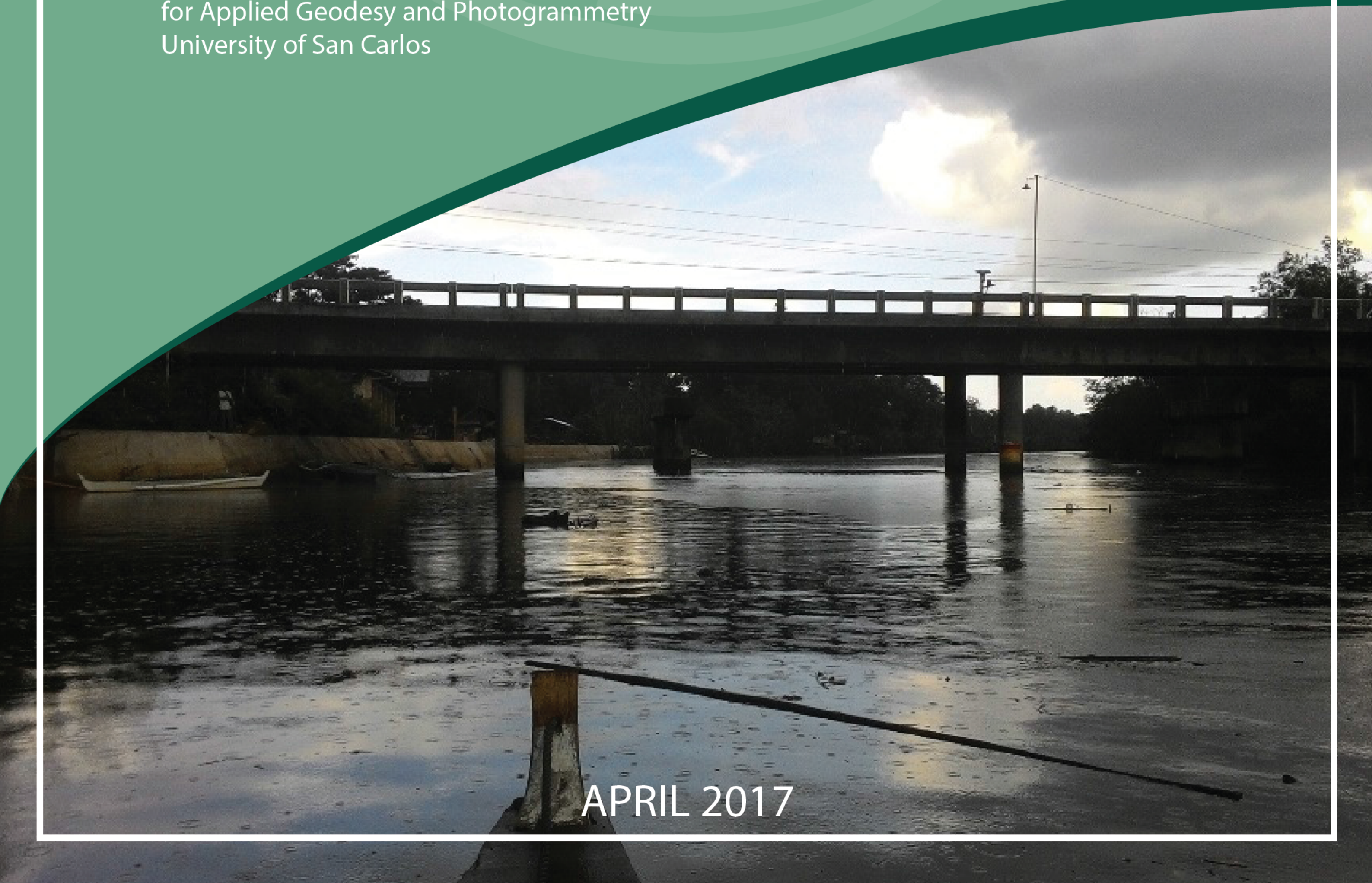
Hazard Mapping of the Philippines Using LIDAR ( Phil-LIDAR 1 )

# LiDAR Surveys and Flood Mapping of Ipil River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of San Carlos



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

# CHAPTER 1: OVERVIEW OF THE PROGRAM AND IPIL RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland Emerito S. Otadoy, and Engr. Aure Flo Oraya

## 1.1 Background of the Phil-LIDAR 1 Program

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

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos (USC). USC 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 17 river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

## 1.2 Overview of the Ipil River Basin

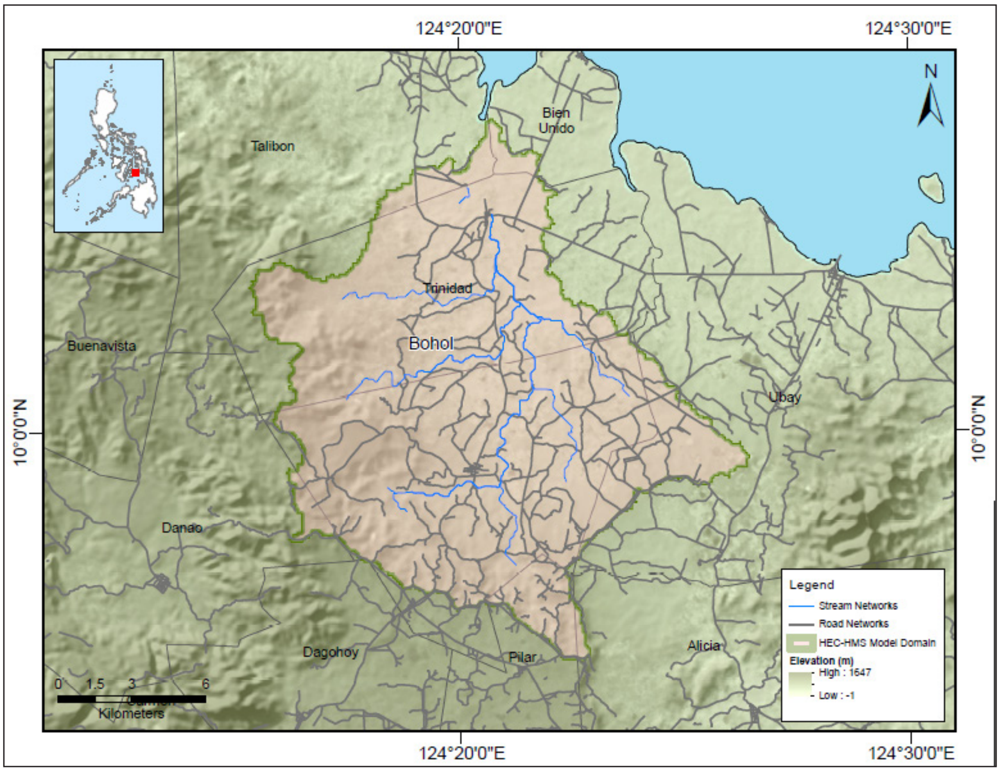


Figure 1. Map of the Ipil River Basin in brown

Ipil River Basin covers majority of the municipalities of Trinidad and San Miguel and minor portions of Bien Unido, Talibon, Danao, Pilar, Alicia and Ubay in the province of Bohol. The DENR River Basin Control Office identified the basin to have a drainage area of 252 $km^2$ and an estimated 151 million cubic meter annual run-off (MCM) (RBCO, 2015).

Its main stem, Ipil River, is part of the 17 river systems in Central Visayas Region. According to the 2015 national census of NSO, a total of 17,672 persons are residing within the immediate vicinity of the river which is distributed among seven (7) barangays in the Municipalities of Trinidad, Talibon and Bien Unido (NSO, 2015). The major industries in the municipalities near Ipil River are farming and fishing. Aside from these, the river also plays a vital part for the commercial activity of the municipality where traders transport their products. (http://www.bohol-philippines.com/trinidad.html, 2016). During the surge of typhoon Yolanda, internationally known as *Haiyan*, last November 2013 a total of 18,772 families or 90,201 individuals were affected by the typhoon from the municipalities of Trinidad and Talibon (http://ndrrmc.gov.ph/attachments/article/1329/FINAL_REPORT_re_Effects_of_Typhoon_YOLANDA_(HAIYAN)_06-09NOV2013.pdf).

# CHAPTER 2: LIDAR DATA ACQUISITION OF THE IPIL 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 LiDAR Acquisition in Ipil Floodplain

### 2.1.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Ipil floodplain in Davao del Sur. These missions were planned for 12 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Ipil floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

| Block Name | Flying Height (m AGL) | Overlap (%) | Field of View (θ) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK51A | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK51B | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK51C | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK51F | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK51S | 1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| BLK51LKS | 1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| LOBOC | 1000 | 30 | 50 | 200 | 30 | 130 | 5 |

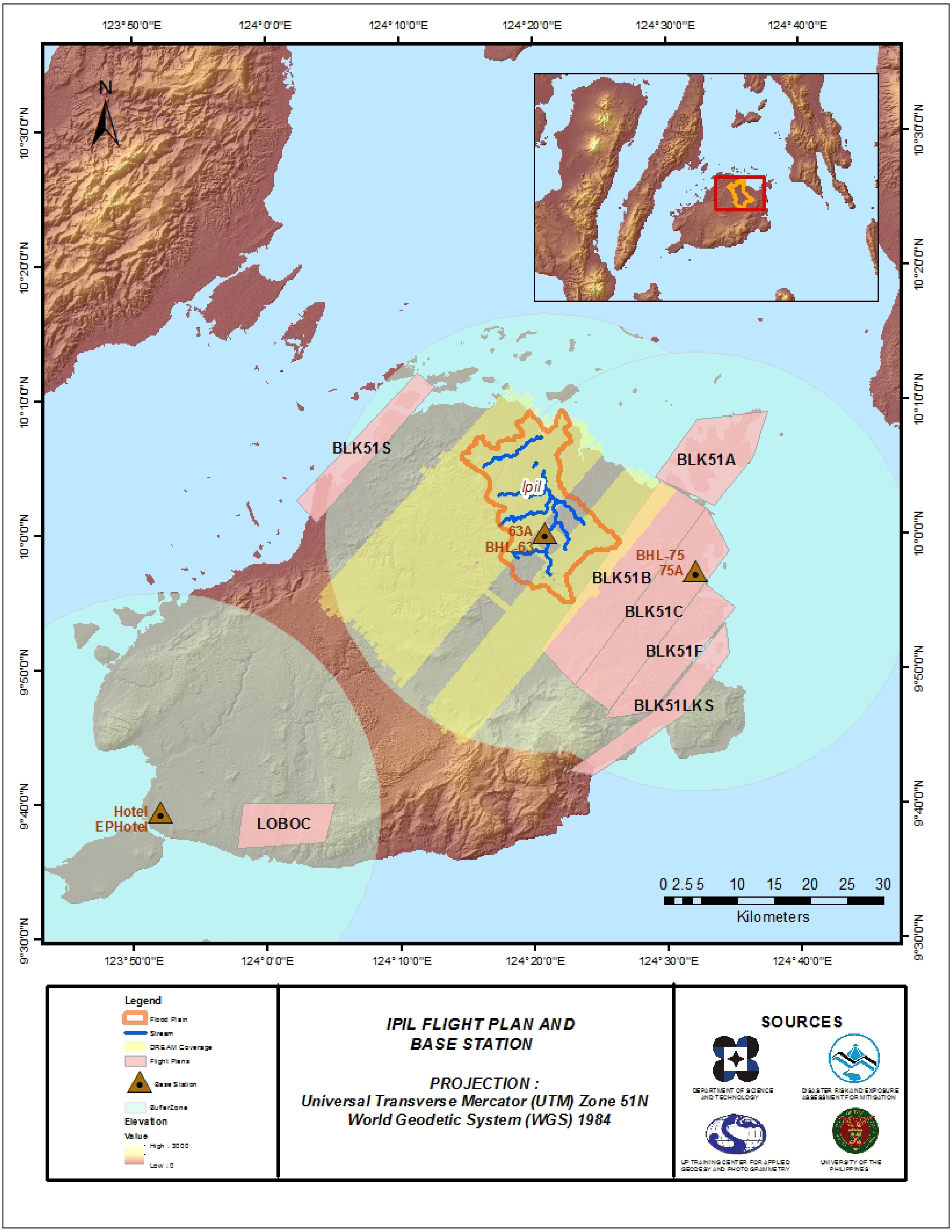



Figure 2. Flight plans and base stations used for the Ipil floodplain survey

## 2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: BHL-63, BHL-95 and BHL-75 which are of second (2nd), order accuracy, respectively. The project team also established one (4) ground control points, 63A, 75A, Hotel, and EPHotel. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the established control point are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (September 12 -23, 2015). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852, TRIMBLE SPS 882 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ipil floodplain are also shown in Figure 2.

Figure 3 to Figure 9 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 8 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.


(a)

Figure 3. GPS set-up over BHL-63 in Hagbuyo Bridge in Brgy. Hagbuyo, San Miguel, Bohol

Table 2. Details of the recovered NAMRIA horizontal control point BHL-63 used as base station for the LiDAR Acquisition

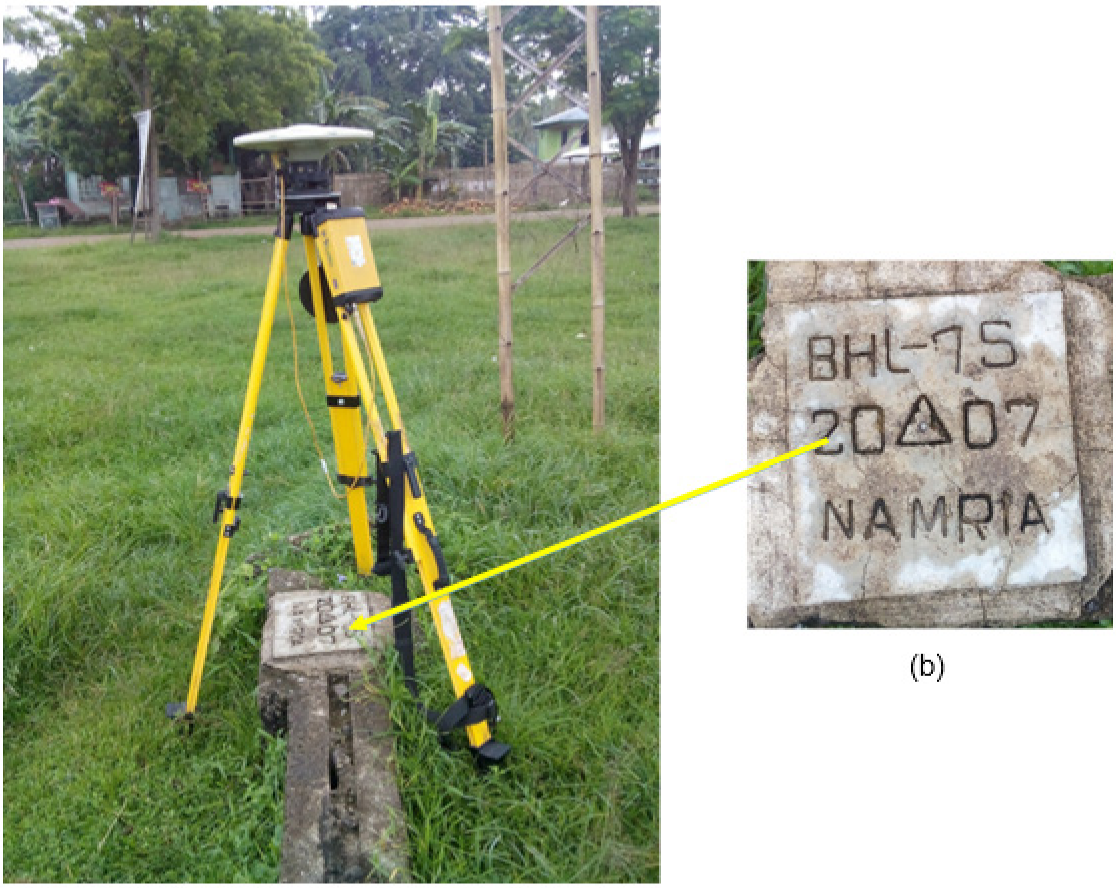
| Station Name | BHL-63 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 10° 0' 13.31407" |
| | Longitude | 124° 20' 43.46219" |
| | Ellipsoidal Height | 20.48700 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting | 428232.81 meters |
| | Northing | 1106210.364 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 10° 0' 9.30688" North |
| | Longitude | 124° 20' 48.73327" East |
| | Ellipsoidal Height | 84.04100 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 647,463.40 meters |
| | Northing | 1,106,052.78 meters |


(a) (b)

Figure 4. GPS set-up over BHL-95 in Brgy. Tiguis, Lila, BohoL (a) and NAMRIA reference point BHL-95 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point BHL-95 used as base station for the LiDAR Acquisition

| Station Name | BHL-95 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 9° 35' 30.9568" |
| | Longitude | 124° 04' 30.0216" |
| | Ellipsoidal Height | 19.00 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting | 398459.94396 meters |
| | Northing | 1060736.81055 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 9° 35' 27.03243" North |
| | Longitude | 124° 04' 35.33150" East |
| | Ellipsoidal Height | 82.798 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 618128.686 meters |
| | Northing | 1060360.033 meters |




(a) (b)

Figure 5. GPS set-up over BHL-75 at Barangay Plaza of San Jose, Mabini, Bohol (a) and NAMRIA reference point BHL-75 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point BHL-75 used as base station for the LiDAR acquisition

| | | |
|---|---|---|
| Station Name | BHL-75 | |
| Order of Accuracy | 2th | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 9° 57' 16.74294" |
| | Longitude | 124° 32' 0.35318" |
| | Ellipsoidal Height | 12.84500 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting | 448840.052 meters |
| | Northing | 1100750.724 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 9° 57' 16.76483" North |
| | Longitude | 124° 32' 5.62696" East |
| | Ellipsoidal Height | 76.97400 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 668,101.47 meters |
| | Northing | 1,100,718.38 meters |

(a)

Figure 6. GPS set-up over established point 63A in Hagbuyo Bridge, Brgy, Hagbuyo, San Miguel, Bohol (a)

Table 5. Details of the established control point 63A used as base station for the LiDAR Acquisition

| Station Name | 63A | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 10° 00’ 13.84084” North |
| | Longitude | 124° 20’ 43.58209” East |
| | Ellipsoidal Height | 20.464 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 647466.981 meters |
| | Northing | 1106068.972 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 10 00’ 09.83363” North |
| | Longitude | 124° 20’ 48.85315” East |
| | Ellipsoidal Height | 84.018 meters |

(a)

Figure 7. GPS set-up over established point 75A at the Basketball court in the Barangay Plaza of San Jose, Mabini, Bohol (a).

Table 6. Details of the established control point 75A used as base station for the LiDAR Acquisition

| Station Name | 75A | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 9° 57' 17.24192" North |
| | Longitude | 124° 32' 00.58209" East |
| | Ellipsoidal Height | 12.668 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 668103.303 meters |
| | Northing | 1100733.718 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 9° 57' 13.26378" North |
| | Longitude | 124° 32' 05.68974" East |
| | Ellipsoidal Height | 76.796 meters |

(a)

Figure 8. GPS set-up over established point Hotel at Panda Tea Garden Suites Tagbilaran, Bohol (a).

Table 7. Details of the established control point Hotel used as base station for the LiDAR Acquisition

| Station Name | Hotel | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 9° 39' 32.15822" North |
| | Longitude | 123° 51' 54.83035" East |
| | Ellipsoidal Height | 49.4981 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 594927.168 meters |
| | Northing | 1067756.448 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 9° 39' 28.19791" North |
| | Longitude | 123° 52' 00.13618" East |
| | Ellipsoidal Height | 113.124 meters |

(a)

Figure 9. GPS set-up over established point EPHotel at Panda Tea Garden Suites Tagbilaran, Bohol (a)

Table 8. Details of the established control point 63A used as base station for the LiDAR Acquisition

| Station Name | EPHotel | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude | 9° 39' 32.38755" North |
| | Longitude | 123° 51' 54.91053" East |
| | Ellipsoidal Height | 49.956 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting | 594929.497 meters |
| | Northing | 1067763.497 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude | 9° 39' 28.42722" North |
| | Longitude | 123° 52' 00.21636" East |
| | Ellipsoidal Height | 113.100 meters |

Table 9. Ground control points used during LiDAR data acquisition

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| September 12, 2015 | 3409P | 1BLK51B255A | BHL-63 and 63A |
| September 12, 2015 | 3411P | 1BLK51C255B | BHL-63 and 63A |
| September 15, 2015 | 4321P | 1BLK51C258A | BHL-75 and 75A |
| September 17, 2015 | 3429P | 1BLK51260A | BHL-75 and 75A |
| September 22, 2015 | 3449P | 1BLK51G265A | BHL-75 and 75A |
| September 23, 2015 | 3453P | 1BLK51S266A | Hotel and EPHotel |

## 2.3 Flight Missions

Six (6) missions under DREAM program covered around 239.8 (Table 10) within Ipil floodplain. Six (6) missions under Phil-LiDAR program were conducted to complete the LiDAR data acquisition in Ipil floodplain, for a total of Twenty hours and Twenty-four minutes (20+24) of flying time for RP-C9122. The missions were acquired using the Gemini LiDAR system. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions under DREAM program which covers Ipil floodplain

| Flight Number | Mission Name | Area Surveyed within the Floodplain ($km^2$) |
|---|---|---|
| 765P | 1BHL1C321A | 54.47 |
| 769P | 1BHL1BC322A | 63.32 |
| 773P | 1BHL1BS323A | 16.17 |
| 777P | 1BHL1D324A | 39.30 |
| 793P | 1BHL1BDS328A | 8.13 |
| 833P | 1BHL1E338A | 58.41 |
| TOTAL | | 239.8 |

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

| Date Surveyed | Flight Number | Flight Plan Area (km²) | Surveyed Area (km²) | Area Surveyed within the Floodplain (km²) | Area Surveyed Outside the Floodplain (km²) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| September 12, 2015 | 3409P | 111.44 | 196.08 | 0 | 196.08 | NA | 4 | 23 |
| September 12, 2015 | 3411P | 295.43 | 109.96 | 0 | 109.96 | NA | 2 | 47 |
| September 15, 2015 | 4321P | 107.84 | 54.28 | 0 | 54.28 | NA | 2 | 35 |
| September 17, 2015 | 3429P | 107.84 | 234.68 | 0 | 234.68 | NA | 4 | 17 |
| September 22, 2015 | 3449P | 486.5 | 123.69 | 0 | 123.68 | NA | 3 | 47 |
| September 23, 2015 | 3453P | 147.15 | 124.39 | 0 | 124.39 | NA | 2 | 35 |
| TOTAL | | 1256.2 | 843.08 | 0 | 843.07 | NA | 20 | 24 |

Table 12. 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) |
|---|---|---|---|---|---|---|---|
| 3409P | 1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| 3411P | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| 4321P | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| 3429P | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| 3449P | 800/1000 | 30 | 50 | 200 | 30 | 130 | 5 |
| 3409P | 1000 | 30 | 50 | 200 | 30 | 130 | 5 |

## 2.4 Survey Coverage

Ipil floodplain is located along the province of Bohol with majority of the floodplain situated within the municipalities of Alicia, Bien Unido, Pilar, San Miguel, Talibon, Trinidad and Ubay. The list of municipaliti es and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Ipil floodplain is presented in Figure 10.

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

| Province | Municipality/ City | Area of Municipality/City (km²) | Total Area Surveyed (km²) | Percentage of Area Surveyed |
|---|---|---|---|---|
| BOHOL | Albuquerque | 26.84 | 9.46 | 35% |
| | Alicia | 118.35 | 84.53 | 71% |
| | Balilihan | 123.46 | 1.60 | 1% |
| | Batuan | 90.27 | 2.93 | 3% |
| | Buenavista | 107.95 | 7.50 | 7% |
| | Candijay | 94.72 | 78.68 | 83% |
| | Carmen | 221.41 | 3.05 | 1% |
| | Catigbian | 84.38 | 4.34 | 5% |
| | Duero | 74.75 | 11.07 | 15% |
| | Guindulman | 100.84 | 35.31 | 35% |
| | Inabanga | 103.67 | 19.33 | 19% |
| | Jetafe | 99.31 | 18.08 | 18% |
| | Loay | 29.63 | 11.57 | 39% |
| | Loboc | 57.40 | 41.84 | 73% |
| | Mabini | 87.74 | 87.52 | 100% |
| | Pilar | 121.42 | 24.10 | 20% |
| | Pres. Carlos P. Garcia | 48.06 | 45.09 | 94% |
| | Sevilla | 68.37 | 2.17 | 3% |
| | Sierra Bullones | 85.93 | 4.00 | 5% |
| | Sikatuna | 21.88 | 2.55 | 12% |
| | Ubay | 232.66 | 109.18 | 47% |
| Total | | 1999.04 | 603.9 | 30.21% |

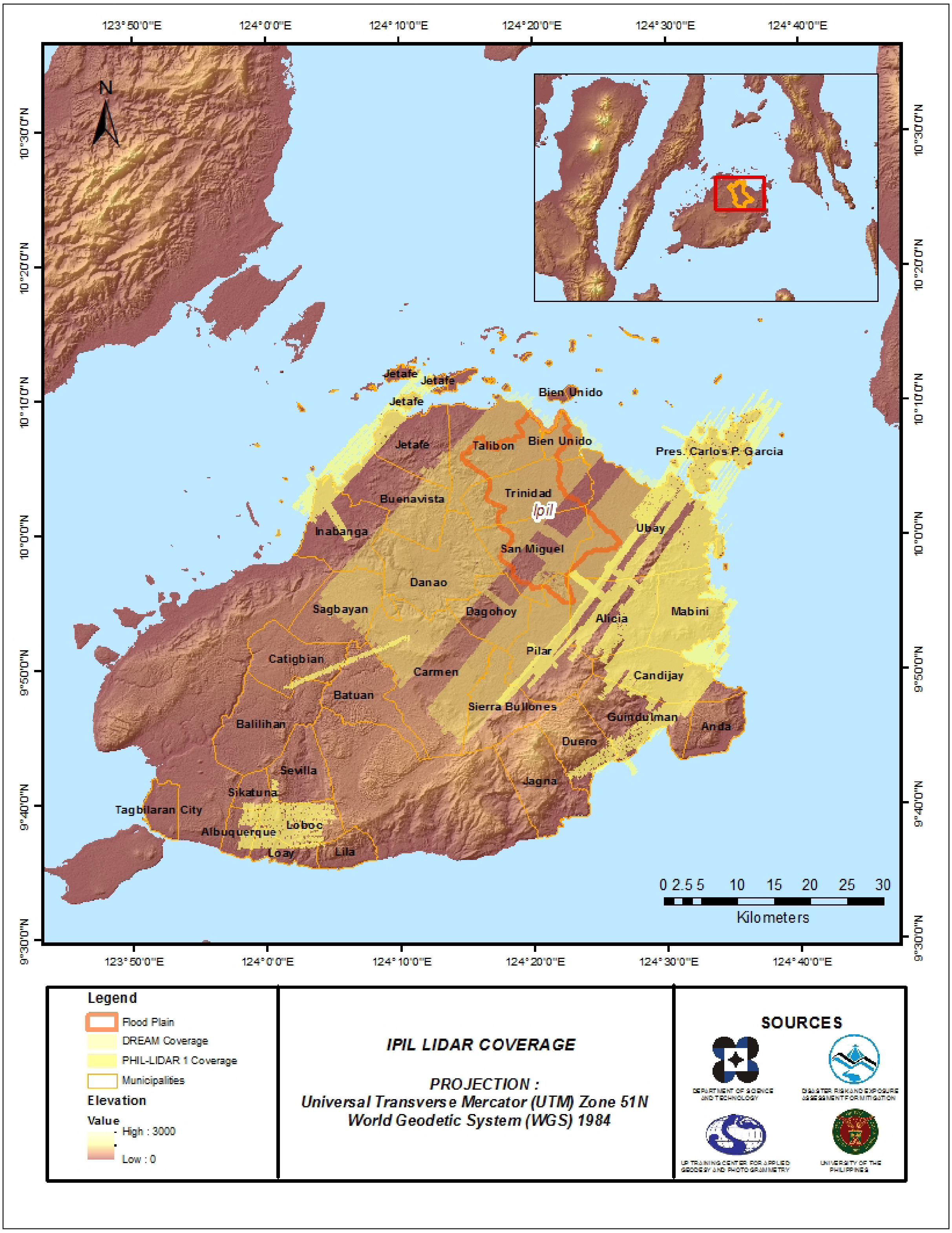



Figure 10. Actual LiDAR survey coverage for Ipil floodplain

# CHAPTER 3: LIDAR DATA PROCESSING FOR IPIL 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 LiDAR Data Processing for Ipil Floodplain

### 3.1.1 Overview of the LiDAR Date 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 11.

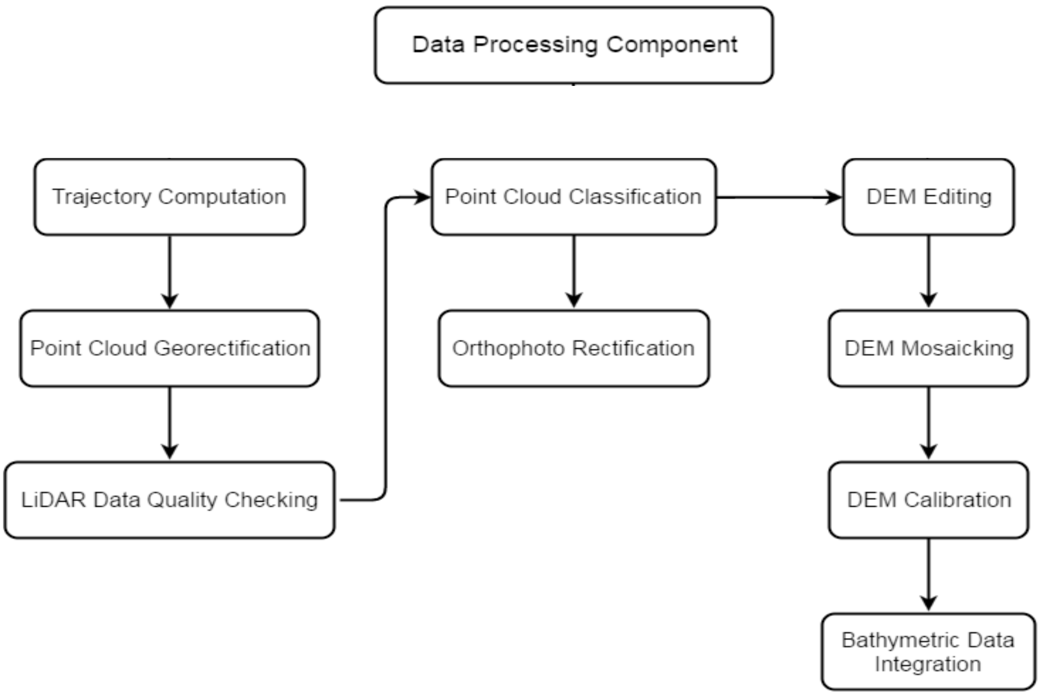



Figure 11. Schematic Diagram for Data Pre-Processing Component

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ipil floodplain can be found in **Annex 5**. Missions flown during the first survey conducted on November 2013 and second survey on September 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Bohol. The Data Acquisition Component (DAC) transferred a total of 253.49 Gigabytes of Range data, 2.46 Gigabytes of POS data and 117.86 Megabytes of GPS base station data to the data server on December 11, 2013 for the first survey and September 23, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ipil was fully transferred on October 28, 2015, as indicated on **Annex 5: Data Transfer Sheets for Ipil floodplain**.

## 3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 765P, one of the Ipil flights, which is the North, East, and Down position RMSE values are shown in Figure 12. 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 November 17, 2013 00:00AM. The y-axis is the RMSE value for that particular position.

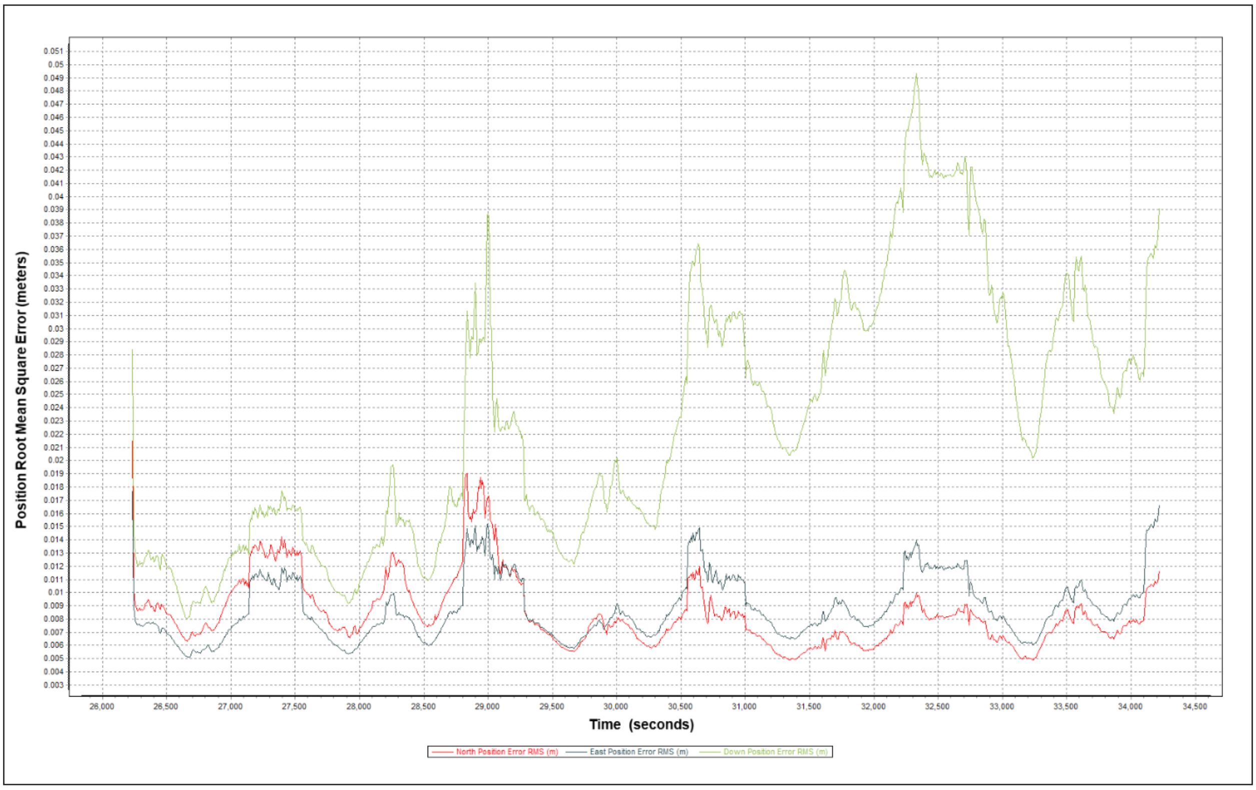



Figure 12. Smoothed Performance Metrics of an Ipil Flight 765P

The time of flight was from 26200 seconds to 34200 seconds, which corresponds to morning of November 17, 2013. 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 12 shows that the North position RMSE peaks at 1.50 centimeters, the East position RMSE peaks at 1.50 centimeters, and the Down position RMSE peaks at 4.90 centimeters, which are within the prescribed accuracies described in the methodology.

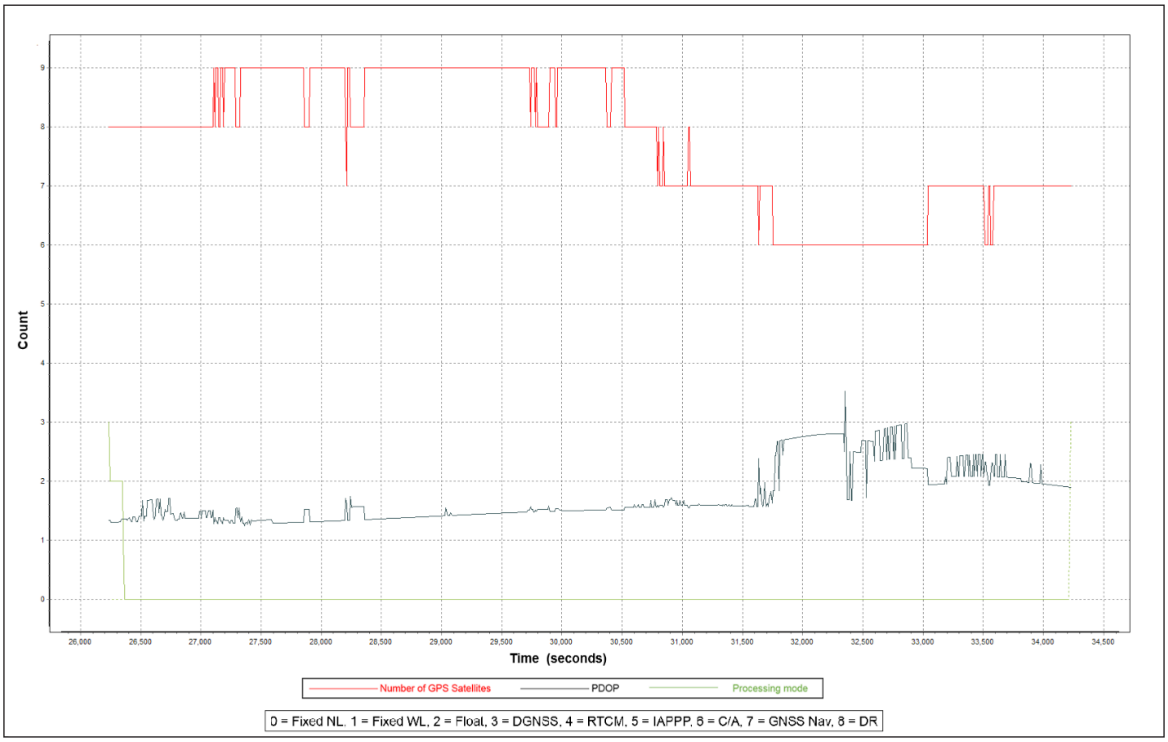



Figure 13. Solution Status Parameters of Ipil Flight 765P

The Solution Status parameters of flight 765P, one of the Ipil flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. 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 Ipil flights is shown in Figure 14.

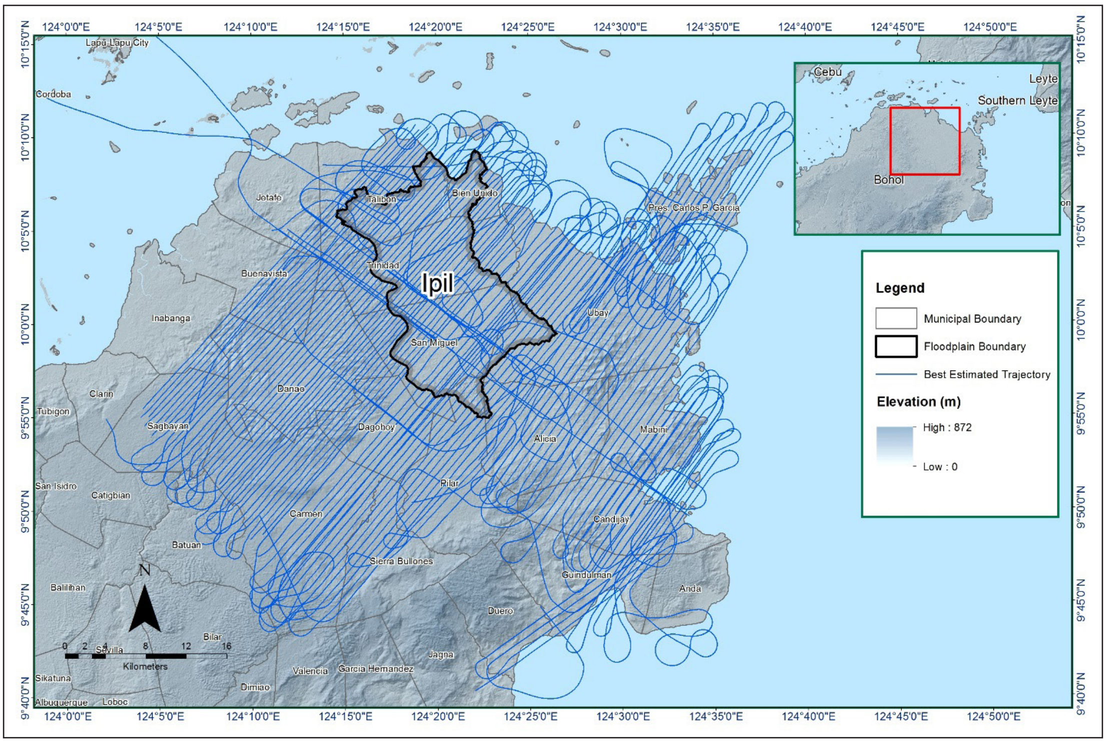



Figure 14. The best estimated trajectory of the LiDAR missions conducted over the Ipil floodplain

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 117 flight lines, with each flight line containing two channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ipil floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Ipil flights

| Parameter | | Computed Value |
|---|---|---|
| Boresight Correction stdev | (<0.001degrees) | 0.000181 |
| IMU Attitude Correction Roll and Pitch Corrections stdev | (<0.001degrees) | 0.000962 |
| GPS Position Z-correction stdev | (<0.01meters) | 0.0028 |

The optimum accuracy is obtained for all Ipil 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 B-1. Mission Summary Reports**.

## 3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Ipil Floodplain is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

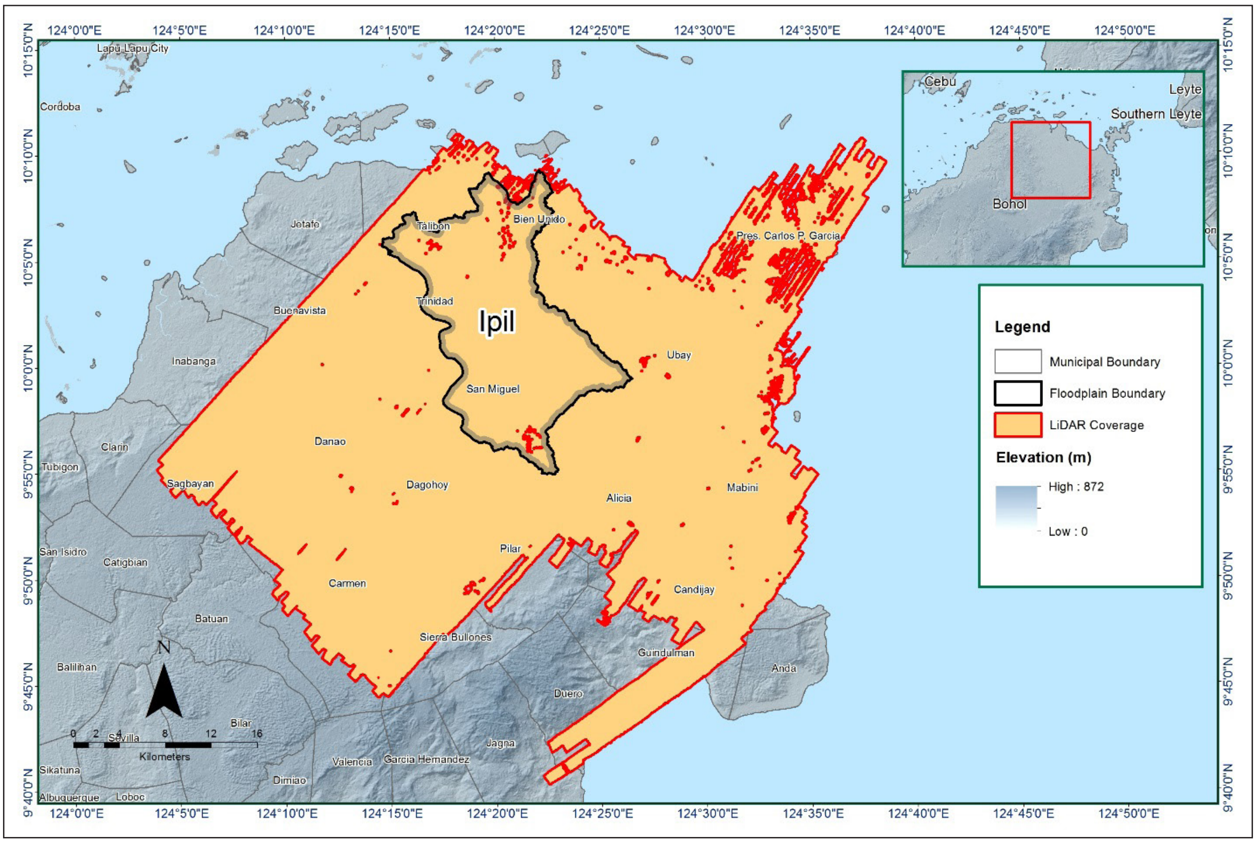



Figure 15. Boundary of the processed LiDAR data over Ipil Floodplain

The total area covered by the Ipil missions is 1,994.07 sq.km that is comprised of thirteen (13) flight acquisitions grouped and merged into twelve (12) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Ipil floodplain

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Bohol_Blk1B | 769P | 184.09 |
| Bohol_Blk1B_supplement1 | 773P | 91.00 |
| Bohol_Blk1B_supplement2 | 793P | 149.54 |
| Bohol_Blk1C | 765P | 155.48 |
| Bohol_Blk1D | 777P | 107.10 |
| | 793P | |
| Bohol_Blk1D_supplement | 805P | 248.32 |
| Bohol_Blk1E | 833P | 317.41 |
| Bohol_Blk51B | 3409P | 205.05 |
| Bohol_Blk51C | 3411P | 107.09 |
| Bohol_Blk51C_additional | 3429P | 203.43 |
| Bohol_Blk51F | 3421P | 94.64 |
| | 3453P | |
| Bohol_Blk51A | 3449P | 130.92 |
| TOTAL | | 1,994.07 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 16. 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.

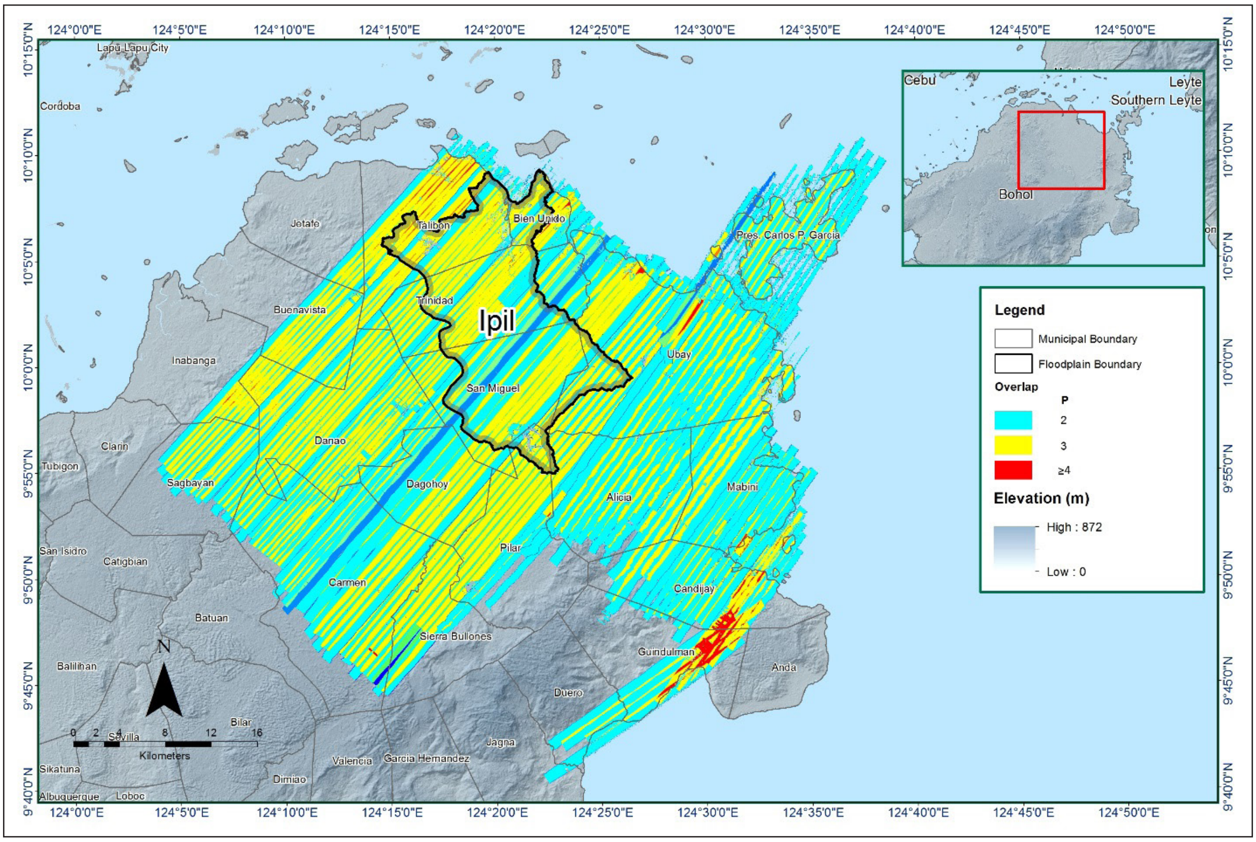



Figure 16. Image of data overlap for Ipil floodplain

The overlap statistics per block for the Ipil floodplain can be found in **Annex B-1**. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.19% and 65.08% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 17. It was determined that all LiDAR data for Ipil floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.28 points per square meter.

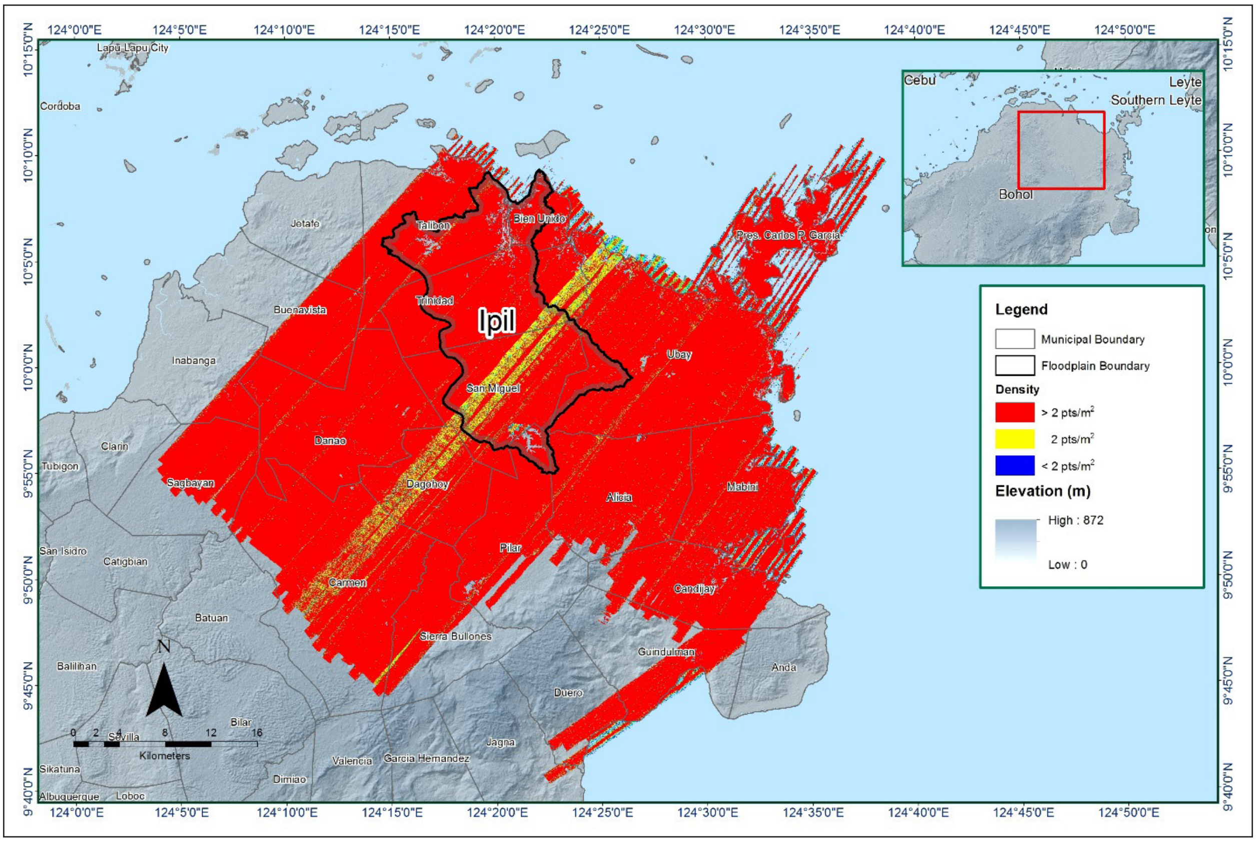



Figure 17. Pulse density map of merged LiDAR data for Ipil floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. 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.

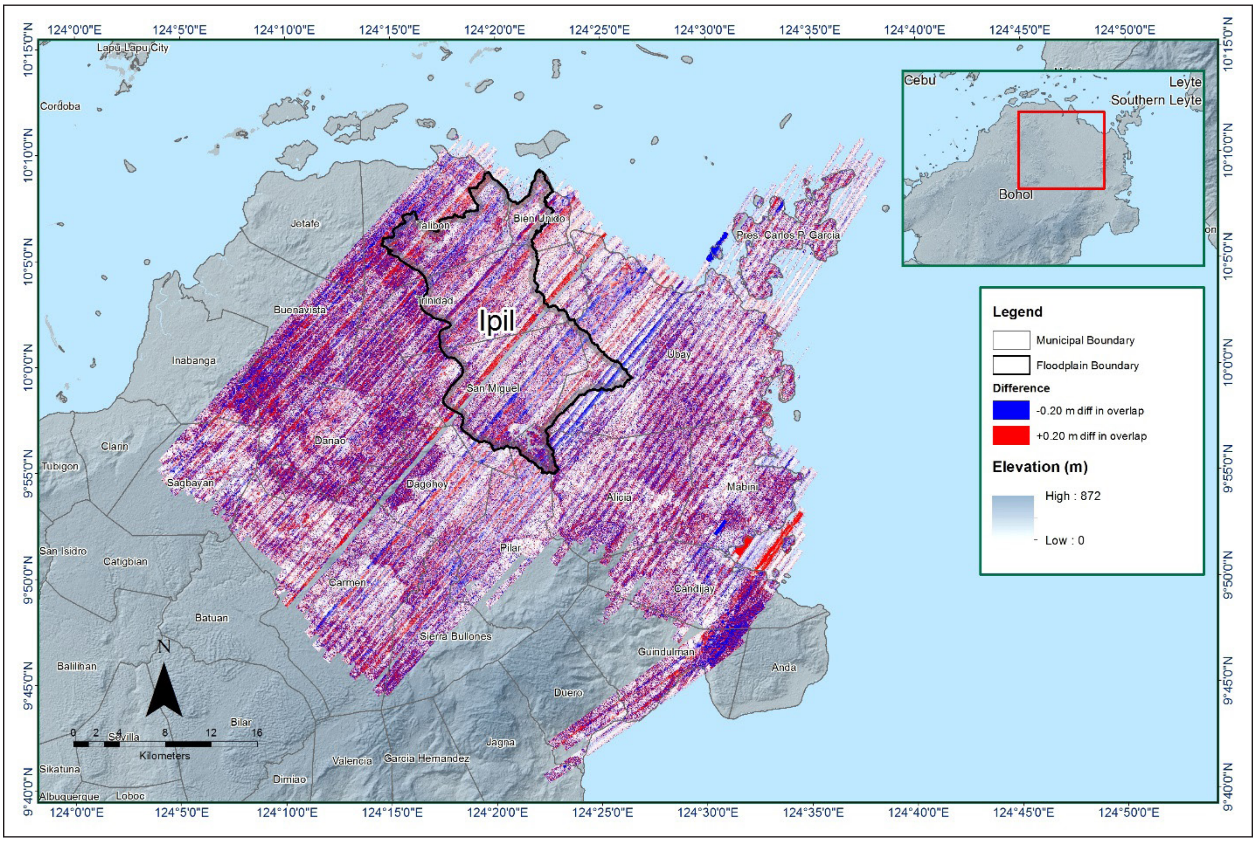



Figure 18. Elevation difference map between flight lines for Ipil floodplain

A screen capture of the processed LAS data from an Ipil flight 765P loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

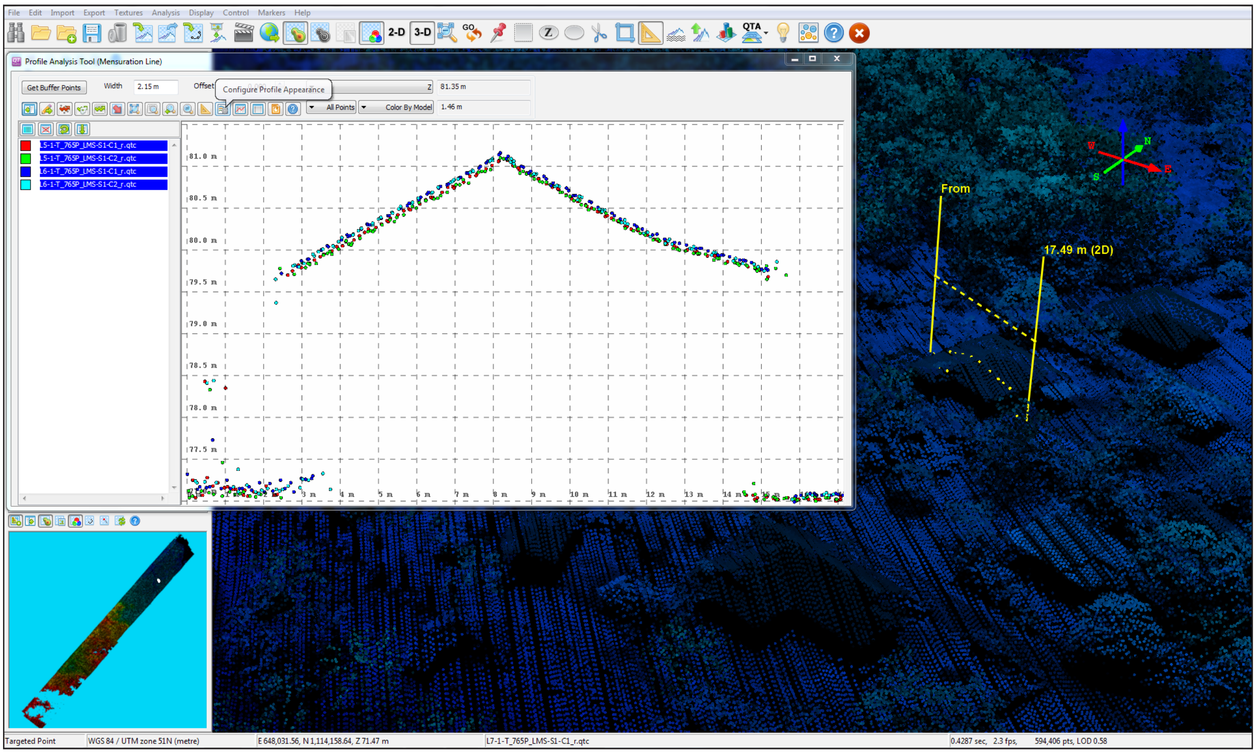



Figure 19. Quality checking for a Ipil flight 765P using the Profile Tool of QT Modeler

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Ipil classification results in TerraScan

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 1,692,438,923 |
| Low Vegetation | 1,390,686,753 |
| Medium Vegetation | 2,073,165,732 |
| High Vegetation | 1,056,021,851 |
| Building | 32,131,151 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ipil floodplain is shown in Figure 20. A total of 2,892 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 701.49 meters and 1.91 meters respectively.

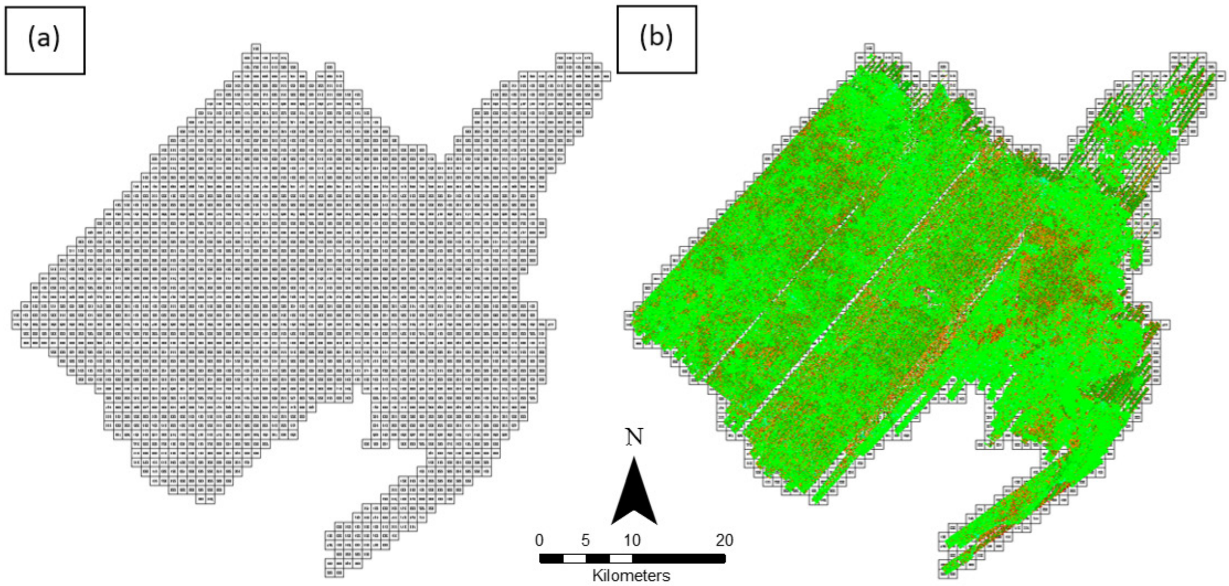



Figure 20. Tiles for Ipil floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 21. 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.

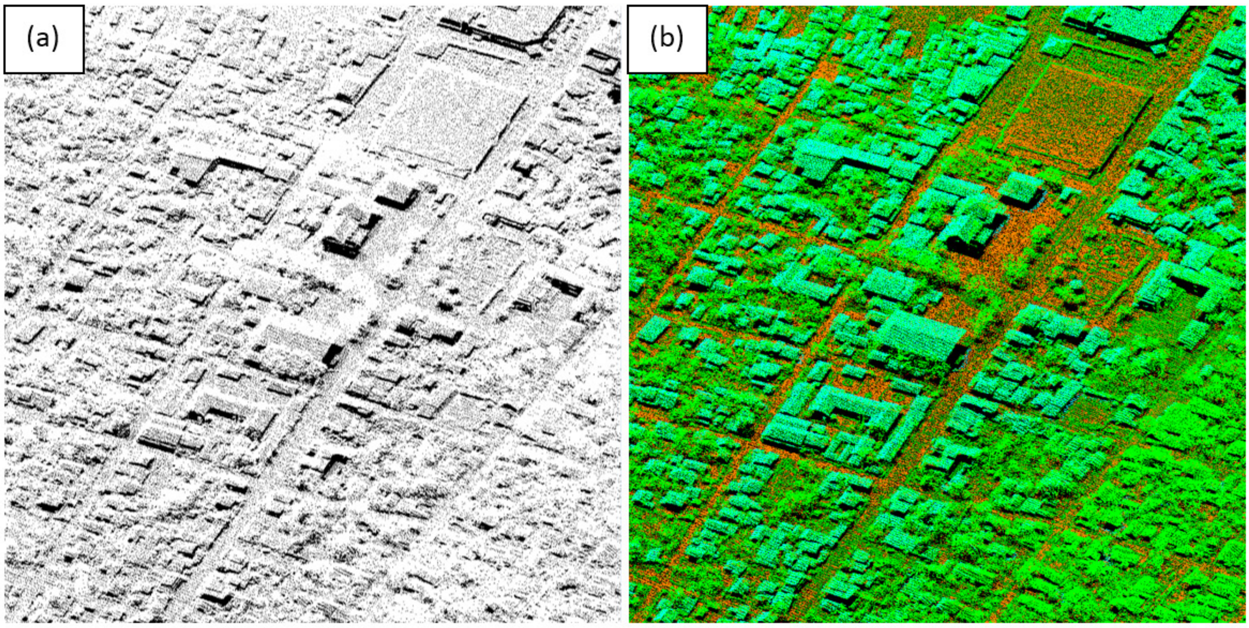



Figure 21. Point cloud before (a) and after (b) classification

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

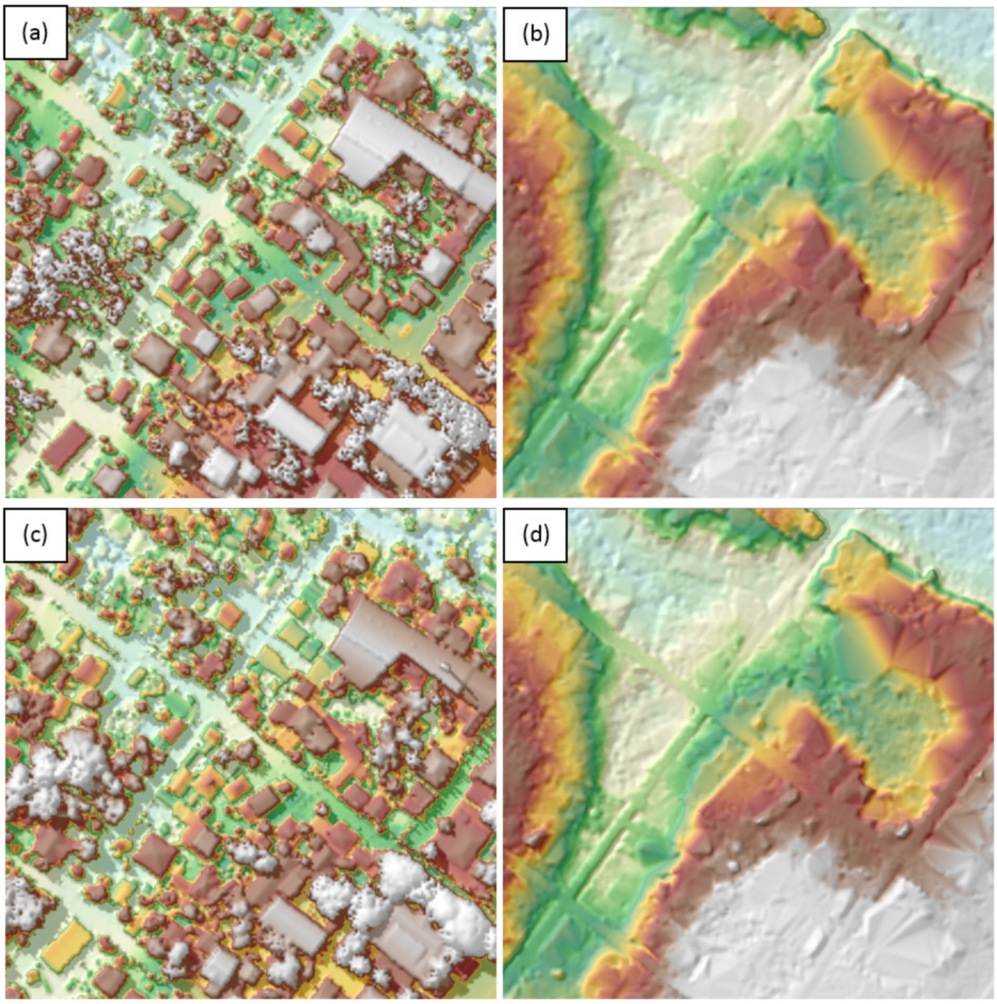



Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ipil floodplain

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Ipil floodplain.

