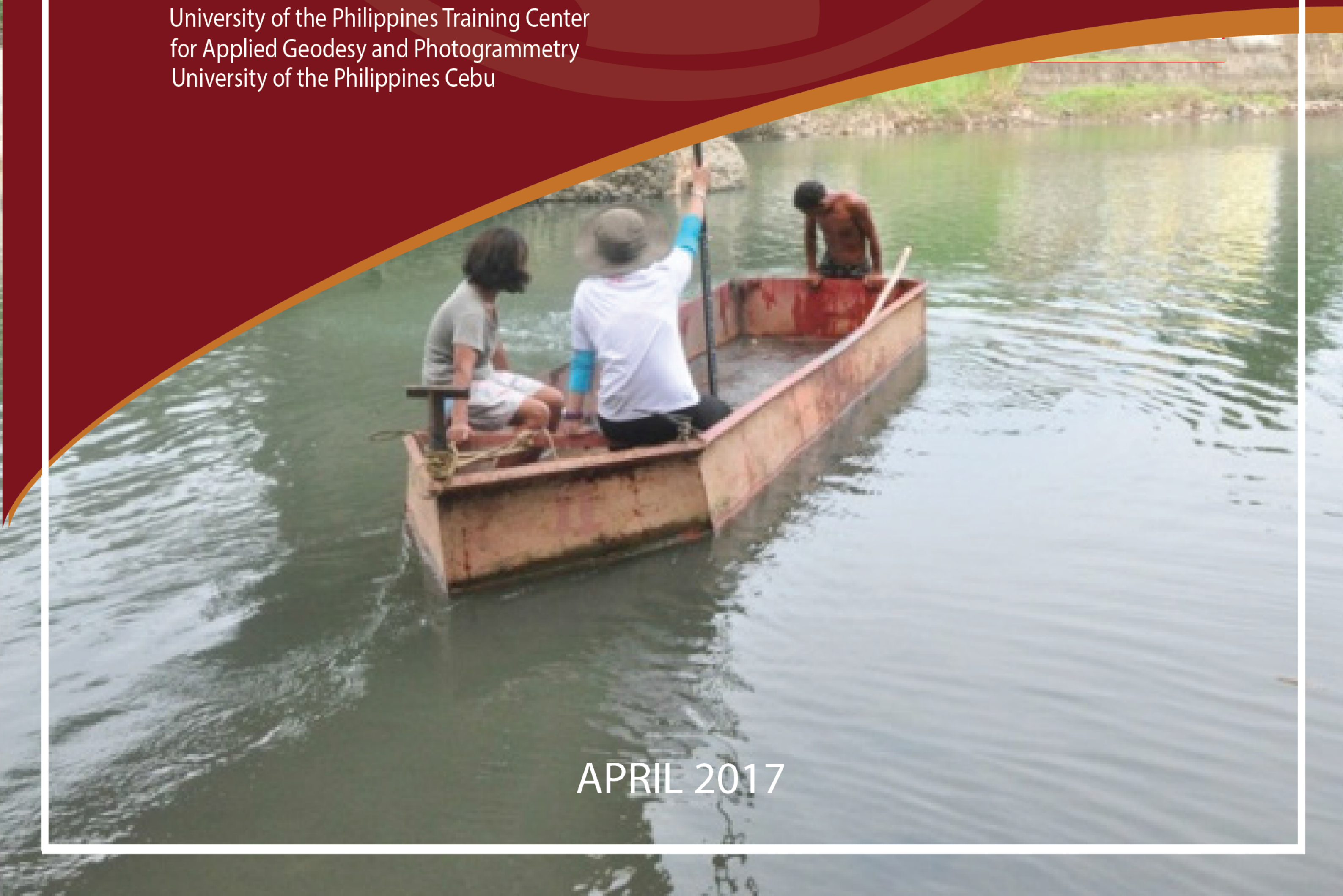
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Malogo River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Cebu



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LIST OF ACRONYMS AND ABBREVIATIONS

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
BSWM	Bureau of Soils and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSO	National Statistics Office
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
RBCO	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
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MALOGO RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer R. Sinogaya, PhD.

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 a 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Cebu (UPC). UPC 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 twenty-two (22) river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Malogo River Basin

The Malogo (also known as Malago) River Basin is located at the midwest of the Negros Island, between the Municipalities of Enrique B. Magalona (EB Magalona) and Victorias City in Negros Occidental. The floodplain also covers Silay City. According to the River Basin Control Office (RBCO) of the Department of Environment and Natural Resources (DENR), it has an estimated drainage area of 163 km^2, and an estimated annual run-off of 270 million cubic meters (MCM). The basin's main stem, the Malogo River, is part of the river systems in the Negros Island Region.

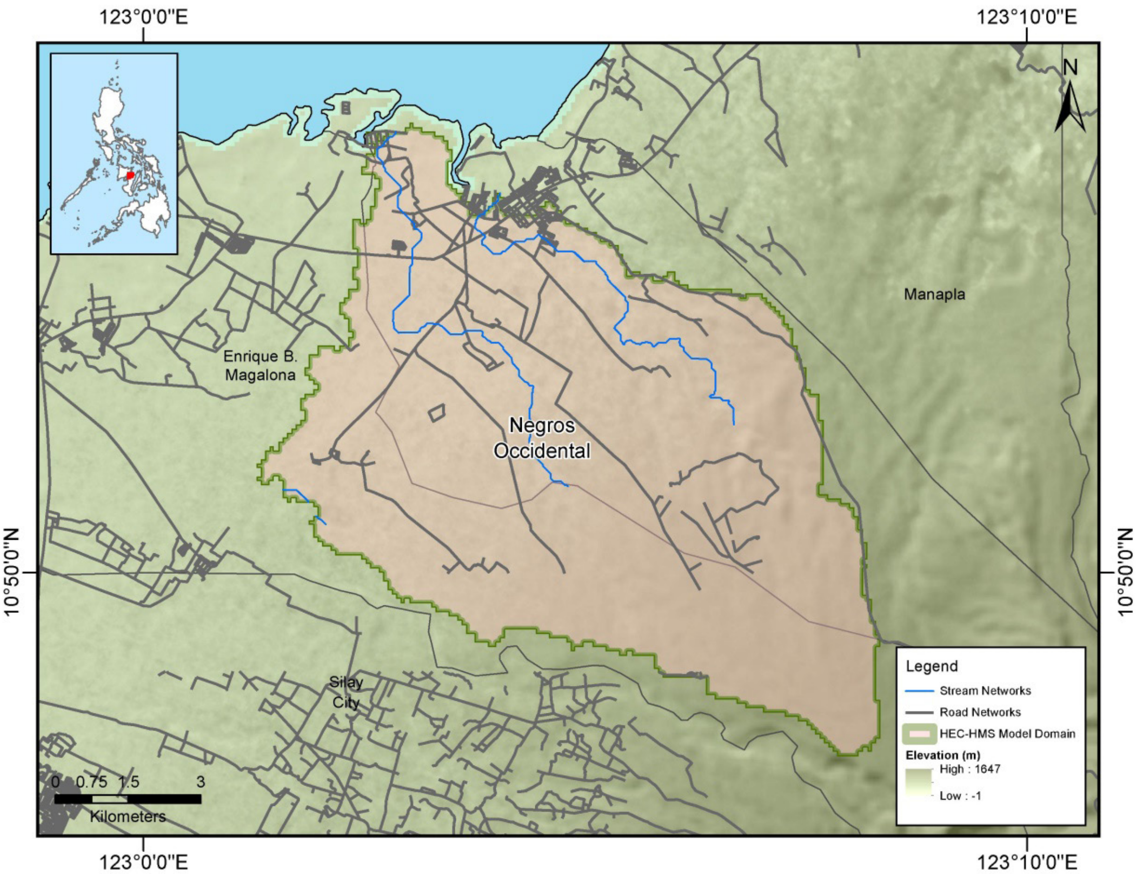

Figure 1. Location map of the Malogo River Basin (in brown)

According to the 2010 census of the National Statistics Office (NSO), the total population of residents within the immediate vicinity of the Malogo River is about 27,481. The population density of Victorias City is about 247 people per square kilometer.

The area's economy is primarily focused on agriculture, largely on sugar cane plantation cultivation, and sugar production and distribution. Locals in the coastal areas also practice fishing as a source of livelihood.

The recent flooding events were due to the presence of active low pressure areas in the Western Visayas Region that caused intermittent rains. In 2011, flashfloods brought about by heavy rains completely inundated the homes of around 2,000 families in EB Magalona, and affected around 1,400 families in Victorias City.

The LiDAR survey covered the Malogo floodplain by 100%, comprising of two (2) blocks of LiDAR data. The data was calibrated, and then mosaicked with an RMSE of -0.08, and then bathy burned. The bathy survey conducted reached a gathered 12,098 points and covered a total length of 12.24 kilometers, from Nanca, EB Magalona until the mouth of the river. There were 24,778 buildings, 431.96-kilometer roads, 912 water bodies, and 27 bridges that were digitized, based on the LiDAR data. Feature extraction attribution was conducted among the building features, wherein 23,860 are residential, 416 are schools, and 22 are medical institutions.

The flood hazard maps generated for the floodplain, for the 5-year, 25-year, and 100 year rainfall return periods, covers the following municipalities: Silay City, encompassing fifteen (15) barangays; EB Magalona, encompassing twenty-one (21) barangays; Manapla, encompassing one (1) barangay; Victorias City, encompassing twenty-four (24) barangays; and Talisay City, encompassing one (1) barangay. A flood depth validation was conducted using 270 randomly generated points, which were spread throughout the six (6) ranges of depth (i.e., 0-0.2 meters, 0.21-0.5 meters, 0.51-1 meter, 1.01-2 meters, 2.10-5 meters, and more than 5 meters) using the 25-year rainfall flood depth map. The validation yielded an RMSE value of 0.830 meters.

A rating curve was developed at the Nanca Bridge in the Municipality of EB Magalona, Negros Occidental, establishing the relationship between the observed water levels and the outflow of the watershed. This was used to compute for the Malogo River outflow at the Nanca Bridge, for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas, through HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MALOGO FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Jasmine T. Alviar, and Darryl M. Austria

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Malogo floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Negros Occidental. The missions were planned for seventeen (17) lines and ran for at most four (4) hours, including take-off, landing, and turning time. The Pegasus LiDAR system was used for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 illustrates the flight plans for the Malogo floodplain.

Table 1. Flight planning parameters for the Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Around (Minutes)
BLK44A	1000	30	50	200	30	130	5
BLK44B	1000	30	50	200	30	130	5
BLK44C	1000	30	50	200	30	130	5

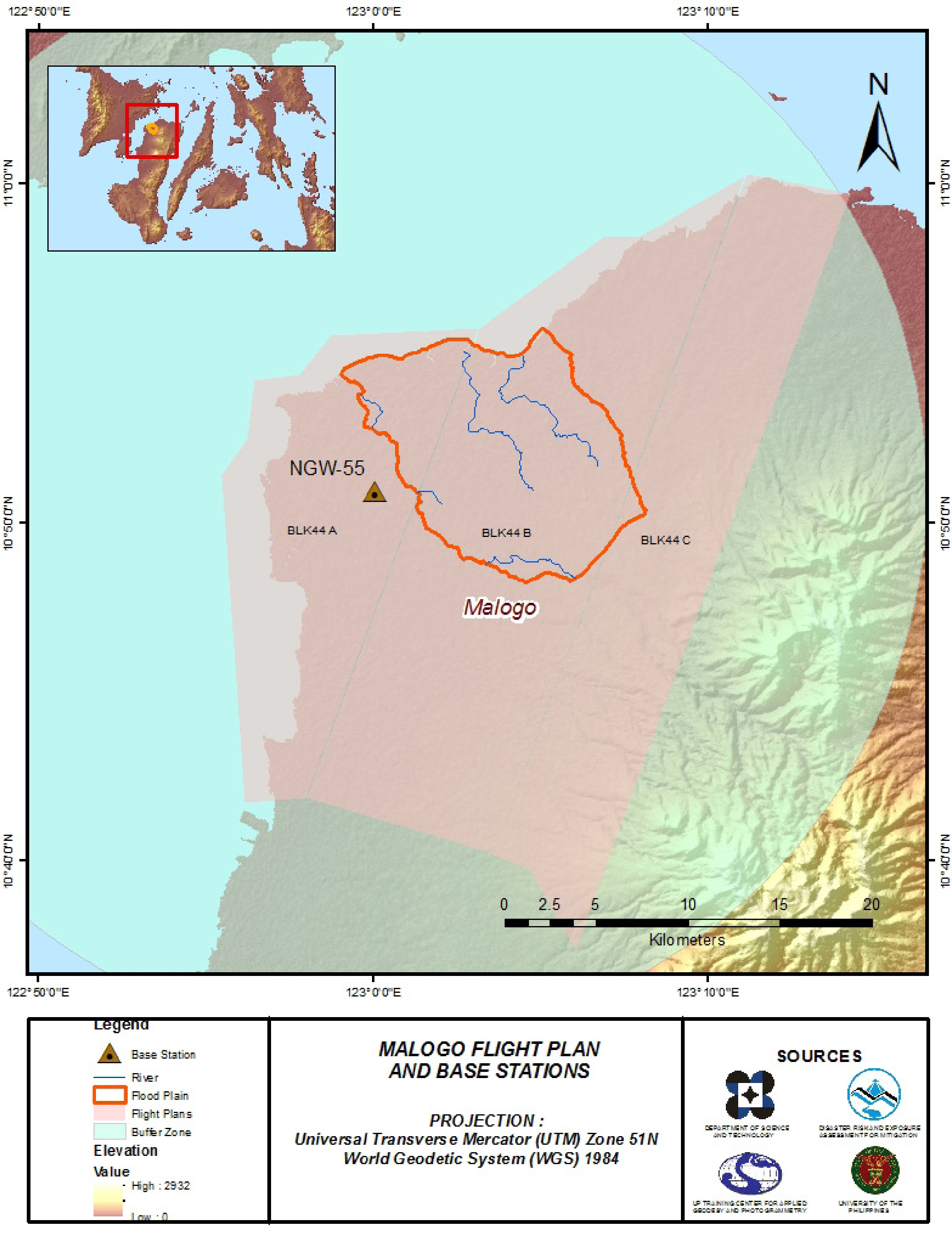

Figure 2. Flight plans and base stations used to cover the Malogo floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover one (1) NAMRIA reference point of second (2^{nd}) order accuracy, NGW-55. The certification for this reference point is found in Annex 2. This was used as the base station for the duration of the survey, held on April 26, 2014. The base station was observed using a dual frequency GPS receiver, Trimble SPS 882. The location of the base station, along with the flight plans used during the aerial LiDAR acquisition in the Malogo floodplain, is shown in Figure 2. The composition of the full project team is given in Annex 3.

Figure 3 exhibits the recovered NAMRIA reference point within the area, and Table 2 provides the details about the reference station. Table 3 lists the details of the data acquisition for the occupied ground control point.

(a) (b)

Figure 3. (a) GPS set-up positioned about 9 km. from the junction of the national highway and the road heading towards the sugar central, located at Barangay Tanza, E.B. Magalona, Negros Occidental; and (b) NAMRIA reference point NGW-55, as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal reference point NGW-55, used as the base station for the LiDAR acquisition

Station Name	NGW-55	
Order of Accuracy	2^{rd}	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 51’ 0.88734” North 122° 59’ 57.75865” East 12.016 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	1199766.082 meters 499931.926 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 50’ 56.54743” North 123° 0’ 2.96548” East 70.280 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	499931.95 meters 1199346.14 meters

Table 3. Ground control point used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Point
April 26, 2014	1391P	1BLK44CB115A	NGW-55
April 26, 2014	1393P	1BLK44AB115B	NGW-55

2.3 Flight Missions

A total of two (2) flight missions were conducted to complete LiDAR data acquisition in the Malogo floodplain, for a total of eight (8) hours and forty-six (46) minutes of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. The flight logs for the missions are presented in Annex 5. Table 4 indicates the total area of actual coverage per mission, with the corresponding flight duration. Table 5 presents the actual parameters used during the LiDAR data acquisition.

Table 4. Flight missions for the LiDAR data acquisition in the Malogo 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
April 26, 2014	1391P	603.43	325.21	40.2	285.01	0	4	23
April 26, 2014	1393P	566.11	426.64	110.63	316.01	0	4	23
TOTAL		1169.54	751.85	150.83	601.02	0	8	46

Table 5. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1391P	1000	15	50	200	30	130	5
1393P	1200	15	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Malogo floodplain, located in the province of Negros Occidental, with majority of the floodplain situated within the City of Victorias. The Municipalities of Manapla and EB Magalona are mostly covered by the survey. The municipalities and cities surveyed, with at least one (1) square kilometer coverage, are enumerated in Table 6. The actual coverage of the LiDAR acquisition for the Malogo floodplain is illustrated in Figure 4. The flight status report is presented in Annex 6.

Table 6. List of Municipalities/Cities surveyed during the Malogo floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Negros Occidental	Manapla	99.18	92.24	93%
	Enrique B. Magalona	140.32	116.97	83%
	Victorias City	103.55	78.26	76%
	Silay City	196.52	147.32	75%
	Talisay City	199.01	108.53	55%
	Bacolod City	152.24	47.46	31%
	Cadiz City	516.18	33.42	6%
	Murcia	364.20	3.15	1%
	Total	1,771.2	627.35	35.42%

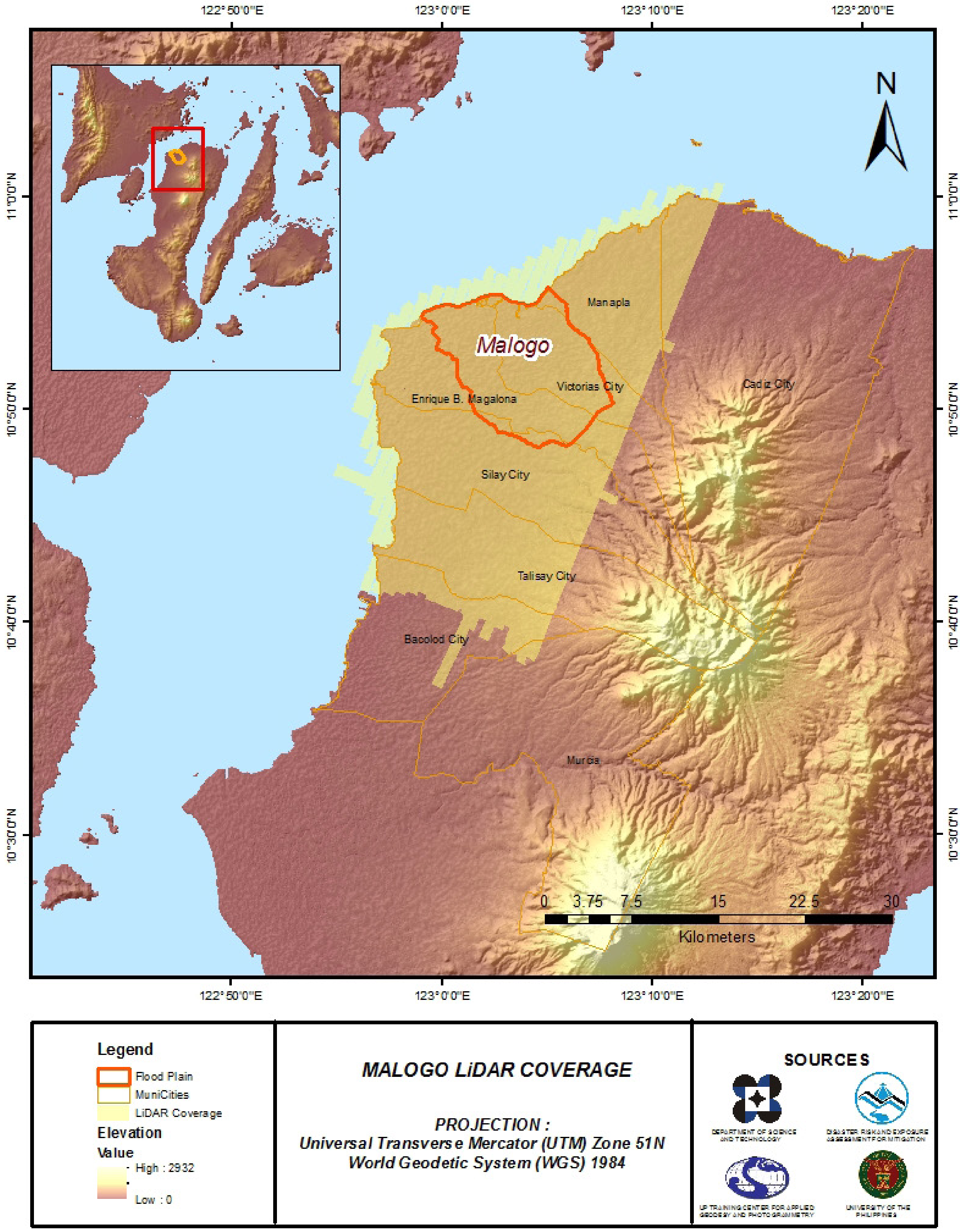

Figure 4. Actual LiDAR survey coverage for the Malogo floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE MALOGO FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the DAC were 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 was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and the vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

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

These processes are summarized in the diagram in Figure 5.

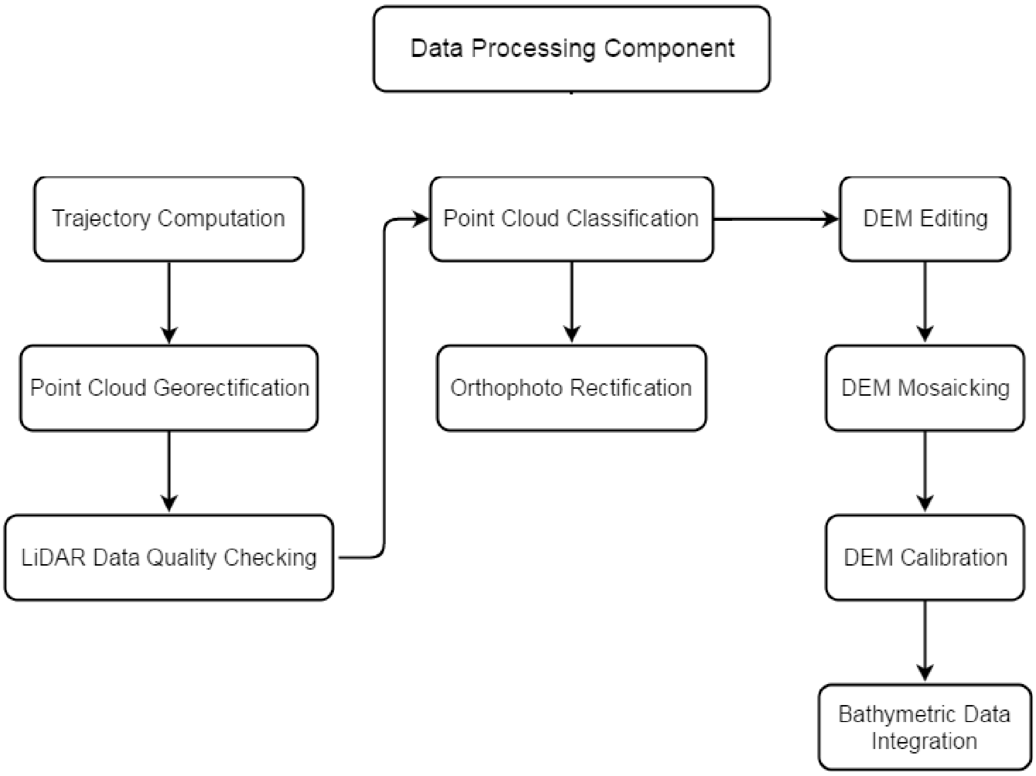


Figure 5. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Malogo floodplain can be found in Annex 4. Missions flown during the first and second survey conducted in April 2014 over Negros used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The DAC transferred a total of 61.30 Gigabytes of Range data, 0.52 Gigabytes of POS data, 24.60 Megabytes of GPS base station data, and 97 Gigabytes of raw image data to the data server on April 26, 2014 for the first survey, and on April 27, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Malogo survey was fully transferred on May 26, 2014, as indicated on the data transfer sheets for the Malogo floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 1391P, one of the Malogo flights, which are the North, East, and Down position RMSE values, are exhibited in Figure 6. 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 fell on April 26, 2014 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

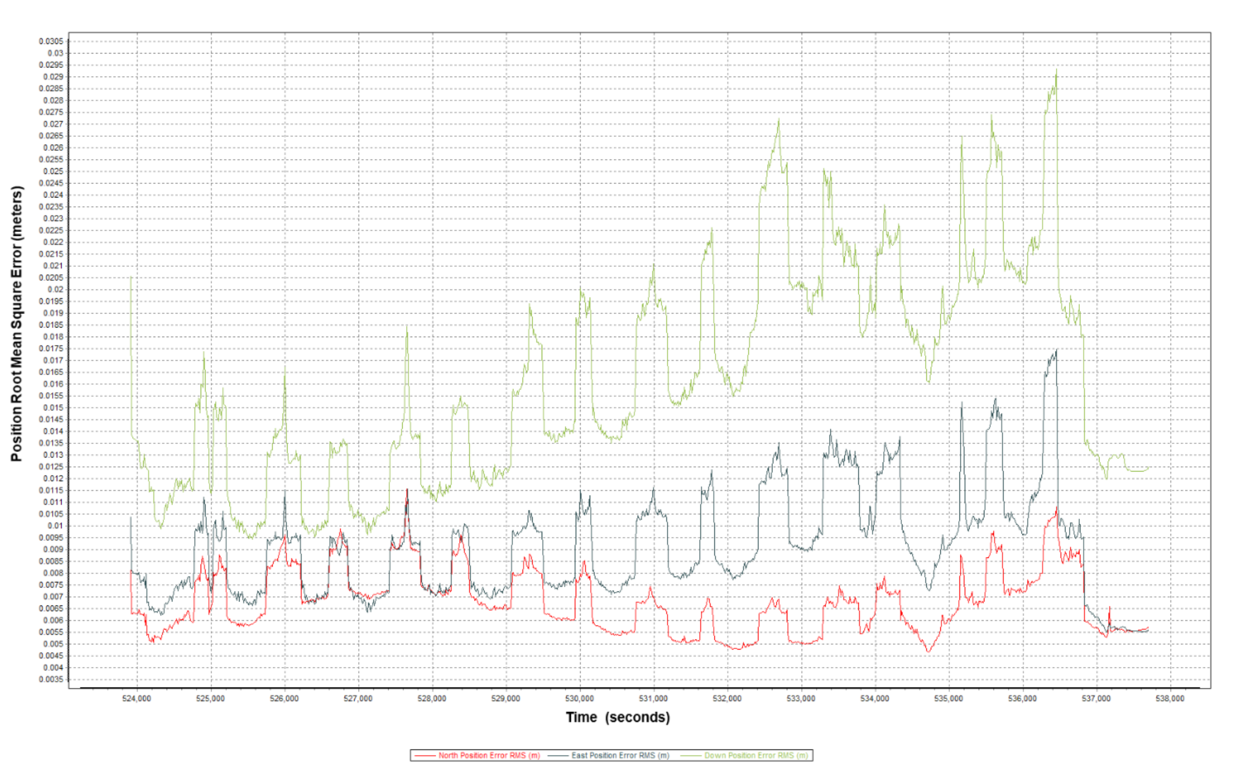


Figure 6. Smoothed Performance Metrics of Malogo Flight 1391P

The time of flight was from 524000 seconds to 538000 seconds, which corresponds to the morning of April 26, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 6 demonstrates that the North position RMSE peaked at 1.20 centimeters, the East position RMSE peaked at 1.75 centimeters, and the Down position RMSE peaked at 2.95 centimeters, which are within the prescribed accuracies described in the methodology.

Figure 7. Solution Status Parameters of Malogo Flight 1391P

The Solution Status parameters of Flight 1391P, one of the Malogo flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are illustrated in Figure 7. The graphs indicate that the number of satellites during the acquisition did not go below 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some peaks to up to 1 or 2, attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Malogo flights is depicted in Figure 8.

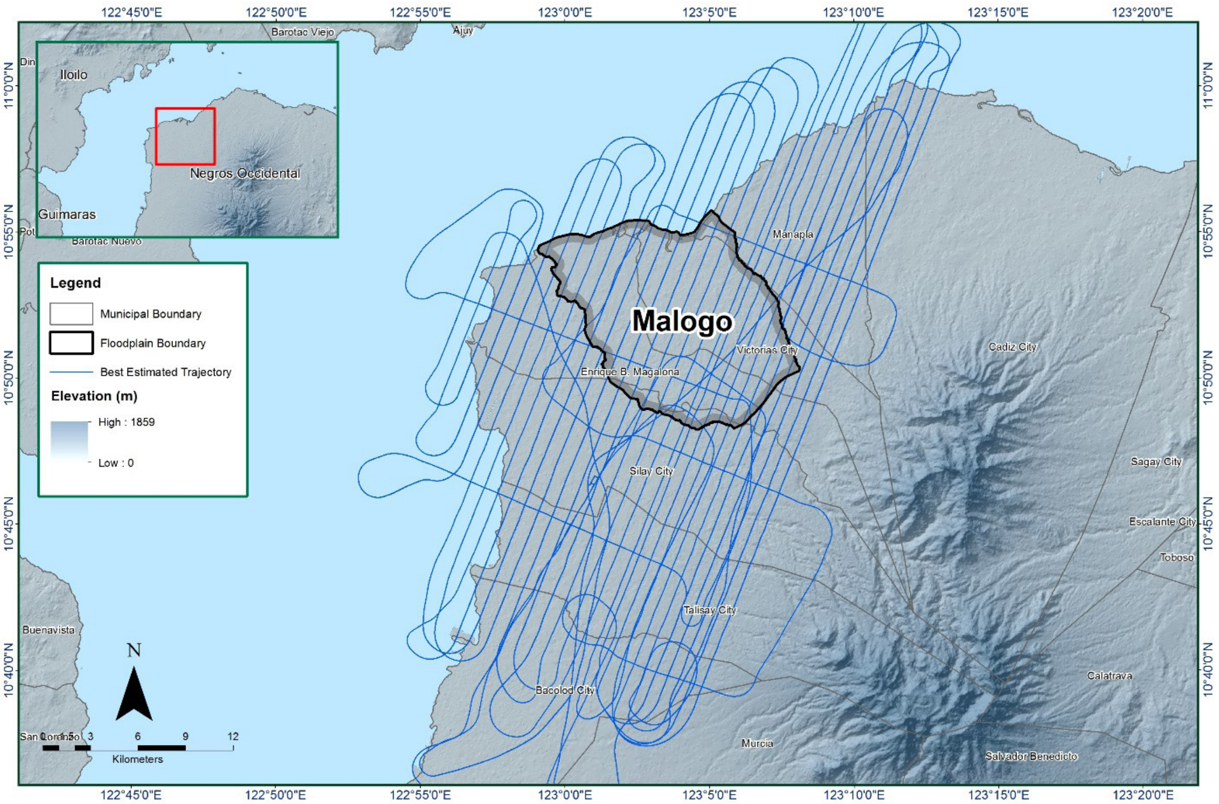


Figure 8. The best estimated trajectory conducted over the Malogo floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains thirty-one (31) flight lines, with each flight line containing one (1) channel, since the Pegasus system contains two (2) channels. The summary of the self-calibration results for all flights over Malogo floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 7.

Table 7. Self-calibration results for Malogo flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000499
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000966
GPS Position Z-correction stdev	(<0.01meters)	0.0085

Optimum accuracy was obtained for all Malogo flights, based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for the individual blocks are available in Annex 7: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of an SAR Elevation Data over the Malogo floodplain are represented in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

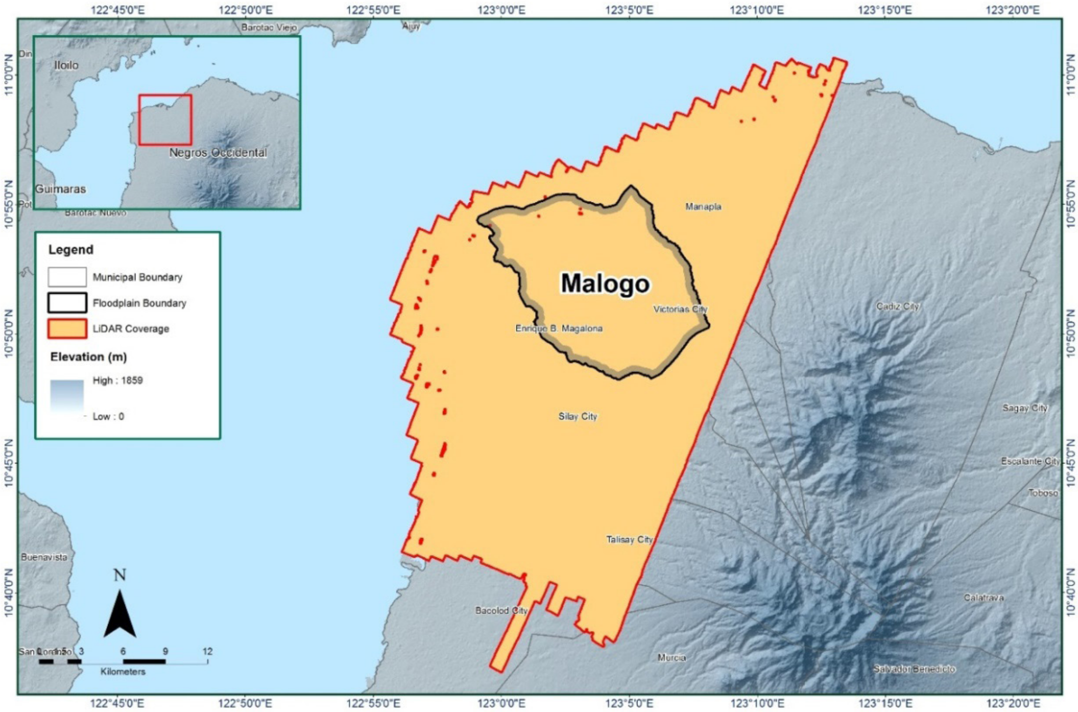


Figure 9. Boundaries of the processed LiDAR data over the Malogo floodplain

The total area covered by the Malogo missions is 737.31 square kilometers, comprised of two (2) flight acquisitions grouped and merged into two (2) blocks, as outlined in Table 8.

Table 8. List of LiDAR blocks for the Malogo floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Negros_Blk44AB	1393P	416.93
Negros_Blk44C	1391P	320.38
TOTAL		**737.31 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 10. Since the Pegasus system employs two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

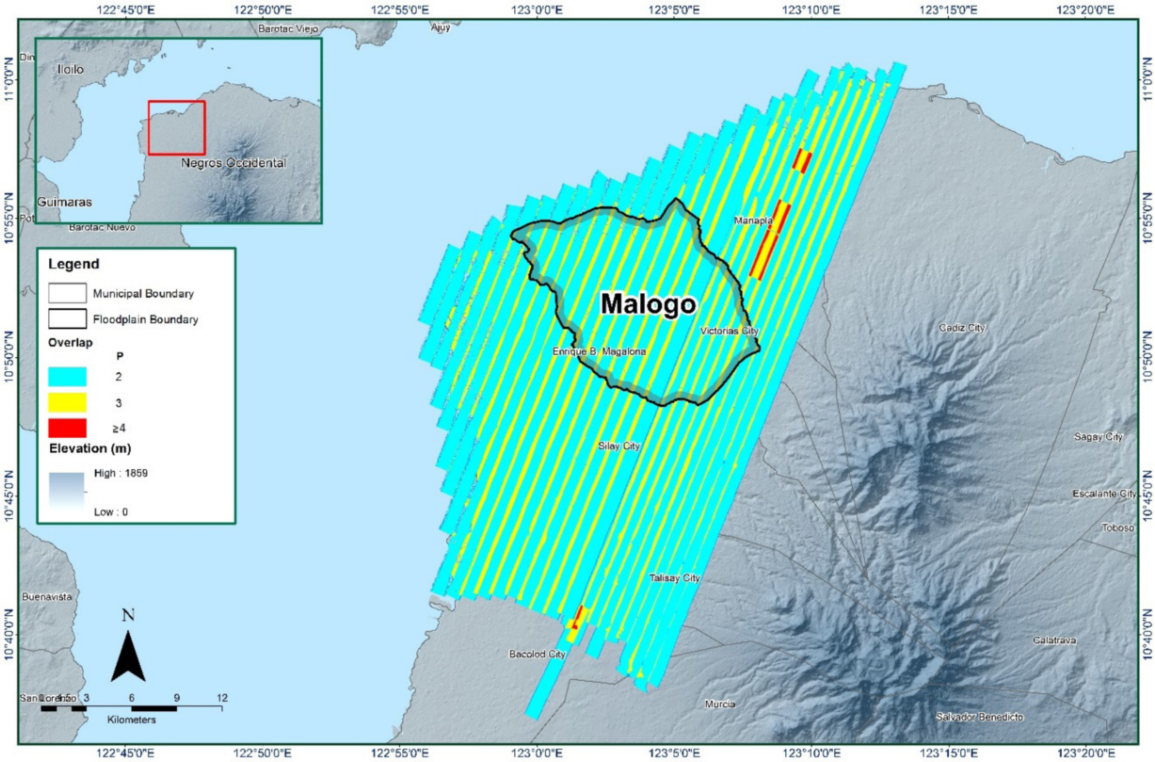


Figure 10. Image of data overlap for the Malogo floodplain

The overlap statistics per block for the Malogo floodplain can be found in Annex 7. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 21.28% and 26.54%, respectively.

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 illustrated in Figure 11. It was determined that all LiDAR data for the Malogo floodplain satisfy the point density requirement, and that the average density for the entire survey area is 1.97 points per square meter.

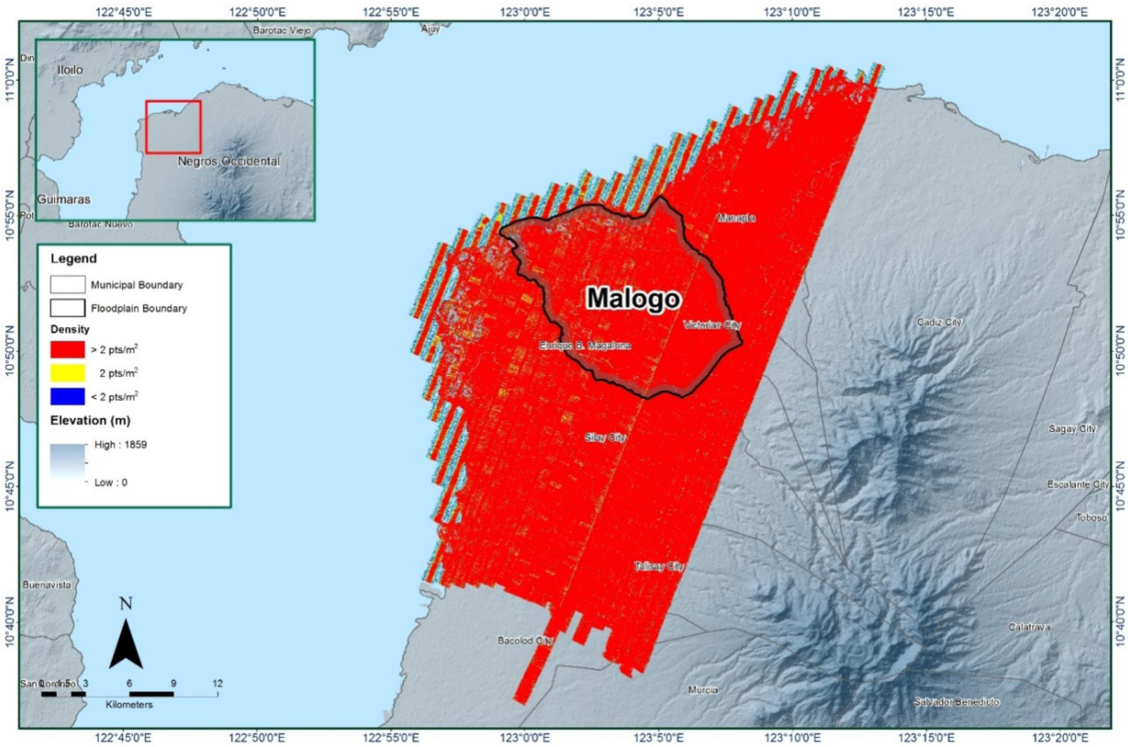


Figure 11. Pulse density map of merged LiDAR data for the Malogo floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 12. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to elevations of its adjacent flight line. Areas with bright red or bright blue need were investigated further using Quick Terrain (QT) Modeler software.

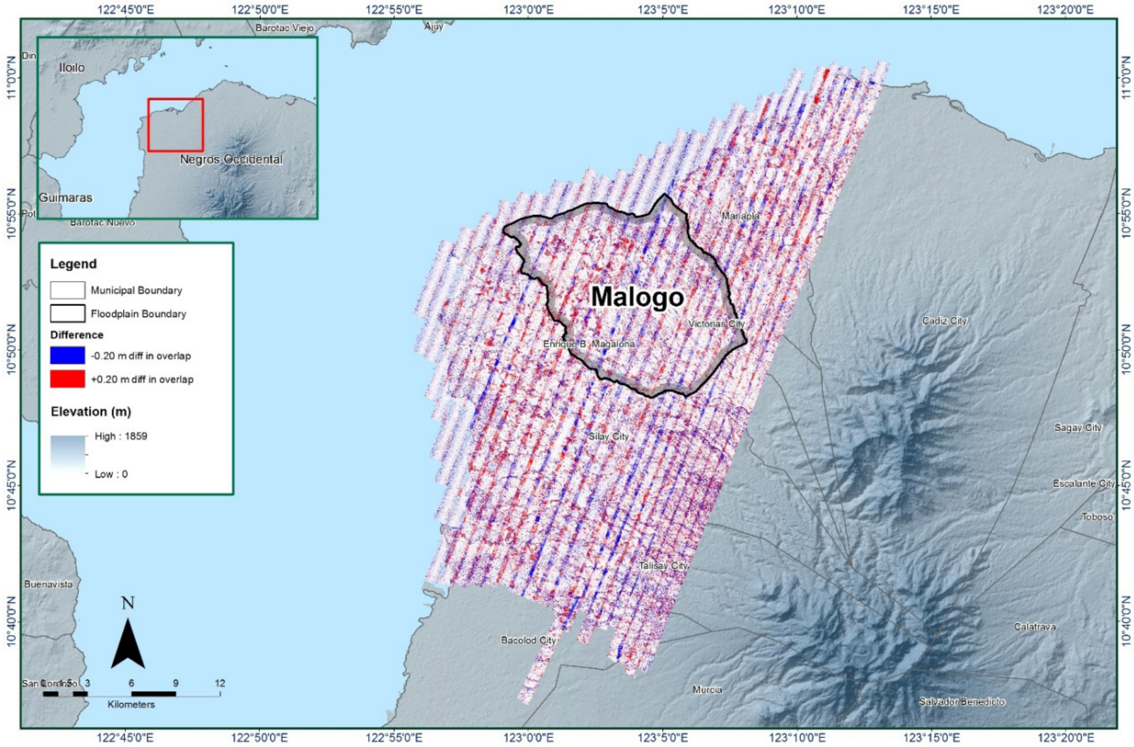


Figure 12. Elevation difference map between flight lines for the Malogo floodplain

A screen capture of the processed LAS data from Malogo Flight 1391P loaded in the QT Modeler is provided in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

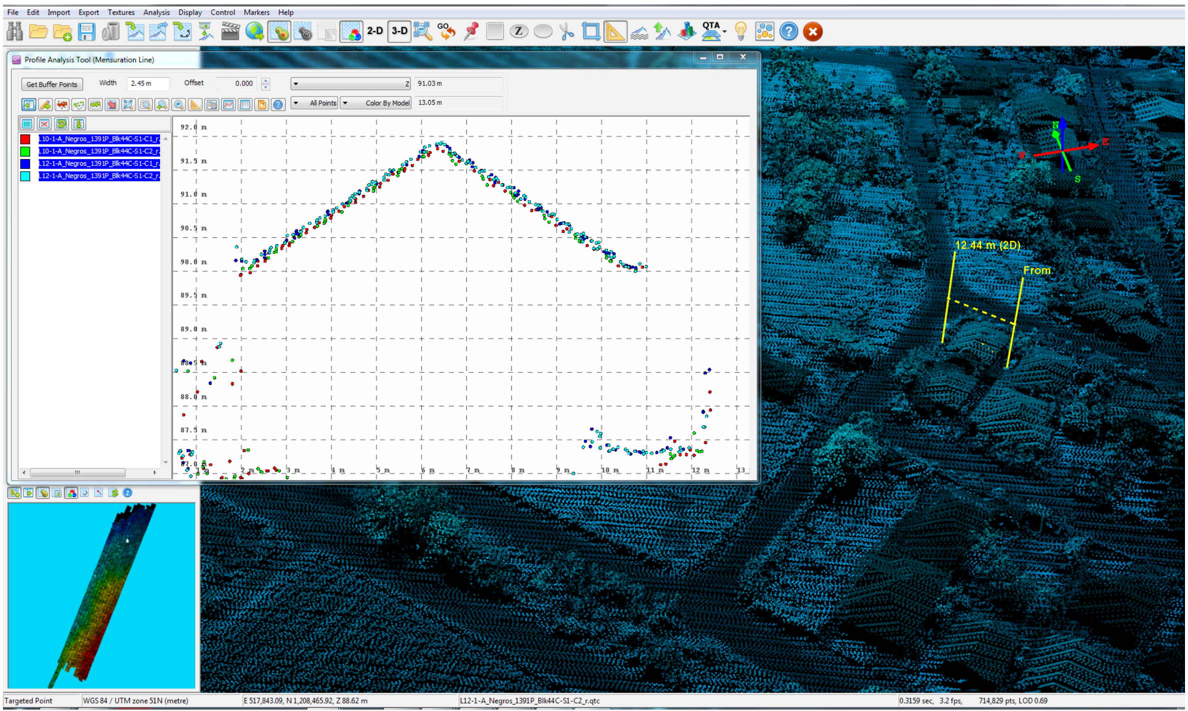


Figure 13. Quality checking for Malogo flight 1391P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 9. Malogo classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	702,779,218
Low Vegetation	603,568,652
Medium Vegetation	749,580,182
High Vegetation	162,036,982
Building	26,647,635

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Malogo floodplain, are presented in Figure 14. A total of 893 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 9. The point cloud had a maximum and minimum height of 395.70 meters and 59.93 meters, respectively.

