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

# LiDAR Surveys and Flood Mapping of Gandara River


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


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For questions/queries regarding this report, contact:

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

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

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

# CHAPTER 1: OVERVIEW OF THE PROGRAM AND GANDARA RIVER

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

## 1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 28 river basins in the Western Visayas Region. The university is located in Baybay City, Leyte, Philippines.

## 1.2 Overview of the Gandara River Basin

Gandara River Basin covers nine (9) municipalities and two (2) cities in the province of Samar and one municipality in the Northern Samar. According to the DENR River Basin Control Office, it has a catchment area of 1,067 km2 with an estimated 293 million cubic meters (MCM) annual run-off (RBCO, 2015).

Within the main river stem, Gandara River is part of the river systems in Western Visayas. The river stream network including the left and right arm of Gandara River pass along Municipalities of Pagsanghan, Gandara, and San Jorge, all in the province of Samar. According to the 2010 national census conducted by NSO, a total of 19, 274 locals are residing in the immediate vicinity of the river which are distributed among twenty-one (21) barangays within the following municipalities of Samar: Pagsanghan, Gandara and San Jorge. The river serves as source of water for agricultural, navigation, recreation and even domestic purposes in the Western Samar region (Fabillar, 2013). On February of 2008, an estimated number of 500 to 1,740 persons were affected by the floodwaters in Gandara due to continuous heavy rains.


Figure 1. Map Gandara River Basin (in brown)

# CHAPTER 2: LIDAR DATA ACQUISITION OF THE GANDARA FLOODPLAIN

*Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, Ms. Mary Catherine Elizabeth M. Baliguas*

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

## 2.1 Flight Plans

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

Table 1. Flight planning parameters for Pegasus LiDAR system

| Block Name | Flying Height (m AGL) | Overlap (%) | Field of View (θ) | Pulse in Air | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|
| BLK33C | 600 | 30 | 50 | 1 | 130 | 5 |
| BLK33D | 600 | 30 | 50 | 1 | 130 | 5 |
| CALIB | 600 | 30 | 50 | 1 | 130 | 5 |

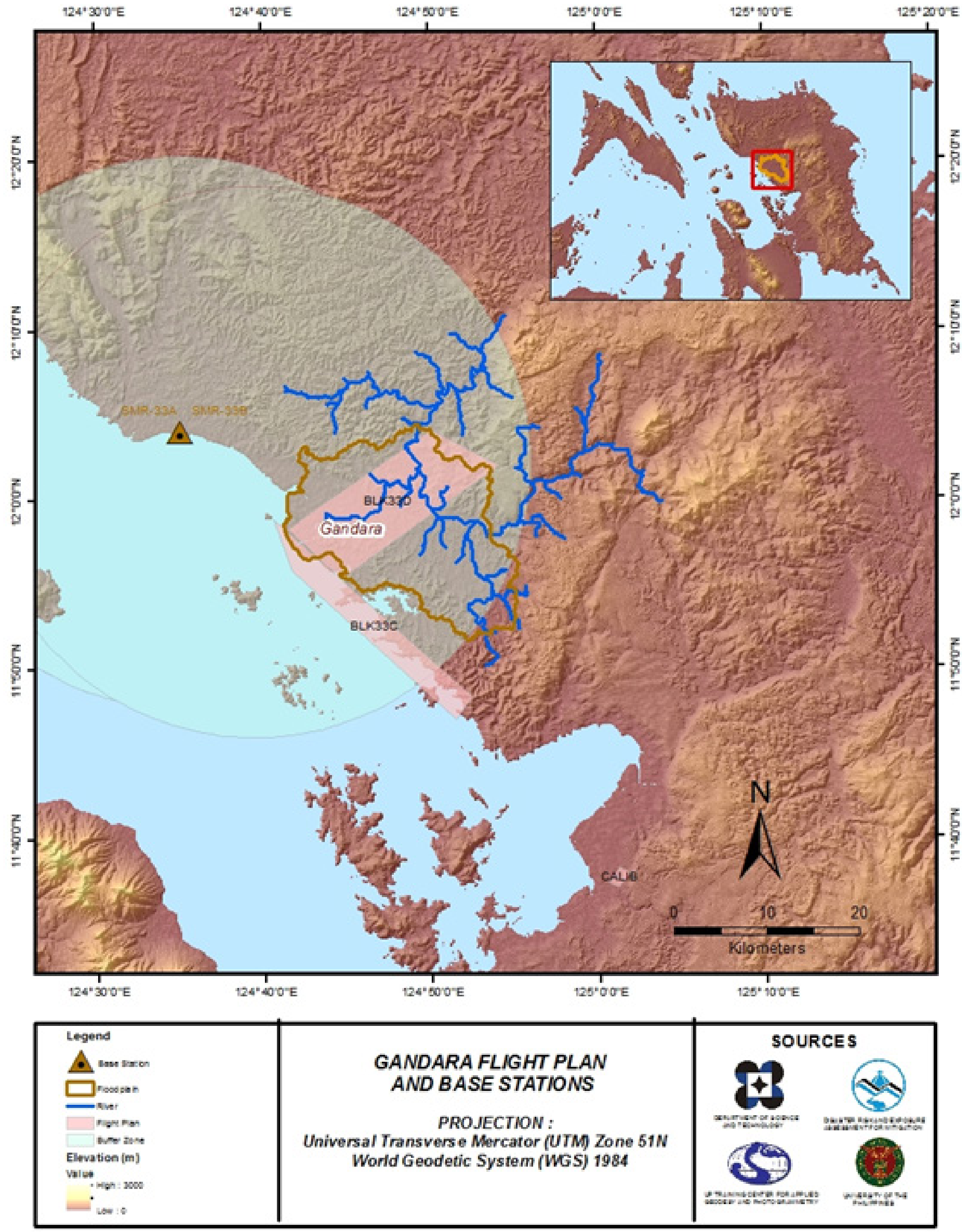



Figure 2. Flight Plan and base stations used for the Gandara Floodplain survey using Pegasus sensor.

## 2.2 Ground Base Station

The project team also established two (2) ground control points, SMR-33A AND SMR-33B, which are of second (2nd) order accuracy. The baseline processing reports for established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (November 8-13, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Gandara floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Gandara Floodplain LiDAR Survey. Table 2 and Table 3 show the details about the NAMRIA reference point and established points, and Table 4 shows the list of all ground control points occupied during the acquisition together with the dates they were utilized during the survey.

Table 2. Details of the recovered NAMRIA horizontal control point SMR-33A used as base station for the LiDAR Acquisition.

| **Station Name** | **SMR-33A** | |
|---|---|---|
| **Order of Accuracy** | **2nd** | |
| **Relative Error (horizontal positioning)** | **1 in 50,000** | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 04' 06.98588" North<br>124° 34' 54.39749" East<br>5.512 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 672169.393 meters<br>1334554.024 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 04' 02.47512" North<br>124° 34' 59.48472" East<br>64.658 meters |

Table 3. Details of the established control point SMR-33B used as base station for the LiDAR acquisition.

| **Station Name** | **SMR-33B** | |
|---|---|---|
| **Order of Accuracy** | **2nd** | |
| **Relative Error (horizontal positioning)** | **1 in 50,000** | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 04' 07.12856" North<br>124° 34' 55.36866" East<br>5.717 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92) | Easting<br>Northing | 672198.738 meters<br>1334558.577 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 12° 04' 02.61782" North<br>124° 35' 00.45589" East<br>64.863 meters |

Table 4. Ground control points used during the LiDAR data acquisition.

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| Nov. 8, 2016 | 10225L | 4BLK33AC313A | SMR-33A and SMR-33B |
| Nov. 11, 2016 | 10231L | 4BLK33D316A | SMR-33A and SMR-33B |
| Nov. 13, 2016 | 10235L | 4BLK33D318A | SMR-33A and SMR-33B |

## 2.3 Flight Missions

Three (3) missions were conducted to complete the LiDAR data acquisition in Gandara floodplain, for a total of fourteen hours and forty-four minutes (14hrs 44 mins.) of flying time for RP-C9522. All missions were acquired using the ALS80 LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for the LiDAR data acquisition of the Gandara 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 |
| Nov. 8, 2016 | 10225L | 76.55 | 79.58 | 3.47 | 76.11 | 4 | 5 | 5 |
| Nov. 11, 2016 | 10231L | 152.14 | 59.87 | 53.33 | 6.54 | 4 | 23 | 35 |
| Nov. 13, 2016 | 10235L | 2.68 | 3.18 | NA | 3.18 | 4 | 35 | 23 |
| TOTAL | | 231.37 | 142.63 | 56.8 | 85.83 | 14 | 44 | 31 |

Table 6. Actual parameters used during the LiDAR data acquisition of the Gandara Floodplain.

| Flight Number | Flying Height | Overlap (%) | Field of View (θ) | Pulse in Air | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|
| 10225L | 600 | 30 | 50 | 1 | 130 | 5 |
| 10231L | 600 | 30 | 50 | 1 | 130 | 5 |
| 10235L | 600 | 30 | 50 | 1 | 130 | 5 |

## 2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Gandara floodplain (See Annex 7). It is located in the province of Samar with majority of the floodplain situated within the city of Calbayog in Samar Province. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 7. Figure 3, on the other hand, shows the actual coverage of the LiDAR acquisition for the Gandara floodplain.

Table 7. The list of municipalities and cities surveyed of the Gandara Floodplain LiDAR acquisition.

| Province | Municipality/City | Area of Municipality/City (km2) | Total Area Surveyed (km2) | Percentage of Area Surveyed |
|---|---|---|---|---|
| Samar | Pagsanghan | 29.46 | 8.25 | 28.02% |
| | Tarangnan | 89.57 | 20.51 | 22.90% |
| | Gandara | 296.92 | 25.43 | 8.56% |
| | Catbalogan City | 177.02 | 11.71 | 6.62% |
| | San Jorge | 280.03 | 12.49 | 4.46% |
| | Santa Margarita | 130.73 | 2.31 | 1.76% |

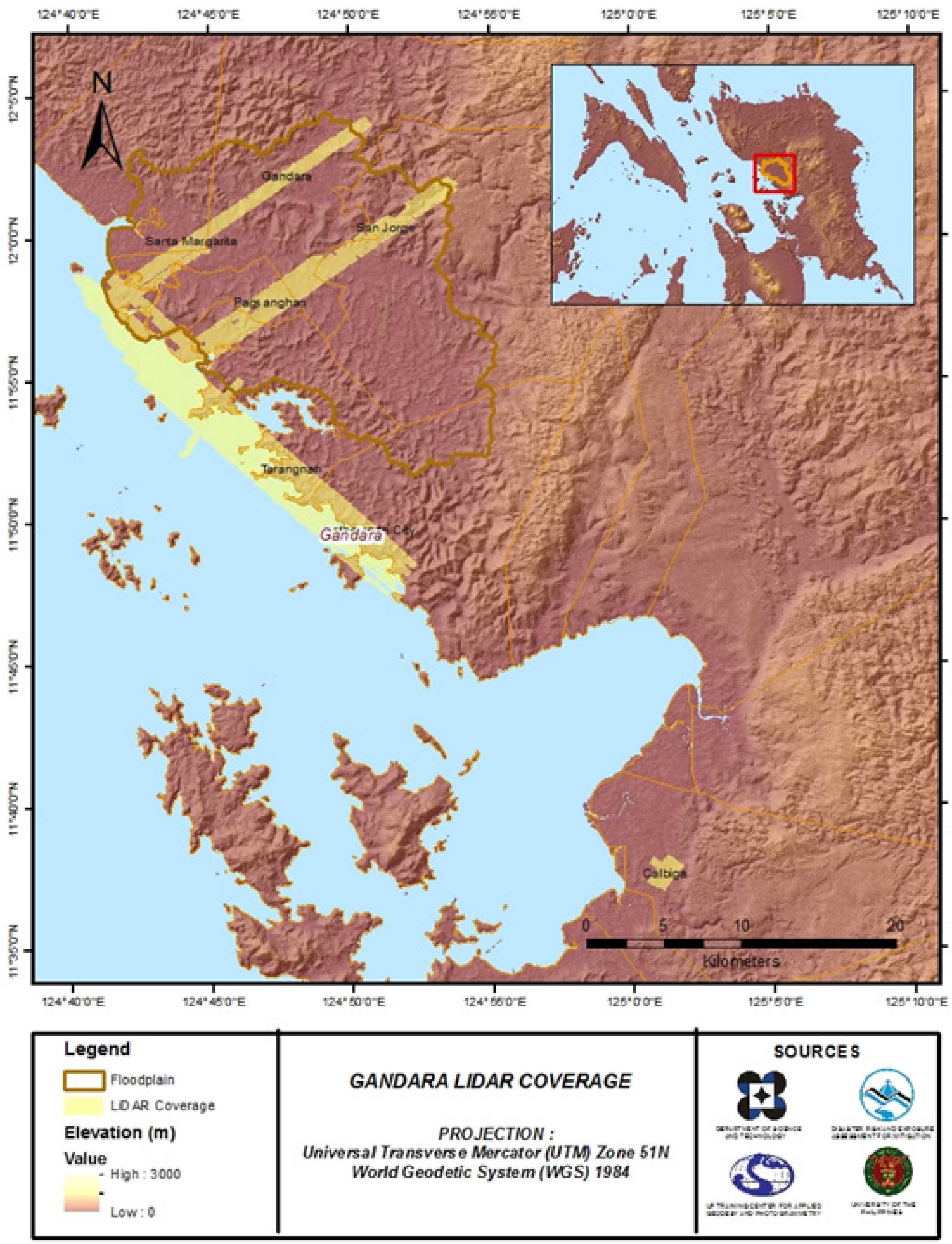



Figure 3. Actual LiDAR survey coverage of the Gandara Floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING OF THE GANDARA FLOODPLAIN

*Engr. Ma. Ailyn L. Olanda, Engr. Merven Mattew D. Natino, Jovy Anne S. Narisma, Engr. Karl Adrian P. Vergara*

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

## 3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 4

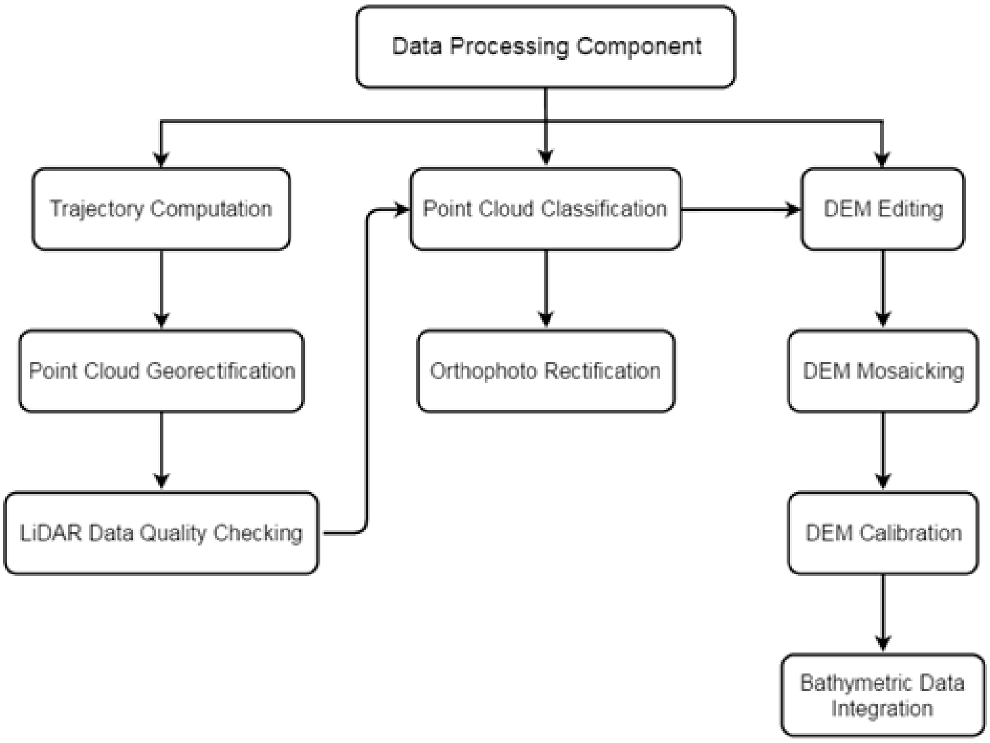



Figure 4. Schematic diagram for the data pre-processing.

## 3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Gandara floodplain can be found in Annex 5. Missions flown during the first survey conducted on November 2016 used the Airborne LiDAR Sensor ALS80-HP Leica Geosystems over the Province of Samar.

The Data Acquisition Component (DAC) transferred a total of 37.29 Gigabytes of RawLaser data, 1.25 Gigabytes of GNSSIMU data, 20.47 Megabytes of GPS base station data, and 151.1 Gigabytes of RCD30 raw image data to the data server on November 29, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Gandara was fully transferred on December 5, 2016, as indicated on the Data Transfer Sheets for Gandara floodplain.

## 3.3 Trajectory Computation

The Estimated Position Accuracy parameters of the computed trajectory for flight 10225L, one of the Gandara flights, which is the North, East, and Height position estimated standard deviations are shown in Figure 4. The sum of these standard deviation values are indicated in the plot as the Trace values. 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 8, 2016 00:00AM. The y-axis is the estimated value of the standard deviation for that particular position.

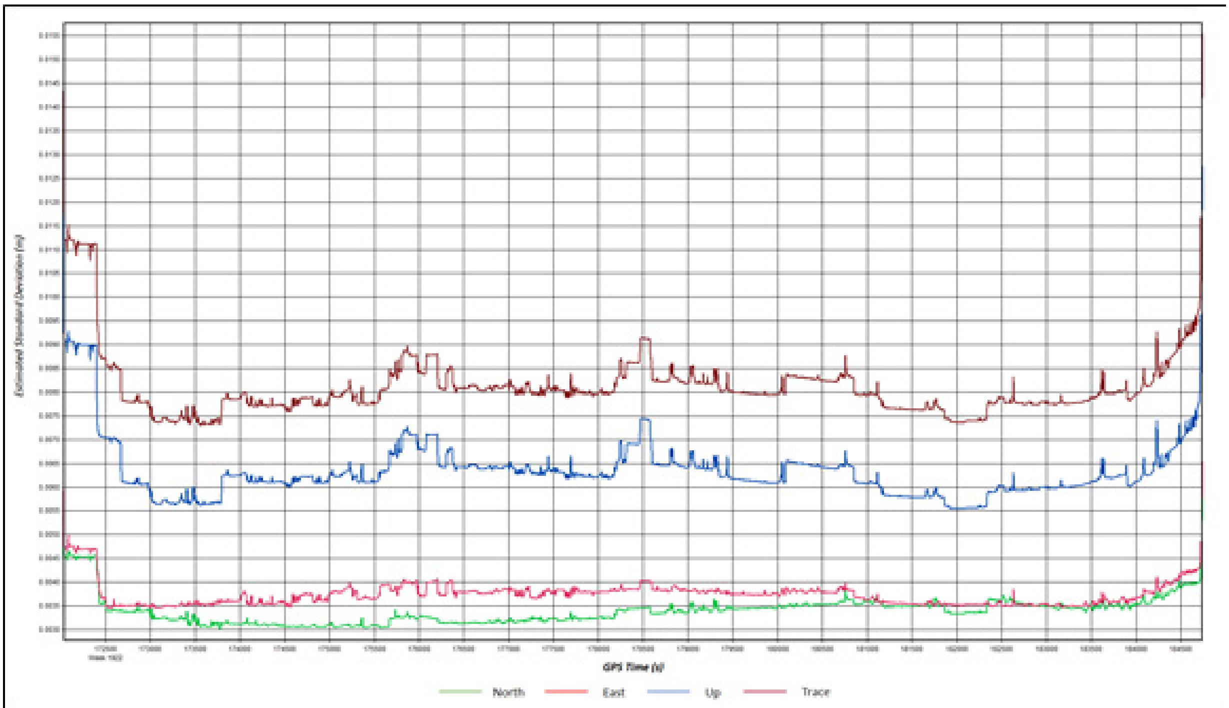



Figure 5. Smoothed Performance Metric Parameters of Gandara Flight 10225L.

The time of flight was from 3,000 seconds to 16,500 seconds, which corresponds to morning of February 7, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize 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 4 shows that the North position RMSE peaks at 1.80 centimeters, the East position RMSE peaks at 1.90 centimeters, and the Down position RMSE peaks at 5.00 centimeters, which are within the prescribed accuracies described in the methodology.

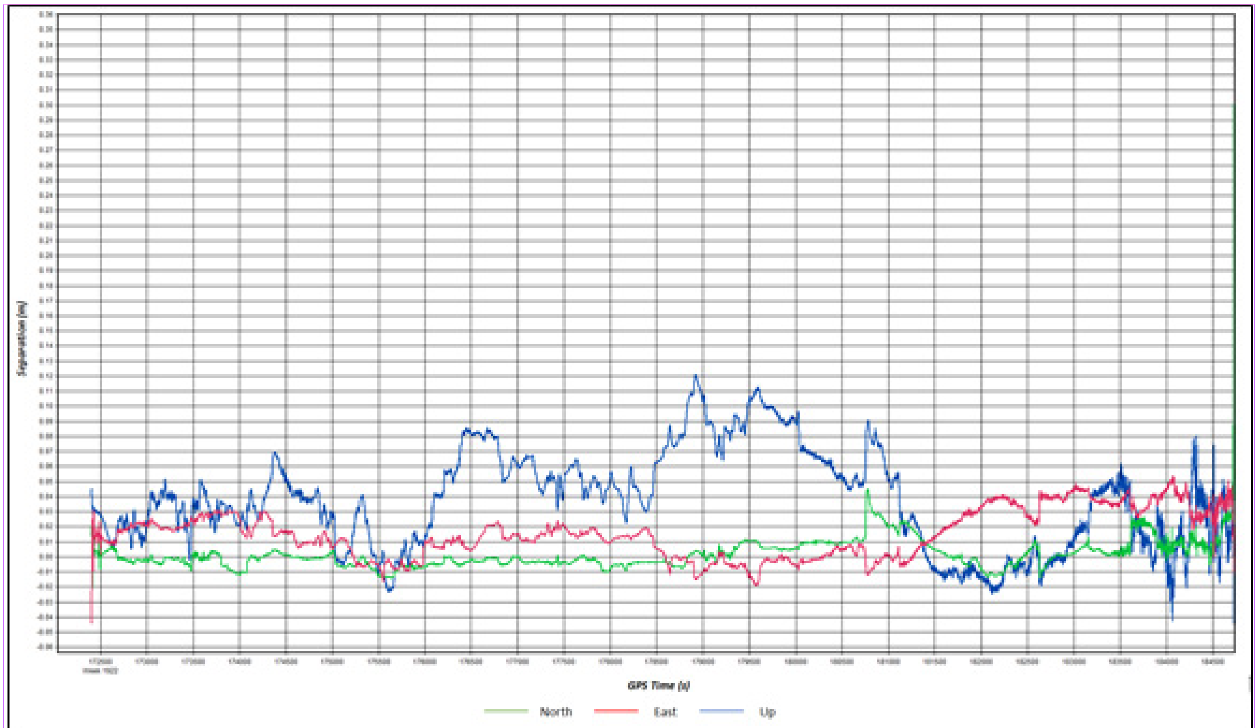



Figure 6. Solution Status Parameters of Gandara Flight 10225L.

The Combined Separation Plot of flight 10225L which displays the position difference between forward and reverse processing result, is shown in Figure 5. The values for this plot should be within +/- 10 cm to come up with an accurate trajectory solution. From the figure, the separation values are within -2 cm and 10 cm except for some period when the aircraft performed turning. 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 10. Also, the PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. 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 Gandara flights is shown in Figure 6.

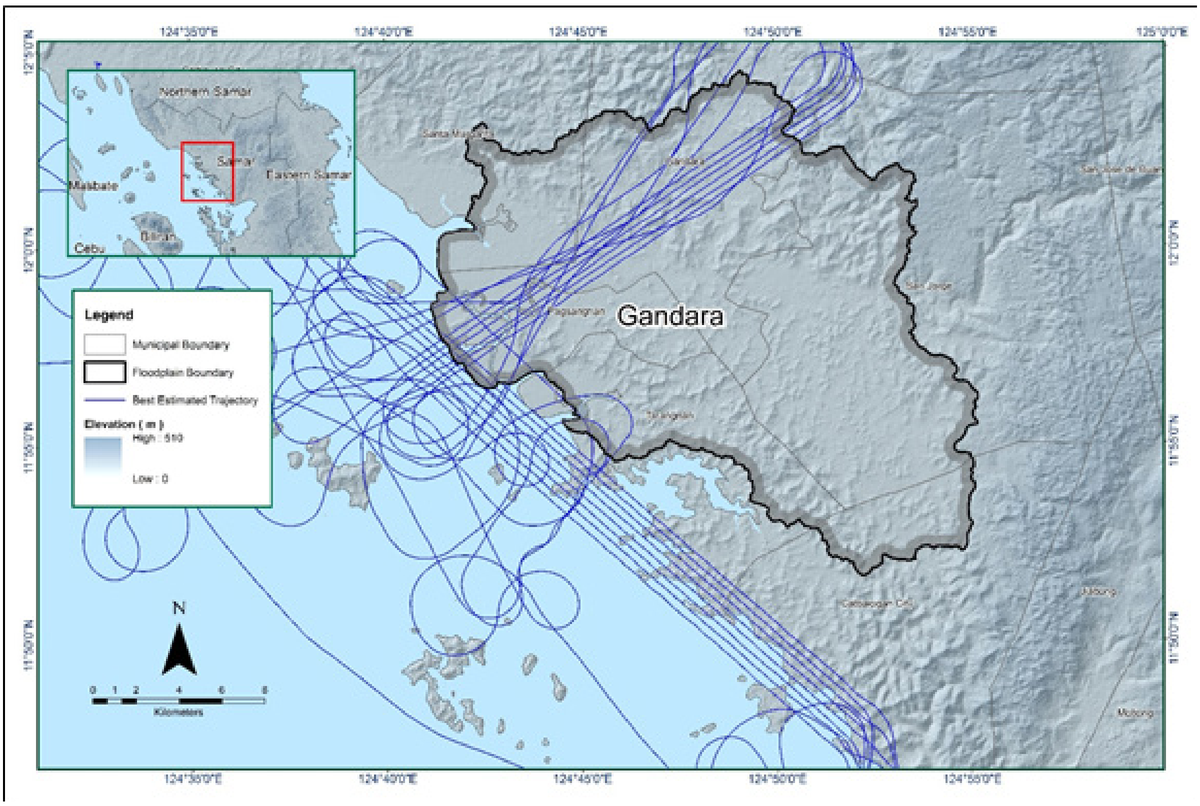



Figure 7. Best Estimated Trajectory of the LiDAR missions conducted over the Gandara Floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS contains 17 flight lines, with each flight line contains two channels, since the Leica ALS80-HP contains two channels. The summary of the self-calibration results obtained from LiDAR processing in the Leica Geosystems' CloudPro software for all flights over the Gandara floodplain are given in Table 7.

Table 8. Self-Calibration Results values for Lun Masla flights.

| Boresight Parameters | Value | |
|---|---|---|
| | Channel A | Channel B |
| Roll Error | -0.00026404361 | -0.0002590997 |
| Pitch Error | 0.0005049565 | 0.0006872629 |
| Heading Error | -0.0021014205 | -0.0020822516 |

The boresight parameter correction values above are derived from Terra Match and are applied to compute for the LAS files of Gandara flights. The boresight parameter correction values for individual blocks are presented in the Mission Summary Reports (Annex 8).

## 3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Gandara Floodplain is shown in Figure 7. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

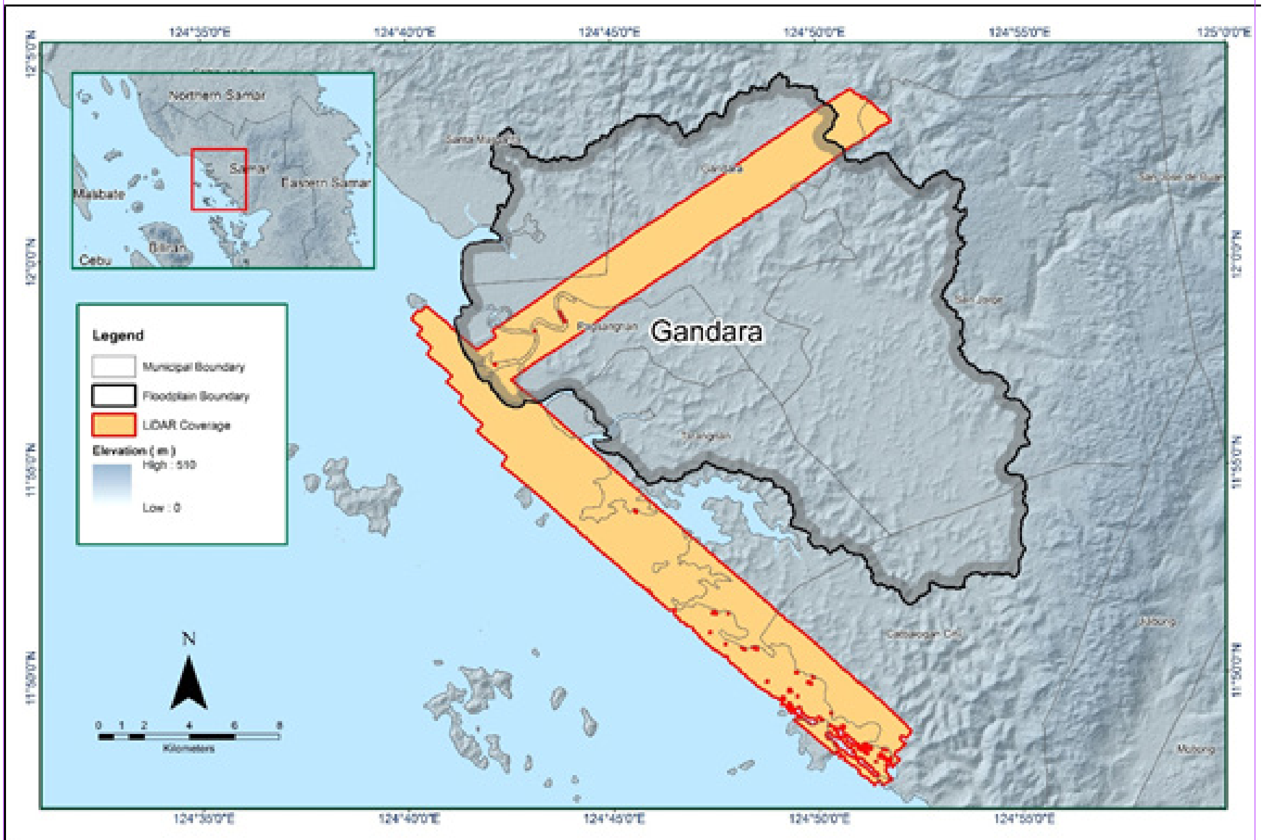



Figure 8. Boundaries of the processed LiDAR data over the Manicahan Floodplain.

The total area covered by the Gandara missions is 120.01 sq.km that is comprised of two (2) flight acquisitions grouped and merged into two (2) blocks as shown in in Table 9.

Table 9. List of LiDAR blocks for Lun Masla Floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Calbayog_Blk33D | 10225L | 46.22 |
| Calbayog_Blk33C | 10235L | 76.79 |
| TOTAL | | 120.01 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 8. Since the Leica system employs two channels, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

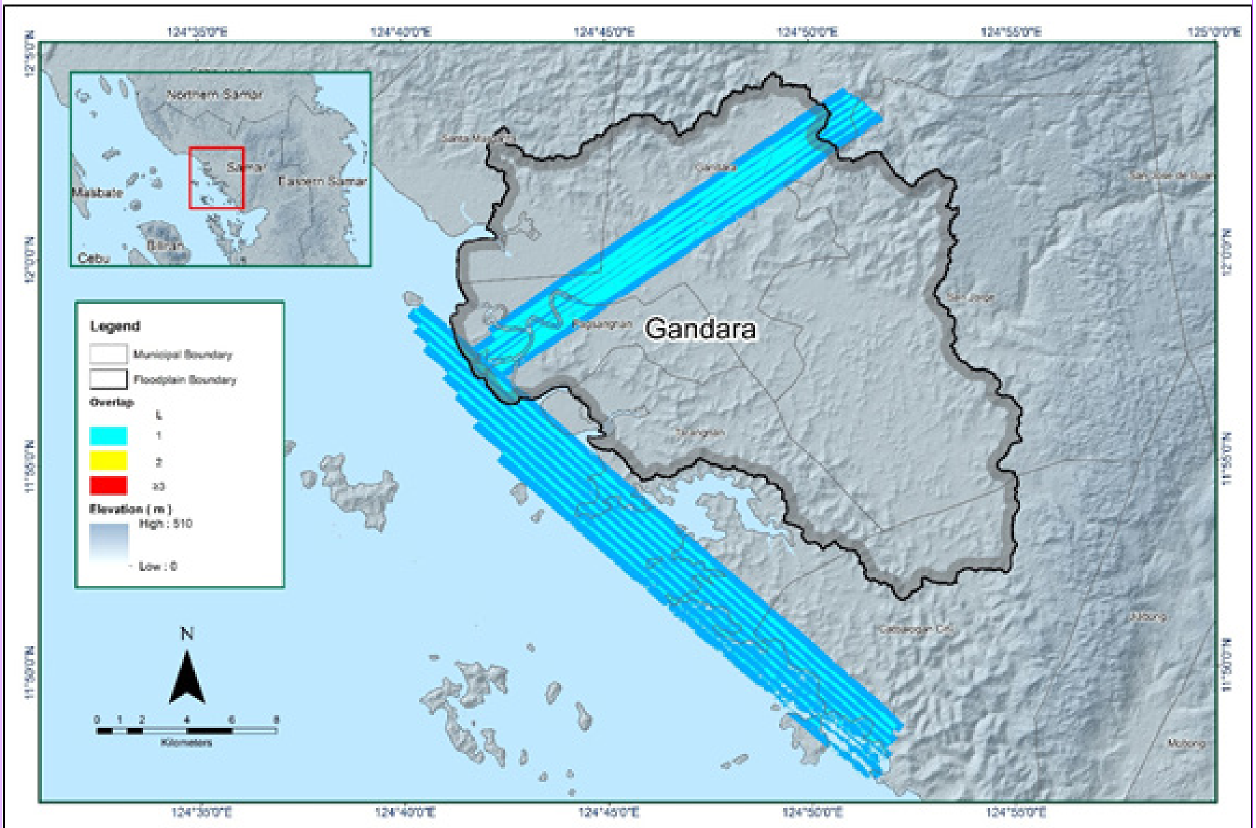



Figure 9. Image of data overlap for Gandara floodplain.

The overlap statistics per block for the Gandara floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps 28.35% and 52.90% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 10. As seen in the figure below, it was determined that all LiDAR data for the Gandara Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 6.965 points per square meter.

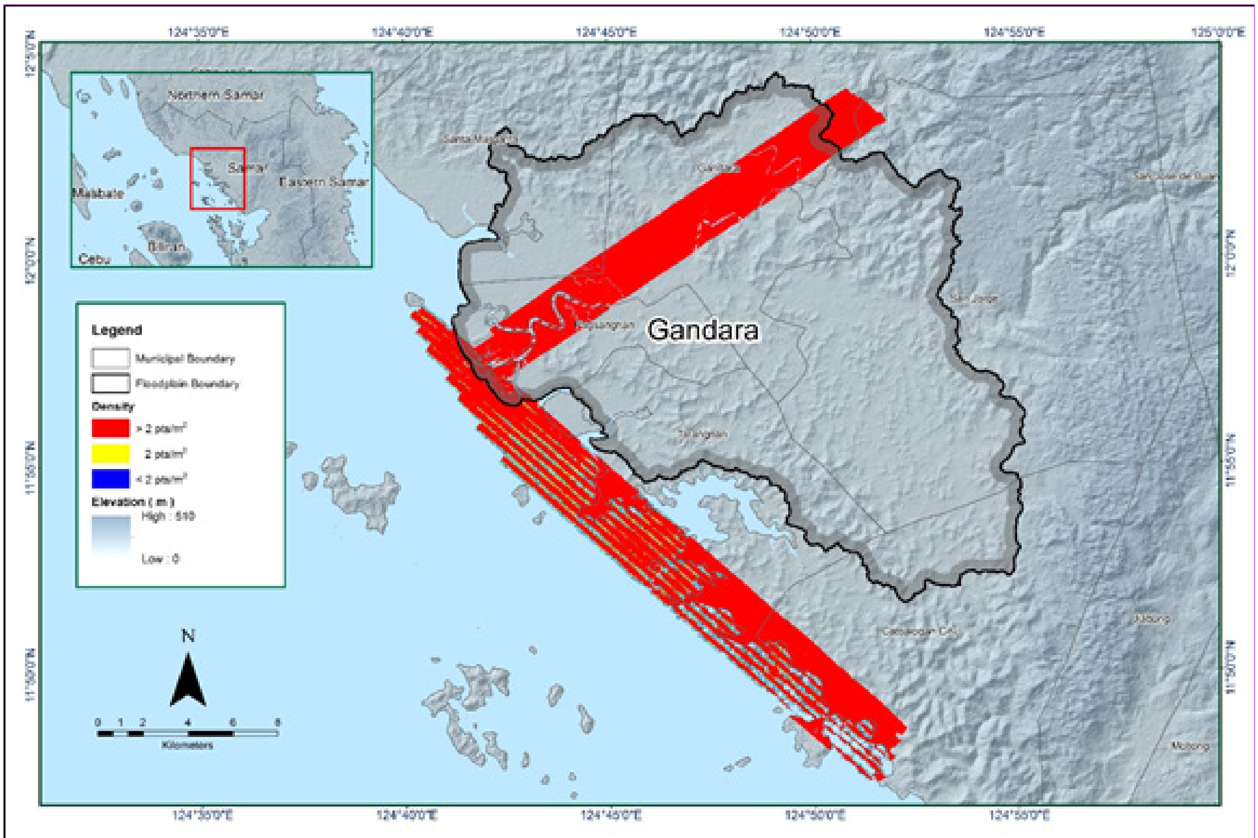



Figure 10. Pulse density map of the merged LiDAR data for Gandara floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 10. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20 m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

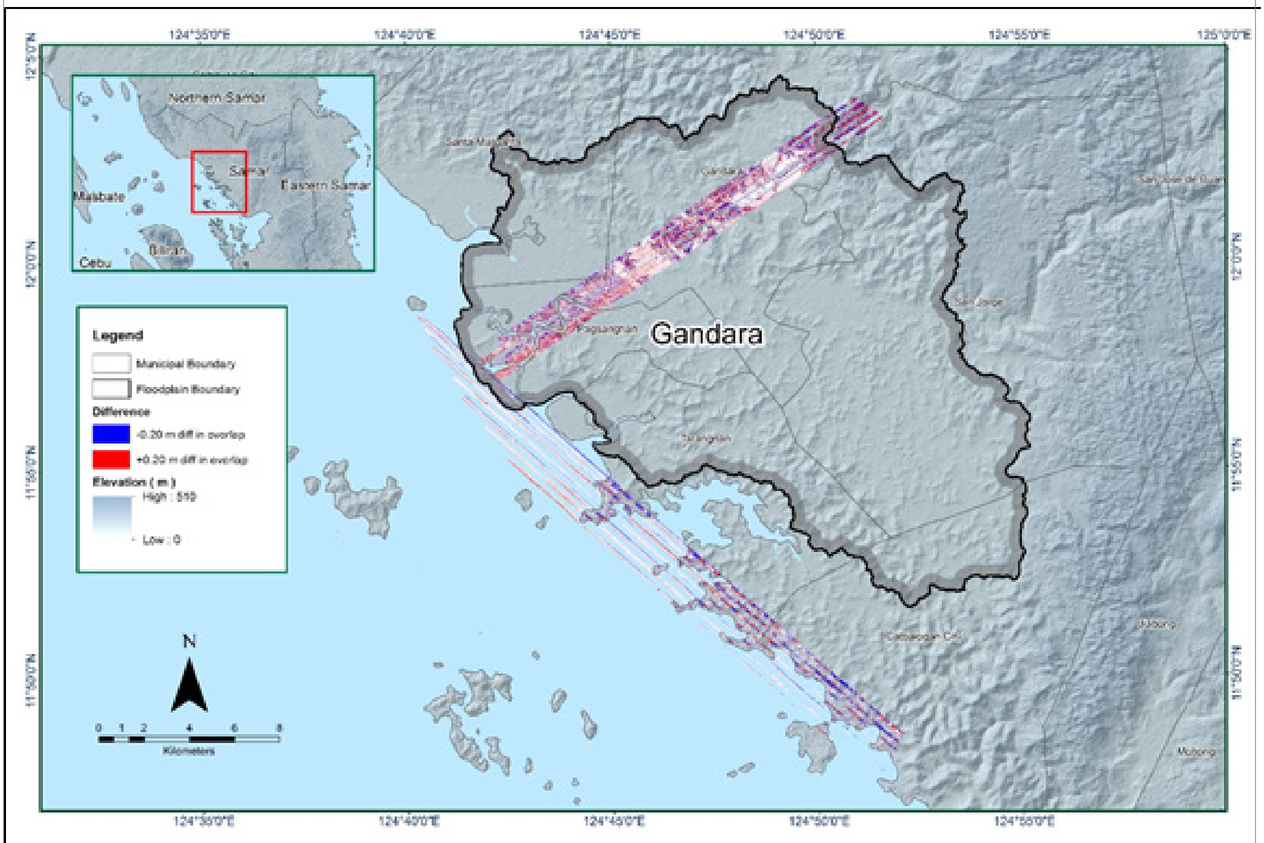



Figure 11. Elevation difference Map between flight lines for the Gandara Floodplain Survey.

A screen-capture of the processed LAS data from Gandara flight 10225L loaded in QT Modeler is shown in Figure 12. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

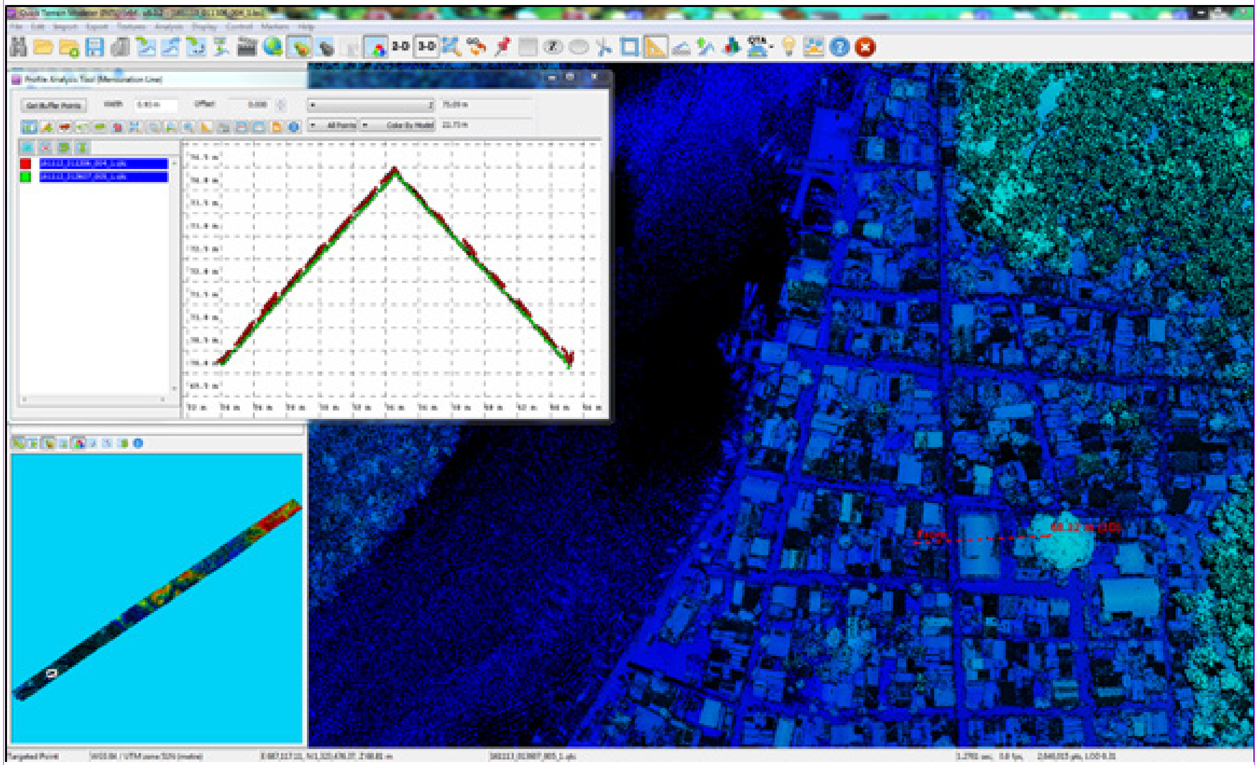


Figure 12. Quality checking for Gandara flight 10225L using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Lun Masla classification results in TerraScan.

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 30,263,508 |
| Low Vegetation | 15,622,662 |
| Medium Vegetation | 50,739,555 |
| High Vegetation | 58,886,849 |
| Building | 1,567,659 |

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Gandara floodplain is shown in Figure 12. A total of 409 with 1 km. X 1 km tiles (one kilometer by one kilometer) size were produced. Correspondingly, 8 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 457.78 meters and 60.74 meters respectively.

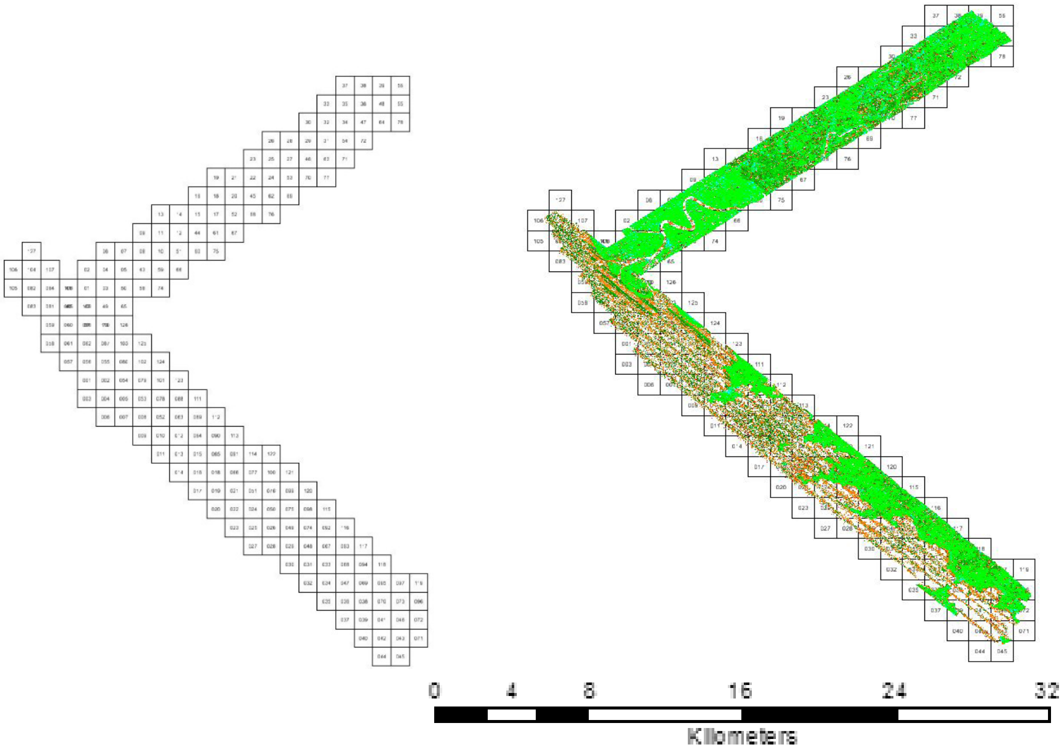



Figure 13. Tiles for Gandara floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 13. The ground points are highlighted in orange, while the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

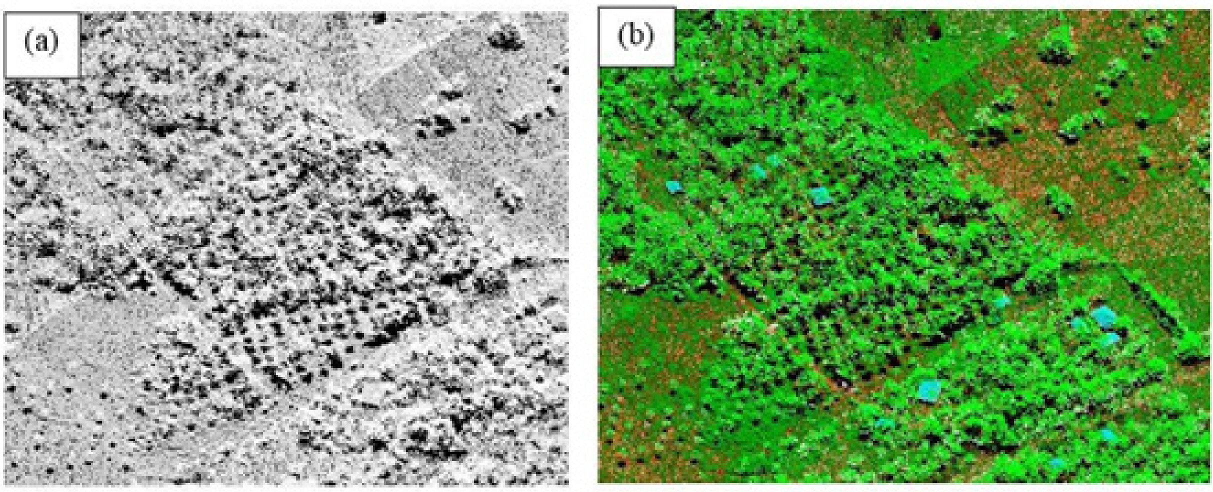



Figure 14. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show in Figure 15. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

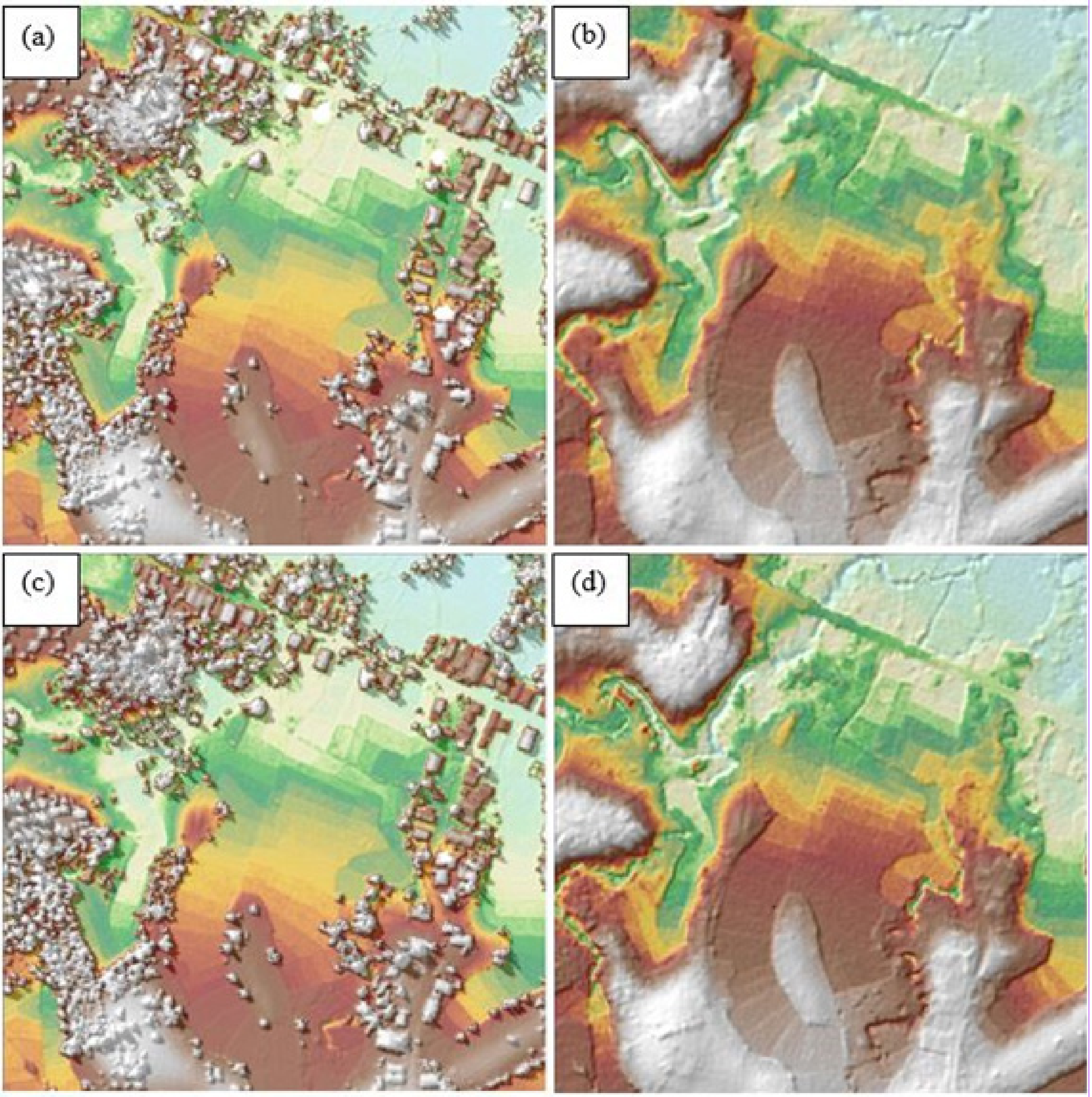



Figure 15. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Gandara floodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 201 with 1km by 1km tiles area covered by the Gandara floodplain is shown in Figure 15. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Gandara floodplain attained a total of 126.98 sq.km orthophotogaph coverage comprised of 1,903 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 16

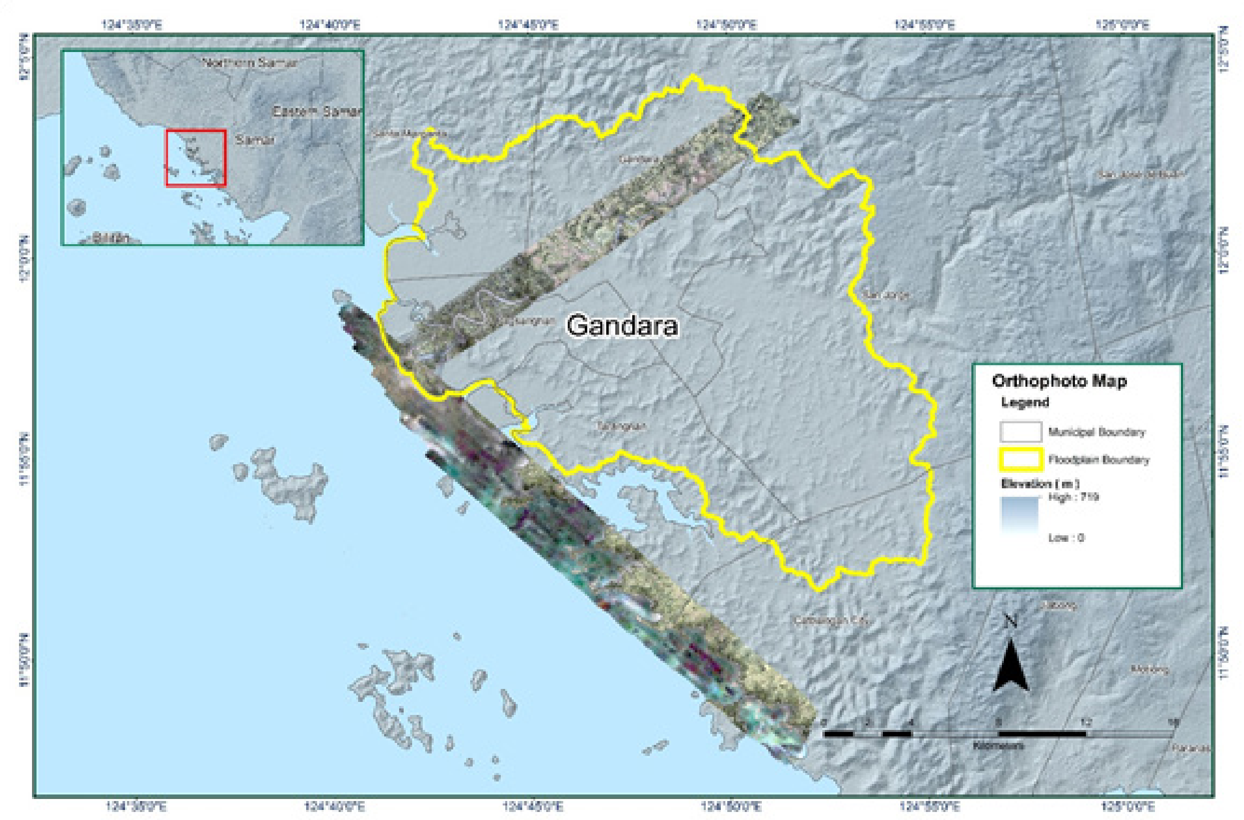



Figure 16. Gandara Floodplain with the available orthophotographs

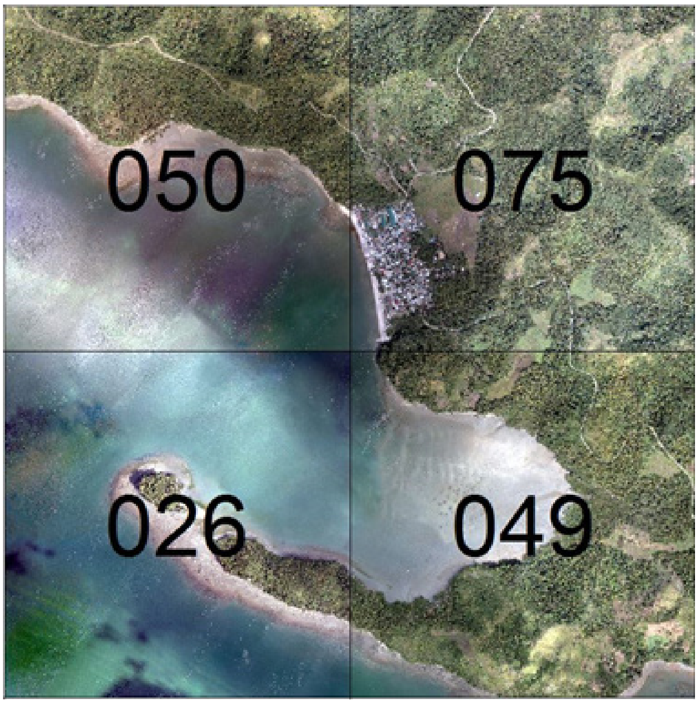



Figure 17. Sample orthophotograph tiles for the Gandara Floodplain.

## 3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Gandara flood plain. These blocks are composed of Calbayog blocks with a total area of 120.01 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding areas.

| LiDAR Blocks | Area (sq. km) |
|---|---|
| Calbayog_Blk33D | 46.22 |
| Calbayog_Blk33C | 76.79 |
| TOTAL | 120.01 sq.km |

Figure 18 shows portions of a DTM before and after manual editing. As evident in the figure, the river embankment (Figure 18a) was misclassified and removed during the classification process and was retrieved and reclassified (Figure 18b) through manual editing to allow the correct water flow. Likewise, the bridge (Figure 18c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 18d).

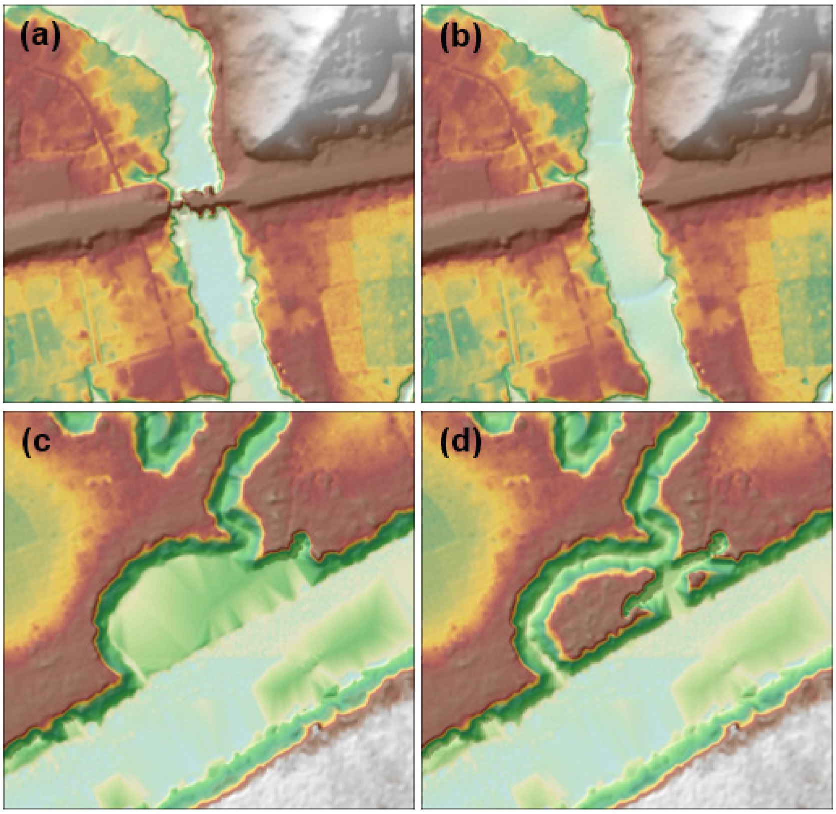



Figure 18. Portions in the DTM of the Gandara Floodplain – a river enbankment before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

## 3.9 Mosaicking of Blocks

The Calbayog_Blk33D was used as the reference block at the start of mosaicking because this was the first available block for processing in the flood plain. Table 12 shows the shift values applied to the LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Gandara Floodplain is shown in Figure 19. The entire Gandara floodplain is 12.31% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 12. Shift values of each LiDAR block of Gandara Floodplain.

