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

LiDAR Surveys and Flood Mapping of Llorente River

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

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LLORENTE RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University. VSU 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 15 river basins in Northern Mindanao. The university is located in Baybay, Leyte.

1.2 Overview of Llorente River Basin

Llorente River Basin covers portions of the Municipalities of Balangiga, Quinapondan, General Macarthur, Balangkayan and Llorente. According to DENR-RBCO, it has a drainage area of 340 km2 and an estimated 646 million cubic meter (MCM) annual run- off.

Its main stem, Llorente River, is among the 31 river systems in Eastern Visayas Region. Its water, according to its beneficial use, is categorized as Class C which is for fishery, recreation/boating, and supply for manufacturing processes after treatment. The river is named after the Municipality of Llorente where it is situated. It has a total population of 18, 731 based on the 2010 census, is one of the areas hit by Typhoon Haiyan (Yolanda) last November 8, 2013.

In line with this, the DVBC conducted a survey in Llorente River from September 10 to 24, 2014 (Samar Phase 1) and from December 4 to 18, 2014 (Samar Phase 2). The scope of work covered for Samar Phase 1 were: reconnaissance, establishment of a control points, cross-section, as-built and water level marking in MSL of Llorente Bridge in Brgy. 11, Municipality Llorente, Eastern Samar. For Samar Phase 2, using PPK survey technique, it covered the Llorente River bathymetric survey from Brgy. Cantomco down to Brgy. Tabok (mouth of the river), with an estimated length of 9.20 km.

***SAME CONTENT WITH CHAPTER 4. SUMMARY OF ACTIVITIES (NO INTRO GIVEN)

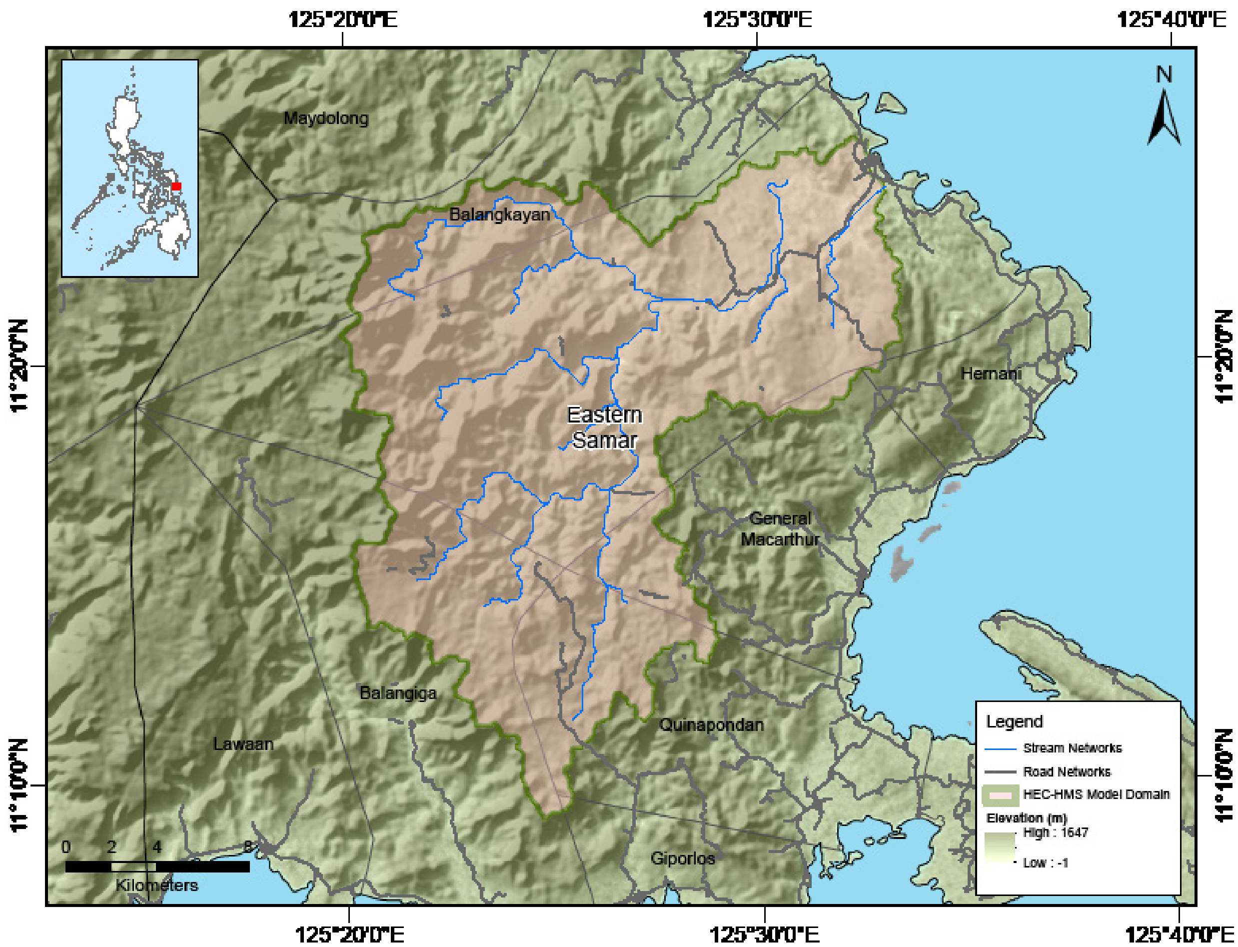

Figure 1. Map of Llorente River Basin (no figure given)

CHAPTER 2: LIDAR ACQUISITION IN LLORENTE FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, For. Ma. Verlina Tonga, Jasmine Alviar

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Llorente floodplain in Eastern Samar. These missions were planned for 10 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the Aquarius LiDAR system is found in Table 1Error! Reference source not found.. Figure 2 shows the flight plan for Llorente floodplain.

Table *1*. Flight planning parameters for Aquarius LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK33P	600	30	44	50	45	130	5
BLK33M	600	30	44	50	45	130	5

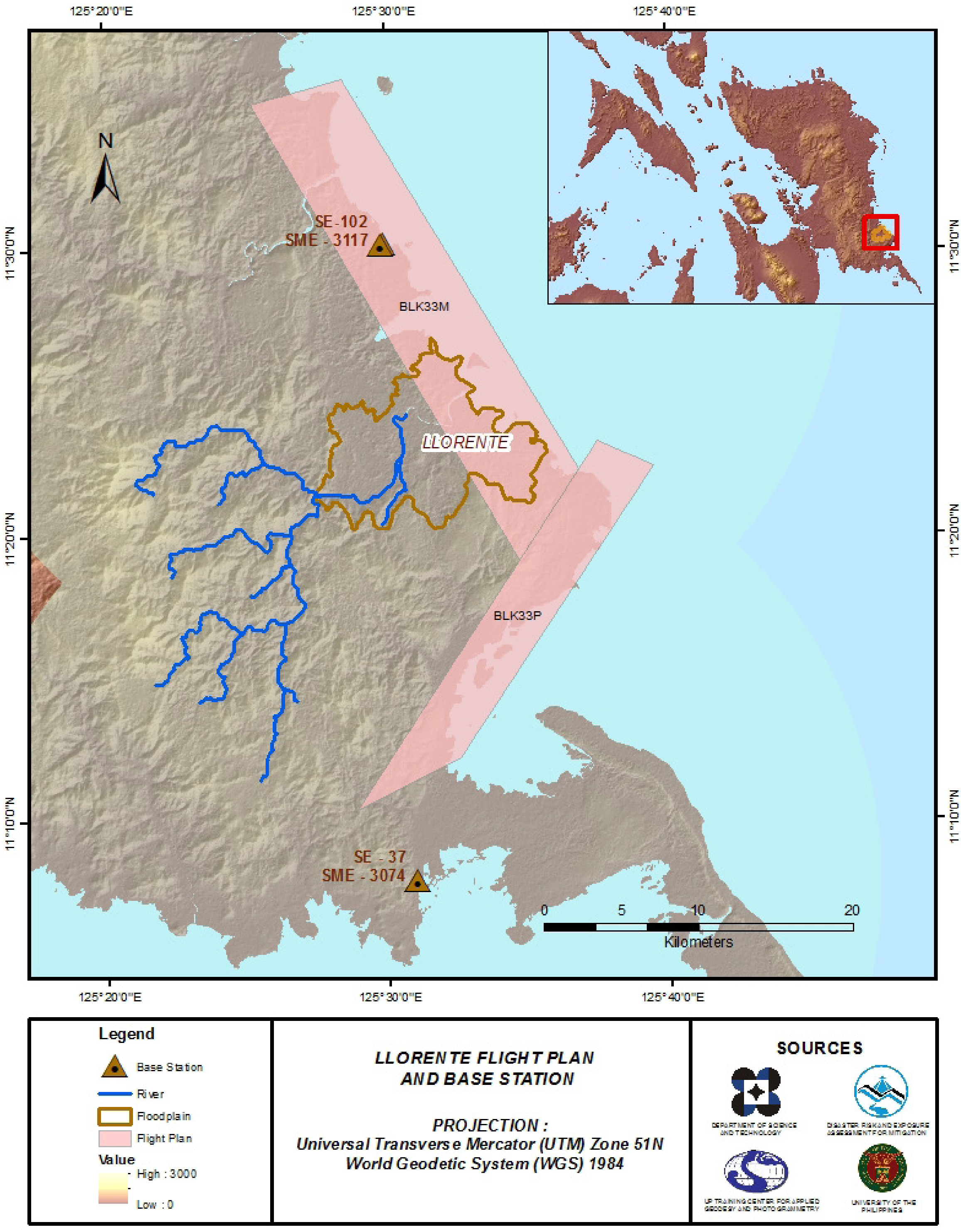

Figure 2. Flight plans and base stations for Llorente Floodplain.

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA horizontal ground control points which are of second (2nd) and fourth (4th) order accuracy, SME-3074 and SME-3117, respectively. Two (2) NAMRIA benchmarks were recovered, SE-37, which is of second (2nd) order horizontal accuracy and SE-102 which is of first (1st) order vertical accuracy. These benchmarks were used as vertical reference points and were also established as ground control point. The certification for the base station is found in ANNEX 2 while the baseline processing reports for established ground control points are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (April 15 – June 11, 2014) especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852 and SPS985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Llorente floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition,

Table 2 to 5 show the details about the following NAMRIA control stations and established points while

Table 6. Ground Control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
07-Jun-14	1550A	3BLK33P158A	SME-3074; SE-37
08-Jun-14	1554A	3BLK33PSM159A	SME-3117; SE-102
08-Jun-14	1556A	3BLK33MS159B	SME-3117; SE-102

shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

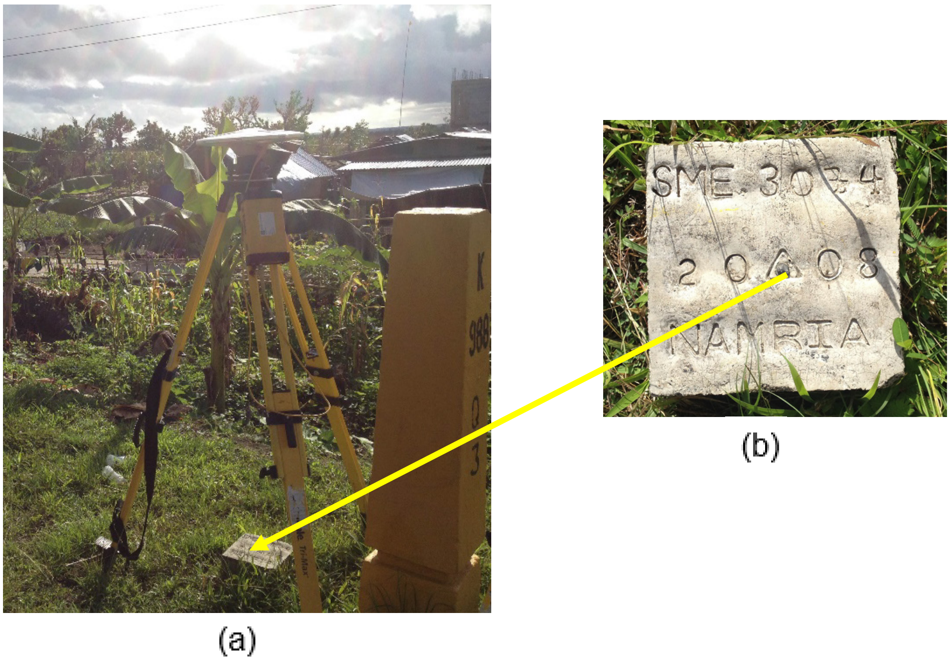

Figure 3. GPS set-up over SME-3074 near KM Post No. 988 in Quinapondan, Eastern Samar court (a) and NAMRIA reference point SME-3074 (b) as recovered by the field team.

Table 2. Details of the reprocessed NAMRIA horizontal control point SME-3074 used as base station for the LiDAR Acquisition.

Station Name	SME-3074	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 7’ 59.28388” North
	Longitude	125° 30’ 54.00697” East
	Ellipsoidal Height	5.502 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 7’ 55.08848” North
	Longitude	125° 30’ 59.16728” East
	Ellipsoidal Height	69.272 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	774,710.018 meters
	Northing	1,231,788.037 meters

(a)

(b)

Figure 4. *GPS set-up over SME-3117* inside the premises of Maydolong National High School, Maydolong, Eastern Samar. *(a) and NAMRIA reference point SME-3117 (b) as recovered by the field team.*

Table *3. Details of the recovered NAMRIA horizontal control point SME-3117 used as base station for the LiDAR Acquisition.*

Station Name	SME-3117	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11o 30’ 19.94572” North
	Longitude	125o 29’ 48.45875” East
	Ellipsoidal Height	-0.71500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	554197.385 meters
	Northing	1272291.016 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11o 30’ 15.65415” North
	Longitude	125o 29’ 53.58658” East
	Ellipsoidal Height	62.09300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	772367.30 meters
	Northing	1272983.11 meters

(a) (b)

Figure 5. GPS set-up over SE-37 along National Highway in Barangay Santo Niño, Quinapondan, Eastern Samar and NAMRIA reference point SE-37 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA reference point SE-37 with processed coordinates used as base station for the LiDAR Acquisition.

Station Name	SE - 37	
Order of Accuracy	2nd	
Elevation (Mean Sea Level)	1.3583 meters	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 07' 59.95" North
	Longitude	125° 30' 54.91"East
	Ellipsoidal Height	5.49 m meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 07' 55.05187" North
	Longitude	125° 30' 59.16996" East
	Ellipsoidal Height	69.239 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	774,864.486 meters
	Northing	1,231,736.179 meters

(a) (b)

Figure 6. GPS set-up over SE-102 located along the National Highway, in front of Maydolong High School, in Maydolong, Eastern Samar (a) and NAMRIA reference point SE-102 (b) as recovered by the field team.

Table *5. Details of the recovered NAMRIA vertical control point SE-102 used as vertical reference point for the LiDAR acquisition with established coordinates.*

Station Name	SE-102	
Order of Accuracy (vertical)	1st	
Elevation (Mean Sea Level)	2.5962 meters	
Relative Error (vertical positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 30’ 18.33686” North
	Longitude	125° 29’ 43.39145” East
	Ellipsoidal Height	0.393 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 30’ 14.04528” North
	Longitude	125° 29’ 48.51933” East
	Ellipsoidal Height	63.198 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	772214.094 meters
	Northing	12.72932.317 meters

Table 6. Ground Control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
07-Jun-14	1550A	3BLK33P158A	SME-3074; SE-37
08-Jun-14	1554A	3BLK33PSM159A	SME-3117; SE-102
08-Jun-14	1556A	3BLK33MS159B	SME-3117; SE-102

2.3 Flight Missions

Three (3) missions were conducted to complete the LiDAR data acquisition in Llorente floodplain, for a total of twelve hours and fifty one minutes (12+51) of flying time for RP-C9122. All missions were acquired using the Aquarius LiDAR system. Table 7 Error! Reference source not found.shows the total area of actual

coverage and the corresponding flying hours per mission, while
Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Llorente floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within Floodplain (km2)	Area Surveyed Outside Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
07-Jun-14	1550A	98.56	96.95	-	96.95	753	3	11
08-Jun-14	1554A	269.79	123.51	4.52	118.99	1527	4	36
08-Jun-14	1556A	171.23	133.83	29.19	104.64	1679	4	48
TOTAL		539.58	354.30	33.71	320.59	3,959	12	51

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)
1550A	600	30	44	50	45	130	5
1554A	600	30	44	50	45	130	5
1556A	600	30	44	50	45	130	5

2.4 Survey Coverage

Llorente Floodplain is located in the province of Eastern Samar with majority of the floodplain situated within the municipality of Hernani. The list of municipalities and cities surveyed is shown in Table 9. The actual coverage of the LiDAR acquisition for Llorente floodplain is presented in Figure 7.

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

Province	Municipality/City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Eastern Samar	Hernani	46.44	37.55	81%
	General Macarthur	114.65	22.16	19%
	Quinapondan	136.47	19.60	14%
	Llorente	344.09	42.98	12%
	Maydolong	202.95	19.33	10%
	Balangkayan	170.56	9.33	5%
	Borongan City	596.08	26.21	4%
	TOTAL	1611.24	177.16	11%

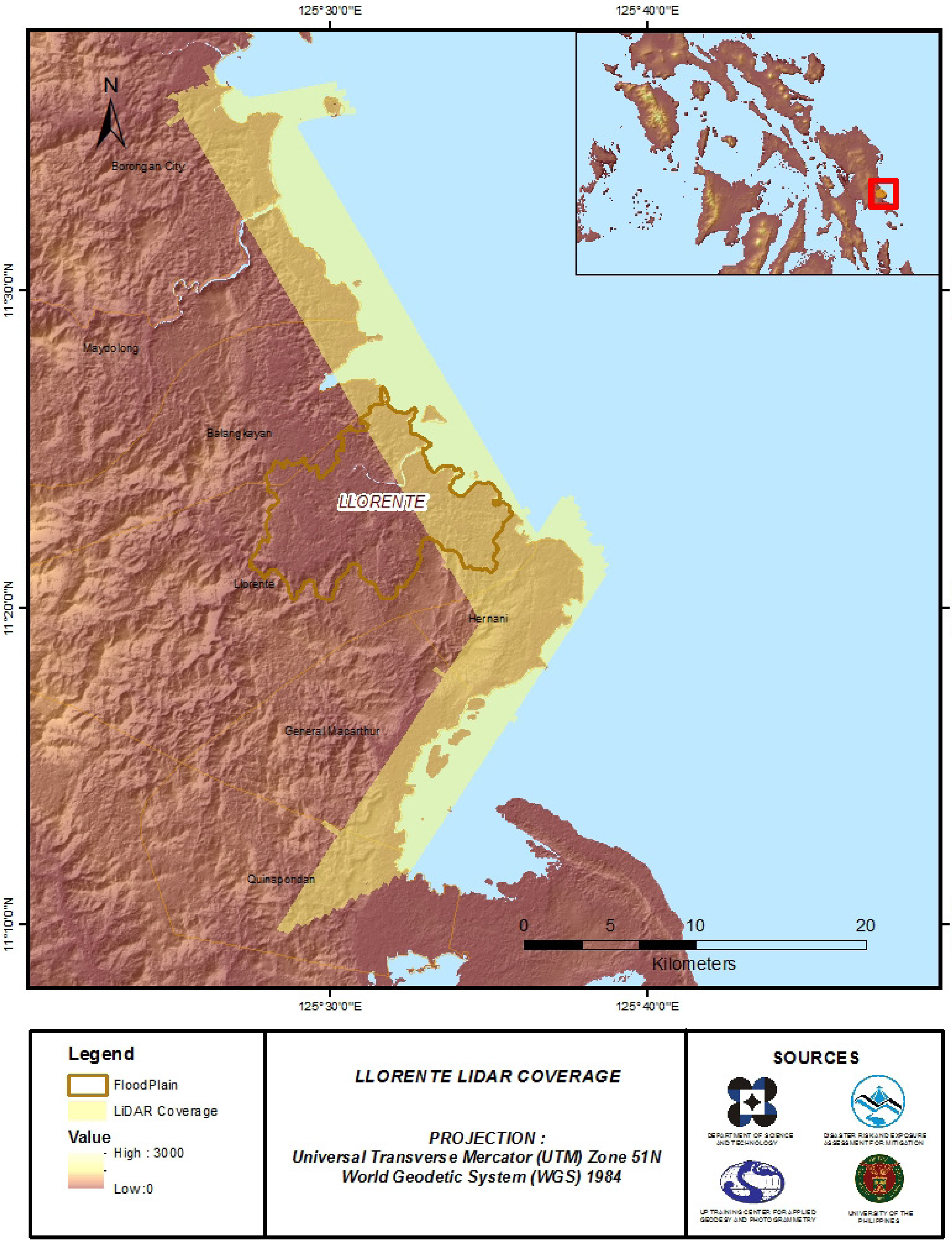

Figure 7. Actual LiDAR survey coverage for Llorente floodplain.

CHAPTER 3: DATA PROCESSING OF THE LLORENTE 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.

