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

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SIPALAY RIVER

Enrico C. Paringit, Dr. Eng., Dr. Jonnifer Sinogaya, and Chito Patino

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) and the Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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 22 river basins in the Western Visayas Region. The university is located in Cebu City in the province of Cebu, Visayas.

1.2 Overview of the Sipalay River Basin

The Sipalay River Basin is located in the province of Negros Occidental, located at the southwest of Negros Island. The floodplain and drainage area of 98.72 km2 and 83.573 km2, respectively, covers the municipalities of Candoni and Hinobaan, and the city of Sipalay.

The Sipalay River Basin covers the majority of Sipalay City, Municipalities of Candoni and Cauayan in Negros Occidental, and two (2) municipalities in Negros Oriental. The Department of Environment and Natural Resources (DENR) River Basin Control Office identified the basin to have a drainage area of 327 km^2 and an estimated 416 million cubic meter (MCM) annual run-off (RBCO, 2016).

Its main stem, Sipalay River, is part of the twenty-two (22) river systems in the Western Visayas Region. According to the 2015 national census of the National Statistics Office (NSO), a total of 19,312 persons are residing within the immediate vicinity of the river, which is distributed among six (6) barangays in Sipalay City (NSO, 2015).

The main industry of Sipalay City focuses on mining, since the city has one of the largest copper mines in the country. Agriculture and fisheries are also among the other industries that give livelihood to the locals. Lowland agriculture consists mainly of rice and corn farming, with fruit production being gradually developed in the uplands. Moreover, the Sipalay River has been tapped as the main irrigation system in the city by the National Irrigation Administration (Source: http://www.sipalaycity.gov.ph/about-the-city/industries/).

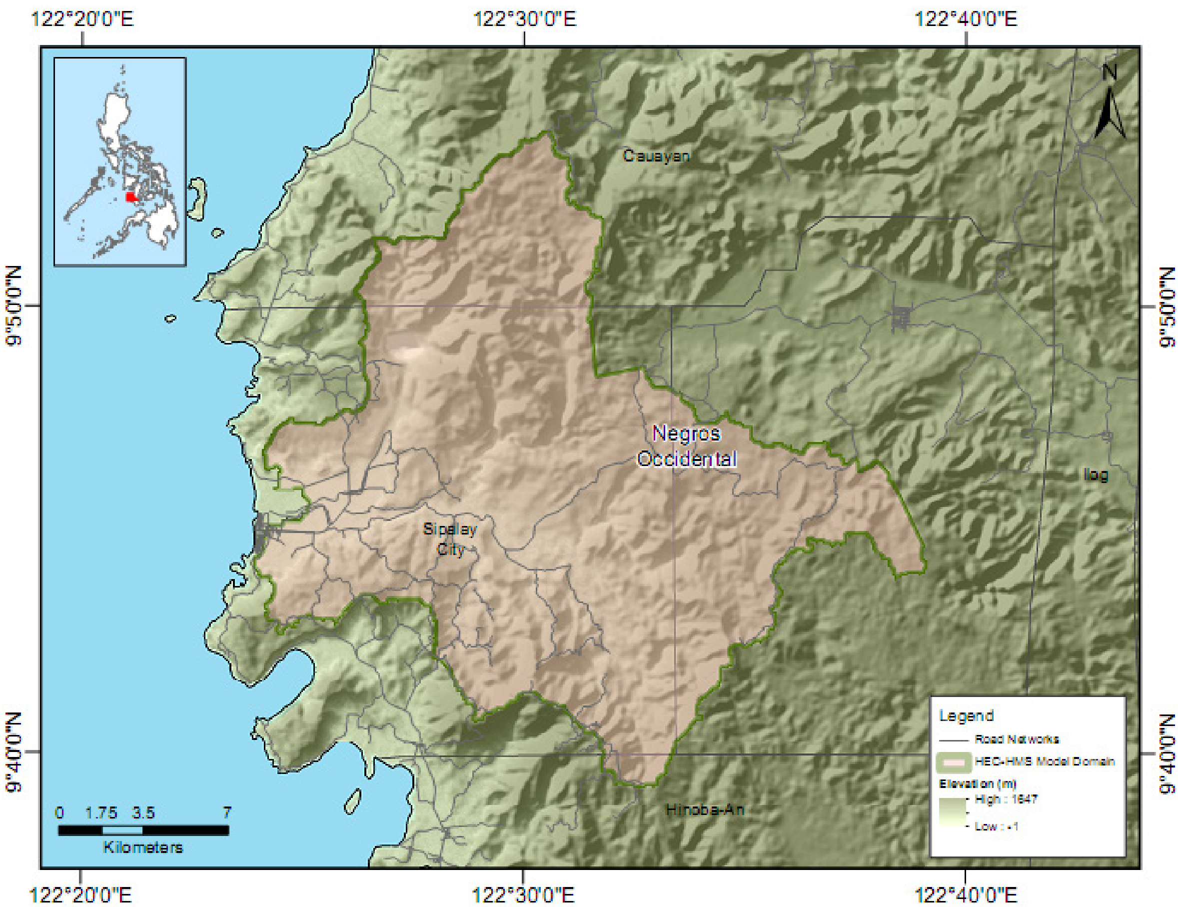

Figure 1. Map of the Sipalay River Basin (in brown)

On October 2013, flooding caused by heavy rains brought by the southwestern monsoon, locally known as *habagat*, affected 9,157 families in southern Negros Occidental, amongthem being Sipalay City. The flooding damaged several rice fields and other properties, reported to be valued at around PHP5.337 million (Source: http://newsinfo.inquirer.net/502337/flooding-leaves-2-dead-5-missing-in-negros-oriental).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SIPALAY FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Sipalay Floodplain, the Data Acquisition Component (DAC) created flightplans within the delineated priority area for the Sipalay floodplain in Negros Occidental. These missions were planned for fourteen (14) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time using the Gemini and Aquarius sensors (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 2shows the flight plan for the Sipalay floodplain survey.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK53A	600	30	36	70	50	120	5
BLK53B	600	30	36	70	50	120	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK53C	1200	30	40	200	50	130	5

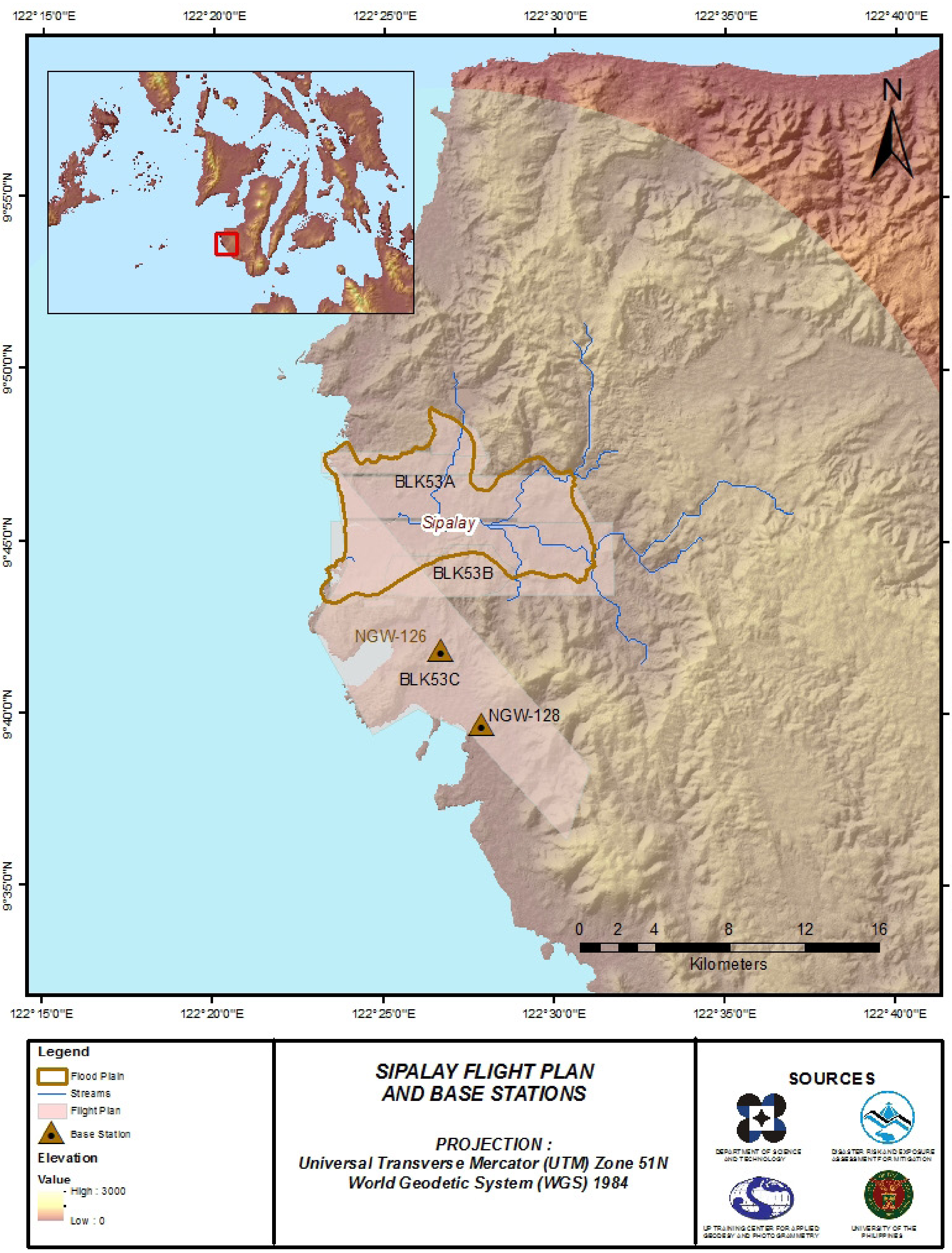
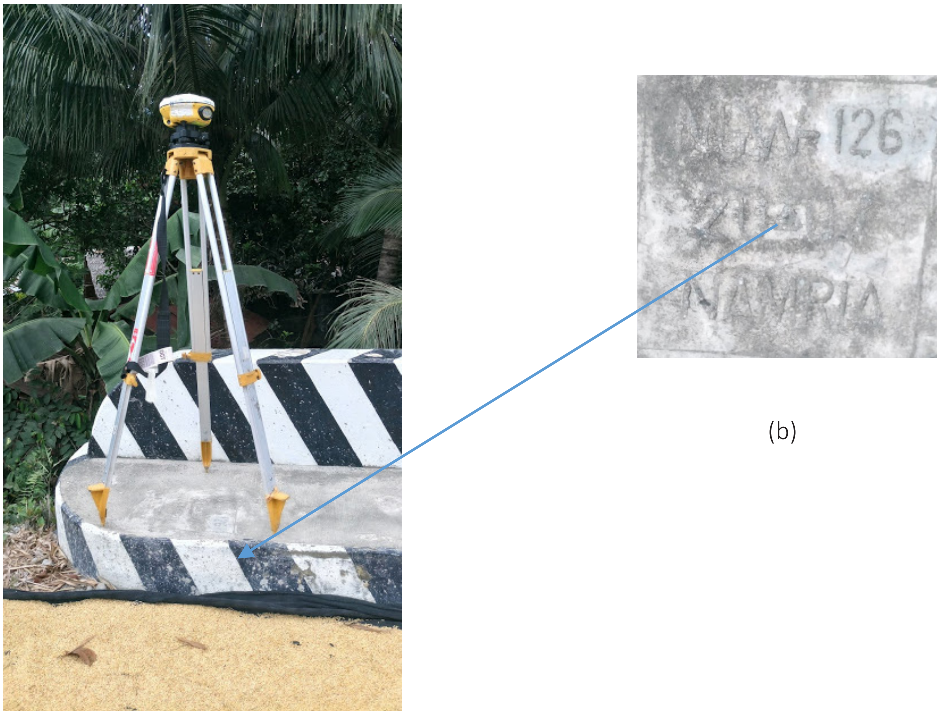


Figure 2. Flight plan and base station used to cover Sipalay Floodplain survey.

2.2 Ground Base Stations

The field team for this undertaking was able to recover two (2) NAMRIA reference points: NGW-126 and NGW-128, which are of second (2^{nd}) order accuracy. The certification for the NAMRIA reference points are found in Annex 2, while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey, held on October 31, 2014 and January 28-29, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. The flight plans and locations of base stations used during the aerial LiDAR acquisition in Sipalay floodplain are shown in Figure 2. The composition of the project team is shown in Annex 4.

Figure 3 to Figure 4 show the recovered NAMRIA control stations within the area.Table 3 to Table 4present the details onthe following NAMRIA control stations and established points.Table 5enumeratesthe list of all ground control points occupied during the acquisition with the corresponding dates of utilization.



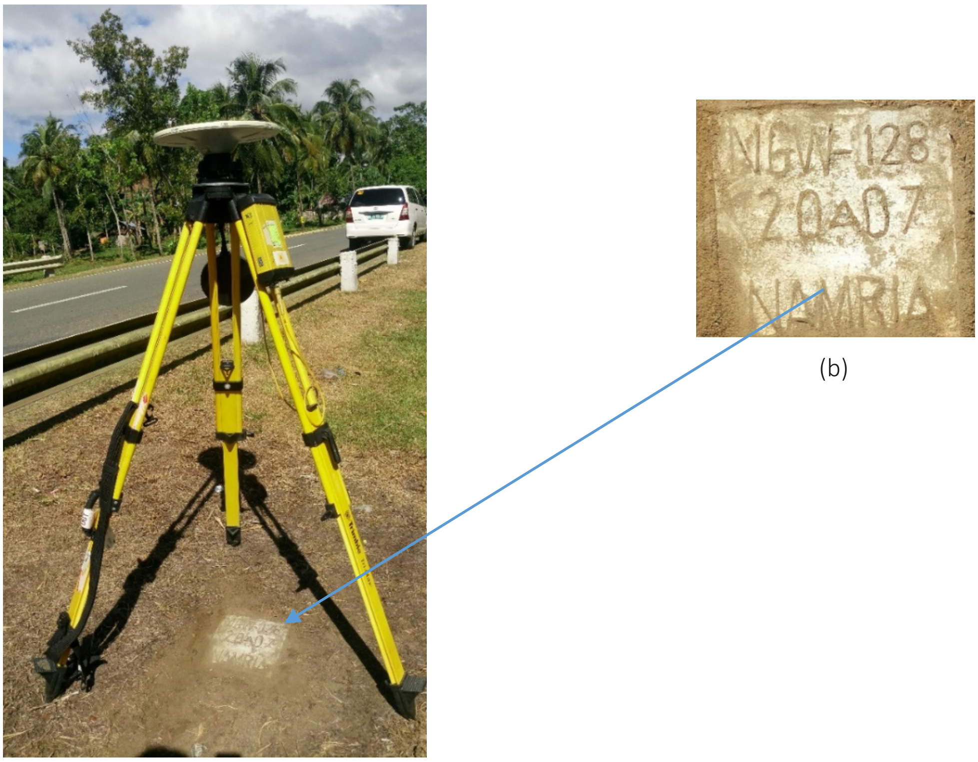
(b)

(a)

Figure 3. GPS set-up over NGW-126 at Maricalum Bridge, Sipalay, Negros Occidental (a), and NAMRIA reference point NGW-126 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGW-126 used as base station for the LiDAR Acquisition.

Station Name	NGW-126	
Order of Accuracy	2nd	
Relative Error (Horizontal Positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 53’ 56.09927”
	Longitude	122° 26’ 33.87232”
	Ellipsoidal Height	20.29100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	438,848.628 m
	Northing	1,072,482.031 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9° 41’ 52.00368” North
	Longitude	122° 26’ 39.18513” East
	Ellipsoidal Height	79.82600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	438,870.03 meters
	Northing	1,072,106.54 meters



(a) (b)

Figure 4. GPS set-up over NGW-128 at the road beside the headwall in Barangay Talagacay, Hinobaan, Negros Occidental (a), and NAMRIA reference point NGW-128 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point NGW-128 used as base station for the LiDAR Acquisition.

Station Name	NGW-128	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 39' 46.23234" 122° 27' 45.10885" 67.85800 m
Grid Coordinates, PTM	Easting Northing	441,013.849 m 1,068,488.805 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 39' 42.14773" 122° 27' 5042475" 67.85800 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	441,034.50 m 1,068,114.82 m

Table 5. Ground Control Points used during LiDAR Data Acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
October 31, 2014	7588G	2BLK53C304A	NGW-126
January 28, 2016	10072AC	3BLK53B028A	NGW-126 and NGW-128
January 29, 2016	10075AC	3BLK53S029B	NGW-126 and NGW-128

2.3 Flight Missions

A total of three (3) flight missions were conducted to complete the LiDAR data acquisition of theSipalay floodplain, amounting to twelve hours and twenty-four minutes (12+24) of flying time for aircrafts RP-C9022 and RP-C9322. All missions were acquired using the Aquarius and GeminiLiDAR systems. Table 6 shows the total area of actual coverage per mission and the corresponding flying hoursfor each mission, while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight Missions for LiDAR Data Acquisition in Sipalay Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
October 31, 2014	7588G	97.93	80.29	11.99	68.30	NA	4	5
January 28, 2016	10072AC	58.48	76.30	40.04	36.26	NA	4	15
January 29, 2016	10075AC	103.54	26.37	12.56	13.81	NA	4	4
Total		259.95	182.96	64.59	118.37	NA	12	24

Table 7. Actual Parameters used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View (θ)	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)	Average Turn Time (Minutes)
October 31, 2014	7588G	1200	30	40	200	50	120	5
January 28, 2016	10072AC	500	30	36	200	45	120	5
January 29, 2016	10075AC	500	60	36	50	40	125	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Sipalay floodplain (See Annex 7). It is located in the province of Negros Occidental, with the floodplain situated within the City of Sipalay. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 8. The actual coverage of the LiDAR acquisition for Sipalay floodplain is presented inFigure 5.

Table 8 . List of municipalities and cities surveyed in Negros Occidental

Province	Municipality/City	Area of Municipality/ City	Total Area Surveyed	Percentage of Area Surveyed
Negros Occidental	Hinoba-An	464.36	12.50	2.69%
	Sipalay City	326.67	121.10	37.07%
Total		791.03	133.6	16.89%

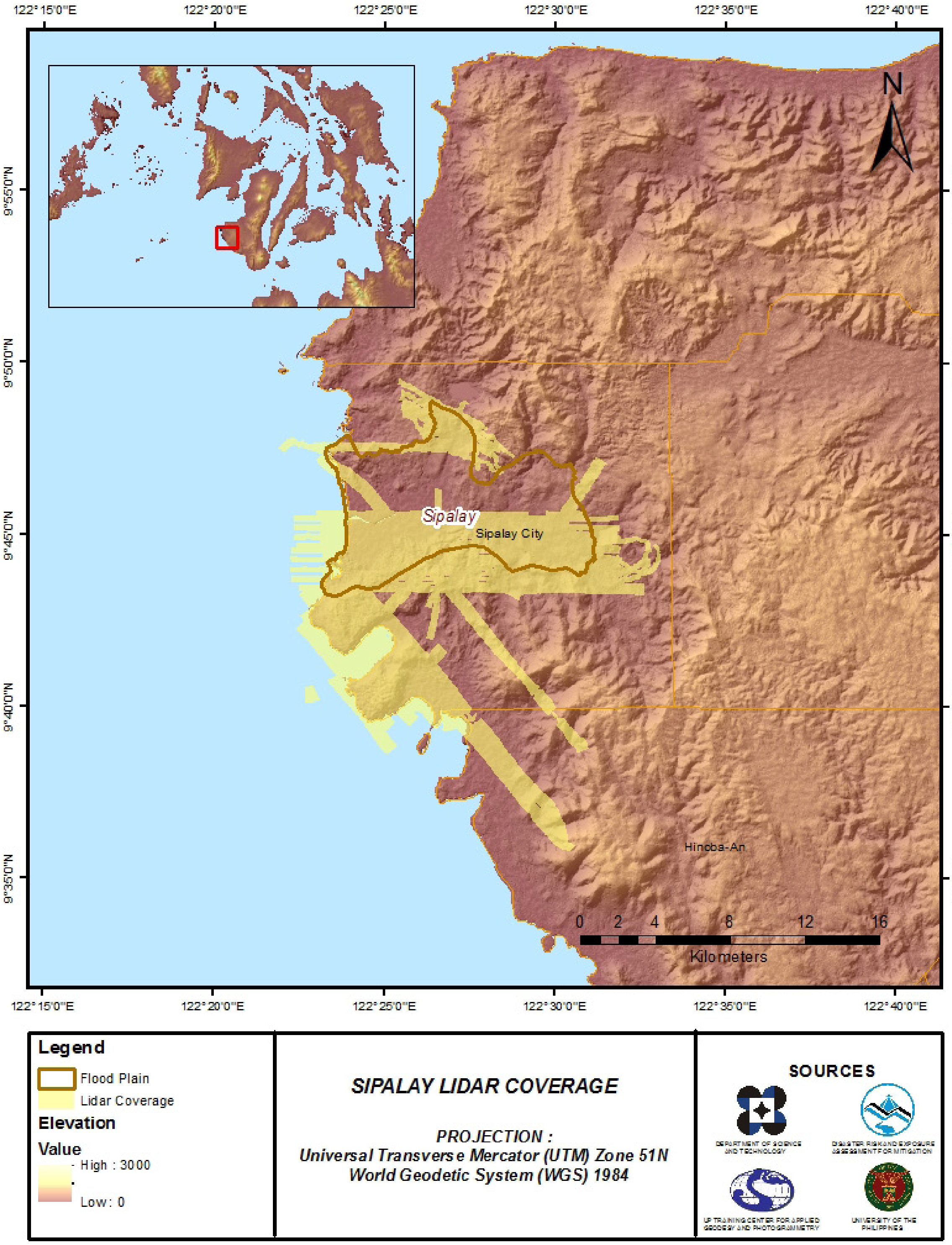


Figure 5. Actual LiDAR survey coverage of the Sipalay floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SIPALAY FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component 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, vertical and horizontal accuracies, were met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model. Using the elevation of points gathered in the field, the LiDAR-derived digital models 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 are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds, and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 6.

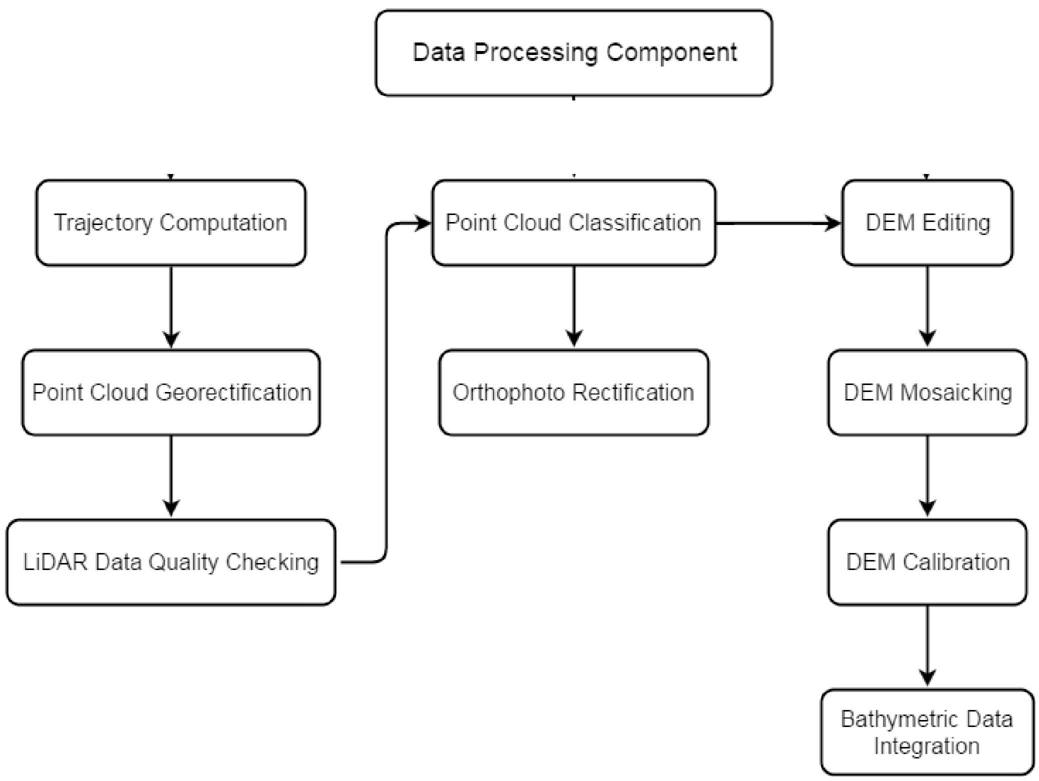


Figure 6 . Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for the Sipalay floodplain can be found in Annex5. Missions flown during the first survey conducted in October 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system, while missions acquired during the second survey in January 2016 were flown using the Aquarius system, and lastly, the third survey was done on May 2016 using the Leica System over Sipalay, Negros Occidental. The Data Acquisition Component (DAC) transferred a total of 33.44 Gigabytes of Range data, 925 Megabytes of POS data, 52.49 Megabytes of GPS base station data, and 96.3 Gigabytes of Image data to the data server from October 31, 2014 up to January 30, 2016 for Optech LiDAR systems. Anda total of 390.9 Gigabytes of Raw Laser data, 452 Megabytes of GNSSIMU data, 62.6 Megabytes of base station data and 34.9 Gigabytes of RCD30 raw image data were transferred on May 16, 2016 for Leica LiDAR system. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sipalay was fully transferred on June 21, 2016, as indicated on the Data Transfer Sheets for the Sipalay floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metricparameters of the computed trajectory for flight 7588G, one of the Sipalayflights, which arethe North, East, and Down position RMSE values are shown in Figure 7. 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 onOctober 31, 2014 00:00AMon that week. The y-axis is the RMSE value for that particular position.

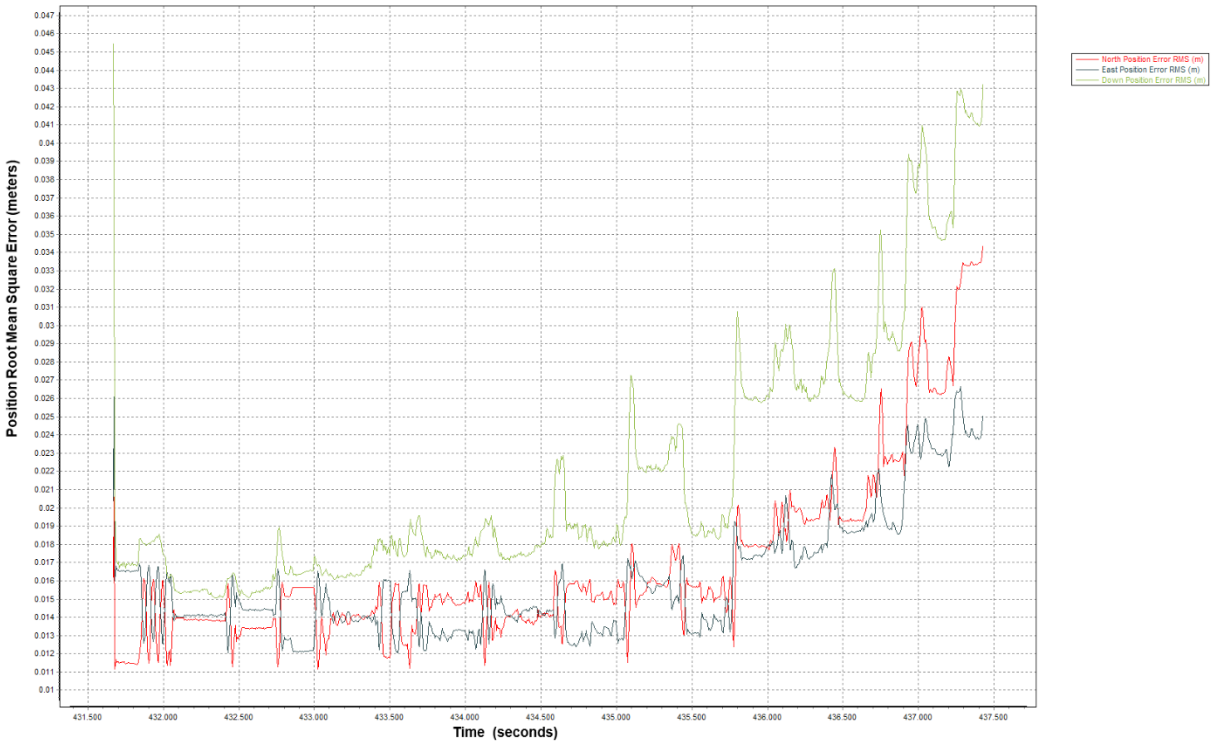


Figure 7. Smoothed Performance Metric Parameters of Sipalay Flight 7588G.

The time of flight was from 431500 seconds to 437500 seconds, which corresponds to morning of October 31, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting tocomputefor the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaks at 3.50 centimeters, the East position RMSE peaks at 2.70 centimeters, and the Down position RMSE peaks at 4.40 centimeters, which are within the prescribed accuracies described in the methodology.

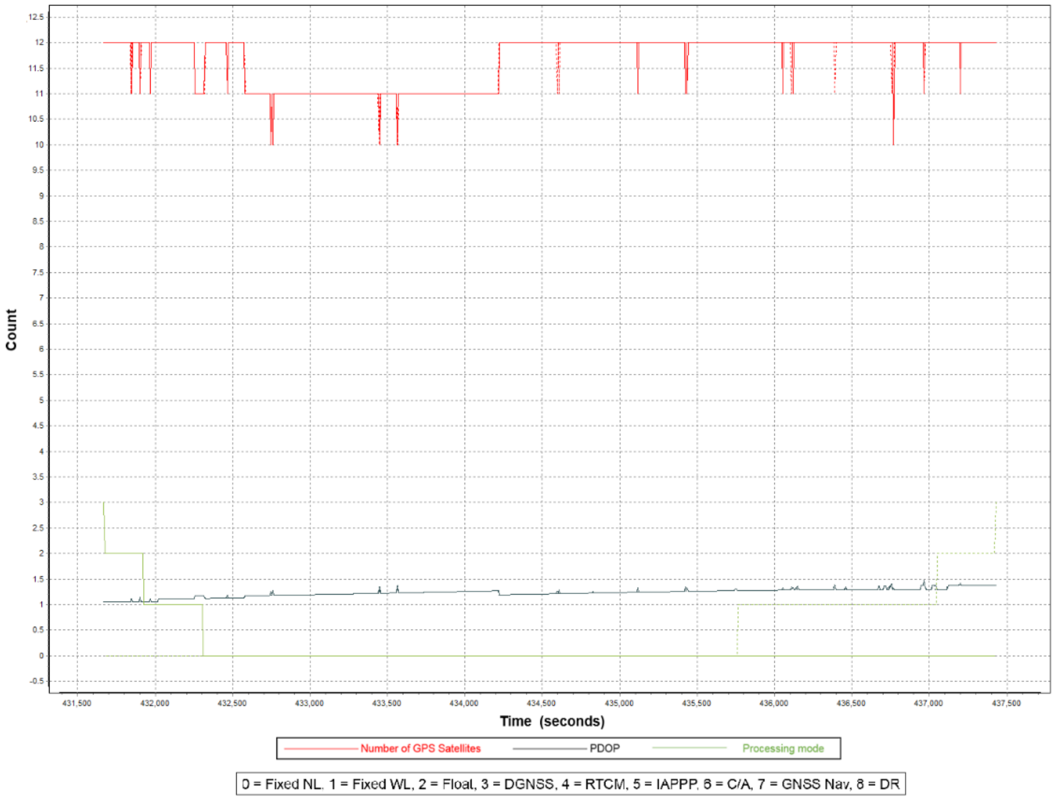


Figure 8. Solution Status Parameters of Sipalay Flight 7588G.

The Solution Statusparameters of flight 7588G, one of the Sipalayflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to six(6). Majority of the time, the number of satellites tracked was between ten (10) and twelve (12). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode stayed at the value of zero (0) for majority of the survey with some peaks up to two (2), attributed to the turns performed by the aircraft. The value of zero (0) corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sipalay flights is shown in Figure 9.

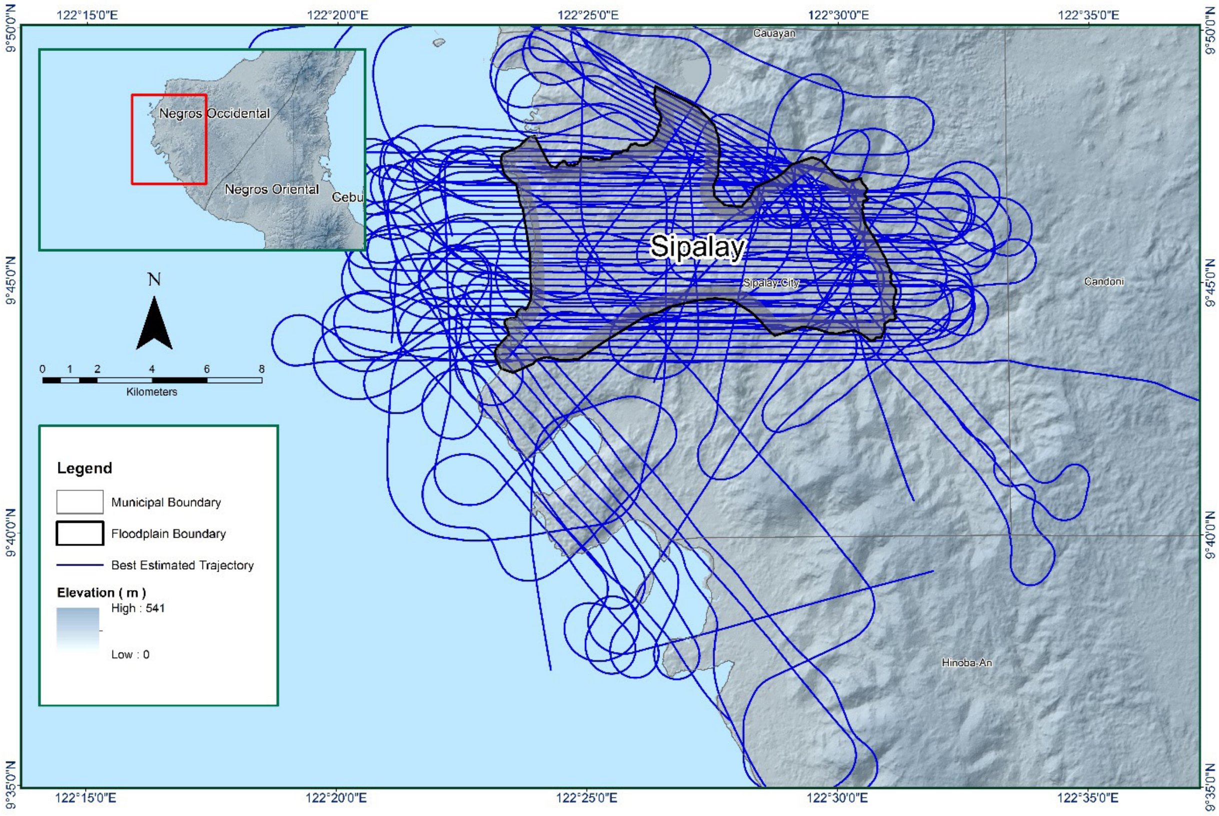


Figure 9. Best Estimated Trajectory for Sipalay floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains eighty-three (83)flight lines, with each flight line containing one (1) channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Sipalay floodplain are given in Table 9.