## 3.8 DEM Editing and Hydro-Correction

Twelve (12) mission blocks were processed for Ipil flood plain. These blocks are composed of Bohol blocks with a total area of 1,994.07 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area

| LiDAR Blocks | Area (sq.km) |
|---|---|
| Bohol_Blk1B | 184.09 |
| Bohol_Blk1B_supplement1 | 91.00 |
| Bohol_Blk1B_supplement2 | 149.54 |
| Bohol_Blk1C | 155.48 |
| Bohol_Blk1D | 107.10 |
| Bohol_Blk1D_supplement | 248.32 |
| Bohol_Blk1E | 317.41 |
| Bohol_Blk51B | 205.05 |
| Bohol_Blk51C | 107.09 |
| Bohol_Blk51C_additional | 203.43 |
| Bohol_Blk51F | 94.64 |
| Bohol_Blk51A | 130.92 |
| TOTAL | 1,994.07 sq.km |

Portions of DTM before and after manual editing are shown in Figure 23. The mountain (Figure 23a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23b). Another, the bridge (Figure 23c) is also considered to be impedance to the flow of water along the river and has to be removed (Figure 23d) in order to hydrologically correct the river. These are shown in the figure below.

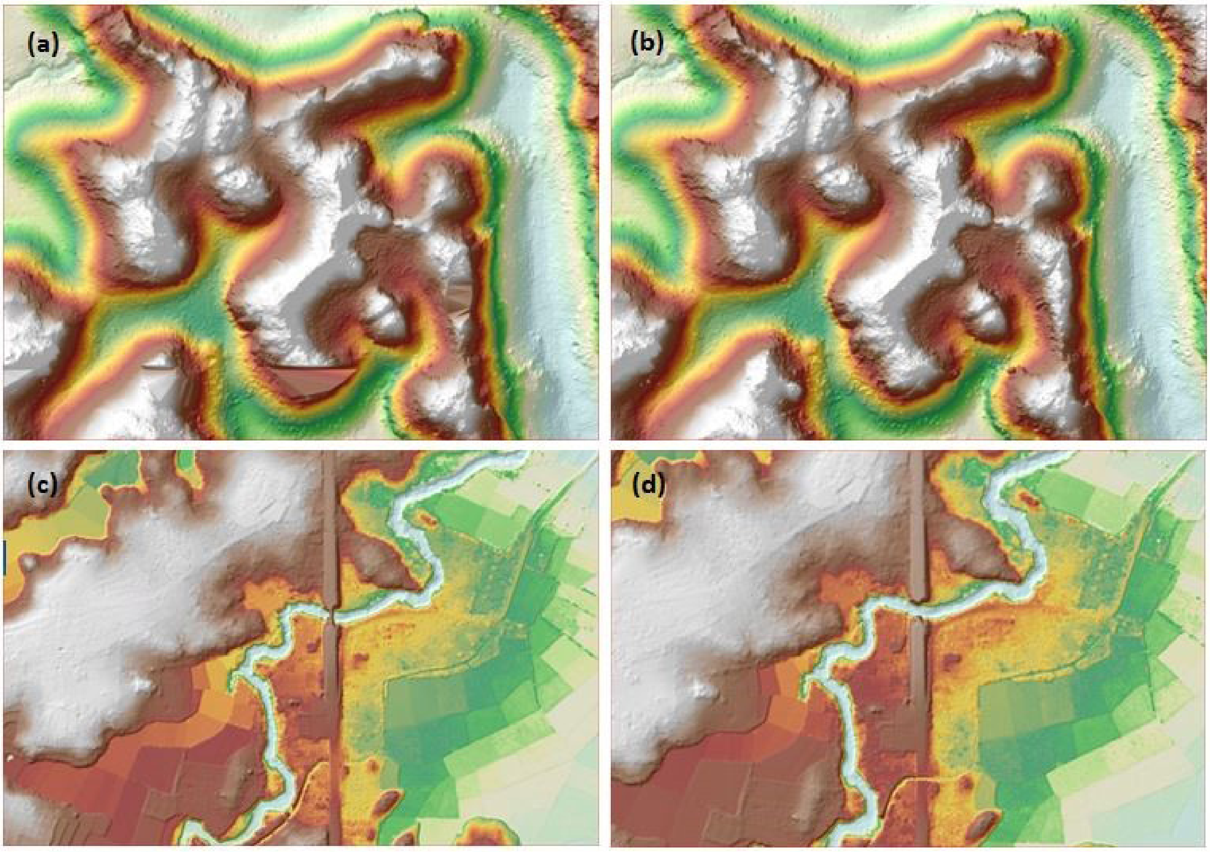



Figure 23. Portions in the DTM of Ipil floodplain – a mountain before (a) and (b) after data retrieval; and a bridge before (c) before and after (d) manual editing

## 3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Bohol DEM overlapping with the blocks to be mosaicked. Table 18 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Ipil floodplain is shown in Figure 24. It can be seen that the entire Ipil floodplain is 100% covered by LiDAR data.

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

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| Bohol_Blk1B | 0.00 | 0.00 | -0.40 |
| Bohol_Blk1B_supplement1 | 0.00 | 0.00 | +0.07 |
| Bohol_Blk1B_supplement2 | 0.00 | 0.00 | -5.62 |
| Bohol_Blk1C | 0.00 | 0.00 | -0.40 |
| Bohol_Blk1D | 0.00 | 0.00 | 0.00 |
| Bohol_Blk1D_supplement | 0.00 | 0.00 | -0.36 |
| Bohol_Blk1E | 0.00 | 0.00 | -0.51 |
| Bohol_Blk51B | 0.00 | 0.00 | -0.35 |
| Bohol_Blk51C | 0.00 | 0.00 | -3.61 |
| Bohol_Blk51C_additional | 0.00 | 0.00 | -3.48 |
| Bohol_Blk51F | 1.00 | -3.00 | -4.03 |
| Bohol_Blk51A_ | 0.00 | 0.00 | -3.77 |

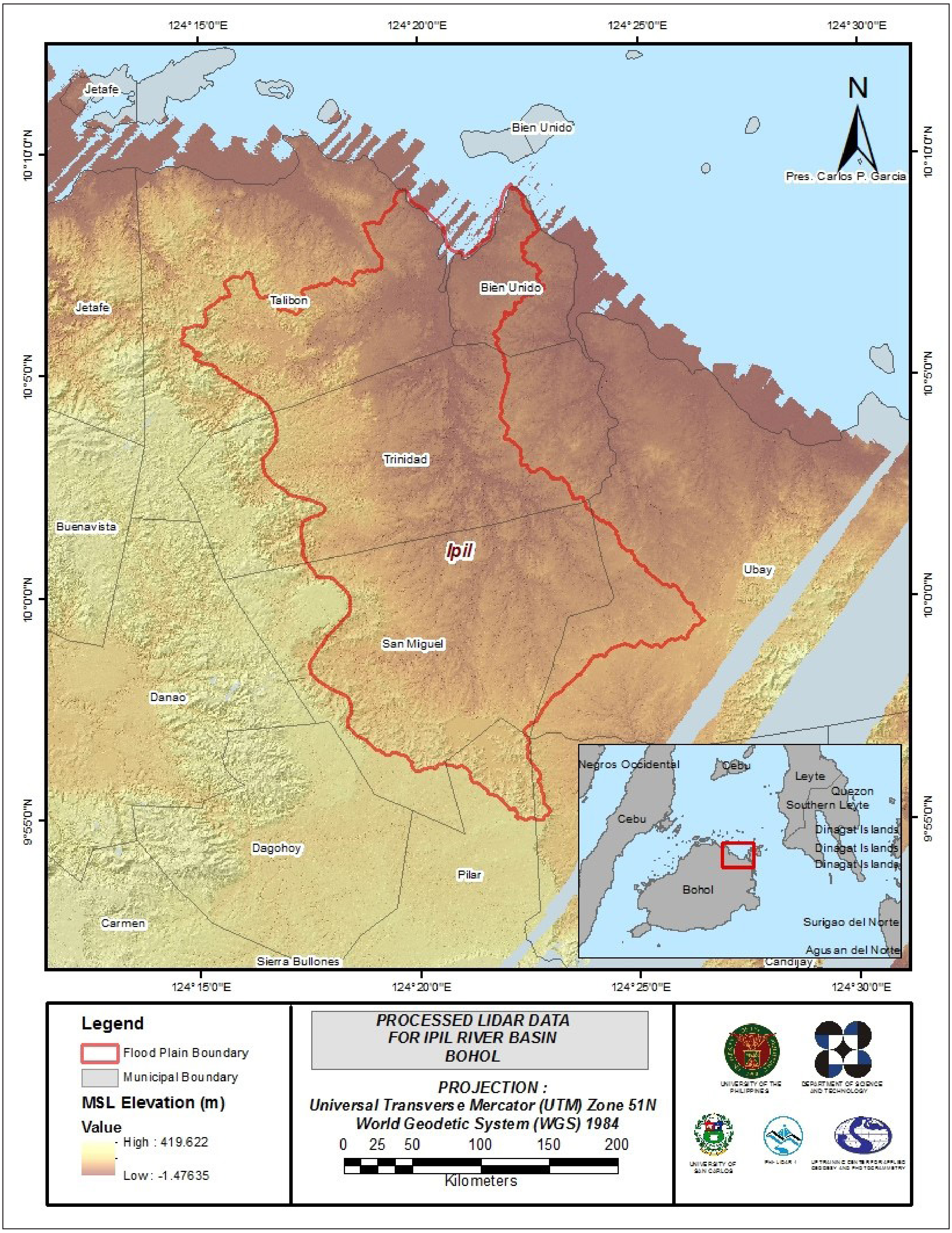



Figure 24. Map of Processed LiDAR Data for Ipil Flood Plain

## 3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ipil to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 1448 survey points were gathered for calibration and validation of Ipil LiDAR data. However, the point dataset was not used for the calibration of the LiDAR data for Ipil because during the mosaicking process, each LiDAR block was referred to the calibrated Bohol DEM. Therefore, the mosaicked DEM of Ipil can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Bohol LiDAR DTM and ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 1.29 meters with a standard deviation of 0.19 meters. Calibration of Bohol LiDAR data was done by subtracting the height difference value, 1.29 meters, to Bohol mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between Bohol LiDAR data and calibration data. These values were also applicable to the Ipil DEM.

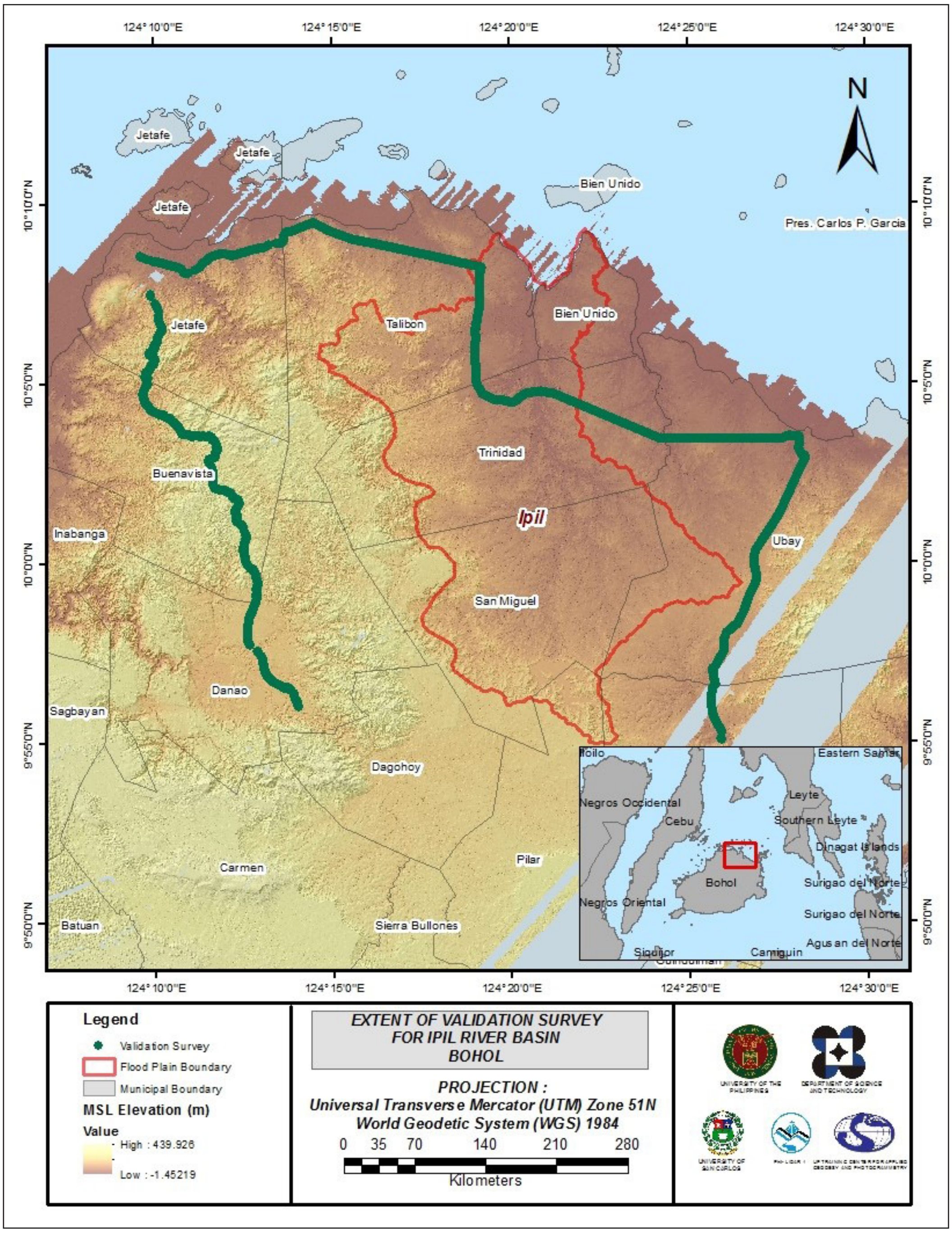



Figure 25. Map of Ipil Flood Plain with validation survey points in green

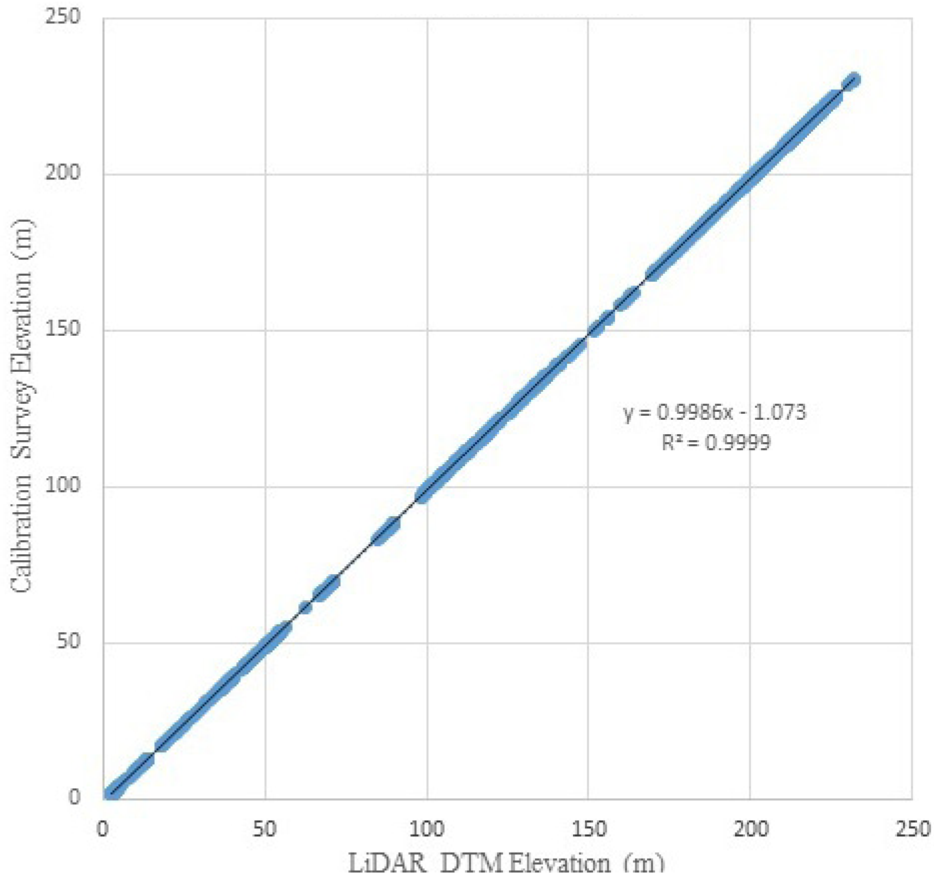



Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 19. Calibration Statistical Measures

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 1.29 |
| Standard Deviation | 0.19 |
| Average | -1.28 |
| Minimum | -1.65 |
| Maximum | -0.86 |

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

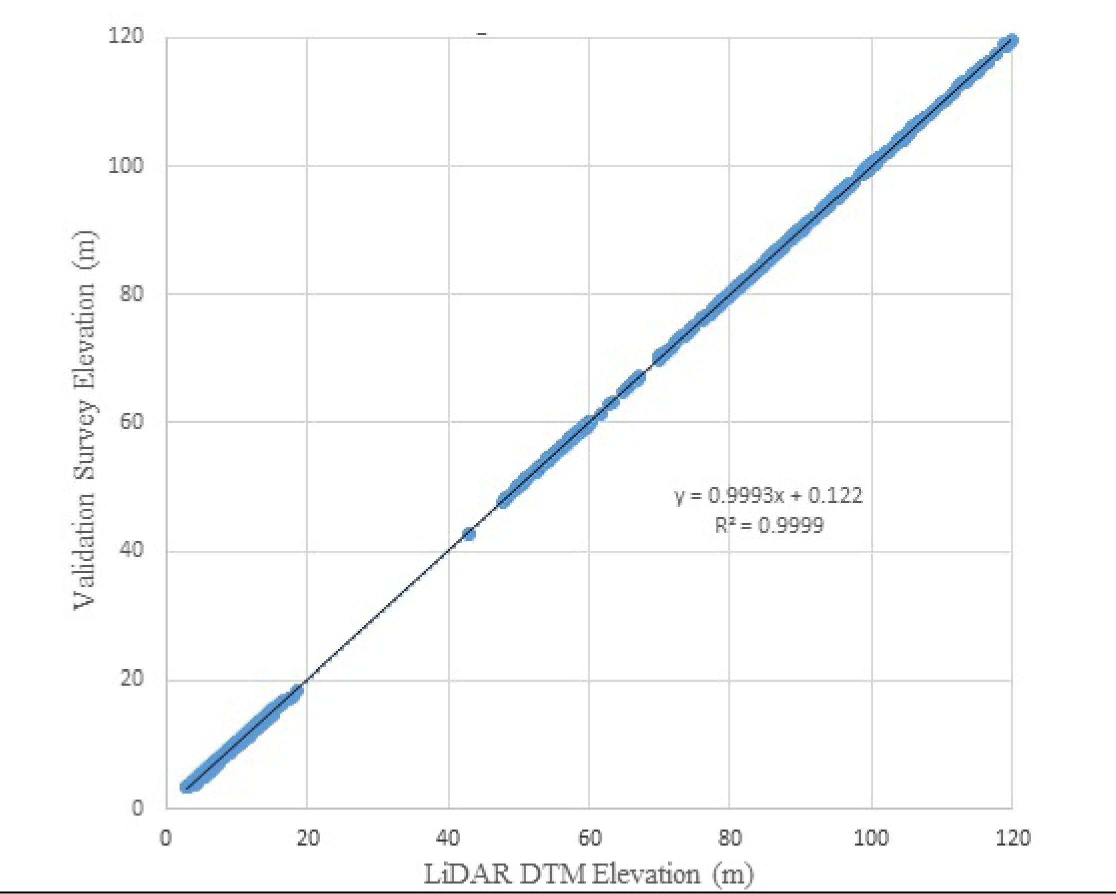



Figure 27. Correlation plot between validation survey points and LiDAR data

Table 20. Validation Statistical Measures

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.20 |
| Standard Deviation | 0.18 |
| Average | 0.08 |
| Minimum | -0.39 |
| Maximum | 0.40 |

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

For bathy integration, centerline and zigzag data were available for Ipil with 13,300 bathymetric survey points. The resulting raster surface produced was done by Krigging interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.58 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ipil integrated with the processed LiDAR DEM is shown in Figure 28.

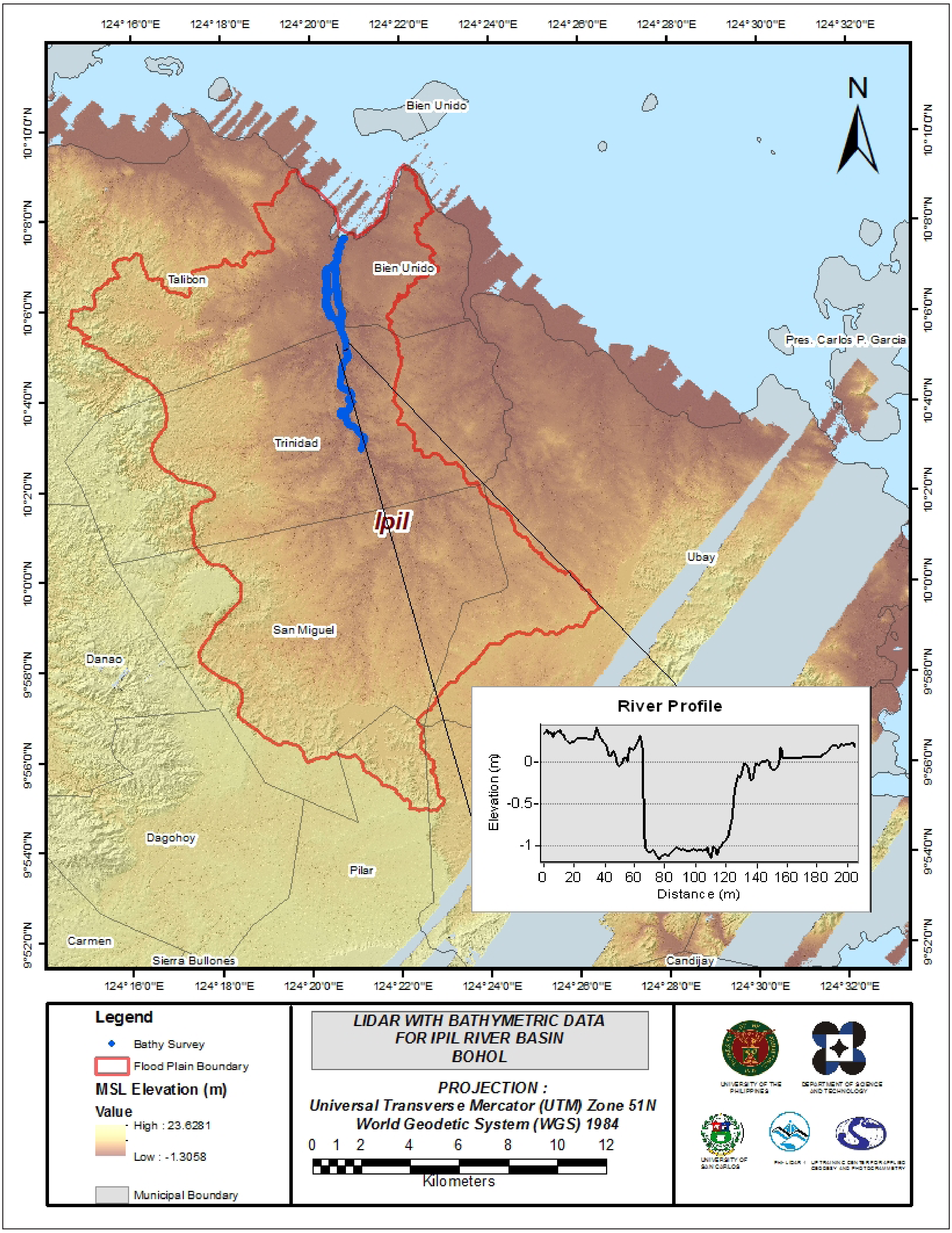



Figure 28. Map of Ipil Flood Plain with bathymetric survey points shown in blue

## 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

Ipil floodplain, including its 200 m buffer, has a total area of 270.51 sq km. For this area, a total of 8.0 sq km, corresponding to a total of 1210 building features, are considered for QC. Figure 29 shows the QC blocks for Ipil floodplain.

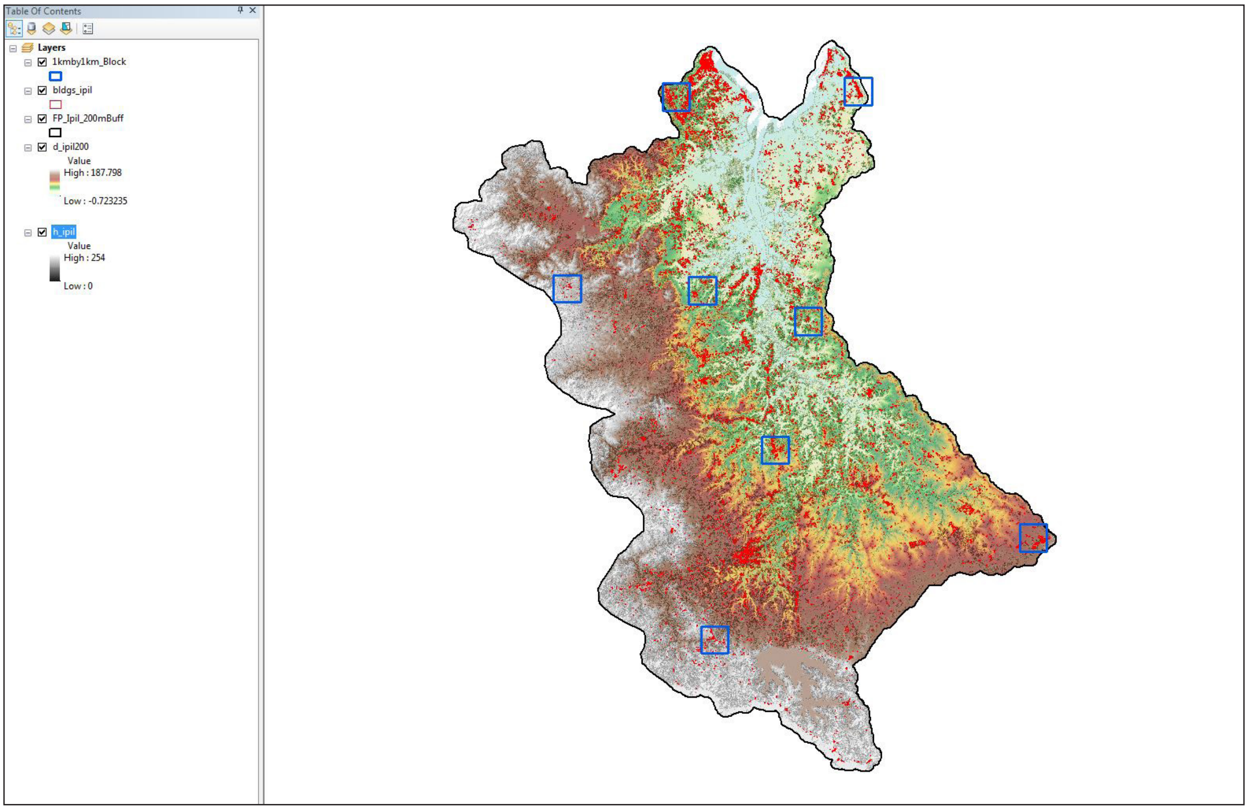



Figure 29. Blocks (in blue) of Ipil building features that were subjected to QC

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

Table 21. Quality Checking Ratings for Ipil Building Features

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Ipil | 99.91 | 100.00 | 84.79 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 26,511 building features in Ipil floodplain. Of these building features, 2,510 were filtered out after height extraction, resulting to 24,001 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 13.63 m.

### 3.12.3 Feature Attribution

In attribution, combination of participatory mapping and actual field validation was done. Representatives from LGU were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

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

Table 22. Building Features Extracted for Ipil Floodplain

| Facility Type | No. of Features |
|---|---|
| Residential | 23,570 |
| School | 196 |
| Market | 28 |
| Agricultural/Agro-Industrial Facilities | 47 |
| Medical Institutions | 10 |
| Barangay Hall | 20 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 16 |
| Telecommunication Facilities | 0 |
| Transport Terminal | 4 |
| Warehouse | 1 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 4 |
| Police Station | 3 |
| Water Supply/Sewerage | 0 |
| Religious Institutions | 20 |
| Bank | 0 |
| Factory | 4 |
| Gas Station | 6 |
| Fire Station | 0 |
| Other Government Offices | 15 |
| Other Commercial Establishments | 57 |
| Total | 24,001 |

Table 23. Total Length of Extracted Roads for Ipil Floodplain

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/Municipal Road | Provincial Road | National Road | Others | |
| Ipil | 409.37 | 0 | 70.04 | 31.61 | 0 | 511.02 |

Table 24. Number of Extracted Water Bodies for Ipil Floodplain

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Ipil | 6 | 1 | 0 | 1 | 0 | 8 |

A total of 36 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 30 shows the Digital Surface Model (DSM) of Ipil floodplain overlaid with its ground features.

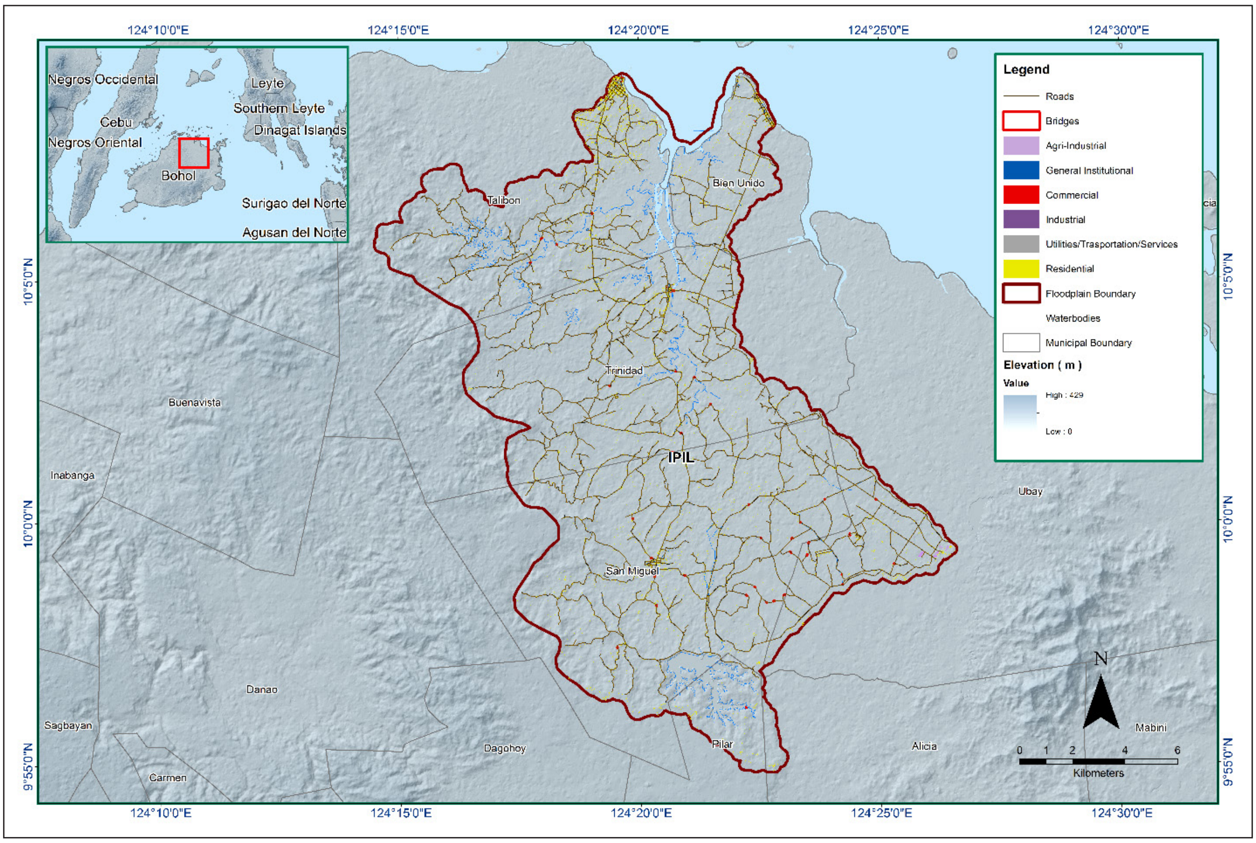



Figure 30. Extracted features for Ipil floodplain

# CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE IPIL 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

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Ipil River on September 2-10, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Tugas Bridge in Brgy.Hinlayagan Ilaud and Trinidad Bridge in Brgy. Poblacion, Trinidad, Bohol; validation points acquisition of about 89 km covering the Ipil River Basin area; and bathymetric survey from its upstream in Brgy. Hinlayagan Ilaud, Municipality of Trinidad to the mouth of the river located in Brgy. Balintawak, in the Municipality of Bien Unidos, with an approximate length of 13.739 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 31).

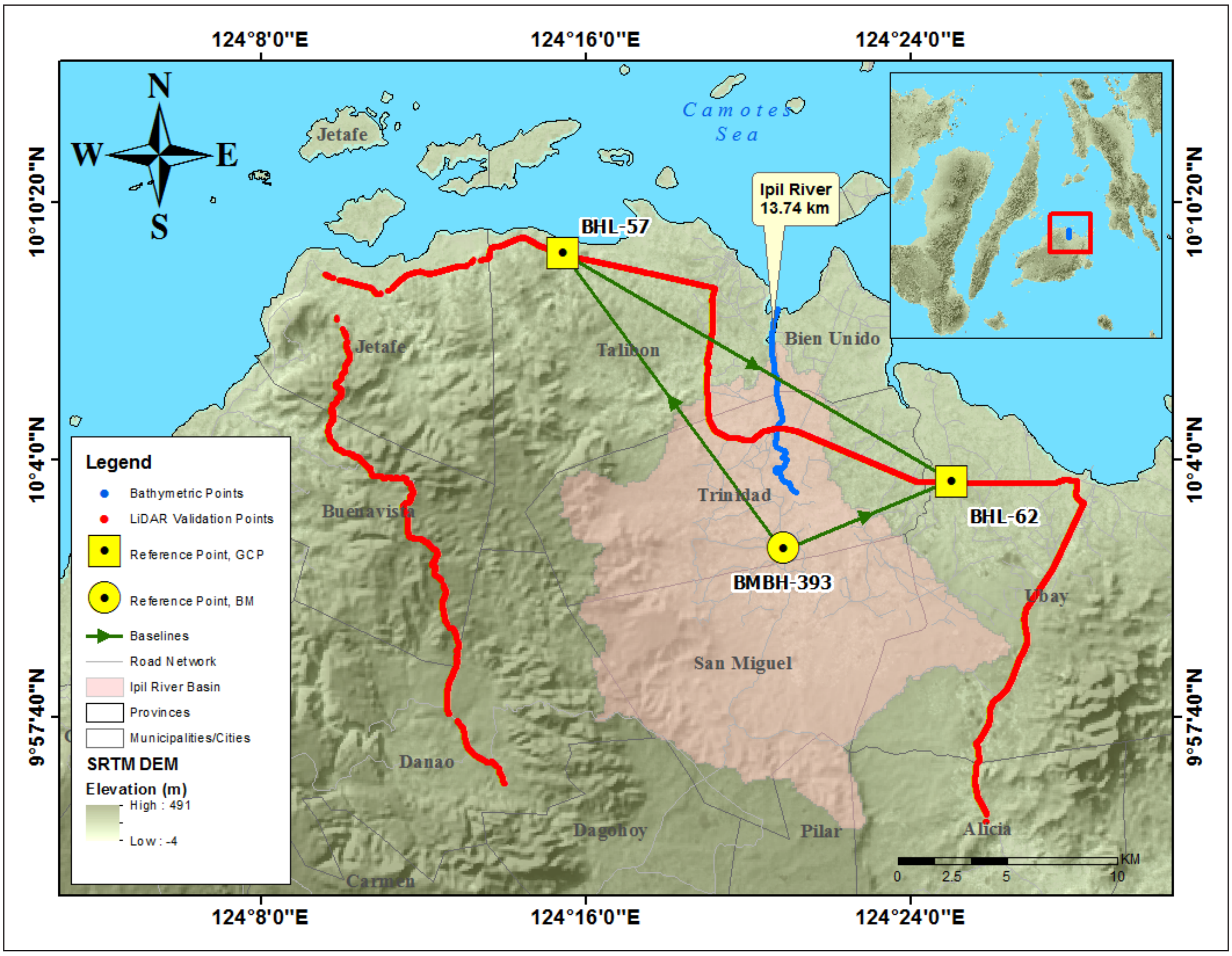



Figure 31. Extent of the bathymetric survey (in blue) in Ipil River and the LiDAR data validation survey (in red)

## 4.2 Control Survey

The GNSS network used for Ipil River Basin is composed of a single loop established on September 3, 2016 occupying the following reference points: BHL-57, a second-order GCP in Brgy. Tanghaligue, Municipality of Talibon; BHL-62, a second-oder GCP in Brgy. Humayhumay, Municipality of Ubay; and BH-393, a first-order BM at Hinlayagan Bridge, Brgy. Hinlayagan Ilaya, Municipality of Trinidad.

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

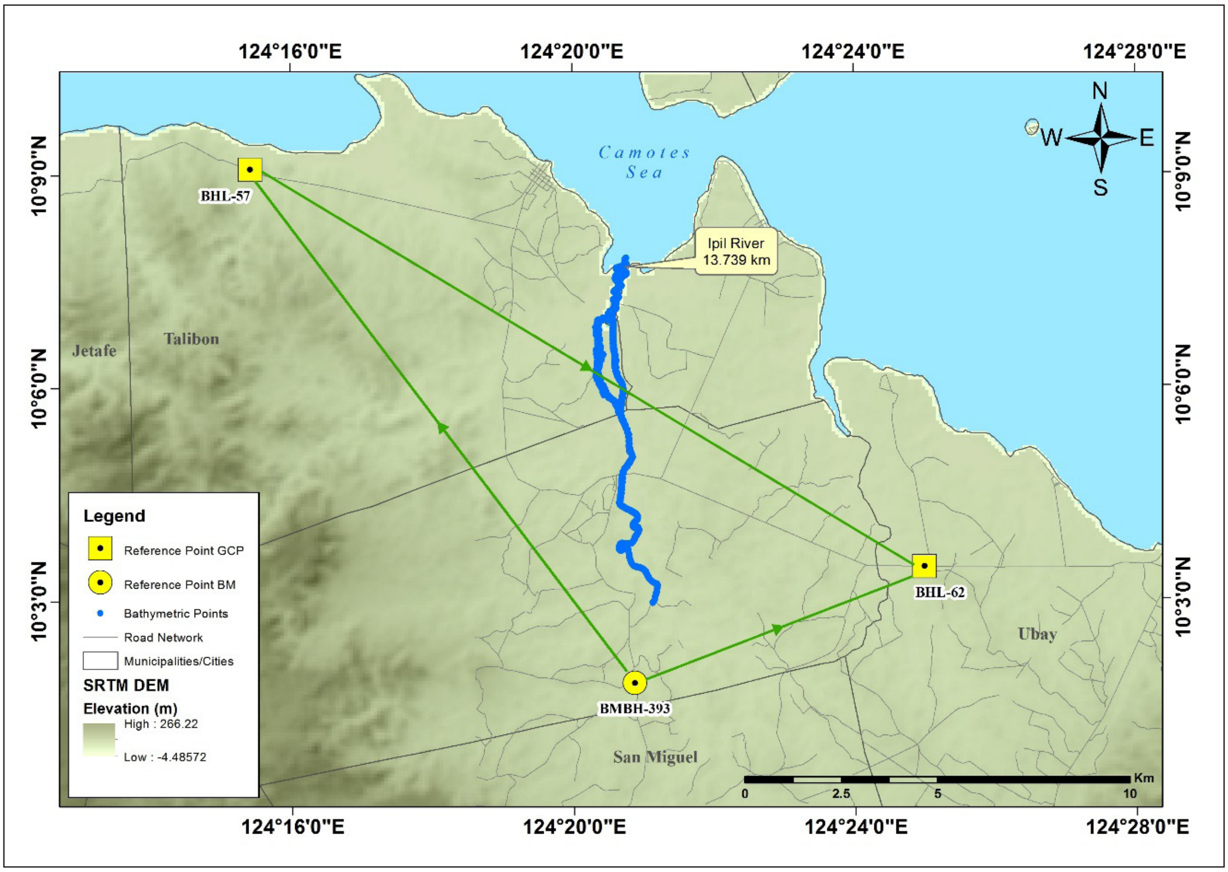



Figure 32. GNSS Network covering Ipil River

Table 25. List of Reference and Control Points occupied for Ipil River Survey

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | BM Ortho (m) | Date Established |
| BHL-57 | 2nd order, GCP | 10°09’04.81120”N | 124°15’25.59670”E | 77.040 | - | 2013 |
| BHL-62 | 2nd order, GCP | 10°03’27.40372”N | 124°24’59.17305”E | 72.344 | - | 2013 |
| BH-393 | 1st order, BM | - | - | - | 10.781 | 2016 |

The GNSS set-ups on recovered reference points and established control points in Ipil River are shown in Figure 33 to Figure 35.


Figure 33. GNSS base set up, Trimble® SPS 882, at BHL-57 located along Ubay-Talibon Road, Brgy. Tanghaligue, Municipality of Talibon, Bohol


Figure 34. NSS receiver setup, Trimble® SPS 882, at BHL-62 located along Ubay-Talibon Road, Brgy. Humayhumay, Municipality of Ubay, Bohol


Figure 35. GNSS receiver setup, Trimble® SPS 852, at BH-393 located at the approach of Hinlayagan Bridge, Brgy. Hinlayagan Ilaya, Municipality of Trinidad, Bohol

## 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 Ipil River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline Processing Summary Report for Ipil River Survey

| Observation | Date of Observation | Solution Type | H.Prec. (Meter) | V.Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | Height (Meter) |
|---|---|---|---|---|---|---|---|
| BMBH-393 --- BHL-57 (B3) | 09-03-2016 | Fixed | 0.004 | 0.020 | 323°23’48” | 16654.717 | 1.627 |
| BMBH-393 --- BHL-62 (B2) | 09-03-2016 | Fixed | 0.004 | 0.018 | 68°15’50” | 8108.333 | -3.073 |
| BHL-57 --- BHL-62 (B1) | 09-03-2016 | Fixed | 0.004 | 0.018 | 120°40’53” | 20308.187 | -4.683 |

As shown Table 26 a total of three (3) baselines were processed with reference points BHL-57 and BHL-62 held fixed for coordinate value; and BH-393 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:

$$z_e < 10\ cm<20cm \text{ and } z_e < 10\ cm$$

Where:

*xe* is the Easting error,

*ye* is the Northing error, and

*ze* is the Elevation error

for each control point. See the Network Adjustment Report shown in Table 27 to Table 30 for complete details.

The three (3) control points, BHL-57, BHL-62, and BH-393 were occupied and observed simultaneously to form a GNSS loop. Coordinates of BHL-57 and BHL-62; and elevation value of BH-393 were held fixed during the processing of the control points as presented in Table 29. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 27.Control Point Constraints

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| BHL-57 | Local | Fixed | Fixed | | |
| BHL-62 | Local | Fixed | Fixed | | |
| BMBH-393 | Grid | | | | Fixed |
| Fixed = 0.000001 (Meter) | | | | | |

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 28. The fixed controls BHL-57 and BHL-62 have no values for grid error elevation error.

Table 28. Adjusted Grid Coordinates

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| BHL-57 | 637719.837 | ? | 1122411.173 | ? | 12.562 | 0.029 | LL |
| BHL-62 | 655222.653 | ? | 1112117.428 | ? | 7.569 | 0.028 | LL |
| BMBH-393 | 647704.108 | 0.004 | 1109084.107 | 0.004 | 10.781 | ? | e |

With the mentioned equation,  for horizontal and  for the vertical; the computation for the accuracy are as follows:

a. **BHL-57**

horizontal accuracy = Fixed

vertical accuracy = 2.9 cm < 10 cm

**b. BHL-62**

horizontal accuracy = Fixed

vertical accuracy = 2.8 cm < 10 cm

**c. BH-393**

horizontal accuracy = $\sqrt{((0.4)^2 + (0.4)^2}$

= $\sqrt{(0.16 + 0.16)}$

= 0.32 < 20 cm

vertical accuracy = Fixed

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

Table 29. Adjusted Geodetic Coordinates

| Point ID | Latitude | Longitude | Ellipsoidal Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| BHL-57 | N10°09'04.81120" | E124°15'25.59670" | 77.040 | 0.029 | LL |
| BHL-62 | N10°03'27.40372" | E124°24'59.17305" | 72.344 | 0.028 | LL |
| BMBH-393 | N10°01'49.69638" | E124°20'51.82322" | 75.412 | ? | e |

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

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

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

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | UTM ZONE 51 N | | |
|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | Northing | Easting | BM Ortho (m) |
| BHL-57 | 2nd order, GCP | 10°09'04.81120"N | 124°15'25.59670"E | 77.040 | 1122411.173 | 637719.837 | 12.562 |
| BHL-62 | 2nd order, GCP | 10°03'27.40372"N | 124°24'59.17305"E | 72.344 | 1112117.428 | 655222.653 | 7.569 |
| BH-393 | 1st order, BM | 10°01'49.69638"N | 124°20'51.82322"E | 75.412 | 1109084.107 | 647704.108 | 10.781 |

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

Cross-section and as-built survey were conducted on September 4, 2016 at the downstream side of Tugas Bridge in Brgy. Hinlayagan Ilaud, Municipality of Trinidad, Bohol, and Trinidad Bridge in Brgy. Poblacion, Municipality of Trinidad, Bohol as shown in Figure 36 and Figure 38. A Trimble® SPS 882 and Trimble® SPS 885 GNSS PPK survey technique were utilized for this survey as shown in Figure 37 and Figure 39.

Figure 36. Tugas Bridge facing upstream


Figure 37. Bridge As-Built Survey using PPK Technique in Tugas Bridge

Figure 38. Trinidad Bridge facing downstream


Figure 39. Bridge As-Built Survey using PPK Technique in Trinidad Bridge

The cross-sectional line of Tugas Bridge is about 49.733 m with nineteen (19) cross-sectional points using the control point BHL-57 as the GNSS base station; while the cross-sectional line of Trinidad Bridge is about 110.151 m with seventy-nine (79) cross-sectional points using the control point BH-393 as the GNSS base station. The cross-section diagrams and their location maps are shown in Figure 40 to Figure 43, while its bridge data forms are shown in Figure 44 and Figure 45, respectively.

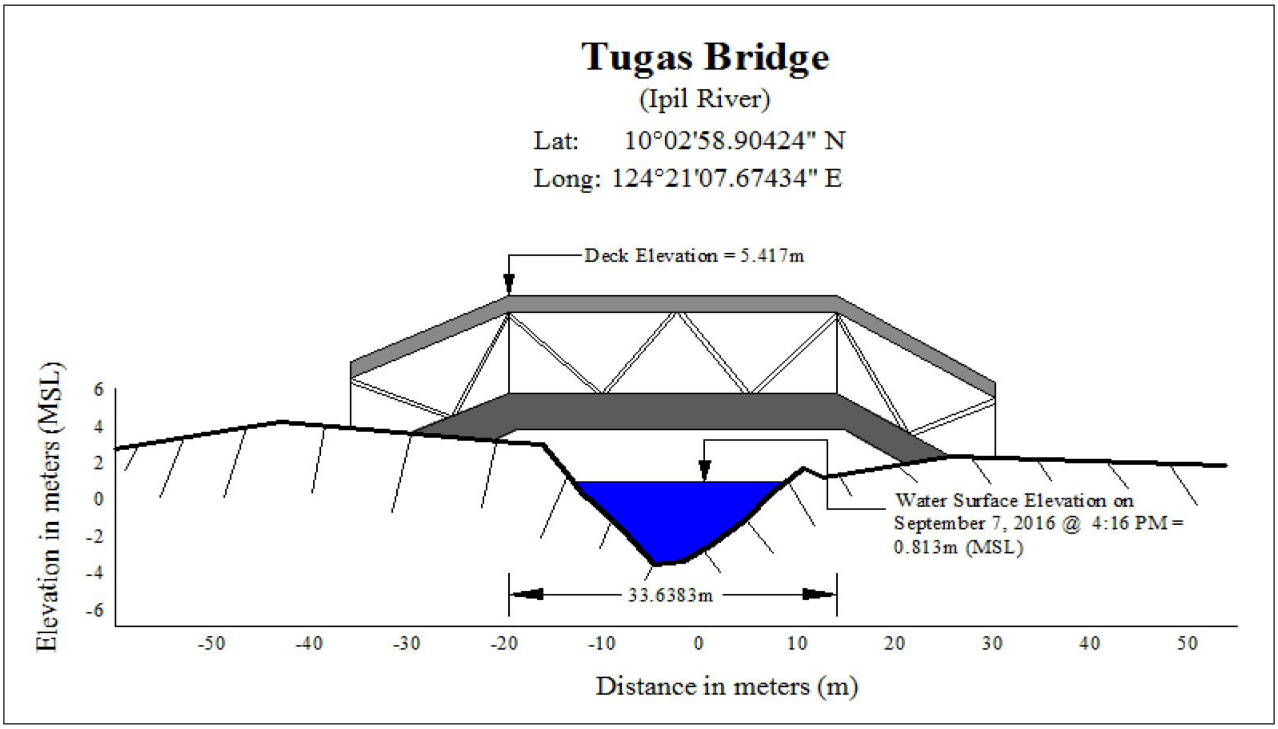



Figure 40. Tugas Bridge cross-section diagram

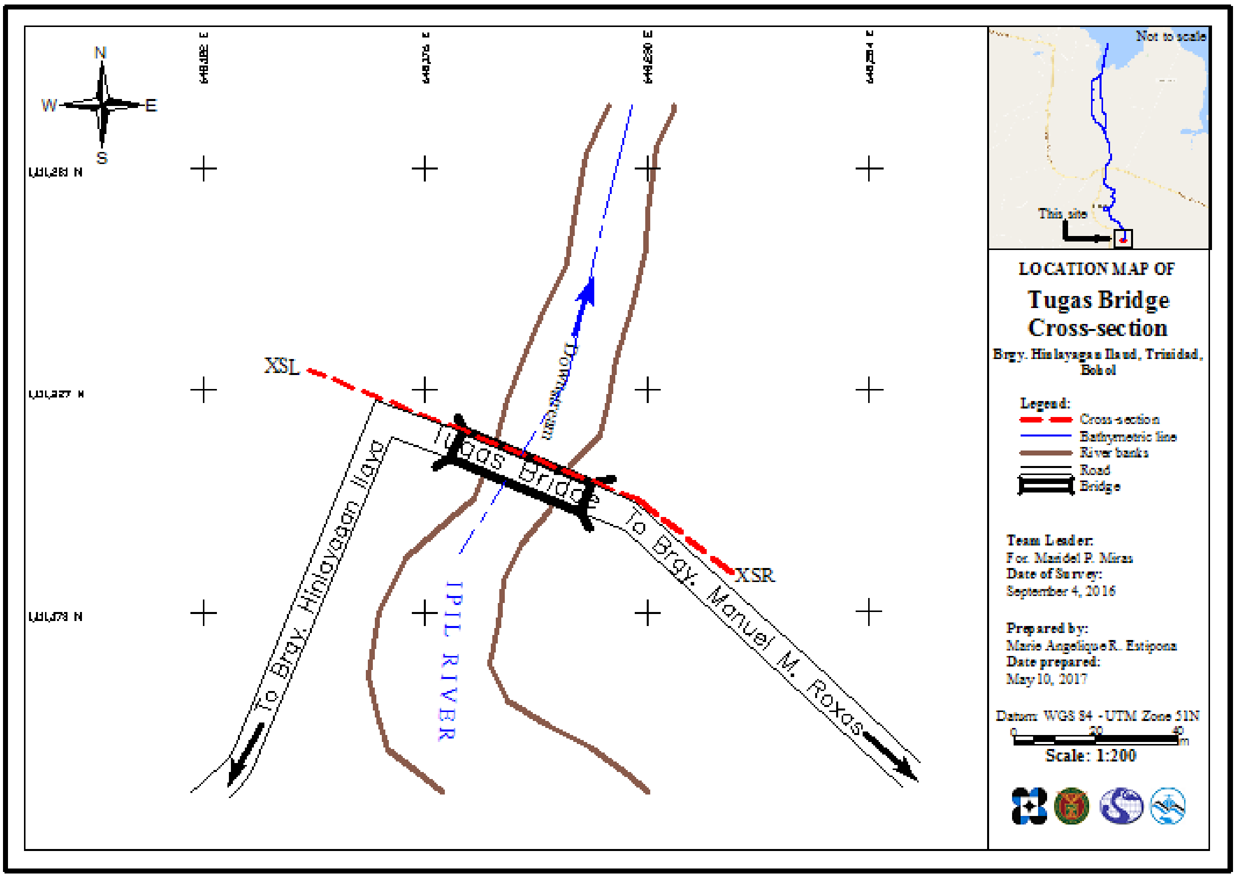



Figure 41. Tugas bridge cross-section location map

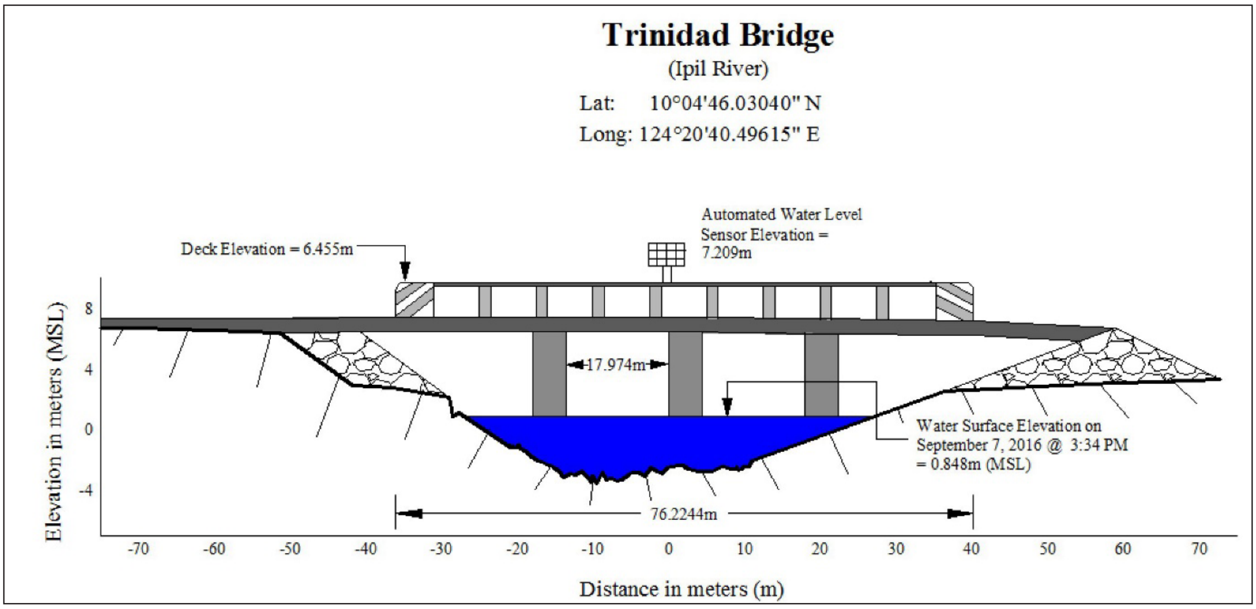



Figure 42. Trinidad Bridge cross-section diagram

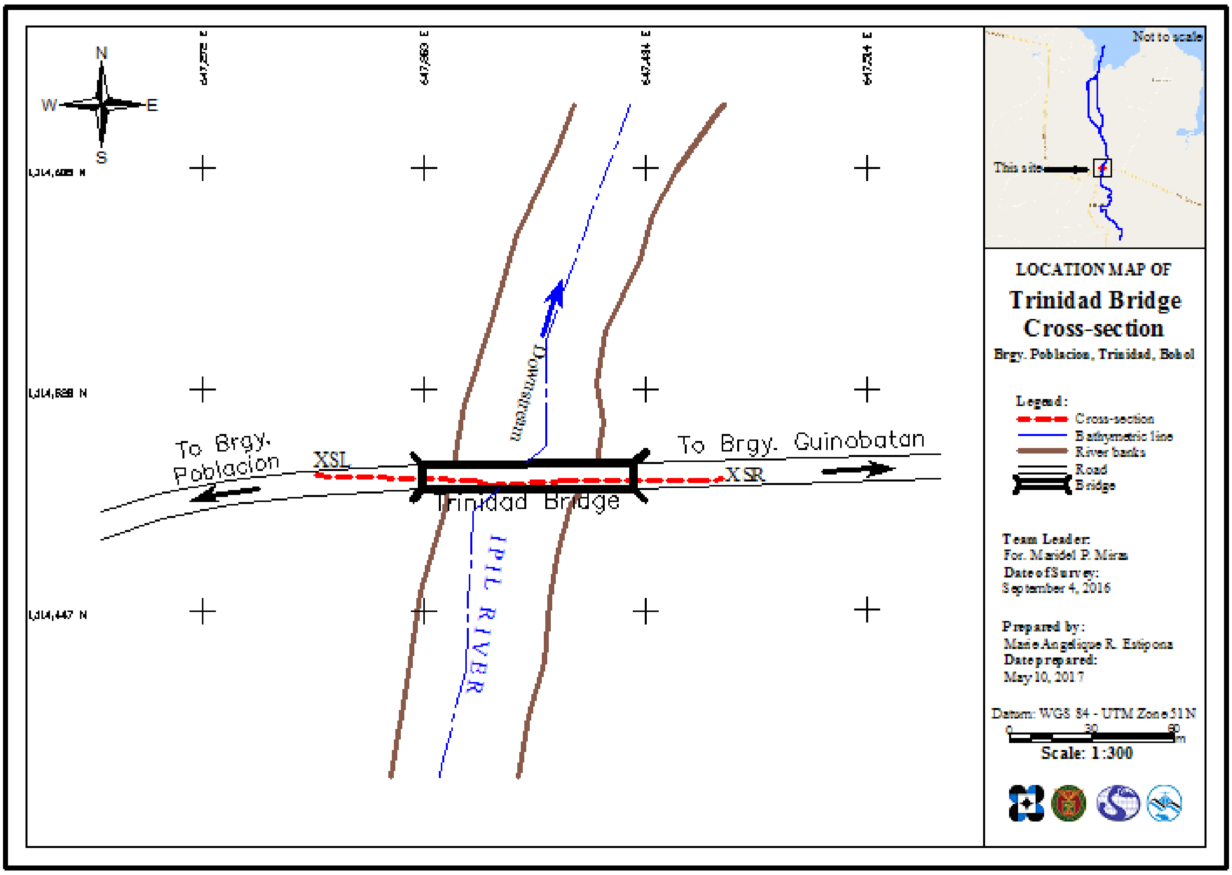



Figure 43. Trinidad bridge cross-section location map

**Bridge Data Form**

**Bridge Name:** **Tugas Bridge** **Date:** **September 4, 2016**

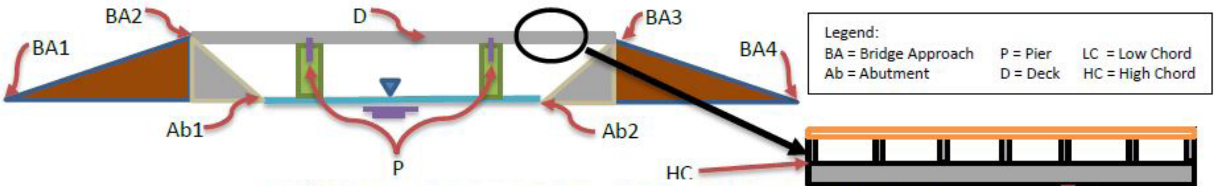
**River Name:** **Ipil River** **Time:** **12:00 PM**

**Location (Brgy, City,Region):** **Brgy. Hinlayagan Ilaud, Municipality of Trinidad, Bohol**

**Survey Team:** **Mady Miras, Randell Pabroquez, Janina Jupiter**

**Flow condition:** normal **Weather Condition:** fair

**Latitude:** **10°02'58.90424" N** **Longitude:** **124°21'07.67434" E**




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

**Elevation:** **Not available** **Width:** **2.5 m** **Span (BA3-BA2):** **30.460 m**

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | Not available | Not available | Not available |

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

| | Station(Distance from BA1) | Elevation | | Station(Distance from BA1) | Elevation |
|---|---|---|---|---|---|
| BA1 | 0 | 4.990 m | BA3 | 39.378 m | 4.961 m |
| BA2 | 8.919 m | 5.417 m | BA4 | 50.989 m | 2.306 m |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | Not available | Not available |
| Ab2 | Not available | Not available |

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

Shape: Not available Number of Piers: Not available Height of column footing: Not available

| | Station (Distance from BA1) | Elevation | Pier Diameter |
|---|---|---|---|
| Not available | Not available | Not available | Not available |

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

Figure 44. Bridge as-built form of Tugas Bridge

**Bridge Data Form**

**Bridge Name:** **Trinidad Bridge** **Date:** **September 4, 2016**

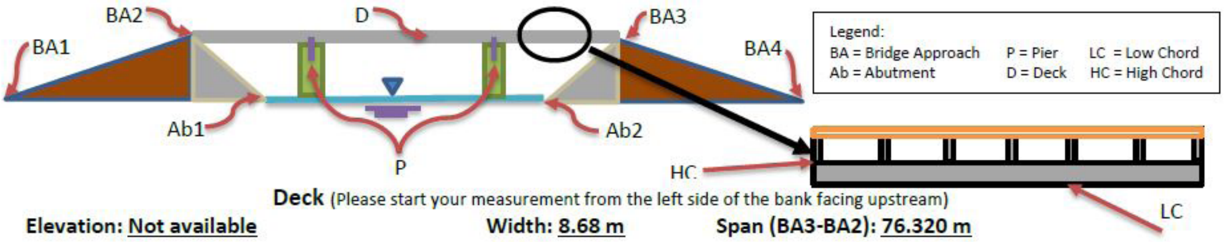
**River Name:** **Ipil River** **Time:** **1:00 PM**

**Location (Brgy, City,Region):** **Brgy. Poblacion, Municipality of Trinidad, Bohol**

**Survey Team:** **Mady Miras, Randell Pabroquez, Janina Jupiter**

**Flow condition:** normal **Weather Condition:** fair

**Latitude:** **10°04'46.03040" N** **Longitude:** **124°20'40.49615" E**




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

**Elevation:** **Not available** **Width:** **8.68 m** **Span (BA3-BA2):** **76.320 m**

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | Not available | Not available | Not available |

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

| | Station(Distance from BA1) | Elevation | | Station(Distance from BA1) | Elevation |
|---|---|---|---|---|---|
| BA1 | 0 | 6.383 m | BA3 | 91.689 m | 6.182 m |
| BA2 | 15.369 m | 6.455 m | BA4 | 110.312 m | 5.703 m |

**Abutment:** Is the abutment sloping? **Yes**; If yes, fill in the following information:

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | Not available | Not available |
| Ab2 | Not available | Not available |

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

Shape: Not available Number of Piers: Not available Height of column footing: Not available

| | Station (Distance from BA1) | Elevation | Pier Diameter |
|---|---|---|---|
| Pier 1 | 35.534 m | 6.460 m | 1 m |
| Pier 2 | 53.524 m | 6.398 m | 1 m |
| Pier 3 | 71.521 m | 6.310 m | 1 m |

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

Figure 45. Bridge as-built form of Trinidad Bridge

Water surface elevation of Ipil River in Tugas Bridge was determined using Trimble® SPS 885 GNSS PPK survey technique on September 7, 2016 at 4:16 PM with a value of 0.813 m in MSL as shown in Figure 46. Meanwhile, water surface elevation of Ipil River in Trinidad Bridge was determined using Trimble® SPS 882 GNSS PPK survey technique on September 7, 2016 at 3:34 PM with a value of 0.848 m in MSL as shown in Figure 47. These were translated onto markings on the wall under the bridge using the same technique as shown in Figure 46 and Figure 47, respectively. The markings will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for Ipil River, USC.

Figure 46. Water-level markings on Tugas Bridge

Figure 47. Water-level markings on Trinidad Bridge

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 5 and 7, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 885, mounted in front of a vehicle as shown in Figure 48. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 2.168 m and 1.336 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with BH-393 occupied as the GNSS base station.


Figure 48. Validation points acquisition survey set up along Ipil River Basin

The survey branched into two directions – the first branch started from Brgy. Sto. Niño, Municipality of Jetafe, going south it traversed thirteen (13) barangays and ended in Brgy. Concepcion, Municipality of Danao; and the second branch started in Brgy. Poblacion, Municipality of Jetafe ,going east it traversed thirty-three (33) barangays and ended in Brgy. Cabatang, Municipality of Alicia. A total of 13,056 points were gathered with approximate length of 87.888 km using BH-393 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 49.

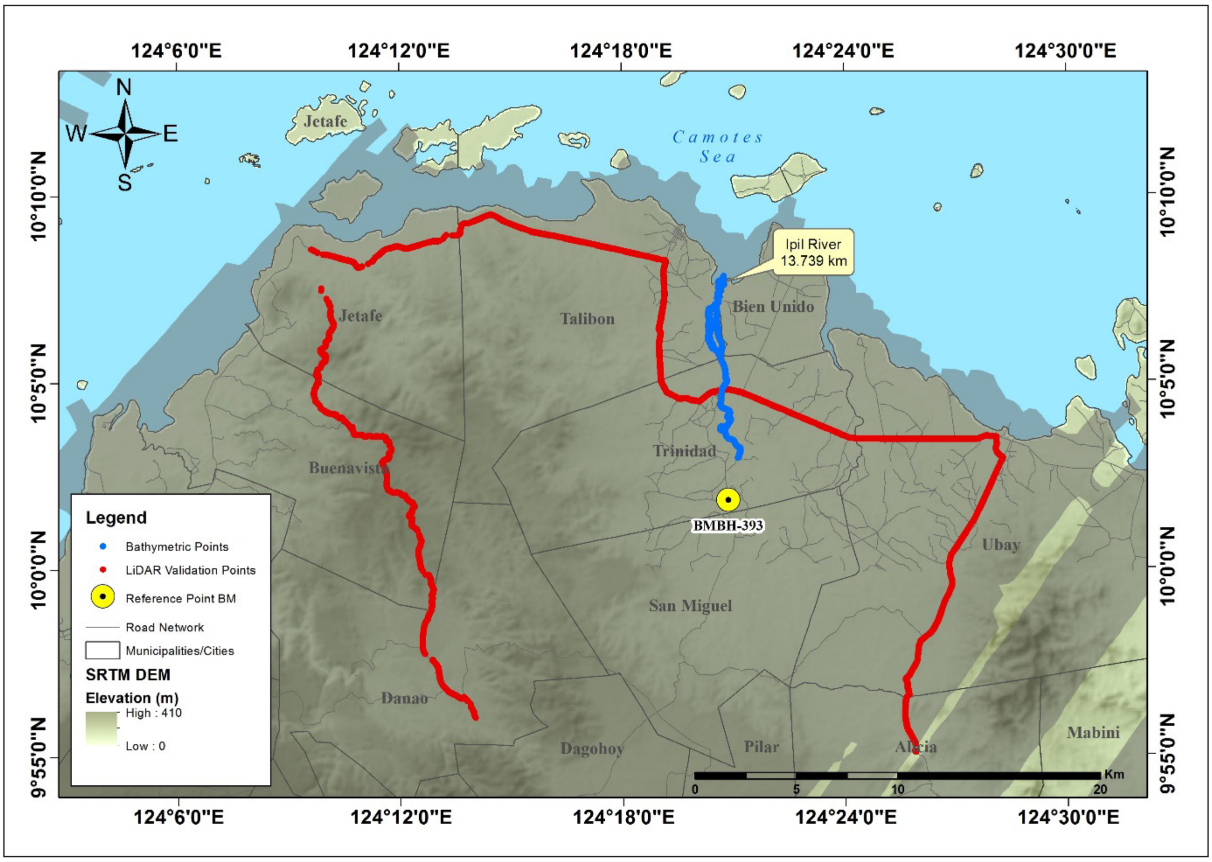



Figure 49. Validation point acquisition survey of Ipil River Basin

## 4.7 River Bathymetric Survey

Bathymetric survey was executed on September 5 and 6, 2016 using an Ohmex ™ single beam echo sounder and Trimble® SPS 885 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 50. The survey started at the upstream portion of the river in Brgy. Hinlayagan Ilaud, Municipality of Trinidad, with coordinates 10°02’58.32639”N, 124°21’08.27857”E, and ended at the mouth of the river in Brgy. Balintawak, Municipality of Talibon with coordinates 10°07’49.14771”N, 124°20’45.83735”E. The partner HEI, USC, suggested an additional 3 km to be surveyed from the major tributary of the river because of flood-affected communities residing there. The survey continued on September 7, 2016, starting in Brgy. Poblacion, Municipality of Trinidad, with coordinates 10°05’35.24563”N, 124°20’41.17341”E and ended in the same mouth of the river.