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| Calbayog_Blk33D | 0.00 | 0.00 | 0.00 |
| Calbayog_Blk33C | 0.00 | 1.00 | 0.85 |

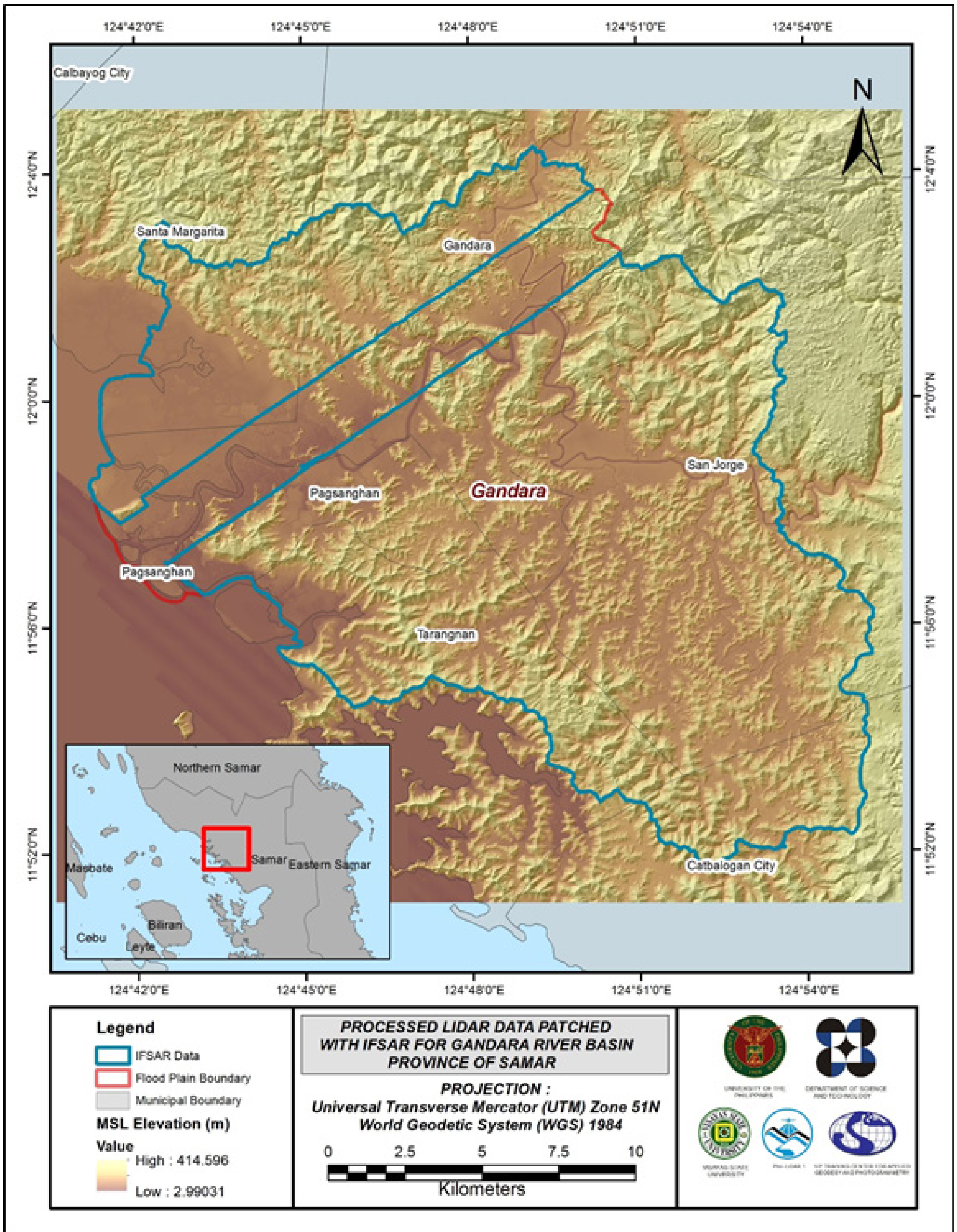



Figure 19. Map of processed LiDAR data for the Gandara Floodplain.

## 3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Gnadara and Jibatang to collect points with which the LiDAR dataset is validated is shown in Figure 19, with the validation survey points highlighted in green. A total of 17,140 survey points were used for calibration and validation of Gandara and Jibatang LiDAR data. Random selection of 80% of the survey points, resulting to 13,712 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR-IFSAR elevation values and the ground survey elevation values is shown in Figure 20. Statistical values were computed from extracted LiDAR-IFSAR 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-IFSAR DTM and calibration elevation values is 3.68 meters with a standard deviation of 0.79 meters. Calibration of Gandara LiDAR-IFSAR data was done by subtracting the height difference value, 3.68 meters, to Gandara mosaicked LiDAR-IFSAR data. Table 11 shows the statistical values of the compared elevation values between the Gandara LiDAR data and the calibration data.

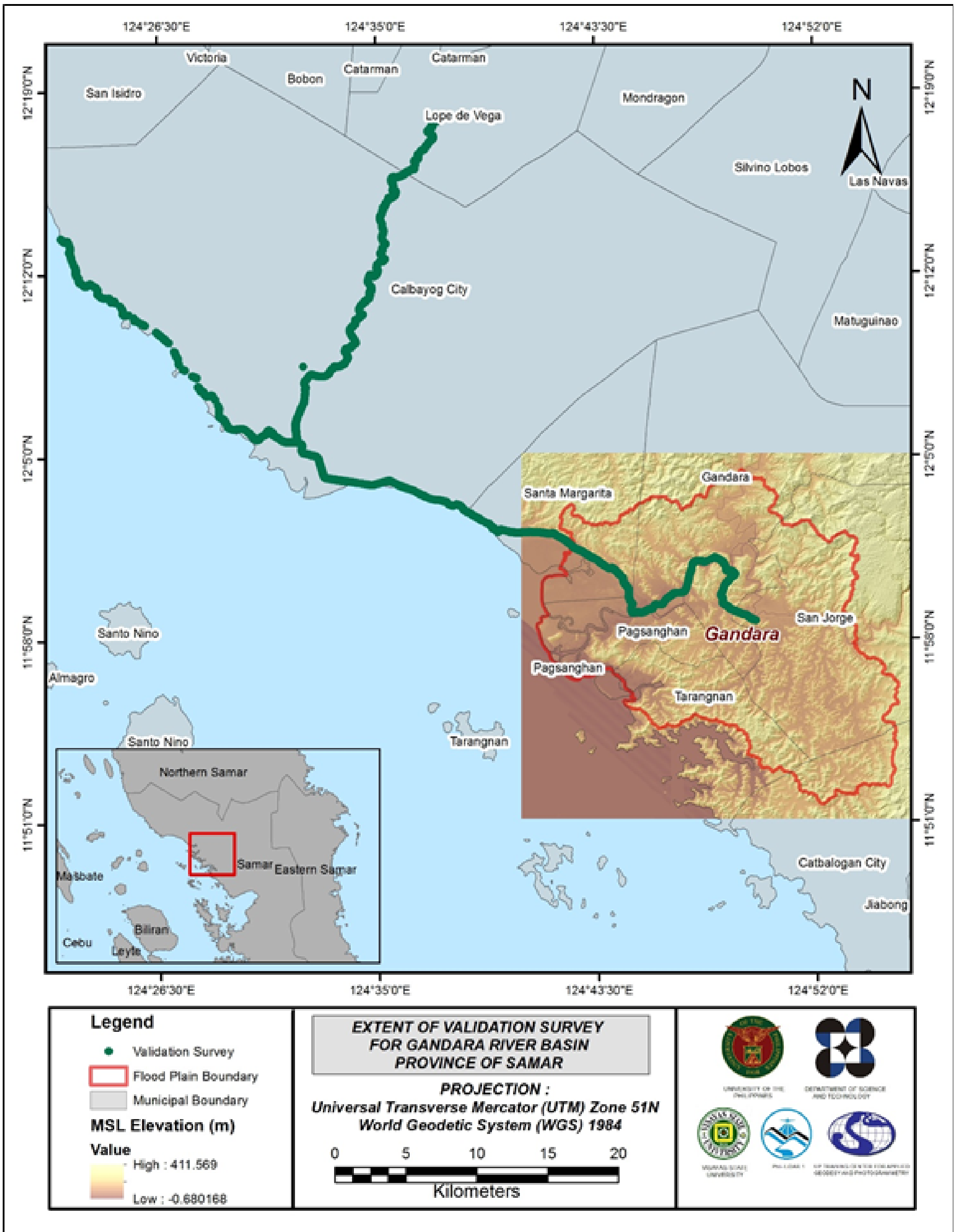



Figure 20. Map of Gandara Floodplain with validation survey points in green.

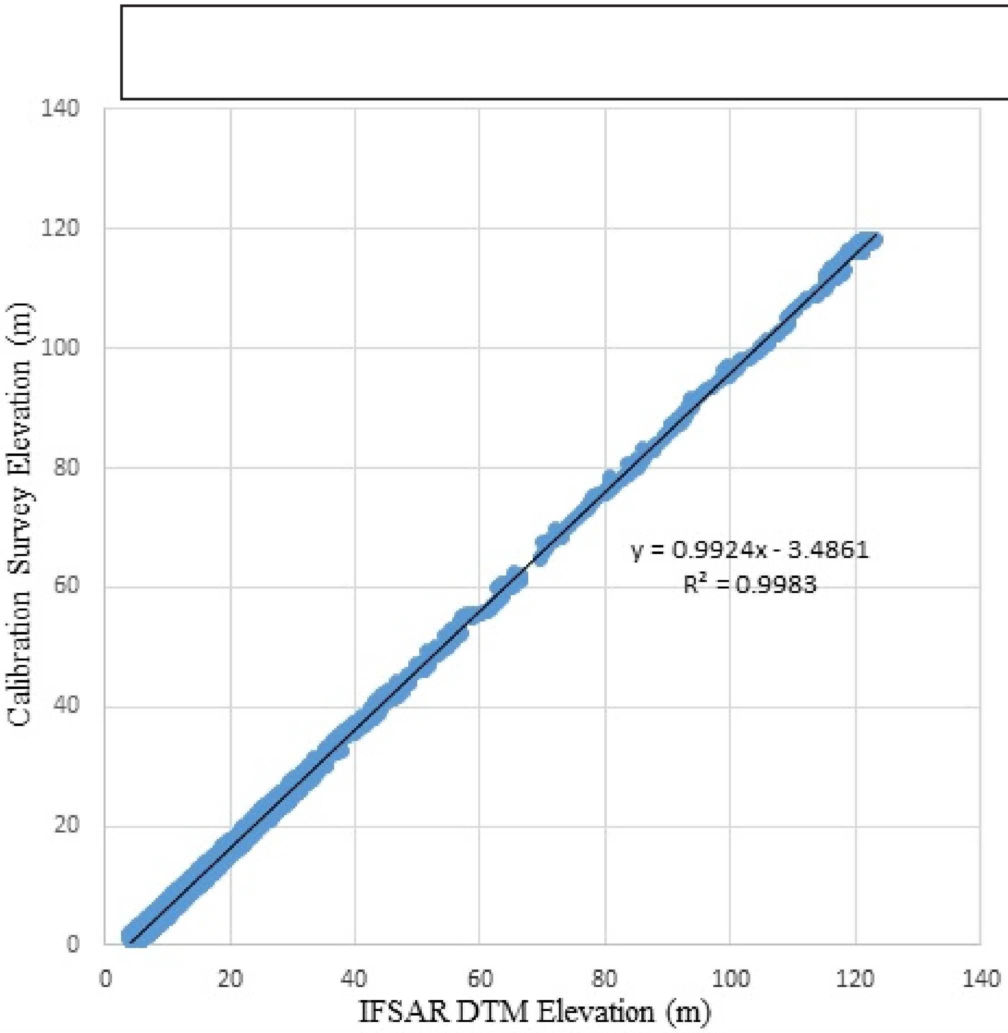



Figure 21. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures.

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 3.68 |
| Standard Deviation | 0.79 |
| Average | -3.60 |
| Minimum | -5.31 |
| Maximum | -2.07 |

Note: Calibration points lie within the IFSAR data, thus, Standard Deviation value obtained is still acceptable.

A total of 818 survey points lie within the Gandara flood plain and were used for the validation of the calibrated Gandara DTM. A good correlation between the calibrated mosaicked LiDAR elevation and the ground survey elevation values, which point toward the quality of the LiDAR DTM is shown in Figure 21. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 1.57 meters with a standard deviation of 1.54 meters, as shown in Table 12.

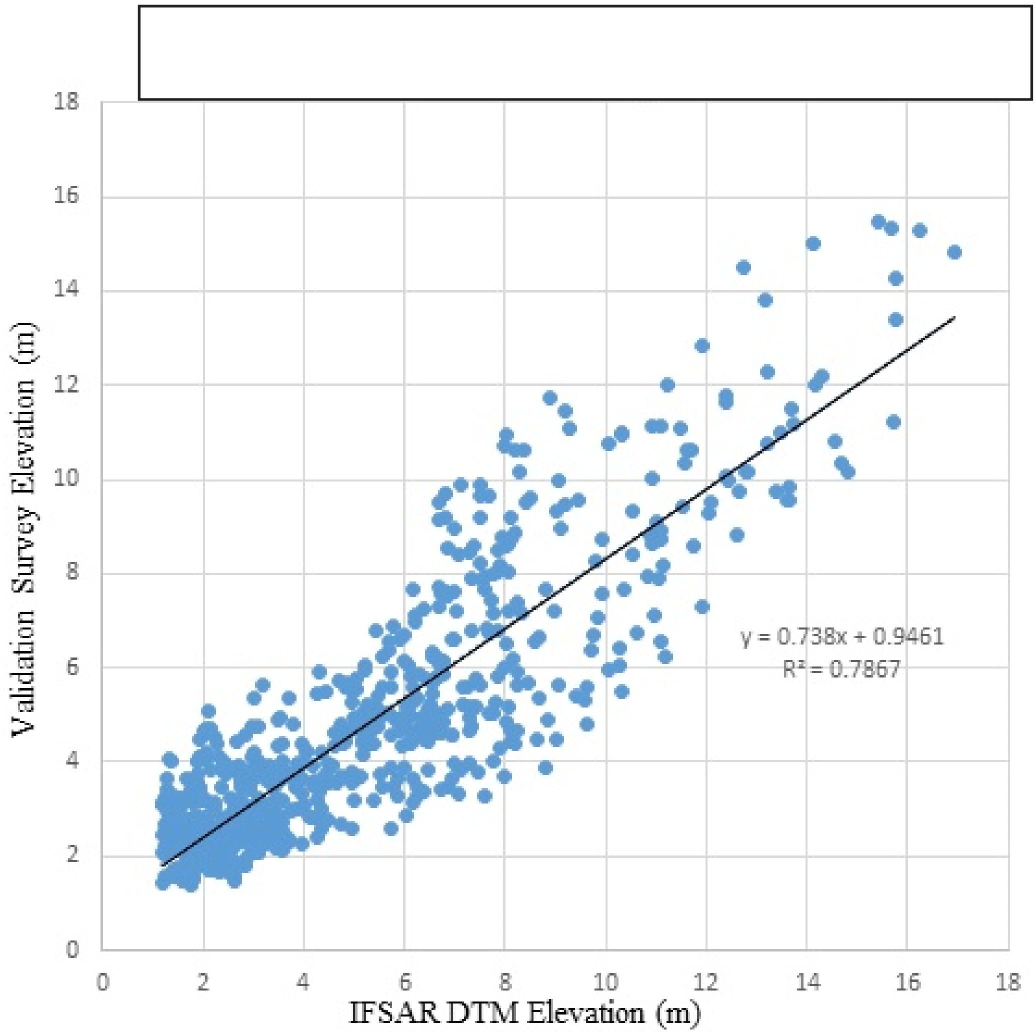



Figure 22. Correlation plot between the validation survey points and the LiDAR data.

Table 14. Validation Statistical Measures

| Validation Statistical Measures | Value (meters) |
| --- | --- |
| RMSE | 1.57 |
| Standard Deviation | 1.54 |
| Average | -0.33 |
| Minimum | -4.93 |
| Maximum | 2.99 |

Note: Validation points lie within the IFSAR data, thus, the RMSE and Standard Deviation values obtained are still acceptable.

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

For bathy integration, centerline and zigzag data was available for Gandara with 47,577 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation with barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.52 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Gandara integrated with the processed LiDAR DEM is shown in Figure 22.

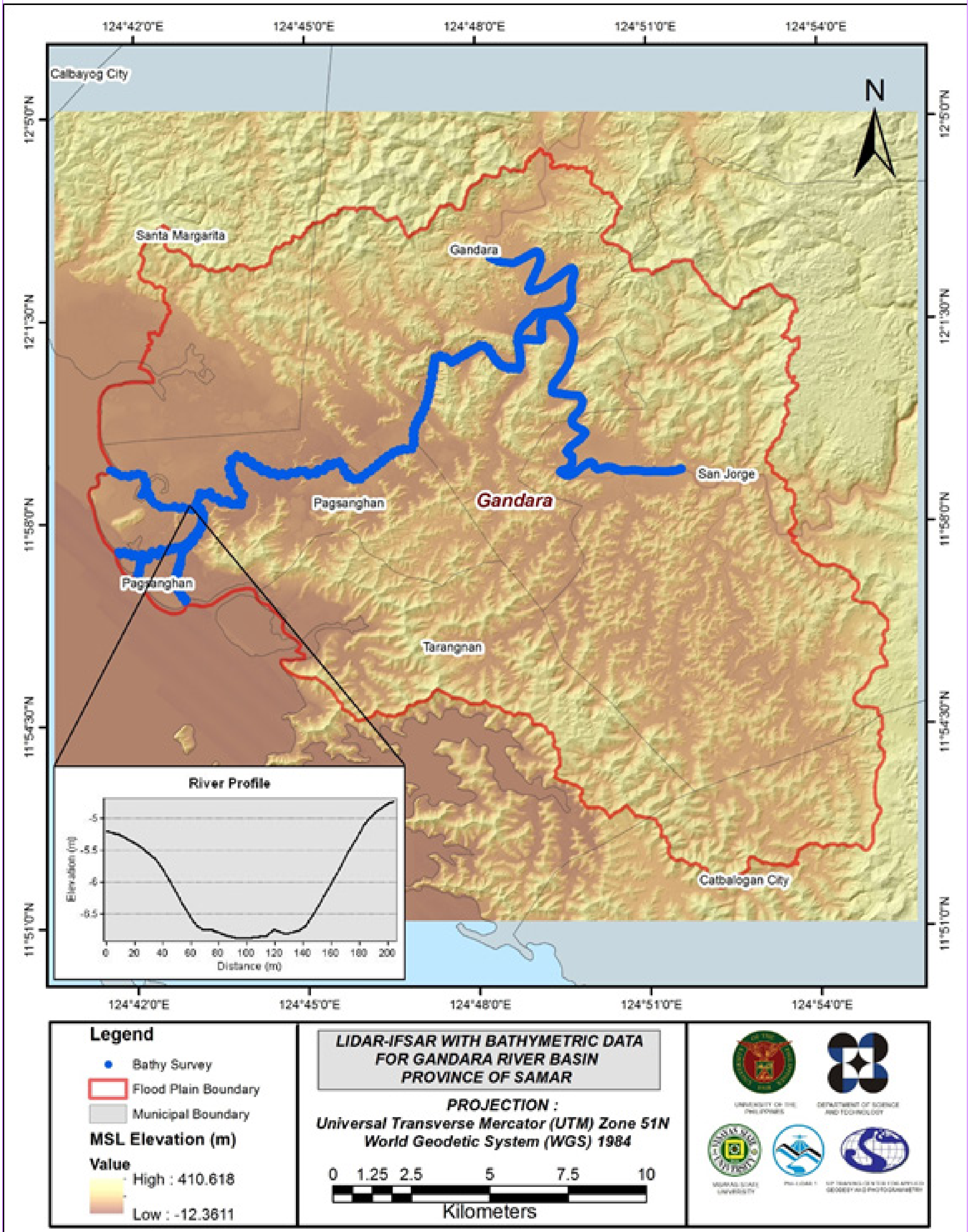



Figure 23. Map of Gandara floodplain with bathymetric survey points in blue.

## 3.12 Feature Extraction

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

### 3.12.1 Quality Checking of Digitized Features' Boundary

Gandara floodplain, including its 200 m buffer, has a total area of 378.31 sq km. For this area, a total of 2.0 sq km, corresponding to a total of 312 building features, are considered for QC. Figure 23 shows the QC blocks for the Gandara floodplain.

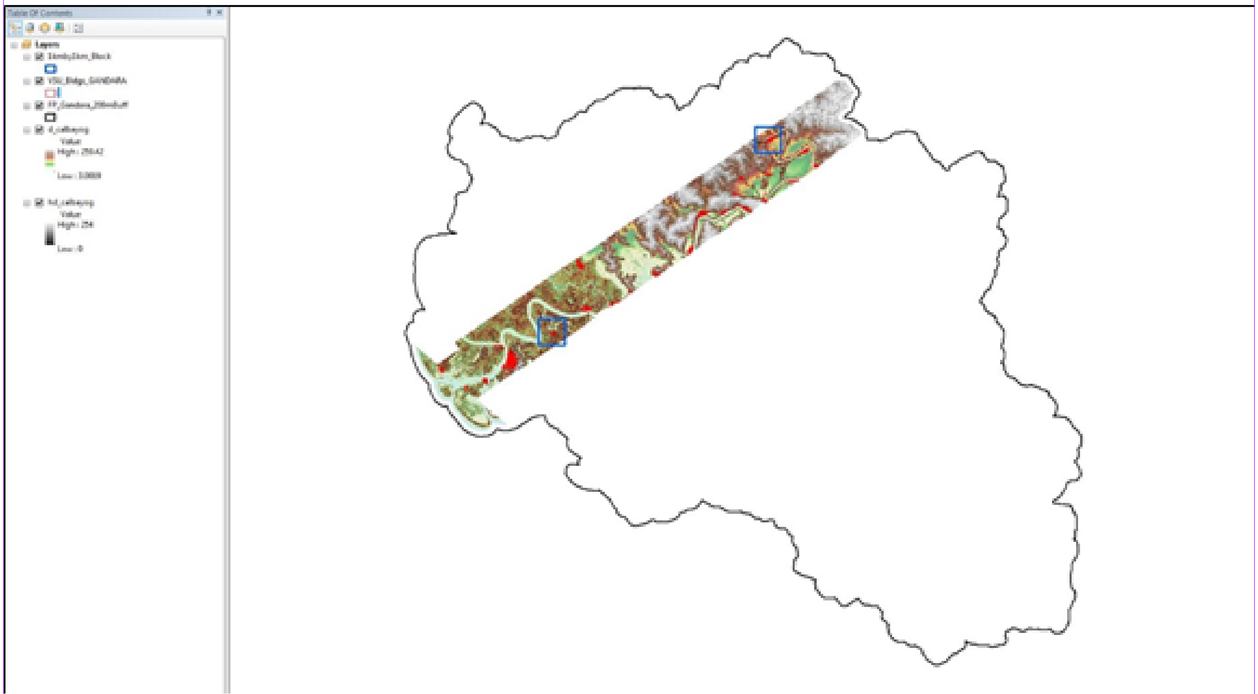


Figure 24. Blocks (in blue) of Gandara building features that were subjected to QC.

Quality checking of Gandara building features resulted in the ratings shown in Table 13.

Table 15. Details of the quality checking ratings for the building features extracted for the Gandara River Basin

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Gandara | 100.00 | 99.04 | 87.82 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 3,965 building features in Gandara floodplain. Of these building features, 35 was filtered out after height extraction, resulting to 3,930 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.30 m.

### 3.12.3 Feature Attribution

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

Table 14 summarizes the number of building features per type, while Table 15 shows the total length of each road type. Table 16, on the other hand, shows the number of water features extracted per type.

Table 16. Building features extracted for Gandara Floodplain

| Facility Type | No. of Features |
|---|---|
| Residential | 3,752 |
| School | 94 |
| Market | 3 |
| Agricultural/Agro-Industrial Facilities | 2 |
| Medical Institutions | 7 |
| Barangay Hall | 19 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 4 |
| Telecommunication Facilities | 0 |
| Transport Terminal | 0 |
| Warehouse | 0 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 0 |
| Police Station | 1 |
| Water Supply/Sewerage | 1 |
| Religious Institutions | 24 |
| Bank | 0 |
| Factory | 0 |
| Gas Station | 0 |
| Fire Station | 1 |
| Other Government Offices | 17 |
| Other Commercial Establishments | 5 |
| Total | 3,930 |

Table 17. Total length of extracted roads for Gandara Floodplain.

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/Municipal Road | Provincial Road | National Road | Others | |
| Gandara | 13.57 | 3.88 | 7.22 | 7.96 | 0.00 | 32.63 |

Table 18. Number of extracted water bodies for Manicahan Floodplain.

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Rivers/ Streams | Lakes/Ponds | Sea | Dam | Fish Pen | |
| Gandara | 120 | 29 | 0 | 0 | 0 | 149 |

A total of 15 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 given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 24 shows the completed Digital Surface Model (DSM) of the Gandara floodplain overlaid with its ground features.

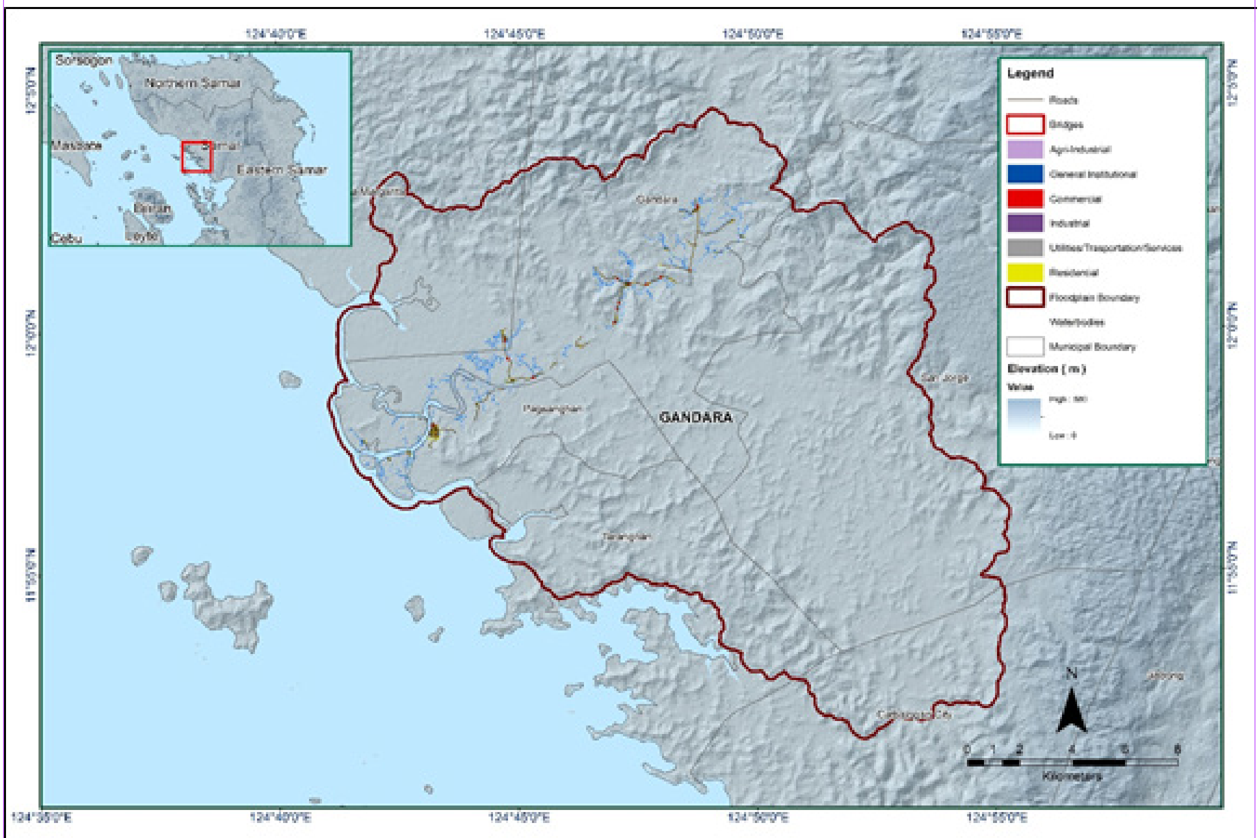



Figure 25. Extracted features of the Gandara Floodplain.

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

*Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano Engr. Bernard Paul D. Maramot, Engr. Precious Annie C. Lopez, Mr. Jann Russell J. Manzano*

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

## 4.1 Summary of Activities

The DVBC team conducted a field survey in two river basin in Western Samar, including Gandara river basin, on December 3 to 15, 2015 with the following scope of work: reconnaissance; control survey; cross-section and bridge as-built survey of Lapaz-Bulao Bridge located in Brgy. Guindapunan, Municipality of San Jorge and of the Sto. Niño Bridge located in Brgy. Sto. Niño, Municipality of Gandara; validation point acquisition of about 101.96 km covering Gandara River Basin; and bathymetric survey from Brgy. Buenavsta II, Municipality of San Jorge and Brgy. Sto. Niño, Municipality of Gandara down to its mouth in Brgy. Lungib, Gandara with an estimated length of 42.137 km using Trimble® SPS 882 GNSS PPK survey technique and an OHMEX™ single beam echo sounder. (See Figure 25).

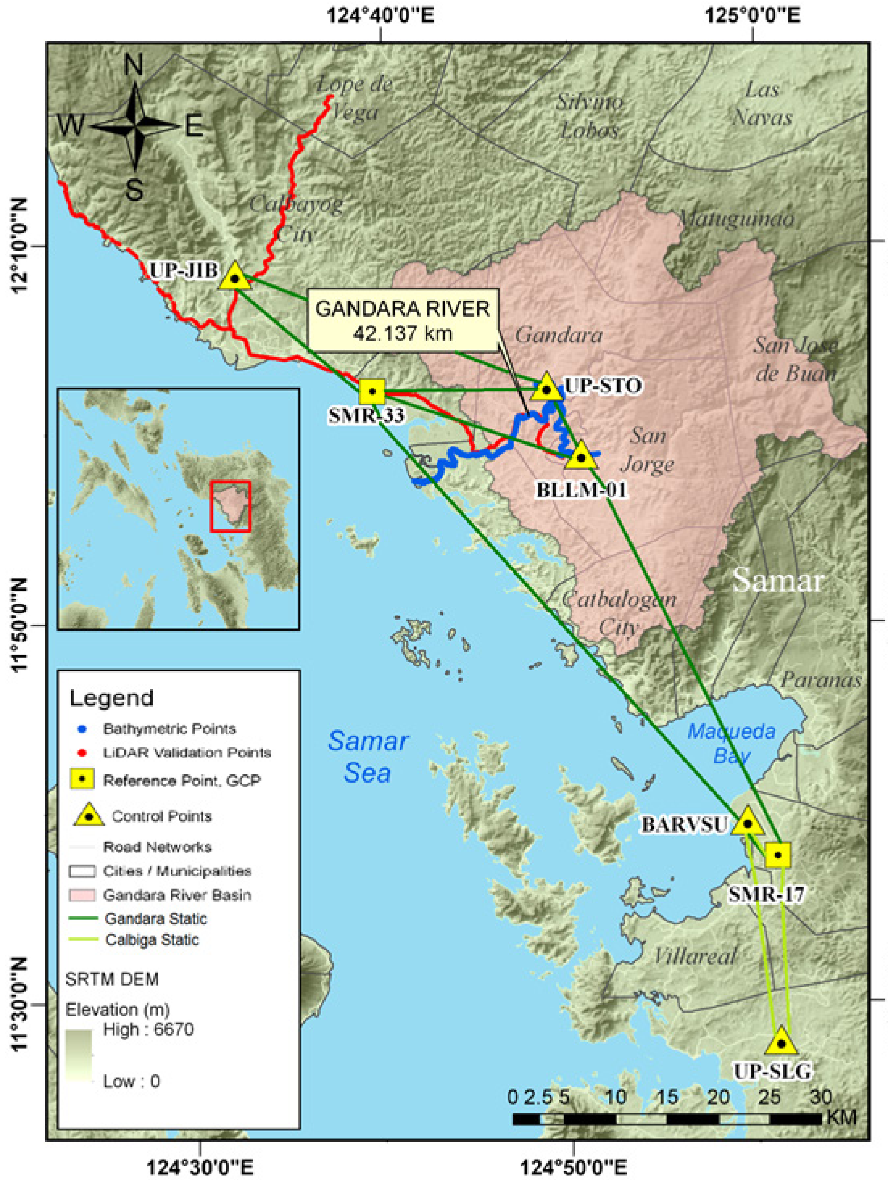



Figure 26. Extent of the bathymetric survey (in blue line) in Gandara River and the LiDAR data validation survey (in red).

## 4.2 Control Survey

A GNSS network was established by VSU on September 7, 2015 occupying the control points SMR-17, UP-SLG and BARVSU. The control point UP-SLG was used to give MSL value for this network. Its MSL value was derived from the benchmark SE-85 in Brgy. Tabok, Municpality of Llorente from the network established by DVBC on September 2014.

The GNSS network used for Gandara River Basin is composed of three (3) loops established on December 5 and 6, 2015 occupying the following reference points: SMR-17, a second order GCP in Brgy. Macaalan, Municipality of Calbiga; and SMR-33, a second order GCP in Brgy. Monbon, Municipality of Sta. Margarita.

Two (2) control points were established along the approach of bridges namely: UP-JIB, at Jibatang Bridge in Brgy. Oquando, Calbayog City; and UP-STO, at Sto. Niño Bridge in Brgy. Sto. Niño, Municipality of Gandara. A NAMRIA established control point, BLLM-01, in Brgy. Guindapunan, Municipality of San Jorge, was also occupied to use as marker.

Table 17 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 26 shows the GNSS network established in the Gandara River Survey.

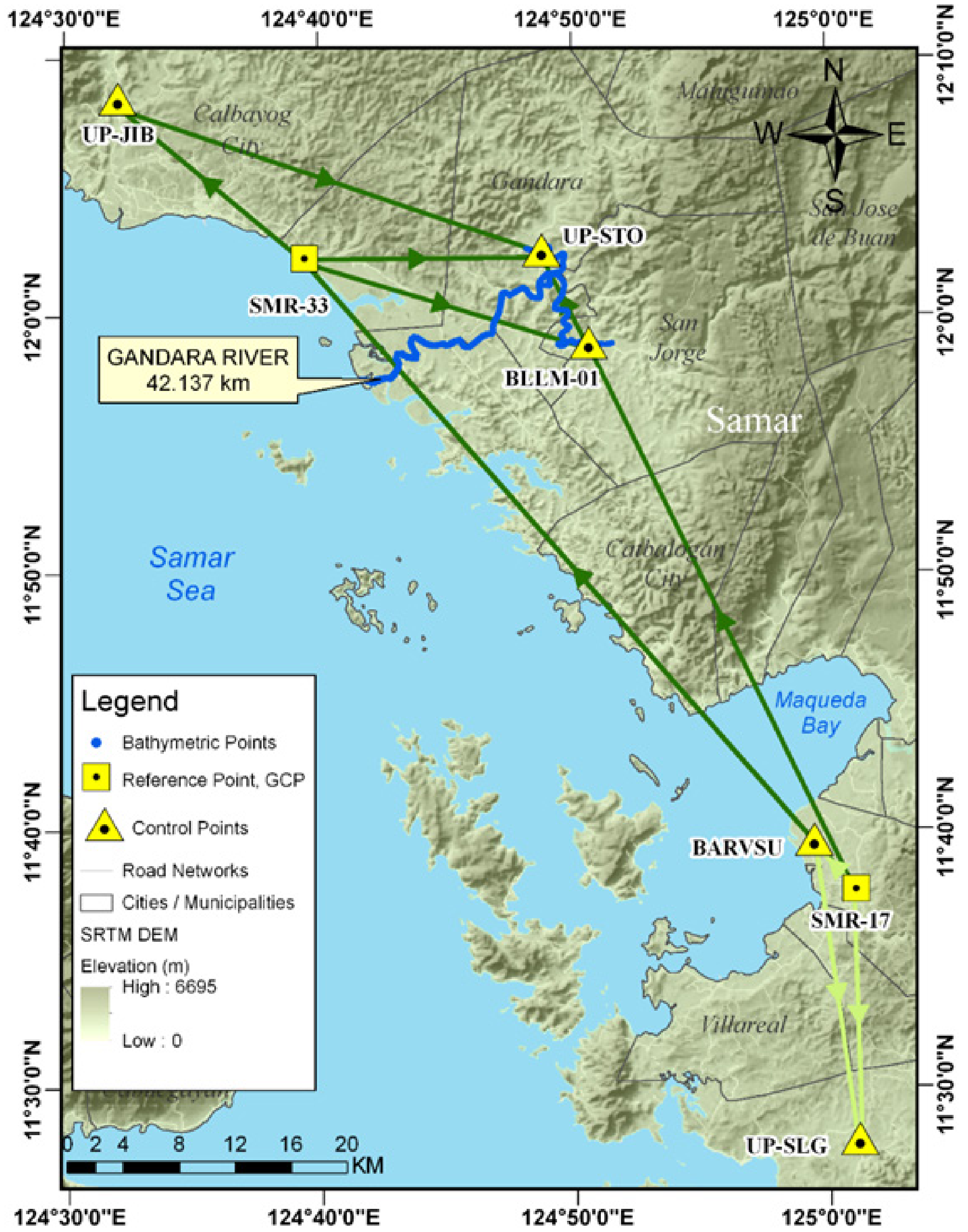



Figure 27. The GNSS Network established in the Gandara River Survey.

Table 19. References used and control points established in the Gandara River Survey (Source: NAMRIA, UP-TCAGP).

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (Meter) | BM Ortho in MSL (m) | Date Established |
| **Control Survey on December 5 and 6, 2015** | | | | | | |
| SMR-17 | 2nd Order | 11°37'39.96040" | 125°01'03.14252" | 72.836 | 10.153 | 2001 |
| SMR-33 | 2nd Order | 12°02'14.98810" | 124°39'27.22840" | 61.237 | - | 2007 |
| BLLM-01 | Used as Marker | - | - | - | - | 2013 |
| UP-JIB | UP established | - | - | - | - | Dec 5. 2015 |
| UP-STO | UP established | - | - | - | - | Dec 6, 2015 |
| **Control Survey on September 7, 2015** | | | | | | |
| SMR-17 | 2nd Order | 11°37'39.96040" | 125°01'03.14252" | 72.837 | 10.153 | 2001 |
| UP-SLG | UP established | 11°27'57.59924" | 125°01'08.87429" | 73.067 | 9.947 | Sep 7, 2015 |
| BARVSU | VSU established | 11°39'35.28570" | 124°59'25.89204" | 64.121 | 1.636 | 2012 |

Figure 28 to Figure 32 depict the setup of the GNSS on recovered reference points and established control points in the Gandara River.


Figure 28. Trimble® SPS 985 set-up at SMR-17 located at the Calbiga overpass Bridge approach in Brgy. Macaalan, Municipality of Calbiga, Samar


Figure 29. Trimble® SPS 852 set-up at SMR-33 located inside the compound of Sta. Margarita Elementary School in Brgy. Monbon, Municipality of Sta. Margarita, Samar.


Figure 30. Trimble SPS® 882 set-up at BLLM-01 located beside the basketball court in Bgry. Guindapunan, Municipality of San Jorge, Samar


Figure 31. Trimble SPS® 985 set-up at UP-JIB, Jibatang Bridge approach in Brgy. Oquendo, Calbayog City, Samar


Figure 32. Trimble SPS® SPS 855, at UP-STO, Sto, Niño Bridge approach in Brgy. Sto, Niño, Municipality of Gandara, Samar.

## 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. Table 20 presents the baseline processing results of control points in the Gandara River Basin, as generated by the TBC software.

Table 20. The Baseline processing report for the Gandara River GNSS static observation survey.

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) |
|---|---|---|---|---|---|---|
| BLLM-01 --- SMR-17 (B1) | 9-7-2015 | Fixed | 0.005 | 0.014 | 154°14'25" | 43513.866 |
| UP-STO --- BLLM-01 (B9) | 9-7-2015 | Fixed | 0.003 | 0.015 | 153°23'51" | 7419.683 |
| UP-JIB --- UP-STO (B7) | 9-7-2015 | Fixed | 0.003 | 0.015 | 109°54'58" | 32215.774 |
| SMR-33 --- SMR-17 (B3) | 9-7-2015 | Fixed | 0.076 | 0.023 | 139°05'18" | 59941.952 |
| SMR-33 --- BLLM-01 (B4) | 9-7-2015 | Fixed | 0.003 | 0.011 | 106°46'07" | 21220.616 |
| SMR-33 --- UP-JIB (B5) | 9-7-2015 | Fixed | 0.004 | 0.014 | 310°51'34" | 17574.856 |
| SMR-33 --- UP-STO (B8) | 9-7-2015 | Fixed | 0.004 | 0.014 | 88°16'51" | 16999.634 |

As shown in Table 20, a total of seven (7) baselines were processed with reference points SMR-17 and SMR-33 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

## 4.4 Network Adjustment

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

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

Where:

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

For complete details, see the Network Adjustment Report shown in Table 19 to Table 21.

The five (5) control points, SMR-17, SMR-33, BLLM-01, UP-JIB and UP-STO were occupied and observed simultaneously to form a GNSS loop. Elevation value of SMR-17 and coordinates of point SMR-33 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 21. Control Point Constraints

| Point ID | Type | East σ (Meter) | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| SMR-17 | Grid | Fixed | Fixed | | Fixed |
| SMR-33 | Local | Fixed | Fixed | | |
| Fixed = 0.000001(Meter) | | | | | |

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 22. All fixed control points have no values for grid and elevation errors.

Table 22. Adjusted grid coordinates for the control points used in the Gandara River floodplain survey.

| Point ID | Easting | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| SMR-17 | 719966.306 | ? | 1286174.169 | ? | 10.153 | ? | ENe |
| SMR-33 | 680439.007 | ? | 1331244.394 | ? | 1.419 | 0.055 | LL |
| BLLM-01 | 700794.759 | 0.008 | 1325244.195 | 0.007 | 5.476 | 0.051 | |
| UP-JIB | 667077.807 | 0.012 | 1342660.924 | 0.008 | 4.825 | 0.071 | |
| UP-STO | 697428.302 | 0.009 | 1331856.947 | 0.008 | 12.485 | 0.064 | |

The network is fixed at reference point SMR-17 with known elevation, and SMR-33 with known coordinates. As shown in Table 20, the standard errors (xe and ye) of BLLM-01 are 0.80 cm and 0.70 cm; UP-JIB with 1.20 cm and 0.80 cm; and UP-STO with 0.90 cm and 0.80 cm, respectively.

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

a. **SMR-17**
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. **SMR-33**
horizontal accuracy = Fixed
vertical accuracy = 5.5 < 10 cm

c. **BLLM-01**
horizontal accuracy = $\sqrt{((0.8)^2 + (0.7)^2}$
= $\sqrt{(0.64 + 0.49)}$
= 1.06 cm < 20 cm
vertical accuracy = 5.1 < 10 cm

d. **UP-JIB**
horizontal accuracy = $\sqrt{((1.2)^2 + (0.8)^2}$
= $\sqrt{(1.44 + 0.64)}$
= 1.44 cm < 20 cm
vertical accuracy = 7.1 < 10 cm

e. **UP-STO**
horizontal accuracy = $\sqrt{((0.9)^2 + (0.8)^2}$
= $\sqrt{(0.81 + 0.64)}$
= 1.20 cm < 20 cm
vertical accuracy = 6.4 < 10 cm

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

Table 23. Adjusted geodetic coordinates for control points used in the Gandara River Floodplain validation.

| Point ID | Latitude | Longitude | Ellipsodal Height (m) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| SMR-17 | N6°00’46.46952” | E125°17'47.59324" | 72.836 | ? | ENe |
| SMR-33 | N12°02'14.98810" | E124°39'27.22840" | 61.237 | 0.055 | LL |
| BLLM-01 | N11°58'55.52345" | E124°50'38.84504" | 65.971 | 0.051 | |
| UP-JIB | N12°08’29.05729” | E124°32’07.59990” | 63.991 | 0.071 | |
| UP-STO | N12°02'31.42690" | E124°48'49.02005" | 72.560 | 0.064 | |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 21. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Gandara River GNSS Static Survey are seen in Table 22.

Table 24. The reference and control points utilized in the Gandara River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | UTM ZONE 51 N | | |
|---|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (meter) | Northing (m) | Easting (m) | BM Ortho (m) |
| **Control Survey on December 5 and 6, 2015** | | | | | | | |
| SMR-17 | 2nd Order, GCP | 11d37'39.9604N" | 125d01'03.1425"E | 72.836 | 1286174.169 | 719966.306 | 10.153 |
| SMR-33 | 2nd Order, GCP | 12d02'14.9881"N | 124d39'27.2284"E | 61.237 | 1331244.394 | 680439.007 | 1.419 |
| BLLM-01 | Used as marker | 11d58'55.5235"N | 124d50'38.8450"E | 65.971 | 1325244.195 | 700794.759 | 5.476 |
| UP-JIB | UP Established | 12d08'29.0573"N | 124d32'07.5999"E | 63.991 | 1342660.924 | 667077.807 | 4.825 |
| UP-STO | UP Established | 12d02'31.4269"N | 124d48'49.0201"E | 72.56 | 1331856.947 | 697428.302 | 12.485 |
| **Control Survey on September 7, 2015** | | | | | | | |
| SMR-17 | 2nd Order, GCP | 11d37'39.9604N" | 125d01'03.1425"E | 72.836 | 1286174.169 | 719966.306 | 10.153 |
| UP-SLG | Up Established | 11d27'57.59924" | 125d01'08.87429" | 73.067 | 1268277.803 | 720266.264 | 9.947 |
| BARVSU | VSU Established | 11d39'35.28570" | 124d59'25.89204" | 64.121 | 1289697.625 | 716995.082 | 1.636 |

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

Cross-section and as-built survey were conducted on December 8 and 9, 2015 along the downstream side of the Lapaz-Bulao Bridge located in Brgy. Guindapunan, Municipality of San Jorge using total station open traverse method as shown in Figure 32, and of the Sto. Niño Bridge located in Brgy. Sto. Niño, Municipality of Gandara using Trimble® SPS 985 GNSS PPK survey technique as shown in Figure 33, respectively.

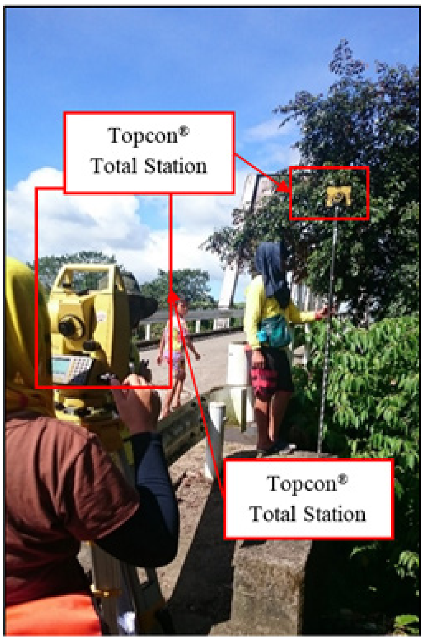



Figure 33. Cross-section and bridge as-built survey at the downstream side of Lapaz-Bulao Bridge, Brgy. Guindapunan, Municipality of San Jorge, Samar

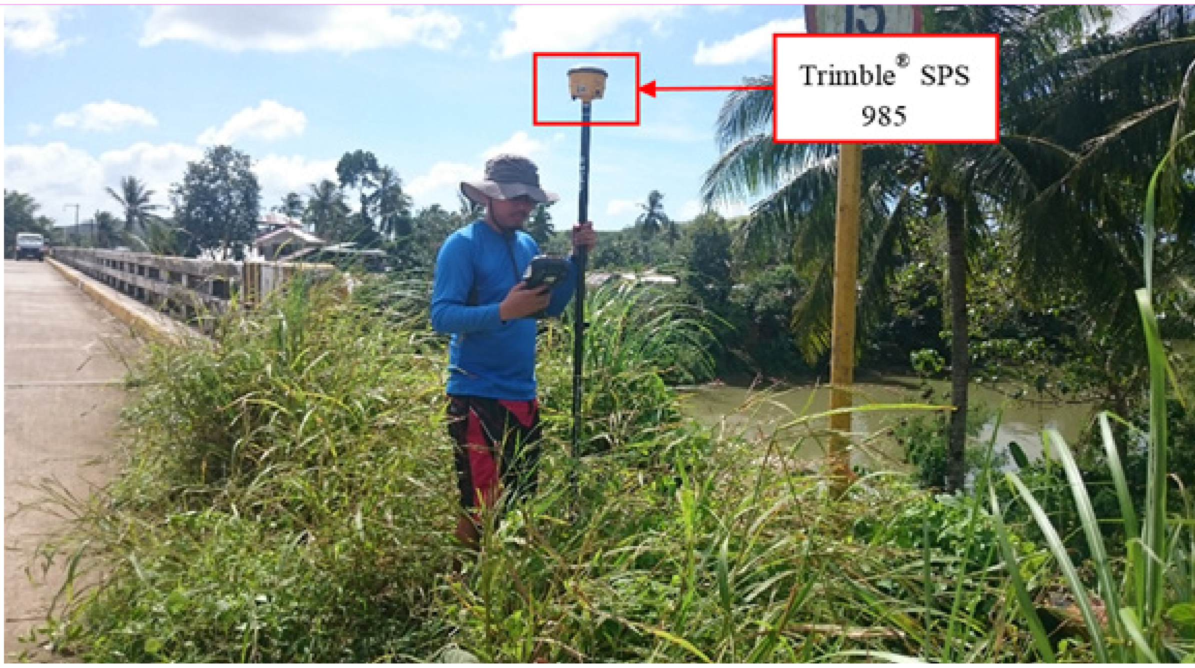



Figure 34. Cross-section and bridge as-built survey at the downstream side of Sto. Niño Bridge, Brgy. Sto. Niño, Municipality of Gandara, Samar.

A total of eighty-three (83) points with corresponding length of 218.89 meters were gathered from the survey of Lapaz-Bulao, and seventy-nine (79) points with corresponding length of 259.78 meters were gathered from the survey of Sto. Niño Bridge using UP-STO as its GNSS base station. The cross-section diagrams, location maps and bridge data forms for the two bridges are show in Figure 34 to Figure 39, respectively.

Water surface elevation in MSL of Gandara River at Sto. Niño bridge was determined using Trimble® SPS 882 in PPK mode technique on December 9, 2015 at 3:09 PM with a value of -0.334 meters in MSL. This value will be translated into a marking on the bridge's pier by the VSU to serve as their reference for flow data gathering and depth gauge deployment.

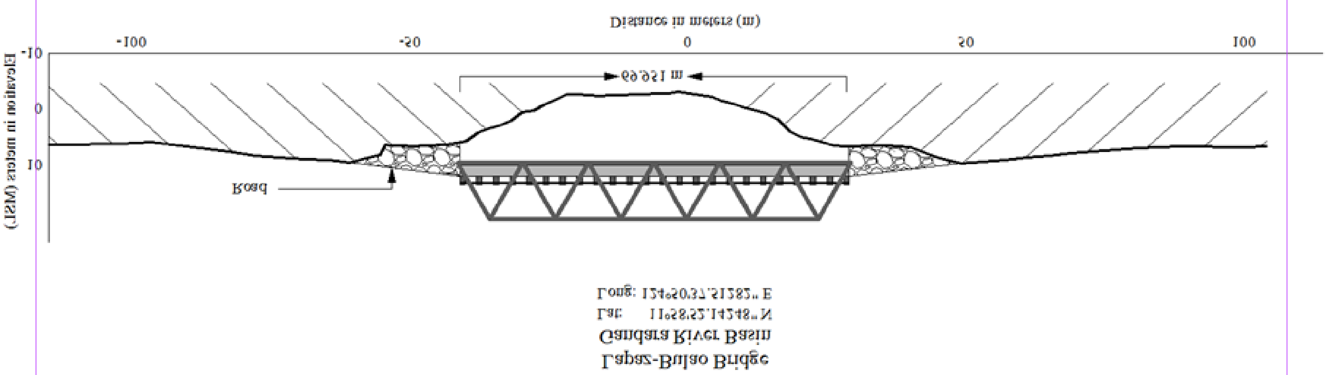



Figure 35. The Gandara cross-section survey in Lapaz-Bulao Bridge drawn to scale.

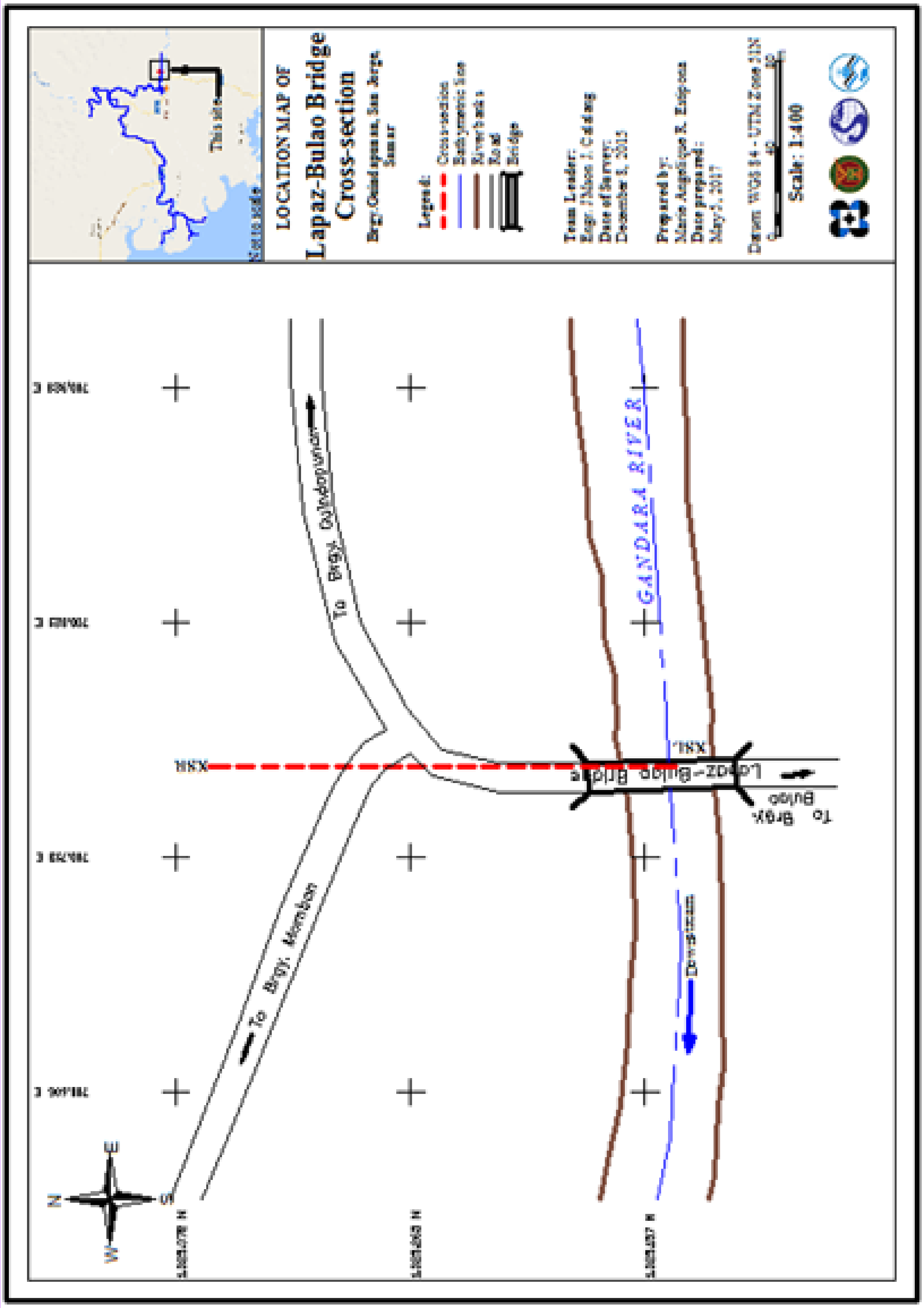
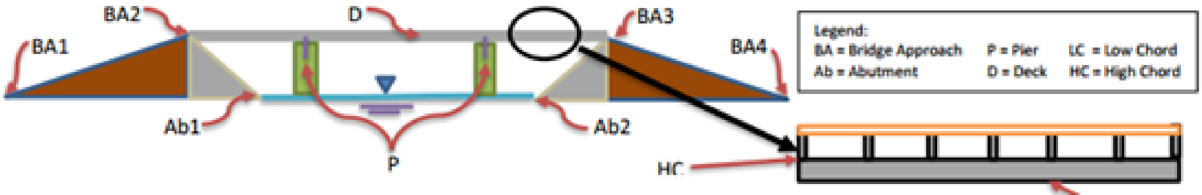



Figure 36. Location map of the Gandara cross-section survey in Lapaz-Bulao Bridge.

**Bridge Data Form**

**Bridge Name: Lapaz-Bulao Bridge** | **Date: December 8, 2015**
**River Name: Gandara River** | **Time: 10:59 AM**
**Location: Brgy. Guindapunan, Municipality of San Jorge, Samar**
**Survey Team: JMson Calalang, Marie Angelique Estipona, Caren Joy Ordoña**
**Flow condition:** low ✓ normal high **Weather Condition:** ✓ fair rainy
**Latitude: 11°58'52.14248"N** **Longitude: 124°50'37.51282"E**




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

**Elevation: 11.066 m.** **Width: 8 m.** **Span (BA3-BA2): 69.9507 m.**

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | | | |

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

| | Station(Distance from BA1) | Elevation | | Station(Distance from BA1) | Elevation |
|---|---|---|---|---|---|
| BA1 | 0 | 9.53 | BA3 | 88.90572 | 12.076 |
| BA2 | 18.95502 | 11.066 | BA4 | 105.0597 | 8.434 |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | 7.310867 | 6.519 |
| Ab2 | 101.757 | 6.415 |

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

Shape: Cylindrical Number of Piers: 0 Height of column footing: N/A

| | Station (Distance from BA1) | Elevation | Pier Width |
|---|---|---|---|
| Pier 1 | | | |
| Pier 2 | | | |
| Pier 3 | | | |
| Pier 4 | | | |

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

Figure 37. Bridge As-built form of Lapaz-Bulao Bridge.

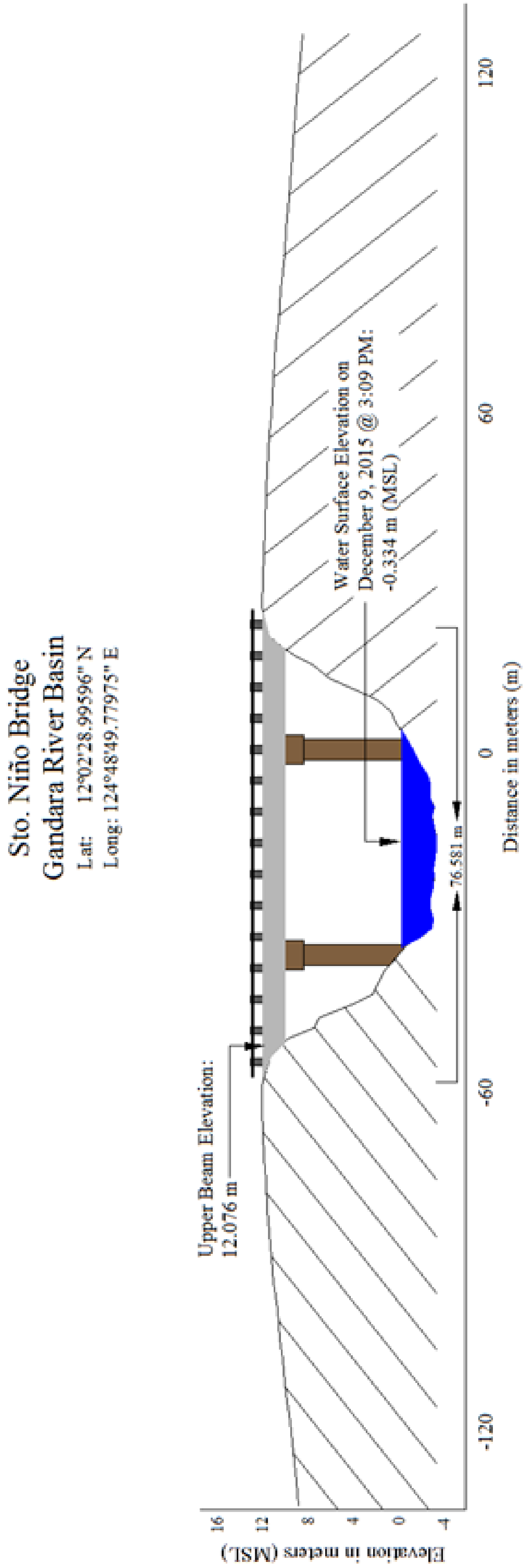



Figure 38. The Gandara cross-section survey in Sto.Niño Bridge drawn to scale

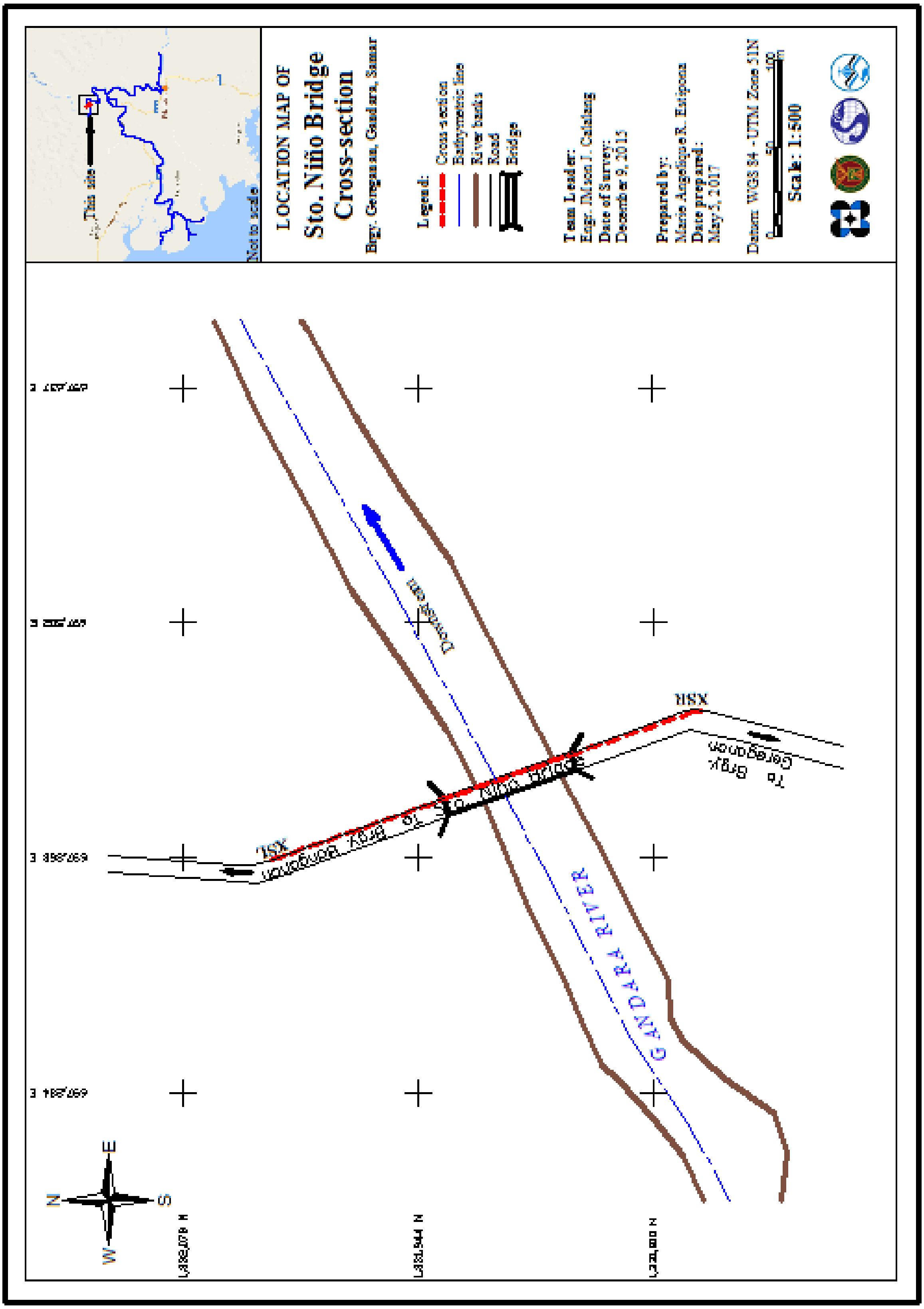
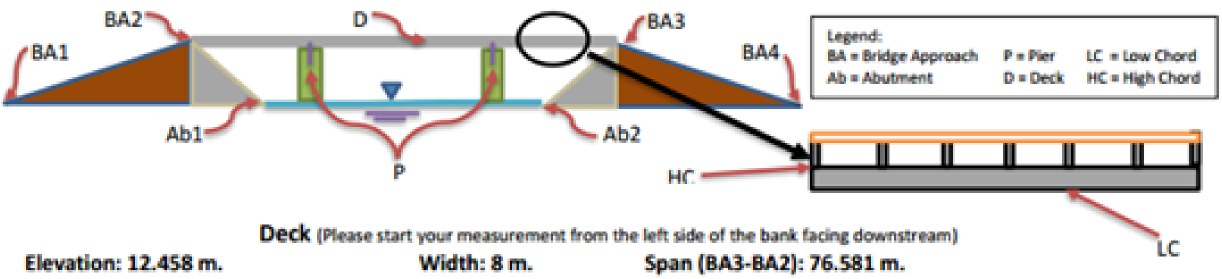



Figure 39. Location map of the Gandara cross-section survey inSto. Niño Bridge.

