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

# LiDAR Surveys and Flood Mapping of Bangkerohan River


University of the Philippines Training Center for Applied Geodesy and Photogrammetry
Visayas State University
Department of Science and Technology


APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid Program and is to be cited as:

E.C. Paringit, and F. Morales, (Eds.). (2017), LiDAR Surveys and Flood Mapping of Bangkerohan River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry 201pp



For questions/queries regarding this report, contact:

**Engr. Florentino Morales, Jr.**
Project Leader, PHIL-LiDAR 1 Program
Visayas State University
Baybay, Leyte, Philippines 6521
ffmorales_jr@yahoo.com

**Enrico C. Paringit, Dr. Eng.**
Program Leader, PHIL-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-193-5

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ACRONYMS AND ABBREVIATIONS

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

# CHAPTER 1: OVERVIEW OF THE PROGRAM AND BANGKEROHAN RIVER

Enrico C. Paringit, Dr. Eng., and Engr. Florentino Morales, Jr.

## 1.1 Background of the Phil-LiDAR 1 Program

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

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

The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS" (Paringit, et. Al. 2017).

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU 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 28 river basins in the Eastern Visayas Region. The university is located in Baybay in the province of Leyte.

## 1.2 Overview of the Mainit-Tubay River Basin

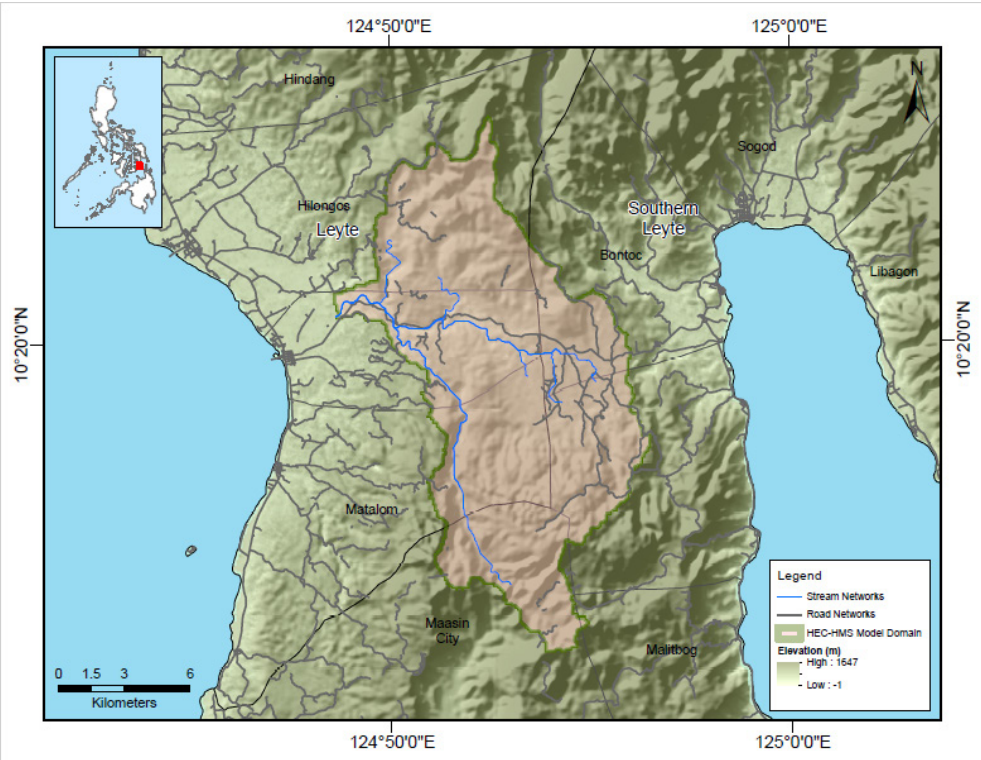



Figure 1. Map of the Bangkerohan River Basin (in brown)

The Bangkerohan River Basin covers the Municipalities of Bato, Hilangos, Bontoc and Matalom in the province of Leyte, and the Municipality of Tomas Oppus, and Maasin City in the province of Souther Leyte. According to DENR - River Basin Control Office, it has a drainage area of 2098 km2 and an estimated 397 million cubic meter (MCM) annual run-off (RCBO, 2015).

Its main stem, Bangkerohan River, is part of the 28 river systems under the PHIL-LiDAR 1 partner HEI, Visayas State University (VSU). According to the 2010 national census of NSO, a total of 10,856 persons are residing in the immediate vicinity of the river which are distributed among four (4) barangays in the Municipality of Bato and five (5) barangays in the Municipality of Hilangos. Bangkerohan River plays a vital role in providing irrigation to vast agricultural land in Hilongos and Bato as these municipalities have the biggest economy in the south-western part of Leyte Island. Their economy is heavily dependent on fishing industries and also agriculture, making them vulnerable whenever the river overflows. Last November 2013, Yolanda hit the area but not as destructive compare to what happened in Tacloban City. Flooding was said to be minimal and not that significant. In fact, refugees from Tacloban City was temporarily relocated in the Municipality of Hilongos where the Tent City was built (http://www.hilongos.com.ph/en/cityinfo,Cityinfo.html, 2015).

# 2CHAPTER 2: LIDAR DATA ACQUISITION OF THE BANGKEROHAN FLOODPLAIN

*Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Gladys Mae Apat , Engr. Merven Mattew D. Natino, Jovy Anne S. Narisma, Engr. Wilbert Ian M. San Juan , Nereo Joshua G. Pecson, Areanne Katrice K. Umali*

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

## 2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Bangkerohan floodplain in Leyte. These missions were planned for 16 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Bangkerohan floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

| Block Name | Flying Height (m AGL) | Overlap (%) | Field of view (ø) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK49 A | 600 | 30 | 36 | 70 | 50 | 120 | 5 |
| BLK49B | 600 | 30 | 36 | 70 | 50 | 120 | 5 |

Table 2. Flight planning parameters for Gemini LiDAR system

| Block Name | Flying Height (m AGL) | Overlap (%) | Field of view (ø) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK 34aA | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |
| BLK49 A | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |
| BLK49 B | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |
| BLK50 A | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |
| BLK50 B | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |
| BLK50 C | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |
| BLK50 D | 1000 | 30 | 36 | 100 | 50 | 125 | 5 |

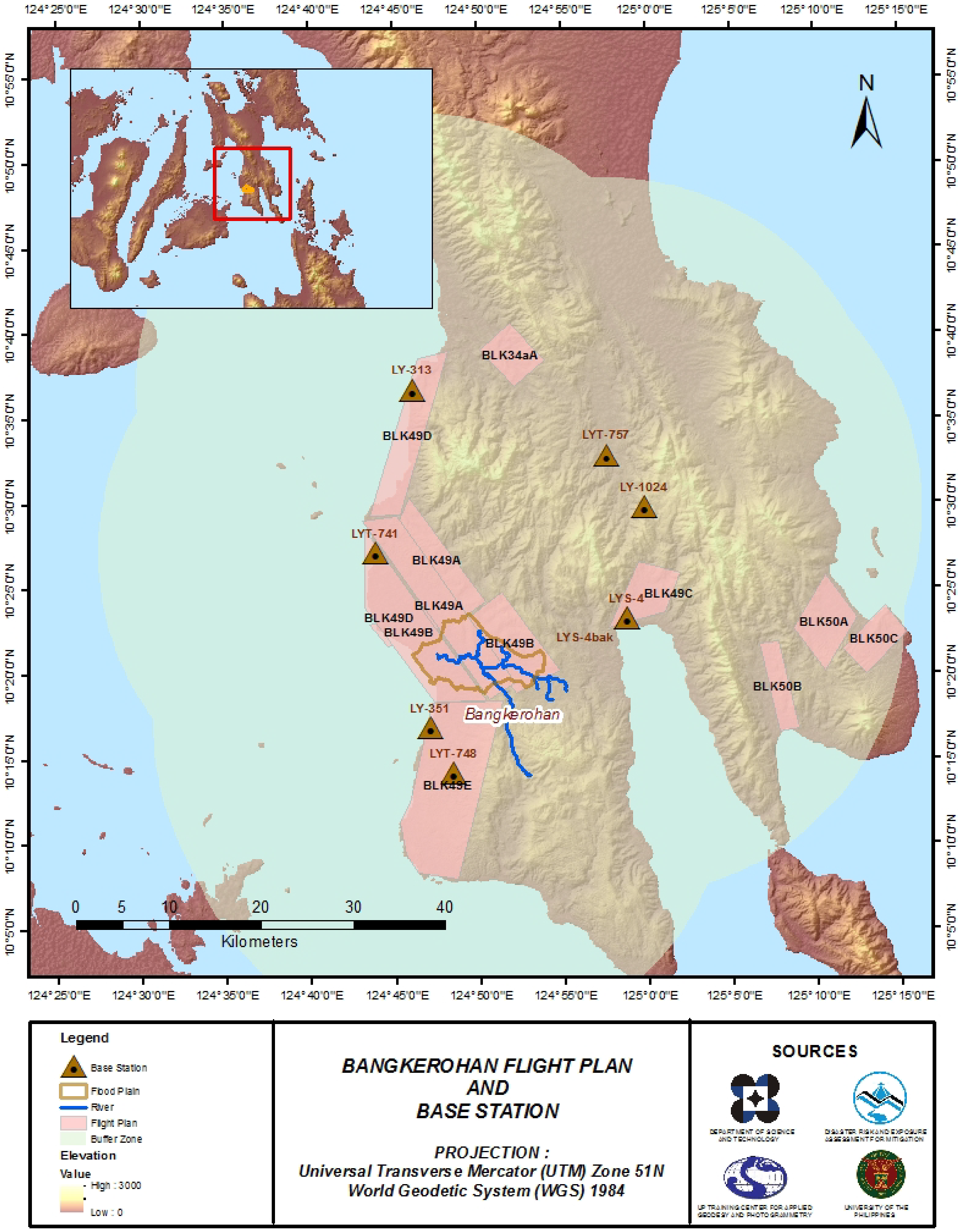



Figure 2. Flight plans and base stations used for Bangkerohan floodplain survey

## 2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA horizontal ground control points: LYT-93 and LYT-757 which are all of second (2nd) order accuracy. The project team also re-established ground control point LYT-104, a NAMRIA reference point of third 3rd order accuracy. Three (3) NAMRIA benchmarks were recovered: LY-199, LY-1024, and LY-110 which are all of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. 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 (May 8 -9, 2014 and January 24 -February 12, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Bangkerohan floodplain are shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area. Table 3 to Table 9 show the details about the following NAMRIA control stations and established points, while Table 10 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

(a)


(b)

Figure 3. GPS set-ip over LY-1024 located at the SE end of the sidewalk of Agas-agas Bridge (a) and NAMRIA refereence point LY-1024 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point LY-1024 used as base station for the LiDAR Acquisition

| Station Name | LY-1024 | |
|---|---|---|
| Order of Accuracy | 1st Order | |
| Relative Error (Horizontal positioning) | 1:100,000 | |
| Geographic Coordinates,<br>Philippine Reference of 1992 Datum<br>(PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10° 29’ 46.27” North<br>124° 59’ 49.85” East<br>366.202 m |
| Grid Coordinates,<br>Philippine Transverse Mercator Zone 5<br>(PTM Zone 5 PRS 92) | Easting<br>Northing | |
| Geographic Coordinates,<br>World Geodetic System 1984 Datum<br>(WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10° 29’ 42.20218” North<br>124° 59’ 55.07713” East<br>430.223 m |
| Grid Coordinates,<br>Philippine Transverse Mercator Zone 51 North<br>(UTM 51N PRS 1992) | Easting<br>Northing | 718586.237 m<br>1160895.197 m |

(a)

(b)

Figure 4. GPS set-up over LYT-757 as recovered on the opposite side of the kilometer post 997 in barangay Mahayahay, Leyte (a) and NAMRIA reference point LYT-757 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point LYT-757 used as base station for the LiDAR acquisition

| Station Name | LYT-757 | |
|---|---|---|
| Order of Accuracy | 2nd Order | |
| Relative Error (Horizontal positioning) | 1:50,000 | |
| Geographic Coordinates,<br>Philippine Reference of 1992 Datum<br>(PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10° 32’ 54.87” North<br>124° 57’ 31.14” East<br>99.55 m |
| Grid Coordinates,<br>Philippine Transverse Mercator Zone 5<br>(PTM Zone 5 PRS 92) | Easting<br>Northing | 495474.491 m<br>1166401.318 m |
| Geographic Coordinates,<br>World Geodetic System 1984 Datum<br>(WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10° 32’ 50.77355” North<br>124o 57’ 36.36037” East<br>163.36300 m |
| Grid Coordinates,<br>Philippine Transverse Mercator Zone 51 North<br>(UTM 51N PRS 1992) | Easting<br>Northing | 714331.34 m<br>1166663.62 m |

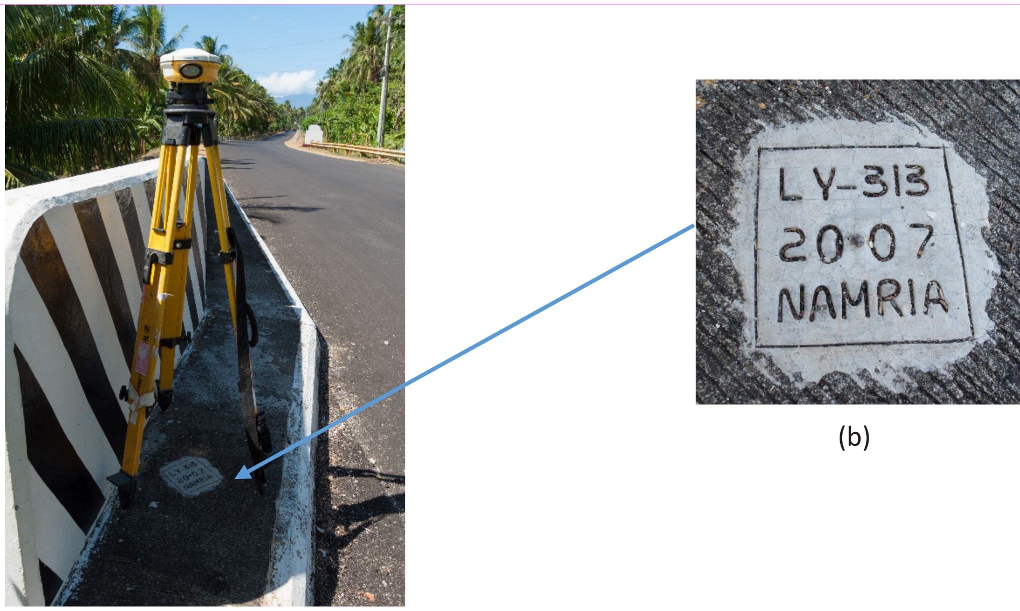
(a)


(b)

Figure 5. GPS set-up over LYT-748 as recovered at the back of Hitoog Elementary School, Brgy. Hitoog, Municipality of Matalom, Leyte (a) and NAMRIA reference point LYT-748 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point LYT-748 used as base station for the LiDAR acquisition

| Station Name | LYT-748 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (Horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates,<br>Philippine Reference of 1992 Datum<br>(PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°14’16.77457”<br>124°48’19.08041”<br>77.51500 meters |
| Grid Coordinates,<br>Philippine Transverse Mercator Zone 5<br>(PTM Zone 5 PRS 92) | Easting<br>Northing | 478669.714 meters<br>1132057.716 meters |
| Geographic Coordinates,<br>World Geodetic System 1984 Datum<br>(WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°14’12.74720” North<br>124°48’24.32650” East<br>141.66500 meters |
| Grid Coordinates,<br>Philippine Transverse Mercator Zone 51 North<br>(UTM 51N PRS 1992) | Easting<br>Northing | 697740.37 meters<br>1132208.87 meters |




(a) (b)

Figure 6. GPS set-up over LY-313 as recovered in Brgy. Pandan, Baybay, Leyte (a) and NAMRIA reference point LY-313 (b) as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point LY-313 used as base station for the LiDAR acquisition

| Station Name | LY-313 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (Horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°36'46.67221"<br>124°46'01.67926"<br>6.279 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 693326.992 meters<br>1173661.007 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°36'42.54525" North<br>124°46'06.89257" East<br>64.460 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 4054.782 meters<br>17681.110 meters |


(a) (b)

Figure 7. GPS set-up over LYT-741 as recovered in Brgy. Doos Del Norte, Hindang, Leyte (a) and NAMRIA reference point LYT-741 (b) as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point LYT-741 used as base station for the LiDAR acquisition

| Station Name | LYT-741 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (Horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°27'11.95722''<br>124°43' 45.08400''<br>4.48300 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 470351.659 meters<br>1155878.867 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°27'7.86786'' North<br>124°43'50.31177" East<br>67.94500 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 689272.22 meters<br>1155979.90 meters |

Table 8. Details of the recovered NAMRIA horizontal control point LY-351 used as base station for the LiDAR acquisition

| Station Name | LY-351 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (Horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°16'52.30167''<br>124°47'03.77264''<br>4.48300 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 695421.839 meters<br>1136974.636 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°16'48.26132'' North<br>124°47'09.01515" East<br>70.885 meters |

Table 9. Details of the recovered NAMRIA horizontal control point LYS-4 used as base station for the LiDAR acquisition

| Station Name | LYS-4 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (Horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°23'20.19669''<br>124°58'38.53353''<br>15.25600 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 497522.022 meters<br>1148746.143 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 10°23'16.14540'' North<br>124°58'43.76469" East<br>79.47900 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 716491.34 meters<br>1149017.84 meters |

Table 10. Ground control points used during LiDAR data acquisition

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| February 12, 2016 | 3781G | 2BLK34A043A | LY-1024 & LYT-757 |
| April 10, 2016 | 3921G | 2BLK34a101A | LY-313 & LYT-741 |
| April 10, 2016 | 3923G | 2BLK49AB101B | LY-313 & LYT-741 |
| April 11, 2016 | 3925G | 2BLK49DE102A | LY-313 & LYT-741 |
| April 14, 2016 | 3937G | 2BLK50DS105A | LYS-4 & LYS-4 |
| January 22, 2015 | 7754AC | 3BLK49B022A | LYT-748 & LY-351 |
| January 23, 2015 | 7756AC | 3BLK49A023A | LYT-748 & LY-351 |

## 2.3 Flight Missions

Seven (7) missions were conducted to complete LiDAR data acquisition in Bangkerohan Floodplain, for a total of twenty eight hours and six minutes (28+6) of flying time for RP-C9122 and RP-C9322. All missions were acquired using Aquarius and Gemini LiDAR systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

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

| Date Surveyed | Flight Number | Flight Plan Area (km²) | Surveyed Area (km²) | Area Surveyed within the Floodplain (km²) | Area Surveyed Outside the Floodplain (km²) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| February 12, 2016 | 3781G | 76.83 | 98.64 | 11.7 | 86.94 | 315 | 3 | 23 |
| April 10, 2016 | 3921G | 116.67 | 65.7 | 25.05 | 131.66 | NA | 4 | 27 |
| April 10, 2016 | 3923G | 92.9 | 208.28 | 25.06 | 183.22 | NA | 2 | 48 |
| April 11, 2016 | 3925G | 152.03 | 76.02 | 5.72 | 70.31 | NA | 4 | 20 |
| April 14, 2016 | 3937G | 167.53 | 95.63 | 0 | 95.63 | NA | 4 | 40 |
| January 22, 2015 | 7754AC | 86.31 | 101.85 | 21.61 | 80.24 | NA | 4 | 35 |
| January 23, 2015 | 7756AC | 76.83 | 90.31 | 30.61 | 59.69 | NA | 3 | 53 |
| TOTAL | | 769.1 | 736.43 | 119.75 | 707.69 | 315 | 24 | 246 |

Table 12. Actual parameters used during LiDAR acquisition

| Flight Number | Flying Height (m AGL) | Overlap (%) | Field of View (θ) | Pulse Repetition Frequency (kHz) | Scan Frequency (Hz) | Average Speed (Kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 3781G | 1000 | 30 | 40 | 100 | 50 | 120 | 5 |
| 3921G | 1000 | 30 | 40 | 100 | 50 | 120 | 5 |
| 3923G | 1200 | 30 | 40 | 100 | 50 | 120 | 5 |
| 3925G | 1200 | 30 | 40 | 100 | 50 | 120 | 5 |
| 3937G | 1000 | 30 | 40 | 100 | 50 | 120 | 5 |
| 7754AC | 600 | 30 | 36 | 70 | 50 | 120 | 5 |
| 7756AC | 600 | 30 | 36 | 70 | 50 | 120 | 5 |

## 2.4 Survey Coverage

Bangkerohan floodplain is located in the province of Leyte with majority of the floodplain situated within the municipality of Bato. Municipalities of Hilongos and Hindang are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Bangkerohan floodplain is presented in Figure 8.

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

| Province | Municipality/ City | Area of Municipality/City (km²) | Total Area Surveyed (km²) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Leyte | Bato | 57.55 | 57.52 | 100 |
| | Hilongos | 156.8 | 120.09 | 77 |
| | Hindang | 106.77 | 51.9 | 49 |
| | Matalom | 110.13 | 25.48 | 23 |
| | Abuyog | 256.63 | 39.62 | 15 |
| | Mahaplag | 180.3 | 24.78 | 14 |
| | Inopacan | 196.05 | 25.18 | 13 |
| | Baybay City | 404.37 | 48.82 | 12 |
| Southern Leyte | Hinundayan | 53.28 | 17.84 | 33 |
| | Sogod | 217.2 | 40 | 18 |
| | Hinunangan | 136.38 | 24.56 | 18 |
| | Maasin City | 206.86 | 30.21 | 15 |
| | Bontoc | 89.13 | 8.83 | 10 |
| Total | | 2171.45 | 514.83 | 23.71% |

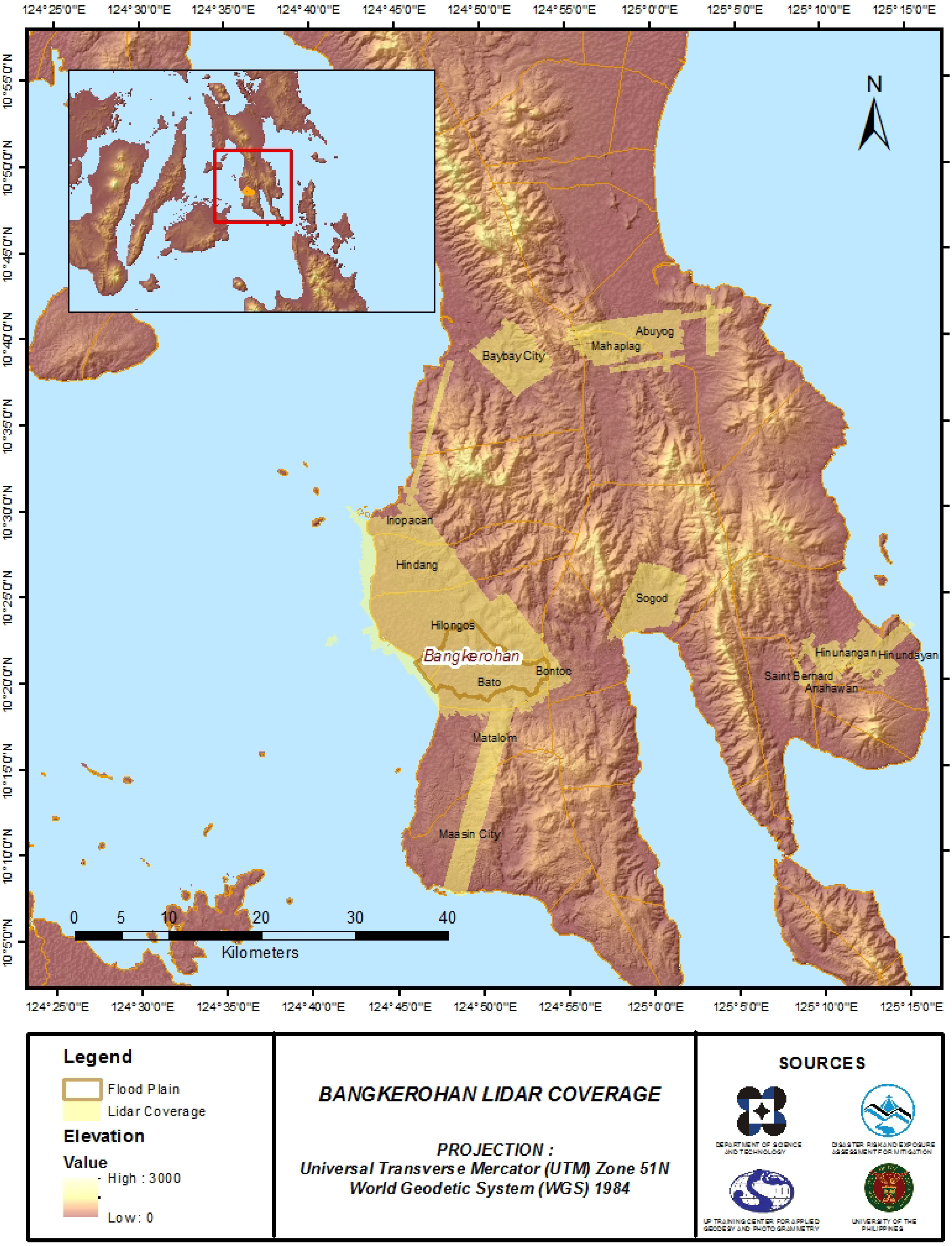



Figure 8. Actual LiDAR survey coverage for Bangkerohan floodplain

# CHAPTER 3: LIDAR DATA PROCESSING FOR BANGKEROHAN FLOODPLAIN

*Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Gladys Mae Apat , Engr. Merven Mattew D. Natino, Jovy Anne S. Narisma, Engr. Wilbert Ian M. San Juan , Nereo Joshua G. Pecson, Areanne Katrice K. Umali*

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

## 3.1 LiDAR Data Processing for Bangkerohan Floodplain

### 3.1.1 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 9.

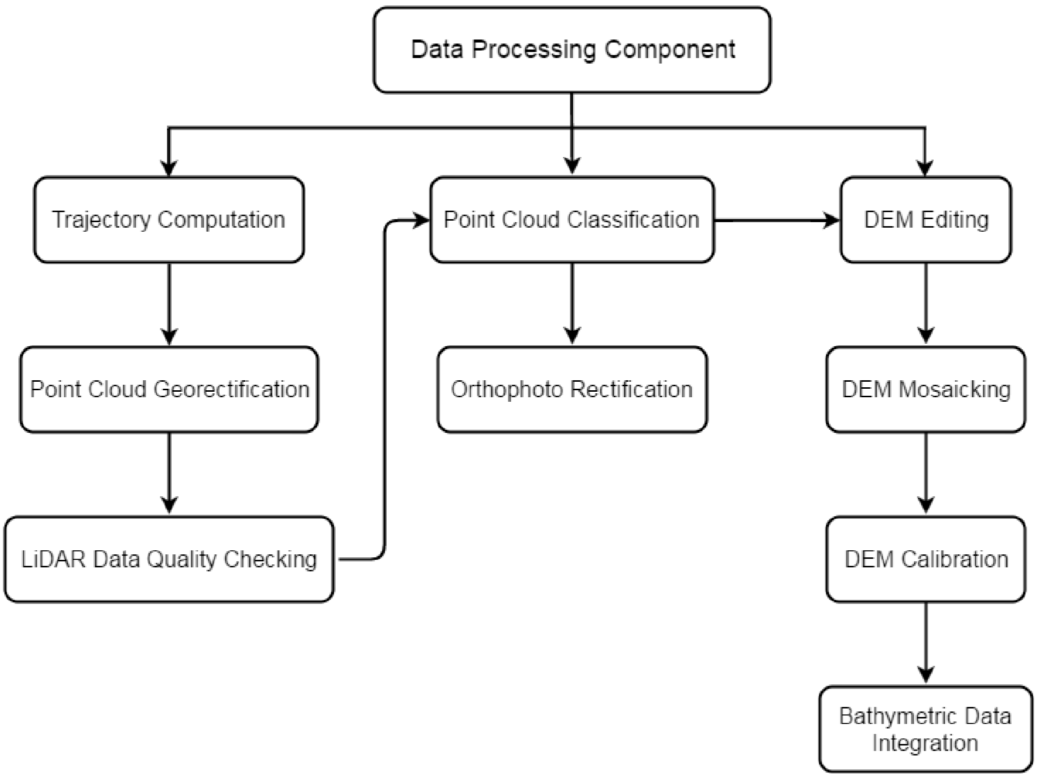



Figure 9.Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Bangkerohan floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on January 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on February 2016 were flown using the Gemini system over Bato, Leyte. The Data Acquisition Component (DAC) transferred a total of 93.46 Gigabytes of Range data, 1.72 Gigabytes of POS data, and 163.35 Megabytes of GPS base station data to the data server on April 16, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Bangkerohan was fully transferred on May 6, 2014, as indicated on the Data Transfer Sheets for Bangkerohan floodplain.

## 3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7756AC, one of the Bangkerohan flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on January 23, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

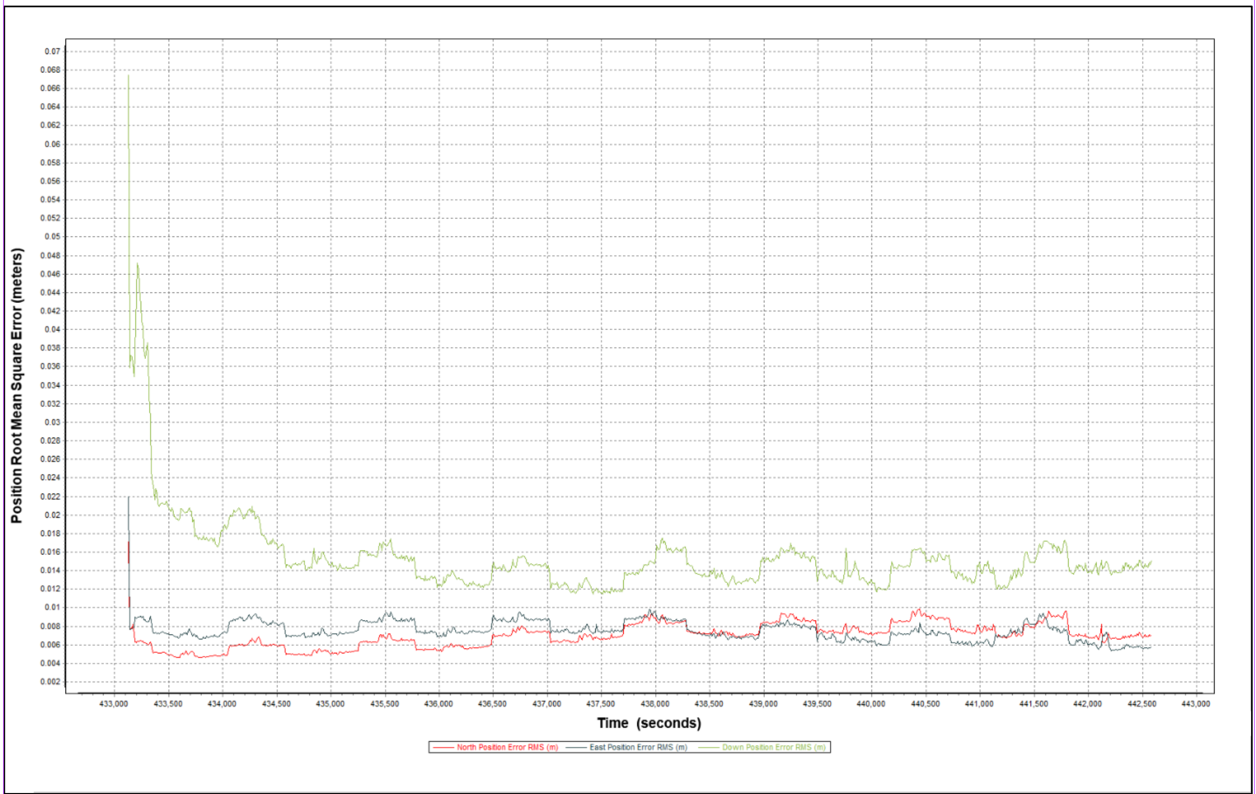



Figure 10. Smoothed Performance Metrics of a Bangkerohan Flight 7756AC

The time of flight was from 433000 seconds to 442500 seconds, which corresponds to morning of January 21, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1.10 centimeters, and the Down position RMSE peaks at 3.0 centimeters, which are within the prescribed accuracies described in the methodology.

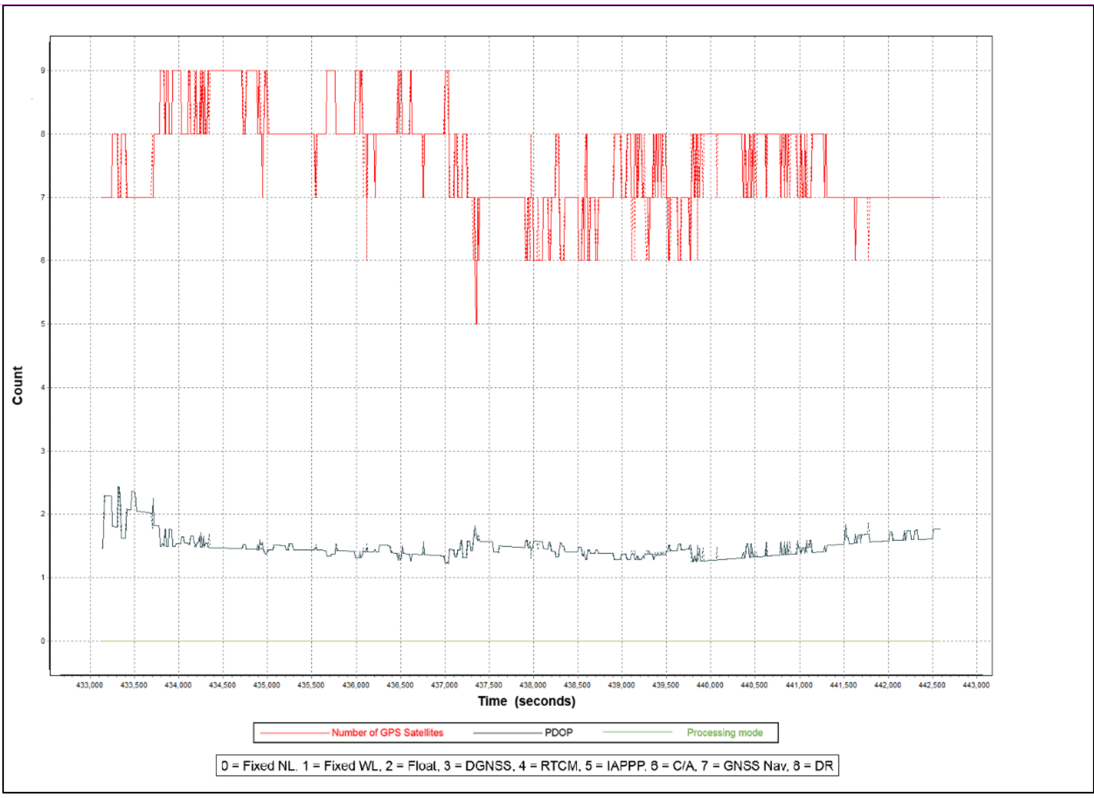



Figure 11. Solution Status Parameters of Bangkerohan Flight 7756AC

The Solution Status parameters of flight 7756AC, one of the Bangkerohan flights, which inidicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Most 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 remained at 0 for majority of the survey. 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 Bangkerohan flights is shown in Figure 12.

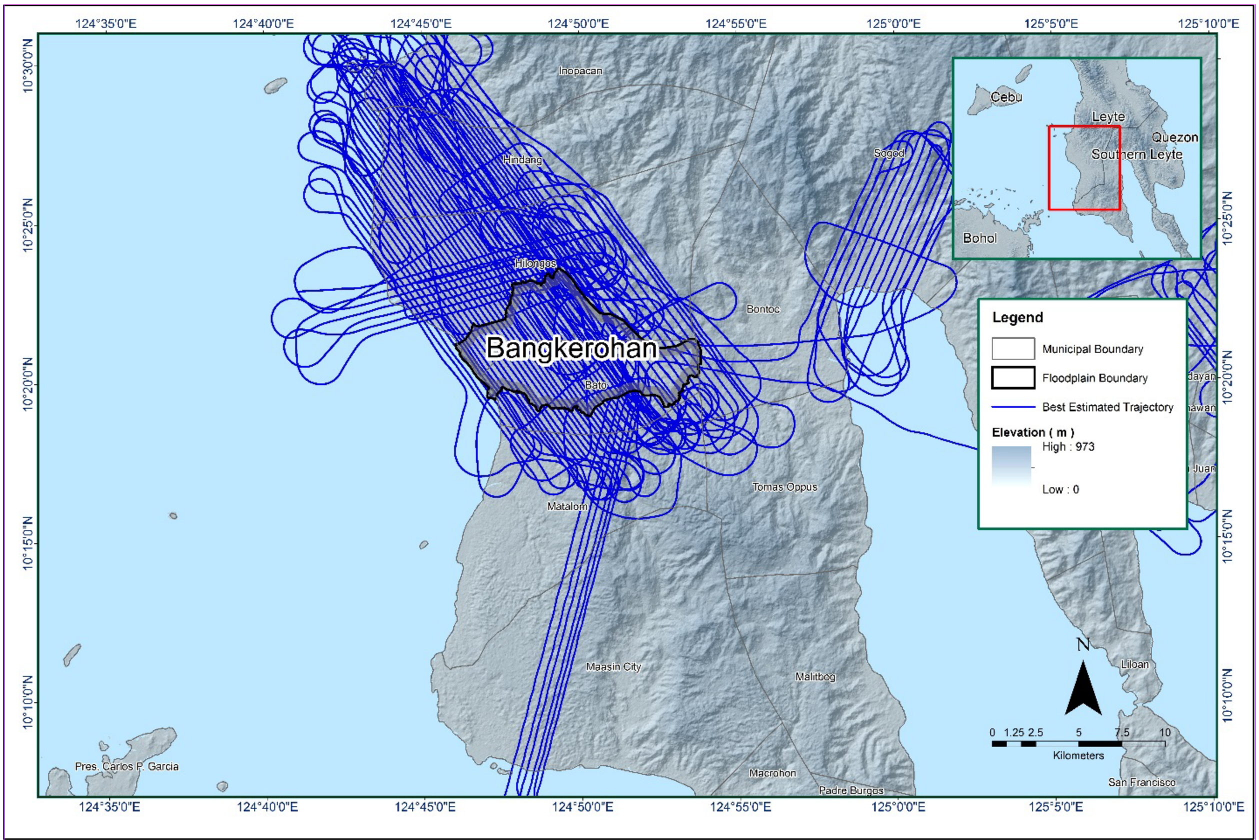



Figure 12. The best estimated trajectory of the LiDAR missions conducted over the Bangkerohan floodplain

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 85 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems 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 Bangkerohan floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Bangkerohan flights

| Parameter | Value |
|---|---|
| Boresight Correction stdev(<0.001degrees) | 0.000260 |
| IMU Attitude Correction Roll and Pitch Corrections stdev(<0.001degrees) | 0.000627 |
| GPS Position Z-correction stdev(<0.01meters) | 0.0095 |

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

## 3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Bangkerohan Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

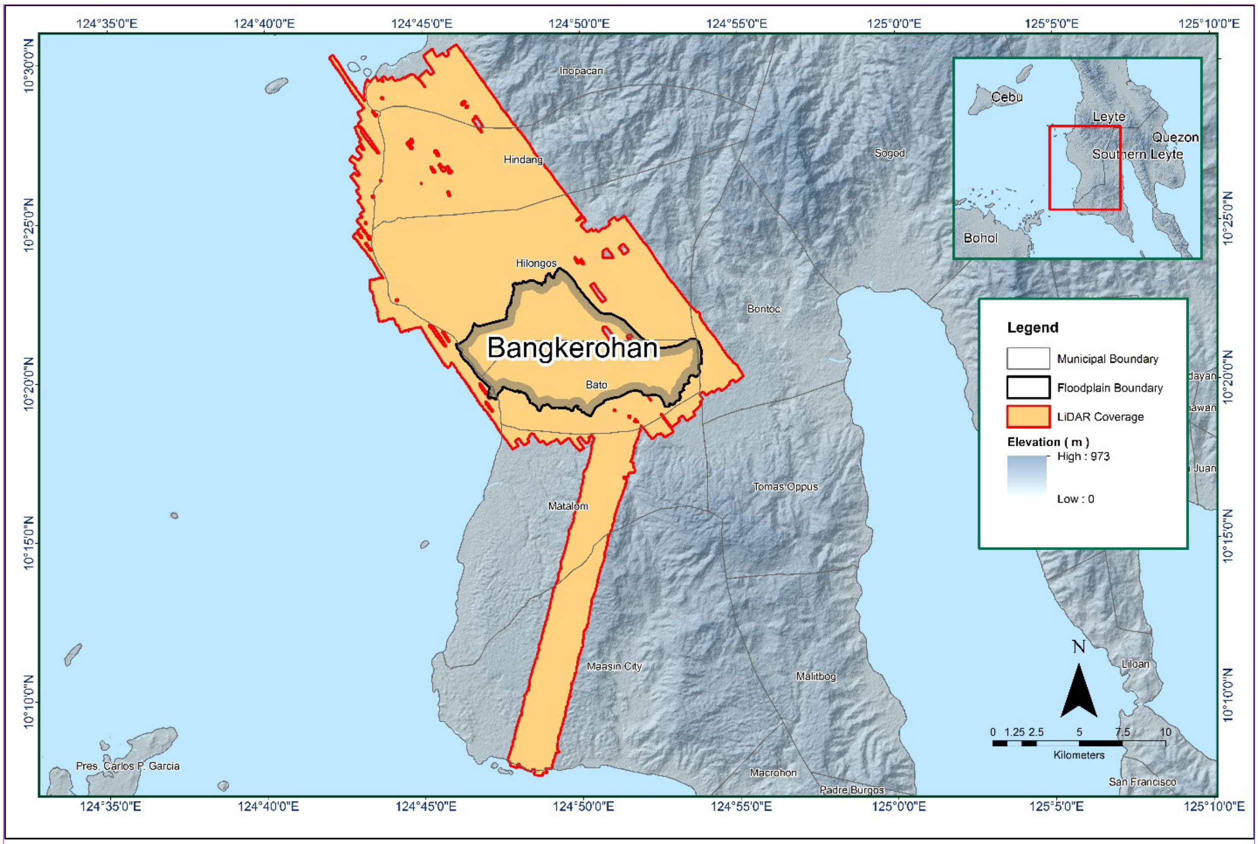



Figure 13. Boundary of the processed LiDAR data over Bangkerohan Floodplain

The total area covered by the Bangkerohan missions is 435.31 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into six (6) blocks as shown in Table B-2.

Table 15. List of LiDAR blocks for Bangkerohan floodplain

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Leyte_Blk49A_additional | 3781G | 27.17 |
| Ormoc_Blk49A | 7756AC | 84.37 |
| Ormoc_Blk49B | 7754AC | 95.46 |
| Ormoc_South_Blk49A | 3921G | 117.63 |
| | 3923G | |
| Ormoc_South_Blk49A_additional | 3925G | 28.9 |
| Ormoc_South_Blk49B | 3925G | 31.64 |
| Ormoc_South_Blk49E | 3937G | 50.14 |
| **TOTAL** | | **578.26 sq.km** |

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Gemini and Aquarius systems 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.

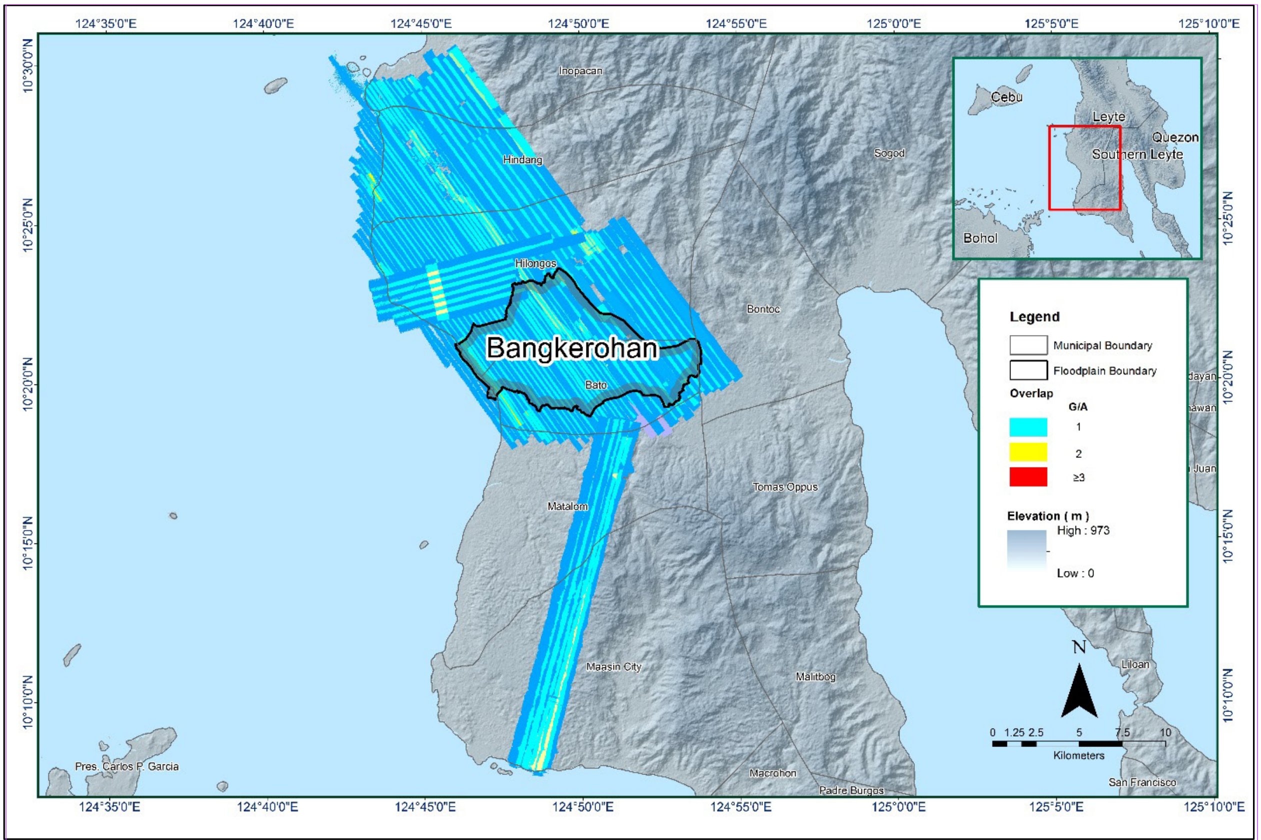



Figure 14. Image of data overlap for Bangkerohan floodplain

The overlap statistics per block for the Bangkerohan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 31.34% and 44.81% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Bangkerohan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.91 points per square meter.

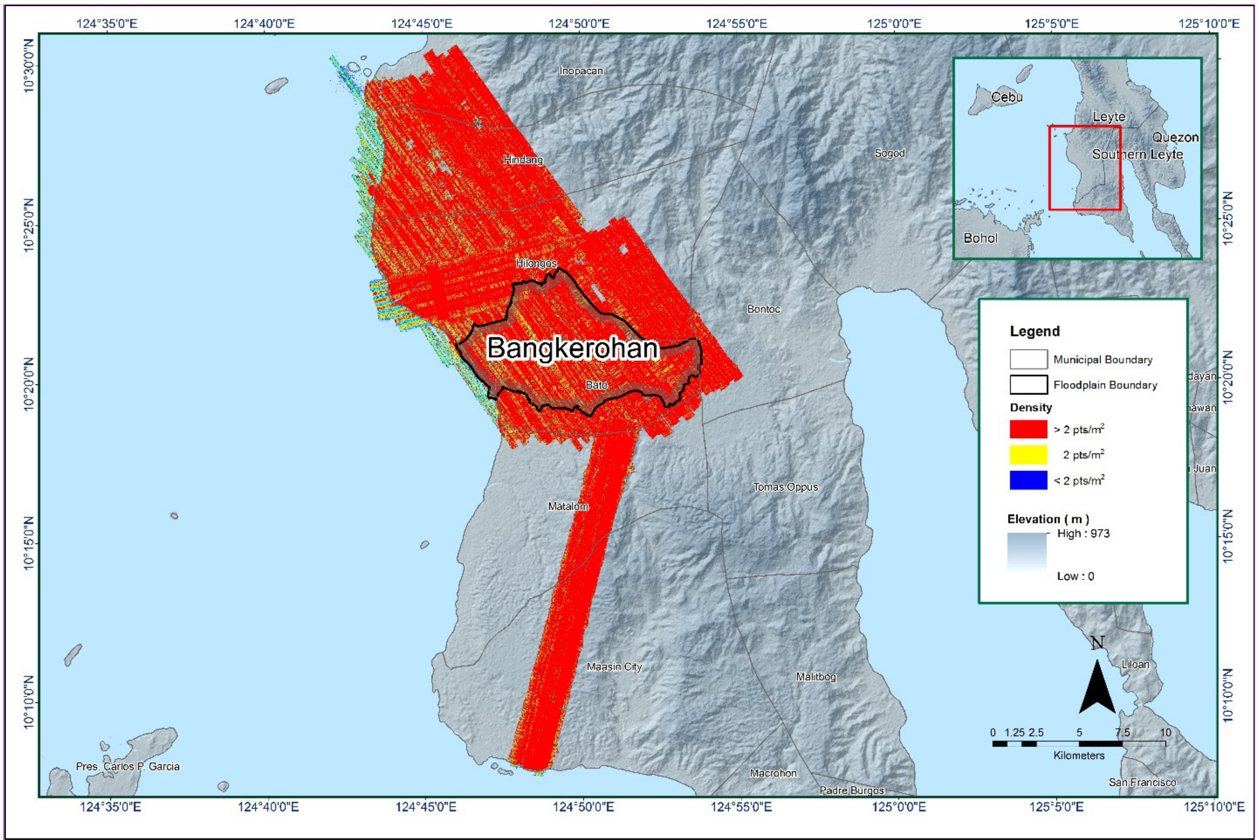



Figure 15. Density map of merged LiDAR data for Bangkerohan floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m 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.

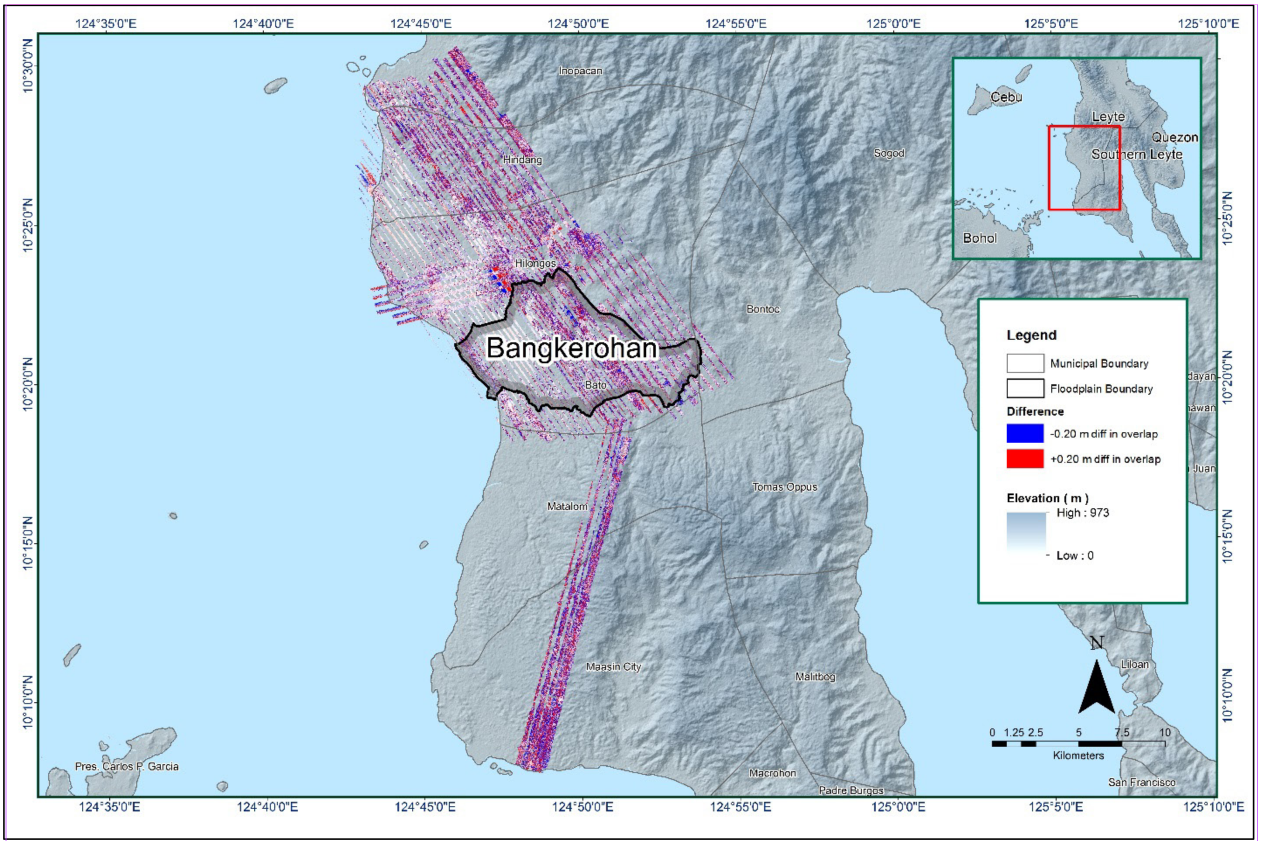



Figure 16. Elevation difference map between flight lines for Bangkerohan floodplain

A screen capture of the processed LAS data from a Bangkerohan flight 7756AC loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

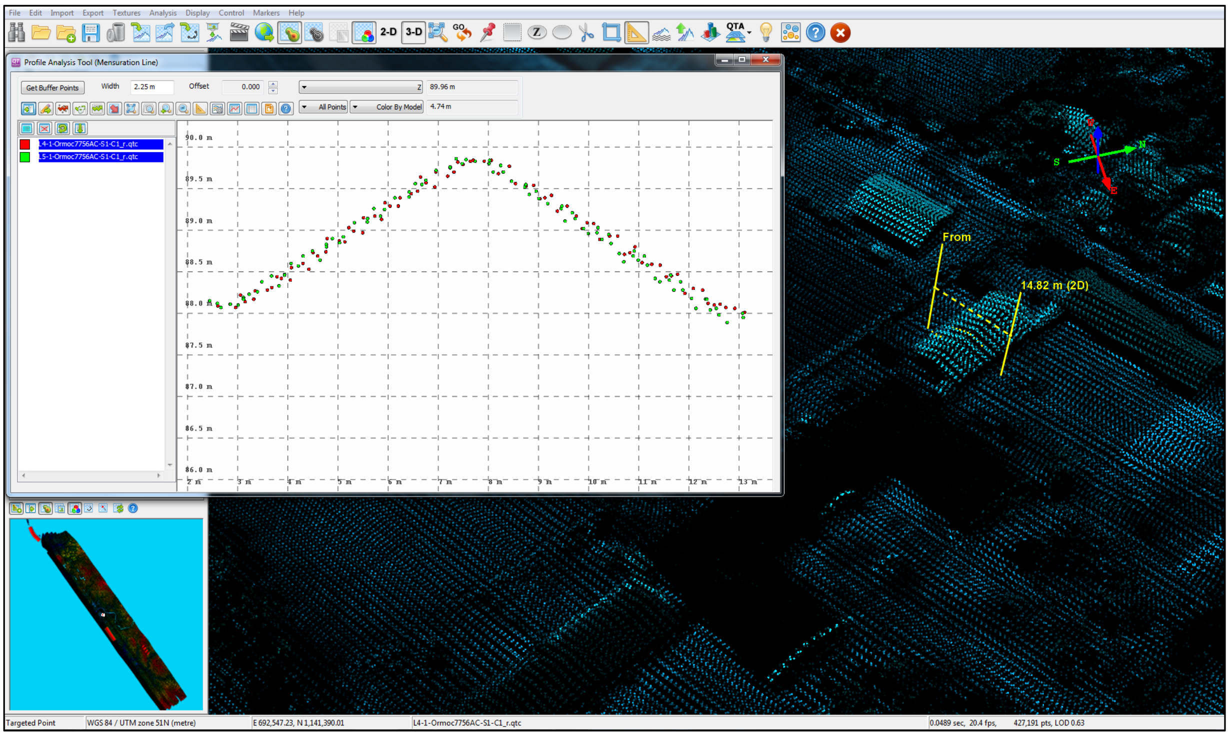



Figure 17. Quality checking for a Bangkerohan flight 7756AC using the Profile Tool of QT Modeler

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Bangkerohan classification results in TerraScan

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 240,000,002 |
| Low Vegetation | 257,736,005 |
| Medium Vegetation | 506,678,013 |
| High Vegetation | 675,281,411 |
| Building | 15,297,141 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Bangkerohan floodplain is shown in Figure 18. A total of 701 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 593.04 meters and 52.98 meters respectively.

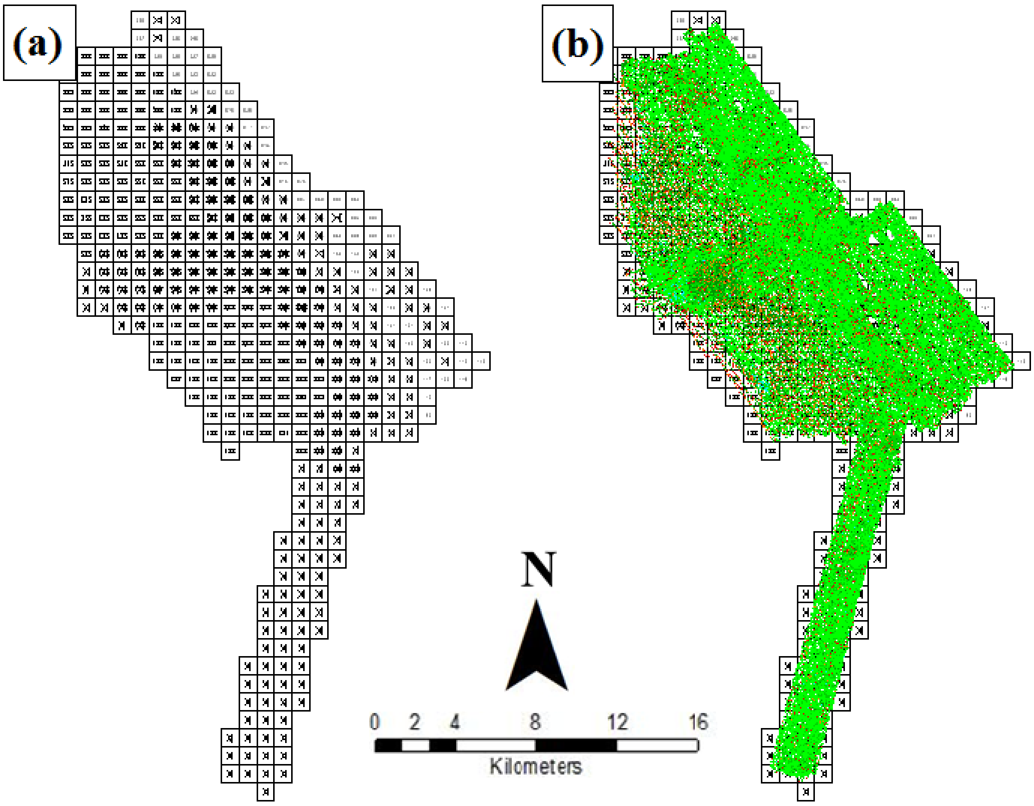



Figure 18. Tiles for Bangkerohan floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

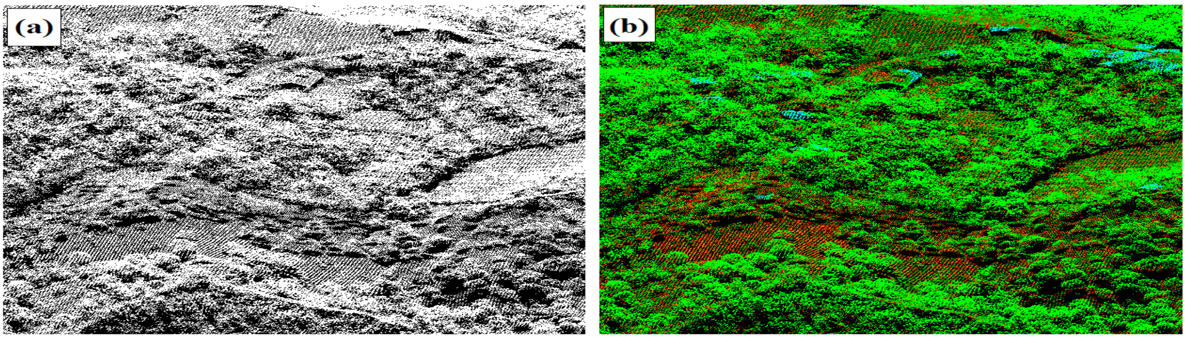


Figure 19. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

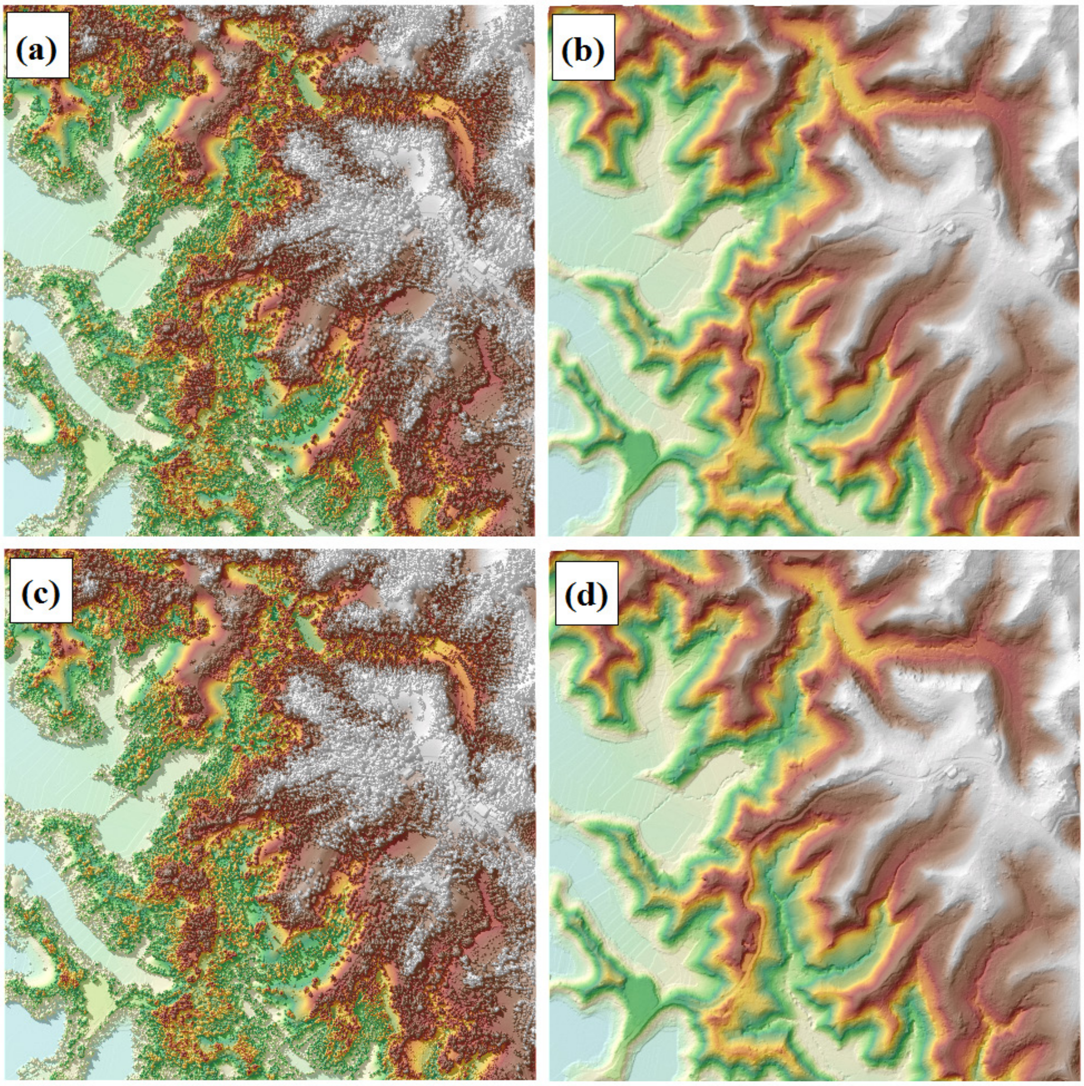


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Bangkerohan floodplain.

