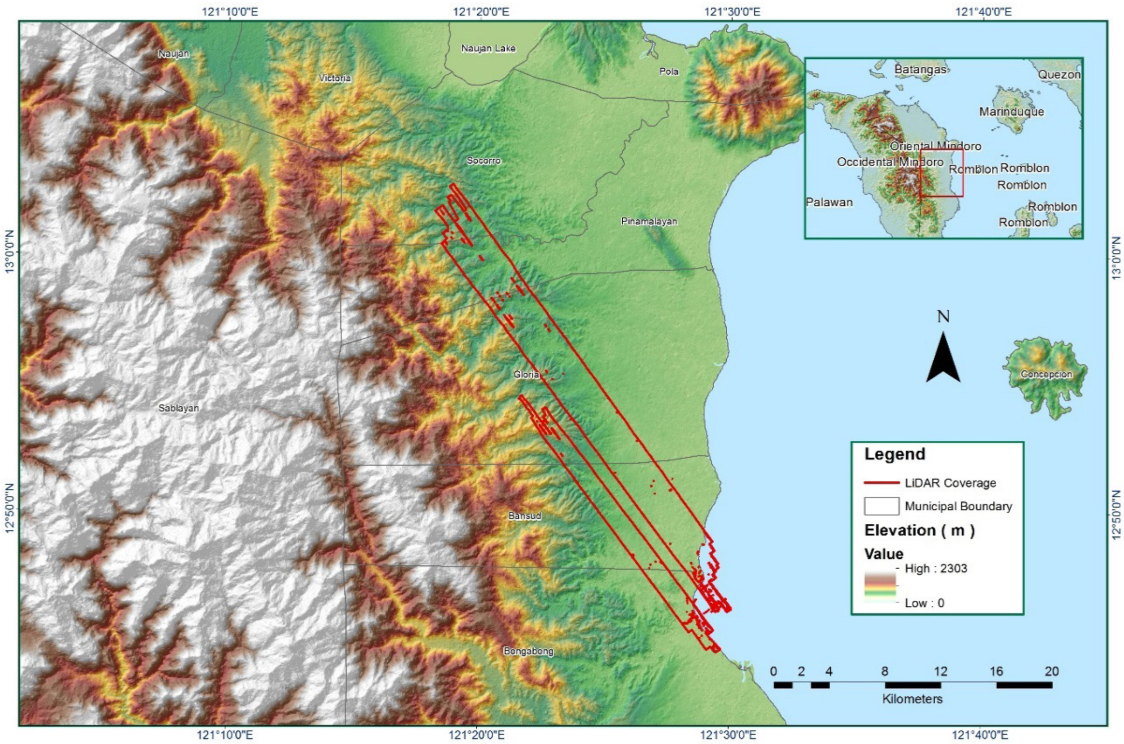


Figure A-8.25. Coverage of LiDAR data

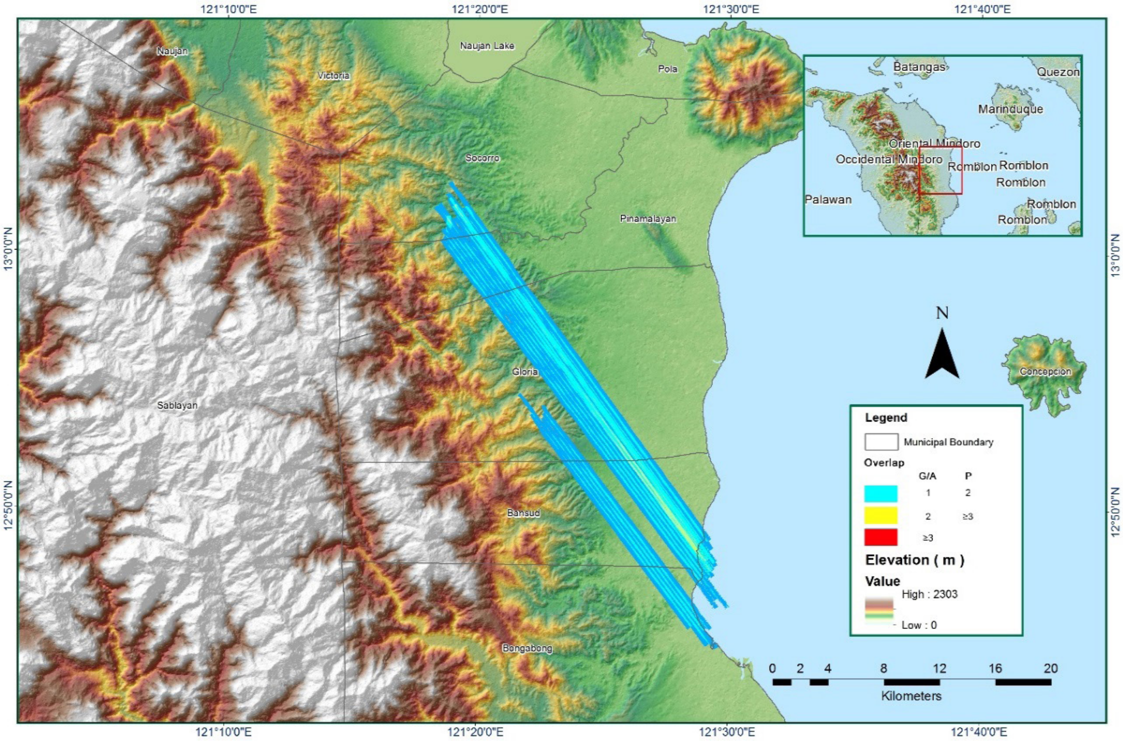


Figure A-8.26. Image of data overlap

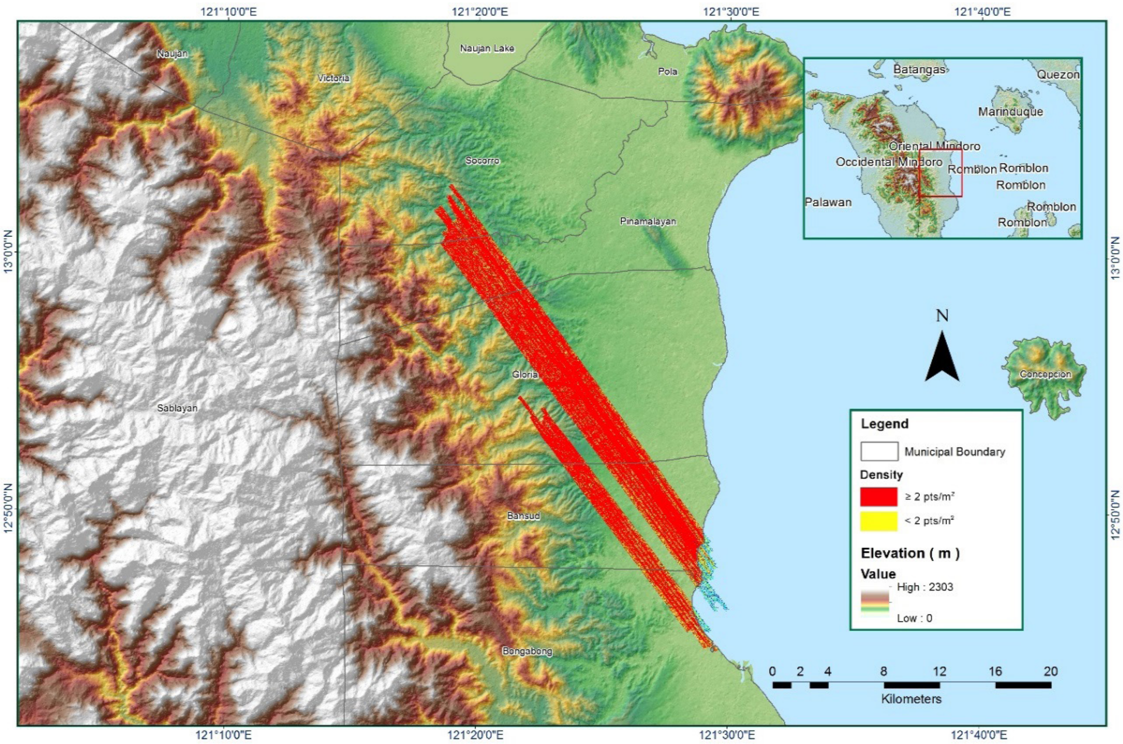


Figure A-8.27. Density map of merged LiDAR data

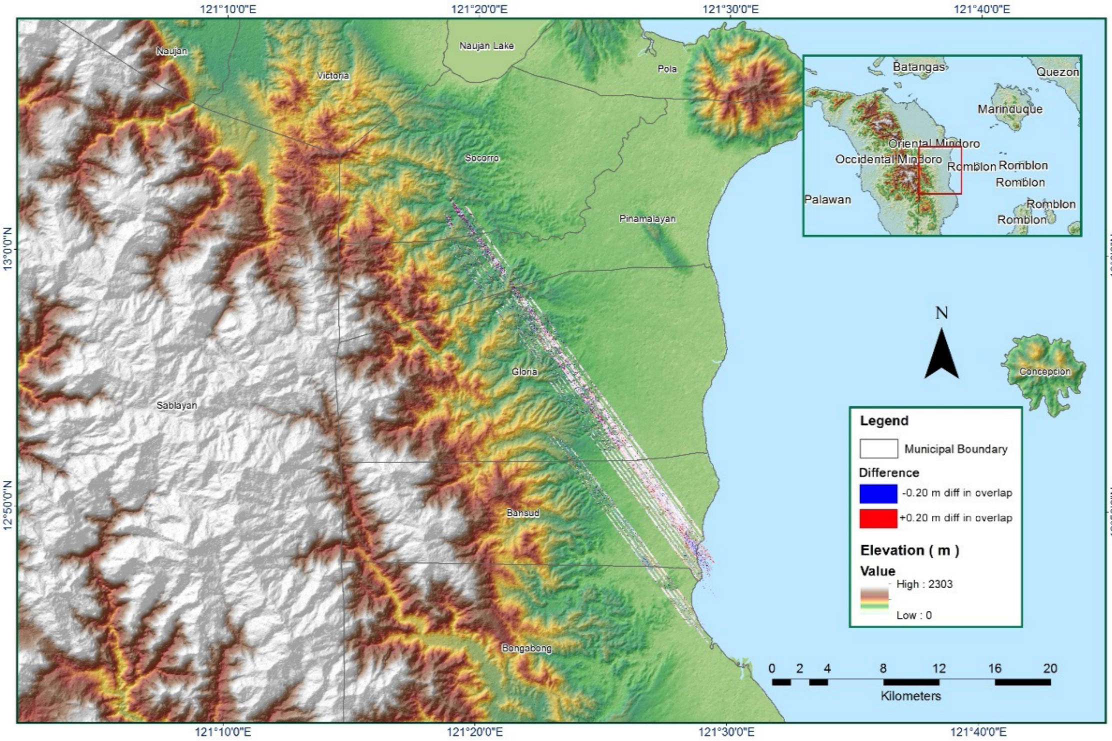


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk28E_supplement

Flight Area	Oriental Mindoro
Mission Name	**Blk28E_supplement**
Inclusive Flights	1092A
Range data size	12.7 GB
POS	242 MB
Image	23.7 GB
Base data size	15.4 MB
Transfer date	February 21, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	5.6
Boresight correction stdev (<0.001deg)	0.000491
IMU attitude correction stdev (<0.001deg)	0.001513
GPS position stdev (<0.01m)	0.0156
Minimum % overlap (>25)	25.89%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	70
Maximum Height	344.97 m
Minimum Height	50.00 m
Classification (# of points)	
Ground	32,795,240
Low vegetation	33,440,686
Medium vegetation	23,067,538
High vegetation	28,790,559
Building	759,771
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Jovy Narisma