Figure 50. Bathymetric survey using OHMEX™ single beam echo sounder in Ipil River

The bathymetric survey for Ipil River gathered a total of 33,406 points covering a total estimated length of 13.739 km of the river traversing Barangays Hinlayagan Ilaud, Mabuhay Cabigohan, and Poblacion in Municipality of Trinidad; and Barangays San Roque, San Agustin, and Balintawak in Municipality of Talibon. A CAD drawing was also produced to illustrate the riverbed profile of Ipil River. As shown in Figure 52 and Figure 53, the highest and lowest elevation has a -7.159-m difference. The highest elevation observed was 0.073 m in MSL located in Brgy. Balintawak, Municipality of Talibon while the lowest was -7.086 m below MSL located at the middle portion of the river located in Brgy. Mabuhay Cabigohan, Municipality of Trinidad.

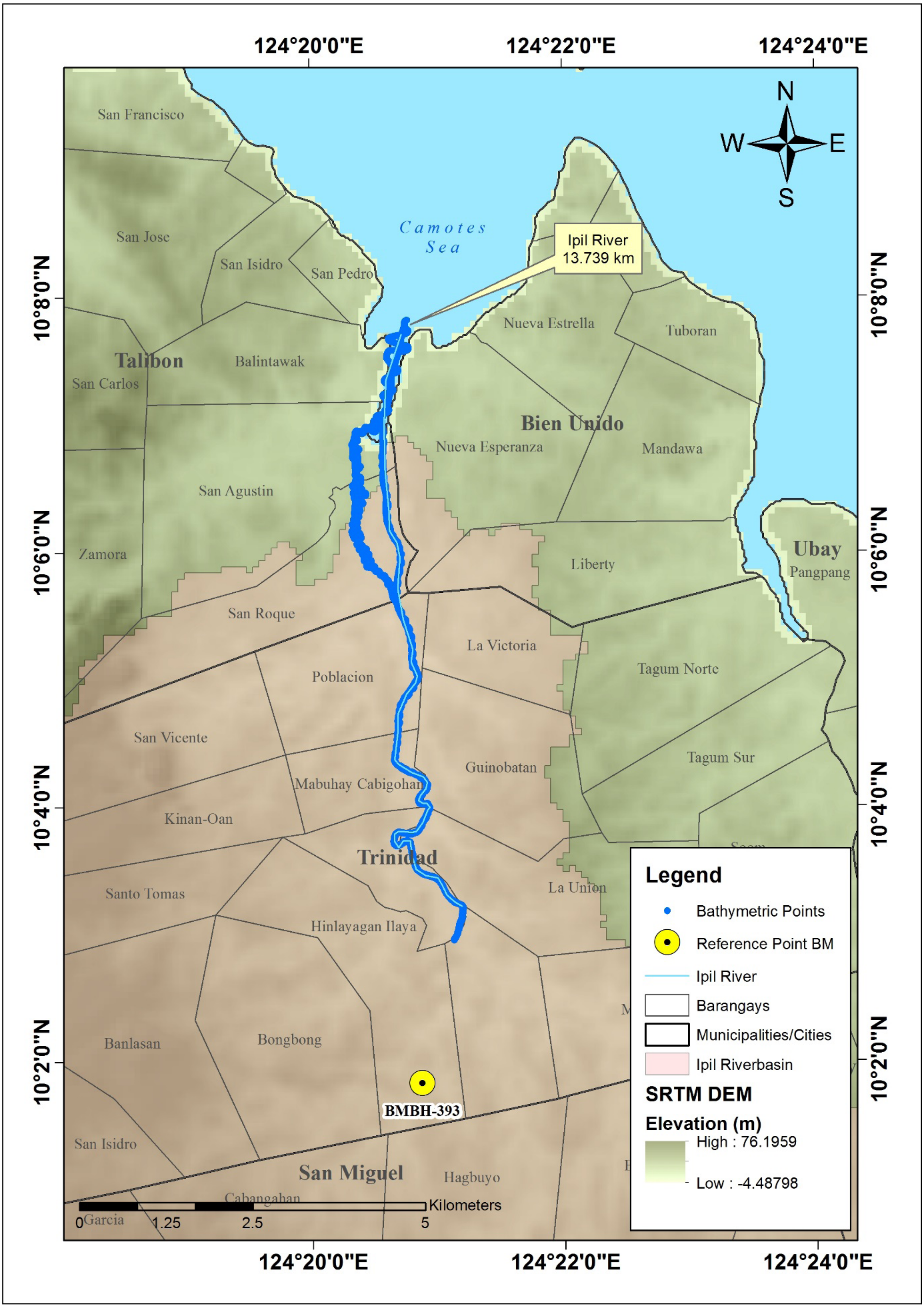



Figure 51. Bathymetric survey of Ipil River

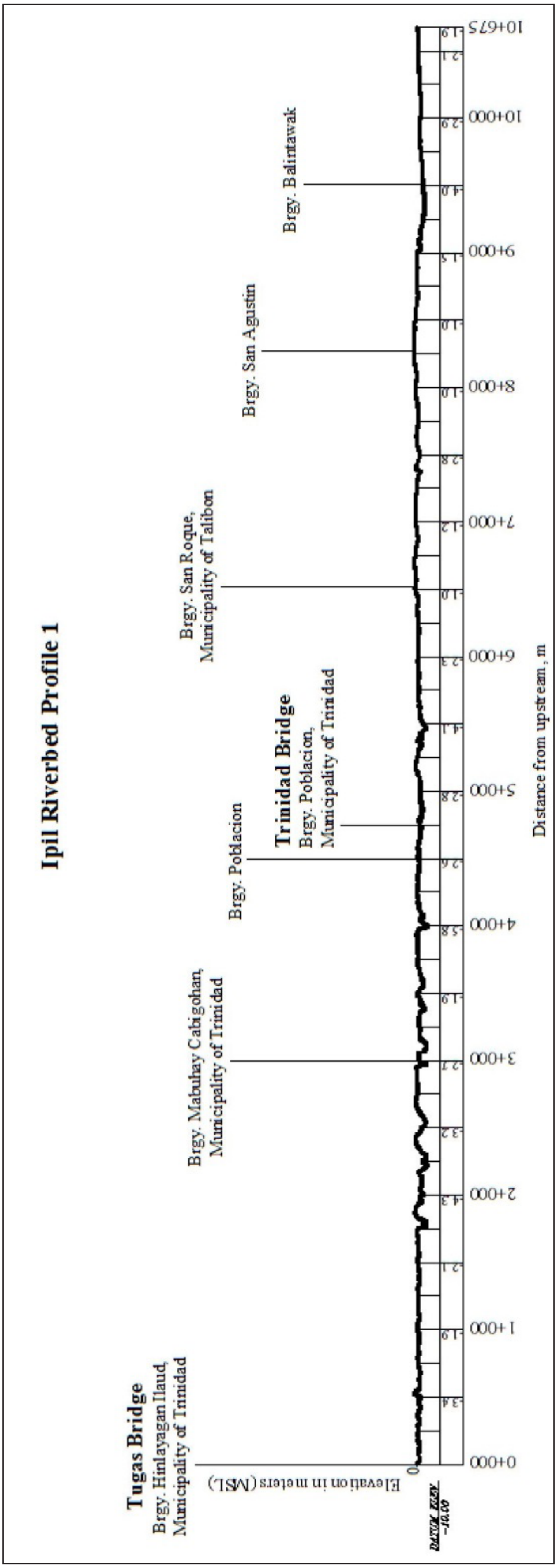



Figure 52. Ipil Riverbed Profile, from Tugas Bridge in Brgy. Hinlayagan Ilaud upstream

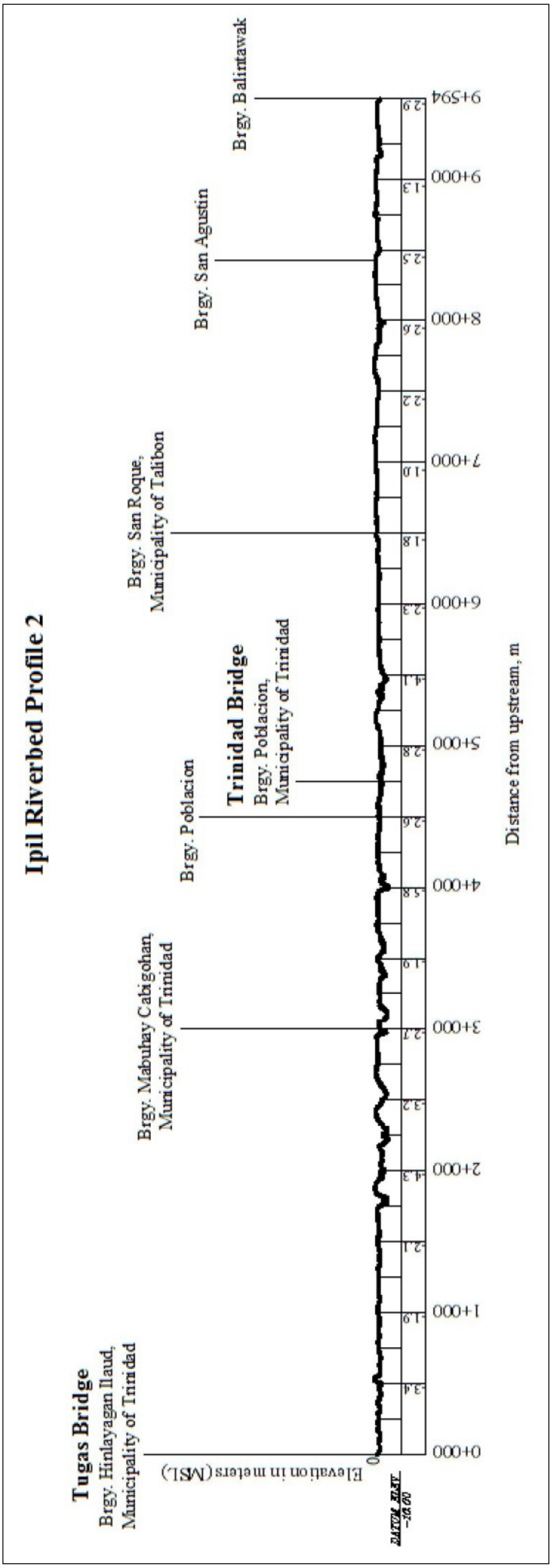



Figure 53. Ipil Riverbed Profile, from Tugas Bridge in Brgy. Hinlayagan Ilaud

# CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Pauline Racoma

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

### 5.1.2 Precipitation

Precipitation data was taken from automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The nearby rain gauge station of Ipil River basin is located in the Municipality of San Miguel.

The total rain from the San Miguel rain gauge is 12.5 mm. It peaked to 6 mm on September 11, 2016, 22:00. The lag time between the peak rainfall and discharge is 4 hours and 15 minutes, as shown in Figure 57.

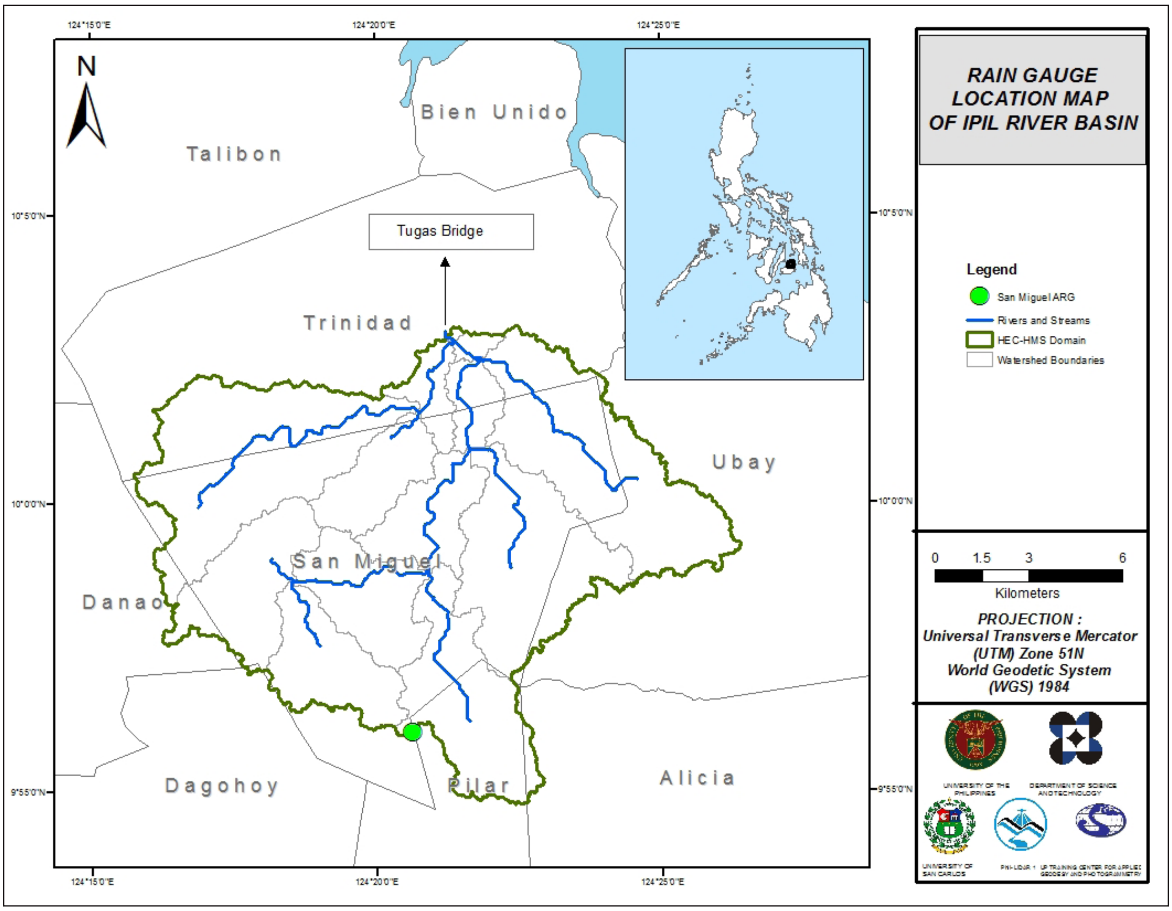



Figure 54. The location map of Ipil HEC-HMS model used for calibration

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Tugas Bridge, Trinidad (10°2'58.56"N and 124°21'7.2"E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

For Tugas Bridge, the rating curve is expressed as shown in Figure 56.

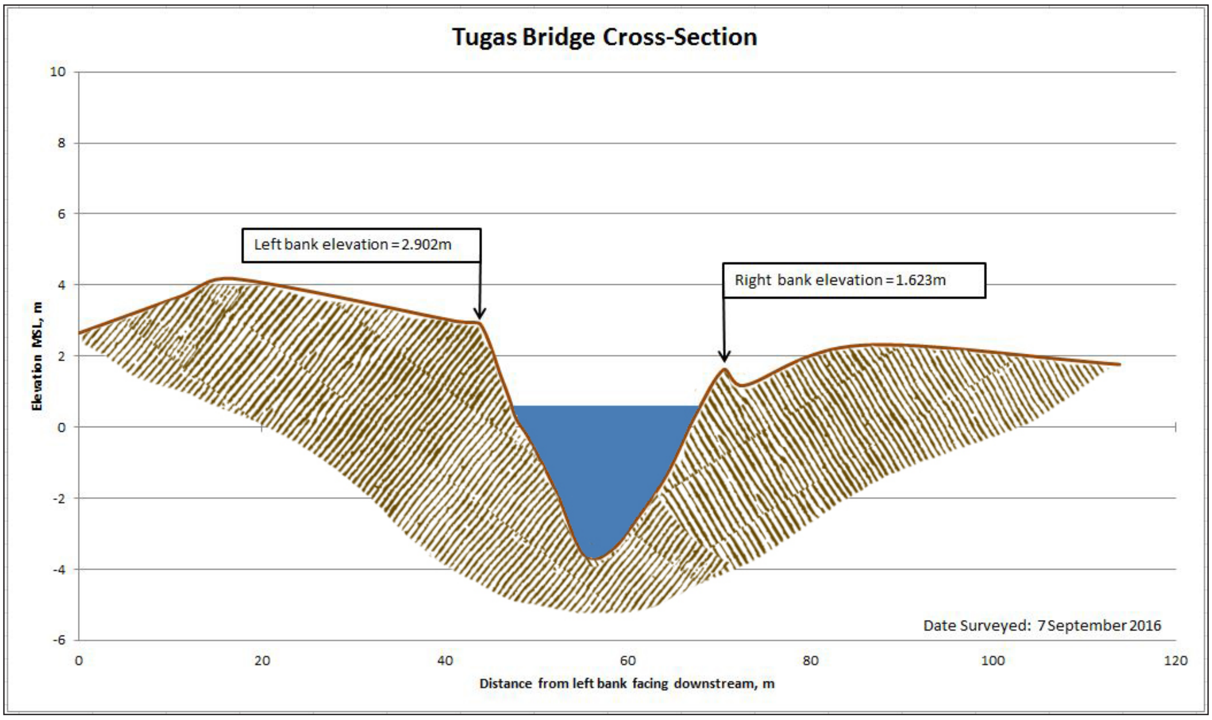



Figure 55. Cross-Section Plot of Tugas Bridge

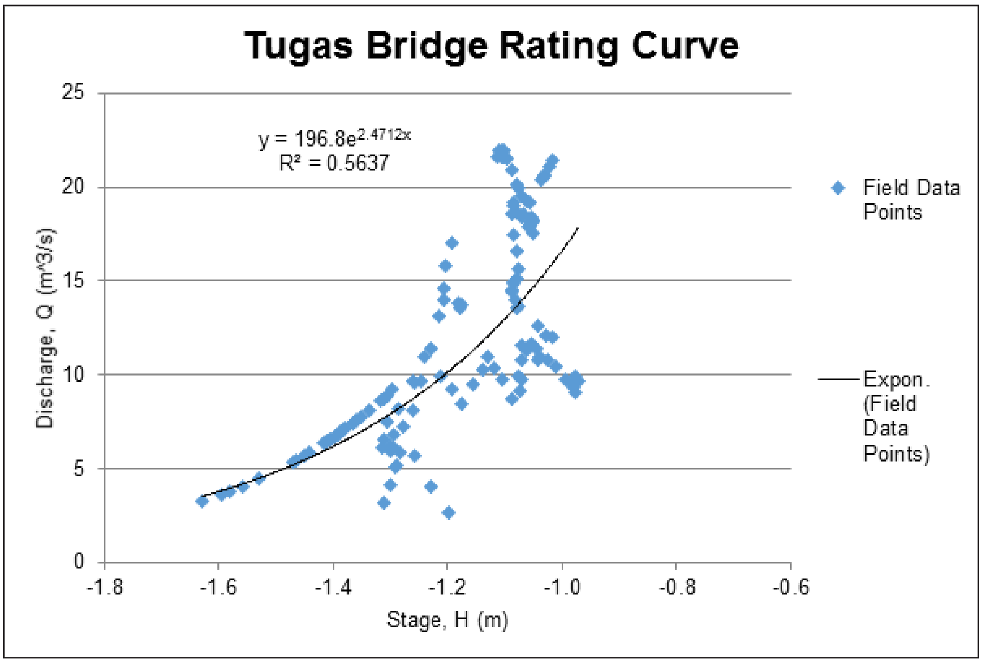



Figure 56. Rating Curve at Tugas Bridge, Trinidad

This rating curve equation was used to compute the river outflow at Tugas Bridge for the calibration of the HEC-HMS model shown in Figure 5. Peak discharge is 21.963 $m^3/s$ at 1:00, September 12, 2016.

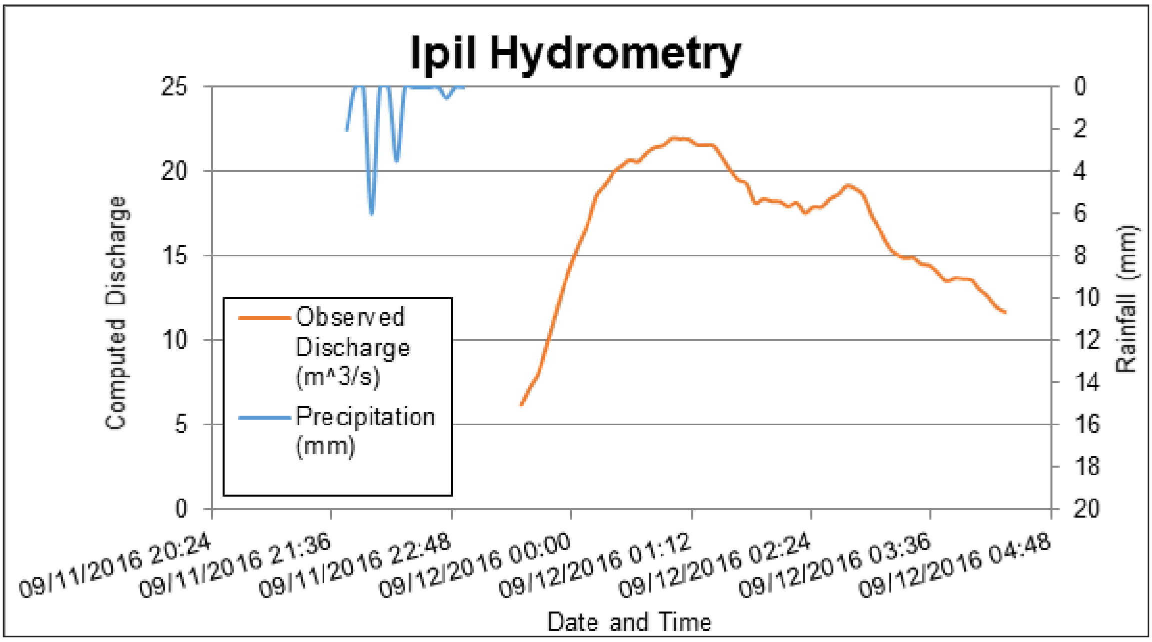



Figure 57. Rainfall and outflow data at Ipil used for modeling

## 5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Tagbilaran Point Gauge. This station chosen based on its proximity to the Ipil watershed. The extreme values for this watershed were computed based on a 39-year record.

Table 31. RIDF values for Tagbilaran Point Rain Gauge computed by PAGASA

| COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T (yrs) | 10 mins | 20 mins | 30 mins | 1 hr | 2 hrs | 3 hrs | 6 hrs | 12 hrs | 24 hrs |
| 2 | 14.4 | 21.9 | 26.5 | 34 | 43.7 | 50.4 | 62.6 | 73.8 | 84.1 |
| 5 | 23.1 | 35.4 | 41.8 | 54.6 | 65.1 | 76.5 | 95.1 | 108.2 | 121.2 |
| 10 | 28.8 | 44.3 | 52 | 68.3 | 79.3 | 93.7 | 116.7 | 131 | 145.7 |
| 15 | 32.1 | 49.3 | 57.7 | 76.1 | 87.3 | 103.5 | 128.8 | 143.9 | 159.6 |
| 20 | 34.3 | 52.8 | 61.7 | 81.5 | 92.9 | 110.3 | 137.3 | 152.9 | 169.3 |
| 25 | 36.1 | 55.5 | 64.8 | 85.6 | 97.3 | 115.5 | 143.8 | 159.8 | 176.7 |
| 50 | 41.5 | 63.8 | 74.4 | 98.5 | 110.6 | 131.7 | 164 | 181.1 | 199.7 |
| 100 | 46.8 | 72.1 | 83.8 | 111.2 | 123.8 | 147.7 | 184 | 202.3 | 222.6 |

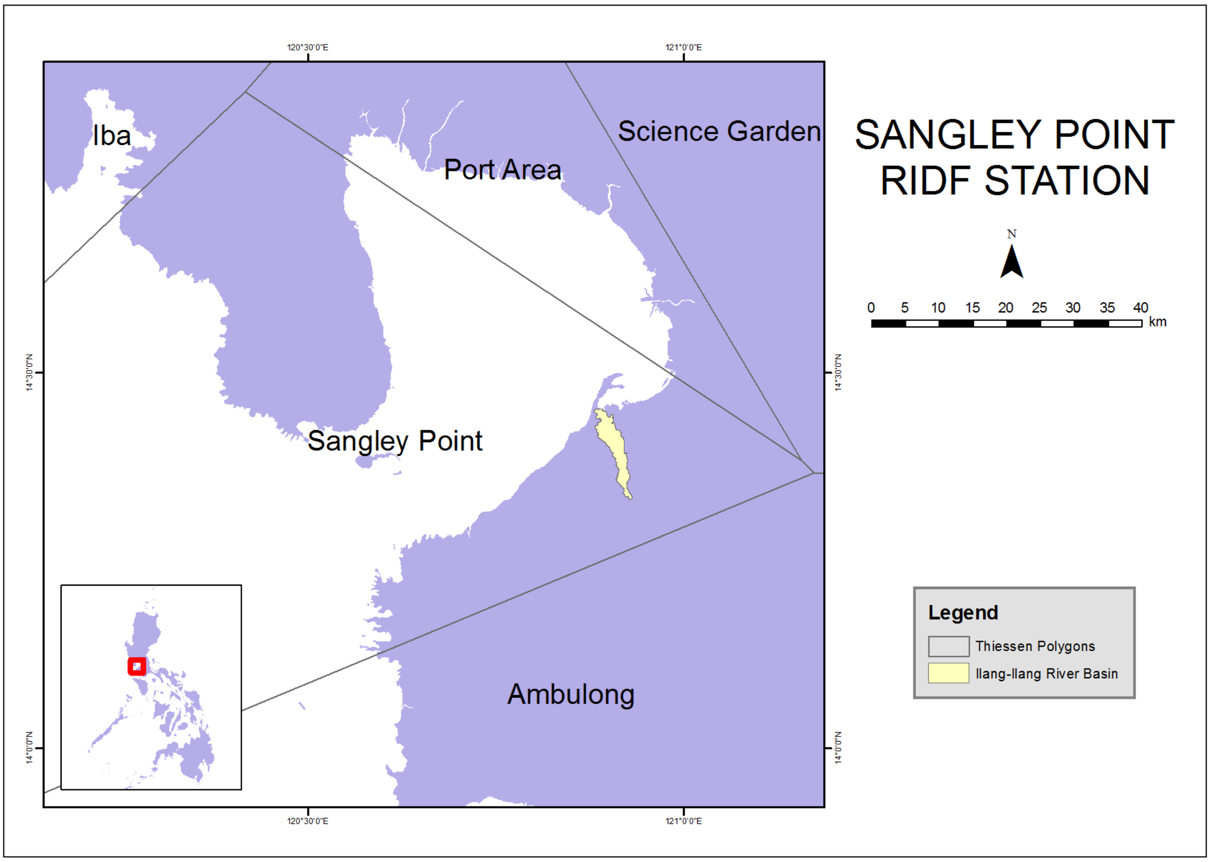



Figure 58. Tagbilaran Point RIDF location relative to Ipil River Basin

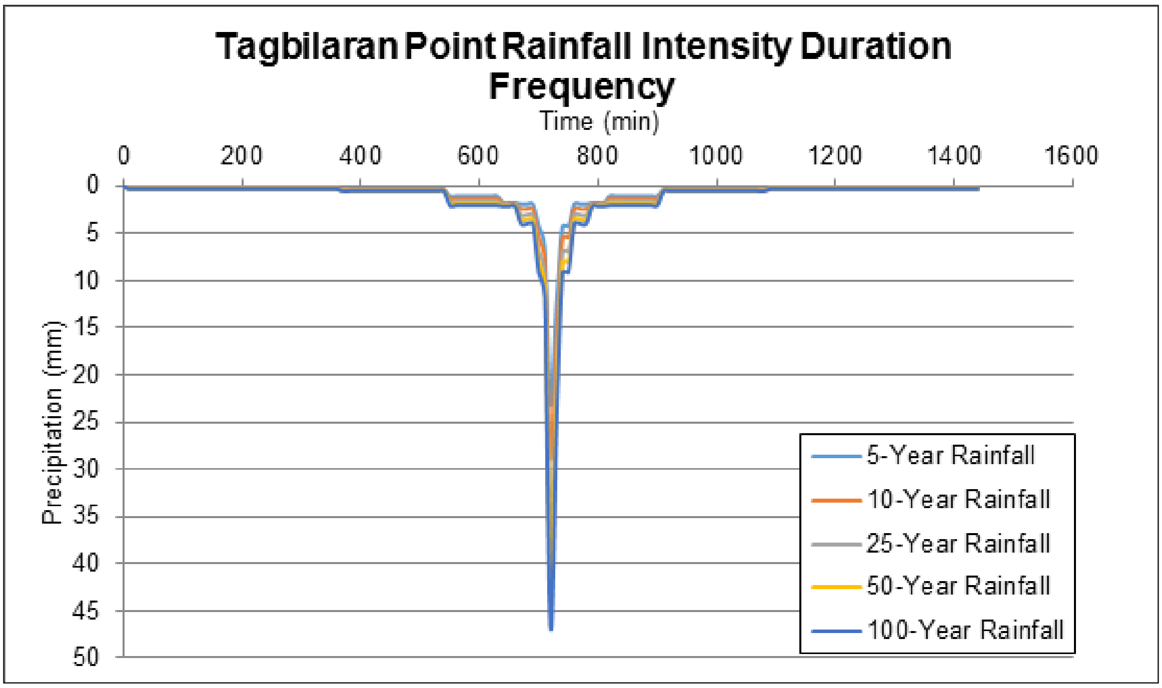



Figure 59. Synthetic storm generated for a 24-hr period rainfall for various return periods

## 5.3 HMS Model

The soil shapefile (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Environment and Natural Resources Management (Figure 60). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA) and can be seen in Figure 61.

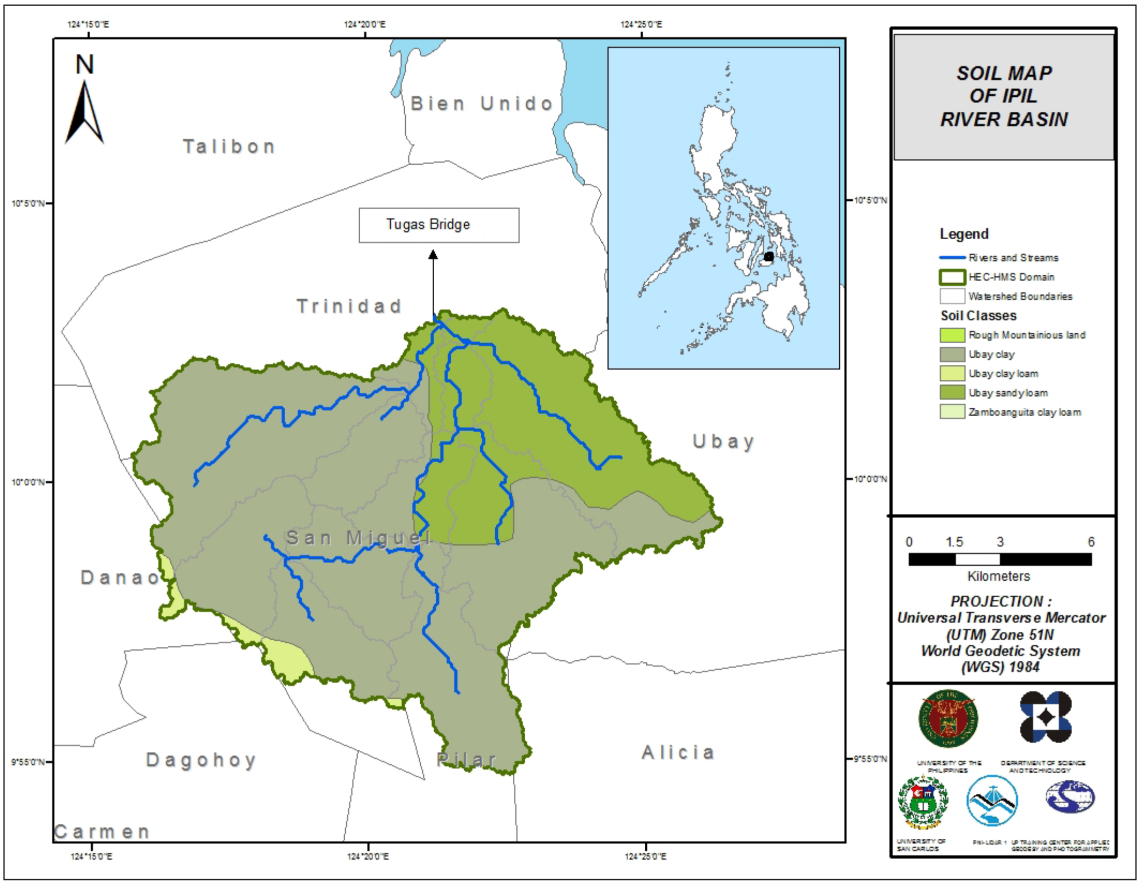



Figure 60. The soil map of the Ipil River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

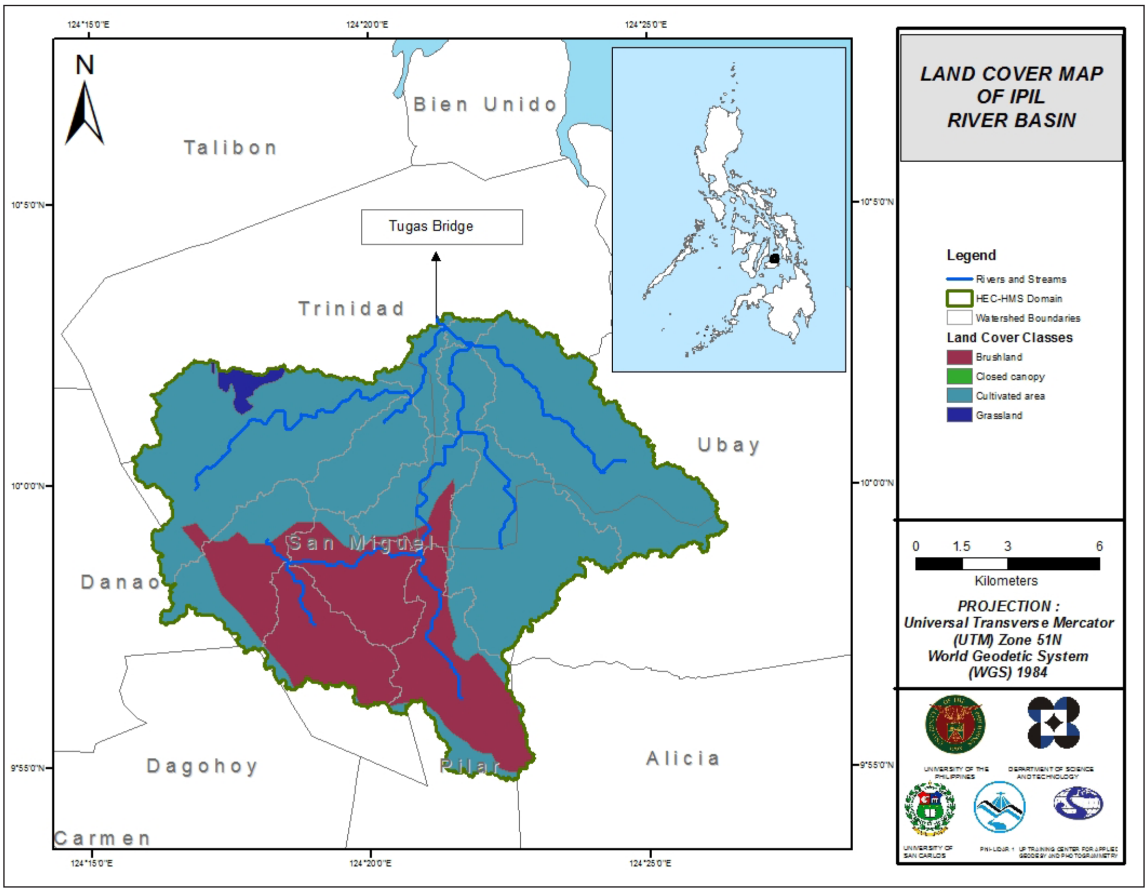



Figure 61. The land cover map of the Ipil River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: National Mapping and Resource Information Authority)

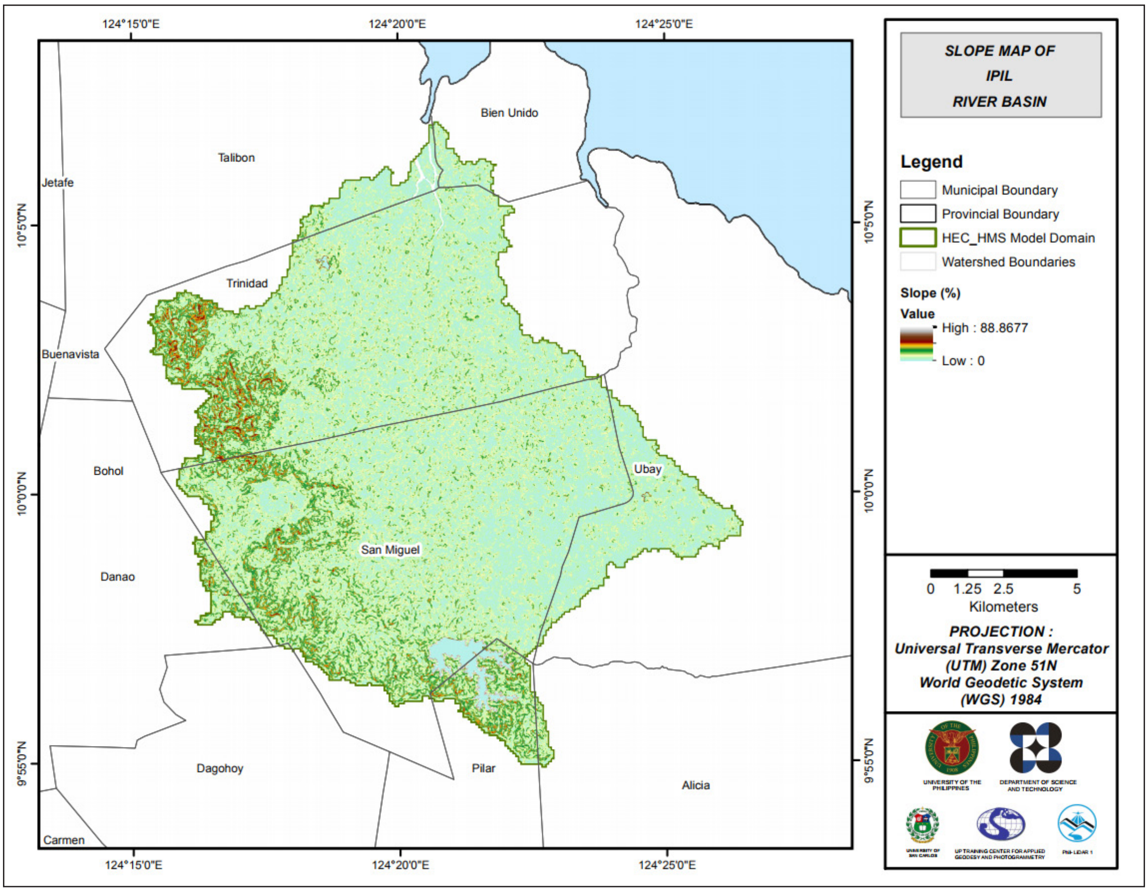



Figure 62. The slope map of the Ipil River Basin

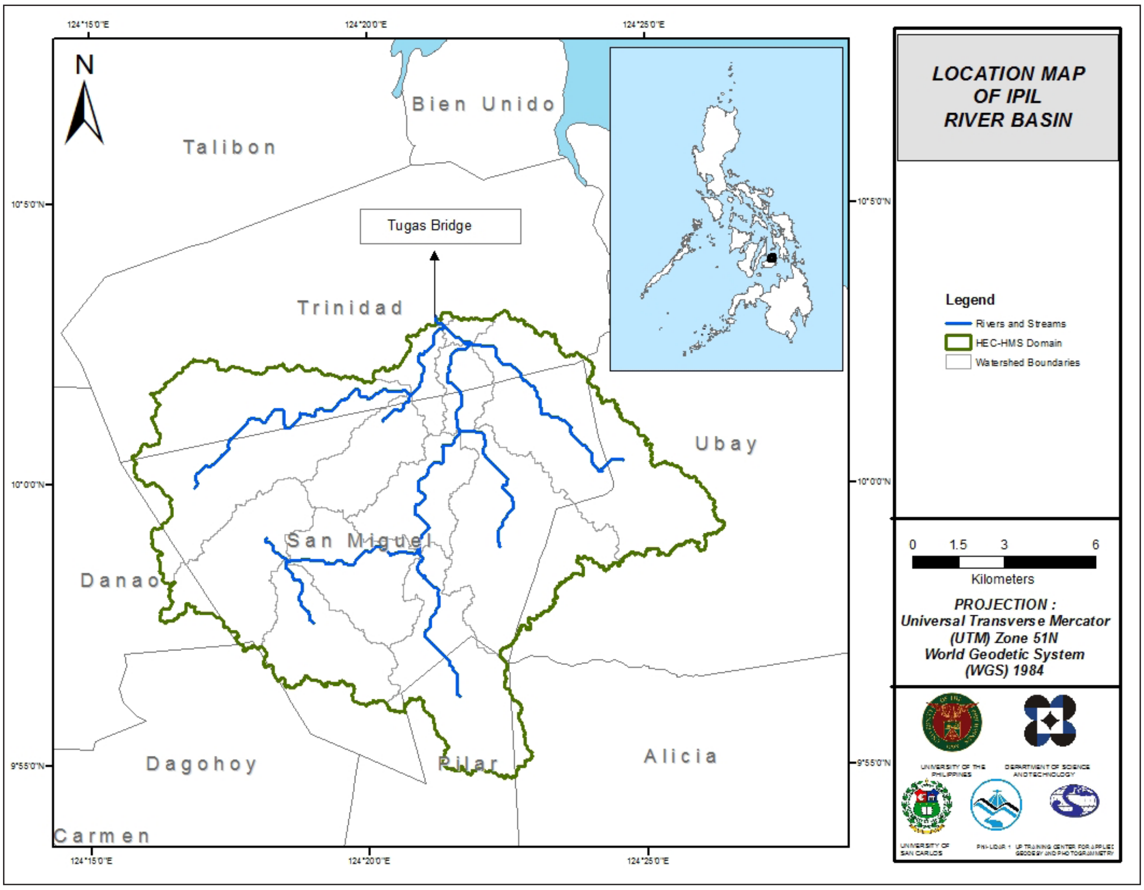



Figure 63. Stream Delineation Map of Ipil River Basin

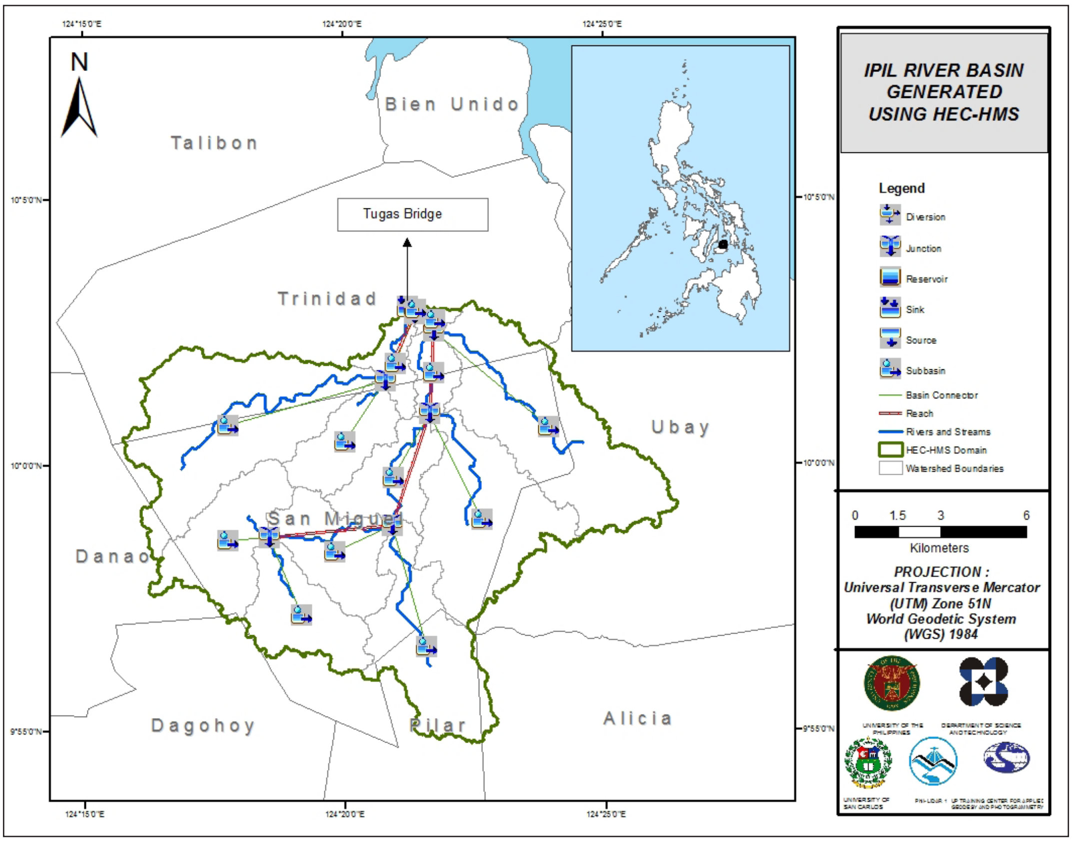



Figure 64. The Ipil River Basin Model Domain generated using HEC-HMS.

## 5.4 Cross-section Data

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

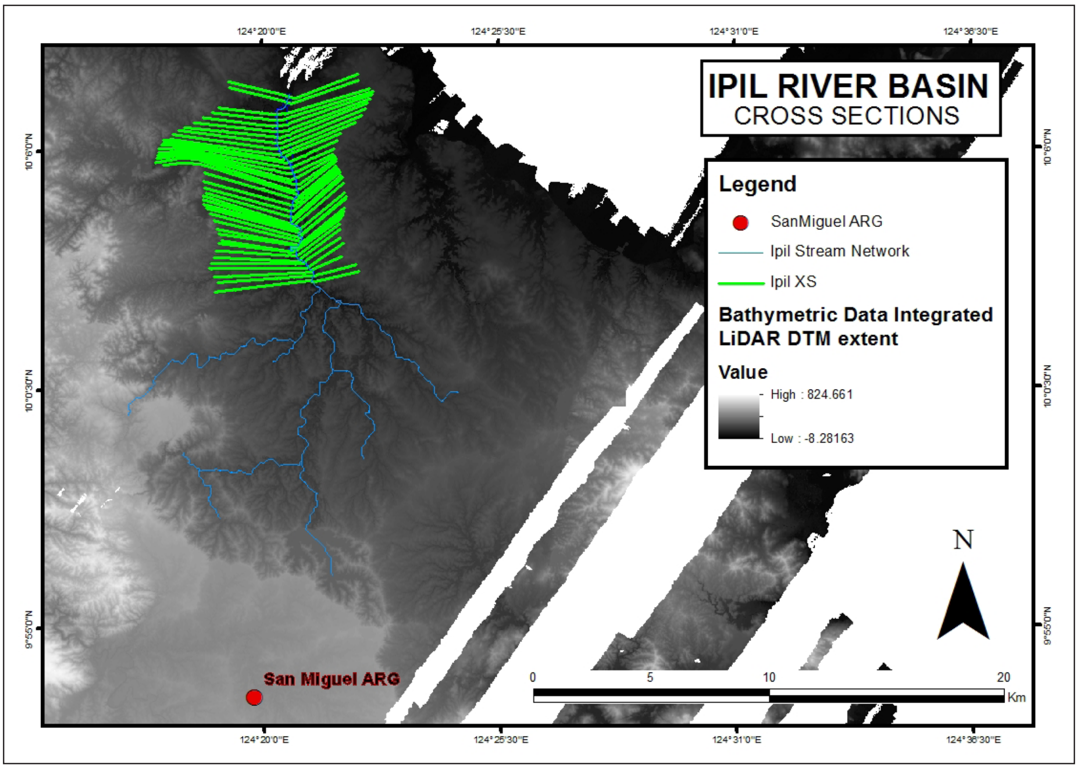



Figure 65. River cross-section of Ipil River generated through Arcmap HEC GeoRAS tool

## 5.5 Flo 2D Model

No input.

## 5.6 Results of HMS Calibration

After calibrating the Ipil HEC-HMS river basin model, its accuracy was measured against the observed values (see Annex 9: Ipil Model Basin Parameters). Figure 66 shows the comparison between the two discharge data.

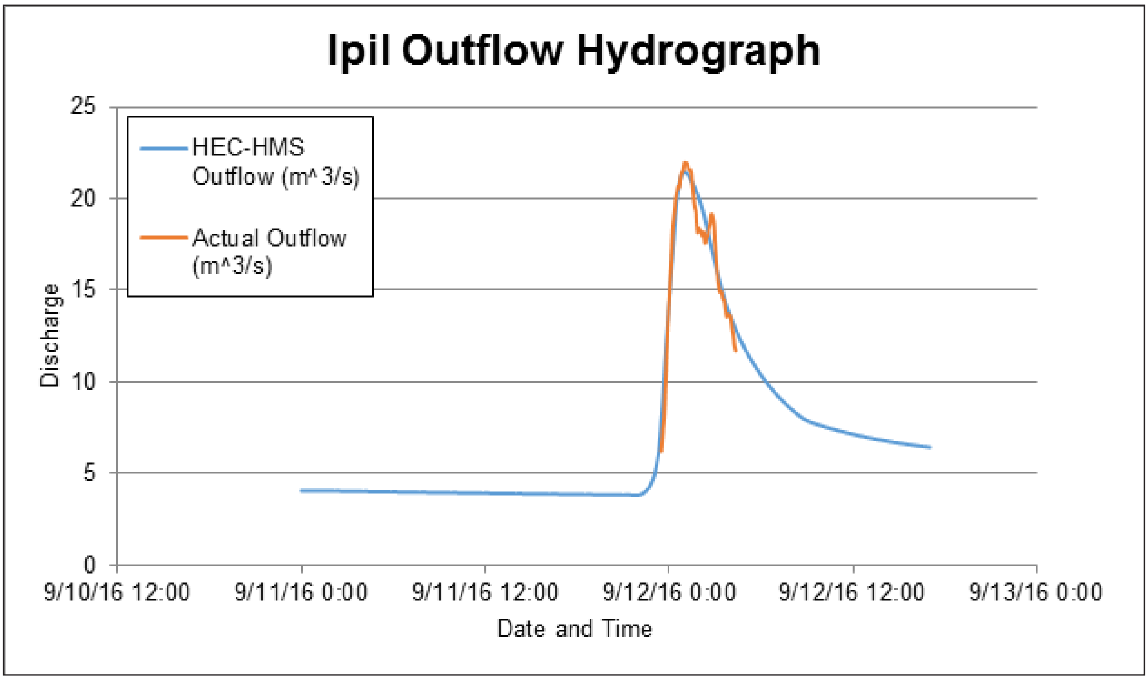



Figure 66. Outflow Hydrograph of Ipil produced by the HEC-HMS model compared with observed outflow

Table 32. Range of calibrated values for the Ipil River Basin.

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve Number | Initial Abstraction (mm) | 0.51-4.95 |
| | | | Curve Number | 66.74-97.46 |
| | | | Impervious (%) | 0 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.44-12.06 |
| | | | Storage Coefficient (hr) | 1.48-11.38 |
| | Baseflow | Recession | Recession Constant | 0.64-1 |
| | | | Ratio to Peak | 0.13-0.2 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.02-0.04 |

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values 0.51 to 4.95 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Ipil river basin, the curve number is 66.74 to 97.46.

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 0.44 to 12.06 minutes determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.64 to 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.13 to 0.2 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.02 to 0.04 corresponds to the common roughness in Ipil, which is determined to be cultivated with mature field crops (Brunner, 2010).

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

| Accuracy Measure | Value |
|---|---|
| $r^2$ | 0.9437 |
| NSE | 0.9353 |
| PBIAS | -1.3024 |
| RSR | 0.2522 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.9806 $m^3/s$.

The Pearson correlation coefficient ($r^2$) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9437.

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 0.9353.

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 -1.3024.

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 0.28.

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

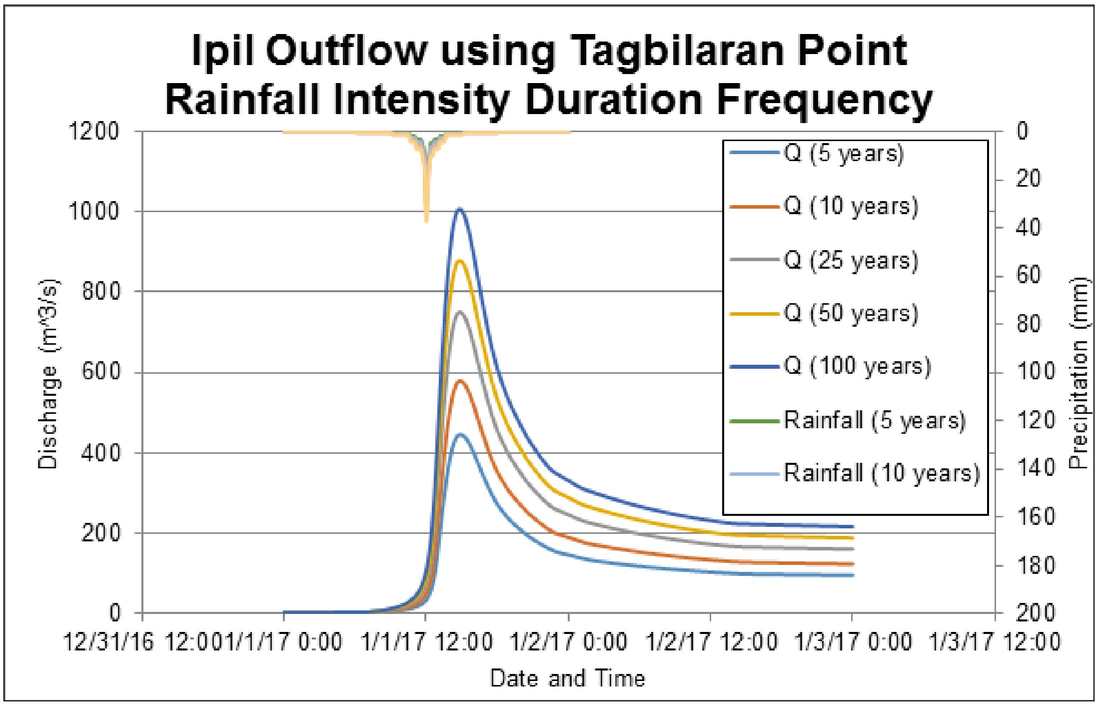



Figure 67. Outflow hydrograph at Ipil generated using Tagbilaran PointRIDF simulated in HEC-HMS

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

Table 34. Peak values of the Ipil HECHMS Model outflow using the Tagbilaran RIDF

| RIDF Period | Total Precipitation (mm) | Peak rainfall (mm) | Peak outflow ($m^3/s$) | Time to Peak |
|---|---|---|---|---|
| 5-Year | 116.5 | 21.8 | 446.442 | 02:50 |
| 10-Year | 143.3 | 25.6 | 579.615 | 02:50 |
| 25-Year | 177.2 | 30.3 | 750.749 | 02:50 |
| 50-Year | 202.4 | 33.8 | 879.362 | 02:50 |
| 100-Year | 227.3 | 37.2 | 1007.088 | 02:50 |

## 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. The sample generated map of Ipil River using the calibrated HMS base flow is shown in Figure 68.

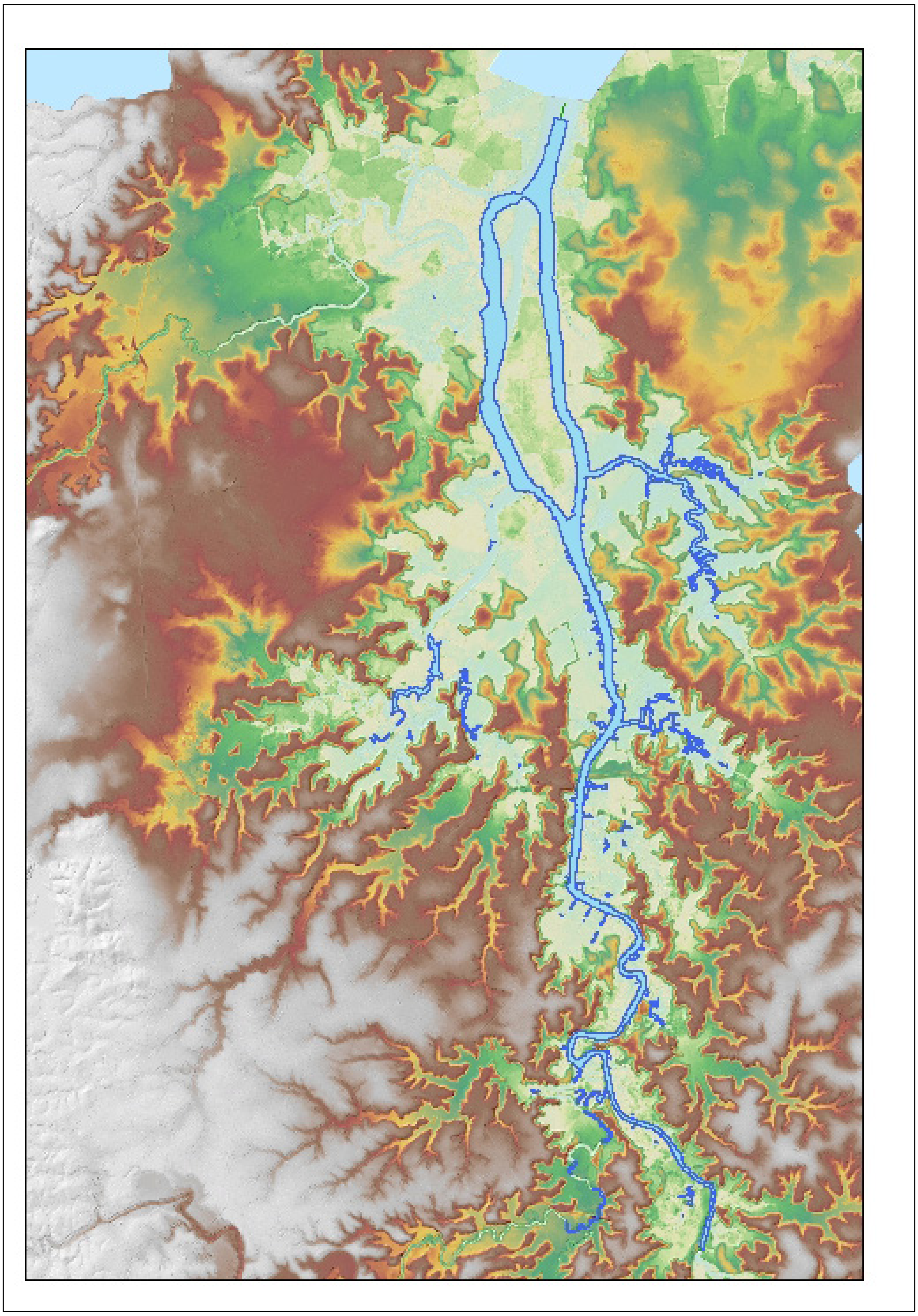


Figure 68. Sample output of Ipil RAS Model

## 5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 69 to Figure 74 shows the 5-, 25-, and 100-year rain return scenarios of the Ipil floodplain.