## 3.7LiDAR Image Processing and Orthophotograph Rectification

The 55 1km by 1km tiles area covered by Bangkerohan floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Bangkerohan floodplain survey attained a total of 15.33 km2 in orthophotogaph coverage, comprised of 67 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

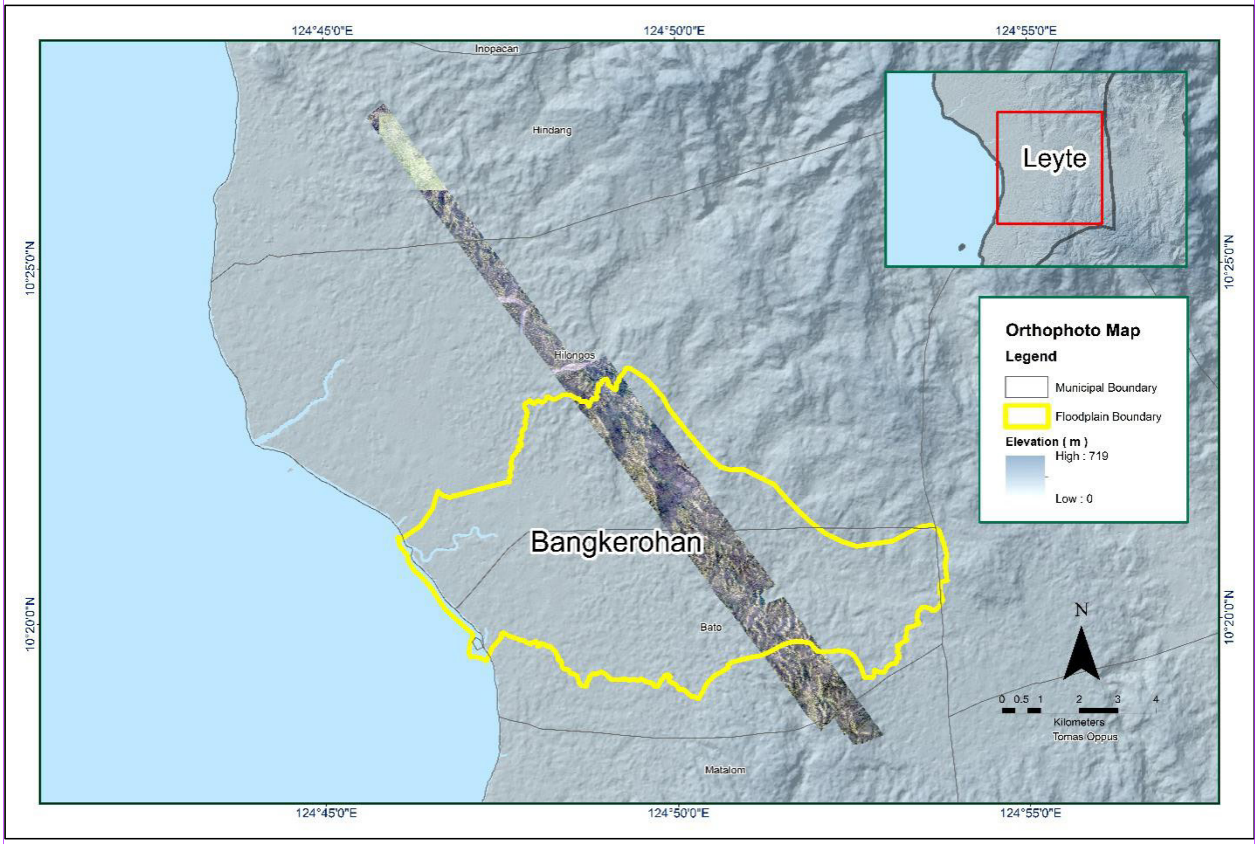



Figure 21. Bangkerohan floodplain with available orthophotographs

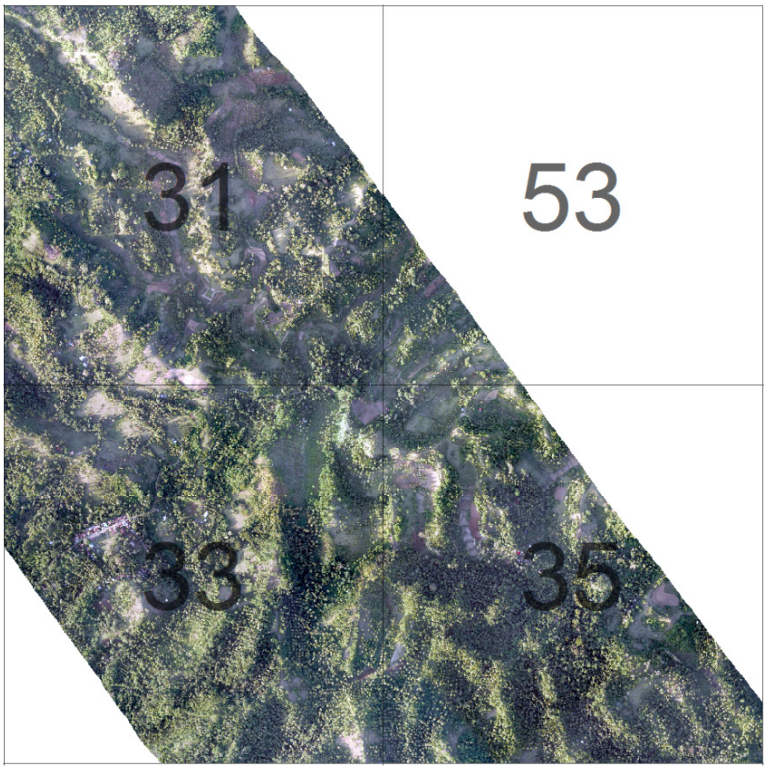



Figure 22. Sample orthophotograph tiles for Bangkerohan floodplain

## 3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Bangkerohan flood plain. These blocks are composed of Leyte, Ormoc and Ormoc_South blocks with a total area of 435.31 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area

| LiDAR Blocks | Area (sq.km) |
|---|---|
| Leyte_Blk49A_Additional | 27.17 |
| Ormoc_Blk49A | 84.37 |
| Ormoc_Blk49B | 95.46 |
| Ormoc_South_Blk49A | 117.63 |
| Ormoc_South_Blk49B | 31.64 |
| Ormoc_South_Blk49A_Additional | 28.90 |
| Ormoc_South_Blk49E | 50.14 |
| **TOTAL** | **435.31 sq.km** |

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. The river embankment (Figure 23c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23d) to allow the correct flow of water. Water surfaces with no data also have to be interpolated by manual editing.

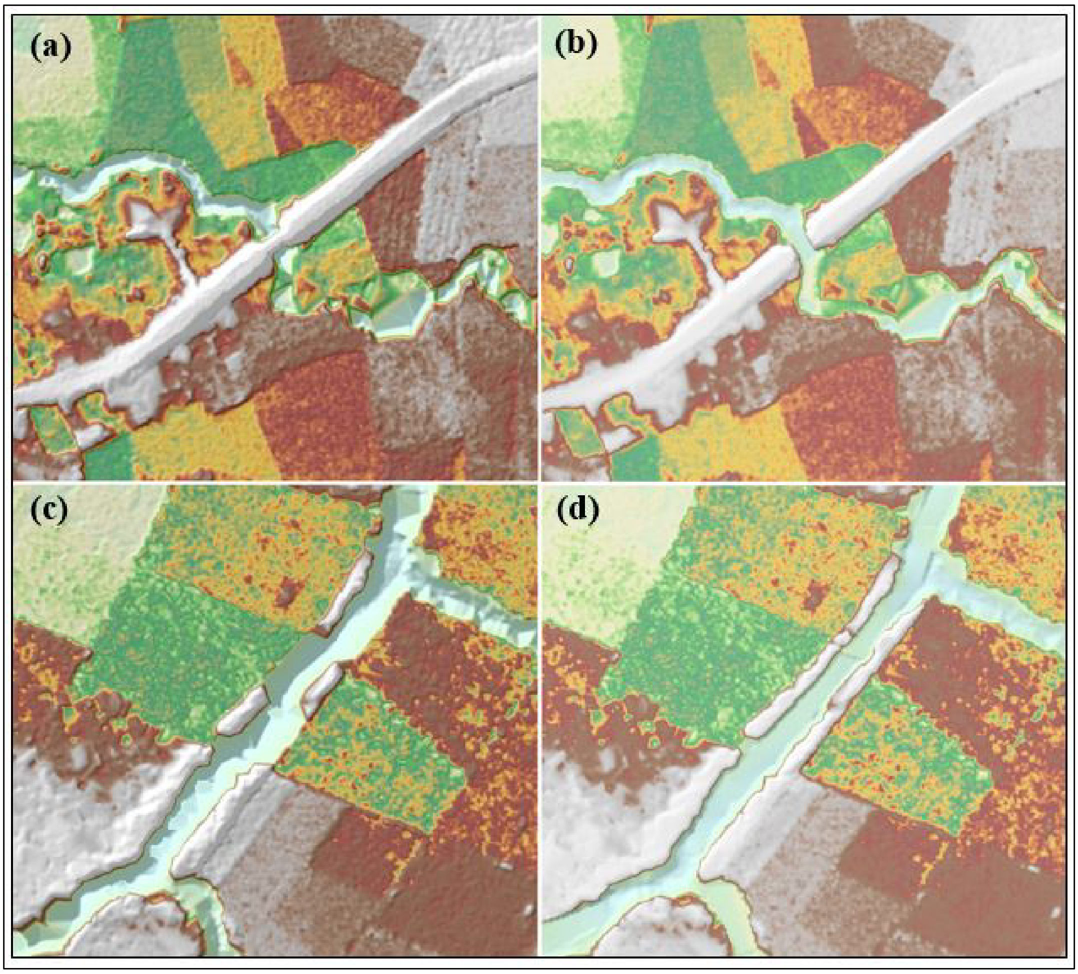



Figure 23. Portions in the DTM of Bangkerohan floodplain – a bridge before (a) and after (b) manual editing; a terrain before (c) and after (d) interpolation; and a building before (e) and after (f) manual editing

## 3.9 Mosaicking of Blocks

Ormoc_Blk49B was used as the reference block at the start of mosaicking because this block was made available for editing and mosaicking before the other blocks. Table 18 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Bangkerohan floodplain is shown in Figure 24. It can be seen that the entire Bangkerohan floodplain is 99.38% covered by LiDAR data.

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

| Mission Blocks | Shift Values | | |
|---|---|---|---|
| | x | y | z |
| Ormoc_Blk49B | -1.00 | -1.00 | -0.15 |
| Ormoc_Blk49A | 0.00 | -1.00 | -0.15 |
| Ormoc_South_Blk49B | -1.00 | -0.50 | 0.00 |
| Ormoc_South_Blk49A_Additional | 0.00 | -1.00 | -0.29 |
| Leyte_Blk49A_Additional | 0.00 | -1.00 | -0.11 |
| Ormoc_South_Blk49A | 0.00 | -1.00 | -0.63 |
| Ormoc_South_Blk49E | 0.00 | -1.00 | -0.81 |


Figure 24 . Map of Processed LiDAR Data for Bangkerohan Flood Plain

## 3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ormoc City and Bato Municipality to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 25,710 survey points were gathered for all the flood plains within Ormoc City and Bato Municipality wherein Bangkerohan is located. Random selection of 80% of the survey points, resulting to 20,568 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.26 meters with a standard deviation of 0.19 meters. Calibration of the LiDAR data was done by adding the height difference value, 0.26 meters, to the mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

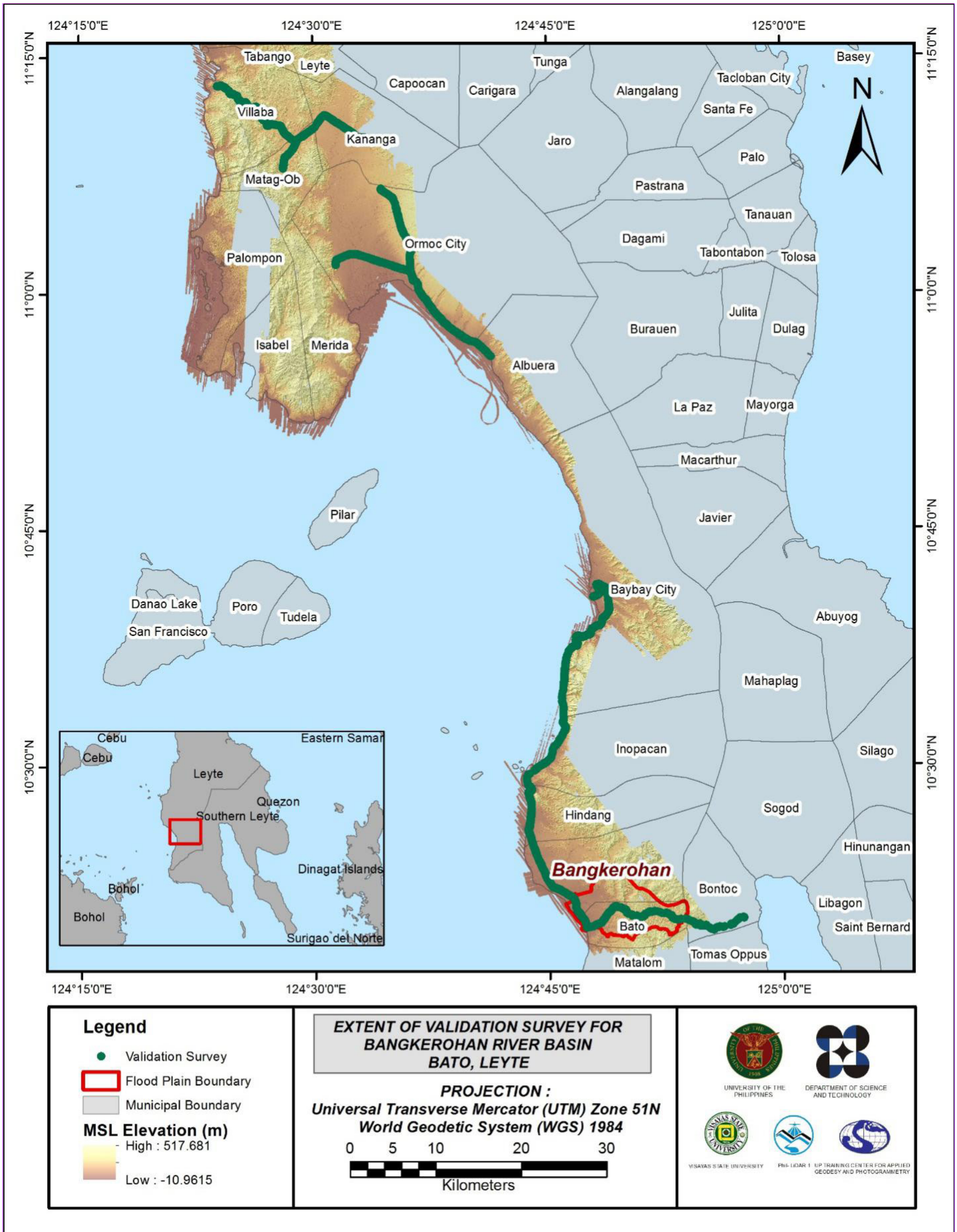



Figure 25. Map of Bangkerohan Flood Plain with validation survey points in green

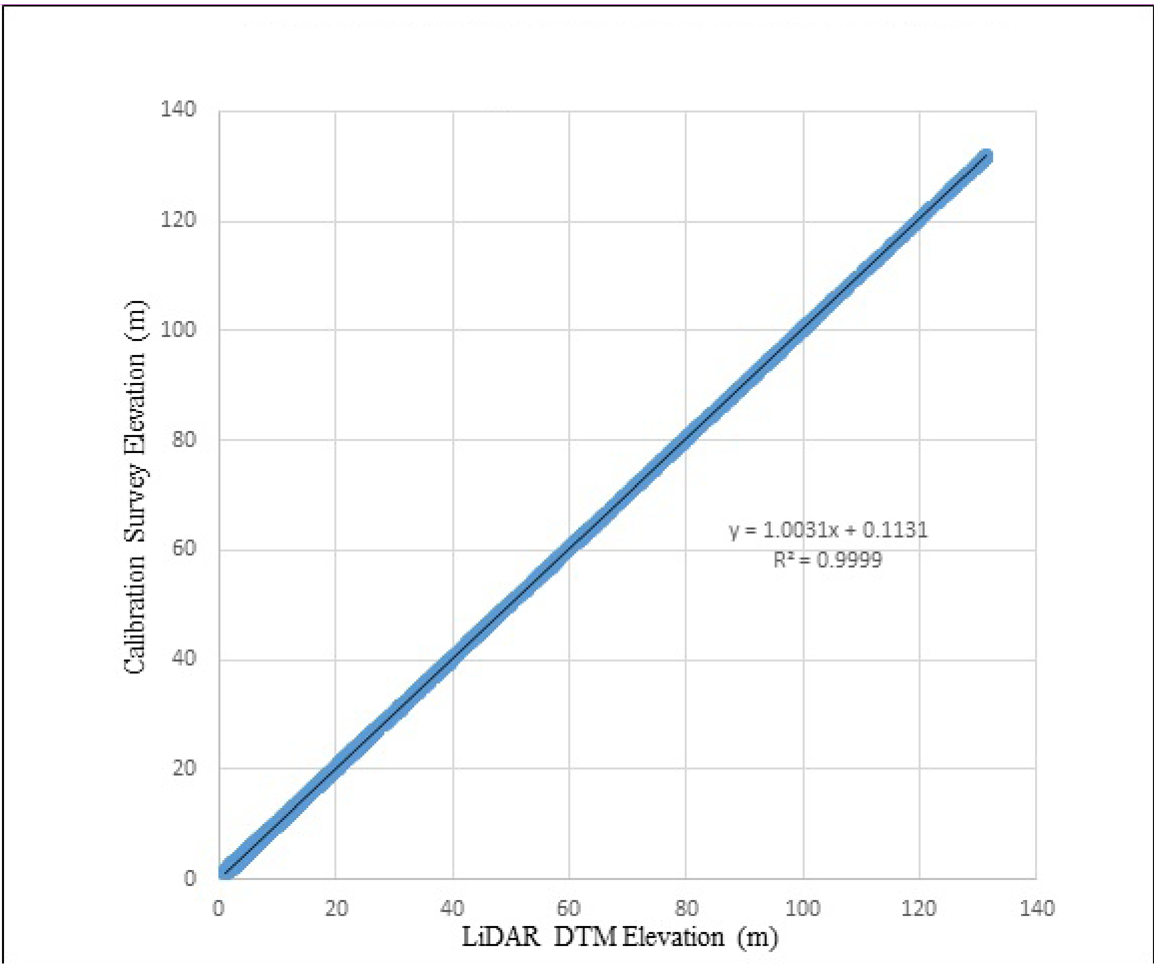



Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 19. Calibration Statistical Measures

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 0.26 |
| Standard Deviation | 0.19 |
| Average | 0.16 |
| Minimum | -0.30 |
| Maximum | 0.60 |

The remaining 20% of the total survey points, resulting to 5,142 points, were used for the validation of calibrated Salug DTM. The good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.18 meters, as shown in Table 20.

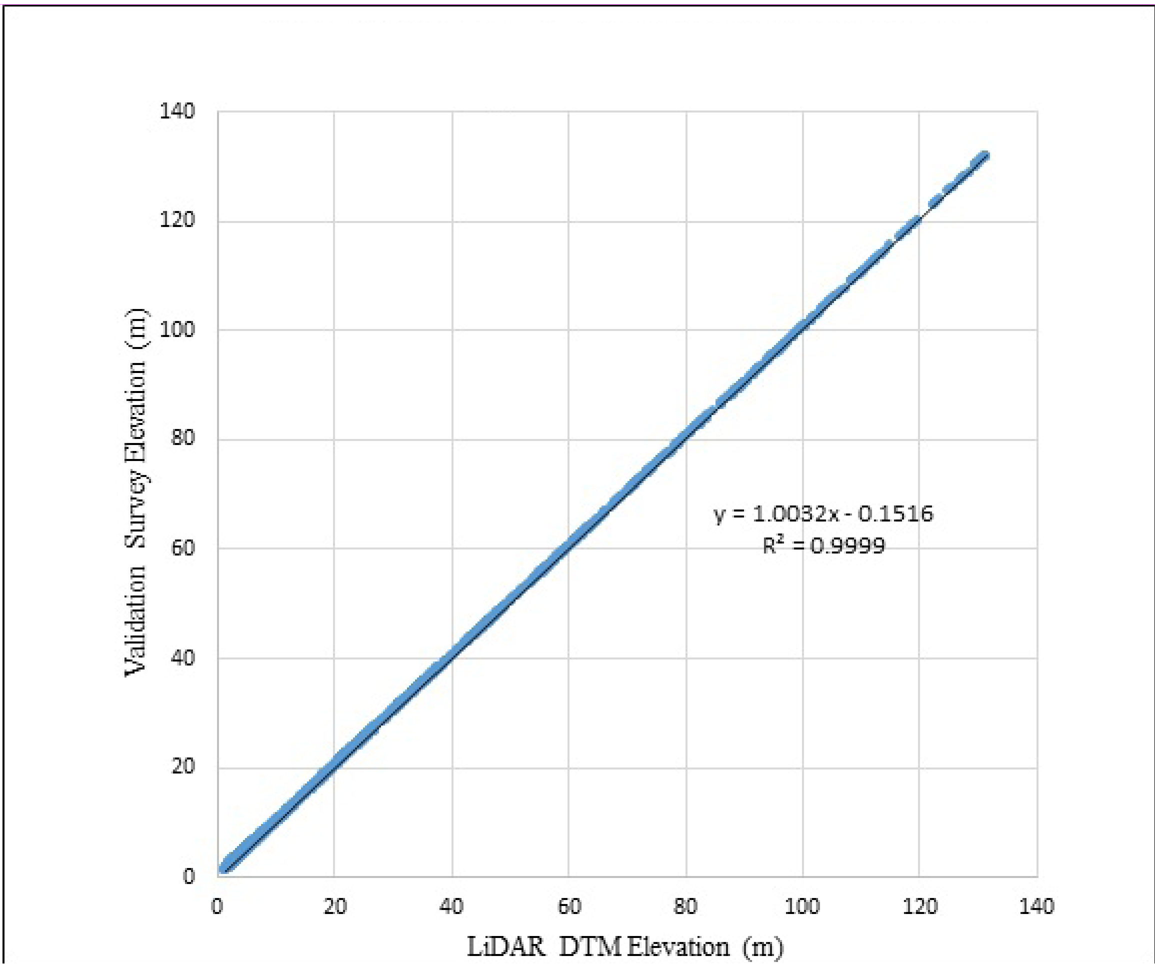



Figure 27. Correlation plot between validation survey points and LiDAR data

Table 20. Validation Statistical Measures

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.20 |
| Standard Deviation | 0.18 |
| Average | -0.10 |
| Minimum | -0.47 |
| Maximum | 0.29 |

## 3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline, cross-section and zigzag data was available for Bangkerohan with 7067 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.37 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bangkerohan integrated with the processed LiDAR DEM is shown in Figure 28.

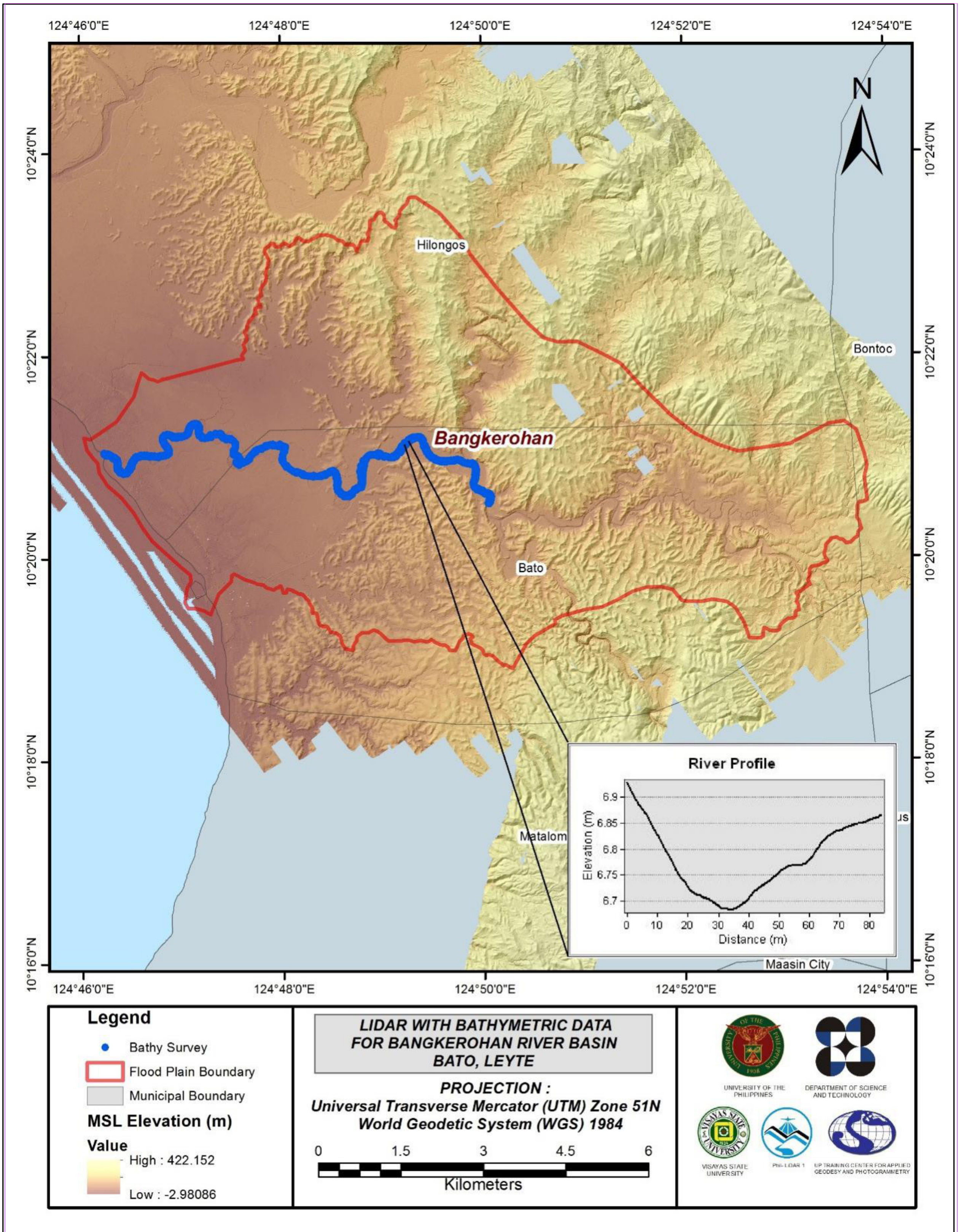



Figure 28. Map of Bangkerohan Flood Plain with bathymetric survey points shown in blue

## 3.12 Feature Extraction

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

### 3.12.1 Quality Checking of Digitized Features' Boundary

Bangkerohan floodplain, including its 200 m buffer, has a total area of 175.88 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1276 building features, are considered for QC. Figure 29 shows the QC blocks for Bangkerohan floodplain.

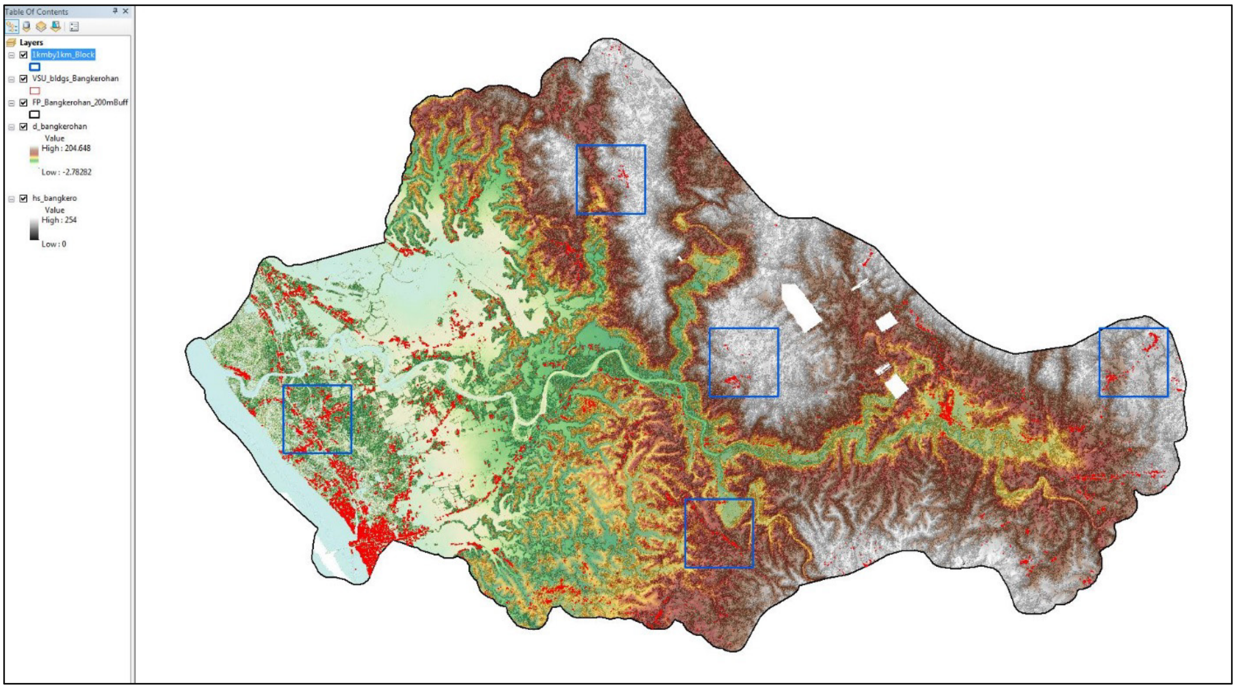



Figure 29. Blocks (in blue) of Bangkerohan building features that were subjected to QC

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

Table 21. Quality Checking Ratings for Bangkerohan Building Features

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Bangkerohan | 98.04 | 94.02 | 86.64 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 8607 building features in Bangkerohan floodplain. Of these building features, 37 was filtered out after height extraction, resulting to 8570 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 11.88 m.

### 3.12.3 Feature Attribution

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

Table 22 summarizes the number of building features per type. On the other hand, Table 23 shows the total length of each road type, while Table 24 shows the number of water features extracted per type.

Table 22. Building Features Extracted for Bangkerohan Floodplain

| Facility Type | No. of Features |
|---|---|
| Residential | 8083 |
| School | 176 |
| Market | 29 |
| Agricultural/Agro-Industrial Facilities | 22 |
| Medical Institutions | 13 |
| Barangay Hall | 25 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 18 |
| Telecommunication Facilities | 1 |
| Transport Terminal | 5 |
| Warehouse | 19 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 7 |
| Police Station | 0 |
| Water Supply/Sewerage | 1 |
| Religious Institutions | 58 |
| Bank | 4 |
| Factory | 0 |
| Gas Station | 5 |
| Fire Station | 0 |
| Other Government Offices | 20 |
| Other Commercial Establishments | 84 |
| **Total** | **8570** |

Table 23. . Total Length of Extracted Roads for Bangkerohan Floodplain.

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/ Municipal Road | Provincial Road | National Road | Others | |
| Bangkerohan | 49.44 | 3.1 | 4.56 | 17.78 | 0.00 | **74.89** |

Table 24. Number of Extracted Water Bodies for Bangkerohan Floodplain

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Bangkerohan | 29 | 1 | 0 | 0 | 0 | 30 |

A total of 29 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

### 3.12.4Final 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 30 shows the Digital Surface Model (DSM) of Bangkerohan floodplain overlaid with its ground features.

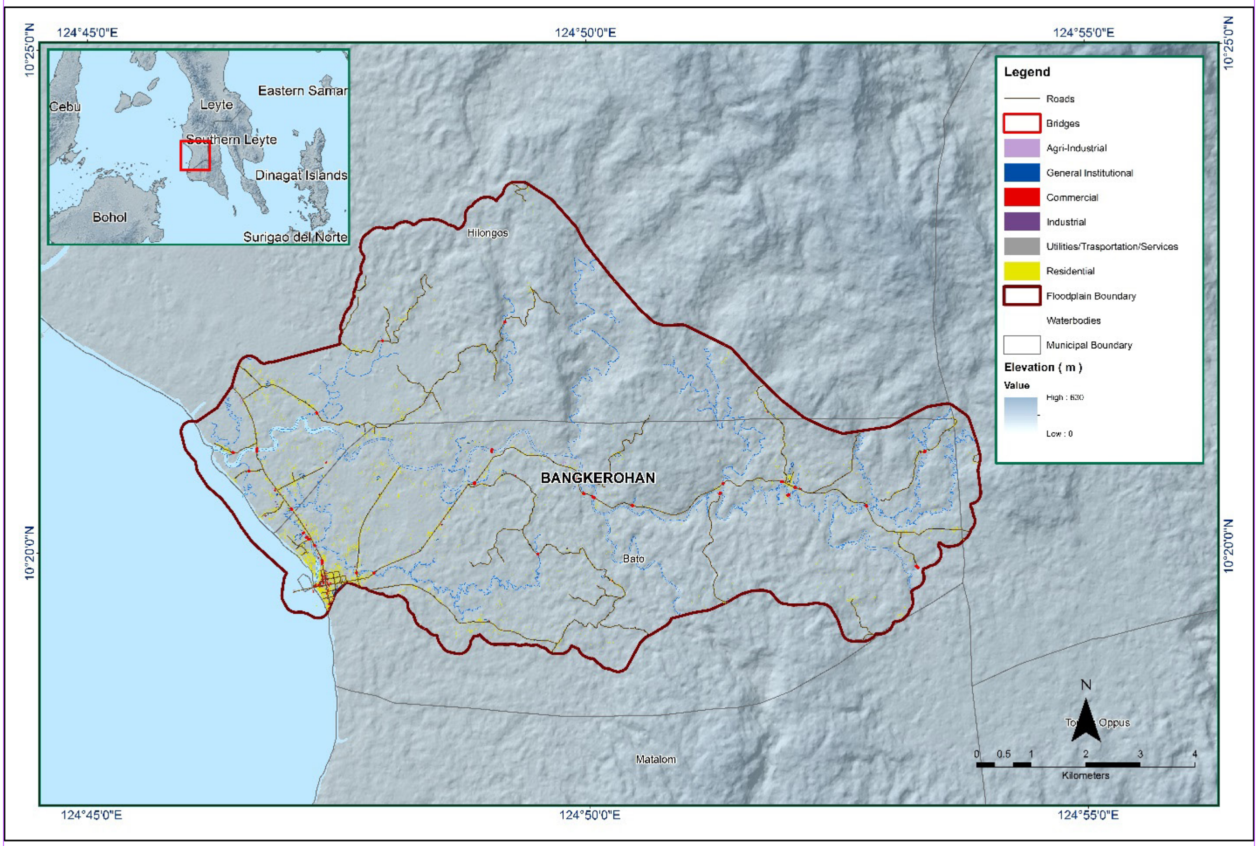



Figure 30. Extracted features for Bangkerohan floodplain

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

*Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Gladys Mae Apat , Engr. Merven Mattew D. Natino, Jovy Anne S. Narisma, Engr. Wilbert Ian M. San Juan , Nereo Joshua G. Pecson, Areanne Katrice K. Umali*

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

## 4.1 Summary of Activities

The project team conducted a field survey in Bangkerohan River on March 9-22, 2016 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section survey of Cambanog Bridge; validation points data acquisition of about 75 km; and bathymetric survey from Brgy. Naga in the Municipality of Bato down to the mouth of the river in Brgy. Bantigue in the Municipality of Hilongos with an approximate length of 11.254 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (see Figure 31).

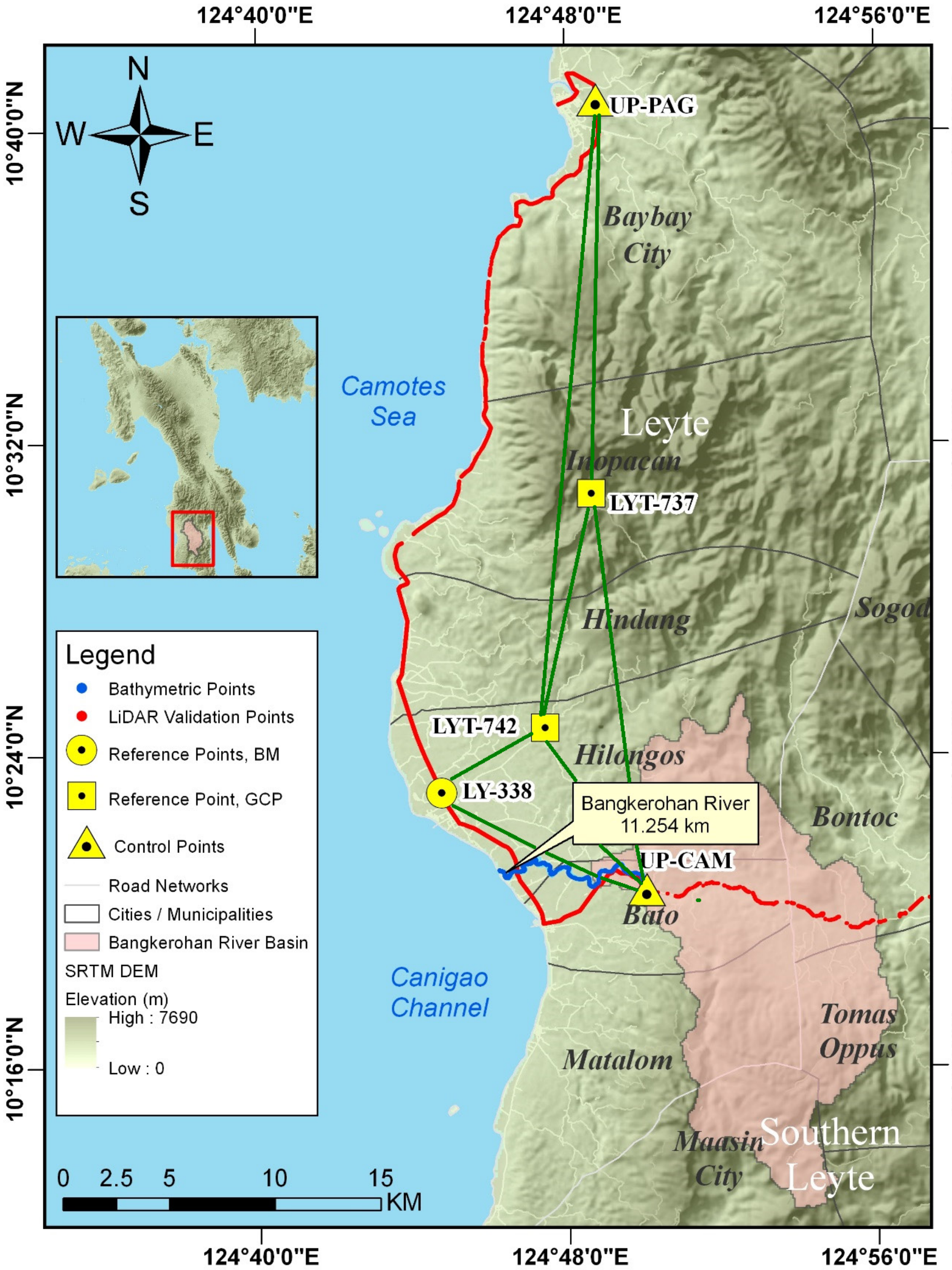



Figure 31. Extent of the bathymetric survey (in blue) in Bangkerohan River Basin and the LiDAR validation survey (in red)

## 4.2 Control Survey

The GNSS network used for Bangkerohan River Basin is composed of three (3) loops established on March 10 and 11, 2016 occupying the following reference points: LYT-737, a second-order GCP, in Brgy. Cabulisan, Municipality of Inopacan; LYT-742, a second-order GCP, in Brgy. Tambis, Municipality of Hilongos; and LY-338, a first-order BM, in Brgy. San Juan, Municipality of Hilongos.

Two (2) control points were established along the approach of a bridge namely: UP-CAM at Cambanog Bridge in Brgy. Naga, Municipality of Bato; and UP-PAG at Pagbanganan Bridge in Brgy. Poblacion Zone 12, City of Baybay.

The summary of reference and control points and its location is summarized in Table 25 while GNSS network established is illustrated in Figure 32.

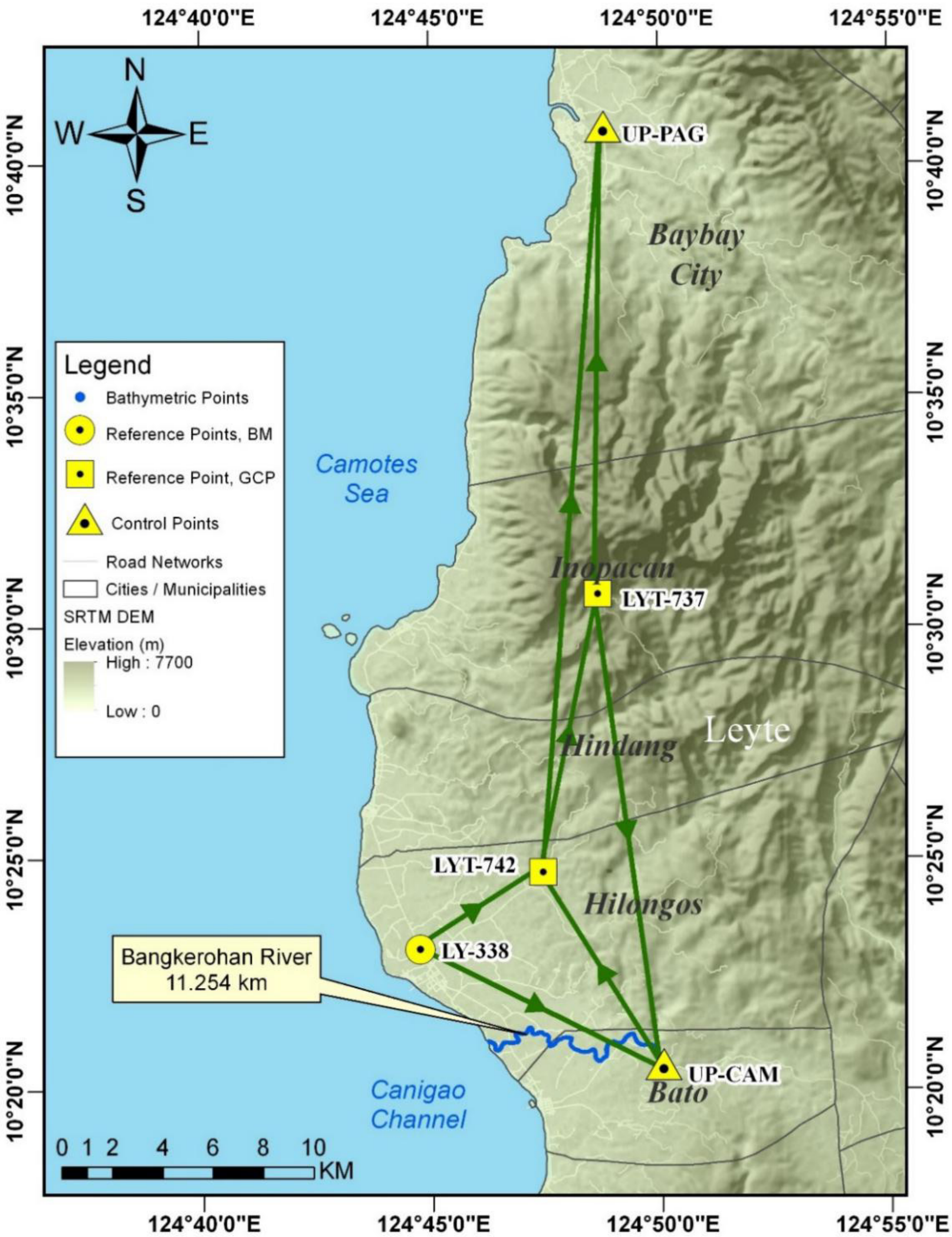



Figure 32. GNSS Network of Bangkerohan River field survey

Table 25. List of Reference and Control Points occupied for Bangkerohan River Survey (Source: NAMRIA; UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | MSL Elevation (m) | Date established |
| LYT-737 | 2nd order, GCP | 10°30'42.1282"N | 124°48'38.7024"E | 600.703 | - | 2007 |
| LYT-742 | 2nd order, GCP | 10°24'41.5778"N | 124°47'25.4388"E | 110.425 | - | 03-14-2016 |
| LY-338 | 1st order, BM | - | - | 73.006 | 8.483 | 2007 |
| UP-CAM | Established | - | - | - | - | 03-10-2016 |
| UP-PAG | Established | - | - | - | - | 03-11-2016 |

The GNSS set up made in the location of the reference and control points are exhibited in Figure 33 to Figure 37.


Figure 33. GNSS base set up, Trimble® SPS 852, at LYT-737, located at the back of Cabulisan Elementary School in Brgy. Cabulisan, Municipality of Inopacan, Leyte


Figure 34. GNSS base set up, Trimble® SPS 852, at LYT-742, located near a chapel and basketball court in Brgy. Tambis, Municipality of Hilongos, Leyte


Figure 35. GNSS receiver set up, Trimble® SPS 855, at LY-338, a first-order BM, located at the approach of Salug Birdge along Sta. Indang-Hilongos Road in Brgy. San Juan, Municipality of Hilongos, Leyte


Figure 36. GNSS receiver set up, Trimble® SPS 882, at UP-CAM, an established control point, located at the approach of Cambanog Bridge in Brgy. Naga, Municipality of Bato, Leyte


Figure 37. GNSS receiver set up, Trimble® SPS 855, at UP-PAG, an established control point, located at Pagbanganan Bridge approach in Brgy. Brgy. Poblacion Zone 12, City of Baybay, Leyte

## 4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Bangkerohan River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline Processing Report for Bangkerohan River Basin Static Survey

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) |
|---|---|---|---|---|---|---|
| LYT-742 --- LYT-737 | 03-11-2016 | Fixed | 0.003 | 0.014 | 11°22'12" | 11299.872 |
| LYT-737 --- UPCAM | 03-11-2016 | Fixed | 0.004 | 0.024 | 172°18'02" | 18901.31 |
| LYT-742 --- UPPAG | 03-11-2016 | Fixed | 0.003 | 0.012 | 4°53'18" | 29783.6899 |
| LY-338 --- UP-CAM | 03-10-2016 | Fixed | 0.005 | 0.028 | 115°25'44" | 10691.421 |
| LYT-737 --- UP-PAG | 03-11-2016 | Fixed | 0.003 | 0.012 | 0°57'35" | 18599.831 |
| UP-CAM --- LYT-742 | 03-10-2016 | Fixed | 0.003 | 0.022 | 148°06'41" | 9012.871 |
| LYT-737 --- LYT-742 | 03-11-2016 | Fixed | 0.003 | 0.013 | 11°22'12" | 11299.875 |
| LY-338 --- LYT-742 | 03-10-2016 | Fixed | 0.004 | 0.023 | 237°58'44" | 5771.913 |

As shown in Table 26, a total of eight (8) baselines were processed with reference points LYT-737 and LYT-742, and LY-338 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

## 4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 27 to Table 29 for the complete details.

The five (5) control points, LY-338, LYT-737, LYT- 742, UP-CAM and UP-PAG were occupied and observed simultaneously to form a GNSS loop. Elevation value of LY-338 and coordinates of points LYT-737 and LYT-742 were held fixed during the processing of the control points as presented in Table 27. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 27. Control Point Constraints for control points used in the Bangkerohan River floodplain validation

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| LYT-737 | Local | Fixed | Fixed | | |
| LYT-742 | Local | Fixed | Fixed | | |
| LY-338 | Grid | | | | Fixed |
| Fixed = 0.000001 (Meter) | | | | | |

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 28. The fixed control points LYT-737 and LYT-742 have no values for grid errors; and LY-338, for elevation error.

Table 28. Adjusted Grid Coordinates for control points used in the Bangkerohan River floodplain validation

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| LYT-737 | 698162.797 | ? | 1162560.388 | ? | 536.080 | 0.089 | LL |
| LYT-742 | 695997.844 | ? | 1151468.957 | ? | 45.879 | 0.084 | LL |
| LY-338 | 691121.157 | 0.012 | 1148380.761 | 0.009 | 8.483 | ? | e |
| UP-CAM | 700802.490 | 0.010 | 1143842.626 | 0.010 | 21.206 | 0.089 | |
| UP-PAG | 698366.197 | 0.015 | 1181160.649 | 0.011 | 6.881 | 0.092 | |

The network is fixed at reference points LYT-737 and LYT-742 with known coordinates, and LY-338 with known elevation. As shown in Table 28, the standard errors (xe and ye) of LY-338 are 1.20 cm and 0.90 cm; UP-CAM with 1.0 cm and 1.0 cm; and UP-PAG with 1.50 and 1.10 cm, respectively. With the mentioned equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for horizontal and $|z_e < 10\ cm$ for the vertical; the computation for the accuracy are as follows:

a. LYT-737
horizontal accuracy = Fixed
vertical accuracy = 8.90 < 10 cm

b. LYT-742
horizontal accuracy = Fixed
vertical accuracy = 8.40 < 10 cm

c. LY-338
horizontal accuracy = √((1.20)² + (0.90)²
= √ (1.44 + 0.81)
= 1.5 cm < 20 cm
vertical accuracy = Fixed

d. UP-CAM
horizontal accuracy = √((1.0)² + (1.0)²
= √ (1.0 + 1.0)
= 1.41 cm < 20 cm
vertical accuracy = 8.90 cm < 10 cm

e. UP-PAG
horizontal accuracy = √((1.50)² + (1.10)²
= √ (2.25 + 1.21)
= 1.86 cm < 20 cm
vertical accuracy = 9.20 cm < 10 cm

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

Table 29. Adjusted Geodetic Coordinates for control points used in the Bangkerohan River floodplain validation

| Point ID | Latitude | Longitude | Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| LYT-737 | 10°30'42.12820"N | 124°48'38.70244"E | 600.703 | 0.089 | LL |
| LYT-742 | 10°24'41.57783"N | 124°47'25.43883"E | 110.425 | 0.084 | LL |
| LY-338 | 10°23'01.95953"N | 124°44'44.56153"E | 73.006 | ? | e |
| UP-CAM | 10°20'32.50055"N | 124°50'01.93960"E | 85.886 | 0.089 | |
| UP-PAG | 10°40'47.39583"N | 124°48'48.95238"E | 71.261 | 0.092 | |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 30.

Table 30. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | UTM ZONE 51 N | | |
|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | Northing (m) | Easting (m) | BM Ortho (m) |
| LYT-737 | 2nd order, GCP | 10°30'42.1282"N | 124°48'38.7024"E | 600.703 | 1162560.388 | 698162.797 | 536.080 |
| LYT-742 | 2nd order, GCP | 10°24'41.5778"N | 124°47'25.4388"E | 110.425 | 1151468.957 | 695997.844 | 45.879 |
| LY-338 | 1st order, BM | 10°23'01.9595"N | 124°44'44.5615"E | 73.006 | 1148380.761 | 691121.157 | 8.483 |
| UP-CAM | UP Established | 10°20'32.5005"N | 124°50'01.9396"E | 85.886 | 1143842.626 | 700802.490 | 21.206 |
| UP-PAG | UP Established | 10°40'47.3958"N | 124°48'48.9523"E | 71.261 | 1181160.649 | 698366.197 | 6.881 |

## 4.5 Cross-section and Bridge As-Built Survey and Water Level Marking

Cross-section and as-built survey was conducted on March 12, 2016 at the downstream side of Cambanog Bridge in Brgy. Naga, Municipality of Bato, Leyte as shown in Figure 38 using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 39.

Figure 38. Cambanog Bridge facing downstream

Figure 39. Cross-section survey at the downstream side of Cambanog Bridge

The cross-sectional line length in Cambanog Bridge is about 231.70 m with 33 cross-sectional points acquired using UP-CAM as the GNSS base station. The location map, the cross section diagram and the bridge data form are shown in Figure 40, 41, and 42, respectively.

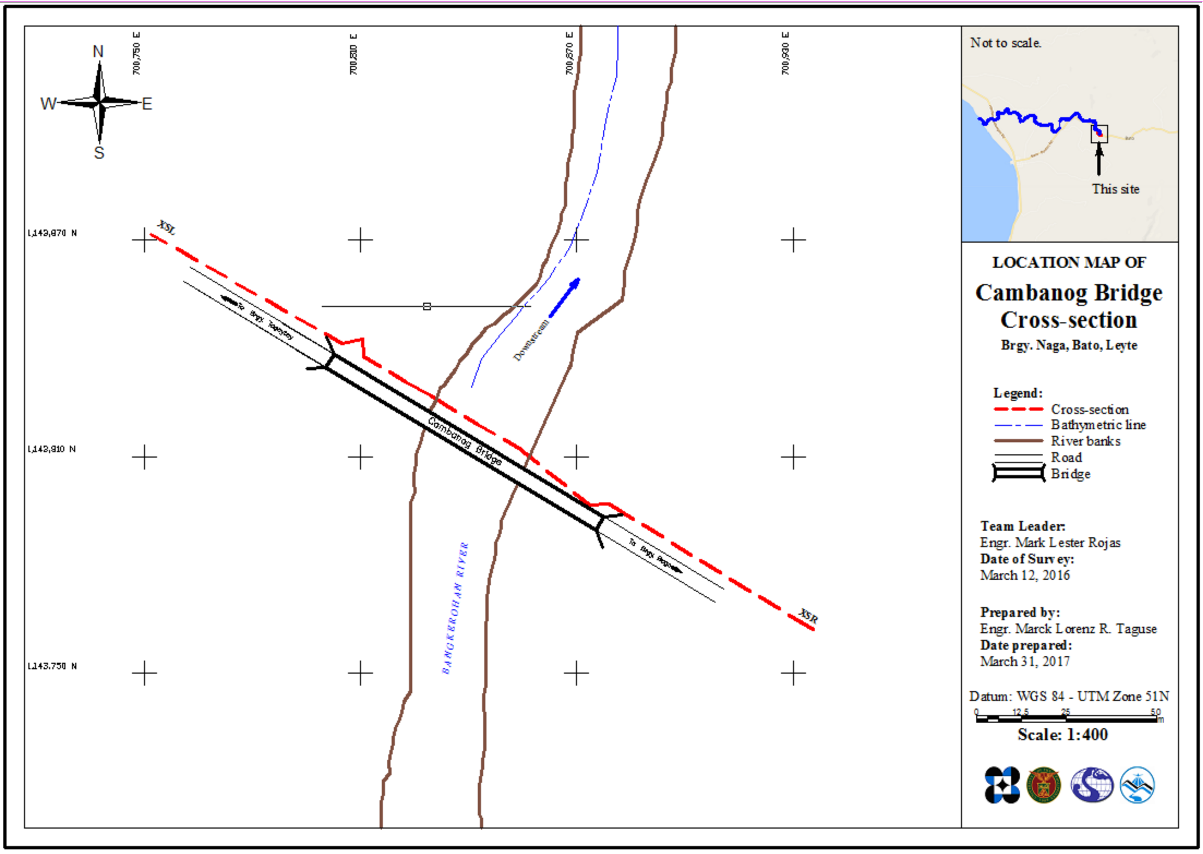



Figure 40. Location map of  Cambanog Bridge Cross Section

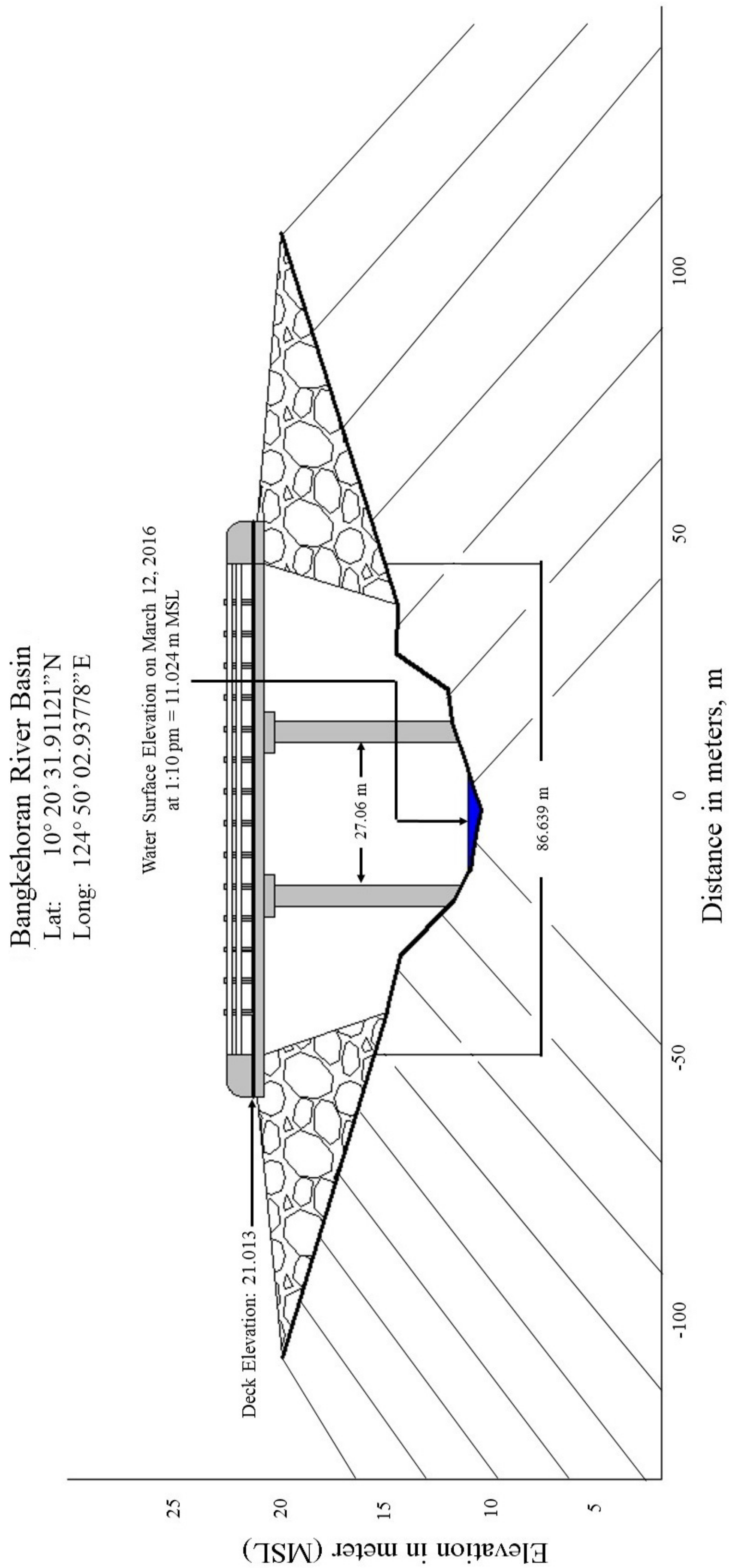



Figure 41. Cambagon Bridge cross-section diagram

**Bridge Data Form**

**Bridge Name:** CAMBANOG BRIDGE **Date:** March 12, 2016

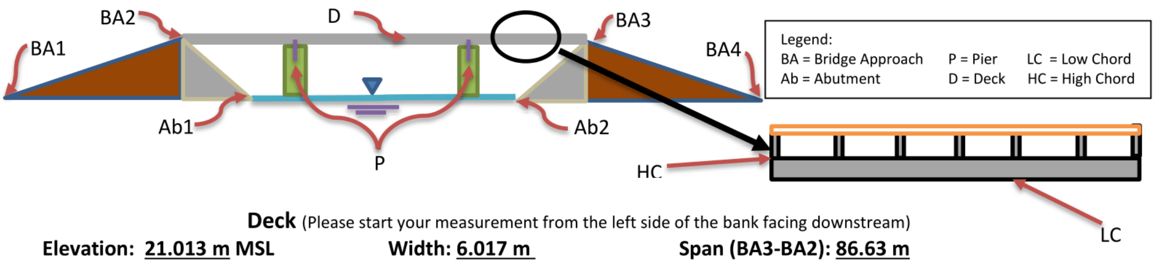
**River Name:** BANGKEROHAN RIVER **Time:** 1:10 PM

**Location (Brgy, City, Region):** Brgy. Naga, Bato, Leyte

**Survey Team:** Leyte Team © Team Mark

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

**Latitude:** 10° 20' 31.91129" N **Longitude:** 124° 50' 02.93778" E




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

**Elevation:** **21.013 m MSL** **Width:** **6.017 m** **Span (BA3-BA2):** **86.63 m**

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | 68.238 | 12.191 | 19.701 |
| 2 | 81.473 | 21.170 | 19.680 |
| 3 | 93.791 | 21.105 | 19.615 |
| 4 | 104.908 | 21.062 | 19.572 |
| 5 | 119.473 | 21.013 | 19.523 |

**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 | 19.820 | **BA3** | 147.634 | 20.897 |
| **BA2** | 60.995 | 21.203 | **BA4** | 213.853 | 19.870 |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| **Ab1** | 65.642 | 14.836 |
| **Ab2** | 143.071 | 14.359 |

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

**Shape:** Oblong **Number of Piers:** two (2) **Height of column footing:** n/a

| | Station (Distance from BA1) | Elevation | Pier Width |
|---|---|---|---|
| **Pier 1** | 89.802 | 18.066 | 1.42 |
| **Pier 2** | 118.918 | 17.999 | 1.42 |

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

Figure 42. Cambanog Bridge Data Form

Water surface elevation in MSL of Bangkerohan River, as shown in Figure 43, was determined using Trimble® SPS 882 in PPK mode technique on March 12, 2016 at 1:10 PM with a value of 11.024 m in MSL. This was translated onto marking on one of the bridge's pier using digital level which will be used by Visayas State University PHIL-LiDAR 1. The marking will serve as their reference for flow data gathering and depth gauge deployment for Bangkerohan River.

Figure 43. a) Getting the MSL elevation of the markings written on the pier and b) Water-level markings for Bangkerohan River

## 4.6. Validation Points Acquisition Survey

Validation points acquisition survey was conducted on March 10 and 11, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882 mounted on a pole which was attached to the side of vehicle as shown in Figure 44. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.929 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with LYT-742, UP-PAG, UP-CAM, and LYT-737 occupied as the GNSS base stations all throughout the conduct of the survey.


Figure 44. Validation points acquisition survey set up

The validation points acquisition survey for the Bangkerohan River Basin traversed Baybay City and the following municipalities of Leyte: Inopacan, Hindang, and Bato; as well as Municipality of Bontoc in Southern Leyte. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 18,832 points with an approximate length of 75 km was acquired for the validation point acquisition survey as shown in the map in Figure 45.

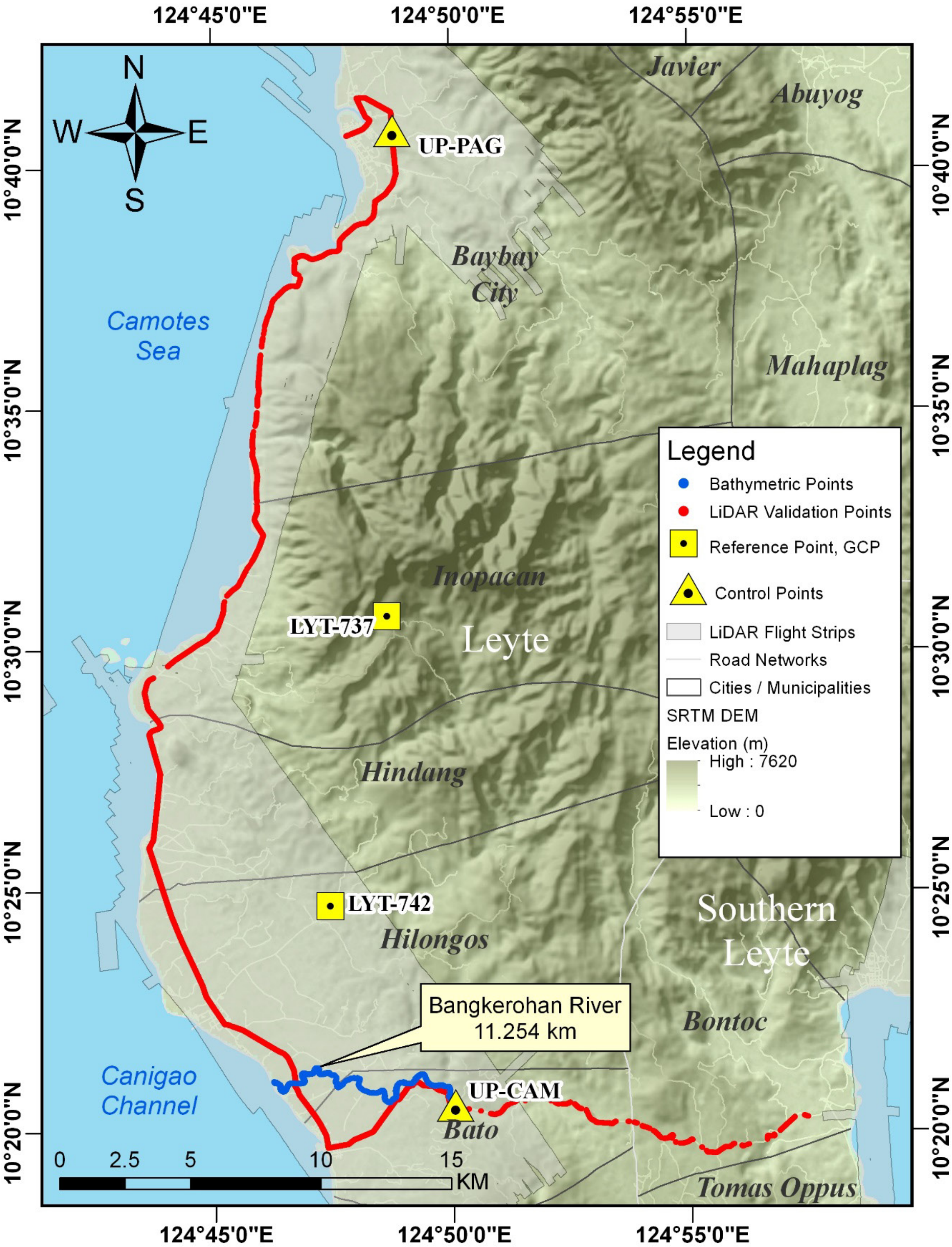



Figure 45. Validation point acquisition survey for the Bangkerohan River Basin

## 4.7 Bathymetric Survey

Bathymetric survey was executed on March 12 and 14, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique utilizing the continuous topo mode and Ohmex™ single beam echo sounder, as illustrated in Figure 46. The survey started from middle upstream part of the river in Brgy. Talunok, Municipality of Hilongos with coordinates 10°21'11.56069"N, 124°47'12.74276"E, and ended at the mouth of the river in Brgy. Bantigue, also in Hilongos with coordinates 10°21'02.24072"N, 124°46'13.94549"E.

Manual bathymetry in the other hand was done on March 12, 2016 using Trimble® SPS 882 in GNSS PPK survey technique also utilizing the continuous topo mode. The survey started from Cambanog Bridge located in the upstream of the river in Brgy. Tagaytay, Municipality of Bato with coordinates 10°20'32.23471"N, 124°50'03.03192"E, traversed by foot down to the middle portion of the river where the bathymetric survey by boat started. The control point UP-CAM was used as the GNSS base station all throughout the survey.

Figure 46. Bathymetry by boat set up for Bangkerohan River survey

A CAD drawing was also produced to illustrate the riverbed profile of Bangkerohan River. As shown in Figure 47, the highest and lowest elevation has a 14-meter difference. The highest elevation observed was 10.592 m above MSL located in Brgy. Naga, Municipality of Bato while the lowest was 3.784 m below MSL located in Brgy. Tabunok, Municipality of Hilongos. The bathymetric survey gathered a total of 7,177 points covering 11.254 km of the river traversing the ff. barangays from the upstream - Brgy. Naga (Municipality of Bato), Brgy. Tabunok, Brgy. Daang Lungsod, Brgy. Tibunok (Municipality of Hilongos), Brgy. Catandog 2 and Brgy. Bantigue. The remaining 400 m delineated bathymetric line, was not surveyed because according to the locals, the upstream area of Cambanog Bridge in Barangays Tagaytay and Bago was not flood prone.