Table 9. Self-Calibration Results values for Sipalay flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000327
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000972
GPS Position Z-correction stdev	(<0.01meters)	0.0086

Optimum accuracy wasobtained for all Sipalay flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Mission Summary Reports in Annex 8.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over the Sipalay Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

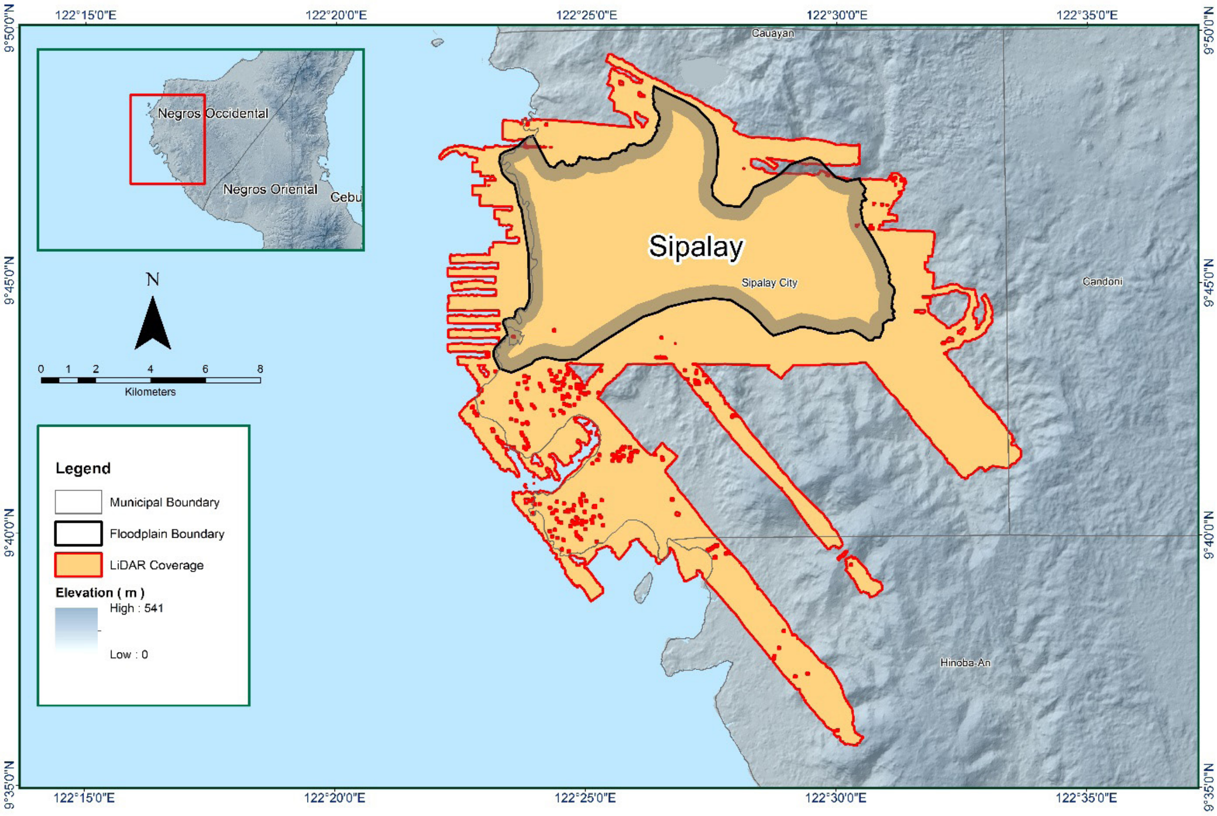


Figure 10. Boundaries of the processed LiDAR data over Sipalay Floodplain.

The total area covered by the Sipalay missions is 275.16 sq.km that is comprised of five (5) flight acquisitions grouped and merged into five (5) blocks, as shown in Table 10.

Table 10. List of LiDAR blocks for Sipalay floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dumaguete_Blk53C	7588G	70.22
Dumaguete_Reflights_Blk53D	10072AC	65.71
Dumaguete_Reflights_Blk53C	10153L	68.78
Dumaguete_Reflights_Blk53D_supplement	10047AC	43.94
Dumaguete_Reflights_Blk53D_additional	10075AC	26.51
TOTAL		275.16

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 11. Since the Gemini and Aquarius systemsboth employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Leica system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

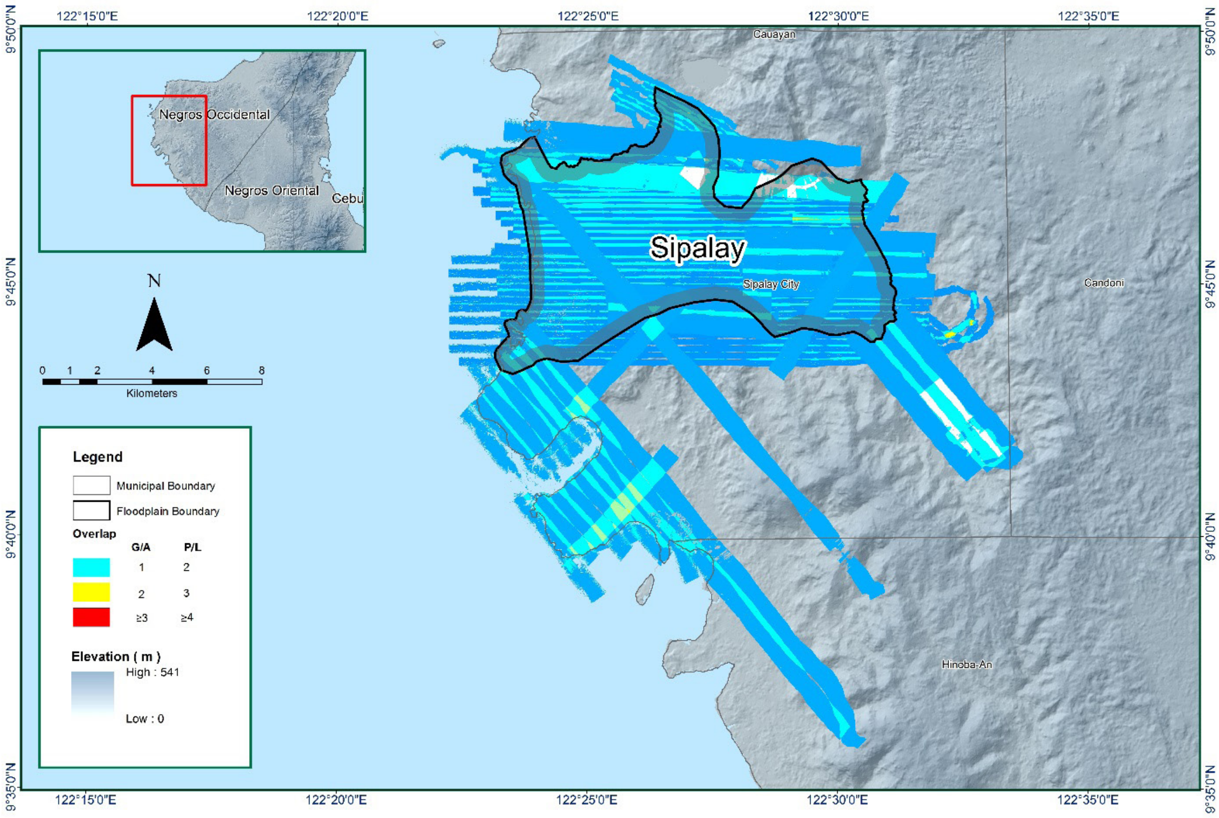


Figure 11. Image of data overlap for Sipalay floodplain.

The overlap statistics per block for the Sipalay floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.74% and 38.49% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure B-7. It was determined that all LiDAR data for the Sipalay floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.75 points per square meter.

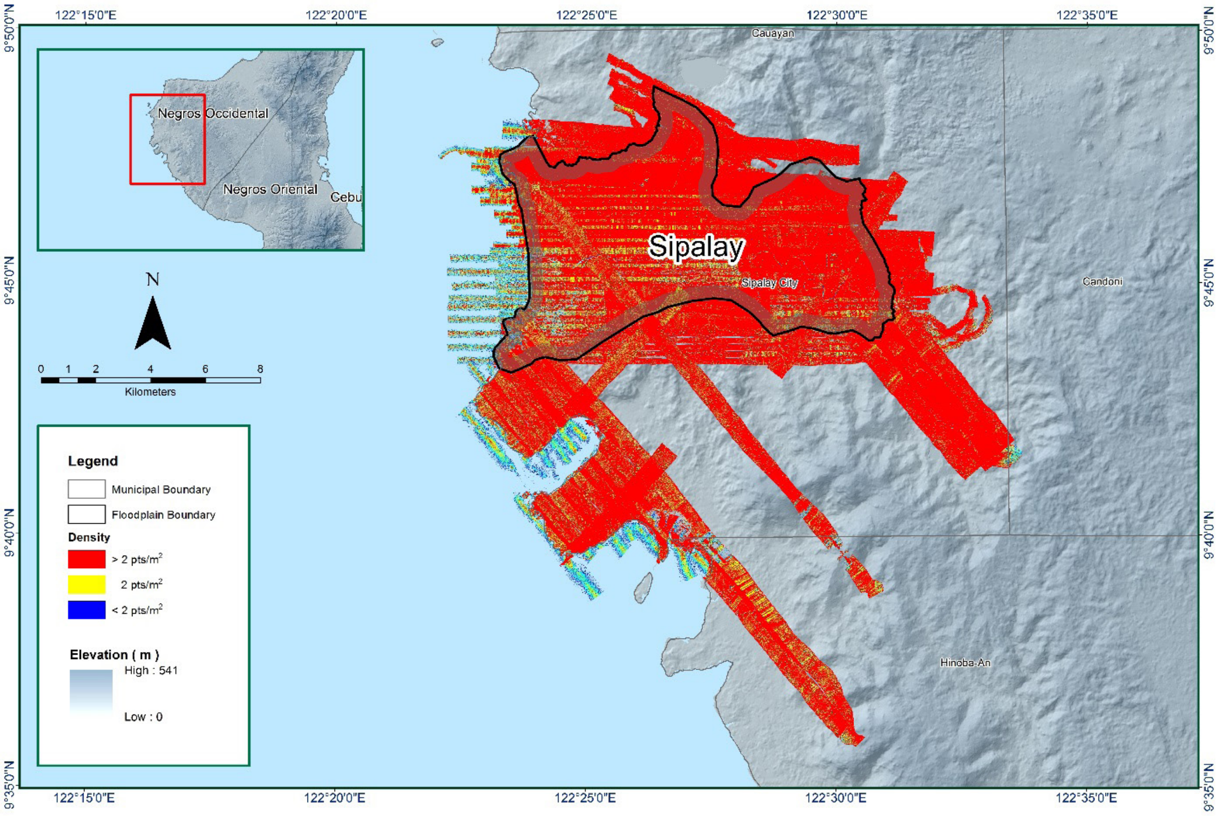


Figure 12. Pulse density map of merged LiDAR data for Sipalay floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

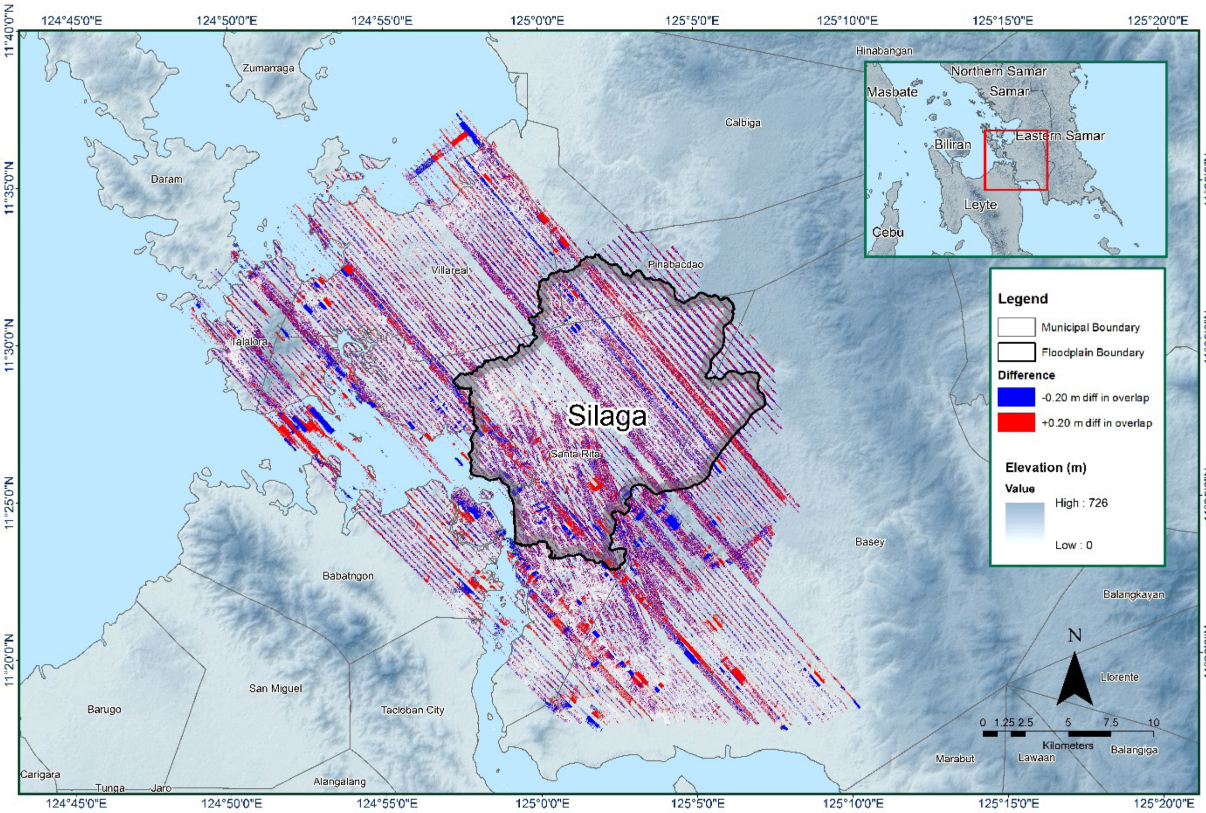


Figure 13. Elevation difference map between flight lines for Sipalay floodplain survey.

A screen capture of the processed LAS data from Sipalay flight 7588G loaded in QT Modeler is shown in Figure 14. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

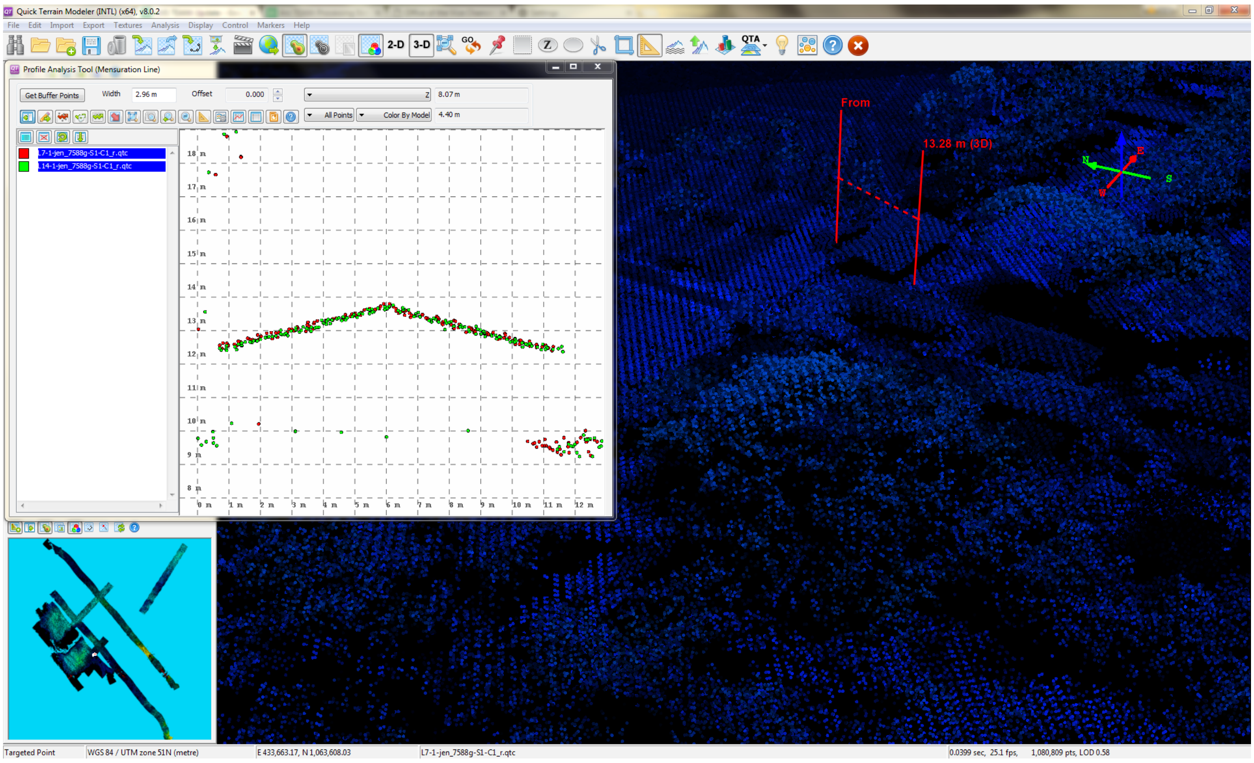


Figure 14. Quality checking for Sipalay flight 7588G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Sipalay classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	178,925,315
Low Vegetation	144,945,652
Medium Vegetation	239,039,998
High Vegetation	509,399,118
Building	15,186,793

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sipalay floodplain is shown in Figure 15. A total of 542 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 551.31 meters and 51.21 meters respectively.

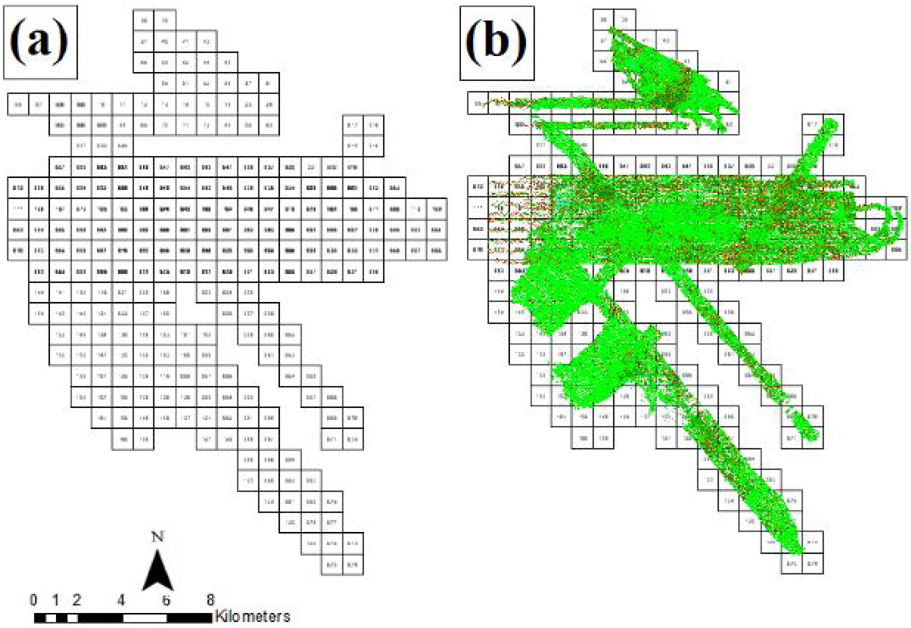


Figure 15. Tiles for Sipalay floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 16. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

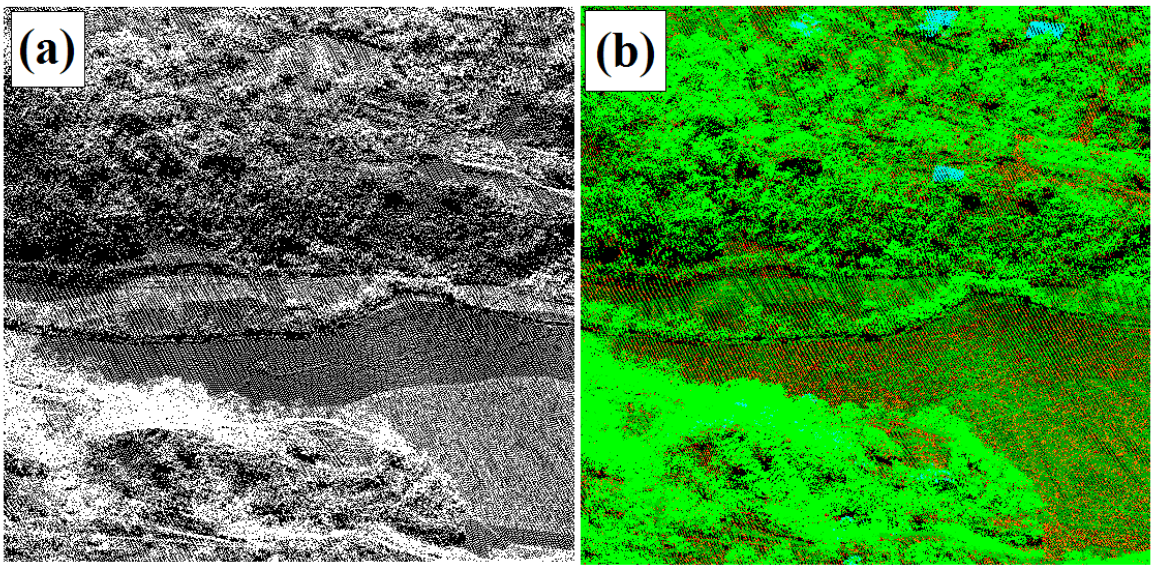


Figure 16. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 17. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

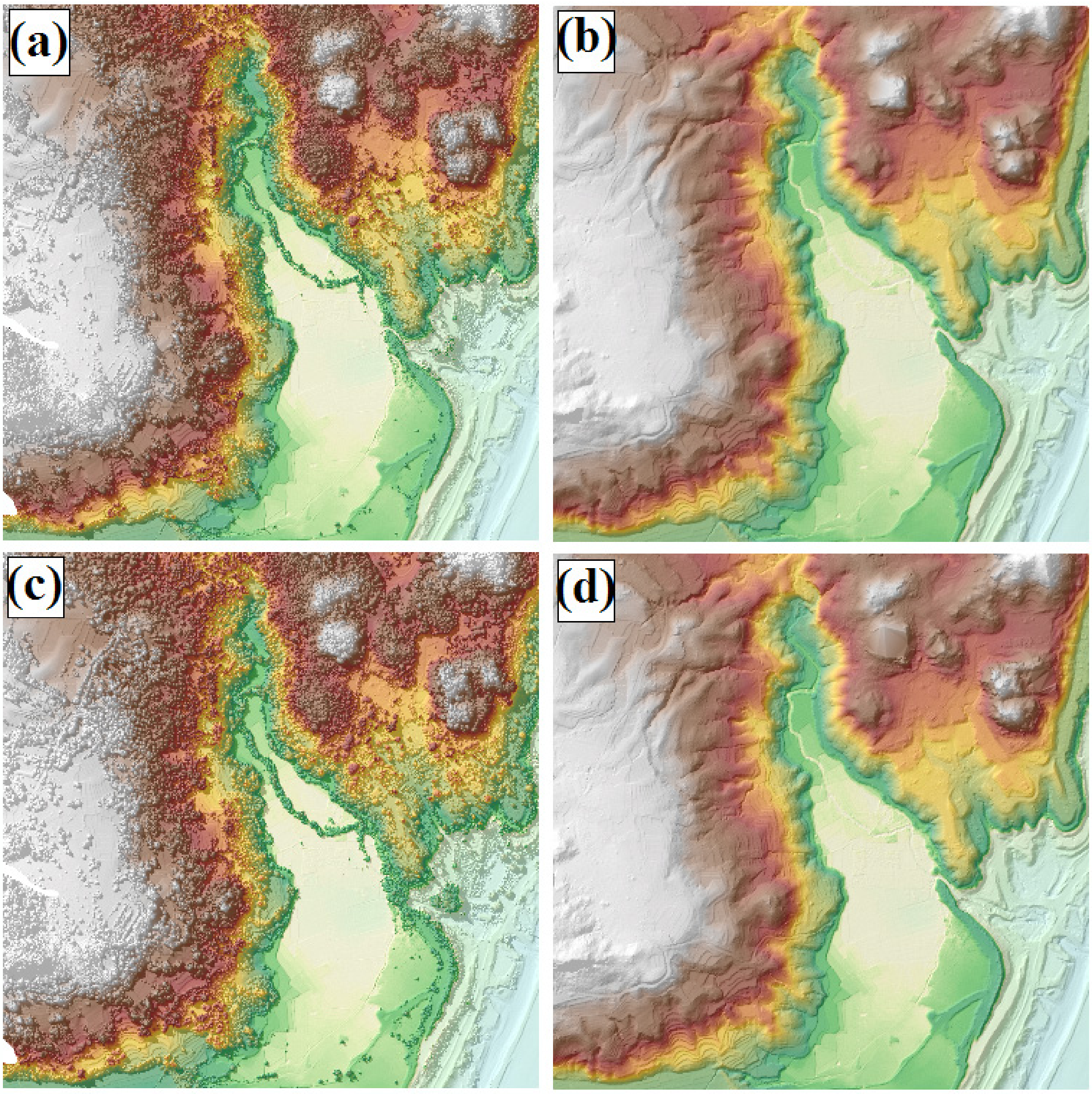


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sipalay floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,171km by 1km tiles area covered by theSipalay floodplain is shown in Figure 18. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sipalay floodplain survey attained a total of 72.77 sq.km in orthophotogaph coverage, comprised of 401 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

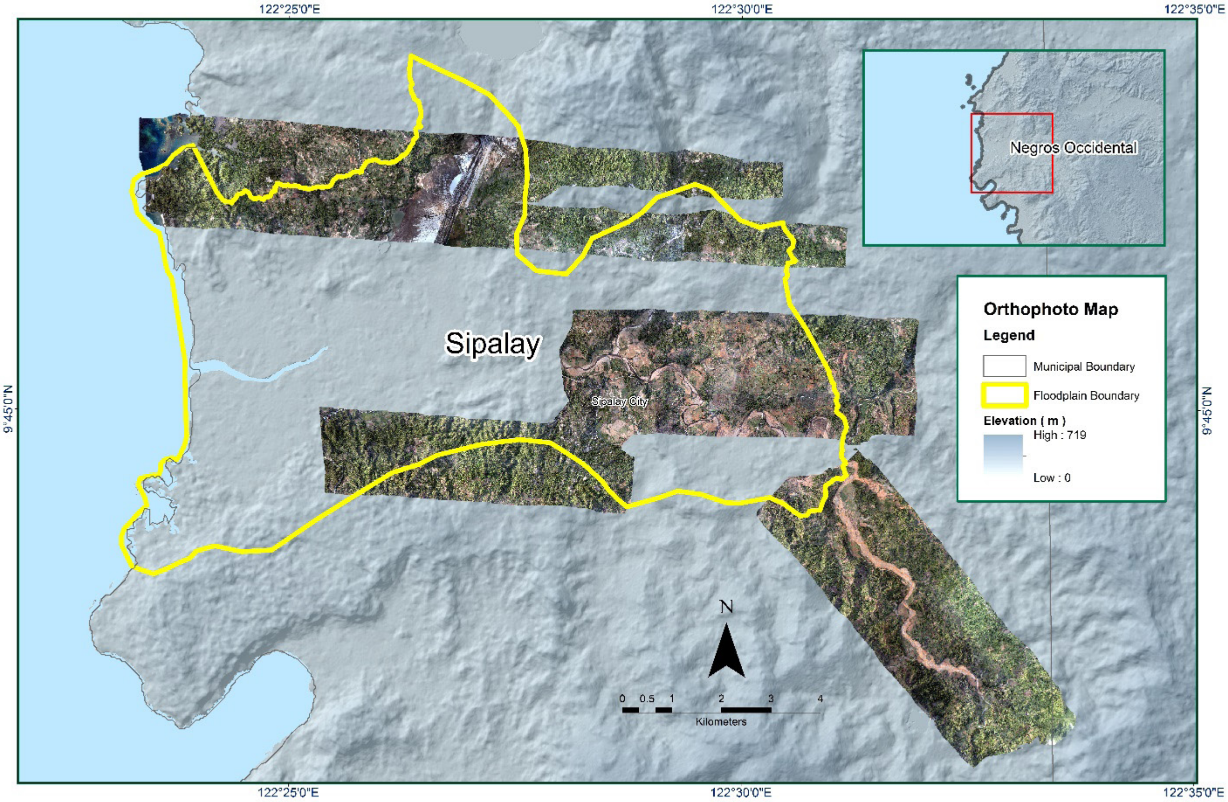


Figure 18. Sipalay floodplain with available orthophotographs.

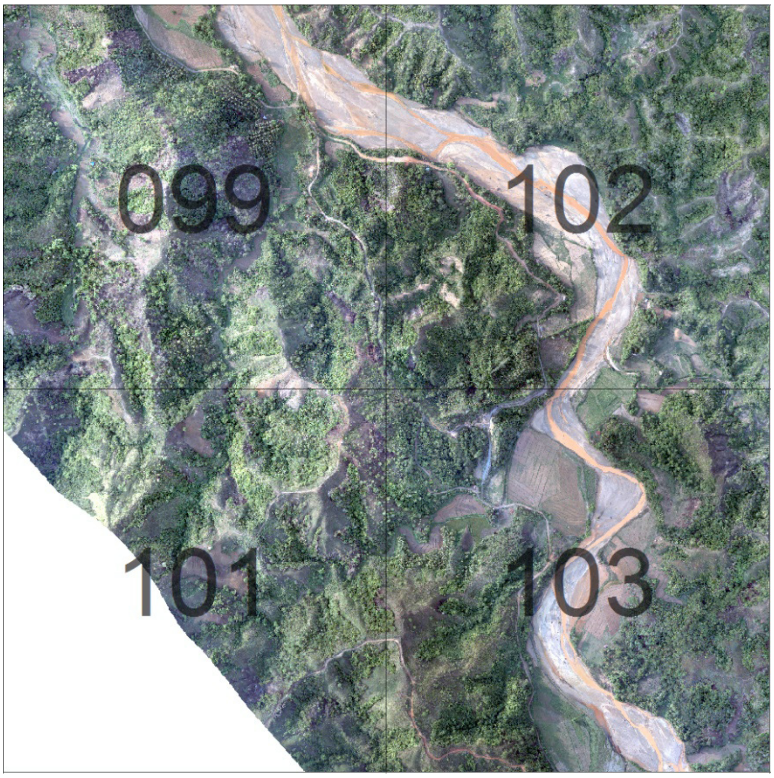


Figure 19. Sample orthophotograph tiles for Sipalay floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for the Sipalay floodplain. These blocks are composed of Dumaguete reflights, with a total area of 275.16 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Dumaguete_reflight_Blk53D	65.71
Dumaguete_reflight_Blk53D_supplement	43.94
Dumaguete_reflight_Blk53D_additional	26.51
Dumaguete_reflight_Blk53C	68.78
Dumaguete_Blk53C	70.22
TOTAL	275.16sq. km

Portions of DTM before and after manual editing are shown inFigure 20. It shows that the paddy field (Figure 20a) was misclassified and removed during classification process and was retrieved to complete the surface (Figure 20b). The bridges (Figure 20c) impeded the flow of water along the river and was removed (Figure 20d) in order to hydrologically correct the river. Another example is a road that was misclassified (Figure 20e) and was retrieved through manual editing (Figure 20f).

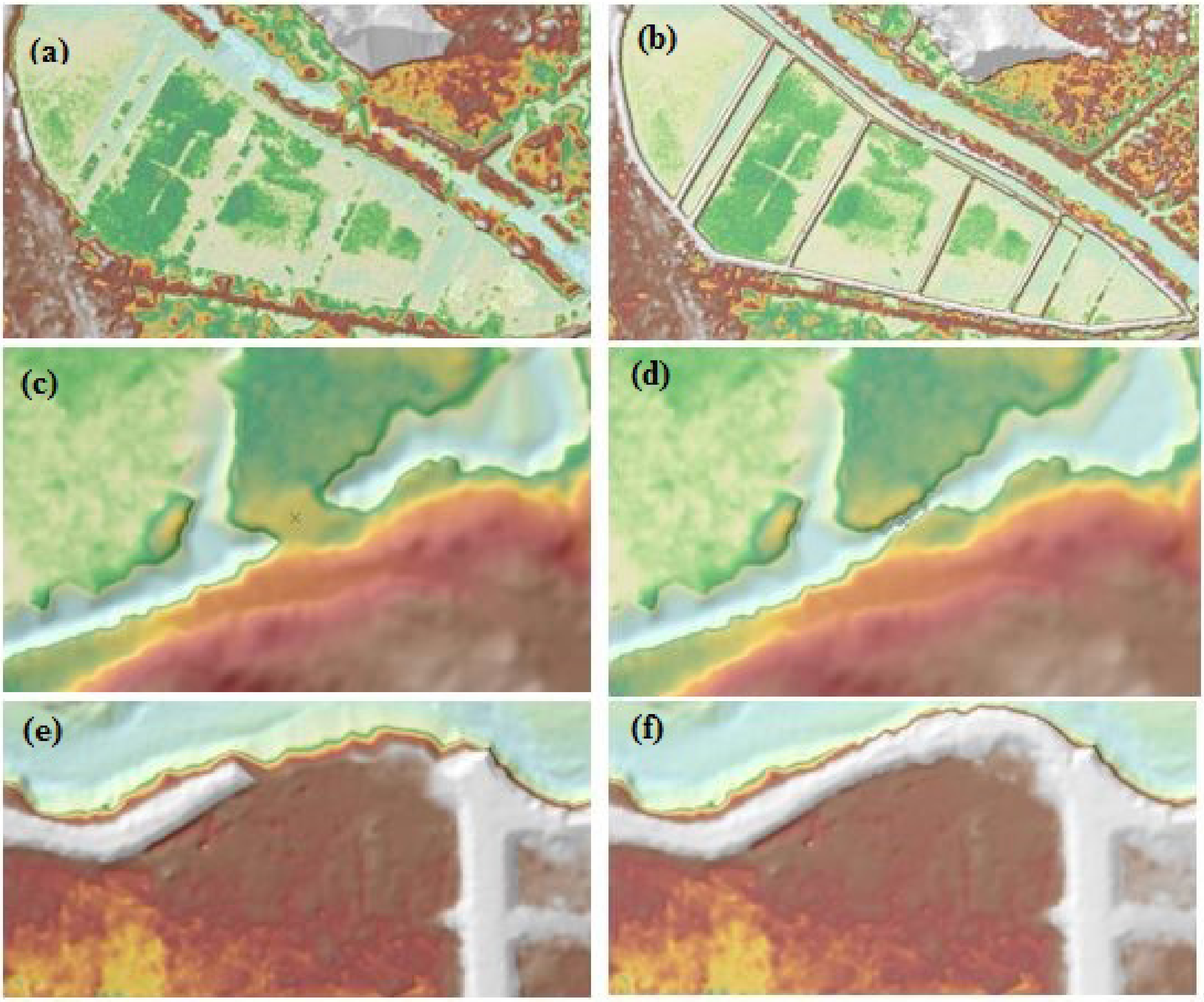


Figure 20. Portions in the DTM of Sipalay floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing; and a road before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

Dumaguete_reflight_Blk53D was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy.Table 13shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for the Sipalay floodplain is shown in Figure 21. It can be seen that the entire Sipalay floodplain is 98.05% covered by LiDAR data.