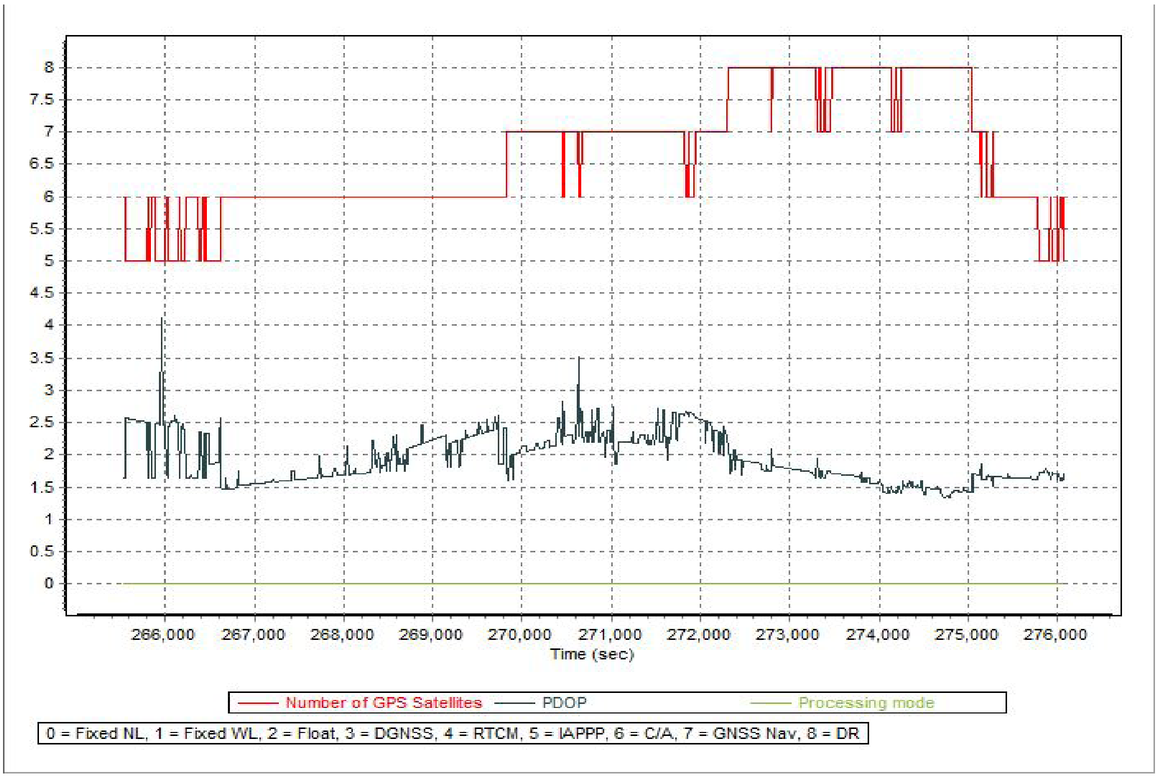


Figure A-8.29. Solution Status

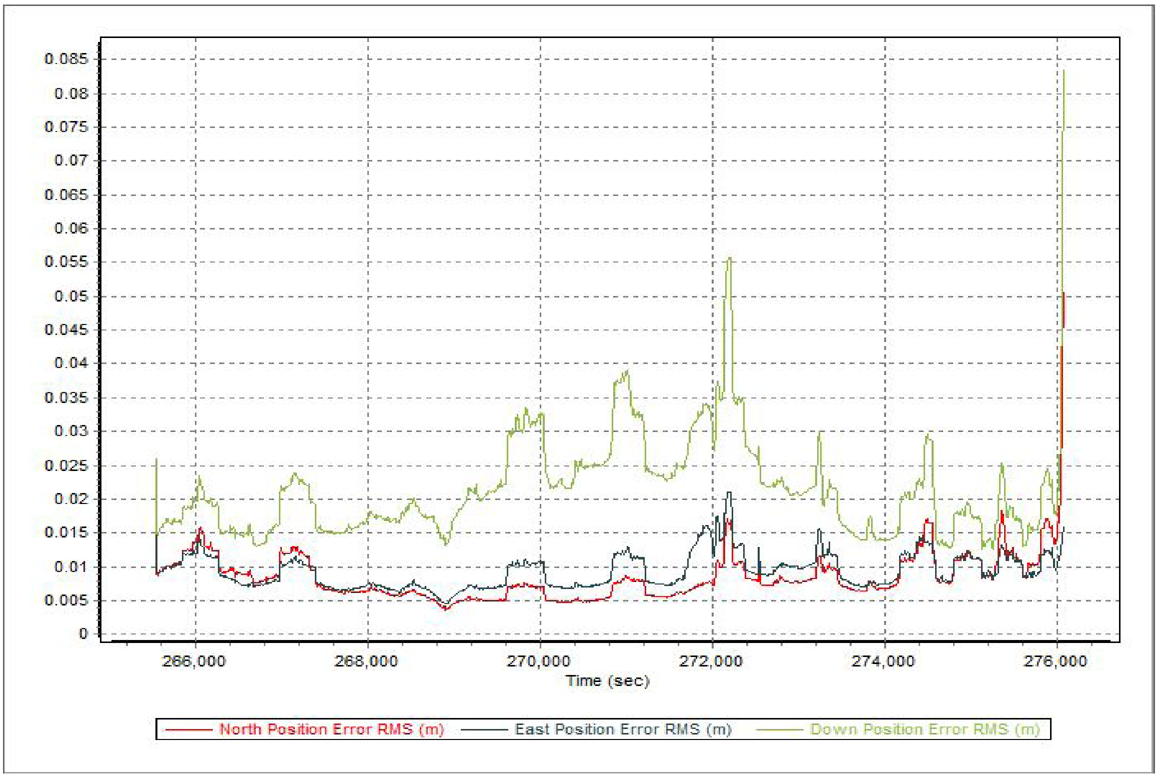


Figure A-8.30. Smoothed Performance Metrics Parameters

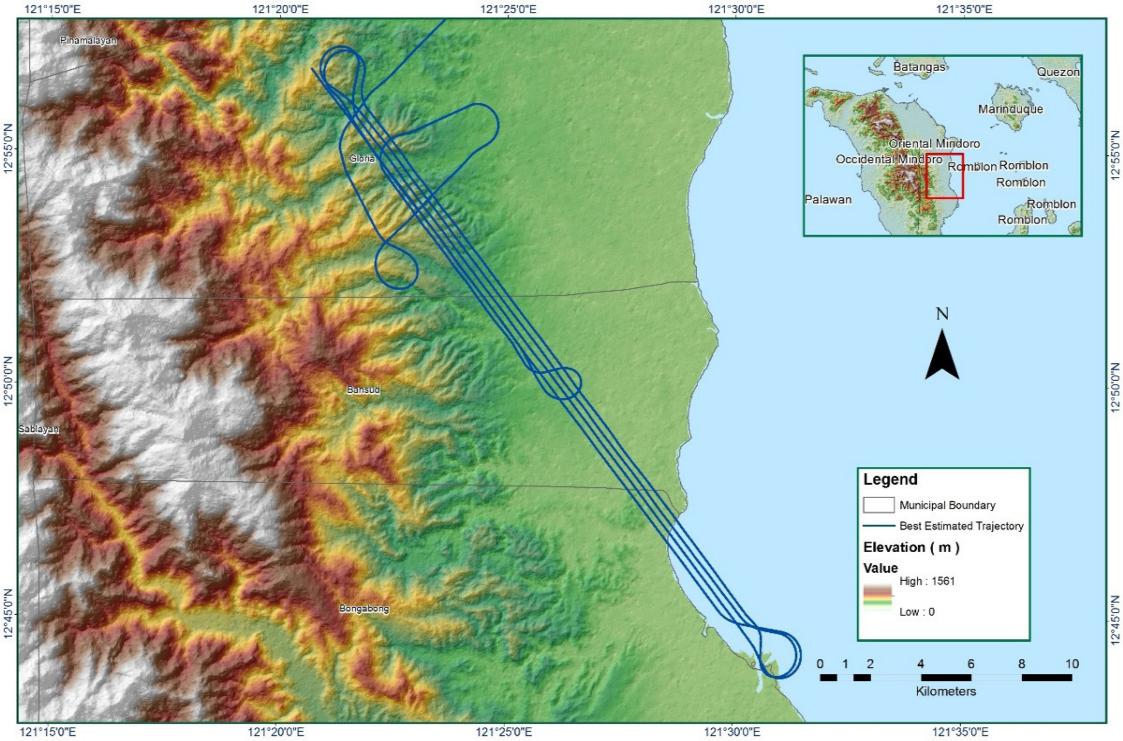


Figure A-8.31. Best Estimated Trajectory

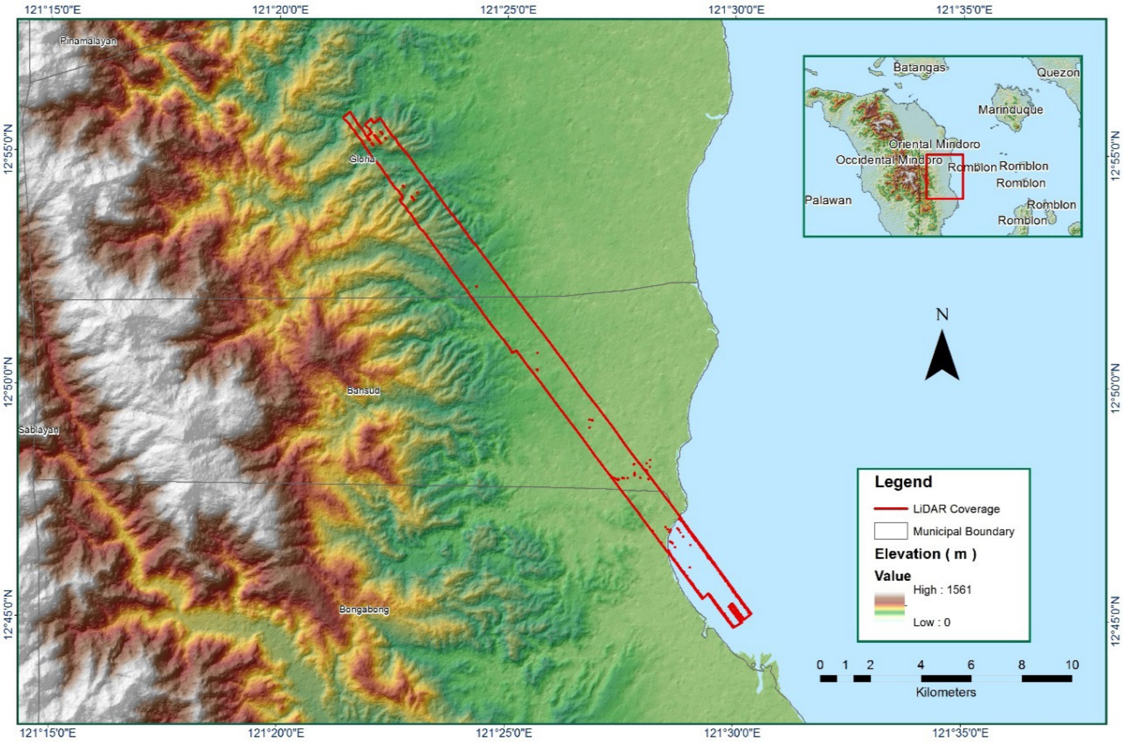


Figure A-8.32. Coverage of LiDAR data

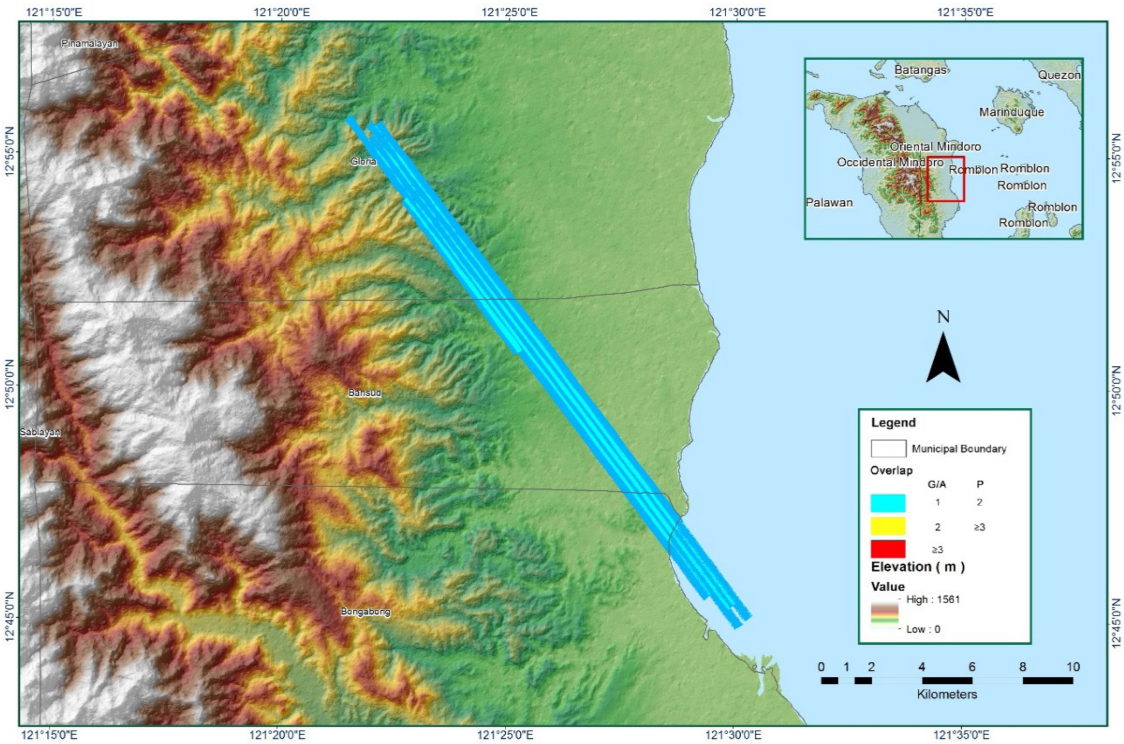


Figure A-8.33. Image of data overlap

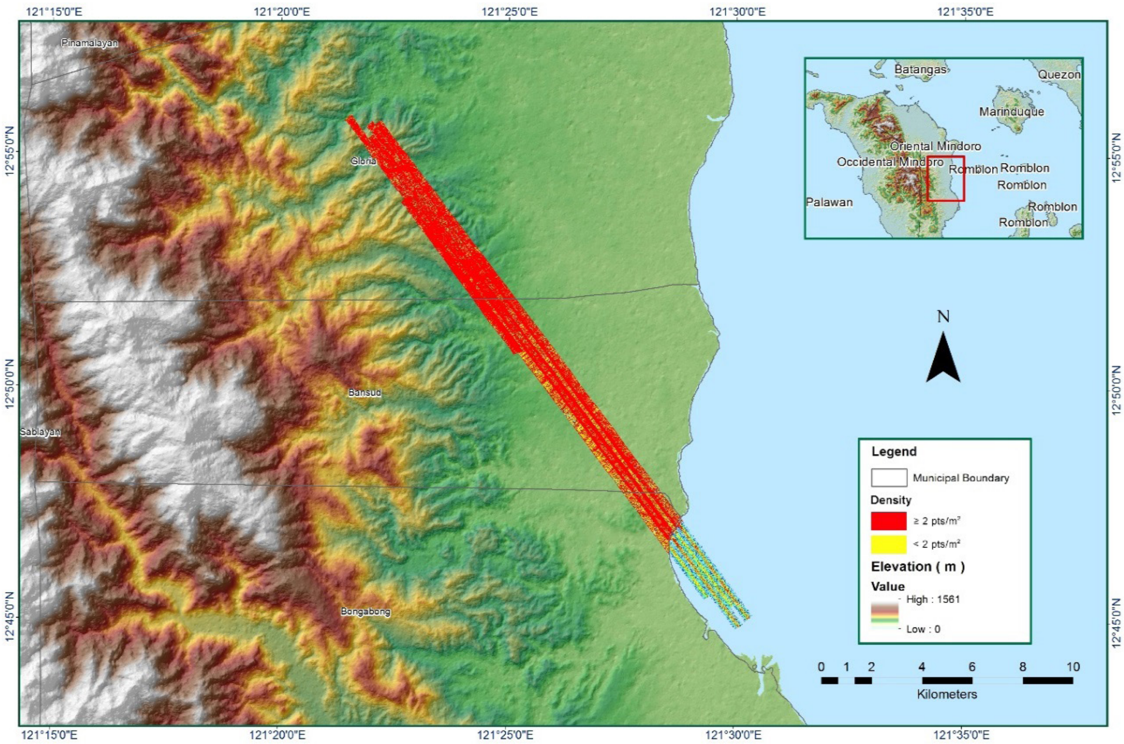


Figure A-8.34. Density map of merged LiDAR data

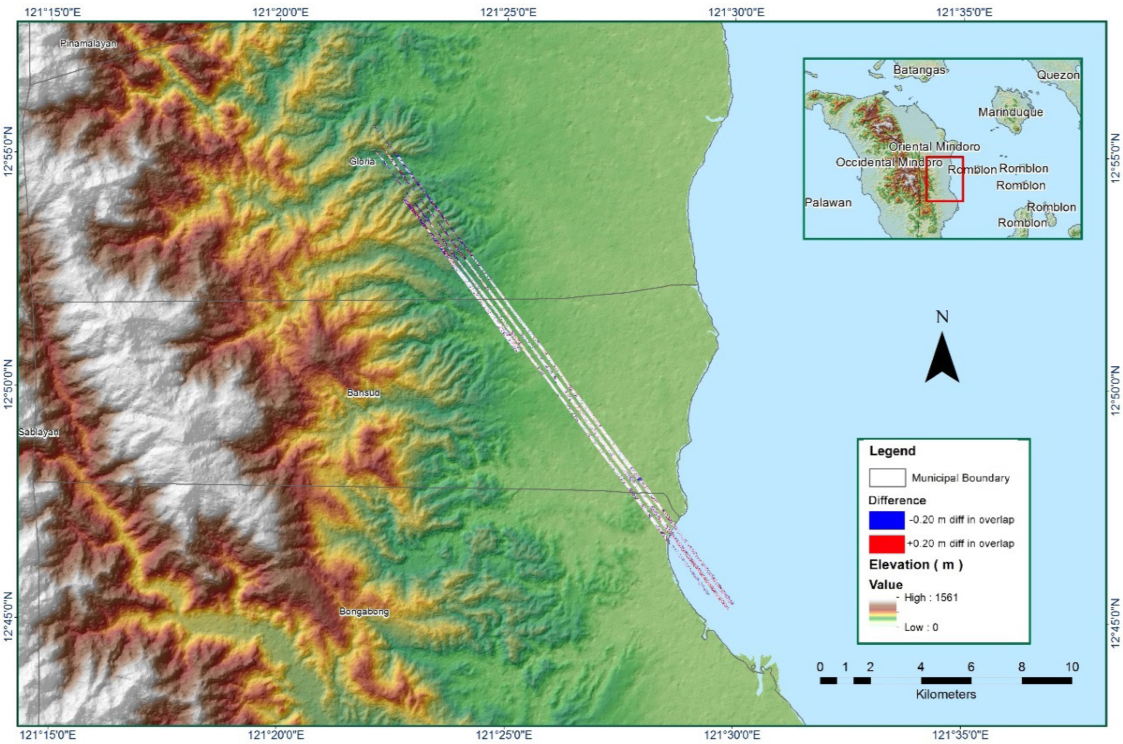


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk28C

Flight Area	**Oriental Mindoro Reflights**
Mission Name	**Blk28C**
Inclusive Flights	8302G
Range data size	14.5 GB
POS	228 MB
Image	28.2 GB
Base data size	11.5 MB
Transfer date	November 12, 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)	1.58
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.86
Boresight correction stdev (<0.001deg)	0.006431
IMU attitude correction stdev (<0.001deg)	0.044182
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	35.65
Ave point cloud density per sq.m. (>2.0)	3.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	78
Maximum Height	172.45
Minimum Height	51.2
Classification (# of points)	
Ground	23,964,162
Low vegetation	31,143,186
Medium vegetation	61,650,233
High vegetation	57,492,838
Building	320,789
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Chelou Prado, Alex John Escobido

