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

LiDAR Surveys and Flood Mapping of Vinas River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mapua Institute of Technology

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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
MIT	MAPUA Institute of Technology
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND VINAS RIVER

Dr. Aldrine Francis A. Uy and Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the MAPUA Institute of Technology (MIT). MIT 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 26 river basins in the CALABARZON and Bicol Region. The university is located in Intramuros, Manila.

1.2 Overview of the Vinas River Basin

The Vinas River Basin covers the Municipalities of Calauag, Guinayangan, and Tagkawayan in Quezon Province. The DENR River Basin Control Office, identified the basin to has a drainage area of 159 km² and an estimated annual run-off of 254 million cubic meter (MCM) (RBCO, 2015).

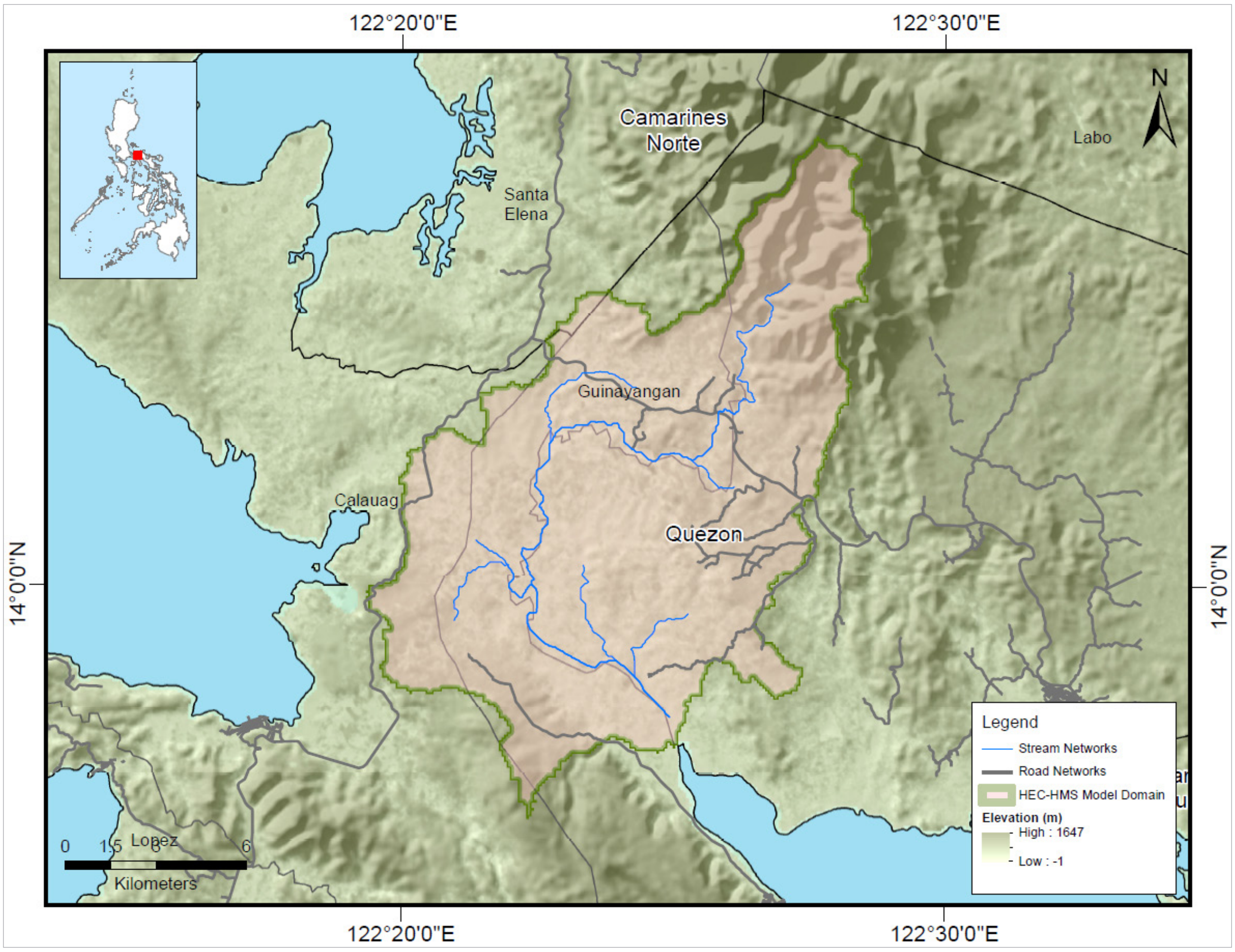

Figure 1. Map of Vinas River Basin (in brown).

Its main stem, Vinas River, is part of the 28 river systems in the Southern Tagalog Region. According to the 2010 national census of NSO, a total of 7,309 locals are residing in the immediate vicinity of the river which are distributed among the five (5) barangays in Municipality of Tagkawayan and six (6) barangays in Municipality of Guinayangan. Community around the river are said to be self-sufficient due to isolation from the main roads. Farming and fishing are the basic sources of income in the two municipalities surrounding Vinas River. Some of the major products are citrus and sugpo (BC J., 2015, August, The Guinayangan Republic from http://peoplesrepublicofguinayangan.blogspot.com/). The most recent and significant flooding in the area that cause evacuation of people was on July 2014 caused by Typhoon "Glenda".

CHAPTER 2: LIDAR DATA ACQUISITION OF THE VINAS 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).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Vinas floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Vinas Floodplain in Quezon Province. These flight missions were planned for 10 lines and ran for at most four hours (4) including take-off, landing and turning time using one sensor – the Pegasus (see ANNEX 1 for sensor specifications). The flight planning parameters for the LiDAR system are outlined in Error! Reference source not found.. Error! Reference source not found., on the other hand, shows the flight plan for Vinas floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 20A	900	30	50	200	30	130	5
BLK 20B	700/1100	30	50	200	30	130	5
BLK 20C	800/900	30	50	200	30	130	5

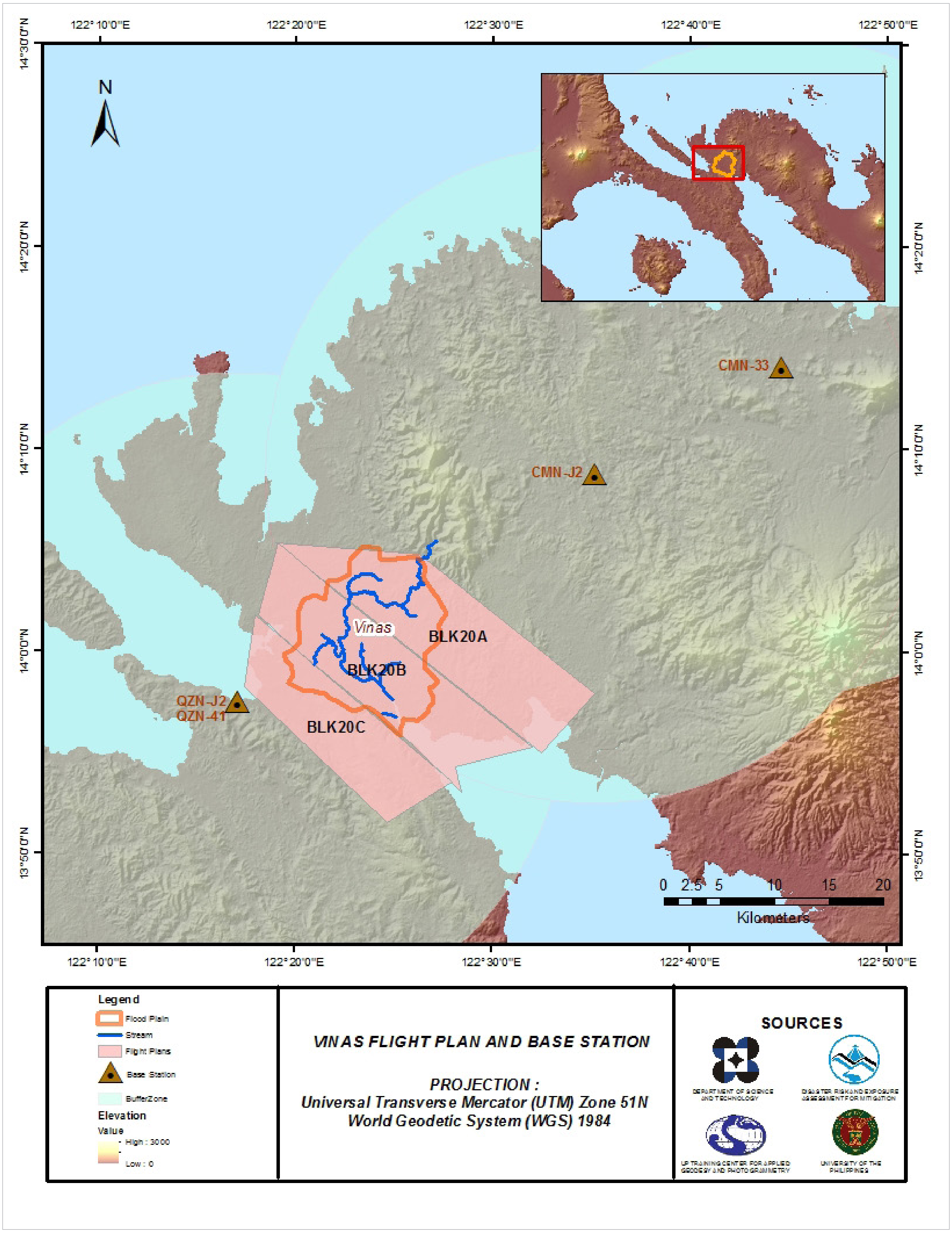

Figure 2. Flight plans and base stations used for Vinas floodplain using the Pegasus sensor.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points, QZN-41 and QZN-33 which are of second (2^{nd}) order accuracy and ABR-3221 which is of fourth (4^{th}) order accuracy. The project team established two (2) ground control points, QZN-J2 and QZN-J2.

The certification for the NAMRIA reference points and benchmarks 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 from April 4 to April 18, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and Topcon GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Vinas floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Vinas Floodplain LiDAR Survey. Figure 3Error! Reference source not found. to Figure 6 Error! Reference source not found.show the recovered NAMRIA reference points within the area of the floodplain, while Error! Reference source not found. Table 2 to Table 5 show the details about the following NAMRIA control stations and established points. Table 6, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

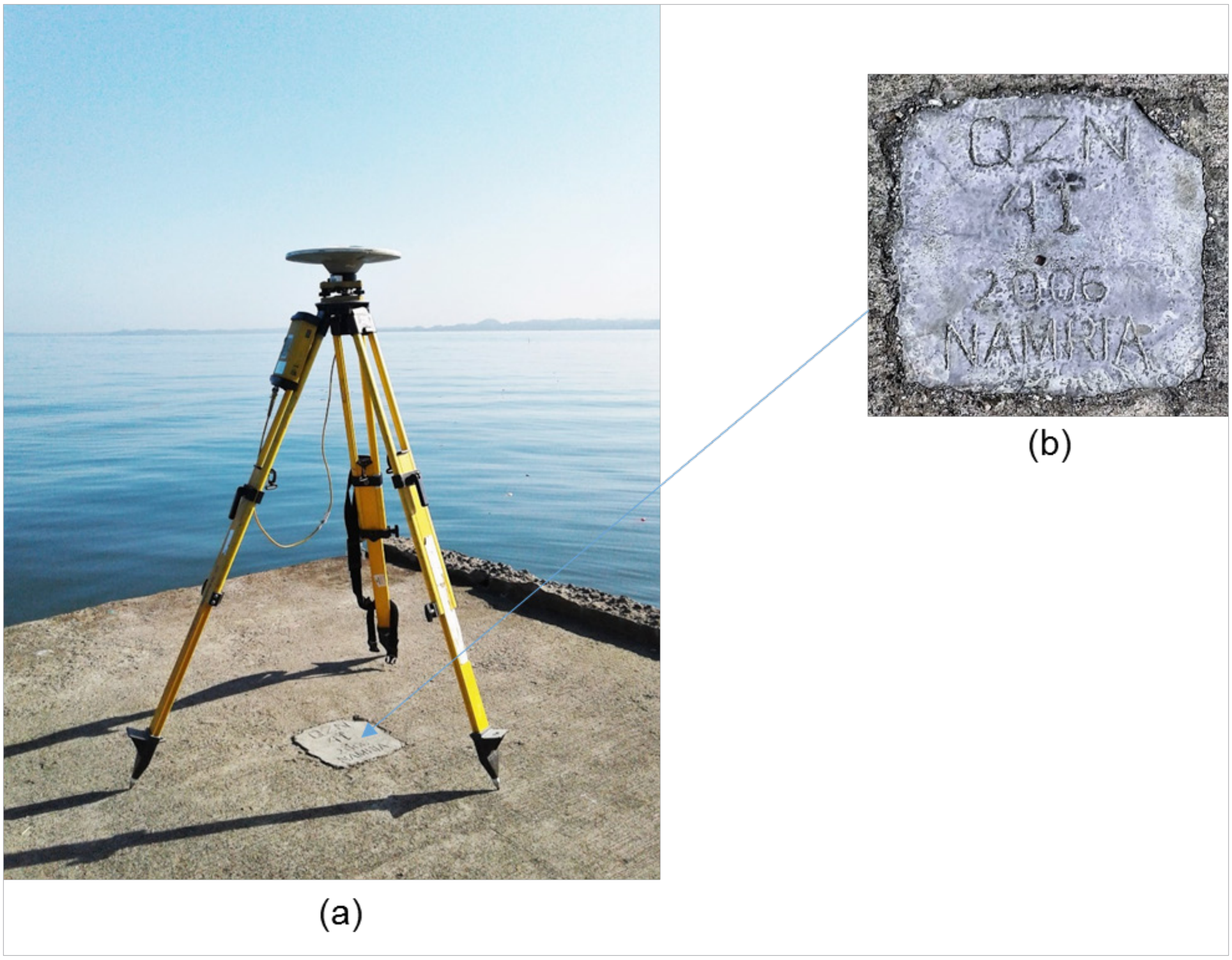

Figure 3. GPS set-up over QZN-41 at Barangay Sabang Uno, Vinas, Quezon (a) and NAMRIA reference point QZN-41 (b) as recovered by the field team.

Table 2. Details of the reprocessed NAMRIA horizontal control point QZN-41 used as base station for the LiDAR acquisition.

Station Name	**QZN-41**	
Order of Accuracy	**2^{nd} order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57’ 35.21424” North 122° 16’ 58.66932” East 3.94900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	422523.318 meters 1543840.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57’ 30.05147” North 122° 17’ 3.61061“ East 52.42200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	422550.44 meters 1543300.04 meters

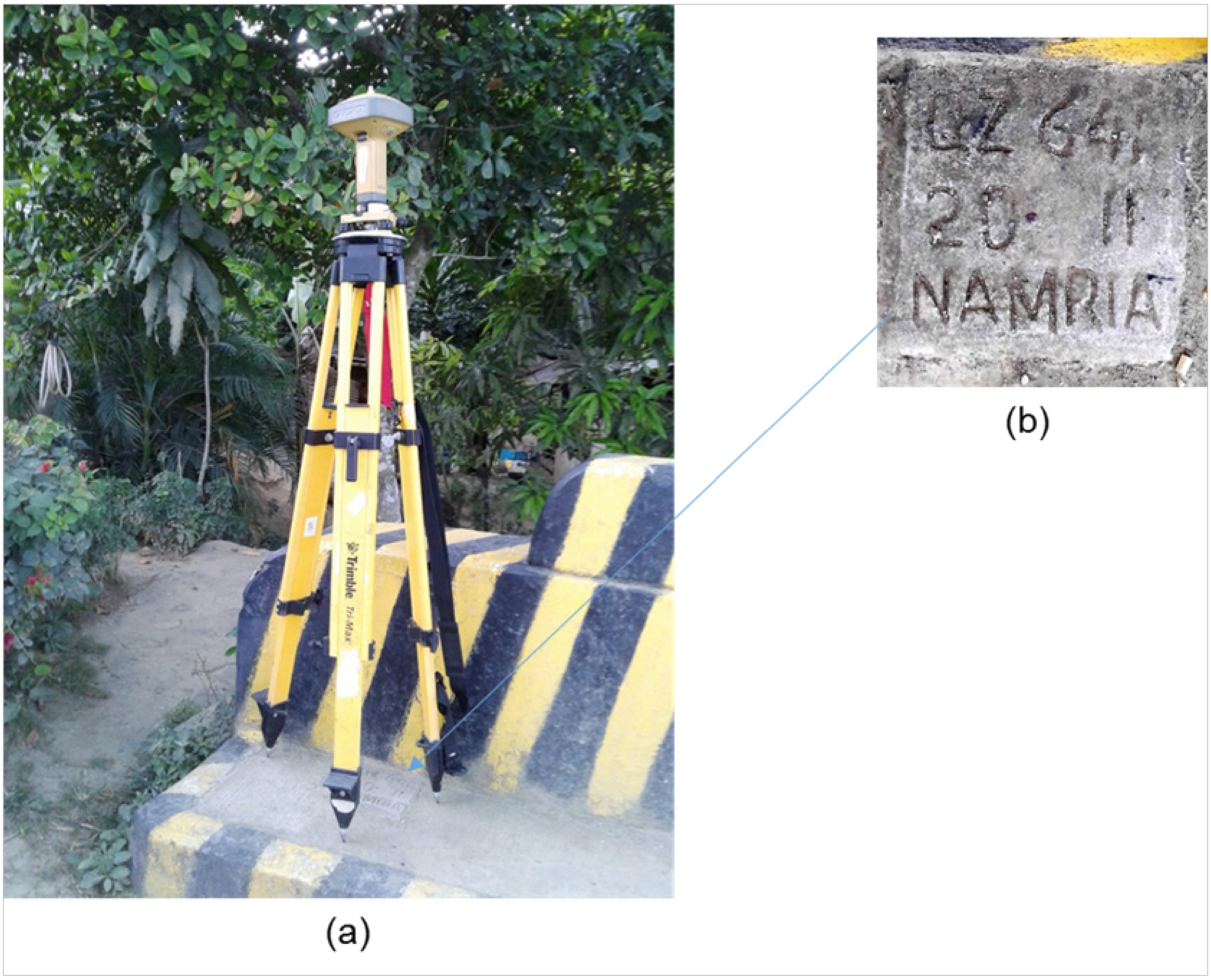

Figure 4. GPS set-up over CMN-33 at Barangay Bato Balani, Jose Panganiban, Camarines Norte. (a) and NAMRIA reference point CMN-33 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point CMN-33 used as base station for the LiDAR acquisition.

Station Name	CMN-33	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 14' 11.70144" North 122° 44' 31.91442" East 8.58900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	72178.341 meters 1574360.987 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 14' 6.51050" North 122° 44' 36.82890" East 7.40600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	472188.08 meters 1573809.93 meters

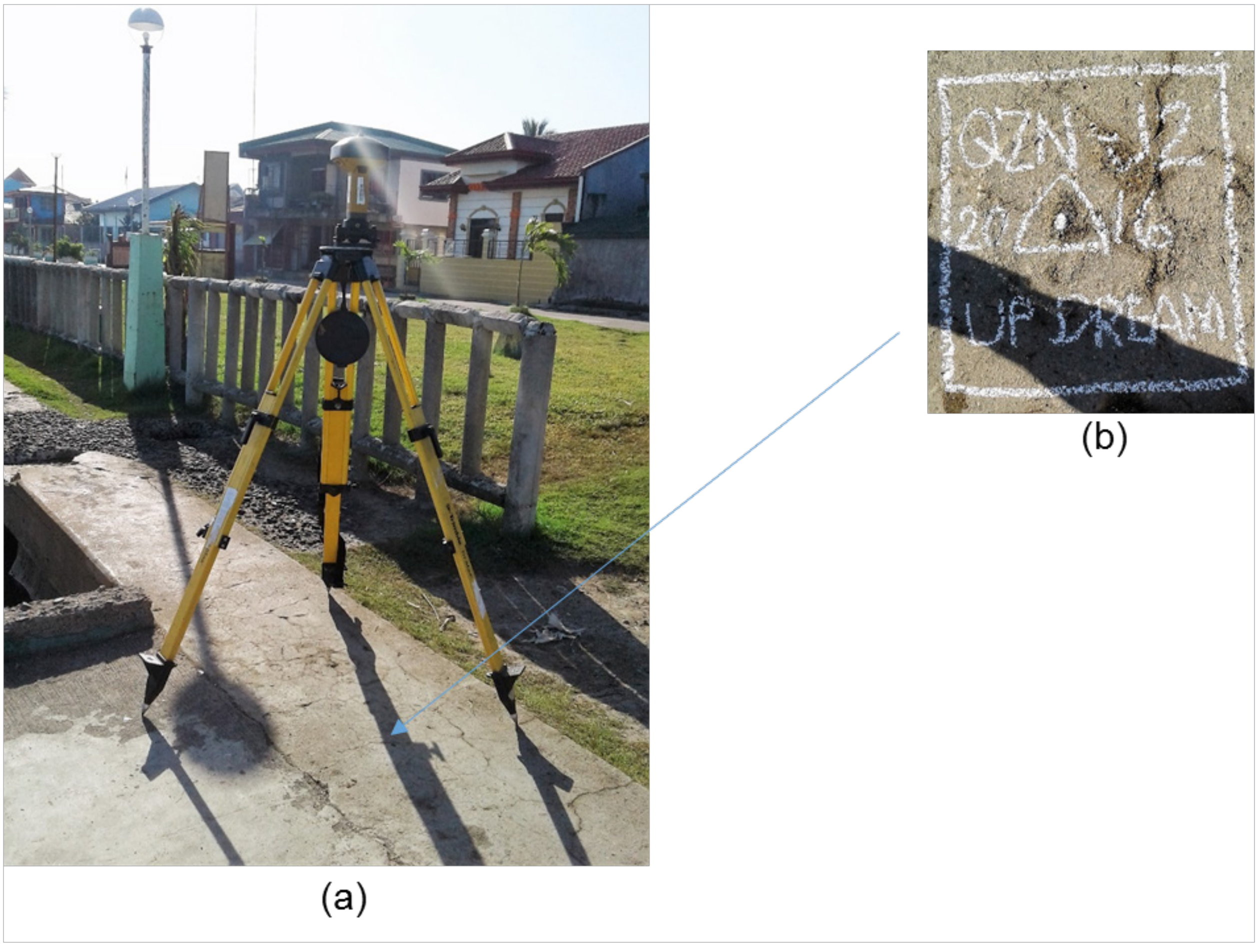

Figure 5. GPS set-up over QZN-J2 as established in at Barangay Sabang Uno, Vinas, Quezon (a) and reference point QZN-J2 (b) as established by the field team.

Table 4. Details of the reprocessed NAMRIA horizontal control point QZN-J2 used as base station for the LiDAR Acquisition.

Station Name	QZN-J2	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57' 34.99489" North 122° 16' 58.78731" East 4.043 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	422553.956 meters 1543293.290 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	13° 57' 29.83213" North 122° 17' 03.72860" East 52.516 meters

(b)

(a)

Figure 6. GPS set-up over CMN-J2 as established in at Barangay Maibago, Labo, Camarines Norte (a) and reference point CMN-J2 (b) as established by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point CMN-J2 used as base station for the LiDAR Acquisition.

Station Name	**CMN-J2**	
Order of Accuracy	**2^{nd} order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 08’ 53.88940” North 122° 35’ 03.56309” East 51.531 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	455138.726 meters 1564071.272 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 08’ 48.70654” North 122° 37’ 08.48618” East 100.212 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
08 APR 2016	23230P	1BLK20A099A	CMN-33 & CMN-J2
11 APR 2016	23242P	1BLK20A102A	QZN-41 & QZN-J2
11 APR 2016	23244P	1BLK20B102B	QZN-41 & QZN-J2
13 APR 2016	23252P	1BLK20104B	QZN-41 & QZN-J2

2.3 Flight Missions

A total of four (4) missions were conducted to complete the LiDAR data acquisition in Vinas floodplain, for a total of fourteen hours and forty-seven minutes (14+47) minutes of flying time for RP-C9122 (See ANNEX 6). All missions were acquired using the Pegasus LiDAR system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 7, while the actual parameters used during the LiDAR data acquisition are presented in Table 8.

Table 7. Flight missions for LiDAR data acquisition in Vinas 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
08 APRIL 2016	23230P	186.03	240.80	59.5	181.30	NA	4	23
11 APRIL 2016	23242P	169.09	232.31	108.48	123.83	953	4	35
11 APRIL 2016	23244P	126.25	107.53	5.75	101.79	357	2	50
13 APRIL 2016	23252P	126.25	82.26	7.26	75	12	2	59
TOTAL		**607.62**	**662.9**	**180.99**	**481.92**	**1322**	**14**	**47**

Table 8. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23230P	900	30	50	200	30	130	5
23242P	700/1100	30	50	200	30	130	5
23244P	800/900	30	50	200	30	130	5
23252P	900	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Vinas floodplain (See ANNEX 7). It is situated within the provinces of Quezon and Camarines Norte. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 9. Figure 7, on the other hand, shows the actual coverage of the LiDAR acquisition for the Vinas floodplain.

Table 9. List of municipalities and cities surveyed during Vinas floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Camarines Norte	Santa Elena	210.29	38.77	18%
Camarines Sur	Del Gallego	279.27	4.09	1%
Quezon	Calauag	323.42	113.02	35%
	Guinayangan	236.85	138.38	58%
	Lopez	378.81	5.43	1%
	Tagkawayan	551.73	224.28	41%
Total		**1980.37**	**523.97**	**26.46%**

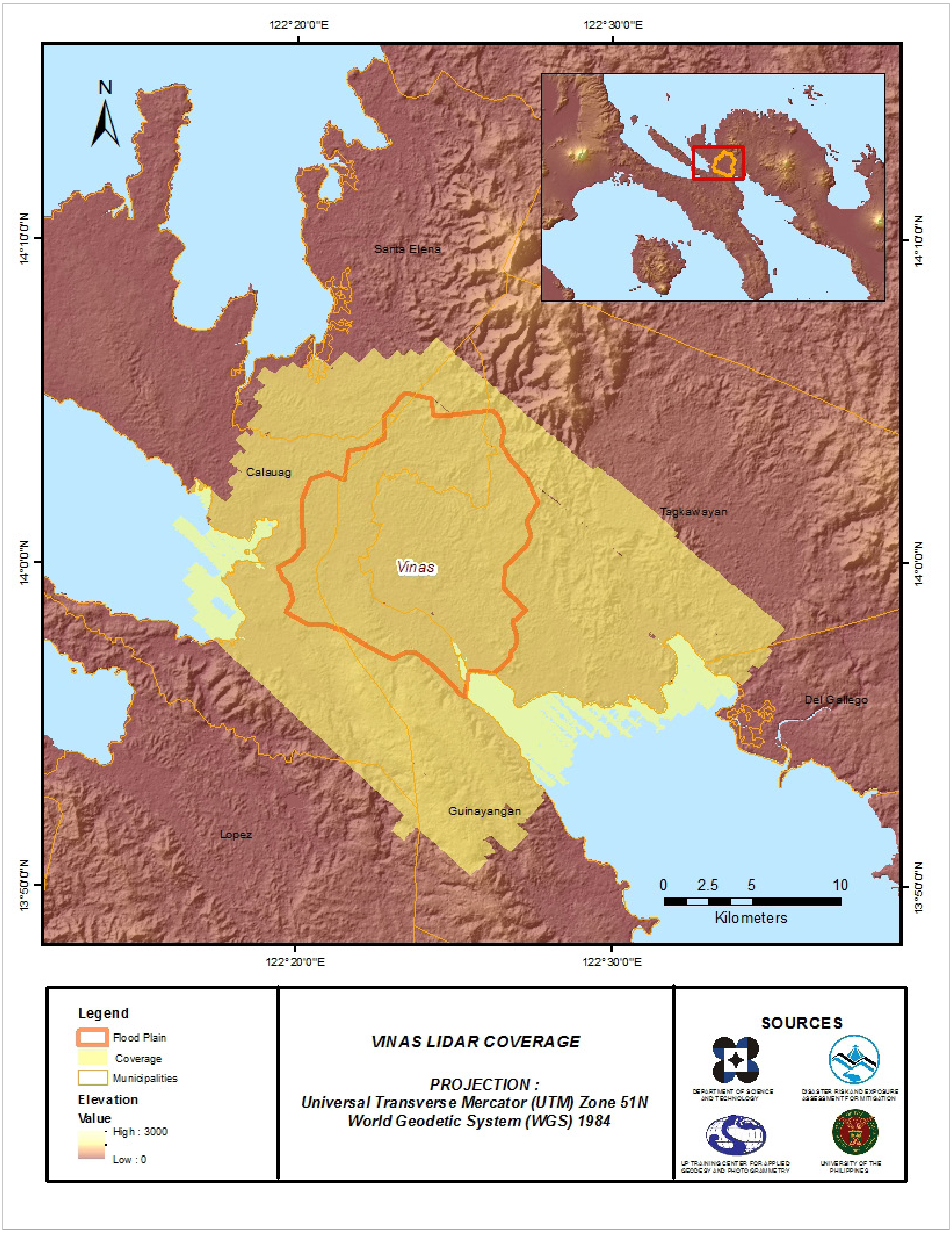

Figure 7. Actual LiDAR survey coverage for Vinas floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE VINAS FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

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

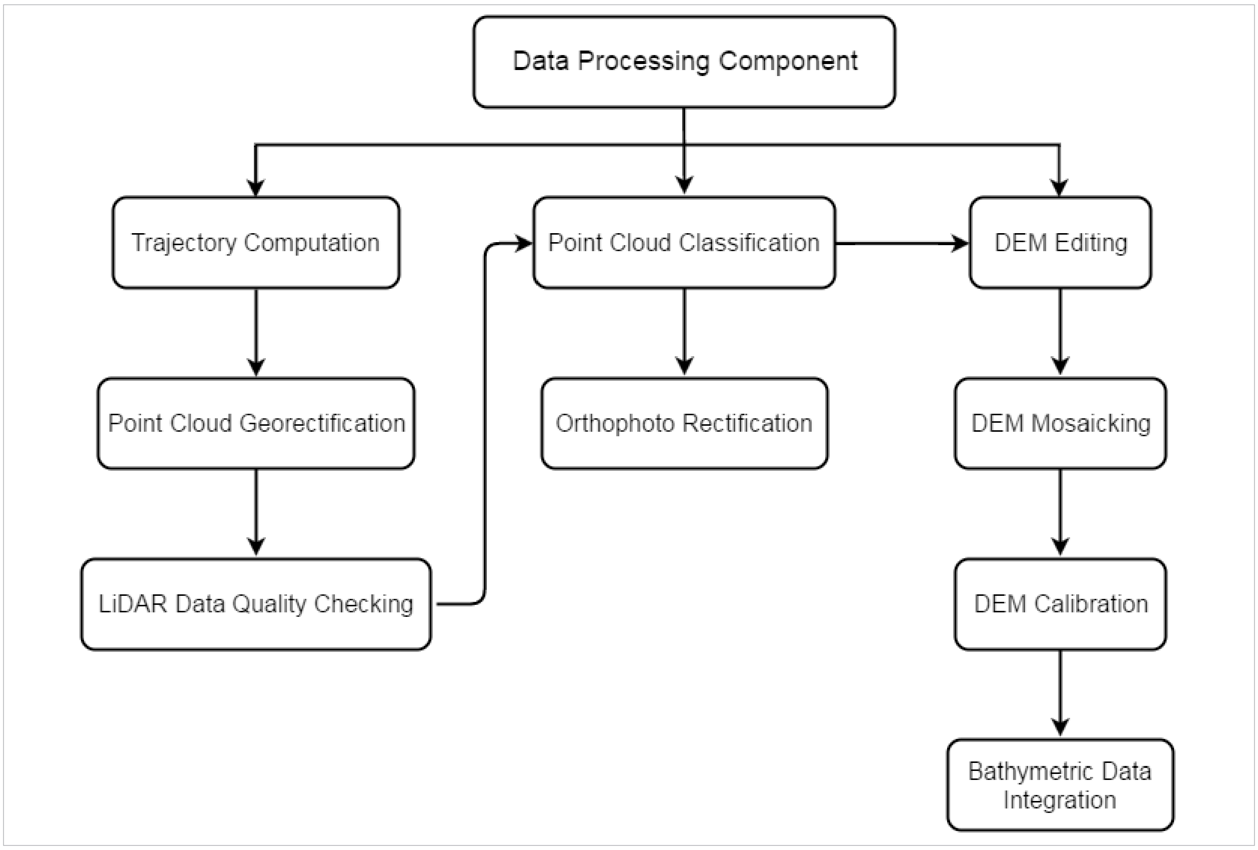

Figure 8. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Vinas floodplain can be found in ANNEX 5. Missions flown during the survey conducted on April 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Quezon and Camarines Norte.

The Data Acquisition Component (DAC) transferred a total of 86.20 Gigabytes of Range data, 0.91 Gigabytes of POS data, 532.5 Megabytes of GPS base station data, and 159 Gigabytes of raw image data to the data server on May 11, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Vinas was fully transferred on May 16, 2016, as indicated on the Data Transfer Sheets for Vinas floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23230P, one of the Vinas flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on April 8, 2016 00:00 AM. The y-axis is the RMSE value for that particular position.

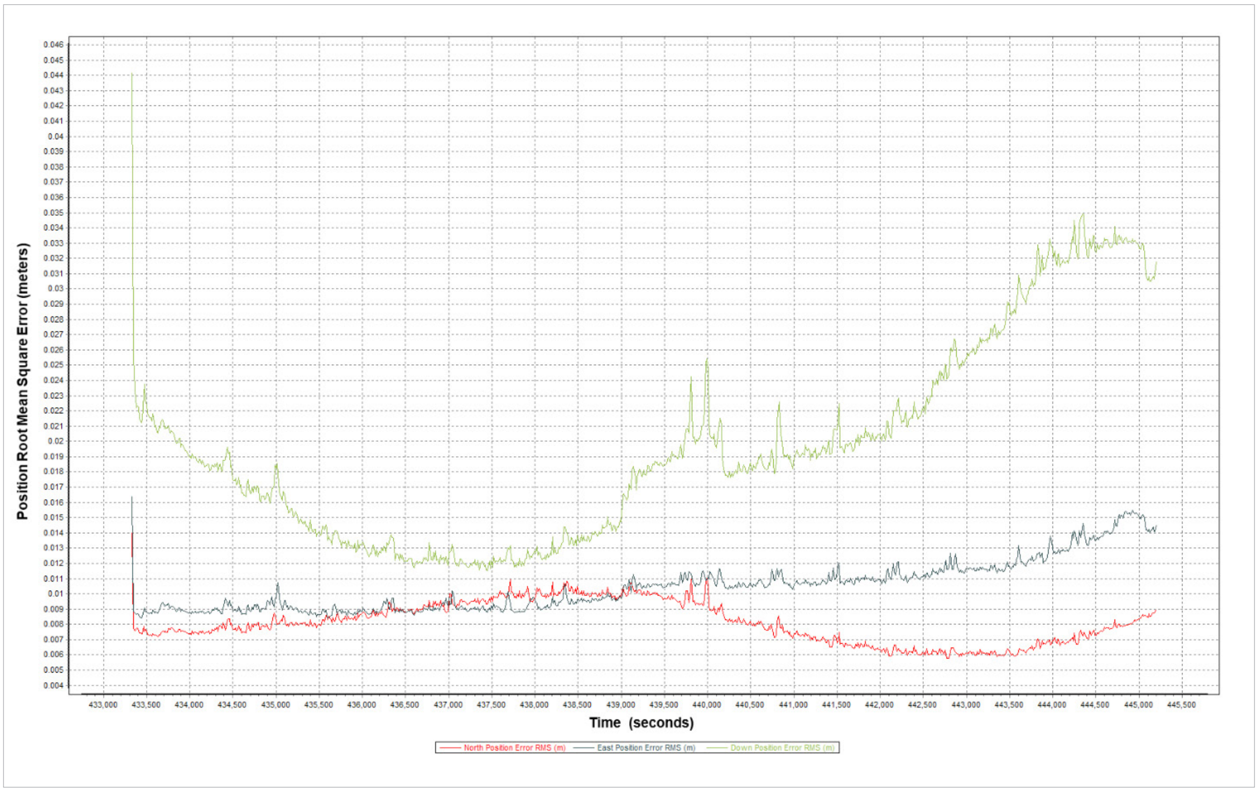

Figure 9. Smoothed Performance Metrics of Vinas Flight 23230P.

The time of flight was from 433,000 seconds to 445,500 seconds, which corresponds to afternoon of April 8, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1.50 centimeters, and the Down position RMSE peaks at 3.40 centimeters, which are within the prescribed accuracies described in the methodology.

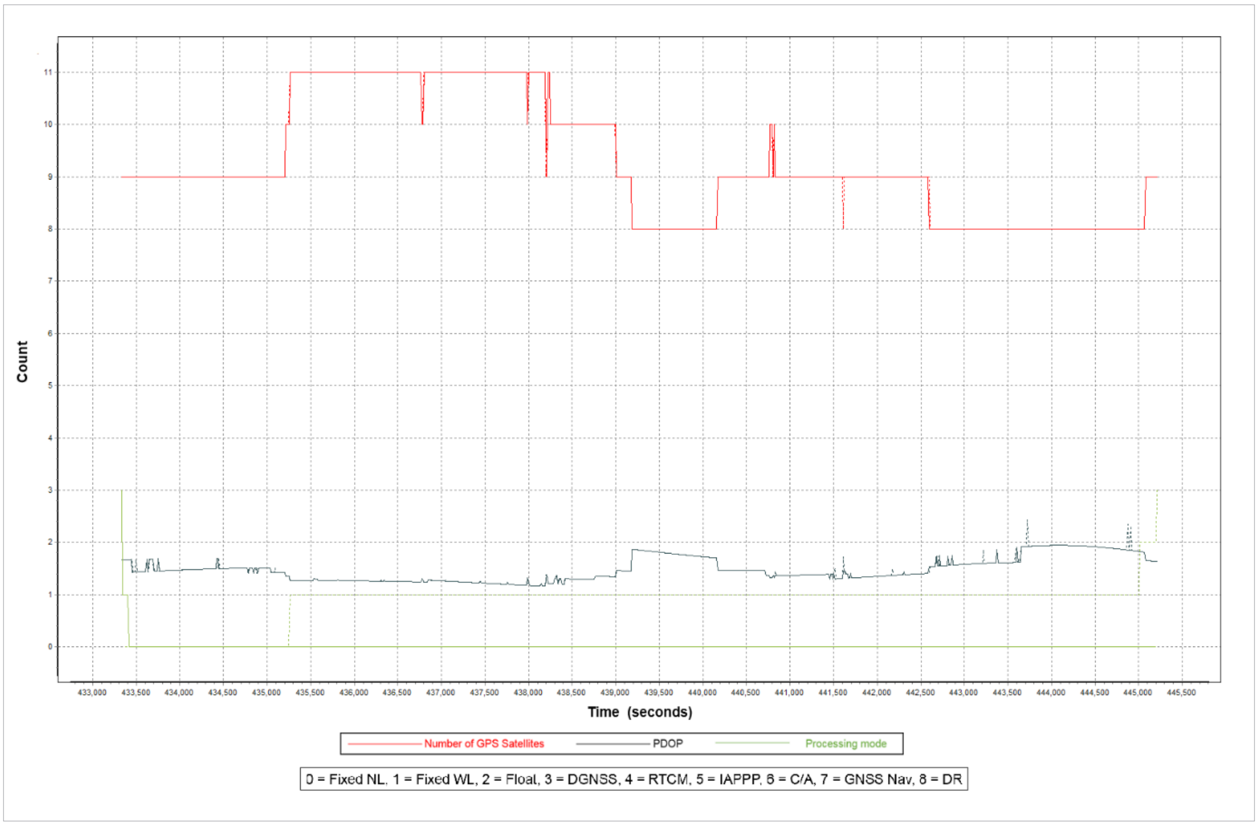

Figure 10. Solution Status Parameters of Vinas Flight 23230P.

The Solution Status parameters of flight 23230P one of the Vinas flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 8. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Vinas flights is shown in Figure 11.

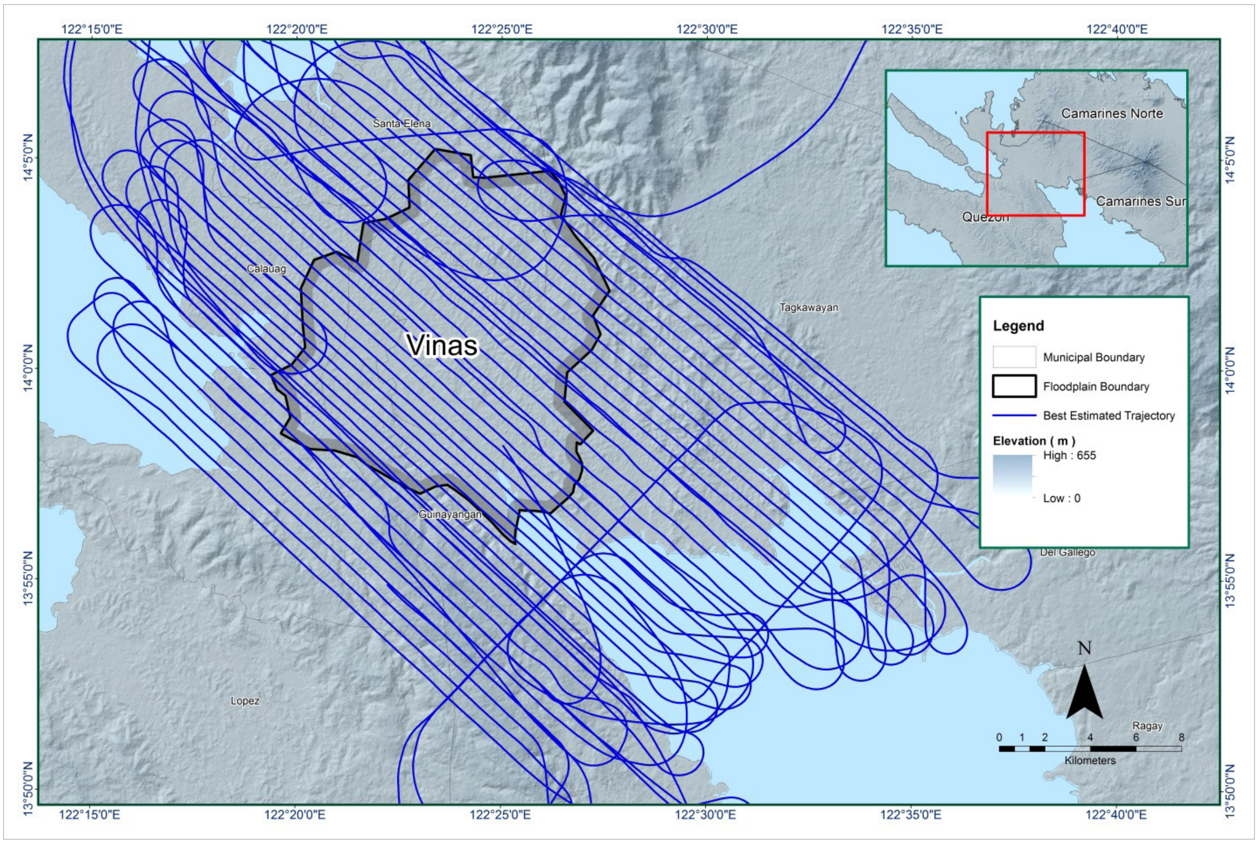

Figure 11. Best Estimated Trajectory of the LiDAR missions conducted over the Vinas Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 56 flight lines, with each flight line containing two channel, since the Pegasus system contains two channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Vinas floodplain are given in Table 10.

Table 10. Self-calibration Results values for Vinas flights.

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000445
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000629
GPS Position Z-correction stdev	(<0.01meters)	0.0022

The optimum accuracy were obtained for all Vinas flights based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are available in the Mission Summary Reports in Error! Reference source not found.8.

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Vinas Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

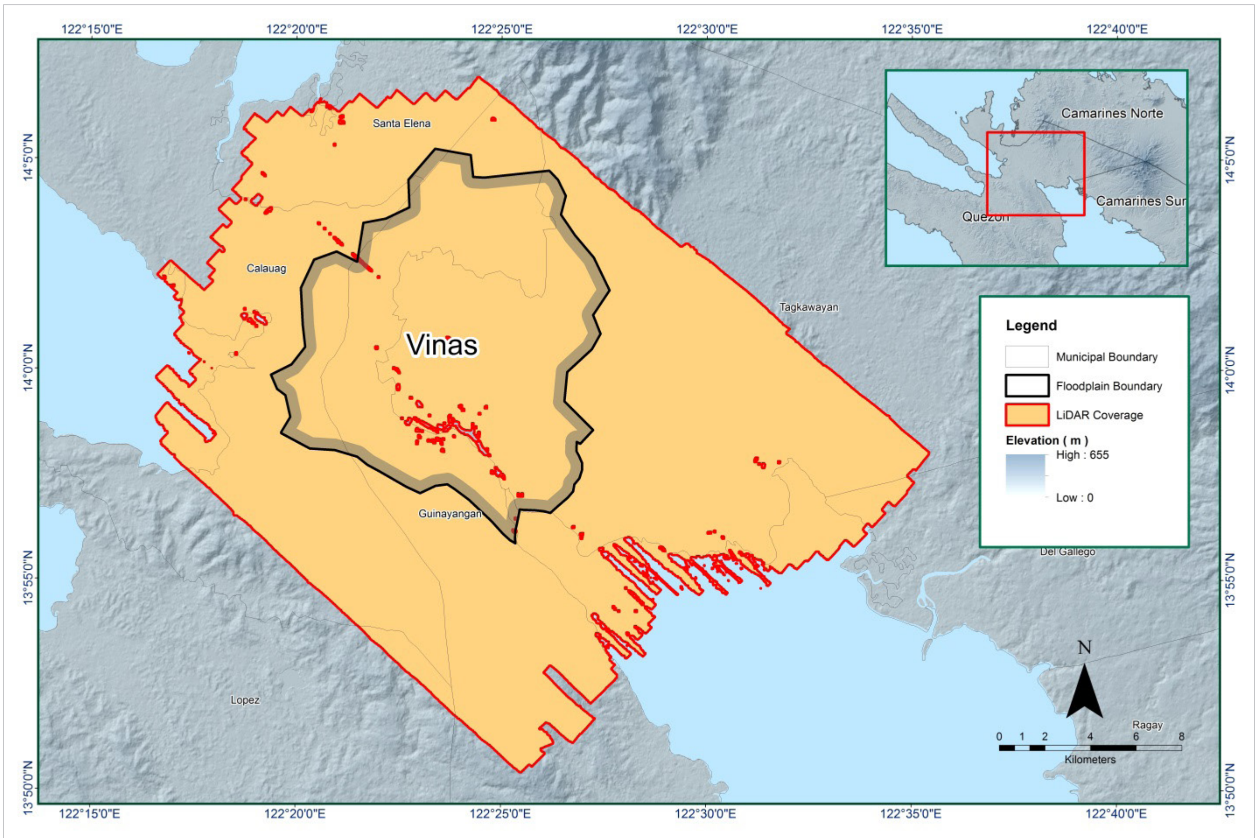

Figure 12. Boundaries of the processed LiDAR data over the Vinas Floodplain.

The total area covered by the Vinas missions is 642.66 square kilometers (sq. kms.) that is comprised of four (4) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for the Vinas floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bagasbas_Blk20F	23230P	240.05
Bagasbas_Blk20G	23242P	226.72
Bagasbas_Blk21A	23244P	99.14
Bagasbas_Blk21A_supplement	23252P	76.75
TOTAL		**642.66 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

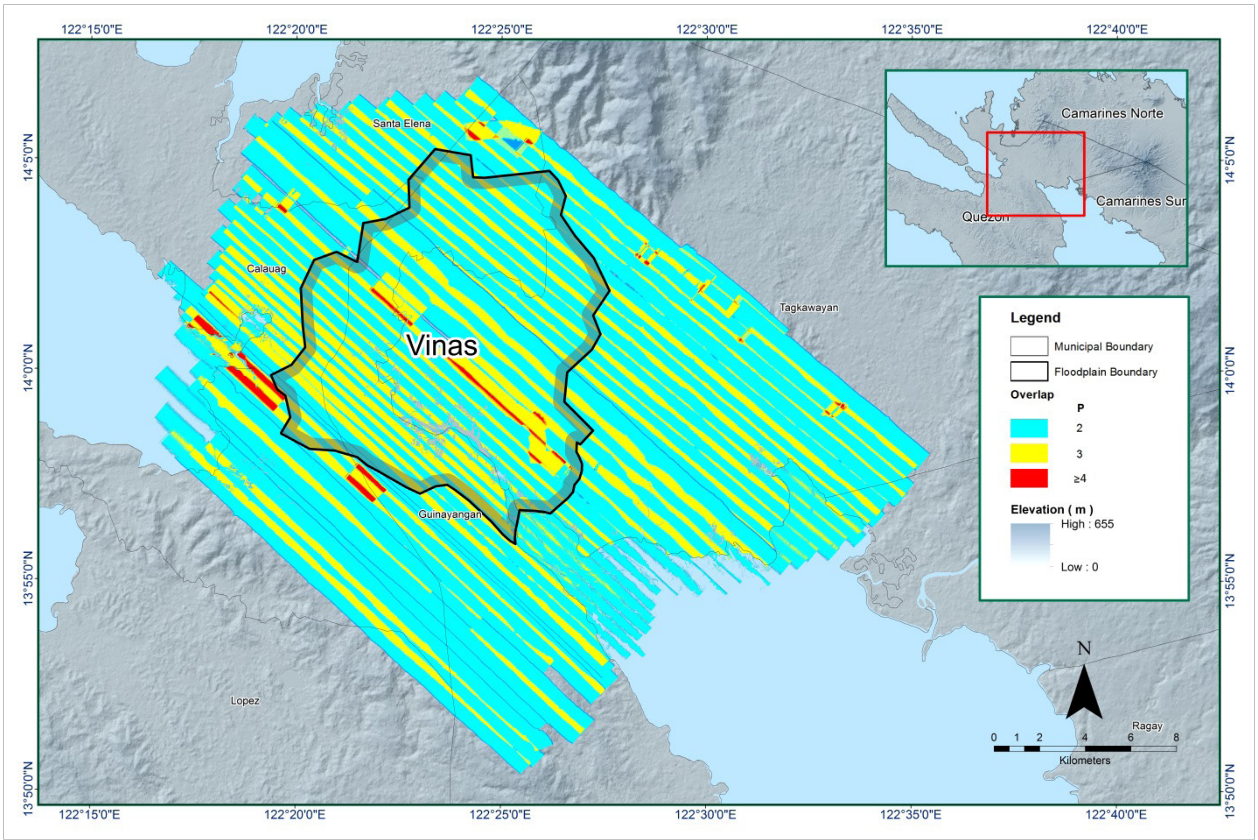

Figure 13. Image of data overlap for Vinas floodplain.

The overlap statistics per block for the Vinas floodplain can be found in the Mission Summary Reports (ANNEX 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 29.12% and 38.27% which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for the Vinas floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.46 points per square meter.

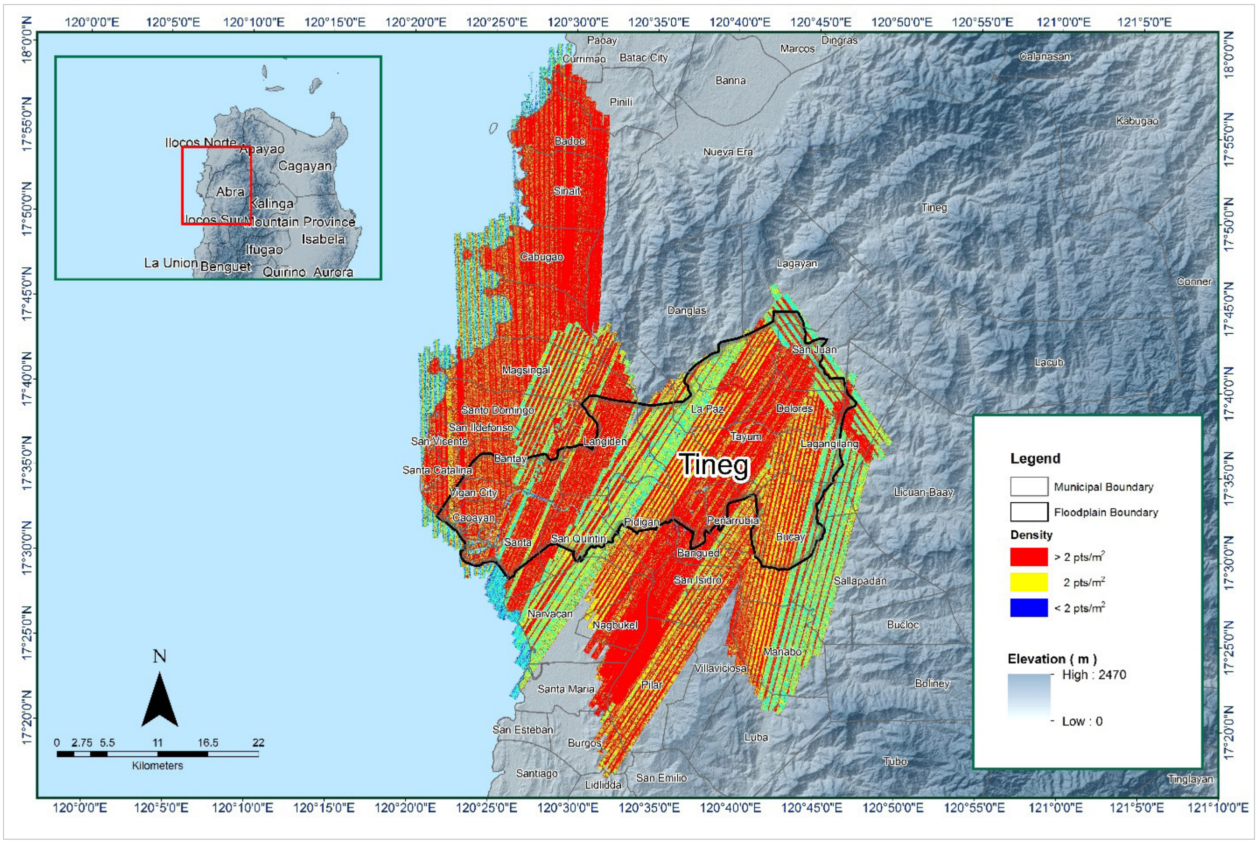

Figure 14. Pulse density map of the merged LiDAR data for Vinas floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

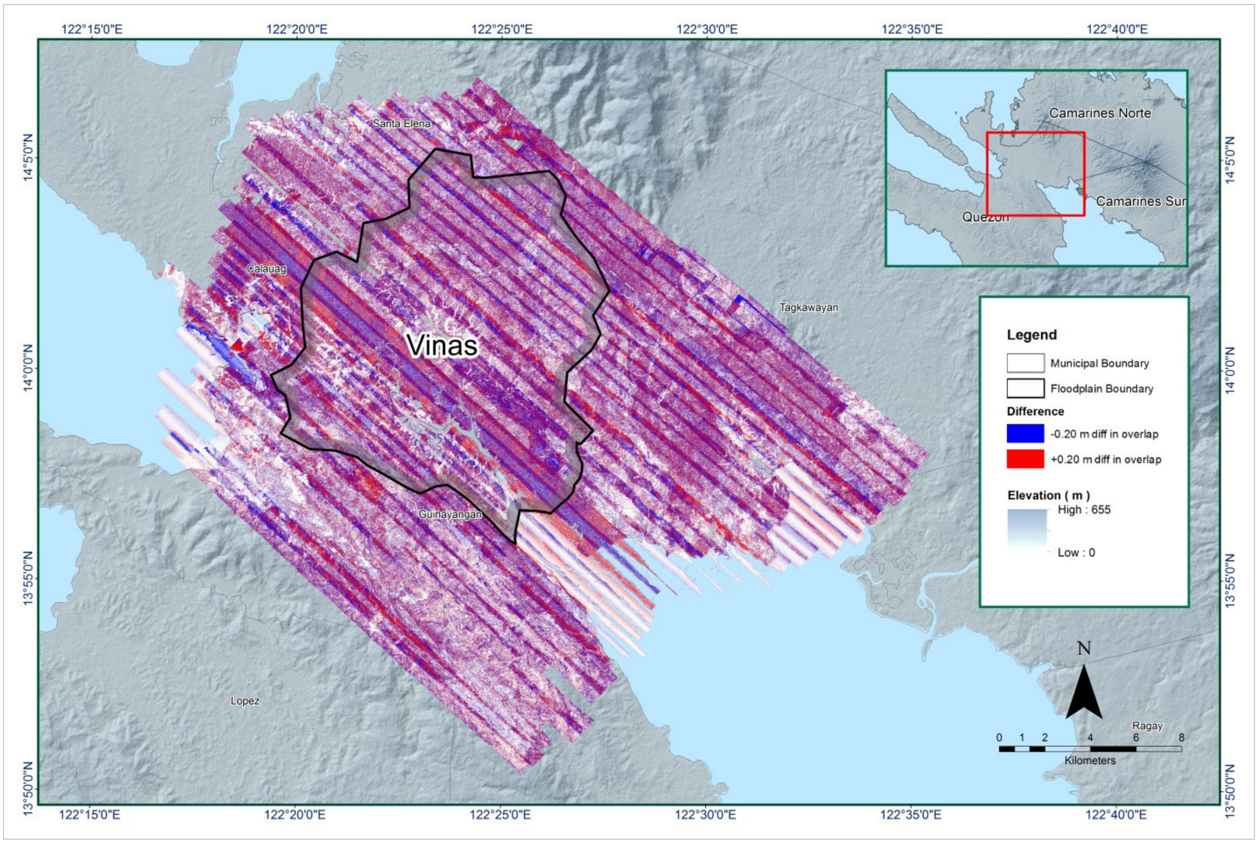

Figure 15. Elevation difference Map between flight lines for the Vinas Floodplain Survey

A screen capture of the processed LAS data from a Vinas flight 23230P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

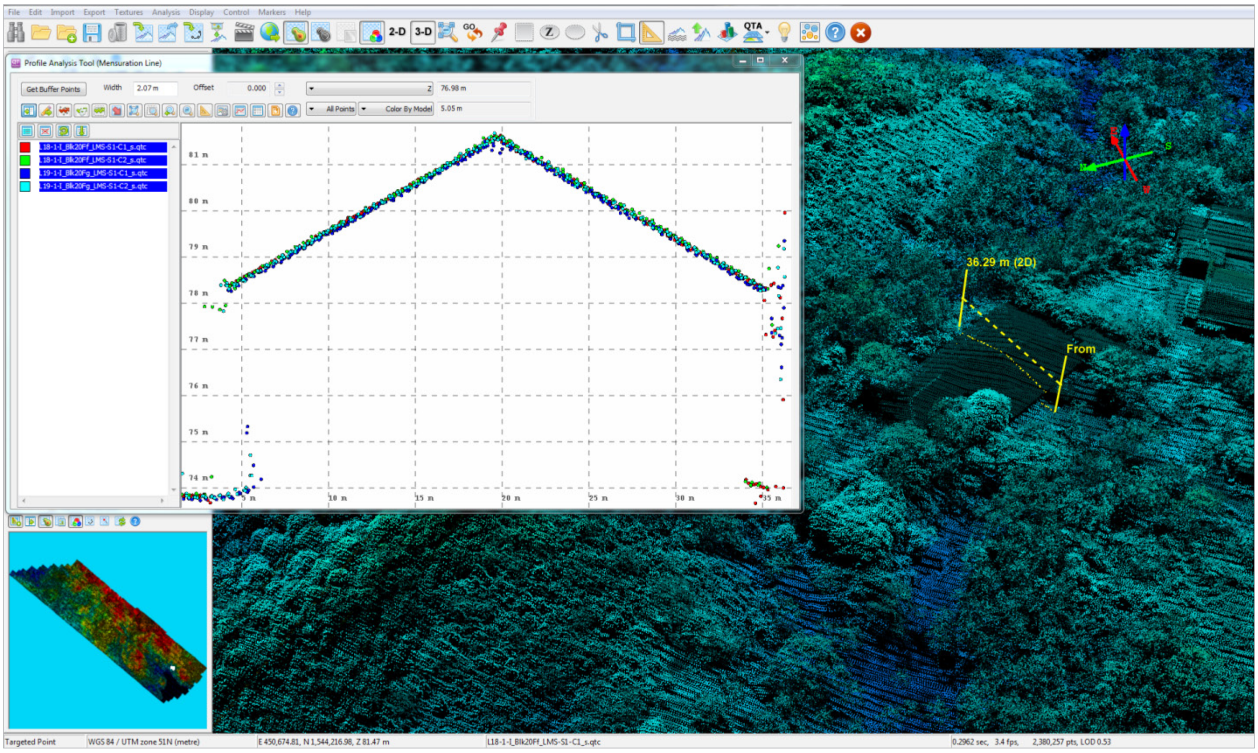

Figure 16. Quality checking for aVinas flight 23230P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Vinas classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	522,469,406
Low Vegetation	359,727,918
Medium Vegetation	1,063,323,799
High Vegetation	2,186,900,021
Building	36,696,631

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Vinas floodplain is shown in Error! Reference source not found.. A total of 913 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 942.63 meters and 39.01 meters, respectively.