Table 13 . Shift Values of each LiDAR Block of Sipalay floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dumaguete_reflight_Blk53D	0.00	0.00	0.00
Dumaguete_reflight_Blk53Ds	0.00	1.00	-0.10
Dumaguete_reflight_Blk53Da	0.00	1.00	-0.20
Dumaguete_reflight_Blk53C	0.00	1.00	0.21
Dumaguete_Blk53C	0.00	0.00	60.48

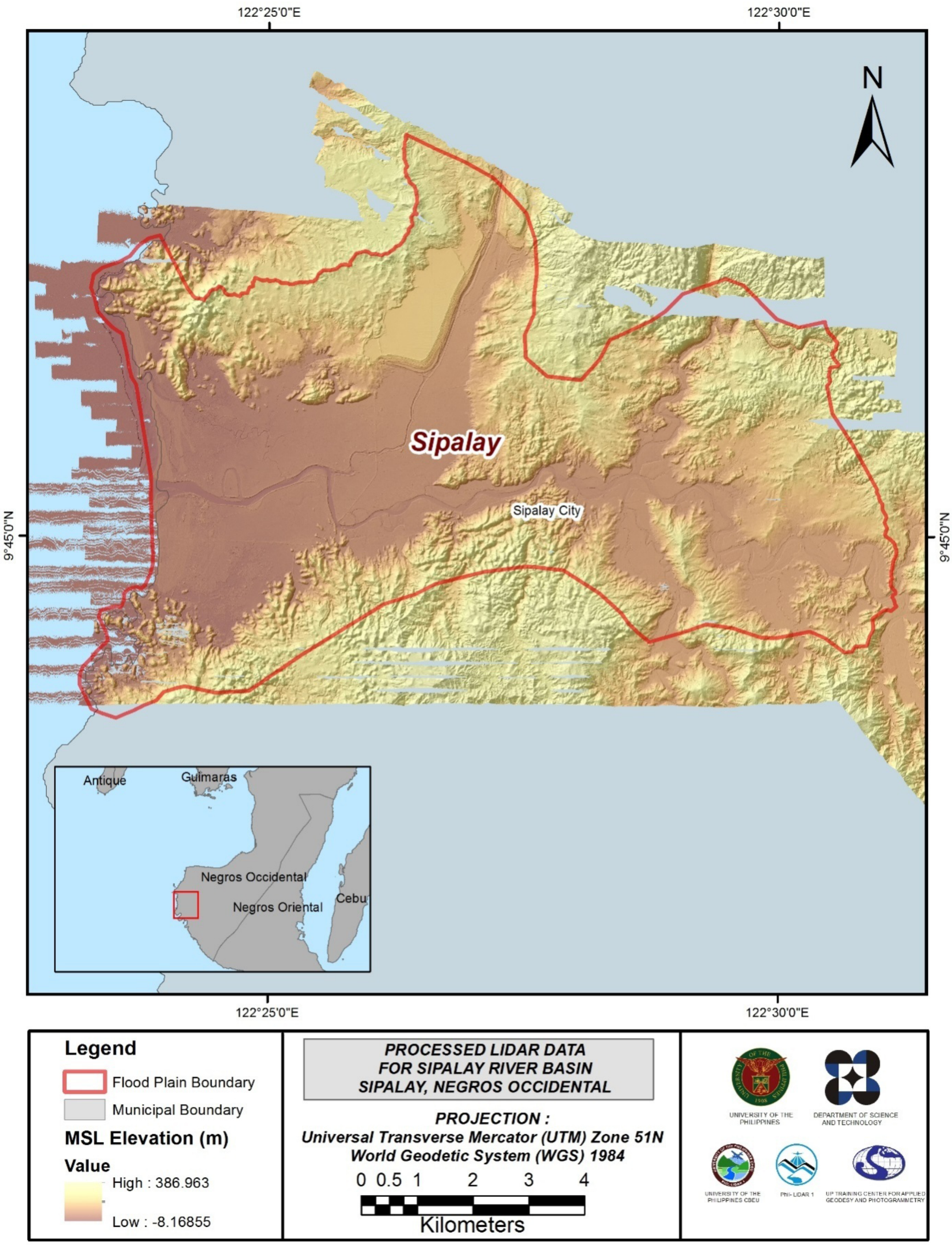


Figure 21 . Map of Processed LiDAR Data for Sipalay Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the Data Validation and Bathymetry Component (DVBC) conducted a validation survey along the Sipalay floodplain. The extent of the validation survey done by DVBC the in Sipalay to collect points with which the LiDAR dataset is validated is shown in Figure 22, with the validation survey points highlighted in green. A total of 3,754 survey points were used for calibration and validation of Sipalay LiDAR data. Random selection of 80% of the survey points, resulting to 2,662 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 23. 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 0.59 meters with a standard deviation of 0.10 meters. Calibration of Sipalay LiDAR data was done by subtracting the height difference value, 0.59 meters, to Sipalay mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

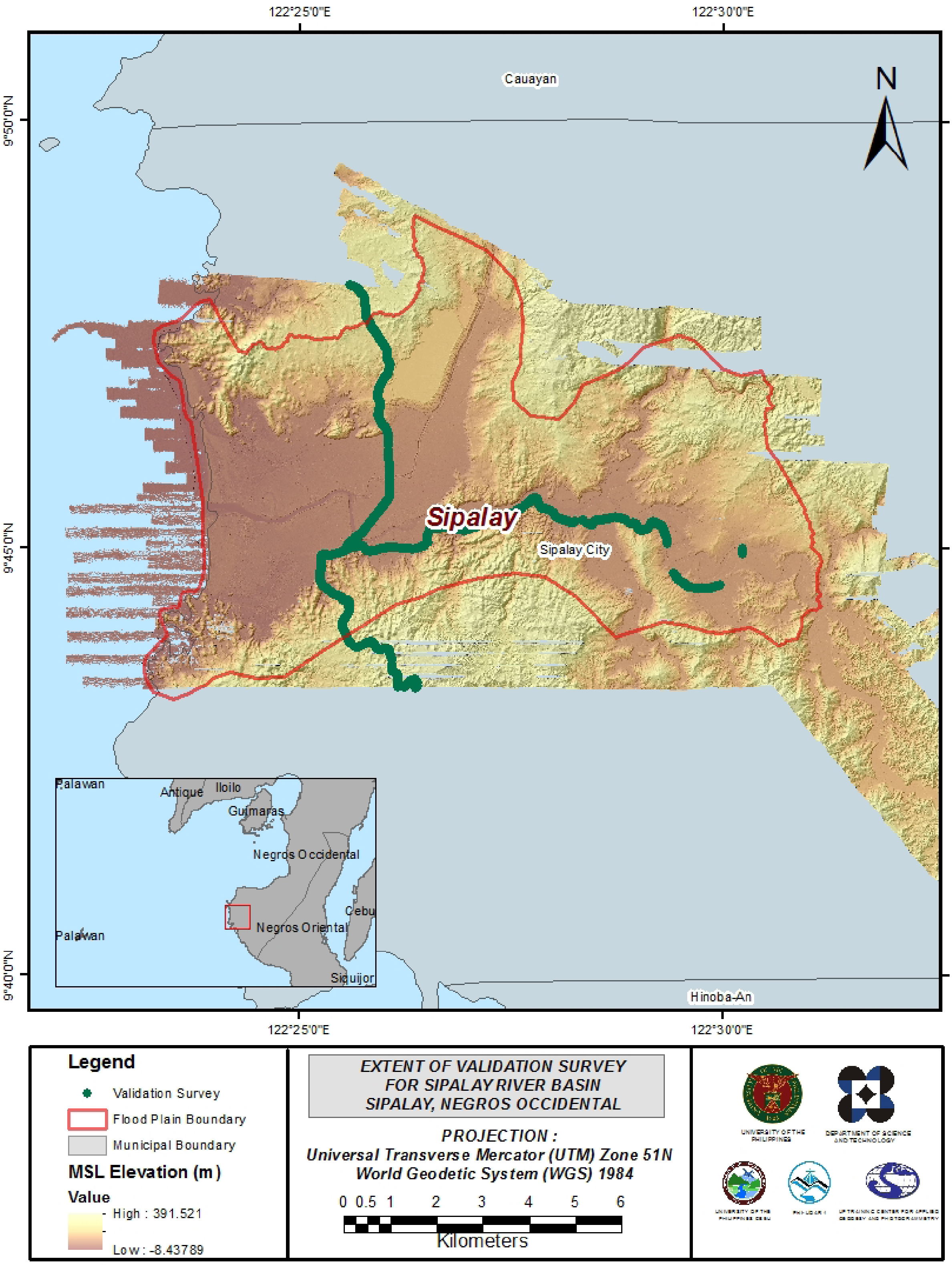


Figure 22. Map of Sipalay Flood Plain with validation survey points in green.

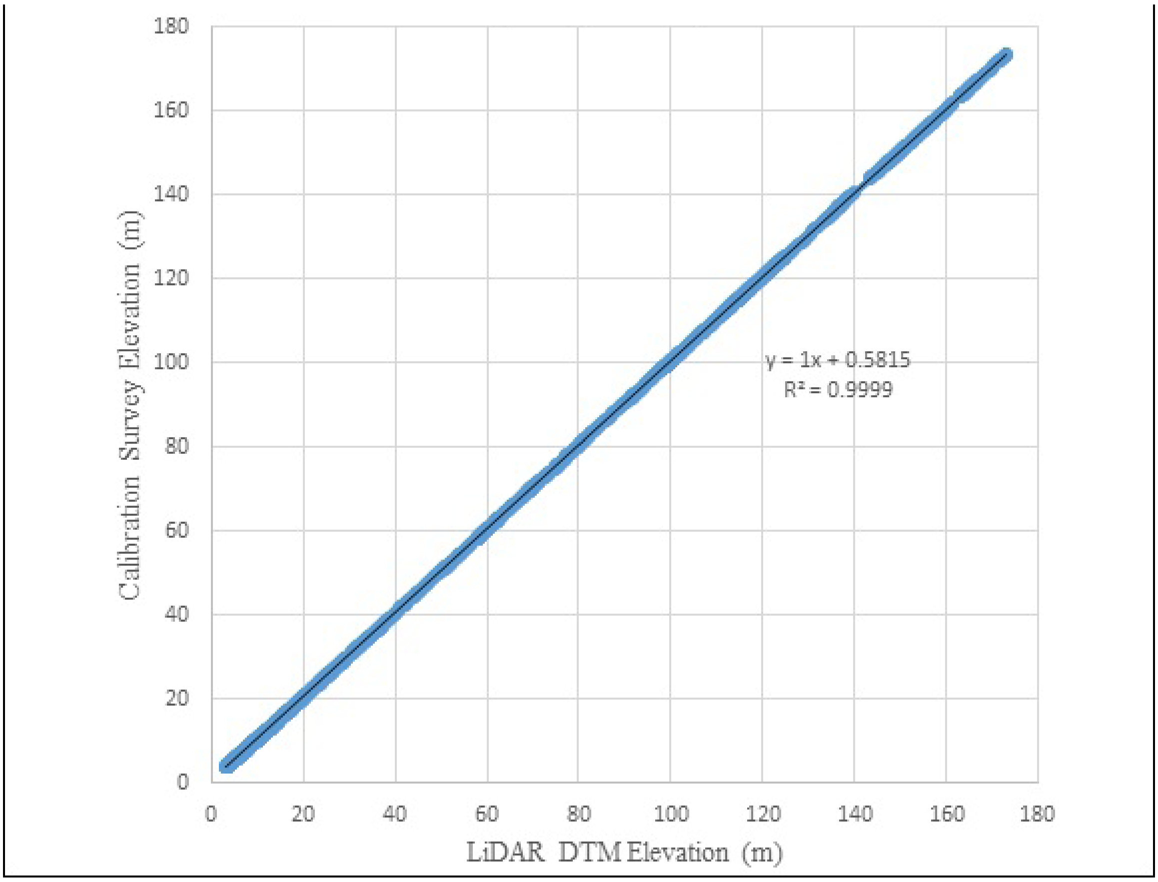


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.59
Standard Deviation	0.10
Average	-0.58
Minimum	-0.97
Maximum	-0.09

The remaining 20% of the total survey points, resulting to 668 points, were used for the validation of calibrated Sipalay 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 inFigure 24.The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.12 meters with a standard deviation of 0.12 meters, as shown in Table 15.

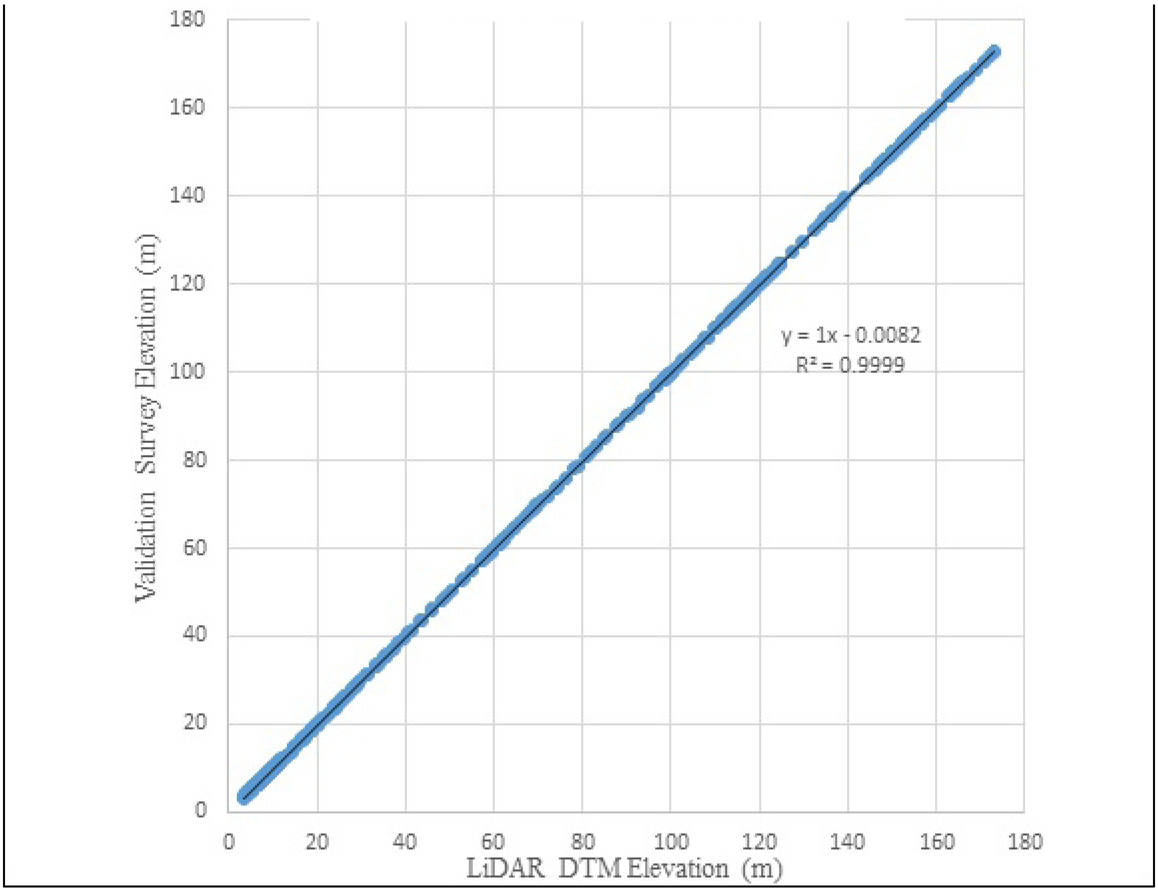


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.12
Average	0.01
Minimum	-0.37
Maximum	0.47

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, a total of 19,388 bathymetric survey points in centerline and zigzag was used for Sipalay. The resulting raster surface produced was done by 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 0.23 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sipalay integrated with the processed LiDAR DEM is shown in Figure 25.

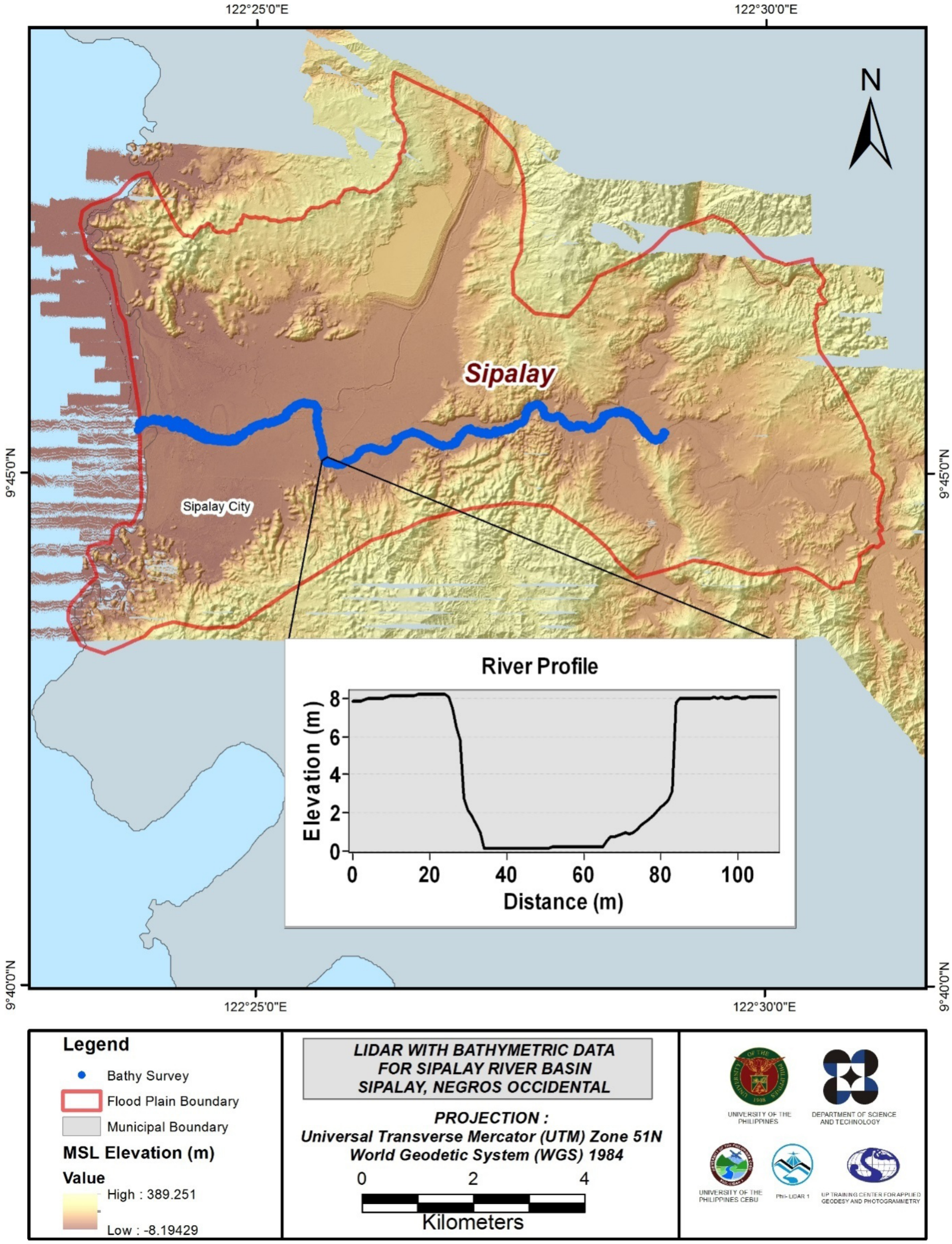


Figure 25. Map of Sipalay floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

The Sipalay floodplain, including its 200-m buffer, has a total area of 94.12 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 496 building features, are considered for QC. Figure 26 shows the QC blocks for Sipalay floodplain.

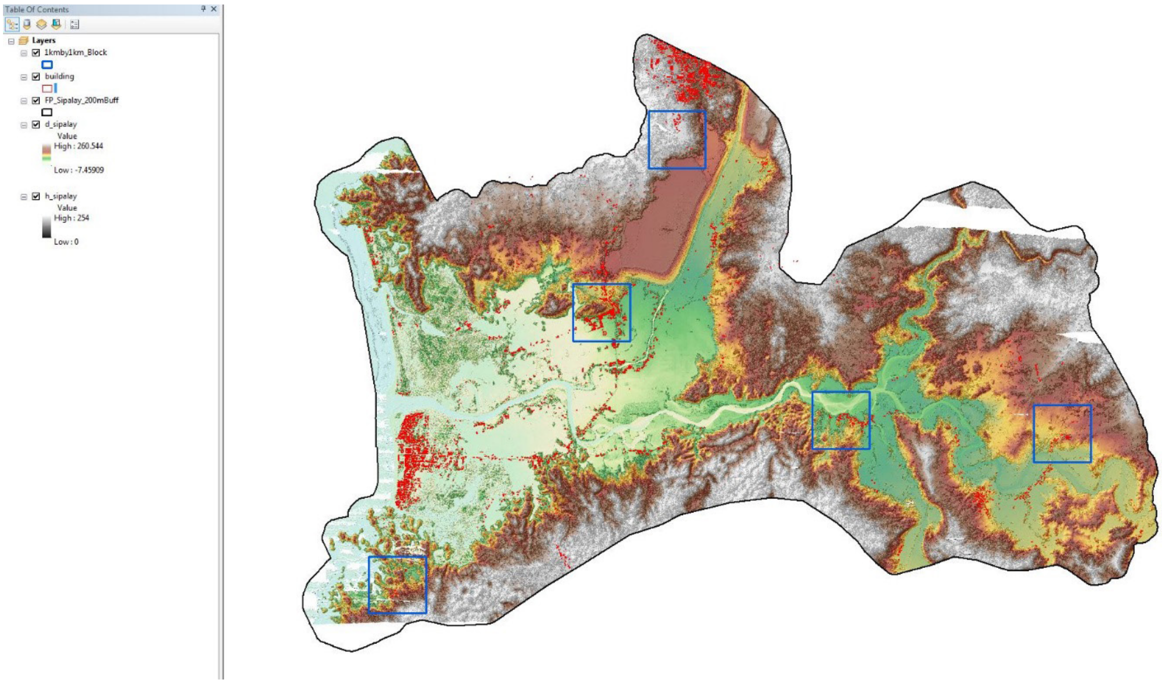


Figure 26. Blocks (in blue) of Sipalay building features that were subjected to QC.

Quality checking of Sipalay building features resulted in the ratings shown in Table 16.

Table 16. Quality Checking Ratings for Sipalay Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Sipalay	100.00	100.00	86.69	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,317 building features in the Sipalay floodplain. Of these building features, 219 were filtered out after height extraction, resulting to 5,098 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 10.98 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping, in coordination with the local government units (LGU) of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments, in order to identify and map out features.
Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map 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 every after 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 flood plain of the river basin.

Table 17 summarizes the number of building features per type. Table 18 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 17. Building Features Extracted for Sipalay Floodplain.

Facility Type	No. of Features
Residential	4,690
School	170
Market	23
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	12
Barangay Hall	9
Military Institution	19
Sports Center/Gymnasium/Covered Court	7
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	5
Power Plant/Substation	4
NGO/CSO Offices	0
Police Station	4
Water Supply/Sewerage	0
Religious Institutions	27
Bank	2
Factory	0
Gas Station	6
Fire Station	0
Other Government Offices	16
Other Commercial Establishments	91
Others	9
Total	**5,098**

Table 18. Total Length of Extracted Roads for Sipalay Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Sipalay	105.89	36.59	1.52	40.37	3.6	**187.98**

Table 19. Number of Extracted Water Bodies for Sipalay Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Sipalay	15	0	0	0	15	38

A total of twenty (20) 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 27 shows the Digital Surface Model (DSM) of Sipalay floodplain overlaid with its ground features.

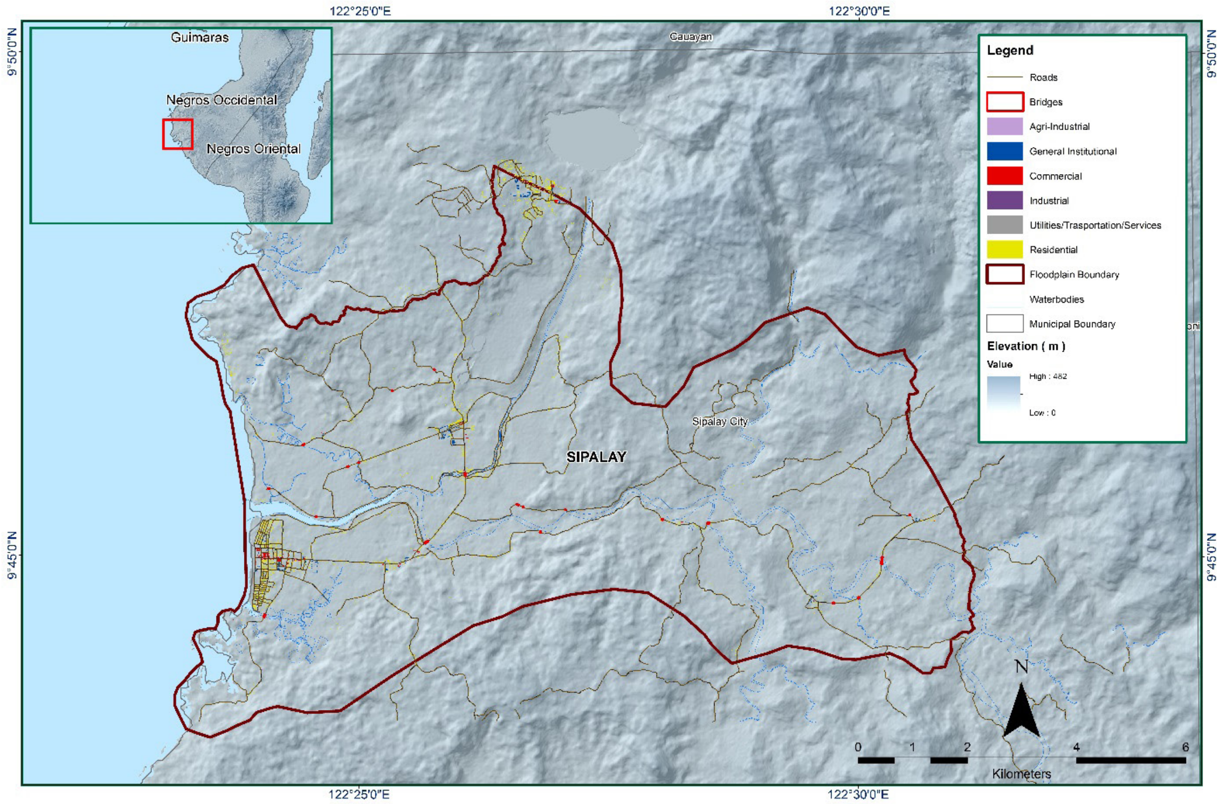


Figure 27. Extracted features for Sipalay floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, 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 DVBC conducted field surveys in the Sipalay River on October 17 – 31, 2016. The scope of work was comprised of (i) initial reconnaissance; (ii) control point survey; (iii) cross section and bridge as-built surveys at Cabadiangan Bridge in Brgy. Cabadianganand at Barasbarasan Bridge in Brgy. Manlucahoc, both locatedin Sipalay City; (iv) validation points acquisition of about 74 km covering the Municipalities of Cauayan and Hinoba-An, and Sipalay City, in Negros Occidental; and (v) bathymetric survey from the upstream location in Brgy. Cabadiangan, down to the downstream end of the river located in Brgy. Nauhang, both in Sipalay City, with an approximate total length of 12.311 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique.

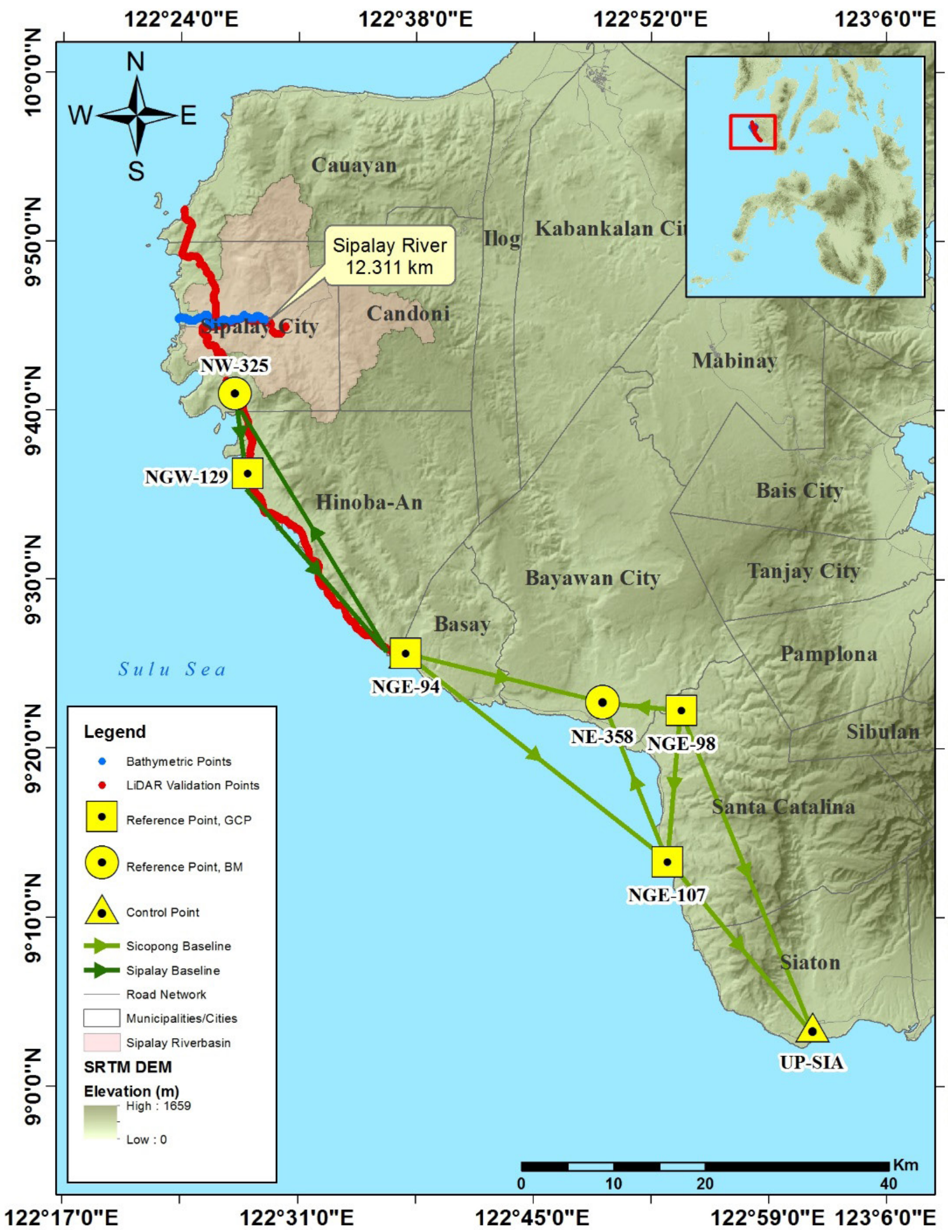


Figure 28. Extent of the bathymetric survey (in blue line) in Sipalay River and the LiDAR data validation survey (in red).

4.2 Control Survey

A GNSS baseline was established for a previous Phil-LiDAR 1 DVBC fieldwork in Tiabanan River on March 11, 2016, occupying the control points: NGE-98, a 2nd order GCP in Brgy. Caranoche, Municipality of Santa Catalina; NGE-107, a 2nd order GCP in Brgy. Mabuhay, Municipality of Santa Catalina; and NE-358, a 1st order Benchmark in Brgy. Ubos, Bayawan City.These are all located in Negros Oriental.

The GNSS network used for Sipalay River Basin is composed of three (3) loops established on October 28, 2016 occupying the reference points: NGE-94, a fixed control point in Brgy. Bongalonan, Municipality of Basay, Negros Oriental, with values derived from the field survey in Tiabanan River in March 2016; NGW-129, a 2nd order GCP in Brgy I, Municipality of Hinoba-An, Negros Occidental; and NW-325, a 1st order Benchmark in Brgy. Cayhagan, Sipalay City, Negros Occidental

The summary of reference and control points and theirlocations is presentedin Table 20, while the GNSS network established in the Sipalay River Survey is illustrated in Figure 29.

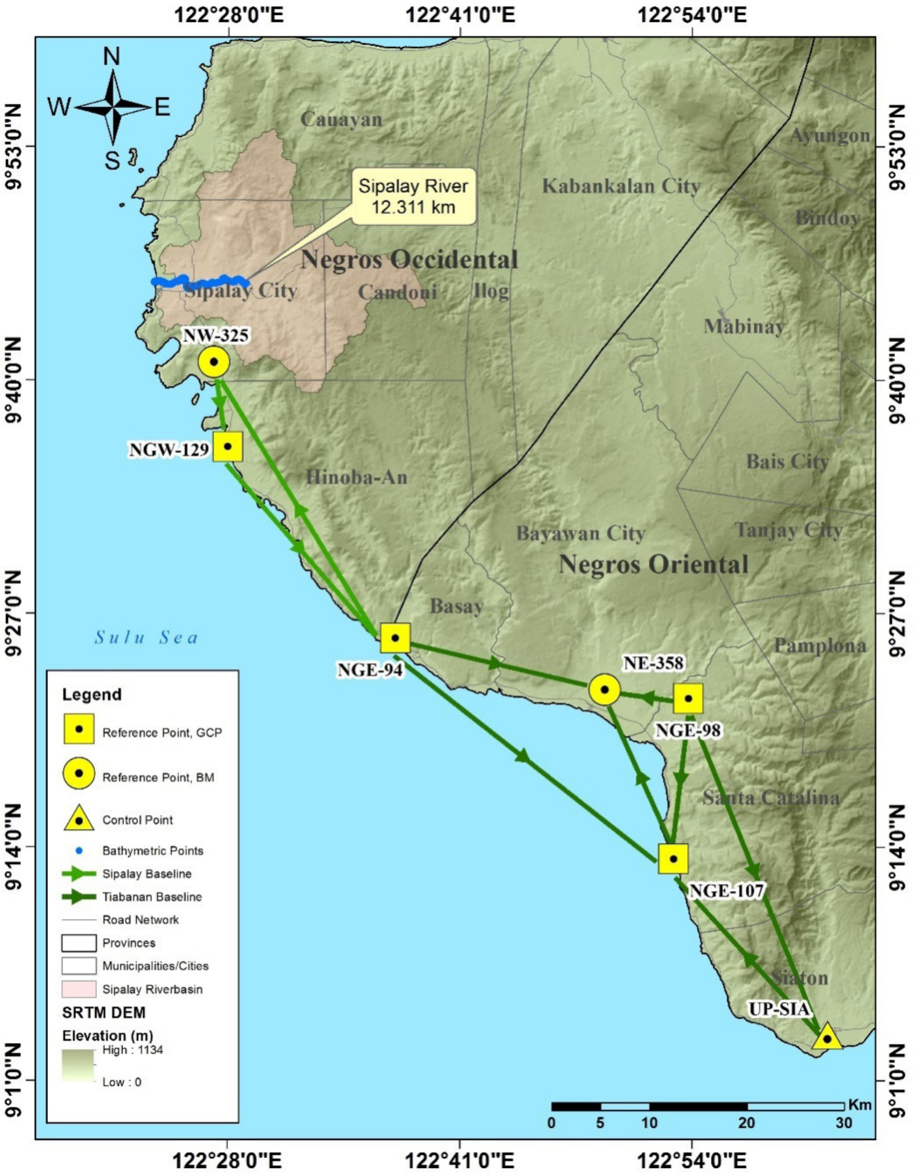


Figure 29. The GNSS Network established in the Sipalay River Survey,

Table 20. References used and control points establishedfor Sipalay River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey on March 11, 2016						
NGE-98	2nd Order, GCP	9°22’16.41564”	122°53’48.54064”	132.087	69.180	03-11-16
NGE-107	2nd Order, GCP	9°13’19.76274”	122°52’59.03199”	69.527	7.670	03-11-16
NE-358	1st Order, BM	9°22’46.06928”	122°49’07.51892”	67.723	5.116	03-11-16
NGE-94	Used as Marker	9°25’37.57022”	122°37’23.12090”	68.846	7.244	03-11-16

Control Survey on October 28, 2016						
NGE-94	2nd Order, GCP	9°25'37.57022"	122°37'23.12090"	68.845	7.244	10-28-16
NGW-129	2nd Order, GCP	9°36'16.62831"	122°27'58.05587"	66.116	-	10-28-16
NW-325	1st Order, BM	-	-	73.115	12.115	10-28-16

The GNSS set-ups on recovered reference points and established control points in the Sipalay River are shown in Figure 30 to Figure 32.

Figure 30. GNSS receiver setup, Trimble® SPS 882, at NGE-94, located at the approach of Tiabanan Bridge, in Brgy. Bongalonan, Municipality of Basay, Negros Oriental

Figure 31. GNSS base set up, Trimble® SPS 855, at NGW-129 located at the approach of Hinoba-An Bridge, in Brgy. I, Municipality of Hinoba-An, Negros Oriental

Figure 32. GNSS receiver setup, Trimble® SPS 855 at NW-325, located at approach of Porong Bridge in Brgy. Cayhagan, Sipalay 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 +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking wasperformed. Masking is the removal of portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. The baseline processing results of control points in the Sipalay River Basin is summarized in Table 21, generated by the TBC software.

Table 21. Baseline Processing Summary Report for Sipalay River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
NW-325 --- NGW-129 (B2)	10-28-16	Fixed	0.003	0.014	170°45'25"	8823.881	-7.040
NGW-129 --- NGE-94 (B1)	10-28-16	Fixed	0.003	0.016	138°42'42"	26124.908	2.674
NW-325 --- NGE-94 (B3)	10-28-16	Fixed	0.003	0.017	146°38'29"	33928.729	-4.397

As shown in Table 21,a total of three (3) baselines were processed, with coordinates and elevation values of reference point NGE-94 from previous fieldwork in the Tiabanan River; coordinate values of NGW-12; and elevation values of NW-325 held fixed. All baselines passed the required accuracy.

4.4 Network Adjustment

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

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

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 shown in Table 22 to Table 25 for complete details.

The nine (9) control points, LYT-101, LYT-708, CAM-VSU, LIM-VSU, MAG-VSU, NHS-VSU, PAL-VSU, SJQ-VSU and BM-1 were occupied and observed simultaneously to form a GNSS loop. Coordinates of LYT-101 and LYT-708 and elevation values LYT-101 were held fixed during the processing of the control points, as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. Constraints applid to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGE-94	Grid	Fixed	Fixed		Fixed
NGW-129	Global	Fixed	Fixed		
NW-325	Grid				Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 23. All fixed control points have no values for grid and elevation errors.

Table 23. Adjusted grid coordinates for the control points used in the Sipalay River floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGE-94	458621.676	?	1042094.324	?	7.244	?	ENe
NGW-129	441419.725	?	1061743.822	?	5.424	0.091	LL
NW-325	440016.797	0.021	1070452.290	0.015	12.115	?	e

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

a. NGE-94
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. NGW-129
Horizontal Accuracy = Fixed
Vertical Accuracy = 9.1 < 10 cm

c. NW-325
Horizontal Accuracy = $\sqrt{((2.1)^2 + (1.5)^2}$
= $\sqrt{(4.41 + 2.25)}$
= 2.58 < 20 cm
Vertical Accuracy = Fixed

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

Table 24. Adjusted geodetic coordinates for control points used in the Sipalay River floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
NGE-94	N9°25'37.57023"	E122°37'23.12090"	68.845	?	ENe
NGW-129	N9°36'16.62831"	E122°27'58.05587"	66.116	0.091	LL
NW-325	N9°41'00.10119"	E122°27'11.57224"	73.115	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy,as shown in Table 24. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. Thecomputed coordinates of the reference and control points utilized in the Sipalay River GNSS Static Survey are indicated in Table 25.