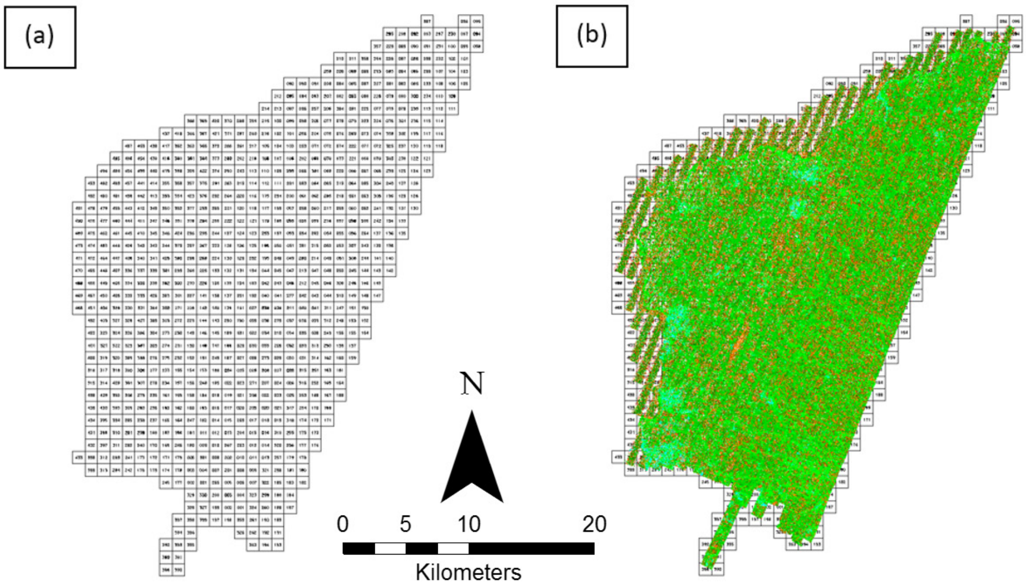


Figure 14. (a) Tiles for the Malogo floodplain, and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 15. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

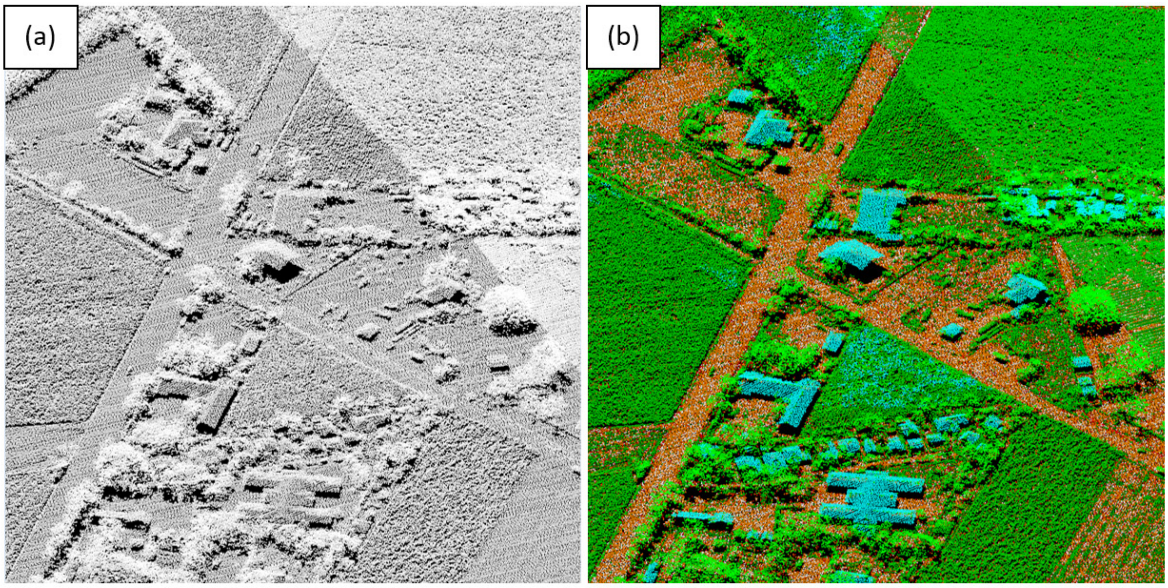


Figure 15. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 16, in top view display. The figures show that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

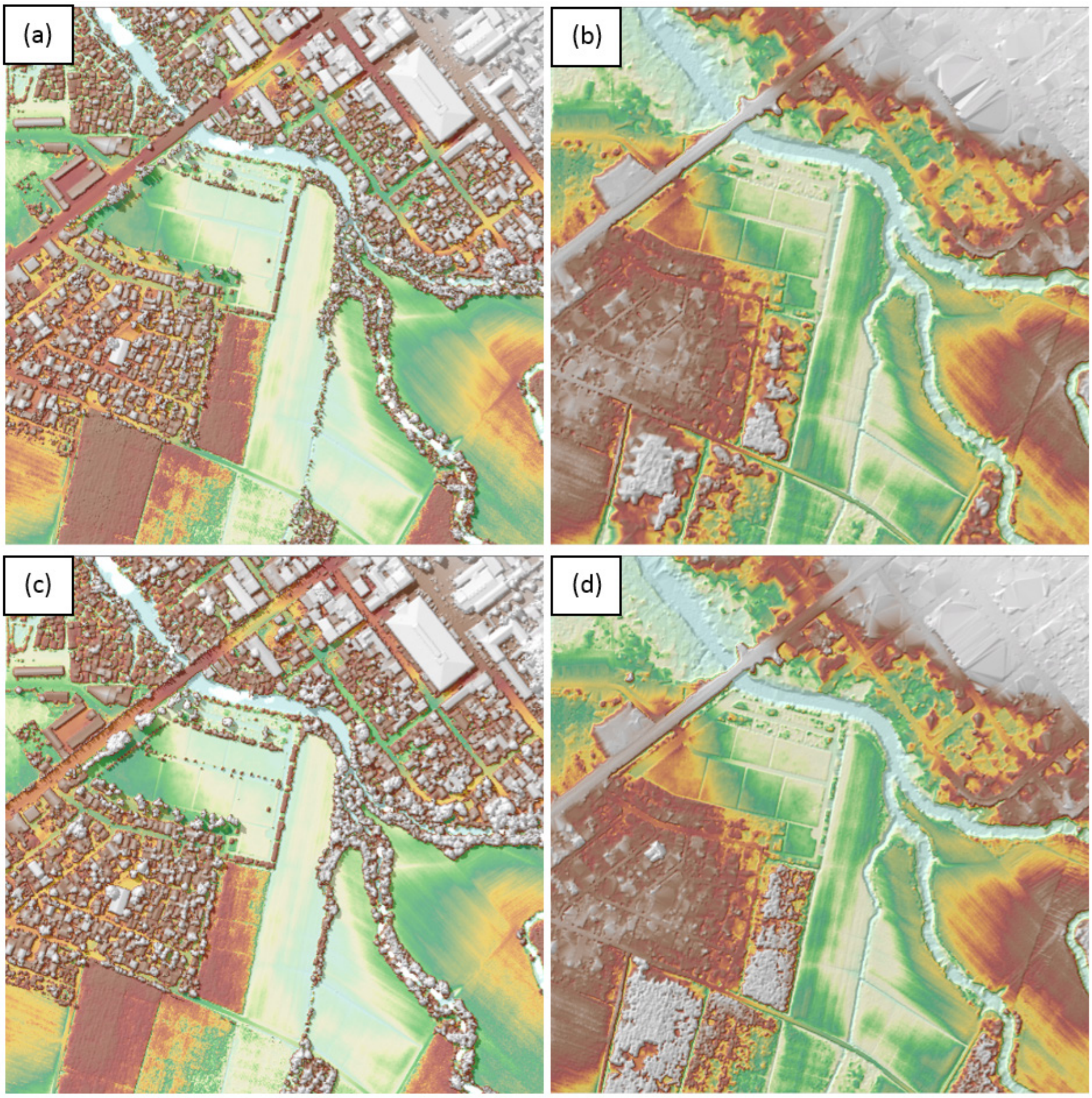


Figure 16. The production of (a) last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of the Malogo floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 473 1km by 1km tiles area covered by the Malogo floodplain is exhibited in Figure 17. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Malogo floodplain survey attained a total of 676.86 square kilometers in orthophotographic coverage, comprised of 1,332 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 18.

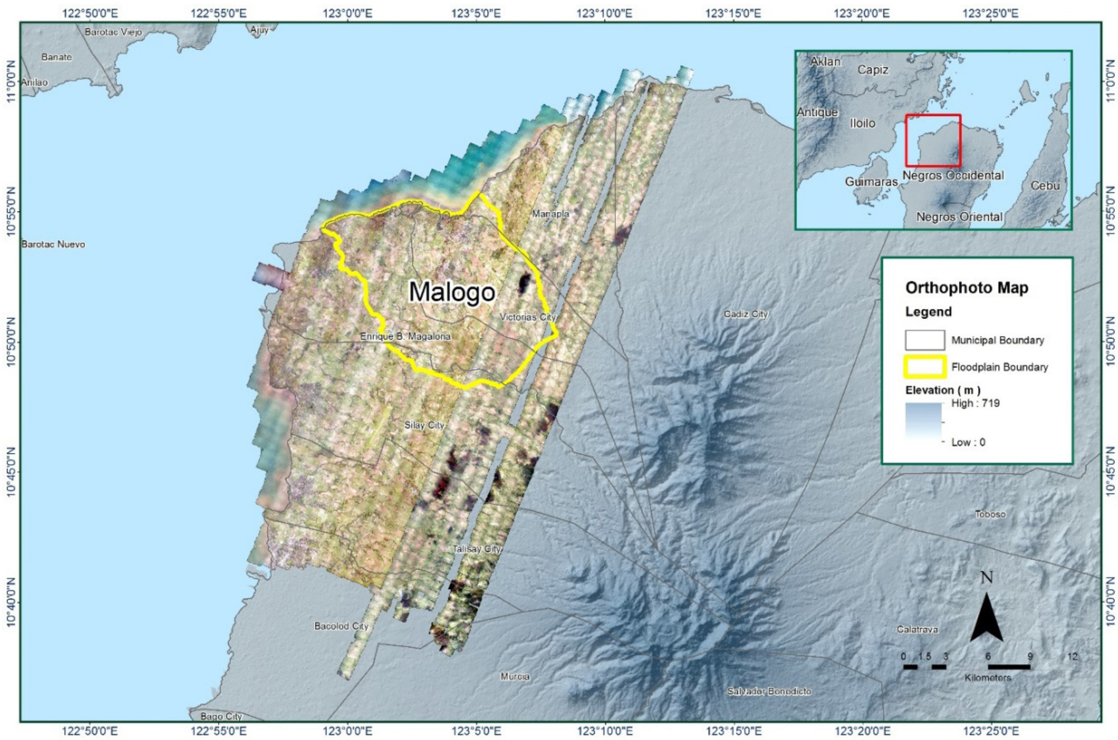


Figure 17. Malogo floodplain with available orthophotographs

Figure 18. Sample orthophotograph tiles for the Malogo floodplain

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for the Malogo floodplain. These blocks are composed of Negros blocks, with a total area of 737.31 square kilometers. Table 10 specifies the name and corresponding area of each block, in square kilometers.

Table 10. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Negros_Blk44AB	416.93
Negros_Blk44C	320.38
TOTAL	**737.31 sq.km**

Portions of the DTM before and after manual editing are presented in Figure 19. It shows that the paddy field (Figure 19a) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 19b). Bridges (Figure 19c) would impede the flow of water along the river, and had to be removed (Figure 19d) in order to hydrologically correct the river. Another case was a building that was still present in the DTM after classification (Figure 19e), and had to be removed through manual editing (Figure 19f).

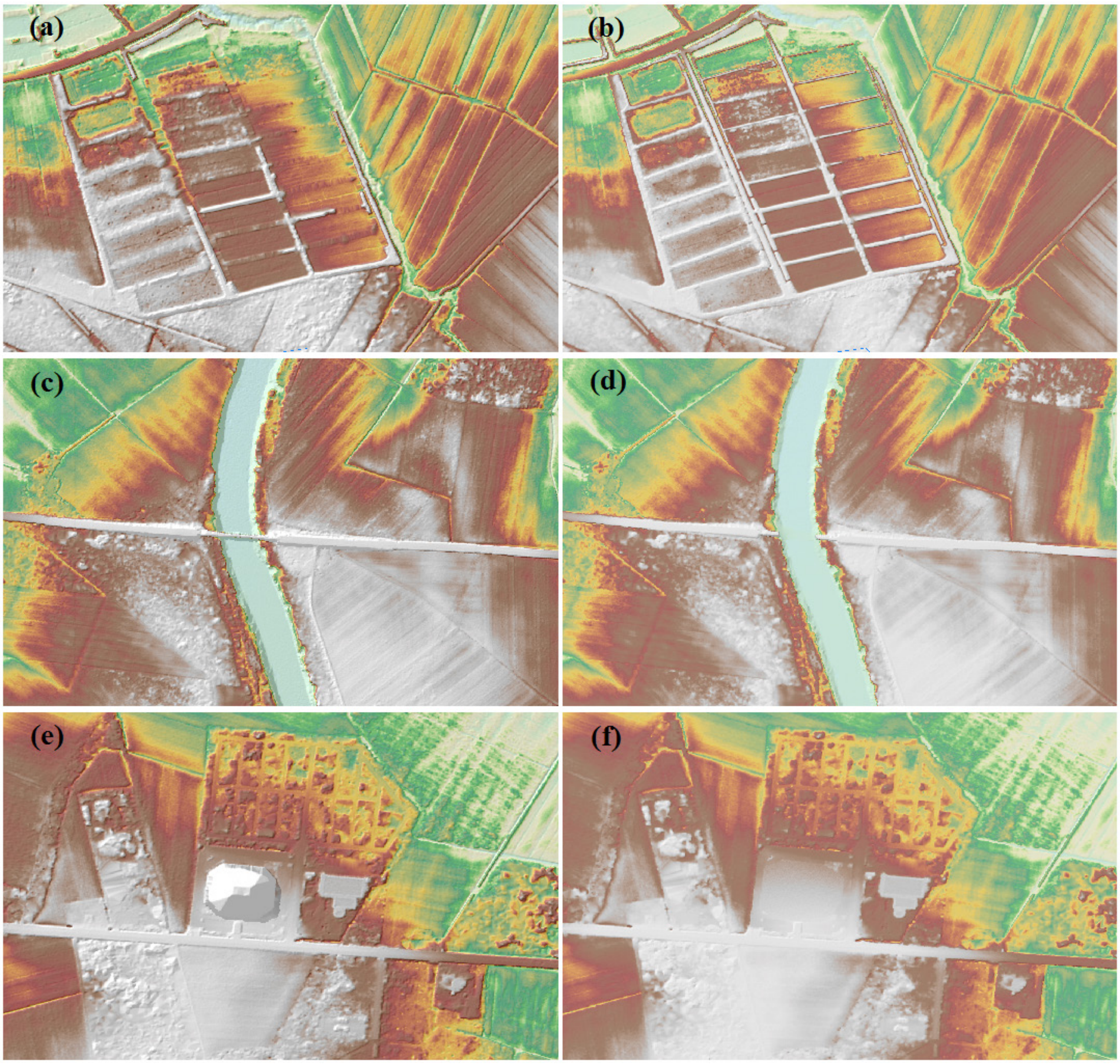


Figure 19. Portions in the DTM of the Malogo floodplain – a paddy field (a) before and (b) after data retrieval; a bridge (c) before and (d) after manual editing; and a building (e) before and (f) after manual editing

3.9 Mosaicking of Blocks

The Negros_Blk44AB block was used as the reference block at the start of mosaicking, because it covers seventy-eight percent (78%) of the total area of the Malogo floodplain. Table 11 summarizes the area of each LiDAR block and the shift values applied during mosaicking.

The mosaicked LiDAR DTM for the Malogo floodplain is illustrated in Figure 20. It demonstrates that the entire Malogo floodplain is 100% covered by the LiDAR data.

Table 11. Shift values of each LiDAR block of the Malogo floodplain

Mission Blocks	**Shift Values (meters)**		
	x	**y**	**z**
Negros_Blk44AB	0.00	0.00	0.00
Negros_Blk44C	0.00	0.00	0.15

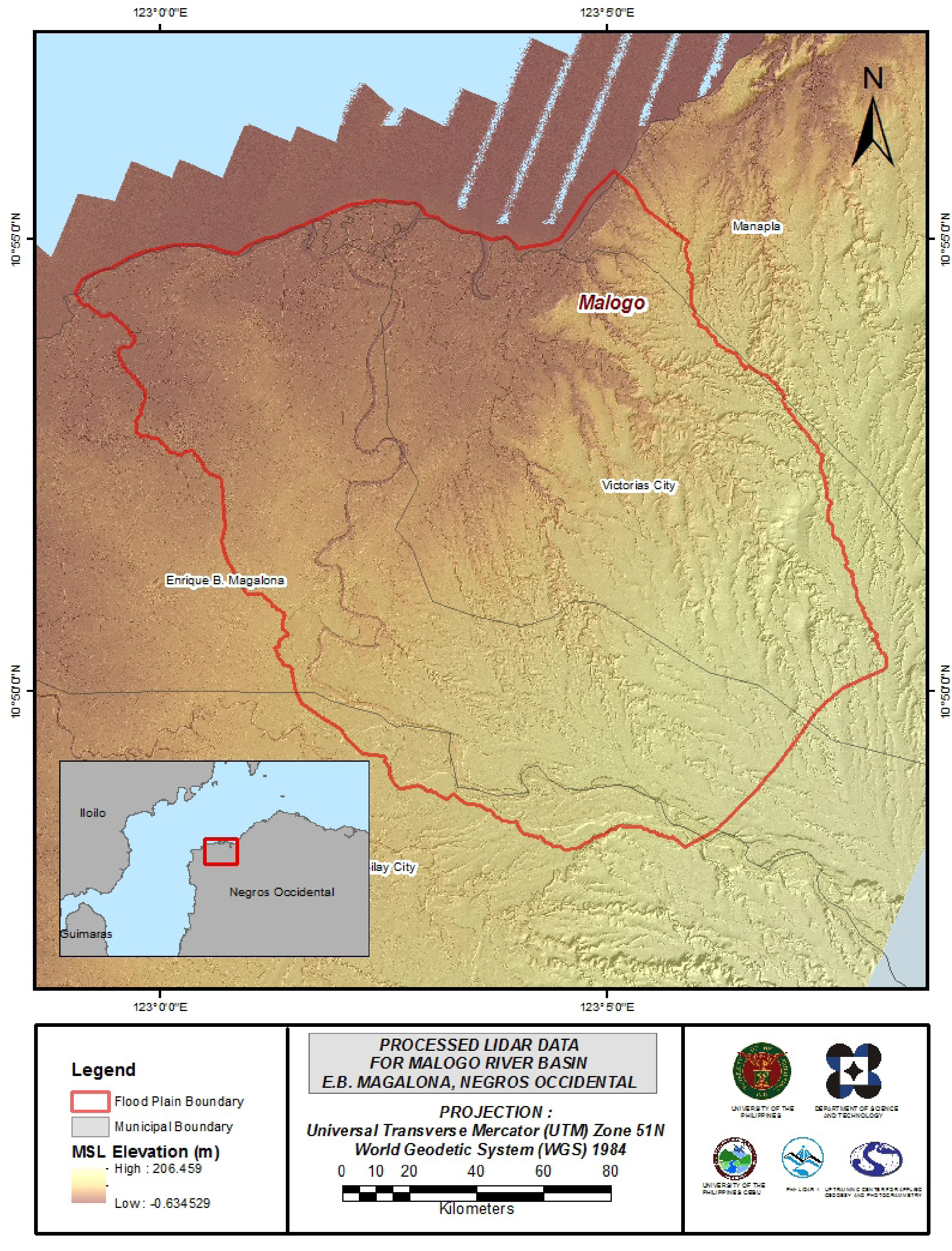


Figure 20. Map of the processed LiDAR data for the Malogo floodplain

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 the Negros Island to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 39,705 points were gathered for all the floodplains within the Negros Island wherein the Malogo is located. Random selection of 80% of the survey points, resulting to 31,385 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.94 meters with a standard deviation of 0.15 meters. Calibration of Malogo LiDAR data was done by subtracting the height difference value, 0.94 meters, to the mosaicked LiDAR data for Malogo. Table 12 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

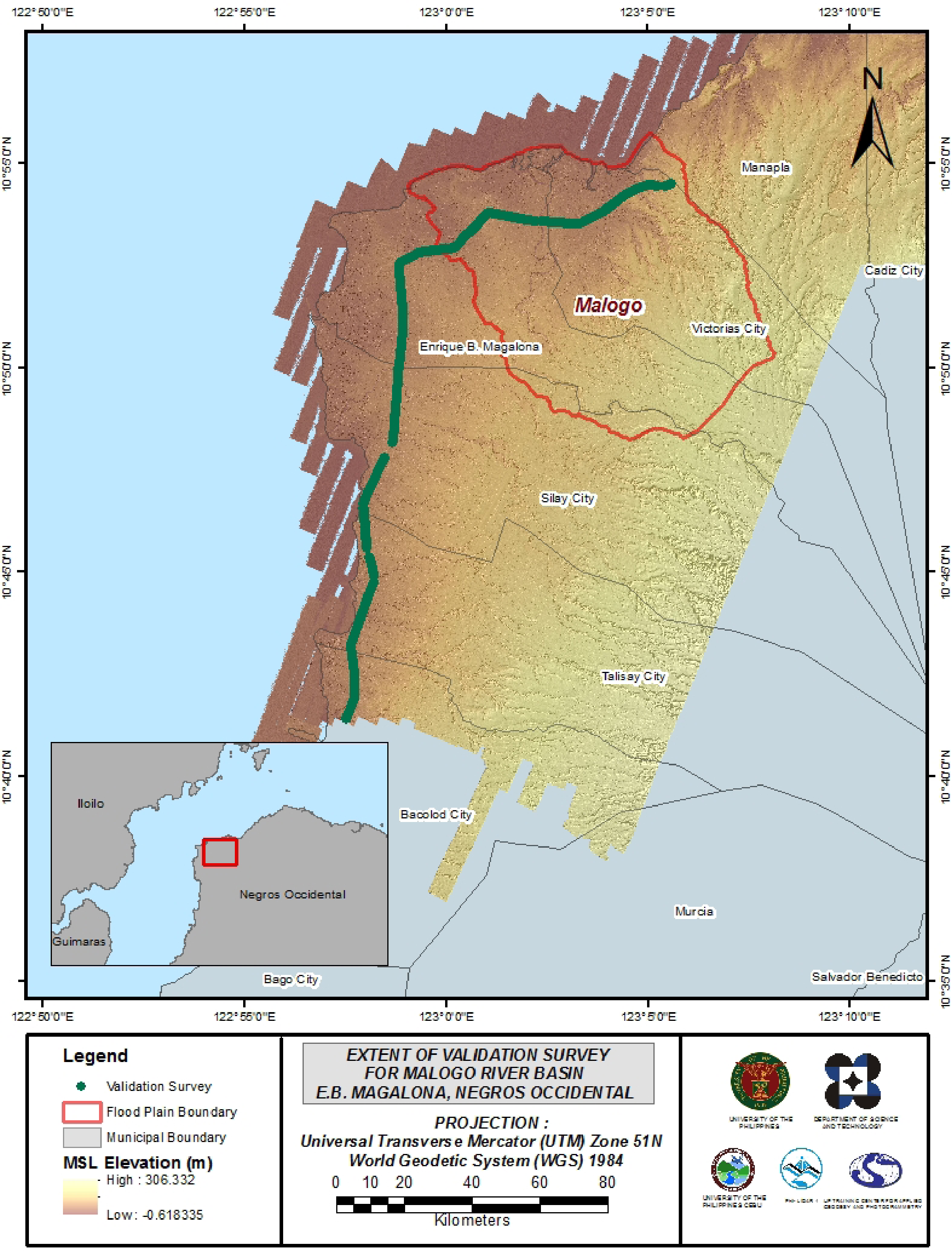


Figure 21. Map of the Malogo floodplain, with validation survey points in green

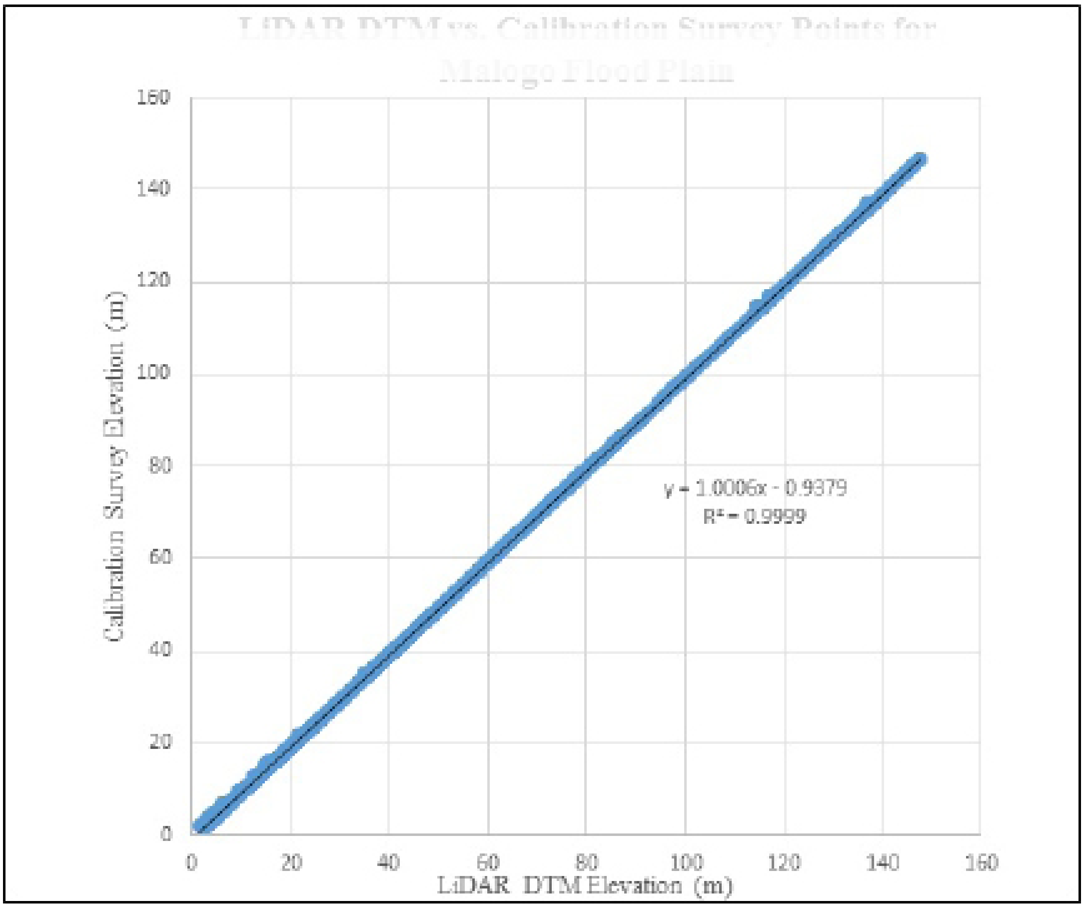


Figure 22. Correlation plot between the calibration survey points and the LiDAR data

Table 12. Calibration statistical measures

Calibration Statistical Measures	Value (m)
Height Difference	0.94
Standard Deviation	0.15
Average	-0.93
Minimum	-1.21
Maximum	0.89

A total of 269 survey points that are within Malogo flood plain were used for the validation of the calibrated Malogo DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.08 meters with a standard deviation of 0.08 meters, as shown in Table 13.

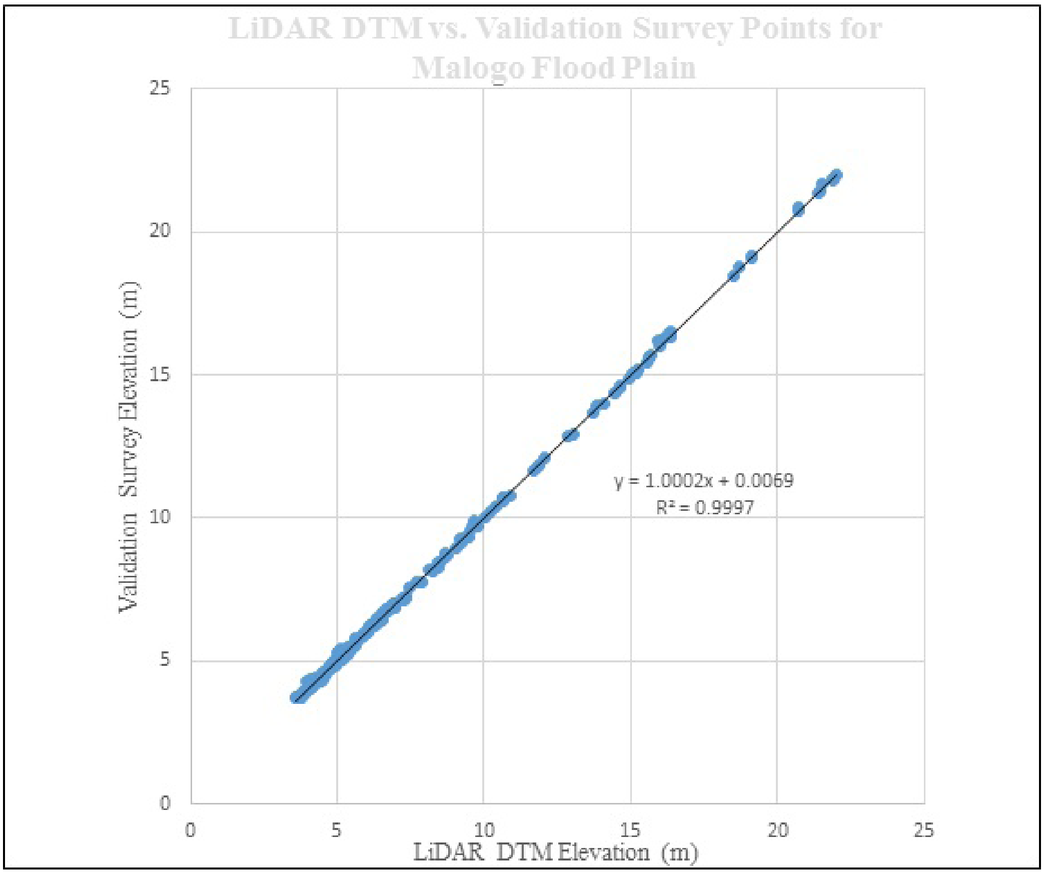


Figure 23. Correlation plot between the validation survey points and the LiDAR data

Table 13. Validation statistical measures

Validation Statistical Measures	Value (m)
RMSE	0.08
Standard Deviation	0.08
Average	0.008
Minimum	-0.16
Maximum	0.36

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Malogo, with 12,098 bathymetric survey points. The resulting raster surface produced was obtained through the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.08 meters. The extent of the bathymetric survey executed by the DVBC in the Malogo River, integrated with the processed LiDAR DEM, is shown in Figure 24.

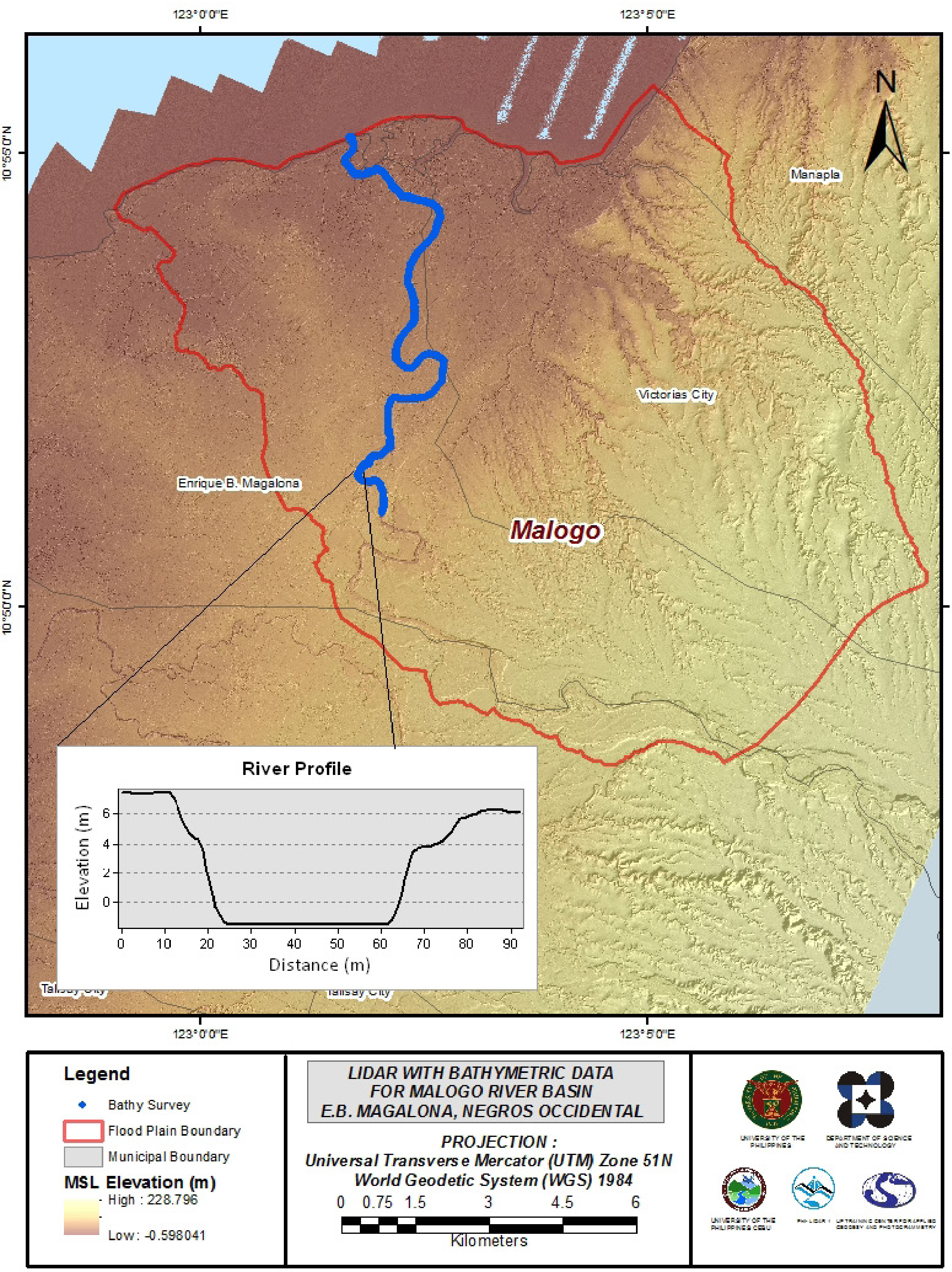


Figure 24. Map of the Malogo floodplain, with the bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Malogo floodplain, including its 200-meter buffer zone, has a total area of 139.98 square kilometers. Of this area, a total of 5.0 square kilometers, corresponding to a total of 4,689 building features, were considered for quality checking (QC). Figure 25 illustrates the QC blocks for the Malogo floodplain.

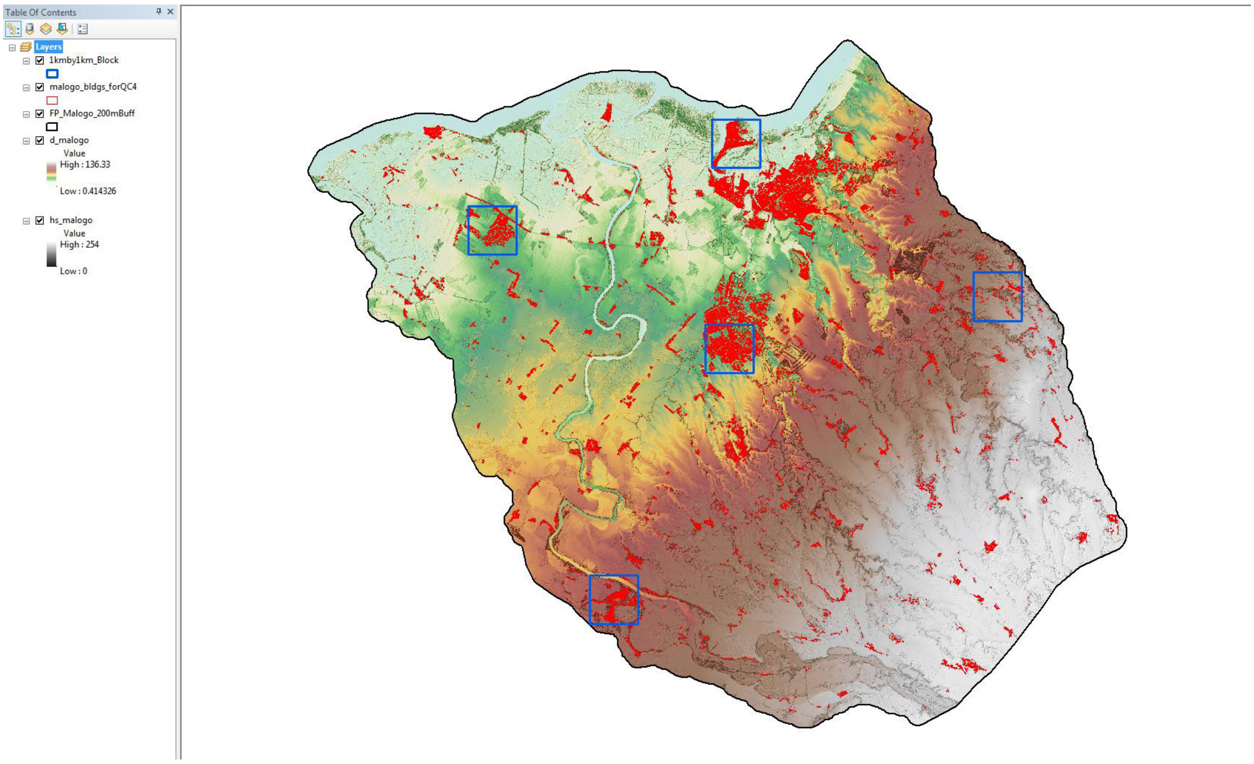


Figure 25. Blocks (in blue) of Malogo building features that were subjected to QC

Quality checking of the Malogo building features resulted in the ratings specified in Table 14.

Table 14. Quality checking ratings for the Malogo building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Malogo	99.98	100.00	99.79	PASSED

3.12.2 Height Extraction

Height extraction was done for 24,835 building features in the Malogo floodplain. Of these building features, 57 were filtered out after height extraction, resulting in 24,778 buildings with height attributes. The lowest building height is at 2.0 meters, while the highest building is at 10.37 meters.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping, in coordination with the local government units (LGUs) of the municipalities/cities. The research associates of the Phil-LiDAR 1 team visited the local barangay units and interviewed key local personnel and officials with expert knowledge of their local environments, to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed maps include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team after every interview, for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the floodplain of the river basin.

Table 15 summarizes the number of building features per type. Table 16 indicates the total length of each road type, and Table 17 provides the number of water features extracted per type.

Table 15. Building features extracted for the Malogo floodplain

Facility Type	No. of Features
Residential	23860
School	416
Market	20
Agricultural/Agro-Industrial Facilities	45
Medical Institutions	22
Barangay Hall	31
Military Institution	0
Sports Center/Gymnasium/Covered Court	16
Telecommunication Facilities	2
Transport Terminal	2
Warehouse	30
Power Plant/Substation	11
NGO/CSO Offices	1
Police Station	3
Water Supply/Sewerage	6
Religious Institutions	55
Bank	5
Factory	21
Gas Station	5
Fire Station	1
Other Government Offices	31
Other Commercial Establishments	175
Others	20
Total	24778

Table 16. Total length of extracted roads for the Malogo floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Malogo	385.51	1.23	0.00	45.21	0.00	**431.96**

Table 17. Number of extracted water bodies for the Malogo floodplain

Flood-plain	Water Body Type						Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	Others	
Malogo	9	901	0	0	0	2	**912**

A total of twenty-seven (27) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 26 represents the Digital Surface Model (DSM) of the Malogo floodplain, overlaid with its ground features.

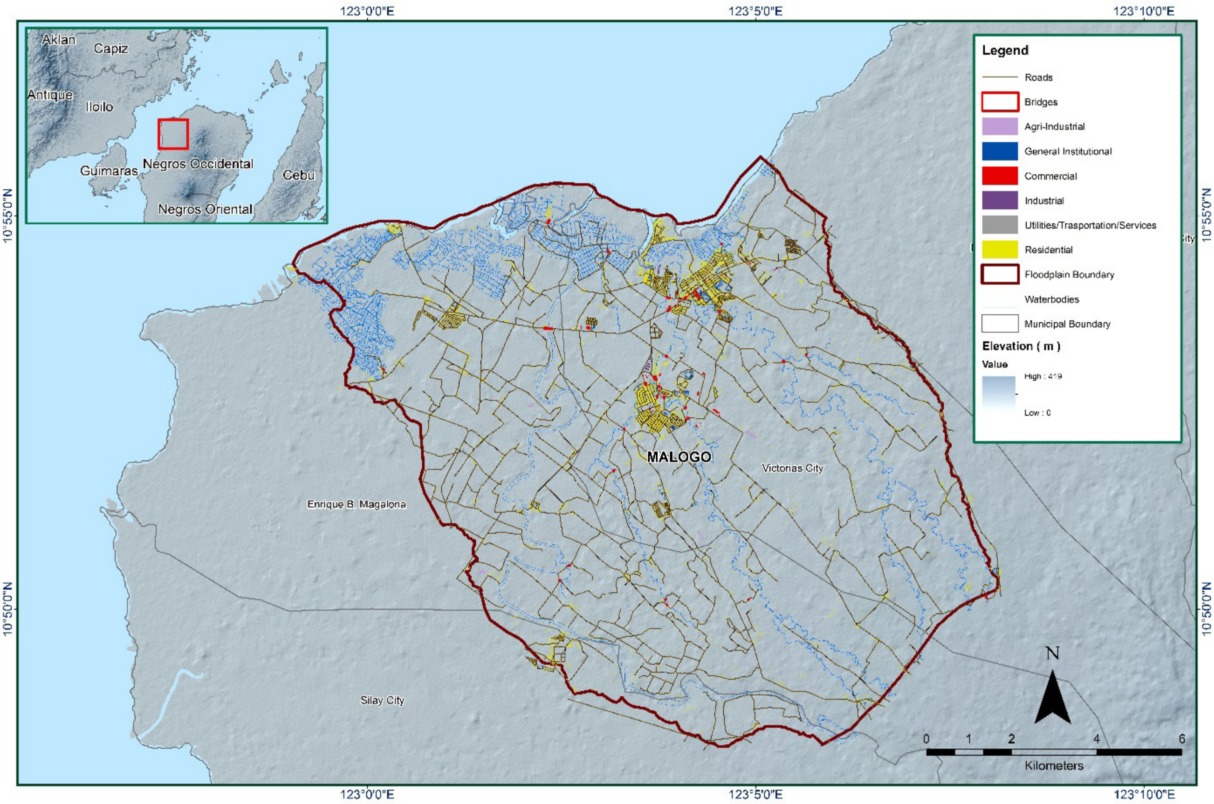


Figure 26. Extracted features for the Malogo floodplain

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field surveys in the Malogo River on December 4-16, 2014. The scope of work was comprised of: (i.) initial reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey; (ii.) courtesy calls with the barangays near the survey areas, for information dissemination of the team's activities, and for assistance with securing a boat and a local aide; (iii.) control survey for the establishment of a control point; (iv.) cross-section and bridge as-built surveys and water level marking in MSL of the Malogo Bridge piers; (v.) ground validation data acquisition of about 35.18 kilometers; and (v.) bathymetric survey from Barangay Nanca in the Municipality of EB Magalona down to the mouth of the river in Barangay Pasil, with an estimated length of 12 kilometers, using an Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 in GNSS PPK survey technique. The extent of the surveys is exhibited in Figure 27.

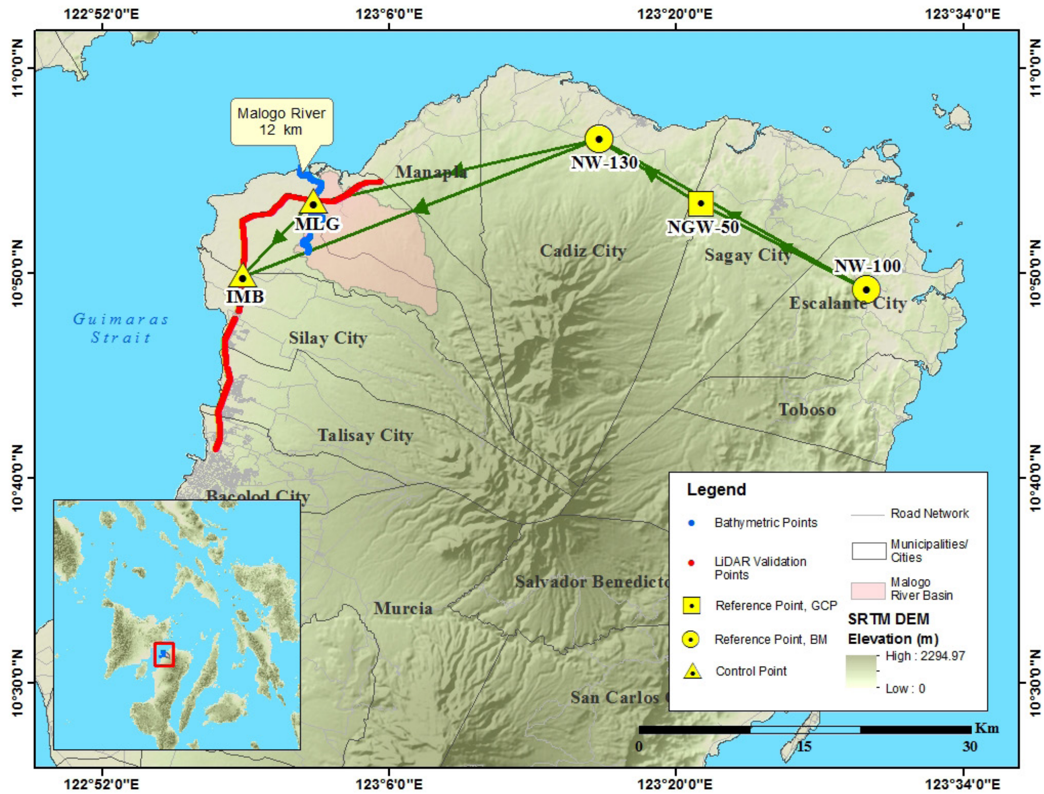


Figure 27. Extent of the bathymetric survey (in blue line) in the Malogo River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Malogo River survey is composed of a single loop and two (2) baselines established on September 9 and 14, 2014, occupying the following reference points: (i.) NGW-50, a second-order GCP in Barangay Paraiso, Sagay City; and (ii.) NW-100, a first-order BM in Barangay Jonobjonob, Escalante City, Negros Occidental.

Two (2) control points were established along the approach of bridges, namely: (i.) IMB at the Imbang Bridge in Barangay Lantad, Silay City; and (ii.) MLG at the Malogo Bridge in Barangay Alicante, Victorias City. The point NW-130, a NAMRIA-established control point, along the approach of the Trozo Bridge in Barangay Daga, Cadiz City, was also occupied as a marker during the survey.

An offset amount of 0.0188 meters between the geoid (EGM2008) and MSL values of the benchmark NW-100 was applied on September 10-24, 2014, for referring the elevation of the control points to MSL. This was done as the direct processing into BMOrtho will yield a low accuracy level.

The summary of the reference and control points is given in Table 18, while the GNSS network established is illustrated in Figure 28.

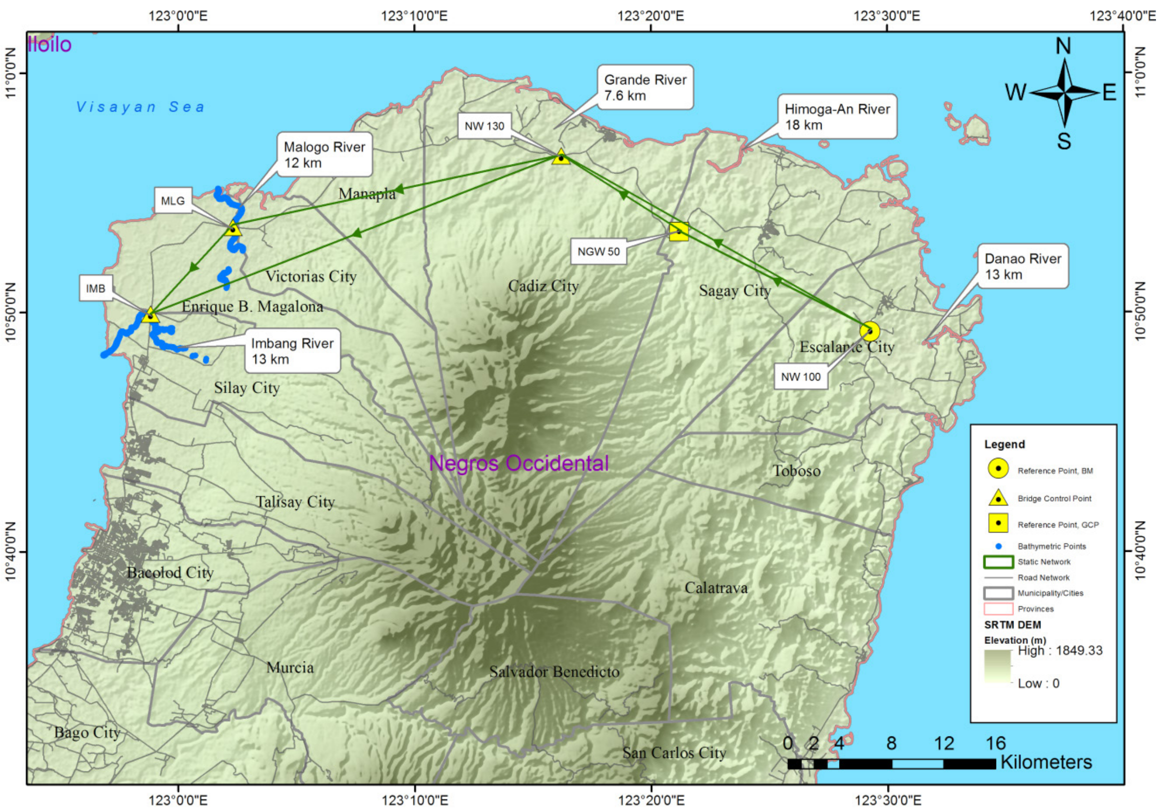


Figure 28. GNSS network of the Malogo River field survey

Table 18. References and control points occupied in the Negros Occidental survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
NGW-50	2nd order, GCP	10°53’22.52478”	123°21’11.86863”	74.422	13.0512	2013
NW-100	1st order, BM	-	-	68.325	7.2272	2007
NW-130	Used as Marker	-	-	-	-	2017
IMB	UP Established	-	-	-	-	9-13-2014
MLG	UP established	-	-	-	-	9-13-2014

The GNSS set-ups on the recovered reference points and established control points in the Malogo River are exhibited in Figure 29 to Figure 33.