**Bridge Data Form**

| | |
|---|---|
| **Bridge Name: Sto. Niño Bridge** | **Date: December 9, 2016** |
| **River Name: Gandara River** | **Time: 3:09 PM** |
| **Location: Brgy. Gereganan, Municipality of Gandara, Samar** | |
| **Survey Team: JMson Calalang, Marie Angelique Estipona, Caren Joy Ordoña** | |
| **Flow condition:** low ✓ normal high | **Weather Condition:** ✓ fair rainy |
| **Latitude: 12°02'28.99596"N** | **Longitude: 124°48'49.77975"E** |




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

**Elevation: 12.458 m.** **Width: 8 m.** **Span (BA3-BA2): 76.581 m.**

| | Station | High Chord Elevation | Low Chord Elevation |
|---|---|---|---|
| 1 | | | |

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

| | Station(Distance from BA1) | Elevation | | Station(Distance from BA1) | Elevation |
|---|---|---|---|---|---|
| BA1 | 0 | 8.968 | BA3 | 150.543 | 12.076 |
| BA2 | 73.962 | 12.458 | BA4 | 255.530 | 8.434 |

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

| | Station (Distance from BA1) | Elevation |
|---|---|---|
| Ab1 | 87.809 | 1.780 |
| Ab2 | 135.927 | 0.607 |

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

Shape: Cylindrical Number of Piers: 0 Height of column footing: N/A

| | Station (Distance from BA1) | Elevation | Pier Width |
|---|---|---|---|
| Pier 1 | 94.137 | 12.461 | |
| Pier 2 | 129.956 | 12.453 | |
| Pier 3 | | | |
| Pier 4 | | | |

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

Figure 40. Bridge As-built form of Sto.Niño Bridge.

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 6 and 12, 2015 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 40. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 2.21 m was 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 SMR-33 and UP-JIB occupied as the GNSS base stations all throughout the conduct of the survey.


Figure 41. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The validation points acquisition survey for the Gandara River Basin traversed Calbayog City and the following municipalities of Samar: Lope de Vega, Santa Margarita, Gandara and San Jorge. The route of the survey aims to perpendicularly traverse LiDAR flight strips for the basin. A total of 17,138 points with an approximate length of 101.96 km was acquired for the validation points acquisition survey as shown in the map in Figure 41.


Figure 42. The extent of the LiDAR ground validation survey (in red) for Gandara River Basin.

## 4.7 River Bathymetric Survey

Bathymetric survey of Gandara River was conducted on December 7 to 9, 2015 using OHMEXTM and a Trimble® SPS 882 GNSS rover receiver attached to a pole on the side of the boat as shown in Figure 42.

The survey began from the upstream part of the river in Brgy. Sto. Niño, Municipality of Gandara with coordinates 12°02’35.2746”N 124°48’14.2664”E, and Brgy. Buenavista, Municipality of San Jorge with coordinates 11°58’53.5060”N 124°51’35.0441”E; and ended in Brgy. Lungib with coordinates 11°57’30.4400”N 124°41’41.3240”E also in Municipality of Gandara. The control point UP-STO was used as GNSS base for the whole bathymetric survey.


Figure 43. Set up of the bathymetric survey in Gandara River.

A CAD drawing was also produced to illustrate the riverbed profile of Gandara River. As shown in Figure 43 to Figure 48, the highest and lowest elevation has a 9.5-meter difference. The highest elevation observed was -0.7 m above MSL located in Brgy. Catorse de Agosto, Municipality of Gandara while the lowest was -16.584 m below MSL also located in the same barangay. The bathymetric survey gathered a total of 53,056 points covering 10.399 km of the river traversing the Municipalities of Gandara, San Jorge and Pagsanghan, in the province of Samar.


Figure 44. The extent of the Gandara River Bathymetry Survey and the LiDAR bathymetric data validation points.

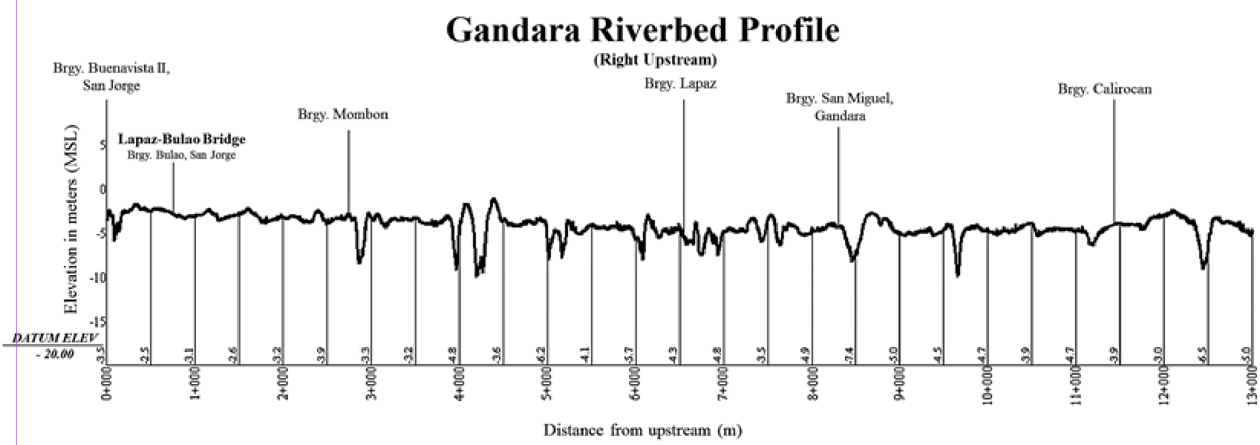



Figure 45. The Gandara River Bed Profile from the right tributary (1st part)

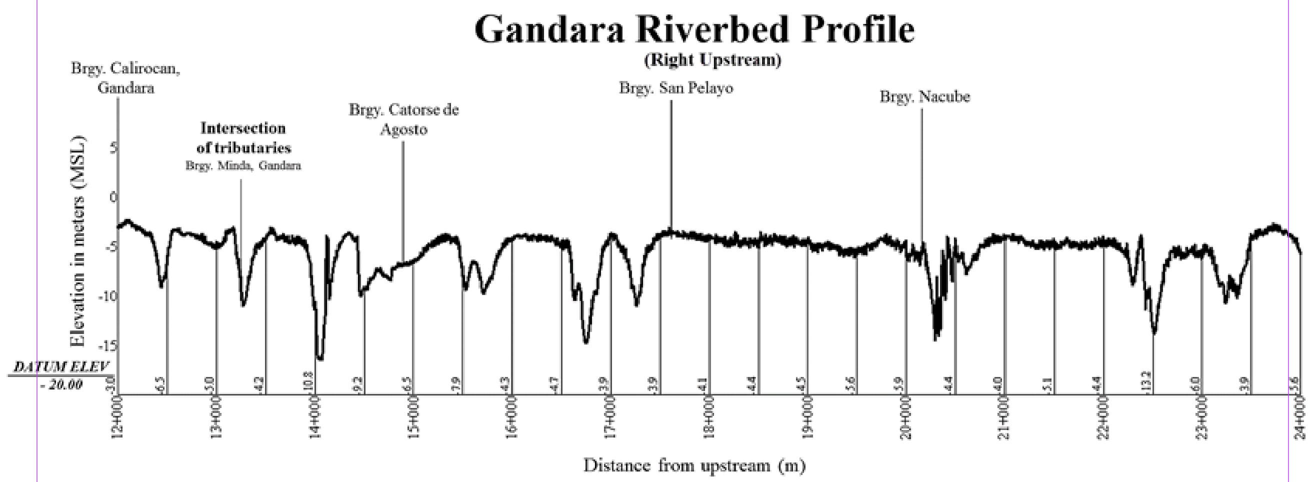



Figure 46. The Gandara River Bed Profile from the right tributary (2nd part)

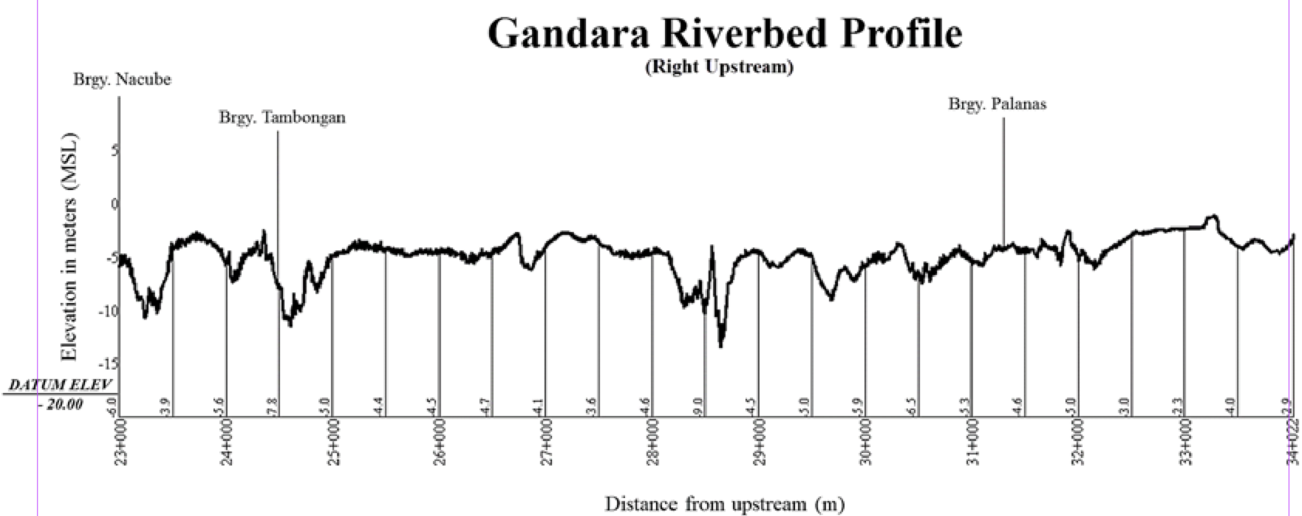



Figure 47. The Gandara River Bed Profile from the right tributary (3rd part)

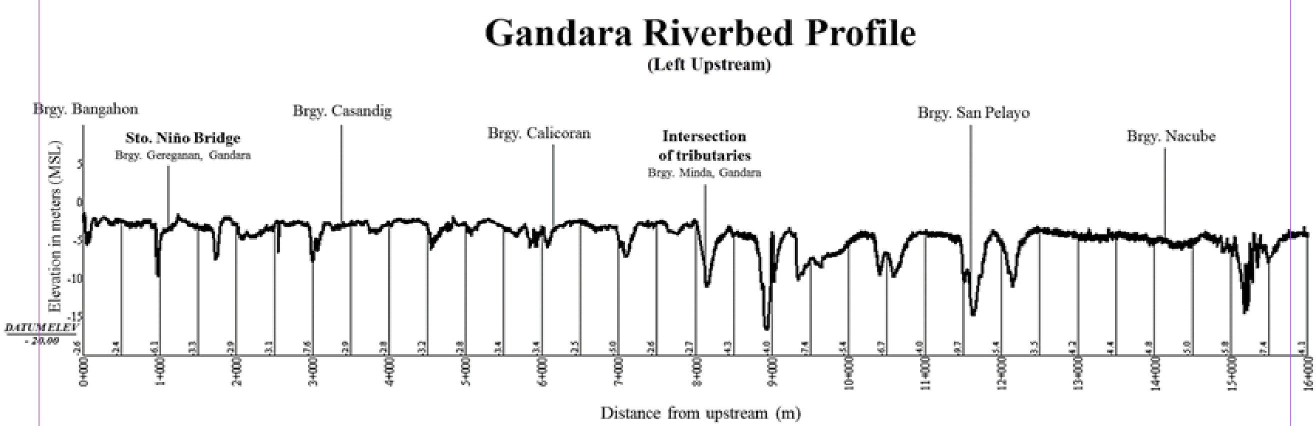



Figure 48. The Gandara River Bed Profile from the left tributary (1st part)

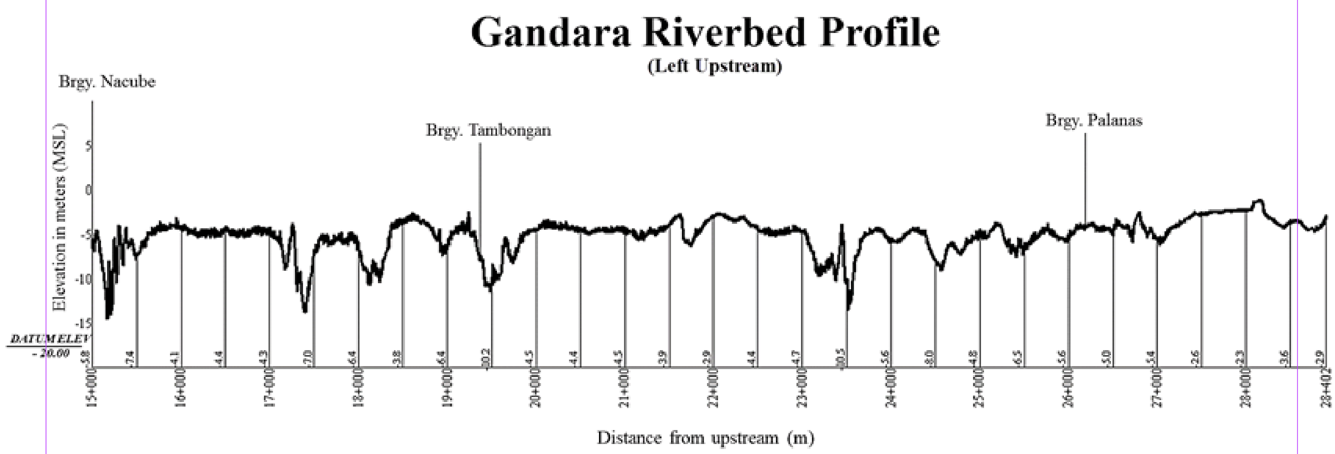



Figure 49. The Gandara River Bed Profile from the left tributary (2nd part)

# 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*

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

## 5.1 Data used in Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Gandara River Basin were monitored, collected, and analyzed.

### 5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute as illustrated in Figure 49. The total rain collected from the Gandara Bridge rain gauge is 156 mm. It peaked to 4.8 mm December 7, 2014 at 12:30 am. The lag time between the peak rainfall and discharge is fourteen hours and fifty minutes (4 hrs. 50 mins).

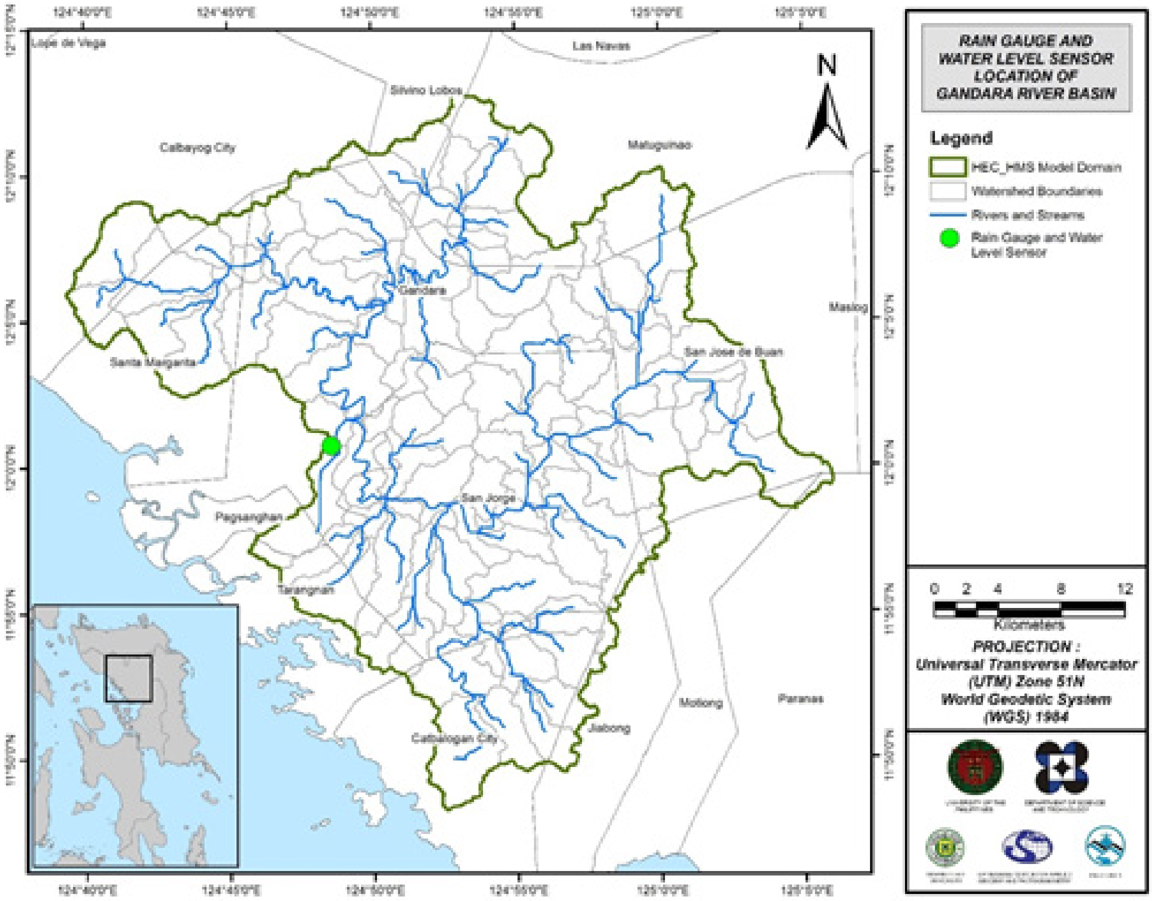



Figure 50. Location Map of the Gandara HEC-HMS model used for calibration.

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sto. Nino Bridge, Gandara, Samar (12°0'40.155"N, 124°48'33.702"E). It gives the relationship between the observed water levels from the Gandara Bridge Automated Water Level Sensor (AWLS) and the combined discharge from baseflow and bankfull.

For Gandara Bridge, the rating curve is expressed as Q=119.48e0.2625h as shown in Figure 51.

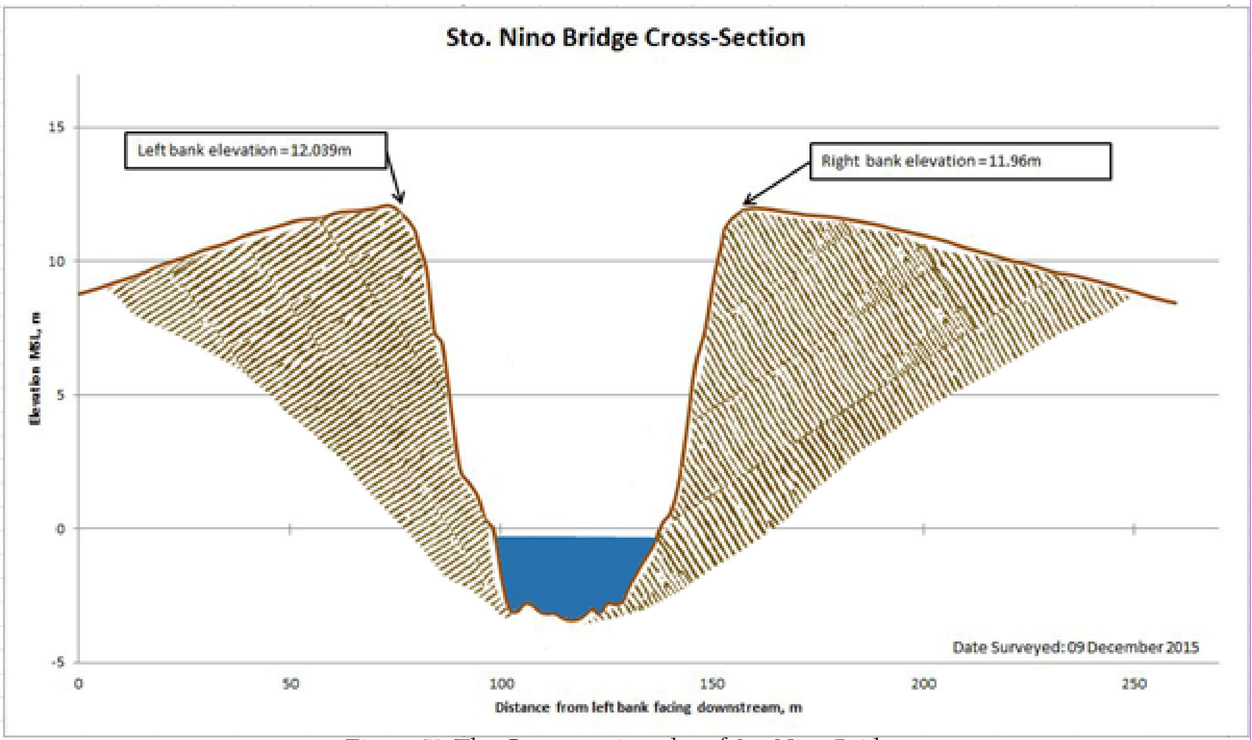



Figure 51. The Cross-section plot of Sto.Niño Bridge

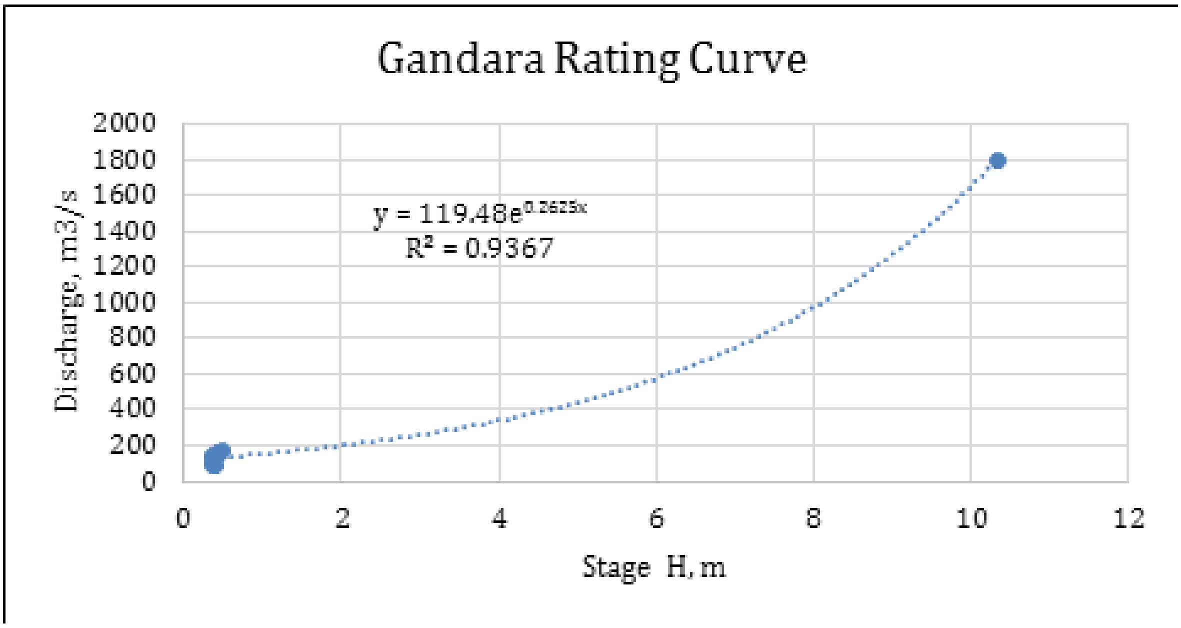



Figure 52. The rating curve at Manicahan Spillway, Salaan, Zamboanga City.

This rating curve equation was used to compute the river outflow at Gandara Bridge for the calibration of the HEC-HMS model shown in Figure 52. Total rain from Gandara Bridge rain gauge is 156 mm. It peaked to 4.8 mm December 7, 2014 at 12:30 am. The lag time between the peak rainfall and discharge is fourteen hours and fifty minutes.

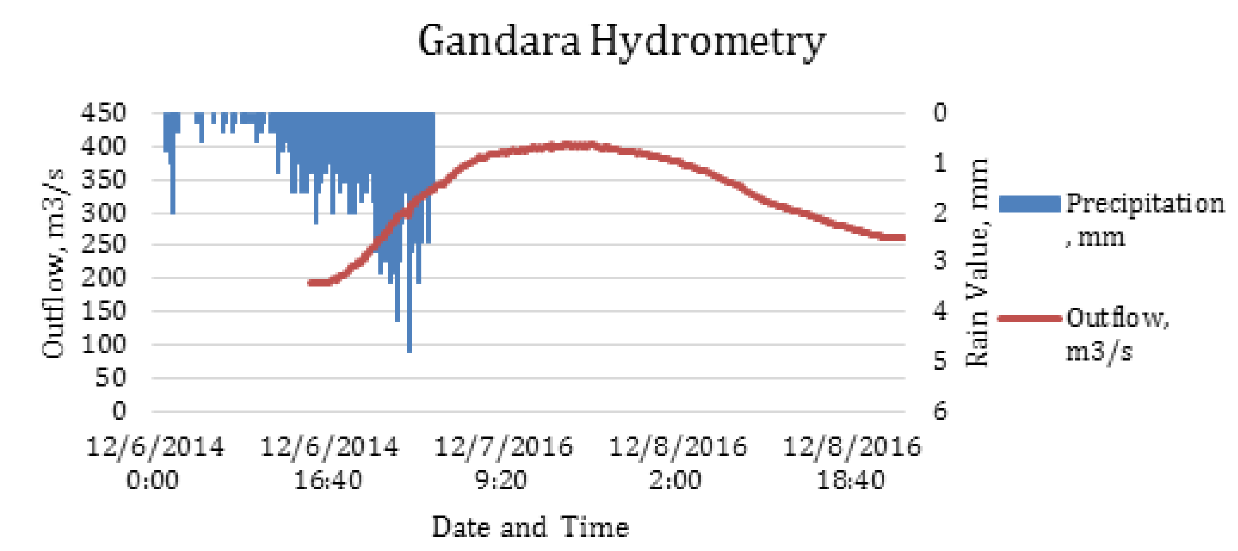



Figure 53. Rainfall at Gandara ARG and outflow data which was used for modeling.

## 5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City Rain Gauge (Table 25). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 54). This station was selected based on its proximity to the Gandara watershed. The extreme values for this watershed were computed based on a 55-year record.

Table 25. RIDF values for the Gandara River Basin based on average RIDF data of Catbalogan station, as computed by PAGASA

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

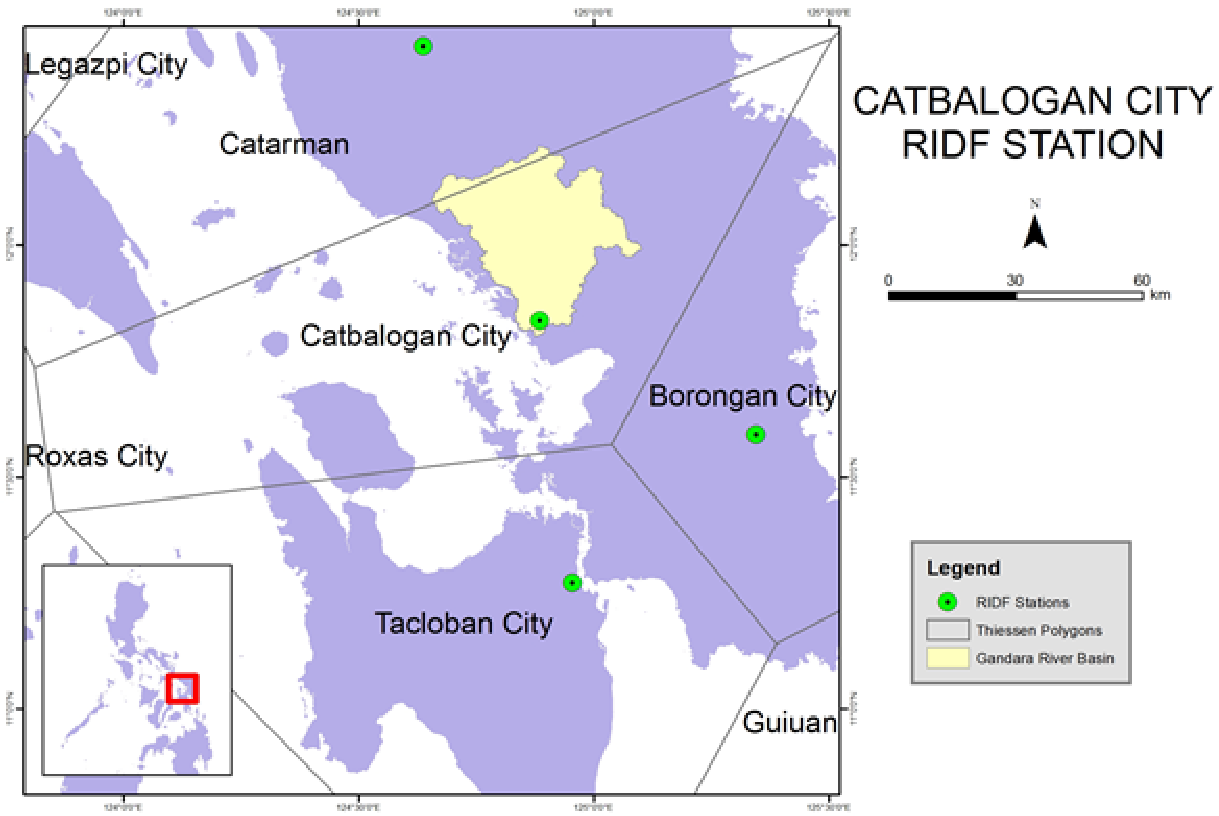



Figure 54. The location of the Catbalogan RIDF station relative to the Gandara River Basin.

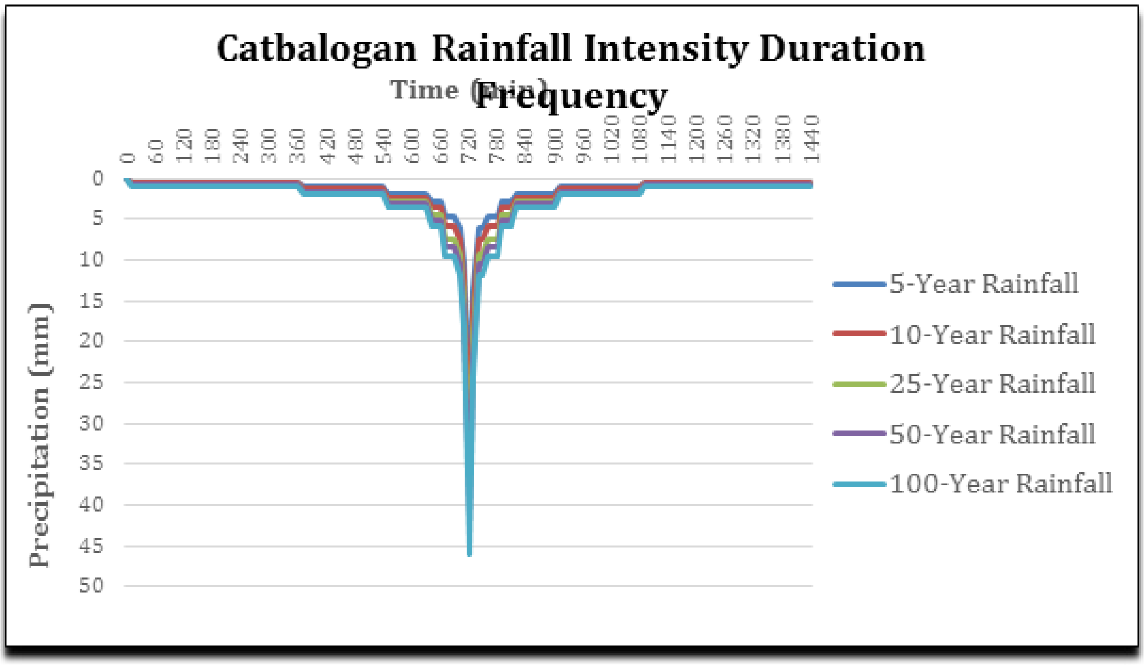



Figure 55. The synthetic storm generated for a 24-hour period rainfall for various return periods.

## 5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Gandara River Basin are shown in Figure 55 and Figure 56 respectively.

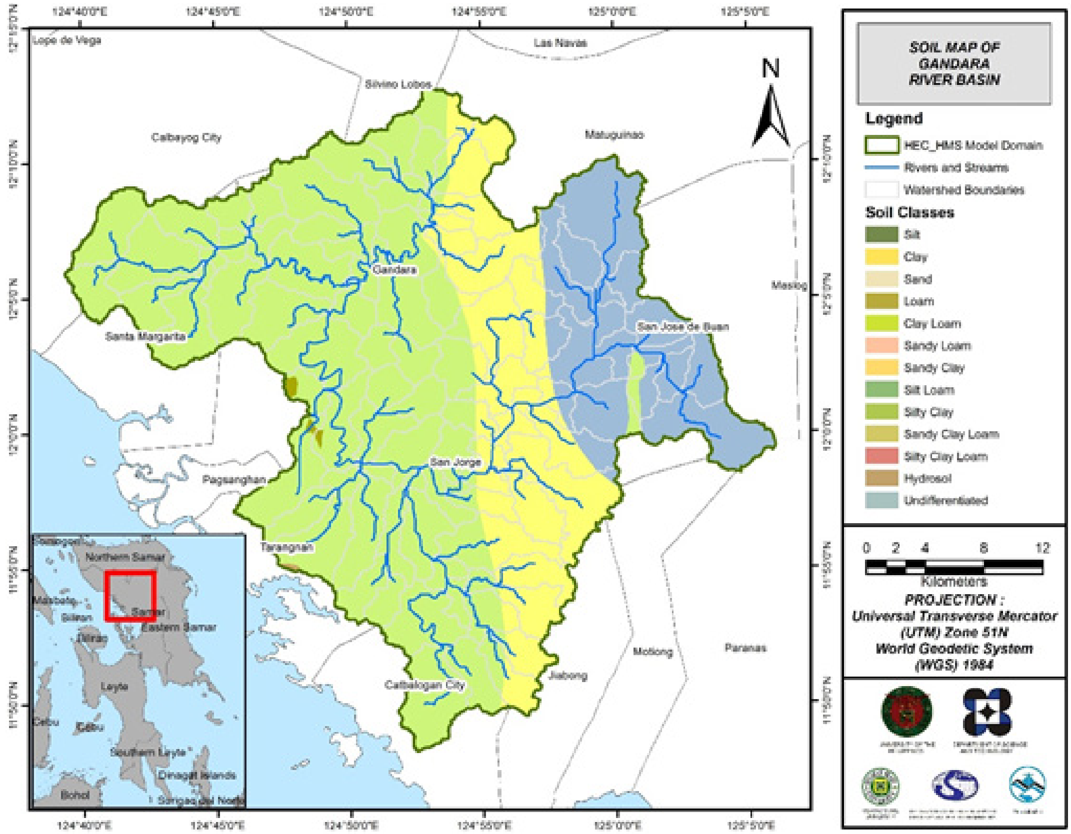



Figure 56. Soil Map of Gandara River Basin.

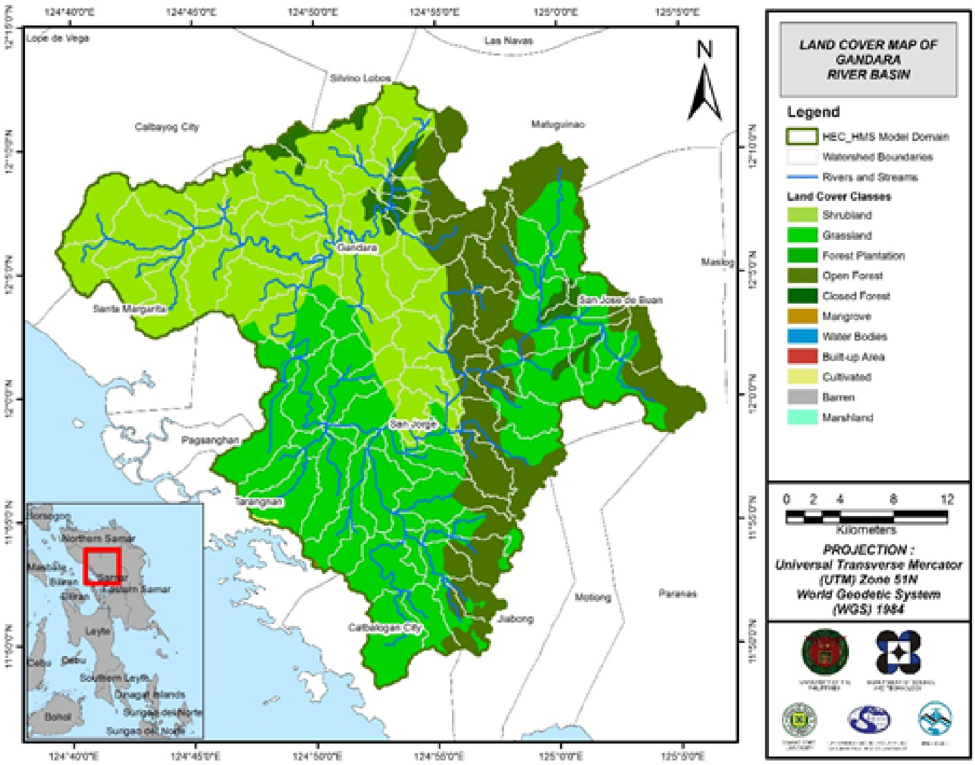



Figure 57. Land Cover Map of Gandara River Basin.

For Catubig, the soil class identified were clay, clay loam, and undifferentiated. The land cover types identified were shrubland, open forest, closed forest,¬ and cultivated.

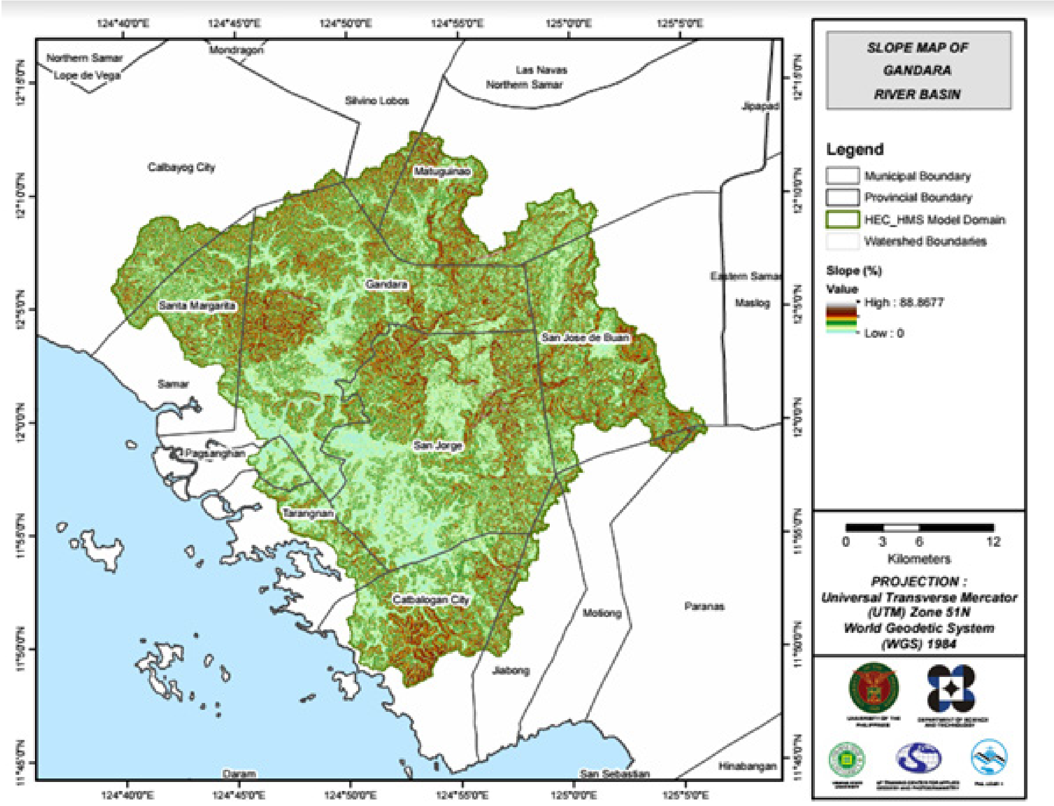



Figure 58. Slope Map of the Gandara River Basin.

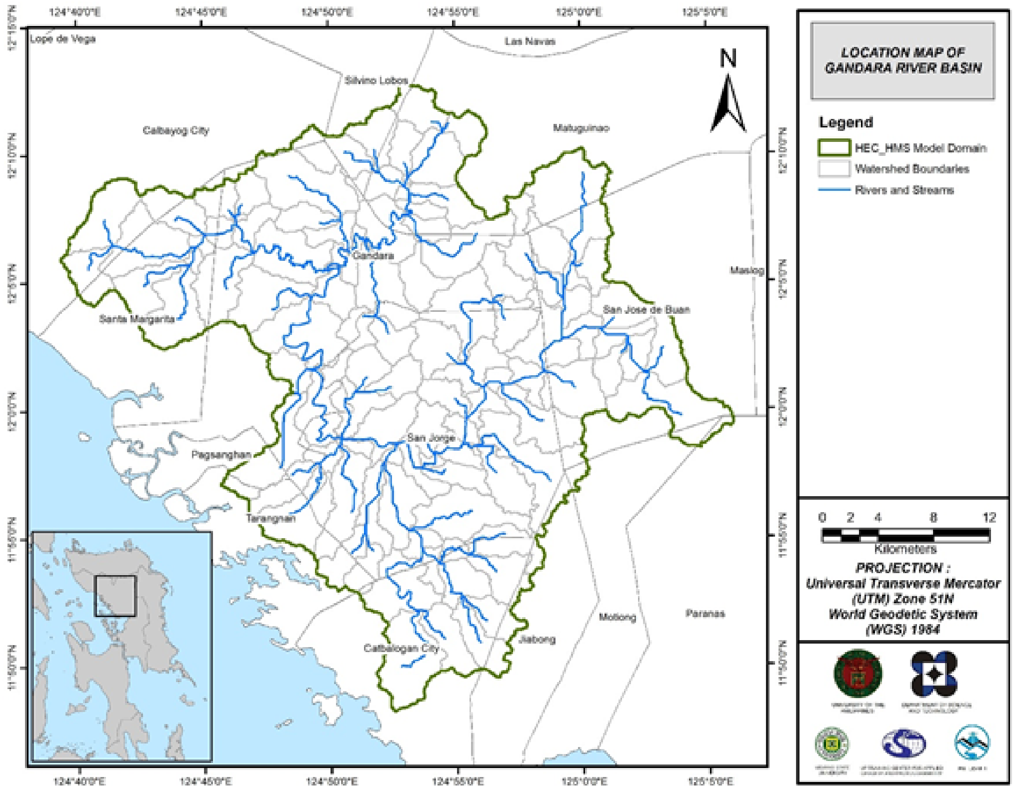



Figure 59. Stream Delineation Map of Gandara River Basin.

Using the SAR-based DEM, the Gandara river basin was delineated and further subdivided into subbasins. The model consists of 107 sub basins, 53 reaches, and 52 junctions as shown in Figure 59. The main outlet is at Gandara Bridge.

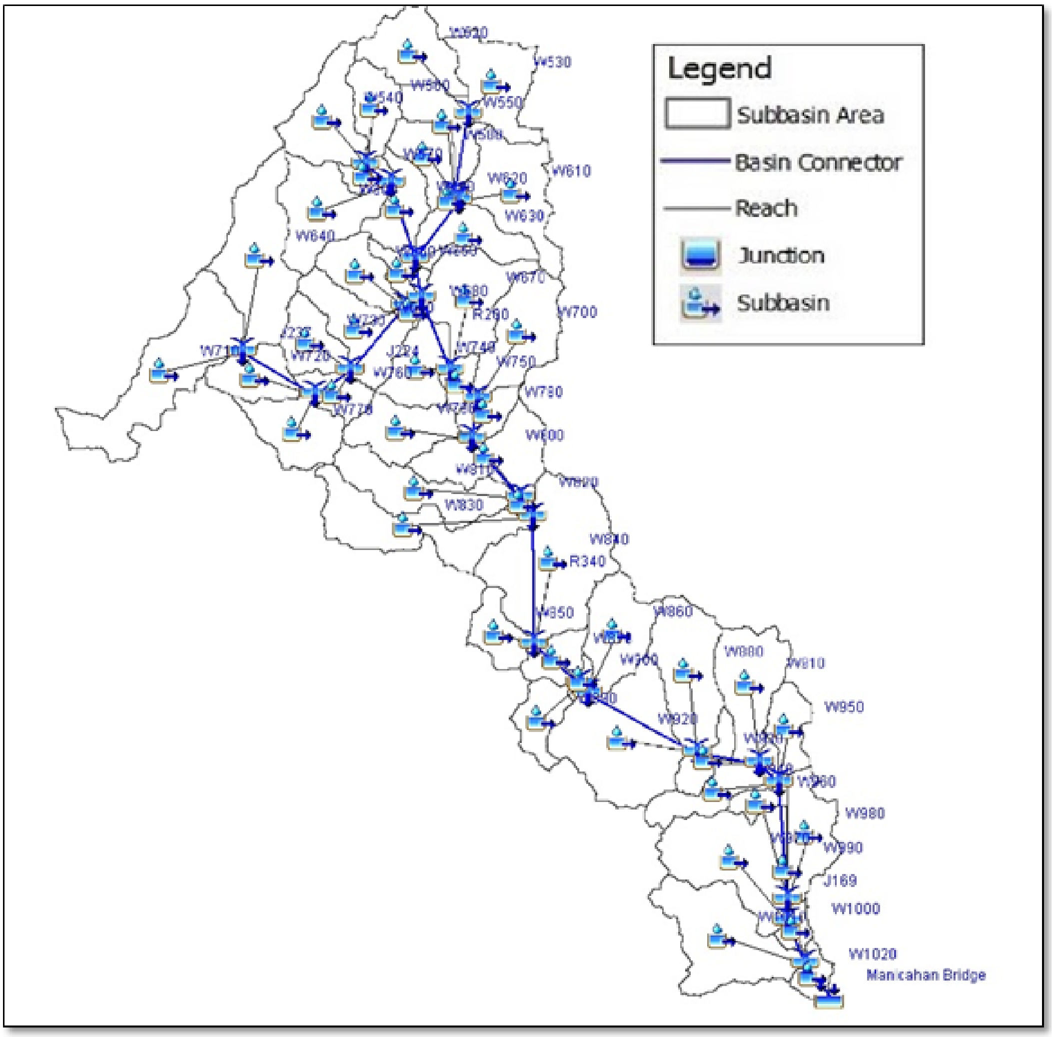



Figure 60. Gandara river basin model generated in HEC-HMS.

## 5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 60).

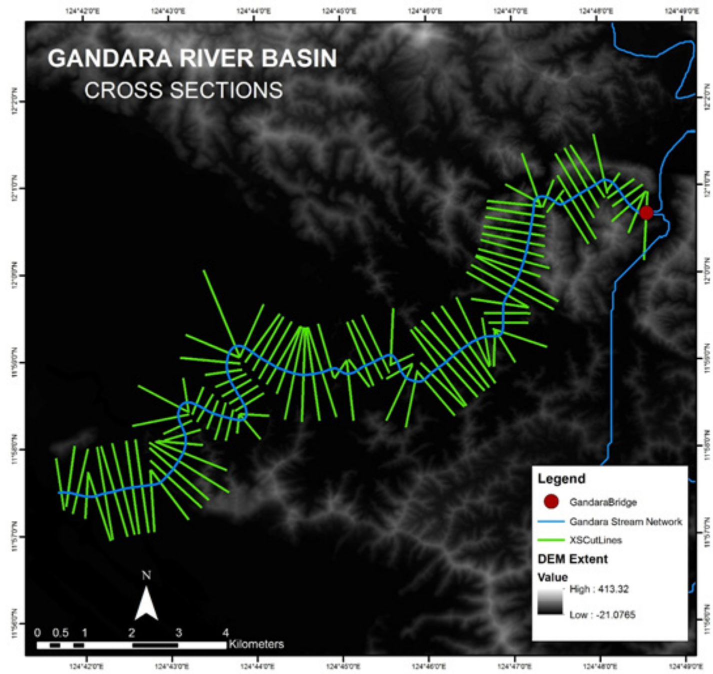



Figure 61. River cross-section of the Gandara River through the ArcMap HEC GeoRas tool.

## 5.5 Flo 2D Model

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

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

Figure 62. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 42.98120 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 77633184.00 m2.

There is a total of 32939065.69 m3 of water entering the model. Of this amount, 32939065.69 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. 8022761.00 m3 of this water is lost to infiltration and interception, while 14108712.95 m3 is stored by the flood plain. The rest, amounting up to 10807569.59 m3, is outflow.

## 5.6 Results of HMS Calibration

After calibrating the Gandara HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

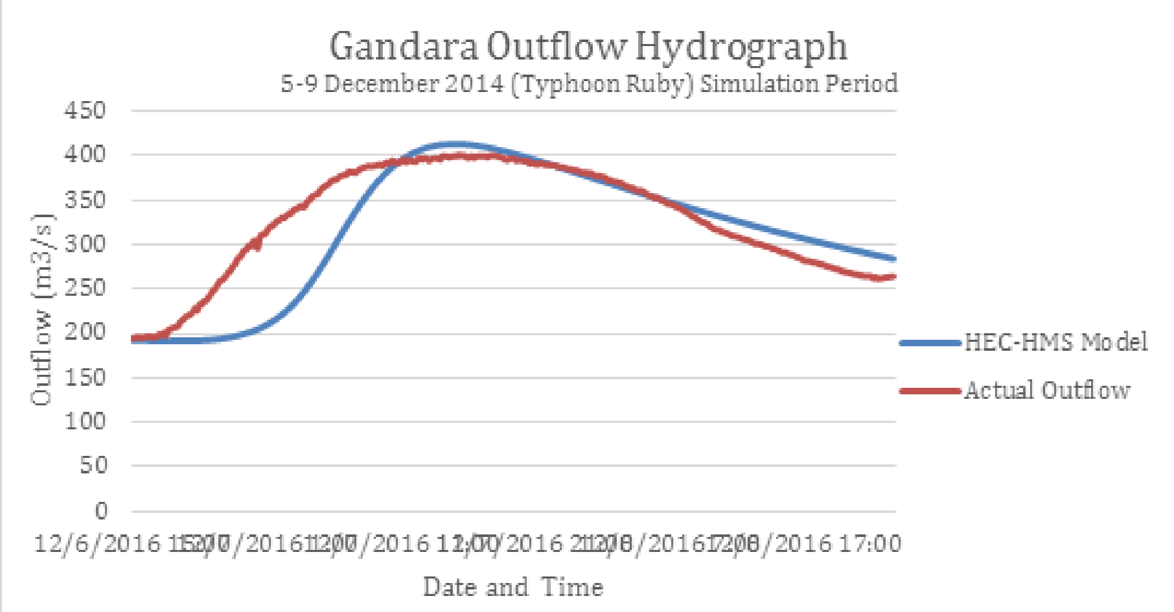



Figure 63. Outflow Hydrograph of Gandara Bridge produced by the HEC-HMS model compared with observed outflow.

Table 24 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 26. Range of calibrated values for the Gandara River Basin.

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve number | Initial Abstraction (mm) | 10 - 60 |
| | | | Curve Number | 33 - 59 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.1 - 33 |
| | | | Storage Coefficient (hr) | 20 - 118 |
| | Baseflow | Recession | Recession Constant | 0.95 |
| | | | Ratio to Peak | 0.15 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.035 |

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 10 mm to 60 mm means that there is a high 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 33 to 59 for curve number is lower than the advisable for Philippine watersheds depending on the soil and land cover of the area.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.1 hours to 118 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.95 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.15 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.035 is slightly lower compared to the common roughness of watersheds.

Table 27. Summary of the Efficiency Test of the Gandara HMS Model

| Accuracy measure | Value |
|---|---|
| RMSE | 28.4 |
| r2 | 0.94 |
| NSE | 0.55 |
| PBIAS | 3.69 |
| RSR | 0.67 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It computed as 28.4 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.94.

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 0.55.
A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 3.69.

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 0.67.

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

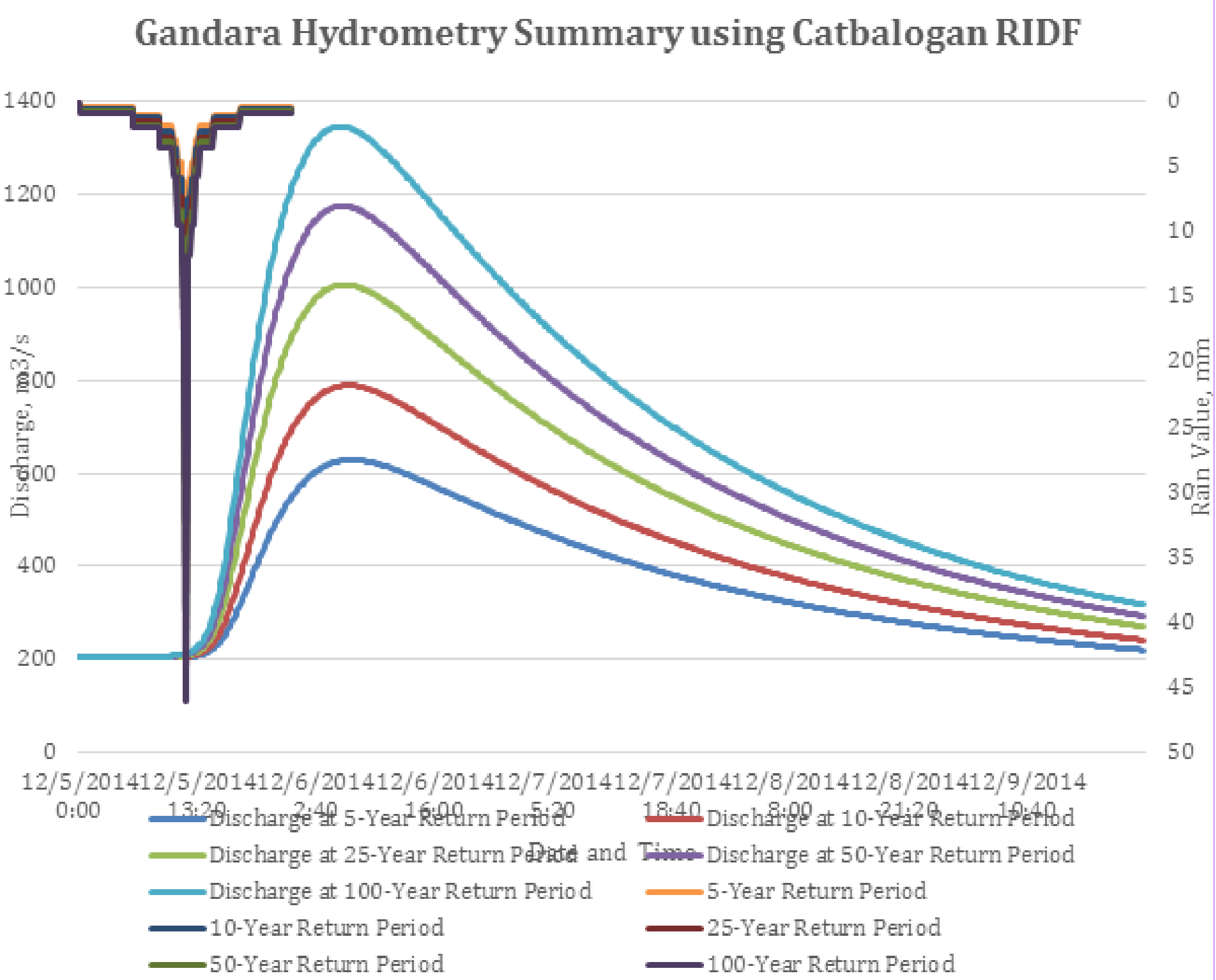



Figure 64. The Outflow hydrograph at the Gandara Station, generated using the Catbalogan RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Gandara discharge using the Catbalogan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 26.

Table 28. The peak values of the Gandara HEC-HMS Model outflow using the Catbalogan City RIDF.

| RIDF Period | Total Precipitation (mm) | Peak rainfall (mm) | Peak outflow (m 3/s) | Time to Peak |
|---|---|---|---|---|
| 5-Year | 225.3 | 27.2 | 629.2 | 18 hours, 40 minutes |
| 10-Year | 272.1 | 31.8 | 788.8 | 18 hours, 20 minutes |
| 25-Year | 331.3 | 37.5 | 1005.3 | 17 hours, 50 minutes |
| 50-Year | 375.2 | 41.8 | 1173.8 | 17 hours, 30 minutes |
| 100-Year | 418.8 | 46 | 1344.5 | 17 hours, 20 minutes |

## 5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 64 shows a generated sample map of the Gandara River using the calibrated HMS base flow.


Figure 65. Sample output map of the Gandara RAS Model.

## 5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 5-, 25-, and 100-year rain return scenarios of the Gandara floodplain. The floodplain, with an area of 325.45 sq. km., covers six (6) municipalities namely Catbalogan City, Gandara, Pagsanghan, San Jorge, Santa Margarita, and Tarangnan. Table 26 shows the percentage of area affected by flooding in Zamboanga City.

Table 29. City affected in Gandara floodplain.

| City / Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|
| Catbalogan City | 177.02 | 18.13 | 10.24% |
| Gandara | 296.92 | 96.08 | 32.36% |
| Pagsanghan | 29.46 | 29.43 | 99.90% |
| San Jorge | 280.03 | 117.25 | 41.87% |
| Santa Margarita | 130.73 | 6.96 | 5.33% |
| Tarangnan | 89.57 | 53.37 | 59.58% |

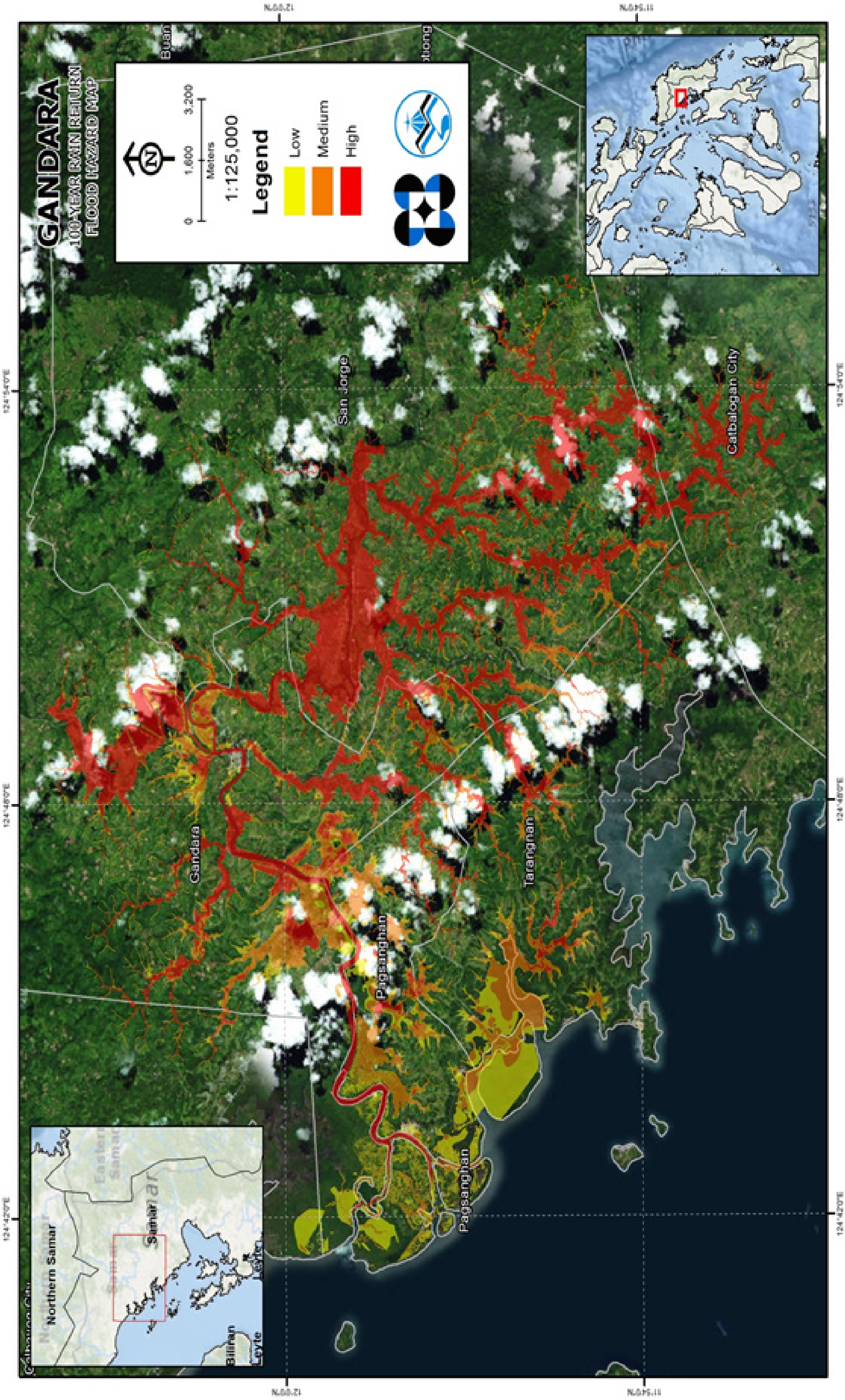



Figure 66. A 100-year Flood Hazard Map for Gandara Floodplain overlaid on Google Earth imagery.