Table 25. Reference and control points used and its location
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on March 11, 2016							
NGE-98	2nd Order, GCP	9°22'16.41564"	122d53'48.54064"	132.087	1035896.031	488670.521	69.180
NGE-107	2nd Order, GCP	9°13'19.76274"	122d52'59.03199"	69.527	1019415.410	487155.076	7.670

NE-358	1st Order, BM	9°22'46.06928"	122d49'07.51892"	67.723	1036810.192	480099.830	5.116
NGE-94	Used as Marker	9°25'37.57022"	122d37'23.12090"	68.846	1042094.324	458621.676	7.244
Control Survey on October 28,2016							
NGE-94	Fixed	9°25'37.57023"	122°37'23.12090"	68.845	1042094.324	458621.676	7.244
NGW-129	2nd Order, GCP	9°36'16.62831"	122°27'58.05587"	66.116	1061743.822	441419.725	5.424
NW-325	1st Order, BM	9°41'00.10119"	122°27'11.57224"	73.115	1070452.29	440016.797	12.115

4.5 Cross-section and Bridge As-Built Survey and WaterLevel Marking

The cross-section and as-built survey were conducted on October 26, 2016 at the downstream side of Barasbarasan Bridge in Brgy. Manlucahoc and Cabadiangan Bridge in Brgy. Cabadiangan, both in Sipalay City, as shown in Figure 33 and Figure 34, respectively. A survey grade GNSS receiver Trimble® SPS 985 in PPK survey technique was utilized for this survey, as depictedin Figure 35.

Figure 33. Barasbarasan Bridge facing upstream

Figure 34. Cabadiangan Bridge facing upstream

Figure 35. The Bridge As-Built Survey of A) Barasabarasan Bridge and B) Cabadiangan Bridge

The length of the cross-sectional line surveyed in Barasbarasan Bridge is about 221 m with seventy-six (76) cross-sectional points, while the length of the cross-sectional line along Cabadiangan Bridge is about 55 m with thirty-four (34) cross-sectional points; both using the control point NGW-129 as the GNSS base station. The location maps, cross-section diagrams, and the accomplished bridge data forms are shown in Figure 36to Figure 37, Figure 38 to Figure 39, and Figure 40 to Figure 41, respectively.

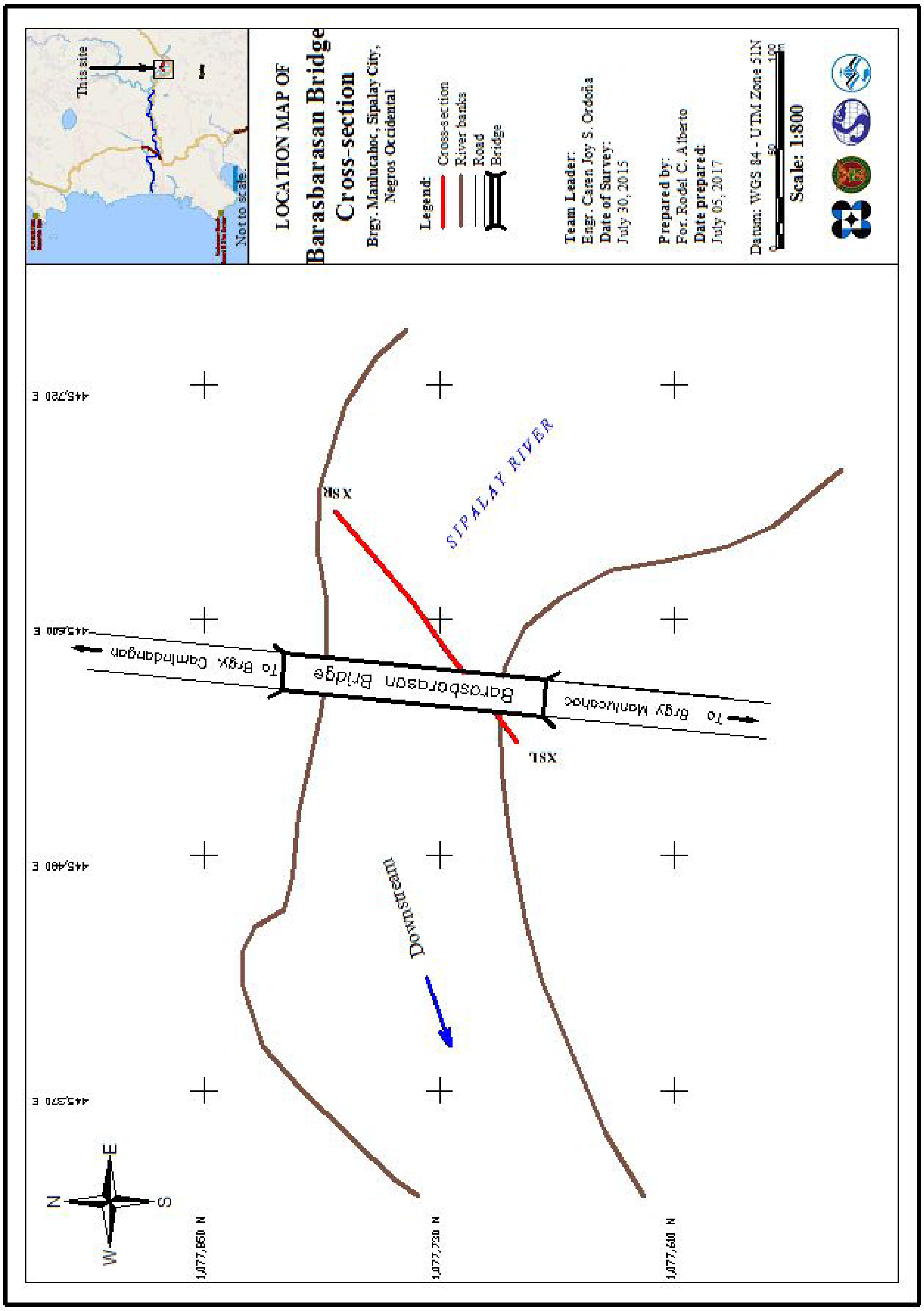


Figure 36. Location map of the Barasbarasan Bridge cross-section survey

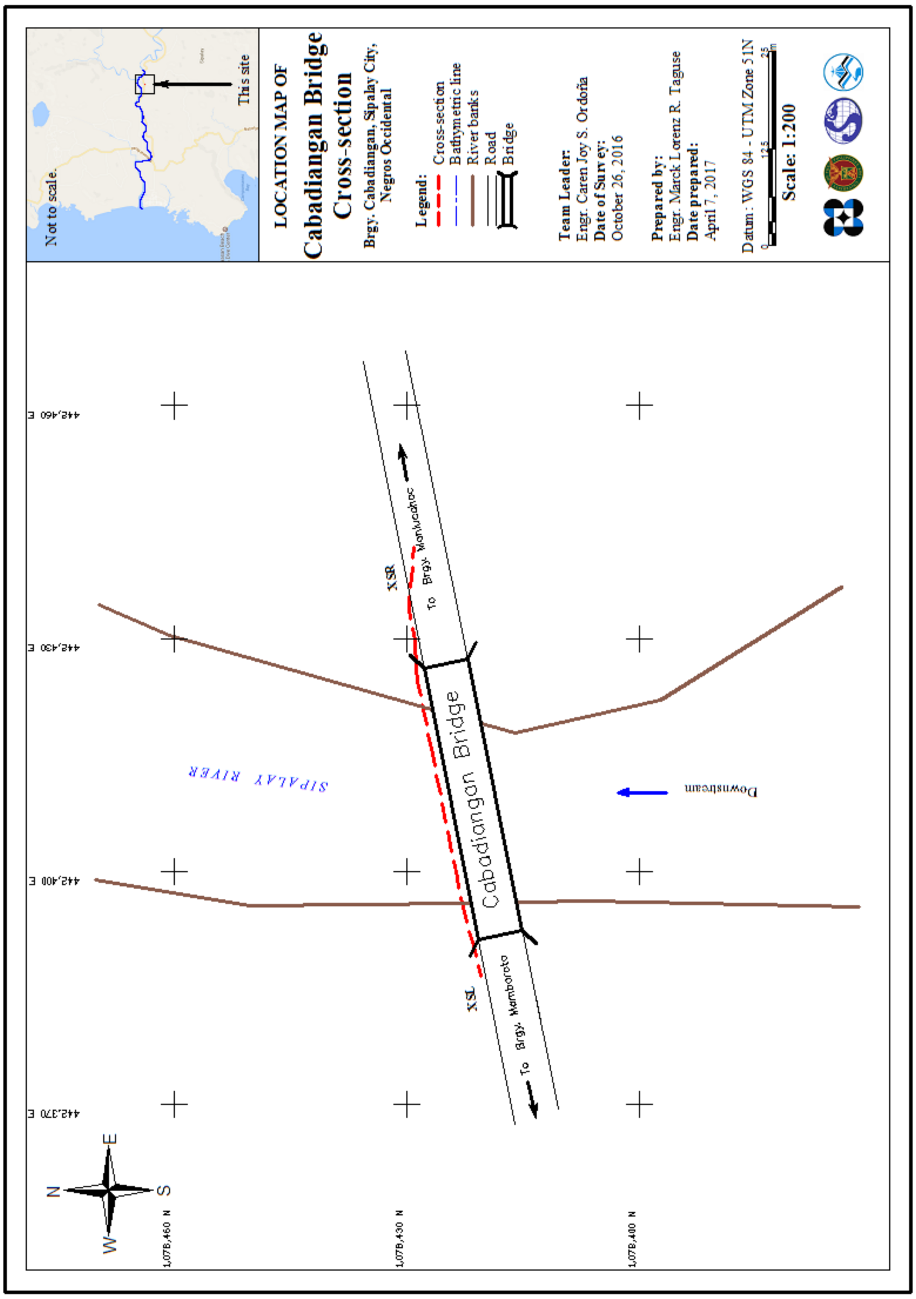


Figure 37. Location map of the Cabadiangan Bridge cross-section survey

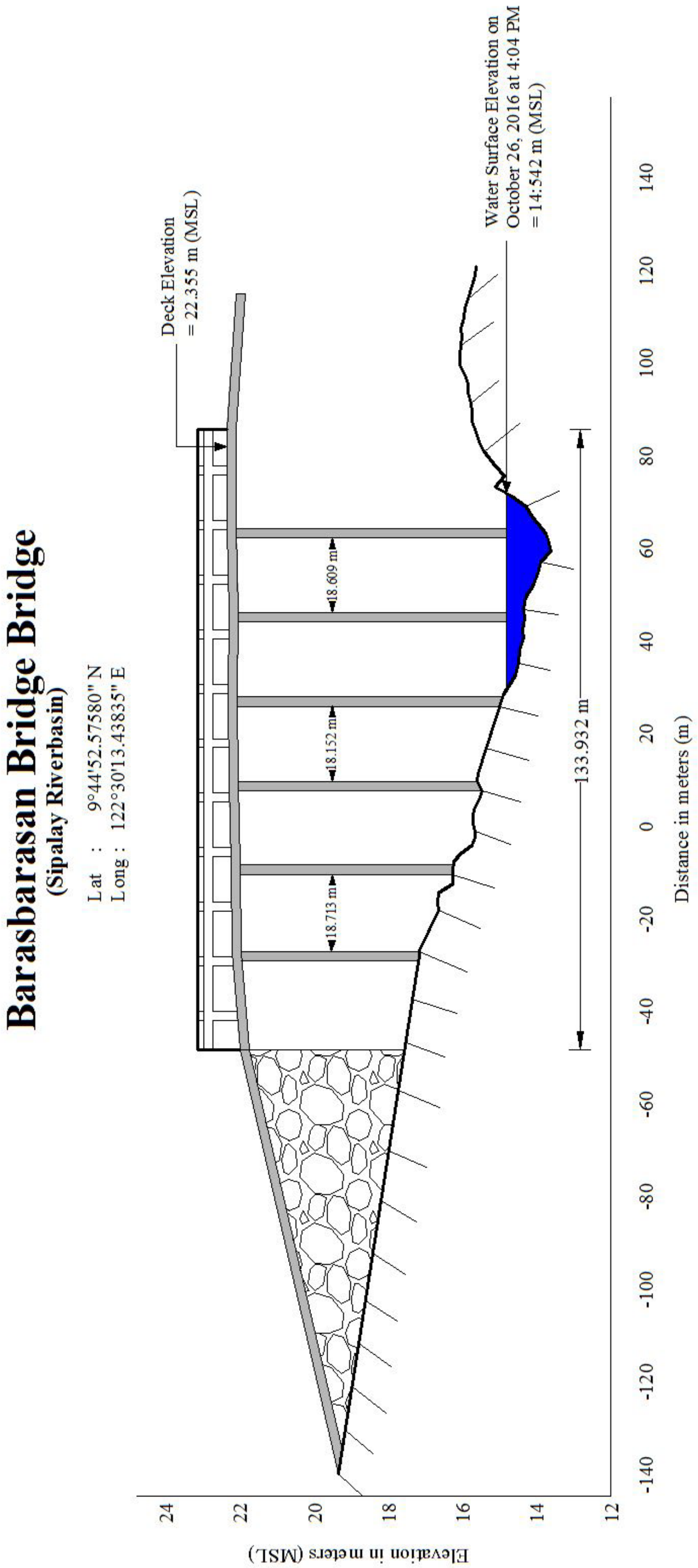


Figure 38. The Barasbarasan Bridge cross-section survey diagram

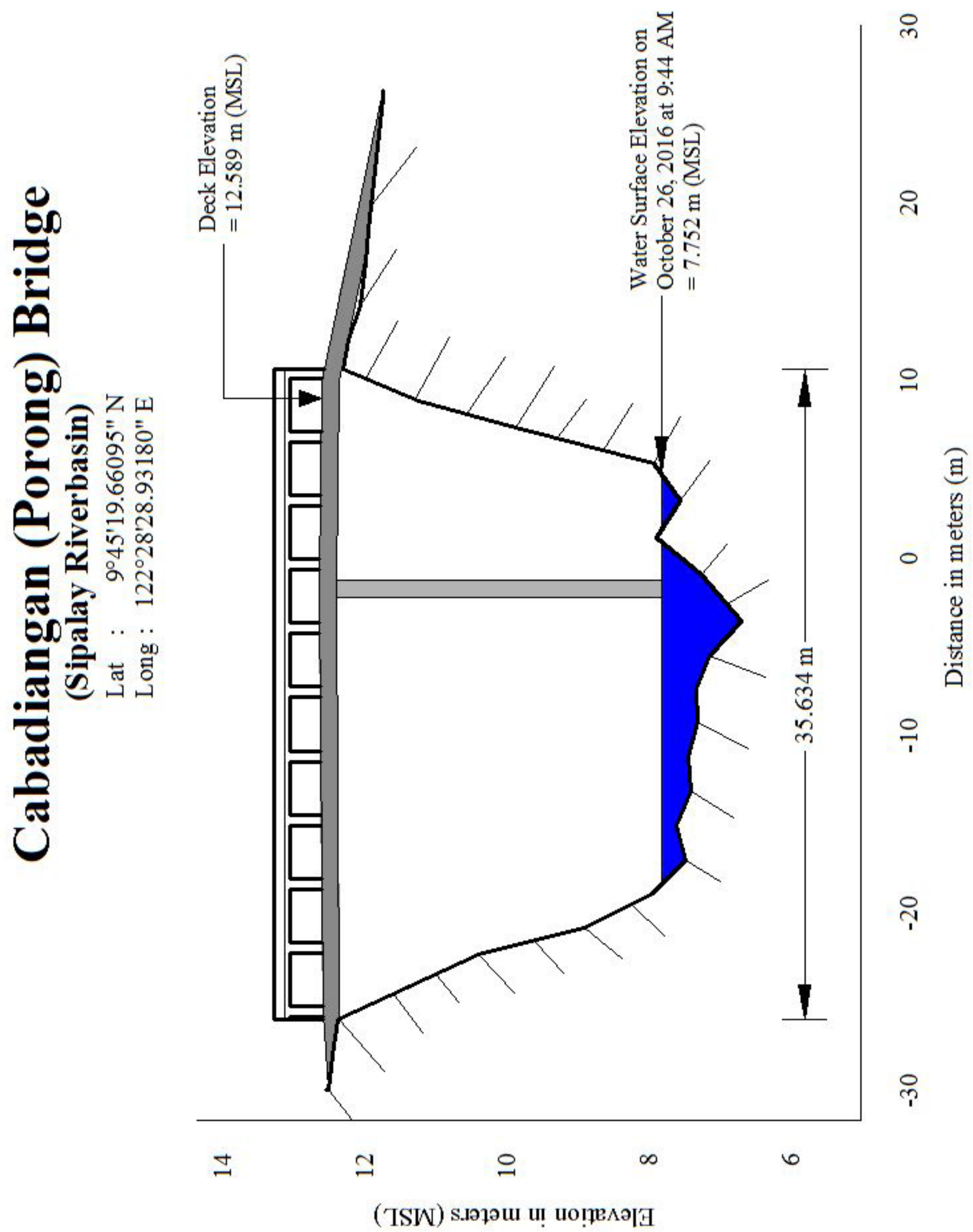
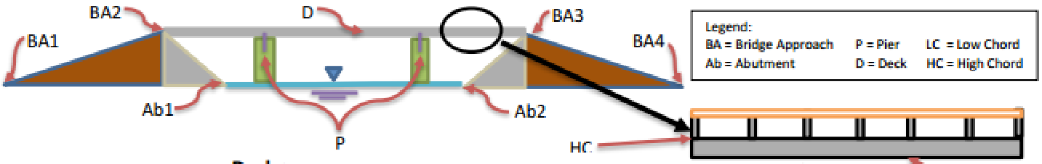


Figure 39. The Cabadiangan Bridge cross-section survey diagram

Bridge Data Form

Bridge Name: Barasbarasan Bridge	**Date:** October 26, 2016
River Name: Sipalay River	**Time:** 4:04 PM
Location (Brgy, City,Region): Brgy. Manlucahoc, Sipalay City, Negros Occidental	
Survey Team: Caren Joy Ordoña, Marion Dimain, Janina Jupiter	
Flow condition: average	**Weather Condition:** fair
Latitude: 9°44'52.57580" N	**Longitude:** 122°30'13.43835" E



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

Elevation: 22.355 m **Width:** not available **Span (BA3-BA2):** 133.932 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	19.328 m	BA3	225.558 m	22.355 m
BA2	91.619 m	21.992 m	BA4	254.828 m	22.101 m

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

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

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

Shape: round Number of Piers: 6 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	112.833 m	22.218 m	1.25 m
Pier 2	131.547 m	22.241 m	1.25 m
Pier 3	149.651 m	22.290 m	1.25 m
Pier 4	167.805 m	22.323 m	1.25 m
Pier 5	186.104 m	22.286 m	1.25 m
Pier 6	204.173 m	22.343 m	1.25 m

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

Figure 40. The Barasbarasan Bridge as-built survey data

Bridge Data Form

Bridge Name: Cabadiangan (Porong) Bridge **Date:** October 26, 2016

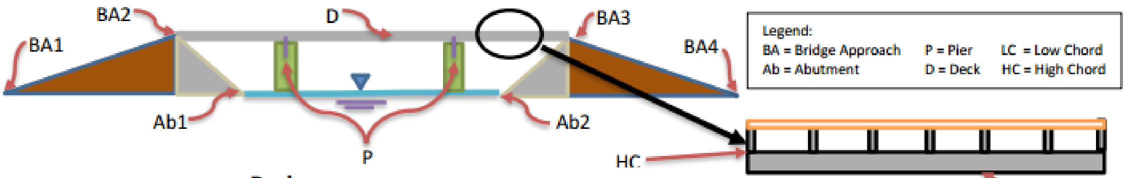
River Name: Sipalay River **Time:** 9:44 AM

Location (Brgy, City,Region): Brgy. Cabadiangan, Sipalay City, Negros Occidental

Survey Team: Caren Joy Ordoña, Marion Dimain, Janina Jupiter

Flow condition: average **Weather Condition:** fair

Latitude: 9°45'19.66095" N **Longitude:** 122°28'28.93180" E



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

Elevation: 12.589 m **Width:** not available **Span (BA3-BA2):** 35.634 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	12.495 m	BA3	39.976 m	12.589 m
BA2	4.342 m	12.580 m	BA4	254.828 m	11.723 m

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

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

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

Shape: round Number of Piers: 1 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	28.246 m	12.625 m	0.40 m

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

Figure 41. The Cabadiangan Bridge as-built survey data

The water surface elevation of the Sipalay River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on October 26, 2016 at 4:04 PM, with a value of 14.542 m in MSL for Barasbarasan Bridge; and on October 26, 2016 at 9:44 AM, with a value of 7.752 m in MSL for Cabadiangan Bridge, as shown in Figure 40 and Figure 41, respectively. These values were translated into markings on the bridges' piers using the same technique, as shown in Figure 42 and Figure 43. The markingsnowserve as the reference for flow data gathering and depth gauge deployment of the University of the Philippines Cebu, the partner HEI responsible for monitoring of the Sipalay River.

Figure 42. Water-level markings on Barasbarasan Bridge

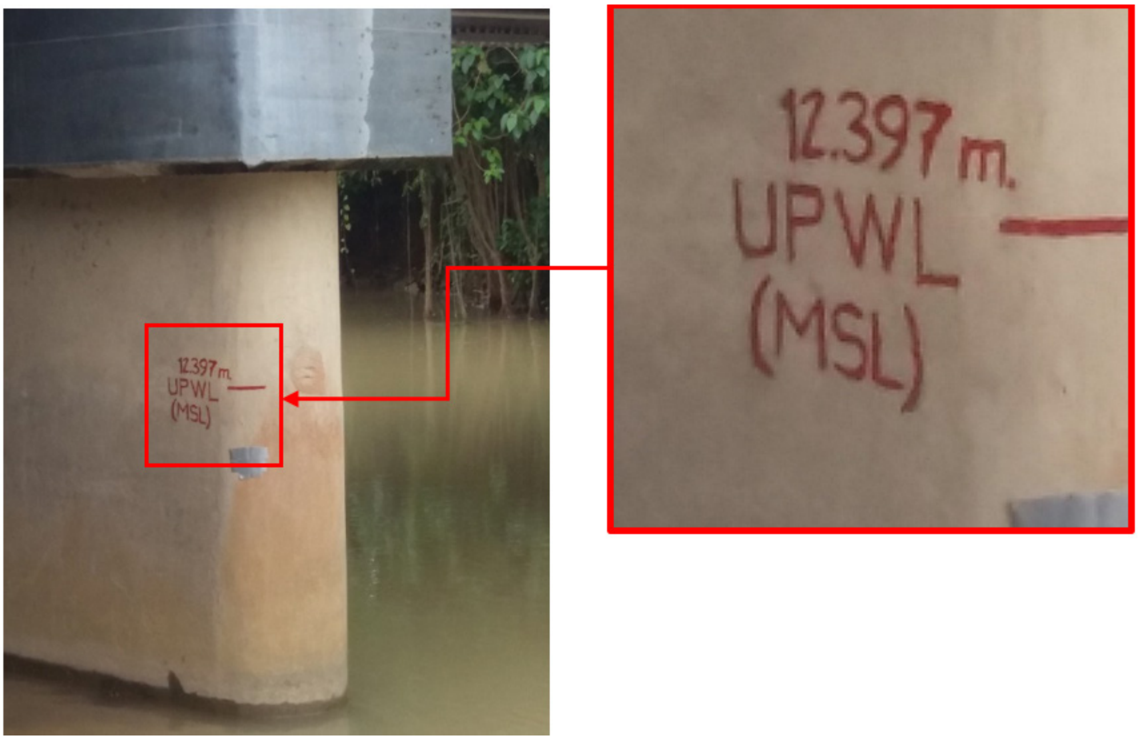


Figure 43. Water-level markings on Cabadiangan Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 26-28, 2016, using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted at the side of a vehicle, as shown in Figure 44. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.20 m, measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with NGW-129 and NW-325 occupied as the GNSS base stations in the conduct of the survey.

Figure 44. The validation points acquisition survey set up using a GNSS receiver along the Sipalay River Basin

The survey started in Brgy. Bulata, Municipality of Cauayangoing south traversing the National Highway, covering eight (8) barangays in Sipalay City and ten (10) barangays in the Municipality of Hinoba-An, and ended in Brgy. Bongalonan in the Municipality of Basay. It gathered a total of 12,549 points with approximate length of 74 km, using NGW-129 and NW-325 as GNSS base stations for the entire extent of the validation points acquisition survey, as illustrated in the map in Figure 45.

Figure 45. Extent of the LiDAR ground validation survey of Sipalay River basin

4.7 Bathymetric Survey

A manual bathymetric survey was executed on October 27, 2016, using Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode and an OHMEX™ Single beam echo sounder, as illustrated in Figure 46. The survey started in Brgy. Mambaroto, Sipalay City, with coordinates 9°45'05.37284"N, 122°25'43.59433"E, and ended at the mouth of the river in Brgy. Nauhang, Sipalay City, with coordinates 9°45'24.60996"N, 122°23'50.00358"E.

Figure 46. Bathymetric survey using a Trimble® SPS 882 in GNSS PPTK survey technique in Sipalay River.

Another manual bathymetric survey was also executed on October 27, 2016, using Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode, as illustrated in Figure 47. The survey started in Brgy. Cabadiangan, Sipalay City, with coordinates 9°45'23.61717"N, 122°29'00.37413"E, and ended at the starting point of the bathymetric survey using a boat. The control point NW-325 was used as GNSS base station all throughout the entire survey.

Figure 47. Manual Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in Sipalay River

The bathymetric survey for Sipalay River gathered a total of 22,718 points, covering 12.311 km of the river traversing Barangays 3, 5, Cabadiangan, Gil Montilla, Mambaroto and Nauhang in Sipalay City(Figure 48).

To further illustrate this,a CAD drawing was also produced to illustrate the riverbed profile of the Sipalay River, as seenin Figure 49.The profile shows that the highest and lowest elevation has a 10-m difference. The highest elevation observed was 8.113 m above MSL located in Brgy. Cabandiangan, Sipalay City; while the lowest was-2.883 m below MSL located in Brgy. 5, Sipalay City. The survey coverage was extended 1km upstream to cover densely populated communities along the riverbanks.

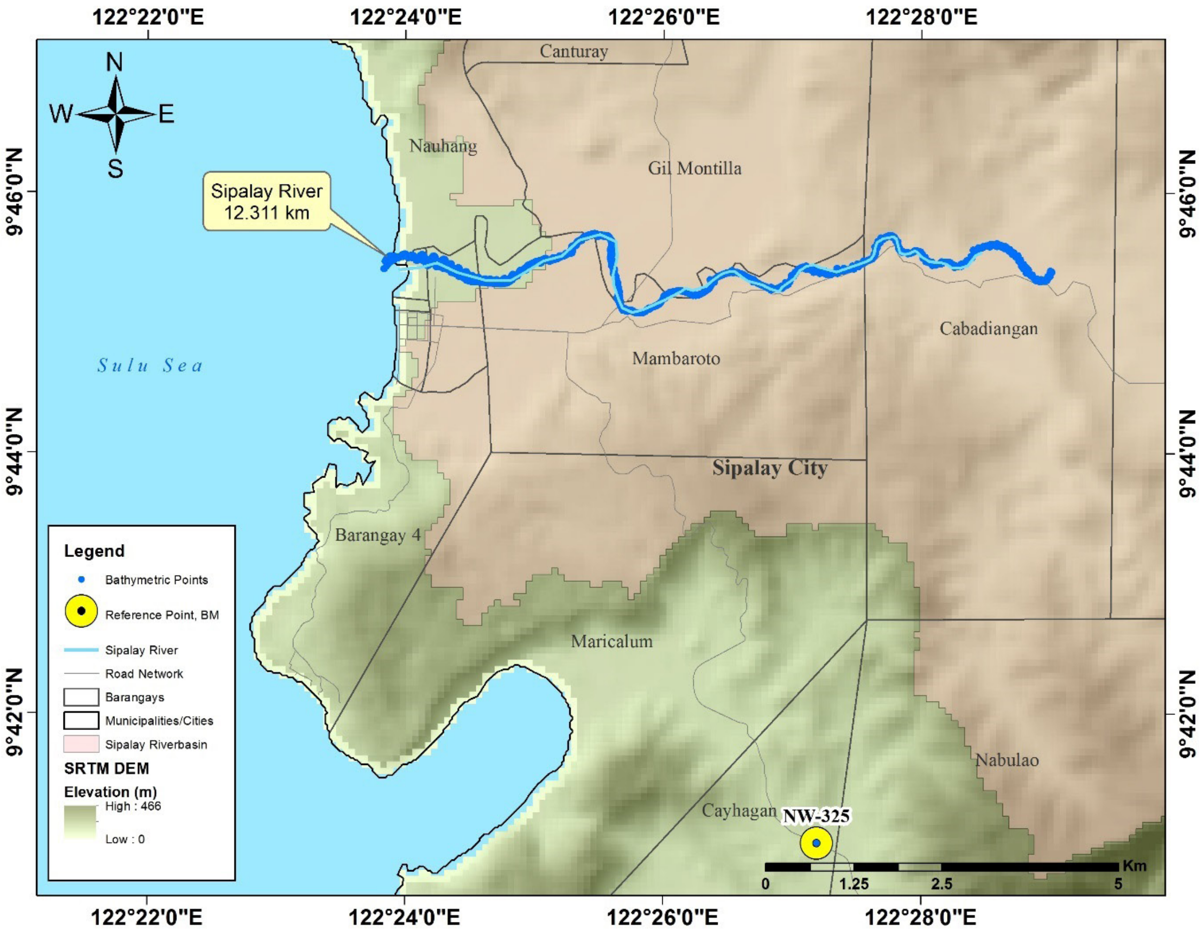


Figure 48. Extent of the bathymetric survey of Sipalay River

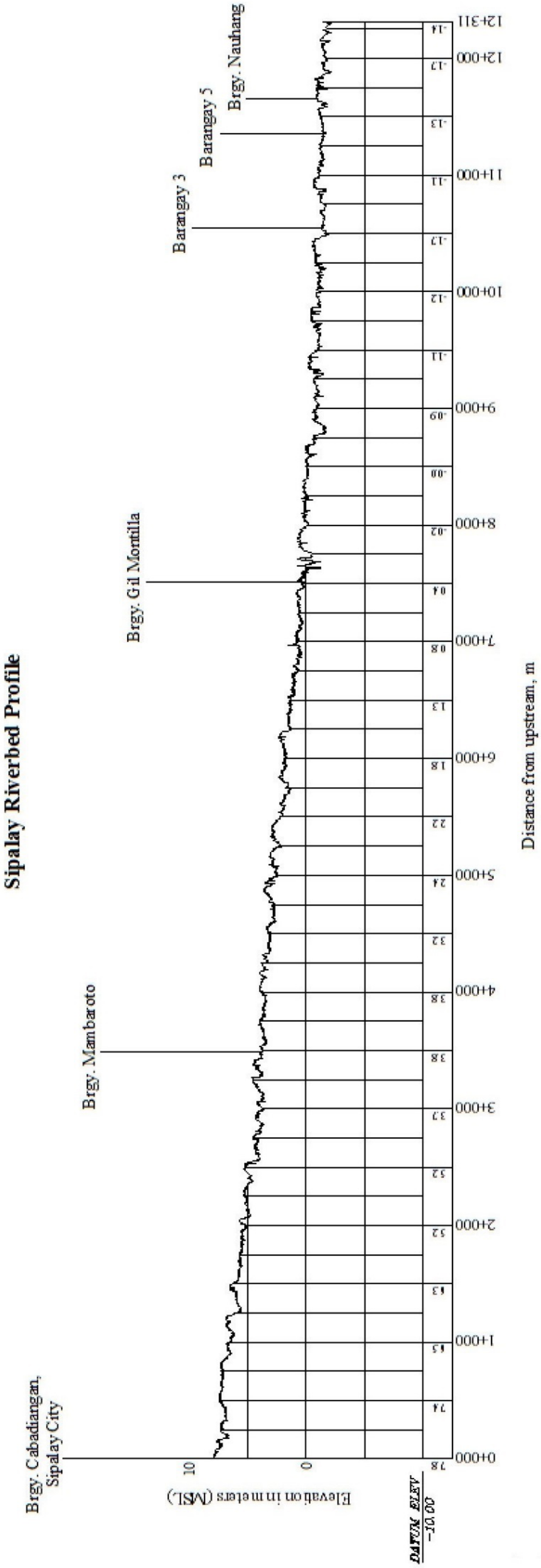


Figure 49. The Sipalay riverbed profile

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 and Mariel Monteclaro

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UPCebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Manlucahoc, Sipalay City, Negros Occidental (Figure 50). The precipitation data collection started from September 15, 2016 at 3:00 PM to September 16, 2016 at 2:00, with a recording interval of5 minutes.

The total precipitation for this event in Brgy Manlucahoc ARG was 21.2 mm, with a peak rainfall of 1.6 mm. on September 15, 2016 at 11:35 in the evening. The lag time between the peak rainfall and discharge is 2 hours and 5 minutes.

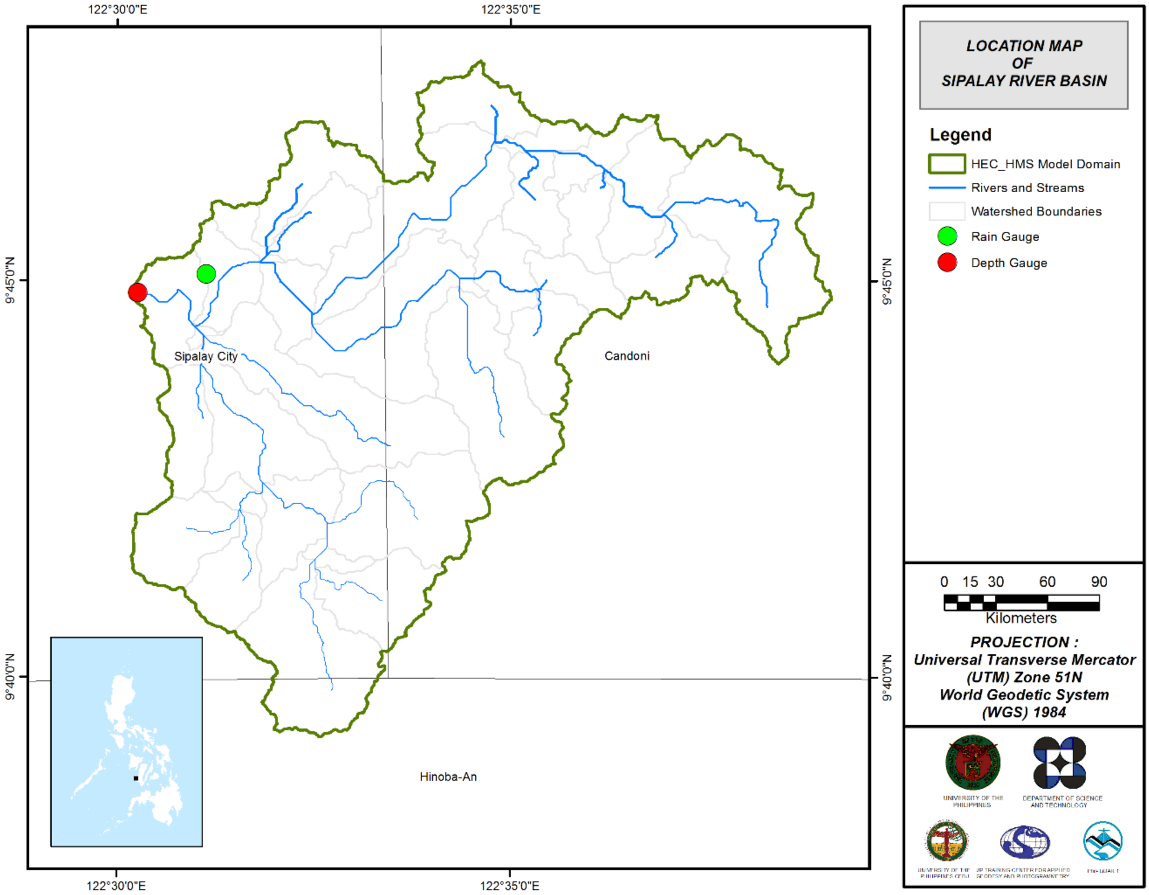


Figure 50. Location map of the Sipalay HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 51) at the Barasbarasan Bridge, Sipalay City, Negros Occidental (9°44'58.37"N, 122°30'14.13"E)to establish the relationship between the observed water levels (H) at Barasbarasan Bridge and outflow (Q) of the watershed at this location.
For Barasbarasan Bridge, the rating curve is expressed as: $Q = 6E\text{-}17e^{3.4348x}$, as shown in Figure 52.

