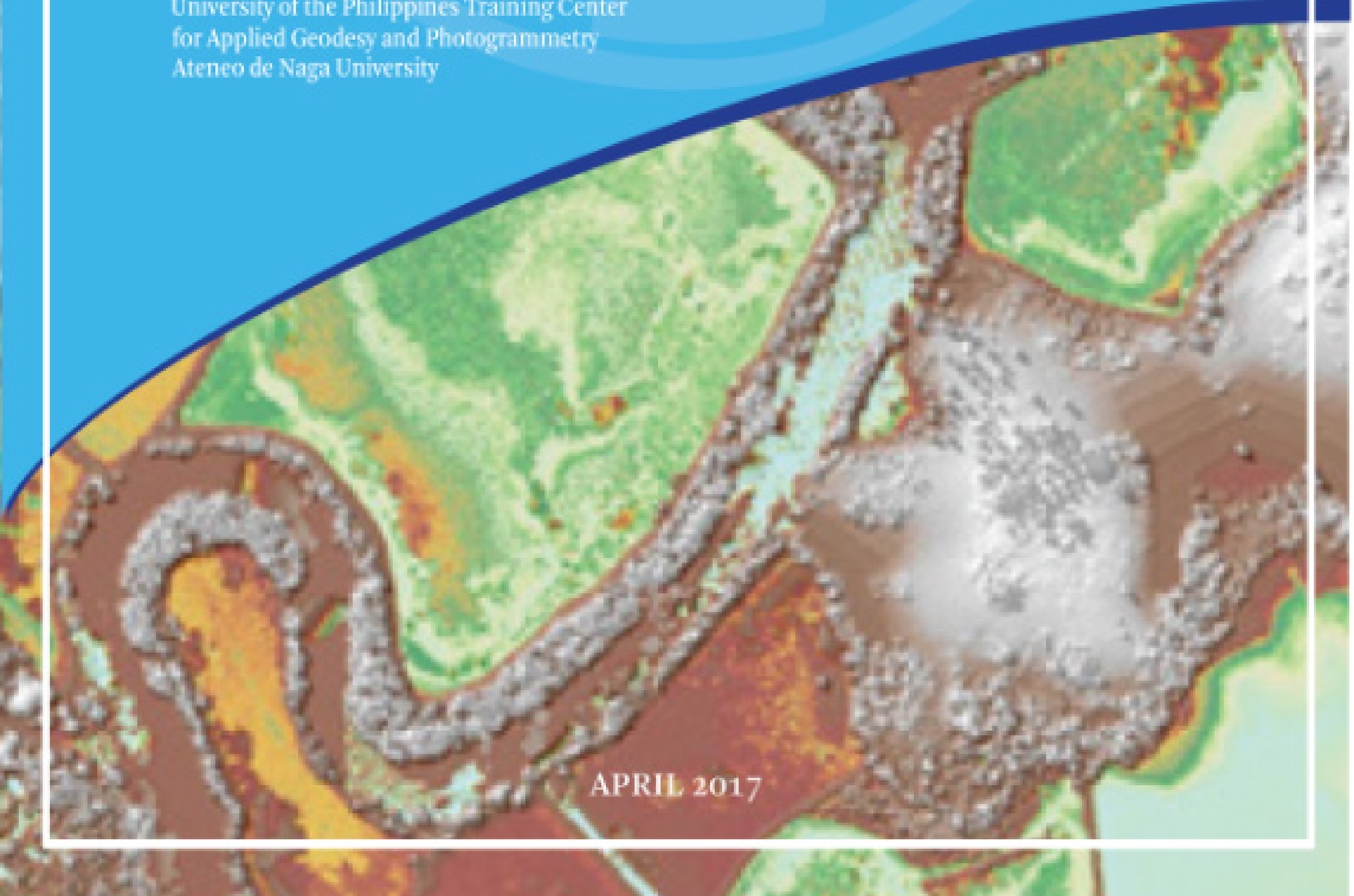
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR ( PHIL-LIDAR 1)

# LiDAR Surveys and Flood Mapping of Guiom River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Naga University



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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAC | Asian Aerospace Corporation |
| Ab | abutment |
| ADNU | Ateneo de Naga University |
| 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] |
| 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 |

# CHAPTER 1: OVERVIEW OF THE PROGRAM AND THE GUIOM RIVER

Enrico C. Parigit, Dr. Eng., Ms. Joanaviva Plopenio, and Engr. Ferdinand Bien

## 1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga University (ADNU). ADNU 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 Bicol Region. The university is located in Naga City in the province of Bicol.

## 1.2 Overview of the Guiom River Basin

Guiom river basin is under the jurisdiction of three (3) municipalities: Cawayan (second class), Uson (third class) and Dimasalang (fourth class). Based from the 2015 census, Cawayan is populated with a total of 67,033; Uson has 56,168 population and Dimasalang with 26,192. The DENR River Basin Control Office (RBCO) states that the Guiom River Basin has a drainage area of 152 km² and an estimated 206 cubic meter (MCM) annual run-off (RBCO, 2015).

Guiom River is approximately 20km long. It is among the twenty-four (24) river systems in Bicol Region. According to the 2015 national census of PSA, a total of 12,718 persons are residing within the immediate vicinity of the river, which is distributed among barangays Calapayan, Dalipe, Guiom, Itombato, Maihao, Pananawan, Villahermosa, Pin-As and Iraya in the Municipality of Cawayan. The surrounding areas are basically brushland as shown in the land cover map, with a small area dedicated to fishponds, specifically near the mouth of the river. There is a low mountain range to the east of the river basin, otherwise, the north and south are gently rolling land. The river basin area is still classified as Type III where rainfall is evenly distributed throughout the year except for the months of November to April when it is relatively dry.

The economy of Masbate Province largely rests on livestock and agriculture with coconut, rice, and corn as the main crops and top products (Philippine Statistics Authority, 2017).

As of December 7, 2014, 578 families in Cawayan, Masbate were affected by Typhoon Ruby as per NDRRMC report (National Disaster Risk Reduction and Management Council, 2014).

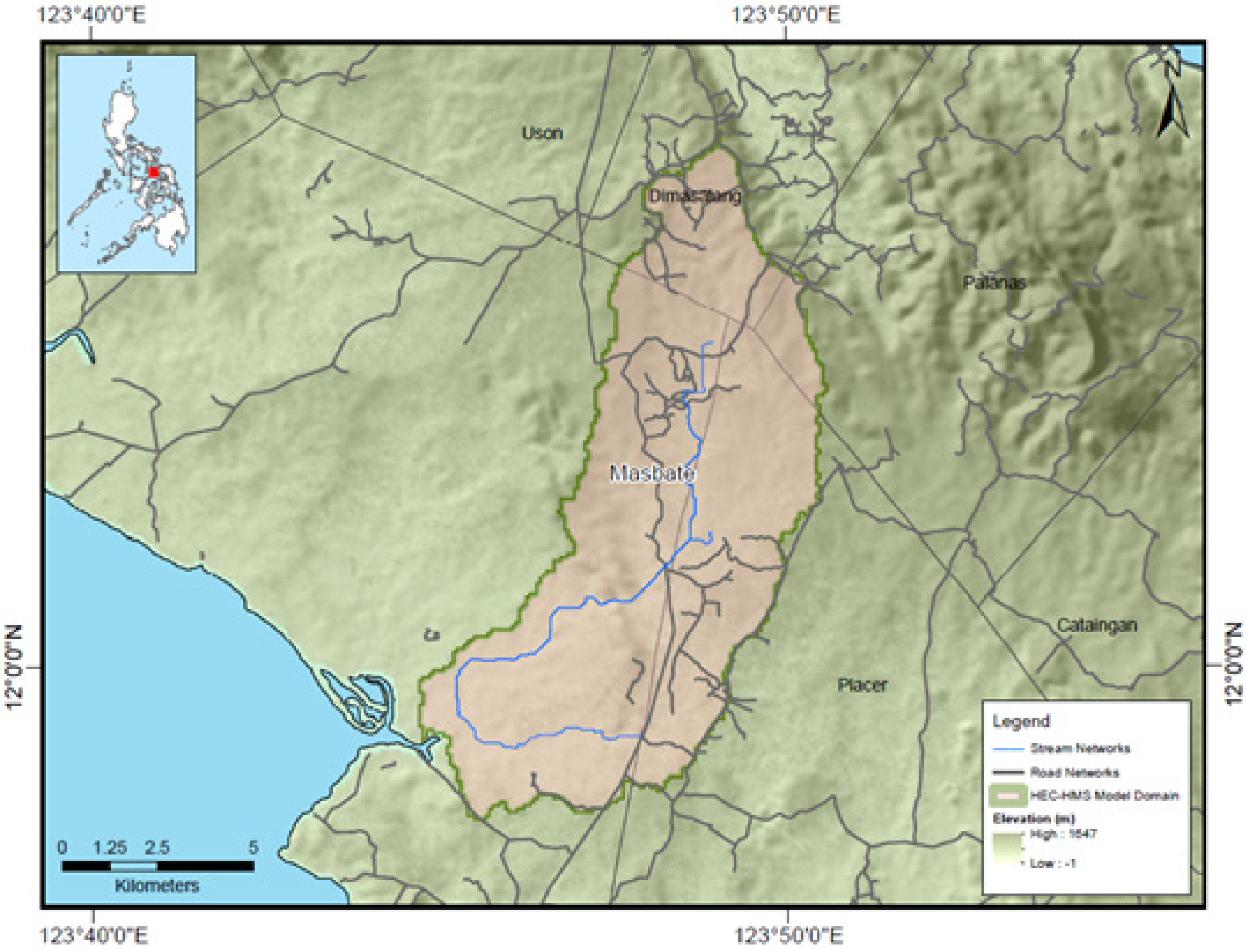


Figure 1. Map of the Guiom River Basin

# CHAPTER 2: LIDAR DATA ACQUISITION OF THE GUIOM FLOODPLAIN

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

## 2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Guiom floodplain in Masbate. These missions were planned for 10 lines that run for at most four hours and a half (4.5 hours) including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plan for Guiom floodplain survey.

Table 1. Flight planning parameters for Pegasus 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 32H | 600, 800 | 25, 30 | 40, 50 | 200, 250 | 30, 36 | 130 | 5 |
| BLK 32I | 1000, 1200 | 25, 40 | 50 | 200 | 30 | 130 | 5 |
| BLK 32J | 800, 1000, 1200 | 25 | 50 | 200 | 30 | 130 | 5 |

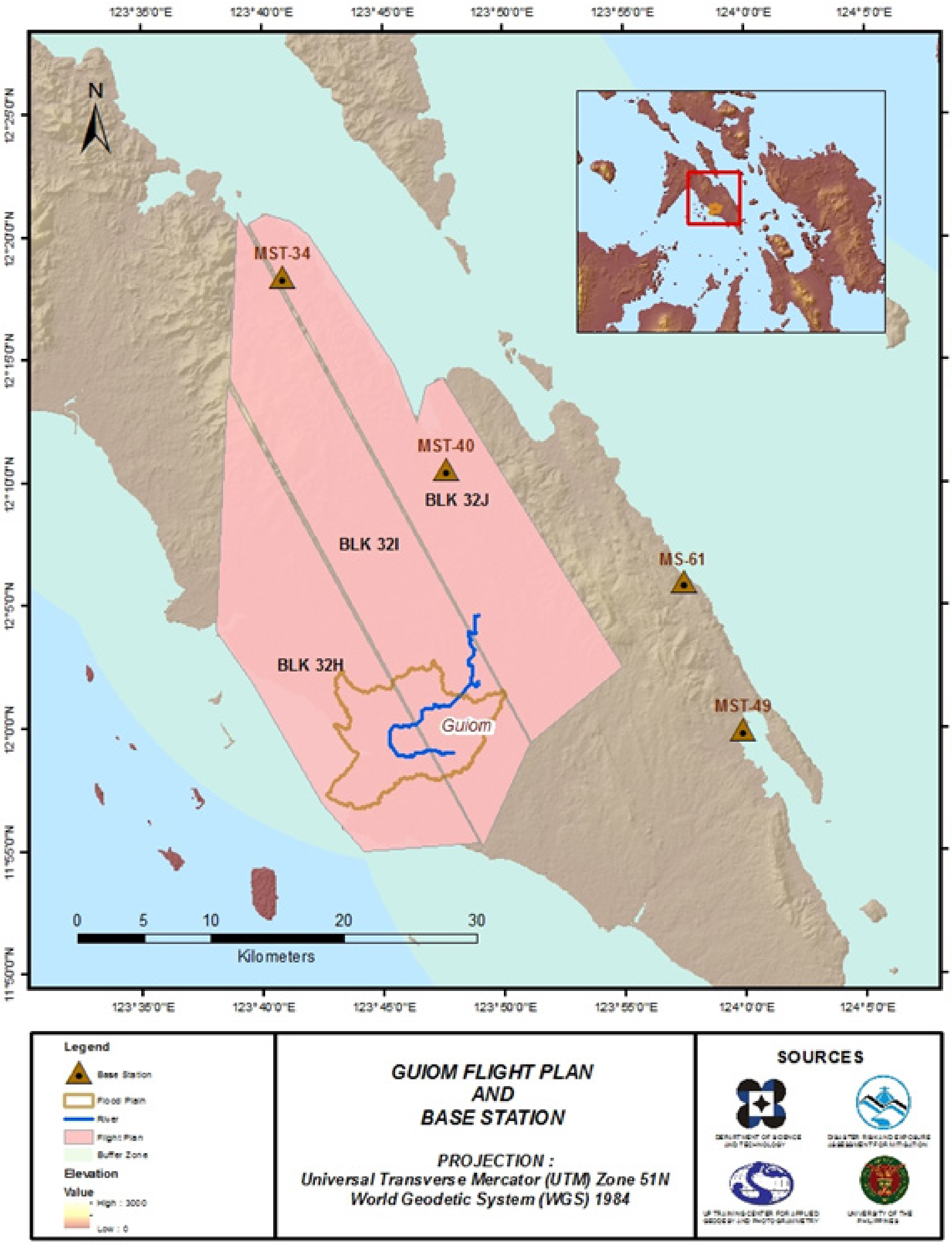


Figure 2. Flight plans and base stations used for Guiom floodplain.

## 2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: MST-34, MST-40 and MST-49 which are of second (2nd) order accuracy. One NAMRIA (1) benchmark was recovered: MS-61 which is of first (1st) order accuracy. This benchmark was used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference points and benchmark are found in Annex 2, while the baseline processing report for the NAMRIA benchmark is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (March 21 - April 1, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Guiom floodplain are shown in Figure 2.

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


(a)

Figure 3. GPS set-up over MST-34 as recovered in Sagawsawan Bridge, Brgy. Umabay Exterior, municipality of Mobo, Masbate (a) and NAMRIA reference point MST-34 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MST-34 used as base station for the LiDAR acquisition.

| Station Name | MST-34 | |
|---|---|---|
| **Order of Accuracy** | **2nd** | |
| **Relative Error (Horizontal positioning)** | **1 in 50,000** | |
| Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 18' 29.18323" North<br>123° 40' 46.86556" East<br>11.91000 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 573933.177 meters<br>1361109.053 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 18' 24.53692" North<br>123° 40' 51.93952" East<br>68.23000 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 573907.30 meters<br>1360632.64 meters |


Figure 4. GPS set-up over MST-40 as recovered in Buenavista Bridge in Brgy. Buenavista, municipality of Uson, Masbate (a) and NAMRIA reference point MST-40 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MST-40 used as base station for the LiDAR acquisition.

| Station Name | MST-40 | |
|---|---|---|
| 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 | 12° 10' 39.45274" North<br>123° 47' 33.62147" East<br>4.72600 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting<br>Northing | 586266.511 meters<br>1346708.7 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 10' 34.84826" North<br>123° 47' 38.70589" East<br>61.65900 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 586236.32 meters<br>1346237.33 meters |


(b)

(a)

Figure 5. GPS set-up over MST-49 as recovered in front of the Cataingan Municipal Hall, municipality of Cataingan, Masbate (a) and NAMRIA reference point MST-49 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MST-49 used as base station for the LiDAR acquisition.

| **Station Name** | **MST-49** | |
|---|---|---|
| **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 | 12° 00’ 01.41677” North<br>123° 59’ 46.24265” East<br>21.25500 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting<br>Northing | 608487.281 meters<br>1327175.1 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 11° 59’ 56.87354” North<br>123° 59’ 51.34085” East<br>79.14000 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 608449.31 meters<br>1326710.57 meters |

(b)

(a)

Figure 6. GPS set-up over MS-61 as recovered in Nabangig Bridge, Brgy. Nabangig, municipality of Palanas, Masbate (a) and NAMRIA reference point MS-61 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA Benchmark MS-61 used as base station for the LiDAR acquisition.

| Station Name | MS-61 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (Horizontal positioning) | 1:50000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 06’ 1.51238” North<br>123° 57’ 21.24483” East<br>4.74 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 05’ 56.94091” North<br>123° 57’ 26.33451” East<br>65.257 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 604178.664 meters<br>1337699.951 meters |

Table 6. Ground control points used during LiDAR data acquisition.

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| March 21, 2014 | 1247P | 1BLK32IJ080A | MST-34 and MST-40 |
| March 27, 2014 | 1271P | 1BLK32H086A | MST-49 and MS-61 |
| March 28, 2014 | 1275P | 1BLK32HI087A | MST-40 and MST-49 |
| March 29, 2014 | 1281P | 1BLK32I088B | MST-40 and MST-49 |
| April 1, 2014 | 1293P | 1BLK32H091B | MST-40 and MST-49 |
| November 12, 2015 | 2842P | 1BLK2DSG319A | CGY-87, APA-13, CGY-110 |

## 2.3 Flight Missions

Five (5) missions were conducted to complete LiDAR data acquisition in Guiom Floodplain, for a total of fifteen hours and fourteen minutes (15+14) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR systems. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for the LiDAR data acquisition of the Guiom Floodplain.

| Date Surveyed | Flight Number | Flight Plan Area (km2) | Surveyed Area (km2) | Area Surveyed within the Floodplain ($km^2$) | Area Surveyed Outside the Floodplain (km2) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| March 21, 2014 | 1247P | 276.40 | 327.01 | 3.51 | 323.50 | 846 | 4 | 0 |
| March 27, 2014 | 1271P | 267.86 | 169.46 | 22.75 | 146.71 | 1184 | 4 | 23 |
| March 28, 2014 | 1275P | 267.86 | 126.66 | 34.41 | 92.25 | 620 | 2 | 53 |
| March 29, 2014 | 1281P | 283.20 | 126.99 | 21.33 | 105.66 | 0 | 1 | 53 |
| April 1, 2014 | 1293P | 267.86 | 82.51 | 10.27 | 72.24 | 423 | 2 | 5 |
| TOTAL | | 1363.20 | 832.63 | 92.27 | 740.36 | 740.36 | 15 | 14 |

Table 8. Actual parameters used during LiDAR data acquisition

| Flight Number | Flying Height (m AGL) | Overlap (%) | FOV (θ) | PRF (khz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 1247P | 1000, 1200 | 25 | 50 | 200 | 30 | 130 | 5 |
| 1271P | 800, 600 | 25, 30 | 50 | 200 | 30 | 130 | 5 |
| 1275P | 800 | 25 | 40 | 250 | 36 | 130 | 5 |
| 1281P | 1000 | 40 | 50 | 200 | 30 | 130 | 5 |
| 1293P | 800 | 25 | 40 | 250 | 36 | 130 | 5 |
| 2854P | 1100/900 | 30 | 50 | 200 | 30 | 130 | 5 |

## 2.4 Survey Coverage

Guiom floodplain is located in the province of Masbate, with majority of the floodplain situated within the municipality of Cawayan and Placer. Municipalities of Cawayan, Uson and Mobo are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Guiom Floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed of the Pamplona Floodplain LiDAR acquisition.

| Province | Municipality/ City | Area of Municipality/City (km2) | Total Area Surveyed (km2) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Masbate | Cawayan | 261.38 | 245.26 | 94% |
| | Dimasalang | 100.44 | 25.56 | 25% |
| | Milagros | 530.43 | 82.98 | 16% |
| | Mobo | 143.02 | 92.96 | 65% |
| | Palanas | 138.17 | 16.07 | 12% |
| | Placer | 253.55 | 106.79 | 42% |
| | Uson | 183.76 | 133.69 | 73% |
| Total | | 1610.75 | 703.31 | 43.66% |

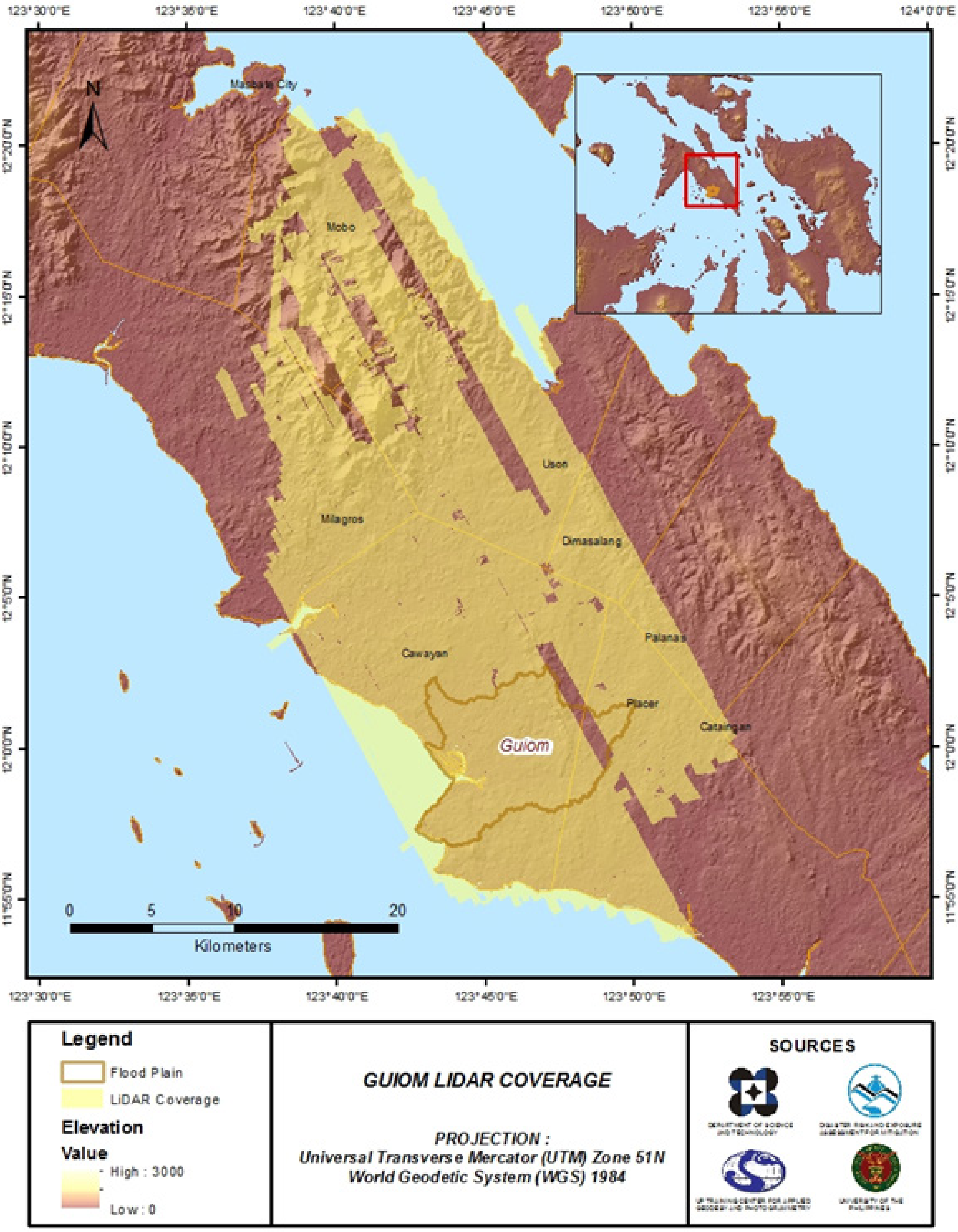


Figure 7. Actual LiDAR survey coverage for Guiom floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING OF THE GUIOM FLOODPLAIN

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

## 3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 8.

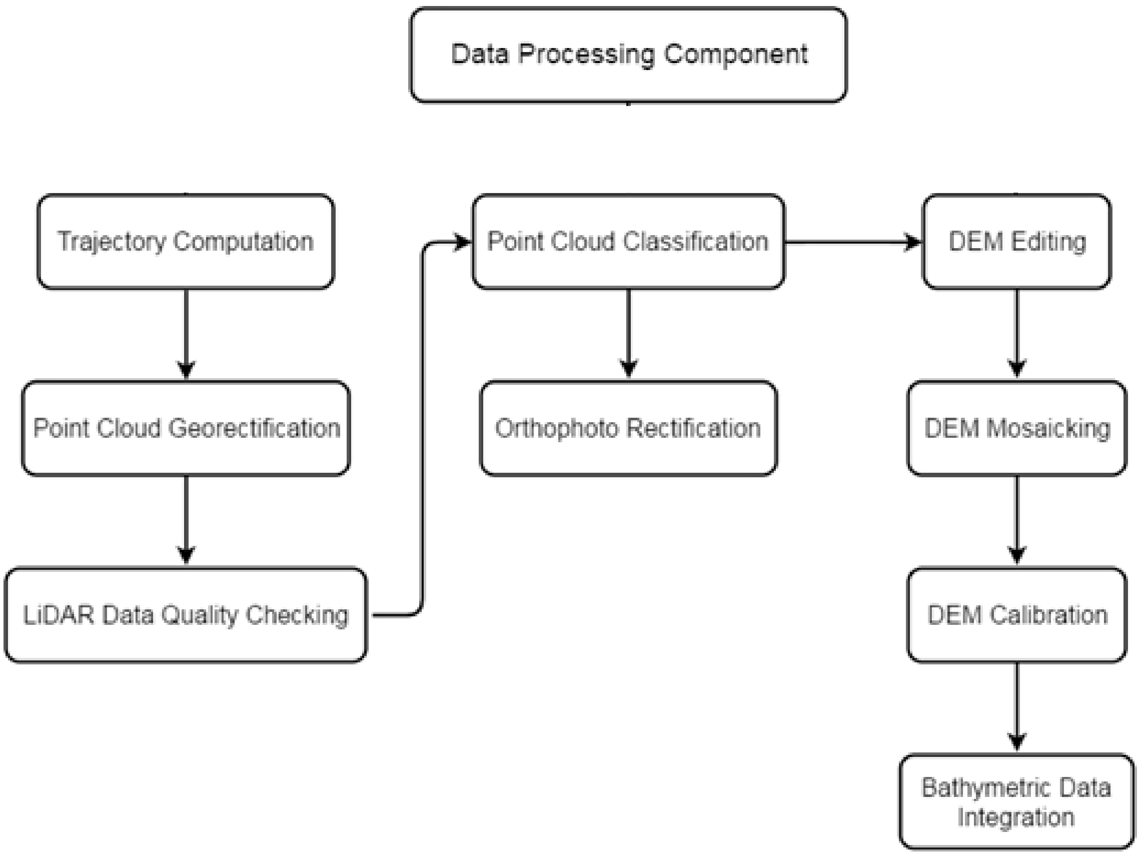



Figure 8. Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Guiom floodplain can be found in Annex 5. Missions flown during the two surveys conducted on March 2014 and April 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Cawayan, Masbate. The Data Acquisition Component (DAC) transferred a total of 125.10 Gigabytes of Range data, 0.88 Gigabytes of POS data, 32.85 Megabytes of GPS base station data, and 193.10 Gigabytes of raw image data to the data server on April 3, 2014 for the first survey and April 23, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Guiom was fully transferred on April 23, 2014, as indicated on the Data Transfer Sheets for Guiom floodplain.

## 3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1293P, one of the Guiom flights, which is the North, East, and Down position RMSE values are shown in Figure 9. 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 March 30, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

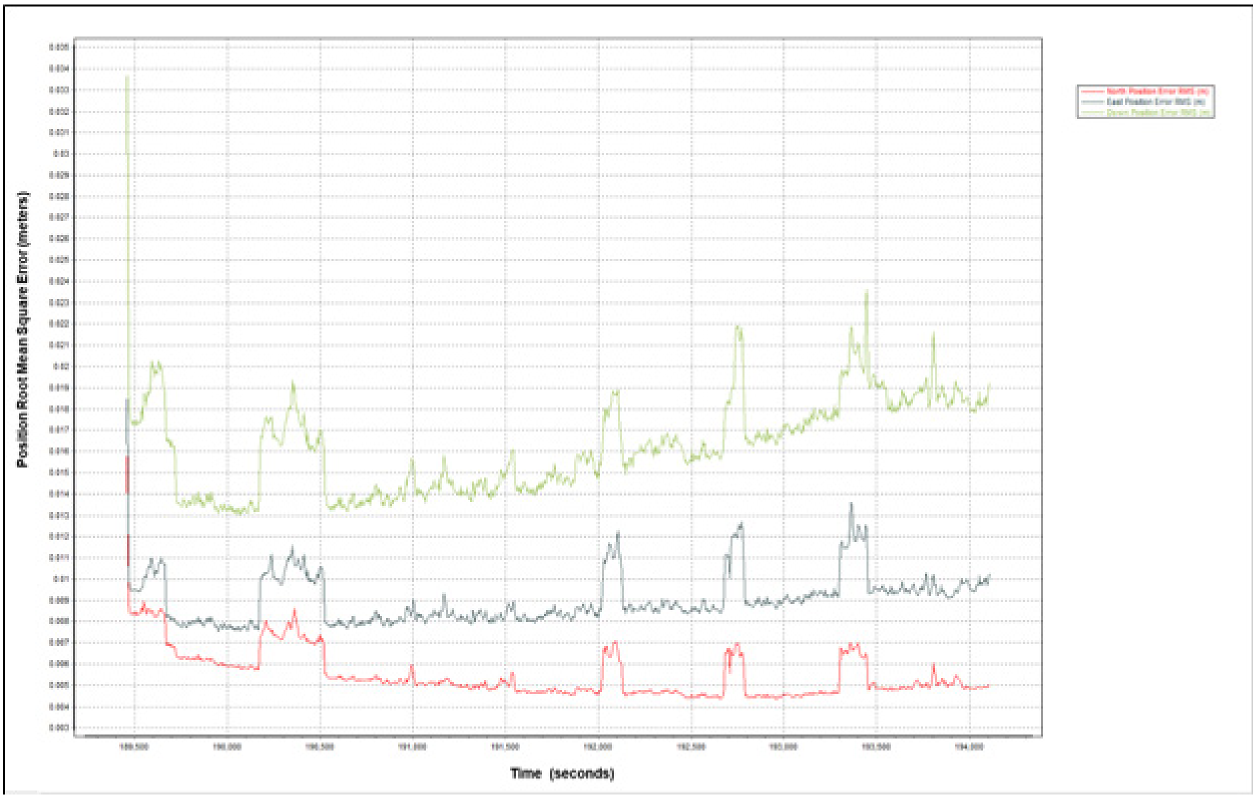



Figure 9. Smoothed Performance Metrics of a Guiom Flight 1293P.

The time of flight was from 189500 seconds to 194000 seconds, which corresponds to morning of April 1, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 0.90 centimeters, the East position RMSE peaks at 1. 40 centimeters, and the Down position RMSE peaks at 2.40 centimeters, which are within the prescribed accuracies described in the methodology.

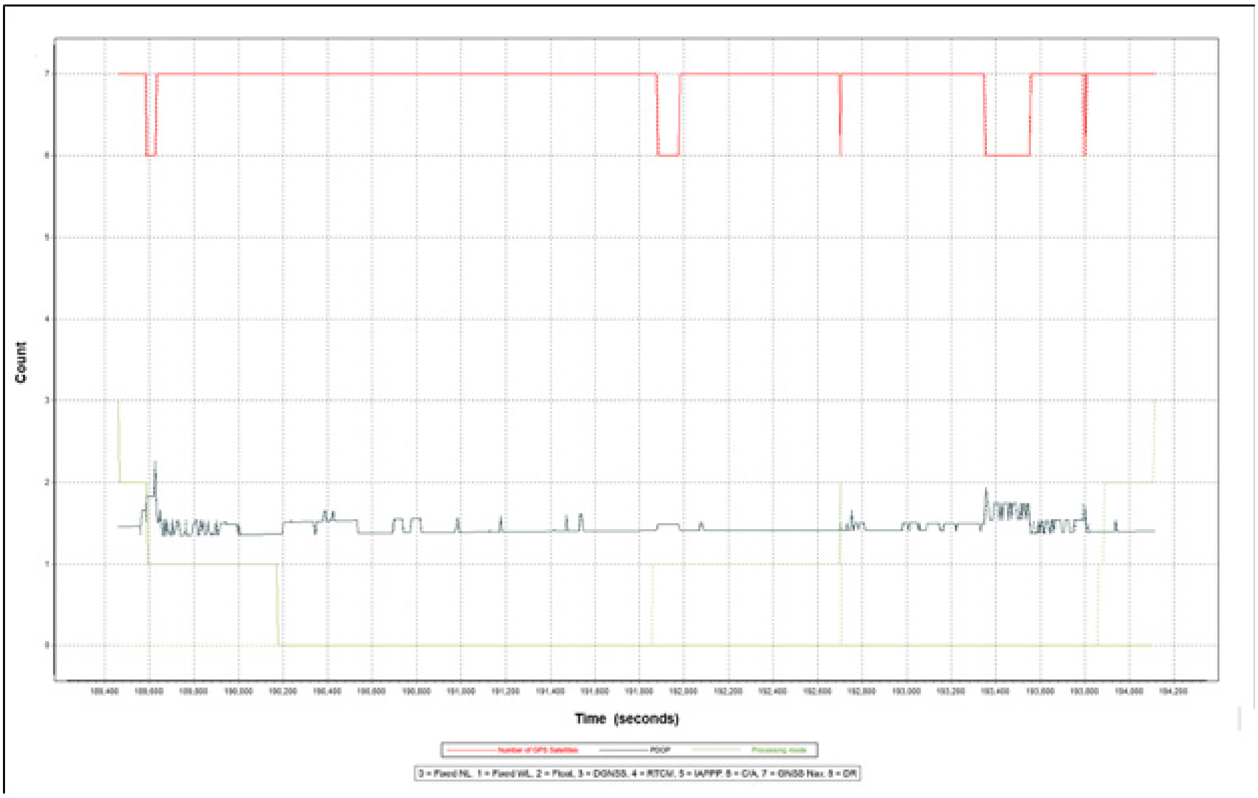



Figure 10. Solution Status Parameters of Guiom Flight 1293P.

The Solution Status parameters of flight 1293P, one of the Guiom flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 6 and 7. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Guiom flights is shown in Figure 11.

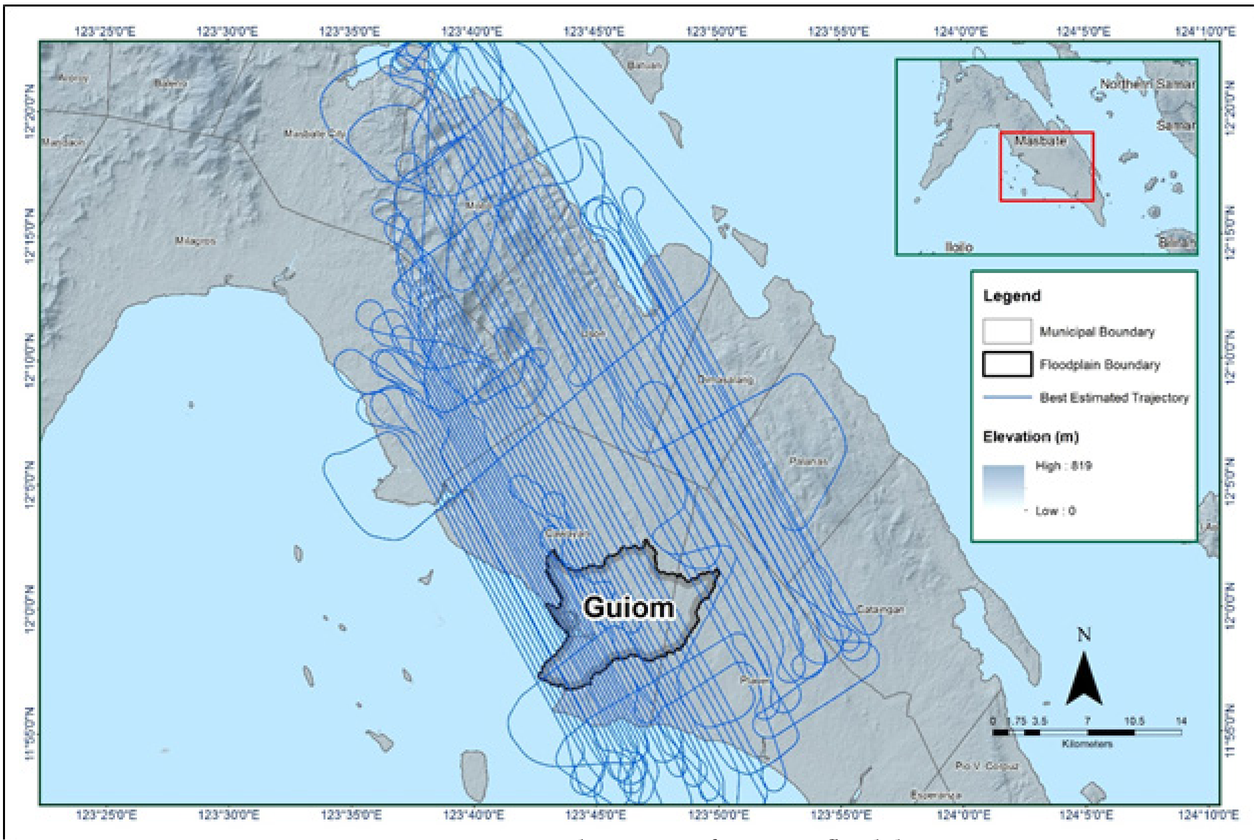


Figure 11. Best Estimated Trajectory for Guiom floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 81 flight lines, with each flight line containing two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Guiom floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Guiom flights.

| Parameter | Acceptable Value | Computed Value |
|---|---|---|
| Boresight Correction stdev | <0.001degrees | 0.000200 |
| IMU Attitude Correction Roll and Pitch Correction stdev | <0.001degrees | 0.000846 |
| GPS Position Z-correction stdev | <0.01meters | 0.0022 |

The optimum accuracy is obtained for all Guiom 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 Guiom Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

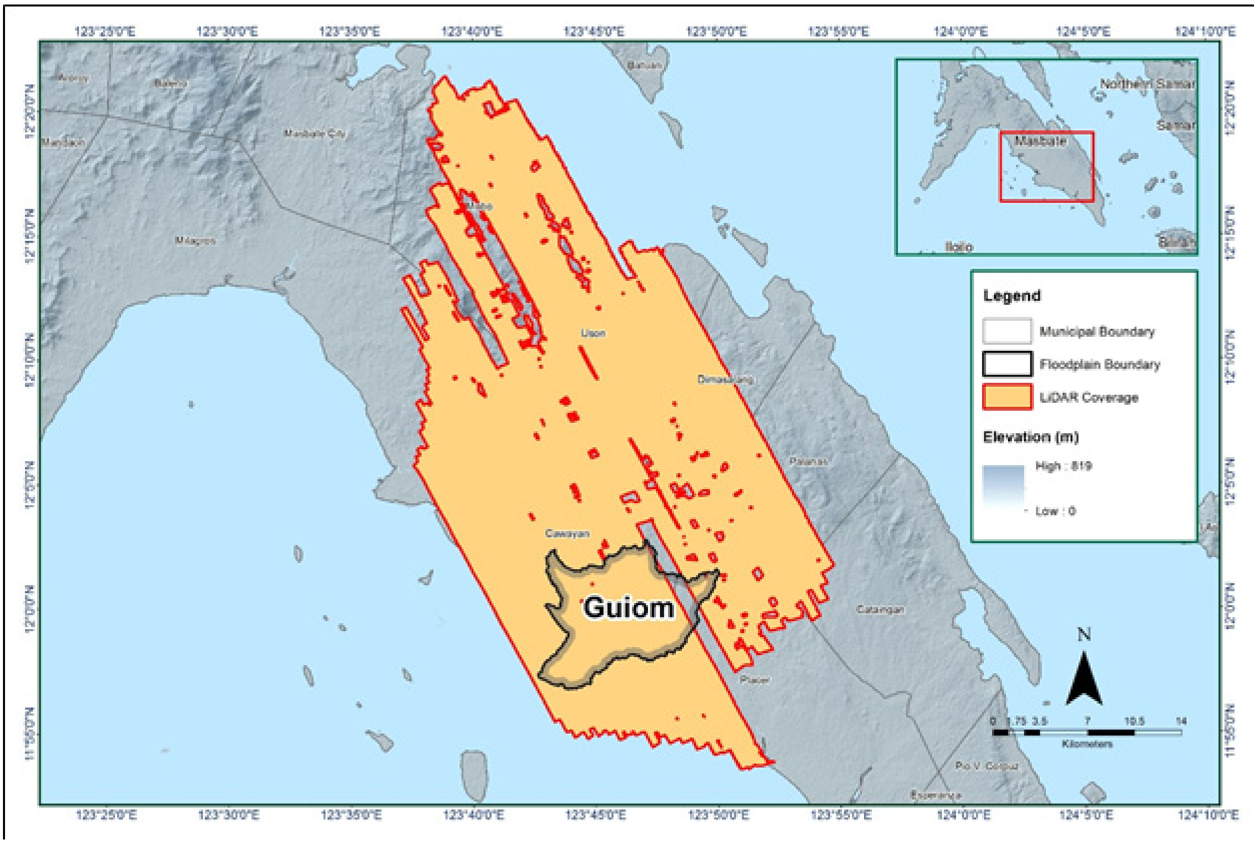



Figure 12. Boundary of the processed LiDAR data over Guiom Floodplain

The total area covered by the Guiom missions is 855.86 sq.km that is comprised of five (5) flight acquisitions grouped and merged into two (2) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Guiom floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Masbate Blk32IJ | 1247P | 540.53 |
| | 1281P | |
| Masbate Blk32H | 1293P | 315.33 |
| | 1275P | |
| | 1271P | |
| TOTAL | | 855.86 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 13. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

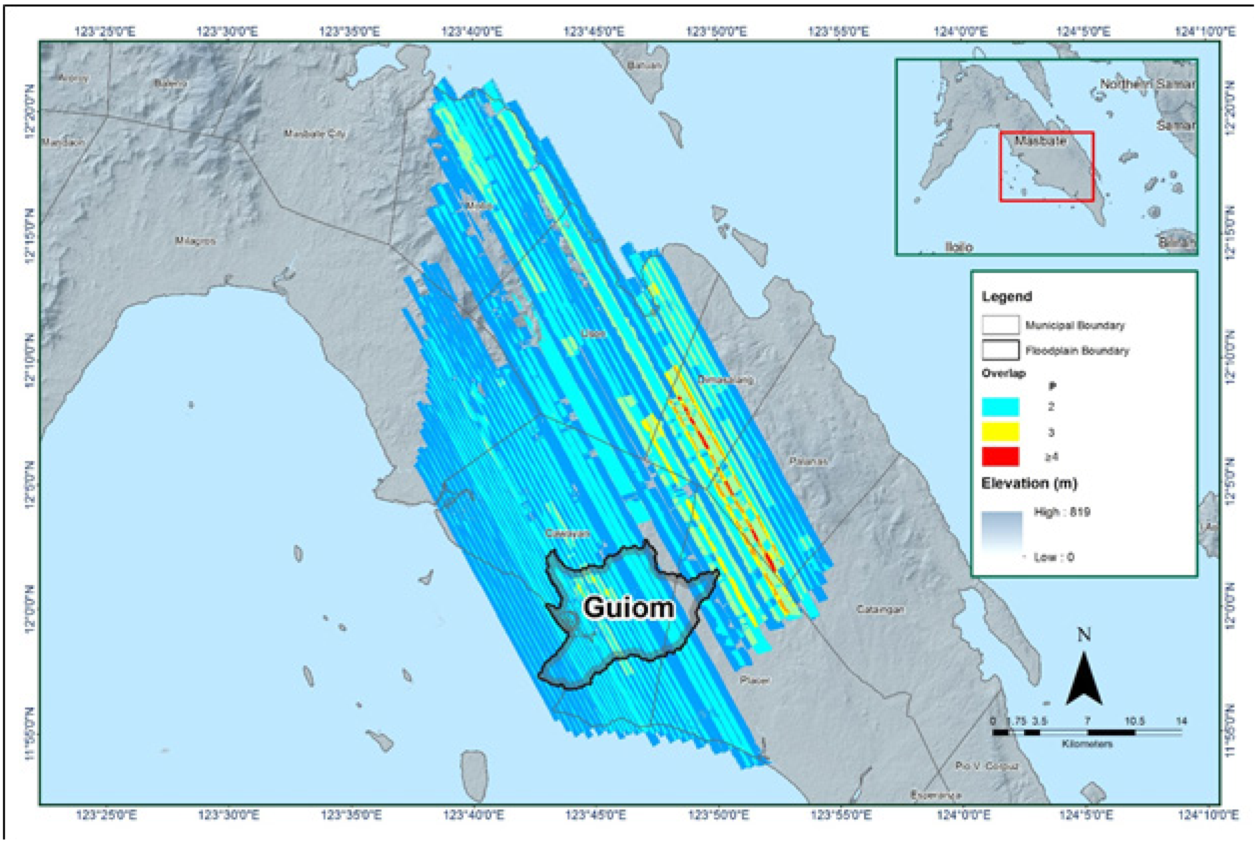



Figure 13. Image of data overlap for Guiom floodplain.

The overlap statistics per block for the Guiom 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 2.25% and 17.09% respectively.

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 14. It was determined that all LiDAR data for Guiom floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.52 points per square meter.

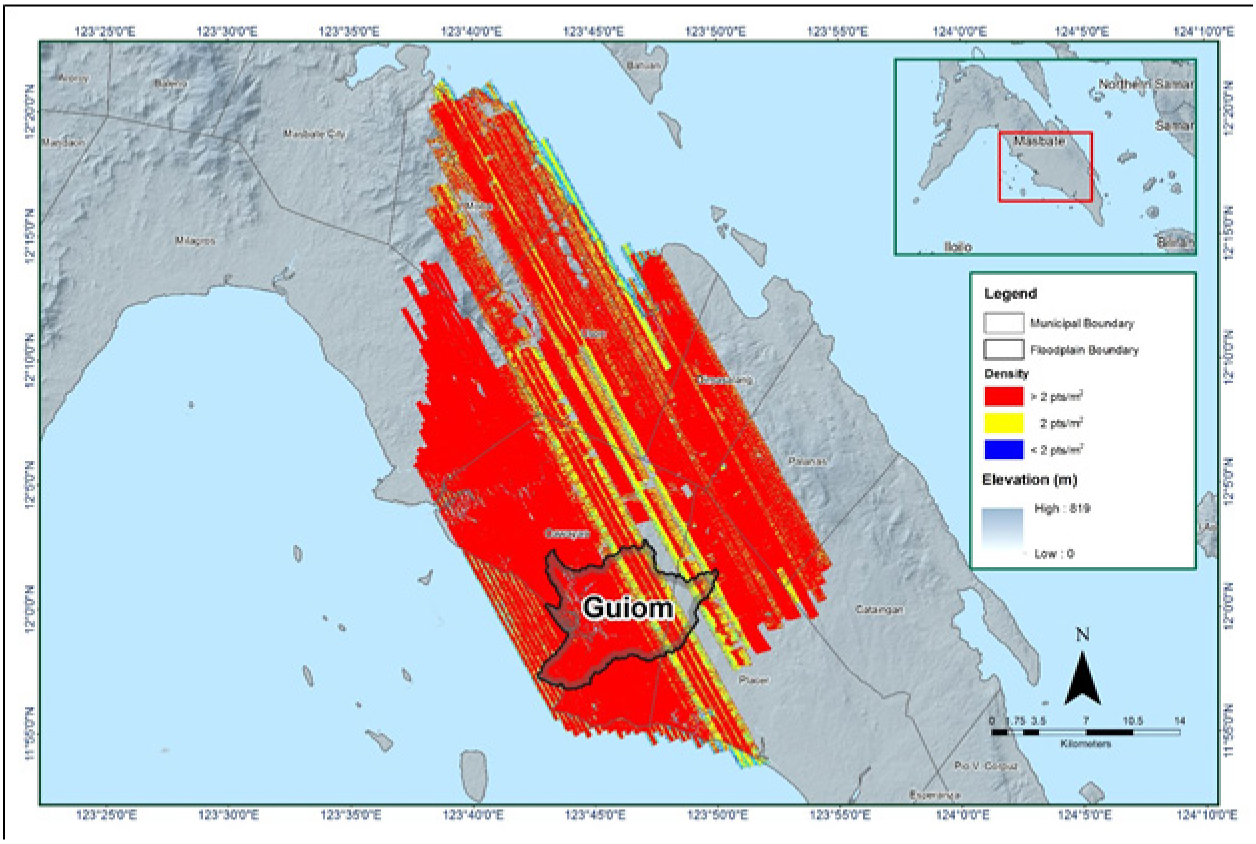



Figure 14. Density map of merged LiDAR data for Guiom floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. 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.