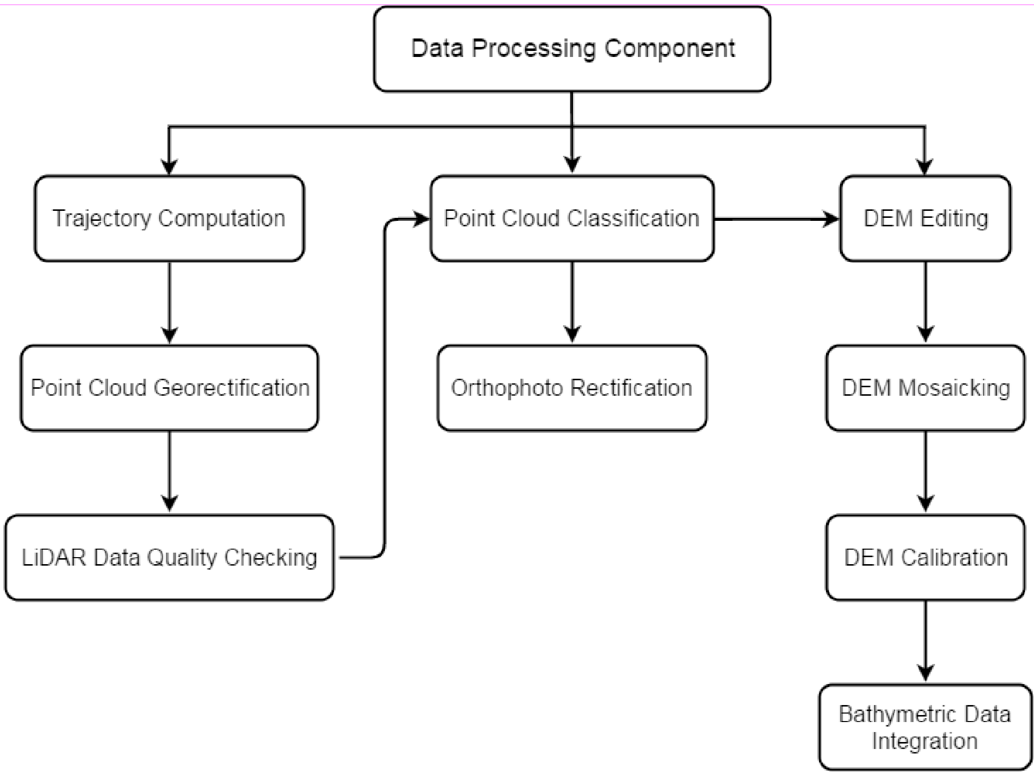


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Llorente floodplain can be found in Annex 5. All missions flown during the first and second survey respectively conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Llorente, Eastern Samar. The Data Acquisition Component (DAC) transferred a total of 41.20 Gigabytes of Range data, 747 Megabytes of POS data, 39.80 Megabytes of GPS base station data, and 249.9 Gigabytes of raw image data to the data server on June 7, 2014 for the first survey and June 8, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Llorente was fully transferred on June 19, 2014, as indicated on the Data Transfer Sheets for Llorente floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1550A, one of the Llorente 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 June 7, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

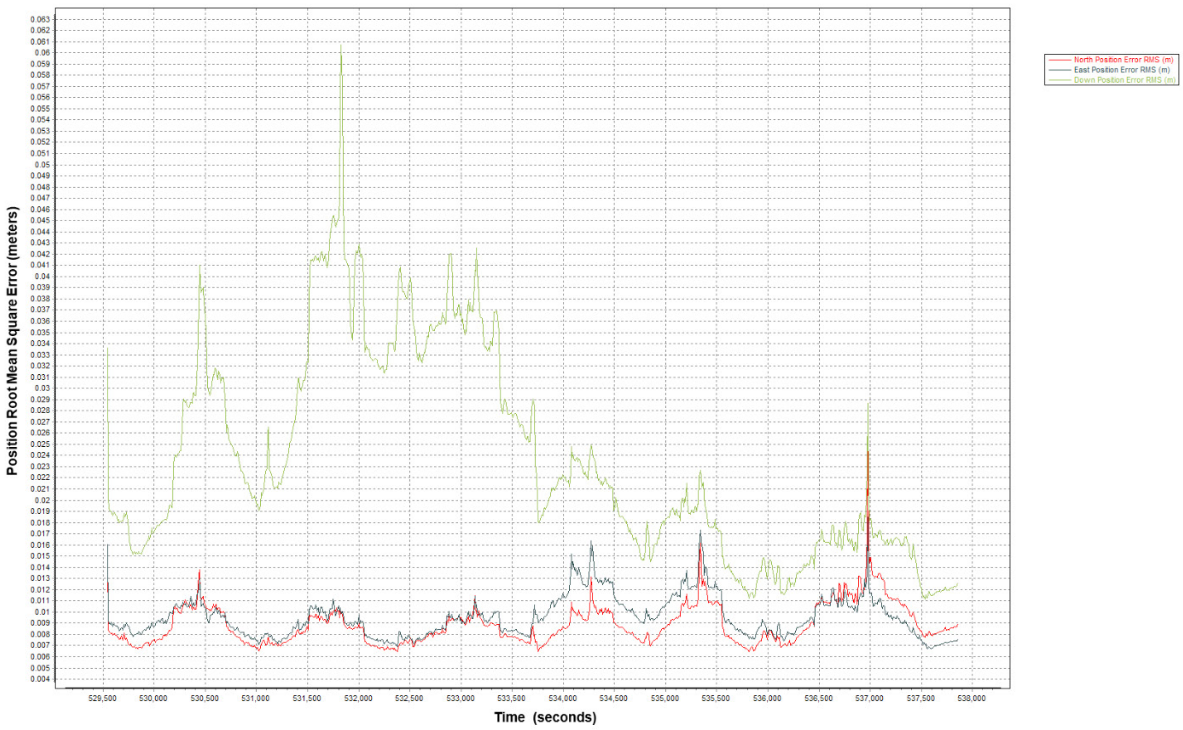


Figure 9. Smoothed Performance Metrics of Llorente Flight 1550A.

The time of flight was from 529500 seconds to 538000 seconds, which corresponds to morning of June 7, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system 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 9 shows that the North position RMSE peaks at 2.50 centimeters, the East position RMSE peaks at 1.90 centimeters, and the Down position RMSE peaks at 6.10 centimeters, which are within the prescribed accuracies described in the methodology.

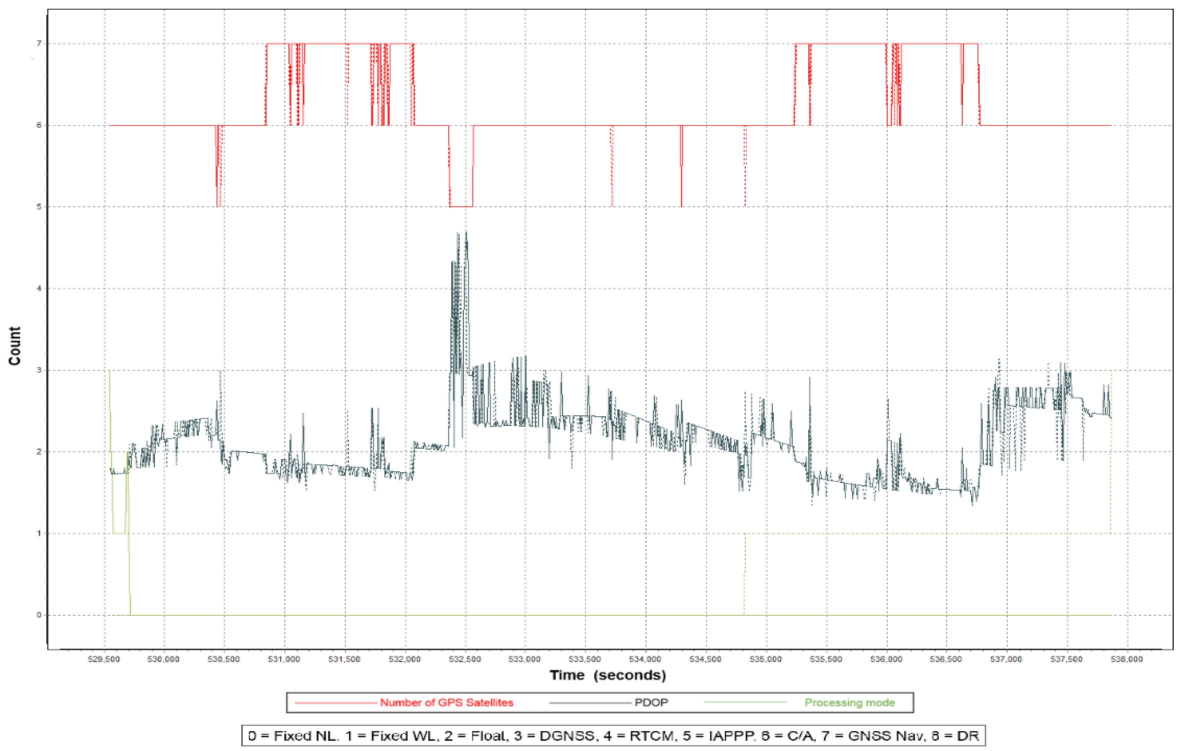


Figure 10 Solution Status Parameters of Llorente Flight 1550A.

The Solution Status parameters of flight 1550A, one of the Llorente flights, which indicate 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 go down below 6. Majority of the time, the number of satellites tracked was between 5 and 7. The PDOP value also go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Llorente flights is shown in Figure 11.

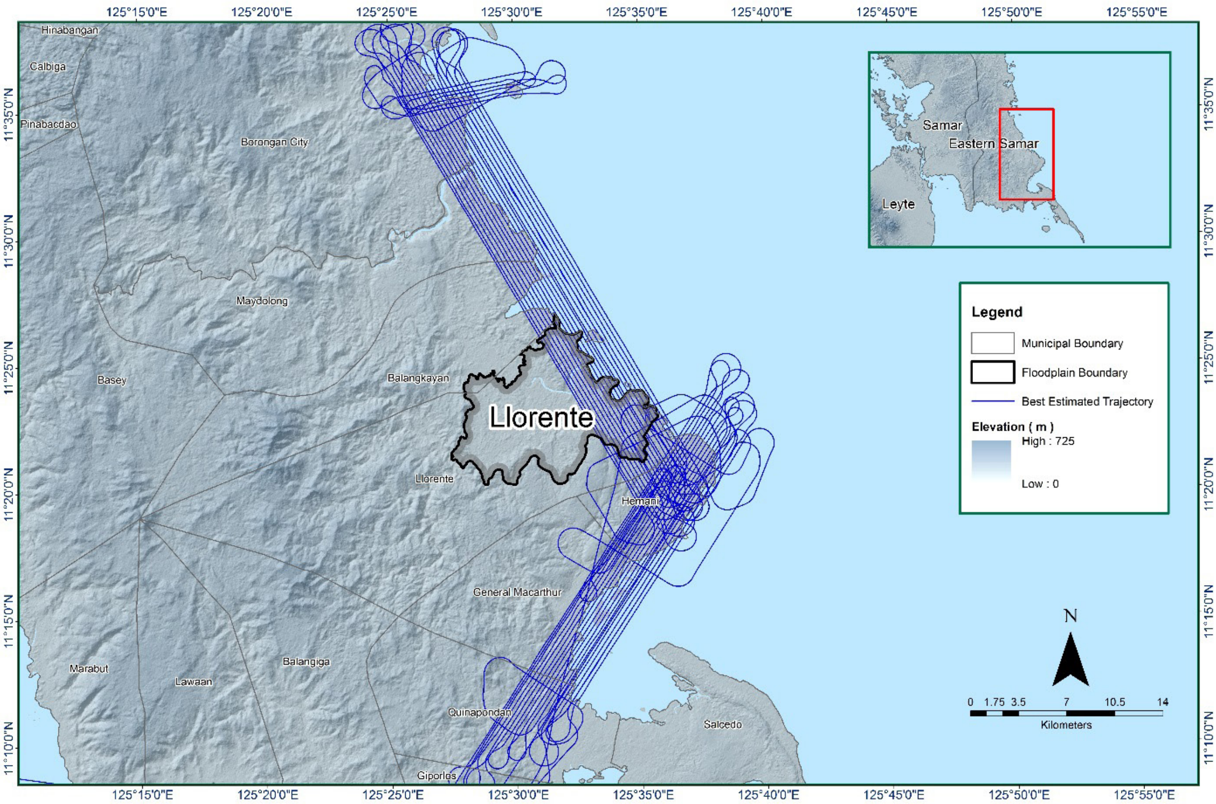


Figure 11. Best estimated trajectory for Llorente floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 52 flight lines, with each flight line containing one channel, since the Aquarius system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Llorente floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Llorente flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000508
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000905
GPS Position Z-correction stdev	(<0.01meters)	0.0037

The optimum accuracy is obtained for all Llorente flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

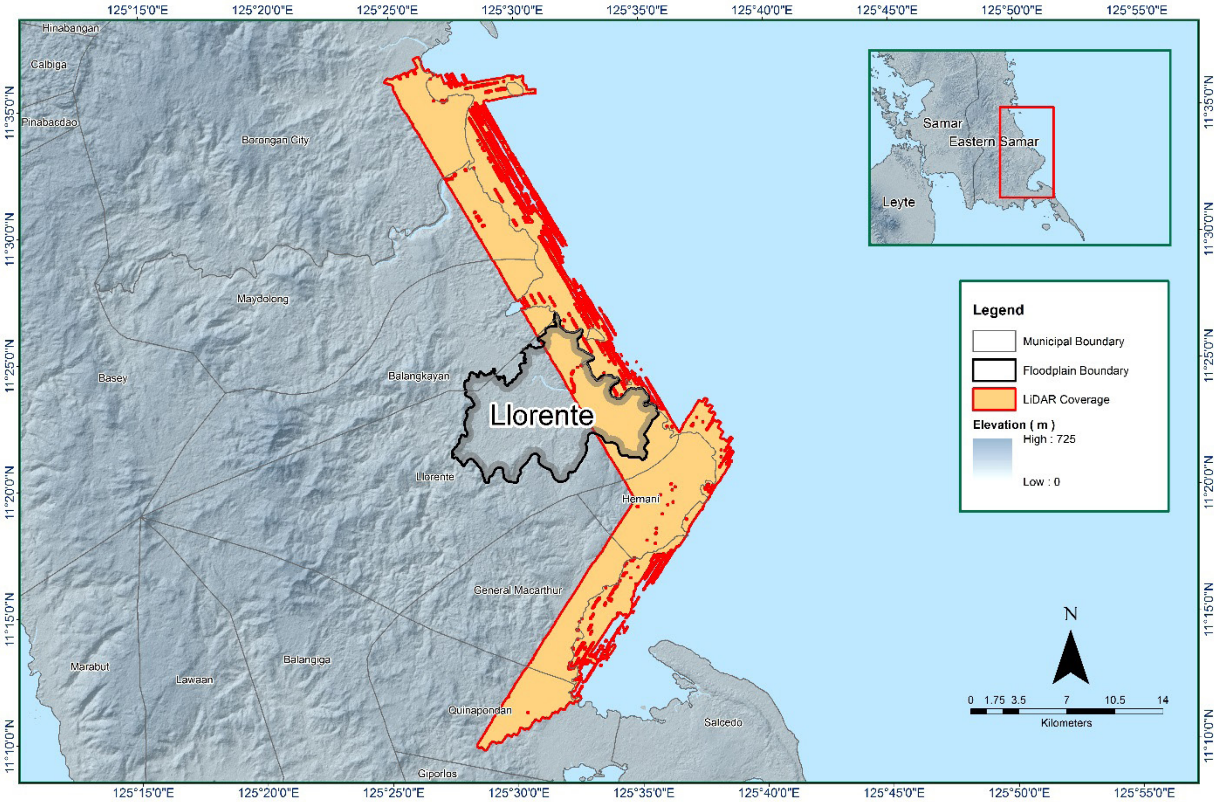


Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Llorente Floodplain.

The total area covered by the Llorente missions is 251.08 sq.km that is comprised of three (3) flight acquisitions grouped and merged into three (3) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Llorente floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk33M	1554A	145.49
	1556A	
Samar_Leyte_Blk33P	1550A	101.32
	1554A	
Samar_Leyte_Blk33P_additional	1554A	4.27
TOTAL		251.08 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 Aquarius system employs only one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

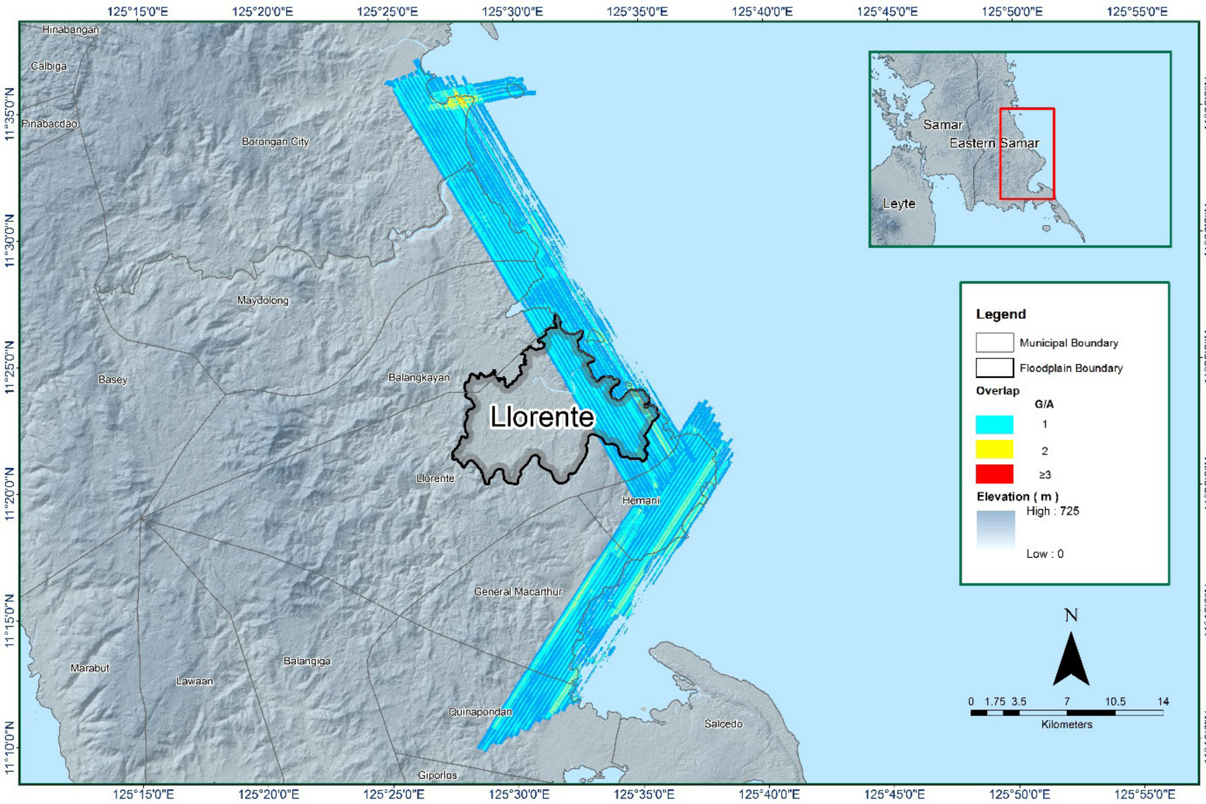


Figure 13. Image of data overlap for Llorente floodplain.

The overlap statistics per block for the Llorente floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 41.81% and 47.89% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Llorente floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.81 points per square meter.

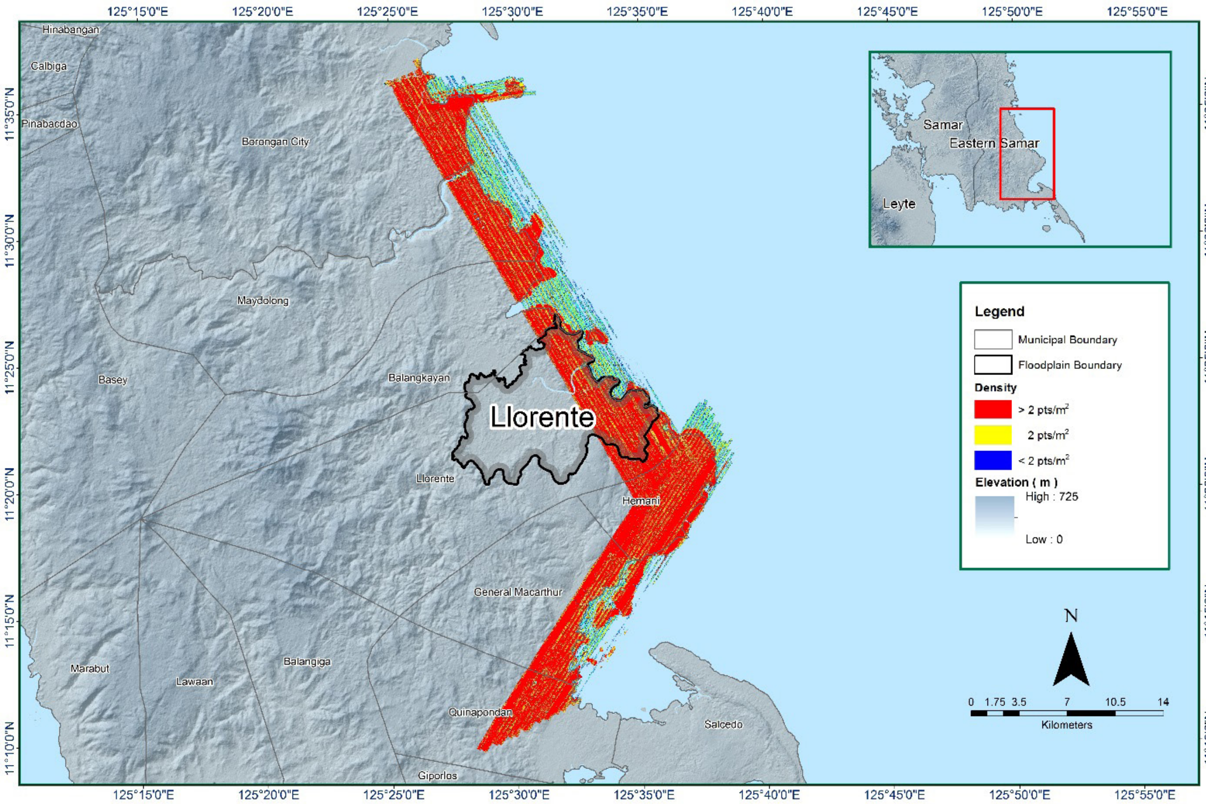


Figure 14. Density map of merged LiDAR data for Llorente floodplain.

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.

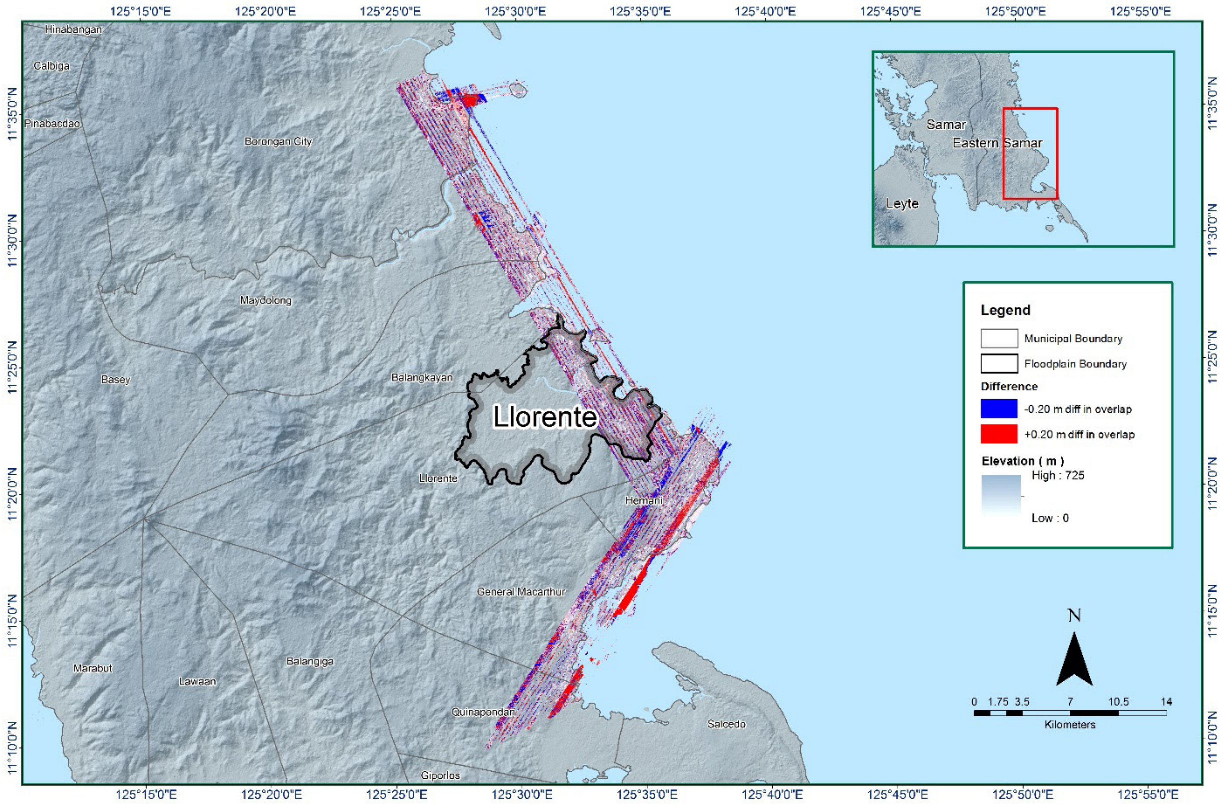


Figure 15. Elevation difference map between flight lines for Llorente floodplain.