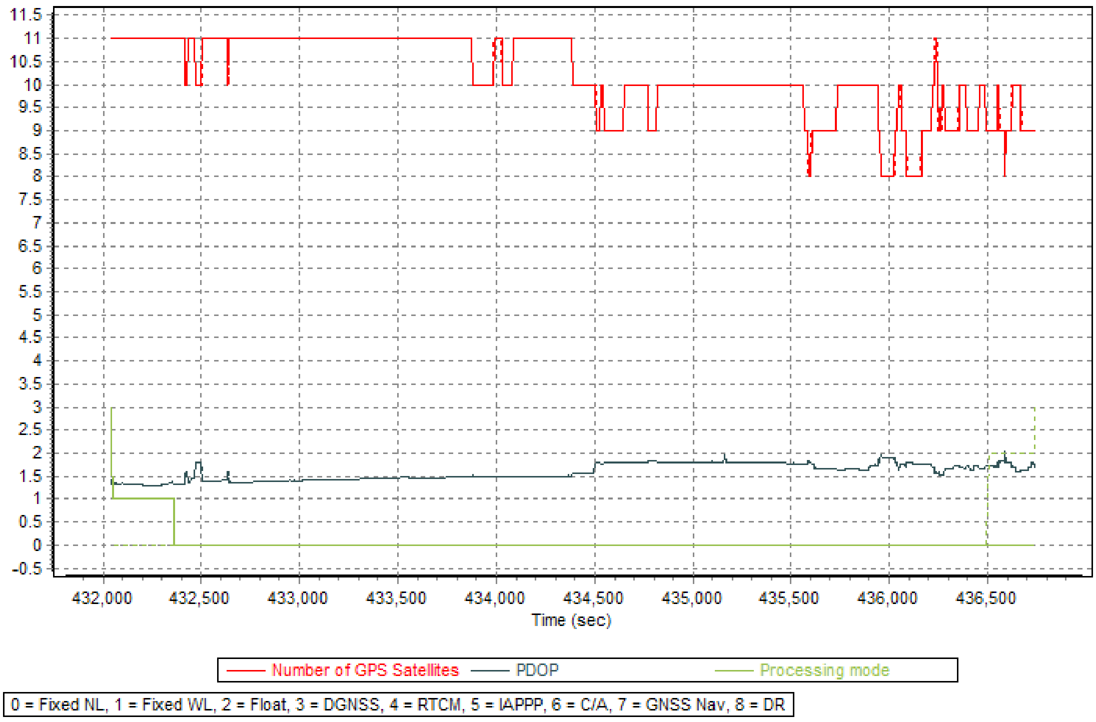


Figure A-8.36. Solution Status

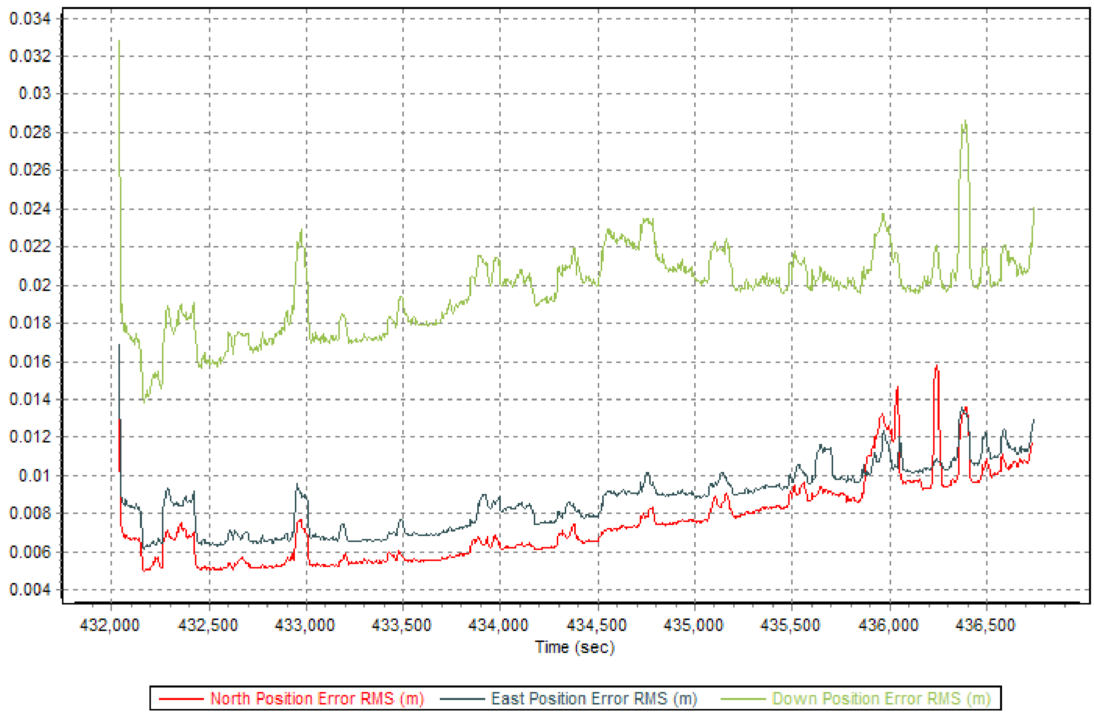


Figure A-8.37. Smoothed Performance Metrics Parameters

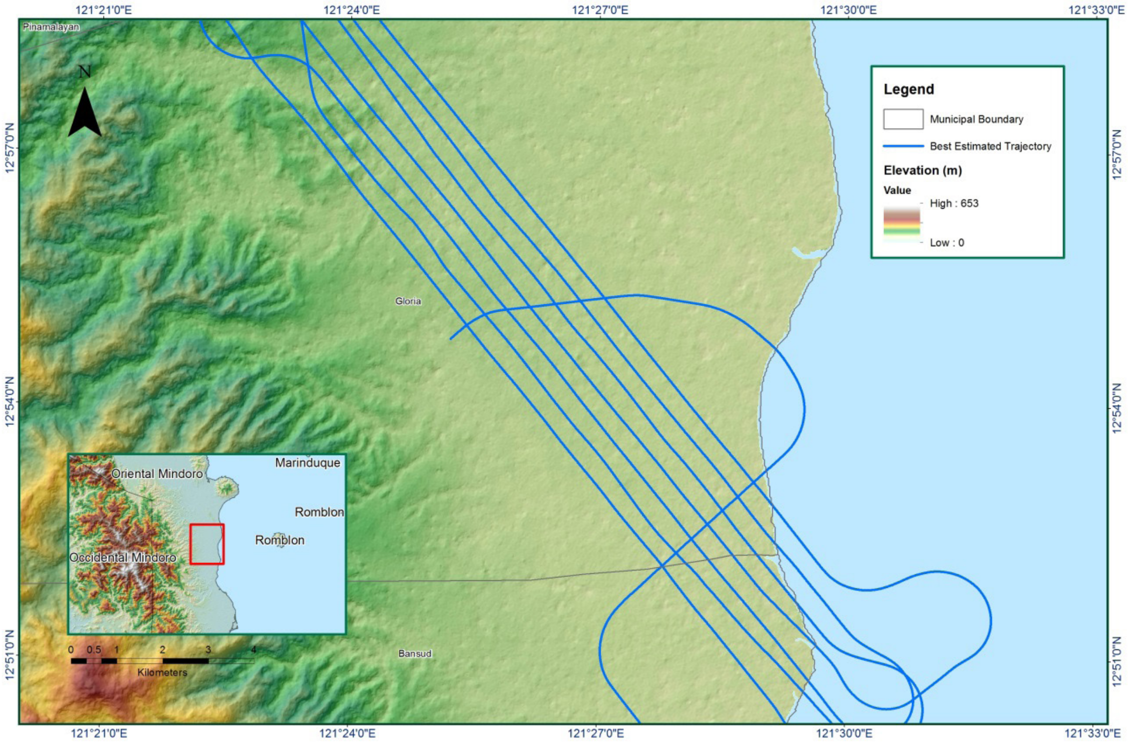


Figure A-8.38. Best Estimated Trajectory

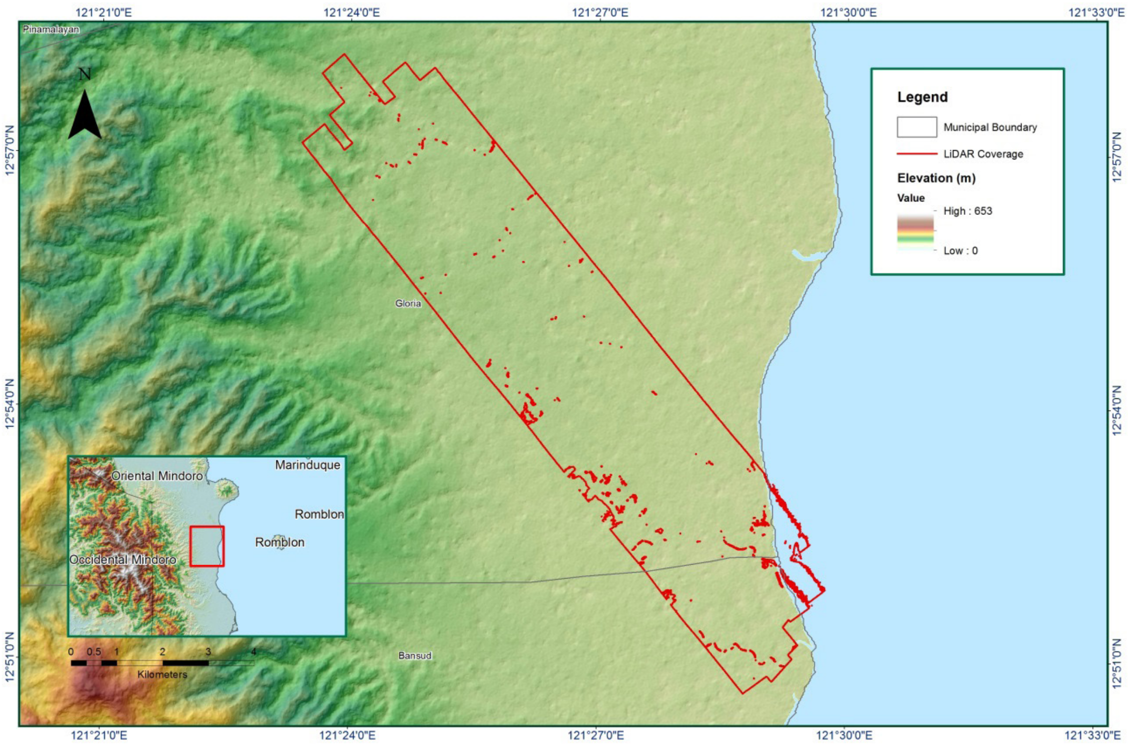


Figure A-8.39. Coverage of LiDAR data

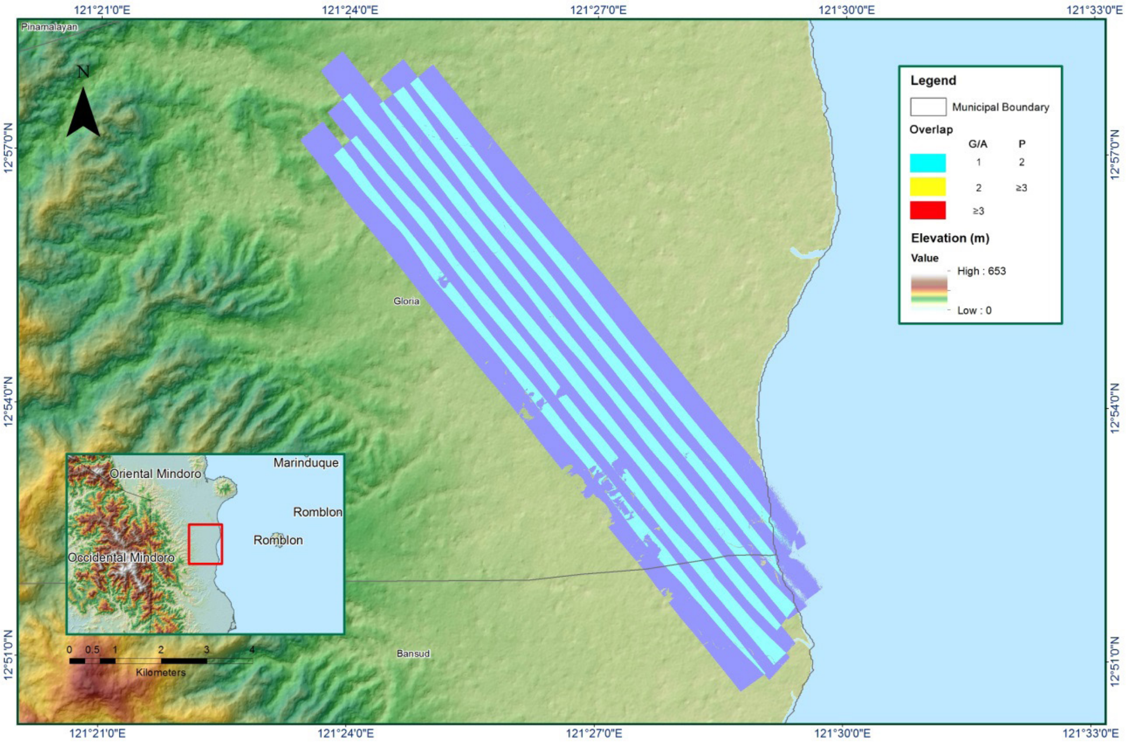


Figure A-8.40. Image of data overlap

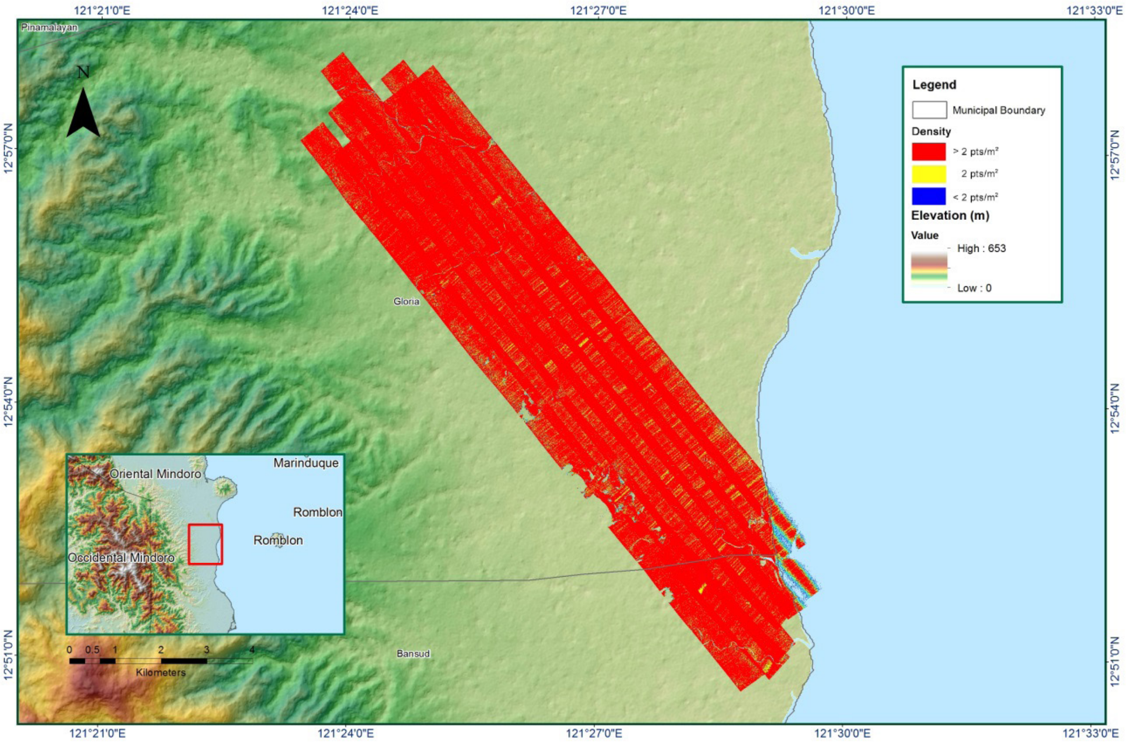


Figure A-8.41. Density map of merged LiDAR data

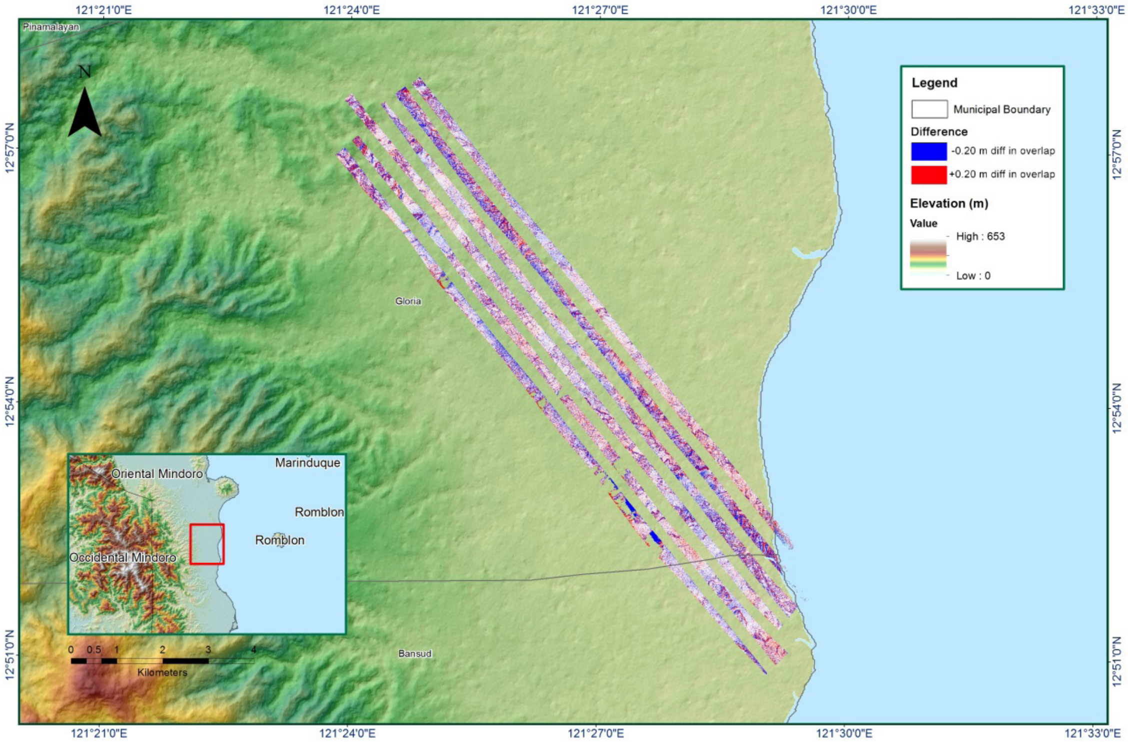


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk28E

Flight Area	Oriental Mindoro Reflights
Mission Name	**Blk28E**
Inclusive Flights	8306G, 8308G
Range data size	24.7 GB
POS	455 MB
Image	NA
Base data size	16.67 MB
Transfer date	November 12, 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)	1.10
RMSE for East Position (<4.0 cm)	0.987
RMSE for Down Position (<8.0 cm)	1.40
Boresight correction stdev (<0.001deg)	0.000735
IMU attitude correction stdev (<0.001deg)	0.001016
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	39.53
Ave point cloud density per sq.m. (>2.0)	4.69
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	56
Maximum Height	437.09
Minimum Height	53.72
Classification (# of points)	
Ground	18,836,742
Low vegetation	24,281,146
Medium vegetation	45,637,220
High vegetation	49,797,647
Building	1,096,309
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Engr. Justine Francisco, Marie Denise Bueno