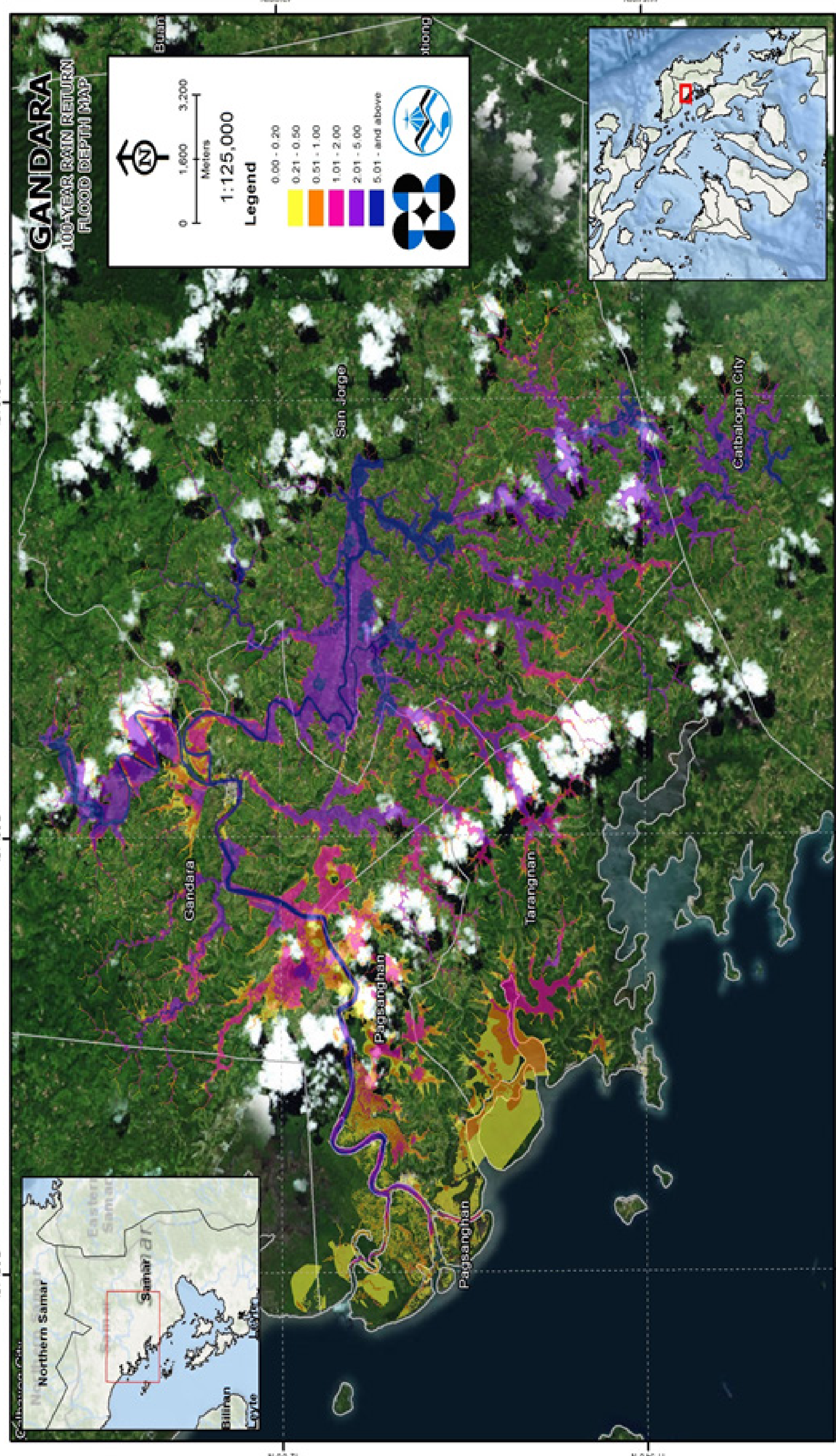



Figure 67. A 100-year Flow Depth Map for Gandara Floodplain overlaid on Google Earth imagery.

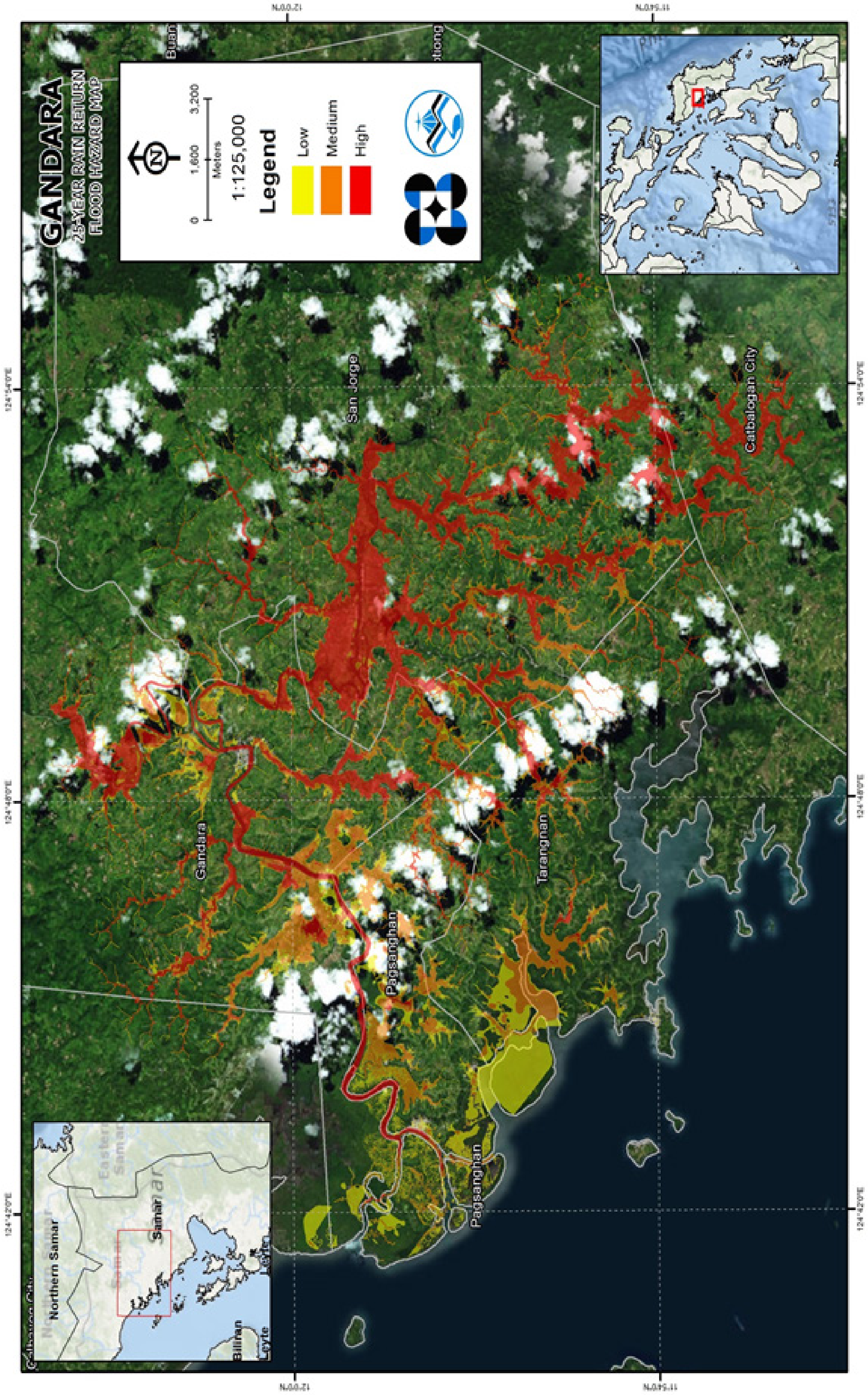



Figure 68. A 25-year Flood Hazard Map for Gandara Floodplain overlaid on Google Earth imagery.

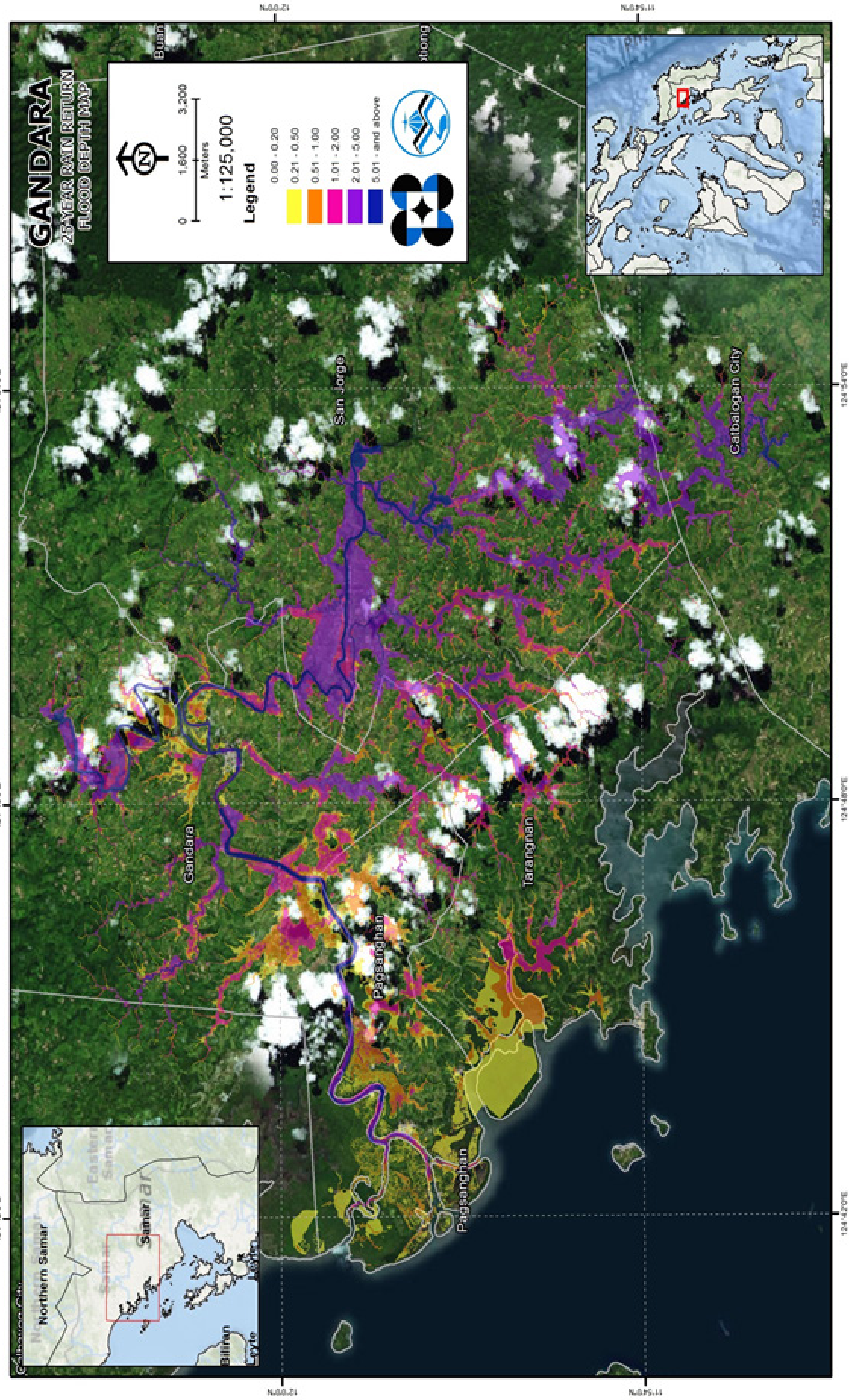



Figure 69. A 25-year Flow Depth Map for Gandara Floodplain overlaid on Google Earth imagery.

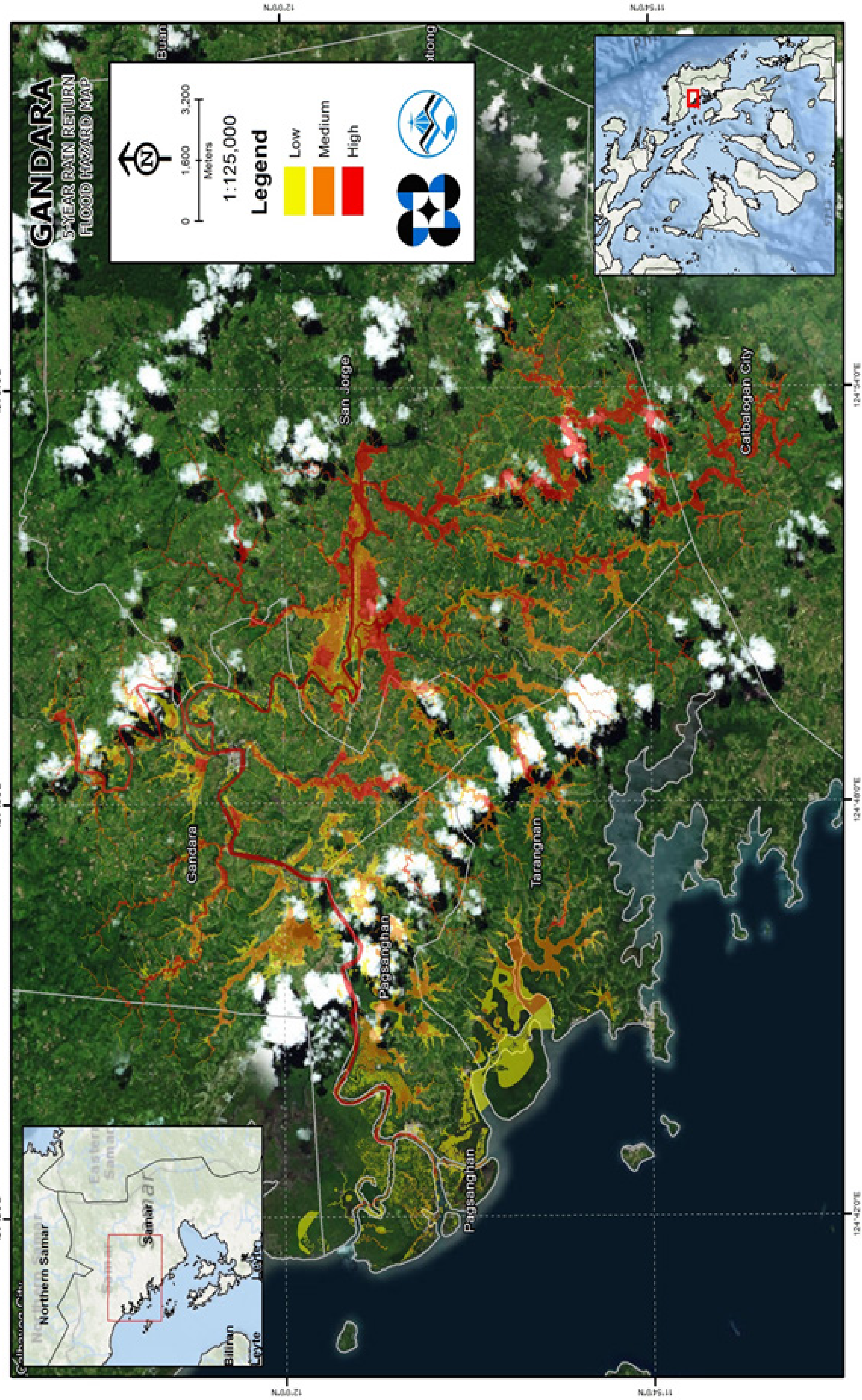



Figure 70. A 5-year Flood Hazard Map for Gandara Floodplain overlaid on Google Earth imagery.

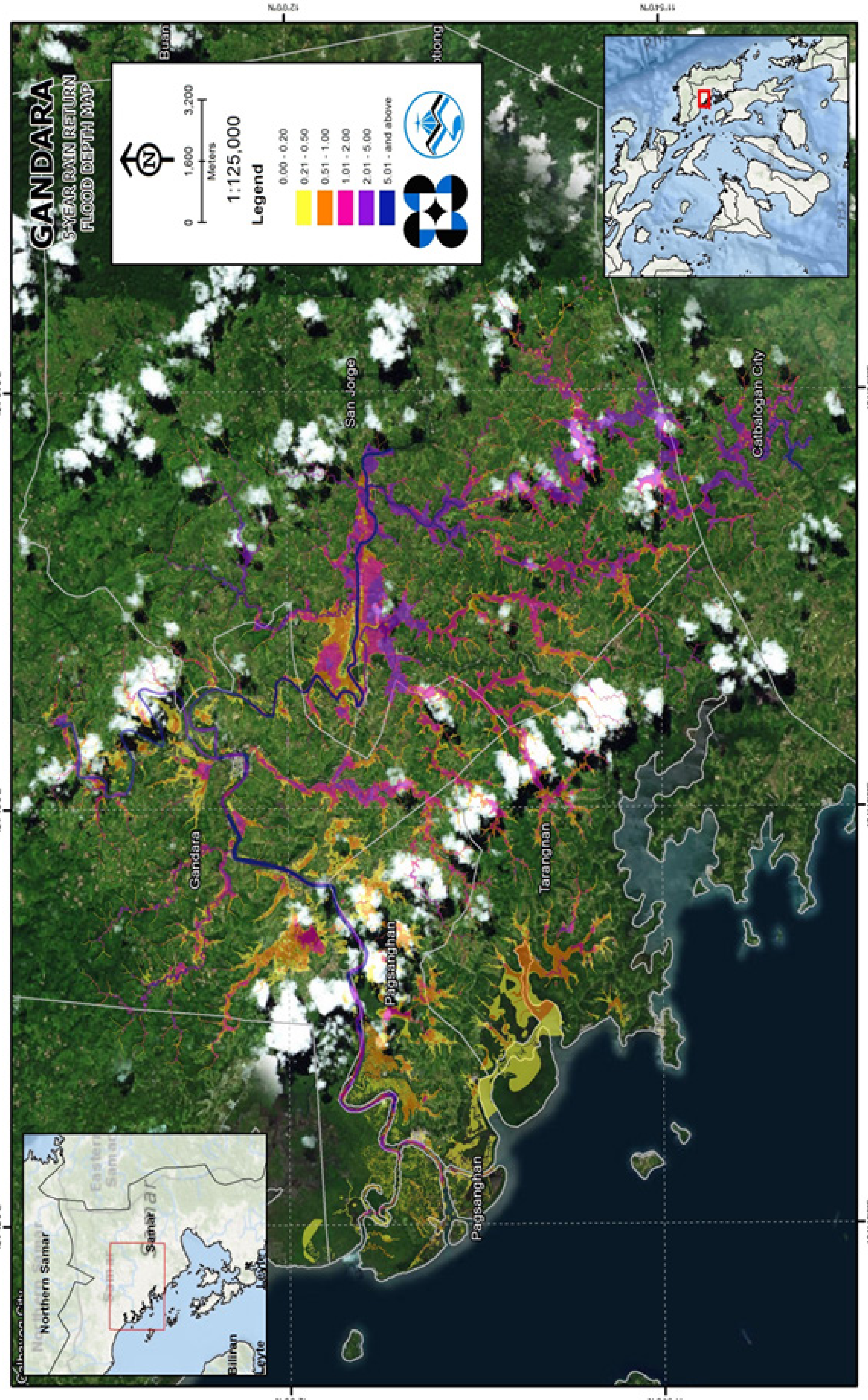



Figure 71. A 5-year Flood Depth Map for Gandara Floodplain overlaid on Google Earth imagery.

## 5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Gandara River Basin, grouped accordingly by city/municipality. For the said basin, six (6) municipalities consisting of 124 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 8.16% of the municipality of Catbalogan City with an area of 177.02 sq. km. will experience flood levels of less 0.20 meters, while 0.18% of the area will experience flood levels of 0.21 to 0.50 meters; 0.24%, 0.60%, 0.93%, and 0.12% 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 27 are the affected areas in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding, respectively.

Table 30. Affected Areas in Alabel, Sarangani during 5-Year Rainfall Return Period

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Catbalogan City (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Albalate | Bangon | Cagusipan | Cagutian | Palanyogon | Totoringon |
| 0.03-0.20 | 4.47 | 5.53 | 0.06 | 1.98 | 2.3 | 0.12 |
| 0.21-0.50 | 0.11 | 0.11 | 0.0026 | 0.048 | 0.04 | 0.0005 |
| 0.51-1.00 | 0.18 | 0.16 | 0.0015 | 0.055 | 0.03 | 0.0001 |
| 1.01-2.00 | 0.54 | 0.38 | 0.00012 | 0.11 | 0.038 | 0.0001 |
| 2.01-5.00 | 0.64 | 0.83 | 0 | 0.16 | 0.016 | 0 |
| > 5.00 | 0.074 | 0.13 | 0 | 0 | 0 | 0 |

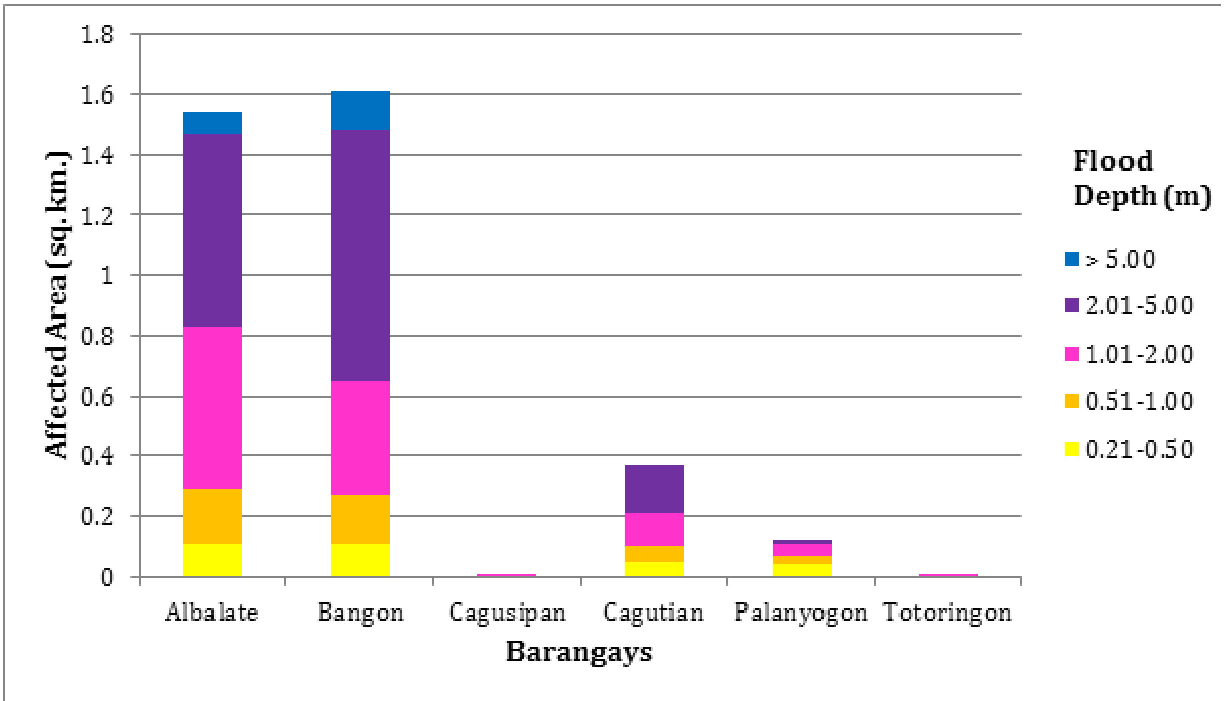



Figure 72. Affected Areas in Catbalogan City, Samar during 5-Year Rainfall Return Period.

For the 5-year return period, municipality of Gandara, with an area of 296.92 sq. km., 25.33% will experience flood levels of less 0.20 meters. 2.53% of the area will experience flood levels of 0.21 to 0.50 meters while 1.87%, 1.39%, 0.74%, and 0.49% 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 28 to Table 32 are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Adela Heights | Arong | Bangahon | Bunyagan | Caliro-can | Caparangasan | Casab-Ahan | Casandig |
| 0.03-0.20 | 0.25 | 0.67 | 1.02 | 1.64 | 1.5 | 1.54 | 1.71 | 0.56 |
| 0.21-0.50 | 0.16 | 0.046 | 0.19 | 0.21 | 0.23 | 0.093 | 0.12 | 0.21 |
| 0.51-1.00 | 0.046 | 0.017 | 0.14 | 0.083 | 0.094 | 0.059 | 0.14 | 0.066 |
| 1.01-2.00 | 0.033 | 0.017 | 0.032 | 0.08 | 0.016 | 0 | 0.16 | 0.01 |
| 2.01-5.00 | 0.0001 | 0.011 | 0.052 | 0.043 | 0.19 | 0 | 0.086 | 0.028 |
| > 5.00 | 0 | 0 | 0.063 | 0.024 | 0.11 | 0 | 0.15 | 0.078 |

Table 32. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Catorse De Agosto | Concep-cion | Diaz | Dumalo-Ong | Gerali | Gereganan | Hinugacan | Hiparayan |
| 0.03-0.20 | 0.86 | 2.42 | 1.55 | 0.23 | 1.8 | 0.8 | 3.58 | 1.02 |
| 0.21-0.50 | 0.048 | 0.67 | 0.07 | 0.13 | 0.051 | 0.089 | 0.4 | 0.11 |
| 0.51-1.00 | 0.015 | 0.99 | 0.056 | 0.082 | 0.041 | 0.067 | 0.44 | 0.11 |
| 1.01-2.00 | 0.018 | 0.31 | 0.053 | 0.12 | 0.033 | 0.017 | 0.61 | 0.081 |
| 2.01-5.00 | 0.099 | 0.079 | 0.022 | 0.037 | 0.034 | 0.015 | 0.2 | 0.066 |
| > 5.00 | 0.041 | 0.075 | 0.0007 | 0.0022 | 0.025 | 0.071 | 0 | 0.09 |

Table 33. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Jasminez | Lungib | Macugo | Malayog | Marcos | Minda | Nacube | Nalihugan |
| 0.03-0.20 | 4.84 | 0.85 | 2.71 | 0.91 | 0.55 | 0.52 | 2.4 | 0.78 |
| 0.21-0.50 | 0.26 | 0.12 | 0.11 | 0.2 | 0.082 | 0.031 | 0.53 | 0.02 |
| 0.51-1.00 | 0.24 | 0.055 | 0.099 | 0.051 | 0.038 | 0.03 | 0.35 | 0.014 |
| 1.01-2.00 | 0.21 | 0.0033 | 0.088 | 0 | 0.0074 | 0.019 | 0.14 | 0.017 |
| 2.01-5.00 | 0.15 | 0 | 0.021 | 0 | 0.0053 | 0.061 | 0.046 | 0.01 |
| > 5.00 | 0.029 | 0 | 0.00017 | 0 | 0.035 | 0.023 | 0.14 | 0 |

Table 34. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Natimonan | Ngoso | Palanas | Pizarro | Pologon | Samoyao | San Agustin | San Miguel |
| 0.03-0.20 | 2.79 | 0.77 | 1.23 | 2.57 | 4.55 | 2.6 | 2.94 | 4.45 |
| 0.21-0.50 | 0.21 | 0.042 | 0.31 | 0.14 | 0.49 | 0.19 | 0.17 | 0.28 |
| 0.51-1.00 | 0.15 | 0.05 | 0.025 | 0.12 | 0.67 | 0.2 | 0.23 | 0.17 |
| 1.01-2.00 | 0.07 | 0.054 | 0.0003 | 0.11 | 0.72 | 0.14 | 0.4 | 0.11 |
| 2.01-5.00 | 0.022 | 0.0078 | 0 | 0.097 | 0.11 | 0.081 | 0.15 | 0.14 |
| > 5.00 | 0.055 | 0 | 0 | 0.046 | 0 | 0.0003 | 0 | 0.18 |

Table 35. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | San Pelayo | San Ramon | Santo Niño | Sidmon | Tagnao | Tambongan |
| 0.03-0.20 | 3.06 | 0.0062 | 1.15 | 6.17 | 4.54 | 3.68 |
| 0.21-0.50 | 0.52 | 0 | 0.051 | 0.19 | 0.19 | 0.56 |
| 0.51-1.00 | 0.26 | 0 | 0.052 | 0.11 | 0.14 | 0.063 |
| 1.01-2.00 | 0.11 | 0 | 0.03 | 0.12 | 0.14 | 0.042 |
| 2.01-5.00 | 0.045 | 0 | 0.004 | 0.079 | 0.09 | 0.13 |
| > 5.00 | 0.15 | 0 | 0.012 | 0.0043 | 0.0064 | 0.035 |

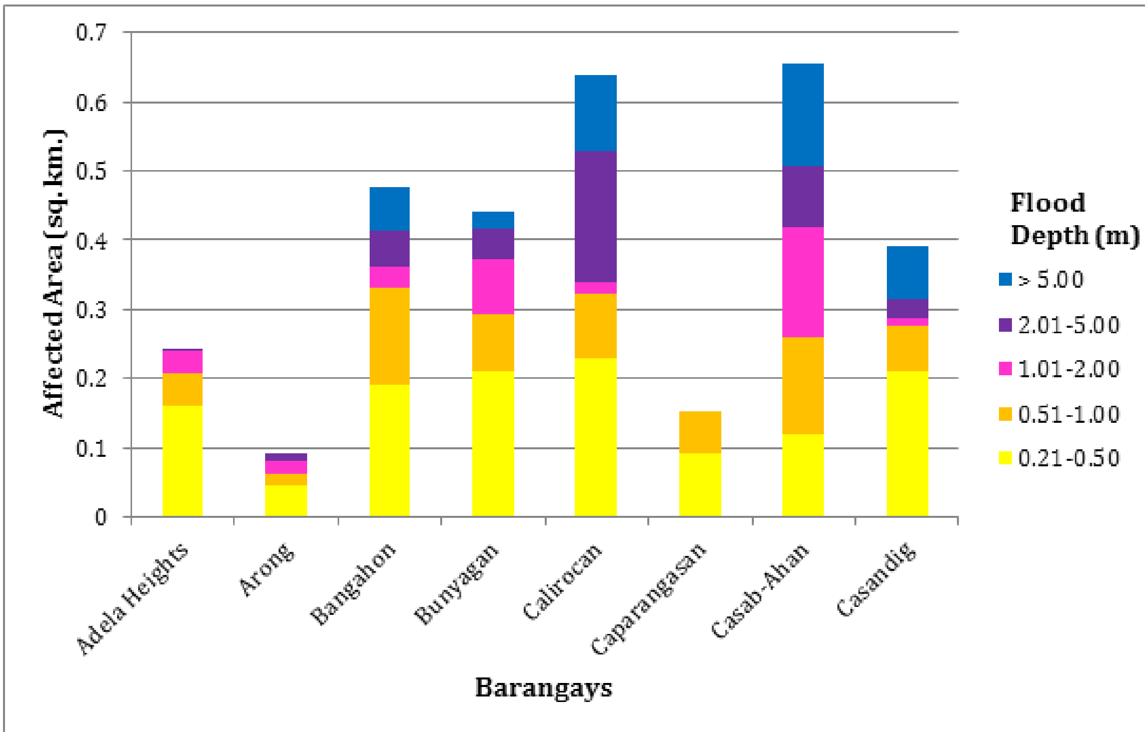



Figure 73. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

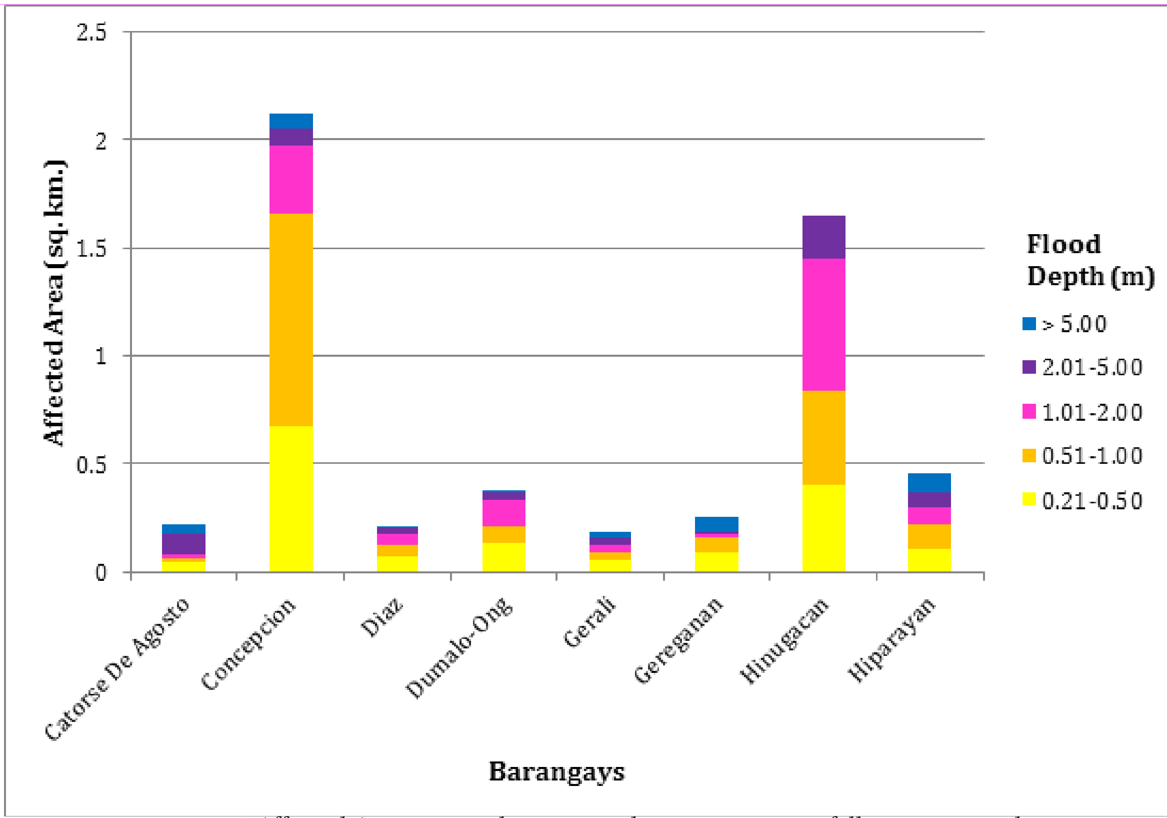



Figure 74. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

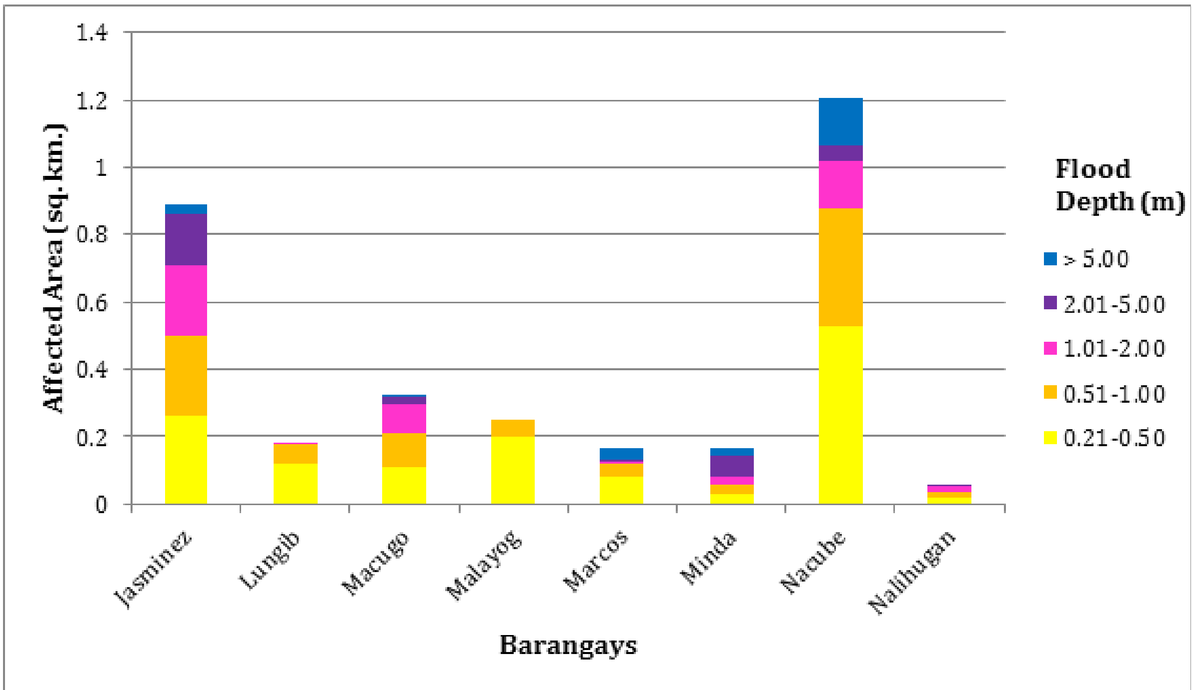



Figure 75. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

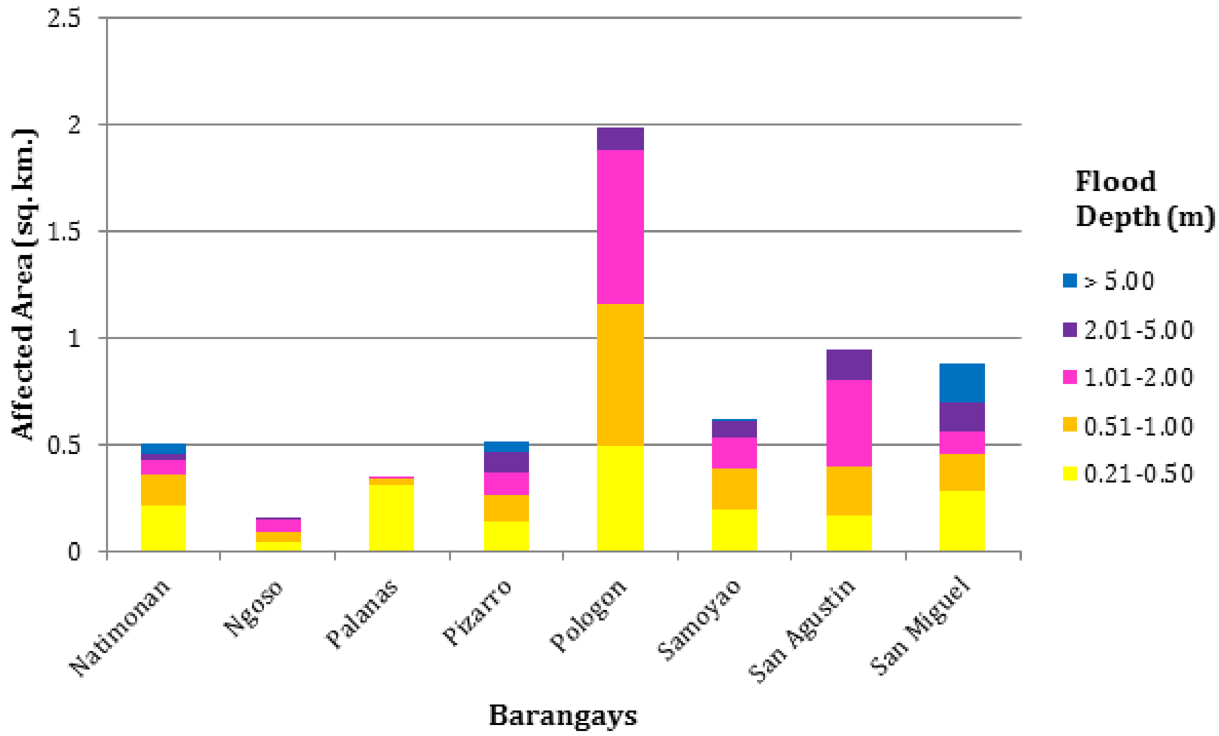



Figure 76. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

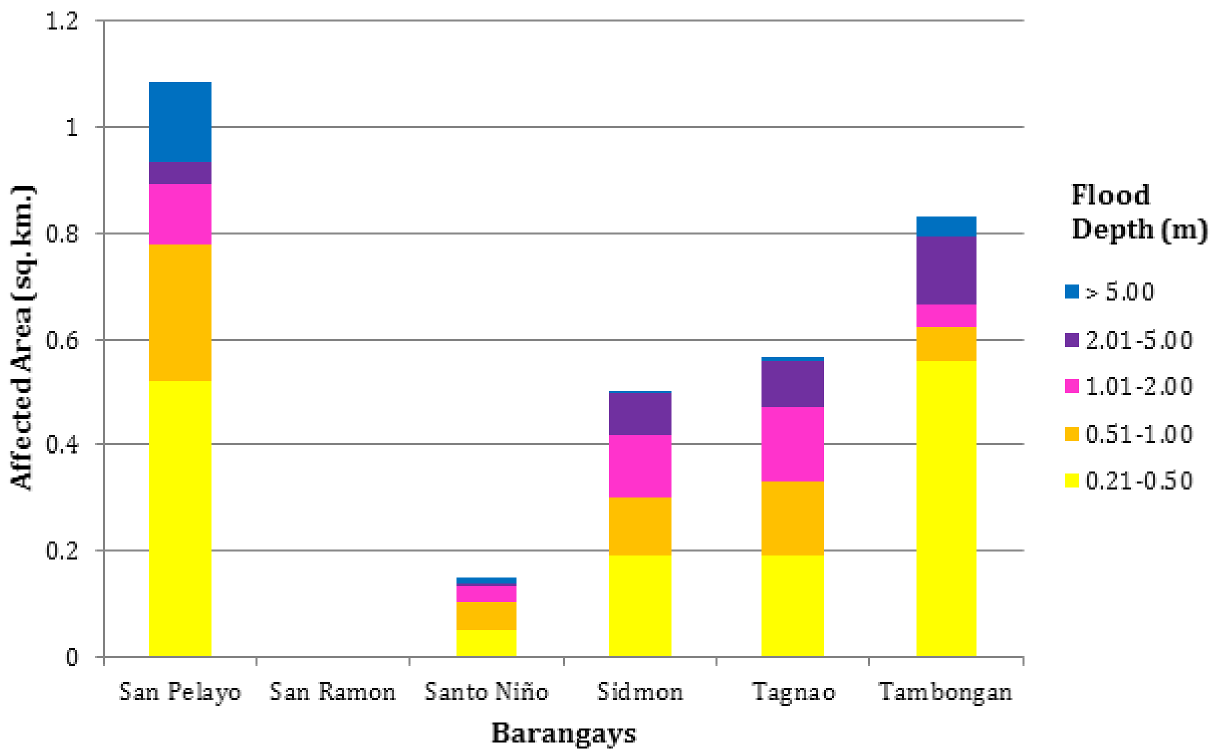



Figure 77. Affected Areas in Gandara, Samar during 5-Year Rainfall Return Period.

For the 25-year return period, 7.92% of the municipality of Catbalogan City with an area of 177.02 sq. km. will experience flood levels of less 0.20 meters, while 0.16% of the area will experience flood levels of 0.21 to 0.50 meters; 0.17%, 0.32%, 1.48%, 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. Table 33 depicts the areas affected in Catbalogan City in square kilometers by flood depth per barangay.

Table 36. Affected areas in Catbalogan City, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Catbalogan City (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Albalate | Bangon | Cagusipan | Cagutian | Palanyogon | Totoringon |
| **0.03-0.20** | 4.3 | 5.34 | 0.059 | 1.91 | 2.29 | 0.12 |
| **0.21-0.50** | 0.096 | 0.094 | 0.0034 | 0.046 | 0.041 | 0.0007 |
| **0.51-1.00** | 0.11 | 0.11 | 0.0018 | 0.042 | 0.032 | 0.0002 |
| **1.01-2.00** | 0.24 | 0.22 | 0.00028 | 0.064 | 0.041 | 0.0001 |
| **2.01-5.00** | 1.14 | 1.17 | 0 | 0.29 | 0.025 | 0 |
| **> 5.00** | 0.14 | 0.22 | 0 | 0 | 0 | 0 |

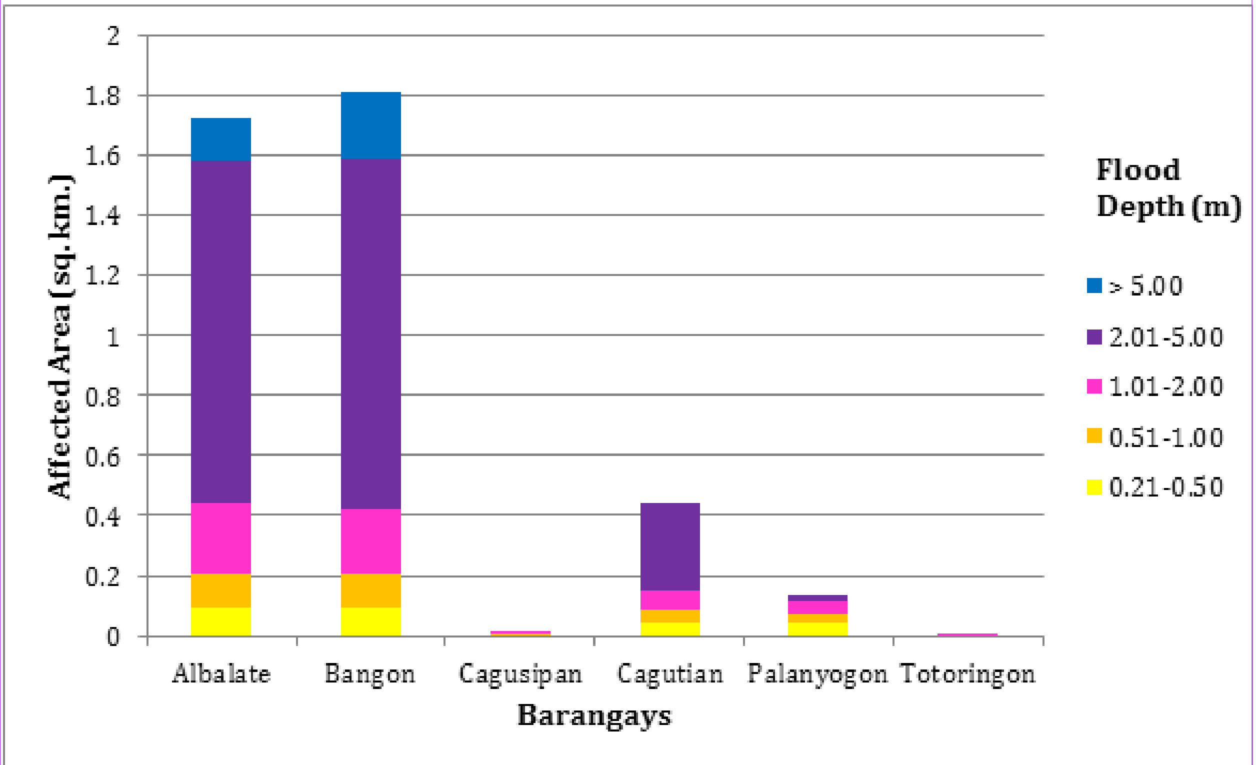



Figure 78. Affected areas in Catbalogan City, Samar during a 25-Year Rainfall Return Period.

For the municipality of Gandara, with an area of 296.92 sq. km., 22.85% will experience flood levels of less 0.20 meters. 2.3% of the area will experience flood levels of 0.21 to 0.50 meters while 2.1%, 2.47%, 1.9%, and 0.77% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 34 to Table 38 depict the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Adela Heights | Arong | Bangahon | Bunyagan | Caliro-can | Caparangasan | Casab-Ahan | Casandig |
| **0.03-0.20** | 0.17 | 0.63 | 0.48 | 1.56 | 1.19 | 1.39 | 1.58 | 0.45 |
| **0.21-0.50** | 0.19 | 0.065 | 0.04 | 0.2 | 0.26 | 0.23 | 0.066 | 0.23 |
| **0.51-1.00** | 0.085 | 0.023 | 0.043 | 0.13 | 0.26 | 0.071 | 0.089 | 0.15 |
| **1.01-2.00** | 0.043 | 0.02 | 0.28 | 0.048 | 0.11 | 0.0017 | 0.21 | 0.014 |
| **2.01-5.00** | 0.0004 | 0.014 | 0.53 | 0.12 | 0.069 | 0 | 0.27 | 0.017 |
| **> 5.00** | 0 | 0 | 0.12 | 0.032 | 0.25 | 0 | 0.17 | 0.1 |

Table 38. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Catorse De Agosto | Concep-cion | Diaz | Dumalo-Ong | Gerali | Gereganan | Hinugacan | Hiparayan |
| 0.03-0.20 | 0.83 | 1.92 | 1.49 | 0.17 | 1.76 | 0.48 | 3.27 | 0.69 |
| 0.21-0.50 | 0.062 | 0.54 | 0.061 | 0.082 | 0.058 | 0.055 | 0.22 | 0.033 |
| 0.51-1.00 | 0.023 | 1.1 | 0.05 | 0.11 | 0.049 | 0.11 | 0.33 | 0.037 |
| 1.01-2.00 | 0.014 | 0.8 | 0.1 | 0.14 | 0.04 | 0.22 | 0.67 | 0.13 |
| 2.01-5.00 | 0.071 | 0.024 | 0.04 | 0.078 | 0.027 | 0.11 | 0.74 | 0.43 |
| > 5.00 | 0.082 | 0.15 | 0.0007 | 0.014 | 0.045 | 0.089 | 0 | 0.16 |

Table 39. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Jasminez | Lungib | Macugo | Malayog | Marcos | Minda | Nacube | Nalihugan |
| 0.03-0.20 | 4.68 | 0.75 | 2.54 | 0.79 | 0.51 | 0.5 | 1.62 | 0.76 |
| 0.21-0.50 | 0.24 | 0.2 | 0.09 | 0.27 | 0.083 | 0.036 | 0.43 | 0.023 |
| 0.51-1.00 | 0.23 | 0.074 | 0.069 | 0.11 | 0.062 | 0.026 | 0.71 | 0.015 |
| 1.01-2.00 | 0.3 | 0.0071 | 0.1 | 0 | 0.021 | 0.027 | 0.59 | 0.024 |
| 2.01-5.00 | 0.24 | 0 | 0.21 | 0 | 0.003 | 0.041 | 0.08 | 0.024 |
| > 5.00 | 0.05 | 0 | 0.015 | 0 | 0.04 | 0.054 | 0.18 | 0 |

Table 40. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Natimonan | Ngoso | Palanas | Pizarro | Pologon | Samoyao | San Agustin | San Miguel |
| 0.03-0.20 | 2.64 | 0.74 | 1.07 | 2.39 | 4.14 | 2.48 | 2.82 | 4.05 |
| 0.21-0.50 | 0.21 | 0.041 | 0.42 | 0.1 | 0.38 | 0.16 | 0.12 | 0.13 |
| 0.51-1.00 | 0.19 | 0.035 | 0.07 | 0.097 | 0.57 | 0.19 | 0.12 | 0.13 |
| 1.01-2.00 | 0.14 | 0.078 | 0.0024 | 0.13 | 1.01 | 0.26 | 0.33 | 0.38 |
| 2.01-5.00 | 0.034 | 0.03 | 0 | 0.24 | 0.44 | 0.13 | 0.51 | 0.43 |
| > 5.00 | 0.062 | 0 | 0 | 0.13 | 0.017 | 0.002 | 0.0025 | 0.22 |

Table 41. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | San Pelayo | San Ramon | Santo Niño | Sidmon | Tagnao | Tambongan |
| 0.03-0.20 | 2.51 | 0.0062 | 1.12 | 6.06 | 4.42 | 3.19 |
| 0.21-0.50 | 0.18 | 0 | 0.048 | 0.21 | 0.19 | 0.89 |
| 0.51-1.00 | 0.36 | 0 | 0.055 | 0.12 | 0.14 | 0.19 |
| 1.01-2.00 | 0.69 | 0 | 0.045 | 0.14 | 0.19 | 0.019 |
| 2.01-5.00 | 0.24 | 0 | 0.02 | 0.14 | 0.16 | 0.12 |
| > 5.00 | 0.16 | 0 | 0.015 | 0.0049 | 0.016 | 0.092 |

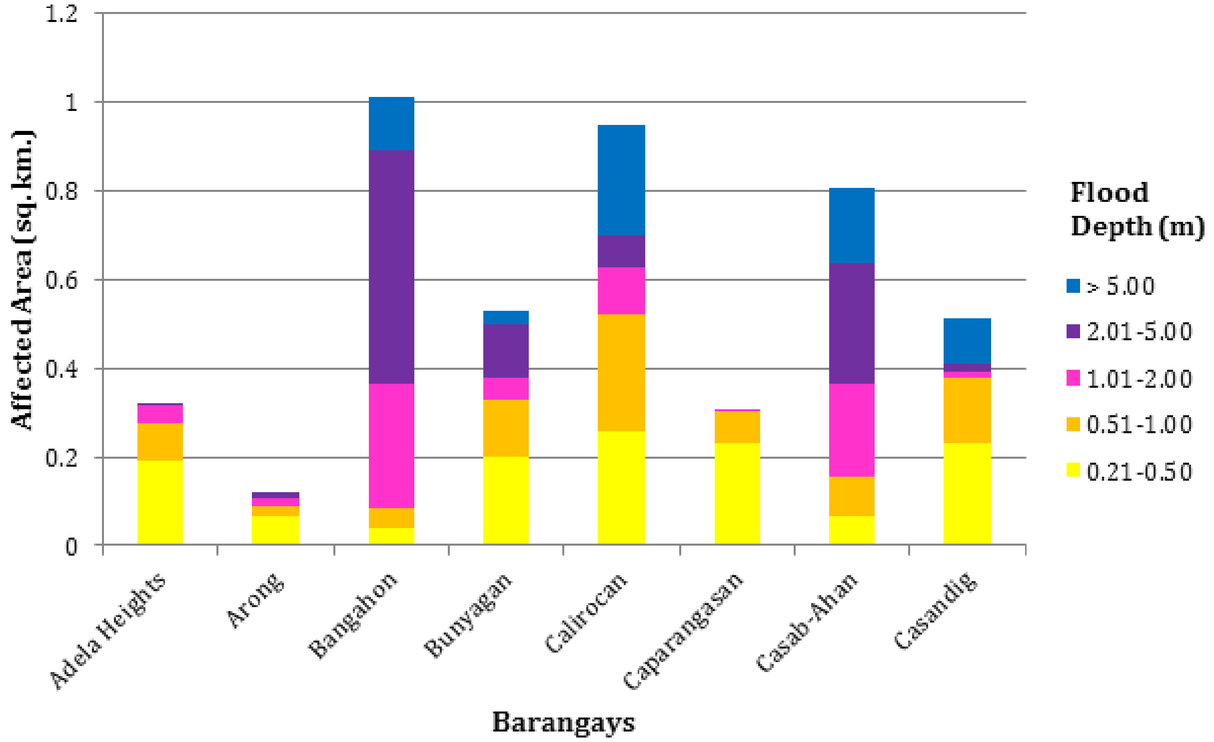



Figure 79. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

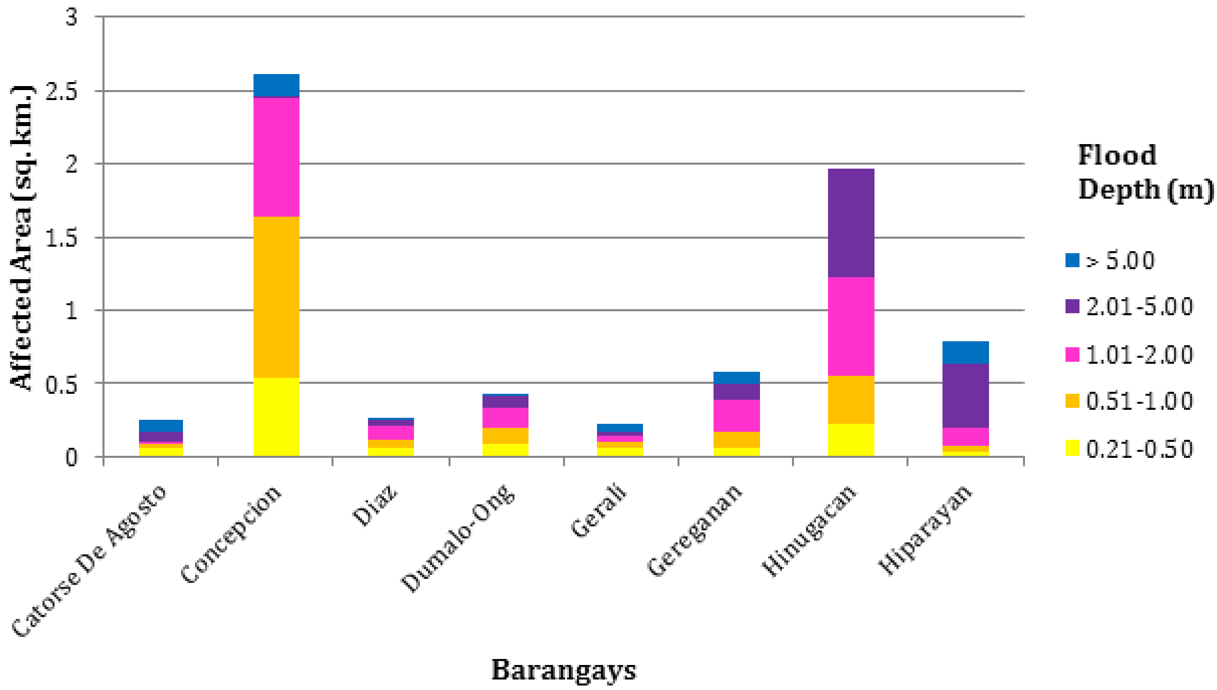



Figure 80. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

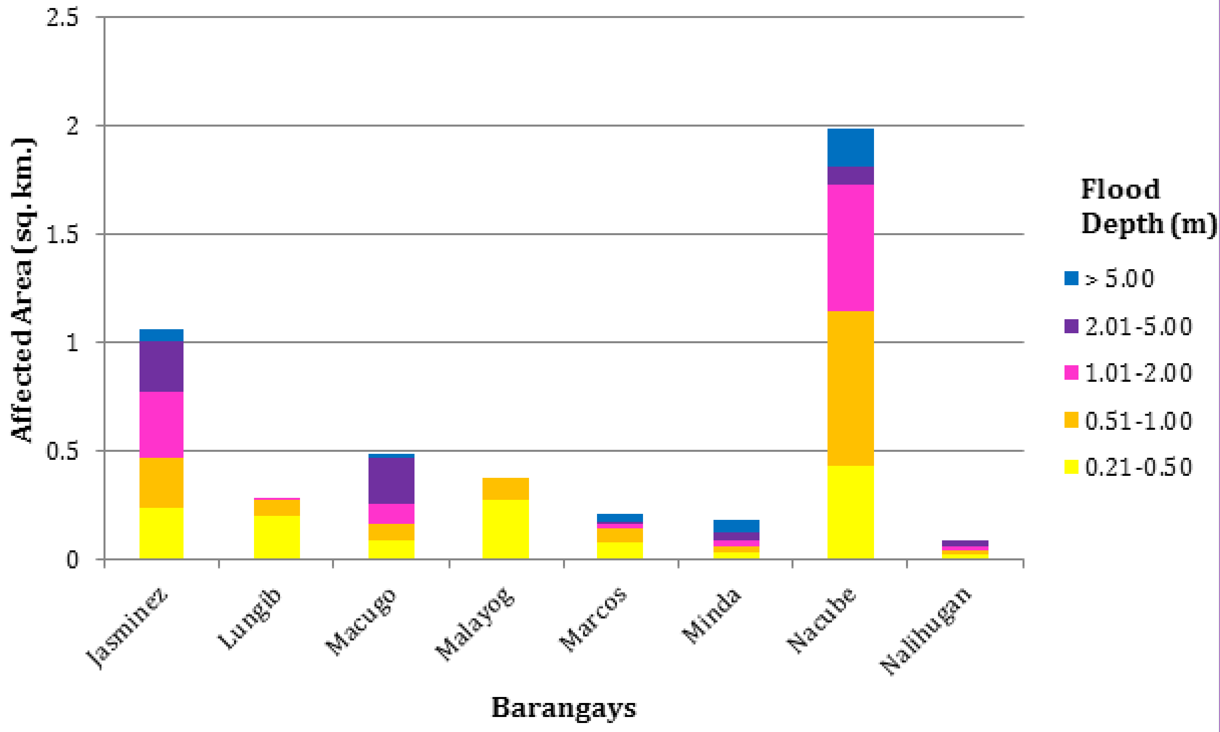



Figure 81. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

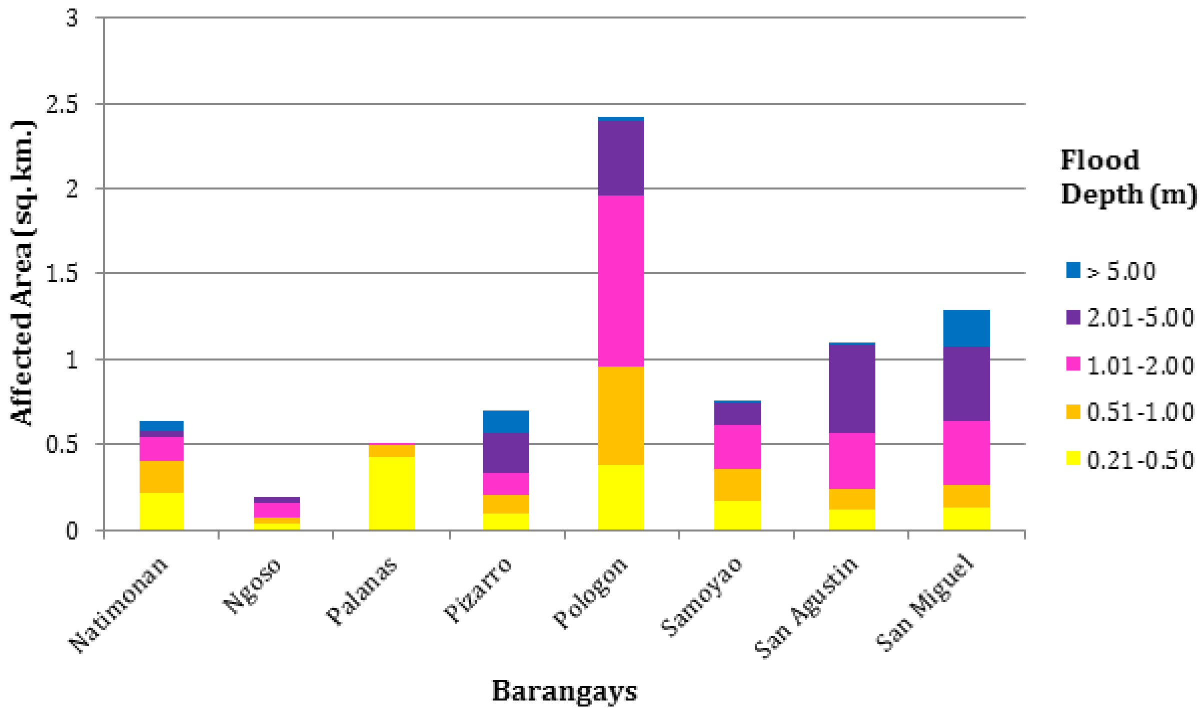



Figure 82. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

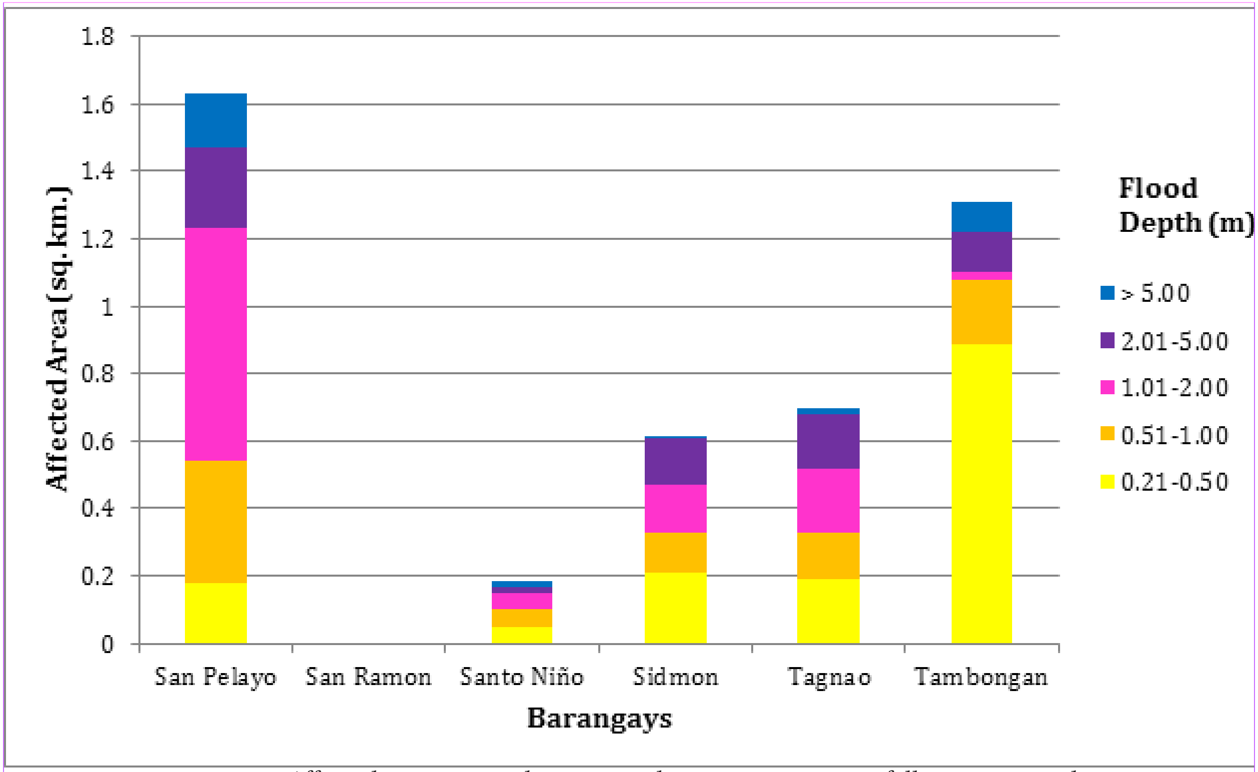



Figure 83. Affected areas in Gandara, Samar during a 25-Year Rainfall Return Period.