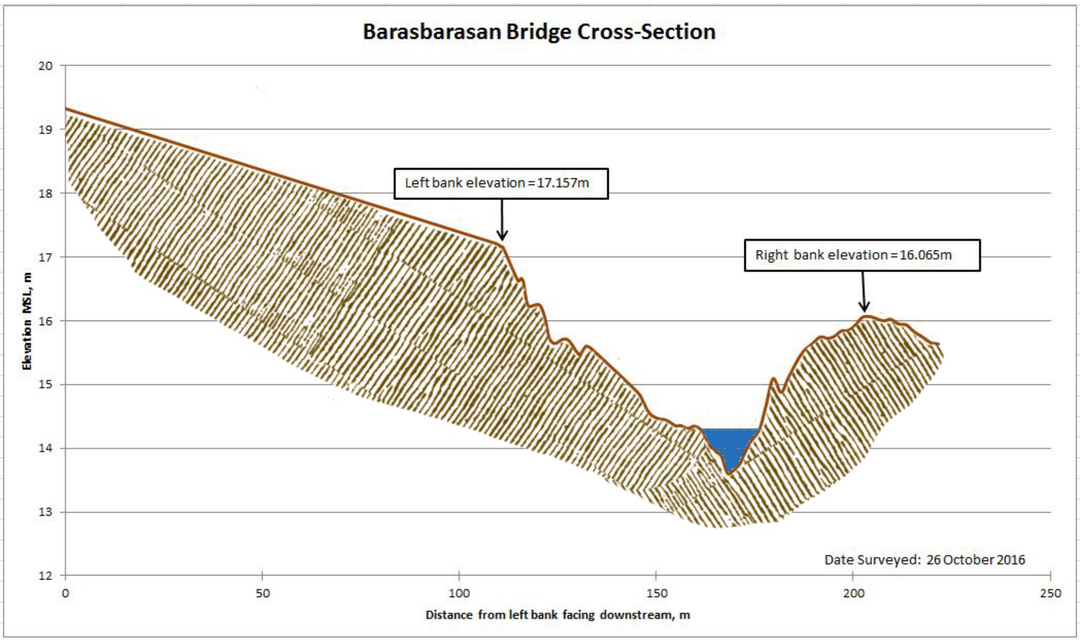


Figure 51. Cross-section plot of the Barasbarasan Bridge

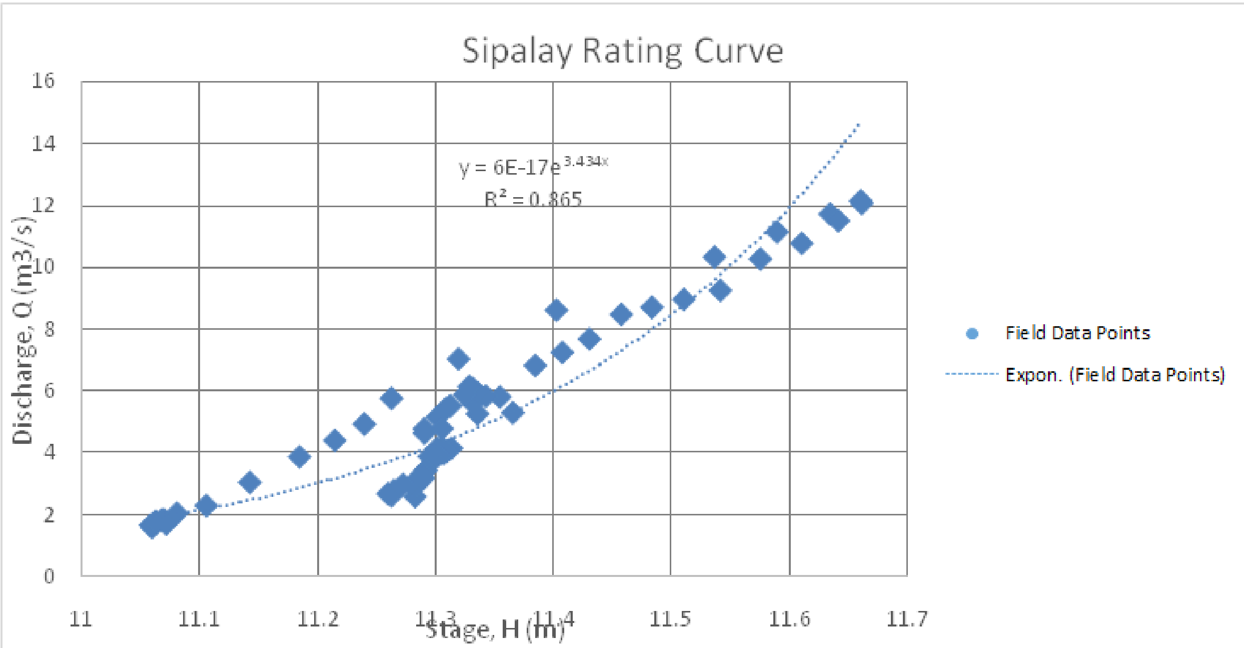


Figure 52. Rating curve of the Barasbarasan Bridge, Sipalay City

This rating curve equation was used to compute the river outflow at the Barasbarasan Bridge for the calibration of the HEC-HMS model shown in Figure 53. The total rainfall for this event is 21.2mm, and the peak discharge is 12.094m^3/s at 1:40 AM on September 16, 2016.

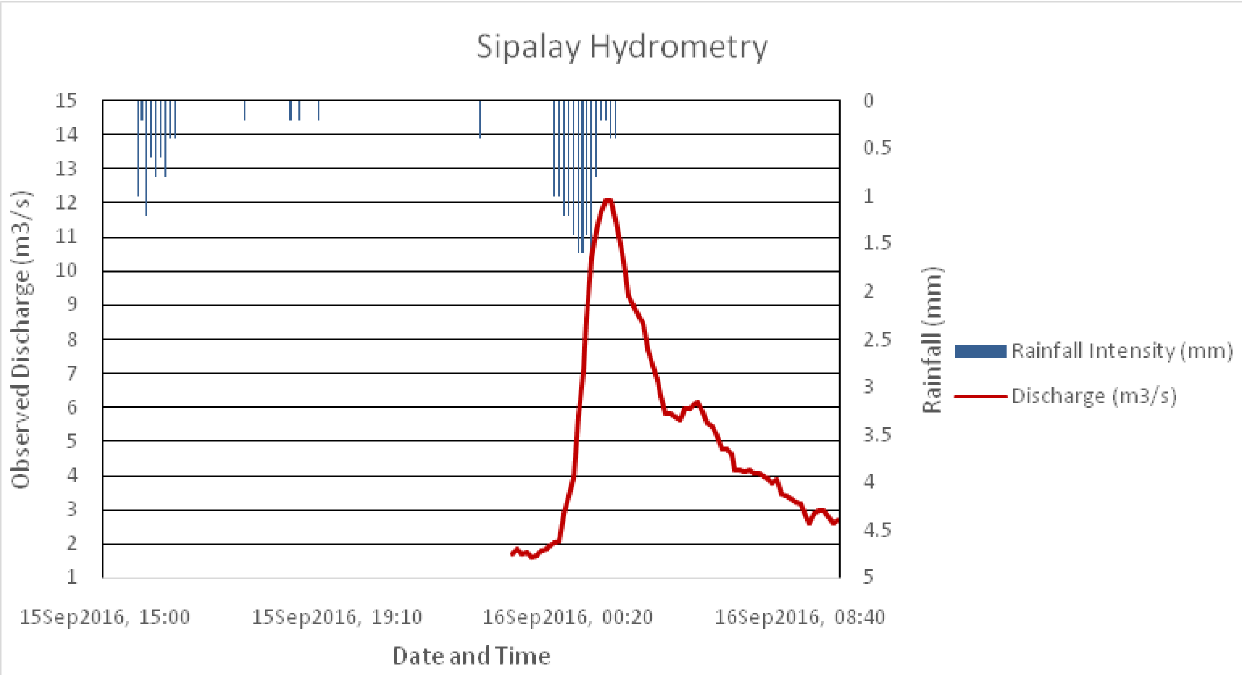


Figure 53. Rainfall and outflow data of the Sipalay River Basin, which was used for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed the Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge (Table 26). This station was selected based on its proximity to the Sipalay watershed (Figure 54). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the valuessuch that certain peak values will be attained at a certain time (Figure 55). The extreme values for this watershed were computed based on a 59-year record.

Table 26. RIDF values for 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

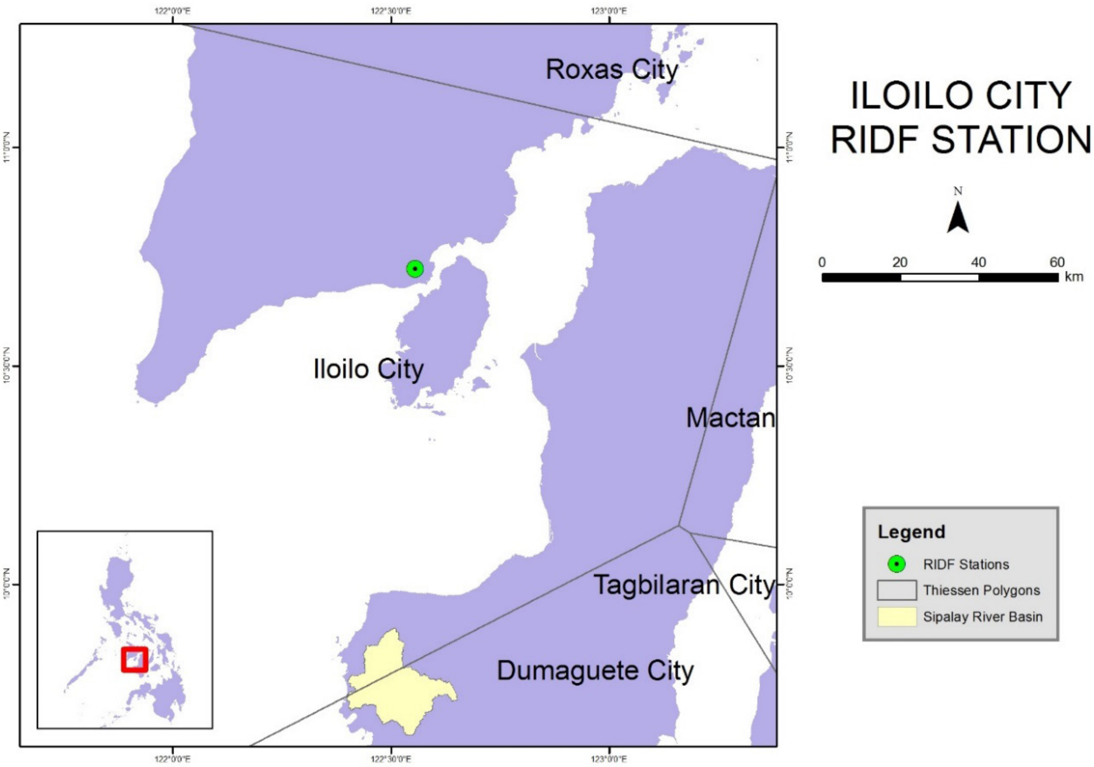


Figure 54. Location of the Iloilo RIDF station relative to the Sipalay River Basin.

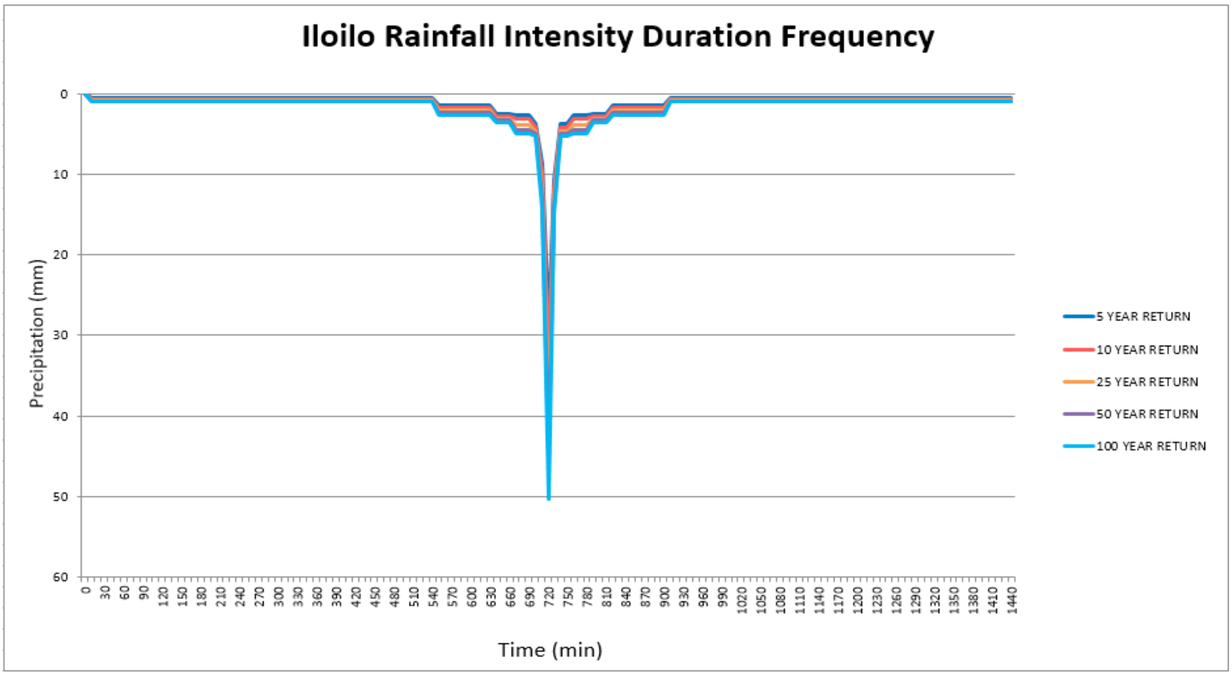


Figure 55. Synthetic storm generated for a 24-hr period rainfall for various return periods.

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 of the Sipalay River Basin are shown in Figure56and Figure 57, respectively.

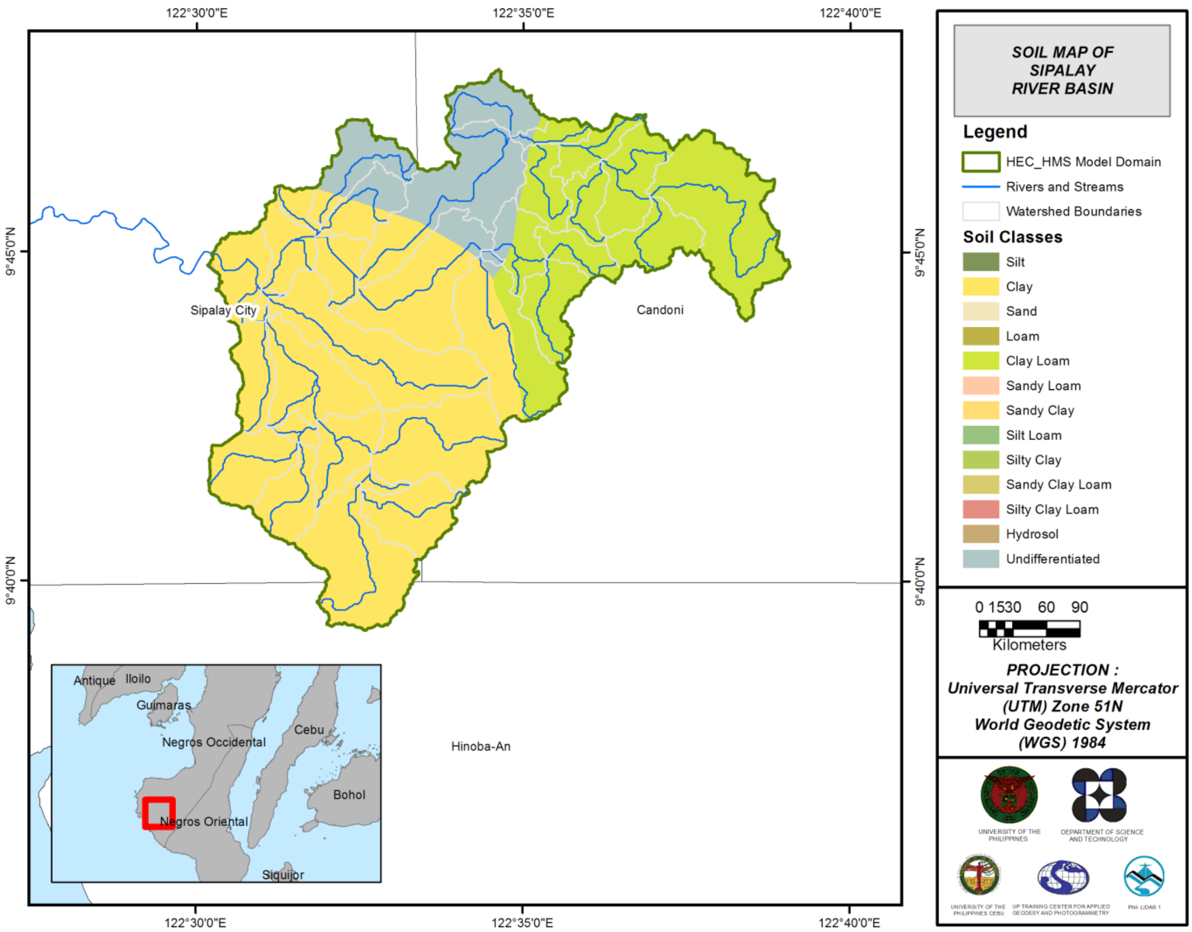


Figure 56. The soil map of the Sipalay River Basin (Source: DA)

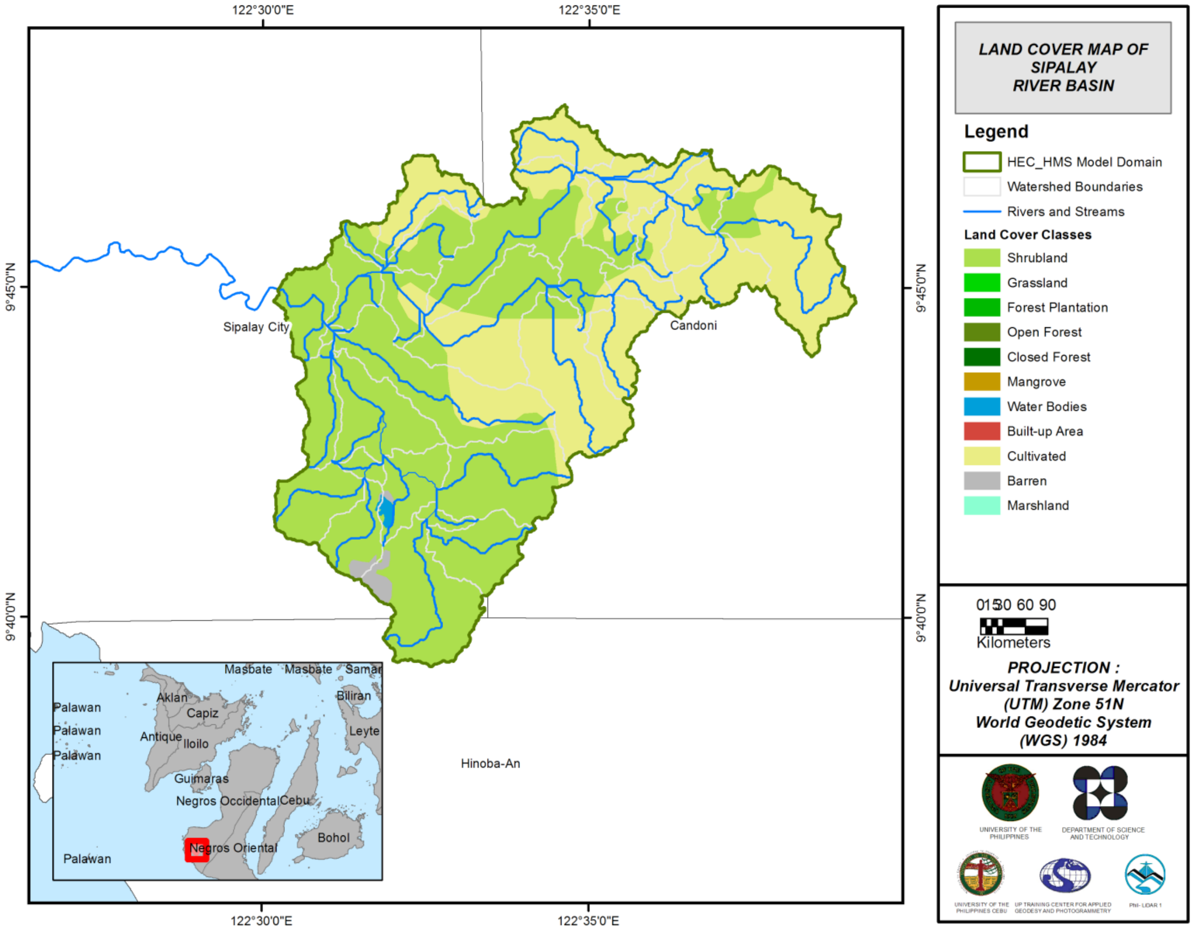


Figure 57. The land cover map of the Sipalay River Basin (Source: NAMRIA).

For Sipalay, three soil classes were identified. These are clay, clay loam, and undifferentiated soil. Moreover, three land cover classes were identified. These are shrubland, barren, and cultivated area.

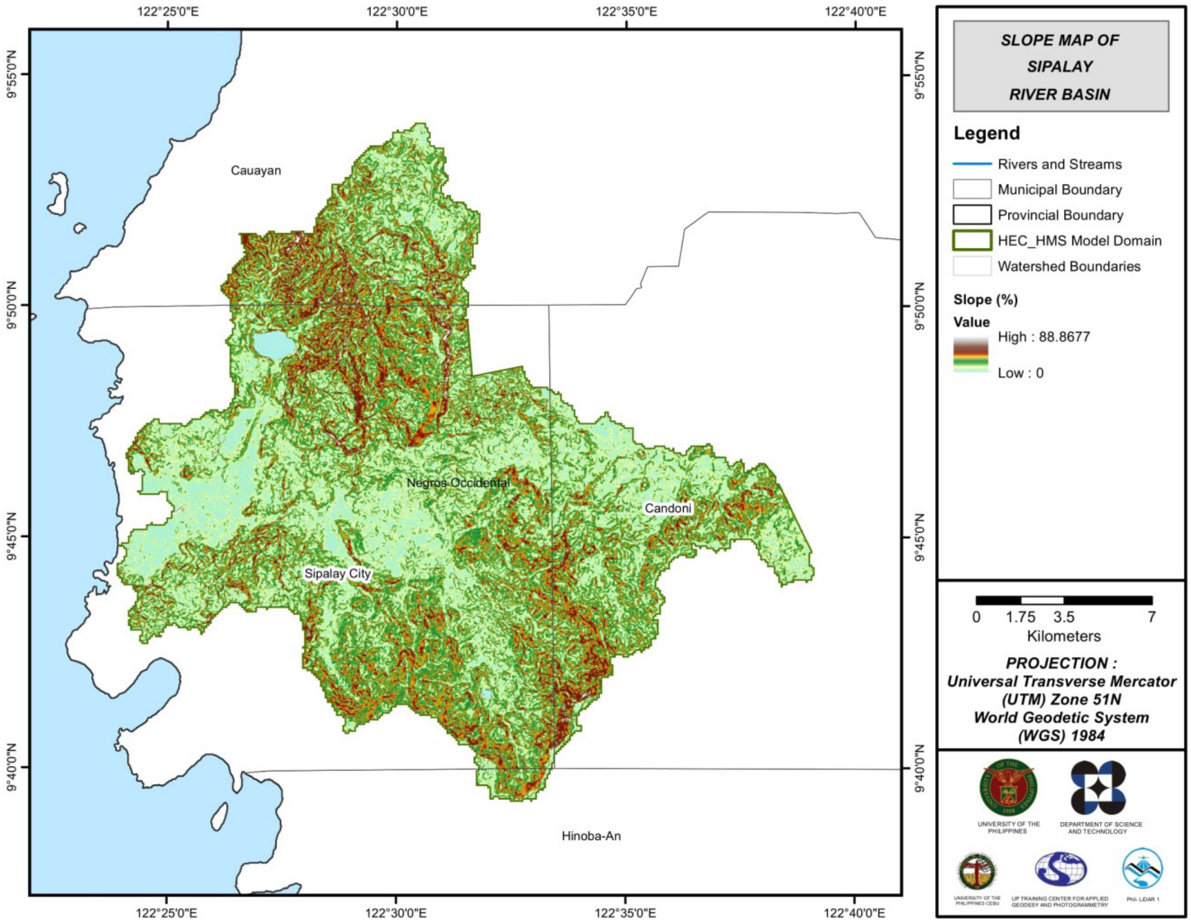


Figure 58. Slope map of Sipalay River Basin

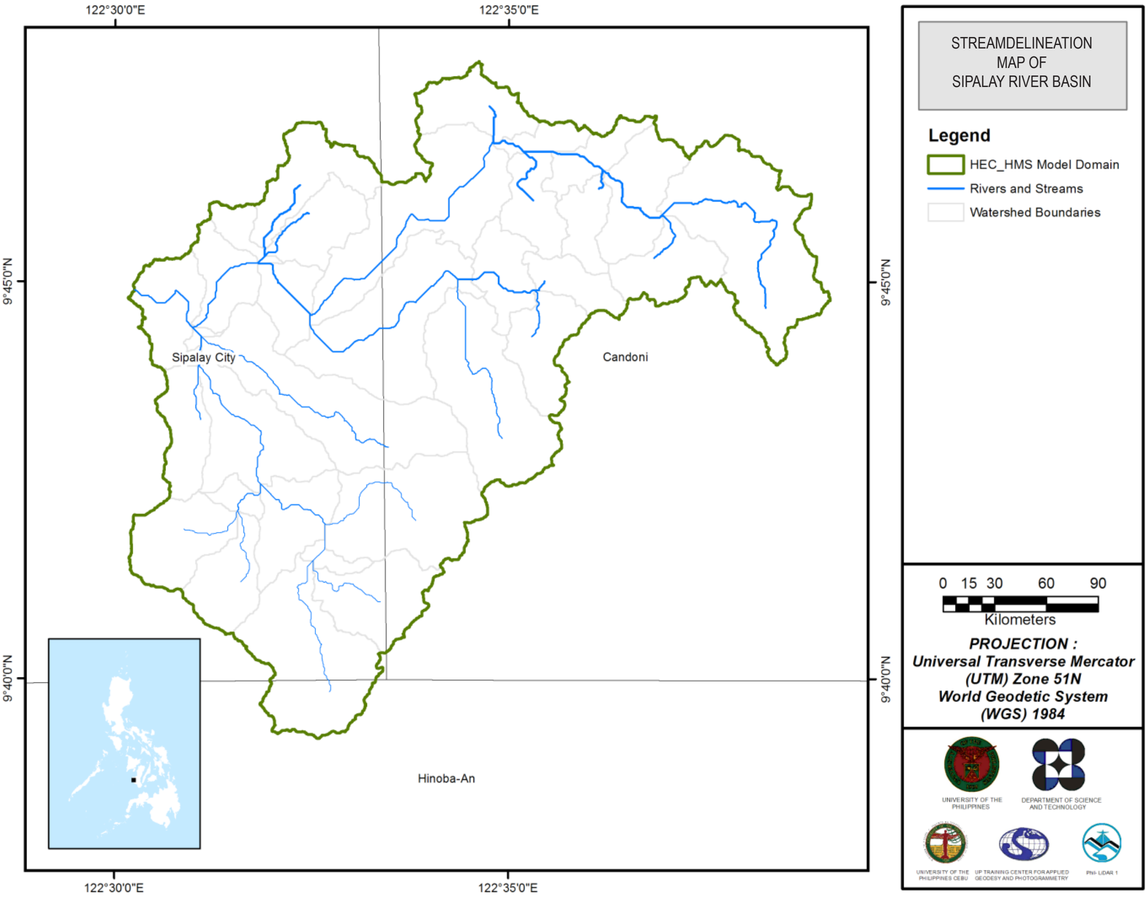


Figure 59. Stream delineation map of Sipalay River Basin

Using the SAR-based DEM, the Sipalay basin was delineated and further subdivided into sub basins. The model consists of forty-nine (49)sub basins, twenty-four (24) reaches, and twenty-four (24) junctions, as shown in Figure 60(See Annex 10). The main outlet is at the Barasbarasan Bridge.

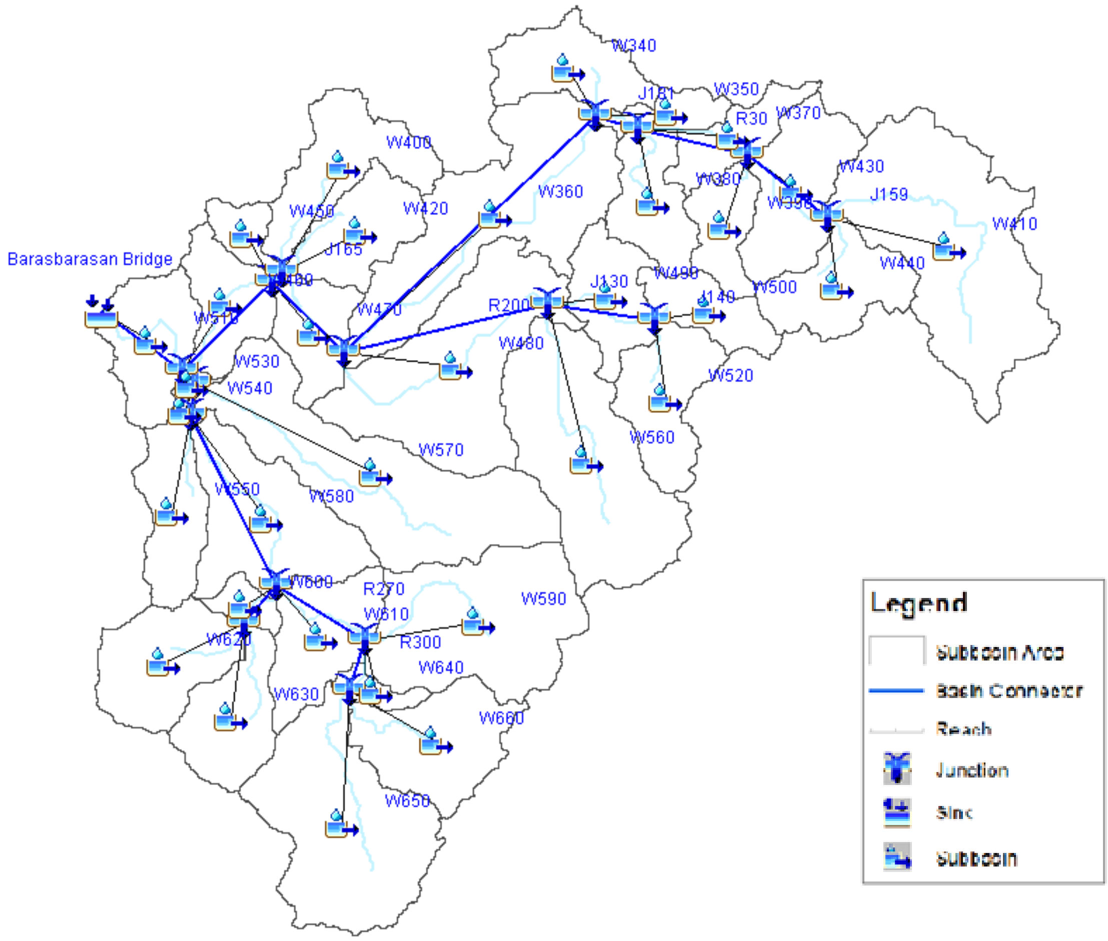


Figure 60. The Sipalay river basin model generated using HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived fromthe LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 61).

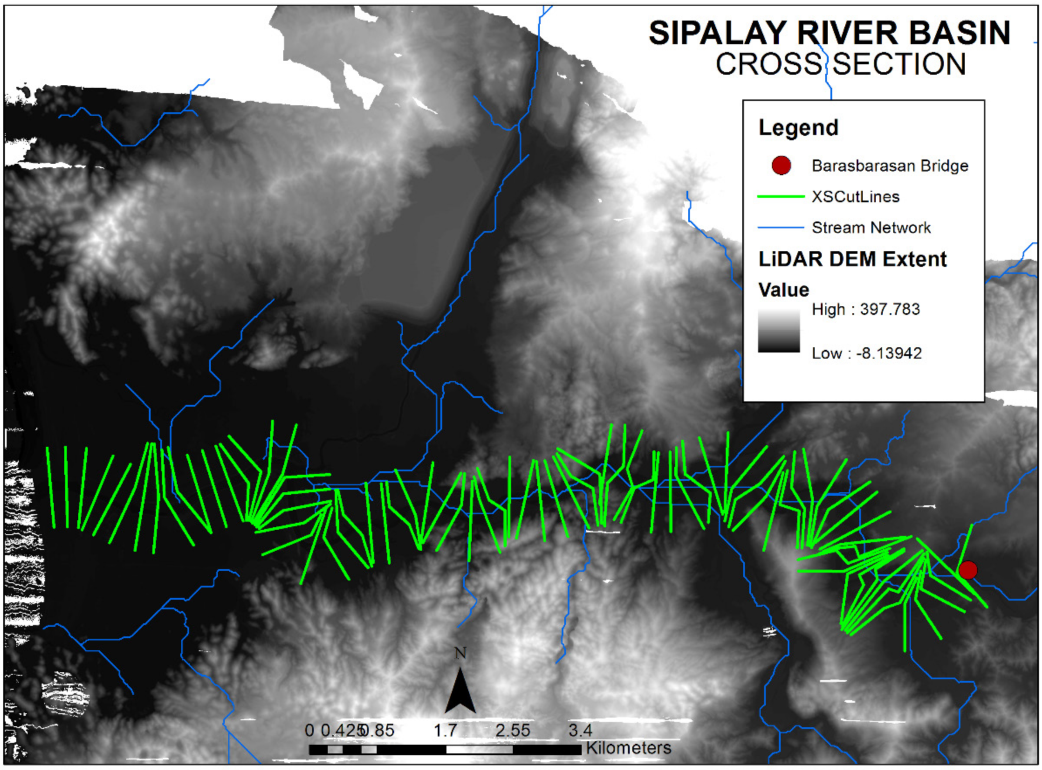


Figure 61. River cross-section of the Sipalay River generated through the Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

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

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

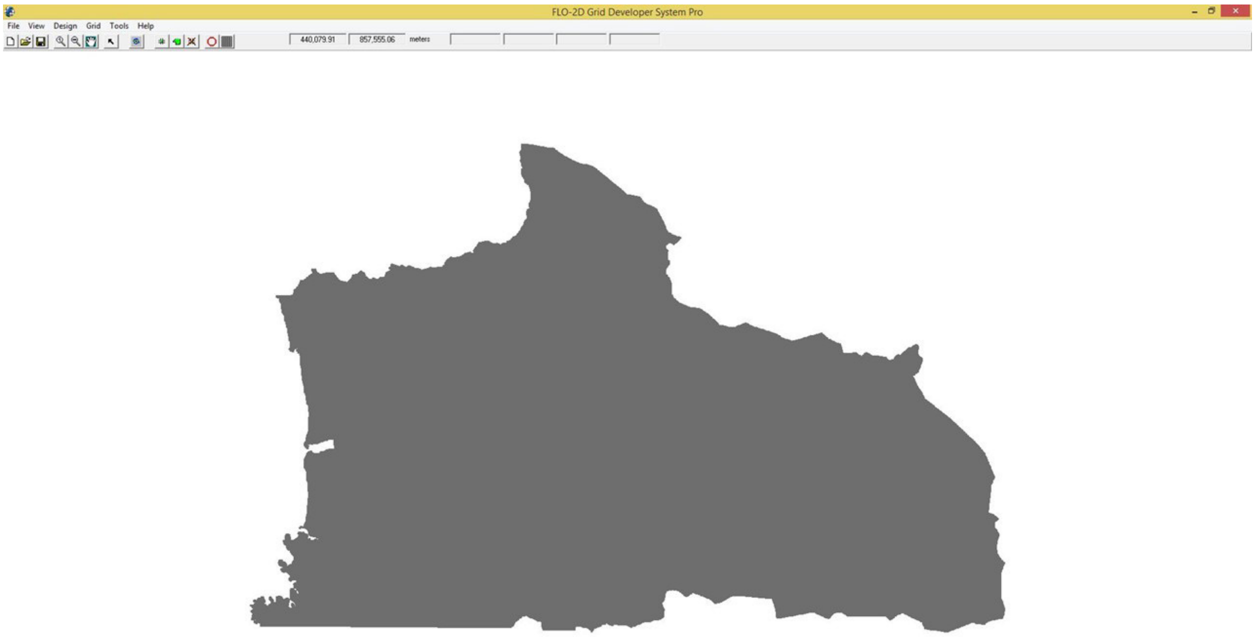


Figure 62. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

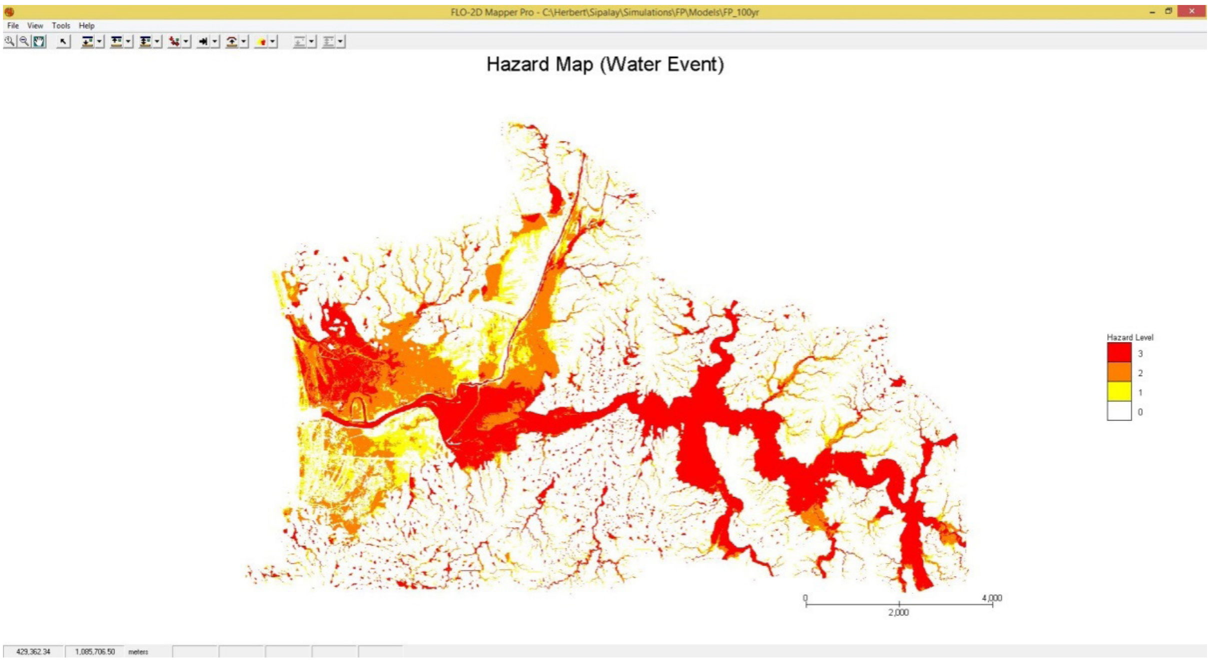


Figure 63. Generated 100-year rain return hazard map from FLO-2D Mapper.