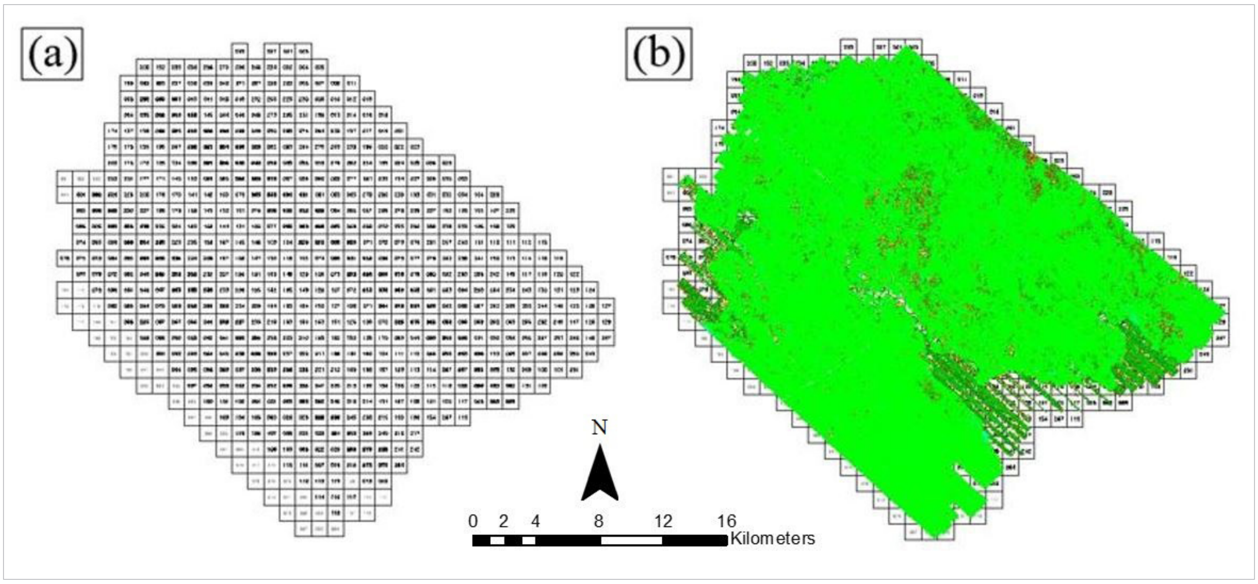

Figure 17. Tiles for Vinas floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, while the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

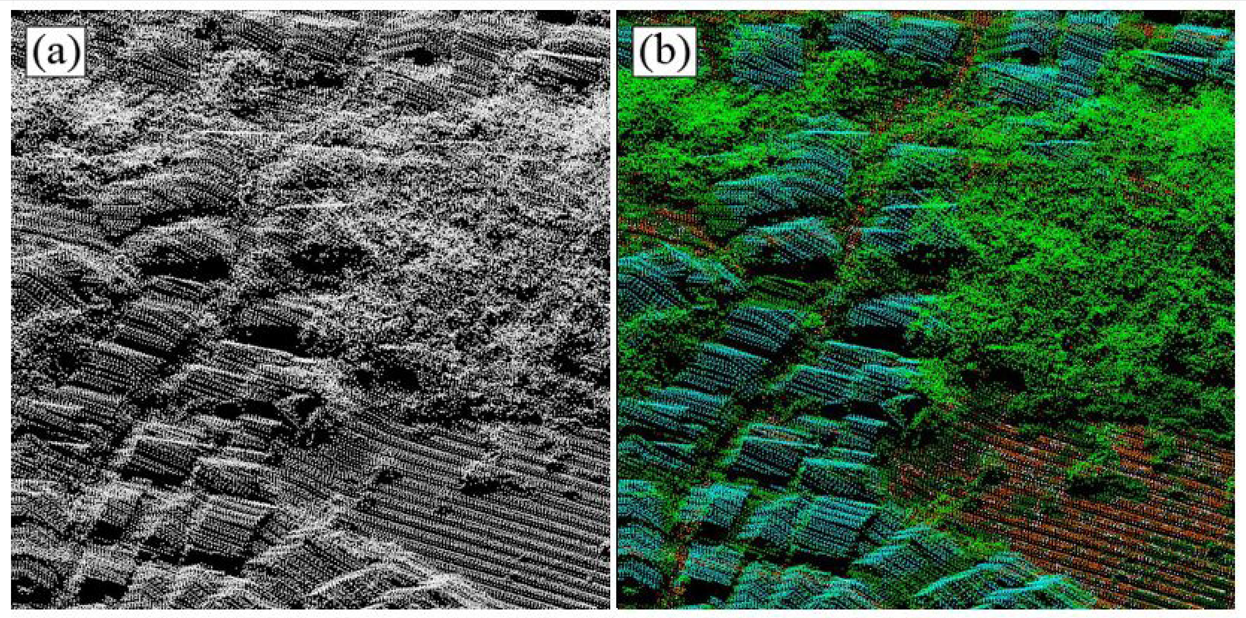

Figure 18. Point cloud before (a) and after (b) classification.

The production of the 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 19Error! Reference source not found.. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

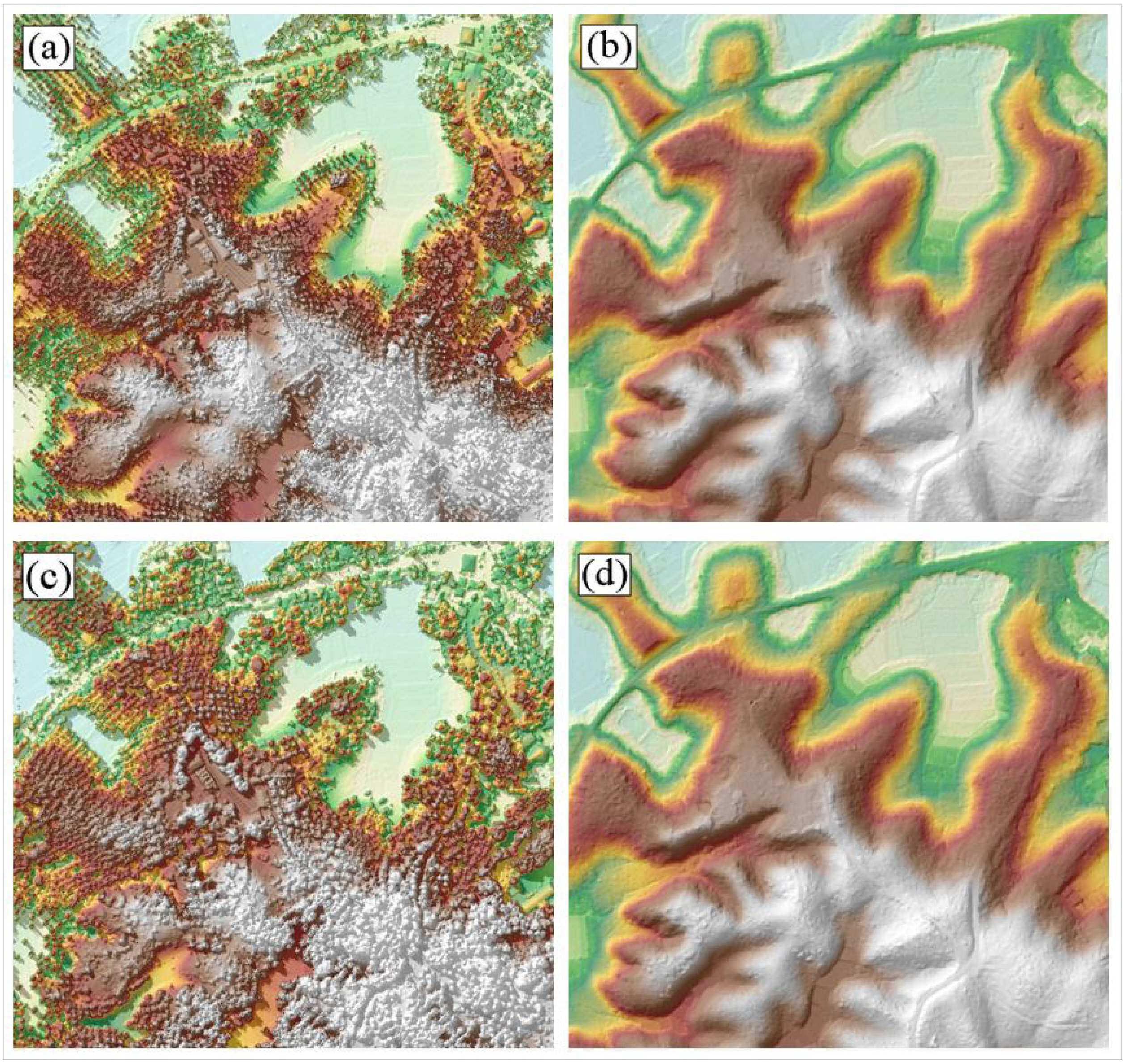

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Vinas floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 486 1km by 1km tiles area covered by Vinas floodplain is shown in Figure 20, after tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Vinas floodplain has a total of 321.78 sq.km orthophotogaph coverage comprised of 1,573 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

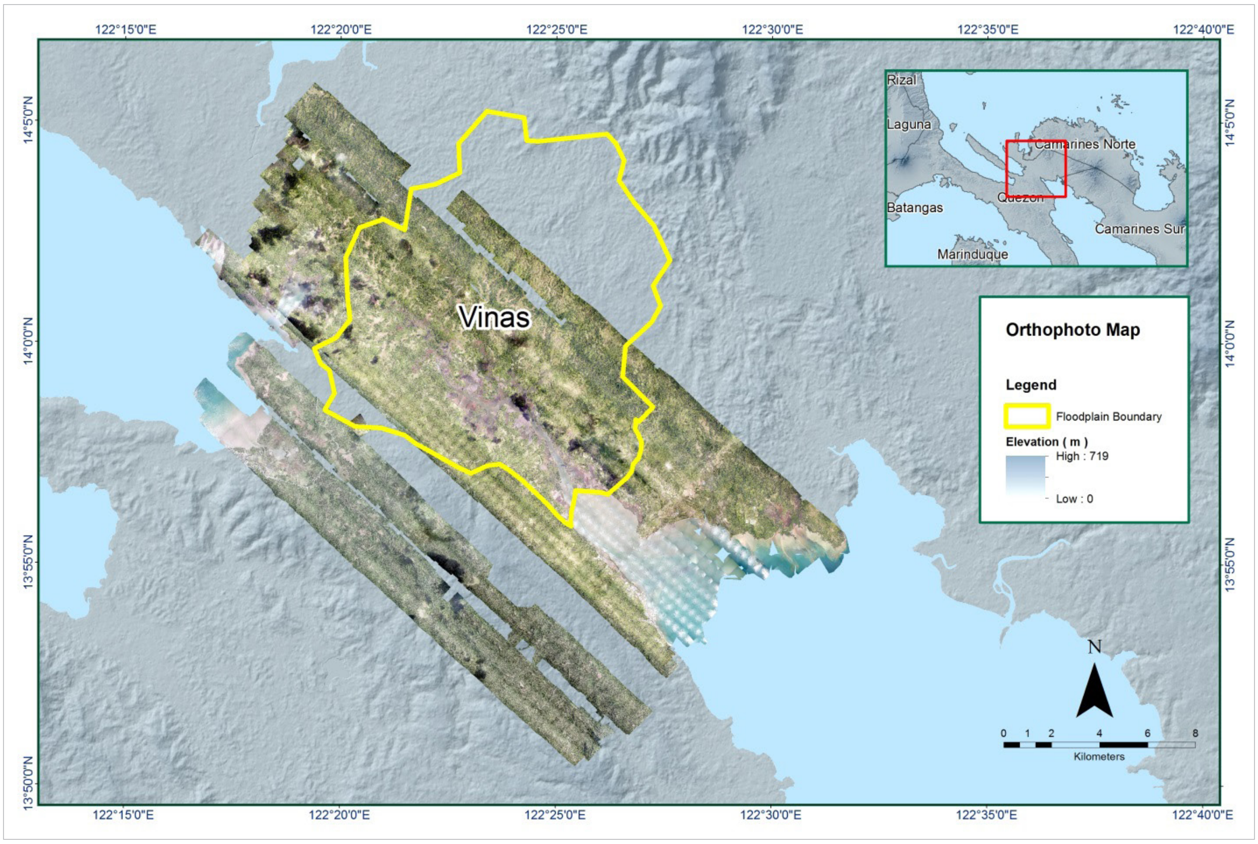

Figure 20. Vinas floodplain with available orthophotographs.

Figure 21. Sample orthophotograph tiles for Vinas floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Vinas flood plain. These blocks are composed of Bagasbas blocks with a total area of 624.66 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Bagasbas_Blk20F	240.05
Bagasbas_Blk20G	226.72
Bagasbas_Blk21A	99.14
Bagasbas_Blk21A_supplement	76.75
TOTAL	**642.66 sq.km**

Figure 22 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Error! Reference source not found.a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Error! Reference source not found.b). A paddy field (Figure 22c) was misclassified and removed during the classification process. To complete the surface, the road (Figure 22d) was retrieved and reclassified through manual editing to allow the correct water flow.

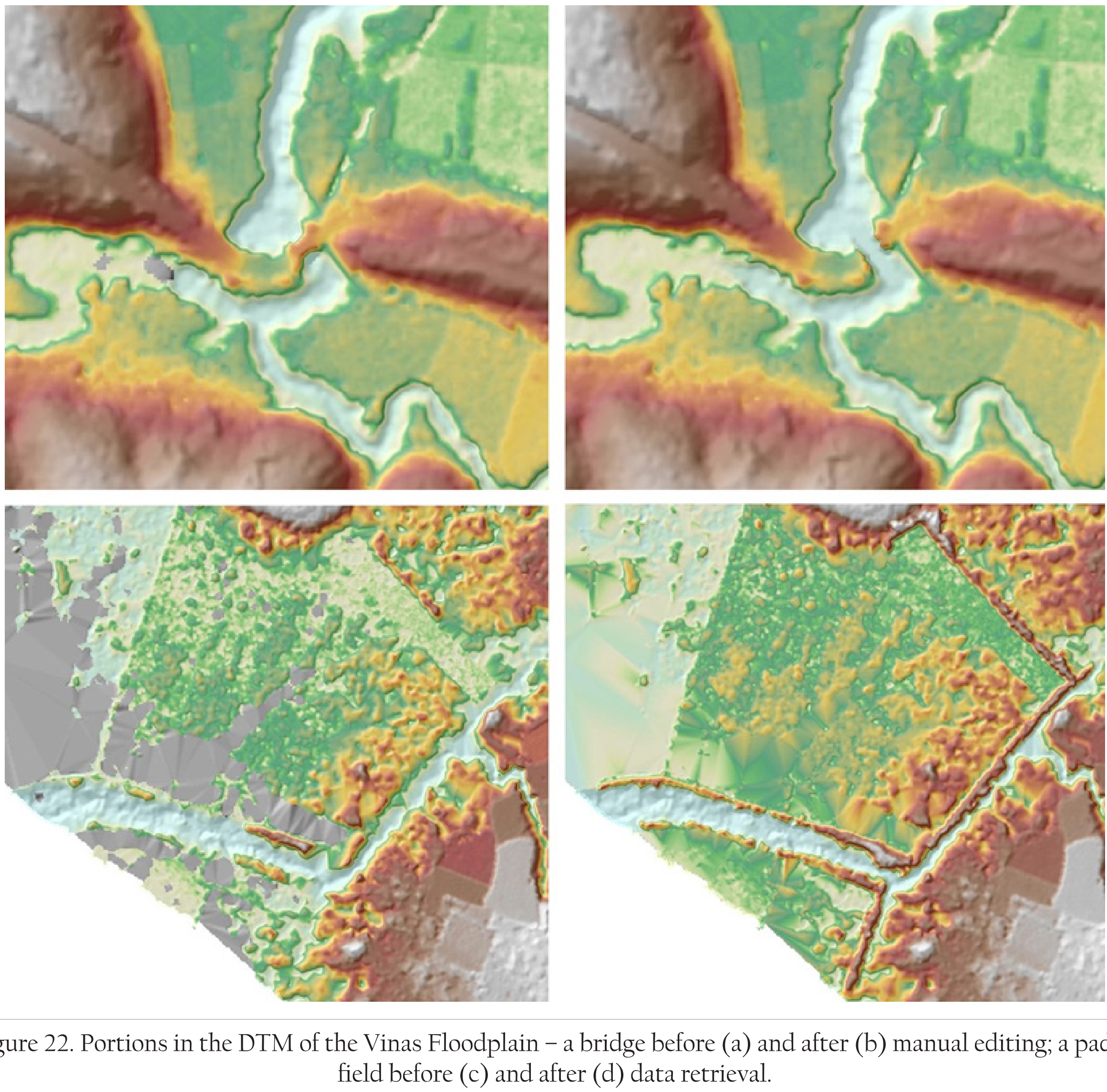

Figure 22. Portions in the DTM of the Vinas Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Bagasbas_Blk20F was used as the reference block at the start of mosaicking because this block was referred to a base with an acceptable order of accuracy. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Vinas floodplain is shown in Figure 23. It can be seen that the entire Vinas floodplain is 100% covered by LiDAR data.

Table 14. Shift values of each LiDAR block of Vinas Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Bagasbas_Blk20F	0.00	0.00	0.00
Bagasbas_Blk20G	0.00	0.00	0.00
Bagasbas_Blk21A	-3.24	1.76	-0.05
Bagasbas_Blk21A_supplement	-3.24	1.76	0.40

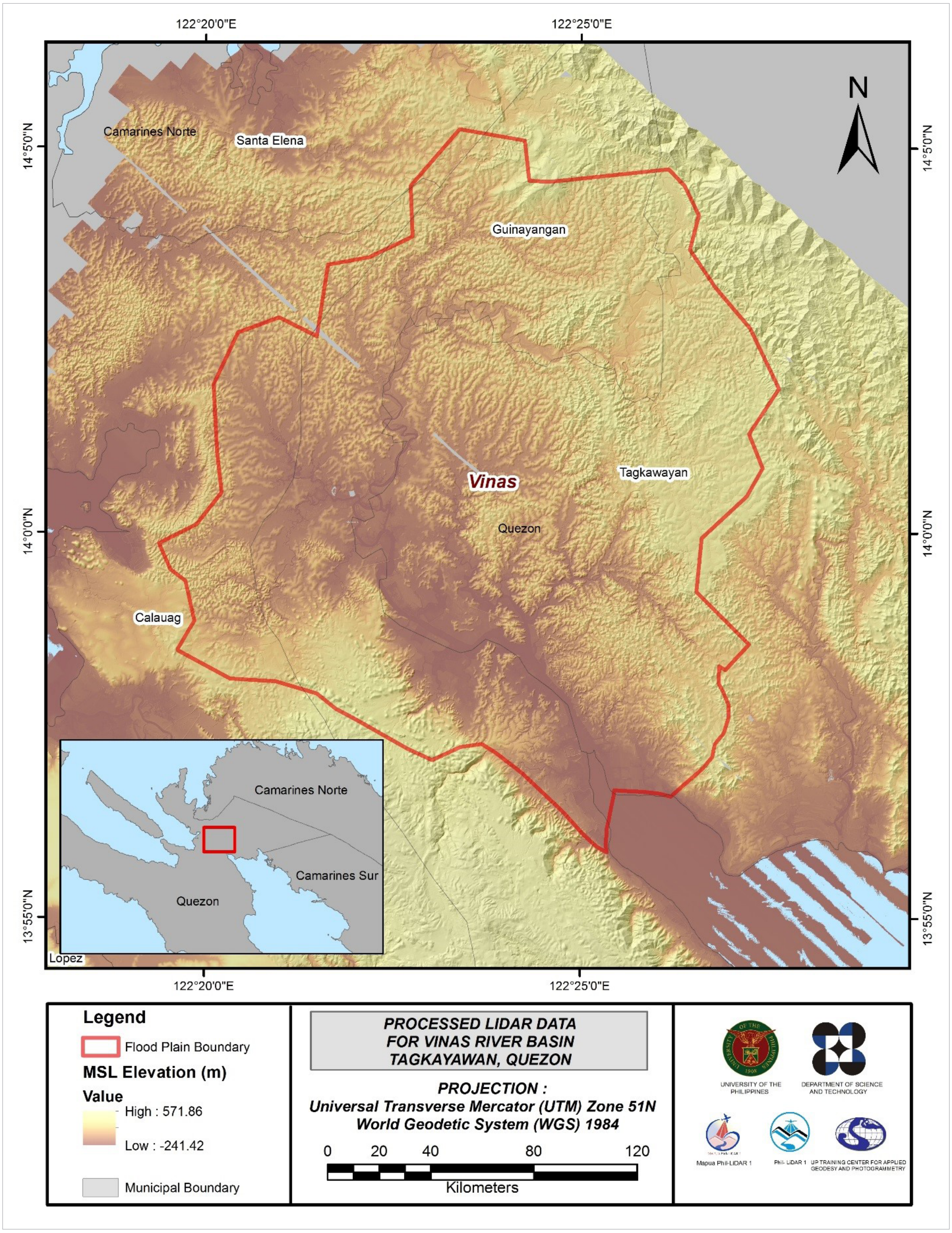

Figure 23. Map of processed LiDAR data for the Vinas Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Vinas to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 15,500 survey points were gathered for all the flood plains within the provinces of Quezon and Camarines Sur wherein the Vinas floodplain is located. Random selection of 80% of the survey points, resulting to 12400 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 3.08 meters with a standard deviation of 0.17 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 3.08 meters, to the mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

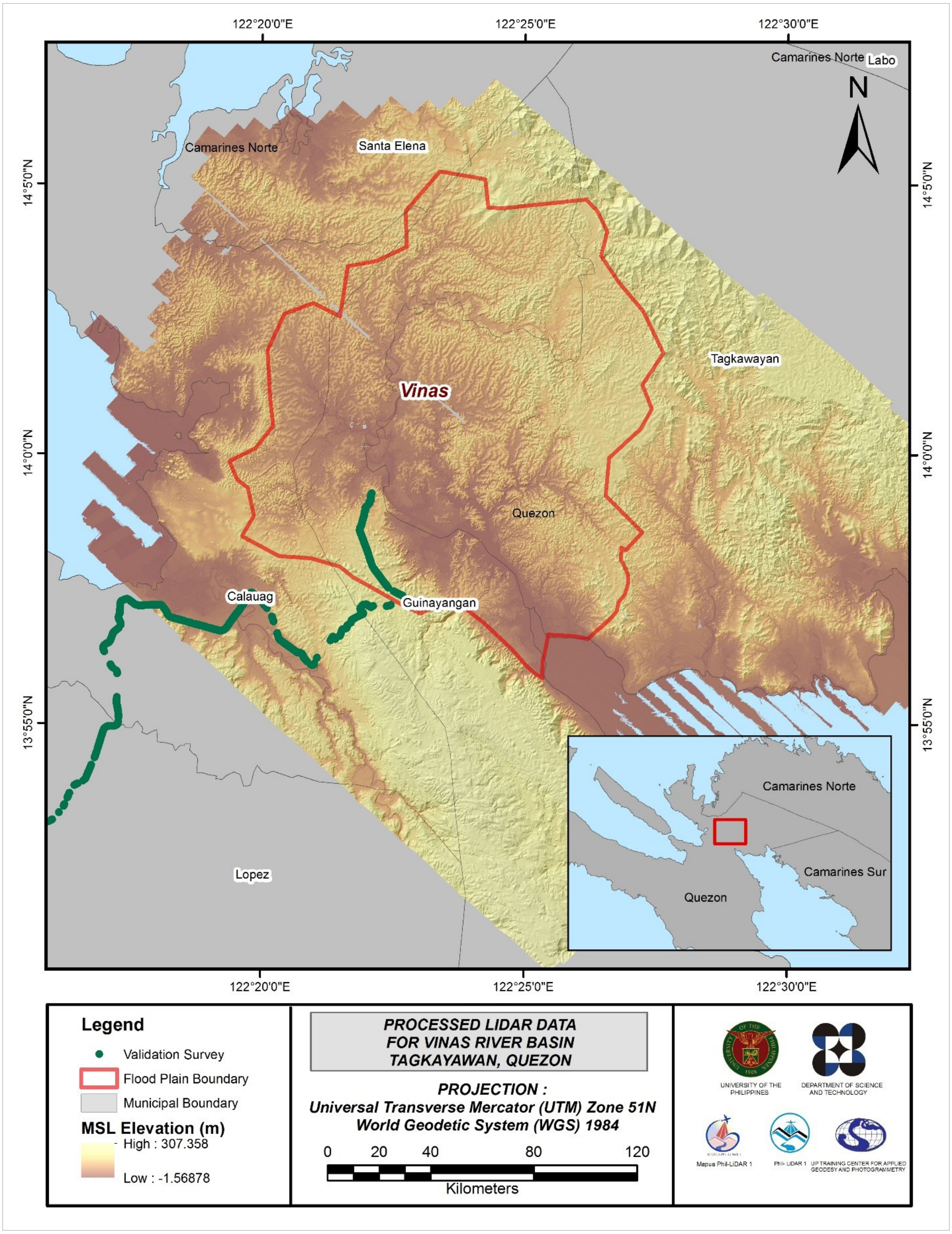

Figure 24. Map of Vinas Floodplain with validation survey points in green.

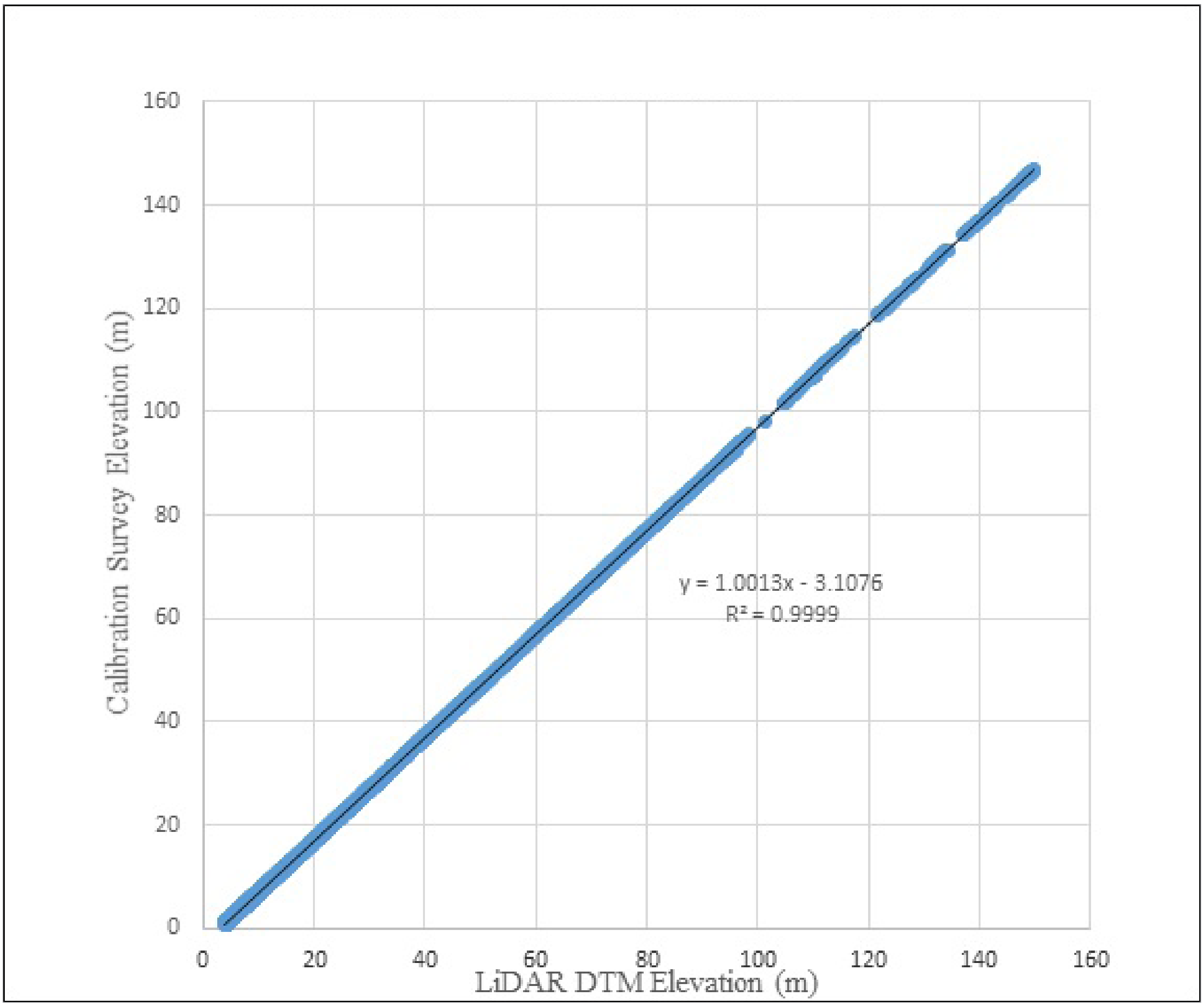

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.08
Standard Deviation	0.17
Average	-3.07
Minimum	-3.40
Maximum	-2.60

The remaining 20% of the total survey points that are near Vinas flood plain, resulting to 477 points, were used for the validation of calibrated Vinas DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.06 meters, as shown in Table 16.

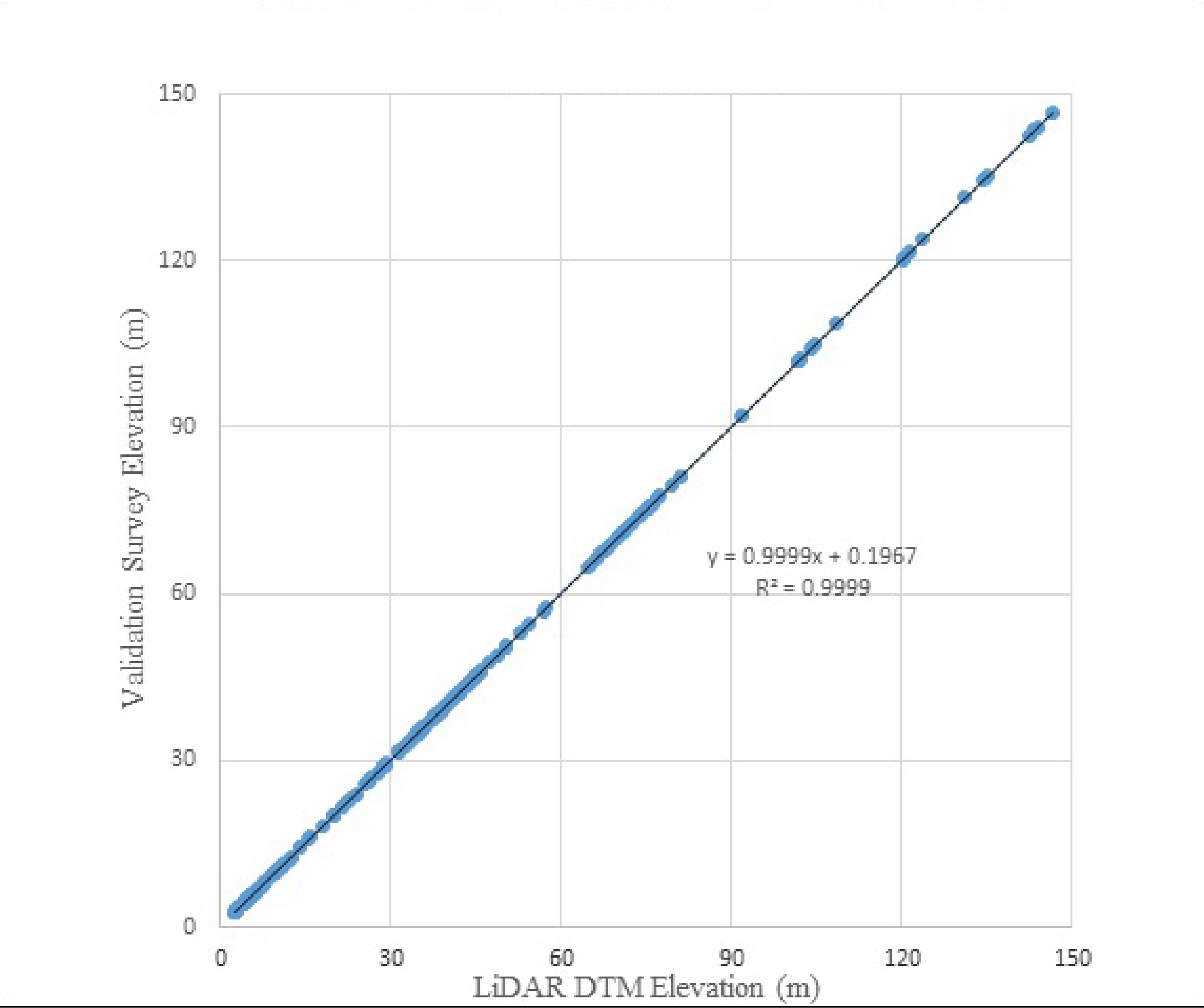

Figure 26. Correlation plot between the validation survey points and the LiDAR data.

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.06
Average	0.19
Minimum	0.04
Maximum	0.29

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data were available for Vinas with 11,786 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.54 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Vinas integrated with the processed LiDAR DEM is shown in Figure 27.

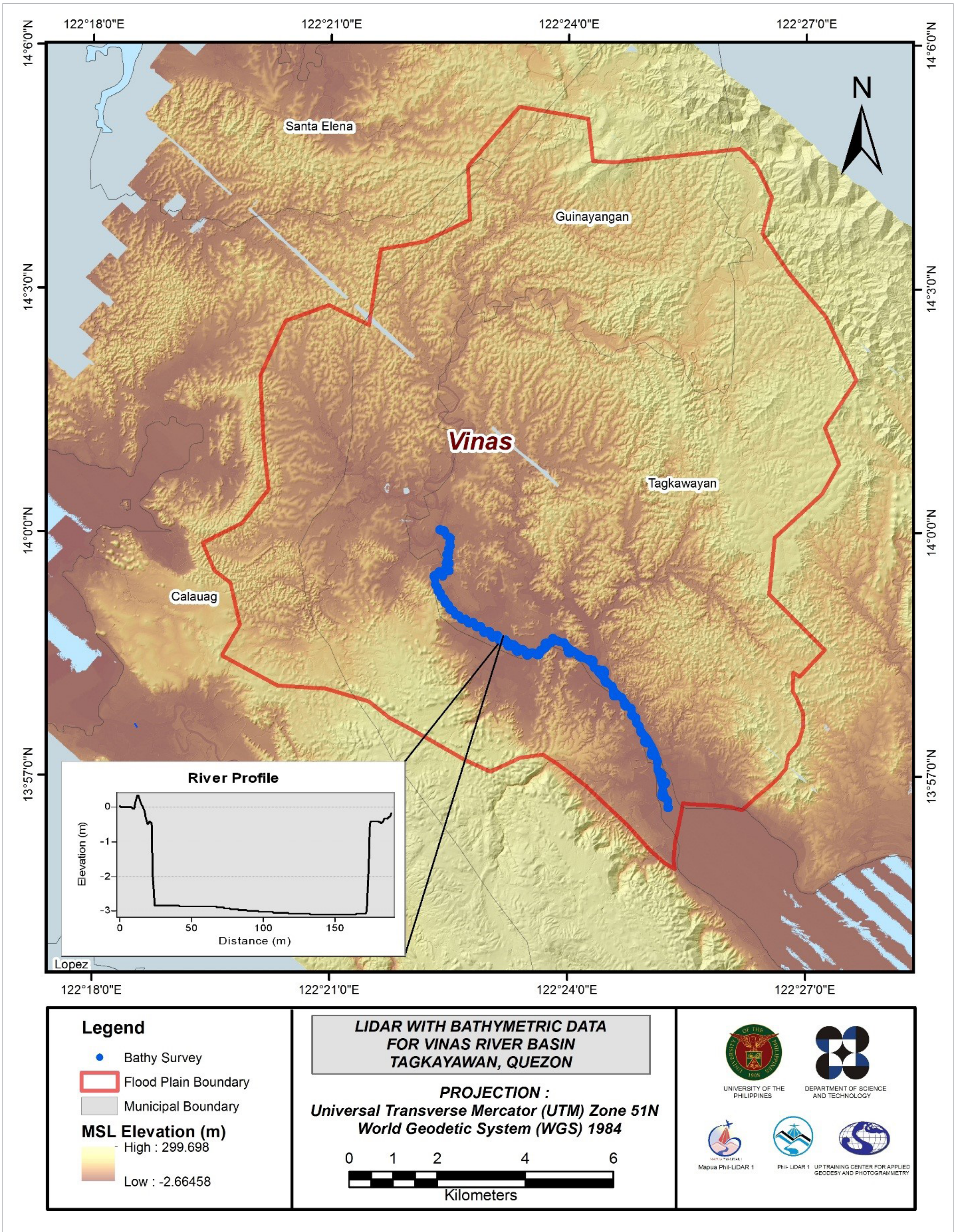

Figure 27. Map of Vinas floodplain with bathymetric survey points in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Vinas floodplain, including its 200 m buffer, has a total area of 171.49 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 562 building features, are considered for QC. Figure 28 shows the QC blocks for Vinas floodplain.

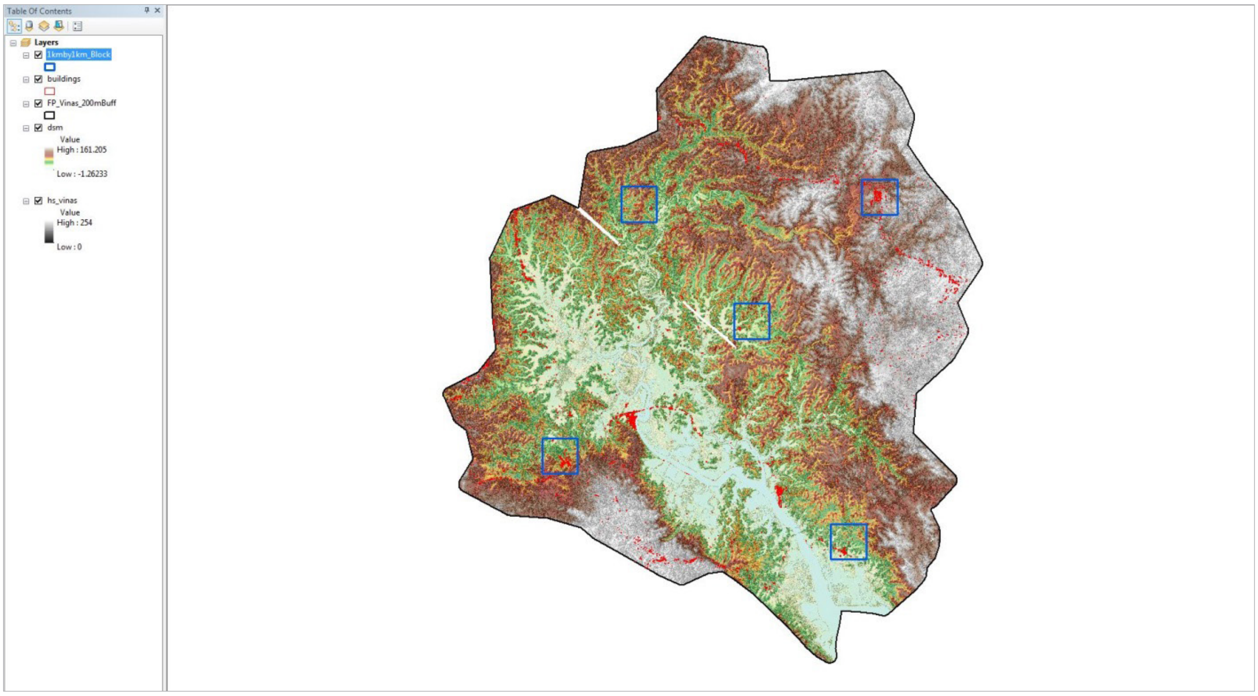

Figure 28. Blocks (in blue) of Vinas building features that was subjected to QC.

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

Table 17. Details of the quality checking ratings for the building features extracted for the Vinas River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Vinas	98.79	100	95.63	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,085 building features in Vinas floodplain. Of these building features, none was filtered out after height extraction, resulting to 4,769 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 7.98 meters.

3.12.3 Feature Attribution

The attributes were obtained by field data gathering. GPS devices were used to determine the coordinates of important features. These points are uploaded and overlaid in ArcMap and are then integrated with the shapefiles.

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

Table 18. Building features extracted for Vinas Floodplain.

Facility Type	No. of Features
Residential	4,635
School	51
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	7
Barangay Hall	33
Military Institution	0
Sports Center/Gymnasium/Covered Court	3
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	1
Religious Institutions	28
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	5
Other Commercial Establishments	6
Total	**4,769**

Table 19. Total length of extracted roads for Vinas Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Vinas	163.87	4.66	11.46	22.54	0.00	**202.53**

Table 20. Number of extracted water bodies for Vinas Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Vinas	2	253	0	0	0	255

A total of 39 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

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

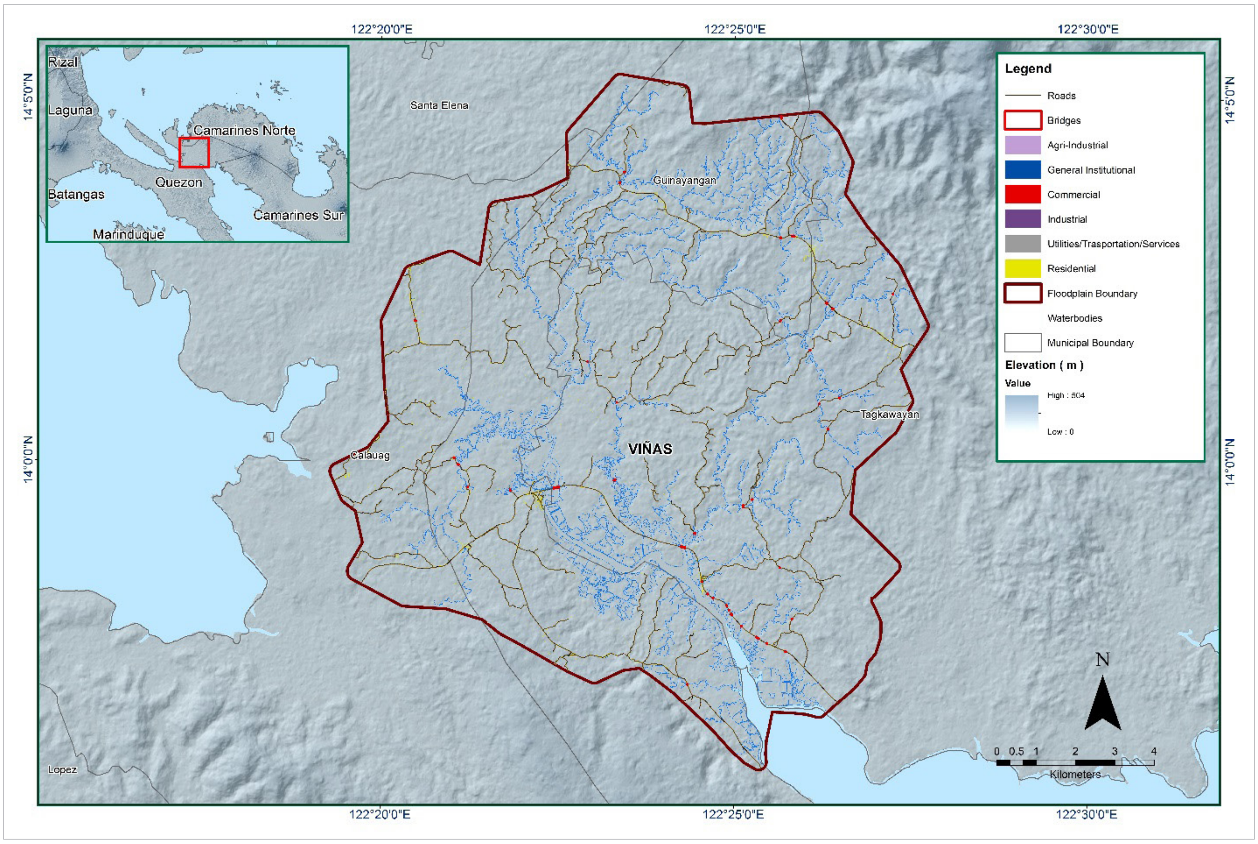

Figure 29. Extracted features of the Vinas Floodplain.

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

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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).

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Vinas River on May 2, 2016 to May 16, 2016. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (iii) the cross section survey and bridge as-built survey, and water level marking at Cabibihan Bridge in Brgy. Cabugwang, Municipality of Tagkawayan; (iv) validation points acquisition of about 67 km covering the Vinas River Basin area; and (v) bathymetric survey from its upstream in Brgy. Cabugwang, Municipality of Tagkawayan down to the mouth of the river in Brgy. Hinabaan, Municipality of Guinayangan, with an approximate length of 9.840 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique. Figure 30 illustrates the extent of the entire survey in Vinas River.

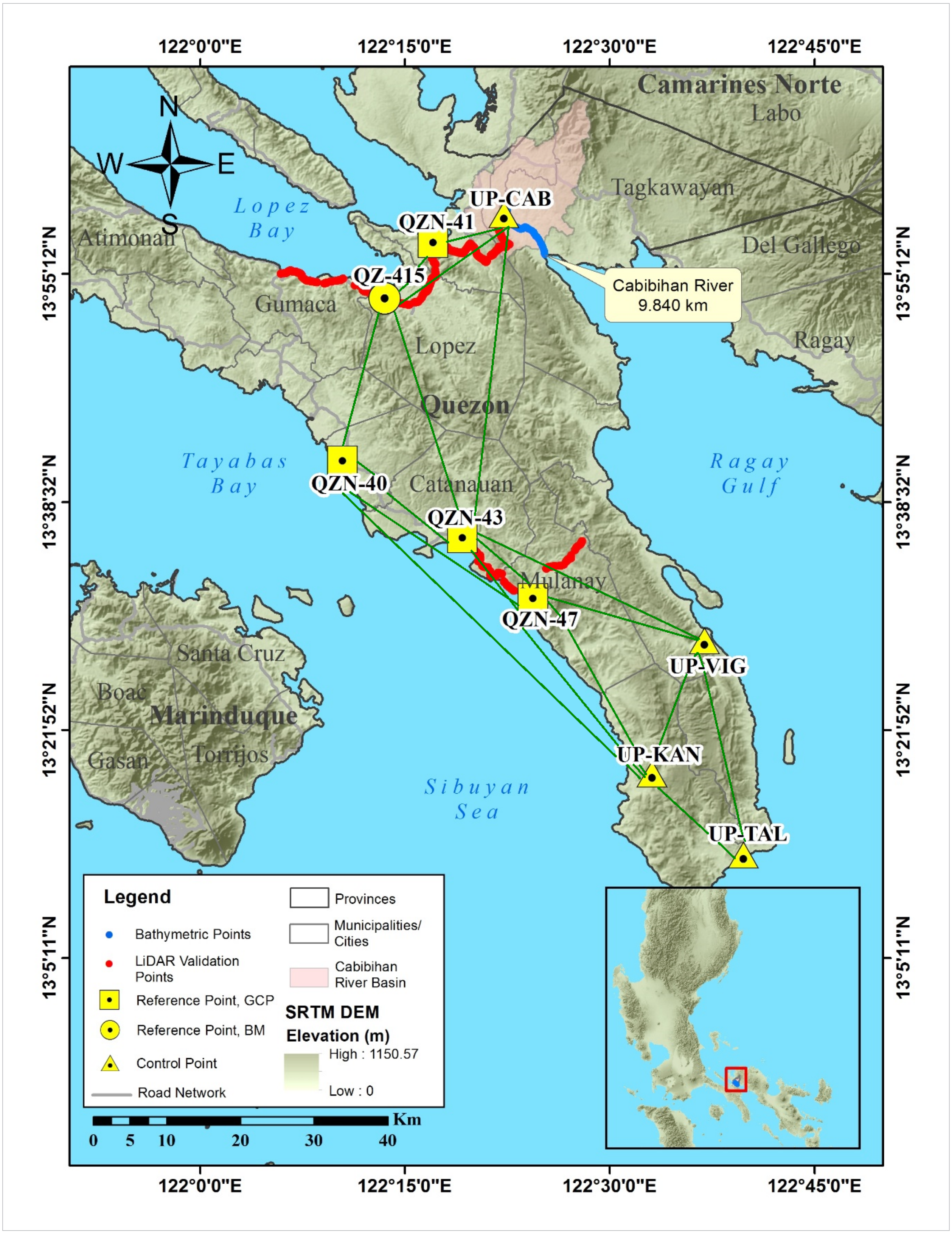


Figure 30. Vinas River Survey Extent

4.2 Control Survey

The GNSS network utilized for the Vinas River Basin is composed of nine (9) loops and a baseline that was established on May 4, 2016 and May 11, 2016 which occupied the following reference points: QZN-40, a second-order GCP in Brgy. Matandang Sabang Silangan, Municipality of Catanauan; QZN-47, a second order GCP in Barangay II, Municipality of Mulanay; and QZ-415, a BM with Accuracy Class at 95% CL 8cm in Brgy. Pansol, Municipality of Lopez.

Four (4) control points were established along the approach of bridges, namely: UP-KAN, at Kanguinsa Bridge in Brgy. Silongin, Municipality of San Francisco; UP-TAL at Talisay Bridge in Brgy. Pagsangahan, also in Municipality of San Francisco; and UP-VIG at Vigo Bridge in Brgy. Vigo Central, Municipality of San Narciso. The UP established control point UP-CAB is located in a residential court in Brgy. Aloneros, Municipality of Guinayangan. A NAMRIA established control point; QZN-41, a second order GCP in Barangay I, Municipality of Calauag was also occupied and used as marker for the network.

Table 21 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Vinas River Survey.

Table 21. List of reference and control points used during the survey in Vinas River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
QZN-40	2nd Order, GCP	13°41'32.47595" N	122°10'25.77273" E	51.703	-	2006
QZN-43	2nd Order, GCP	13°35'55.81611" N	122°19'13.53031" E	51.015	-	2006
QZN-47	2nd Order, GCP	13°31'29.52488" N	122°24'23.44821" E	53.862	-	2006
QZ-415	1st order Order, BM	-	-	57.290	8.613	2007
QZN-41	Used as Marker	-	-	-	-	2006
UP-CAB	UP Established	-	-	-	-	05-04-2016
UP-KAN	UP Established	-	-	-	-	05-11-2016
UP-TAL	UP Established	-	-	-	-	05-11-2016
UP-VIG	UP Established	-	-	-	-	05-11-2016

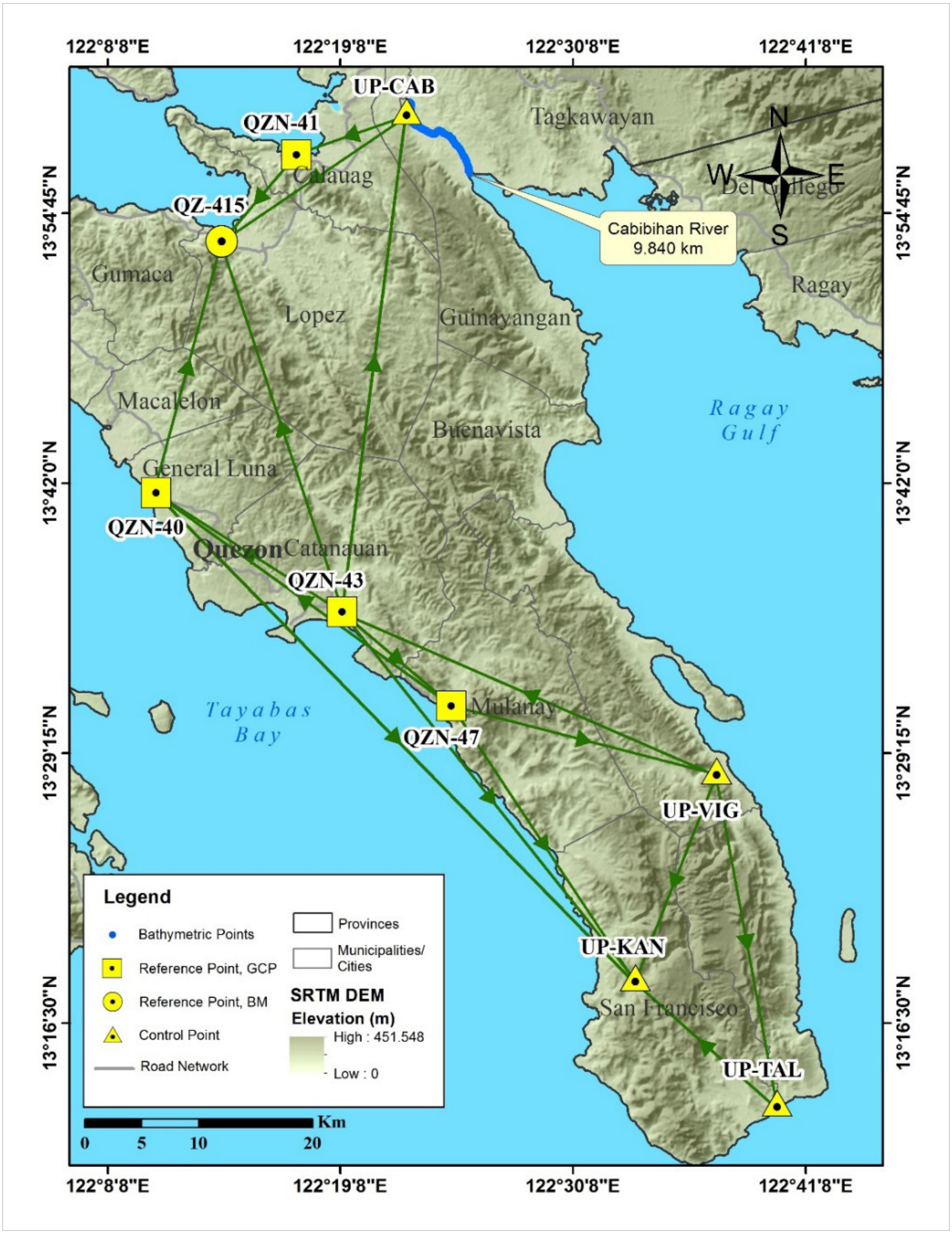


Figure 31. Vinas River Basin Control Survey Extent.

Error! Reference source not found. to Figure 40 Error! Reference source not found.depict the setup of the GNSS on recovered reference points and established control points in the Vinas River.

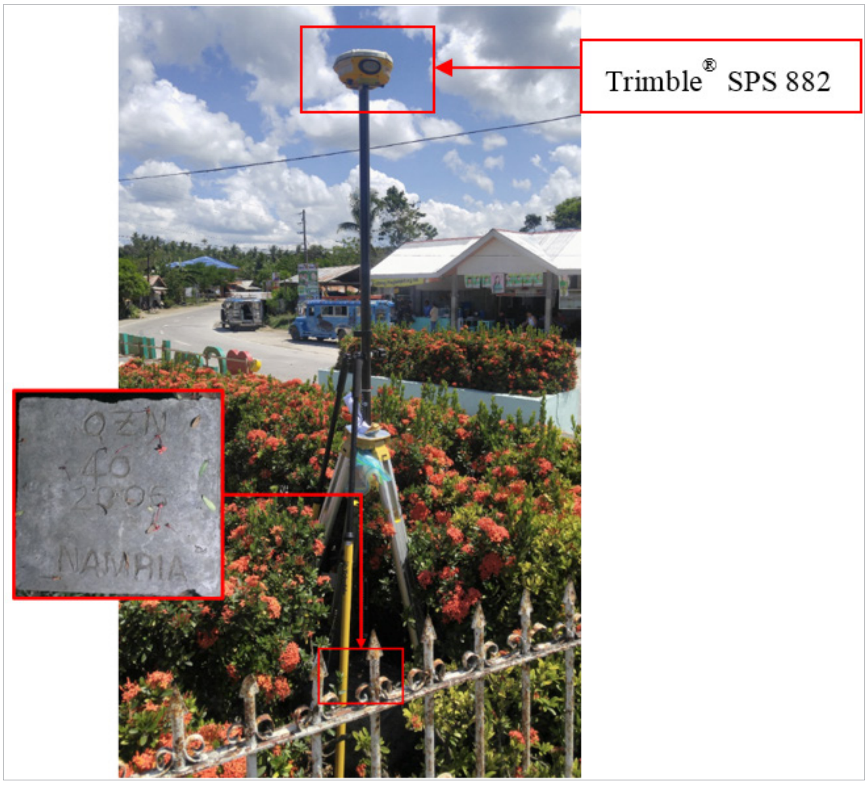


Figure 32. GNSS base set up, Trimble® SPS 882, at QZN-40, located inside a triangular plant area found at the center of a triangular island in Brgy. San Jose, Municipality of Gen. Luna, Quezon.