A screen capture of the processed LAS data from Llorente flight 1550A 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.

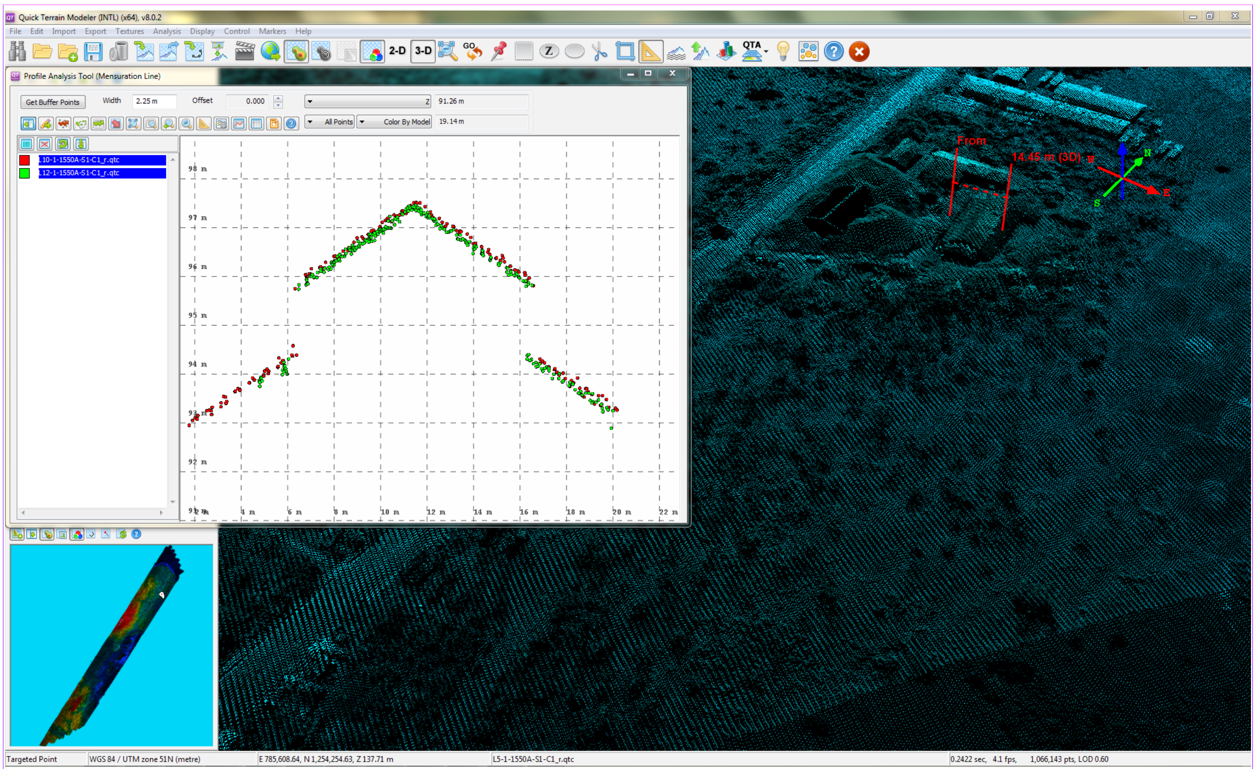


Figure 16. Quality checking for Llorente flight 1550A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Llorente classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	435,987,559
Low Vegetation	458,889,143
Medium Vegetation	390,666,975
High Vegetation	694,566,509
Building	16,172,085

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Llorente floodplain is shown in Figure 17. A total of 421 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 350.99 meters and 50.38 meters respectively.

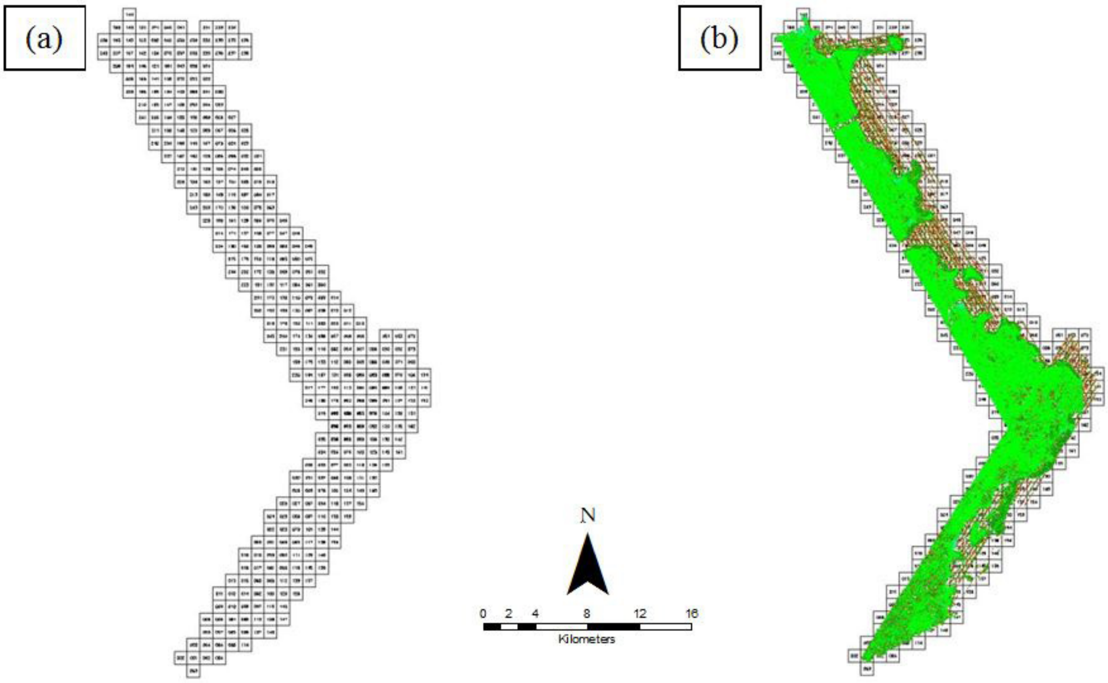


Figure 17. Tiles for Silaga floodplain (a) and classification results (b) in TerraScan.

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

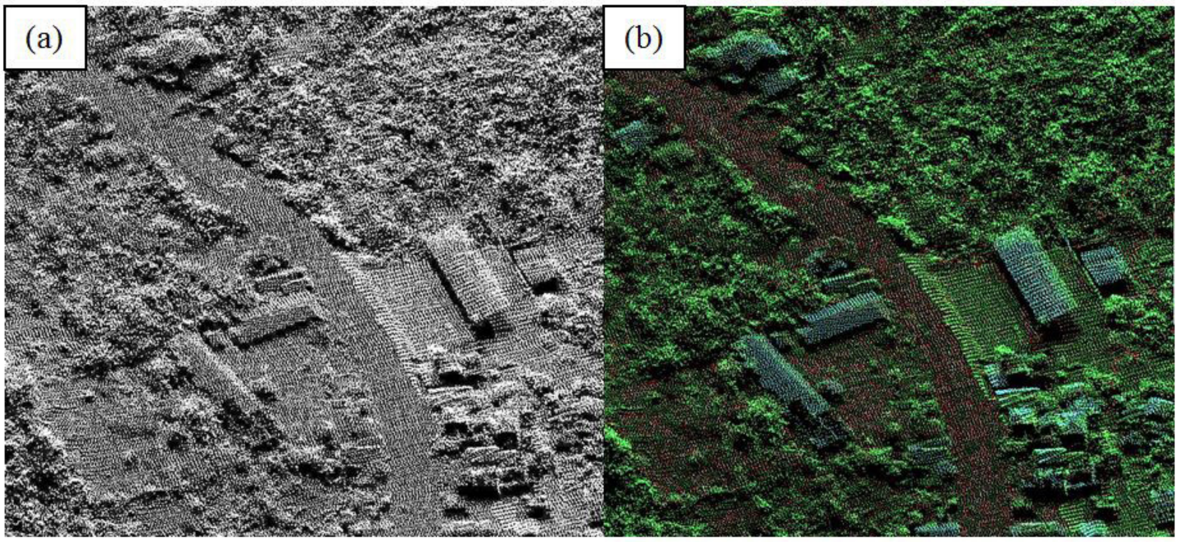


Figure 18. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

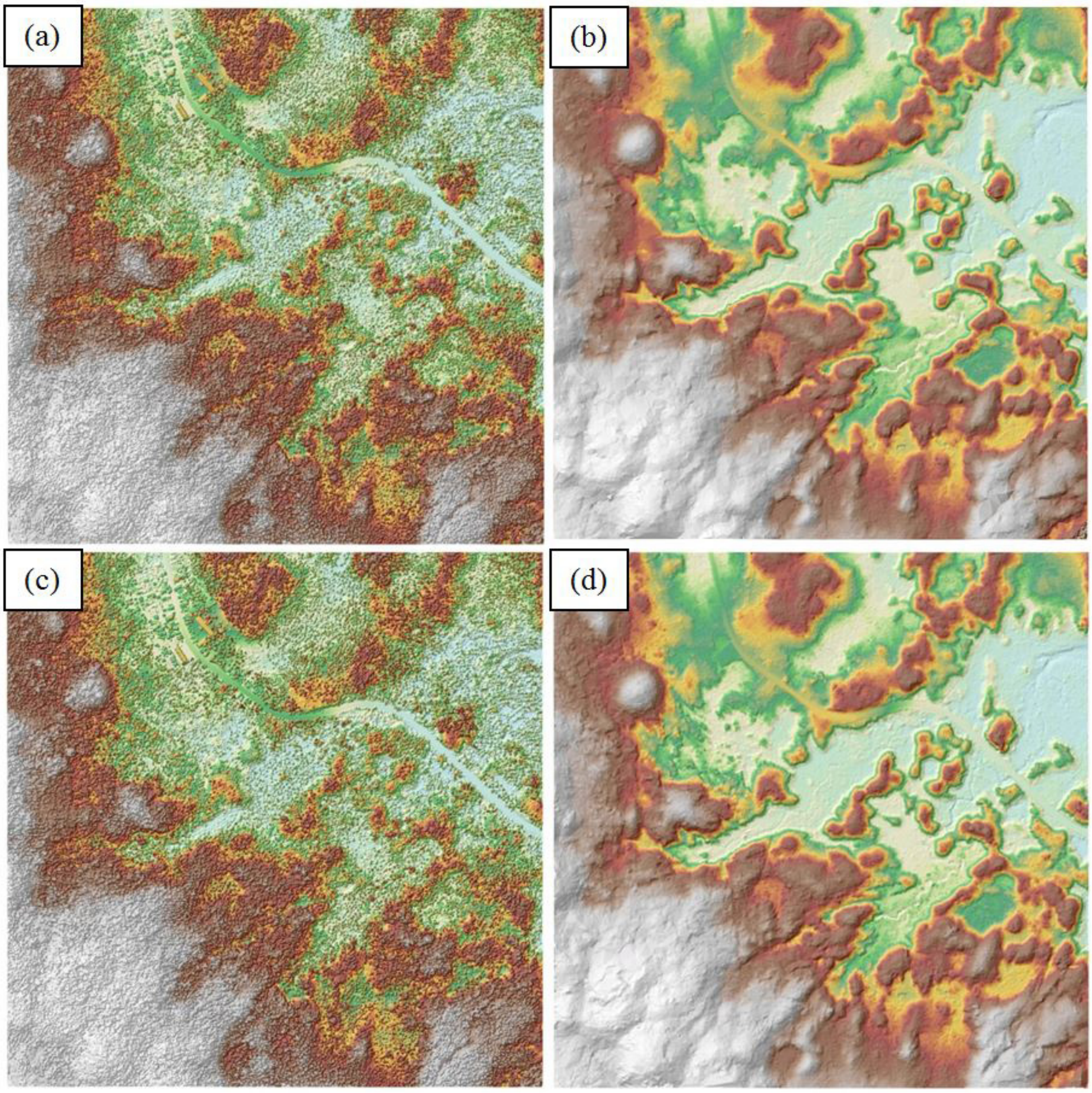


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Llorente floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 301 1km by 1km tiles area covered by Llorente 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 Llorente floodplain has a total of 205.88 sq.km orthophotograph coverage comprised of 2,782 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21

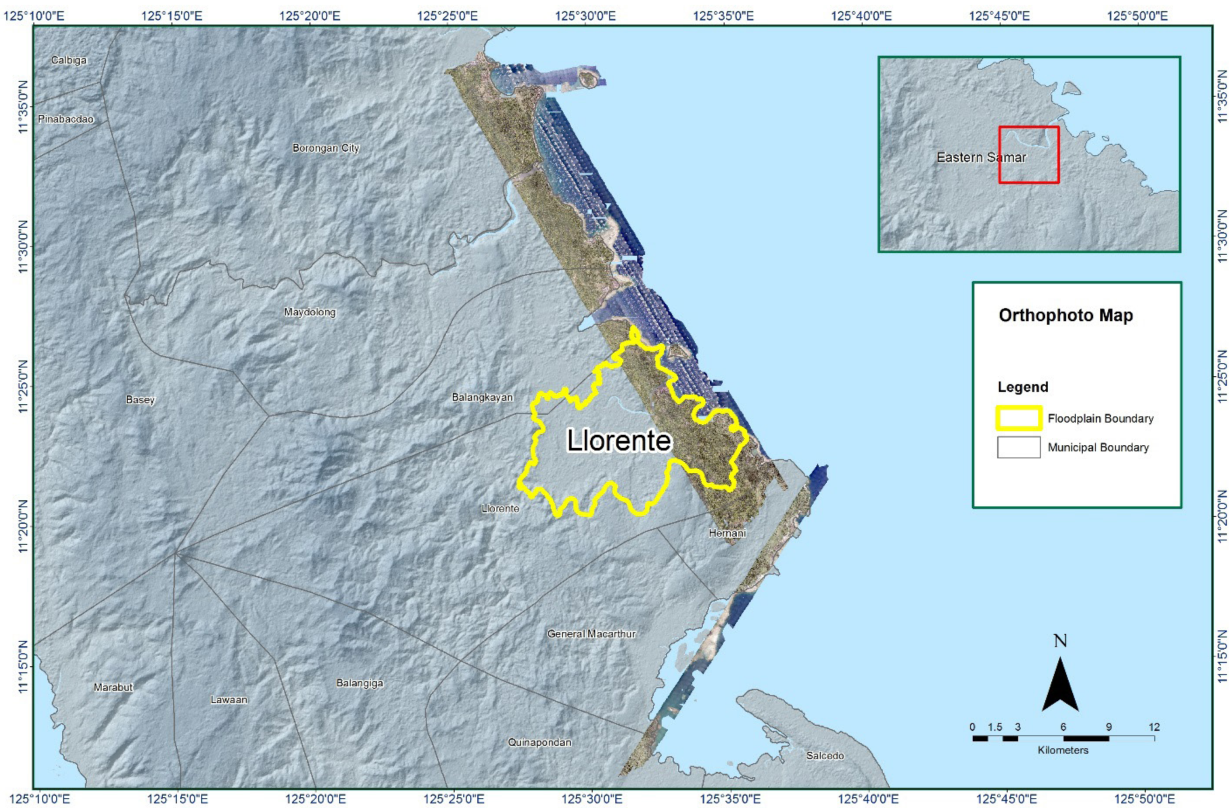


Figure 20. Llorente floodplain with available orthophotographs.

Figure 21. Sample orthophotograph tiles for Llorente floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Llorente flood plain. These blocks are composed of Samar_ Leyte blocks with a total area of 251.08 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Samar_Leyte_Blk33M	145.49
Samar_Leyte_Blk33P	101.32
Samar_Leyte_Blk33P_additional	4.27
TOTAL	251.08 sq.km

Portions of DTM before and after manual editing are shown in Figure 22. It shows that the river embankment (Figure B-22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure-22b) to allow the correct flow of water. The bridge (Figure-22c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22d) in order to hydrologically correct the river.

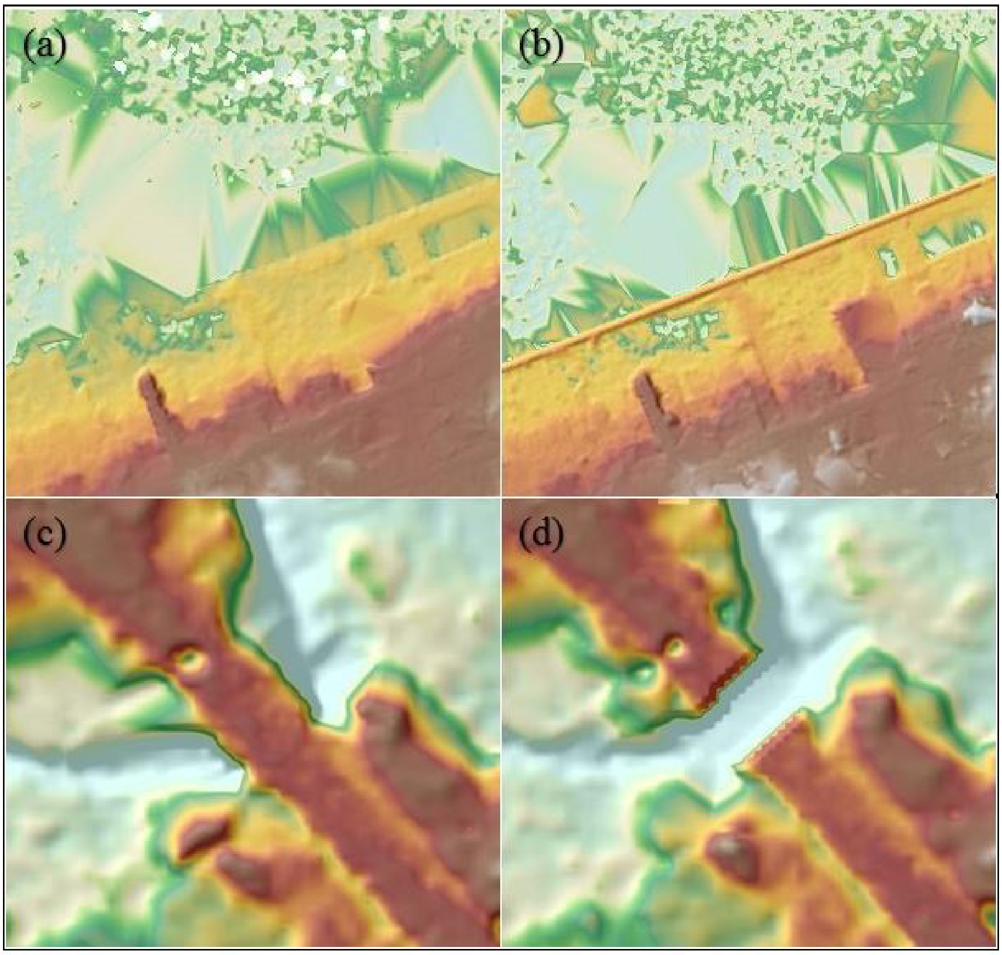


Figure 22. Portions in the DTM of Llorente floodplain – a river embankment before (a) and after (b) data retrieval and a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Tacloban DEM overlapping with the blocks to be mosaicked. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Llorente floodplain is shown in Figure 23. The entire Llorente flood plain is 33.91% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 14. Shift Values of each LiDAR Block of Llorente floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
SamarLeyte_Blk33P	-2.00	4.00	-4.45
SamarLeyte_Blk33M	-1.00	2.00	-1.00
SamarLeyte_Blk33P_additional	-2.00	2.00	-4.45

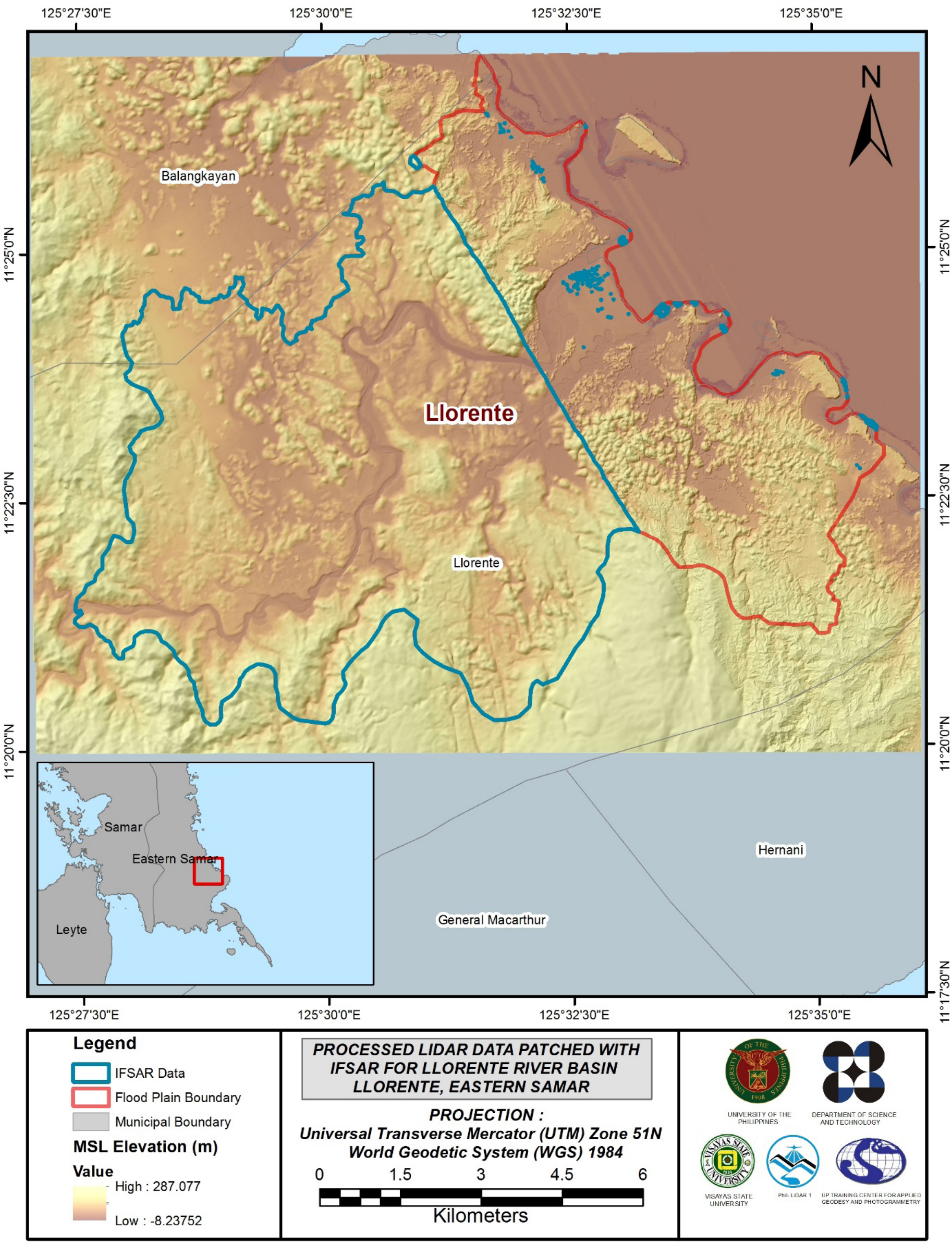


Figure 23. Map of Processed LiDAR Data for Llorente Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Samar to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 30,120 survey points were gathered for all the floodplains within Eastern and Western Samar wherein the Llorente is located. However, the point dataset was not used for the calibration of the LiDAR data for Llorente because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Llorente can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban 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 0.14 meters with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, to Tacloban mosaicked LiDAR data. Table B-6 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Llorente DEM.