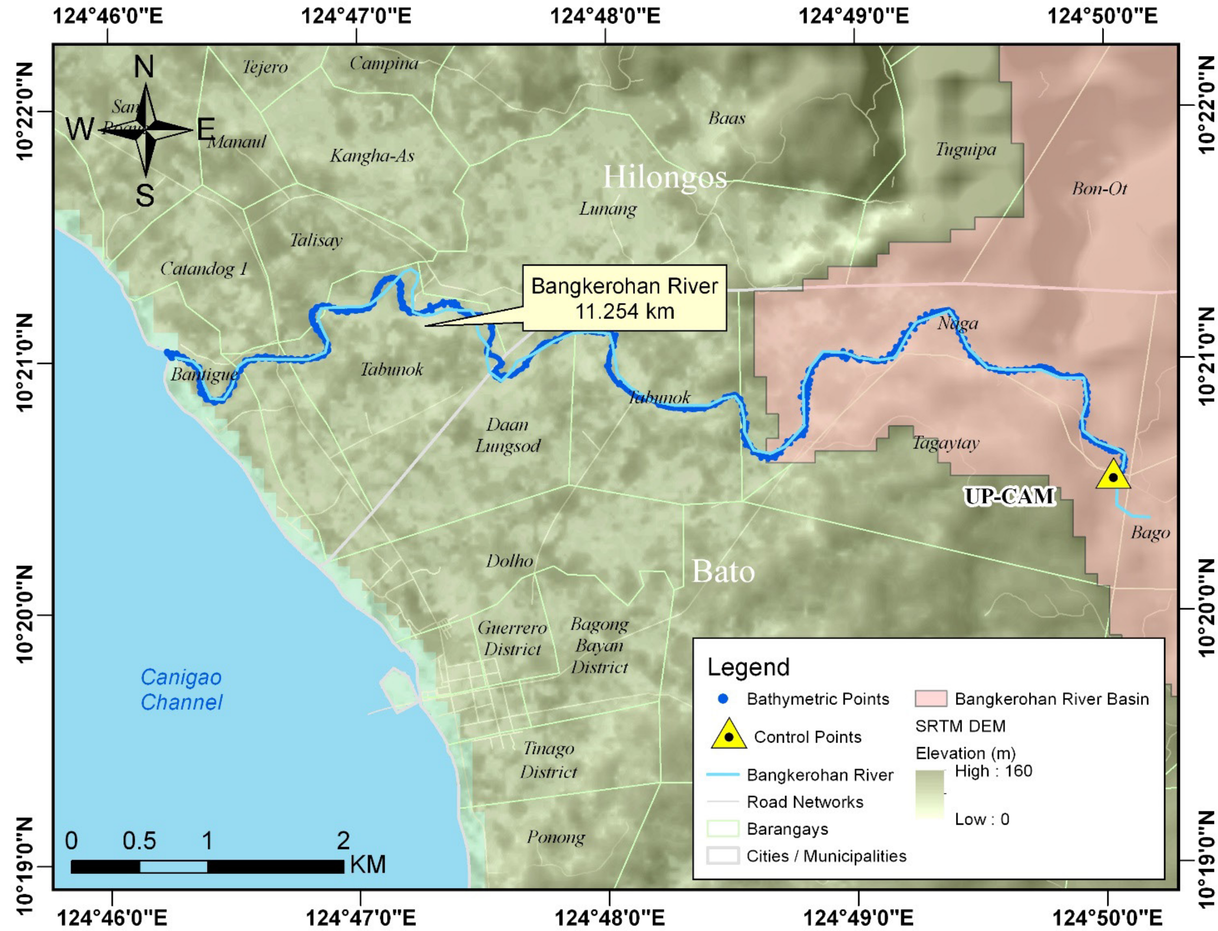



Figure 47. Bathymetric survey of Bangkerohan River

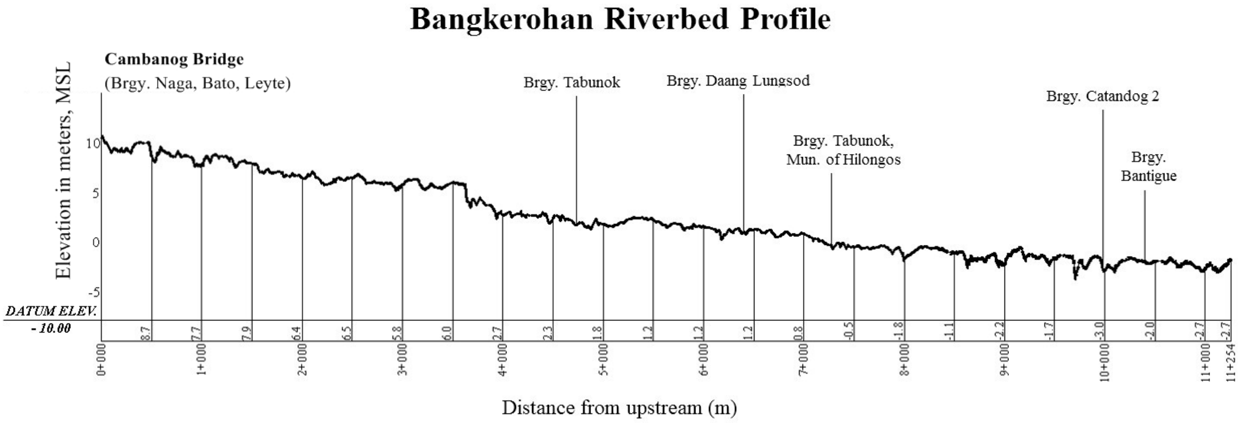



Figure 48. Riverbed profile of Bangkerohan River

# CHAPTER 5: RESULTS AND DISCUSSION FMC

*Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Gladys Mae Apat , Engr. Merven Mattew D. Natino, Jovy Anne S. Narisma, Engr. Wilbert Ian M. San Juan , Nereo Joshua G. Pecson, Areanne Katrice K. Umali*

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

## 5.1 Data Used for Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

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

### 5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauges (ARGs) temporarily installed by the Visayas State University Phil-Lidar 1 Flood Modeling Component (FMC). This was the Abuyog ARs. The location of the rain gauges is seen in Figure 49.

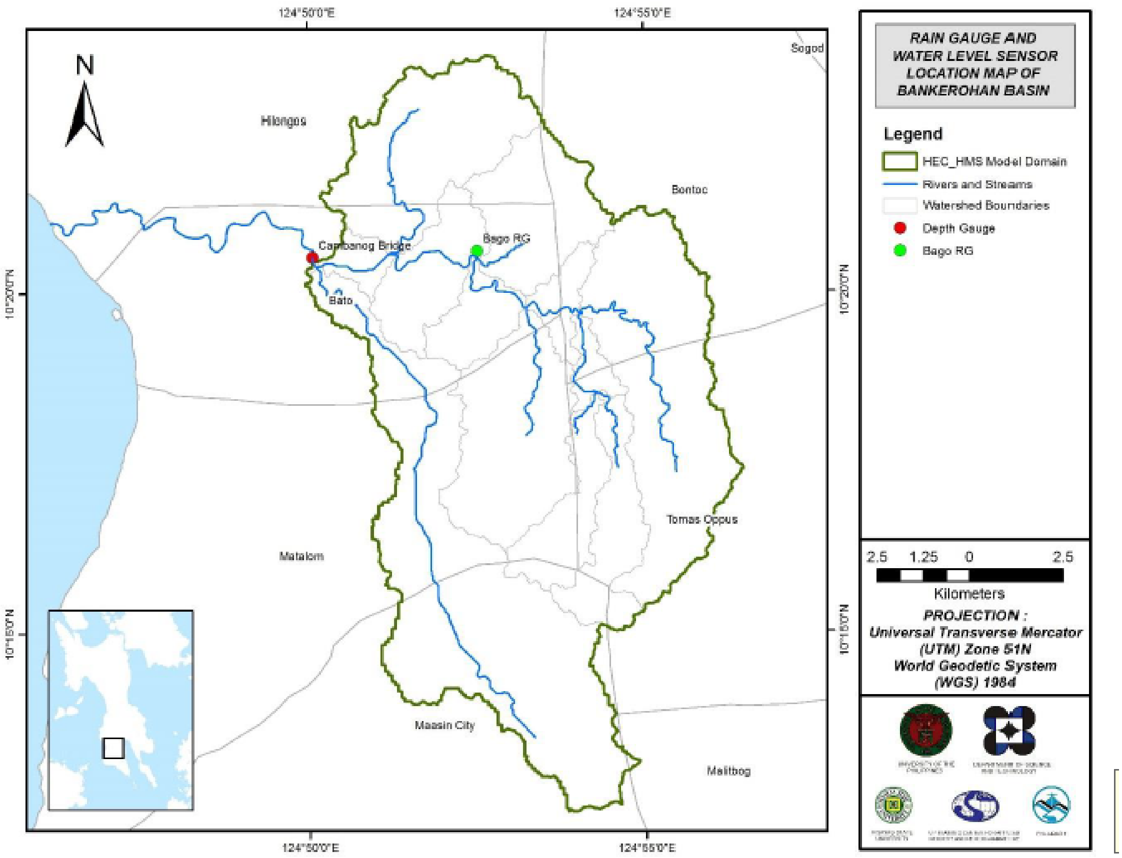



Figure 49. The location map of Bangkerohan HEC-HMS model used for calibration

Total rain from Abuyog rain gauge is 84.76 mm. It peaked to 4.060 mm on 24 November 2016, 20:00. The lag time between the peak rainfall and discharge is 2 hour and 50 minutes.

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Cambanog Bridge, Barangay Bago, Bato, Leyte (10°20'24.8"N, 124°50'36.8"E). It gives the relationship between the observed water levels at Cambanog Bridge and outflow of the watershed at this location.

For Cambanog Bridge, the rating curve is expressed as Q= 0.0856e1.0439H as shown in Figure 51.

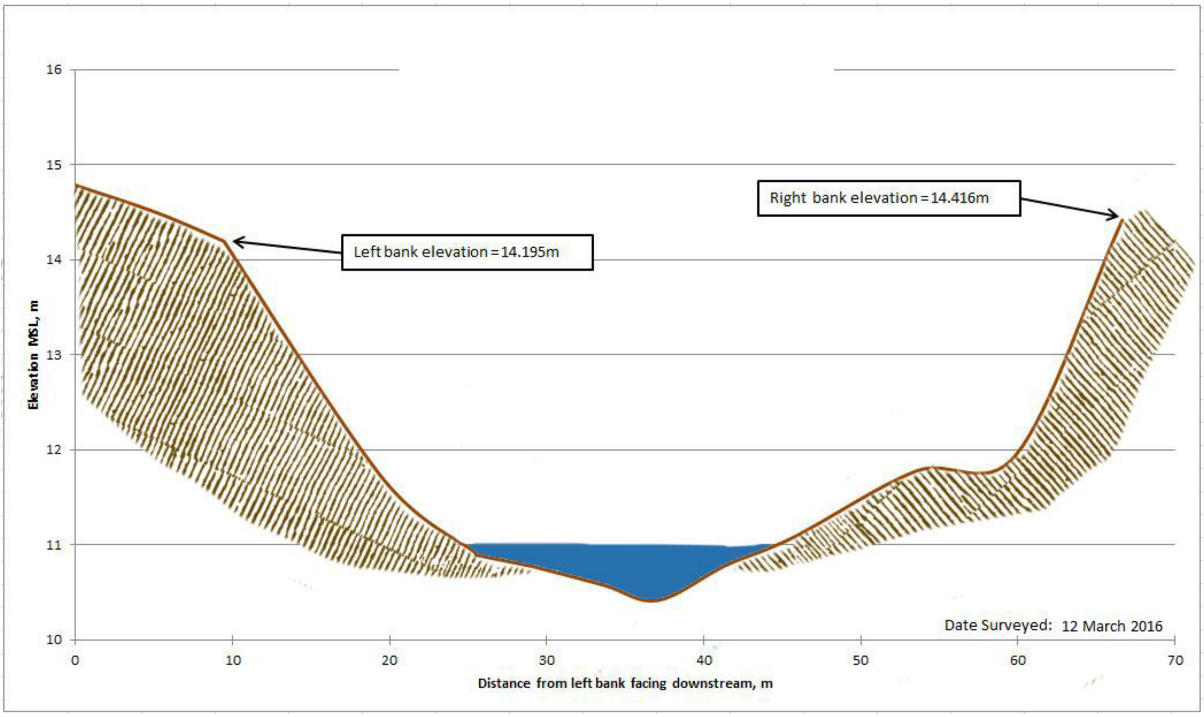



Figure 50. Cross-Section Plot of Cambanog Bridge

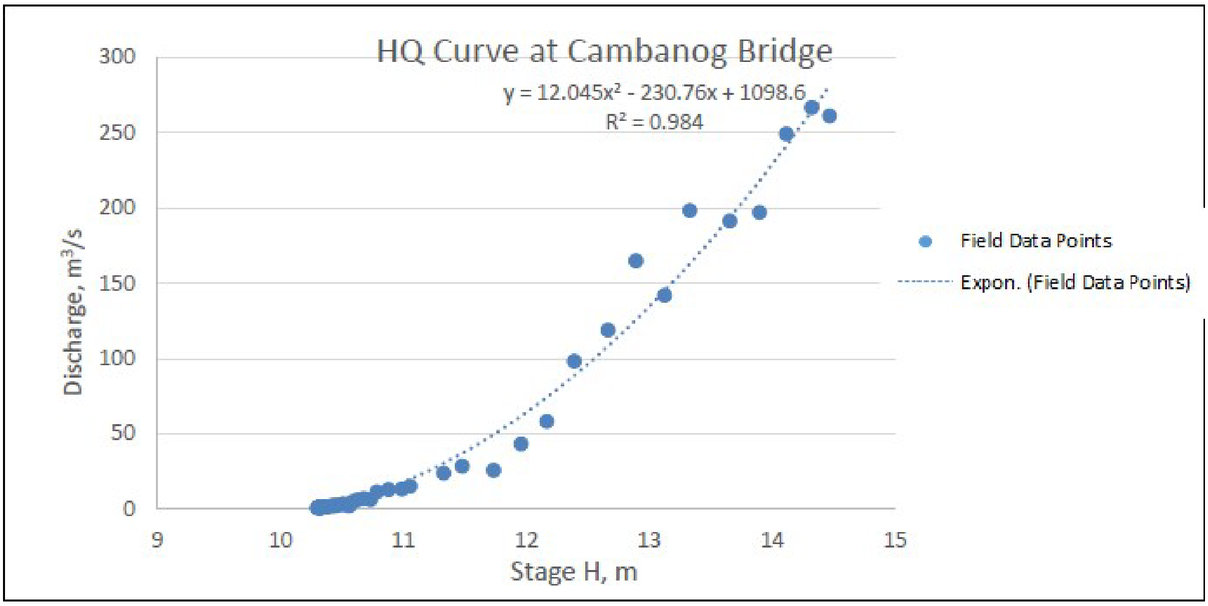



Figure 51. Rating Curve at Cambanog Bridge, Barangay Bago, Bato, Leyte

This rating curve equation was used to compute the river outflow at Cambanog Bridge for the calibration of the HEC-HMS model.

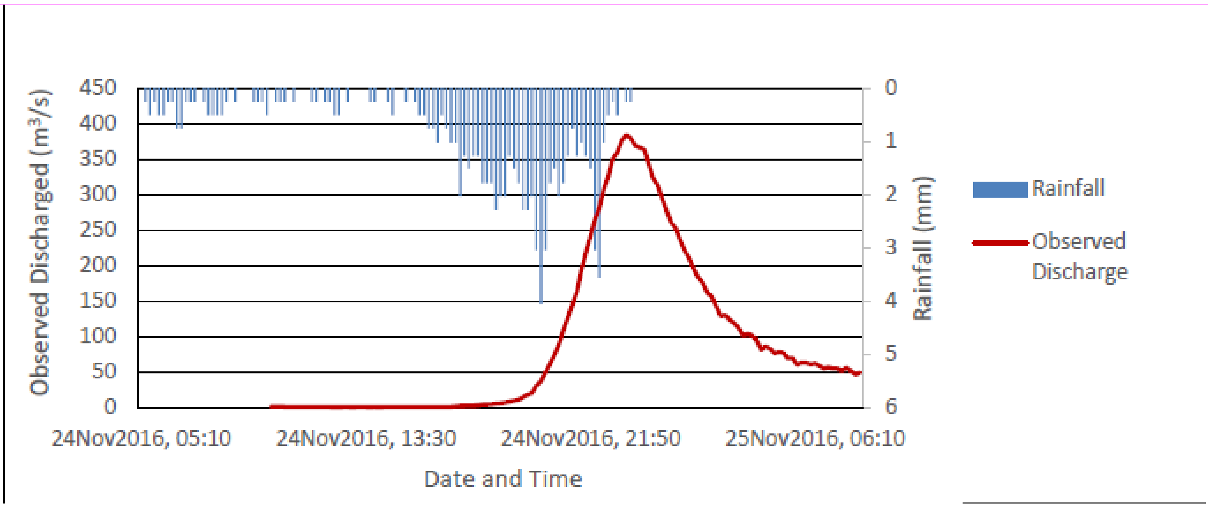



Figure 52. Rainfall and outflow data at Bangkerohan used for modeling

## 5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Maasin Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to Bangkerohan watershed. The extreme values for this watershed were computed based on a 16-year record.

Table 31.. RIDF values for Maasin Rain Gauge computed by PAGASA

| T (yrs) | 10 min | 20 min | 30 min | 1 hr | 2 hrs | 3 hrs | 6 hrs | 12 hrs | 24 hrs |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 18.5 | 28.1 | 35.6 | 48.1 | 68 | 82.1 | 104.6 | 124.9 | 145 |
| 5 | 25.9 | 38.3 | 63.8 | 63.8 | 90.4 | 108.8 | 137.5 | 165.2 | 190.8 |
| 10 | 30.8 | 45 | 74.2 | 74.2 | 105.3 | 126.5 | 159.3 | 191.9 | 221.2 |
| 15 | 33.5 | 48.8 | 80.1 | 80.1 | 113.7 | 136.5 | 171.5 | 206.9 | 238.4 |
| 20 | 35.5 | 51.5 | 84.2 | 84.2 | 119.6 | 143.5 | 180.1 | 217.5 | 250.4 |
| 25 | 37 | 53.6 | 87.3 | 87.3 | 124.1 | 148.9 | 186.7 | 225.6 | 259.6 |
| 50 | 41.5 | 59.9 | 97.1 | 97.1 | 138.1 | 165.5 | 207.1 | 250.6 | 288.1 |
| 100 | 46.1 | 66.2 | 106.8 | 106.8 | 151.9 | 181.9 | 227.4 | 275.4 | 316.3 |

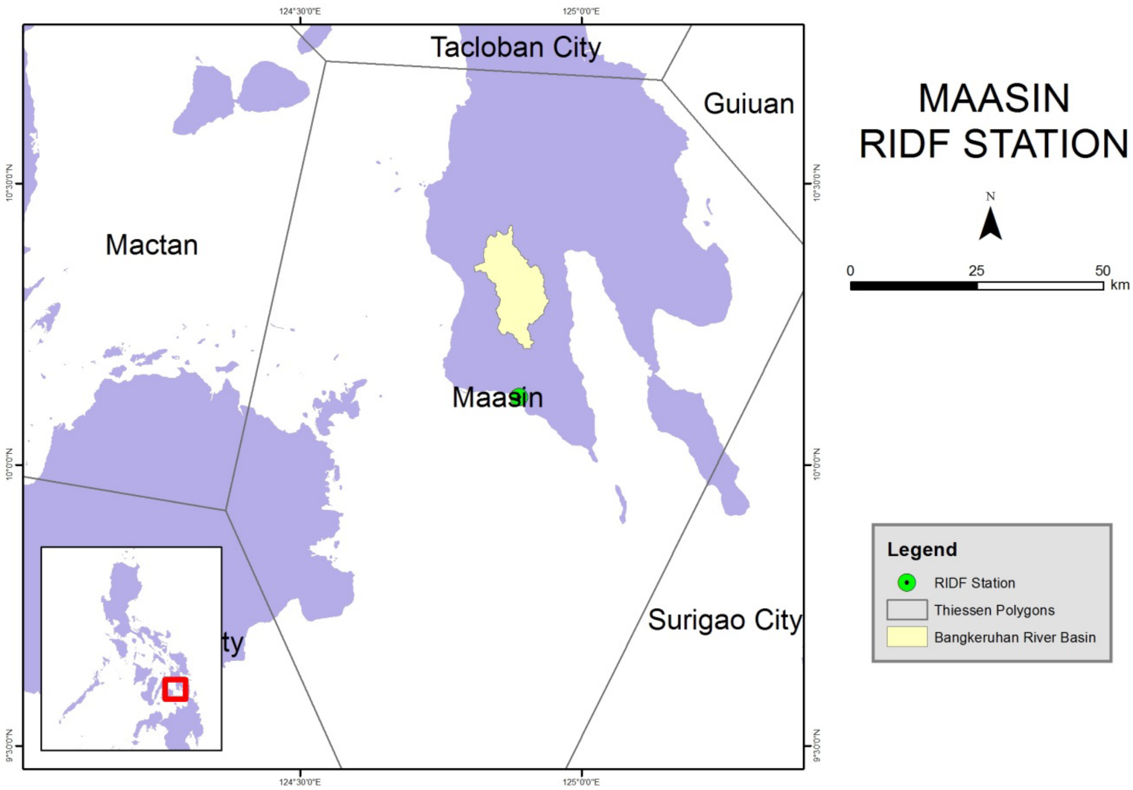



Figure 53. Location of Maasin RIDF Station relative to Bangkerohan River Basin

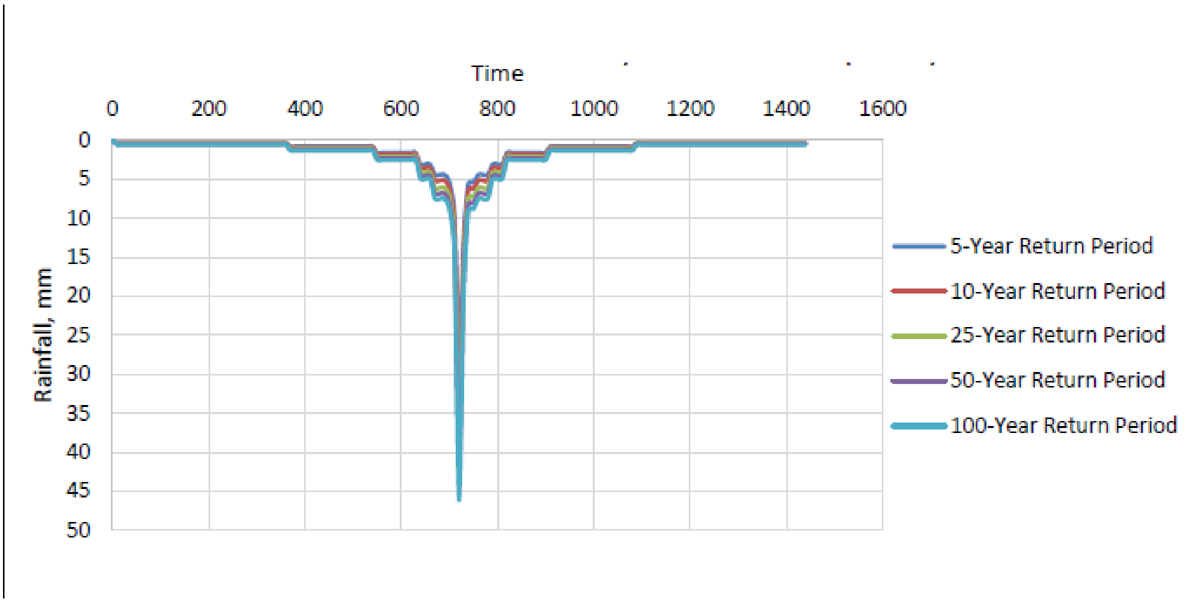



Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

## 5.3 HMS Model

The soil shapefile (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Bangkerohan River Basin are shown in Figures 55 and 56, respectively.

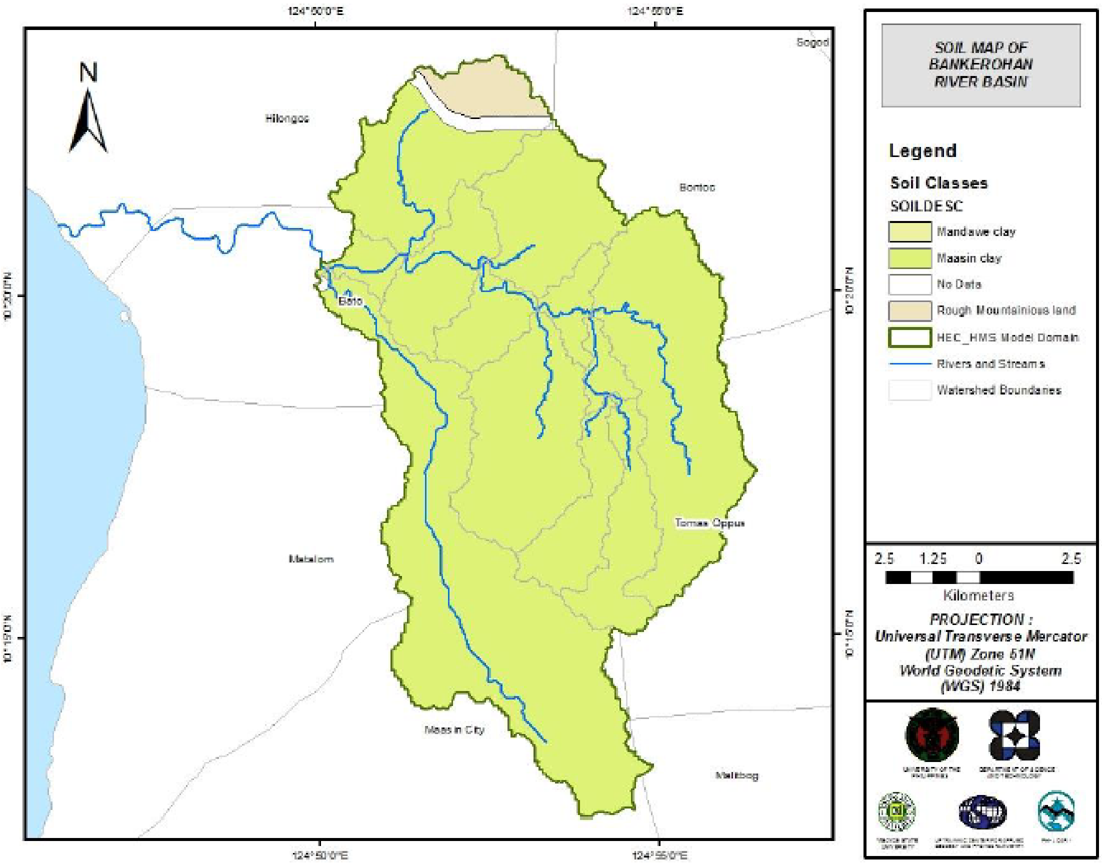



Figure 55. Soil Map of Bangkerohan River Basin (Source: Bureau of Soils and Water Management)

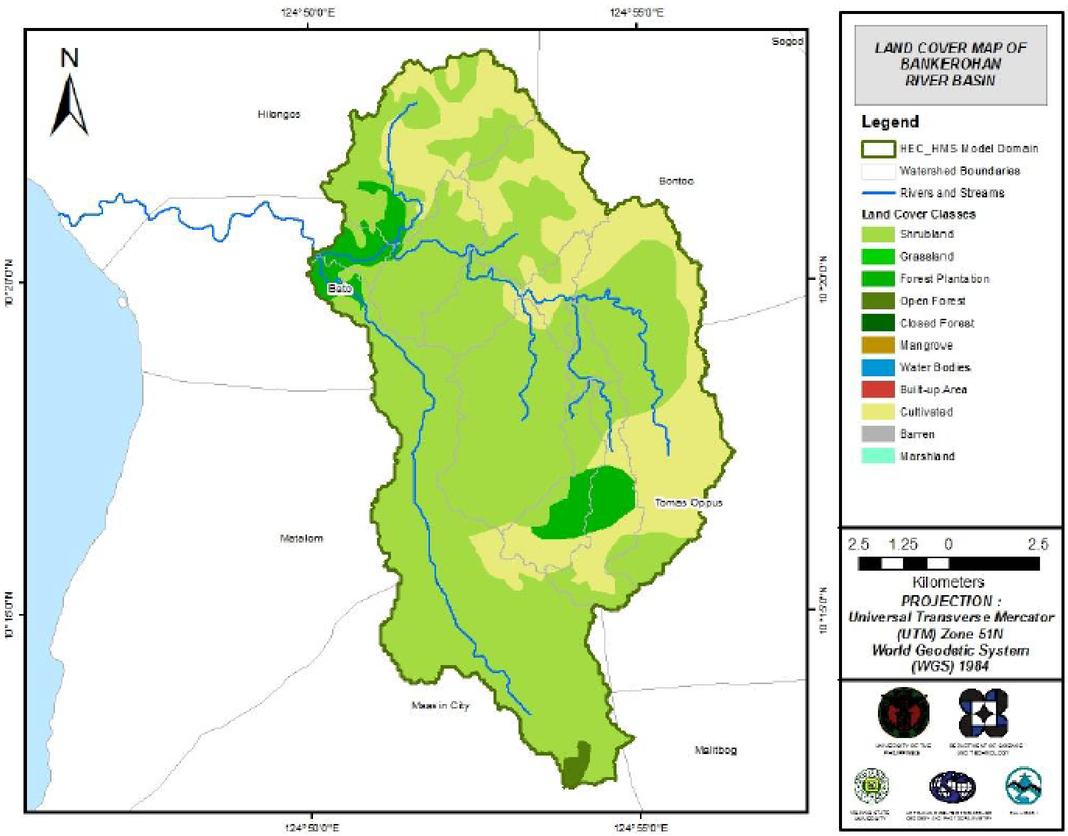



Figure 56. Land Cover Map of Bangkerohan River Basin (Source: NAMRIA)

For Bangkerohan, the soil classes identified were clay, and rough mountainous land. The land cover types identified were shrubland, grassland, forest plantation, open forest, and cultivated.

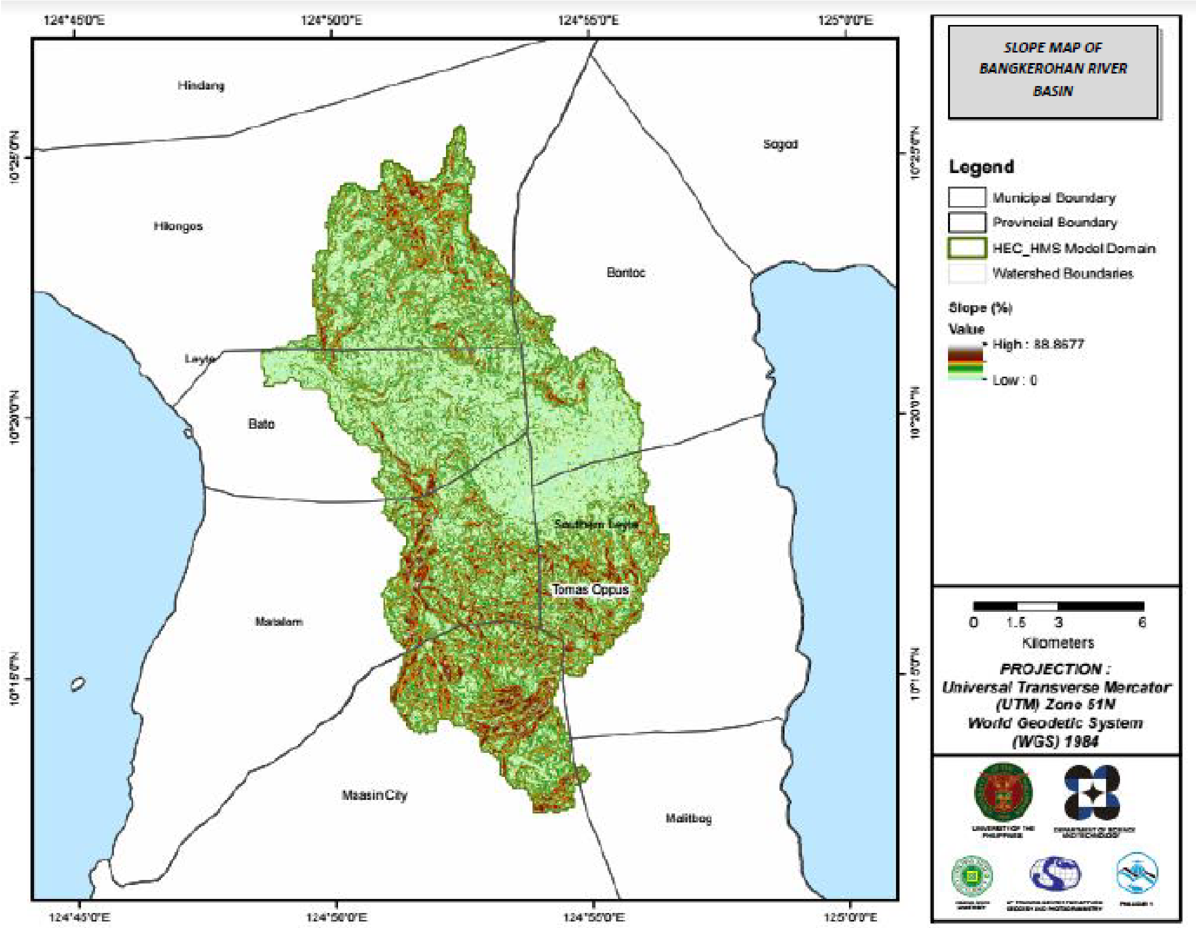



Figure 57. Slope Map of the Bangkerohan River Basin

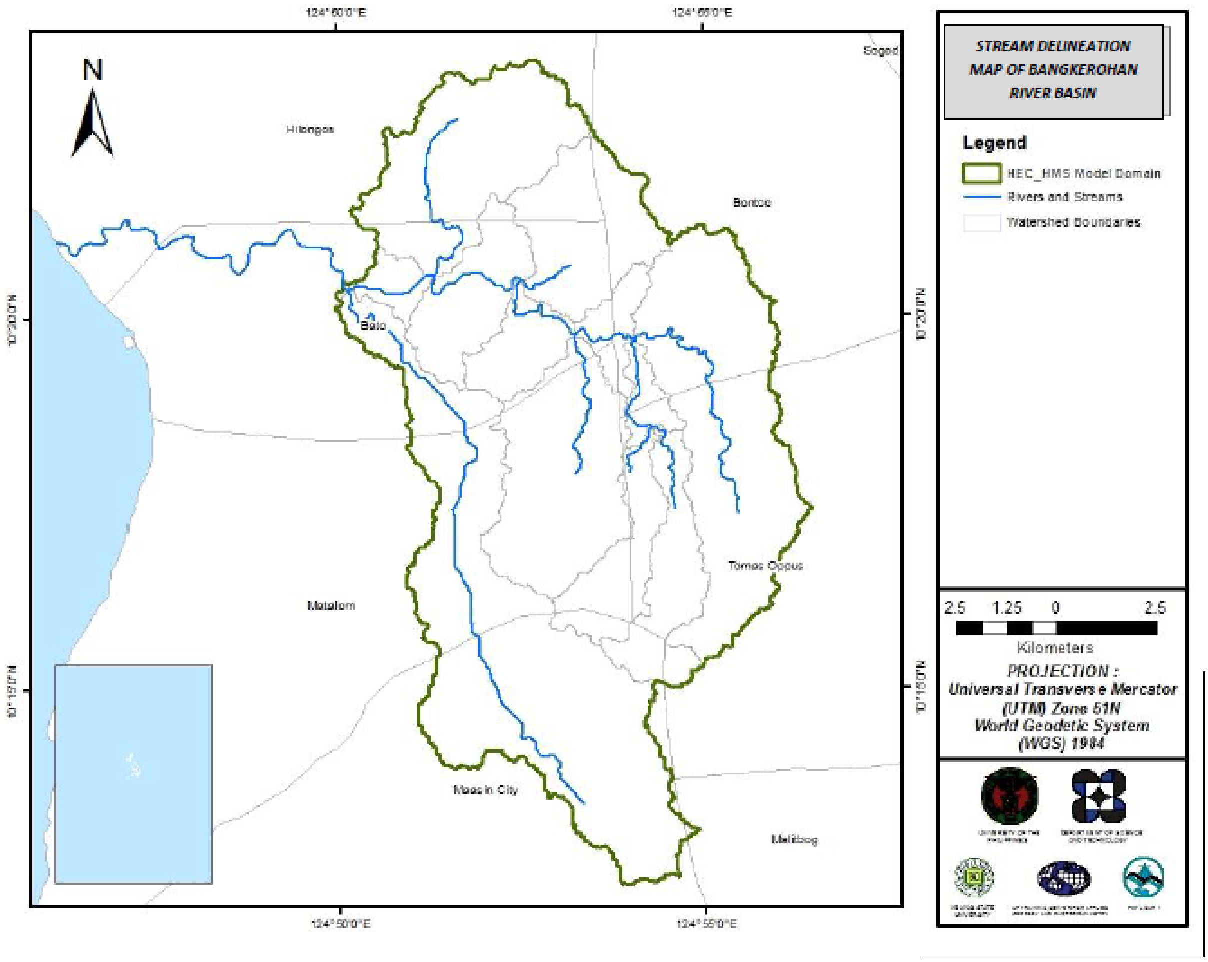



Figure 58. Stream Delineation Map of the Bangkerohan River Basin

Using the SAR-based DEM, the Bangkerohan basin was delineated and further subdivided into subbasins. The model consists of 13 sub basins, 6 reaches, and 6 junctions. The main outlet is Cambanog Bridge.

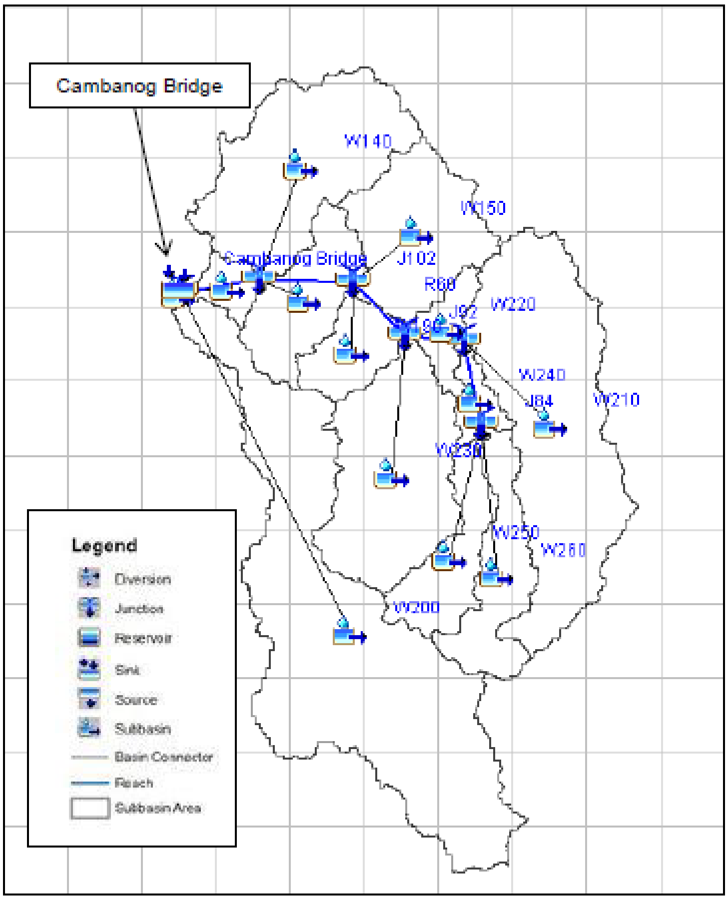



Figure 59. The Bangkerohan river basin model generated using HEC-HMS

## 5.4 Cross-section Data

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

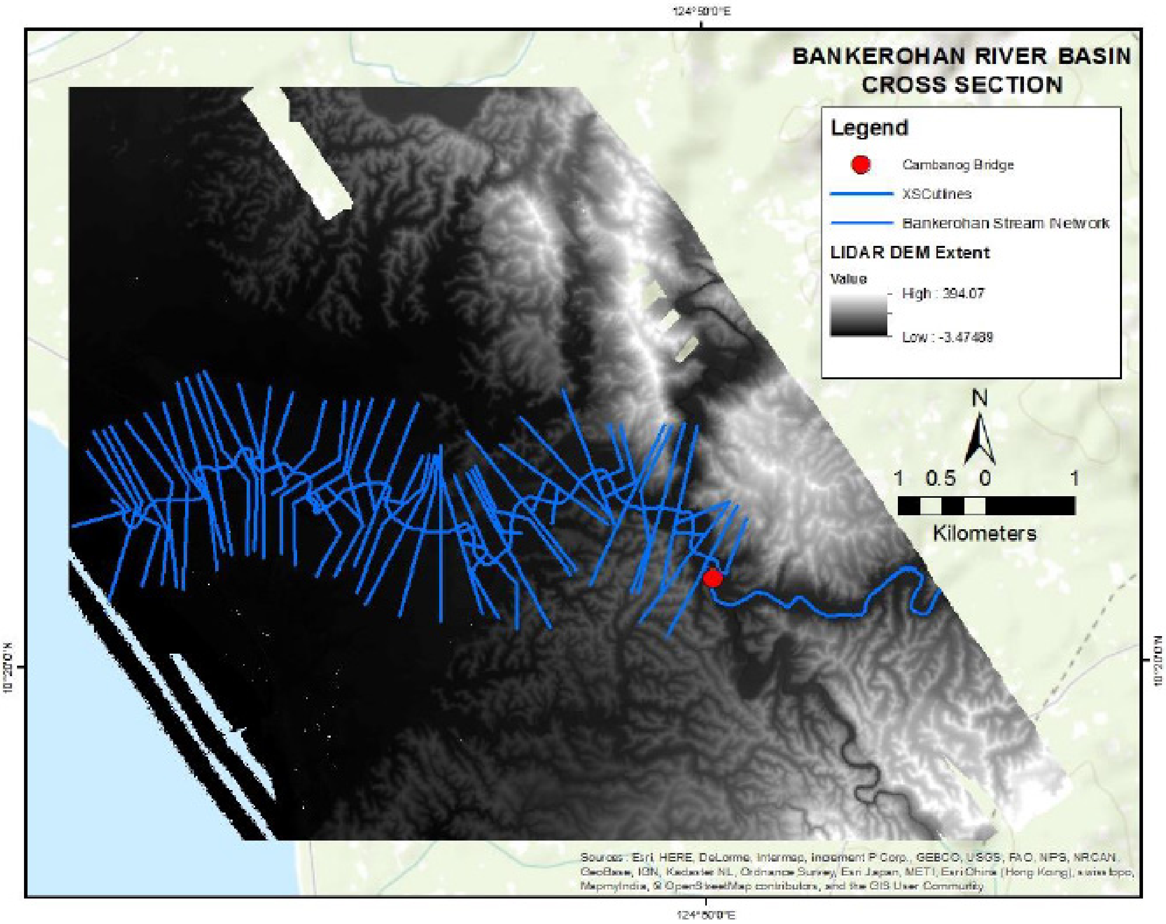



Figure 60. River cross-section of Bangkerohan River generated through Arcmap HEC GeoRAS tool

## 5.5 Flo 2D Model

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

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

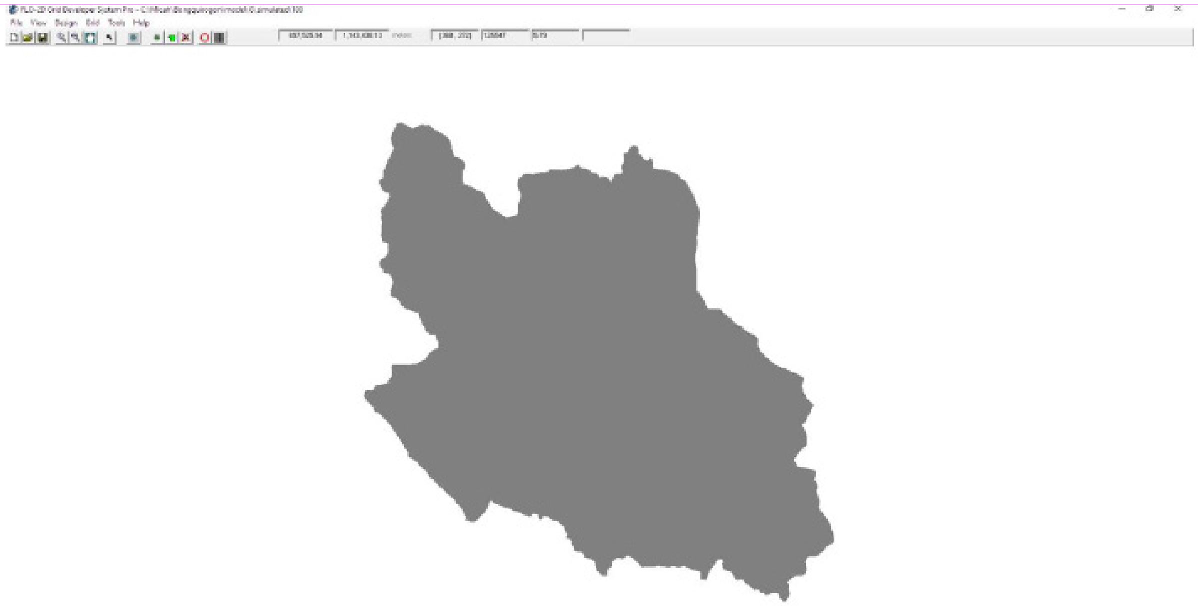


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 40.65039 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Bangkerohan are in Figures 65, 67, and 69.

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 47 009 900.00 m2. The generated flood depth maps for Bangkerohan are in Figures 66, 68, and 70.

There is a total of 43 448 011.06 $m^3$ of water entering the model. Of this amount, 12 945 606.61 $m^3$ is due to rainfall while 30 502 404.45 $m^3$ is inflow from other areas outside the model. 6 445 176.50 $m^3$ of this water is lost to infiltration and interception, while 9 334 302.55 $m^3$ is stored by the flood plain. The rest, amounting up to 27 668 533.30 $m^3$, is outflow.

## 5.6 Results of HMS Calibration

After calibrating the Bangkerohan HEC-HMS river basin model, its accuracy was measured against the observed values (see also Annex 9. Bangkerohan Model Basin Parameters). Figure 62 shows the comparison between the two discharge data.

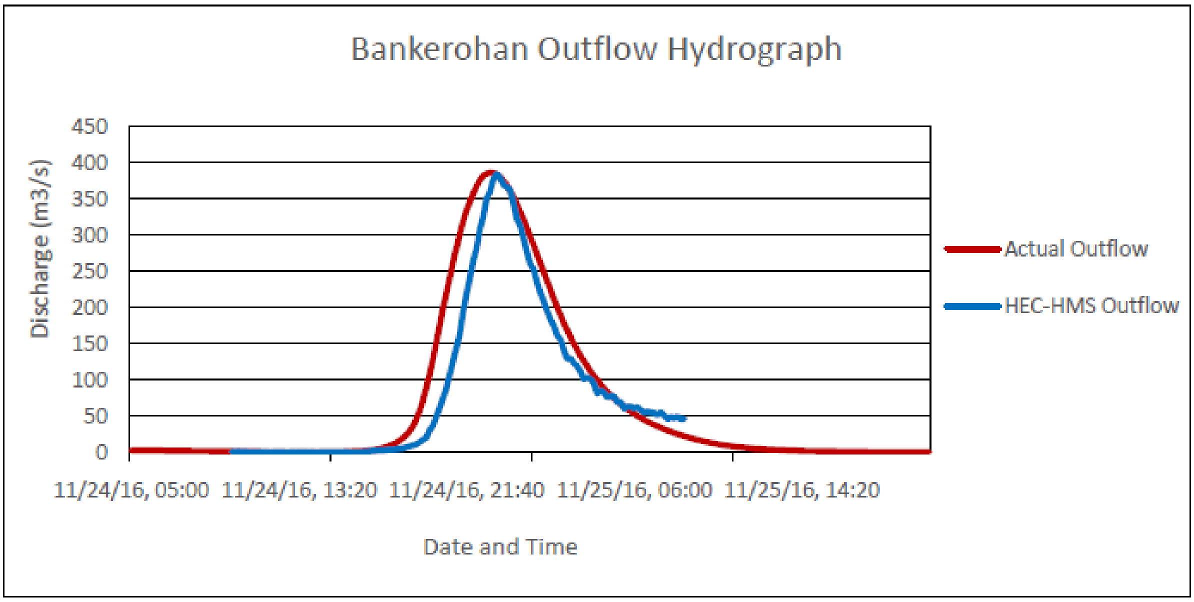



Figure 62. Outflow Hydrograph of Bangkerohan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 32. Range of Calibrated Values for Bangkerohan

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 5 – 9 |
| | | | Curve Number | 87 - 99 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.26 – 6.73 |
| | | | Storage Coefficient (hr) | 0.03 – 0.69 |
| | Baseflow | Recession | Recession Constant | 0.00005 |
| | | | Ratio to Peak | 0.8 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.04 |

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 5mm to 9mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 87 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.03 to 6.73 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 0.00005 indicates that the basin is likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.8 indicates a gentler slope of receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Bangkerohan watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 33. Summary of the Efficiency Test of Bangkerohan HMS Model

| | |
|---|---|
| RMSE | 26.5 |
| r2 | 0.92 |
| NSE | 0.86 |
| PBIAS | -22.49 |
| RSR | 0.38 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 26.5 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.92.

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 0.86.

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 -22.49.

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 0.38.

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

### 5.7.1 Hydrograph using the Rainfall Runoff Mode

The summary graph (Figure 63) shows the Bangkerohan outflow using the Maasin Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

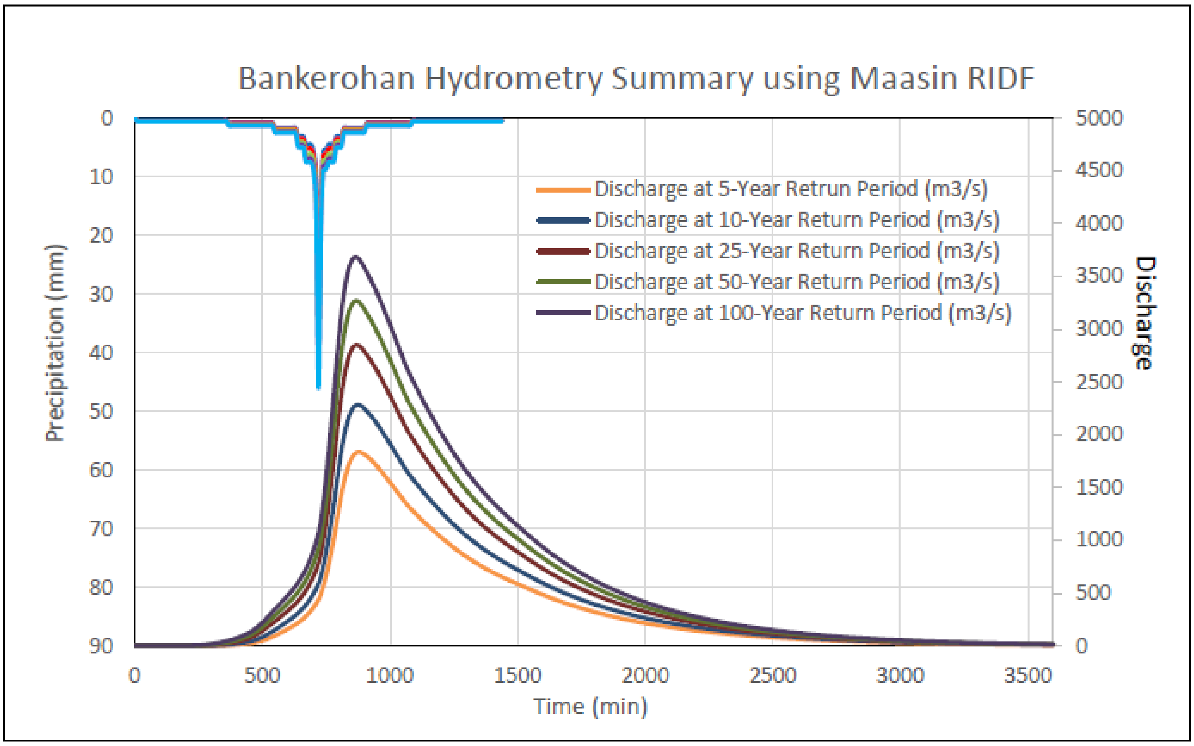



Figure 63. Outflow hydrograph at Bangkerohan Station generated using Maasin RIDF simulated in HEC-HMS

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

Table 34. Peak values of the Bangkerohan 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-Year** | 286.50 | 34.40 | 1834.10 | 9 hours, 40 minutes |
| **10-Year** | 351.20 | 42.30 | 2283 | 9 hours, 30 minutes |
| **25-Year** | 433 | 52.20 | 2852 | 9 hours, 30 minutes |
| **50-Year** | 493.70 | 59.60 | 3270 | 9 hours, 30 minutes |
| **100-Year** | 553.90 | 66.90 | 3682.30 | 9 hours, 20 minutes |

## 5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, the typhoon “Marce” output map river was shown, since it was calibrated. The sample generated map of Bangkerohan River using the calibrated HMS base flow is shown in Figure 64.


Figure 64. Sample output of Bangkerohan RAS Model

## 5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 5-, 25-, and 100-year rain return scenarios of the Bangkerohan floodplain.

The floodplain, with an area of 45.78 sq. km., covers two municipalities namely Bato and Hilongos. Table 35 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Bangkerohan floodplain

| Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|
| Bato | 57.55 | 22.46 | 39% |
| Hilongos | 156.80 | 23.33 | 15% |

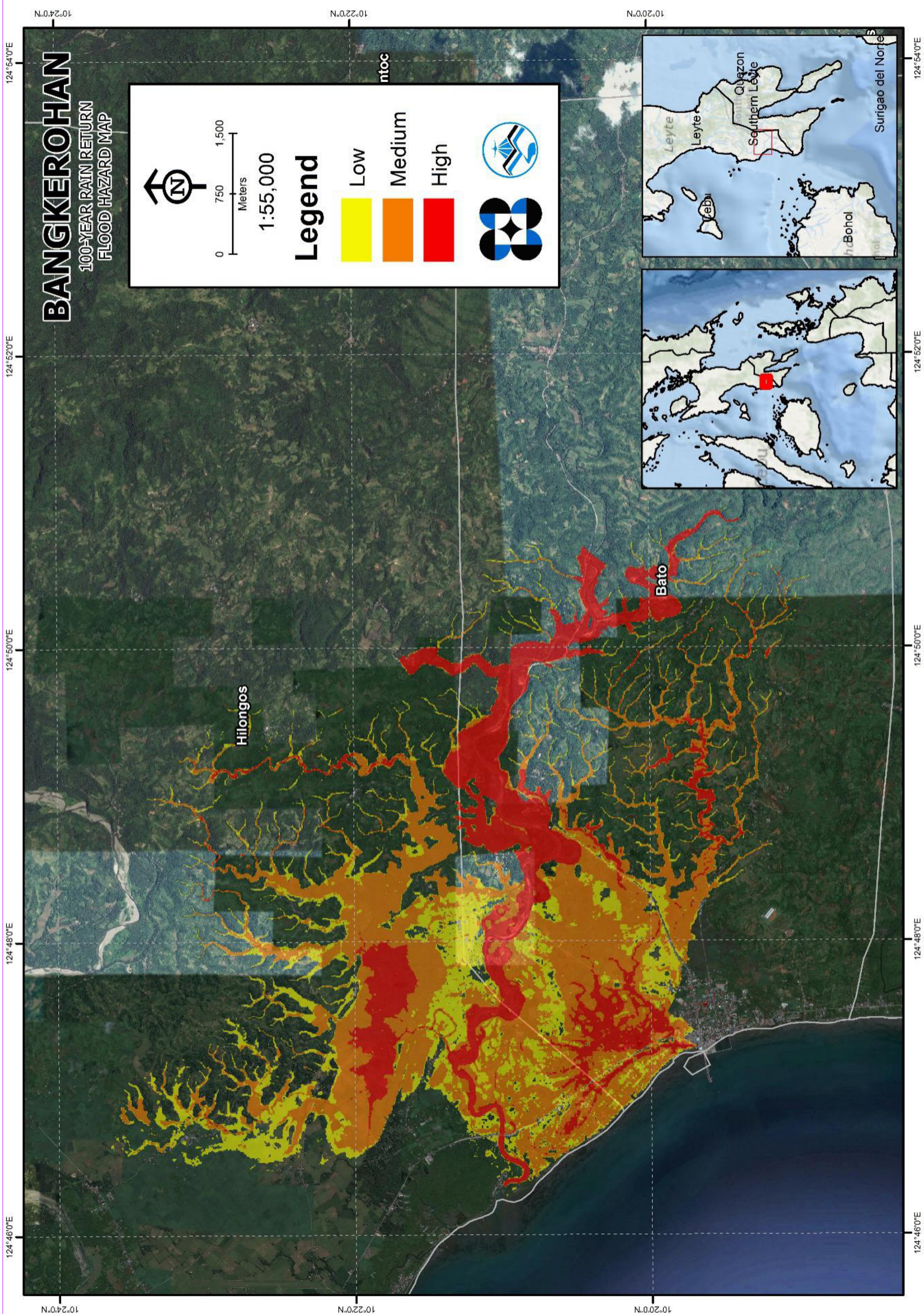



Figure 65. 100-year Flood Hazard Map for Bangkerohan Floodplain overlaid on Google Earth imagery

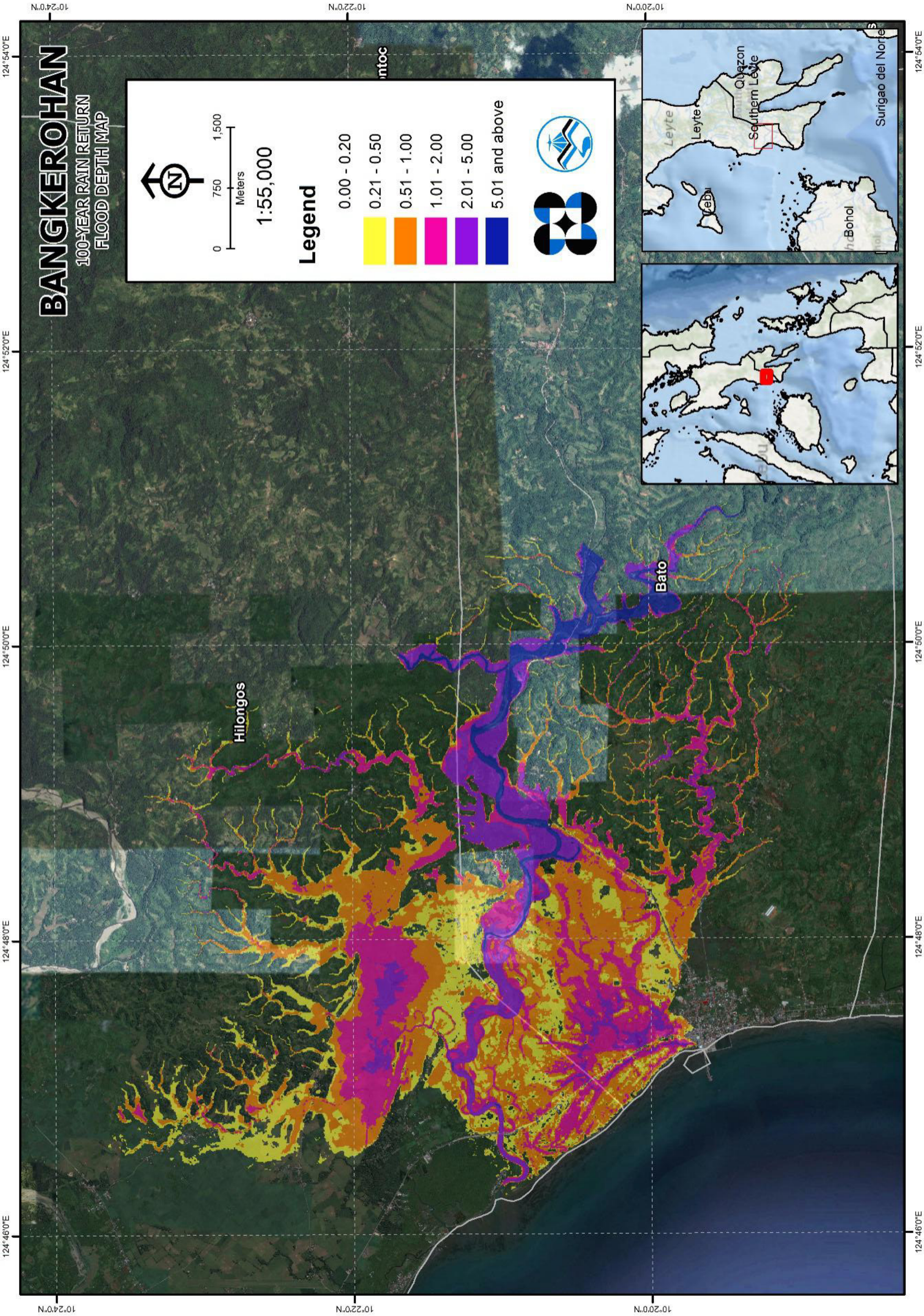



Figure 66. 100-year Flow Depth Map for Bangkerohan Floodplain overlaid on Google Earth imagery

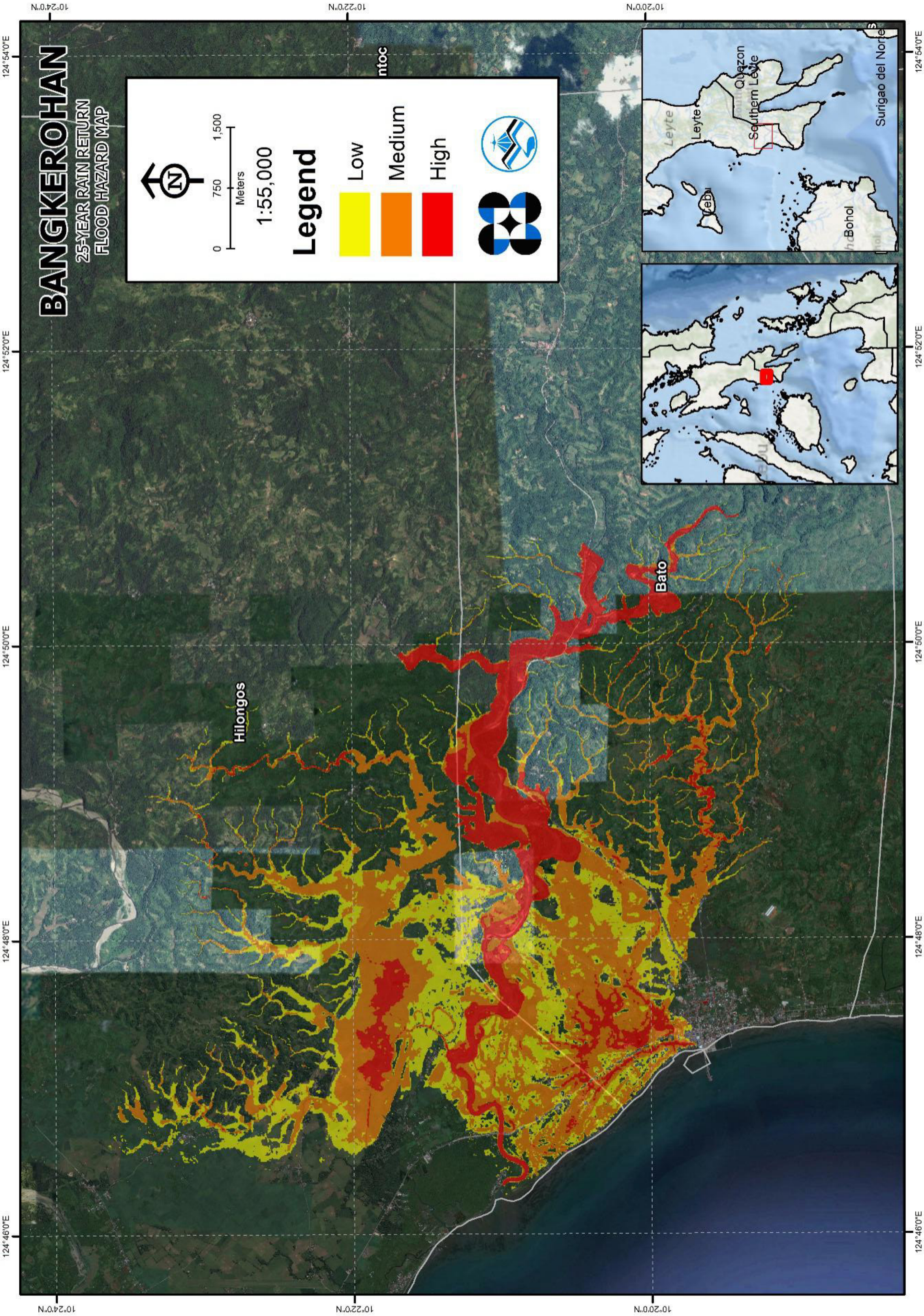



Figure 67. 25-year Flood Hazard Map for Bangkerohan Floodplain overlaid on Google Earth imagery