For the municipality of Pagsanghan, with an area of 29.46 sq. km., 67.18% will experience flood levels of less 0.20 meters. 13.41% of the area will experience flood levels of 0.21 to 0.50 meters while 11.06%, 6.16%, 1.24%, and 0.79% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 39 and Table 40 depicts the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Pagsanghan, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Pagsanghan (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Bangon | Buenos Aires | Calanyugan | Caloloma | Cambaye | Canlapwas |
| 0.03-0.20 | 0.77 | 3.39 | 3.49 | 1.96 | 0.5 | 0.96 |
| 0.21-0.50 | 0.23 | 0.49 | 0.14 | 0.76 | 0.077 | 0.63 |
| 0.51-1.00 | 0.035 | 0.83 | 0.23 | 0.9 | 0.01 | 0.018 |
| 1.01-2.00 | 0.0022 | 0.33 | 0.54 | 0.26 | 0.00013 | 0 |
| 2.01-5.00 | 0 | 0.065 | 0.064 | 0.13 | 0 | 0 |
| > 5.00 | 0 | 0.05 | 0 | 0.043 | 0 | 0 |

Table 43. Affected areas in Pagsanghan, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Pagsanghan (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Libertad | Pañge | San Luis | Santo Niño | Viejo | Villahermosa Occidental | Villahermosa Oriental |
| 0.03-0.20 | 0.47 | 1.29 | 3.12 | 0.87 | 0.38 | 1.6 | 0.99 |
| 0.21-0.50 | 0.19 | 0.22 | 0.42 | 0.066 | 0.099 | 0.51 | 0.12 |
| 0.51-1.00 | 0.27 | 0.23 | 0.4 | 0.084 | 0.027 | 0.14 | 0.084 |
| 1.01-2.00 | 0.067 | 0.34 | 0.21 | 0.021 | 0.003 | 0.022 | 0.019 |
| 2.01-5.00 | 0.0042 | 0.014 | 0.078 | 0.0026 | 0.0063 | 0 | 0.0001 |
| > 5.00 | 0.00057 | 0.02 | 0.12 | 0 | 0 | 0 | 0 |

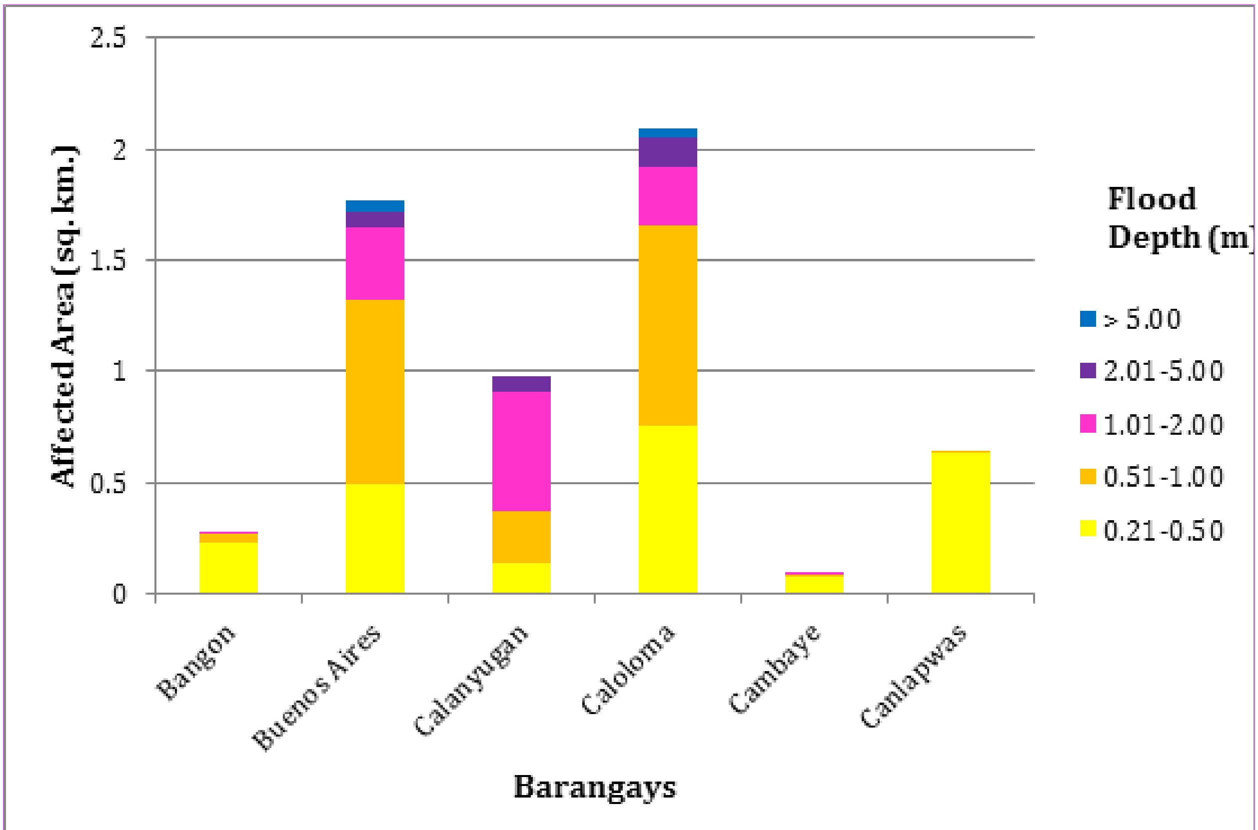



Figure 84. Affected areas in Pagsanghan, Samar during a 25-Year Rainfall Return Period.

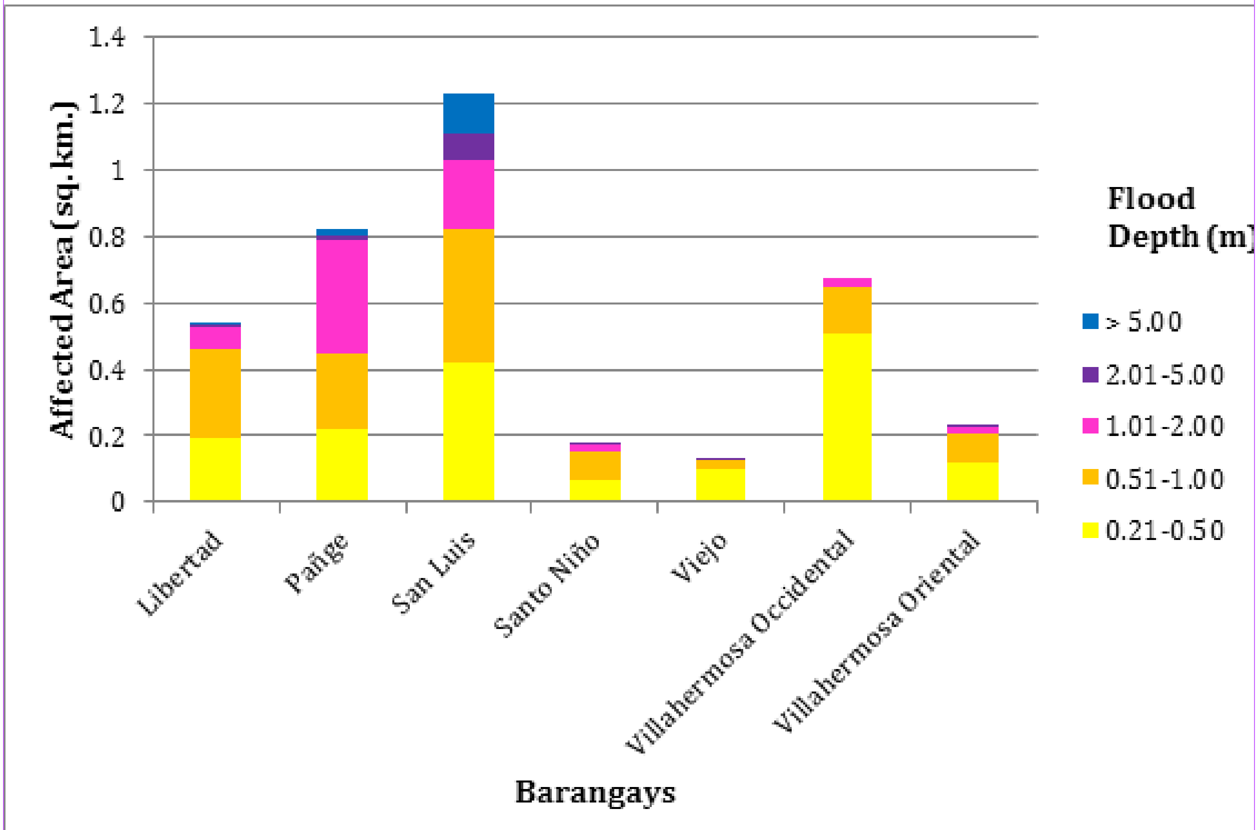



Figure 85. Affected areas in Pagsanghan, Samar during a 25-Year Rainfall Return Period.

For the municipality of San Jorge, with an area of 280.03 sq. km., 30.06% will experience flood levels of less 0.20 meters. 1.01% of the area will experience flood levels of 0.21 to 0.50 meters while 1.18%, 2.54%, 6.16%, and 0.93% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 41 to Table 45 depict the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Anquiana | Aurora | Bay-Ang | Blanca Aurora | Buenavista I | Buenavista II | Bulao | Bungliw |
| 0.03-0.20 | 0.29 | 1.89 | 3.75 | 0.79 | 4.49 | 1.67 | 1.1 | 8.8 |
| 0.21-0.50 | 0.0063 | 0.066 | 0.12 | 0.019 | 0.1 | 0.038 | 0.029 | 0.42 |
| 0.51-1.00 | 0.0077 | 0.11 | 0.12 | 0.011 | 0.086 | 0.037 | 0.034 | 0.39 |
| 1.01-2.00 | 0.022 | 0.38 | 0.11 | 0.012 | 0.17 | 0.08 | 0.077 | 0.61 |
| 2.01-5.00 | 0.35 | 0.28 | 0.045 | 0.0047 | 1.22 | 0.45 | 1.71 | 1.41 |
| > 5.00 | 0.027 | 0 | 0.041 | 0 | 0.56 | 0.063 | 0.17 | 0.074 |

Table 45. areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cabugao | Cag-Olo-Olo | Calundan | Cantaguic | Canya-ki | Cogtoto-og | Erenas | Gayondato |
| 0.03-0.20 | 3.98 | 1.13 | 0.073 | 4.12 | 1.31 | 1.4 | 0.96 | 0.61 |
| 0.21-0.50 | 0.08 | 0.033 | 0.0017 | 0.18 | 0.055 | 0.035 | 0.045 | 0.01 |
| 0.51-1.00 | 0.04 | 0.028 | 0.00032 | 0.24 | 0.094 | 0.016 | 0.038 | 0.011 |
| 1.01-2.00 | 0.053 | 0.041 | 0.0012 | 0.66 | 0.25 | 0.02 | 0.042 | 0.0053 |
| 2.01-5.00 | 0.13 | 0.04 | 0 | 1.02 | 0.095 | 0.057 | 0.075 | 0.0008 |
| > 5.00 | 0.037 | 0.00003 | 0 | 0.016 | 0 | 0.18 | 0.002 | 0 |

Table 46. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Guadalupe | Guindapunan | Hernandez | Himay | Janipon | La Paz | Libertad | Mabuhay |
| 0.03-0.20 | 2.03 | 1.13 | 0.88 | 2.49 | 1.42 | 0.82 | 5.34 | 0.81 |
| 0.21-0.50 | 0.061 | 0.039 | 0.025 | 0.065 | 0.051 | 0.037 | 0.13 | 0.026 |
| 0.51-1.00 | 0.1 | 0.049 | 0.035 | 0.05 | 0.046 | 0.044 | 0.067 | 0.046 |
| 1.01-2.00 | 0.27 | 0.36 | 0.075 | 0.072 | 0.06 | 0.1 | 0.067 | 0.11 |
| 2.01-5.00 | 1.03 | 0.73 | 0.68 | 0.051 | 0.1 | 0.99 | 0.062 | 0.35 |
| > 5.00 | 0.0004 | 0.037 | 0.0084 | 0 | 0.0089 | 0.089 | 0.0081 | 0.024 |

Table 47. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mancol | Matalud | Mombon | Puhagan | Quezon | Ranera | Rawis |
| 0.03-0.20 | 0.098 | 3.15 | 0.00056 | 6.11 | 3.33 | 9.25 | 1.08 |
| 0.21-0.50 | 0.0026 | 0.12 | 0.0003 | 0.12 | 0.16 | 0.31 | 0.045 |
| 0.51-1.00 | 0.0034 | 0.045 | 0.0032 | 0.07 | 0.4 | 0.44 | 0.061 |
| 1.01-2.00 | 0.028 | 0.028 | 0.29 | 0.1 | 0.49 | 1.15 | 0.16 |
| 2.01-5.00 | 0.43 | 0.016 | 0.7 | 0.33 | 0.056 | 1.64 | 1.2 |
| > 5.00 | 0.016 | 0 | 0.17 | 0.28 | 0 | 0.62 | 0.052 |

Table 48. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rosalim | San Isidro | San Jorge I | San Jorge II | San Juan | Sapinit | Sinit-An |
| 0.03-0.20 | 2.05 | 0.86 | 0.46 | 0.44 | 0.47 | 0.71 | 4.89 |
| 0.21-0.50 | 0.086 | 0.022 | 0.018 | 0.013 | 0.017 | 0.019 | 0.21 |
| 0.51-1.00 | 0.12 | 0.028 | 0.021 | 0.025 | 0.022 | 0.026 | 0.34 |
| 1.01-2.00 | 0.27 | 0.077 | 0.03 | 0.052 | 0.093 | 0.11 | 0.59 |
| 2.01-5.00 | 0.17 | 0.39 | 0.046 | 0.19 | 0.4 | 0.36 | 0.45 |
| > 5.00 | 0 | 0.031 | 0.036 | 0.023 | 0.026 | 0.013 | 0.0024 |

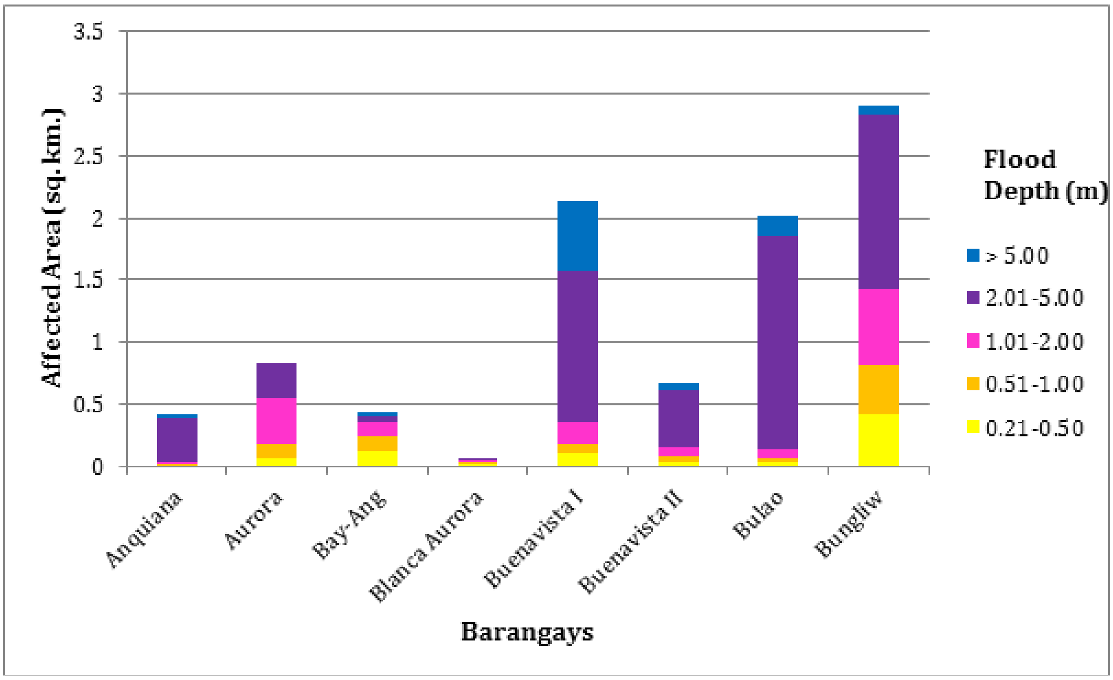



Figure 86. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

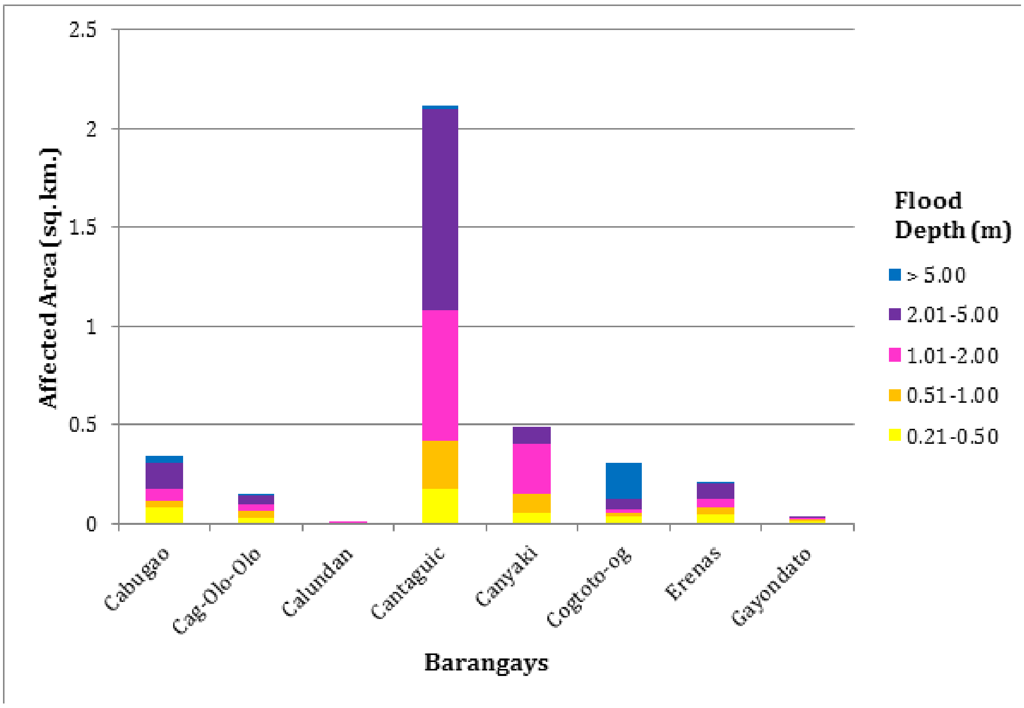



Figure 87. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

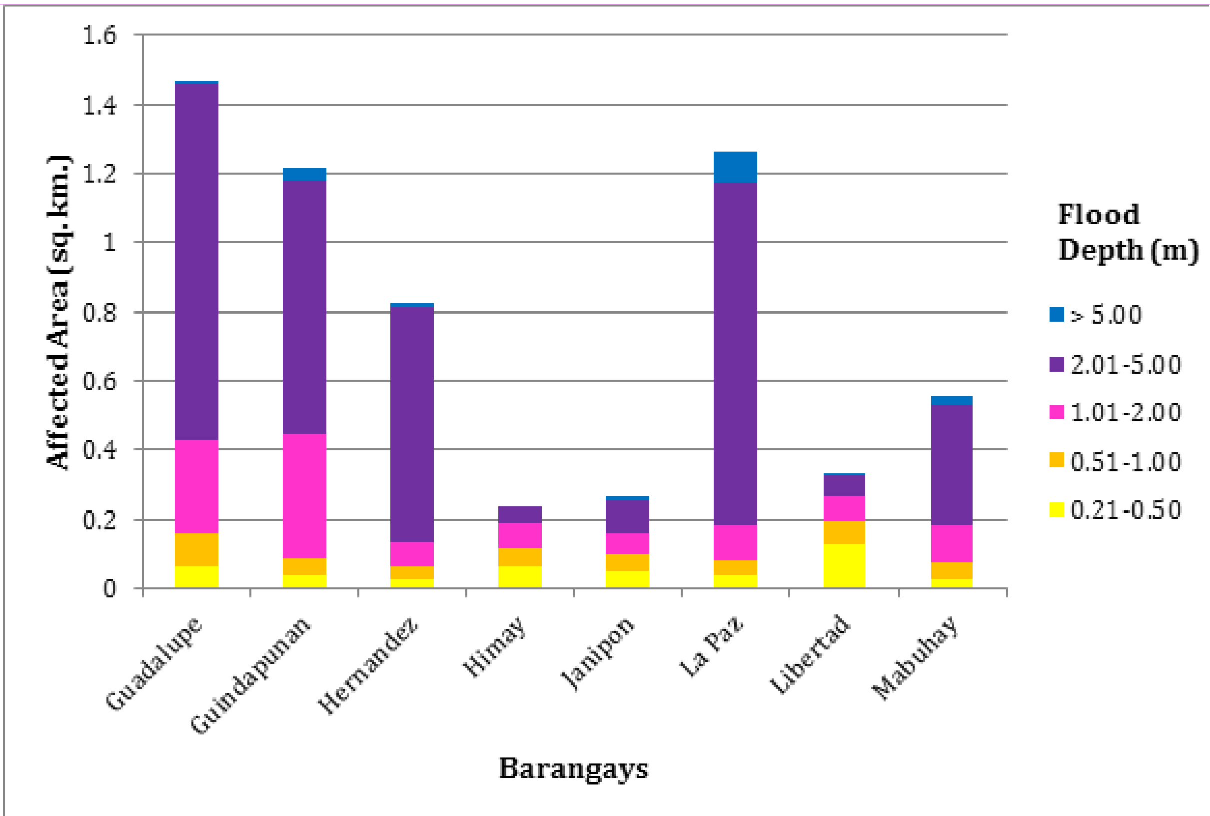



Figure 88. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

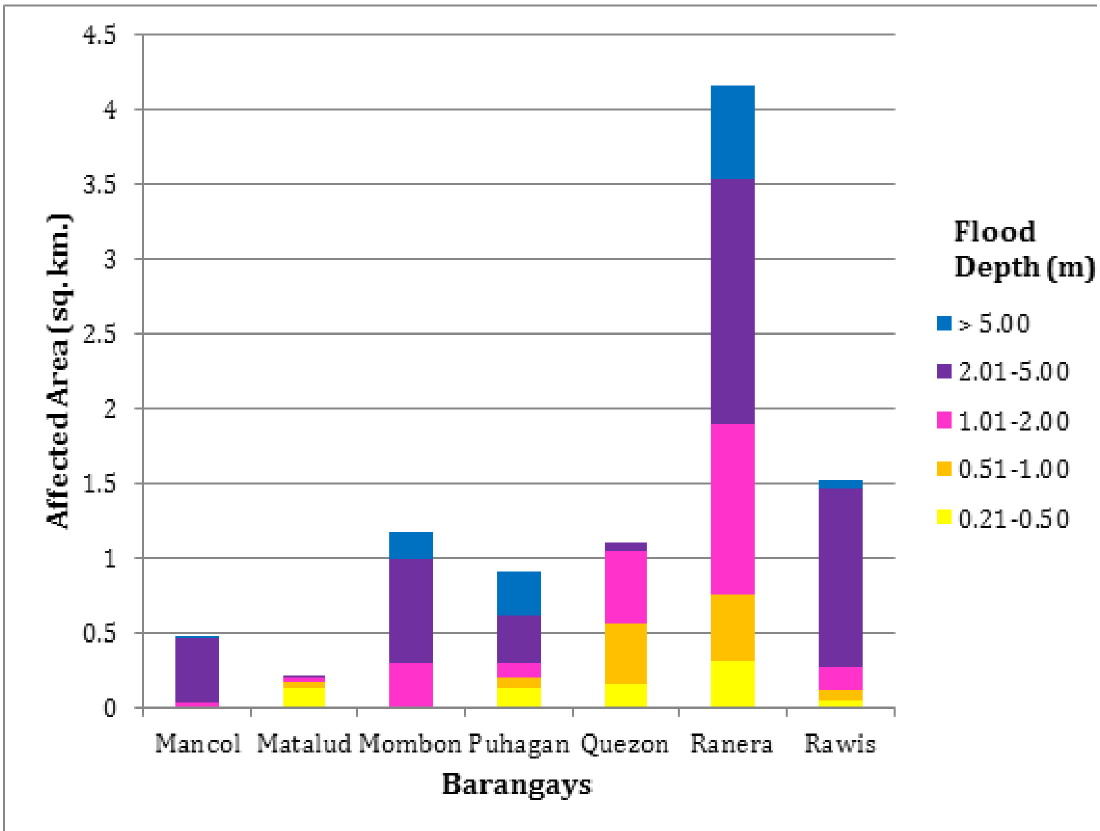



Figure 89. Affected areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

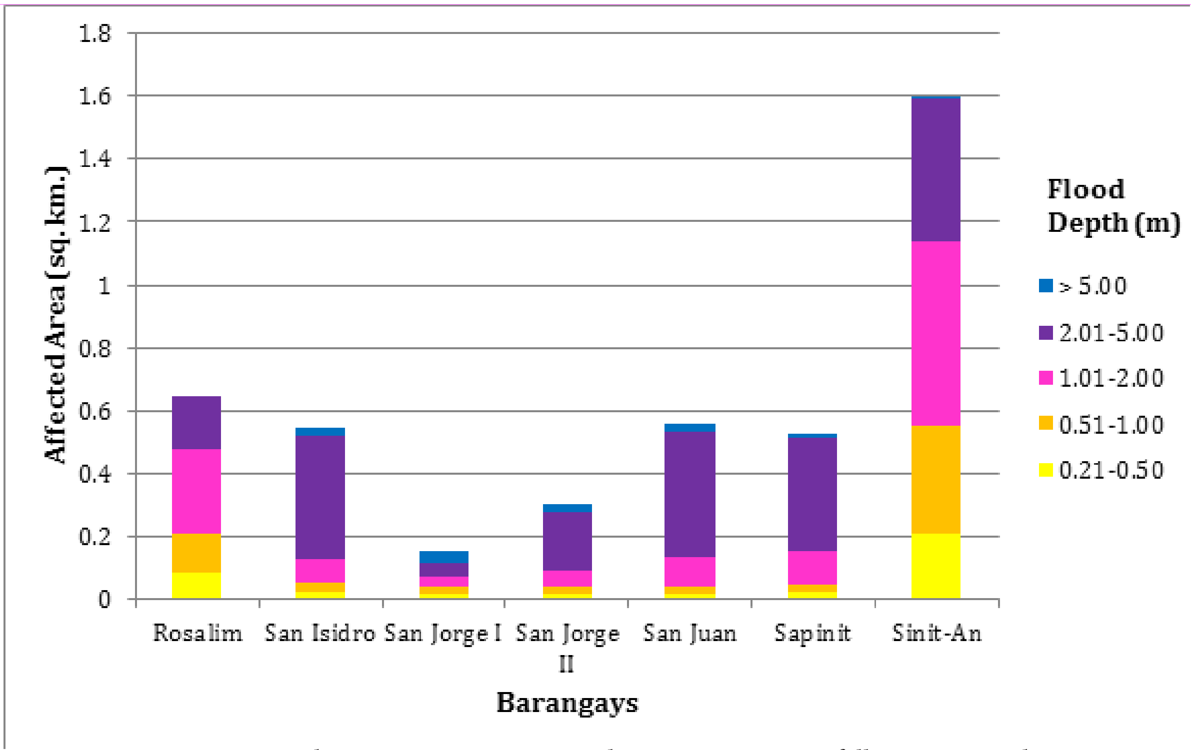



Figure 90. cted areas in San Jorge, Samar during a 25-Year Rainfall Return Period.

For the municipality of Santa Margarita, with an area of 130.73 sq. km., 4.53% will experience flood levels of less 0.20 meters. 0.47% of the area will experience flood levels of 0.21 to 0.50 meters while 0.11%, 0.15%, 0.06%, and 0.0002%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 46 depicts the affected areas in square kilometers by flood depth per barangay.

Table 49. Area of affected barangays in Santa Margarita (in sq. km.)

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | |
|---|---|---|---|---|---|
| | Balud | Ilo | Nabulo | Panabatan | Sundara |
| **0.03-0.20** | 0.93 | 0.021 | 4.18 | 0.13 | 0.66 |
| **0.21-0.50** | 0.04 | 0 | 0.11 | 0.16 | 0.31 |
| **0.51-1.00** | 0.052 | 0 | 0.087 | 0 | 0.011 |
| **1.01-2.00** | 0.11 | 0 | 0.085 | 0 | 0 |
| **2.01-5.00** | 0.0061 | 0 | 0.074 | 0 | 0 |
| **> 5.00** | 0 | 0 | 0.0003 | 0 | 0 |

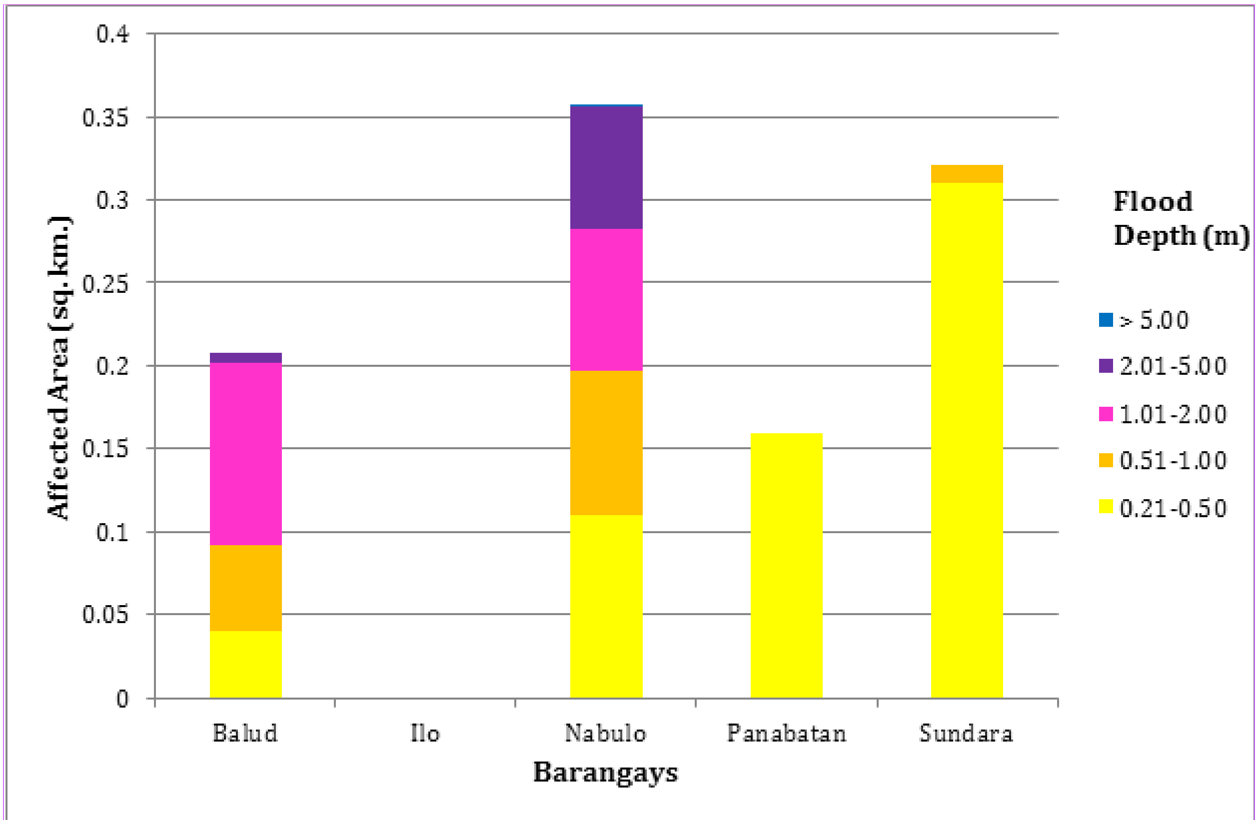



Figure 91. Affected areas in Santa Margarita, Samar during a 25-Year Rainfall Return Period.

For the municipality of Tarangnan, with an area of 89.57 sq. km., 46.19% will experience flood levels of less 0.20 meters. 6.04% of the area will experience flood levels of 0.21 to 0.50 meters while 3.42%, 3.1%, 0.84%, and 0.02%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 47 to Table 49 depict the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected areas in Tarangnan, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Tarangnan (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Awang | Bahay | Balonga-As | Balugo | Bangon Gote | Binalayan | Cabunga-An | Cagtutulo |
| **0.03-0.20** | 3.33 | 1.78 | 1.86 | 3.39 | 1.38 | 3.47 | 1.53 | 1.31 |
| **0.21-0.50** | 0.077 | 0.06 | 0.12 | 0.099 | 0.056 | 0.2 | 0.13 | 0.034 |
| **0.51-1.00** | 0.064 | 0.11 | 0.18 | 0.12 | 0.098 | 0.17 | 0.07 | 0.026 |
| **1.01-2.00** | 0.1 | 0.11 | 0.19 | 0.14 | 0.29 | 0.089 | 0.12 | 0.048 |
| **2.01-5.00** | 0.066 | 0.0052 | 0.01 | 0.036 | 0.066 | 0.017 | 0 | 0.074 |
| **> 5.00** | 0.013 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0067 |

Table 51. Affected areas in Tarangnan, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Tarangnan (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Canunghan | Catan-Agan | Dapdap | Gallego | Imelda Poblacion | Lahong | Marabut | Pajo |
| 0.03-0.20 | 0.7 | 3.39 | 2.91 | 2.02 | 0.54 | 0.75 | 1.83 | 6.11 |
| 0.21-0.50 | 0.02 | 0.13 | 3.51 | 0.064 | 0.068 | 0.074 | 0.03 | 0.3 |
| 0.51-1.00 | 0.02 | 0.23 | 0.61 | 0.054 | 0.041 | 0.33 | 0.031 | 0.47 |
| 1.01-2.00 | 0.0048 | 0.41 | 0.024 | 0.024 | 0.0066 | 0.16 | 0.051 | 0.8 |
| 2.01-5.00 | 0 | 0.11 | 0.0013 | 0.0037 | 0 | 0 | 0.063 | 0.28 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0003 | 0 |

Table 52. Affected areas in Tarangnan, Samar during a 25-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Tarangnan (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Poblacion A | Poblacion B | Poblacion C | Poblacion D | Poblacion E | Santa Cruz | Talinga | Tizon |
| 0.03-0.20 | 0.26 | 0.28 | 0.08 | 0.26 | 0.13 | 1.42 | 2.48 | 0.16 |
| 0.21-0.50 | 0.047 | 0.039 | 0.00042 | 0.011 | 0.0058 | 0.032 | 0.3 | 0.0063 |
| 0.51-1.00 | 0.065 | 0.012 | 0.0004 | 0.0014 | 0.0023 | 0.034 | 0.32 | 0.0025 |
| 1.01-2.00 | 0.015 | 0.0001 | 0.00032 | 0.00088 | 0.0003 | 0.023 | 0.17 | 0.0021 |
| 2.01-5.00 | 0 | 0 | 0.0002 | 0 | 0 | 0.0078 | 0.012 | 0.000039 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0.000011 | 0 | 0 |

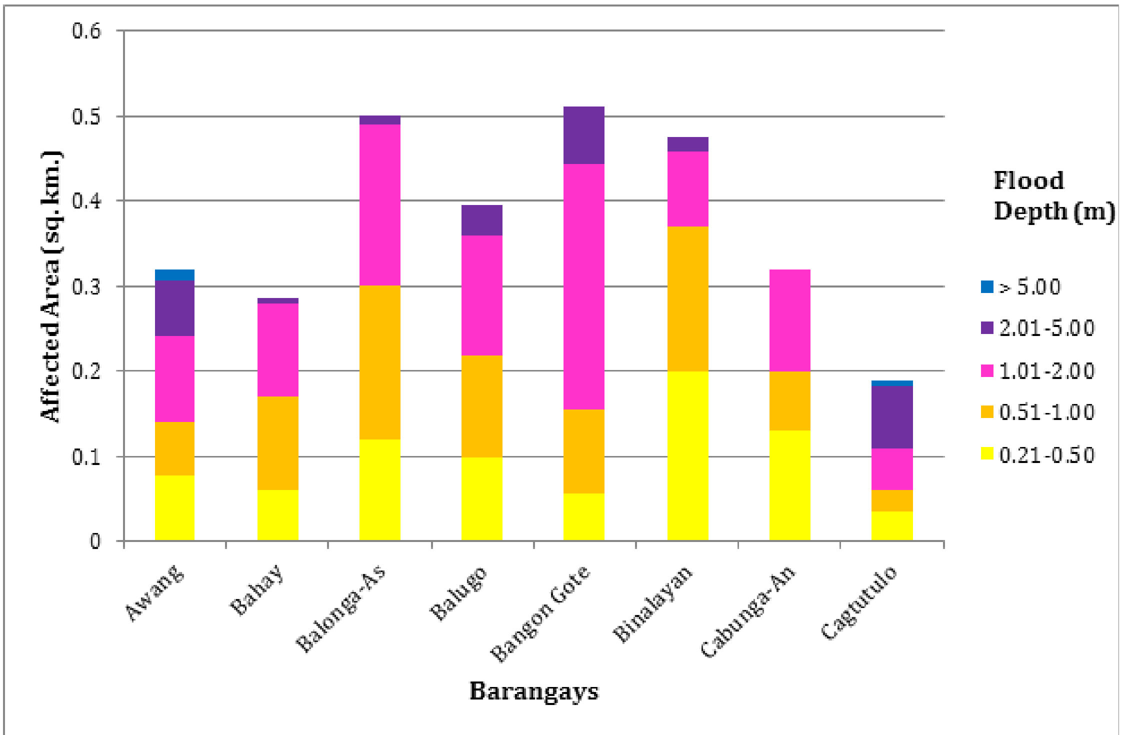


Figure 92. Affected areas in Tarangnan, Samar during a 25-Year Rainfall Return Period.

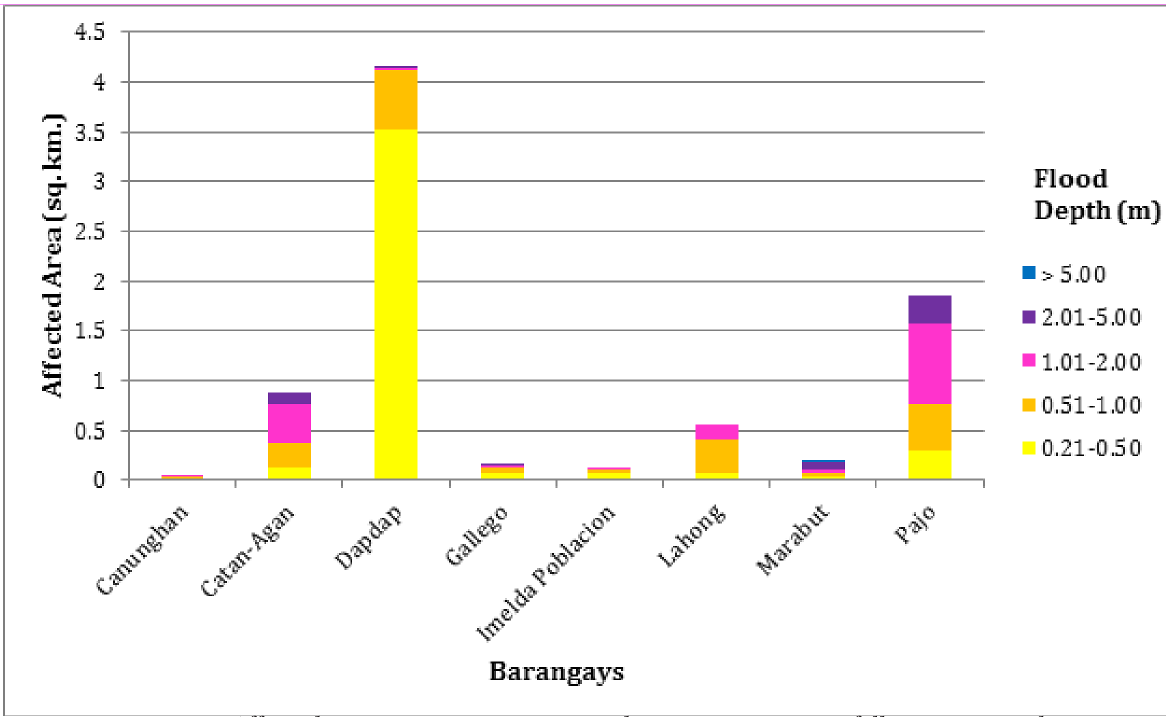



Figure 93. Affected areas in Tarangnan, Samar during a 25-Year Rainfall Return Period.

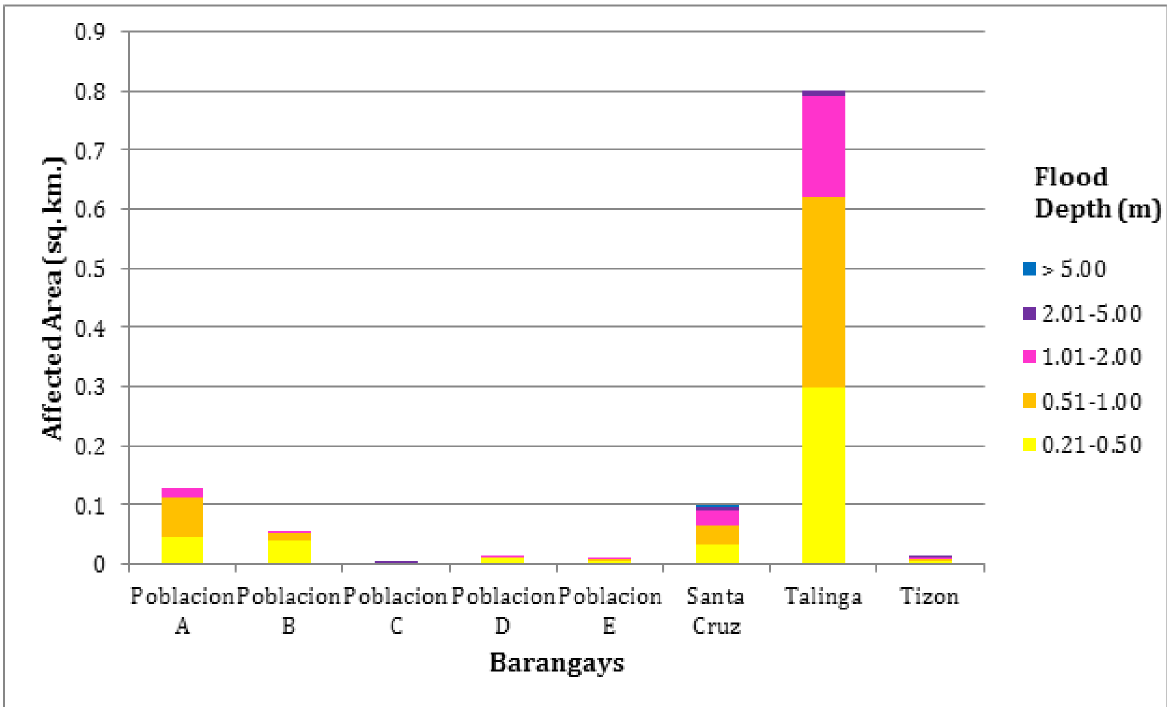



Figure 94. Affected areas in Tarangnan, Samar during a 25-Year Rainfall Return Period.

For the 100-year return period, 7.76% of the municipality of Catbalogan City with an area of 177.02 sq. km. will experience flood levels of less 0.20 meters, while 0.17% of the area will experience flood levels of 0.21 to 0.50 meters; 0.15%, 0.25%, 1.44%, and 0.48% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 50 depicts the areas affected in Catbalogan City in square kilometers by flood depth per barangay.

Table 53. Affected areas in Catbalogan City, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Catbalogan City (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Albalate | Bangon | Cagusipan | Cagutian | Palanyogon | Totoringon |
| 0.03-0.20 | 4.19 | 5.23 | 0.058 | 1.86 | 2.27 | 0.12 |
| 0.21-0.50 | 0.11 | 0.091 | 0.0039 | 0.043 | 0.044 | 0.0008 |
| 0.51-1.00 | 0.093 | 0.09 | 0.0022 | 0.041 | 0.034 | 0.0001 |
| 1.01-2.00 | 0.17 | 0.18 | 0.00028 | 0.058 | 0.04 | 0.0002 |
| 2.01-5.00 | 1.17 | 1.1 | 0 | 0.25 | 0.034 | 0.0001 |
| > 5.00 | 0.29 | 0.46 | 0 | 0.093 | 0 | 0 |

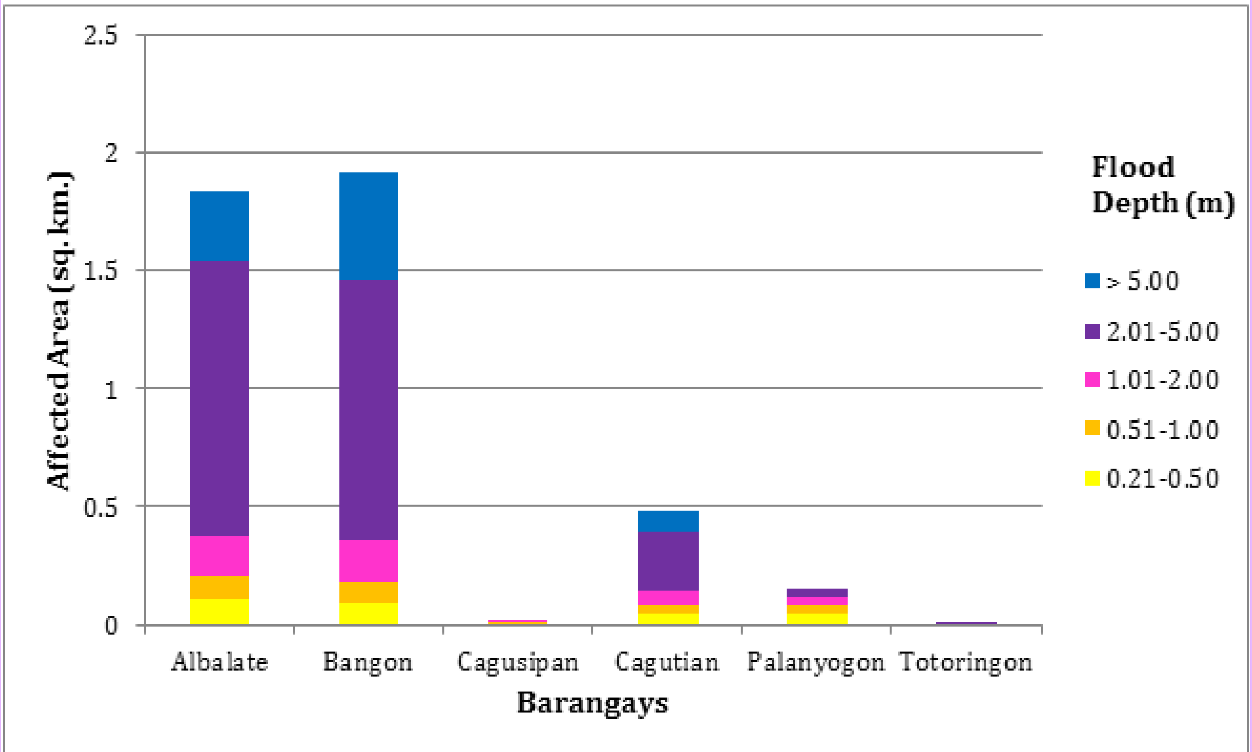



Figure 95. Affected areas in Catbalogan City, Samar during a 100-Year Rainfall Return Period.

For the municipality of Gandara, with an area of 296.92 sq. km., 21.5% will experience flood levels of less 0.20 meters. 2.16% of the area will experience flood levels of 0.21 to 0.50 meters while 1.87%, 2.72%, 3.05%, and 1.05% 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. Table 51 to Table 55 depict the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

| Affect-ed area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Adela Heights | Arong | Bangahon | Bunyagan | Calirocan | Caparan-gasan | Casab-Ahan | Casandig |
| 0.03-0.20 | 0.1 | 0.61 | 0.43 | 1.52 | 0.8 | 1.13 | 1.54 | 0.048 |
| 0.21-0.50 | 0.13 | 0.071 | 0.033 | 0.18 | 0.13 | 0.48 | 0.059 | 0.025 |
| 0.51-1.00 | 0.16 | 0.033 | 0.029 | 0.16 | 0.35 | 0.077 | 0.065 | 0.07 |
| 1.01-2.00 | 0.073 | 0.021 | 0.052 | 0.04 | 0.48 | 0.0041 | 0.14 | 0.16 |
| 2.01-5.00 | 0.028 | 0.017 | 0.8 | 0.13 | 0.085 | 0 | 0.38 | 0.54 |
| > 5.00 | 0 | 0 | 0.15 | 0.046 | 0.29 | 0 | 0.19 | 0.11 |

Table 55. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Catorse De Agosto | Concepcion | Diaz | Dumalo-Ong | Gerali | Gereganan | Hinugacan | Hiparayan |
| 0.03-0.20 | 0.81 | 1.66 | 1.47 | 0.14 | 1.68 | 0.34 | 3.16 | 0.62 |
| 0.21-0.50 | 0.071 | 0.45 | 0.062 | 0.066 | 0.063 | 0.013 | 0.15 | 0.029 |
| 0.51-1.00 | 0.03 | 0.85 | 0.038 | 0.092 | 0.058 | 0.043 | 0.26 | 0.031 |
| 1.01-2.00 | 0.015 | 1.28 | 0.085 | 0.17 | 0.087 | 0.13 | 0.67 | 0.038 |
| 2.01-5.00 | 0.048 | 0.16 | 0.094 | 0.11 | 0.046 | 0.43 | 0.98 | 0.38 |
| > 5.00 | 0.11 | 0.15 | 0.0007 | 0.021 | 0.051 | 0.097 | 0.0042 | 0.38 |

Table 56. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Jasminez | Lungib | Macugo | Malayog | Marcos | Minda | Nacube | Nalihugan |
| 0.03-0.20 | 4.61 | 0.67 | 2.47 | 0.66 | 0.46 | 0.47 | 1.42 | 0.74 |
| 0.21-0.50 | 0.23 | 0.26 | 0.081 | 0.35 | 0.083 | 0.039 | 0.3 | 0.025 |
| 0.51-1.00 | 0.21 | 0.088 | 0.056 | 0.14 | 0.075 | 0.034 | 0.61 | 0.013 |
| 1.01-2.00 | 0.32 | 0.012 | 0.092 | 0.0016 | 0.036 | 0.037 | 0.85 | 0.018 |
| 2.01-5.00 | 0.29 | 0 | 0.24 | 0 | 0.025 | 0.032 | 0.24 | 0.04 |
| > 5.00 | 0.065 | 0 | 0.094 | 0 | 0.041 | 0.07 | 0.18 | 0.004 |

Table 57. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Natimonan | Ngoso | Palanas | Pizarro | Pologon | Samoyao | San Agustin | San Miguel |
| 0.03-0.20 | 2.41 | 0.73 | 0.97 | 2.29 | 3.97 | 2.42 | 2.76 | 3.97 |
| 0.21-0.50 | 0.12 | 0.041 | 0.48 | 0.095 | 0.27 | 0.13 | 0.1 | 0.13 |
| 0.51-1.00 | 0.14 | 0.03 | 0.11 | 0.084 | 0.48 | 0.14 | 0.097 | 0.077 |
| 1.01-2.00 | 0.17 | 0.082 | 0.0054 | 0.1 | 0.95 | 0.29 | 0.2 | 0.21 |
| 2.01-5.00 | 0.38 | 0.049 | 0.000009 | 0.23 | 0.8 | 0.22 | 0.72 | 0.69 |
| > 5.00 | 0.071 | 0 | 0 | 0.28 | 0.075 | 0.0065 | 0.0083 | 0.26 |

Table 58. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Gandara (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | San Pelayo | San Ramon | Santo Niño | Sidmon | Tagnao | Tambongan |
| 0.03-0.20 | 2.42 | 0.0062 | 1.09 | 6 | 4.34 | 2.9 |
| 0.21-0.50 | 0.15 | 0 | 0.042 | 0.22 | 0.19 | 1.08 |
| 0.51-1.00 | 0.22 | 0 | 0.049 | 0.13 | 0.14 | 0.28 |
| 1.01-2.00 | 0.87 | 0 | 0.048 | 0.14 | 0.17 | 0.024 |
| 2.01-5.00 | 0.3 | 0 | 0.048 | 0.19 | 0.23 | 0.11 |
| > 5.00 | 0.19 | 0 | 0.017 | 0.011 | 0.027 | 0.11 |

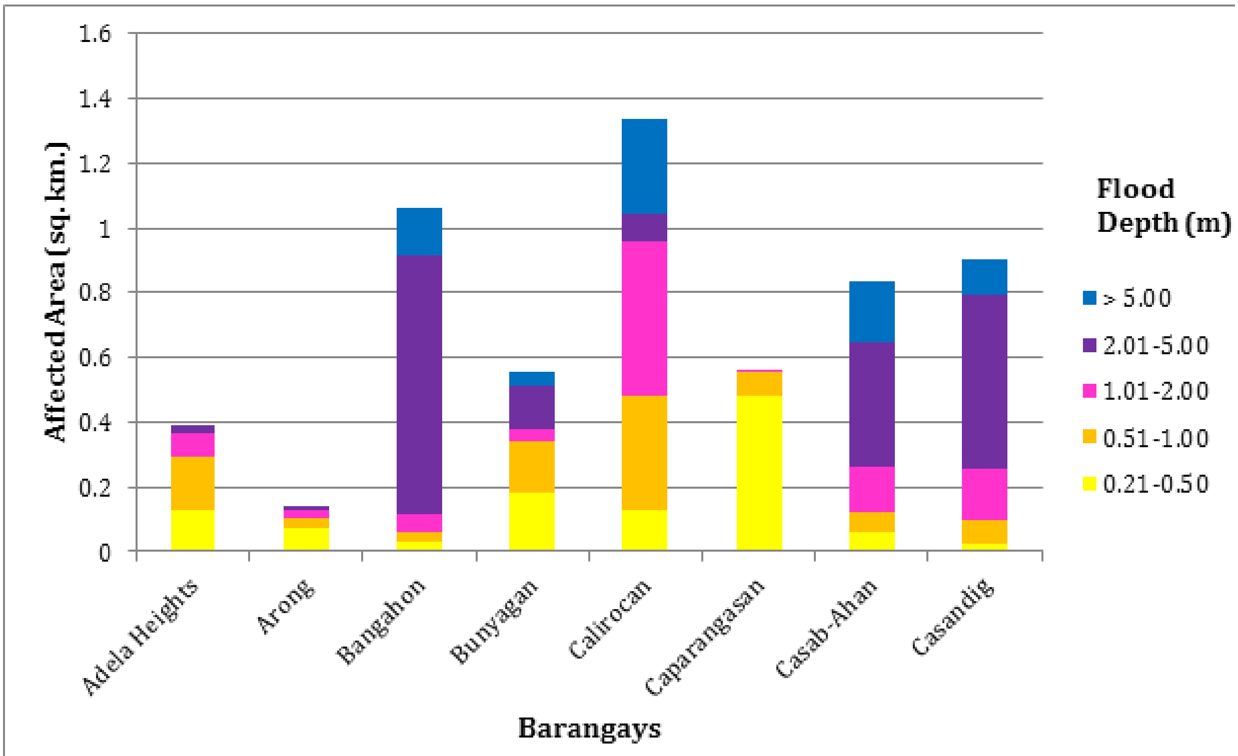



Figure 96. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

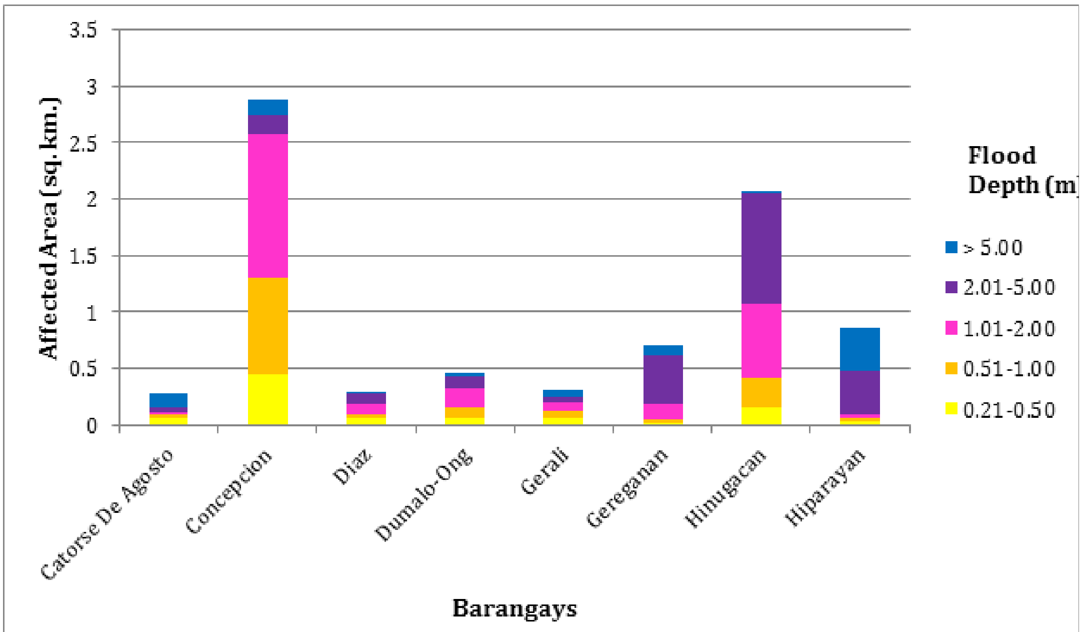



Figure 97. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

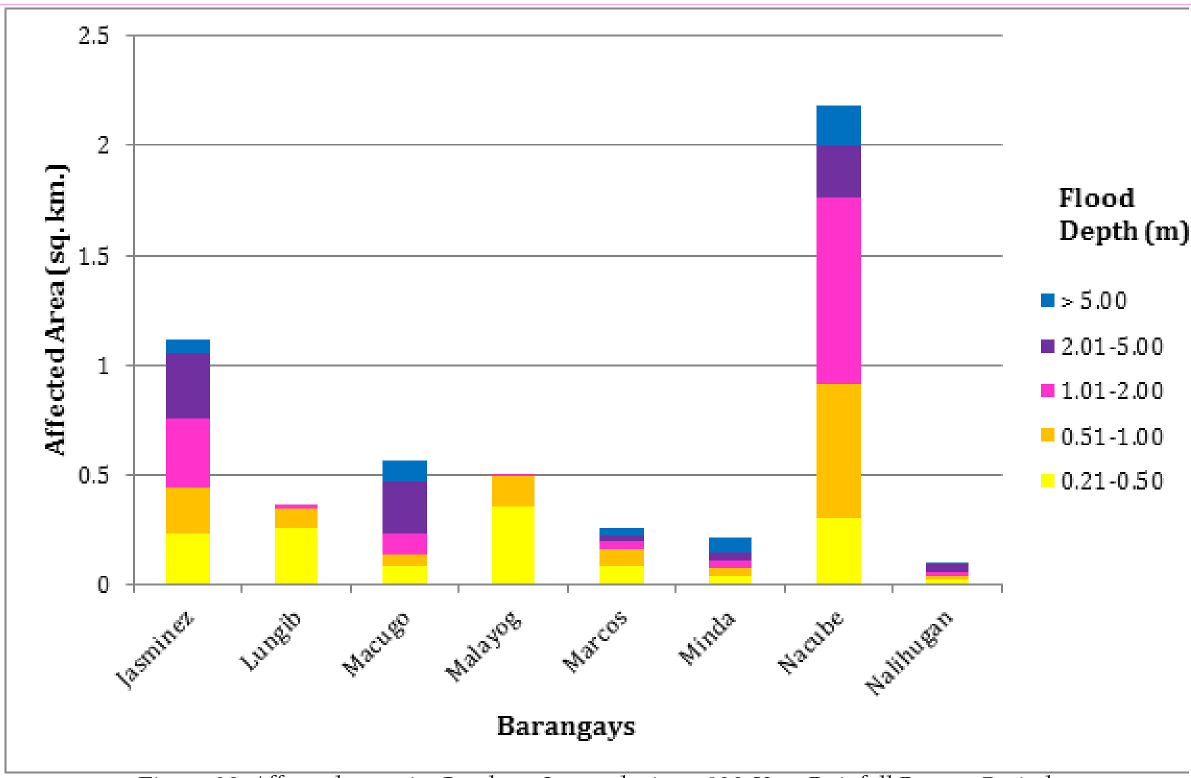



Figure 98. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

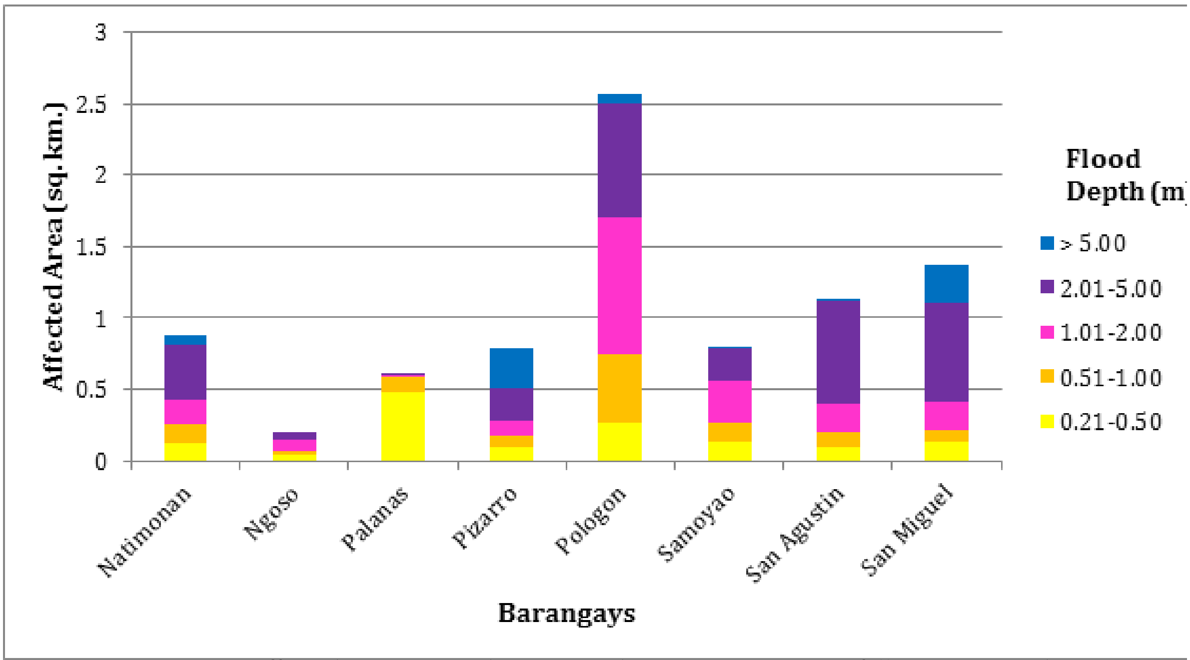



Figure 99. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

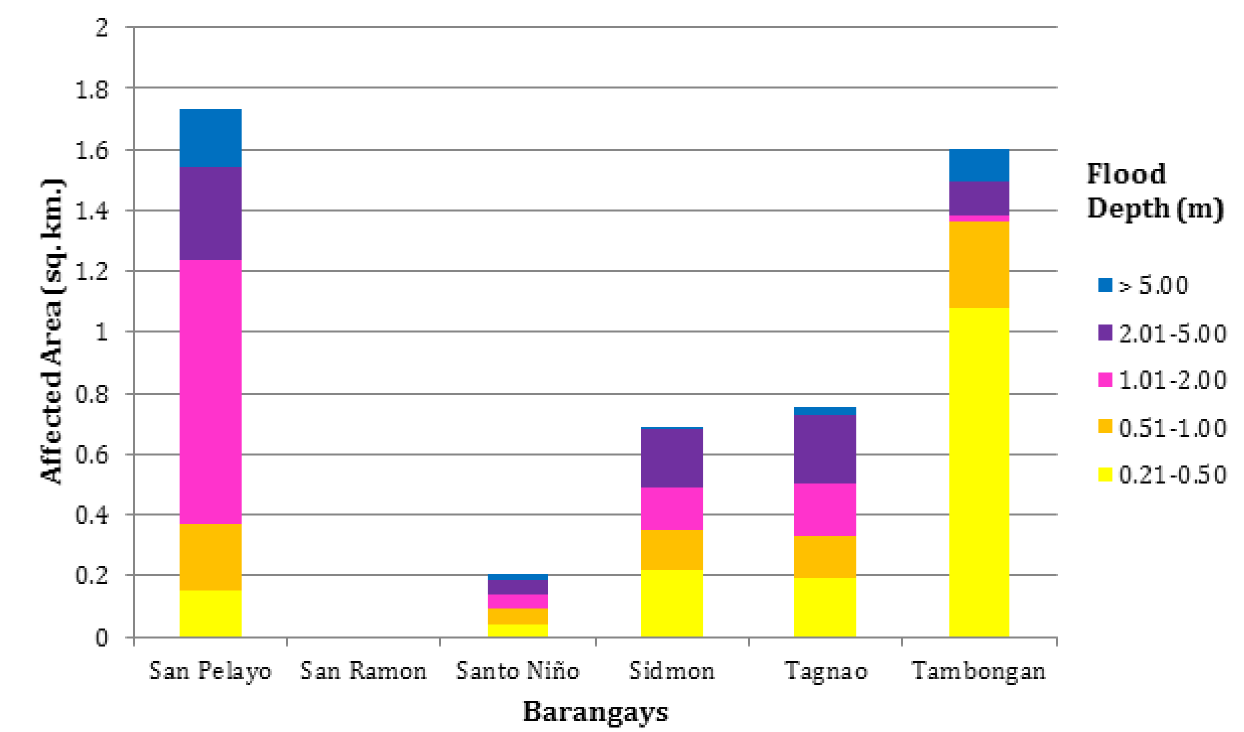



Figure 100. Affected areas in Gandara, Samar during a 100-Year Rainfall Return Period.