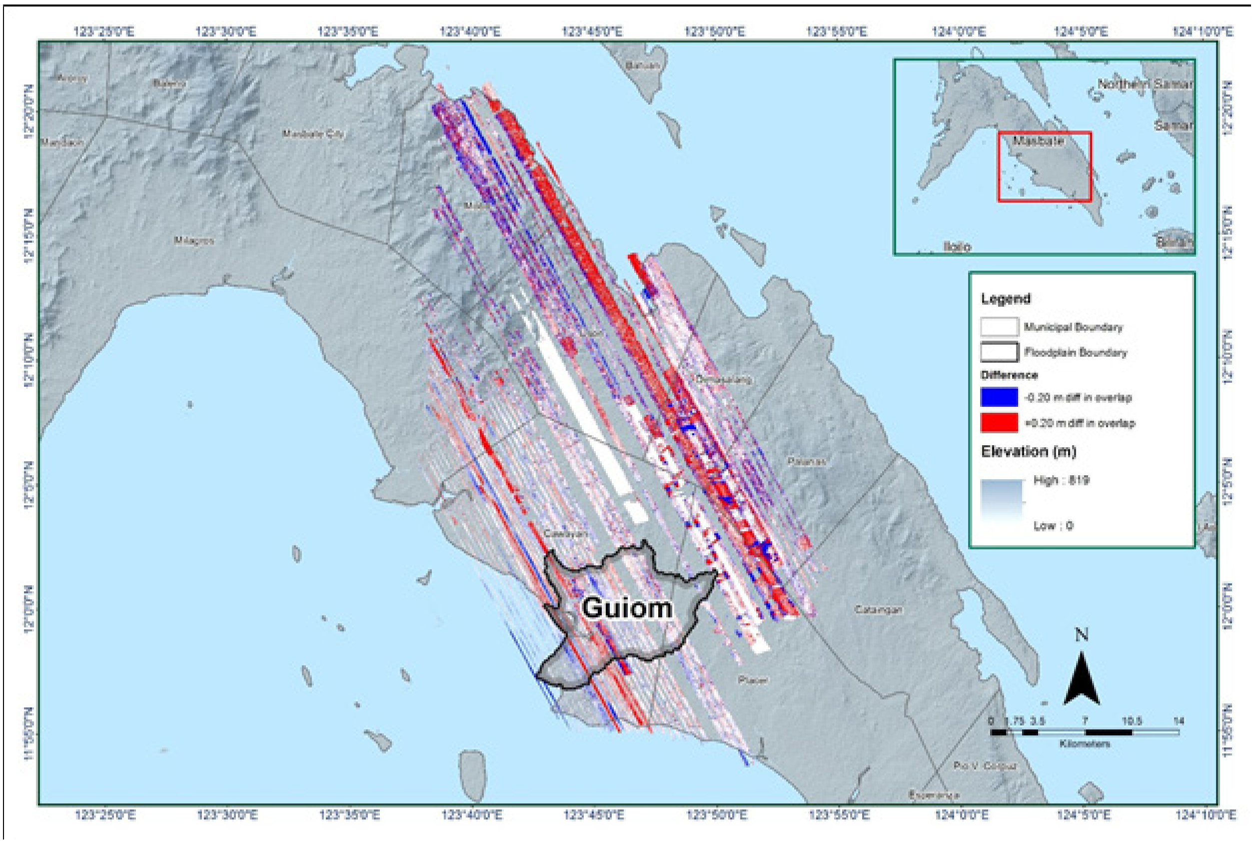



Figure 15. Elevation difference map between flight lines for Guiom floodplain.

A screen capture of the processed LAS data from a Guiom flight 1293P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

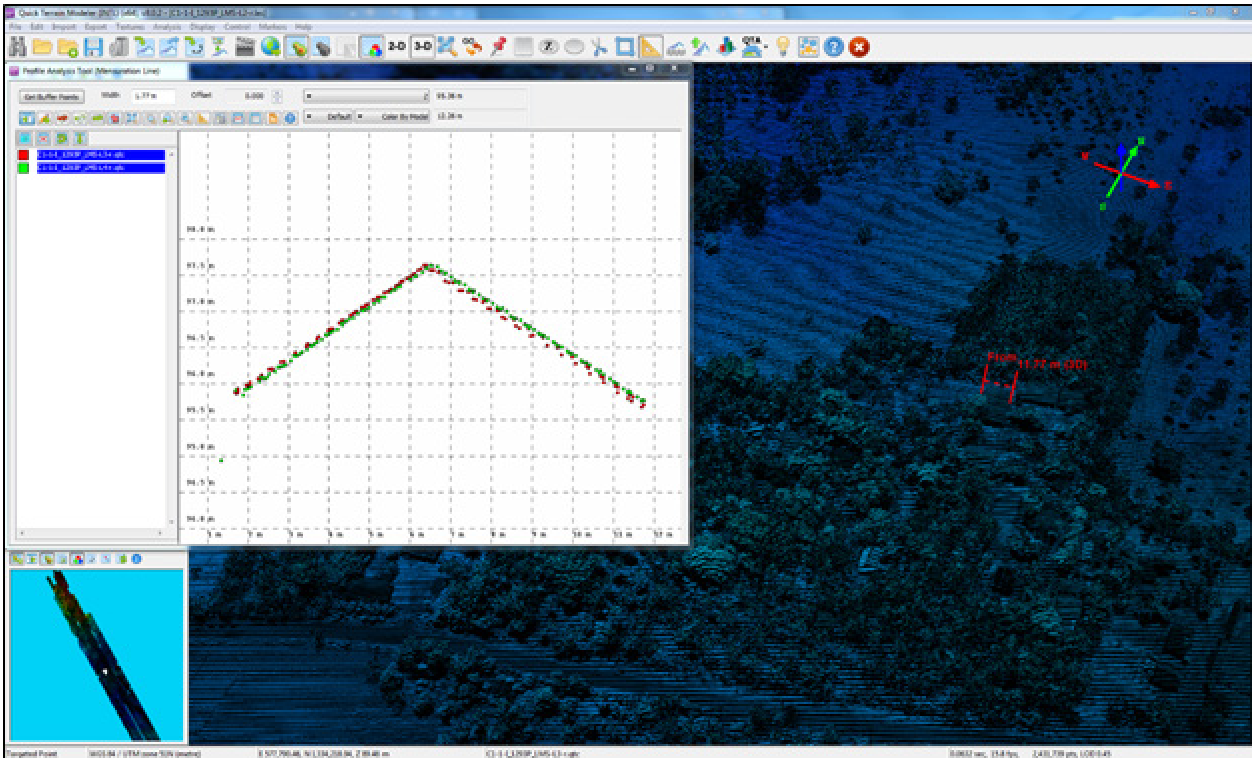


Figure 16. Quality checking for a Guiom flight 1293P using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Guiom classification results in TerraScan.

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 977,567,939 |
| Low Vegetation | 585,853,057 |
| Medium Vegetation | 679,020,469 |
| High Vegetation | 343,997,895 |
| Building | 6,934,479 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Guiom floodplain is shown in Figure 17. A total of 1,070 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 603.95 meters and 42.31 meters respectively.

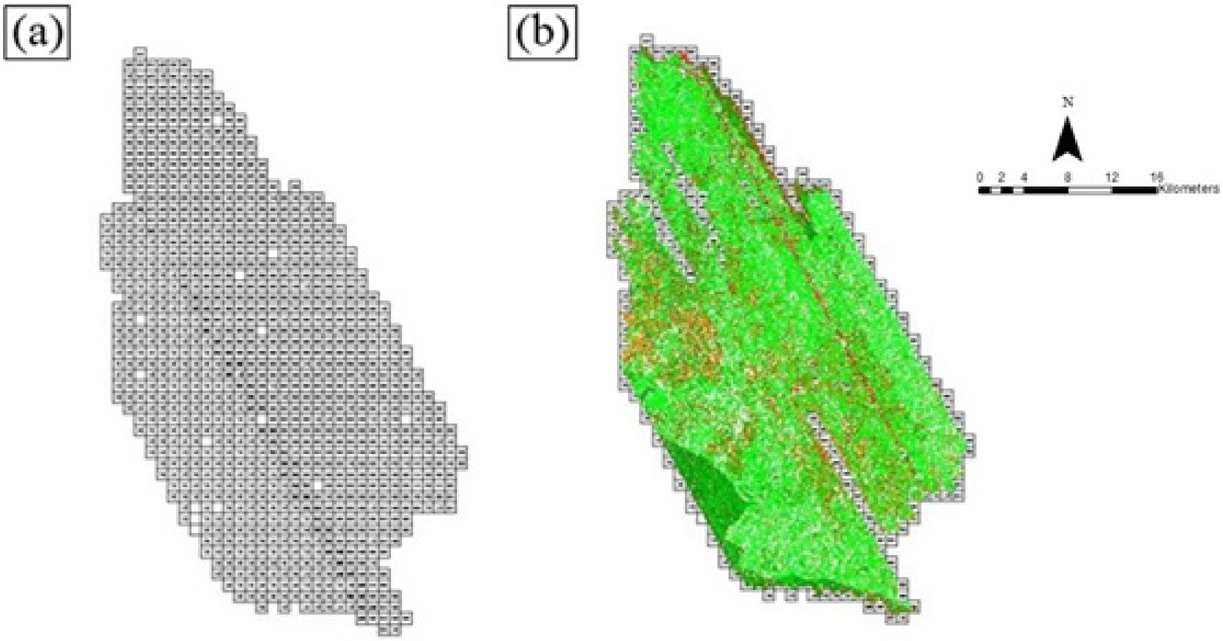



Figure 17. Tiles for Guiom floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

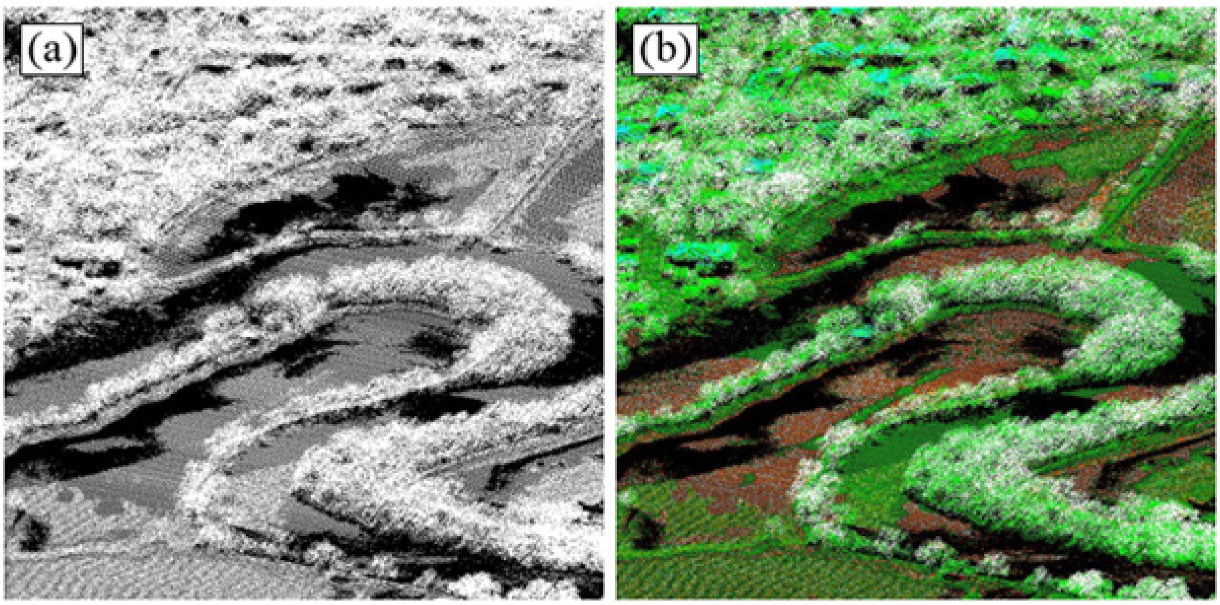



Figure 18. Point cloud before (a) and after (b) classification.

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

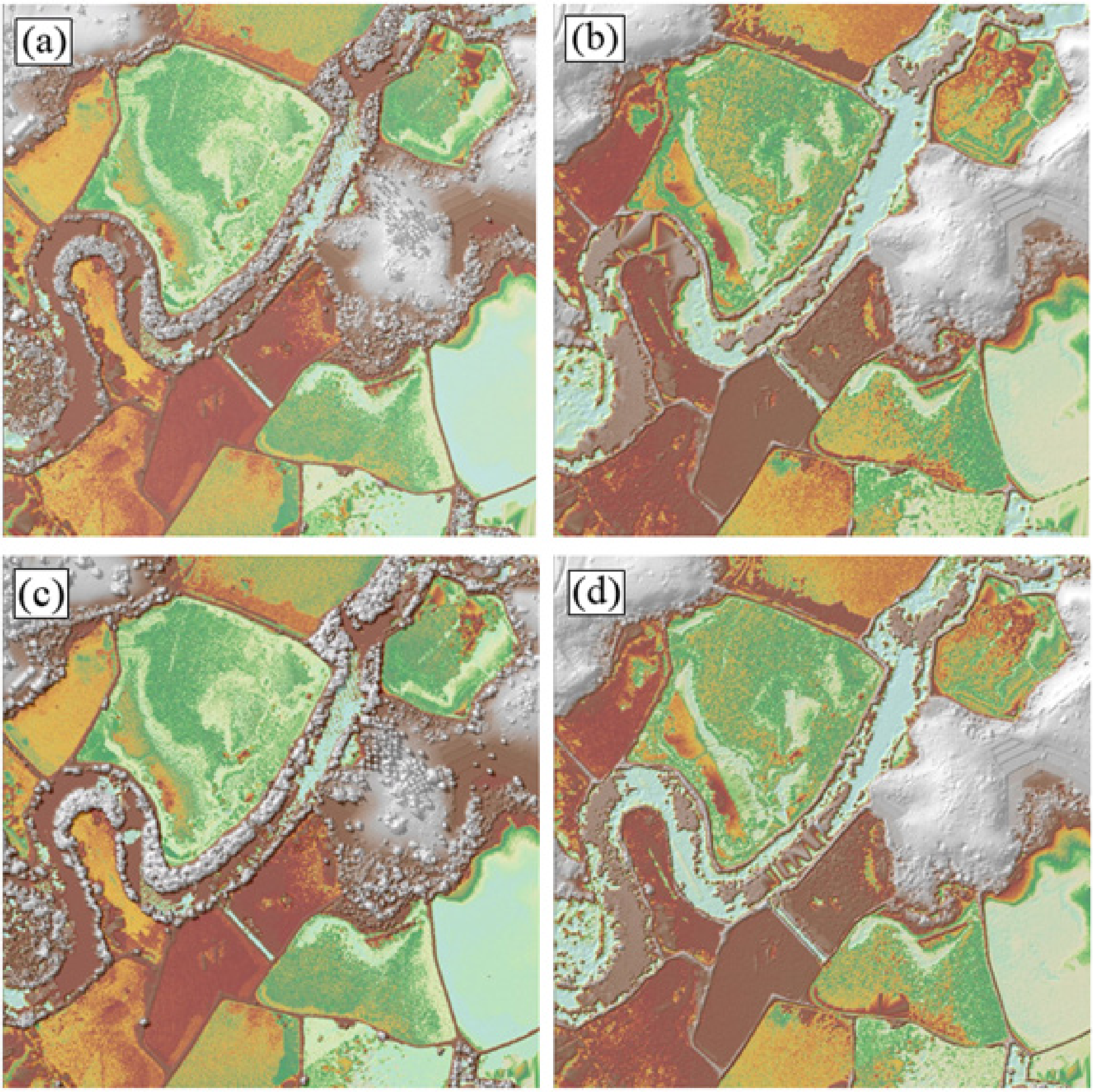



Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Guiom floodplain.

### 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 891 1km by 1km tiles area covered by Guiom floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Guiom floodplain has a total of 754.40 sq.km orthophotogaph coverage comprised of 3,712 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

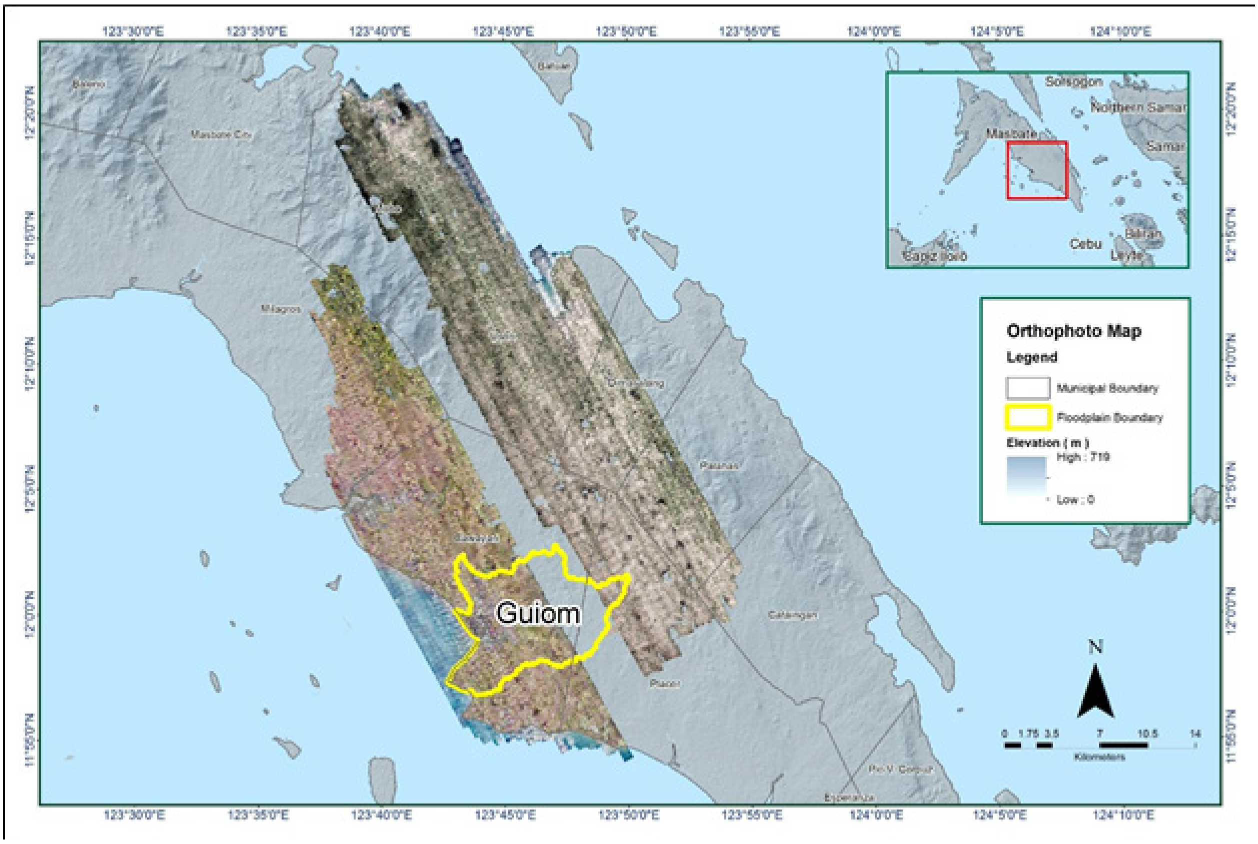



Figure 20. Guiom floodplain with available orthophotographs.


Figure 21. Sample orthophotograph tiles for Guiom floodplain.

## 3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Guiom flood plain. These blocks are composed of Masbate blocks with a total area of 855.86 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

| LiDAR Blocks | Area (sq.km) |
|---|---|
| Masbate_Blk32H | 315.33 |
| Masbate_Blk32IJ | 540.53 |
| TOTAL | 855.86 sq.km |

Portions of DTM before and after manual editing are shown in Figure 22. It shows that the mountain ridge (Figure 22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22b) to allow the correct flow of water. The triangulated riverbank (Figure 22c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22d) in order to hydrologically correct the river.

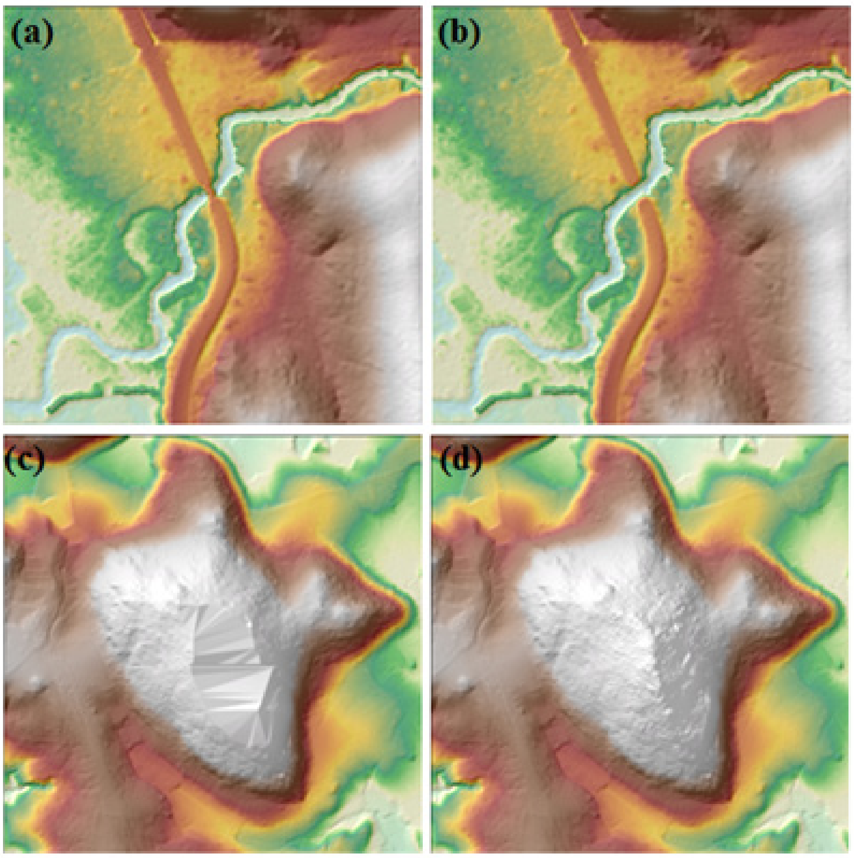



Figure 22. Portions in the DTM of Guiom floodplain – a bridge before (a) and after (b) manual editing; a mountain before (c) and after (d) data retrieval;

## 3.9 Mosaicking of Blocks

Masbate_Blk32D was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Guiom floodplain is shown in Figure 23. The entire Guiom flood plain is 94.49% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

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

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| Masbate_Blk32H | 0.00 | 0.00 | 1.64 |
| Masbate_Blk32IJ | 0.00 | 0.00 | 1.67 |

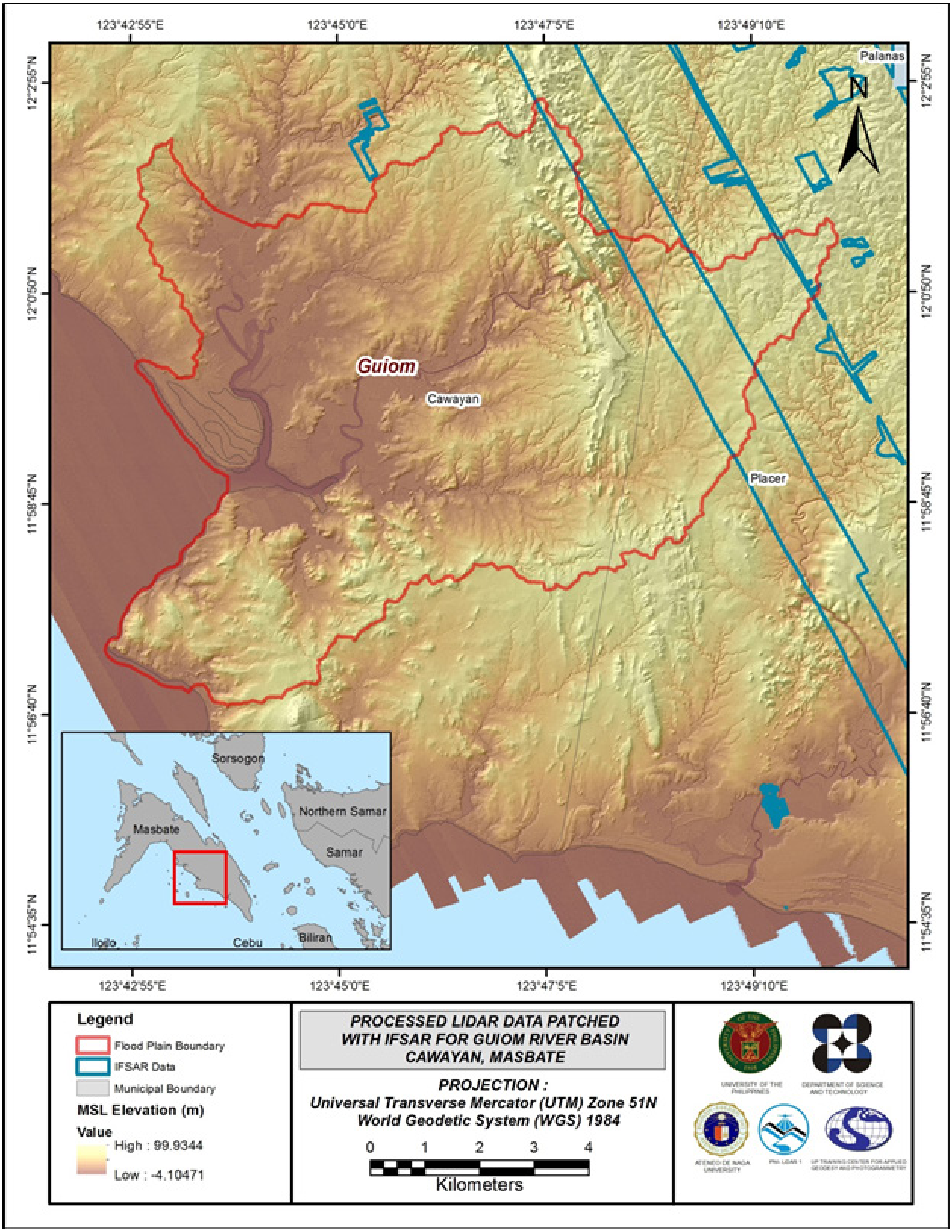



Figure 23. Map of Processed LiDAR Data for Guiom Flood Plain.

## 3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Guiom to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 2,639 survey points from Asid floodplain were used for calibration and validation of Guiom LiDAR data. Random selection of 80% of the survey points, resulting to 2,591 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 3.22 meters with a standard deviation of 0.16 meters. Calibration of Guiom LiDAR data was done by subtracting the height difference value, 3.22 meters, to Guiom mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

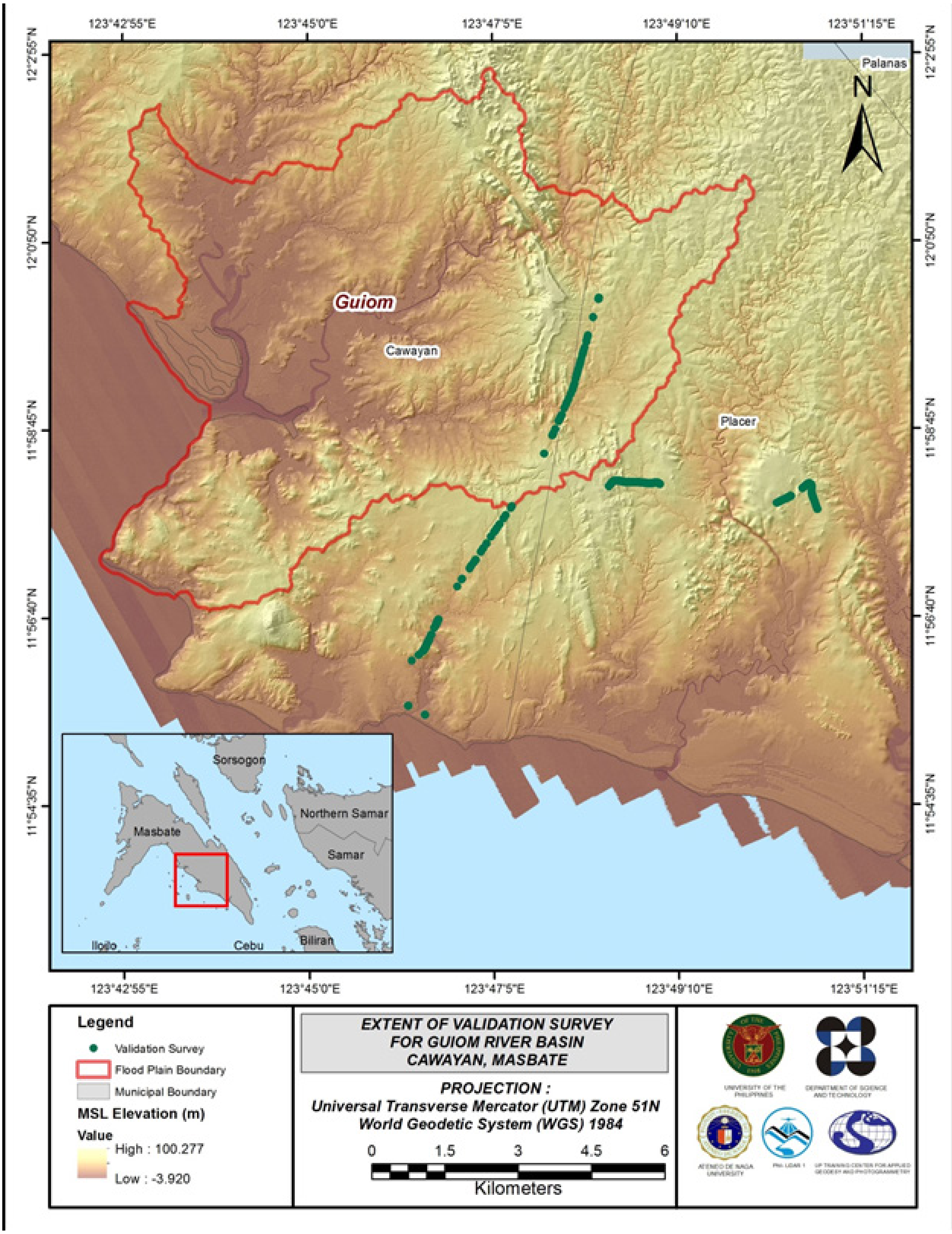



Figure 24. Map of Guiom Flood Plain with validation survey points in green.

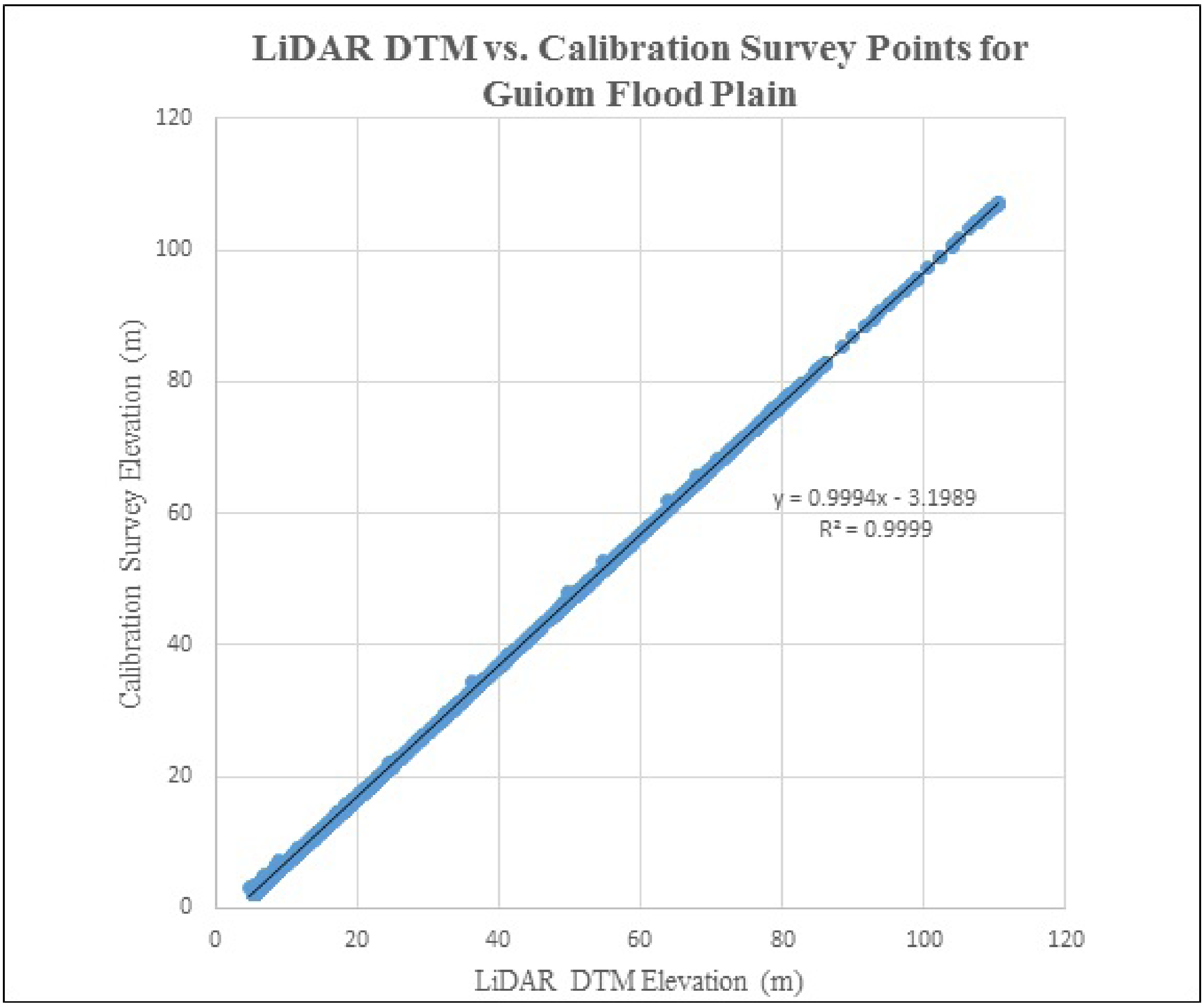



Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 3.22 |
| Standard Deviation | 0.16 |
| Average | -3.22 |
| Minimum | -3.53 |
| Maximum | -1.66 |

A total of 2105 survey points were collected by DVBC for Guiom floodplain. Random selection of points within and near the boundaries of the floodplain, resulting to 386 points, were used for the validation of the calibrated Guiom 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.14 meters with a standard deviation of 0.14 meters, as shown in Table 16.

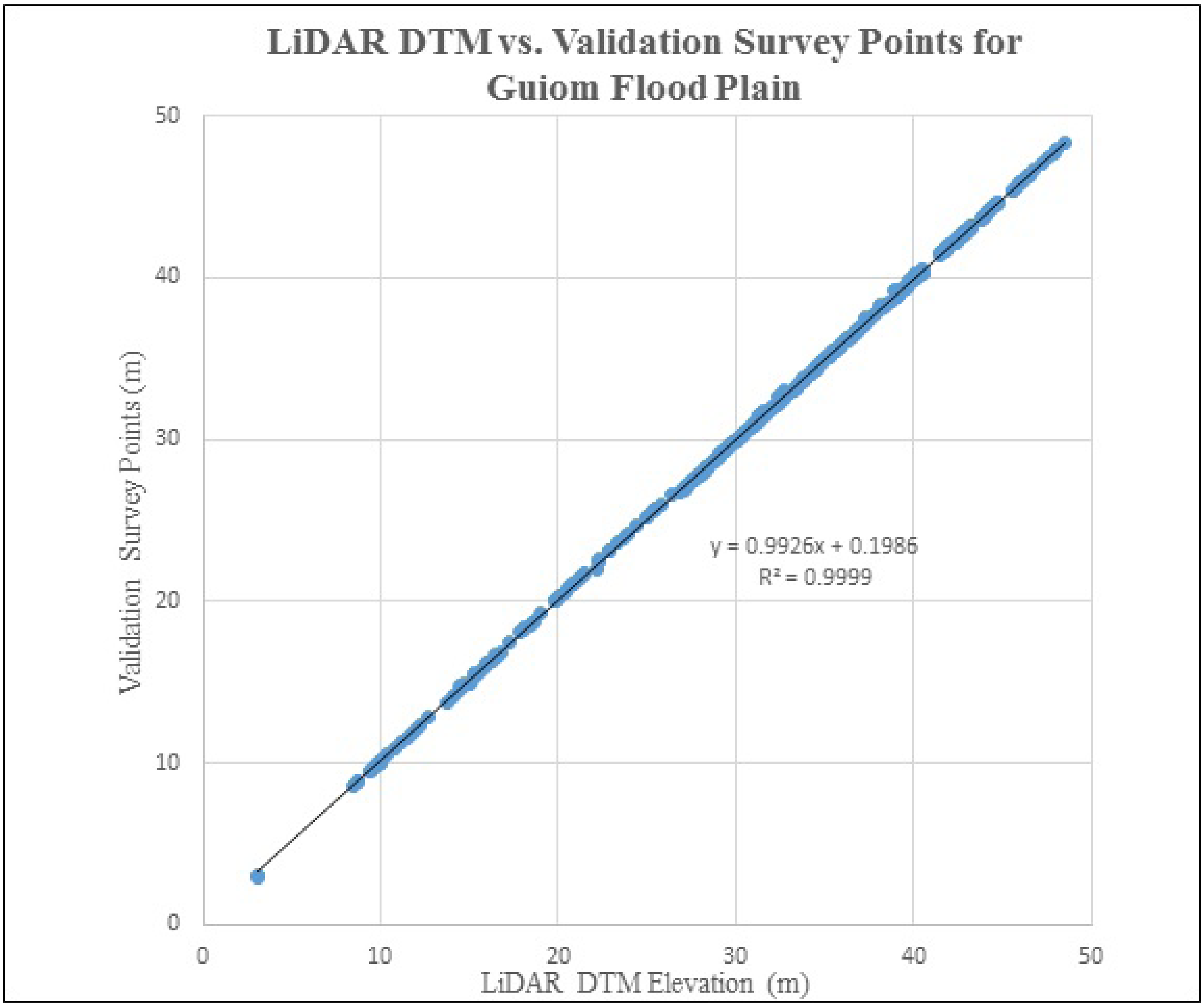



Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.14 |
| Standard Deviation | 0.14 |
| Average | 0.04 |
| Minimum | -0.24 |
| Maximum | 0.23 |

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

For bathy integration, centerline and zigzag data was available for Guiom with 11,914 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.497 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Guiom integrated with the processed LiDAR DEM is shown in Figure 27.

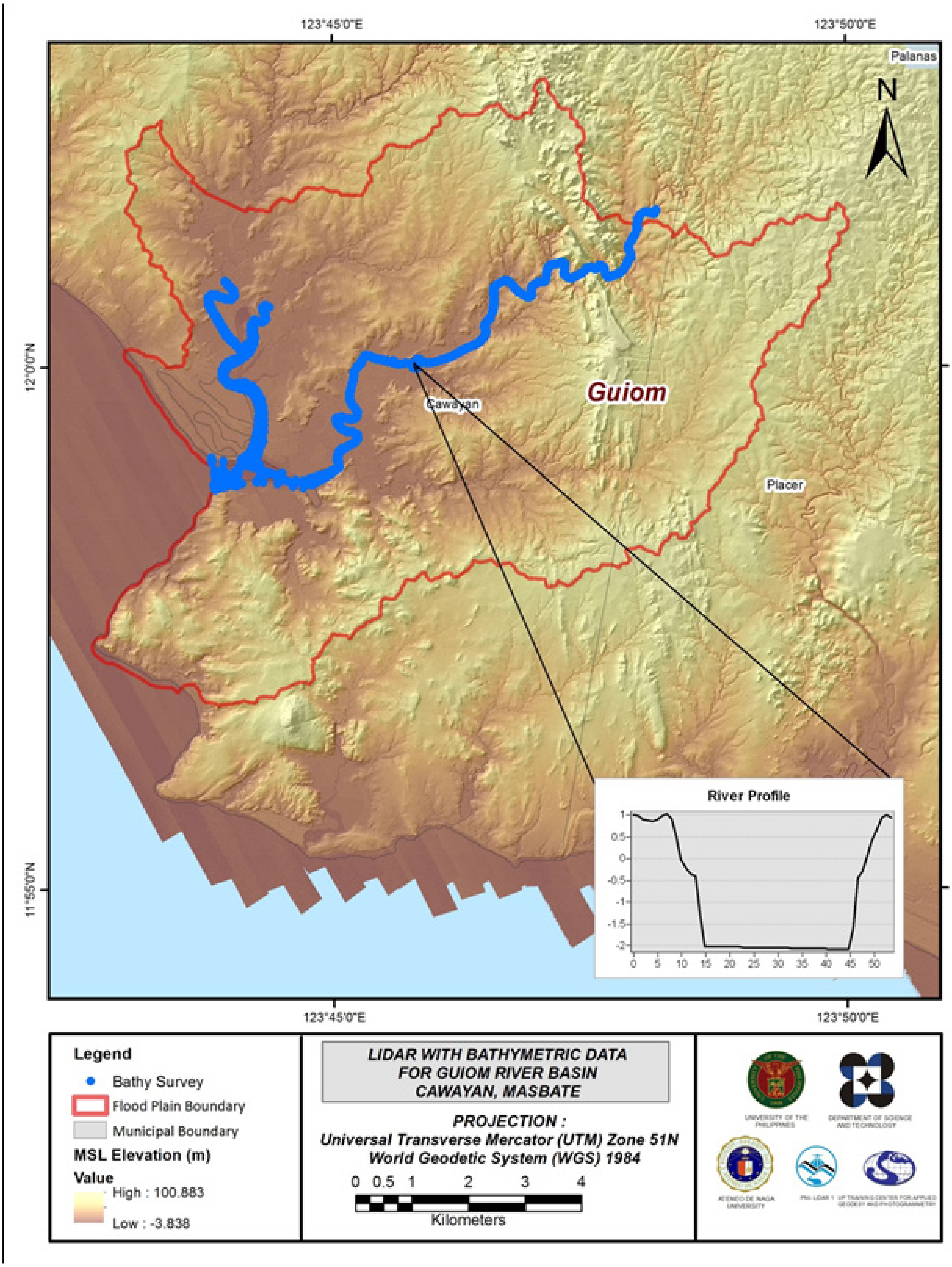



Figure 27. Map of Guiom Flood Plain with bathymetric survey points shown in blue.

## 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

Guiom floodplain, including its 200 m buffer, has a total area of 92.23 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,006 building features, are considered for QC. Figure 28 shows the QC blocks for Guiom floodplain.

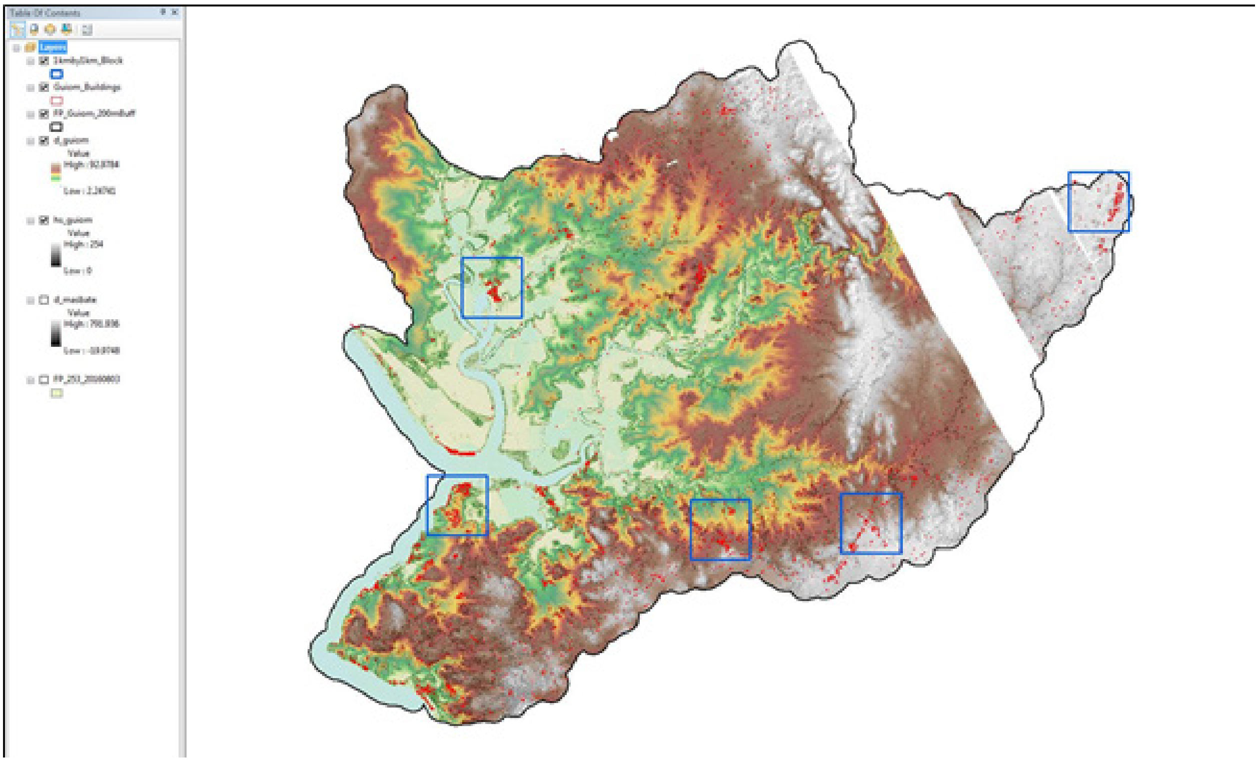


Figure 28. QC blocks for Guiom building features.

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

Table 17. Quality Checking Ratings for Guiom Building Features.

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Guiom | 100 | 100 | 99.11 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 6,198 building features in Guiom floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,448 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.55 m.

### 3.12.3 Feature Attribution

Feature Attribution was done for 5,448 building features in Guiom Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process.  The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features.  This effectively allows unified and standardized sets of data.

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

Table 18. Building Features Extracted for Guiom Floodplain.

| Facility Type | No. of Features |
|---|---|
| Residential | 5,365 |
| School | 56 |
| Market | 2 |
| Agricultural/Agro-Industrial Facilities | 1 |
| Medical Institutions | 8 |
| Barangay Hall | 5 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 0 |
| Telecommunication Facilities | 0 |
| Transport Terminal | 0 |
| Warehouse | 0 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 0 |
| Police Station | 0 |
| Water Supply/Sewerage | 0 |
| Religious Institutions | 10 |
| Bank | 0 |
| Factory | 0 |
| Gas Station | 0 |
| Fire Station | 0 |
| Other Government Offices | 1 |
| Other Commercial Establishments | 0 |
| **Total** | **5,448** |

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

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/Municipal Road | Provincial Road | National Road | Others | |
| Guiom | 85.44 | 0 | 0 | 0 | 0 | 85.44 |

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

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Guiom | 1 | 225 | 1 | 0 | 0 | 227 |

A total of 7 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

### 3.12.4 Final Quality Checking of Extracted Features

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

Figure 29 shows the Digital Surface Model (DSM) of Guiom floodplain overlaid with its ground features.