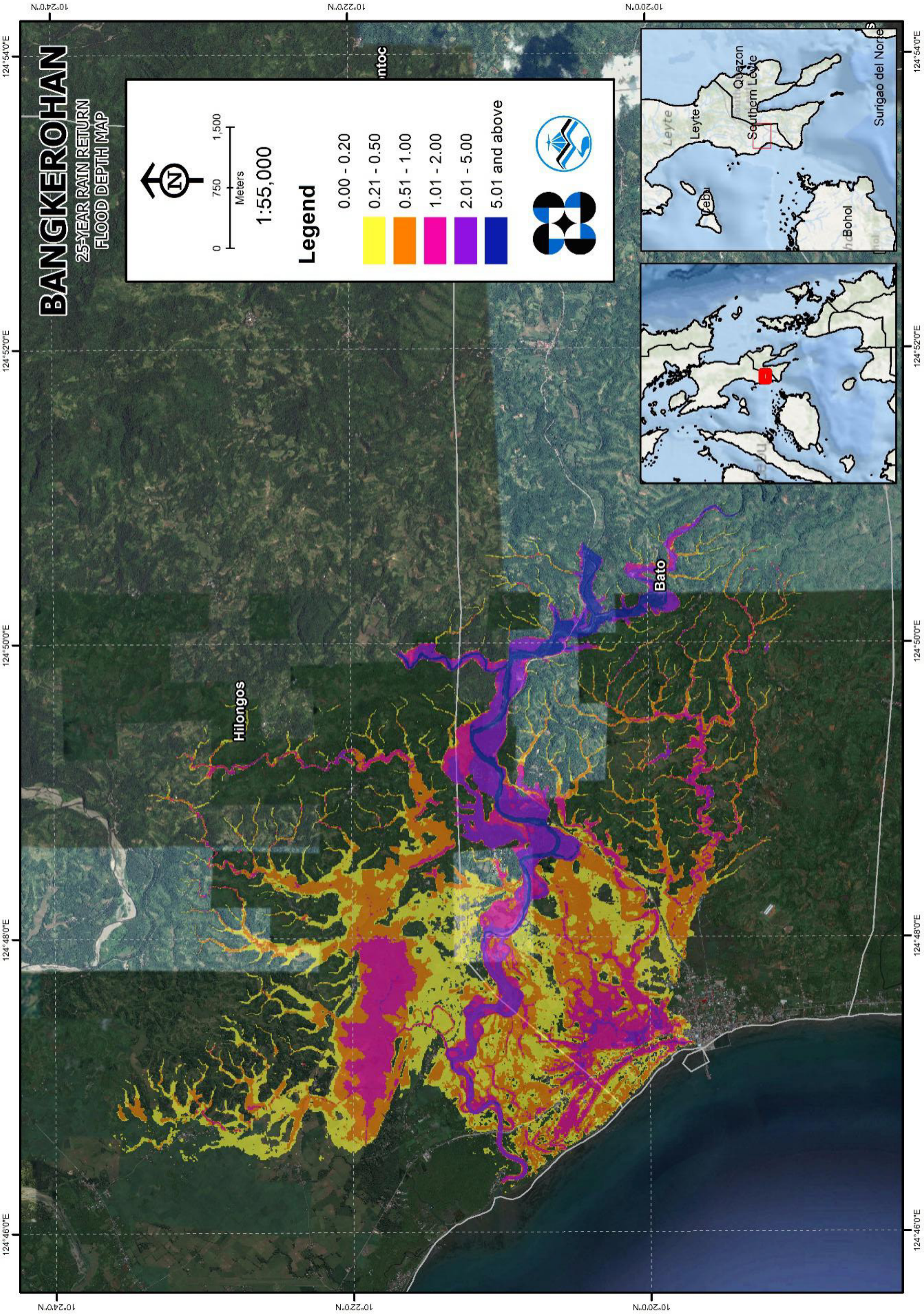



Figure 68. 25-year Flow Depth Map for Bangkerohan Floodplain overlaid on Google Earth imagery

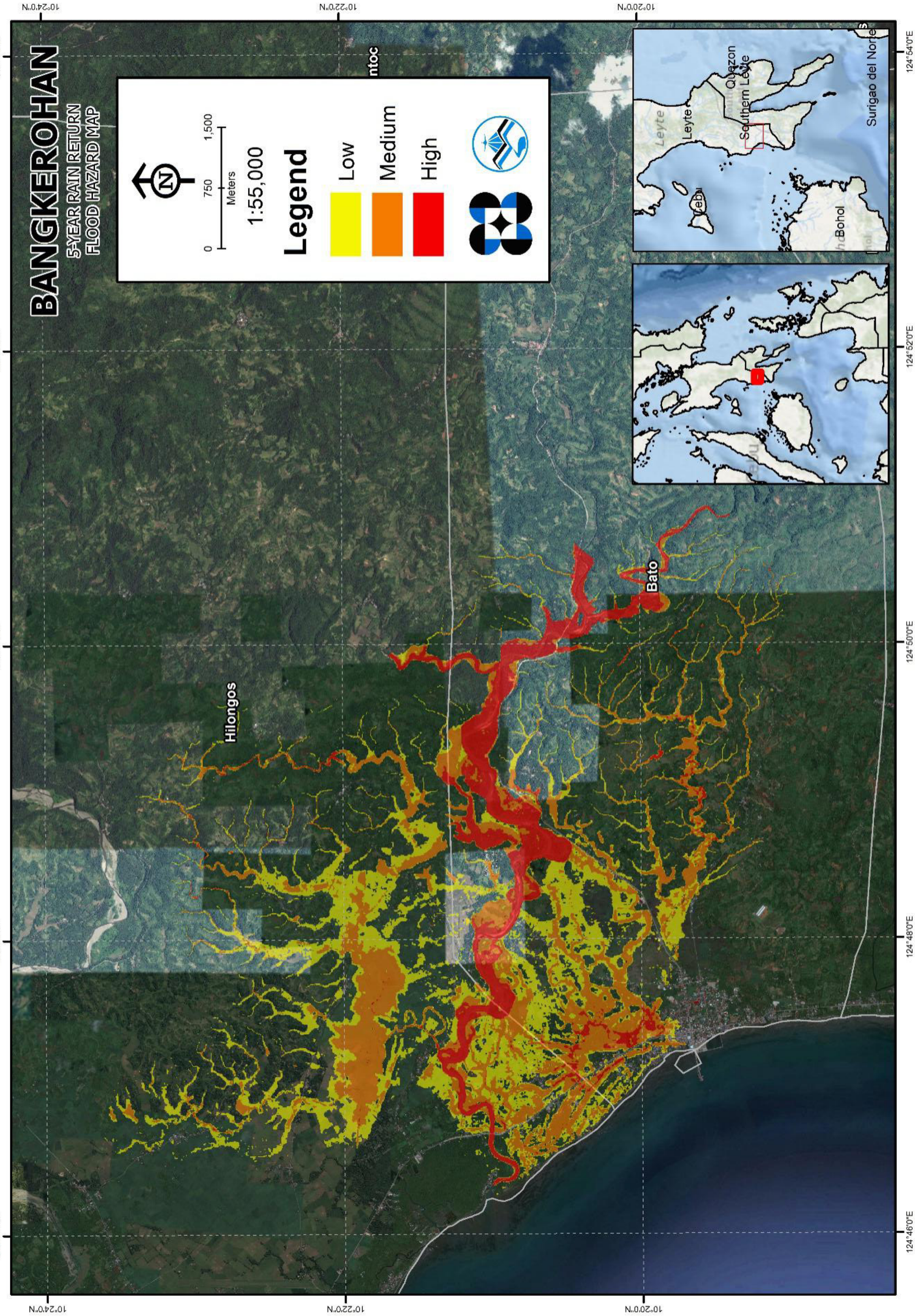



Figure 69. 5-year Flood Hazard Map for Bangkerohan Floodplain overlaid on Google Earth imagery

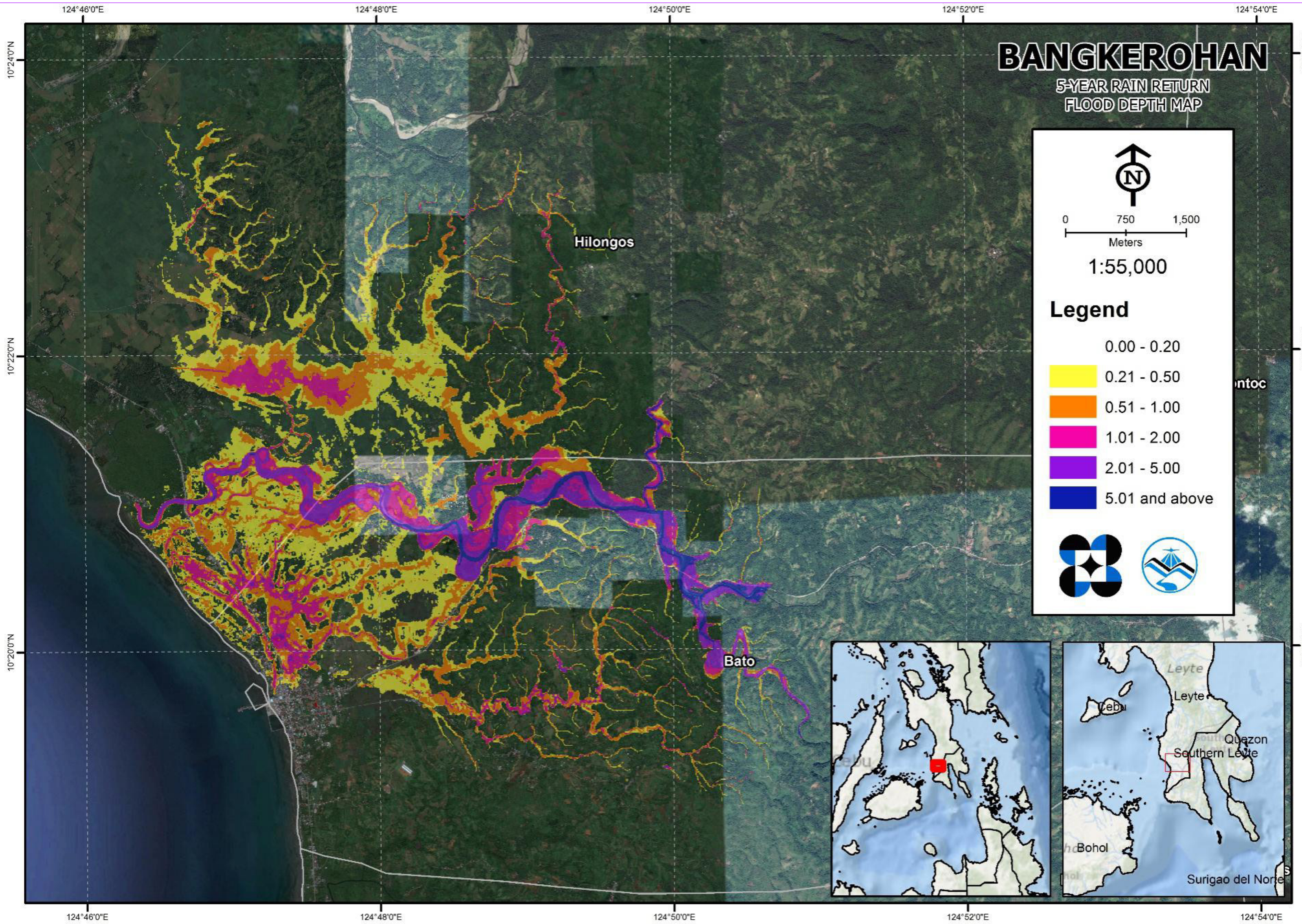



Figure 70. 5-year Flow Depth Map for Bangkerohan Floodplain overlaid on Google Earth imagery

## 5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Bangkerohan river basin, grouped by municipality, are listed below. For the said basin, two municipality consisting of 8 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 25.4755% of the municipality of Bato with an area of 57.552 sq. km. will experience flood levels of less 0.20 meters. 4.2989% of the area will experience flood levels of 0.21 to 0.50 meters while 3.5015%, 2.6694%, 2.311%, and 0.7611% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in the tables below are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Bato, Leyte during 5-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Bato | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Alegria | Alejos | Amagos | Bago | Bagong Bayan District | Daan Lungsod | Dolho | Guerrero District |
| Affected Area (sq. km.) | 0.03-0.20 | 0.465312591 | 4.303232302 | 0.674928363 | 0.805755289 | 0.31563515 | 0.310336274 | 0.619104036 | 0.156308949 |
| | 0.21-0.50 | 0.021555114 | 0.497906208 | 0.024562077 | 0.027668717 | 0.203795246 | 0.411050108 | 0.398485801 | 0.022214588 |
| | 0.51-1.00 | 0.01315183 | 0.554044539 | 0.016271224 | 0.017224195 | 0.105753193 | 0.285350121 | 0.355856381 | 0.028461129 |
| | 1.01-2.00 | 0.004668391 | 0.152570687 | 0.012121091 | 0.029584967 | 0.022769692 | 0.174492587 | 0.219689287 | 0.034121716 |
| | 2.01-5.00 | 0.0012 | 0.020160874 | 0.023401515 | 0.143897725 | 0 | 0.130376558 | 0.015205646 | 0.002214922 |
| | > 5.00 | 0 | 0 | 0.0023 | 0.110310498 | 0 | 0 | 0 | 0 |

Table 37. Affected Areas in Bato, Leyte during 5-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Bato | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Iniguihan District | Mabini | Marcelo | Naga | San Agustin | Tabunok | Tagaytay | Tugas |
| Affected Area (sq. km.) | 0.03-0.20 | 0.092227762 | 0.875292187 | 0.1638378 | 1.081636558 | 1.29030447 | 0.814592385 | 2.298525492 | 0.394528178 |
| | 0.21-0.50 | 0.030464416 | 0.036302154 | 0.004035836 | 0.090418495 | 0.063065102 | 0.450999197 | 0.176355713 | 0.015209874 |
| | 0.51-1.00 | 0.036231771 | 0.011293516 | 0.002035505 | 0.17811695 | 0.064100132 | 0.193777658 | 0.135790795 | 0.017738933 |
| | 1.01-2.00 | 0.041578727 | 0.004905416 | 0.001715618 | 0.488099553 | 0.068521526 | 0.215194866 | 0.063053208 | 0.003250067 |
| | 2.01-5.00 | 0.003041409 | 0.01499185 | 0.0006 | 0.66106045 | 0.109785514 | 0.141991867 | 0.062117884 | 0 |
| | > 5.00 | 0 | 0.005977926 | 0 | 0.263277282 | 0.004165527 | 0.034402604 | 0.01761039 | 0 |

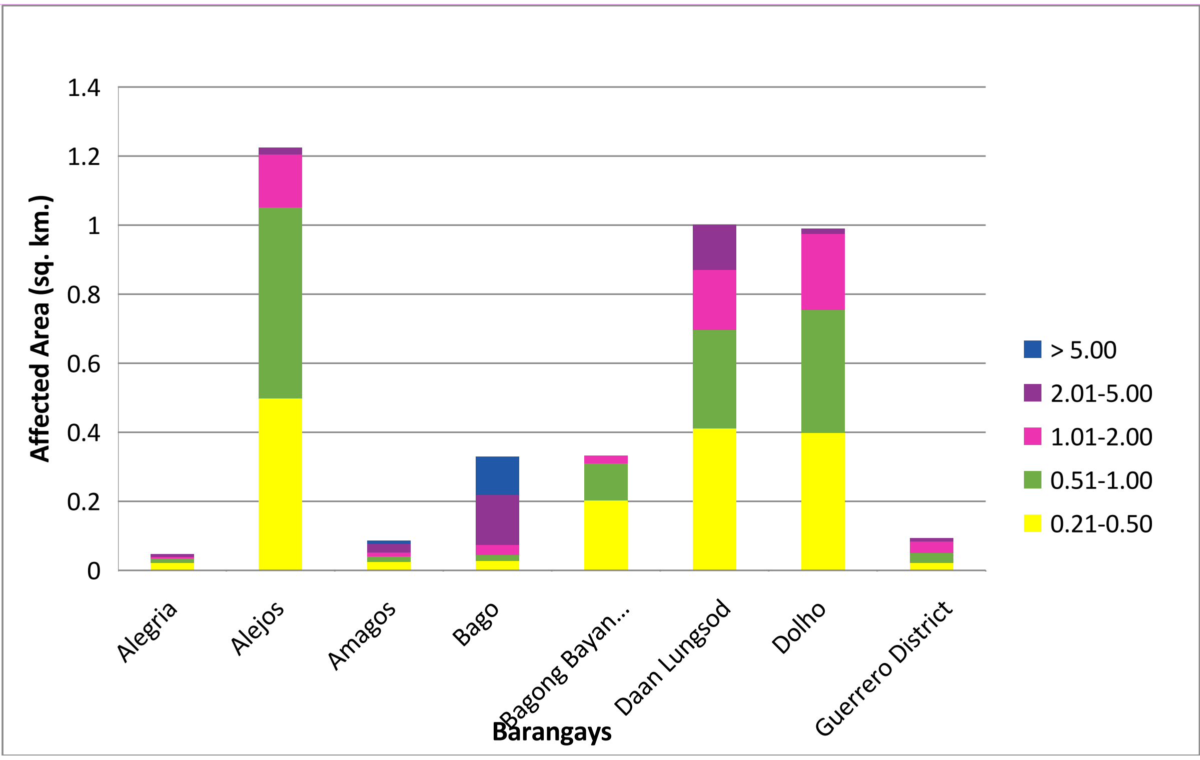



Figure 71. Affected Areas in Bato, Leyte during 5-Year Rainfall Return Period

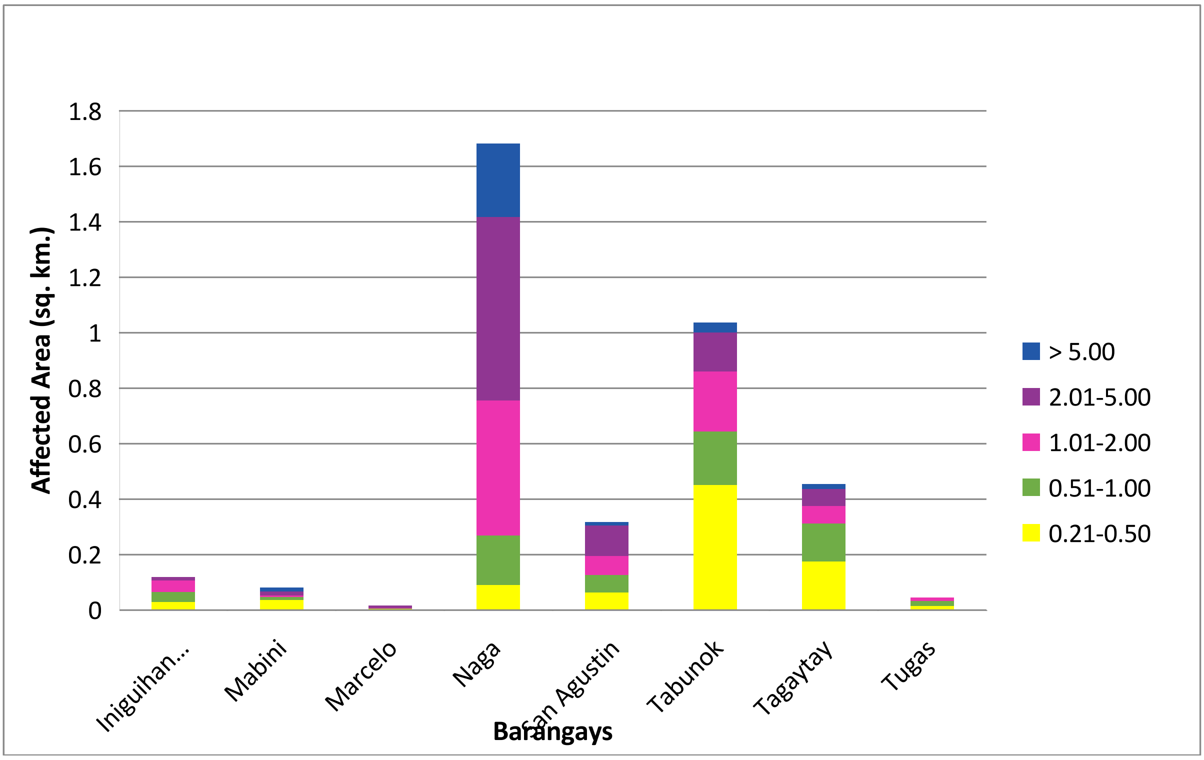



Figure 72. Affected Areas in Bato, Leyte during 5-Year Rainfall Return Period

For the 5-year return period, 10.13% of the municipality of Hilongos with an area of 156.796 sq. km. will experience flood levels of less 0.20 meters. 2.54% of the area will experience flood levels of 0.21 to 0.50 meters while 1.427%, 0.5635%, 0.197%, and 0.0119% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in the tables below are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Hilongos, Leyte during 5-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Hilongos | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Baas | Bagumbayan | Bantigue | Bon-Ot | Campina | Catandog 1 | Catandog 2 | Concepcion |
| Affected Area (sq. km.) | 0.03-0.20 | 3.744365732 | 1.876891 | 0.212757 | 0.752237 | 1.355471 | 0.103178 | 0.215441 | 1.503482 |
| | 0.21-0.50 | 1.001180944 | 0.066406 | 0.099159 | 0.030222 | 0.210651 | 0.0046 | 0.137742 | 0.220672 |
| | 0.51-1.00 | 0.351557789 | 0.062879 | 0.096484 | 0.023767 | 0.050766 | 1E-04 | 0.162776 | 0.058581 |
| | 1.01-2.00 | 0.051113864 | 0.026133 | 0.037329 | 0.024357 | 0.002334 | 0 | 0.116362 | 0.007373 |
| | 2.01-5.00 | 0.0002 | 0.0018 | 0.016107 | 0.037626 | 0 | 0 | 0.018076 | 0 |
| | > 5.00 | 0 | 0 | 0 | 0.015589 | 0 | 0 | 0 | 0 |

Table 39. Affected Areas in Hilongos, Leyte during 5-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Hilongos | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kang-Iras | Kangha-As | Lunang | Manaul | Tabunok | Talisay | Tejero | Tuguipa |
| Affected Area (sq. km.) | 0.03-0.20 | 1.199978329 | 0.330048 | 1.580587 | 0.047635 | 0.162593 | 0.185011 | 1.181078 | 1.433327 |
| | 0.21-0.50 | 0.035962589 | 0.327097 | 0.797345 | 0.008462 | 0.643571 | 0.112458 | 0.213816 | 0.084104 |
| | 0.51-1.00 | 0.021777598 | 0.285186 | 0.54867 | 0.002092 | 0.406124 | 0.035191 | 0.03075 | 0.10163 |
| | 1.01-2.00 | 0.02277792 | 0.208227 | 0.132077 | 0 | 0.193114 | 0.008729 | 0.002092 | 0.051591 |
| | 2.01-5.00 | 0.0018 | 0.0001 | 0.007652 | 0 | 0.21203 | 0.009646 | 0 | 0.00409 |
| | > 5.00 | 0 | 0 | 0 | 0 | 0.0031 | 0 | 0 | 0 |

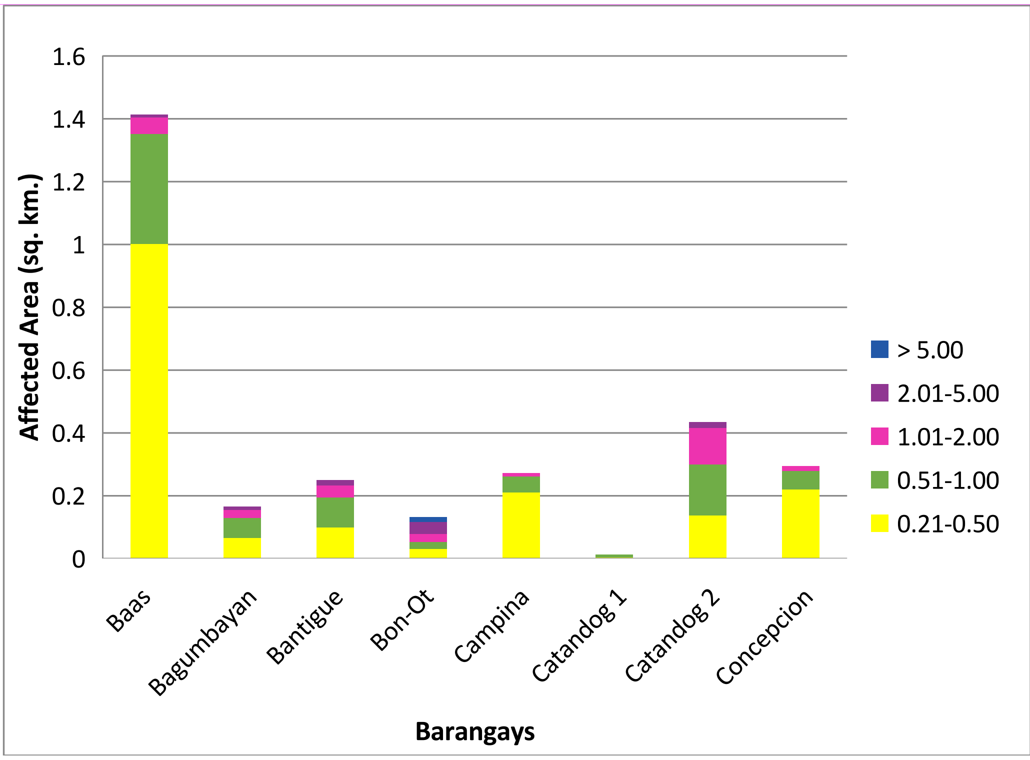



Figure 73. Affected Areas in Hilongos, Leyte during 5-Year Rainfall Return Period

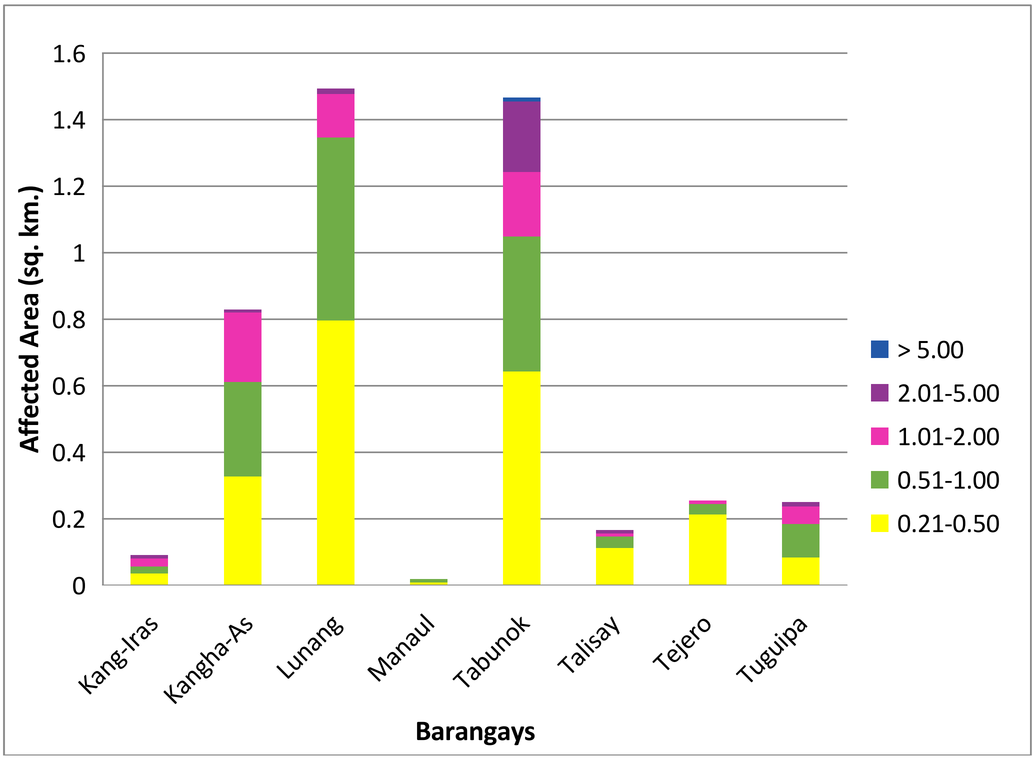



Figure 74. Affected Areas in Hilongos, Leyte during 5-Year Rainfall Return Period

For the 25-year return period, 22.0154% of the municipality of Bato with an area of 57.552 sq. km. will experience flood levels of less 0.20 meters. 3.988% of the area will experience flood levels of 0.21 to 0.50 meters while 4.789%, 3.636%, 3.23%, and 1.357% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in the tables below are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Bato, Leyte during 25-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Bato | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Alegria | Alejos | Amagos | Bago | Bagong Bayan District | Daan Lungsod | Dolho | Guerrero District |
| Affected Area (sq. km.) | 0.03-0.20 | 0.456673982 | 4.059124488 | 0.657552908 | 0.749609913 | 0.130971362 | 0.113162859 | 0.125818515 | 0.08477802 |
| | 0.21-0.50 | 0.019913603 | 0.371046219 | 0.026509522 | 0.022274203 | 0.21768448 | 0.364635524 | 0.407077976 | 0.066869763 |
| | 0.51-1.00 | 0.018608585 | 0.680224801 | 0.020011382 | 0.015236451 | 0.224689355 | 0.381259629 | 0.528050442 | 0.032676825 |
| | 1.01-2.00 | 0.007812717 | 0.365288018 | 0.012009309 | 0.029770254 | 0.074594099 | 0.2940577 | 0.469473181 | 0.049946306 |
| | 2.01-5.00 | 0.002879282 | 0.052244056 | 0.027801581 | 0.08870526 | 1.46329E-05 | 0.158484418 | 0.077917552 | 0.009050219 |
| | > 5.00 | 0 | 0 | 0.009695863 | 0.228832147 | 0 | 0 | 0 | 0 |

Table 41. Affected Areas in Bato, Leyte during 25-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Bato | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Iniguihan District | Mabini | Marcelo | Naga | San Agustin | Tabunok | Tagaytay | Tugas |
| Affected Area (sq. km.) | 0.03-0.20 | 0.052789227 | 0.856099058 | 0.161575042 | 0.980184717 | 1.224354871 | 0.420725813 | 2.20852556 | 0.38826422 |
| | 0.21-0.50 | 0.029320119 | 0.04579415 | 0.004556858 | 0.050096017 | 0.052685906 | 0.462034613 | 0.138809697 | 0.016072055 |
| | 0.51-1.00 | 0.039802804 | 0.014311897 | 0.003275467 | 0.065268776 | 0.057680039 | 0.487454037 | 0.168405133 | 0.019229881 |
| | 1.01-2.00 | 0.061742779 | 0.006699922 | 0.002015578 | 0.274980645 | 0.06478488 | 0.264553588 | 0.108247496 | 0.006999336 |
| | 2.01-5.00 | 0.019888922 | 0.008605776 | 0.0008 | 1.021555055 | 0.122605402 | 0.171814925 | 0.096501297 | 1E-04 |
| | > 5.00 | 0 | 0.017269822 | 0 | 0.370518035 | 0.077824422 | 0.0443718 | 0.033014578 | 0 |

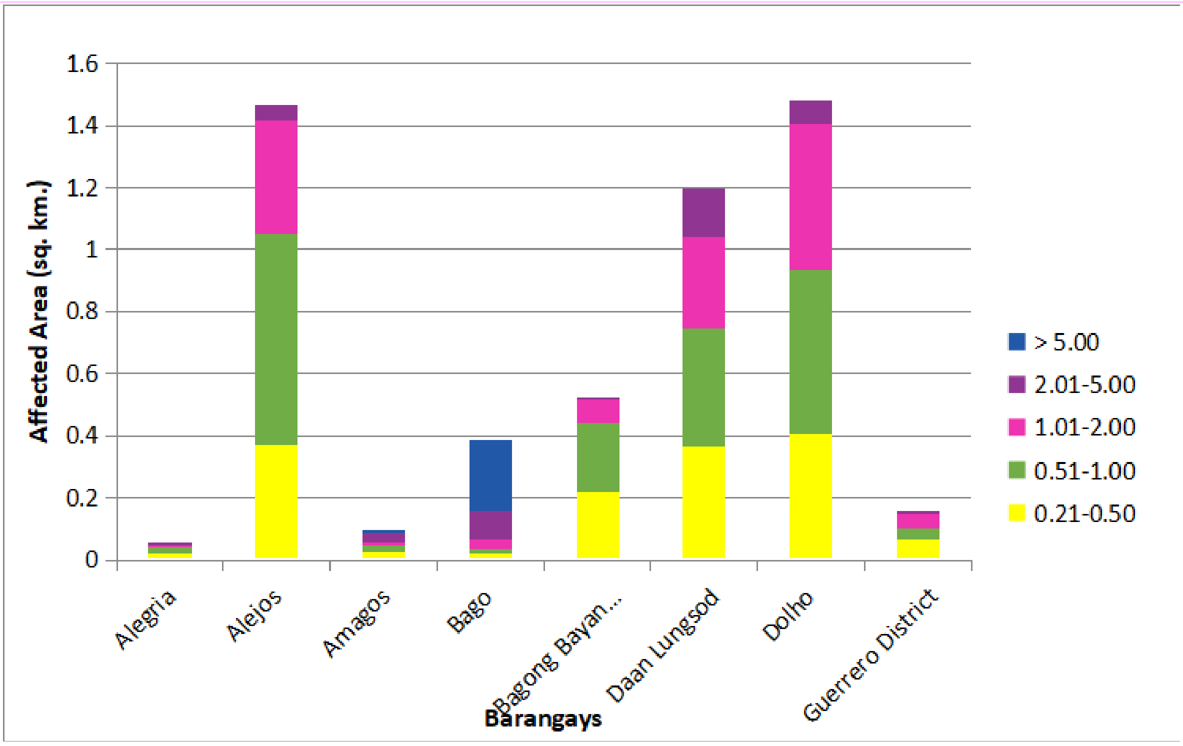



Figure 75. Affected Areas in Bato, Leyte during 25-Year Rainfall Return Period

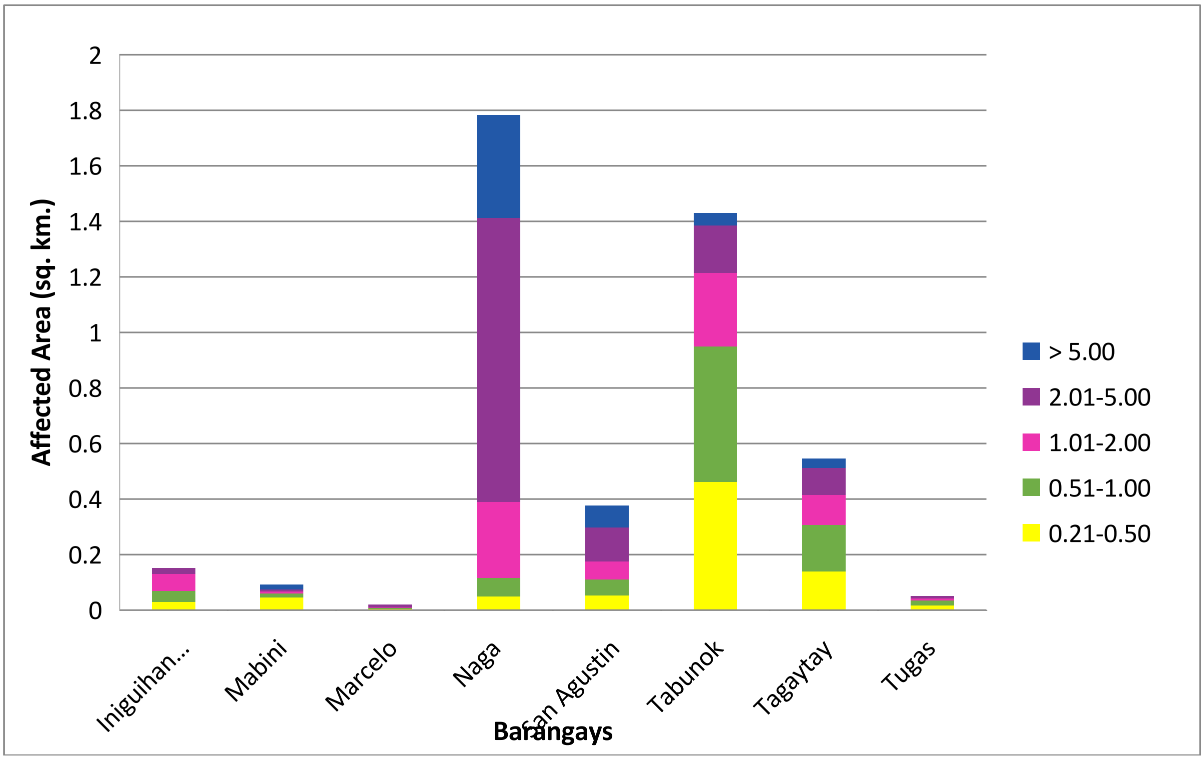



Figure 76. Affected Areas in Bato, Leyte during 25-Year Rainfall Return Period

For the 25-year return period, 8.586% of the municipality of Hilongos with an area of 156.796 sq. km. will experience flood levels of less 0.20 meters. 2.587% of the area will experience flood levels of 0.21 to 0.50 meters while 2.22%, 1.19%, 0.272%, and 0.0216% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in the tables below are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Hilongos, Leyte during 25-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Hilongos | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Baas | Bagumbayan | Bantigue | Bon-Ot | Campina | Catandog 1 | Catandog 2 | Concepcion |
| Affected Area (sq. km.) | 0.03-0.20 | 3.401191504 | 1.845624 | 0.167454 | 0.725306 | 1.198545 | 0.100178 | 0.117105 | 1.384811 |
| | 0.21-0.50 | 0.777439208 | 0.069049 | 0.08789 | 0.021998 | 0.262845 | 0.0076 | 0.151432 | 0.269039 |
| | 0.51-1.00 | 0.766714632 | 0.067099 | 0.130906 | 0.011906 | 0.139864 | 1E-04 | 0.189796 | 0.123837 |
| | 1.01-2.00 | 0.201247802 | 0.048286 | 0.050377 | 0.027615 | 0.017969 | 0 | 0.171292 | 0.012322 |
| | 2.01-5.00 | 0.001824608 | 0.004056 | 0.025208 | 0.066289 | 0 | 0 | 0.020773 | 1E-04 |
| | > 5.00 | 0 | 0 | 0 | 0.030683 | 0 | 0 | 0 | 0 |

Table 43. Affected Areas in Hilongos, Leyte during 25-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Hilongos | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kang-Iras | Kangha-As | Lunang | Manaul | Tabunok | Talisay | Tejero | Tuguipa |
| Affected Area (sq. km.) | 0.03-0.20 | 1.176107526 | 0.097081 | 0.727552 | 0.02043 | 0.056782 | 0.144889 | 0.9118 | 1.387567 |
| | 0.21-0.50 | 0.046031466 | 0.207272 | 0.99418 | 0.025116 | 0.516178 | 0.125084 | 0.413908 | 0.081182 |
| | 0.51-1.00 | 0.024341068 | 0.397504 | 0.789157 | 0.01157 | 0.580298 | 0.061204 | 0.098575 | 0.088786 |
| | 1.01-2.00 | 0.028010355 | 0.447201 | 0.540015 | 0.001072 | 0.230302 | 0.010112 | 0.003453 | 0.076756 |
| | 2.01-5.00 | 0.007805996 | 0.0016 | 0.015432 | 0 | 0.233682 | 0.009746 | 0 | 0.040455 |
| | > 5.00 | 0 | 0 | 0 | 0 | 0.0033 | 0 | 0 | 0 |

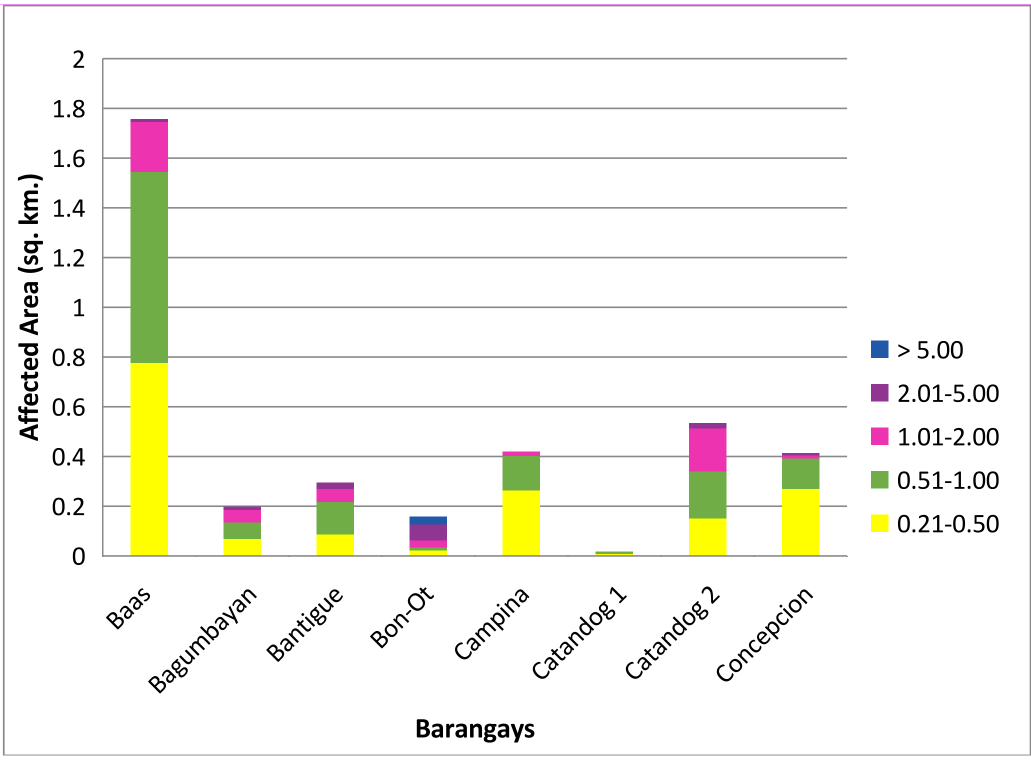



Figure 77. Affected Areas in Hilongos, Leyte during 25-Year Rainfall Return Period

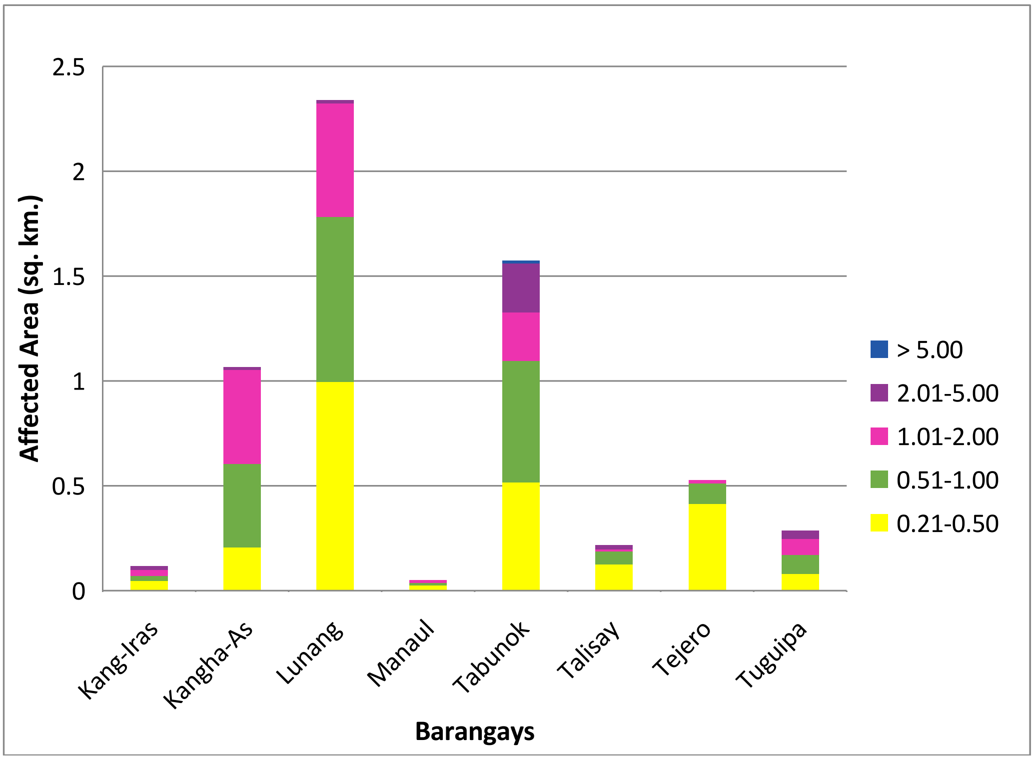



Figure 78. Affected Areas in Hilongos, Leyte during 25-Year Rainfall Return Period

For the 25-year return period, 22.0154% of the municipality of Bato with an area of 57.552 sq. km. will experience flood levels of less 0.20 meters. 3.988% of the area will experience flood levels of 0.21 to 0.50 meters while 4.789%, 3.636%, 3.23%, and 1.357% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in the tables below are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected Areas in Bato, Leyte during 100-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Bato | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Alegria | Alejos | Amagos | Bago | Bagong Bayan District | Daan Lungsod | Dolho | Guerrero District |
| Affected Area (sq. km.) | 0.03-0.20 | 0.449986159 | 3.939324134 | 0.649603501 | 0.710188218 | 0.058976778 | 0.052013252 | 0.029400316 | 0.030909792 |
| | 0.21-0.50 | 0.017988459 | 0.309981704 | 0.025486573 | 0.020605948 | 0.192607775 | 0.278369298 | 0.211396555 | 0.088743369 |
| | 0.51-1.00 | 0.022193087 | 0.605792221 | 0.021934213 | 0.0159635 | 0.290444052 | 0.413178855 | 0.64590528 | 0.054713463 |
| | 1.01-2.00 | 0.011644948 | 0.572169605 | 0.011857873 | 0.02022413 | 0.105507751 | 0.374880158 | 0.569327942 | 0.048623617 |
| | 2.01-5.00 | 0.004075273 | 0.100646944 | 0.028584645 | 0.072167375 | 0.000416925 | 0.193164097 | 0.152311058 | 0.020331064 |
| | > 5.00 | 0 | 0 | 0.016117464 | 0.295292219 | 0 | 0 | 0 | 0 |

Table 45. Affected Areas in Bato, Leyte during 100-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Bato | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Iniguihan District | Mabini | Marcelo | Naga | San Agustin | Tabunok | Tagaytay | Tugas |
| Affected Area (sq. km.) | 0.03-0.20 | 0.037315901 | 0.840246125 | 0.159576594 | 0.930550725 | 1.181288609 | 0.245540763 | 2.155817516 | 0.383490441 |
| | 0.21-0.50 | 0.028790234 | 0.053379012 | 0.005353122 | 0.046586329 | 0.048514679 | 0.412518678 | 0.111826705 | 0.016106759 |
| | 0.51-1.00 | 0.040964159 | 0.018421801 | 0.003679425 | 0.051428789 | 0.051213815 | 0.590246182 | 0.179891576 | 0.019630016 |
| | 1.01-2.00 | 0.061216768 | 0.007140601 | 0.002615618 | 0.157041852 | 0.051933127 | 0.353202649 | 0.138672165 | 0.011299838 |
| | 2.01-5.00 | 0.035257023 | 0.007397279 | 0.001 | 1.116517374 | 0.105221293 | 0.193629807 | 0.120636091 | 0.0002 |
| | > 5.00 | 0 | 0.022178231 | 0 | 0.46048422 | 0.161770747 | 0.055820499 | 0.046609429 | 0 |

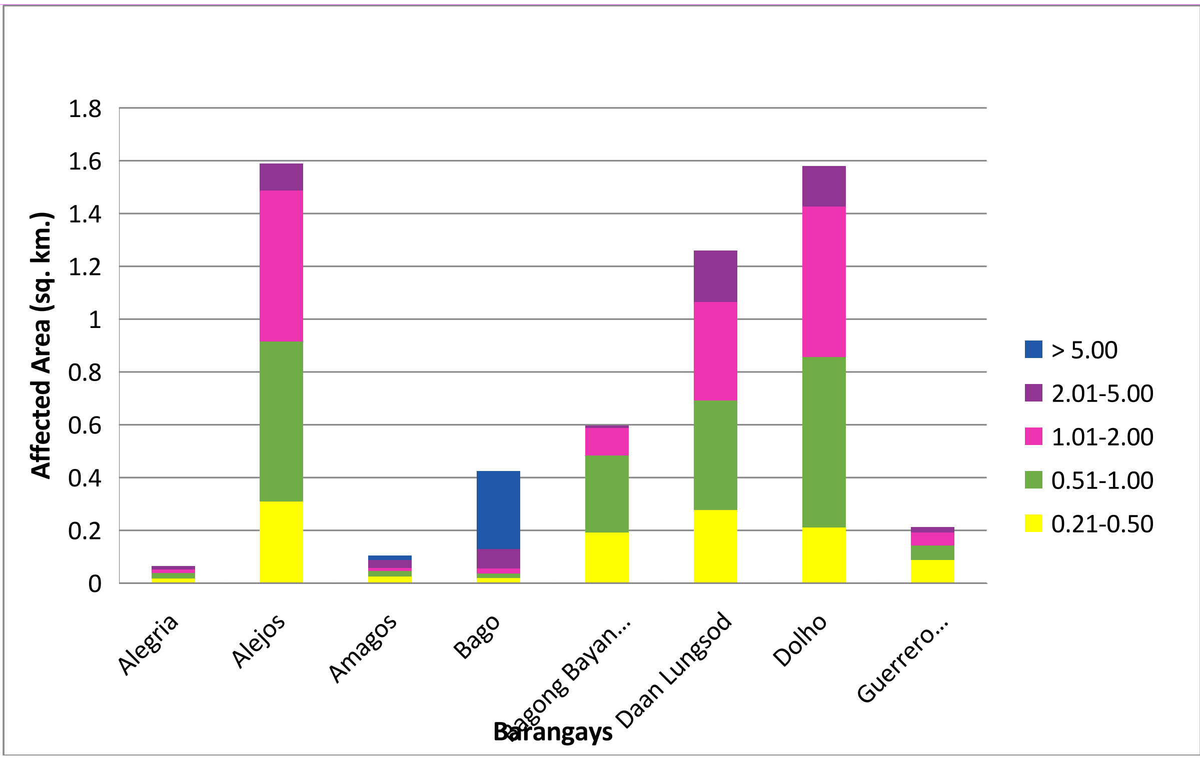



Figure 79. Affected Areas in Bato, Leyte during 100-Year Rainfall Return Period

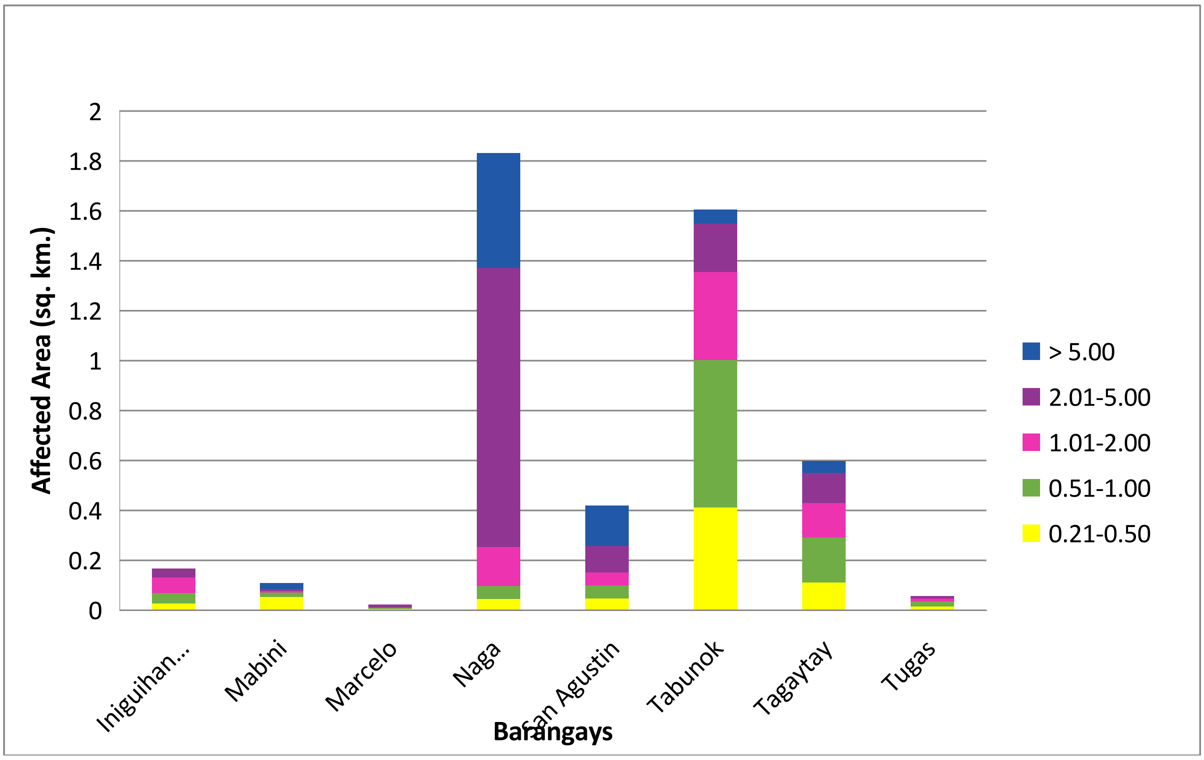



Figure 80. Affected Areas in Bato, Leyte during 100-Year Rainfall Return Period

For the 100-year return period, 8.032% of the municipality of Hilongos with an area of 156.796 sq. km. will experience flood levels of less 0.20 meters. 2.129% of the area will experience flood levels of 0.21 to 0.50 meters while 2.622%, 1.596%, 0.4665%, and 0.031% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in the tables below are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Hilongos, Leyte during 100-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Hilongos | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Baas | Bagumbayan | Bantigue | Bon-Ot | Campina | Catandog 1 | Catandog 2 | Concepcion |
| Affected Area (sq. km.) | 0.03-0.20 | 3.277952454 | 1.822928 | 0.144956 | 0.709103 | 1.136602 | 0.093208 | 0.065857 | 1.322047 |
| | 0.21-0.50 | 0.572548758 | 0.07528 | 0.071458 | 0.025292 | 0.239411 | 0.01427 | 0.140352 | 0.272256 |
| | 0.51-1.00 | 0.927484575 | 0.06357 | 0.14805 | 0.012406 | 0.204297 | 0.0004 | 0.211264 | 0.162176 |
| | 1.01-2.00 | 0.347230219 | 0.065216 | 0.066992 | 0.011609 | 0.038913 | 0 | 0.208642 | 0.033329 |
| | 2.01-5.00 | 0.023202324 | 0.007115 | 0.030379 | 0.080352 | 0 | 0 | 0.024283 | 0.0003 |
| | > 5.00 | 0 | 0 | 0 | 0.045034 | 0 | 0 | 0 | 0 |

Table 47. Affected Areas in Hilongos, Leyte during 100-Year Rainfall Return Period

| BANGKEROHAN BASIN | | Affected Barangays in Hilongos | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kang-Iras | Kangha-As | Lunang | Manaul | Tabunok | Talisay | Tejero | Tuguipa |
| Affected Area (sq. km.) | 0.03-0.20 | 1.16073505 | 0.049338 | 0.536649 | 0.011494 | 0.021125 | 0.114113 | 0.767597 | 1.360179 |
| | 0.21-0.50 | 0.050835315 | 0.080018 | 0.708275 | 0.018744 | 0.388012 | 0.13044 | 0.469833 | 0.081457 |
| | 0.51-1.00 | 0.026200881 | 0.367485 | 0.928585 | 0.025759 | 0.692767 | 0.085924 | 0.183798 | 0.071394 |
| | 1.01-2.00 | 0.030622922 | 0.5671 | 0.74457 | 0.002192 | 0.272349 | 0.010512 | 0.006509 | 0.09742 |
| | 2.01-5.00 | 0.013902267 | 0.086718 | 0.148251 | 0 | 0.242679 | 0.010046 | 0 | 0.064292 |
| | > 5.00 | 0 | 0 | 0 | 0 | 0.0036 | 0 | 0 | 0 |

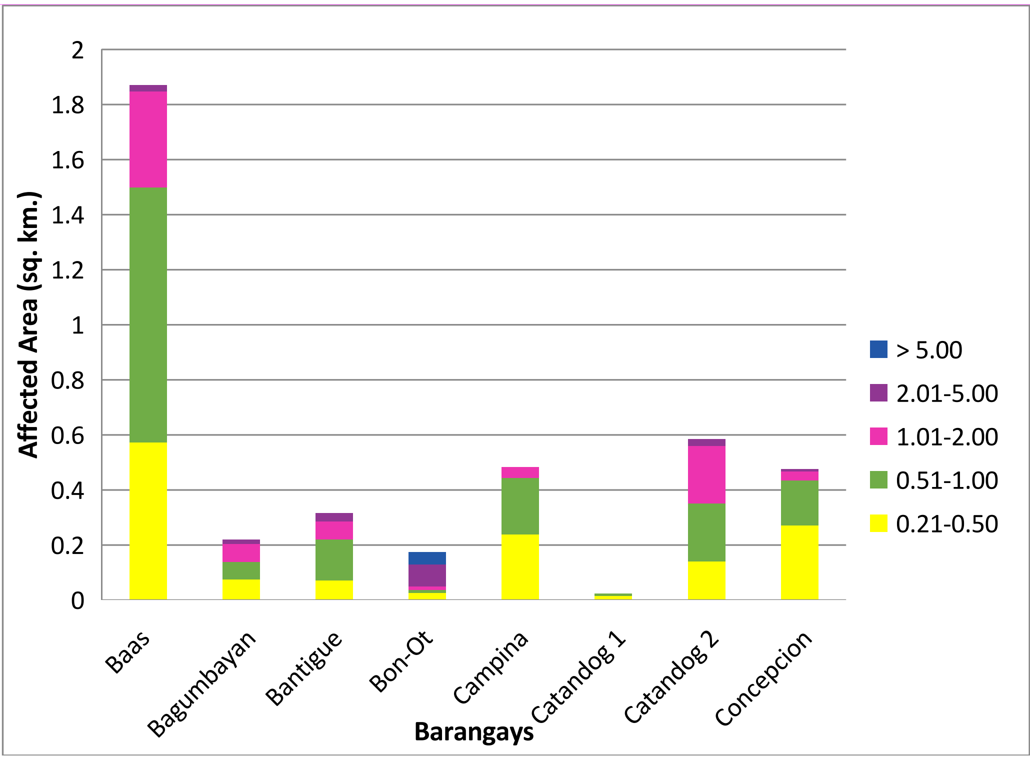



Figure 81. Affected Areas in Hilongos, Leyte during 100-Year Rainfall Return Period

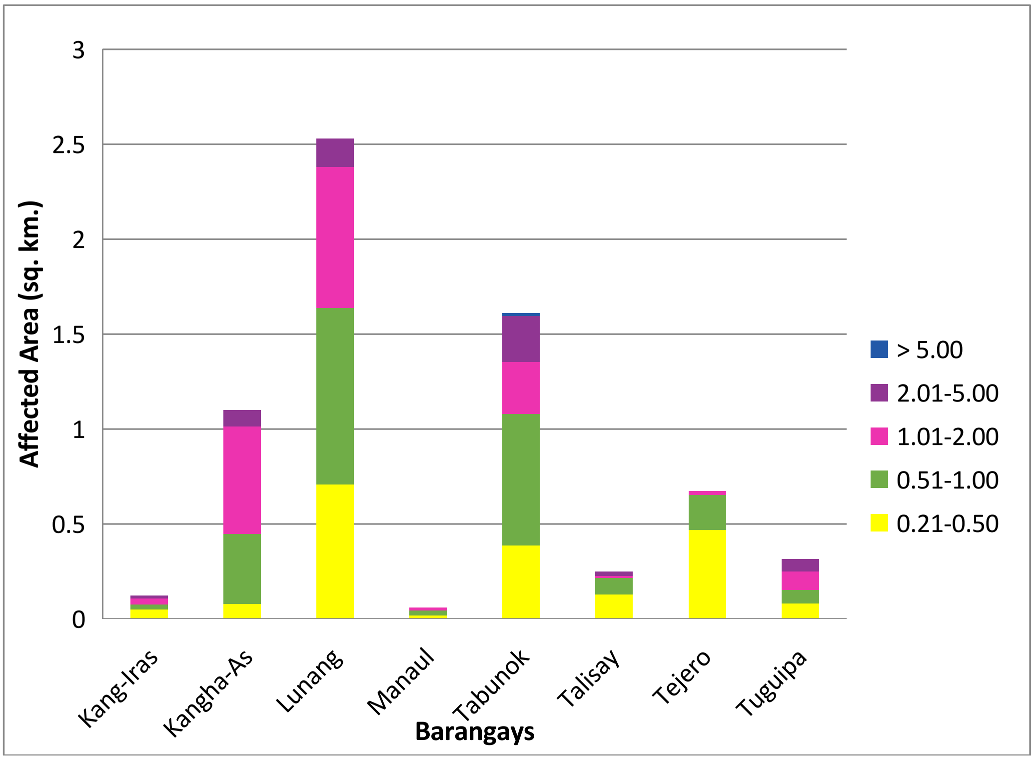



Figure 82. Affected Areas in Hilongos, Leyte during 100-Year Rainfall Return Period

Among the barangays in the municipality of Bato, Alejos is projected to have the highest percentage of area that will experience flood levels at 9.605%. Meanwhile, Naga posted the second highest percentage of area that may be affected by flood depths at 4.8%.

Among the barangays in the municipality of Hilongos, Baas is projected to have the highest percentage of area that will experience flood levels at 3.28%. Meanwhile, Lunang posted the second highest percentage of area that may be affected by flood depths at 1.955%.

Moreover, the generated flood hazard maps for the Bangkerohan Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - "Low", "Medium", and "High" - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

Table 48. Area covered by each warning level with respect to the rainfall scenario

| Warning Level | Area Covered in sq. km | | |
|---|---|---|---|
| | 5 year | 25 year | 100 year |
| Low | 6.48 | 6.34 | 5.19 |
| Medium | 5.89 | 8.78 | 10.29 |
| High | 2.89 | 4.54 | 5.85 |

Of the 27 identified Education Institutions in Bangkerohan Flood plain, 4 schools were assessed to be exposed to the Low level flooding during a 5 year scenario. In the 25 year scenario, 7 schools were assessed to be exposed to the Low level flooding while 3 schools were assessed to be exposed to Medium level flooding. For the 100 year scenario, 4 schools were assessed for Low level flooding and 8 schools for Medium level flooding. See Annex 12 for a detailed enumeration of schools inside Bangkerohan floodplain.

Of the 7 identified Medical Institutions in Bangkerohan Flood plain, none were assessed to be exposed to the any level of flooding during a 5 year scenario. In the 25 year scenario, Naga Health Center was assessed to be exposed to the Medium level flooding. For the 100 year scenario, Naga Health Center and Alejos Health Center were assessed for Medium level flooding. See Annex 13 for a detailed enumeration of health insitutions inside Bangkerohan floodplain.

## 5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, a validation survey work was performed. Field personnel gathered 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 through interviews of some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.
The flood validation consisted of 243 points randomly selected all over the Bangkerohan flood plain. It has an RMSE value of 0.95.

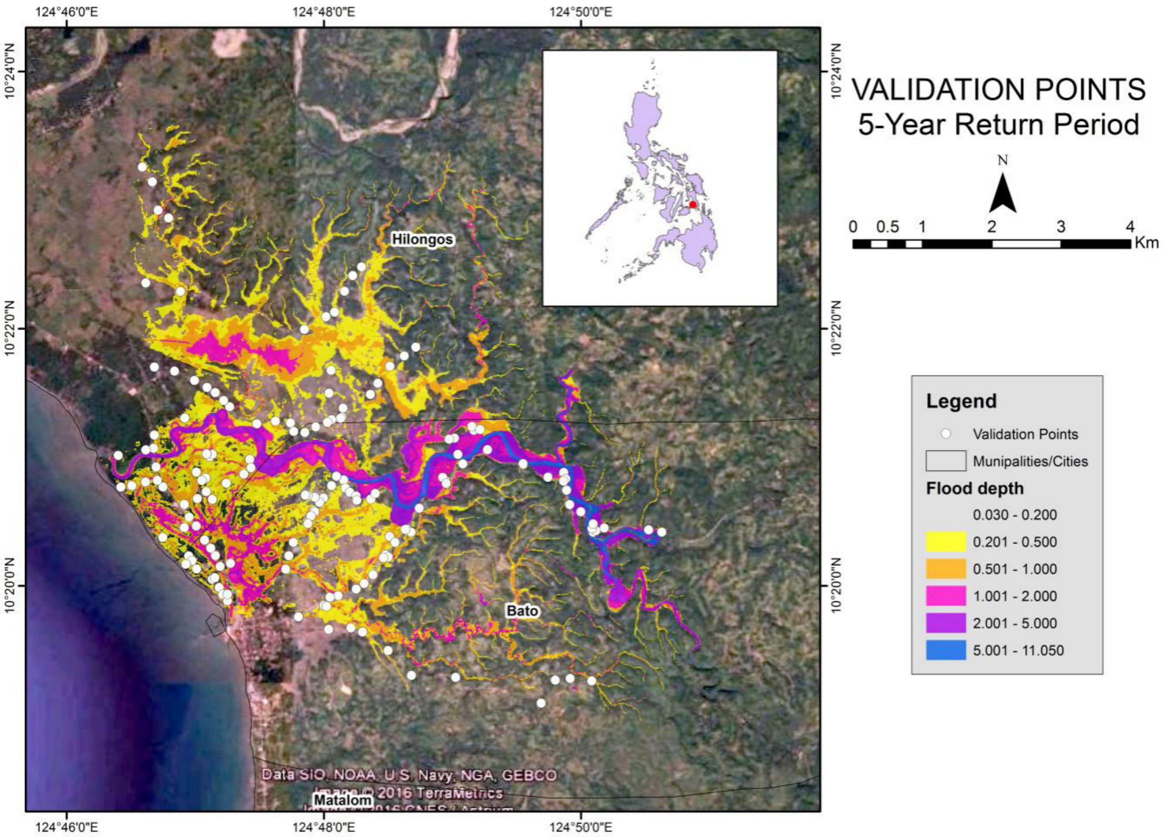



Figure 83. Validation points for 5-year Flood Depth Map of Bangkerohan Floodplain

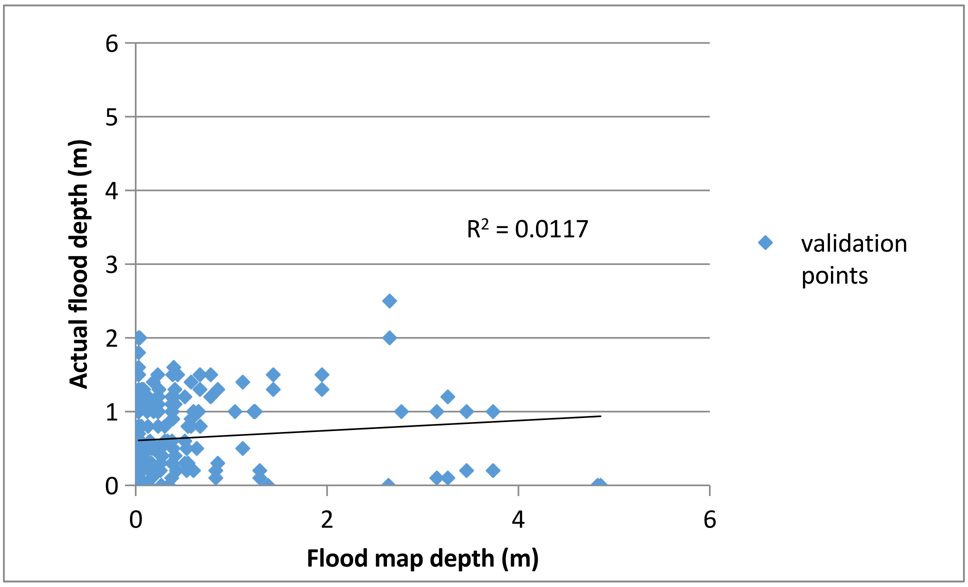



Figure 84.Flood map depth vs actual flood depth

Table 49. Actual Flood Depth vs Simulated Flood Depth in Bangkerohan

| MAINIT-TUBAY BASIN | | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0-0.20 | 0.21-0.50 | 0.51-1.00 | 1.01-2.00 | 2.01-5.00 | >5.00 | Total |
| Actual Flood Depth (m) | 0-0.20 | 50 | 15 | 10 | 2 | 1 | 0 | 78 |
| | 0.21-0.50 | 29 | 14 | 9 | 3 | 0 | 0 | 55 |
| | 0.51-1.00 | 40 | 8 | 7 | 5 | 0 | 0 | 60 |
| | 1.01-2.00 | 29 | 24 | 0 | 13 | 0 | 0 | 66 |
| | 2.01-5.00 | 1 | 0 | 0 | 3 | 0 | 0 | 4 |
| | >5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 149 | 61 | 26 | 26 | 1 | 0 | 263 |

The overall accuracy generated by the flood model is estimated at 31.94%, with 84 points correctly matching the actual flood depths. In addition, there were 69 points estimated one level above and below the correct flood depths while there were 77 points and 33 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 45 points were overestimated while a total of 134 points were underestimated in the modelled flood depths of Bangkerohan.