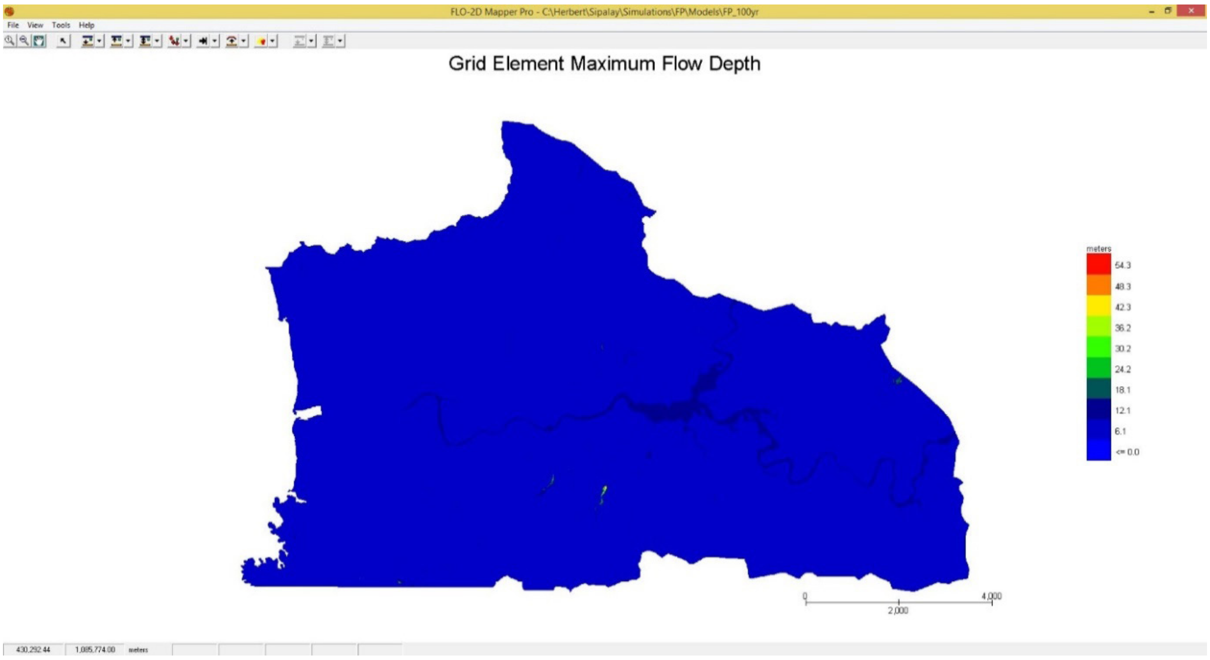


Figure 64. Generated 100-year rain return flow depth map from FLO-2D Mapper.

5.6 Results of HMS Calibration

After calibrating the Sipalay HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 65shows the comparison between the two discharge data.

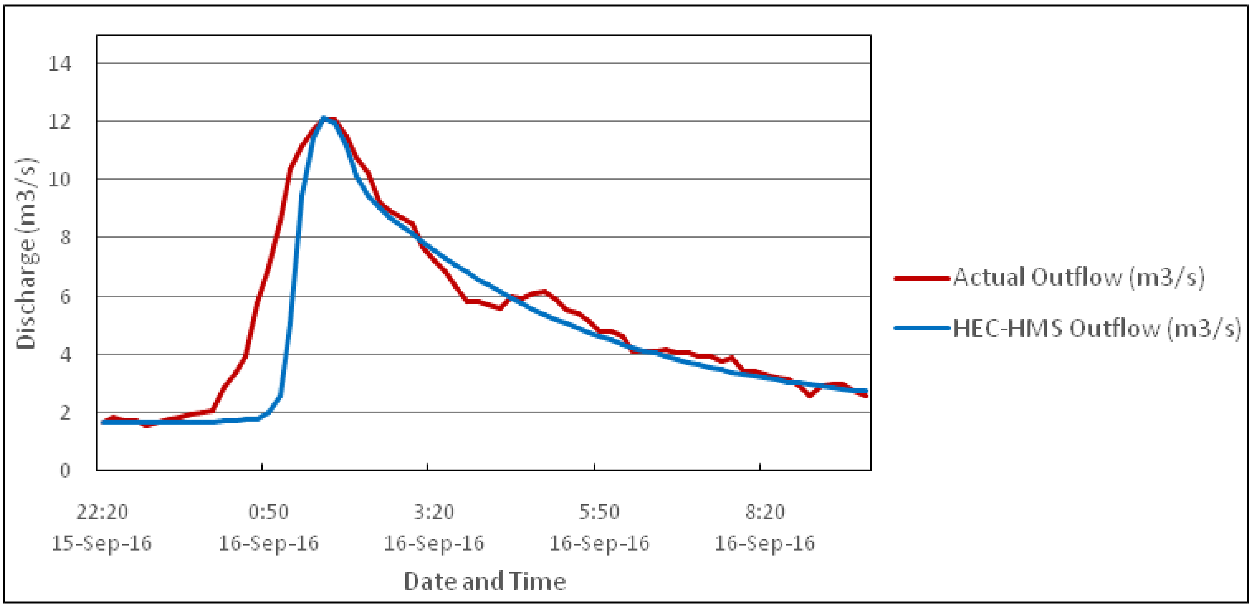


Figure 65. Outflow hydrograph of Sipalay produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 27 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of Calibrated Values for Sipalay.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3.4-51.2
			Curve Number	36.75-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.33-4.25
			Storage Coefficient (hr)	0.11-2.1
	Baseflow	Recession	Recession Constant	0.001
			Ratio to Peak	0.75
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.27-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 3.4 mm to 51.2 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 36.75 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Sipalay, the basin mostly consists of shrublands and cultivated area, and the soil consists of clay, clay loam, and undifferentiated soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.33 hours to 4.25 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events,whileratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.65 indicates a gradual receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Sipalay river basin reaches' Manning's coefficients range from 0.27 to 1, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

Table 28. Efficiency Test of the Sipalay HMS Model.

RMS Error	1.3
r^2	0.9032
NSE	0.79
RSR	0.46
PBIAS	10.04

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as1.3 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9032.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model, where the optimal value is 1. The model attained an efficiency coefficient of 0.79.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 10.04.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.46.

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 66) shows the Sipalay outflow using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 165.2m^3 in a 5-year return period, to 304.5m^3 for a 100-year return period.

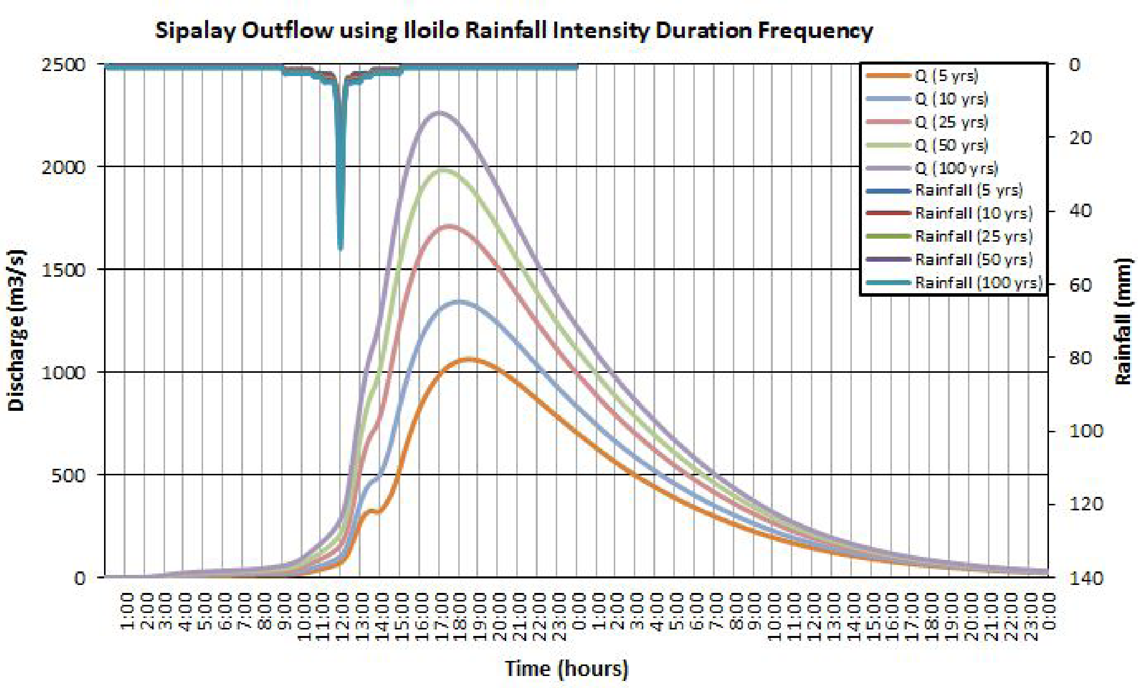


Figure 66. Outflow hydrograph at the Sipalay Station, generated using Iloilo RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Sipalay discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return periods is shown in Table 29.

Table 29. Peak values of the Sipalay 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	1062.6	6 hours, 30 minutes
10-Year	198.9	33.9	1342.9	6 hours
25-Year	241.5	40.5	1710.3	5 hours, 30 minutes
50-Year	273.1	45.4	1984.1	5 hours, 10 minutes
100-Year	304.5	50.3	2262.9	5 hours

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For his publication, only a sample map is presented. The sample generated map of the Sipalay River using the calibrated HMS event flow is shown in Figure 67

Figure 67. Sample output map of the Sipalay RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 68to Figure 73show the 100-, 25-, and 5-year rain return scenarios of the Sipalay floodplain.The floodplain, with an area of 114.86 sq.km., covers one municipality namely, Sipalay City.

Table 30. Municipalities affected in the Sipalay floodplain

Municipality	Total Area	Area Flooded	% Flooded
Sipalay City	327.23	114.76	35.07

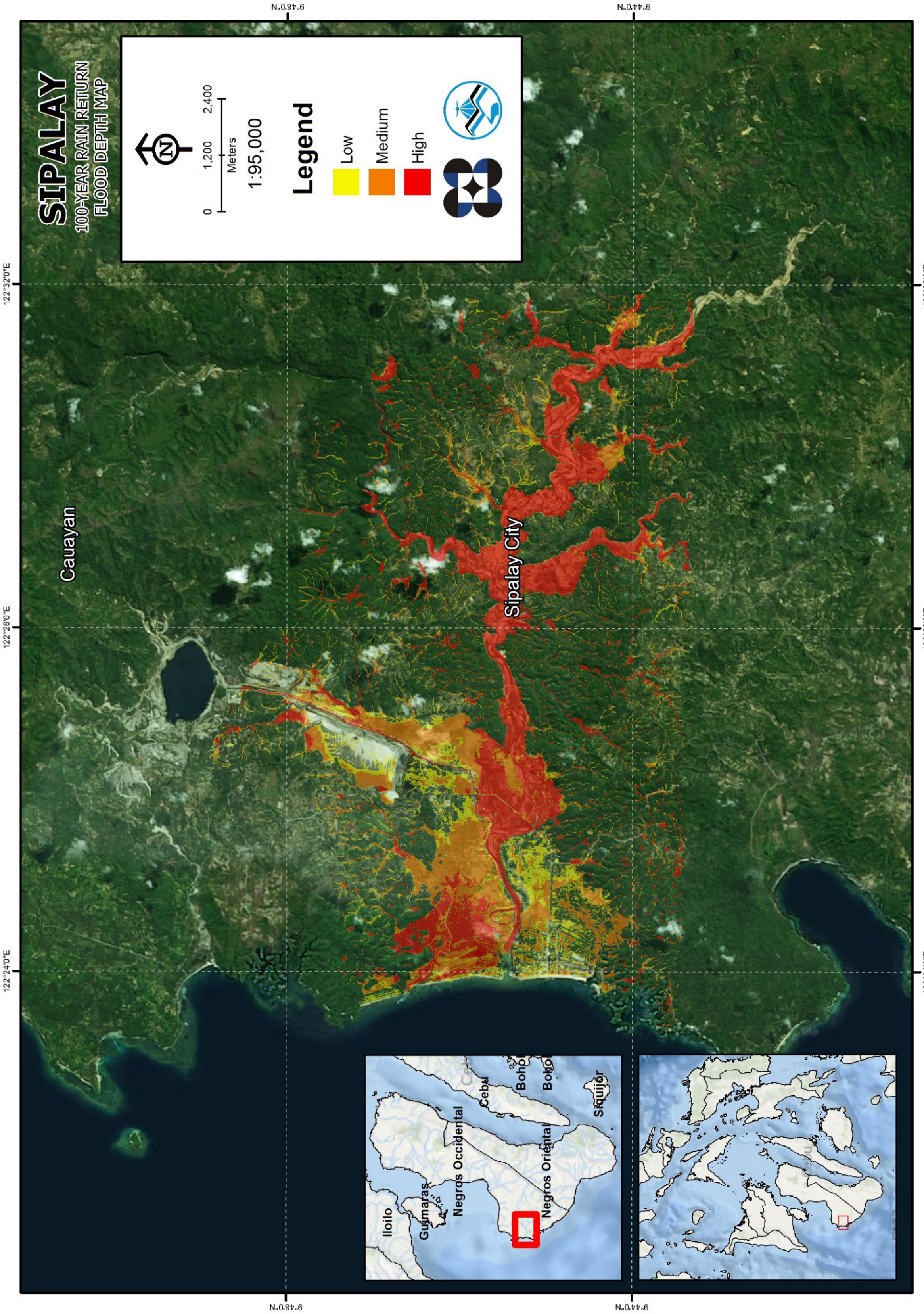


Figure 68. 100-year Flood Hazard Map for Sipalay Floodplain overlaid on Google Earth imagery.

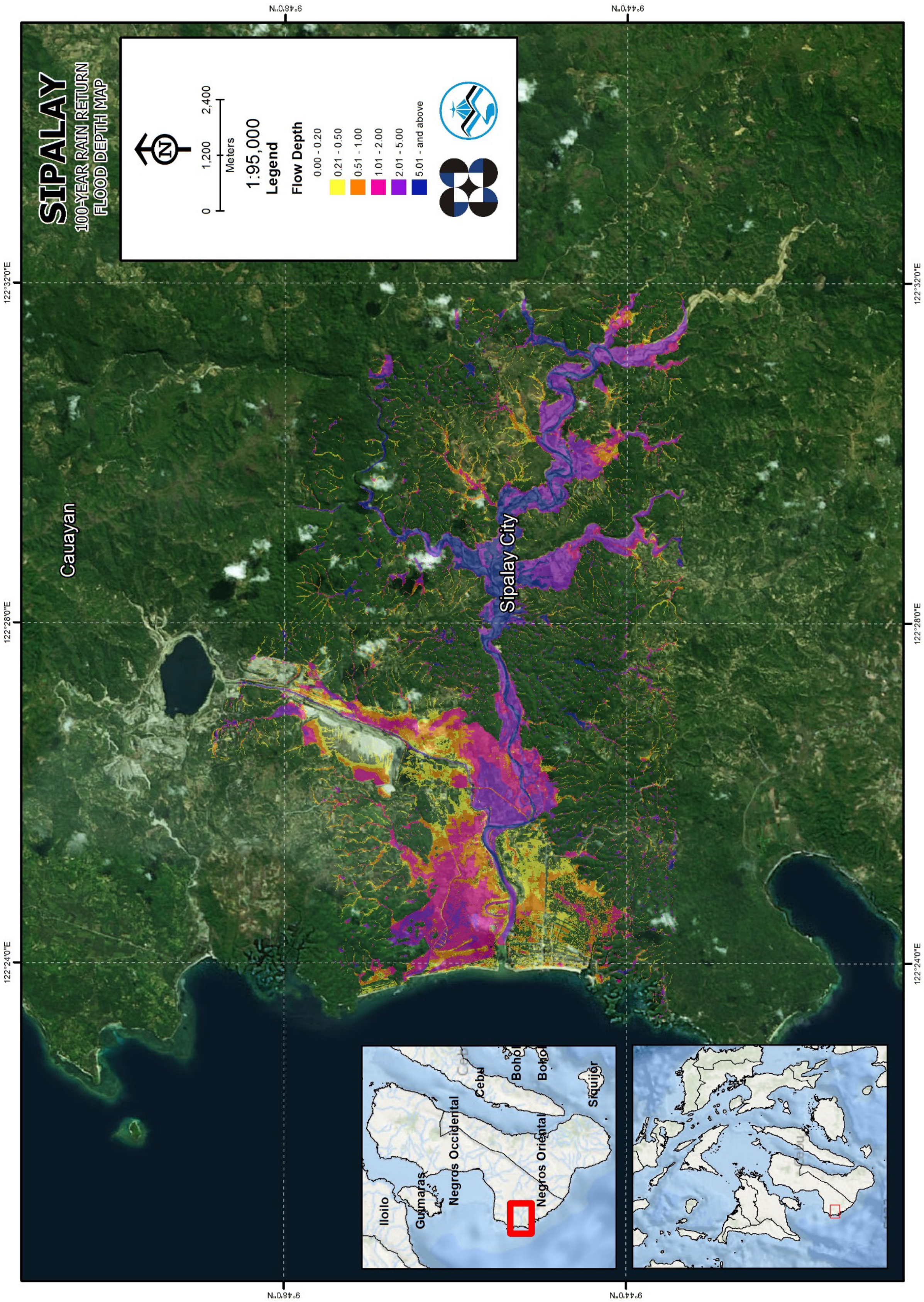


Figure 69. 100-year Flow Depth Map for Sipalay Floodplain overlaid on Google Earth imagery

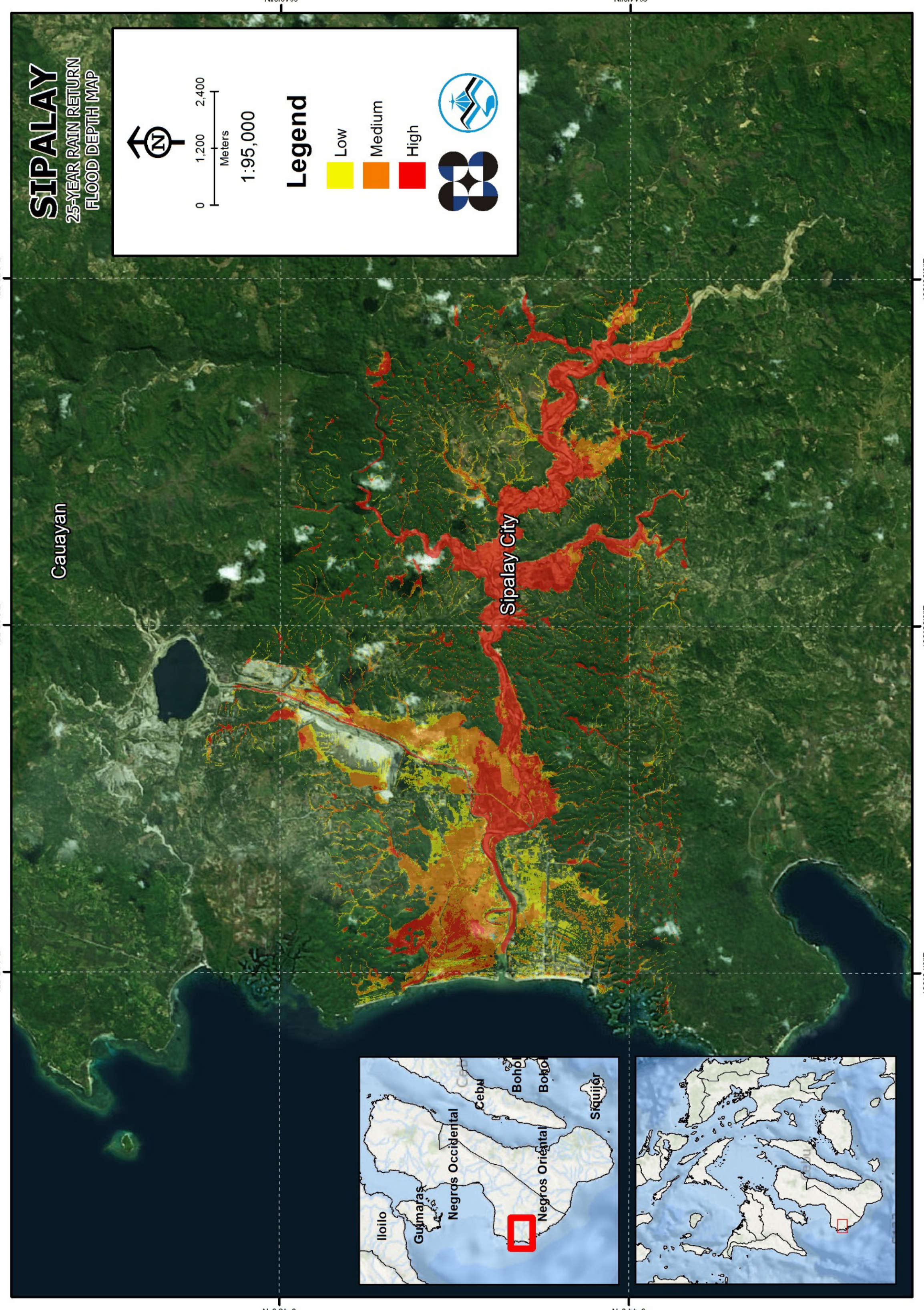


Figure 70. 25-year Flood Hazard Map for Sipalay Floodplain overlaid on Google Earth imagery.

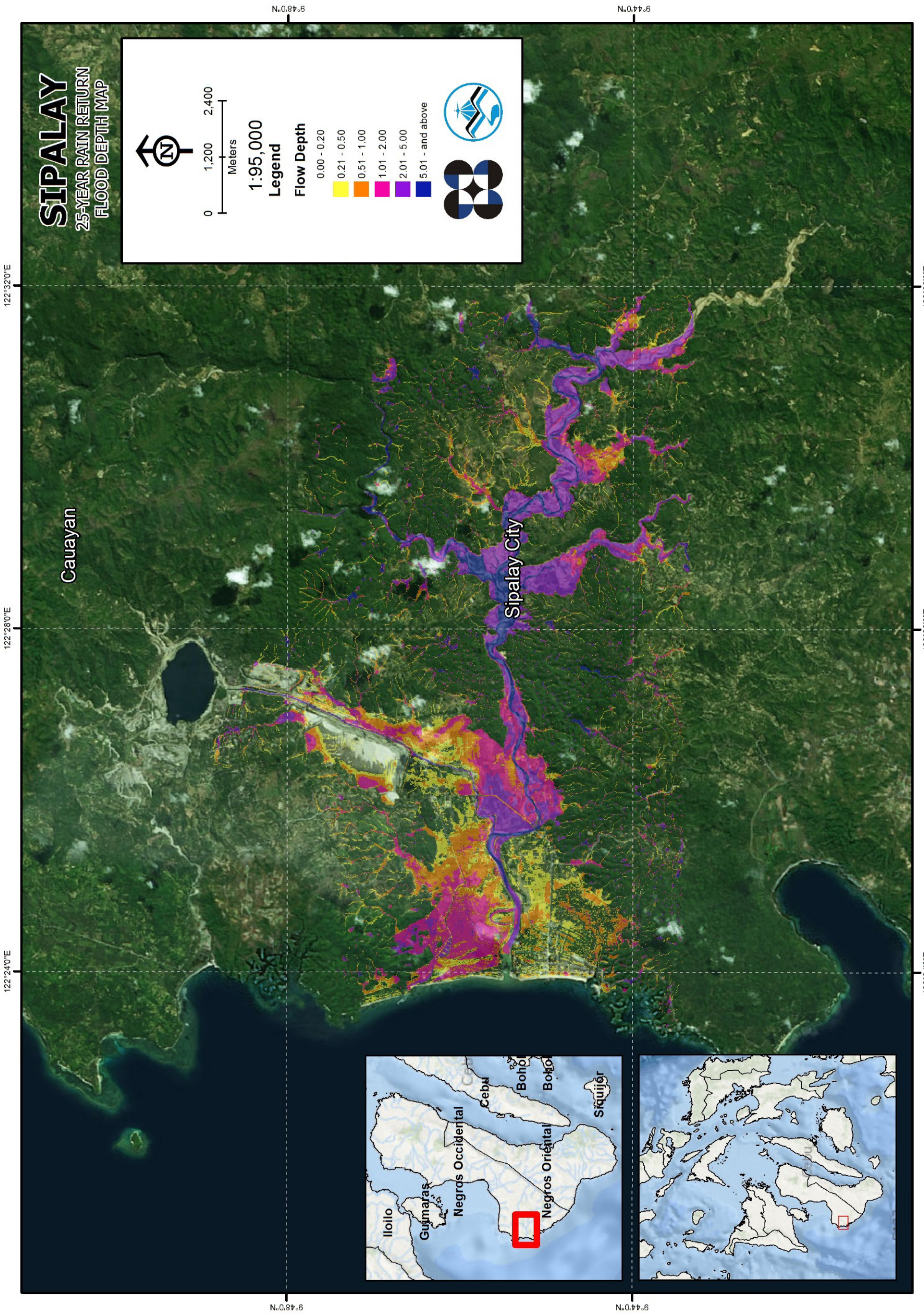


Figure 71. 25-year Flow Depth Map for Sipalay Floodplain overlaid on Google Earth imagery

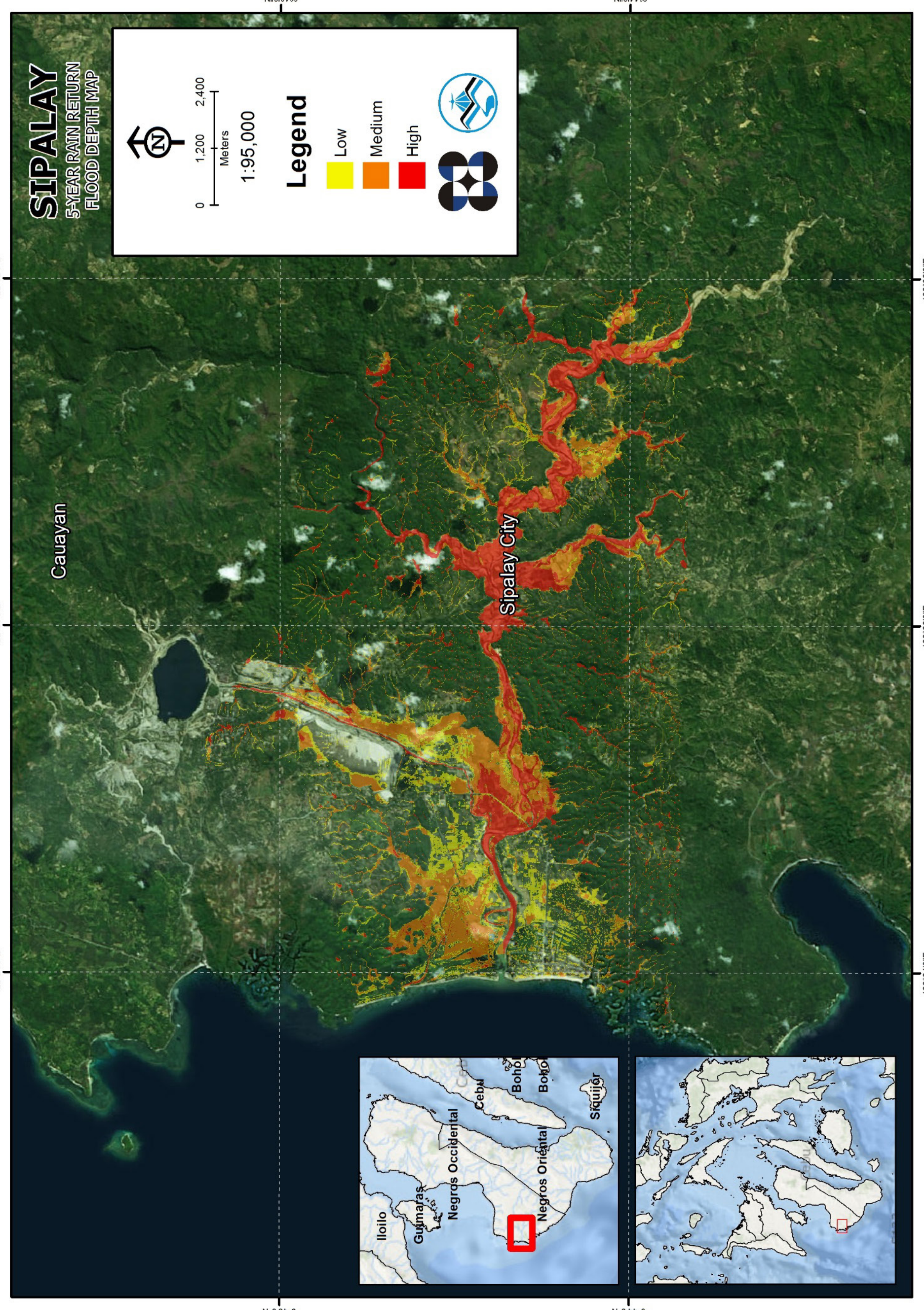


Figure 72. 5-year Flood Hazard Map for Sipalay Floodplain overlaid on Google Earth imagery.