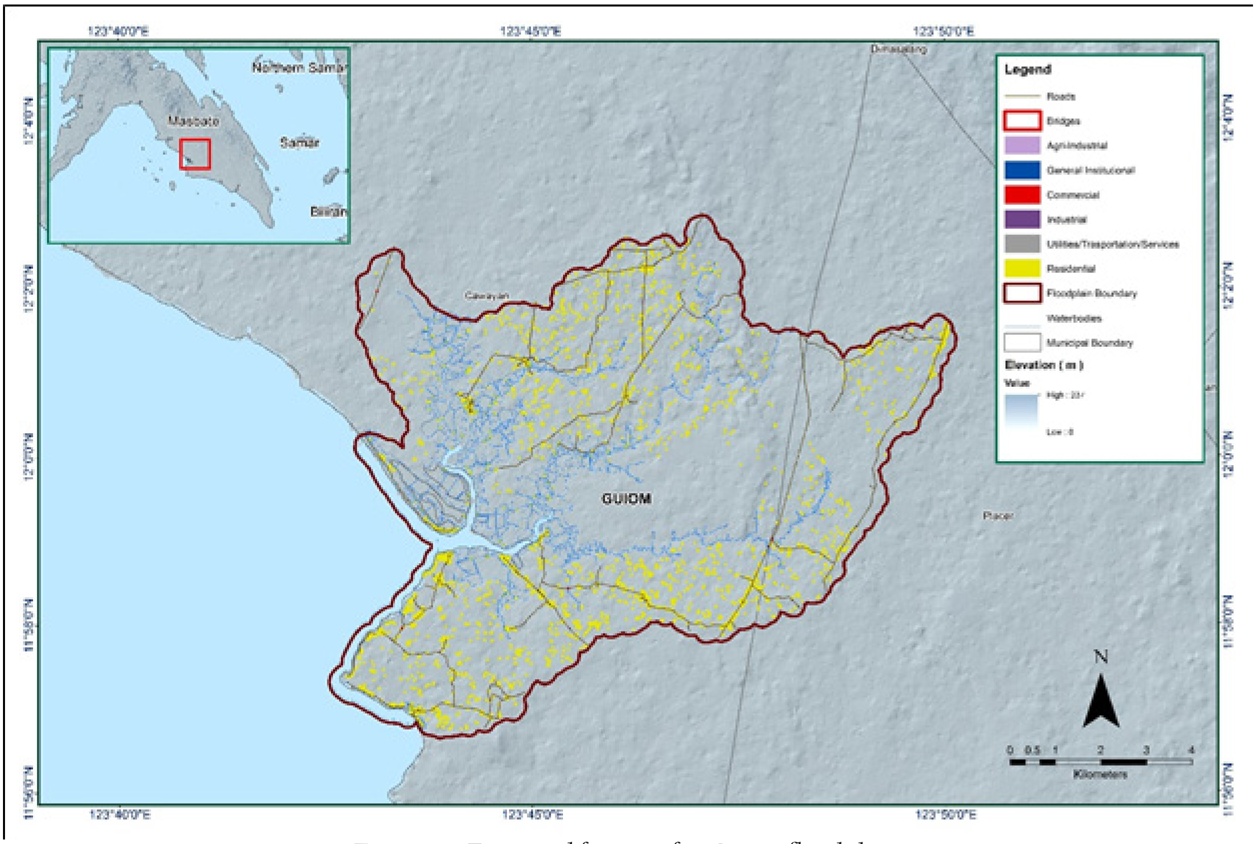



Figure 29. Extracted features for Guiom floodplain.

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

*Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, and Vie Marie Paola M. Rivera*

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

## 4.1 Summary of Activities

H.O. Noveloso Surveying (HONS) conducted a field survey in Guiom River on Jan. 14, 2017, Jan 18-19, 2017, Feb. 9-11, 2017, Feb. 13, 2017, Feb. 17, 2017, and March 3, 2017 with the following scope: reconnaissance; control survey for the establishment of a control point; and cross-section and as-built survey at Baldoza Bridge in Brgy. Villahermosa, Municipality of Cawayan, Masbate; and bathymetric survey of the main river from its uptream in Brgy. Villahermosa to the mouth of the river located in Brgy. Guiom, Municipality of Cawayan, Masbate, tributary 1 from its upstream in Brgy. Iraya to Brgy. Dalipe, Municipality of Cawayan, Masbate, and tributary 2 from its upstream in Brgy. Dalipe to the mouth of the river in Brgy. Guiom, Municipality of Cawayan, Masbate with an approximate length of 19.277 km using a dual frequency Topcon™ GR-5 and a Hydrolite™ Single Beam Echo Sounder. The entire survey extent is illustrated in Figure 30.

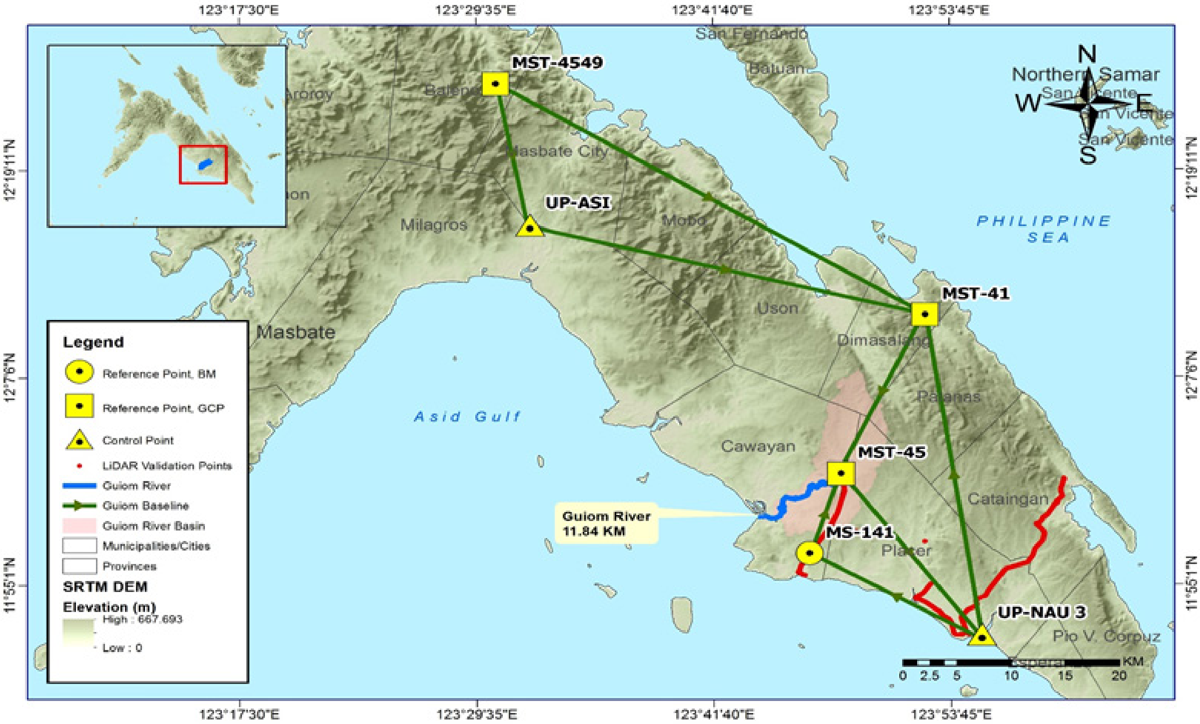



Figure 30. Guiom River Survey Extent

## 4.2 Control Survey

A GNSS network was established on December 4, 5 and 11, on 2015 for a previous Phil-LIDAR 1 survey in Lanang River occupying the following reference points: MST-27, a second order GCP in Brgy. Matiporon, Municipality of Milagros, Masbate; and MS-269, a first order BM in Brgy. Luy-A, Municipality of Aroroy, Masbate.

The GNSS network used for Guiom River Basin is composed of three (3) loops established on January 27 and February 14, 2017 occupying the following reference points: MST-4549, a fixed control from previous field survey in Lanang River located in Brgy. Canjunday, Municipality of Baleno, Masbate; UP-ASI, also a fixed control located in Brgy. Cayabon, Municipality of Milagros, Masbate; and MS-141, a first order BM located in Brgy. San Vicente, Municipality of Cawayan, Masbate.

A control point was established namely UP-NAU-3 located near the mouth of the Nauco Aguada River in Brgy, Taboc, Municipality of Placer, Masbate. NAMRIA established control point MST-41 in Brgy. San Vicente, Municipality of Cawayan; and MST-45, in Brgy. Villahermosa, Municipality of Cawayan, Masbate; were also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 31.

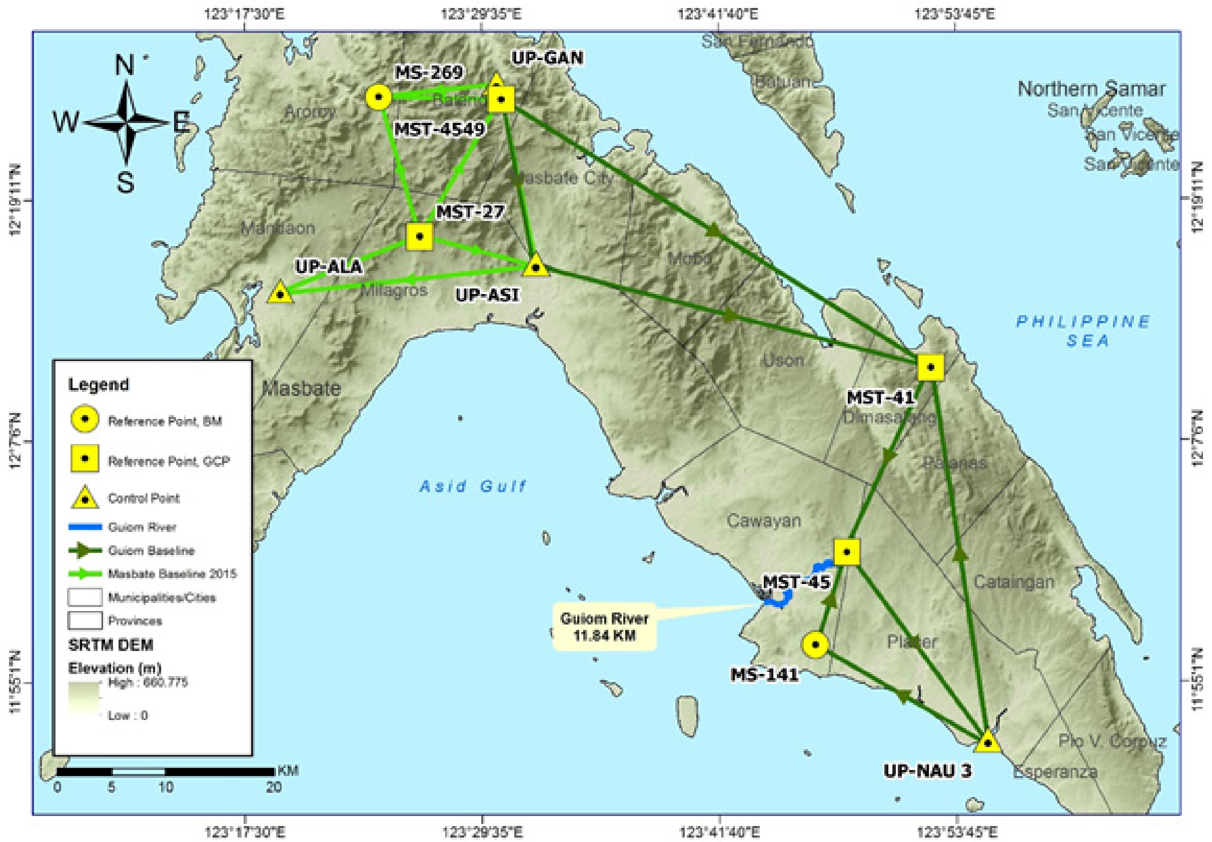



Figure 31. GNSS Network covering Guiom River

Table 21. List of Reference and Control Points occupied for Guiom River Survey

(Source: NAMRIA; UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS '84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (Meter) | Elevation in MSL (Meter) | Date Established |
| Control Survey on September 18, 2015 | | | | | | |
| MST-27 | 2nd Order GCP | 12°17'22.32360" | 123°26'26.50548" | 109.123 | 53.606 | 2007 |
| MS-269 | 1st Order BM | 12°24'21.62817" | 123°24'21.39816" | 82.132 | 27.408 | 2007 |
| Control Survey for Guiom River on January 27 and February 14, 2017 | | | | | | |
| MST-4549 | Fixed Control | 12°24'13.29041" | 123°30'36.98735" | 76.969 | 21.829 | 2013 |
| UP-ASI | Fixed Control | 12°15'59.72358" | 123°32'20.76940" | 66.451 | 10.476 | 2007 |
| MS-141 | 1st Order BM | - | - | - | - | 2007 |
| MST-41 | Used as Marker | - | - | - | - | 2-14-2017 |
| MST-45 | Used as Marker | - | - | - | - | 1-27-2017 |
| UP-NAU 3 | Established | - | - | - | - | 1-27-2017 |

The GNSS set-ups on recovered reference points and established control points in Guiom River are shown in Figure 32 to Figure 37.


Figure 32. GNSS base set up, Trimble® SPS 985, at MST-4549, located in Brgy. Canjunday, Municipality of Baleno, Masbate


Figure 33. GNSS receiver setup, Trimble® SPS 985, at UP-ASI, located Brgy. Cayabon, Municipality of Milagros, Masbate


Figure 34. GNSS receiver setup, Trimble® SPS 985, at MS-141, located in Brgy. San Vicente, Municipality of Cawayan, Masbate

Figure 35. GNSS receiver setup, Trimble® SPS 985, at MST-41, located in Brgy. Gaid, Municipality of Dimasalang, Masbate


Figure 36. GNSS receiver setup, Trimble® SPS 985, at MST-45, located in Brgy. Villahermosa, Municipality of Cawayan, Masbate


Figure 37. GNSS receiver setup, Trimble® SPS 985, at UP-NAU3, located in Brgy. Taboc, Municipality of Placer, Masbate

## 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 Guiom River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Summary Report for Guiom River Survey

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| UP-NAU 3 --- MS-141 (B6) | 1-27-2017 | Fixed | 0.004 | 0.019 | 298°53'38" | 18166.522 | 11.403 |
| MS-141 --- MST-45 (B3) | 1-27-2017 | Fixed | 0.004 | 0.016 | 18°57'41" | 9036.475 | 2.254 |
| MST-4549 --- UPASI (B8) | 1-27-2017 | Fixed | 0.003 | 0.014 | 168°18'59" | 15487.632 | -10.554 |
| UP-NAU 3 --- MST-41 (B10) | 1-27-2017 | Fixed | 0.003 | 0.015 | 351°30'42" | 34736.682 | 4.574 |
| MST-45 --- UP-NAU 3 (B4) | 2-14-207 | Fixed | 0.003 | 0.014 | 143°09'49" | 21636.574 | -13.668 |
| MST-41 --- MST-45 (B11) | 2-14-207 | Fixed | 0.004 | 0.020 | 204°41'47" | 18750.039 | 9.089 |
| UP-ASI --- MST-41 (B9) | 1-27-2017 | Fixed | 0.003 | 0.016 | 104°48'50" | 37813.501 | -2.533 |
| MST-4549 --- MST-41 (B7) | 1-27-2017 | Fixed | 0.004 | 0.019 | 122°01'41" | 46820.813 | -13.099 |

As shown Table 22 a total of eight (8) baselines were processed with reference points MST-4549 and UP-ASI held fixed for coordinate values; and, MST-4549, MS-ASI, and UP-ASI fixed for elevation values. 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 form:

$$\sqrt{((x^e)^2+(y^e)^2)} < 20\text{cm and } z^e < 10 \text{ cm}$$

where:

$x^e$ is the Easting Error,
$y^e$ is the Northing Error, and
$z^e$ is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table C-3 to Table C-6 for complete details.

The six (6) control points, MST-4549, MST-41, MST-45, MS-141, UP-ASI, and, UP-NAU3 were occupied and observed simultaneously to form a GNSS loop. Coordinates of MST-4549 and UP-ASI; and elevation values of MST-4549, MS-141, and UP-ASI were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Control Point Constraints

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| MS-141 | Grid | | | | Fixed |
| MST-4549 | Grid | Fixed | Fixed | | Fixed |
| UP-ASI | Grid | Fixed | Fixed | | Fixed |
| Fixed = 0.000001 (Meter) | | | | | |

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed controls MST-4549 and UP-ASI have no values for grid errors while MST-4549, MS-141, and UP-ASI have no value for elevation error.

Table 24. Adjusted Grid Coordinates

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| MST-4549 | 555464.635 | ? | 1371246.784 | ? | 21.829 | ? | ENe |
| MST-41 | 595192.614 | 0.004 | 1346499.397 | 0.004 | 7.564 | 0.045 | |
| MST-45 | 587415.558 | 0.005 | 1329444.427 | 0.004 | 15.819 | 0.017 | |
| MS-141 | 584504.292 | 0.005 | 1320892.702 | 0.005 | 13.221 | ? | e |
| UP-ASI | 558628.712 | ? | 1356091.508 | ? | 10.476 | ? | ENe |
| UP-NAU 3 | 600433.760 | 0.007 | 1312170.323 | 0.006 | 1.747 | 0.024 | |

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. a. MST-4549

| | | |
|---|---|---|
| horizontal accuracy | = | Fixed |
| vertical accuracy | = | Fixed |

b. b. MST-41

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.4)^2 + (0.4)^2}$ |
| | = | $\sqrt{(0.16 + 0.16)}$ |
| | = | 0.57 < 20 cm |
| vertical accuracy | = | 4.5 cm < 10 cm |

c. c. MST-45

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.5)^2 + (0.4)^2}$ |
| | = | $\sqrt{(0.25 + 0.16)}$ |
| | = | 0.64 < 20 cm |
| vertical accuracy | = | 1.7 cm < 10 cm |

d. d. MS-141

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.5)^2 + (0.5)^2}$ |
| | = | $\sqrt{(0.25 + 0.25)}$ |
| | = | 0.71 < 20 cm |
| vertical accuracy | = | Fixed |

e. UP-ASI

| | | |
|---|---|---|
| horizontal accuracy | = | Fixed |
| vertical accuracy | = | Fixed |

f. UP-NAU 3

| | | |
|---|---|---|
| horizontal accuracy | = | $\sqrt{((0.7)^2 + (0.6)^2}$ |
| | = | $\sqrt{(0.49 + 0.36)}$ |
| | = | 0.92 < 20 cm |
| vertical accuracy | = | 2.4 cm < 10 cm |

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

Table 25. Adjusted Geodetic Coordinates

| Point ID | Latitude | Longitude | Ellipsoid | Height | Constraint |
|---|---|---|---|---|---|
| MST-4549 | N12°24'13.29041" | E123°30'36.98735" | 76.969 | ? | ENe |
| MST-41 | N12°10'44.36122" | E123°52'30.02722" | 64.943 | 0.045 | |
| MST-45 | N12°01'29.95768" | E123°48'11.03606" | 73.746 | 0.017 | |
| MS-141 | N11°56'51.84368" | E123°46'33.96438" | 71.378 | ? | e |
| UP-ASI | N12°15'59.72358" | E123°32'20.76940" | 66.451 | ? | ENe |
| UP-NAU 3 | N11°52'06.32015" | E123°55'19.63857" | 60.400 | 0.024 | |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. 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) |
| Control Survey for Lanang River on December 4, 5 and 12, 2015 | | | | | | | |
| MST-27 | 2nd Order, GCP | 12°17'22.32360" | 123°26'26.50548" | 109.123 | 1358609.337 | 547922.386 | 53.606 |
| MS-269 | 1st Order, BM | 12°24'21.62817" | 123°24'21.39816" | 82.132 | 1371483.424 | 544123.788 | 27.408 |
| Control Survey for Guiom River on January 27 and February 14, 2017 | | | | | | | |
| MST-4549 | 4th order, GCP | 12°24'13.29041" | 123°30'36.98735" | 76.969 | 1371246.784 | 555464.635 | 21.829 |
| MST-41 | Used as Marker | 12°10'44.36122" | 123°52'30.02722" | 64.943 | 1346499.397 | 595192.614 | 7.564 |
| MST-45 | Used as Marker | 12°01'29.95768" | 123°48'11.03606" | 73.746 | 1329444.427 | 587415.558 | 15.819 |
| MS-141 | 1st order, BM | 11°56'51.84368" | 123°46'33.96438" | 71.378 | 1320892.702 | 584504.292 | 13.221 |
| UP-ASI | UP established | 12°15'59.72358" | 123°32'20.76940" | 66.451 | 1356091.508 | 558628.712 | 10.476 |
| UP-NAU3 | UP established | 11°52'06.32015" | 123°55'19.63857" | 60.4 | 1312170.323 | 600433.760 | 1.747 |

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

Cross-section and as-built surveys were conducted on February 9, 2017 at the downstream side of Baldoza Bridge in Brgy. Villahermosa, Cawayan, Masbate as shown in Figure 38. A Sokkia™ Set 3030 Total Station was utilized for this survey as shown in Figure 39.

Figure 38. Downstream side of Baldoza Bridge

Figure 39. As-built survey of Baldoza Bridge

The cross-sectional line of Baldoza Bridge is about 74 m with four hundred thirty-six (436) cross-sectional points using the control point UP-GUI-1 as the GNSS base station. The cross-section diagrams and the bridge data form for Baldoza Bridge are shown in Figure 41 and 42.

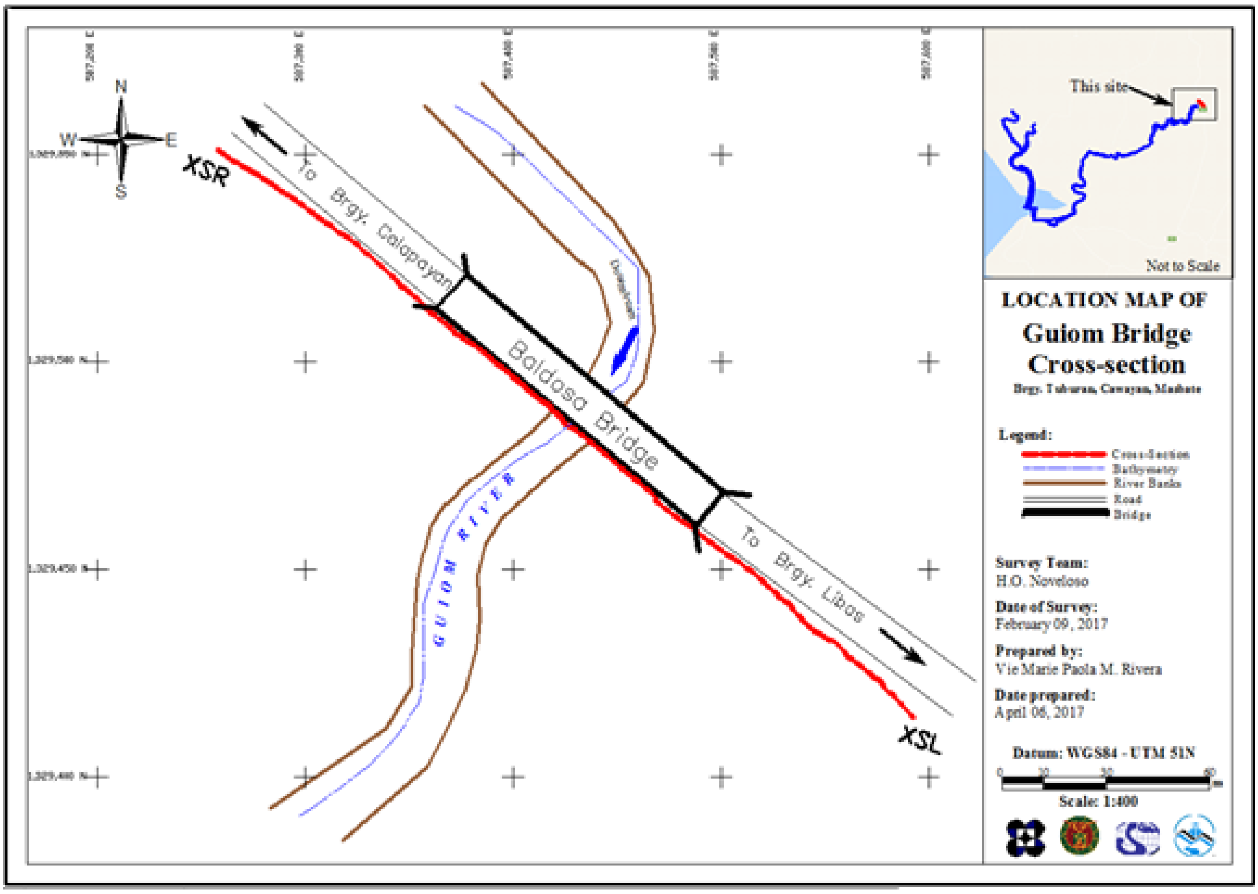



Figure 40. Location map of Guiom Bridge (also known as Baldoza Bridge) cross section survey

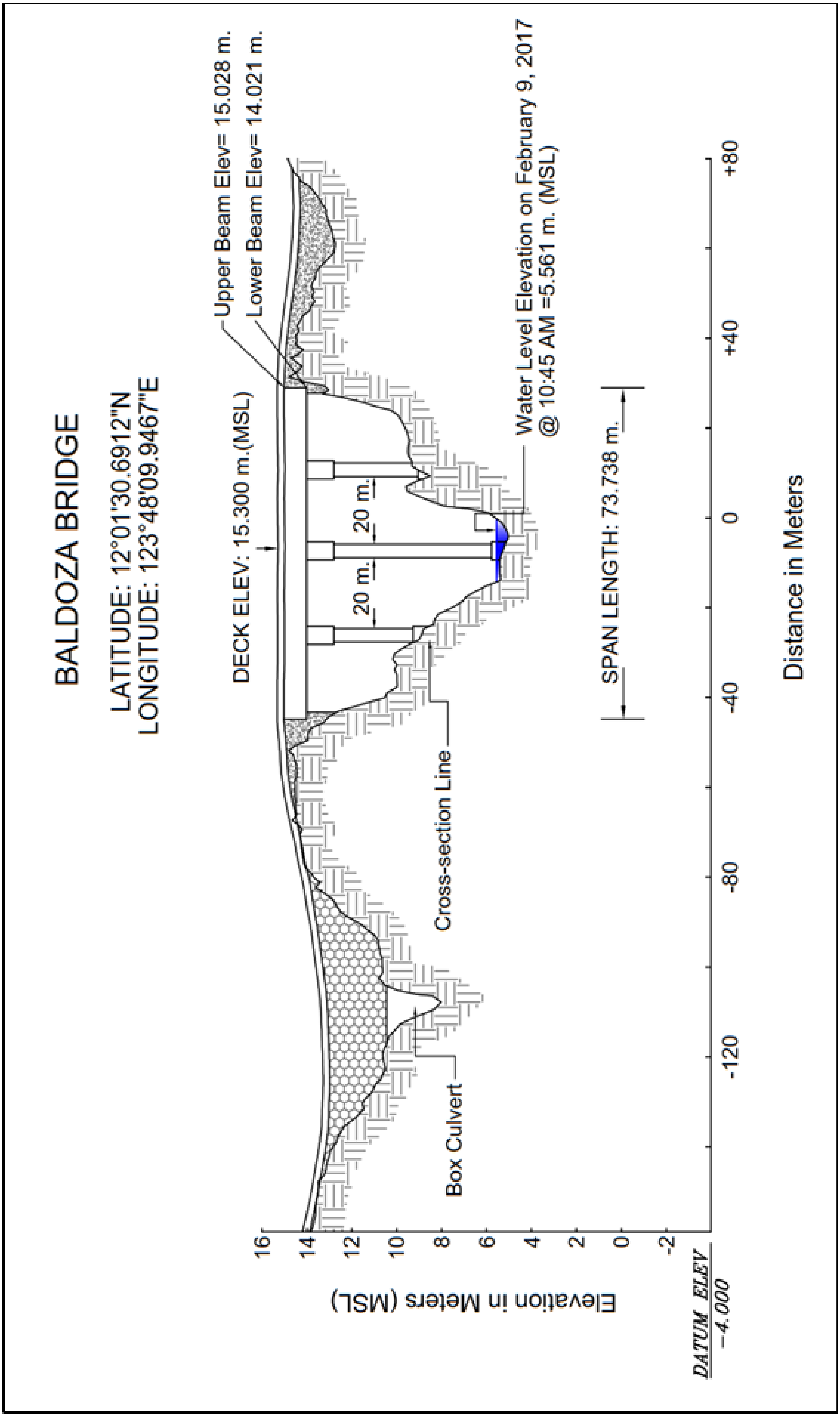



Figure 41. Baldoza Bridge cross-section diagram

## BRIDGE DATA FORM

Bridge Name: Baldoza Bridge

River Name: Guiom River

Location (Brgy., City, Region): Brgy. Villahermosa, Cawayan, Masbate

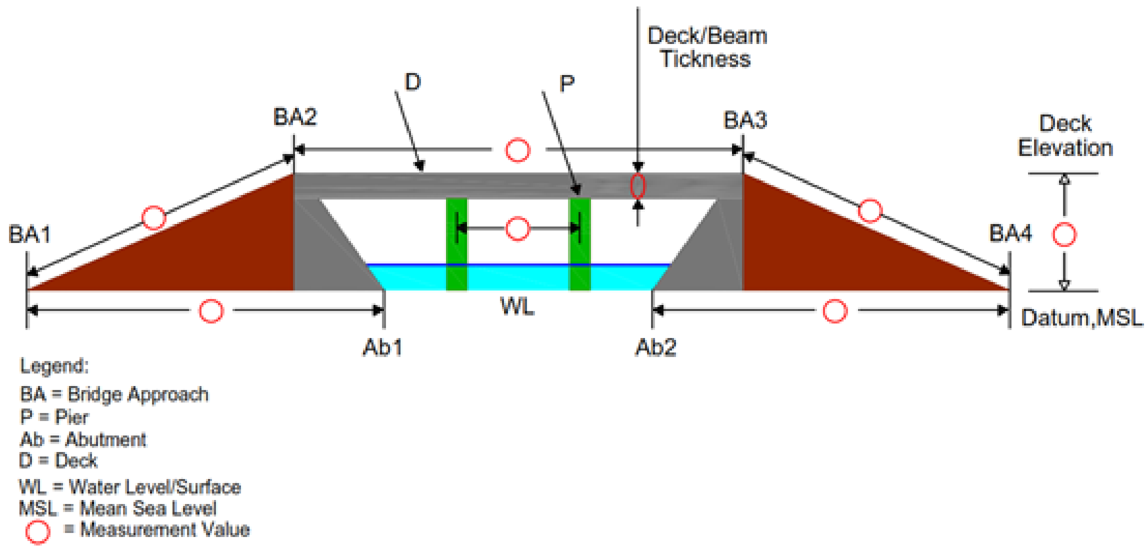
Survey Team: Julieto Cabilin, Urbano Castillo, Jodel dela Cruz, Oscar Agustin, Rhey Joseph Domingo, and Eduardo Cuizon

Date and Time: February 9, 2017 @ 8:00 am - 5:00 pm

Flow Condition: Low Normal High

Weather Condition: Fair Rainy

### Cross-sectional View (not to scale)




| Line Segment | Measurement, m | Remarks |
|---|---|---|
| 1. BA1-BA2 | 5.903 m. | Concrete |
| 2. BA2-BA3 | 73.738 m. | Concrete |
| 3. BA3-BA4 | 8.563 m. | Concrete |
| 4. BA1-Ab1 | 8.012 m. | Concrete |
| 5. Ab2-BA4 | 9.842 m. | Concrete |
| 6. Deck/Beam thickness | 1.007 m. | Concrete |
| 7. Deck Elevation | 15.300 m. MSL | Concrete |
| 8. P1-P2 | 20.000 m. | Concrete |
| 9. P2-P3 | 20.000 m. | Concrete |

Note: Observer should be facing downstream

Figure 42. Bridge data form

Water surface elevation of Guiom River was determined by Sokkia™ Set 3030 Total Station on February 9, 2017 at the sidewalk of Baldoza Bridge in Brgy. Villahermosa, Cawayan, Masbate with a value of 15.464 m in MSL. This was translated into marking on the bridge's sidewalk 2.5 meters away from the centerline as shown in Figure 43. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Guiom River, the Ateneo de Naga University.


Figure 43. Water surface elevation marking on Baldoza Bridge sidewalk

Water surface elevation of Guiom River was also determined by a Sokkia™ Set-3030 Total Station on February 9, 2017 at 10:45 AM at Baldoza Bridge area with a value of 5.561 m in MSL as shown in Figure 43. This was translated into marking on the bridge's pier as shown in Figure 44.


Figure 44. Water level markings on Baldoza Bridge

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on January 28, 2017 using a survey grade GNSS Rover receiver, Trimble® SPS 882, which was attached on top of the vehicle as shown in Figure 45. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.902 m and measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-NAU-3 occupied as the GNSS base station in the conduct of the survey.

The first day of the validation points acquisition survey ran from Mabuaya Bridge in Brgy. Matiporon, Milagros to Brgy. Poblacion, Aroroy via Baleno in an almost semi-circumferential route. The reference point MST-4549 was utilized during this survey. The second day of this survey also started in Mabuaya Bridge going to Brgy. Poblacion in Aroroy via Mandaon, the opposite side of the circumferential road. This survey also covered Mandaon Road which started from Brgy. Mabatobato going southwest towards Brgy. Nailaban, both in the Municipality of Mandaon. The reference point MST-27 was used as base station for the last route.

The survey gathered a total of 4,673 points with approximate length of 46.08 km using MST-27 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 46.

Figure 45. Validation points acquisition survey set-up for Guiom River


Figure 46. Validation points acquisition covering the Guiom River Basin Area

## 4.7 River Bathymetric Survey

Bathymetric survey was executed on January 14, February 10-11, February 13, and February 17, 2017 using dual frequency Topcon™ GR-5 and a Hydrolite™ Single Beam Echo Sounder mounted in a motor boat as illustrated in Figure 47.

For the main river, survey started in Brgy. Itombato, Cawayan, Masbate, with coordinates 12°00'15.9435"N, 123°46'27.3032"E and ended at the mouth of the river in Brgy. Guiom, also in the Municipality of Cawayan, with coordinates 11°58' 54.8113"N, 123°44' 47.4367"E.

For tributary 1, the bathymetric survey started in Brgy. Iraya, Cawayan, Masbate, with coordinates 12°00' 49.6891"N, 123°43' 57.0166"E and ended in Brgy. Dalipe, also in Cawayan, with coordinates 12°00'07.1113"N, 123°44'06.5826"E.

For tributary 2, the bathymetric survey started in Brgy. Dalipe, Cawayan, Masbate, with coordinates 12°00' 35.3944"N, 123°44' 21.2158"E and ended at the mouth of the river in Brgy. Guiom, also in Cawayan, with coordinates 11°59'08.5259"N, 123°44'08.9241"E.

Figure 47. Bathymetric survey using Topcon™ GR-5 in Guiom River

Manual bathymetric survey, on the other hand, was executed on March 3, 2017 using a Topcon™ GR-5 RTK in continuous topo mode as illustrated in Figure 48. The survey in the main river started from Brgy. Villahermosa, Cawayan, Masbate with coordinates 12°01'30.9514"N, 123°48'10.3481"E traversing the river and ended in Brgy. Itombato, also in the Municipality of Cawayan with coordinates 12°00'15.6112"N, 123°46'27.9834"E. The survey continued from Brgy. Guiom, Cawayan, Masbate with coordinates 11°58'56.1542"N, 123°44'46.0805"E, traversing the river and ended in Brgy. Guiom as well with coordinates 11°58'50.6272"N, 123°43'52.6295"E. The control points UP-GUI-1, UP-GUI-4, UP-GUI-5, UP-GUI-6, and UP-GUI-8 were used as GNSS base stations all throughout the entire survey.

Figure 48. Manual bathymetric survey using a using Topcon™ GR-5 in Guiom River

The bathymetric survey for Guiom River gathered a total of 9,624 points covering 19.277 km of the river traversing barangays Calapayan, Dalipe, Guiom, Itombato, Maihao, Pananawan, Villahermosa, Pin-As and Iraya in the Municipality of Cawayan. A CAD drawing was also produced to illustrate the riverbed profile of Guiom River. As shown in Figure C-22 to C-24, the highest and lowest elevation has a 9.770 m difference. The highest elevation observed was 5.266 m above MSL located in Brgy. Villahermosa, in the Municipality of Cawayan, Masbate; while the lowest was -4.504 m below MSL located in Brgy. Iraya, also in the Municipality of Cawayan.

Gathering of random points for the checking of HONS's bathymetric data was performed by DVBC on January 30, 2017 using a survey grade GNSS Rover receiver attached to a boat as seen in Figure 49. A map showing the DVBC bathymetric checking points is shown in Figure 50.

Figure 49. Gathering of random bathymetric points along Guiom River

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 value of 0.973 for the bathymetric data is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.133 for the bathymetric data was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

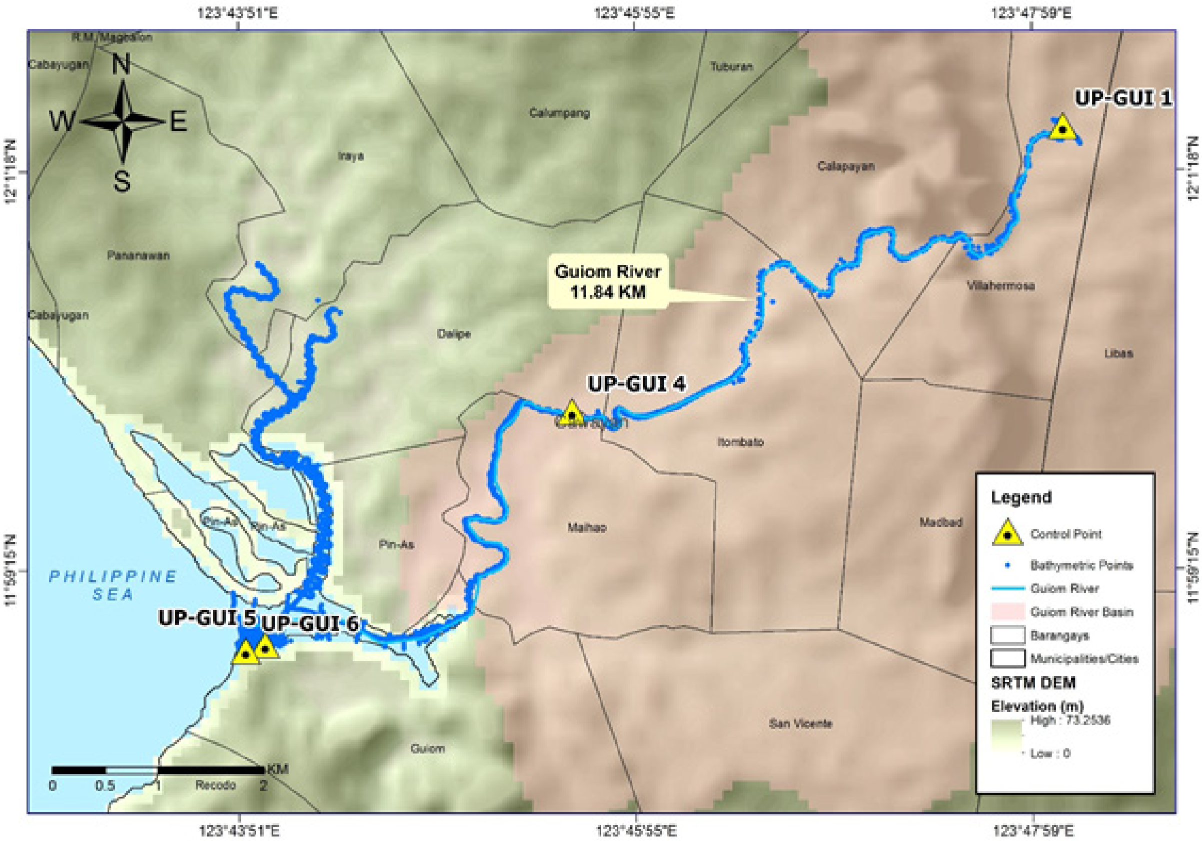



Figure 50. Bathymetric Survey Map of Guiom River

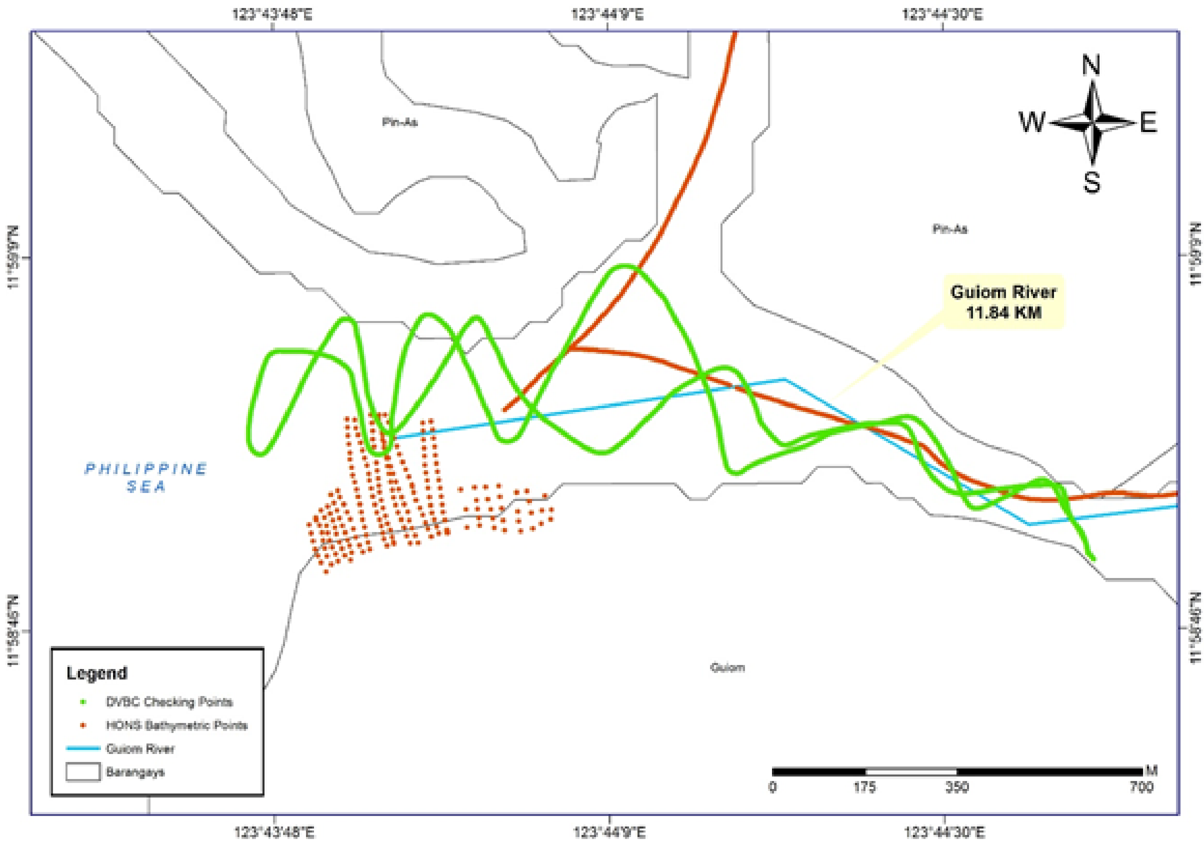



Figure 51. Quality checking points gathered along Guiom River by DVBC

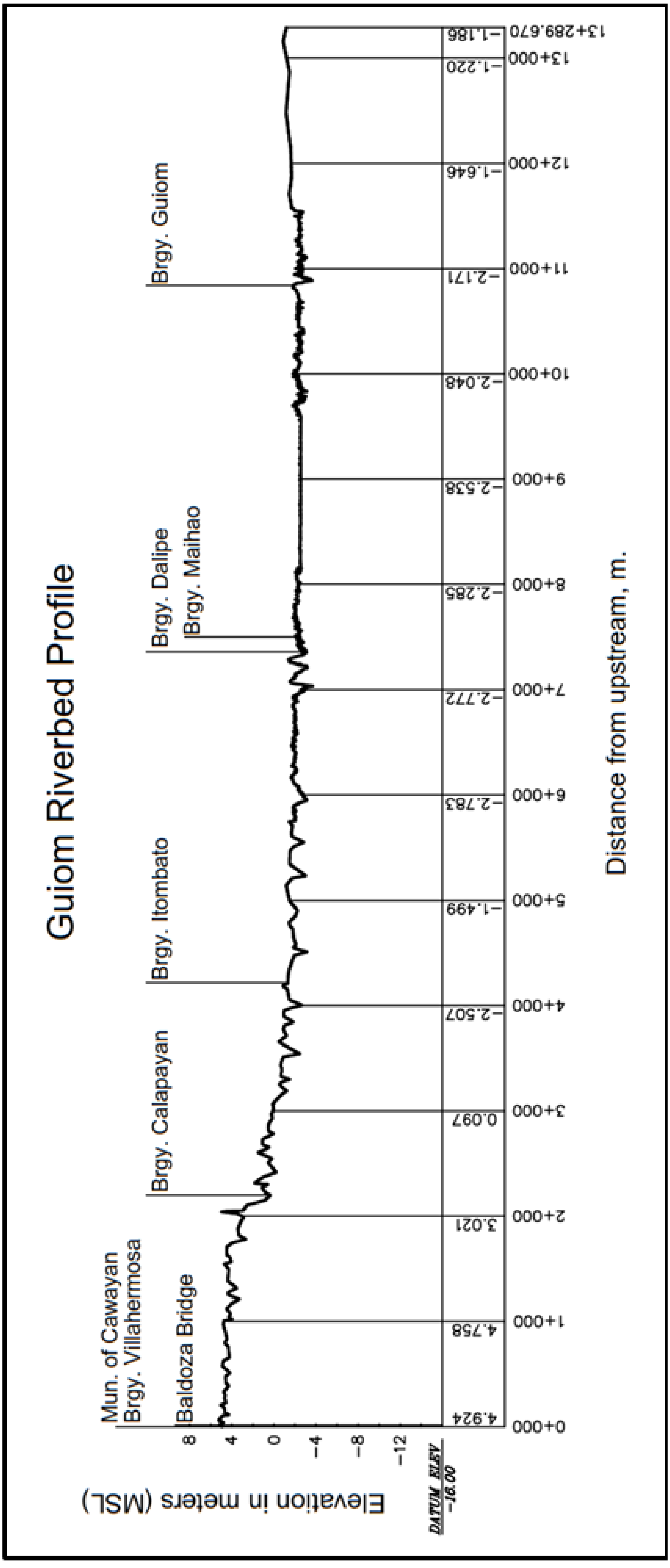



Figure 52. Guiom Riverbed Profile

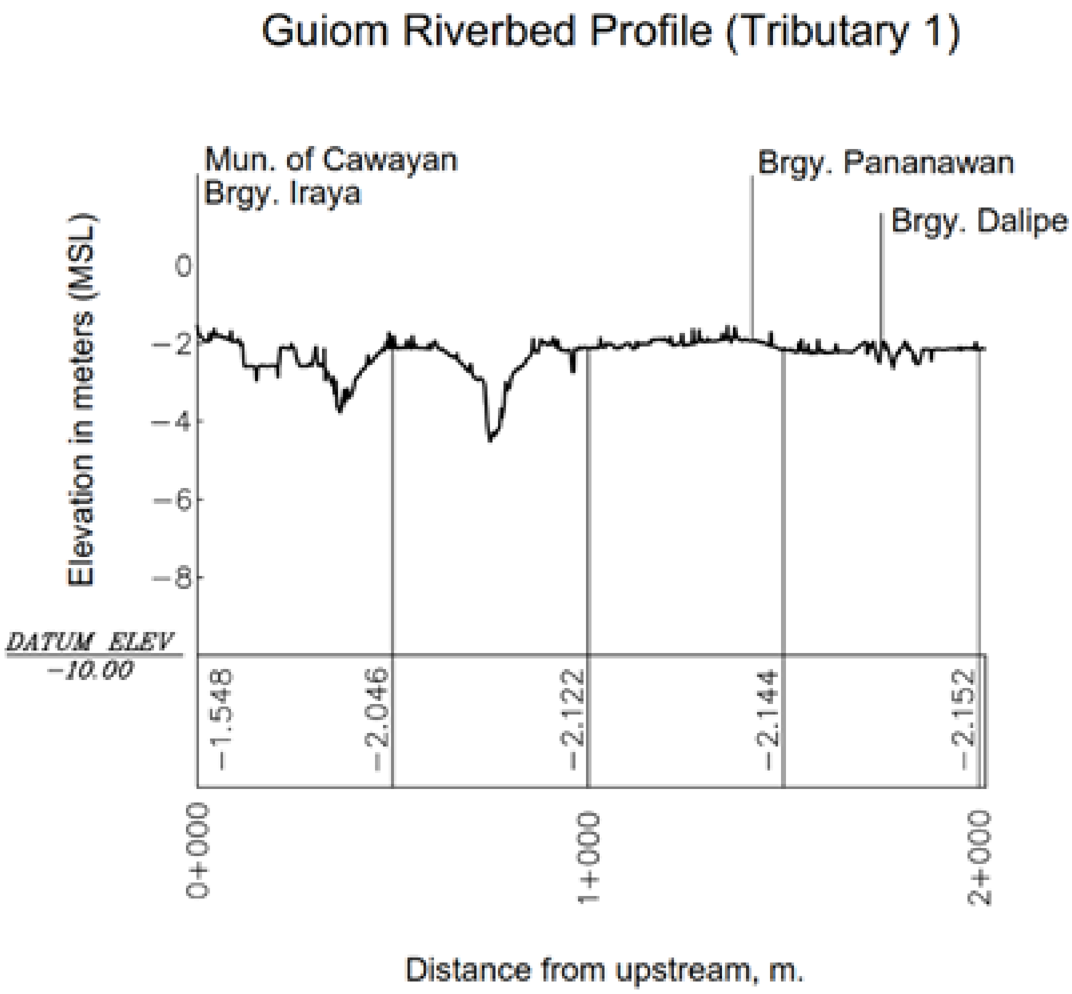



Figure 53. Guiom Riverbed Profile Tributary 1)

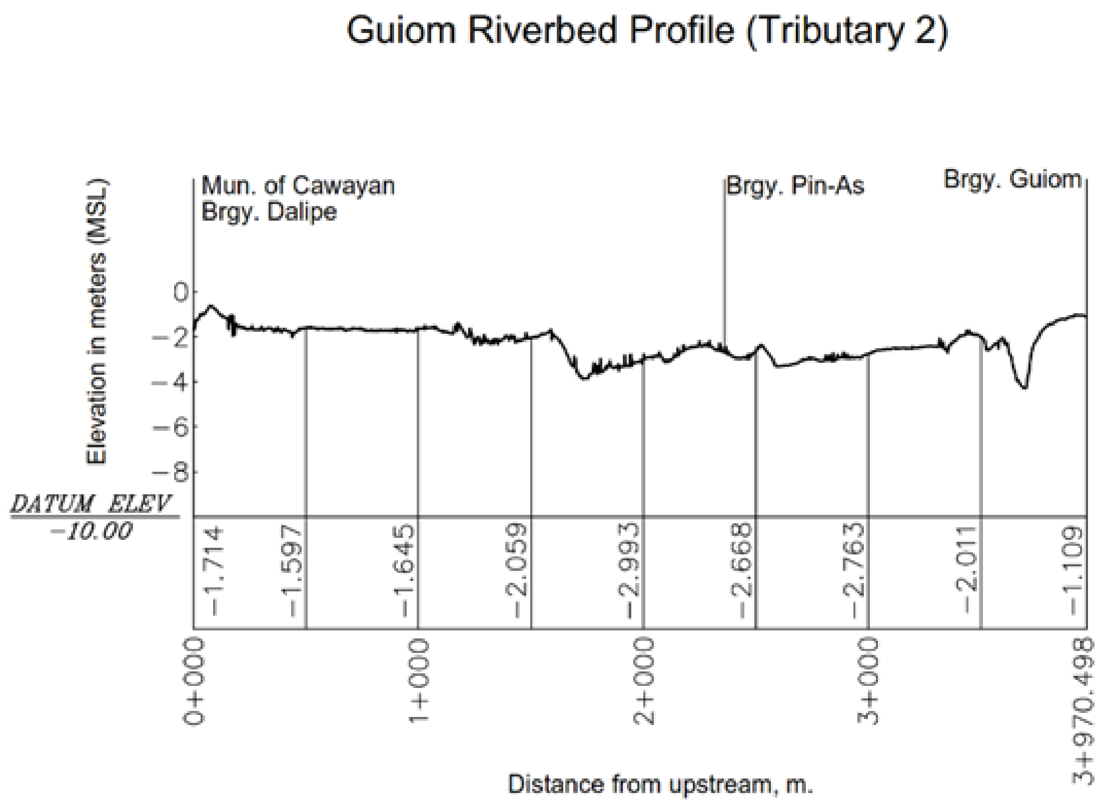



Figure 54. Guiom Riverbed Profile (Tributary 2)

# CHAPTER 5: FLOOD MODELING AND MAPPING

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

## 5.1 Data Used for Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

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

### 5.1.2 Precipitation

Precipitation data was taken from one rain gauge (RGs) installed by the ADNU-FMC team. The rain gauge was installed at Brgy. Aroroy (Figure 55). The precipitation data collection started from February 16, 2017 at 2:00 PM to February 17, 2017 at 2:20 PM with a 10-minute recording interval.