Table 50. Summary of Accuracy Assessment in Bangkerohan

| | No. of Points | % |
|---|---|---|
| Correct | 84 | **31.94** |
| Overestimated | 45 | **17.11** |
| Underestimated | 134 | **50.95** |
| Total | 263 | **100** |

# 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 Bangkerohan Floodplain Survey

1. AQUARIUS SENSOR

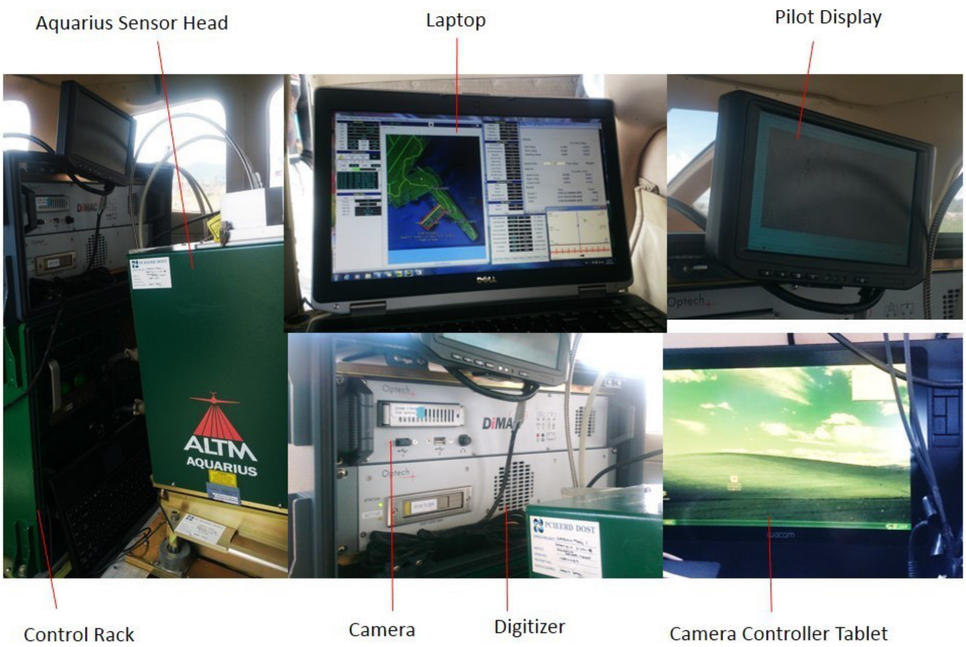



Figure A-1.1. Aquarius Sensor

Table A-1.1.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 |

2. GEMINI SENSOR

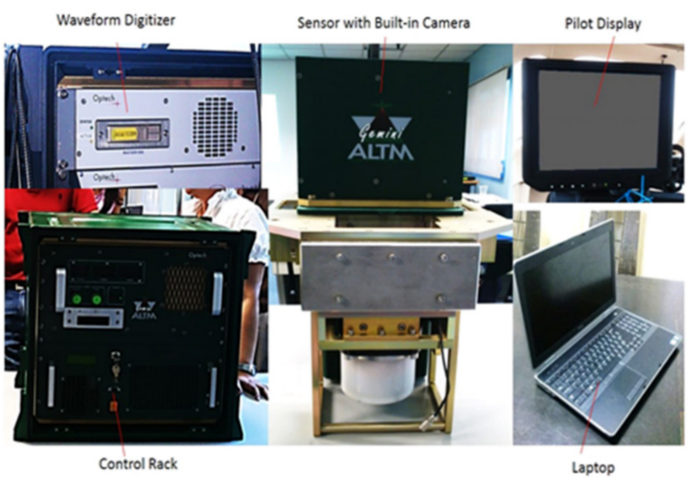



Figure A-1.2. Gemini Sensor

Table A-1.2. 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);<br>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<br>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 |

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

1. LY-1024

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

February 10, 2016

**CERTIFICATION**

To whom it may concern:

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

Province: **SOUTHERN LEYTE**
Station Name: **LY-1024**

| | | |
|---|---|---|
| Island: **Visayas** | Municipality: **SOGOD** | Barangay: **KAHUPIAN** |
| Elevation: **364.7756 +/- 0.07** | Accuracy Class at 95% C.L: **7 CM** | Datum: **Mean Sea Level** |
| Latitude: | Longitude: | |

Location Description

BM-LY-1024 is in the Province of Leyte, Municipality of Sogod, Brgy. Kahupian along the Mahaplag-Sugod National Highway. The station is located at the SE end of the sidewalk of Agas-agas Bridge at KM post 1006 + 972.6 and 4 m from the road centerline.

Mark is the head of a 4 in copper nail set flush on a 15 cm x 15 cm cement putty with inscriptions "LY-1024, 2012, NAMRIA".

| | |
|---|---|
| Requesting Party: | **UP DREAM** |
| Purpose: | **Reference** |
| OR Number: | **8089774 I** |
| T.N.: | **2016-0331** |

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

9902102016122104

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

CIP/4701/12/09/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. LY-1024

2. LYT-757

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

January 27, 2016

**CERTIFICATION**

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LYT-757**
Order: **2nd**

| | | | |
|---|---|---|---|
| Island: **VISAYAS** | Barangay: **MAHAYAHAY** | | |
| Municipality: **MAHAPLAG** | MSL Elevation: | | |
| | ***PRS92 Coordinates*** | | |
| Latitude: **10° 32' 54.86740"** | Longitude: **124° 57' 31.14319"** | Ellipsoidal Hgt: | **99.55943 m.** |
| | ***WGS84 Coordinates*** | | |
| Latitude: **10° 32' 50.77355"** | Longitude: **124° 57' 36.36037"** | Ellipsoidal Hgt: | **163.36300 m.** |
| | ***PTM / PRS92 Coordinates*** | | |
| Northing: **1166401.318 m.** | Easting: **495474.491 m.** | Zone: | **5** |
| | ***UTM / PRS92 Coordinates*** | | |
| Northing: **1,166,663.62** | Easting: **714,331.34** | Zone: | **51** |

Location Description

LYT-757
About 7.0 km. from poblacion mahaplag taking the national road to southern leyte, there is a restaurant named "Dragonfly restaurant" located at the right side of the highway and on the left isde is the junction going to the proper of brgy. mahayahay. The LYT-757 is located on the left side, 30 meters before you reach the junction. LYT-757 is almost on the opposite side of the kilometer post # 997. 30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-757, 2007, LAMP".

| | |
|---|---|
| Requesting Party: | **UP DREAM** |
| Purpose: | **Reference** |
| OR Number: | **8089687 I** |
| T.N.: | **2016-0239** |

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. LYT-757

3. LY-313

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

April 14, 2016

**CERTIFICATION**

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LY-313**

| | | |
|---|---|---|
| Island: **Visayas** | Municipality: **BAYBAY** | Barangay: |
| Elevation: **5.0757 +/- 0.0678 m.** | Accuracy Class at 95% C.L: **7 cm** | Datum: **Mean Sea Level** |
| Latitude: | Longitude: | |

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

(RECOMPUTED MARCH 2014)
Mark is head of a 4" copper nail set and centered on a 10 x 10 cm. cement putty with inscriptions "LY-313, 2007, NAMRIA".

It is located in the Municipality of Leyte, Baybay Brgy. Pandan.
Located at the footwalk, W corner of 20 m. long bridge, 40 m. SW of Brgy. Maitum marker and 80 m. W of KM post 1068. It is 400 m. NE of the Basketball court and Church at the boundary of BRgy. Pandan and Maitum marker.
It can be reached approx. by 7 min. drive from Baybay going to South to Maasin.

| | |
|---|---|
| Requesting Party: | **UP DREAM** |
| Purpose: | **Reference** |
| OR Number: | **8084228 I** |
| T.N.: | **2016-0917** |

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

9 9 0 4 1 4 2 0 1 6 1 5 3 4 5 3

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. LY-313

4. LYT-741

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

April 14, 2016

**CERTIFICATION**

To whom it may concern:

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

| | | |
|---|---|---|
| | Province: **LEYTE** | |
| | Station Name: **LYT-741** | |
| | Order: **2nd** | |
| Island: **VISAYAS** | Barangay: **DOOS DEL NORTE** | |
| Municipality: **HINDANG** | MSL Elevation: | |
| | ***PRS92 Coordinates*** | |
| Latitude: **10° 27' 11.95722"** | Longitude: **124° 43' 45.08400"** | Ellipsoidal Hgt: **4.48300 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **10° 27' 7.86786"** | Longitude: **124° 43' 50.31177"** | Ellipsoidal Hgt: **67.94500 m.** |
| | ***PTM / PRS92 Coordinates*** | |
| Northing: **1155878.867 m.** | Easting: **470351.659 m.** | Zone: **5** |
| | ***UTM / PRS92 Coordinates*** | |
| Northing: **1,155,979.90** | Easting: **689,272.22** | Zone: **51** |

Location Description

LYT-741
Brgy. doos del norte is about 2.6 km. from the poblacion pf hindang taking the national road to babay. upon reaching the said barangay, locate the brgy. hall, The LYT-741 is located on the opposite side of the road for about 36 m. far from the gate of the brgy hall.30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-741, 2007, LAMP".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0916**

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

9 9 0 4 1 4 2 0 1 6 1 5 3 4 2 6

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/4701/12/09/814

Figure A-2.4. LYT-741

5. LYS-4

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

April 14, 2016

**CERTIFICATION**

To whom it may concern:

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

Province: **SOUTHERN LEYTE**
Station Name: **LYS-4**
Order: **1st**

Island: **VISAYAS**
Municipality: **SOGOD**
Barangay: **POBLACION**
MSL Elevation:

***PRS92 Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Latitude: | **10° 23' 20.19669"** | Longitude: | **124° 58' 38.53353"** | Ellipsoidal Hgt: | **15.25600 m.** |

***WGS84 Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Latitude: | **10° 23' 16.14540"** | Longitude: | **124° 58' 43.76469"** | Ellipsoidal Hgt: | **79.47900 m.** |

***PTM / PRS92 Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Northing: | **1148746.143 m.** | Easting: | **497522.022 m.** | Zone: | **5** |

***UTM / PRS92 Coordinates***

| | | | | | |
|---|---|---|---|---|---|
| Northing: | **1,149,017.84** | Easting: | **716,491.34** | Zone: | **51** |

Location Description

LYS-4
From Tacloban City, travel 220 km. S until you reach Sogod Nat'l. High School (SNHS), adjacent to Sogod Elem. School. Station is located at the middle of the open ground of SNHS, NW of the NW corner of the basketball court at a distance of about 15 m. All reference marks (RM) are heads of a 2 in. copper nail, centered on a 0.15 m. x 0.15 m. x 0.2 m. concrete monument, flush with the ground surface and inscribed with the RM nos. and arrow pointing to the station. Station mark is the head of a 4 in. copper nail centered on a 0.3 m. x 0.3 m. x 1 m. concrete monument leveled on the ground, with inscriptions "LYS-4 2006 NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0918**

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

9 9 0 4 1 4 2 0 1 6 1 5 3 5 1 4

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.5. LYS-4

6. LYT-748

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

February 05, 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: **LEYTE**
Station Name: **LYT-748**
Order: **2nd**

| | | |
|---|---|---|
| Island: **VISAYAS** | Barangay: **HITOOG** | |
| Municipality: **MATALOM** | MSL Elevation: | |
| | ***PRS92 Coordinates*** | |
| Latitude: **10° 14' 16.77457"** | Longitude: **124° 48' 19.08041"** | Ellipsoidal Hgt: **77.51500 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **10° 14' 12.74720"** | Longitude: **124° 48' 24.32650"** | Ellipsoidal Hgt: **141.66500 m.** |
| | ***PTM / PRS92 Coordinates*** | |
| Northing: **1132057.716 m.** | Easting: **478669.714 m.** | Zone: **5** |
| | ***UTM / PRS92 Coordinates*** | |
| Northing: **1,132,208.87** | Easting: **697,740.37** | Zone: **51** |

Location Description

LYT-748
From the Matalom proper, go to brgy. caridad del sur 500 meters along the highway taking the road to maasin city. you'll fin a junction to the right is going to matalom hospital and to the left is going to brgy. hitdog. from the highway, brgy. hitdog is about 6 km. far. you will pass through 3 junctions along the way but always take the way to the right, and on the 4th junction, take the left turn. upon reaching the brgy. hall and basketaballcourt of Brgy. Hitdog, you will have to take a walk for about 300 meters to "hitdog elemetary school". LYT-748 is located 50 meters behind the said school. 30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-748, 2007, LAMP".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8077605 I**
T.N.: **2015-0215**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. LYT-748

7. LY-351

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

February 05, 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: **LEYTE**
Station Name: **LY-351**

| | | |
|---|---|---|
| Island: **Visayas** | Municipality: **MATALOM** | Barangay: |
| Elevation: **6.0371 m.** | Order: **1st Order** | Datum: **Mean Sea Level** |
| Latitude: | Longitude: | |

Location Description

(RECOMPUTED MARCH 2014)
Mark is head of a 4" copper nail set and centered on a 10 x 10 cm. cement putty with inscriptions "LY-351, 2007, NAMRIA".

It is located in the Municipality of Leyte, Matalom Brgy. Poblacion.
Located at the NW corner of a 150 m. long bridge called Matalom bridge, about 50 m. W of Matalom Public Markert and 200 m. after Matalom Municipal hall. It is about 200 m. before KM post 1110 and 500 m. after KM post 1109.
It can be reached approx. by 50 min. drive from Baybay going to South to Maasin.

| | |
|---|---|
| Requesting Party: | **PHIL-LIDAR I** |
| Purpose: | **Reference** |
| OR Number: | **8077605 I** |
| T.N.: | **2015-0221** |

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

9 9 0 2 0 5 2 0 1 5 1 4 5 8 4 6

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.7. LY-351

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

1. LY-1024

## Baseline Processing Report

### Processing Summary

| Observation | From | To | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|---|
| LYT-757 --- LY-1024 (B2) | LYT-757 | LY-1024 | Fixed | 0.004 | 0.018 | 143°56'41" | 7166.614 | 266.642 |
| LYT-757 --- LY-1024 (B1) | LYT-757 | LY-1024 | Fixed | 0.005 | 0.015 | 143°56'41" | 7166.626 | 266.671 |
| LYT-757 --- LY-1024 (B3) | LYT-757 | LY-1024 | Fixed | 0.004 | 0.015 | 143°56'41" | 7166.633 | 266.676 |

### Acceptance Summary

| Processed | Passed | Flag | Fail |
|---|---|---|---|
| 3 | 3 | 0 | 0 |

### Vector Components (Mark to Mark)

| From: | LYT-757 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 714331.338 m | Latitude | N10°32'54.86738" | Latitude | N10°32'50.77355" |
| Northing | 1166663.617 m | Longitude | E124°57'31.14322" | Longitude | E124°57'36.36037" |
| Elevation | 98.243 m | Height | 99.559 m | Height | 163.363 m |

| To: | LY-1024 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 718586.237 m | Latitude | N10°29'46.27905" | Latitude | N10°29'42.20218" |
| Northing | 1160895.197 m | Longitude | E124°59'49.85591" | Longitude | E124°59'55.07713" |
| Elevation | 364.735 m | Height | 366.202 m | Height | 430.223 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 4254.899 m | NS Fwd Azimuth | 143°56'41" | ΔX | -4212.979 m |
| ΔNorthing | -5768.419 m | Ellipsoid Dist. | 7166.614 m | ΔY | -1336.202 m |
| ΔElevation | 266.492 m | ΔHeight | 266.642 m | ΔZ | -5648.050 m |

Figure A-3.1. LY-1024

2. LY-351

Vector Components (Mark to Mark)

| From: | LYT-748 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 697740.363 m | Latitude | N10°14'16.77457" | Latitude | N10°14'12.74720" |
| Northing | 1132208.868 m | Longitude | E124°48'19.08040" | Longitude | E124°48'24.32650" |
| Elevation | 77.125 m | Height | 77.515 m | Height | 141.665 m |

| To: | LY-351 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 695421.839 m | Latitude | N10°16'52.30167" | Latitude | N10°16'48.26132" |
| Northing | 1136974.636 m | Longitude | E124°47'03.77264" | Longitude | E124°47'09.01515" |
| Elevation | 6.314 m | Height | 6.886 m | Height | 70.885 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -2318.524 m | NS Fwd Azimuth | 334°22'44" | ΔX | 2407.375 m |
| ΔNorthing | 4765.768 m | Ellipsoid Dist. | 5299.406 m | ΔY | 551.878 m |
| ΔElevation | -70.810 m | ΔHeight | -70.629 m | ΔZ | 4689.241 m |

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000101466 | | |
| Y | -0.0000137204 | 0.0000248169 | |
| Z | -0.0000039125 | 0.0000060432 | 0.0000023641 |

2

Figure A-3.2. LY-351

3. LY-313

### LY-313 - LYT-741 (9:21:42 AM-1:52:00 PM) (S3)

| | |
|---|---|
| Baseline observation: | LY-313 --- LYT-741 (B3) |
| Processed: | 4/15/2016 6:17:08 PM |
| Solution type: | Fixed |
| Frequency used: | Dual Frequency (L1, L2) |
| Horizontal precision: | 0.003 m |
| Vertical precision: | 0.014 m |
| RMS: | 0.005 m |
| Maximum PDOP: | 2.723 |
| Ephemeris used: | Broadcast |
| Antenna model: | Trimble Relative |
| Processing start time: | 4/10/2016 9:21:57 AM (Local: UTC+8hr) |
| Processing stop time: | 4/10/2016 1:52:00 PM (Local: UTC+8hr) |
| Processing duration: | 04:30:03 |
| Processing interval: | 1 second |

Vector Components (Mark to Mark)

| From: | LYT-741 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 689272.210 m | Latitude | N10°27'11.95721" | Latitude | N10°27'07.86786" |
| Northing | 1155979.897 m | Longitude | E124°43'45.08400" | Longitude | E124°43'50.31177" |
| Elevation | 3.600 m | Height | 4.482 m | Height | 67.945 m |

| To: | LY-313 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 693326.992 m | Latitude | N10°36'46.67221" | Latitude | N10°36'42.54525" |
| Northing | 1173661.007 m | Longitude | E124°46'01.67926" | Longitude | E124°46'06.89257" |
| Elevation | 5.229 m | Height | 6.279 m | Height | 69.460 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 4054.782 m | NS Fwd Azimuth | 13°13'57" | ΔX | -1573.287 m |
| ΔNorthing | 17681.110 m | Ellipsoid Dist. | 18139.132 m | ΔY | -5017.663 m |
| ΔElevation | 1.629 m | ΔHeight | 1.796 m | ΔZ | 17360.172 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.001 m | σ NS fwd Azimuth | 0°00'00" | σ ΔX | 0.004 m |
| σ ΔNorthing | 0.001 m | σ Ellipsoid Dist. | 0.001 m | σ ΔY | 0.006 m |
| σ ΔElevation | 0.007 m | σ ΔHeight | 0.007 m | σ ΔZ | 0.002 m |

2

Figure A-3.3. LY-313

4. LYS-4bak

## LYS-4bak - LYS-4 (12:29:42 PM-2:25:33 PM) (S1)

| | |
|---|---|
| Baseline observation: | LYS-4bak --- LYS-4 (B1) |
| Processed: | 4/15/2016 6:41:08 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: | 1.827 |
| Ephemeris used: | Broadcast |
| Antenna model: | Trimble Relative |
| Processing start time: | 4/13/2016 12:29:42 PM (Local: UTC+8hr) |
| Processing stop time: | 4/13/2016 2:25:33 PM (Local: UTC+8hr) |
| Processing duration: | 01:55:51 |
| Processing interval: | 1 second |

### Vector Components (Mark to Mark)

| From: | LYS-4 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 716491.318 m | Latitude | N10°23'20.19669" | Latitude | N10°23'16.14540" |
| Northing | 1149017.838 m | Longitude | E124°58'38.53353" | Longitude | E124°58'43.76469" |
| Elevation | 14.251 m | Height | 15.255 m | Height | 79.479 m |

| To: | LYS-4bak | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 716490.354 m | Latitude | N10°23'20.14352" | Latitude | N10°23'16.09223" |
| Northing | 1149016.198 m | Longitude | E124°58'38.50151" | Longitude | E124°58'43.73267" |
| Elevation | 14.202 m | Height | 15.207 m | Height | 79.430 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -0.964 m | NS Fwd Azimuth | 210°48'17" | ΔX | 0.657 m |
| ΔNorthing | -1.640 m | Ellipsoid Dist. | 1.902 m | ΔY | 0.760 m |
| ΔElevation | -0.049 m | ΔHeight | -0.049 m | ΔZ | -1.616 m |

### Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.000 m | σ NS fwd Azimuth | 0°00'35" | σ ΔX | 0.001 m |
| σ ΔNorthing | 0.000 m | σ Ellipsoid Dist. | 0.000 m | σ ΔY | 0.001 m |
| σ ΔElevation | 0.001 m | σ ΔHeight | 0.001 m | σ ΔZ | 0.000 m |

2

Figure A-3.4. LYS-4bak

# Annex 4. The LIDAR Survey Team Composition

| Date 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 S. SARMIENTO | UP-TCAGP |
| Survey Supervisor | Chief Science Research Specialist (CSRS) | ENGR. LOUIE P. BALICANTA | UP-TCAGP |
| | Supervising Science Research Specialist (Supervising SRS) | ENGR. CHRISTOPHER CRUZ | UP-TCAGP |
| | | ENGR. LOVELYN ASUNCION | UP-TCAGP |
| FIELD TEAM | | | |
| LiDAR Operation | Senior Science Research Specialist (SSRS) | JULIE PEARL MARS<br>JASMINE ALVIAR<br>PAULINE JOANNE ARCEO | UP-TCAGP |
| | Research Associate (RA) | KRISTINE JOY ANDAYA | UP-TCAGP |
| | | ENGR. LARAH KRISELLE PARAGAS | UP-TCAGP |
| | | GRACE SINADJAN | UP-TCAGP |
| | | JONATHAN ALMALVEZ | UP-TCAGP |
| | | ENGR. KENNETH QUISADO | UP-TCAGP |
| | | ENGR. IRO NIEL ROXAS | UP-TCAGP |
| Ground Survey, Data download and transfer | RA | ENGR. FRANK NICOLAS ILEJAY | UP-TCAGP |
| | | JERIEL PAUL ALAMBAN, GEOL. | UP-TCAGP |
| LiDAR Operation | Airborne Security | SSG RANDY SISON | PHILIPPINE AIR FORCE (PAF) |
| | | SSG RAYMUND DOMINE | PAF |
| | Pilot | CAPT. ALBERT PAUL LIM | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. RANDY LAGCO | AAC |
| | | CAPT. JACKSON JAVIER | AAC |
| | | CAPT. NIEL ACHILLES AGAWIN | AAC |

# Annex 5. Data Transfer Sheet for Bangkerohan Floodplain

DATA TRANSFER SHEET
02/13/2015(ORMOC)

| 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 | |
| 21-Jan-15 | 7753AC | 3BLK35B21A | AQUARIUS | NA | 270 | 527 | 167 | NA | NA | 11.1 | NA | 29.1 | 1KB | 1KB | 3 | NA | Z:\DAC\RAW DATA |
| 22-Jan-15 | 7754AC | 3BLK49B022A | AQUARIUS | NA | 280 | 566 | 258 | NA | NA | 12 | NA | 66.1 | 1KB | 1KB | 4 | NA | Z:\DAC\RAW DATA |
| 23-Jan-15 | 7756AC | 3BLK49A023A | AQUARIUS | NA | 279 | 548 | 231 | NA | NA | 11.9 | NA | 34 | 1KB | 1KB | 3 | NA | Z:\DAC\RAW DATA |
| 25-Jan-15 | 7760AC | 3BLK35A025A | AQUARIUS | NA | 289 | 671 | 243 | NA | NA | 12.3 | 223 | 26.4 | 1KB | 1KB | 4 | NA | Z:\DAC\RAW DATA |
| 27-Jan-15 | 7764AC | 3BLK35CD027A | GEMINI | NA | 169/107 | 611 | 228 | NA | NA | 11.7 | 207 | 37.1 | 1KB | 1KB | 3 | NA | Z:\DAC\RAW DATA |
| 28-Jan-15 | 7766AC | 3BLK49CD028A | AQUARIUS | NA | 136 | 366 | 216 | NA | NA | 6.71 | 185MB | 27.1 | 1KB | 1KB | 3 | NA | Z:\DAC\RAW DATA |
| 28-Jan-15 | 7767AC | 3BLK35X028B | AQUARIUS | NA | 123 | 310 | 148 | NA | NA | 6.4 | 98.6 | 18.5 | 1KB | 1KB | 3 | NA | Z:\DAC\RAW DATA |
| 29-Jan-15 | 7768AC | 3BLK50A029A | AQUARIUS | NA | 152 | 360 | 234 | NA | NA | 7.39 | 111 | 40.2 | 1KB | 1KB | 3 | NA | Z:\DAC\RAW DATA |

**Received from**

Name C. Joaquin
Position
Signature [signature]

**Received by**

Name AC Bongat 2/13/15
Position SSRS
Signature [signature]

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

DATA TRANSFER SHEET
Leyte 2/11/16

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS(MB) | POS | RAW IMAGES/CASI | MISSION LOG FILE/CASI LOGS | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| 22-Jan | 3765G | 2BLK34AD022A | gemini | NA | 93 | 690 | 255 | na | na | 25.2 | na | 4.38 | 1KB | 1KB | 23/57/22/58/ 21/55/21/21 | na | Z:\DAC\RAW DATA |
| 22-Jan-16 | 3767G | 2BLK34AG022B | gemini | NA | 75 | 490 | 204 | na | na | 19.1 | na | 3.4 | 1KB | 1KB | 57/11 | na | Z:\DAC\RAW DATA |
| 23-Jan-16 | 3769G | 2BLK34ADEG023A | gemini | NA | 82 | 670 | 260 | na | na | 23.8 | na | 9.58 | 1KB | 1KB | na | na | Z:\DAC\RAW DATA |
| 23-Jan-16 | 3771G | 2BLK34BCG023B | gemini | NA | 77 | 526 | 212 | na | na | 20.3 | na | 9.2 | 1KB | 1KB | 57/22 | na | Z:\DAC\RAW DATA |
| 24-Jan-16 | 3773G | 2BLK34CG024A | gemini | NA | 63 | 582 | 248 | na | na | 16.8 | na | 4.74 | 1KB | 1KB | 27/26/59 | na | Z:\DAC\RAW DATA |

Received from
Name C. JOAQUIN
Position
Signature

Received by
Name AC Bongat 2/12/16
Position
Signature

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

DATA TRANSFER SHEET

ORMOC(SOUTH LEYTE) 5/2/2016

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS | POS | RAW IMAGES/CASI | MISSION LOG FILE/CASI LOGS | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| April 10,2016 | 3921G | 2BLK34a101A | GEMINI | NA | 270 | 673 | 275 | NA | NA | 20.5 | NA | 19.1 | 1KB | 1KB | 23 | NA | Z:\DAC\RAW DATA |
| April 10,2016 | 3923G | 2BLK49AB101B | GEMINI | NA | 375 | 377 | 168 | NA | NA | 8.5 | NA | 19.1 | 1 KB | 1KB | 23 | NA | Z:\DAC\RAW DATA |
| April 11,2016 | 3925G | 2BLK49DE102A | GEMINI | NA | 138 | 570 | 252 | NA | NA | 9.56 | NA | 6.82 | 1 KB | 1KB | 23 | NA | Z:\DAC\RAW DATA |
| April 13,2016 | 3933G | 2BLK50ABC104A | GEMINI | NA | 581 | 474 | 262 | NA | NA | 16.2 | NA | 17.4 | 1KB | 1KB | NA | NA | Z:\DAC\RAW DATA |
| April 14,2016 | 3937G | 2BLK50DS105A | GEMINI | NA | 763 | 557 | 292 | NA | NA | 14.7 | NA | 10.5 | 1KB | 1KB | 28 | NA | Z:\DAC\RAW DATA |
| April 16,2016 | 3945G | 2BLK35AB107A | GEMINI | NA | 216 | 940 | 267 | NA | NA | 17.1 | NA | 19.5 | 1KB | 1KB | 6 | NA | Z:\DAC\RAW DATA |
| April 16,2016 | 3947G | 2BLK35CS107B | GEMINI | NA | 492 | 1.03 | 278 | NA | NA | 21 | NA | 19.5 | 1KB | 1KB | 10 | NA | Z:\DAC\RAW DATA |

**Received from**

Name R. PUNTO

Position RA

Signature [signature]

**Received by**

Name Ae Bongat

Position SSRS

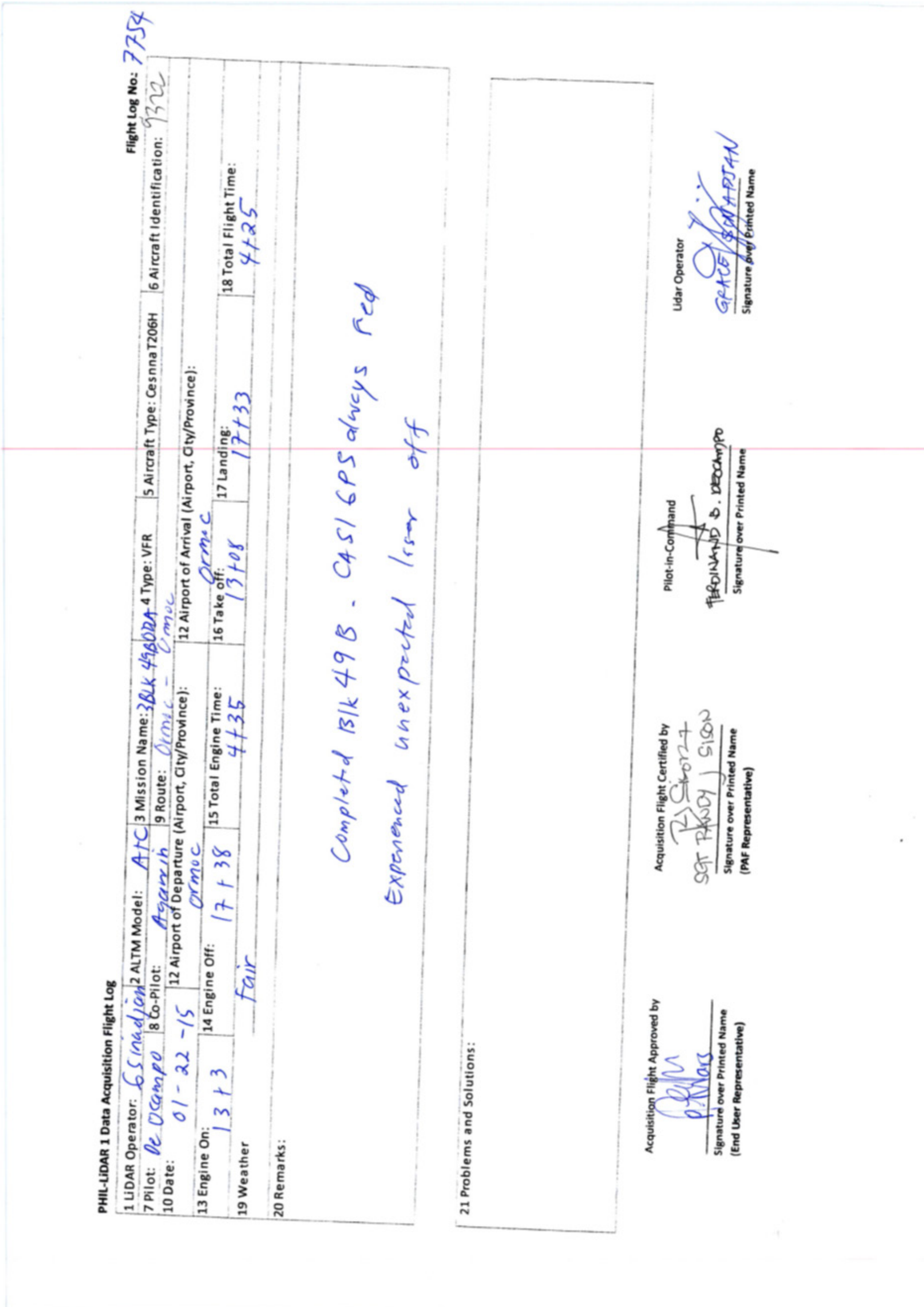
Signature [signature] 5/6/16

16-217

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

# Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 7754A



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7754

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: G Sinadjan | 2 ALTM Model: AQC | 3 Mission Name: 3Blk49BDA | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: De Ocampo | 8 Co-Pilot: Agawin | 9 Route: Ormoc - Ormoc | | | |
| 10 Date: 01-22-15 | 12 Airport of Departure (Airport, City/Province): Ormoc | | 12 Airport of Arrival (Airport, City/Province): Ormoc | | |
| 13 Engine On: 13+3 | 14 Engine Off: 17+38 | 15 Total Engine Time: 4+35 | 16 Take off: 13+08 | 17 Landing: 17+33 | 18 Total Flight Time: 4+25 |
| 19 Weather: Fair | | | | | |

20 Remarks:

Completed Blk 49B. CASI GPS always red

Experienced unexpected laser off

21 Problems and Solutions:

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

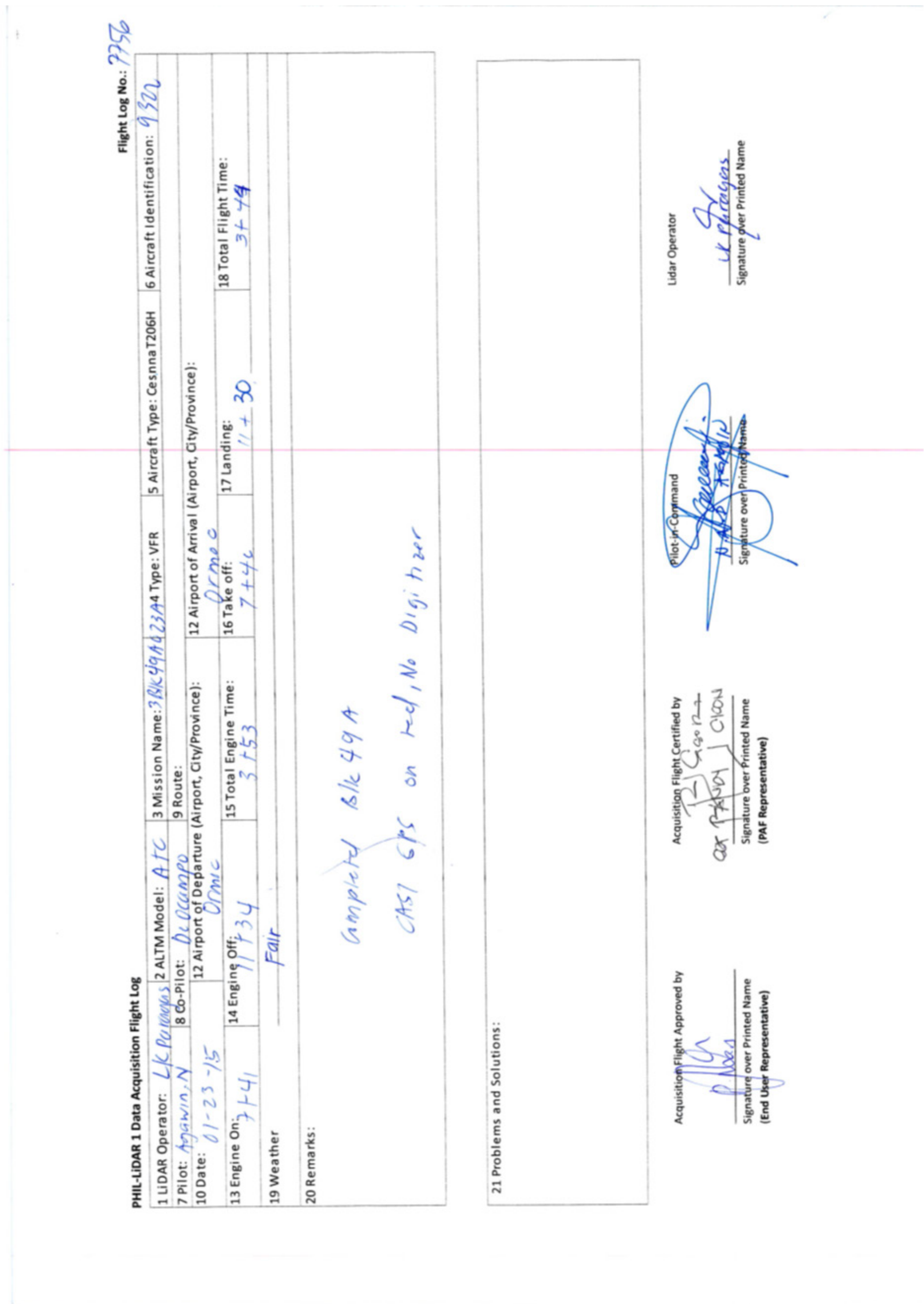
Acquisition Flight Certified by — SGT RANDY J SISON — Signature over Printed Name (PAF Representative)

Pilot-in-Command — FERDINAND B. DE OCAMPO — Signature over Printed Name

Lidar Operator — GRACE SINADJAN — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 7754A

2. Flight Log for Mission 7756A



**PHIL-LiDAR 1 Data Acquisition Flight Log**

Flight Log No.: 7756

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: LK Paragas | 2 ALTM Model: ATC | 3 Mission Name: 3BLK49A423A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9322 |
| 7 Pilot: Agawin, N | 8 Co-Pilot: De Ocampo | 9 Route: | | | |
| 10 Date: 01-23-15 | 12 Airport of Departure (Airport, City/Province): Ormoc | | 12 Airport of Arrival (Airport, City/Province): Ormoc | | |
| 13 Engine On: 7+41 | 14 Engine Off: 11+34 | 15 Total Engine Time: 3+53 | 16 Take off: 7+46 | 17 Landing: 11+30 | 18 Total Flight Time: 3+44 |
| 19 Weather: Fair | | | | | |

20 Remarks:

Completed Blk 49A

CASI GPS on red, No Digitizer

21 Problems and Solutions:

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

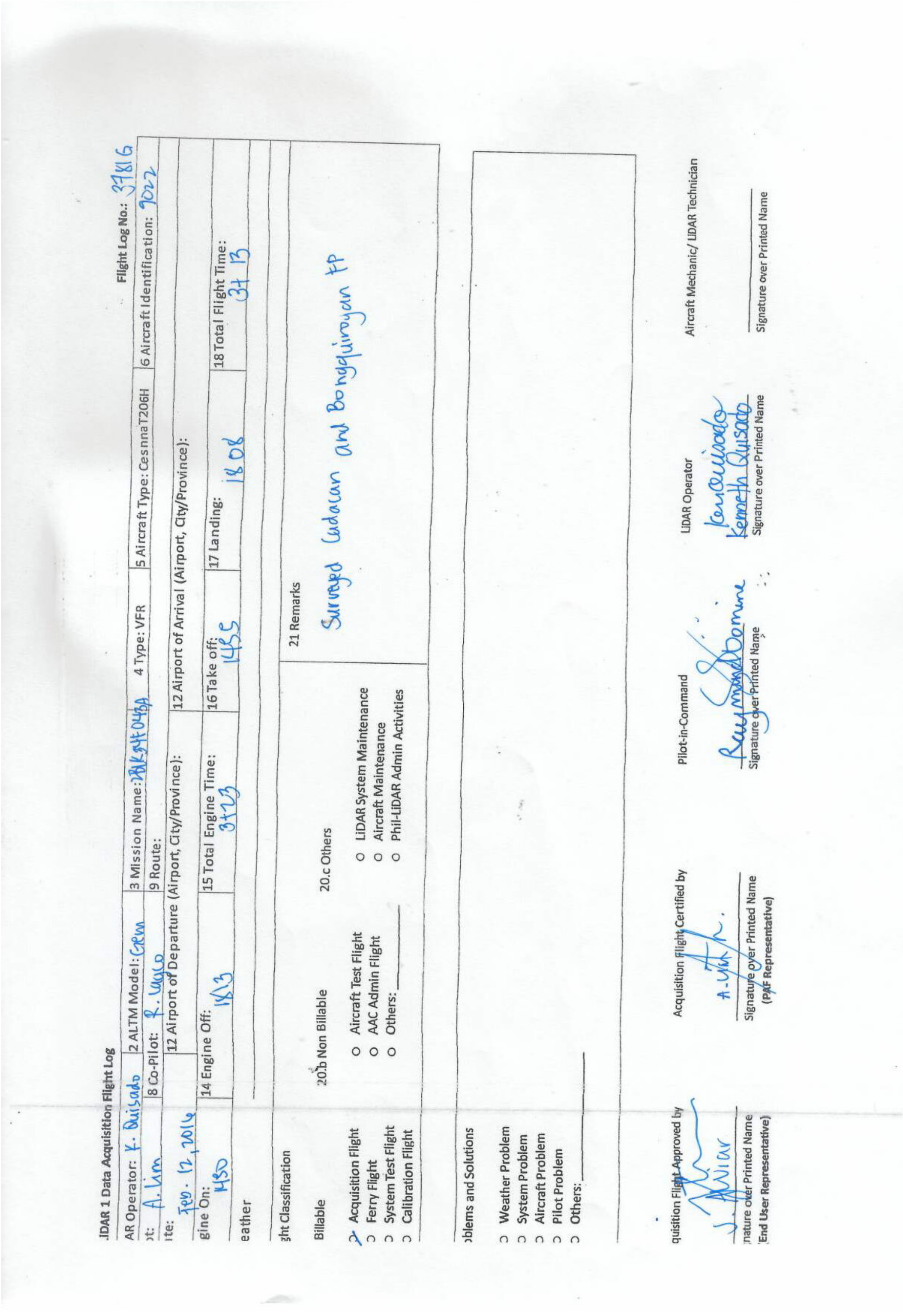
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — LK Paragas — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 7756A

3. Flight Log for Mission 3781G



LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3781G

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: K. Quisado | 2 ALTM Model: Gem | 3 Mission Name: 2BLK34TO45A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: A. Lim | 8 Co-Pilot: R. Uyglo | 9 Route: | | | |
| 10 Date: Feb. 12, 2016 | 12 Airport of Departure (Airport, City/Province): | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 1430 | 14 Engine Off: 1813 | 15 Total Engine Time: 3+23 | 16 Take off: 1435 | 17 Landing: 1808 | 18 Total Flight Time: 3+13 |
| 19 Weather | | | | | |

20 Flight Classification

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

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

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

21 Remarks

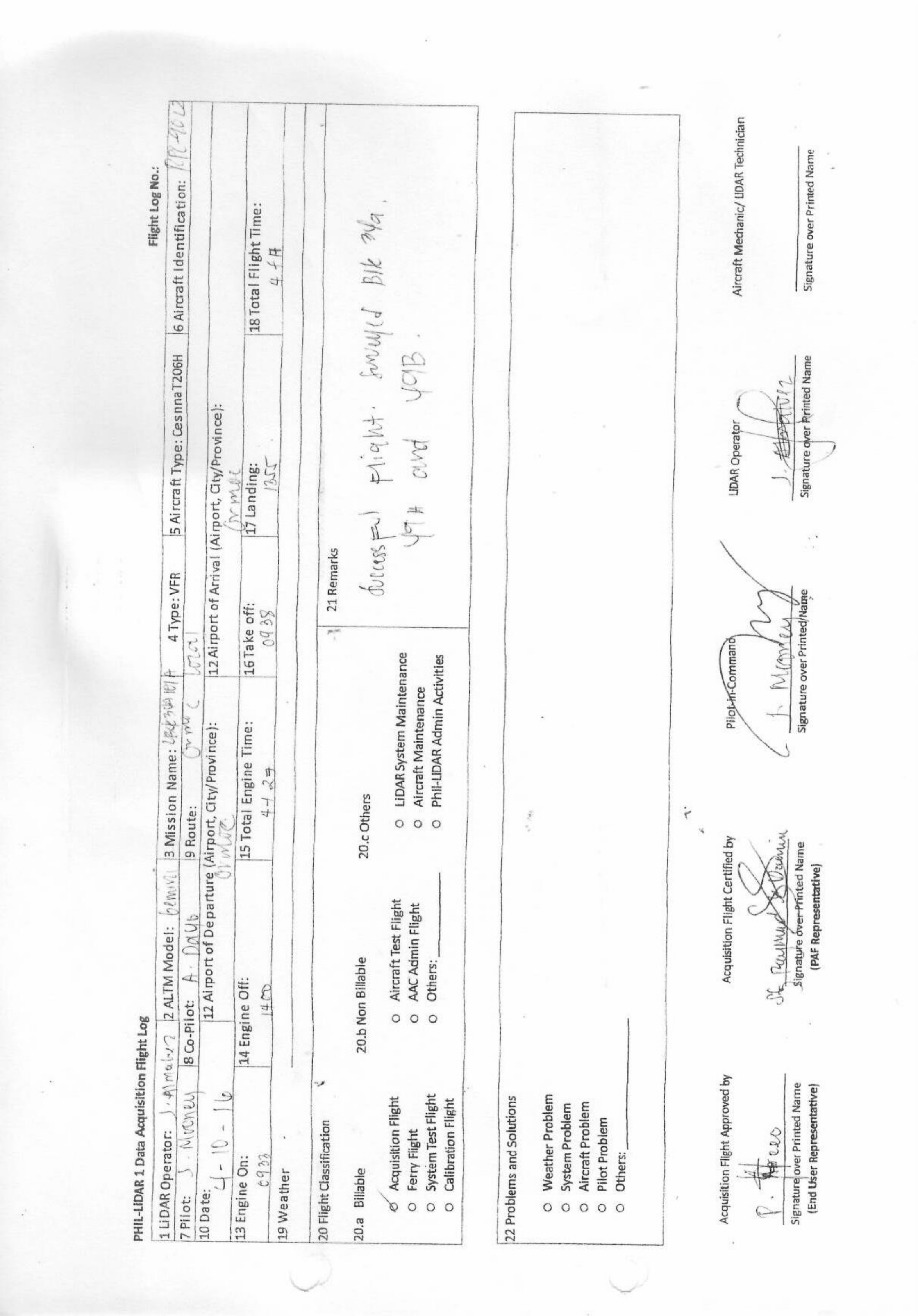
Surveyed Cadacan and Bongquinoyan FP

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LiDAR Technician |
|---|---|---|---|---|
| J. Alviar | A. Ylik | Raymund Domine | Kenneth Quisado | |
| 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-6.3. Flight Log for Mission 3781G

4. Flight Log for Mission 3921G


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J. Almalvez | 2 ALTM Model: Gemini | 3 Mission Name: | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: |
| 7 Pilot: J. Mooney | 8 Co-Pilot: A. Dayo | 9 Route: Ormoc Local | | | |
| 10 Date: 4-10-16 | 12 Airport of Departure (Airport, City/Province): Ormoc | | 12 Airport of Arrival (Airport, City/Province): Ormoc | | |
| 13 Engine On: 0933 | 14 Engine Off: 1400 | 15 Total Engine Time: 4+27 | 16 Take off: 0938 | 17 Landing: 1355 | 18 Total Flight Time: 4+17 |
| 19 Weather | | | | | |

20 Flight Classification

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

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

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

21 Remarks

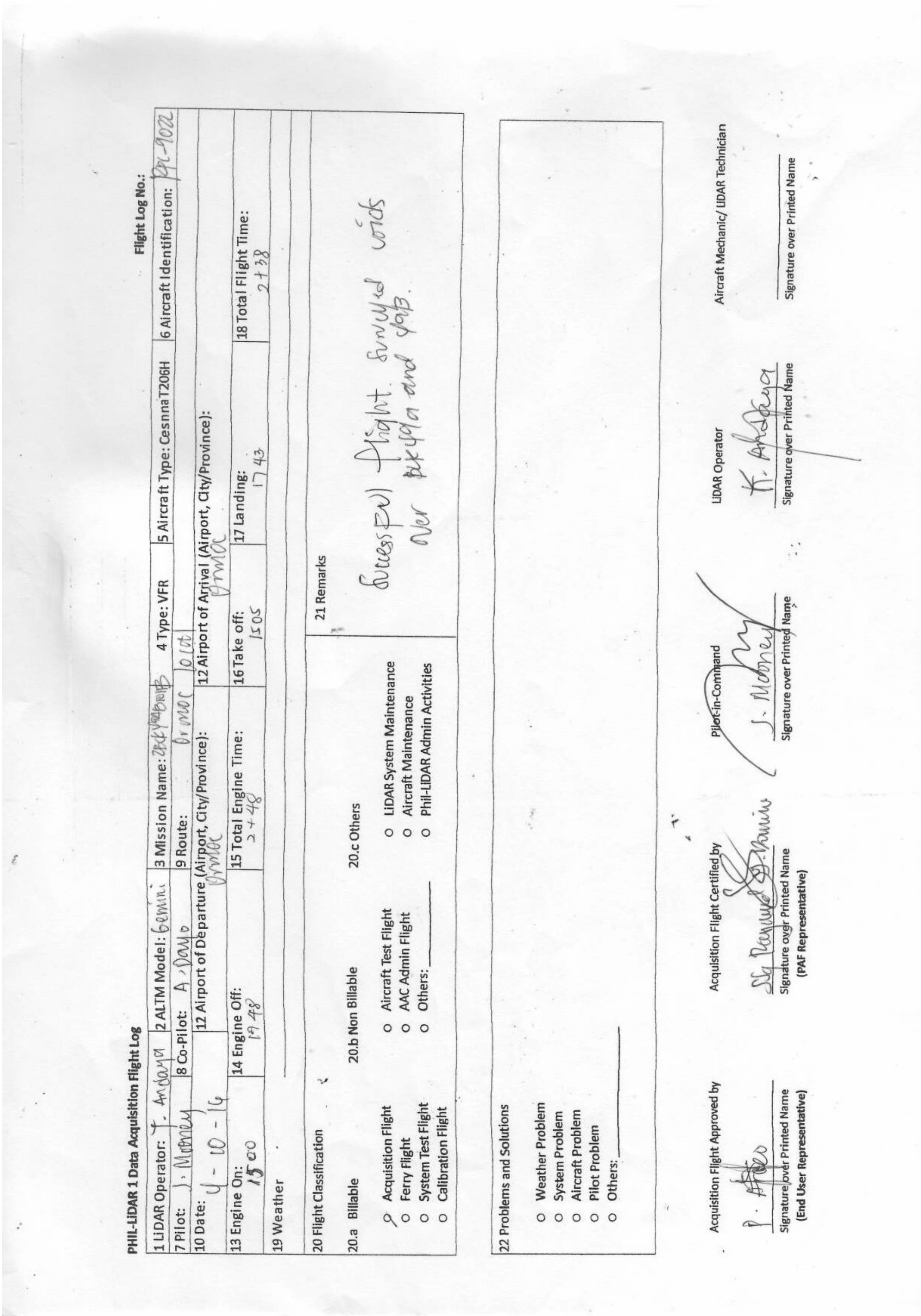
Successful flight. Surveyed BLK 49a, 49A and 49B.

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LiDAR Technician |
|---|---|---|---|---|
| P. [signature] | [signature] | J. Mooney | J. Almalvez | |
| 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-6.4. Flight Log for Mission 3921G

5. Flight Log for Mission 3923G



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: T. Andaya | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK49A49B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RPC-9022 |
| 7 Pilot: J. Mooney | 8 Co-Pilot: A. Dayo | 9 Route: Ormoc (Iloilo) | | | |
| 10 Date: 4-10-16 | 12 Airport of Departure (Airport, City/Province): Ormoc | | 12 Airport of Arrival (Airport, City/Province): Ormoc | | |
| 13 Engine On: 1500 | 14 Engine Off: 1948 | 15 Total Engine Time: 2+48 | 16 Take off: 1505 | 17 Landing: 1743 | 18 Total Flight Time: 2+38 |
| 19 Weather | | | | | |

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

Successful flight. Surveyed voids over BLK49A and 49B.

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)

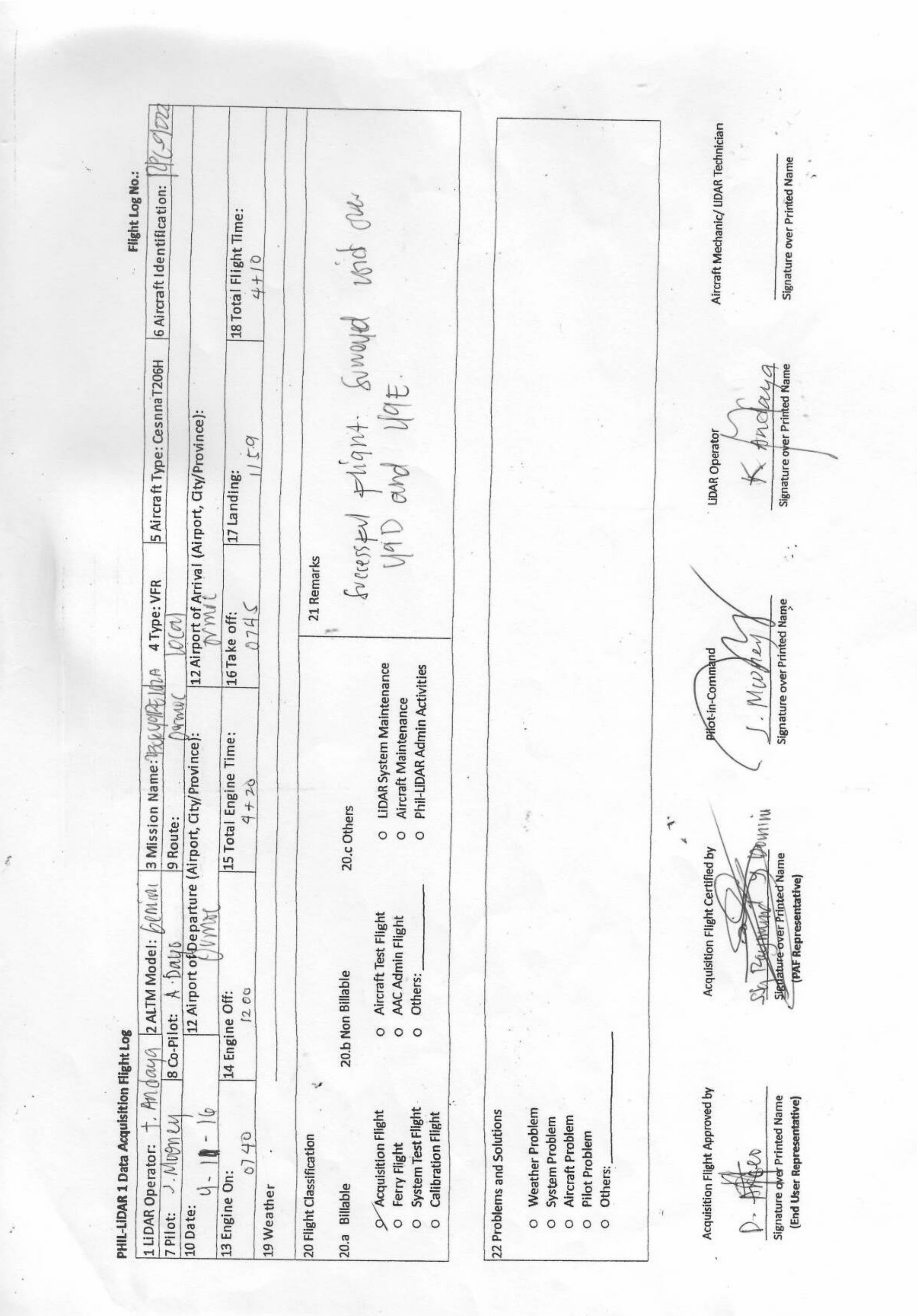
Pilot-in-Command — J. Mooney — Signature over Printed Name

LiDAR Operator — K. Andaya — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3923G

6. Flight Log for Mission 3925G



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. Andaya | 2 ALTM Model: Gemini | 3 Mission Name: 3BLK90PE109A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP-C9022 |
| 7 Pilot: J. Mooney | 8 Co-Pilot: A. Dayo | 9 Route: Dmgt local | | | |
| 10 Date: 4-18-16 | 12 Airport of Departure (Airport, City/Province): Dmgt | | 12 Airport of Arrival (Airport, City/Province): Dmgt | | |
| 13 Engine On: 0740 | 14 Engine Off: 1200 | 15 Total Engine Time: 4+20 | 16 Take off: 0745 | 17 Landing: 1159 | 18 Total Flight Time: 4+10 |
| 19 Weather | | | | | |

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

Successful flight. Surveyed void over U9D and U9E.

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

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

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

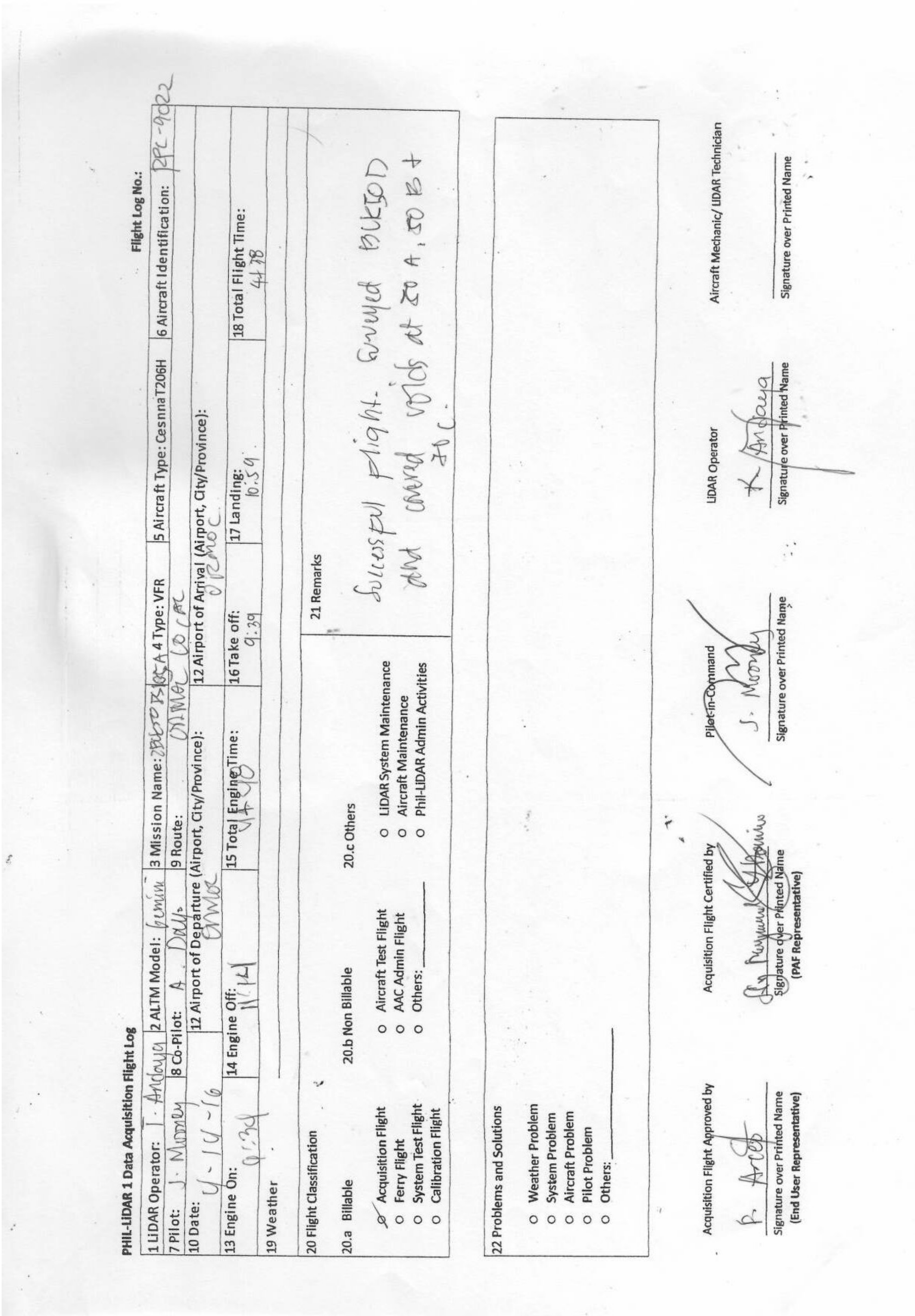
Pilot-in-Command: J. Mooney — Signature over Printed Name

LiDAR Operator: K. Andaya — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: Signature over Printed Name

Figure A-6.6. Flight Log for Mission 3925G

7. Flight Log for Mission 3937G



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. Andaya | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK50B105A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RPC-9022 |
| 7 Pilot: J. Mooney | 8 Co-Pilot: A. Dayo | 9 Route: Ormoc Local | | | |
| 10 Date: 4-14-16 | 12 Airport of Departure (Airport, City/Province): Ormoc | | 12 Airport of Arrival (Airport, City/Province): Ormoc | | |
| 13 Engine On: 9:34 | 14 Engine Off: 11:14 | 15 Total Engine Time: 1+40 | 16 Take off: 9:39 | 17 Landing: 10:59 | 18 Total Flight Time: 1+38 |
| 19 Weather | | | | | |

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

Successful flight. Surveyed BLK50D and covered voids at 50 A, 50 B + 50 C.