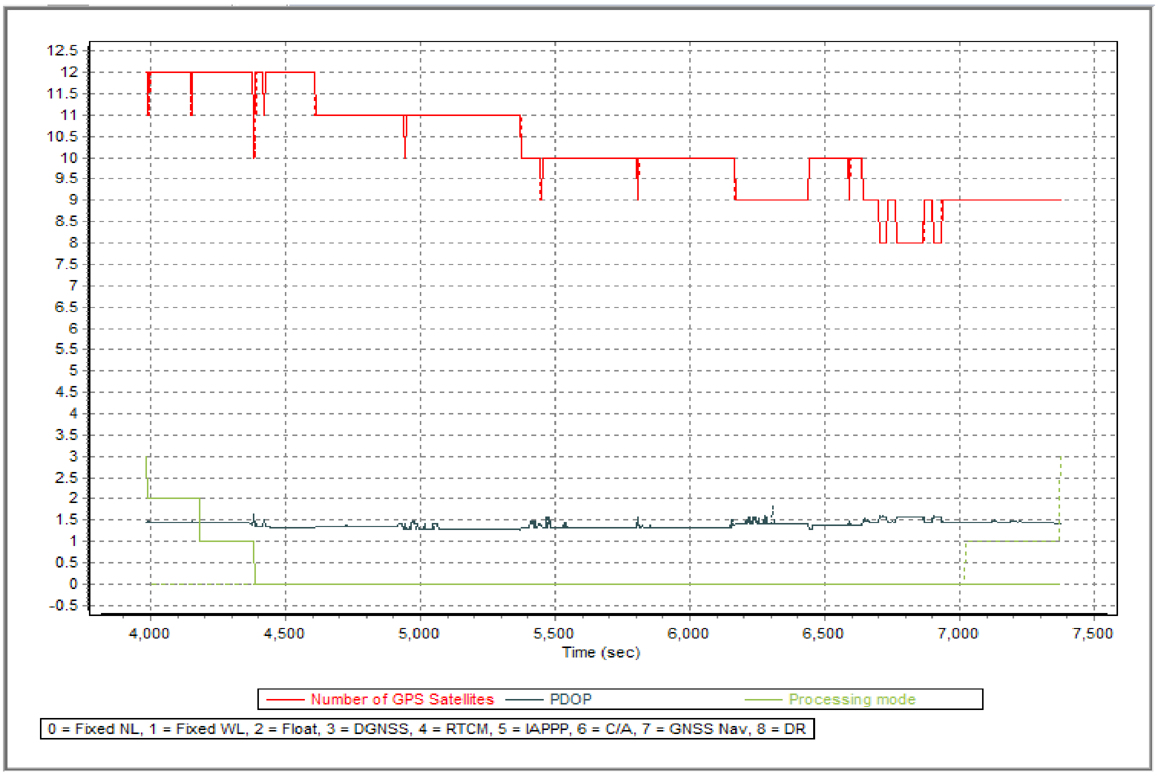


Figure A-8.43. Solution Status

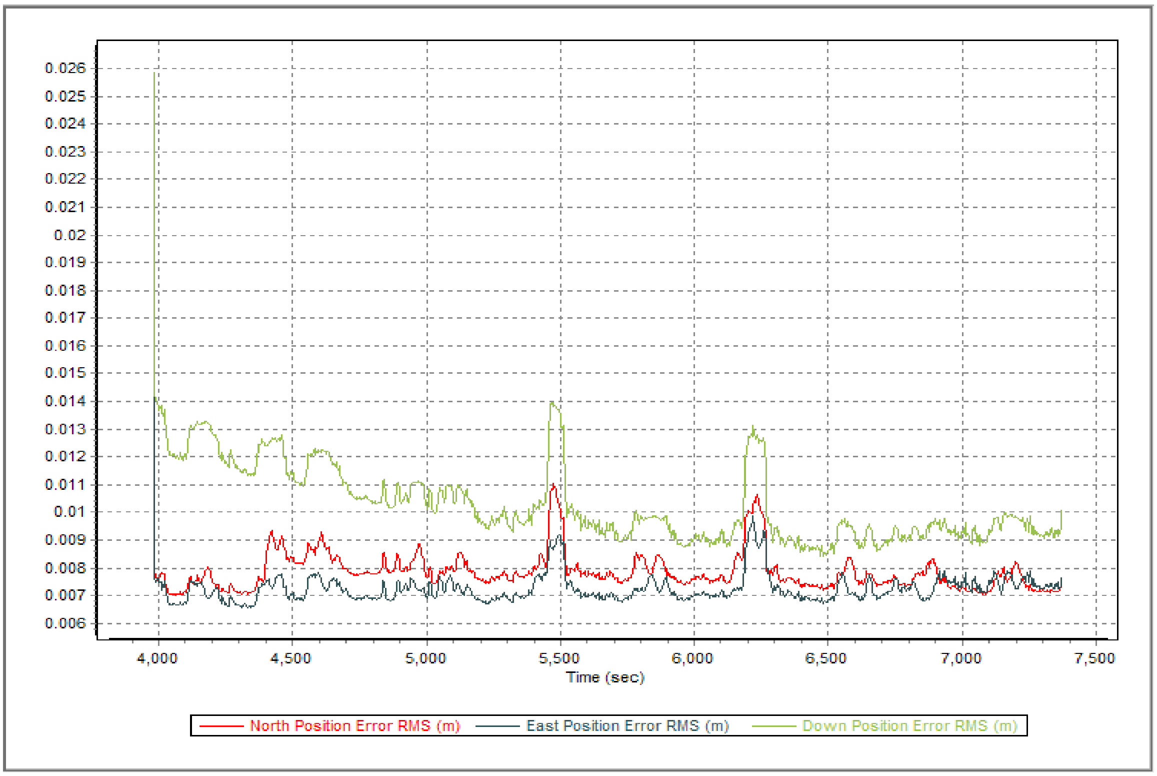


Figure A-8.44. Smoothed Performance Metrics Parameters

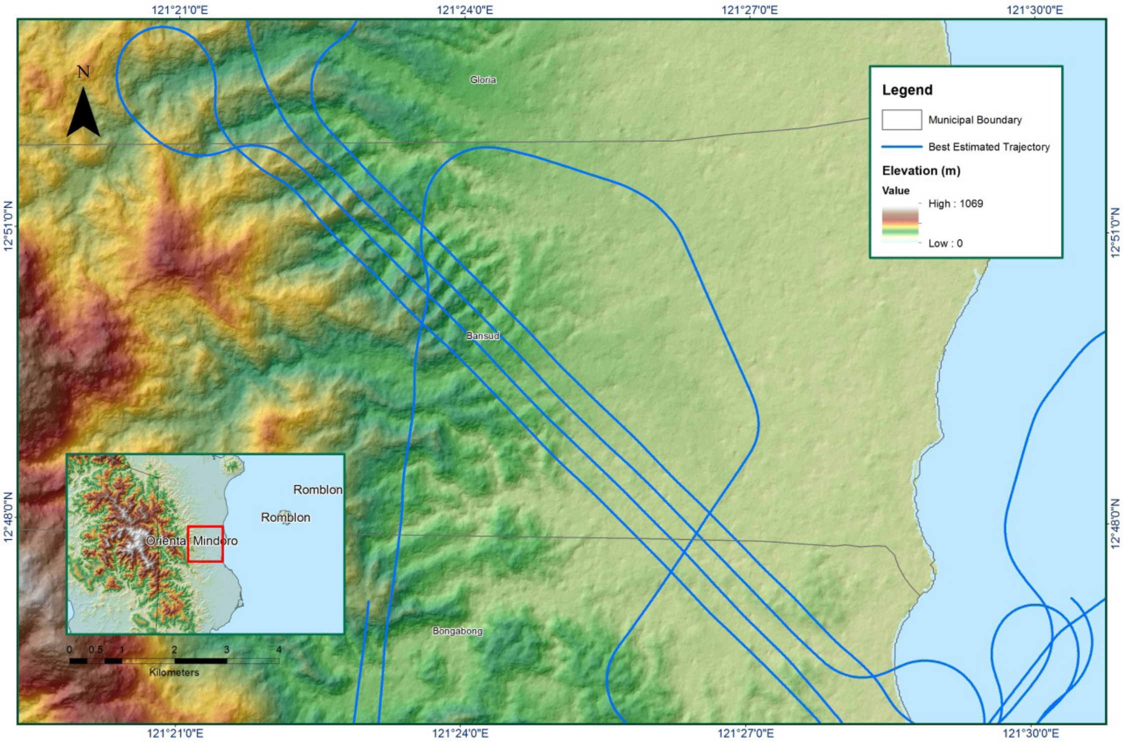


Figure A-8.45. Best Estimated Trajectory

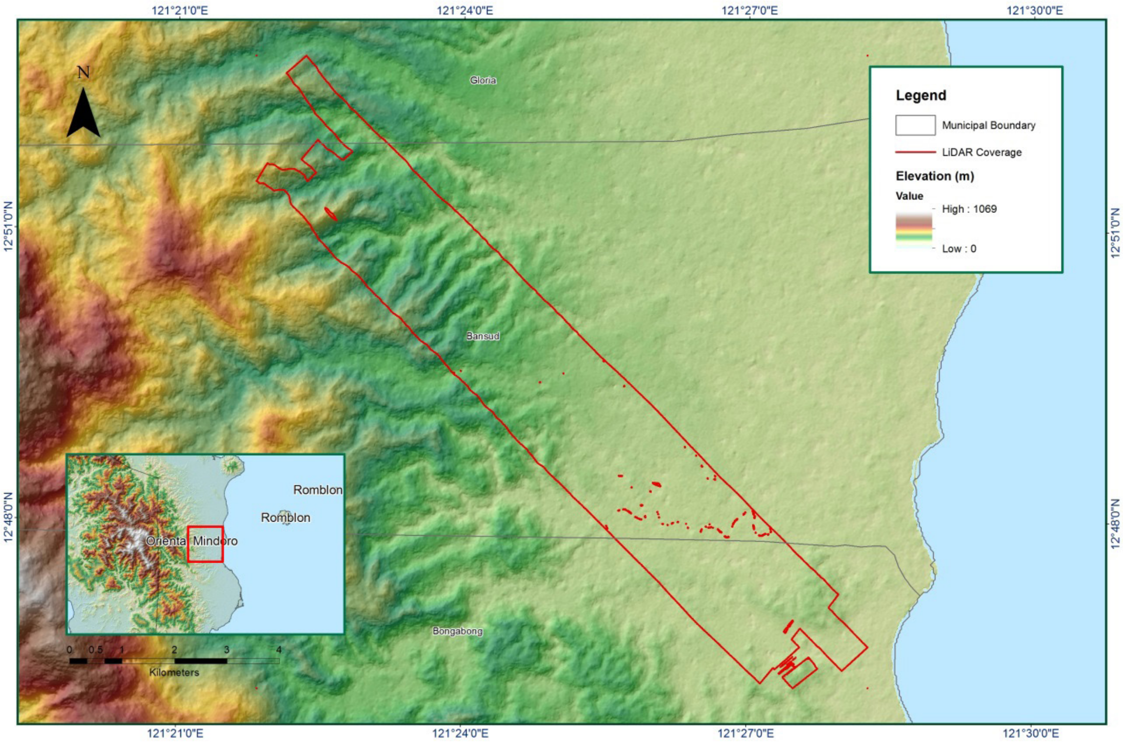


Figure A-8.46. Coverage of LiDAR data

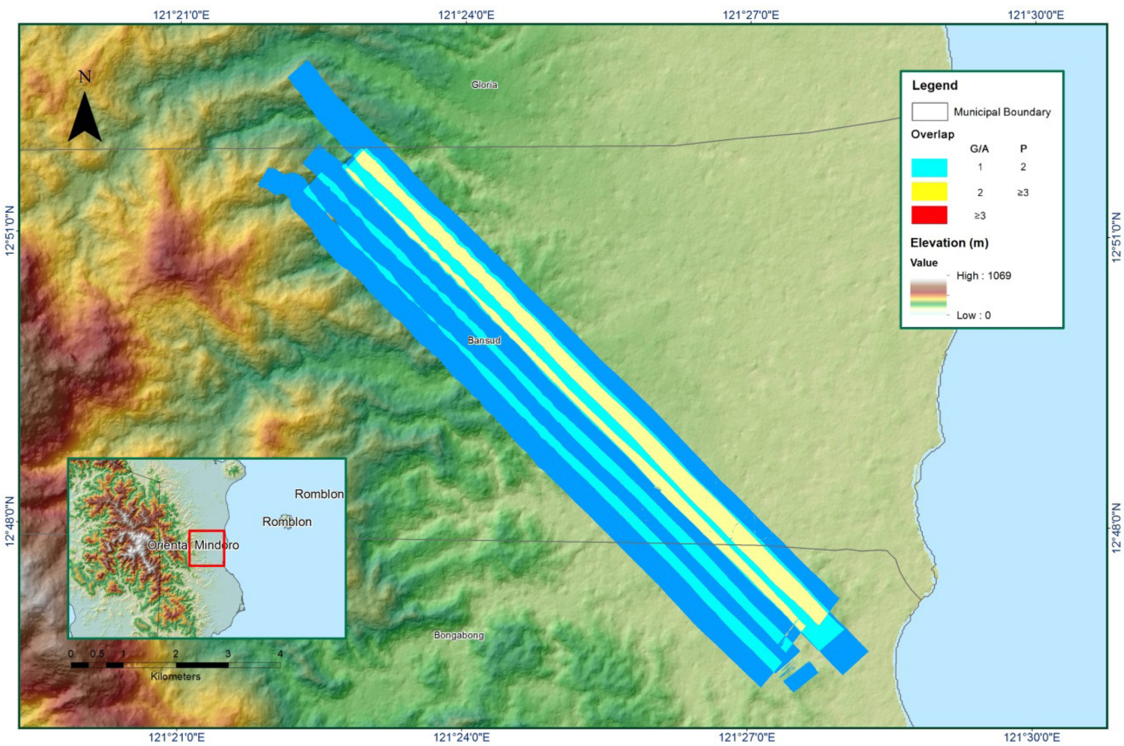


Figure A-8.47. Image of data overlap

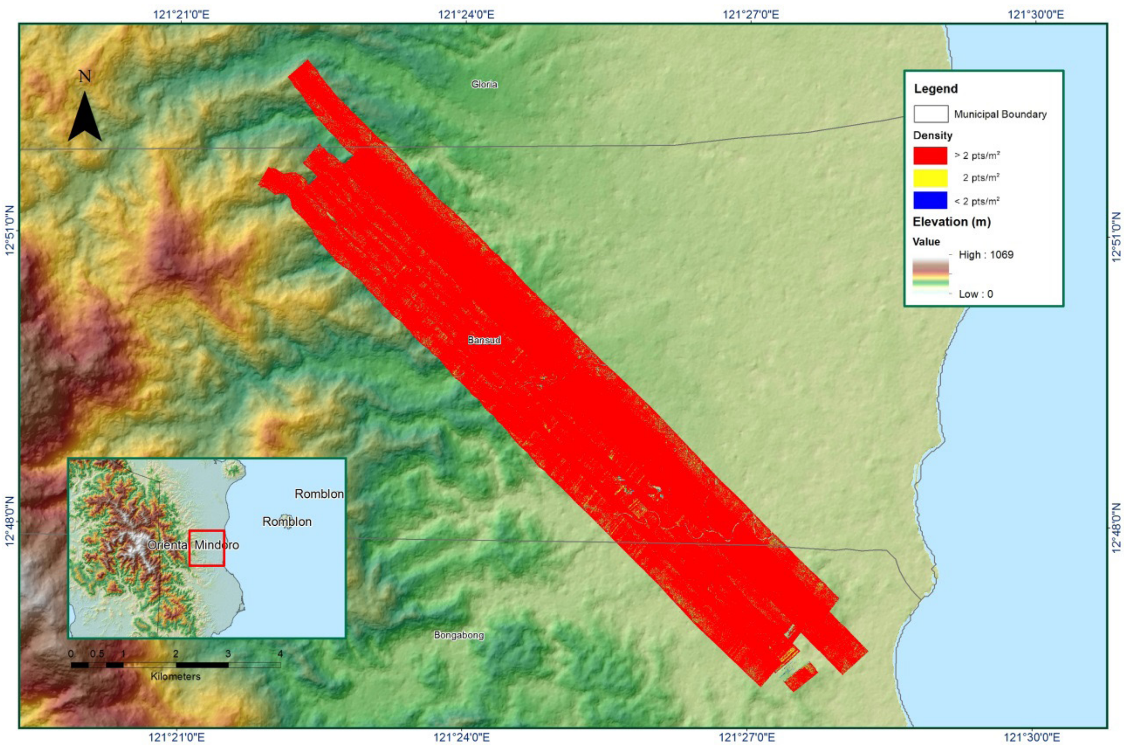


Figure A-8.48. Density map of merged LiDAR data

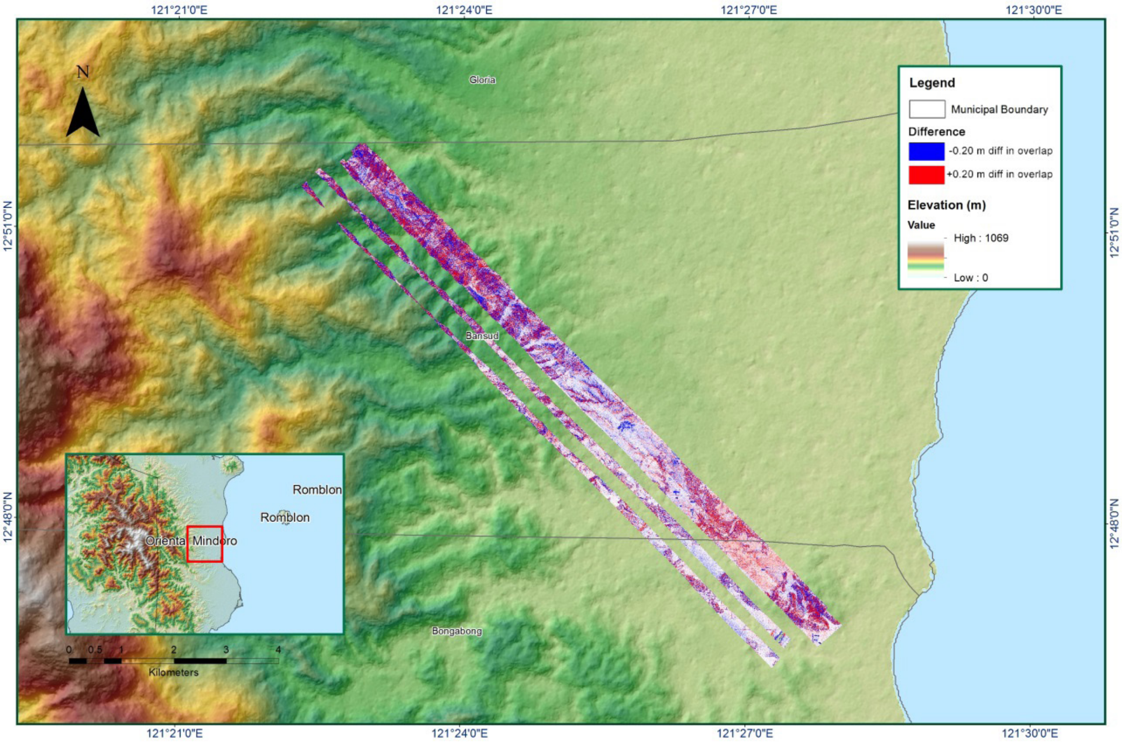


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk28H_supplement

Flight Area	Oriental Mindoro Reflights
Mission Name	**Blk28H_supplement**
Inclusive Flights	8304G, 8306G
Range data size	24.9 GB
POS	434 MB
Image	24.8 GB
Base data size	17.2 MB
Transfer date	November 12, 2015
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)	1.33
RMSE for East Position (<4.0 cm)	1.40
RMSE for Down Position (<8.0 cm)	3.05
Boresight correction stdev (<0.001deg)	0.000292
IMU attitude correction stdev (<0.001deg)	0.000461
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	38.13
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	78
Maximum Height	374.61
Minimum Height	41.25
Classification (# of points)	
Ground	33,733,252
Low vegetation	20,442,478
Medium vegetation	63,131502
High vegetation	145,339525
Building	5,009,201
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Melanie Hingpit, Maria Tamsyn Malabanan