The total precipitation for this event in the deployed rain gauge is 132.4mm. It has a peak rainfall of 4.8mm on February 17, 2017 at 2:50 AM. The lag time between the peak rainfall and discharge is 6 hours and 30 minutes.

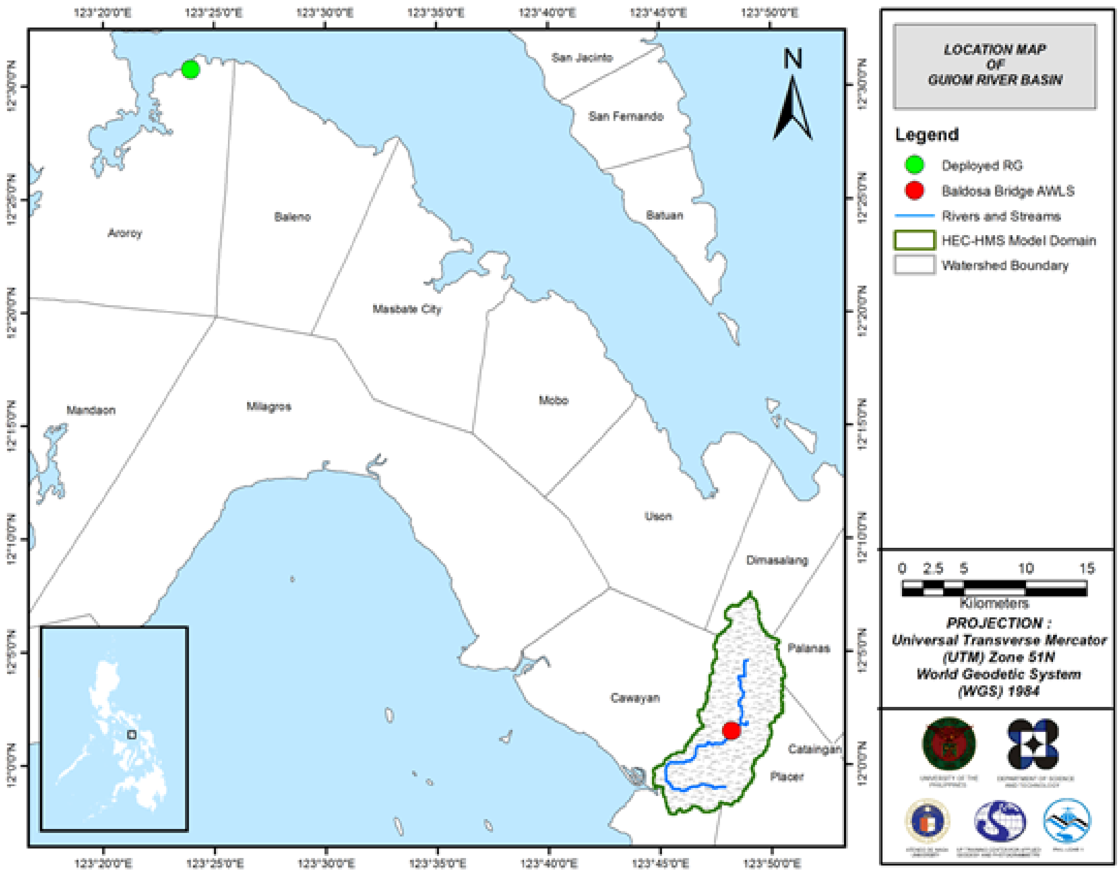


Figure 55. The location map of Guiom HEC-HMS model used for calibration

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Baldosa Bridge, Guiom, Masbate (12°1’30.1”N, 123°48’11.1”E). It gives the relationship between the observed water levels at Ilog Bridge and outflow of the watershed at this location.

For Baldosa Bridge, the rating curve is expressed as Q = 2E-14e49.118h as shown in Figure 57.

(This image is not available for this river basin.)

Figure 56. The cross-section plot of Baldosa Bridge

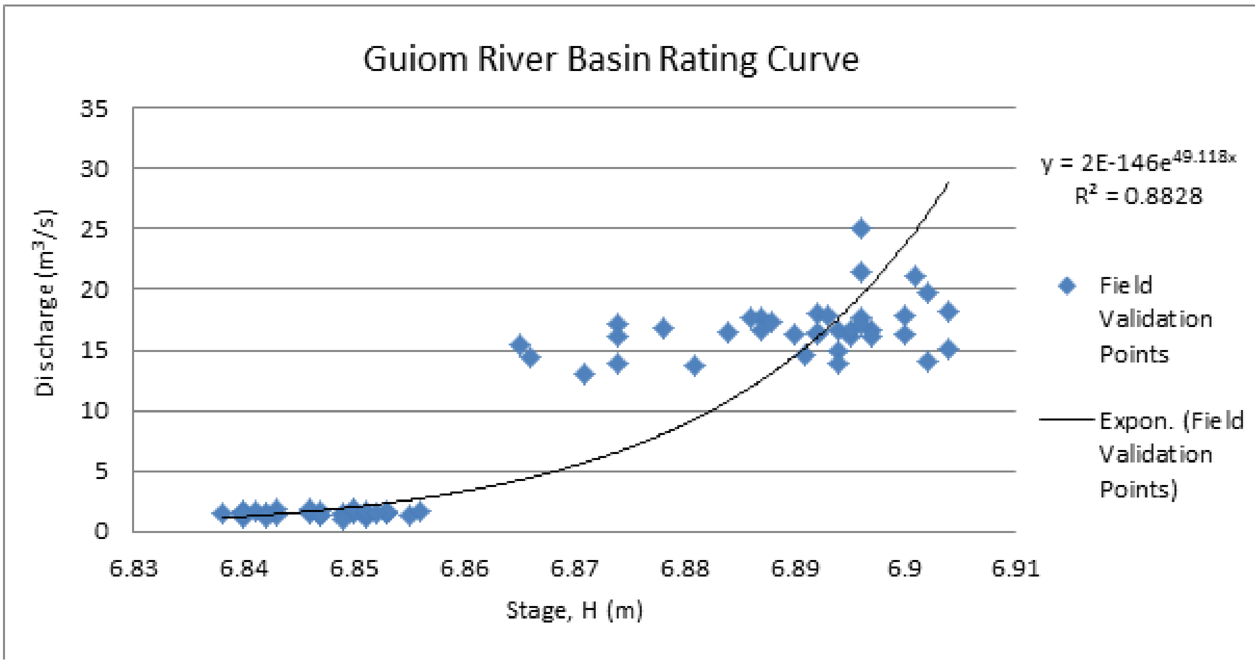


Figure 57. The rating curve of Baldosa Bridge in Guiom, Masbate

This rating curve equation was used to compute the river outflow at Baldosa Bridge for the calibration of the HEC-HMS model shown in Figure 58. The total rainfall for this event is 132.4mm and the peak discharge is 37.6m3/s at 9:20 AM, February 17, 2017.

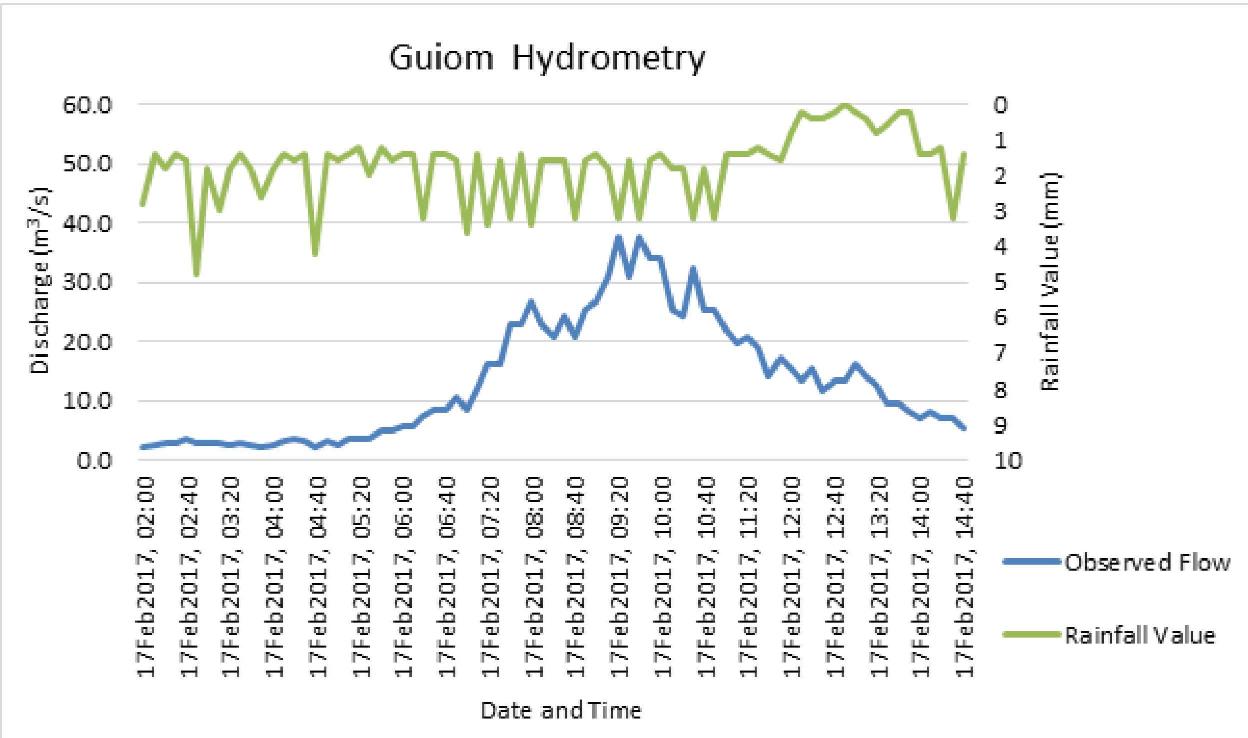


Figure 58. Rainfall and outflow data of the Guiom River Basin, which was used for modeling

## 5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Catarman RIDF. 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 was chosen based on its proximity to the Guiom watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 27. RIDF values for Guiom Rain Gauge computed by PAG-ASA

| COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T (yrs) | 10 mins | 20 mins | 30 mins | 1 hr | 2 hrs | 3 hrs | 6 hrs | 12 hrs | 24 hrs |
| 2 | 22.5 | 34.2 | 42.4 | 57.5 | 80.9 | 96.4 | 125.2 | 156.6 | 180 |
| 5 | 29.9 | 45.4 | 56.2 | 77 | 110.3 | 135.9 | 183.5 | 229.5 | 255.4 |
| 10 | 34.7 | 52.8 | 65.4 | 90 | 129.7 | 162 | 222.1 | 277.8 | 305.4 |
| 15 | 37.5 | 57 | 70.5 | 97.3 | 140.7 | 176.7 | 243.9 | 305.1 | 333.6 |
| 20 | 39.4 | 60 | 74.2 | 102.4 | 148.4 | 187.1 | 259.1 | 324.1 | 353.3 |
| 25 | 40.9 | 62.2 | 76.9 | 106.3 | 154.3 | 195 | 270.9 | 338.8 | 368.5 |
| 50 | 45.5 | 69.2 | 85.5 | 118.4 | 172.6 | 219.5 | 307.1 | 384.1 | 415.3 |
| 100 | 50 | 76.1 | 94 | 130.5 | 190.7 | 243.8 | 343 | 429 | 461.8 |

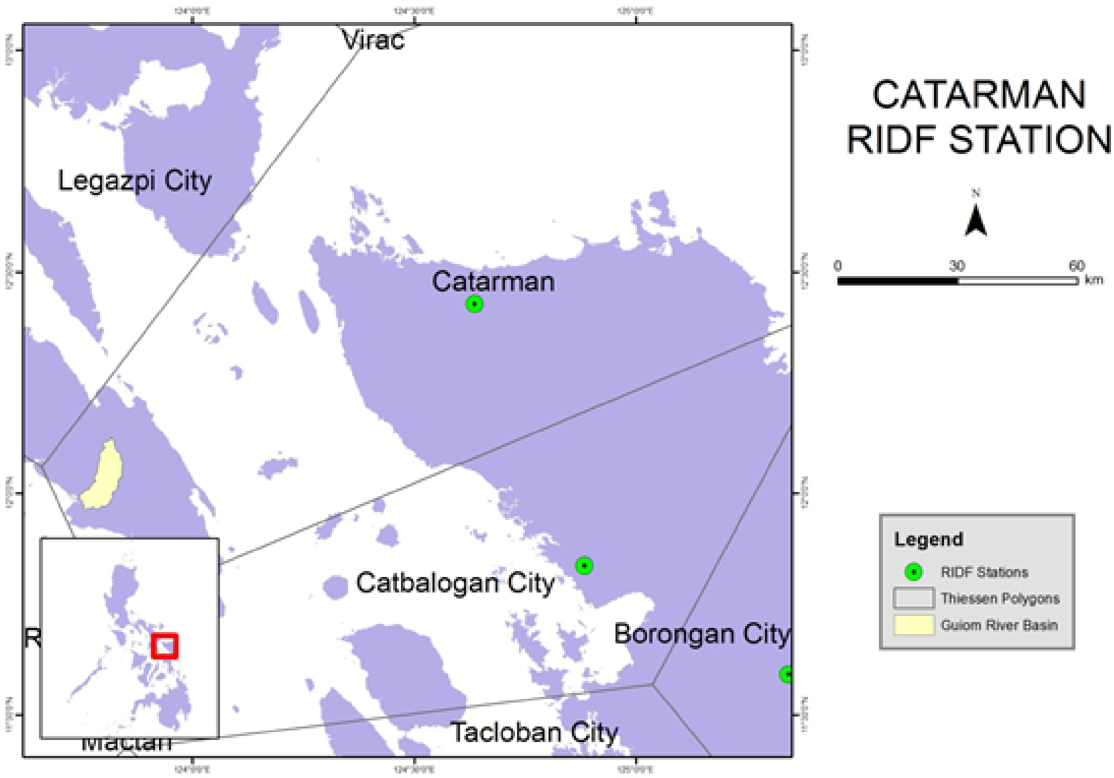


Figure 59. The location of the Catarman RIDF station relative to the Guiom River Basin

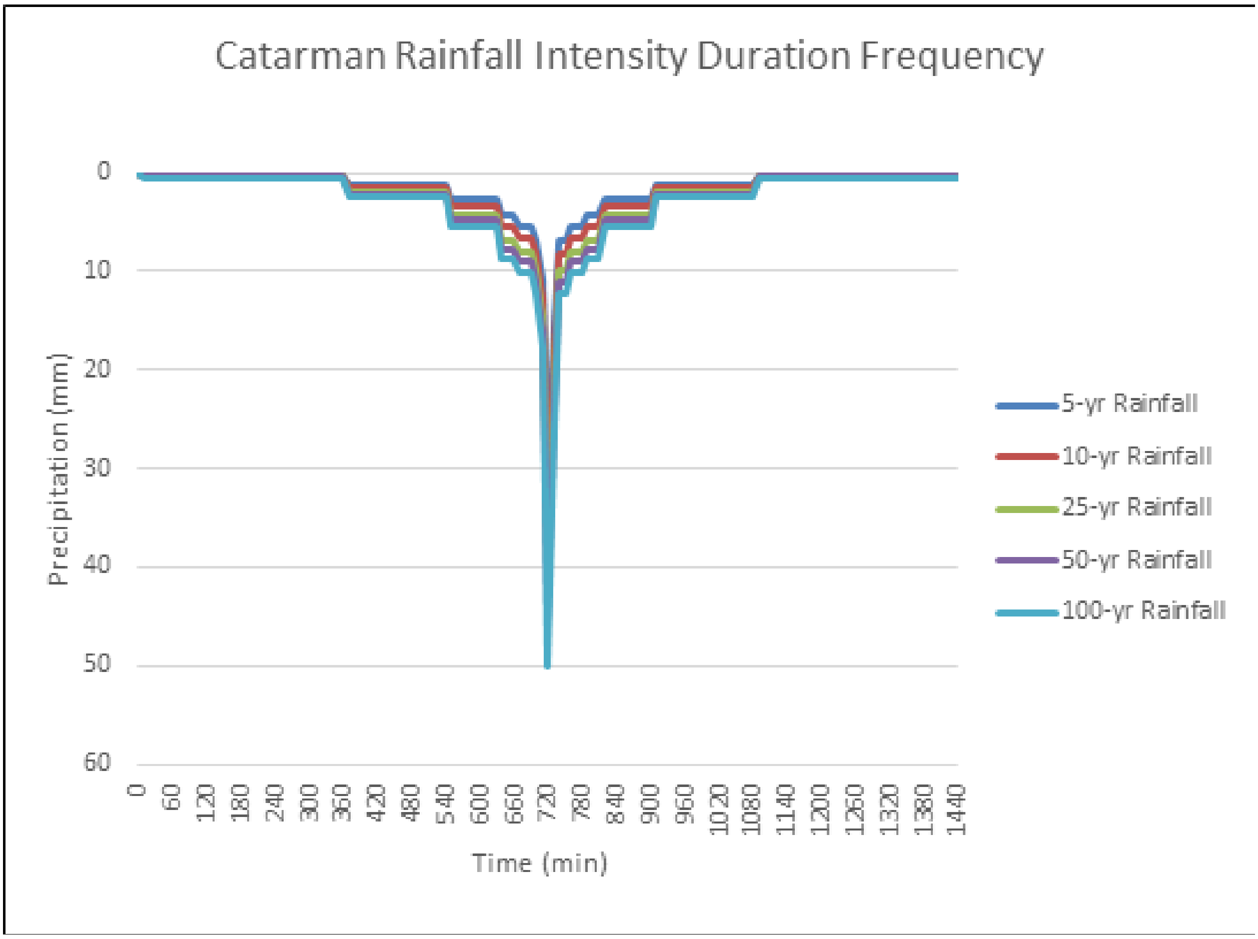


Figure 60. The synthetic storm generated for a 24-hour period rainfall for various return periods

## 5.3 HMS Model

The soil dataset was generated before 2004 bythe Bureau of Soils and Water Management (BSWM); this is under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Guiom River Basin are shown in Figures 61 and 62, respectively.

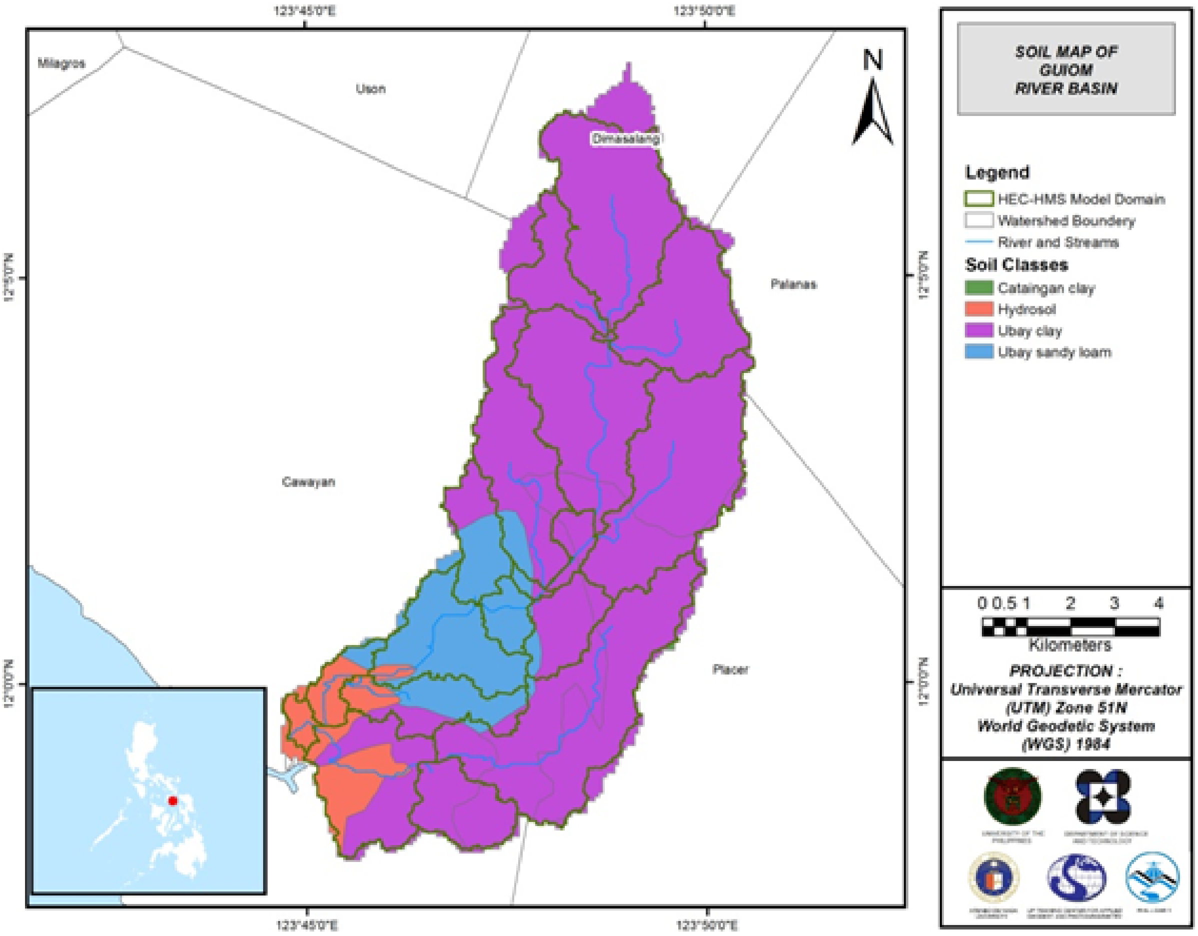


Figure 61. Soil map of Guiom River Basin

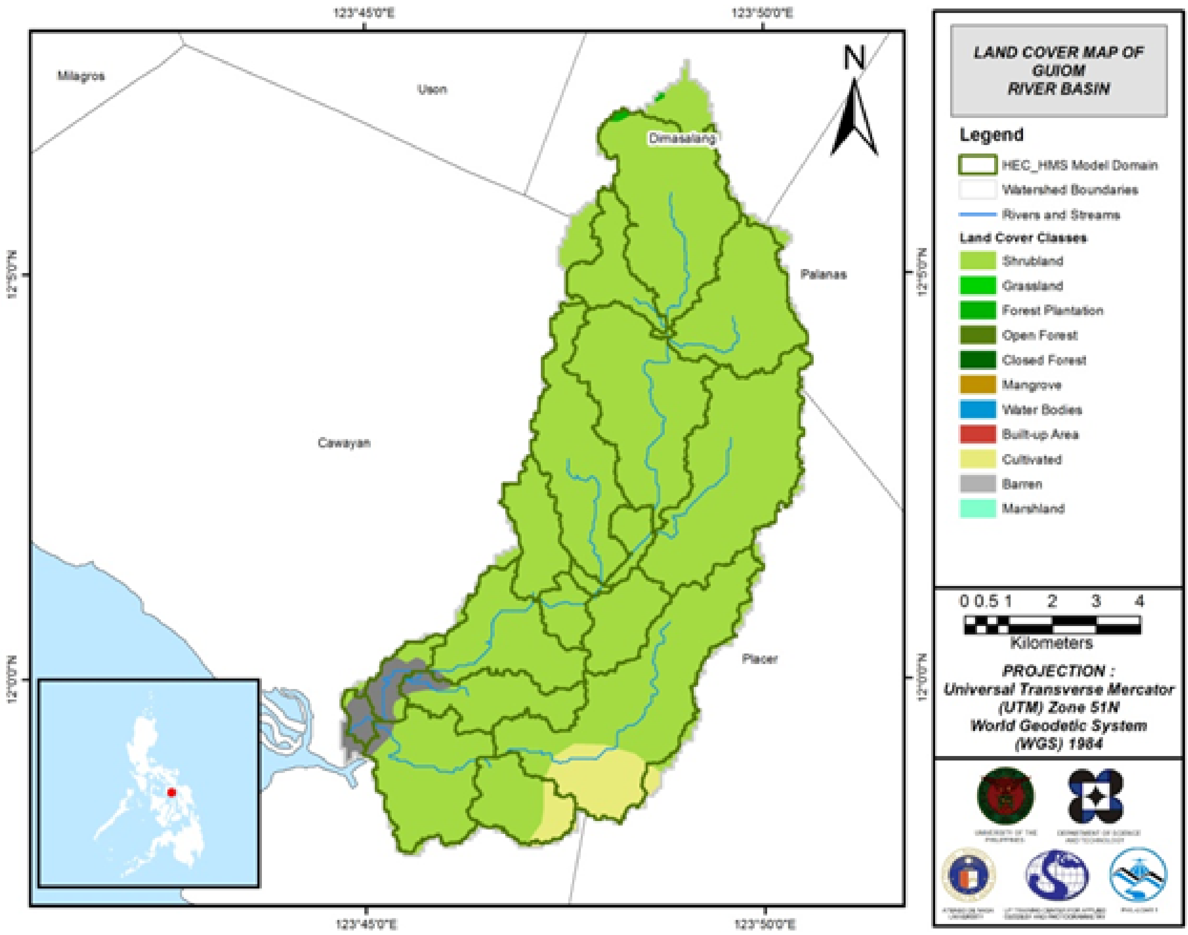


Figure 62. Land cover map of Guiom River Basin

For Guiom, four soil classes were identified. These are Cataingan clay, Ubay clay and sandy loam, and hydrosol. Moreover, four land cover classes were identified. These are shrubland, forest plantation, cultivates, and barren areas.

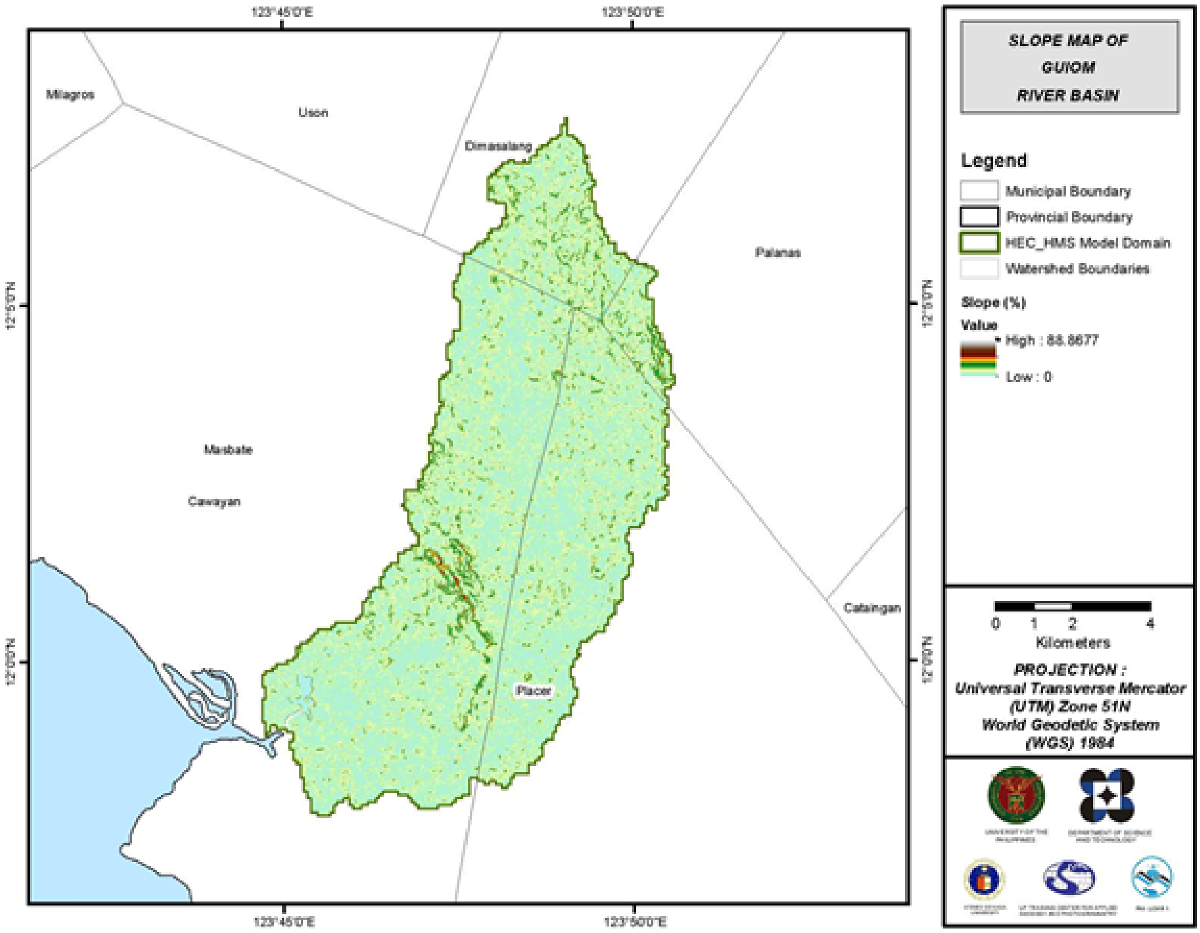


Figure 63. Slope map of Guiom River Basin

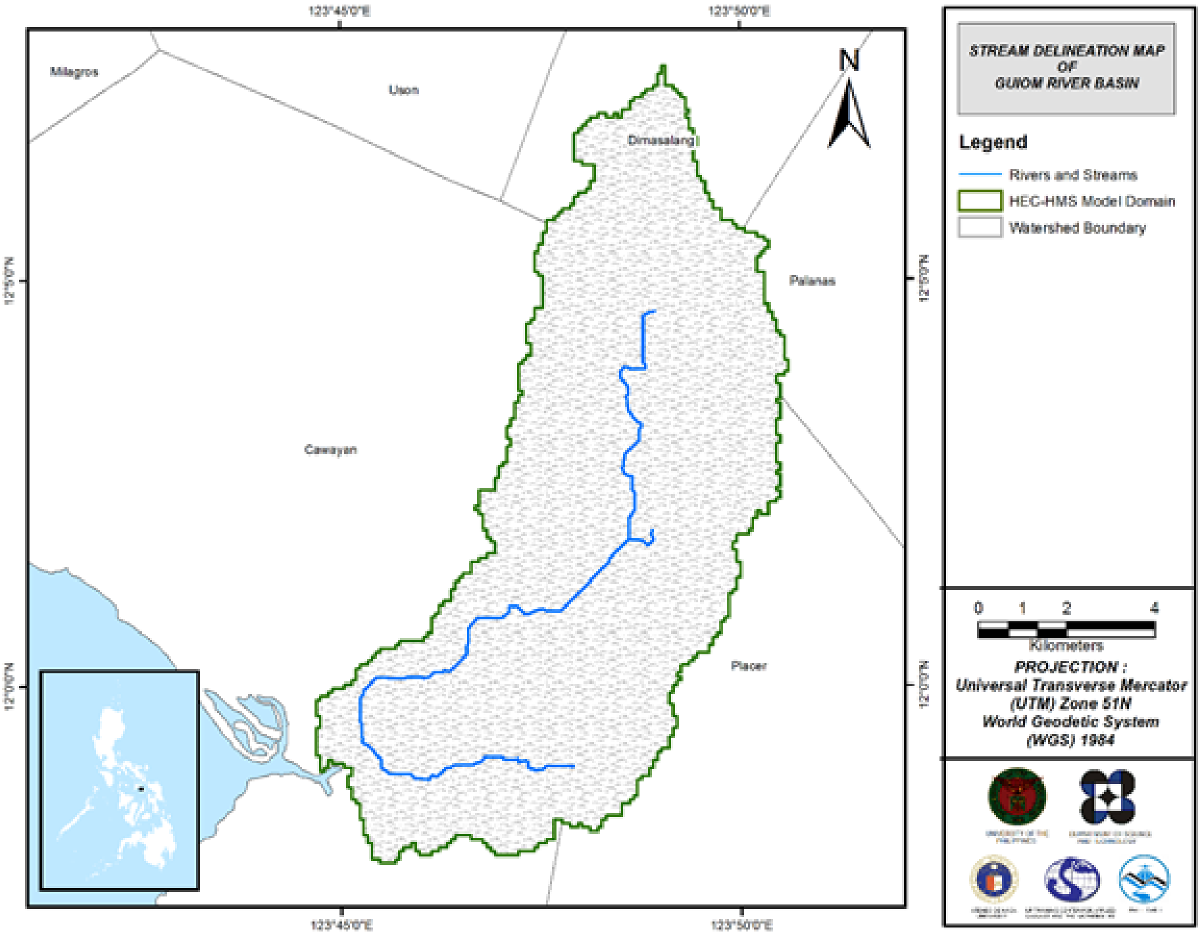


Figure 64. Stream delineation map of Guiom River Basin

Using the SAR-based DEM, the Guiom basin was delineated and further divided into subbasins. The model consists of 19 sub basins, 9 reaches, and 9 junctions, as shown in Figure 65. The main outlet is Baldosa Bridge.

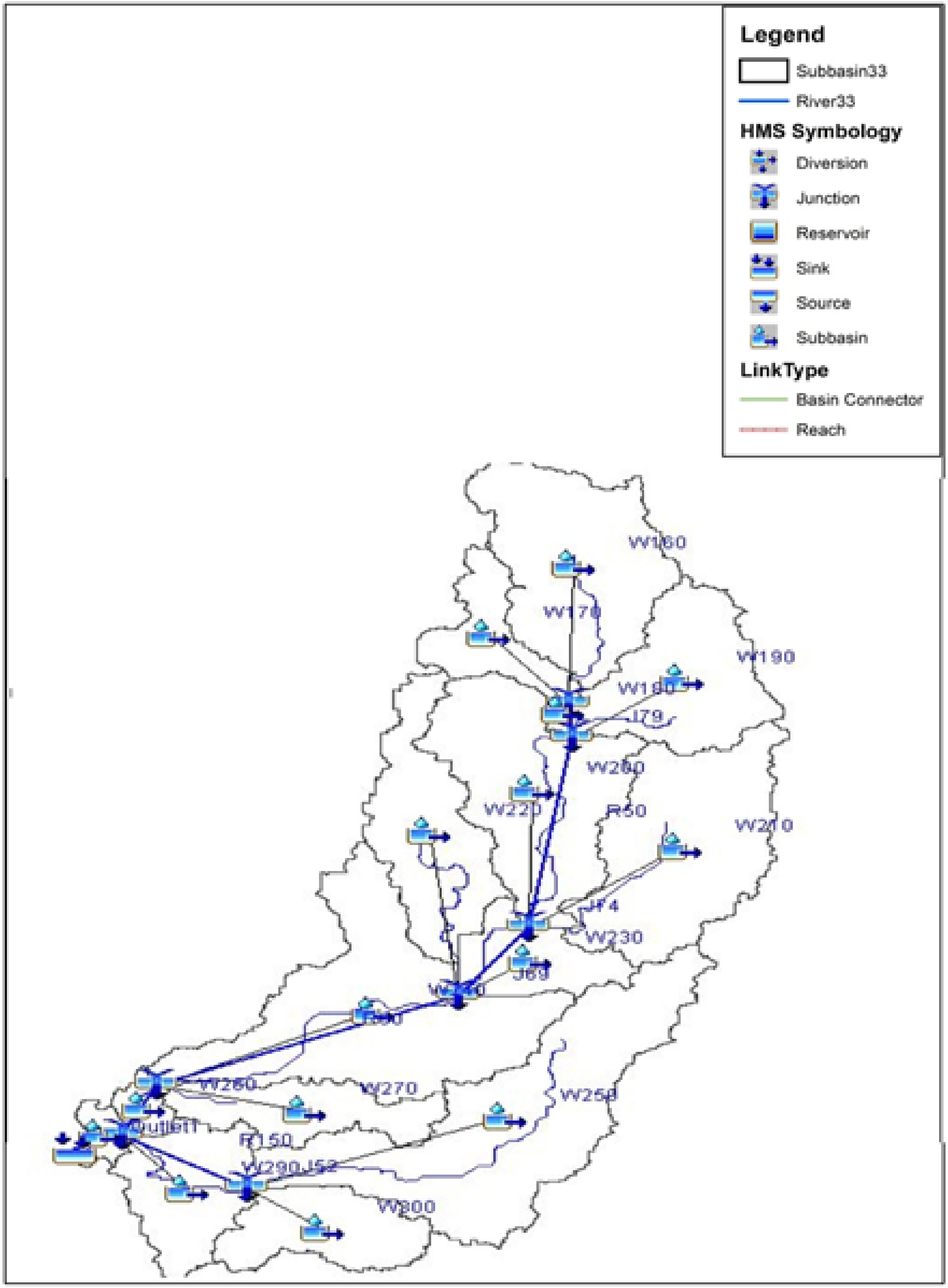


Figure 65. The Guiom River Basin model generated in HEC-HMS

## 5.4 Cross-section Data

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

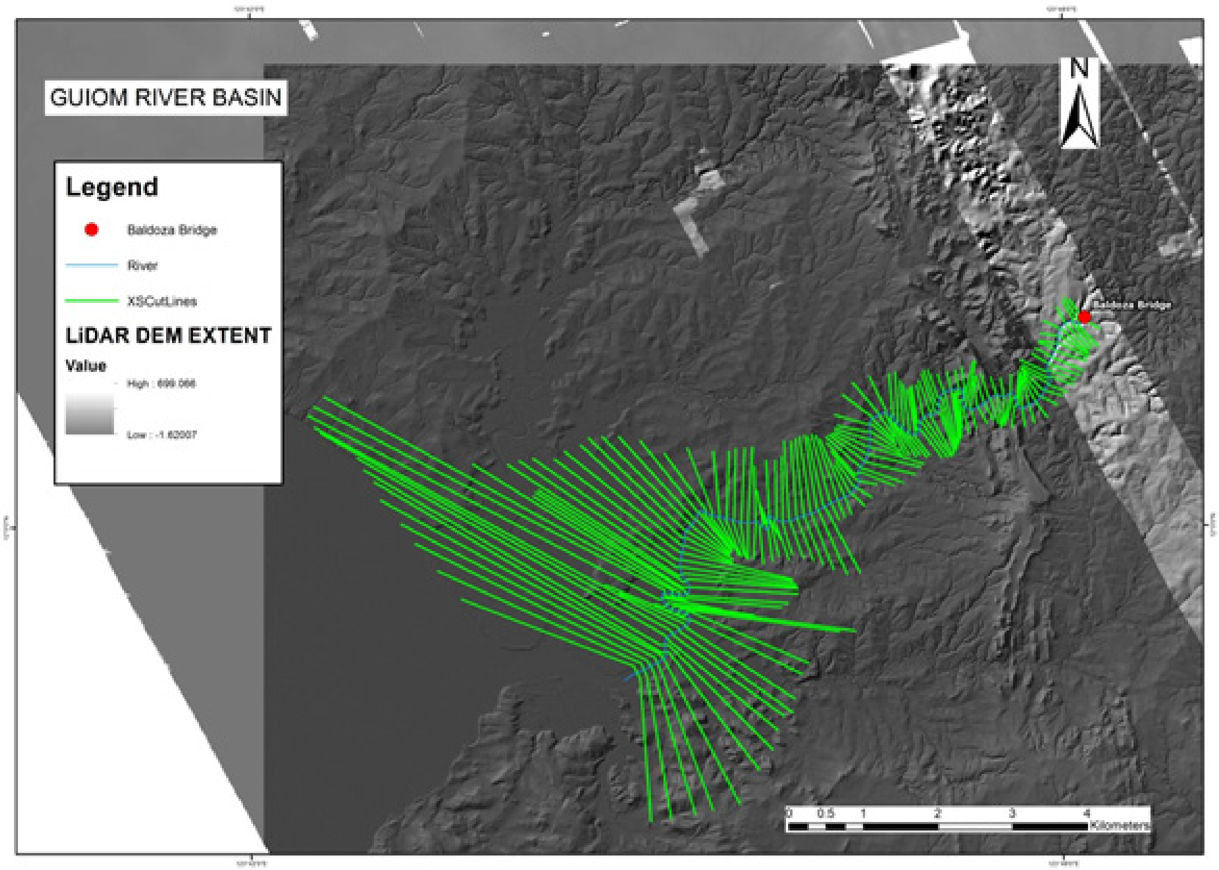


Figure 66. River cross-section of Guiom River generated through Arcmap HEC GeoRAS tool

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

Figure 67. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 113.99390 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 0m2/s. The generated hazard maps for Guiom are in Figures 71, 73, and 75.

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 100,743,168.00 m2. The generated flood depth maps for Guiom are in Figures 72, 74, and 76.

There is a total of 47,873,512.00 m3 of water entering the model. Of this amount, 31,410,340.18 m3 is due to rainfall while 16,463,171.82 m3 is inflow from other areas outside the model. 9,364,535.00 m3 of this water is lost to infiltration and interception, while 17,622,463.32 m3 is stored by the flood plain. The rest, amounting up to 20,886,404.84 m3, is outflow.

## 5.6 Results of HMS Calibration

After calibrating the Guiom HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 68 shows the comparison between the two discharge data.

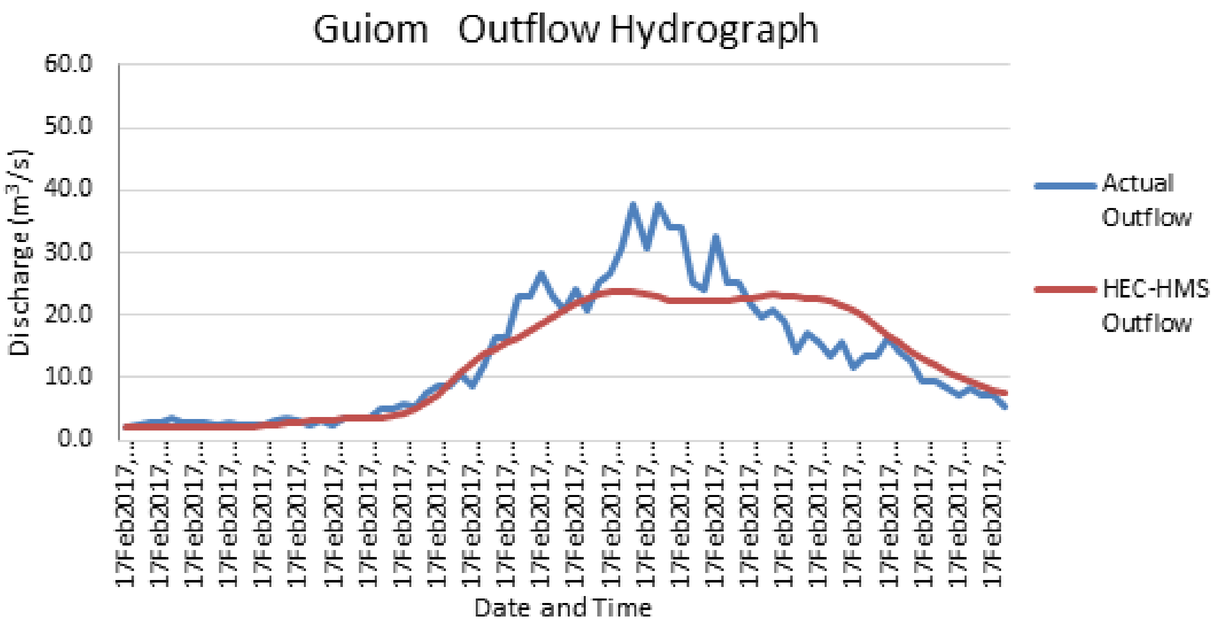


Figure 68. Outflow hydrograph of Guiom River Basin produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of calibrated values for the Guiom River Basin

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 0.03 – 500 |
| | | | Curve Number | 36 – 99 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.02 – 0.2 |
| | | | Storage Coefficient (hr) | 0.02 – 0.3 |
| | Baseflow | Recession | Recession Constant | 0.00001 |
| | | | Ratio to Peak | 0.01 – 0.4 |
| Reach | Routing | Muskingum-Cunge | Slope | 0.0005 – 0.01 |
| | | | Manning's Coefficient | 0.0001 – 0.5 |

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.03mm to 500mm means that there is minimal to high amount of infiltration or rainfall interception by vegetation.

The 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 36 to 99 for curve number is wider than the advisable for Philippine watersheds (70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Guiom, the basin mostly consists of shrubland and the soil consists of Ubay clay and sandy loam, and hydrosol.

The 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 0.02 hours to 0.2 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. For Guiom, it will take at least 5 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness in Guiom watershed, which is determined to be have a smooth surface (Brunner, 2010).

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

| Accuracy measure | Value |
|---|---|
| RMSE | 4.628 |
| r2 | 0.796 |
| NSE | 0.791 |
| PBIAS | 3.575 |
| RSR | 0.457 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 4.628 (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 0.796

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 0.791.

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 3.575.

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 0.457.

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

### 5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 15) shows the Guiom outflow using the synthetic storm events using the Catarman 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 from 134.5m3/s in a 5-year return period to 294.6m3/s in a 100-year return period.