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LiDAR Technician |
|---|---|---|---|---|
| R. Arceo | | J. Mooney | K. Andaya | |
| 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 3937G

# Annex 7. Flight Status Reports

FLIGHT STATUS REPORT
LEYTE
Table A-7.1. Flight status report

| FLIGHT NO | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 3781G | BLK49A | 2BLK34F043A | K QUISADO | February 12, 2016 | SURVEYED CADACAN AND BONGQUIROGAN FPs |
| 3921G | BLK 34 a, BLK 49A & B | 2BLK34a101A | J.ALMALVEZ | April 10, 2016 | SURVEYED BLK34a, 49A and 49B |
| 3923G | BLK49 A & B | 2BLK49AB101B | K. ANDAYA | April 10, 2016 | SURVEYED VOIDS OVER BLK 49A AND 49B |
| 3925G | BLK50 D & E | 2BLK49DE102A | K. ANDAYA | April 11, 2016 | SURVEYED VOIDS OVER BLK 49D AND 49E |
| 3937G | BLK50 A,B,C & D | 2BLK50DS105A | K.ANDAYA | April 14, 2016 | SURVEYED VLOCK 50D AND COVERED VOIDS AT 50A, 50B AND 50C |
| 7754AC | BLK49 B | 3BLK49B022A | G SINADJAN | January 22, 2015 | Completed Blk49B. CASI GPS always red. Experienced unexpected laser off |
| 7756AC | BLK49 A | 3BLK49A023A | LK PARAGAS | January 23, 2015 | Completed Blk49A. CASI GPS always red |

| | | | | | | |
|---|---|---|---|---|---|---|
| Flight No. : | 3781G | | | | | |
| Area: | BLK 34aC, 34aB, 49A – Cadacan 2 and Bongquirogan FPs | | | | | |
| Mission Name: | 2BLK34043A | | | | | |
| Parameters: | PRF 100 | SF | 50 | SCA | 18 | |

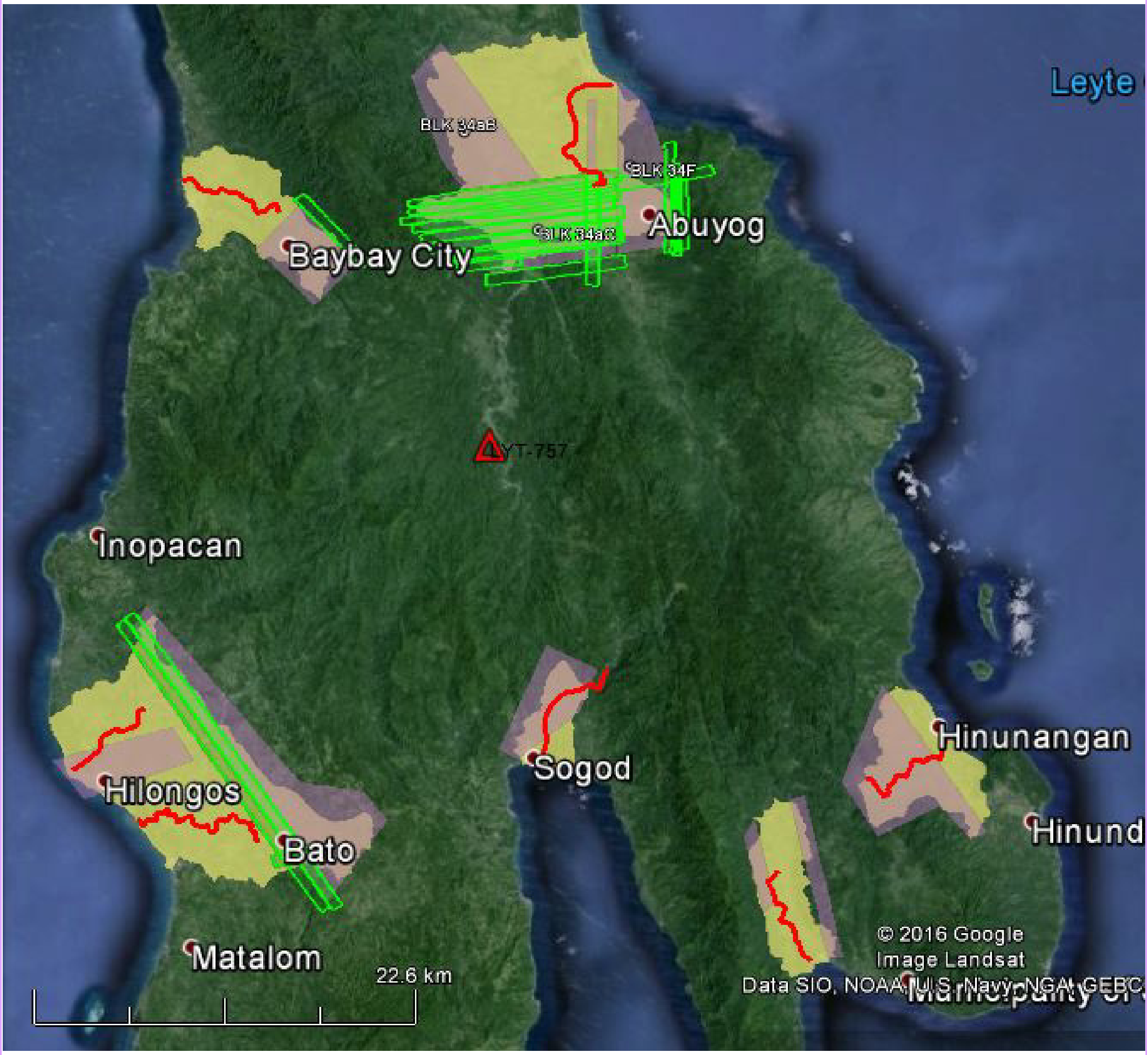



Figure A-7.1. Swath for Flight No. 3781G

| | | |
|---|---|---|
| FLIGHT NO.: | 3921G | |
| AREA: | Ormoc | |
| MISSION NAME: | 2BLK34a101A | |
| ALT: 1000m | SCAN FREQ: 50 | SCAN ANGLE: 18 |
| SURVEYED AREA: | 144.9 | |


Figure A-7.2. Swath for Flight No. 3921G

| | | |
|---|---|---|
| FLIGHT NO.: | 3923G | |
| AREA: | Ormoc | |
| MISSION NAME: | 2BLK49AB101B | |
| ALT: 1000m | SCAN FREQ: 50 | SCAN ANGLE: 18 |
| SURVEYED AREA: | 59.94 | |


Figure A-7.3. Swath for Flight No. 3923G

| | | |
|---|---|---|
| FLIGHT NO.: | 3925G | |
| AREA: | Ormoc | |
| MISSION NAME: | 2BLK49DE102A | |
| ALT: 1000m | SCAN FREQ: 50 | SCAN ANGLE: 18 |
| SURVEYED AREA: | 73.96 | |

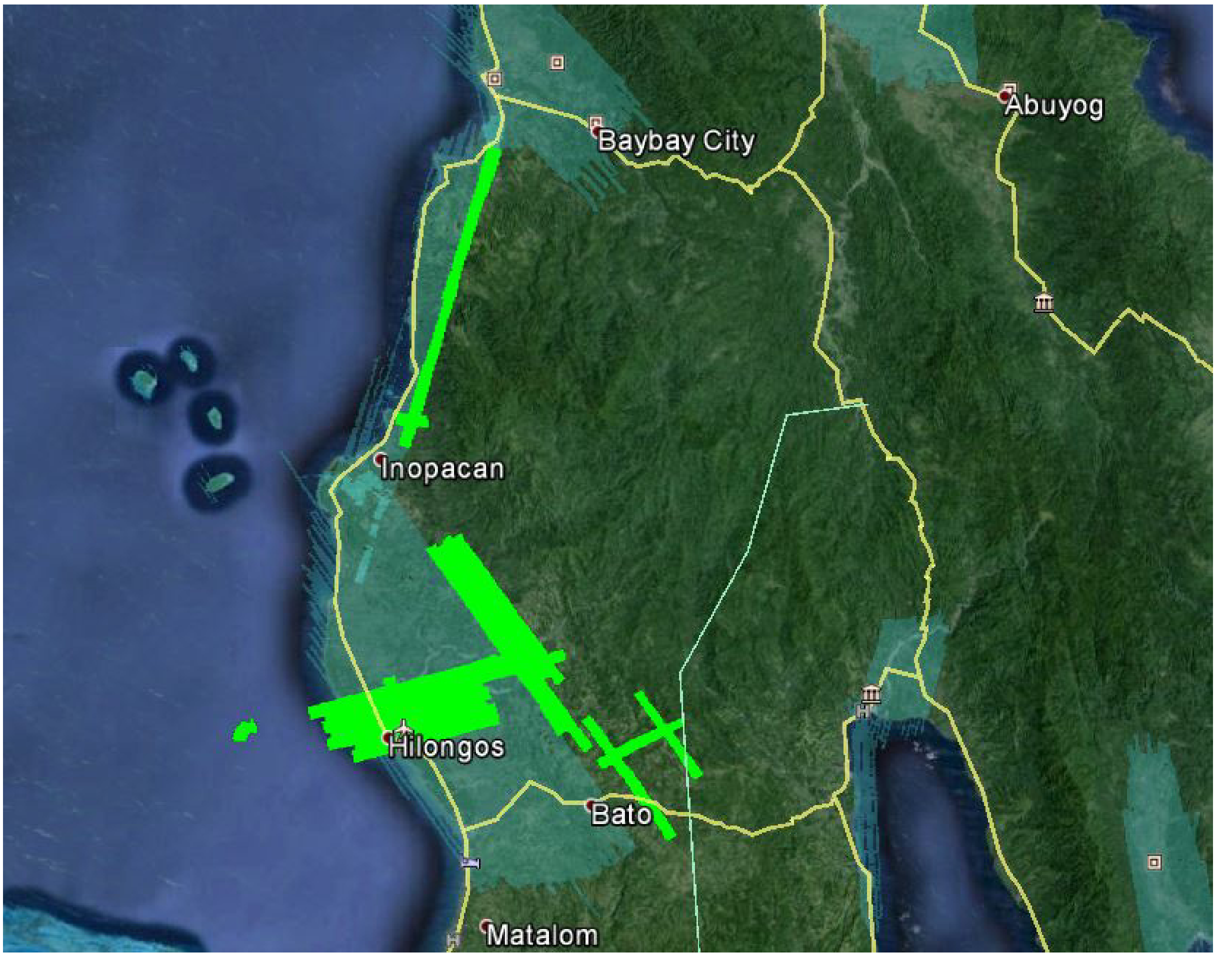



Figure A-7.4. Swath for Flight No. 3925G

| | | |
|---|---|---|
| FLIGHT NO.: | 3937G | |
| AREA: | Ormoc | |
| MISSION NAME: | 2BLK50DS105A | |
| ALT: 850 | SCAN FREQ: 40 | SCAN ANGLE: 25 |
| SURVEYED AREA: | 92.6 | |

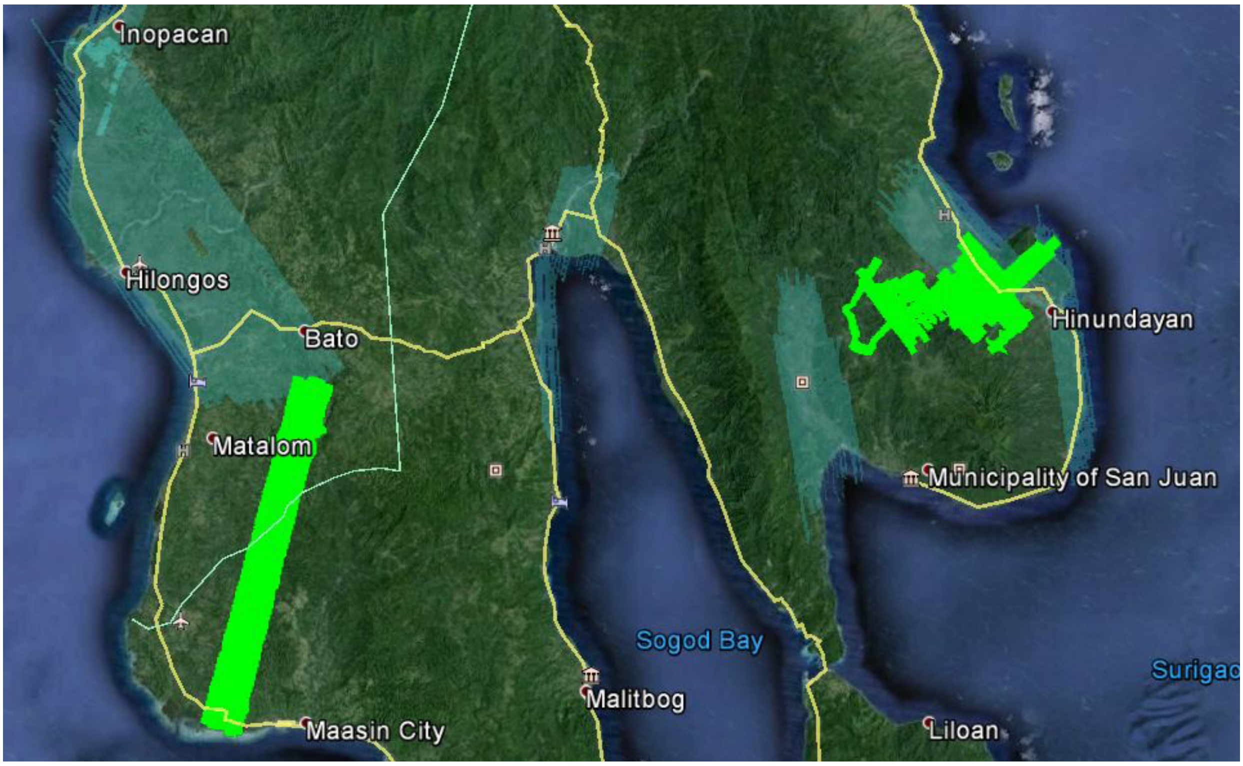



Figure A-7.5. Swath for Flight No. 3937G

| | |
|---|---|
| Flight No. : | 7754AC |
| Area: | BLK49B |
| Mission name: | 3BLK49B022A |
| Parameters: | Altitude: 600; Scan Frequency: 45; Scan Angle: 18; Overlap: 35% |
| Area covered: | 75.84sq.km. |

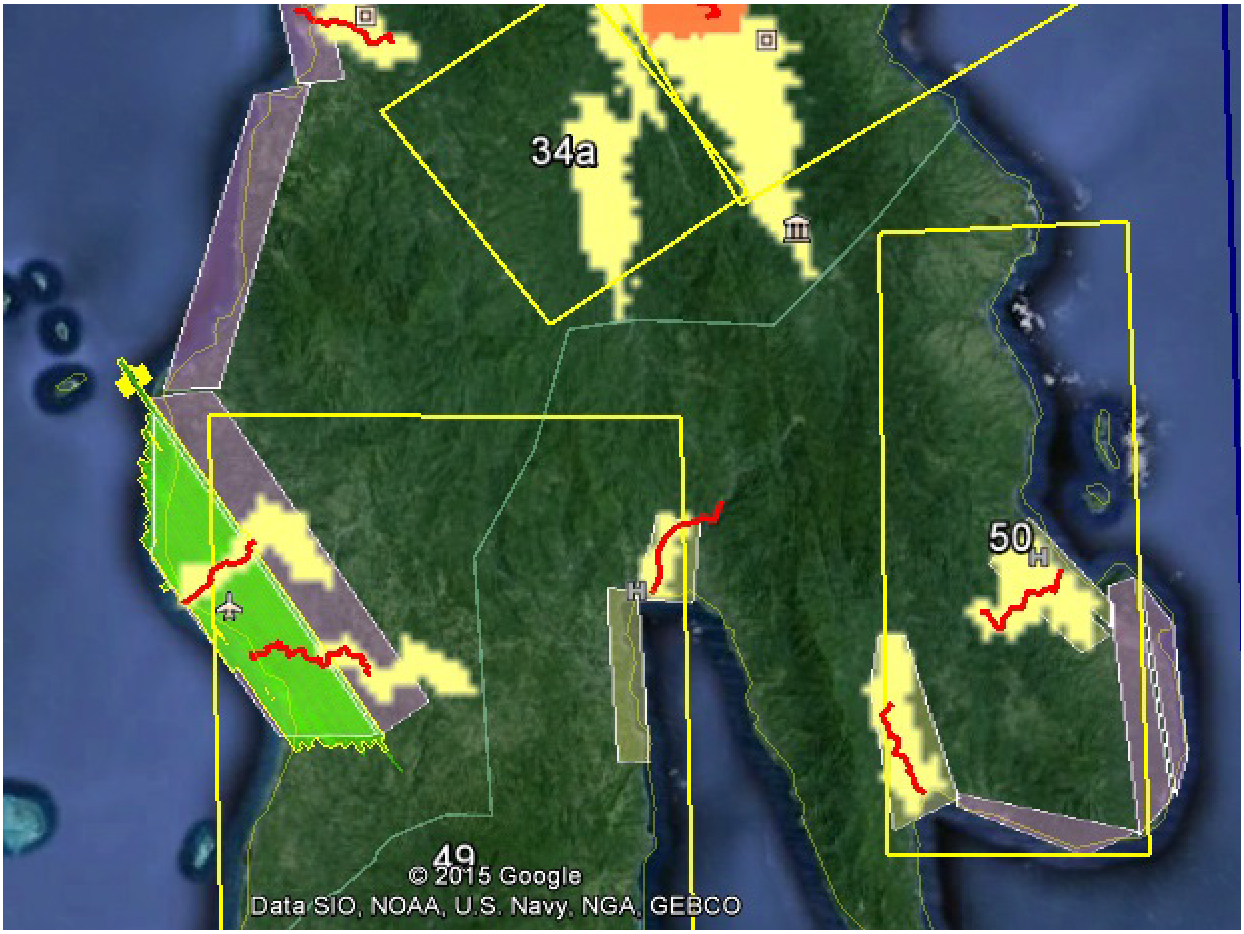



Figure A-7.6. Swath for Flight No. 7754AC

| | |
|---|---|
| Flight No. : | 7756AC |
| Area: | BLK49A |
| Mission name: | 3BLK49A023A |
| Parameters: | Altitude: 600 ; Scan Frequency: 45; Scan Angle: 18; Overlap: 35% |
| Area covered: | 97.327sq.km. |

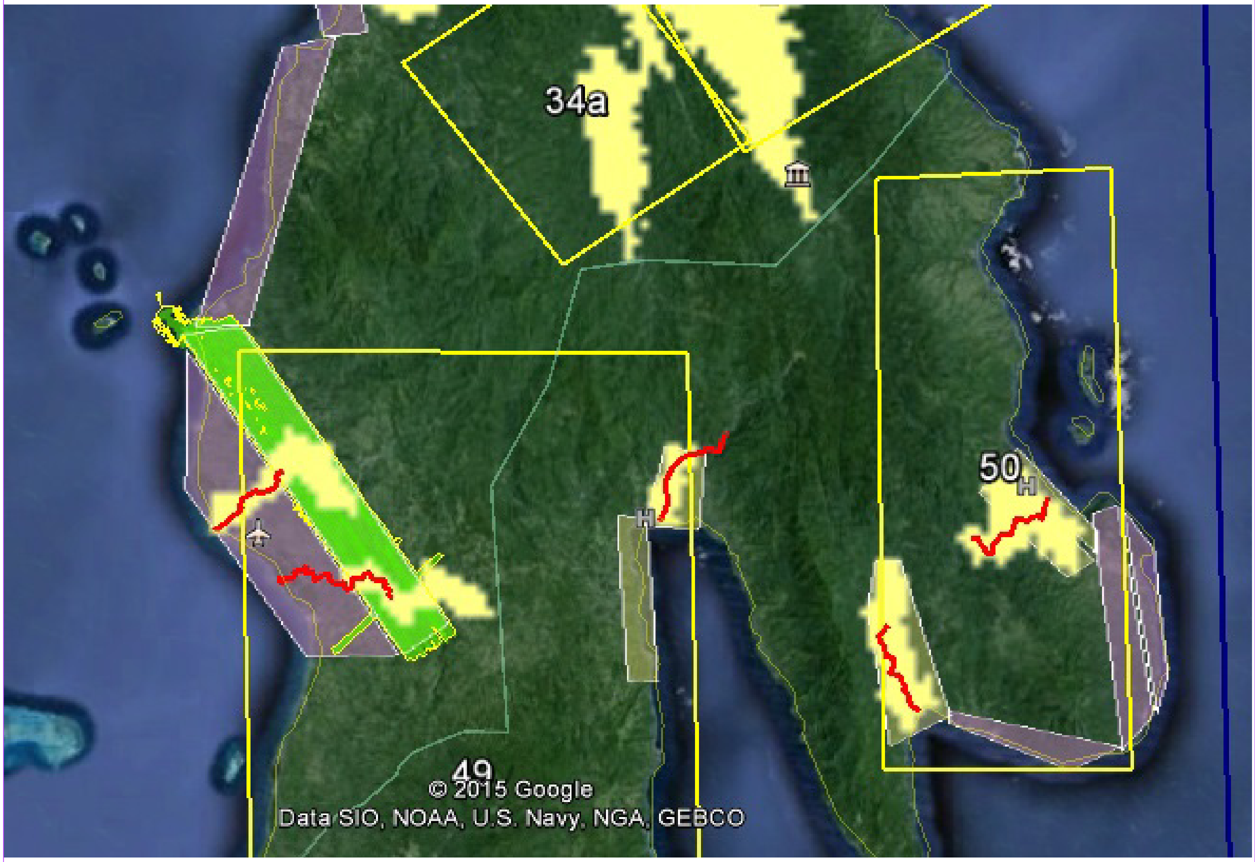



Figure A-7.7. Swath for Flight No. 7756AC

# Annex 8. Mission Summary Reports

| | |
|---|---|
| **Flight Area** | Leyte |
| **Mission Name** | 49A_Additional |
| **Inclusive Flights** | 3781G |
| **Range data size** | 11.3 MB |
| **Base data size** | 8.87 MB |
| **POS data size** | 191 GB |
| **Image** | n/a |
| **Transfer date** | March 04, 2016 |
| | |
| ***Solution Status*** | |
| **Number of Satellites (>6)** | Yes |
| **PDOP (<3)** | Yes |
| **Baseline Length (<30km)** | No |
| **Processing Mode (<=1)** | Yes |
| | |
| ***Smoothed Performance Metrics(in cm)*** | |
| **RMSE for North Position (<4.0 cm)** | 1.1 |
| **RMSE for East Position (<4.0 cm)** | 1.1 |
| **RMSE for Down Position (<8.0 cm)** | 3.0 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.000966 |
| **IMU attitude correction stdev (<0.001deg)** | 0.001913 |
| **GPS position stdev (<0.01m)** | 0.0079 |
| | |
| **Minimum % overlap (>25)** | 0.12 |
| **Ave point cloud density per sq.m. (>2.0)** | 3.23 |
| **Elevation difference between strips (<0.20m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 61 |
| **Maximum Height** | 347.41 m |
| **Minimum Height** | 73.84 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 9,887,748 |
| **Low vegetation** | 5,981,068 |
| **Medium vegetation** | 21,000,152 |
| **High vegetation** | 47,560,273 |
| **Building** | 64,860 |
| **Orthophoto** | Yes |
| **Processed by** | Engr. Analyn Naldo, Karl Adrian Vergara, Engr. Merven Matthew Natino |

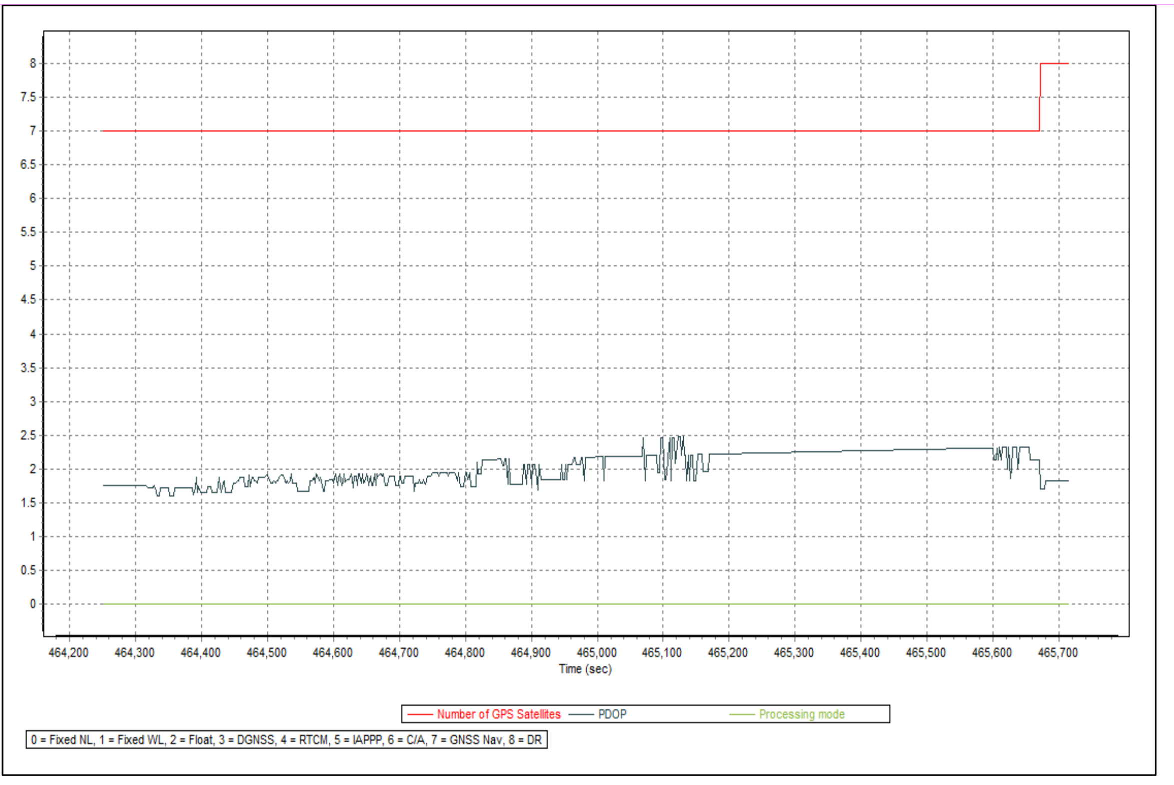



Figure A-8.1 Solution Status

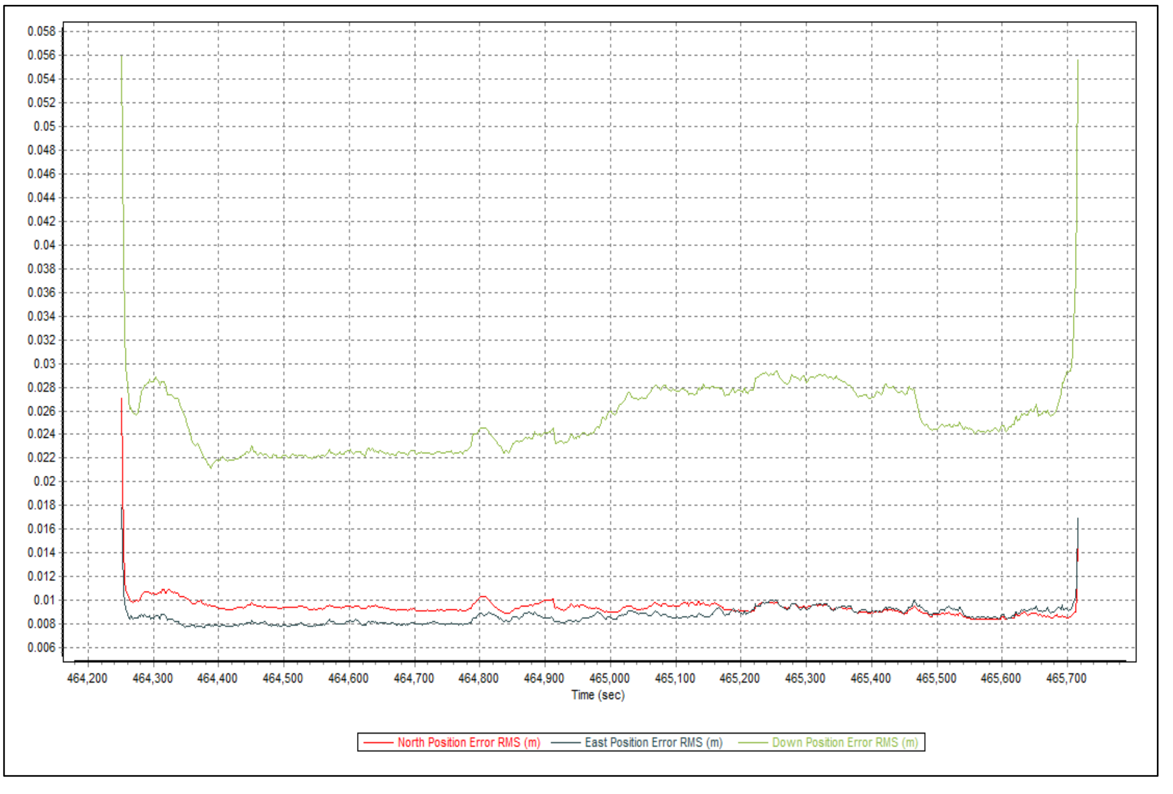



Figure A-8.2 Smoothed Performance Metric Parameters

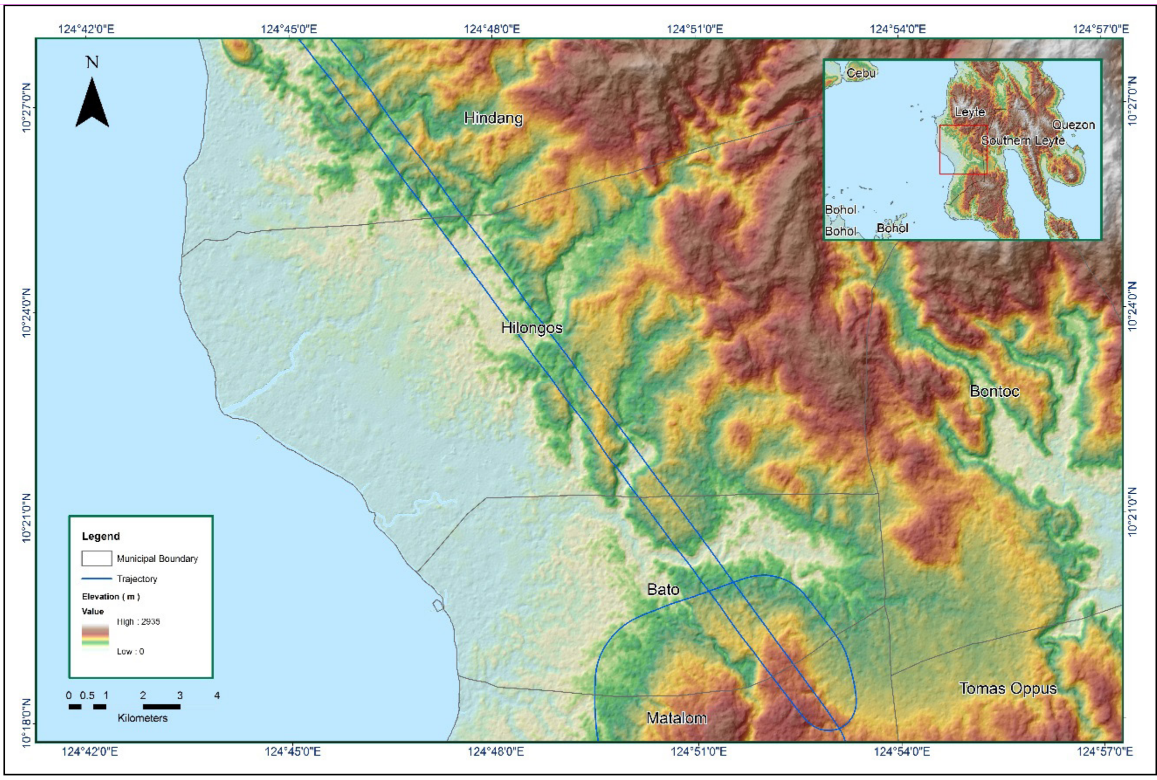



Figure A-8.3 Best Estimated Trajectory

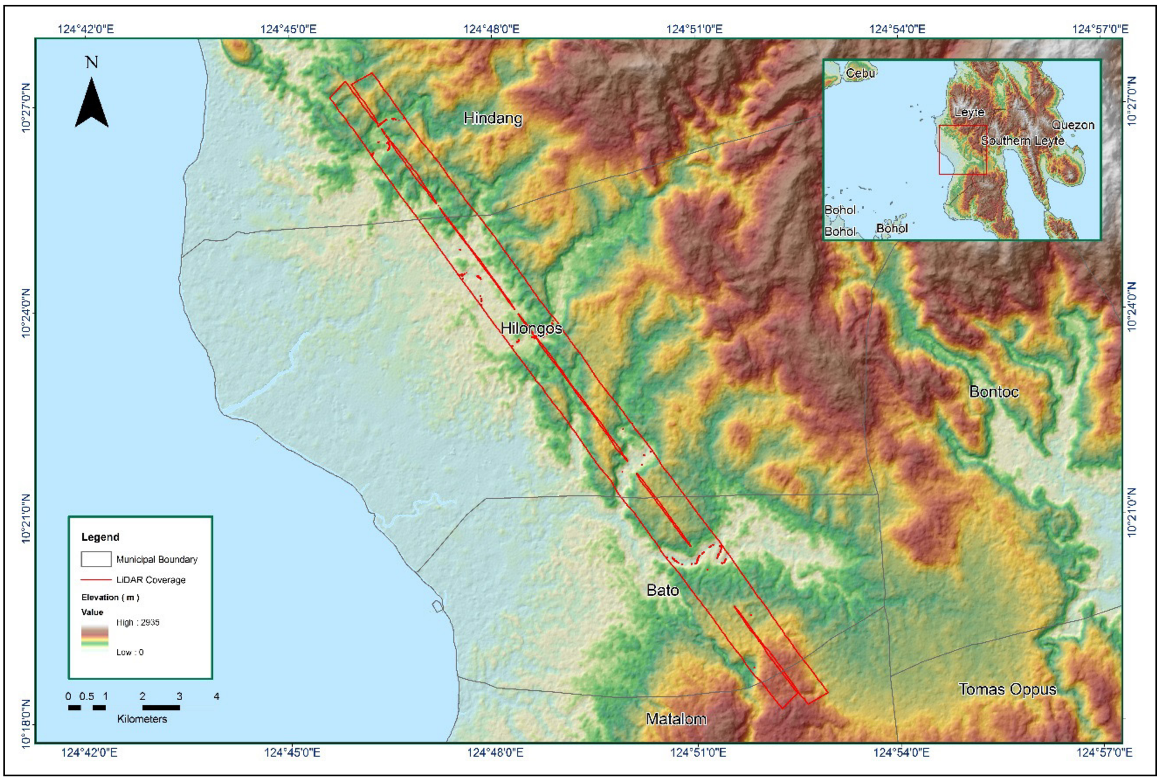



Figure A-8.4 Coverage LiDAR Data

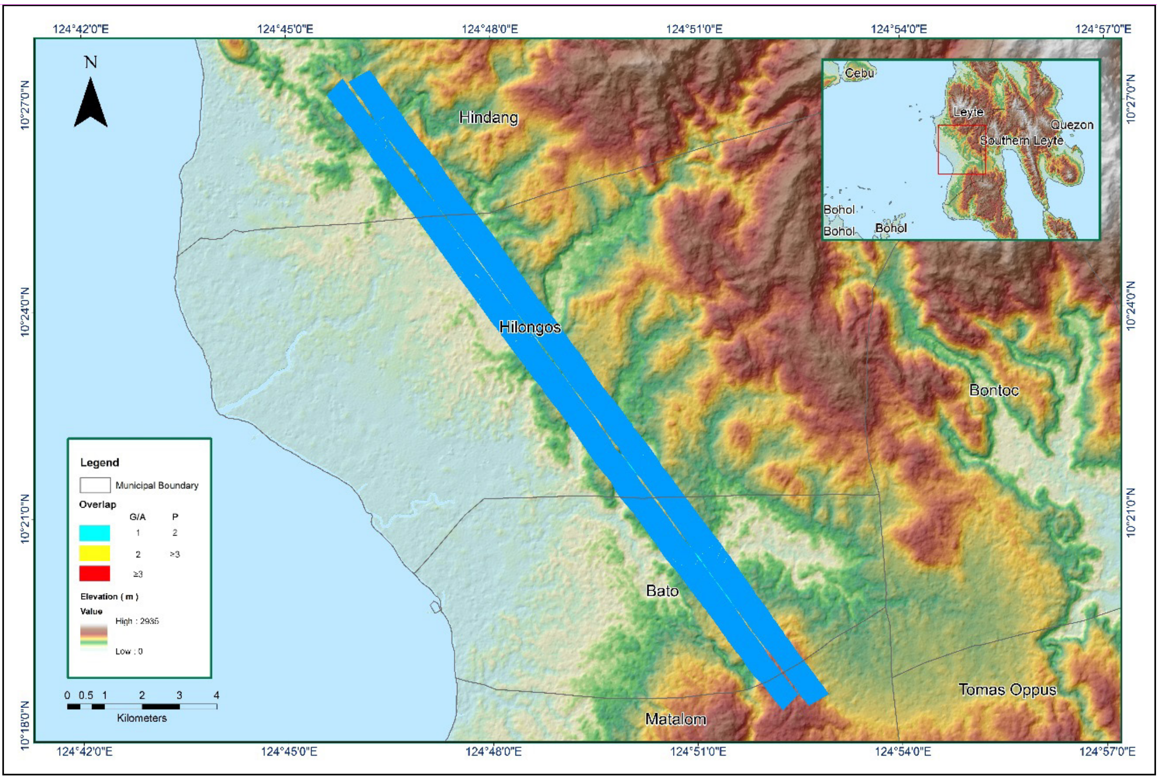



Figure A-8.5 Image Data Overlap

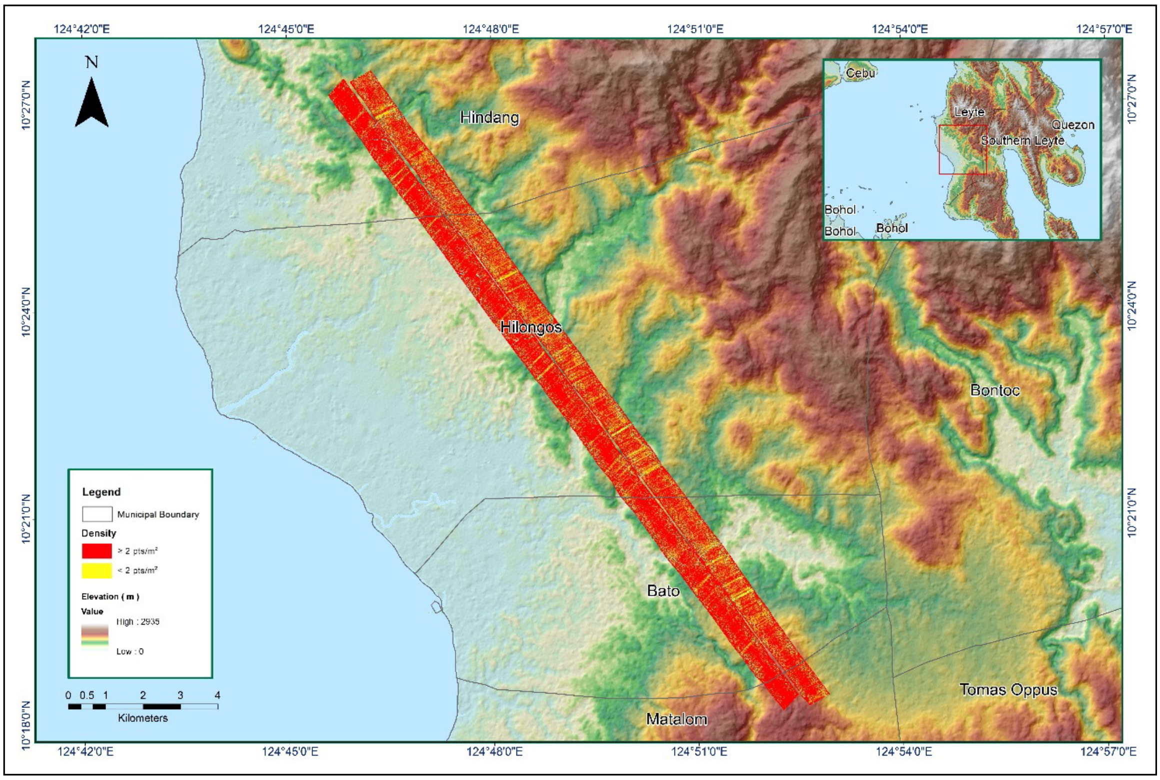



Figure A-8.6 Density Map of Merged LiDAR Data

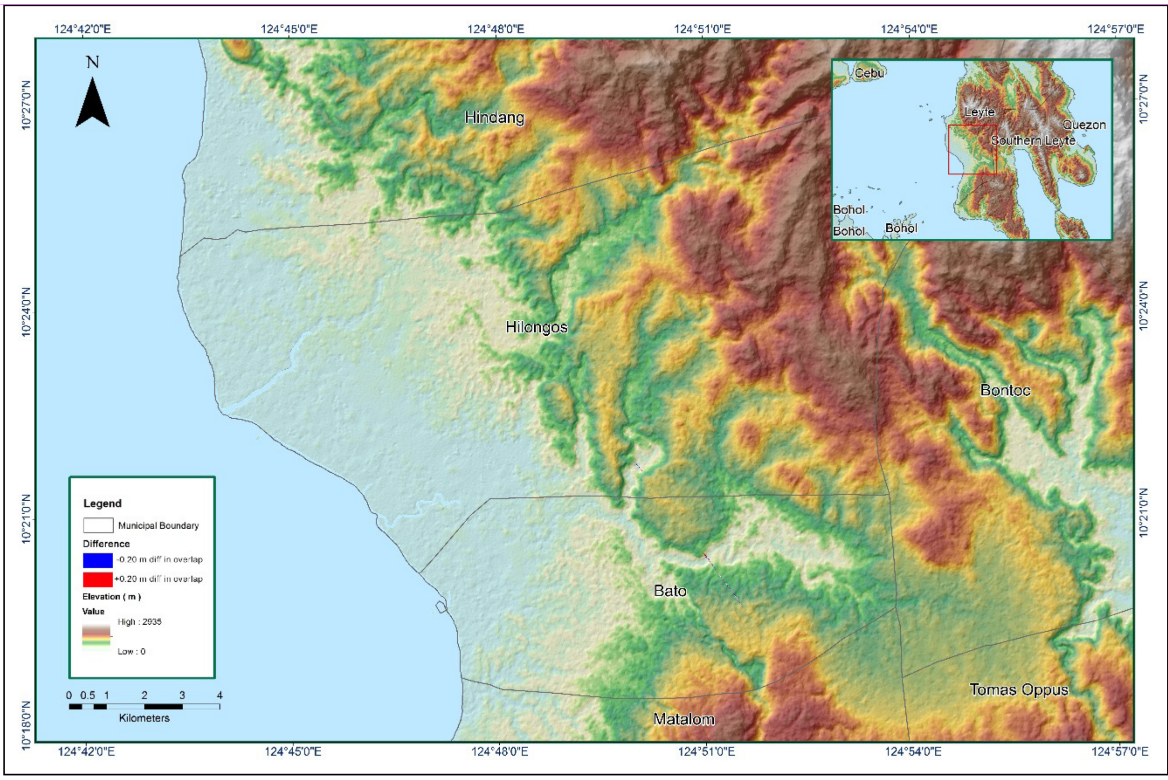



Figure A-8.7 Elevation difference between flightlines

| | |
|---|---|
| **Flight Area** | Ormoc |
| **Mission Name** | Blk49A |
| **Inclusive Flights** | 7756AC |
| **Range data size** | 11.9 GB |
| **Base data size** | 34 MB |
| **POS** | 231 MB |
| **Image** | 0 GB |
| **Transfer date** | February 13,2015 |
| | |
| ***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)** | 0.98 |
| **RMSE for East Position (<4.0 cm)** | 0.98 |
| **RMSE for Down Position (<8.0 cm)** | 2.10 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.000260 |
| **IMU attitude correction stdev (<0.001deg)** | 0.000627 |
| **GPS position stdev (<0.01m)** | 0.0095 |
| | |
| **Minimum % overlap (>25)** | 44.81 |
| **Ave point cloud density per sq.m. (>2.0)** | 3.32 |
| **Elevation difference between strips (<0.20 m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 125 |
| **Maximum Height** | 294.65 m |
| **Minimum Height** | 52.68 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 53,265,686 |
| **Low vegetation** | 48,235,650 |
| **Medium vegetation** | 77,404,104 |
| **High vegetation** | 122,939,501 |
| **Building** | 2,393,404 |
| **Orthophoto** | No |
| **Processed by** | Engr. Jommer Medina,Engr. Melissa Fernandez, Engr. Antonio Chua, Jr. |

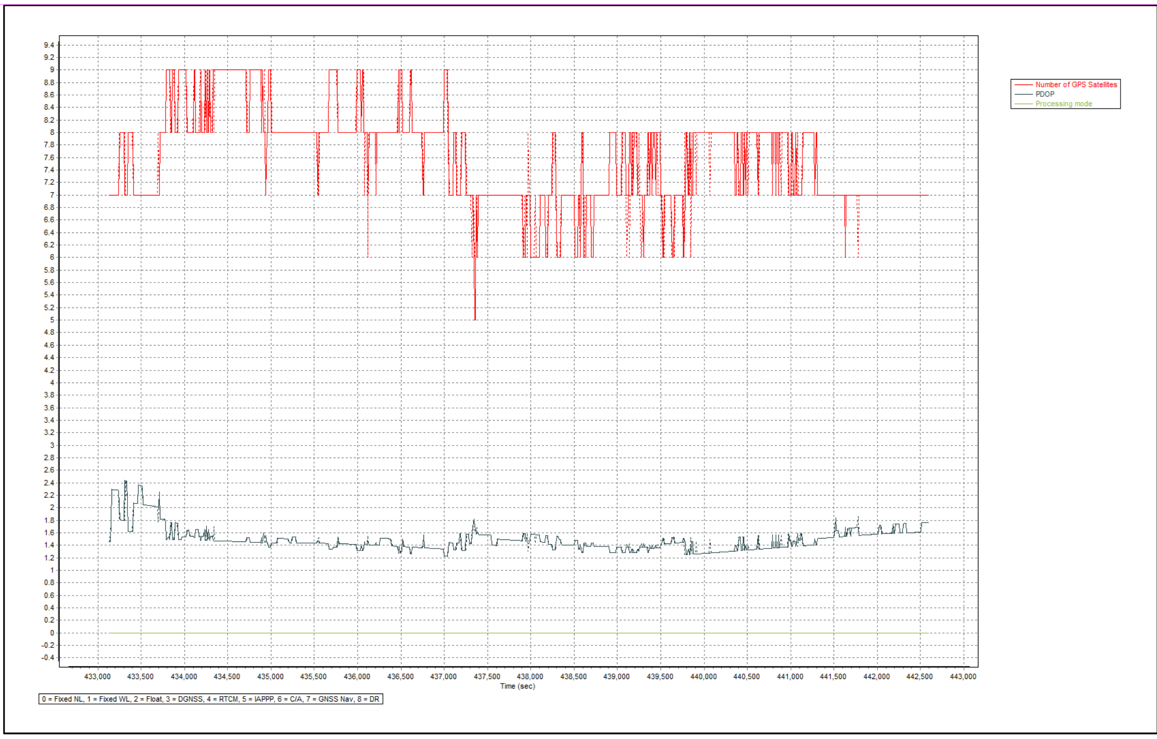



Figure A-8.8 Solution Status

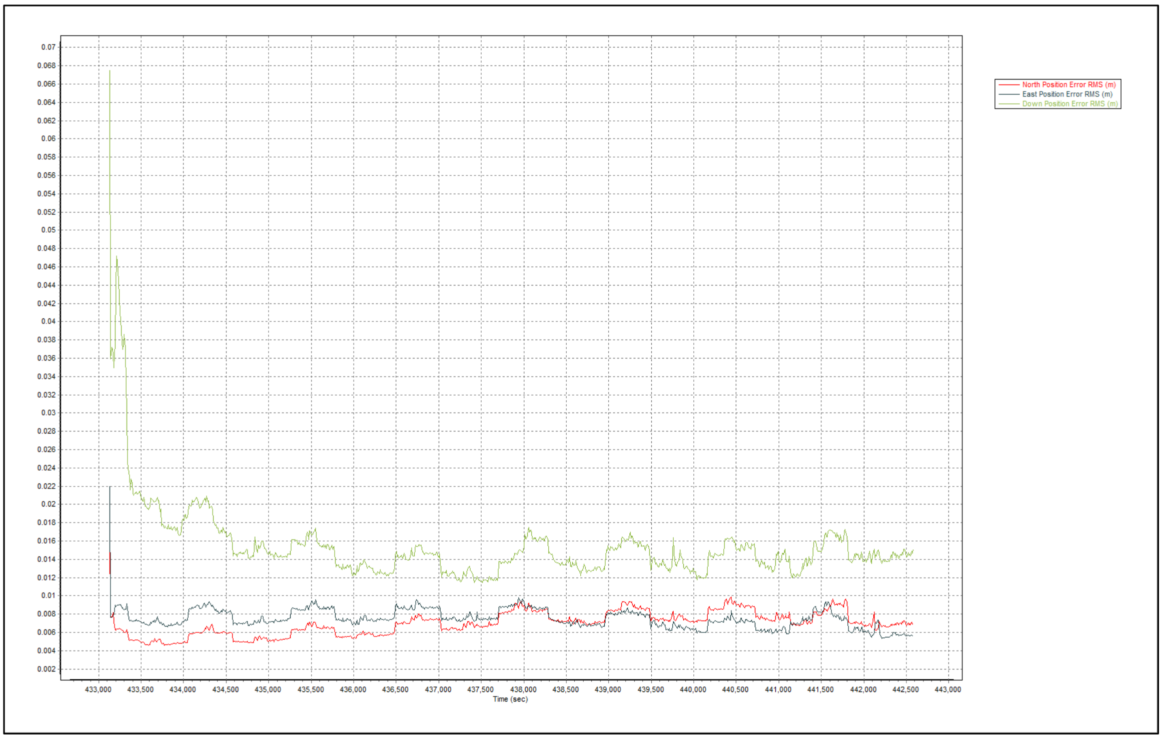



Figure A-8.9 Smoothed Performance Metric Parameters

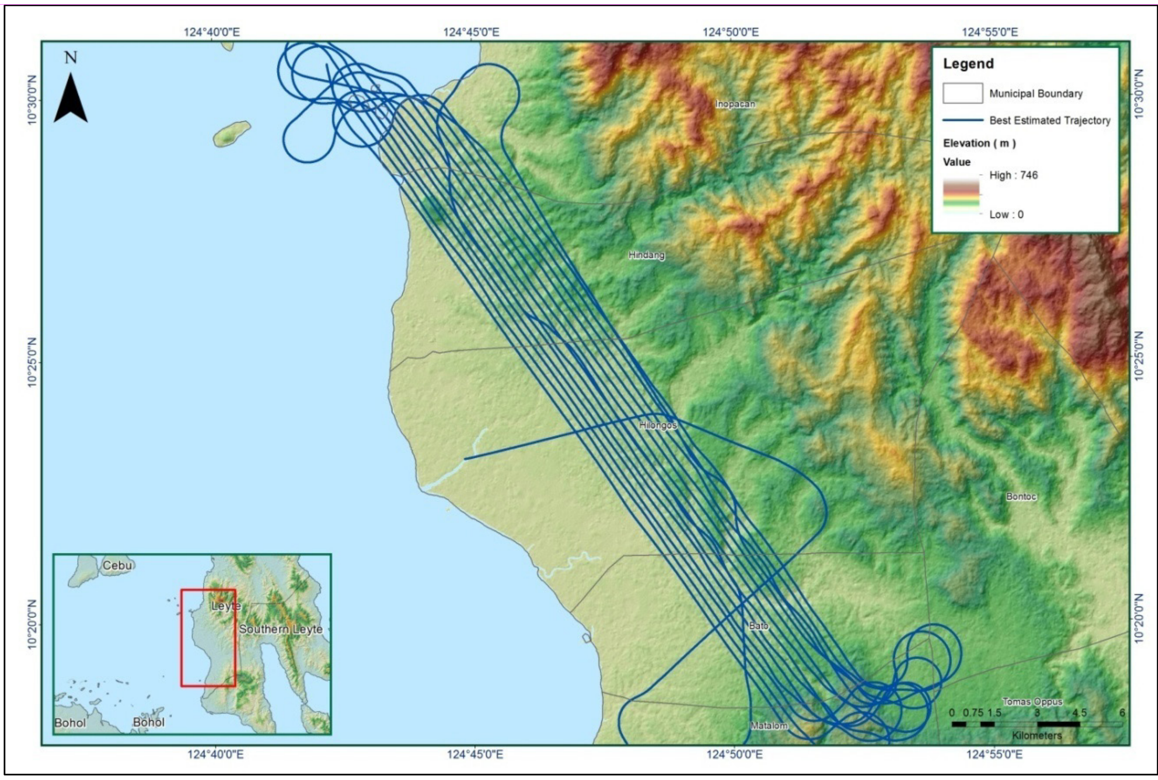



Figure A-8.10 Best Estimated Trajectory

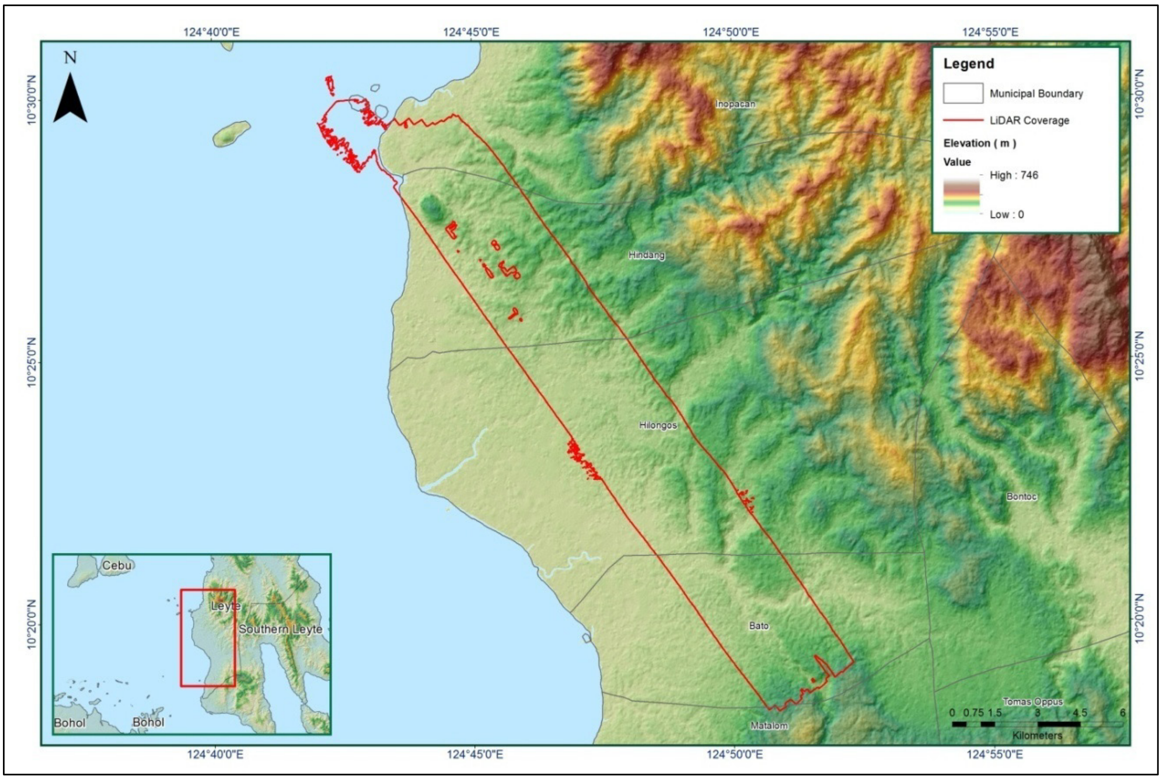



Figure A-8.11 Coverage of LiDAR Data

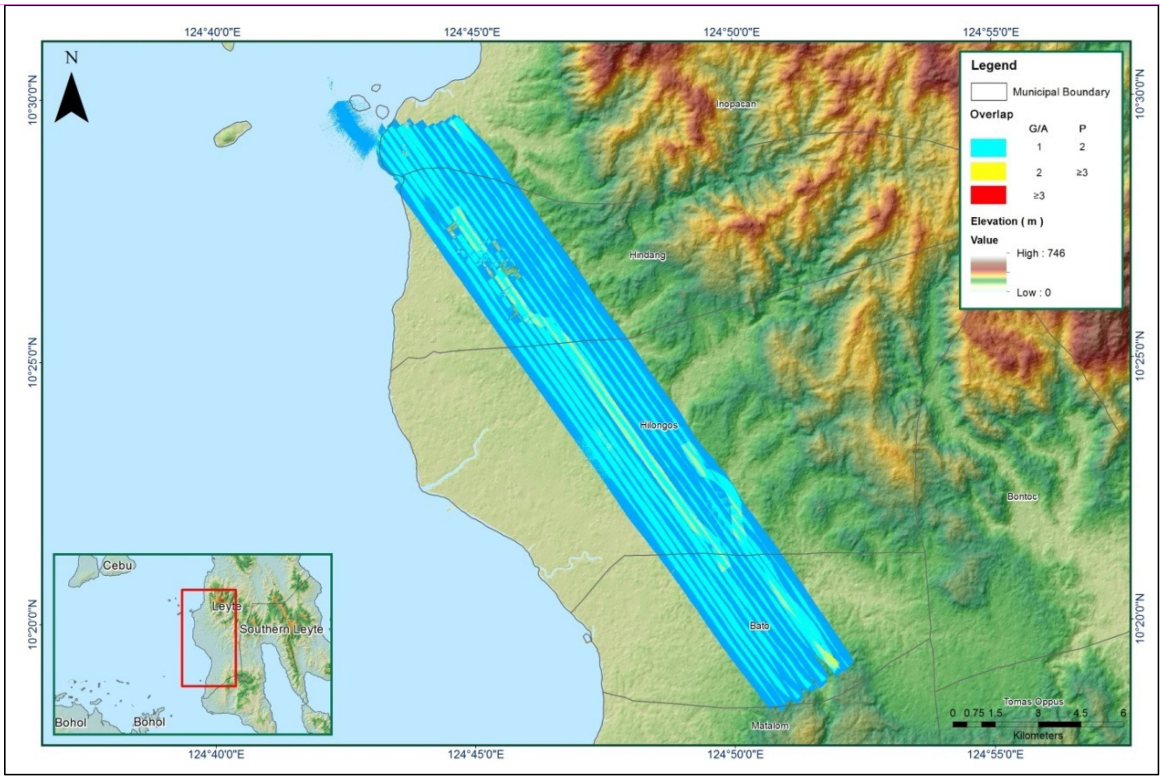



Figure A-8.12 Image Data Overlap

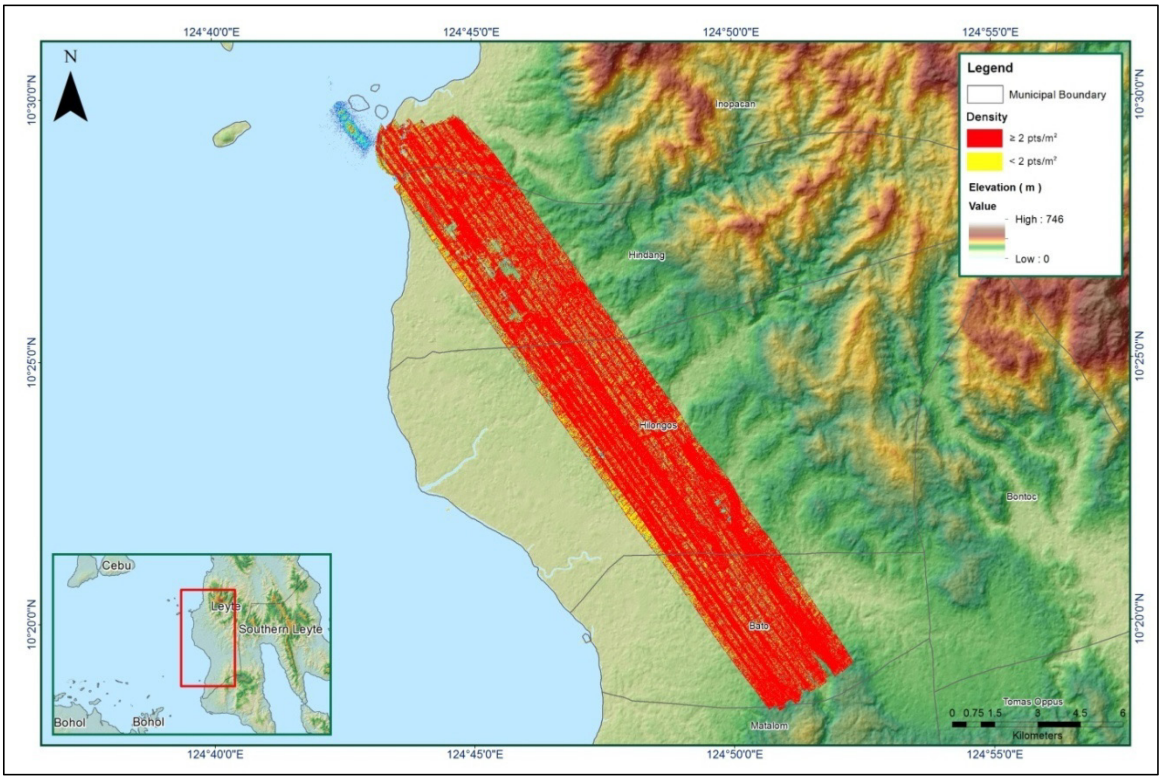



Figure A-8.13 Density map of merged LiDAR data

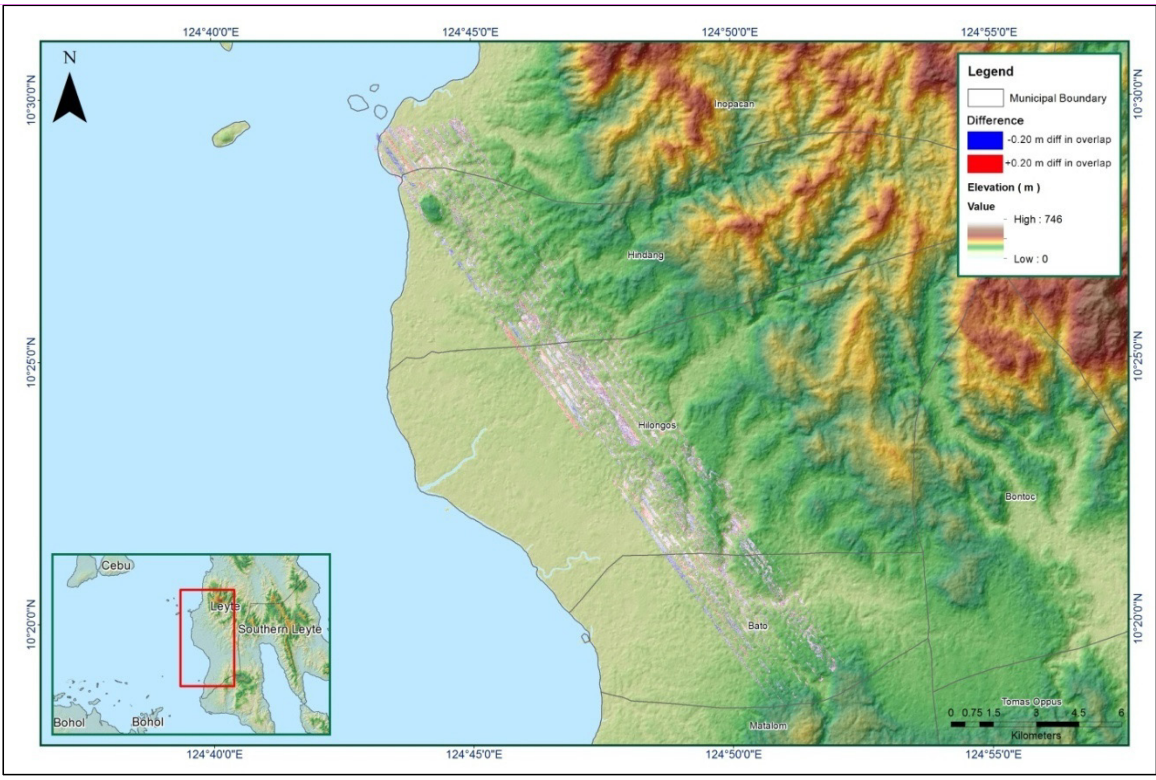



Figure A-8.14 Elevation difference between flight lines

| | |
|---|---|
| **Flight Area** | Ormoc |
| **Mission Name** | Blk49B |
| **Inclusive Flights** | 7754AC |
| **Range data size** | 12.0 GB |
| **Base data size** | 66.1 MB |
| **POS** | 258 MB |
| **Image** | 0 GB |
| **Transfer date** | February 13, 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)** | 1.42 |
| **RMSE for East Position (<4.0 cm)** | 1.60 |
| **RMSE for Down Position (<8.0 cm)** | 3.80 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.000342 |
| **IMU attitude correction stdev (<0.001deg)** | 0.002225 |
| **GPS position stdev (<0.01m)** | 0.0084 |
| | |
| **Minimum % overlap (>25)** | 31.63 |
| **Ave point cloud density per sq.m. (>2.0)** | 2.70 |
| **Elevation difference between strips (<0.20 m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 147 |
| **Maximum Height** | 433.58 m |
| **Minimum Height** | 56.86 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 59,726,113 |
| **Low vegetation** | 67,930,344 |
| **Medium vegetation** | 37,488,409 |
| **High vegetation** | 46,296,894 |
| **Building** | 4,163,025 |
| **Orthophoto** | No |
| **Processed by** | Engr. Jennifer Saguran, Engr. Krisha Marie Bautista, Engr. Velina Angela Bemida |