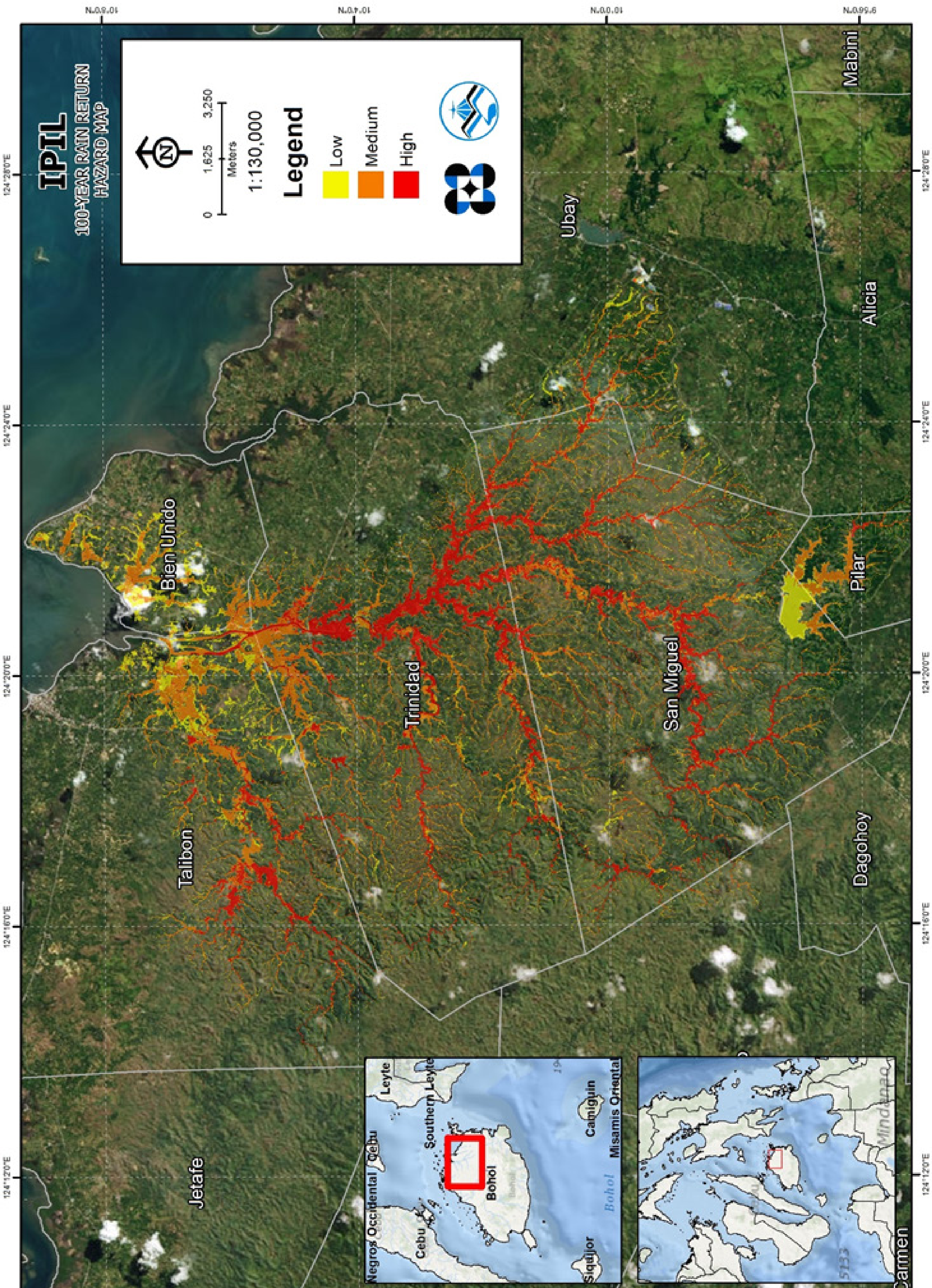



Figure 69. 100-year Flood Hazard Map for Ipil Floodplain

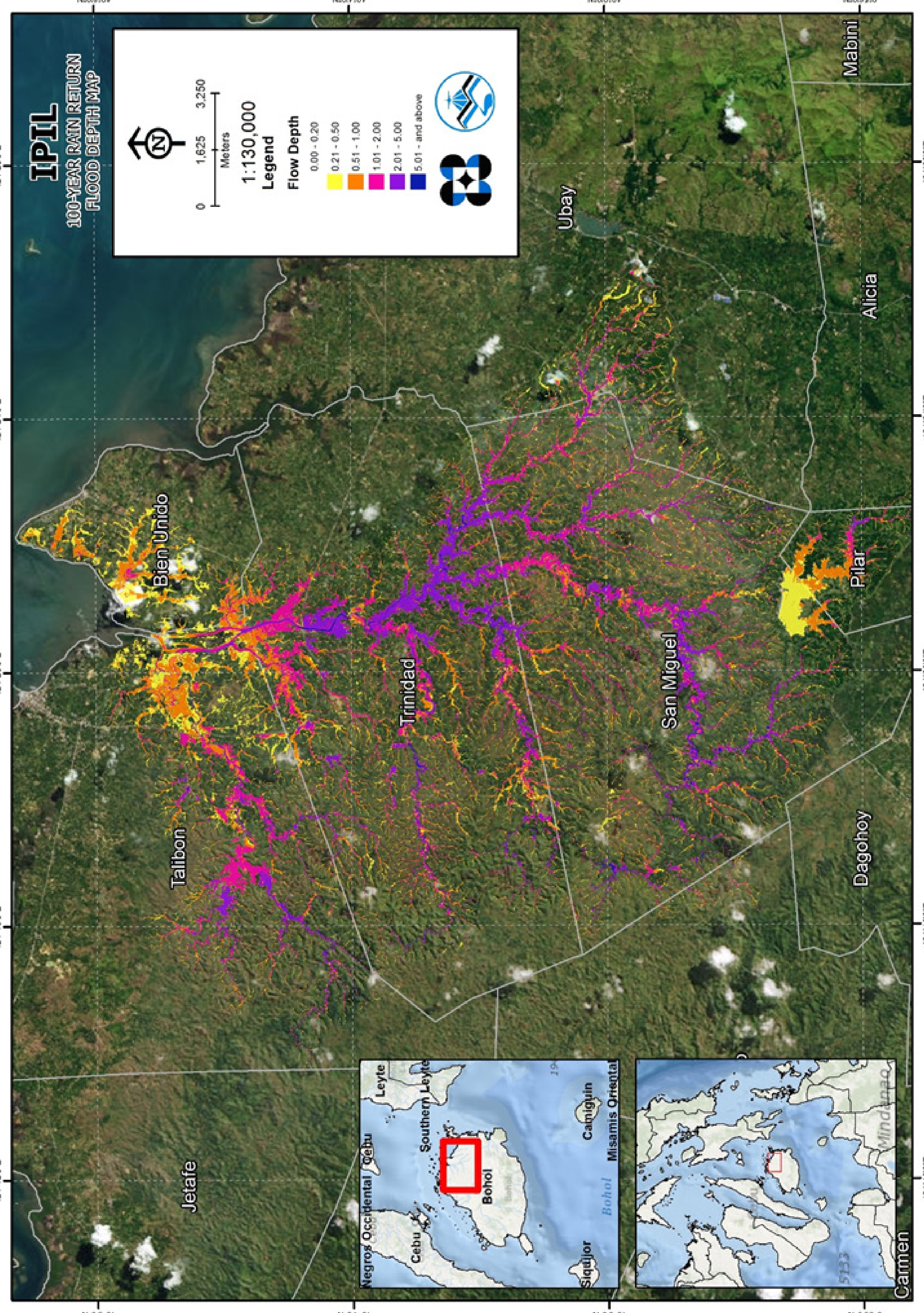



Figure 70. 100-year Flow Depth Map for Ipil Floodplain

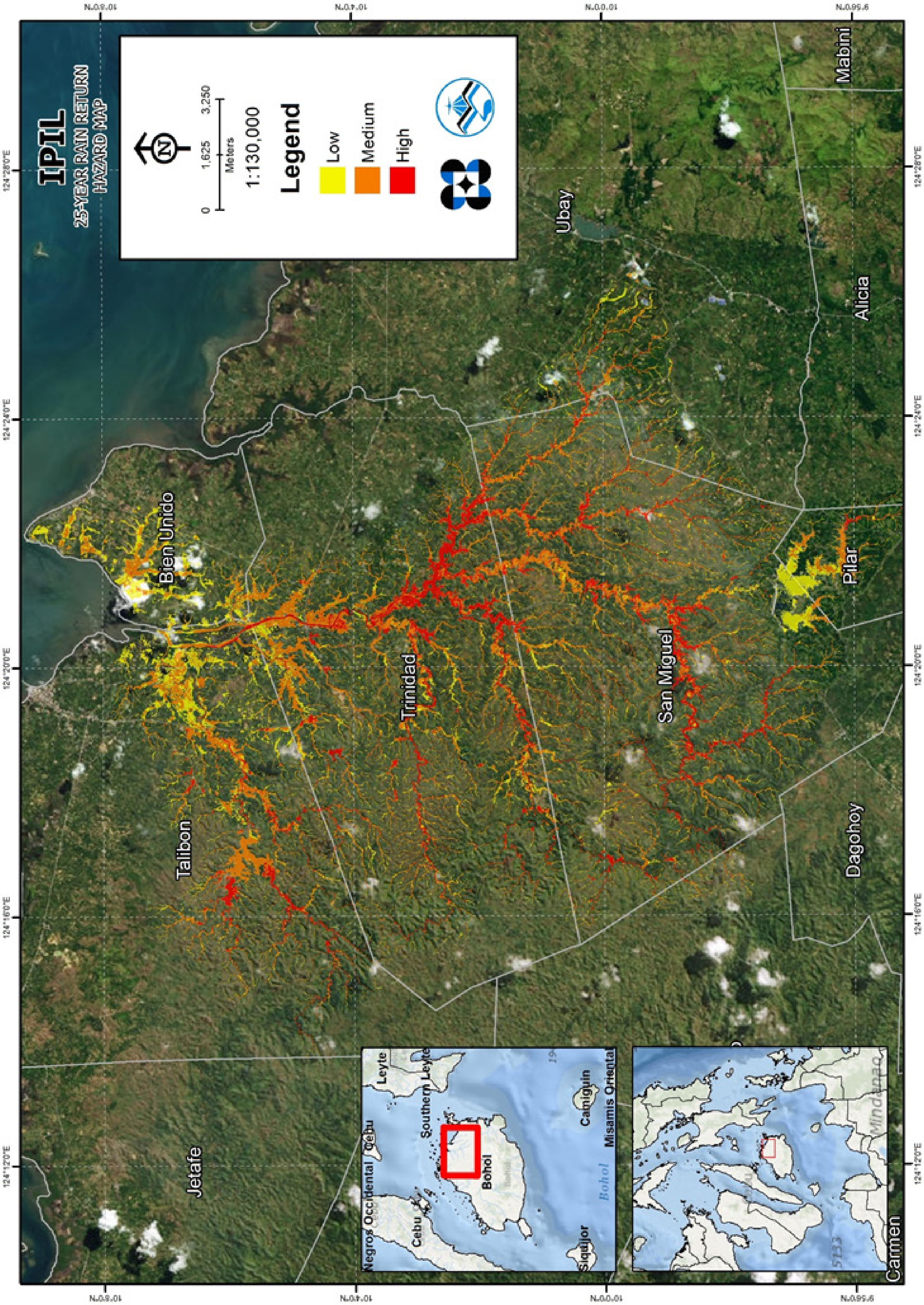



Figure 71. 25-year Flood Hazard Map for Ipil Floodplain

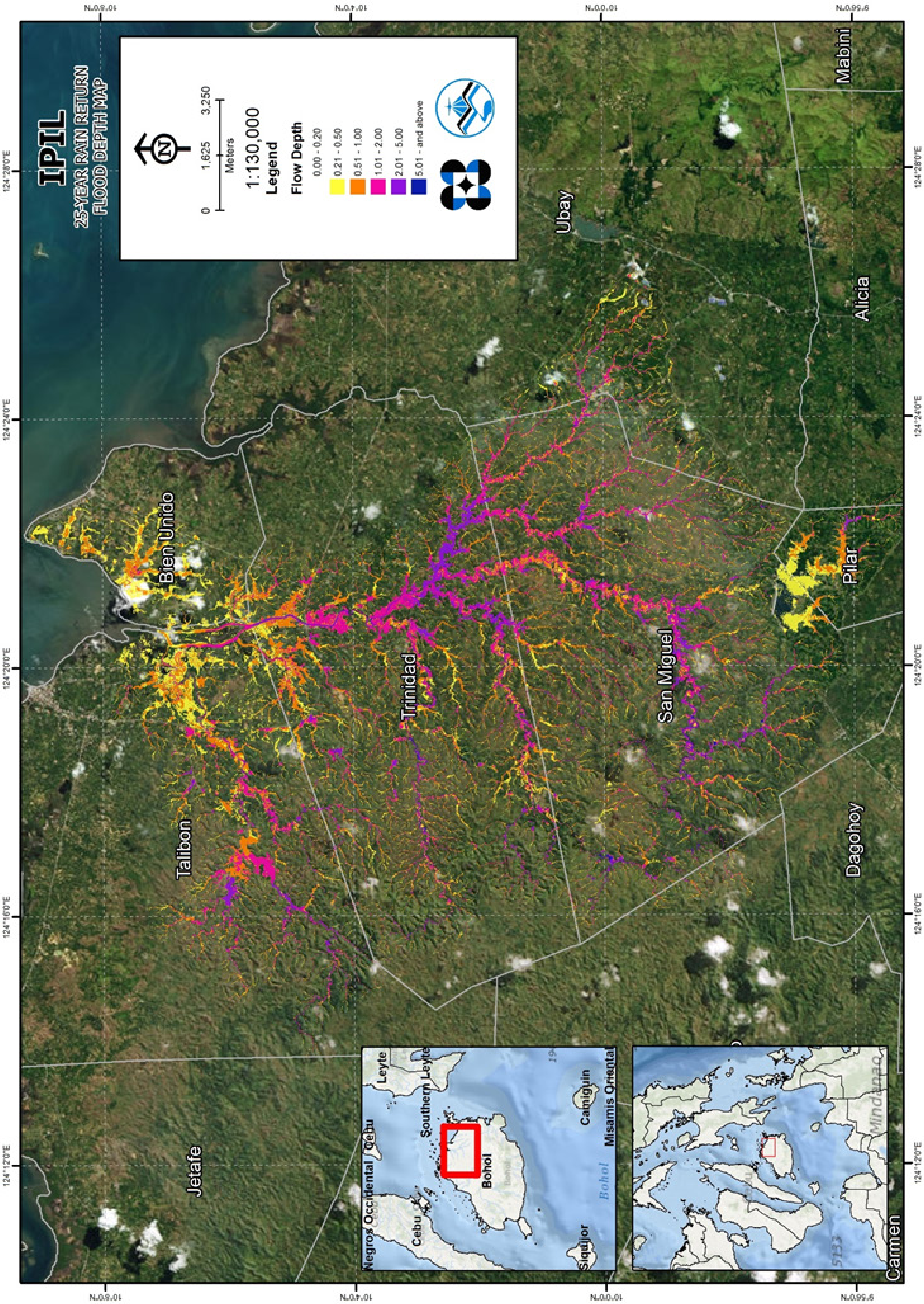



Figure 72. 25-year Flow Depth Map for Ipil Floodplain

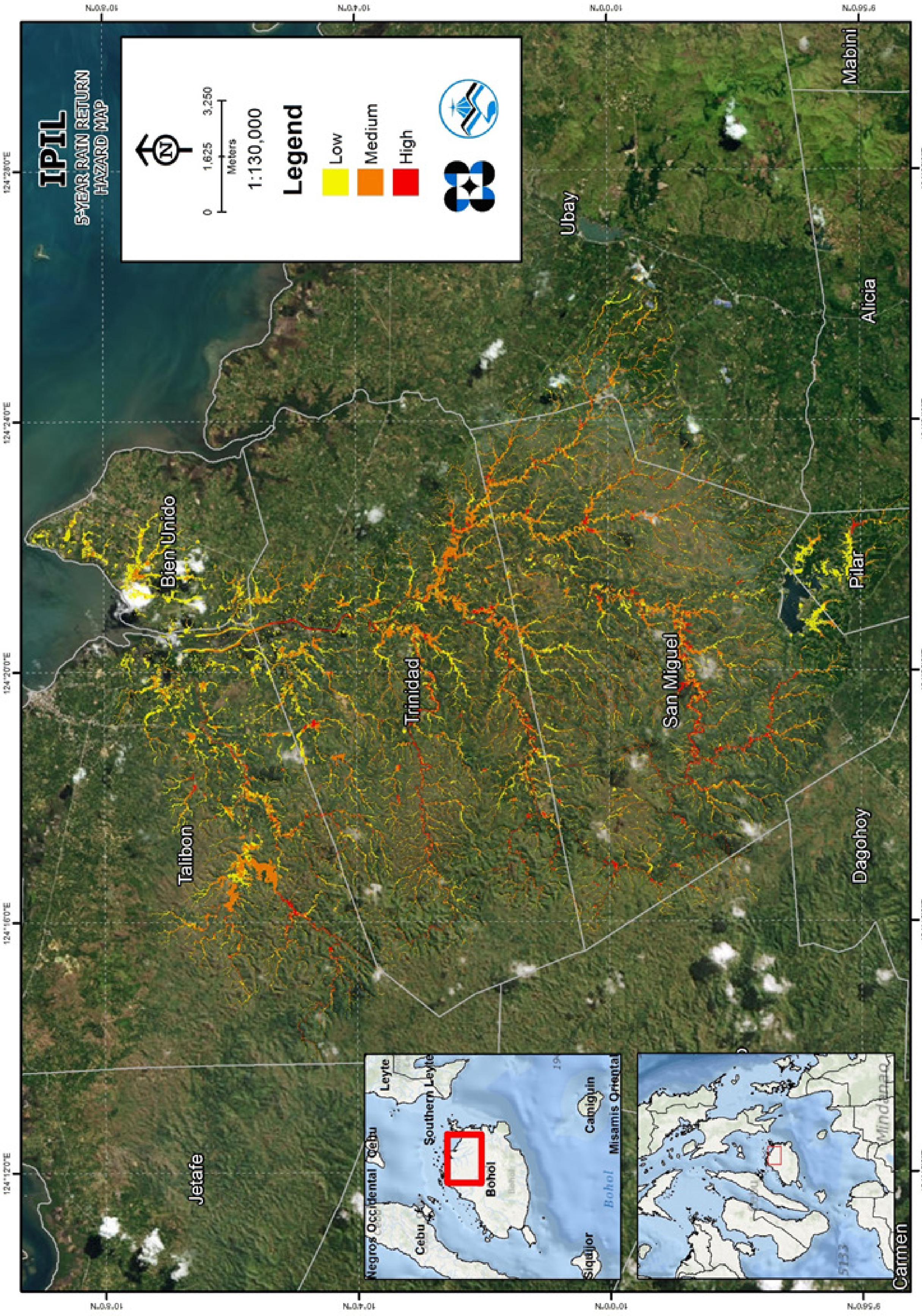



Figure 73. 5-year Flood Hazard Map for Ipil Floodplain

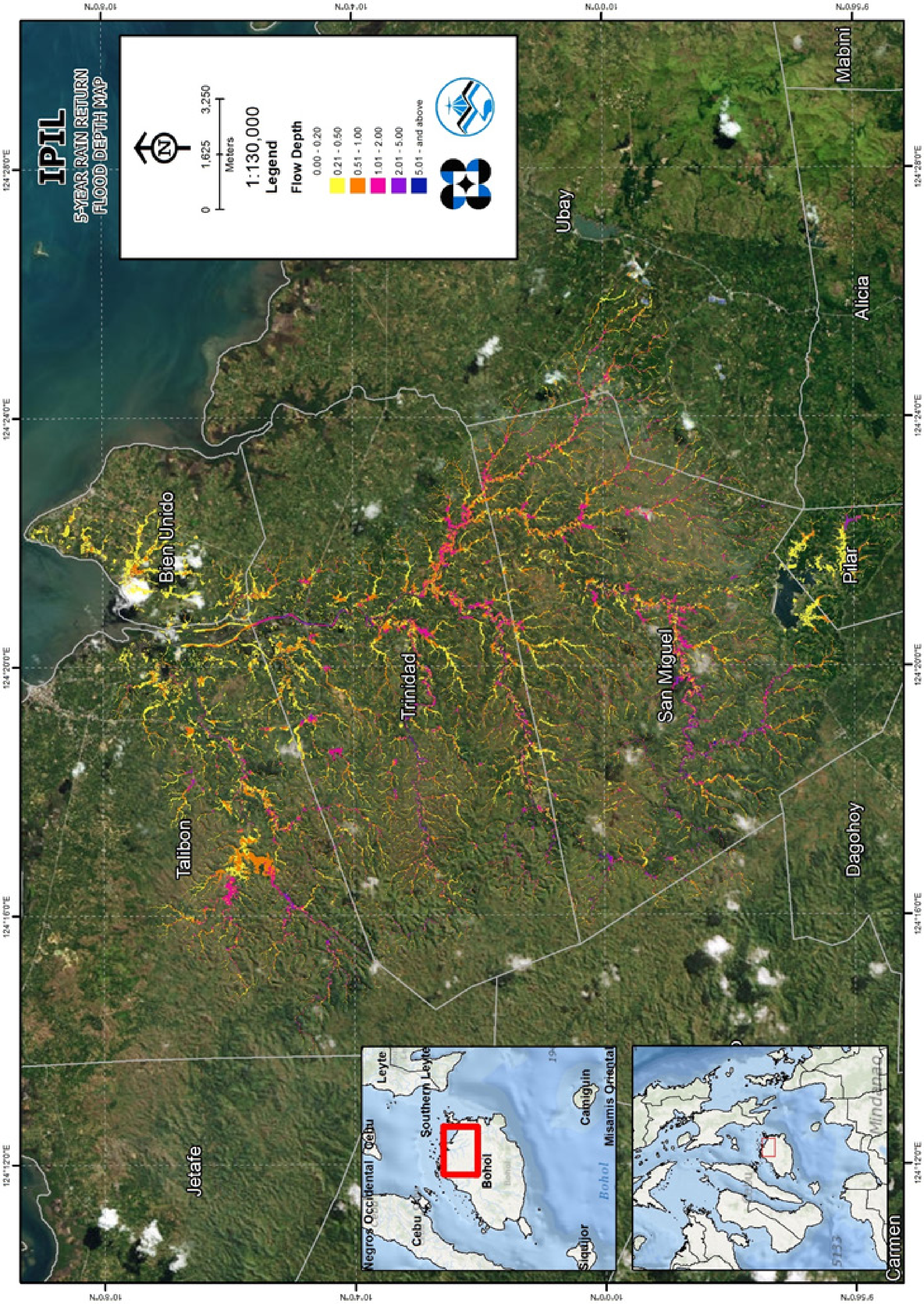



Figure 74. 5-year Flow Depth Map for Ipil Floodplain

## 5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Ipil river basin, grouped by municipality, are listed below. For the said basin, ten municipalities consisting of 67 barangays are expected to experience flooding when subjected to 5-yr rainfall return period. The complete list of educational and health institutions affected by flooding in Ipil Floodplain can be seen in Annexes 12-13.

For the 5-year return period, 1.02% of the municipality of Alicia with an area of 81.7 sq. km. will experience flood levels of less 0.20 meters. 0.023% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.0079%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Alicia, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Alicia (in sq. km.) |
|---|---|
| | Katipunan |
| 0.03-0.20 | 0.84 |
| 0.21-0.50 | 0.019 |
| 0.51-1.00 | 0.01 |
| 1.01-2.00 | 0.0064 |
| 2.01-5.00 | 0.0018 |
| > 5.00 | 0 |

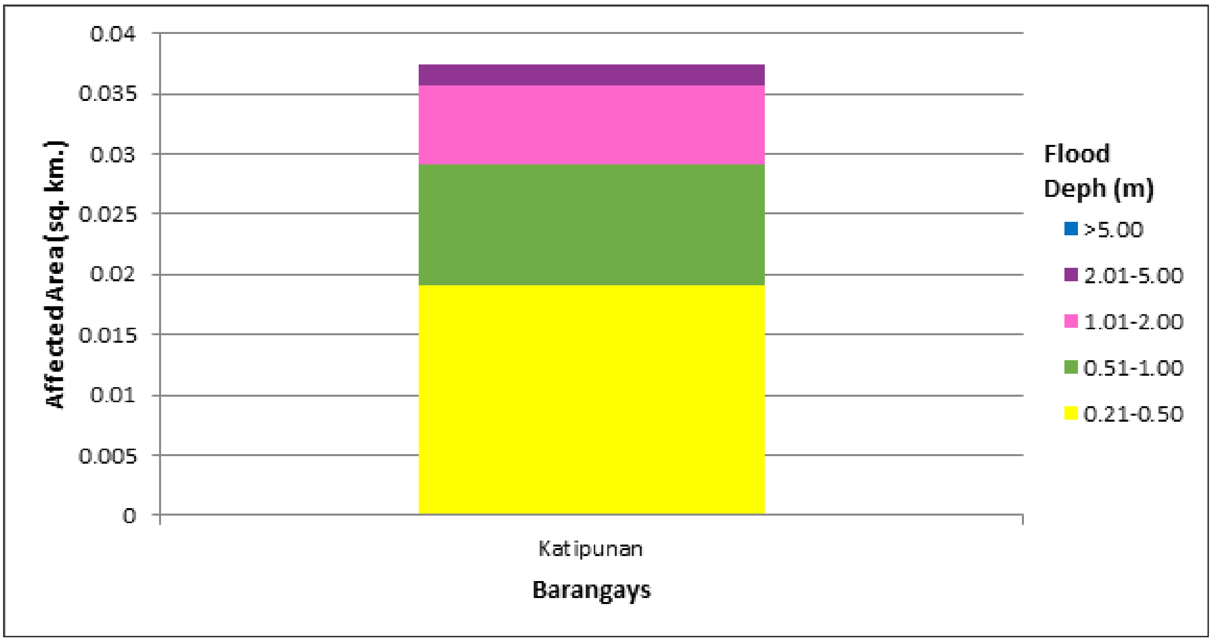



Figure 75. Affected Areas in Alicia, Bohol during 5-Year Rainfall Return Period

For the municipality of Bien Unido, with an area of 27.07 sq. km., 44.6% will experience flood levels of less 0.20 meters. 6.40% of the area will experience flood levels of 0.21 to 0.50 meters while 1.04%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Bien Unido, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Bien Unido (in sq. km.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Liberty | Mandawa | Nueva Esperanza | Nueva Estrella | Poblacion | Puerto San Pedro | Tuboran |
| 0.03-0.20 | 1.12 | 1.03 | 5.51 | 3.05 | 0.59 | 0.78 | 0.00017 |
| 0.21-0.50 | 0.15 | 0.057 | 0.78 | 0.55 | 0.062 | 0.13 | 0 |
| 0.51-1.00 | 0.058 | 0.0049 | 0.13 | 0.076 | 0.0088 | 0.002 | 0 |
| 1.01-2.00 | 0.0091 | 0 | 0.0079 | 0.0052 | 0 | 0 | 0 |
| 2.01-5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

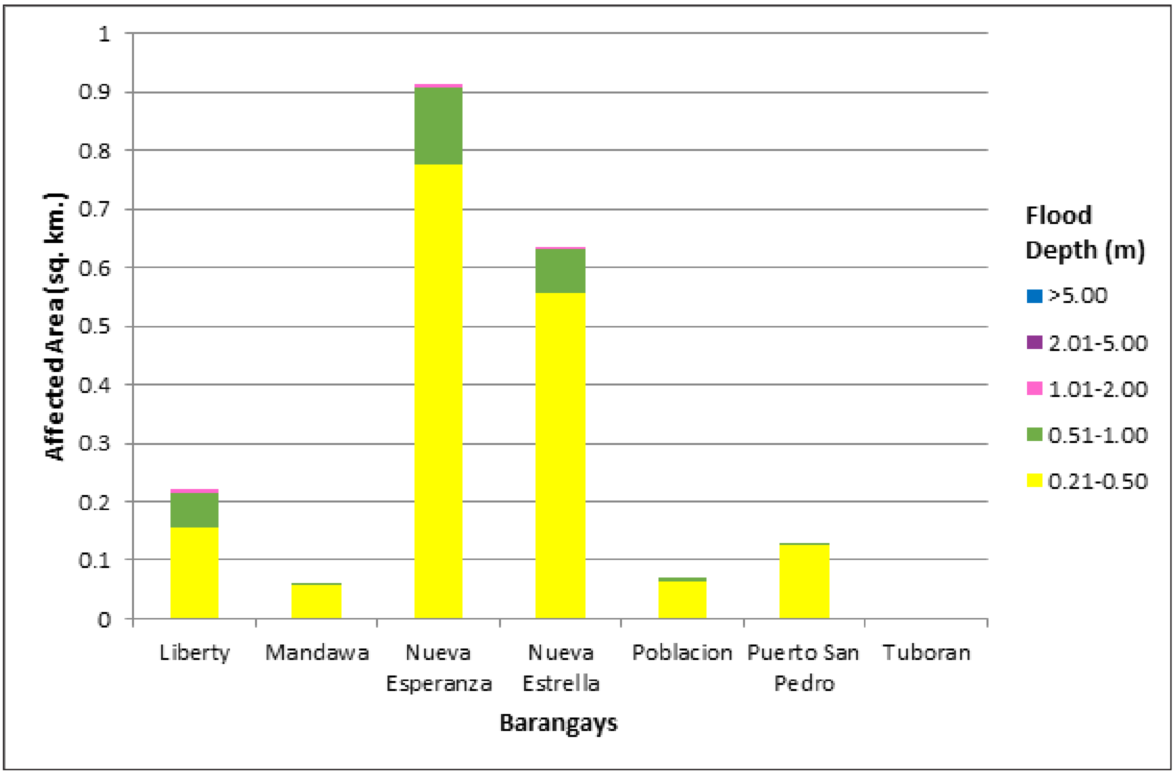



Figure 76. Affected Areas in Bien Unido, Bohol during 5-Year Rainfall Return Period

For the municipality of Dagohoy, with an area of 92.47 sq. km., 0.024% will experience flood levels of less 0.20 meters. 0.001% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0002% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Dagohoy, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Dagohoy (in sq. km.) |
|---|---|
| | Cagawasan |
| 0.03-0.20 | 0.023 |
| 0.21-0.50 | 0.00097 |
| 0.51-1.00 | 0.00019 |
| 1.01-2.00 | 0 |
| 2.01-5.00 | 0 |
| > 5.00 | 0 |

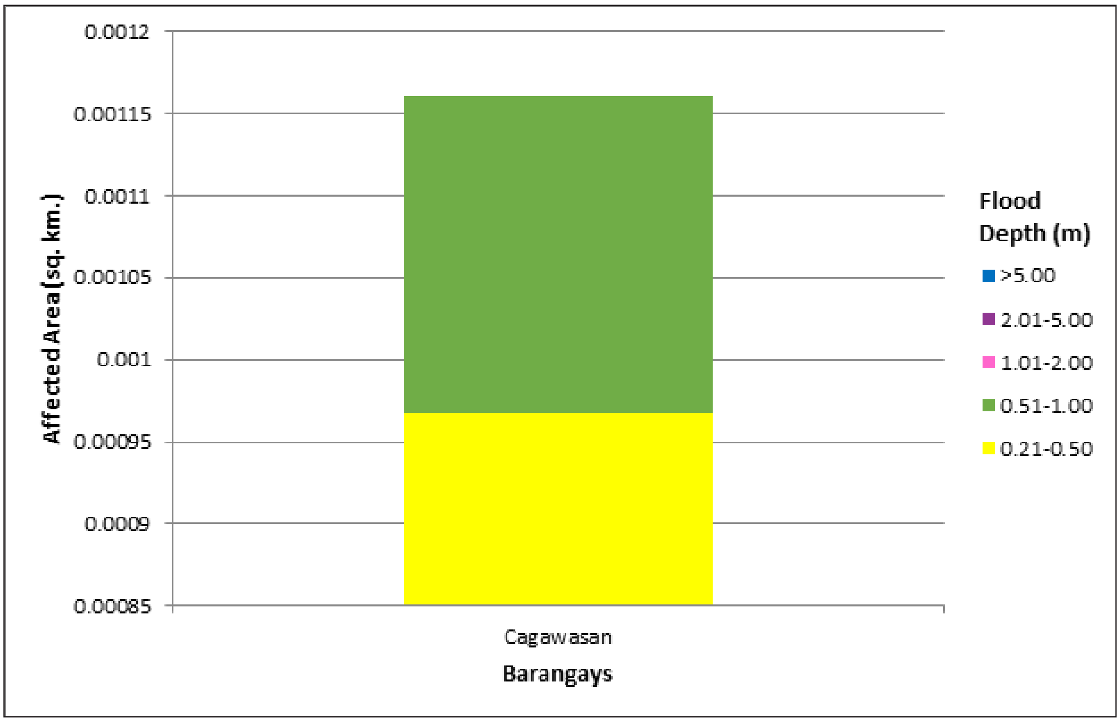



Figure 77. Affected Areas in Dagohoy, Bohol during 5-Year Rainfall

For the municipality of Danao, with an area of 109 sq. km., 2.46% will experience flood levels of less 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.02%, 0.007%, and 0.0006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Danao, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Danao (in sq. km.) | |
|---|---|---|
| | Dagohoy | San Miguel |
| 0.03-0.20 | 0.89 | 1.74 |
| 0.21-0.50 | 0.035 | 0.051 |
| 0.51-1.00 | 0.024 | 0.031 |
| 1.01-2.00 | 0.0041 | 0.019 |
| 2.01-5.00 | 0.0033 | 0.0042 |
| > 5.00 | 0 | 0.0006 |

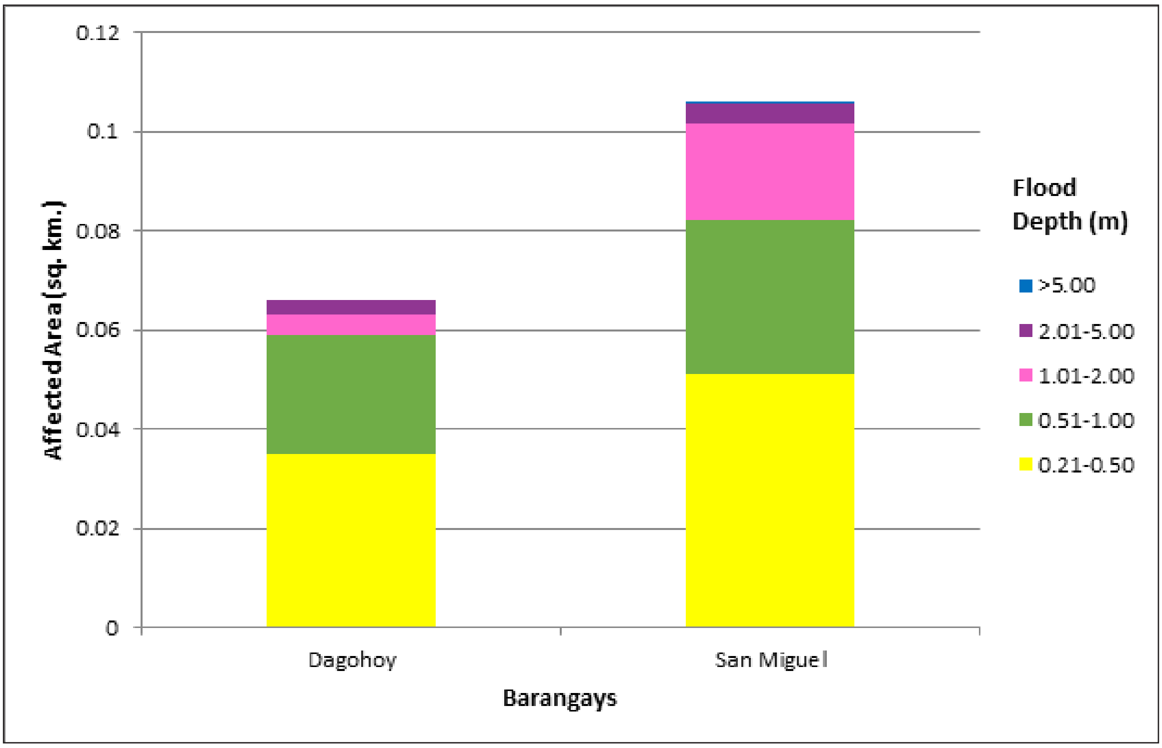



Figure 78. Affected Areas in Danao, Bohol during 5-Year Rainfall Return Period

For the municipality of Jetafe, with an area of 94.04 sq. km., 0.025% will experience flood levels of less 0.20 meters. 0.0002% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0001% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 39 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Jetafe, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Jetafe (in sq. km.) |
|---|---|
| | Cabasakan |
| 0.03-0.20 | 0.024 |
| 0.21-0.50 | 0.0002 |
| 0.51-1.00 | 0.0001 |
| 1.01-2.00 | 0 |
| 2.01-5.00 | 0 |
| > 5.00 | 0 |


Figure 79. Figure. Affected Areas in Jetafe, Bohol during 5-Year Rainfall Return Period

For the municipality of Pilar, with an area of 114.4 sq. km., 6.28% will experience flood levels of less 0.20 meters. 0.69% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.04%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Pilar, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Pilar (in sq. km.) |
|---|---|
| | La Suerte |
| **0.03-0.20** | 7.18 |
| **0.21-0.50** | 0.79 |
| **0.51-1.00** | 0.22 |
| **1.01-2.00** | 0.044 |
| **2.01-5.00** | 0.034 |
| **> 5.00** | 0 |

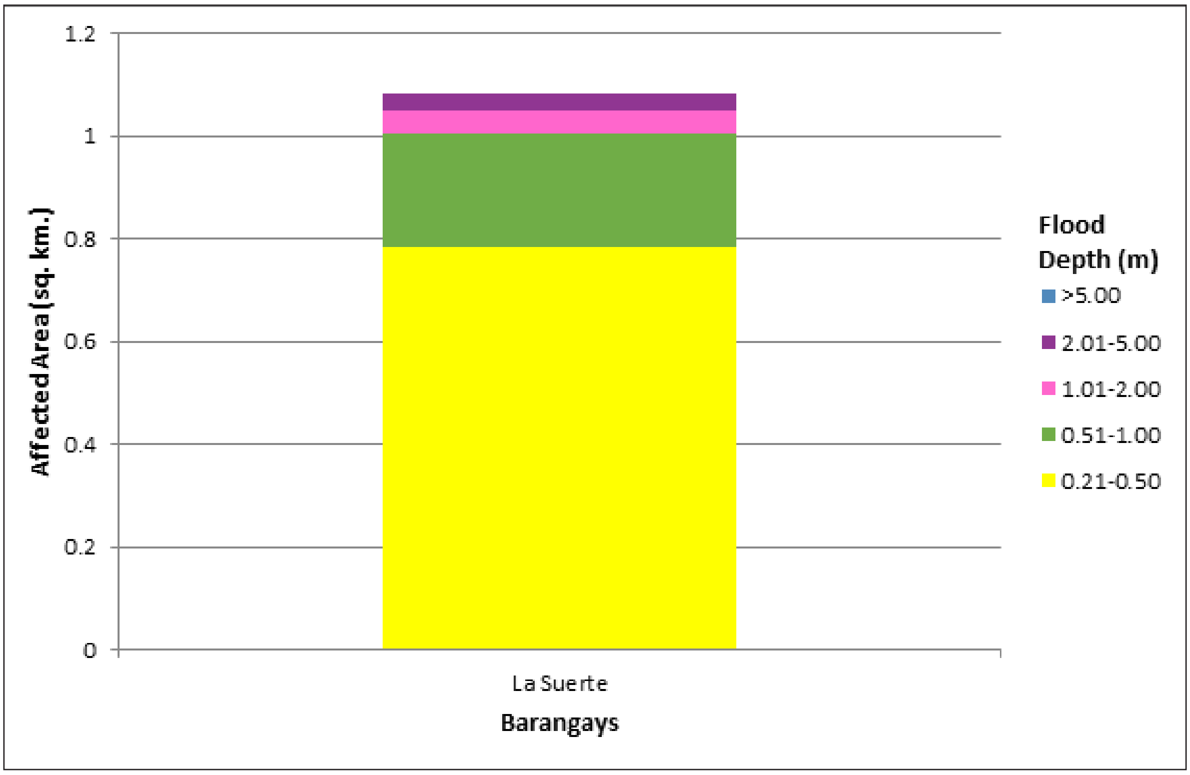



Figure 80. Affected Areas in Pilar, Bohol during 5-Year Rainfall Return Period

For the municipality of San Miguel, with an area of 107 sq. km., 86.93% will experience flood levels of less 0.20 meters. 4.52% of the area will experience flood levels of 0.21 to 0.50 meters while 3.43%, 2.02%, 0.57%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and 42 are the affected areas in square kilometres by flood depth per barangay.

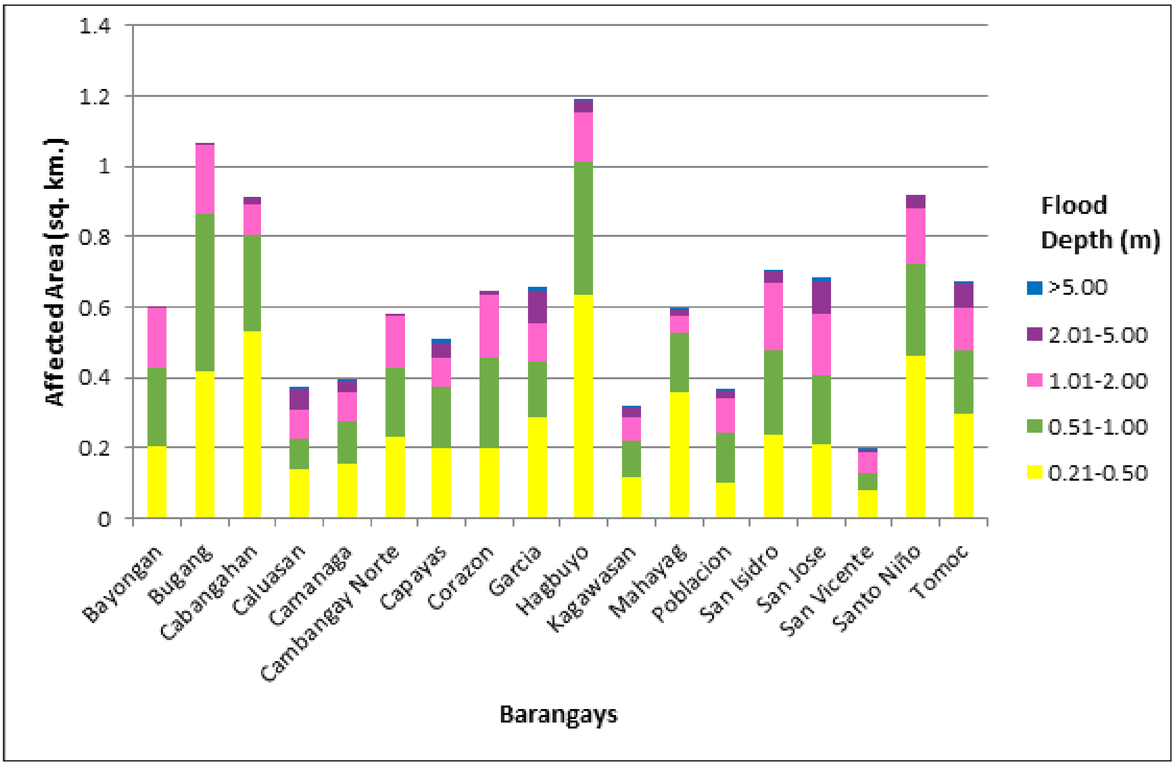



Figure 81. Affected Areas in San Miguel, Bohol during 5-Year Rainfall Return Period

Table 41. Affected Areas in San Miguel, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in San Miguel (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bayongan | Bugang | Cabangahan | Caluasan | Camanaga | Cambangay Norte | Capayas | Corazon | Garcia |
| 0.03-0.20 | 5.62 | 5.41 | 7.58 | 4.8 | 4.3 | 3.54 | 4.57 | 4.14 | 7.38 |
| 0.21-0.50 | 0.2 | 0.42 | 0.53 | 0.14 | 0.15 | 0.23 | 0.2 | 0.2 | 0.29 |
| 0.51-1.00 | 0.23 | 0.45 | 0.27 | 0.091 | 0.12 | 0.2 | 0.18 | 0.26 | 0.16 |
| 1.01-2.00 | 0.17 | 0.2 | 0.088 | 0.082 | 0.078 | 0.14 | 0.08 | 0.18 | 0.11 |
| 2.01-5.00 | 0.008 | 0.0084 | 0.02 | 0.059 | 0.032 | 0.0056 | 0.044 | 0.011 | 0.088 |
| > 5.00 | 0 | 0 | 0 | 0.0051 | 0.0001 | 0 | 0.0094 | 0 | 0.012 |

Table 42. Affected Areas in San Miguel, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in San Miguel (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hagbuyo | Kagawasan | Mahayag | Poblacion | San Isidro | San Jose | San Vicente | Santo Niño | Tomoc |
| 0.03-0.20 | 7.88 | 3.17 | 5.39 | 1.63 | 3.81 | 3.81 | 1.78 | 10.07 | 8.42 |
| 0.21-0.50 | 0.63 | 0.12 | 0.35 | 0.1 | 0.24 | 0.21 | 0.081 | 0.46 | 0.3 |
| 0.51-1.00 | 0.38 | 0.11 | 0.17 | 0.14 | 0.24 | 0.2 | 0.047 | 0.26 | 0.18 |
| 1.01-2.00 | 0.14 | 0.063 | 0.053 | 0.095 | 0.19 | 0.17 | 0.06 | 0.16 | 0.12 |
| 2.01-5.00 | 0.034 | 0.027 | 0.013 | 0.023 | 0.034 | 0.092 | 0.0047 | 0.039 | 0.068 |
| > 5.00 | 0.0013 | 0.002 | 0.0002 | 0.0035 | 0.0033 | 0.014 | 0.00055 | 0 | 0.0014 |

For the municipality of Talibon, with an area of 148 sq. km., 31.2% will experience flood levels of less 0.20 meters. 2.41% of the area will experience flood levels of 0.21 to 0.50 meters while 1.51%, 0.61%, 0.17%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Talibon, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Talibon (in sq. km.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Balintawak | Magsaysay | Rizal | San Agustin | San Carlos | San Isidro | San Jose | San Roque | Sikatuna | Zamora |
| 0.03-0.20 | 2.84 | 13.19 | 2.13 | 6.71 | 1.21 | 0.089 | 0.068 | 5.04 | 4.4 | 10.51 |
| 0.21-0.50 | 0.32 | 0.4 | 0.08 | 0.91 | 0.093 | 0.0016 | 0.0004 | 0.57 | 0.42 | 0.76 |
| 0.51-1.00 | 0.087 | 0.42 | 0.052 | 0.31 | 0.014 | 0.0011 | 0 | 0.21 | 0.57 | 0.57 |
| 1.01-2.00 | 0.013 | 0.31 | 0.029 | 0.05 | 0.0026 | 0 | 0 | 0.026 | 0.25 | 0.22 |
| 2.01-5.00 | 0 | 0.13 | 0.0071 | 0.035 | 0.0008 | 0 | 0 | 0.0013 | 0.0067 | 0.074 |
| > 5.00 | 0 | 0.0001 | 0 | 0.0005 | 0 | 0 | 0 | 0 | 0 | 0.0012 |

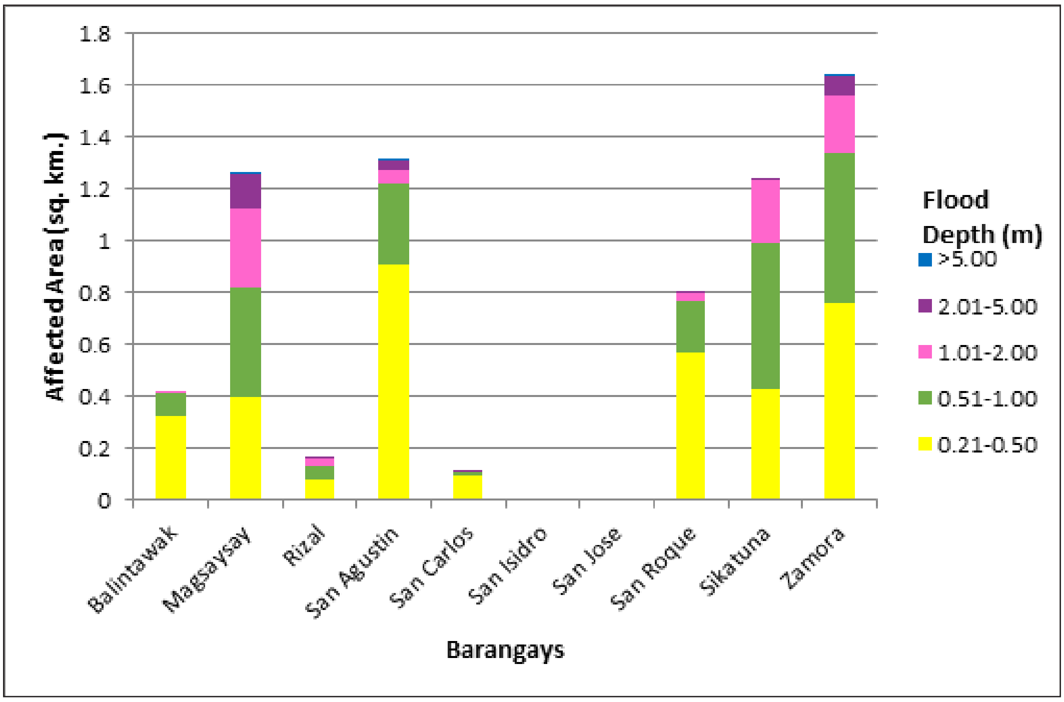



Figure 82. Affected Areas in Talibon, Bohol during 5-Year Rainfall Return Period

For the municipality of Trinidad, with an area of 143 sq. km., 51.83% will experience flood levels of less 0.20 meters. 3.73% of the area will experience flood levels of 0.21 to 0.50 meters while 2.61%, 1.29%, 0.39%, 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 more than 5 meters, respectively. Listed in Tables 44-45 are the affected areas in square kilometres by flood depth per barangay.

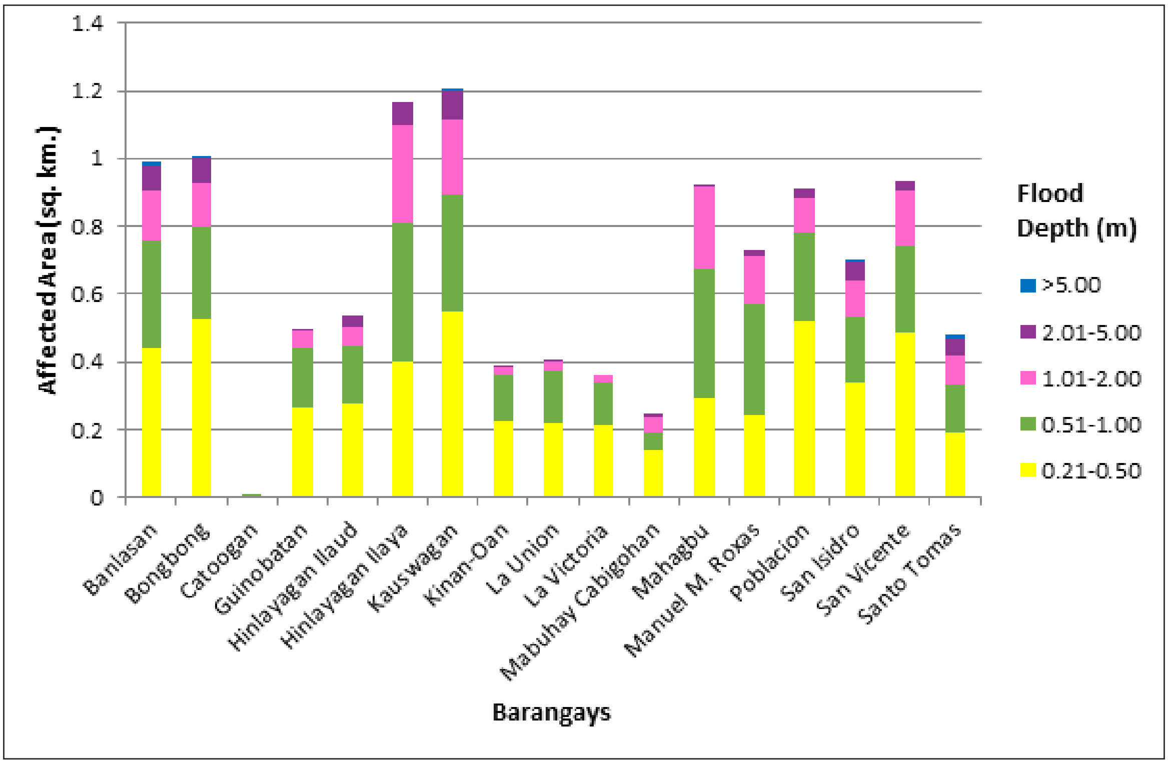



Figure 83. Affected Areas in Trinidad, Bohol during 5-Year Rainfall Return Period

Table 44. Affected Areas in Trinidad, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Trinidad (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Banlasan | Bongbong | Catoogan | Guinobatan | Hinlayagan Ilaud | Hinlayagan Ilaya | Kauswagan | Kinan-Oan | La Union |
| **0.03-0.20** | 8.03 | 5.8 | 0.076 | 3.62 | 1.65 | 4.78 | 15.29 | 3.8 | 2.89 |
| **0.21-0.50** | 0.44 | 0.52 | 0.0042 | 0.27 | 0.28 | 0.4 | 0.55 | 0.23 | 0.22 |
| **0.51-1.00** | 0.31 | 0.28 | 0.00007 | 0.17 | 0.17 | 0.41 | 0.35 | 0.13 | 0.16 |
| **1.01-2.00** | 0.15 | 0.13 | 0 | 0.049 | 0.055 | 0.29 | 0.22 | 0.022 | 0.027 |
| **2.01-5.00** | 0.078 | 0.077 | 0 | 0.0049 | 0.034 | 0.069 | 0.087 | 0.0014 | 0.0063 |
| **> 5.00** | 0.0064 | 0.0007 | 0 | 0 | 0 | 0 | 0.0012 | 0 | 0 |

Table 45. Affected Areas in Trinidad, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Trinidad (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | La Victoria | Mabuhay Cabigohan | Mahagbu | Manuel M. Roxas | Poblacion | San Isidro | San Vicente | Santo Tomas |
| **0.03-0.20** | 2.31 | 1.8 | 3.92 | 2.73 | 3.1 | 5.25 | 5.58 | 3.39 |
| **0.21-0.50** | 0.21 | 0.14 | 0.29 | 0.24 | 0.52 | 0.34 | 0.48 | 0.19 |
| **0.51-1.00** | 0.13 | 0.051 | 0.38 | 0.33 | 0.26 | 0.19 | 0.26 | 0.14 |
| **1.01-2.00** | 0.019 | 0.043 | 0.24 | 0.14 | 0.1 | 0.11 | 0.17 | 0.083 |
| **2.01-5.00** | 0 | 0.014 | 0.0019 | 0.017 | 0.029 | 0.058 | 0.029 | 0.052 |
| **> 5.00** | 0 | 0 | 0 | 0 | 0 | 0.0001 | 0 | 0.0076 |

For the municipality of Ubay, with an area of 264.8 sq. km., 6.09% will experience flood levels of less 0.20 meters. 0.26% of the area will experience flood levels of 0.21 to 0.50 meters while 0.17%, 0.09%, and 0.006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Ubay, Bohol during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Ubay (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Buenavista | Bulilis | Camali-An | Gabi | Hambabauran | Lomangog | Los Angeles | Pag-Asa | Tubog |
| **0.03-0.20** | 0.052 | 0.78 | 4.07 | 1.36 | 6.82 | 1.26 | 0.52 | 1.22 | 0.032 |
| **0.21-0.50** | 0.0006 | 0.022 | 0.15 | 0.059 | 0.29 | 0.082 | 0.021 | 0.074 | 0.0016 |
| **0.51-1.00** | 0.0001 | 0.016 | 0.13 | 0.039 | 0.19 | 0.019 | 0.014 | 0.041 | 0.0001 |
| **1.01-2.00** | 0.0001 | 0.012 | 0.088 | 0.0095 | 0.11 | 0.0018 | 0.0064 | 0.012 | 0 |
| **2.01-5.00** | 0 | 0.0014 | 0.0033 | 0 | 0.0095 | 0 | 0.00048 | 0 | 0 |
| **> 5.00** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

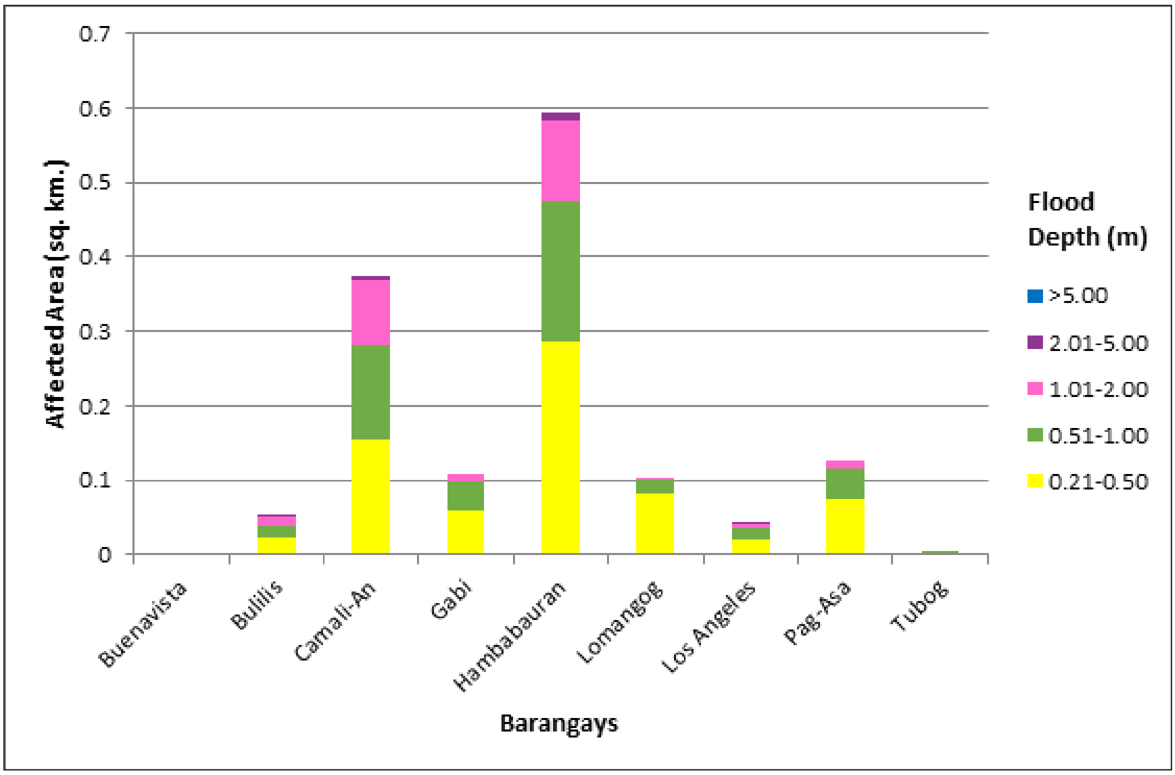



Figure 84. Affected Areas in Ubay, Bohol during 5-Year Rainfall Return Period

For the 25-year return period, 1.01% of the municipality of Alicia with an area of 81.7 sq. km. will experience flood levels of less 0.20 meters. 0.025% of the area will experience flood levels of 0.21 to 0.50 meters while 0.015%, 0.012%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 47 are the affected areas in square kilometres by flood depth per barangay.

Table 47. Affected Areas in Alicia, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Alicia (in sq. km.) |
|---|---|
| | Katipunan |
| **0.03-0.20** | 0.83 |
| **0.21-0.50** | 0.02 |
| **0.51-1.00** | 0.012 |
| **1.01-2.00** | 0.0098 |
| **2.01-5.00** | 0.0022 |
| **> 5.00** | 0 |

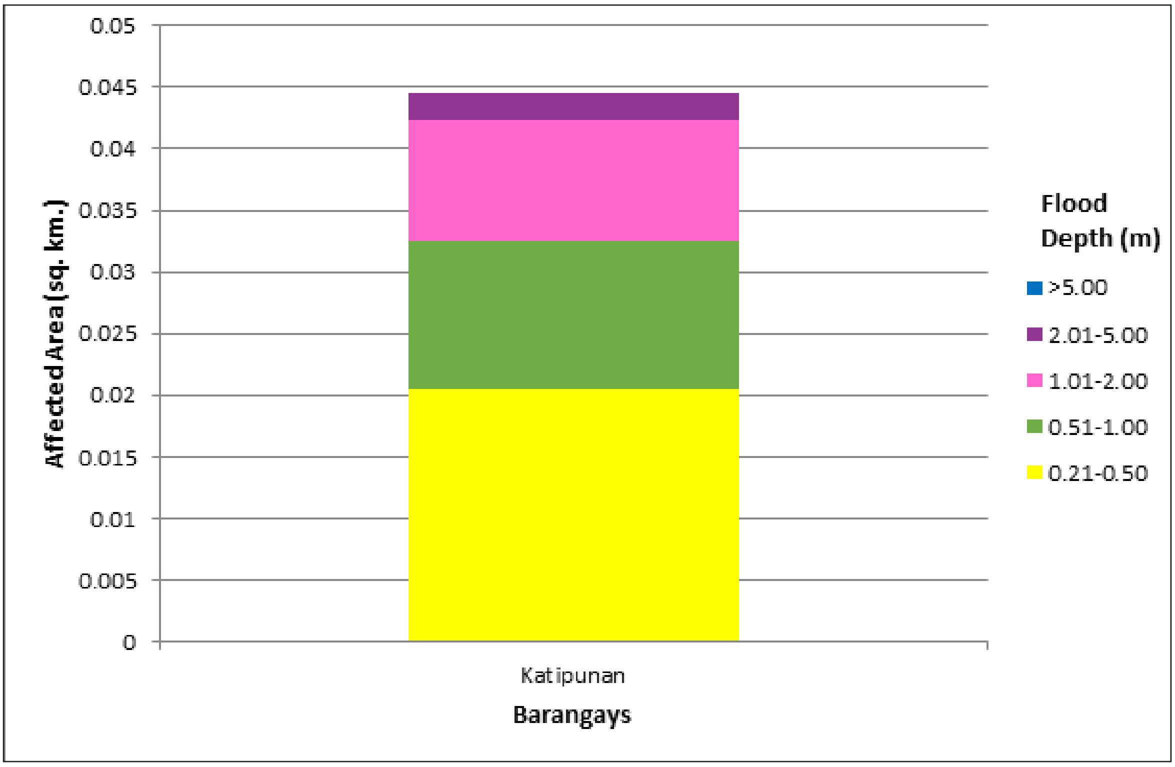



Figure 85. Affected Areas in Alicia, Bohol during 25-Year Rainfall Return Period

For the municipality of Bien Unido, with an area of 27.07 sq. km., 40.21% will experience flood levels of less 0.20 meters. 8.16% of the area will experience flood levels of 0.21 to 0.50 meters while 3.49%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 48 are the affected areas in square kilometres by flood depth per barangay.

Table 48. Affected Areas in Bien Unido, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Bien Unido (in sq. km.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Liberty | Mandawa | Nueva Esperanza | Nueva Estrella | Poblacion | Puerto San Pedro | Tuboran |
| **0.03-0.20** | 1.01 | 0.96 | 4.92 | 2.78 | 0.54 | 0.68 | 0.00017 |
| **0.21-0.50** | 0.16 | 0.12 | 1.12 | 0.56 | 0.089 | 0.17 | 0 |
| **0.51-1.00** | 0.15 | 0.013 | 0.36 | 0.34 | 0.03 | 0.053 | 0 |
| **1.01-2.00** | 0.026 | 0.00039 | 0.031 | 0.013 | 0 | 0.0013 | 0 |
| **2.01-5.00** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **> 5.00** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

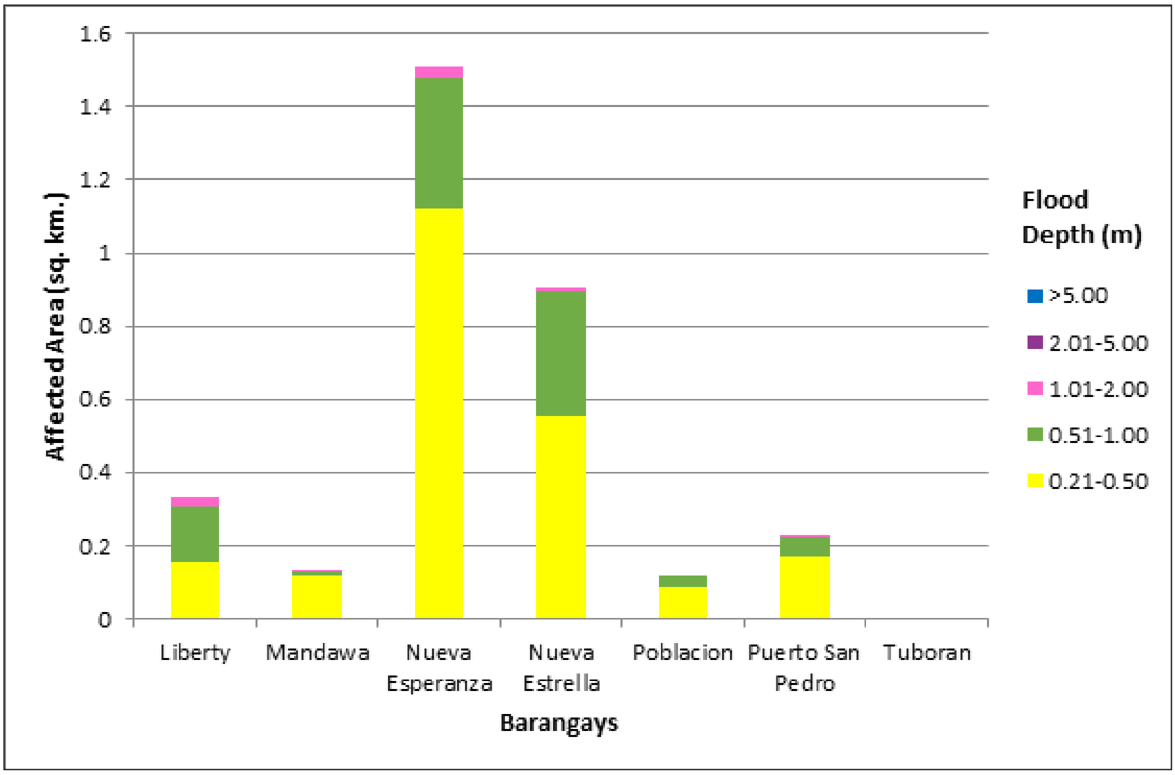



Figure 86. Affected Areas in Bien Unido, Bohol during 25-Year Rainfall Return Period

For the municipality of Dagohoy, with an area of 92.47 sq. km., 0.024% will experience flood levels of less 0.20 meters. 0.001% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0002% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 49 are the affected areas in square kilometres by flood depth per barangay.

Table 49. Affected Areas in Dagohoy, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Dagohoy (in sq. km.) |
|---|---|
| | Cagawasan |
| 0.03-0.20 | 0.022 |
| 0.21-0.50 | 0.0013 |
| 0.51-1.00 | 0.00019 |
| 1.01-2.00 | 0 |
| 2.01-5.00 | 0 |
| > 5.00 | 0 |

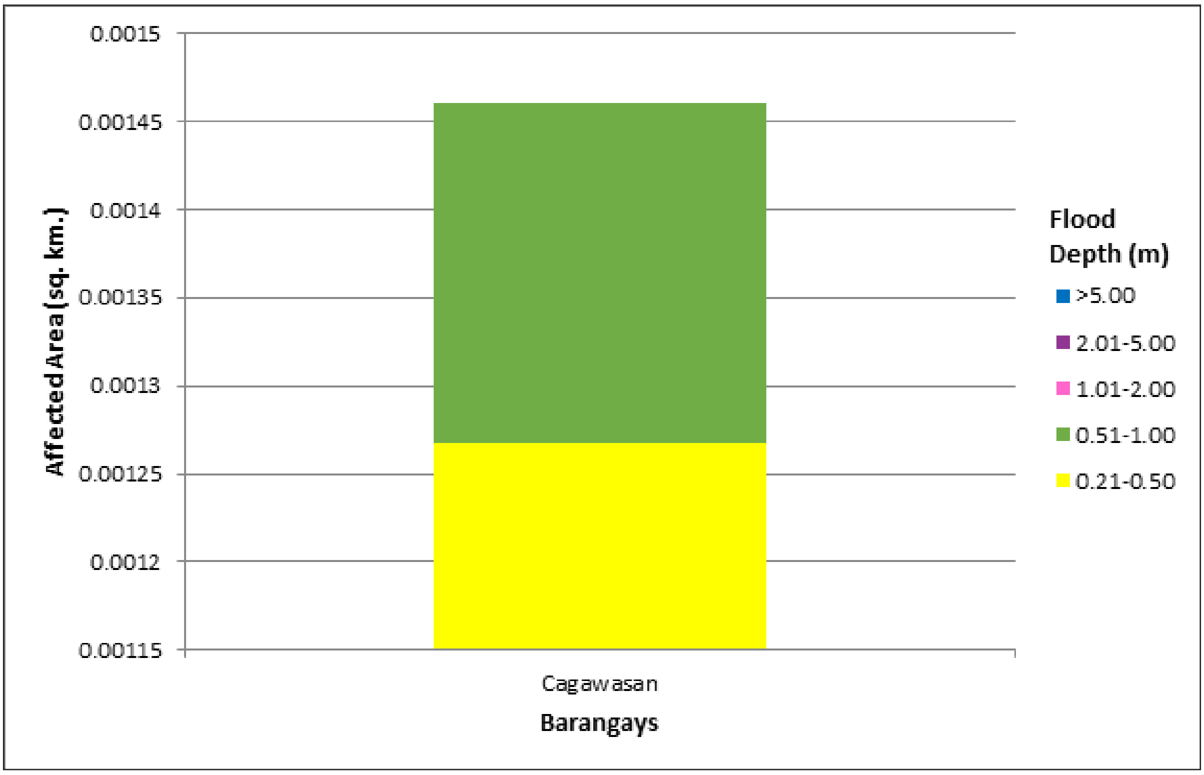



Figure 87. Affected Areas in Dagohoy, Bohol during 25-Year Rainfall

For the municipality of Danao, with an area of 109 sq. km., 2.43% will experience flood levels of less 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.03%, 0.01%, and 0.0006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected Areas in Danao, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Danao (in sq. km.) | |
|---|---|---|
| | Dagohoy | San Miguel |
| **0.03-0.20** | 0.88 | 1.71 |
| **0.21-0.50** | 0.032 | 0.06 |
| **0.51-1.00** | 0.029 | 0.037 |
| **1.01-2.00** | 0.01 | 0.027 |
| **2.01-5.00** | 0.0043 | 0.0074 |
| **> 5.00** | 0 | 0.0006 |

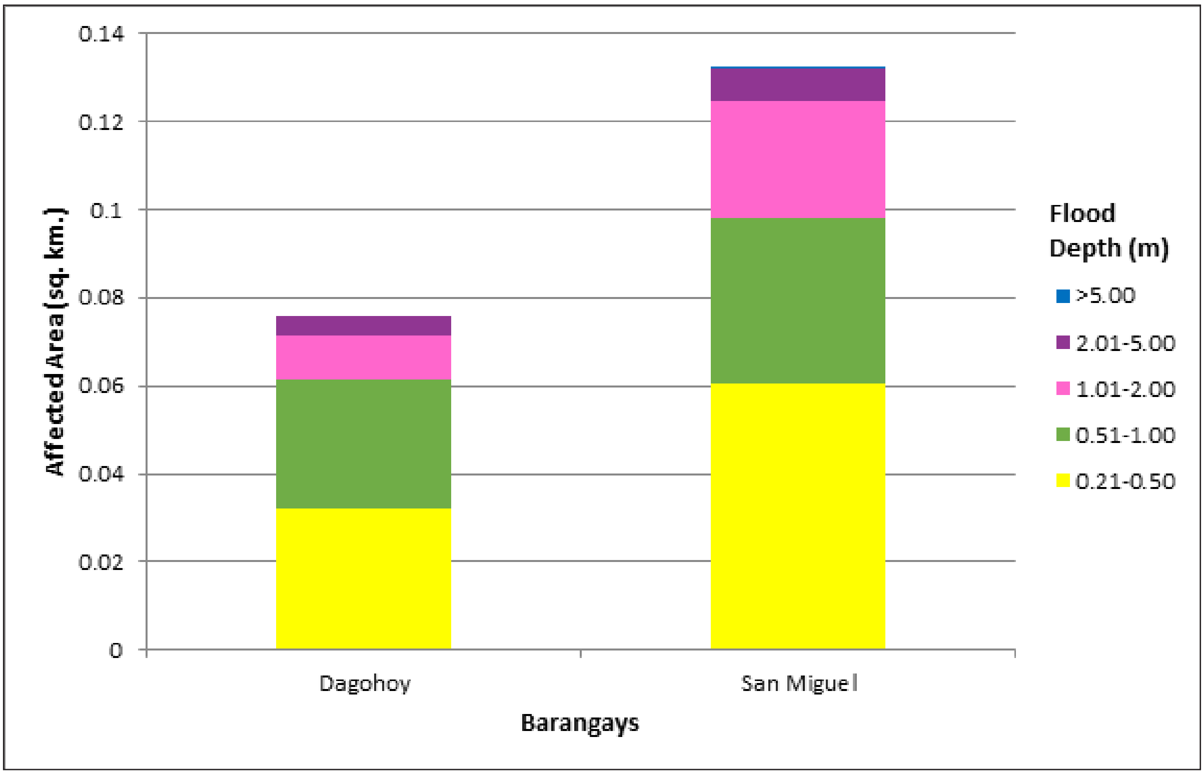



Figure 88. Affected Areas in Danao, Bohol during 25-Year Rainfall Return Period

For the municipality of Jetafe, with an area of 94.04 sq. km., 0.025% will experience flood levels of less 0.20 meters. 0.0002% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0002%, and 0.0001% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 51 are the affected areas in square kilometres by flood depth per barangay.

Table 51. Affected Areas in Jetafe, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Jetafe (in sq. km.) |
|---|---|
| | Cabasakan |
| **0.03-0.20** | 0.024 |
| **0.21-0.50** | 0.00017 |
| **0.51-1.00** | 0.0002 |
| **1.01-2.00** | 0.0001 |
| **2.01-5.00** | 0 |
| **> 5.00** | 0 |


Figure 89. Affected Areas in Jetafe, Bohol during 25-Year Rainfall Return Period

For the municipality of Pilar, with an area of 114.4 sq. km., 5.78% will experience flood levels of less 0.20 meters. 0.7% of the area will experience flood levels of 0.21 to 0.50 meters while 0.62%, 0.08%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 52 are the affected areas in square kilometres by flood depth per barangay.