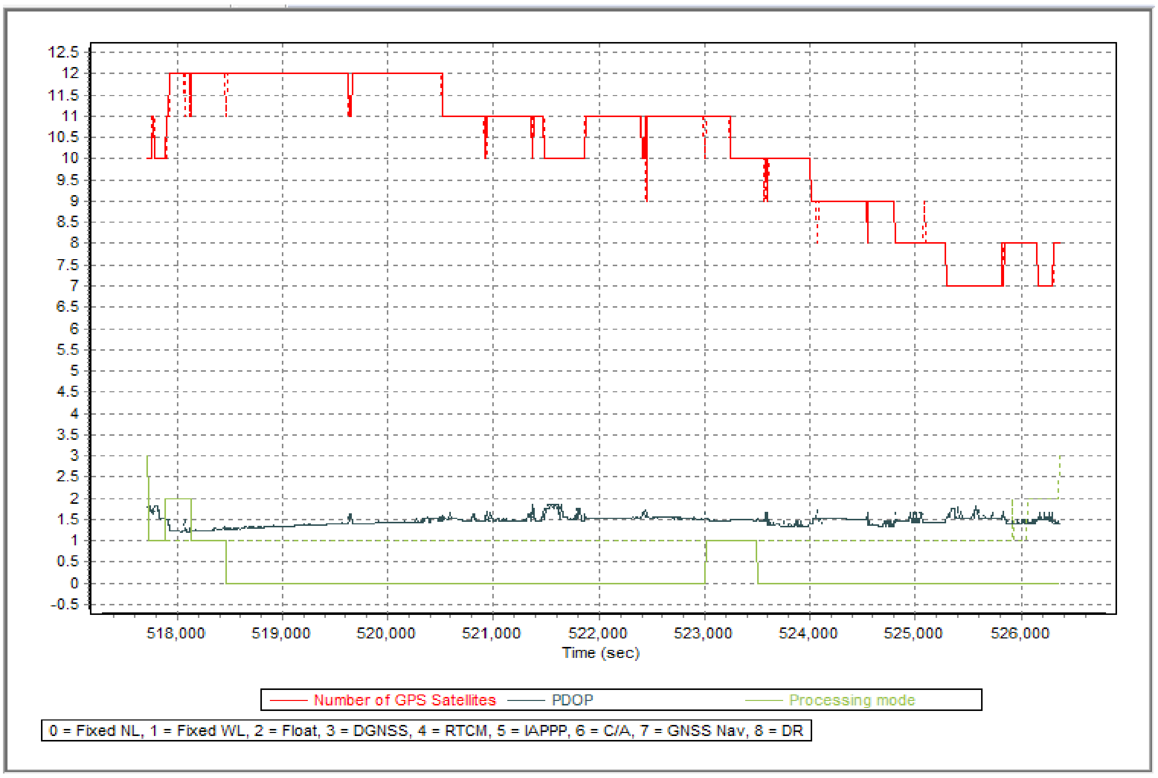


Figure A-8.50. Solution Status

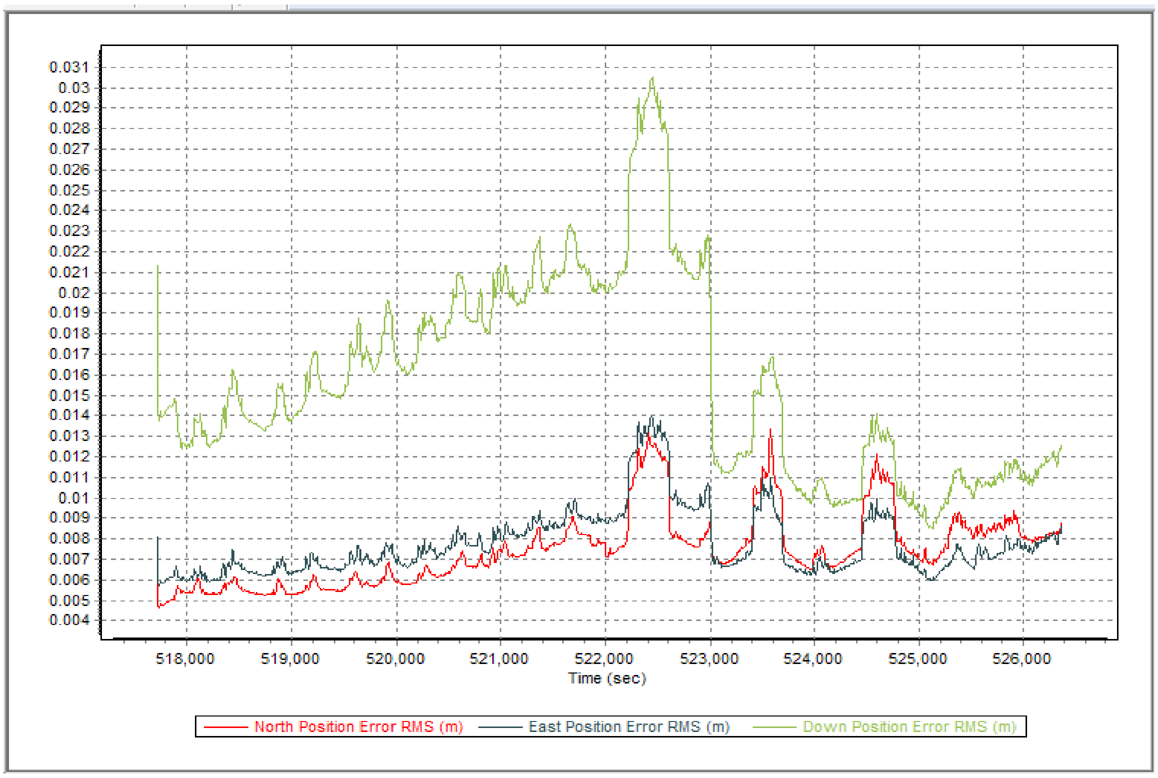


Figure A-8.51. Smoothed Performance Metrics Parameters

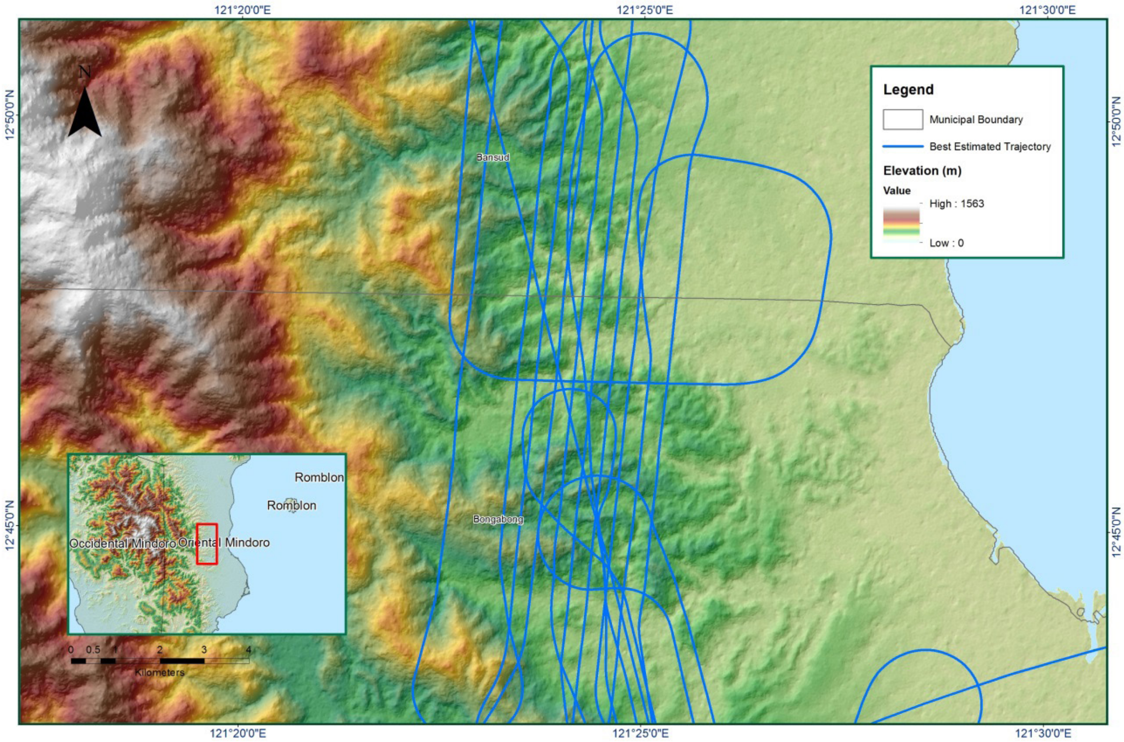


Figure A-8.52. Best Estimated Trajectory

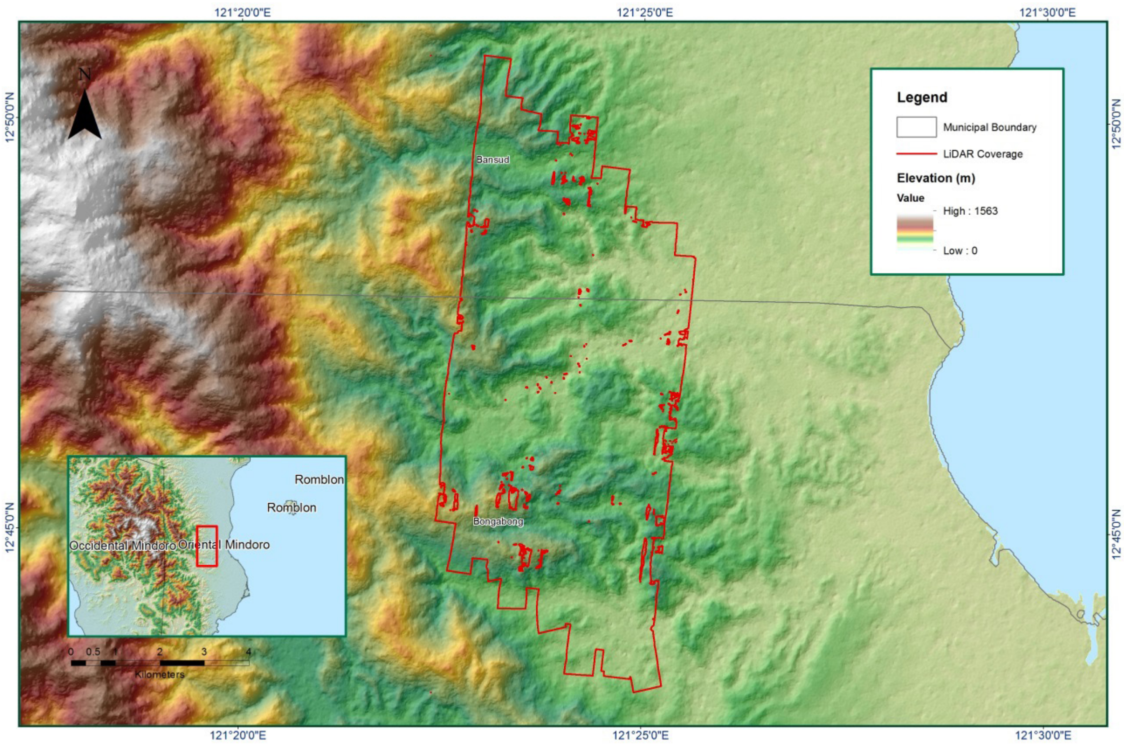


Figure A-8.53. Coverage of LiDAR data

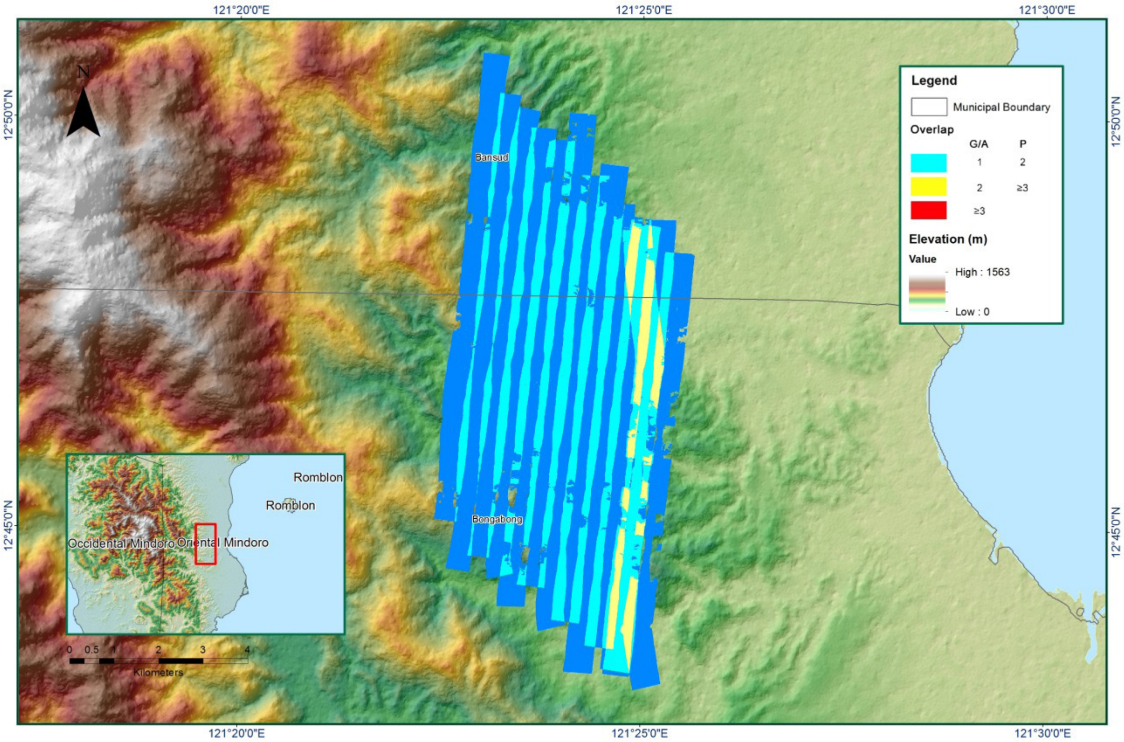


Figure A-8.54. Image of data overlap

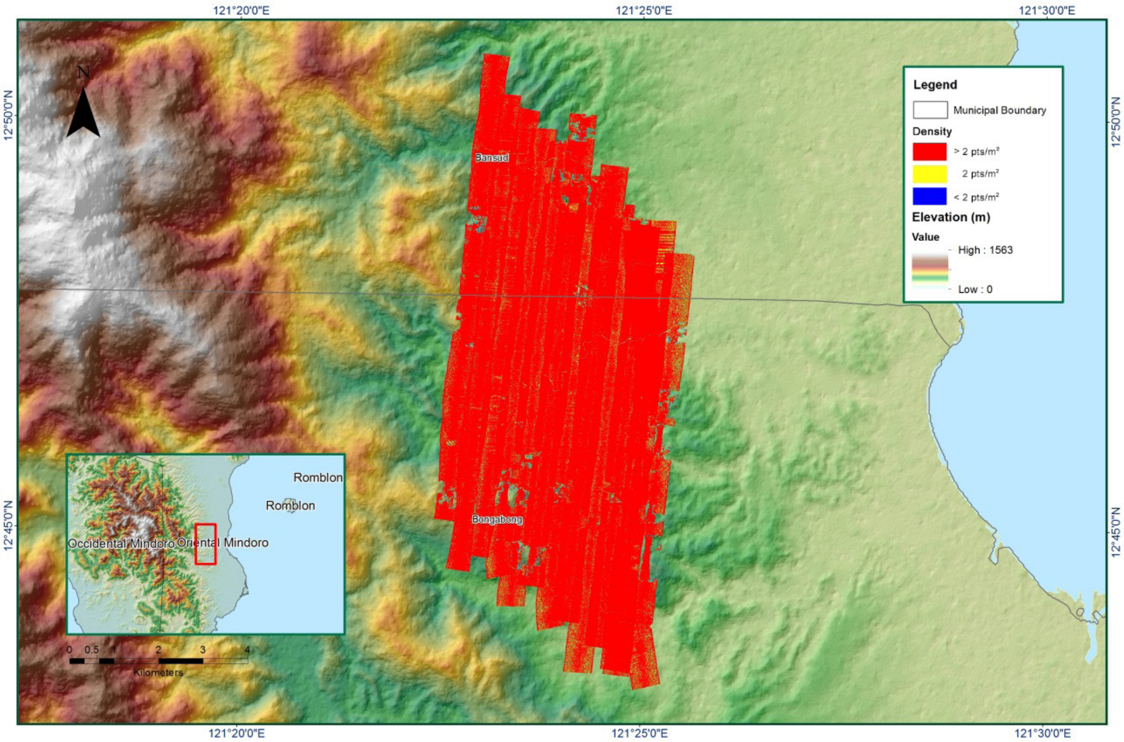


Figure A-8.55. Density map of merged LiDAR data

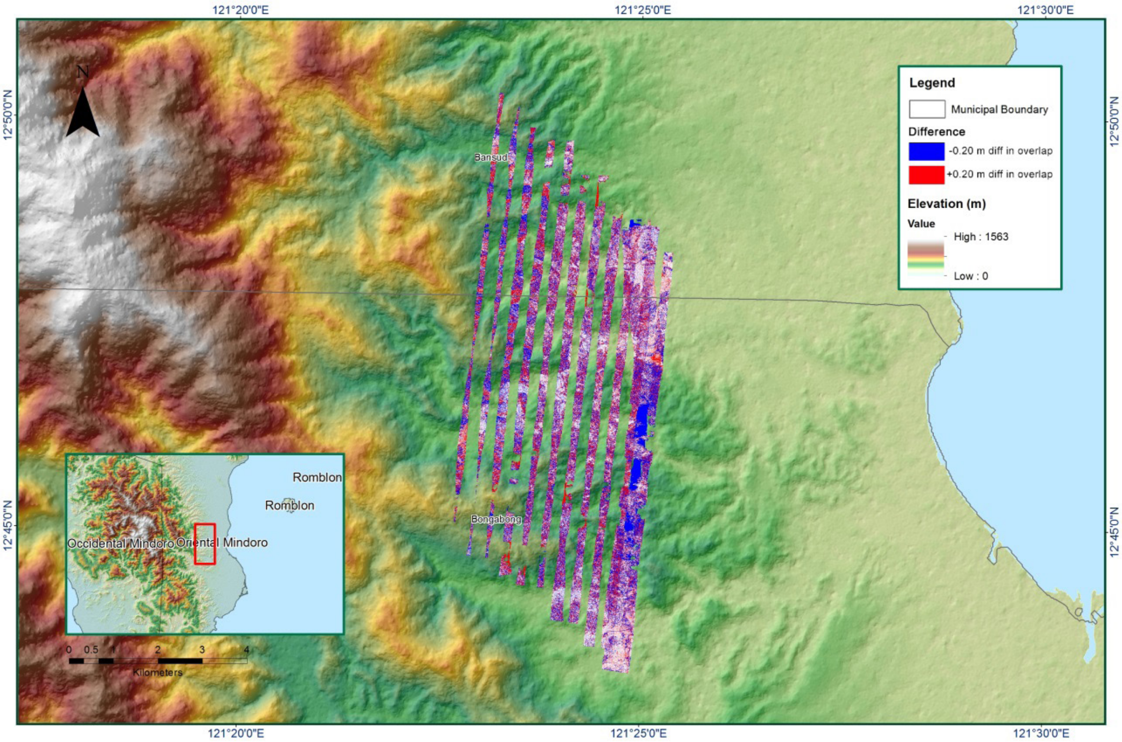


Figure A-8.56. Elevation difference between flight lines

Annex 9. Bansud Model Basin Parameters

Table A-9.1. Bansud 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	8.3096	81.91	0	3.2931	11.272	3.8262	0.19753	0.5
W330	10.472	75.115	0	3.2716	1.3948	1.965	0.2963	0.4706