For the municipality of Pagsanghan, with an area of 29.46 sq. km., 63.44% will experience flood levels of less 0.20 meters. 13.56% of the area will experience flood levels of 0.21 to 0.50 meters while 11.15%, 9.07%, 1.85%, and 0.91% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 56 and Table 57 depict the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected areas in Pagsanghan, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Pagsanghan (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Bangon | Buenos Aires | Calanyugan | Caloloma | Cambaye | Canlapwas |
| 0.03-0.20 | 0.71 | 3.17 | 3.43 | 1.78 | 0.45 | 0.87 |
| 0.21-0.50 | 0.27 | 0.36 | 0.14 | 0.73 | 0.12 | 0.71 |
| 0.51-1.00 | 0.054 | 0.78 | 0.18 | 0.96 | 0.012 | 0.026 |
| 1.01-2.00 | 0.0029 | 0.7 | 0.52 | 0.41 | 0.00048 | 0 |
| 2.01-5.00 | 0 | 0.094 | 0.2 | 0.13 | 0 | 0 |
| > 5.00 | 0 | 0.051 | 0 | 0.06 | 0 | 0 |

Table 60. Affected areas in Pagsanghan, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Pagsanghan (in sq. km.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Libertad | Pañge | San Luis | Santo Niño | Viejo | Villahermosa Occidental | Villahermosa Oriental |
| 0.03-0.20 | 0.44 | 1.18 | 2.94 | 0.86 | 0.36 | 1.53 | 0.97 |
| 0.21-0.50 | 0.17 | 0.22 | 0.48 | 0.065 | 0.11 | 0.51 | 0.11 |
| 0.51-1.00 | 0.24 | 0.26 | 0.36 | 0.088 | 0.034 | 0.19 | 0.1 |
| 1.01-2.00 | 0.15 | 0.42 | 0.36 | 0.029 | 0.0042 | 0.043 | 0.033 |
| 2.01-5.00 | 0.0037 | 0.027 | 0.08 | 0.0032 | 0.0068 | 0 | 0.0001 |
| > 5.00 | 0.0011 | 0.026 | 0.13 | 0 | 0 | 0 | 0 |

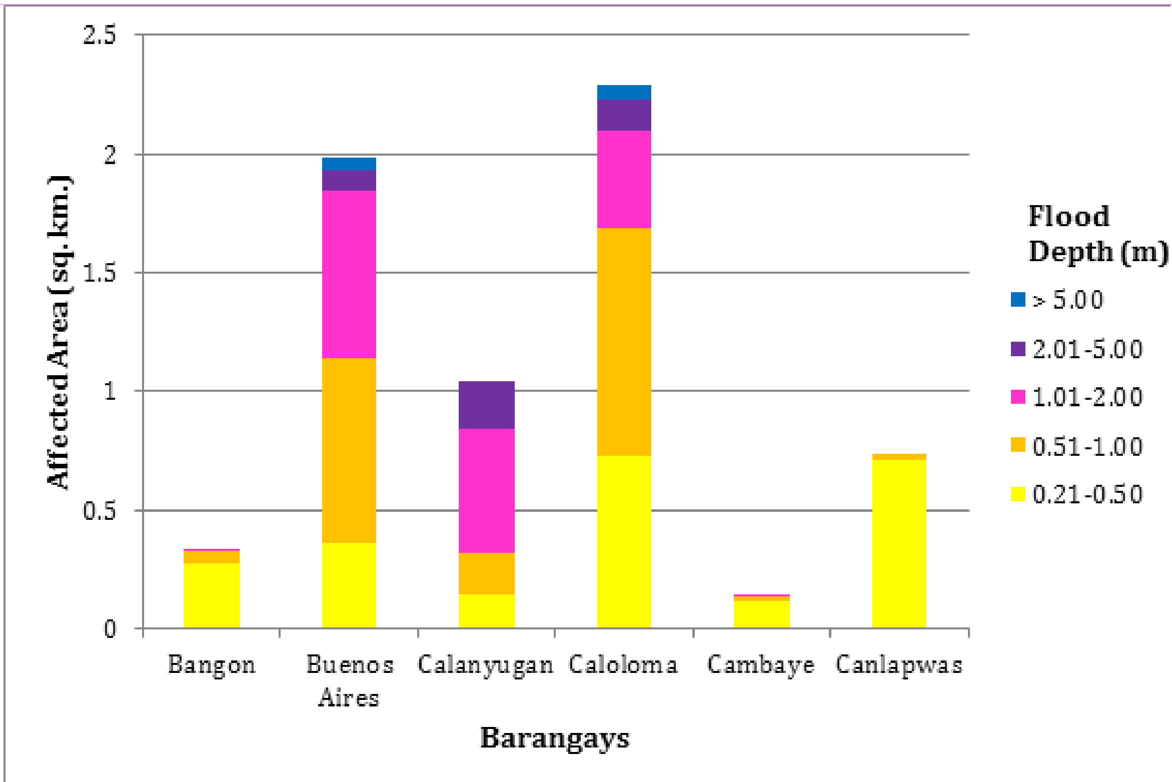



Figure 101. Affected areas in Pagsanghan, Samar during a 100-Year Rainfall Return Period.

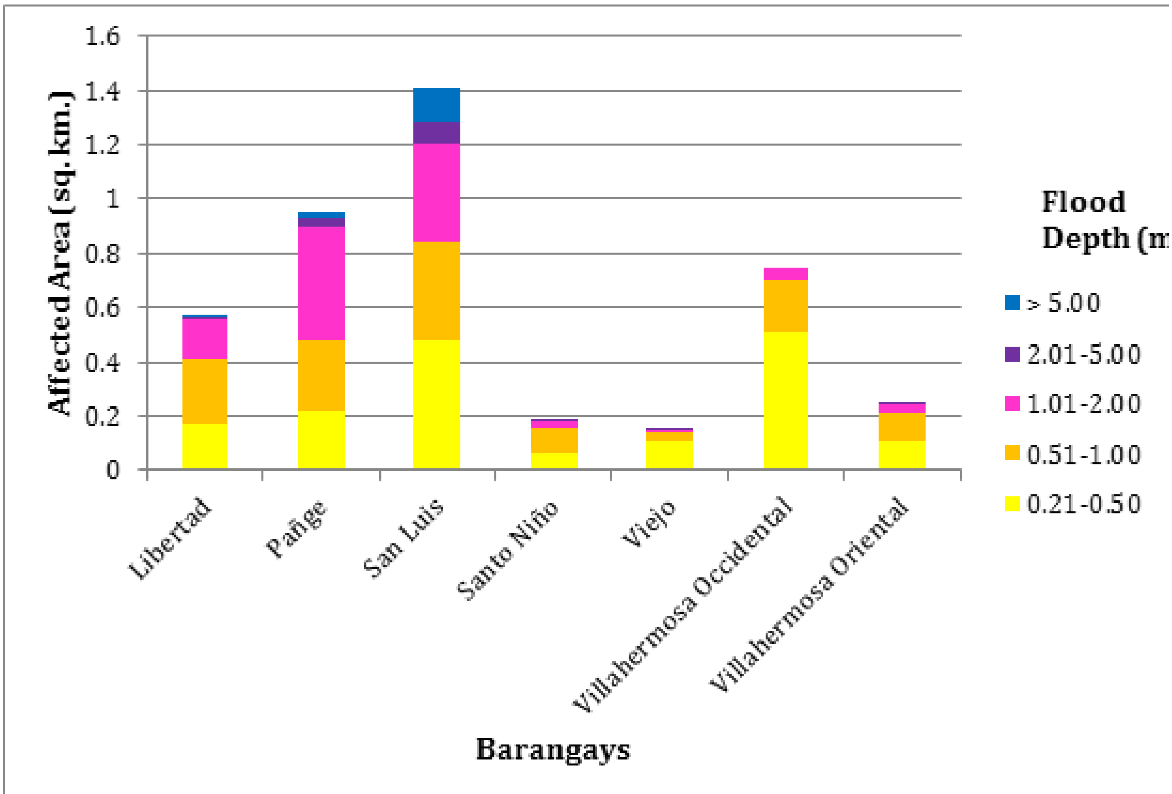



Figure 102. Affected areas in Pagsanghan, Samar during a 100-Year Rainfall Return Period.

For the municipality of San Jorge, with an area of 280.03 sq. km., 29.25% will experience flood levels of less 0.20 meters. 0.96% of the area will experience flood levels of 0.21 to 0.50 meters while 1%, 1.97%, 6.24%, and 2.46% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 58 to Table 62 depict the affected areas in square kilometers by flood depth per barangay.

Table 61. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Anquiana | Aurora | Bay-Ang | Blanca Aurora | Buenavista I | Buenavista II | Bulao | Bungliw |
| 0.03-0.20 | 0.27 | 1.83 | 3.66 | 0.78 | 4.32 | 1.63 | 1.05 | 8.59 |
| 0.21-0.50 | 0.0057 | 0.057 | 0.12 | 0.023 | 0.1 | 0.038 | 0.024 | 0.43 |
| 0.51-1.00 | 0.0061 | 0.085 | 0.14 | 0.012 | 0.079 | 0.03 | 0.027 | 0.37 |
| 1.01-2.00 | 0.016 | 0.29 | 0.15 | 0.012 | 0.12 | 0.054 | 0.046 | 0.53 |
| 2.01-5.00 | 0.2 | 0.45 | 0.071 | 0.0065 | 0.63 | 0.28 | 1.24 | 1.37 |
| > 5.00 | 0.21 | 0 | 0.048 | 0 | 1.37 | 0.32 | 0.73 | 0.41 |

Table 62. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cabugao | Cag-Olo-Olo | Calundan | Cantaguic | Canyaki | Cogtoto-og | Erenas | Gayonda-to |
| 0.03-0.20 | 3.94 | 1.12 | 0.073 | 3.93 | 1.28 | 1.37 | 0.93 | 0.6 |
| 0.21-0.50 | 0.089 | 0.034 | 0.0021 | 0.16 | 0.048 | 0.039 | 0.047 | 0.011 |
| 0.51-1.00 | 0.042 | 0.029 | 0.00032 | 0.21 | 0.065 | 0.017 | 0.032 | 0.01 |
| 1.01-2.00 | 0.049 | 0.04 | 0.0013 | 0.49 | 0.19 | 0.019 | 0.039 | 0.007 |
| 2.01-5.00 | 0.14 | 0.052 | 0 | 1.42 | 0.22 | 0.027 | 0.1 | 0.0013 |
| > 5.00 | 0.06 | 0.00042 | 0 | 0.027 | 0 | 0.24 | 0.0065 | 0 |

Table 63. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Guadalupe | Guindapunan | Hernandez | Himay | Janipon | La Paz | Libertad | Mabuhay |
| 0.03-0.20 | 1.92 | 1.09 | 0.83 | 2.47 | 1.39 | 0.79 | 5.3 | 0.77 |
| 0.21-0.50 | 0.051 | 0.031 | 0.023 | 0.069 | 0.048 | 0.026 | 0.14 | 0.021 |
| 0.51-1.00 | 0.089 | 0.036 | 0.029 | 0.05 | 0.043 | 0.03 | 0.071 | 0.031 |
| 1.01-2.00 | 0.23 | 0.11 | 0.063 | 0.076 | 0.067 | 0.056 | 0.071 | 0.089 |
| 2.01-5.00 | 1.08 | 0.97 | 0.49 | 0.065 | 0.12 | 0.98 | 0.075 | 0.24 |
| > 5.00 | 0.12 | 0.12 | 0.27 | 0 | 0.014 | 0.21 | 0.014 | 0.22 |

Table 64. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mancol | Matalud | Mombon | Puhagan | Quezon | Ranera | Rawis | Mabuhay |
| **0.03-0.20** | 0.09 | 3.12 | 0.000058 | 6.03 | 3.28 | 8.86 | 1.01 | 0.77 |
| **0.21-0.50** | 0.0014 | 0.13 | 0.0001 | 0.13 | 0.14 | 0.29 | 0.039 | 0.021 |
| **0.51-1.00** | 0.0037 | 0.05 | 0.00028 | 0.071 | 0.3 | 0.34 | 0.053 | 0.031 |
| **1.01-2.00** | 0.0072 | 0.032 | 0.0017 | 0.091 | 0.54 | 0.9 | 0.11 | 0.089 |
| **2.01-5.00** | 0.39 | 0.022 | 0.96 | 0.27 | 0.17 | 1.84 | 1.26 | 0.24 |
| **> 5.00** | 0.084 | 0 | 0.19 | 0.41 | 0 | 1.18 | 0.13 | 0.22 |

Table 65. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in San Jorge (in sq. km.) | | | | | |
|---|---|---|---|---|---|---|
| | Rosalim | San Isidro | San Jorge I | San Jorge II | San Juan | Sapinit |
| **0.03-0.20** | 2.01 | 0.82 | 0.44 | 0.42 | 0.44 | 0.68 |
| **0.21-0.50** | 0.074 | 0.018 | 0.015 | 0.0079 | 0.012 | 0.016 |
| **0.51-1.00** | 0.1 | 0.024 | 0.014 | 0.0094 | 0.016 | 0.023 |
| **1.01-2.00** | 0.22 | 0.056 | 0.031 | 0.037 | 0.037 | 0.06 |
| **2.01-5.00** | 0.3 | 0.41 | 0.069 | 0.16 | 0.44 | 0.27 |
| **> 5.00** | 0 | 0.072 | 0.044 | 0.11 | 0.084 | 0.19 |

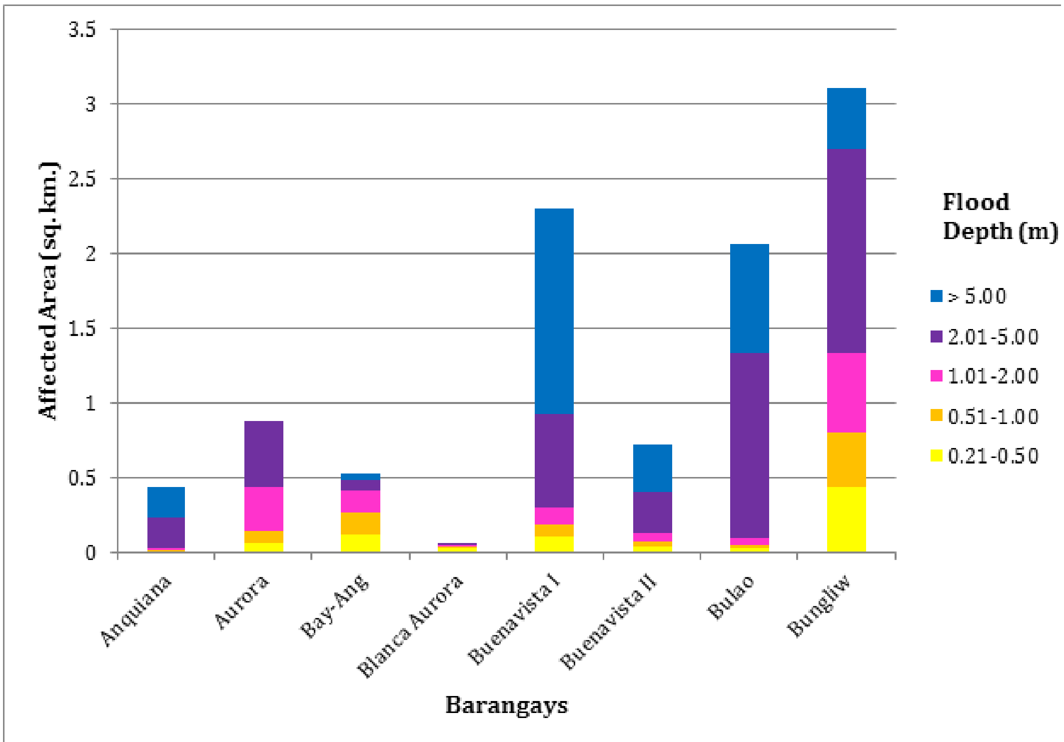



Figure 103. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

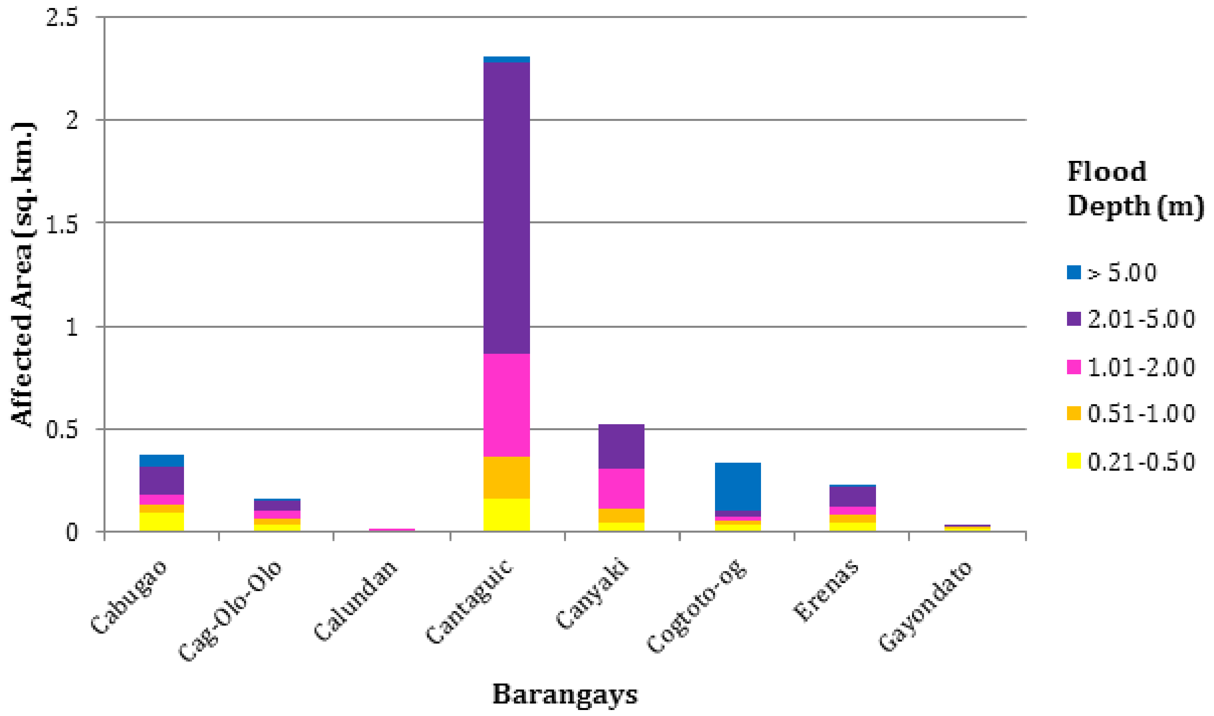



Figure 104. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

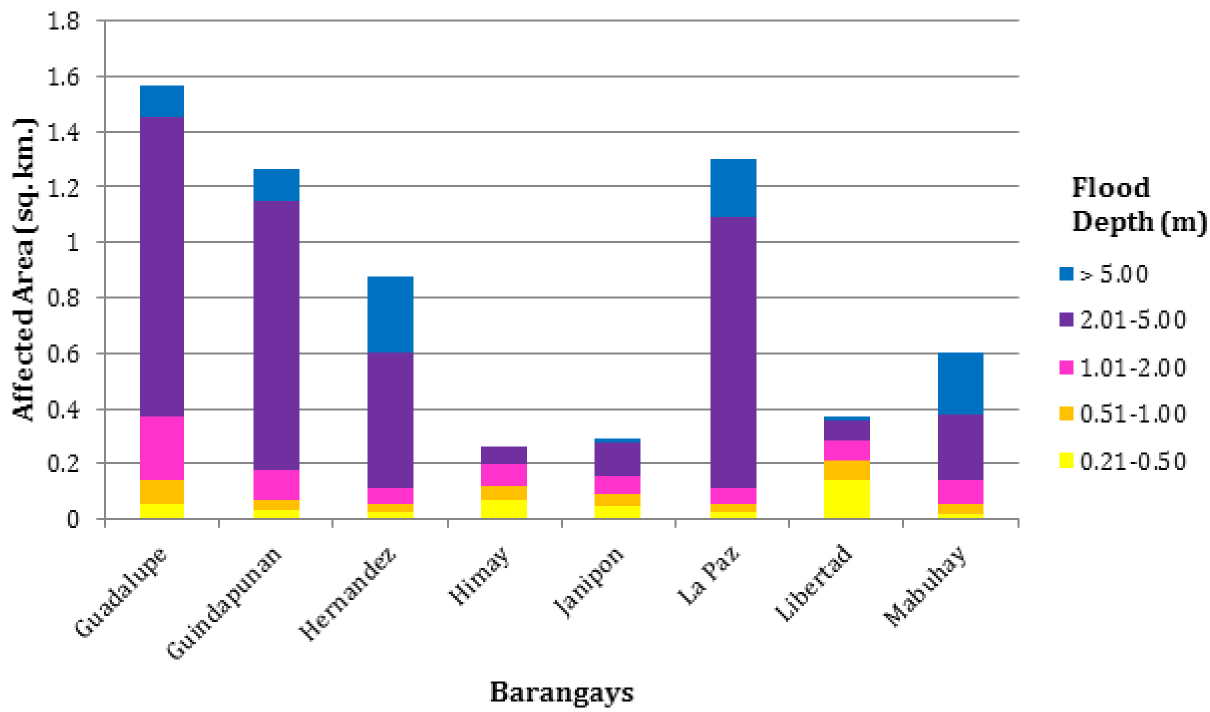



Figure 105. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

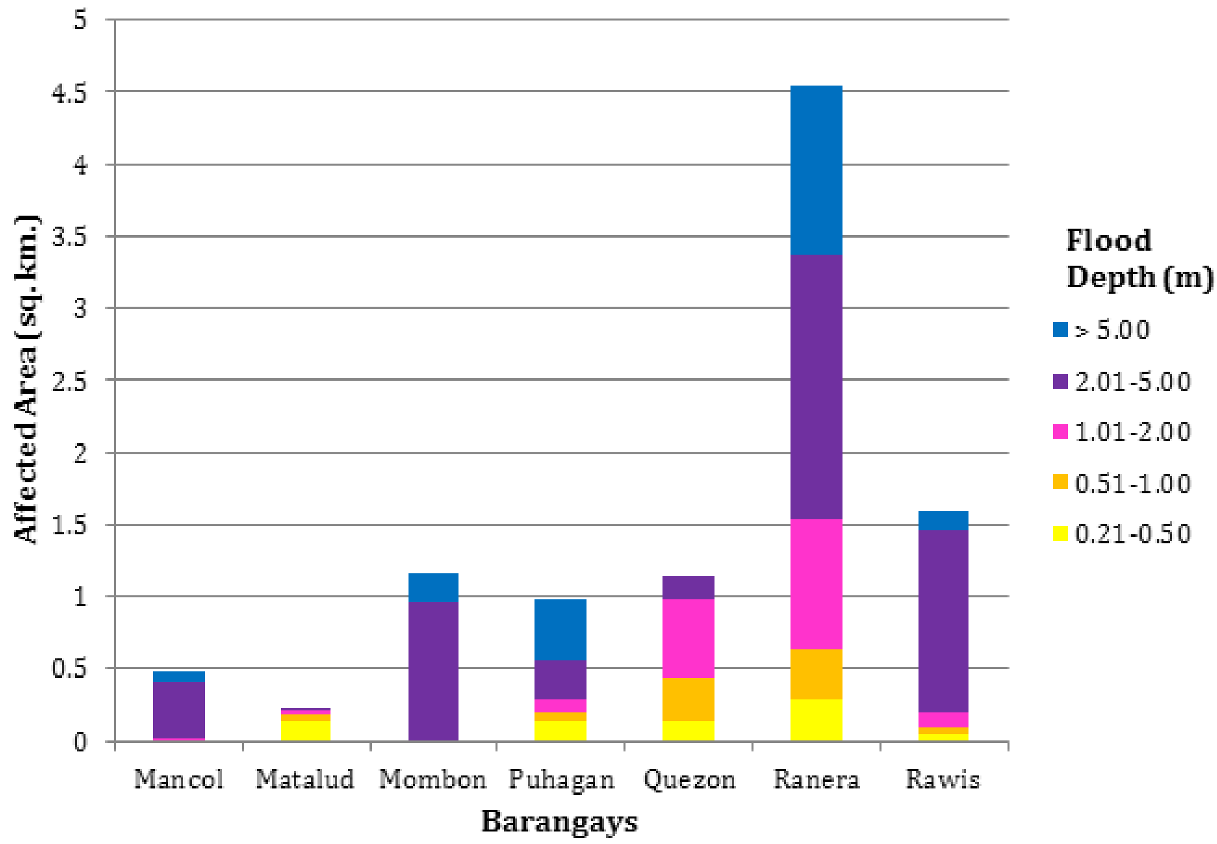



Figure 106. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

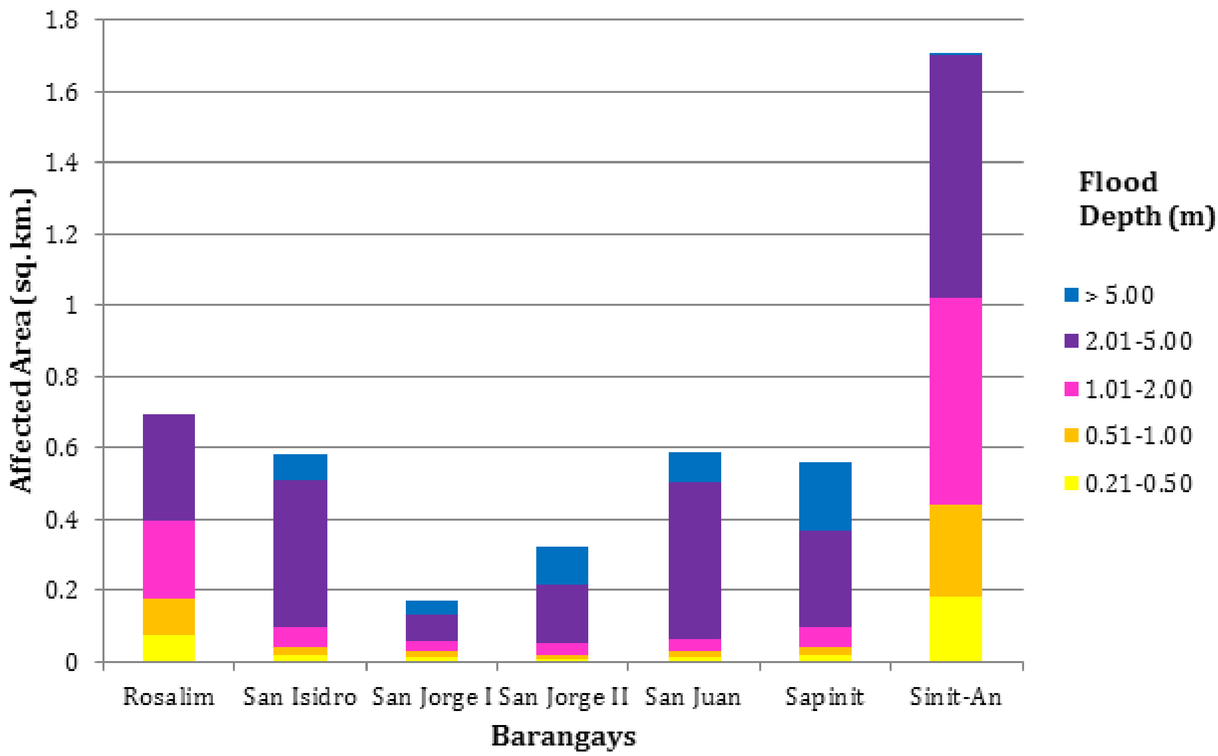



Figure 107. Affected areas in San Jorge, Samar during a 100-Year Rainfall Return Period.

For the municipality of Santa Margarita, with an area of 130.73 sq. km., 4.41% will experience flood levels of less 0.20 meters. 0.56% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.17%, 0.08%, 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. Table 63 depicts the affected areas in square kilometers by flood depth per barangay.

Table 66. Affected areas in Santa Margarita, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq.km.) by flood depth (in m.) | Area of affected barangays in Santa Margarita (in sq. km.) | | | | |
|---|---|---|---|---|---|
| | Balud | Ilo | Nabulo | Panabatan | Sundara |
| 0.03-0.20 | 0.92 | 0.021 | 4.15 | 0.098 | 0.57 |
| 0.21-0.50 | 0.033 | 0 | 0.12 | 0.19 | 0.39 |
| 0.51-1.00 | 0.048 | 0 | 0.09 | 0 | 0.021 |
| 1.01-2.00 | 0.12 | 0 | 0.096 | 0 | 0 |
| 2.01-5.00 | 0.015 | 0 | 0.086 | 0 | 0 |
| > 5.00 | 0 | 0 | 0.00088 | 0 | 0 |

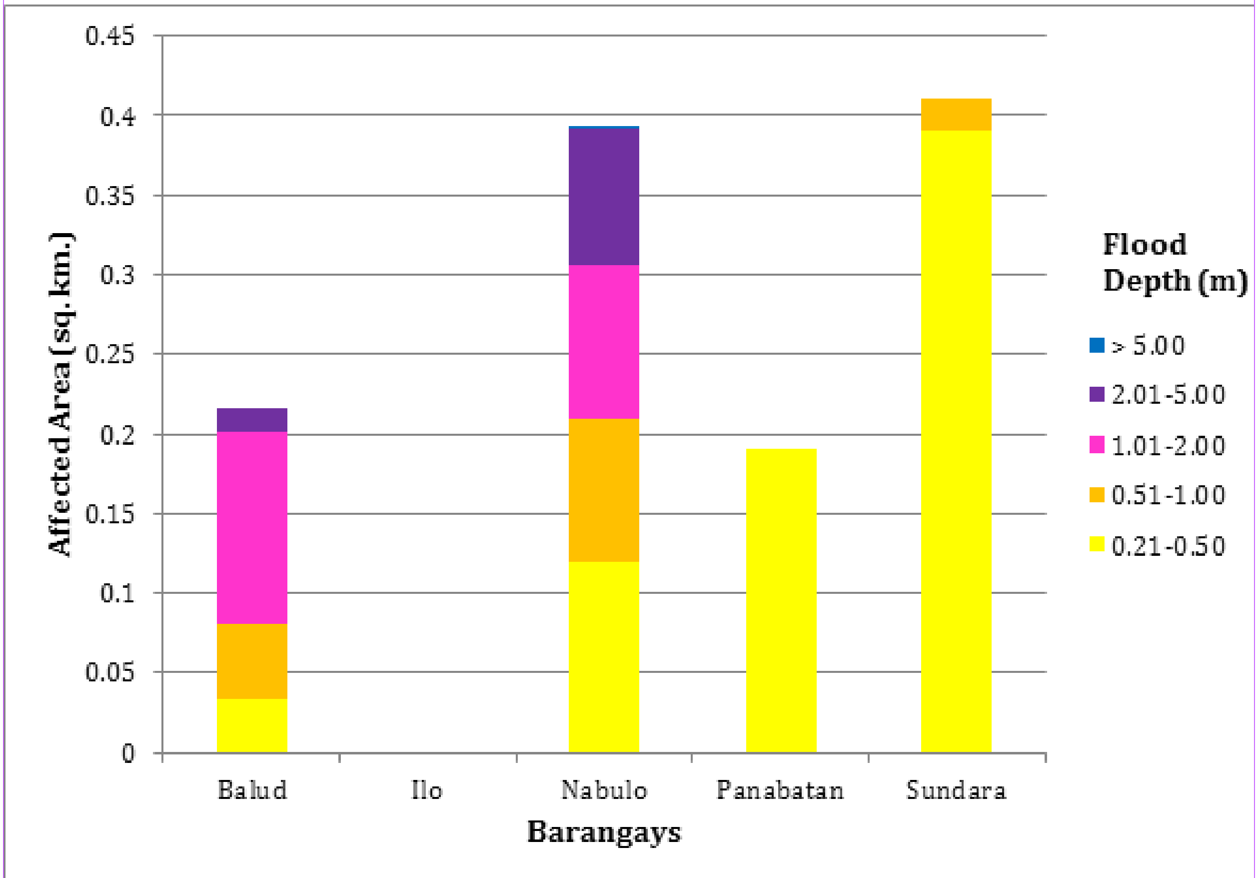



Figure 108. Affected areas in Santa Margarita, Samar during a 100-Year Rainfall Return Period.

For the municipality of Tarangnan, with an area of 89.57 sq. km., 45.23% will experience flood levels of less 0.20 meters. 5.86% of the area will experience flood levels of 0.21 to 0.50 meters while 3.58%, 3.52%, 1.39%, and 0.04%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 64 to Table 66 depicts the affected areas in square kilometers by flood depth per barangay.

Table 67. Affected areas in Tarangnan, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Tarangnan (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Awang | Bahay | Balonga-As | Balugo | Bangon Gote | Binalayan | Cabunga-An | Cagtutulo |
| 0.03-0.20 | 3.31 | 1.76 | 1.84 | 3.36 | 1.35 | 3.43 | 1.49 | 1.29 |
| 0.21-0.50 | 0.076 | 0.059 | 0.1 | 0.1 | 0.053 | 0.19 | 0.16 | 0.034 |
| 0.51-1.00 | 0.064 | 0.092 | 0.16 | 0.1 | 0.076 | 0.18 | 0.055 | 0.025 |
| 1.01-2.00 | 0.1 | 0.13 | 0.24 | 0.16 | 0.33 | 0.11 | 0.15 | 0.046 |
| 2.01-5.00 | 0.085 | 0.015 | 0.024 | 0.054 | 0.077 | 0.029 | 0 | 0.088 |
| > 5.00 | 0.019 | 0 | 0 | 0 | 0 | 0 | 0 | 0.012 |

Table 68. Affected areas in Tarangnan, Samar during a 100-Year Rainfall Return Period.

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Tarangnan (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Canunghan | Catan-Agan | Dapdap | Gallego | Imelda Poblacion | Lahong | Marabut | Pajo |
| 0.03-0.20 | 0.7 | 3.34 | 2.56 | 2.01 | 0.53 | 0.73 | 1.81 | 6.01 |
| 0.21-0.50 | 0.017 | 0.12 | 3.49 | 0.069 | 0.071 | 0.056 | 0.031 | 0.26 |
| 0.51-1.00 | 0.023 | 0.18 | 0.96 | 0.055 | 0.042 | 0.27 | 0.03 | 0.4 |
| 1.01-2.00 | 0.006 | 0.43 | 0.048 | 0.029 | 0.014 | 0.27 | 0.051 | 0.74 |
| 2.01-5.00 | 0.0001 | 0.2 | 0.0018 | 0.0058 | 0 | 0 | 0.075 | 0.56 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0015 | 0 |

Table 69. Affected areas in Tarangnan, Samar during a 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth (in m.) | Area of affected barangays in Tarangnan (in sq. km.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Poblacion A | Poblacion B | Poblacion C | Poblacion D | Poblacion E | Santa Cruz | Talinga | Tizon |
| 0.03-0.20 | 0.24 | 0.28 | 0.079 | 0.26 | 0.13 | 1.4 | 2.44 | 0.16 |
| 0.21-0.50 | 0.043 | 0.041 | 0.00063 | 0.015 | 0.0082 | 0.036 | 0.21 | 0.0068 |
| 0.51-1.00 | 0.069 | 0.016 | 0.0004 | 0.0018 | 0.0025 | 0.034 | 0.37 | 0.003 |
| 1.01-2.00 | 0.025 | 0.0001 | 0.00052 | 0.0011 | 0.0005 | 0.026 | 0.24 | 0.0022 |
| 2.01-5.00 | 0 | 0 | 0.0002 | 0 | 0 | 0.011 | 0.016 | 0.00014 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0.00013 | 0 | 0 |

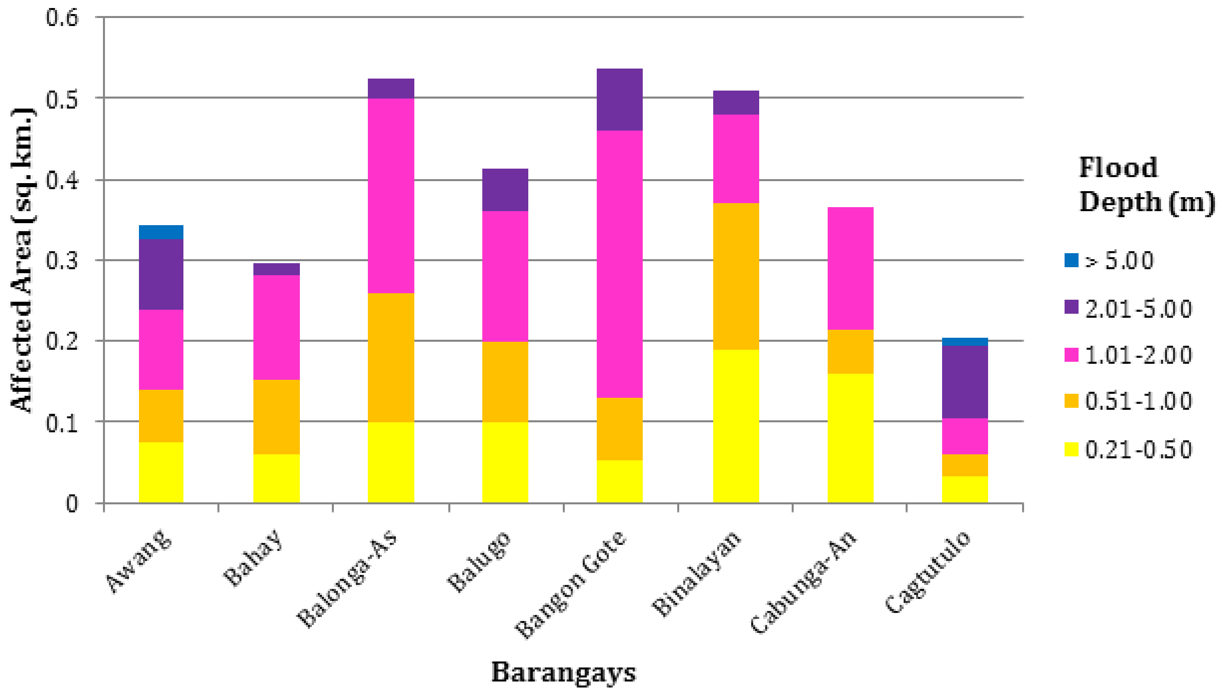



Figure 109. Affected areas in Tarangnan, Samar during a 100-Year Rainfall Return Period.

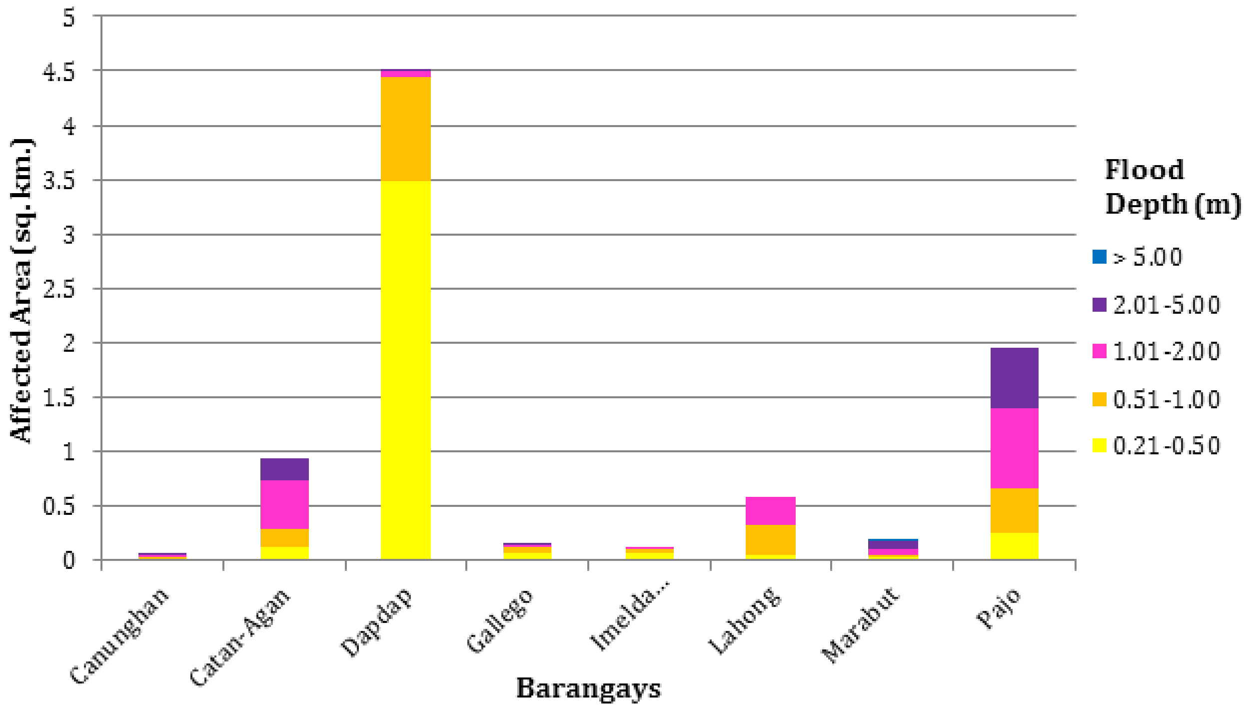



Figure 110. Affected areas in Tarangnan, Samar during a 100-Year Rainfall Return Period.

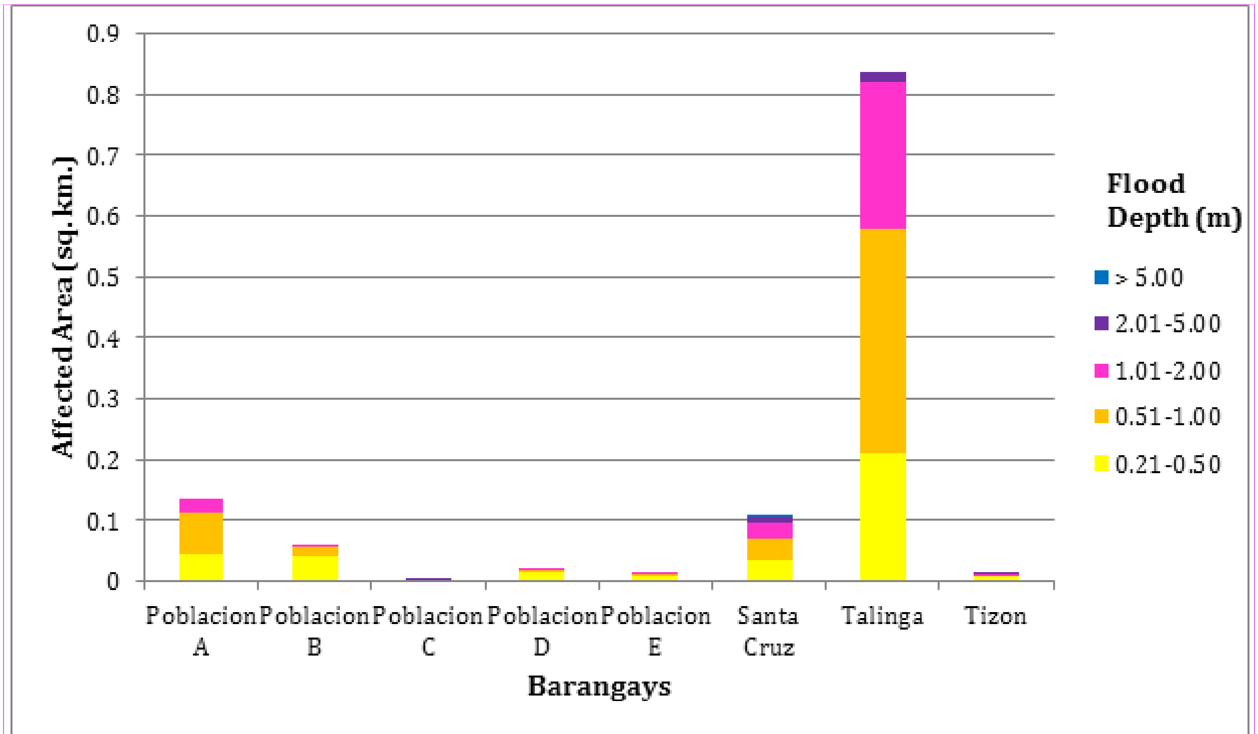



Figure 111. Affected areas in Tarangnan, Samar during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Catbalogan City, Bangon is projected to have the highest percentage of area that will experience flood levels of at 4.03%. On the other hand, Albalate posted the percentage of area that may be affected by flood depths of at 3.4%.

Among the barangays in the municipality of Gandara, Pologon is projected to have the highest percentage of area that will experience flood levels of at 2.2%. On the other hand, Jasminez posted the percentage of area that may be affected by flood depths of at 1.93%.

Among the barangays in the municipality of Pagsanghan, Buenos Aires is projected to have the highest percentage of area that will experience flood levels of at 17.51%. On the other hand, Calanyugan posted the percentage of area that may be affected by flood depths of at 15.13%.

Among the barangays in the municipality of San Jorge, Ranera is projected to have the highest percentage of area that will experience flood levels of at 4.79%. On the other hand, Bungliw posted the percentage of area that may be affected by flood depths of at 4.18%.

Among the barangays in the municipality of Santa Margarita, Nabulo is projected to have the highest percentage of area that will experience flood levels of at 3.47%. On the other hand, Balud posted the percentage of area that may be affected by flood depths of at 0.87%.

Among the barangays in the municipality of Tarangnan, Pajo is projected to have the highest percentage of area that will experience flood levels of at 8.88%. On the other hand, Dapdap posted the percentage of area that may be affected by flood depths of at 7.88%.

Moreover, the generated flood hazard maps for the Gandara 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 70. Area covered by each warning level with respect to the rainfall scenarios

| Warning Level | Area Covered in sq. km. | | |
|---|---|---|---|
| | 5 year | 25 year | 100 year |
| Low | 22.02 | 21.55 | 20.32 |
| Medium | 29.44 | 29.03 | 28.67 |
| High | 23.40 | 41.80 | 52.07 |
| **TOTAL** | **74.86** | **92.38** | **101.06** |

Of the 14 identified Education Institutions in Gandara Flood plain, 3 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 2 were assessed to be exposed to Medium level flooding in the same scenario. In the 25 year scenario, 1 schools were assessed to be exposed to the Medium level flooding while 4 schools were assessed to be exposed to High level flooding. For the 100 year scenario, 2 schools were assessed for Low level flooding and 2 schools for Medium level flooding. In the same scenario, 4 school were assessed to be exposed to High level flooding. See Annex 12 for a detailed enumeration of schools inside Gandara floodplain.

Of the 5 identified Medical Institutions in Gandara Flood plain, 1 was assessed to be exposed to the Low level flooding during a 25 year scenario. In the 100 year scenario, 1 was assessed to be exposed to the Low level flooding while 2 were assessed to be exposed to High level flooding. See Annex 13 for a detailed enumeration of medical institutions inside Gandara floodplain.

## 5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 111.

The flood validation consists of 75 points randomly selected all over the Dipolog flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.35 m. Table 35 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

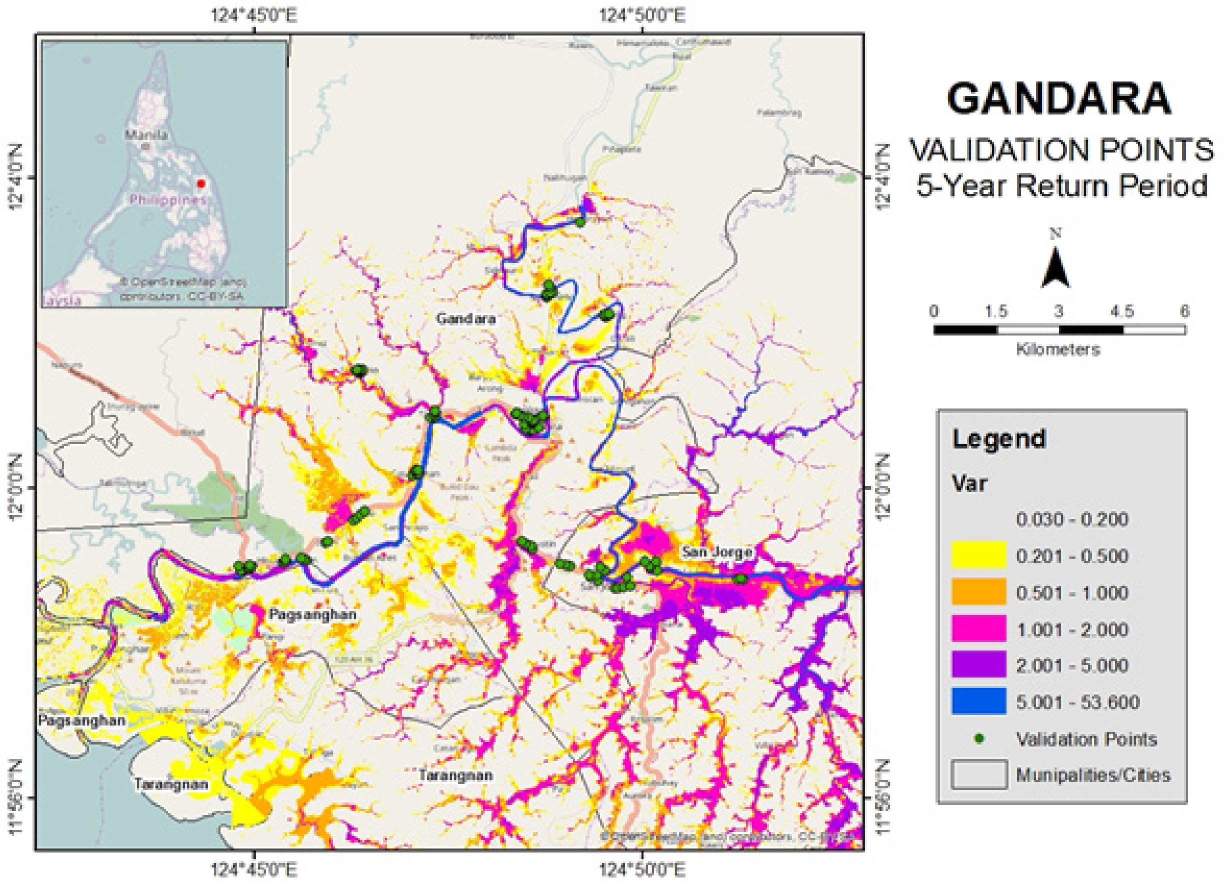



Figure 112. Validation Points for a 5-year Flood Depth Map of the Gandara Floodplain.

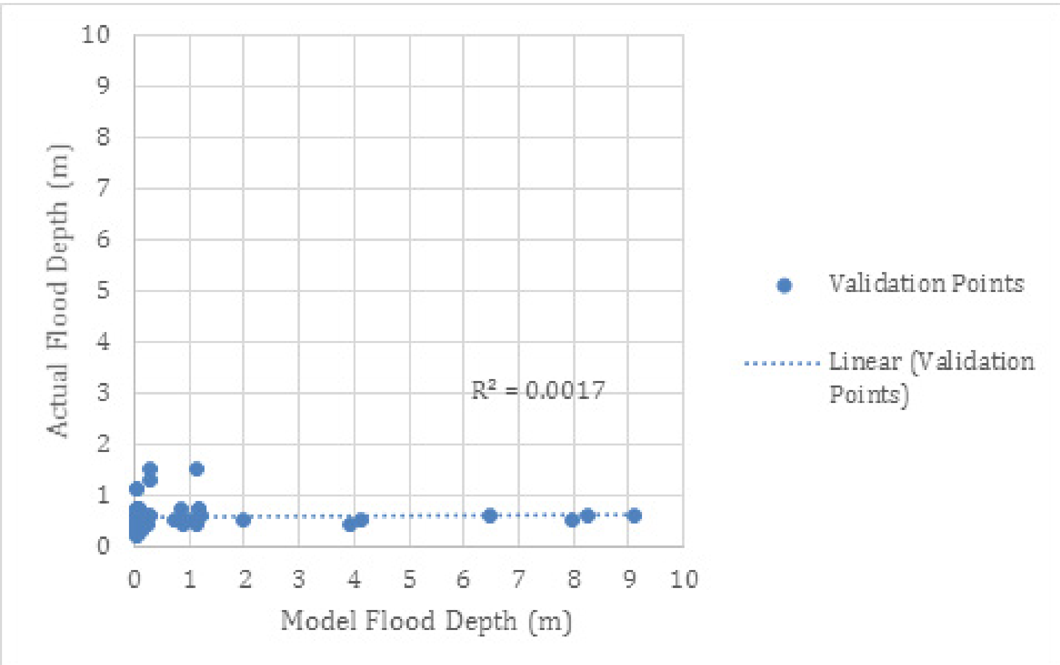



Figure 113. Flood map depth versus actual flood depth.

Table 71. Actual Flood Depth versus Simulated Flood Depth at different levels in the Gandara River Basin.

| Actual Flood Depth (m) / GANDARA BASIN | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-0.20 | 0.21-0.50 | 0.51-1.00 | 1.01-2.00 | 2.01-5.00 | > 5.00 | Total |
| 0-0.20 | 52 | 20 | 25 | 11 | 13 | 0 | 121 |
| 0.21-0.50 | 1 | 2 | 2 | 2 | 7 | 0 | 14 |
| 0.51-1.00 | 1 | 0 | 0 | 11 | 5 | 0 | 17 |
| 1.01-2.00 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 2.01-5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 54 | 22 | 27 | 24 | 26 | 0 | 153 |

The overall accuracy generated by the flood model is estimated at 6.67% with 5 points correctly matching the actual flood depths. In addition, there were 44 points estimated one level above and below the correct flood depths while there were 16 points and 8 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 55 points were underestimated in the modelled flood depths of Gandara.

Table 69 depicts the summary of the Accuracy Assessment in the Gandara River Basin Flood Depth Map.