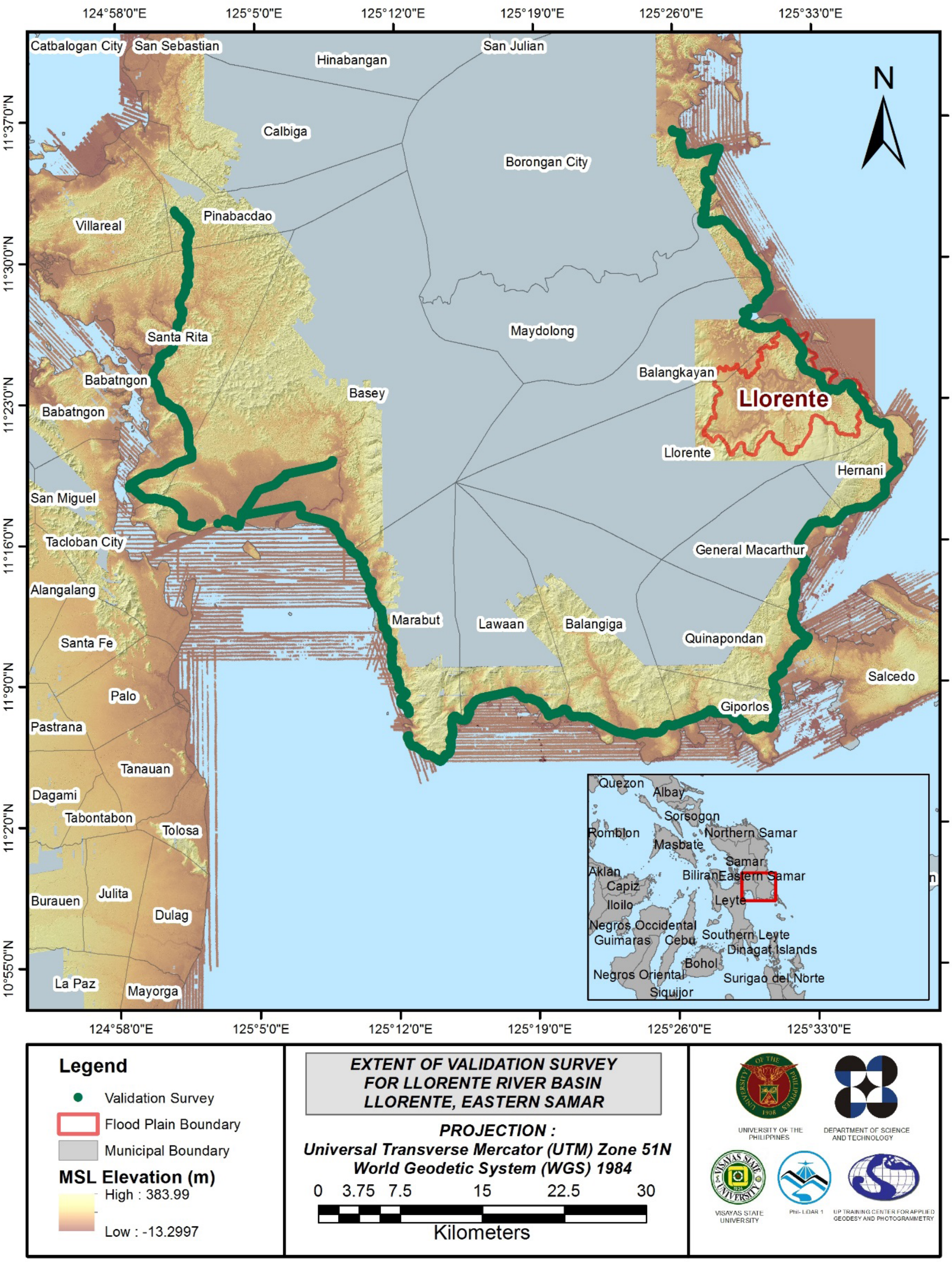


Figure 24. Map of Llorente Flood Plain with validation survey points in green.

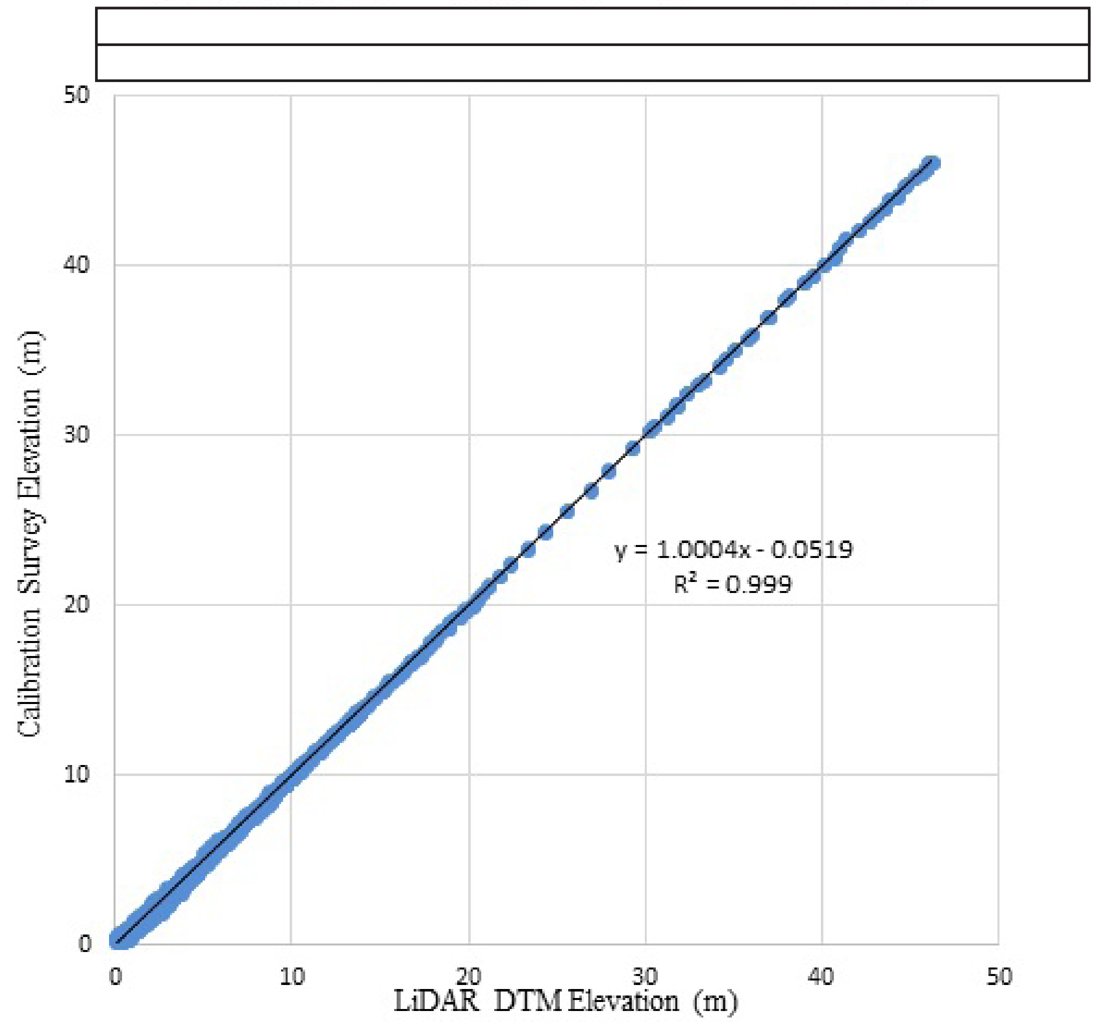


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.65
Maximum	0.50

A total of 1,493 survey points lie within Llorente flood plain and were used for the validation of the calibrated Llorente 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.14 meters, as shown in Table 15.

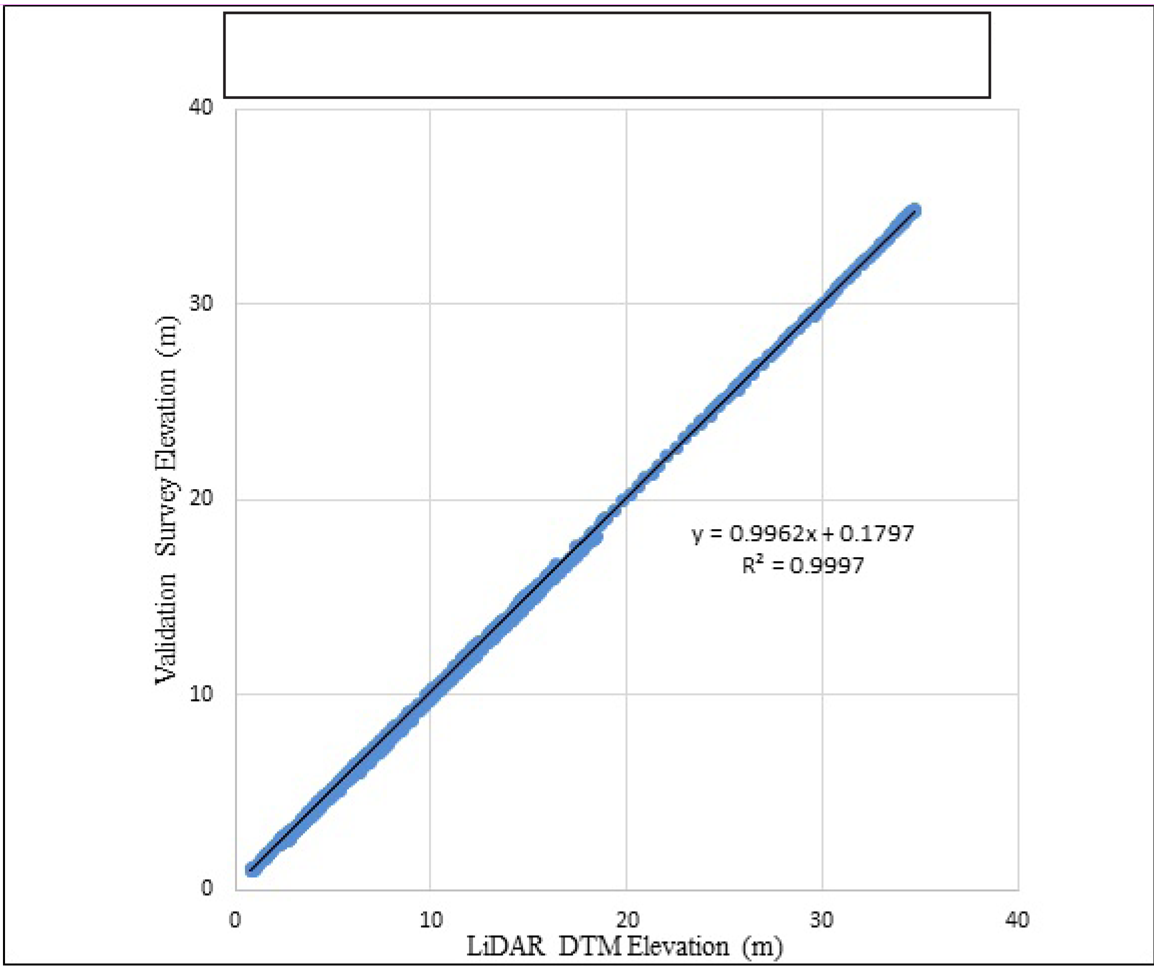


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.14
Average	0.15
Minimum	-0.20
Maximum	0.35

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data were available for Llorente with 419 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers method method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.26 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Llorente integrated with the processed LiDAR DEM is shown in Figure 27.

3.12 Feature Extraction

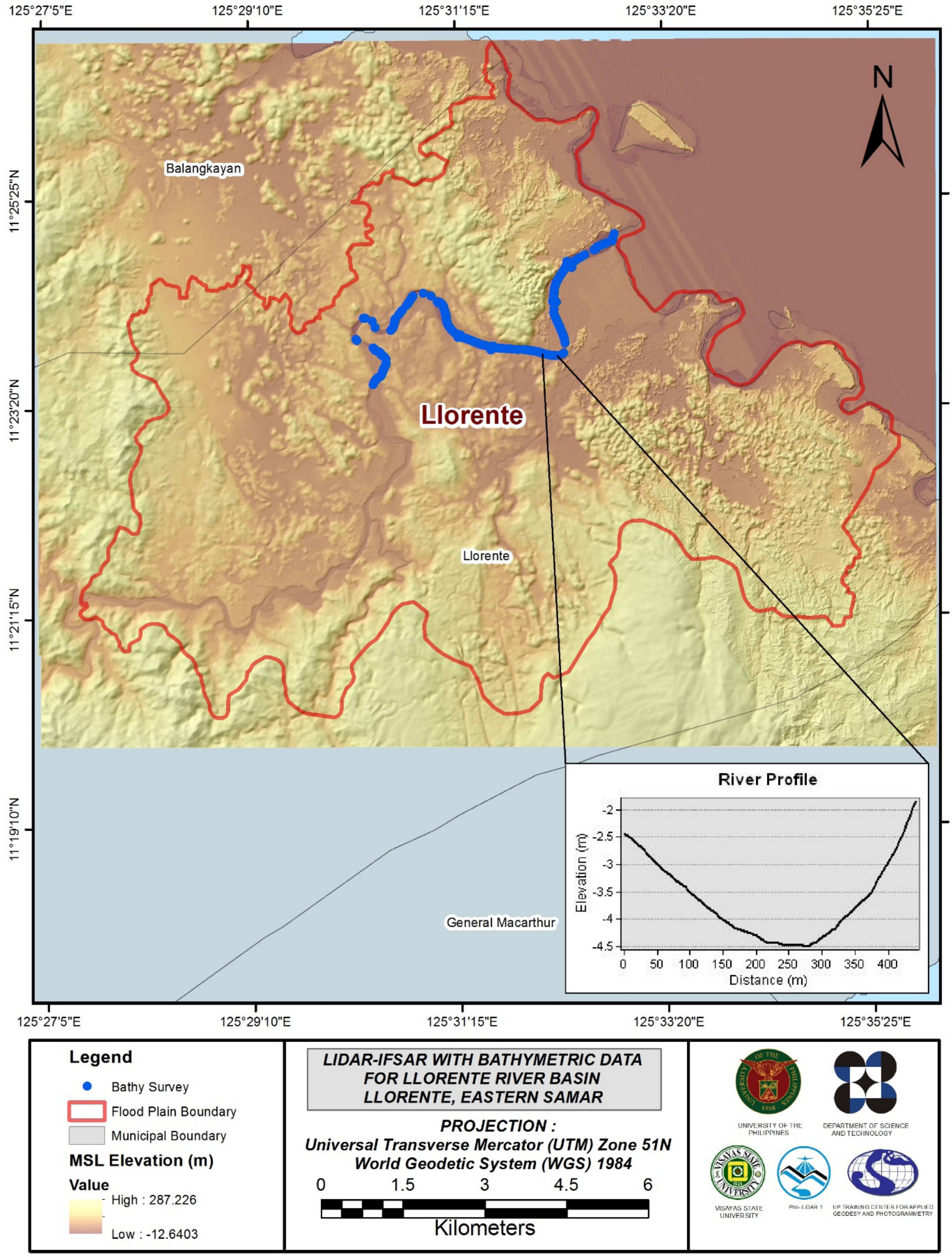


Figure 27. Map of Llorente Flood Plain with bathymetric survey points shown in blue.

3.12.1 Quality Checking of Digitized Features' Boundary

Llorente floodplain, including its 200 m buffer, has a total area of 109.12 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 499 building features, are considered for QC. Figure 28 shows the QC blocks for Llorente floodplain.

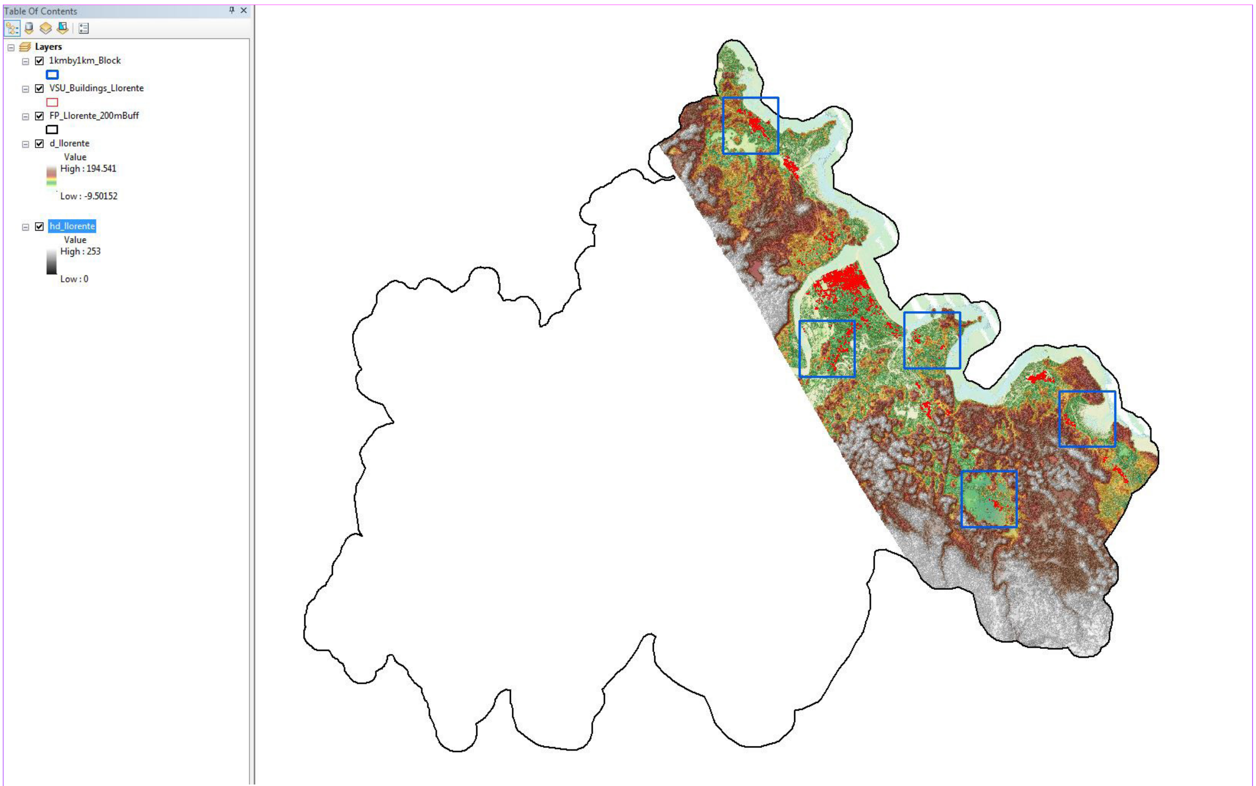


Figure 28. QC blocks for Llorente building features.

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

Table 16. Quality Checking Ratings for Llorente Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Llorente	98.04	100.00	96.99	PASSED

3.12.2 Height Extraction

Height extraction was done for 2,911 building features in Llorente floodplain. Of these building features, 16 were filtered out after height extraction, resulting to 2,895 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 5.14 m.

3.12.3 Feature Attribution

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

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

Table 17. Building Features Extracted for Llorente Floodplain.

Facility Type	No. of Features
Residential	2,720
School	104
Market	3
Agricultural/Agro-Industrial Facilities	3
Medical Institutions	5
Barangay Hall	14
Military Institution	0
Sports Center/Gymnasium/Covered Court	6
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	10
Bank	1
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	14
Other Commercial Establishments	12
Total	2,895

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

Floodplain	**Road Network Length (km)**					**Total**
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Llorente	8.52	8.99	0.0	13.11	0.00	**30.62**

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

Floodplain	**Water Body Type**					**Total**
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Llorente	7	2	0	0	0	**9**

A total of 6 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.

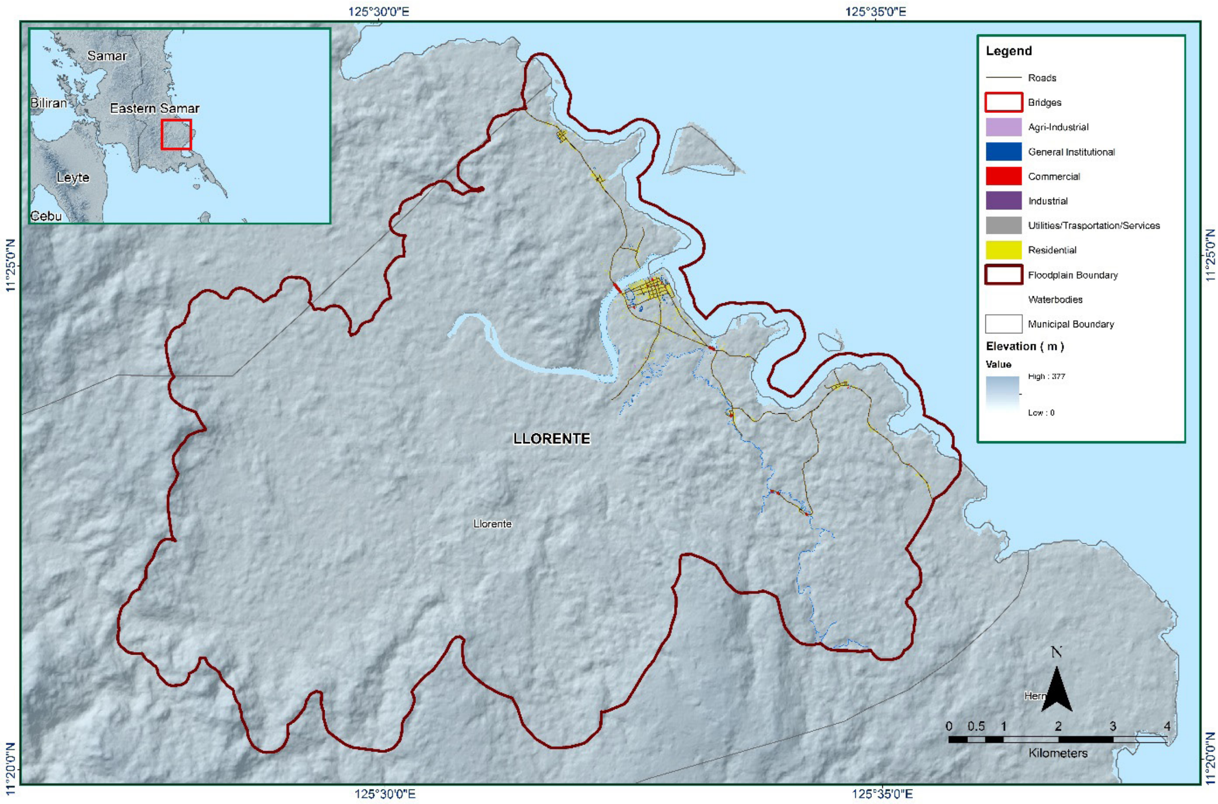


Figure 29. Extracted features for Llorente floodplain.