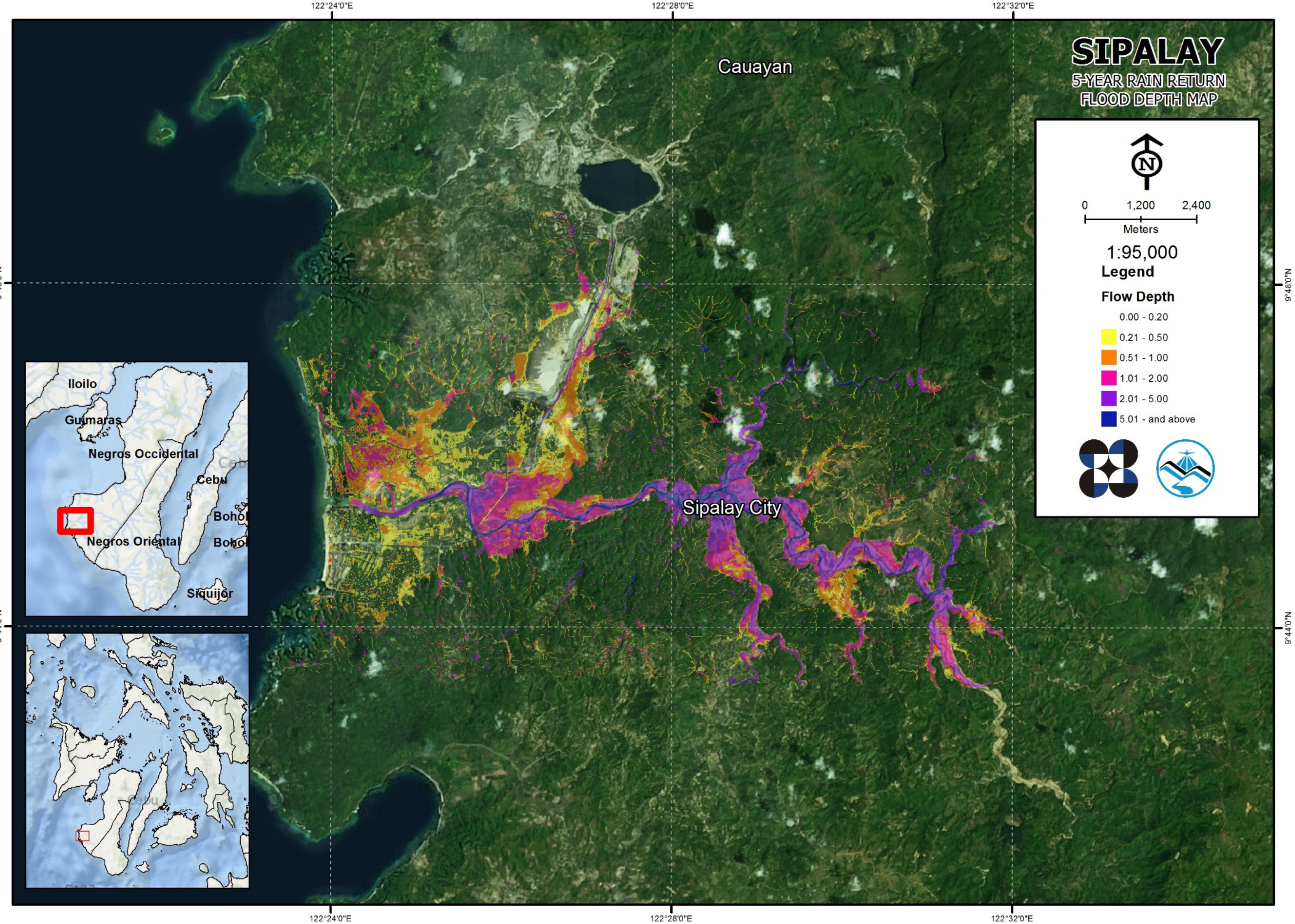


Figure 73. 5-year Flood Depth Map for Sipalay Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

The affected barangays in the Sipalay River Basin, grouped by municipality, are listed below. For the said basin, one (1) city consisting of fourteen (14) barangays is expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 26.49% of the city of Sipalay, with an area of 327.233 sq. km., will experience flood levels of less 0.20 meters. 2.39% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.05%, 1.90%, 1.81%, and 0.42%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more 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 Sipalay City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sipalay City (in sq. km.)													
	Baran-gay 1	Baran-gay 2	Baran-gay 3	Baran-gay 4	Baran-gay 5	Cabadi-angan	Camin-dangan	Can-turay	Gil Mon-tilla	Mam-baroto	Man-lucahoc	Mari-calum	Nau-hang	San Jose
0.03-0.20	0.06	0.39	0.96	2.97	0.14	19.35	1.3	2.65	10.13	10.95	21.14	5.14	3.11	8.39
0.21-0.50	0.02	0.09	0.33	0.28	0.03	0.72	0.04	0.16	2.28	1.19	1.22	0.18	0.71	0.59
0.51-1.00	0	0.01	0.1	0.18	0.01	0.72	0.02	0.09	2.09	0.65	1.21	0.13	1.17	0.34
1.01-2.00	0	0	0.04	0.05	0	1.27	0.01	0.03	1.28	1.07	1.46	0.13	0.62	0.26
2.01-5.00	0	0	0.04	0.04	0	2.59	0.01	0.01	0.53	0.58	1.89	0.1	0.02	0.12
> 5.00	0	0	0	0	0	0.64	0	0	0.12	0.25	0.28	0.01	0	0.05

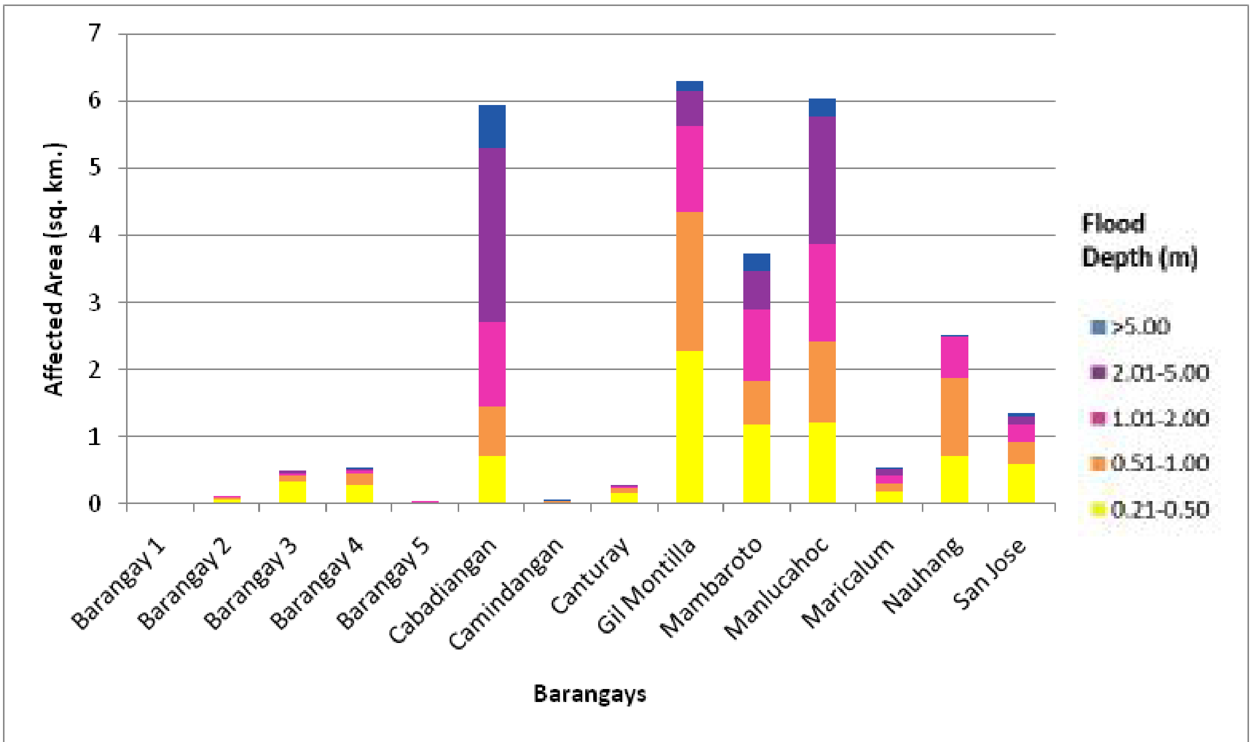


Figure 74. Affected Areas in Sipalay City, Negros Occidental during 5-Year Rainfall Return Period

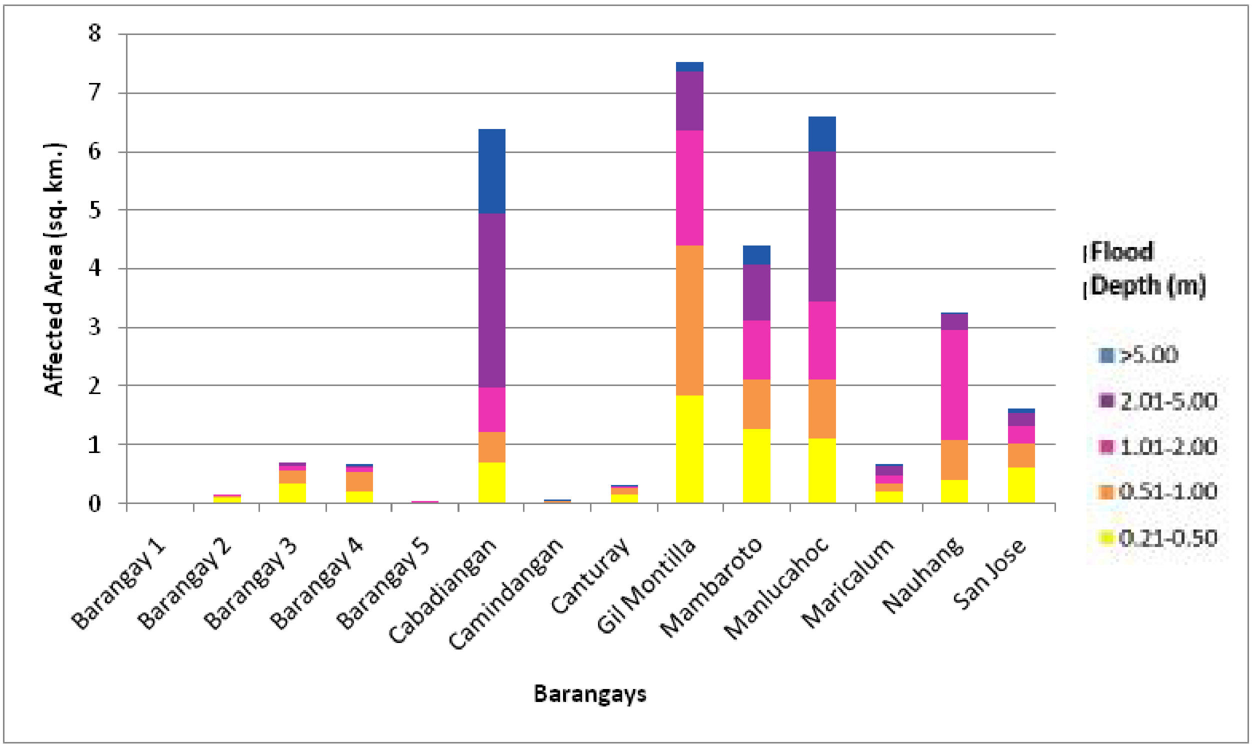
For the 25-year return period, 25.11% of the city of Sipalay, with an area of 327.233 sq. km., will experience flood levels of less 0.20 meters. 2.19% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.09%, 2.34%, 2.52%, and 0.81%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 are the affected areas, in square kilometers, by flood depth per barangay.

Table 32. Affected Areas in Sipalay City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sipalay City (in sq. km.)													
	Baran-gay 1	Baran-gay 2	Baran-gay 3	Baran-gay 4	Baran-gay 5	Cabadi-angan	Camin-dangan	Can-turay	Gil Mon-tilla	Mam-baroto	Man-lucahoc	Mari-calum	Nau-hang	San Jose
0.03-0.20	0.05	0.35	0.76	2.82	0.11	18.92	1.28	2.61	8.88	10.28	20.59	5.01	2.38	8.14
0.21-0.50	0.03	0.12	0.36	0.22	0.04	0.71	0.05	0.17	1.85	1.27	1.11	0.21	0.41	0.64
0.51-1.00	0.01	0.02	0.22	0.31	0.02	0.51	0.02	0.1	2.57	0.84	1.01	0.15	0.66	0.4
1.01-2.00	0	0.01	0.07	0.1	0	0.78	0.01	0.06	1.94	1.03	1.32	0.14	1.89	0.3
2.01-5.00	0	0	0.06	0.05	0	2.94	0.01	0.02	1.02	0.93	2.56	0.15	0.28	0.22
> 5.00	0	0	0	0.01	0	1.46	0	0	0.16	0.33	0.61	0.03	0	0.07

Figure 75. Affected Areas in Sipalay City, Negros Occidental during 25-Year Rainfall Return Period

For the 100-year return period, 24.38% of the city of Sipalay, with an area of 327.233 sq. km. will experience flood levels of less 0.20 meters. 2.13% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.0%, 2.53%, 2.74%, and 1.28%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 are the affected areas, in square kilometers,by flood depth per barangay.


Affected Area (sq. km.)
0
1
2
3
4
5
6
7
8
Barangay 1
Barangay 2
Barangay 3
Barangay 4
Barangay 5
Cabadiangan
Camindangan
Canturay
Gil Montilla
Mambaroto
Manlucahoc
Maricalum
Nauhang
San Jose
Barangays
Flood Depth (m)
>5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sipalay City (in sq. km.)													
	Baran-gay 1	Baran-gay 2	Baran-gay 3	Baran-gay 4	Baran-gay 5	Cabadi-angan	Camin-dangan	Can-turay	Gil Mon-tilla	Mam-baroto	Man-lucahoc	Mari-calum	Nau-hang	San Jose
0.03-0.20	0.05	0.31	0.63	2.72	0.1	18.63	1.27	2.58	8.39	9.82	20.24	4.92	2.18	7.94
0.21-0.50	0.03	0.14	0.35	0.2	0.04	0.74	0.05	0.17	1.65	1.3	1.08	0.22	0.32	0.66
0.51-1.00	0.01	0.03	0.31	0.28	0.02	0.49	0.02	0.11	2.17	1.04	0.9	0.15	0.54	0.46
1.01-2.00	0	0.01	0.11	0.25	0.01	0.63	0.02	0.06	2.8	0.93	1.08	0.16	1.89	0.34
2.01-5.00	0	0	0.06	0.06	0	2.39	0.01	0.02	1.24	1.2	2.83	0.18	0.7	0.28
> 5.00	0	0	0	0.01	0	2.43	0	0	0.18	0.38	1.06	0.05	0	0.08

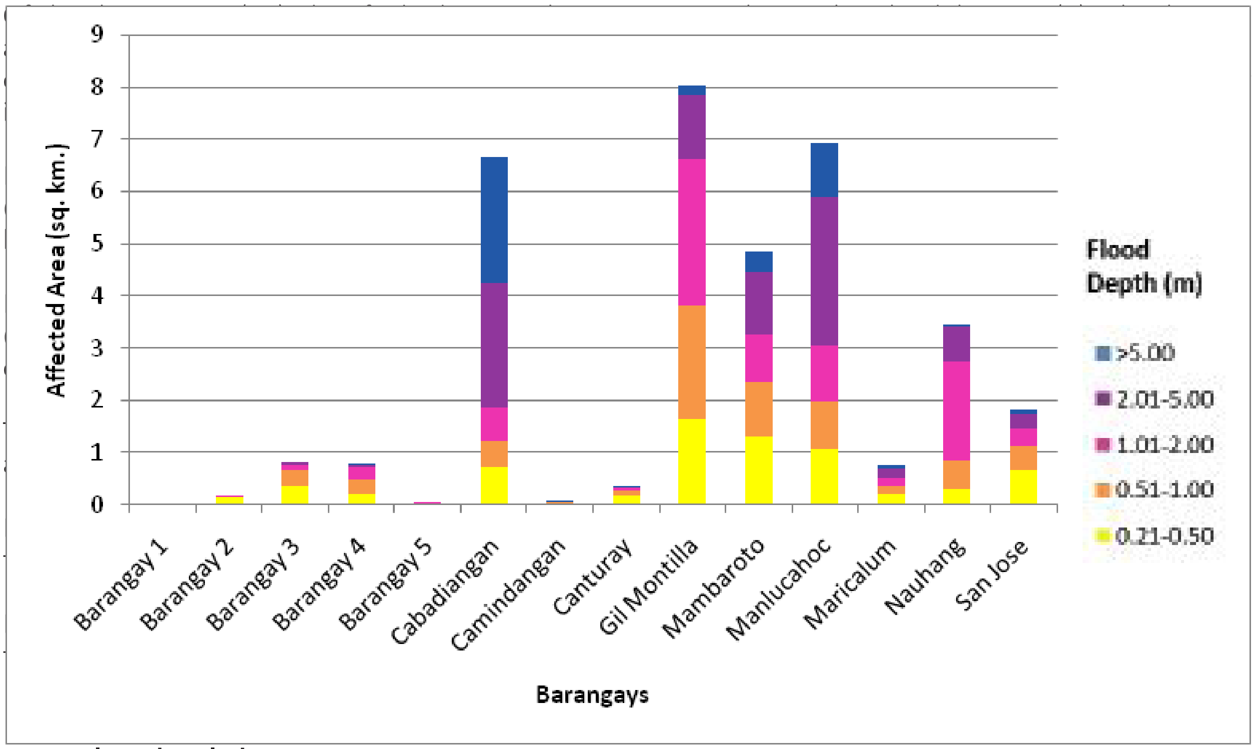
Figure 76. Affected Areas in Sipalay City, Negros Occidental during 100-Year Rainfall Return Period

Among the barangays in the city of Sipalay, Manlucahoc is projected to have the highest percentage of area that will experience flood levels at 8.31%. Meanwhile, Cabadiangan posted the second highest percentage of area that may be affected by flood depths at 7.73%.

The generated flood hazard maps for the Sipalay Floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Annex 12 and Annex 13 present the educational and health institutions exposed to flooding, respectively. Using the flood depth units of PAGASA for hazard maps – "Low", "Medium", and "High" – the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-yr, 25-yr, and 100-yr).

Table 34. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	7.94179	7.23913	7.00599
Medium	10.4335	11.3723	11.3177
High	10.0656	14.32	17.000299



5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gathered secondary data regarding flood 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 different scenarios are identified for validation.

The validation personnel went to the specified points identified in theriver basin andgathered data onthe actual flood level in each location. Data gathering wasconducted 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 the particular area.

After which, the actual data from the field were compared to the simulated data, to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus thecorresponding validation depths are illustratedin Figure 78.

The flood validation consists of 271 points randomly selected all over the Sipalay floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.28m. Table 35shows a contingency matrix of the comparison.The validation points are found in Annex 11.

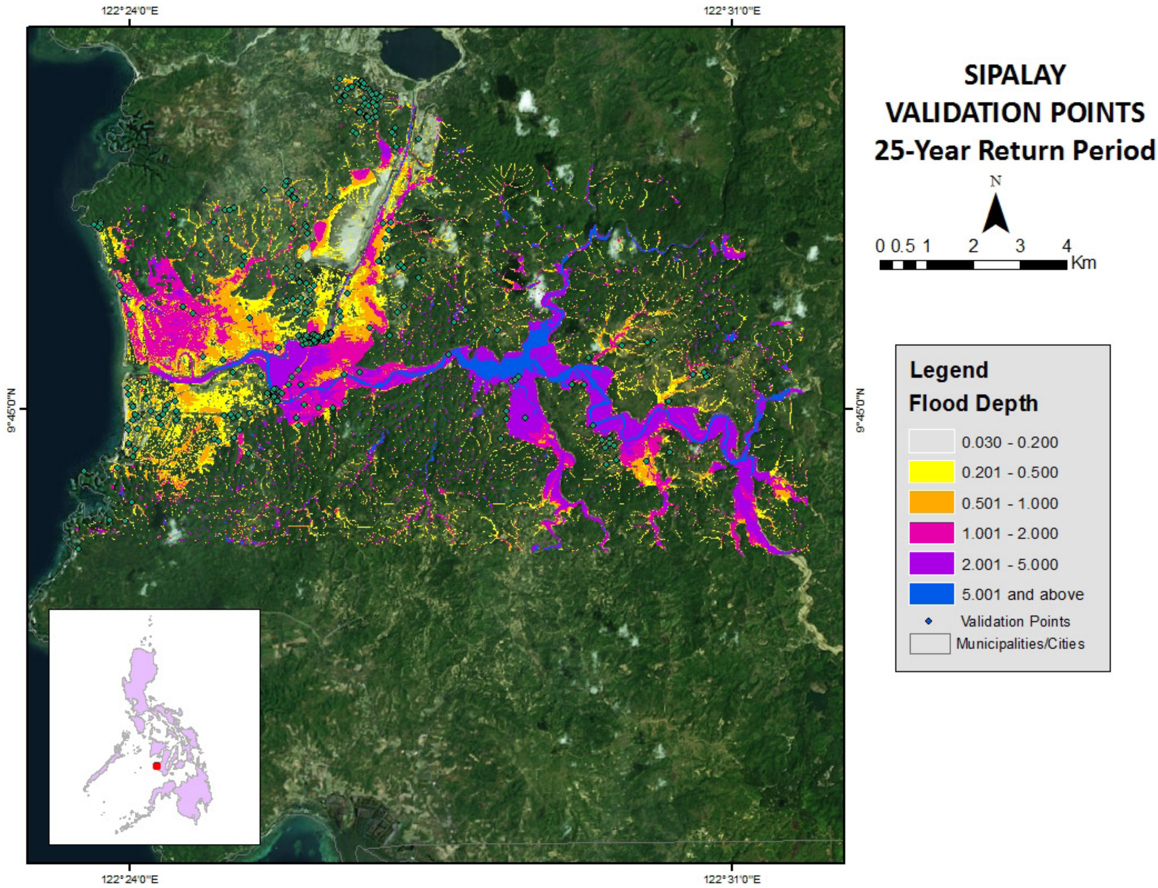


Figure 77. Validation points for a 25-year Flood Depth Map of the Sipalay Floodplain

Figure 78. Flood map depth vs actual flood depth

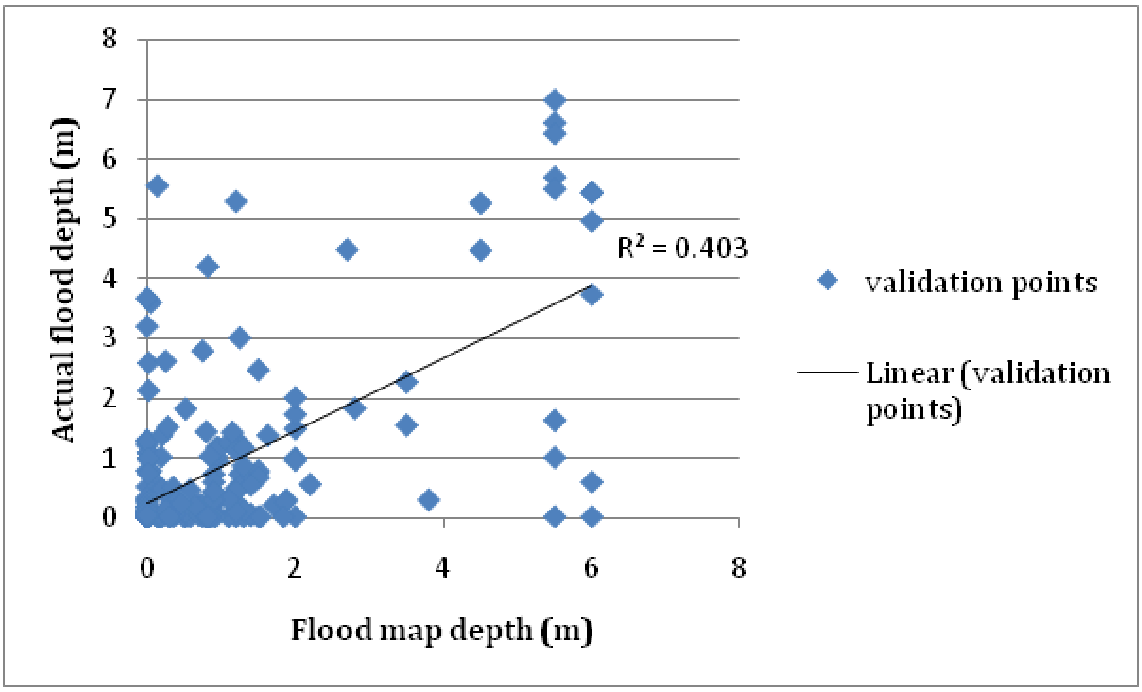
Table 35. Actual flood depth vs simulated flood depth at different levels in the Sipalay River Basin.

		Modeled Flood Depth (m)						
	SIPALAY 0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total	
Actual Flood Depth (m)	0-0.20	104	7	7	9	5	1	133
	0.21-0.50	10	5	1	1	1	0	18
	0.51-1.00	18	10	3	7	2	0	40
	1.01-2.00	14	7	8	10	3	1	43
	2.01-5.00	3	1	1	2	3	1	11
	> 5.00	14	0	1	2	2	7	26
	Total	163	30	21	31	16	10	271

The overall accuracy generated by the flood model is estimated at 48.71%, with 132 points correctly matching the actual flood depths. In addition, there were 51 points estimated one level above and below the correct flood depths, while there were 39 points and 26 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 46 points were overestimated, while a total of 93 points were underestimated in the modeled flood depths of Sipalay. Table 36 depicts the summary of the Accuracy Assessment in the Sipalay River Basin Survey.

Table 36. Summary of Accuracy Assessment in the Sipalay River Basin Survey

	No. of Points	%
Correct	132	48.71
Overestimated	46	16.97
Underestimated	93	34.32
Total	271	100



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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 LiDAR Sensors used in the Sipalay Floodplain Survey

1. OPTECH Technical Specifications of Gemini

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);
	220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg
	Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

2. OPTECH Technical Specifications of Aquarius

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitiude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

3. ITRES Technical Specifications of CASI

Sensor Type	
VNIR Push-broom Sensor	
(Compact Airborne Spectrographic Imager)	
Performance	
Spectral Range (Continuous Coverage)	380-1050 nm
# Spectral Channels	Up to 288
#Across-Track Pixels	1500
Total Field of View	40 deg
IFOV	0.49 mRad
t/#	t/3.5
Spectral Width Sampling Row	2.4 nm
Spectral Resolution (FWHM)	<3.5 nm
Pixel Size	20x20 microns
Dynamic Range	14-bits (16384:1)
Sustained Date Rate (Mpix/Second)	9.6 Mpix/Sec
Spectral Smile/Keystone Distortion	±0.35 pixels
Peak Signal Noise Ration	SNR models for various radiance conditions are available
Relative humidity	0-95% no-condensing

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

1. NGW-126

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

October 30, 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-126**

Order: **2nd**

Island: **VISAYAS**	Barangay: **MARICALUM**		
Municipality: **SIPALAY**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **9º 41' 56.09927"**	Longitude: **122º 26' 33.87232"**	Ellipsoidal Hgt:	**20.29100 m.**
	WGS84 Coordinates		
Latitude: **9º 41' 52.00368"**	Longitude: **122º 26' 39.18513"**	Ellipsoidal Hgt:	**79.82600 m.**
	PTM / PRS92 Coordinates		
Northing: **1072482.031 m.**	Easting: **438848.628 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **1,072,106.64**	Easting: **438,870.03**	Zone:	**51**

Location Description

NGW-126
The station is located on the SE corner of Maricalum bridge which is at the km 177+175. Mark is the head of a 4" copper nail flushed at the center of a 30 x 30 cm. cement putty embedded on the bridge sidewalk with inscriptions "NGW-126; 2007; NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2590**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. NGW-128

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

January 27, 2016

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS OCCIDENTAL**
Station Name: **NGW-128**
Order: **2nd**

Island: **VISAYAS**
Municipality: **HINOBA-AN**
Barangay: **TALAGACAY**
MSL Elevation:

PRS92 Coordinates

Latitude: **9° 39' 46.23234"** Longitude: **122° 27' 45.10886"** Ellipsoidal Hgt: **8.19400 m.**

WGS84 Coordinates

Latitude: **9° 39' 42.14773"** Longitude: **122° 27' 50.42475"** Ellipsoidal Hgt: **67.85800 m.**

PTM / PRS92 Coordinates

Northing: **1068488.805 m.** Easting: **441013.849 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **1,068,114.82** Easting: **441,034.50** Zone: **51**

Location Description

NGW-128
The station is located on the SE side of the road beside the headwall. Mark is the head of a 4" copper nail flushed at the center of a 30 x 30 cm. cement putty embedded on top of the RCBC with inscriptions "NGW-128; 2007; NAMRIA".

The station is located along the Sipalay-Hinobaan national road.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0243**

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

www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

Annex data not provided in the raw DAC file.

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Supervising Science Research Specialist	LOVELY GRACIA ACUÑA	UP-TCAGP
	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
		AUBREY MATIRA-PAGADOR	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
		MA. REMEDIOS VILLANUEVA	UP-TCAGP
		JONALYN GONZALES	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JONATHAN ALMALVEZ	UP-TCAGP
		GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		SSG. ERWIN DELOS SANTOS	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC
		CAPT. MARK TANGONAN	AAC
	Co-Pilot	CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. GEROME MOONEY	AAC

Annex 5. Data Transfer Sheets for the Sipalay Floodplain Flights

DATA TRANSFER SHEET
12/09/2014(dumaguete, bislig)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
31-Oct	7588G	2BLK53C304A	GEMINI	5.53	109	236	236	NA	NA	9.8	NA	6.53	1KB	1KB	4	13	Z:\DAC\RAW DATA
31-Oct	7589G	2BLK57C304B	GEMINI	NA	76	162	87.6	NA	NA	6.34	NA	6.53	1KB	1KB	NA	32	Z:\DAC\RAW DATA
2-Sep	1898A	3BLK66C245A	AQUARIUS	NA	978	1.51	286	NA	NA	17.5	NA	11.6	1KB	1KB	6	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature [signature]

Received by

Name JOIDA PRIETO
Position SUPSRS
Signature [signature] 12/9/14

14-76

DATA TRANSFER SHEET
Dumaguete 2/9/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
25-Jan	10066AC	3BLK54AB025A	Aquarius	NA	114	342	157	27.6	211	5.25	na	3.97	1KB	1KB	10KB	15KB	Z:\DAC\RAW DATA
28-Jan	10072AC	3BLK53B028A	Aquarius	NA	231	508	227	43.3	44.3	10.5	140	9.96	1KB	1KB	3KB	8KB	Z:\DAC\RAW DATA
29-Jan	10074AC	3BLK53A029A	Aquarius	NA	45	375	247	35	150	7.74	na	18	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
29-Jan	10075AC	3BLK53S029B	Aquarius	NA	28	292	215	18	42.3/198	5.4	na	18	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
30-Jan	10076AC	3BLK53V030A	Aquarius	NA	99	302	193	53.1	150/42.3/198	5.06	68	18.4	1KB	NA	16KB	28KB	Z:\DAC\RAW DATA
30-Jan	10077AC	3BLK56V030B	Aquarius	NA	83	391	198	27	145/26.7/237	5.46	na	18.4	1KB	NA	24KB	37KB	Z:\DAC\RAW DATA

Received from

Name Jonalyn S. Gonzalez
Position Research Associate
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature]

16-08

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 7588G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log Flight Log No.: 7588GC

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini/CASI	3 Mission Name: 2BLK53C304A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route: Dumaguete			
10 Date: Oct 31, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province): Dumaguete		
13 Engine On: 0657	14 Engine Off: 1102	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks: Surveyed 8 lines of BLK53C (without CASI due to system fatal error).

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature] Gefone Hipolito	[signature] SSg Raymundo Y Domingo	[signature] R. SAMAR	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 10072A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1415P

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44H124A	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: May 2, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1446H	14 Engine Off: 1909H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

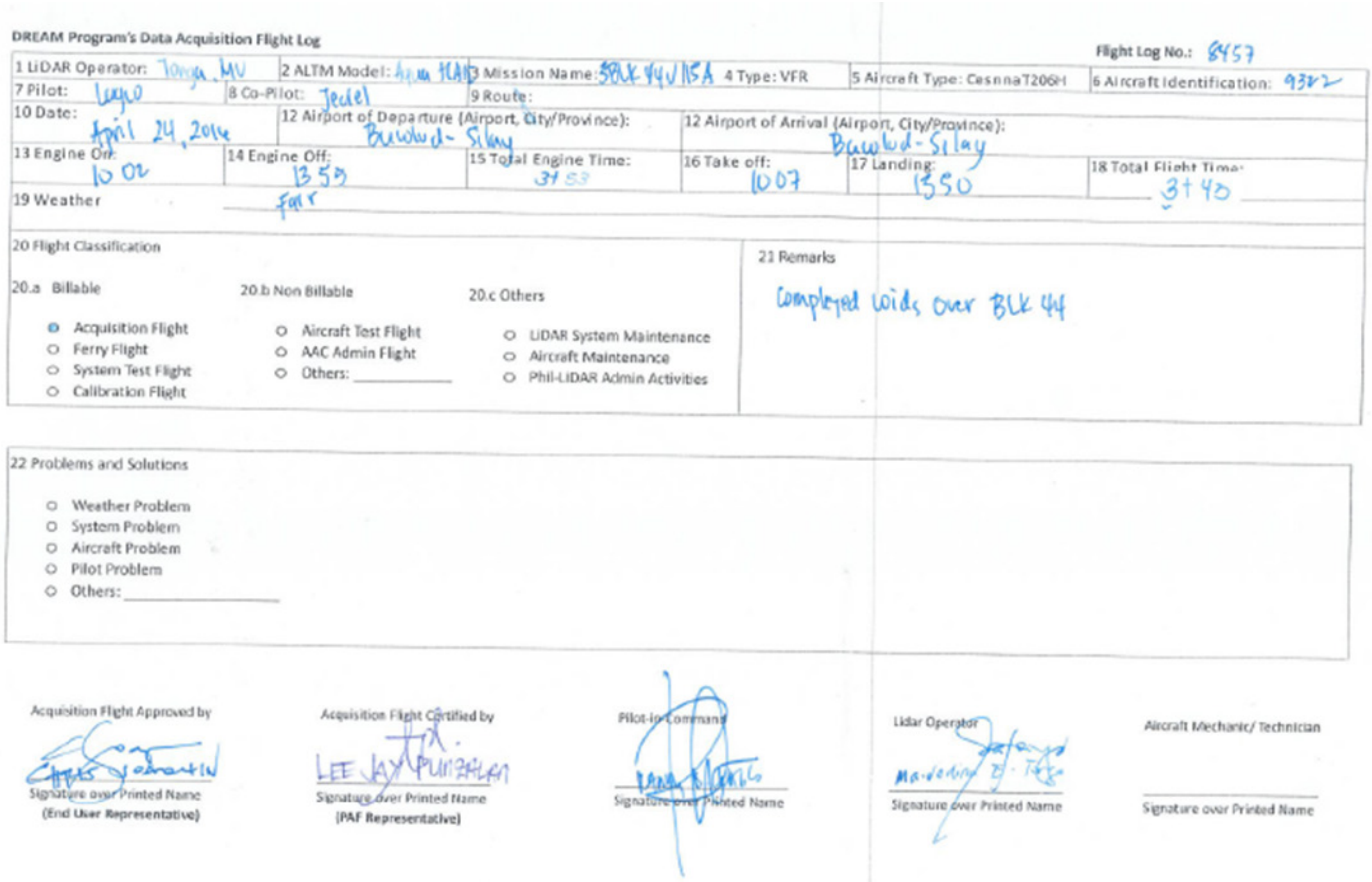
Mission successful at 1200m; surveyed BLK44H; gap in the middle

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
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

3. Flight Log for 10075A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8457

1 LiDAR Operator: Tonga, MV	2 ALTM Model: Aqua 1CAD	3 Mission Name: 5BLK44J115A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Lago	8 Co-Pilot: Jeciel	9 Route:			
10 Date: April 24, 2014	12 Airport of Departure (Airport, City/Province): Bacolod - Silay		12 Airport of Arrival (Airport, City/Province): Bacolod - Silay		
13 Engine On: 1002	14 Engine Off: 1359	15 Total Engine Time: 3+53	16 Take off: 1007	17 Landing: 1350	18 Total Flight Time: 3+43
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed voids over BLK 44

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

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

Acquisition Flight Certified by: LEE JAY PUNZALAN — Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: Signature over Printed Name

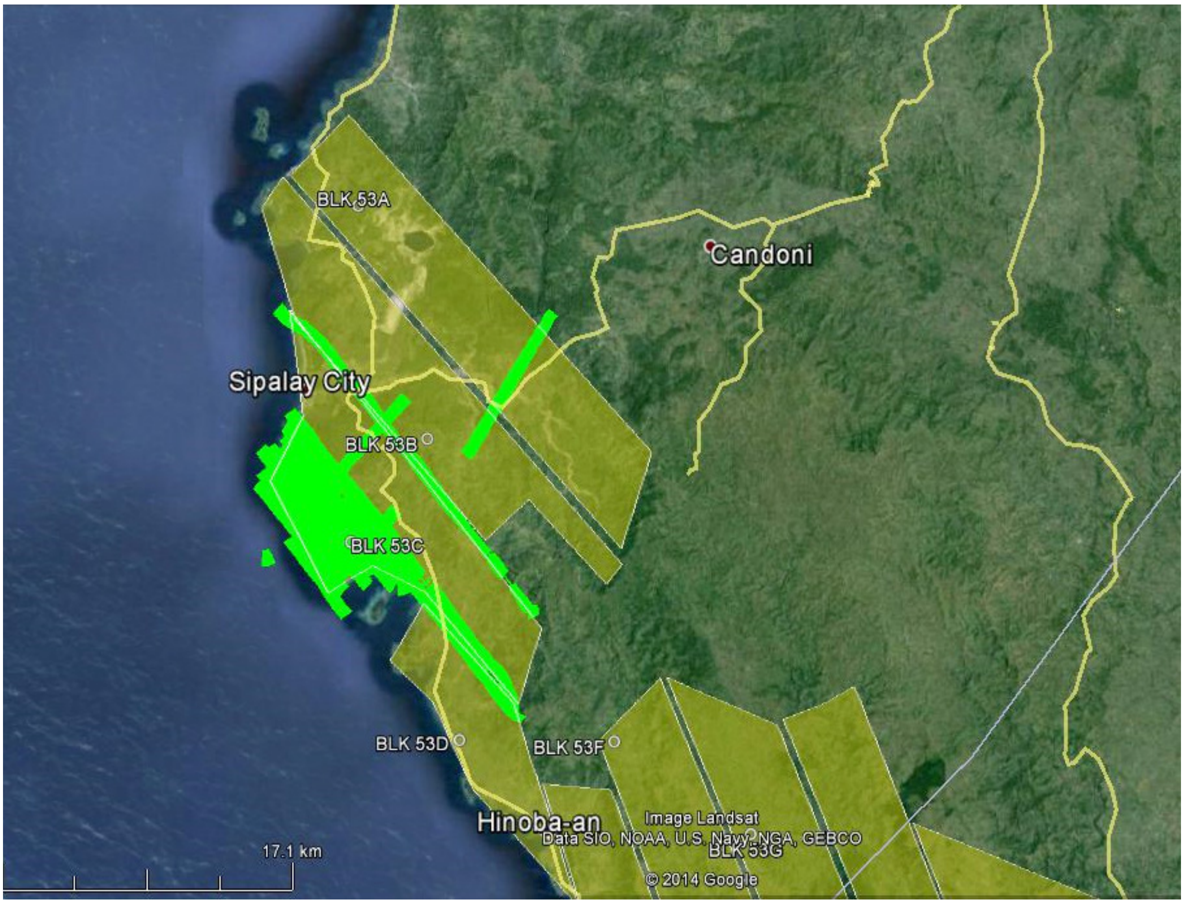
Annex 7. Flight Status Reports

FLIGHT STATUS REPORT
SIPALAY
October 31, 2014 and January 28-29, 2016

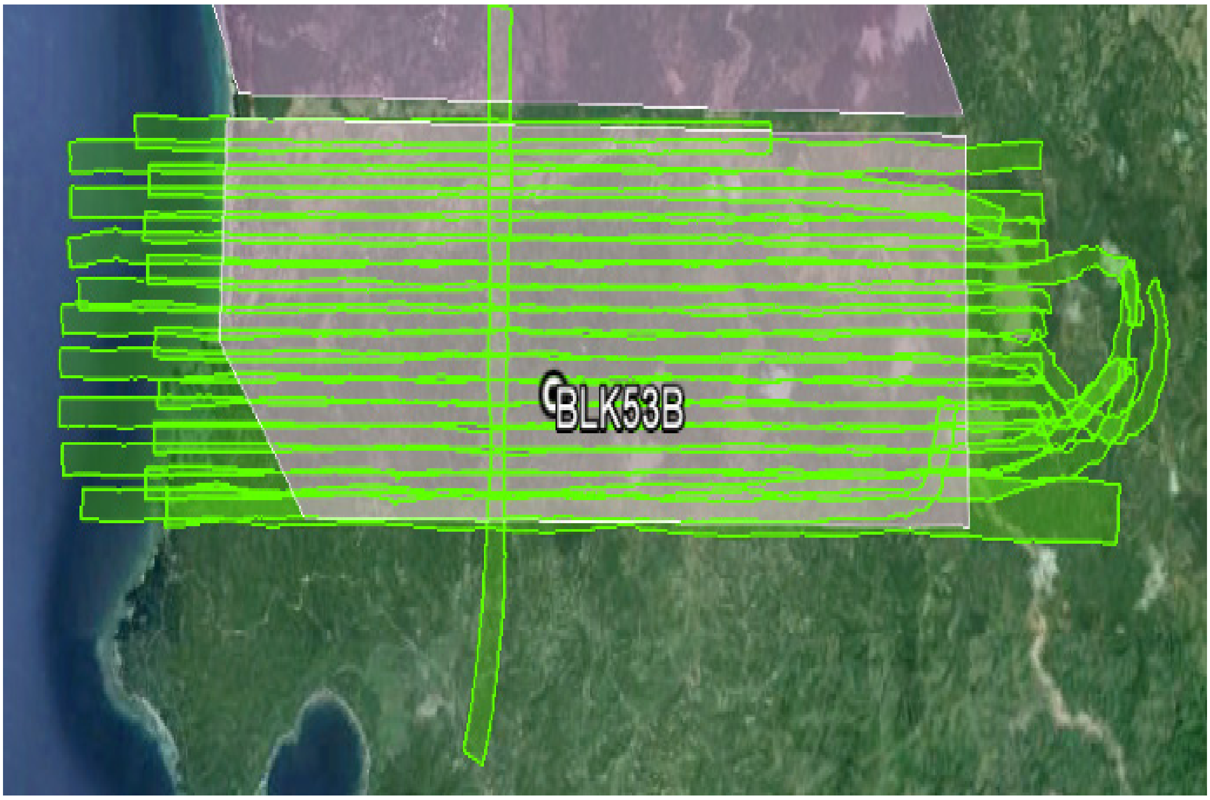
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7588G	BLK53C	2BLK53C304A	MVE Tonga	October 31, 2014	Surveyed 8 lines of BLK53C (w/o CASI due to system fatal error)
10072A	BLK53B	3BLK53B028A	J Gonzales	January 28, 2016	SUCCESSFUL FLIGHT, COMPLETED BLK53A AND BLK53B
10075A	BLK53A, BLK53B	3BLK3ABS029B	MVE Tonga	January 29, 2016	SUCCESSFUL FLIGHT, COMPLETED BLK53A AND BLK53B