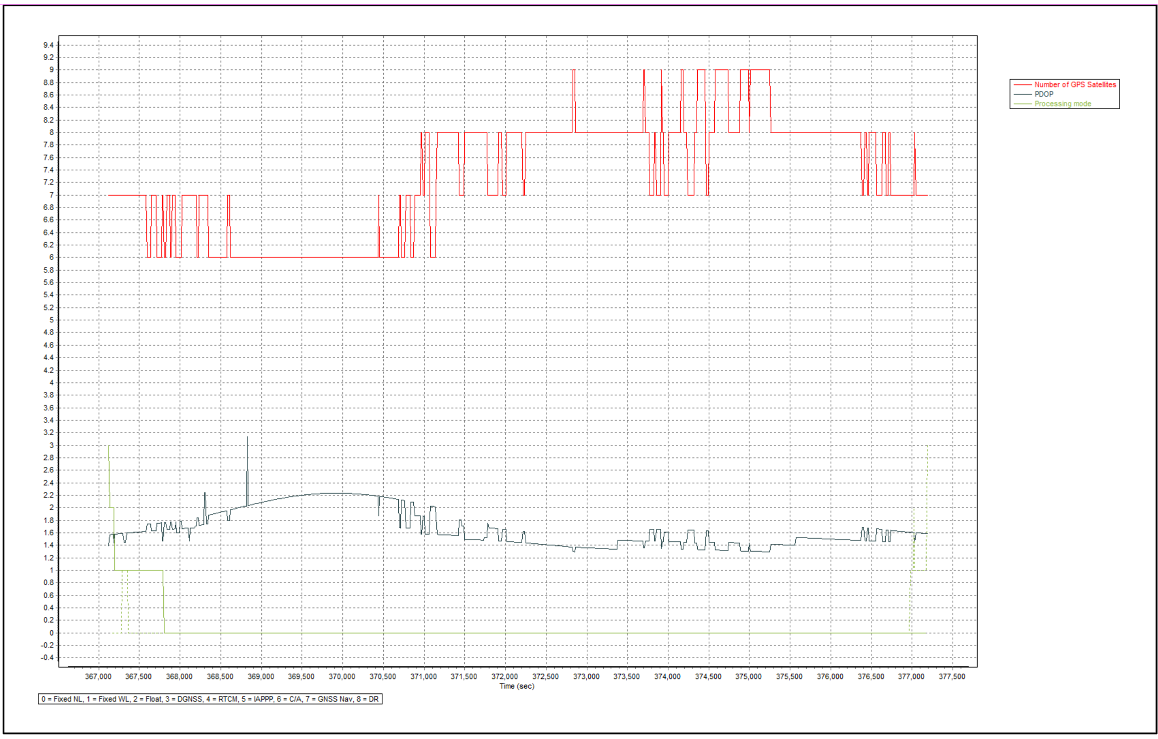



Figure A-8.15 Solution Status

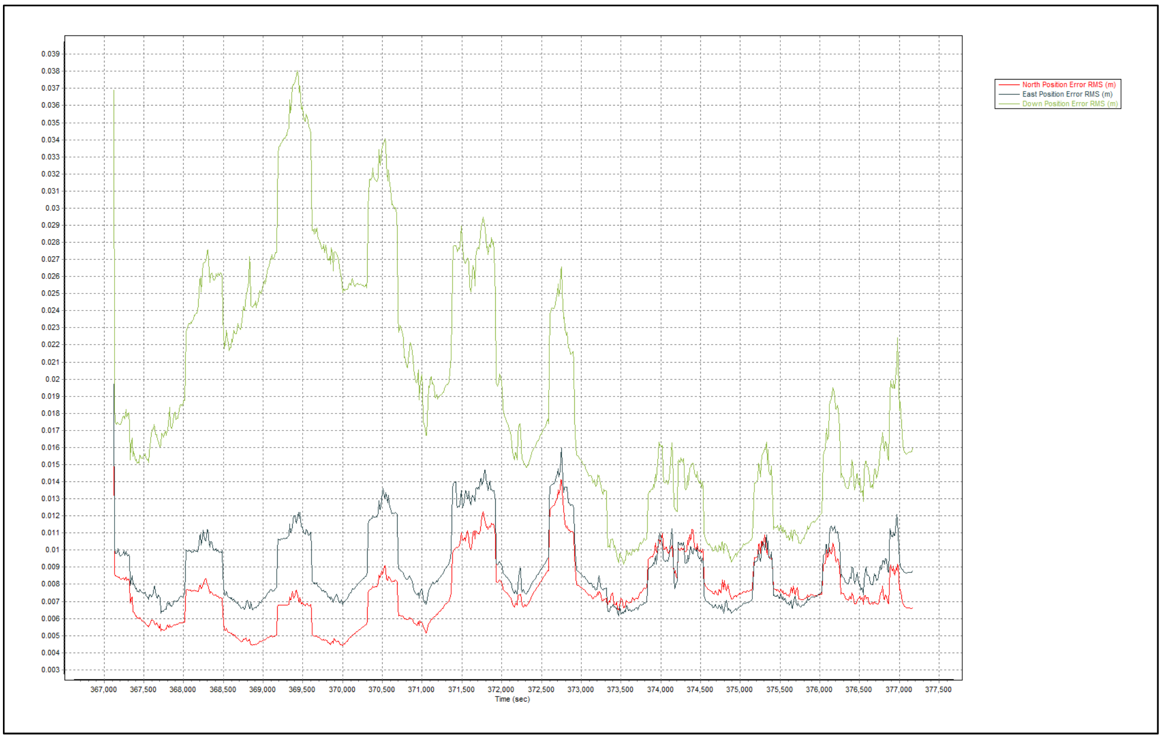



Figure A-8.16 Smoothed Performance Metric Parameters

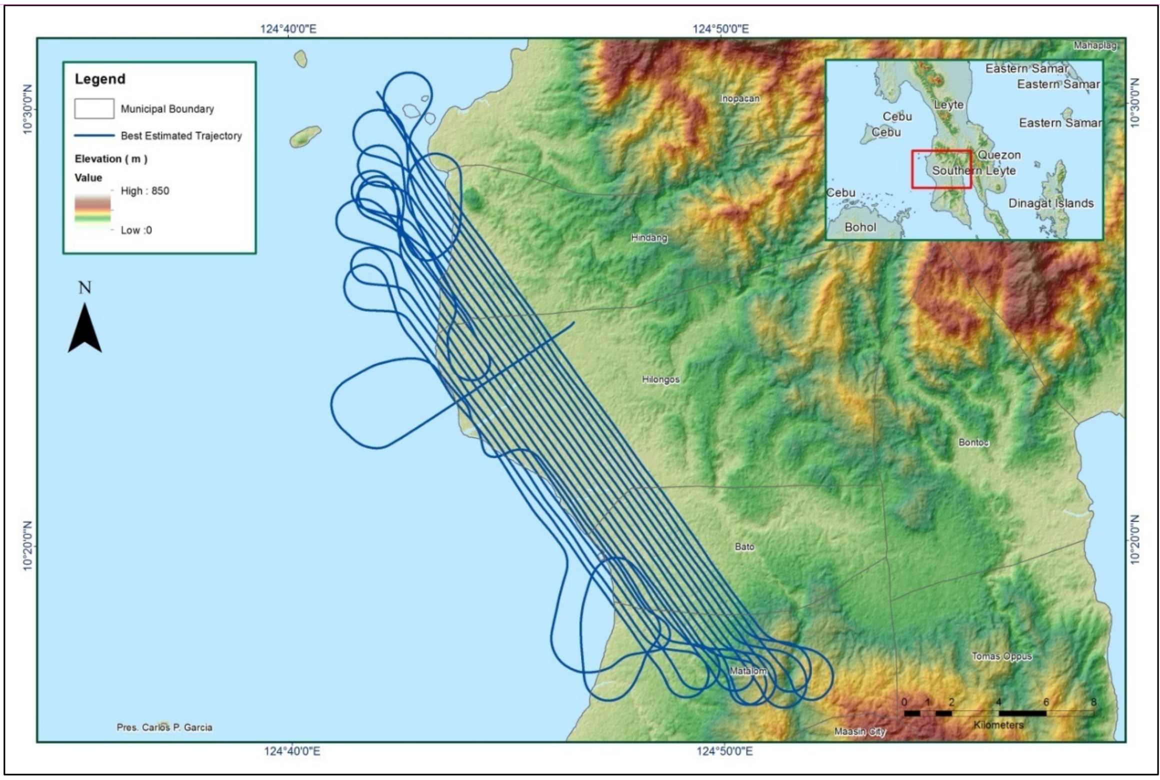



Figure A-8.17 Best Estimated Trajectory

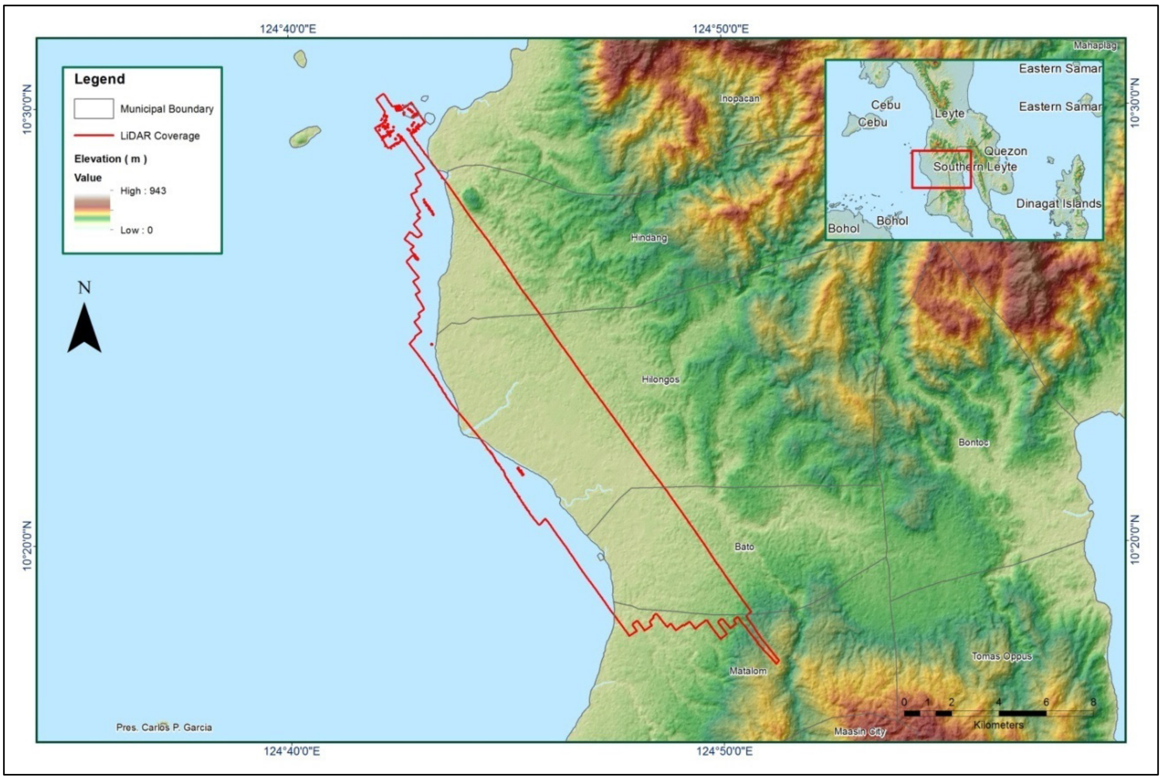



Figure A-8.18 Coverage of LiDAR Data

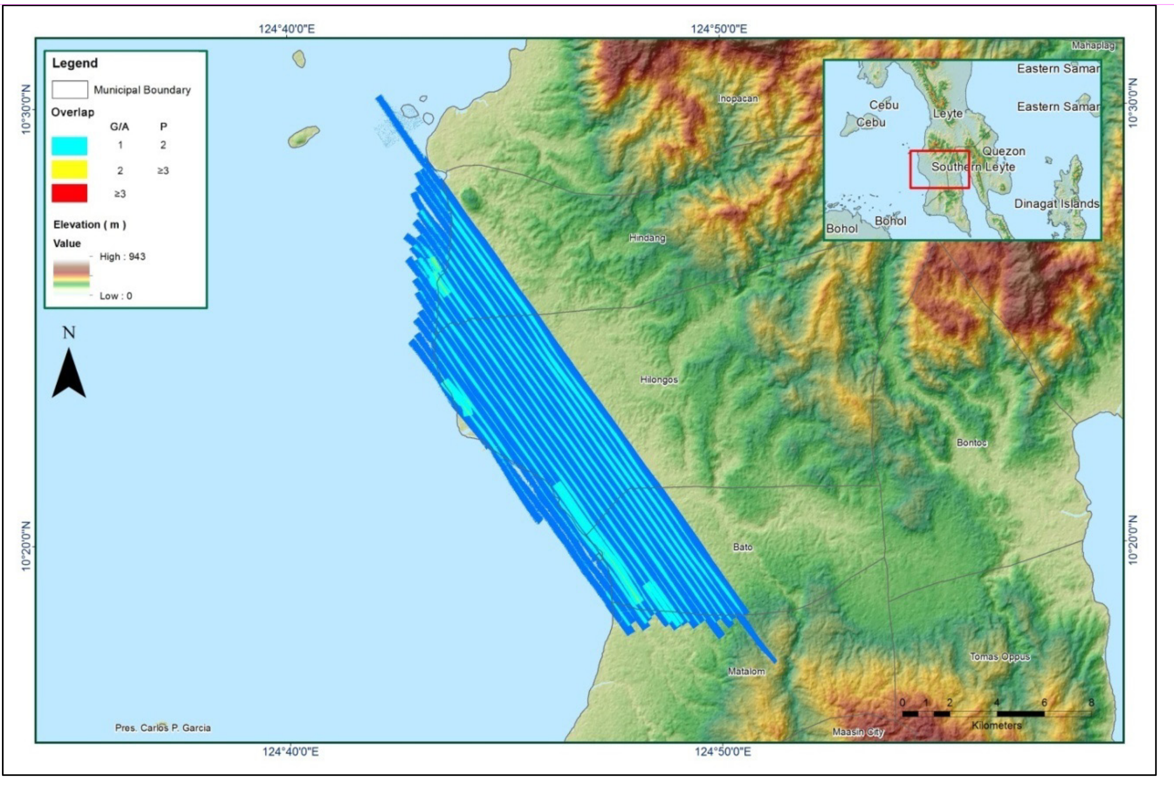



Figure A-8.19 Image Data Overlap

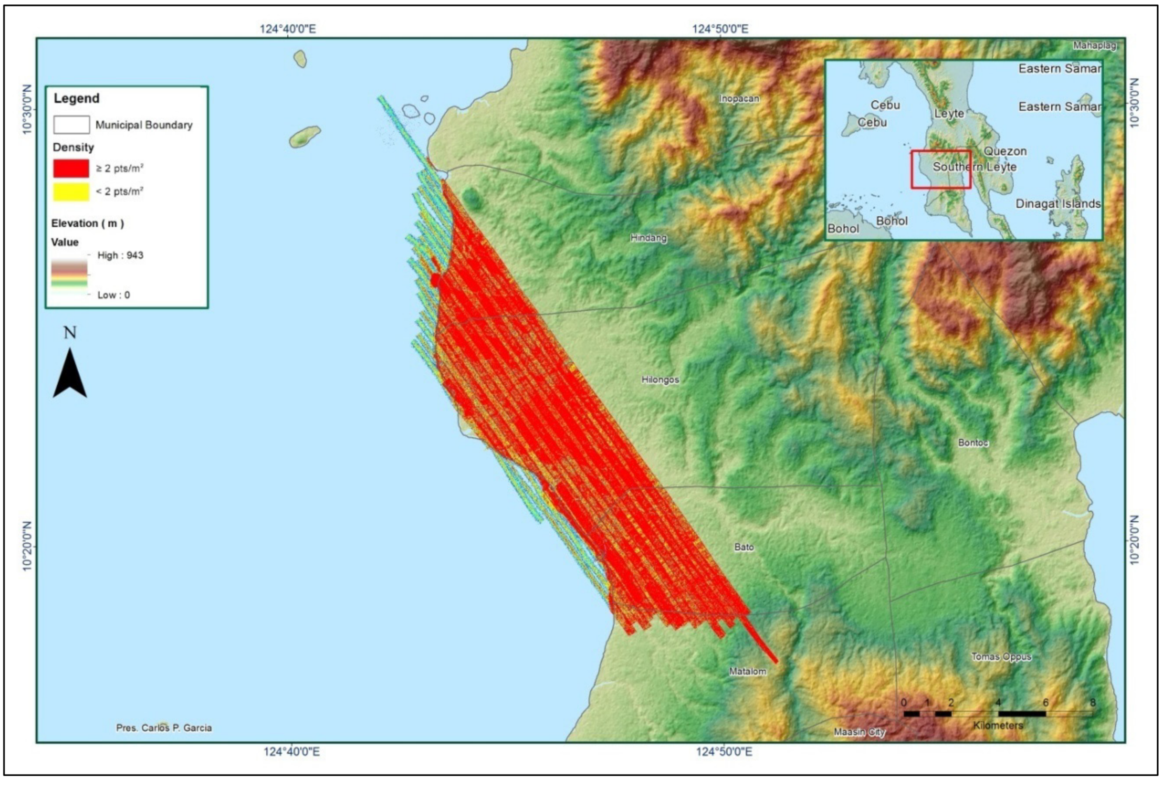



Figure A-8.20 Density map of merged LiDAR data

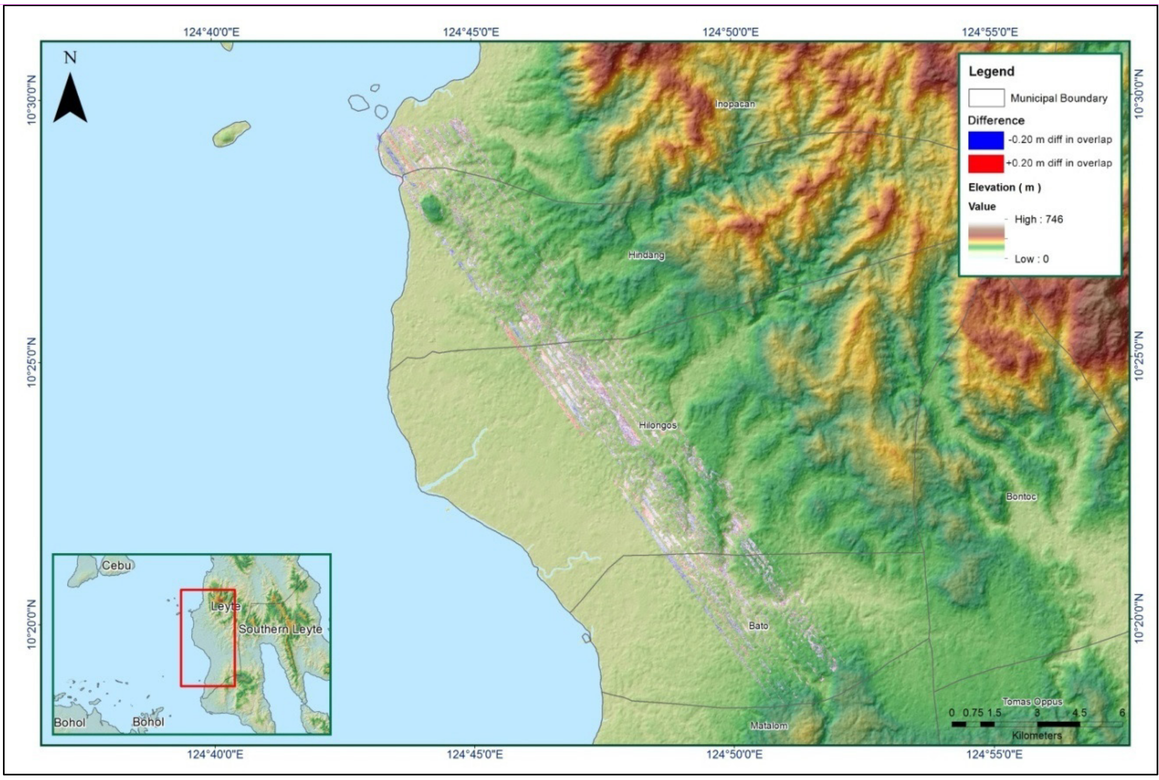



Figure A-8.21 Elevation difference between flight lines

| | |
|---|---|
| **Flight Area** | Ormoc South |
| **Mission Name** | Blk49A |
| **Inclusive Flights** | 3921G, 3923G |
| **Range data size** | 29 GB |
| **Base data size** | 443 MB |
| **POS** | 38.2 MB |
| **Image** | NA |
| **Transfer date** | May 6, 2016 |
| | |
| ***Solution Status*** | |
| **Number of Satellites (>6)** | Yes |
| **PDOP (<3)** | Yes |
| **Baseline Length (<30km)** | Yes |
| **Processing Mode (<=1)** | No |
| | |
| ***Smoothed Performance Metrics (in cm)*** | |
| **RMSE for North Position (<4.0 cm)** | 1.21 |
| **RMSE for East Position (<4.0 cm)** | 1.75 |
| **RMSE for Down Position (<8.0 cm)** | 2.76 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.000174 |
| **IMU attitude correction stdev (<0.001deg)** | 0.000700 |
| **GPS position stdev (<0.01m)** | 0.0065 |
| | |
| **Minimum % overlap (>25)** | 31.34 |
| **Ave point cloud density per sq.m. (>2.0)** | 4.84 |
| **Elevation difference between strips (<0.20 m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 169 |
| **Maximum Height** | 480.55 m |
| **Minimum Height** | 65.17 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 51,839,234 |
| **Low vegetation** | 37,957,751 |
| **Medium vegetation** | 140,088,597 |
| **High vegetation** | 297,623,794 |
| **Building** | 650,432 |
| **Orthophoto** | No |
| **Processed by** | Engr. Analyn Naldo, Engr. Jennifer Saguran,Engr. Velina Angela Bemida,Engr. Monalyne Rabino |

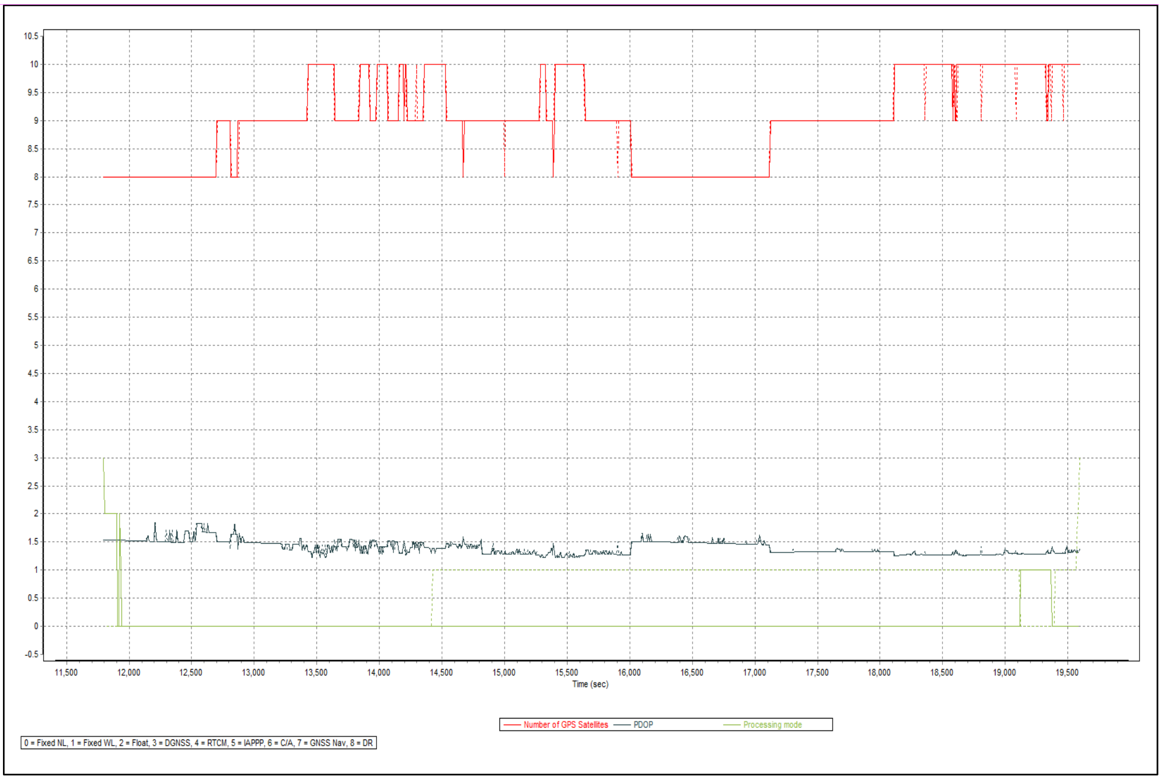



Figure A-8.22 Solution Status

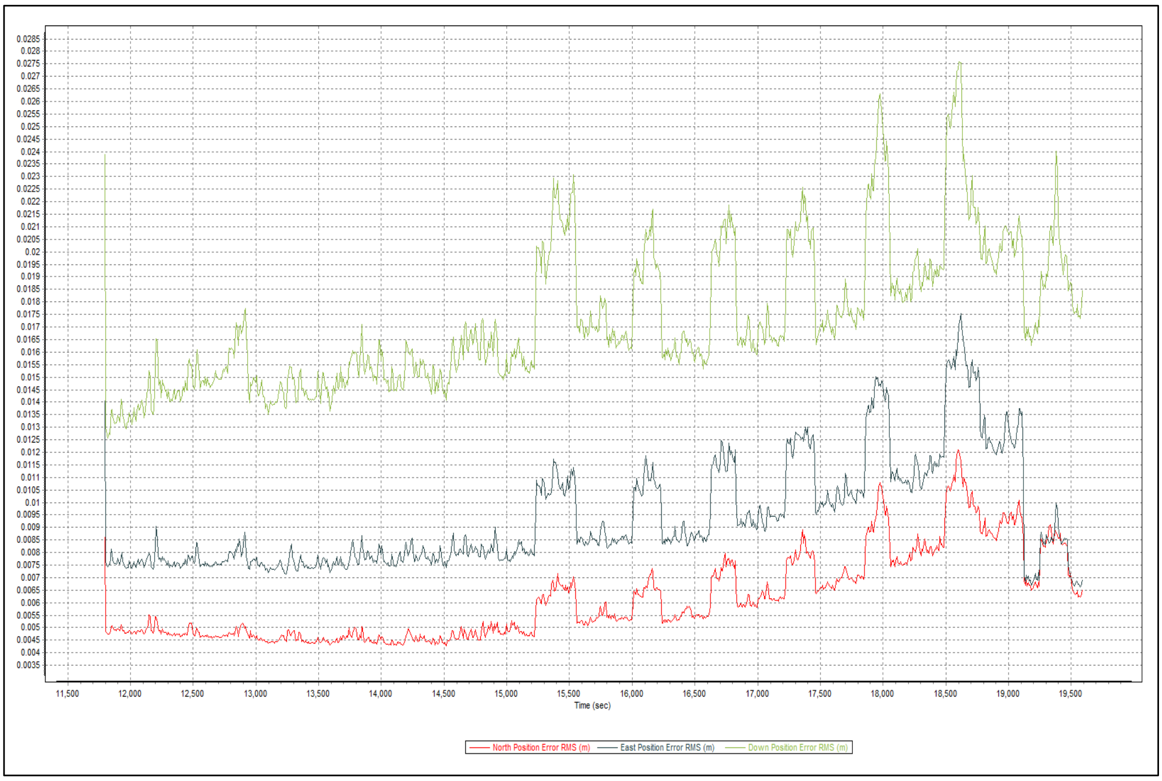



Figure A-8.23 Smoothed Performance Metric Parameters

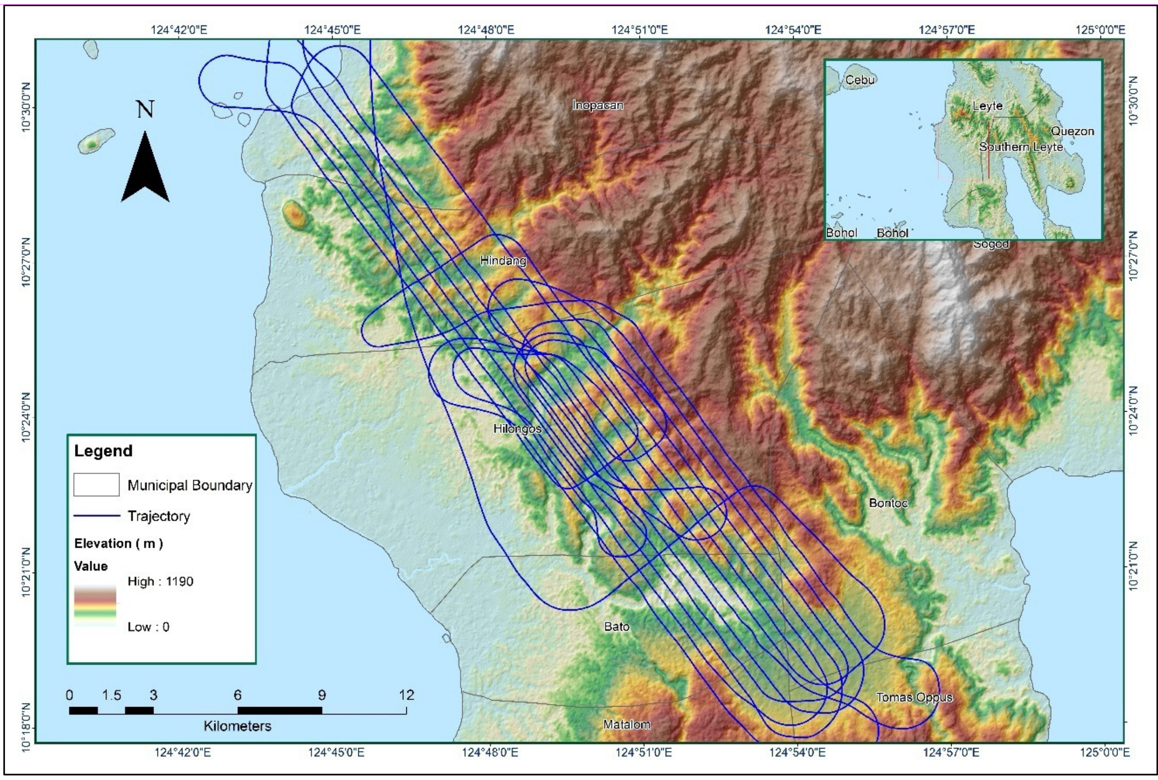



Figure A-8.24 Best Estimated Trajectory

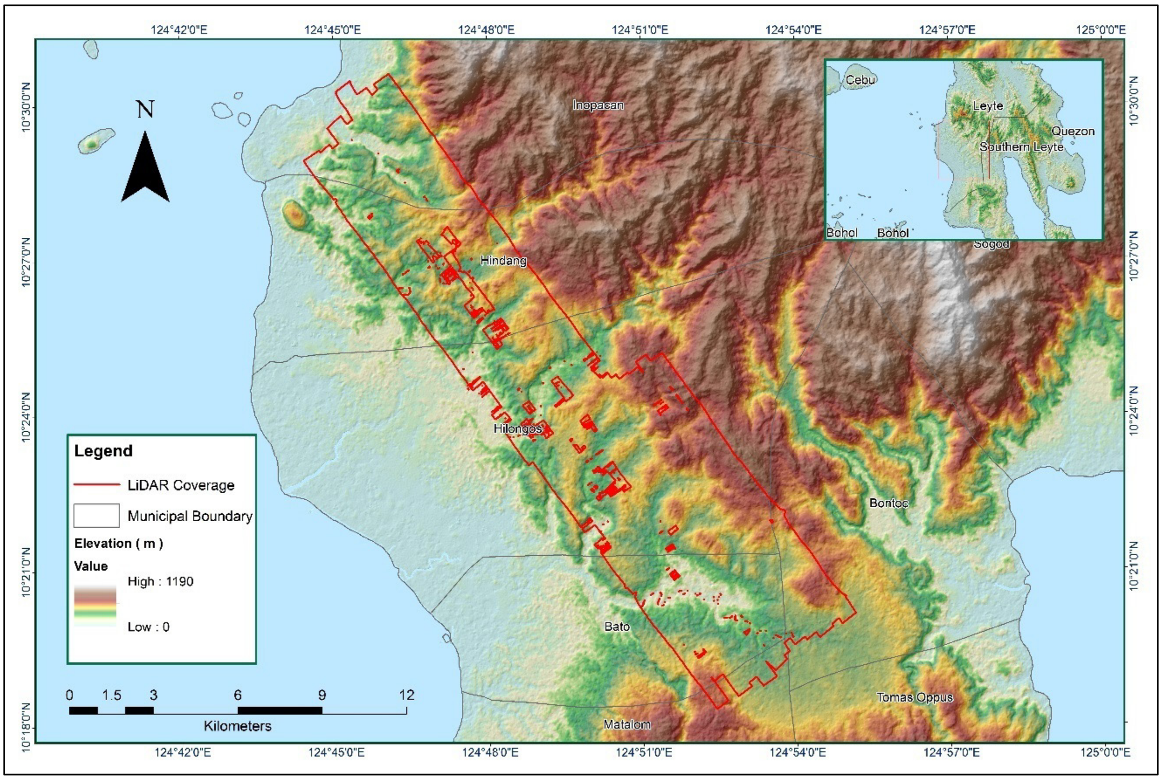



Figure A-8.25 Coverage of LiDAR Data

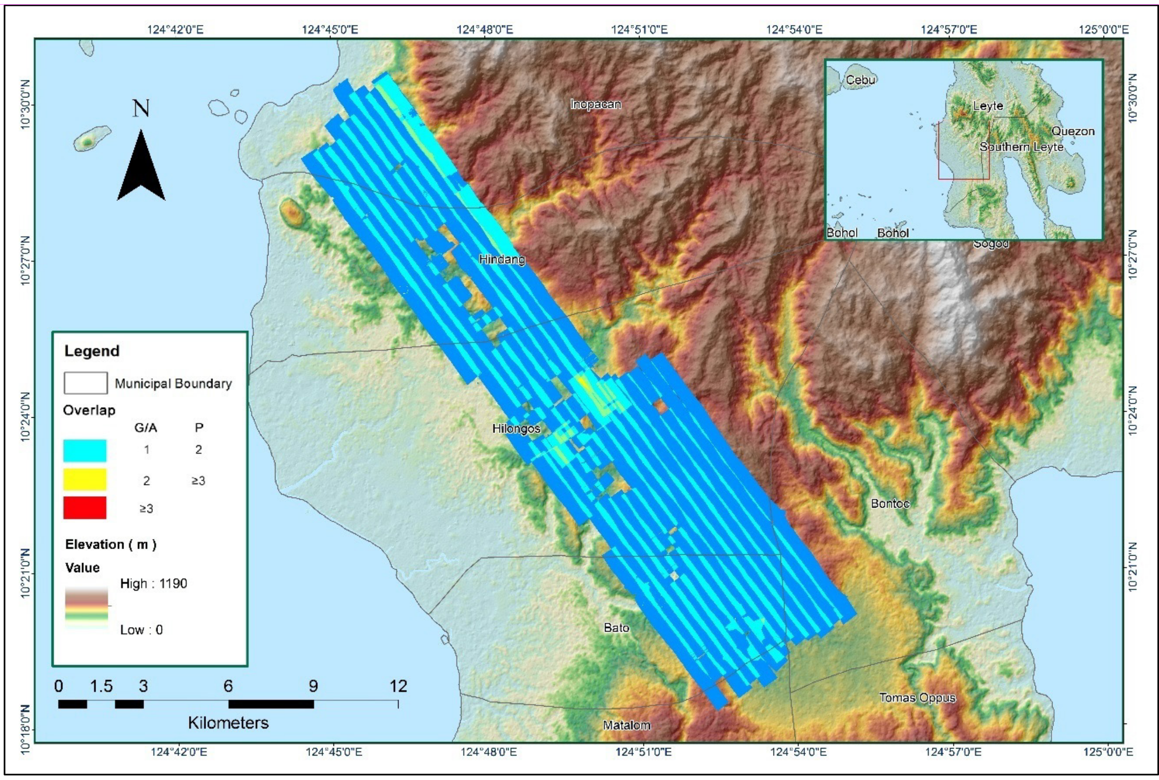



Figure A-8.26 Image Data Overlap

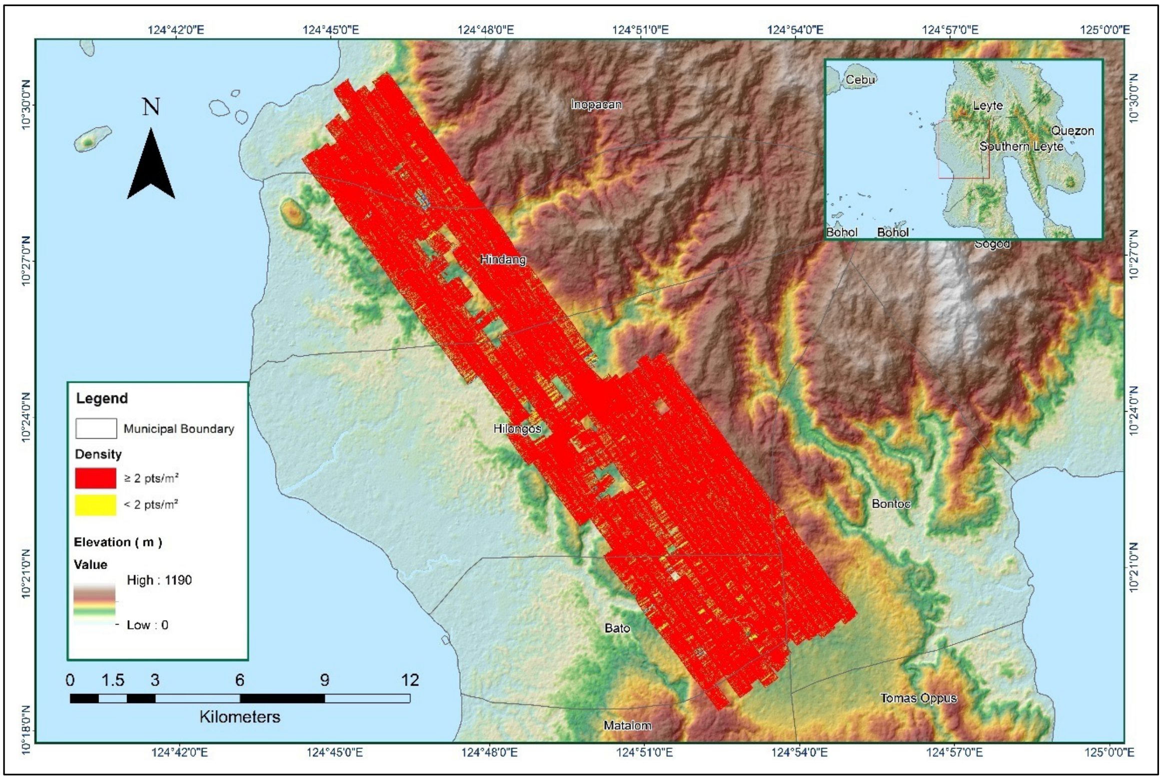



Figure A-8.27 Density map of merged LiDAR data

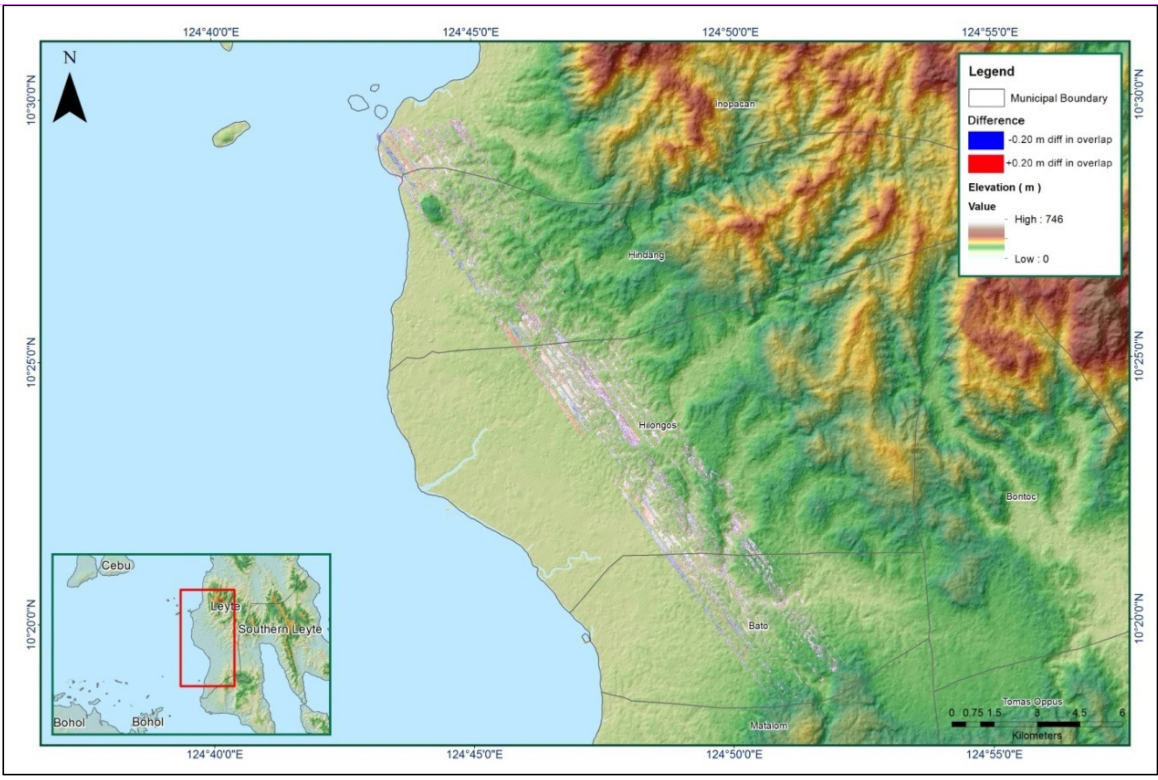



Figure A-8.28 Elevation difference between flight lines

| | |
|---|---|
| **Flight Area** | Ormoc South |
| **Mission Name** | Blk49B |
| **Inclusive Flights** | 3925G |
| **Range data size** | 9.56 GB |
| **Base data size** | 252 MB |
| **POS** | 6.82 MB |
| **Image** | NA |
| **Transfer date** | May 6, 2016 |
| | |
| ***Solution Status*** | |
| **Number of Satellites (>6)** | Yes |
| **PDOP (<3)** | Yes |
| **Baseline Length (<30km)** | No |
| **Processing Mode (<=1)** | Yes |
| | |
| ***Smoothed Performance Metrics (in cm)*** | |
| **RMSE for North Position (<4.0 cm)** | 1.11 |
| **RMSE for East Position (<4.0 cm)** | 1.28 |
| **RMSE for Down Position (<8.0 cm)** | 2.98 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.000490 |
| **IMU attitude correction stdev (<0.001deg)** | 0.000662 |
| **GPS position stdev (<0.01m)** | 0.0102 |
| | |
| **Minimum % overlap (>25)** | 17.47 |
| **Ave point cloud density per sq.m. (>2.0)** | 3.62 |
| **Elevation difference between strips (<0.20 m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 53 |
| **Maximum Height** | 291.27 m |
| **Minimum Height** | 62.43 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 17,573,377 |
| **Low vegetation** | 19,151,419 |
| **Medium vegetation** | 35,326,556 |
| **High vegetation** | 37,079,112 |
| **Building** | 956,549 |
| **Orthophoto** | No |
| **Processed by** | Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan |

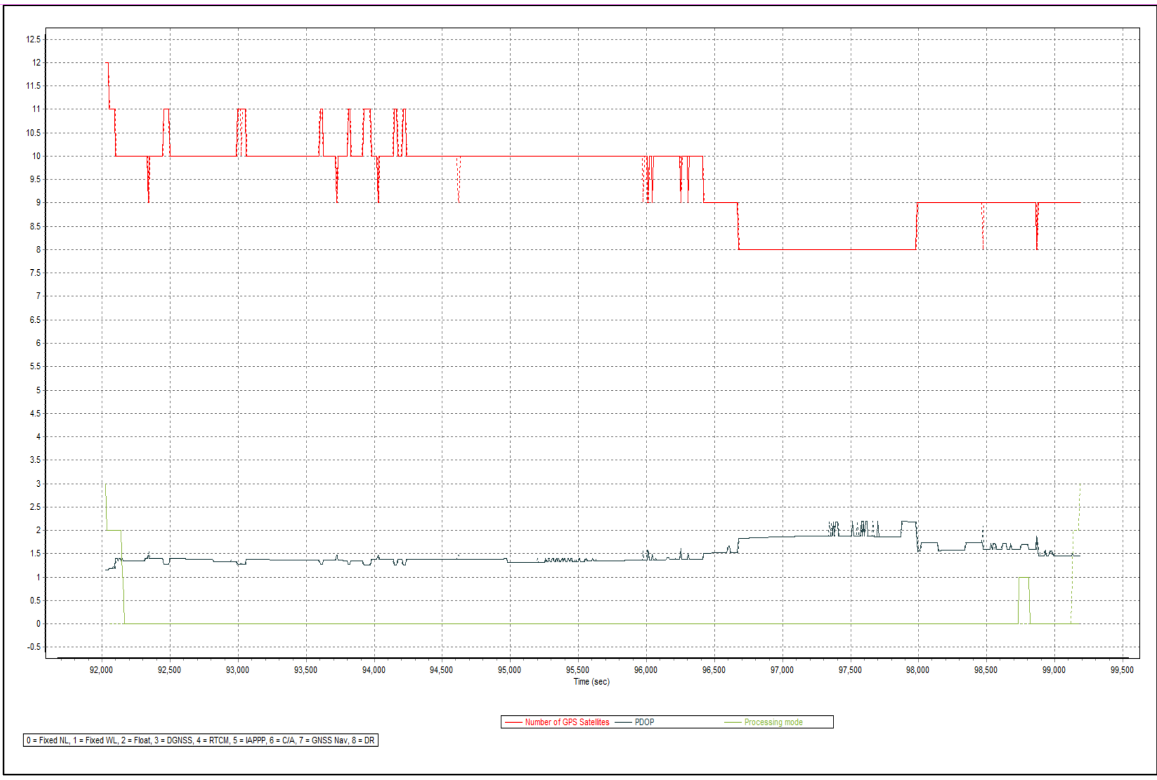



Figure A-8.29 Solution Status


Figure A-8.30 Smoothed Performance Metric Parameters

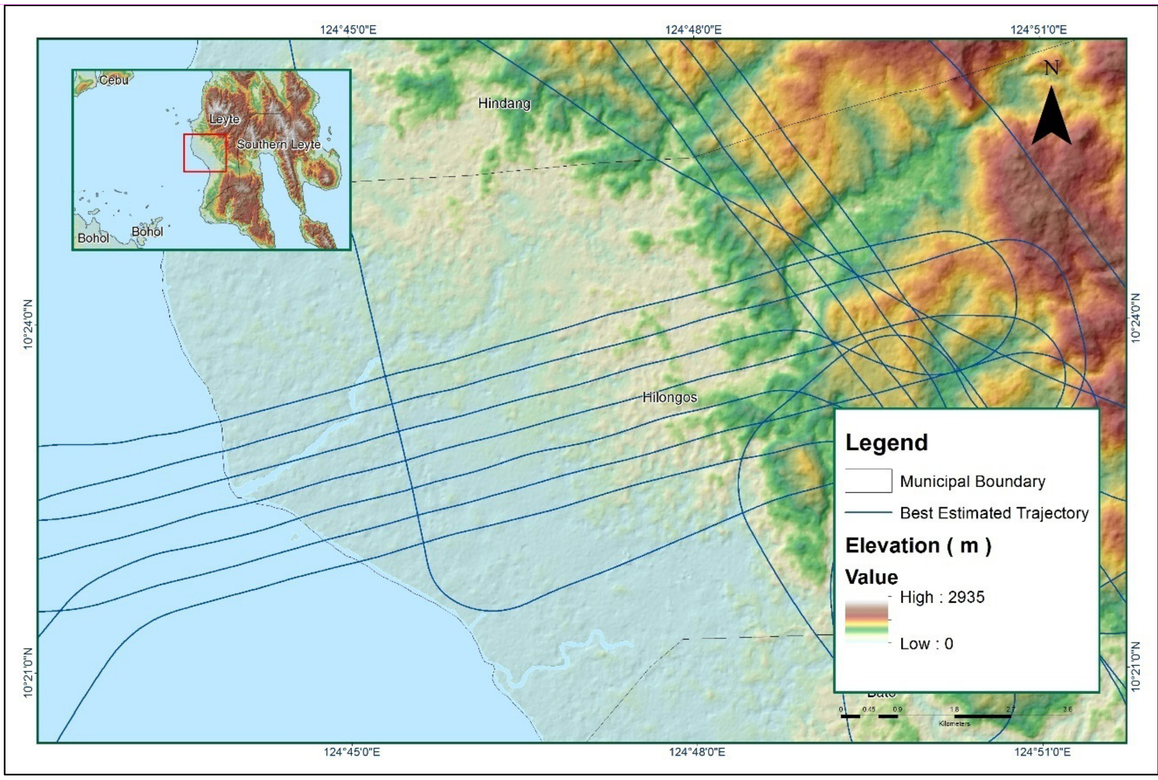



Figure A-8.31 Best Estimated Trajectory

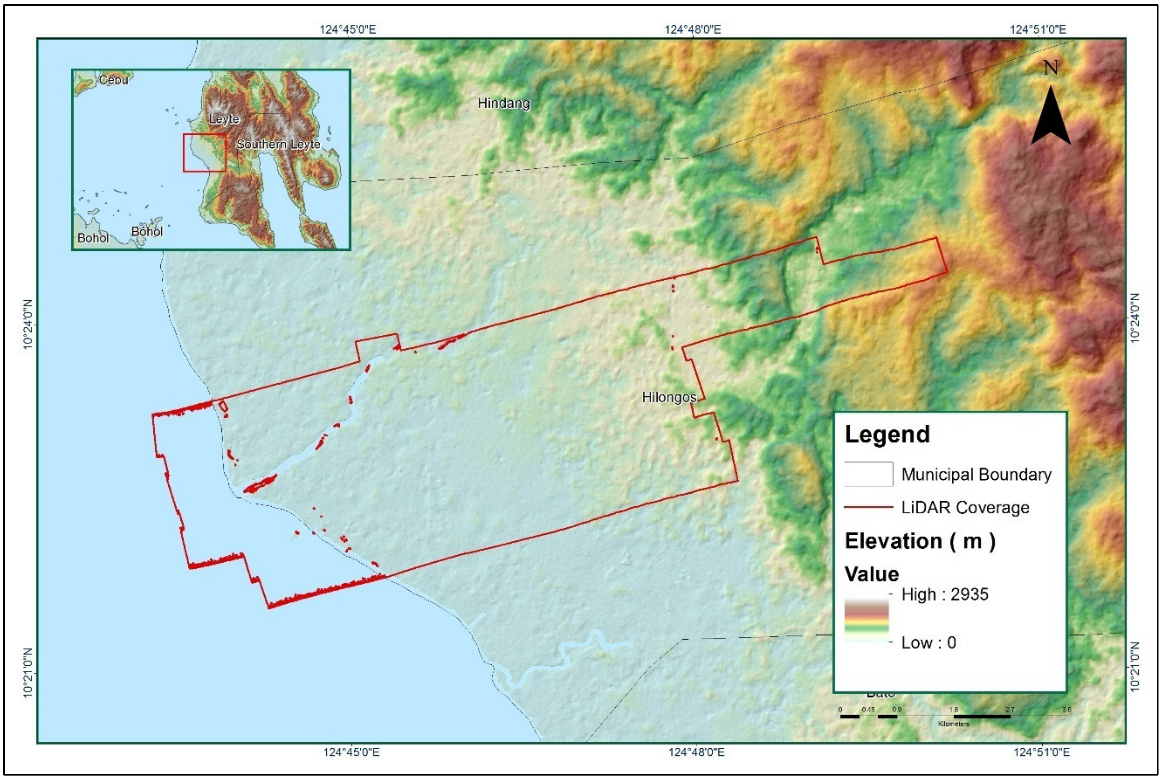



Figure A-8. 32 Coverage of LiDAR Data

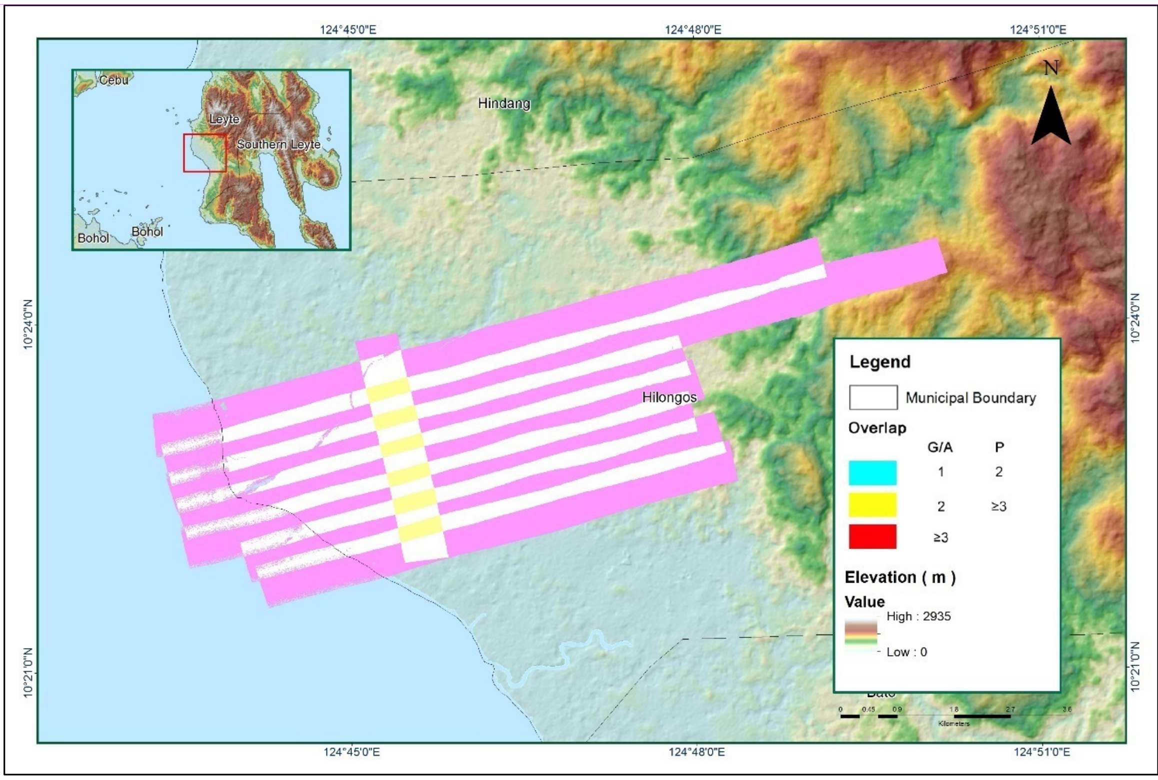



Figure A-8.32 Image Data Overlap

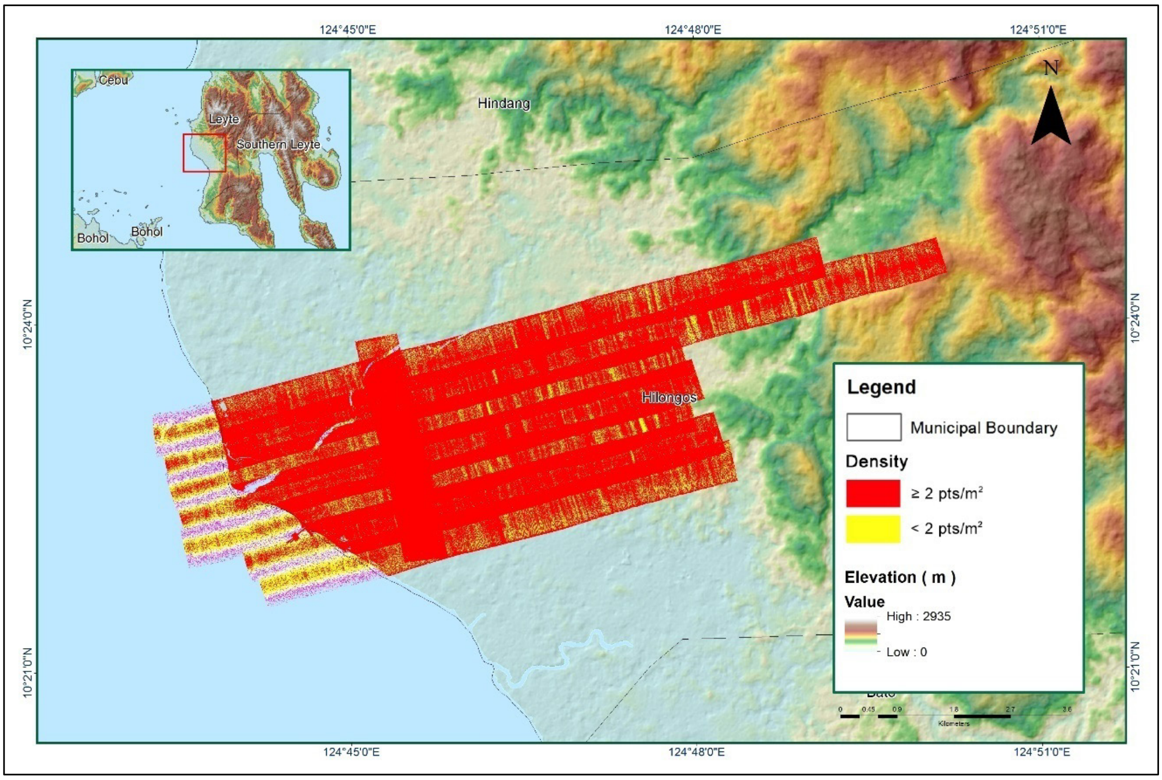



Figure A-8.33/ Density map of merged LiDAR data

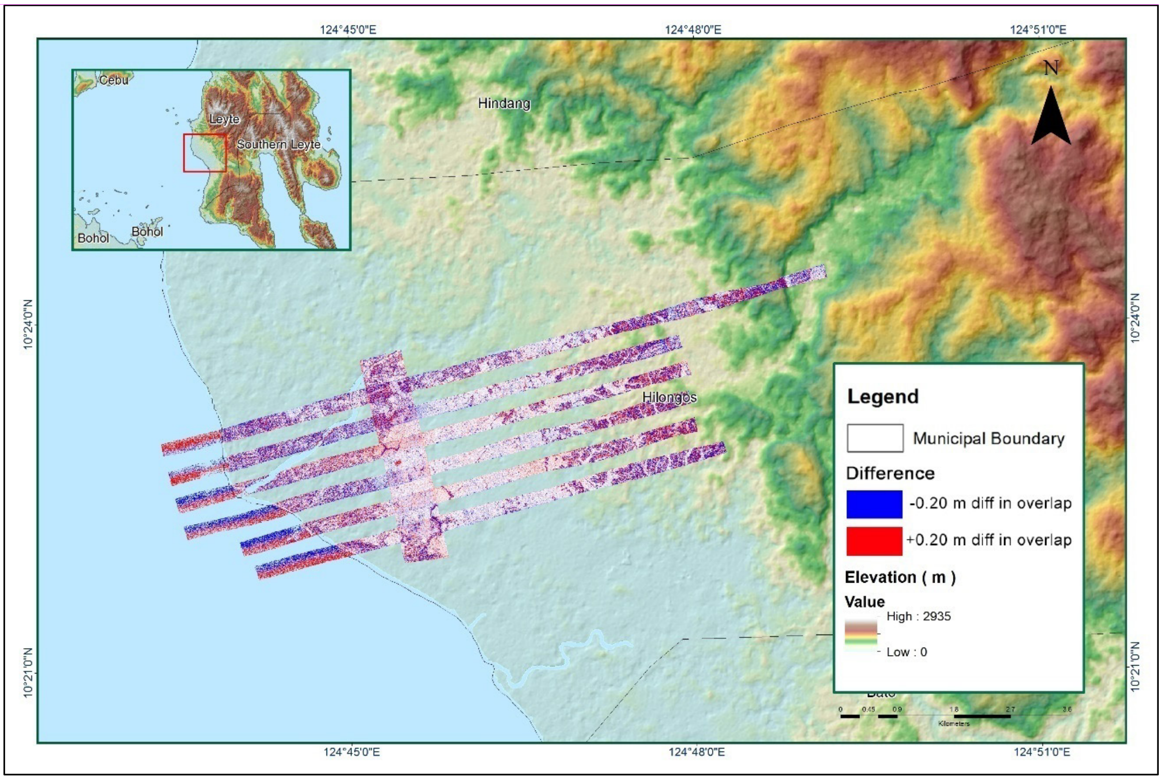



Figure A-8.34 Elevation difference between flight lines

| | |
|---|---|
| **Flight Area** | Ormoc South |
| **Mission Name** | Blk49A_additional |
| **Inclusive Flights** | 3925G |
| **Range data size** | 9.56 GB |
| **Base data size** | 252 MB |
| **POS** | 6.82 MB |
| **Image** | NA |
| **Transfer date** | May 6, 2016 |
| | |
| ***Solution Status*** | |
| **Number of Satellites (>6)** | Yes |
| **PDOP (<3)** | Yes |
| **Baseline Length (<30km)** | No |
| **Processing Mode (<=1)** | No |
| | |
| ***Smoothed Performance Metrics (in cm)*** | |
| **RMSE for North Position (<4.0 cm)** | 0.977 |
| **RMSE for East Position (<4.0 cm)** | 1.22 |
| **RMSE for Down Position (<8.0 cm)** | 1.89 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.000818 |
| **IMU attitude correction stdev (<0.001deg)** | 0.018148 |
| **GPS position stdev (<0.01m)** | 0.0273 |
| | |
| **Minimum % overlap (>25)** | 31.34 |
| **Ave point cloud density per sq.m. (>2.0)** | 4.21 |
| **Elevation difference between strips (<0.20 m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 68 |
| **Maximum Height** | 429.74 m |
| **Minimum Height** | 80.81 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 17,634,616 |
| **Low vegetation** | 8,633,681 |
| **Medium vegetation** | 27,765,599 |
| **High vegetation** | 63,962,261 |
| **Building** | 98,554 |
| **Orthophoto** | No |
| **Processed by** | Engr. Jennifer Saguran,Engr. Velina Angela Bemida,Karl Adrian Vergara |