Figure 29. GNSS base receiver set-up, Trimble® SPS 852 at NGW-50, in the Himoga-An Bridge, Barangay Paraiso, Sagay City, Negros Occidental

Figure 30. GNSS base receiver set-up, Trimble® SPS 852 at NW-100, in the Danao Bridge,

Figure 31. GNSS base receiver set-up, Trimble® SPS 852 over NW-130, in the Troso Bridge, Barangay Daga, Cadiz City, Negros Occidental

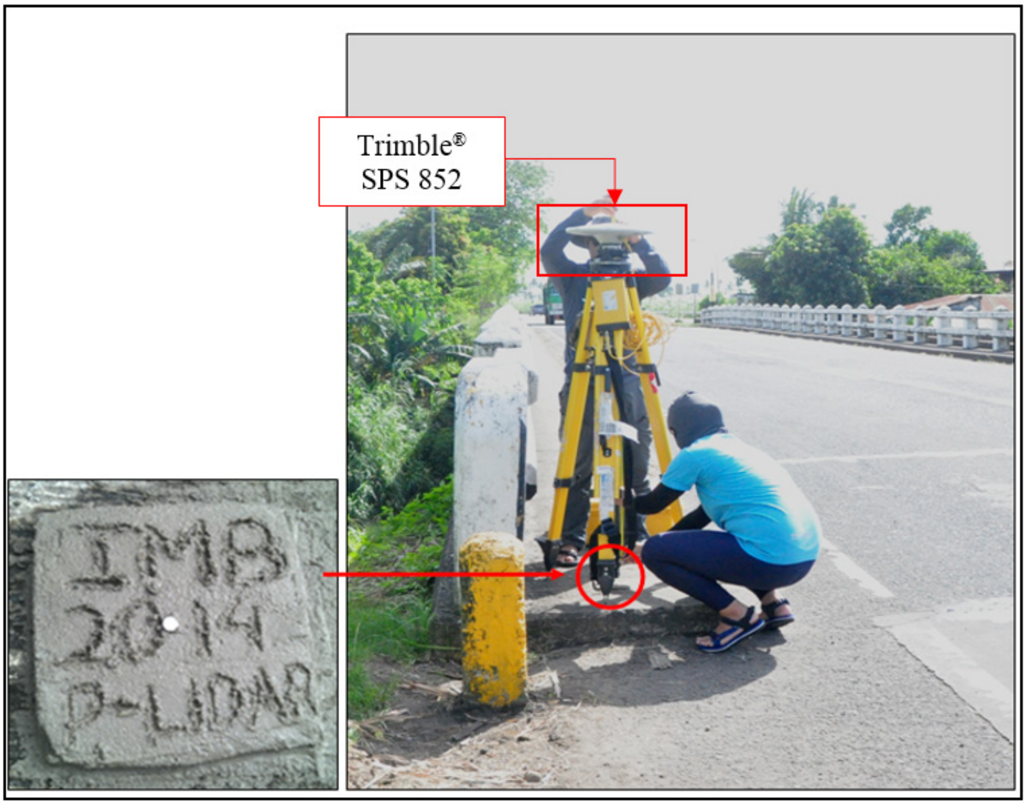


Figure 32. GNSS base receiver set-up, Trimble® SPS 852 at IMB, in the Imbang Bridge, Barangay Lantad, Silay City, Negros Occidental

Figure 33. GNSS base receiver set-up, Trimble® SPS 852 at MLG, in the Malogo Bridge, Barangay Alicante, Victorias City, Negros Occidental

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the +/- 20-centimeter and +/- 10-centimenter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of the control points in the Malogo River Basin, as generated by the TBC software, is summarized in Table 19.

Table 19. Baseline Processing Report for the Malogo River survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NGW 50 --- NW 130 (B4)	09-11-2014	Fixed	0.005	0.008	302°49'33"	10801.487	-2.613
NW 130 --- NW 100 (B5)	9-11-2014	Fixed	0.185	0.037	119°37'31"	27388.571	-3.542
NGW 50 --- NW 100 (B6)	9-11-2014	Fixed	0.004	0.006	117°34'16"	16614.558	-6.178

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 centimeters, and z less than 10 centimeters, or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report presented in Table 20 to Table 23 for complete details.

The three (3) control points – NGW-50, NW-100, and NW-130 – were occupied and observed simultaneously to form a GNSS loop. The coordinates of NGW-50, and the elevation values of NW-100 were held fixed during the processing of the control points, as reflected in Table 20. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 20. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGW 50	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 21. The fixed control point NGW-50 did not yield values for elevation errors.

Table 21. Adjusted grid coordinates for the control points used in the Malogo floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGW 50	538610.026	?	1203793.905	?	13.070	?	LLh
NW 100	553341.183	0.013	1196123.819	0.007	7.170	0.020	
NW 130	529529.956	0.017	1209636.397	0.008	10.639	0.024	

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

a. **NGW-50**
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. **NW-100**
Horizontal Accuracy = √((1.3)² + (0.7)²
= √ (1.69 + 0.49)
= 1.48 < 20 cm
Vertical Accuracy = 2.0 cm < 10 cm

c. **NW-130**
Horizontal Accuracy = √((1.7)² + (0.8)²
= √ (2.89 + 0.64)
= 1.88 < 20 cm
Vertical Accuracy = 2.4 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the three (3) occupied control points are within the required precision.

Table 22. Adjusted geodetic coordinates for control points used in the Malogo River floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
NGW 50	N10°53’22.52478”	E123°21’11.86863”	74.422	?	LLh
NW 130	N10°56’33.04992”	E123°16’12.93293”	71.819	0.024	
NW 100	N10°49’12.14033”	E123°29’16.71793”	68.325	0.020	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 22. 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 Malogo River GNSS Static Survey are indicated in Table 23.

Table 23. Reference and control points used in the Malogo 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	Ellip-soi-dal Height (m)	Northing	Easting	MSL Eleva-tion (m)
NGW-50	2nd order, GCP	10°53’22.52478”	123°21’11.86863”	74.422	1203793.905	538610.026	13.051
NW-100	1st order BM	10°49’12.14033”	123°29’16.71793”	68.325	1196123.819	553341.183	7.227
NW-130	Used as Marker	10°56’33.04992”	123°16’12.93293”	71.819	1209636.397	529529.956	10.643
IMB	UP Estab-lished	10°49’57.92767”	122°58’49.65411”	68.641	1197487.542	497864.124	8.554
MLG	UP Estab-lished	10°53’34.18449”	123°02’17.25034”	70.160	1204129.792	504166.429	9.825

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

The cross-section and bridge as-built surveys were conducted on September 17 and 19, 2014 along the downstream side of the Malogo Bridge in Barangay Pasil, Victorias City, using the GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique (Figure 34).

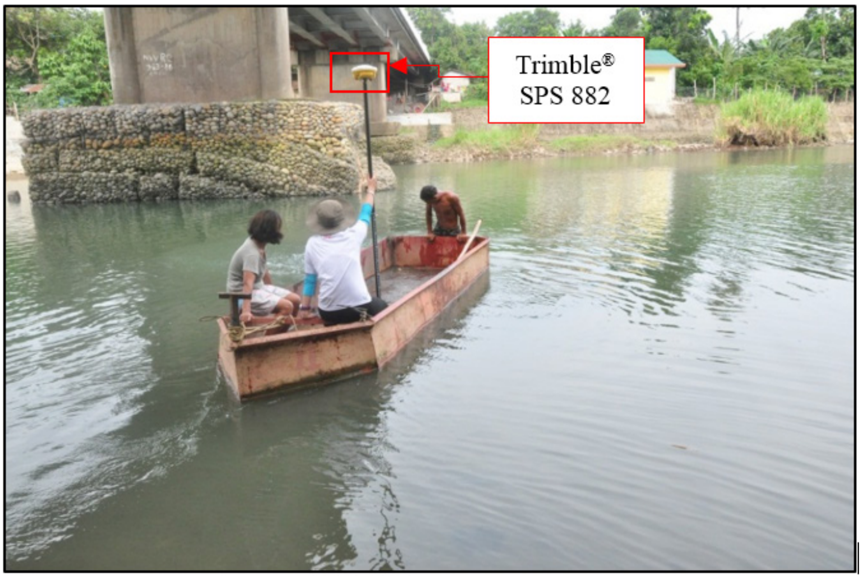


Figure 34. Cross-section survey at the Malogo Bridge in Victorias City

The length of the cross-sectional line surveyed in the Malogo Bridge is about 166.42 meters with sixty-two (62) points acquired, using MLG as the GNSS base station. The location map, cross-section diagram, and bridge as-built form are illustrated in Figure 35 to Figure 37.

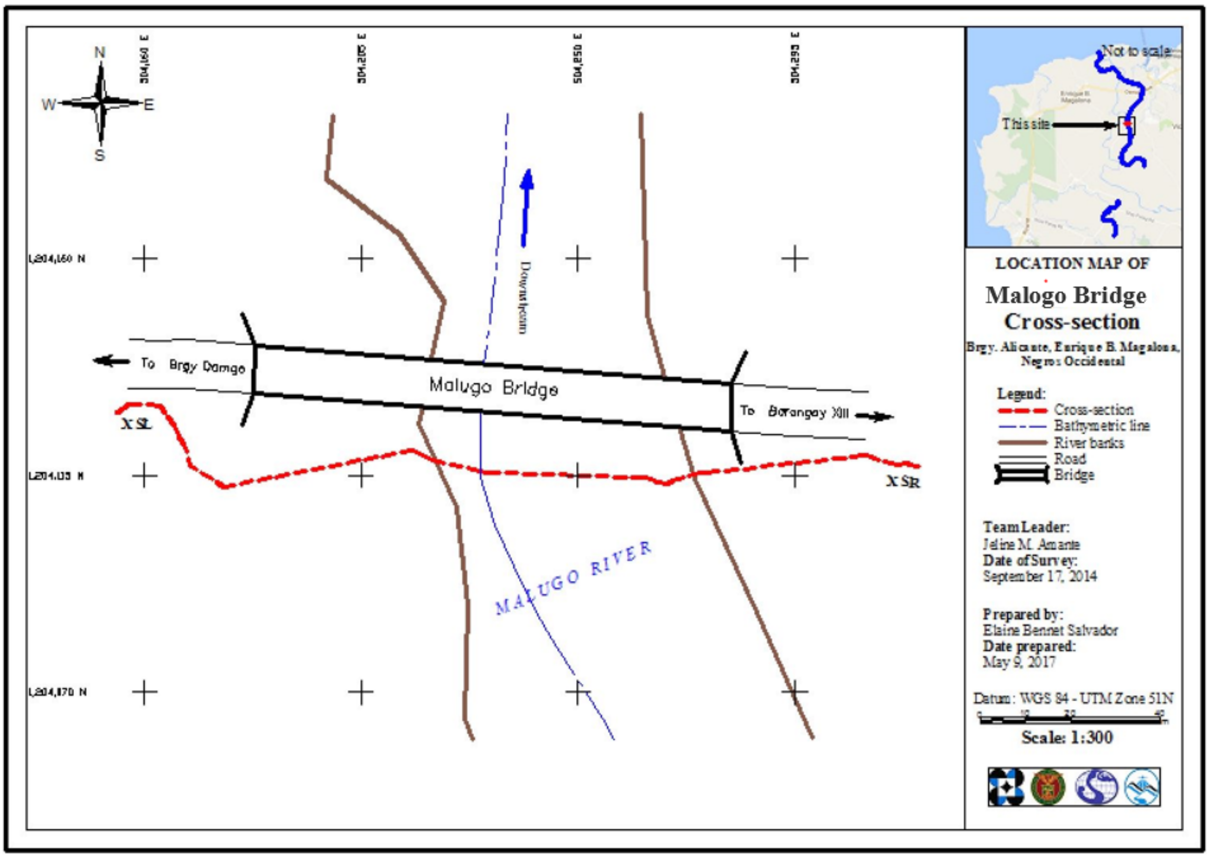


Figure 35. Malogo bridge cross-section location map

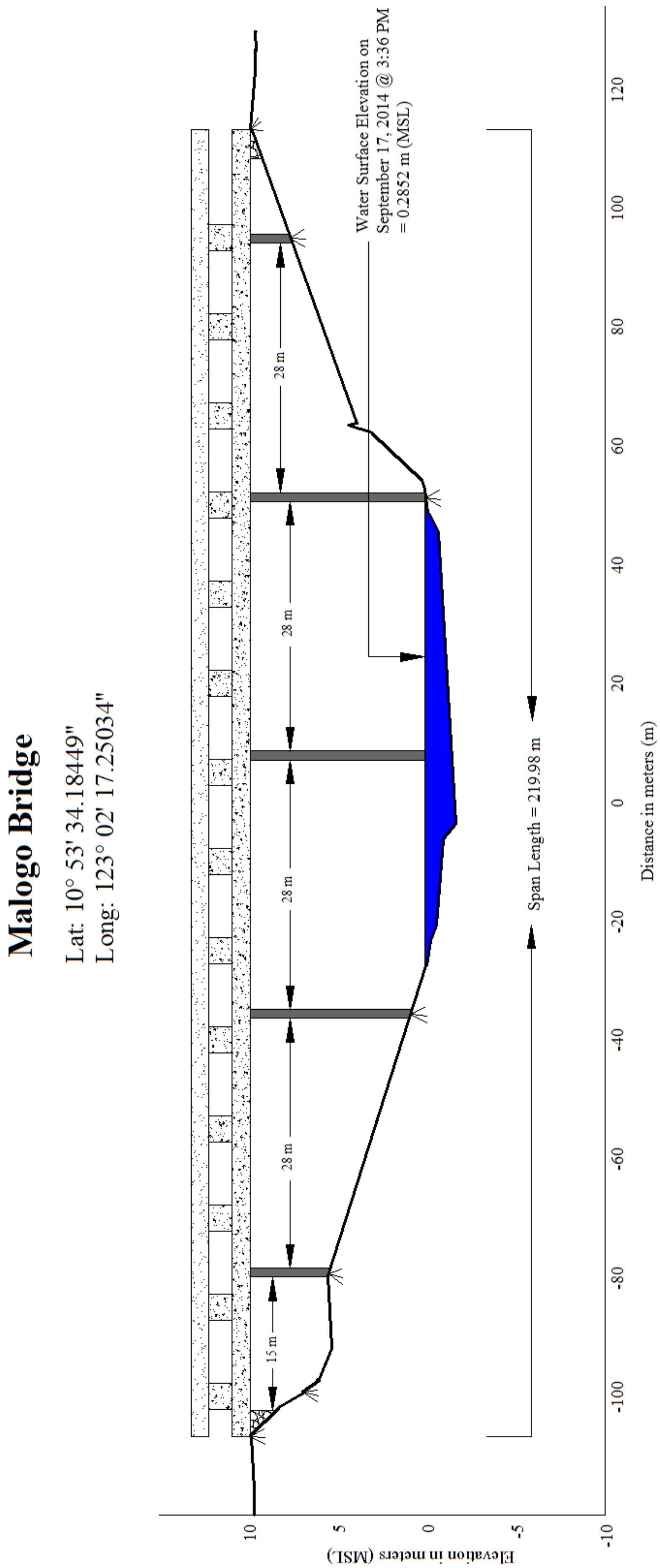


Figure 36. Malogo Bridge cross-section diagram

Bridge Data Form

Bridge Name: Malogo Bridge **Date:** September 17 &19, 2014

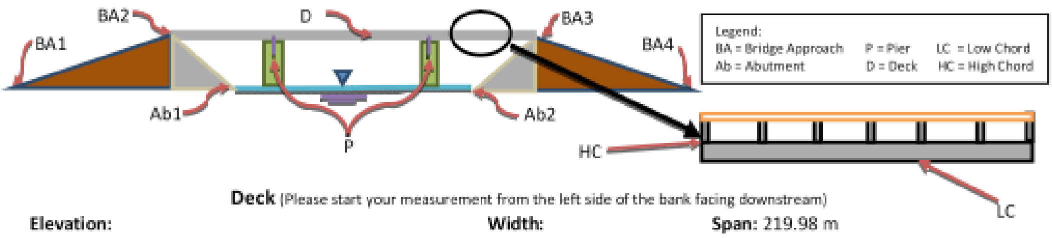
River Name: Malago/Malogo River **Time:** 2: 00 PM

Location (Brgy, City,Region): E.B. Magalona, Negros Occidental

Survey Team: Negros Occidental Survey Team

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

Latitude: 10d53'34.18449"N **Longitude:** 123d02'17.25034" E



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

Elevation: **Width:** **Span:** 219.98 m

	Station	High Chord Elevation	Low Chord Elevation
1		-	-
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	9.6382 m	BA3	153.3 m	9.582 m
BA2	6.74 m	9.8162 m	BA4	162.11	9.6772

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

	Station (Distance from BA1)	Elevation
Ab1	n/a	n/a
Ab2	143.36 m	5.3452 m

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

Shape: rectangular **Number of Piers:** 6 **Height of column footing:** _______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	21.42	9.7342	
Pier 2	49.52	9.8442	
Pier 3	77.5	9.7012	
Pier 4	105.47	9.8102	
Pier 5	133.47	9.9622	
Pier 6	148.26	9.9702	

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

Figure 37. Malogo Bridge data form

The water surface elevation of the Malogo Bridge on the left and right banks was acquired using the GNSS receiver, Trimble® SPS 882, in GNSS PPK survey technique on September 17, 2014 at 15:36 hrs. The resulting water surface elevation data, 0.2852 meters above MSL, was translated into markings on the piers of the Malogo Bridge. The markings on the bridge served as a reference for flow data gathering and depth gauge deployment of the UPC PHIL-LIDAR 1 team (Figure 38).

Figure 38. MSL markings on the Malogo Bridge pier

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 15, 2014 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole that was attached in front of a vehicle, as depicted in Figure 39. It was secured with a steel rod and strapped with cable ties to ensure that it was horizontally and vertically balanced. The antenna height of 1.906 meters was measured from the ground up to the bottom of the notch of the GNSS rover receiver. Points were gathered along concrete roads of the Osmeña Avenue and the national highway at a speed of 10-20 kilometers per hour to minimize changes in elevation of the acquired data. The survey was able to cut across the flight strips of the DAC with the aid of available topographic maps and Google Earth™ images. The gathered data were processed using the Trimble® Business Center Software.

The GNSS base station was set-up over IMB in Imbang, and gathered validation points from Barangay VI in the Municipality of Manapla until Bacolod City. The ground validation line gathered 3,955 points, covering 35.18 kilometers in length. Figure 40 presents the ground validation survey results.

Figure 39. (A) GNSS Receiver Trimble® SPS 882 installation on the vehicle; (B) Final set-up of the GNSS Receiver with antenna height measured from the ground up to the bottom of the notch of the GNSS rover receiver; and (C) Occupied GNSS base station, IMB, in Imbang Bridge. Silay City

Figure 40. Extent of the LiDAR ground validation survey from Barangay VI, Manapla to Bacolod City

4.7 Bathymetric Survey

The bathymetric survey was executed on December 6, 12, and 15, 2014 using an Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882, installed on a boat in PPK survey technique, as demonstrated Figure 41. The survey began in the upstream portion of the river in Barangay Nanca, Municipality of EB Magalona, with coordinates 10°51'03.01634" 123°02'02.27181"; and it extended down to the mouth of the river in Barangay Pasil, Municipality of EB Magalona, with coordinates 10°55'10.82917" 123°01'40.30489".

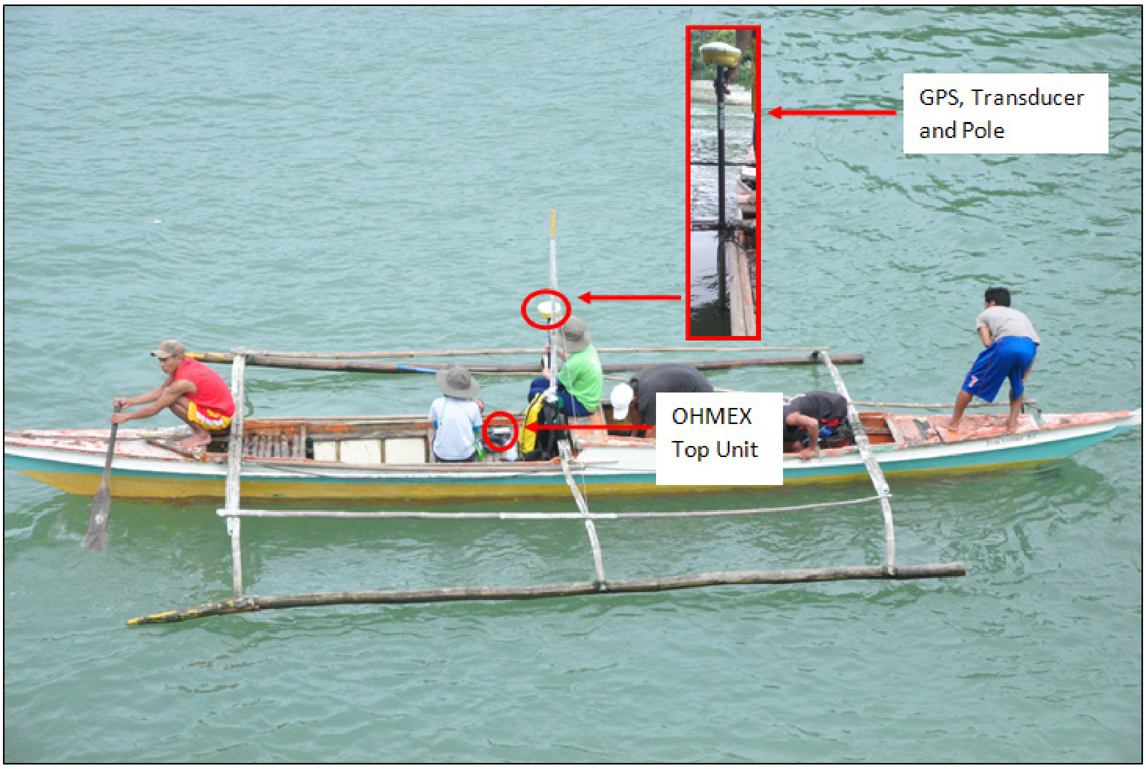


Figure 41. Set-up of the bathymetric survey in Barangay Pasil, Silay City (downstream side of the Malogo River)

The bathymetric survey for the Malogo River gathered a total of 1,195 points, covering approximately 12 kilometers in length, using IMB as the GNSS base station. The survey covered Barangay Pasil to Barangay Nanca, Municipality of EB Magalona, as depicted in Figure 42. A CAD drawing of the centerline riverbed profile was also produced, as presented in Figure 43. The profile shows that the lowest elevation, 5.2758 meters below MSL, was recorded at approximately 3.5 kilometers downstream of the Malogo Bridge in Barangay Alicante, Municipality of EB Magalona. On the other hand, the highest elevation was 4.961 meters in MSL, located in Barangay Nanca. The 1.7-kilometer data gap in the Malogo River along Barangay XX in Victorias City is due to the presence of rapids, rocks, and boulders, which could not be traversed by boat or by foot.

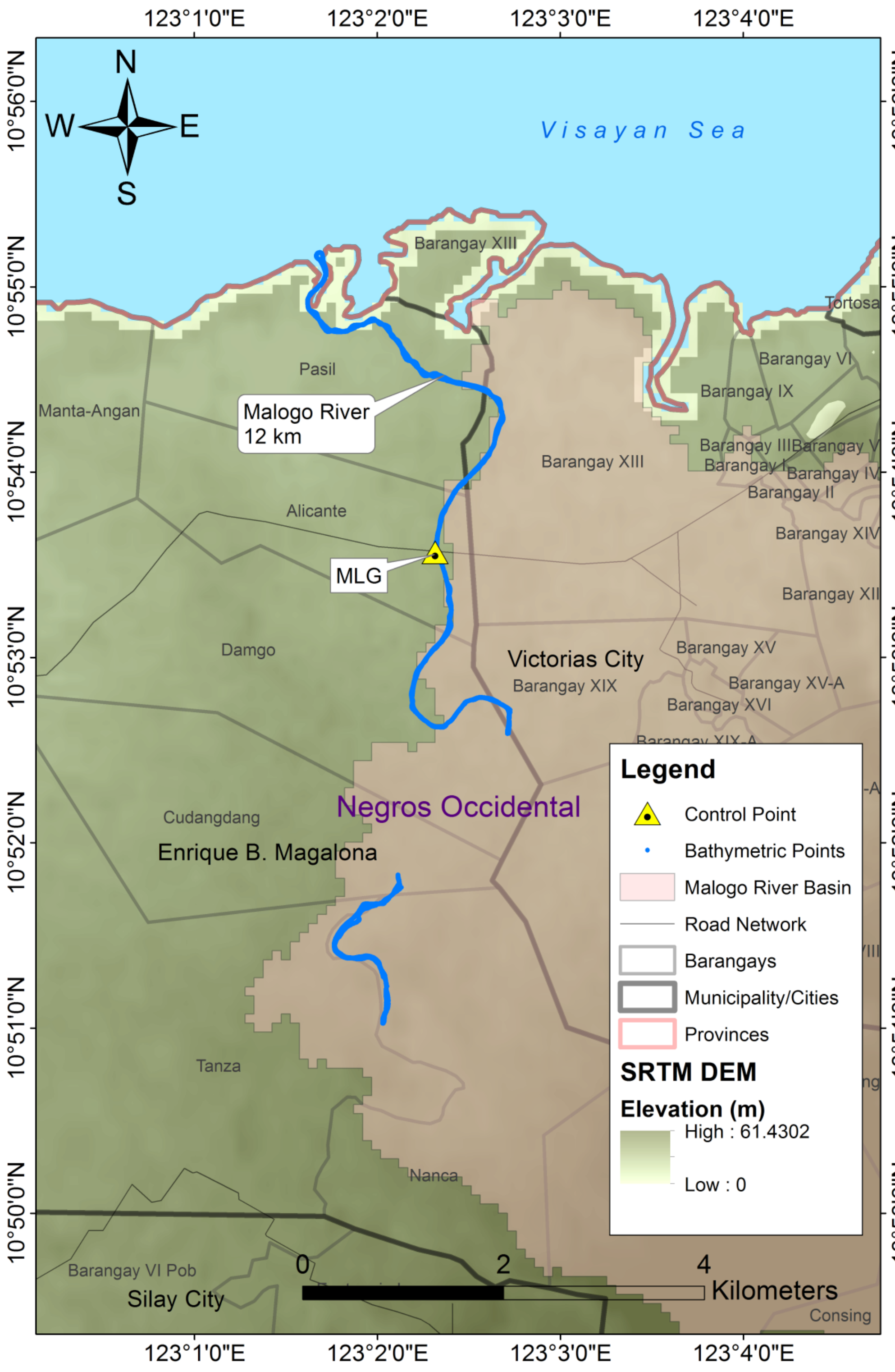


Figure 42. Extent of the bathymetric survey of the Malogo River

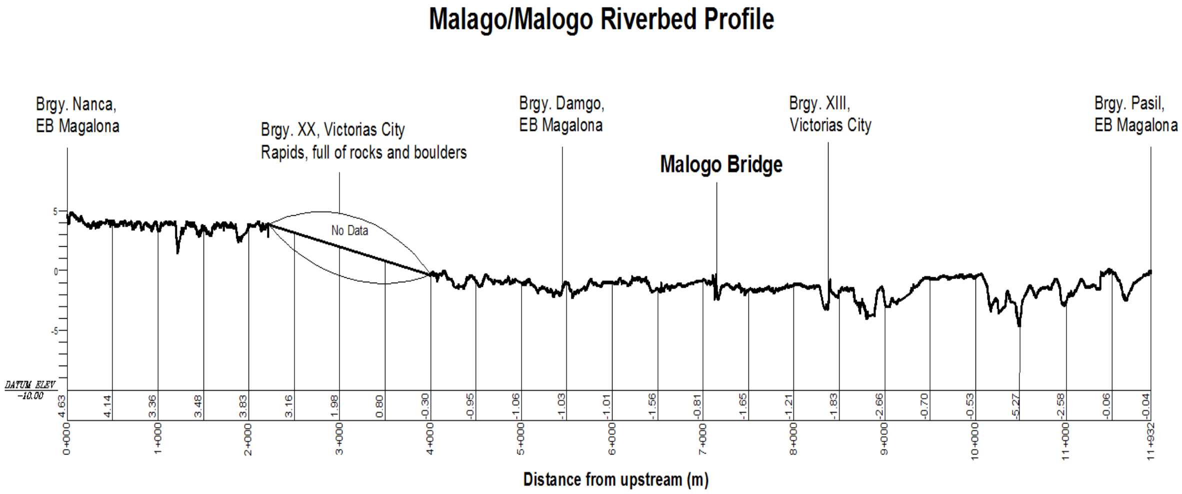


Figure 43. Riverbed profile of the Malogo River

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, Narvin Clyd Tan, and Marvin Arias

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UPC Flood Modeling Component (FMC) team. The ARG was installed at Barangay Nanca, EB Magalona, Negros Occidental (Figure 44). The precipitation data collection occurred on January 16, 2017 at 03:00 hrs. until January 17, 2017 at 00:10 hrs., with a recording interval of ten (10) minutes.

The total precipitation for this event in the Barangay Nanca ARG was 60.8 millimeters. It had a peak rainfall of 2.20 millimeters on January 17, 2017 at 10:10 hrs. The lag time between the peak rainfall and discharge was three (3) hours.

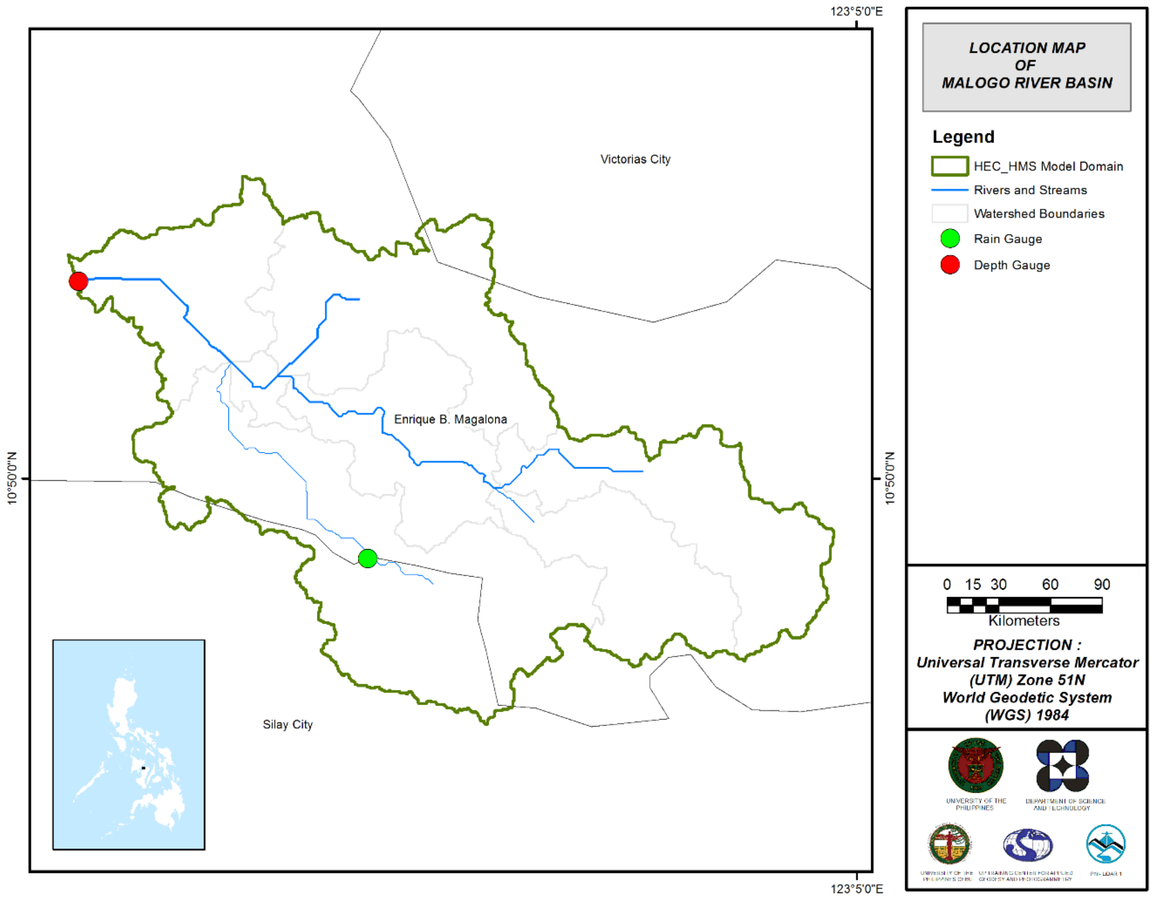


Figure 44. Location map of the Malogo HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 45) at the Nanca Bridge in EB Magalona, Negros Occidental (10°51'15.88"N, 123° 2'2.22"E) to establish the relationship between the observed water levels (H) at the Nanca Bridge and the outflow (Q) of the watershed at this location.
For the Nanca Bridge, the rating curve is expressed as $Q=4E\text{-}40e^{2.8881x}$, as illustrated in Figure 46.

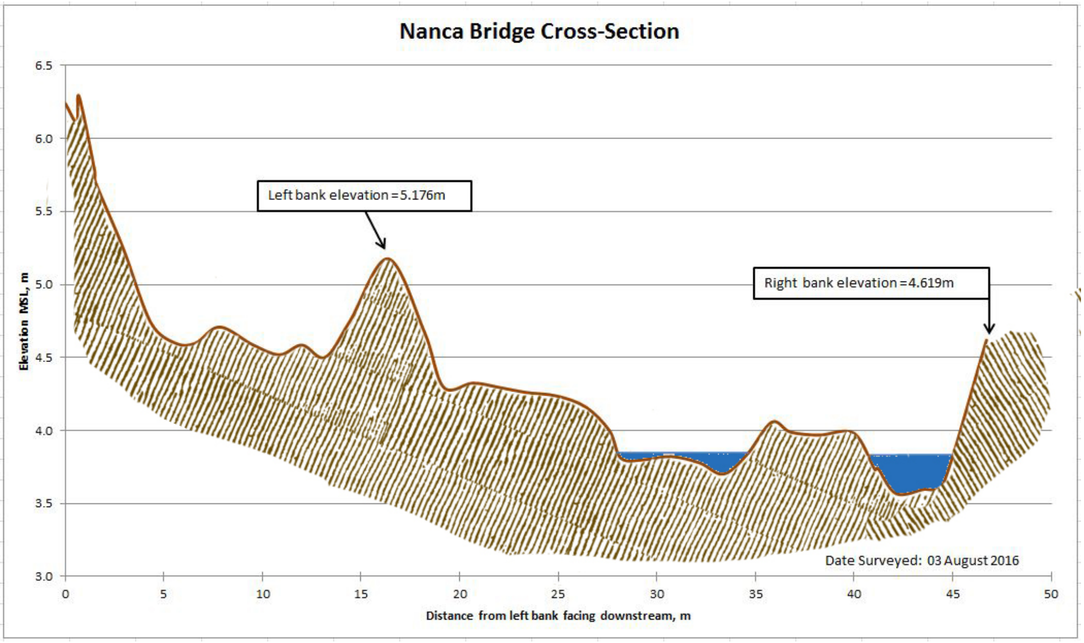


Figure 45. Cross-section plot of the Nanca Bridge

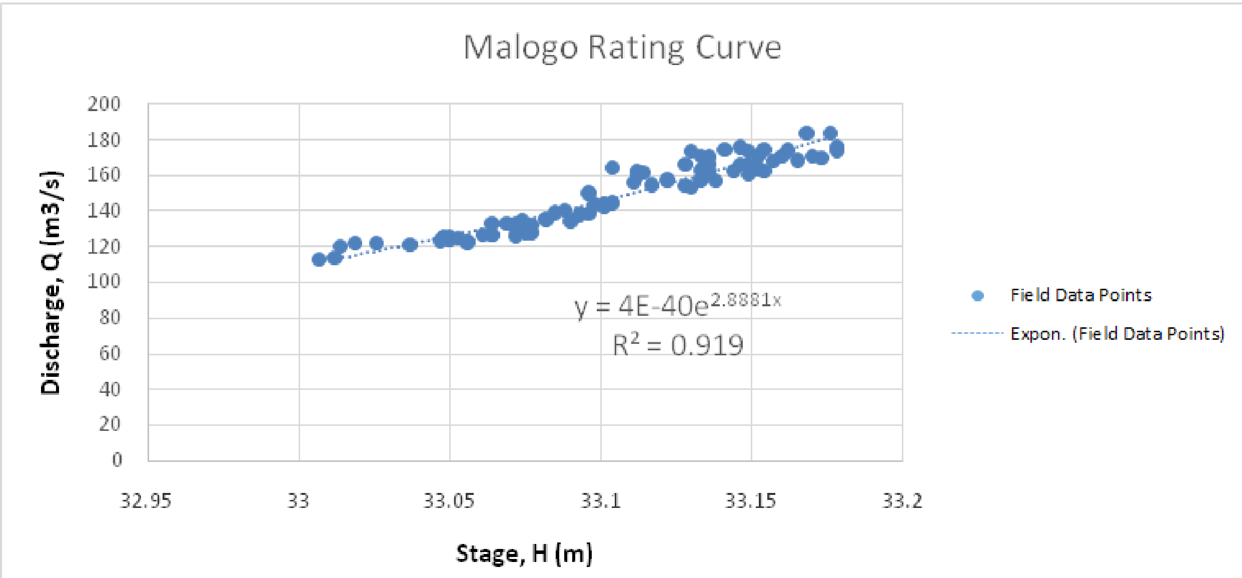


Figure 46. Rating curve at the Nanca Bridge, EB Magalona, Negros Occidental

This rating curve equation was used to compute for the river outflow at the Nanca Bridge, for the calibration of the HEC-HMS model presented in Figure 47. The total rainfall for this event was 60.8 millimeters, and the peak discharge was 399.9 m^3 per second on January 16, 2017 at 16:10 hrs.

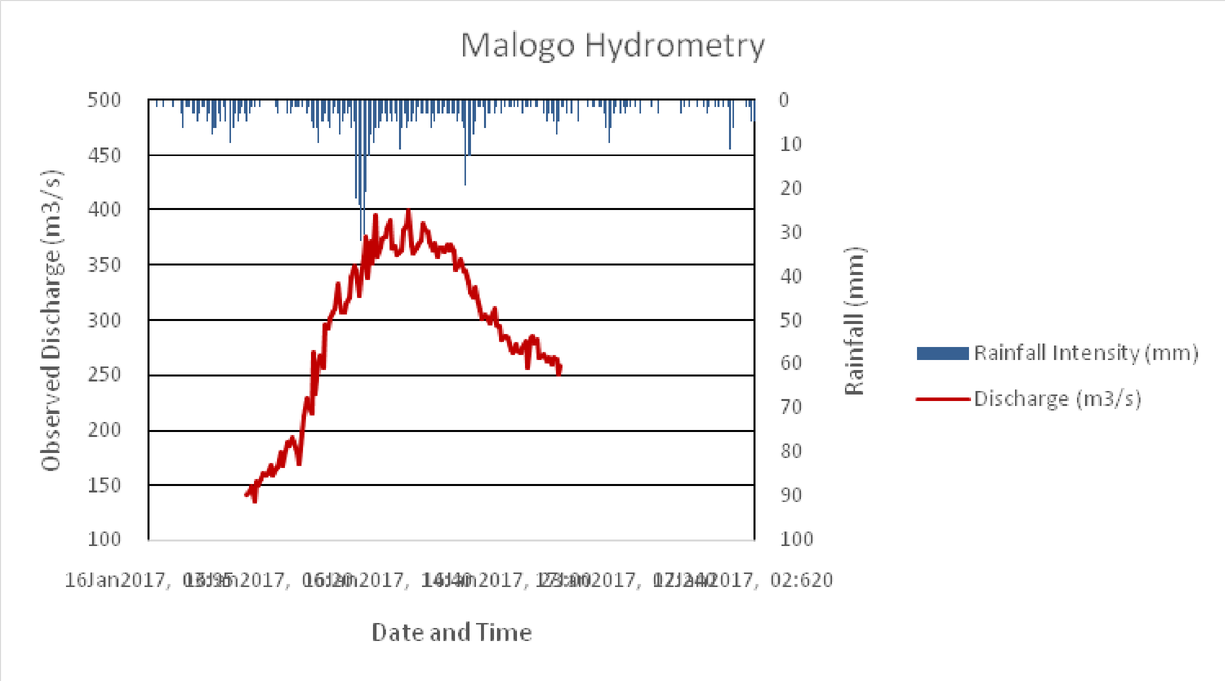


Figure 47. Rainfall and outflow data at Malogo, used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge (Table 24). This station was selected based on its proximity to the Malogo watershed (Figure 48). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 59-year record.

Table 24. RIDF values for the Iloilo Rain Gauge, computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
5	28.7	39.4	48	59.4	74.9	90	114.7	131.7	165.2
10	33.9	45.6	55.6	68.1	85	103.6	133.6	155.4	198.9
25	40.5	53.5	65.3	79.2	97.6	120.8	157.6	185.3	241.5
50	45.4	59.4	72.4	87.3	107	133.5	175.3	207.4	273.1
100	50.3	65.2	79.5	95.4	116.4	146.2	193	229.4	304.5

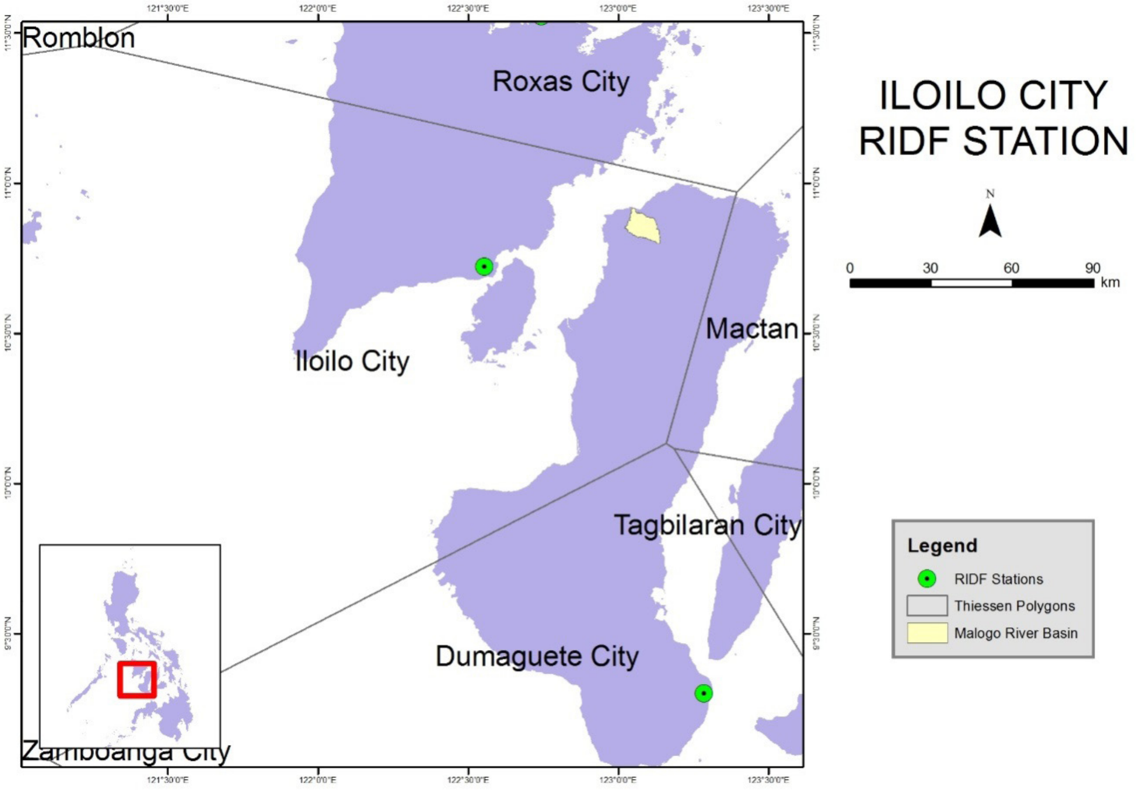


Figure 48. Location of the Iloilo RIDF station relative to the Malogo River Basin

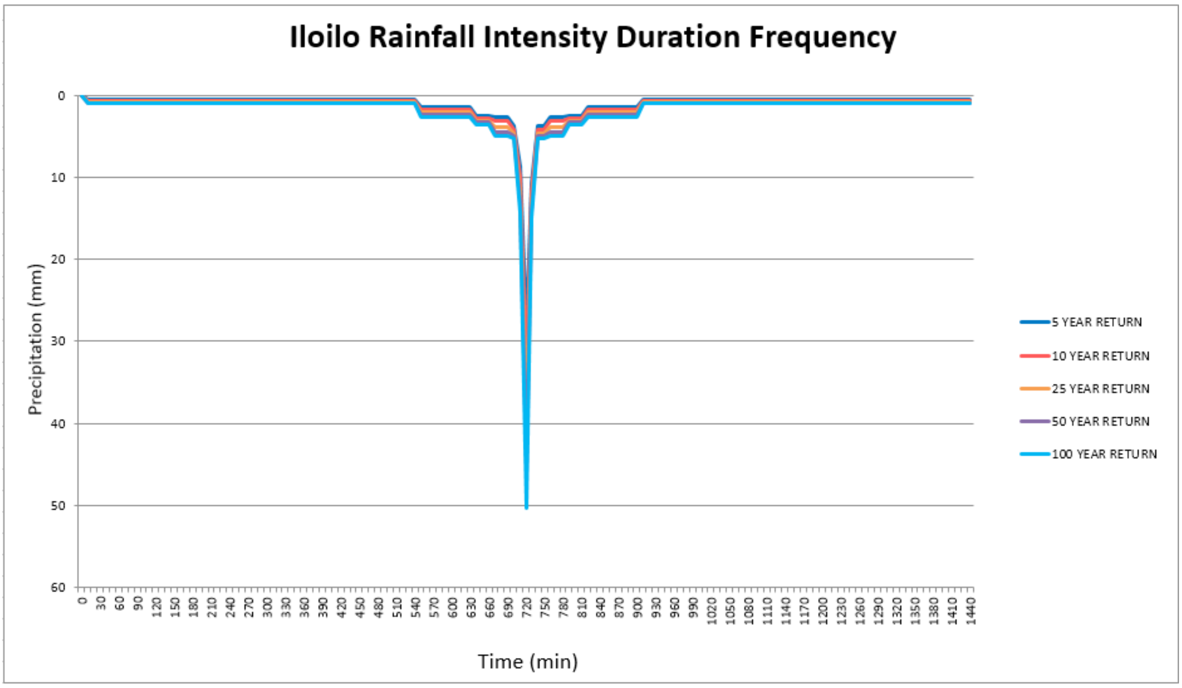


Figure 49. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Malogo River Basin are exhibited in Figures 50 and 51, respectively.