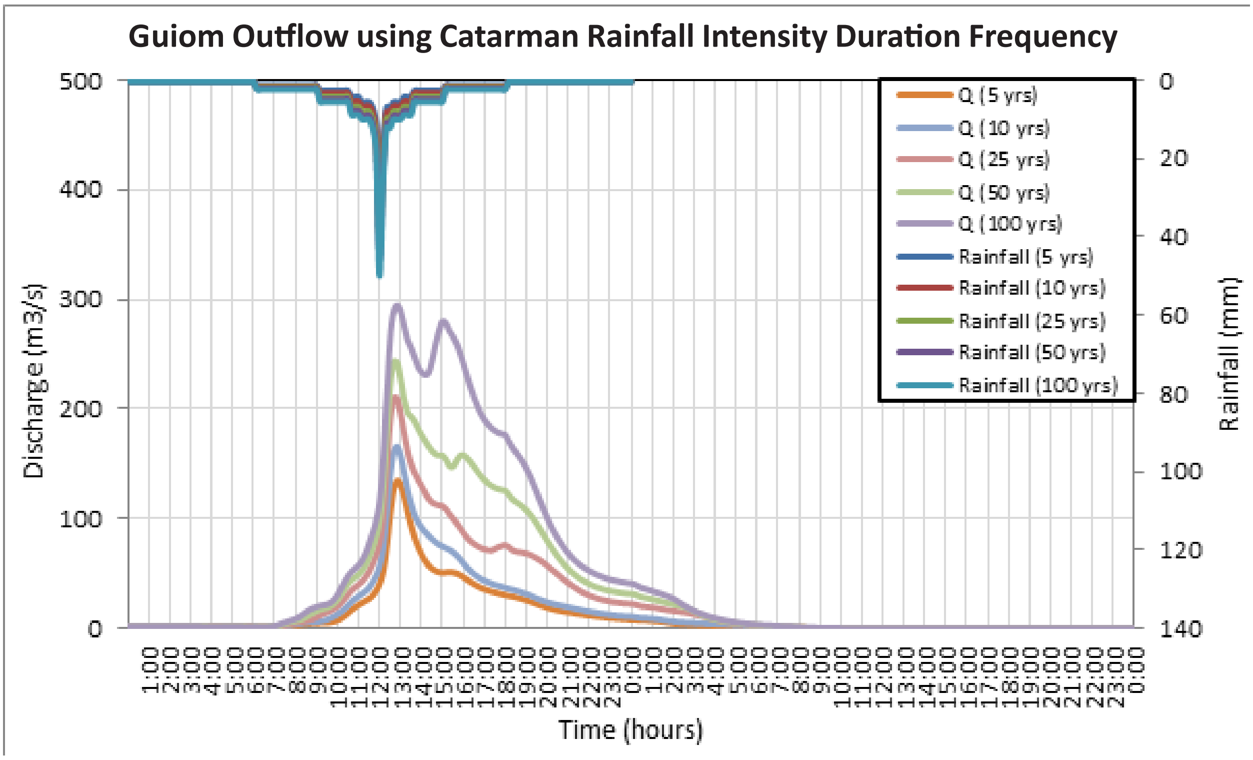


Figure 69. The outflow hydrograph at the Guiom Basin, generated using the simulated rain events for 24-hour period for Catarman station

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

Table 30. Outlines the peak values of the Guiom HEC-HMS Model outflow using the Catarman RIDF 24-hour values.

| RIDF Period | Total Precipitation (mm) | Peak rainfall (mm) | Peak outflow (m 3/s) | Time to Peak |
|---|---|---|---|---|
| 5-Year | 255.4 | 29.9 | 134.5 | 50 minutes |
| 10-Year | 305.4 | 34.7 | 165.7 | 50 minutes |
| 25-Year | 368.5 | 40.9 | 210.1 | 50 minutes |
| 50-Year | 415.3 | 45.5 | 243 | 40 minutes |
| 100-Year | 461.8 | 50 | 294.6 | 50 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, only a sample output map river was to be shown, since only the ADNU-DVC base flow was calibrated. Figure 70 shows a generated sample map of the Guiom River using the calibrated HMS base flow.


Figure 70. The sample output map of the Guiom RAS Model

## 5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 71 to 76 show the 5-, 25-, and 100-year rain return scenarios of the Guiom flood plain. The flood plain, with an area of 205.73km2, covers three (3) municipalities, namely Cawayan, Palanas, and Placer. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Guiom flood plain

| Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|
| Cawayan | 261.38 | 117.18 | 44.83 |
| Palanas | 138.17 | 2.31 | 1.67 |
| Placer | 253.55 | 85.03 | 33.53 |
| Luna | 320.66 | 89.26 | 27.84% |

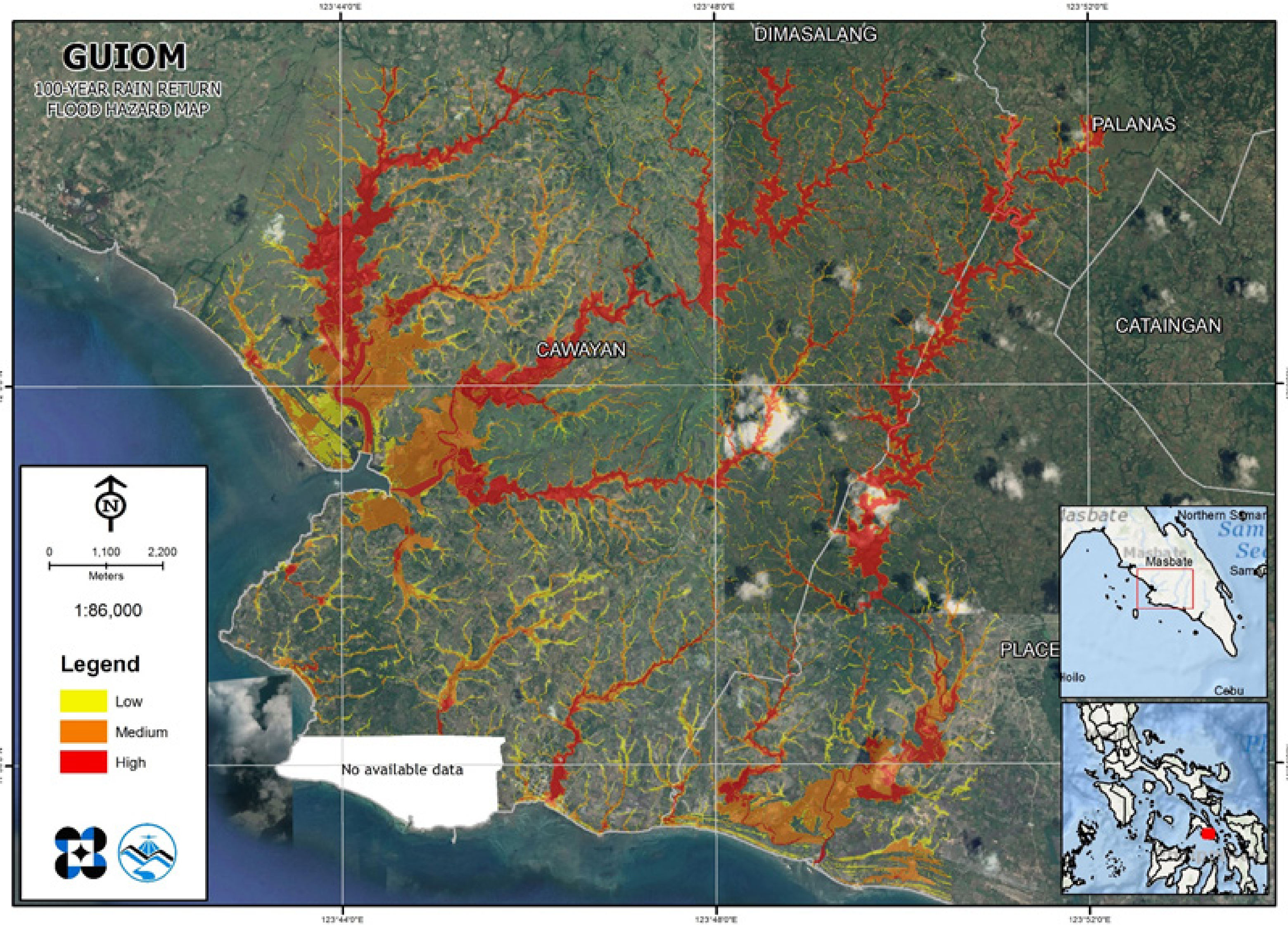


Figure 71. 100-year flood hazard map for the Guiom flood plain overlaid on Google Earth imagery

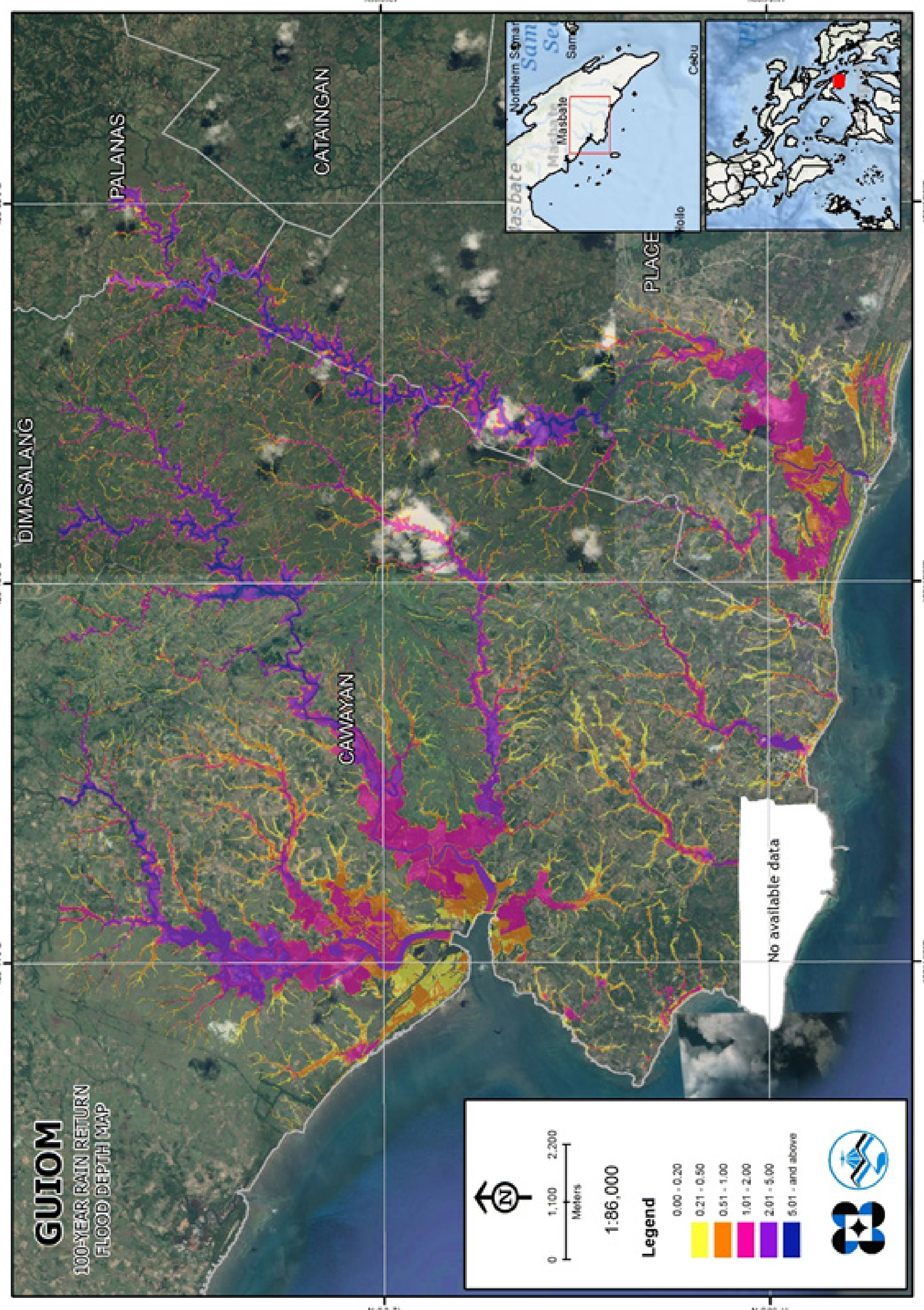


Figure 72. 100-year flow depth map for the Guiom flood plain overlaid on Google Earth imagery

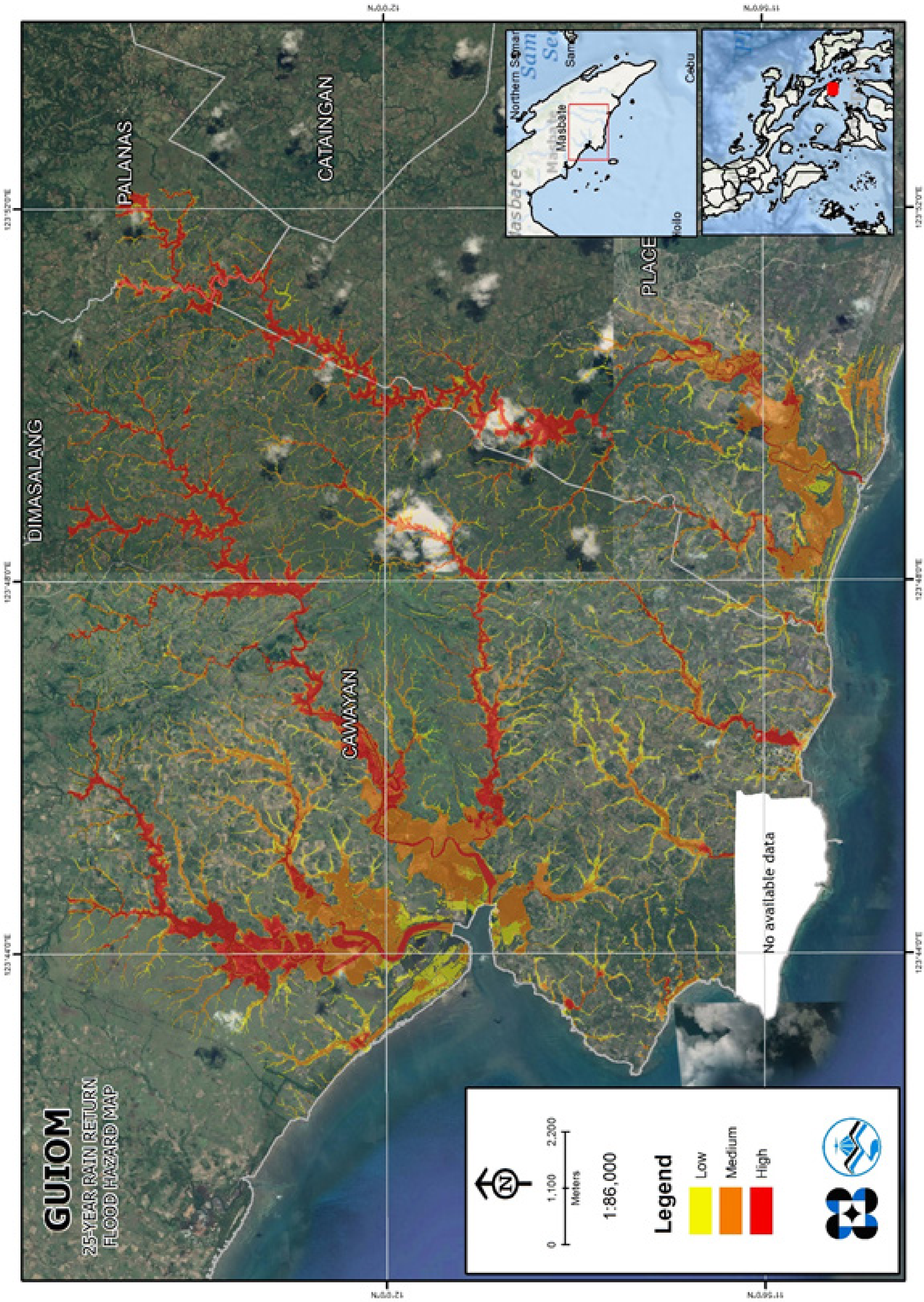


Figure 73. 25-year flood hazard map for the Guiom flood plain overlaid on Google Earth imagery

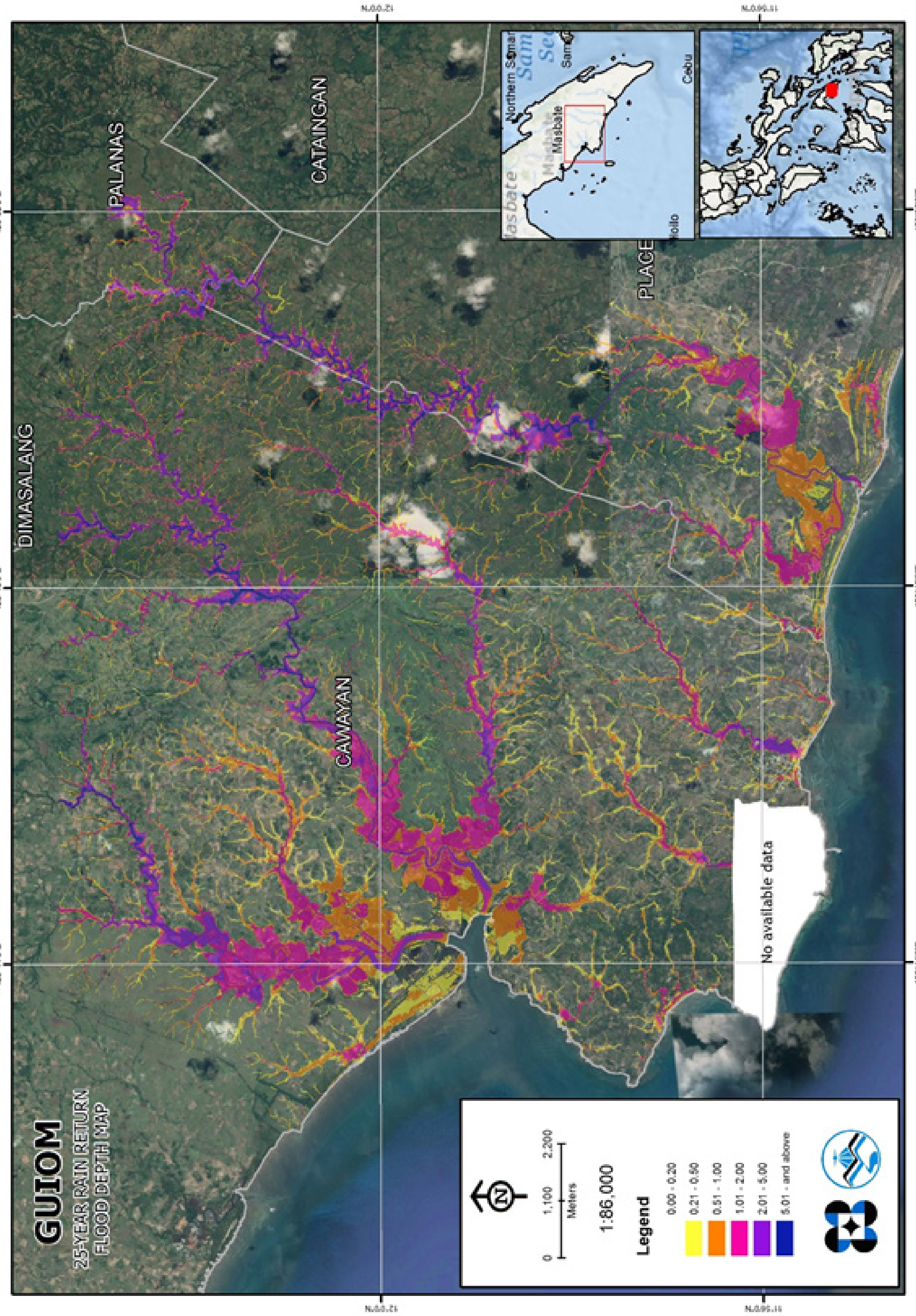


Figure 74. 25-year flow depth map for the Guiom flood plain overlaid on Google Earth imagery

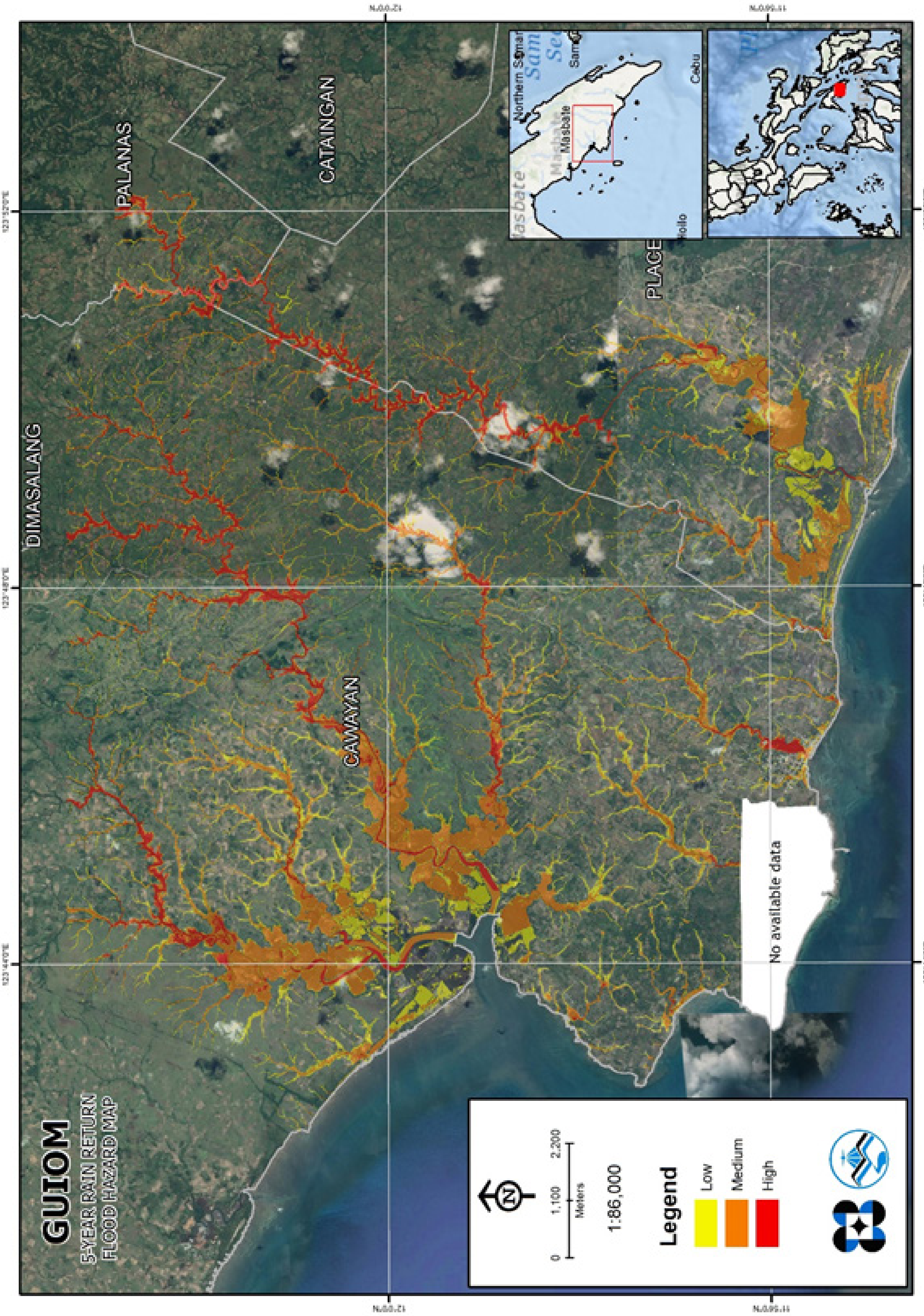


Figure 75. 5-year flood hazard map for the Guiom flood plain overlaid on Google Earth imagery

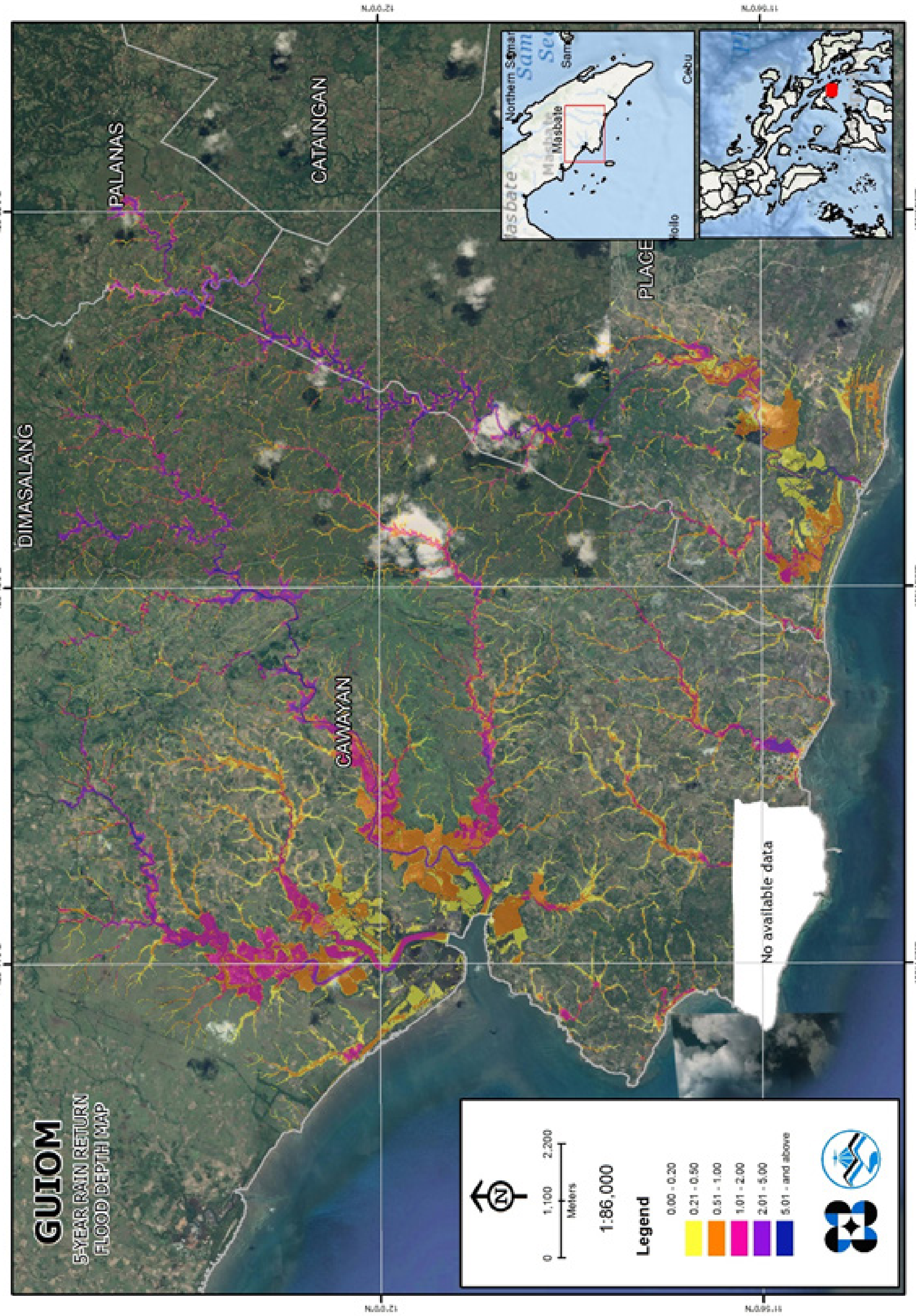


Figure 76. 5-year flow depth map for the Guiom flood plain overlaid on Google Earth imagery

## 5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Guiom River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 33 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 36.12% of the municipality of Cawayan with an area of 261.38 sq. km. will experience flood levels of less than 0.20 meters. 3.03% of the area will experience flood levels of 0.21 to 0.50 meters, while 3%, 2.02%, 0.58%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figures 77 and 78 depict the areas affected in Cawayan in square kilometers by flood depth per barangay.

Table 32. Affected areas in Cawayan, Masbate during the 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Cawayan | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Begia | Cabayugan | Cabungahan | Calapayan | Calumpang | Dalipe | Divisoria | Guiom | Iraya | Itombato | Madbad |
| 0.03-0.20 | 4.45 | 1.36 | 4.21 | 6.49 | 7.51 | 3.54 | 2.84 | 5.63 | 3.36 | 4.99 | 4.05 |
| 0.21-0.50 | 0.21 | 0.044 | 0.19 | 0.33 | 0.54 | 1.09 | 0.22 | 0.64 | 0.35 | 0.44 | 0.19 |
| 0.51-1.00 | 0.068 | 0.019 | 0.17 | 0.29 | 0.49 | 0.77 | 0.11 | 0.72 | 0.81 | 0.55 | 0.14 |
| 1.01-2.00 | 0.0014 | 0.0014 | 0.15 | 0.23 | 0.24 | 0.55 | 0.11 | 0.22 | 1.25 | 0.58 | 0.14 |
| 2.01-5.00 | 0 | 0.0002 | 0.14 | 0.21 | 0.2 | 0.037 | 0.13 | 0.031 | 0.13 | 0.1 | 0.016 |
| > 5.00 | 0 | 0 | 0.013 | 0.056 | 0.042 | 0 | 0 | 0 | 0 | 0.0079 | 0 |

Table 33. Affected areas in Cawayan, Masbate during the 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Cawayan | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mahayahay | Maihao | Pananawan | Pin-As | Poblacion | R.M. Magbalon | Recodo | San Jose | San Vicente | Tubog | Tuburan | Villahermosa |
| 0.03-0.20 | 0.098 | 2.41 | 4.88 | 1.69 | 5.64 | 6.57 | 5.52 | 0.2 | 9.33 | 2.31 | 3.82 | 3.49 |
| 0.21-0.50 | 0.0043 | 0.29 | 0.63 | 0.49 | 0.46 | 0.34 | 0.32 | 0.014 | 0.71 | 0.15 | 0.14 | 0.14 |
| 0.51-1.00 | 0.0075 | 1.21 | 0.53 | 0.39 | 0.33 | 0.25 | 0.21 | 0.0074 | 0.4 | 0.16 | 0.091 | 0.14 |
| 1.01-2.00 | 0.011 | 0.42 | 0.4 | 0.017 | 0.09 | 0.16 | 0.14 | 0.005 | 0.22 | 0.15 | 0.029 | 0.18 |
| 2.01-5.00 | 0.0002 | 0.12 | 0.019 | 0 | 0.008 | 0.081 | 0.0009 | 0 | 0.06 | 0.017 | 0.0053 | 0.22 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0.009 | 0 | 0 | 0 | 0 | 0 | 0.071 |

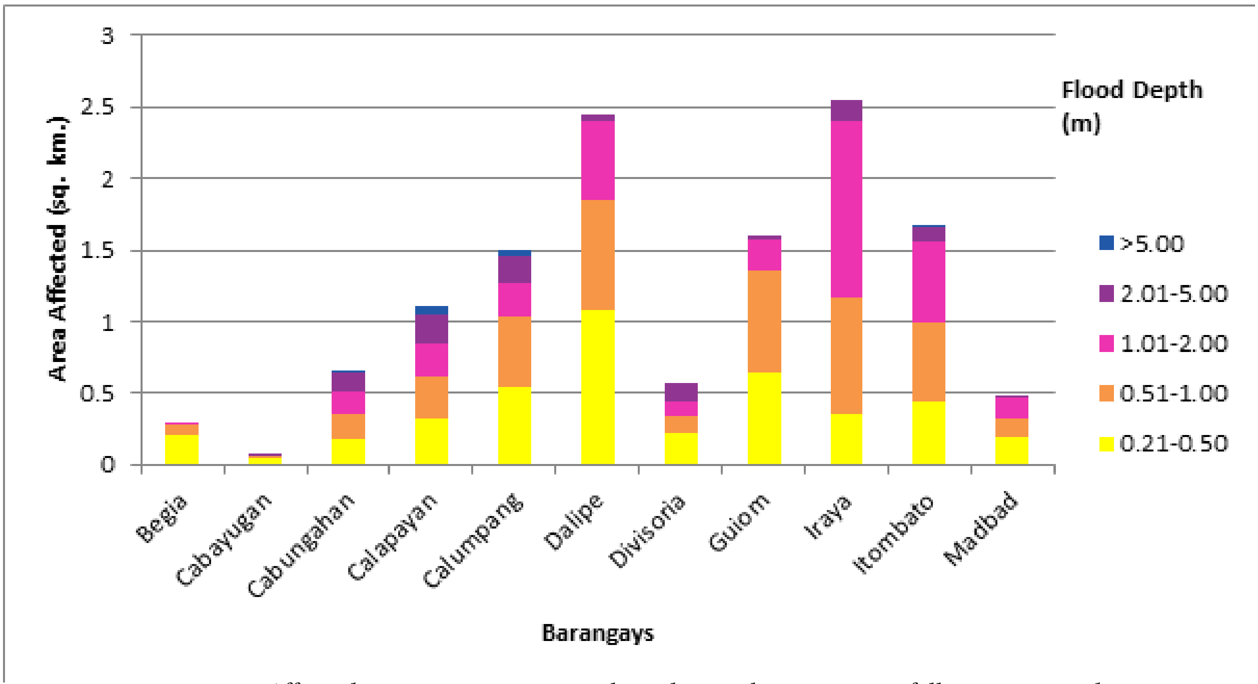


Figure 77. Affected areas in Cawayan, Masbate during the 5-Year Rainfall Return Period

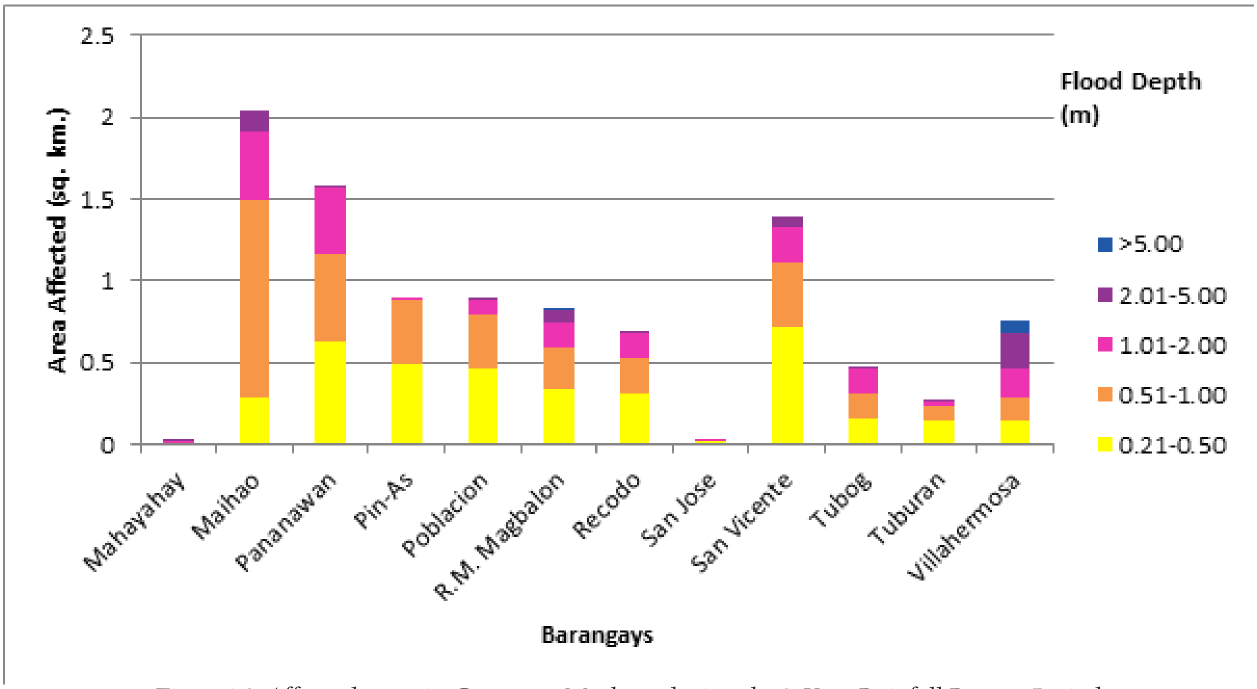


Figure 78. Affected areas in Cawayan, Masbate during the 5-Year Rainfall Return Period

For the municipality of Palanas with an area of 138.17 sq. km., 1.31% will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.07%, 0.11%, 0.1%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 79 depicts the areas affected in Palanas in square kilometers by flood depth per barangay.

Table 34. Affected areas in Palanas, Masbate during the 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Palanas (in sq. km) | |
|---|---|---|
| | Antipolo | Malatawan |
| **0.03-0.20** | 1.17 | 0.65 |
| **0.21-0.50** | 0.068 | 0.031 |
| **0.51-1.00** | 0.085 | 0.018 |
| **1.01-2.00** | 0.14 | 0.016 |
| **2.01-5.00** | 0.12 | 0.011 |
| **> 5.00** | 0.0019 | 0 |

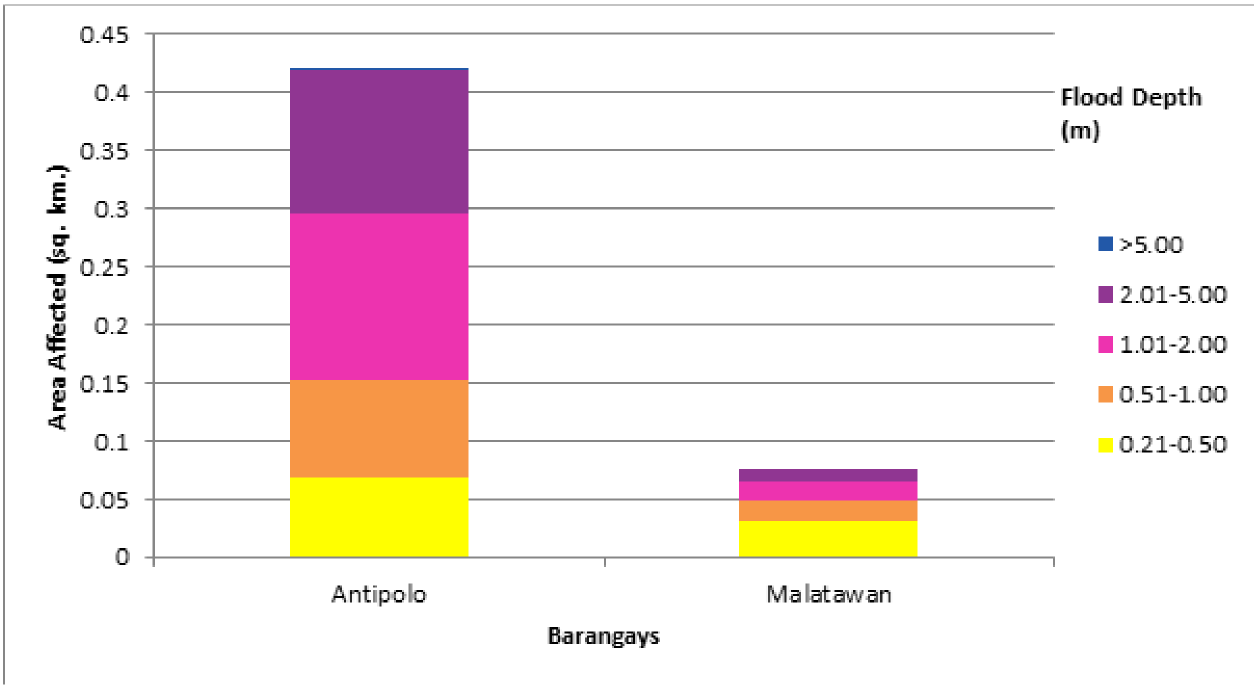


Figure 79. Affected areas in Palanas, Masbate during the 5-Year Rainfall Return Period

For the municipality of Placer with an area of 253.55 sq. km., 28.04% will experience flood levels of less than 0.20 meters. 1.95% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.76%, 1.03%, 0.63%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 80 depicts the areas affected in Placer in square kilometers by flood depth per barangay.

Table 35. Affected areas in Placer, Masbate during the 5-Year Rainfall Return Period
(insert table)

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Placer | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Camayabsan | Dangpanan | Libas | Luna | Nainday | Puro | Santa Cruz | Tan-Awan |
| **0.03-0.20** | 5.22 | 4.12 | 19.98 | 0.077 | 5.55 | 15.38 | 13.89 | 6.86 |
| **0.21-0.50** | 0.49 | 0.62 | 0.96 | 0.0004 | 1.02 | 0.73 | 0.64 | 0.47 |
| **0.51-1.00** | 0.43 | 0.67 | 0.8 | 0.0009 | 1.13 | 0.47 | 0.56 | 0.41 |
| **1.01-2.00** | 0.14 | 0.3 | 0.72 | 0.0002 | 0.13 | 0.37 | 0.65 | 0.31 |
| **2.01-5.00** | 0.0082 | 0.014 | 0.34 | 0 | 0.077 | 0.16 | 0.77 | 0.23 |
| **> 5.00** | 0 | 0 | 0.027 | 0 | 0.0019 | 0.014 | 0.21 | 0.065 |

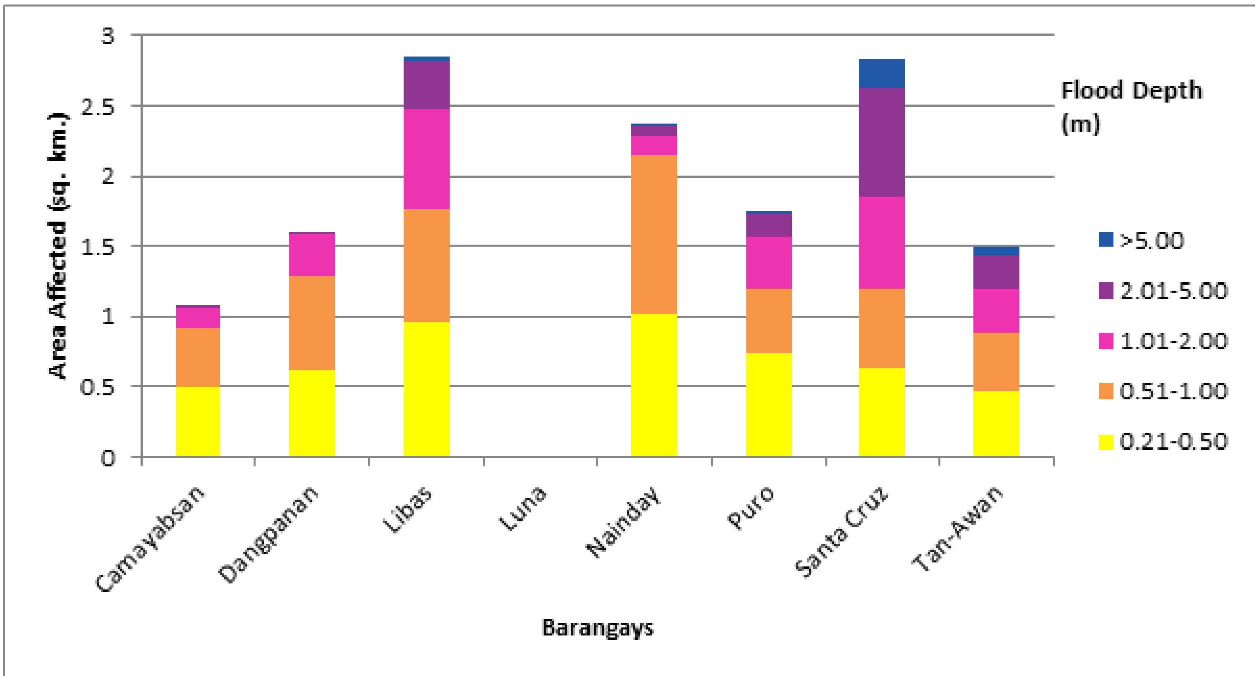


Figure 80. Affected areas in Placer, Masbate during the 5-Year Rainfall Return Period

For the 25-year rainfall return period, 34.22% of the municipality of Cawayan with an area of 261.38 sq. km. will experience flood levels of less than 0.20 meters. 2.9% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.94%, 3.3%, 1.3%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figures 81 and 82 depict the areas affected in Cawayan in square kilometers by flood depth per barangay.

Table 36. Affected areas in Cawayan, Masbate during the 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Cawayan | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Begia | Cabayugan | Cabungahan | Calapayan | Calumpang | Dalipe | Divisoria | Guiom | Iraya | Itombato | Madbad |
| 0.03-0.20 | 4.36 | 1.34 | 4.05 | 6.22 | 7.19 | 2.86 | 2.69 | 5.34 | 3.11 | 4.73 | 3.92 |
| 0.21-0.50 | 0.25 | 0.057 | 0.19 | 0.33 | 0.52 | 0.55 | 0.28 | 0.62 | 0.25 | 0.38 | 0.2 |
| 0.51-1.00 | 0.11 | 0.025 | 0.18 | 0.33 | 0.57 | 1.41 | 0.14 | 0.74 | 0.38 | 0.44 | 0.15 |
| 1.01-2.00 | 0.006 | 0.0026 | 0.2 | 0.27 | 0.3 | 0.97 | 0.11 | 0.5 | 1.59 | 0.82 | 0.16 |
| 2.01-5.00 | 0 | 0.0002 | 0.19 | 0.36 | 0.36 | 0.18 | 0.19 | 0.042 | 0.58 | 0.27 | 0.091 |
| > 5.00 | 0 | 0 | 0.058 | 0.1 | 0.08 | 0 | 0.0002 | 0 | 0 | 0.017 | 0.0007 |

Table 37. Affected areas in Cawayan, Masbate during the 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Cawayan | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mahayahay | Maihao | Pananawan | Pin-As | Poblacion | R.M. Magbalon | Recodo | San Jose | San Vicente | Tubog | Tuburan | Villahermosa |
| 0.03-0.20 | 0.096 | 2.27 | 4.57 | 1.28 | 5.41 | 6.38 | 5.37 | 0.19 | 8.95 | 2.18 | 3.76 | 3.18 |
| 0.21-0.50 | 0.0023 | 0.19 | 0.63 | 0.55 | 0.52 | 0.34 | 0.37 | 0.016 | 0.83 | 0.17 | 0.16 | 0.15 |
| 0.51-1.00 | 0.0058 | 0.45 | 0.45 | 0.5 | 0.37 | 0.3 | 0.25 | 0.0087 | 0.46 | 0.15 | 0.12 | 0.14 |
| 1.01-2.00 | 0.012 | 1.38 | 0.68 | 0.26 | 0.21 | 0.22 | 0.2 | 0.0068 | 0.27 | 0.22 | 0.041 | 0.21 |
| 2.01-5.00 | 0.005 | 0.16 | 0.14 | 0.0068 | 0.021 | 0.13 | 0.01 | 0 | 0.19 | 0.062 | 0.012 | 0.4 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0.033 | 0 | 0 | 0.0028 | 0 | 0 | 0.16 |

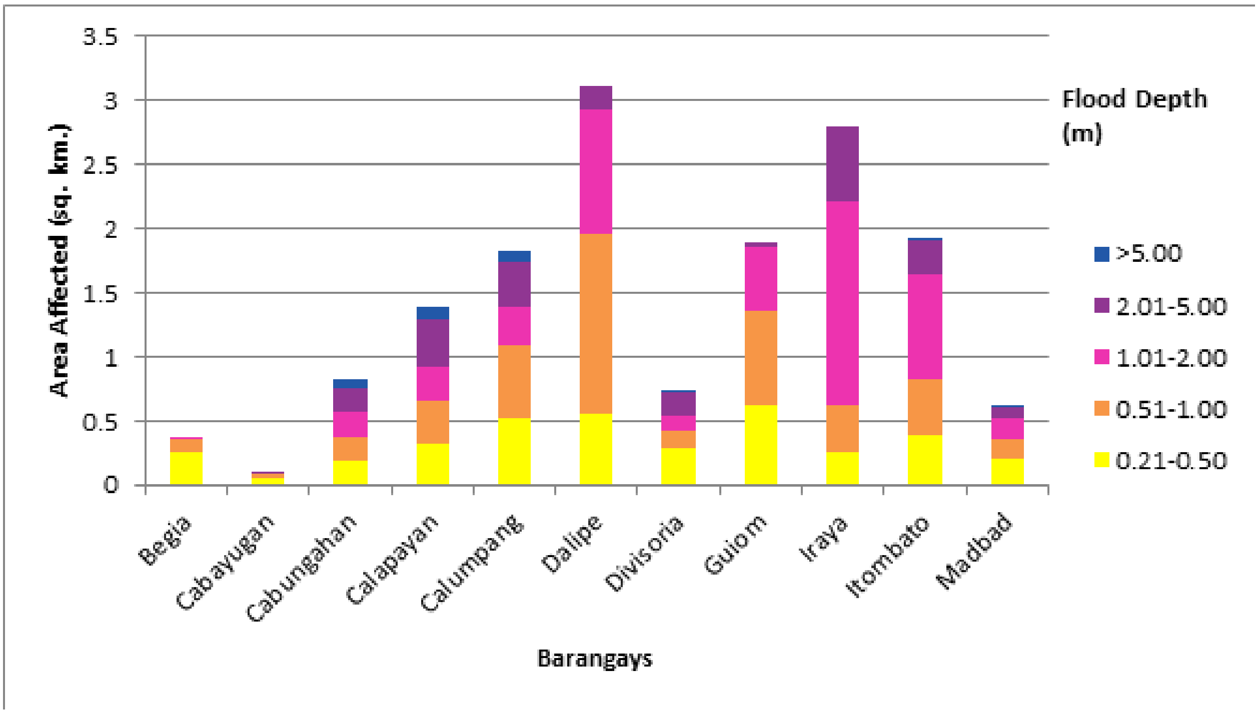


Figure 81. Affected areas in Cawayan, Masbate during the 25-Year Rainfall Return Period

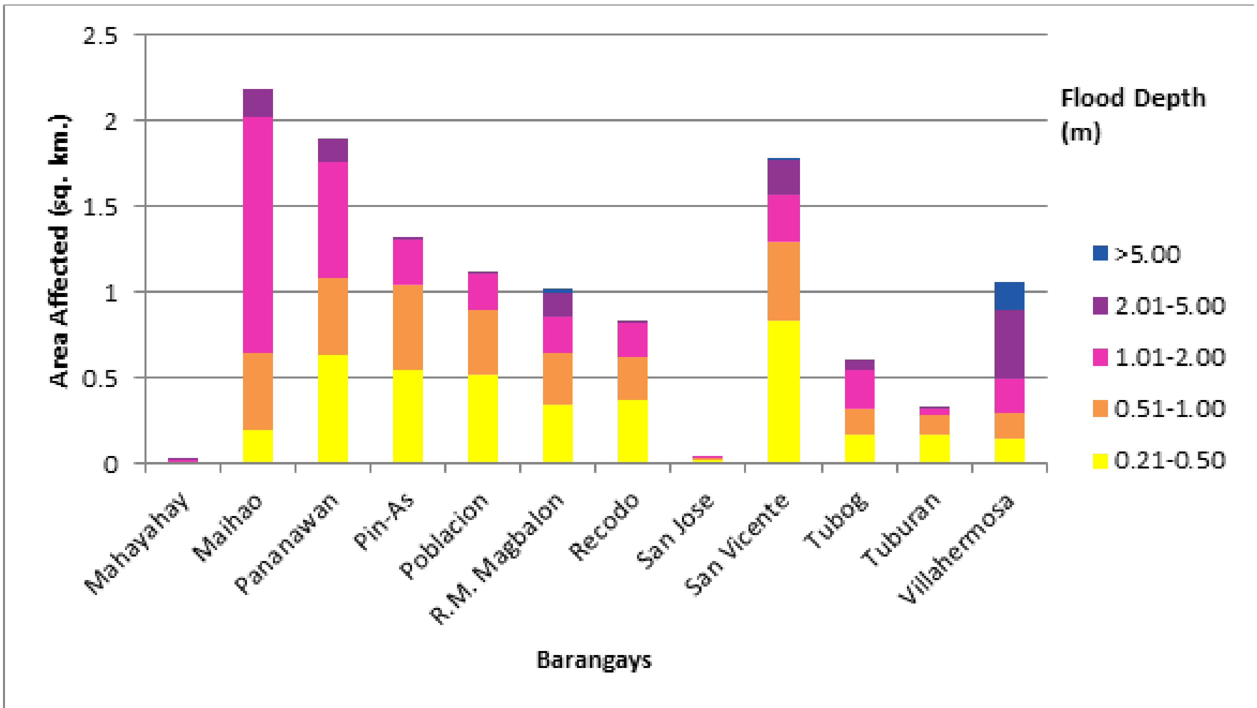


Figure 82. Affected areas in Cawayan, Masbate during the 25-Year Rainfall Return Period

For the municipality of Palanas with an area of 138.17 sq. km., 1.21% will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.08%, 0.12%, 0.18%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 83 depicts the areas affected in Palanas in square kilometers by flood depth per barangay.