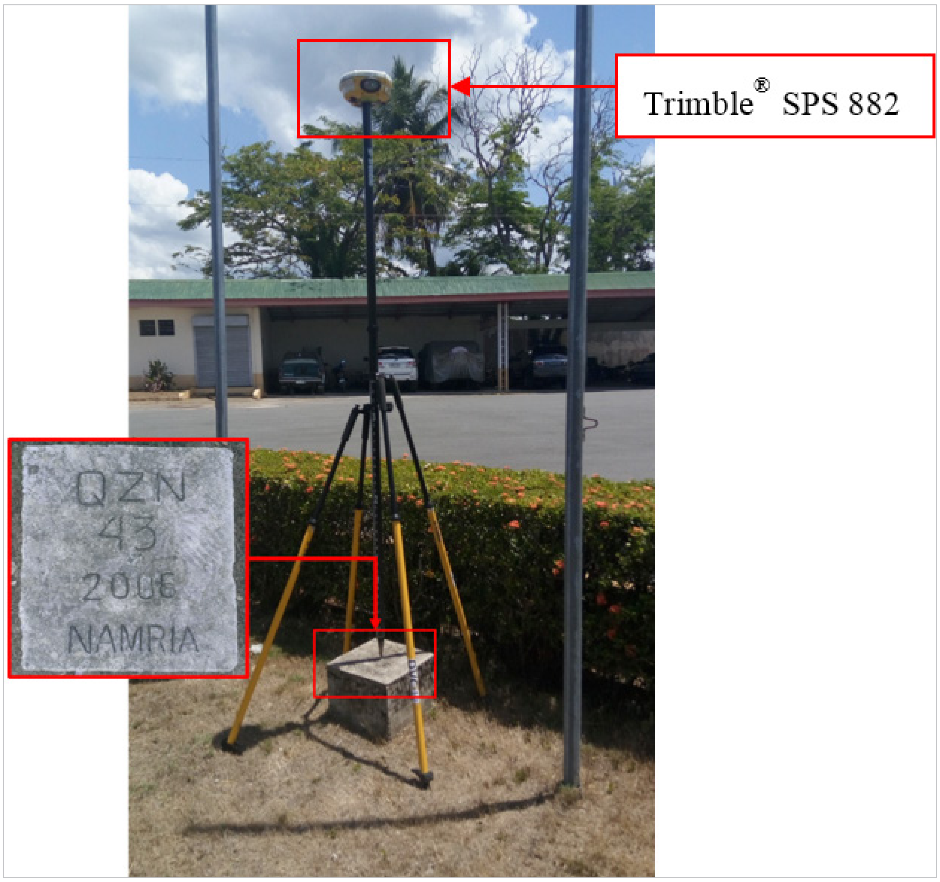


Figure 33. GNSS base set up, Trimble® SPS 882, at QZN-43, located inside the DPWH compound in Brgy. Matandang Sabang Silangan, Municipality of Catanauan, Quezon.

Figure 34. GNSS base set up, Trimble® SPS 852, at QZN-47, located at the back of the Principal's Office of Mulanay Elementary School in Barangay II, Municipality of Mulanay, Quezon.

Figure 35. GNSS base set up, Trimble® SPS 985, at QZ-415, located at the approach of Pansol Bridge in Brgy. Pansol, Municipality of Lopez, Quezon.

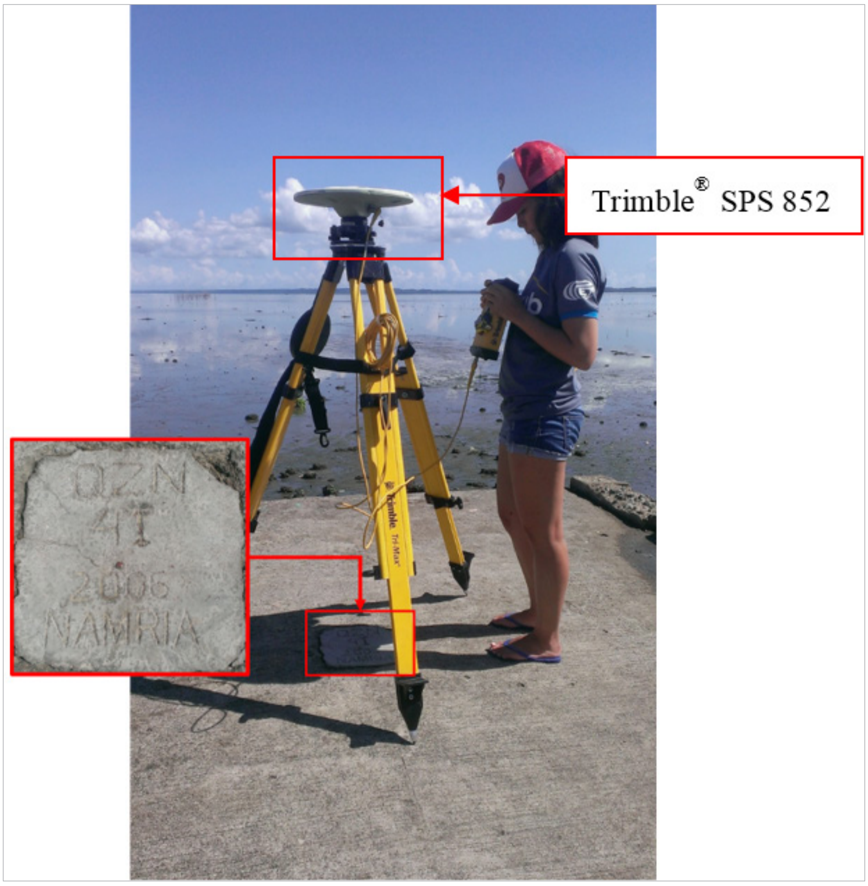


Figure 36. GNSS base set up, Trimble® SPS 852, at QZN-41, located in front of Brgy. Sabang basketball court found in Calauag Port, Barangay I, Municipality of Calauag, Quezon.

Figure 37. GNSS base set up, Trimble® SPS 882, at UP-CAB, located inside a basketball court in Brgy. Aloneros, Municipality of Guinayangan, Quezon.

Figure 38. GNSS base set up, Trimble® SPS 852, at UP-KAN, located at the approach of Kanguinsa in Brgy. Silongin, Municipality of San Francisco, Quezon.

Figure 39. GNSS base set up, Trimble® SPS 852, at UP-TAL, located at the approach of Talisay Bridge in Brgy. Pagsangahan, Municipality of San Francisco, Quezon.

Figure 40. GNSS base set up, Trimble® SPS 882, at UP-VIG, located at the approach of Vigo Bridge in Brgy. Vigo Central, Municipality of San Francisco, Quezon.

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 was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 22 presents the baseline processing results of control points in the Vinas River Basin, as generated by the TBC software.

Table 22. The Baseline processing report for the Vinas River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
QZN-47 --- QZN-40	05-11-2016	Fixed	0.003	0.011	306°22'36"	31263.486
QZN-47 --- QZN-43	05-11-2016	Fixed	0.003	0.013	131°16'56"	12401.416
QZN-47 --- UP-VIG	05-11-2016	Fixed	0.003	0.012	103°58'19"	23335.323
QZN-47 --- UP-KAN	05-11-2016	Fixed	0.005	0.019	146°21'08"	28388.037
QZN-40 --- QZ-415	05-11-2016	Fixed	0.003	0.023	14°21'16"	22613.475
UP-CAB --- QZ-415	05-04-2016	Fixed	0.004	0.025	234°09'16"	19401.067
QZN-40 --- UP-KAN	05-11-2016	Fixed	0.011	0.027	135°49'24"	58749.581
QZN-43 --- QZ-415	05-11-2016	Fixed	0.006	0.033	342°23'19"	33841.349
QZN-43 --- UP-KAN	05-11-2016	Fixed	0.005	0.018	141°46'15"	40492.330
UP-TAL --- UP-KAN	05-11-2016	Fixed	0.005	0.018	312°01'33"	16293.271
UP-VIG --- UP-TAL	05-11-2016	Fixed	0.003	0.014	169°50'51"	29356.882
UP-VIG --- QZN-43	05-11-2016	Fixed	0.003	0.014	293°25'54"	34821.073
UP-VIG --- UP-KAN	05-11-2016	Fixed	0.005	0.021	201°04'03"	19280.526
QZN-41 --- UP-CAB	05-04-2016	Fixed	0.004	0.024	247°44'12"	10141.643
QZN-41 --- QZ-415	05-04-2016	Fixed	0.003	0.022	220°07'13"	9835.756
QZN-40 --- QZN-43	05-11-2016	Fixed	0.003	0.014	303°07'59"	18937.828
UP-CAB --- QZN-43	05-11-2016	Fixed	0.004	0.019	7°10'02"	43963.480

As shown in Table 22, a total of seventeen (17) baselines were processed with reference points QZN-40, QZN-43 and QZN-47 fixed for grid values; and QZ-415 held fixed for elevation. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. 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 for each control point; or in equation form:

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

Where:

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

For complete details, see the Network Adjustment Report shown in Table 23 to Table 26.

The nine (9) control points, QZN-40, QZN-43, QZN-47, QZ-415, QZN-41, UP-CAB, UP-KAN, UP-TAL and UP-VIG were occupied and observed simultaneously to form a GNSS loop. Elevation value of QZ-415 and coordinates of points QZN-40, QZN-43 and QZN-47 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Constraints applied to the adjustment of the control points.

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
QZN-40	Global	Fixed	Fixed		
QZN-43	Global	Fixed	Fixed		
QZN-47	Global	Fixed	Fixed		
QZ-415	Grid				Fixed
Fixed = 0.000001(Meter)					

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24Error! Reference source not found.. The fixed control points QZN-40, QZN-43 and QZN-47 has no values for grid and elevation errors.

Table 24. Adjusted grid coordinates for the control points used in the Vinas River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
QZN-40	410660.624	?	1513855.137	?	2.622	0.075	LL
QZN-43	426485.118	?	1503462.996	?	1.574	0.073	LL
QZN-47	435778.405	?	1495257.875	?	4.163	0.079	LL
QZ-415	416340.495	0.010	1535736.431	0.010	8.613	?	e
QZN-41	422699.129	0.014	1543236.263	0.014	1.392	0.082	
UP-CAB	432091.726	0.012	1547052.366	0.013	3.211	0.073	
UP-KAN	451445.231	0.012	1471596.832	0.011	25.095	0.086	
UP-TAL	463529.271	0.016	1460676.916	0.014	4.949	0.095	
UP-VIG	458401.312	0.010	1489570.998	0.008	6.030	0.083	

The results of the computation for accuracy are as follows:

a. QZN-40

horizontal accuracy = Fixed

vertical accuracy = 7.5 cm < 10 cm

b. QZN-43

horizontal accuracy = Fixed

vertical accuracy = 7.3 cm < 10 cm

c. QZN-47

horizontal accuracy = Fixed

vertical accuracy = 7.9 cm < 10 cm

d. QZ-415

horizontal accuracy $= \sqrt{((1.0)^2 + (1.0)^2}$
$= \sqrt{(1.0 + 1.0)}$
$= 1.41 cm < 20 cm$

vertical accuracy = Fixed

e. QZN-41

horizontal accuracy $= \sqrt{((1.40)^2 + (1.40)^2}$
$= \sqrt{(1.96+ 1.96)}$
$= 1.98 cm < 20 cm$

vertical accuracy = 8.2 cm < 10 cm

f. UP-CAB

horizontal accuracy $= \sqrt{((1.20)^2 + (1.30)^2}$
$= \sqrt{(1.44 + 1.69)}$
$= 1.77 cm < 20 cm$

vertical accuracy = 7.3 cm < 10 cm

g. UP-KAN

horizontal accuracy $= \sqrt{((1.20)^2 + (1.10)^2}$
$= \sqrt{(1.44 + 1.21)}$
$= 1.63 cm < 20 cm$

vertical accuracy = 8.6 cm < 10 cm

h. UP-TAL

horizontal accuracy $= \sqrt{((1.60)^2 + (1.40)^2}$
$= \sqrt{(2.56 + 1.96)}$
$= 2.13 cm < 20 cm$

vertical accuracy = 9.5 cm < 10 cm

i. UP-VIG

horizontal accuracy $= \sqrt{((1.10)^2 + (0.80)^2}$
$= \sqrt{(1.21 + 0.64)}$
$= 1.36 cm < 20 cm$

vertical accuracy = 8.3 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the two (2) occupied control points are within the required precision.

Table 25. Adjusted geodetic coordinates for control points used in the Vinas River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
QZN-40	N13°41'32.47595"	E122°10'25.77273"	51.703	0.075	LL
QZN-43	N13°35'55.81611"	E122°19'13.53031"	51.015	0.073	LL
QZN-47	N13°31'29.52488"	E122°24'23.44821"	53.862	0.079	LL
QZ-415	N13°53'25.29589"	E122°13'32.50380"	57.290	?	e
QZN-41	N13°57'30.05268"	E122°17'03.60722"	50.089	0.082	
UP-CAB	N13°59'35.12930"	E122°22'16.30558"	52.023	0.073	
UP-KAN	N13°18'40.40211"	E122°33'06.07511"	75.768	0.086	
UP-TAL	N13°12'45.55145"	E122°39'48.22322"	55.864	0.095	
UP-VIG	N13°28'25.87675"	E122°36'56.35787"	56.412	0.083	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Vinas River GNSS Static Survey are seen in Table 26.

Table 26. The reference and control points utilized in the Vinas River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
QZN-40	2nd Order GCP	13°41'32.476" N	122°10'25.773" E	51.703	1513855.137	410660.624	2.622
QZN-43	2nd Order GCP	13°35'55.816" N	122°19'13.530" E	51.015	1503462.996	426485.118	1.574
QZN-47	2nd Order GCP	13°31'29.525" N	122°24'23.448" E	53.862	1495257.875	435778.405	4.163
QZ-415	1st Order BM	13°53'25.296" N	122°13'32.504" E	57.290	1535736.431	416340.495	8.613
QZN-41	Used as Marker	13°57'30.053" N	122°17'03.607" E	50.089	1543236.263	422699.129	1.392
UP-CAB	UP Established	13°59'35.129" N	122°22'16.306" E	52.023	1547052.366	432091.726	3.211
UP-KAN	UP Established	13°18'40.402" N	122°33'06.075" E	75.768	1471596.832	451445.231	25.10
UP-TAL	UP Established	13°12'45.551" N	122°39'48.223" E	55.864	1460676.916	463529.271	4.949
UP-VIG	UP Established	13°28'25.877" N	122°36'56.356" E	56.412	1489570.998	458401.312	6.030

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

The bridge cross-section was conducted on May 6 and 7, 2016 at the downstream part of Cabibihan Bridge in Brgy. Cabugwang, Municipality of Tagkawayan using GNSS receiver Trimble® SPS 882 in PPK survey technique paired with an Ohmex™ single beam echo sounder; and a Total Station through Open Traverse Method (Figure 41).

Figure 41. Cross-Section Survey for Vinas (also known as Cabibihan River) using Trimble® Total Station, in Open Traverse Method.

The length of the cross-sectional line surveyed at Cabibihan Bridge is about 186.373 m with 62 cross-sectional points using the control point UP-CAB as the GNSS base station. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 42 to Figure 44.

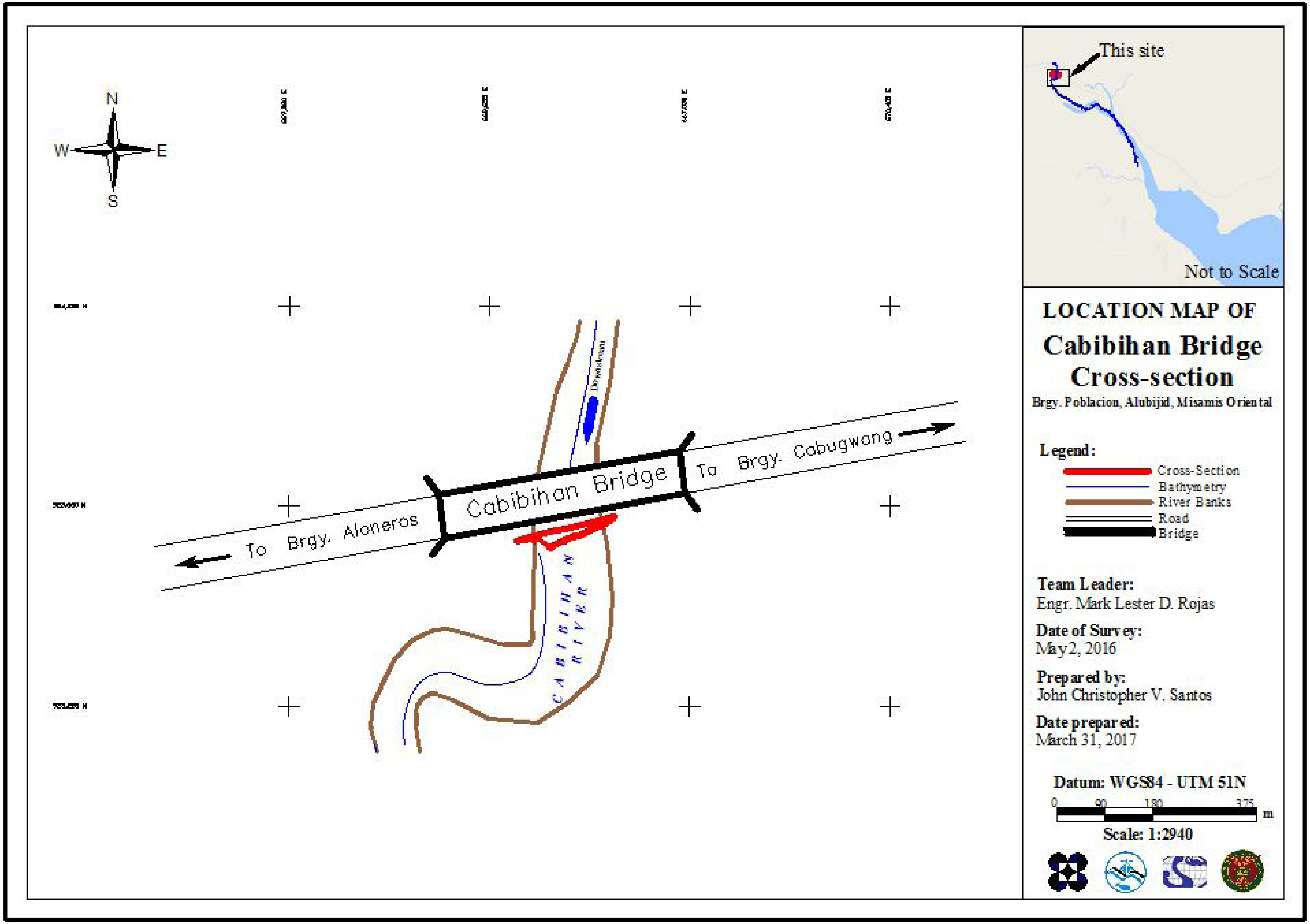


Figure 42. Location map of the Vinas (also known as Cabibihan) Bridge Cross Section.

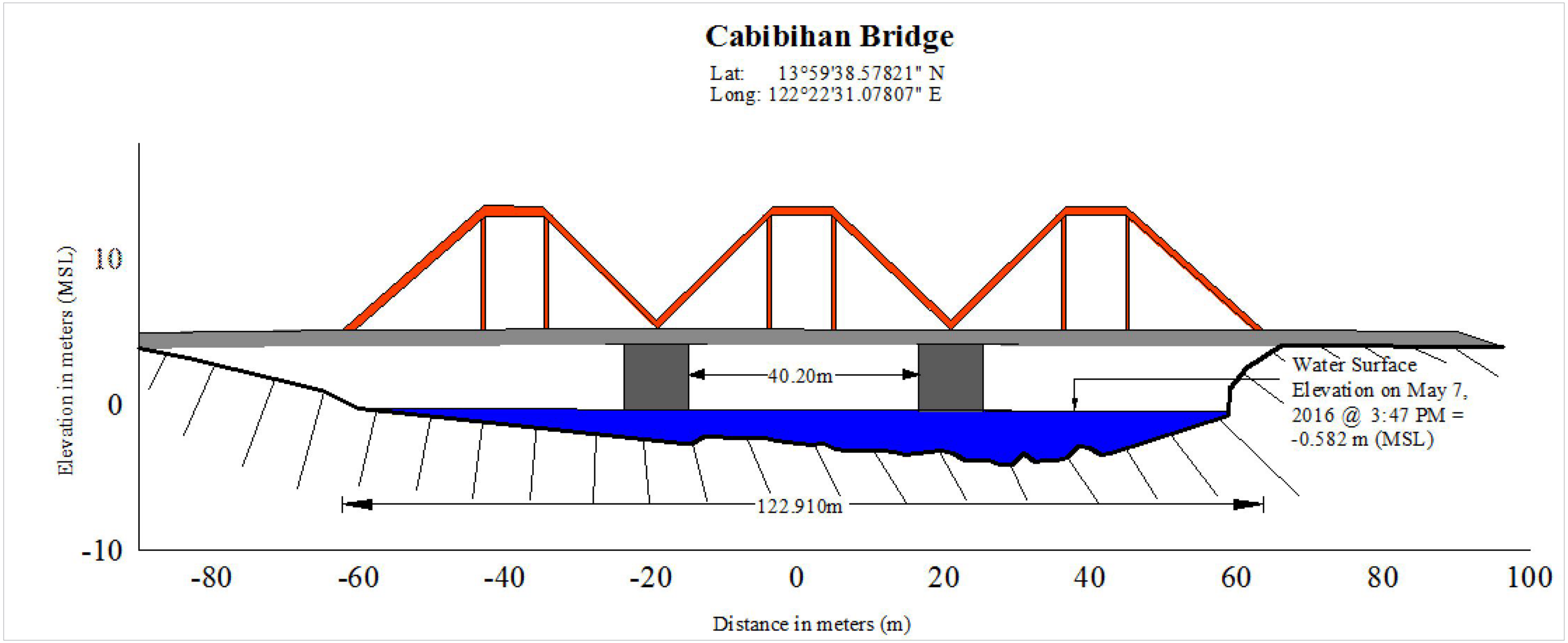


Figure 43. Location map of the Vinas (also known as Cabibihan) Bridge Cross Section.

Bridge Data Form

Bridge Name: **Cabibihan Bridge** **Date:** **May 7, 2016**

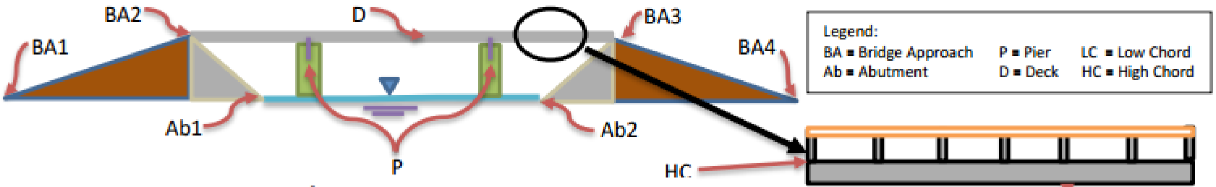
River Name: **Cabibihan River** **Time:** **03:27 PM**

Location (Brgy, City,Region): **Brgy. Cabugwan, Municipality of Tagkawayan, Quezon**

Survey Team: **Michael Labrador, Erlan Mendoza, Romalyn Boado, Mark Rojas, Marla Morris, Pauline Racoma**

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

Latitude: **13˚59'38.83061" N** **Longitude:** **122˚22'32.02329" E**



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

Elevation: **3.781 m** **Width:** **N/A** **Span (BA3-BA2):** **122.910 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	3.781 m	BA3	152.326 m	3.927 m
BA2	29.416 m	3.945 m	BA4	186.373 m	3.833 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	148.839 m	-0.801 m

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

Shape: Circular Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	70.716 m	4.046 m	Not available
Pier 2	110.915 m	4.003 m	Not available

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

Figure 44. The Vinas (also known as Cabibihan) Bridge as-built survey data.

The water surface elevation of Vinas River was determined using a survey grade GNSS receiver Trimble® SPS 882 in Open Traverse Method on May 7, 2016 at 3:47 PM with a value of -0.582 m (MSL). This was translated into marking on the top of a bridge's pier using Total Station Open Traverse Method as shown in Figure 45. It now serves as the reference for flow data gathering and depth gauge deployment of the MAPUA Institute of Technology (MIT), the partner HEI responsible for the monitoring of Vinas River.

Figure 45. Water level markings on Vinas (also known as Cabibihan) Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on May 4, 5, and 6, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of the vehicle as shown in Figure 46. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was 1.895 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with QZN-41, QZN-43 and UP-CAB occupied as the GNSS base stations in the conduct of the survey.

Figure 46. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The survey started from Brgy. Aloneros in the Municipality of Guinayangan, going west traversing the Municipalities of Calauag, Lopez and ended in Brgy. San Diego Poblacion, Municipality of Gumaca; and from Brgy. Matandang Sabang Silangan, Municipality of Catanauan going south towards Barangay II in Municipality of Mulanay, and ended in Brgy. Anonang also in Mulaay. These routes aim to cut flight strips made by the Data Acquisition Component, perpendicularly. The survey gathered 5,788 points with approximate length of 67.44 km using QZN-41, QZN-43 and UP-CAB as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 47Error! Reference source not found..

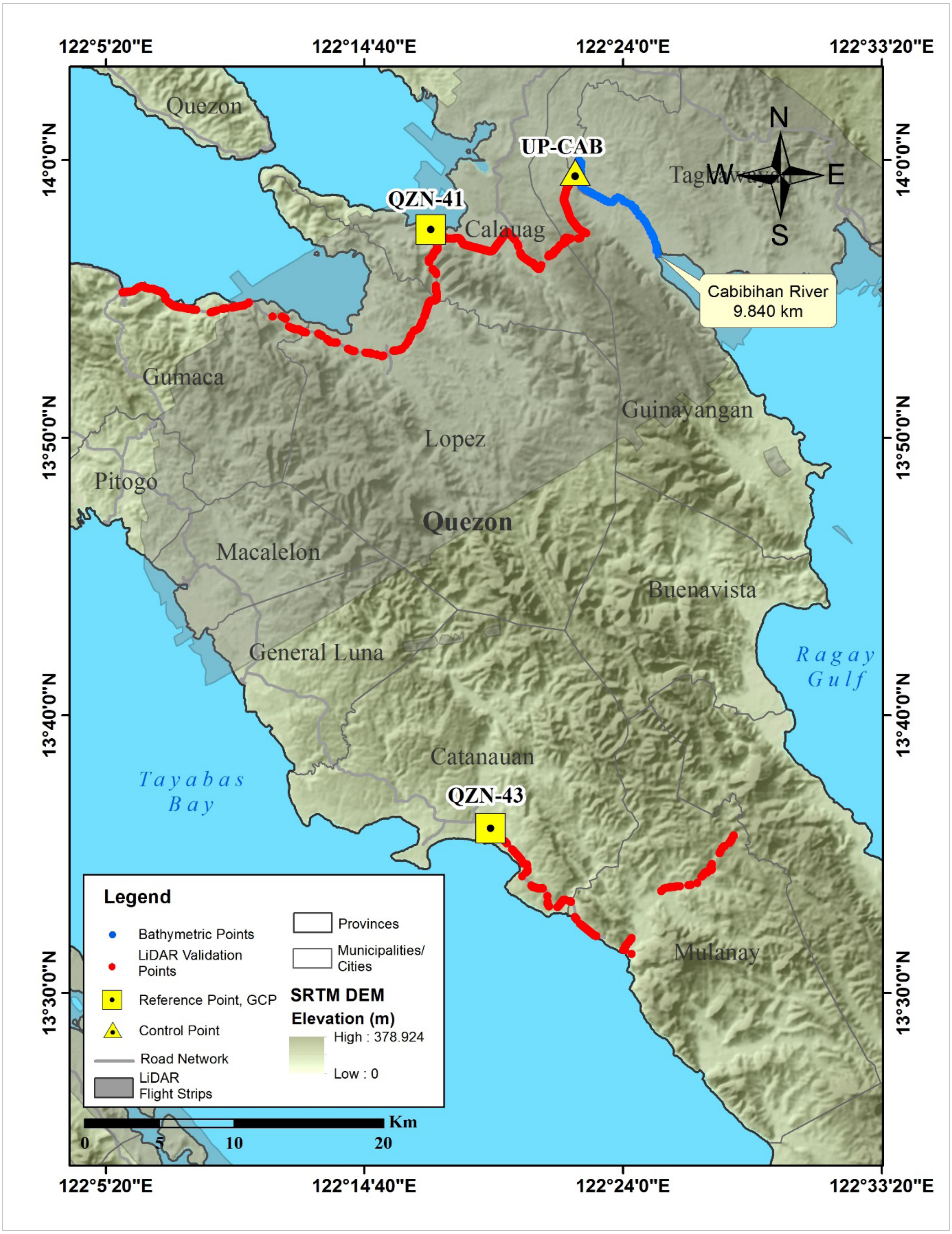


Figure 47. The extent of the LiDAR ground validation survey (in red) for Vinas River Basin.

4.7 River Bathymetric Survey

A bathymetric survey was performed on May 6, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and Ohmex™ single beam echo sounder, as illustrated in Error! Reference source not found.. The extent of the survey is from the upstream part of the river in Brgy Cabgwang, Municipality of Tagkawayan with coordinates 14°00'02.22846"N, 122°22'23.37538"E, down to the mouth of the river in Brgy. Hinabaan, in Municipality of Guinayangan with coordinates 13°56'35.85764"N, 122°25'16.15873"E, as shown in the map in Figure 49.

Figure 48. Set up of the bathymetric survey at Cabibihan River.

Overall, the bathymetric survey for Vinas River gathered a total of 11,978 points covering 9.840 km of the river traversing Barangays Aloneros, Balinarin, Bukal Maligaya, Gapas, Hinabaan and Tikay in Municipality of Guinayangan; and Barangays Cabugwang, Manato Station, Mangayao, Sequiwan and Victoria in Municipality of Tagkawayan. To further illustrate this, a CAD drawing of the riverbed profile of the Cabibihan River was produced. As seen in Figure 50, the highest and lowest elevation has a 14-meter difference. The highest elevation observed is -0.607 m below MSL located at the upstream portion of the river near around the Cabibihan Bridge in Brgy. Cabugwang while the lowest elevation observed is -14.864 m below MSL located at the midporion of the river also in Brgy. Cabugwang, in Municipality of Tagkawayan.

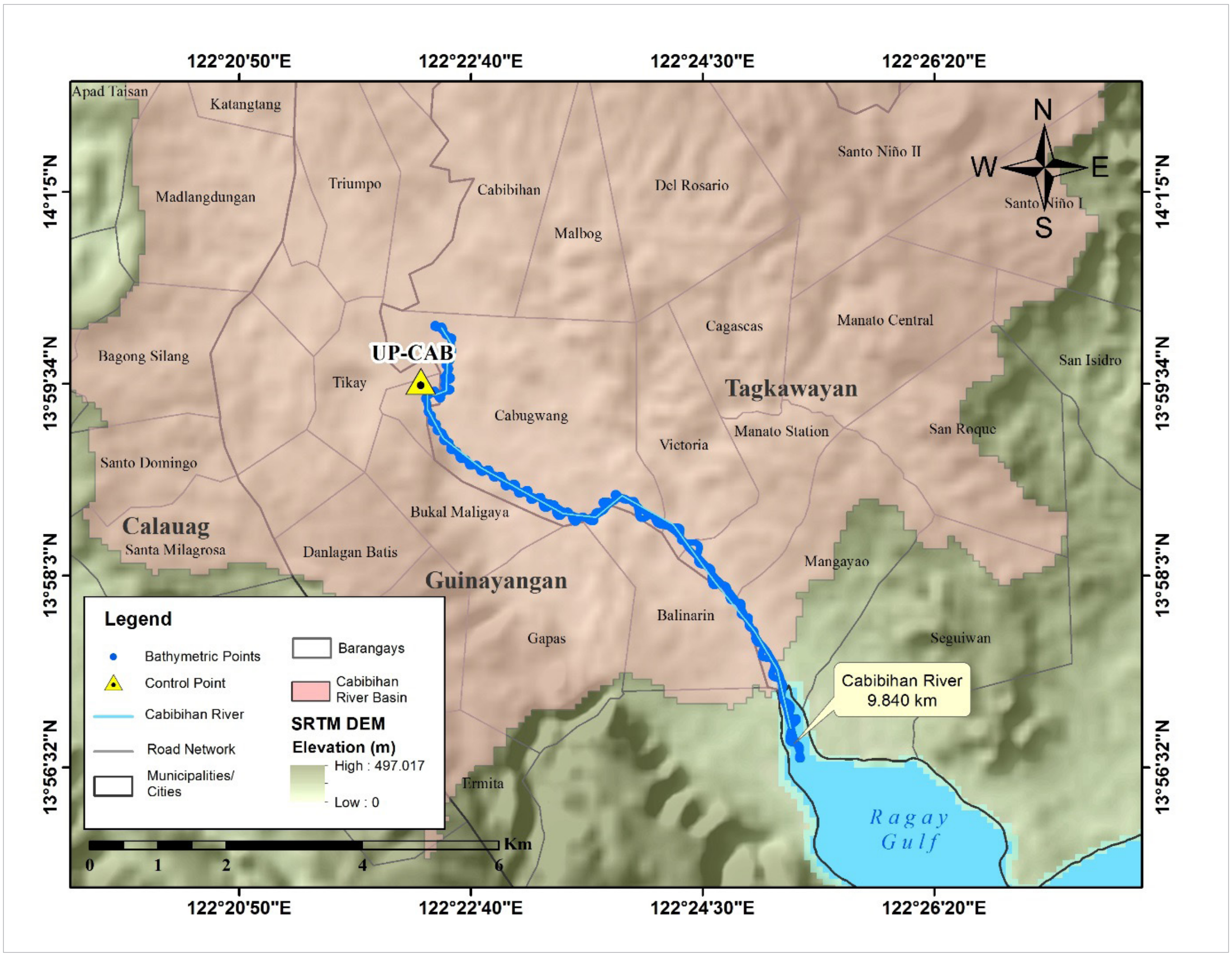


Figure 49. The extent of the Vinas (also known as Cabibihan) River Bathymetry Survey.

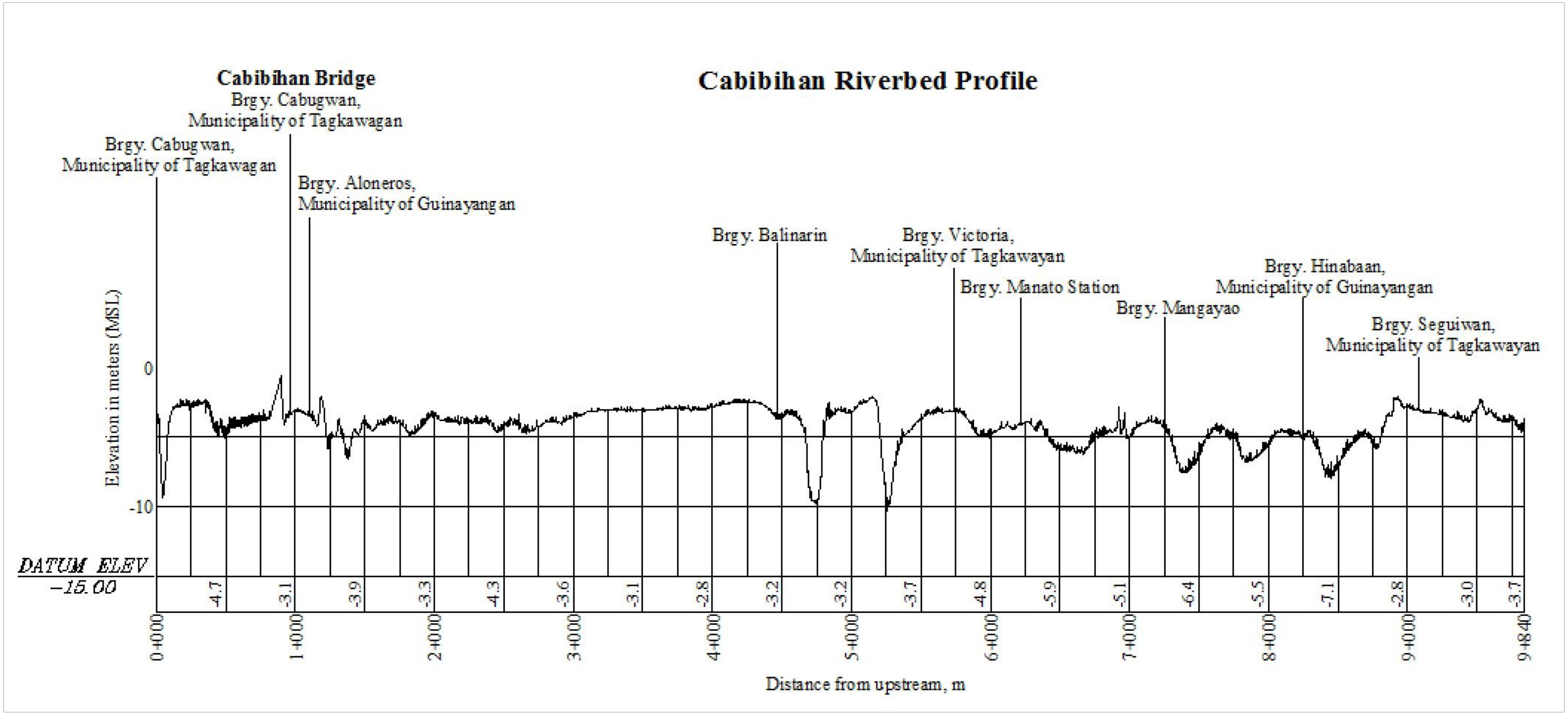


Figure 50. The Vinas (also known as Cabibihan) Riverbed Profile.

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 Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by Weather Philippines, founded in 2012 by Aboitiz Foundation and Union Bank. The ARG was installed in Santa Elena, Camarines Norte specifically: 122°23’40.115”E 14°11’10.291”N as illustrated in Figure 51. The precipitation data collection started from November 22, 2016 00:00 am to November 23, 2016 at 00:00 am with a 10-minute recording interval.

The total precipitation for this event in Santa Elena ARG was 11 mm. It has a peak rainfall of 2 mm on 22 November 2016 at 13:40 pm as well as on 13:50pm. The lag time between the peak rainfall and discharge is 2 hours and 30 minutes.

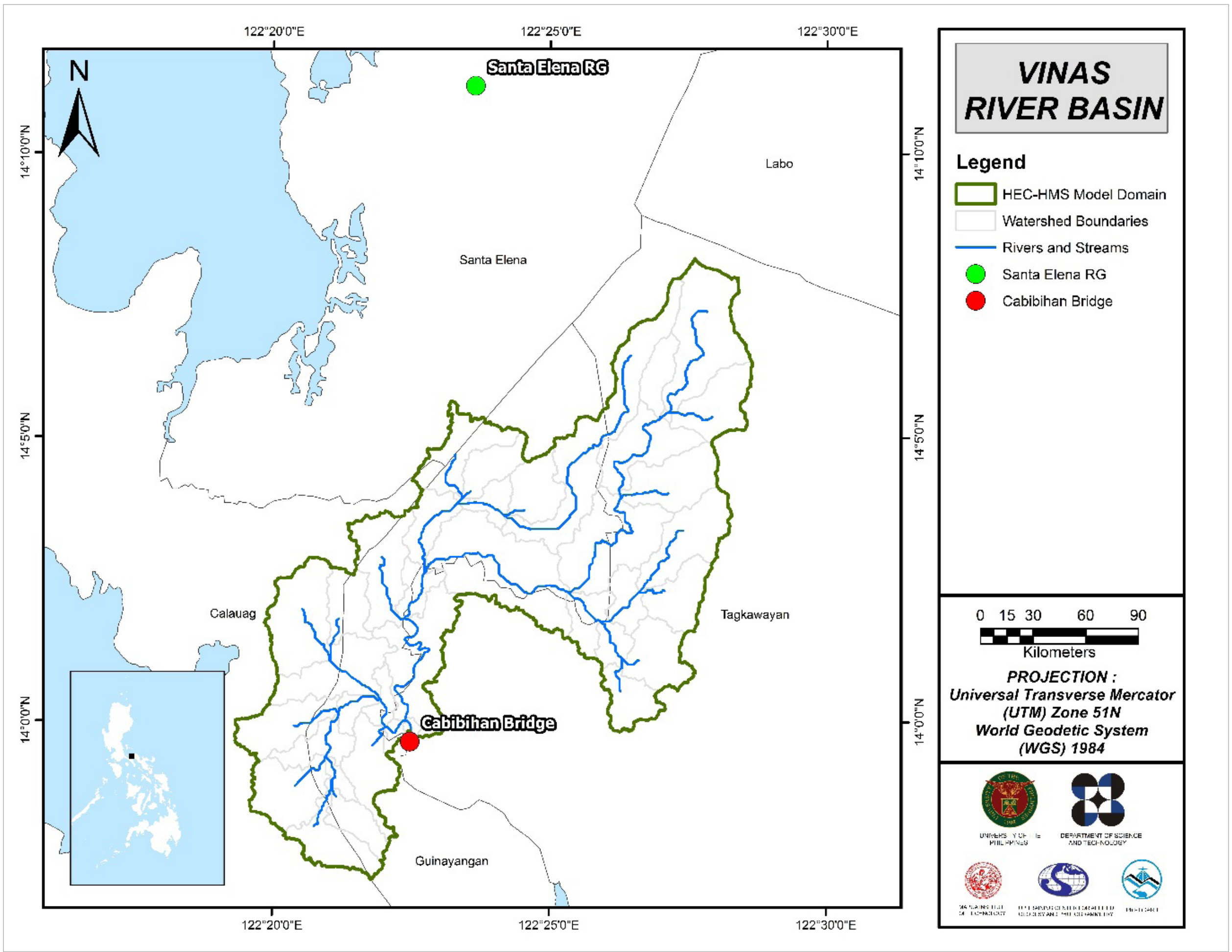


Figure 51. Location Map of the Vinas HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed at Cabibihan Bridge, Real, Quezon (122°22'30.949"E 13°59'37.861"N) to establish the relationship between the observed water levels (H) from Cabibihan Bridge and the outflow (Q) of the watershed recorded using the flow meter at this location.

This image is not available for the Vinas River Basin.

Figure 52. Cross-Section Plot of Vinas (also known as Cabibihan) Bridge.

For San Juan Bridge, the rating curve is expressed as $Q = 2.5658e0.8518h$ as shown in Figure 53.

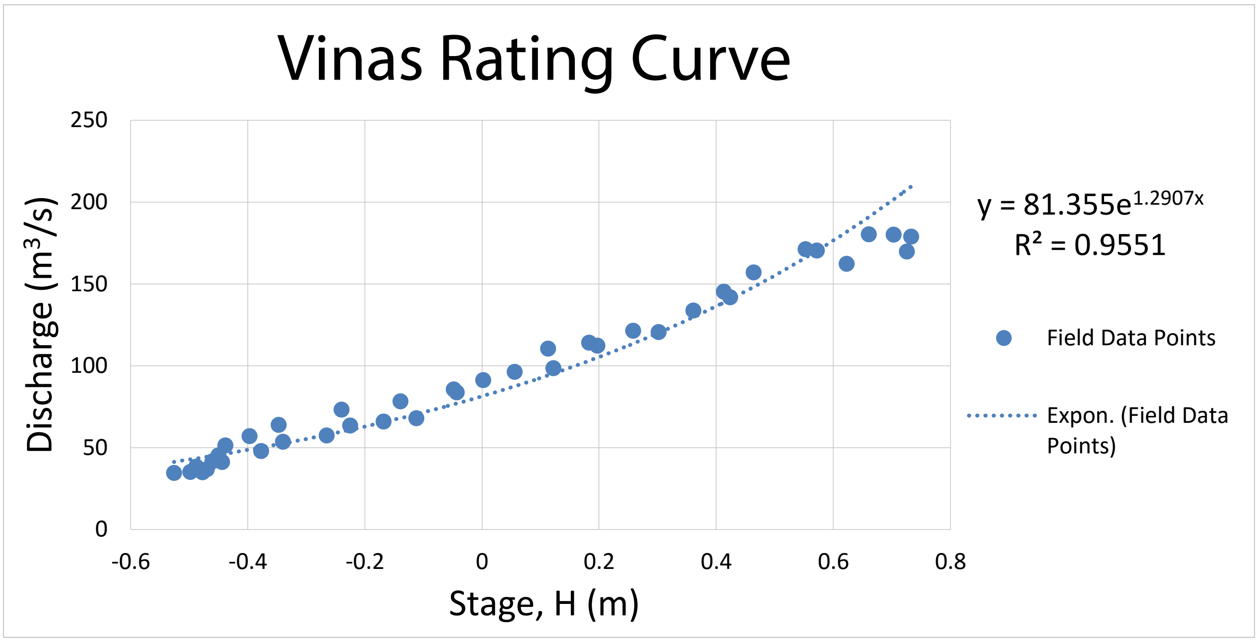


Figure 53. Rating Curve at Cabibihan Bridge, Real, Quezon.

This rating curve equation was used to compute the river outflow at Cabibihan Bridge for the calibration of the HEC-HMS model shown in Figure 54. The peak discharge is 180.2 m³/s at 04:20 PM, November 22, 2016.

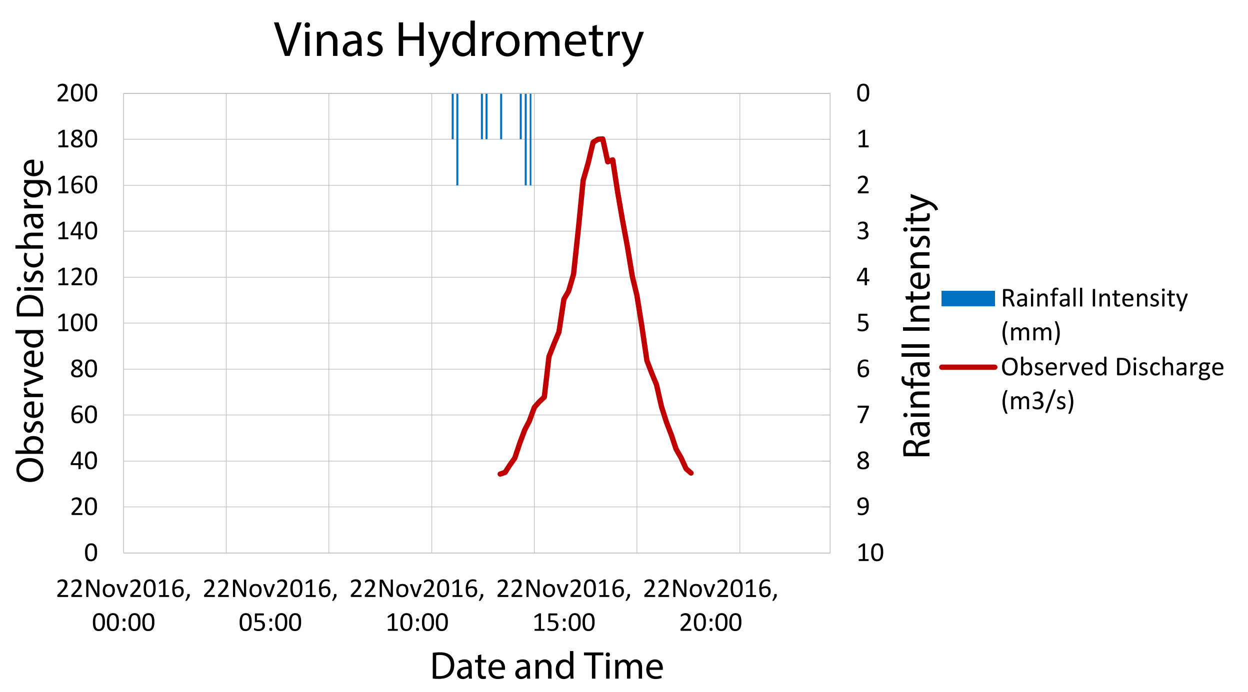


Figure 54. Rainfall and outflow data at Vinas River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Laoag Rain Gauge (Table 27). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 56). This station was selected based on its proximity to the Vinas watershed. The extreme values for this watershed were computed based on a 31-year record.

Table 27. RIDF values for the Alabat Rain Gauge, as computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	20.9	31.3	39.8	55.3	77	94.2	118.3	143.2	173.4
5	27.6	41.3	52.9	74.6	108.5	134.8	172.8	208.6	252
10	32.1	48	61.6	87.3	129.4	161.6	209	251.9	303.9
15	34.6	51.8	66.5	94.5	141.1	176.8	229.3	276.3	333.3
20	36.4	54.4	69.9	99.6	149.4	187.4	243.6	293.4	353.8
25	37.7	56.5	72.6	103.5	155.7	195.6	254.6	306.6	369.6
50	41.9	62.7	80.7	115.4	175.3	220.7	288.4	347.2	418.4
100	46.1	69	88.8	127.3	194.7	245.7	322	387.5	466.7

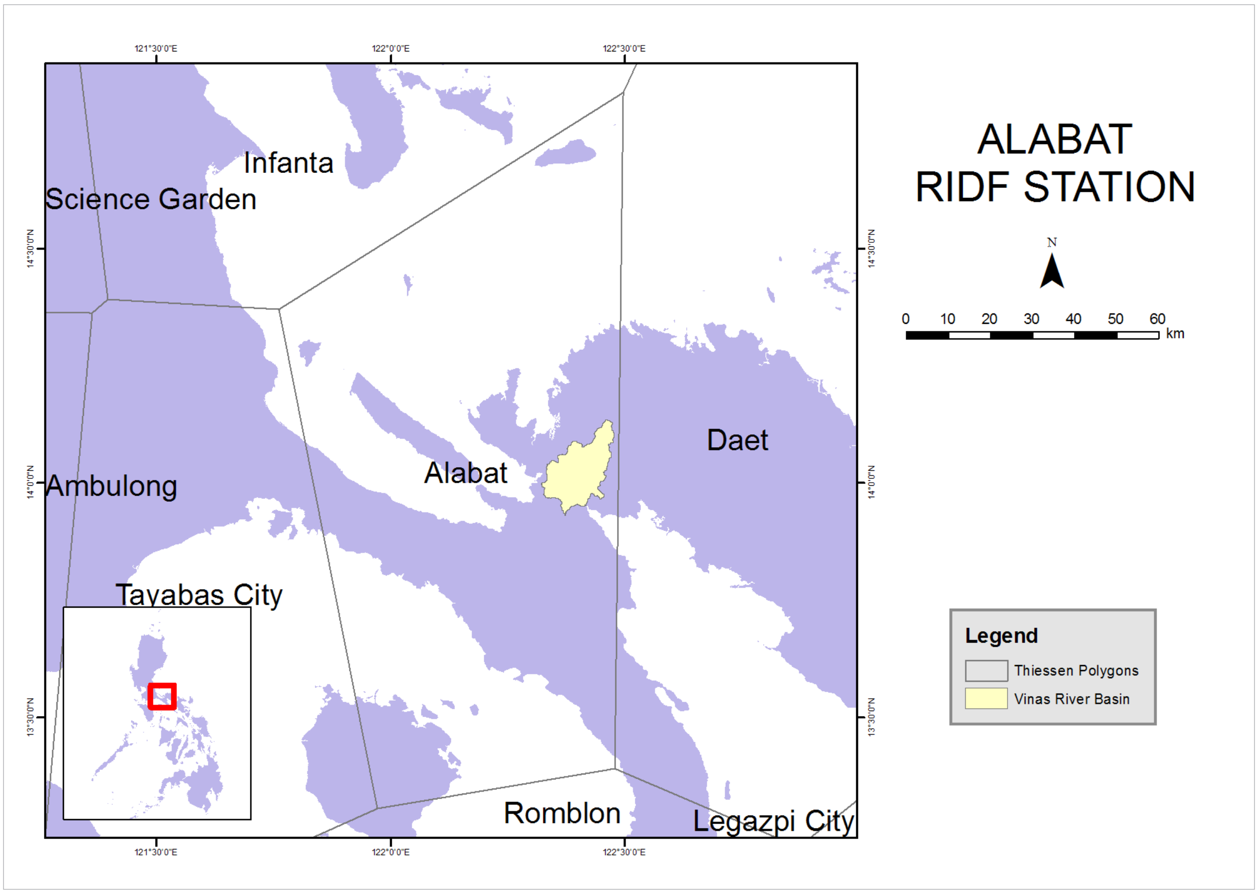


Figure 55. Location of Alabat RIDF Station relative to Vinas River Basin.

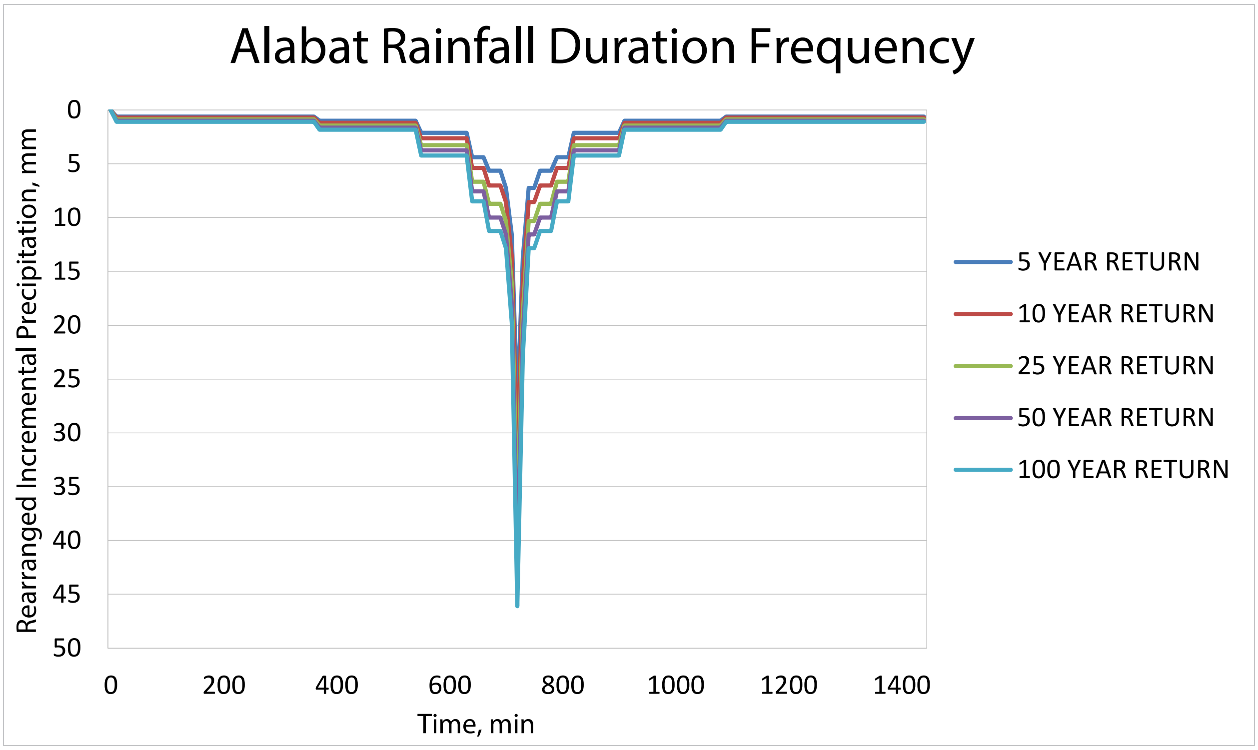


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 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). The soil and land cover of the Vinas River Basin are shown in Figure 57 and Figure 58 respectively.

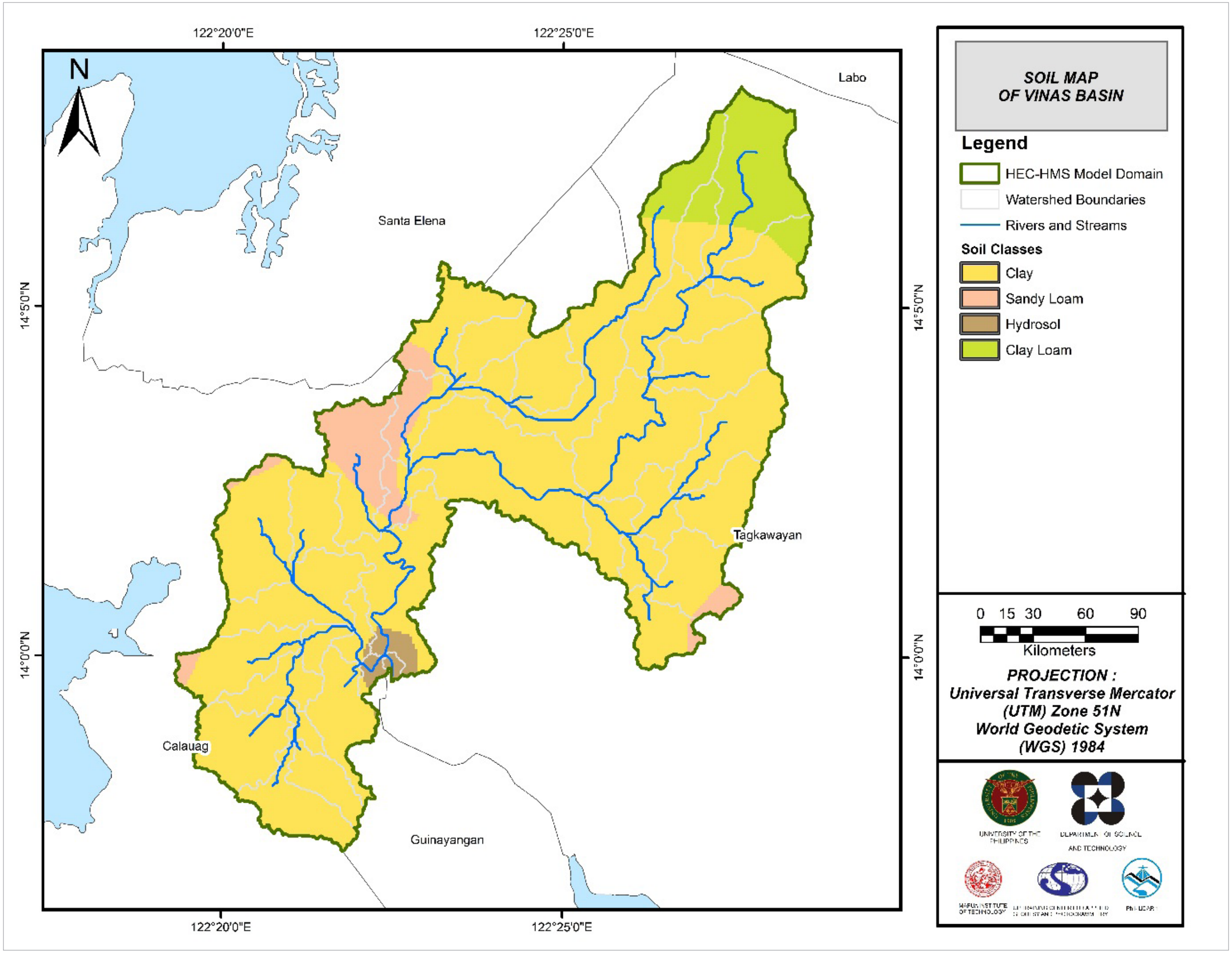


Figure 57. Soil Map of Vinas River Basin.