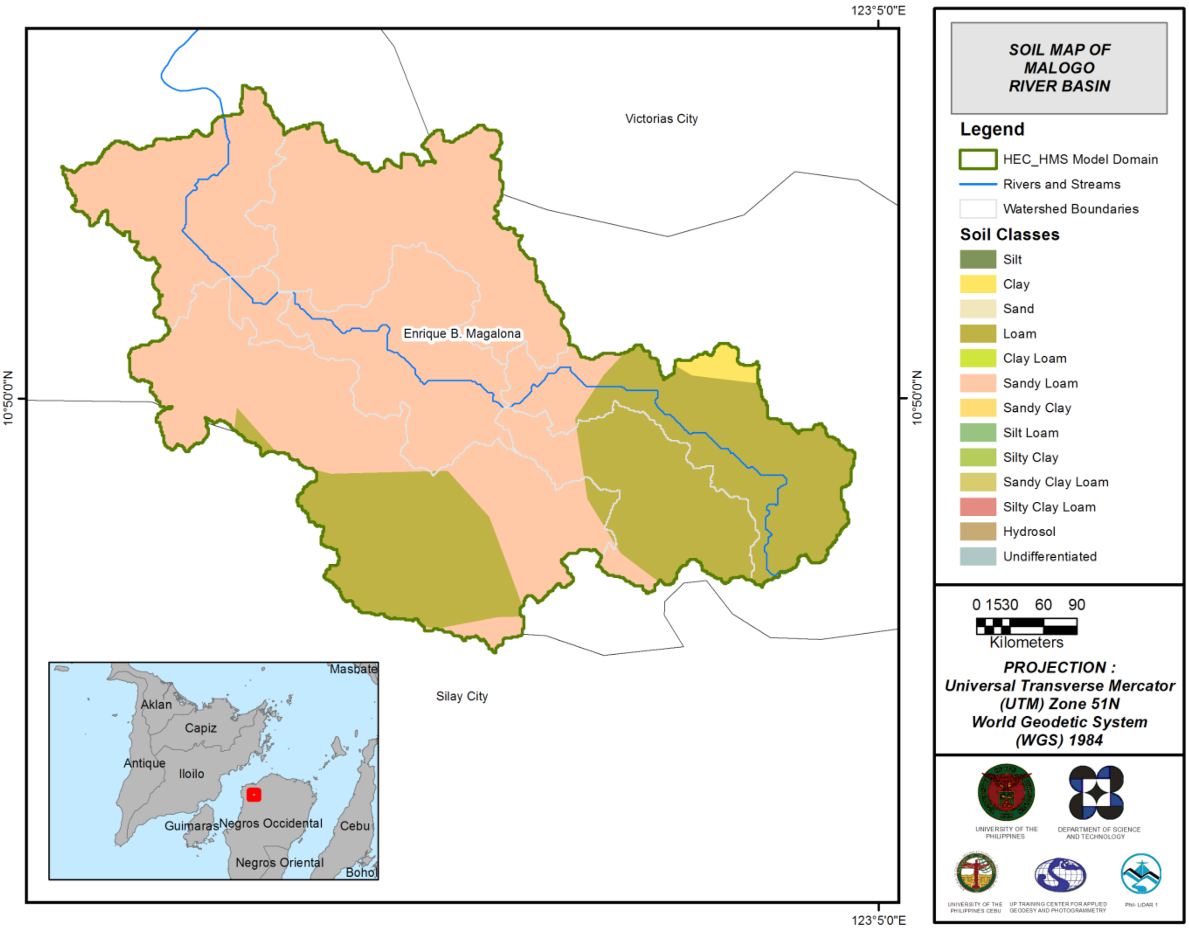


Figure 50. Soil map of the Malogo River Basin (Source: DA)

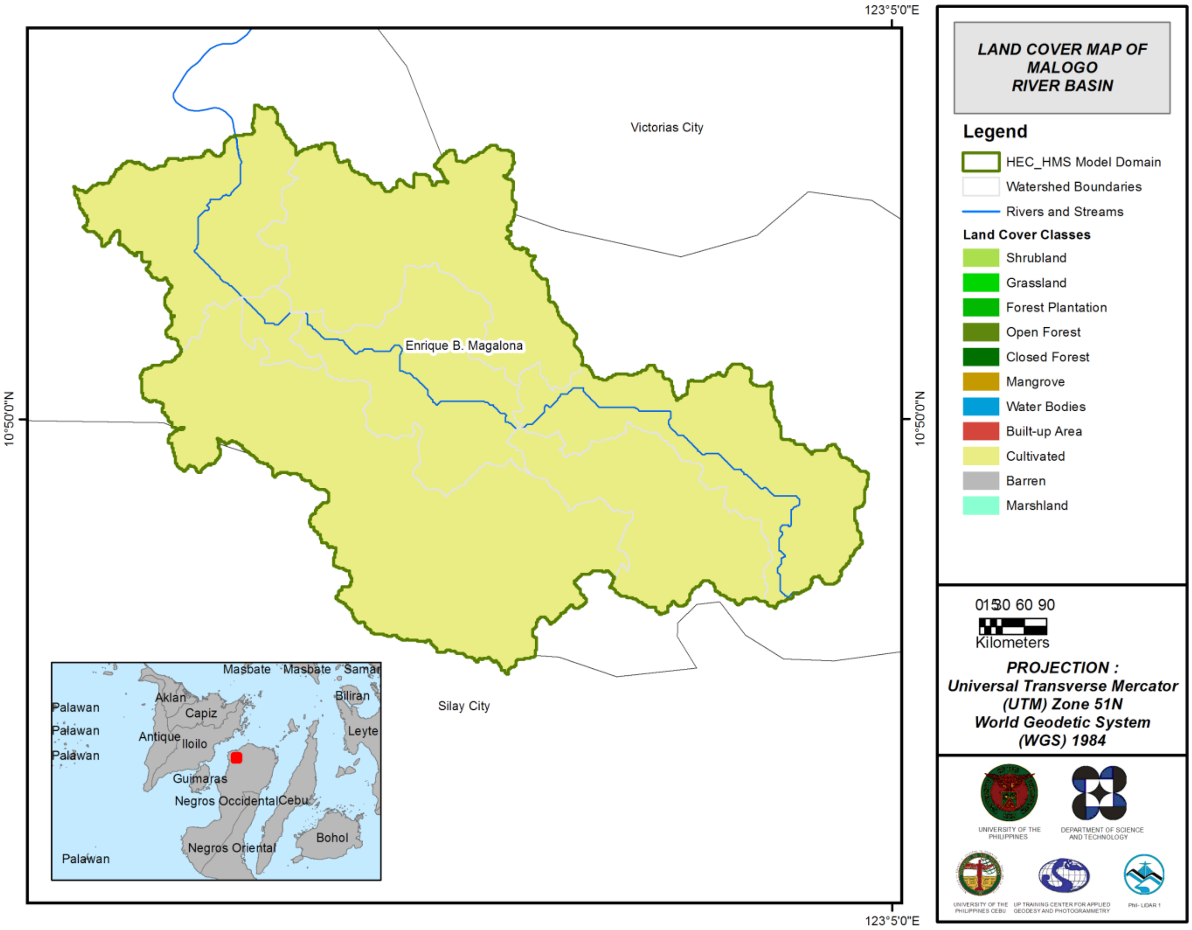


Figure 51. Land cover map of the Malogo River Basin (Source: NAMRIA)

Three (3) soil classes were identified in the Malogo River Basin. These are loam, sandy loam, and clay. Moreover, one (1) land cover class was identified, which is cultivated areas.

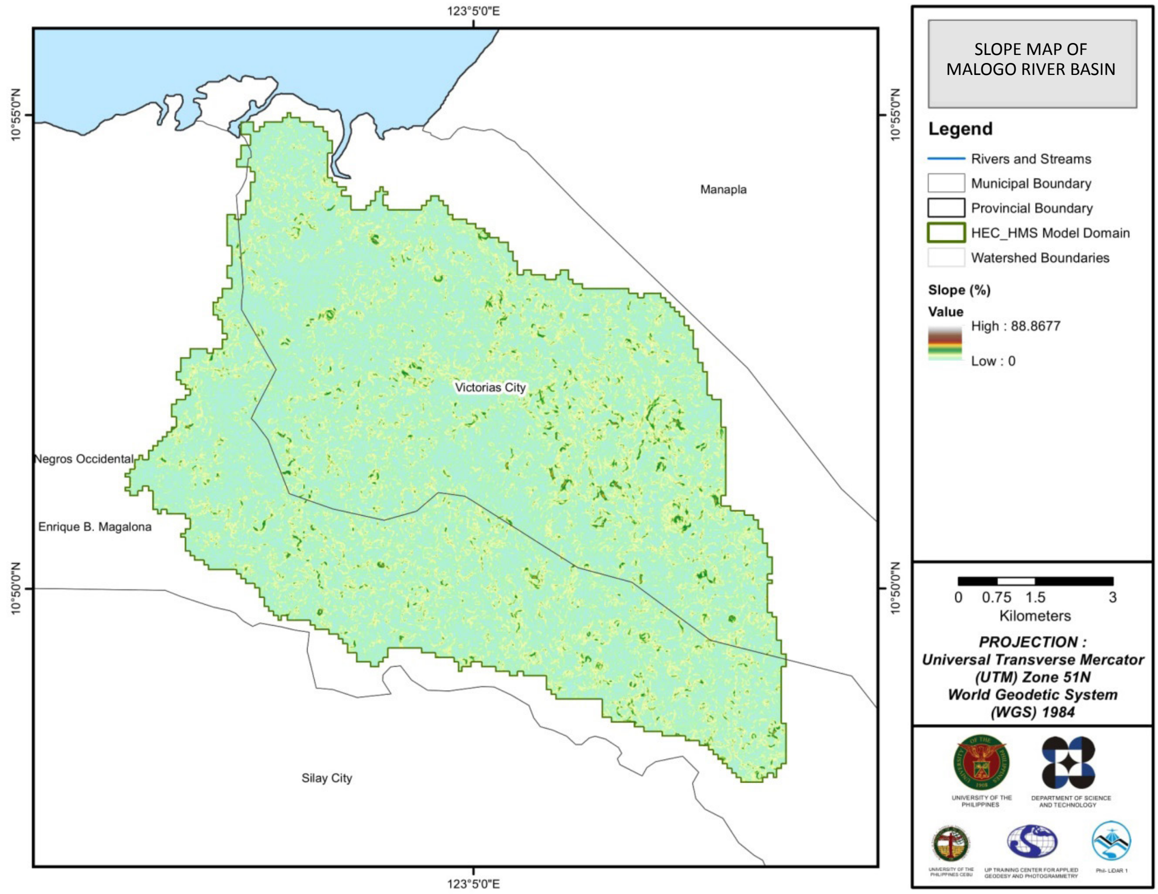


Figure 52. Slope map of the Malogo River Basin

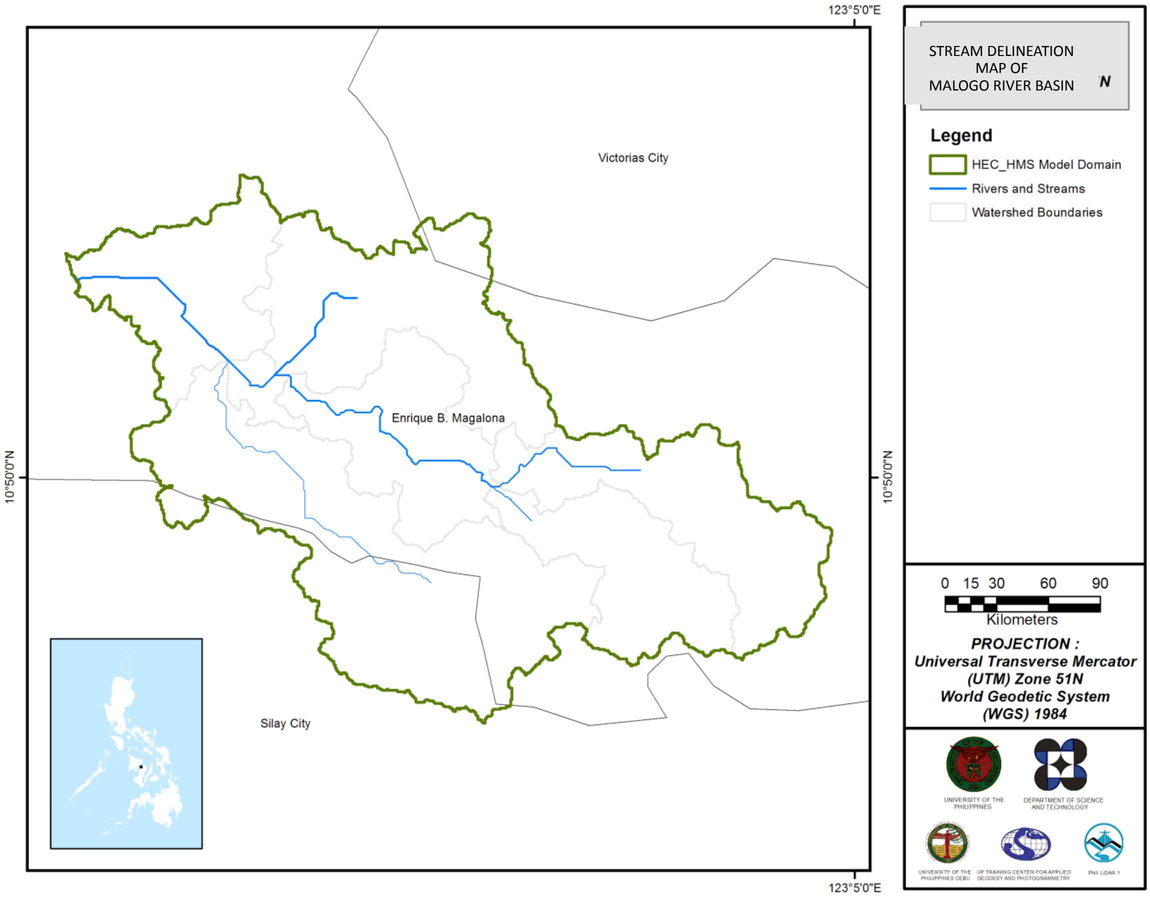


Figure 53. Stream delineation map of the Malogo river basin

Using the SAR-based DEM, the Malogo basin was delineated and further subdivided into sub-basins. The model consists of seven (7) sub-basins, three (3) reaches, and three (3) junctions, as illustrated in Figure 54. The main outlet is at the Nanca Bridge. See Annex 9 for the Malogo Model Reach Parameters.

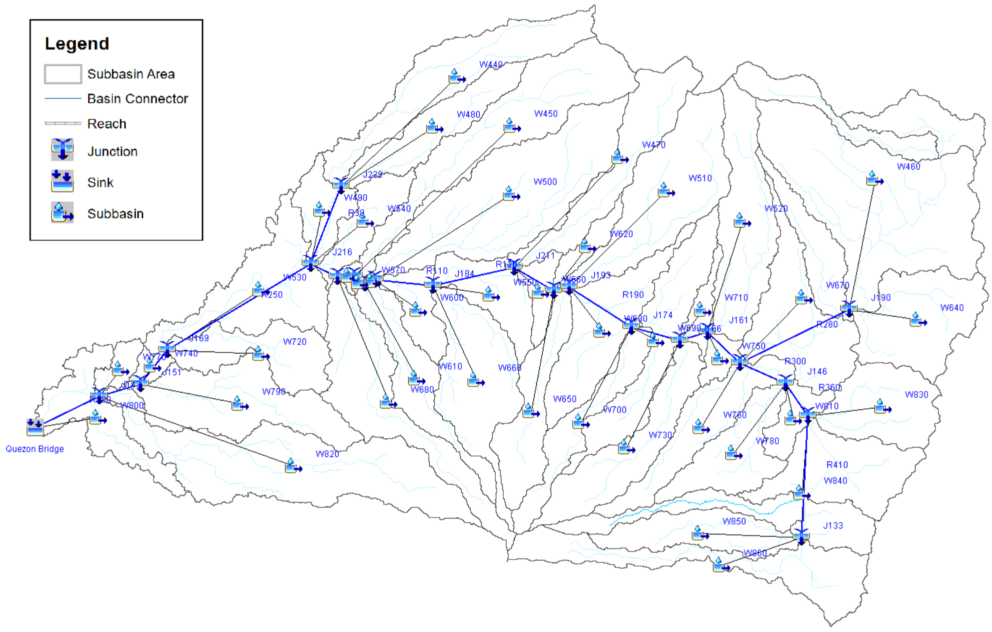


Figure 54. The Malogo River Basin model, generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model were derived from the LiDAR DEM data. These were defined using the Arc GeoRAS tool and post-processed in ArcGIS (Figure 55).

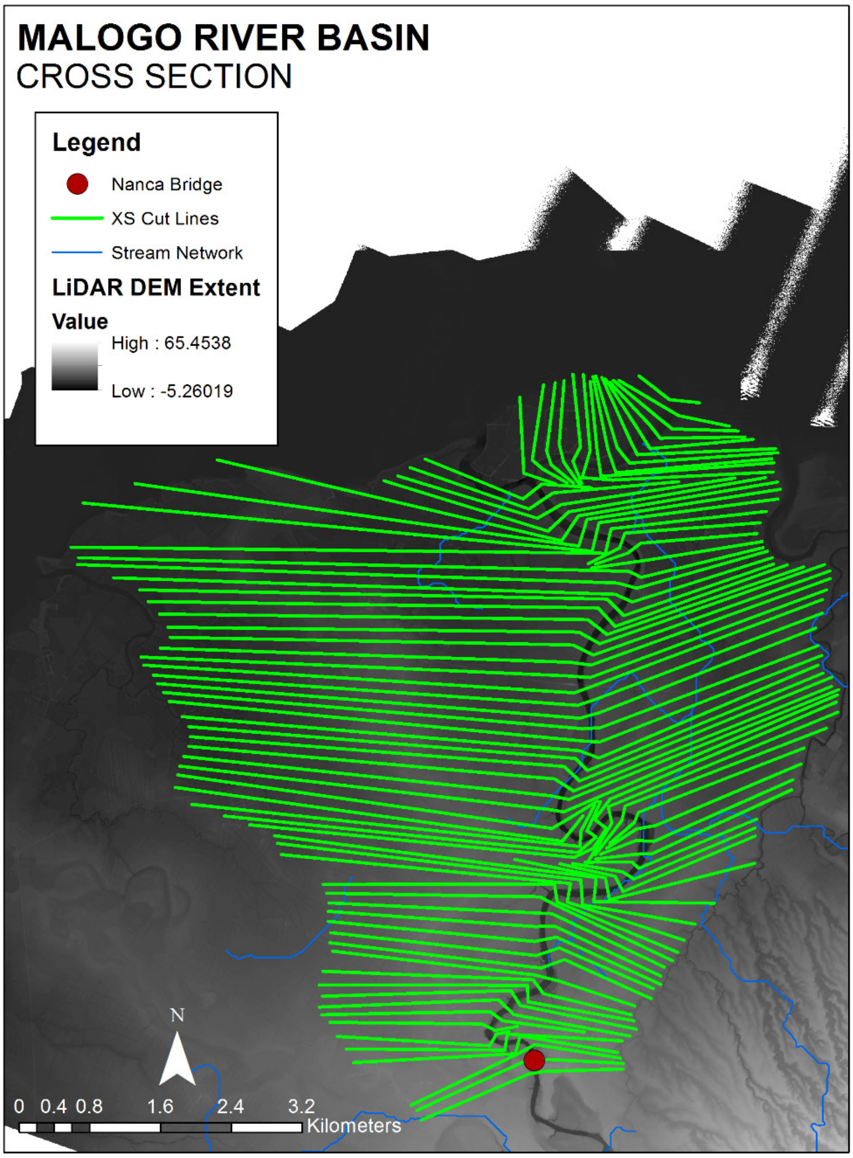


Figure 55. River cross-section of the Malogo River, generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling; such as, x- and y- coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it was observed that the water will generally flow from the south of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively.

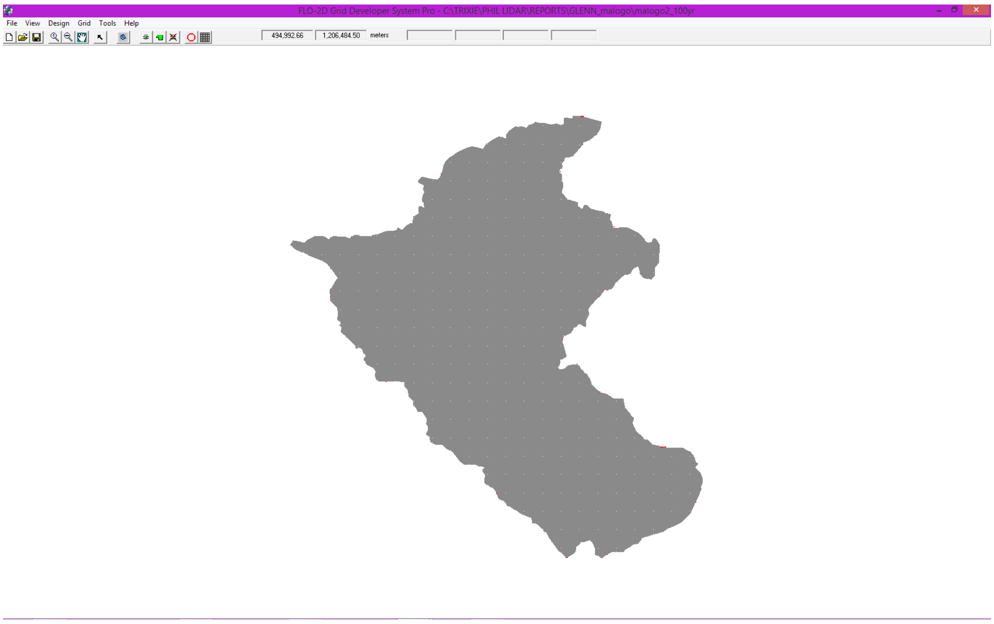


Figure 56. Screenshot of a sub-catchment, with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 27.58203 hours. After the simulation, the FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows the flood hazard levels, as well as the extent and inundation. Assigning the appropriate flood depths and velocity values for Low, Medium, and High created the following flood hazard map. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (maximum depth) was set at 0.2 meters; while the minimum vh (product of maximum velocity (v) and maximum depth (h)) was set at 0 m^2/s.00

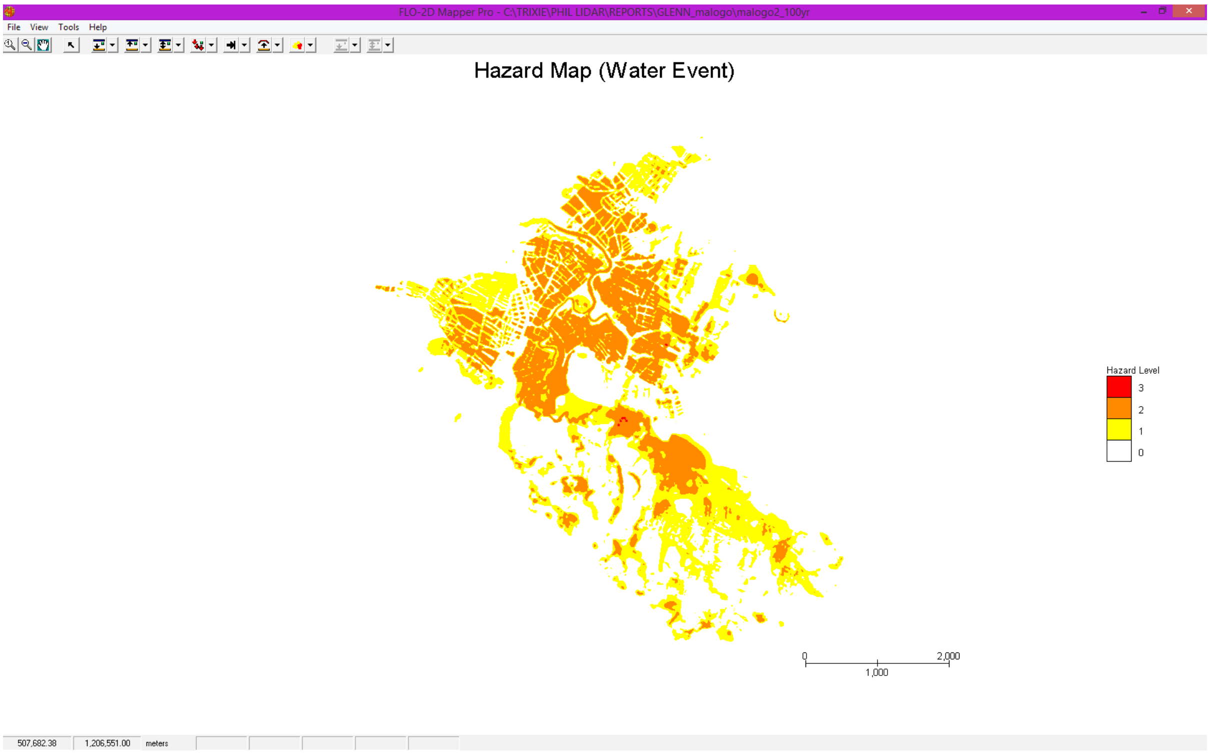


Figure 57. Generated 100-year rain return hazard map from the FLO-2D Mapper

The creation of a flood hazard map from the model also automatically generated a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 21957300.00 m^2.

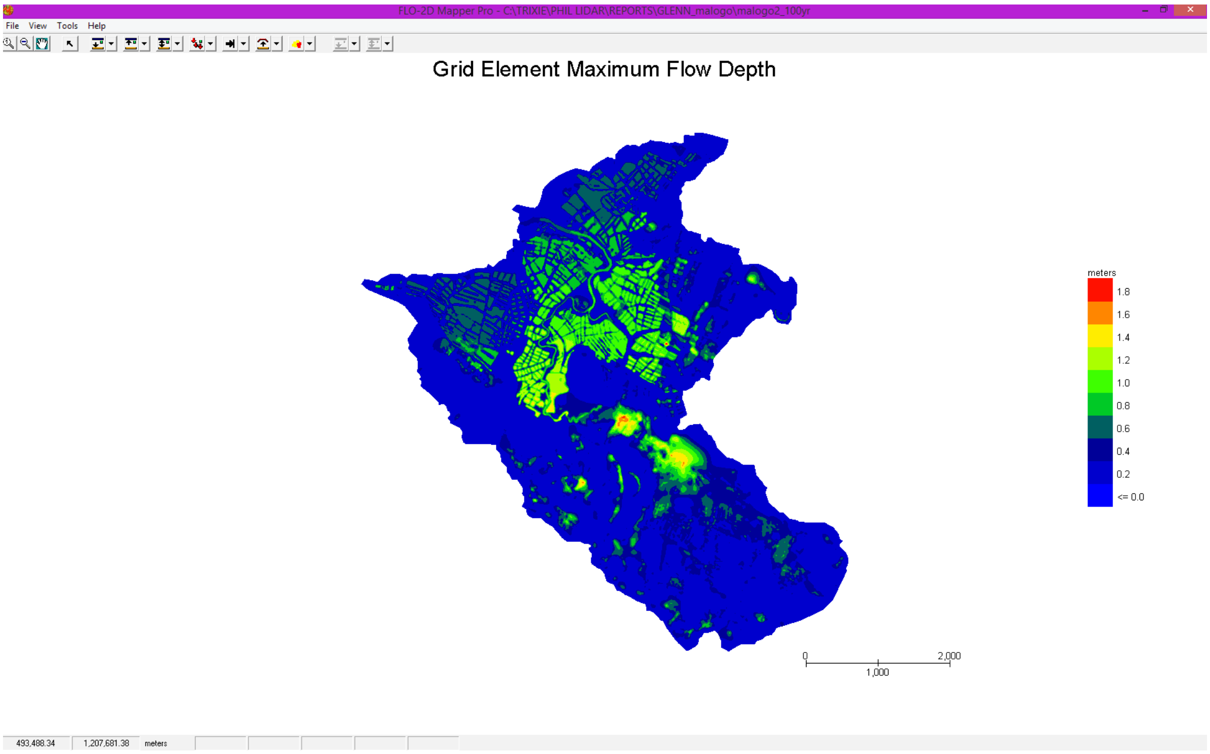


Figure 58. Generated 100-year rain return flow depth map from the FLO-2D Mapper

There was a total of 44530945.60 m^3 of water that entered the model. Of this amount, 6644245.62 m^3 was due to rainfall, while 37886699.99 m^3 was inflow from other areas outside the model. 3295583.50 m^3 of this water was lost to infiltration and interception, while 9121167.79 m^3 was stored by the floodplain. The rest, amounting to up to 32114193.48 m^3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Malogo HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 depicts the comparison between the two (2) discharge data. The Malogo Model Basin Parameters are available in Annex 8.

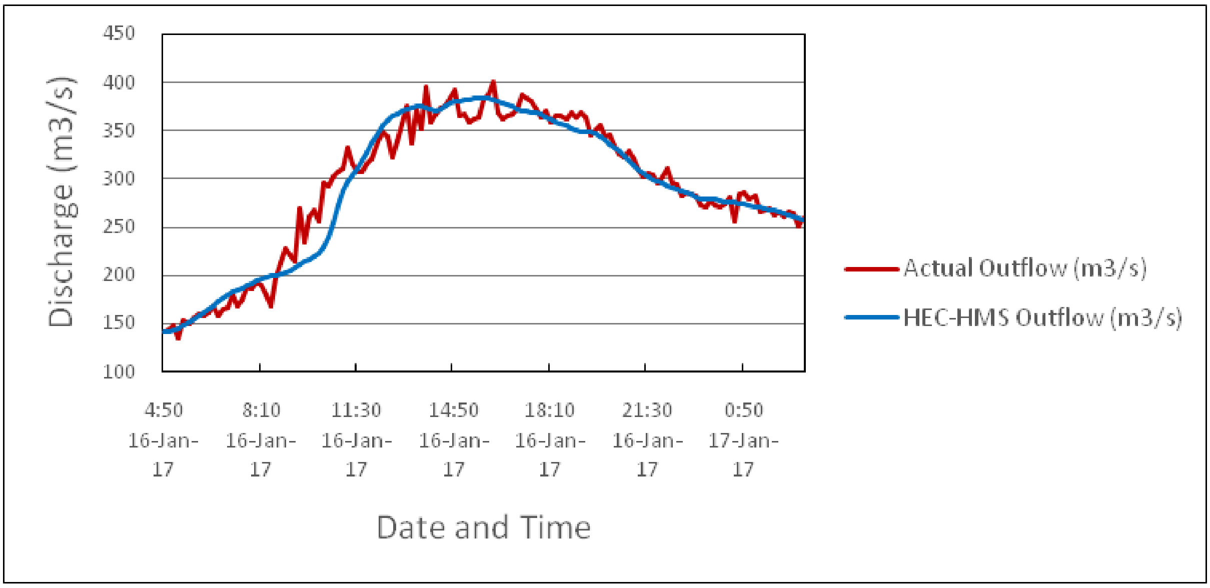


Figure 59. Outflow hydrograph of Malogo produced by the HEC-HMS model, compared with observed outflow

Enumerated in Table 25 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 25. Range of calibrated values for the Malogo River Basin model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.64-0.79
			Curve Number	67-76.7
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.74-14.5
			Storage Coefficient (hr)	0.01-0.072
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.085-0.41

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values of 0.64 - 0.79 millimeters for the initial abstraction signifies a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. A range of 67 - 76.7 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Malogo, the basin mostly consists of brush lands and cultivated areas, and the soil consists of clay, loam, and sandy loam.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 45 minutes to 14.5 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 1 indicates that the basin is unlikely to quickly return to its original discharge, and will be higher instead. A ratio to peak of 0.5 indicates a gradual receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.085-0.41 corresponds to the common roughness of Philippine watersheds. The Malogo River Basin is determined to be cultivated with medium to dense brush lands (Brunner, 2010).

Table 26. Efficiency Test of the Malogo HMS Model

Accuracy Measure	Value
RMS Error	17.0
r^2	0.9738
NSE	0.95
RSR	0.23
PBIAS	0.67

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 17 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured as 0.9738.

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 0.95.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is 0.67.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained an RSR value of 0.23.

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 60) illustrates the Malogo outflow using the Iloilo RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods – from 165.2m^3 in a 5-year return period, to 304.5m^3 in a 100-year return period.

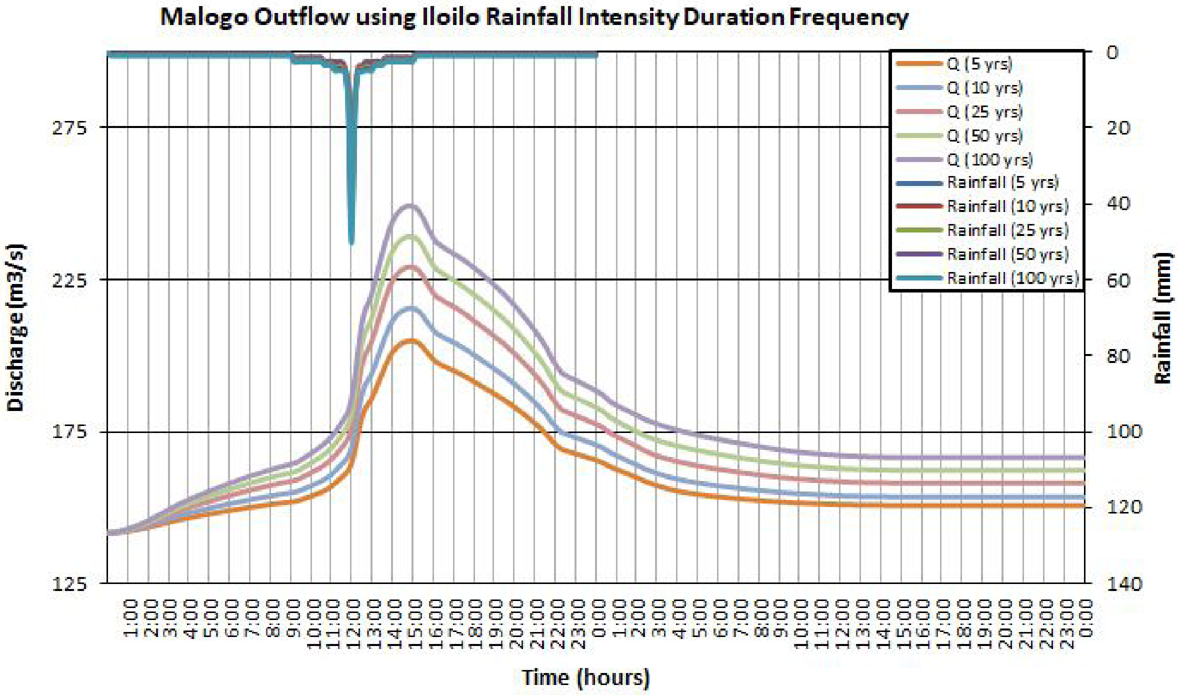


Figure 60. Outflow hydrograph at the Malogo Station generated using the Iloilo RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Malogo discharge using the Iloilo RIDF curves in five (5) different return periods is shown in Table 27.

Table 27. Peak values of the Malogo HEC-HMS Model outflow, using the Iloilo RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	165.2	28.7	204.86	3 hours
10-Year	198.9	33.9	215.56	2 hours, 50 minutes
25-Year	241.5	40.5	229.2	2 hours, 50 minutes
50-Year	273.1	45.4	239.3	2 hours, 50 minutes
100-Year	304.5	50.3	249.36	2 hours, 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the extent of real-time flood inundation of the river, after it has been automated and uploaded on the DREAM website. The sample generated map of the Malogo River, using the calibrated HMS event flow is presented in Figure 61.

Figure 61. Sample output map of the Malogo RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10-meter resolution. Figure 62 to Figure 67 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Imbang-Malogo floodplain. The floodplain, with an area of 535.61 square kilometers, covers eight (8) municipalities; namely, Cadiz City, Calatrava, Enrique B. Magalona, Manapla, Salvador Benedicto, Silay City, Talisay City, and Victorias City.

Table 28. Municipalities affected in the Imbang-Malogo floodplain

Municipality	Total Area	Area Flooded	% Flooded
Cadiz City	516.184	40.44	7.84
Calatrava	344.54	0.044	0.013
Enrique B. Magalona	140.32	132.52	34.44
Manapla	99.18	0.99	1.002
Salvador Benedicto	182.22	0.42	0.23
Silay City	196.525	181.41	92.31
Talisay City	199.01	100.21	50.35
Victorias City	103.55	79.53	76.8

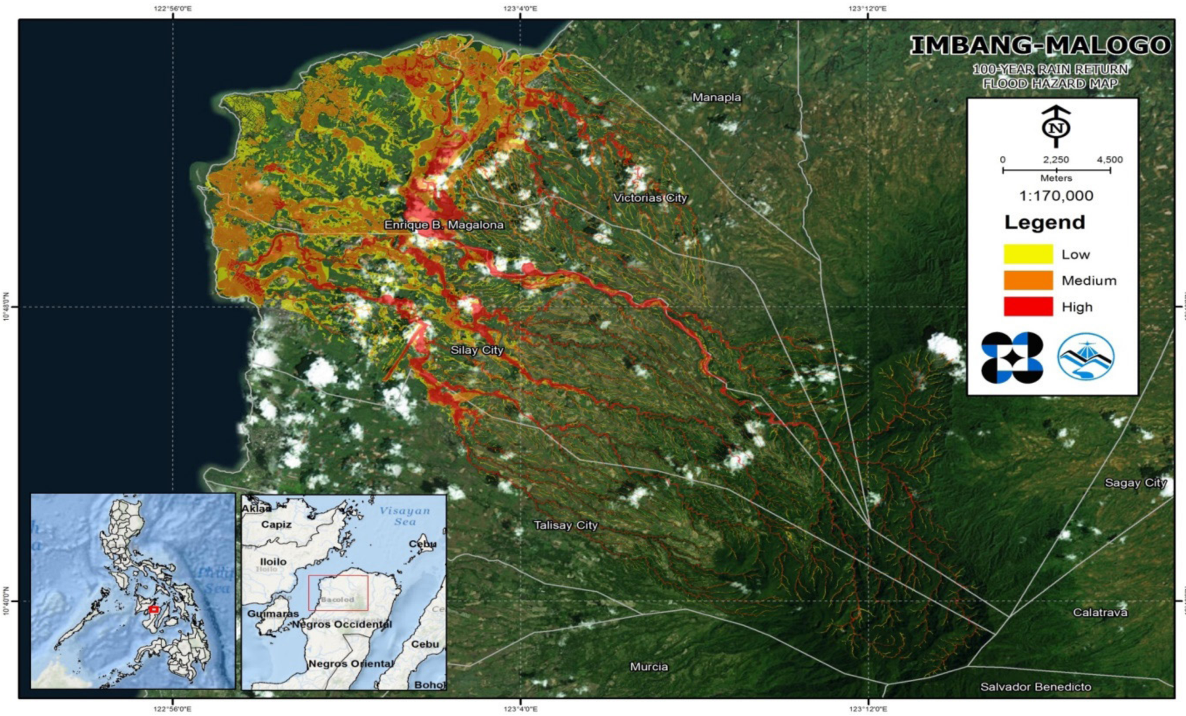


Figure 62. 100-year flood hazard map for the Imbang-Malogo floodplain, overlaid on Google Earth imagery

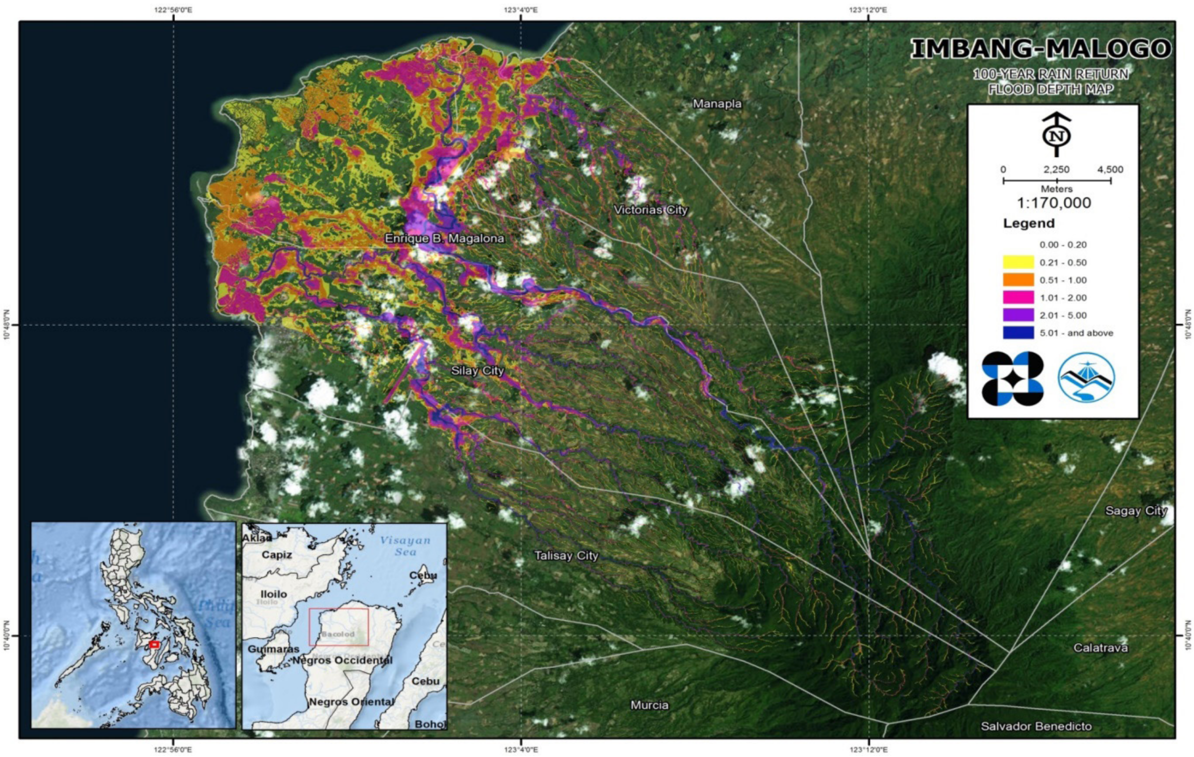


Figure 63. 100-year flow depth map for the Imbang-Malogo floodplain, overlaid on Google Earth imagery

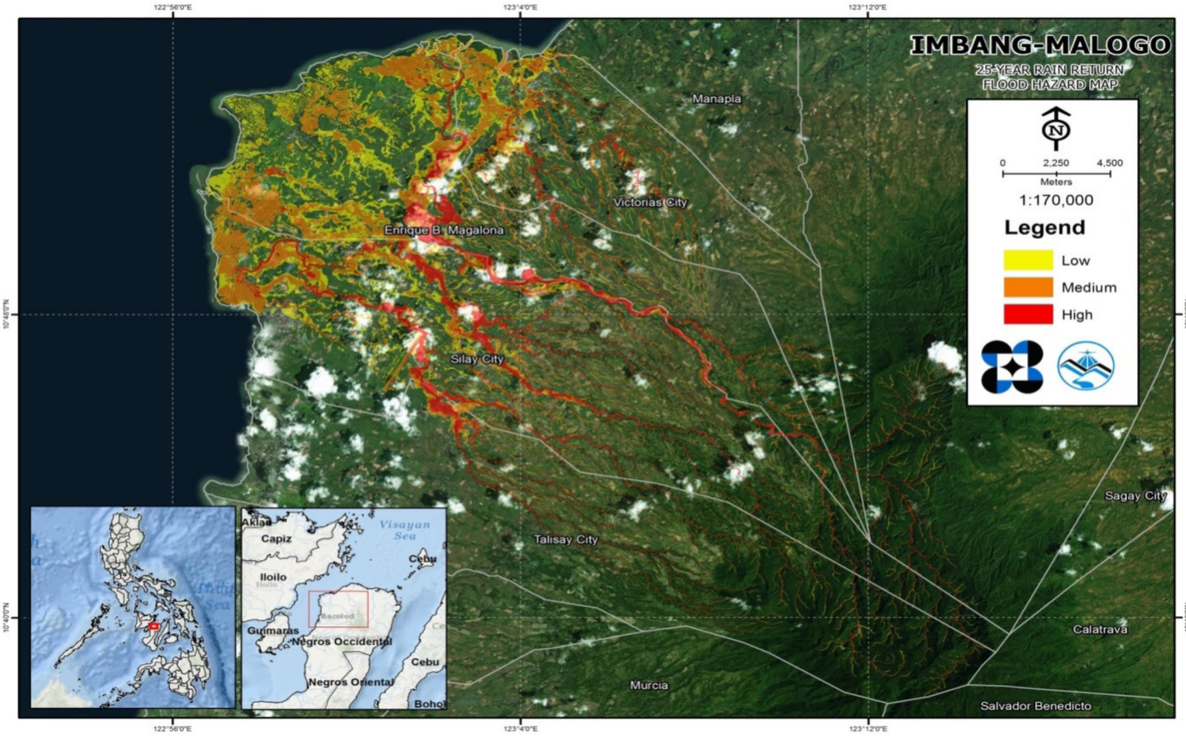


Figure 64. 25-year flood hazard map for the Imbang-Malogo floodplain, overlaid on Google Earth imagery

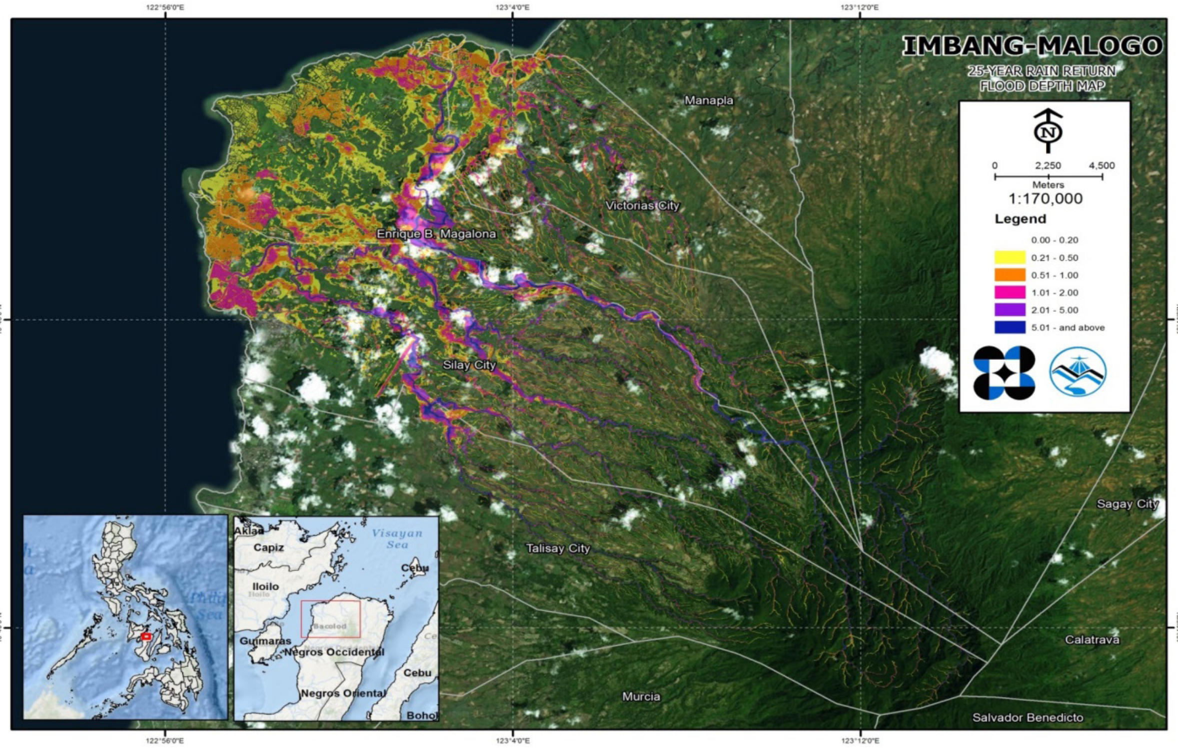


Figure 65. 25-year flow depth map for the Imbang-Malogo floodplain, overlaid on Google Earth imagery

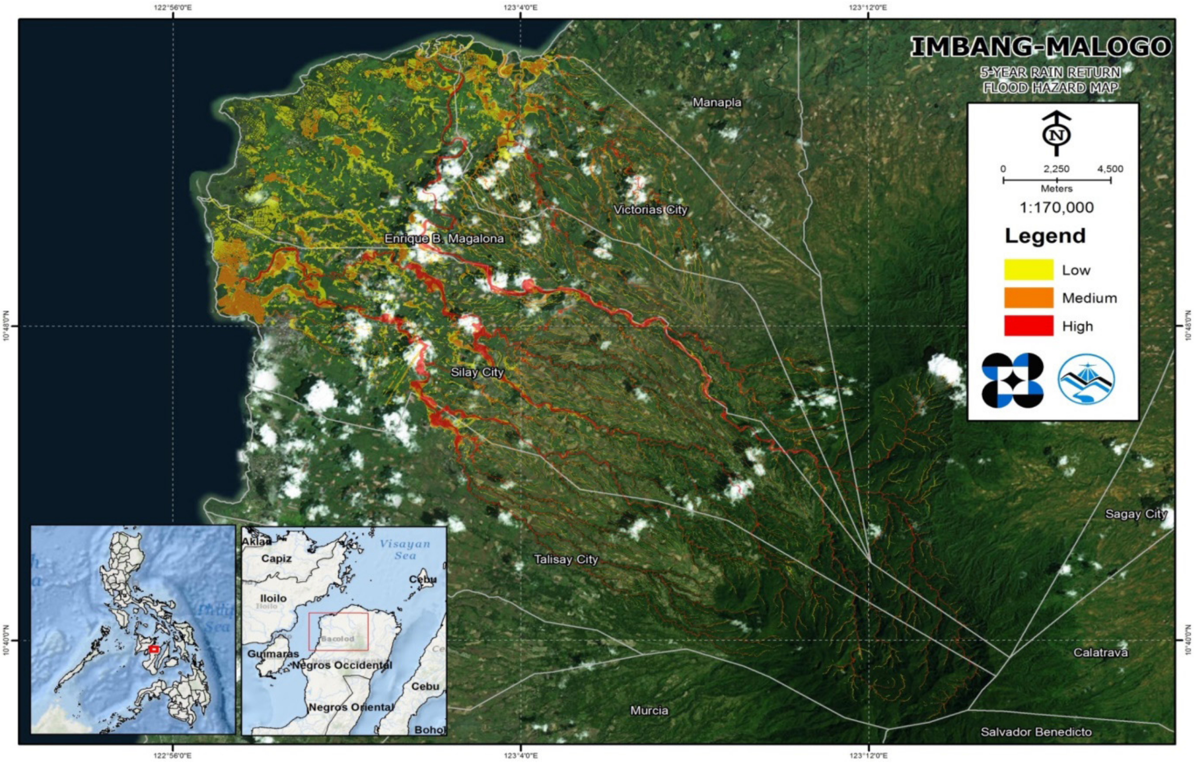


Figure 66. 5-year flood hazard map for the Imbang-Malogo floodplain, overlaid on Google Earth imagery

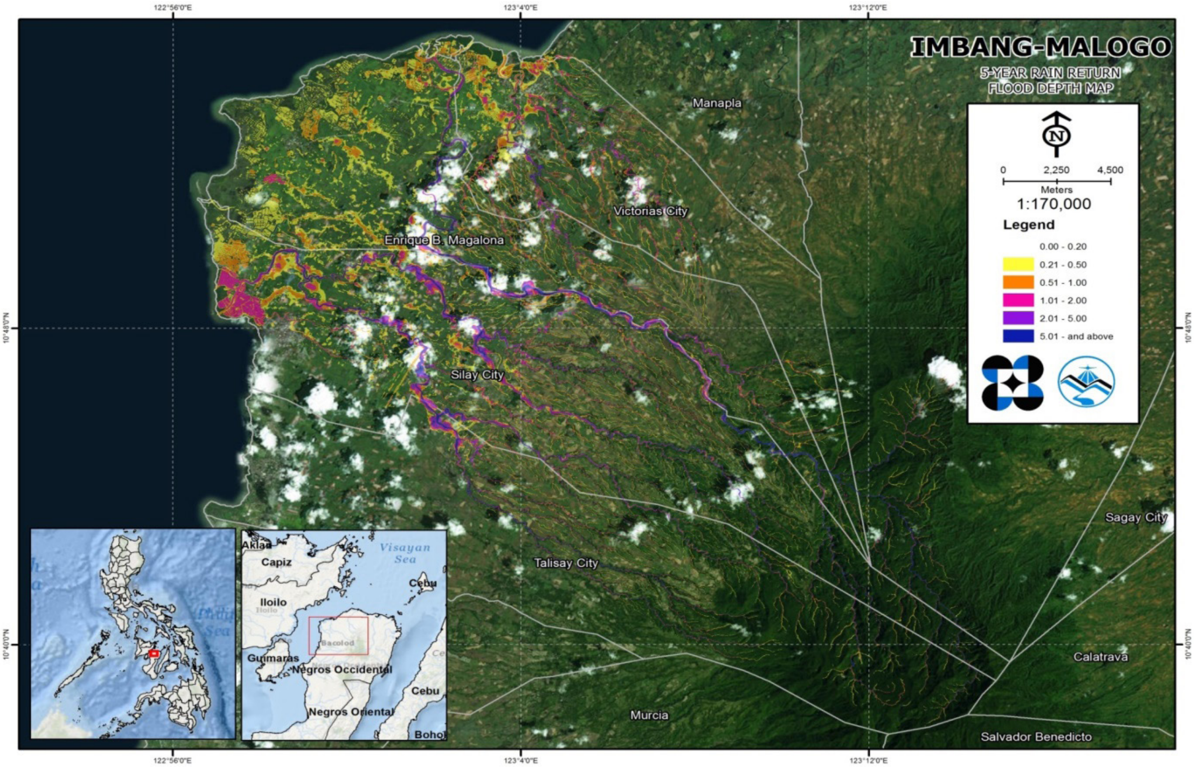


Figure 67. 5-year flow depth map for the Imbang-Malogo floodplain, overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

The affected barangays in the Malogo (Imbang-Malogo) River Basin, grouped by municipality, are listed below. For the said basin, eight (8) municipalities consisting of seventy-five (75) barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 7.46% of the City of Cadiz, with an area of 516.184 square kilometers, will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.074%, 0.054%, 0.05%, and 0.041% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 29 are the affected areas, in square kilometers, by flood depth per barangay.