CHAPTER 4: SURVEY AND MEASUREMENTS IN THE LLORENTE RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo Engr. Romalyn Francis P. Boado, Mr. Erlan Patrick T. Mendoza, Mr. Michael Anthony C. Labrador, For. Maridel P. Miras, For. Rodel C. Alberto, Engr. Caren Joy S. Ordoña

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

4.1 Summary of Activities

Llorente River Basin covers portions of the Municipalities of Balangiga, Quinapondan, General Macarthur, Balangkayan and Llorente. According to DENR-RBCO, it has a drainage area of 340 km2 and an estimated 646 million cubic meter (MCM) annual run- off.

Its main stem, Llorente River, is among the 31 river systems in Eastern Visayas Region. Its water, according to its beneficial use, is categorized as Class C which is for fishery, recreation/boating, and supply for manufacturing processes after treatment. The river is named after the Municipality of Llorente where it is situated. It has a total population of 18, 731 based on the 2010 census, is one of the areas hit by Typhoon Haiyan (Yolanda) last November 8, 2013.

In line with this, the DVBC conducted a survey in Llorente River from September 10 to 24, 2014 (Samar Phase 1) and from December 4 to 18, 2014 (Samar Phase 2). The scope of work covered for Samar Phase 1 were: reconnaissance, establishment of a control points, cross-section, as-built and water level marking in MSL of Llorente Bridge in Brgy. 11, Municipality Llorente, Eastern Samar. For Samar Phase 2, using PPK survey technique, it covered the Llorente River bathymetric survey from Brgy. Cantomco down to Brgy. Tabok (mouth of the river), with an estimated length of 9.20 km.

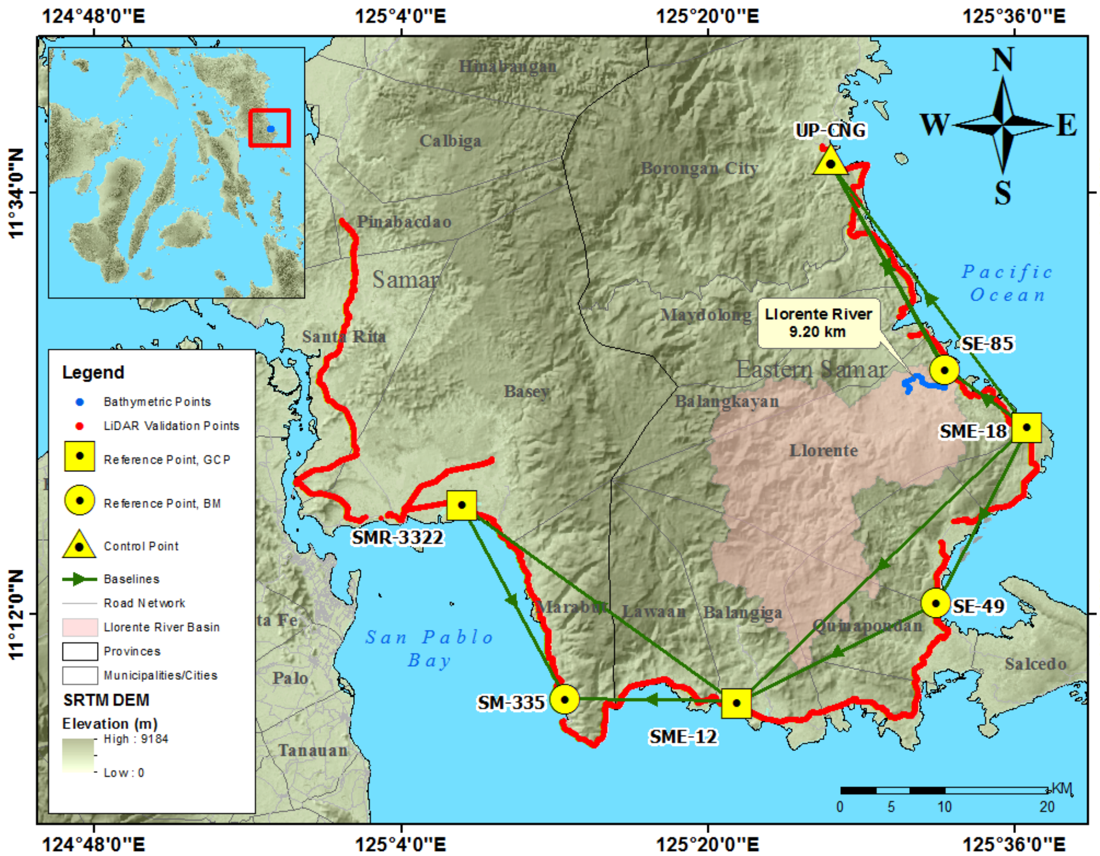


Figure 30. Extent of the bathymetric survey (in blue line) in Llorente River and the LiDAR data validation survey (red)

4.2 Control Survey

The GNSS network used for Llorente River Basin is composed of three (3) loops and a baseline established on September 12, 13, 17 and 19, 2014 occupying the following reference points: SME-18, a second-order GCP in Brgy. Cancildes, Municipality of Hernani; and SE-85, a first-order BM in Brgy. Barangay 11 Poblacion, Municipality of Llorente; both in Eastern Samar.

Two control points were established along the approach of bridges namely: UP-CNG at Can-Obing Bridge in Brgy. Can-Abong, Borongan City, East Samar; and UP-BSY at Basey Bridge, in Brgy. Guirang, Municipality of Basey, Samar. NAMRIA established control points: SME-12 in Brgy. San Miguel, Municipality of Balangiga; SE-49 in Brgy. Aguinaldo, Municipality of General Macarthur, both in Easter Samar; and SMR-3322 in Brgy. Binongtu-an, Municipality of Basey; and SM-335 in Pinalanga, Municipality of Marabut, both in Samar; were also used as marker during the survey.

The summary of reference and control points and its location is summarized in Table 20 while the GNSS network established is illustrated in Figure 31.

Figure 31. GNSS Network of Samar and Eastern Samar Field Survey

Table 20. List of references ad control Points used in Llorente River survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Estab-lished
SME-18	2nd Order GCP	11d21’43.08127”	125d36’37.41862”	78.217	17.66	Sep 12, 2014
SE-85	1st Order BM	11d24’45.65441”	125d32’20.98934”	67.52	6.31	Sep 12, 2014
SME-12	Used as Marker	11d07’19.15395”	125d21’29.28283”	67.212	2.721	Sep 13, 2014
SMR-3322	Used as Marker	11d17’40.55190”	125d07’10.82309”	70.666	6.636	Sep 17, 016
SE-49	Used as Marker	11d12’34.48802”	125d31’52.42238”	66.981	3.779	Sep 13, 2014
SM-33S	Used as Marker	11d07’33.79721”	125d12’32.14831”	68.705	3.951	Sep 17, 2014
UP-CNG	UP Established	11d35’44.92939”	125d26’23.62776”	67.094	6.035	Sep 12, 2014
UP-BSY	UP Established	11d27’57.66166”	125d01’08.84182”	73.078	9.958	Sep 19, 2014

The GNSS set-ups on recovered reference points and established control points in Balangiga River are shown in Figure 32 to Figure 37.

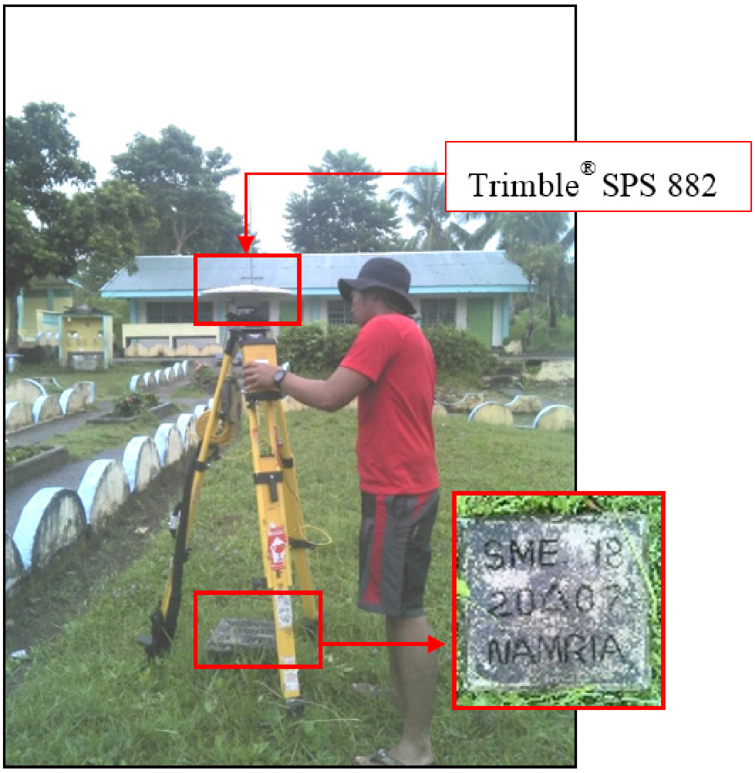


Figure 32. GNSS base receiver setup, Trimble® SPS 852 at SME-18, located inside San Jose Elem. School, Brgy. Canciledes, Municipality of Hernani, Eastern Samar

Figure 33. GNSS receiver, Trimble® SPS 882, at SE-85, located at the approach of Llorente Bridge in Bry. 11, Mun. of Llorente, Eastern Samar

Figure 34. GNSS receiver occupation, Trimble® SPS 882, at SME-12 in Brgy. San Miguel, Mun. of Balangiga, Eastern Samar

Figure 35. GNSS base occupation, Trimble® SPS 852, at SMR-3322, located at the approach of Golden Bridge in Brgy. Binongtu-an, Mun. of Basey, Samar

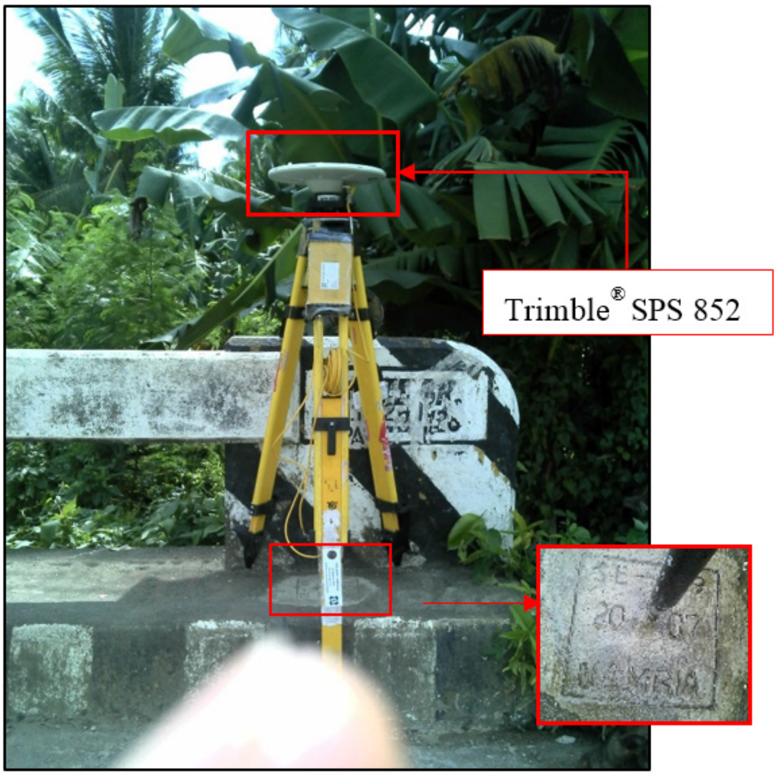


Figure 36. GNSS base occupation, Trimble® SPS 852, at SE-49, in Brgy. Aguinaldo, Mun. of General Macarthur, Eastern Samar

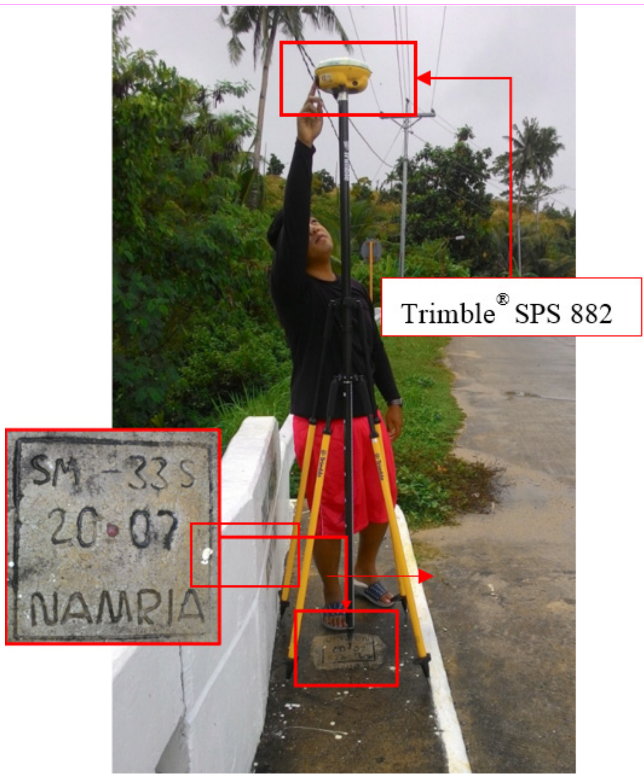


Figure 37. GNSS base occupation, Trimble® SPS 882, at SM-335, in Brgy. Pinalanga, Mun. of Maravut, Samar

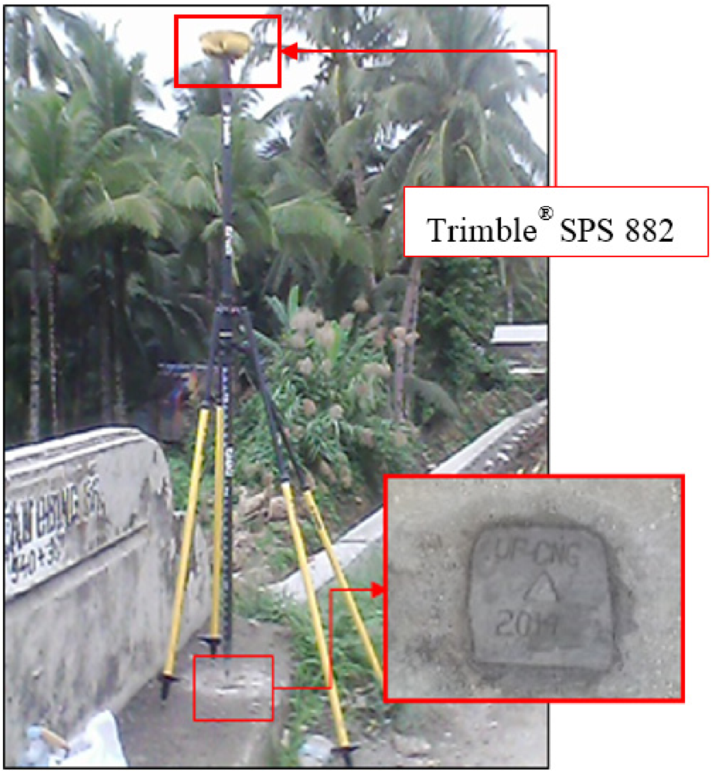


Figure 38. GNSS receiver occupation, Trimble® SPS 882, at UP-CNG, located at the approach of Can-Obing Bridge in Brgy. Can-Abong, Borongan City, Eastern Samar

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 is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Llorente River Basin is summarized in Table 21, generated by TBC software.

Table 21. Baseline Processing Report for Llorente River static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SME-18 --- SE-85	09-12-14	Fixed	0.004	0.015	305°49’17”	9586.978	-10.699
SME-18 --- SE-85	09-12-14	Fixed	0.005	0.033	305°49’17”	9586.977	-10.719
SME-18 --- UP-CNG	09-12-14	Fixed	0.003	0.013	324°17’44”	31862.046	-11.107
SME-18 --- SE-49	09-13-14	Fixed	0.003	0.016	207°09’17”	18943.356	-11.212
UP-CNG --- SE-85	09-12-14	Fixed	0.005	0.041	331°52’51”	22970.859	-0.416
SE-85 --- UP-CNG	09-12-14	Fixed	0.007	0.019	331°52’51”	22970.857	-0.437
SE-49 --- SME-12	09-13-14	Fixed	0.004	0.019	242°52’57”	21244.542	0.227
SME-12 --- SM-33S	09-17-14	Fixed	0.004	0.017	271°35’44”	16305.472	1.501
SME-12 --- SM-33S	09-17-14	Fixed	0.019	0.033	271°35’44”	16305.477	1.450
SME-12 --- SMR-3322	09-17-14	Fixed	0.003	0.014	306°16’15”	32291.859	3.461
SME-18 --- SME-12	09-13-14	Fixed	0.004	0.018	226°05’03”	38255.209	-11.019
SMR-3322 --- UP-BSY	09-19-14	Fixed	0.003	0.012	38°27’35”	6709.313	1.891
SMR-332 --- SM-33S	09-17-14	Fixed	0.004	0.014	152°23’19”	21038.056	-1.964
SMR-3322 --- SM-33S	09-17-14	Fixed	0.006	0.038	152°23’20”	21038.062	-1.978

As shown Error! Reference source not found. a total of fourteen (14) baselines were processed with coordinates of SME-18 and elevation value of reference point SE-85 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 22 to Table 25 for complete details.

The eight (8) control points, SME-18, SE-85, SME-12, SMR-3322, SE-49, SM-335, UP-CNG and UP-BSY were occupied and observed simultaneously to form a GNSS loop. Coordinates of SME-18 and elevation values SE-85 were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SE-85	Grid				Fixed
SME-18	Local	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

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

Table 23. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SE-49	776407.626	0.007	1240340.446	0.005	3.779	0.050	
SE-85	777079.164	0.006	1262825.941	0.004	6.310	?	e
SM-335	741264.593	0.010	1230815.204	0.007	3.951	0.061	
SME-12	757572.894	0.007	1230490.556	0.005	2.721	0.051	
SME-18	784907.431	?	1257282.043	?	17.660	0.032	LL
SMR-3322	731377.313	0.009	1249392.087	0.007	6.636	0.060	
UP-CNG	766068.484	0.005	1282999.389	0.004	6.035	0.036	

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

SME-18

horizontal accuracy	=	Fixed
vertical accuracy	=	3.2 < 10 cm

SE-85

horizontal accuracy	=	$\surd((0.6)^2 + (0.4)^2$
	=	$\surd\ (0.36 + 0.16)$
	=	0.72 < 20 cm
vertical accuracy	=	Fixed

SME-12

horizontal accuracy	=	$\surd((0.7)^2 + (0.5)^2$
	=	$\surd\ (0.49 + 0.25)$
	=	0.86 < 20 cm
vertical accuracy	=	5.1 < 10 cm

SMR-3322

horizontal accuracy	=	$\surd((0.9)^2 + (0.7)^2$
	=	$\surd\ (0.81 + 0.49)$
	=	1.14 < 20 cm
vertical accuracy	=	6.0 < 10 cm

SE-49

horizontal accuracy	=	$\surd((0.7)^2 + (0.5)^2$
	=	$\surd\ (0.49 + 0.25)$
	=	0.86 < 20 cm
vertical accuracy	=	5.0 < 10 cm

SM-335

horizontal accuracy	=	$\surd((1.0)^2 + (0.7)^2$
	=	$\surd\ (1.0 + 0.49)$
	=	1.22 < 20 cm
vertical accuracy	=	6.1 < 10 cm

UP-CNG

horizontal accuracy	=	$\surd((0.5)^2 + (0.4)^2$
	=	$\surd\ (0.25 + 0.16)$
	=	0.65 < 20 cm
vertical accuracy	=	3.6 < 10 cm

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

Table 24. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
SE-49	N11°12’34.48802”	E125°31’52.42238	66.981	0.050	
SE-85	N11°24’45.65441”	E125°32’20.98934	67.520	?	e
SM-335	N11°07’33.79721”	E125°12’32.14831	68.705	0.061	
SME-12	N11°07’19.15395”	E125°21’29.28283	67.212	0.051	
SME-18	N11°21’43.08127”	E125°36’37.41862	78.217	0.032	LL
SMR-3322	N11°17’40.55190”	E125°07’10.82309	70.666	0.060	
UP-CNG	N11°35’44.92939”	E125°26’23.62776	67.094	0.036	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 24. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 25.

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

Control Point	Order of Accuracy	Geographic coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SME-18	2nd Order, GCP	11d21’43.08127”	125d36’37.41862”	78.217	1257282.043	784907.431	17.66
SE-85	1st Order, BM	11d24’45.65441”	125d32’20.98934”	67.52	1262825.941	777079.164	6.31
SME-12	Used as Marker	11d07’19.15395”	125d21’29.28283”	67.212	1230490.556	757572.894	2.721
SMR-3322	Used as Marker	11d17’40.55190”	125d07’10.82309”	70.666	1249392.087	731377.313	6.636
SE-49	Used as Marker	11d12’34.48802”	125d31’52.42238”	66.981	1240340.446	776407.626	3.779
SM-335	Used as Marker	11d07’33.79721”	125d12’32.14831”	68.705	1230815.204	741264.593	3.951
UP-CNG	UP Established	11d35’44.92939”	125d26’23.62776”	67.094	1282999.389	766068.484	6.035
UP-BSY	UP Established	11d20’31.52354”	125d09’28.44378”	72.554	1254677.422	735513.124	8.581

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

Cross-section and as-built survey were conducted on September 12, 2014 using a GNSS receiver Trimble® SPS 882 in PPK survey technique along the upstream portion of Llorente Bridge in Brgy. 11, Municipality Llorente, Eastern Samar as shown in Figure 39.

Figure 39. Llorente Bridge facing downstrem

The cross-sectional line of Llorente Bridge is about 317.71 m with a total of 35 points. Figure 40 to 42 show the summary of gathered cross-section and as-built data in a diagram, its location map, and as-built form.