Table 38. Affected areas in Palanas, Masbate during the 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Palanas (in sq. km) | |
|---|---|---|
| | Antipolo | Malatawan |
| 0.03-0.20 | 1.04 | 0.63 |
| 0.21-0.50 | 0.076 | 0.036 |
| 0.51-1.00 | 0.085 | 0.021 |
| 1.01-2.00 | 0.15 | 0.02 |
| 2.01-5.00 | 0.23 | 0.02 |
| > 5.00 | 0.0042 | 0 |

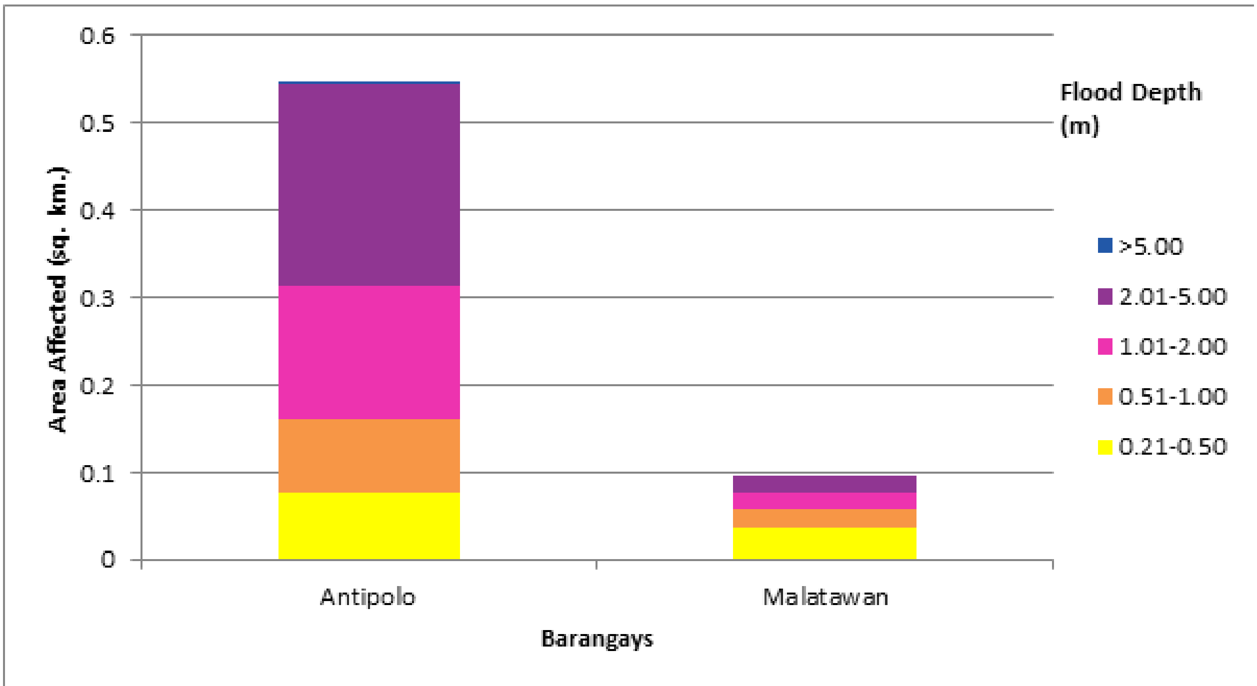


Figure 83. Affected areas in Palanas, Masbate during the 25-Year Rainfall Return Period

For the municipality of Placer with an area of 253.55 sq. km., 26.5% will experience flood levels of less than 0.20 meters. 1.87% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.86%, 1.95%, 1.1%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 84 depicts the areas affected in Placer in square kilometers by flood depth per barangay.

Table 39. Affected areas in Placer, Masbate during the 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Placer | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Camayabsan | Dangpanan | Libas | Luna | Nainday | Puro | Santa Cruz | Tan-Awan |
| **0.03-0.20** | 4.98 | 3.74 | 19.22 | 0.077 | 4.95 | 14.78 | 13.01 | 6.41 |
| **0.21-0.50** | 0.55 | 0.51 | 1.06 | 0.00067 | 0.65 | 0.83 | 0.71 | 0.43 |
| **0.51-1.00** | 0.4 | 0.72 | 0.86 | 0.0007 | 1.05 | 0.55 | 0.66 | 0.48 |
| **1.01-2.00** | 0.35 | 0.7 | 0.93 | 0.0006 | 1.15 | 0.54 | 0.8 | 0.47 |
| **2.01-5.00** | 0.019 | 0.038 | 0.67 | 0.0001 | 0.085 | 0.39 | 1.17 | 0.42 |
| **> 5.00** | 0 | 0.0025 | 0.083 | 0 | 0.016 | 0.042 | 0.36 | 0.15 |

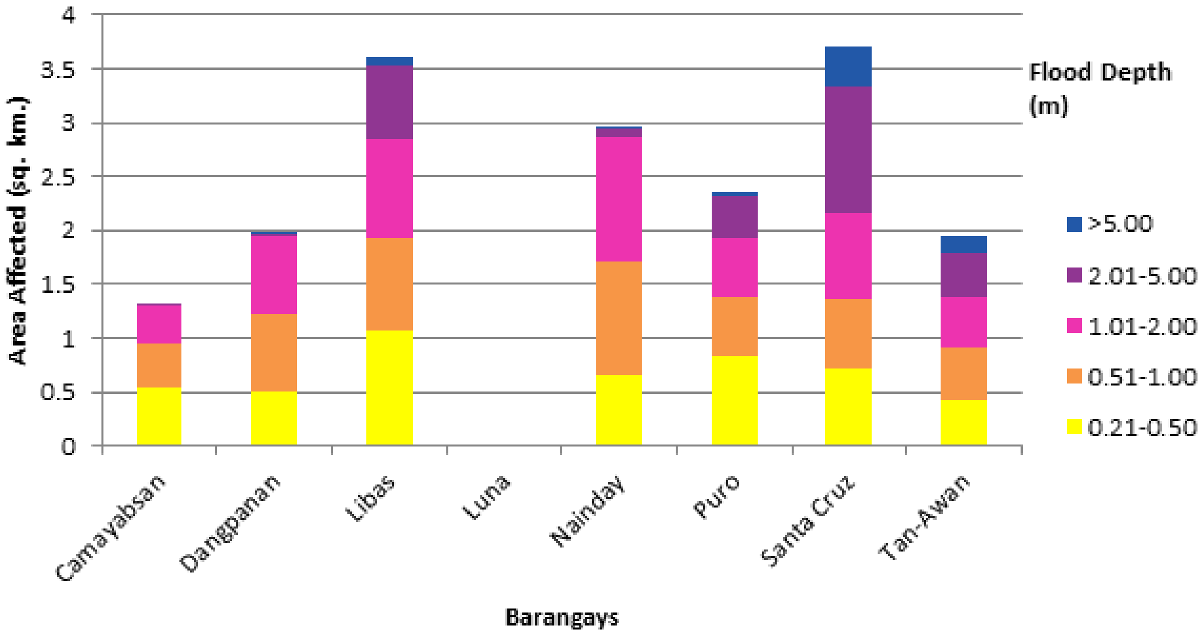


Figure 84. Affected areas in Placer, Masbate during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 33.2% of the municipality of Cawayan with an area of 261.38 sq. km. will experience flood levels of less than 0.20 meters. 2.89% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.82%, 3.57%, 2.08%, and 0.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figures 85 and 86 depict the areas affected in Cawayan in square kilometers by flood depth per barangay.

Table 40. Affected areas in Cawayan, Masbate during the 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Cawayan | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Begia | Cabayugan | Cabungahan | Calapayan | Calumpang | Dalipe | Divisoria | Guiom | Iraya | Itombato | Madbad |
| 0.03-0.20 | 4.3 | 1.32 | 3.96 | 6.05 | 7 | 2.69 | 2.6 | 5.22 | 2.98 | 4.59 | 3.85 |
| 0.21-0.50 | 0.28 | 0.068 | 0.2 | 0.34 | 0.51 | 0.41 | 0.33 | 0.53 | 0.22 | 0.39 | 0.2 |
| 0.51-1.00 | 0.14 | 0.028 | 0.19 | 0.33 | 0.59 | 1.11 | 0.16 | 0.65 | 0.3 | 0.41 | 0.17 |
| 1.01-2.00 | 0.012 | 0.0042 | 0.22 | 0.28 | 0.39 | 1.49 | 0.12 | 0.76 | 1.05 | 0.67 | 0.16 |
| 2.01-5.00 | 0 | 0.0002 | 0.23 | 0.45 | 0.42 | 0.28 | 0.2 | 0.09 | 1.34 | 0.58 | 0.14 |
| > 5.00 | 0 | 0 | 0.083 | 0.15 | 0.1 | 0 | 0.0003 | 0 | 0 | 0.027 | 0.0014 |

Table 41. Affected areas in Cawayan, Masbate during the 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Cawayan | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mahayahay | Maihao | Pananawan | Pin-As | Poblacion | R.M. Magbalon | Recodo | San Jose | San Vicente | Tubog | Tuburan | Villahermosa |
| 0.03-0.20 | 0.095 | 2.21 | 4.37 | 1.07 | 5.27 | 6.25 | 5.27 | 0.19 | 8.7 | 2.1 | 3.72 | 2.98 |
| 0.21-0.50 | 0.0022 | 0.16 | 0.65 | 0.52 | 0.56 | 0.34 | 0.4 | 0.016 | 0.93 | 0.19 | 0.18 | 0.14 |
| 0.51-1.00 | 0.0043 | 0.25 | 0.51 | 0.58 | 0.39 | 0.33 | 0.27 | 0.011 | 0.51 | 0.15 | 0.13 | 0.15 |
| 1.01-2.00 | 0.012 | 1.56 | 0.62 | 0.41 | 0.28 | 0.27 | 0.23 | 0.0085 | 0.29 | 0.25 | 0.054 | 0.21 |
| 2.01-5.00 | 0.0079 | 0.27 | 0.32 | 0.014 | 0.033 | 0.17 | 0.025 | 0.0002 | 0.29 | 0.1 | 0.018 | 0.46 |
| > 5.00 | 0 | 0 | 0 | 0 | 0.0005 | 0.041 | 0 | 0 | 0.0048 | 0 | 0 | 0.3 |

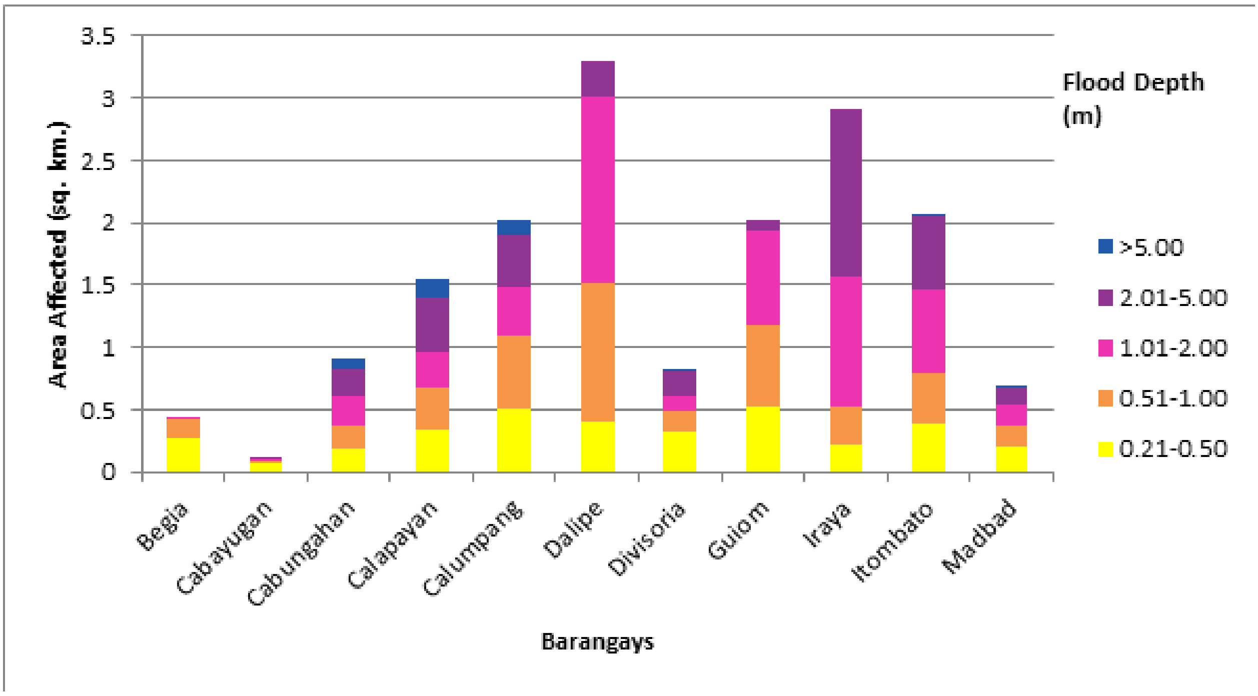


Figure 85. Affected areas in Cawayan, Masbate during the 100-Year Rainfall Return Period

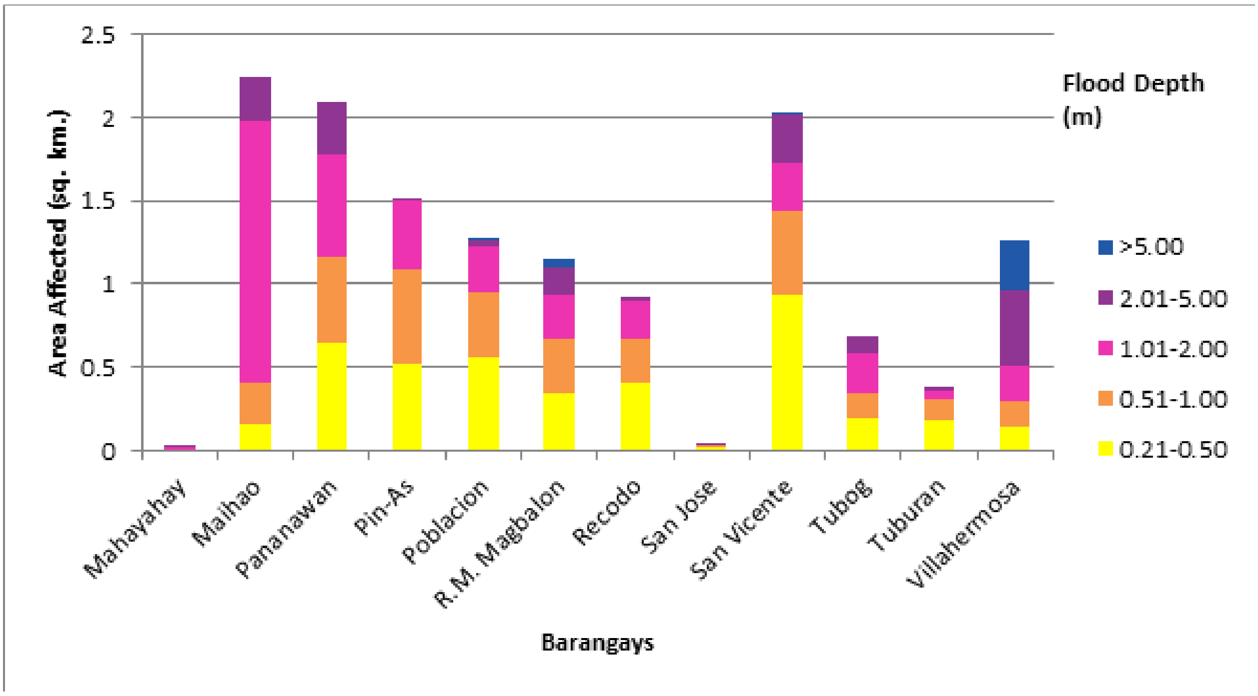


Figure 86. Affected areas in Cawayan, Masbate during the 100-Year Rainfall Return Period

For the municipality of Palanas with an area of 138.17 sq. km., 1.14% will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.09%, 0.13%, 0.23%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 87 depicts the areas affected in Palanas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Palanas, Masbate during the 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Palanas (in sq. km) | |
|---|---|---|
| | Antipolo | Malatawan |
| 0.03-0.20 | 0.95 | 0.62 |
| 0.21-0.50 | 0.081 | 0.036 |
| 0.51-1.00 | 0.095 | 0.027 |
| 1.01-2.00 | 0.16 | 0.02 |
| 2.01-5.00 | 0.29 | 0.025 |
| > 5.00 | 0.016 | 0.00078 |

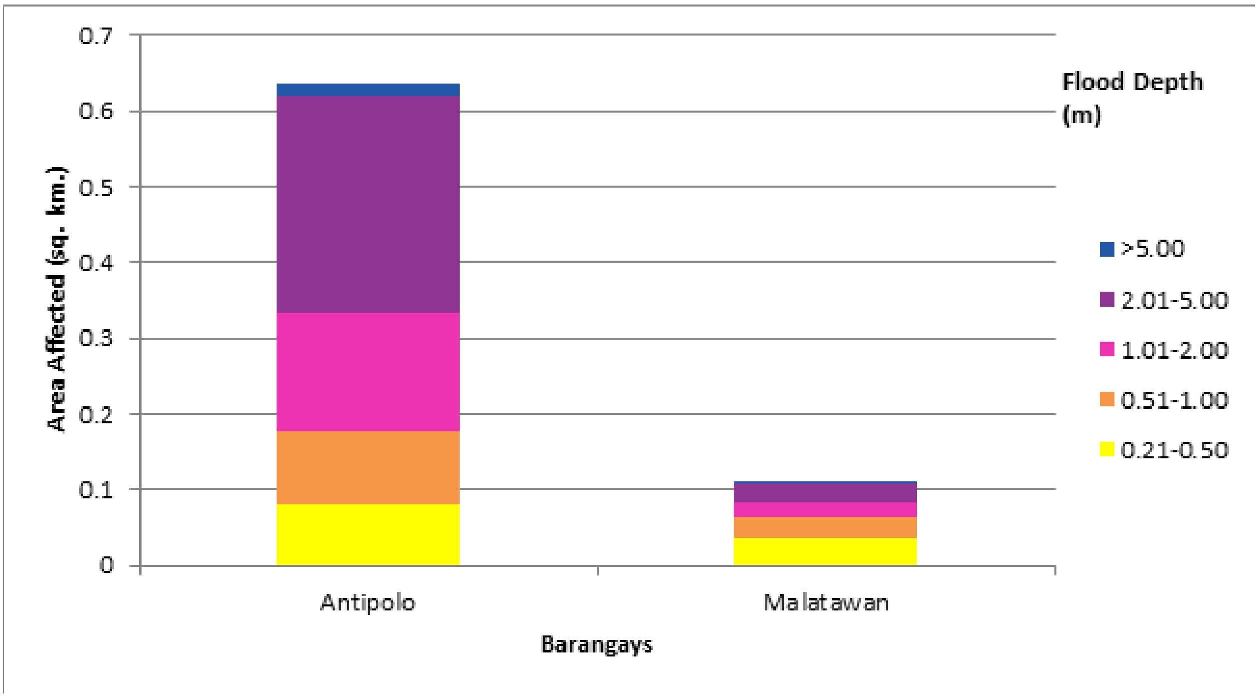


Figure 87. Affected areas in Palanas, Masbate during the 100-Year Rainfall Return Period

For the municipality of Placer with an area of 253.55 sq. km., 25.58% will experience flood levels of less than 0.20 meters. 1.95% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.72%, 2.43%, 1.44%, and 0.42% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 88 depicts the areas affected in Placer in square kilometers by flood depth per barangay.

Table 43. Affected areas in Placer, Masbate during the 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of barangays affected in Placer | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Camayabsan | Dangpanan | Libas | Luna | Nainday | Puro | Santa Cruz | Tan-Awan |
| **0.03-0.20** | 4.83 | 3.56 | 18.7 | 0.076 | 4.7 | 14.4 | 12.43 | 6.16 |
| **0.21-0.50** | 0.58 | 0.48 | 1.12 | 0.0011 | 0.73 | 0.9 | 0.7 | 0.43 |
| **0.51-1.00** | 0.37 | 0.55 | 0.92 | 0.00062 | 0.75 | 0.62 | 0.72 | 0.44 |
| **1.01-2.00** | 0.48 | 1.03 | 1.02 | 0.0009 | 1.6 | 0.56 | 0.91 | 0.57 |
| **2.01-5.00** | 0.029 | 0.098 | 0.9 | 0.0001 | 0.099 | 0.56 | 1.44 | 0.53 |
| **> 5.00** | 0 | 0.0029 | 0.17 | 0 | 0.037 | 0.089 | 0.52 | 0.23 |

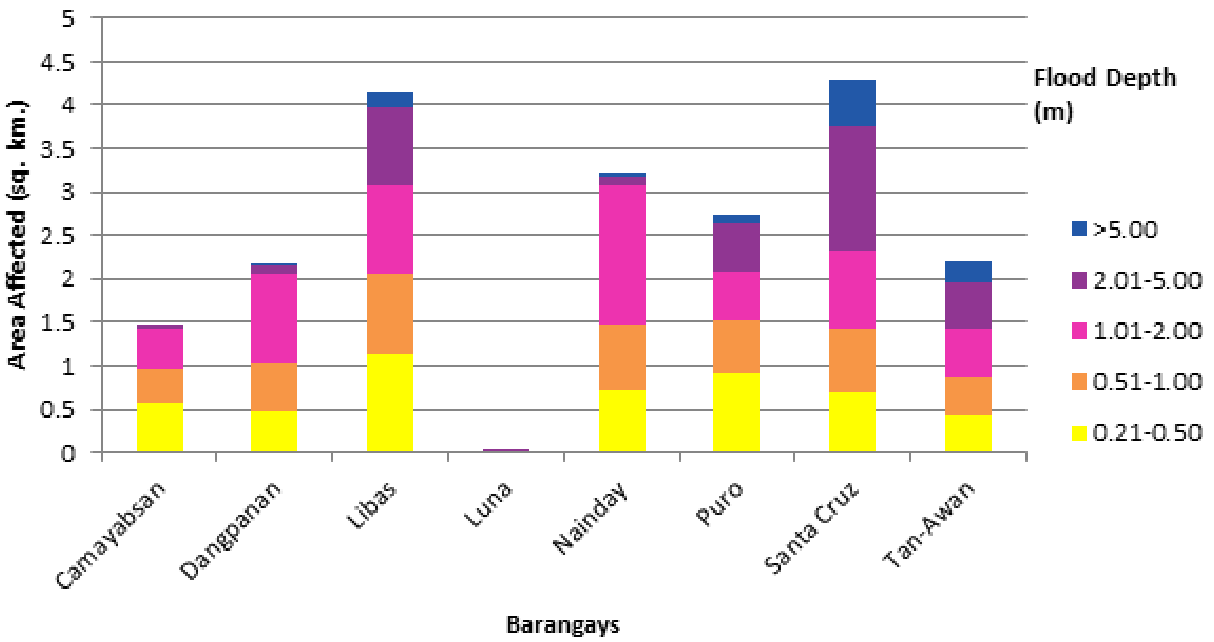


Figure 88. Affected areas in Placer, Masbate during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Cawayan, San Vicente is projected to have the highest percentage of area that will experience flood levels at 4.1%. Meanwhile, Calumpang posted the second highest percentage of area that may be affected by flood depths at 3.45%.

Among the barangays in the municipality of Palanas, Antipolo is projected to have the highest percentage of area that will experience flood levels at 1.15%. Meanwhile, Malatawan posted the second highest percentage of area that may be affected by flood depths at 0.53%.

Among the barangays in the municipality of Placer, Libas is projected to have the highest percentage of area that will experience flood levels of at 9%. Meanwhile, Puro posted the second highest percentage of area that may be affected by flood depths at 6.76%.

## 5.11 Flood Validation

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

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

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

After which, the actual data from the field was 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 204 points randomly selected all over the Guiom flood plain. It has an RMSE value of 0.304377.

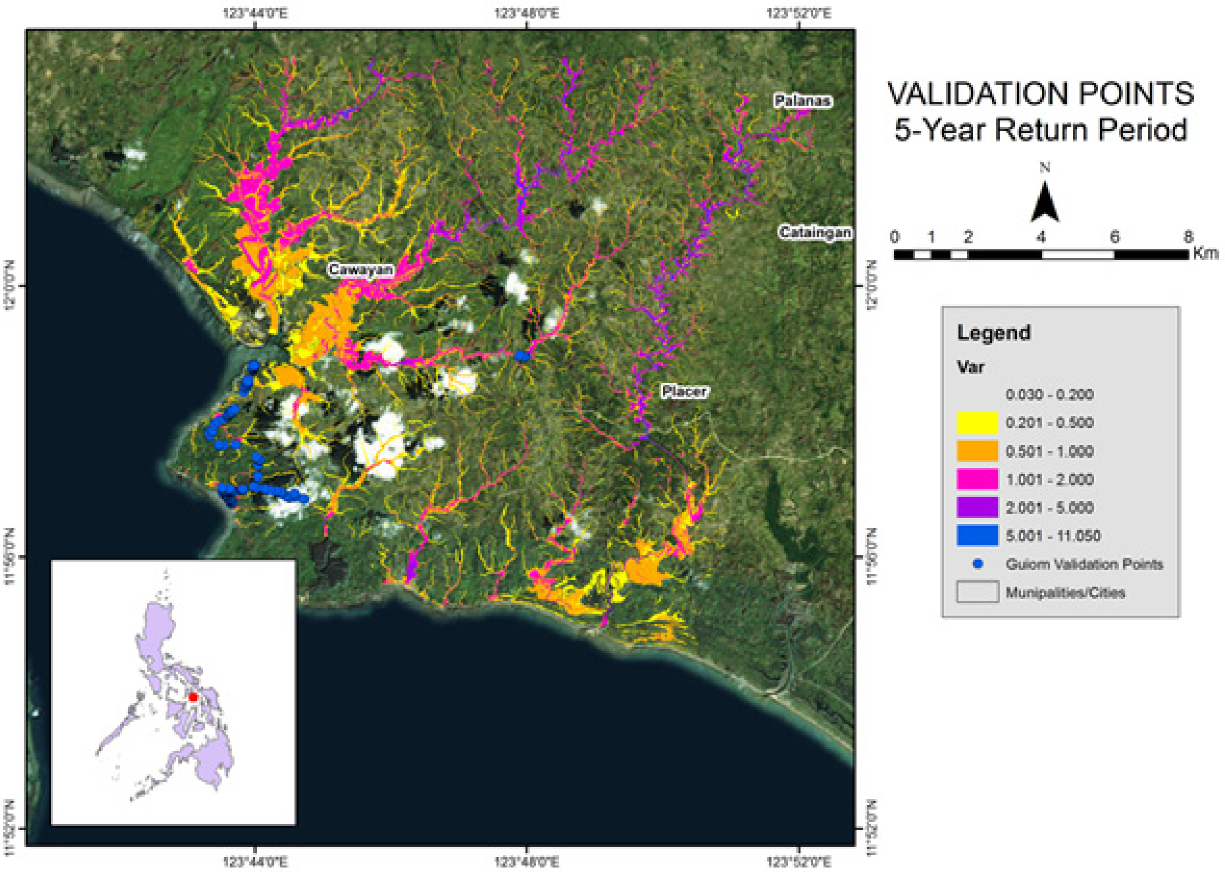


Figure 89. The validation points for the 5-Year flood depth map of the Guiom flood plain

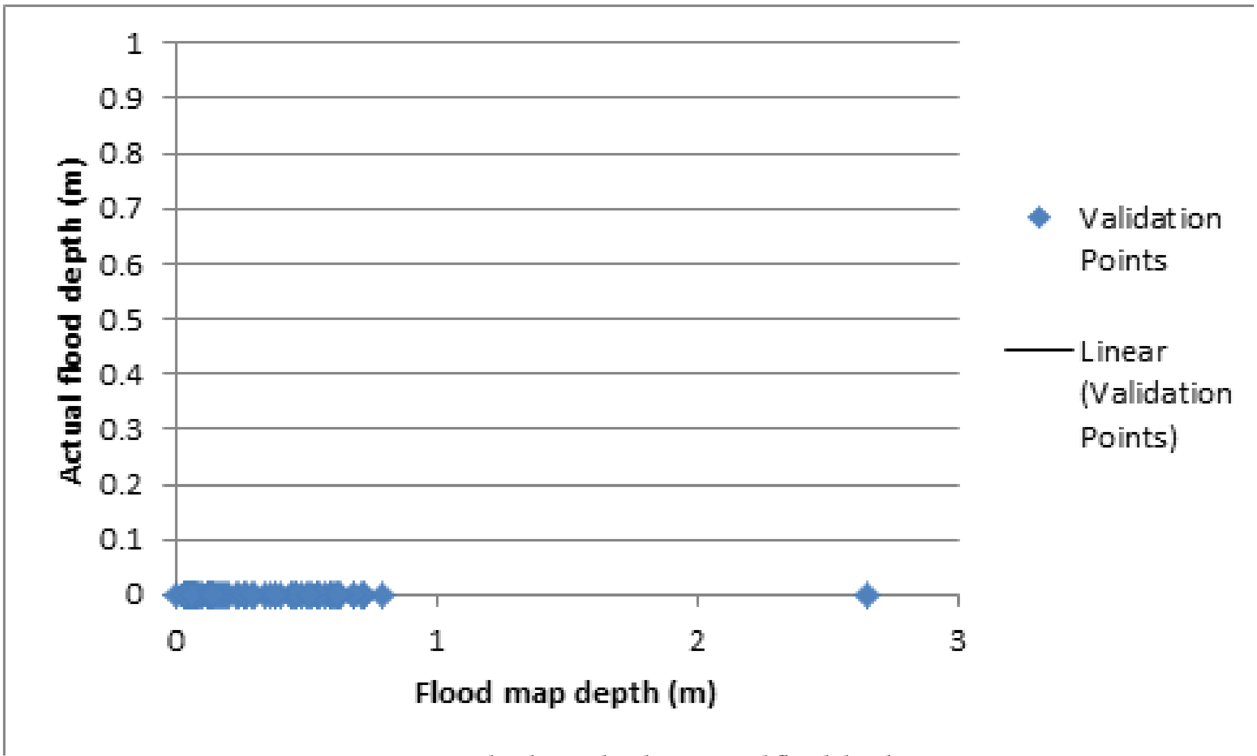


Figure 90. Flood map depth vs. Actual flood depth

Table 44. Actual flood vs. Simulated flood depth at different levels in the Guiom River Basin

| Actual Flood Depth (m) | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-0.20 | 0.21-0.50 | 0.51-1.00 | 1.01-2.00 | 2.01-5.00 | > 5.00 | Total |
| 0-0.20 | 161 | 20 | 22 | 0 | 1 | 0 | 204 |
| 0.21-0.50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.51-1.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.01-2.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.01-5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 5.00 | | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 161 | 20 | 22 | 0 | 1 | 0 | 204 |

On the whole, the overall accuracy generated by the flood model is estimated at 78.92%, with 161 points correctly matching the actual flood depths. In addition, there were 20 points estimated one level above and below the correct flood depths, 22 points estimated two levels above and below, and 1 point estimated three or more levels above and below the correct flood depths. A total of 43 points were overestimated while no points were underestimated in the modelled flood depths of Guiom. Table 33 depicts the summary of the accuracy assessment in the Guiom River Basin survey.

Table 45. The Summary of Accuracy Assessment in the Guiom River Basin Survey

| | No. of Points | % |
|---|---|---|
| Correct | 161 | 78.92 |
| Overestimated | 43 | 21.08 |
| Underestimated | 0 | 0.00 |
| Total | 204 | 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. Optech Technical Specification of the Pegasus Sensor

Table A-1.1. Parameters and Specification of Pegasus Sensor

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

1 TARGET REFLECTIVITY ≥20%

2 DEPENDENT ON SELECTED OPERATIONAL PARAMETERS USING NOMINAL FOV OF UP TO 40° IN STANDARD ATMOSPHERIC CONDITIONS WITH 24-KM VISIBILITY

3 ANGLE OF INCIDENCE ≤20˚

4 TARGET SIZE ≥ LASER FOOTPRINT5 DEPENDENT ON SYSTEM CONFIGURATION

# Annex 2. NAMRIA Certificates of Reference Points Used

1. MST-34

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-34**
Order: **2nd**

Island: **LUZON**
Municipality: **MOBO**
Barangay: **UMABAY EXTERIOR**

*PRS92 Coordinates*

| | | |
|---|---|---|
| Latitude: **12° 18' 29.18323"** | Longitude: **123° 40' 46.86556"** | Ellipsoidal Hgt: **11.91000 m.** |

*WGS84 Coordinates*

| | | |
|---|---|---|
| Latitude: **12° 18' 24.53692"** | Longitude: **123° 40' 51.93952"** | Ellipsoidal Hgt: **68.23000 m.** |

*PTM Coordinates*

| | | |
|---|---|---|
| Northing: **1361109.053 m.** | Easting: **573933.177 m.** | Zone: **4** |

*UTM Coordinates*

| | | |
|---|---|---|
| Northing: **1,360,632.64** | Easting: **573,907.30** | Zone: **51** |

Location Description

MST-34
From Masbate City Proper, travel for about 9.5 km. along the Nat'l. Highway going to Uson Town Proper until reaching Brgy. Umabay Ext., Mobo Town. Station is located at the left wing of Sagawsawan Bridge, 12 m. NE of a signboard and 20 m. SE of a store. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "MST-34 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-823**

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

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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

2. MST-40

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

April 10, 2014

**CERTIFICATION**

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-40**
Order: **2nd**

Island: **LUZON**
Municipality: **USON**
Barangay: **BUENAVISTA**

| | | | | | |
|---|---|---|---|---|---|
| | | ***PRS92 Coordinates*** | | | |
| Latitude: | **12º 10' 39.45274"** | Longitude: | **123º 47' 33.62147"** | Ellipsoidal Hgt: | **4.72600 m.** |
| | | ***WGS84 Coordinates*** | | | |
| Latitude: | **12º 10' 34.84826"** | Longitude: | **123º 47' 38.70589"** | Ellipsoidal Hgt: | **61.65900 m.** |
| | | ***PTM Coordinates*** | | | |
| Northing: | **1346708.7 m.** | Easting: | **586266.511 m.** | Zone: | **4** |
| | | ***UTM Coordinates*** | | | |
| Northing: | **1,346,237.33** | Easting: | **586,236.32** | Zone: | **51** |

Location Description

MST-40
From Masbate City Proper, travel for about 32.6 km. along the Nat'l. Highway going to Uson Town Proper until reaching Brgy. Buenavista. Station is located at the right wing of Buenavista Bridge, 11 m. from the "15 T" signboard. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-40 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-825**

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

990410201414O116

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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3. MST-49

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

April 10, 2014

## CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-49**
Order: **2nd**

Island: **LUZON**
Municipality: **CATAINGAN**
Barangay: **QUEZON**

| | | |
|---|---|---|
| | *PRS92 Coordinates* | |
| Latitude: **12° 0' 1.41677"** | Longitude: **123° 59' 46.24265"** | Ellipsoidal Hgt: **21.25500 m.** |
| | *WGS84 Coordinates* | |
| Latitude: **11° 59' 56.87354"** | Longitude: **123° 59' 51.34085"** | Ellipsoidal Hgt: **79.14000 m.** |
| | *PTM Coordinates* | |
| Northing: **1327175.1 m.** | Easting: **608487.281 m.** | Zone: **4** |
| | *UTM Coordinates* | |
| Northing: **1,326,710.57** | Easting: **608,449.31** | Zone: **51** |

Location Description

MST-49
From Masbate City Proper, travel for about 74.8 km. along the Nat'l. Highway going to Placer Town Proper to reach Brgy. Quezon, Cataingan Town. Station is located in front (17 m. SE) of Cataingan Mun. Hall, 10 N of the Mun. Trial Court and 15 m. E of the COMELEC Bldg. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-49 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-826**

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

9904102014140133

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

4. MS-61

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MS-61**

| | | |
|---|---|---|
| Island: **LUZON** | Municipality: **PALANAS** | Barangay: **NABANGIG** |
| Elevation: **7.0705 m.** | Order: **1st Order** | Datum: **Mean Sea Level** |

Location Description

MS-061

Station is in the Municipality of Palanas, along National Highway leading to town of Cataingan, at Brgy. Nabangig, atop Nabangig Bridge (km 061+156). It is 55m from the Municipality's Boundary Arc. Mark is the head of a 3" copper nail set flush in cement putty with inscription "MS-061 2007 NAMRIA."

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-840**

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

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

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

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

1. MS-61

MS-61 - MST-49 (6:30:34 AM-11:24:24 AM) (S1)

| | |
|---|---|
| Baseline observation: | MS-61 --- MST-49 (B1) |
| Processed: | 5/13/2014 11:54:33 AM |
| Solution type: | Fixed |
| Frequency used: | Dual Frequency (L1, L2) |
| Horizontal precision: | 0.006 m |
| Vertical precision: | 0.025 m |
| RMS: | 0.009 m |
| Maximum PDOP: | 3.505 |
| Ephemeris used: | Broadcast |
| Antenna model: | NGS Absolute |
| Processing start time: | 3/26/2014 6:30:54 AM (Local: UTC+8hr) |
| Processing stop time: | 3/26/2014 11:24:24 AM (Local: UTC+8hr) |
| Processing duration: | 04:53:30 |
| Processing interval: | 5 seconds |

Vector Components (Mark to Mark)

| From: | MST-49 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 608602.644 m | Latitude | N11°59'56.87354" | Latitude | N11°59'56.87354" |
| Northing | 1326654.175 m | Longitude | E123°59'51.34085" | Longitude | E123°59'51.34085" |
| Elevation | 21.031 m | Height | 79.140 m | Height | 79.140 m |

| To: | MS-61 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 604178.664 m | Latitude | N12°05'56.94091" | Latitude | N12°05'56.94091" |
| Northing | 1337699.951 m | Longitude | E123°57'26.33451" | Longitude | E123°57'26.33451" |
| Elevation | 7.554 m | Height | 65.257 m | Height | 65.257 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -4423.979 m | NS Fwd Azimuth | 338°22'53" | ΔX | 4935.367 m |
| ΔNorthing | 11045.776 m | Ellipsoid Dist. | 11901.865 m | ΔY | 524.472 m |
| ΔElevation | -13.477 m | ΔHeight | -13.883 m | ΔZ | 10817.803 m |

# Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

| **Data Acquisition Component Sub-Team** | **Designation** | **Name** | **Agency/ Affiliation** |
|---|---|---|---|
| Data Acquisition Component Leader | Data Component Project Leader – I | ENGR. CZAR JAKIRI SARMIENTO | UP-TCAGP |
| Survey Supervisor | Chief Science Research Specialist (CSRS) | ENGR. CHRISTOPHER CRUZ | UP-TCAGP |
| | Supervising Science Research Specialist (Supervising SRS) | LOVELY GRACIA ACUÑA | UP-TCAGP |
| | | LOVELYN ASUNCION | UP-TCAGP |

FIELD TEAM

| | | | |
|---|---|---|---|
| LiDAR Operation | Senior Science Research Specialist (SSRS) | GEROME B. HIPOLITO | UP-TCAGP |
| | Research Associate (RA) | MARY CATHERINE ELIZABETH BALIGUAS | UP-TCAGP |
| | RA | ENGR. IRO NIEL ROXAS | UP-TCAGP |
| Ground Survey, Data Download and Transfer | RA | GRACE SINADJAN | UP-TCAGP |
| LiDAR Operation | Airborne Security | SSG MARLON TORRE | PHILIPPINE AIR FORCE (PAF) |
| | Pilot | CAPT. JEFFREY JEREMY ALAJAR | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. BRYAN DONGUINES | AAC |

# Annex 5. Data Transfer Sheet for Guiom Floodplain

DATA TRANSFER SHEET
Apr 3, 2014

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS | POS | RAW IMAGES | MISSION LOG FILE | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| Mar 19, 2014 | 1241P | 1BLK32E078A | PEGASUS | 703MB | 2.80MB | 8.99MB | 281MB | 33.3GB | 297KB | 6.0GB | N/A | 5.78MB | 121B | 825B | 82.6KB | N/A | Z:\Airborne_Raw\1241P |
| Mar 20, 2014 | 1243P | 1BLK32E079A | PEGASUS | 1.14GB | 2.37MB | 6.18MB | 169MB | 41GB | 335KB | 21.3GB | N/A | 5.45MB | 225B | 688B | 80.3KB | N/A | Z:\Airborne_Raw\1243P |
| Mar 20, 2014 | 1245P | 1BLK32J079B | PEGASUS | 2.33GB | 2.22MB | 6.76MB | 189MB | 49.2GB | 363KB | 22.7GB | N/A | 5.45MB | 225B | 377B | 115KB | N/A | Z:\Airborne_Raw\1245P |
| Mar 21, 2014 | 1247P | 1BLK32J080A | PEGASUS | 4.09GB | 3.96MB | 9.60MB | 244MB | 55.2GB | 426KB | 40.8GB | N/A | 5.78MB | 96B | 527B | 137KB | N/A | Z:\Airborne_Raw\1247P |
| Mar 25, 2014 | 1263P | 1BLK32K084A | PEGASUS | 2.21GB | 2.98MB | 8.71MB | 217MB | 48.9GB | 366KB | 26.6GB | N/A | 4.64MB | 92B | 936B | 136KB | N/A | Z:\Airborne_Raw\1263P |
| Mar 26, 2014 | 1267P | 1BLK32M085A | PEGASUS | 3.67GB | 4.25MB | 10.8MB | 283MB | 58.2GB | 451KB | 36.4GB | N/A | 5.94MB | 92B | 758B | 254KB | N/A | Z:\Airborne_Raw\1267P |
| Mar 27, 2014 | 1271P | 1BLK32H086A | PEGASUS | 3.43GB | 3.99MB | 11.1MB | 259MB | 74.8GB | 585KB | 33.8GB | N/A | 5.24MB | 92B | 678B | 156KB | N/A | Z:\Airborne_Raw\1271P |
| Mar 28, 2014 | 1275P | 1BLK32H087A | PEGASUS | 2.18GB | 2.11MB | 6.13MB | 164MB | 38.4GB | 315KB | 21.1GB | N/A | 6.67MB | 93B | 350B | 145KB | N/A | Z:\Airborne_Raw\1275P |
| Mar 29, 2014 | 1281P | 1BLK32K088B | PEGASUS | 1.45GB | 1.58MB | 3.74MB | 102MB | N/A | N/A | 13.8GB | N/A | 7.37MB | 93B | 455B | 26.5KB | N/A | Z:\Airborne_Raw\1281P |
| Mar 31, 2014 | 1289P | 1BLK32K090A | PEGASUS | 1.45GB | 1.63MB | 4.32MB | 116MB | 22.6GB | 162KB | 14.1GB | N/A | 8.08MB | 93B | 253B | 31.9KB | N/A | Z:\Airborne_Raw\1289P |

Received from

Name Faith Joy Sabile
Position
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

DATA TRANSFER SHEET
4/22/2014(MASBATE)