Table 29. Affected areas in Cadiz City, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)
	Celestino Villacin
0.03-0.20	38.51
0.21-0.50	0.81
0.51-1.00	0.38
1.01-2.00	0.28
2.01-5.00	0.25
> 5.00	0.21

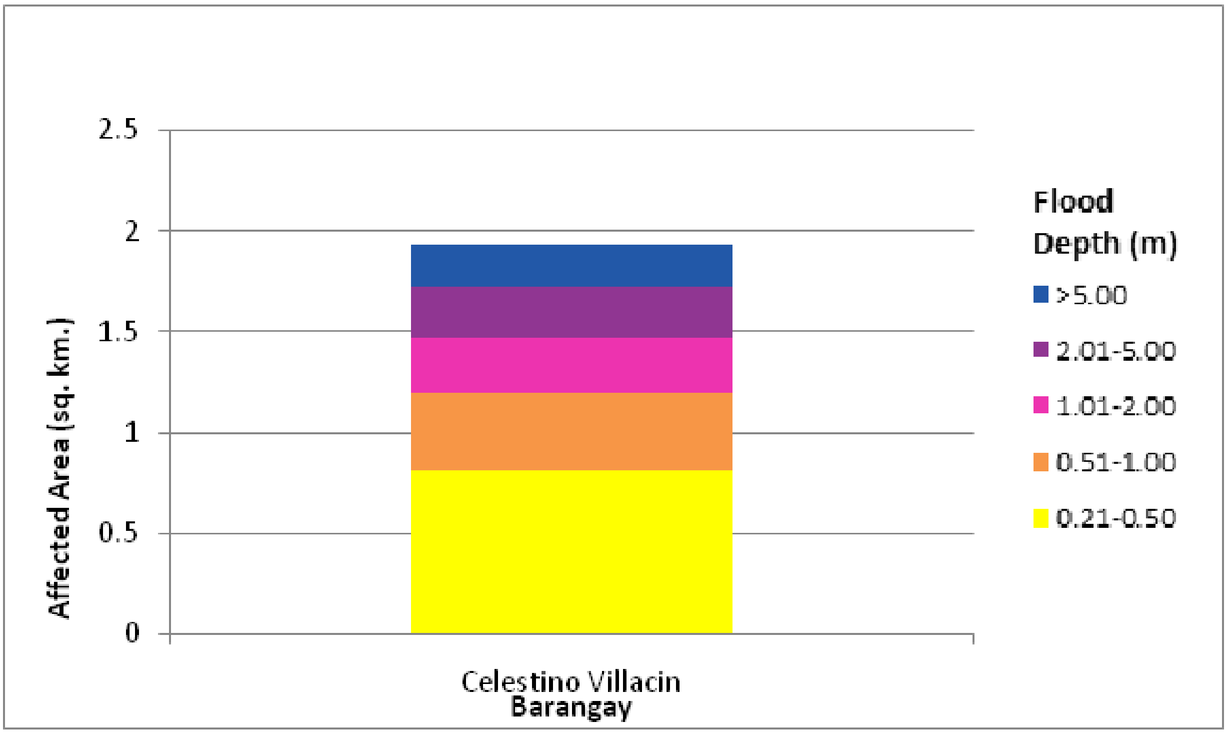


Figure 68. Affected areas in Cadiz City, Negros Occidental during a 5-year rainfall return period

For the Municipality of Calatrava, with an area of 344.54 square kilometers, 0.013% will experience flood levels of less than 0.20 meters. 0.000014% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 30 are the affected areas, in square kilometers, by flood depth per barangay.

Table 30. Affected areas in Calatrava, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calatrava (in sq. km.)
	Lalong
0.03-0.20	0.044
0.21-0.50	0.000049
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

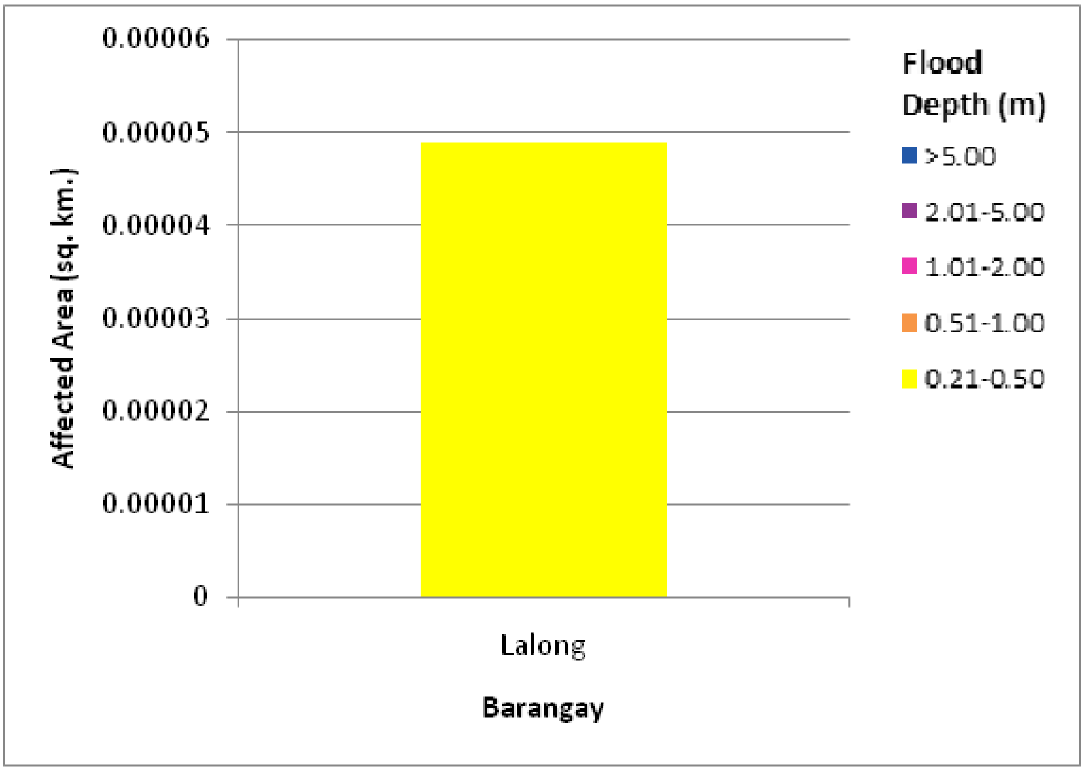


Figure 69. Affected areas in Calatrava, Negros Occidental during a 5-year rainfall return period

For the Municipality of Enrique B. Magalona, with an area of 140.2 square kilometers, 75.86% will experience flood levels of less than 0.20 meters. 11.99% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.774%, 1.275%, 0.9416%, 0.596% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 31 are the affected areas, in square kilometers, by flood depth per barangay.

Table 31. Affected areas in Enrique B. Magalona, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)											
	Alcaygan	Alicante	Batea	Canlusong	Consing	Cudangdang	Damgo	Gahit	Latasan	Madalag	Manta-Angan	Nanca
0.03-0.20	6.66	3.38	1.56	9.44	15.99	5.03	7.69	0.75	4.39	2.28	2.49	5.37
0.21-0.50	0.63	0.54	0.61	0.29	0.89	0.92	1.39	0.21	1.48	0.89	0.47	0.66
0.51-1.00	0.41	0.13	0.048	0.22	0.7	0.11	0.31	0.0028	0.073	0.093	0.1	0.4
1.01-2.00	0.11	0.037	0	0.15	0.44	0.01	0.049	0	0.086	0	0	0.24
2.01-5.00	0.022	0.057	0	0.097	0.31	0.03	0.12	0	0	0	0	0.25
> 5.00	0.059	0.0061	0	0.14	0.11	0.049	0.11	0	0	0	0	0.24

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)										
	Pasil	Poblacion I	Poblacion II	Poblacion III	San Isidro	San Jose	Santo Niño	Tabigue	Tanza	Tomongtong	Tuburan
0.03-0.20	2.69	0.46	0.17	0.72	11.98	5.02	4.86	1.63	11.01	1.87	1.02
0.21-0.50	1.34	0.0091	0.0023	0.043	0.56	1.63	0.8	0.56	2.44	0.19	0.27
0.51-1.00	0.57	0	0	0.021	0.32	0.5	0.14	0.34	0.76	0.0075	0.035
1.01-2.00	0.18	0	0	0	0.25	0.066	0.05	0.017	0.094	0.0003	0.0068
2.01-5.00	0.077	0	0	0	0.33	0.0001	0	0	0.034	0	0
> 5.00	0.0036	0	0	0	0.029	0	0	0	0.08	0	0

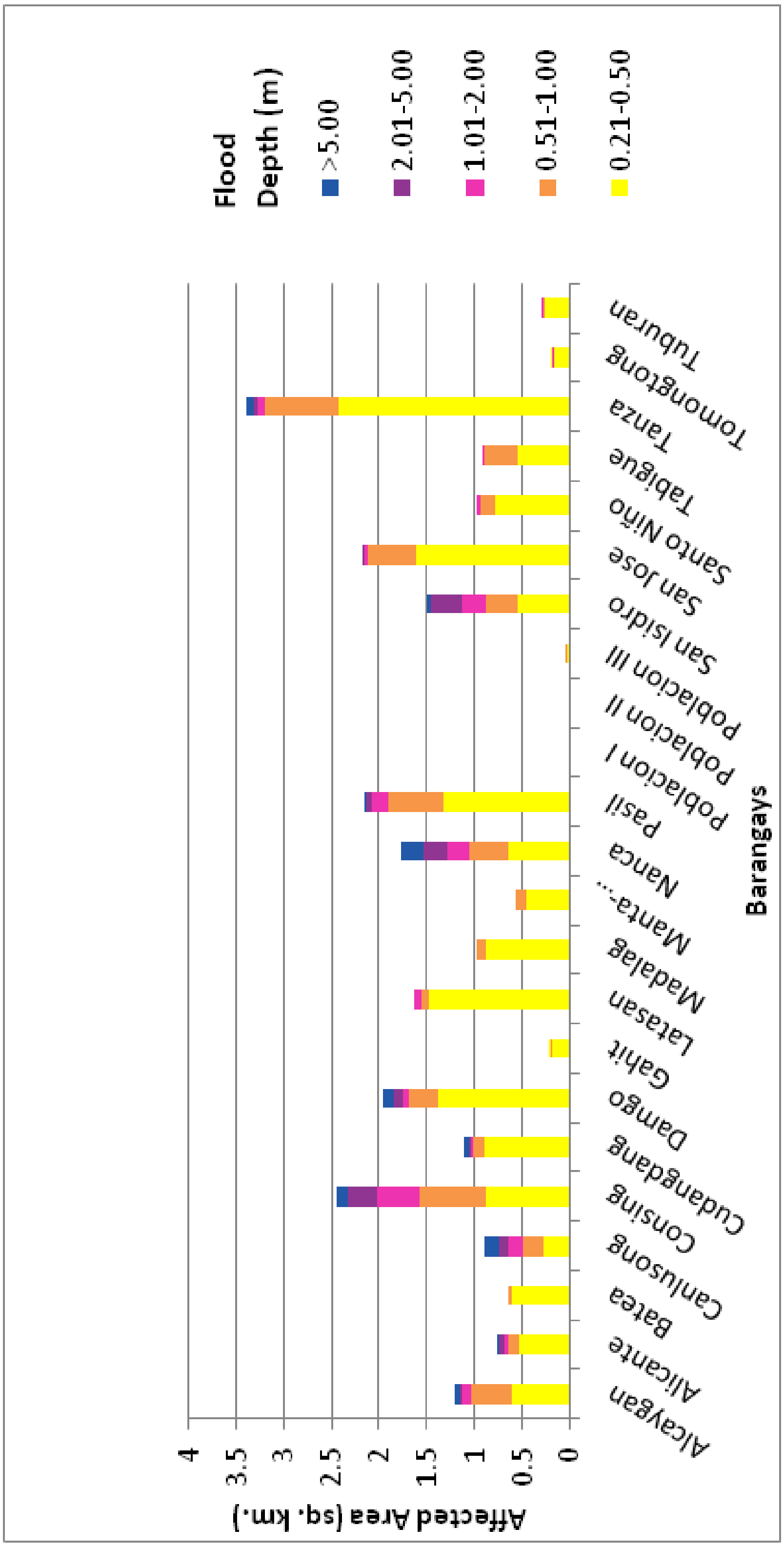


Figure 70. Affected areas in Enrique B. Magalona, Negros Occidental during a 5-year rainfall return period

For the Municipality of Manapla, with an area of 99.18 square kilometers, 80% will experience flood levels of less than 0.20 meters. 0.125% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.52%, 0.018%, 0.0029% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 32 are the affected areas, in square kilometers, by flood depth per barangay.

Table 32. Affected areas in Manapla, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Manapla (in sq. km.)
	Tortosa
0.03-0.20	0.8
0.21-0.50	0.12
0.51-1.00	0.052
1.01-2.00	0.018
2.01-5.00	0.0029
> 5.00	0

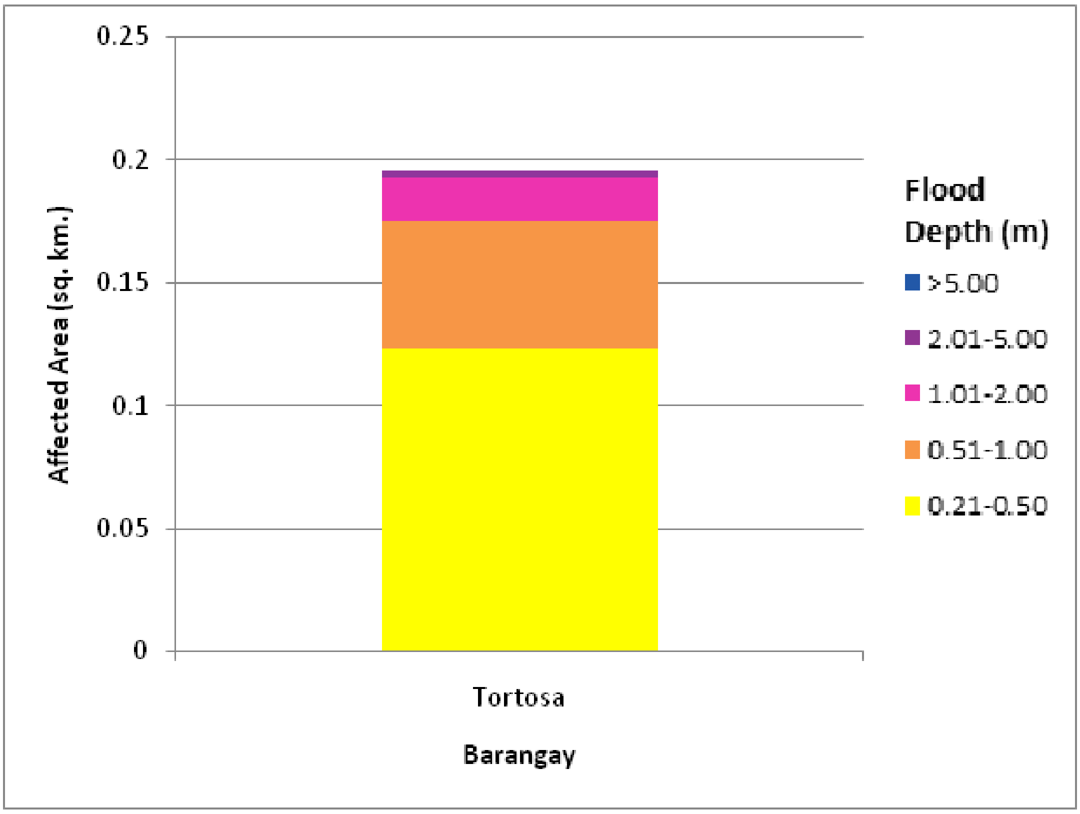


Figure 71. Affected areas in Manapla, Negros Occidental during a 5-year rainfall return period

For the Municipality of Salvador Benedicto, with an area of 182.22 square kilometers, 0.23% will experience flood levels of less than 0.20 meters; and 0.000019% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 33 are the affected areas, in square kilometers, by flood depth per barangay.

Table 33. Affected areas in Salvador Benedicto, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Salvador Benedicto (in sq. km.)	
	Igmay-an	Pandanan
0.03-0.20	0.32	0.1
0.21-0.50	0	0.000035
0.51-1.00	0	0
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

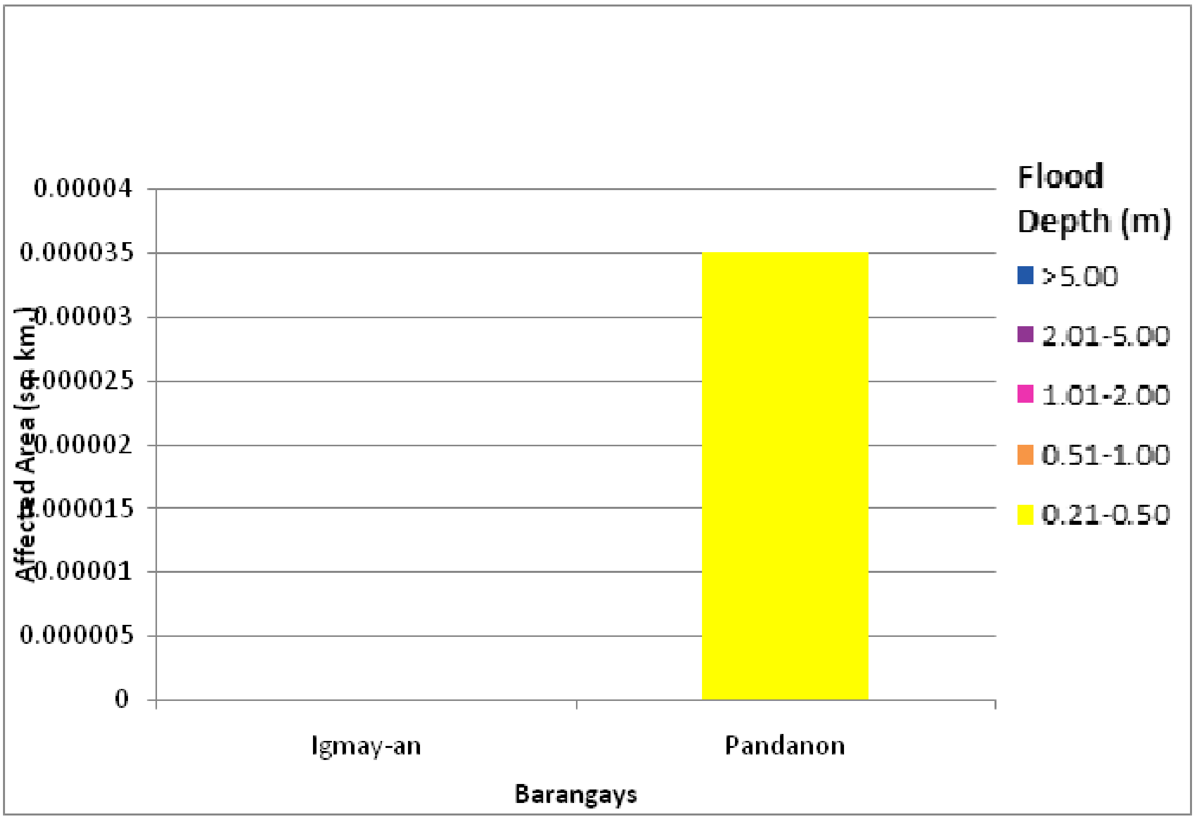


Figure 72. Affected areas in Salvador Benedicto, Negros Occidental during a 5-year rainfall return period

For the City of Silay, with an area of 199.01 square kilometers, 74.2% will experience flood levels of less than 0.20 meters. 6.4% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.3%, 3.55%, 2.47%, and 1.28% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 34 are the affected areas, in square kilometers, by flood depth per barangay.

Table 34. Affected areas in Silay City, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Bagtic	Balaring	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI Poblacion
0.03-0.20	9.42	3.47	0.17	0.22	0.27	3.41	1.26	7.65
0.21-0.50	0.82	1.54	0.022	0.01	0	0.33	0.098	1.9
0.51-1.00	0.53	1.06	0.0038	0.0032	0	0.15	0.025	0.98
1.01-2.00	0.53	0.42	0.001	0	0	0.11	0	0.58
2.01-5.00	0.47	0.01	0.0003	0	0	0.13	0	0.42
> 5.00	0.25	0.0046	0	0	0	0.063	0	0.33

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Eustaquio Lopez	Guimbala-On	Guinhalaran	Kaptian Ramon	Lantad	Mambulac	Patag	Rizal
0.03-0.20	20.12	30.61	0.49	29.55	2.61	0.5	30.31	5.77
0.21-0.50	2.73	1.48	0.058	1.29	0.75	0.05	0.65	1.02
0.51-1.00	1.47	1.16	0.028	1.07	1.07	0.075	0.39	0.48
1.01-2.00	1.25	0.91	0.0065	0.94	1.57	0.11	0.29	0.27
2.01-5.00	1.55	0.93	0	0.84	0.14	0	0.33	0.048
> 5.00	0.94	0.14	0	0.45	0.038	0	0.28	0.015

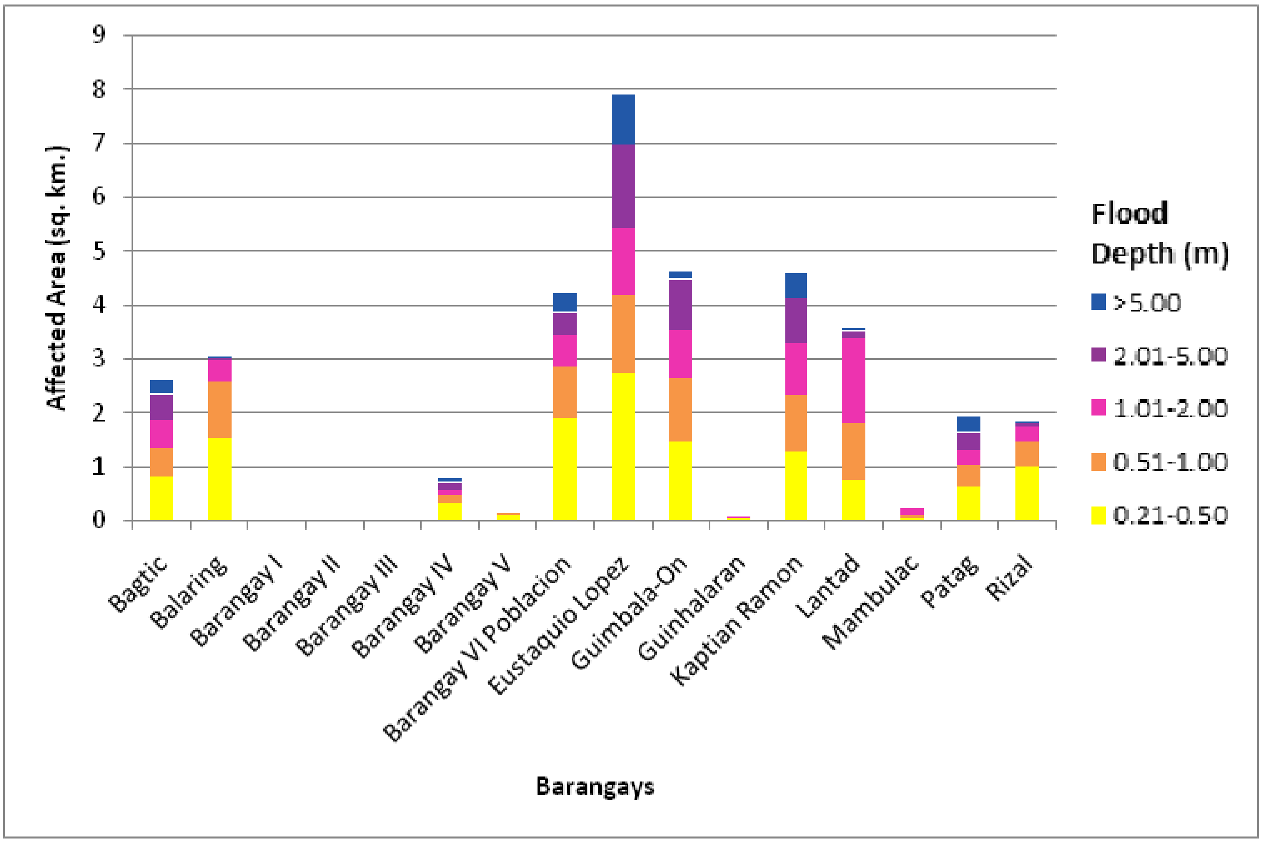


Figure 73. Affected areas in Silay City, Negros Occidental during a 5-year rainfall return period

For the City of Talisay, with an area of 199.01 square kilometers, 46% will experience flood levels of less than 0.20 meters. 1.3% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.85%, 0.72%, 0.76%, and 0.2% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 35 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected areas in Talisay City, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay City (in sq. km.)				
	Cabatangan	Dos Hermanas	Katilingban	Matab-Ang	San Fernando
0.03-0.20	15.76	9.46	16.02	0.0052	51.41
0.21-0.50	0.36	0.53	0.48	0	1.14
0.51-1.00	0.19	0.51	0.4	0	0.6
1.01-2.00	0.16	0.47	0.35	0	0.46
2.01-5.00	0.11	0.66	0.21	0	0.52
> 5.00	0.0087	0.25	0.0097	0	0.14

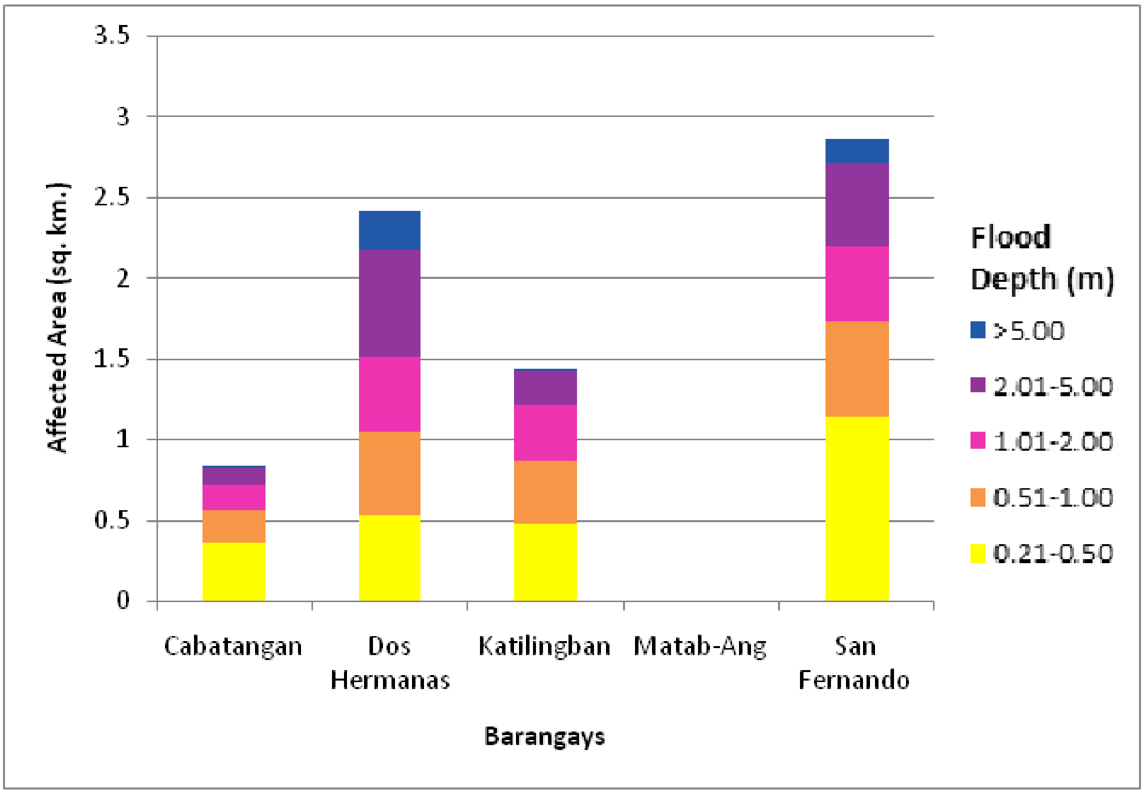


Figure 74. Affected areas in Talisay City, Negros Occidental during a 5-year rainfall return period

For the City of Victorias, with an area of 199.01 square kilometers, 63% will experience flood levels of less than 0.20 meters. 6% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.45%, 2.3%, 0.8%, and 0.2% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected areas in Victorias City, Negros Occidental during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)								
	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI	Brgy. VI-A	Brgy.VII	Brgy. VIII
0.03-0.20	0.12	0.042	0.076	0.12	0.3	0.31	1.26	0.083	8.22
0.21-0.50	0.036	0.0039	0.063	0.0049	0.003	0.15	0.098	0.0085	0.37
0.51-1.00	0.037	0.0096	0.012	0.0028	0.0011	0.22	0.025	0.0077	0.43
1.01-2.00	0.029	0.003	0.00046	0.0013	0.0012	0.11	0	0.0086	0.29
2.01-5.00	0.0038	0	0	0	0	0	0	0	0.063
> 5.00	0	0	0	0	0	0	0	0	0.0026

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)								
	Brgy. IX	Brgy. X	Brgy. XI	Brgy. XII	Brgy. XIII	Brgy. XIV	Brgy. XV	Brgy. XV-A	Brgy. XVI
0.03-0.20	0.21	9.36	10.7	7.2	6.61	5.73	0.21	0.62	0.18
0.21-0.50	0.052	0.44	0.28	0.45	2.05	0.28	0.068	0.074	0.1
0.51-1.00	0.057	0.37	0.21	0.47	1.46	0.19	0.054	0.0072	0.0091
1.01-2.00	0.033	0.32	0.1	0.46	0.38	0.18	0.0095	0	0.011
2.01-5.00	0	0.097	0.043	0.19	0.15	0.062	0.011	0	0.027
> 5.00	0	0.0021	0.062	0.018	0	0	0.00062	0	0.0087

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)							
	Brgy. XVI-A	Brgy. XVII	Brgy. XVIII	Brgy. XVIII-A	Brgy. XIX	Brgy. XIX-A	Brgy. XX	Brgy. XXI
0.03-0.20	0.00078	0.58	0.33	2.89	1.96	0.39	5.51	2.21
0.21-0.50	0.01	0.059	0.027	0.13	0.33	0.32	0.64	0.18
0.51-1.00	0.0025	0.037	0.022	0.12	0.062	0.15	0.49	0.14
1.01-2.00	0.0035	0.014	0.03	0.055	0.0056	0.044	0.27	0.07
2.01-5.00	0.0087	0.013	0.062	0.025	0.02	0.022	0.045	0.0017
> 5.00	0	0.015	0.046	0.015	0.024	0.0045	0	0

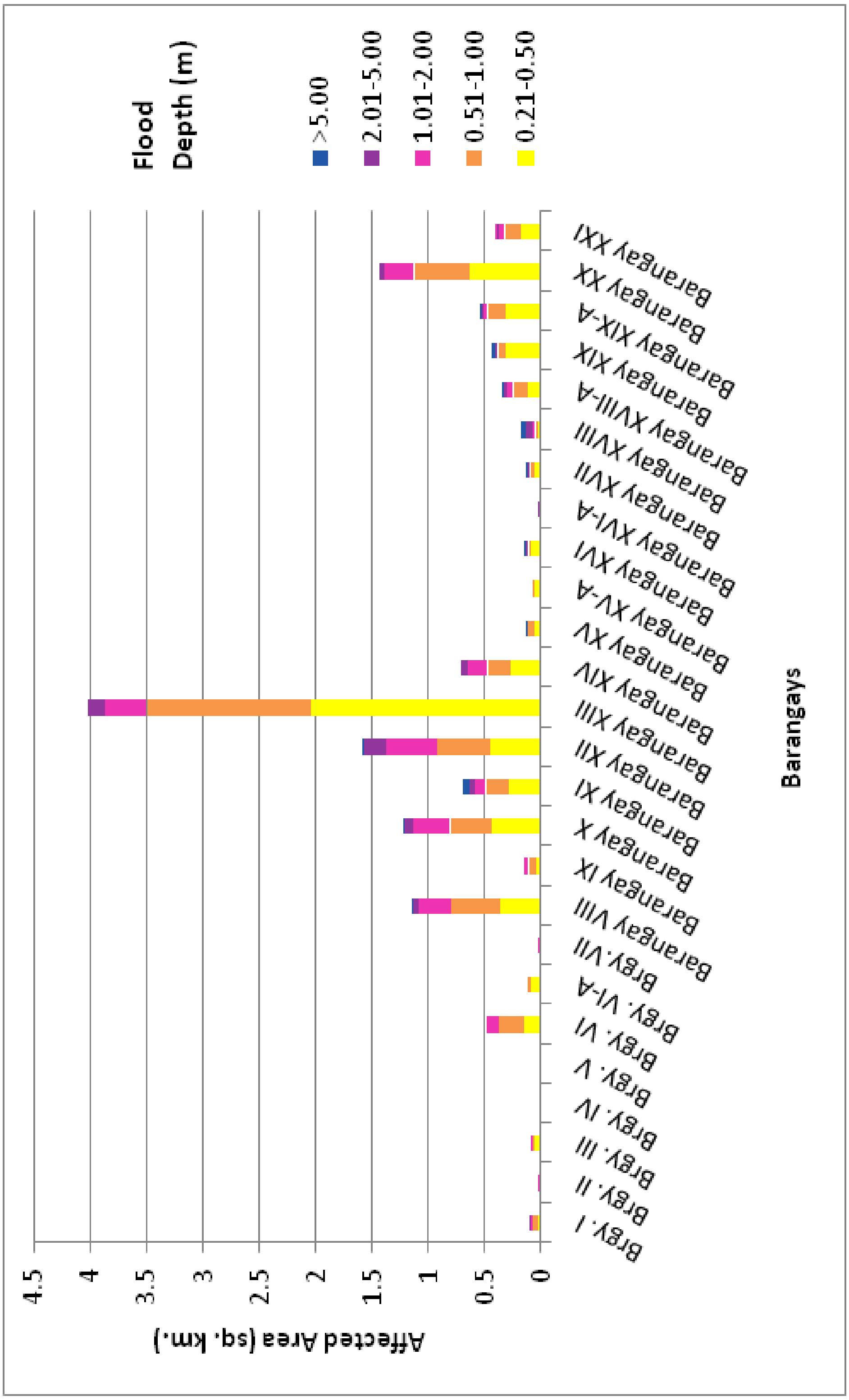


Figure 75. Affected areas in Victorias City, Negros Occidental a during 5-year rainfall return period

For the 25-year return period, 7.38% of the City of Cadiz, with an area of 516.184 square kilometers, will experience flood levels of less than 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.08%, 0.06%, 0.059%, and 0.057% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Cadiz City, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)
	Celestino Villacin
0.03-0.20	38.08
0.21-0.50	0.99
0.51-1.00	0.46
1.01-2.00	0.32
2.01-5.00	0.3
> 5.00	0.3

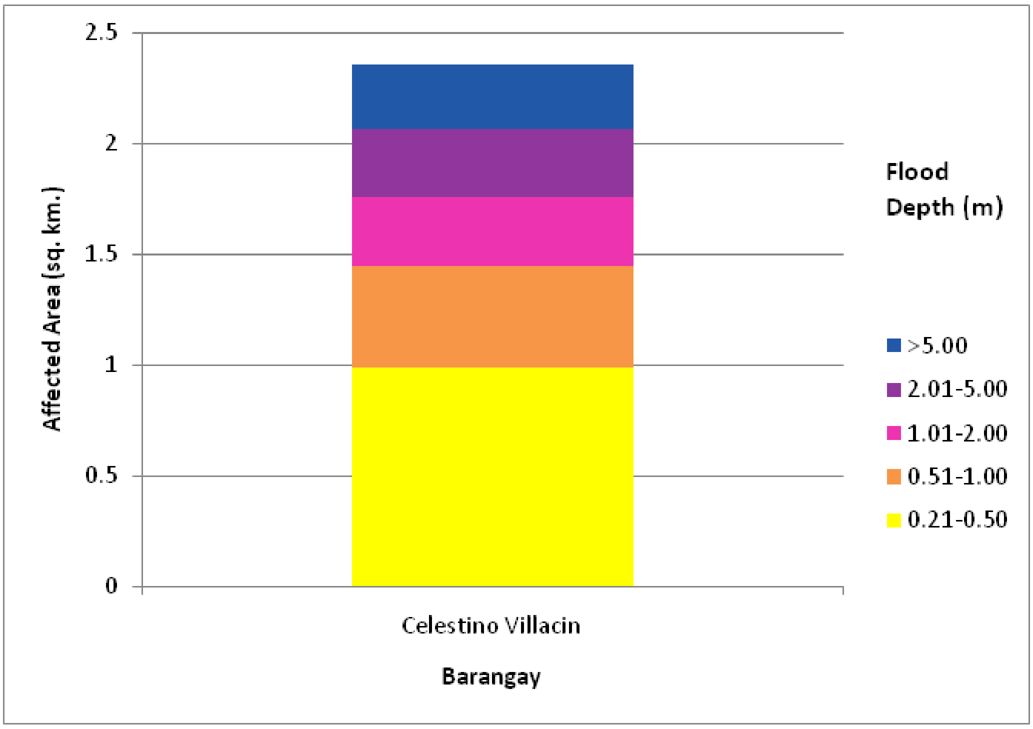


Figure 76. Affected areas in Cadiz City, Negros Occidental during a 25-year rainfall return period

For the Municipality of Calatrava, with an area of 344.54 square kilometers, 0.013% will experience flood levels of less than 0.20 meters. 0.000014% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Calatrava, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calatrava (in sq. km.)
	Lalong
0.03-0.20	0.044
0.21-0.50	0.000049
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

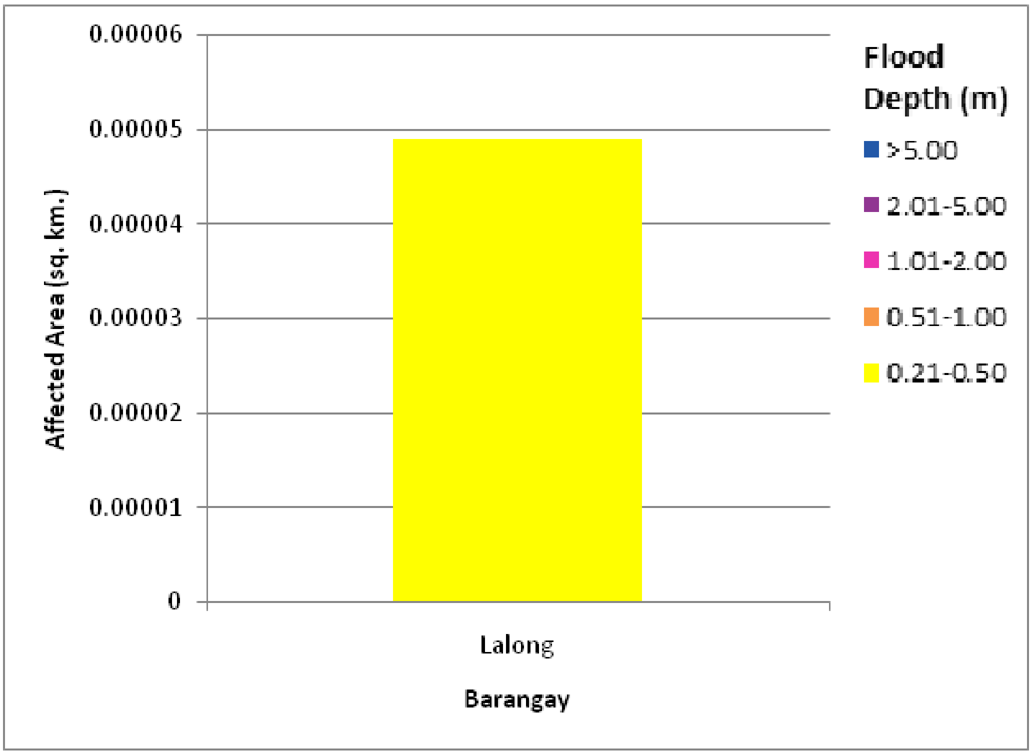


Figure 77. Affected areas in Calatrava, Negros Occidental during a 25-year rainfall return period

For the Municipality of Enrique B. Magalona, with an area of 140.2 square kilometers,, 60.41% will experience flood levels of less than 0.20 meters. 14.84% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 10.9%, 5.14%, 2.07%, 1.06% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Enrique B. Magalona, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)											
	Alcaygan	Alicante	Batea	Canlusong	Consing	Cudangdang	Damgo	Gahit	Latasan	Madalag	Manta-Angan	Nanca
0.03-0.20	6.39	2.45	1.1	9.26	15.42	3.72	5.51	0.54	1.48	1.46	2.24	3.77
0.21-0.50	0.64	0.88	0.75	0.31	0.95	1.53	1.91	0.38	1.51	1.28	0.56	0.66
0.51-1.00	0.52	0.51	0.37	0.23	0.82	0.43	1.37	0.04	2.19	0.52	0.24	0.54
1.01-2.00	0.22	0.19	0	0.22	0.64	0.32	0.48	0	0.85	0.0092	0.022	0.78
2.01-5.00	0.036	0.064	0	0.13	0.43	0.066	0.16	0	0	0	0	0.91
> 5.00	0.068	0.046	0	0.18	0.19	0.076	0.22	0	0	0	0	0.48

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)										
	Pasil	Poblacion I	Poblacion II	Poblacion III	San Isidro	San Jose	Santo Niño	Tabigue	Tanza	Tomongtong	Tuburan
0.03-0.20	1.12	0.45	0.15	0.69	11.59	3.17	4.11	1.25	6.75	1.38	0.76
0.21-0.50	0.74	0.015	0.017	0.055	0.61	2.02	1.23	0.46	3.14	0.68	0.48
0.51-1.00	1.81	0.0002	0	0.024	0.39	1.56	0.45	0.7	2.51	0.015	0.075
1.01-2.00	1.08	0	0	0.0088	0.33	0.46	0.069	0.15	1.38	0.0007	0.0089
2.01-5.00	0.11	0	0	0	0.45	0.0041	0	0	0.53	0	0
> 5.00	0.01	0	0	0	0.1	0	0	0	0.11	0	0

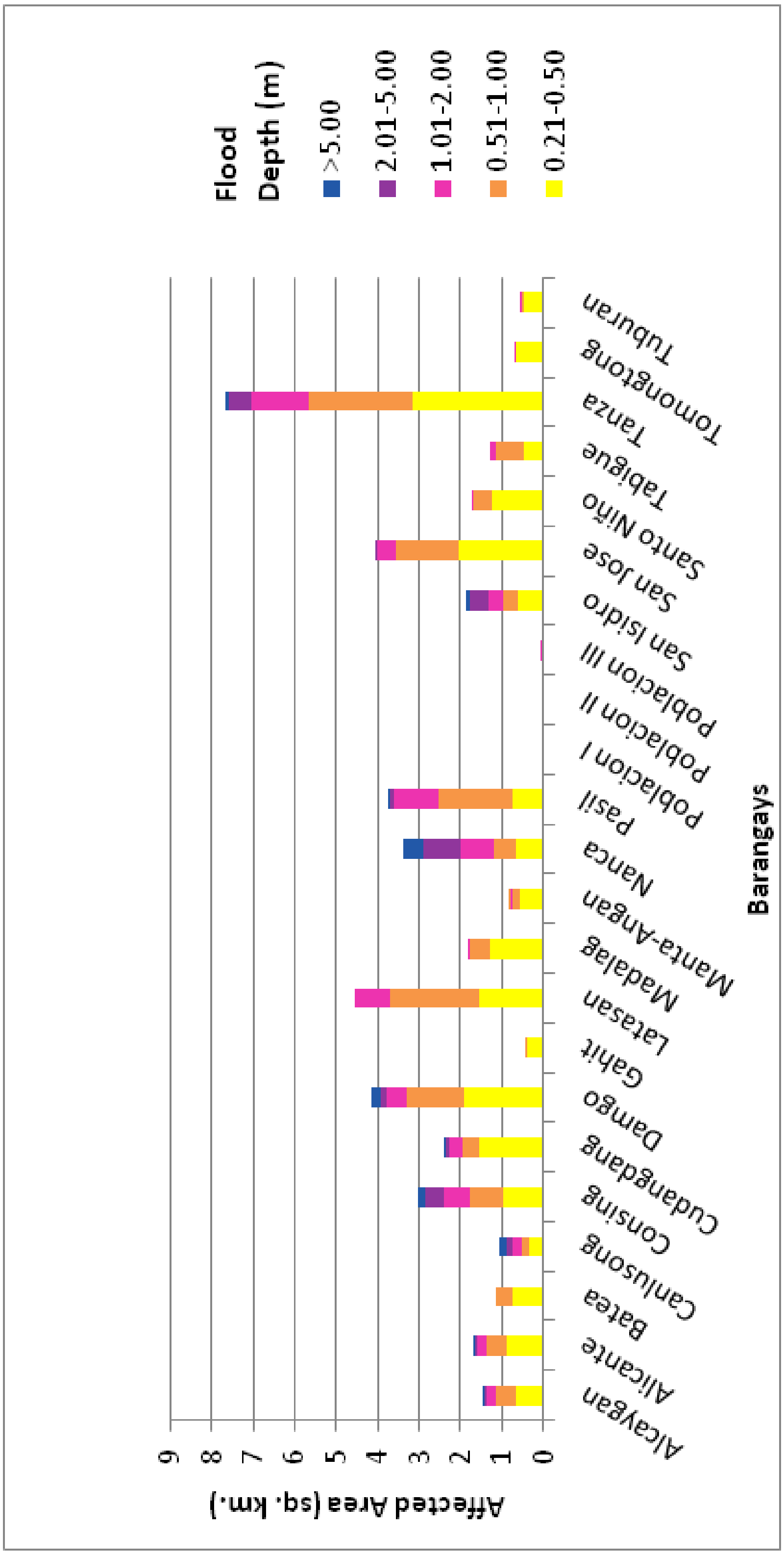


Figure 78. Affected areas in Enrique B. Magalona, Negros Occidental during a 25-year rainfall return period

For the Municipality of Manapla, with an area of 99.18 square kilometers, 73% will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.12%, 0.024%, 0.005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 40 are the affected areas, in s square kilometers, by flood depth per barangay.