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

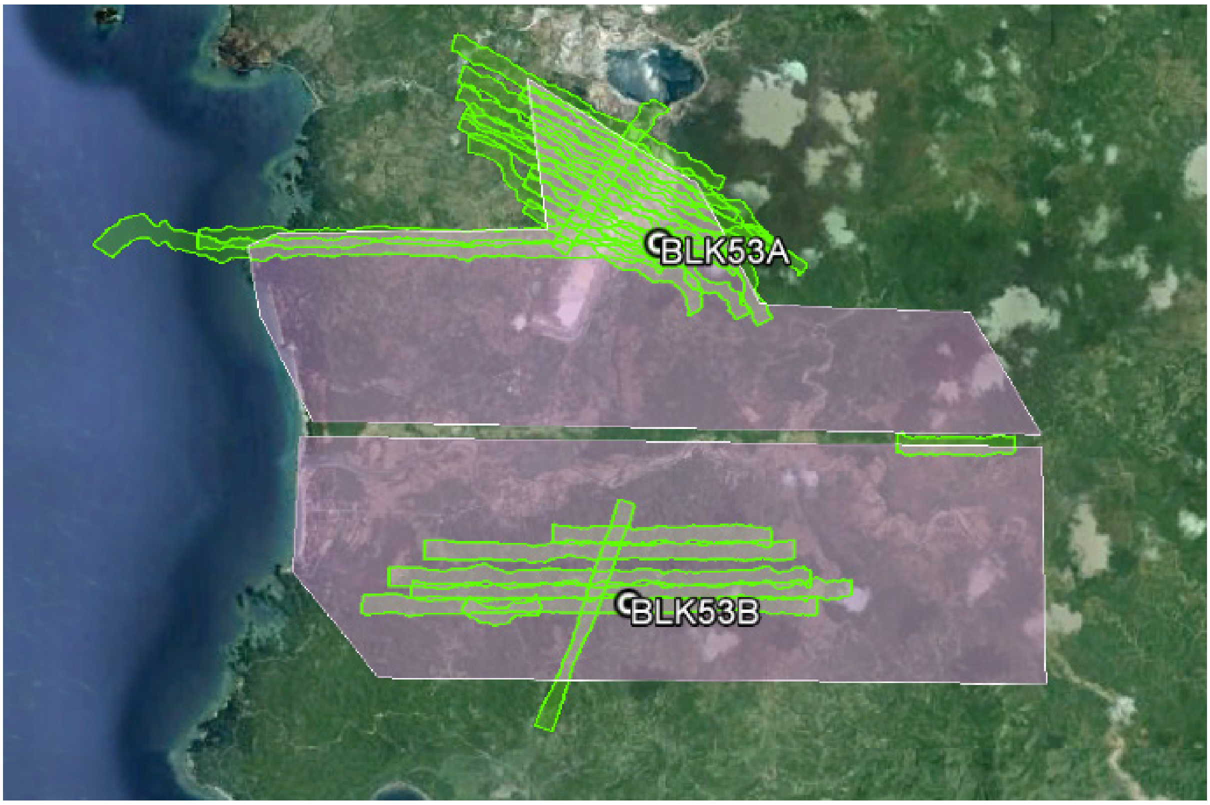
Flight No.:	7588G
Area:	BLK 53C
Mission Name:	2BLK53C304A
Total Area Surveyed:	80.28 sq km



FLIGHT NO.:	10072
AREA:	BLK53B
MISSION NAME:	3BLK53B028A
ALT: 500 m	SCAN FREQ: 45 SCAN ANGLE: 18
SURVEYED AREA:	70.95 km2



FLIGHT NO.:	10075
AREA:	BLK53AS AND BLK53BS
MISSION NAME:	3BLK53ABS029B
ALT: 500 m	SCAN FREQ: 40 SCAN ANGLE: 18
SURVEYED AREA:	24.657 km2



Annex 8. Mission Summary Reports

NO MISSION SUMMARY REPORTS ANNEX FOR SIPALAY. INSERT HERE

Annex 9. Sipalay 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
W500	23.76	58.35	0	4.2412461	2.025135	Discharge	0.0796387	0.001	Ratio to Peak	0.75
W510	23.76	58.35	0	3.3179979	1.57311	Discharge	0.0643662	0.001	Ratio to Peak	0.75
W520	22.43904	60.0831	0	1.3963	0.632205	Discharge	0.0303471	0.001	Ratio to Peak	0.75
W530	10.70208	80.8783	0	1.4812	0.673806	Discharge	0.0242258	0.001	Ratio to Peak	0.75
W540	23.3184	58.9308	0	1.6999	0.780864	Discharge	0.0216181	0.001	Ratio to Peak	0.75
W550	9.80448	83.6935	0	1.1201	0.496986	Discharge	0.0296655	0.001	Ratio to Peak	0.75
W560	14.29344	73.4192	0	1.5279621	0.6966855	Discharge	0.0591487	0.001	Ratio to Peak	0.75
W570	12.9408	76.2364	0	2.5924	1.21779	Discharge	0.057709	0.001	Ratio to Peak	0.75
W580	6.418848	95.2955	0	1.5639666	0.448203	Discharge	0.10321	0.001	Ratio to Peak	0.75
W590	6.527616	84.7128	0	1.6981	0.7799715	Discharge	0.0288447	0.001	Ratio to Peak	0.75
W600	14.84544	72.3286	0	2.2892877	1.069425	Discharge	0.0288973	0.001	Ratio to Peak	0.75
W610	8.0352	94.9916	0	0.60806	0.3265815	Discharge	0.0114202	0.001	Ratio to Peak	0.75
W620	6.11184	77.5291	0	0.996072	0.24507	Discharge	0.0092383	0.001	Ratio to Peak	0.75
W630	12.35328	88.1192	0	0.98069	0.4362645	Discharge	0.0378294	0.001	Ratio to Peak	0.75
W640	8.307648	80.546	0	1.994	0.6450255	Discharge	0.0292812	0.001	Ratio to Peak	0.75
W650	11.0688	65.2086	0	1.5409653	0.9248715	Discharge	0.0167584	0.001	Ratio to Peak	0.75
W660	18.91008	88.4255	0	0.93387	0.7030485	Discharge	0.0120013	0.001	Ratio to Peak	0.75
W670	12.25536	90.8302	0	0.93266	0.4058145	Discharge	0.0200886	0.001	Ratio to Peak	0.75
W680	7.364448	88.9538	0	0.94128	0.910917	Discharge	0.0181885	0.001	Ratio to Peak	0.75
W690	11.97984	86.8181	0	1.1467	0.6171165	Discharge	0.0238701	0.001	Ratio to Peak	0.75
W700	8.806752	97.1188	0	3.1074456	0.228921	Discharge	0.19374	0.001	Ratio to Peak	0.75
W710	5.381472	75.7107	0	1.4934	1.47	Discharge	0.0263837	0.001	Ratio to Peak	0.75
W720	11.69184	88.5358	0	0.99317	0.197379	Discharge	0.0400809	0.001	Ratio to Peak	0.75
W730	9.261216	36.75	0	0.52914	0.434847	Discharge	0.000261567	0.001	Ratio to Peak	0.75

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
W740	51.1488	59.4086	0	2.5796	0.2097165	Discharge	0.0380266	0.001	Ratio to Peak	0.75
W750	22.9488	74.5153	0	1.3518561	1.211595	Discharge	0.0293795	0.001	Ratio to Peak	0.75
W760	13.75488	84.1748	0	1.3559973	0.6104595	Discharge	0.0229238	0.001	Ratio to Peak	0.75
W770	9.60672	75.6939	0	1.0941	0.612486	Discharge	0.0163437	0.001	Ratio to Peak	0.75
W780	8.3088	83.6504	0	1.4131	0.140616	Discharge	0.0308894	0.001	Ratio to Peak	0.75
W790	9.8784	85.5011	0	1.2875	0.6527535	Discharge	0.0268462	0.001	Ratio to Peak	0.75
W800	9.3	88.35	0	0.74795	0.858879	Discharge	0.0133112	0.001	Ratio to Peak	0.75
W810	5.632704	91.6731	0	0.892815	0.31479	Discharge	0.0115004	0.001	Ratio to Peak	0.75
W820	7.018176	92.402	0	1.1069	0.3857175	Discharge	0.0434159	0.001	Ratio to Peak	0.75
W830	6.787776	95.6504	0	1.1005	0.490539	Discharge	0.0414148	0.001	Ratio to Peak	0.75
W840	5.775264	65.15	0	0.60116	0.4874205	Discharge	0.000205745	0.001	Ratio to Peak	0.75
W850	18.94656	87.727	0	1.3304	0.2476845	Discharge	0.0141353	0.001	Ratio to Peak	0.75
W860	8.39568	88.35	0	0.3313317	0.5999805	Discharge	0.0010803	0.001	Ratio to Peak	0.75
W870	12.04896	88.35	0	1.185	0.1102605	Discharge	0.0446844	0.001	Ratio to Peak	0.75
W880	12.05088	84.4149	0	1.5255	0.528759	Discharge	0.0378262	0.001	Ratio to Peak	0.75
W890	9.573792	99	0	1.2583	0.7091385	Discharge	0.043434	0.001	Ratio to Peak	0.75
W900	3.48336	88.35	0	1.4433	0.5646375	Discharge	0.0591726	0.001	Ratio to Peak	0.75
W910	8.0352	95.0395	0	1.2023	0.655221	Discharge	0.0480874	0.001	Ratio to Peak	0.75
W920	9.03024	88.35	0	1.379	0.537243	Discharge	0.0409778	0.001	Ratio to Peak	0.75
W930	8.0352	88.5283	0	0.9159633	0.6237315	Discharge	0.0389953	0.001	Ratio to Peak	0.75
W940	8.05584	88.422	0	0.8609	0.397047	Discharge	0.0402718	0.001	Ratio to Peak	0.75
W950	8.092224	91.0662	0	0.74635	0.370083	Discharge	0.0178759	0.001	Ratio to Peak	0.75
W960	7.212768	88.35	0	0.5176374	0.3140025	Discharge	0.0033674	0.001	Ratio to Peak	0.75
W970	8.0352	90.5078	0	1.0536	0.2020305	Discharge	0.0423802	0.001	Ratio to Peak	0.75
W980	7.394112	88.35	0	0.7720293	0.464457	Discharge	0.02165	0.001	Ratio to Peak	

Annex 10. Sipalay Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R50	Automatic Fixed Interval	2832.79	0.010802	0.7	Trapezoid	27.22	1
R80	Automatic Fixed Interval	5412.5	0.028127	0.7	Trapezoid	27.22	1
R110	Automatic Fixed Interval	1956.43	1.14E-04	0.7	Trapezoid	27.22	1
R140	Automatic Fixed Interval	1788.23	0.039402	0.7	Trapezoid	27.22	1
R150	Automatic Fixed Interval	1776.1	0.017973	0.9604	Trapezoid	27.22	1
R160	Automatic Fixed Interval	2859.48	0.027589	0.2744	Trapezoid	27.22	1
R180	Automatic Fixed Interval	1188.53	0.004638	0.43922	Trapezoid	27.22	1
R190	Automatic Fixed Interval	2734.63	0.006155	0.29879	Trapezoid	27.22	1
R200	Automatic Fixed Interval	281.421	0.021598	1	Trapezoid	27.22	1
R210	Automatic Fixed Interval	2441.08	0.003018	0.29879	Trapezoid	27.22	1
R220	Automatic Fixed Interval	7513.4	0.004429	0.2744	Trapezoid	27.22	1
R230	Automatic Fixed Interval	2537.65	0.003425	1	Trapezoid	27.22	1
R250	Automatic Fixed Interval	1695.24	0.023097	0.44904	Trapezoid	27.22	1
R270	Automatic Fixed Interval	2817.94	0.001878	0.46667	Trapezoid	27.22	1
R280	Automatic Fixed Interval	720.711	0.008073	1	Trapezoid	27.22	1
R310	Automatic Fixed Interval	1886.93	0.006688	0.68257	Trapezoid	27.22	1
R330	Automatic Fixed Interval	2798.36	0.000792	0.29879	Trapezoid	27.22	1
R340	Automatic Fixed Interval	2543.5	0.007243	0.7	Trapezoid	27.22	1
R350	Automatic Fixed Interval	296.985	0.012667	0.7	Trapezoid	27.22	1
R360	Automatic Fixed Interval	5057.84	0.044347	0.7	Trapezoid	27.22	1
R370	Automatic Fixed Interval	4053.75	0.00372	0.7	Trapezoid	27.22	1
R420	Automatic Fixed Interval	4466.47	0.006052	0.7	Trapezoid	27.22	1
R430	Automatic Fixed Interval	2105.22	0.006033	0.7	Trapezoid	27.22	1
R470	Automatic Fixed Interval	967.696	0.013128	0.7	Trapezoid	27.22	1

Annex 11. Sipalay Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/Scenario
	Lat	Long					
1	122.4372	9.763344	0.959999979	0.95	0.000	Ruping	5-Year
2	122.429	9.753277	1.00999999	2	0.980	Ramil	5-Year
3	122.4381	9.763022	1.049999952	0.9	0.022	Ruping	5-Year
4	122.4358	9.764389	1.039999962	0.93	0.012	Ruping	5-Year
5	122.4264	9.751296	0.75999999	1.5	0.548	Ruping	5-Year
6	122.4327	9.774982	0.800000012	0	0.640		
7	122.4371	9.763374	1.190000057	0.94	0.063	Ruping	5-Year
8	122.4348	9.762848	0.800000012	1.5	0.490	Yolanda	5-Year
9	122.4374	9.763627	0.74000001	0.9	0.026	Ruping	5-Year
10	122.4327	9.757609	2.480000019	1.5	0.960	Ruping	5-Year
11	122.4352	9.762788	0.680000007	1.5	0.672	Yolanda	5-Year
12	122.4328	9.774759	1.230000019	0	1.513		
13	122.436	9.762971	1.220000029	1.25	0.001	Tisoy	5-Year
14	122.4329	9.774571	0.029999999	0	0.001		
15	122.4373	9.763102	0	0.95	0.903	Ruping	5-Year
16	122.4358	9.763018	1.25999999	1.25	0.000	Tisoy	5-Year
17	122.4341	9.762705	0.029999999	2	3.881	Ramil	5-Year
18	122.4355	9.764454	1.179999948	0.97	0.044	Ruping	5-Year
19	122.4335	9.762444	0.970000029	2	1.061	Ramil	5-Year
20	122.4294	9.753085	1.5	2	0.250	Ramil	5-Year
21	122.4348	9.762783	0	1.5	2.250	Yolanda	5-Year
22	122.4341	9.762649	0	2	4.000	Ramil	5-Year
23	122.433	9.754787	1.74000001	2	0.068	Ruping	5-Year
24	122.4284	9.7522	2.279999971	3.5	1.488	Ramil	5-Year
25	122.4284	9.752187	0	3.5	12.250	Ramil	5-Year
26	122.4389	9.764897	5.449999809	6	0.303	Ruping	5-Year
27	122.4387	9.764705	0	6	36.000	Ruping	5-Year
28	122.4283	9.752199	0	3.5	12.250	Ramil	5-Year
29	122.4277	9.752219	6.610000134	5.5	1.232	Ramil	5-Year
30	122.4276	9.752501	6.429999828	5.5	0.865	Ramil	5-Year
31	122.438	9.764473	4.96999979	6	1.061	Ruping	5-Year
32	122.4279	9.751913	6.989999771	5.5	2.220	Ramil	5-Year
33	122.4279	9.752156	1.019999981	5.5	20.070	Ramil	5-Year
34	122.4334	9.763334	0.029999999	6	35.641	Ruping	5-Year
35	122.4279	9.751979	0	5.5	30.250	Ramil	5-Year
36	122.4332	9.763254	5.440000057	6	0.314	Ruping	5-Year
42	122.4357	9.76337	0.610000014	0.9	0.084	Tisoy	5-Year
43	122.4307	9.754718	2.019999981	2	0.000	Ruping	5-Year
44	122.4284	9.753863	1.559999943	3.5	3.764	Ramil	5-Year
46	122.4358	9.764105	4.480000019	4.5	0.000	Ruping	5-Year
48	122.4367	9.763964	5.269999981	4.5	0.593	Ruping	5-Year
51	122.4277	9.753387	1.639999986	5.5	14.900	Ramil	5-Year
53	122.4339	9.763571	3.74000001	6	5.108	Ruping	5-Year
55	122.4364	9.764026	0	4.5	20.250	Ruping	5-Year

56	122.4281	9.751553	5.699999809	5.5	0.040	Ramil	5-Year
57	122.4279	9.752374	0.029999999	5.5	29.921	Ramil	5-Year
58	122.4285	9.751588	5.510000229	5.5	0.000	Ramil	5-Year
59	122.4443	9.80758	0.029999999	0.15	0.014	Ruping	5-Year
60	122.4463	9.812053	0.029999999	0.75	0.518	Marce	5-Year
61	122.4471	9.806529	0.029999999	0.01	0.000	Yolanda	5-Year
62	122.4467	9.809921	3.609999895	0.05	12.674		
63	122.4458	9.806867	0.029999999	0.02	0.000	Yolanda	5-Year
64	122.4479	9.810078	0.109999999	0	0.012		
65	122.4444	9.812995	2.140000105	0.02	4.494	Marce	5-Year
66	122.4475	9.80773	0.029999999	0.02	0.000	Yolanda	5-Year
67	122.4438	9.813253	1.100000024	0.02	1.166	Marce	5-Year
68	122.4458	9.806895	0	0.02	0.000	Yolanda	5-Year
69	122.4464	9.805794	0.779999971	0.04	0.548	Marce	5-Year
70	122.4459	9.806569	1.100000024	0.02	1.166	Yolanda	5-Year
71	122.4477	9.806603	0.029999999	0	0.001		
72	122.446	9.806647	0.980000019	0.02	0.922	Yolanda	5-Year
73	122.4477	9.811215	0.029999999	0.01	0.000	Marce	5-Year
74	122.4472	9.810046	1.039999962	0.05	0.980		
75	122.4462	9.809418	0.029999999	0	0.001		
76	122.4466	9.811462	2.799999952	0.75	4.202	Marce	5-Year
77	122.4452	9.813299	0.790000021	0.05	0.548	Seniang	5-Year
78	122.4442	9.813208	2.599999905	0.02	6.656	Marce	5-Year
79	122.4452	9.813446	0.029999999	0.14	0.012	Nitang	5-Year
80	122.4474	9.809279	3.680000067	0	13.542		
82	122.445	9.813574	0	0.14	0.020	Nitang	5-Year
83	122.4455	9.812212	1.309999943	0	1.716		
84	122.4452	9.812408	0	0	0.000		
85	122.4451	9.808844	1.289999962	0	1.664		
86	122.4469	9.811035	0.029999999	0.01	0.000	Marce	5-Year
87	122.4444	9.807496	0.029999999	0.15	0.014	Ruping	5-Year
88	122.4453	9.813191	0	0.05	0.003	Seniang	5-Year
89	122.4471	9.809459	0	0.05	0.003	Yolanda	5-Year
90	122.4133	9.772964	0.029999999	0.18	0.023	Ineng	5-Year
91	122.4506	9.786091	0.569999993	0.13	0.194	Yolanda	5-Year
92	122.4138	9.779996	0.029999999	0.83	0.640	Yolanda	5-Year
93	122.4086	9.751512	0.310000002	1.88	2.465		
94	122.418	9.759535	0.74000001	1.25	0.260	Ramil	5-Year
95	122.4185	9.782994	0.090000004	0	0.008		
96	122.4199	9.756994	0.230000004	1.23	1.000		
97	122.4446	9.757032	1.029999971	0.19	0.706	Ramil	5-Year
98	122.4313	9.784862	0.029999999	0	0.001		
99	122.3961	9.728472	0.029999999	0	0.001		
100	122.4464	9.765619	0.879999995	1.3	0.176		
101	122.4651	9.769129	3.210000038	0	10.304		
102	122.4141	9.760017	1.00999999	0.02	0.980	Ruping	5-Year
103	122.4617	9.760461	5.300000191	1.2	16.810	Ramil	5-Year
104	122.4719	9.744102	0.029999999	0	0.001		

105	122.456	9.802264	0.029999999	0	0.001		
106	122.4221	9.779537	0.529999971	0	0.281		
107	122.4213	9.745942	0.029999999	1.2	1.369	Ramil	5-Year
108	122.391	9.737798	0	0	0.000		
109	122.4356	9.773894	0.200000003	0	0.040		
110	122.3999	9.768406	0.310000002	3.8	12.180	Ramil	5-Year
111	122.4712	9.765183	0.029999999	0	0.001		
112	122.4558	9.775452	0.029999999	0	0.001		
113	122.4707	9.776939	0.029999999	0	0.001		
114	122.4729	9.748021	0.029999999	0	0.001		
115	122.489	9.75984	0.029999999	0	0.001		
116	122.5047	9.741616	0.029999999	0	0.001		
117	122.3993	9.75411	0.029999999	0.52	0.240	Ondoy	5-Year
118	122.4924	9.73913	0.029999999	0	0.001		
119	122.4252	9.75653	0.219999999	1.71	2.220	Nitang	5-Year
120	122.4567	9.778774	0.029999999	0	0.001		
121	122.4627	9.76677	0.029999999	0	0.001		
122	122.4415	9.756721	0.75	0.016	0.539		
123	122.4954	9.762288	0.050000001	0	0.003		
124	122.4163	9.744128	0.029999999	0.84	0.656		
125	122.5004	9.762983	0.050000001	0	0.003		
126	122.4259	9.792537	0.029999999	0	0.001		
127	122.5016	9.763268	0.029999999	0	0.001		
128	122.4336	9.75079	1.269999981	1.1	0.029	Senyang	5-Year
129	122.4766	9.748332	4.210000038	0.82	11.492	Ruping	5-Year
130	122.5045	9.751501	0.029999999	0	0.001		
131	122.3979	9.773839	1.389999986	0.2	1.416	Lando	5-Year
132	122.473	9.749579	0.079999998	0	0.006		
133	122.3944	9.786447	0	0.9	0.810	Ramil	5-Year
134	122.4055	9.748291	0.569999993	2.2	2.657	Ruping	5-Year
135	122.4266	9.753083	0.5	1.2	0.490	Ramil	5-Year
136	122.4394	9.750248	0.540000021	1.25	0.504	Ramil	5-Year
137	122.4511	9.803122	0.029999999	0	0.001		
138	122.488	9.754635	0.029999999	0	0.001		
139	122.4325	9.777826	0.109999999	0	0.012		
140	122.3931	9.785668	0.029999999	0	0.001		
141	122.4858	9.754823	3.019999981	1.25	3.133	Ruping	5-Year
142	122.474	9.755265	0.029999999	1.5	2.161	Ruping	5-Year
143	122.4408	9.767845	0.029999999	1.1	1.145	Ramil	5-Year
144	122.4348	9.77298	0.029999999	0	0.001		
145	122.4433	9.803795	0.029999999	0	0.001		
146	122.3997	9.745828	1.149999976	1.2	0.003	Ruping	5-Year
147	122.4315	9.791187	0.029999999	0	0.001		
148	122.4327	9.764109	0.029999999	0.5	0.221	Pablo	5-Year
149	122.4339	9.768413	0.029999999	0.2	0.029	Ramil	5-Year
150	122.4215	9.777764	0.029999999	0	0.001		
151	122.4407	9.769036	0.5	0.2	0.090	Ruping	5-Year
152	122.3996	9.742847	0.200000003	0.3	0.010	Ruping	5-Year

153	122.4322	9.748186	1.840000033	2.8	0.922	Ramil	5-Year
154	122.4325	9.769078	0.029999999	0.3	0.073	Ramil	5-Year
155	122.4039	9.749551	0.050000001	1.4	1.822	Ruping	5-Year
156	122.4025	9.769645	1.450000048	0.8	0.423	Ruping	5-Year
157	122.4199	9.748281	0.029999999	0	0.001		
158	122.3941	9.784992	0.029999999	0	0.001		
159	122.4182	9.748786	0.029999999	0	0.001		
160	122.4915	9.743906	0.029999999	0	0.001		
161	122.3994	9.746798	0.560000002	1.4	0.706	Ruping	5-Year
162	122.4016	9.748463	0.349999994	0.3	0.002	Ruping	5-Year
163	122.4343	9.764031	0.029999999	1.3	1.613	Ruping	5-Year
164	122.43	9.793395	0.029999999	0	0.001		
165	122.434	9.785729	0.029999999	0	0.001		
166	122.4521	9.777659	0.029999999	0	0.001		
167	122.5122	9.756348	0.050000001	0	0.003		
168	122.4421	9.812105	0.029999999	0	0.001		
169	122.4483	9.778737	0.239999995	0.7	0.212	Yolanda	5-Year
170	122.4184	9.788474	0.319999993	0	0.102		
171	122.403	9.751817	0.189999998	0.3	0.012	Ruping	5-Year
172	122.4004	9.740728	0.07	1.4	1.769	Ruping	5-Year
173	122.4201	9.744352	0.270000011	1.86	2.528	Ruping	5-Year
174	122.3989	9.771231	0.079999998	0.4	0.102	Ramil	5-Year
175	122.4162	9.786225	0.029999999	0	0.001		
176	122.4211	9.748783	0.029999999	0.35	0.102	Ramil	5-Year
177	122.409	9.748054	0.270000011	0.85	0.336	Undang	5-Year
178	122.4006	9.747816	0.129999995	1.31	1.392	Ruping	5-Year
179	122.4308	9.791898	0.029999999	0	0.001		
180	122.4071	9.750808	0.330000013	0.97	0.410	Ramil	5-Year
181	122.4102	9.769873	0.449999988	1.2	0.563	Ramil	5-Year
182	122.4502	9.764309	0.039999999	0	0.002		
183	122.3991	9.728264	0.029999999	0.58	0.303		
184	122.401	9.742254	0.039999999	0.9	0.740	Ruping	5-Year
185	122.4455	9.809238	0.029999999	0	0.001		
186	122.4004	9.750939	0.439999998	0.9	0.212	Ruping	5-Year
187	122.4344	9.78409	0.029999999	0	0.001		
188	122.4067	9.74986	0.270000011	0.9	0.397	Ramil	5-Year
189	122.4414	9.810753	0.029999999	0	0.001		
190	122.4194	9.748863	0.029999999	0	0.001		
191	122.4064	9.748996	0.109999999	1.2	1.188	Ruping	5-Year
192	122.4366	9.750115	1.389999986	1.63	0.058	Ramil	5-Year
193	122.4501	9.784786	0.479999989	0.58	0.010	Ruping	5-Year
194	122.4439	9.803415	0.029999999	0	0.001		
195	122.4315	9.771253	0.029999999	0	0.001		
196	122.4005	9.750487	0.519999981	0.35	0.029	Ruping	5-Year
197	122.4306	9.794248	0.090000004	0	0.008		
198	122.4944	9.740149	0.310000002	0.4	0.008	Ruping	5-Year
199	122.4302	9.77711	0.029999999	0	0.001		
200	122.4171	9.743808	0.280000001	0.4	0.014	Ramil	5-Year

201	122.4348	9.771183	0.300000012	0	0.090		
202	122.4421	9.772414	0.219999999	0.75	0.281	Ramil	5-Year
203	122.4407	9.809587	0.029999999	0	0.001		
204	122.4487	9.810573	0.029999999	0	0.001		
205	122.4327	9.746765	0.119999997	0.9	0.608	Ramil	5-Year
206	122.4228	9.741459	0.180000007	0	0.032		
207	122.4302	9.794168	0.050000001	0	0.003		
208	122.4406	9.814112	0.039999999	0	0.002		
209	122.4192	9.788513	0.119999997	0	0.014		
210	122.4499	9.779202	0.109999999	0	0.012		
211	122.4517	9.768804	0.029999999	0	0.001		
212	122.3938	9.785246	0	0	0.000		
213	122.4453	9.810374	0.029999999	0	0.001		
214	122.4278	9.753853	1.529999971	0.28	1.562	Ramil	5-Year
215	122.3997	9.752772	0.109999999	0.52	0.168	Yolanda	5-Year
216	122.4342	9.78532	0.029999999	0	0.001		
217	122.4516	9.80081	0.189999998	0	0.036		
218	122.4288	9.761766	0.029999999	1.84	3.276	Ramil	5-Year
219	122.4003	9.731932	1.830000043	0.52	1.716	Yolanda	5-Year
220	122.4515	9.804453	0.029999999	0	0.001		
221	122.4323	9.790815	0.029999999	0	0.001		
222	122.4482	9.778604	0	0.7	0.490	Yolanda	5-Year
223	122.4302	9.770923	0.079999998	0	0.006		
224	122.4939	9.742771	0.029999999	0	0.001		
225	122.492	9.742493	0.349999994	0	0.122		
226	122.4232	9.749075	0.079999998	0.38	0.090	Ramil	5-Year
227	122.4524	9.778077	0.029999999	0	0.001		
228	122.4315	9.75628	0.319999993	1.1	0.608	Ramil	5-Year
229	122.4331	9.771434	0.270000011	0	0.073		
230	122.4382	9.763576	0.029999999	0.8	0.593	Ramil	5-Year
231	122.5093	9.756647	0.029999999	0	0.001		
232	122.4014	9.7461	0.109999999	0.3	0.036	Ruping	5-Year
233	122.4122	9.768605	0.029999999	1.53	2.250	Ramil	5-Year
234	122.5	9.739795	1.039999962	0.85	0.036	Pablo	5-Year
235	122.4462	9.808815	0.090000004	0	0.008		
236	122.4202	9.789064	0.029999999	0	0.001		
237	122.4508	9.803585	0.07	0	0.005		
238	122.4026	9.755116	0.029999999	0.92	0.792	Yolanda	5-Year
239	122.3943	9.785945	0.029999999	0	0.001		
240	122.4089	9.747758	0	0.85	0.723	Undang	5-Year
241	122.4531	9.777442	0.029999999	0	0.001		
242	122.4417	9.810741	0.029999999	0	0.001		
243	122.4416	9.751537	1.440000057	1.15	0.084	Ramil	5-Year
244	122.3899	9.722784	0	0.25	0.063		
245	122.4754	9.756273	4.489999771	2.7	3.204	Ramil	5-Year
246	122.5114	9.757039	0.029999999	0	0.001		
247	122.4344	9.770711	0.140000001	0.25	0.012	Yolanda	5-Year
248	122.44	9.812243	0.029999999	0	0.001		

249	122.4478	9.808853	0.029999999	0	0.001		
250	122.4317	9.790954	0.029999999	0	0.001		
251	122.4342	9.764135	0	1.3	1.690	Ruping	5-Year
252	122.4931	9.744228	0.029999999	0	0.001		
253	122.4386	9.791223	0.029999999	0	0.001		
254	122.4091	9.749149	0.200000003	0	0.040		
255	122.4314	9.792436	0.029999999	0	0.001		
256	122.4929	9.743329	0.029999999	0	0.001		
257	122.3996	9.743241	0.310000002	0.9	0.348	Yolanda	5-Year
258	122.4495	9.782915	0.059999999	0.7	0.410	Yolanda	5-Year
259	122.4232	9.767678	0.029999999	0.86	0.689	Yolanda	5-Year
260	122.4531	9.769794	0.029999999	0	0.001		
261	122.4897	9.746791	2.630000114	0.25	5.664	Pablo	5-Year
262	122.4343	9.77423	0.029999999	0.8	0.593	Ruping	5-Year
263	122.4009	9.748815	0.209999993	0.65	0.194	Yolanda	5-Year
264	122.3976	9.738465	0.029999999	0.82	0.624	Ramil	5-Year
265	122.4089	9.749578	0.140000001	0	0.020		
266	122.5118	9.756264	0.029999999	0	0.001		
267	122.406	9.746926	0.449999988	0.9	0.203	Ramil	5-Year
268	122.4313	9.77558	0.25	0.46	0.044		
269	122.449	9.785886	1.179999948	1.3	0.014	Yolanda	5-Year
270	122.4431	9.812528	0.059999999	0	0.004		
271	122.4746	9.755563	0.029999999	0.3	0.073	Ramil	5-Year

Annex 12. Educational Institutions Affected by Flooding in Sipalay Floodplain

Negros Occidental				
Sipalay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay 5 Elementary School	Barangay 1		Low	Low
Sipalay City National High School	Barangay 1	Low	Low	Low
Barangay 1 Day Care Center	Barangay 2	Low	Low	Low
Alternative Learning School	Barangay 3			
Bethel Day Care Center	Barangay 3			
Ginaro P. Alvarez Elementary School	Barangay 3	Low	Low	Low
Holy Rosary Academy	Barangay 3	Low	Low	Low
Barangay 5 Elementary School	Barangay 5			Low
Maranatha Pentecostal School	Barangay 5			
Cabadiangan Day Care Center	Cabadiangan	High	High	High
Cabadiangan Elementary School	Cabadiangan			
Gil Montilla National HS- Cabadiangan Ext	Cabadiangan	High	High	High
CANSAURO ELEMENTARY SCHOOL	Gil Montilla			
CENTRAL PHILIPPINE STATE UNIVERSITY-SIPALAY CAMPUS	Gil Montilla			
HINABLAN DAY CARE CENTER	Gil Montilla	Medium	Medium	Medium
MONTILLA ELEMENTARY SCHOOL	Gil Montilla			
MONTILLA HIGH SCHOOL	Gil Montilla	Low	Low	Low
PUROK LUBI DAY CARE CENTER	Gil Montilla	High	High	High
PUROK MANI DAY CARE CENTER	Gil Montilla			
PUROK SAGING DAY CARE CENTER	Gil Montilla			
RURAL IMPROVEMENT CLUB CHILDREN CENTER	Gil Montilla	Low	Low	Low
Agripino Alvarez Elementary School	Mambaroto			Low
Mambaroto Day Care Center	Mambaroto			Low
Barasbarasan Annex	Manlucahoc			
Barasbarasan Elementary School	Manlucahoc			
Day Care Center	Manlucahoc			
Gilmontella National High School- Manlucahoc Ext*	Manlucahoc			
Gilmontella National High School- Senior High	Manlucahoc			
Indangawan Day Care Center	Manlucahoc			
Manlucahoc Elementary School	Manlucahoc			
Patag-Magbanwa Elementary School	Manlucahoc	High	High	High
BRGY NAUHANG DAY CARE CENTER	Nauhang	Medium	Medium	High
Binulig Central Elementary School	San Jose			
Cabarrus Catholic College	San Jose			
Cabarrus Catholic College High School Building	San Jose		Low	Low
Former Primary Elementary Building of Cabarrus Co*	San Jose			
Gil Montilla Extension High School	San Jose			

Annex 13. Medical Institutions Affected by Flooding in Sipalay Floodplain

Negros Occidental				
Sipalay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Birthing Unit	Barangay 2			
City Health Office	Barangay 2	Low	Low	Low
Jeamac Diagnostic Center	Barangay 2			
Sipalay City Infirmary	Barangay 2	Low	Low	Low
Brgy. 1 & 2 Health Center	Barangay 3			Low
City Health Office	Barangay 3			
Cabadiangan Barangay Health Center	Cabadiangan	High	High	High
MONTILLA BRGY HEALTH CENTER	Gil Montilla	Low	Low	Low
Mambaroto Health Center	Mambaroto			Low
NAUHANG HEALTH CENTER	Nauhang	Low	Medium	Medium

Annex 14. UPC Phil-LiDAR 1 Team Composition

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