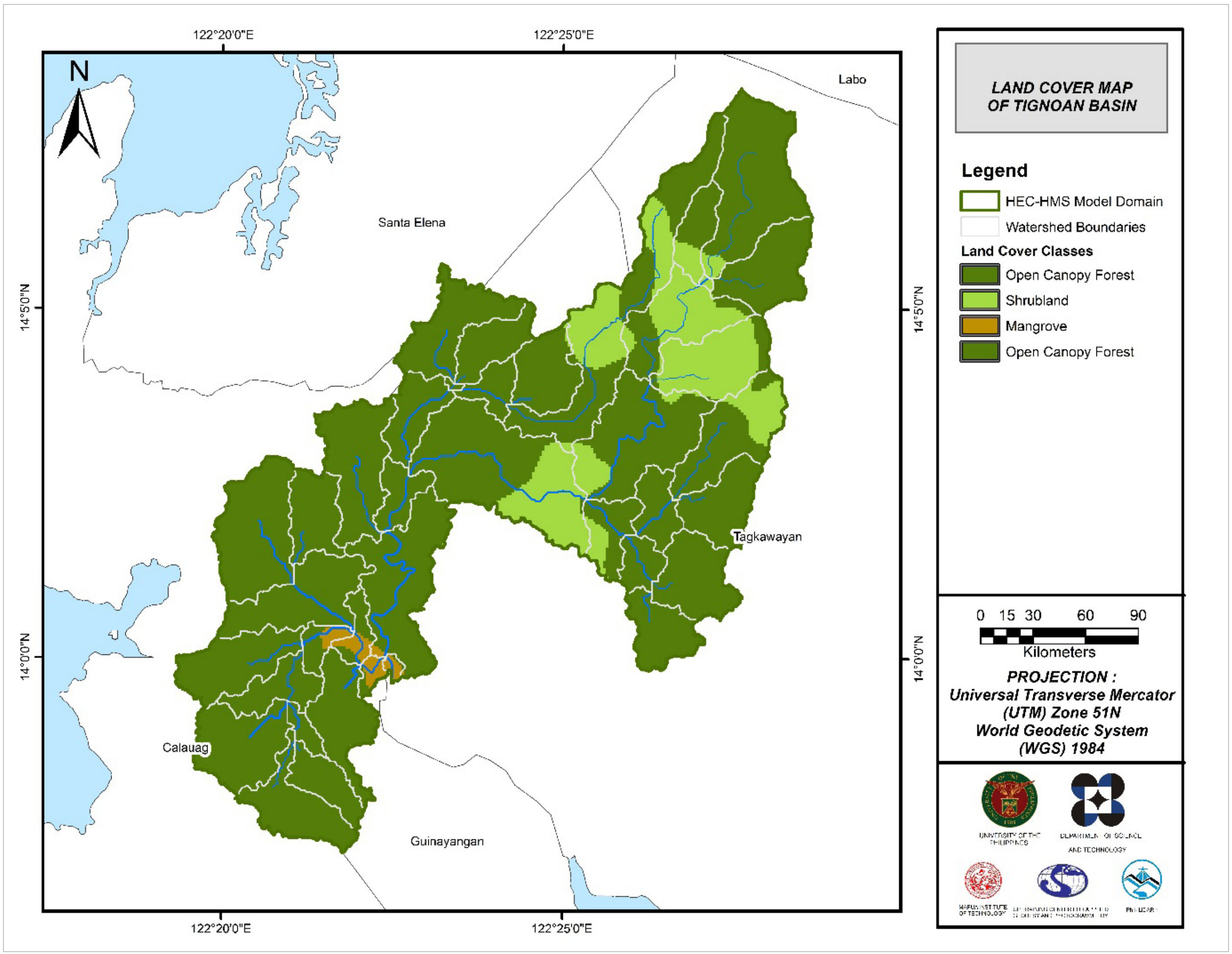


Figure 58. Land Cover Map of Vinas River Basin.

For Vinas, four (4) soil classes were identified. These are clay loam, clay, sandy loam and hydrosols. Moreover, three (3) land cover classes were identified. These are shrubland, mangroves and open canopy forest

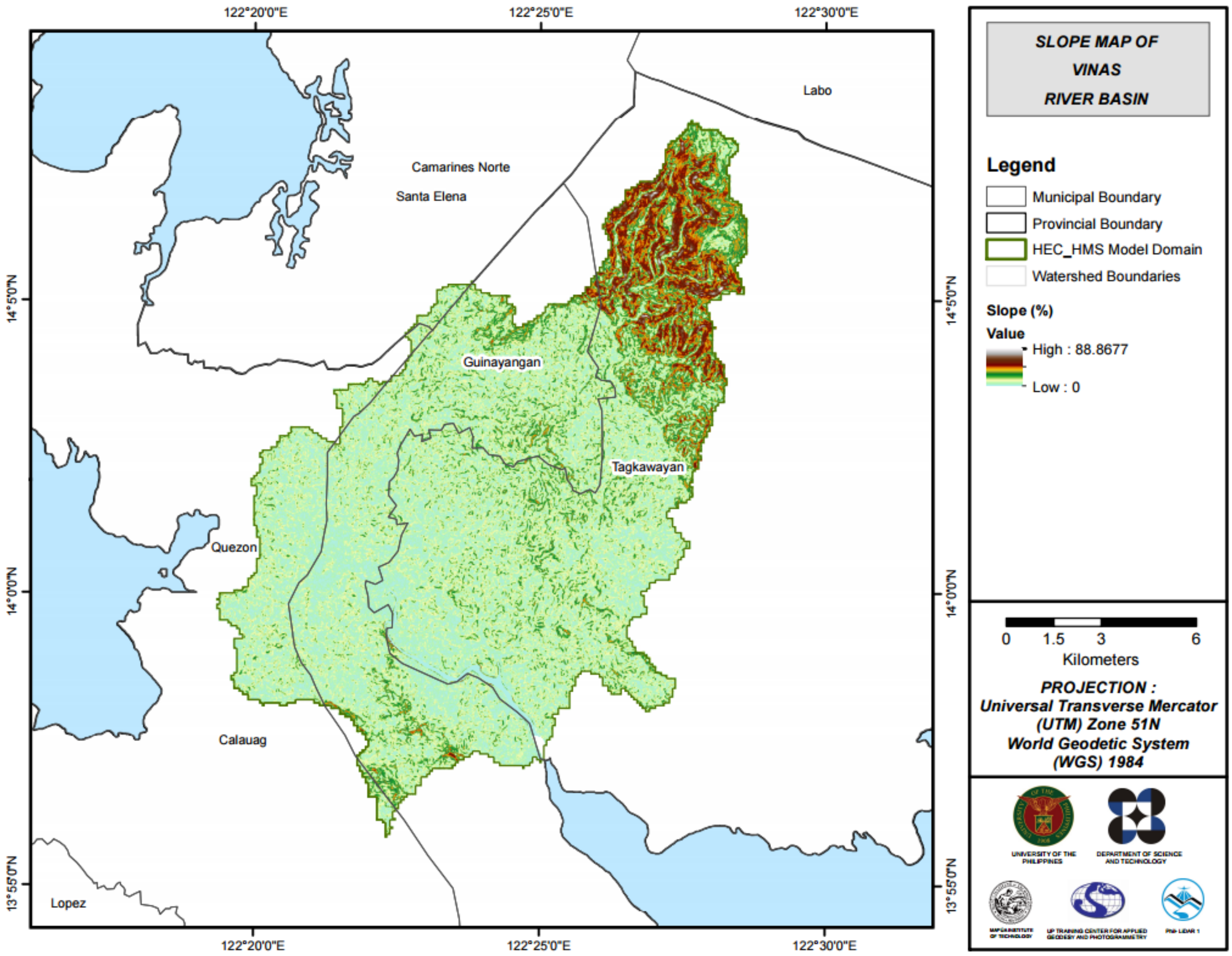


Figure 59. Slope Map of the Vinas River Basin.

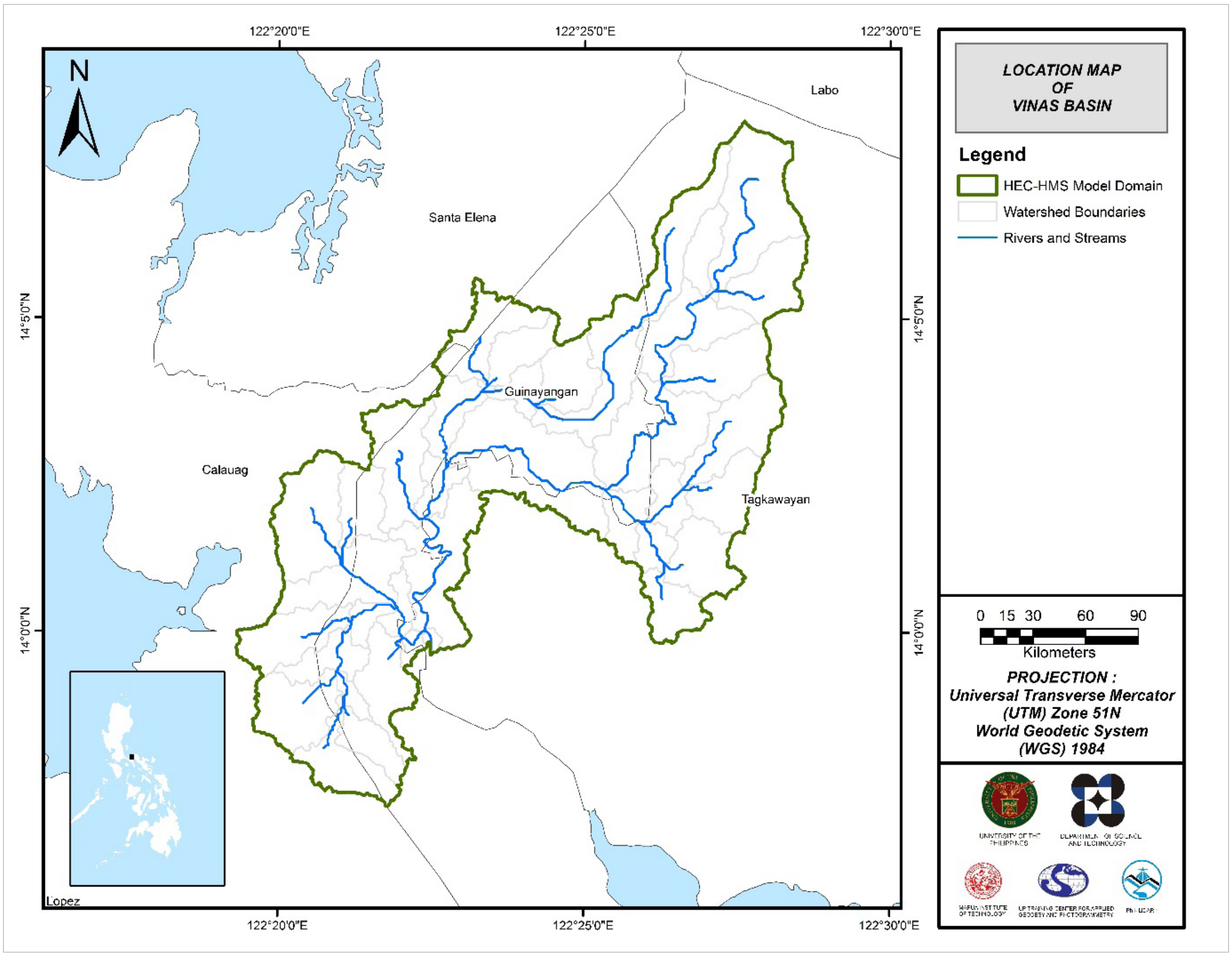


Figure 60. Stream Delineation Map of Vinas River Basin

Using the SAR-based DEM, the Vinas basin was delineated and further subdivided into subbasins. The model consists of 39 sub basins, 19 reaches, and 19 junctions as shown in Figure 61 (See ANNEX 10). The main outlet is at the easternmost tip of the watershed.

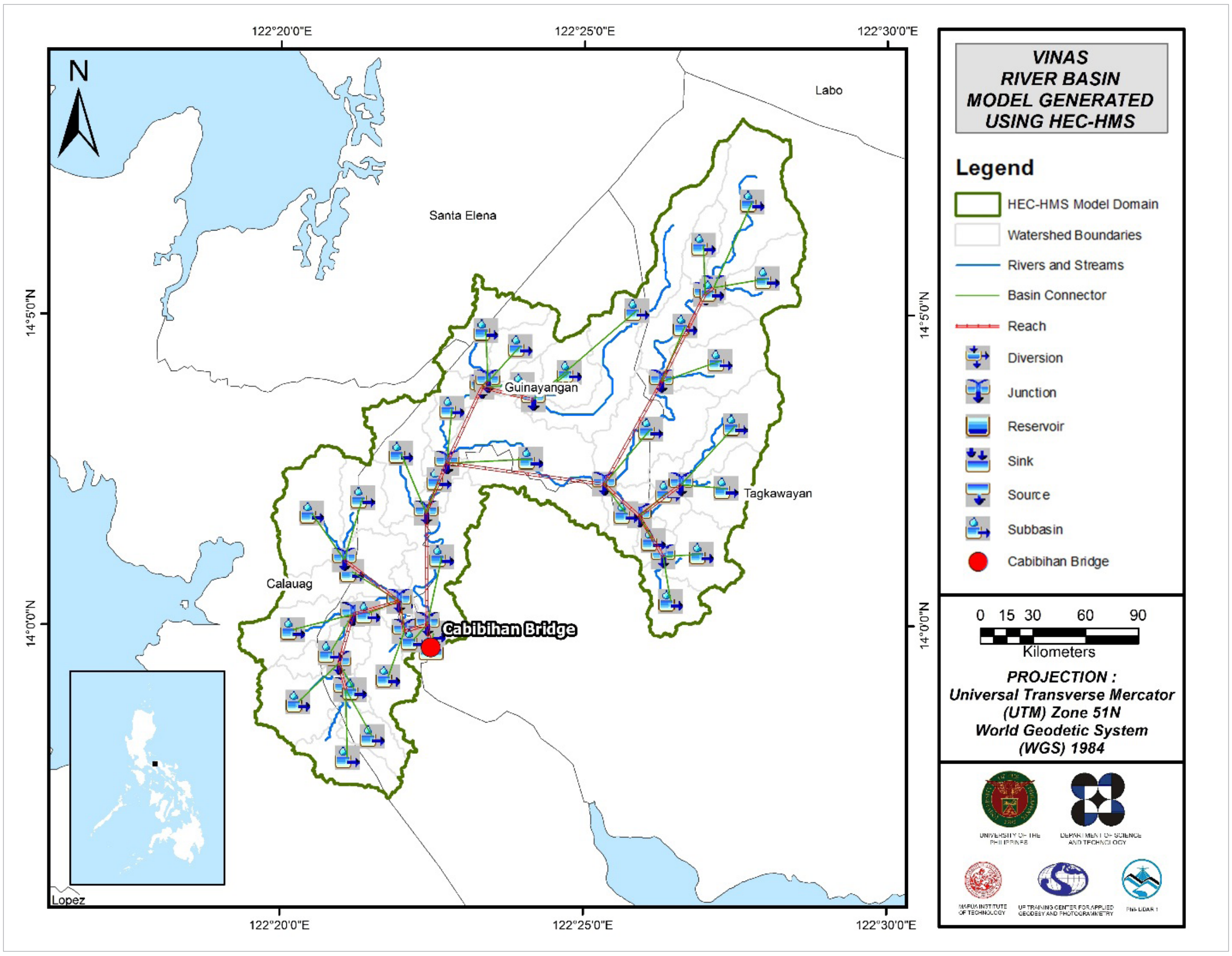


Figure 61. Vinas river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 62).

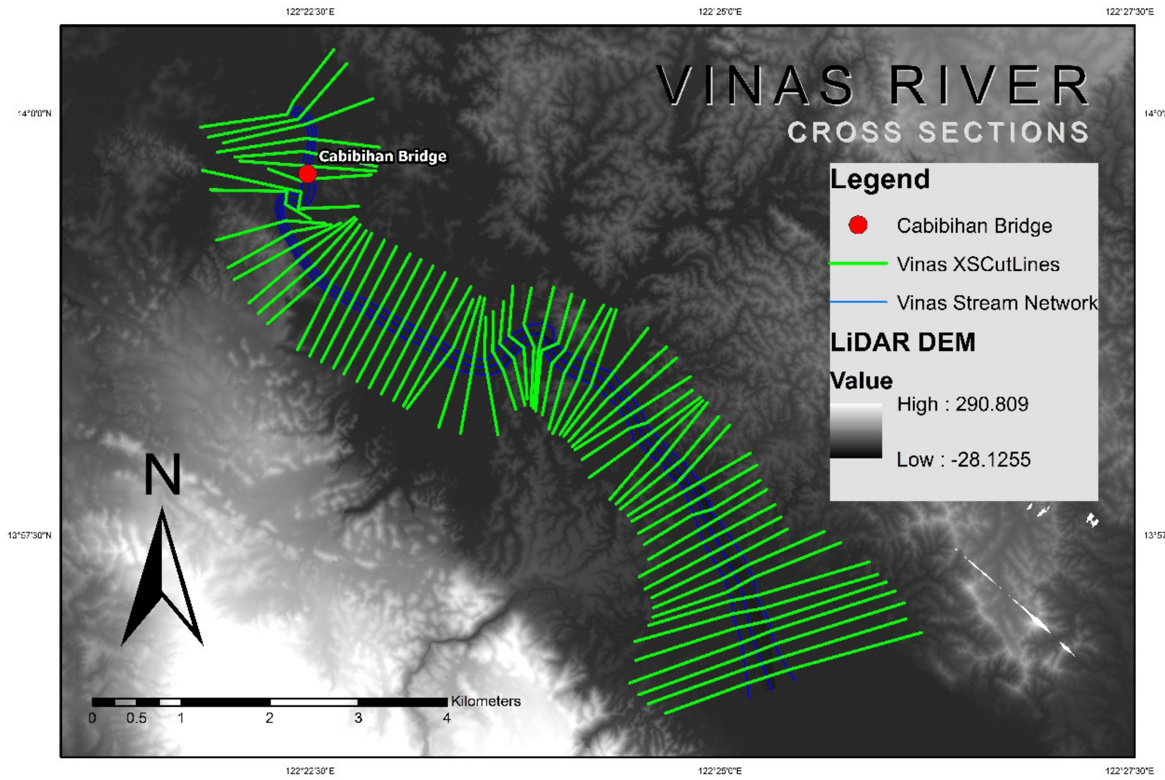


Figure 62. River cross-section of the Vinas River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

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

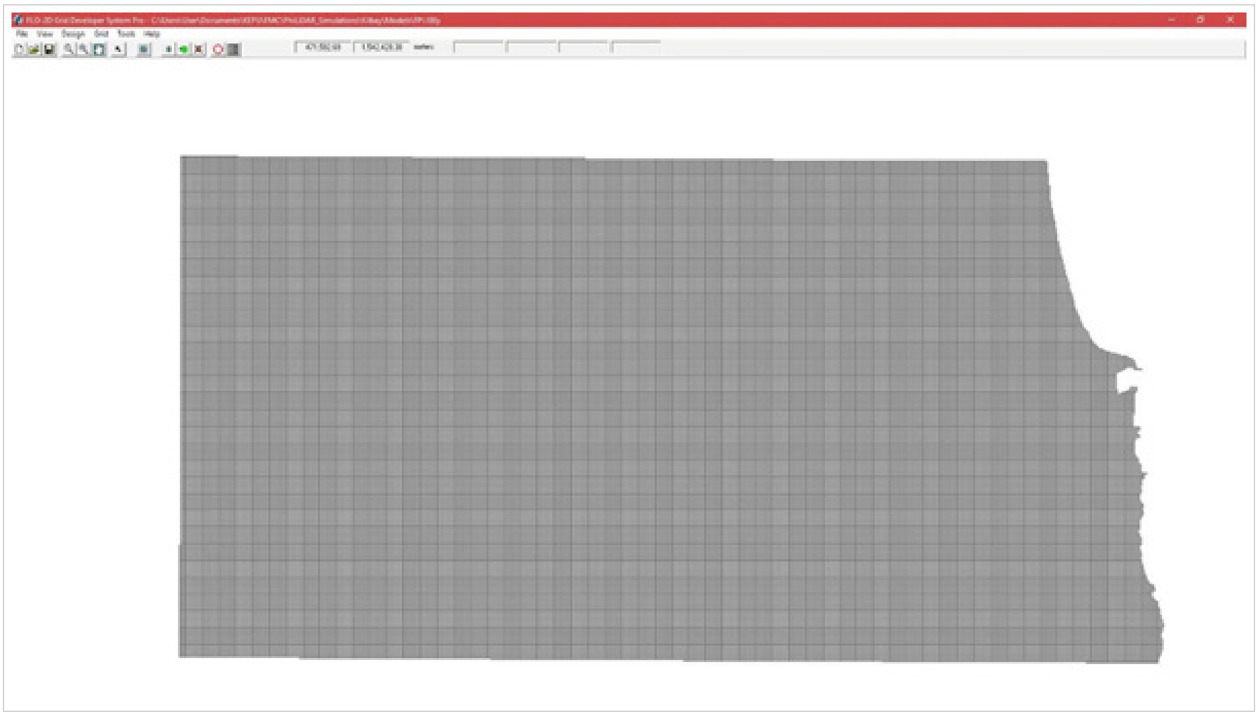


Figure 63. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 100.06329 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 **m²/s**. The generated hazard maps for Vinas are in Figure 67, 70Error! Reference source not found., and 72.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 63 792 800.00 **m²**. The generated flood depth maps for Vinas are in Figure 68, 71, and 73.

There is a total of 465 228 177.98 m³ of water entering the model. Of this amount, 25 253 779.51 m³ is due to rainfall while 439 974 398.47 m³ is inflow from other areas outside the model. 11 329 565.00 m³ of this water is lost to infiltration and interception, while 24 641 579.81 m³ is stored by the flood plain. The rest, amounting up to 429 257 024.59 m³, is outflow.

5.6 Results of HMS Calibration

After calibrating the Vinas HEC-HMS river basin model (See ANNEX 9), its accuracy was measured against the observed values. Error! Reference source not found.Error! Reference source not found. shows the comparison between the two discharge data.

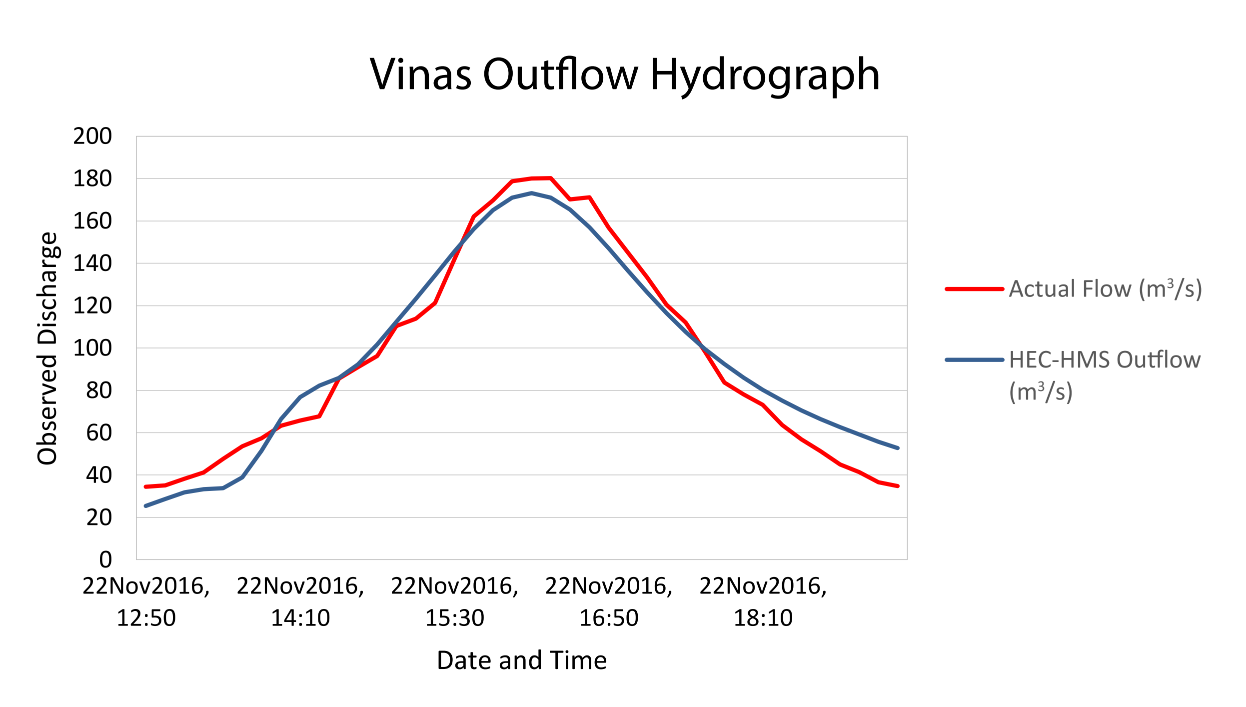


Figure 64. Outflow Hydrograph of Vinas produced by the HEC-HMS model compared with observed outflow.

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

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

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.17 – 4.82
			Curve Number	99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.017 – 0.58
			Storage Coefficient (hr)	0.02
	Baseflow	Recession	Recession Constant	0.00001 – 0.000013
			Ratio to Peak	0.39 – 1.00
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.00042 – 0.43

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.17mm to 4.82mm means that there is a minimal 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 curve number for all subbasins of Vinas watershed is 99. For Vinas, the soil classes identified were clay loam, clay, sandy loam and hydrosols. The land cover types identified were shrubland, mangroves and open canopy forest.

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 0.017 hours to 0.58 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. The Recession Constant values in the basin range from 0.00001 to 0.000013 and the Ratio to Peak of the different subbasins range from 0.39 to 1.00. The receding limb of the outflow hydrograph is initially steep but then takes longer to return to its original discharge values.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Vinas river basin reaches' Manning's coefficients that range from 0.00042 to 0.43 showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

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

Accuracy measure	Value
RMSE	10.1
r^2	0.96
NSE	0.96
PBIAS	-1.29
RSR	0.21

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 10.1(m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.96.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.96.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -1.29.

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 0.21.

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

This image is not available for this river basin.

Figure 65. The Outflow hydrograph at the Vinas Station, generated using the Alabat RIDF simulated in HEC-HMS.

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

Table 30. The peak values of the Vinas HEC-HMS Model outflow using the Maasin RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak	Lag Time
5-yr	252	27.6	2190.1	18 hours, 0 minutes	1 hour 10 minutes
10-yr	303.9	32.1	2694.6	18 hours, 0 minutes	1 hour 10 minutes
25-yr	369.6	37.7	3262.2	19 hours, 0 minutes	1 hour 10 minutes
50-yr	418.4	41.9	3659.4	19 hours, 0 minutes	1 hour 10 minutes
100-yr	466.7	46.1	4086	18 hours, 50 minutes	1 hour 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. Figure 66 shows a generated sample map of the Vinas River using the calibrated HMS event flow.

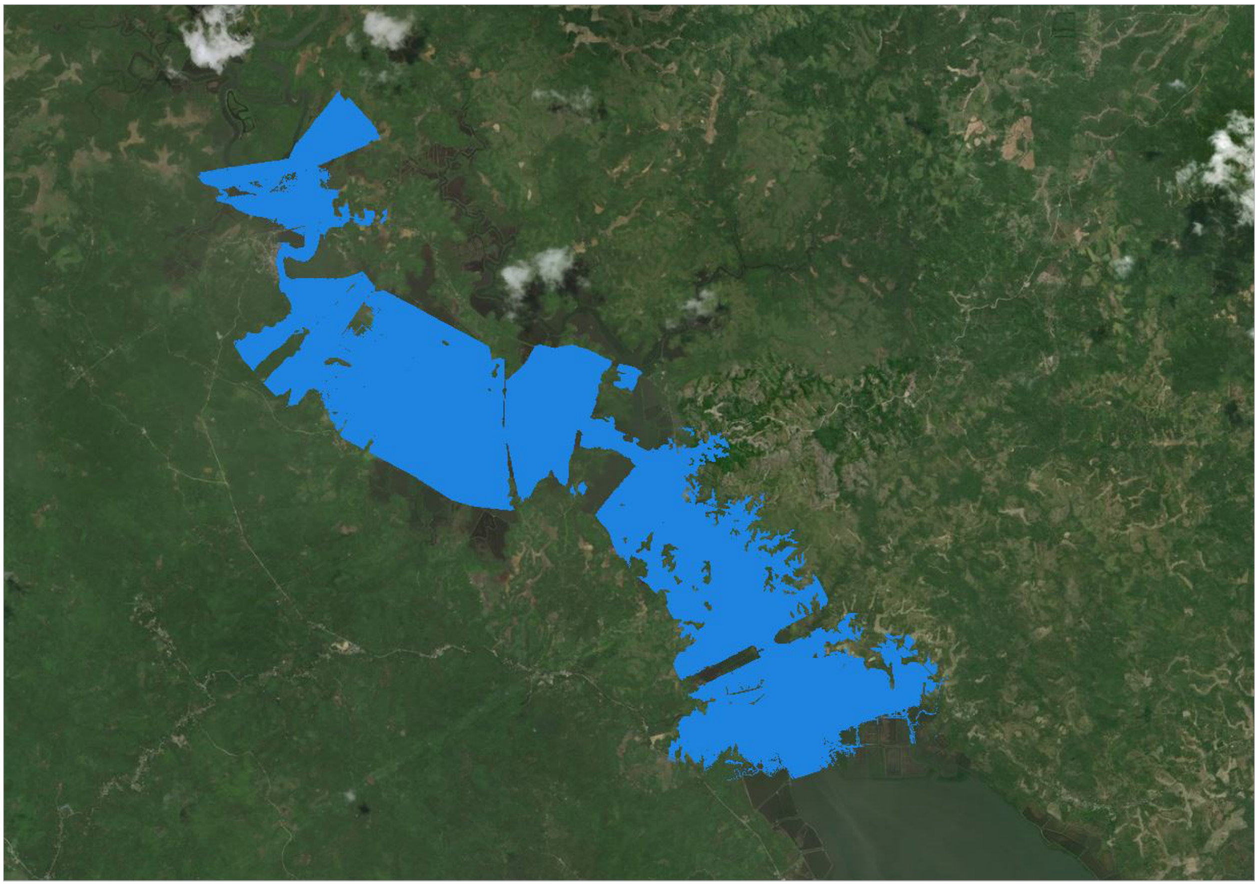


Figure 66. Sample output map of the Vinas RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 67 to Figure 72 show the 5-, 25-, and 100-year rain return scenarios of the Vinas floodplain. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Vinas floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Guinayangan	255.57	89.639	35.07
Calauag	312.32	19.4	7.85%
Tagkawayan	551.33	98.34	17.84%

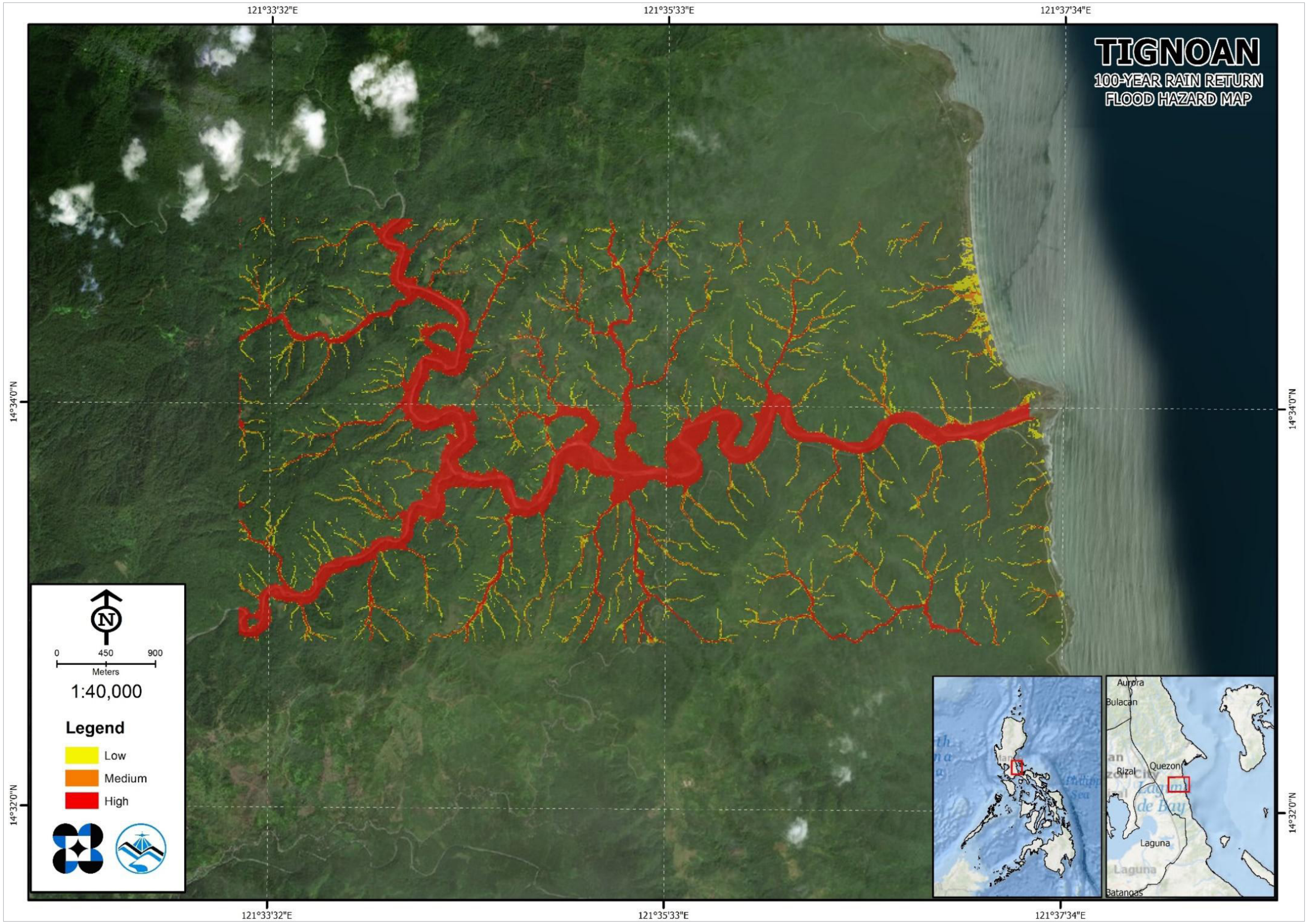


Figure 67. A 100-year Flood Hazard Map for Vinas Floodplain overlaid on Google Earth imagery.

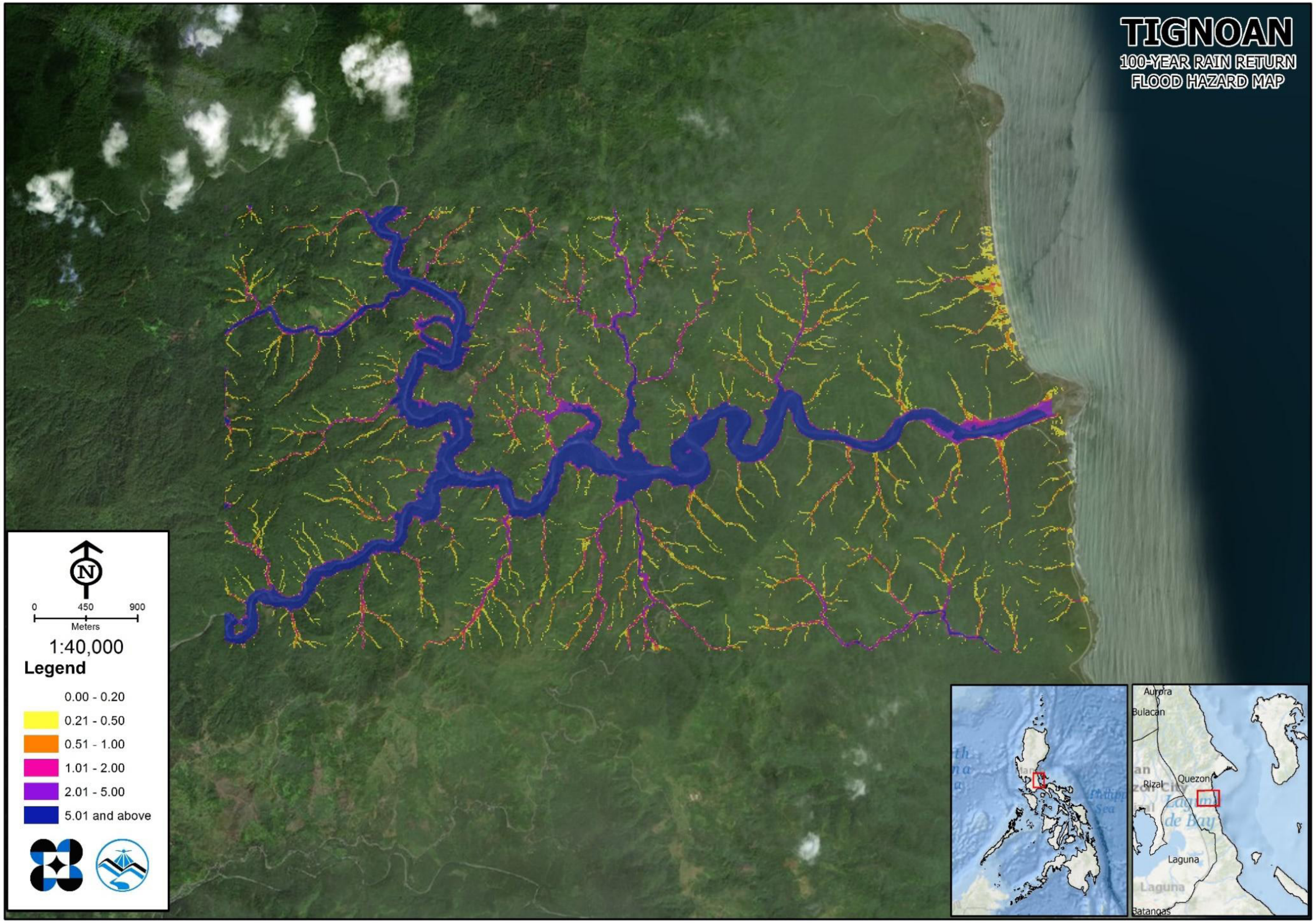


Figure 68. A 100-year Flow Depth Map for Vinas Floodplain overlaid on Google Earth imagery.

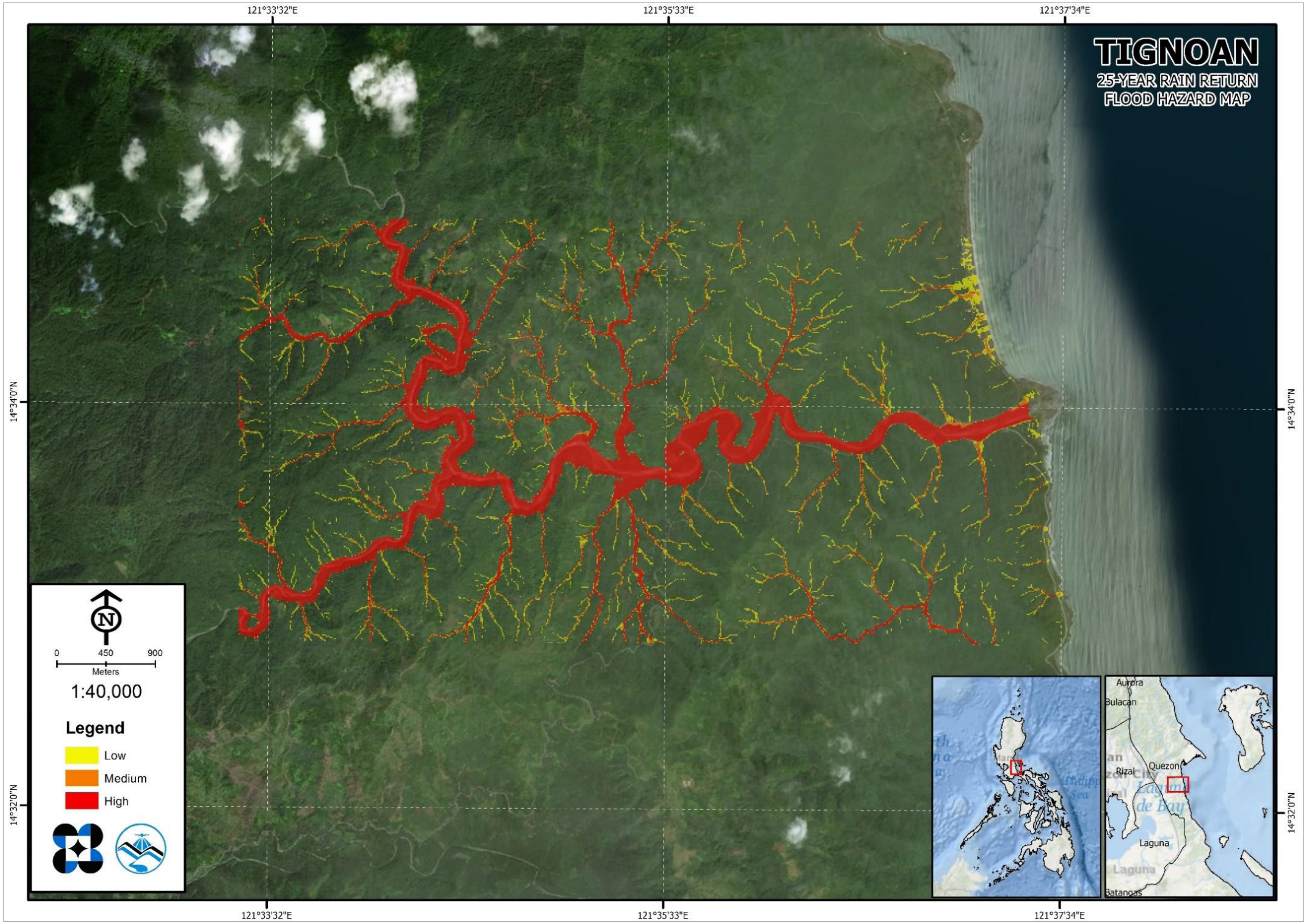


Figure 69. A 25-year Flood Hazard Map for Vinas Floodplain overlaid on Google Earth imagery.

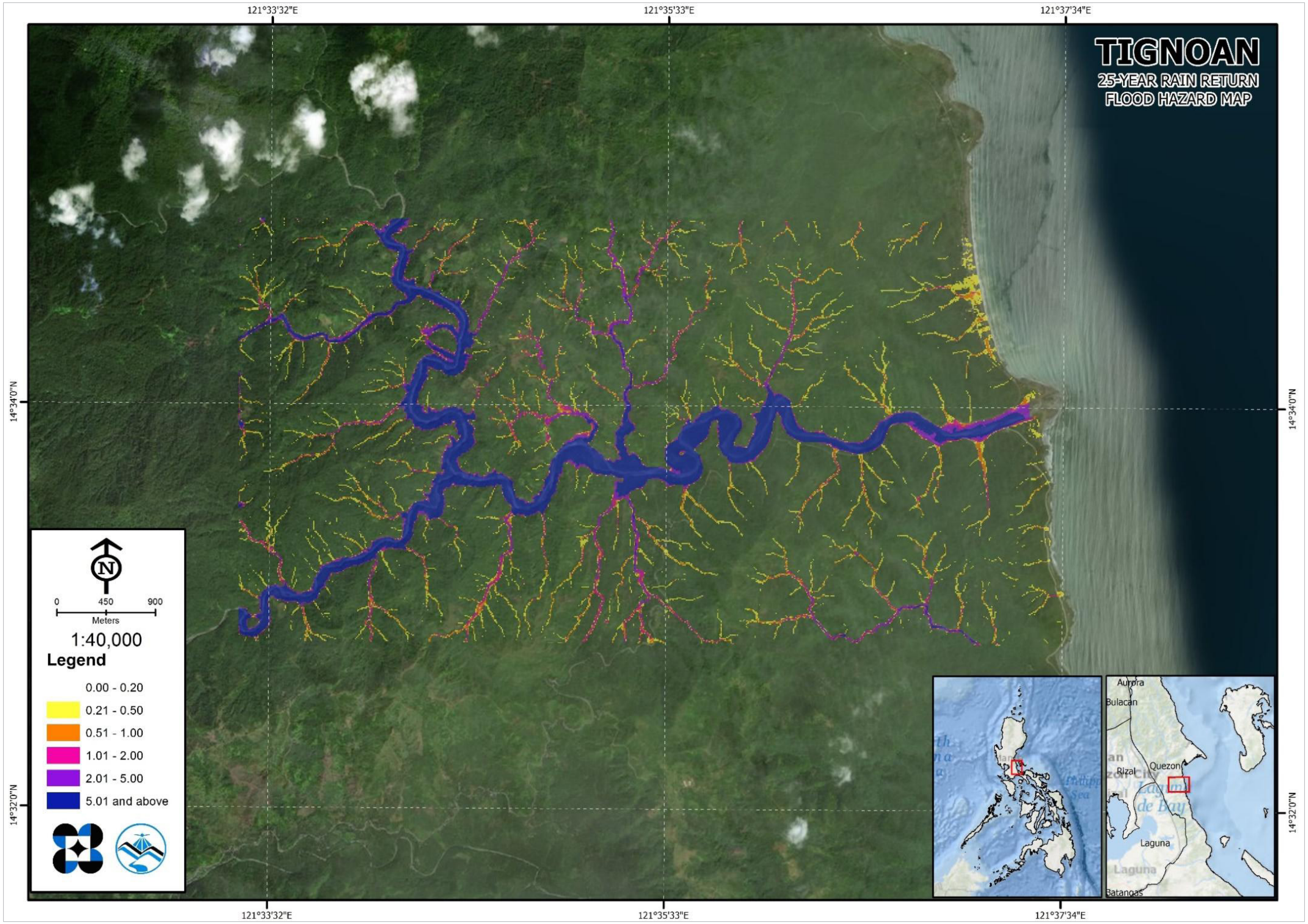


Figure 70. A 25-year Flow Depth Map for Vinas Floodplain overlaid on Google Earth imagery.

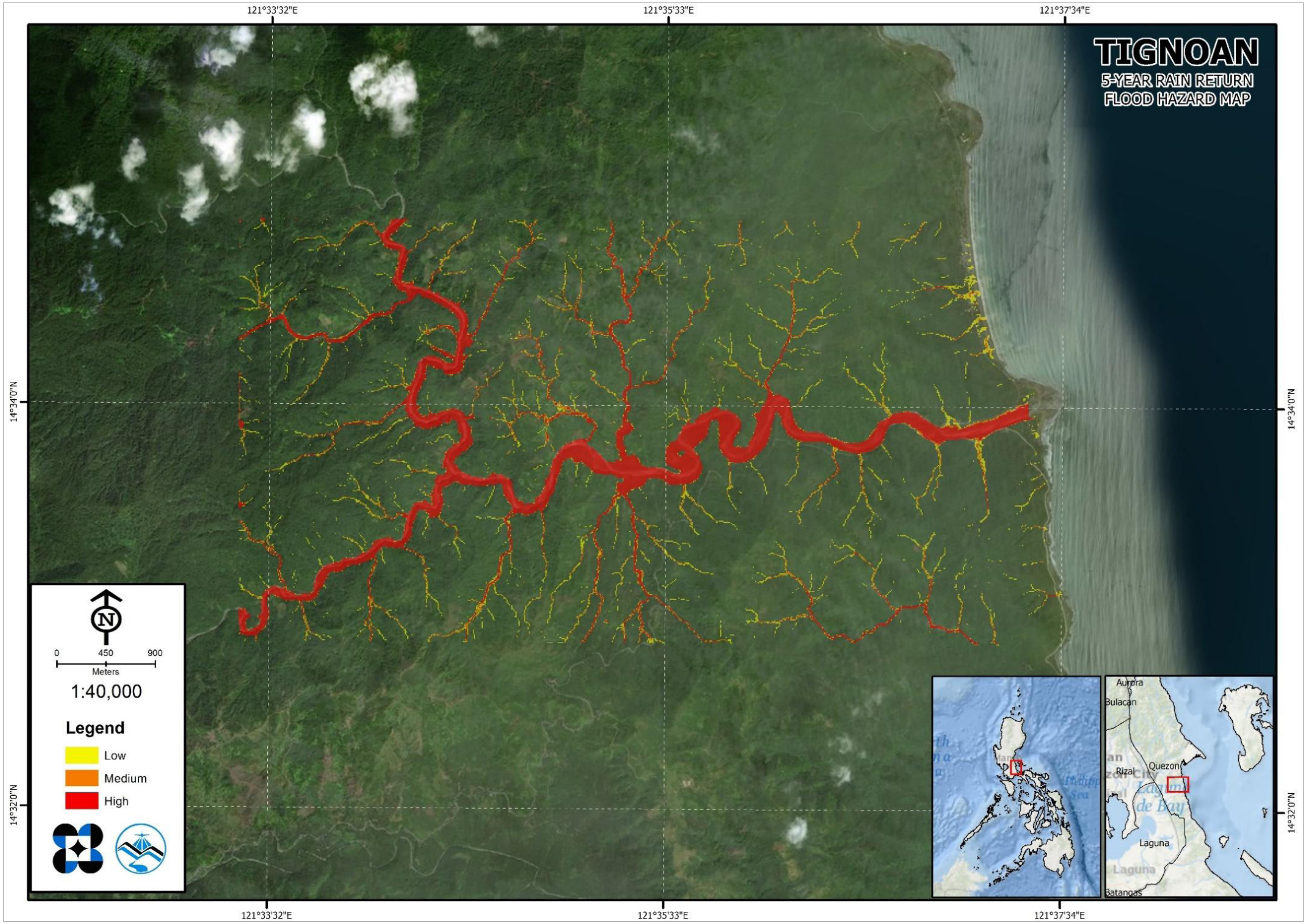


Figure 71. A 5-year Flood Hazard Map for Vinas Floodplain overlaid on Google Earth imagery.

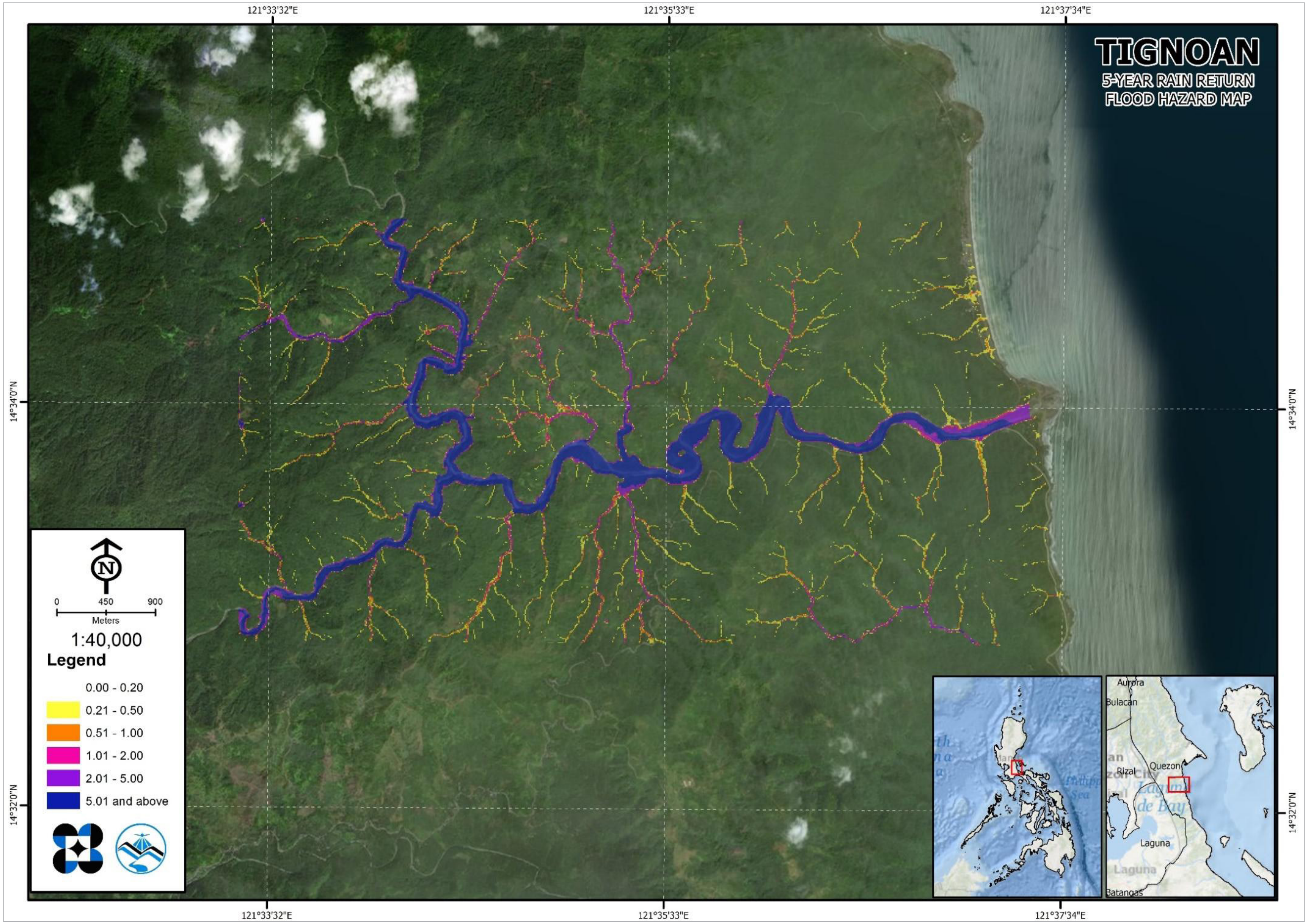


Figure 72. A 5-year Flood Depth Map for Vinas Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Vinas River Basin, grouped accordingly by municipality. For the said basin, three municipalities consisting of 55 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 26.62% of the municipality of Guinayangan with an area of 255.57 sq. km. will experience flood levels of less than 0.20 meters. 1.91% of the area will experience flood levels of 0.21 to 0.50 meters while 2.01%, 1.53%, 1.28%, and 0.34% 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. ANNEX 12 and ANNEX 13 show the educational and health institutions exposed to flooding.

Table 32. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)										
	Aloneros	Bagong Silang	Balinarin	Bukal Maligaya	Cabibihan	Danlagan Batis	Banlagan Cabayao	Danlagan Central	Danlagan Reserva	Del Rosario	Ermita
0.03-0.20	0.38	4.18	2.55	1.77	1.33	2.41	0	1.63	1.13	2.84	2.48
0.21-0.50	0.02	0.14	0.61	0.42	0.11	0.16	0	0.2	0.068	0.079	0.17
0.51-1.00	0.019	0.13	0.37	0.46	0.21	0.1	0	0.27	0.078	0.07	0.079
1.01-2.00	0.053	0.18	0.07	0.064	0.48	0.06	0	0.39	0.073	0.091	0.02
2.01-5.00	0.028	0.52	0.052	0.012	0.26	0.039	0	0.15	0.071	0.13	0.01
> 5.00	0.026	0.45	0.016	0	0.0074	0.0001	0	0.0011	0.0007	0.013	0.0001

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)										
	Gapas	Hinabaan	Salakan	San Antonio	San Jose	San Luis I	San Luis II	San Miguel	San Pedro II	San Roque	Santa Cruz
0.03-0.20	4.32	2.08	0.35	2.76	6.82	4.23	6.7	0.26	3.55	0.28	4.68
0.21-0.50	0.51	0.5	0.018	0.22	0.2	0.17	0.2	0.055	0.12	0.011	0.26
0.51-1.00	0.92	0.6	0.032	0.12	0.21	0.28	0.22	0.13	0.091	0.0018	0.1
1.01-2.00	0.17	0.44	0.015	0.034	0.27	0.41	0.39	0.13	0.074	0.001	0.038
2.01-5.00	0.049	0.041	0.00096	0.006	0.37	0.3	0.75	0.039	0.038	0.0011	0.014
> 5.00	0.012	0	0	0.003	0.02	0.022	0.27	0	0.0063	0	0.0001

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)	
	Tikay	Triumpo
0.03-0.20	1.45	2.36
0.21-0.50	0.22	0.24
0.51-1.00	0.32	0.45
1.01-2.00	0.16	0.36
2.01-5.00	0.015	0.054
> 5.00	0.0001	0

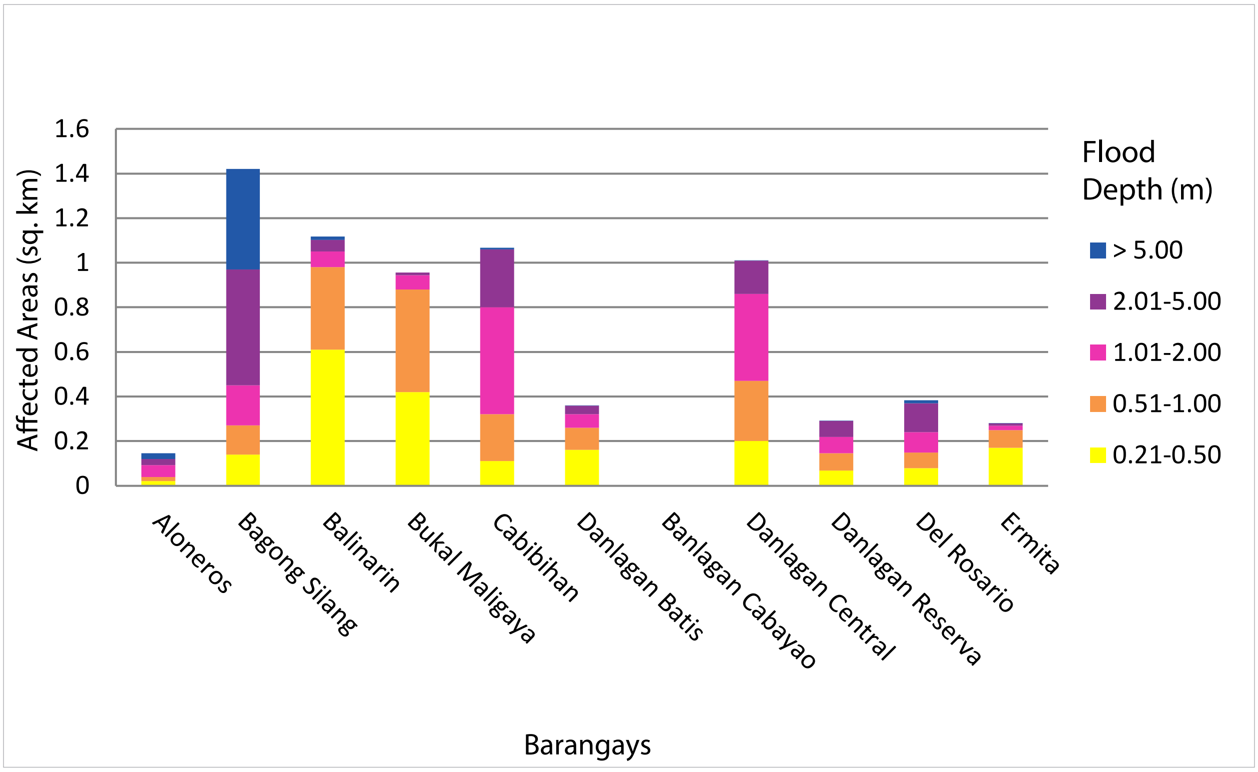


Figure 73. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period.

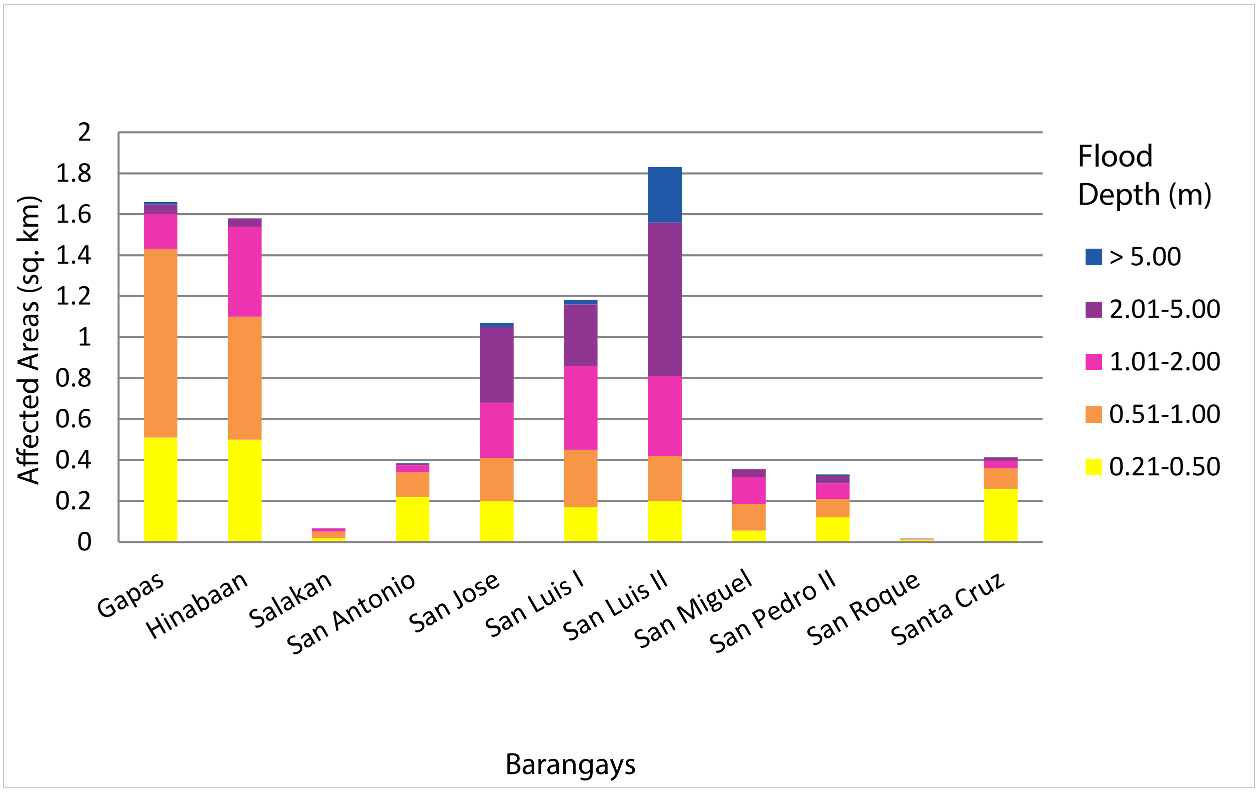


Figure 74. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period.