Table 72. Actual flood vs simulated flood depth at different levels in the Lun Masla River Basin.

| | No. of Points | % |
|---|---|---|
| Correct | 5 | **6.67** |
| Overestimated | 15 | 20.00 |
| Underestimated | 55 | 73.33 |
| Total | 75 | 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)

# ANNEXES

## Annex 1. Optech Technical Specification of the Aquarius Sensor

Table A-1.1. Parameters and Specifications of ALS80 Sensor

| Parameter | Specification |
|---|---|
| Operational altitude | 100 to 3500 m max AGL |
| Maximum measurement rate | 1000 kHz |
| Maximum scan rate | 200 Hz for sine; 158 for triangle;120 for raster |
| Field of view (degrees, full angle, user-adjustable) | 0 to 72 |
| Roll Stabilization (automatic adaptive, degrees) | 72 – active FOV |
| Number of returns | unlimited |
| Number of intensity measurements | 3(first, second and third) |
| Data Storage | ALS80: removable SSD hard disk (800GB each volume) |
| Power Consumption | 922 W @ 22.0 -30.3 VDC |
| Dimensions and weight | Scanner:37 W x 68 L x 26 H cm; 47 kg; |
| Operating temperature | Control Electronics: 45 W x 47 D x 25 H cm; 33 kg |
| | 0-40˚C |

# Annex 2. NAMRIA Certificate of Reference Points Used in the LiDAR Survey

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

1. ASMR-33A

**Vector Components (Mark to Mark)**

| From: | SMR-33 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 680286.501 m | Latitude | N12°02'19.48512" | Latitude | N12°02'14.98810" |
| Northing | 1331298.782 m | Longitude | E124°39'22.13923" | Longitude | E124°39'27.22840" |
| Elevation | 4.559 m | Height | 4.974 m | Height | 64.378 m |

| To: | Established-1 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 672169.393 m | Latitude | N12°04'06.98588" | Latitude | N12°04'02.47512" |
| Northing | 1334554.024 m | Longitude | E124°34'54.39749" | Longitude | E124°34'59.48472" |
| Elevation | 5.112 m | Height | 5.512 m | Height | 64.658 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -8117.107 m | NS Fwd Azimuth | 292°11'54" | ΔX | 7055.762 m |
| ΔNorthing | 3255.242 m | Ellipsoid Dist. | 8745.652 m | ΔY | 4033.409 m |
| ΔElevation | 0.552 m | ΔHeight | 0.538 m | ΔZ | 3230.203 m |

**Standard Errors**

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.003 m | σ NS fwd Azimuth | 0°00'00" | σ ΔX | 0.008 m |
| σ ΔNorthing | 0.003 m | σ Ellipsoid Dist. | 0.004 m | σ ΔY | 0.014 m |
| σ ΔElevation | 0.017 m | σ ΔHeight | 0.017 m | σ ΔZ | 0.006 m |

**Aposteriori Covariance Matrix (Meter²)**

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000678489 | | |
| Y | -0.0001087526 | 0.0002021737 | |
| Z | -0.0000413164 | 0.0000775710 | 0.0000377481 |

Figure A-3.1. Established SMR-33A Control point

2. SMR-33B

**Vector Components (Mark to Mark)**

| From: | SMR-33 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 680286.501 m | Latitude | N12°02'19.48512" | Latitude | N12°02'14.98810" |
| Northing | 1331298.782 m | Longitude | E124°39'22.13923" | Longitude | E124°39'27.22840" |
| Elevation | 4.559 m | Height | 4.974 m | Height | 64.378 m |

| To: | Established-2 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 672198.738 m | Latitude | N12°04'07.12856" | Latitude | N12°04'02.61782" |
| Northing | 1334558.577 m | Longitude | E124°34'55.36866" | Longitude | E124°35'00.45589" |
| Elevation | 5.317 m | Height | 5.717 m | Height | 64.863 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | -8087.762 m | NS Fwd Azimuth | 292°17'53" | ΔX | 7031.987 m |
| ΔNorthing | 3259.796 m | Ellipsoid Dist. | 8720.123 m | ΔY | 4016.149 m |
| ΔElevation | 0.758 m | ΔHeight | 0.743 m | ΔZ | 3234.534 m |

**Standard Errors**

| Vector errors: | | | | | |
|---|---|---|---|---|---|
| σ ΔEasting | 0.002 m | σ NS fwd Azimuth | 0°00'00" | σ ΔX | 0.005 m |
| σ ΔNorthing | 0.001 m | σ Ellipsoid Dist. | 0.002 m | σ ΔY | 0.007 m |
| σ ΔElevation | 0.009 m | σ ΔHeight | 0.009 m | σ ΔZ | 0.002 m |

**Aposteriori Covariance Matrix (Meter²)**

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000217539 | | |
| Y | -0.0000322317 | 0.0000554524 | |
| Z | -0.0000095804 | 0.0000159517 | 0.0000058465 |

Figure A-3.2. Established SMR-33B Control point

# Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

| Data Acquisition Component | 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. LOUIE P. BALICANTA | |
| Survey Supervisor | Chief Science Research Specialist (CSRS) | ENGR. CHRISTOPHER CRUZ | |
| | Supervising Science Research Specialist (Supervising SRS) | LOVELY GRACIA ACUÑA | |
| | | ENGR. GEROME HIPOLITO | |
| FIELD TEAM | | | |
| LiDAR Operation | Senior Science Research Specialist (SSRS) | JASMIN ALVIAR | UP-TCAGP |
| | Research Associate (RA) | JASMIN DOMINGO | |
| | | SANDRA POBLETE | |
| Ground Survey, Data Download and Transfer | RA | JONATHAN ALMALVEZ | |
| LiDAR Operation | Airborne Security | TSG. SANDY UY | PHILIPPINE AIR FORCE (PAF) |
| | Pilot | CAPT. KHALIL ANTONY CHI | ASIAN AEROSPACE CORPORATION (AAC) |
| | | CAPT. GEO VILLACASTIN | |

# Annex 5. Data Transfer Sheets

DATA TRANSFER SHEET
CALBAYOG 11/25/2016

| DATE | FLIGHT NO. | MISSION NAME | SENSOR | KML (swath) | GnssImu | LogFiles | TestData | RawLaser | RawTDC | RawWFD | WebCam | RCD30 RAW IMAGES | BASE STATION(S) | | SERVER LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | BASE STATION(S) | Base Info (.txt) | |
| 8-Nov-16 | 10225L | 4BLK33AC 313A | ALS 80 | 413 | 547 | 167 | 39.5 | 653/19.2 | 155/8.36 | NA | 7.52/177 | 8.48 | 6.19 | 1KB | Z:\DAC\RAW DATA |
| 11-Nov-16 | 10231L | 4BLK33D3 16A | ALS 80 | 35 | 568 | 151 | 21.7 | 4.35/1.8/4.35/229 | 647/1.37/3.23/183 | NA | 62.1/21.5/80.2/2.45 | 26.6 | 9.33 | 1KB | Z:\DAC\RAW DATA |
| 13-Nov-16 | 10235L | 4BLK33D3 18A | ALS 80 | NA | 650 | 176 | 19 | 10.6/918 | 7.96/703 | NA | 149/12 | 49.5 | 8.53 | 1KB | Z:\DAC\RAW DATA |

Received from

Name R. PUNTO
Position RA
Signature [signature]

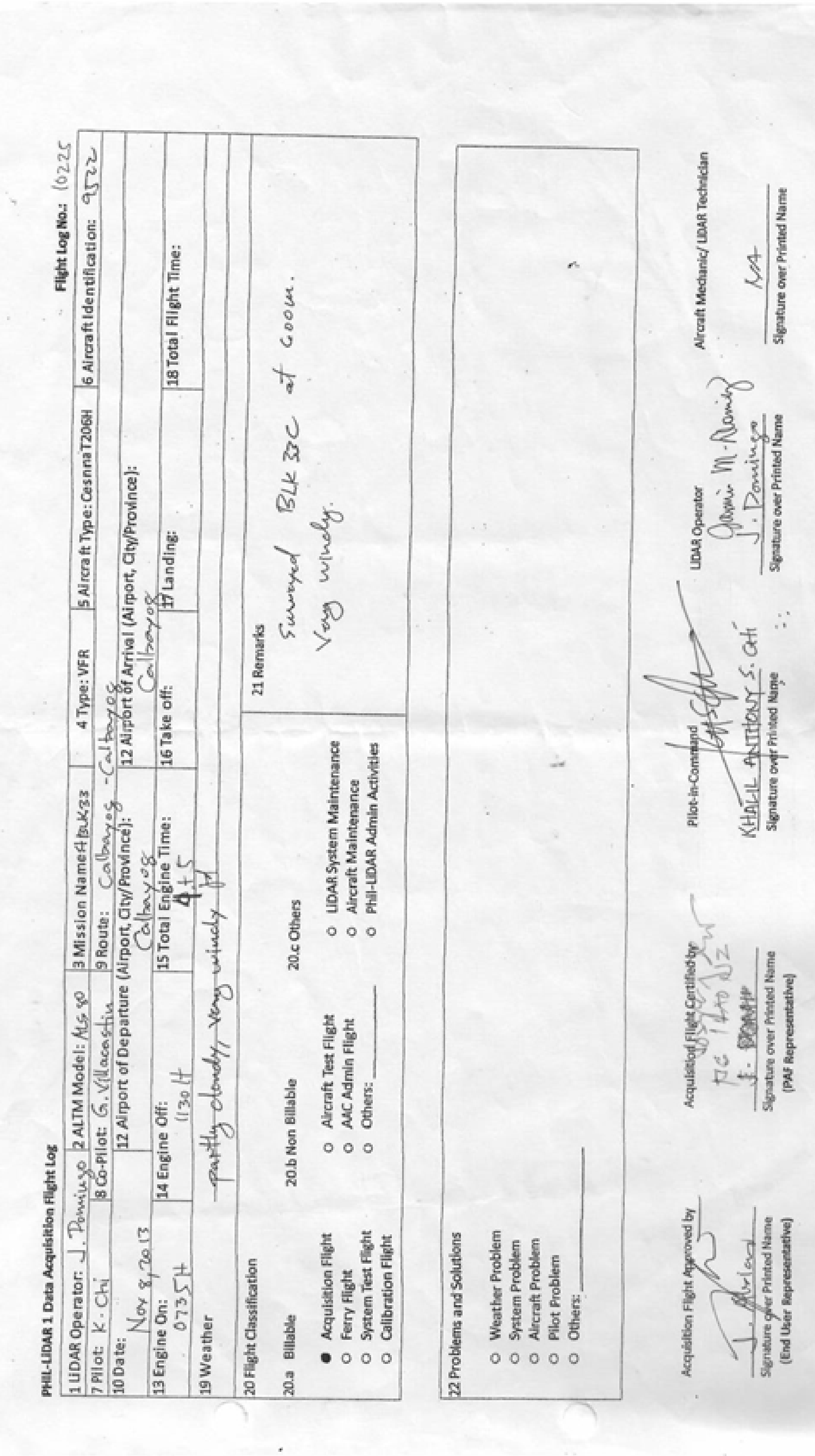
Received by

Name ACBongat
Position SSRS
Signature [signature] 11/29/16

Figure A-5.1. Transfer Sheet for Gandara Floodplain

# Annex 6. Flight logs for the flight missions

1. Flight Log for 10225L Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10225

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: J. Domingo | 2 ALTM Model: AS 80 | 3 Mission Name: 4BLK33 | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9522 |
| 7 Pilot: K. Chi | 8 Co-Pilot: G. Villacastin | 9 Route: Calbayog - Calbayog | | | |
| 10 Date: Nov 8, 2013 | 12 Airport of Departure (Airport, City/Province): Calbayog | | 12 Airport of Arrival (Airport, City/Province): Calbayog | | |
| 13 Engine On: 0735H | 14 Engine Off: 1130H | 15 Total Engine Time: 4+5 | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather: partly cloudy, very windy | | | | | |

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

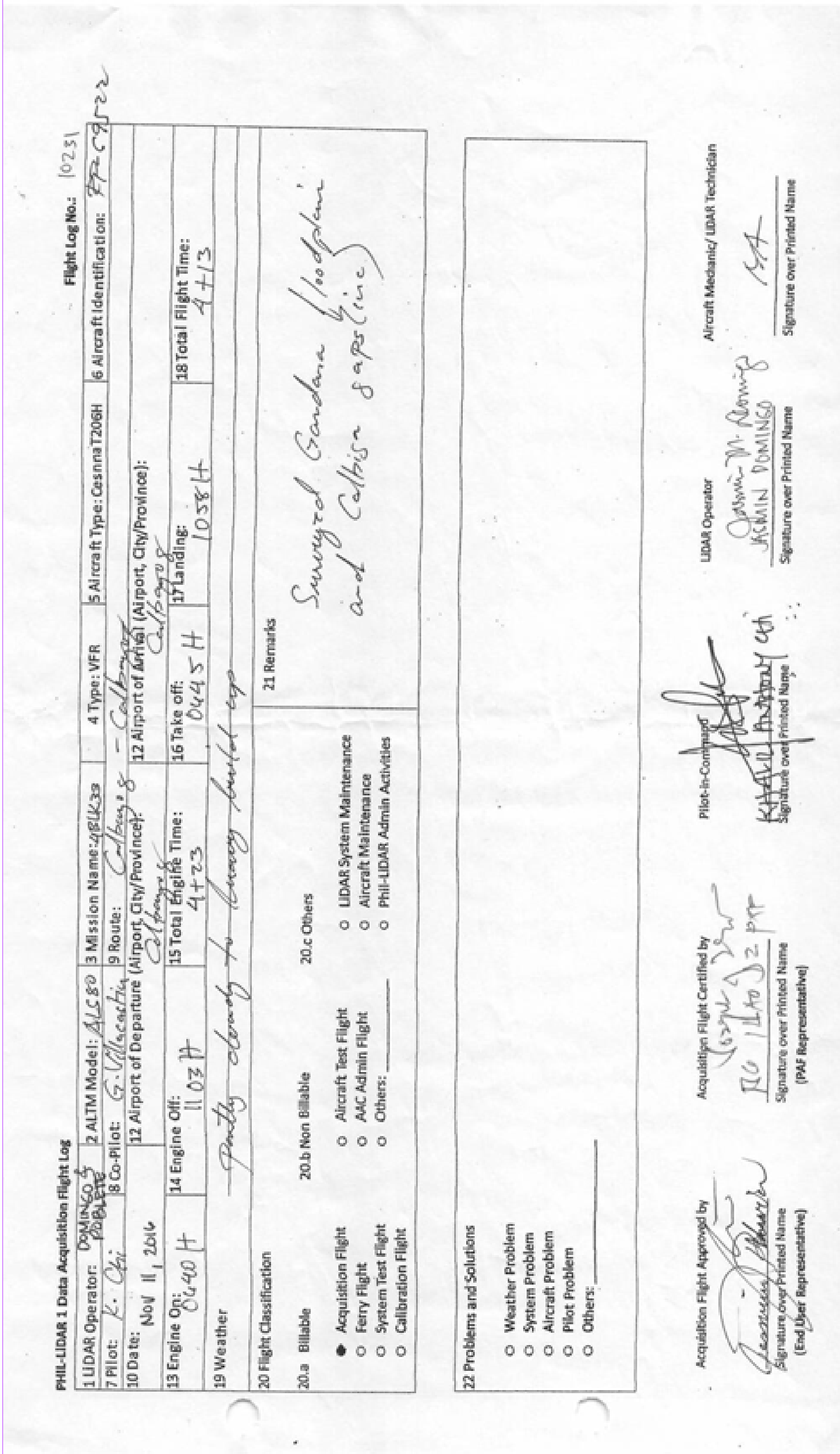
Surveyed BLK 33C at 600m.
Very windy.

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. [illegible] | [illegible] | KHALIL ANTHONY S. CHI | J. Domingo | 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-6-1. Flight Log for 10225L Mission

2. Flight Log for 10231L Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10231

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: DOMINGO & POBLETE | 2 ALTM Model: ALC80 | 3 Mission Name: 4BLK33 | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: RP-C9522 |
| 7 Pilot: K. Chi | 8 Co-Pilot: G. Villacastin | 9 Route: Calbayog - Calbayog | | | |
| 10 Date: Nov 11, 2016 | 12 Airport of Departure (Airport, City/Province): Calbayog | | 12 Airport of Arrival (Airport, City/Province): Calbayog | | |
| 13 Engine On: 0440 H | 14 Engine Off: 1103 H | 15 Total Engine Time: 4+23 | 16 Take off: 0445 H | 17 Landing: 1058 H | 18 Total Flight Time: 4+13 |
| 19 Weather: Partly cloudy to heavy build up | | | | | |

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 Gandara floodplain and Calbiga gaps (inc)

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

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

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

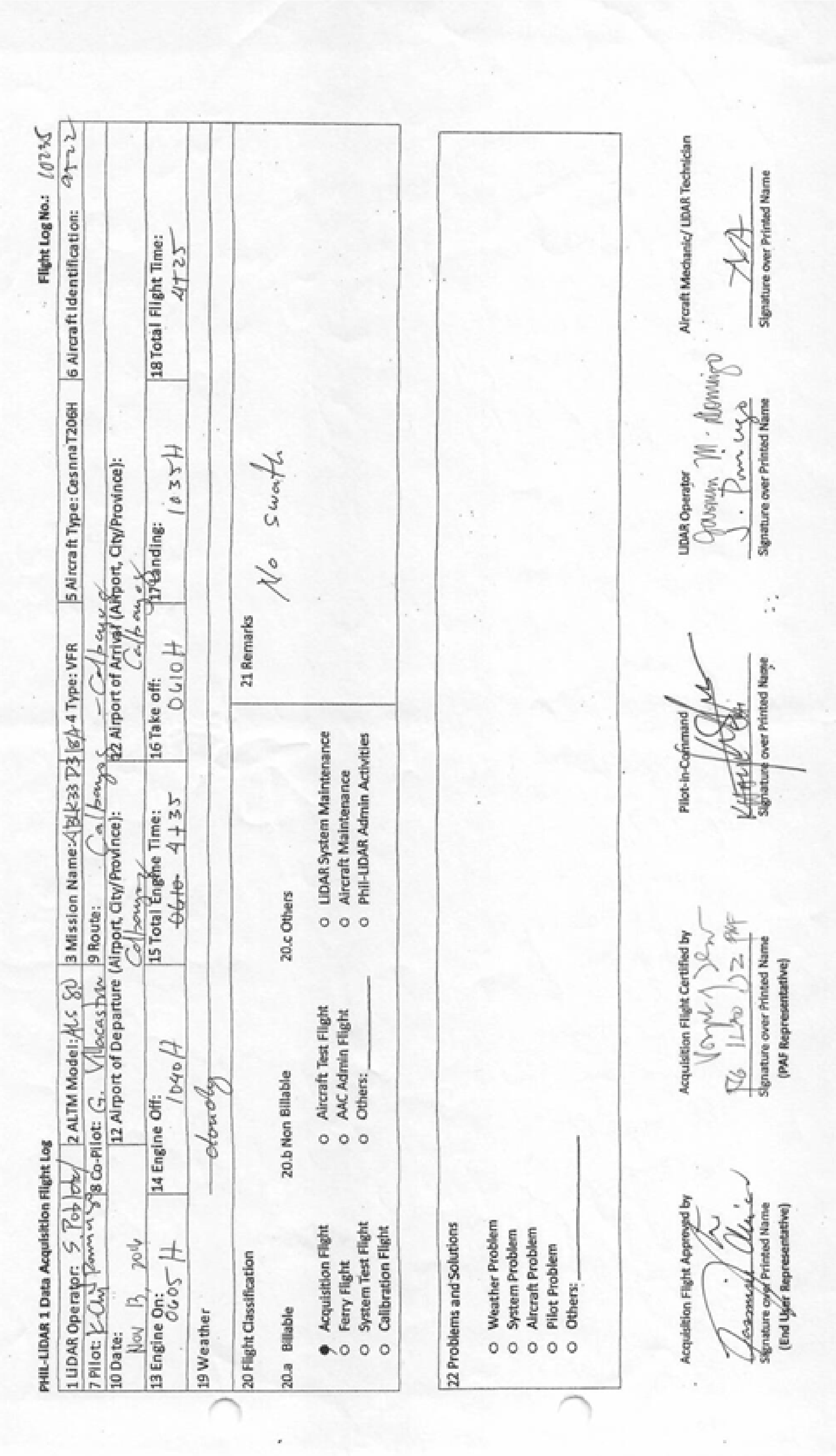
Pilot-in-Command — KHALIL ANTHONY CHI — Signature over Printed Name

LiDAR Operator — JASMIN DOMINGO — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6-1. Flight Log for 10225L Mission

3. Flight Log 10235L Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10235

| | | | | | |
|---|---|---|---|---|---|
| 1 LIDAR Operator: S. Poblete | 2 ALTM Model: ALS 80 | 3 Mission Name: 4BLK33 D318A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9722 |
| 7 Pilot: K. Chi Ramirez | 8 Co-Pilot: G. Villacastin | 9 Route: Calbayog – Calbayog | | | |
| 10 Date: Nov 13, 2014 | 12 Airport of Departure (Airport, City/Province): Calbayog | | 12 Airport of Arrival (Airport, City/Province): Calbayog | | |
| 13 Engine On: 0605 H | 14 Engine Off: 1040 H | 15 Total Engine Time: ~~0610~~ 4+35 | 16 Take off: 0610 H | 17 Landing: 1035 H | 18 Total Flight Time: 4+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

No swath

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 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 10235L Mission

# Annex 7. Flight status reports

FLIGHT STATUS REPORT
CALBAYOG
(NOVEMBER 7-21, 2016)

| FLIGHT NO | AREA | MISSION | OPERATOR | DATE FLOWN | REMARKS |
|---|---|---|---|---|---|
| 10225L | TARANGNAN BLK 33C | 4BLK33AC313A | J DOMINGO | NOV 8 | SURVEYED BLK 33C ALONG COASTAL AREA OF GANDARA FLOODPLAIN AT 600M<br><br>78.64 SQ.KM |
| 10231L | PAGSANGAHAN, GANDARA FP BLK 33D; CALBIGA (1 LINE) | 4BLK33D316A | J DOMINGO/ S POBLETE | NOV 11 | SURVEYED BLK 33D AT 600M, HEAVY BUIILD UP<br><br>60.24 SQ.KM |
| 10235L | GANDARA FP BLK 33D; CALBIGA GAPS | 4BLK33D318A | J DOMINGO/ S POBLETE | NOV 13 | SURVEYED BLK 33D AND CALBIGA GAPS AT 600M; LOST REAL TIME SWATH IN-FLIGHT<br><br>61.21 SQ.KM |

**LAS/SWATH BOUNDARIES PER MISSION FLIGHT**

Flight No. : 10225L
Area: BLK 33C
Mission Name: 4BLK33AC313A
Parameters: FOV 50 SIDELAP 30 FLYING HT. 600M


Figure A-7.1. LAS/SWATH of Flight No. 10225L

*Note: Shown here are old flight plans

| | | | |
|---|---|---|---|
| Flight No. : | 10231L | | |
| Area: | BLK 33D | | |
| Mission Name: | 4BLK33D316A | | |
| Parameters: | FOV 50 | SIDELAP 30 | FLYING HT. 600M |

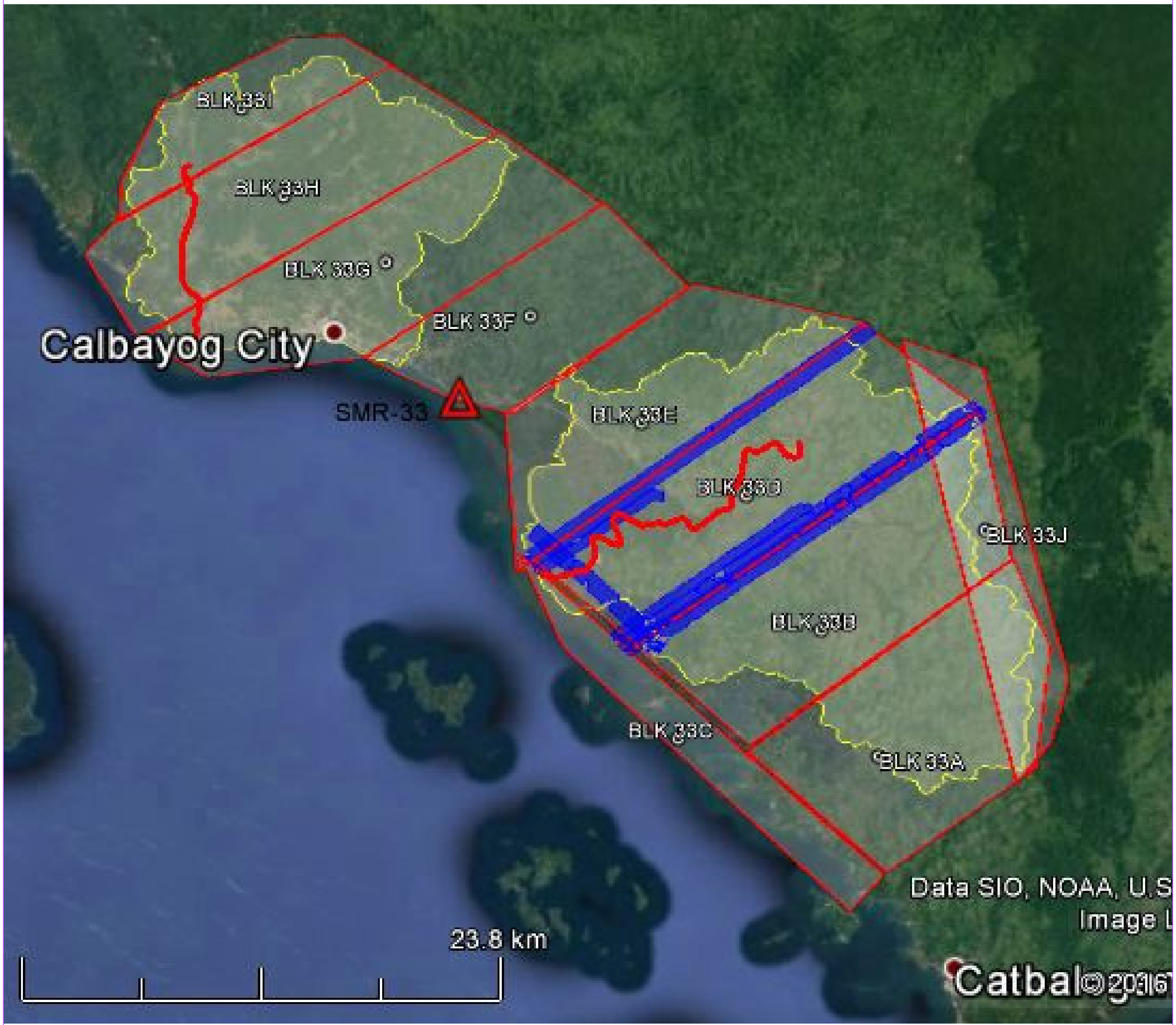



Figure A-7.2. LAS/SWATH of Flight No. 10231L

| | | | |
|---|---|---|---|
| Flight No. : | 10235L | | |
| Area: | BLK 33D | | |
| Mission Name: | 4BLK33D318A | | |
| Parameters: | FOV 50 | SIDELAP 30 | FLYING HT. 600M |


Figure A-7.1 LAS/SWATH of Flight No. 10235L

Figure A-7.1 LAS/SWATH of Flight No. 10235L

# Annex 8. Mission Summary Report

Table A-8.1. Mission Summary Report for Mission Blk33C

| Flight Area | South Cotabato/Saranggani |
|---|---|
| Mission Name | Blk33C |
| Inclusive Flights | 10225L |
| Range data size | 19.76 GB |
| POS | 547 MB |
| Image | 8.848 |
| Base Station Data | 11/29/2016 |
| Transfer date | |
| | |
| *Solution Status* | Yes |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | |
| | |
| *Smoothed Performance Metrics(in cm)* | 0.35 |
| RMSE for North Position (<4.0 cm) | 0.40 |
| RMSE for East Position (<4.0 cm) | 0.75 |
| RMSE for Down Position (<8.0 cm) | |
| | |
| Boresight correction stdev (<0.001deg) | 28.35 |
| IMU attitude correction stdev (<0.001deg) | 10.14 |
| GPS position stdev (<0.01m) | Yes |
| | |
| Minimum % overlap (>25) | 127 |
| Ave point cloud density per sq.m. (>2.0) | 210.54 m |
| Elevation difference between strips (<0.20m) | 53.42 m |
| | |
| Number of 1km x 1km blocks | |
| Maximum Height | 191,265,570 |
| Minimum Height | 93,129,601 |

| | |
|---|---|
| Classification (# of points) | 191,265,570 |
| Ground | 93,129,601 |
| Low vegetation | 132,826,641 |
| Medium vegetation | 255,754,880 |
| High vegetation | 11,852,181 |
| Building | |
| | Yes |
| Orthophoto | Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat |
| Processed by | Engr. Analyn Naldo, Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Melissa Fernandez |

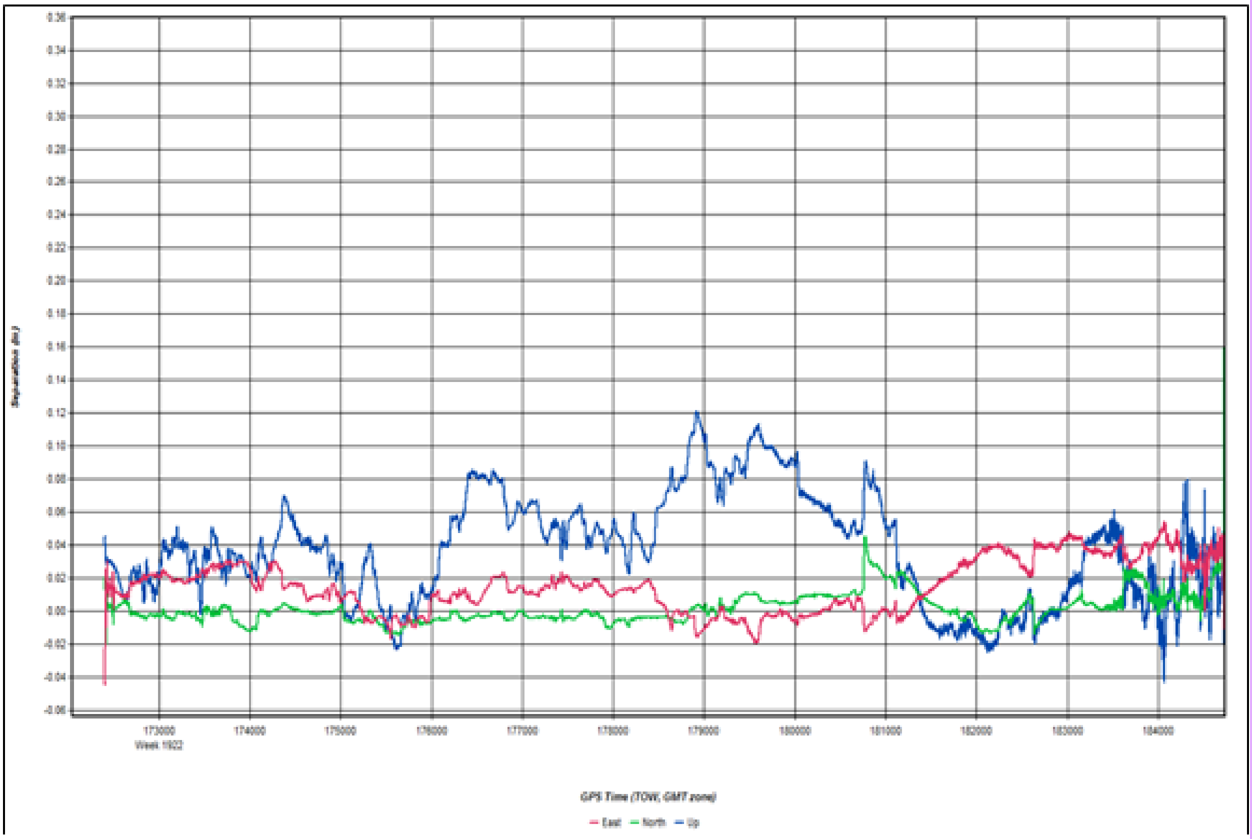



Figure A-8.1. Combined Separation

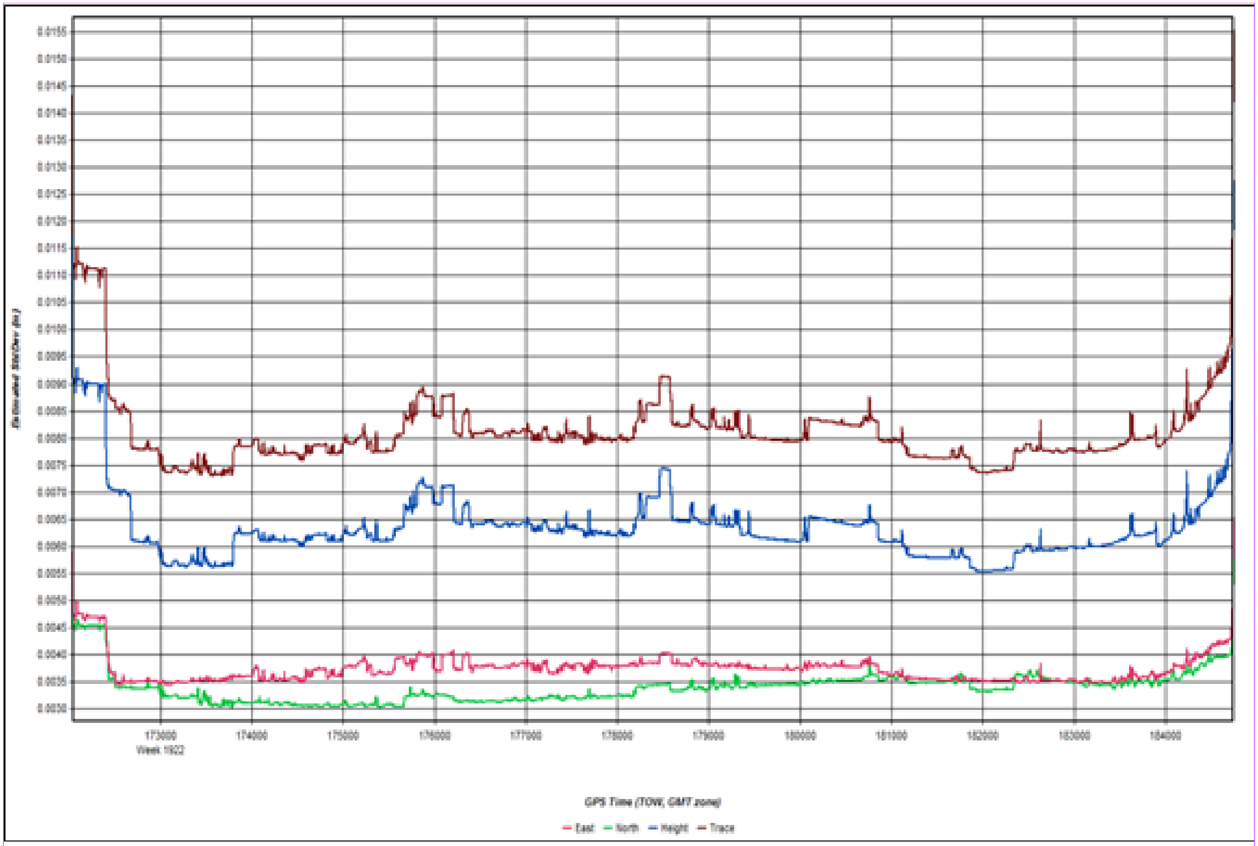



Figure A-8.2. Estimated Position of Accuracy

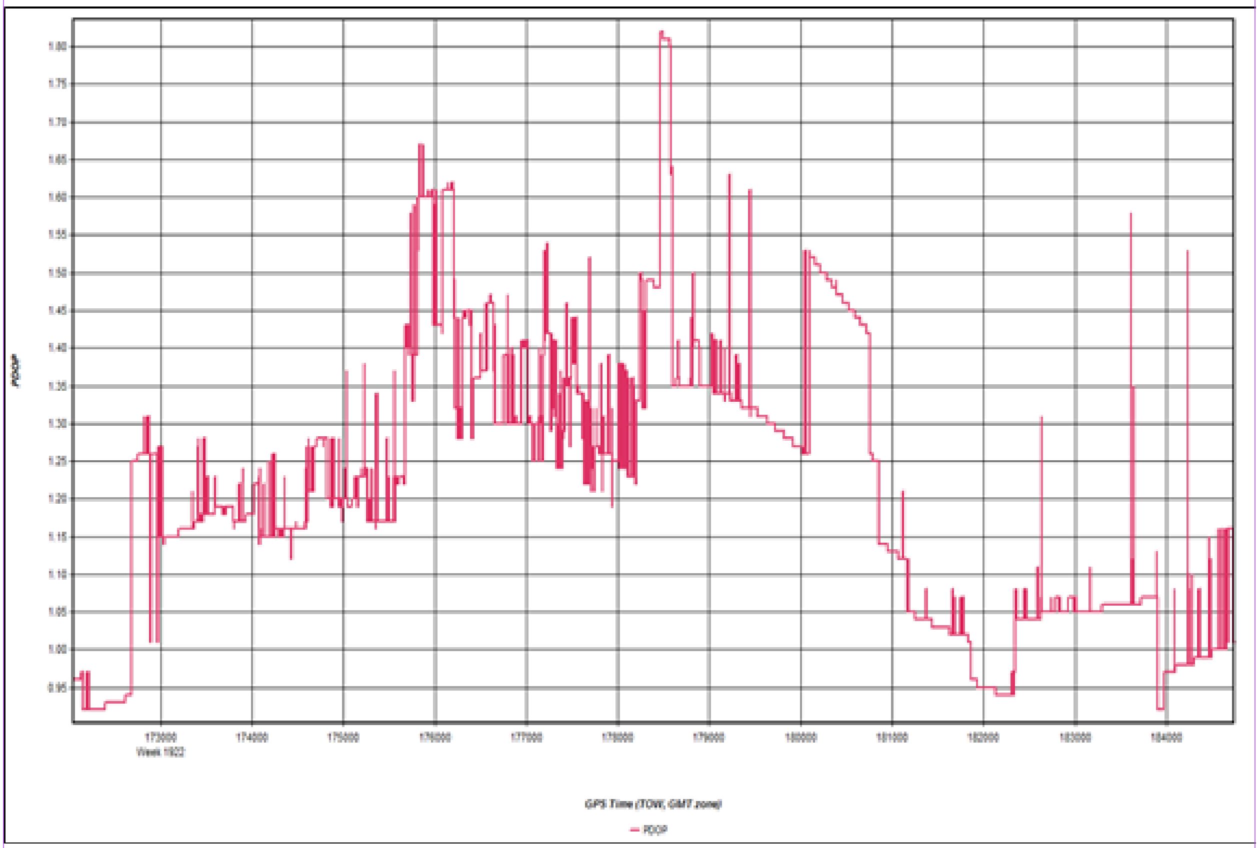



Figure A-8.3. PDOP

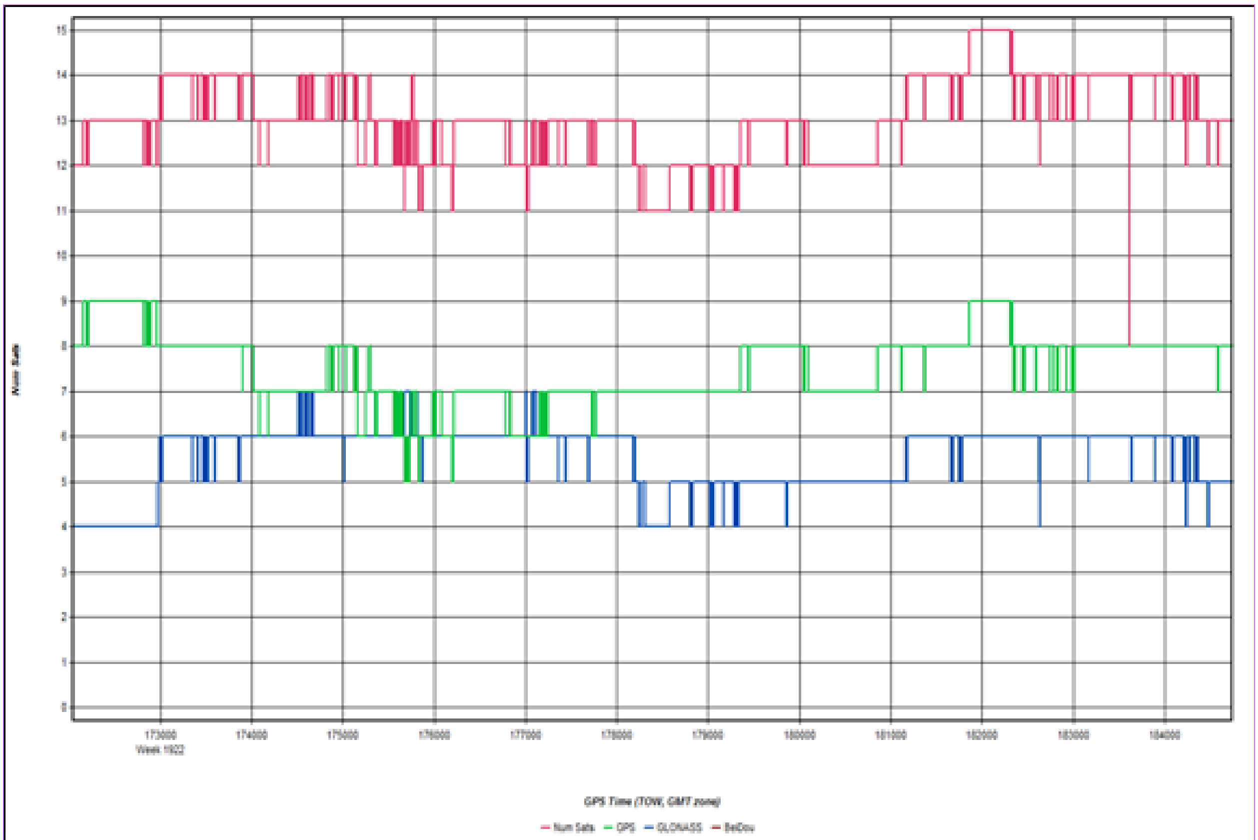



Figure A-8.4. Number of Satellites

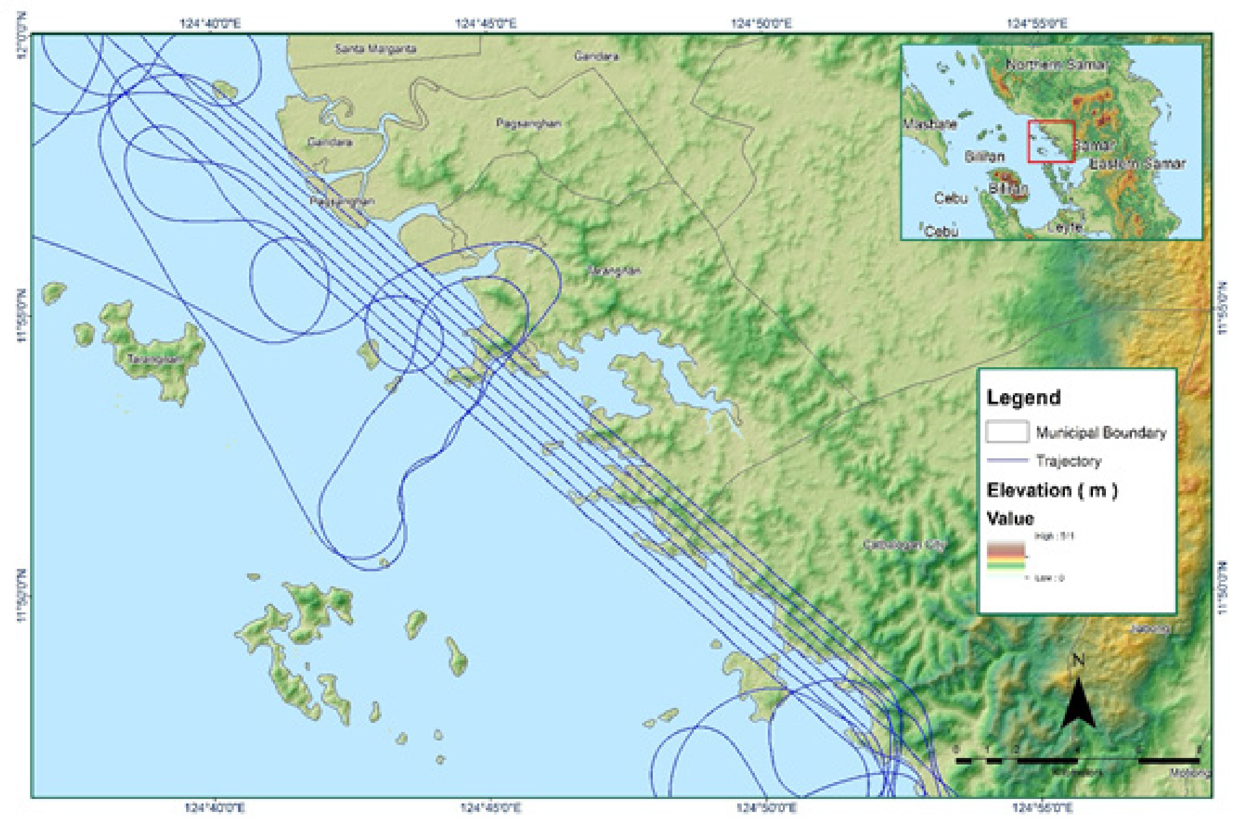



Figure A-8.5. Best Estimated Trajectory

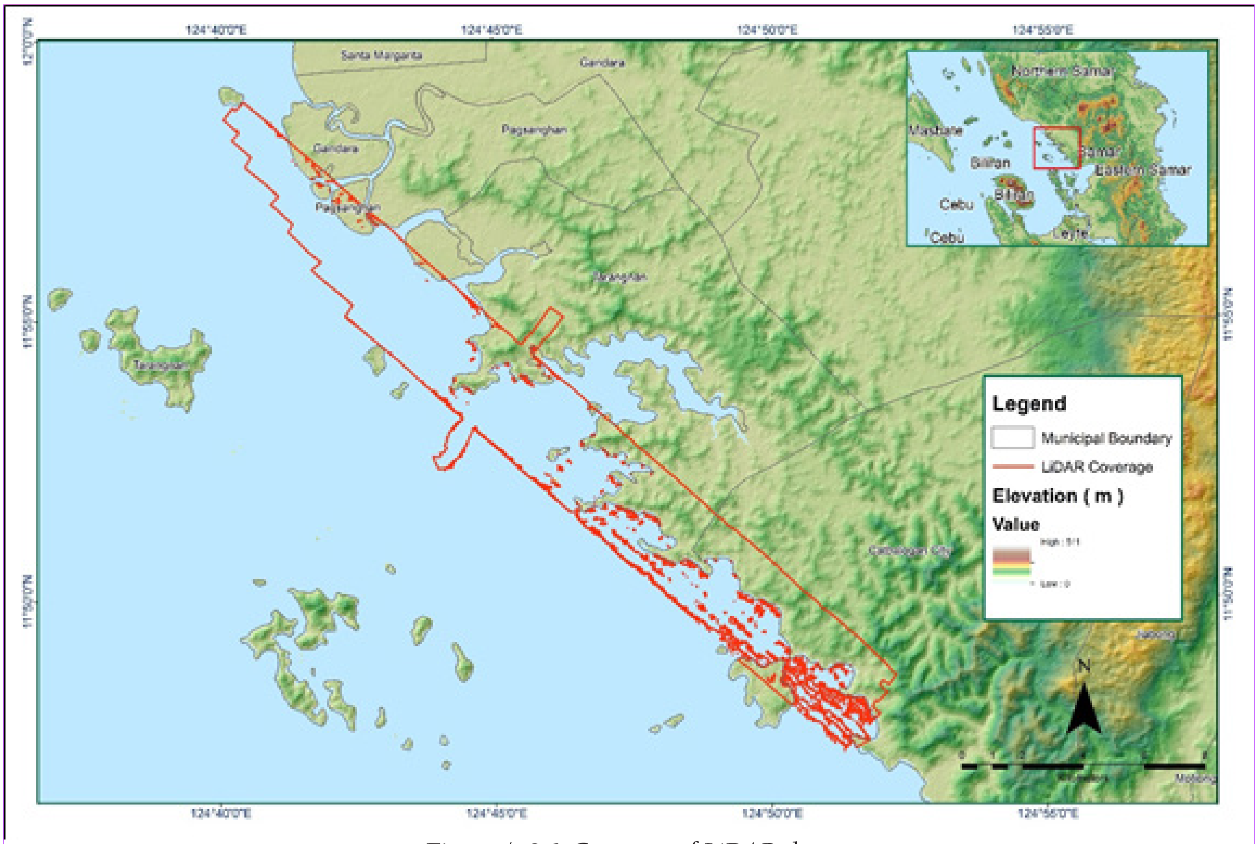



Figure A-8.6. Coverage of LiDAR data

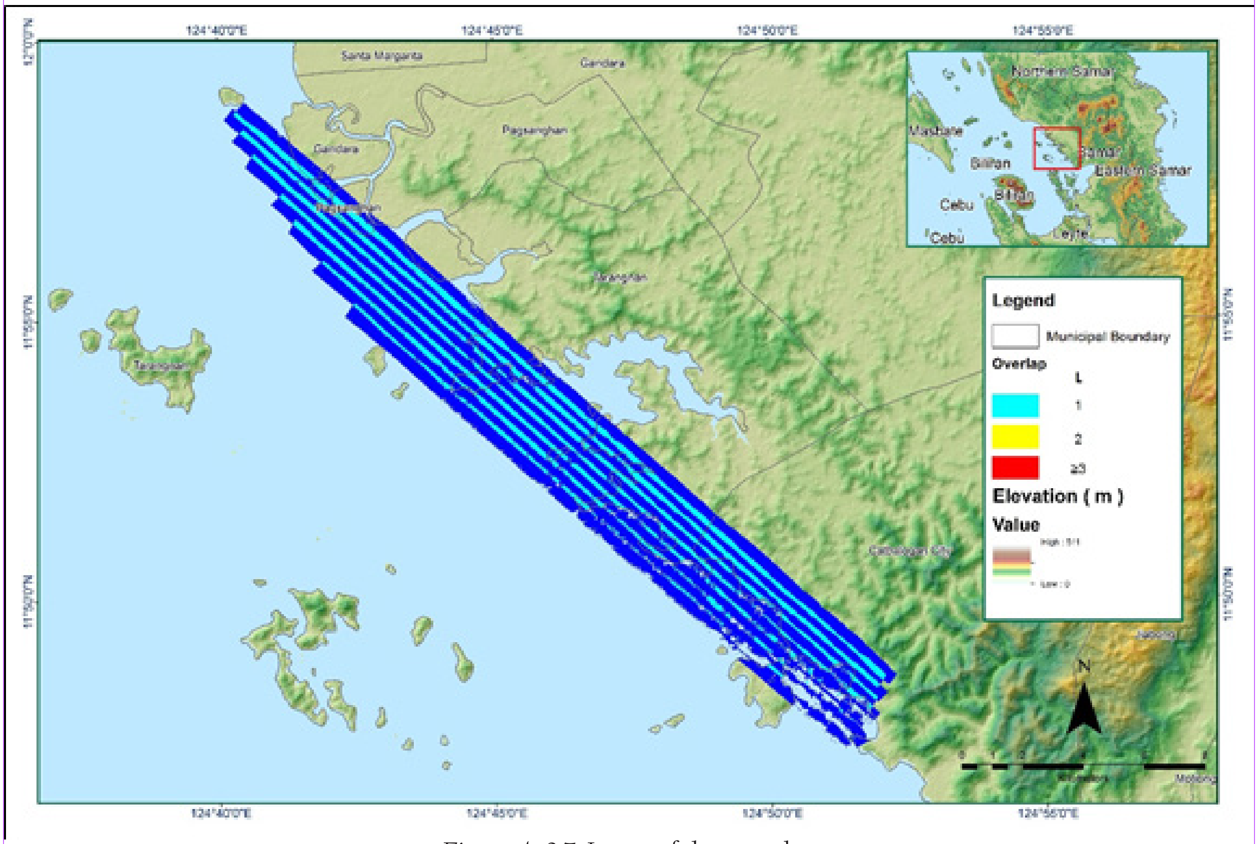



Figure A-8.7. Image of data overlap

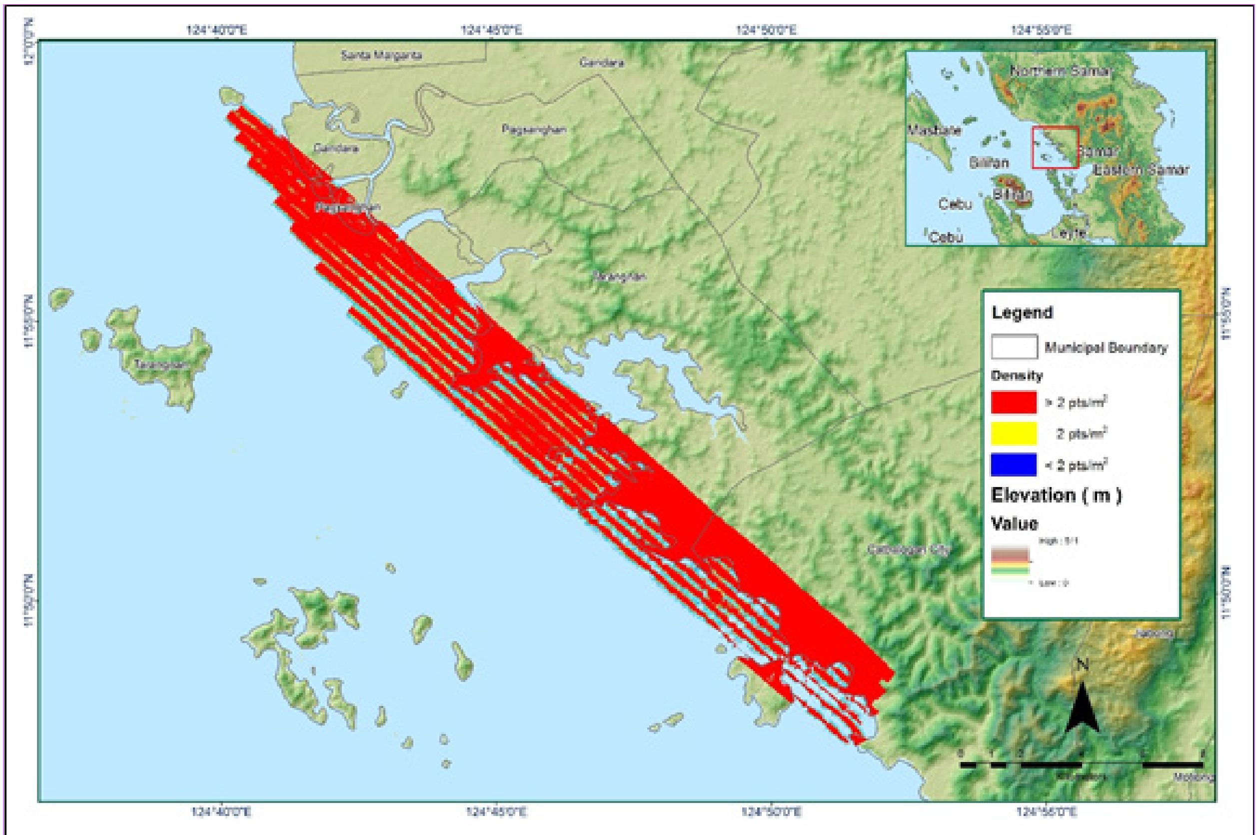



Figure A-8.8. Density map of merged LiDAR data

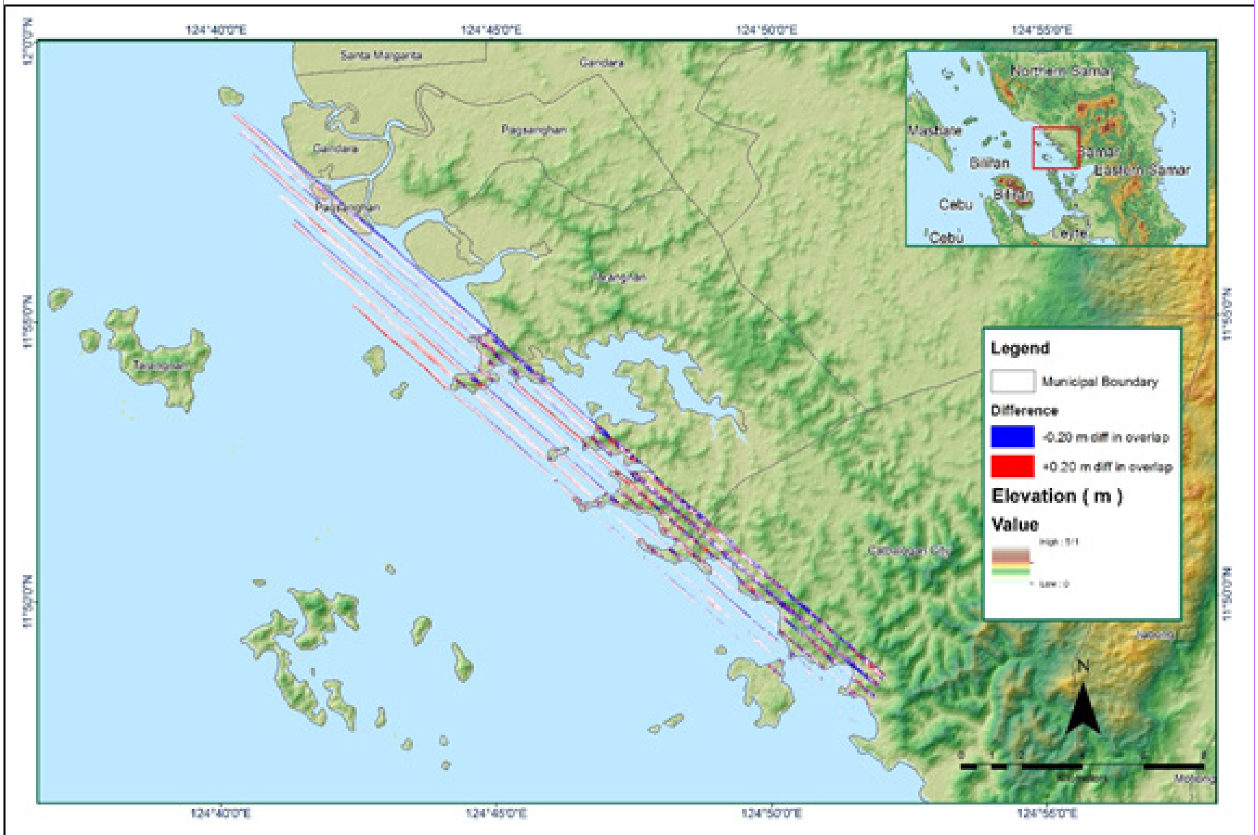



Figure A-8.9. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk33D

| **Flight Area** | **South Cotabato/Saranggani** |
|---|---|
| Mission Name | Blk33D |
| Inclusive Flights | 10235L |
| RawLaser | 11.52 GB |
| GnssImu | 650 MB |
| Image | 49.5 GB |
| Transfer date | 11/29/2016 |
| | |
| Solution Status | |
| *Number of Satellites (>6)* | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Combined Separation (-0.1 up to 0.1) | Yes |
| | |
| Estimated Position Accuracy (in cm) | |
| *Estimated Standard Devation for North Position (<4.0 cm)* | 0.70 |
| Estimated Standard Devation for East Position (<4.0 cm) | 0.70 |
| Estimated Standard Devation for Height Position (<8.0 cm) | 1.15 |
| | |
| | |
| Minimum % overlap (>25) | 52.90 |
| Ave point cloud density per sq.m. (>2.0) | 17.72 |
| Elevation difference between strips (<0.20 m) | Yes |
| | |
| Number of 1km x 1km blocks | 78 |
| Maximum Height | 336.44 m |
| Minimum Height | 54.61 m |
| | |
| Classification (# of points) | |
| Ground | 84,549,091 |
| Low vegetation | 72,774,213 |

| | |
|---|---|
| Medium vegetation | 184,192,909 |
| High vegetation | 389,527,929 |
| Building | 34,689,199 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. James Kevin Dimaculangan, Engr. Harmond Santos, Engr. Gladys Mae Apat |
| Building | 3,063,181 |
| | |
| Orthophoto | No |
| Processed by | Engr. Analyn Naldo, Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Melissa Fernandez |