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS (MB) | POS (MB) | RAW IMAGES | MISSION LOG FILE | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| 4/1/2014 | 1291P | 1BLK32KL091A | PEGASUS | 2.91 | 3.36 | 9.99 | 256 | 43.6 | 332 | 29.8 | NA | 7.81 | 1KB | 602 | 376 | NA | Z:\Airborne_Raw\1291P |
| 4/1/2014 | 1293P | 1BLK32H091B | PEGASUS | 1.75 | 1.48 | 3.85 | 115 | 24.7 | 213 | 15.6 | NA | 7.81 | 1KB | 221 | 68.5 | NA | Z:\Airborne_Raw\1293P |
| 4/2/2014 | 1295P | 1BLK32E092A | PEGASUS | 2.93 | 3.42 | 8.9 | 225 | 54.2 | 404 | 29.2 | NA | 887KB | 1KB | 512 | 137 | NA | Z:\Airborne_Raw\1295P |
| 4/3/2014 | 1299P | 1BLK32FG093A | PEGASUS | 2.68 | 3.23 | 8.65 | 232 | 33.4 | 267 | 26.8 | NA | 7.59 | 1KB | 358 | 113 | NA | Z:\Airborne_Raw\1299P |
| 4/3/2014 | 1301P | 1BLK32F093B | PEGASUS | 1.95 | 2.42 | 5.95 | 149 | 44.6 | 352 | 19.6 | NA | 7.59 | 1KB | 538 | 201 | NA | Z:\Airborne_Raw\1301P |
| 4/4/2014 | 1303P | 1BLK32A094A | PEGASUS | 2.77 | 3.48 | 2.99 | 218 | 52.5 | 404 | 29.4 | NA | 6.67 | 1KB | 694 | 186 | NA | Z:\Airborne_Raw\1303P |
| 4/4/2014 | 1305P | 1BLK32A094B | PEGASUS | 2.41 | 2.85 | 6.88 | 161 | 44.3 | 324 | 23.3 | NA | 6.67 | 1KB | 400 | 2.41 | NA | Z:\Airborne_Raw\1305P |
| 4/5/2014 | 1307P | 1BLK32DG095A | PEGASUS | 3.84 | 4.49 | 4.12 | 271 | 67.2 | 514 | 37.7 | NA | 6.49 | 1KB | 623 | 270 | NA | Z:\Airborne_Raw\1307P |
| 4/8/2014 | 1319P | 1BLK32B098A | PEGASUS | 3.66 | 4.32 | 9.93 | 254 | 17.7 | 526 | 36.2 | NA | 4.95 | 1KB | 731 | 382 | NA | Z:\Airborne_Raw\1319P |
| 4/10/2014 | 1327P | 1BLK32D100A | PEGASUS | 2.16 | 2.47 | 6.99 | 175 | 37 | 277 | 21.7 | NA | 5.27 | 1KB | 747 | 243 | NA | Z:\Airborne_Raw\1327P |
| 4/11/2014 | 1331P | 1BLK32B101A | PEGASUS | 1.76 | 1.9 | 6.09 | 134 | 29.8 | 232 | 17.6 | NA | 4.09 | 1KB | 574 | 316 | NA | Z:\Airborne_Raw\1331P |

Received from

Name CARLOS JOAQUIN

Position RA

Signature 4/23/14

Received by

Name JOIDA F. PRIETO

Position SSRS

Signature 4/23/14

# Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1247P Mission

**DREAM Data Acquisition Flight Log**

Flight Log No.: 1247P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. ROXAS | 2 ALTM Model: PEG | 3 Mission Name: 1BLK32I08BA ~~1BLK32J08DA~~ | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: M. TANGONAN | 8 Co-Pilot: B. DONGUINES | 9 Route: | | | |
| 10 Date: Mar. 21, 2014 | 12 Airport of Departure (Airport, City/Province): RPWJ | | 12 Airport of Arrival (Airport, City/Province): RPVJ | | |
| 13 Engine On: 1013 | 14 Engine Off: 1413 | 15 Total Engine Time: 4+0 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | cloudy | | | | |

20 Remarks:

Completed BLK32J and surveyed 5 lines of BLK32I

21 Problems and Solutions:

| | | | |
|---|---|---|---|
| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
| G. H. PILLITO | MARVIN TORRES | M. TANGONAN | I. ROXAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

2. Flight Log for 1271P Mission

**DREAM Data Acquisition Flight Log**

**Flight Log No.:** 1271P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MCE BALICUAS | 2 ALTM Model: PEG | 3 Mission Name: 1BLK32H086A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: M. TANGONAN | 8 Co-Pilot: B. DONGUINES | 9 Route: | | | |
| 10 Date: Mar. 27, 2014 | 12 Airport of Departure (Airport, City/Province): RPVJ | | 12 Airport of Arrival (Airport, City/Province): RPVJ | | |
| 13 Engine On: 0827 | 14 Engine Off: 1250 | 15 Total Engine Time: 4+23 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather: Cloudy | | | | | |
| 20 Remarks: Finish lines of BLK 32H; without digitizer. | | | | | |

21 Problems and Solutions:

| | | | |
|---|---|---|---|
| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
| G. HIPOLITO | MARJORIE TORRES | M.L. TANGONAN | CATHERINE BALICUAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

3. Flight Log for 1275P Mission

**DREAM Data Acquisition Flight Log** | **Flight Log No.:** 1275P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J. Roxas | 2 ALTM Model: PEG | 3 Mission Name: 1BLK32H[illegible]A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: JJ ALADAR | 8 Co-Pilot: BJ DONGUINES | 9 Route: RPVJ | | | |
| 10 Date: 28 Mar 2014 | 12 Airport of Departure (Airport, City/Province): MASBATE | | 12 Airport of Arrival (Airport, City/Province): MASBATE | | |
| 13 Engine On: 1115 | 14 Engine Off: 1408 | 15 Total Engine Time: 2+53 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather | Partly cloudy | | | | |

20 Remarks: Surveyed 8 lines at BLK 32H and 2 lines at BLK32I and covered voids at BLK32E enroute to base

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| Geo-[illegible] | MARVIN TORRE | JJ ALADAR | J. ROXAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

4. Flight Log for 1281P Mission

**DREAM Data Acquisition Flight Log** — **Flight Log No.:** 128P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: MCE BALICUAS | 2 ALTM Model: PEG | 3 Mission Name: 1BLK32I088B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: JJ ALFONAR | 8 Co-Pilot: BJ DONGUINES | 9 Route: RPVJ | | | |
| 10 Date: 29 March 2014 | 12 Airport of Departure (Airport, City/Province): RPVJ | | 12 Airport of Arrival (Airport, City/Province): RPVJ | | |
| 13 Engine On: 1217 | 14 Engine Off: 1410 | 15 Total Engine Time: 1+53 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather: Partly cloudy | | | | | |

20 Remarks:

Surveyed 6 lines at BLK32I but with voids due to clouds

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| G. HINOZITO | MARIANO TORRE | JJ ALFONAR | CATHERINE BALICUAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

5. Flight Log for 1293P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1293P

| | | | | | |
|---|---|---|---|---|---|
| 1 LIDAR Operator: I. ROXAS | 2 ALTM Model: PEG | 3 Mission Name: 1BLK32H091A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: JJ ALAJAR | 8 Co-Pilot: BJ DONGUINES | 9 Route: REVJ | | | |
| 10 Date: 01 APRIL 2014 | 12 Airport of Departure (Airport, City/Province): REVJ | | 12 Airport of Arrival (Airport, City/Province): REVJ | | |
| 13 Engine On: 1214 | 14 Engine Off: 1419 | 15 Total Engine Time: 2 05 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather: cloudy | | | | | |
| 20 Remarks: surveyed 8 lines at BLK32H auto pilot disengaging | | | | | |

21 Problems and Solutions:

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | Lidar Operator |
|---|---|---|---|
| G. Hipolito | | JJ ALAJAR | IRO ROXAS |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name |

# Annex 7. Flight Status Reports

GUIOM FLOODPLAIN
(March 21 - April 1, 2014)

| FLIGHT NO. | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 1247P | BLK32J | 1BLK32IJ080A | I. Roxas | 21-Mar-14 | Completed BLK32J and surveyed 5 lines of BLK32I |
| 1271P | BLK32H | 1BLK32H086A | MCE. Baliguas | 27-Mar-14 | Surveyed 18 lines at BLK32H; without digitizer |
| 1275P | BLK32H | 1BLK32HI087A | I. Roxas | 28-Mar-14 | Surveyed 8 lines at BLK32H and 2 lines at BLK32I and covered voids at BLK32E en route to base |
| 1281P | BLK32I | 1BLK32I088B | MCE. Baliguas | 29-Mar-14 | Surveyed 6 lines at BLK32I but with voids due to clouds |
| 1293P | BLK32H | 1BLK32H091B | I. Roxas | 01-Apr-14 | Surveyed 8 lines at BLK32H; auto pilot disengaging |
| 2854P | BLK2DS, BLK2G | 1BLK2DSG319A | G SINADJAN | November 15, 2015 | SURVEYED 18 LINES FOR BLK2D AND BLK2G |

SWATH PER FLIGHT MISSION

| | | | |
|---|---|---|---|
| FLIGHT NO. : | 1247P | SCAN FREQ: | 30 HZ |
| AREA: | BLK32J | SCAN ANGLE: | 25 DEG |
| MISSION NAME: | 1BLK32IJ080A | PRF: | 200 KHZ |
| ALTITUDE: | 1000 M/1200 M | SIDELAP: | 30% |


Figure A-7.1. Swath for Flight No. 1247P

| | | | |
|---|---|---|---|
| FLIGHT NO. : | 1271P | SCAN FREQ: | 30 HZ |
| AREA: | BLK32H | SCAN ANGLE: | 25 DEG |
| MISSION NAME: | 1BLK32H086A | PRF: | 200 KHZ |
| ALTITUDE: | 800 M/600 M | SIDELAP: | 25% / 30% |


Figure A-7.2. Swath for Flight No. 1271P

| | | | |
|---|---|---|---|
| FLIGHT NO. : | 1275P | SCAN FREQ: | 36 HZ |
| AREA: | BLK32H | SCAN ANGLE: | 20 DEG |
| MISSION NAME: | 1BLK32HI087A PRF: | 250 KHZ | |
| ALTITUDE: | 800 M | SIDELAP: | 25% |

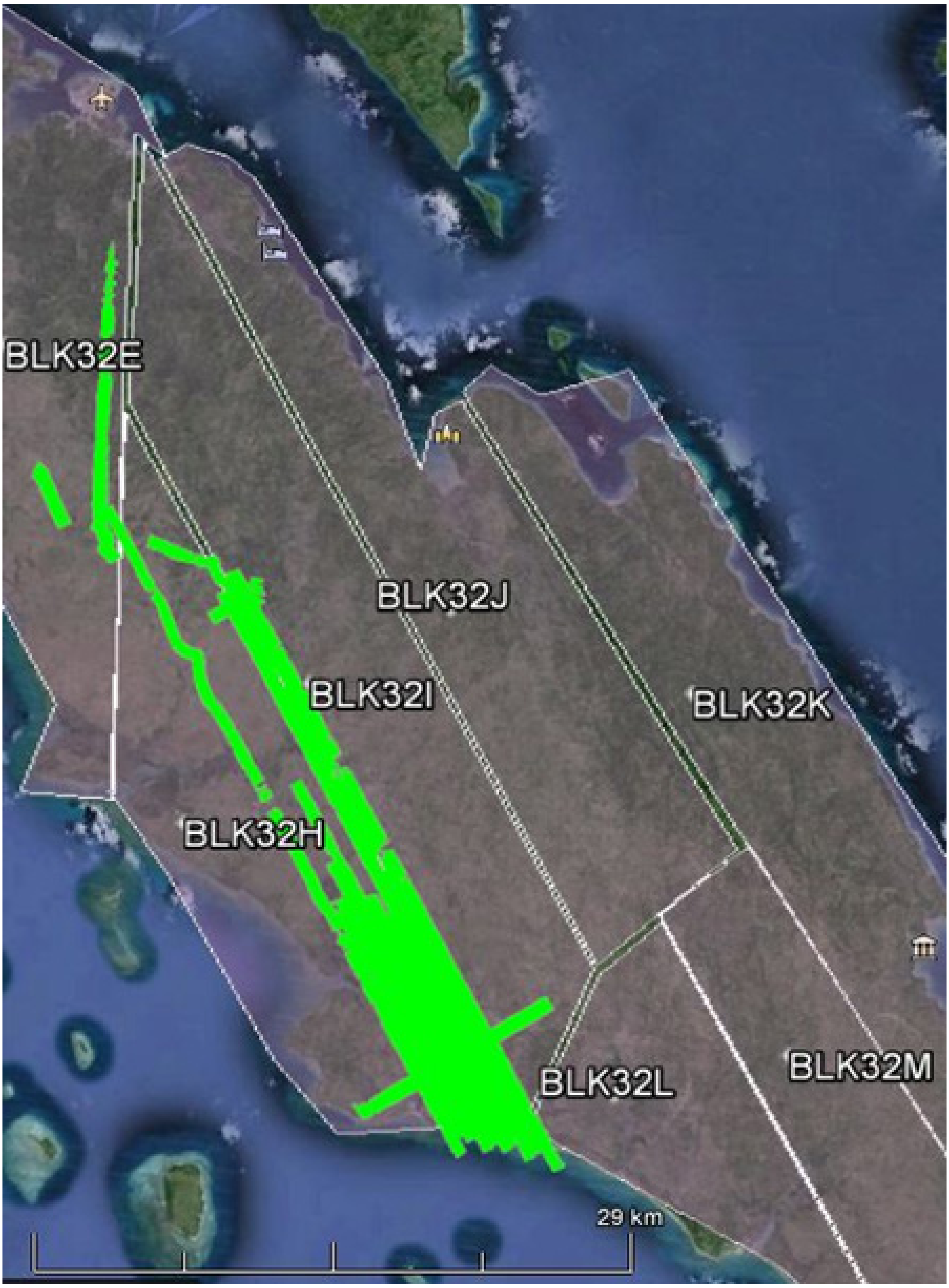


Figure A-7.3. Swath for Flight No. 1275P

| | | | |
|---|---|---|---|
| FLIGHT NO. : | 1281P | SCAN FREQ: | 30 HZ |
| AREA: | BLK32I | SCAN ANGLE: | 25 DEG |
| MISSION NAME: | 1BLK32I088B | PRF: | 200 KHZ |
| ALTITUDE: | 1000 M | SIDELAP: | 40% |

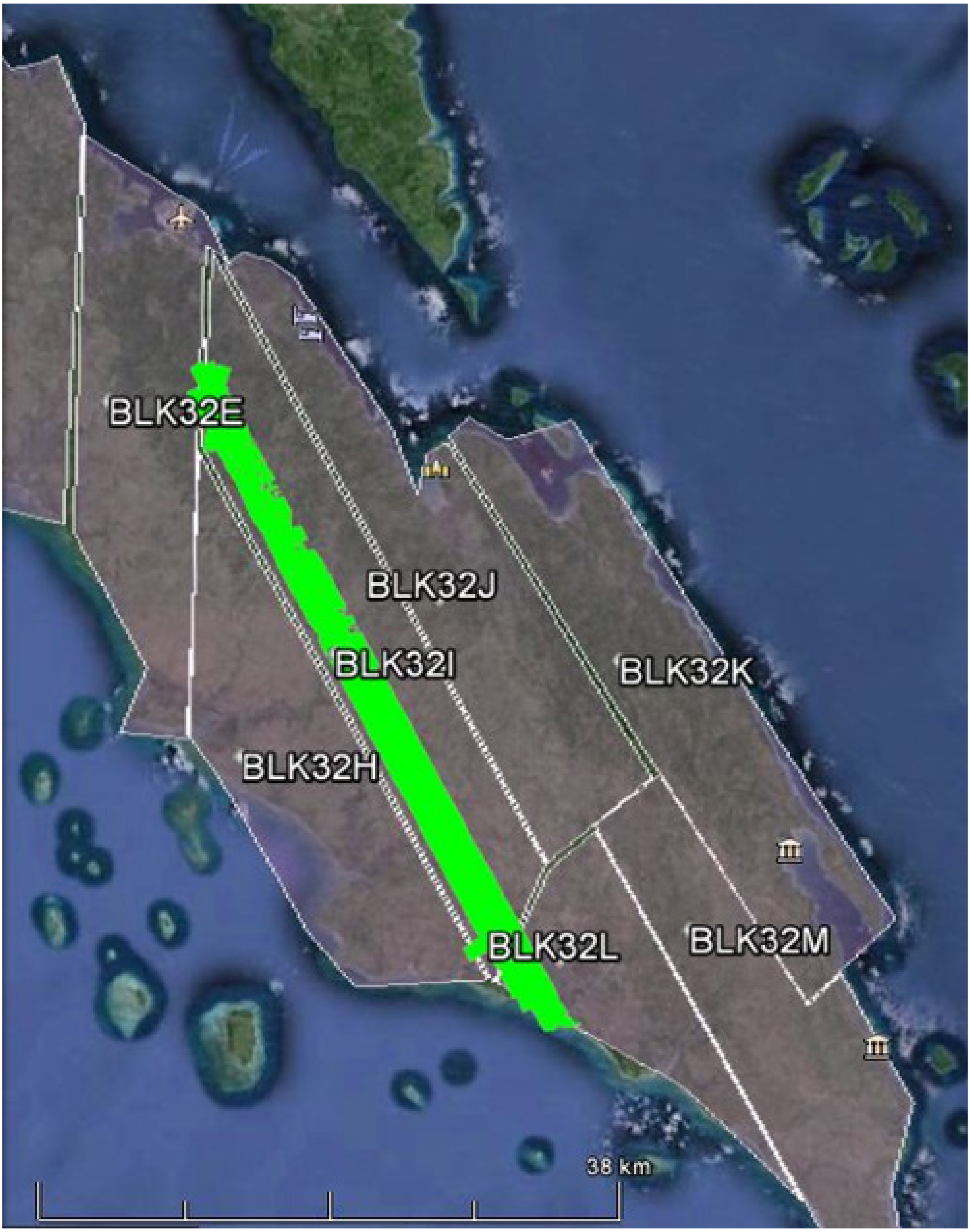


Figure A-7.4. Swath for Flight No. 1281P

| | | | |
|---|---|---|---|
| FLIGHT NO. : | 1293P | SCAN FREQ: | 36 HZ |
| AREA: | BLK32H | SCAN ANGLE: | 20 DEG |
| MISSION NAME: | 1BLK32H091B | PRF: | 250 KHZ |
| ALTITUDE: | 800 M | SIDELAP: | 25% |

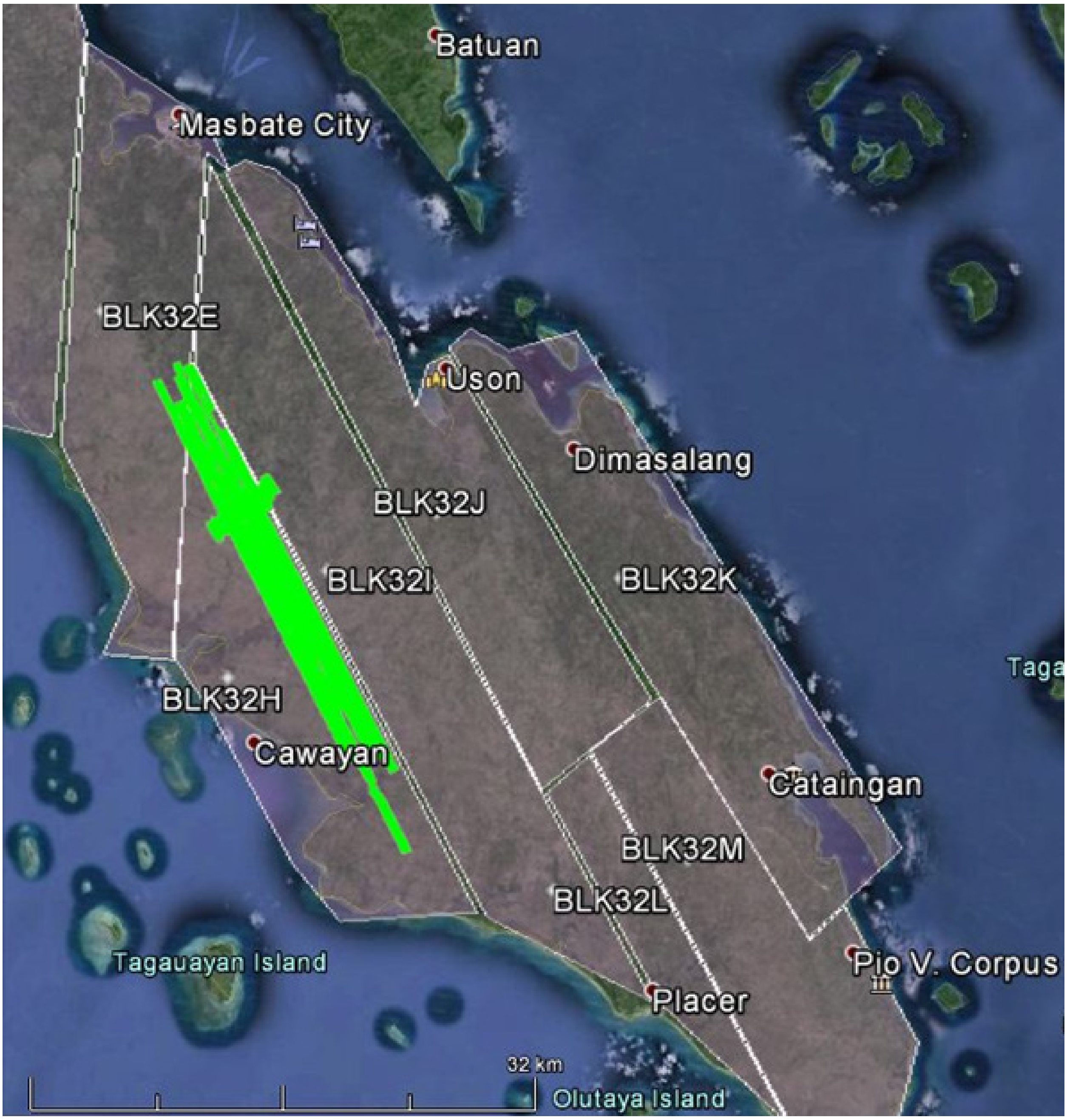


Figure A-7.5. Swath for Flight No. 1293P

# Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk2D_supplement

| Flight Area | Masbate |
|---|---|
| Mission Name | Blk32IJ |
| Inclusive Flights | 1245P, 1247P, 1281P |
| Mission Name | 1BLK32J079B, 1BLK32IJ080A, 1BLK32I088B |
| Range data size | 77.3 GB |
| POS | 535 MB |
| Base data size | 18.58 MB |
| Image | 104.4 GB |
| Transfer date | April 23 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.63 |
| RMSE for East Position (<4.0 cm) | 1.70 |
| RMSE for Down Position (<8.0 cm) | 3.20 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000398 |
| IMU attitude correction stdev (<0.001deg) | 0.001191 |
| GPS position stdev (<0.01m) | 0.00270 |
| | |
| Minimum % overlap (>25) | 17.09% |
| Ave point cloud density per sq.m. (>2.0) | 2.30 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 683 |
| Maximum Height | 603.95 m |
| Minimum Height | 42.31 m |
| | |
| Classification (# of points) | |
| Ground | 476,127,438 |
| Low vegetation | 250,199,416 |
| Medium vegetation | 363,150,463 |
| High vegetation | 265,574,430 |
| Building | 4,664,222 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Roa Shalemar Redo, Engr. John Dill Macapagal |

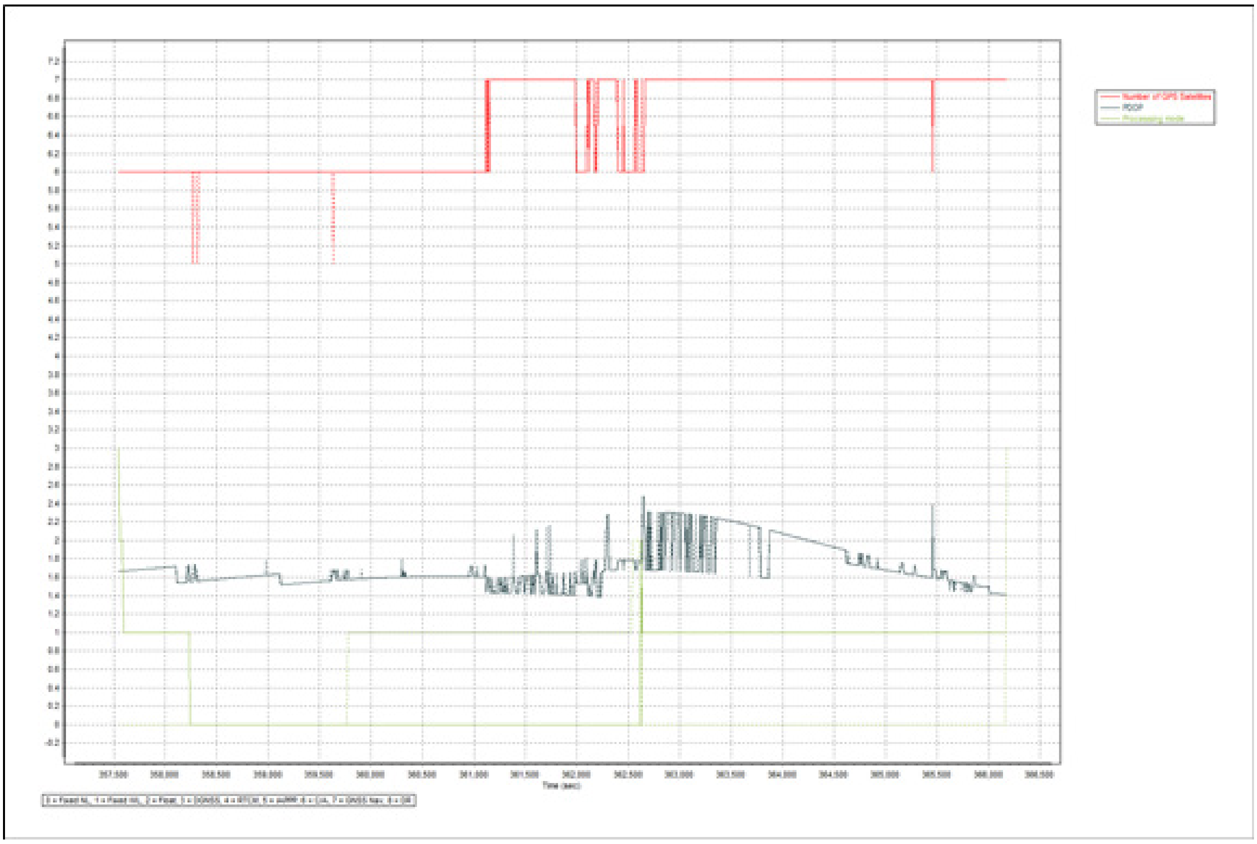

Figure A-8.1. Solution Status

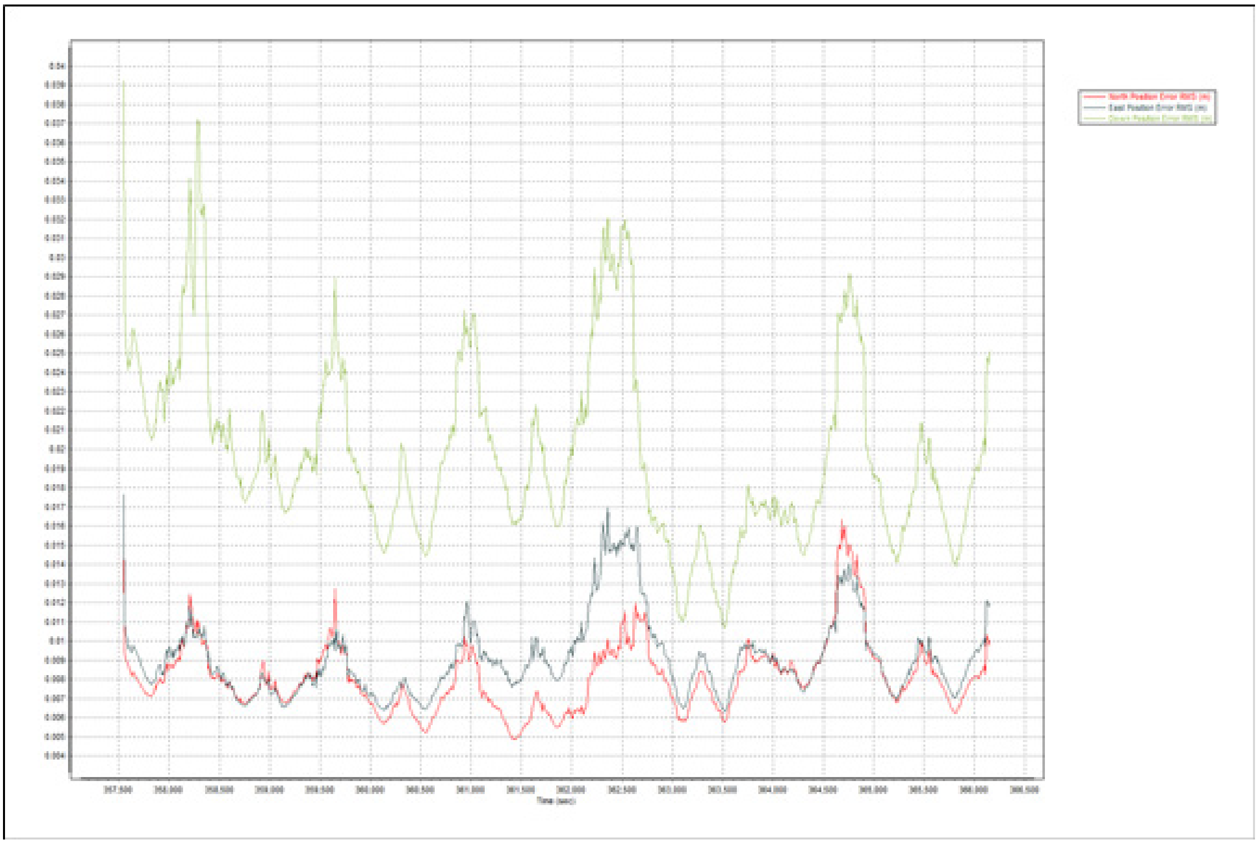

Figure A-8.2. Smoothed Performance Metrics Parameters

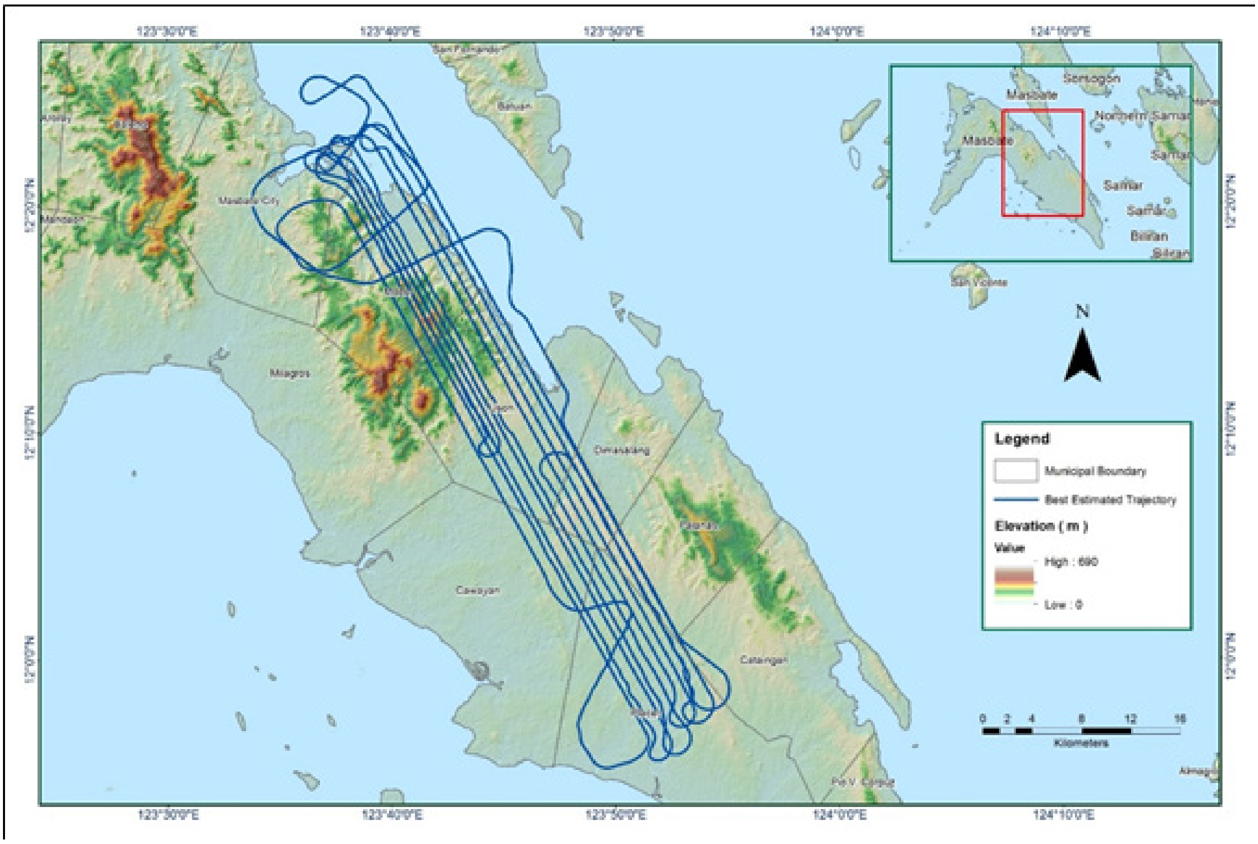


Figure A-8.3. Best Estimated Trajectory

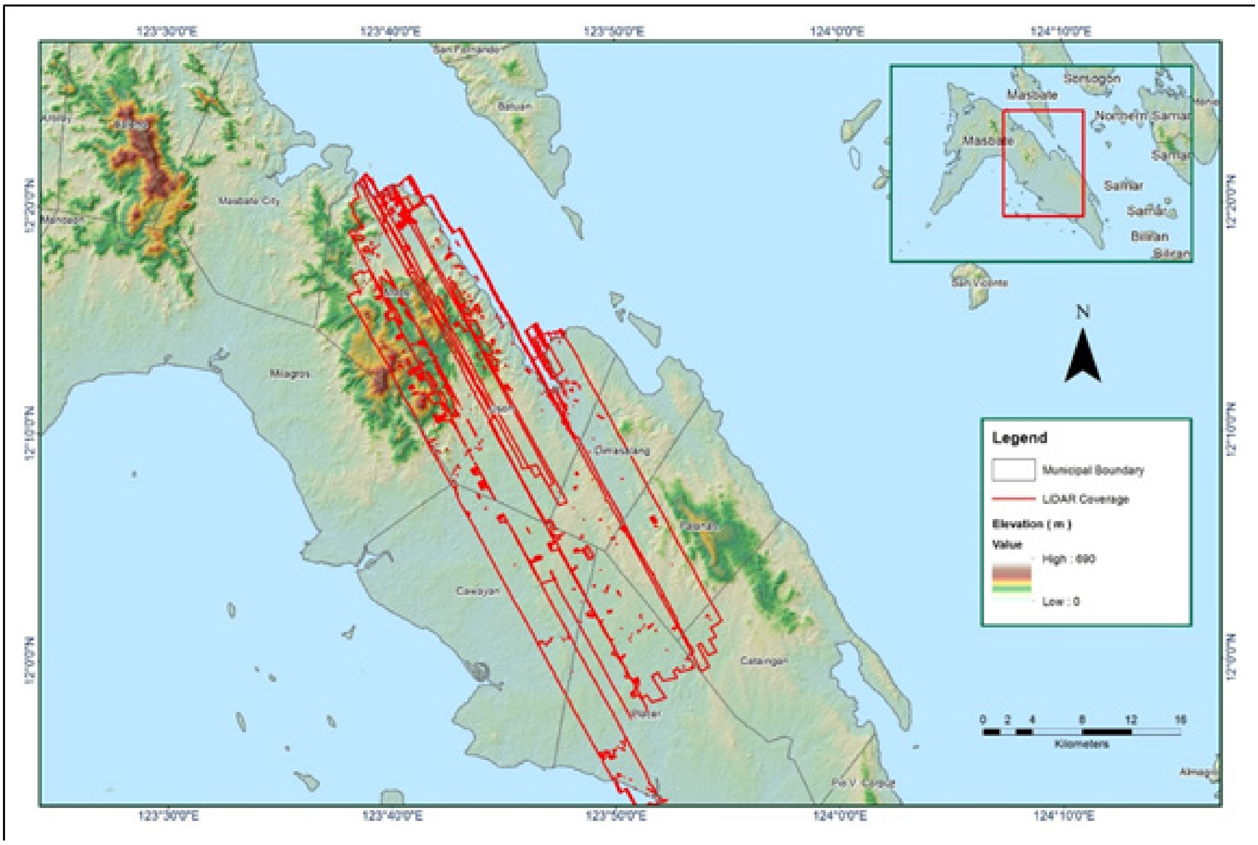


Figure A-8.4. Coverage of LiDAR data

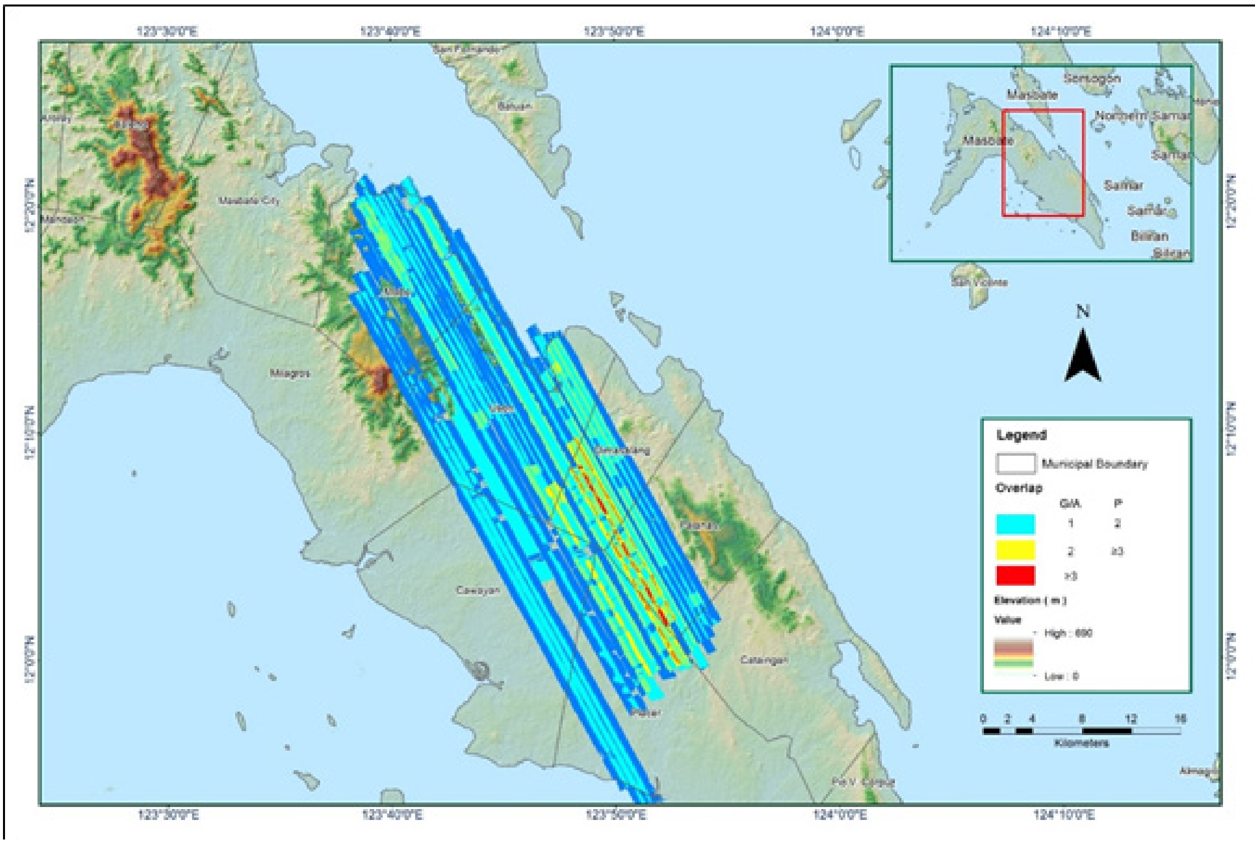


Figure A-8.5. Image of Data Overlap

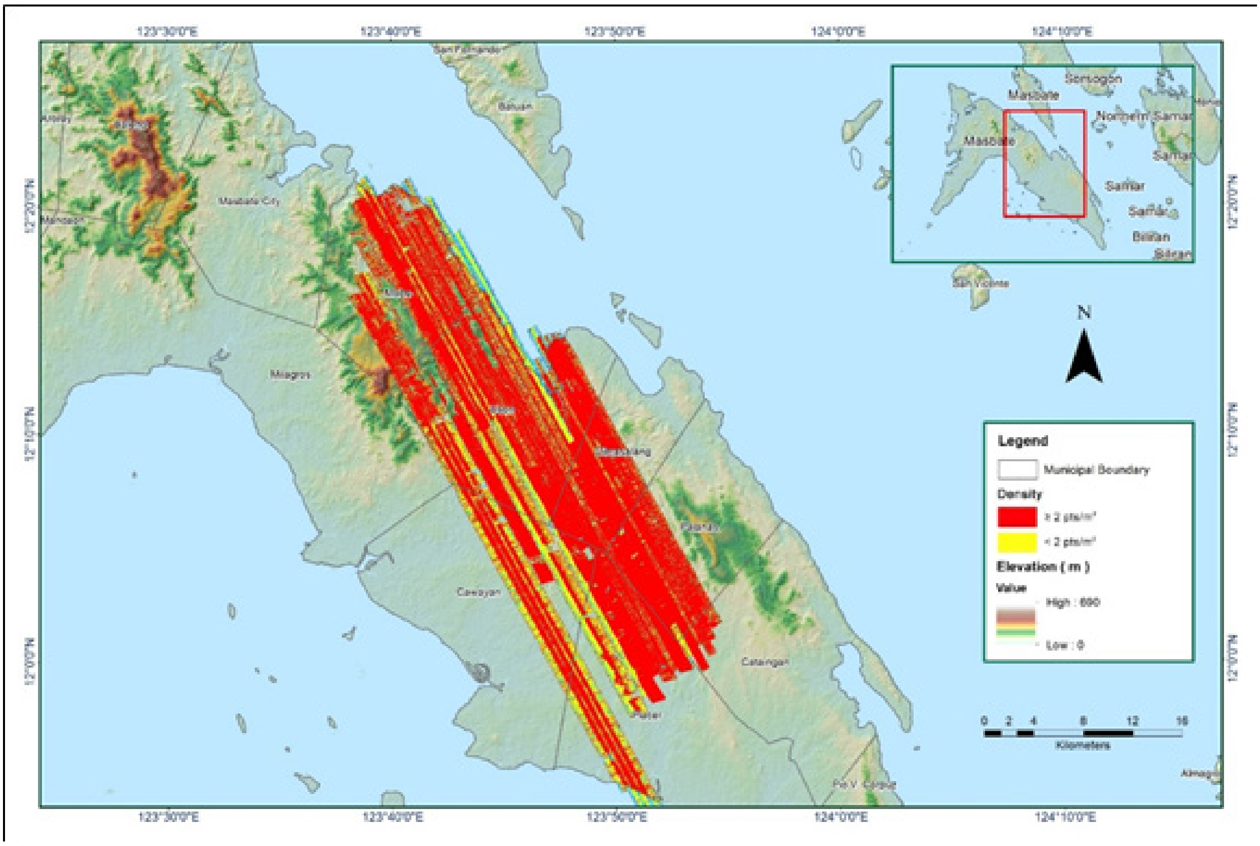


Figure A-8.6. Density map of merged LiDAR data

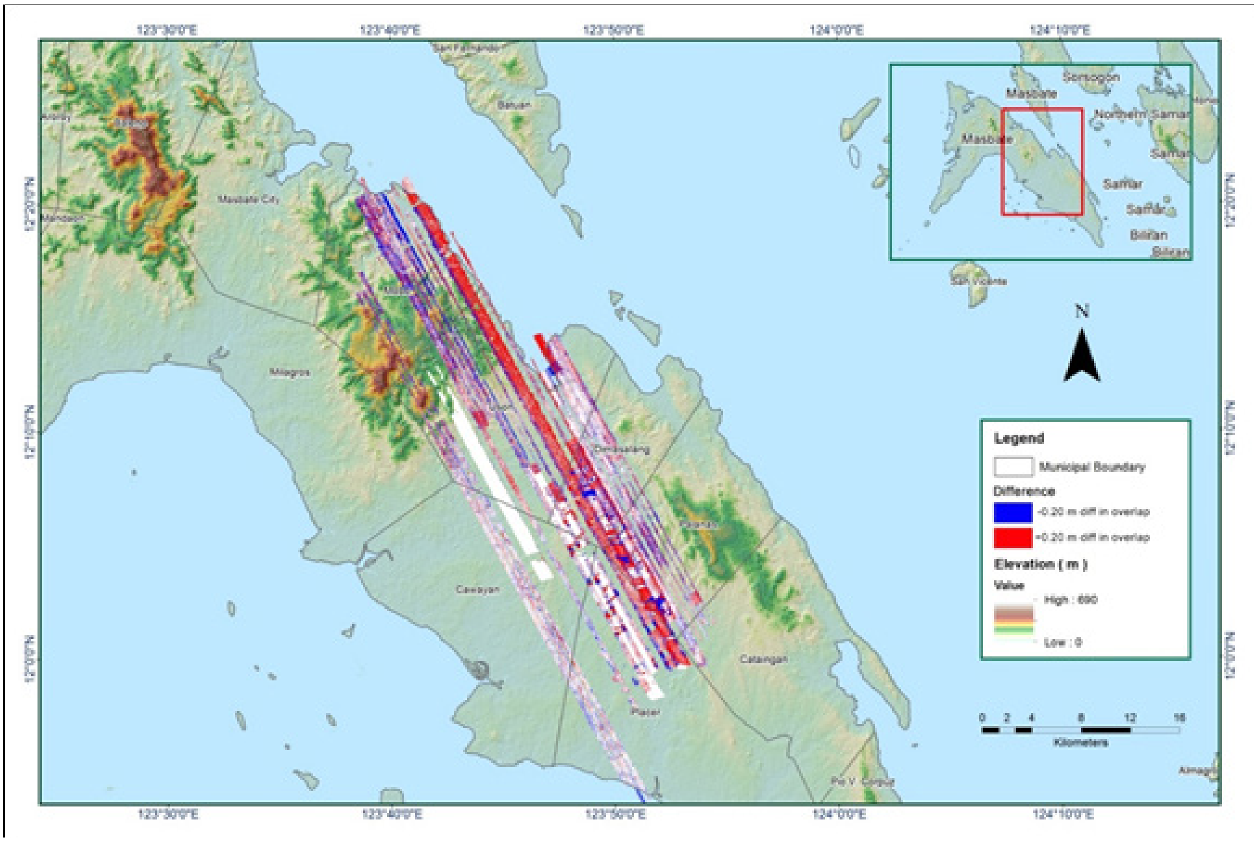


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk2B

| Flight Area | Cagayan Reflights(Tuguegarao) |
|---|---|
| Mission Name | Blk32H |
| Inclusive Flights | 1271P, 1275P, 1293P |
| Mission Name | 1BLK32H086A, 1BLK32DG095A, 1BLK32H091B |
| Range data size | 70.5 GB |
| POS | 538 MB |
| Base data size | 19.72 MB |
| Image | 138.0 GB |
| Transfer date | April 23 2014 |
| | |
| Solution Status | |
| Number of Satellites (>6) | No |
| PDOP (<3) | No |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | Yes |
| | |
| Smoothed Performance Metrics (in cm) | |
| RMSE for North Position (<4.0 cm) | 5.04 |
| RMSE for East Position (<4.0 cm) | 3.40 |
| RMSE for Down Position (<8.0 cm) | 7.90 |
| | |
| Boresight correction stdev (<0.001deg) | 0.00058 |
| IMU attitude correction stdev (<0.001deg) | 0.00828 |
| GPS position stdev (<0.01m) | 0.00270 |
| | |
| Minimum % overlap (>25) | 2.25 |
| Ave point cloud density per sq.m. (>2.0) | 2.74 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 387 |
| Maximum Height | 555.56m |
| Minimum Height | 47.88m |
| | |
| Classification (# of points) | |
| Ground | 501,440,501 |
| Low vegetation | 335,653,641 |
| Medium vegetation | 315,870,006 |
| High vegetation | 78,423,465 |
| Building | 2,270,257 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Irish Cortez, Engr. Harmond Santos, |
| Engr. Gladys Mae Apat | |