Table 52. Affected Areas in Pilar, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Pilar (in sq. km.) |
|---|---|
| | La Suerte |
| 0.03-0.20 | 6.61 |
| 0.21-0.50 | 0.8 |
| 0.51-1.00 | 0.71 |
| 1.01-2.00 | 0.088 |
| 2.01-5.00 | 0.053 |
| > 5.00 | 0 |

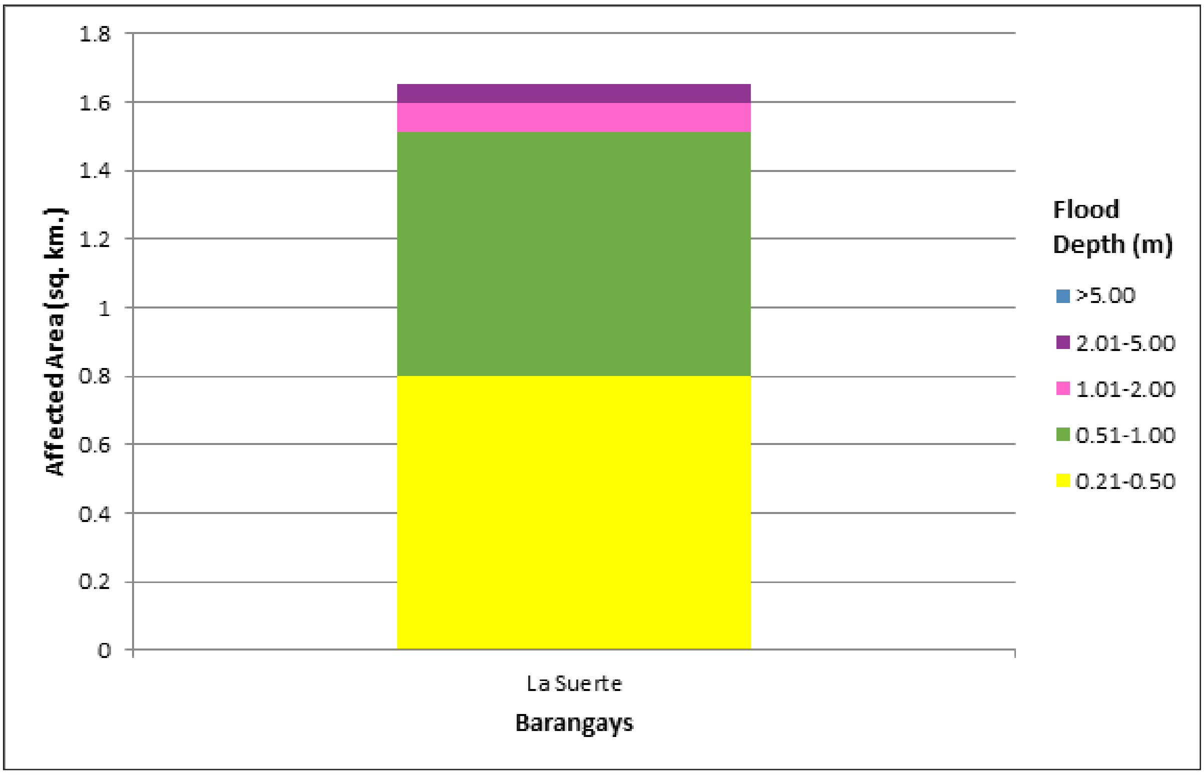



Figure 90. Affected Areas in Pilar, Bohol during 25-Year Rainfall Return Period

For the municipality of San Miguel, with an area of 107 sq. km., 83.25% will experience flood levels of less 0.20 meters. 4.28% of the area will experience flood levels of 0.21 to 0.50 meters while 4.11%, 4.09%, 1.66%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 53 are the affected areas in square kilometres by flood depth per barangay.

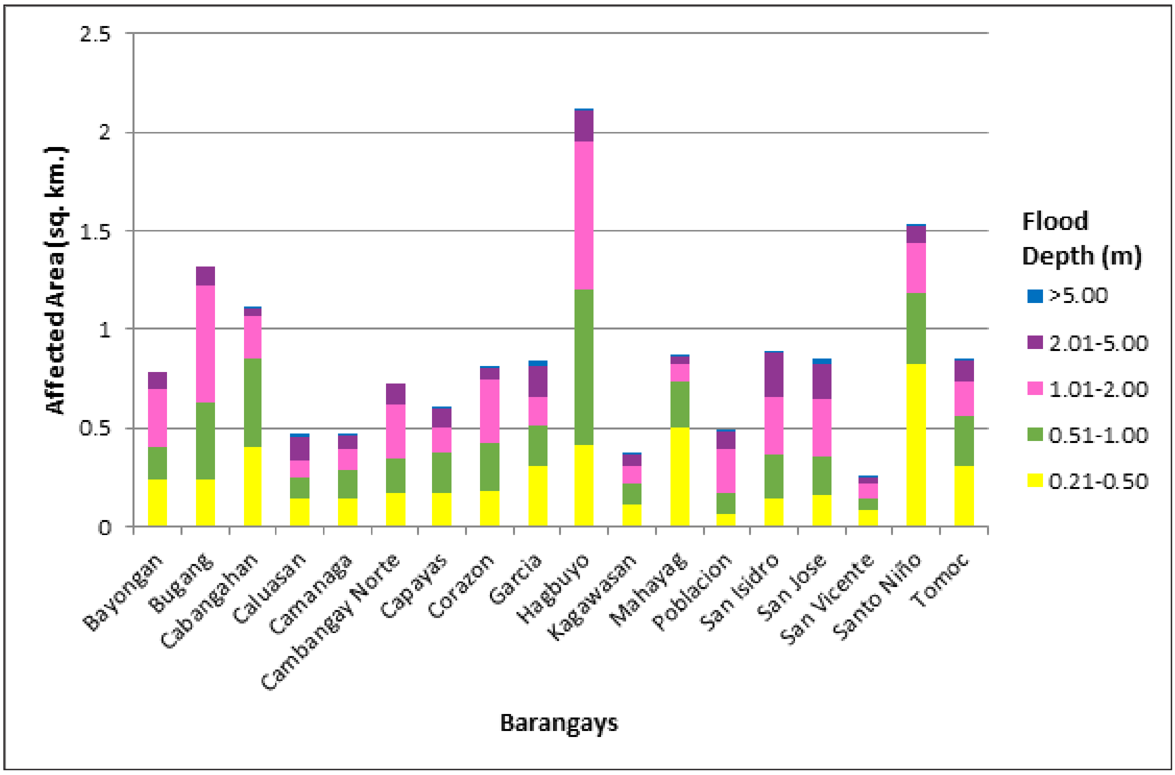



Figure 91. Affected Areas in San Miguel, Bohol during 25-Year Rainfall Return Period

Table 53. Affected Areas in San Miguel, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in San Miguel (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bayongan | Bugang | Cabangahan | Caluasan | Camanaga | Cambangay Norte | Capayas | Corazon | Garcia |
| **0.03-0.20** | 5.45 | 5.15 | 7.39 | 4.7 | 4.22 | 3.4 | 4.47 | 3.98 | 7.19 |
| **0.21-0.50** | 0.23 | 0.24 | 0.4 | 0.14 | 0.14 | 0.17 | 0.17 | 0.18 | 0.31 |
| **0.51-1.00** | 0.17 | 0.39 | 0.45 | 0.1 | 0.15 | 0.18 | 0.2 | 0.24 | 0.2 |
| **1.01-2.00** | 0.29 | 0.59 | 0.21 | 0.084 | 0.1 | 0.27 | 0.13 | 0.32 | 0.15 |
| **2.01-5.00** | 0.081 | 0.099 | 0.045 | 0.12 | 0.066 | 0.11 | 0.093 | 0.058 | 0.15 |
| **> 5.00** | 0 | 0 | 0.0004 | 0.025 | 0.0027 | 0 | 0.018 | 0.0006 | 0.033 |

Table 54. Affected Areas in San Miguel, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in San Miguel (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hagbuyo | Kagawasan | Mahayag | Poblacion | San Isidro | San Jose | San Vicente | Santo Niño | Tomoc |
| **0.03-0.20** | 6.97 | 3.12 | 5.12 | 1.51 | 3.62 | 3.64 | 1.73 | 9.47 | 8.23 |
| **0.21-0.50** | 0.41 | 0.11 | 0.5 | 0.064 | 0.14 | 0.16 | 0.083 | 0.83 | 0.31 |
| **0.51-1.00** | 0.79 | 0.12 | 0.24 | 0.11 | 0.22 | 0.19 | 0.06 | 0.35 | 0.25 |
| **1.01-2.00** | 0.75 | 0.084 | 0.088 | 0.22 | 0.3 | 0.29 | 0.075 | 0.26 | 0.17 |
| **2.01-5.00** | 0.15 | 0.057 | 0.033 | 0.083 | 0.23 | 0.18 | 0.025 | 0.086 | 0.12 |
| **> 5.00** | 0.0086 | 0.007 | 0.0004 | 0.0092 | 0.01 | 0.026 | 0.001 | 0.0015 | 0.0097 |

For the municipality of Talibon, with an area of 148 sq. km., 28.93% will experience flood levels of less 0.20 meters. 2.74% of the area will experience flood levels of 0.21 to 0.50 meters while 2.29%, 1.42%, 0.51%, and 0.009% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometres by flood depth per barangay.

Table 55. Affected Areas in Talibon, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Talibon (in sq. km.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Balintawak | Magsaysay | Rizal | San Agustin | San Carlos | San Isidro | San Jose | San Roque | Sikatuna | Zamora |
| **0.03-0.20** | 2.69 | 12.96 | 2.1 | 4.99 | 1.19 | 0.088 | 0.068 | 4.58 | 4.22 | 9.94 |
| **0.21-0.50** | 0.36 | 0.37 | 0.076 | 1.66 | 0.087 | 0.0016 | 0.0004 | 0.68 | 0.2 | 0.64 |
| **0.51-1.00** | 0.18 | 0.34 | 0.066 | 1.09 | 0.041 | 0.0011 | 0 | 0.35 | 0.51 | 0.81 |
| **1.01-2.00** | 0.034 | 0.49 | 0.044 | 0.23 | 0.0034 | 0.0002 | 0 | 0.23 | 0.51 | 0.56 |
| **2.01-5.00** | 0.0008 | 0.28 | 0.017 | 0.042 | 0.0019 | 0 | 0 | 0.0096 | 0.21 | 0.19 |
| **> 5.00** | 0 | 0.0031 | 0 | 0.0029 | 0 | 0 | 0 | 0 | 0 | 0.0066 |

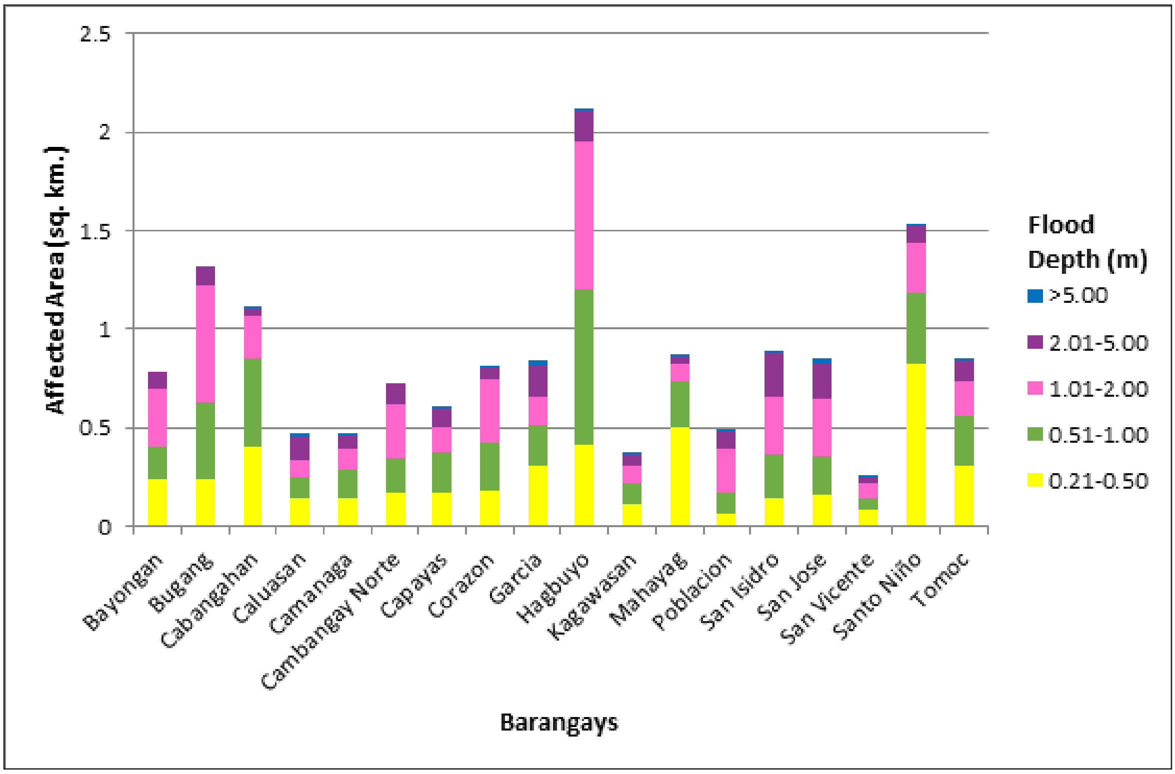



Figure 92. Affected Areas in Talibon, Bohol during 25-Year Rainfall Return Period

For the municipality of Trinidad, with an area of 143 sq. km., 48.26% will experience flood levels of less 0.20 meters. 2.98% of the area will experience flood levels of 0.21 to 0.50 meters while 3.7%, 3.18%, 1.69%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 56-57 are the affected areas in square kilometres by flood depth per barangay.

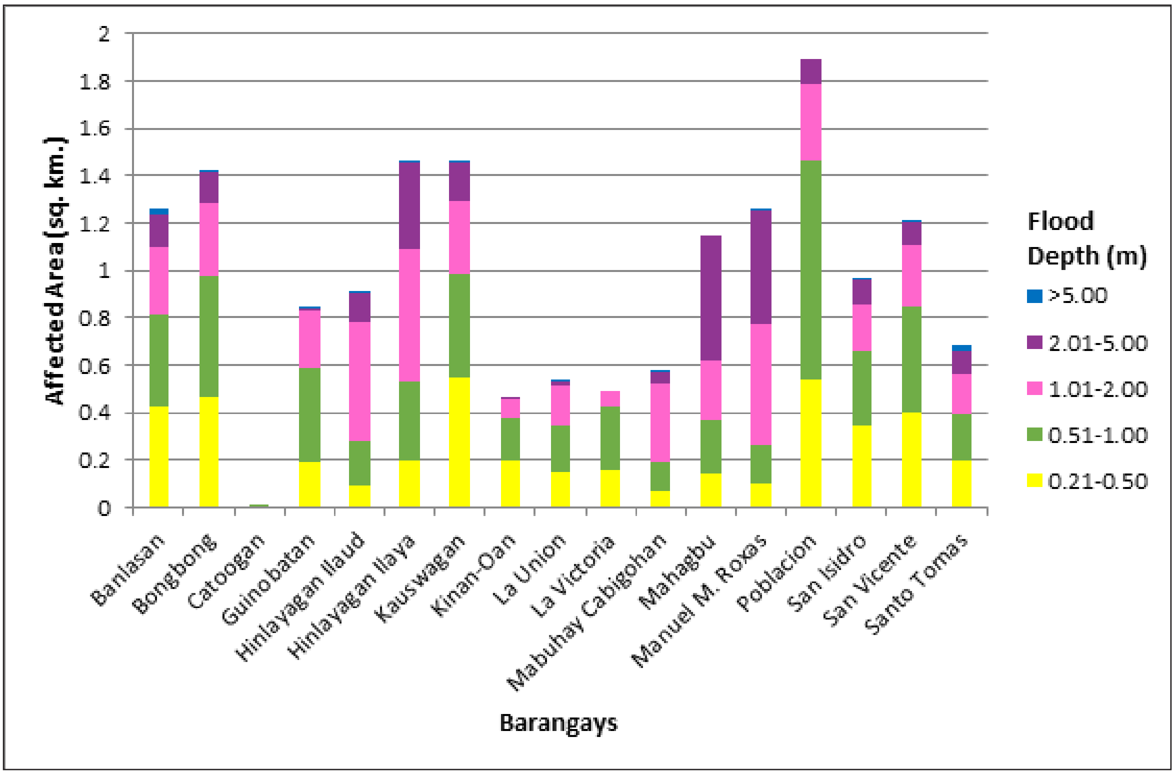



Figure 93. Affected Areas in Trinidad, Bohol during 25-Year Rainfall Return Period

Table 56. Table 56. Affected Areas in Trinidad, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Trinidad (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Banlasan | Bongbong | Catoogan | Guinobatan | Hinlayagan Ilaud | Hinlayagan Ilaya | Kauswagan | Kinan-Oan | La Union |
| **0.03-0.20** | 7.76 | 5.39 | 0.073 | 3.27 | 1.28 | 4.48 | 15.03 | 3.72 | 2.77 |
| **0.21-0.50** | 0.42 | 0.47 | 0.0058 | 0.19 | 0.096 | 0.2 | 0.55 | 0.2 | 0.15 |
| **0.51-1.00** | 0.39 | 0.51 | 0.0011 | 0.39 | 0.19 | 0.33 | 0.44 | 0.18 | 0.19 |
| **1.01-2.00** | 0.28 | 0.3 | 0 | 0.24 | 0.5 | 0.56 | 0.31 | 0.082 | 0.17 |
| **2.01-5.00** | 0.14 | 0.13 | 0 | 0.012 | 0.12 | 0.36 | 0.16 | 0.0046 | 0.014 |
| **> 5.00** | 0.023 | 0.0038 | 0 | 0.0003 | 0.0014 | 0.0091 | 0.0038 | 0 | 0.00069 |

Table 57. Affected Areas in Trinidad, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Trinidad (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | La Victoria | Mabuhay Cabigohan | Mahagbu | Manuel M. Roxas | Poblacion | San Isidro | San Vicente | Santo Tomas |
| **0.03-0.20** | 2.18 | 1.47 | 3.69 | 2.21 | 2.12 | 4.98 | 5.32 | 3.18 |
| **0.21-0.50** | 0.16 | 0.072 | 0.14 | 0.099 | 0.54 | 0.35 | 0.4 | 0.2 |
| **0.51-1.00** | 0.26 | 0.12 | 0.23 | 0.17 | 0.92 | 0.31 | 0.45 | 0.2 |
| **1.01-2.00** | 0.067 | 0.33 | 0.24 | 0.51 | 0.32 | 0.19 | 0.25 | 0.17 |
| **2.01-5.00** | 0 | 0.051 | 0.53 | 0.48 | 0.11 | 0.1 | 0.099 | 0.1 |
| **> 5.00** | 0 | 0.0001 | 0 | 0.0009 | 0 | 0.0027 | 0.0003 | 0.02 |

For the municipality of Ubay, with an area of 264.8 sq. km., 5.91% will experience flood levels of less 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.16%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 58 are the affected areas in square kilometres by flood depth per barangay.

Table 58. Affected Areas in Ubay, Bohol during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Ubay (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Buenavista | Bulilis | Camali-An | Gabi | Hambabauran | Lomangog | Los Angeles | Pag-Asa | Tubog |
| **0.03-0.20** | 0.052 | 0.76 | 3.92 | 1.33 | 6.65 | 1.21 | 0.51 | 1.18 | 0.031 |
| **0.21-0.50** | 0.00032 | 0.033 | 0.2 | 0.067 | 0.34 | 0.12 | 0.022 | 0.097 | 0.0029 |
| **0.51-1.00** | 0.0007 | 0.016 | 0.13 | 0.045 | 0.22 | 0.031 | 0.017 | 0.045 | 0.0002 |
| **1.01-2.00** | 0.0001 | 0.017 | 0.16 | 0.023 | 0.19 | 0.0092 | 0.0085 | 0.031 | 0 |
| **2.01-5.00** | 0 | 0.004 | 0.045 | 0.000003 | 0.024 | 0.0001 | 0.0016 | 0.0014 | 0 |
| **> 5.00** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

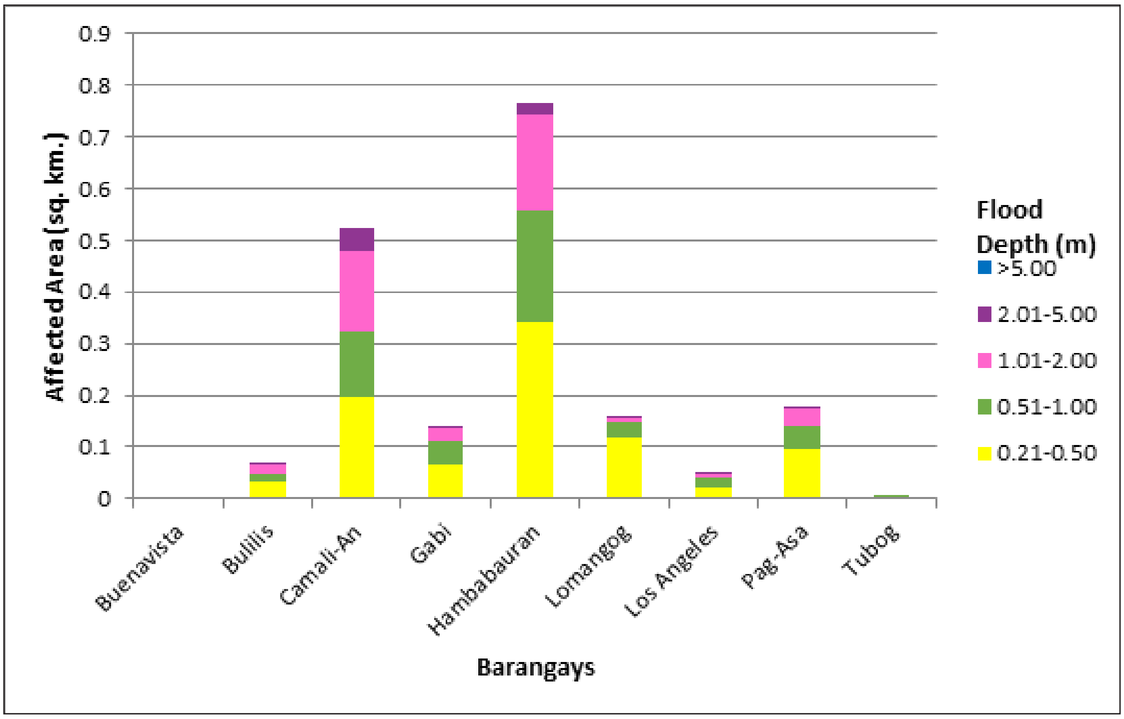



Figure 94. Affected Areas in Ubay, Bohol during 25-Year Rainfall Return Period

For the 100-year return period, 1.01% of the municipality of Alicia with an area of 81.7 sq. km. will experience flood levels of less 0.20 meters. 0.026% of the area will experience flood levels of 0.21 to 0.50 meters while 0.017%, 0.013%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 59 are the affected areas in square kilometres by flood depth per barangay.

Table 59. Affected Areas in Alicia, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Alicia (in sq. km.) |
|---|---|
| | Katipunan |
| **0.03-0.20** | 0.82 |
| **0.21-0.50** | 0.021 |
| **0.51-1.00** | 0.014 |
| **1.01-2.00** | 0.011 |
| **2.01-5.00** | 0.0033 |
| **> 5.00** | 0 |

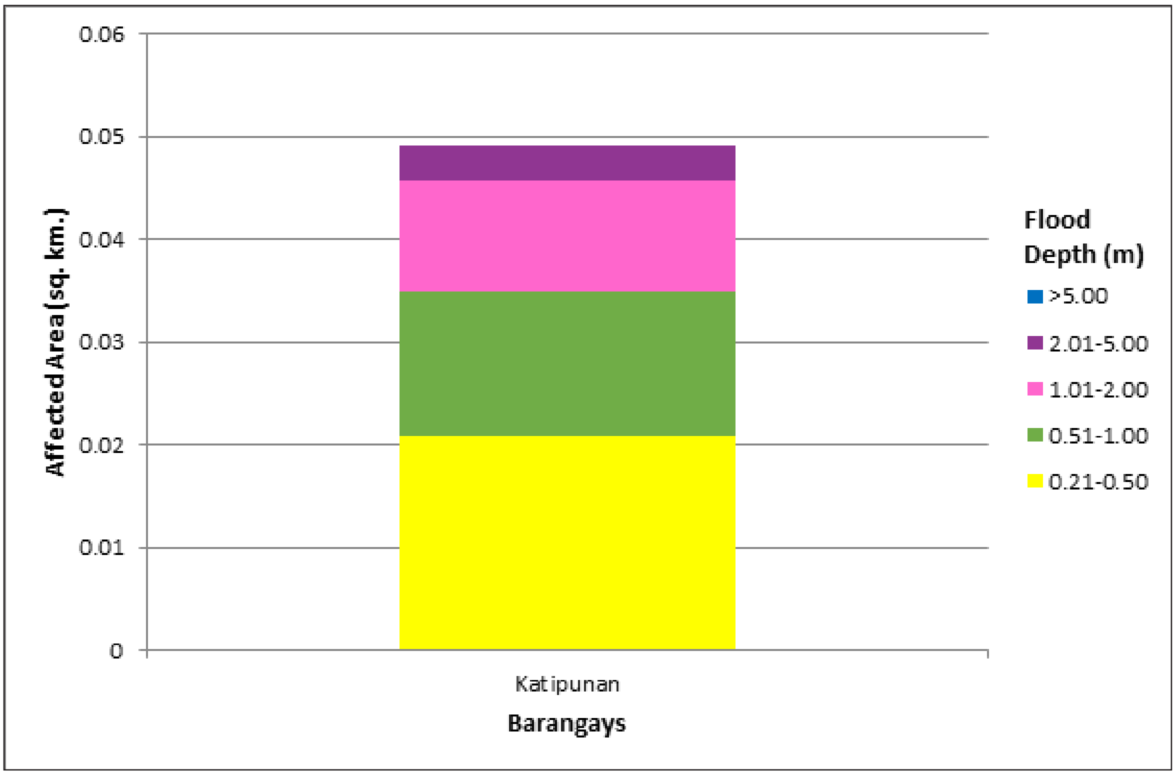



Figure 95. Affected Areas in Alicia, Bohol during 100-Year Rainfall Return Period

For the municipality of Bien Unido, with an area of 27.07 sq. km., 37.65% will experience flood levels of less 0.20 meters. 7.74% of the area will experience flood levels of 0.21 to 0.50 meters while 5.99%, 0.26%, and 0.001 of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 60 are the affected areas in square kilometres by flood depth per barangay.

Table 60. Affected Areas in Bien Unido, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Bien Unido (in sq. km.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Liberty | Mandawa | Nueva Esperanza | Nueva Estrella | Poblacion | Puerto San Pedro | Tuboran |
| **0.03-0.20** | 0.95 | 0.9 | 4.54 | 2.63 | 0.52 | 0.65 | 0.00017 |
| **0.21-0.50** | 0.075 | 0.17 | 1.13 | 0.52 | 0.077 | 0.13 | 0 |
| **0.51-1.00** | 0.25 | 0.022 | 0.66 | 0.51 | 0.063 | 0.13 | 0 |
| **1.01-2.00** | 0.065 | 0.00039 | 0.098 | 0.032 | 0 | 0.0046 | 0 |
| **2.01-5.00** | 0.0004 | 0 | 0 | 0 | 0 | 0 | 0 |
| **> 5.00** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

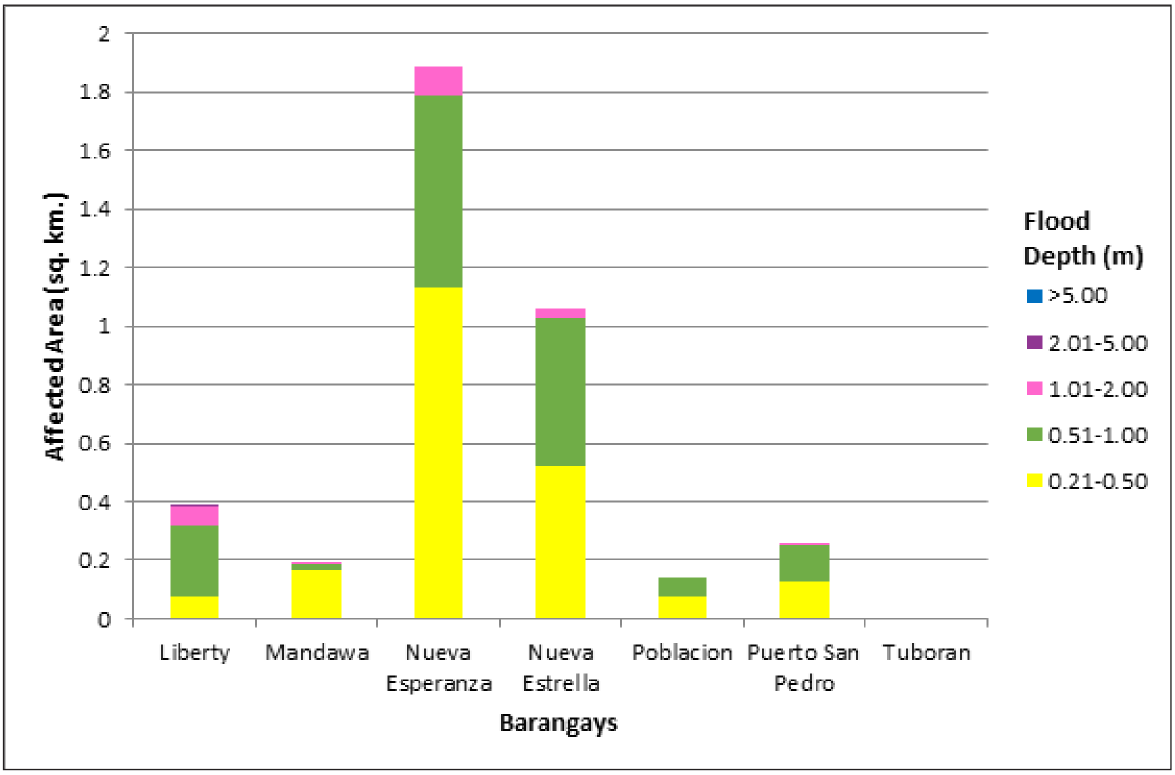



Figure 96. Affected Areas in Bien Unido, Bohol during 100-Year Rainfall Return Period

For the municipality of Dagohoy, with an area of 92.47 sq. km., 0.024% will experience flood levels of less 0.20 meters. 0.001% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0006% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 61 are the affected areas in square kilometres by flood depth per barangay.

Table 61. Affected Areas in Dagohoy, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Dagohoy (in sq. km.) |
|---|---|
| | Cagawasan |
| 0.03-0.20 | 0.022 |
| 0.21-0.50 | 0.0012 |
| 0.51-1.00 | 0.00056 |
| 1.01-2.00 | 0 |
| 2.01-5.00 | 0 |
| > 5.00 | 0 |

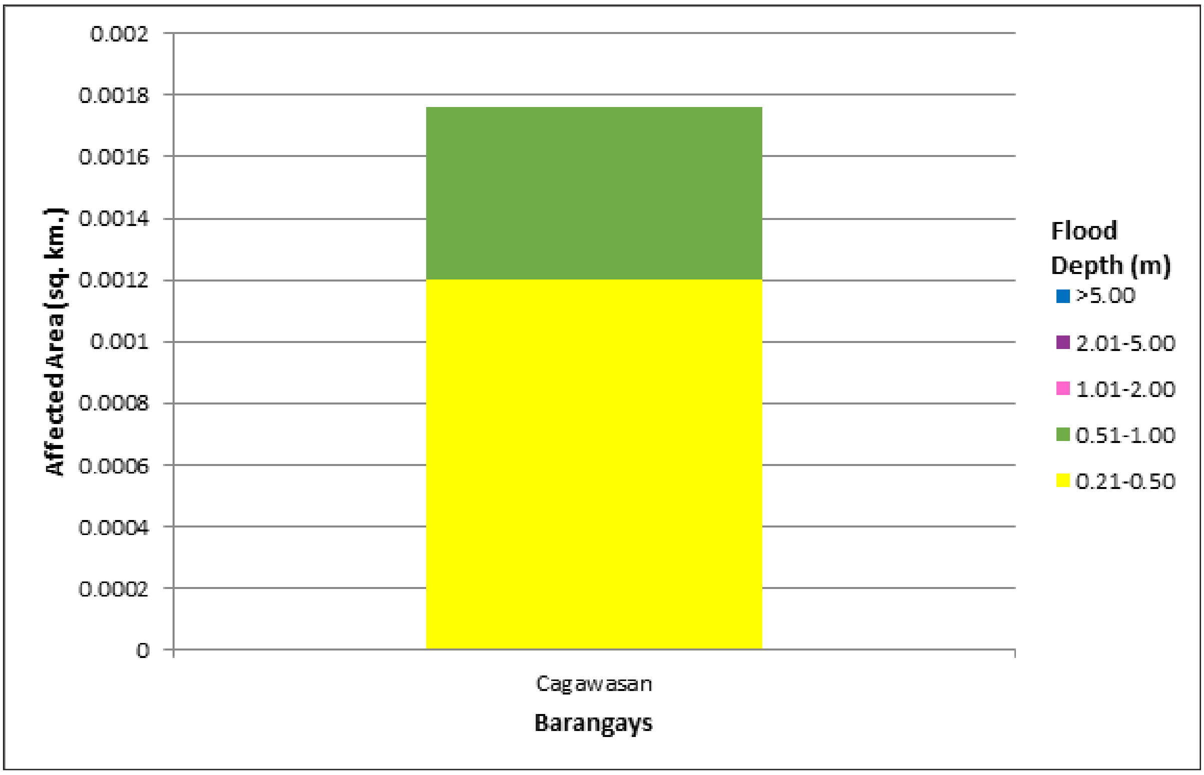



Figure 97. Affected Areas in Dagohoy, Bohol during 100-Year Rainfall

For the municipality of Danao, with an area of 109 sq. km., 2.40% will experience flood levels of less 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.04%, 0.01%, and 0.0006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 62 are the affected areas in square kilometres by flood depth per barangay.

Table 62. Affected Areas in Danao, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Danao (in sq. km.) | |
|---|---|---|
| | Dagohoy | San Miguel |
| **0.03-0.20** | 0.88 | 1.7 |
| **0.21-0.50** | 0.031 | 0.063 |
| **0.51-1.00** | 0.03 | 0.044 |
| **1.01-2.00** | 0.016 | 0.03 |
| **2.01-5.00** | 0.0045 | 0.011 |
| **> 5.00** | 0 | 0.0007 |

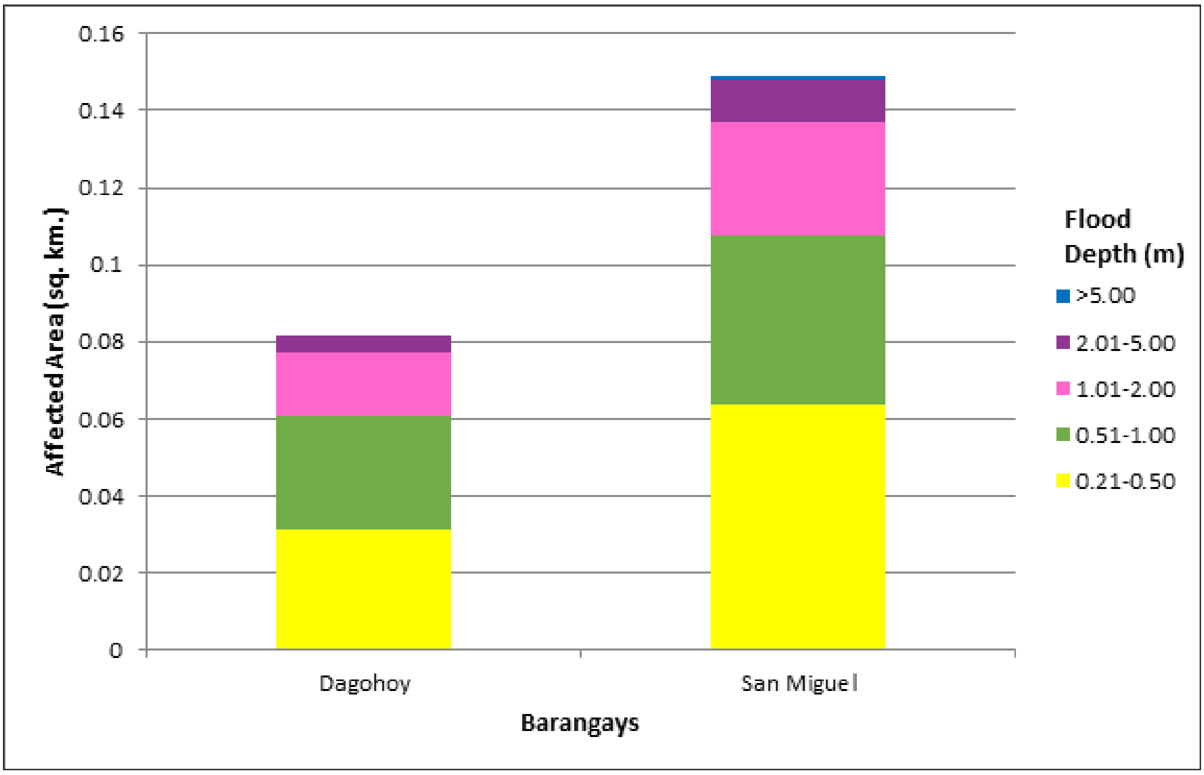



Figure 98. Affected Areas in Danao, Bohol during 100-Year Rainfall Return Period

For the municipality of Jetafe, with an area of 94.04 sq. km., 0.025% will experience flood levels of less 0.20 meters. 0.0002% of the area will experience flood levels of 0.21 to 0.50 meters while 0.0002%, and 0.0001% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 63 are the affected areas in square kilometres by flood depth per barangay.

Table 63. Affected Areas in Jetafe, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Jetafe (in sq. km.) |
|---|---|
| | Cabasakan |
| **0.03-0.20** | 0.024 |
| **0.21-0.50** | 0.00024 |
| **0.51-1.00** | 0.0002 |
| **1.01-2.00** | 0.0001 |
| **2.01-5.00** | 0 |
| **> 5.00** | 0 |

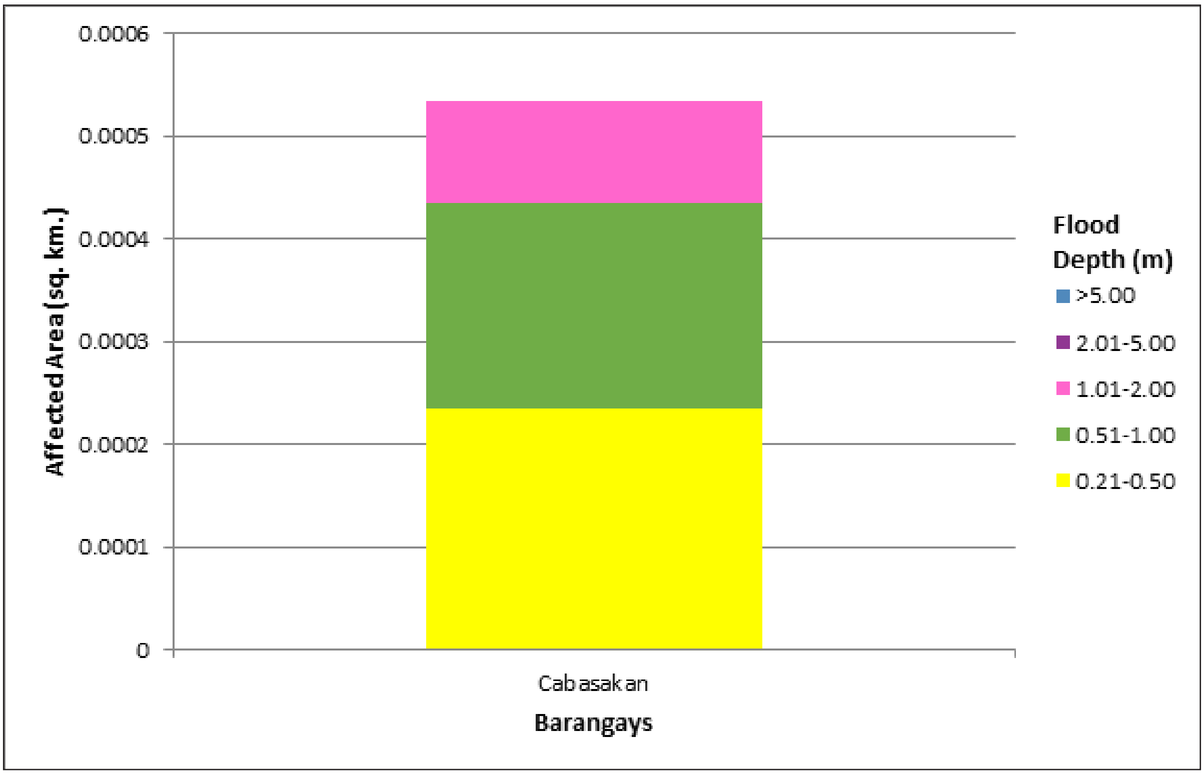



Figure 99. Affected Areas in Jetafe, Bohol during 100-Year Rainfall Return Period

For the municipality of Pilar, with an area of 114.4 sq. km., 5.67% will experience flood levels of less 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters while 0.94%, 0.23%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 64 are the affected areas in square kilometres by flood depth per barangay.

Table 64. Affected Areas in Pilar, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Pilar (in sq. km.) |
|---|---|
| | La Suerte |
| **0.03-0.20** | 6.48 |
| **0.21-0.50** | 0.38 |
| **0.51-1.00** | 1.07 |
| **1.01-2.00** | 0.26 |
| **2.01-5.00** | 0.065 |
| **> 5.00** | 0 |

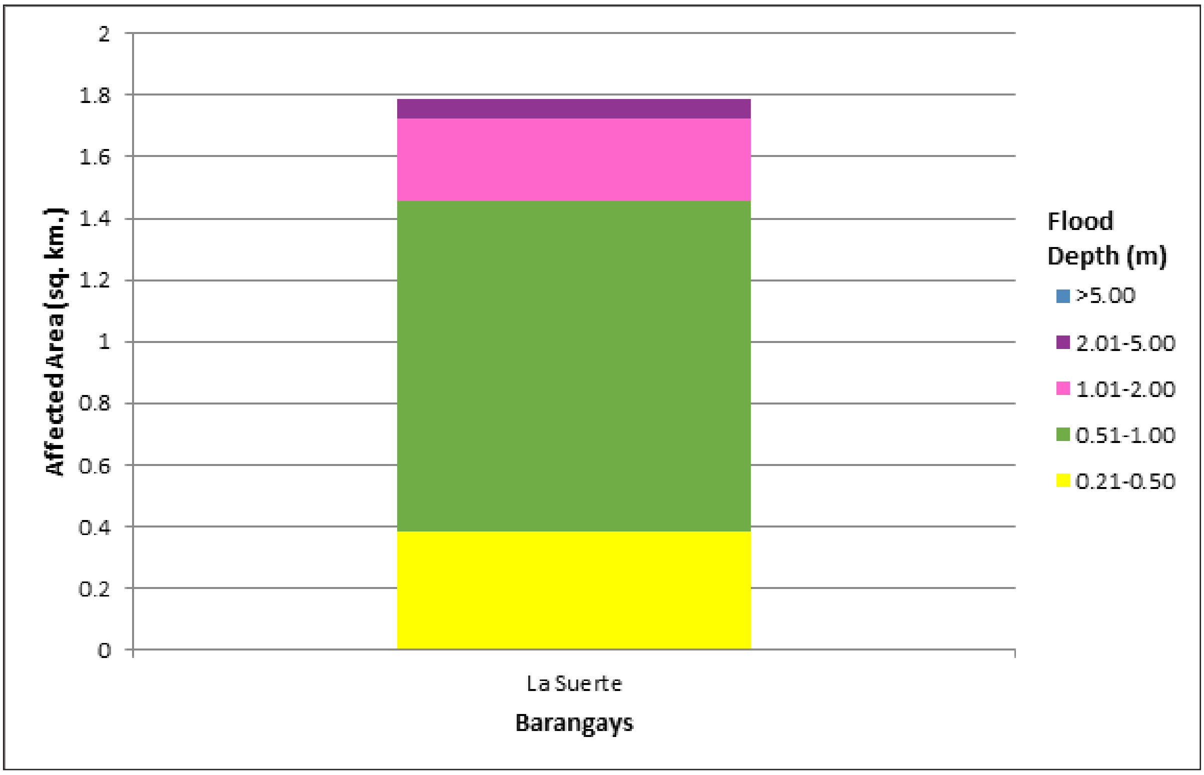



Figure 100. Affected Areas in Pilar, Bohol during 100-Year Rainfall Return Period

For the municipality of San Miguel, with an area of 107 sq. km., 81.03% will experience flood levels of less 0.20 meters. 4.43% of the area will experience flood levels of 0.21 to 0.50 meters while 3.87%, 4.63%, 3.32%, and 0.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 65 are the affected areas in square kilometres by flood depth per barangay.

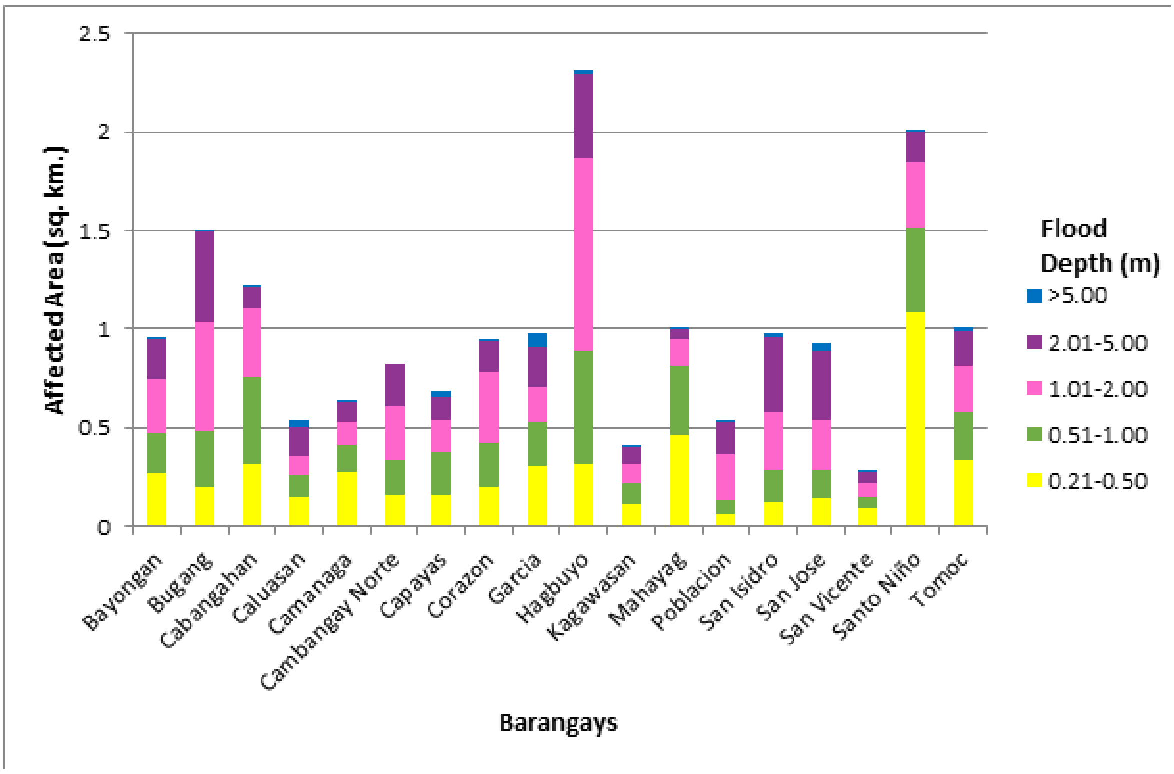



Figure 101. Affected Areas in San Miguel, Bohol during 100-Year Rainfall Return Period

Table 65. Affected Areas in San Miguel, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in San Miguel (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bayongan | Bugang | Cabangahan | Caluasan | Camanaga | Cambangay Norte | Capayas | Corazon | Garcia |
| **0.03-0.20** | 5.28 | 4.98 | 7.29 | 4.64 | 4.05 | 3.3 | 4.39 | 3.85 | 7.06 |
| **0.21-0.50** | 0.26 | 0.2 | 0.32 | 0.15 | 0.27 | 0.16 | 0.16 | 0.2 | 0.3 |
| **0.51-1.00** | 0.21 | 0.29 | 0.43 | 0.11 | 0.14 | 0.17 | 0.21 | 0.22 | 0.23 |
| **1.01-2.00** | 0.28 | 0.55 | 0.35 | 0.095 | 0.12 | 0.27 | 0.17 | 0.37 | 0.17 |
| **2.01-5.00** | 0.2 | 0.45 | 0.11 | 0.14 | 0.097 | 0.22 | 0.12 | 0.15 | 0.21 |
| **> 5.00** | 0.0001 | 0.0001 | 0.0014 | 0.04 | 0.0081 | 0 | 0.029 | 0.001 | 0.06 |

Table 66. Affected Areas in San Miguel, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in San Miguel (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hagbuyo | Kagawasan | Mahayag | Poblacion | San Isidro | San Jose | San Vicente | Santo Niño | Tomoc |
| **0.03-0.20** | 6.77 | 3.07 | 4.99 | 1.45 | 3.54 | 3.56 | 1.69 | 9 | 8.08 |
| **0.21-0.50** | 0.32 | 0.11 | 0.46 | 0.059 | 0.12 | 0.14 | 0.088 | 1.09 | 0.34 |
| **0.51-1.00** | 0.57 | 0.11 | 0.36 | 0.073 | 0.17 | 0.14 | 0.06 | 0.43 | 0.24 |
| **1.01-2.00** | 0.98 | 0.099 | 0.13 | 0.23 | 0.28 | 0.25 | 0.071 | 0.32 | 0.23 |
| **2.01-5.00** | 0.44 | 0.087 | 0.047 | 0.17 | 0.39 | 0.35 | 0.06 | 0.16 | 0.17 |
| **> 5.00** | 0.016 | 0.011 | 0.0006 | 0.013 | 0.017 | 0.041 | 0.0014 | 0.0036 | 0.022 |

For the municipality of Talibon, with an area of 148 sq. km., 27.58% will experience flood levels of less 0.20 meters. 2.62% of the area will experience flood levels of 0.21 to 0.50 meters while 2.68%, 2.07%, 0.92%, and 0.028% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 67 are the affected areas in square kilometres by flood depth per barangay.

Table 67. Affected Areas in Talibon, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Talibon (in sq. km.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Balintawak | Magsaysay | Rizal | San Agustin | San Carlos | San Isidro | San Jose | San Roque | Sikatuna | Zamora |
| **0.03-0.20** | 2.58 | 12.8 | 2.08 | 4.38 | 1.18 | 0.088 | 0.068 | 3.96 | 4.09 | 9.61 |
| **0.21-0.50** | 0.38 | 0.36 | 0.073 | 1.41 | 0.075 | 0.0017 | 0.0004 | 0.86 | 0.17 | 0.56 |
| **0.51-1.00** | 0.25 | 0.34 | 0.073 | 1.7 | 0.063 | 0.0012 | 0.0001 | 0.6 | 0.26 | 0.68 |
| **1.01-2.00** | 0.055 | 0.4 | 0.054 | 0.48 | 0.0059 | 0.0005 | 0 | 0.33 | 0.81 | 0.93 |
| **2.01-5.00** | 0.0013 | 0.53 | 0.024 | 0.05 | 0.0021 | 0 | 0 | 0.086 | 0.31 | 0.36 |
| **> 5.00** | 0 | 0.022 | 0.0001 | 0.0041 | 0 | 0 | 0 | 0 | 0 | 0.015 |

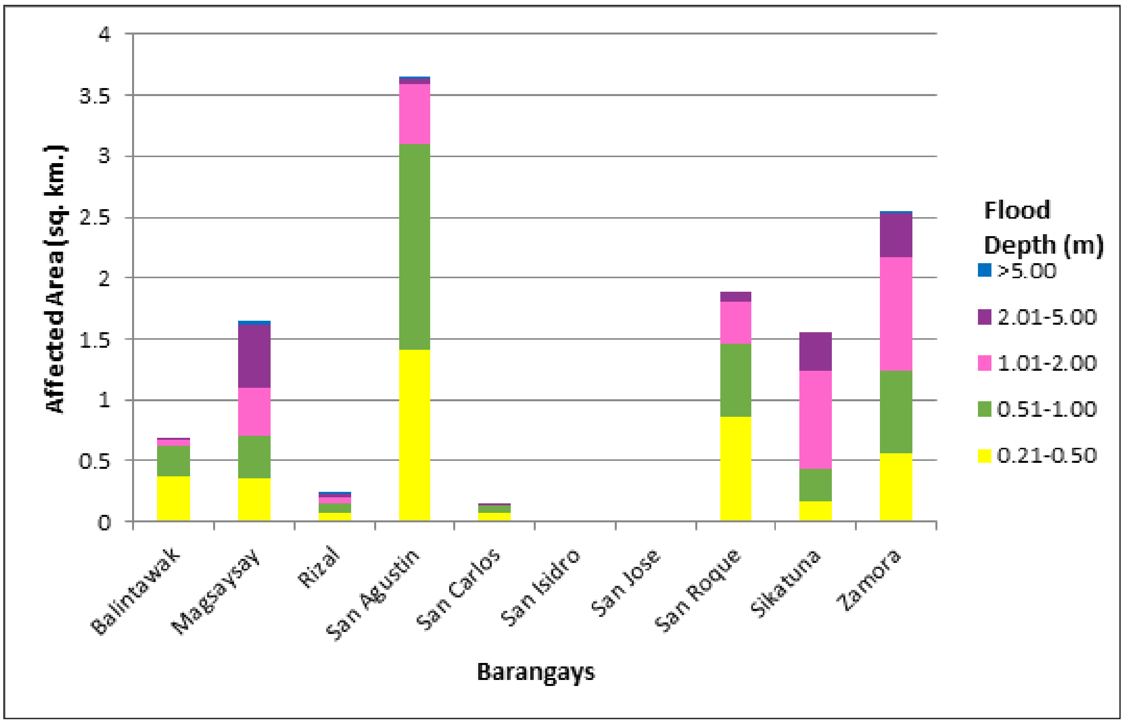



Figure 102. Affected Areas in Talibon, Bohol during 100-Year Rainfall Return Period

For the municipality of Trinidad, with an area of 143 sq. km., 46.73% will experience flood levels of less 0.20 meters. 2.37% of the area will experience flood levels of 0.21 to 0.50 meters while 3.34%, 3.69%, 3.54%, and 0.2% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 68-69 are the affected areas in square kilometres by flood depth per barangay.

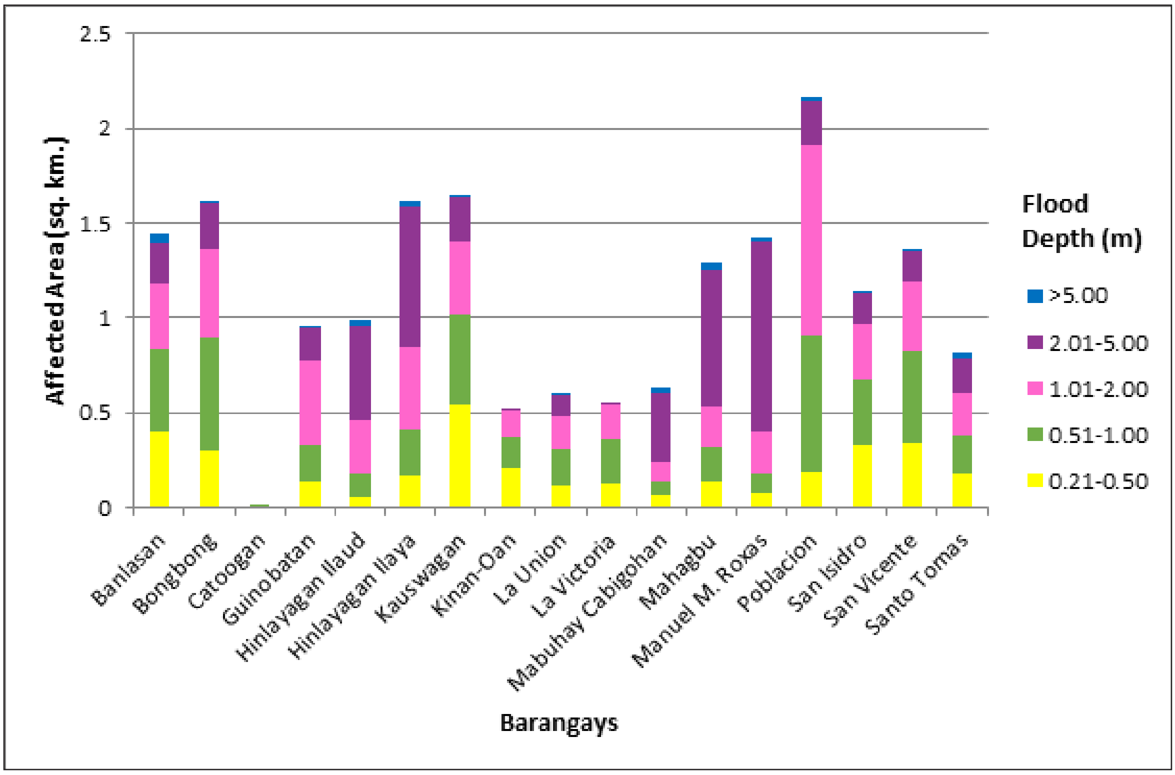



Figure 103. Affected Areas in Trinidad, Bohol during 100-Year Rainfall Return Period

Table 68. Affected Areas in Trinidad, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Trinidad (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Banlasan | Bongbong | Catoogan | Guinobatan | Hinlayagan Ilaud | Hinlayagan Ilaya | Kauswagan | Kinan-Oan | La Union |
| **0.03-0.20** | 7.58 | 5.19 | 0.071 | 3.16 | 1.2 | 4.32 | 14.85 | 3.66 | 2.71 |
| **0.21-0.50** | 0.4 | 0.3 | 0.006 | 0.14 | 0.059 | 0.17 | 0.55 | 0.21 | 0.12 |
| **0.51-1.00** | 0.44 | 0.59 | 0.0027 | 0.19 | 0.12 | 0.24 | 0.48 | 0.16 | 0.2 |
| **1.01-2.00** | 0.34 | 0.47 | 0 | 0.45 | 0.28 | 0.43 | 0.39 | 0.15 | 0.17 |
| **2.01-5.00** | 0.21 | 0.24 | 0 | 0.18 | 0.5 | 0.75 | 0.23 | 0.0091 | 0.1 |
| **> 5.00** | 0.044 | 0.015 | 0 | 0.0048 | 0.028 | 0.031 | 0.012 | 0 | 0.0013 |

Table 69. Affected Areas in Trinidad, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Trinidad (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | La Victoria | Mabuhay Cabigohan | Mahagbu | Manuel M. Roxas | Poblacion | San Isidro | San Vicente | Santo Tomas |
| **0.03-0.20** | 2.13 | 1.41 | 3.54 | 2.03 | 1.85 | 4.81 | 5.16 | 3.05 |
| **0.21-0.50** | 0.13 | 0.063 | 0.13 | 0.078 | 0.19 | 0.33 | 0.34 | 0.18 |
| **0.51-1.00** | 0.23 | 0.076 | 0.19 | 0.1 | 0.72 | 0.34 | 0.49 | 0.2 |
| **1.01-2.00** | 0.18 | 0.1 | 0.21 | 0.22 | 1 | 0.29 | 0.36 | 0.22 |
| **2.01-5.00** | 0.0007 | 0.36 | 0.72 | 1.01 | 0.23 | 0.16 | 0.17 | 0.18 |
| **> 5.00** | 0 | 0.031 | 0.034 | 0.022 | 0.019 | 0.01 | 0.0017 | 0.036 |

For the municipality of Ubay, with an area of 264.8 sq. km., 5.74% will experience flood levels of less 0.20 meters. 0.41% of the area will experience flood levels of 0.21 to 0.50 meters while 0.21%, 0.2%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 70 are the affected areas in square kilometres by flood depth per barangay.

Table 70. Affected Areas in Ubay, Bohol during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | Area of affected barangays in Ubay (in sq. km.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Buenavista | Bulilis | Camali-An | Gabi | Hambabauran | Lomangog | Los Angeles | Pag-Asa | Tubog |
| **0.03-0.20** | 0.052 | 0.75 | 3.76 | 1.31 | 6.5 | 1.17 | 0.51 | 1.14 | 0.03 |
| **0.21-0.50** | 0.00062 | 0.043 | 0.26 | 0.078 | 0.4 | 0.15 | 0.023 | 0.12 | 0.0034 |
| **0.51-1.00** | 0.0003 | 0.017 | 0.15 | 0.046 | 0.23 | 0.035 | 0.019 | 0.044 | 0.00031 |
| **1.01-2.00** | 0.0004 | 0.02 | 0.19 | 0.036 | 0.22 | 0.019 | 0.011 | 0.041 | 0 |
| **2.01-5.00** | 0.0001 | 0.0053 | 0.091 | 0.0001 | 0.057 | 0.0011 | 0.0024 | 0.008 | 0 |
| **> 5.00** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

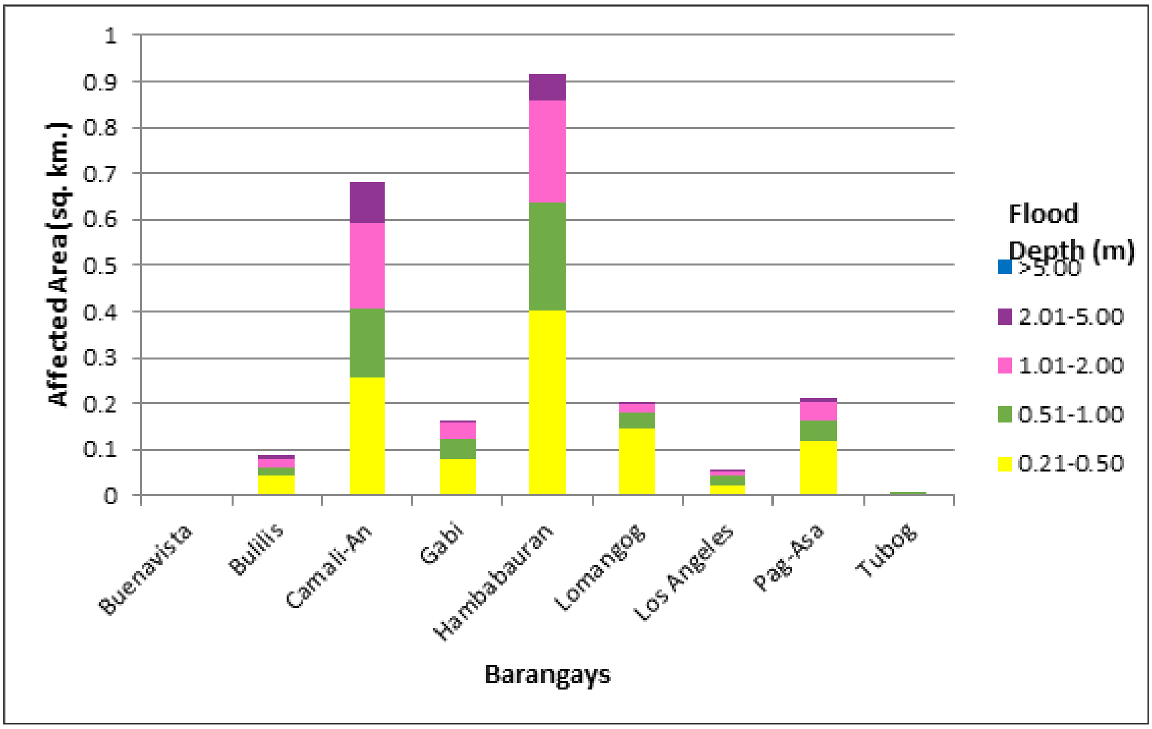



Figure 104. Affected Areas in Ubay, Bohol during 100-Year Rainfall Return Period

Among the barangays in the municipality of Alicia, Katipunan is projected to have the highest percentage of area that will experience flood levels at 1.07%.

Among the barangays in the municipality of Bien Unido, Nueva Esperanza is projected to have the highest percentage of area that will experience flood levels at 23.74%. Meanwhile, Liberty posted the second highest percentage of area that may be affected by flood depths at 4.94%.

Among the barangays in the municipality of Dagohoy, Cagawasan is projected to have the highest percentage of area that will experience flood levels at 0.03%.

Among the barangays in the municipality of Danao, San Miguel is projected to have the highest percentage of area that will experience flood levels at 1.85%. Meanwhile, Dagohoy posted the second highest percentage of area that may be affected by flood depths at 0.96%.

Among the barangays in the municipality of Jetafe, Cabasakan is projected to have the highest percentage of area that will experience flood levels at 0.03%.

Among the barangays in the municipality of Pilar, La Suerte is projected to have the highest percentage of area that will experience flood levels at 7.23%.

Among the barangays in the municipality of San Miguel, Santo Niño is projected to have the highest percentage of area that will experience flood levels at 10.24%. Meanwhile, Tomoc posted the second highest percentage of area that may be affected by flood depths at 8.47%.

Among the barangays in the municipality of Talibon, Magsaysayis projected to have the highest percentage of area that will experience flood levels at 13.46%. Meanwhile, Zamora posted the second highest percentage of area that may be affected by flood depths at 11.32%.

Among the barangays in the municipality of Trinidad, Kauswagan is projected to have the highest percentage of area that will experience flood levels at 11.55%. Meanwhile, Banlasan posted the second highest percentage of area that may be affected by flood depths at 6.32%.

Among the barangays in the municipality of Ubay, Hambabauran is projected to have the highest percentage of area that will experience flood levels at 2.80%. Meanwhile, Lomangog posted the second highest percentage of area that may be affected by flood depths at 0.52%.

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

Table 71. Area covered by each warning level with respect to the rainfall scenario

| Warning Level | Area Covered in sq. km. | | |
|---|---|---|---|
| | 5 year | 25 year | 100 year |
| Low | 17.45 | 17.17 | 15.89 |
| Medium | 14.70 | 22.76 | 24.69 |
| High | 3.19 | 10.14 | 17.28 |
| **TOTAL** | **35.34** | **50.07** | **57.86** |

Of the 31 identified Education Institutions in the Ipil Flood plain, 2 schools were assessed to be exposed to Low level flooding during a 5 year scenario. In the 25 year scenario, 2 schools were assessed to be exposed to low level flooding. In the 100 year scenario, 3 schools were assessed to be exposed to low level flooding. See Appendix D for a detailed enumeration of schools in the Ipil floodplain.

Of the 8 identified Medical Institutions in the Abatan Flood Plain, no medical institutions were assessed to be exposed to any of the flooding scenarios. See **Appendix E** for a detailed enumeration of hospitals and clinics in the Ipil floodplain.

## 5.11 Flood Validation

A survey was done along the floodplain of Ipil River to validate the generated flood maps. The team gathered secondary data regarding flood occurrence in the area. Ground validation points were acquired as well as the other necessary details like date of occurrence, name of typhoon and actual flood depth.

During validation, the team was assisted by the local Disaster Risk Reduction and Management representatives from the Municipalities of Talibon, Bien Unido and Trinidad. Residents along the floodplain were interviewed of the historical flood events they experiences.

Actual flood depth acquired from the ground validation were then computed and compared to the flood depth simulated by the model. An RMSE value of 0.57 was obtained.