W340	10.939	99	0	2.7949	0.8932	0.59652	0.19753	0.31373
W350	11.221	72.643	0	2.2755	1.4331	0.67879	0.19753	0.46118
W360	11.215	84.365	0	2.7047	0.76128	0.72584	0.19753	0.31373
W370	4.6093	99	0	3.2864	1.3984	1.0177	0.19753	0.46118
W380	10.578	73.819	0	2.9564	0.76049	2.9934	0.19753	0.53301
W390	1.73904	99	0	2.2004	2.15466	0.23141	1	0.5
W400	11.221	70.838	0	0.38527	0.8961	0.11637	0.19782	0.32013
W410	10.835	72.147	0	1.2864	1.2742	0.59813	0.19753	0.31373
W420	11.11	99	0	2.2055	0.96296	0.13918	0.19753	0.31373
W430	7.2218	99	0	2.8991	0.82812	2.5565	0.19753	0.31373
W450	7.0283	89.733	0	0.20721	3.4534	0.11359	0.2963	0.46118
W460	2.57904	99	0	3.2885	1.0272	0.67192	1	0.5
W470	3.4398	99	0	0.45974	2.9702	0.59175	0.19753	0.69177
W480	5.4239	99	0	0.43271	1.3863	0.58676	0.19753	0.30746