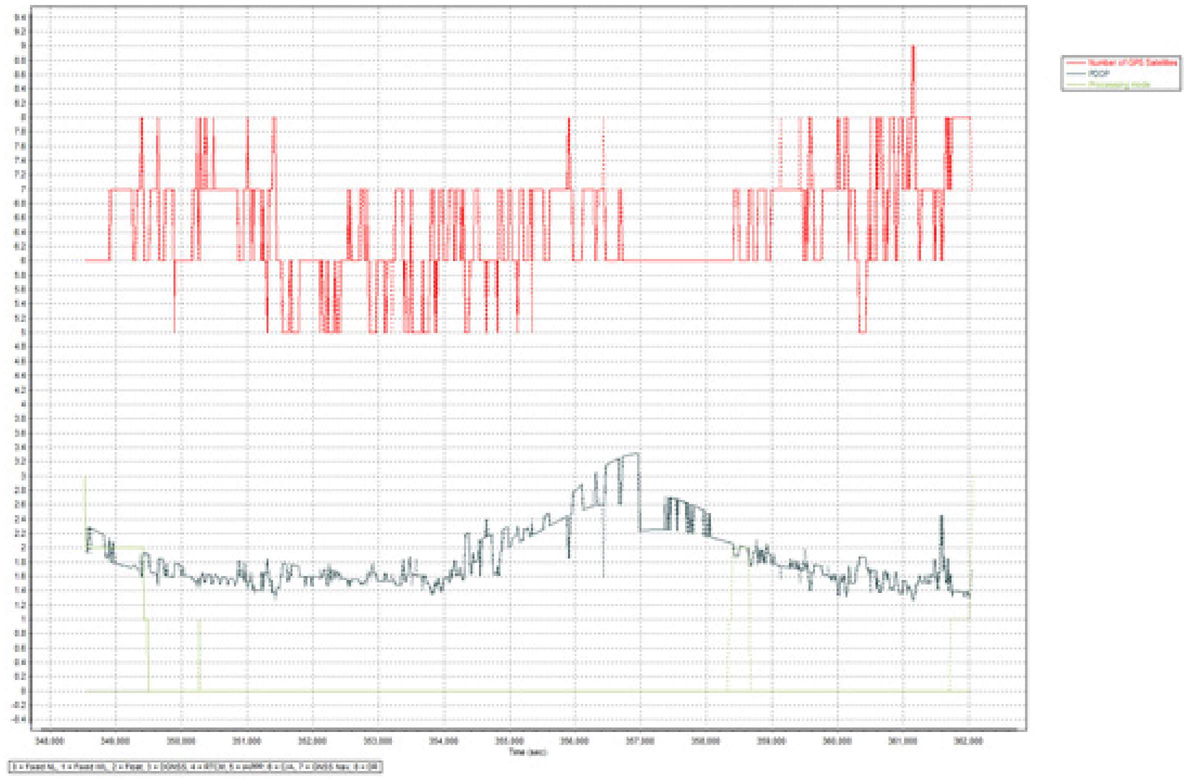

Figure A-8.8. Solution Status Parameters

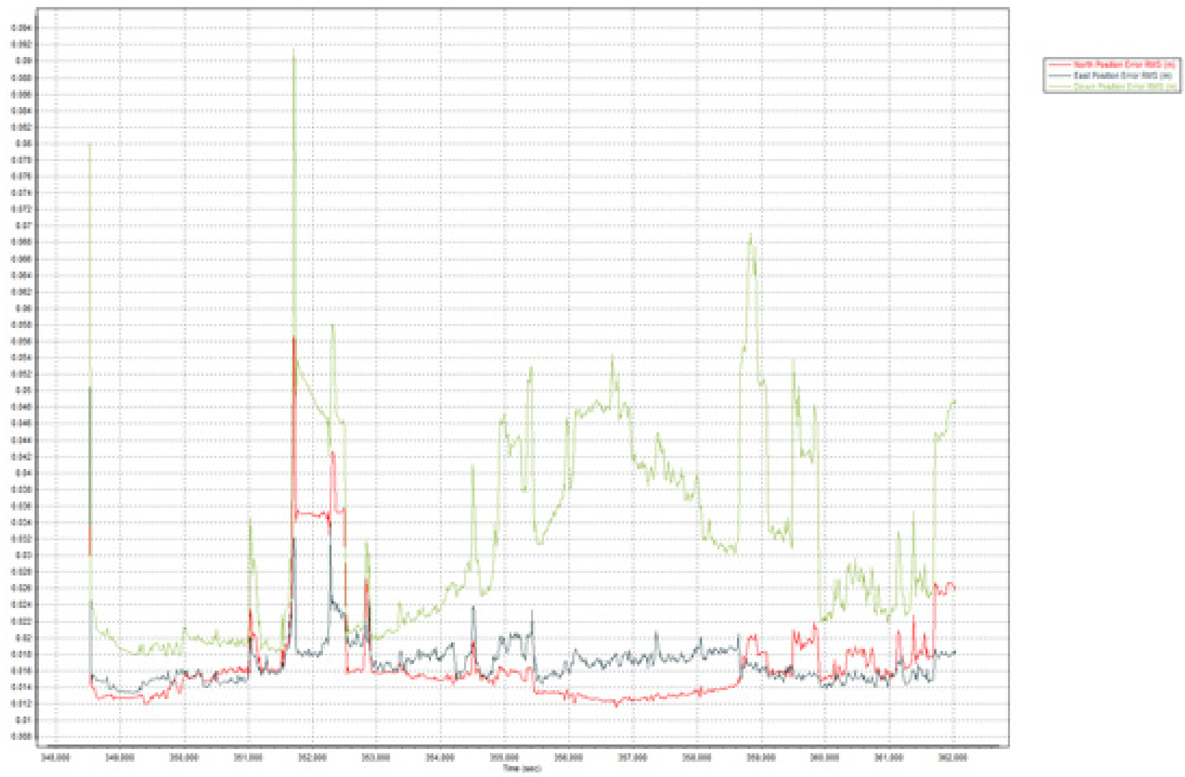

Figure A-8.9. Smoothed Performance Metrics Parameters

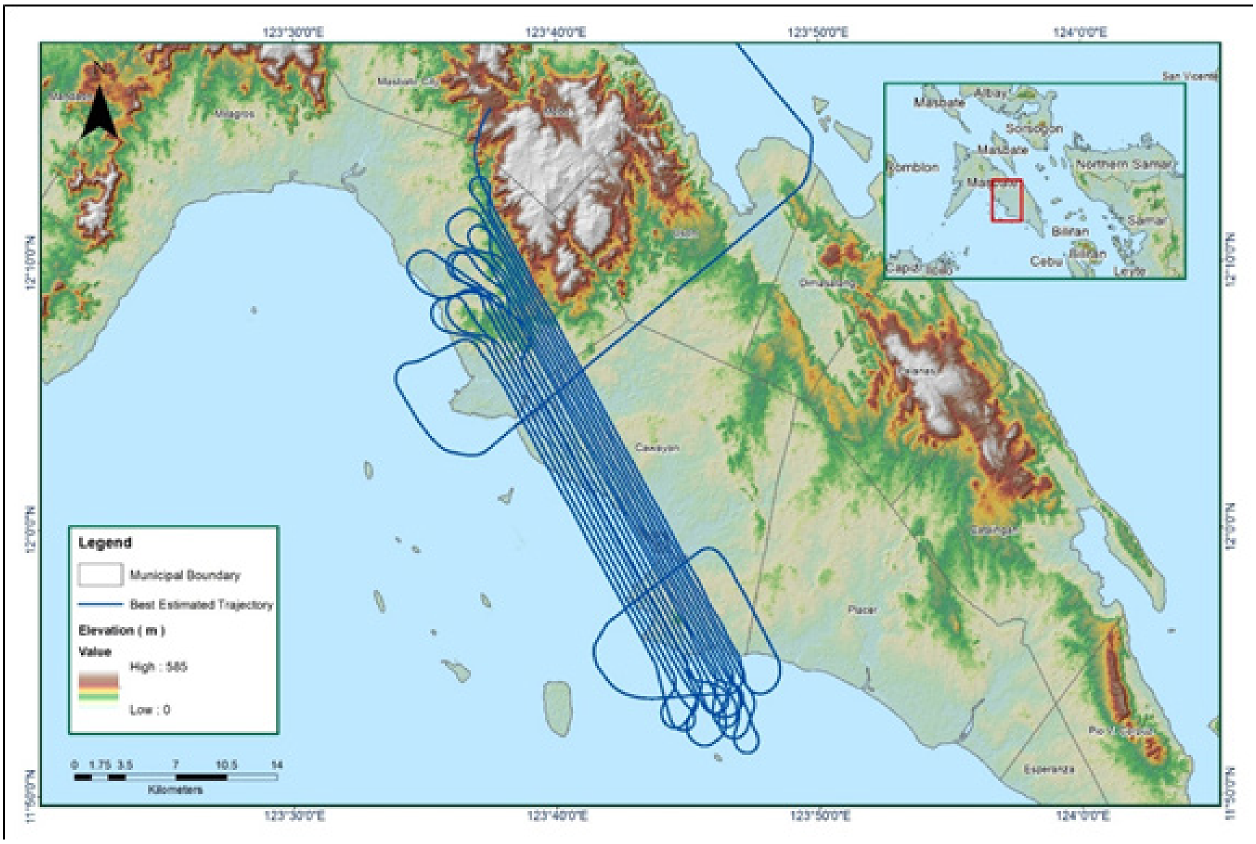


Figure A-8.10. Best Estimated Trajectory

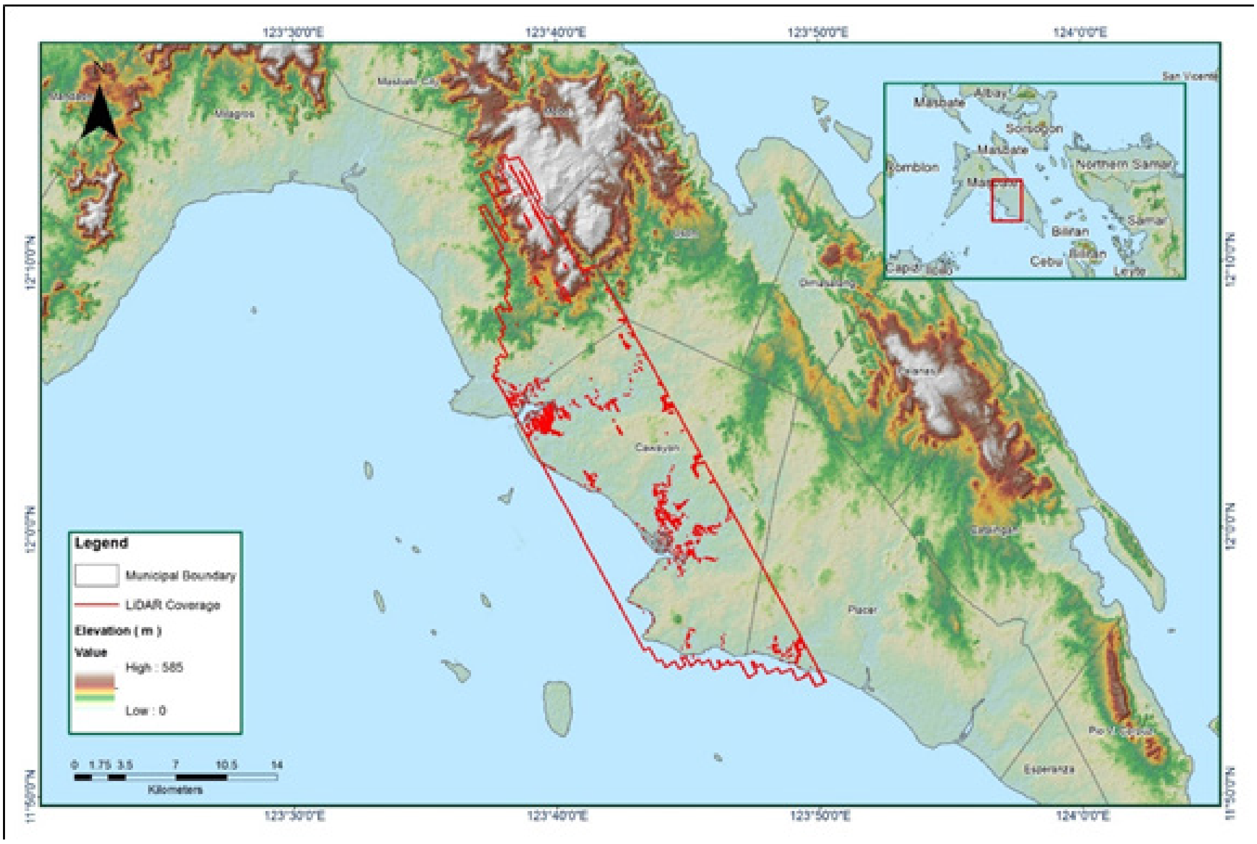


Figure A-8.11. Coverage of LiDAR data

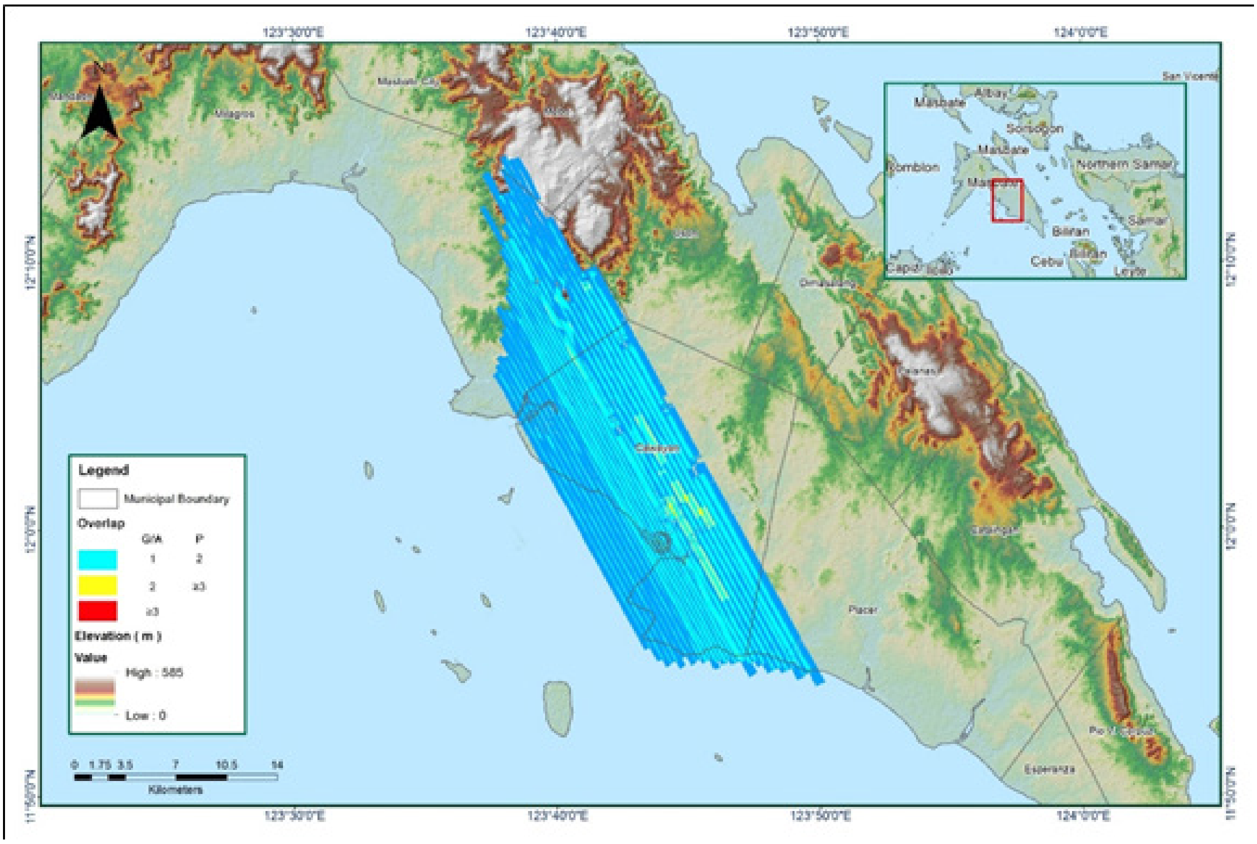


Figure A-8.12. Image of Data Overlap

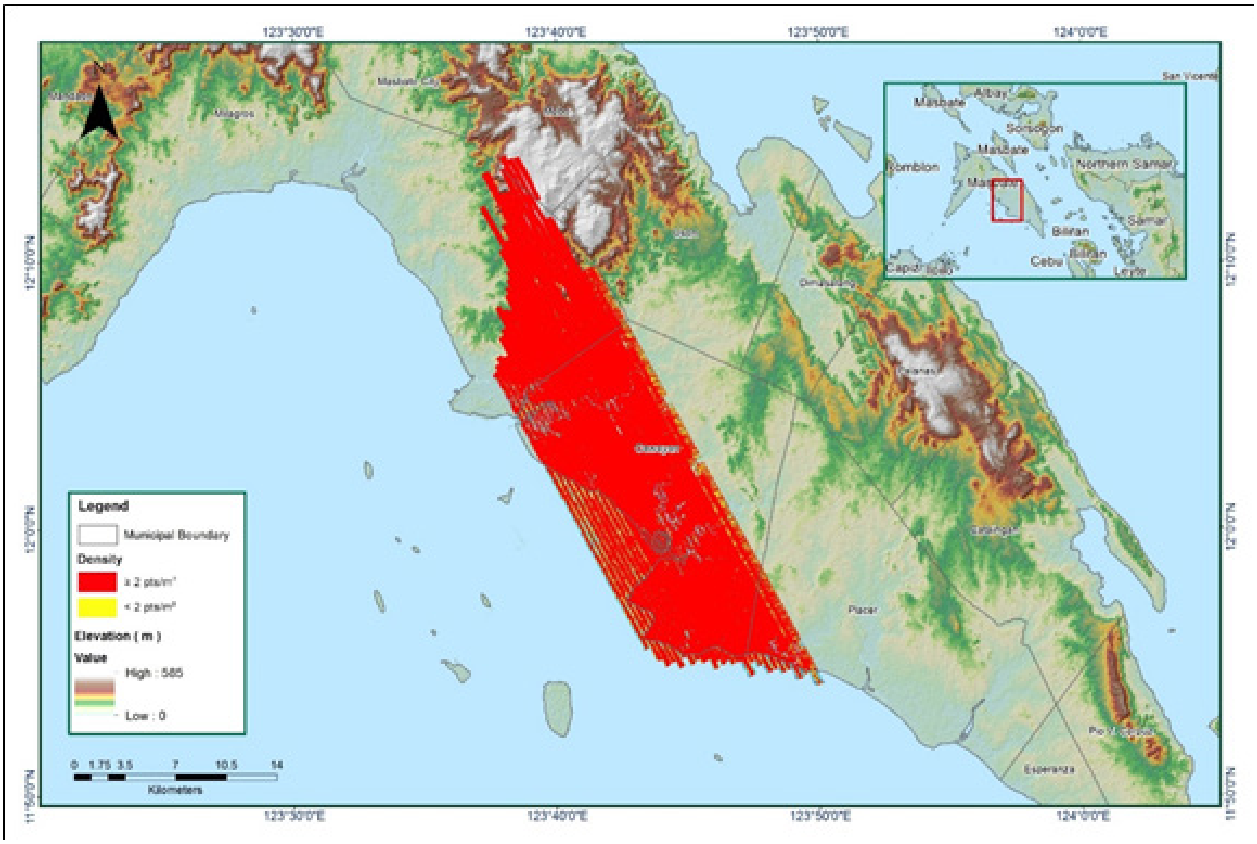


Figure A-8.13. Density map of merged LiDAR data

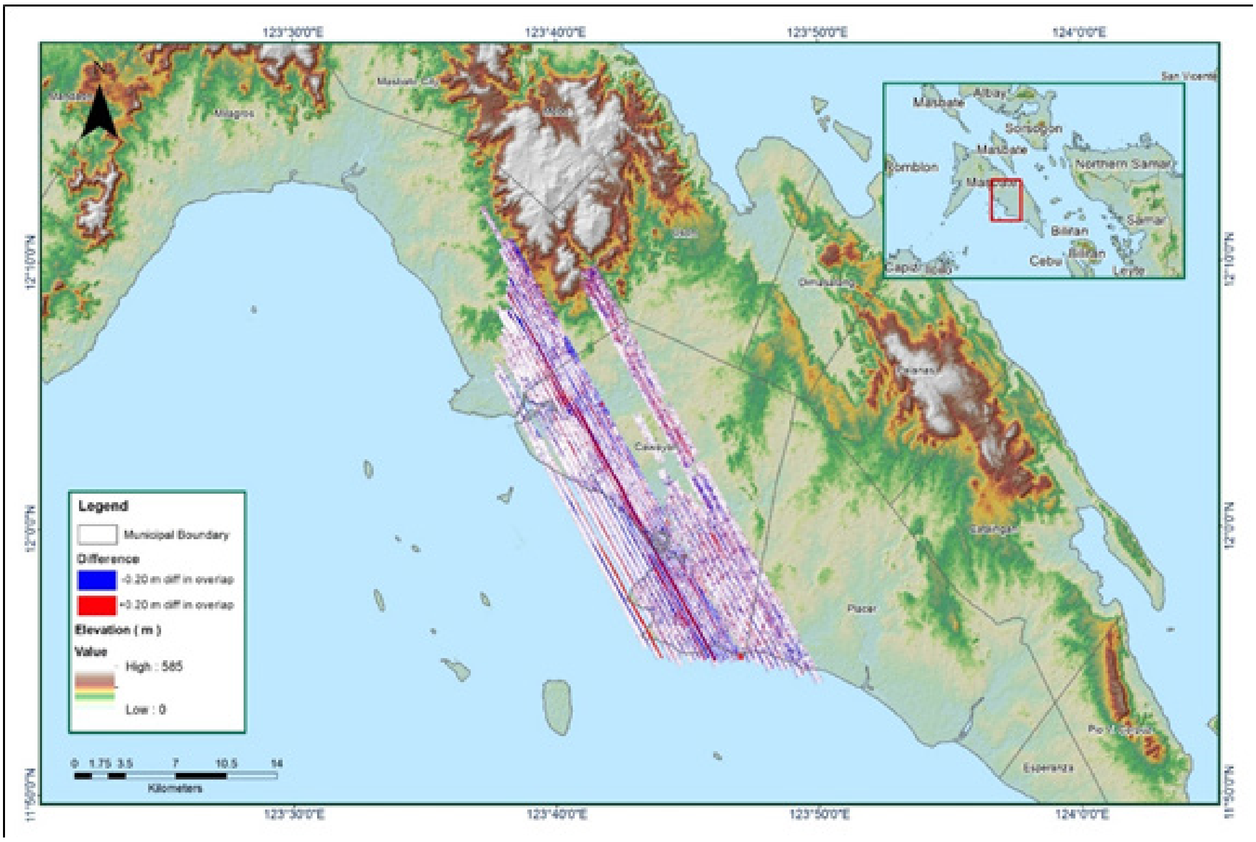


Figure A-8.14. Elevation difference between flight lines

# Annex 9. Guiom Model Basin Parameters

Table A-9.1. Pamplona Model Basin Parameters

| Basin Number | 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 |
| W200 | 500.00000 | 36.52800 | 0 | 0.01667 | 0.06925 | Discharge | 0.2297 | 0.00001 | Ratio to Peak | 0.01807 |
| W210 | 318.24000 | 64.68000 | 0 | 0.01667 | 0.05956 | Discharge | 0.0712 | 0.00001 | Ratio to Peak | 0.01495 |
| W220 | 273.46000 | 37.99000 | 0 | 0.16523 | 0.01667 | Discharge | 0.1598 | 0.00001 | Ratio to Peak | 0.01996 |
| W230 | 287.28000 | 36.54900 | 0 | 0.01667 | 76.93000 | Discharge | 0.0020 | 0.00001 | Ratio to Peak | 0.01565 |
| W240 | 379.47000 | 41.41200 | 0 | 0.14903 | 0.01667 | Discharge | 0.2330 | 0.00001 | Ratio to Peak | 0.40504 |
| W250 | 264.14000 | 36.23400 | 0 | 0.15475 | 0.08321 | Discharge | 0.2750 | 0.00001 | Ratio to Peak | 0.01691 |
| W260 | 313.71000 | 52.69500 | 0 | 0.01667 | 0.08214 | Discharge | 0.1775 | 0.00001 | Ratio to Peak | 0.37829 |
| W270 | 310.98000 | 52.97000 | 0 | 0.01667 | 0.01667 | Discharge | 0.0274 | 0.00001 | Ratio to Peak | 0.01843 |
| W280 | 310.22000 | 63.38600 | 0 | 0.14686 | 0.01667 | Discharge | 0.0078 | 0.00001 | Ratio to Peak | 0.01714 |
| W290 | 32.03600 | 99.00000 | 0 | 0.14605 | 0.01667 | Discharge | 0.0724 | 0.00001 | Ratio to Peak | 0.09082 |
| W300 | 16.37100 | 99.00000 | 0 | 0.14582 | 0.01667 | Discharge | 0.0348 | 0.00001 | Ratio to Peak | 0.01987 |
| W310 | 99.03900 | 99.00000 | 0 | 0.16529 | 0.07983 | Discharge | 0.0706 | 0.00001 | Ratio to Peak | 0.01852 |
| W320 | 0.03371 | 38.40000 | 0 | 0.12604 | 0.28818 | Discharge | 0.1328 | 0.00001 | Ratio to Peak | 0.10634 |
| W330 | 300.00000 | 93.85600 | 0 | 0.01667 | 0.08102 | Discharge | 0.0379 | 0.00001 | Ratio to Peak | 0.02671 |
| W340 | 360.39000 | 51.55700 | 0 | 0.14269 | 0.08055 | Discharge | 0.0941 | 0.00001 | Ratio to Peak | 0.06106 |
| W350 | 500.00000 | 70.00000 | 0 | 0.16662 | 0.07488 | Discharge | 0.0160 | 0.00001 | Ratio to Peak | 0.38082 |
| W360 | 300.00000 | 52.80600 | 0 | 0.01667 | 0.08323 | Discharge | 0.3218 | 0.00001 | Ratio to Peak | 0.02294 |
| W370 | 296.56000 | 37.27100 | 0 | 0.01667 | 0.06925 | Discharge | 0.1553 | 0.00001 | Ratio to Peak | 0.33903 |
| W380 | 500.00000 | 52.92000 | 0 | 0.01667 | 0.05956 | Discharge | 0.0808 | 0.00001 | Ratio to Peak | 0.10925 |

# Annex 10. Guiom Model Reach Parameters

Table A-10.1. Pamplona 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 | 199 | 0.00148 | 0.00010 | Trapezoid | 45.501 | 1 |
| R50 | Automatic Fixed Interval | 5890.5 | 0.00148 | 0.00010 | Trapezoid | 45.501 | 1 |
| R80 | Automatic Fixed Interval | 1742.6 | 0.01013 | 0.00010 | Trapezoid | 45.501 | 1 |
| R90 | Automatic Fixed Interval | 340.01 | 0.01013 | 0.00010 | Trapezoid | 45.501 | 1 |
| R120 | Automatic Fixed Interval | 1784.3 | 0.00256 | 0.45246 | Trapezoid | 45.501 | 1 |
| R130 | Automatic Fixed Interval | 4402.2 | 0.00052 | 0.01466 | Trapezoid | 45.501 | 1 |
| R150 | Automatic Fixed Interval | 2438.5 | 0.00132 | 0.04713 | Trapezoid | 45.501 | 1 |
| R160 | Automatic Fixed Interval | 853.58 | 0.00069 | 0.01319 | Trapezoid | 45.501 | 1 |
| R190 | Automatic Fixed Interval | 4043.8 | 0.002201 | 0.10318 | Trapezoid | 45.501 | 1 |

# Annex 11. Guiom Floodplain Field Validation Points

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 131 | 11.94659 | 123.7275967 | 0.03 | 0 | 0.03 | | 5-Year |
| 128 | 11.94660167 | 123.72741 | 0 | 0 | 0 | | 5-Year |
| 130 | 11.94673833 | 123.727835 | 0.72 | 0 | 0.72 | | 5-Year |
| 129 | 11.94678167 | 123.7278633 | 0.72 | 0 | 0.72 | | 5-Year |
| 134 | 11.94695167 | 123.7275617 | 0.24 | 0 | 0.24 | | 5-Year |
| 136 | 11.94708833 | 123.727475 | 0.27 | 0 | 0.27 | | 5-Year |
| 132 | 11.94709 | 123.7273083 | 0.03 | 0 | 0.03 | | 5-Year |
| 135 | 11.9472 | 123.7272717 | 0.03 | 0 | 0.03 | | 5-Year |
| 138 | 11.94737333 | 123.7270883 | 0.03 | 0 | 0.03 | | 5-Year |
| 137 | 11.947475 | 123.727245 | 0.19 | 0 | 0.19 | | 5-Year |
| 140 | 11.94754333 | 123.7269117 | 0.03 | 0 | 0.03 | | 5-Year |
| 133 | 11.94755333 | 123.7272233 | 0.2 | 0 | 0.2 | | 5-Year |
| 166 | 11.94757 | 123.745495 | 0.07 | 0 | 0.07 | | 5-Year |
| 139 | 11.94767833 | 123.7270583 | 0.38 | 0 | 0.38 | | 5-Year |
| 141 | 11.94768167 | 123.726715 | 0.03 | 0 | 0.03 | | 5-Year |
| 142 | 11.94774833 | 123.7267567 | 0.03 | 0 | 0.03 | | 5-Year |
| 165 | 11.94774167 | 123.7449983 | 0.04 | 0 | 0.04 | | 5-Year |
| 197 | 11.94790833 | 123.7416967 | 0.04 | 0 | 0.04 | | 5-Year |
| 143 | 11.94796833 | 123.7267817 | 0.1 | 0 | 0.1 | | 5-Year |
| 162 | 11.947975 | 123.7416683 | 0.08 | 0 | 0.08 | | 5-Year |
| 198 | 11.948045 | 123.7418417 | 0.03 | 0 | 0.03 | | 5-Year |
| 103 | 11.94809582 | 123.7428857 | 0.03 | 0 | 0.03 | | 5-Year |
| 104 | 11.94809712 | 123.7429557 | 0.03 | 0 | 0.03 | | 5-Year |
| 105 | 11.94810768 | 123.7429893 | 0.03 | 0 | 0.03 | | 5-Year |
| 196 | 11.94811333 | 123.7414567 | 0.06 | 0 | 0.06 | | 5-Year |
| 102 | 11.94812305 | 123.7428693 | 0.03 | 0 | 0.03 | | 5-Year |
| 148 | 11.94819167 | 123.7263417 | 0.03 | 0 | 0.03 | | 5-Year |
| 147 | 11.94824667 | 123.7267583 | 0.57 | 0 | 0.57 | | 5-Year |
| 144 | 11.94825167 | 123.726775 | 0.59 | 0 | 0.59 | | 5-Year |
| 106 | 11.94821355 | 123.7430844 | 0.03 | 0 | 0.03 | | 5-Year |
| 180 | 11.948295 | 123.72672 | 0.59 | 0 | 0.59 | | 5-Year |
| 163 | 11.94827333 | 123.74192 | 0.06 | 0 | 0.06 | | 5-Year |
| 145 | 11.94832333 | 123.72662 | 0.52 | 0 | 0.52 | | 5-Year |
| 146 | 11.94833833 | 123.726745 | 0.59 | 0 | 0.59 | | 5-Year |
| 181 | 11.94839833 | 123.7263283 | 0.3 | 0 | 0.3 | | 5-Year |
| 149 | 11.94842 | 123.72624 | 0.09 | 0 | 0.09 | | 5-Year |
| 182 | 11.948485 | 123.7262767 | 0.54 | 0 | 0.54 | | 5-Year |
| 195 | 11.94845333 | 123.7408867 | 0.34 | 0 | 0.34 | | 5-Year |
| 150 | 11.94856667 | 123.726055 | 0.12 | 0 | 0.12 | | 5-Year |
| 183 | 11.94857667 | 123.7260367 | 0.12 | 0 | 0.12 | | 5-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 199 | 11.94877333 | 123.74311 | 0.06 | 0 | 0.06 | | 5-Year |
| 151 | 11.94887333 | 123.7259117 | 0.6 | 0 | 0.6 | | 5-Year |
| 185 | 11.94906167 | 123.726855 | 0.68 | 0 | 0.68 | | 5-Year |
| 44 | 11.94907129 | 123.7255903 | 0.18 | 0 | 0.18 | | 5-Year |
| 46 | 11.94907127 | 123.7257902 | 0.79 | 0 | 0.79 | | 5-Year |
| 98 | 11.94904092 | 123.7396801 | 0.03 | 0 | 0.03 | | 5-Year |
| 186 | 11.94908667 | 123.72684 | 0.23 | 0 | 0.23 | | 5-Year |
| 152 | 11.94909333 | 123.7269333 | 0.14 | 0 | 0.14 | | 5-Year |
| 101 | 11.94906243 | 123.7400246 | 0.17 | 0 | 0.17 | | 5-Year |
| 164 | 11.94906833 | 123.7430433 | 0.06 | 0 | 0.06 | | 5-Year |
| 43 | 11.94920145 | 123.7254555 | 0.07 | 0 | 0.07 | | 5-Year |
| 100 | 11.94918079 | 123.7399821 | 0.12 | 0 | 0.12 | | 5-Year |
| 45 | 11.94923488 | 123.7256526 | 0.71 | 0 | 0.71 | | 5-Year |
| 97 | 11.94921025 | 123.7397257 | 0.06 | 0 | 0.06 | | 5-Year |
| 154 | 11.94924833 | 123.727315 | 0.03 | 0 | 0.03 | | 5-Year |
| 99 | 11.94925227 | 123.7399175 | 0.13 | 0 | 0.13 | | 5-Year |
| 74 | 11.94929091 | 123.7262875 | 0.54 | 0 | 0.54 | | 5-Year |
| 155 | 11.94929 | 123.72749 | 0.06 | 0 | 0.06 | | 5-Year |
| 42 | 11.9492996 | 123.7255175 | 0.61 | 0 | 0.61 | | 5-Year |
| 73 | 11.94929851 | 123.7261742 | 0.5 | 0 | 0.5 | | 5-Year |
| 72 | 11.94932371 | 123.7263071 | 0.54 | 0 | 0.54 | | 5-Year |
| 62 | 11.949334 | 123.7260712 | 0.44 | 0 | 0.44 | | 5-Year |
| 61 | 11.94934785 | 123.7260768 | 0.45 | 0 | 0.45 | | 5-Year |
| 153 | 11.949375 | 123.7271917 | 0.12 | 0 | 0.12 | | 5-Year |
| 184 | 11.94938833 | 123.7266317 | 0.03 | 0 | 0.03 | | 5-Year |
| 187 | 11.94938833 | 123.7271067 | 0.03 | 0 | 0.03 | | 5-Year |
| 190 | 11.94940167 | 123.7267517 | 0.03 | 0 | 0.03 | | 5-Year |
| 156 | 11.94943667 | 123.7270533 | 0.05 | 0 | 0.05 | | 5-Year |
| 71 | 11.94944434 | 123.7263764 | 0.12 | 0 | 0.12 | | 5-Year |
| 60 | 11.94946291 | 123.7259083 | 0.48 | 0 | 0.48 | | 5-Year |
| 191 | 11.94946167 | 123.7267233 | 0.03 | 0 | 0.03 | | 5-Year |
| 82 | 11.94948974 | 123.727538 | 0.03 | 0 | 0.03 | | 5-Year |
| 63 | 11.94950393 | 123.7263987 | 0.12 | 0 | 0.12 | | 5-Year |
| 192 | 11.94950833 | 123.7268683 | 0.03 | 0 | 0.03 | | 5-Year |
| 157 | 11.94951167 | 123.7274633 | 0.03 | 0 | 0.03 | | 5-Year |
| 189 | 11.94955 | 123.7270817 | 0.13 | 0 | 0.13 | | 5-Year |
| 188 | 11.94955333 | 123.7270067 | 0.03 | 0 | 0.03 | | 5-Year |
| 64 | 11.94956828 | 123.7264518 | 0.03 | 0 | 0.03 | | 5-Year |
| 55 | 11.94957521 | 123.725811 | 0.46 | 0 | 0.46 | | 5-Year |
| 87 | 11.94957211 | 123.7280751 | 0.03 | 0 | 0.03 | | 5-Year |
| 88 | 11.94957439 | 123.7282128 | 0.03 | 0 | 0.03 | | 5-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 54 | 11.9495807 | 123.7258028 | 0.46 | 0 | 0.46 | | 5-Year |
| 57 | 11.94958636 | 123.7259029 | 0.44 | 0 | 0.44 | | 5-Year |
| 96 | 11.94955834 | 123.7396645 | 0.06 | 0 | 0.06 | | 5-Year |
| 58 | 11.94961181 | 123.7260053 | 0.36 | 0 | 0.36 | | 5-Year |
| 70 | 11.94961604 | 123.7265722 | 0.03 | 0 | 0.03 | | 5-Year |
| 86 | 11.94962549 | 123.7279623 | 0.03 | 0 | 0.03 | | 5-Year |
| 65 | 11.94966272 | 123.7265465 | 0.03 | 0 | 0.03 | | 5-Year |
| 69 | 11.94966986 | 123.7267593 | 0.03 | 0 | 0.03 | | 5-Year |
| 56 | 11.94967494 | 123.7259689 | 0.54 | 0 | 0.54 | | 5-Year |
| 59 | 11.94969122 | 123.726208 | 0.07 | 0 | 0.07 | | 5-Year |
| 53 | 11.94970729 | 123.7259024 | 0.4 | 0 | 0.4 | | 5-Year |
| 161 | 11.949685 | 123.7382783 | 0.03 | 0 | 0.03 | | 5-Year |
| 85 | 11.94976232 | 123.7277392 | 0.03 | 0 | 0.03 | | 5-Year |
| 194 | 11.94977 | 123.7384967 | 0.03 | 0 | 0.03 | | 5-Year |
| 81 | 11.94982005 | 123.7271115 | 0.03 | 0 | 0.03 | | 5-Year |
| 68 | 11.94986777 | 123.7268782 | 0.04 | 0 | 0.04 | | 5-Year |
| 80 | 11.94988066 | 123.7270338 | 0.15 | 0 | 0.15 | | 5-Year |
| 66 | 11.9498856 | 123.7266609 | 0.03 | 0 | 0.03 | | 5-Year |
| 84 | 11.94989237 | 123.7274993 | 0.03 | 0 | 0.03 | | 5-Year |
| 67 | 11.94992522 | 123.7266712 | 0.03 | 0 | 0.03 | | 5-Year |
| 160 | 11.94991667 | 123.73701 | 0.26 | 0 | 0.26 | | 5-Year |
| 75 | 11.94995814 | 123.7269061 | 0.26 | 0 | 0.26 | | 5-Year |
| 83 | 11.9499793 | 123.7273717 | 0.03 | 0 | 0.03 | | 5-Year |
| 90 | 11.95004557 | 123.7299977 | 0.03 | 0 | 0.03 | | 5-Year |
| 95 | 11.95006255 | 123.7300983 | 0.03 | 0 | 0.03 | | 5-Year |
| 52 | 11.95007591 | 123.725427 | 0.68 | 0 | 0.68 | | 5-Year |
| 76 | 11.95008458 | 123.7269259 | 0.63 | 0 | 0.63 | | 5-Year |
| 94 | 11.95010999 | 123.7301395 | 0.03 | 0 | 0.03 | | 5-Year |
| 51 | 11.95013541 | 123.7255693 | 0.29 | 0 | 0.29 | | 5-Year |
| 77 | 11.95014558 | 123.726993 | 0.14 | 0 | 0.14 | | 5-Year |
| 89 | 11.95015126 | 123.7301322 | 0.06 | 0 | 0.06 | | 5-Year |
| 92 | 11.95017036 | 123.730438 | 0.03 | 0 | 0.03 | | 5-Year |
| 93 | 11.95018665 | 123.7303544 | 0.07 | 0 | 0.07 | | 5-Year |
| 91 | 11.95022981 | 123.730345 | 0.05 | 0 | 0.05 | | 5-Year |
| 50 | 11.95030273 | 123.7256784 | 0.07 | 0 | 0.07 | | 5-Year |
| 159 | 11.95028333 | 123.7357183 | 0.46 | 0 | 0.46 | | 5-Year |
| 49 | 11.950347 | 123.7255115 | 0.03 | 0 | 0.03 | | 5-Year |
| 48 | 11.95035275 | 123.7254189 | 0.03 | 0 | 0.03 | | 5-Year |
| 79 | 11.9503902 | 123.7272772 | 0.12 | 0 | 0.12 | | 5-Year |
| 78 | 11.95039931 | 123.7271541 | 0.03 | 0 | 0.03 | | 5-Year |
| 158 | 11.95054333 | 123.73372 | 0.04 | 0 | 0.04 | | 5-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 47 | 11.95059623 | 123.7252812 | 0.08 | 0 | 0.08 | | 5-Year |
| 193 | 11.950825 | 123.732965 | 0.03 | 0 | 0.03 | | 5-Year |
| 41 | 11.95315157 | 123.7340232 | 0.03 | 0 | 0.03 | | 5-Year |
| 127 | 11.95582333 | 123.7340383 | 0.03 | 0 | 0.03 | | 5-Year |
| 126 | 11.955945 | 123.7340867 | 0.03 | 0 | 0.03 | | 5-Year |
| 38 | 11.95706923 | 123.7345313 | 0.03 | 0 | 0.03 | | 5-Year |
| 125 | 11.95711667 | 123.73435 | 0.03 | 0 | 0.03 | | 5-Year |
| 39 | 11.95717908 | 123.7345277 | 0.03 | 0 | 0.03 | | 5-Year |
| 40 | 11.9572431 | 123.73457 | 0.03 | 0 | 0.03 | | 5-Year |
| 123 | 11.95728667 | 123.7342967 | 0.03 | 0 | 0.03 | | 5-Year |
| 124 | 11.95733 | 123.7343267 | 0.03 | 0 | 0.03 | | 5-Year |
| 37 | 11.9577914 | 123.7337057 | 0.03 | 0 | 0.03 | | 5-Year |
| 36 | 11.95793147 | 123.7336687 | 0.03 | 0 | 0.03 | | 5-Year |
| 34 | 11.96076354 | 123.7249755 | 0.03 | 0 | 0.03 | | 5-Year |
| 33 | 11.96077973 | 123.724876 | 0.03 | 0 | 0.03 | | 5-Year |
| 121 | 11.96090167 | 123.7245633 | 0.03 | 0 | 0.03 | | 5-Year |
| 122 | 11.96091333 | 123.7257917 | 0.03 | 0 | 0.03 | | 5-Year |
| 120 | 11.961035 | 123.724425 | 0.04 | 0 | 0.04 | | 5-Year |
| 35 | 11.96106952 | 123.7286461 | 0.03 | 0 | 0.03 | | 5-Year |
| 119 | 11.96320667 | 123.722305 | 0.03 | 0 | 0.03 | | 5-Year |
| 32 | 11.96394545 | 123.7220957 | 0.06 | 0 | 0.06 | | 5-Year |
| 118 | 11.964395 | 123.7228167 | 0.03 | 0 | 0.03 | | 5-Year |
| 117 | 11.964485 | 123.72293 | 0.03 | 0 | 0.03 | | 5-Year |
| 31 | 11.96583126 | 123.7235157 | 0.55 | 0 | 0.55 | | 5-Year |
| 30 | 11.96657248 | 123.7242719 | 0.03 | 0 | 0.03 | | 5-Year |
| 179 | 11.96706167 | 123.7255833 | 0.03 | 0 | 0.03 | | 5-Year |
| 29 | 11.9678659 | 123.7266109 | 0.03 | 0 | 0.03 | | 5-Year |
| 28 | 11.96802019 | 123.7264588 | 0.03 | 0 | 0.03 | | 5-Year |
| 25 | 11.96806381 | 123.7267817 | 0.03 | 0 | 0.03 | | 5-Year |
| 27 | 11.96809823 | 123.7265731 | 0.03 | 0 | 0.03 | | 5-Year |
| 24 | 11.96812011 | 123.726866 | 0.05 | 0 | 0.05 | | 5-Year |
| 26 | 11.96813941 | 123.72669 | 0.03 | 0 | 0.03 | | 5-Year |
| 116 | 11.96833667 | 123.7268967 | 0.03 | 0 | 0.03 | | 5-Year |
| 115 | 11.96846667 | 123.7269183 | 0.03 | 0 | 0.03 | | 5-Year |
| 23 | 11.96853779 | 123.7273572 | 0.03 | 0 | 0.03 | | 5-Year |
| 114 | 11.96865 | 123.7271967 | 0.04 | 0 | 0.04 | | 5-Year |
| 22 | 11.96877027 | 123.7278149 | 0.03 | 0 | 0.03 | | 5-Year |
| 113 | 11.96880667 | 123.7274133 | 0.03 | 0 | 0.03 | | 5-Year |
| 112 | 11.96881333 | 123.72757 | 0.03 | 0 | 0.03 | | 5-Year |
| 21 | 11.96906113 | 123.7278248 | 0.03 | 0 | 0.03 | | 5-Year |
| 111 | 11.96944 | 123.7278933 | 0.38 | 0 | 0.38 | | 5-Year |

| Point Number | Validation Coordinates (in WGS84) | | Model Var (m) | Valid-ation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 110 | 11.96973667 | 123.7284067 | 0.03 | 0 | 0.03 | | 5-Year |
| 20 | 11.97396139 | 123.7305122 | 0.03 | 0 | 0.03 | | 5-Year |
| 178 | 11.97488 | 123.7309967 | 0.03 | 0 | 0.03 | | 5-Year |
| 177 | 11.97524833 | 123.7310883 | 0.05 | 0 | 0.05 | | 5-Year |
| 18 | 11.97526895 | 123.7307558 | 0.03 | 0 | 0.03 | | 5-Year |
| 19 | 11.97527174 | 123.7307843 | 0.03 | 0 | 0.03 | | 5-Year |
| 17 | 11.9754221 | 123.730928 | 0.05 | 0 | 0.05 | | 5-Year |
| 16 | 11.97577062 | 123.731267 | 0.03 | 0 | 0.03 | | 5-Year |
| 15 | 11.97590087 | 123.7313355 | 0.03 | 0 | 0.03 | | 5-Year |
| 14 | 11.97598582 | 123.731271 | 0.03 | 0 | 0.03 | | 5-Year |
| 176 | 11.97632167 | 123.7315033 | 0.03 | 0 | 0.03 | | 5-Year |
| 109 | 11.97638333 | 123.731275 | 0.03 | 0 | 0.03 | | 5-Year |
| 175 | 11.976415 | 123.73157 | 0.03 | 0 | 0.03 | | 5-Year |
| 174 | 11.976475 | 123.731505 | 0.03 | 0 | 0.03 | | 5-Year |
| 13 | 11.97663401 | 123.7315606 | 0.03 | 0 | 0.03 | | 5-Year |
| 8 | 11.97895746 | 123.732736 | 0.03 | 0 | 0.03 | | 5-Year |
| 9 | 11.97897174 | 123.7326991 | 0.03 | 0 | 0.03 | | 5-Year |
| 7 | 11.97908751 | 123.7328422 | 0.03 | 0 | 0.03 | | 5-Year |
| 10 | 11.97921656 | 123.7325526 | 0.03 | 0 | 0.03 | | 5-Year |
| 6 | 11.97922238 | 123.7329259 | 0.03 | 0 | 0.03 | | 5-Year |
| 11 | 11.97936812 | 123.732895 | 0.03 | 0 | 0.03 | | 5-Year |
| 5 | 11.97937378 | 123.7330003 | 0.03 | 0 | 0.03 | | 5-Year |
| 4 | 11.97948576 | 123.7330169 | 0.03 | 0 | 0.03 | | 5-Year |
| 12 | 11.97958354 | 123.7330144 | 0.04 | 0 | 0.04 | | 5-Year |
| 3 | 11.97979594 | 123.7331433 | 0.03 | 0 | 0.03 | | 5-Year |
| 108 | 11.97989 | 123.7331017 | 0.04 | 0 | 0.04 | | 5-Year |
| 2 | 11.97995606 | 123.7331874 | 0.03 | 0 | 0.03 | | 5-Year |
| 107 | 11.98001833 | 123.73299 | 0.16 | 0 | 0.16 | | 5-Year |
| 1 | 11.98008857 | 123.7331602 | 0.14 | 0 | 0.14 | | 5-Year |
| 167 | 11.98022833 | 123.73314 | 0.03 | 0 | 0.03 | | 5-Year |
| 170 | 11.98026167 | 123.7327733 | 0.13 | 0 | 0.13 | | 5-Year |
| 171 | 11.98027833 | 123.732655 | 0.03 | 0 | 0.03 | | 5-Year |
| 168 | 11.980305 | 123.73323 | 0.03 | 0 | 0.03 | | 5-Year |
| 173 | 11.98033 | 123.7334267 | 0.03 | 0 | 0.03 | | 5-Year |
| 169 | 11.98043667 | 123.7332467 | 0.03 | 0 | 0.03 | | 5-Year |
| 172 | 11.98049 | 123.733105 | 0.06 | 0 | 0.06 | | 5-Year |
| 204 | 11.98248667 | 123.799715 | 2.65 | 0 | 2.65 | | 5-Year |
| 202 | 11.98250667 | 123.7991767 | 0.62 | 0 | 0.62 | | 5-Year |
| 203 | 11.982565 | 123.7991067 | 0.62 | 0 | 0.62 | | 5-Year |
| 200 | 11.98263167 | 123.7979783 | 0.51 | 0 | 0.51 | | 5-Year |
| 201 | 11.98298667 | 123.798185 | 0.14 | 0 | 0.14 | | 5-Year |