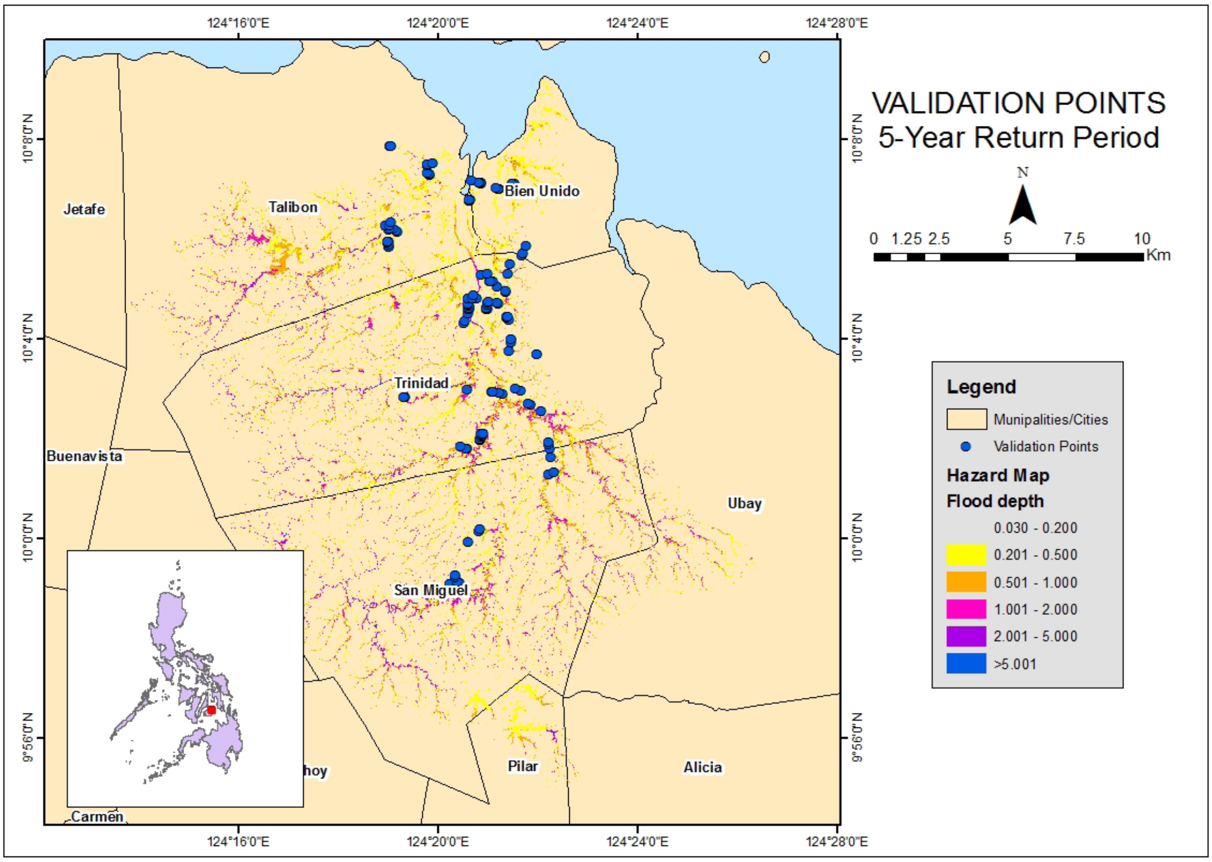



Figure 105. Flood Validation Points of Ipil River Basin

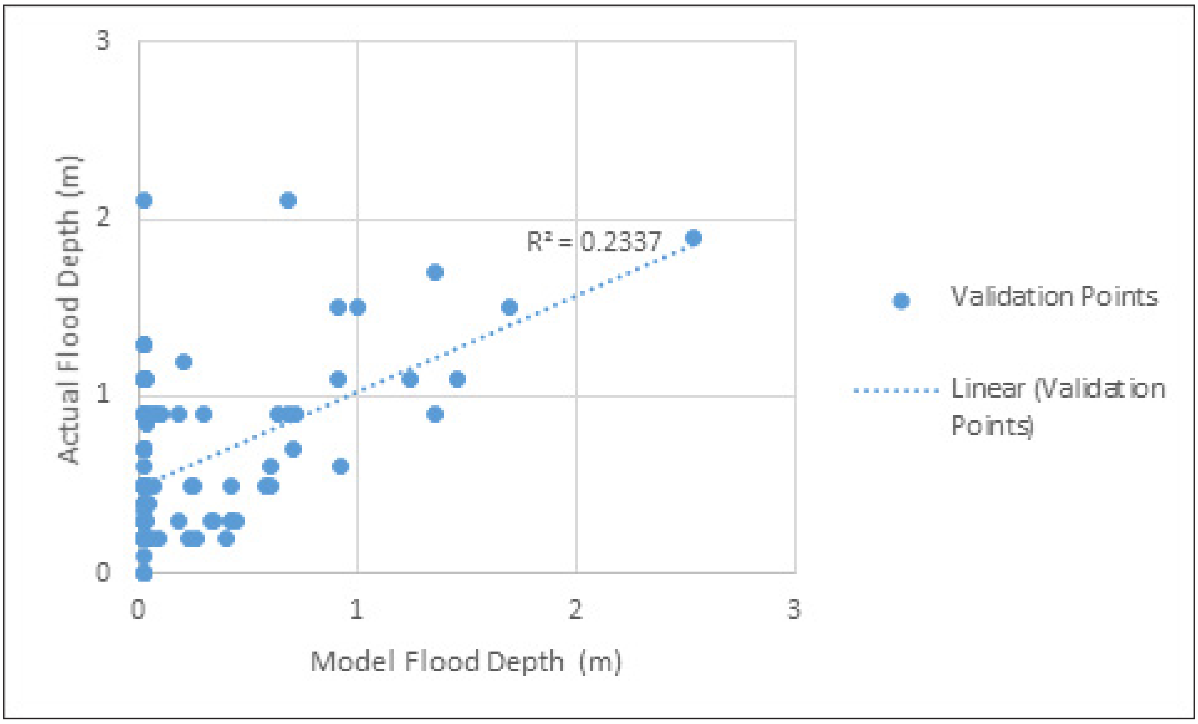



Figure 106. Flood map depth vs actual flood depth

Table 72. Actual Flood Depth vs Simulated Flood Depth in Ipil

| 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 | 35 | 3 | 0 | 0 | 0 | 0 | 38 |
| 0.21-0.50 | 39 | 8 | 3 | 0 | 0 | 0 | 50 |
| 0.51-1.00 | 21 | 1 | 6 | 1 | 0 | 0 | 29 |
| 1.01-2.00 | 13 | 1 | 3 | 4 | 1 | 0 | 22 |
| 2.01-5.00 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 109 | 13 | 13 | 5 | 1 | 0 | 141 |

The overall accuracy generated by the flood model is estimated at 37.59% with 53 points correctly matching the actual flood depths. In addition, there were 50 points estimated one level above and below the correct flood depths while there were 23 points and 14 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 80 points were underestimated in the modelled flood depths of Ipil.

Table 73. Summary of Accuracy Assessment in Ipil River Basin Survey

| No. of Points | | % |
|---|---|---|
| Correct | 53 | 37.59 |
| Overestimated | 8 | 5.67 |
| Underestimated | 80 | 56.74 |
| Total | 141 | 100.00 |

# REFERENCES

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

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

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

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

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

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

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

# ANNEXES

## Annex 1. Technical Specifications of the LIDAR Sensors used in the Ipil Floodplain Survey

1. PEGASUS SENSOR

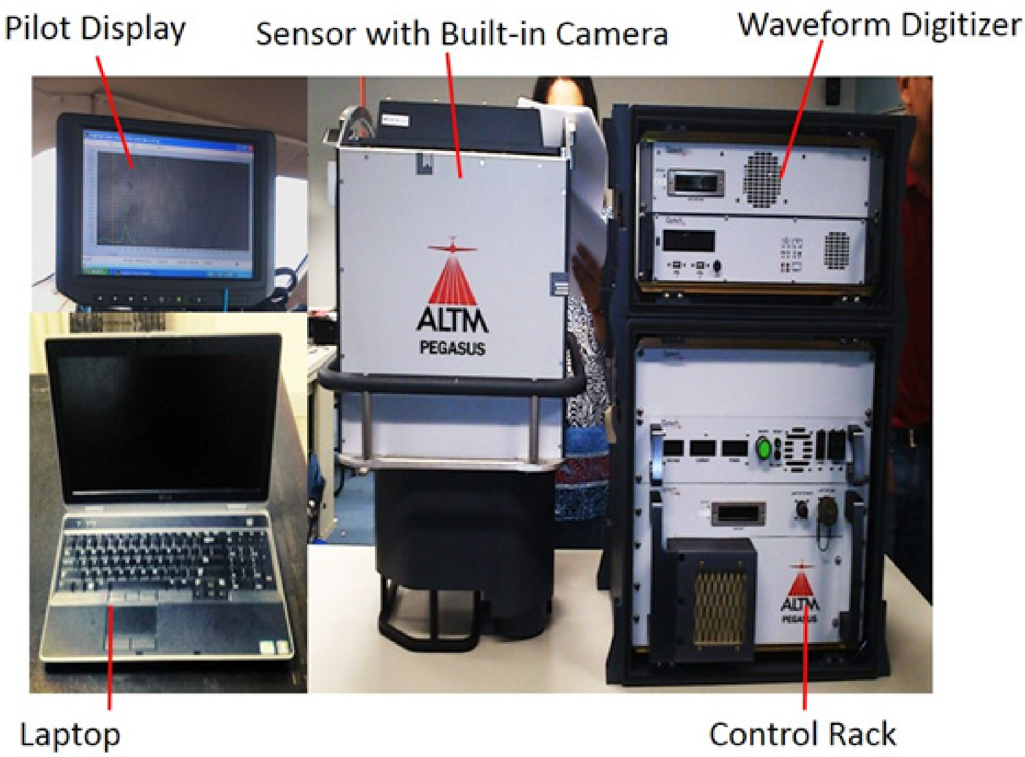



Figure A-1.1. Pegasus Sensor

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

2. D-8900 AERIAL DIGITAL CAMERA

Table A-1.2. Parameters and Specification of D-8900 AERIAL DIGITAL CAMERA

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

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

1 BHL-63

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

November 19, 2013

**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: **BOHOL**
Station Name: **BHL-63**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SAN MIGUEL**
Barangay: **HAGBUYO**

*PRS92 Coordinates*

| | | |
|---|---|---|
| Latitude: **10° 0' 13.39830"** | Longitude: **124° 20' 43.44081"** | Ellipsoidal Hgt: **17.31900 m.** |

*WGS84 Coordinates*

| | | |
|---|---|---|
| Latitude: **10° 0' 9.39110"** | Longitude: **124° 20' 48.71189"** | Ellipsoidal Hgt: **80.87300 m.** |

*PTM Coordinates*

| | | |
|---|---|---|
| Northing: **1106212.953 m.** | Easting: **428232.164 m.** | Zone: **5** |

*UTM Coordinates*

| | | |
|---|---|---|
| Northing: **1,106,055.36** | Easting: **647,462.74** | Zone: **51** |

Location Description

BHL-63

To reach the station travel from San Miguel Town Proper for about 2.5 Km. and look for Hagbuyo Bridge before Hagbuyo Primary School which is about 150 m NE. Mark is the head of a 3 in. copper nail set on a drilled hole on the concrete sidewalk of Hagbuyo Bridge Km. 131+630 embedded with concrete cement putty 30 cm x 30 cm x 15 cm with inscriptions"BHL-63, 2007, NAMRIA". Ref. no. 1 is an electric post about 30 m NW at the opposite side of the road; Ref. no. 2 is a 6.1 pipe with Bridge Tonage sign about 25 m SW.

Requesting Party: **UP-TCAGP/DOST**
Pupose: **Reference**
OR Number: **3947235 B**
T.N.: **2013-1253**

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

9 9 1 1 1 9 2 0 1 3 1 1 1 1 0 0

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

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

Figure A-2.1. BHL-63

2. BHL-95

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

November 19, 2013

**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: **BOHOL**
Station Name: **BHL-95**
Order: **2nd**

Island: **VISAYAS**
Municipality: **LILA**
Barangay: **TIGUIS**

*PRS92 Coordinates*

| | | |
|---|---|---|
| Latitude: **9° 35' 30.96174"** | Longitude: **124° 4' 30.01696"** | Ellipsoidal Hgt: **19.23800 m.** |

*WGS84 Coordinates*

| | | |
|---|---|---|
| Latitude: **9° 35' 27.03717"** | Longitude: **124° 4' 35.32705"** | Ellipsoidal Hgt: **83.04800 m.** |

*PTM Coordinates*

| | | |
|---|---|---|
| Northing: **1060736.963 m.** | Easting: **398459.803 m.** | Zone: **5** |

*UTM Coordinates*

| | | |
|---|---|---|
| Northing: **1,060,413.57** | Easting: **617,967.70** | Zone: **51** |

Location Description

BHL-95

From Loay Town travel NE to Lila, Bohol about 2.5 Km. from Lila Proper on the left side of the road. Mark is the head of a 3 in. copper nail embedded on a concrete monument 30 cm x 30 cm x 1.20 cm set to the ground 0.20 cm above ground level with inscritions, BHL-95, 2007, NAMRIA". Ref. no. 1 Electric post about 30 m SW; Ref. no. 2 Molave Tree near concrete post about 25 m NW; Station is about 60 m to the corner of Brgy. Tiguis on the NE.

Requesting Party: **UP-TCAGP/DOST**
Pupose: **Reference**
OR Number: **3947235 B**
T.N.: **2013-1274**

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

9911192013112455

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

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

Figure A-2.2. BHL-95

3. BHL-75

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

September 21, 2015

**CERTIFICATION**

To whom it may concern:

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

| | | |
|---|---|---|
| | Province: **BOHOL** | |
| | Station Name: **BHL-75** | |
| | Order: **2nd** | |
| Island: **VISAYAS** | Barangay: **SAN JOSE** | |
| Municipality: **MABINI** | MSL Elevation: | |
| | ***PRS92 Coordinates*** | |
| Latitude: **9° 57' 16.74294"** | Longitude: **124° 32' 0.35318"** | Ellipsoidal Hgt: **12.84500 m.** |
| | ***WGS84 Coordinates*** | |
| Latitude: **9° 57' 12.76483"** | Longitude: **124° 32' 5.62696"** | Ellipsoidal Hgt: **76.97400 m.** |
| | ***PTM / PRS92 Coordinates*** | |
| Northing: **1100750.724 m.** | Easting: **448840.052 m.** | Zone: **5** |
| | ***UTM / PRS92 Coordinates*** | |
| Northing: **1,100,718.38** | Easting: **668,101.47** | Zone: **51** |

Location Description

BHL-75

To reach the station travel from Mabini Town Proper for about 16 Km. to Brgy. San Jose and at the Brgy. Plaza is the chapel and basketball court. Mark is the head of a 3 in. copper nail set on a drilled hole on a concrete post foundation embedded with concrete cement putty 30 cm x 30 cm x 5 cm with inscriptions, BHL-75, 2007, NAMRIA". Ref. no. 1 is a post of chapel at the right about 15 m SW; Ref. no. 2 basketball court about 25 m NE.

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8087355 I**
T.N.: **2015-2821**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. BHL-75

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

1. 63A

Table A-3.1. 63A

Vector Components (Mark to Mark)

| From: | BHL-63 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 647463.396 m | Latitude | N10°00'13.31406" | Latitude | N10°00'09.30688" |
| Northing | 1106052.775 m | Longitude | E124°20'43.46219" | Longitude | E124°20'48.73327" |
| Elevation | 19.432 m | Height | 20.487 m | Height | 84.041 m |

| To: | BHL-63A | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 647466.981 m | Latitude | N10°00'13.84084" | Latitude | N10°00'09.83363" |
| Northing | 1106068.972 m | Longitude | E124°20'43.58209" | Longitude | E124°20'48.85315" |
| Elevation | 19.409 m | Height | 20.464 m | Height | 84.018 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 3.585 m | NS Fwd Azimuth | 12°42'51" | ΔX | -1.416 m |
| ΔNorthing | 16.197 m | Ellipsoid Dist. | 16.591 m | ΔY | -4.400 m |
| ΔElevation | -0.023 m | ΔHeight | -0.023 m | ΔZ | 15.934 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.001 m | σ NS fwd Azimuth | 0°00'10" | σ ΔX | 0.001 m |
| σ ΔNorthing | 0.001 m | σ Ellipsoid Dist. | 0.001 m | σ ΔY | 0.001 m |
| σ ΔElevation | 0.001 m | σ ΔHeight | 0.001 m | σ ΔZ | 0.001 m |

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000011627 | | |
| Y | -0.0000004536 | 0.0000009291 | |
| Z | -0.0000002192 | 0.0000000346 | 0.0000003582 |

2. 75A

Table A-3.2. 75A

Vector Components (Mark to Mark)

| From: | BHL-75 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 668101.461 m | Latitude | N9°57'16.74294" | Latitude | N9°57'12.76483" |
| Northing | 1100718.380 m | Longitude | E124°32'00.35318" | Longitude | E124°32'05.62696" |
| Elevation | 12.452 m | Height | 12.845 m | Height | 76.974 m |

| To: | 75 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 668103.303 m | Latitude | N9°57'17.24192" | Latitude | N9°57'13.26378" |
| Northing | 1100733.718 m | Longitude | E124°32'00.41598" | Longitude | E124°32'05.68974" |
| Elevation | 12.274 m | Height | 12.668 m | Height | 76.796 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 1.842 m | NS Fwd Azimuth | 7°06'44" | ΔX | 0.026 m |
| ΔNorthing | 15.338 m | Ellipsoid Dist. | 15.449 m | ΔY | -3.411 m |
| ΔElevation | -0.178 m | ΔHeight | -0.177 m | ΔZ | 15.069 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.000 m | σ NS fwd Azimuth | 0°00'06" | σ ΔX | 0.001 m |
| σ ΔNorthing | 0.000 m | σ Ellipsoid Dist. | 0.000 m | σ ΔY | 0.001 m |
| σ ΔElevation | 0.001 m | σ ΔHeight | 0.001 m | σ ΔZ | 0.001 m |

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000008194 | | |
| Y | -0.0000008289 | 0.0000012571 | |
| Z | -0.0000003177 | 0.0000004601 | 0.0000003613 |

3. Hotel

Table A-3.3. Hotel

Vector Components (Mark to Mark)

| From: | BHL-95 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 617964.842 m | Latitude | N9°35'31.05836" | Latitude | N9°35'27.13378" |
| Northing | 1060416.528 m | Longitude | E124°04'29.92362" | Longitude | E124°04'35.23370" |
| Elevation | 26.191 m | Height | 26.080 m | Height | 89.890 m |

| To: | Hotel | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 594927.168 m | Latitude | N9°39'32.15822" | Latitude | N9°39'28.19791" |
| Northing | 1067756.448 m | Longitude | E123°51'54.83035" | Longitude | E123°52'00.13618" |
| Elevation | 49.511 m | Height | 49.981 m | Height | 113.124 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -23037.674 m | NS Fwd Azimuth | 287°51'07" | ΔX | 19772.484 m |
| ΔNorthing | 7339.920 m | Ellipsoid Dist. | 24184.956 m | ΔY | 11856.935 m |
| ΔElevation | 23.320 m | ΔHeight | 23.900 m | ΔZ | 7306.139 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.025 m | σ NS fwd Azimuth | 0°00'00" | σ ΔX | 0.027 m |
| σ ΔNorthing | 0.009 m | σ Ellipsoid Dist. | 0.023 m | σ ΔY | 0.035 m |
| σ ΔElevation | 0.037 m | σ ΔHeight | 0.037 m | σ ΔZ | 0.011 m |

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0007210250 | | |
| Y | -0.0002800594 | 0.0012254248 | |
| Z | -0.0001804231 | 0.0001515697 | 0.0001230081 |

4. EPHotel

Table A-3.4. EPHotel

Vector Components (Mark to Mark)

| From: | Hotel | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 594927.168 m | Latitude | N9°39'32.15823" | Latitude | N9°39'28.19791" |
| Northing | 1067756.448 m | Longitude | E123°51'54.83035" | Longitude | E123°52'00.13618" |
| Elevation | 49.511 m | Height | 49.981 m | Height | 113.124 m |

| To: | EP Hotel | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 594929.594 m | Latitude | N9°39'32.38755" | Latitude | N9°39'28.42722" |
| Northing | 1067763.497 m | Longitude | E123°51'54.91053" | Longitude | E123°52'00.21635" |
| Elevation | 49.487 m | Height | 49.956 m | Height | 113.100 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 2.426 m | NS Fwd Azimuth | 19°08'04" | ΔX | -1.357 m |
| ΔNorthing | 7.049 m | Ellipsoid Dist. | 7.457 m | ΔY | -2.364 m |
| ΔElevation | -0.025 m | ΔHeight | -0.024 m | ΔZ | 6.941 m |

Standard Errors

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.002 m | σ NS fwd Azimuth | 0°00'49" | σ ΔX | 0.003 m |
| σ ΔNorthing | 0.001 m | σ Ellipsoid Dist. | 0.001 m | σ ΔY | 0.002 m |
| σ ΔElevation | 0.003 m | σ ΔHeight | 0.003 m | σ ΔZ | 0.001 m |

Aposteriori Covariance Matrix (Meter²)

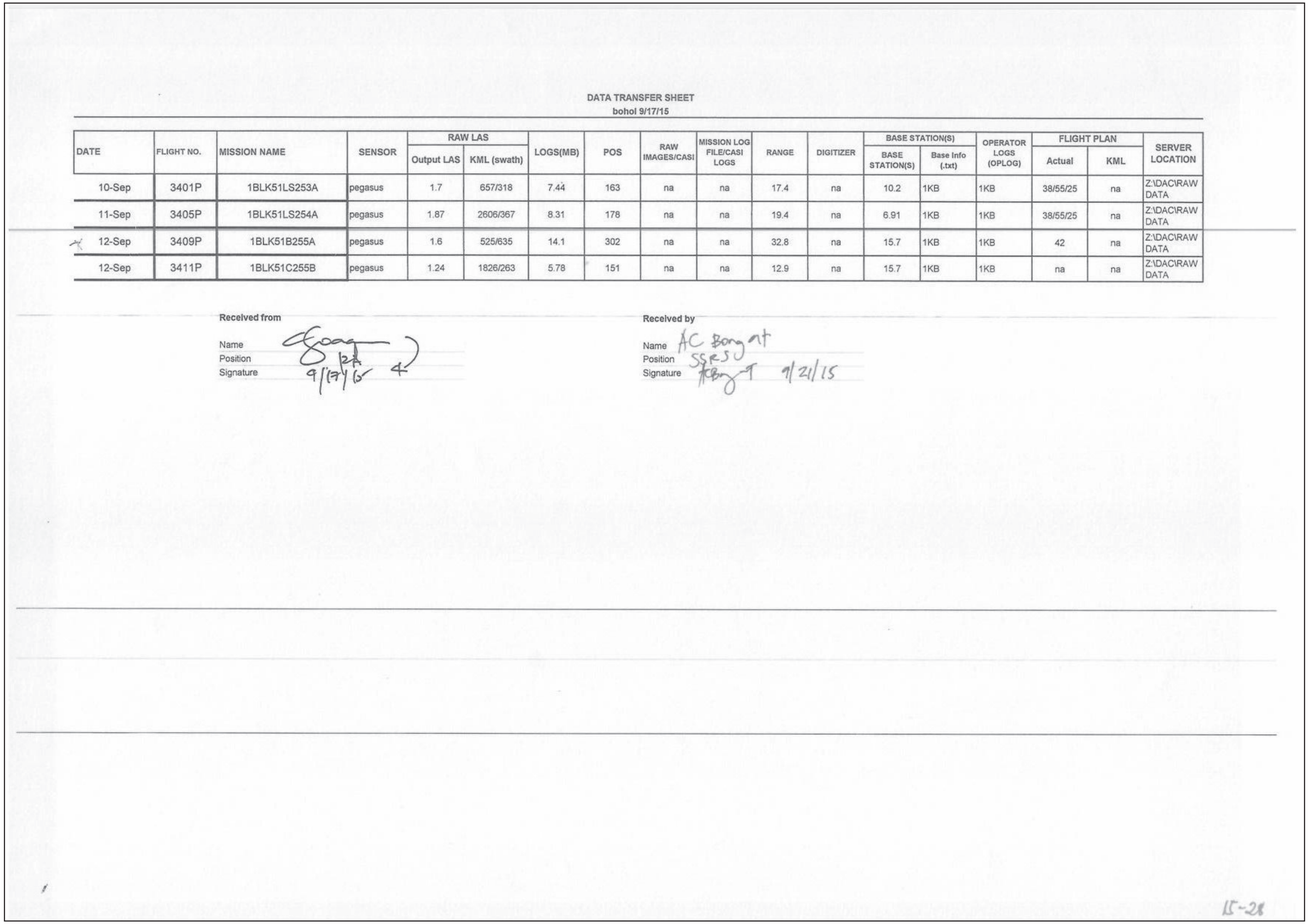
| | X | Y | Z |
|---|---|---|---|
| X | 0.0000064477 | | |
| Y | -0.0000028257 | 0.0000057669 | |
| Z | -0.0000013924 | 0.0000012411 | 0.0000013056 |

# Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LIDAR Survey Team Composition

| Data Acquisition Component Sub-Team | Designation | Name | Agency/ Affiliation |
|---|---|---|---|
| PHIL-LIDAR 1 | Program Leader | ENRICO C. PARINGIT, D.ENG | UP-TCAGP |
| Data Acquisition Component Leader | Data Component Project Leader – I | ENGR. CZAR JAKIRI SARMIENTO | UP-TCAGP |
| Survey Supervisor | Chief Science Research Specialist (CSRS) | ENGR. CHRISTOPHER CRUZ | UP-TCAGP |
| LiDAR Operation | Supervising Science Research Specialist (Supervising SRS) | LOVELY GRACIA ACUñA | UP-TCAGP |
| | | LOVELYN ASUNCION | UP-TCAGP |
| FIELD TEAM | | | |
| LiDAR Operation | Senior Science Research Specialist (SSRS) | JASMINE ALVIAR | UP-TCAGP |
| | Research Associate (RA) | IRO NIEL ROXAS | UP-TCAGP |
| | | KRISTINE JOY ANDAYA | UP-TCAGP |
| Ground Survey, Data Download and Transfer | RA | MA. KATRINA RANESES | UP-TCAGP |
| LiDAR Operation | Airborne Security | SSG. MIKE BERONILLA | PHILIPPINE AIR FORCE (PAF) |
| | Pilot | CAPT. CESAR ALFONSO III | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. RANDY LAGCO | AAC |

# Annex 5. Data Transfer Sheet for Ipil Floodplain



DATA TRANSFER SHEET
bohol 9/17/15

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS(MB) | POS | RAW IMAGES/CASI | MISSION LOG FILE/CASI LOGS | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| 10-Sep | 3401P | 1BLK51LS253A | pegasus | 1.7 | 657/318 | 7.44 | 163 | na | na | 17.4 | na | 10.2 | 1KB | 1KB | 38/55/25 | na | Z:\DAC\RAW DATA |
| 11-Sep | 3405P | 1BLK51LS254A | pegasus | 1.87 | 2606/367 | 8.31 | 178 | na | na | 19.4 | na | 6.91 | 1KB | 1KB | 38/55/25 | na | Z:\DAC\RAW DATA |
| 12-Sep | 3409P | 1BLK51B255A | pegasus | 1.6 | 525/635 | 14.1 | 302 | na | na | 32.8 | na | 15.7 | 1KB | 1KB | 42 | na | Z:\DAC\RAW DATA |
| 12-Sep | 3411P | 1BLK51C255B | pegasus | 1.24 | 1826/263 | 5.78 | 151 | na | na | 12.9 | na | 15.7 | 1KB | 1KB | na | na | Z:\DAC\RAW DATA |

Received from
Name
Position
Signature 9/17/15

Received by
Name AC Bongat
Position SSRS
Signature 9/21/15

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

DATA TRANSFER SHEET
Bohol 10/01/15

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | RAW LAS | | LOGS(MB) | POS | RAW IMAGES/CASI | MISSION LOG FILE/CASI LOGS | RANGE | DIGITIZER | BASE STATION(S) | | OPERATOR LOGS (OPLOG) | FLIGHT PLAN | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Output LAS | KML (swath) | | | | | | | BASE STATION(S) | Base Info (.txt) | | Actual | KML | |
| 15-Sep | 3421P | 1BLK51C258A | pegasus | 731 | na | 5.94 | 152 | na | na | 8.79 | na | 7.05 | 1KB | 1KB | na | na | Z:\DAC\RAW DATA |
| 17-Sep | 3429P | 1BLK51260A | pegasus | 2.37 | na | 12.2 | 261 | na | na | 23.8 | na | 8.35 | 1KB | 1KB | na | na | Z:\DAC\RAW DATA |
| 21-Sep | 3445P | 1BLK51S264A | pegasus | 542 | na | 4.54 | 124 | na | na | 5.95 | na | 9.84 | 1KB | 1KB | 121/121 | na | Z:\DAC\RAW DATA |
| 22-Sep | 3449P | 1BLK51G265A | pegasus | 1.22 | na | 9.1 | 221 | na | na | 18 | na | 13.1 | 1KB | 1KB | 75/86 | na | Z:\DAC\RAW DATA |
| 23-Sep | 3453P | 1BLK51S266A | pegasus | 591 | 25/123 | 7.82 | 148 | na | na | 16.5 | na | 4.75 | 1KB | 1KB | na | na | Z:\DAC\RAW DATA |

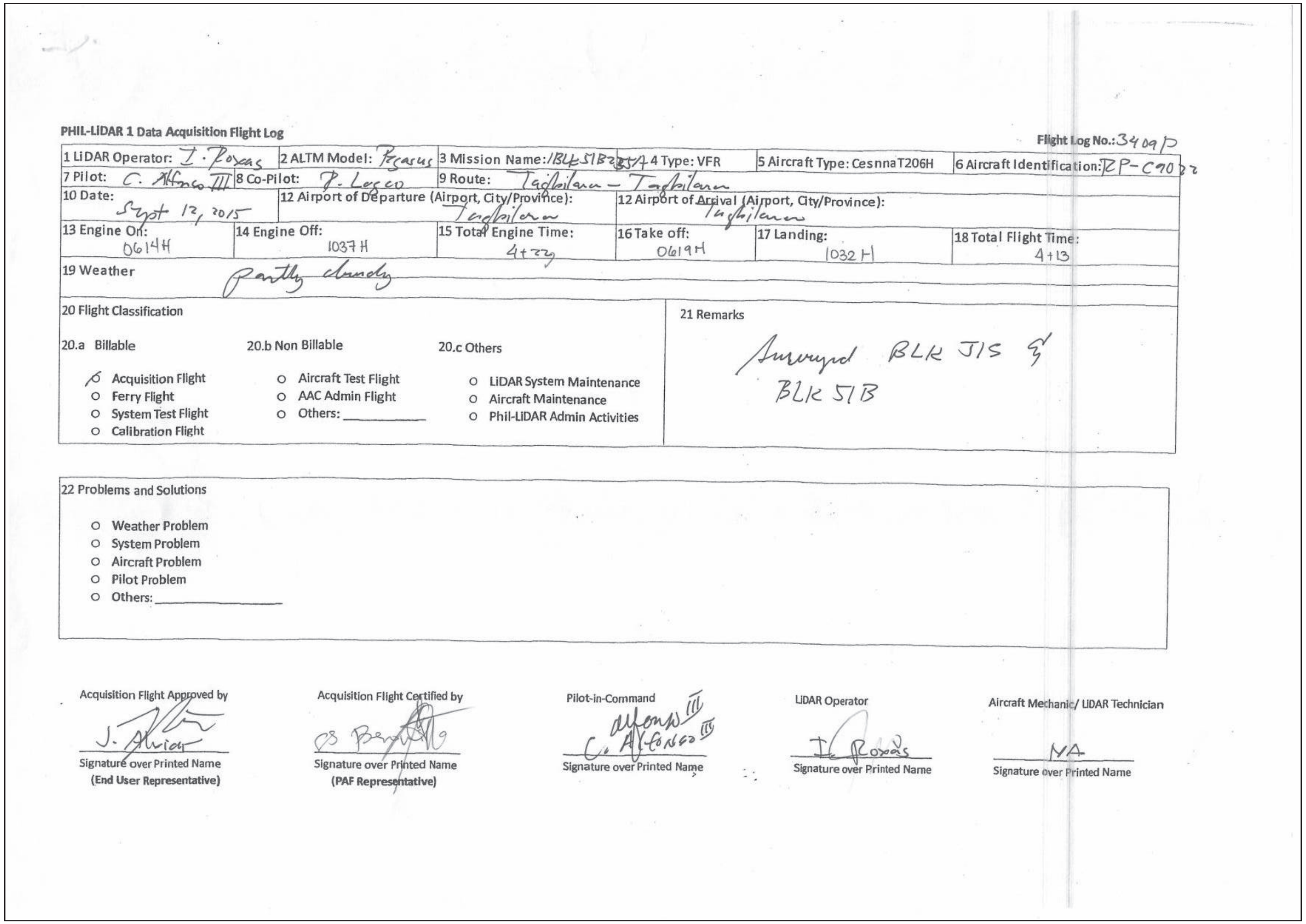
Received from
Name C. JOAQUIN
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature 10/28/2015

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

# Annex 6. Flight logs for the flight missions

1. Flight Log for Mission 1BLK51B255A


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3409P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. Roxas | 2 ALTM Model: Pegasus | 3 Mission Name: 1BLK51B255A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP-C9022 |
| 7 Pilot: C. Alfonso III | 8 Co-Pilot: P. Lozero | 9 Route: Tagbilaran – Tagbilaran | | | |
| 10 Date: Sept 12, 2015 | 12 Airport of Departure (Airport, City/Province): Tagbilaran | | 12 Airport of Arrival (Airport, City/Province): Tagbilaran | | |
| 13 Engine On: 0614H | 14 Engine Off: 1037 H | 15 Total Engine Time: 4+23 | 16 Take off: 0619H | 17 Landing: 1032 H | 18 Total Flight Time: 4+13 |
| 19 Weather: Partly cloudy | | | | | |

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 51S & BLK 51B

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

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

Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

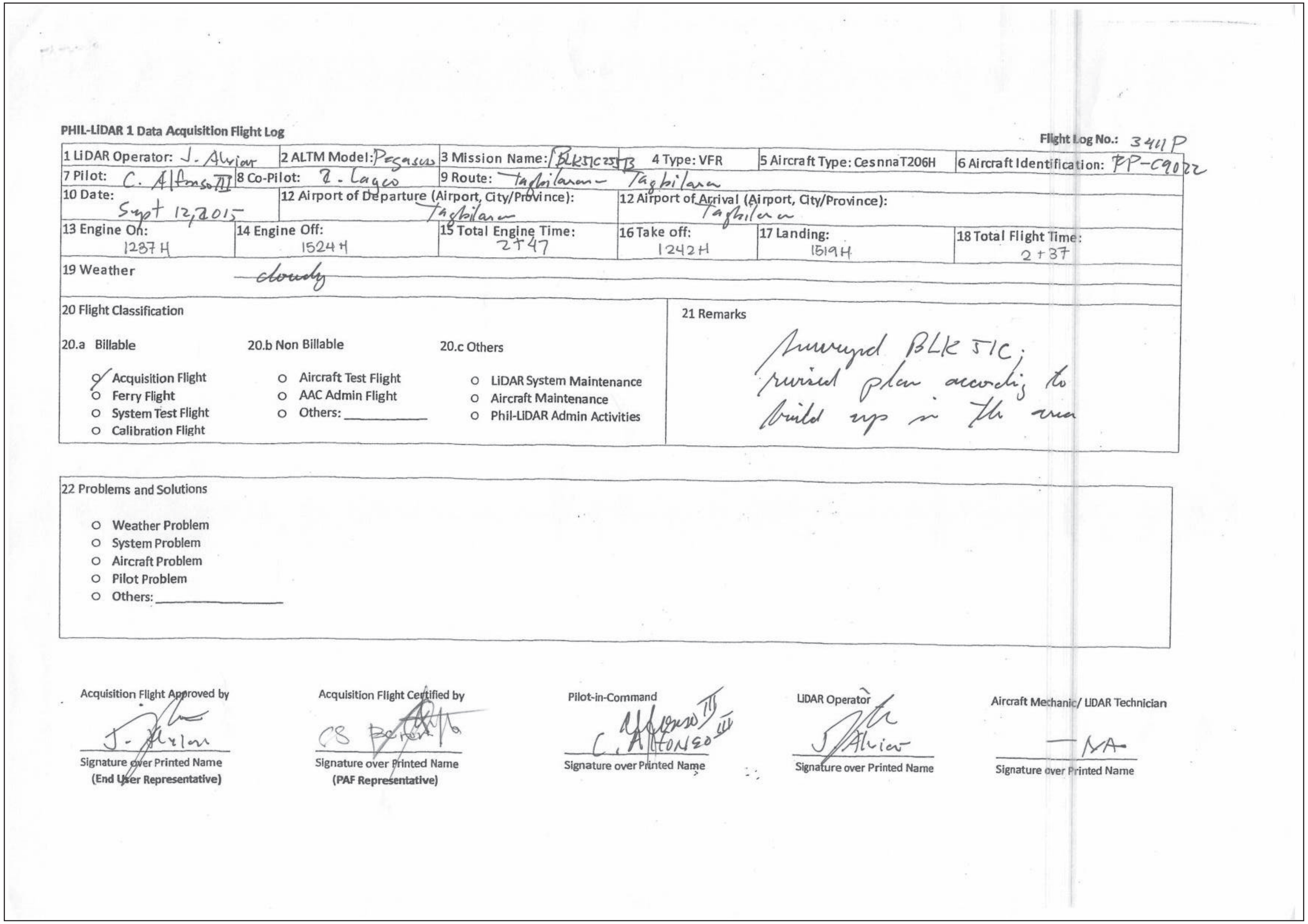
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LiDAR Operator: I. Roxas — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: NA — Signature over Printed Name

Figure A-6. 1. Flight Log for Mission 1BLK51B255A

2. Flight Log for Mission 1BLK51C255B


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 341P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J. Alviar | 2 ALTM Model: Pegasus | 3 Mission Name: 1BLK51C255B | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP-C9022 |
| 7 Pilot: C. Alfonso III | 8 Co-Pilot: R. Lagco | 9 Route: Tagbilaran - Tagbilaran | | | |
| 10 Date: Sept 12, 2015 | 12 Airport of Departure (Airport, City/Province): Tagbilaran | | 12 Airport of Arrival (Airport, City/Province): Tagbilaran | | |
| 13 Engine On: 1237H | 14 Engine Off: 1524H | 15 Total Engine Time: 2+47 | 16 Take off: 1242H | 17 Landing: 1519H | 18 Total Flight Time: 2+37 |
| 19 Weather: cloudy | | | | | |

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 51C; revised plan according to build ups in the area

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LiDAR Technician |
|---|---|---|---|---|
| J. Alviar | CS Bo... | C. Alfonso III | J. Alviar | NA |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name | Signature over Printed Name |

Figure A-6.2. Flight Log for Mission 1BLK51C255B

3. Flight Log for Mission 1BLK51C258A

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

Flight Log No.: 34211

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: ANDAYA | 2 ALTM Model: Peg | 3 Mission Name: 1BLK51C258A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP-C9022 |
| 7 Pilot: C. Alfonso III | 8 Co-Pilot: Iasud | 9 Route: TAGBILARAN - TAGBILARAN | | | |
| 10 Date: Sept 15, 2015 | 12 Airport of Departure (Airport, City/Province): TAGBILARAN | | 12 Airport of Arrival (Airport, City/Province): TAGBILARAN | | |
| 13 Engine On: 0648 H | 14 Engine Off: 0923 H | 15 Total Engine Time: 2+35 | 16 Take off: 0653 H | 17 Landing: 0918 H | 18 Total Flight Time: 2+25 |
| 19 Weather: Cloudy | | | | | |

**20 Flight Classification**

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

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

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

**21 Remarks**

Surveyed BLK 51C at 800m

**22 Problems and Solutions**

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LIDAR Technician |
|---|---|---|---|---|
| J. Alviar | SS Bega | C. Alfonso III | K. Andaya | |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name | Signature over Printed Name |

Figure A-6.3. Flight Log for Mission 1BLK51C258A

4. Flight Log for Mission 1BLK51260A

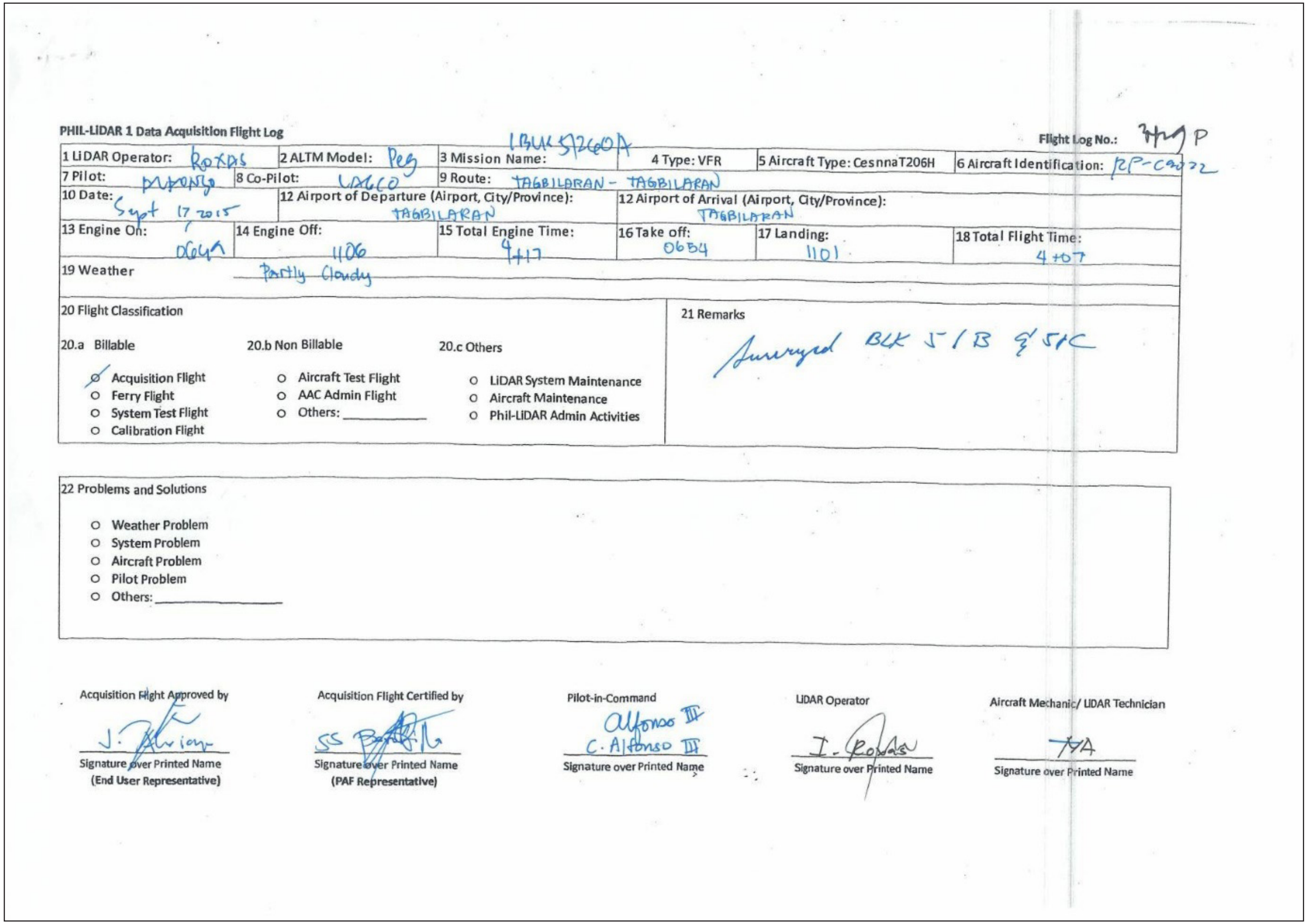
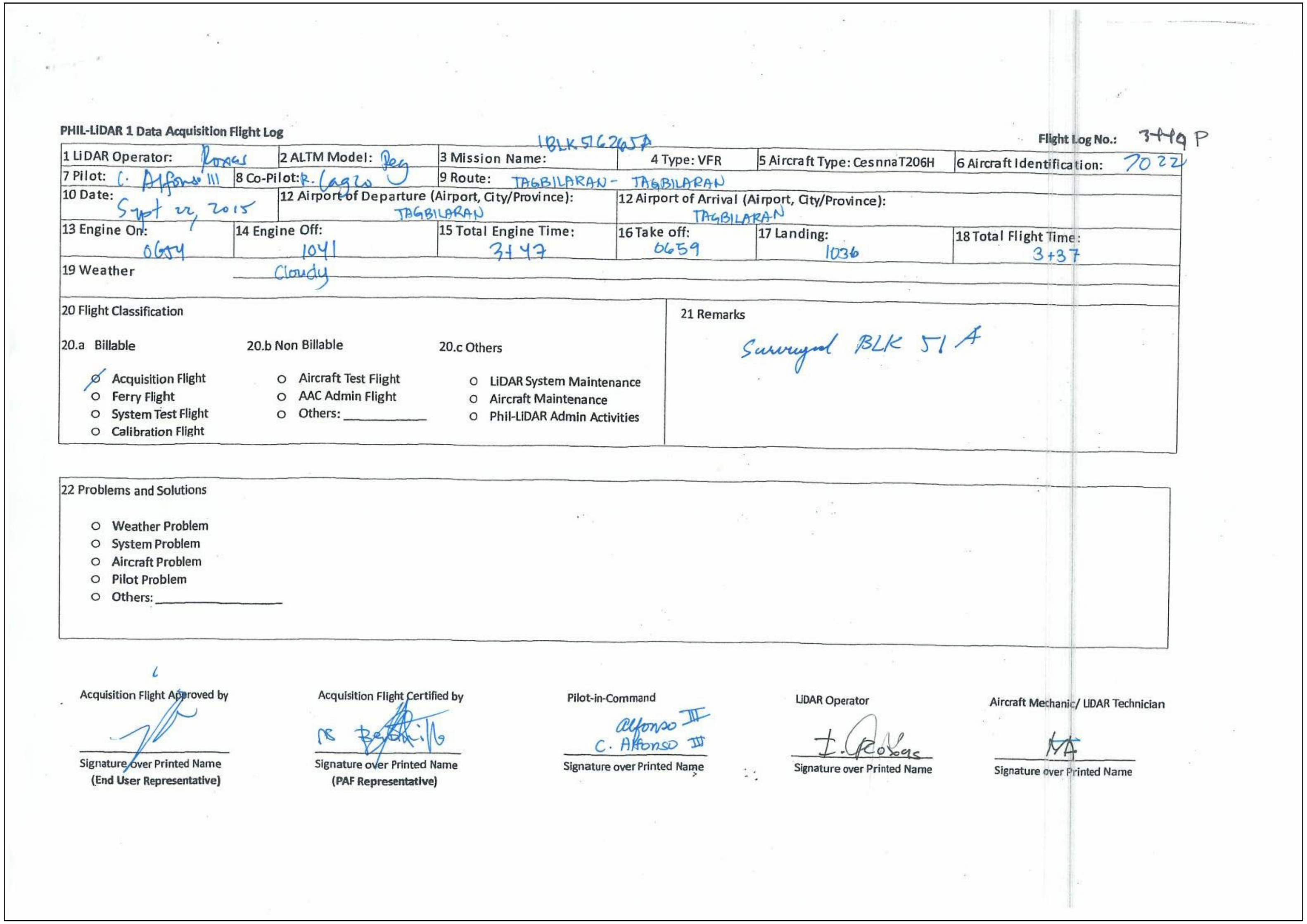



Figure A-6.4. Flight Log for Mission 1BLK51260A

5. Flight Log for Mission 1BLK51G265A



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3449P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: Roxas | 2 ALTM Model: Peg | 3 Mission Name: 1BLK51G265A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 7022 |
| 7 Pilot: C. Alfonso III | 8 Co-Pilot: R. Lagto | 9 Route: TAGBILARAN - TAGBILARAN | | | |
| 10 Date: Sept 22, 2015 | 12 Airport of Departure (Airport, City/Province): TAGBILARAN | | 12 Airport of Arrival (Airport, City/Province): TAGBILARAN | | |
| 13 Engine On: 0654 | 14 Engine Off: 1041 | 15 Total Engine Time: 3+47 | 16 Take off: 0659 | 17 Landing: 1036 | 18 Total Flight Time: 3+37 |
| 19 Weather: Cloudy | | | | | |

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 51A

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LiDAR Technician |
|---|---|---|---|---|
| [signature] | [signature] | Alfonso III C. Alfonso III | I. Roxas | [signature] |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name | Signature over Printed Name |

Figure A-6.5. Flight Log for Mission 1BLK51G265A

6. Flight Log for Mission 1BLK51S266A

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3449P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: Roxas | 2 ALTM Model: Peg | 3 Mission Name: 1BLK51S266A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 7022 |
| 7 Pilot: C. Alfonso III | 8 Co-Pilot: R. Lagto | 9 Route: TAGBILARAN - TAGBILARAN | | | |
| 10 Date: Sept 22, 2015 | 12 Airport of Departure (Airport, City/Province): TAGBILARAN | | 12 Airport of Arrival (Airport, City/Province): TAGBILARAN | | |
| 13 Engine On: 0654 | 14 Engine Off: 1041 | 15 Total Engine Time: 3+47 | 16 Take off: 0659 | 17 Landing: 1036 | 18 Total Flight Time: 3+37 |
| 19 Weather: Cloudy | | | | | |

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 51A

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

| Acquisition Flight Approved by | Acquisition Flight Certified by | Pilot-in-Command | LiDAR Operator | Aircraft Mechanic/ LiDAR Technician |
|---|---|---|---|---|
| [signature] | [signature] | Alfonso III<br>C. Alfonso III | I. Roxas | [signature] |
| Signature over Printed Name (End User Representative) | Signature over Printed Name (PAF Representative) | Signature over Printed Name | Signature over Printed Name | Signature over Printed Name |

Figure A-6.6. Flight Log for Mission 1BLK51S266A

# Annex 7. Flight Status Reports

BOHOL

(September 12-23, 2015)

Table A-7.1. Flight Status Report

| FLIGHT NO | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 3409P | BLK 51S INABANGA FP AND BLK 51B<br>MATULID FP | 1BLK51B255A | I ROXAS | SEPT 12 | SURVEYED BLK 51B AT 1000M THEN 850M ALT; ABNORMAL AVPOSVIEW TERMINATION; DIGI HD WRITING ERROR; SWATH NOT UPDATING – RESTARTED LASER – INC SWATH AND LAS |
| 3411P | BLK 51C AND 51F<br>MATULID FP | 1BLK51C255B | J ALVIAR | SEPT 12 | SURVEYED BLK 51C AND PARTS OF BLK 51F AT 800M ALT; LOST CHANNEL A PROMPT BUT BOTH LASERS WERE STILL ACQUIRING RANGES |
| 3421P | BLK 51F | 1BLK51C258A | KJ ANDAYA | SEPT 15 | SURVEYED BLK 51F AT 800M; TOO CLOUDY |
| 3429P | BLK 51C, 51B, 51F | 1BLK51260A | I ROXAS | SEPT 17 | SURVEYED BLK 51B, 51F, AND 51C; CHANGED MISSION NAME FROM 1BLK75260A TO 1BLK51260A; DESCENDED FROM 1000M TO 800M |
| 3449P | BLK 51A | 1BLK51G265A | I ROXAS | SEPT 22 | SURVEYED BLK 51A AT 800M |
| 3453P | BLK 51LKS, 51F<br>LOBOC FP | 1BLK51S266A | J ALVIAR | SEPT 23 | SURVEYED GAPS IN LOBOC FP; IRREGULAR SWATH AND LAS |

## LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No.: 3409P
Area: BLK51S,BLK51B
Mission Name: 1BLK51B255A
Parameters: Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

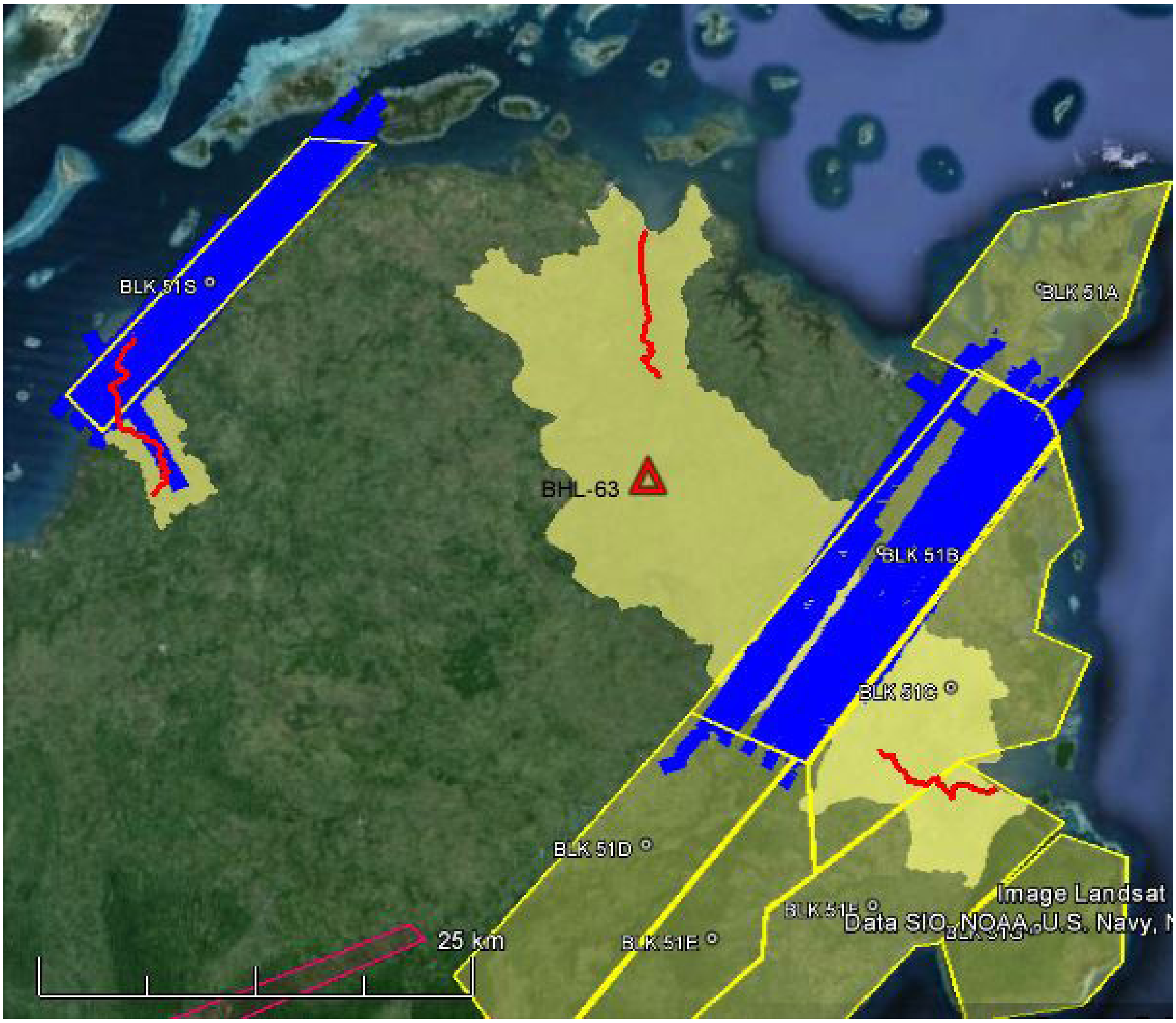



Figure A-7.1. Swath for Flight No. 3409P

| | |
|---|---|
| Flight No.: | 3411P |
| Area: | BLK51C, BLK51F |
| Mission Name: | 1BLK51C255B |
| Parameters: | Altitude: 800-1000m; Scan Frequency: 30; Scan Angle: 50 |

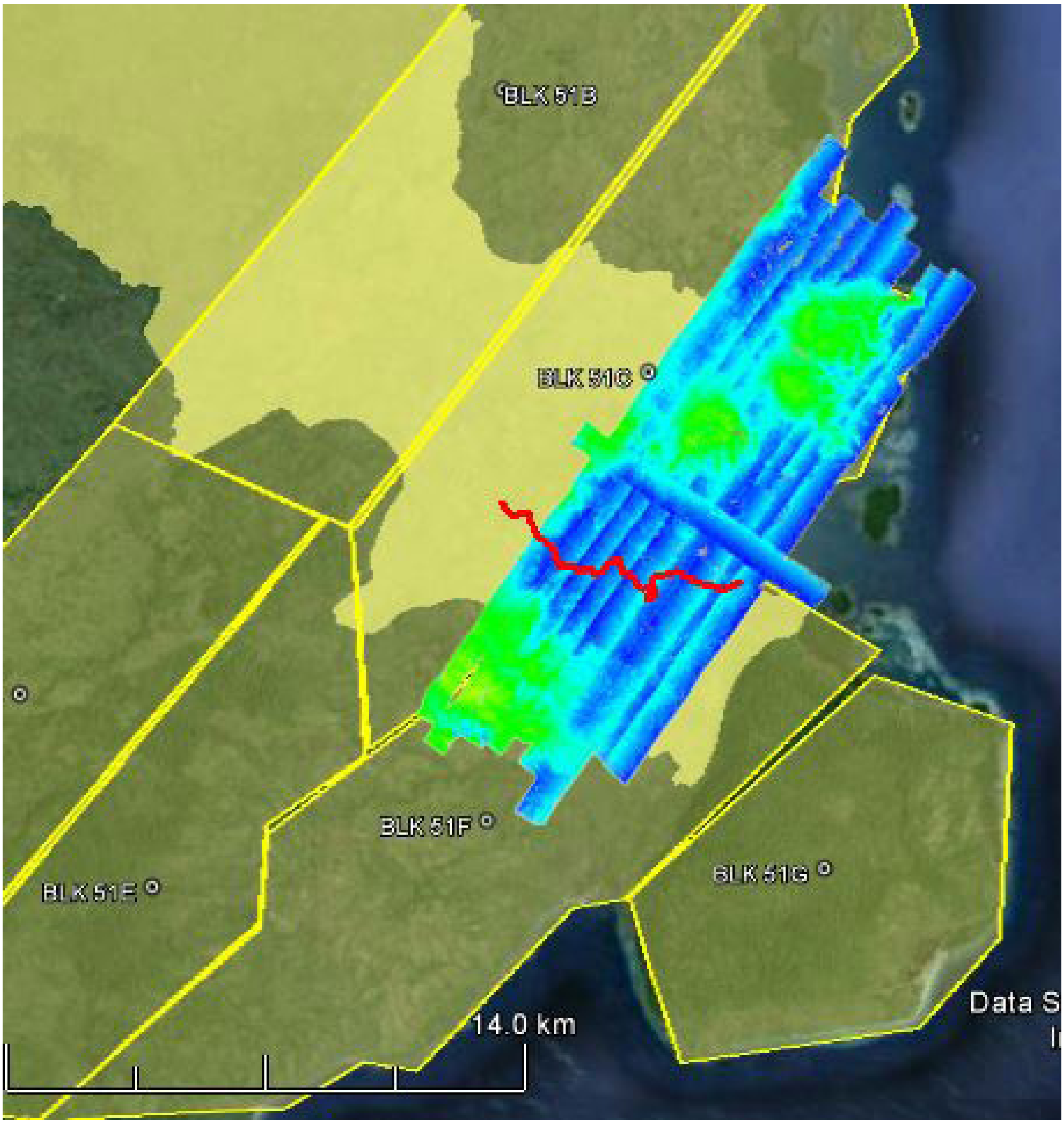



Figure A-7.2. Swath for Flight No. 3411P

Flight No.: 3421P
Area: BLK51F
Mission Name: 1BLK51C258A
Parameters: Altitude: 800-1000m; Scan Frequency: 30; Scan Angle: 50

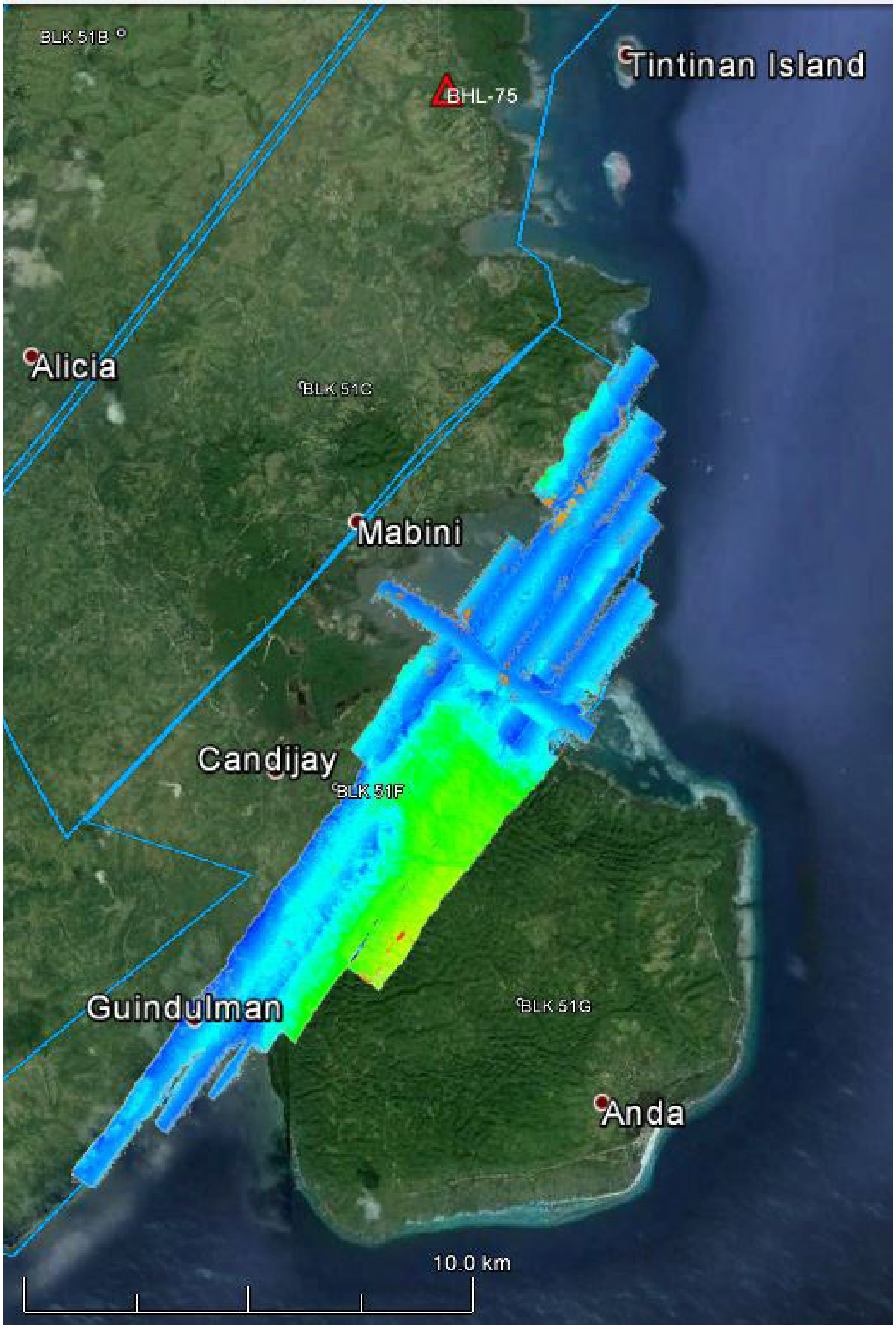



Figure A-7.3. Swath for Flight No. 3421P

| | |
|---|---|
| Flight No.: | 3429P |
| Area: | BLK51B, BLK51F,BLK51C |
| Mission Name: | 1BLK51260A |
| Parameters: | Altitude: 800-1000m; Scan Frequency: 30; Scan Angle: 50 |

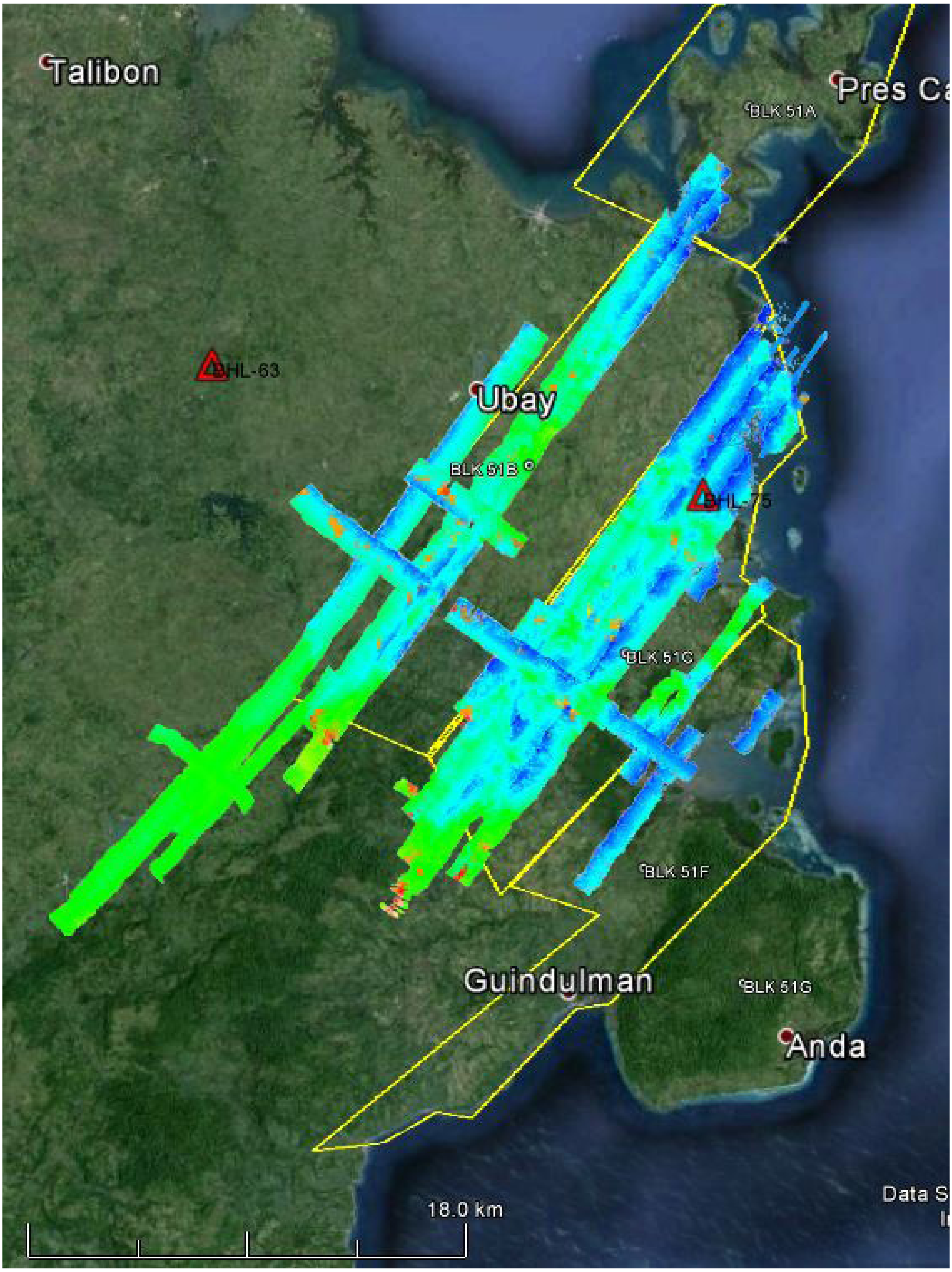



Figure A-7.4. Swath for Flight No. 3429P

Flight No.: 3449P
Area: BLK51A
Mission Name: 1BLK51G265A
Parameters: Altitude: 800-1000m; Scan Frequency: 30; Scan Angle: 50