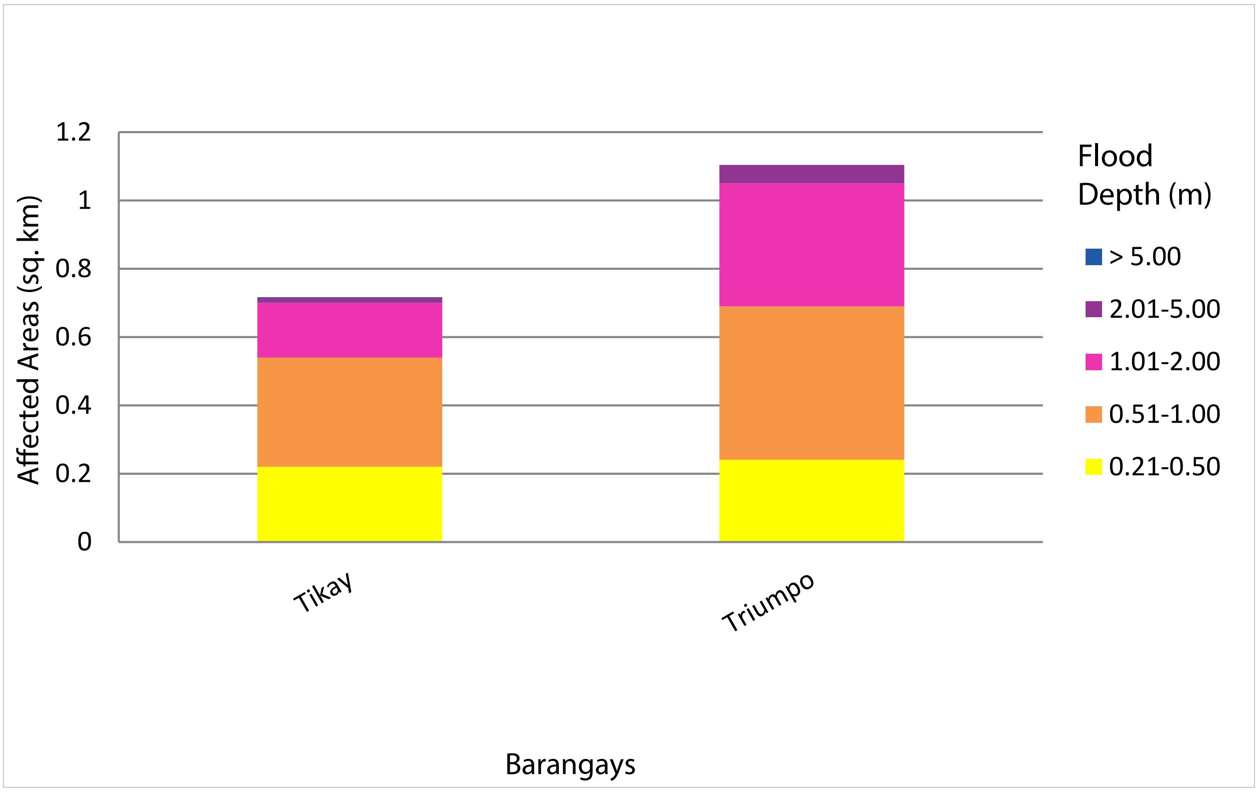


Figure 75. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period.

For the municipality of Calauag, with an area of 118.377 sq. km., 14.04% will experience flood levels of less 0.20 meters. 0.52% of the area will experience flood levels of 0.21 to 0.50 meters while 0.77%, 0.76%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Table 33 depicts the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)					
	Anahawan	Apad Taisan	Bagong Silang	Doña Aurora	Katangtang	Lungib
0.03-0.20	0.55	0.63	3.08	1.21	0.88	0.38
0.21-0.50	0.037	0.021	0.17	0.042	0.084	0.015
0.51-1.00	0.015	0.041	0.2	0.039	0.24	0.0095
1.01-2.00	0.0032	0.012	0.18	0.046	0.079	0.0094
2.01-5.00	0	0	0.038	0.017	0.0033	0.0091
> 5.00	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)					
	Pansol	Rizal Ilaya	San Roque Ilaya	Santa Milagrosa	Santo Domingo	Viñas
0.03-0.20	1.5	0.19	1.17	2.88	1.98	1.98
0.21-0.50	0.11	0.0044	0.045	0.14	0.07	0.07
0.51-1.00	0.08	0.0031	0.016	0.13	0.069	0.17
1.01-2.00	0.034	0.0016	0.0027	0.1	0.08	0.05
2.01-5.00	0.0014	0.0008	0.0001	0.064	0.081	0.001
> 5.00	0.0009	0	0	0.0008	0.0002	0

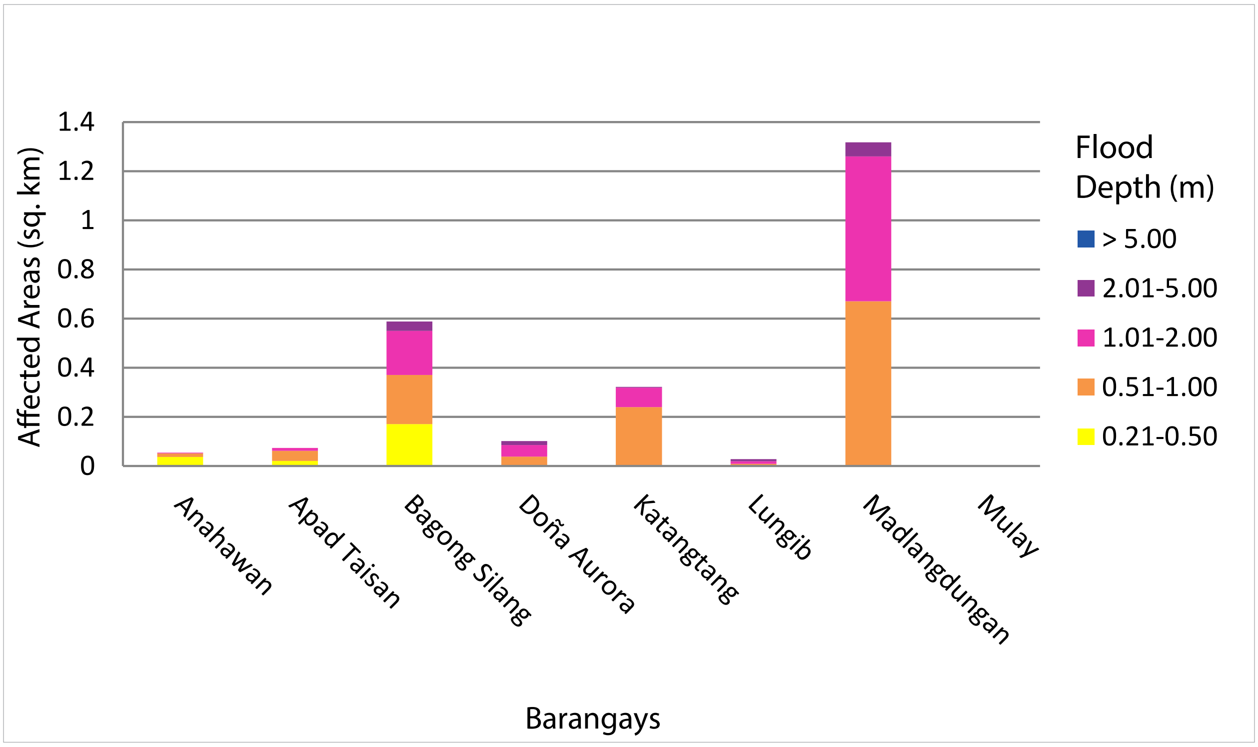


Figure 76. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period.

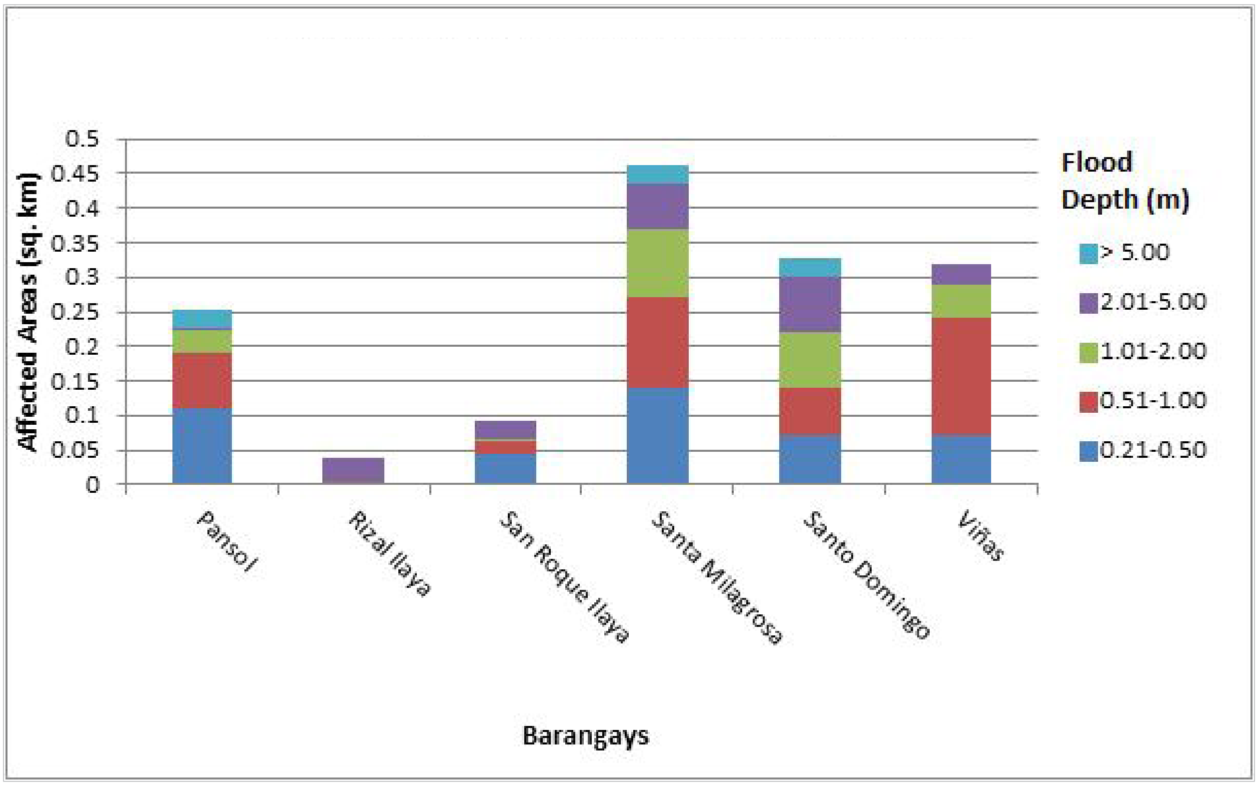


Figure 77. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period.

For the municipality of Tagkawayan, with an area of 130.22 sq. km., 3.05% will experience flood levels of less 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.11%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Illustrated in Table 34 are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Tagkawayan, Quezon during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagkawayan (in sq. km.)									
	Bagong Silang	Cabibihan	Cabugwang	Cagascas	Del Rosario	Katimo	Kinatakutan	Malbog	Manato Central	Manato Station
0.03-0.20	13.72	4.21	4.29	2.63	7.7	4.92	1.28	2.42	4.53	2.36
0.21-0.50	0.39	0.35	1.19	0.1	0.27	0.58	0.11	0.11	0.18	0.12
0.51-1.00	0.35	0.58	1.11	0.15	0.47	0.35	0.17	0.24	0.19	0.099
1.01-2.00	0.5	0.71	1.33	0.14	0.41	0.12	0.2	0.42	0.28	0.12
2.01-5.00	0.83	0.68	0.63	0.19	0.23	0.027	0.082	0.14	0.2	0.17
> 5.00	0.19	0.11	0.1	0	0.056	0	0	0	0	0.000044

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagkawayan (in sq. km.)						
	Mangayao	San Isidro	San Roque	Santo Niño I	Santo Niño II	Seguiwan	Victoria
0.03-0.20	4.29	0.43	3.48	3.42	8.78	6.47	2.45
0.21-0.50	0.29	0.018	0.14	0.15	0.29	0.79	0.22
0.51-1.00	0.26	0.022	0.11	0.14	0.24	0.46	0.33
1.01-2.00	0.28	0.02	0.14	0.14	0.25	0.23	0.51
2.01-5.00	0.21	0.0075	0.077	0.078	0.28	0.059	0.1
> 5.00	0.024	0	0	0	0.051	0	0

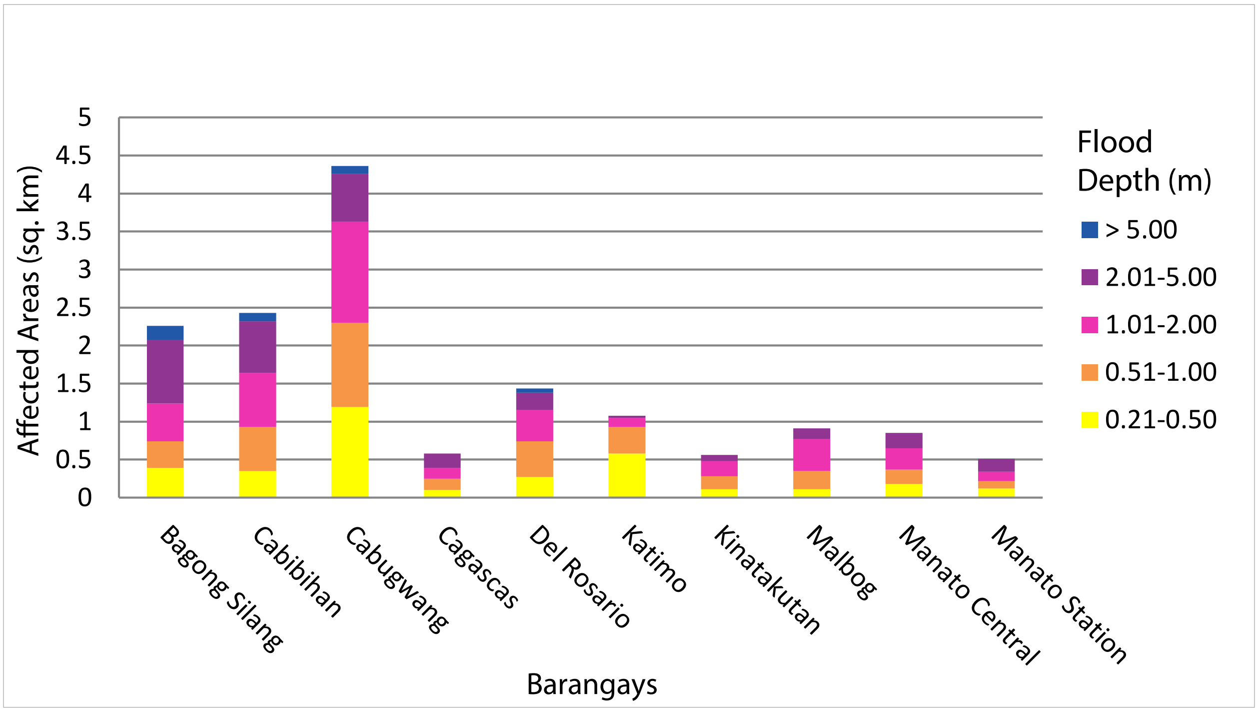


Figure 78. Affected Areas in Tagkawayan, Quezon during 5-Year Rainfall Return Period.

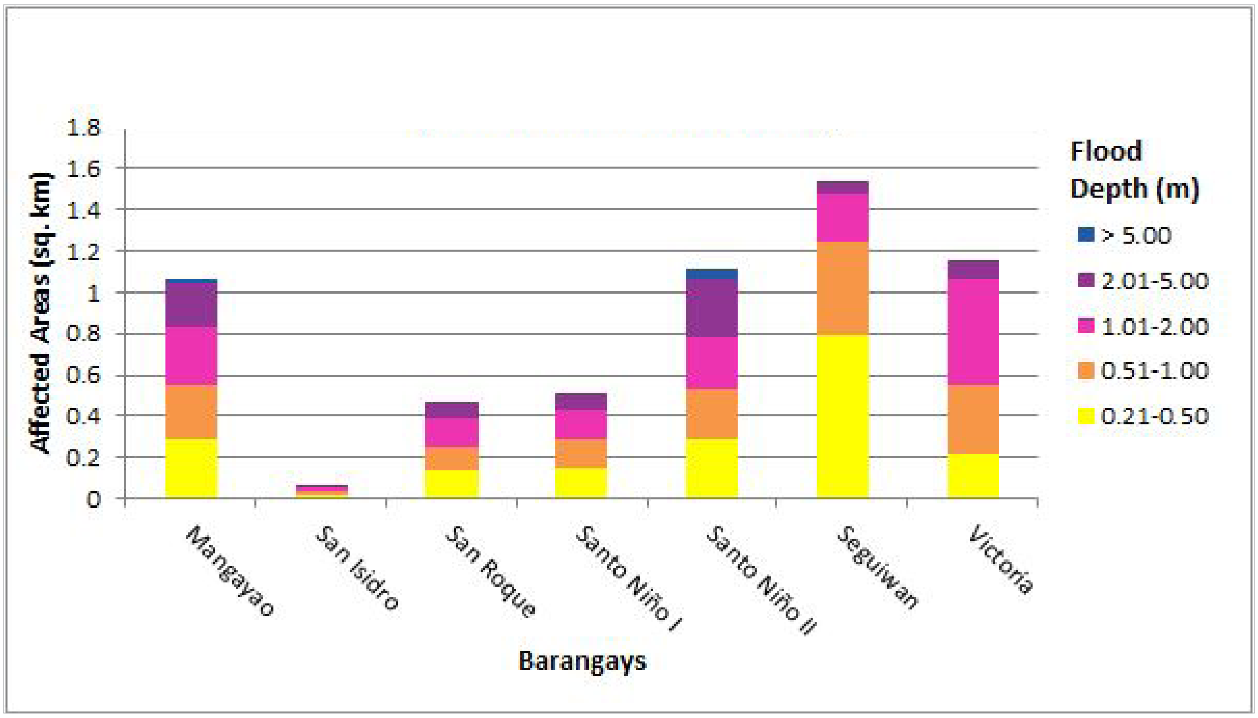


Figure 79. Affected Areas in Tagkawayan, Quezon during 5-Year Rainfall Return Period.

For the 25-year return period, 25.58% of the municipality of Guinayangan with an area of 255.57 sq. km. will experience flood levels of less than 0.20 meters. 1.67% of the area will experience flood levels of 0.21 to 0.50 meters while 1.77%, 2.30%, 1.78%, and 0.65% 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 Error! Reference source not found. are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Guinayangan, Quezon during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)										
	Aloneros	Bagong Silang	Balinarin	Bukal Maligaya	Cabibihan	Danlagan Batis	Banlagan Cabayao	Danlagan Central	Danlagan Reserva	Del Rosario	Ermita
0.03-0.20	0.36	3.91	2.38	1.6	1.26	2.35	0	1.51	1.09	2.77	2.43
0.21-0.50	0.02	0.12	0.53	0.16	0.072	0.17	0	0.13	0.066	0.085	0.18
0.51-1.00	0.016	0.13	0.51	0.21	0.12	0.12	0	0.23	0.078	0.075	0.1
1.01-2.00	0.027	0.18	0.17	0.74	0.37	0.07	0	0.49	0.092	0.091	0.034
2.01-5.00	0.071	0.44	0.043	0.019	0.58	0.06	0	0.28	0.094	0.16	0.013
> 5.00	0.03	0.81	0.042	0.0001	0.0091	0.00037	0	0.011	0.0031	0.041	0.0012

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)										
	Gapas	Hinabaan	Salakan	San Antonio	San Jose	San Luis I	San Luis II	San Miguel	San Pedro II	San Roque	Santa Cruz
0.03-0.20	4.08	1.9	0.35	2.69	6.64	4.05	6.49	0.22	3.51	0.28	4.58
0.21-0.50	0.36	0.45	0.017	0.24	0.21	0.15	0.2	0.023	0.12	0.014	0.3
0.51-1.00	0.58	0.58	0.033	0.15	0.22	0.22	0.19	0.055	0.1	0.0026	0.13
1.01-2.00	0.88	0.6	0.022	0.058	0.28	0.46	0.33	0.23	0.09	0.0013	0.055
2.01-5.00	0.068	0.13	0.0014	0.011	0.46	0.5	0.88	0.084	0.047	0.0013	0.021
> 5.00	0.02	0.0004	0	0.003	0.089	0.043	0.45	0	0.01	0	0.0005

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)	
	Tikay	Triumpo
0.03-0.20	1.31	2.27
0.21-0.50	0.18	0.15
0.51-1.00	0.31	0.31
1.01-2.00	0.26	0.5
2.01-5.00	0.11	0.24
> 5.00	0.0002	0

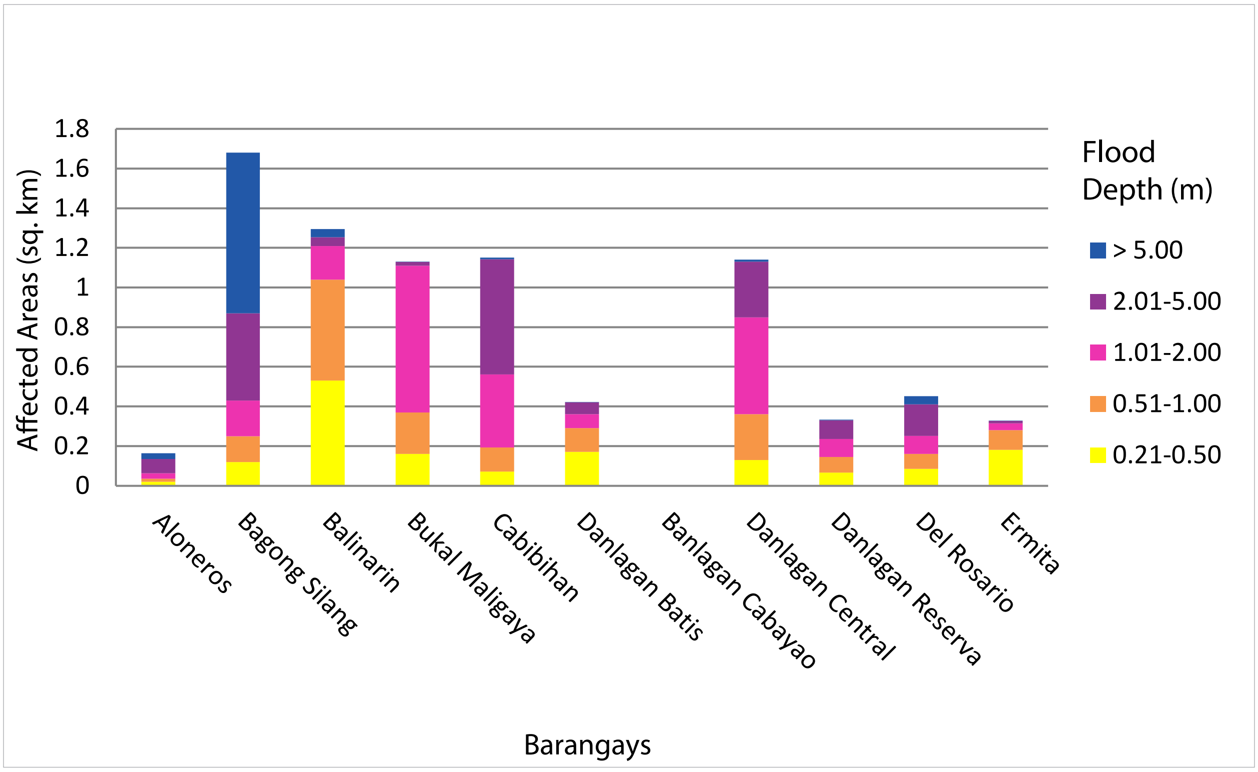


Figure 80. Affected Areas in Guinayangan, Quezon during 25-Year Rainfall Return Period.

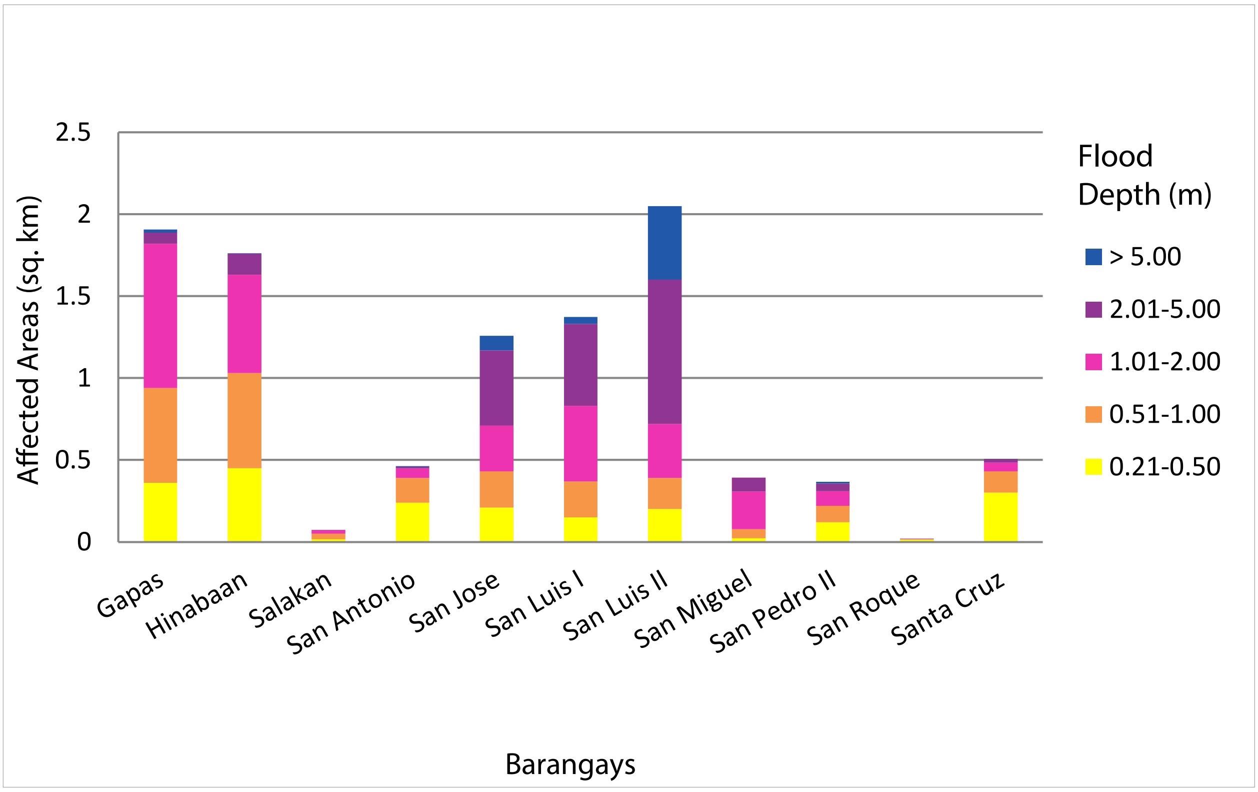


Figure 81. Affected Areas in Guinayangan, Quezon during 25-Year Rainfall Return Period.

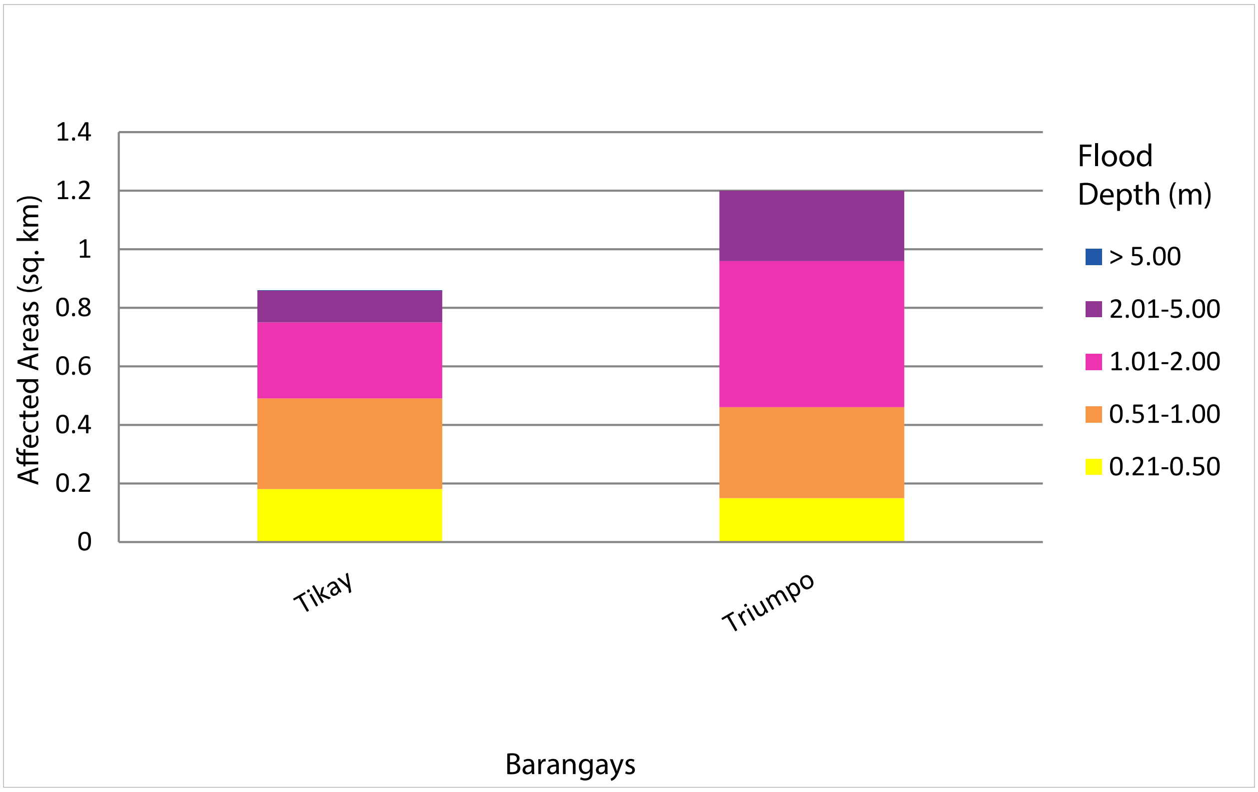


Figure 82. Affected Areas in Guinayangan, Quezon during 25-Year Rainfall Return Period.

For the municipality of Calauag with an area of 312.32 sq. km. will experience flood levels of less than 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.50%, 0.55%, 0.18%, and 0.00% 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 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)					
	Anahawan	Apad Taisan	Bagong Silang	Doña Aurora	Katangtang	Lungib
0.03-0.20	0.54	0.62	2.99	1.2	0.86	0.37
0.21-0.50	0.039	0.02	0.15	0.041	0.052	0.016
0.51-1.00	0.02	0.035	0.21	0.041	0.2	0.011
1.01-2.00	0.0056	0.024	0.21	0.052	0.17	0.013
2.01-5.00	0	0.0002	0.097	0.025	0.011	0.013
> 5.00	0	0	0	0	0	0.0011

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)					
	Pansol	Rizal Ilaya	San Roque Ilaya	Santa Milagrosa	Santo Domingo	Viñas
0.03-0.20	1.46	0.19	1.15	2.82	1.93	1.96
0.21-0.50	0.12	0.0044	0.053	0.15	0.07	0.063
0.51-1.00	0.095	0.0034	0.023	0.14	0.069	0.15
1.01-2.00	0.046	0.0017	0.0048	0.12	0.089	0.098
2.01-5.00	0.0038	0.0014	0.0001	0.098	0.12	0.0017
> 5.00	0.0009	0	0	0.0016	0.0043	0

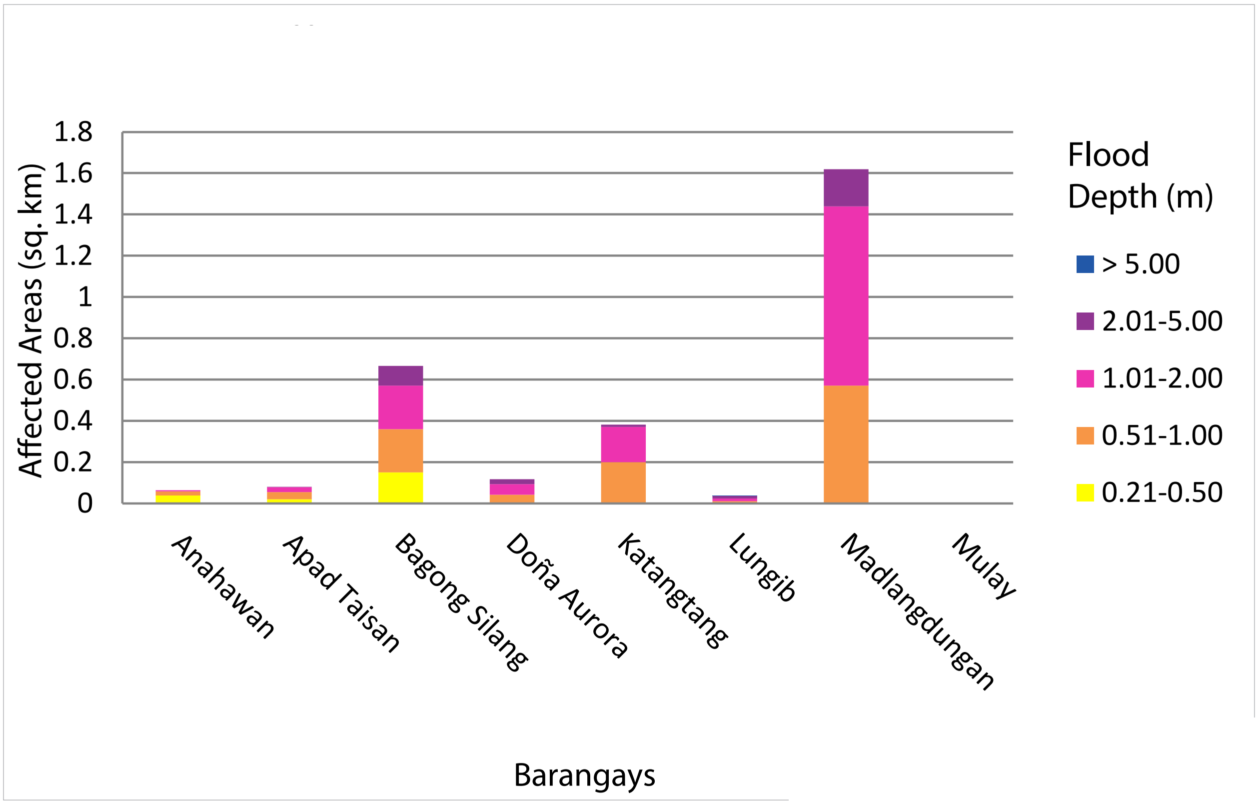


Figure 83. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period.

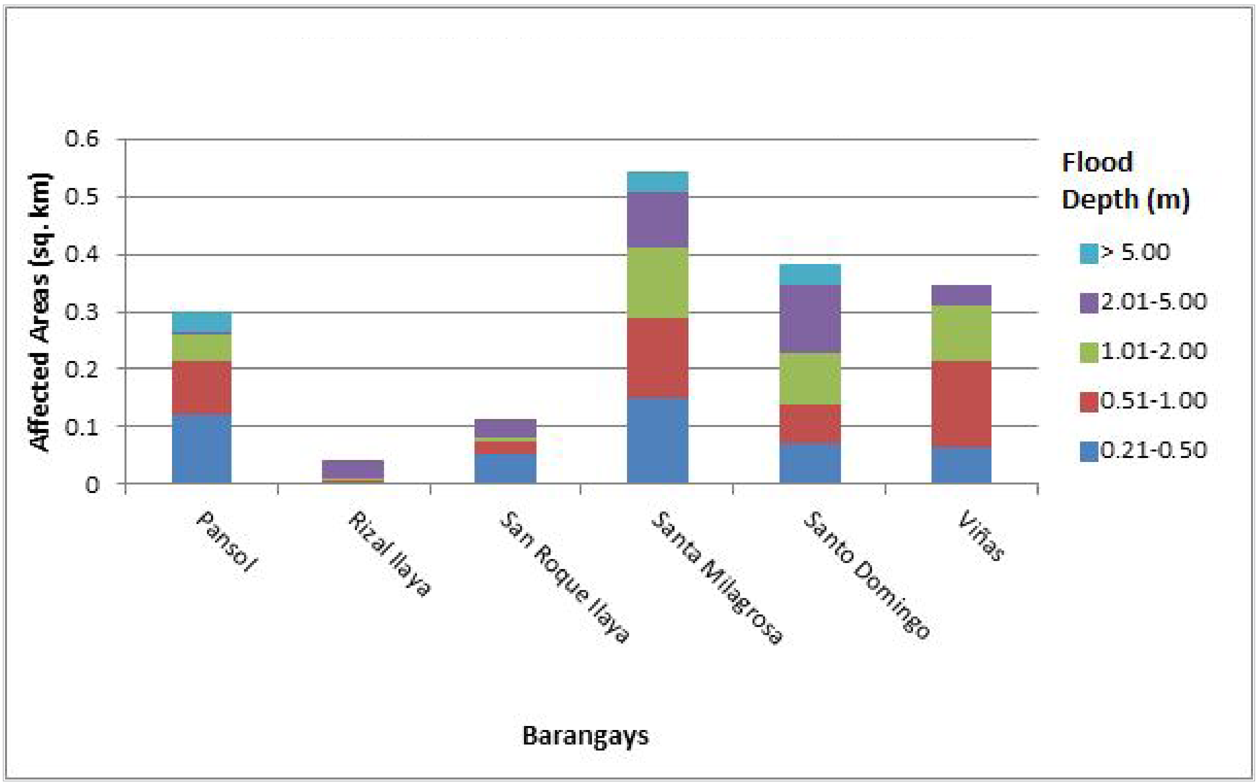


Figure 84. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period.

For the municipality of Tagkawayan with an area of 551.33 sq. km. will experience flood levels of less than 0.20 meters. 0.75% of the area will experience flood levels of 0.21 to 0.50 meters while 0.91%, 1.29%, 1.25%, and 0.21% 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 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Tagkawayan, Quezon during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagkawayan (in sq. km.)									
	Bagong Silang	Cabibihan	Cabugwang	Cagascas	Del Rosario	Katimo	Kinatakutan	Malbog	Manato Central	Manato Station
0.03-0.20	13.42	3.99	2.99	2.57	7.54	4.68	1.18	2.34	4.4	2.3
0.21-0.50	0.38	0.19	0.32	0.082	0.27	0.62	0.1	0.092	0.18	0.13
0.51-1.00	0.34	0.46	0.94	0.13	0.35	0.44	0.15	0.16	0.18	0.1
1.01-2.00	0.49	0.7	2.35	0.15	0.57	0.22	0.27	0.3	0.26	0.11
2.01-5.00	0.95	1.11	1.77	0.28	0.3	0.044	0.15	0.43	0.36	0.22
> 5.00	0.38	0.2	0.27	0.0065	0.11	0	0	0.0002	0.003	0.011

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagkawayan (in sq. km.)						
	Mangayao	San Isidro	San Roque	Santo Niño I	Santo Niño II	Seguiwan	Victoria
0.03-0.20	4.15	0.42	3.41	3.33	8.58	6.19	2.38
0.21-0.50	0.27	0.018	0.14	0.15	0.31	0.76	0.15
0.51-1.00	0.29	0.022	0.12	0.15	0.25	0.67	0.28
1.01-2.00	0.27	0.023	0.13	0.16	0.27	0.29	0.56
2.01-5.00	0.33	0.012	0.15	0.13	0.34	0.11	0.23
> 5.00	0.046	0	0.0007	0.0015	0.14	0	0.0088

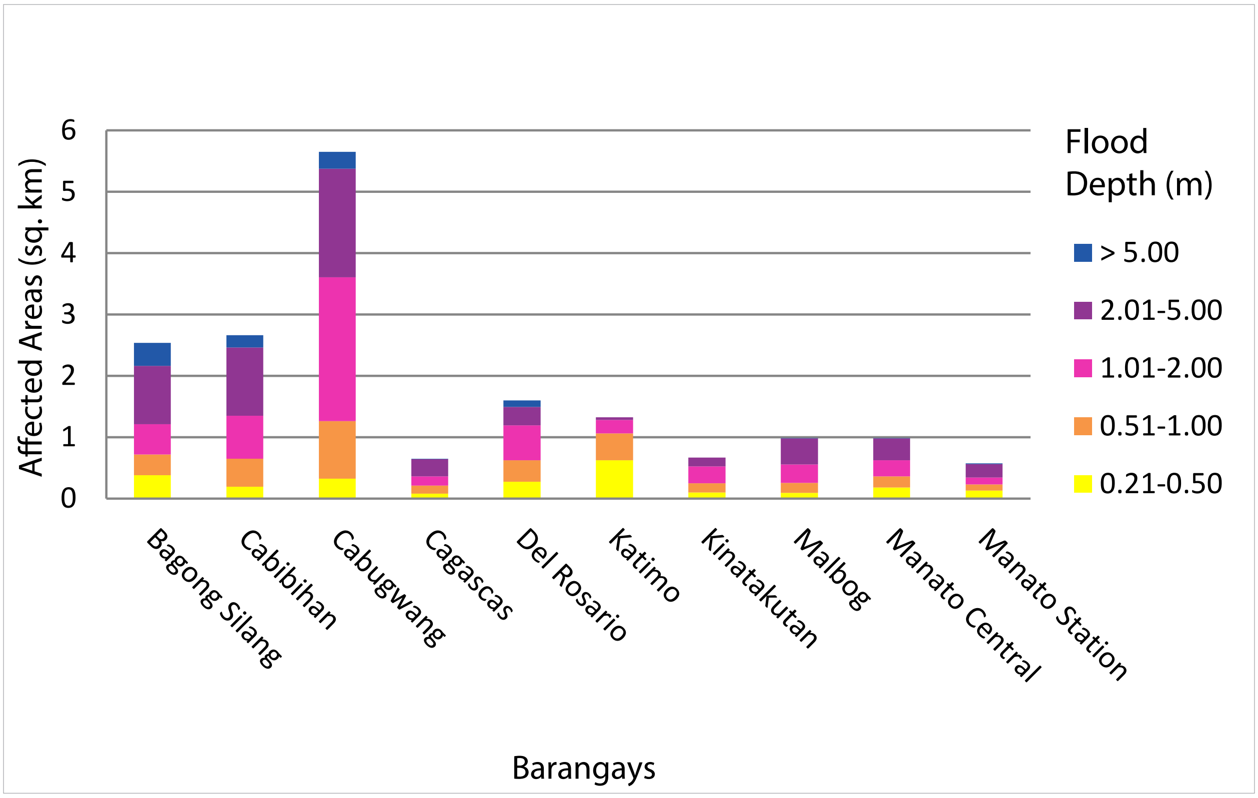


Figure 85. Affected Areas in Tagkawayan, Quezon during 25-Year Rainfall Return Period.

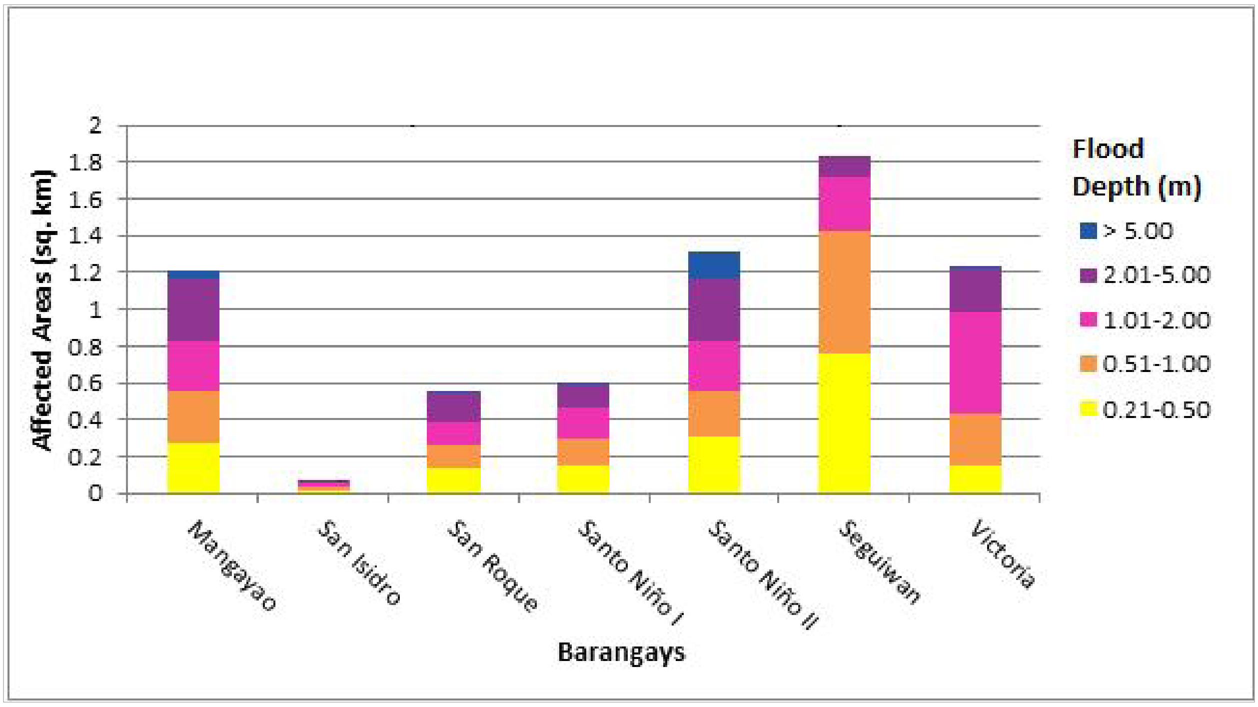


Figure 86. Affected Areas in Tagkawayan, Quezon during 25-Year Rainfall Return Period.

For the 100-year return period, 25.77% of the municipality of Guinayangan with an area of 255.57 sq. km. will experience flood levels of less than 0.20 meters. 1.58% of the area will experience flood levels of 0.21 to 0.50 meters while 1.73%, 2.34%, 2.72%, and 0.93% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)										
	Aloneros	Bagong Silang	Balinarin	Bukal Maligaya	Cabibihan	Danlagan Batis	Banlagan Cabayao	Danlagan Central	Danlagan Reserva	Del Rosario	Ermita
0.03-0.20	0.35	3.73	2.22	1.54	1.22	2.3	0	1.45	1.06	2.72	2.39
0.21-0.50	0.022	0.12	0.44	0.11	0.059	0.18	0	0.083	0.072	0.09	0.19
0.51-1.00	0.014	0.12	0.58	0.13	0.092	0.13	0	0.17	0.073	0.079	0.11
1.01-2.00	0.021	0.19	0.31	0.25	0.32	0.079	0	0.46	0.11	0.099	0.053
2.01-5.00	0.084	0.42	0.063	0.69	0.68	0.073	0	0.43	0.11	0.16	0.017
> 5.00	0.034	1.03	0.054	0.0004	0.028	0.0012	0	0.056	0.0069	0.073	0.0027

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)										
	Gapas	Hinabaan	Salakan	San Antonio	San Jose	San Luis I	San Luis II	San Miguel	San Pedro II	San Roque	Santa Cruz
0.03-0.20	3.93	1.78	0.34	2.64	6.52	3.94	6.37	0.2	3.48	0.27	4.51
0.21-0.50	0.3	0.38	0.019	0.24	0.21	0.14	0.19	0.017	0.12	0.019	0.32
0.51-1.00	0.32	0.58	0.023	0.17	0.21	0.19	0.19	0.034	0.11	0.0031	0.16
1.01-2.00	0.72	0.67	0.036	0.082	0.29	0.43	0.3	0.18	0.099	0.0016	0.073
2.01-5.00	0.69	0.25	0.0023	0.016	0.5	0.62	0.85	0.18	0.055	0.0015	0.027
> 5.00	0.025	0.0022	0	0.0002	0.16	0.084	0.64	0	0.014	0	0.0022

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)	
	Tikay	Triumpo
0.03-0.20	1.25	2.22
0.21-0.50	0.14	0.12
0.51-1.00	0.27	0.27
1.01-2.00	0.37	0.47
2.01-5.00	0.13	0.39
> 5.00	0.0003	0

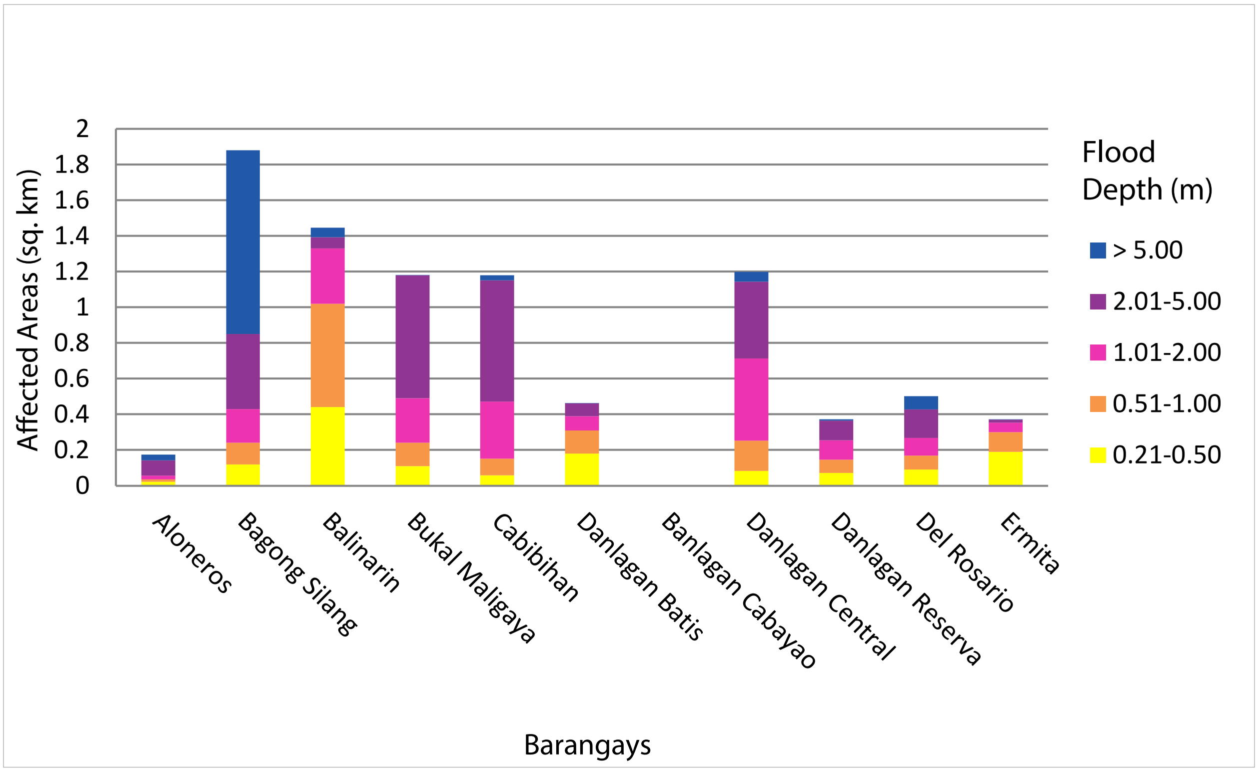


Figure 87. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period.

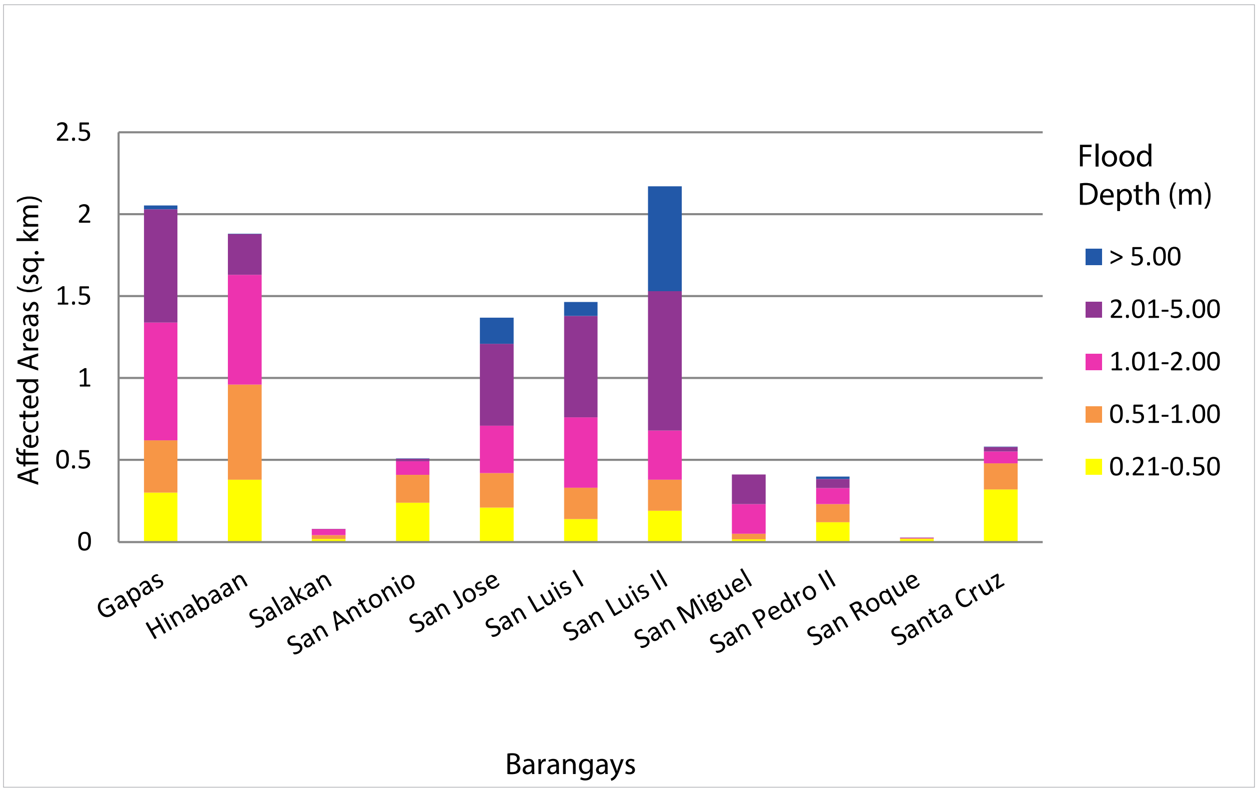


Figure 88. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period.

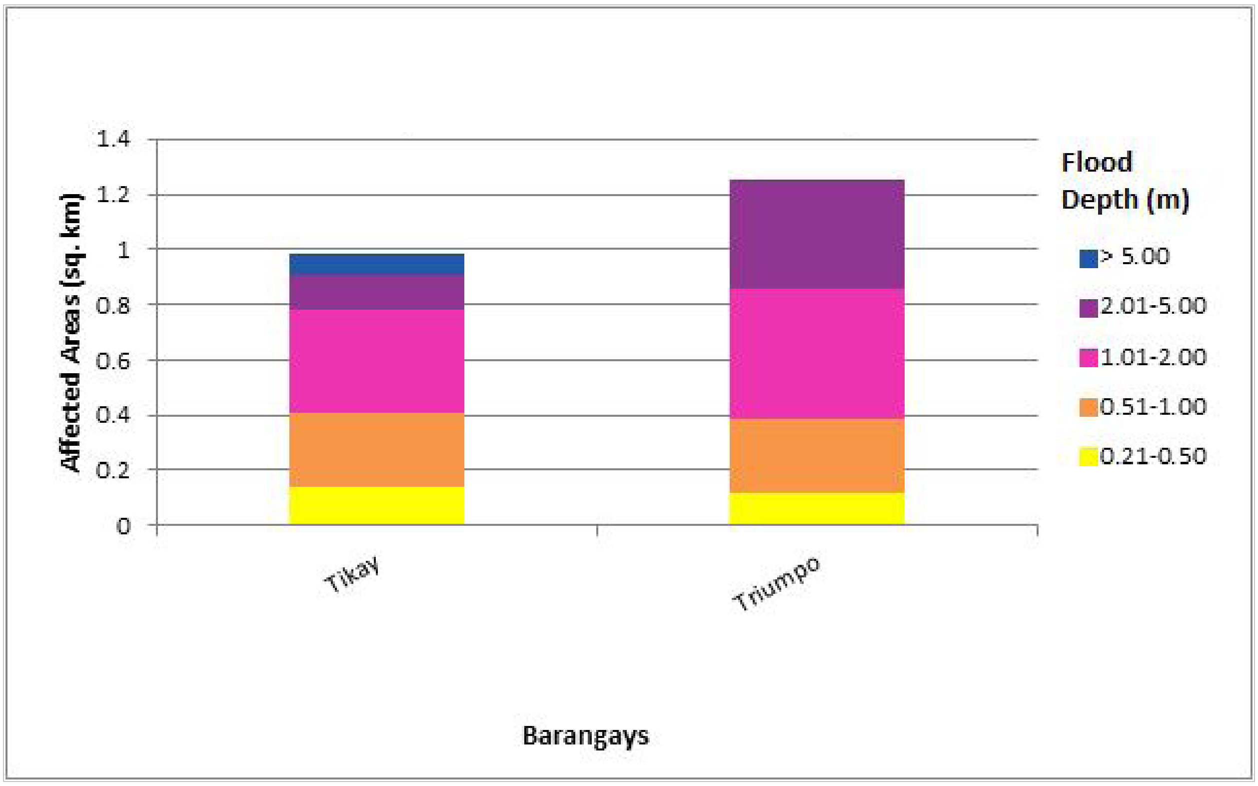


Figure 89. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period.