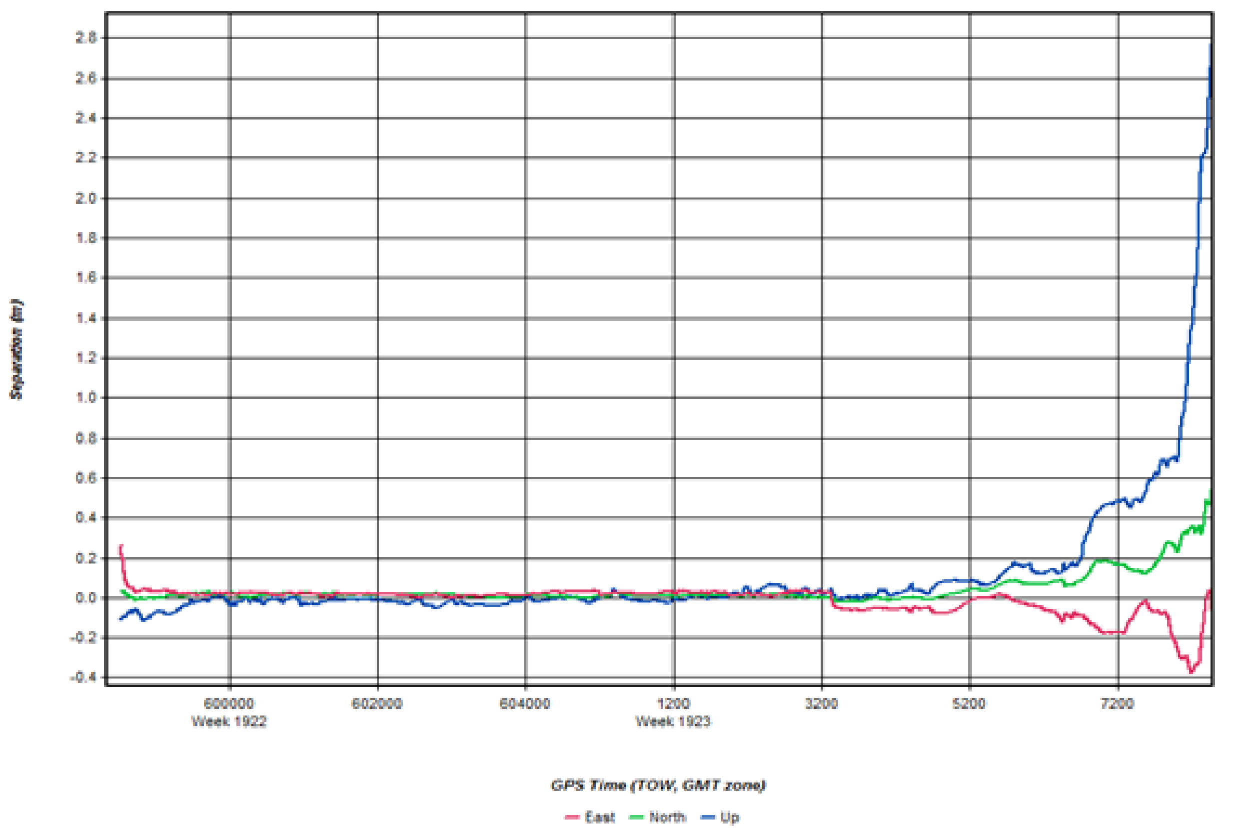



Figure A-8.10. Combined Separation

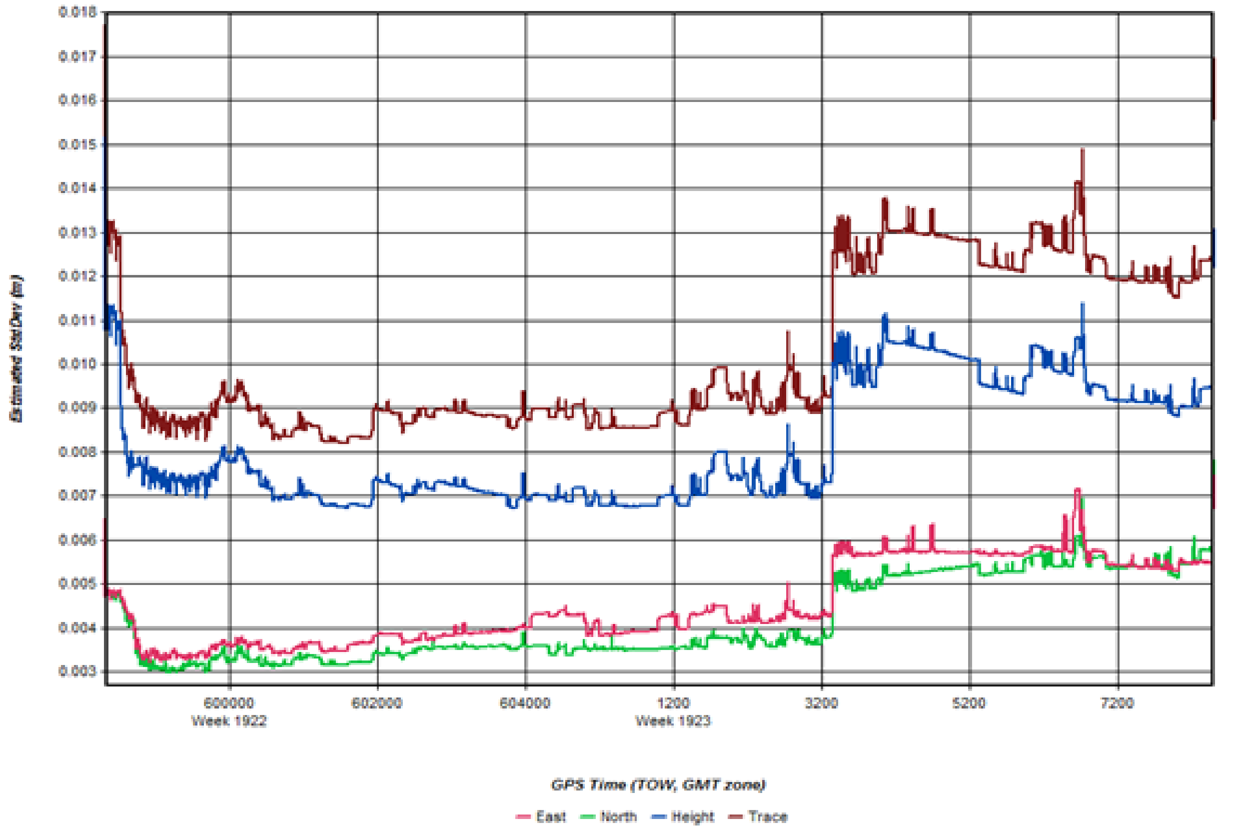



Figure A-8.11. Estimated Position of Accuracy

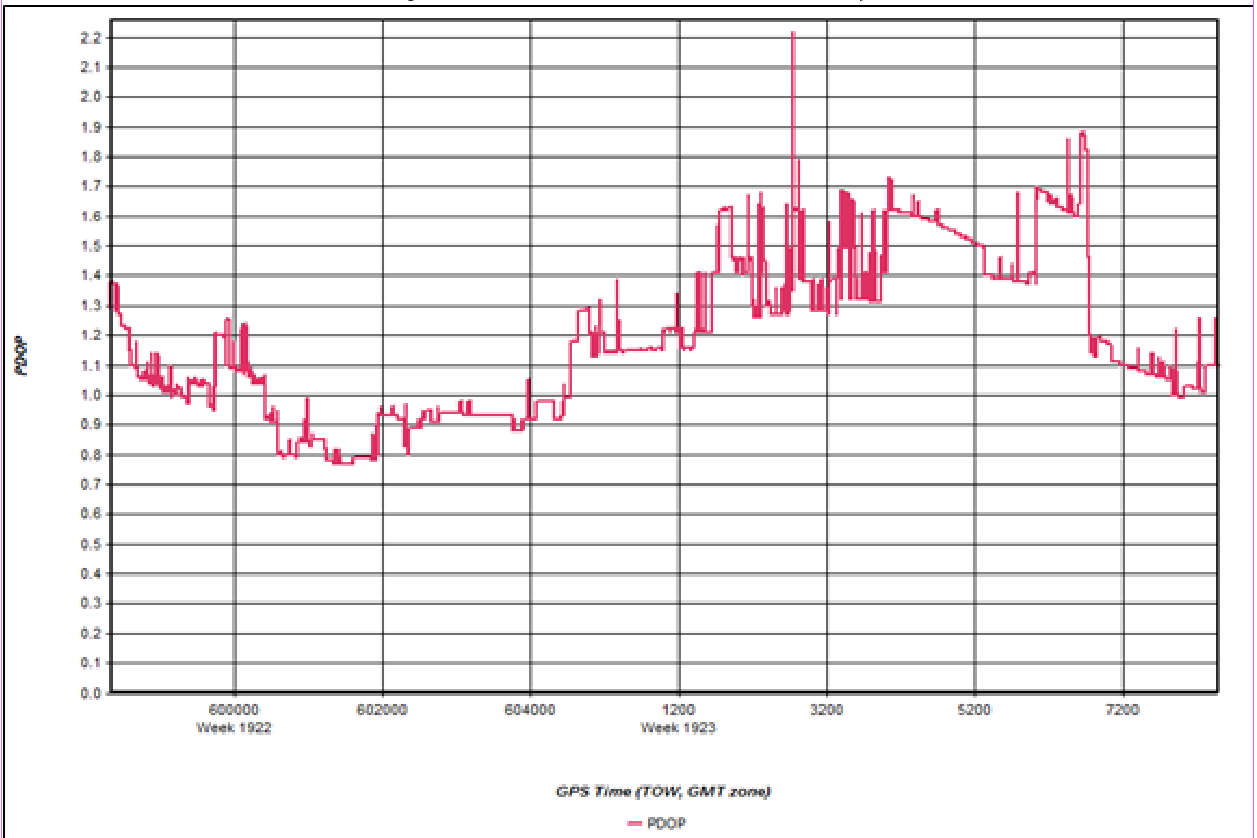



Figure A-8.12. PDOP

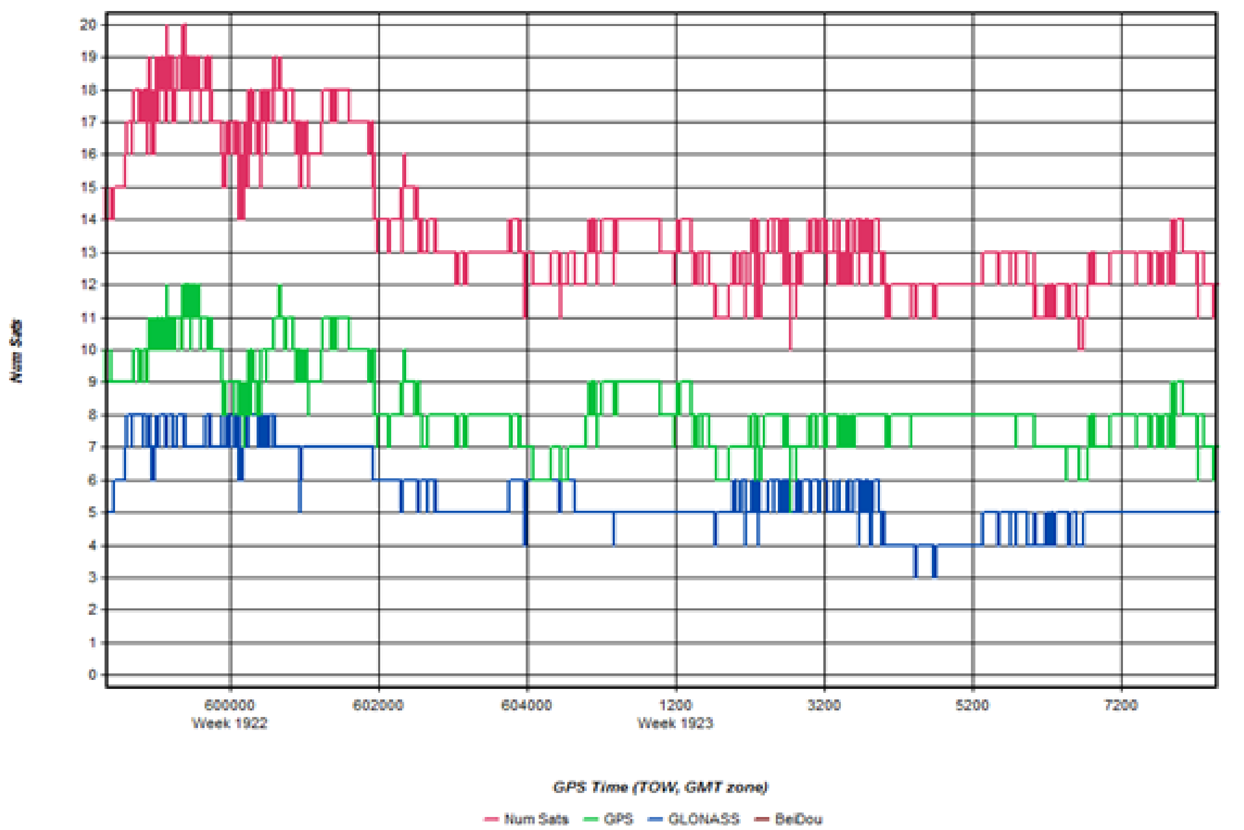



Figure A-8.13. Number of Satellites

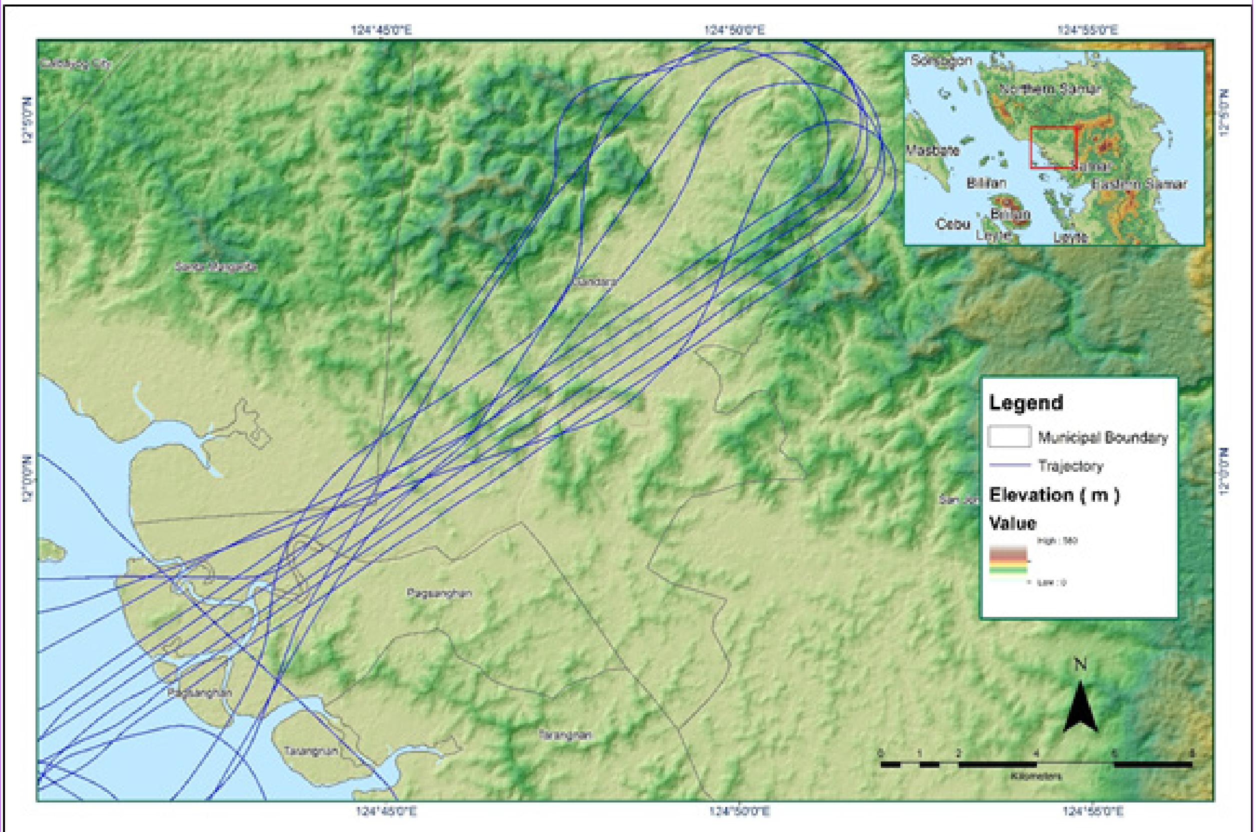



Figure A-8.14. Best Estimated Trajectory

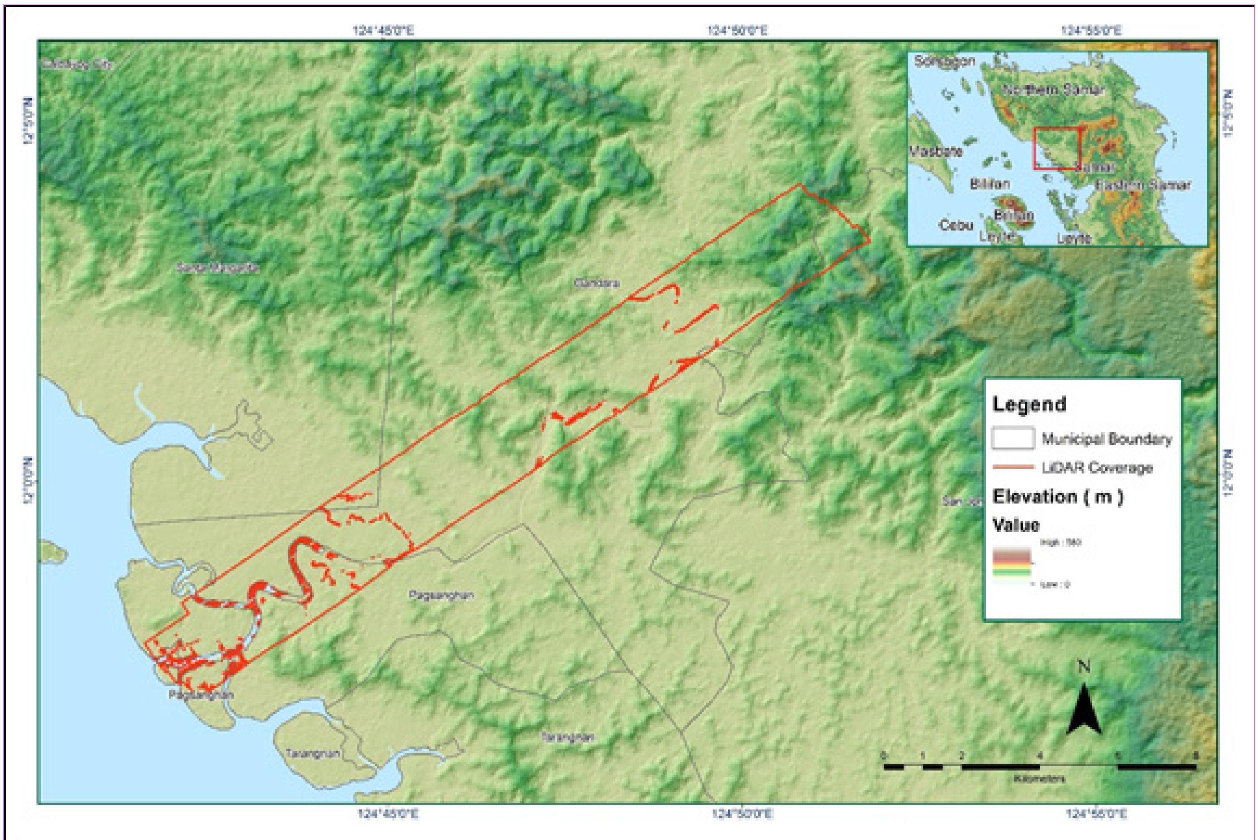



Figure A-8.15. Coverage of LiDAR data

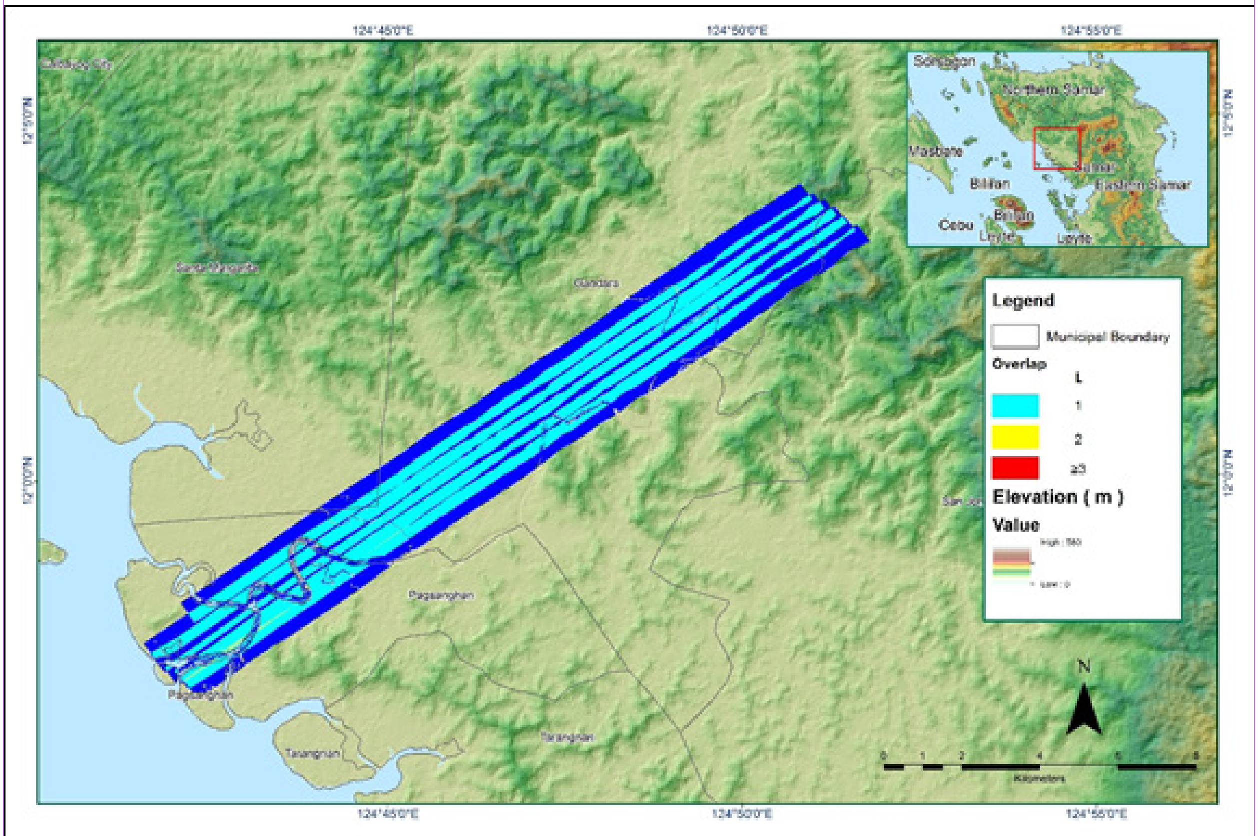



Figure A-8.16. Image of data overlap

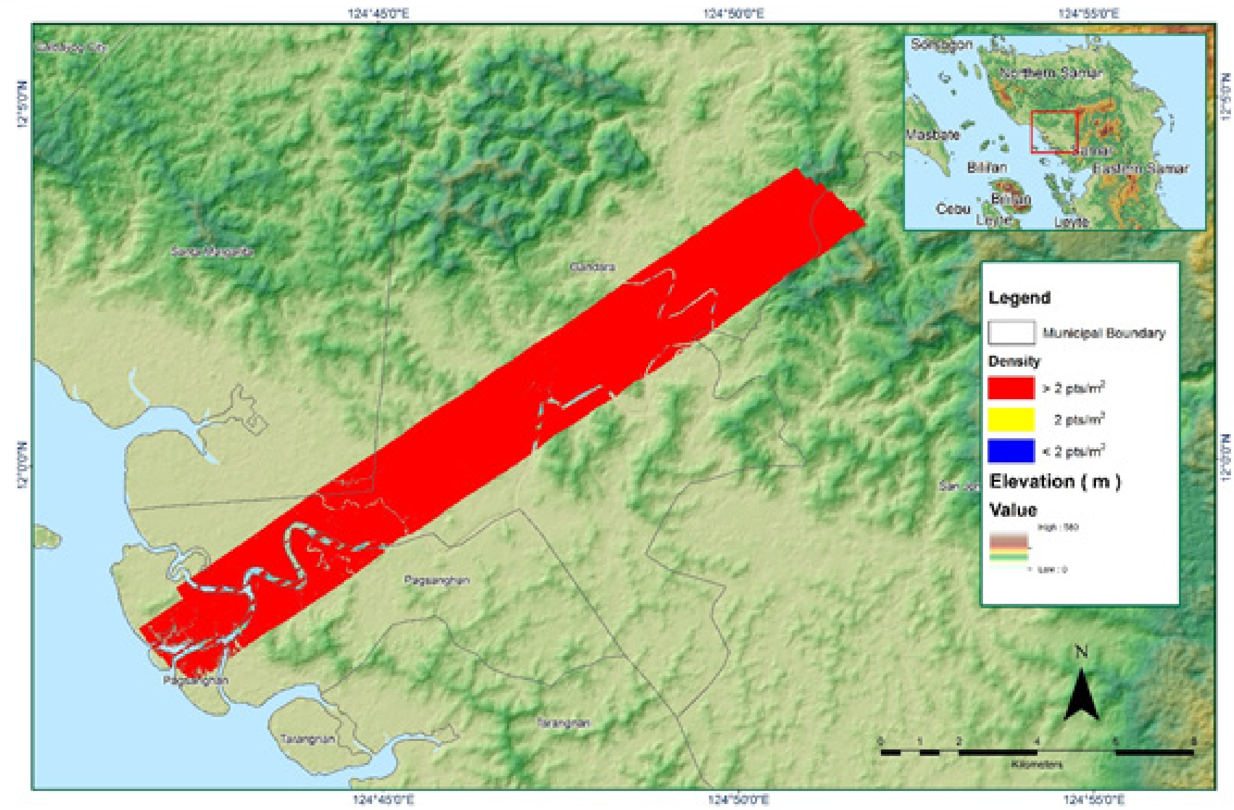



Figure A-8.17. Density map of merged LiDAR data

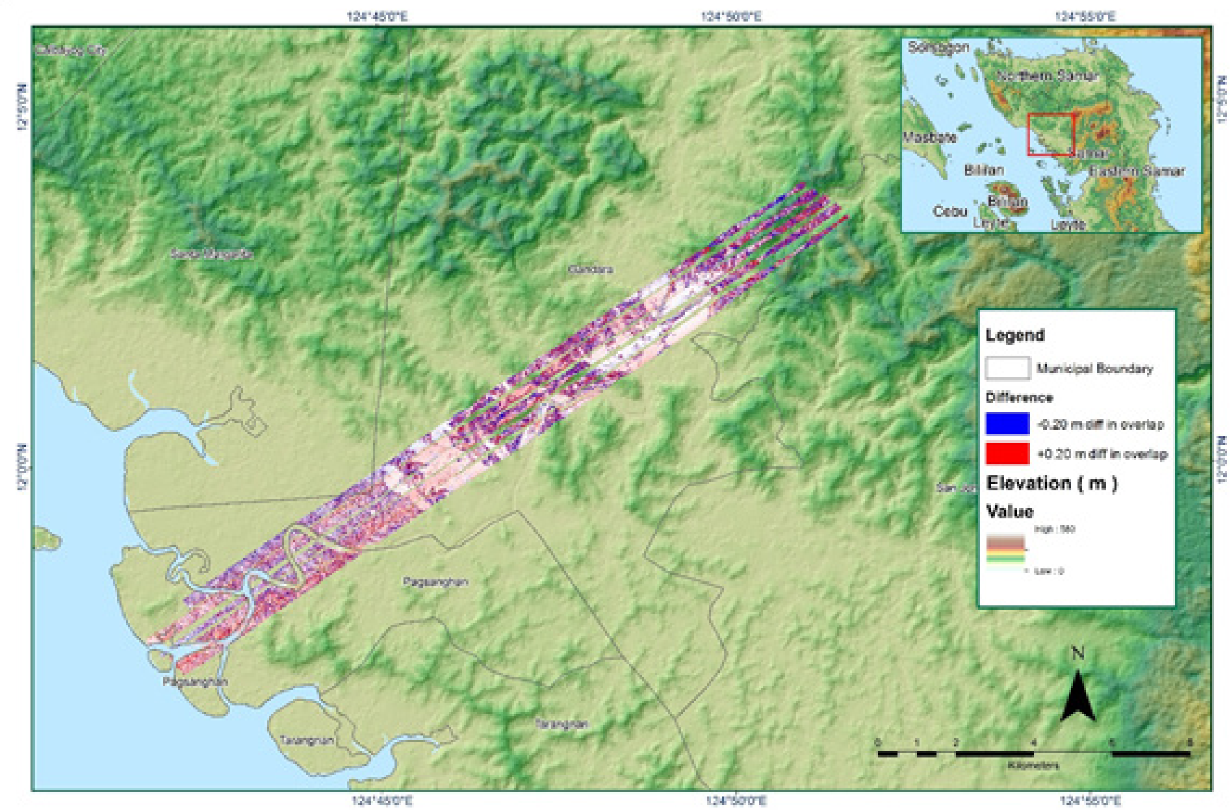



Figure A-8.18 Elevation difference between flight lines

# Annex 9. Lun Masla Model Basin Parameters

Table A-9.1. Gandara Model Basin Parameters

| Basin Number | SCS CURVE NUMBER LOSS | | | CLARK UNIT HYDROGRAPH TRANSFORM | | RECESSION BASEFLOW | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Type | Initial Discharge (M3/S) | Recession Constant | Threshold Type | Ratio to Peak |
| W2140 | 15.685 | 54.658 | 0 | 4.1624 | 30.657 | Discharge | 1.6813 | 0.95 | Ratio to Peak | 0.15 |
| W2130 | 19.824 | 51.669 | 0 | 5.4036 | 38.748 | Discharge | 2.2639 | 0.95 | Ratio to Peak | 0.15 |
| W2120 | 20.041 | 51.522 | 0 | 9.3432 | 39.171 | Discharge | 4.5765 | 0.95 | Ratio to Peak | 0.15 |
| W2110 | 17.734 | 53.137 | 0 | 5.6828 | 34.661 | Discharge | 2.1754 | 0.95 | Ratio to Peak | 0.15 |
| W2100 | 18.46 | 52.618 | 0 | 3.98208 | 36.08 | Discharge | 1.8628 | 0.95 | Ratio to Peak | 0.15 |
| W2090 | 20.668 | 51.1 | 0 | 14.6504 | 40.396 | Discharge | 3.6119 | 0.95 | Ratio to Peak | 0.15 |
| W2080 | 15.745 | 54.612 | 0 | 4.8276 | 30.774 | Discharge | 2.2102 | 0.95 | Ratio to Peak | 0.15 |
| W2070 | 20.668 | 51.1 | 0 | 5.5256 | 40.396 | Discharge | 0.78233 | 0.95 | Ratio to Peak | 0.15 |
| W2060 | 20.668 | 51.1 | 0 | 3.39548 | 40.396 | Discharge | 0.57583 | 0.95 | Ratio to Peak | 0.15 |
| W2050 | 17.806 | 53.084 | 0 | 6.5256 | 34.80355 | Discharge | 2.2722 | 0.95 | Ratio to Peak | 0.15 |
| W2040 | 20.668 | 51.1 | 0 | 3.30112 | 40.396 | Discharge | 0.83058 | 0.95 | Ratio to Peak | 0.15 |
| W2030 | 20.668 | 51.1 | 0 | 7.6304 | 40.396 | Discharge | 1.2795 | 0.95 | Ratio to Peak | 0.15 |
| W2020 | 20.41 | 51.273 | 0 | 8.51 | 39.891 | Discharge | 1.676 | 0.95 | Ratio to Peak | 0.15 |
| W2010 | 19.052 | 52.202 | 0 | 7.9964 | 37.239 | Discharge | 4.0095 | 0.95 | Ratio to Peak | 0.15 |
| W2000 | 20.607 | 51.141 | 0 | 4.9948 | 40.277 | Discharge | 1.3523 | 0.95 | Ratio to Peak | 0.15 |
| W1990 | 20.999 | 50.88 | 0 | 9.7308 | 41.043 | Discharge | 3.7748 | 0.95 | Ratio to Peak | 0.15 |
| W1980 | 20.668 | 51.1 | 0 | 8.4176 | 40.396 | Discharge | 1.7079 | 0.95 | Ratio to Peak | 0.15 |
| W1970 | 20.668 | 51.1 | 0 | 15.3836 | 40.396 | Discharge | 2.8359 | 0.95 | Ratio to Peak | 0.15 |
| W1960 | 20.668 | 51.1 | 0 | 12.5752 | 40.396 | Discharge | 1.8004 | 0.95 | Ratio to Peak | 0.15 |
| W1950 | 20.668 | 51.1 | 0 | 14.1784 | 40.396 | Discharge | 3.4008 | 0.95 | Ratio to Peak | 0.15 |
| W1940 | 20.668 | 51.1 | 0 | 2.54596 | 40.396 | Discharge | 0.29781 | 0.95 | Ratio to Peak | 0.15 |
| W1930 | 15.086 | 55.12 | 0 | 6.5856 | 29.48563 | Discharge | 2.4575 | 0.95 | Ratio to Peak | 0.15 |

| Basin Number | SCS CURVE NUMBER LOSS | | | CLARK UNIT HYDROGRAPH TRANSFORM | | RECESSION BASEFLOW | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Type | Initial Discharge (M3/S) | Recession Constant | Threshold Type | Ratio to Peak |
| W1920 | 20.533 | 51.19 | 0 | 2.05464 | 40.133 | Discharge | 0.10084 | 0.95 | Ratio to Peak | 0.15 |
| W1910 | 20.668 | 51.1 | 0 | 6.0396 | 40.396 | Discharge | 0.84168 | 0.95 | Ratio to Peak | 0.15 |
| W1900 | 20.668 | 51.1 | 0 | 3.87456 | 40.396 | Discharge | 1.0193 | 0.95 | Ratio to Peak | 0.15 |
| W1890 | 20.668 | 51.1 | 0 | 4.3672 | 40.396 | Discharge | 1.6151 | 0.95 | Ratio to Peak | 0.15 |
| W1880 | 20.668 | 51.1 | 0 | 2.57248 | 40.396 | Discharge | 0.3431 | 0.95 | Ratio to Peak | 0.15 |
| W1870 | 20.668 | 51.1 | 0 | 7.2944 | 40.396 | Discharge | 2.4996 | 0.95 | Ratio to Peak | 0.15 |
| W1860 | 20.668 | 51.1 | 0 | 6.5296 | 40.396 | Discharge | 1.2842 | 0.95 | Ratio to Peak | 0.15 |
| W1850 | 20.668 | 51.1 | 0 | 4.5968 | 40.396 | Discharge | 0.42112 | 0.95 | Ratio to Peak | 0.15 |
| W1840 | 20.668 | 51.1 | 0 | 0.67424 | 40.396 | Discharge | 0.006373 | 0.95 | Ratio to Peak | 0.15 |
| W1830 | 21.414 | 50.60647 | 0 | 32.9684 | 41.856 | Discharge | 3.0914 | 0.95 | Ratio to Peak | 0.15 |
| W1820 | 17.656 | 53.193 | 0 | 10.09 | 34.51 | Discharge | 5.697 | 0.95 | Ratio to Peak | 0.15 |
| W1810 | 28.298 | 46.468 | 0 | 7.6012 | 55.31 | Discharge | 3.1716 | 0.95 | Ratio to Peak | 0.15 |
| W1800 | 20.668 | 51.1 | 0 | 2.51884 | 40.396 | Discharge | 0.74684 | 0.95 | Ratio to Peak | 0.15 |
| W1790 | 20.668 | 51.1 | 0 | 5.2812 | 40.396 | Discharge | 1.4325 | 0.95 | Ratio to Peak | 0.15 |
| W1780 | 21.291 | 50.688 | 0 | 15.4304 | 41.614 | Discharge | 3.9621 | 0.95 | Ratio to Peak | 0.15 |
| W1770 | 10.348 | 59.0625 | 0 | 0.1466368 | 20.226 | Discharge | 0.000666 | 0.95 | Ratio to Peak | 0.15 |
| W1760 | 20.668 | 51.1 | 0 | 7.9336 | 40.396 | Discharge | 1.987587 | 0.95 | Ratio to Peak | 0.15 |
| W1750 | 20.668 | 51.1 | 0 | 5.078 | 40.396 | Discharge | 1.4965 | 0.95 | Ratio to Peak | 0.15 |
| W1740 | 17.361 | 53.407 | 0 | 2.92844 | 33.933 | Discharge | 1.011 | 0.95 | Ratio to Peak | 0.15 |
| W1730 | 17.139 | 53.57 | 0 | 3.93232 | 33.498 | Discharge | 2.0367 | 0.95 | Ratio to Peak | 0.15 |
| W1720 | 14.854 | 55.3 | 0 | 1.68356 | 29.033 | Discharge | 0.54327 | 0.95 | Ratio to Peak | 0.15 |
| W1710 | 20.668 | 51.1 | 0 | 3.93224 | 40.396 | Discharge | 1.4801 | 0.95 | Ratio to Peak | 0.15 |
| W1700 | 30.909 | 45.07 | 0 | 4.9712 | 60.414 | Discharge | 1.1955 | 0.95 | Ratio to Peak | 0.15 |
| W1690 | 51.939 | 36.279 | 0 | 6.7428 | 101.517 | Discharge | 3.1002 | 0.95 | Ratio to Peak | 0.15 |
| W1680 | 47.126 | 37.97466 | 0 | 10.3428 | 92.109 | Discharge | 5.1822 | 0.95 | Ratio to Peak | 0.15 |

| Basin Number | SCS CURVE NUMBER LOSS | | | CLARK UNIT HYDROGRAPH TRANSFORM | | RECESSION BASEFLOW | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Type | Initial Discharge (M3/S) | Recession Constant | Threshold Type | Ratio to Peak |
| W1670 | 24.474 | 48.679 | 0 | 6.268 | 47.836 | Discharge | 1.3436 | 0.95 | Ratio to Peak | 0.15 |
| W1660 | 20.668 | 51.1 | 0 | 5.9996 | 40.396 | Discharge | 2.298 | 0.95 | Ratio to Peak | 0.15 |
| W1650 | 43.009 | 39.556 | 0 | 5.9404 | 84.06245 | Discharge | 2.0746 | 0.95 | Ratio to Peak | 0.15 |
| W1640 | 46.379 | 38.25206 | 0 | 9.9936 | 90.649 | Discharge | 2.976 | 0.95 | Ratio to Peak | 0.15 |
| W1630 | 54.701 | 35.373 | 0 | 5.9572 | 106.9146 | Discharge | 1.1881 | 0.95 | Ratio to Peak | 0.15 |
| W1620 | 40.743 | 40.483 | 0 | 5.5784 | 79.63362 | Discharge | 1.1876 | 0.95 | Ratio to Peak | 0.15 |
| W1610 | 41.175 | 40.30302 | 0 | 3.75832 | 80.478 | Discharge | 1.0953 | 0.95 | Ratio to Peak | 0.15 |
| W1600 | 51.155 | 36.545 | 0 | 5.37 | 99.985 | Discharge | 1.2033 | 0.95 | Ratio to Peak | 0.15 |
| W1590 | 53.314 | 35.822 | 0 | 5.3288 | 104.2053 | Discharge | 2.1646 | 0.95 | Ratio to Peak | 0.15 |
| W1580 | 20.668 | 51.1 | 0 | 3.56036 | 40.396 | Discharge | 1.5116 | 0.95 | Ratio to Peak | 0.15 |
| W1570 | 20.668 | 51.1 | 0 | 3.59948 | 40.396 | Discharge | 1.2295 | 0.95 | Ratio to Peak | 0.15 |
| W1560 | 18.277 | 52.747 | 0 | 6.5136 | 35.724 | Discharge | 3.9693 | 0.95 | Ratio to Peak | 0.15 |
| W1550 | 21.985 | 50.236 | 0 | 6.5068 | 42.971 | Discharge | 1.9456 | 0.95 | Ratio to Peak | 0.15 |
| W1540 | 57.9423 | 34.366 | 0 | 7.2828 | 113.2509 | Discharge | 1.0138 | 0.95 | Ratio to Peak | 0.15 |
| W1530 | 20.668 | 51.1 | 0 | 14.3164 | 40.396 | Discharge | 4.5856 | 0.95 | Ratio to Peak | 0.15 |
| W1520 | 60.537 | 33.6 | 0 | 11.5188 | 118.3217 | Discharge | 0.018973 | 0.95 | Ratio to Peak | 0.15 |
| W1510 | 18.533 | 52.566 | 0 | 5.7472 | 36.224 | Discharge | 1.804539 | 0.95 | Ratio to Peak | 0.15 |
| W1500 | 20.668 | 51.1 | 0 | 7.2004 | 40.396 | Discharge | 3.3554 | 0.95 | Ratio to Peak | 0.15 |
| W1490 | 50.714 | 36.696 | 0 | 10.222 | 99.122 | Discharge | 1.7877 | 0.95 | Ratio to Peak | 0.15 |
| W1480 | 37.89831 | 41.711 | 0 | 10.4648 | 74.074 | Discharge | 2.8649 | 0.95 | Ratio to Peak | 0.15 |
| W1470 | 20.668 | 51.1 | 0 | 10.3636 | 40.396 | Discharge | 1.5563 | 0.95 | Ratio to Peak | 0.15 |
| W1460 | 20.668 | 51.1 | 0 | 8.0484 | 40.396 | Discharge | 3.5903 | 0.95 | Ratio to Peak | 0.15 |
| W1450 | 20.668 | 51.1 | 0 | 7.7208 | 40.396 | Discharge | 2.2571 | 0.95 | Ratio to Peak | 0.15 |
| W1440 | 59.871 | 33.793 | 0 | 5.4564 | 117.0203 | Discharge | 1.3526 | 0.95 | Ratio to Peak | 0.15 |
| W1430 | 60.537 | 33.6 | 0 | 5.0772 | 118.3217 | Discharge | 0.46501 | 0.95 | Ratio to Peak | 0.15 |

| Basin Number | SCS CURVE NUMBER LOSS | | | CLARK UNIT HYDROGRAPH TRANSFORM | | RECESSION BASEFLOW | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Type | Initial Discharge (M3/S) | Recession Constant | Threshold Type | Ratio to Peak |
| W1420 | 20.668 | 51.1 | 0 | 10.4688 | 40.396 | Discharge | 3.956 | 0.95 | Ratio to Peak | 0.15 |
| W1410 | 20.668 | 51.1 | 0 | 7.6036 | 40.396 | Discharge | 3.3586 | 0.95 | Ratio to Peak | 0.15 |
| W1400 | 20.668 | 51.1 | 0 | 8.8836 | 40.396 | Discharge | 0.81011 | 0.95 | Ratio to Peak | 0.15 |
| W1390 | 20.668 | 51.1 | 0 | 1.98608 | 40.396 | Discharge | 0.31228 | 0.95 | Ratio to Peak | 0.15 |
| W1380 | 20.668 | 51.1 | 0 | 7.0368 | 40.396 | Discharge | 2.0456 | 0.95 | Ratio to Peak | 0.15 |
| W1370 | 20.668 | 51.1 | 0 | 13.2932 | 40.396 | Discharge | 3.6182 | 0.95 | Ratio to Peak | 0.15 |
| W1360 | 20.668 | 51.1 | 0 | 6.7348 | 40.396 | Discharge | 3.3638 | 0.95 | Ratio to Peak | 0.15 |
| W1350 | 20.668 | 51.1 | 0 | 5.6656 | 40.396 | Discharge | 1.172 | 0.95 | Ratio to Peak | 0.15 |
| W1340 | 20.667 | 51.101 | 0 | 4.558 | 40.394 | Discharge | 1.8931 | 0.95 | Ratio to Peak | 0.15 |
| W1330 | 19.707 | 51.75 | 0 | 10.9508 | 38.519 | Discharge | 2.8977 | 0.95 | Ratio to Peak | 0.15 |
| W1320 | 20.668 | 51.1 | 0 | 5.25 | 40.396 | Discharge | 0.40592 | 0.95 | Ratio to Peak | 0.15 |
| W1310 | 17.222 | 53.509 | 0 | 2.74416 | 33.661 | Discharge | 1.0317 | 0.95 | Ratio to Peak | 0.15 |
| W1300 | 20.668 | 51.1 | 0 | 1.95552 | 40.396 | Discharge | 0.38607 | 0.95 | Ratio to Peak | 0.15 |
| W1290 | 16.895 | 53.749 | 0 | 5.9932 | 33.022 | Discharge | 3.6695 | 0.95 | Ratio to Peak | 0.15 |
| W1280 | 20.668 | 51.1 | 0 | 6.3384 | 40.396 | Discharge | 3.1709 | 0.95 | Ratio to Peak | 0.15 |
| W1270 | 20.668 | 51.1 | 0 | 3.44408 | 40.396 | Discharge | 0.84581 | 0.95 | Ratio to Peak | 0.15 |
| W1260 | 20.668 | 51.1 | 0 | 4.4208 | 40.396 | Discharge | 1.1125 | 0.95 | Ratio to Peak | 0.15 |
| W1250 | 20.668 | 51.1 | 0 | 6.2464 | 40.396 | Discharge | 1.3714 | 0.95 | Ratio to Peak | 0.15 |
| W1240 | 20.668 | 51.1 | 0 | 1.61604 | 40.396 | Discharge | 0.083246 | 0.95 | Ratio to Peak | 0.15 |
| W1230 | 20.668 | 51.1 | 0 | 5.9988 | 40.396 | Discharge | 2.1783 | 0.95 | Ratio to Peak | 0.15 |
| W1220 | 17.379 | 53.394 | 0 | 1.78248 | 33.967 | Discharge | 0.68746 | 0.95 | Ratio to Peak | 0.15 |
| W1210 | 20.668 | 51.1 | 0 | 3.43056 | 40.396 | Discharge | 1.2717 | 0.95 | Ratio to Peak | 0.15 |
| W1200 | 20.104 | 51.479 | 0 | 3.707 | 39.294 | Discharge | 1.2077 | 0.95 | Ratio to Peak | 0.15 |
| W1190 | 16.272 | 54.213 | 0 | 3.65132 | 31.805 | Discharge | 1.9977 | 0.95 | Ratio to Peak | 0.15 |
| W1180 | 19.095 | 52.172 | 0 | 1.90248 | 37.323 | Discharge | 0.2035 | 0.95 | Ratio to Peak | 0.15 |

| Basin Number | SCS CURVE NUMBER LOSS | | | CLARK UNIT HYDROGRAPH TRANSFORM | | RECESSION BASEFLOW | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Abstraction (mm) | Curve Number | Impervious (%) | Time of Concentration (HR) | Storage Coefficient (HR) | Initial Type | Initial Discharge (M3/S) | Recession Constant | Threshold Type | Ratio to Peak |
| W1170 | 20.637 | 51.121 | 0 | 5.7816 | 40.335 | Discharge | 1.4564 | 0.95 | Ratio to Peak | 0.15 |
| W1160 | 20.377 | 51.29483 | 0 | 1.70364 | 39.828 | Discharge | 0.068542 | 0.95 | Ratio to Peak | 0.15 |
| W1150 | 20.108 | 51.477 | 0 | 8.772 | 39.301 | Discharge | 4.699 | 0.95 | Ratio to Peak | 0.15 |
| W1140 | 45.51 | 38.58 | 0 | 15.2316 | 88.951 | Discharge | 6.271 | 0.95 | Ratio to Peak | 0.15 |
| W1130 | 20.668 | 51.1 | 0 | 3.7088 | 40.396 | Discharge | 1.2478 | 0.95 | Ratio to Peak | 0.15 |
| W1120 | 19.326 | 52.012 | 0 | 6.9584 | 37.773 | Discharge | 2.6807 | 0.95 | Ratio to Peak | 0.15 |
| W1110 | 19.157 | 52.129 | 0 | 4.1036 | 37.444 | Discharge | 1.929 | 0.95 | Ratio to Peak | 0.15 |
| W1100 | 17.653 | 53.195 | 0 | 3.739 | 34.504 | Discharge | 2.6123 | 0.95 | Ratio to Peak | 0.15 |
| W1090 | 15.917 | 54.481 | 0 | 2.70356 | 31.11028 | Discharge | 1.3069 | 0.95 | Ratio to Peak | 0.15 |
| W1080 | 20.668 | 51.1 | 0 | 4.3788 | 40.396 | Discharge | 1.9019 | 0.95 | Ratio to Peak | 0.15 |

# Annex 10. Gandara Model Reach Parameters

Table A-10.1. Gandara Model Reach Parameters

| Reach | MUSKINGUM CUNGE CHANNEL ROUTING | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (M) | Slope (M/M) | Manning's n | Shape | Width (M) | Side Slope (xH:1V) |
| R60 | Automatic Fixed Interval | 4609.1 | 0.02 | 0.035 | Trapezoid | 16.2 | 1 |
| R70 | Automatic Fixed Interval | 2449.8 | 0 | 0.035 | Trapezoid | 11.8 | 1 |
| R80 | Automatic Fixed Interval | 759.41 | 0.11 | 0.035 | Trapezoid | 12.2 | 1 |
| R90 | Automatic Fixed Interval | 1338.4 | 0.01 | 0.035 | Trapezoid | 15.2 | 1 |
| R110 | Automatic Fixed Interval | 1896.1 | 0.11 | 0.035 | Trapezoid | 12.8 | 1 |
| R160 | Automatic Fixed Interval | 674.56 | 0 | 0.035 | Trapezoid | 6 | 1 |
| R180 | Automatic Fixed Interval | 2739.5 | 0 | 0.035 | Trapezoid | 12.2 | 1 |
| R190 | Automatic Fixed Interval | 2769.7 | 0.03 | 0.035 | Trapezoid | 10.4 | 1 |
| R220 | Automatic Fixed Interval | 1232.7 | 0 | 0.035 | Trapezoid | 11.2 | 1 |
| R230 | Automatic Fixed Interval | 8626.1 | 0 | 0.035 | Trapezoid | 17.8 | 1 |
| R240 | Automatic Fixed Interval | 2660.4 | 0 | 0.035 | Trapezoid | 10.4 | 1 |
| R250 | Automatic Fixed Interval | 3056.6 | 0 | 0.035 | Trapezoid | 13 | 1 |
| R260 | Automatic Fixed Interval | 3853 | 0.11 | 0.035 | Trapezoid | 23.6 | 1 |
| R280 | Automatic Fixed Interval | 7051 | 0 | 0.035 | Trapezoid | 13.4 | 1 |
| R300 | Automatic Fixed Interval | 1548.8 | 0 | 0.035 | Trapezoid | 8.2 | 1 |
| R320 | Automatic Fixed Interval | 4546.3 | 0 | 0.035 | Trapezoid | 26 | 1 |

| Reach | MUSKINGUM CUNGE CHANNEL ROUTING | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (M) | Slope (M/M) | Manning's n | Shape | Width (M) | Side Slope (xH:1V) |
| R340 | Automatic Fixed Interval | 12803 | 0 | 0.035 | Trapezoid | 17.4 | 1 |
| R390 | Automatic Fixed Interval | 5227.7 | 0 | 0.035 | Trapezoid | 37.6 | 1 |
| R400 | Automatic Fixed Interval | 90.711 | 0.03 | 0.035 | Trapezoid | 20 | 1 |
| R410 | Automatic Fixed Interval | 2800.2 | 0 | 0.035 | Trapezoid | 30.2 | 1 |
| R440 | Automatic Fixed Interval | 6265.7 | 0 | 0.035 | Trapezoid | 31.5 | 1 |
| R500 | Automatic Fixed Interval | 2314.4 | 0 | 0.035 | Trapezoid | 34 | 1 |
| R510 | Automatic Fixed Interval | 3016.7 | 0.01 | 0.035 | Trapezoid | 17.5 | 1 |
| R520 | Automatic Fixed Interval | 3165.6 | 0.01 | 0.035 | Trapezoid | 33.2 | 1 |
| R550 | Automatic Fixed Interval | 7967.5 | 0.01 | 0.035 | Trapezoid | 14 | 1 |
| R560 | Automatic Fixed Interval | 12398 | 0 | 0.035 | Trapezoid | 41.2 | 1 |
| R570 | Automatic Fixed Interval | 2969.1 | 0.11 | 0.035 | Trapezoid | 32.4 | 1 |
| R590 | Automatic Fixed Interval | 3389.2 | 0.01 | 0.035 | Trapezoid | 33.2 | 1 |
| R600 | Automatic Fixed Interval | 3438.7 | 0.01 | 0.035 | Trapezoid | 30 | 1 |
| R610 | Automatic Fixed Interval | 1402.3 | 0.11 | 0.035 | Trapezoid | 33.2 | 1 |
| R620 | Automatic Fixed Interval | 2719.5 | 0.03 | 0.035 | Trapezoid | 8.5 | 1 |
| R660 | Automatic Fixed Interval | 7.0711 | 0.11 | 0.035 | Trapezoid | 5 | 1 |

| Reach | MUSKINGUM CUNGE CHANNEL ROUTING | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (M) | Slope (M/M) | Manning's n | Shape | Width (M) | Side Slope (xH:1V) |
| R670 | Automatic Fixed Interval | 2424.1 | 0 | 0.035 | Trapezoid | 95.4 | 1 |
| R700 | Automatic Fixed Interval | 3049.9 | 0 | 0.035 | Trapezoid | 25.6 | 1 |
| R720 | Automatic Fixed Interval | 4612.7 | 0 | 0.035 | Trapezoid | 15.4 | 1 |
| R730 | Automatic Fixed Interval | 144.85 | 0.11 | 0.035 | Trapezoid | 44 | 1 |
| R740 | Automatic Fixed Interval | 10011 | 0 | 0.035 | Trapezoid | 50.6 | 1 |
| R750 | Automatic Fixed Interval | 1997.4 | 0.03 | 0.035 | Trapezoid | 35.8 | 1 |
| R760 | Automatic Fixed Interval | 604.26 | 0.01 | 0.035 | Trapezoid | 15 | 1 |
| R770 | Automatic Fixed Interval | 4577.9 | 0 | 0.035 | Trapezoid | 43.8 | 1 |
| R780 | Automatic Fixed Interval | 1377.4 | 0.11 | 0.035 | Trapezoid | 30 | 1 |
| R800 | Automatic Fixed Interval | 2748.4 | 0 | 0.035 | Trapezoid | 38 | 1 |
| R810 | Automatic Fixed Interval | 1940.7 | 0 | 0.035 | Trapezoid | 25.6 | 1 |
| R820 | Automatic Fixed Interval | 2192.2 | 0 | 0.035 | Trapezoid | 9.5 | 1 |
| R840 | Automatic Fixed Interval | 1867.4 | 0.11 | 0.035 | Trapezoid | 27.2 | 1 |
| R850 | Automatic Fixed Interval | 3525.8 | 0 | 0.035 | Trapezoid | 36.6 | 1 |
| R920 | Automatic Fixed Interval | 5092 | 0.11 | 0.035 | Trapezoid | 15 | 1 |
| R930 | Automatic Fixed Interval | 5670.7 | 0.11 | 0.035 | Trapezoid | 26.2 | 1 |

| Reach | MUSKINGUM CUNGE CHANNEL ROUTING | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (M) | Slope (M/M) | Manning's n | Shape | Width (M) | Side Slope (xH:1V) |
| R950 | Automatic Fixed Interval | 1962 | 0 | 0.035 | Trapezoid | 24.2 | 1 |
| R990 | Automatic Fixed Interval | 1798.9 | 0 | 0.035 | Trapezoid | 25 | 1 |
| R1000 | Automatic Fixed Interval | 3609.9 | 0.03 | 0.035 | Trapezoid | 9 | 1 |
| R1020 | Automatic Fixed Interval | 4059.5 | 0.03 | 0.035 | Trapezoid | 15.25 | 1 |
| R1030 | Automatic Fixed Interval | 9515.6 | 0 | 0.035 | Trapezoid | 13.5 | 1 |

# Annex 11. Gandara Field Validation Points

Table A-11.1. Gandara Field Validation Points

| GPS Code | Latitude | Longitude | Model Var (m) | Validation Point (m) | Error | Event (Typhoon, Habagat, etc) | Date of Occurrence | Return Period of Event |
|---|---|---|---|---|---|---|---|---|
| 650 | 11.97878888 | 124.8305036 | 0.03 | 1.1 | -1.07 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 750 | 11.98064161 | 124.8298359 | 0.29 | 1.5 | -1.21 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 850 | 11.97831832 | 124.8278911 | 0.27 | 1.3 | -1.03 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 1460 | 11.98009025 | 124.8237338 | 0.03 | 0.7 | -0.67 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 1760 | 11.97860582 | 124.8290492 | 0.03 | 1.1 | -1.07 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 1889 | 12.00279876 | 124.7847395 | 0.04 | 0.6 | -0.56 | Yolanda | November 7-8, 2013 | 5-Year |
| 1949 | 11.97830097 | 124.8272566 | 1.14 | 1.5 | -0.36 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 1999 | 12.04186865 | 124.8134126 | 7.98 | 0.5 | 7.48 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 2160 | 11.98229335 | 124.836271 | 8.27 | 0.6 | 7.67 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 2250 | 11.98323288 | 124.8346738 | 0.17 | 0.6 | -0.43 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 2350 | 11.98295075 | 124.8348669 | 0.28 | 0.6 | -0.32 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 2450 | 11.98405196 | 124.8361284 | 0.03 | 0.6 | -0.57 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 2532 | 12.03744175 | 124.8260938 | 0.03 | 0.3 | -0.27 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 2542 | 12.03742339 | 124.8252898 | 0.07 | 0.3 | -0.23 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 2552 | 12.03704336 | 124.8259578 | 0.11 | 0.3 | -0.19 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 2562 | 12.03669878 | 124.8253563 | 0.04 | 0.7 | -0.66 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 2622 | 11.98399622 | 124.8337371 | 9.12 | 0.6 | 8.52 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 3711 | 11.9802475 | 124.8547435 | 1.17 | 0.7 | 0.47 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 4116 | 11.98026912 | 124.8536594 | 1.17 | 0.7 | 0.47 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 4411 | 11.98230693 | 124.8251789 | 0.86 | 0.7 | 0.16 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 4511 | 11.98123279 | 124.8234752 | 0.07 | 0.7 | -0.63 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 4711 | 11.98131326 | 124.8217153 | 0.03 | 0.5 | -0.47 | Ruby | December 6-7, 2014 | 5-Year |
| 5020 | 11.98084102 | 124.8219712 | 0.03 | 0.5 | -0.47 | Ruby | December 6-7, 2014 | 5-Year |

| GPS Code | Latitude | Longitude | Model Var (m) | Validation Point (m) | Error | Event (Typhoon, Habagat, etc) | Date of Occurrence | Return Period of Event |
|---|---|---|---|---|---|---|---|---|
| 5220 | 11.9830463 | 124.8175405 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 5320 | 11.98327487 | 124.8166412 | 0.17 | 0.4 | -0.23 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 5420 | 11.9835726 | 124.8154978 | 0.03 | 0.4 | -0.37 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 6011 | 11.9878669 | 124.8081179 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 6115 | 11.98833151 | 124.8074141 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 6213 | 11.9868578 | 124.8096182 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 6411 | 11.98282929 | 124.8242049 | 0.03 | 0.5 | -0.47 | Ruby | December 6-7, 2014 | 5-Year |
| 7011 | 12.0128189 | 124.8109919 | 0.04 | 0.5 | -0.46 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 7115 | 12.0120616 | 124.8090854 | 1.97 | 0.5 | 1.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 7311 | 12.01231943 | 124.809329 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 7911 | 12.01376312 | 124.809484 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 8011 | 12.01502829 | 124.8087922 | 0.03 | 0.4 | -0.37 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 8311 | 12.01350739 | 124.8077356 | 0.09 | 0.5 | -0.41 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 8411 | 12.01576699 | 124.8060185 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 8511 | 12.01534311 | 124.8076201 | 0.24 | 0.4 | -0.16 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 8711 | 12.0127039 | 124.808178 | 0.2 | 0.5 | -0.3 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 9115 | 12.01399891 | 124.8094799 | 0.12 | 0.5 | -0.38 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 9213 | 12.01506316 | 124.8118829 | 3.91 | 0.4 | 3.51 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 10412 | 12.01557538 | 124.8118158 | 4.13 | 0.5 | 3.63 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 10512 | 12.01450425 | 124.8102747 | 0.14 | 0.5 | -0.36 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 10712 | 12.01535543 | 124.811355 | 0.03 | 0.4 | -0.37 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 11612 | 12.01560555 | 124.8069288 | 0.04 | 0.5 | -0.46 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 13412 | 11.98308771 | 124.7487042 | 0.03 | 0.4 | -0.37 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 13612 | 11.98224558 | 124.7468299 | 0.03 | 0.4 | -0.37 | Ruby | December 6-7, 2014 | 5-Year |
| 13812 | 11.98221481 | 124.7474669 | 0.03 | 0.4 | -0.37 | Ruby | December 6-7, 2014 | 5-Year |

| GPS Code | Latitude | Longitude | Model Var (m) | Validation Point (m) | Error | Event (Typhoon, Habagat, etc) | Date of Occurrence | Return Period of Event |
|---|---|---|---|---|---|---|---|---|
| 13912 | 11.98254556 | 124.7485629 | 0.03 | 0.6 | -0.57 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 14213 | 11.98273717 | 124.749027 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 14412 | 11.9830991 | 124.749409 | 0.03 | 0.6 | -0.57 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 15213 | 11.98486266 | 124.7599745 | 0.03 | 0.3 | -0.27 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 15512 | 11.98392288 | 124.7559549 | 0.03 | 0.2 | -0.17 | Yolanda | November 7-8, 2013 | 5-Year |
| 15612 | 11.98421868 | 124.7565999 | 0.03 | 0.2 | -0.17 | Yolanda | November 7-8, 2013 | 5-Year |
| 16612 | 11.9881435 | 124.765251 | 0.03 | 0.4 | -0.37 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 17012 | 11.99306502 | 124.7712148 | 1.09 | 0.5 | 0.59 | Yolanda | November 7-8, 2013 | 5-Year |
| 17116 | 11.994083 | 124.7724846 | 0.03 | 0.5 | -0.47 | Yolanda | November 7-8, 2013 | 5-Year |
| 17213 | 11.9949367 | 124.7736553 | 0.05 | 0.5 | -0.45 | Yolanda | November 7-8, 2013 | 5-Year |
| 17312 | 11.993421 | 124.7719446 | 0.11 | 0.5 | -0.39 | Yolanda | November 7-8, 2013 | 5-Year |
| 17711 | 12.01650526 | 124.7886864 | 1.22 | 0.6 | 0.62 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 17812 | 12.01496777 | 124.7884109 | 0.09 | 0.4 | -0.31 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 18012 | 12.01575416 | 124.7884999 | 0.03 | 0.4 | -0.37 | Ruby | December 6-7, 2014 | 5-Year |
| 18311 | 12.01616504 | 124.7885744 | 0.97 | 0.5 | 0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 18511 | 12.00310168 | 124.7851275 | 6.48 | 0.6 | 5.88 | Yolanda | November 7-8, 2013 | 5-Year |
| 18611 | 12.0024618 | 124.7839223 | 0.03 | 0.6 | -0.57 | Yolanda | November 7-8, 2013 | 5-Year |
| 18711 | 12.0036662 | 124.7846442 | 0.24 | 0.6 | -0.36 | Yolanda | November 7-8, 2013 | 5-Year |
| 18911 | 12.02530517 | 124.7730847 | 0.12 | 0.4 | -0.28 | Yolanda | November 7-8, 2013 | 5-Year |
| 19011 | 12.02500585 | 124.7719891 | 0.88 | 0.4 | 0.48 | Yolanda | November 7-8, 2013 | 5-Year |
| 19115 | 12.0254102 | 124.7719713 | 0.03 | 0.4 | -0.37 | Yolanda | November 7-8, 2013 | 5-Year |
| 19311 | 12.02458198 | 124.7726841 | 1.14 | 0.4 | 0.74 | Yolanda | November 7-8, 2013 | 5-Year |
| 20311 | 12.04104555 | 124.8127088 | 0.07 | 0.7 | -0.63 | Low Pressure 1 | January 10, 2017 | 5-Year |
| 20511 | 12.04179229 | 124.8140332 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 21213 | 12.05700922 | 124.8198349 | 0.07 | 0.7 | -0.63 | Low Pressure 1 | January 10, 2017 | 5-Year |

| GPS Code | Latitude | Longitude | Model Var (m) | Validation Point (m) | Error | Event (Typhoon, Habagat, etc) | Date of Occurrence | Return Period of Event |
|---|---|---|---|---|---|---|---|---|
| 21711 | 12.0431836 | 124.813337 | 0.03 | 0.5 | -0.47 | Heavy Rainfall | September 17-18, 2014 | 5-Year |
| 21811 | 12.04350321 | 124.813164 | 0.75 | 0.5 | 0.25 | Heavy Rainfall | September 17-18, 2014 | 5-Year |

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

Table A-12.1. Educational Institutions in Gandara Floodplain

| SAMAR | | | | |
|---|---|---|---|---|
| GANDARA | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Natimonan Primary School | Adela Heights | | | |
| Bangahon Day Care Center | Calirocan | | | Low |
| Bangahon Elementary School | Calirocan | | | Low |
| Casab-ahan Day Care Center | Casab-Ahan | Low | High | High |
| Casab-ahan Elementary School | Casab-Ahan | Low | High | High |
| Tagnao Day Care Center | Casab-Ahan | Medium | High | High |
| Tagnao Elementary School | Casab-Ahan | Medium | High | High |
| Casandig Day Care Center | Casandig | | | Medium |
| Casandig Elementary School | Casandig | | | Medium |
| Gerali Elementary School | Gerali | | | |
| Sto Niño Integrated School | Gereganan | | | Medium |
| Lungib Day Care Center | Lungib | | | |
| Lungib Elementary School | Lungib | | | |
| Buñagan Elementary School | Tagnao | | | |

| SAMAR | | | | |
|---|---|---|---|---|
| PAGSANGHAN | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Bangon Elementary School | Bangon | | | |
| Campaye Elementary School | Bangon | Low | Medium | Medium |
| Caloloma Elelmentary School | Caloloma | | | |
| Pagsanghan Elementary School | Viejo | | | |
| Pagsanghan National High School | Viejo | | | |

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

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

| SAMAR | | | | |
|---|---|---|---|---|
| GANDARA | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Casab-ahan Health Center | Casab-Ahan | | Medium | High |
| Tagnao Health Center | Casab-Ahan | | | |
| Sto. Niño Health Center | Gereganan | | | High |
| Maternity Clinic | Tambongan | | | |

| SAMAR | | | | |
|---|---|---|---|---|
| PAGSANGHAN | | | | |
| Building Name | Barangay | Rainfall Scenario | | |
| | | 5-year | 25-year | 100-year |
| Bangon Health Center | Bangon | | | |
| Canlapwas Health Center | Viejo | | | Low |