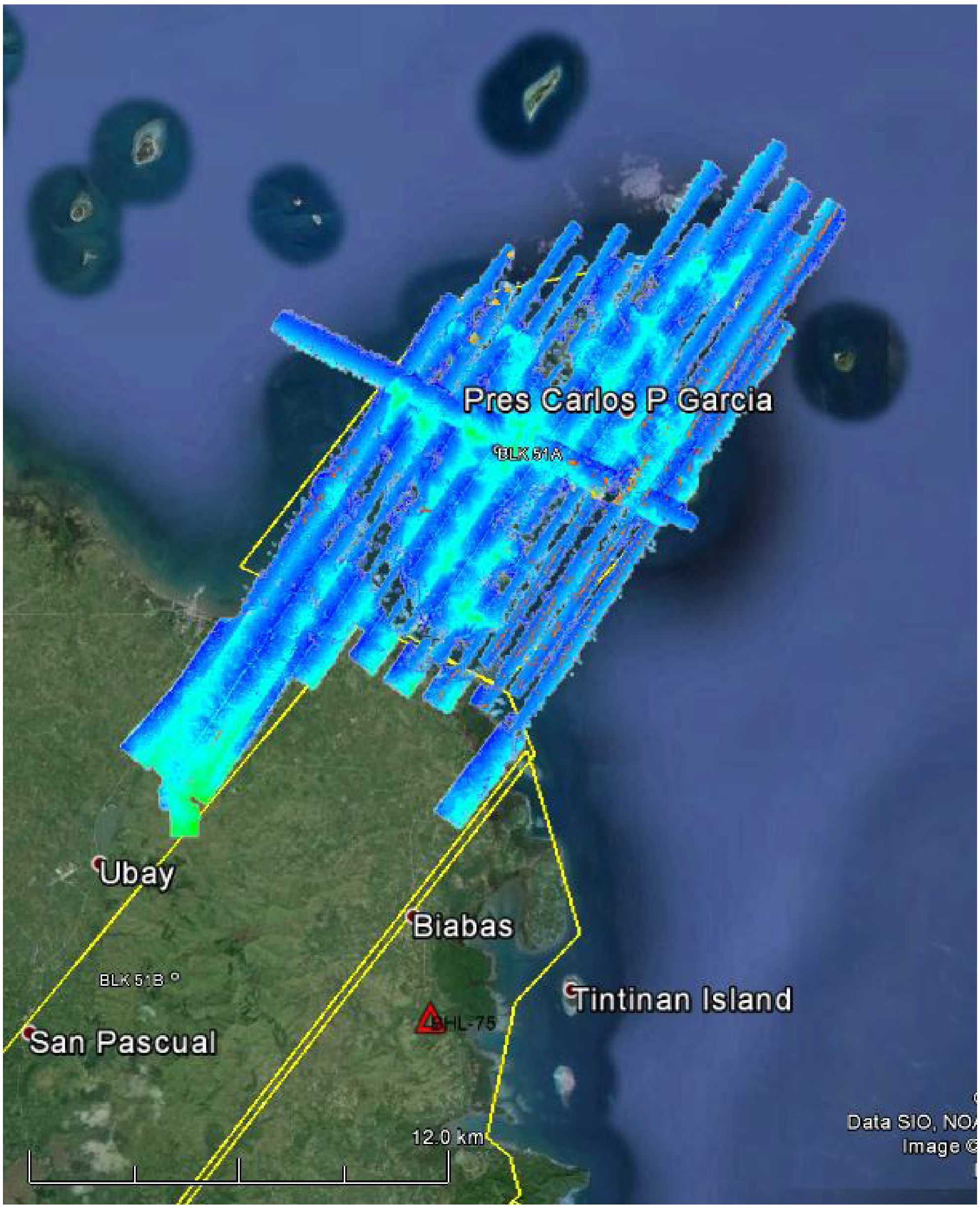



Figure A-7.5. Swath for Flight No. 3449P

Flight No.: 3453P
Area: BLK51F, BLK51LKS
Mission Name: 1BLK51S266A
Parameters: Altitude:1000m; Scan Frequency: 30; Scan Angle: 50

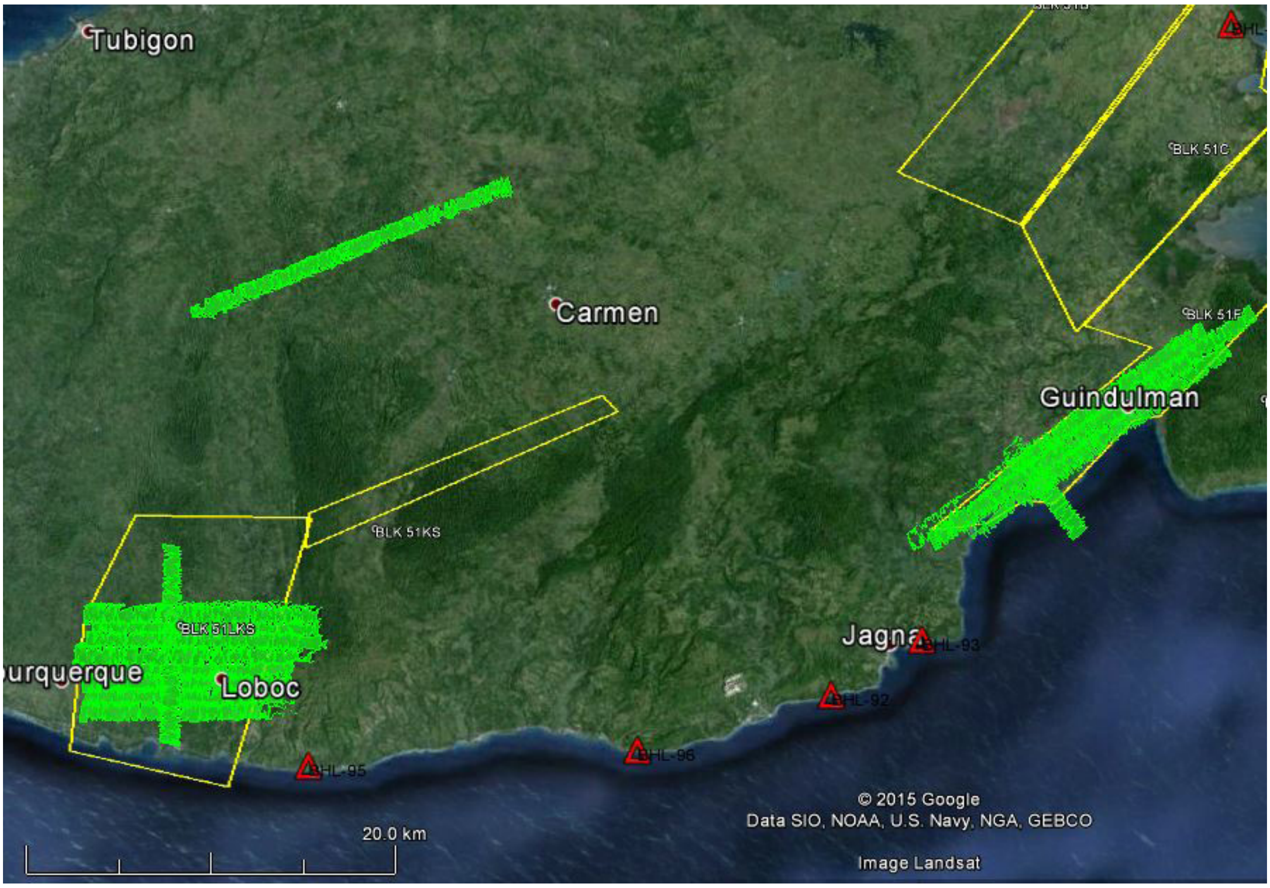



Figure A-7.6. Swath for Flight No. 3453P

# Annex 8: Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk51B

| Flight Area | Bohol |
|---|---|
| Mission Name | **Blk51B** |
| Inclusive Flights | 3409P |
| Range data size | 32.8 GB |
| POS | 302 MB |
| Base Data | 15.7 MB |
| Image | NA |
| Transfer date | September 21, 2015 |
| | |
| *Solution Status* | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| *Smoothed Performance Metrics* (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.318 |
| RMSE for East Position (<4.0 cm) | 1.080 |
| RMSE for Down Position (<8.0 cm) | 2.870 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000157 |
| IMU attitude correction stdev (<0.001deg) | 0.000393 |
| GPS position stdev (<0.01m) | 0.0008 |
| | |
| Minimum % overlap (>25) | 31.38 |
| Ave point cloud density per sq.m. (>2.0) | 2.78 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 258 |
| Maximum Height | 510.48 m |
| Minimum Height | 65.54 m |
| | |
| Classification (# of points) | |
| Ground | 35,543,081 |
| Low vegetation | 22,577,357 |
| Medium vegetation | 31,702,271 |
| High vegetation | 38,654,593 |
| Building | 1,252,854 |
| | |
| Orthophoto | No |
| Processed by | Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Kathryn Claudine Zarate |

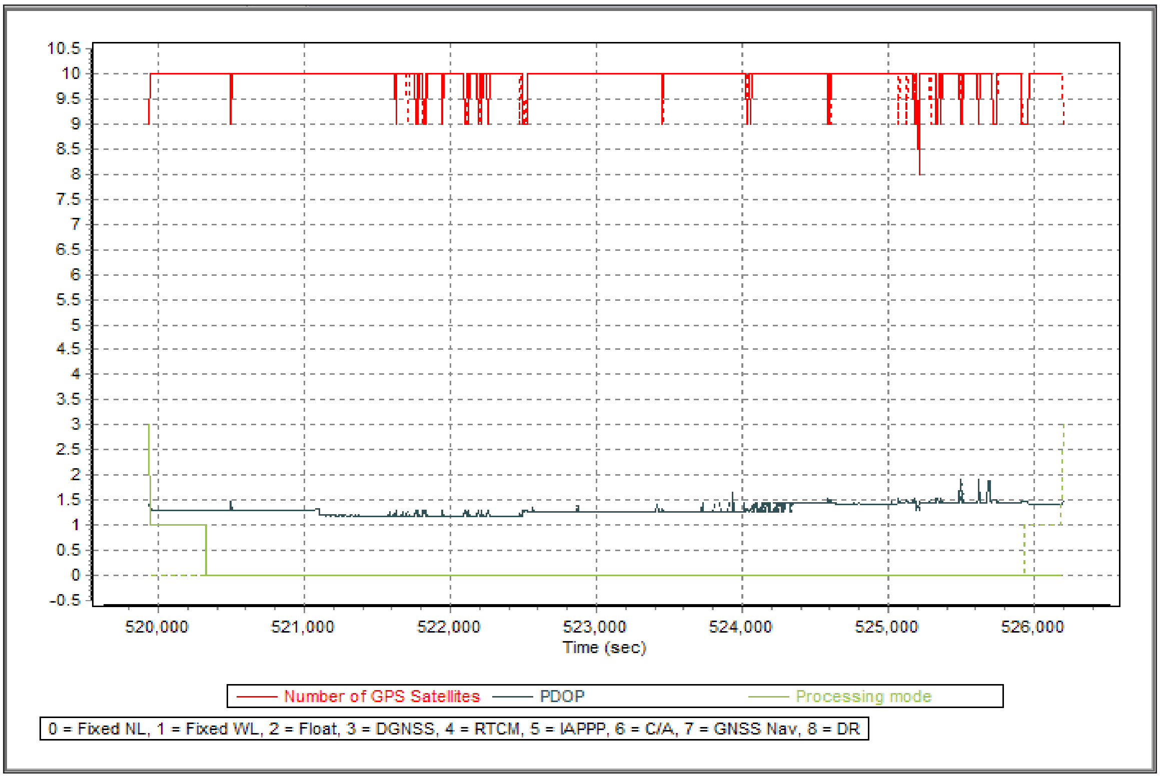



Figure A-8.1. Solution Status

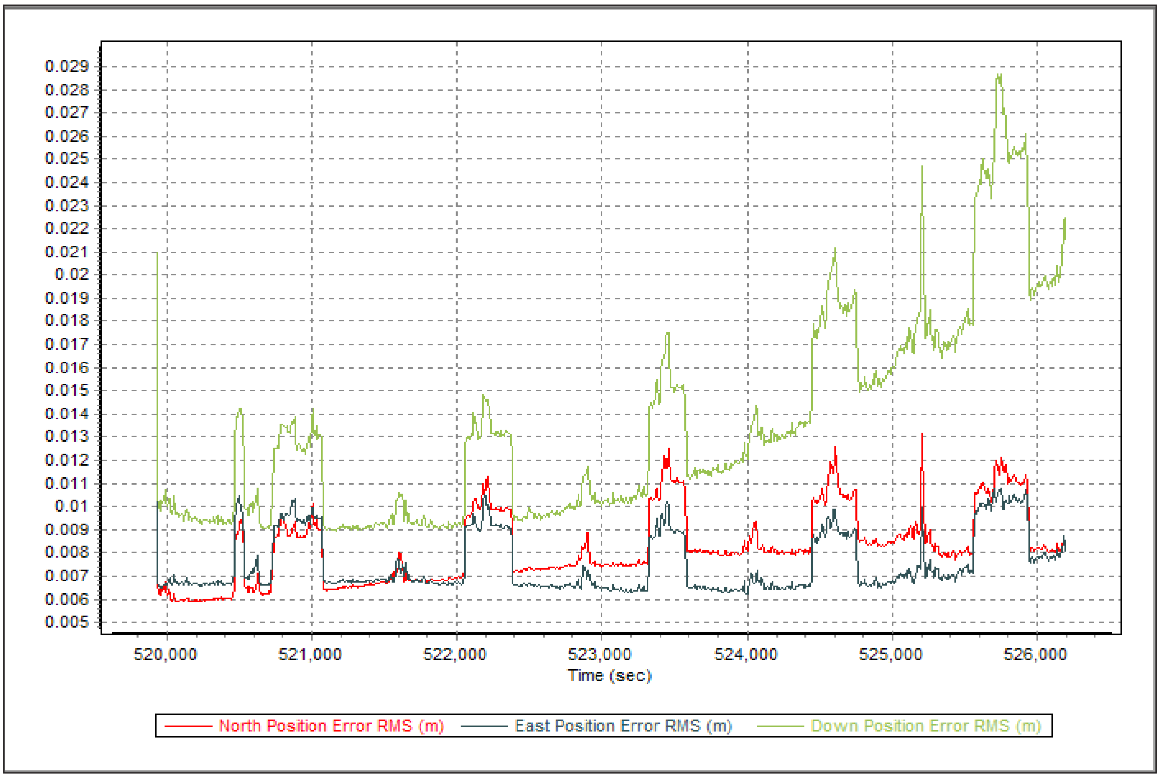



Figure A-8.2. Smoothed Performance Metric Parameters

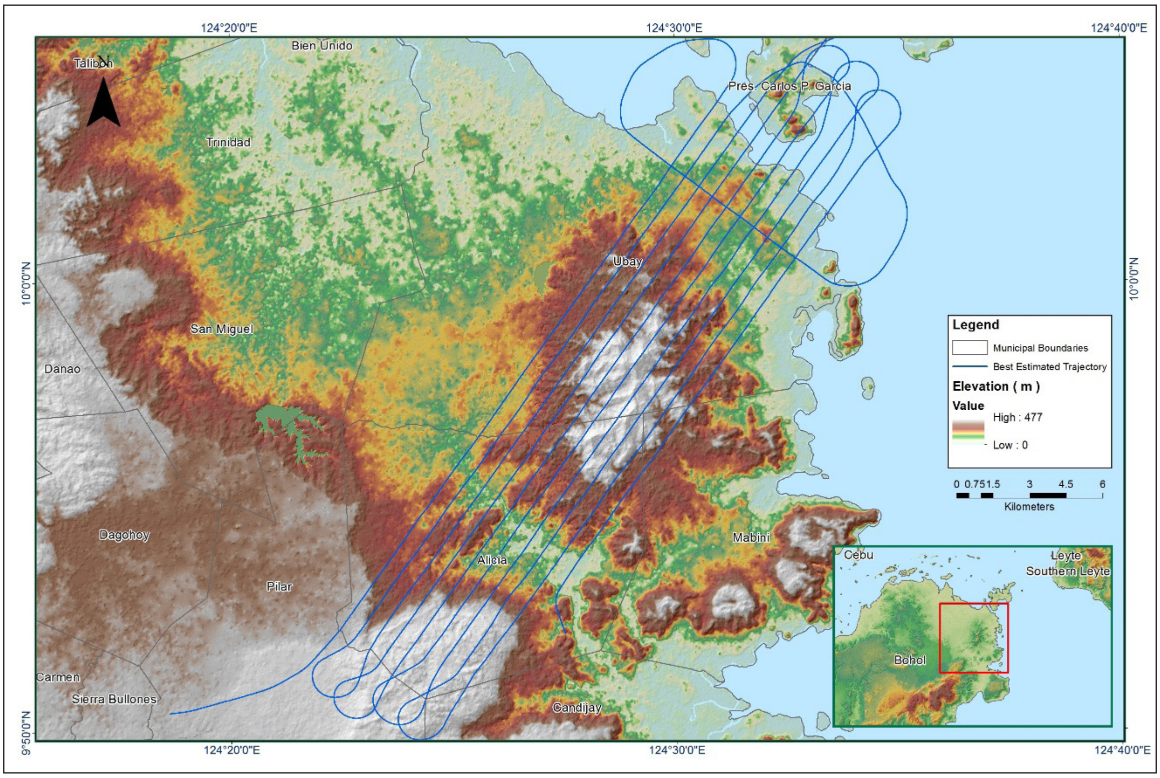



Figure A-8.3. Best Estimate Trajectory

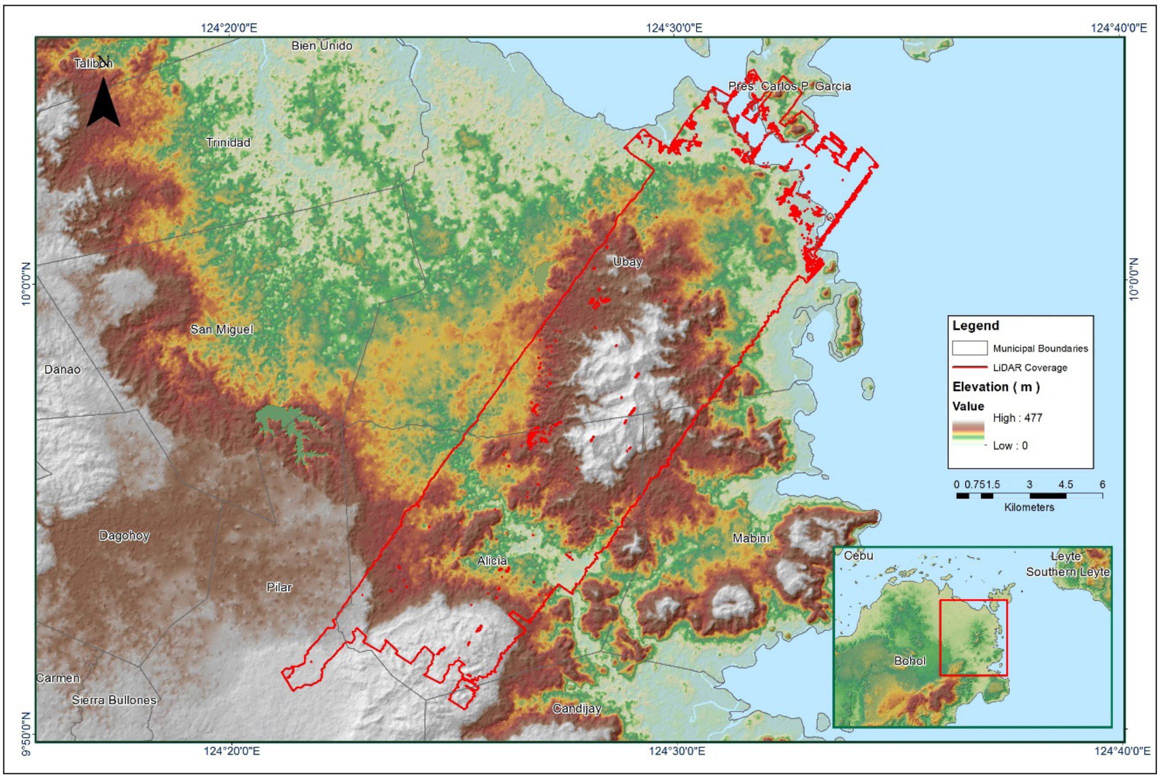



Figure A-8.4. Coverage of LiDAR data

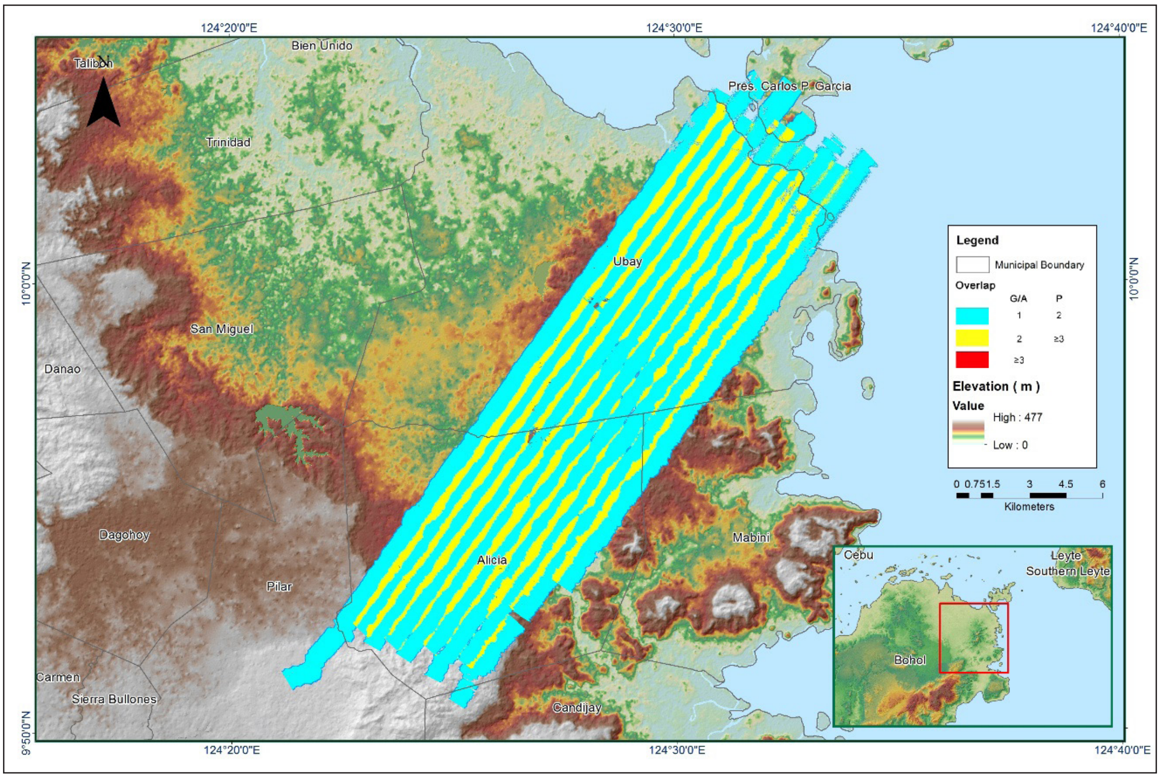



Figure A-8.5. Image of data overlap

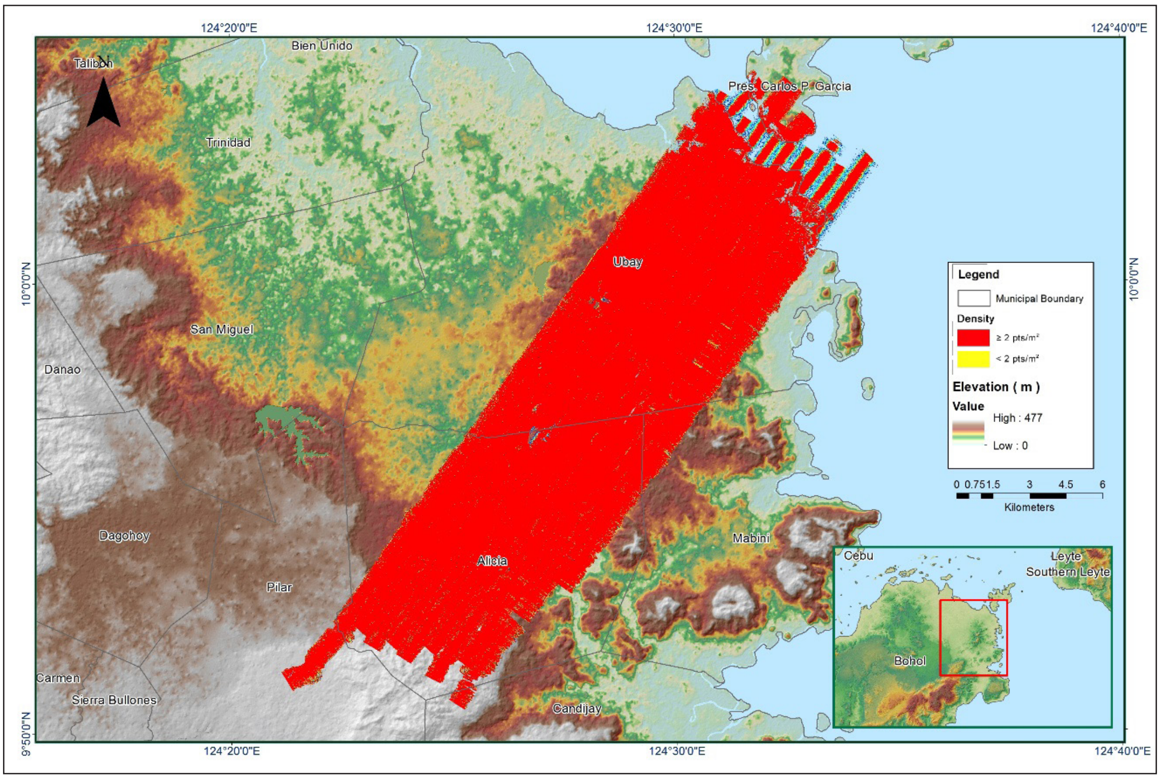



Figure A-8.6. Density Map of merged LiDAR data

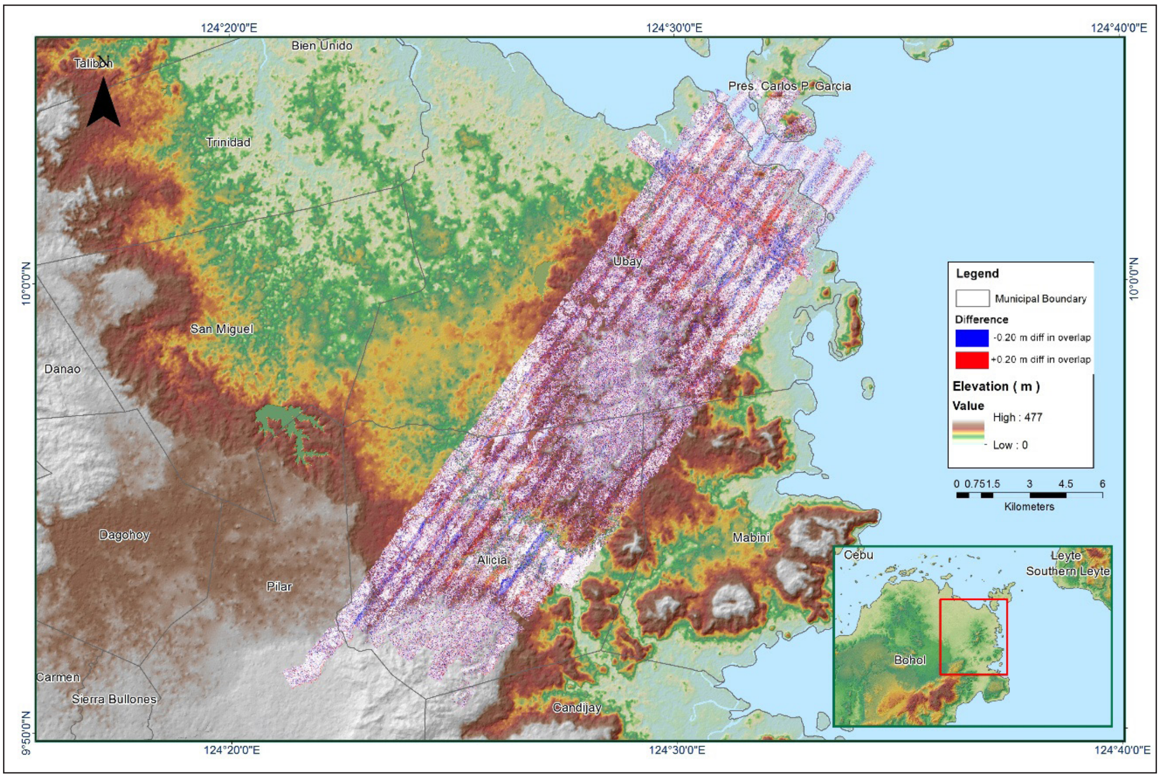



Figure A-8.7. Elevation Difference Between flight lines

Table A-8.2. Mission Summary Report for Mission Blk51C

| Flight Area | Bohol |
|---|---|
| Mission Name | **Blk51C** |
| Inclusive Flights | 3411P, 3429P |
| Range data size | 12.9 GB |
| POS | 151 MB |
| Base Data | 24.05 MB |
| Image | NA |
| Transfer date | September 21, 2015 |
| | |
| *Solution Status* | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| *Smoothed Performance Metrics* (in cm) | |
| RMSE for North Position (<4.0 cm) | 1.350 |
| RMSE for East Position (<4.0 cm) | 1.416 |
| RMSE for Down Position (<8.0 cm) | 3.280 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000206 |

| | |
|---|---|
| IMU attitude correction stdev (<0.001deg) | 0.000581 |
| GPS position stdev (<0.01m) | 0.0091 |
| | |
| Minimum % overlap (>25) | 20.51 |
| Ave point cloud density per sq.m. (>2.0) | 3.55 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 149 |
| Maximum Height | 398.62 m |
| Minimum Height | 58.94 m |
| | |
| *Classification (# of points)* | |
| Ground | 31,388,745 |
| Low vegetation | 12,005,662 |
| Medium vegetation | 16,254,529 |
| High vegetation | 41,356,718 |
| Building | 946,900 |
| | |
| Orthophoto | No |
| Processed by | Engr. Jennifer Saguran, Engr. Edgardo Gubatanga, Engr. Krisha Marie Bautista |

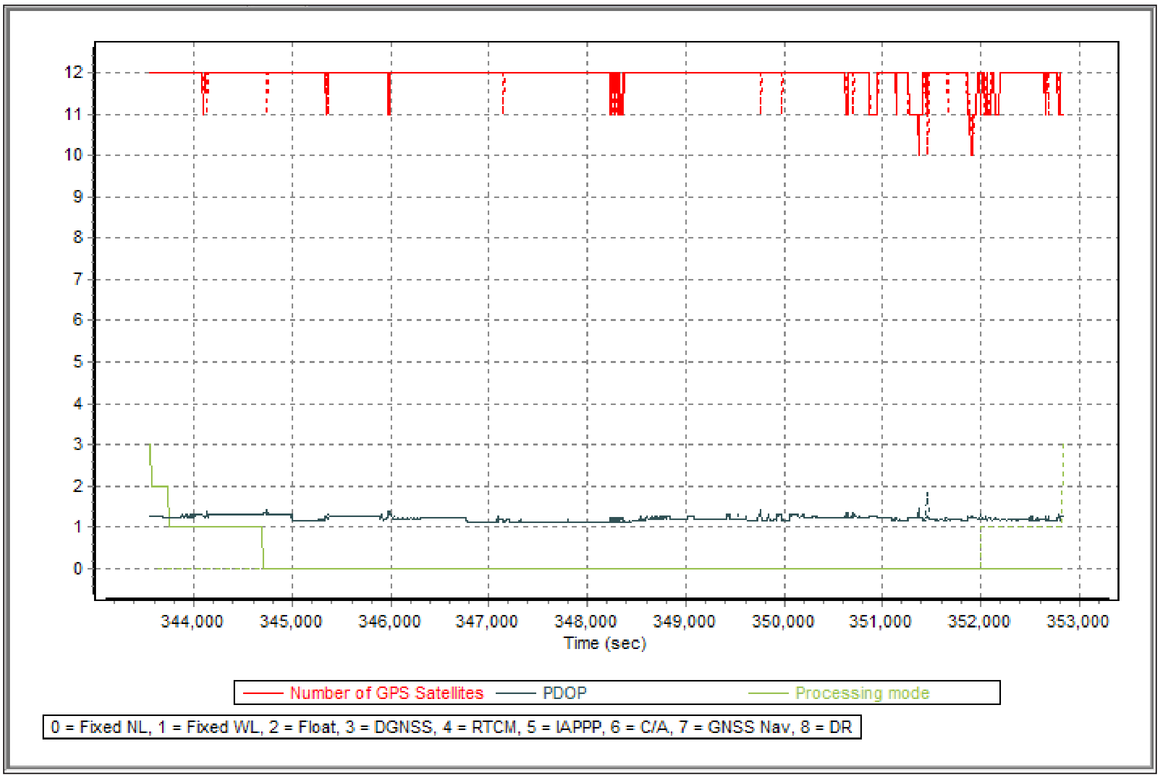



Figure A-8.8. Solution Status

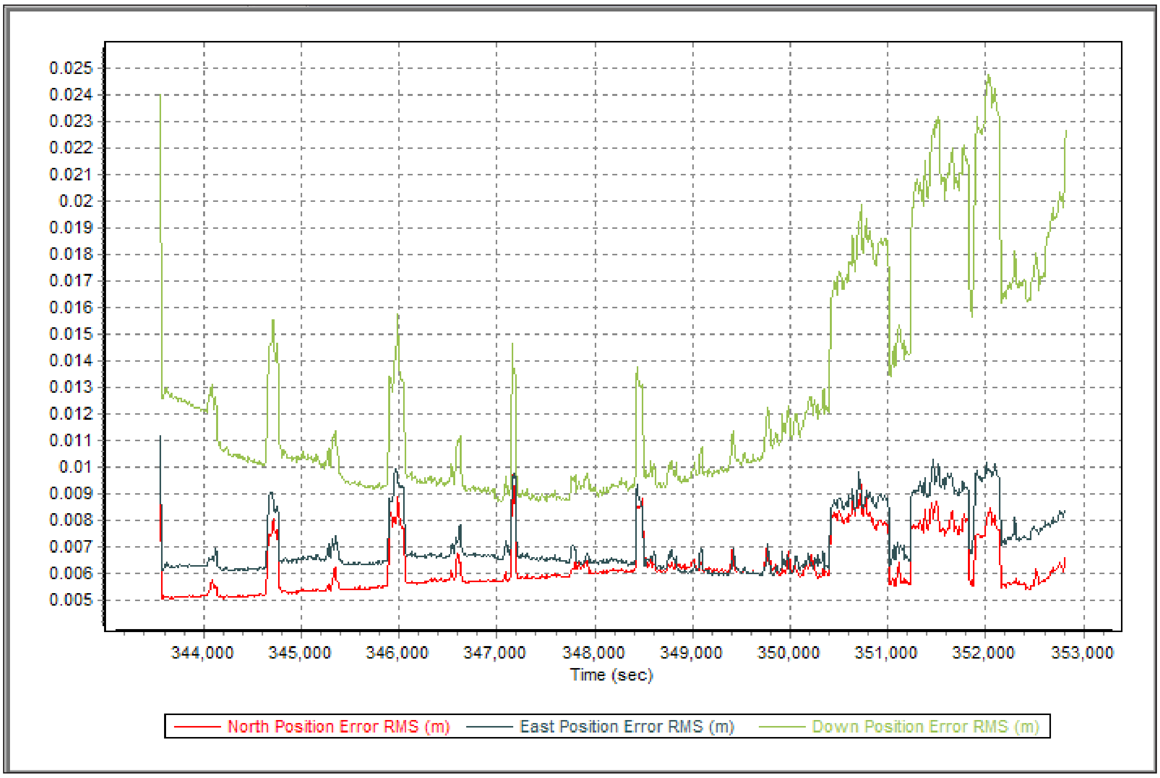



Figure A-8.9. Smoothed Performance Metric Parameters

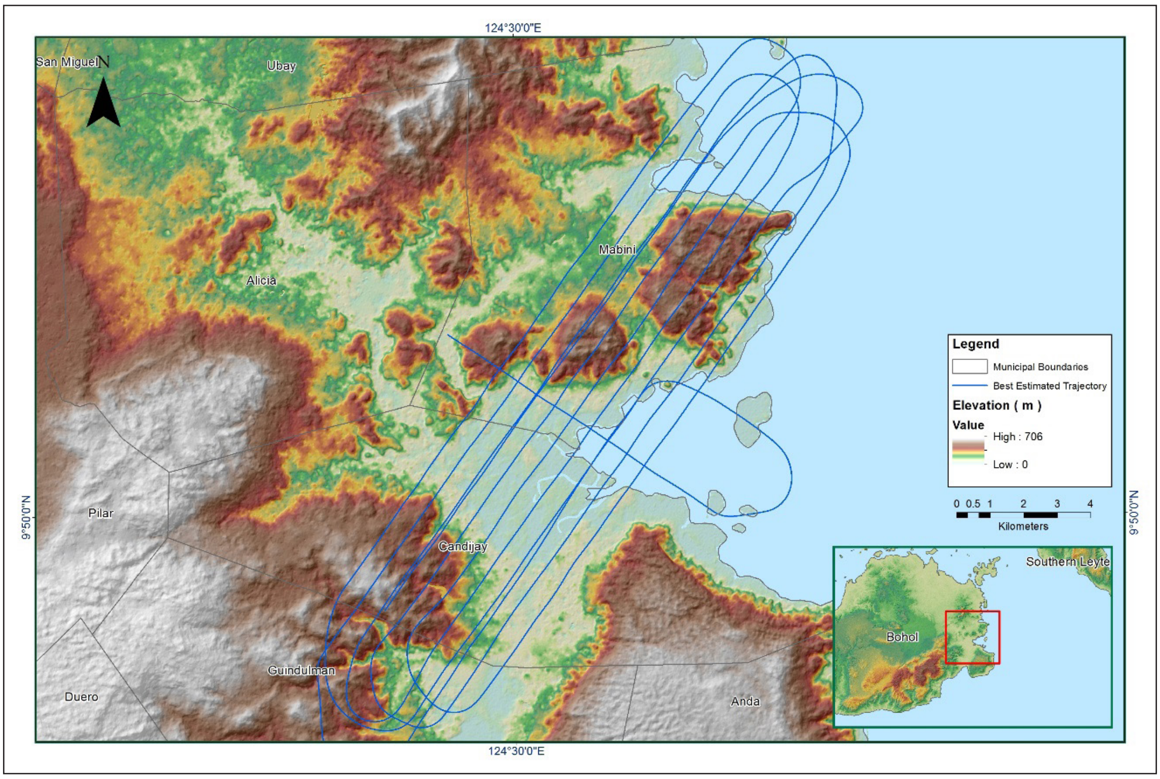



Figure A-8.10. Best Estimate Trajectory

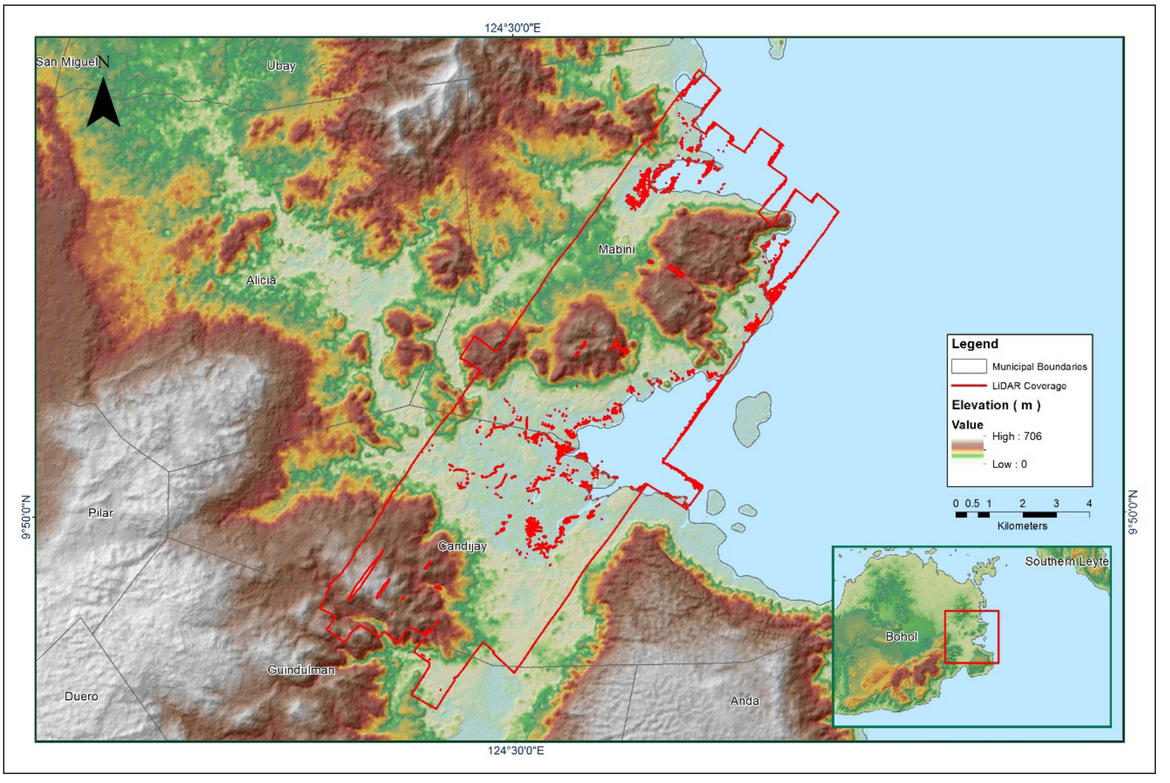



Figure A-8.11. Coverage of LiDAR data

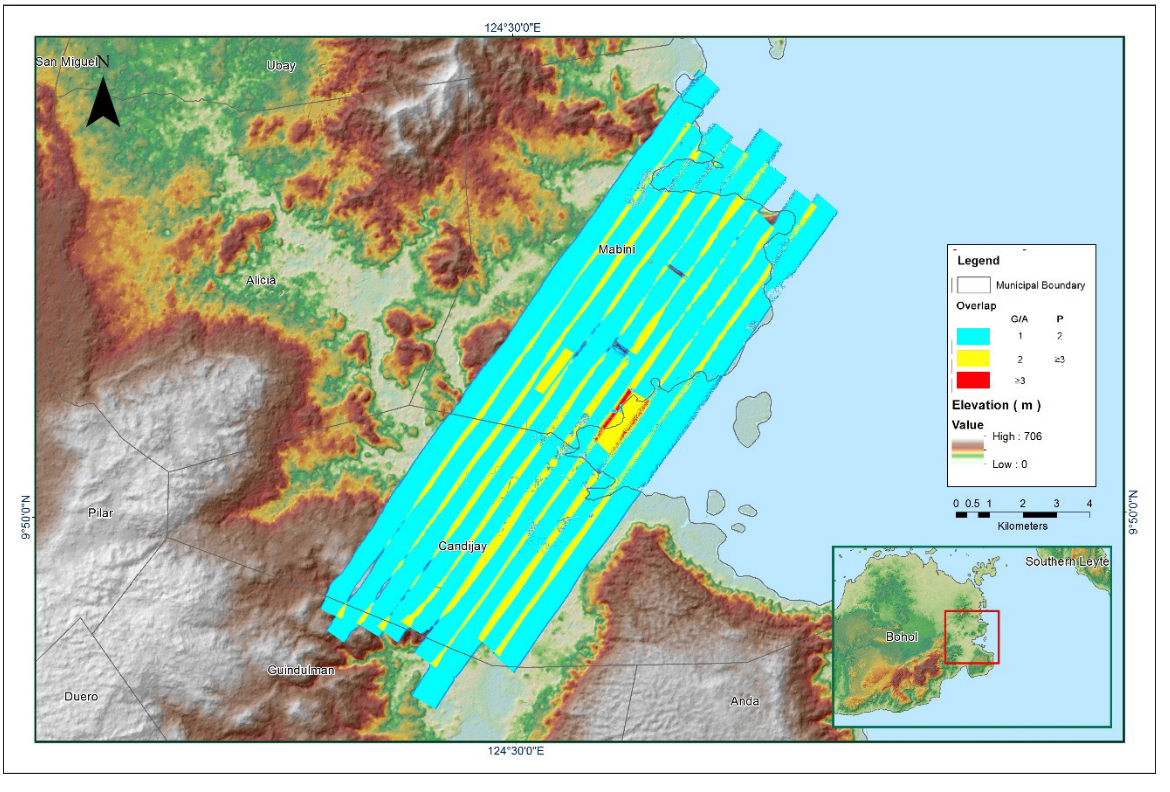



Figure A-8.12. Image of data overlap

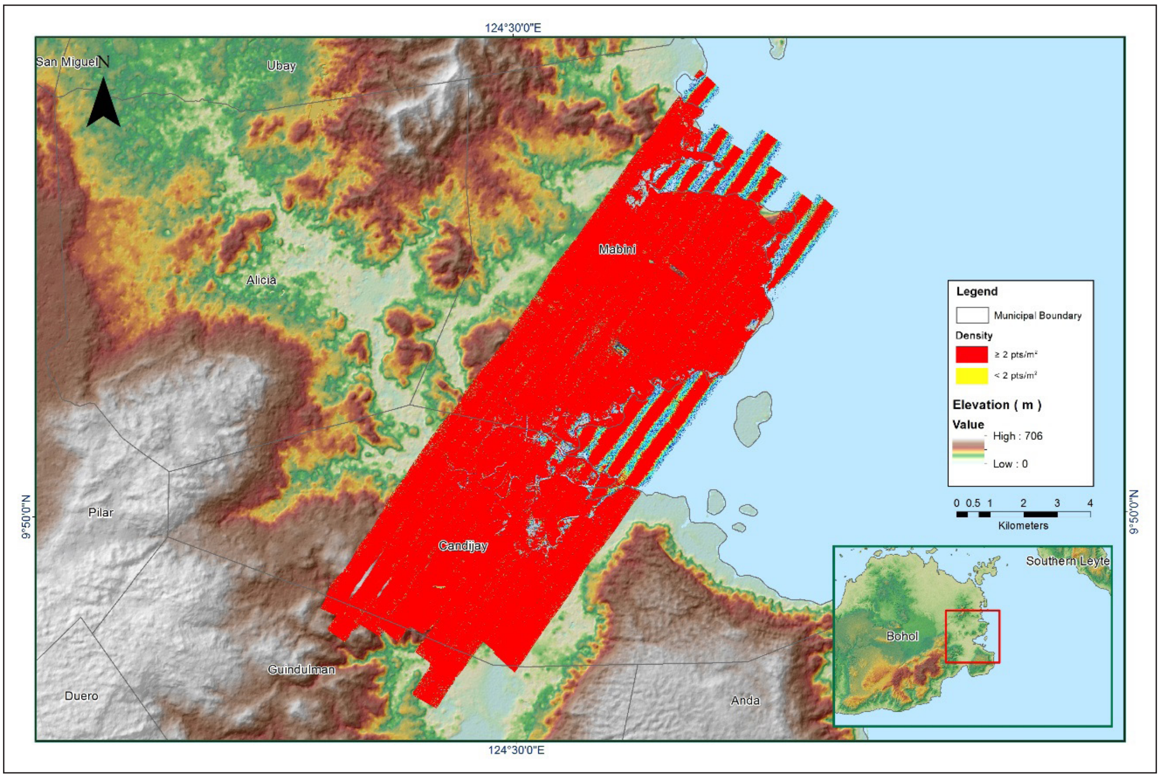



Figure A-8.13. Density Map of merged LiDAR data

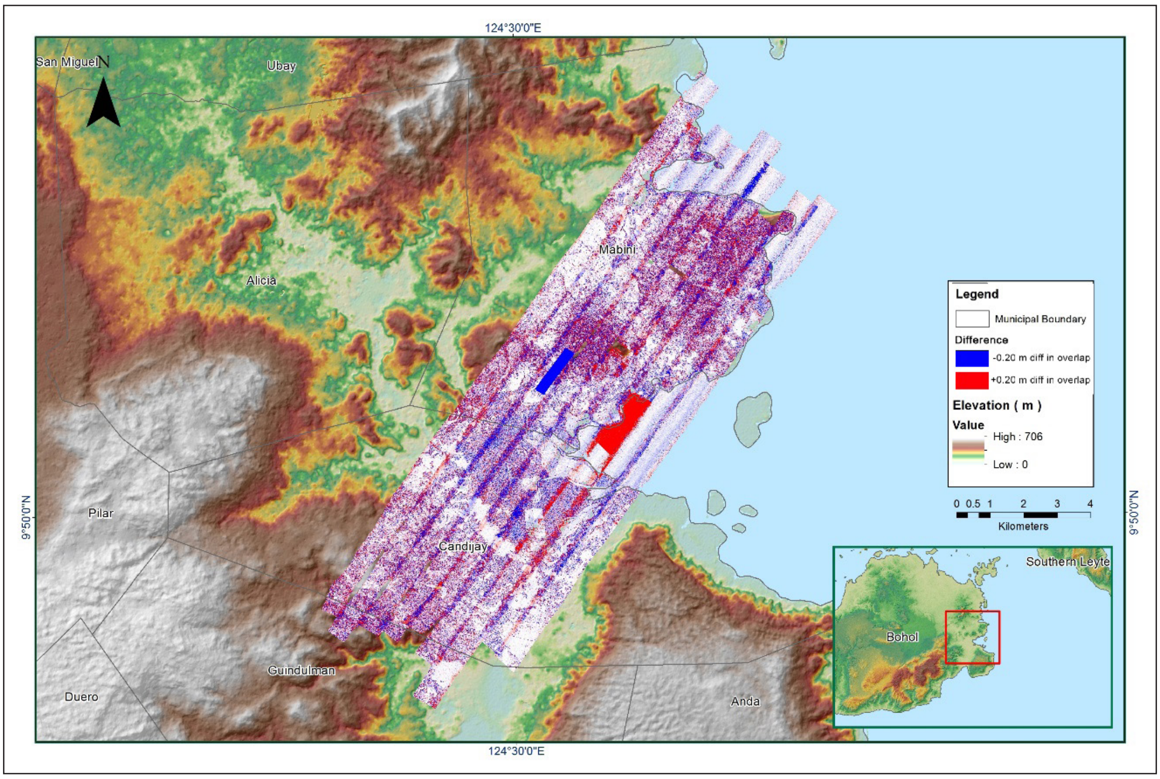



Figure A-8.14. Elevation Difference Between flight lines

Table A-8.3. Mission Summary Report for Mission Blk51C Additional

| Flight Area | Bohol |
|---|---|
| Mission Name | **Blk51C_additional** |
| Inclusive Flights | 3429P |
| Range data size | 23.8 GB |
| POS | 261 MB |
| Base Data | 8.35 MB |
| Image | NA |
| Transfer date | October 28, 2015 |
| | |
| *Solution Status* | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | No |
| Processing Mode (<=1) | Yes |
| | |
| *Smoothed Performance Metrics* (in cm) | |
| RMSE for North Position (<4.0 cm) | 0.966 |
| RMSE for East Position (<4.0 cm) | 1.029 |
| RMSE for Down Position (<8.0 cm) | 2.475 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000206 |
| IMU attitude correction stdev (<0.001deg) | 0.000581 |
| GPS position stdev (<0.01m) | 0.0091 |
| | |
| Minimum % overlap (>25) | 26.40 |
| Ave point cloud density per sq.m. (>2.0) | 2.67 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 376 |
| Maximum Height | 493.11 m |
| Minimum Height | 66.88 m |
| | |
| *Classification (# of points)* | |
| Ground | 47,220,916 |
| Low vegetation | 24,759,582 |
| Medium vegetation | 33,557,086 |
| High vegetation | 62,237,981 |
| Building | 1,894,697 |
| | |
| Orthophoto | No |
| Processed by | Engr. Jennifer Saguran, Engr. Chelou Prado, Kathryn Claudyn Zarate |

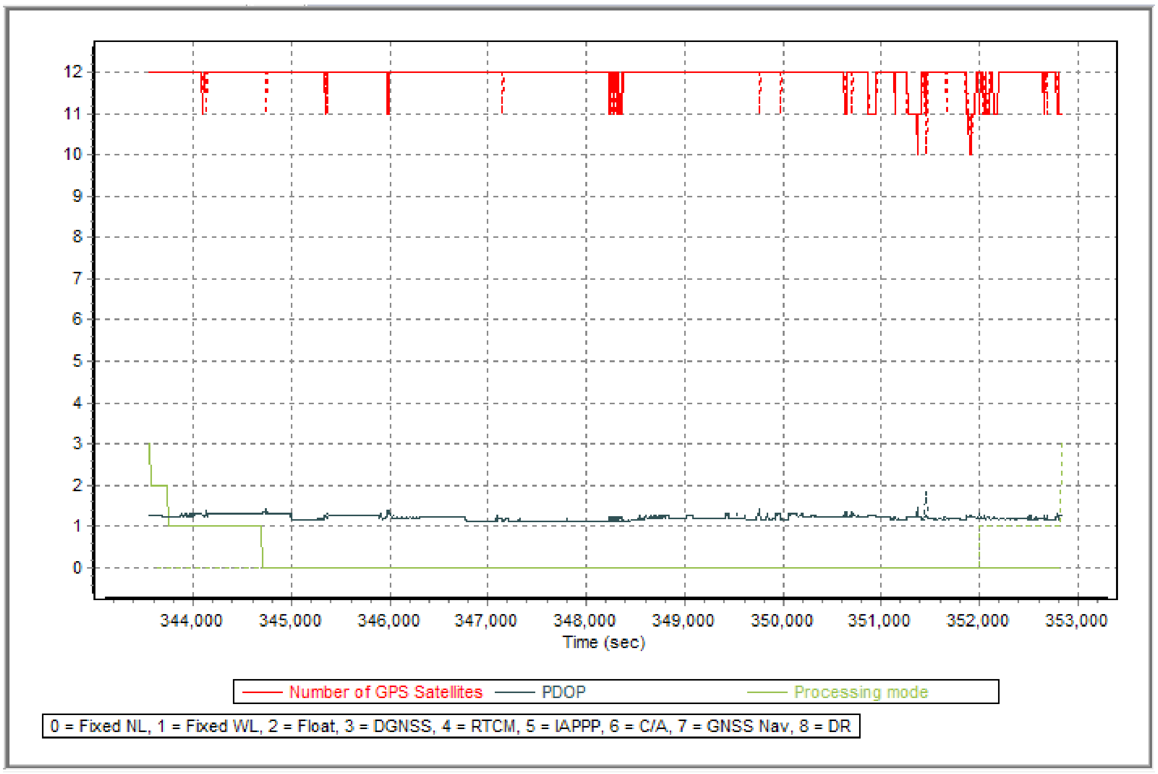



Figure A-8.15. Solution Status

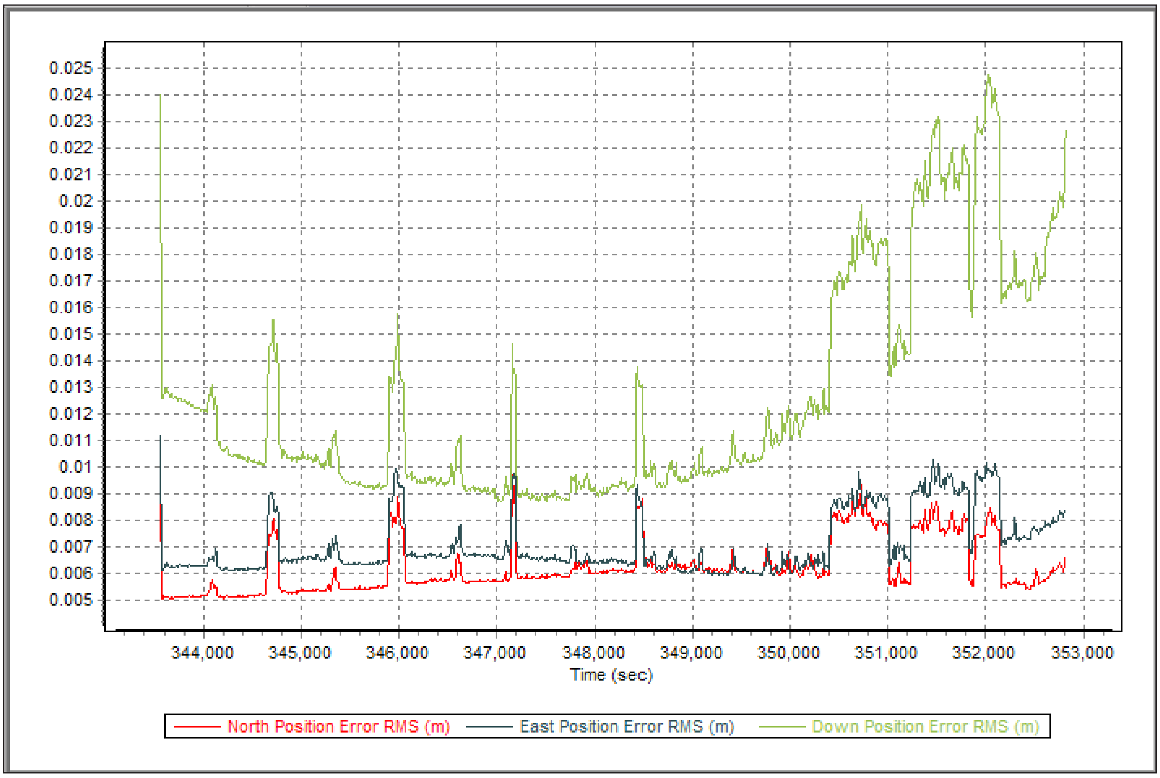



Figure A-8.16. Smoothed Performance Metric Parameters

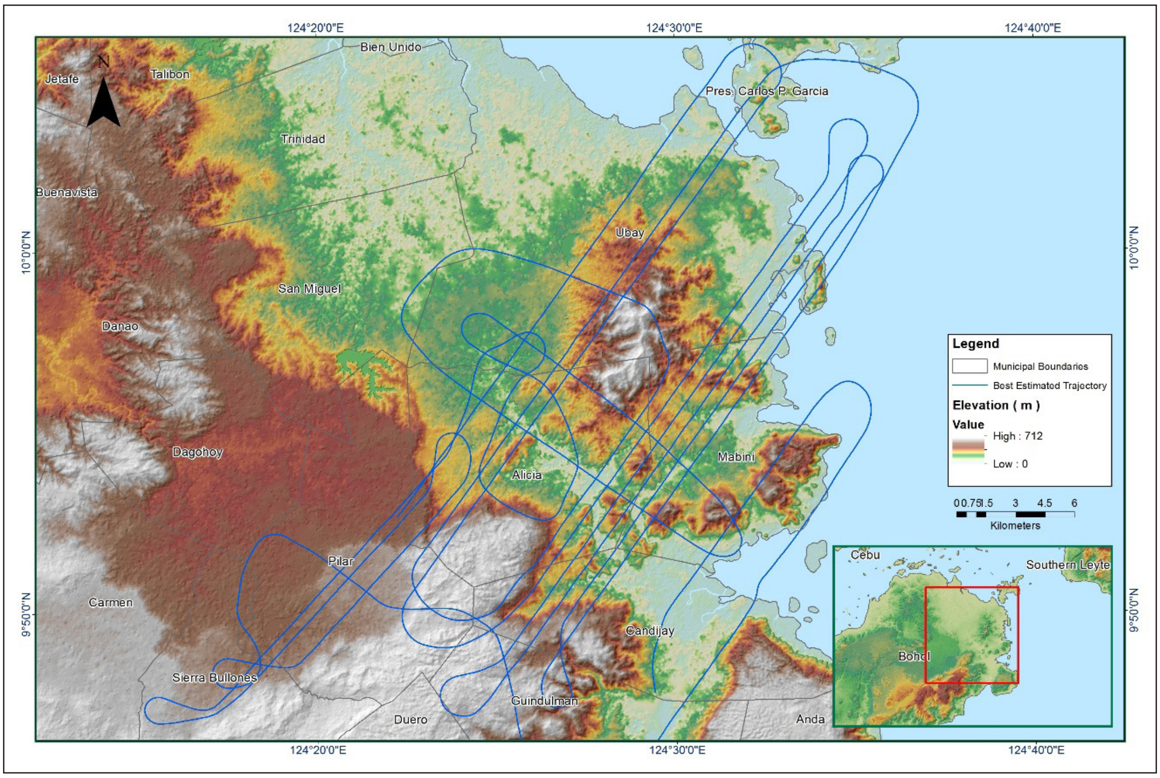



Figure A-8.17. Best Estimate Trajectory

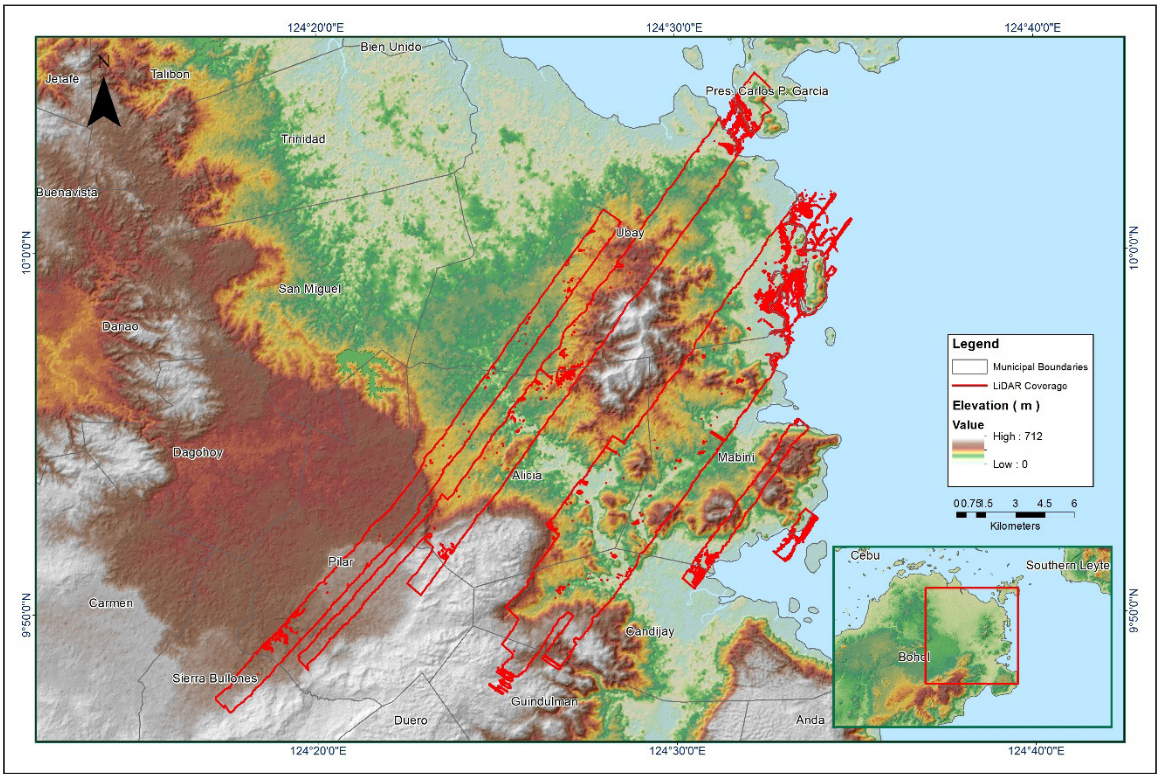



Figure A-8.18. Coverage of LiDAR data

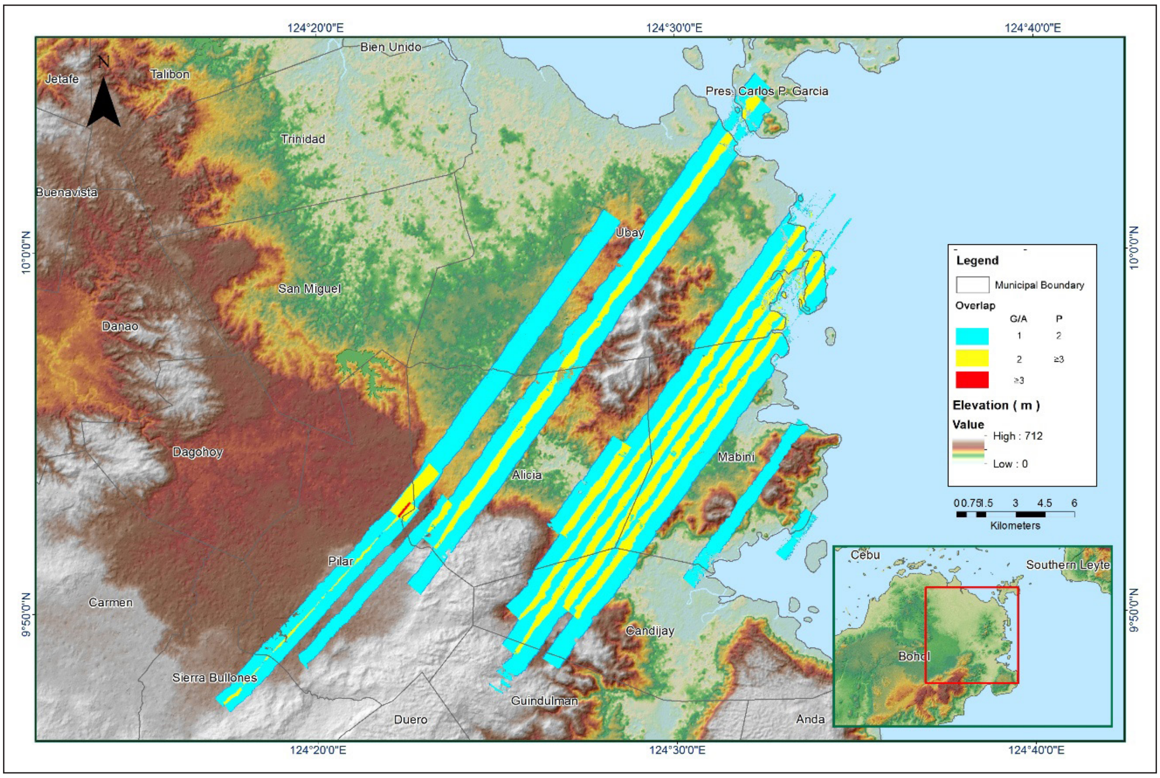



Figure A-8.19. Image of data overlap

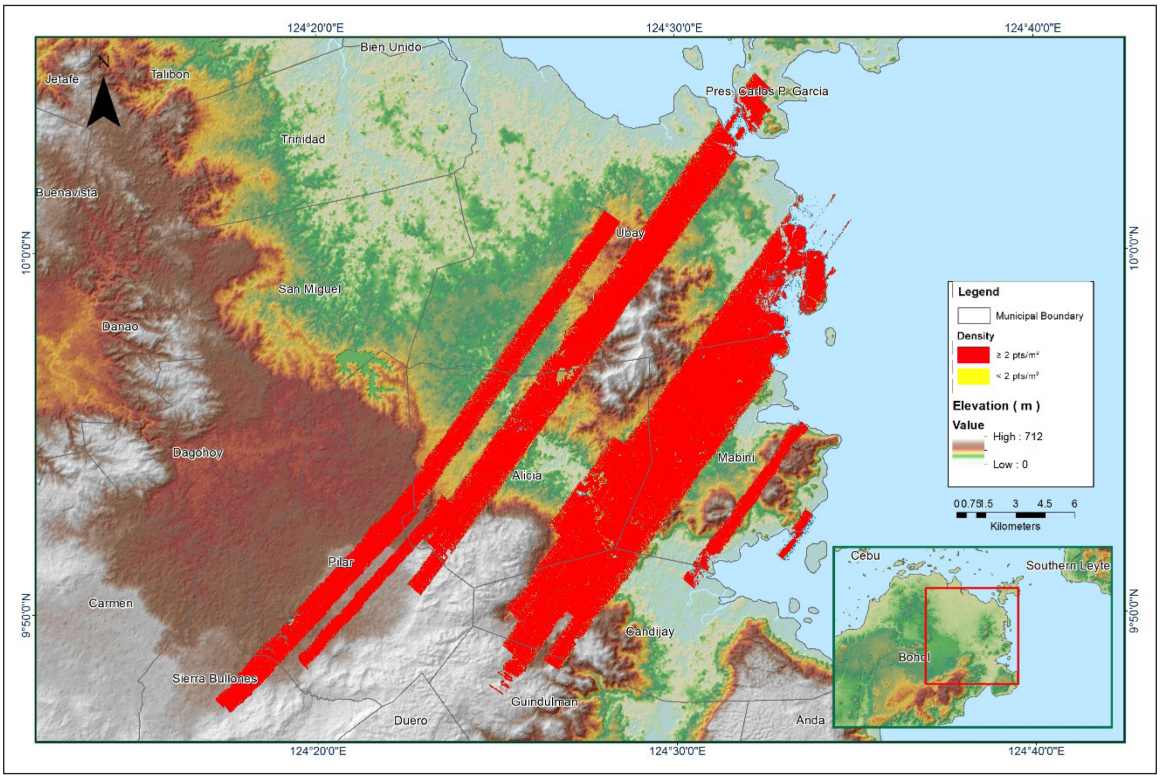



Figure A-8.20. Density Map of merged LiDAR data

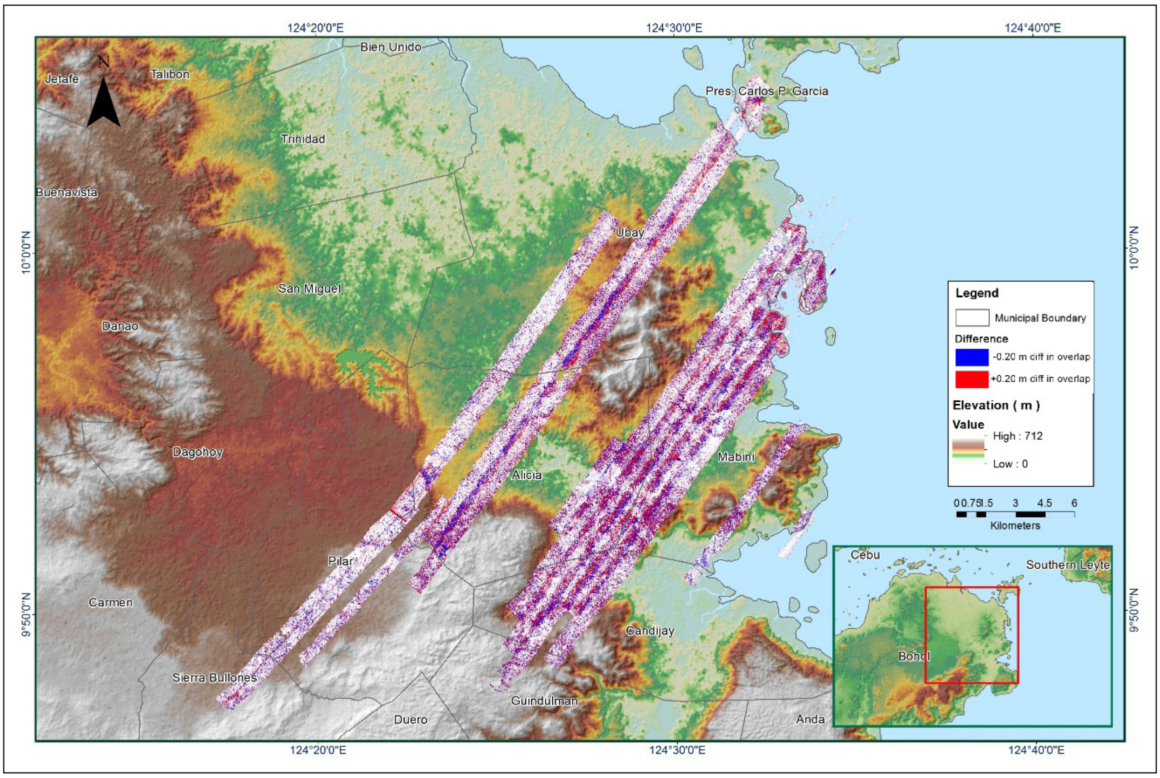



Figure A-8.21. Elevation Difference Between flight lines

Table A-8.4. Mission Summary Report for Mission Blk51F

| Flight Area | Bohol |
|---|---|
| Mission Name | **Blk51F** |
| Inclusive Flights | 3421P, 3453P |
| Range data size | 8.79 GB |
| POS | 152 MB |
| Base Data | 11.8 MB |
| Image | NA |
| Transfer date | October 28, 2015 |
| | |
| *Solution Status* | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| *Smoothed Performance Metrics* (in cm) | |
| RMSE for North Position (<4.0 cm) | 0.878 |
| RMSE for East Position (<4.0 cm) | 1.017 |
| RMSE for Down Position (<8.0 cm) | 1.852 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000328 |

| | |
|---|---|
| IMU attitude correction stdev (<0.001deg) | 0.001372 |
| GPS position stdev (<0.01m) | 0.0177 |
| | |
| Minimum % overlap (>25) | 41.46 |
| Ave point cloud density per sq.m. (>2.0) | 4.14 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 155 |
| Maximum Height | 395.58 m |
| Minimum Height | 67.56 m |
| | |
| *Classification (# of points)* | |
| Ground | 20,632,320 |
| Low vegetation | 9,004,364 |
| Medium vegetation | 9,589,867 |
| High vegetation | 14,454,767 |
| Building | 338,961 |
| | |
| Orthophoto | No |
| Processed by | Engr. Analyn Naldo, Engr. Merven Matthew Natino, Marie Denise Bueno |