For the municipality of Calauag with an area of 312.32 sq. km. will experience flood levels of less than 0.20 meters. 0.31% of the area will experience flood levels of 0.21 to 0.50 meters while 0.46%, 0.53%, 0.33%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)					
	Anahawan	Apad Taisan	Bagong Silang	Doña Aurora	Katangtang	Lungib
0.03-0.20	0.53	0.62	2.94	1.19	0.84	0.37
0.21-0.50	0.039	0.02	0.15	0.038	0.045	0.015
0.51-1.00	0.026	0.029	0.21	0.045	0.13	0.012
1.01-2.00	0.0083	0.035	0.22	0.052	0.25	0.014
2.01-5.00	0	0.0003	0.15	0.034	0.014	0.015
> 5.00	0	0	0.00093	0	0	0.0014

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)					
	Pansol	Rizal Ilaya	San Roque Ilaya	Santa Milagrosa	Santo Domingo	Viñas
0.03-0.20	1.44	0.19	1.14	2.76	1.89	1.94
0.21-0.50	0.11	0.0055	0.059	0.15	0.074	0.063
0.51-1.00	0.1	0.0039	0.026	0.15	0.067	0.12
1.01-2.00	0.057	0.0016	0.0081	0.13	0.095	0.14
2.01-5.00	0.0067	0.0019	0.0002	0.12	0.13	0.0033
> 5.00	0.0009	0	0	0.0061	0.023	0

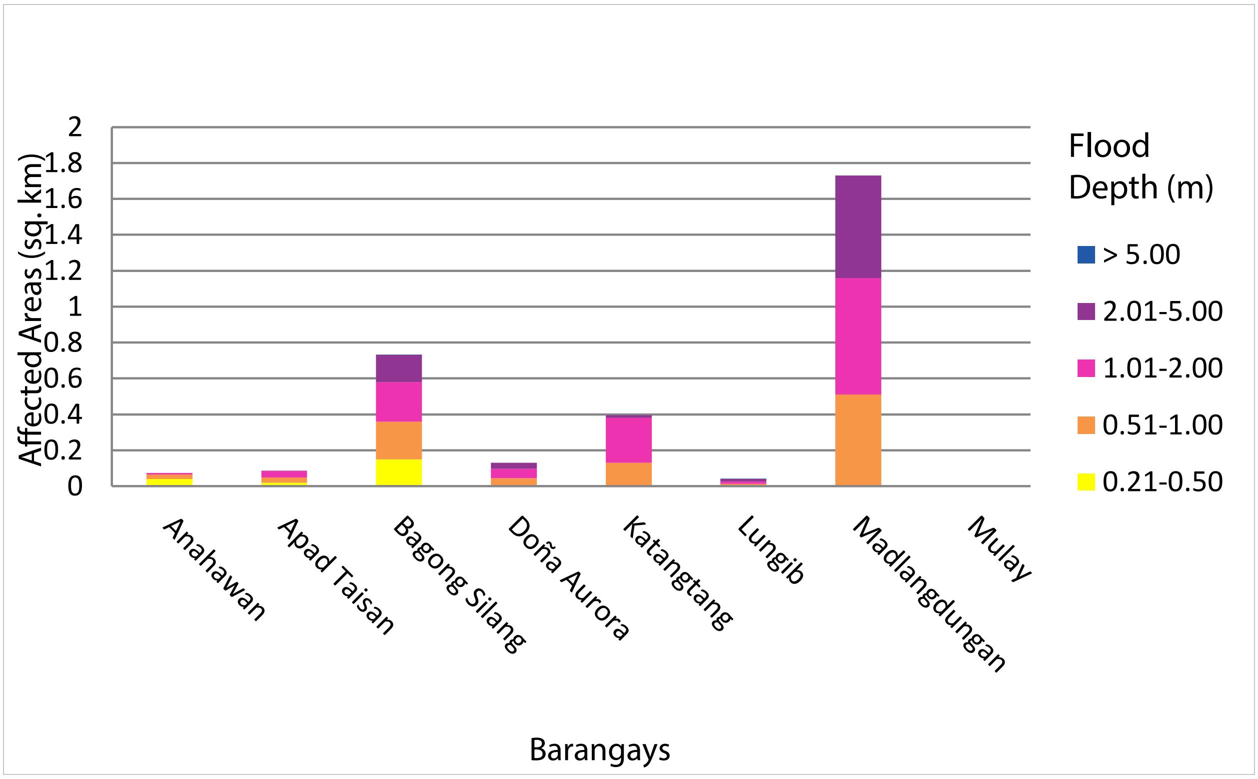


Figure 90. Affected Areas in Calauag, Quezon during 100-Year Rainfall Return Period.

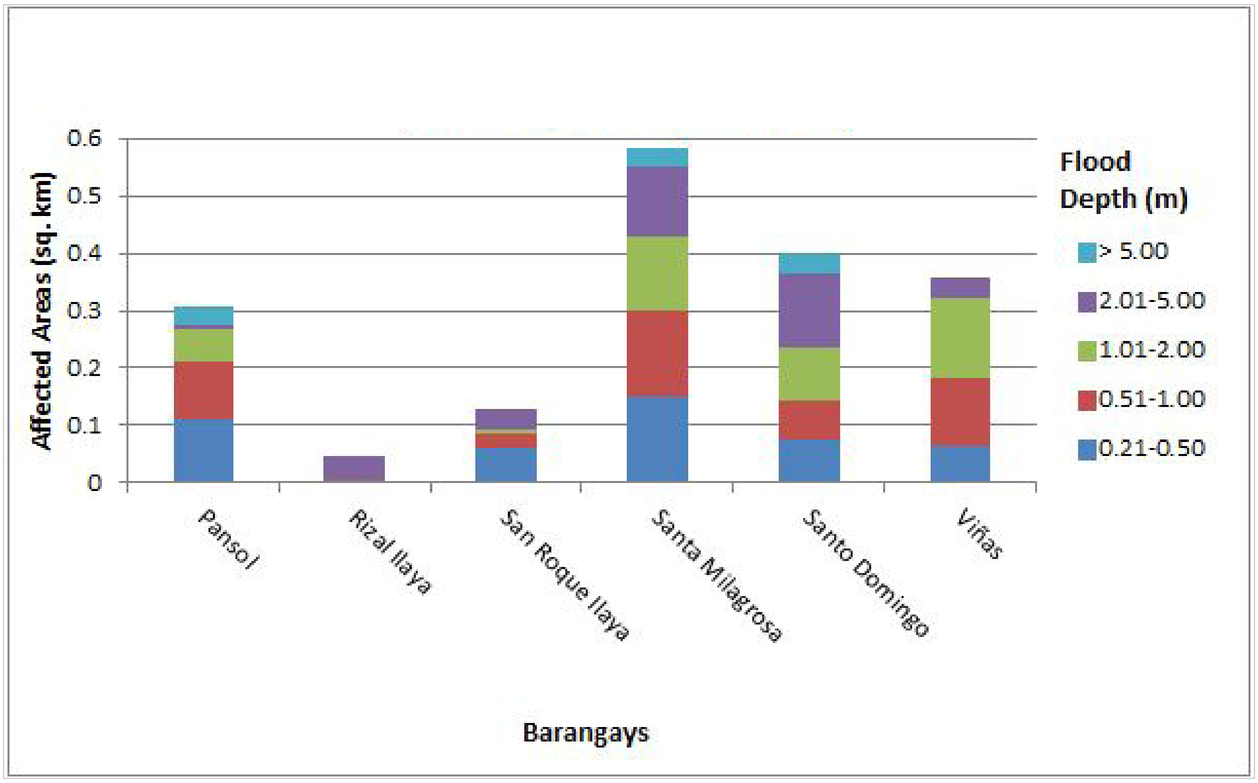


Figure 91. Affected Areas in Calauag, Quezon during 100-Year Rainfall Return Period.

For the municipality of Tagkawayan with an area of 551.33 sq. km. will experience flood levels of less than 0.20 meters. 0.71% of the area will experience flood levels of 0.21 to 0.50 meters while 0.80%, 1.15%, 1.73%, and 0.37% 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 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Tagkawayan, Quezon during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagkawayan (in sq. km.)									
	Bagong Silang	Cabibihan	Cabugwang	Cagascas	Del Rosario	Katimo	Kinatakutan	Malbog	Manato Central	Manato Station
0.03-0.20	13.24	3.89	2.7	2.53	7.43	4.55	1.11	2.28	4.3	2.25
0.21-0.50	0.38	0.16	0.19	0.083	0.26	0.59	0.097	0.085	0.18	0.11
0.51-1.00	0.34	0.32	0.36	0.1	0.31	0.52	0.15	0.13	0.18	0.14
1.01-2.00	0.45	0.72	1.44	0.15	0.58	0.28	0.3	0.27	0.26	0.12
2.01-5.00	0.97	1.26	3.45	0.32	0.4	0.06	0.2	0.57	0.45	0.21
> 5.00	0.59	0.3	0.51	0.035	0.16	0	0.0012	0.0002	0.011	0.049

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagkawayan (in sq. km.)						
	Mangayao	San Isidro	San Roque	Santo Niño I	Santo Niño II	Seguiwan	Victoria
0.03-0.20	4.06	0.41	3.36	3.28	8.44	6.01	2.31
0.21-0.50	0.26	0.017	0.14	0.15	0.32	0.76	0.12
0.51-1.00	0.31	0.023	0.13	0.16	0.26	0.73	0.23
1.01-2.00	0.26	0.025	0.13	0.17	0.29	0.37	0.53
2.01-5.00	0.4	0.016	0.18	0.16	0.35	0.15	0.39
> 5.00	0.079	0	0.0057	0.0092	0.23	0.0004	0.032

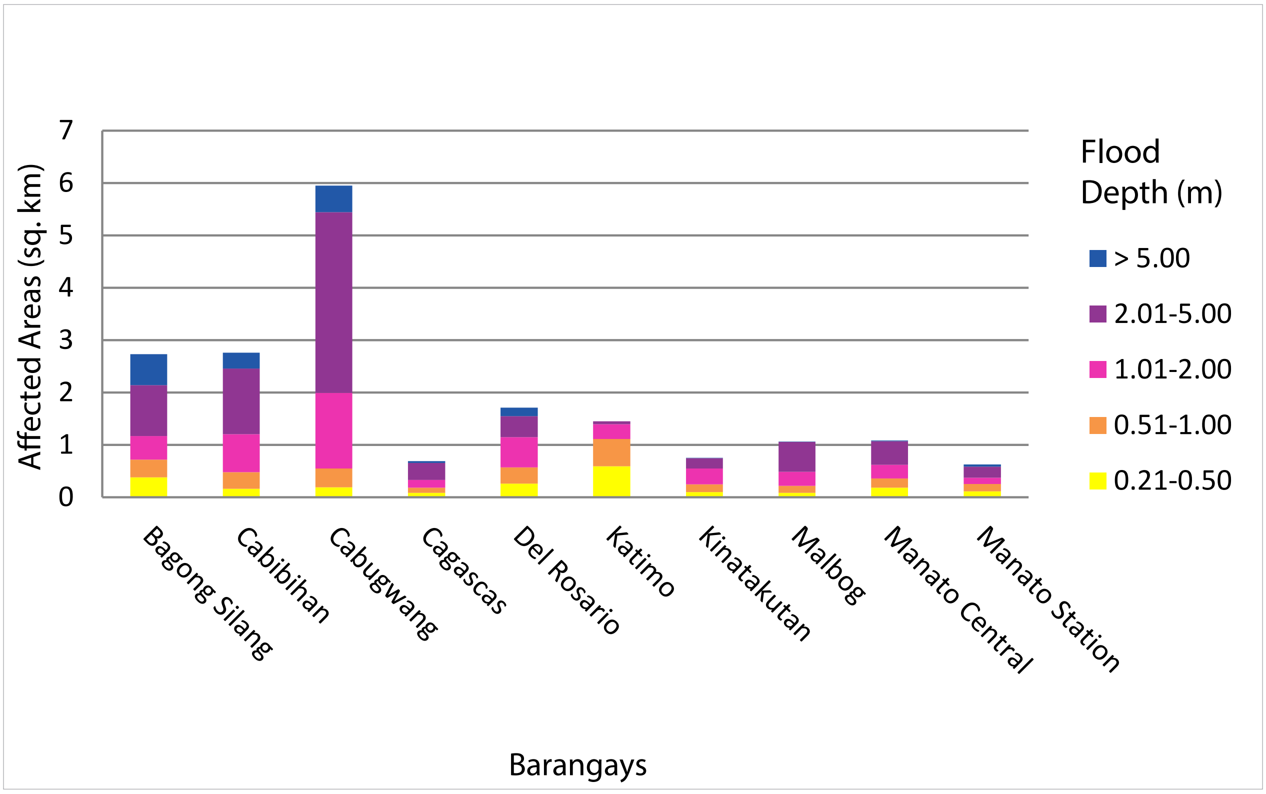


Figure 92. Affected Areas in Tagkawayan, Quezon during 100-Year Rainfall Return Period.

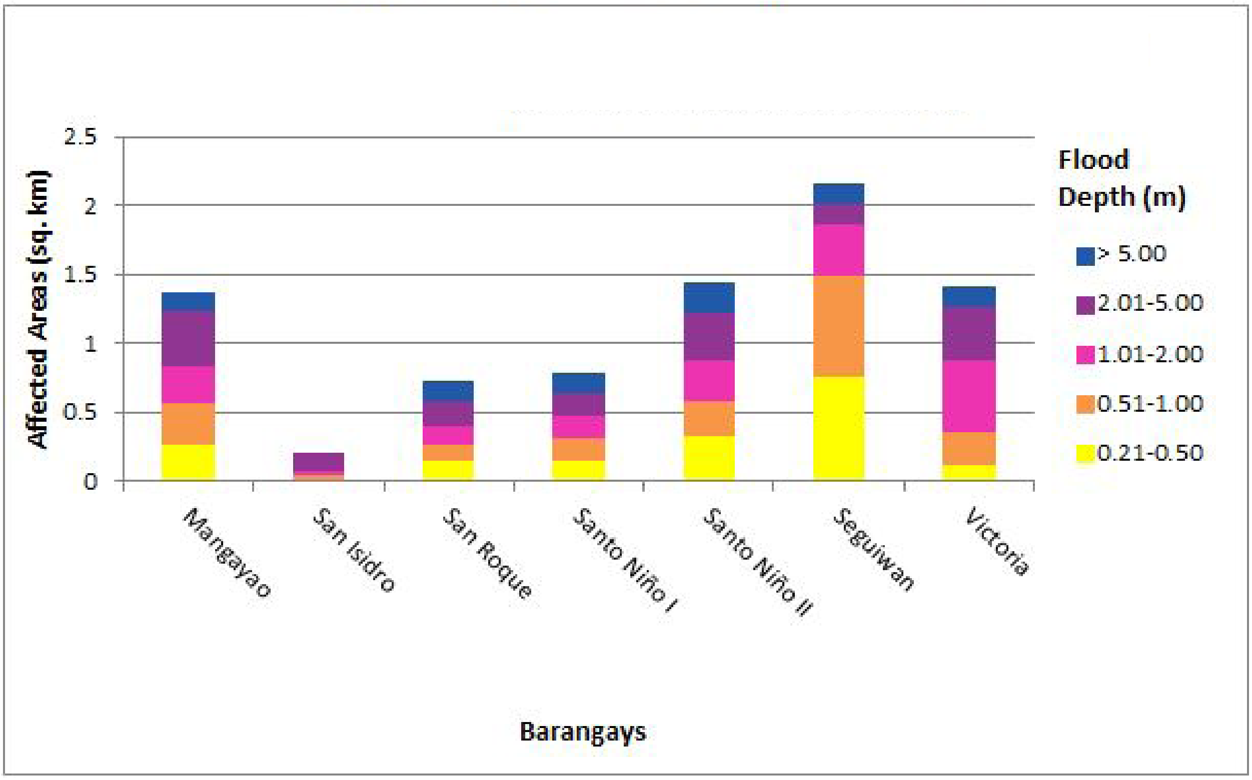


Figure 93. Affected Areas in Tagkawayan, Quezon during 100-Year Rainfall Return Period.

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

Table 41. Area covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	11.46	9.30	8.66
Medium	19.74	19.74	17.26
High	13.25	21.93	28.75
Total	**44.45**	**50.97**	**54.67**

Of the 14 identified Education Institutes in Vinas Flood plain, three (3) schools were found exposed to Medium-level flooding in the 5-year scenario. For the 25- and 100-year scenarios, 1 school was found exposed to medium-level flooding, while 2 schools were discovered exposed to high-level flooding. See ANNEX 12 for a detailed enumeration of schools in the Vinas floodplain.

Of the eight (8) Medical Institutions were identified in the Vinas Floodplain, none were assessed to be exposed to any flood levels for all the rain scenarios. See ANNEX 13 for a detailed enumeration of hospitals and clinics in the Vinas floodplain.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 94.

The flood validation survey was conducted in December 2016. The flood validation consists of 180 points randomly selected all over the Vinas flood plain. Comparing it with the flood depth of the nearest storm event, the map has an RMSE value of 0.72m. The validation points are found in ANNEX 11.

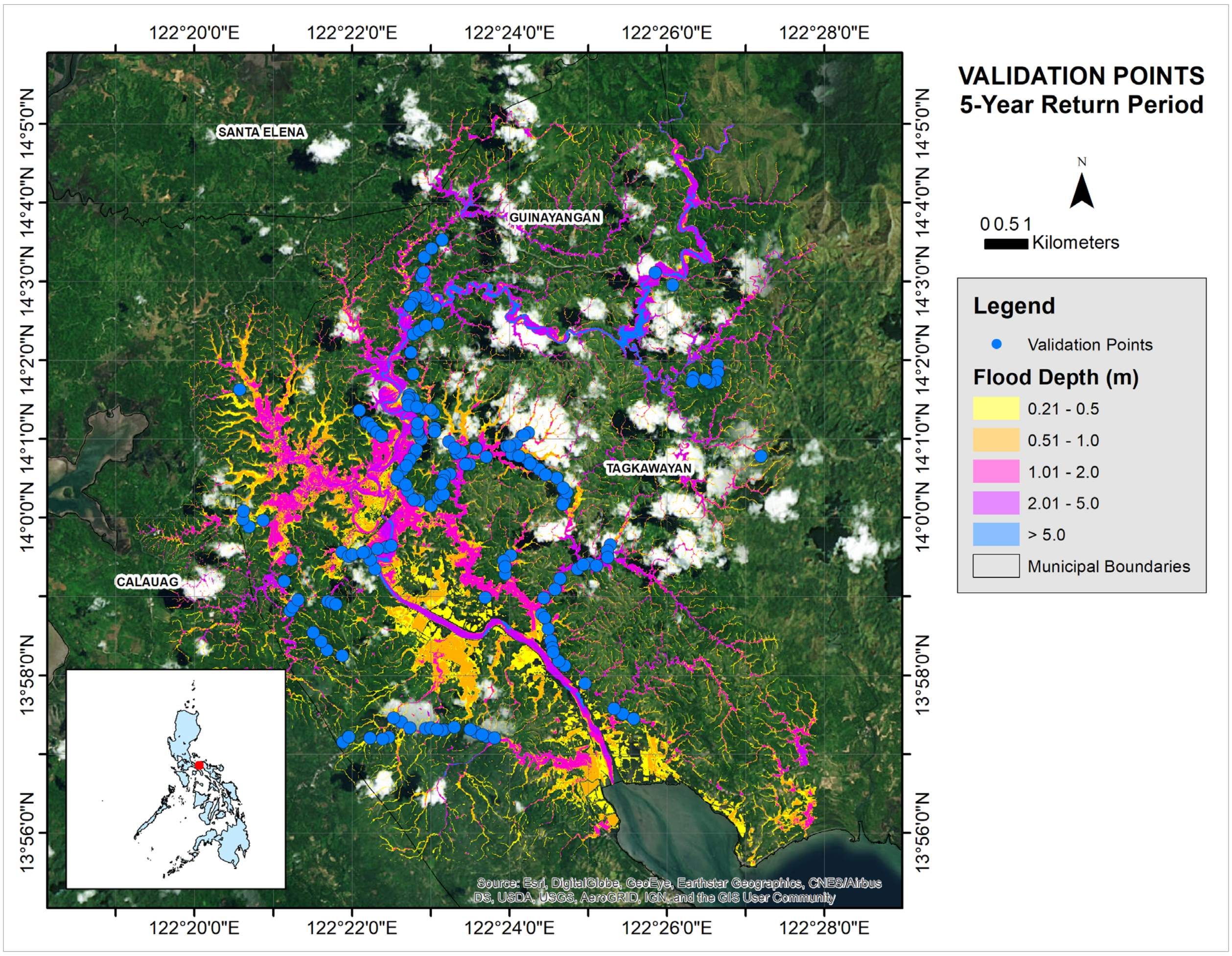


Figure 94. Validation Points for a 5-year Flood Depth Map of the Vinas Floodplain.

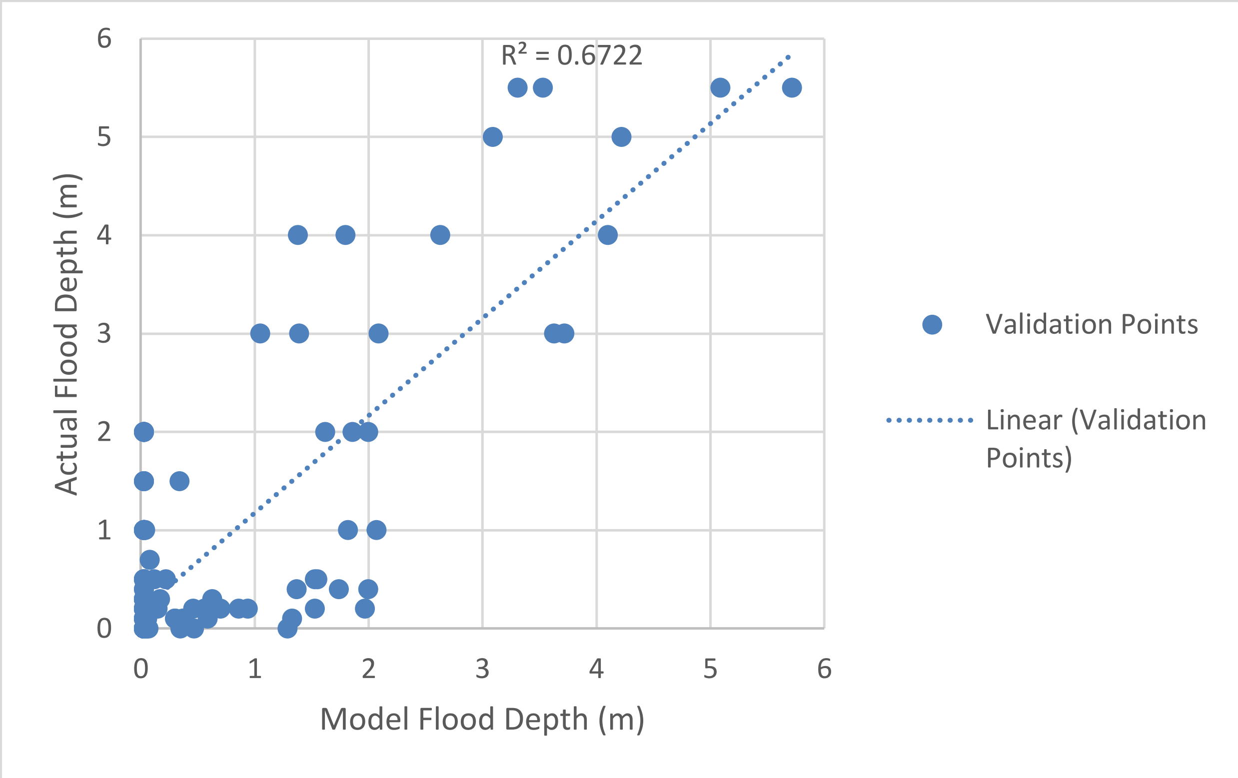


Figure 95. Flood depth map vs actual flood depth.

Table 42. Actual Flood Depth versus Simulated Flood Depth at different levels in the Vinas River Basin.

VINAS BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	103	6	5	4	0	0	**118**
	0.21-0.50	18	1	1	5	0	0	**25**
	0.51-1.00	8	0	0	1	1	0	**10**
	1.01-2.00	8	1	0	3	0	0	**12**
	2.01-5.00	0	0	0	4	7	0	**11**
	> 5.00	0	0	0	0	2	2	**4**
	Total	**137**	**8**	**6**	**17**	**10**	**2**	**180**

On the whole, the overall accuracy generated by the flood model is estimated at 64.44%, with 116 points correctly matching the actual flood depths. In addition, there were 32 points estimated one level above and below the correct flood depths while there were 20 points and 12 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 4 points were overestimated while a total of 41 points were underestimated in the modelled flood depths of Vinas. Table 43 depicts the summary of the Accuracy Assessment in the Vinas River Basin Flood Depth Map.

Table 43. Summary of the Accuracy Assessment in the Vinas River Basin Survey.

	No. of Points	%
Correct	116	64.44
Overestimated	23	12.78
Underestimated	41	22.78
Total	**180**	**100.00**

REFERENCES

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

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

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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.

ANNEX

ANNEX 1. Technical Specifications of the LIDAR Sensors used in the Vinas Floodplain Survey

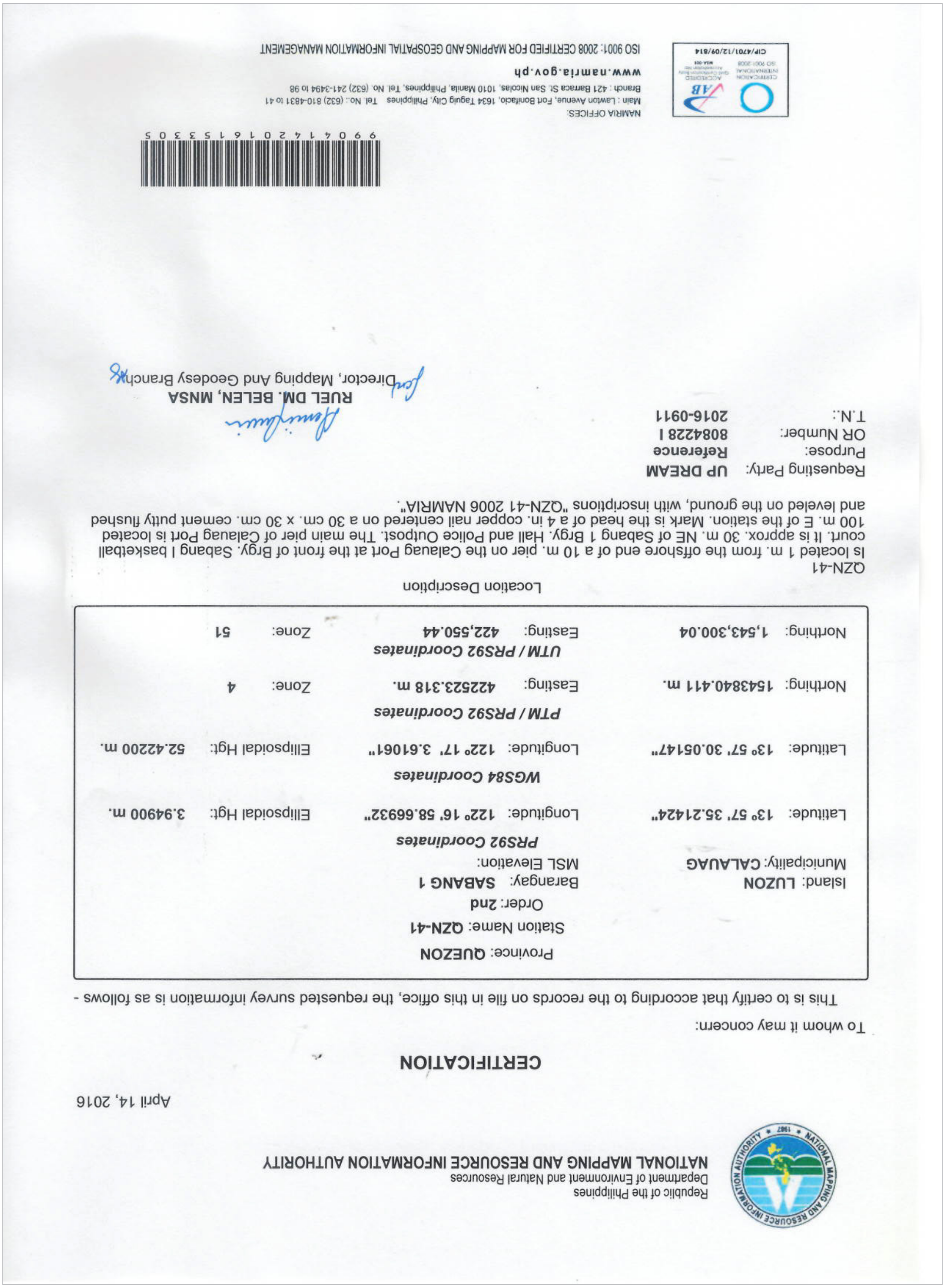
1. PEGASUS SENSOR

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

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

ANNEX 2. NAMRIA certification of reference points used in the LiDAR survey

1. QZN-41



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

April 14, 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: **QUEZON**
Station Name: **QZN-41**
Order: **2nd**

Island: **LUZON** | Barangay: **SABANG 1**
Municipality: **CALAUAG** | MSL Elevation:

PRS92 Coordinates		
Latitude: **13° 57' 35.21424"**	Longitude: **122° 16' 58.66932"**	Ellipsoidal Hgt: **3.94900 m.**
WGS84 Coordinates		
Latitude: **13° 57' 30.05147"**	Longitude: **122° 17' 3.61061"**	Ellipsoidal Hgt: **52.42200 m.**
PTM / PRS92 Coordinates		
Northing: **1543840.411 m.**	Easting: **422523.318 m.**	Zone: **4**
UTM / PRS92 Coordinates		
Northing: **1,543,300.04**	Easting: **422,550.44**	Zone: **51**

Location Description

QZN-41
Is located 1 m. from the offshore end of a 10 m. pier on the Calauag Port at the front of Brgy. Sabang I basketball court. It is approx. 30 m. NE of Sabang 1 Brgy. Hall and Police Outpost. The main pier of Calauag Port is located 100 m. E of the station. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty flushed and leveled on the ground, with inscriptions "QZN-41 2006 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0911**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 QZN-41

2. CMN-33

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

March 11, 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: **CAMARINES NORTE**
Station Name: **CMN-33**
Order: **2nd**

Island: **LUZON**		Barangay: **BATOBALANI**	
Municipality: **JOSE PANGANIBAN**		MSL Elevation:	

PRS92 Coordinates

Latitude:	**14° 14' 11.70144"**	Longitude:	**122° 44' 31.91442"**	Ellipsoidal Hgt:	**8.58900 m.**

WGS84 Coordinates

Latitude:	**14° 14' 6.51050"**	Longitude:	**122° 44' 36.82890"**	Ellipsoidal Hgt:	**57.40600 m.**

PTM / PRS92 Coordinates

Northing:	**1574360.987 m.**	Easting:	**472178.341 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,573,809.93**	Easting:	**472,188.08**	Zone:	**51**

Location Description

CMN-33

From Mun. of Labo, travel NW along Maharlika Highway for about 5.5 Km. up to Brgy. Talobatib, upon reaching Brgy. Talobatib turn right at road junction, then travel for about 7 Km. up to Brgy. Batobalani. Station is located at Brgy. Batobalani. It was established NW wing of Malaquit Bridge, 100 m S of road junction going to Paracale. Mark is the head of a 3 in. copper nail centered on a drilled hole with 30 cm x 30 cm cement putty, embedded at concrete bridge, with inscriptions, "CMN-33, 2007, NAMRIA".

Requesting Party:	**PHIL-LIDAR 1**
Purpose:	**Reference**
OR Number:	**8090013 I**
T.N.:	**2016-0613**

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

9 9 0 3 1 1 2 0 1 6 1 7 0 5 4 7

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

Figure A-2.2 CMN-33

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

1. AQZN-J2

Table A-3.1 QZN-J2

QZN-41 - QZN-J2 (7:40:15 AM-5:03:12 PM) (S6)

Baseline observation:	QZN-41 --- QZN-J2 (B7)
Processed:	4/17/2016 10:34:34 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.000 m
Maximum PDOP:	3.898
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/11/2016 7:40:15 AM (Local: UTC+8hr)
Processing stop time:	4/11/2016 5:03:12 PM (Local: UTC+8hr)
Processing duration:	09:22:57
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	QZN-41				
Grid		**Local**		**Global**	
Easting	422550.436 m	**Latitude**	N13°57'35.21425"	**Latitude**	N13°57'30.05147"
Northing	1543300.040 m	**Longitude**	E122°16'58.66932"	**Longitude**	E122°17'03.61061"
Elevation	3.725 m	**Height**	3.949 m	**Height**	52.422 m

To:	QZN-J2				
Grid		**Local**		**Global**	
Easting	422553.956 m	**Latitude**	N13°57'34.99489"	**Latitude**	N13°57'29.83213"
Northing	1543293.290 m	**Longitude**	E122°16'58.78731"	**Longitude**	E122°17'03.72860"
Elevation	3.819 m	**Height**	4.043 m	**Height**	52.516 m

Vector					
ΔEasting	3.520 m	**NS Fwd Azimuth**	152°17'06"	**ΔX**	-3.911 m
ΔNorthing	-6.750 m	**Ellipsoid Dist.**	7.615 m	**ΔY**	-0.440 m
ΔElevation	0.094 m	**ΔHeight**	0.094 m	**ΔZ**	-6.519 m

2. CMN-J2

Table A-3.2 CMN-J2

Vector Components (Mark to Mark)

From:	CMN-33				
Grid		Local		Global	
Easting	472188.079 m	Latitude	N14°14'11.70144"	Latitude	N14°14'06.51050"
Northing	1573809.933 m	Longitude	E122°44'31.91442"	Longitude	E122°44'36.82890"
Elevation	8.054 m	Height	8.589 m	Height	57.406 m

To:	CMN-J2				
Grid		Local		Global	
Easting	455138.726 m	Latitude	N14°08'53.88940"	Latitude	N14°08'48.70654"
Northing	1564071.272 m	Longitude	E122°35'03.56309"	Longitude	E122°35'08.48618"
Elevation	51.090 m	Height	51.531 m	Height	100.212 m

Vector					
ΔEasting	-17049.354 m	NS Fwd Azimuth	240°12'06"	ΔX	13031.656 m
ΔNorthing	-9738.661 m	Ellipsoid Dist.	19642.244 m	ΔY	11248.492 m
ΔElevation	43.036 m	ΔHeight	42.942 m	ΔZ	-9458.830 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.007 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.011 m
σ ΔElevation	0.014 m	σ ΔHeight	0.014 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000516438		
Y	-0.0000773807	0.0001288439	
Z	-0.0000233071	0.0000375098	0.0000122595

Occupations

	From	To
Point ID:	CMN-33	CMN-J2
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(1)\CMN-33 (Topcon) 1.403M [04-08-16].16O	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(1)\CMN-J2 (Modular) 1.500M [04-08-16].T02
Receiver type:	Unknown	SPS852
Receiver serial number:	U034ESOECQW	5217K84538
Antenna type:	CR.G5	Zephyr Geodetic 2 RoHS
Antenna serial number:	-Unknown-	--------
Antenna height (measured):	1.403 m	1.500 m
Antenna method:	Bottom of antenna mount	Bottom of notch

Tracking Summary

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. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. KENNETH QUISADO	
		JERIEL PAUL ALAMBAN	
Ground Survey	RA	JASMIN DOMINGO	
LiDAR Operation	Airborne Security	TSG. BENJIE CARBOLLEDO	Philippine Air Force (PAF)
	Pilot	CAPT. CESAR ALFONSO III	Asian Aerospace Corporation (AAC)
		CAPT. KHALIL ANTHONY CHI	

ANNEX 5. Data Transfer Sheet for Vinas Floodplain

DATA TRANSFER SHEET

BAGASBAS 5/11/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
April 7,2016	23226P	1BLK20D098A	PEGASUS	NA	506	11.3	226	NA	NA	26.6	NA	130	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 8,2016	23230P	1BLK20A099A	PEGASUS	NA	587	14	287	NA	NA	29.8	NA	112	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 9,2016	23234P	1BLK20D100A	PEGASUS	NA	213	5.3	132	24	202	12.6	NA	138	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 11,2016	23242P	1BLK20A102A	PEGASUS	NA	32	14.2	291	66	478	29	NA	165	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 11,2016	23244P	1BLK20B102B	PEGASUS	NA	247	6.06	158	24.3	180	12.9	NA	165	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April13,2016	23250P	1BLK20G104A	PEGASUS	NA	NA	15.4	306	69.7	520	34.4	NA	90.5	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 13,2016	23252P	1BLK20C104B	PEGASUS	NA	NA	6.34	174	687	7.8	14.5	NA	90.5	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 14,2016	23254P	1BLK20F105A	PEGASUS	NA	NA	6.95	176	14.6	114	8.7	NA	106	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 15,2016	23258P	1BLK20H106A	PEGASUS	NA	NA	13.7	295	NA	NA	28.3	NA	184	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 15,2016	23260P	1BLK20F106B	PEGASUS	NA	NA	4.92	93.7	NA	NA	11.1	NA	184	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

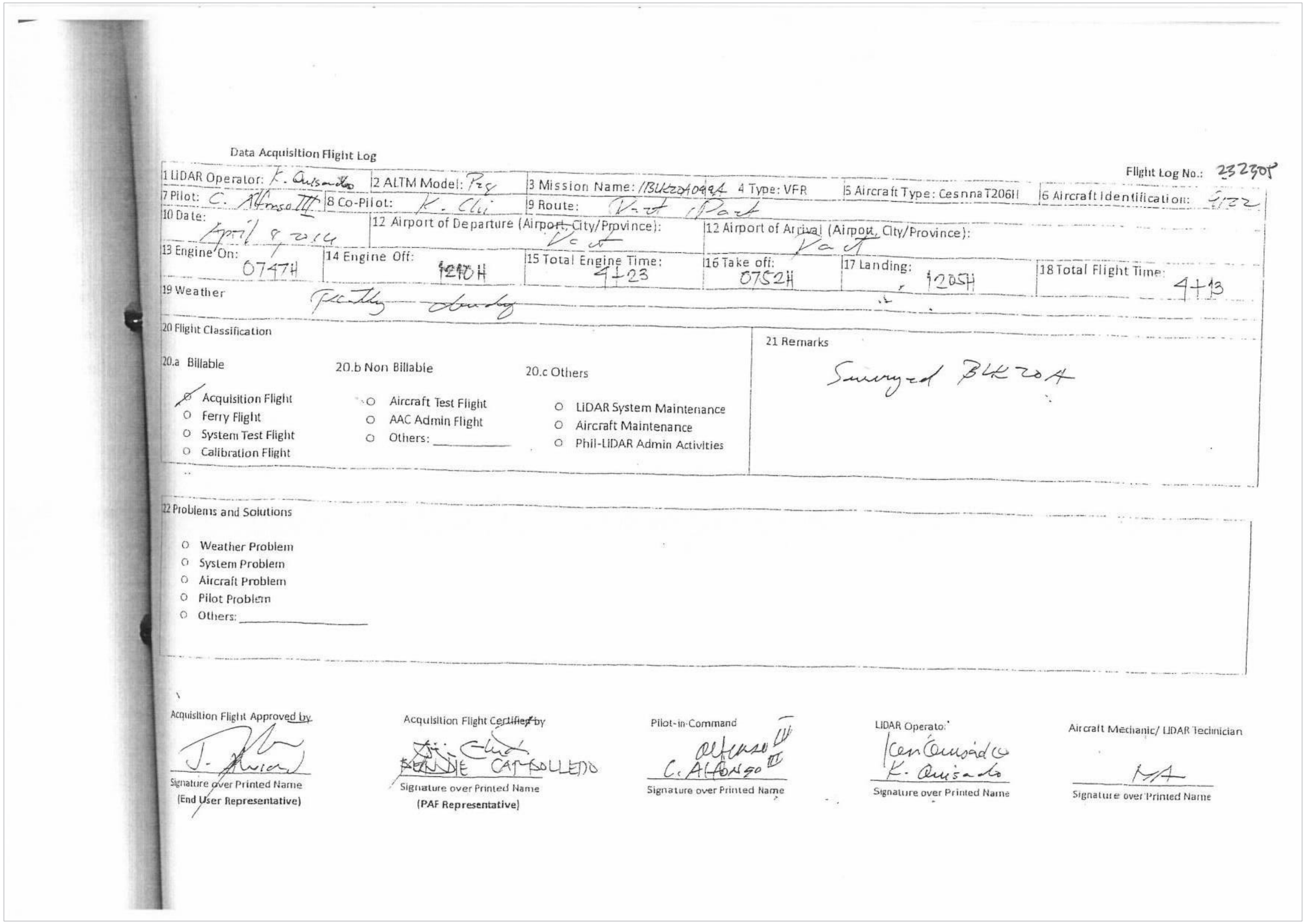
Name AC Bongat
Position SSRS
Signature 5/16/16

16-30

Figure A-5.1 Transfer Sheet for Vinas Floodplain - A

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 23230P Mission



Data Acquisition Flight Log

Flight Log No.: 23230P

1 LIDAR Operator: K. Quisado | 2 ALTM Model: Peg | 3 Mission Name: 1BLK20A099A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9122

7 Pilot: C. Alfonso III | 8 Co-Pilot: K. Chi | 9 Route:

10 Date: April 8 2014 | 12 Airport of Departure (Airport, City/Province): | 12 Airport of Arrival (Airport, City/Province):

13 Engine On: 0747H | 14 Engine Off: 1210H | 15 Total Engine Time: 4+23 | 16 Take off: 0752H | 17 Landing: 1205H | 18 Total Flight Time: 4+13

19 Weather: Partly cloudy

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20A

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

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

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

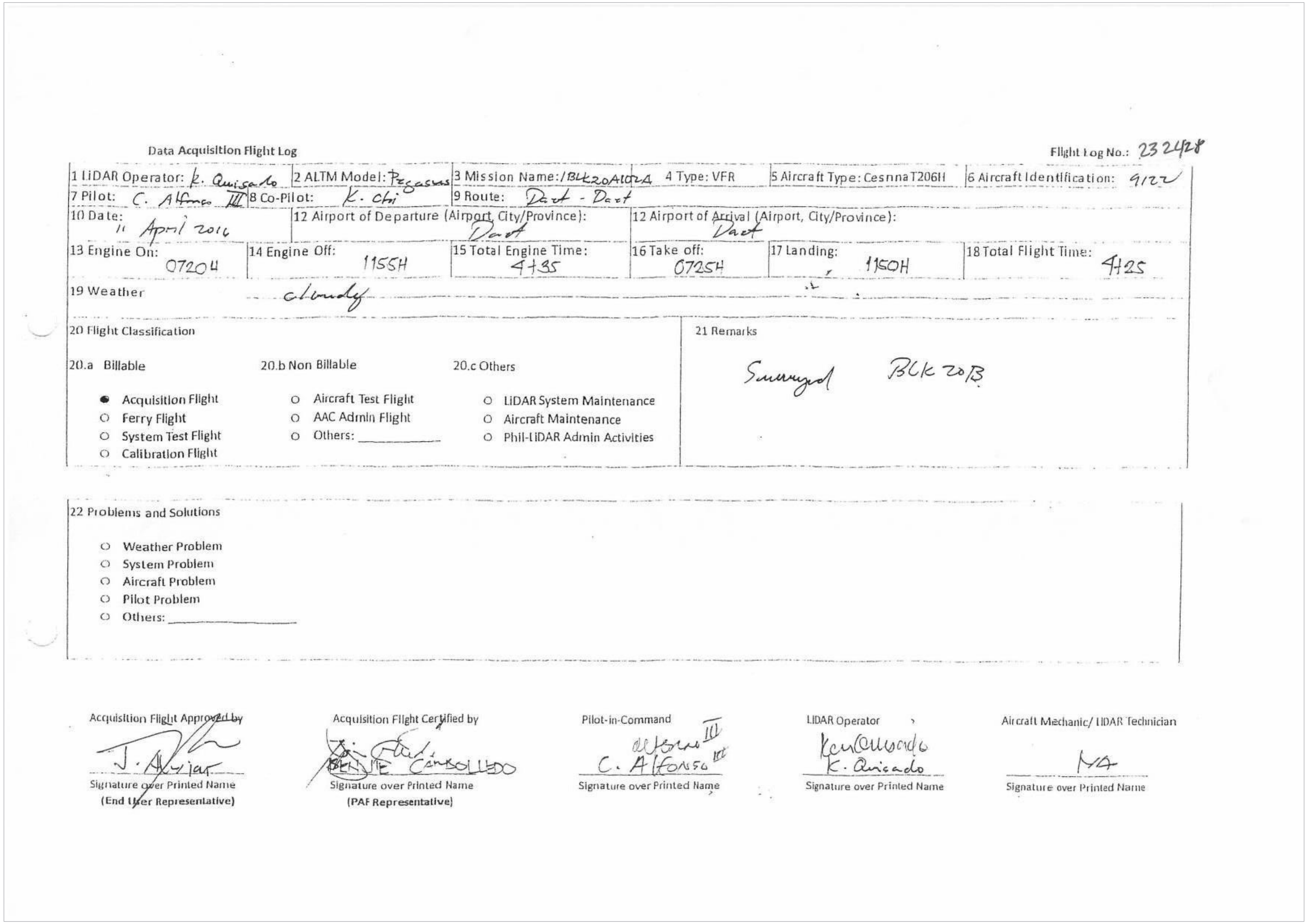
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LIDAR Operator: K. Quisado — Signature over Printed Name

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

Figure A-6.1 Flight Log for Mission 23230

2. Flight Log for 23242P Mission



Data Acquisition Flight Log

Flight Log No.: 232428

1 LIDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: /BLK20A102A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: 11 April 2016	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0720H	14 Engine Off: 1155H	15 Total Engine Time: 4+35	16 Take off: 0725H	17 Landing: 1150H	18 Total Flight Time: 4+25
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20B

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

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

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

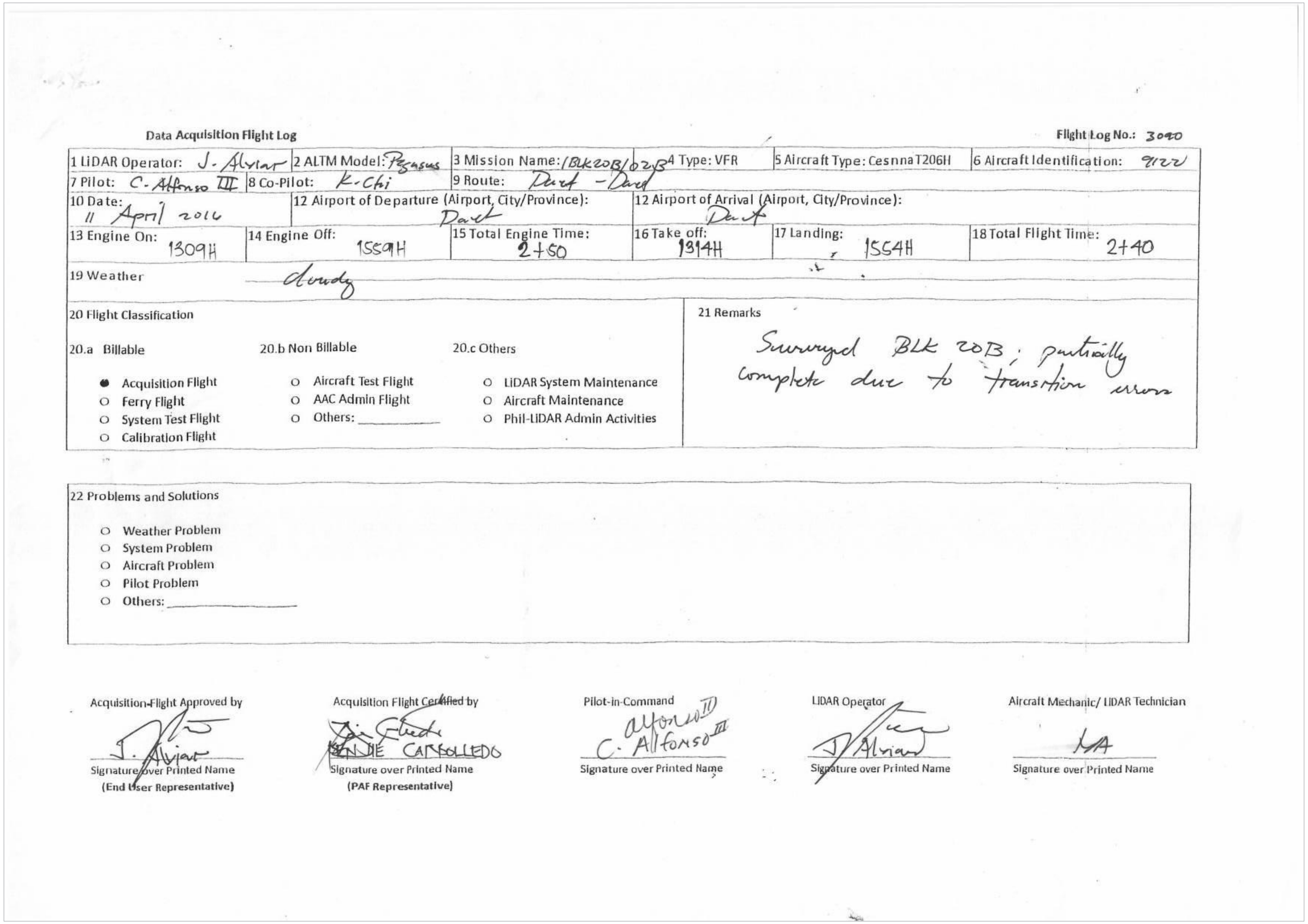
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LIDAR Operator: K. Quisado — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

Figure A-6.2 Flight Log for Mission 23242P

3. Flight Log for 23244P Mission



Data Acquisition Flight Log

Flight Log No.: 3040

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20B102B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Davt - Davt			
10 Date: 11 April 2016	12 Airport of Departure (Airport, City/Province): Davt		12 Airport of Arrival (Airport, City/Province): Davt		
13 Engine On: 1309H	14 Engine Off: 1559H	15 Total Engine Time: 2+50	16 Take off: 1314H	17 Landing: 1554H	18 Total Flight Time: 2+40
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20B; partially complete due to transition errors

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Alviar	[illegible] Carbolledo	C. Alfonso III	J. Alviar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3 Flight Log for Mission 23244P

4. Flight Log for 23252P Mission

Data Acquisition Flight Log — Flight Log No.: 3098

1 LiDAR Operator: JP Alamban	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20104B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 13, 2016	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 1311H	14 Engine Off: 1610H	15 Total Engine Time: 2+59	16 Take off: 1316H	17 Landing: 1605H	18 Total Flight Time: 2+49
19 Weather: partly cloudy					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
● Acquisition Flight	o Aircraft Test Flight	o LiDAR System Maintenance
o Ferry Flight	o AAC Admin Flight	o Aircraft Maintenance
o System Test Flight	o Others: ______	o Phil-LiDAR Admin Activities
o Calibration Flight		

21 Remarks

Surveyed BLK 20C

22 Problems and Solutions

- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ______

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Alviar	Bennie Carbolledo	C. Alfonso III	JP Alamban	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.4 Flight Log for Mission 23252P

ANNEX 7. Flight Status Reports

CAMARINES SUR & QUEZON
(April 4-18, 2016)

Table A-7.1. Flight Status Report

Flight No	Area	Mission	Operator	Date Flown	Remarks
23230P	BLK 20A	1BLK20A099A	K QUISADO	APRIL 8	SURVEYED BLK 20A 244.04 SQ.KM
23242P	BLK 20B	1BLK20A102A	K QUISADO	APRIL 11	SURVEYED VINAS FP 233.83 SQ.KM
23244P	BLK 20C	1BLK20B102B	J ALVIAR	APRIL 11	SURVEYED VINAS FP 103.27 SQ.KM
23252P	BLK 20C	1BLK20C104B	J ALAMBAN	APRIL 13	SURVEYED VINAS< VINAS FPs 82.65 SQ.KM

SWATH PER FLIGHT MISSION

Flight No. : **23230P**
Area: 20A
Mission Name: 1BLK20A099A
Parameters:
ALT 900
PRF 200
SF 30
FOV 50

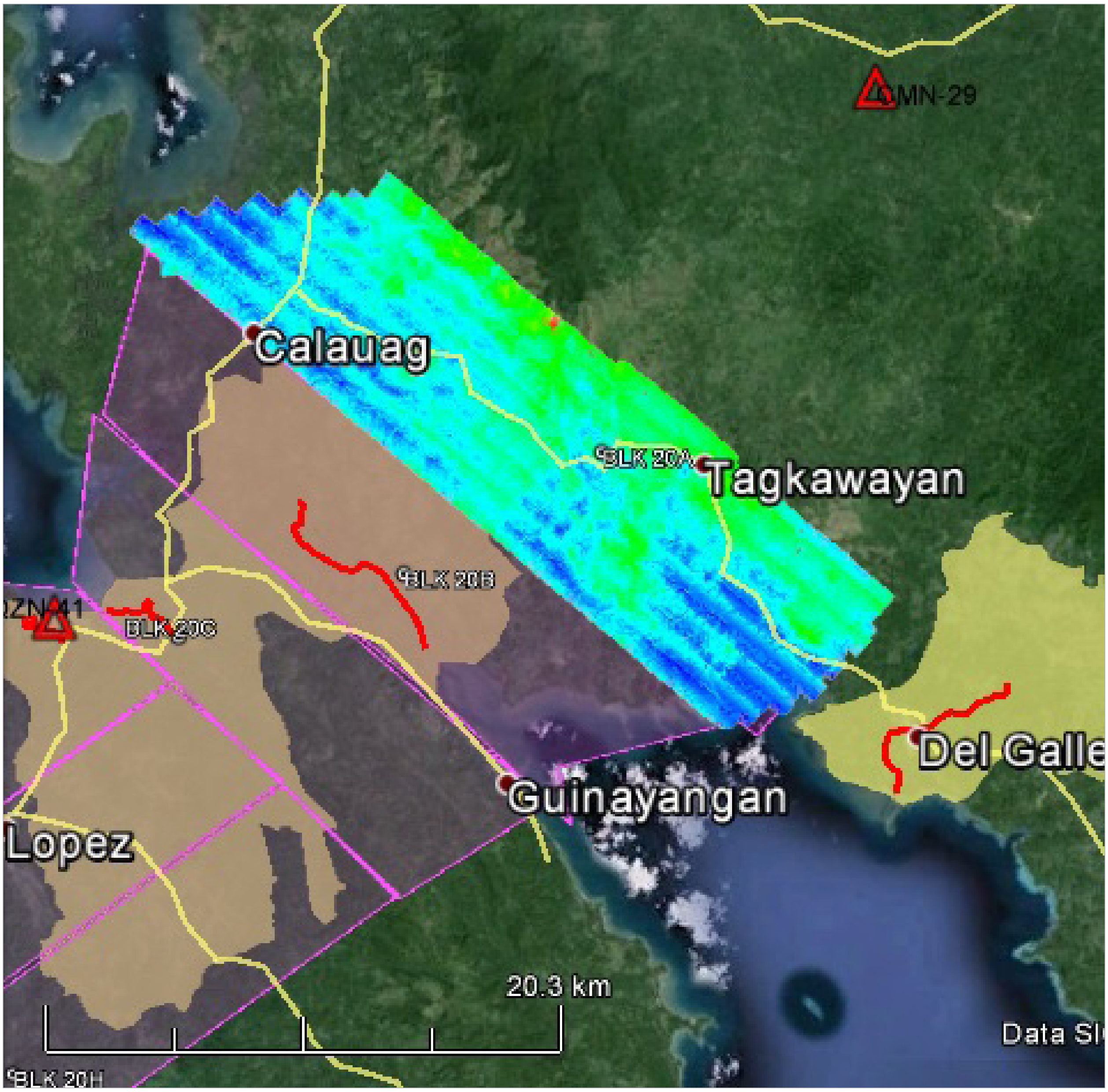


Figure A-7.1 Swath for Flight No. 23230P

Flight No. : **23242P**
Area: 20B
Mission Name: 1BLK20A102A
Parameters:
ALT 700/1100
PRF 200
SF 30
FOV 50

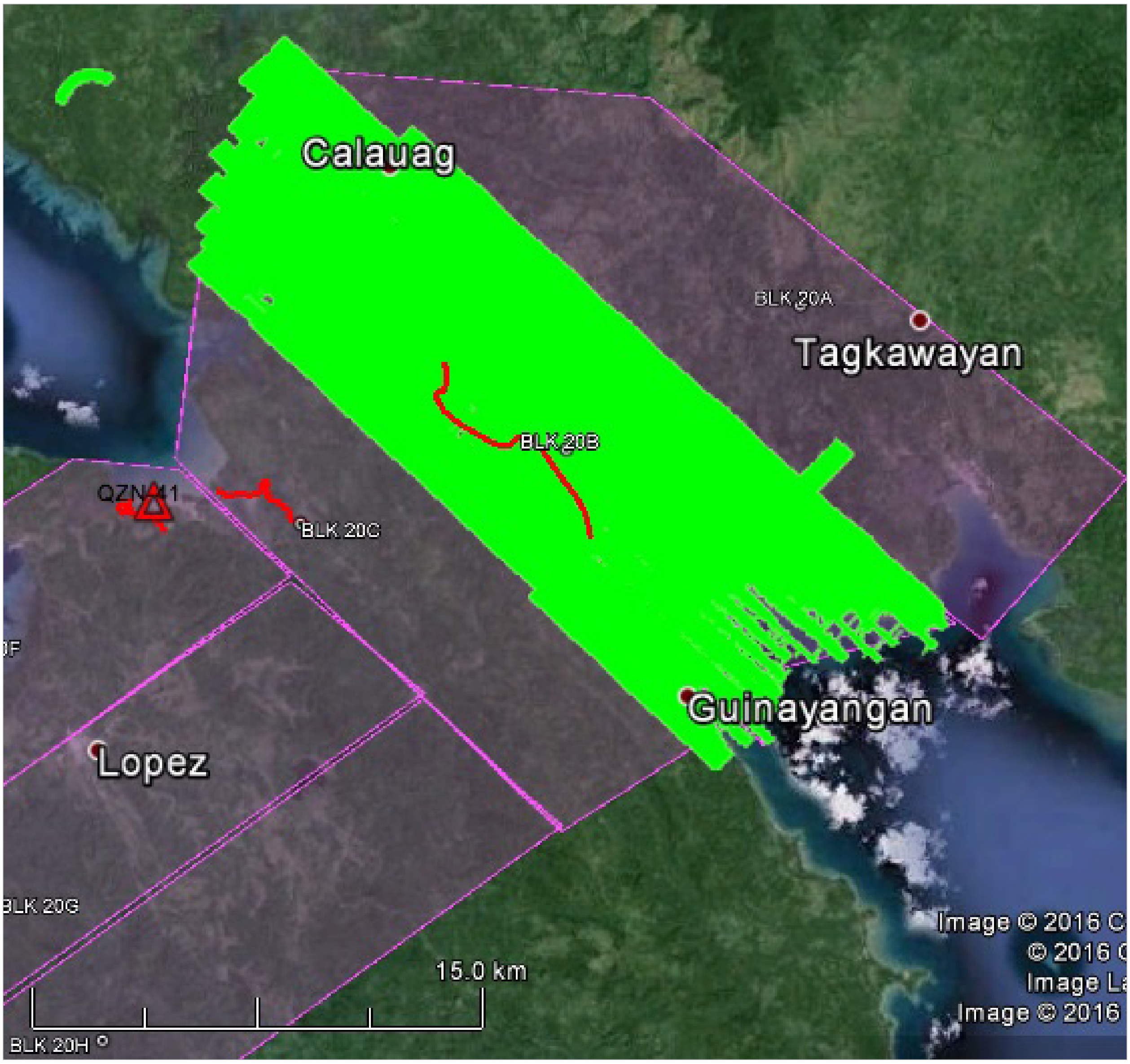


Figure A-7.2 Swath for Flight No. 23242P

Flight No. : **23244P**
Area: 20C
Mission Name: 1BLK20B102B
Parameters:
ALT 800/900
PRF 200
SF 30
FOV 50