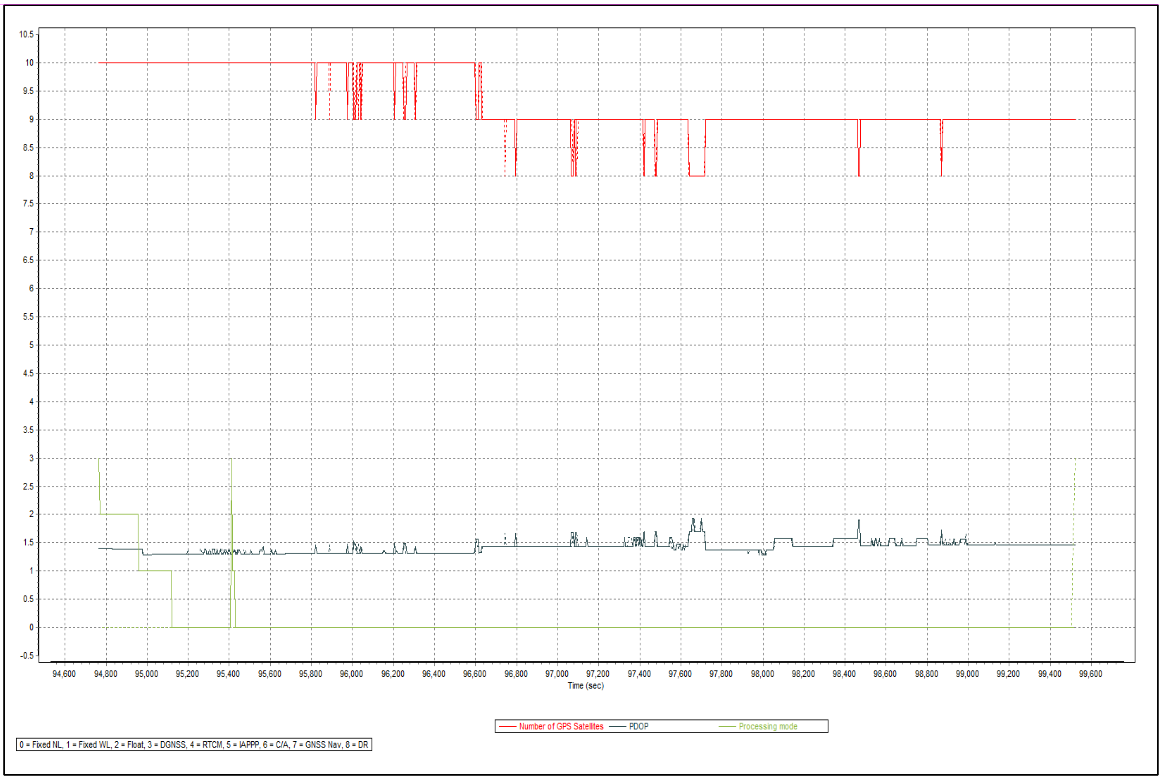



Figure A-8.35 Solution Status

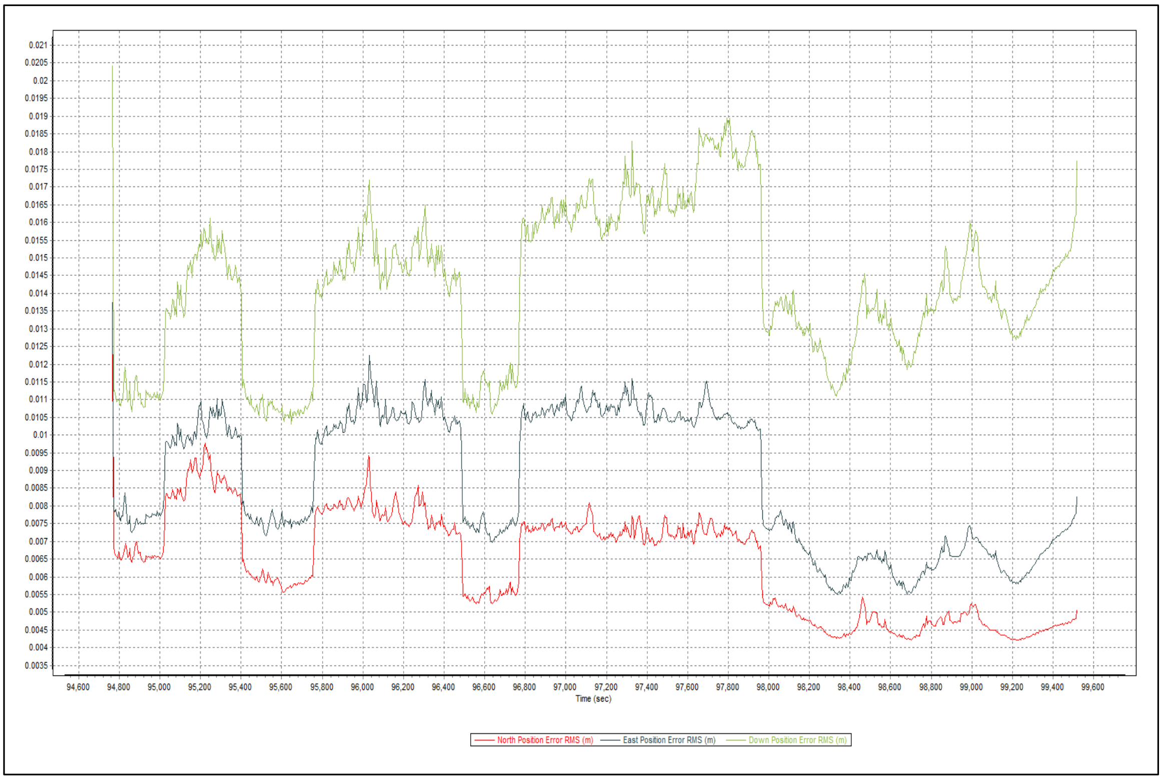



Figure A-8.36 Smoothed Performance Metric Parameters

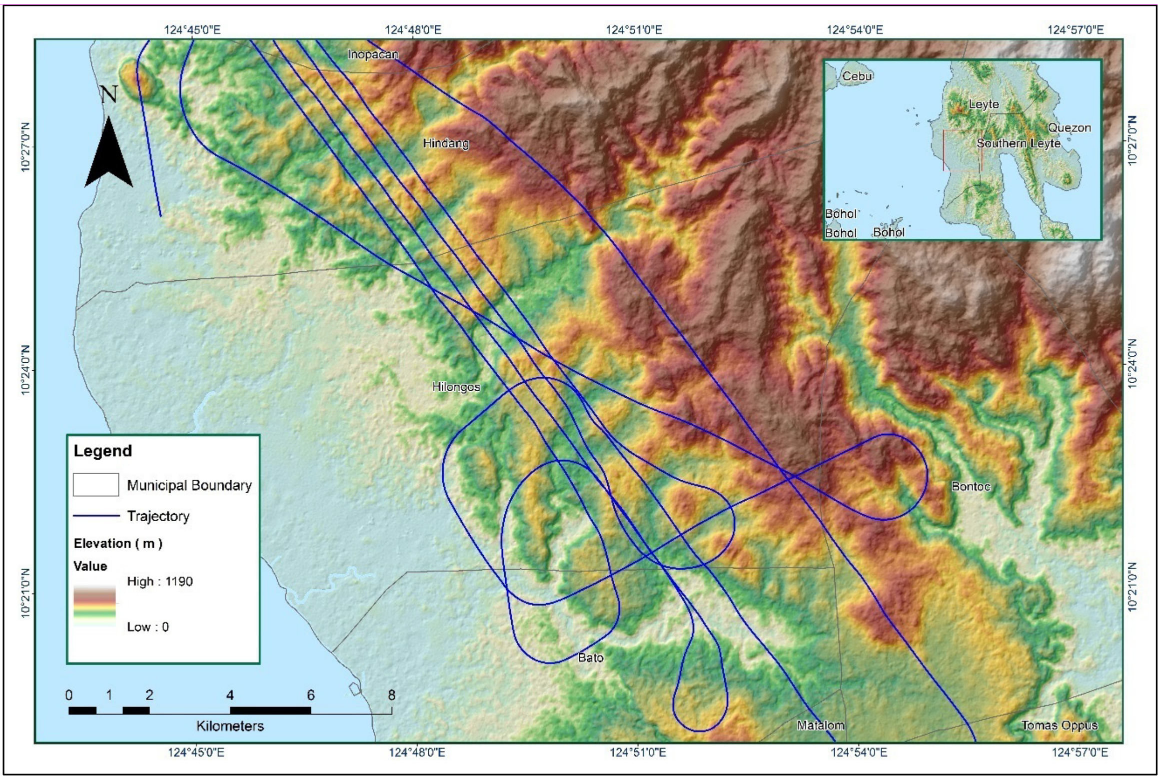



Figure A-8.37 Best Estimated Trajectory

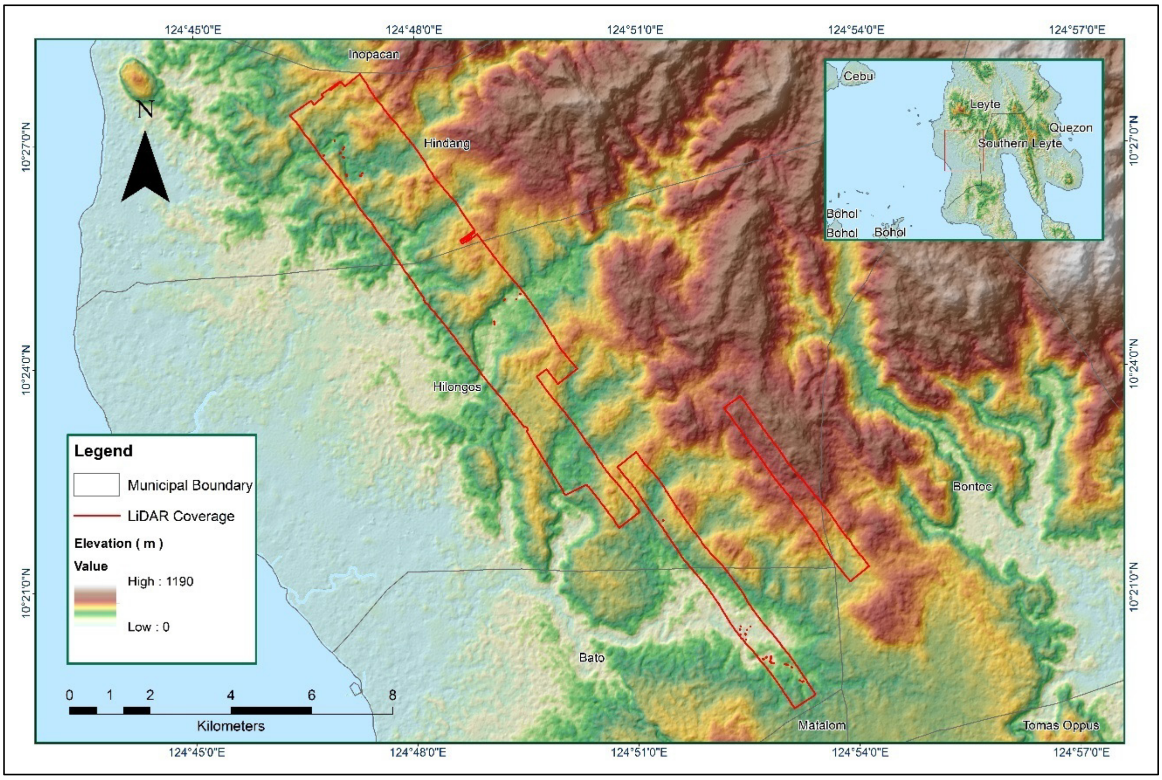



Figure A-8. 38 Coverage of LiDAR Data

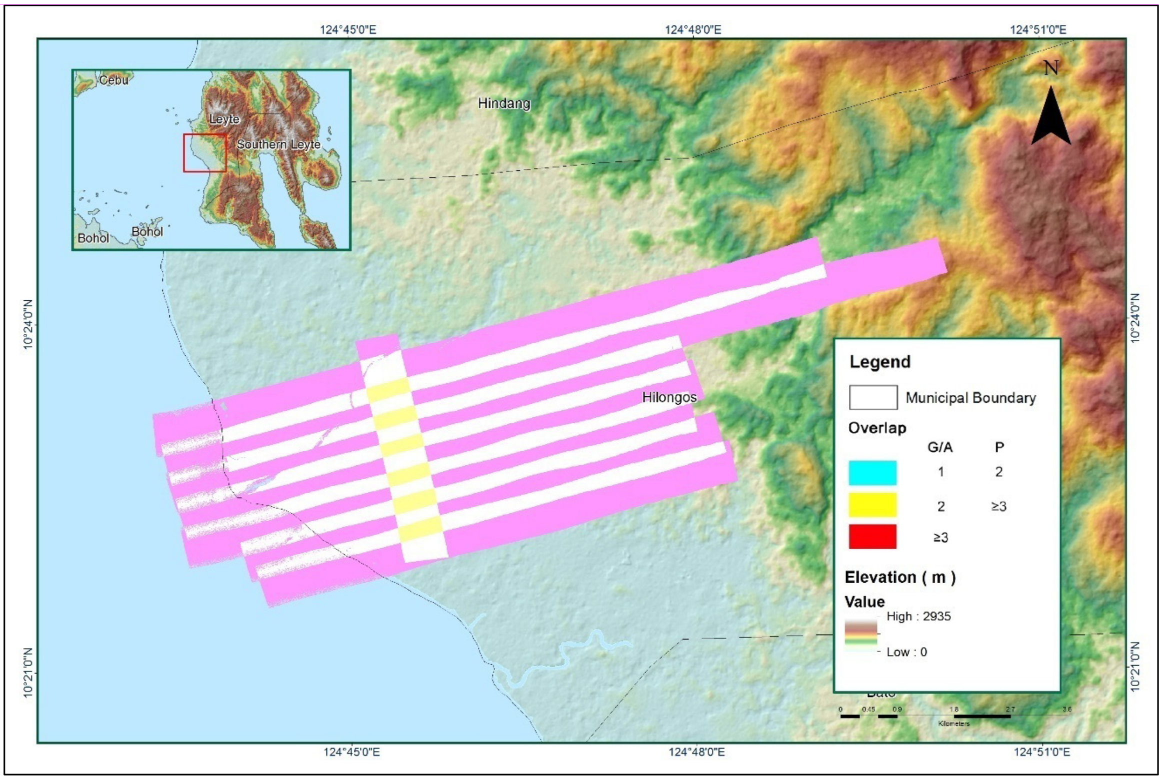



Figure A-8.39 Image Data Overlap

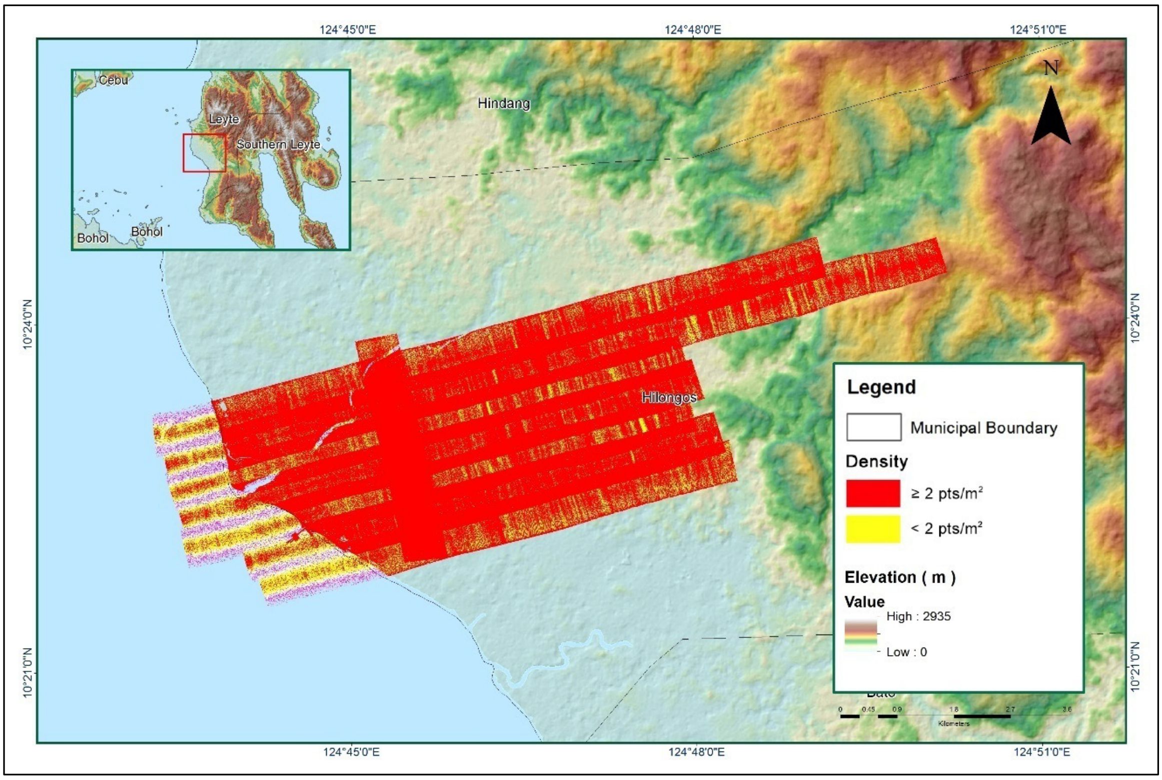



Figure A-8.40 Density map of merged LiDAR data

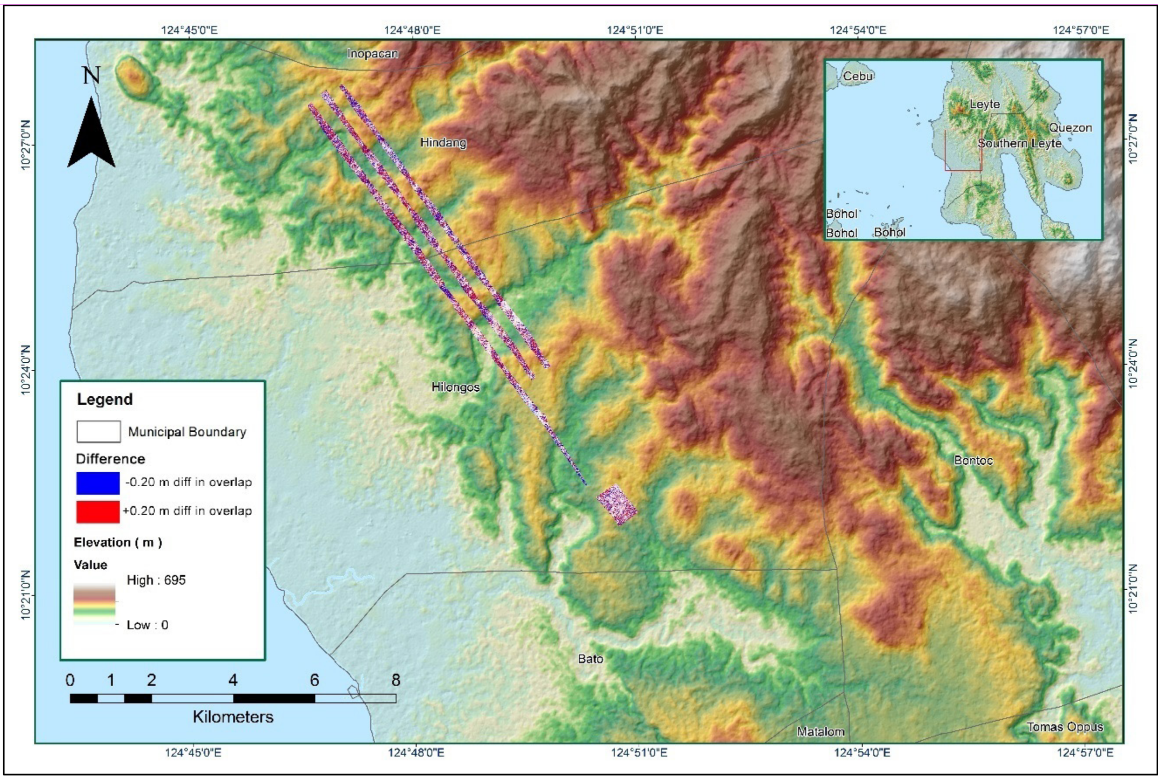



Figure A-8.41 Elevation difference between flight lines

| | |
|---|---|
| **Flight Area** | Ormoc South |
| **Mission Name** | Blk49E |
| **Inclusive Flights** | 3937G |
| **Range data size** | 14.7 GB |
| **Base data size** | 292 MB |
| **POS** | 10.5 MB |
| **Image** | NA |
| **Transfer date** | May 6, 2016 |
| | |
| ***Solution Status*** | |
| **Number of Satellites (>6)** | Yes |
| **PDOP (<3)** | Yes |
| **Baseline Length (<30km)** | No |
| **Processing Mode (<=1)** | Yes |
| | |
| ***Smoothed Performance Metrics (in cm)*** | |
| **RMSE for North Position (<4.0 cm)** | 1.18 |
| **RMSE for East Position (<4.0 cm)** | 1.50 |
| **RMSE for Down Position (<8.0 cm)** | 3.10 |
| | |
| **Boresight correction stdev (<0.001deg)** | 0.001855 |
| **IMU attitude correction stdev (<0.001deg)** | 0.009091 |
| **GPS position stdev (<0.01m)** | 0.0026 |
| | |
| **Minimum % overlap (>25)** | 44.64 |
| **Ave point cloud density per sq.m. (>2.0)** | 5.42 |
| **Elevation difference between strips (<0.20 m)** | Yes |
| | |
| **Number of 1km x 1km blocks** | 80 |
| **Maximum Height** | 593.04 m |
| **Minimum Height** | 62.69 m |
| | |
| ***Classification (# of points)*** | |
| **Ground** | 25,650,234 |
| **Low vegetation** | 13,781,210 |
| **Medium vegetation** | 71,704,250 |
| **High vegetation** | 156,923,410 |
| **Building** | 615,184 |
| **Orthophoto** | No |
| **Processed by** | Engr. Sheila-Maye Santillan, Engr. Velina Angela Bemida, Engr. Czarina Jean Añonuevo |

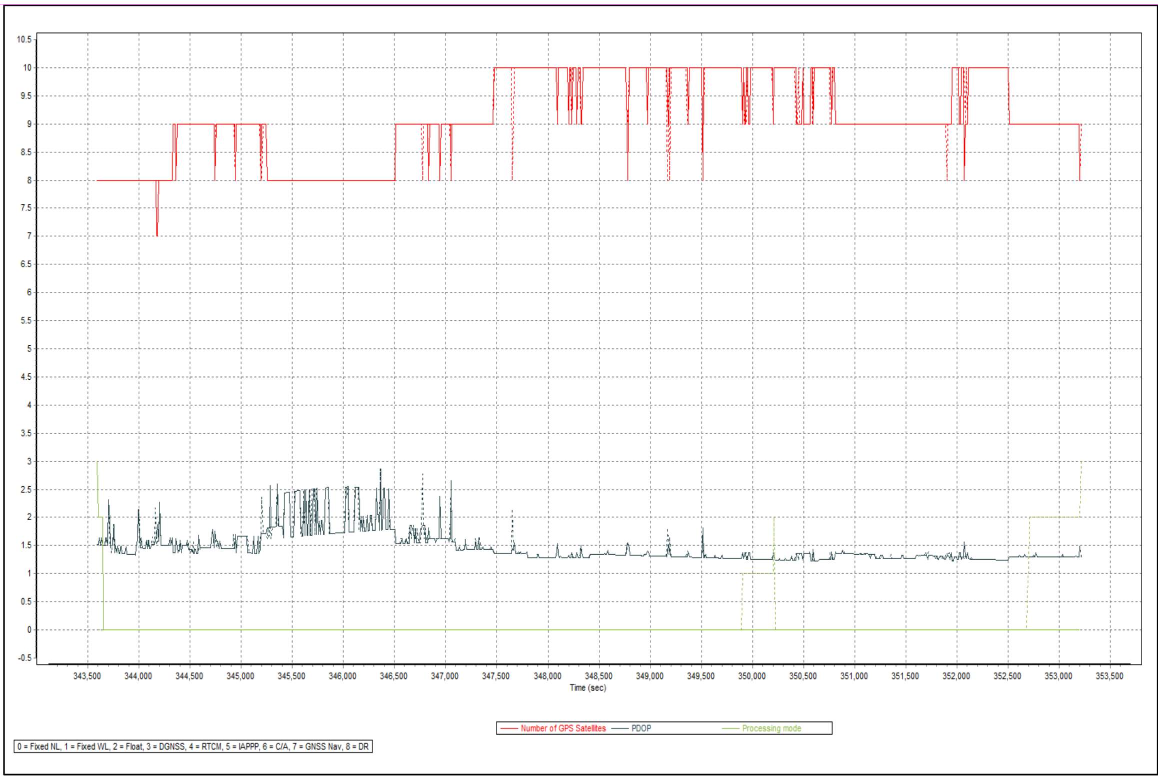



Figure A-8.42 Solution Status

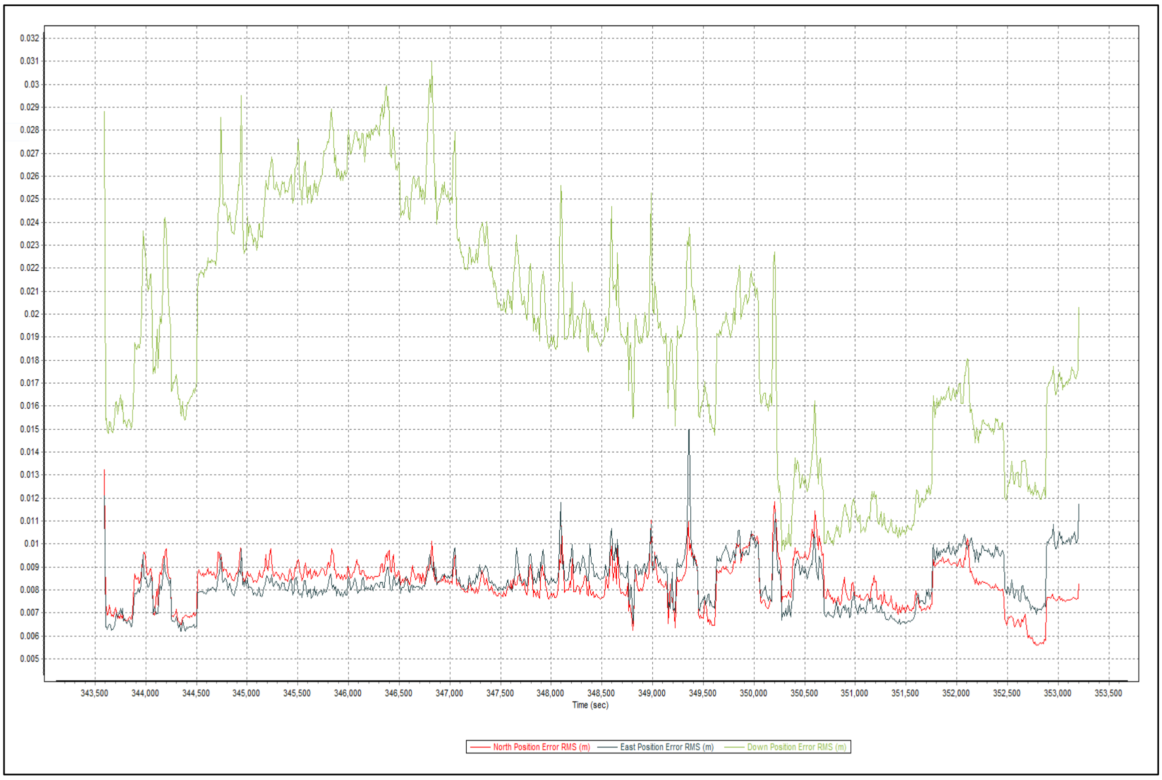



Figure A-8.43 Smoothed Performance Metric Parameters

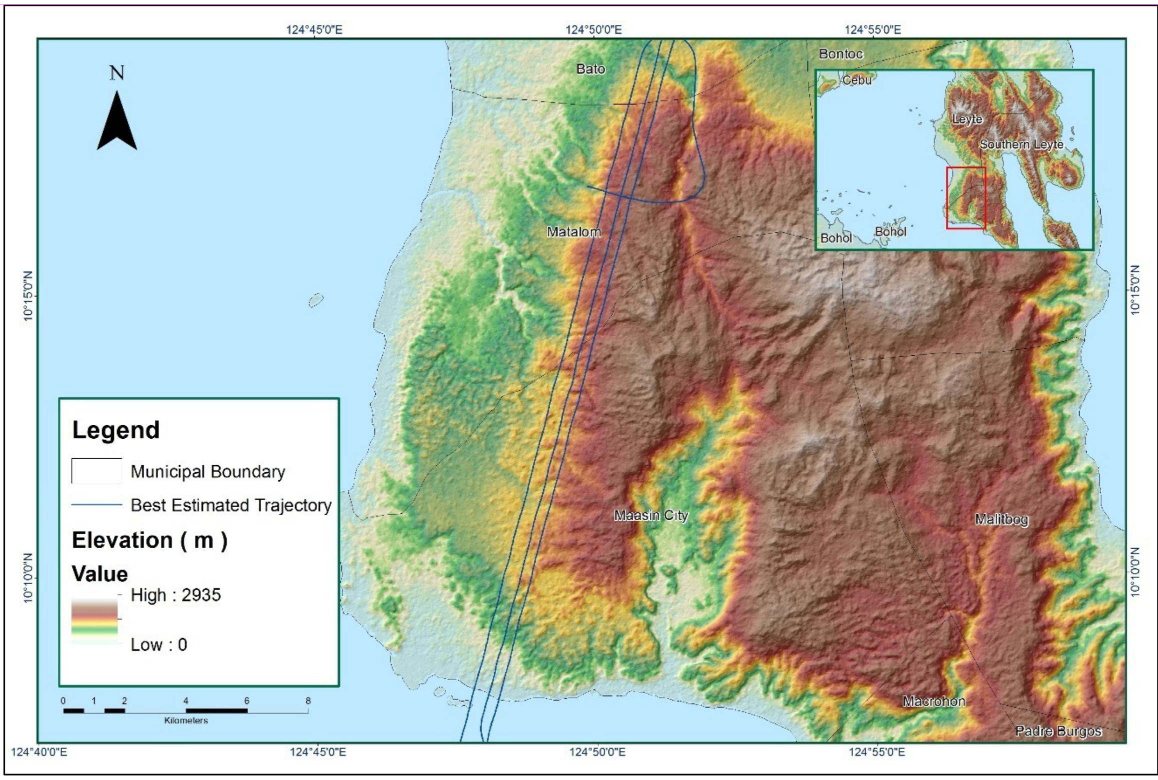



Figure A-8.44 Best Estimated Trajectory

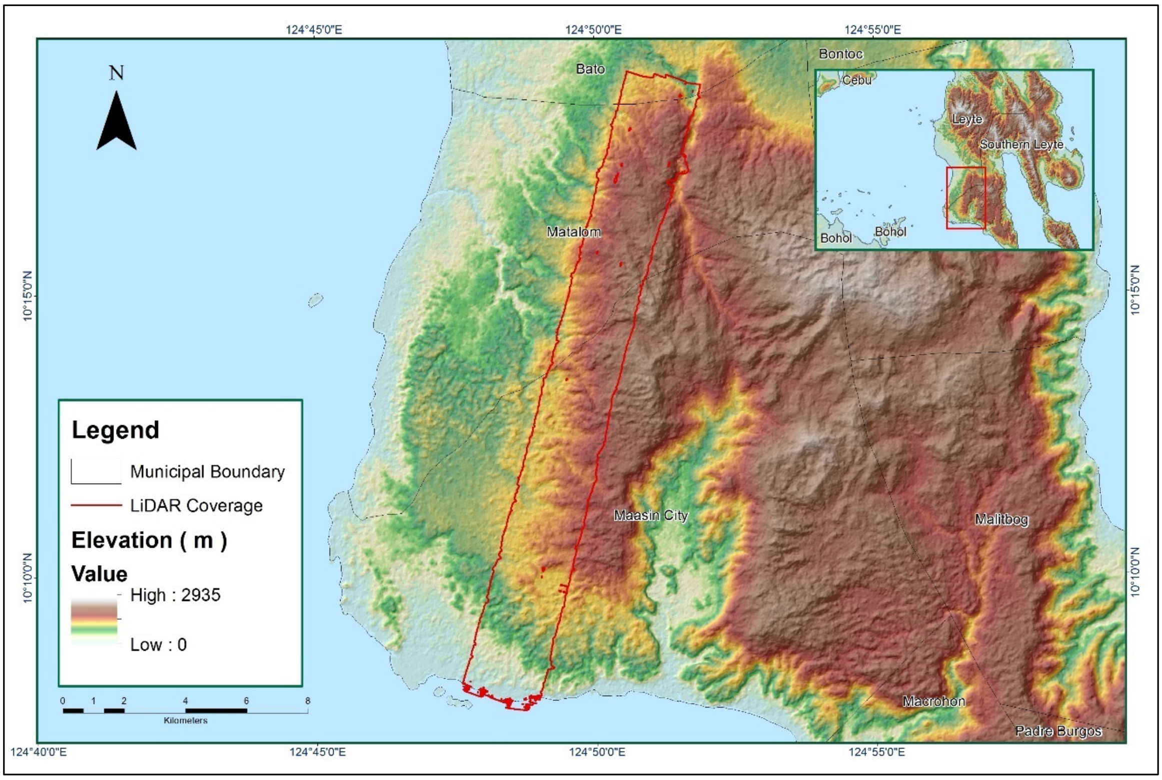



Figure A-8. 45 Coverage of LiDAR Data

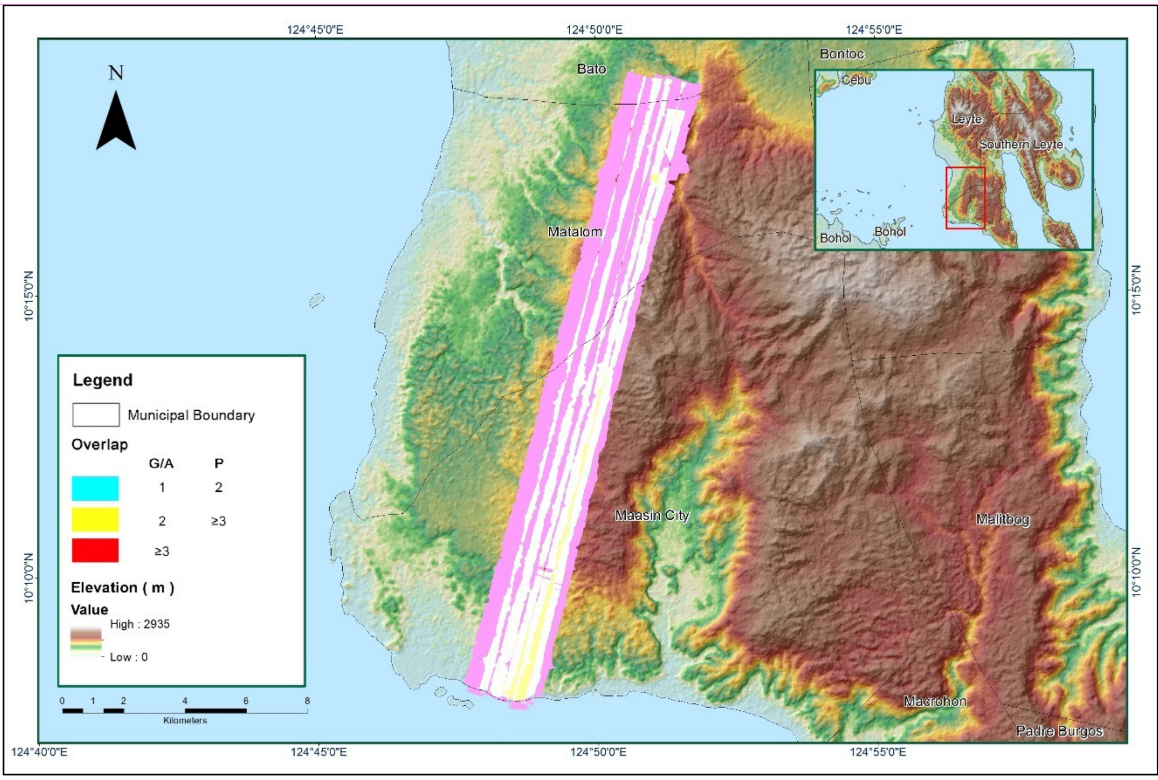



Figure A-8.46 Image Data Overlap

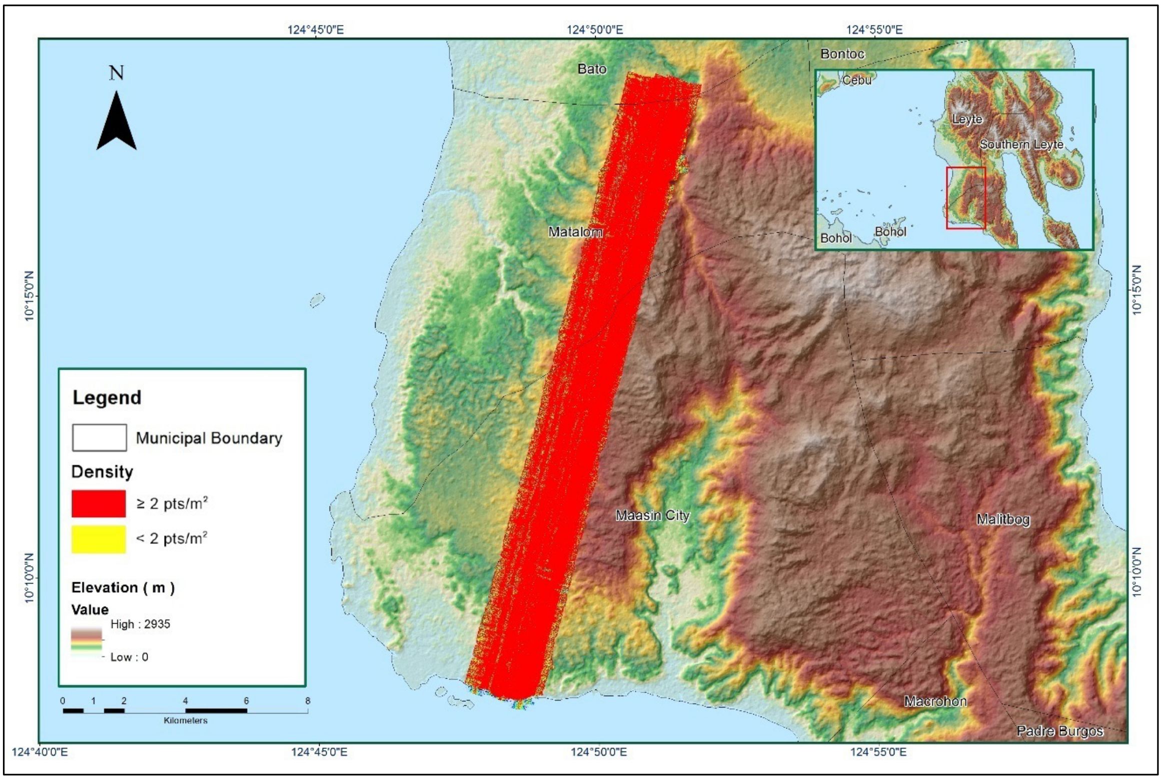



Figure A-8.47 Density map of merged LiDAR data

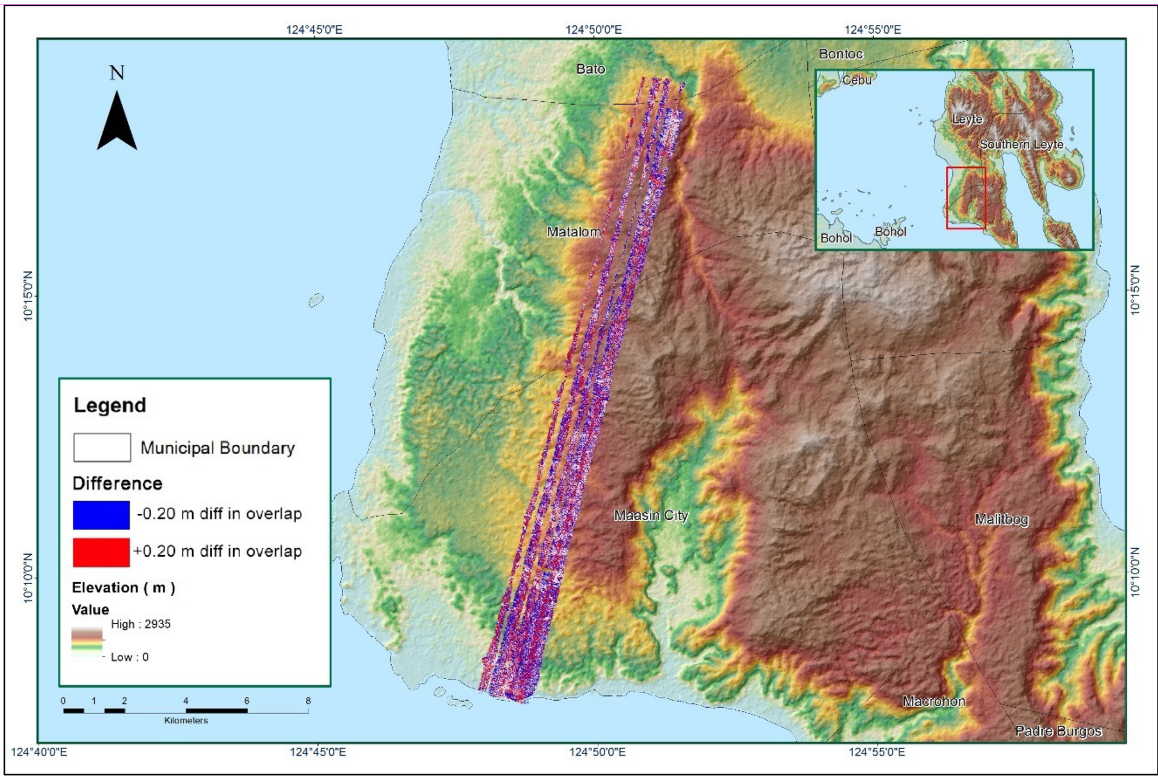



Figure A-8.48 Elevation difference between flight lines

# Annex 9. Bangkerohan Model Basin Parameters

Table A-9.1. Bangkerohan Model Basin Parameters

| Subbasin-tv | SCS Curve Number Loss | | | Clark Unit Hydrograph Transform | | Recession Baseflow | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Type | Initial Discharge (M3/S) | Recession Constant | Threshold Type | Ratio to Peak |
| W260 | 5.5785 | 98.3904 | 0 | 2.146145 | 0.221214 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W250 | 7.099 | 93.7884 | 0 | 1.888505 | 0.194658 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W240 | 9.21 | 88.068 | 0 | 2.011245 | 0.207306 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W230 | 9.117 | 88.3044 | 0 | 2.923245 | 0.301308 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W220 | 4.99905 | 98.3904 | 0 | 1.14304 | 0.117816 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W210 | 5.757 | 97.8264 | 0 | 3.3003 | 0.340176 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W200 | 8.913 | 88.83 | 0 | 6.733125 | 0.69402 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W190 | 9.3045 | 87.828 | 0 | 2.379845 | 0.245304 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W180 | 6.1215 | 96.696 | 0 | 1.08965 | 0.112314 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W170 | 5.2025 | 99.6 | 0 | 0.260139 | 0.026813 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W160 | 8.1115 | 90.954 | 0 | 2.357425 | 0.242982 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W150 | 6.176 | 96.528 | 0 | 1.73413 | 0.178746 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |
| W140 | 8.03 | 91.1748 | 0 | 3.27826 | 0.337902 | Discharge | 0.2 | 0.00005 | Ratio to Peak | 0.8 |

# Annex 10. Bangkerohan Model Reach Parameters

Table A-10.1. Bangkerohan Model Reach Parameters

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R30 | Automatic Fixed Interval | 282.28 | 0.022143 | 0.04 | Trapezoid | 81.3 | 1.5 |
| R40 | Automatic Fixed Interval | 3544.3 | 0.001537 | 0.04 | Trapezoid | 48.432 | 1.5 |
| R50 | Automatic Fixed Interval | 2258.2 | 0.000874 | 0.04 | Trapezoid | 55.68 | 1.5 |
| R60 | Automatic Fixed Interval | 3165.2 | 0.013927 | 0.04 | Trapezoid | 55.074 | 1.5 |
| R70 | Automatic Fixed Interval | 2170.1 | 0.012345 | 0.04 | Trapezoid | 56.022 | 1.5 |
| R80 | Automatic Fixed Interval | 2924.2 | 0.018179 | 0.04 | Trapezoid | 44.628 | 1.5 |

# Annex 11. Bangkerohan Field Validation Points

Table A-11.1. Bangkerohan Field Validation Points

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 1 | 10.32097475 | 124.834753 | 0.030999999 | 1.3 | 1.269000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 2 | 10.32097475 | 124.834753 | 0.030999999 | 1 | 0.969000001 | Bising/March 22-29, 1982 | 5-Year |
| 3 | 10.32097475 | 124.834753 | 0.030999999 | 0.5 | 0.469000001 | Ruby/December 07, 2014 | 5-Year |
| 4 | 10.32129494 | 124.8319467 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 5 | 10.32107952 | 124.8300261 | not covered | 0 | not covered | | 5-Year |
| 6 | 10.31810202 | 124.8281974 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 7 | 10.32143902 | 124.8171036 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 8 | 10.32170934 | 124.8113893 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 9 | 10.32493419 | 124.8083291 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 10 | 10.32731423 | 124.8050369 | 0.134000003 | 0 | -0.134000003 | | 5-Year |
| 11 | 10.32785009 | 124.8035048 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 12 | 10.327662 | 124.8006303 | not covered | 0.2 | not covered | Yolanda/November 08, 2013 | 5-Year |
| 13 | 10.34027399 | 124.8438387 | 4.828000069 | 0 | -4.828000069 | | 5-Year |
| 14 | 10.340577 | 124.8421304 | 1.037999988 | 1 | -0.037999988 | Ruby/December 07, 2014 | 5-Year |
| 15 | 10.34079786 | 124.8363862 | 1.297000051 | 0.2 | -1.097000051 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 16 | 10.34079786 | 124.8363862 | 1.297000051 | 0.1 | -1.197000051 | Bising/March 22-29, 1982 | 5-Year |
| 17 | 10.34027684 | 124.8349375 | 3.734999895 | 1 | -2.734999895 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 18 | 10.34027684 | 124.8349375 | 3.734999895 | 0.2 | -3.534999895 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 19 | 10.34046301 | 124.835288 | 2.64199996 | 0 | -2.64199996 | | 5-Year |
| 20 | 10.34075411 | 124.834762 | 3.457999945 | 1 | -2.457999945 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 21 | 10.34075411 | 124.834762 | 3.457999945 | 0.2 | -3.257999945 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 22 | 10.34132961 | 124.8349472 | 3.147000074 | 1 | -2.147000074 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 23 | 10.34132961 | 124.8349472 | 3.147000074 | 0.1 | -3.047000074 | Seniang/December 28, 2014 | 5-Year |
| 24 | 10.34290692 | 124.8333294 | 1.383000016 | 0 | -1.383000016 | | 5-Year |
| 25 | 10.34383496 | 124.8318895 | 0.030999999 | 0 | -0.030999999 | | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 26 | 10.34571544 | 124.8315077 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 27 | 10.34800278 | 124.8311185 | 2.77699995 | 1 | -1.77699995 | Amy/December 10, 1951 | 5-Year |
| 28 | 10.34718538 | 124.8313982 | 0.837000012 | 0.2 | -0.637000012 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 29 | 10.34718538 | 124.8313982 | 0.837000012 | 0.1 | -0.737000012 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 30 | 10.34688254 | 124.8310978 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 31 | 10.34739492 | 124.8290607 | 1.248000026 | 1 | -0.248000026 | Bising/March 22-29, 1982 | 5-Year |
| 32 | 10.34739492 | 124.8290607 | 1.248000026 | 1 | -0.248000026 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 33 | 10.34900584 | 124.825882 | 0.030999999 | 0.1 | 0.069000001 | Yolanda/November 08, 2013 | 5-Year |
| 34 | 10.34914213 | 124.8258413 | 4.859000206 | 0 | -4.859000206 | | 5-Year |
| 35 | 10.35095572 | 124.8212491 | 3.262000084 | 1.2 | -2.062000084 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 36 | 10.35095572 | 124.8212491 | 3.262000084 | 0.1 | -3.162000084 | Yolanda/November 08, 2013 | 5-Year |
| 37 | 10.34913132 | 124.8180526 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 38 | 10.35035717 | 124.8173892 | 2.654000044 | 2.5 | -0.154000044 | Amy/December 10, 1951 | 5-Year |
| 39 | 10.35035717 | 124.8173892 | 2.654000044 | 2 | -0.654000044 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 40 | 10.35244217 | 124.8169438 | 0.233999997 | 0.8 | 0.566000003 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 41 | 10.35244217 | 124.8169438 | 0.233999997 | 1.2 | 0.966000003 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 42 | 10.35233103 | 124.8162561 | 0.344000012 | 0 | -0.344000012 | | 5-Year |
| 43 | 10.35348974 | 124.81945 | 1.235999942 | 1 | -0.235999942 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 44 | 10.35348974 | 124.81945 | 1.235999942 | 1 | -0.235999942 | Bising/March 22-29, 1982 | 5-Year |
| 45 | 10.35397422 | 124.8192221 | 0.532999992 | 0.2 | -0.332999992 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 46 | 10.35397422 | 124.8192221 | 0.532999992 | 0.5 | -0.032999992 | Bising/March 22-29, 1982 | 5-Year |
| 47 | 10.35357893 | 124.8202697 | 0.377000004 | 0.1 | -0.277000004 | Bising/March 22-29, 1982 | 5-Year |
| 48 | 10.34695395 | 124.8157852 | 1.947000027 | 1.3 | -0.647000027 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 49 | 10.34695395 | 124.8157852 | 1.947000027 | 1.5 | -0.447000027 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 50 | 10.34736944 | 124.8154256 | 1.437999964 | 1.3 | -0.137999964 | Bising/March 22-29, 1982 | 5-Year |
| 51 | 10.34736944 | 124.8154256 | 1.437999964 | 1.5 | 0.062000036 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 52 | 10.34659931 | 124.8158815 | 0.671999991 | 1.3 | 0.628000009 | Bising/March 22-29, 1982 | 5-Year |
| 53 | 10.34659931 | 124.8158815 | 0.671999991 | 1.5 | 0.828000009 | Ruping/Nov. 10-14, 1990 | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 54 | 10.34337882 | 124.8123808 | 0.07 | 0.2 | 0.13 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 55 | 10.34337882 | 124.8123808 | 0.07 | 0.2 | 0.13 | Bising/March 22-29, 1982 | 5-Year |
| 56 | 10.34067205 | 124.810793 | 0.437999994 | 1.5 | 1.062000006 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 57 | 10.34028648 | 124.8113168 | 0.243000001 | 1.3 | 1.056999999 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 58 | 10.34063257 | 124.8105869 | 0.032000002 | 1 | 0.967999998 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 59 | 10.33972062 | 124.8085637 | 0.603999972 | 1 | 0.396000028 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 60 | 10.33972062 | 124.8085637 | 0.603999972 | 0.2 | -0.403999972 | Yolanda/November 08, 2013 | 5-Year |
| 61 | 10.33972062 | 124.8085637 | 0.603999972 | 1 | 0.396000028 | Bising/March 22-29, 1982 | 5-Year |
| 62 | 10.33893406 | 124.8092509 | 0.029999999 | 1 | 0.970000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 63 | 10.33893406 | 124.8092509 | 0.029999999 | 0.2 | 0.170000001 | Yolanda/November 08, 2013 | 5-Year |
| 64 | 10.33893406 | 124.8092509 | 0.029999999 | 1 | 0.970000001 | Bising/March 22-29, 1982 | 5-Year |
| 65 | 10.3373058 | 124.8080046 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 66 | 10.33703858 | 124.808368 | 0.85799998 | 1.3 | 0.44200002 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 67 | 10.33695426 | 124.8077316 | 0.638000011 | 0.5 | -0.138000011 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 68 | 10.3347722 | 124.8063949 | 0.029999999 | 0.3 | 0.270000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 69 | 10.3347722 | 124.8063949 | 0.029999999 | 0.1 | 0.070000001 | Bising/March 22-29, 1982 | 5-Year |
| 70 | 10.33361776 | 124.8052544 | 0.029999999 | 0.1 | 0.070000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 71 | 10.33288116 | 124.8042168 | 0.029999999 | 1 | 0.970000001 | Amy/December 10, 1951 | 5-Year |
| 72 | 10.33204674 | 124.8018646 | 0.029999999 | 0.5 | 0.470000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 73 | 10.33204674 | 124.8018646 | 0.029999999 | 0.3 | 0.270000001 | Bising/March 22-29, 1982 | 5-Year |
| 74 | 10.33204674 | 124.8018646 | 0.029999999 | 0.2 | 0.170000001 | Yolanda/November 08, 2013 | 5-Year |
| 75 | 10.33182898 | 124.8007859 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 76 | 10.33077504 | 124.8000197 | 0.425999999 | 0.2 | -0.225999999 | Seniang/December 28, 2014 | 5-Year |
| 77 | 10.33065425 | 124.800378 | 0.783999979 | 1.2 | 0.416000021 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 78 | 10.33065425 | 124.800378 | 0.783999979 | 1.5 | 0.716000021 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 79 | 10.32930057 | 124.7967258 | not covered | 0.5 | #VALUE! | Bising/March 22-29, 1982 | 5-Year |
| 80 | 10.32930057 | 124.7967258 | not covered | 0.1 | #VALUE! | Ruping/Nov. 10-14, 1990 | 5-Year |
| 81 | 10.34703869 | 124.8025942 | 0.256999999 | 0.2 | -0.056999999 | Ruping/Nov. 10-14, 1990 | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 82 | 10.34598534 | 124.8028335 | 0.131999999 | 0.3 | 0.168000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 83 | 10.34598534 | 124.8028335 | 0.131999999 | 0.3 | 0.168000001 | Bising/March 22-29, 1982 | 5-Year |
| 84 | 10.34543783 | 124.8033768 | 0.046 | 0.2 | 0.154 | Bising/March 22-29, 1982 | 5-Year |
| 85 | 10.34543783 | 124.8033768 | 0.046 | 0.2 | 0.154 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 86 | 10.34494758 | 124.8042173 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 87 | 10.34440032 | 124.8042946 | 0.029999999 | 0.2 | 0.170000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 88 | 10.34440032 | 124.8042946 | 0.029999999 | 1.8 | 1.770000001 | Amy/December 10, 1951 | 5-Year |
| 89 | 10.34440032 | 124.8042946 | 0.029999999 | 1 | 0.970000001 | Bising/March 22-29, 1982 | 5-Year |
| 90 | 10.34457768 | 124.8060976 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 91 | 10.34528369 | 124.8066943 | 0.545000017 | 0.3 | -0.245000017 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 92 | 10.34751889 | 124.8016415 | 0.166999996 | 0.5 | 0.333000004 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 93 | 10.34751889 | 124.8016415 | 0.166999996 | 0.1 | -0.066999996 | Yolanda/November 08, 2013 | 5-Year |
| 94 | 10.34629958 | 124.8010223 | 0.037 | 0.5 | 0.463 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 95 | 10.34629958 | 124.8010223 | 0.037 | 0.5 | 0.463 | Bising/March 22-29, 1982 | 5-Year |
| 96 | 10.3446936 | 124.7999812 | 0.029999999 | 0.1 | 0.070000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 97 | 10.3446936 | 124.7999812 | 0.029999999 | 0.1 | 0.070000001 | Bising/March 22-29, 1982 | 5-Year |
| 98 | 10.34414534 | 124.7994352 | 0.067000002 | 0.3 | 0.232999998 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 99 | 10.34414534 | 124.7994352 | 0.067000002 | 0.4 | 0.332999998 | Bising/March 22-29, 1982 | 5-Year |
| 100 | 10.34481548 | 124.7988198 | 0.029999999 | 1 | 0.970000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 101 | 10.34505595 | 124.7979005 | 0.187000006 | 1 | 0.812999994 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 102 | 10.34506786 | 124.797589 | 0.059999999 | 0.8 | 0.740000001 | Bising/March 22-29, 1982 | 5-Year |
| 103 | 10.34506786 | 124.797589 | 0.059999999 | 0.25 | 0.190000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 104 | 10.34304606 | 124.7987278 | 0.268000007 | 0 | -0.268000007 | | 5-Year |
| 105 | 10.34291572 | 124.7988225 | 0.136999995 | 0.5 | 0.363000005 | Yolanda/November 08, 2013 | 5-Year |
| 106 | 10.34291572 | 124.7988225 | 0.136999995 | 0.5 | 0.363000005 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 107 | 10.34291572 | 124.7988225 | 0.136999995 | 0.5 | 0.363000005 | Bising/March 22-29, 1982 | 5-Year |
| 108 | 10.34235178 | 124.7983493 | 0.30399999 | 0.8 | 0.49600001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 109 | 10.34235178 | 124.7983493 | 0.30399999 | 0.6 | 0.29600001 | Bising/March 22-29, 1982 | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 110 | 10.34138074 | 124.7979518 | 0.546000004 | 0.8 | 0.253999996 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 111 | 10.34138074 | 124.7979518 | 0.546000004 | 0.3 | -0.246000004 | Yolanda/November 08, 2013 | 5-Year |
| 112 | 10.33893591 | 124.7960679 | 0.128999993 | 0.8 | 0.671000007 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 113 | 10.33893591 | 124.7960679 | 0.128999993 | 1.2 | 1.071000007 | Amy/December 10, 1951 | 5-Year |
| 114 | 10.33721603 | 124.795479 | 0.029999999 | 0.5 | 0.470000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 115 | 10.33546831 | 124.7950592 | 0.513999999 | 0.6 | 0.086000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 116 | 10.33546831 | 124.7950592 | 0.513999999 | 1.2 | 0.686000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 117 | 10.33546831 | 124.7950592 | 0.513999999 | 0.3 | -0.213999999 | Ruby/December 07, 2014 | 5-Year |
| 118 | 10.33416619 | 124.7855232 | 0.029999999 | 1 | 0.970000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 119 | 10.33436727 | 124.7858755 | 0.061000001 | 0 | -0.061000001 | | 5-Year |
| 120 | 10.33308308 | 124.7864469 | 0.029999999 | 1.1 | 1.070000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 121 | 10.33308308 | 124.7864469 | 0.029999999 | 2 | 1.970000001 | Amy/December 10, 1951 | 5-Year |
| 122 | 10.33220381 | 124.78692 | 0.029999999 | 0.8 | 0.770000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 123 | 10.33220381 | 124.78692 | 0.029999999 | 0.1 | 0.070000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 124 | 10.33136386 | 124.7875354 | 0.029999999 | 2 | 1.970000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 125 | 10.33136386 | 124.7875354 | 0.029999999 | 1.5 | 1.470000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 126 | 10.33221773 | 124.7875285 | 0.119000003 | 1.2 | 1.080999997 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 127 | 10.33221773 | 124.7875285 | 0.119000003 | 1 | 0.880999997 | Yolanda/November 08, 2013 | 5-Year |
| 128 | 10.33550947 | 124.7835103 | 0.082999997 | 1.3 | 1.217000003 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 129 | 10.33717914 | 124.7824804 | 0.382999986 | 0.3 | -0.082999986 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 130 | 10.33717914 | 124.7824804 | 0.382999986 | 1 | 0.617000014 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 131 | 10.33657984 | 124.7829268 | 0.039000001 | 0.5 | 0.460999999 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 132 | 10.33611523 | 124.7821171 | 0.656000018 | 1 | 0.343999982 | Yolanda/November 08, 2013 | 5-Year |
| 133 | 10.33611523 | 124.7821171 | 0.656000018 | 1 | 0.343999982 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 134 | 10.33621782 | 124.7879065 | 1.118999958 | 1.4 | 0.281000042 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 135 | 10.33621782 | 124.7879065 | 1.118999958 | 0.5 | -0.618999958 | Yolanda/November 08, 2013 | 5-Year |
| 136 | 10.3358346 | 124.7865712 | 0.043000001 | 0.5 | 0.456999999 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 137 | 10.3358346 | 124.7865712 | 0.043000001 | 2 | 1.956999999 | Ruping/Nov. 10-14, 1990 | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 138 | 10.33722701 | 124.7859674 | 0.029999999 | 0.8 | 0.770000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 139 | 10.33818657 | 124.785332 | 0.029999999 | 1.2 | 1.170000001 | Amy/December 10, 1951 | 5-Year |
| 140 | 10.33924688 | 124.7845315 | 0.029999999 | 0.2 | 0.170000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 141 | 10.34107204 | 124.7834789 | 0.85799998 | 0.3 | -0.55799998 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 142 | 10.33957377 | 124.7791255 | 0.264999986 | 0.4 | 0.135000014 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 143 | 10.34086592 | 124.7819312 | 0.412 | 0.4 | -0.012 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 144 | 10.34221751 | 124.7825381 | 0.389999986 | 0.5 | 0.110000014 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 145 | 10.3497054 | 124.7903983 | 0.386999995 | 1.5 | 1.113000005 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 146 | 10.3497054 | 124.7903983 | 0.386999995 | 0.9 | 0.513000005 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 147 | 10.3497054 | 124.7903983 | 0.386999995 | 0.9 | 0.513000005 | Bising/March 22-29, 1982 | 5-Year |
| 148 | 10.34861977 | 124.7905703 | 0.578999996 | 1.4 | 0.821000004 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 149 | 10.34861977 | 124.7905703 | 0.578999996 | 0.8 | 0.221000004 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 150 | 10.34861977 | 124.7905703 | 0.578999996 | 0.9 | 0.321000004 | Bising/March 22-29, 1982 | 5-Year |
| 151 | 10.34778183 | 124.7896416 | 0.674000025 | 0.8 | 0.125999975 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 152 | 10.34778183 | 124.7896416 | 0.674000025 | 0.8 | 0.125999975 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 153 | 10.34660493 | 124.787372 | 0.333000004 | 0.6 | 0.266999996 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 154 | 10.34450518 | 124.7855597 | 0.398000002 | 1.1 | 0.701999998 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 155 | 10.34450518 | 124.7855597 | 0.398000002 | 1.2 | 0.801999998 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 156 | 10.34450518 | 124.7855597 | 0.398000002 | 1.6 | 1.201999998 | Bising/March 22-29, 1982 | 5-Year |
| 157 | 10.34553364 | 124.7847465 | 0.184 | 0.5 | 0.316 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 158 | 10.34553364 | 124.7847465 | 0.184 | 1.4 | 1.216 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 159 | 10.34727347 | 124.7847039 | 0.379000008 | 0.6 | 0.220999992 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 160 | 10.34727347 | 124.7847039 | 0.379000008 | 0.3 | -0.079000008 | Bising/March 22-29, 1982 | 5-Year |
| 161 | 10.34695068 | 124.7842025 | 0.279000014 | 0.4 | 0.120999986 | Bising/March 22-29, 1982 | 5-Year |
| 162 | 10.3480488 | 124.7834893 | 0.409999996 | 1.1 | 0.690000004 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 163 | 10.3480488 | 124.7834893 | 0.409999996 | 1.1 | 0.690000004 | Bising/March 22-29, 1982 | 5-Year |
| 164 | 10.3480488 | 124.7834893 | 0.409999996 | 1.3 | 0.890000004 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 165 | 10.35006733 | 124.7852342 | 0.230000004 | 1.2 | 0.969999996 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 166 | 10.35006733 | 124.7852342 | 0.230000004 | 1.1 | 0.869999996 | Bising/March 22-29, 1982 | 5-Year |
| 167 | 10.35006733 | 124.7852342 | 0.230000004 | 1 | 0.769999996 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 168 | 10.35036195 | 124.7855619 | 0.237000003 | 1.2 | 0.962999997 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 169 | 10.35036195 | 124.7855619 | 0.237000003 | 1.1 | 0.862999997 | Bising/March 22-29, 1982 | 5-Year |
| 170 | 10.35036195 | 124.7855619 | 0.237000003 | 1 | 0.762999997 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 171 | 10.35043437 | 124.7847972 | 0.375999987 | 1.2 | 0.824000013 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 172 | 10.35043437 | 124.7847972 | 0.375999987 | 1.1 | 0.724000013 | Bising/March 22-29, 1982 | 5-Year |
| 173 | 10.35043437 | 124.7847972 | 0.375999987 | 1 | 0.624000013 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 174 | 10.34462747 | 124.7836147 | 0.029999999 | 1.5 | 1.470000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 175 | 10.34386044 | 124.7819337 | 0.165999994 | 0.3 | 0.134000006 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 176 | 10.34613169 | 124.7791646 | 0.143999994 | 0.5 | 0.356000006 | Yolanda/November 08, 2013 | 5-Year |
| 177 | 10.34613169 | 124.7791646 | 0.143999994 | 1.1 | 0.956000006 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 178 | 10.34609799 | 124.7736985 | 0.046 | 0.2 | 0.154 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 179 | 10.34629698 | 124.7751198 | 0.25999999 | 0.5 | 0.24000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 180 | 10.34678757 | 124.7769007 | 0.232999995 | 0.5 | 0.267000005 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 181 | 10.3469817 | 124.7784057 | 0.063000001 | 1.1 | 1.036999999 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 182 | 10.34872262 | 124.7782529 | 0.143999994 | 0.2 | 0.056000006 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 183 | 10.35115739 | 124.7779269 | 0.029999999 | 0.8 | 0.770000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 184 | 10.35020169 | 124.7733411 | 0.029999999 | 0.3 | 0.270000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 185 | 10.35020169 | 124.7733411 | 0.029999999 | 0.1 | 0.070000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 186 | 10.35092949 | 124.7769323 | 0.029999999 | 0.5 | 0.470000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 187 | 10.3528606 | 124.7780535 | 0.029999999 | 1.2 | 1.170000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 188 | 10.3528606 | 124.7780535 | 0.029999999 | 1.2 | 1.170000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 189 | 10.36177073 | 124.8085769 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 190 | 10.36309934 | 124.8104565 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 191 | 10.36427004 | 124.8119448 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 192 | 10.35957064 | 124.8069955 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 193 | 10.35812468 | 124.8060379 | 0.030999999 | 0 | -0.030999999 | | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 194 | 10.35633355 | 124.8025028 | 0.118000001 | 0 | -0.118000001 | | 5-Year |
| 195 | 10.35516872 | 124.8023591 | 0.029999999 | 0.2 | 0.170000001 | Yolanda/November 08, 2013 | 5-Year |
| 196 | 10.35516872 | 124.8023591 | 0.029999999 | 0.5 | 0.470000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 197 | 10.36124141 | 124.8009504 | 0.231000006 | 1 | 0.768999994 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 198 | 10.36124141 | 124.8009504 | 0.231000006 | 1.5 | 1.268999994 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 201 | 10.35830129 | 124.8007045 | 0.029999999 | 0.1 | 0.070000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 202 | 10.35503696 | 124.8021723 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 203 | 10.35485541 | 124.8010048 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 204 | 10.35451493 | 124.8004688 | 0.261000007 | 0.3 | 0.038999993 | Yolanda/November 08, 2013 | 5-Year |
| 205 | 10.35390825 | 124.7989572 | 0.029999999 | 1.2 | 1.170000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 206 | 10.35390825 | 124.7989572 | 0.029999999 | 0.55 | 0.520000001 | Amy/December 10, 1951 | 5-Year |
| 207 | 10.35320543 | 124.7975524 | 0.029999999 | 1.1 | 1.070000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 208 | 10.35334138 | 124.7961067 | 0.029999999 | 0.5 | 0.470000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 209 | 10.35334138 | 124.7961067 | 0.029999999 | 0.1 | 0.070000001 | Bising/March 22-29, 1982 | 5-Year |
| 210 | 10.35443765 | 124.7956808 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 211 | 10.35466815 | 124.7937333 | 0.059999999 | 1.3 | 1.240000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 212 | 10.35432022 | 124.7913373 | 0.149000004 | 0.3 | 0.150999996 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 213 | 10.35432022 | 124.7913373 | 0.149000004 | 0.6 | 0.450999996 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 214 | 10.35653975 | 124.7877836 | 0.071999997 | 1.3 | 1.228000003 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 215 | 10.35733528 | 124.7870097 | 0.029999999 | 1.6 | 1.570000001 | Ruping/Nov. 10-14, 1990 | 5-Year |
| 216 | 10.35733528 | 124.7870097 | 0.029999999 | 0.5 | 0.470000001 | Maming | 5-Year |
| 217 | 10.35733528 | 124.7870097 | 0.029999999 | 0.1 | 0.070000001 | Bising/March 22-29, 1982 | 5-Year |
| 218 | 10.35836985 | 124.7859328 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 219 | 10.35902331 | 124.7848512 | 0.029999999 | 0.4 | 0.370000001 | Ruping/November 5-18, 1990 | 5-Year |
| 220 | 10.35902331 | 124.7848512 | 0.029999999 | 0.7 | 0.670000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 221 | 10.3599418 | 124.7832505 | 0.052000001 | 0.6 | 0.547999999 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 222 | 10.3599418 | 124.7832505 | 0.052000001 | 0.8 | 0.747999999 | Ruping/November 5-18, 1990 | 5-Year |
| 223 | 10.36115047 | 124.7806406 | 0.032000002 | 0.5 | 0.467999998 | Ruping/November 5-18, 1990 | 5-Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return /Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 224 | 10.36115047 | 124.7806406 | 0.032000002 | 0.5 | 0.467999998 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 225 | 10.36167928 | 124.778039 | not covered | 0 | not covered | | 5-Year |
| 226 | 10.35505137 | 124.781997 | 0.238000005 | 0.2 | -0.038000005 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 227 | 10.35505137 | 124.781997 | 0.238000005 | 1 | 0.761999995 | Ruping/November 5-18, 1990 | 5-Year |
| 228 | 10.38098641 | 124.779881 | 0.029999999 | 0.3 | 0.270000001 | Ruping/November 5-18, 1990 | 5-Year |
| 229 | 10.381994 | 124.7785087 | 0.029999999 | 0.2 | 0.170000001 | Ruping/November 5-18, 1990 | 5-Year |
| 230 | 10.38568991 | 124.7777884 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 231 | 10.38759009 | 124.7764771 | 0.029999999 | 0.8 | 0.770000001 | Ruping/November 5-18, 1990 | 5-Year |
| 232 | 10.37258321 | 124.7769149 | 0.029999999 | 1 | 0.970000001 | Yolanda/November 08, 2013 | 5-Year |
| 233 | 10.37258321 | 124.7769149 | 0.029999999 | 0.2 | 0.170000001 | Ruping/November 5-18, 1990 | 5-Year |
| 234 | 10.37147504 | 124.7814144 | 0.029999999 | 0.5 | 0.470000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 235 | 10.37147504 | 124.7814144 | 0.029999999 | 0.4 | 0.370000001 | Ruping/November 5-18, 1990 | 5-Year |
| 236 | 10.3665428 | 124.7974925 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 237 | 10.36821222 | 124.8002896 | 0.030999999 | 0.5 | 0.469000001 | Ruping/November 5-18, 1990 | 5-Year |
| 238 | 10.36821222 | 124.8002896 | 0.030999999 | 0.5 | 0.469000001 | Basyang/Jan. 30 - Feb. 1, 2014 | 5-Year |
| 239 | 10.36878764 | 124.801399 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 240 | 10.37151628 | 124.8026912 | 0.030999999 | 0 | -0.030999999 | | 5-Year |
| 241 | 10.37352702 | 124.8037631 | 0.029999999 | 0 | -0.029999999 | | 5-Year |
| 242 | 10.37463938 | 124.8049147 | 0.030999999 | 0.5 | 0.469000001 | Ruping/November 5-18, 1990 | 5-Year |
| 243 | 10.37463938 | 124.8049147 | 0.030999999 | 0.6 | 0.569000001 | Yolanda/November 08, 2013 | 5-Year |

# Annex 12. Educational Institutions Affected by flooding in Bangkerohan Floodplain

Figure A-8.48 Elevation difference between flight lines

| LEYTE | | | | |
|---|---|---|---|---|
| BATO | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Alejos Elementary School | Alejos | | | |
| San Agustin Day Care Center | Alejos | | | |
| Tugas Elementary School | Alejos | | | |
| Bato Institute of Science & Technology | Dolho | | Low | Medium |
| Dolho Day Care Center | Dolho | | Low | Medium |
| Dolho Elementary School | Dolho | | Low | Medium |
| Charity Pre-School Center | Guerrero District | | | Low |
| Bago Day Care Center | Mabini | | | |
| Bago Elementary School | Mabini | | | |
| Naga Day Care Center | Naga | | Medium | Medium |
| Naga Elementary School | Naga | | | |
| Amagos Day Care Center | San Agustin | | | |
| Amagos Elementary School | San Agustin | | | |
| Tabunok Day Care Center | Tabunok | Low | Low | Medium |
| Tabunok Elementary School | Tabunok | Low | Medium | Medium |
| Tagaytay Day Care Center | Tagaytay | | | |
| Tagaytay Elementary School | Tagaytay | | | |
| Tugas Elementary School | Tugas | | | |

| LEYTE | | | | |
|---|---|---|---|---|
| HILONGOS | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Baas Elementary School | Baas | | | Medium |
| Tuguipa Elementary School | Baas | | | |
| Bantigue Primary School | Bantigue | Low | Medium | Medium |
| Catandog I Day Care Center | Bantigue | | | |
| Catandog I Elementary School | Catandog 1 | | | |
| Catandog II Elementary School | Catandog 2 | | Low | Low |
| Tabunok Elementary School | Lunang | | Low | Low |
| Lunang Elementary School | Tabunok | Low | Low | Low |
| Kanghas Elementary School | Talisay | | | |

# Annex 13. Health Institutions affected by flooding in Bangkerohan Floodplain

Table A-13.1. Health Institutions affected by flooding in Bangkerohan Floodplain

| LEYTE | | | | |
|---|---|---|---|---|
| BATO | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Alejos Health Center | Alejos | | | Medium |
| San Agustin Health Center | Alejos | | | |
| Bago Health Center | Mabini | | | |
| Naga Health Center | Naga | | Medium | Medium |
| Amagos Health Center | San Agustin | | | |
| Tagaytay Health Station | Tagaytay | | | |

| LEYTE | | | | |
|---|---|---|---|---|
| HILONGOS | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Kanghas Health Center | Talisay | | | |