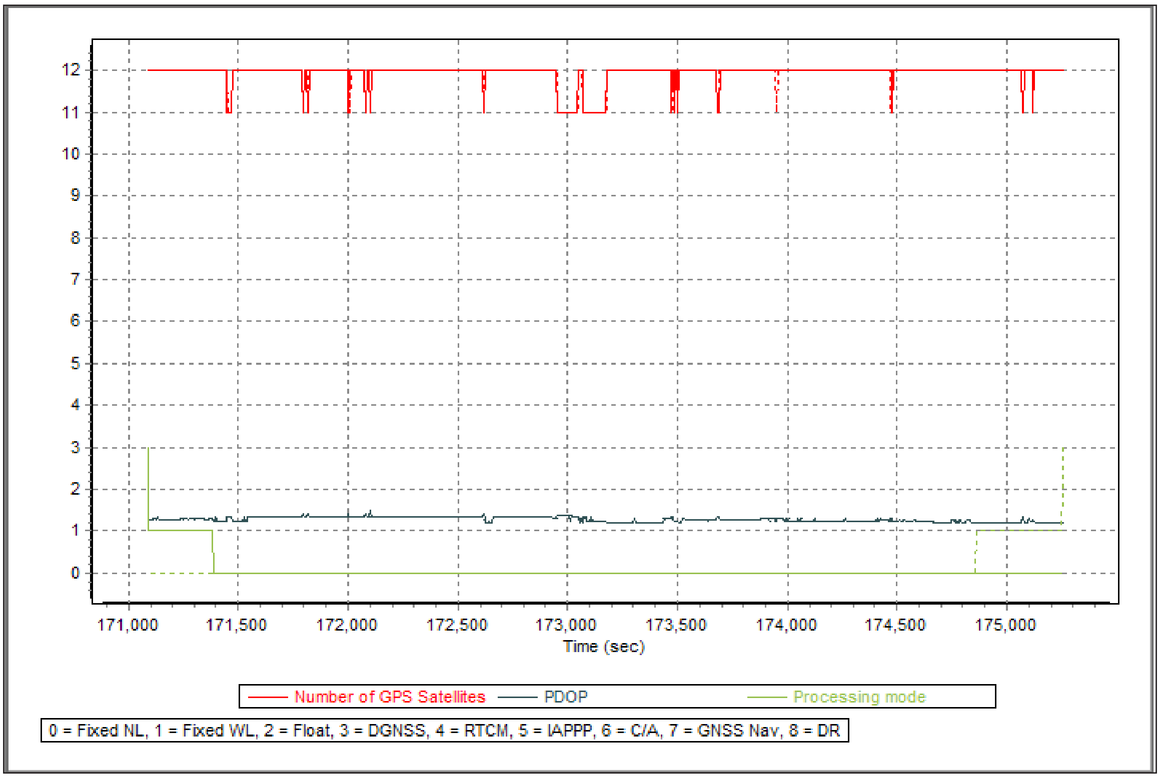



Figure A-8.22. Figure 1.4.1. Solution Status

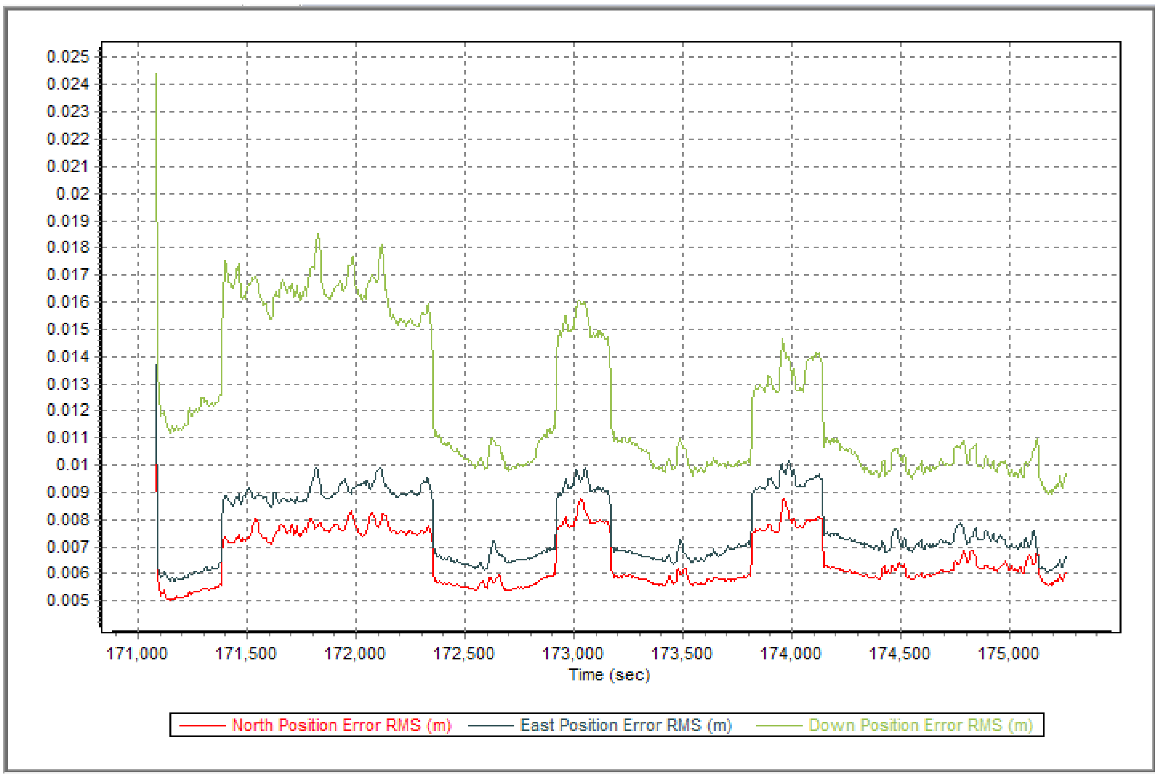



Figure A-8.23. Smoothed Performance Metric Parameters

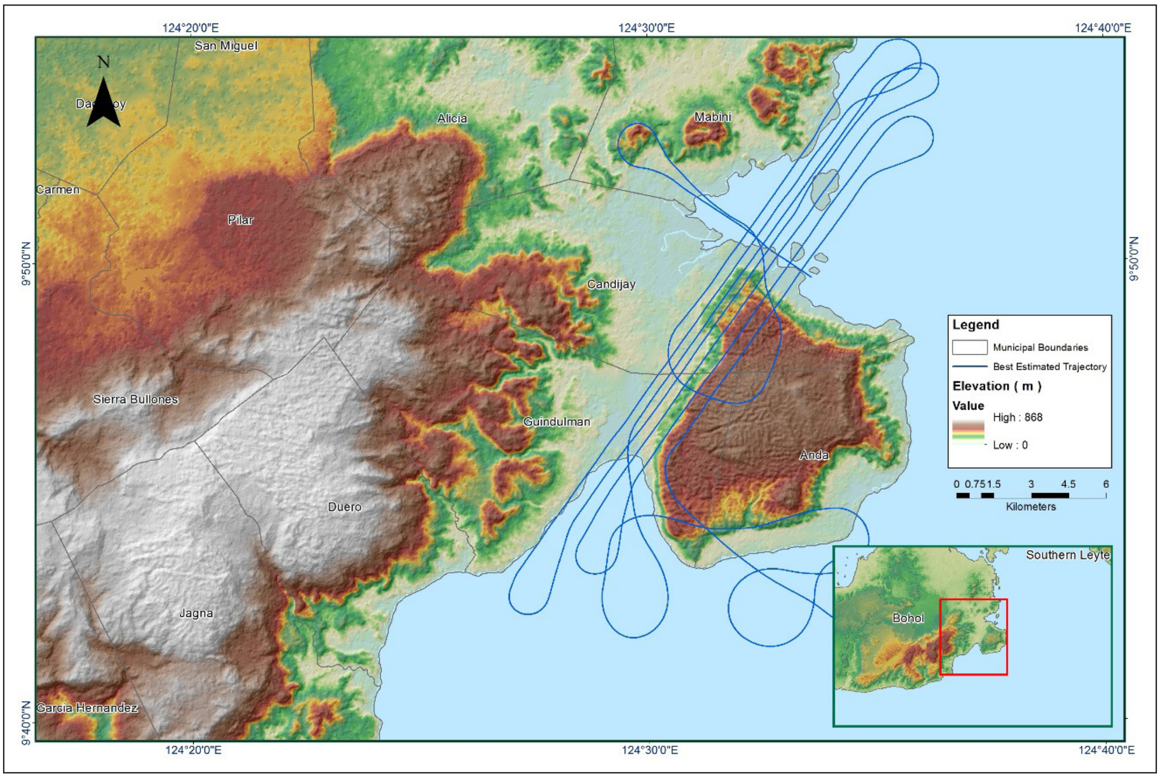



Figure A-8.24. Best Estimate Trajectory

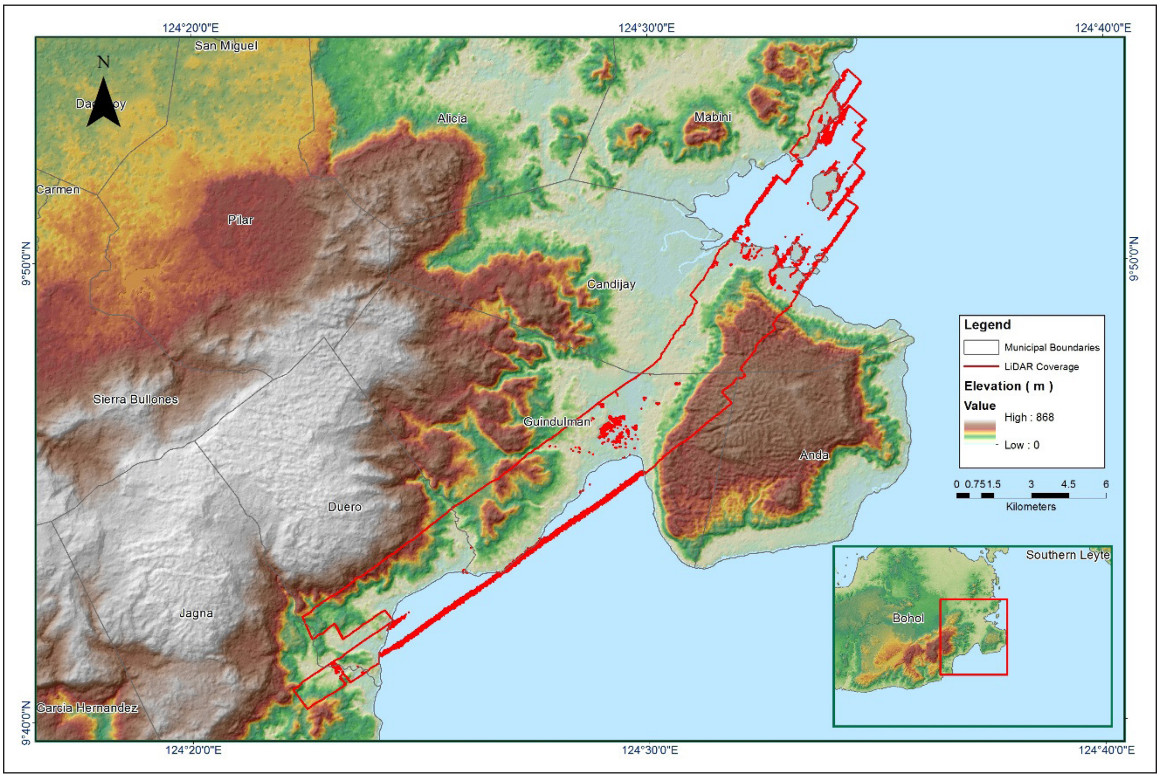



Figure A-8.25. Coverage of LiDAR data

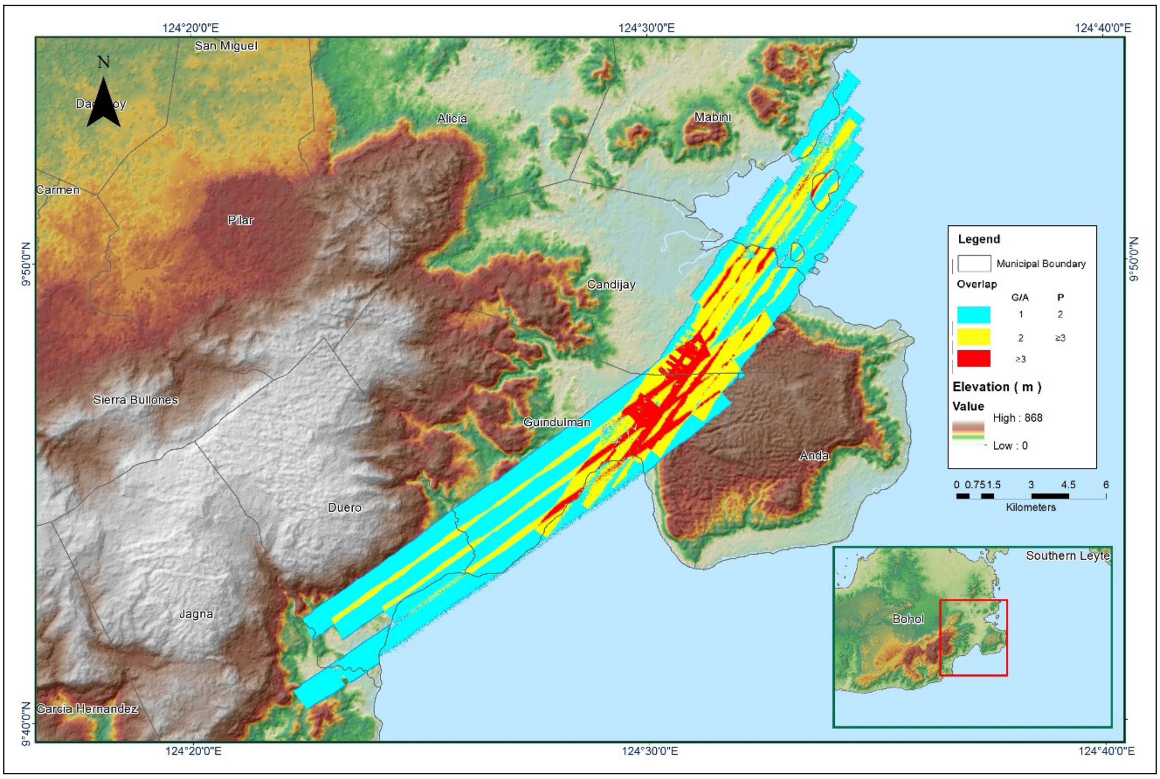



Figure A-8.26. Image of data overlap

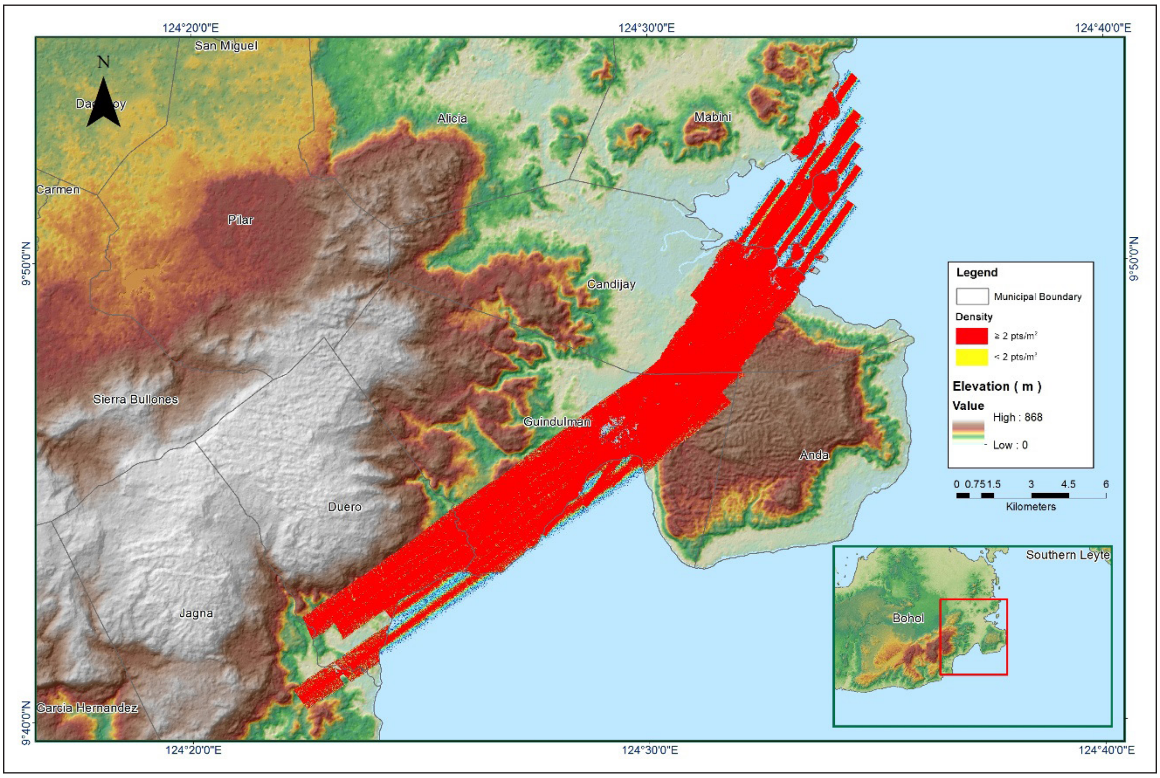



Figure A-8.27. Density Map of merged LiDAR data

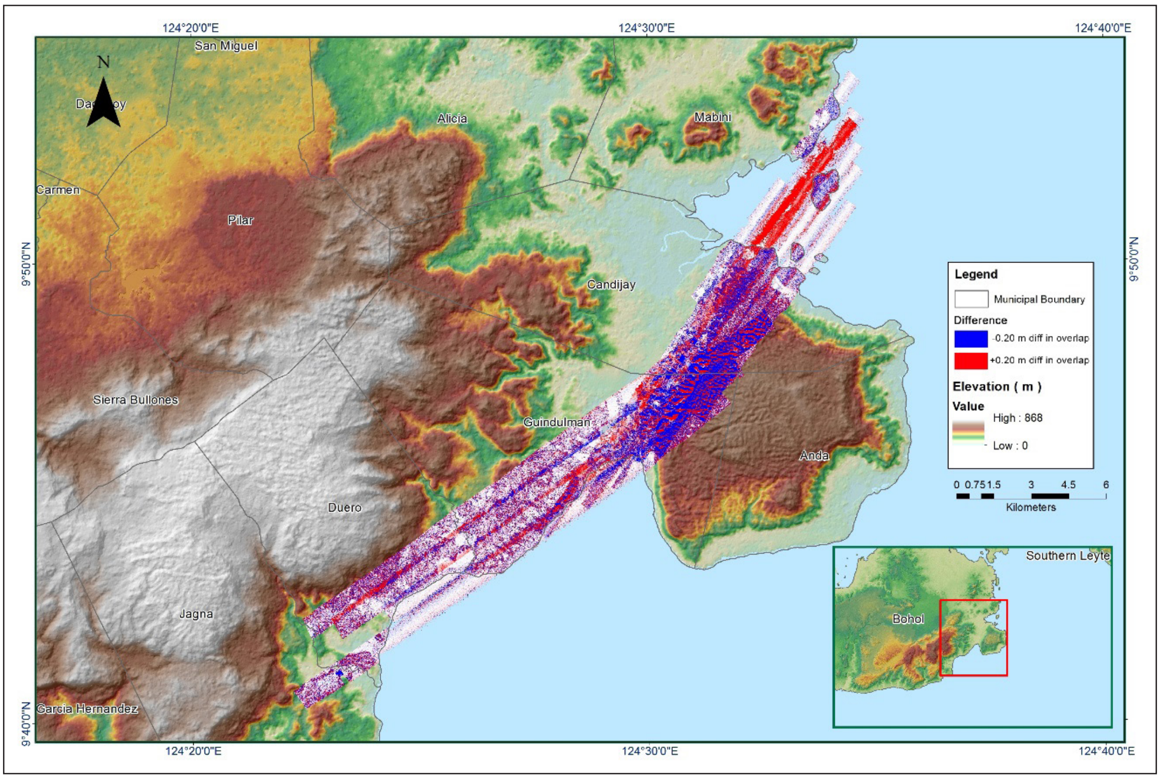



Figure A-8.28. Elevation Difference Between flight lines

Table A-8.4. Mission Summary Report for Mission Blk51A

| **Flight Area** | **Bohol** |
|---|---|
| Mission Name | **Blk51A** |
| Inclusive Flights | 3449P |
| Range data size | 18 GB |
| POS | 221 MB |
| Base Data | 13.1 MB |
| Image | NA |
| Transfer date | October 28, 2015 |
| | |
| *Solution Status* | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | No |
| | |
| *Smoothed Performance Metrics* (in cm) | |
| RMSE for North Position (<4.0 cm) | 0.976 |
| RMSE for East Position (<4.0 cm) | 1.195 |
| RMSE for Down Position (<8.0 cm) | 3.12 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000181 |
| IMU attitude correction stdev (<0.001deg) | 0.000962 |
| GPS position stdev (<0.01m) | 0.0028 |
| | |
| Minimum % overlap (>25) | 24.82 |
| 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 | 210 |
| Maximum Height | 249.28 m |
| Minimum Height | 67.91 m |
| | |
| *Classification (# of points)* | |
| Ground | 27,982,165 |
| Low vegetation | 21,612,607 |
| Medium vegetation | 19,117,741 |
| High vegetation | 20,385,805 |
| Building | 828,221 |
| | |
| Orthophoto | No |
| Processed by | Engr. Regis Guhiting, Engr. Harond Santos, Kathryn Claudine Zarate |

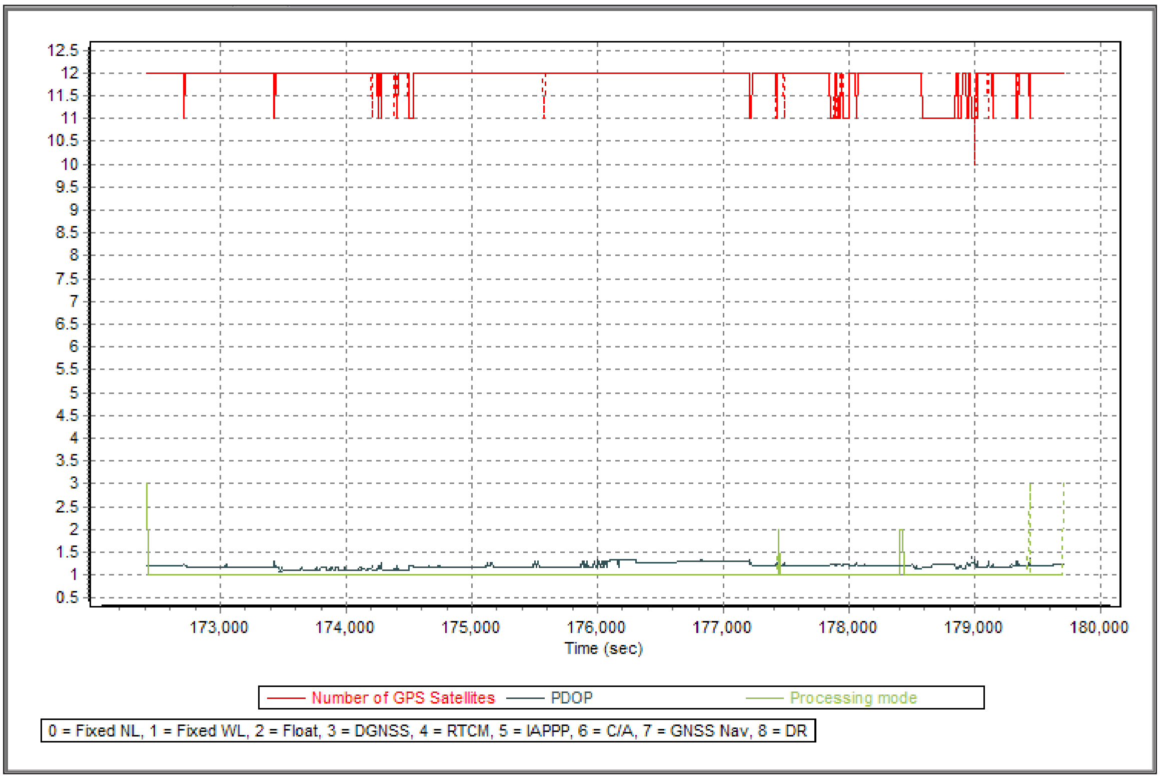



Figure A-8.29. Solution Status

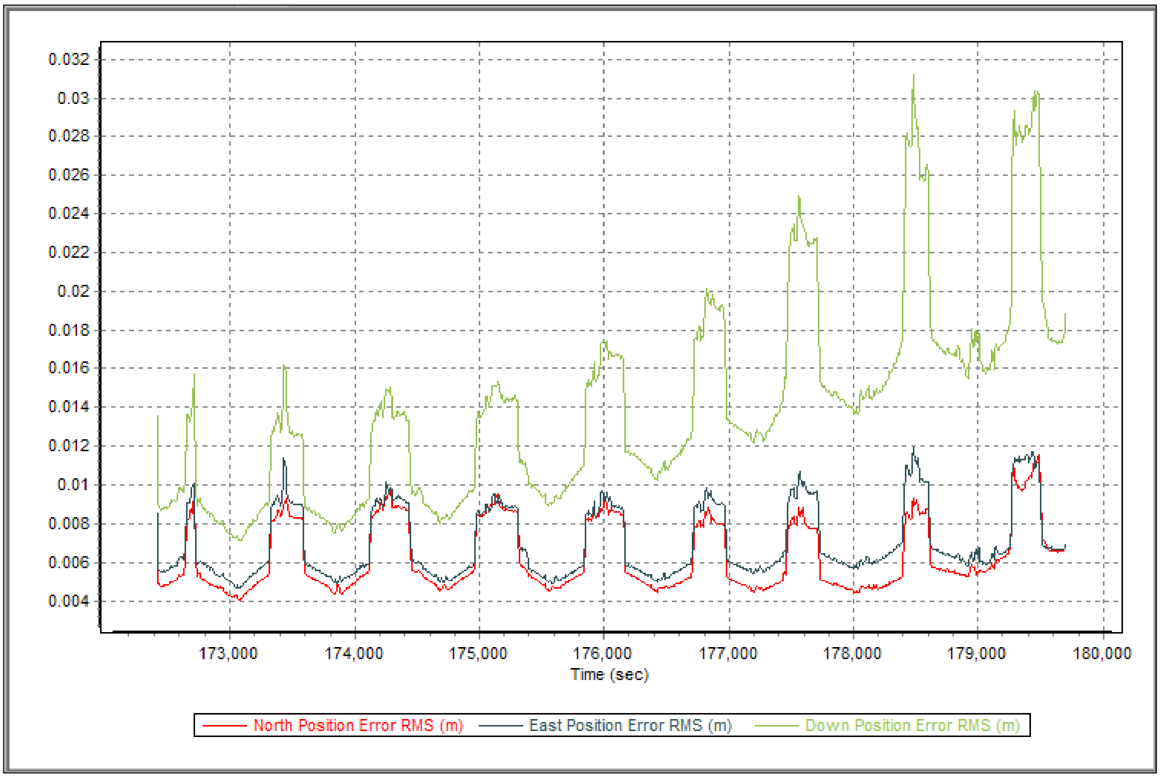



Figure A-8.30. Smoothed Performance Metric Parameters

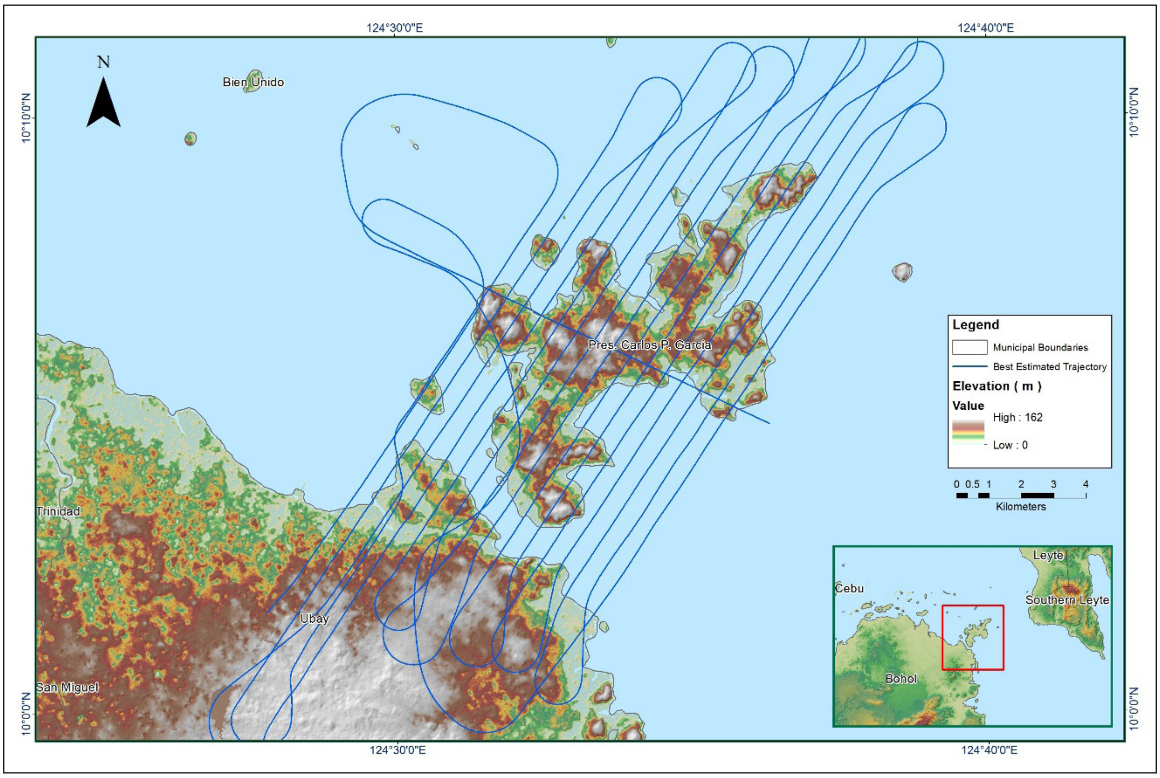



Figure A-8.31. Best Estimate Trajectory

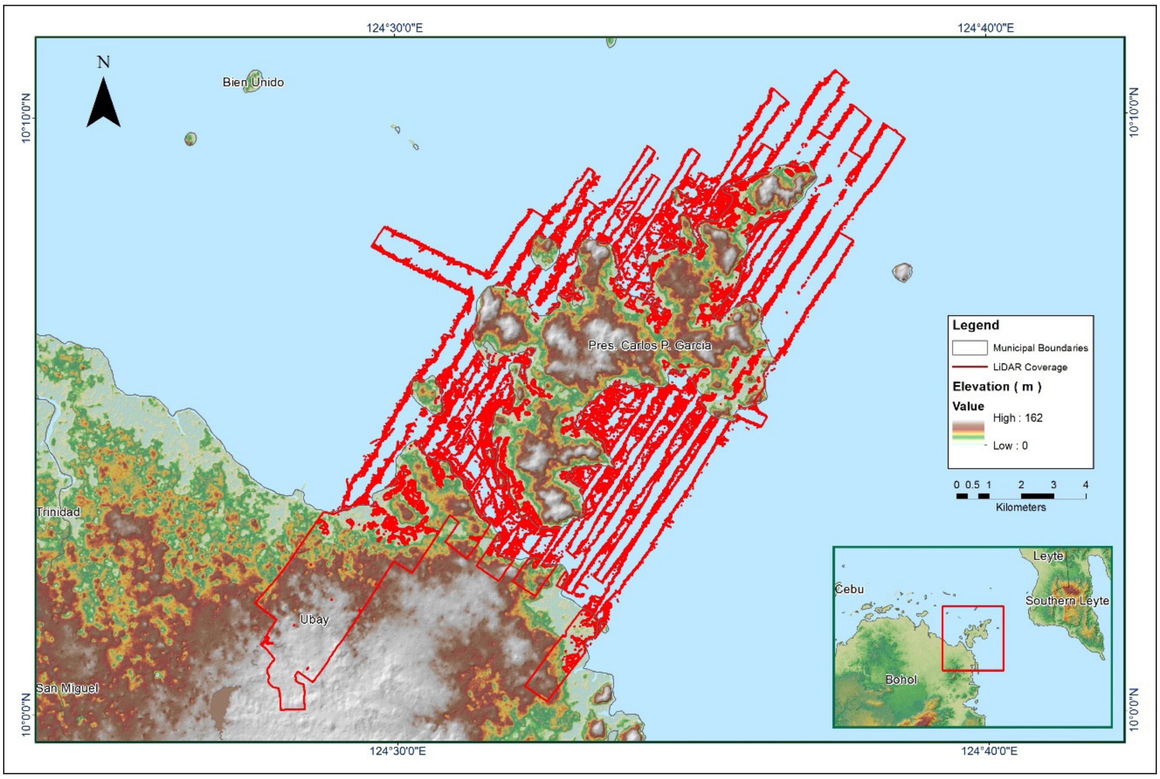



Figure A-8.32. Coverage of LiDAR data

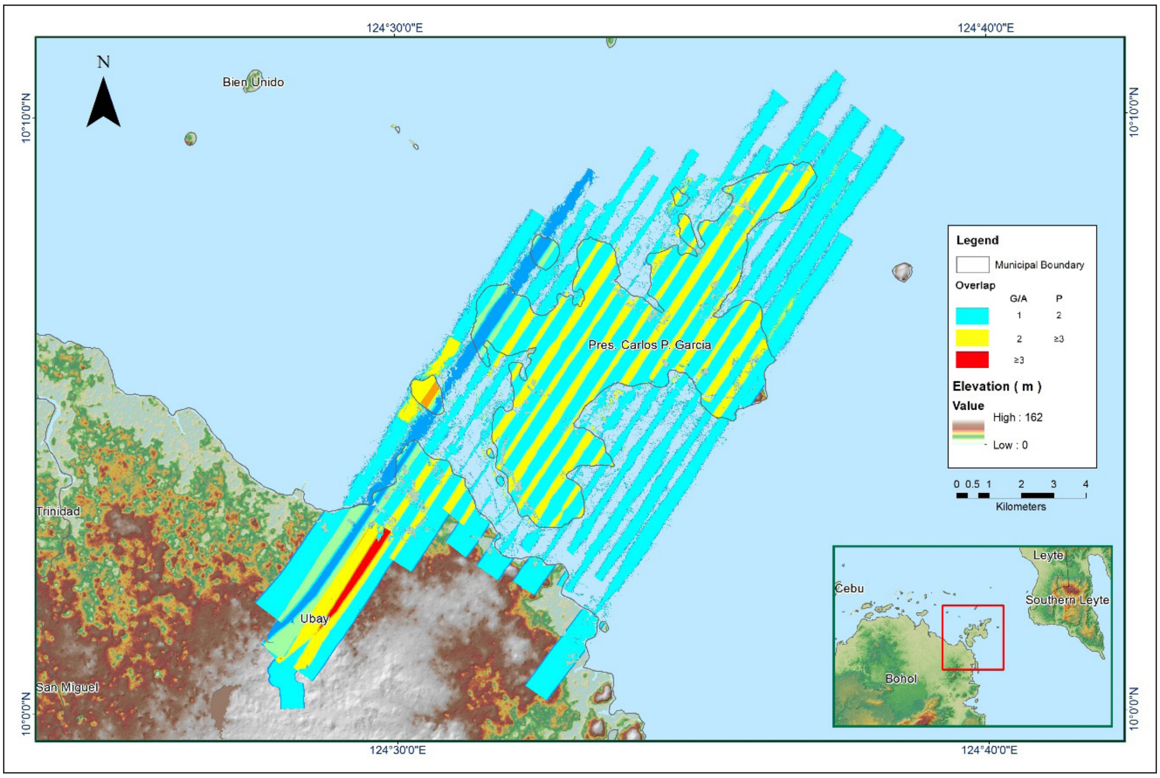



Figure A-8.33. Image of data overlap

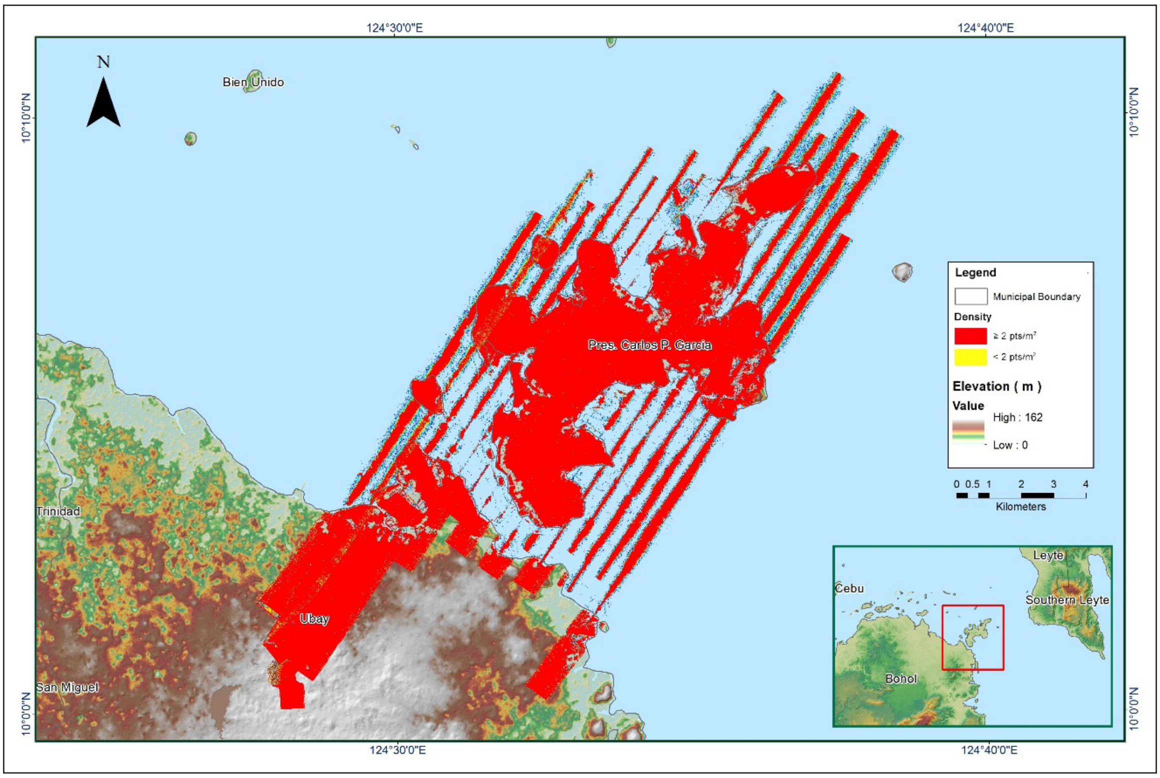



Figure A-8.34. Density Map of merged LiDAR data

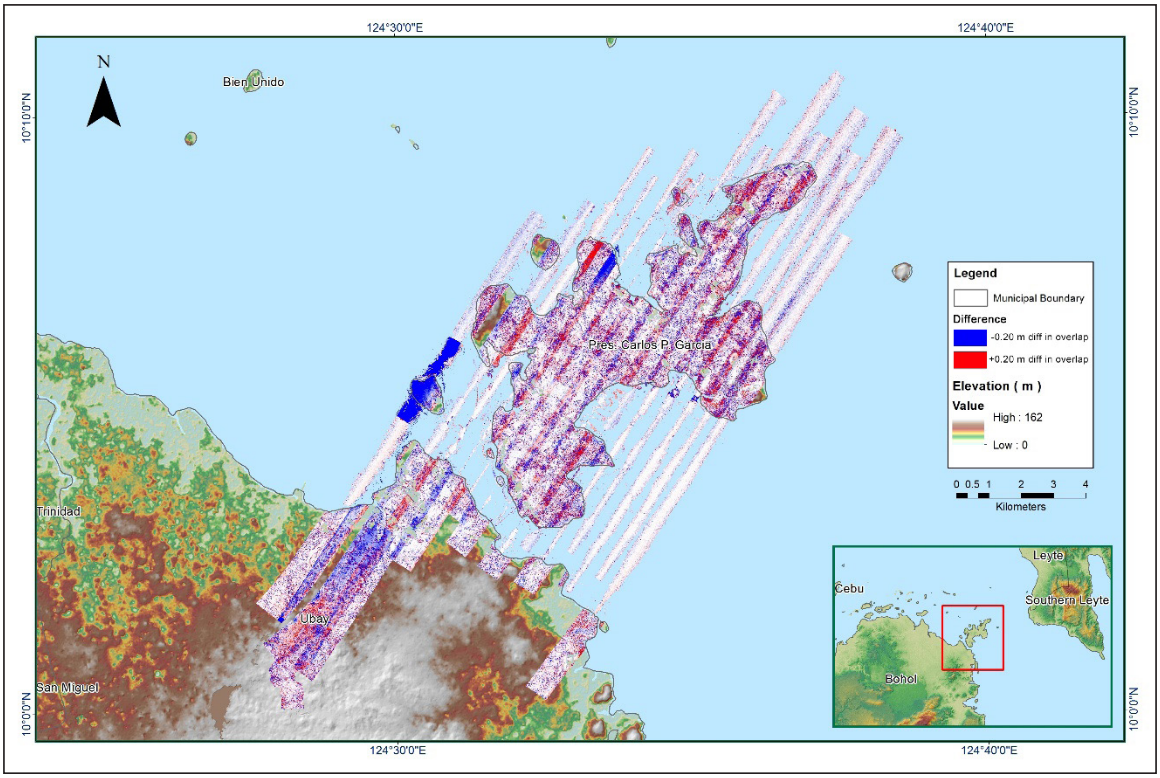



Figure A-8.35. Elevation Difference Between flight lines

# Annex 9. Ipil Model Basin Parameters

Table A-9.1. Ipil Model Basin Parameters

| Basin Number | SCS Curve Number Loss Model | | | Clark Transform Model | | Recession Constant Baseflow Model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction | Curve Number | Impervious | Time of Concentration | Storage Coefficient | Initial Type | Initial Discharge | Recession Constant | Threshold Type | Ratio to Peak |
| W140 | 4.948 | 68.105 | 0 | 0.44063 | 1.5269 | Discharge | 0.004109 | 1 | Ratio to Peak | 0.13333 |
| W150 | 2.5742 | 97.458 | 0 | 2.7814 | 1.8817 | Discharge | 0.095626 | 1 | Ratio to Peak | 0.18824 |
| W160 | 3.2817 | 66.743 | 0 | 2.4588 | 1.6054 | Discharge | 0.025748 | 1 | Ratio to Peak | 0.2 |
| W170 | 3.0798 | 85.586 | 0 | 3.5917 | 1.5875 | Discharge | 0.10022 | 1 | Ratio to Peak | 0.2 |
| W180 | 3.841 | 72.088 | 0 | 12.064 | 8.0833 | Discharge | 0.72018 | 1 | Ratio to Peak | 0.2 |
| W190 | 0.53014 | 93.414 | 0 | 3.5563 | 3.383 | Discharge | 0.76921 | 0.64027 | Ratio to Peak | 0.2 |
| W200 | 0.50966 | 96.056 | 0 | 2.1682 | 1.4798 | Discharge | 0.2069 | 1 | Ratio to Peak | 0.18447 |
| W210 | 2.4329 | 84.407 | 0 | 2.6257 | 2.5758 | Discharge | 0.21866 | 1 | Ratio to Peak | 0.2 |
| W220 | 1.7817 | 89.016 | 0 | 2.4641 | 5.1678 | Discharge | 0.56872 | 1 | Ratio to Peak | 0.2 |
| W230 | 4.3282 | 83.812 | 0 | 1.5289 | 3.5523 | Discharge | 0.33535 | 1 | Ratio to Peak | 0.2 |
| W240 | 4.35 | 79.74 | 0 | 3.2887 | 11.379 | Discharge | 0.45576 | 1 | Ratio to Peak | 0.2 |
| W250 | 2.9125 | 79.468 | 0 | 0.99754 | 1.5268 | Discharge | 0.28536 | 1 | Ratio to Peak | 0.196 |
| W260 | 4.7832 | 73.376 | 0 | 2.8932 | 4.319 | Discharge | 0.27915 | 1 | Ratio to Peak | 0.2 |

## Annex 10. Ipil Model Reach Parameters

Table A-10.1. Ipil Model Reach Parameters

| Reach Number | Muskingum Cunge Routing Model | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R10 | Automatic Fixed Interval | 428.85 | 5E-04 | 0.0299019 | Trapezoid | 15 | 1 |
| R110 | Automatic Fixed Interval | 5206.2 | 0.004 | 0.0197094 | Trapezoid | 15 | 1 |
| R20 | Automatic Fixed Interval | 916.1 | 1E-04 | 0.0292154 | Trapezoid | 15 | 1 |
| R30 | Automatic Fixed Interval | 3106.3 | 0.002 | 0.0407621 | Trapezoid | 15 | 1 |
| R50 | Automatic Fixed Interval | 3851.9 | 0.002 | 0.0150973 | Trapezoid | 15 | 1 |
| R90 | Automatic Fixed Interval | 5538.4 | 0.001 | 0.0178049 | Trapezoid | 15 | 1 |

# Annex 11. Ipil Field Validation Points

Table A-11.1. Ipil Field Validation Points

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error (m) | Event / Date | Return Period of Event |
|---|---|---|---|---|---|---|---|
| | Longitude | Latitude | | | | | |
| 1 | 124.33705 | 9.9833412 | 0.25 | 0.5 | 0.0625 | Ruby | 100 Year |
| 2 | 124.33721 | 9.9834355 | 0.35 | 0.3 | 0.0025 | Ruby | 100 Year |
| 3 | 124.33835 | 9.9841551 | 0.71 | 0.7 | 0.0001 | Seniang | 100 Year |
| 4 | 124.33829 | 9.9841569 | 0.58 | 0.5 | 0.0064 | Yolanda | 100 Year |
| 5 | 124.33759 | 9.9842347 | 0.42 | 0.3 | 0.0144 | Seniang | 100 Year |
| 6 | 124.33749 | 9.9843194 | 0.45 | 0.3 | 0.0225 | Ruby | 100 Year |
| 7 | 124.33744 | 9.9845967 | 0.6 | 0.5 | 0.01 | Queenie | 100 Year |
| 8 | 124.33716 | 9.9846039 | 0.19 | 0.3 | 0.0121 | Ruby | 100 Year |
| 9 | 124.33974 | 9.9848267 | 0.03 | 0.7 | 0.4489 | Ruby | 100 Year |
| 10 | 124.34038 | 9.9851157 | 0.03 | 0.7 | 0.4489 | Ruby | 100 Year |
| 11 | 124.33969 | 9.9853496 | 0.03 | 0.9 | 0.7569 | Seniang | 100 Year |
| 12 | 124.33903 | 9.9868484 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 13 | 124.3392 | 9.9877807 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 14 | 124.34333 | 9.9988243 | 0.4 | 0.2 | 0.04 | Ruby | 100 Year |
| 15 | 124.3471 | 10.002355 | 0.68 | 2.1 | 2.0164 | Yolanda | 100 Year |
| 16 | 124.34732 | 10.002875 | 0.03 | 0.5 | 0.2209 | Seniang | 100 Year |
| 17 | 124.37035 | 10.021354 | 0.03 | 0.5 | 0.2209 | Seniang | 100 Year |
| 18 | 124.37202 | 10.022183 | 0.03 | 1.1 | 1.1449 | Seniang | 100 Year |
| 19 | 124.37092 | 10.027091 | 0.03 | 0.9 | 0.7569 | Ruby | 100 Year |
| 20 | 124.34291 | 10.02972 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 21 | 124.34281 | 10.029748 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 22 | 124.37076 | 10.030026 | 0.03 | 0.5 | 0.2209 | Queenie | 100 Year |
| 23 | 124.34093 | 10.030533 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error (m) | Event / Date | Return Period of Event |
|---|---|---|---|---|---|---|---|
| | Longitude | Latitude | | | | | |
| 24 | 124.37012 | 10.031257 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 25 | 124.37019 | 10.032118 | 0.03 | 0.7 | 0.4489 | Seniang | 100 Year |
| 26 | 124.34732 | 10.032917 | 0.03 | 0.7 | 0.4489 | Ruby | 100 Year |
| 27 | 124.34722 | 10.032925 | 0.03 | 2.1 | 4.2849 | Seniang | 100 Year |
| 28 | 124.34745 | 10.033067 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 29 | 124.34783 | 10.033799 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 30 | 124.34821 | 10.034323 | 0.03 | 1.3 | 1.6129 | Ruby | 100 Year |
| 31 | 124.34773 | 10.034582 | 0.11 | 0.9 | 0.6241 | Ruby | 100 Year |
| 32 | 124.34769 | 10.034754 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 33 | 124.34824 | 10.034825 | 0.03 | 0.35 | 0.1024 | Ruby | 100 Year |
| 34 | 124.36782 | 10.042379 | 0.03 | 0.4 | 0.1369 | Ruby | 100 Year |
| 35 | 124.36427 | 10.044475 | 0.03 | 1.1 | 1.1449 | Ruby | 100 Year |
| 36 | 124.36422 | 10.044479 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 37 | 124.36343 | 10.044826 | 0.03 | 0.4 | 0.1369 | Ruby | 100 Year |
| 38 | 124.32239 | 10.047115 | 0.68 | 0.9 | 0.0484 | Seniang | 100 Year |
| 39 | 124.32228 | 10.047186 | 0.91 | 1.1 | 0.0361 | Seniang | 100 Year |
| 40 | 124.32203 | 10.047269 | 0.59 | 0.5 | 0.0081 | Ruby | 100 Year |
| 41 | 124.35474 | 10.048345 | 0.27 | 0.2 | 0.0049 | Ruby | 100 Year |
| 42 | 124.35362 | 10.048428 | 1.46 | 1.1 | 0.1296 | Seniang | 100 Year |
| 43 | 124.35367 | 10.048548 | 0.92 | 0.6 | 0.1024 | Seniang | 100 Year |
| 44 | 124.35146 | 10.048895 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 45 | 124.35152 | 10.049012 | 0.6 | 0.6 | 0 | Seniang | 100 Year |
| 46 | 124.35173 | 10.049014 | 1.24 | 1.1 | 0.0196 | Seniang | 100 Year |
| 47 | 124.36082 | 10.049173 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 48 | 124.34315 | 10.049721 | 2.54 | 1.9 | 0.4096 | Seniang | 100 Year |
| 49 | 124.35931 | 10.049937 | 0.03 | 1.1 | 1.1449 | Seniang | 100 Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error (m) | Event / Date | Return Period of Event |
|---|---|---|---|---|---|---|---|
| | Longitude | Latitude | | | | | |
| 50 | 124.3662 | 10.061405 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 51 | 124.36634 | 10.061473 | 0.03 | 0.3 | 0.0729 | Seniang | 100 Year |
| 52 | 124.3569 | 10.062657 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 53 | 124.35789 | 10.065454 | 0.03 | 0.5 | 0.2209 | Seniang | 100 Year |
| 54 | 124.3576 | 10.066364 | 0.04 | 0.2 | 0.0256 | Ruby | 100 Year |
| 55 | 124.35776 | 10.066465 | 0.07 | 0.5 | 0.1849 | Ruby | 100 Year |
| 56 | 124.34183 | 10.071758 | 0.03 | 0.9 | 0.7569 | Seniang | 100 Year |
| 57 | 124.34224 | 10.072682 | 0.03 | 1.1 | 1.1449 | Seniang | 100 Year |
| 58 | 124.35698 | 10.072996 | 0.03 | 0.9 | 0.7569 | Seniang | 100 Year |
| 59 | 124.35633 | 10.073556 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 60 | 124.35626 | 10.074051 | 0.03 | 0 | 0.0009 | Seniang | 100 Year |
| 61 | 124.35656 | 10.074103 | 0.03 | 0.1 | 0.0049 | Seniang | 100 Year |
| 62 | 124.34343 | 10.07513 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 63 | 124.34334 | 10.076312 | 0.03 | 0 | 0.0009 | Seniang | 100 Year |
| 64 | 124.34373 | 10.076453 | 0.03 | 0 | 0.0009 | Ruby | 100 Year |
| 65 | 124.35002 | 10.076522 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 66 | 124.34958 | 10.076602 | 0.03 | 1.3 | 1.6129 | Seniang | 100 Year |
| 67 | 124.34959 | 10.076798 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 68 | 124.34372 | 10.076854 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 69 | 124.34965 | 10.07685 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 70 | 124.34365 | 10.077647 | 0.03 | 0.2 | 0.0289 | Senaing | 100 Year |
| 71 | 124.3435 | 10.077939 | 0.03 | 1.1 | 1.1449 | Yolanda | 100 Year |
| 72 | 124.34987 | 10.078004 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 73 | 124.34347 | 10.078393 | 0.06 | 0.2 | 0.0196 | Ruby | 100 Year |
| 74 | 124.35332 | 10.078435 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 75 | 124.35302 | 10.078501 | 0.18 | 0.9 | 0.5184 | Ruby | 100 Year |
| 76 | 124.34987 | 10.078691 | 0.03 | 1.1 | 1.1449 | Yolanda | 100 Year |
| 77 | 124.35029 | 10.078832 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 78 | 124.34381 | 10.079926 | 0.03 | 0.5 | 0.2209 | Yolanda | 100 Year |
| 79 | 124.34344 | 10.079956 | 0.03 | 0.7 | 0.4489 | Yolanda | 100 Year |
| 80 | 124.34618 | 10.080021 | 0.03 | 0.2 | 0.0289 | Yolanda | 100 Year |
| 81 | 124.34487 | 10.080036 | 0.91 | 1.5 | 0.3481 | Seniang | 100 Year |
| 82 | 124.3449 | 10.080082 | 1.35 | 1.7 | 0.1225 | Yolanda | 100 Year |
| 83 | 124.3434 | 10.080099 | 0.03 | 0.9 | 0.7569 | Seniang | 100 Year |
| 84 | 124.34492 | 10.080101 | 1.7 | 1.5 | 0.04 | Yolanda | 100 Year |
| 85 | 124.34533 | 10.081115 | 0.03 | 0.2 | 0.0289 | Yolanda | 100 Year |
| 86 | 124.35588 | 10.082329 | 0.03 | 0.7 | 0.4489 | Yolanda | 100 Year |
| 87 | 124.35601 | 10.082567 | 0.03 | 0.2 | 0.0289 | Yolanda | 100 Year |
| 88 | 124.3531 | 10.084039 | 0.03 | 0.4 | 0.1369 | Seniang | 100 Year |
| 89 | 124.35156 | 10.085705 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 90 | 124.35072 | 10.085929 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 91 | 124.35084 | 10.085952 | 0.03 | 0.6 | 0.3249 | Yolanda | 100 Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error (m) | Event / Date | Return Period of Event |
|---|---|---|---|---|---|---|---|
| | Longitude | Latitude | | | | | |
| 92 | 124.34779 | 10.087821 | 0.03 | 0.3 | 0.0729 | Seniang | 100 Year |
| 93 | 124.34968 | 10.088201 | 0.04 | 0.85 | 0.6561 | Ruby | 100 Year |
| 94 | 124.35652 | 10.08836 | 0.03 | 1.1 | 1.1449 | Ruby | 100 Year |
| 95 | 124.35724 | 10.091578 | 0.03 | 0.9 | 0.7569 | Ruby | 100 Year |
| 96 | 124.36119 | 10.094375 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 97 | 124.36154 | 10.095149 | 0.03 | 0 | 0.0009 | Seniang | 100 Year |
| 98 | 124.31671 | 10.097115 | 0.03 | 0 | 0.0009 | Seniang | 100 Year |
| 99 | 124.31695 | 10.09739 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 100 | 124.36266 | 10.097607 | 0.07 | 0.9 | 0.6889 | Ruby | 100 Year |
| 101 | 124.31683 | 10.098161 | 0.03 | 0.2 | 0.0289 | Seniang | 100 Year |
| 102 | 124.3166 | 10.098849 | 0.03 | 0.2 | 0.0289 | Yolanda | 100 Year |
| 103 | 124.31686 | 10.098905 | 0.03 | 0.7 | 0.4489 | Yolanda | 100 Year |
| 104 | 124.31645 | 10.098933 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 105 | 124.31662 | 10.099193 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 106 | 124.31964 | 10.10235 | 0.24 | 0.5 | 0.0676 | Ruby | 100 Year |
| 107 | 124.31947 | 10.102655 | 0.3 | 0.9 | 0.36 | Ruby | 100 Year |
| 108 | 124.31699 | 10.102921 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 109 | 124.31834 | 10.103489 | 0.64 | 0.9 | 0.0676 | Yolanda | 100 Year |
| 110 | 124.3171 | 10.103509 | 0.33 | 0.3 | 0.0009 | Yolanda | 100 Year |
| 111 | 124.31583 | 10.104585 | 1 | 1.5 | 0.25 | Yolanda | 100 Year |
| 112 | 124.31718 | 10.104599 | 1.36 | 0.9 | 0.2116 | Yolanda | 100 Year |
| 113 | 124.31772 | 10.105576 | 0.42 | 0.3 | 0.0144 | Ruby | 100 Year |
| 114 | 124.34364 | 10.112718 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 115 | 124.34364 | 10.112823 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 116 | 124.34364 | 10.112833 | 0.05 | 0.4 | 0.1225 | Ruby | 100 Year |
| 117 | 124.34394 | 10.112955 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 118 | 124.34382 | 10.11296 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 119 | 124.3537 | 10.116678 | 0.42 | 0.5 | 0.0064 | Ruby | 100 Year |
| 120 | 124.3533 | 10.116789 | 0.21 | 1.2 | 0.9801 | Yolanda | 100 Year |
| 121 | 124.35257 | 10.117098 | 0.05 | 0.9 | 0.7225 | Ruby | 100 Year |
| 122 | 124.35889 | 10.118398 | 0.72 | 0.9 | 0.0324 | Seniang | 100 Year |
| 123 | 124.35879 | 10.118447 | 0.23 | 0.2 | 0.0009 | Seniang | 100 Year |
| 124 | 124.34762 | 10.118581 | 0.1 | 0.2 | 0.01 | Seniang | 100 Year |
| 125 | 124.35815 | 10.118577 | 0.03 | 0.2 | 0.0289 | Yolanda | 100 Year |
| 126 | 124.34753 | 10.118717 | 0.04 | 1.1 | 1.1236 | Yolanda | 100 Year |
| 127 | 124.34748 | 10.118773 | 0.04 | 0.3 | 0.0676 | Ruby | 100 Year |
| 128 | 124.34689 | 10.118922 | 0.03 | 0.3 | 0.0729 | Yolanda | 100 Year |
| 129 | 124.34701 | 10.118938 | 0.03 | 1.1 | 1.1449 | Yolanda | 100 Year |
| 130 | 124.3446 | 10.11941 | 0.03 | 0.5 | 0.2209 | Ruby | 100 Year |
| 131 | 124.3305 | 10.121271 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 132 | 124.33034 | 10.121708 | 0.03 | 0.2 | 0.0289 | Yolanda | 100 Year |
| 133 | 124.32994 | 10.121864 | 0.03 | 1.1 | 1.1449 | Seniang | 100 Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error (m) | Event / Date | Return Period of Event |
|---|---|---|---|---|---|---|---|
| | Longitude | Latitude | | | | | |
| 134 | 124.32966 | 10.124426 | 0.03 | 0.3 | 0.0729 | Ruby | 100 Year |
| 135 | 124.33011 | 10.124717 | 0.03 | 0.2 | 0.0289 | Ruby | 100 Year |
| 136 | 124.32976 | 10.124753 | 0.03 | 1.3 | 1.6129 | Yolanda | 100 Year |
| 137 | 124.32994 | 10.124896 | 0.03 | 0.3 | 0.0729 | Seniang | 100 Year |
| 138 | 124.33165 | 10.125086 | 0.08 | 0.9 | 0.6724 | Seniang | 100 Year |
| 139 | 124.31712 | 10.130834 | 0.03 | 0.5 | 0.2209 | Seniang | 100 Year |
| 140 | 124.31764 | 10.130907 | 0.03 | 0.9 | 0.7569 | Ruby | 100 Year |
| 141 | 124.3176 | 10.130996 | 0.03 | 0.5 | 0.2209 | Seniang | 100 Year |

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

Table A-12.1. Educational Institutions Affected by flooding in Ipil Floodplain

| Bohol | | | | |
|---|---|---|---|---|
| Inabanga | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| La Victoria Elem School | Liberty | | | |
| Bien Unido Academy | Mandawa | Low | Low | Low |
| Bien Unido Central Elem. School | Poblacion | | | |
| Holy Child Academy | Poblacion | | | |
| Montessori School Inc. | Poblacion | | | |
| Pres. CPG National Highschool | Puerto San Pedro | | | |
| Puerto San Pedro Primary School | Puerto San Pedro | | | |
| Hagbuyo Elem School | Hagbuyo | | | |
| San Miguel Central School | Poblacion | | | |
| San Miguel Vocational School | Poblacion | | | |
| San Agustin Elem School | San Agustin | | | |
| San Agustin High School | San Agustin | | | |
| Zamora Elem School | Zamora | | | |
| HInlayagan Ilaya Elem School | Bongbong | | | |
| Kinan-oan elementary school | Bongbong | | | |
| Kinan-oan National High School | Bongbong | | | |
| Bohol Maranatha Christian Academy | Guinobatan | | | |
| Guinobatan Elementary School | Guinobatan | | | |
| Hin Ilaud Elem School | Hinlayagan Ilaya | | | |
| Hinlayagan National HS | Hinlayagan Ilaya | | | |
| Mabuhay Elementary School (Cabiguhan) | Hinlayagan Ilaya | | | |
| Manukan Daycare | Hinlayagan Ilaya | | | |
| La Union Elem School | La Union | Low | Low | Low |
| La Victoria Elem School | La Victoria | | | |
| St. Isidore Academy | Mabuhay Cabigohan | | | |
| Mahagbu Elem School | Mahagbu | | | |
| Daycare Center | Poblacion | | | Low |
| St. Isidore Academy | Poblacion | | | |
| Trinidad Central School | Poblacion | | | |
| Trinidad Municipal College | Poblacion | | | |
| San Roque Elem School | San Vicente | | | |

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

Table A-13.1. Health Institutions affected by flooding in Ipil Flood Plain

| Bohol | | | | |
|---|---|---|---|---|
| Inabanga | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Birth Center | Poblacion | | | |
| HEALTH STATION | Poblacion | | | |
| Brgy.Puertos San Pedro Health Center | Puerto San Pedro | | | |
| Hinlayagan ilaya Health Station | Hagbuyo | | | |
| Hospital | Poblacion | | | |
| Garcia Provincial Hospital | San Jose | | | |
| Brgy Mahagbu Health Center | Mahagbu | | | |
| Trinidad Health Center | Poblacion | | | |