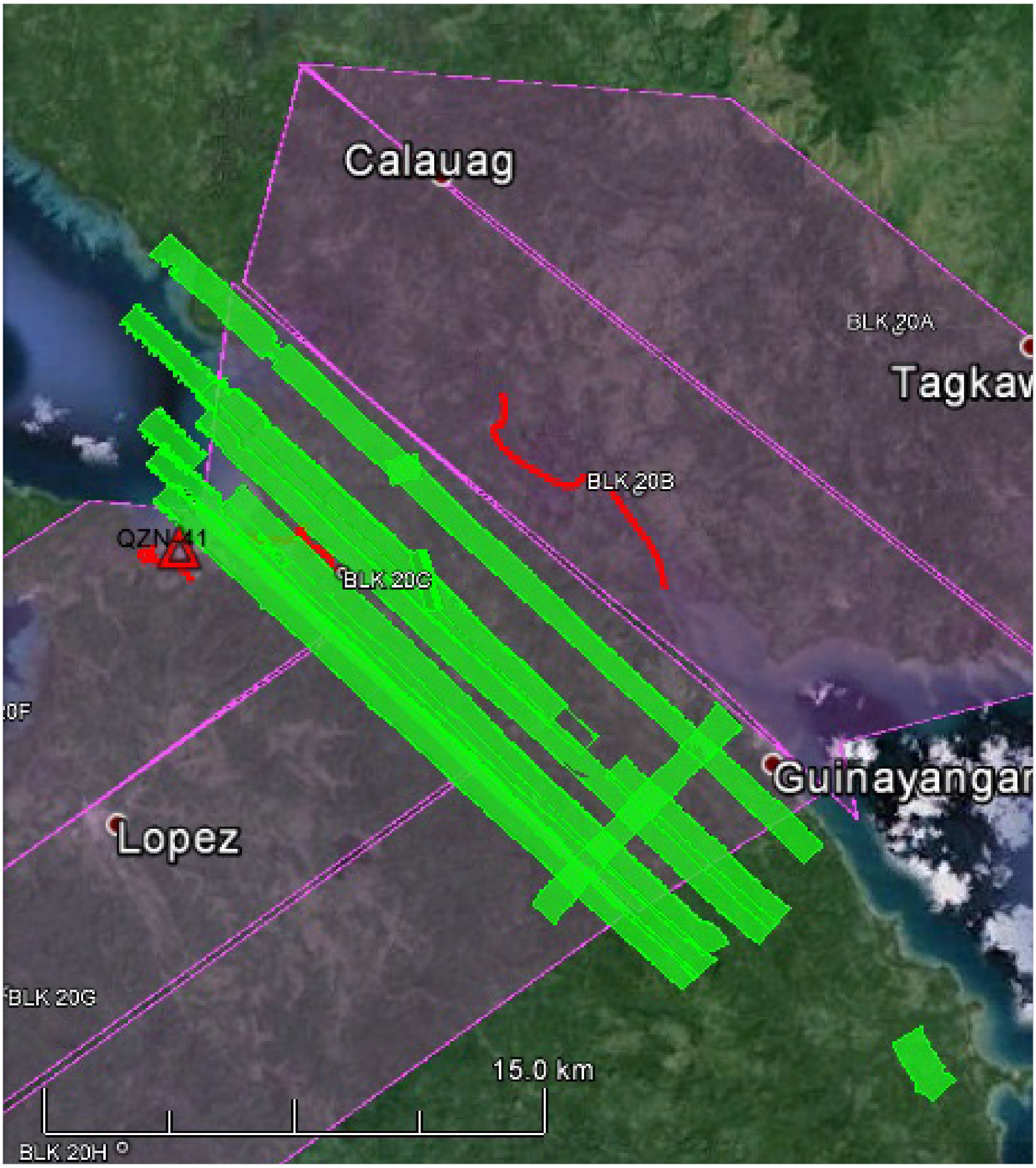


Figure A-7.3 Swath for Flight No. 23244P

Flight No. : **23252P**
Area: 20C
Mission Name: 1BLK20C104B
Parameters:

ALT	900
PRF	200
SF	30
FOV	50

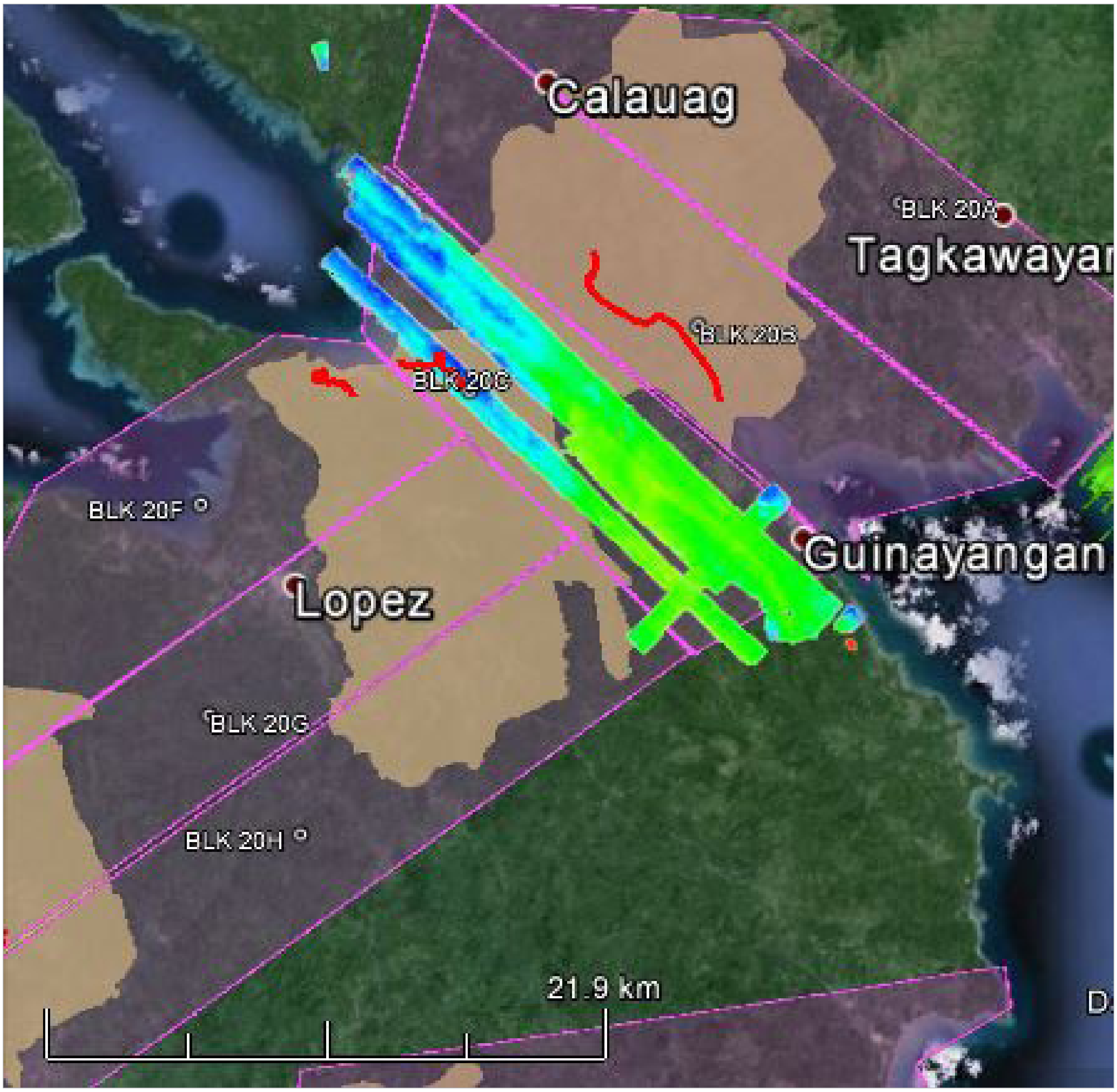


Figure A-7.4 Swath for Flight No. 23252P

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk20F

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20F
Inclusive Flights	23230P
Range data size	29.8 GB
POS data size	287 MB
Base data size	112 MB
Image	n/a
Transfer date	May 16,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000445
IMU attitude correction stdev (<0.001deg)	7.107568
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	29.12%
Ave point cloud density per sq.m. (>2.0)	3.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	296
Maximum Height	359.82
Minimum Height	0.0
Classification (# of points)	
Ground	200360558
Low vegetation	140127872
Medium vegetation	455595296
High vegetation	846243143
Building	17105632
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga, Jr., Engr. Elainne Lopez

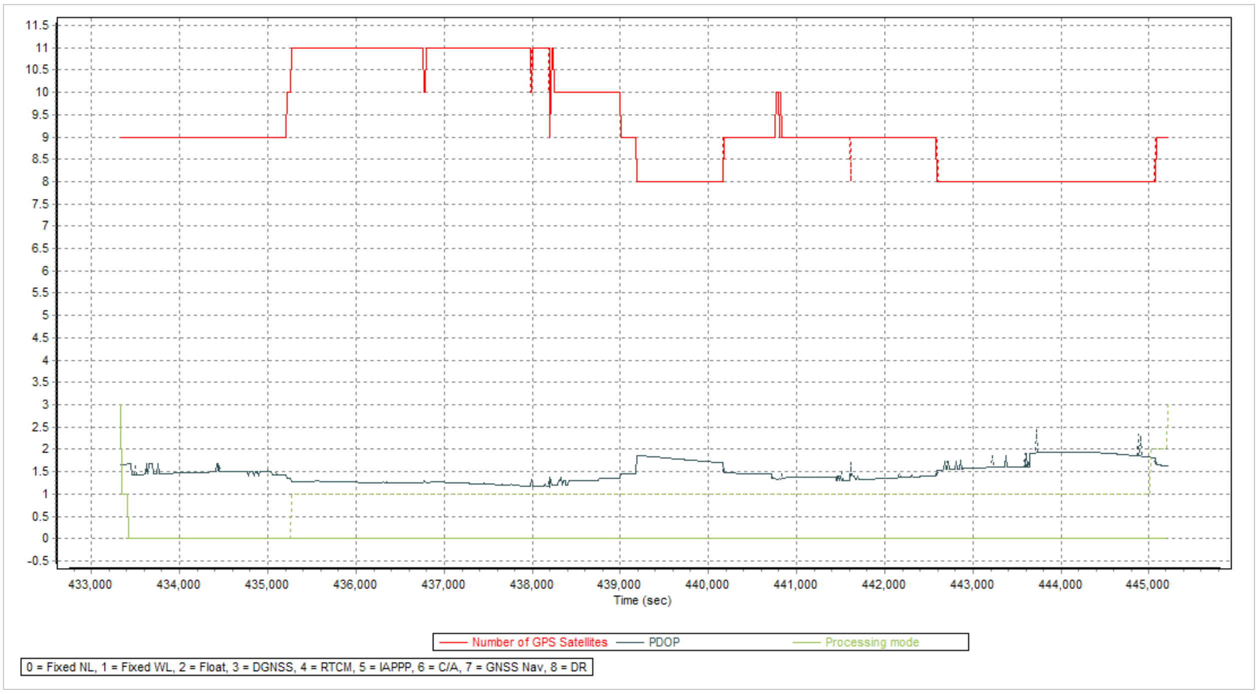


Figure A-8.1 Solution Status

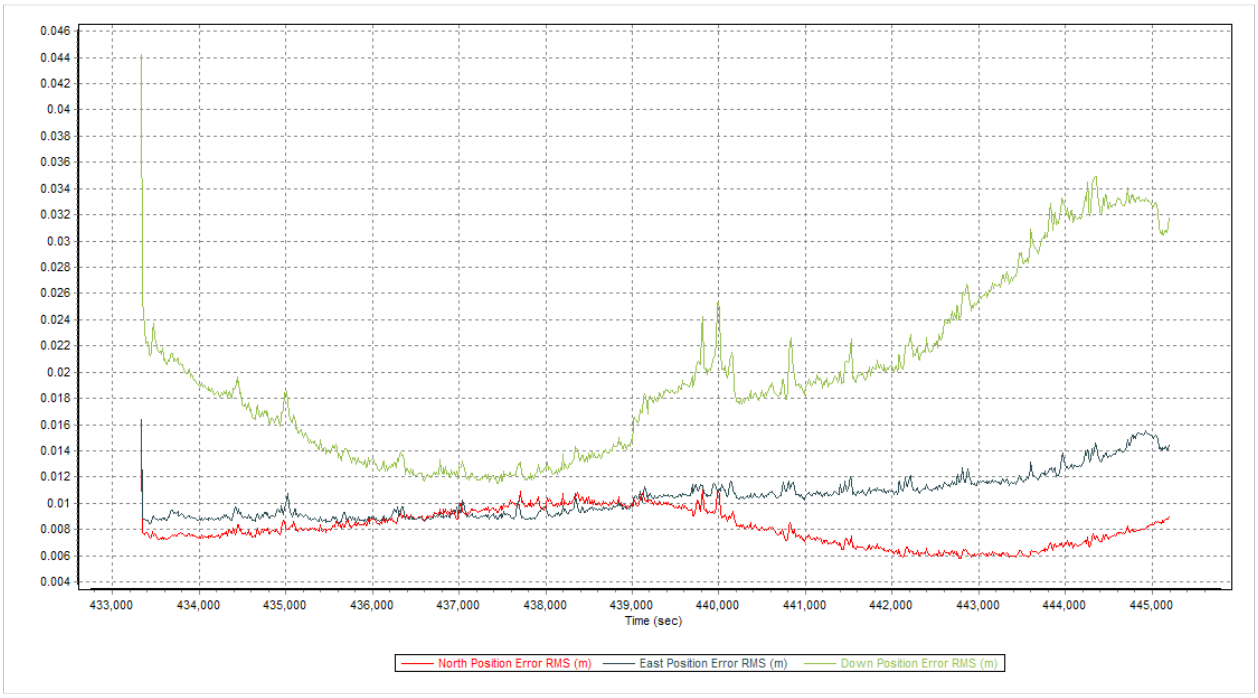


Figure A-8.2 Smoothed Performance Metric Parameters

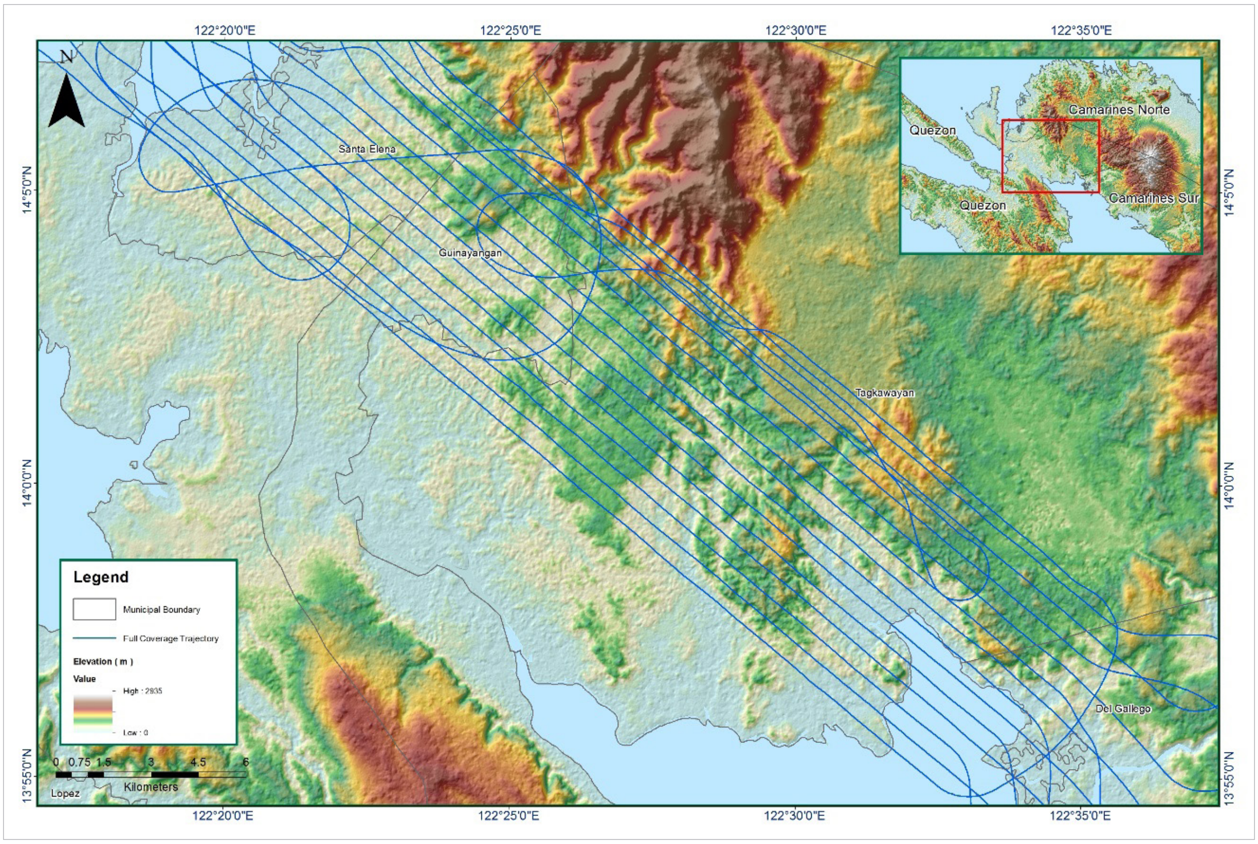


Figure A-8.3 Best Estimated Trajectory

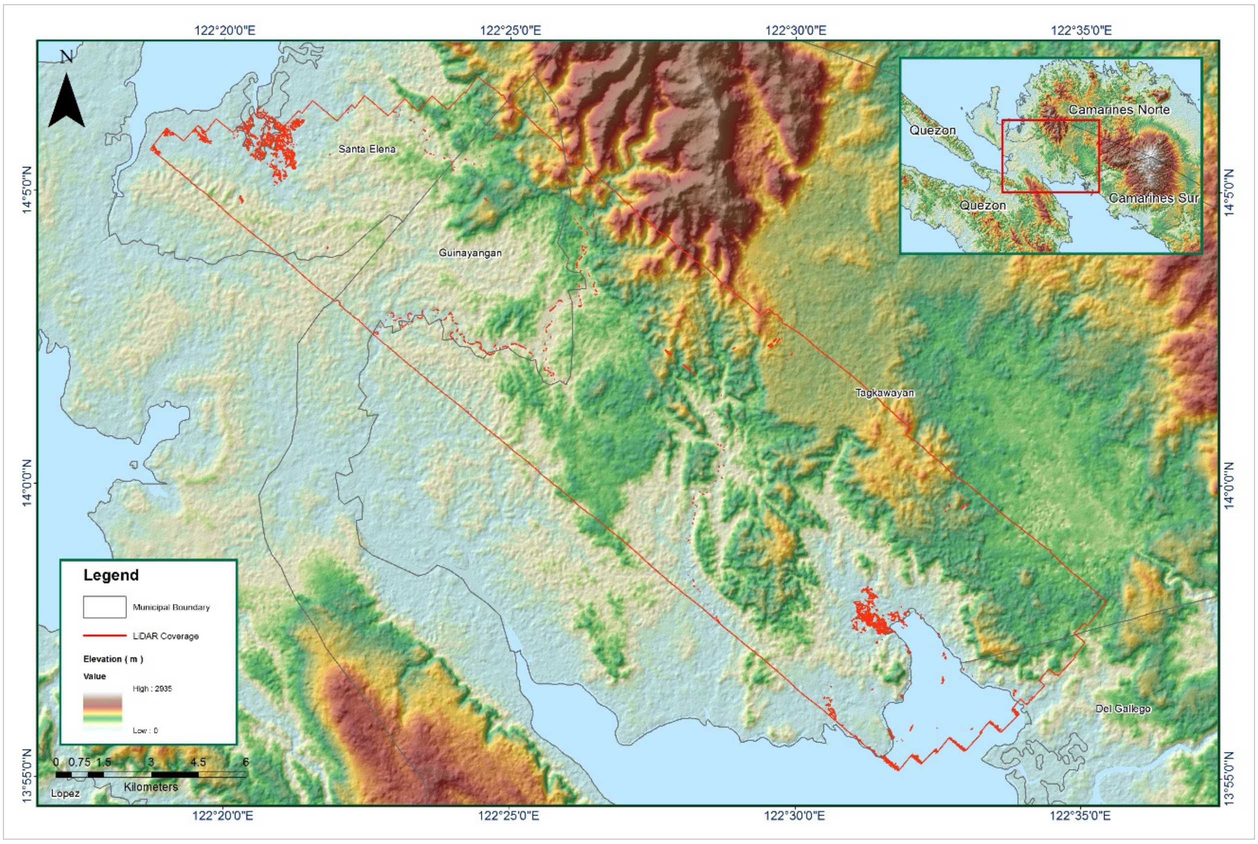


Figure A-8.4 Coverage of LiDAR data

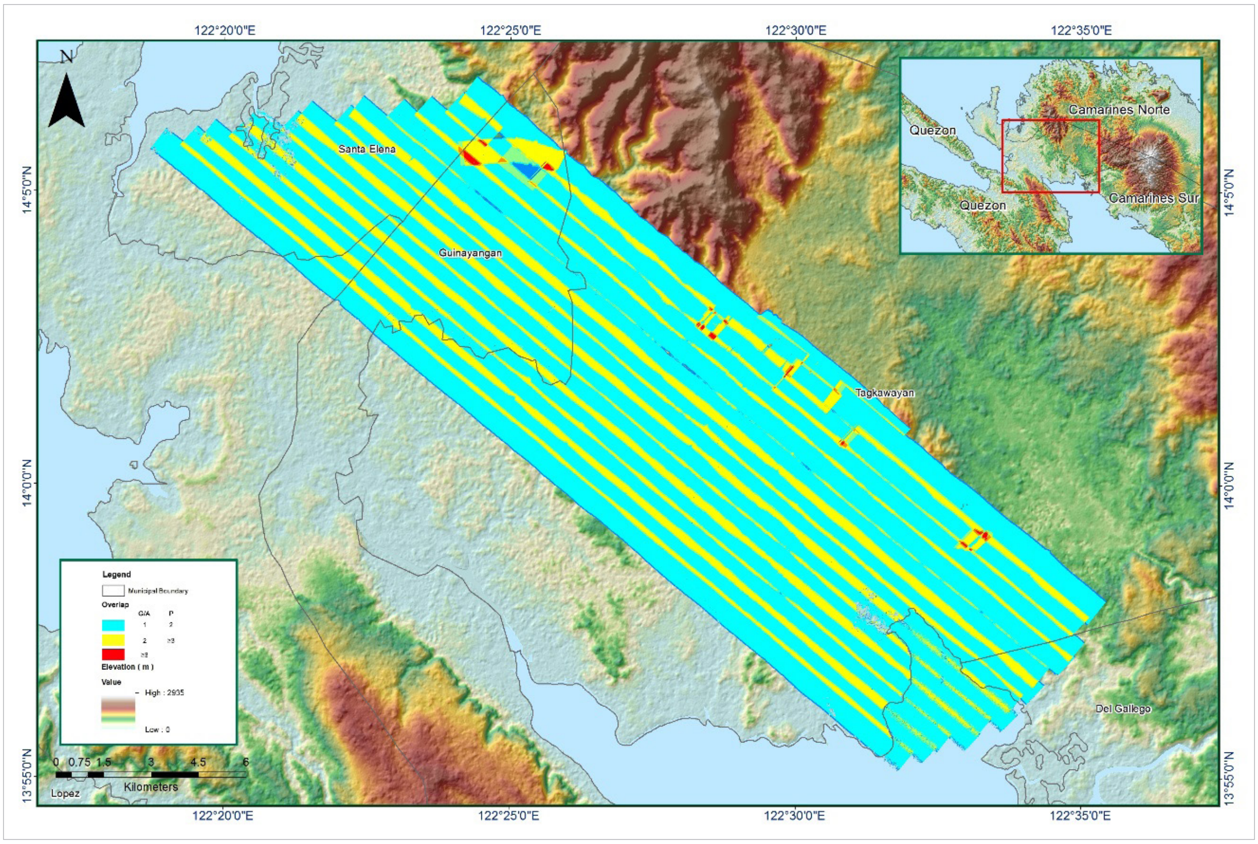


Figure A-8.5 Image of data overlap

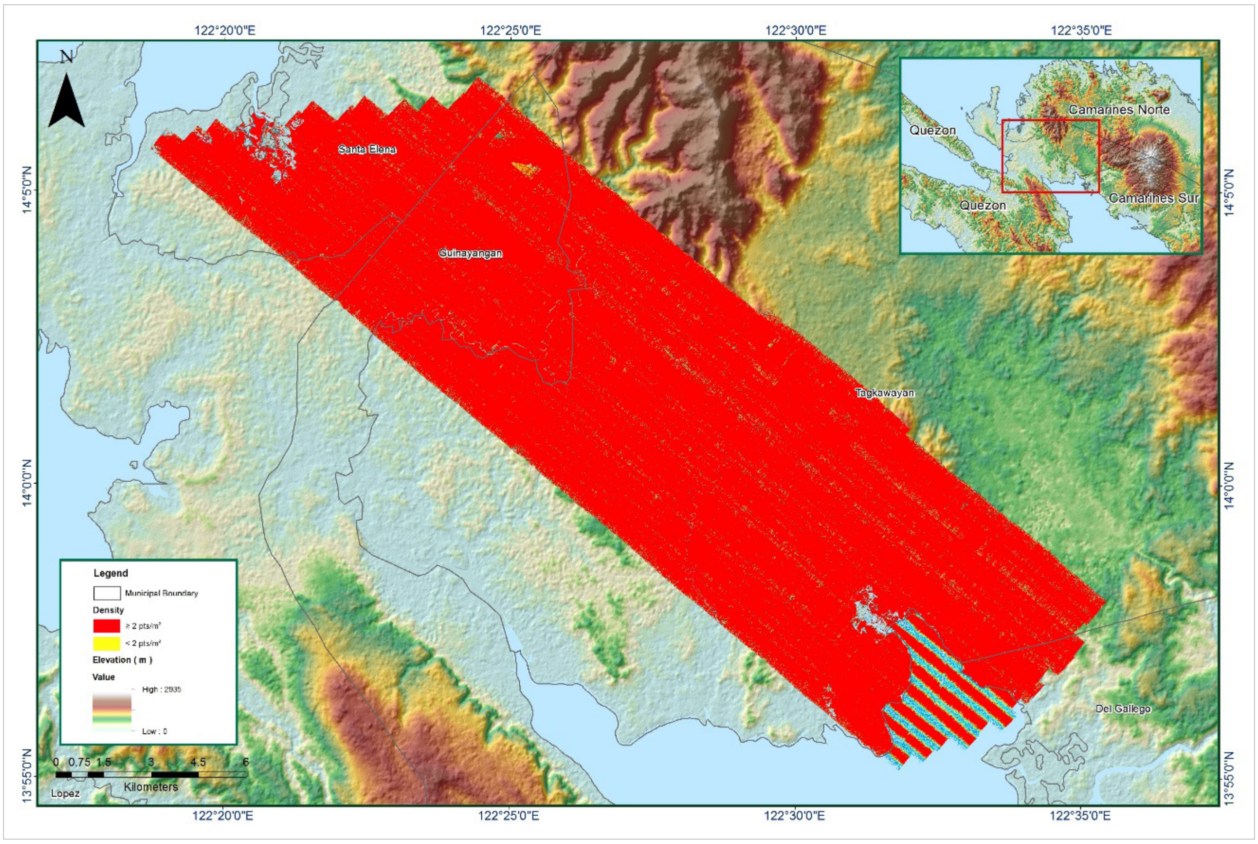


Figure A-8.6 Density map of merged LiDAR data

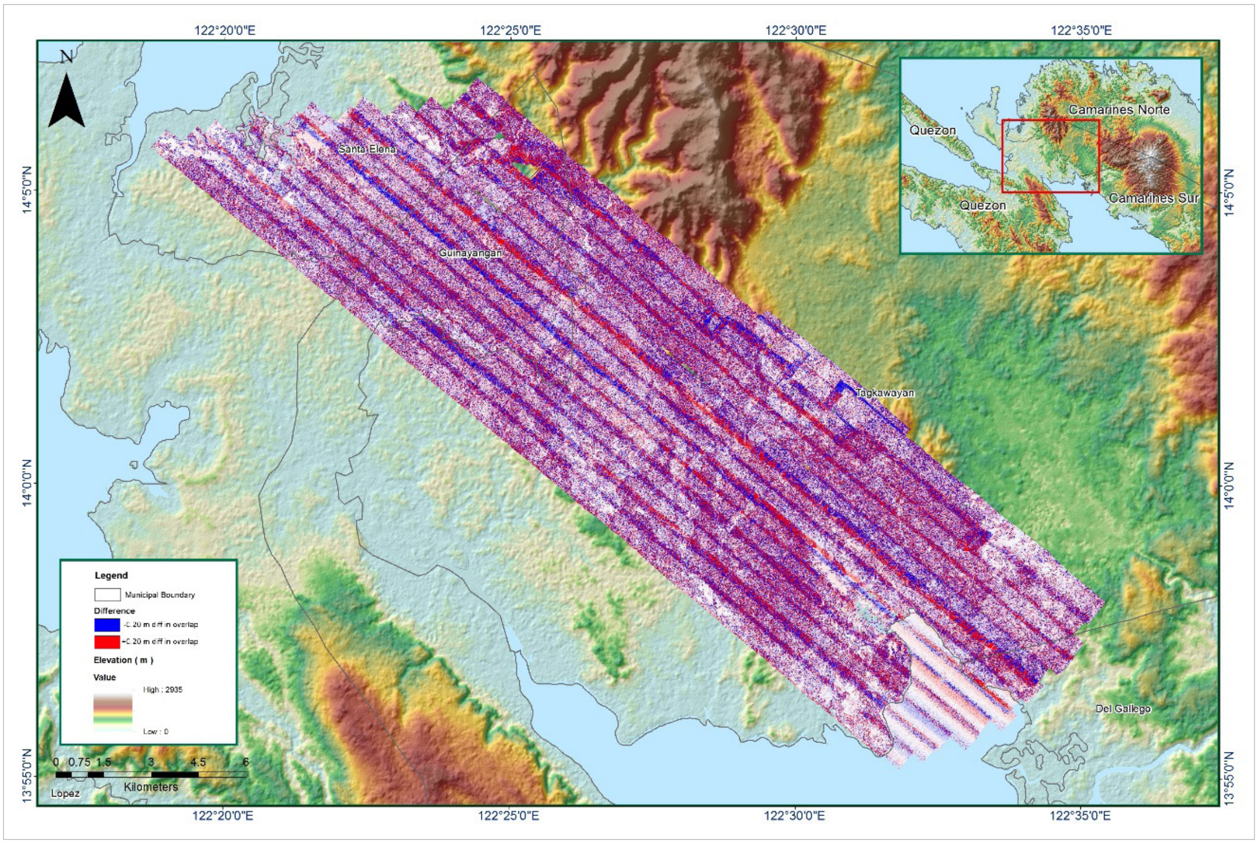


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk20G

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20G
Inclusive Flights	23242P
Range data size	29 GB
POS data size	291 MB
Base data size	165 MB
Image	n/a
Transfer date	May 16,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.5
Boresight correction stdev (<0.001deg)	0.000284
IMU attitude correction stdev (<0.001deg)	0.001684
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	38.27%
Ave point cloud density per sq.m. (>2.0)	3.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	289
Maximum Height	276.85
Minimum Height	39.01
Classification (# of points)	
Ground	179898818
Low vegetation	136928073
Medium vegetation	363415763
High vegetation	720205860
Building	12564567
Orthophoto	
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga, Jr., Engr. Elainne Lopez

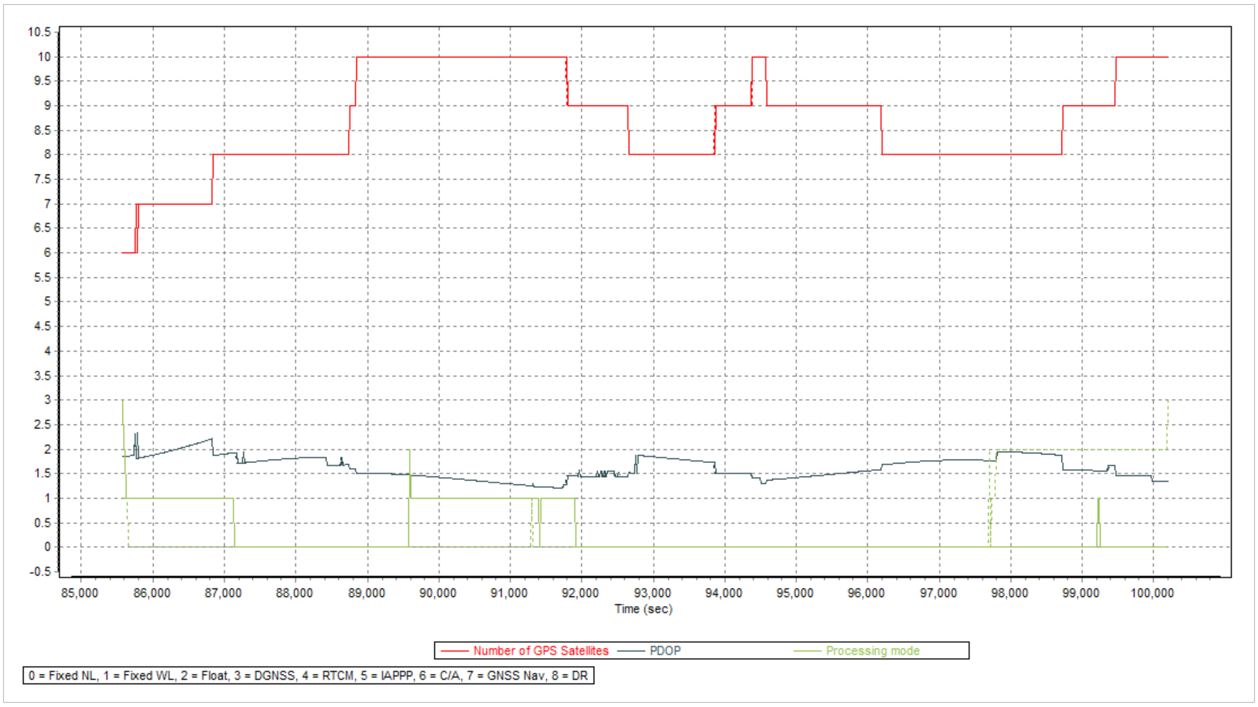


Figure A-8.8 Solution Status

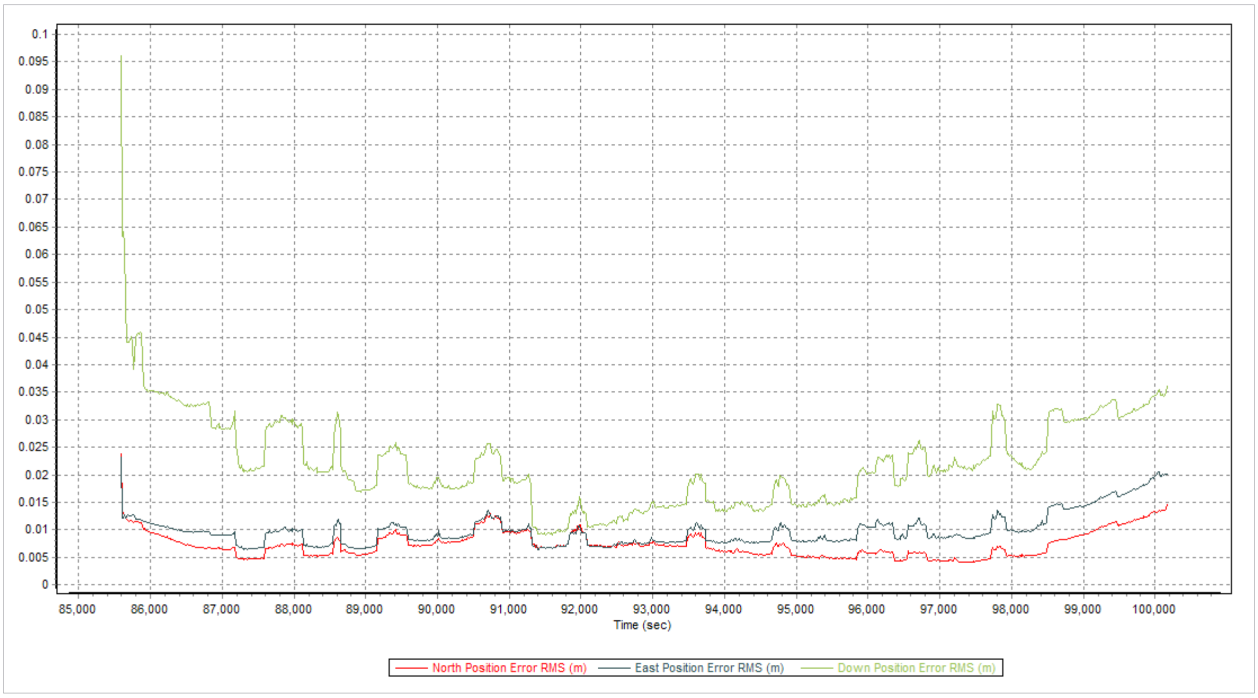


Figure A-8.9 Smoothed Performance Metric Parameters

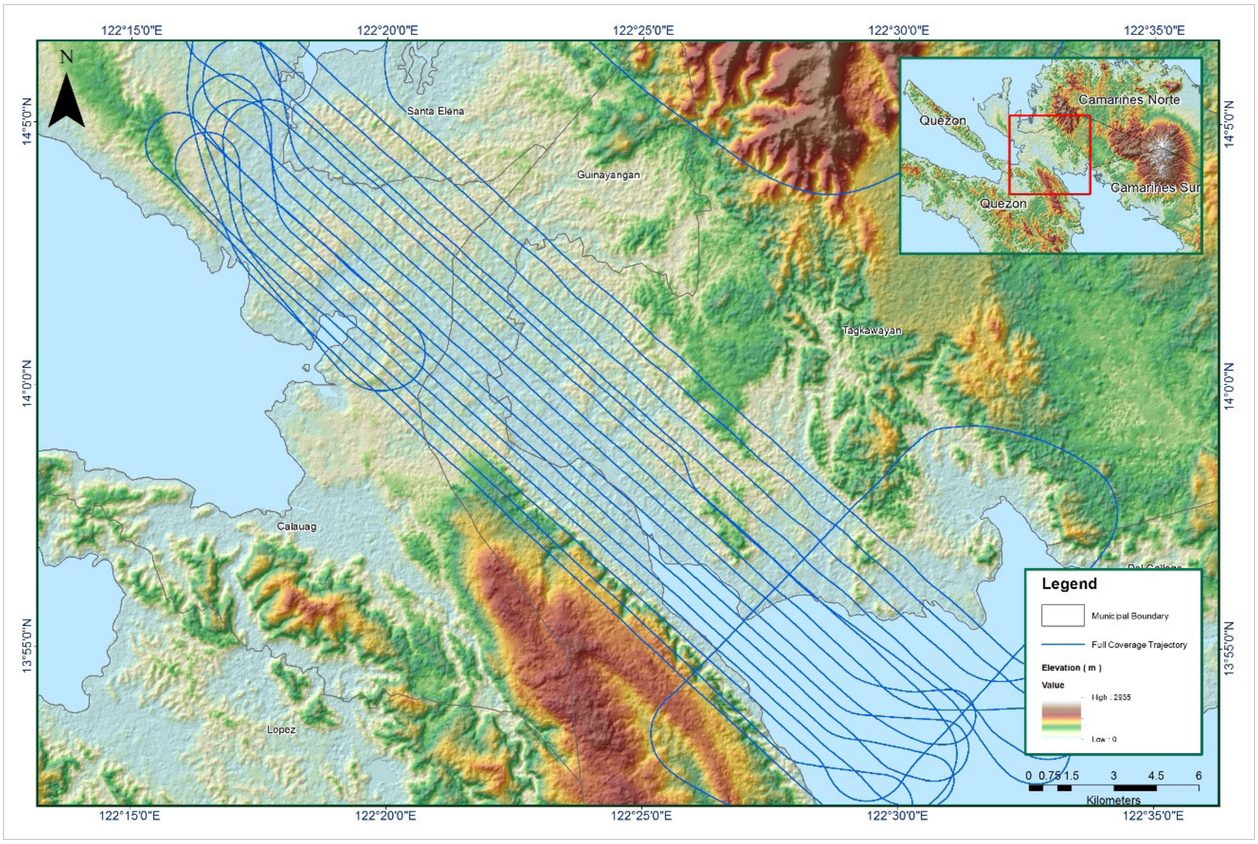


Figure A-8.10 Best Estimated Trajectory

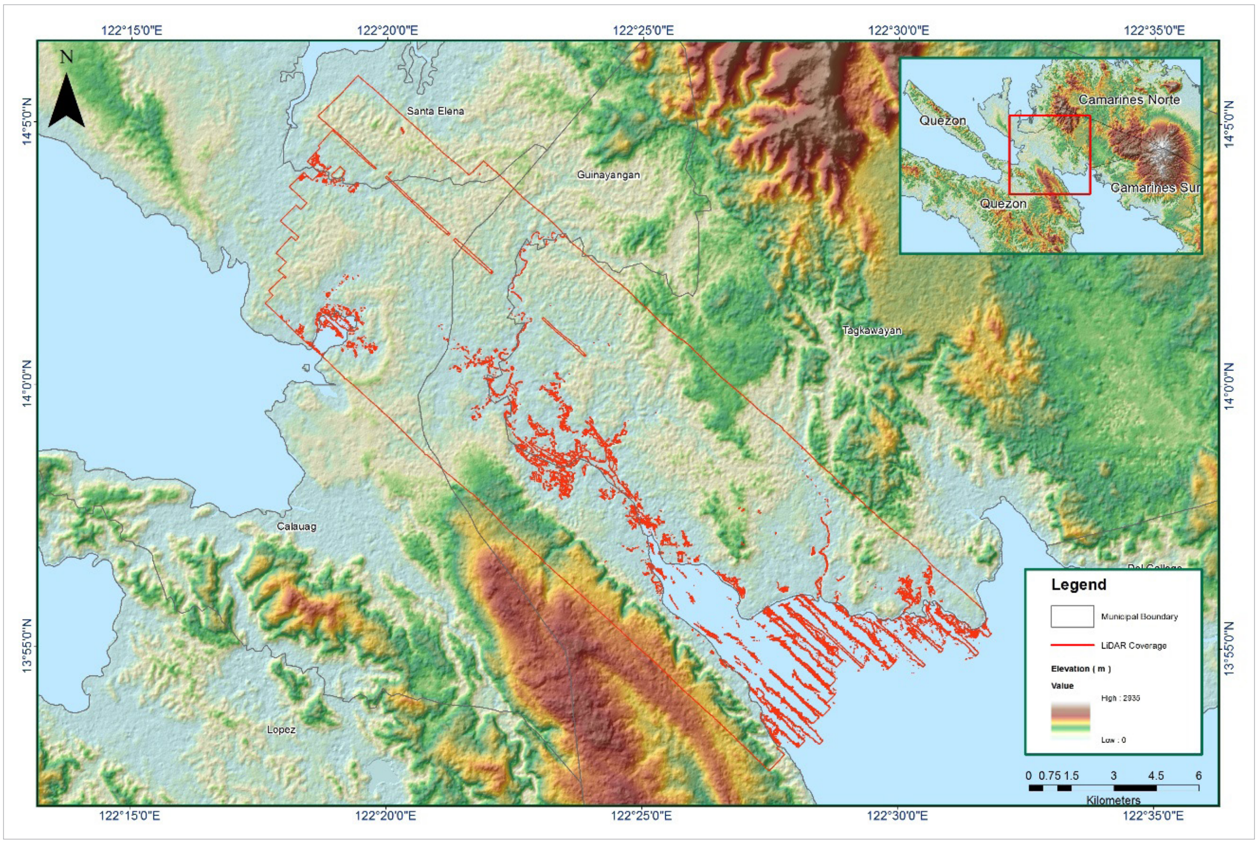


Figure A-8.11 Coverage of LiDAR data

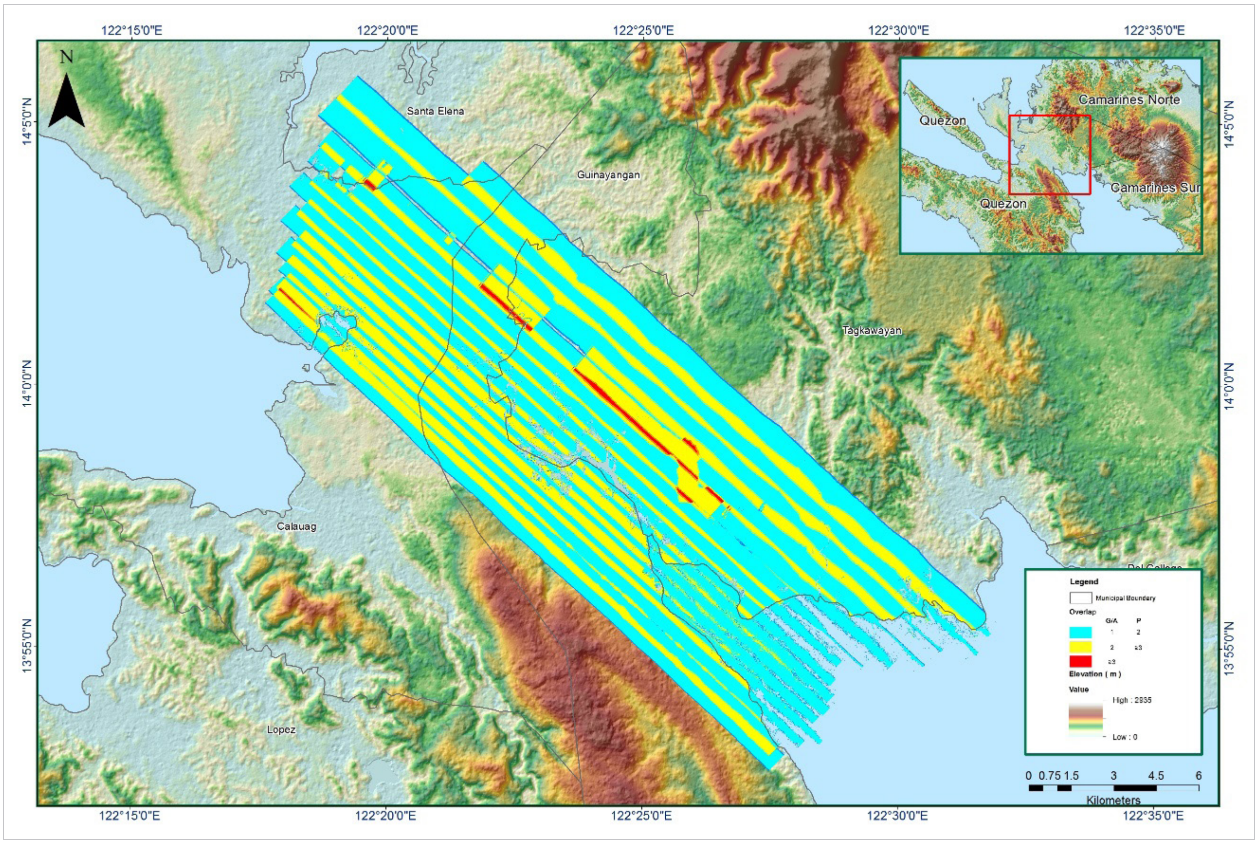


Figure A-8.12 Image of data overlap

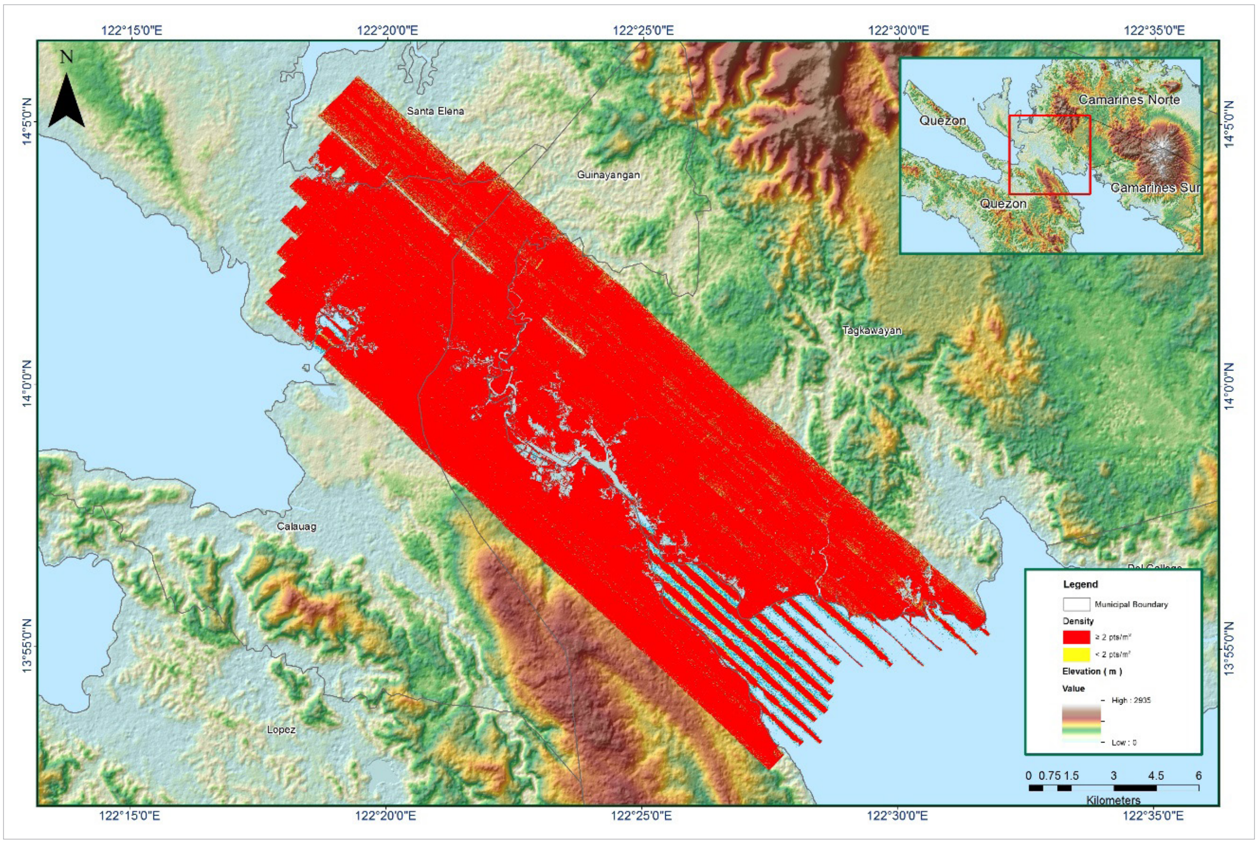


Figure A-8.13 Density map of merged LiDAR data

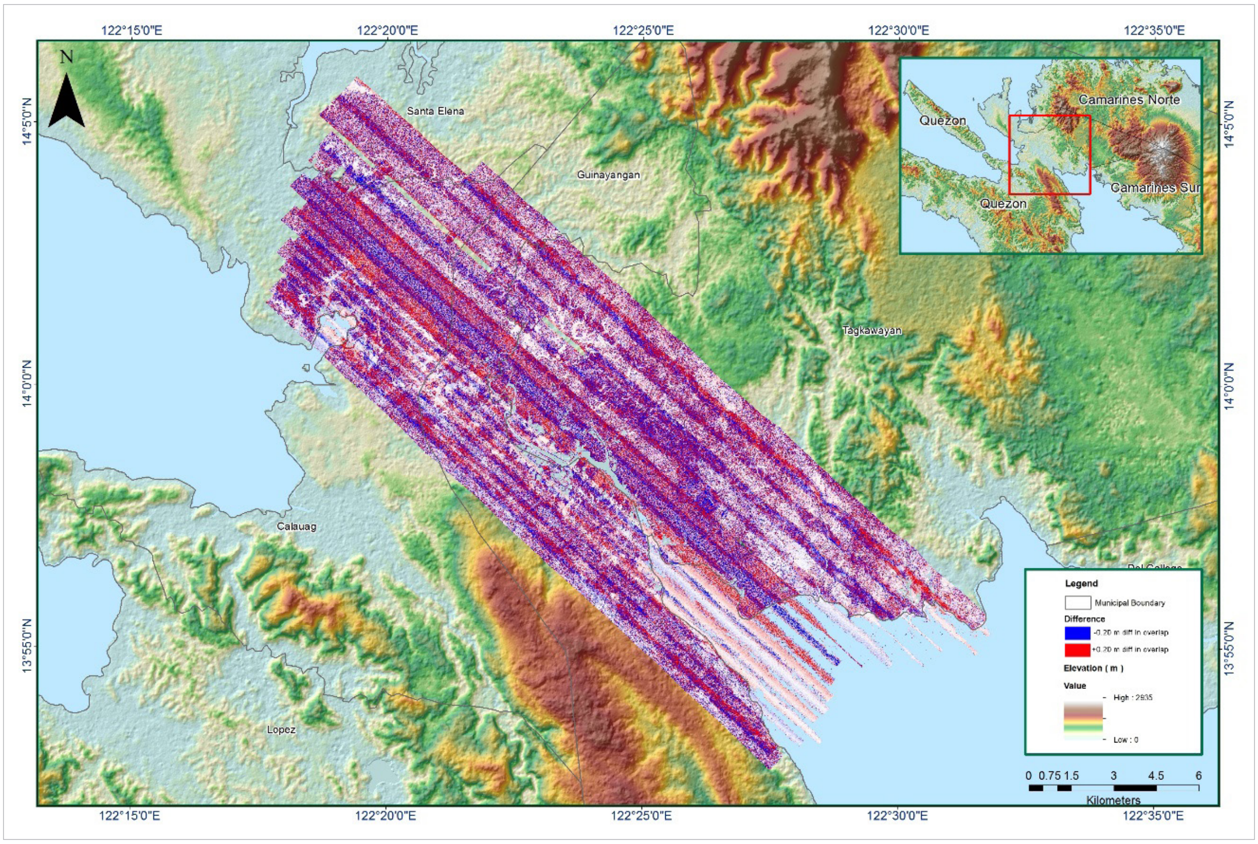


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk21A

Flight Area	Bagasbas
Mission Name	Bagasbas_Blk21A
Inclusive Flights	23244P
Range data size	12.9 GB
POS data size	158 MB
Base data size	165 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000384
IMU attitude correction stdev (<0.001deg)	0.000401
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	17.77%
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	191
Maximum Height	379.74
Minimum Height	49.16
Classification (# of points)	
Ground	79054250
Low vegetation	56911616
Medium vegetation	133134430
High vegetation	353037263
Building	3644040
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Velina Angela Bemida, Engr. Monalyne Rabino