Table 40. Affected areas in Manapla, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Manapla (in sq. km.)
	Tortosa
0.03-0.20	0.73
0.21-0.50	0.12
0.51-1.00	0.12
1.01-2.00	0.024
2.01-5.00	0.0053
> 5.00	0

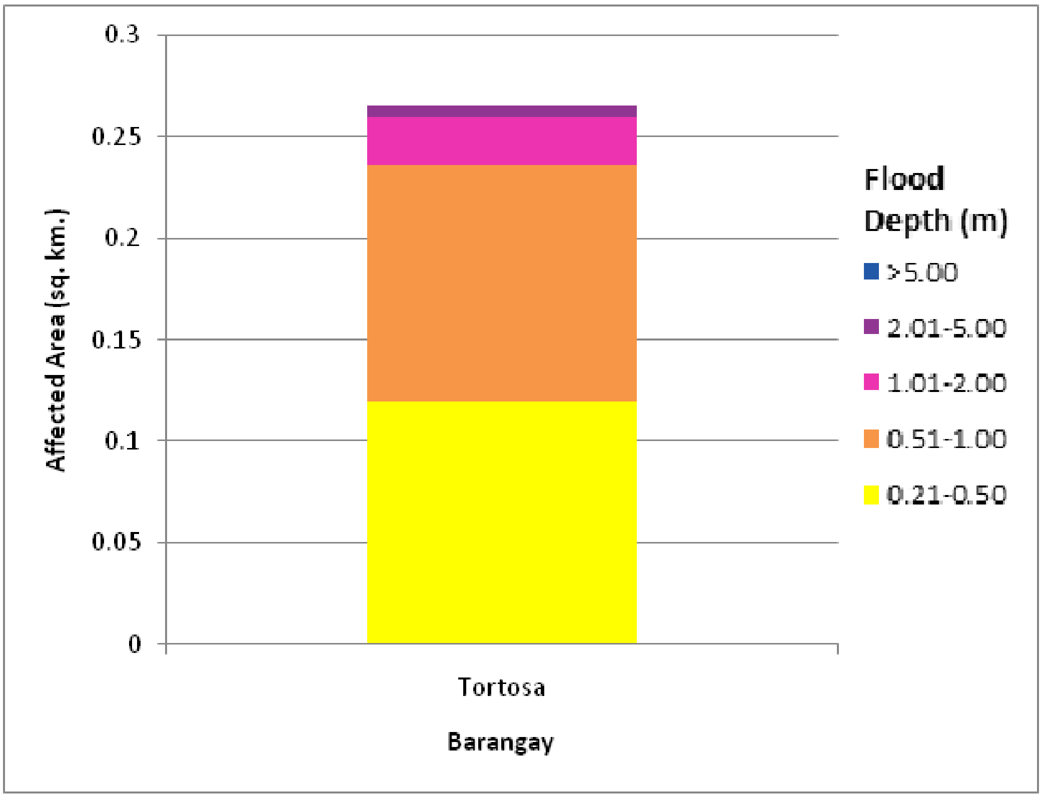


Figure 79. Affected areas in Manapla, Negros Occidental during a 25-year rainfall return period

For the Municipality of Salvador Benedicto, with an area of 182.22 square kilometers, 0.23% will experience flood levels of less than 0.20 meters. 0.000019% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Salvador Benedicto, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Salvador Benedicto (in sq. km.)	
	Igmay-an	Pandanan
0.03-0.20	0.32	0.1
0.21-0.50	0	0.000035
0.51-1.00	0	0
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

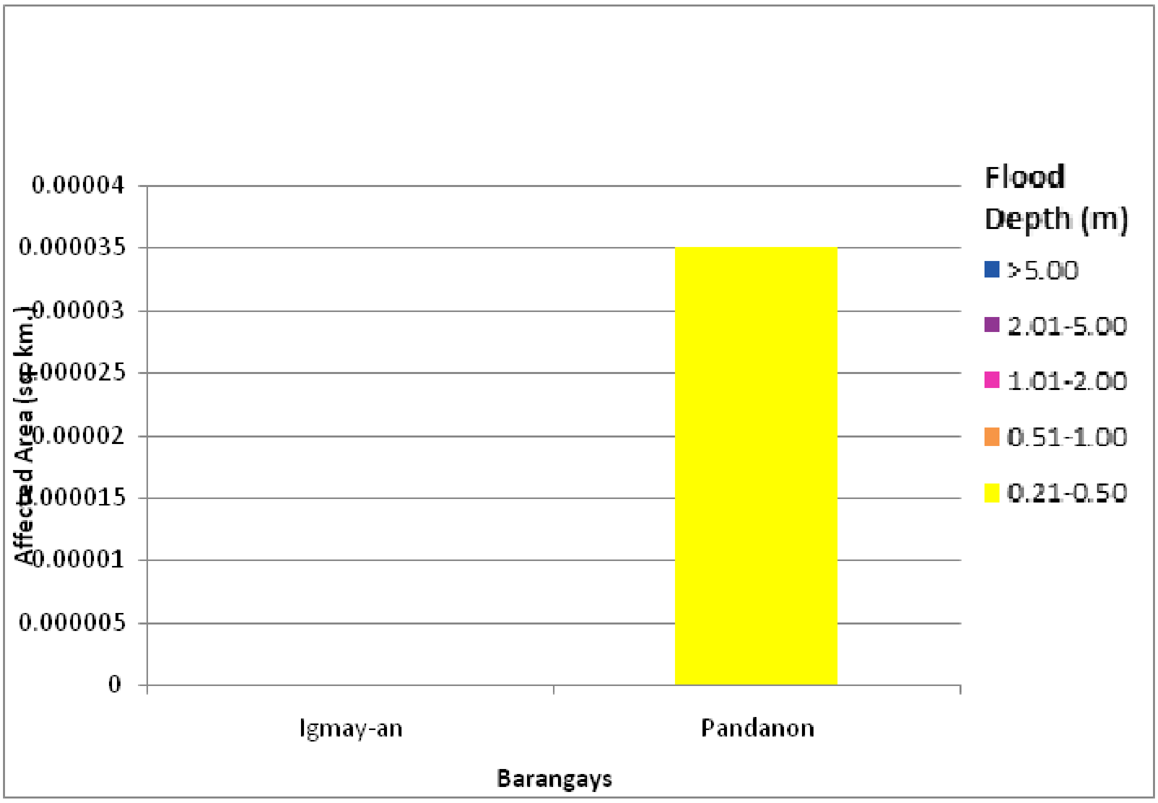


Figure 80. Affected areas in Salvador Benedicto, Negros Occidental during a 25-year rainfall return period

For the City of Silay, with an area of 199.01 square kilometers, 67.93% will experience flood levels of less than 0.20 meters. 7.4% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.3%, 5.3%, 3.48%, and 1.82% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in Silay City, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Bagtic	Balaring	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI Poblacion
0.03-0.20	8.56	2.61	0.15	0.17	0.27	3.11	1.18	5.72
0.21-0.50	0.86	1.02	0.042	0.058	0.00019	0.4	0.13	2.31
0.51-1.00	0.87	2.36	0.0055	0.0035	0	0.19	0.049	1.82
1.01-2.00	0.72	0.49	0.0012	0.00042	0	0.21	0.024	1.11
2.01-5.00	0.62	0.02	0.00062	0	0	0.19	0.000056	0.52
> 5.00	0.38	0.0047	0	0	0	0.081	0	0.37

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Eustaquio Lopez	Guimbala-On	Guinhalaran	Kaptian Ramon	Lantad	Mambulac	Patag	Rizal
0.03-0.20	16.15	29.36	0.4	28.62	1.91	0.44	29.92	4.9
0.21-0.50	3.61	1.5	0.072	1.38	0.9	0.088	0.74	1.43
0.51-1.00	2.3	1.38	0.049	1.23	1.07	0.057	0.45	0.7
1.01-2.00	2.33	1.34	0.046	1.13	2.09	0.14	0.34	0.43
2.01-5.00	2.44	1.25	0.0083	1.13	0.15	0	0.39	0.12
> 5.00	1.21	0.41	0	0.66	0.053	0	0.4	0.019

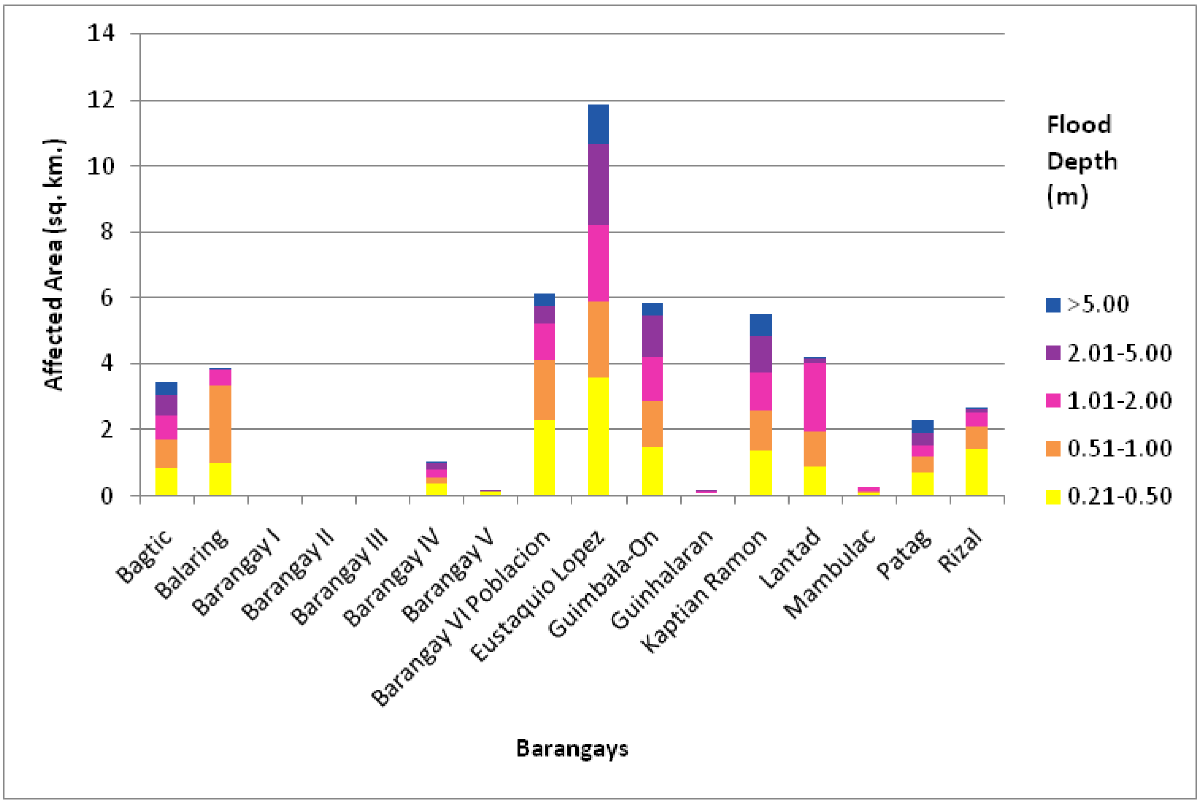


Figure 81. Affected areas in Silay City, Negros Occidental during a 25-year rainfall return period

For the City of Talisay, with an area of 199.01 square kilometers, 45.6% will experience flood levels of less than 0.20 meters. 1.46% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.02%, 0.9%, 1.03%, and 0.35% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Talisay City, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay City (in sq. km.)				
	Cabatangan	Dos Hermanas	Katilingban	Matab-Ang	San Fernando
0.03-0.20	15.59	8.62	15.75	0.0052	50.77
0.21-0.50	0.43	0.58	0.52	0	1.37
0.51-1.00	0.21	0.71	0.42	0	0.7
1.01-2.00	0.18	0.68	0.4	0	0.53
2.01-5.00	0.17	0.91	0.33	0	0.64
> 5.00	0.019	0.39	0.028	0	0.26

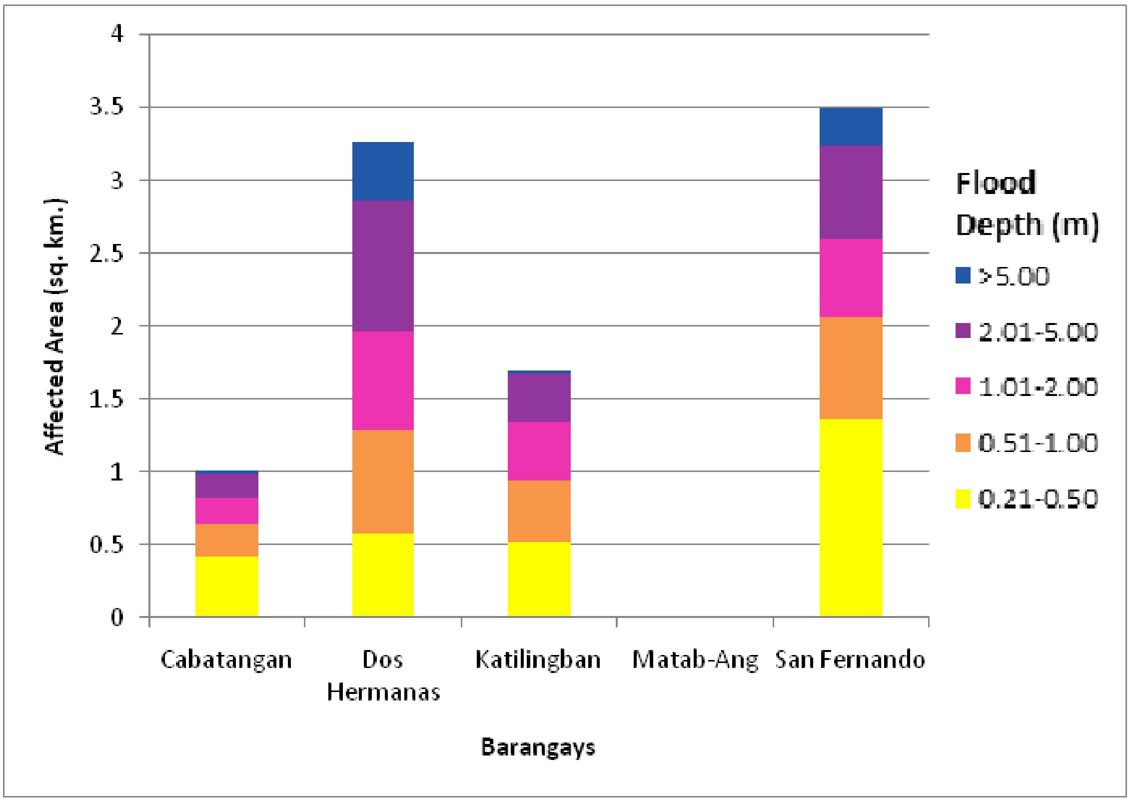


Figure 82. Affected areas in Talisay City, Negros Occidental during a 25-year rainfall return period

For the City of Victorias, with an area of 199.01 square kilometers, 56.87% will experience flood levels of less than 0.20 meters. 6% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.88%, 4.3%, 1.3%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Victorias City, Negros Occidental during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)								
	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI	Brgy. VI-A	Brgy.VII	Brgy. VIII
0.03-0.20	0.092	0.037	0.059	0.11	0.3	0.22	0.2	0.075	8.03
0.21-0.50	0.036	0.0034	0.036	0.0057	0.0057	0.14	0.11	0.012	0.38
0.51-1.00	0.051	0.0065	0.056	0.0038	0.0013	0.26	0.027	0.0065	0.43
1.01-2.00	0.044	0.012	0.00084	0.004	0.0017	0.17	0.0012	0.015	0.44
2.01-5.00	0.0045	0	0	0	0.000075	0	0	0	0.1
> 5.00	0	0	0	0	0	0	0	0	0.0078

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)								
	Brgy. IX	Brgy. X	Brgy. XI	Brgy. XII	Brgy. XIII	Brgy. XIV	Brgy. XV	Brgy. XV-A	Brgy. XVI
0.03-0.20	0.13	9.14	10.55	6.75	4.61	5.56	0.16	0.58	0.13
0.21-0.50	0.11	0.48	0.32	0.48	2.02	0.32	0.051	0.11	0.039
0.51-1.00	0.062	0.39	0.23	0.51	2.71	0.23	0.1	0.016	0.092
1.01-2.00	0.047	0.39	0.17	0.64	1.11	0.2	0.026	0	0.034
2.01-5.00	0	0.18	0.065	0.35	0.18	0.13	0.012	0	0.032
> 5.00	0	0.0036	0.079	0.065	0.0072	0.0034	0.0019	0	0.0099

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)							
	Brgy. XVI-A	Brgy. XVII	Brgy. XVIII	Brgy. XVIII-A	Brgy. XIX	Brgy. XIX-A	Brgy. XX	Brgy. XXI
0.03-0.20	0	0.51	0.3	2.81	1.28	0.13	5	2.11
0.21-0.50	0.0049	0.061	0.029	0.14	0.35	0.23	0.7	0.18
0.51-1.00	0.0073	0.086	0.024	0.13	0.51	0.34	0.65	0.19
1.01-2.00	0.0044	0.028	0.033	0.094	0.19	0.19	0.49	0.11
2.01-5.00	0.0091	0.015	0.063	0.031	0.015	0.038	0.1	0.017
> 5.00	0	0.021	0.071	0.023	0.041	0.0065	0.000079	0

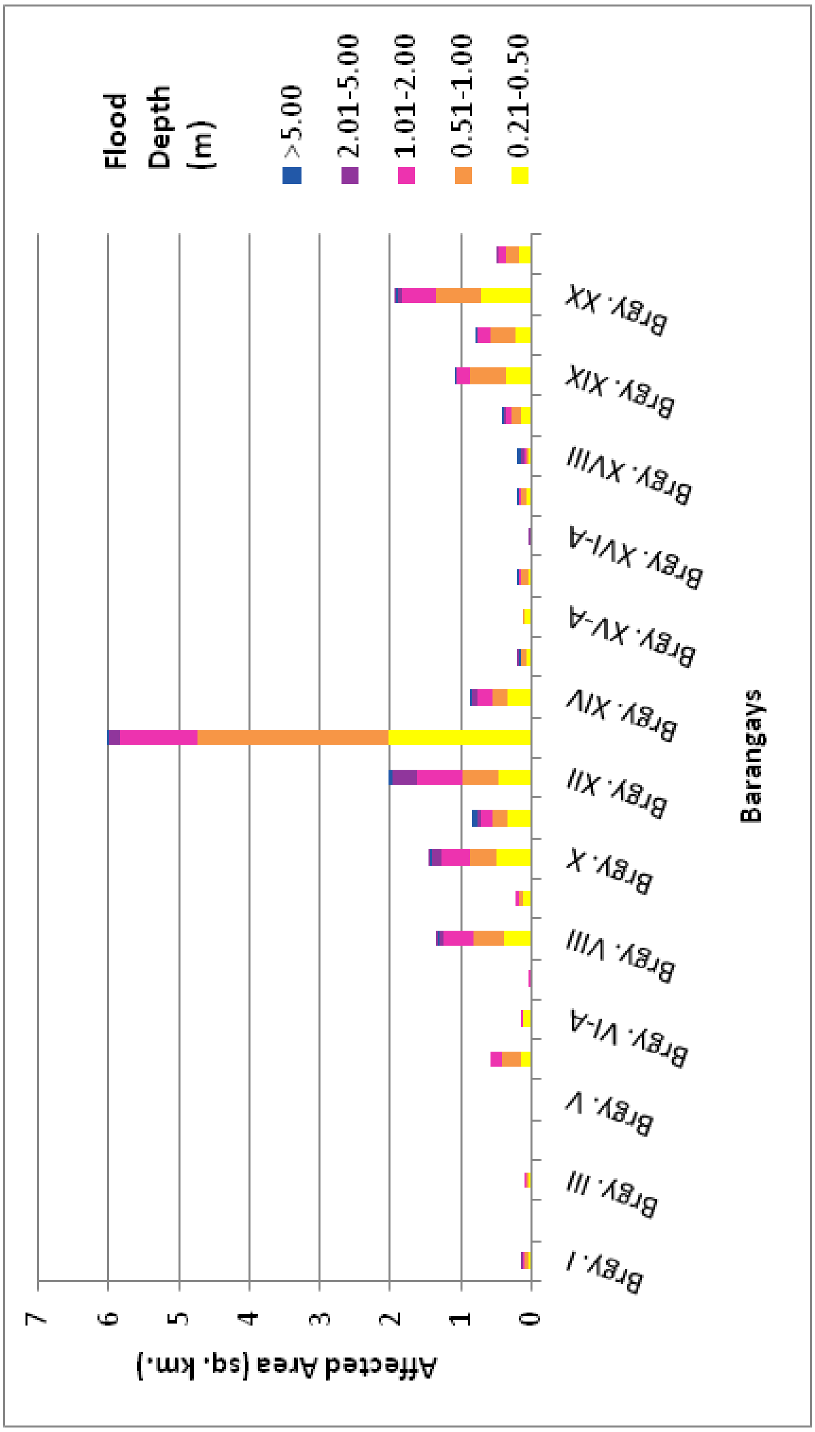


Figure 83. Affected areas in Victorias City, Negros Occidental during a 25-year rainfall return period

For the 100-year return period, 7.3% of the City of Cadiz, with an area of 516.184 square kilometers, will experience flood levels of less than 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.1%, 0.065%, 0.066%, and 0.071% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Cadiz City, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cadiz City (in sq. km.)
	Celestino Villacin
0.03-0.20	37.78
0.21-0.50	1.12
0.51-1.00	0.5
1.01-2.00	0.34
2.01-5.00	0.34
> 5.00	0.37

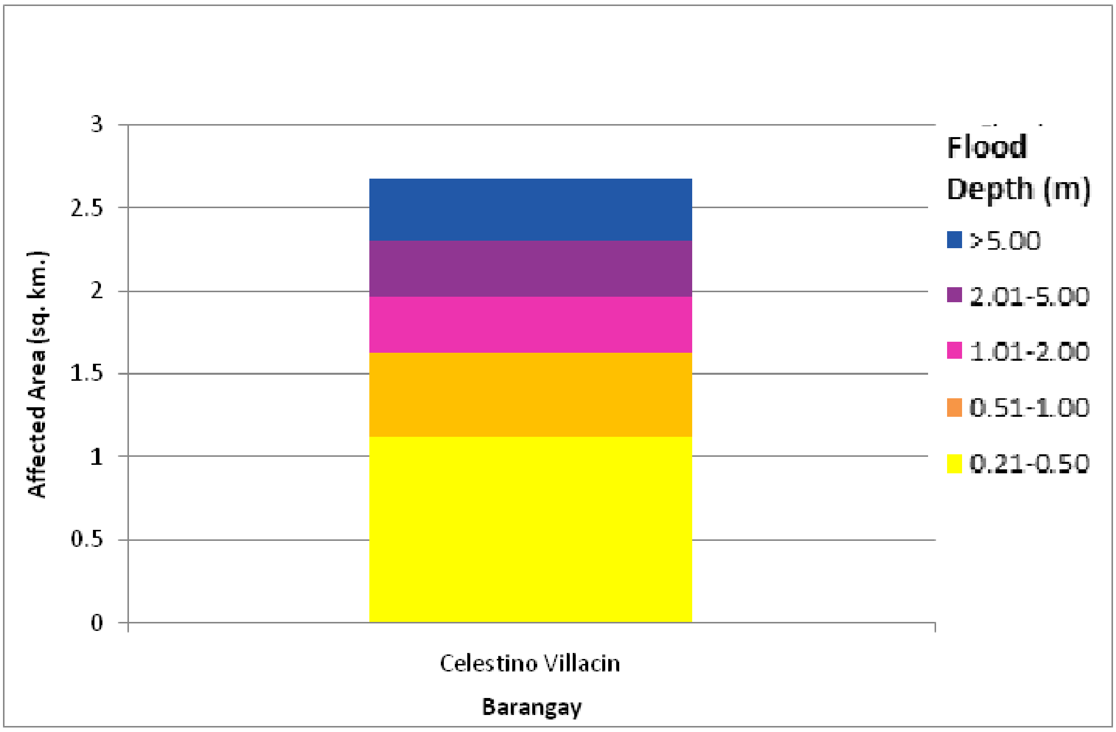


Figure 84. Affected areas in Cadiz City, Negros Occidental during a 100-year rainfall return period

For the Municipality of Calatrava, with an area of 344.54 square kilometers, 0.013% will experience flood levels of less than 0.20 meters. 0.000014% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Calatrava, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calatrava (in sq. km.)
	Lalong
0.03-0.20	0.044
0.21-0.50	0.000049
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

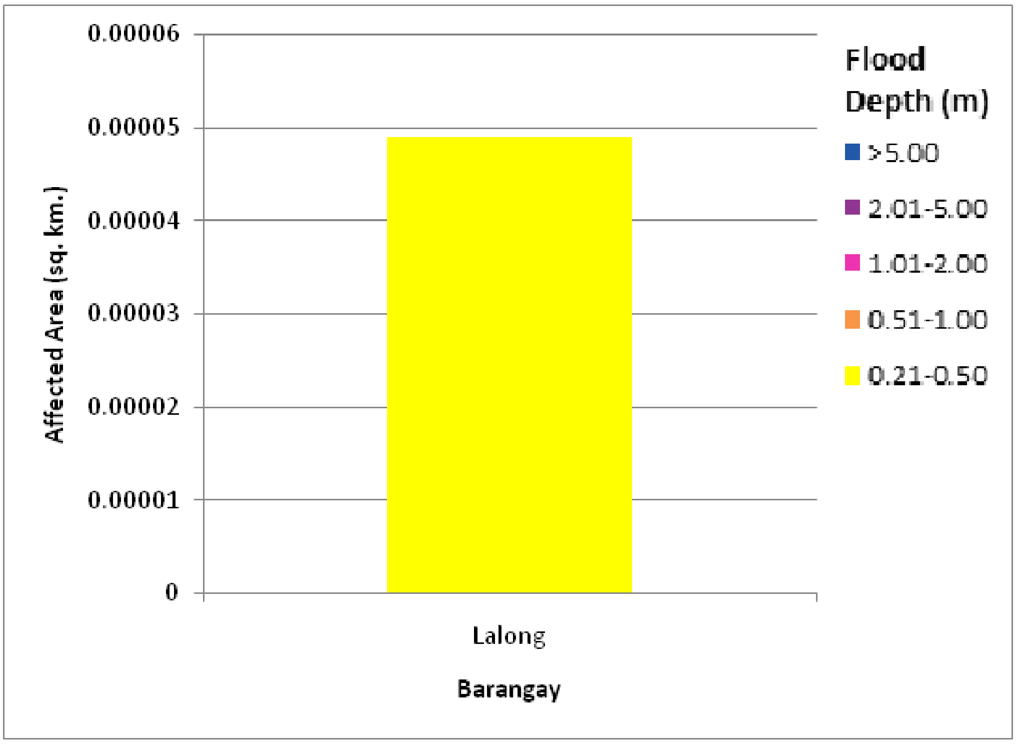


Figure 85. Affected areas in Calatrava, Negros Occidental during a 100-year rainfall return period

For the Municipality of Enrique B. Magalona, with an area of 140.2 square kilometers, 54.35% will experience flood levels of less than 0.20 meters. 14.15% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 13.23%, 8.19%, 3.15%, 1.37% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Enrique B. Magalona, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)											
	Alcaygan	Alicante	Batea	Canlusong	Consing	Cudangdang	Damgo	Gahit	Latasan	Madalag	Manta-Angan	Nanca
0.03-0.20	6.23	1.88	0.87	9.14	15.11	2.85	4.55	0.48	1.12	1.06	2.04	2.72
0.21-0.50	0.65	0.69	0.5	0.33	1.01	1.74	1.89	0.4	0.7	1.15	0.64	0.62
0.51-1.00	0.59	0.89	0.85	0.25	0.87	0.8	1.54	0.084	2.66	1.01	0.28	0.87
1.01-2.00	0.28	0.53	0	0.25	0.75	0.5	1.19	0	1.54	0.055	0.1	0.86
2.01-5.00	0.062	0.11	0	0.15	0.49	0.17	0.24	0	0.0041	0	0	1.37
> 5.00	0.07	0.053	0	0.22	0.23	0.081	0.24	0	0	0	0	0.7

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Enrique B. Magalona (in sq. km.)										
	Pasil	Poblacion I	Poblacion II	Poblacion III	San Isidro	San Jose	Santo Niño	Tabigue	Tanza	Tomongtong	Tuburan
0.03-0.20	0.59	0.44	0.12	0.63	11.32	2.59	3.79	1.07	5.76	1.24	0.66
0.21-0.50	0.62	0.021	0.046	0.12	0.67	1.84	1.33	0.48	3.07	0.81	0.53
0.51-1.00	1.33	0.0005	0	0.021	0.44	2.01	0.66	0.7	2.55	0.025	0.13
1.01-2.00	2.12	0	0	0.018	0.34	0.73	0.076	0.3	1.84	0.0013	0.0096
2.01-5.00	0.19	0	0	0	0.53	0.036	0.0032	0	1.07	0	0
> 5.00	0.011	0	0	0	0.18	0	0	0	0.13	0	0

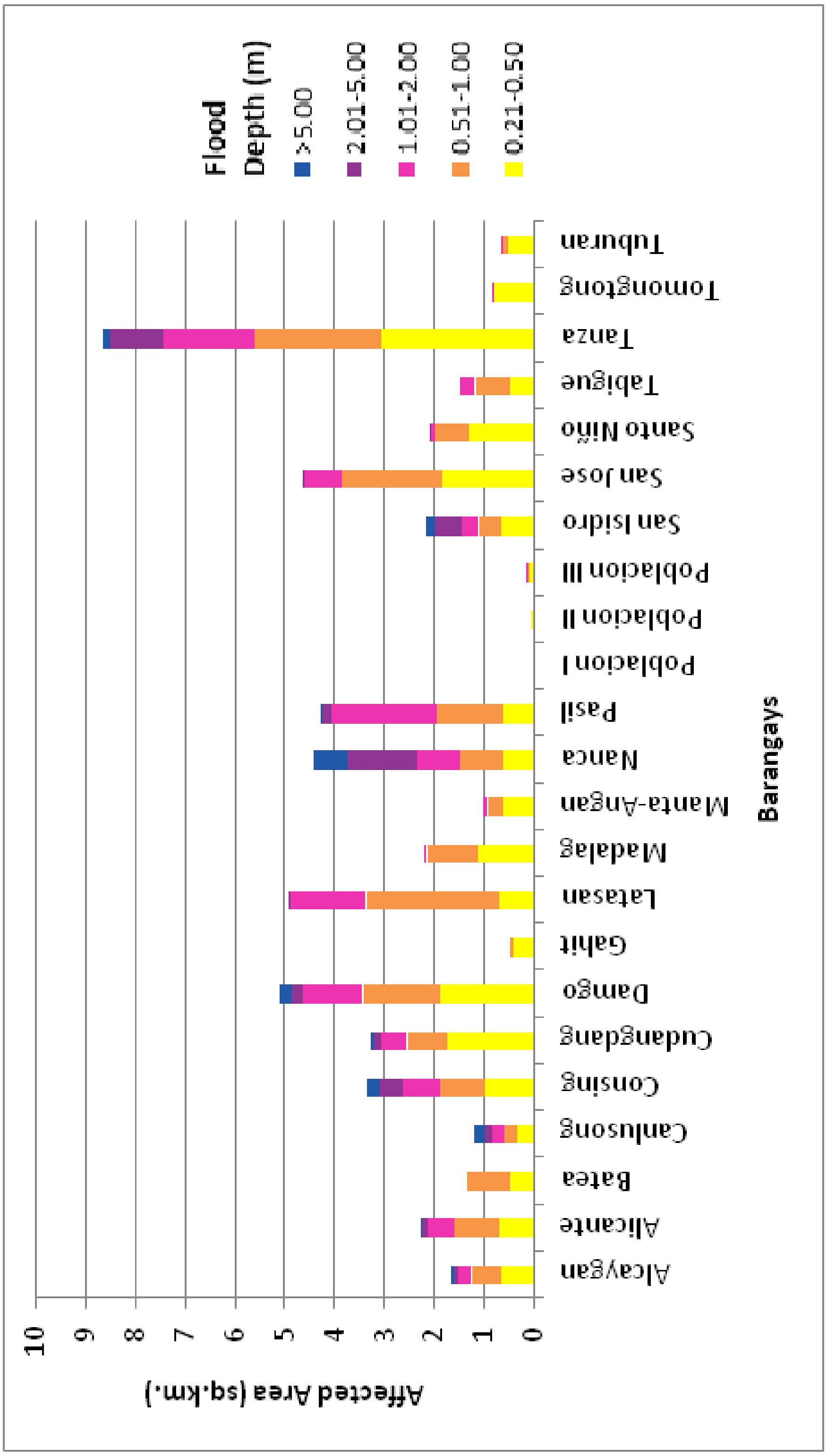


Figure 86. Affected areas in Enrique B. Magalona, Negros Occidental during a 100-year rainfall return period

For the Municipality of Manapla, with an area of 99.18 square kilometers, 70% will experience flood levels of less than 0.20 meters. 0.125% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.14%, 0.03%, 0.007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Manapla, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Manapla (in sq. km.)
	Tortosa
0.03-0.20	0.69
0.21-0.50	0.12
0.51-1.00	0.14
1.01-2.00	0.03
2.01-5.00	0.0073
> 5.00	0

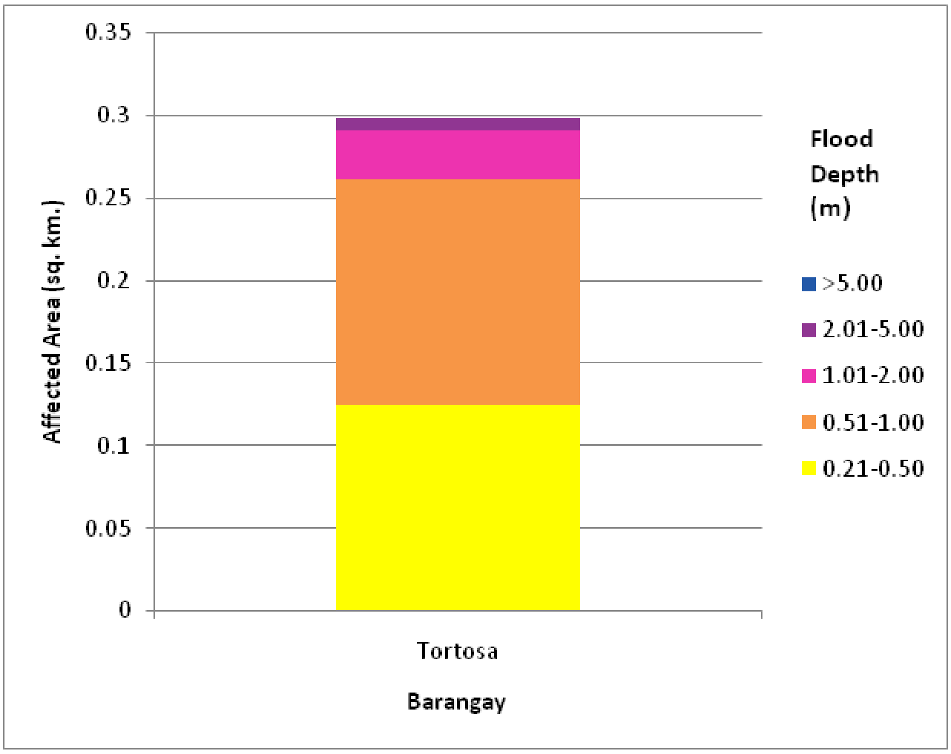


Figure 87. Affected areas in Manapla, Negros Occidental during a 100-year rainfall return period

For the Municipality of Salvador Benedicto, with an area of 182.22 square kilometers, 0.23% will experience flood levels of less than 0.20 meters; and 0.00009% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Salvador Benedicto, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Salvador Benedicto (in sq. km.)	
	Igmay-an	Pandanan
0.03-0.20	0.32	0.1
0.21-0.50	0.00013	0.000035
0.51-1.00	0	0
1.01-2.00	0	0
2.01-5.00	0	0
> 5.00	0	0

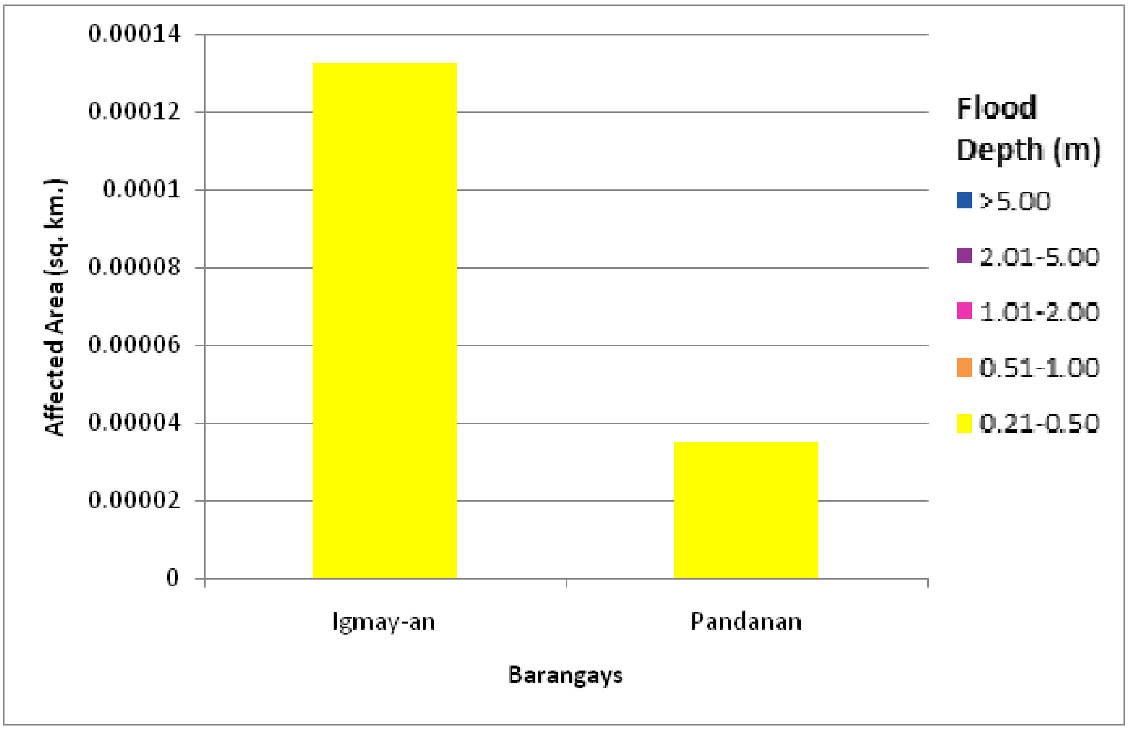


Figure 88. Affected areas in Salvador Benedicto, Negros Occidental during a 100-year rainfall return period

For the City of Silay, with an area of 199.01 square kilometers, 64.77% will experience flood levels of less than 0.20 meters. 7.9% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.9%, 6.43%, 4.14%, and 2.12% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Silay City, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Bagtic	Balaring	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI Poblacion
0.03-0.20	8.19	2.23	0.14	0.097	0.27	2.94	1.12	4.91
0.21-0.50	0.91	0.97	0.046	0.13	0.0017	0.49	0.15	2.16
0.51-1.00	0.88	2.22	0.0068	0.0037	0	0.18	0.053	2.23
1.01-2.00	0.86	1.07	0.0011	0.00072	0	0.24	0.047	1.55
2.01-5.00	0.75	0.024	0.0004	0	0	0.24	0.0062	0.61
> 5.00	0.44	0.0047	0	0	0	0.093	0	0.4

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Silay City (in sq. km.)							
	Eustaquio Lopez	Guimbala-On	Guinhalaran	Kaptian Ramon	Lantad	Mambulac	Patag	Rizal
0.03-0.20	14.05	28.85	0.36	28.11	1.58	0.42	29.66	4.37
0.21-0.50	4.12	1.57	0.072	1.41	0.97	0.11	0.81	1.64
0.51-1.00	2.79	1.46	0.057	1.32	0.98	0.057	0.48	0.9
1.01-2.00	2.7	1.44	0.061	1.24	2.42	0.15	0.38	0.49
2.01-5.00	3.02	1.38	0.033	1.32	0.16	0	0.41	0.18
> 5.00	1.37	0.53	0	0.75	0.064	0	0.49	0.019

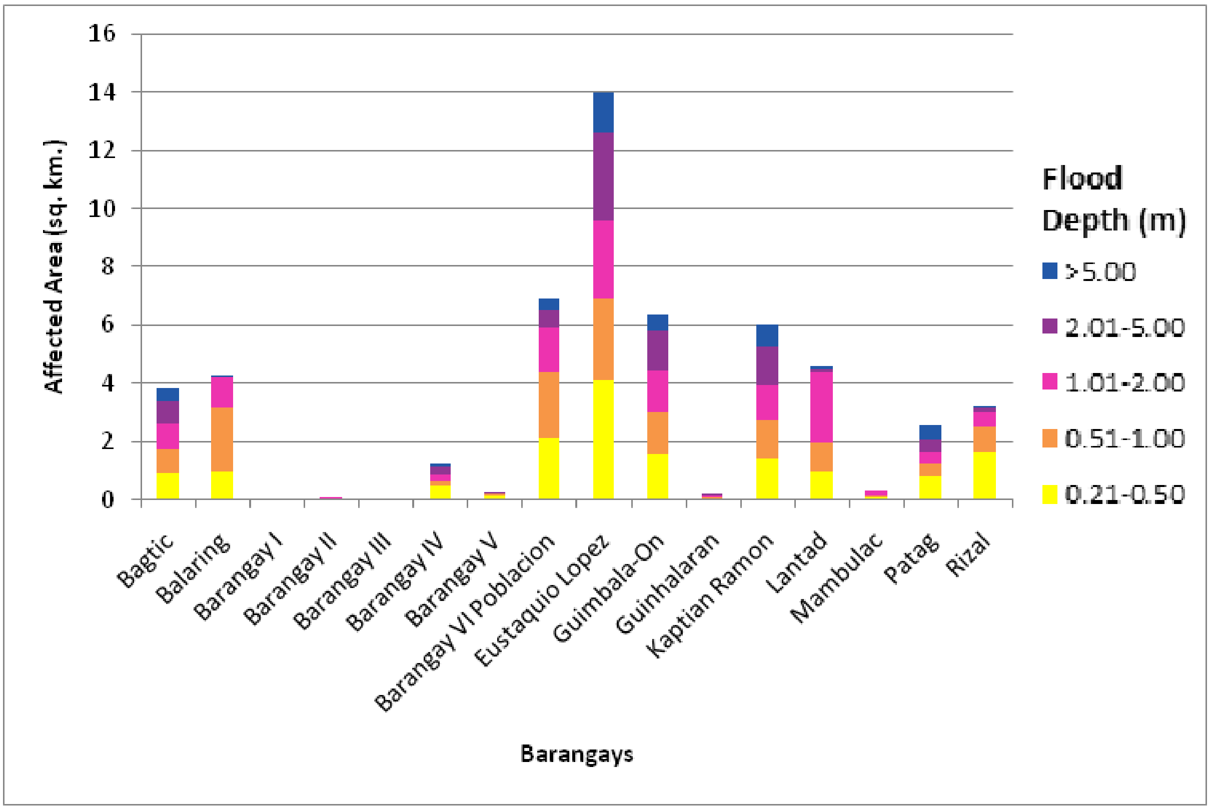


Figure 89. Affected areas in Silay City, Negros Occidental during a 100-year rainfall return period

For the City of Talisay, with an area of 199.01 square kilometers, 45.1% will experience flood levels of less than 0.20 meters. 1.58% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.08%, 1.02%, 1.18%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Talisay City, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay City (in sq. km.)				
	Cabatangan	Dos Hermanas	Katilingban	Matab-Ang	San Fernando
0.03-0.20	15.46	8.31	15.57	0.0052	50.33
0.21-0.50	0.49	0.58	0.56	0	1.51
0.51-1.00	0.23	0.7	0.44	0	0.78
1.01-2.00	0.2	0.8	0.44	0	0.59
2.01-5.00	0.2	1.04	0.41	0	0.71
> 5.00	0.026	0.45	0.045	0	0.35

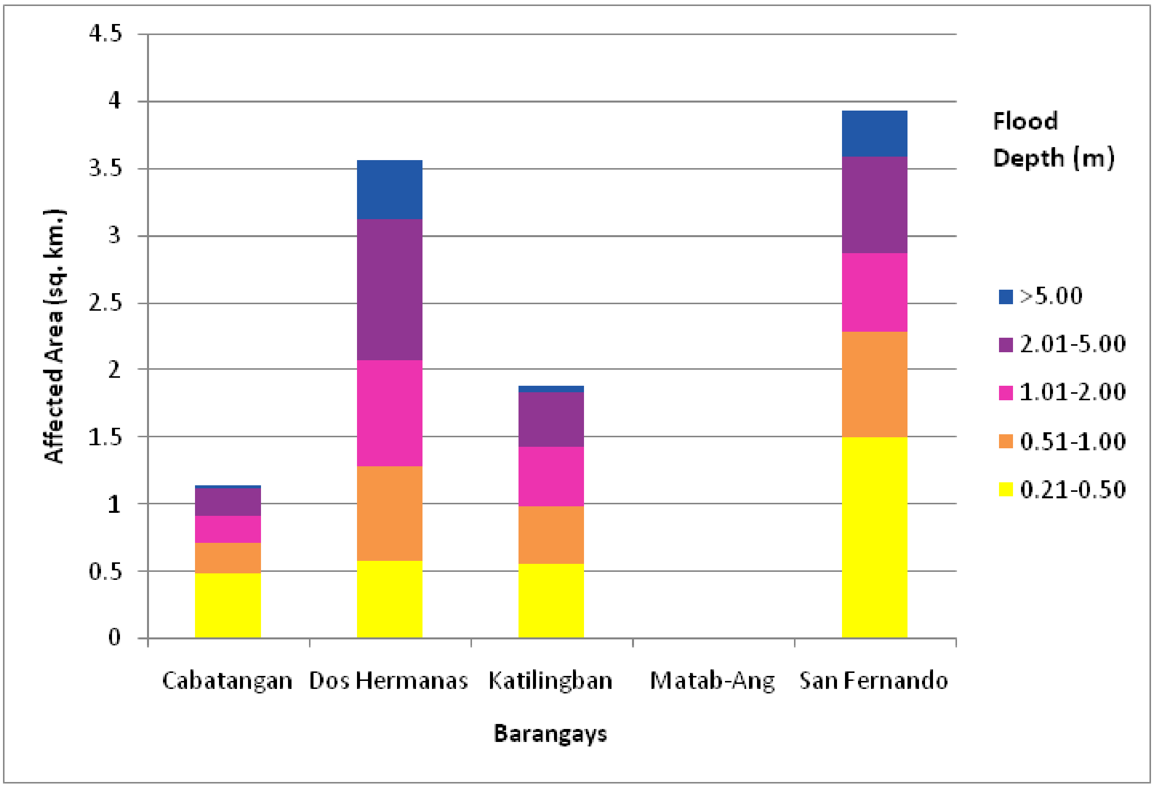


Figure 90. Affected areas in Talisay City, Negros Occidental during a 100-year rainfall return period