W490	2.4435	99	0	4.0707	0.72588	0.10885	0.19753	0.31373
W500	9.6232	99	0	0.84643	3.7271	0.67385	0.2963	0.46118
W510	8.3576	84.981	0	2.2184	1.8771	1.5634	0.19753	0.46118
W520	10.67	74.536	0	2.291	0.96204	1.4882	0.19753	0.46118
W530	10.89	56.549	0	2.1824	1.4606	0.88287	0.19753	0.31373
W540	6.8954	82.176	0	2.0085	1.2386	1.1393	0.19753	0.31373
W550	5.0999	99	0	3.0305	0.85254	1.7669	0.19753	0.21342
W560	10.67	72.283	0	0.88045	2.8976	1.0055	0.29037	0.46118
W570	2.8742	99	0	3.8333	1.2993	0.50654	0.19753	0.31373
W580	8.988	88.547	0	0.16501	2.3809	0.26498	0.66667	0.46118
W590	6.05	99	0	2.6595	0.57211	0.0827423	0.19753	0.31373
W600	6.3973	56.482	0	1.7682	0.99516	3.0043	0.19753	0.46118
W610	4.837	99	0	3.0443	0.75132	0.73746	0.19753	0.31373
W620	7.3927	99	0	2.7733	2.9626	0.49126	0.19753	0.46118
W640	3.17376	99	0	3.5621	2.39352	0.77535	1	0.5
W650	2.4532	99	0	3.8267	0.87324	0.22441	0.19753	0.31373

Annex 10. Bansud Model Reach Parameters

Table A-10.1. Bansud 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)
R100	Automatic Fixed Interval	3815.0	0.0083422	0.0435555	Trapezoid	40	1
R110	Automatic Fixed Interval	953.26	0.0332135	0.0669755	Trapezoid	40	1
R120	Automatic Fixed Interval	2584.5	0.0015508	0.1	Trapezoid	40	1
R130	Automatic Fixed Interval	1025.7	0.0031700	0.0966495	Trapezoid	40	1
R140	Automatic Fixed Interval	13084	0.0143974	0.0883908	Trapezoid	40	1
R150	Automatic Fixed Interval	1598.5	.0009531	0.0922368	Trapezoid	40	1
R160	Automatic Fixed Interval	3504.5	0.0083615	0.1	Trapezoid	40	1
R170	Automatic Fixed Interval	2472.8	0.0178704	0.147	Trapezoid	40	1
R200	Automatic Fixed Interval	2058.2	0.0523968	0.50625	Trapezoid	40	1
R210	Automatic Fixed Interval	5501.1	0.0048693	0.064179	Trapezoid	40	1
R220	Automatic Fixed Interval	459.71	0.18080	0.15211	Trapezoid	40	1
R260	Automatic Fixed Interval	3438.5	0.0056953	0.16567	Trapezoid	40	1
R40	Automatic Fixed Interval	1223.7	0.0314317	0.0946988	Trapezoid	40	1
R50	Automatic Fixed Interval	233.85	.00064963	0.09604	Trapezoid	40	1
R660	Automatic Fixed Interval	601.84	0.0024794	0.0611728	Trapezoid	40	1
R80	Automatic Fixed Interval	1262.0	0.0307474	0.20315	Trapezoid	40	1

Annex 11. Bansud Field Validation Points

Table A-11.1. Bansud Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	12.82508300000	121.47649700000	0.32	0.3	-0.02	Nona		25-Year
2	12.83014800000	121.48409000000	0.1	0.2	0.1	Frank		25-Year
3	12.83225900000	121.46092000000	0.46	0.75	0.29	Caloy		25-Year
4	12.83232700000	121.46107000000	0.87	0	-0.87			25-Year
5	12.83264900000	121.46020200000	0.67	0	-0.67			25-Year
6	12.83281700000	121.47806700000	0.18	0.27	0.09	Nona		25-Year
7	12.83466600000	121.46008900000	0.03	0	-0.03			25-Year
8	12.83598300000	121.46115000000	0.15	0.15	0	Caloy	2007	25-Year
9	12.84034000000	121.46005700000	0.92	0	-0.92			25-Year
10	12.84173500000	121.46000900000	0.03	0.16	0.13	Nona		25-Year
11	12.84404500000	121.45981500000	0.69	0	-0.69			25-Year
12	12.84491900000	121.44448000000	0.04	0.16	0.12	Yolanda		25-Year
13	12.84496200000	121.44875300000	2.18	2	-0.18	Caloy		25-Year
14	12.84498900000	121.44736900000	0.76	0	-0.76			25-Year
15	12.84594000000	121.45108000000	1.26	0.68	-0.58	Nona		25-Year
16	12.84610600000	121.45516600000	0.31	0.8	0.49		2002	25-Year
17	12.84734800000	121.43527000000	1.44	0.82	-0.62	Nona	December 2015	25-Year
18	12.84815500000	121.43651000000	2.55	0.45	-2.1	Nona	December 2015	25-Year
19	12.84919900000	121.43783000000	1.17	0	-1.17	Nona	December 2015	25-Year
20	12.84947200000	121.43847000000	1.08	0.22	-0.86	Caloy	2005	25-Year
21	12.84954200000	121.43896000000	1.1	0.33	-0.77	Nona	December 2015	25-Year
22	12.85017700000	121.47112900000	0.76	0.12	-0.64	Nona	Dec. 15, 2015	25-Year
23	12.85026900000	121.47159100000	0.68	0.84	0.16	Nona	Dec. 15, 2015	25-Year
24	12.85047000000	121.47668900000	0.5	0.69	0.19	Nona	Dec. 15, 2015	25-Year
25	12.85060100000	121.47688200000	0.42	0.56	0.14	Lando	October 2015	25-Year
26	12.85063400000	121.47488200000	0.25	0.16	-0.09	Ofel	October 2012	25-Year
27	12.85066300000	121.46846700000	0.7	0.52	-0.18	Ofel	October 2012	25-Year

28	12.85069600000	121.47016100000	0.95	0.75	-0.2	Nona	Dec. 15, 2015	25-Year
29	12.85074900000	121.46909700000	0.89	0.82	-0.07		Septem-ber 2013	25-Year
30	12.85084000000	121.46826400000	0.67	0.64	-0.03	Ofel	October 2012	25-Year
31	12.85094600000	121.46859900000	0.87	0.86	-0.01	Ofel	October 2012	25-Year
32	12.85107800000	121.47687800000	0.55	0.56	0.01	Nona	Dec. 15, 2015	25-Year
33	12.85105000000	121.46737500000	0.74	0.94	0.2	Nona	Dec. 15, 2015	25-Year
34	12.85123600000	121.47930000000	0.34	0.58	0.24	Nona	Dec. 15, 2015	25-Year
35	12.85126600000	121.48060400000	0.46	0.93	0.47			25-Year
36	12.85148400000	121.47893700000	0.21	0.55	0.34	Nona	Dec. 15, 2015	25-Year
37	12.85147100000	121.46879300000	0.61	0.73	0.12	Caloy	May 2006	25-Year
38	12.85160500000	121.46734700000	0.7	0.86	0.16			25-Year
39	12.85162100000	121.45958900000	2.51	0	-2.51			25-Year
40	12.85164600000	121.45948800000	2.4	0.29	-2.11	Nona	Dec. 15, 2015	25-Year
41	12.85170000000	121.46145500000	0.28	0.69	0.41	Nona	Dec. 15, 2015	25-Year
42	12.85173400000	121.46111600000	0.28	0	-0.28			25-Year
43	12.85183800000	121.47288700000	0.06	0	-0.06			25-Year
44	12.85181900000	121.46079700000	0.34	0	-0.34			25-Year
45	12.85198700000	121.46804500000	0.76	0.69	-0.07	Ofel	October 2012	25-Year
46	12.85189100000	121.43013000000	0.03	0.32	0.29	Caloy	May, 2005	25-Year
47	12.85189100000	121.43013000000	0.05	0.32	0.27	Caloy	May, 2005	25-Year
48	12.85307300000	121.45878100000	0.13	0	-0.13			25-Year
49	12.85688700000	121.45872200000	0.13	0.09	-0.04			25-Year
50	12.85722700000	121.45921600000	0.65	0.87	0.22	Ondoy	Sept. 26, 2009	25-Year
51	12.85747500000	121.46912900000	0.03	0.05	0.02	Nona	Dec. 15, 2015	25-Year
52	12.85753600000	121.46883200000	0.05	0.87	0.82	Ondoy	Sept. 26, 2009	25-Year
53	12.85763400000	121.45830700000	0.38	1.41	1.03	Nona	Dec. 15, 2015	25-Year
54	12.85785100000	121.46783700000	0.03	0.32	0.29	Nona	Dec. 15, 2015	25-Year
55	12.85794400000	121.45908100000	0.62	0.5	-0.12	Caloy	May 2006	25-Year

56	12.85799900000	121.46636200000	0.03	0.1	0.07	Nona	Dec. 15, 2015	25-Year
57	12.85798000000	121.45933700000	0.83	0.19	-0.64		2013	25-Year
58	12.85831100000	121.45226900000	0.13	0.5	0.37	Nona	Dec. 15, 2015	25-Year
59	12.85846200000	121.45962500000	0.9	0.52	-0.38	Yolan-da	Nov. 8, 2013	25-Year
60	12.85858800000	121.45972400000	0.89	0	-0.89	Nona	Dec. 15, 2015	25-Year
61	12.85867300000	121.45992900000	0.98	0.62	-0.36		2013	25-Year
62	12.85871000000	121.46342600000	0.03	0.41	0.38	Nona	Dec. 15, 2015	25-Year
63	12.85873400000	121.45907200000	0.44	0.26	-0.18	Caloy	May 2006	25-Year
64	12.85879300000	121.46221400000	0.11	0.75	0.64	Nona	Dec. 15, 2015	25-Year
65	12.85885500000	121.46128300000	0.03	1.05	1.02	Nona	Dec. 15, 2015	25-Year
66	12.85901600000	121.45953800000	0.51	0.69	0.18	Nona	Dec. 15, 2015	25-Year
67	12.85905200000	121.45907800000	0.27	0.09	-0.18		2011	25-Year
68	12.85918700000	121.45665000000	0.03	0	-0.03			25-Year
69	12.85927500000	121.45919700000	0.18	1.02	0.84	Nona	Dec. 15, 2015	25-Year
70	12.85947000000	121.46043100000	0.13	0.52	0.39	Yolan-da	Nov. 8, 2013	25-Year
71	12.85948800000	121.42250000000	0.03	0.5	0.47	Caloy	2007	25-Year
72	12.86043500000	121.42152000000	0.04	0.31	0.27	Nona	Decem-ber 2015	25-Year
73	12.86075300000	121.42112000000	0.19	0	-0.19			25-Year
74	12.86097300000	121.41956000000	0.18	0.6	0.42	Nona	Decem-ber 2015	25-Year
75	12.86113600000	121.42069000000	0.1	0	-0.1			25-Year
76	12.86134200000	121.41990000000	0.61	0	-0.61			25-Year
77	12.86160600000	121.41929000000	0.1	0	-0.1	Nona	Decem-ber 2015	25-Year
78	12.86186600000	121.41964400000	0.21	0	-0.21			25-Year
79	12.86189500000	121.41945000000	0.58	0	-0.58			25-Year
80	12.86195400000	121.41852000000	0.27	0.48	0.21	Nona	Decem-ber 2015	25-Year
81	12.86244000000	121.41859000000	0.61	0.94	0.33	Nona	Decem-ber 2015	25-Year
82	12.86285700000	121.41855000000	0.65	0.19	-0.46	Nona	Decem-ber 2015	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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