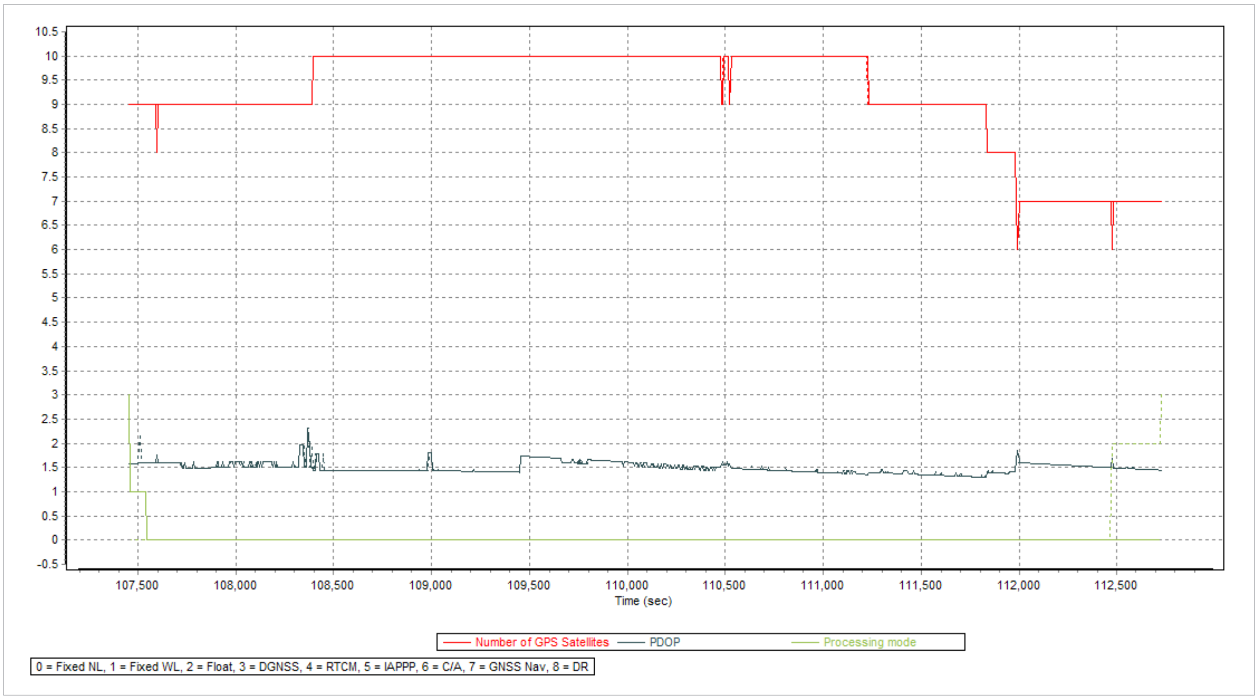


Figure A-8.15 Solution Status

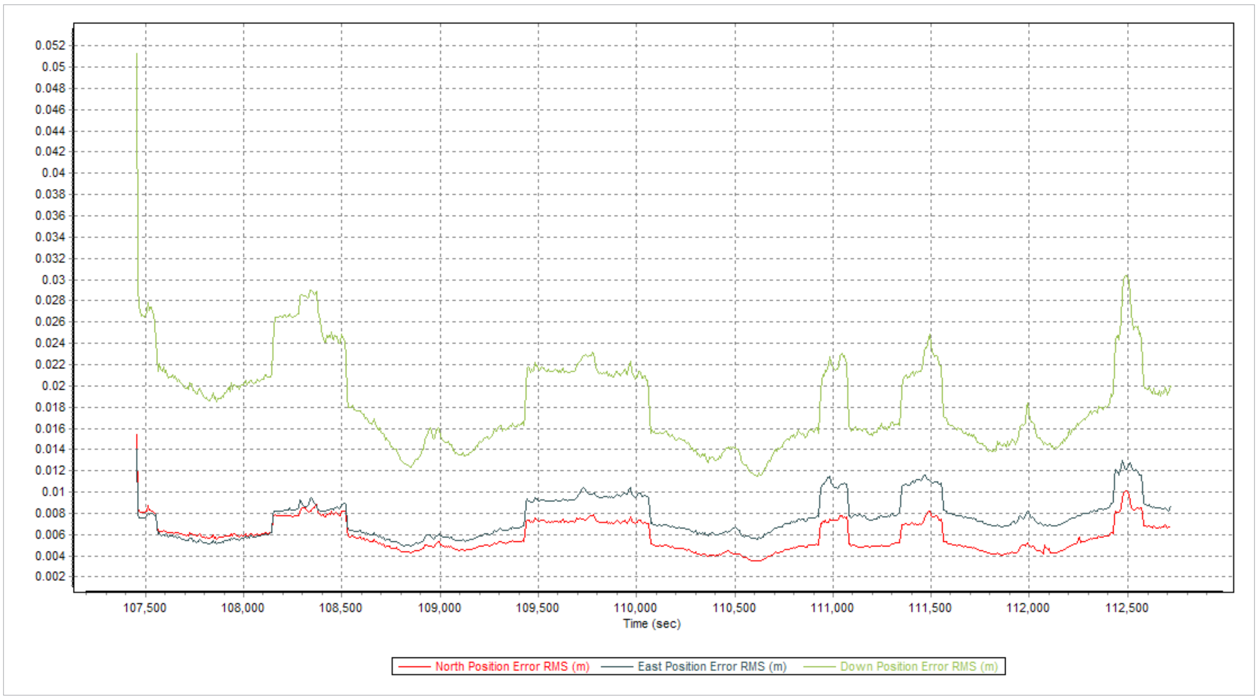


Figure A-8.16 Smoothed Performance Metric Parameters

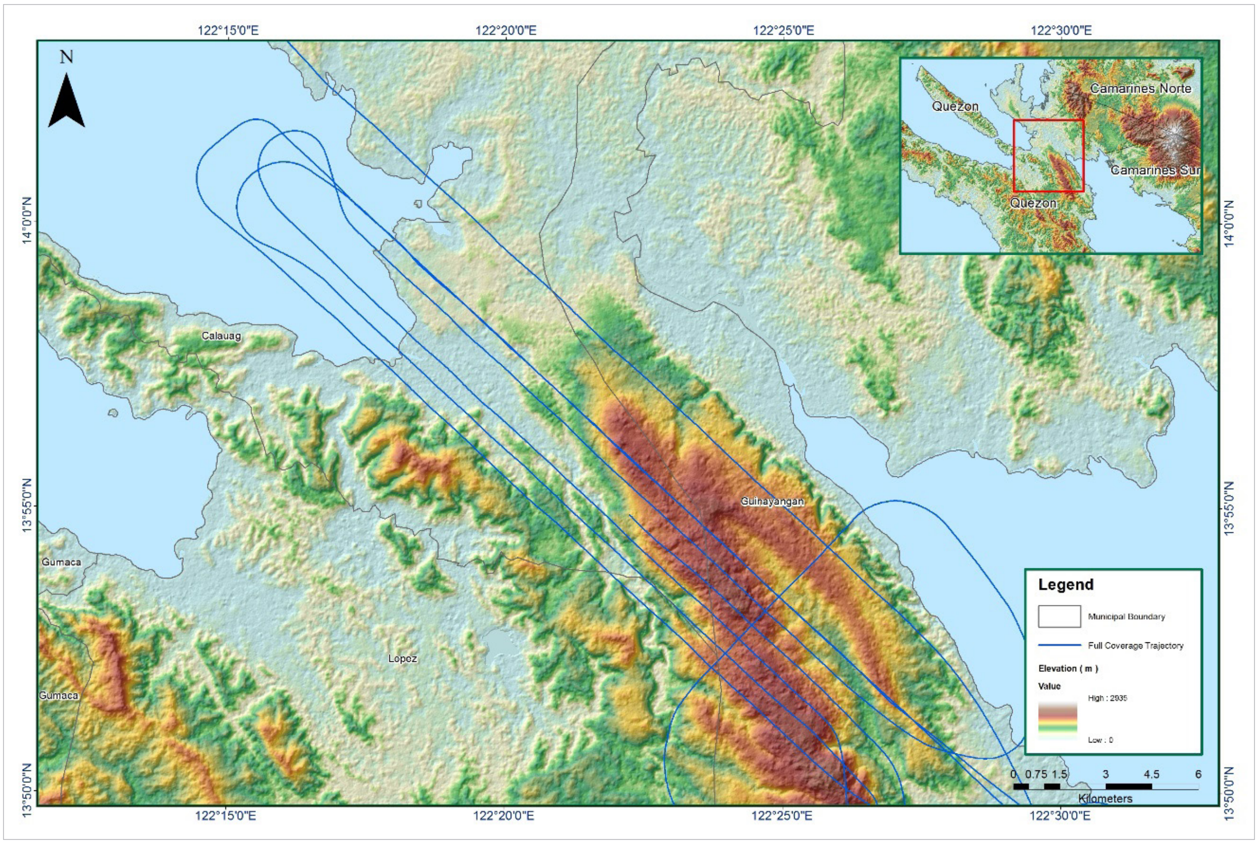


Figure A-8.17 Best Estimated Trajectory

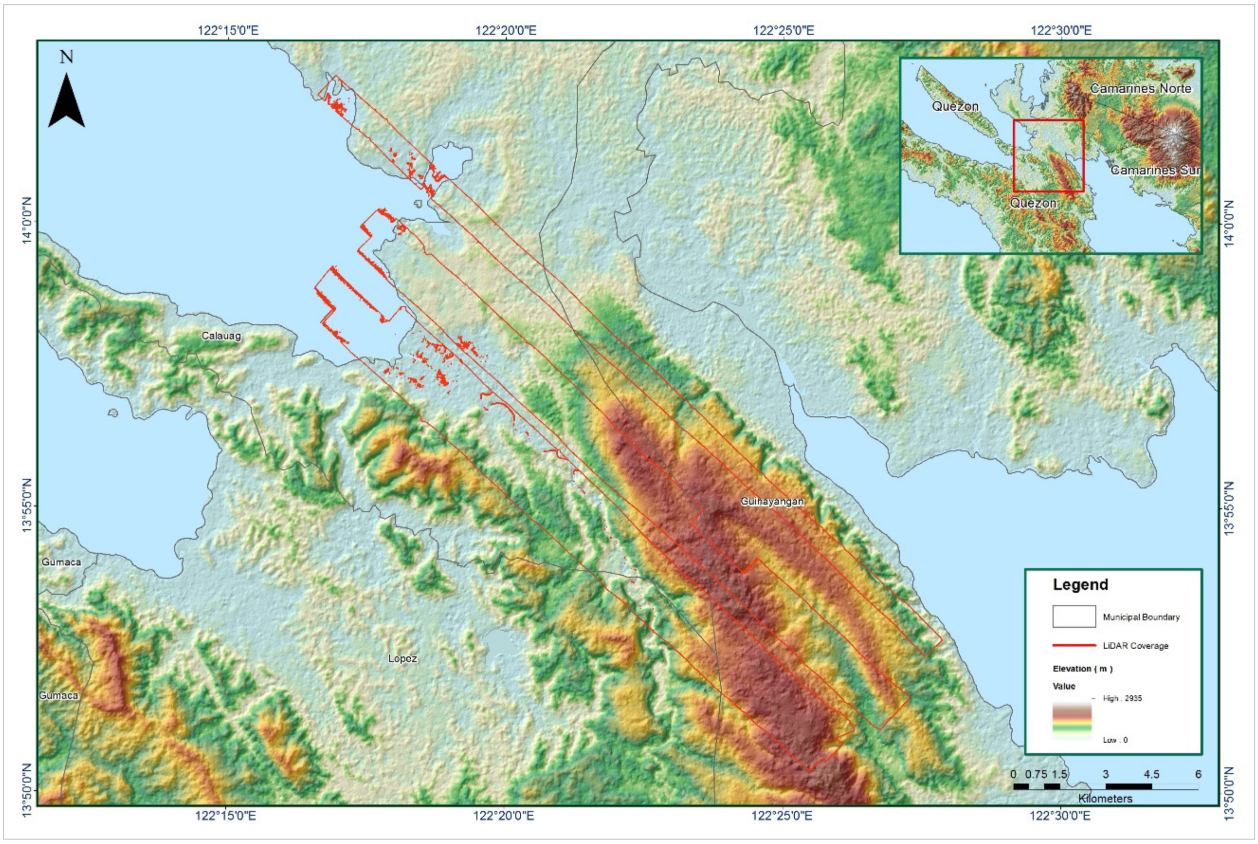


Figure A-8.18 Coverage of LiDAR data

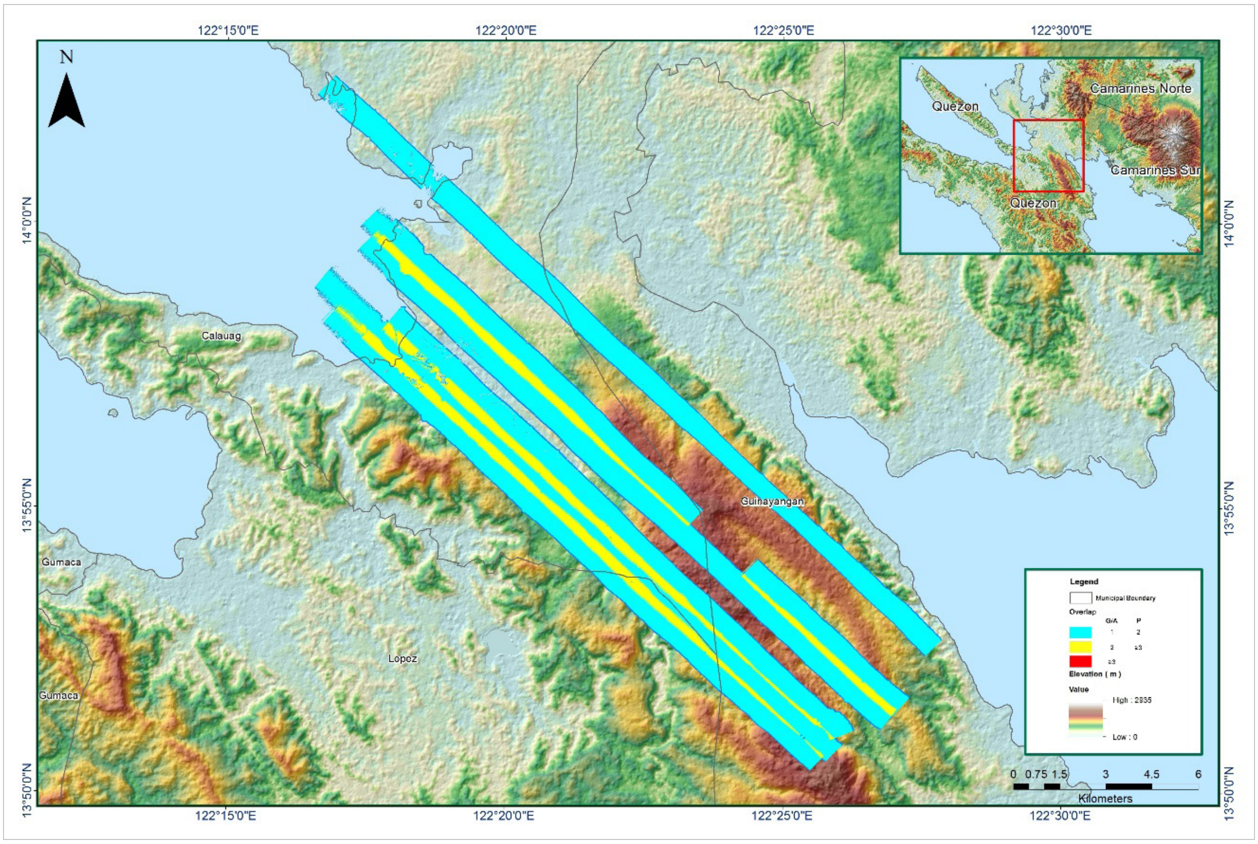


Figure A-8.19 Image of data overlap

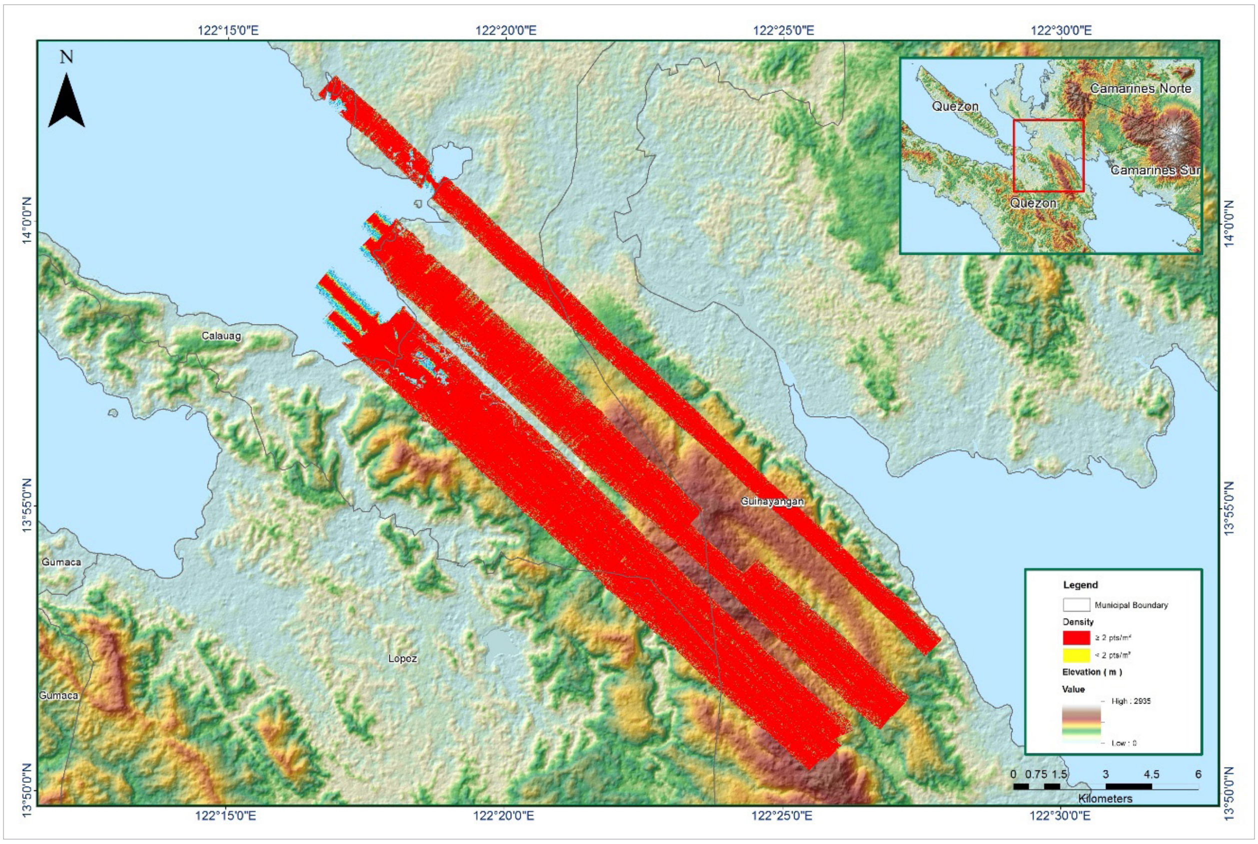


Figure A-8.20 Density map of merged LiDAR data

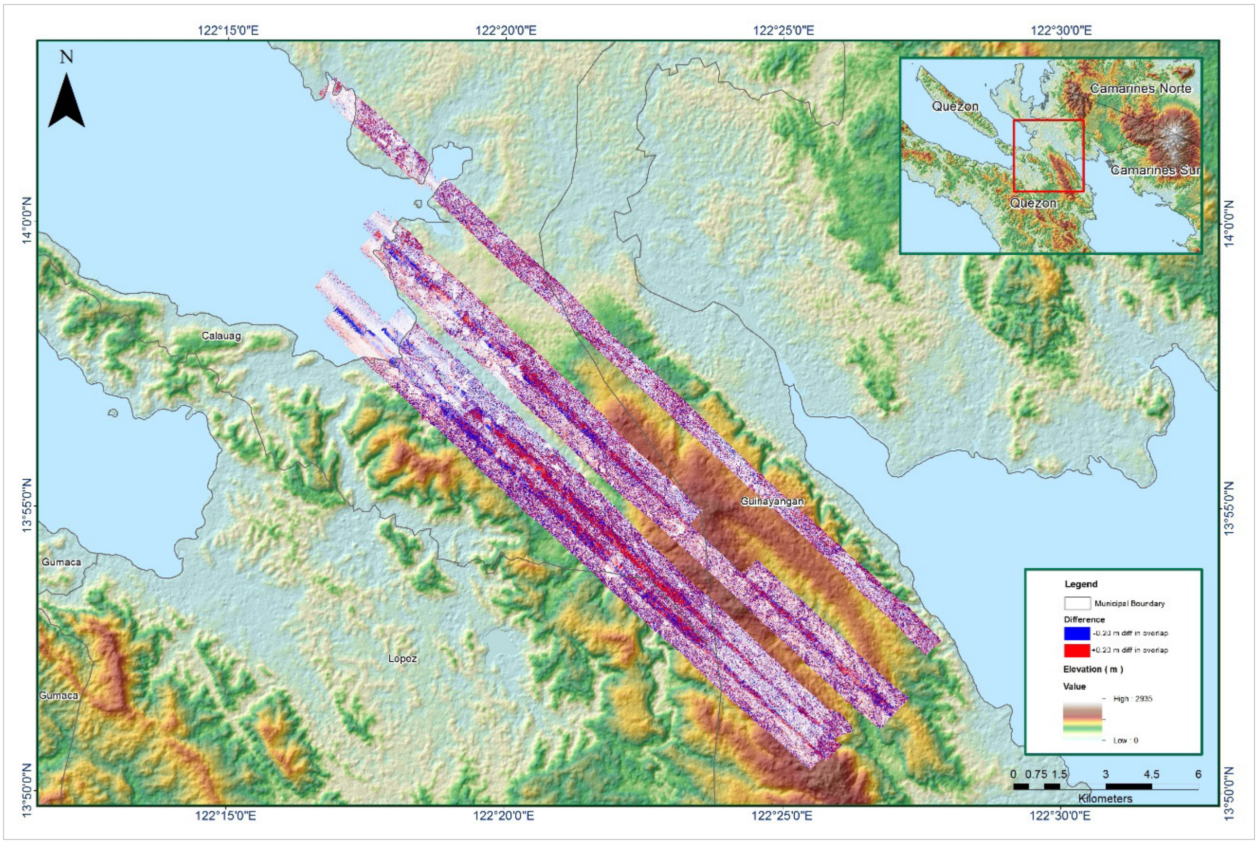


Figure A-8.21 Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk21A_supplement

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21A_supplement
Inclusive Flights	23252P
Range data size	14.5 GB
POS data size	174 MB
Base data size	90.5 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	0.3
Boresight correction stdev (<0.001deg)	0.000333
IMU attitude correction stdev (<0.001deg)	0.000415
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	20.12%
Ave point cloud density per sq.m. (>2.0)	3.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	137
Maximum Height	942.63
Minimum Height	39.34
Classification (# of points)	
Ground	63155780
Low vegetation	25760357
Medium vegetation	111178310
High vegetation	267413755
Building	3382392
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Erica Erin Elazegui, Engr. Monalyne Rabino

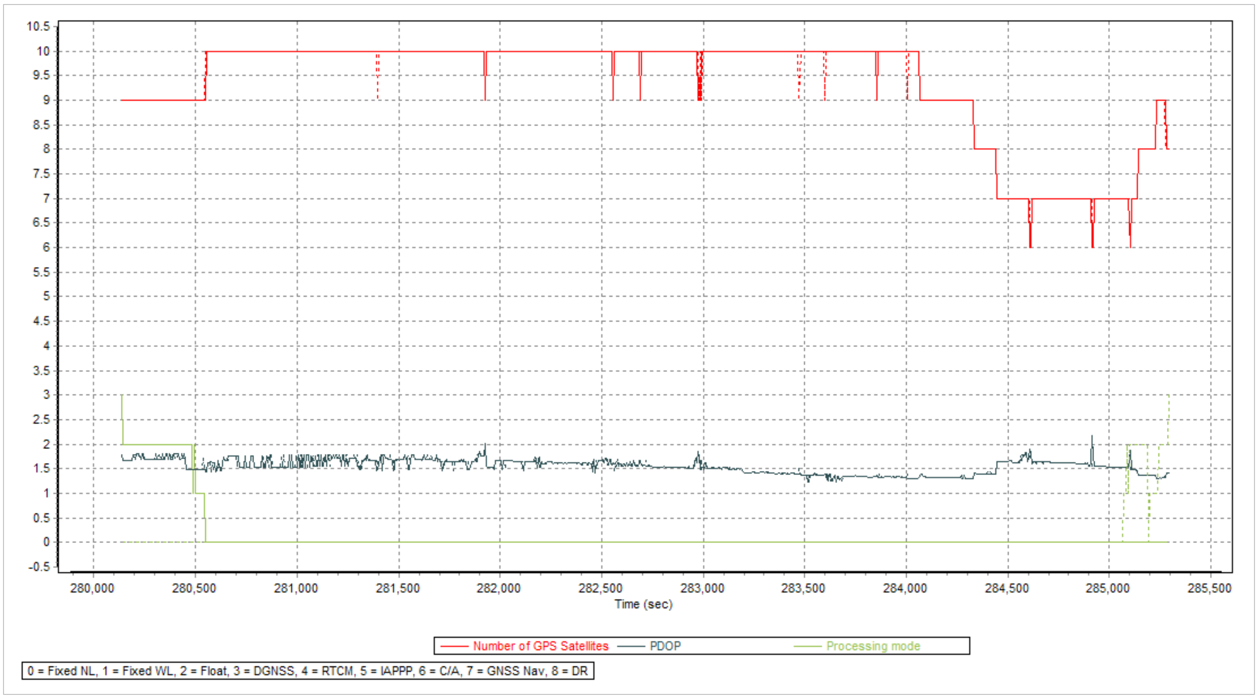


Figure A-8.22 Solution Status

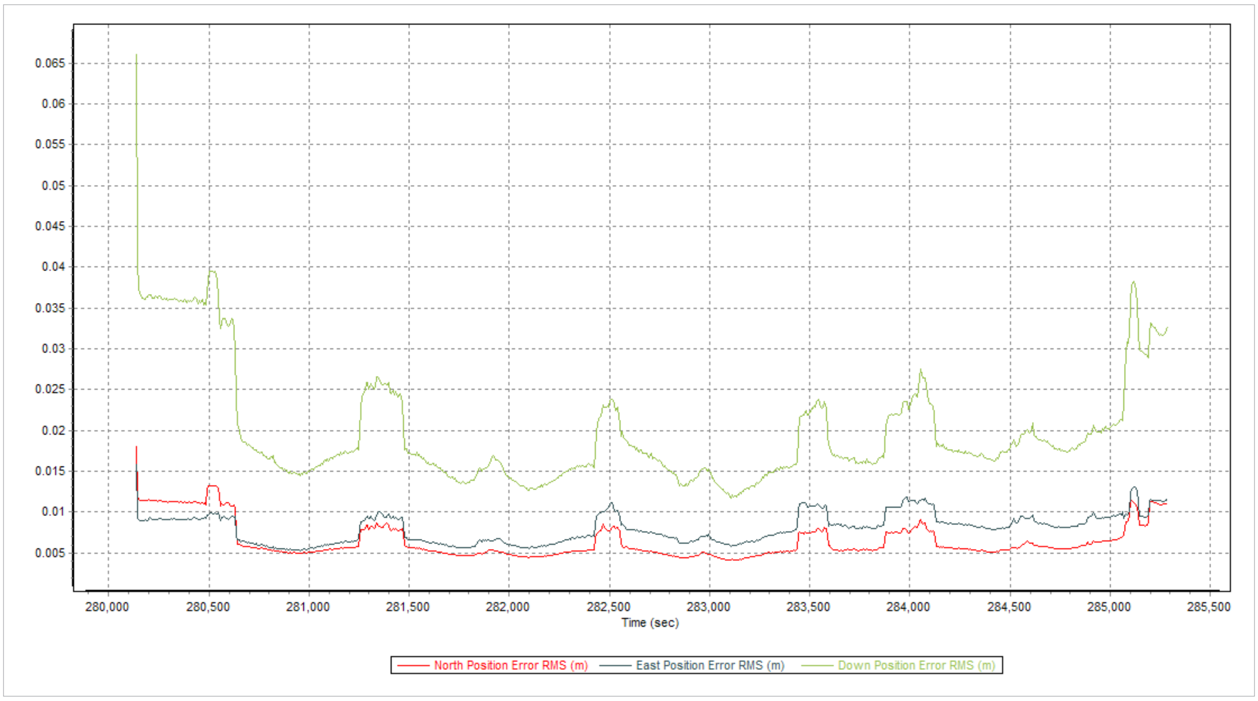


Figure A-8.23 Smoothed Performance Metric Parameters

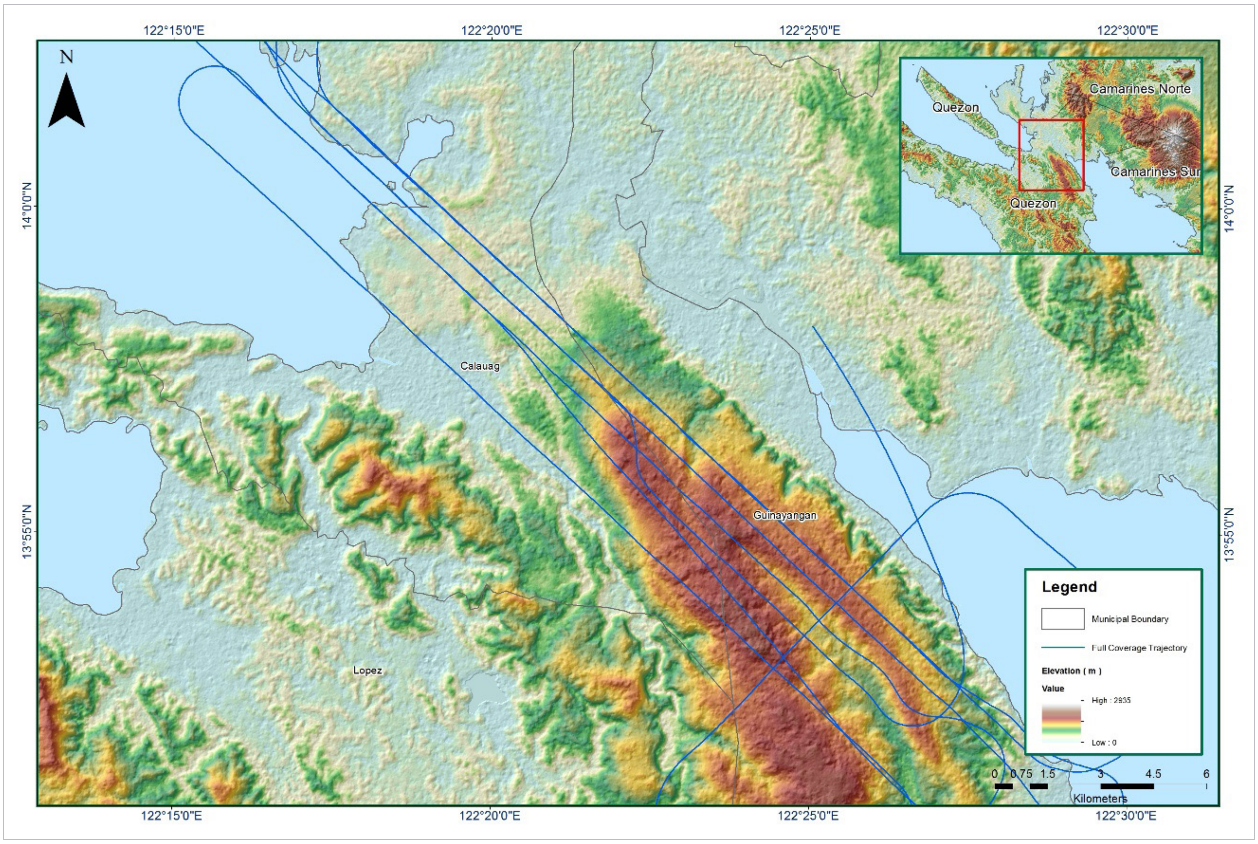


Figure A-8.24 Best Estimated Trajectory

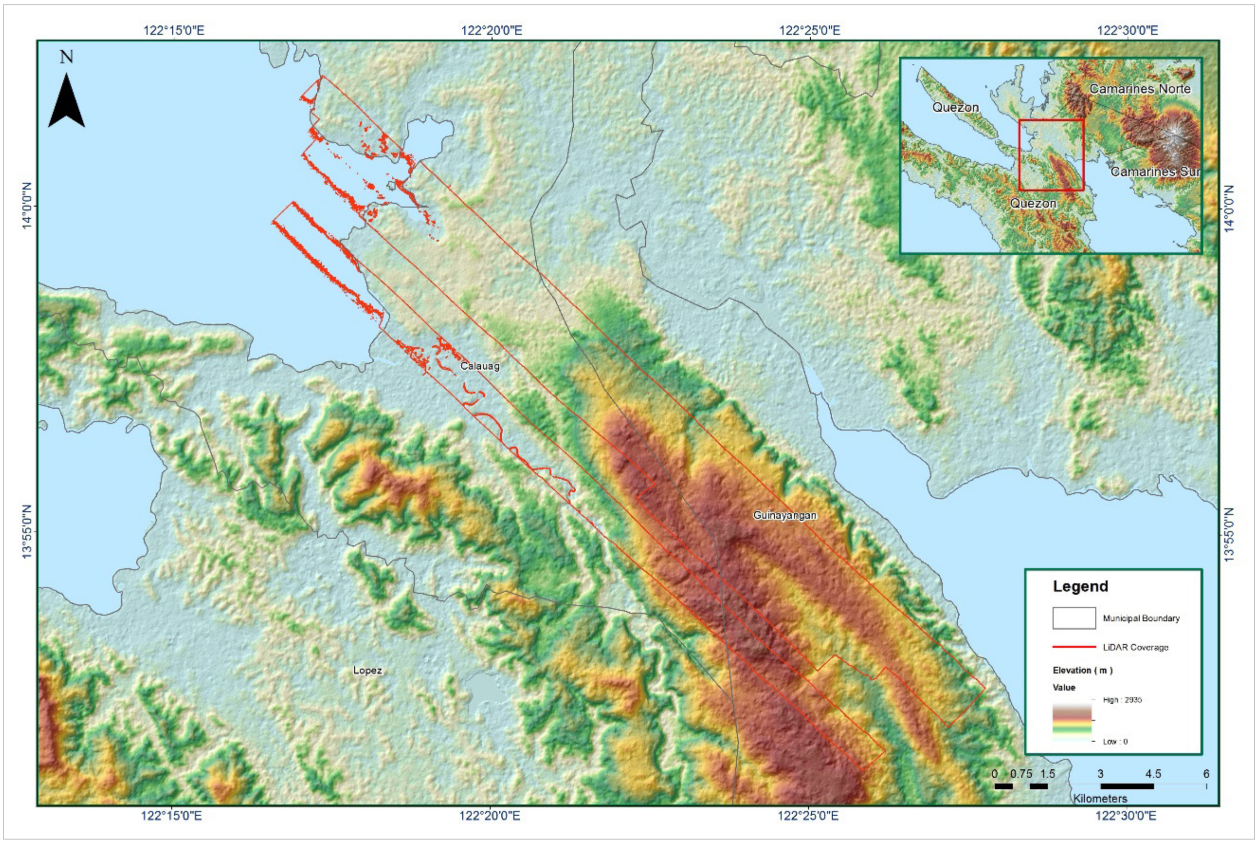


Figure A-8.25 Coverage of LiDAR data

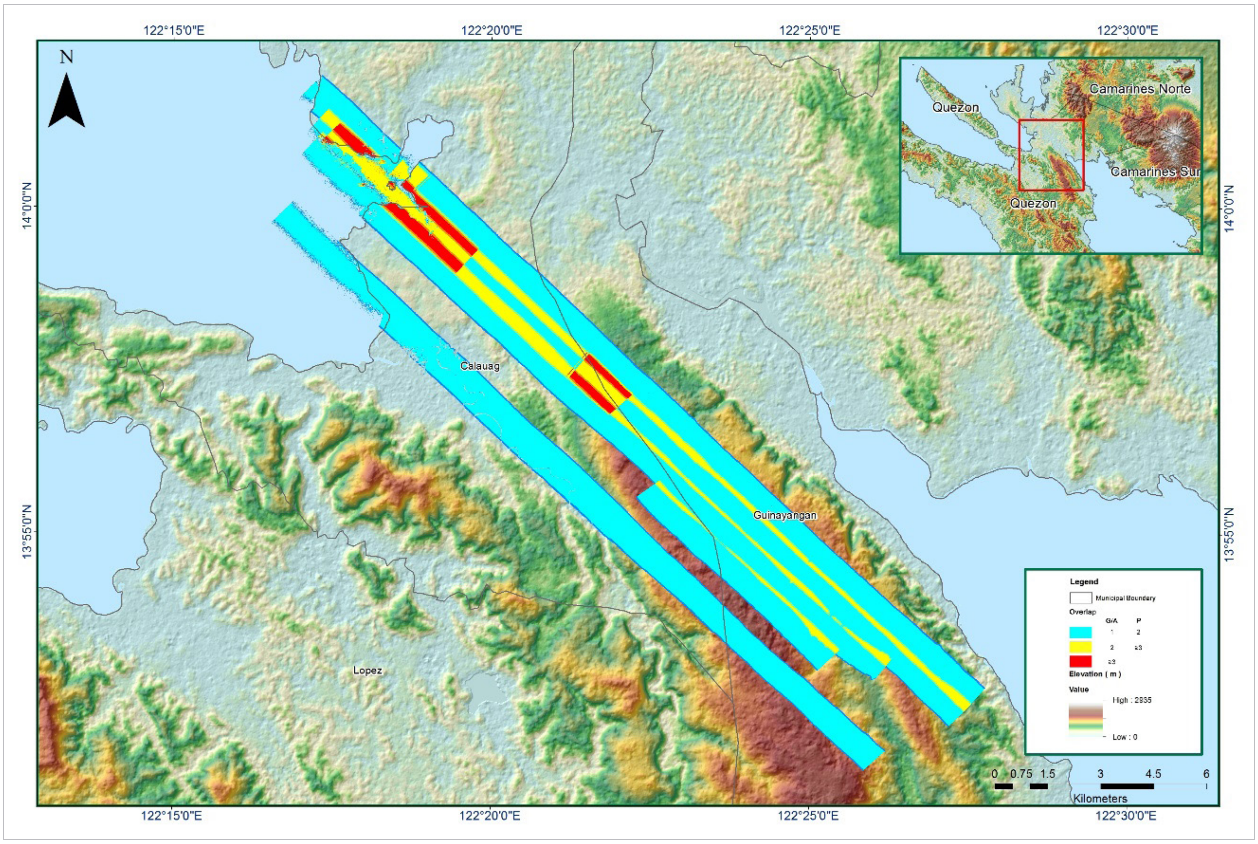


Figure A-8.26 Image of data overlap

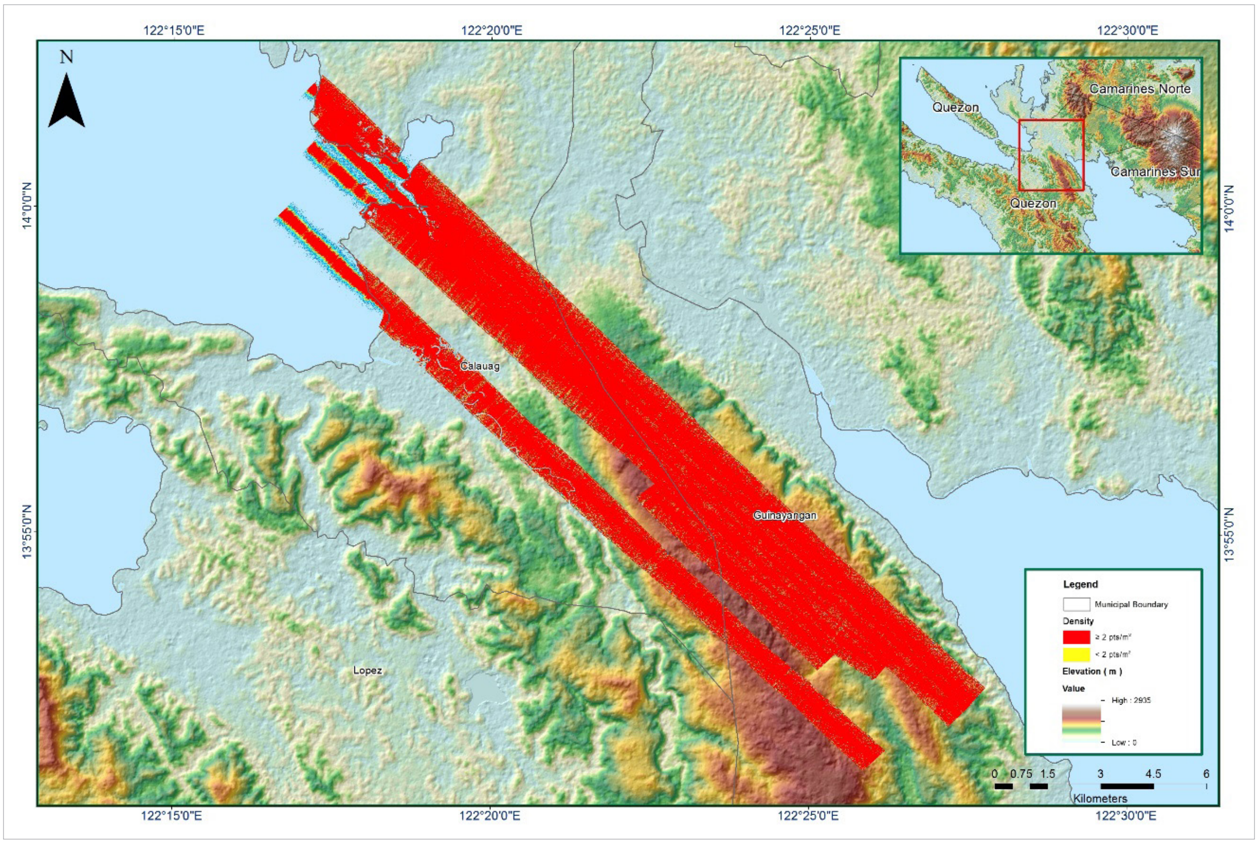


Figure A-8.27 Density map of merged LiDAR data

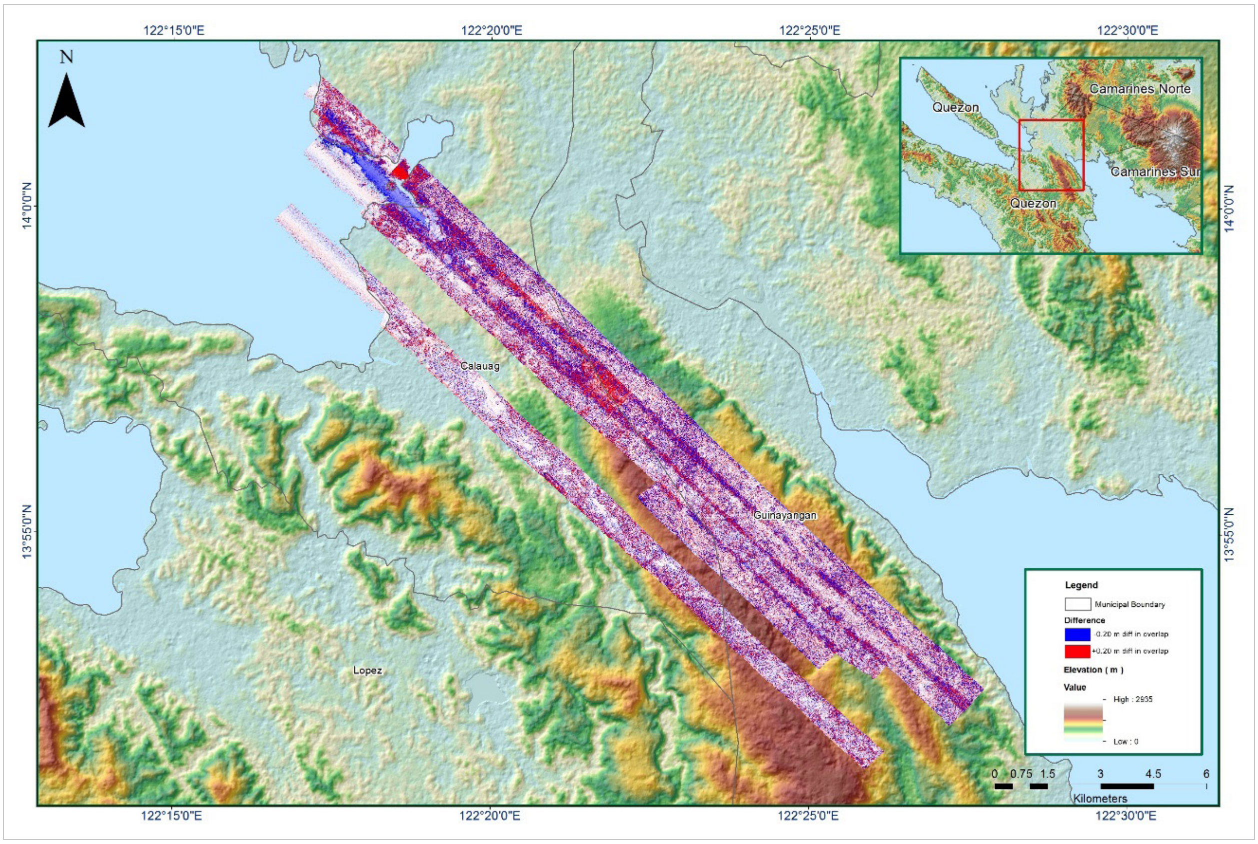


Figure A-8.28 Elevation difference between flight lines

ANNEX 9. Vinas Model Basin Parameters

Table A-9.1 Vinas 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
W400	1.1858	99	15	0.11017	0.02	Discharge	0.99811	1.00E-05	Ratio to Peak	1
W410	1.6136	99	15	0.25989	0.02	Discharge	1.3169	1.00E-05	Ratio to Peak	0.3888
W420	0.51021	99	15	0.02	0.02	Discharge	0.012785	1.00E-05	Ratio to Peak	0.57042
W430	1.0478	99	15	0.040369	0.02	Discharge	0.25006	1.00E-05	Ratio to Peak	0.87818
W440	1.3136	99	15	0.055825	0.02	Discharge	0.50158	1.00E-05	Ratio to Peak	0.59058
W450	1.8645	99	15	0.06402	0.02	Discharge	0.59654	1.00E-05	Ratio to Peak	0.57875
W460	3.3106	99	15	0.12706	0.02	Discharge	0.52264	1.00E-05	Ratio to Peak	0.96139
W470	1.0593	99	15	0.05476	0.02	Discharge	0.58359	1.00E-05	Ratio to Peak	0.62428
W480	3.143	99	15	0.099675	0.02	Discharge	0.30242	1.00E-05	Ratio to Peak	0.88733
W490	2.9179	99	15	0.024787	0.02	Discharge	0.012462	1.00E-05	Ratio to Peak	0.89505
W500	3.285	99	15	0.07853	0.02	Discharge	0.18194	1.00E-05	Ratio to Peak	1
W510	1.6862	99	15	0.22349	0.02	Discharge	0.31474	1.00E-05	Ratio to Peak	0.9484
W520	4.8159	99	15	0.09403	0.02	Discharge	0.39503	1.00E-05	Ratio to Peak	0.99494
W530	2.0011	99	15	0.14904	0.02	Discharge	0.97063	1.00E-05	Ratio to Peak	1
W540	1.3517	99	15	0.08805	0.02	Discharge	0.63116	1.00E-05	Ratio to Peak	0.62372
W550	1.6963	99	15	0.20553	0.02	Discharge	1.3644	1.24E-05	Ratio to Peak	0.97881
W560	1.5427	99	15	0.5789	0.02	Discharge	0.65682	1.27E-05	Ratio to Peak	1
W570	3.6506	99	15	0.17421	0.02	Discharge	0.21764	1.00E-05	Ratio to Peak	0.94813
W580	0.73063	99	15	0.069595	0.02	Discharge	0.41402	1.00E-05	Ratio to Peak	0.60118
W590	2.3393	99	15	0.10171	0.02	Discharge	0.25136	1.00E-05	Ratio to Peak	1

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 (M^3/S)	Recession Constant	Threshold Type	Ratio to Peak
W600	3.5421	99	15	0.016667	0.02	Discharge	0.78366	1.00E-05	Ratio to Peak	0.9965
W610	0.87792	99	15	0.13784	0.02	Discharge	0.3606	1.00E-05	Ratio to Peak	0.96499
W620	1.4779	99	15	0.22229	0.02	Discharge	0.88708	1.00E-05	Ratio to Peak	1
W630	3.0756	99	15	0.099695	0.02	Discharge	0.2797	1.00E-05	Ratio to Peak	1
W640	2.0431	99	15	0.063605	0.02	Discharge	0.17528	1.00E-05	Ratio to Peak	1
W650	1.7258	99	15	0.016667	0.02	Discharge	0.33574	1.00E-05	Ratio to Peak	0.5062
W660	3.0163	99	15	0.12998	0.02	Discharge	0.47132	1.00E-05	Ratio to Peak	0.60823
W670	2.5387	99	15	0.13531	0.02	Discharge	0.64199	1.00E-05	Ratio to Peak	0.87845
W680	2.1734	99	15	0.090975	0.02	Discharge	0.13003	1.00E-05	Ratio to Peak	1
W690	1.9713	99	15	0.08142	0.02	Discharge	0.1482	1.00E-05	Ratio to Peak	0.99663
W700	0.92917	99	15	0.1367	0.02	Discharge	0.51446	1.27E-05	Ratio to Peak	1
W710	1.0549	99	15	0.10735	0.02	Discharge	0.29067	1.31E-05	Ratio to Peak	0.988
W720	1.5626	99	15	0.042006	0.02	Discharge	0.067523	1.00E-05	Ratio to Peak	0.62634
W730	1.1757	99	15	0.030305	0.02	Discharge	0.033774	1.00E-05	Ratio to Peak	0.99901
W740	1.4944	99	15	0.11763	0.02	Discharge	0.47626	1.30E-05	Ratio to Peak	0.81256
W750	0.22917	99	15	0.06402	0.02	Discharge	0.088551	1.00E-05	Ratio to Peak	0.98314
W760	0.1653	99	15	0.10878	0.02	Discharge	0.57128	1.00E-05	Ratio to Peak	0.96243
W770	0.9773	99	15	0.09842	0.02	Discharge	0.45073	1.00E-05	Ratio to Peak	0.43767
W780	0.69661	99	15	0.08019	0.02	Discharge	0.26519	1.00E-05	Ratio to Peak	0.43752

ANNEX 10. Vinas Model Reach Parameters

Table A-10.1 Vinas Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	1714.7	0.004806	0.014838	Trapezoid	55	0.5
R130	Automatic Fixed Interval	3151.2	0.001107	0.055402	Trapezoid	55	0.5
R140	Automatic Fixed Interval	5515.3	0.002653	0.030131	Trapezoid	55	0.5
R170	Automatic Fixed Interval	6132.3	0.003442	0.044017	Trapezoid	55	0.5
R180	Automatic Fixed Interval	1913.7	0.002947	0.078902	Trapezoid	55	0.5
R200	Automatic Fixed Interval	1577.2	0.002898	0.033294	Trapezoid	55	0.5
R210	Automatic Fixed Interval	1736.5	0.003314	0.032013	Trapezoid	55	0.5
R220	Automatic Fixed Interval	1612	0.008983	0.042946	Trapezoid	55	0.5
R270	Automatic Fixed Interval	2158.8	0.002	0.16554	Trapezoid	55	0.5
R280	Automatic Fixed Interval	1697.8	0.000311	0.015626	Trapezoid	55	0.5
R290	Automatic Fixed Interval	5855.1	0.000492	0.016603	Trapezoid	55	0.5
R30	Automatic Fixed Interval	328.7	0.003099	0.012647	Trapezoid	55	0.5
R310	Automatic Fixed Interval	1086.4	0.001254	0.03242	Trapezoid	55	0.5
R320	Automatic Fixed Interval	1004.7	0.002741	0.024959	Trapezoid	55	0.5
R330	Automatic Fixed Interval	751.27	0.002	0.11811	Trapezoid	55	0.5
R350	Automatic Fixed Interval	1846.1	0.005572	0.43408	Trapezoid	55	0.5
R360	Automatic Fixed Interval	963.97	0.001633	0.002326	Trapezoid	55	0.5
R70	Automatic Fixed Interval	4411	0.014545	0.000418	Trapezoid	55	0.5
R90	Automatic Fixed Interval	236.27	0.017842	0.034363	Trapezoid	55	0.5

ANNEX 11. Vinas Field Validation Points

Table A-11.1 Vinas Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
1	13.98913	122.37	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
2	13.99112	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
3	13.99271	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
4	13.99273	122.36	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
5	13.99181	122.37	0.04	0	-0.040	Rosing Nov. 7,1995	5 -Year
6	13.99218	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
7	13.99261	122.37	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
8	13.9708	122.36	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
9	13.97196	122.36	0.05	0	-0.050	Rosing Nov. 7,1995	5 -Year
10	13.97378	122.36	0.07	0	-0.070	Rosing Nov. 7,1995	5 -Year
11	13.97571	122.36	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
12	13.98031	122.35	0.03	0.4	0.370	Rosing Nov. 7,1995	5 -Year
13	13.98107	122.35	0.47	0	-0.470	Rosing Nov. 7,1995	5 -Year
14	13.98261	122.36	1.29	0	-1.290	Rosing Nov. 7,1995	5 -Year
15	13.9865	122.35	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
16	13.99105	122.35	0.03	1.5	1.470	Rosing Nov. 7,1995	5 -Year
17	13.99941	122.35	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
18	13.99804	122.34	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
19	13.99964	122.34	0.35	0	-0.350	Rosing Nov. 7,1995	5 -Year
20	14.00139	122.34	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
21	14.02711	122.34	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
22	14.0227	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
23	14.02015	122.37	0.04	0	-0.040	Rosing Nov. 7,1995	5 -Year
24	14.02003	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
25	14.01903	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
26	14.01806	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
27	14.01725	122.37	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
28	13.98231	122.36	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
29	13.98202	122.36	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
30	13.98166	122.36	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
31	13.99379	122.37	5.090	5.5	0.410	Rosing Nov. 7,1995	5 -Year
32	14.00367	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
33	14.00422	122.38	0.34	1.5	1.160	Rosing Nov. 7,1995	5 -Year
34	14.00572	122.38	0.03	1.5	1.470	Rosing Nov. 7,1995	5 -Year
35	14.00725	122.38	0.03	2	1.970	Rosing Nov. 7,1995	5 -Year
36	14.00804	122.38	0.03	2	1.970	Rosing Nov. 7,1995	5 -Year
37	14.0101	122.38	0.03	1.5	1.470	Rosing Nov. 7,1995	5 -Year
38	14.01181	122.38	0.03	2	1.970	Rosing Nov. 7,1995	5 -Year
39	14.01355	122.38	0.03	2	1.970	Rosing Nov. 7,1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
40	14.01653	122.38	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
41	14.01772	122.38	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
42	14.01823	122.38	2	2	0.000	Rosing Nov. 7,1995	5 -Year
43	14.01846	122.38	1.86	2	0.140	Rosing Nov. 7,1995	5 -Year
44	14.02598	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
45	14.03035	122.38	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
46	14.03491	122.38	0.03	0.5	0.470	Rosing Nov. 7,1995	5 -Year
47	14.03877	122.38	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
48	14.03955	122.38	0.03	0.5	0.470	Rosing Nov. 7,1995	5 -Year
49	14.04062	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
50	14.04109	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
51	14.04453	122.38	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
52	14.04511	122.38	0.3	0.1	-0.200	Rosing Nov. 7,1995	5 -Year
53	14.04608	122.38	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
54	14.04652	122.38	2.07	1	-1.070	Rosing Nov. 7,1995	5 -Year
55	14.04681	122.38	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
56	14.04658	122.38	5.72	5.5	-0.220	Rosing Nov. 7,1995	5 -Year
57	14.0453	122.38	3.53	5.5	1.970	Rosing Nov. 7,1995	5 -Year
58	14.04482	122.38	3.31	5.5	2.190	Rosing Nov. 7,1995	5 -Year
59	14.05096	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
60	14.05189	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
61	14.05515	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
62	14.05691	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
63	14.05878	122.39	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
64	14.05187	122.43	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
65	14.04924	122.43	0.05	0	-0.050	Rosing Nov. 7,1995	5 -Year
66	14.01299	122.45	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
67	14.03237	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
68	14.03073	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
69	14.02899	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
70	14.02861	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
71	14.02922	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
72	14.02977	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
73	14.02884	122.44	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
74	14.01289	122.4	0.3	0.1	-0.200	Rosing Nov. 7,1995	5 -Year
75	14.01509	122.4	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
76	14.0251	122.38	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
77	14.01436	122.38	0.06	0.1	0.040	Rosing Nov. 7,1995	5 -Year
78	14.00252	122.38	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
79	14.00411	122.39	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
80	14.00468	122.39	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
81	14.00492	122.39	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
82	14.0149	122.4	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
83	13.95458	122.39	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
84	14.01454	122.4	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
85	14.01117	122.41	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
86	14.00838	122.41	0.04	0.1	0.060	Rosing Nov. 7,1995	5 -Year
87	14.0049	122.41	0.59	0.1	-0.490	Rosing Nov. 7,1995	5 -Year
88	14.00356	122.41	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
89	13.95338	122.37	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
90	13.95248	122.36	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
91	13.9942	122.42	0.37	0.1	-0.270	Rosing Nov. 7,1995	5 -Year
92	13.97331	122.41	1.33	0.1	-1.230	Rosing Nov. 7,1995	5 -Year
93	14.00922	122.39	0.03	0.1	0.070	Rosing Nov. 7,1995	5 -Year
94	13.95512	122.39	0.04	0.1	0.060	Rosing Nov. 7,1995	5 -Year
95	13.95356	122.37	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
96	13.95671	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
97	13.95759	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
98	13.9922	122.42	0.86	0.2	-0.660	Rosing Nov. 7,1995	5 -Year
99	13.99301	122.42	1.97	0.2	-1.770	Rosing Nov. 7,1995	5 -Year
100	13.95518	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
101	13.97953	122.41	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
102	13.97393	122.41	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
103	13.95844	122.42	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
104	13.95747	122.43	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
105	14.00883	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
106	14.01134	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
107	14.01132	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
108	14.01797	122.4	0.94	0.2	-0.740	Rosing Nov. 7,1995	5 -Year
109	13.9537	122.4	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
110	14.01366	122.39	1.53	0.2	-1.330	Rosing Nov. 7,1995	5 -Year
111	14.01891	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
112	14.02212	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
113	14.02296	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
114	14.02536	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
115	14.02487	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
116	14.02374	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
117	14.01994	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
118	13.95407	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
119	14.01224	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
120	14.01099	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
121	14.00879	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
122	14.00376	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
123	14.01126	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
124	14.01015	122.41	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
125	13.95566	122.39	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
126	14.00369	122.41	0.56	0.2	-0.360	Rosing Nov. 7,1995	5 -Year
127	14.00282	122.41	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
128	13.95498	122.39	0.05	0.2	0.150	Rosing Nov. 7,1995	5 -Year
129	13.95529	122.38	0.03	0.2	0.170	Rosing Nov. 7,1995	5 -Year
130	13.95355	122.37	0.46	0.2	-0.260	Rosing Nov. 7,1995	5 -Year
131	13.95311	122.37	0.7	0.2	-0.500	Rosing Nov. 7,1995	5 -Year
132	13.95547	122.38	0.15	0.2	0.050	Rosing Nov. 7,1995	5 -Year
133	13.95519	122.38	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
134	14.02286	122.38	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
135	13.99202	122.4	0.63	0.3	-0.330	Rosing Nov. 7,1995	5 -Year
136	13.9687	122.41	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
137	13.96491	122.42	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
138	14.01464	122.39	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
139	14.01392	122.39	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
140	14.01608	122.39	0.03	0.3	0.270	Rosing Nov. 7,1995	5 -Year
141	13.95548	122.38	0.17	0.3	0.130	Rosing Nov. 7,1995	5 -Year
142	13.97243	122.41	1.37	0.4	-0.970	Rosing Nov. 7,1995	5 -Year
143	13.9696	122.41	2	0.4	-1.600	Rosing Nov. 7,1995	5 -Year
144	14.01467	122.39	1.74	0.4	-1.340	Rosing Nov. 7,1995	5 -Year
145	14.01378	122.4	0.03	0.4	0.370	Rosing Nov. 7,1995	5 -Year
146	14.01728	122.4	0.03	0.5	0.470	Rosing Nov. 7,1995	5 -Year
147	13.97648	122.41	1.53	0.5	-1.030	Rosing Nov. 7,1995	5 -Year
148	13.97154	122.41	0.12	0.5	0.380	Rosing Nov. 7,1995	5 -Year
149	14.00786	122.39	0.03	0.5	0.470	Rosing Nov. 7,1995	5 -Year
150	14.01572	122.4	0.03	0.5	0.470	Rosing Nov. 7,1995	5 -Year
151	14.01342	122.4	1.55	0.5	-1.050	Rosing Nov. 7,1995	5 -Year
152	14.0053	122.41	0.22	0.5	0.280	Rosing Nov. 7,1995	5 -Year
153	13.97879	122.41	0.08	0.7	0.620	Rosing Nov. 7,1995	5 -Year
154	13.99084	122.4	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
155	14.01224	122.4	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
156	14.01148	122.4	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
157	14.00911	122.41	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
158	14.00627	122.41	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
159	14.00719	122.39	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
160	14.01517	122.4	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
161	14.01742	122.4	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
162	14.0182	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
163	14.02342	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
164	14.00693	122.38	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year
165	14.013	122.4	0.03	0	-0.030	Rosing Nov. 7,1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
166	13.99339	122.37	1.82	1	-0.820	Rosing Nov. 7,1995	5 -Year
167	13.95335	122.4	0.04	1	0.960	Rosing Nov. 7,1995	5 -Year
168	13.98309	122.39	1.62	2	0.380	Rosing Nov. 7,1995	5 -Year
169	13.95955	122.42	0.03	2	1.970	Rosing Nov. 7,1995	5 -Year
170	13.98812	122.4	1.05	3	1.950	Rosing Nov. 7,1995	5 -Year
171	13.98956	122.4	1.39	3	1.610	Rosing Nov. 7,1995	5 -Year
172	13.98708	122.41	2.09	3	0.910	Rosing Nov. 7,1995	5 -Year
173	13.98911	122.41	3.63	3	-0.630	Rosing Nov. 7,1995	5 -Year
174	13.99155	122.42	3.72	3	-0.720	Rosing Nov. 7,1995	5 -Year
175	13.98299	122.41	1.38	4	2.620	Rosing Nov. 7,1995	5 -Year
176	13.98476	122.41	1.8	4	2.200	Rosing Nov. 7,1995	5 -Year
177	13.99031	122.42	4.1	4	-0.100	Rosing Nov. 7,1995	5 -Year
178	13.98986	122.42	2.6	4	1.370	Rosing Nov. 7,1995	5 -Year
179	13.99004	122.42	3.09	5	1.910	Rosing Nov. 7,1995	5 -Year
180	13.99407	122.38	4.22	5	0.780	Rosing Nov. 7,1995	5 -Year

ANNEX 12. Educational Institutions affected by flooding Vinas Flood Plain

Table A-12.1 Educational Institutions in Quezon affected by flooding in Vinas Flood Plain.

Quezon				
Guinayangan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Aloneros High School	Aloneros	None	None	None
Aloneros High School	Tikay	None	None	None
Day Care Center	Aloneros	None	None	None
Day Care Center	Gapas	Medium	Medium	Medium
Gapas Elemetary School	Gapas	None	None	None
San Luis I Elementary School	San Luis I	None	None	None

Quezon				
Tagkawayan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Cabibihan Elementary School	Cabibihan	None	None	None
Cabibihan National High School	Cabibihan	None	None	None
Del Rosario Elemetary School	Del Rosario	None	None	None
Manato Central Elementary School	Manato Central	None	None	None
Manato High School	Victoria	None	None	None
Manato Station Elementary School	Manato Station	Medium	High	High
Manato Station Elementary School	Victoria	Medium	High	High

Quezon				
Calauag				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Viñas Elementary School	Viñas	None	None	None

ANNEX 13. Medical Institutions affected by flooding in Vinas Flood Plain

Table A-13.1 Medical Institutions in Quezon affected by flooding in Vinas Flood Plain

Quezon				
Guinayangan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Aloneros	None	None	None
Health Center	Danlagan Central	None	None	None
Health Center	Danlagan Batis	None	None	None
Health Center	San Luis II	None	None	None

Quezon				
Tagkawayan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Cagascas	None	None	None
Health Center	Santo Niño I	None	None	None
Health Center	Victoria	None	None	None

Quezon				
Calauag				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Bagong Silang	None	None	None