A

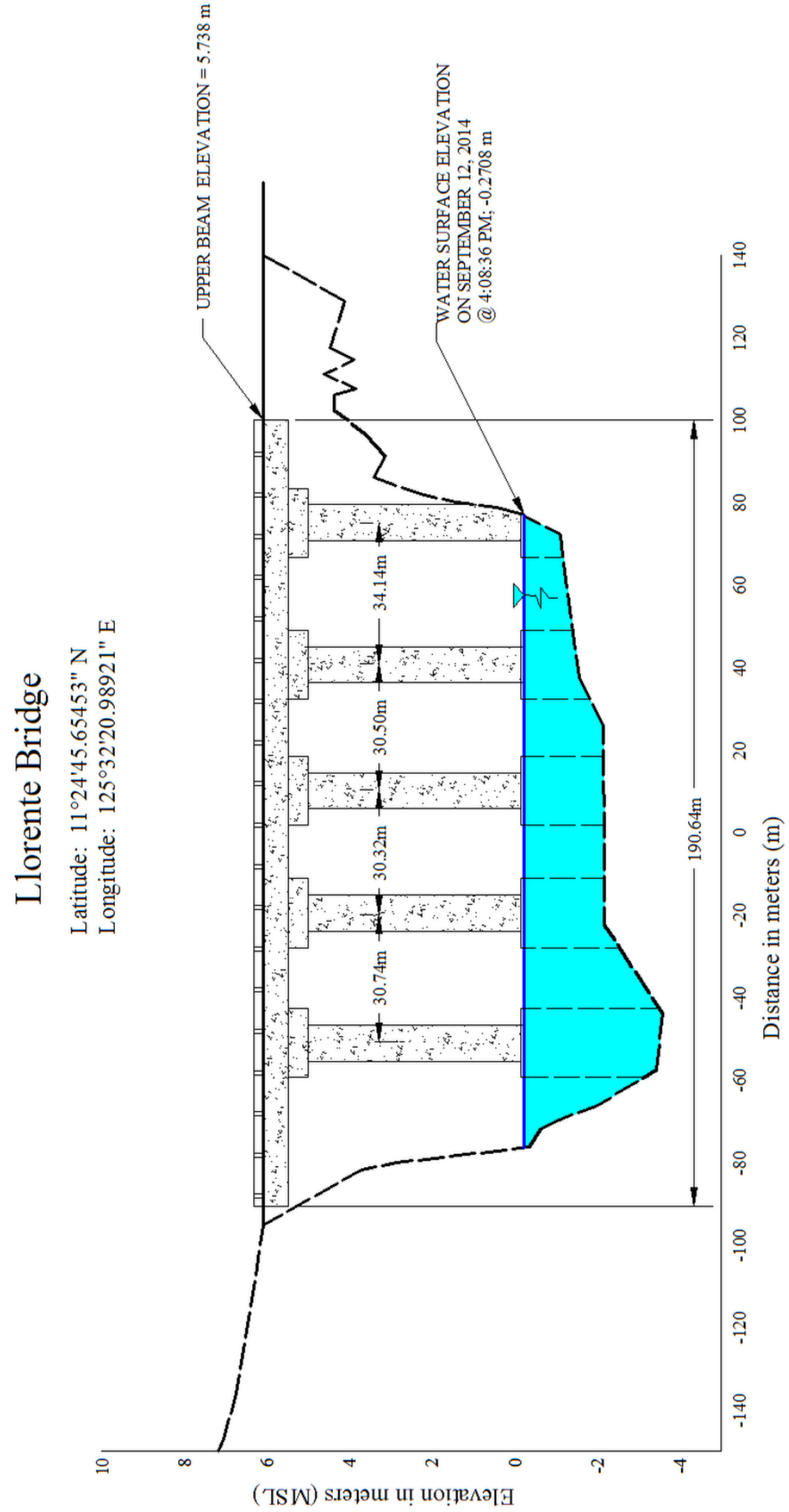


Figure 40. Llorente Bridge cross-section diagram

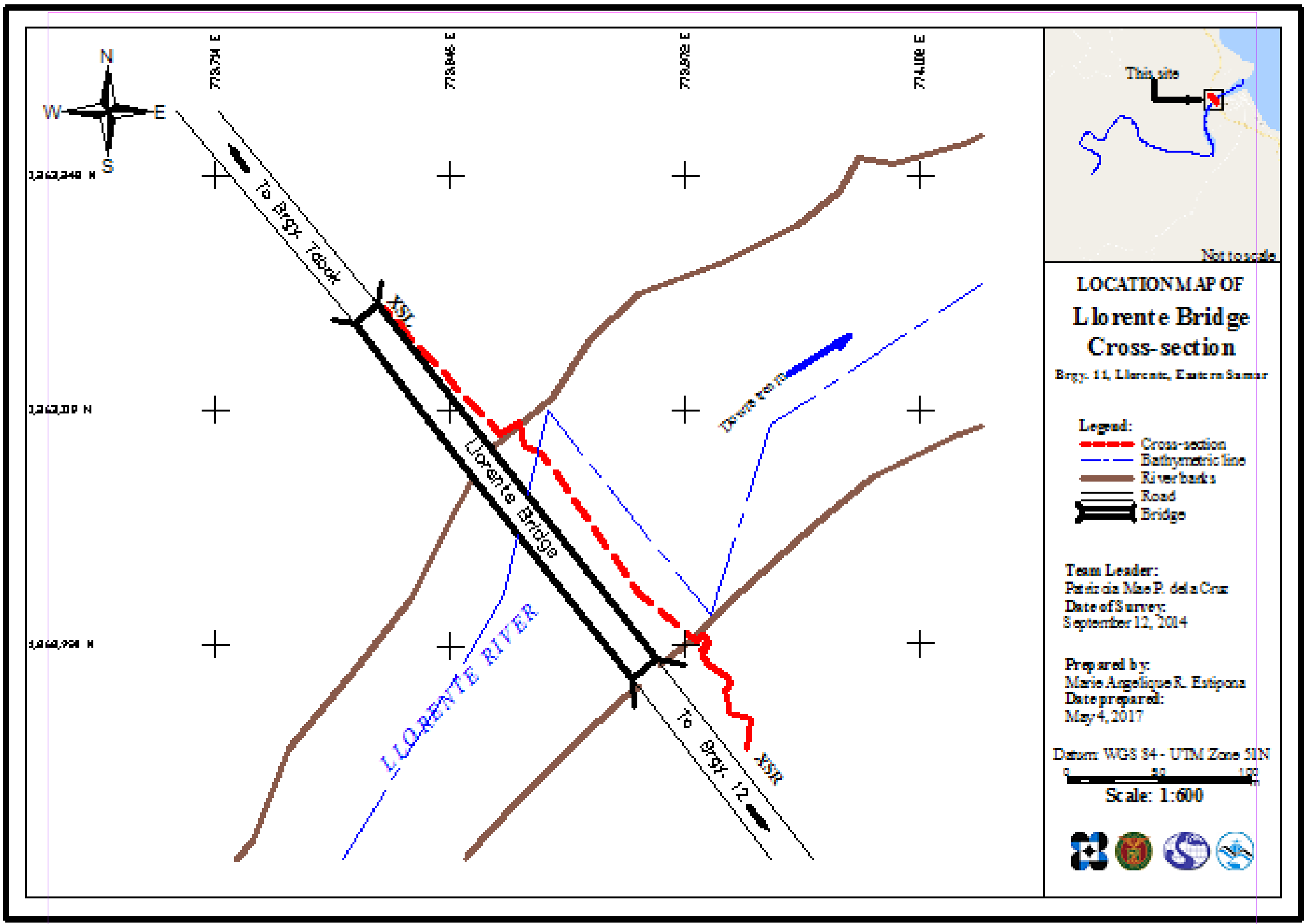


Figure 41. Llorente bridge cross-section location map

Bridge Data Form

Bridge Name: Llorente Bridge **Date:** 12-Sep-14

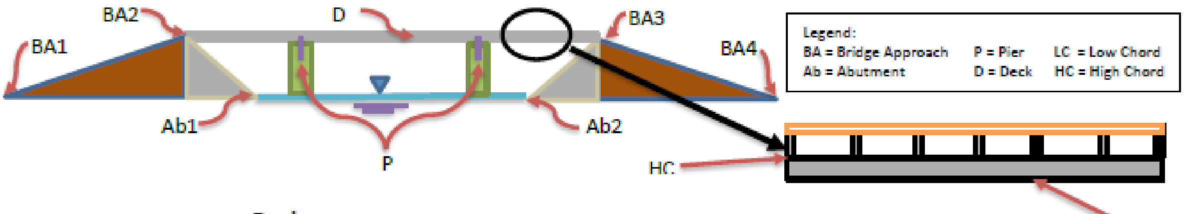
River Name: Llorente River **Time:** 3:45 PM

Location (Brgy, City, Region): Barangay 7, Llorente, Eastern Samar

Survey Team: ____________

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

Latitude: 11d24'45.65448" **Longitude:** 125d32'20.98938"



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

Elevation__________ **Width:** __________ **Span (BA3-BA2):** __________

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0		BA3	282.92 m	6.2752
BA2	92.28 m	6.2922	BA4	354.13 m	6.1512

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

	Station (Distance from BA1)	Elevation
Ab1	103.34 m	-0.1188
Ab2	255.60 m	-0.7680

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

Shape: Circular Number of Piers: 5 Height of column footing: __________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	126.74 m		
Pier 2	157.21 m		
Pier 3	187.95 m		
Pier 4	218.27 m		
Pier 5	248.77 m		

Figure 42. Llorente Bridge Data Form

The water surface elevation of Llorente River was acquired using Trimble® SPS 882 in PPK survey technique on September 12, 2014 at 4:08:36 PM. The resulting water surface elevation data is -0.2708 m above MSL. The markings on the bridge pier shall serve as a reference for flow data gathering and depth gauge deployment of Visayas State University PHIL-LIDAR 1 (see Figure 3).

Figure 43. Actual (A) and finished (B) MSL water level markings in Llorente Bridge's Pier

B

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 14, 15, 17, 18, 19 and 20 2014 using Trimble® SPS 882 receiver mounted on a pole which was attached in front of the vehicle. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS receiver. The survey was conducted using PPK technique on a continuous topography mode.

The six-day survey covered major roads running from the City of Borongan, Eastern Samar to the Municipality of Pinabacdao, Samar. Table 26 summarizes the locations and control points occupied for each day.

Table 26. Ground Validation six days survey within the Samar Phase 1 fieldwork last September 10-24, 2014

DATE	RANGE OF SURVEY	CONTROL POINTS OCCUPIED
Sept. 14, 2014	Purok D1, Borongan to Barangay 10, Llorente, Eastern Samar	UP-CNG
Sept. 15, 2014	Brgy. Canciledes, Hernani to Brgy. San Miguel Balangiga, Eastern Samar	SE-49
Sept. 17, 2014	Brgy. Poblacion V. Balangiga, Eastern Samar to Brgy. Cotato Poblacion, Marabut, Samar	SM-33S
Sept. 18, 2014	Brgy. Pinalang, Marabut to Brgy. Guirang, Basey, Samar	SRM-3322
Sept. 19, 2014	Brgy. Iba, Basey to Brgy. Laygayon, Pinabacdao, Samar	SRM-3322
Sept. 20, 2014	Brgy. Tabok Llorente to Brgy. Canciledes, Hernani, Eastern Samar	SE-85

The survey acquired 30,114 ground validation points with an approximate length of 296.88 km, shown in Figure 44.

Figure 44. LiDAR ground validation survey along Samar and Eastern Region

4.7 Bathymetric Survey

Manual bathymetry was performed all throughout the survey on December 15, 2014 because of the malfunctioning echo sounder. Two (2) types of manual bathymetry were executed, the first is by carrying a range pole with an installed Trimble® SPS 882 receiver for the upstream shallow part of the river, as seen in Figure 46, and by using a portable depth sounder to acquire depth data as shown in Figure 45.

Figure 45. Bathymetric survey using portable depth sounder and stadia rod deployment for depth checking in Llorente River

Figure 46. Bathymetric survey in upstream Llorente River

The survey started in Brgy. Cantomco, Municipality Llorente, Eastern Samar with coordinates 11˚23'33.55387" 125˚30'24.27076" down to the mouth of the river in Brgy. Tabok, Municipality of Llorente, Eastern Samr with coordinates 11˚25'02.52376" 125˚32'50.82653". The control point SE-85 was used as the GNSS base station all throughout the survey.

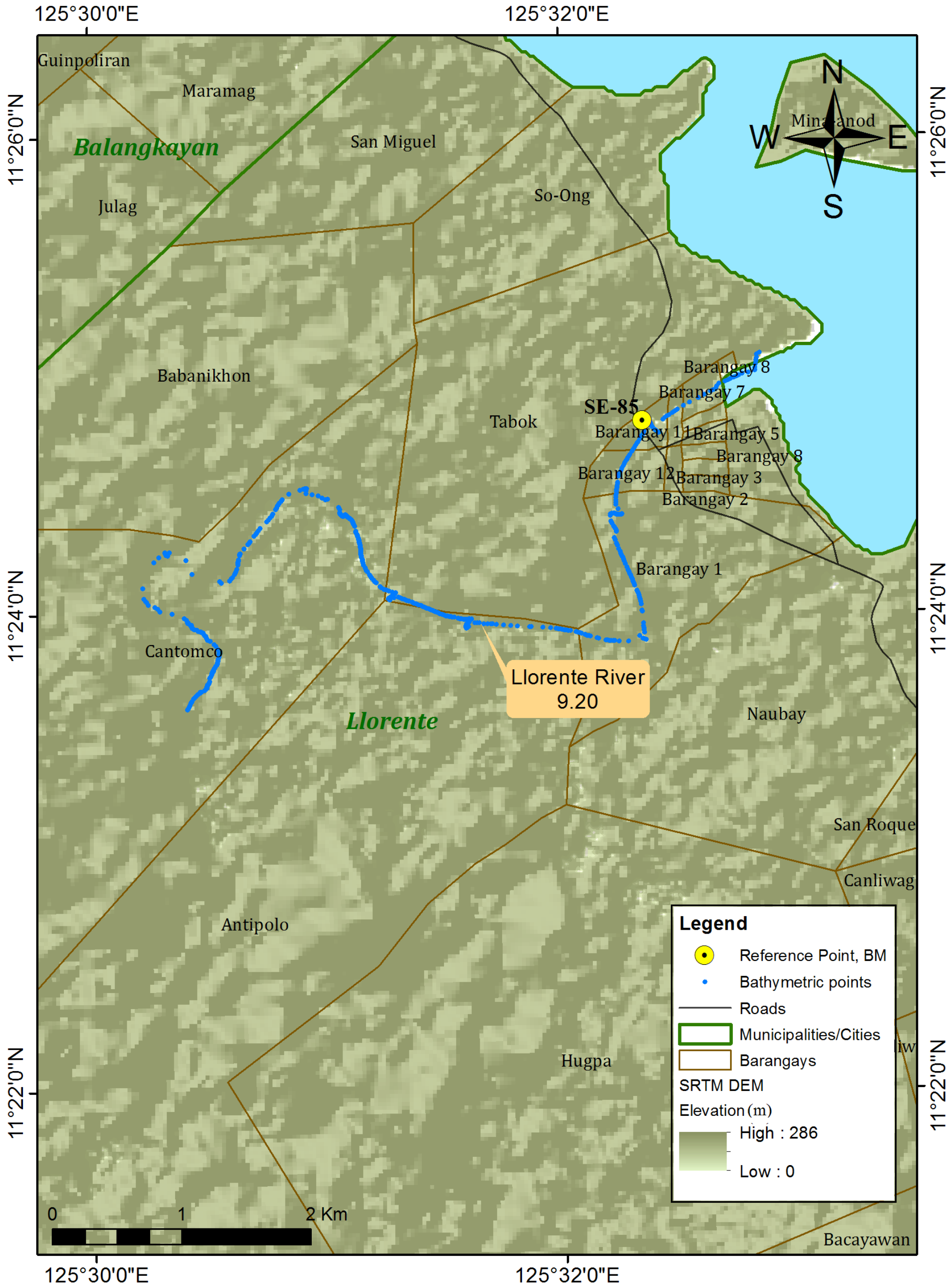


Figure 47. Bathymetric points gathered from Llorente River

The bathymetry line length is about 9.20 km, with a total point of 502. The processed data were generated into a map using a GIS software as shown in Figure 47. A CAD drawing was also produced to illustrate the Llorente riverbed profile. As shown in Figure 48, the change in elevation is gradual, having 0.42 m (MSL) difference between the upstream at Brgy. Santa Rosa and downstream at Brgy. Poblacion V (mouth of the river).

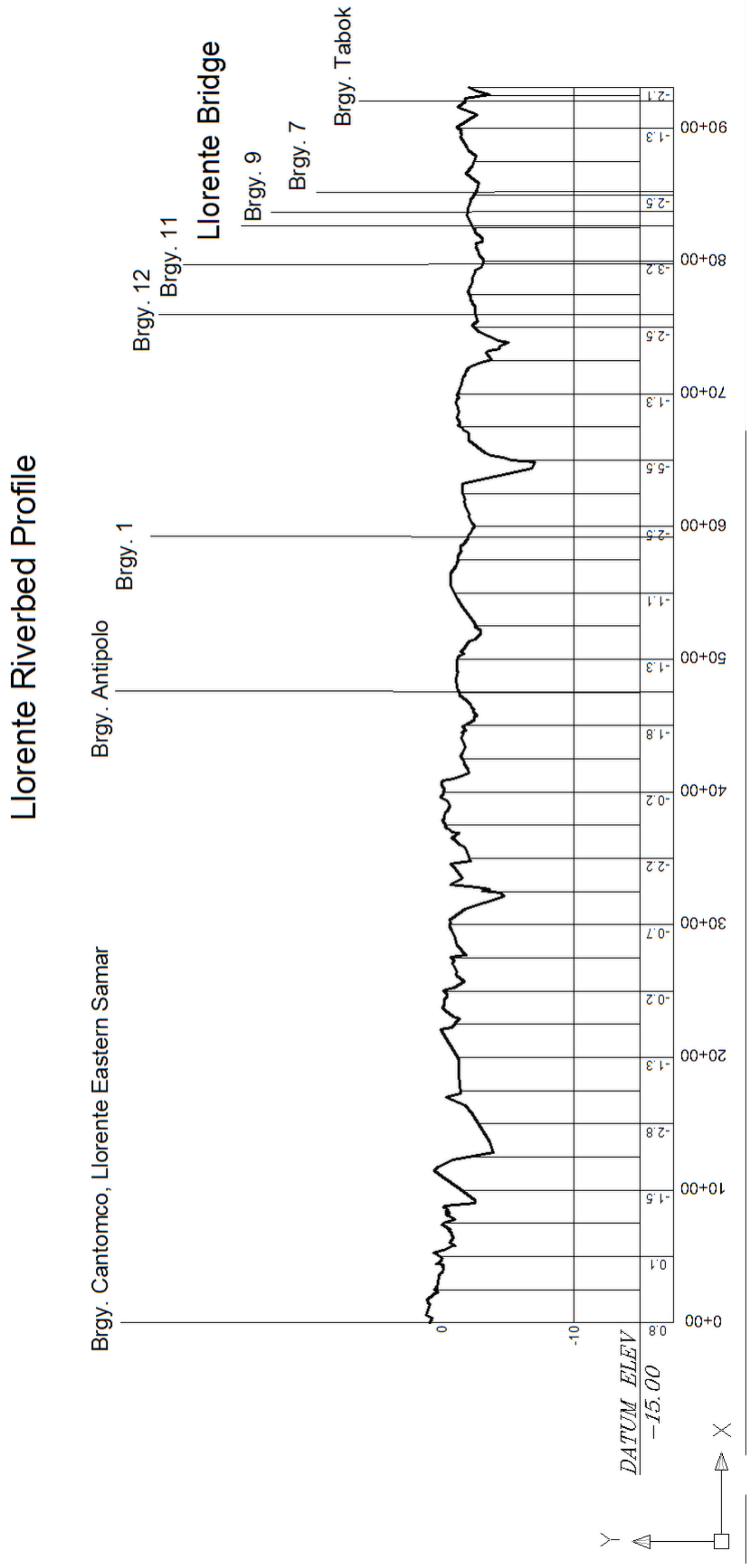


Figure 48. Llorente riverbed centerline profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All data that affect the hydrologic cycle of the Llorente River Basin were monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from the installed rain gauge in Barobo. The location of the rain gauge is seen in Figure 53.

Total rain from Barobo rain gauge is 345.05 mm. It peaked to 19.81mm on 15 January 2017, 15:50. A summary of the data is seen in Table 27. The lag time between the peak rainfall and discharge is four hours and ten minutes.

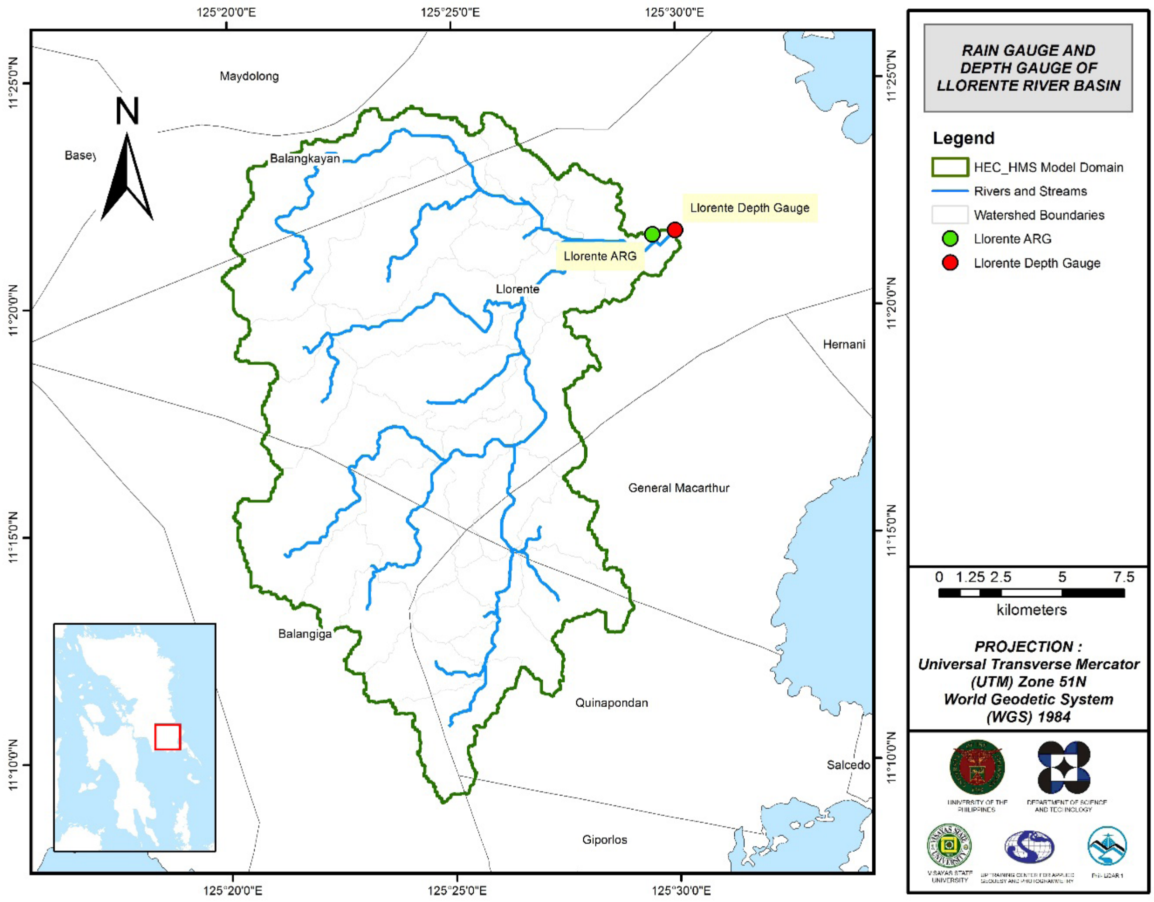


Figure 49. The location map of Llorente HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Barobo Bridge, Llorente, Eastern Samar (11°21'40.47"N, 125°29'56.36"E). It gives the relationship between the observed water levels at Barobo Bridge and outflow of the watershed at this location.

For Barobo Bridge, the rating curve is expressed as $Q = 422.95e^{0.2476h}$ as shown in Figure 51.