For the City of Victorias, with an area of 199.01 square kilometers, 52.42% will experience flood levels of less than 0.20 meters. 5.89% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.21%, 7.28%, 2.45%, and 0.53% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Listed in Table 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Victorias City, Negros Occidental during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)								
	Brgy. I	Brgy. II	Brgy. III	Brgy. IV	Brgy. V	Brgy. VI	Brgy. VI-A	Brgy.VII	Brgy. VIII
0.03-0.20	0.035	0.026	0.047	0.099	0.29	0.073	0.15	0.061	7.89
0.21-0.50	0.022	0.0036	0.0049	0.0063	0.012	0.12	0.047	0.011	0.39
0.51-1.00	0.055	0.0047	0.042	0.0065	0.00096	0.22	0.11	0.006	0.42
1.01-2.00	0.08	0.011	0.058	0.0093	0.0021	0.35	0.018	0.0093	0.53
2.01-5.00	0.034	0.013	0.00028	0.0059	0.000075	0.033	0	0.02	0.14
> 5.00	0	0	0	0	0	0	0	0	0.013

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)								
	Brgy. IX	Brgy. X	Brgy. XI	Brgy. XII	Brgy. XIII	Brgy. XIV	Brgy. XV	Brgy. XV-A	Brgy. XVI
0.03-0.20	0.026	8.98	10.43	5.9	2.89	5.32	0.13	0.54	0.11
0.21-0.50	0.076	0.5	0.35	0.43	1.99	0.32	0.052	0.13	0.041
0.51-1.00	0.15	0.42	0.23	0.55	2.72	0.23	0.093	0.03	0.058
1.01-2.00	0.089	0.44	0.21	0.79	2.74	0.26	0.063	0.002	0.082
2.01-5.00	0.0044	0.25	0.088	0.92	0.28	0.29	0.014	0	0.034
> 5.00	0	0.004	0.09	0.21	0.0093	0.029	0.0012	0	0.01

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Victorias City (in sq. km.)							
	Brgy. XVI-A	Brgy. XVII	Brgy. XVIII	Brgy. XVIII-A	Brgy. XIX	Brgy. XIX-A	Brgy. XX	Brgy. XXI
0.03-0.20	0	0.47	0.28	2.77	1.05	0.062	4.6	2.05
0.21-0.50	0.00028	0.06	0.034	0.15	0.32	0.14	0.68	0.19
0.51-1.00	0.0094	0.096	0.025	0.13	0.45	0.38	0.82	0.21
1.01-2.00	0.0062	0.047	0.032	0.12	0.5	0.29	0.67	0.14
2.01-5.00	0.0099	0.019	0.068	0.038	0.024	0.052	0.17	0.028
> 5.00	0	0.023	0.079	0.026	0.043	0.0066	0.0052	0

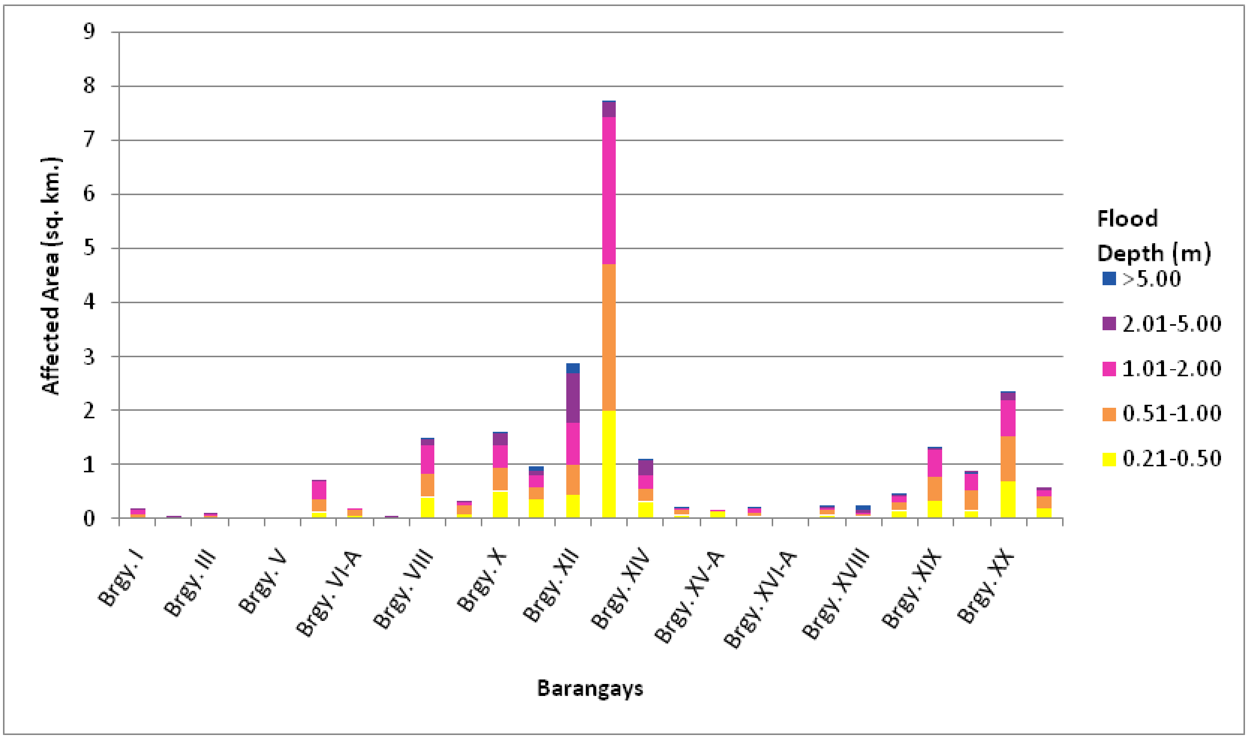


Figure 91. Affected areas in Victorias City, Negros Occidental during a 100-year rainfall return period

Among the barangays in the City of Cadiz, Celestino Villacin is projected to have the highest percentage of area that will experience flood levels, at 7.84%.

Among the barangays in the Municipality of Calatrava, Lalong is projected to have the highest percentage of area that will experience flood levels, at 0.013%.

Among the barangays in the Municipality of Enrique B. Magalona, Consing is projected to have the highest percentage of area that will experience flood levels, at 13.14%. Meanwhile, Tanza posted the second highest percentage of area that may be affected by flood depths, at 10.28%.

Among the barangays in the Municipality of Manapla, Tortosa is projected to have the highest percentage of area that will experience flood levels, at 1%.

Among the barangays in the Municipality of Salvador Benedicto, Igmay-an is projected to have the highest percentage of area that will experience flood levels at 0.17%. Meanwhile, Pandanan posted the second highest percentage of area that may be affected by flood depths, at 0.06%.

Among the barangays in the City of Silay, Guimbala-On is projected to have the highest percentage of area that will experience flood levels, at 17.38%. Meanwhile, Patag posted the second highest percentage of area that may be affected by flood depths, at 16.40%.

Among the barangays in the City of Talisay, San Fernando is projected to have the highest percentage of area that will experience flood levels, at 27.27%. Meanwhile, Cabatangan posted the percentage of area that may be affected by flood depths, at 8.34%.

Among the barangays in the City of Victorias, Barangay XI is projected to have the highest percentage of area that will experience flood levels, at 11.01%. Meanwhile, Barangay X posted the second highest percentage of area that may be affected by flood depths, at 10.23%.

The generated flood hazard maps for the Malogo floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the hazard maps – “Low”, “Medium”, and “High” – the affected institutions were given an individual assessment for each flood hazard scenario (5-year, 25-year, and 100-year).

Table 53. Area covered by each warning level, with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	38.95	45.07	45.30
Medium	28.57	53.42	64.03
High	20.94	31.72	41.69
TOTAL	**88.46**	**130.21**	**151.02**

Of the seventy-five (75) identified educational institutions in the Malogo (Imbang-Malogo) floodplain, eight (8) were assessed to be exposed to Low-level flooding during a 5-year scenario. Meanwhile, six (6) schools were assessed to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, eleven (11) schools were assessed to be exposed to Low-level flooding; while thirteen (13) schools were found to be exposed to Medium-level flooding. For the 100-year scenario, seven (7) schools were assessed to be exposed to Low-level flooding, sixteen (16) to Medium-level flooding, and four (4) to High-level flooding. These schools are located in Barangay II and Barangay XIX-A in Victorias City. See Annex 12 for a detailed enumeration of schools exposed to flooding in the Malogo (Imbang-Malogo) floodplain.

Twenty-three (23) medical institutions were identified in the Malogo (Imbang-Malogo) floodplain. During a 5-year scenario, two (2) were assessed to be exposed to Low-level flooding, one (1) to Medium-level flooding, and one (1) to High-level flooding. In the 25-year scenario, two (2) institutions were found to be exposed to Low-level flooding, four (4) to Medium-level flooding, and one (1) to High-level flooding. For the 100-year scenario, four (4) are projected to be exposed to Medium-level flooding. In the same scenario, four (4) were discovered to be exposed to High-level flooding. These medical institutions are located in Barangay I (St. Jude Laboratory), Barangay IV and VII (Victoria Kaayong Lawas Foundation), and Barangay XVI-A (Barangay 16 Health Center) in Victorias City. See Annex 13 for a detailed enumeration of hospitals and clinics exposed to flooding in the Malogo (Imbang-Malogo) floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in the different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel went to the specified points identified in the river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with 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 the corresponding validation depths are illustrated in Figure 93.

The flood validation consists of two hundred and twenty-nine (229) points, randomly selected all over the Malogo-Imbang floodplain. Comparing these with the flood depth map of the nearest storm event, the RMSE value of 0.83 meters was attained. Table 54 shows a contingency matrix of the comparison. The validation points are found in Annex 10.

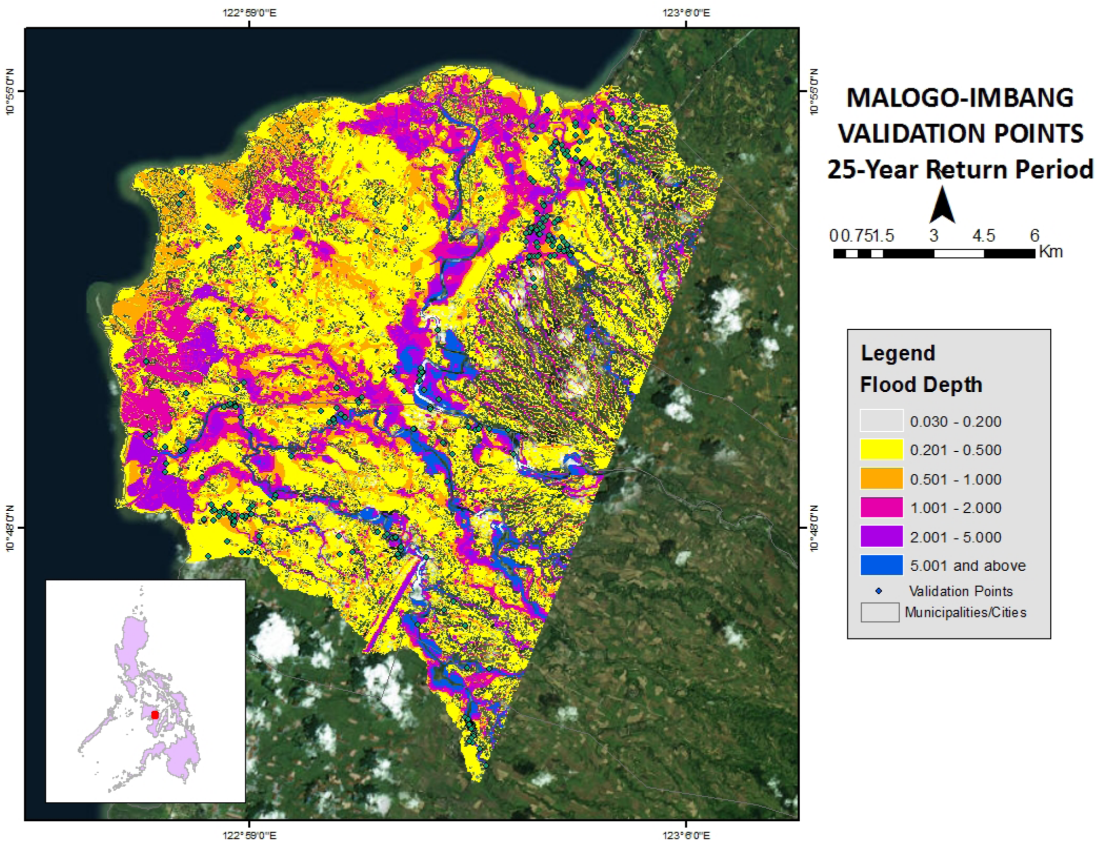


Figure 92. Validation points for a 25-year flood depth map of the Malogo-Imbang floodplain

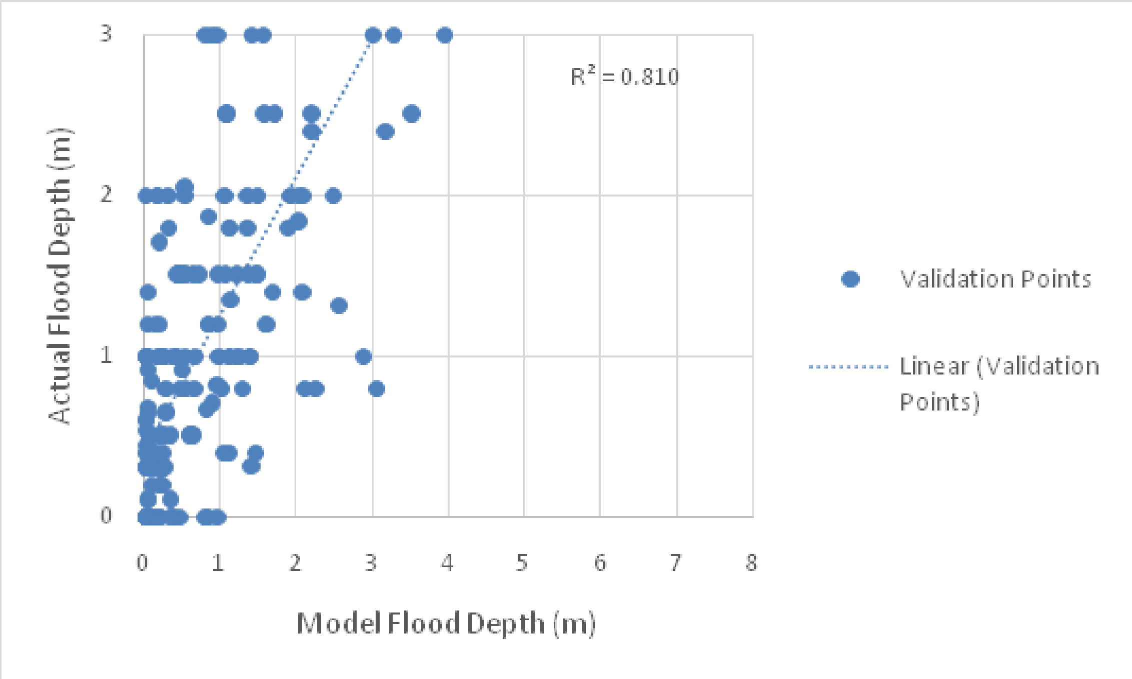


Figure 93. Flood map depth vs. actual flood depth

Table 54. Actual flood depth vs. simulated flood depth in the Malogo-Imbang River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	39	9	4	0	0	0	52
0.21-0.50	16	9	4	4	0	0	33
0.51-1.00	16	9	8	9	4	0	46
1.01-2.00	6	7	11	17	6	0	47
2.01-5.00	0	0	4	6	15	13	38
> 5.00	0	0	0	0	8	5	13
Total	77	34	31	36	33	18	229

The overall accuracy generated by the flood model is estimated at 40.61%, with ninety-three (93) points correctly matching the actual flood depths. In addition, there were eighty-two (82) points estimated one (1) level above and below the correct flood depths. There were thirty-nine (39) points and six (6) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of eighty-three (83) points were underestimated in the modeled flood depths of the Malogo-Imbang floodplain. Table 55 depicts the summary of the Accuracy Assessment in the Malogo-Imbang River Basin Survey.

Table 55. Summary of Accuracy Assessment in the Malogo-Imbang River Basin Survey

	No. of Points	%
Correct	93	**40.61**
Overestimated	53	**23.14**
Underestimated	83	**36.24**
Total	229	**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.

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

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

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

ANNEXES

Annex 1. Technical Specifications of the Pegasus LiDAR Sensor used in the Malogo Floodplain Survey

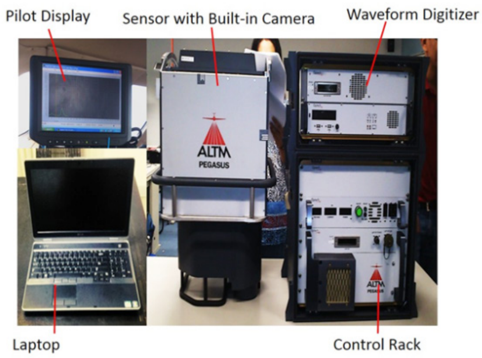

Figure A-1.1. Pegasus Sensor

Table A-1.1. Specifications of the Pegasus LiDAR sensor

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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. NGW-55

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

May 14, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **NEGROS OCCIDENTAL**	
	Station Name: **NGW-55**	
Island: **VISAYAS**	Order: **2nd**	Barangay: **TANZA**
Municipality: **E.B. MAGALONA**		
	PRS92 Coordinates	
Latitude: **10° 51' 0.88734"**	Longitude: **122° 59' 57.75865"**	Ellipsoidal Hgt: **12.01600 m.**
	WGS84 Coordinates	
Latitude: **10° 50' 56.54743"**	Longitude: **123° 0' 2.96548"**	Ellipsoidal Hgt: **70.28000 m.**
	PTM Coordinates	
Northing: **1199766.082 m.**	Easting: **499931.926 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,199,346.14**	Easting: **499,931.95**	Zone: **51**

Location Description

NGW-55
The station is on the SW side of the road heading to sugar central. It is about 9.0 km. from the junction of national highway and the road heading to sugar central. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete headwall with inscriptions "NGW-55; 2007; NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8796150 A**
T.N.: **2014-1106**

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

9905142014161722

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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Figure A-2.1. NGW-55

Annex 3. Baseline Processing Report

There is no baseline processing report for this river basin.

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI S. SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	DAN CHRISTOPHER ALDOVINO	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	RENAN PUNTO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. DAVE GUMBAN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC

Annex 5. Data Transfer Sheets for the Malogo Floodplain Flights

DATA TRANSFER SHEET
5/5/2014(Bacolod ~~Pending~~) Ready

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Apr 21, 2014	1371P	1BLK45DE110A	PEGASUS	1.83GB	300KB	7.87MB	165MB	43.7GB	336KB	16.9GB	N/A	14.8MB	103B	0B	53.3KB/48.8KB/ 39.9KB/53.3KB/	1.67KB	Z:\Airborne_Raw\1371P
Apr 21, 2014	1373P	1BLK45B110B	PEGASUS	1.93GB	1.42MB	7.76MB	149MB	23.2GB	221KB	17.2GB	N/A	14.8MB	103B	230B	39.9KB	1.67KB	Z:\Airborne_Raw\1373P
Apr 22, 2014	1375P	1BLK45B111A	PEGASUS	3.72GB	1.65MB	13.9MB	264MB	46.0GB	366KB	34.9GB	N/A	13.6MB	103B	527B	28.3KB/37.8KB/ 41.0KB	1.67KB	Z:\Airborne_Raw\1375P
Apr 22, 2014	1377P	1BLK45C111B	PEGASUS	1.73GB	1.06MB	7.10MB	154MB	17.5GB	4.19KB/ 164KB	15.6GB	N/A	13.6MB	103B	250B	3.44KB/49.6KB	1.67KB	Z:\Airborne_Raw\1377P
Apr 25, 2014	1387P	1BLK45AC114A	PEGASUS	2.59GB	672KB	13.2MB	275MB	44.2GB	350KB	27.3GB	N/A	7.15MB	103B	457B	73.5KB/62.3KB/ 57.8KB	1.67KB	Z:\Airborne_Raw\1387P
Apr 26, 2014	1391P	1BLK44CB115A	PEGASUS	3.40GB	1.51MB	12.6MB	257MB	52.0GB	159KB/ 168KB	30.7GB	N/A	12.3MB	152B	460B	51KB/48.8KB/7. 25KB/63.8KB/3.	2.01KB	Z:\Airborne_Raw\1391P
Apr 27, 2014	1393P	1BLK44AB115B	PEGASUS	2.92GB	2.91MB	13.3MB	264MB	45.0GB	356KB	30.6GB	N/A	12.3MB	152B	666B	51.3KB/49.1KB	2.01KB	Z:\Airborne_Raw\1393P

Received from

Name GRACE B. SINADJAN
Position RA
Signature

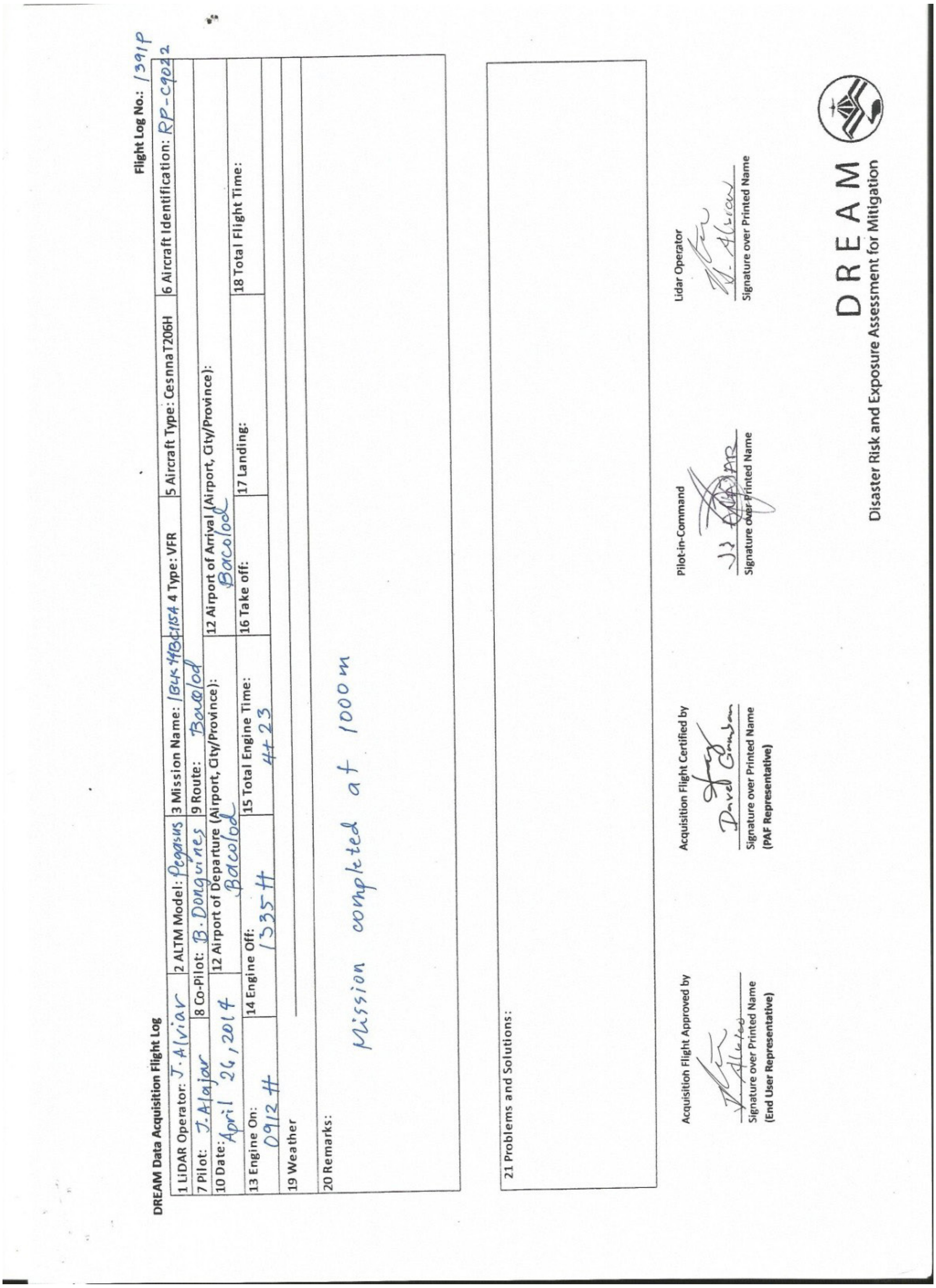
Received by

Name Benjamin Magallon
Position
Signature
5/26/2014

Figure A-5.1. Data Transfer Sheet for the Malogo Floodplain

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1391P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1391P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK4BC115A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: April 26, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 0912 H	14 Engine Off: 1335 H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed at 1000 m					

21 Problems and Solutions:

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

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

Pilot-in-Command — JJ Alajar — Signature over Printed Name

Lidar Operator — J. Alviar — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1391P

2. Flight Log for 1393P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1393P

1 LiDAR Operator: D. Aldovino	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44AB115B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: April 24, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1432 H	14 Engine Off: 1855 H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed at 1200 m					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Alarcon	David Gamban	J. Alajar	D. Aldovino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight Log for Mission 1393P

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT BACOLOD APRIL 26, 2014					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1391P	BLK 44CB	1BLK44CB115A	J. Alviar	Apr 26	Mission completed at 1000m; surveyed BLK 44C and parts of BLK 44B
1393P	BLK 44AB	1BLK44AB115B	D. Aldovino	Apr 26	Mission completed at 1200m, covered BLK 44A and remaining areas of BLK 44B

LAS BOUNDARIES PER FLIGHT

Flight No.:	1391P
Area:	BLK 44B & 44C
Mission Name:	1BLK44BC115A
Parameters:	Altitude: 1000; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%

LAS

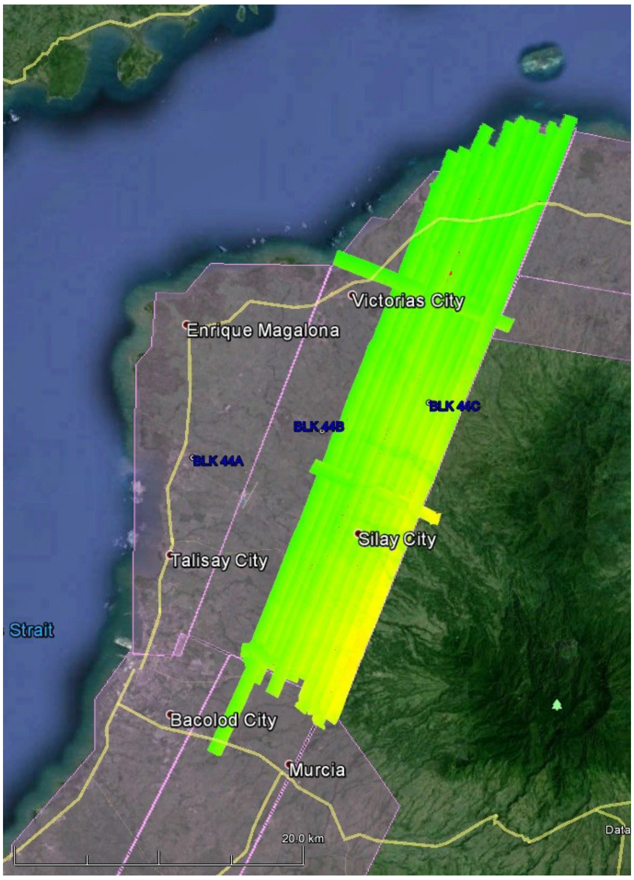


Figure A-7.1. Swath for Flight No. 1391P

Flight No.: 1393P
Area: BLK 44A & 44B
Mission Name: 1BLK44AB115B
Parameters: Altitude: 1200; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%

LAS

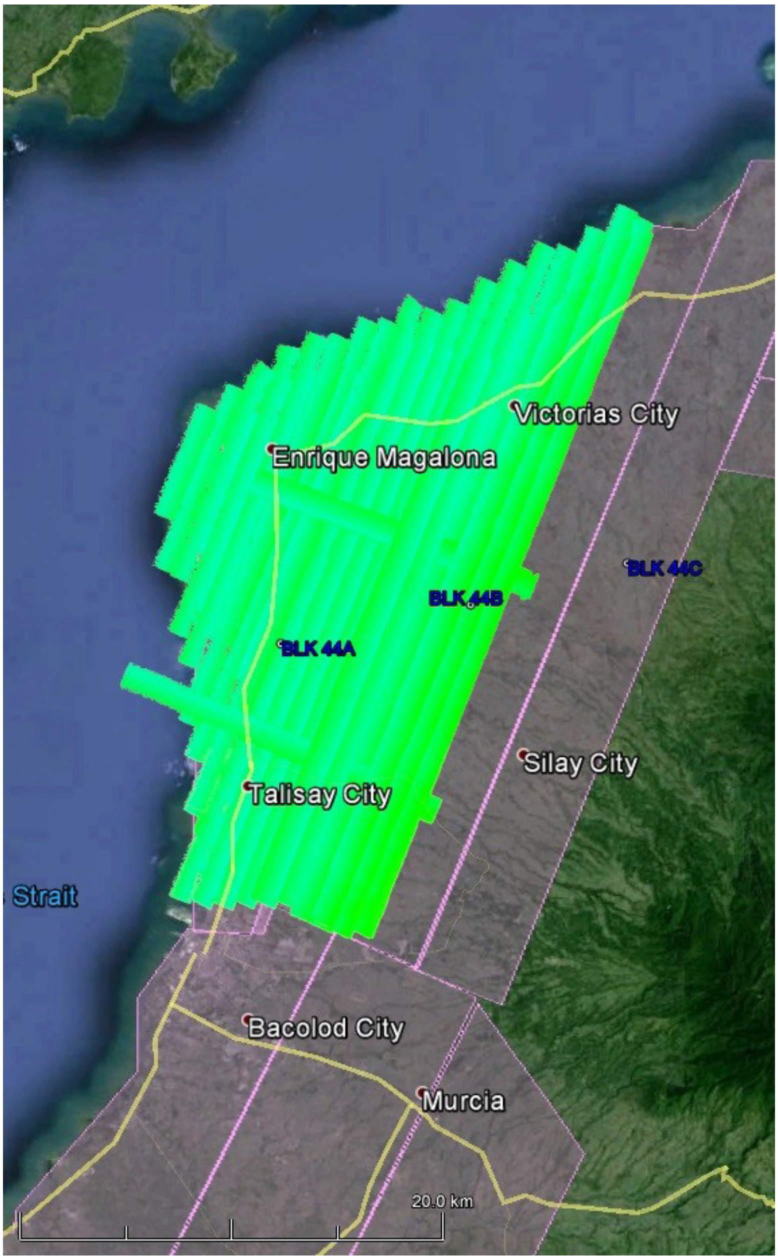


Figure A-7.2. Swath for Flight No. 1393P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk44AB

Flight Area	Negros
Mission Name	Blk44AB
Inclusive Flights	1393P
Range data size	30.6 GB
POS	264 MB
Base data size	12.3 MB
Image	45 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.05
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.16
Boresight correction stdev (<0.001deg)	0.000499
IMU attitude correction stdev (<0.001deg)	0.011782
GPS position stdev (<0.01m)	0.0166
Minimum % overlap (>25)	21.28
Ave point cloud density per sq.m. (>2.0)	3.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	494
Maximum Height	194.95 m
Minimum Height	59.93 m
Classification (# of points)	
Ground	352,505,220
Low vegetation	270,993,261
Medium vegetation	316,234,276
High vegetation	70,400,719
Building	19,489,857
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

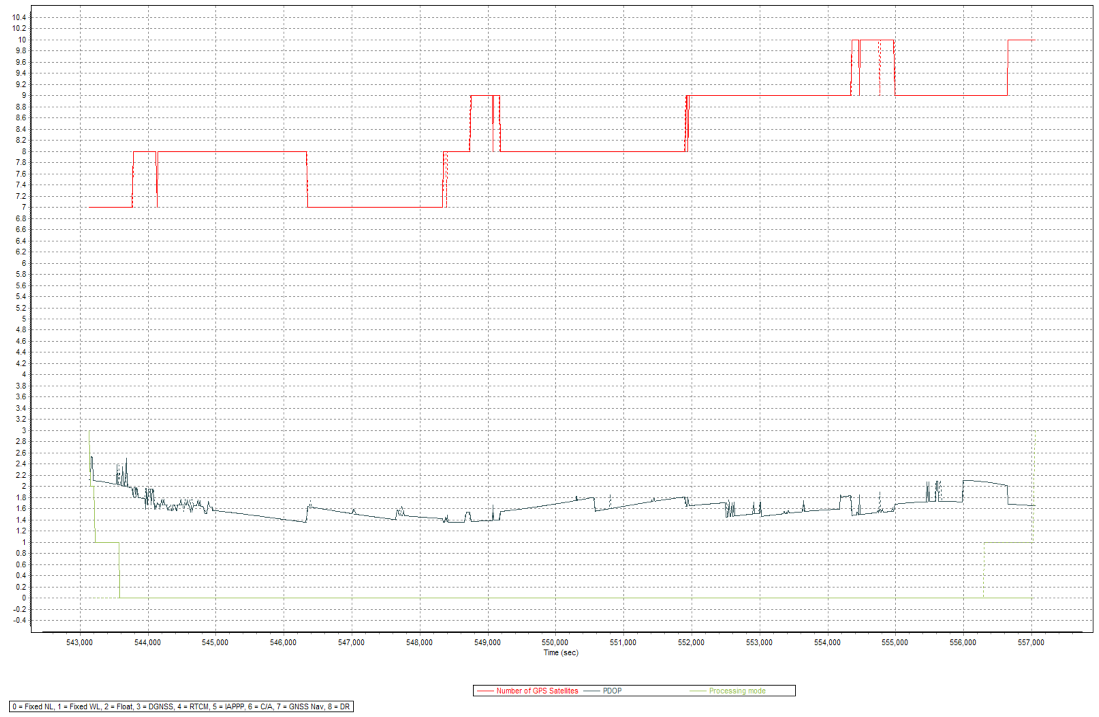


Figure A-8.1. Solution Status

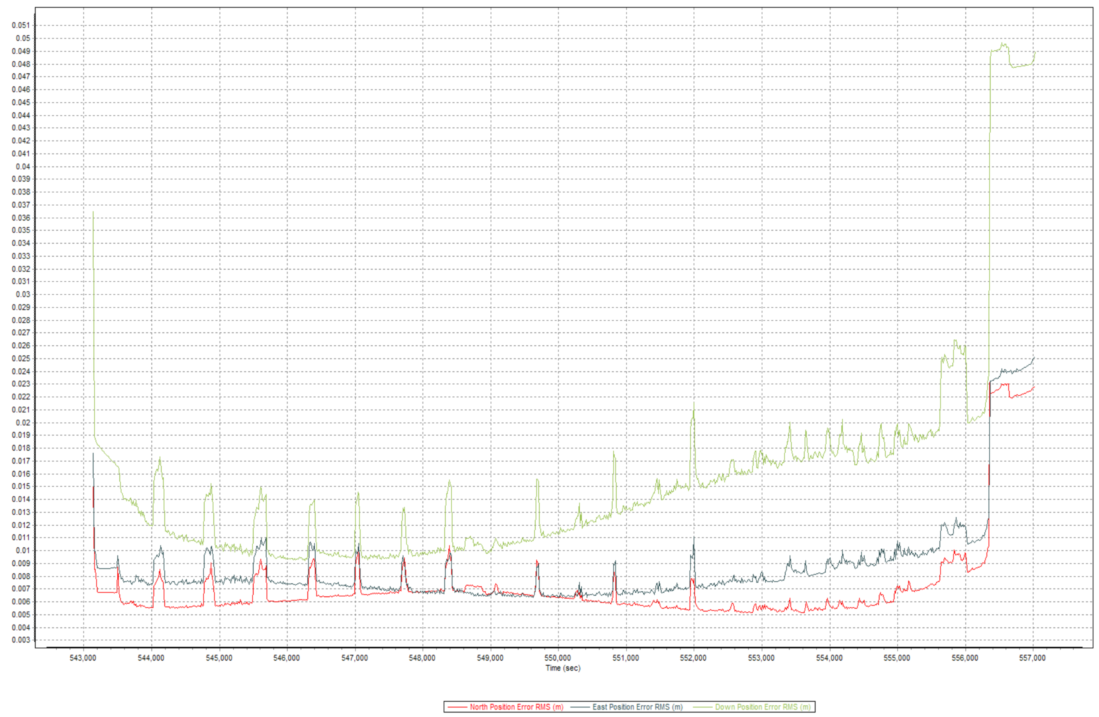


Figure A-8.2. Smoothed Performance Metric Parameters

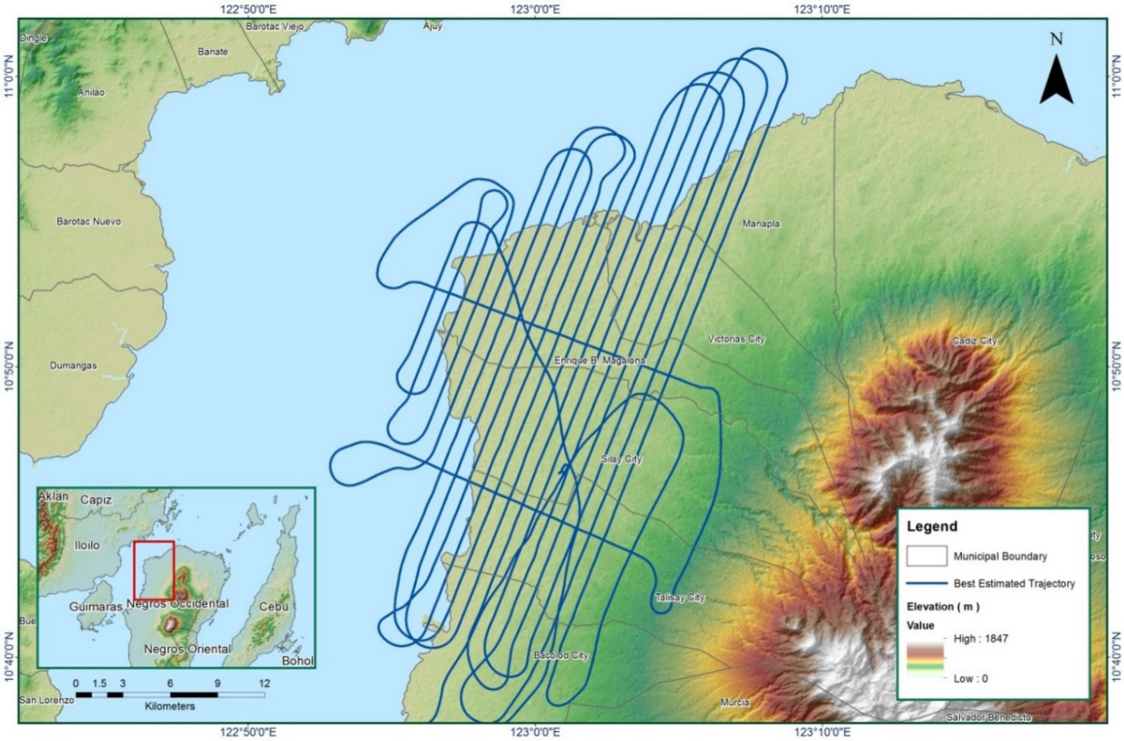


Figure A-8.3. Best Estimated Trajectory

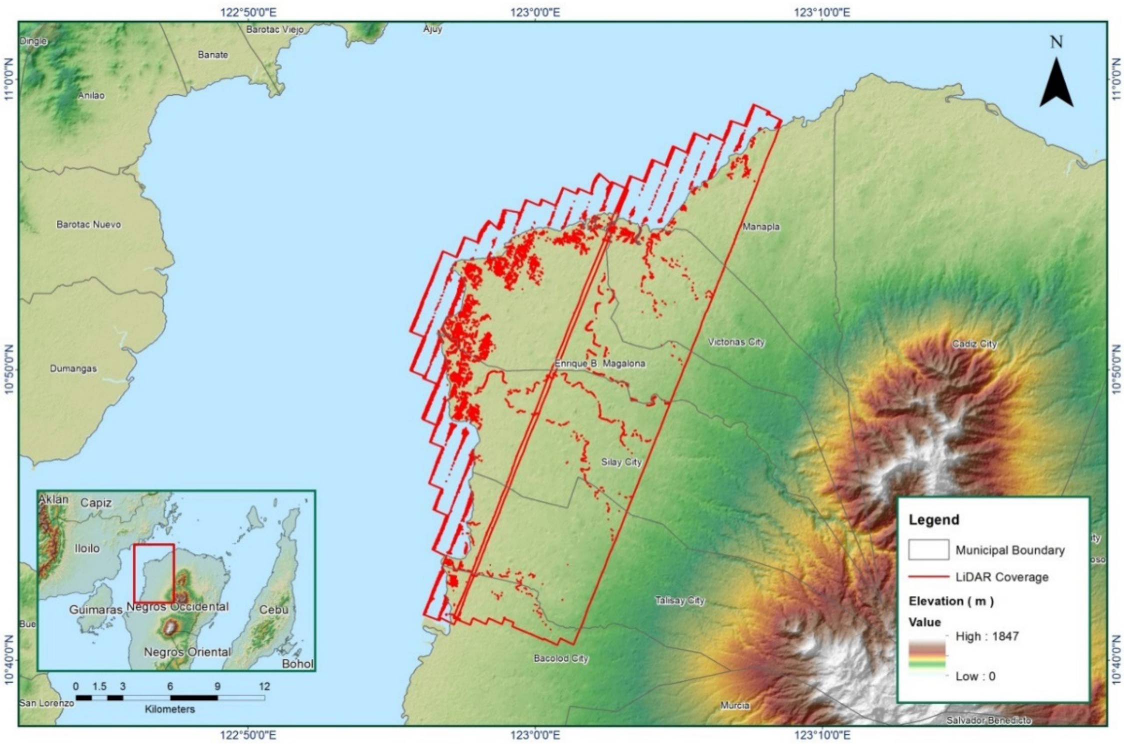


Figure A-8.4. Coverage of LiDAR data

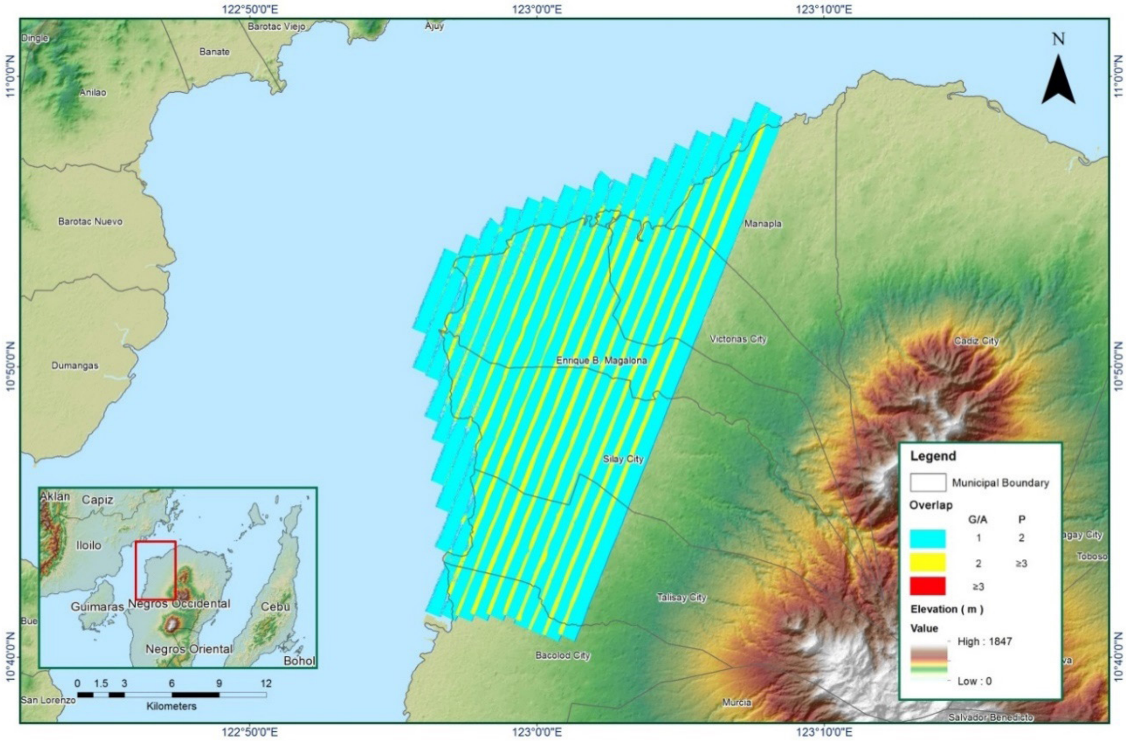


Figure A-8.5. Image of data overlap

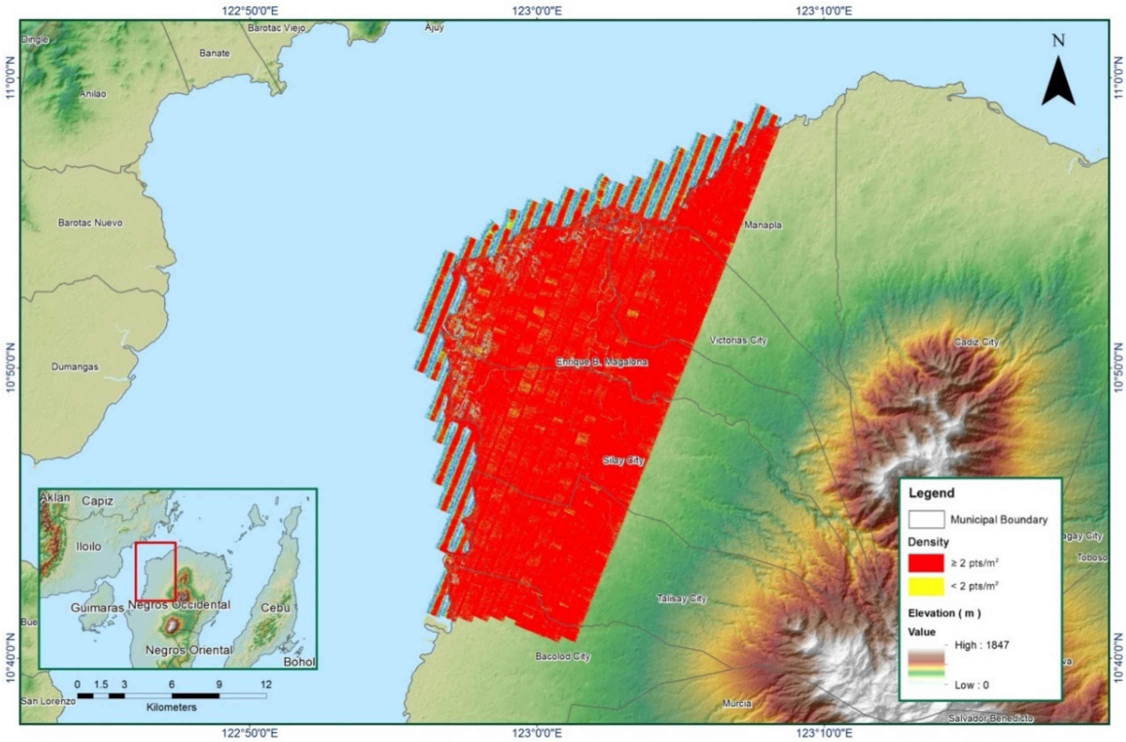


Figure A-8.6. Density map of merged LiDAR data

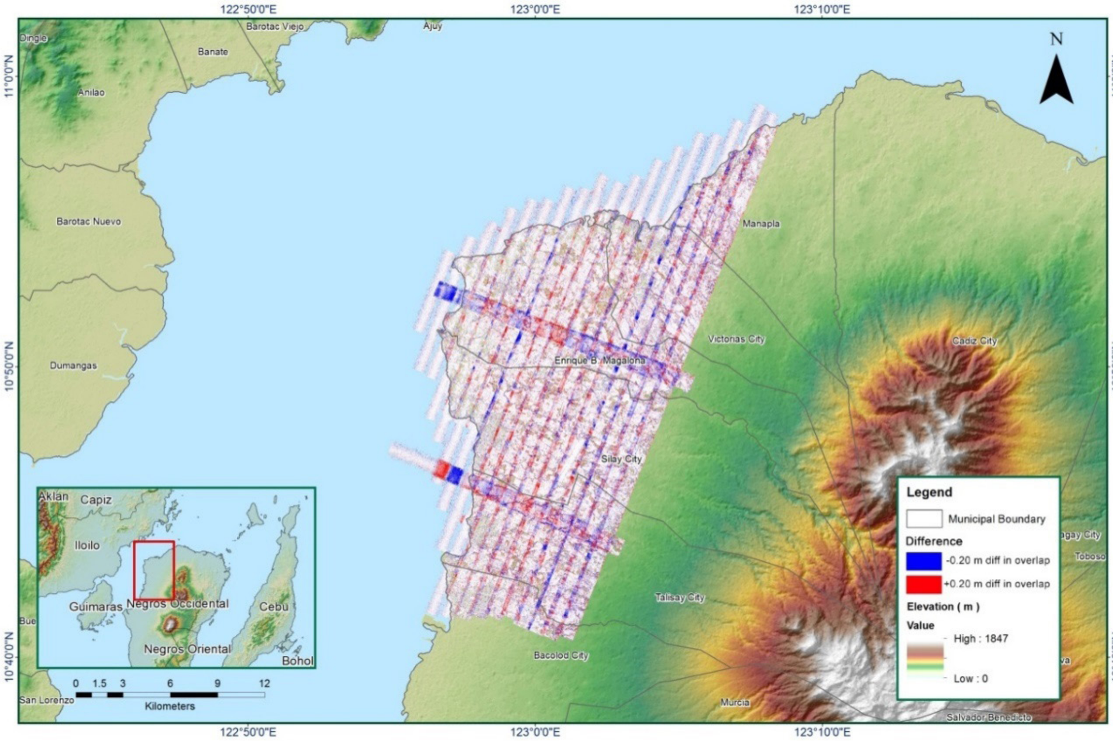


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk44C

Flight Area	Negros
Mission Name	**Blk44C**
Inclusive Flights	1391P
Range data size	30.7 GB
POS	257 MB
Base data size	12.3 MB
Image	52 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.54
RMSE for Down Position (<8.0 cm)	2.73
Boresight correction stdev (<0.001deg)	0.000312
IMU attitude correction stdev (<0.001deg)	0.001371
GPS position stdev (<0.01m)	0.006
Minimum % overlap (>25)	26.54%
Ave point cloud density per sq.m. (>2.0)	4.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	399
Maximum Height	395.70 m
Minimum Height	61.24 m
Classification (# of points)	
Ground	350,273,998
Low vegetation	332,575,391
Medium vegetation	433,345,906
High vegetation	91,636,263
Building	7,157,778
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Engr. Gladys Mae Apat

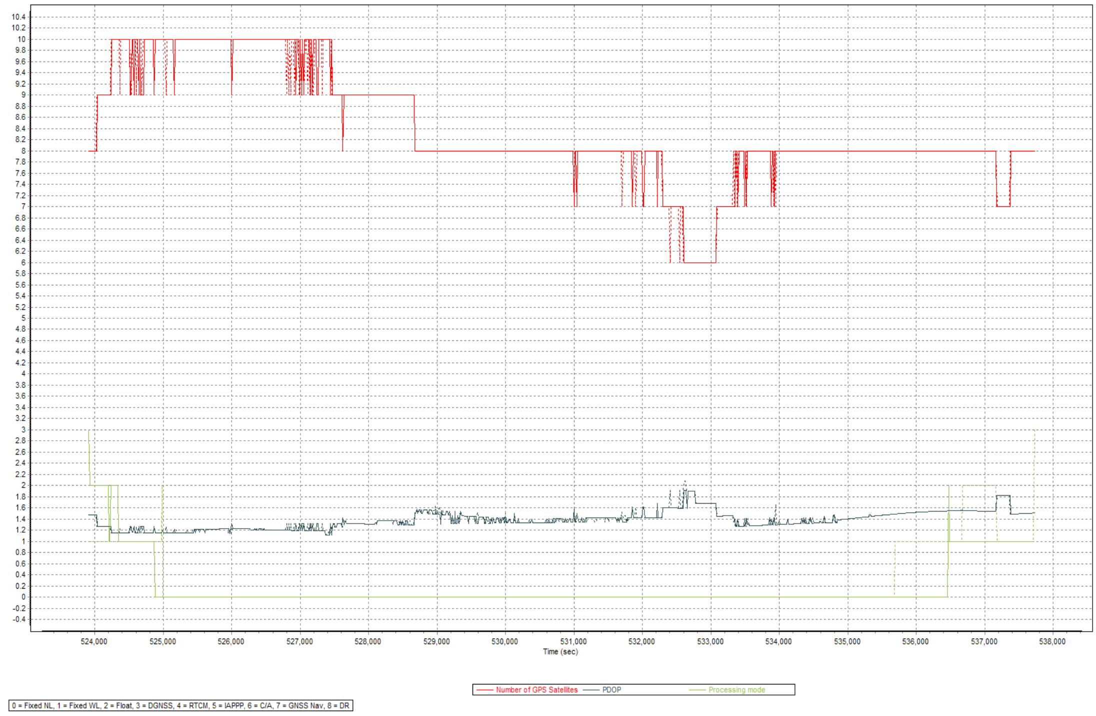


Figure A-8.8. Solution Status

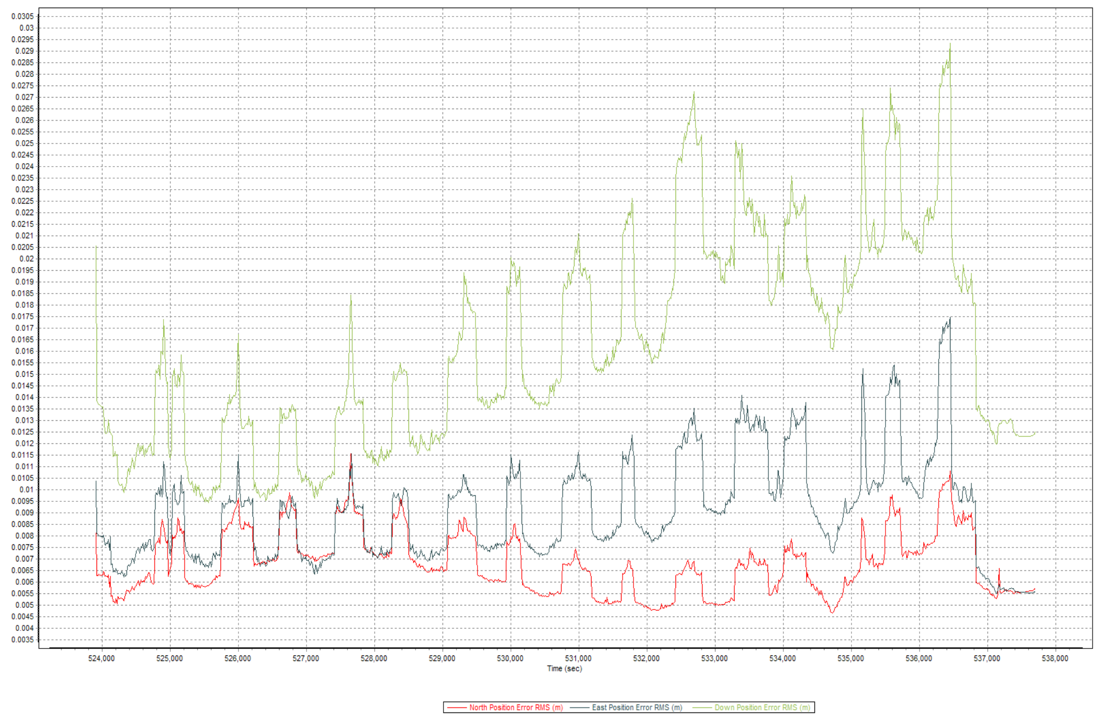


Figure A-8.9. Smoothed Performance Metric Parameters

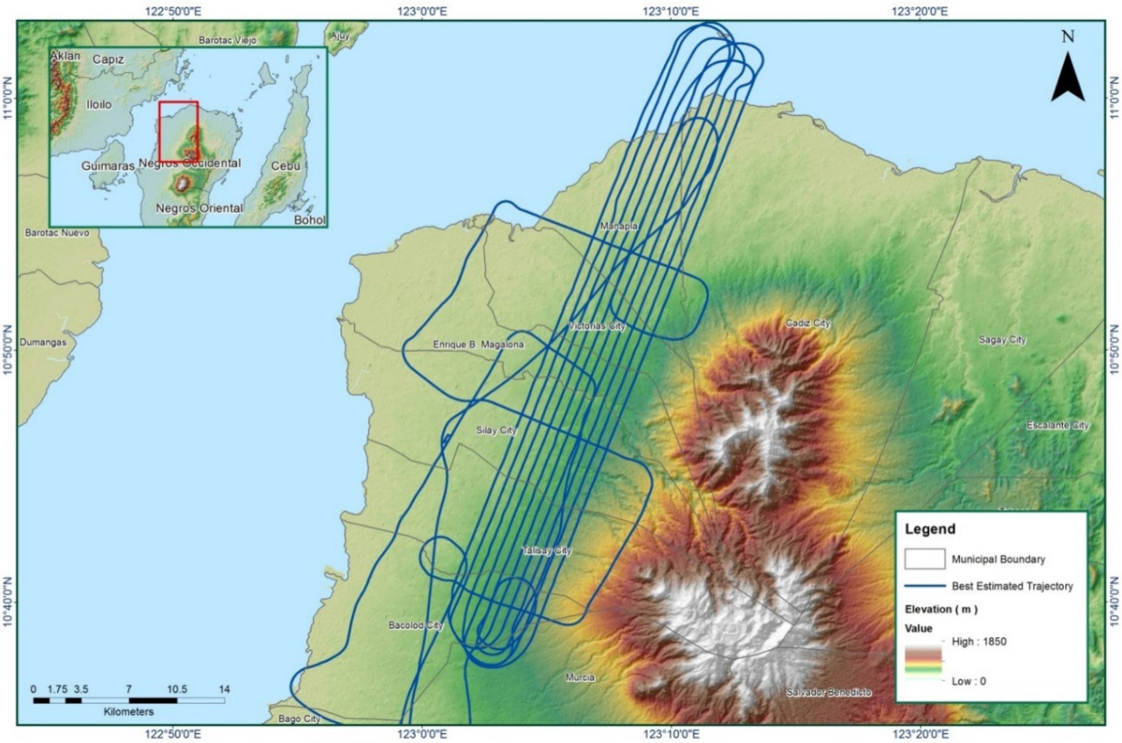


Figure A-8.10. Best Estimated Trajectory

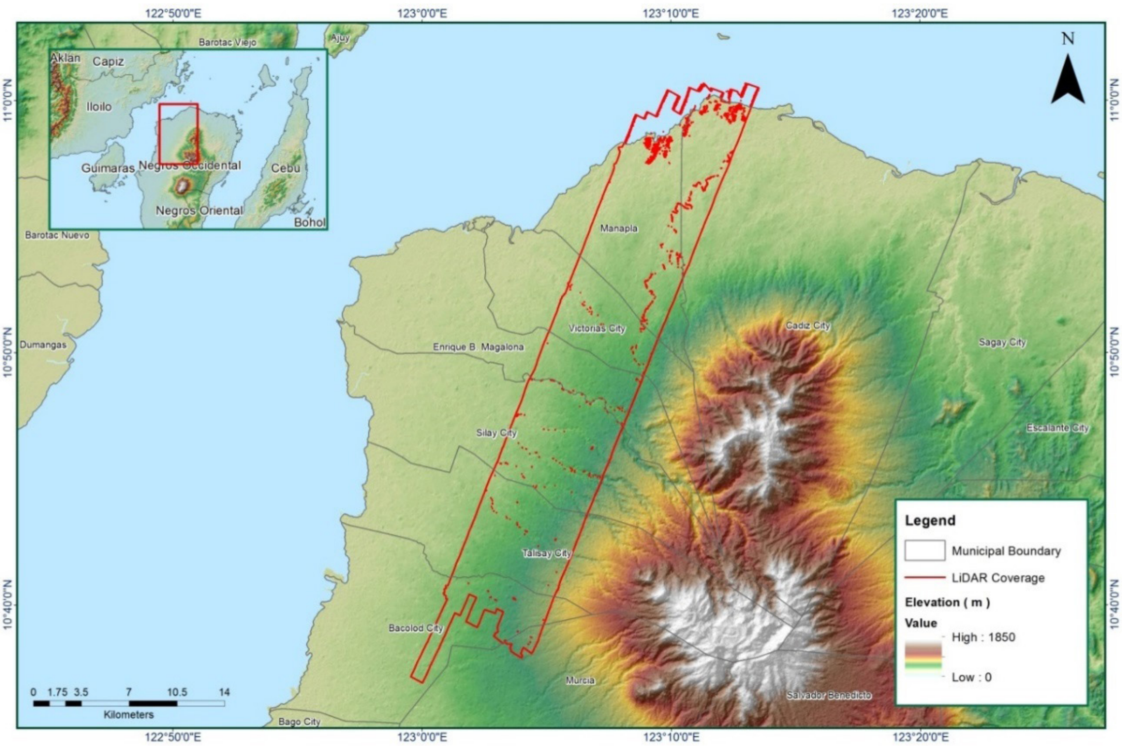


Figure A-8.11. Coverage of LiDAR data

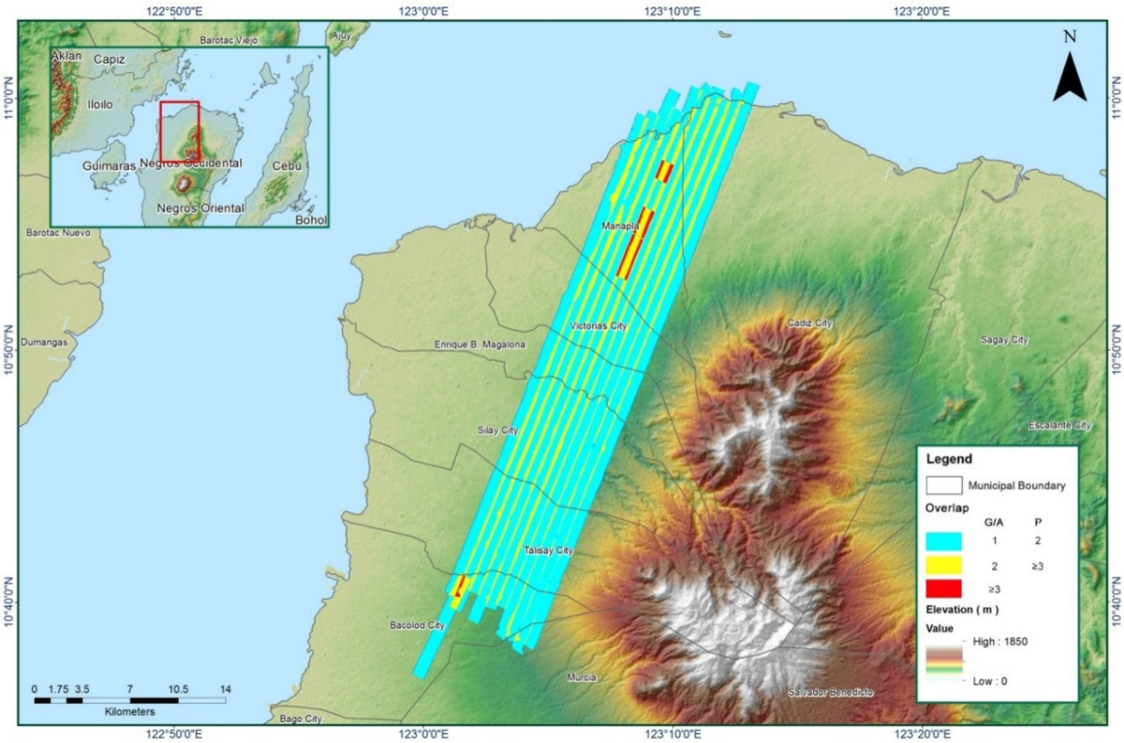


Figure A-8.12. Image of data overlap

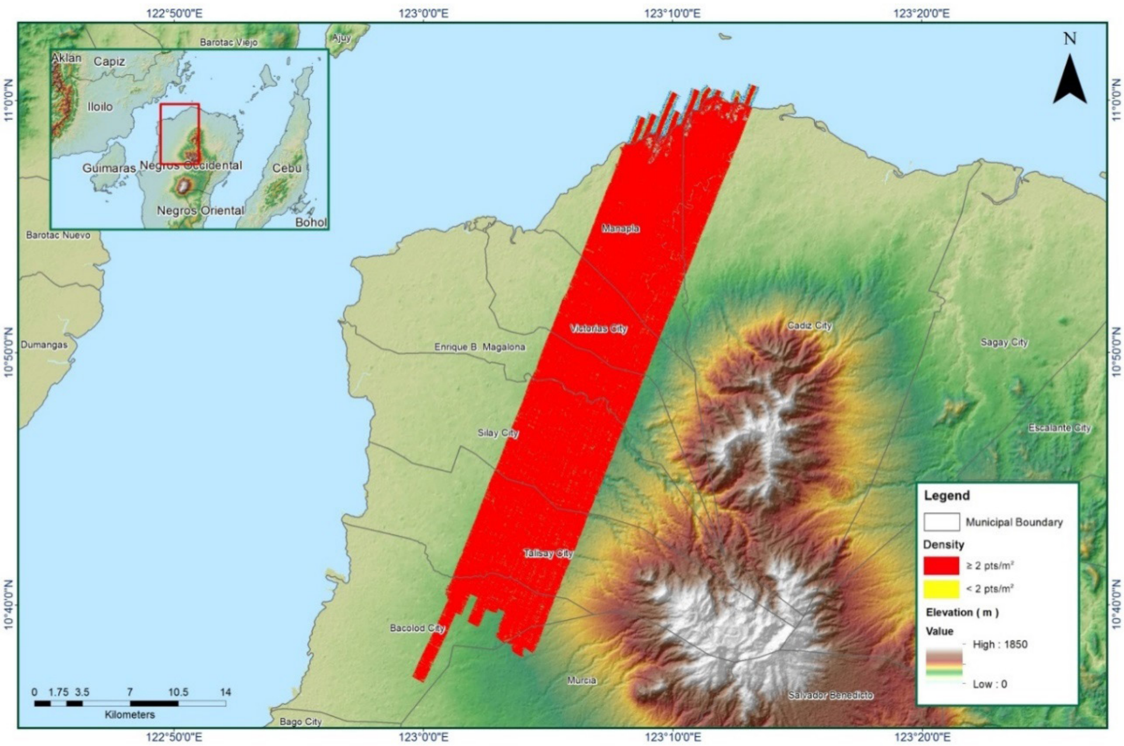


Figure A-8.13. Density map of merged LiDAR data

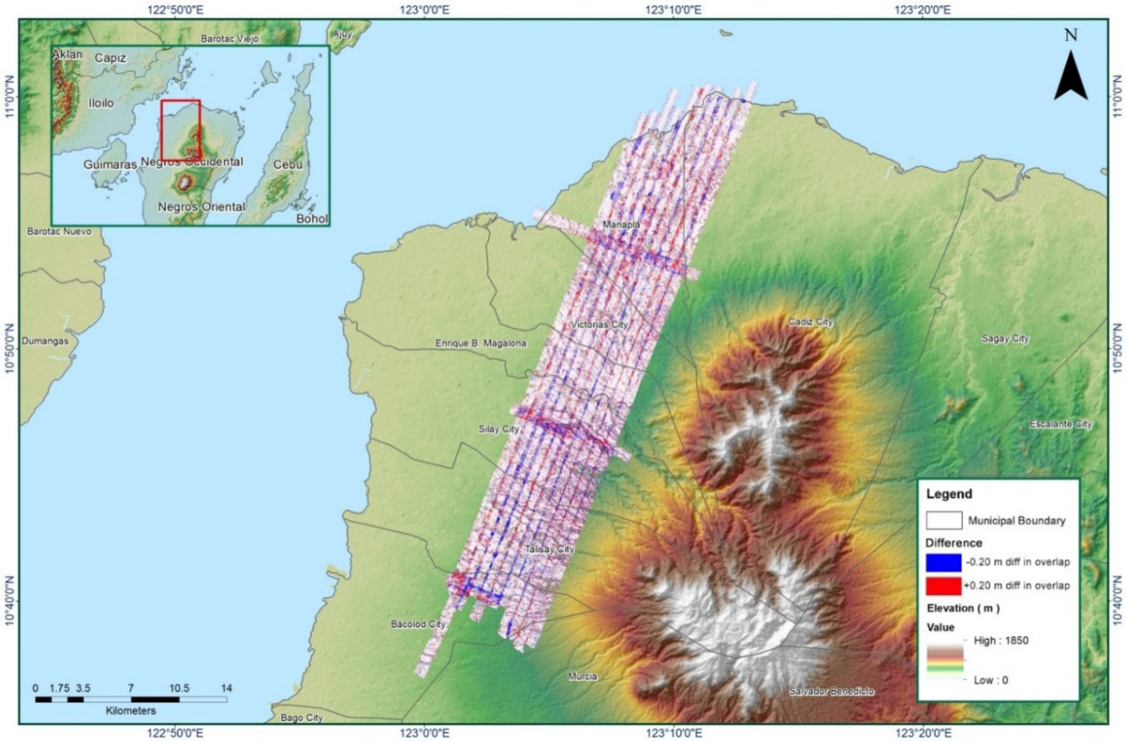


Figure A-8.14. Elevation difference between flight lines

Annex 9. Malogo Model Basin Parameters

Table A-9.1. Malogo 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
W100	0.78432	67	100	0.7493	0.017	Discharge	43.851	1	Ratio to Peak	0.5
W110	0.78432	67	100	3.4815	0.017	Discharge	16.88	1	Ratio to Peak	0.5
W120	0.64436	71.21	100	10.591	0.07164	Discharge	2.3046869	1	Ratio to Peak	0.5
W130	0.71466	76.626	100	3.8515	0.045861	Discharge	25.123	1	Ratio to Peak	0.5
W140	0.75052	75.738	100	14.345	0.042916	Discharge	16.911	1	Ratio to Peak	0.5
W80	0.78432	67	100	9.8943	0.039586	Discharge	15.239	1	Ratio to Peak	0.5
W90	0.78432	67	100	12.576	0.064919	Discharge	21.328	1	Ratio to Peak	0.5

Annex 10. Malogo Model Reach Parameters

Table A-10.1. Malogo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	1799.1	0.773973	0.40172	Trapezoid	55.2	1
R30	Automatic Fixed Interval	1846.3	0.0004104	0.0853891	Trapezoid	55.5	1
R40	Automatic Fixed Interval	554.26	2.83E-05	0.20074	Trapezoid	55.5	1

Annex 11. Malogo Field Validation Points

Table A-11.1. Malogo Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/ Scenario
	Lat	Long					
0	10.8745809	122.978083	0.31	0.2	0.012		
1	10.8868058	123.061748	0.3	0	0.09		
2	10.8319383	123.0066663	0.07	0.3	0.053	Ondoy	5-Year
3	10.8014342	122.9789577	0.24	0.5	0.068	Yolanda	5-Year
4	10.9057249	123.0851087	0.03	0.3	0.073	Yolanda	5-Year
5	10.8024184	122.9821143	0.38	0.19	0.036	Frank	5-Year
6	10.8339583	123.0124295	0.11	0.3	0.036	Ondoy	5-Year
7	10.8347601	123.0135004	0.03	0.3	0.073	Ondoy	5-Year
8	10.8025428	122.9783845	0.23	0.5	0.073	Yolanda	5-Year
9	10.8702984	123.0586352	0.07	0.2	0.017		
10	10.8050407	122.9831773	0.3	0	0.09		
11	10.8725689	123.0637306	0.17	0	0.029		
12	10.8581799	122.9810782	0.24	0.2	0.002	Yolanda	5-Year
13	10.8044394	122.9733988	0.07	0	0.005		
14	10.8934187	123.0585903	0.1	0.3	0.04	Yolanda	5-Year
15	10.8762233	123.0601291	0.14	0	0.02		
16	10.8775627	123.0634627	0.29	0.3	0		
17	10.7977420	122.9859542	0.27	0.3	0.001		
18	10.7960239	122.9859727	0.24	0.3	0.004		
19	10.8926834	123.0593381	0.13	0.3	0.029	Yolanda	5-Year
20	10.9096367	123.0804322	0.03	0	0.001		
21	10.7934128	122.9831484	0.21	0.3	0.008		
22	10.8579906	122.9779704	0.3	0.2	0.01	Yolanda	5-Year
23	10.8024669	122.9791114	0.35	2	2.723	Uring	5-Year
24	10.8742924	123.0660128	0.06	0	0.004		
25	10.8008639	122.9789679	0.58	0.5	0.006	Yolanda	5-Year
26	10.9059750	123.0734382	1.06	0.22	0.706	Frank	100-Year
27	10.9032090	123.0716958	0.4	0	0.16		
28	10.8196487	123.0377283	0.44	0	0.194		
29	10.8894179	122.9654465	0.03	0.4	0.137		
30	10.8888592	122.9649934	0.18	0.4	0.048		
31	10.9008864	123.0683727	0.51	2	2.22	Seniang	5-Year
32	10.8726845	123.0588329	1.02	1.2	0.032	Rosing	5-Year
33	10.8370021	122.9799052	0.15	0.8	0.423		
34	10.8726984	123.0637968	2.07	0	4.285		
35	10.9144104	123.0859862	3.19	1.5	2.856	Yolanda	5-Year
36	10.7483667	123.0414913	1.32	0.4	0.846	Ruping	5-Year
37	10.8800369	123.0608771	0.91	0.8	0.012	Rosing	5-Year
38	10.8727757	123.0607202	0.89	1.2	0.096	Rosing	5-Year
39	10.8728220	123.0648397	0.05	0	0.003		
40	10.9074427	123.0705397	1.21	0.09	1.254	Frank	5-Year

41	10.8832809	123.0630106	0.06	1.5	2.074	Rosing	5-Year
42	10.8703800	123.0635583	1.49	0.7	0.624	Rosing	5-Year
43	10.8388542	122.9819912	1.93	0.8	1.277		
44	10.9031127	123.0654611	0.46	0.8	0.116	Yolanda	5-Year
45	10.8815748	123.0650835	1.43	1.5	0.005	Rosing	5-Year
46	10.8918773	123.0742209	0.33	2	2.789	Ruping	5-Year
47	10.8018799	122.97107	0.71	0	0.504		
48	10.9069206	123.0854576	0.03	1.5	2.161	Yolanda	5-Year
49	10.8203961	122.9649728	1.06	0.4	0.436	Yolanda	5-Year
50	10.8986716	123.0704625	1.05	2	0.903	Ruping	5-Year
51	10.9011583	123.0672174	0.03	0.8	0.593	Seniang	5-Year
52	10.8291992	123.0059503	0.06	0.5	0.194		
53	10.8031539	122.9814927	0.92	0.06	0.74	Frank	100-Year
54	10.8804161	123.0595969	0.03	1	0.941	Rosing	5-Year
55	10.8282116	123.0047014	0.06	0.5	0.194		
56	10.8048239	122.9740335	0.9	1	0.01	Ruping	5-Year
57	10.8727301	123.0581052	0.97	1.2	0.053	Rosing	5-Year
58	10.8224187	123.0353974	0.52	1	0.23	Ondoy	5-Year
59	10.8801659	123.0592741	0.05	1	0.903	Rosing	5-Year
60	10.9098209	123.0867298	0.8	1.5	0.49	Yolanda	5-Year
61	10.8134112	122.9706899	3.21	0.5	7.344	Yolanda	5-Year
62	10.8212151	122.9660136	1.74	1.5	0.058	Yolanda	5-Year
63	10.8207383	122.9655376	0.47	1.5	1.061	Yolanda	5-Year
64	10.8031021	122.9823122	0.89	0.5	0.152	Frank	5-Year
65	10.8860855	123.0620128	0.03	2	3.881	Rosing	5-Year
66	10.8964686	123.0746461	0.04	4	15.682		
67	10.8974997	123.0724066	1.06	4	8.644		
68	10.8124059	123.0361936	0.64	1	0.13		
69	10.8034359	122.9793452	0.72	4	10.758	Yolanda	5-Year
70	10.8791423	123.0583981	0.67	1.2	0.281	Rosing	5-Year
71	10.9023834	123.0649528	1.09	2.5	1.988	Yolanda	5-Year
72	10.8822398	123.0624208	1.49	1.5	0	Rosing	5-Year
73	10.8784755	123.0607576	2.61	0.4	4.884	Rosing	5-Year
74	10.8977340	123.0723741	0.95	4	9.303		
75	10.8824425	123.0663122	1.32	1.5	0.032	Rosing	5-Year
76	10.8804847	123.061902	1.65	2	0.123	Rosing	5-Year
77	10.9025856	123.0669474	0.04	2.5	6.052	Yolanda	5-Year
78	10.8269903	123.0418844	0.03	1	0.941	Yolanda	5-Year
79	10.8270344	123.0449981	0.05	1	0.903	Yolanda	5-Year
80	10.8824007	123.0659042	2.07	1.5	0.325	Rosing	5-Year
81	10.8976570	123.0724987	0.83	4	10.049		
82	10.8079284	122.989912	0.04	0.4	0.13	Yolanda	5-Year
83	10.7971014	123.0214833	0.31	0.5	0.036	Yolanda	5-Year
84	10.8409021	123.0289808	0.66	3	5.476	Yolanda	5-Year
85	10.7493768	123.0411468	0.28	0.5	0.048	Yolanda	5-Year
86	10.8709947	123.0583187	1.65	2	0.123	Rosing	5-Year

87	10.8792160	123.0582352	1.56	1.2	0.13	Rosing	5-Year
88	10.8059064	122.9839983	0.12	0.4	0.078	Yolanda	5-Year
89	10.8085943	122.9903837	0.03	0.4	0.137	Yolanda	5-Year
90	10.8827478	123.0618713	0.87	2	1.277	Rosing	5-Year
91	10.8789446	123.0572717	1.73	5	10.693	Rosing	5-Year
92	10.8954255	123.0773241	2.23	4	3.133		
93	10.8030993	122.9814549	3.22	0.53	7.236	Frank	5-Year
94	10.7447036	123.0433963	0.36	2.5	4.58	Yolanda	5-Year
95	10.8331552	122.9794406	2.16	0.8	1.85	Ruping	5-Year
96	10.7469312	123.0419776	0.05	3	8.703	Yolanda	5-Year
97	10.8420224	123.0292202	2.19	3	0.656	Yolanda	5-Year
98	10.8774680	123.0641495	2.28	4.5	4.928	Rosing	5-Year
99	10.7471323	123.0429359	0.03	3	8.821	Yolanda	5-Year
100	10.8324345	123.0318621	1.96	3	1.082	Yolanda	5-Year
101	10.7428087	123.0424764	0.6	2	1.96	Yolanda	5-Year
102	10.8329919	122.9776987	3.77	0.8	8.821	Ruping	5-Year
103	10.8040933	122.975445	4.65	4	0.423	Yolanda	5-Year
104	10.8812555	123.0609681	2.26	4	3.028	Rosing	5-Year
105	10.7440439	123.0428741	0.15	2.5	5.523	Yolanda	5-Year
106	10.8814382	123.0610093	1.04	4	8.762	Rosing	5-Year
107	10.7740397	123.0282983	4.01	6	3.96		
108	10.7467423	123.04247	5.36	3	5.57	Yolanda	5-Year
109	10.8331701	122.9782473	6.72	0.8	35.046	Ruping	5-Year
110	10.8765897	123.0573313	2.5	5	6.25	Rosing	5-Year
111	10.8786981	123.0573975	2.58	5	5.856	Rosing	5-Year
112	10.7621257	123.0473867	2.19	6	14.516		
113	10.7477642	123.0423951	0.7	3	5.29	Yolanda	5-Year
114	10.8734402	123.0693874	4.05	5	0.903	Rosing	5-Year
115	10.8420561	123.0292251	3.28	3	0.078	Yolanda	5-Year
116	10.7424522	123.0429321	0.75	2	1.563	Yolanda	5-Year
117	10.7972904	123.0223056	1.35	1	0.123	Yolanda	5-Year
118	10.8783117	123.0635787	14.62	4.5	102.414	Rosing	5-Year
119	10.7978116	123.0197462	0.03	1	0.941	Yolanda	5-Year
120	10.7973967	123.0223081	0.03	1	0.941	Yolanda	5-Year
121	10.7439875	123.0430464	1.04	2.5	2.132	Yolanda	5-Year
122	10.7432756	123.0425609	0.43	2	2.465	Yolanda	5-Year
123	10.8318559	123.0318356	0.16	3	8.066	Yolanda	5-Year
124	10.7442574	123.0431514	0.13	2.5	5.617	Yolanda	5-Year
125	10.8062674	122.9731498	9.04	4	25.402	Yolanda	5-Year
126	10.8263530	123.0475295	0.33	4	13.469	Yolanda	5-Year
127	10.8197632	123.0539296	0.03	4	15.761	Yolanda	5-Year
128	10.8368788	123.030154	8.33	3	28.409	Yolanda	5-Year
129	10.7624313	123.0414373	1.85	6	17.223		
130	10.8343395	123.0338788	0.03	3	8.821	Yolanda	5-Year
131	10.8732163	123.0693074	17.02	5	144.48	Rosing	5-Year
132	10.8737412	123.0686642	6.01	5	1.02	Rosing	5-Year

133	10.7982992	123.0201213	6.82	6	0.672	Yolanda	5-Year
134	10.8757952	123.0684582	6.65	5	2.723	Rosing	5-Year
135	10.8755604	123.0684441	11.1	5	37.21	Rosing	5-Year
136	10.8416175	123.0296208	1.47	6	20.521	Yolanda	5-Year
137	10.7469535	123.0425134	0.04	5	24.602	Yolanda	5-Year
138	10.7482192	123.0421674	0.27	5	22.373	Yolanda	5-Year
139	10.8736916	123.0685925	5.75	5	0.563	Rosing	5-Year
140	10.8775760	123.0669058	4.09	5	0.828	Rosing	5-Year
141	10.7481868	123.0418521	2.29	5	7.344	Yolanda	5-Year
142	10.7474757	123.0423077	0.55	5	19.803	Yolanda	5-Year
143	10.8262138	123.0525017	9.44	6	11.834	Yolanda	5-Year
144	10.7464169	123.0430801	0.03	6	35.641	Yolanda	5-Year
145	10.8326924	122.9796781	0.03	6	35.641	Ruping	5-Year
146	10.8324846	122.9764933	0.03	6	35.641	Ruping	5-Year
147	10.7462262	123.0430731	0.14	6	34.34	Yolanda	5-Year
148	10.8323714	122.9796264	5.09	6	0.828	Ruping	5-Year
149	10.8416893	123.0296057	3.58	6	5.856	Yolanda	5-Year
150	10.7460658	123.0431385	0.04	6	35.522	Yolanda	5-Year
151	10.8393352	123.0289784	0.04	4.5	19.892	Yolanda	5-Year
152	10.7471646	123.0424877	7.86	5	8.18	Yolanda	5-Year
153	10.8324760	122.9765631	2.57	6	11.765	Ruping	5-Year
154	10.8280201	123.006029	0.05	6	35.403	Yolanda	5-Year
155	10.8765129	123.0648032	0.03	5	24.701	Rosing	5-Year
156	10.7472688	123.0422225	0.03	5	24.701	Yolanda	5-Year
157	10.8770316	123.0640068	1.34	5	13.396	Rosing	5-Year
158	10.8758524	123.0683544	1.23	5	14.213	Rosing	5-Year
159	10.8765881	123.0674997	2.1	5	8.41	Rosing	5-Year
160	10.7463471	123.0429809	1.97	6	16.241	Yolanda	5-Year
161	10.7487100	123.0418672	1.76	5	10.498	Yolanda	5-Year
162	10.7920221	123.0304933	0.4	6	31.36	Yolanda	5-Year
163	10.8728952	123.0691076	2.87	5	4.537	Rosing	5-Year
164	10.7939908	123.0238663	1.05	6	24.503	Yolanda	5-Year
165	10.7801591	123.0378342	0.77	0	0.593		
166	10.7778756	123.0353872	0.39	0	0.152		
167	10.8867123	122.9643041	0.03	0	0.001		
168	10.7928147	123.0076466	0.03	0	0.001		
169	10.7473131	123.0423087	0.07	3	8.585	Ruping	5-Year
170	10.7469194	123.0424557	0.06	3	8.644	Ruping	5-Year
171	10.7363056	123.0466406	0.06	0	0.004		
172	10.7950123	123.0238468	0.04	2	3.842	Ruping	5-Year
173	10.8528724	123.0338168	0.03	1.5	2.161	Yolanda	5-Year
174	10.7464741	123.0430363	1.54	1	0.292	Ruping	5-Year
175	10.8743990	123.0684124	0.22	1	0.608	Yolanda	100-Year
176	10.8295811	122.9809262	0.52	0.8	0.078	Seniang	5-Year
177	10.7982413	123.0201024	0.06	3	8.644	Yolanda	5-Year

178	10.7472259	123.0420484	1.15	1	0.023	Ruping	5-Year
179	10.7436752	123.042639	0.46	0	0.212		
180	10.8389751	123.0286488	0.66	2.4	3.028	Yolanda	5-Year
181	10.8189858	122.9946334	0.05	0	0.003		
182	10.7987925	123.0177618	1.89	0	3.572		
183	10.8367046	123.0246309	0.21	0.6	0.152	Yolanda	5-Year
184	10.8262836	123.0439185	0.47	0	0.221		
185	10.8999964	123.0677559	1.77	3	1.513	Ruping	5-Year
186	10.8035585	122.9839467	0.52	3	6.15		
187	10.7463048	123.0428409	1.17	1	0.029	Ruping	5-Year
188	10.8304578	123.0078603	0.1	1.32	1.488	Yolanda	5-Year
189	10.7427267	123.0422202	0.24	0	0.058		
190	10.8048369	122.9764789	0.63	1.4	0.593		
191	10.8395303	123.0290473	0.16	2.4	5.018	Yolanda	5-Year
192	10.8263847	123.0445629	0.35	3	7.023	Seniang	5-Year
193	10.8427025	123.0292577	0.03	1.4	1.877	Pepang	5-Year
194	10.8976114	123.0725508	0.07	1.8	2.993	Ruping	5-Year
195	10.8037305	122.9778268	0.22	0.32	0.01		
196	10.8296330	123.0087845	0.03	1.83	3.24	Yolanda	5-Year
197	10.7919548	123.0234114	0.45	0	0.203		
198	10.8666943	123.0593717	1.17	1	0.029	Ondoy	5-Year
199	10.8881947	123.0453609	0.51	0.45	0.004	Ruping	5-Year
200	10.8530151	123.0572868	0.03	0	0.001		
201	10.8024768	122.999631	0.05	0	0.003		
202	10.7737159	123.0411368	0.27	0	0.073		
203	10.7930588	123.0229719	0.26	0	0.068		
204	10.8172537	122.9611334	0.03	0.82	0.624	Yolanda	5-Year
205	10.8785047	123.0608764	0.05	4	15.603		
206	10.8149153	122.9608633	0.24	0.67	0.185	Yolanda	5-Year
207	10.8797817	123.0602208	0.07	1.5	2.045	Yolanda	5-Year
208	10.89842	123.0730029	0.13	1.2	1.145	Ruping	5-Year
209	10.8249260	122.9566443	0.07	0	0.005		
210	10.880147	123.0587377	0.03	1.5	2.161	Yolanda	5-Year
211	10.8725638	123.0595302	0.04	1.5	2.132		
212	10.8065826	122.9778333	0.24	1.87	2.657		
213	10.841633	123.0218422	0.33	0.45	0.014	Ruping	5-Year
214	10.7409289	123.0448885	0.03	0	0.001		
215	10.8228584	123.0350628	0.25	0.92	0.449	Yolanda	5-Year
216	10.9075185	123.0589124	0.03	1	0.941		
217	10.9089374	123.075239	0.03	1	0.941	Yolanda	5-Year
218	10.9082396	123.0705917	0.03	0	0.001		
219	10.8245567	122.955829	0.18	0	0.032		
220	10.8263998	123.0274815	0.27	0.5	0.053	Ruping	5-Year
221	10.9034033	123.0651129	0.07	1	0.865		
222	10.8263358	123.0272037	0.03	1.35	1.742	Yolanda	5-Year

223	10.8801106	123.0249954	0.1	0	0.01		
224	10.8792564	123.0173145	0.03	0	0.001		
225	10.8868181	123.0171978	0.13	0	0.017		
226	10.7978218	123.0070882	0.03	0	0.001		
227	10.8374696	123.0066897	0.06	0.64	0.336		
228	10.8841358	123.0600484	0.08	0	0.006		

Annex 12. Educational Institutions Affected by Flooding in Malogo Floodplain

Table A-12.1. Educational Institutions affected by flooding in the Malogo floodplain – EB Magalona Municipality

Negros Occidental				
Enrique B. Magalona				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Alacaygan Elementary School	Alacaygan			
Alicaygan Day Care Center	Alacaygan			
Alicanter Elementary School	Alicante			
BATEA DAY CARE CENTER	Batea			
BATEA ELEMENTARY SCHOOL	Batea			
BATEA KINDER, GRADE 1 ES	Batea			
Consing Day Care Center	Consing			
Dalinson Elementary School	Consing		Medium	High
EB Magalona National High School - Consing Extension*	Consing	Low	Low	Medium
Jose M. Consing Memorial Elementary School	Consing			
Cudangdang Elementary School	Cudangdang			
Acienda Teresa Elementary School	Damgo			
Barangay Damgo Day Care Center	Damgo			
Nicolas L. Jalandoni Memorial School	Damgo			
Nicolas L. Jalandoni Memorial School Covered Court	Damgo			
MANTA-ANGAN ELEMENTARY SCHOOL	Manta-Angan			
Nanca Day Care Center	Nanca			
Nanca Elementary School	Nanca			
Sitio Pang Pang Day Care Center	Tanza			Medium

Table A-12.2. Educational Institutions affected by flooding in the Malogo floodplain – Silay City

Silay City				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
E. Lopez National High School	Alacaygan	Low	Low	Low

Table A-12.3. Educational Institutions affected by flooding in the Malogo floodplain – Victorias City

Victorias City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Baptist School	Barangay II	Medium	Medium	High
Don Felix	Barangay III			
Jack & Jill	Barangay IV			
Victorias Elem. School 1 & 2	Barangay IV			
Brgy I Daycare	Barangay IX		Low	Medium
Barangay Day Care Center	Barangay V			
Jack & Jill	Barangay V			
Victorias National High School	Barangay V		Low	Low

Victorias North Elementary School	Barangay V			
Barangay VI Day Care Center	Barangay VI	Medium	Medium	Medium
Pinanobol Day Care Center	Barangay VI		Low	Medium
Salvacion Elementary School	Barangay VI		Low	Medium
Victorias Christian Learning Center	Barangay VI	Low	Medium	Medium
Collegio De Sta. Ana De Victorias	Barangay VI-A			
Collegio De Sta. Ana High School Building	Barangay VI-A			
Salvacion Elementary School	Barangay VI-A		Low	Medium
Victorias Christian Learning Center	Barangay VI-A	Low	Medium	Medium
Gaston Day Care Center	Barangay VIII			
JL Suarez Elementary School	Barangay VIII			
Sangay Day Care Center	Barangay VIII			
Victorias National High school Gaston Extension	Barangay VIII			
Estado Elementary School	Barangay X			
Estado National High School	Barangay X			
Our Lady of Guadalupe Church	Barangay X			
Barangay XII Day Care Center	Barangay XII			
La Consolacion Elementary School	Barangay XII			
Nasipunan Gloria Day Care Center	Barangay XII			
Romana Elementary School	Barangay XII			
Daan Banwa Elementary School	Barangay XIII			
Pasil Elementary School	Barangay XIII	Low	Low	Medium
Villa Miranda Day Care Center	Barangay XIII	Low	Medium	Medium
Villa Miranda Elementary School	Barangay XIII	Low	Medium	Medium
Brgy XIV Daycare Center	Barangay XIV			
Central Philippines State University	Barangay XIV			
Negros Occidental National Science High School	Barangay XIV			
Santiago Franco Memorial Elementary School	Barangay XIV			
Barangay XIX Daycare Center	Barangay XIX	Medium	Medium	Medium
Amichole Private School	Barangay XIX-A		Medium	Medium
BRGY 18 DAY CARE CENTER	Barangay XIX-A			Low
Cane Town Daycare Center	Barangay XIX-A	Medium	Medium	High
ST JOSEPH COTTOLENGGO DAY CARE CENTER	Barangay XIX-A			Low
St. La Salle Victorias School	Barangay XIX-A		Low	Low
Victorias National High School Ext.	Barangay XIX-A	Medium	Medium	High
Victorias National High School Ext.	Barangay XIX-A	Low	Medium	High
Barangay XIX Daycare Center	Barangay XV	Medium	Medium	Medium
DON BOSCO TECHNICAL INSTITUTE SR. HS	Barangay XV			
BRGY 15 DAY CARE CENTER	Barangay XV-A		Low	Medium

DON BOSCO TECHNICAL INSTITUTE SR. HS	Barangay XV-A			
VICMICO(Victoria Milling Corp) ELEMENTARY SCHOOL	Barangay XV-A			Low
WOMEN'S CLUB NURSERY CENTER	Barangay XVI		Low	Low
Cuay Cong Day Care Center	Barangay XX			
Laura Viconia Foundation School	Barangay XX			
P.A. Cuay Cong Elementary School	Barangay XX			
Victorias National High School Cuay Cong Extension*	Barangay XX			
Marantha Christian School	Barangay XXI			

Annex 13. Medical Institutions Affected by Flooding in Malogo Floodplain

Table A-13.1. Medical Institutions affected by flooding in the Malogo Floodplain – EB Magalona Municipality

Negros Occidental				
Enrique B. Magalona				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Alicante Health Center	Alicante			
BRGY HEALTH CENTER	Batea			
Consing Health Center	Consing			
Nanca Health Center	Nanca			

Table A-13.2. Medical Institutions affected by flooding in the Malogo Floodplain – Victorias City

Victorias City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy Health Center	Barangay I			Medium
St. Jude Laboratory	Barangay I	Low	Medium	High
Clinic	Barangay II			
St. Jude Laboratory	Barangay II		Low	Medium
City Health Office	Barangay III			
Health Center	Barangay III			
Well Family	Barangay III			
City Health Office	Barangay IV			
Clinic	Barangay IV			
Health Center	Barangay IV			
Victorias Kaayong Lawas Foundation	Barangay IV		Medium	High
Barangay Health Center	Barangay V			
Javelosa Clinic	Barangay VI-A		Low	Medium
Barangay VII Health Center	Barangay VII			
Victorias Kaayong Lawas Foundation	Barangay VII	Low	Medium	High
Barangay XIII Health Center	Barangay XIII			
Villa Miranda Health Center	Barangay XIII	Medium	Medium	Medium
BRGY 15 BRGY HEALTH CENTER	Barangay XV-A			
BRGY 16 HEALTH CENTER	Barangay XVI-A	High	High	High

Annex 14. UPC Phil-LiDAR 1 Team Composition

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