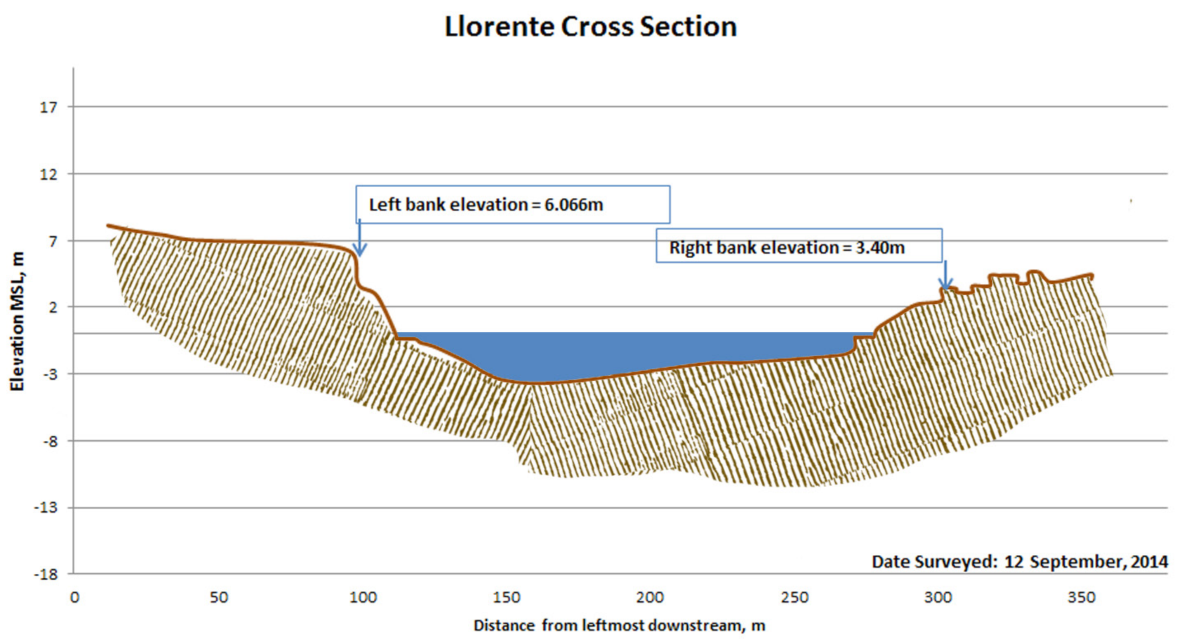


Figure 50. Cross-Section Plot of Llorente Bridge

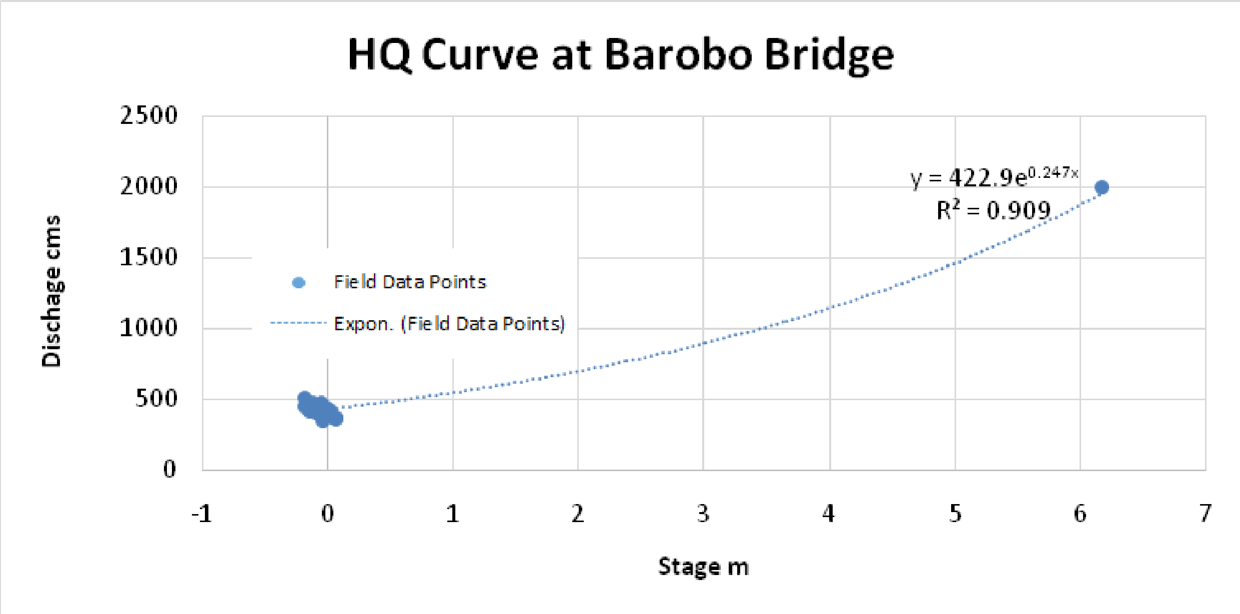


Figure 51. Rating Curve at Llorente Bridge, Llorente, Samar

This rating curve equation was used to compute the river outflow at Llorente Bridge for the calibration of the HEC-HMS model. Total rain from Barobo rain gauge is 345.05 mm. It peaked to 19.81mm on 15 January 2017, 15:50. A summary of the data is seen in Table 27. The lag time between the peak rainfall and discharge is four hours and ten minutes.

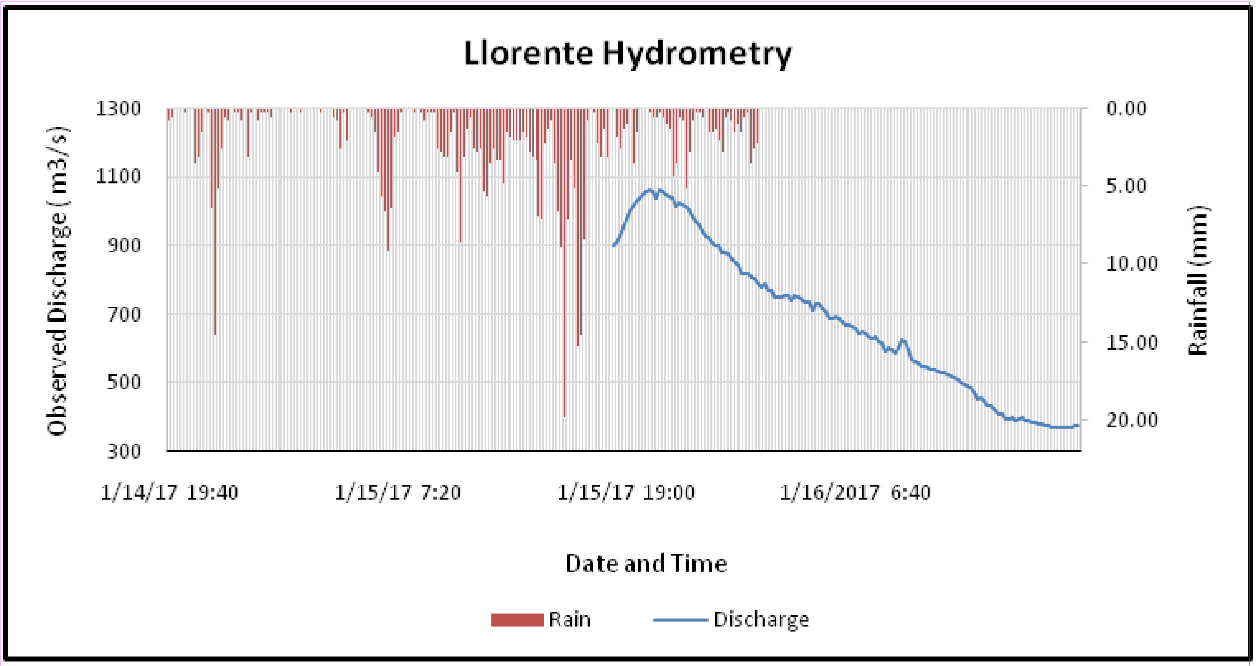


Figure 52. Rainfall and outflow data at Llorente used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Borongan Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Llorente watershed. The extreme values for this watershed were computed based on a 36-year record.

Table 27. RIDF values for Borongan Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	22.5	35.3	44.5	60.6	83.7	100.8	133.7	170.7	201.4
5	31.5	49.1	61	82.3	116.1	140.8	186.5	241	283.8
10	37.4	58.2	71.9	96.6	137.6	167.2	221.4	287.6	338.4
15	40.7	63.3	104.7	104.7	149.8	182.1	241.2	313.9	369.2
20	43	66.9	110.4	110.4	158.3	192.6	255	332.3	390.8
25	44.8	69.7	114.8	114.8	164.8	200.6	265.6	346.4	407.4
50	50.4	78.2	128.3	128.3	185	225.4	298.4	390.1	458.6
100	55.9	86.7	141.6	141.6	205	205	330.9	433.4	509.4

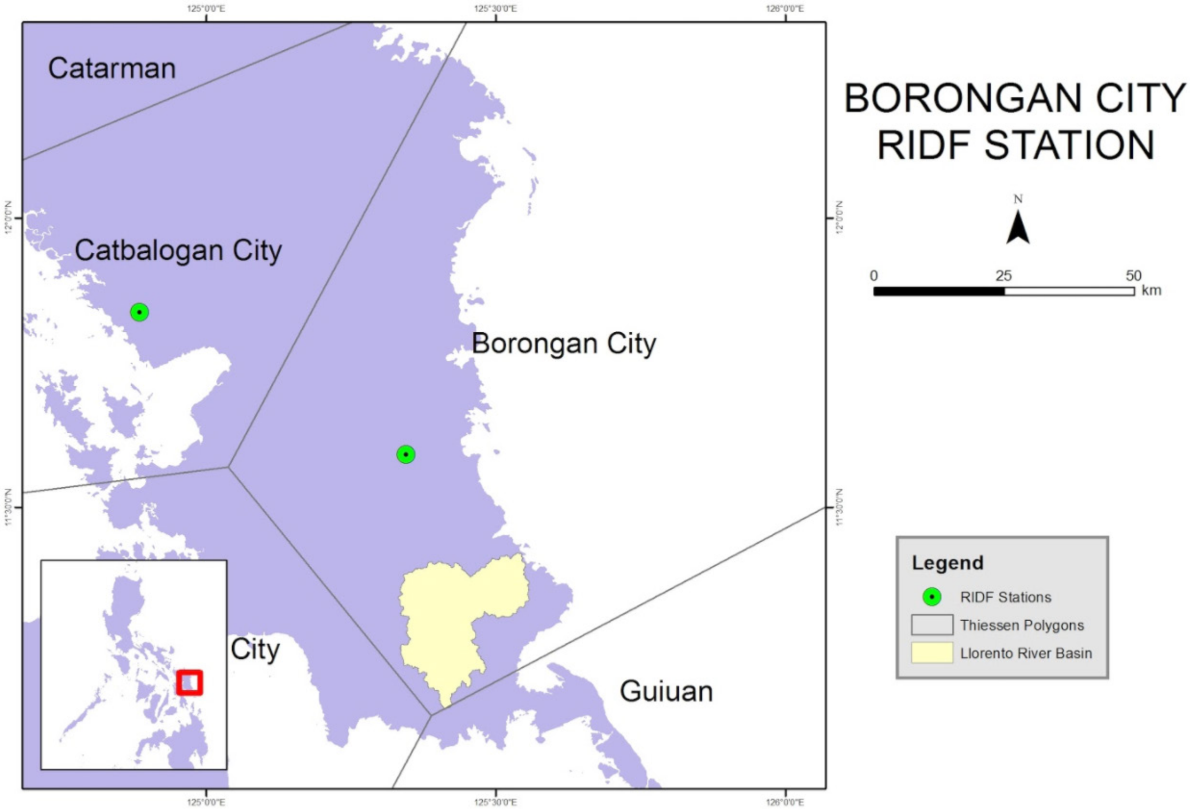


Figure 53. Location of Borongan RIDF Station relative to Llorente River Basin

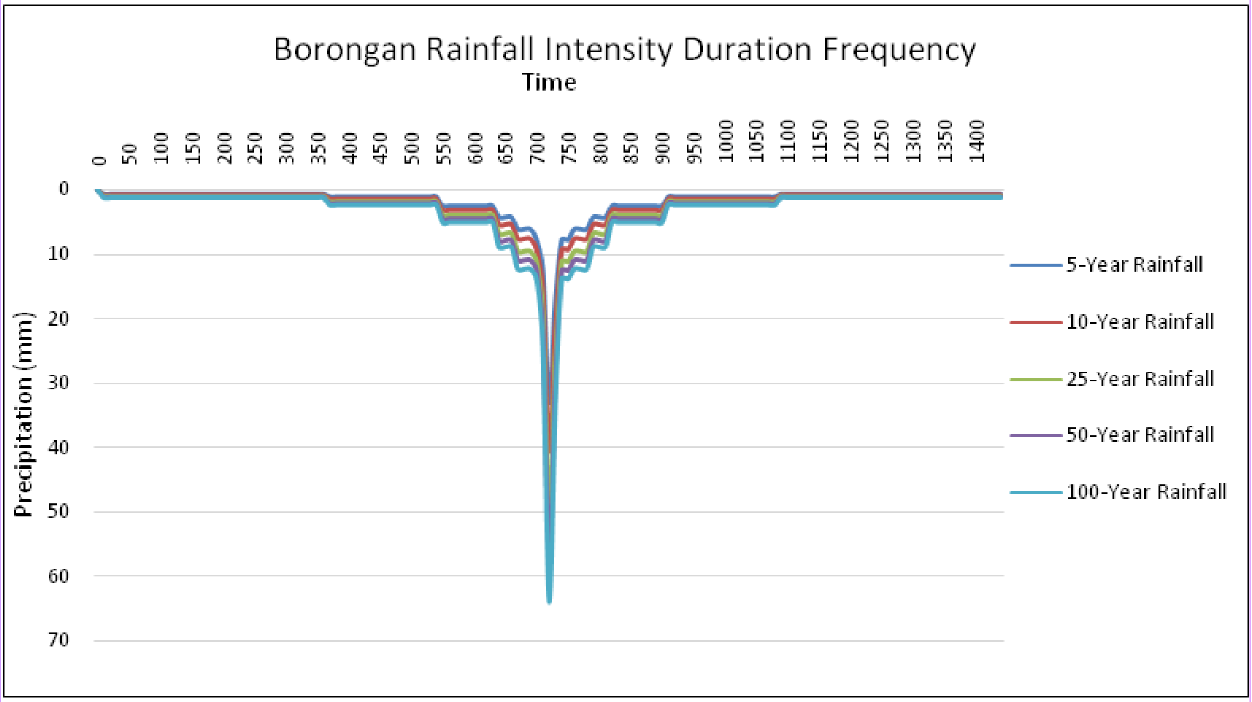


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Llorente River Basin are shown in Figure 55 and Figure 56, respectively.

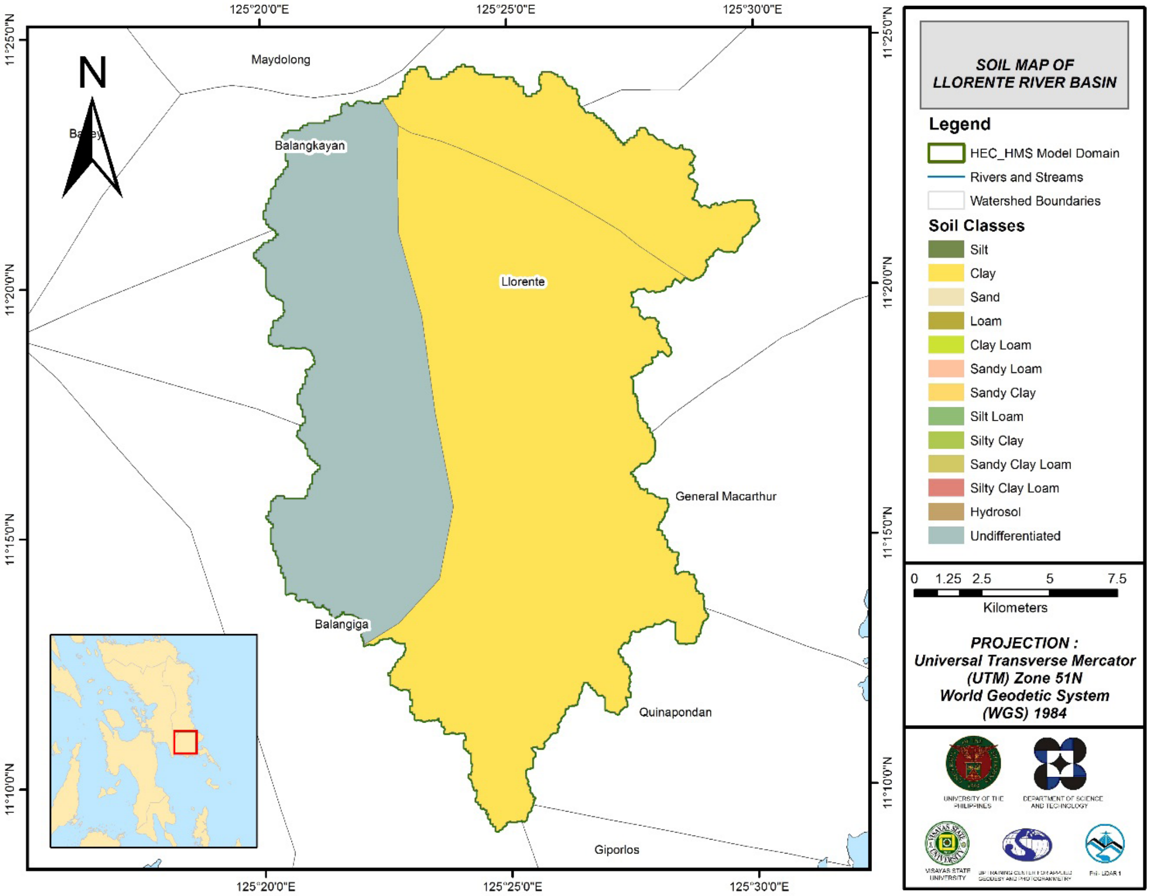


Figure 55. Soil Map of Llorente River Basin

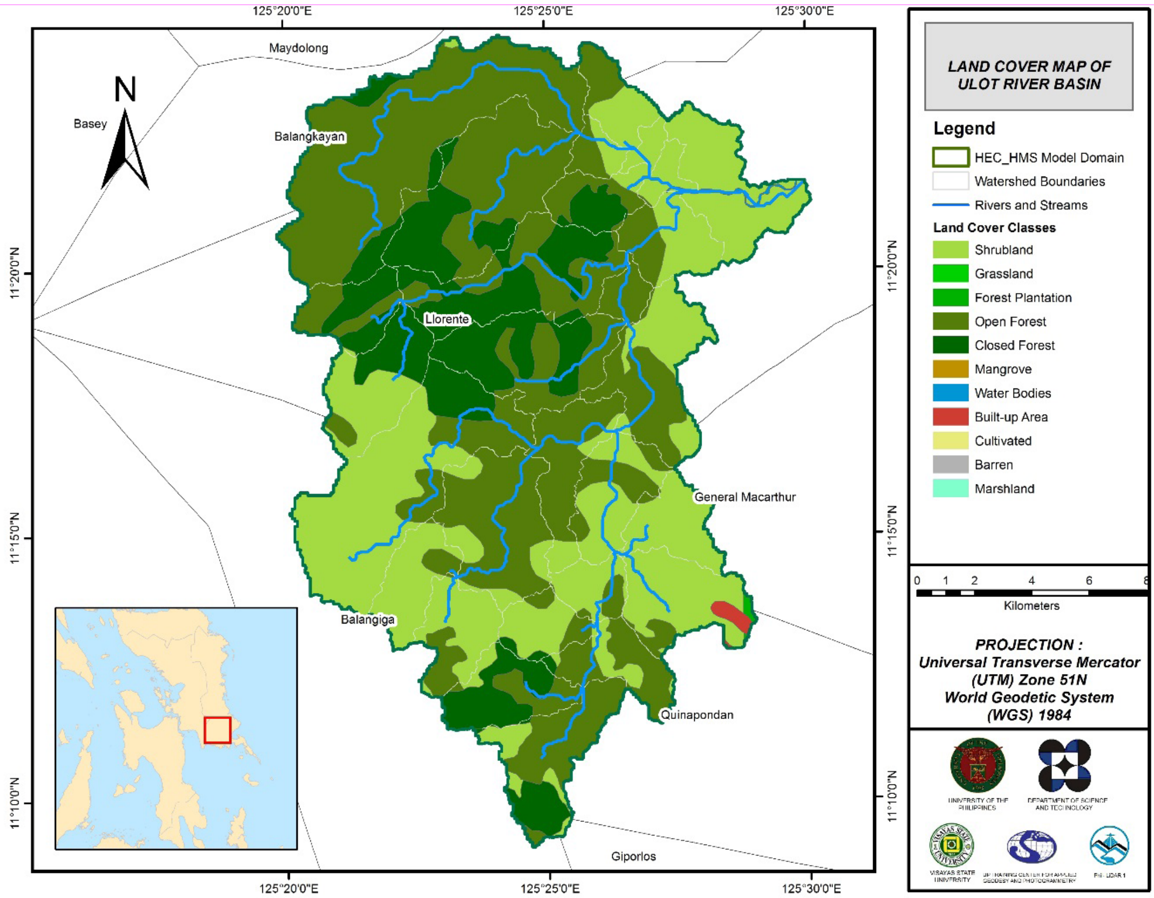


Figure 56. Land Cover Map of Llorente River Basin

For Llorente, the soil classes identified were clay, and undifferentiated. The land cover types identified were forest plantation, open forest, closed forest, cultivated, and built-up area.

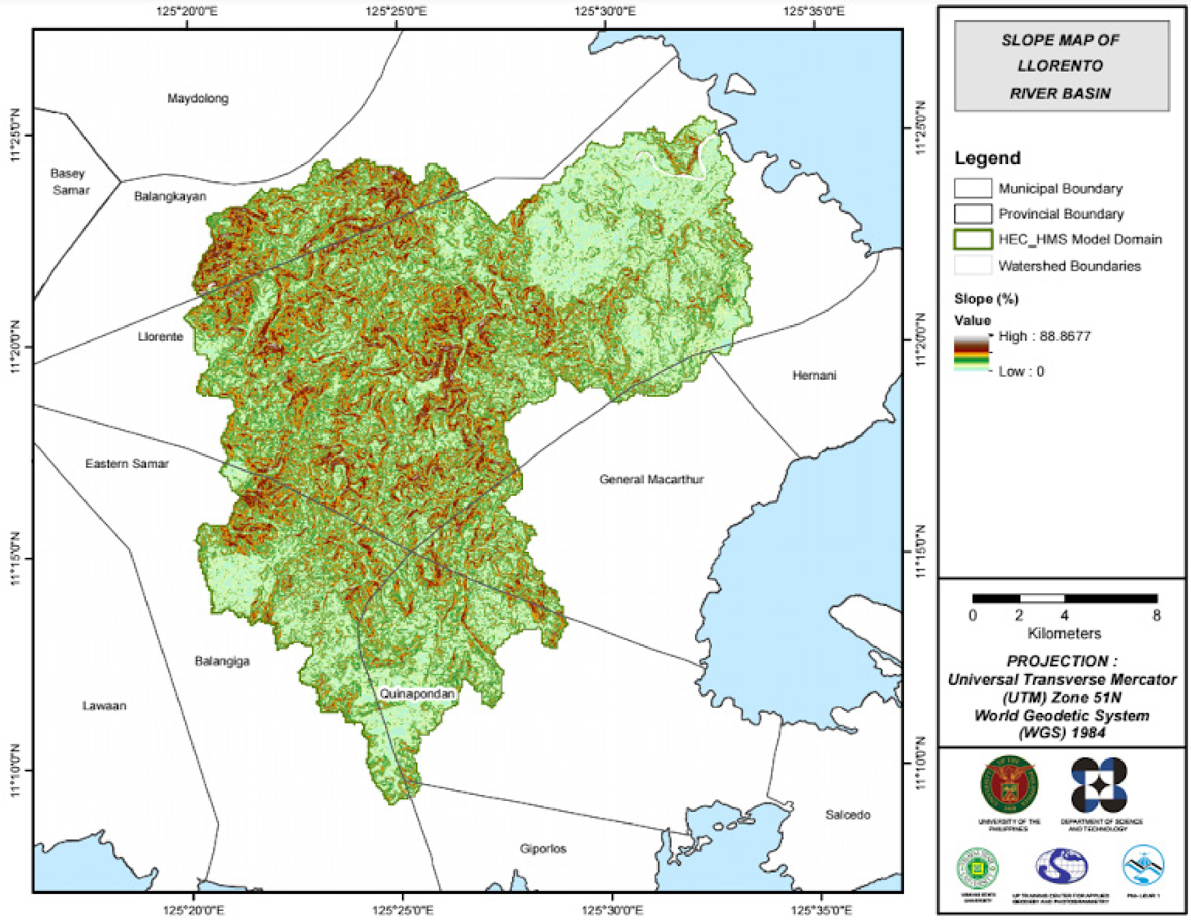


Figure 57. Slope Map of the Llorente River Basin

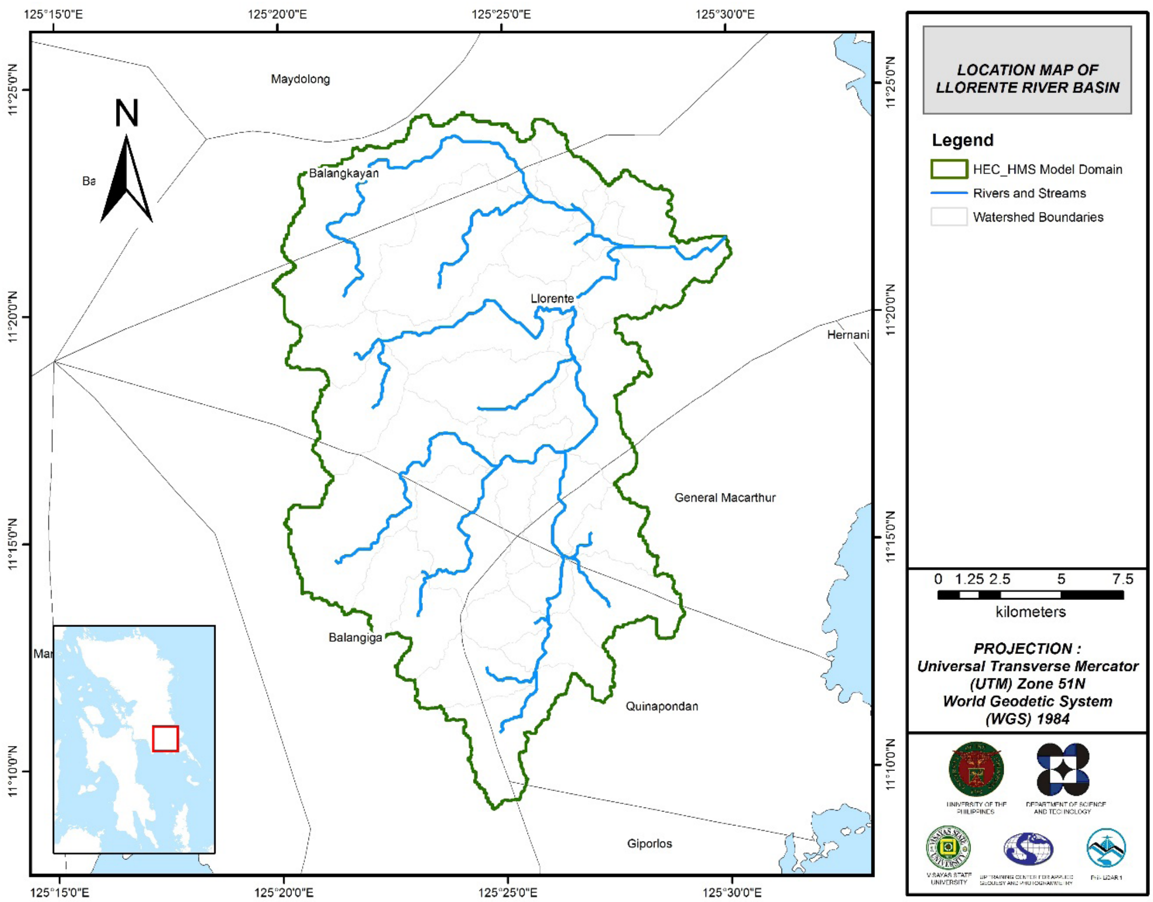


Figure 58. Stream Delineation Map of the Llorente River Basin

Using the SAR-based DEM, the Llorente basin was delineated and further subdivided into subbasins. The model consists of 29 sub basins, 14 reaches, and 14 junctions. The main outlet is Barobo Bridge. This basin model is illustrated in Figure 59.

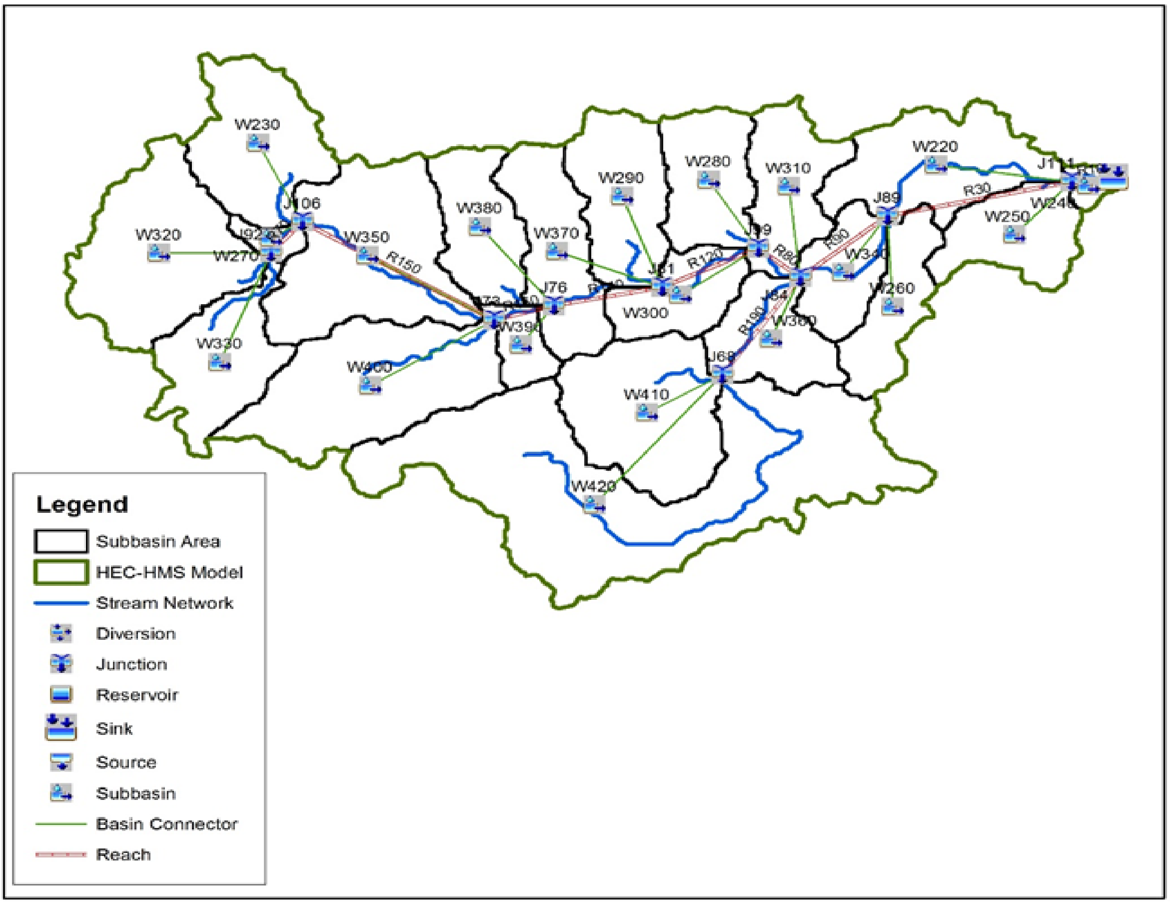


Figure 59. The Llorente river basin model generated using HEC-HMS

5.4 Cross-section Data

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

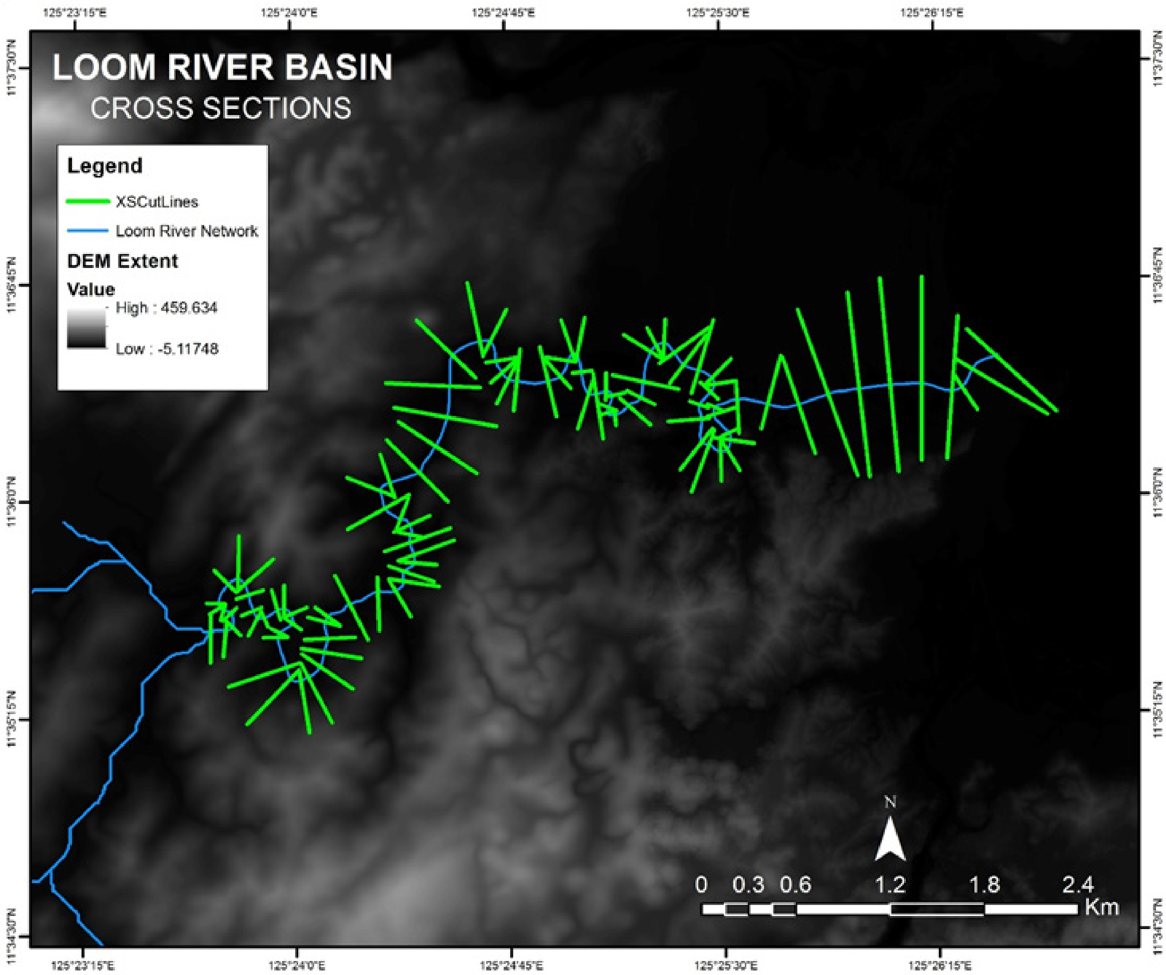


Figure 60. River cross-section of Llorente River generated through Arcmap HEC GeoRAS tool

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 southwest of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

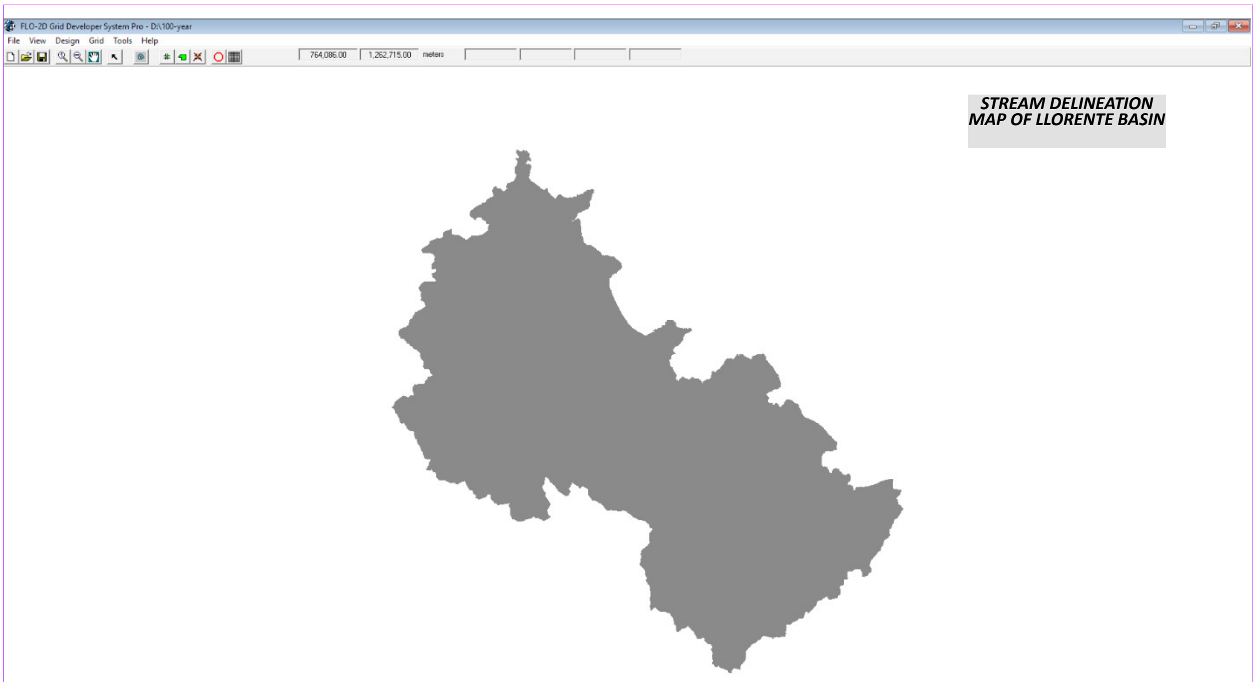


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 88.5 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 75,981,120.00 m2.

A total of 97,326,057.97 m3 of water enters the model. Of this amount, 35,591,094.62 m3 is due to rainfall while 61,734,963.36 m3 is inflow from other areas outside the model. 9,404,835.00 m3 of this water is lost to infiltration and interception, while 57,009,223.13 m3 is stored by the flood plain. The rest, amounting up to 30,912,002.19m3, is outflow.

5.6 Results of HMS Calibration

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

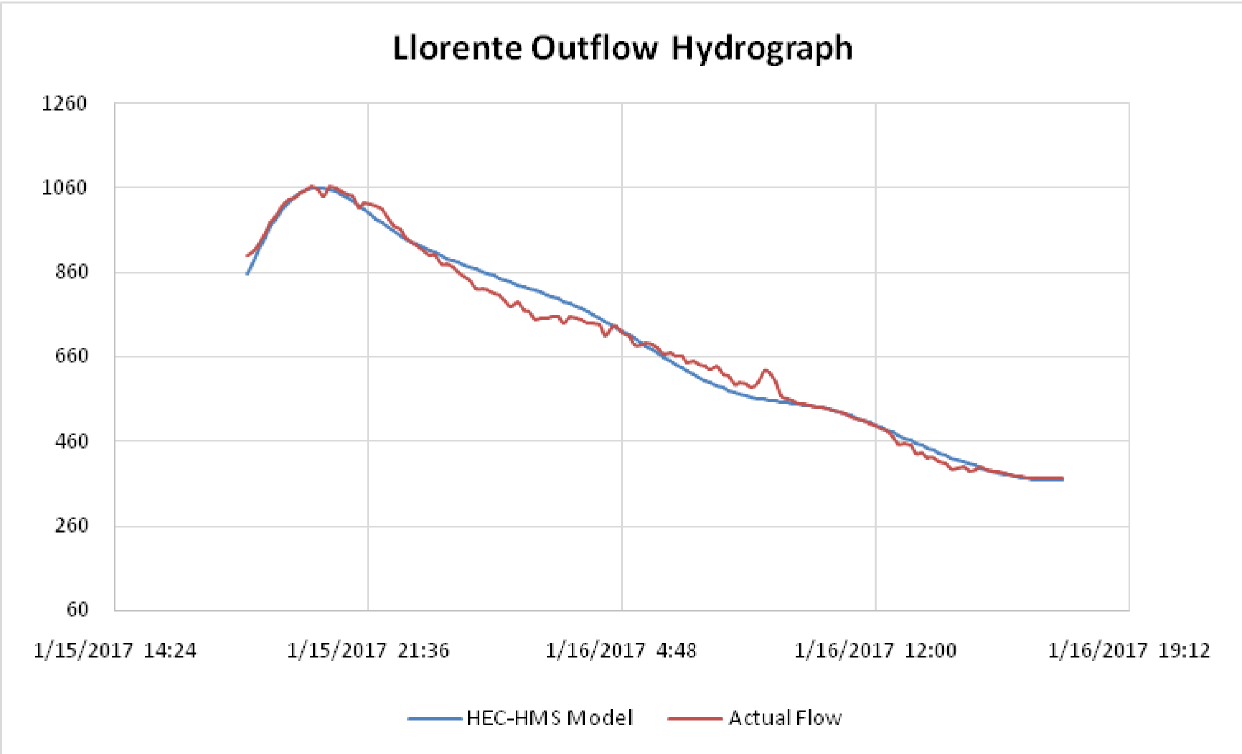


Figure 62. Outflow Hydrograph of Llorente produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of Calibrated Values for Llorente

Basin/Reach Characteristic	Method	Parameter	Range of Calibrated Values
Loss	SCS Curve number	Initial Abstraction (mm)	13 - 51
		Curve Number	49 - 79
Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 13
		Storage Coefficient (hr)	0.7 - 29
Baseflow	Recession	Recession Constant	0.9
		Ratio to Peak	0.1
Routing	Muskingum-Cunge	Slope	0.001 - 0.02
		Manning's n	0.03

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 value of 13 to 51mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 49 to 79 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 0.3 to 29 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.1 indicates a steeper receding limb of the outflow hydrograph.

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

Table 29. Summary of th e Efficiency Test of Llorente HMS Model

RMSE	13.2
r^2	0.91
NSE	0.99
PBIAS	-0.42
RSR	0.12

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 13.2 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.91.

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 0.99.

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 -0.42.

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 0.12.

5.7 Calculated Outflow hydrographys and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

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

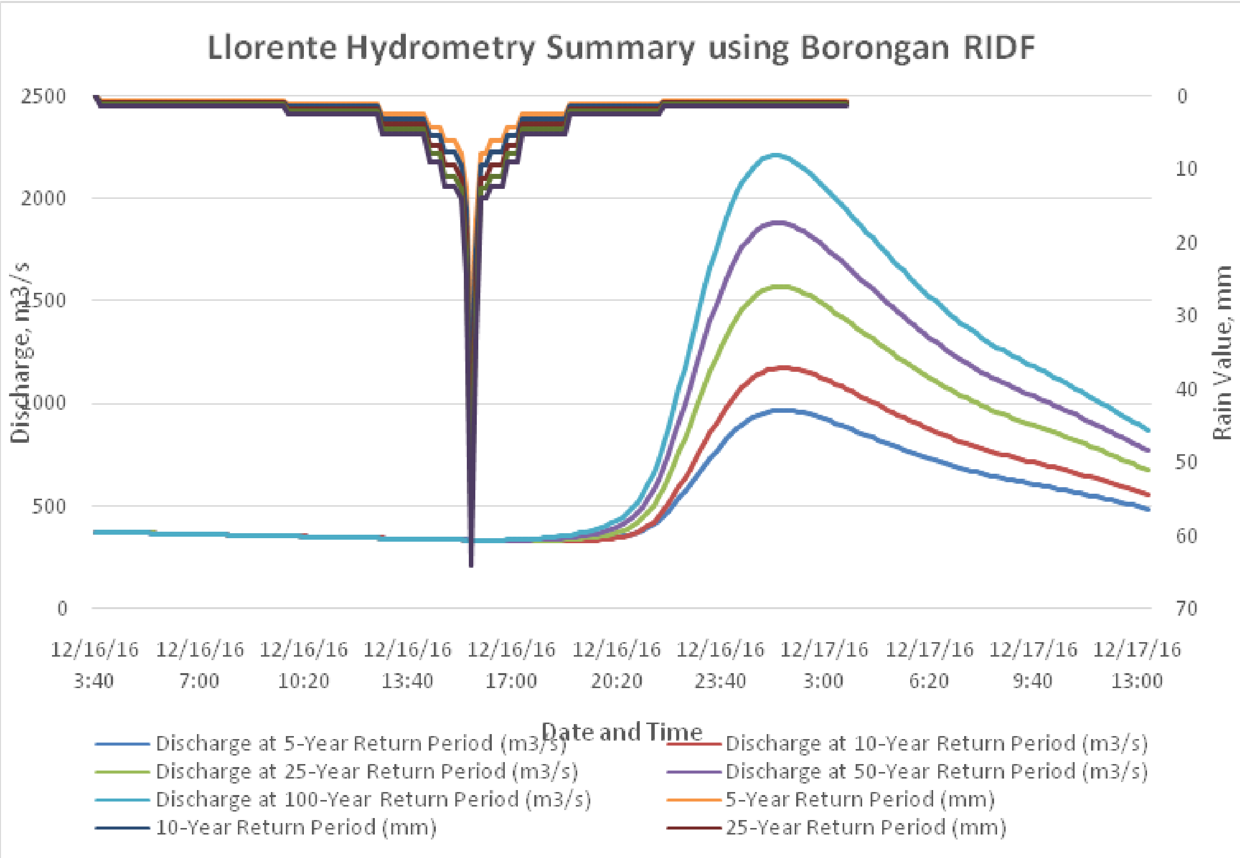


Figure 63. Outflow hydrograph at Llorente Station generated using Borongan RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Llorente HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	278.6	33.2	1004.9	9 hours, 50 minutes
10-Year	344.7	40.6	1235.6	9 hours, 50 minutes
25-Year	428.2	50.1	1624.3	9 hours, 50 minutes
50-Year	490.2	57.1	1916.2	9 hours, 50 minutes
100-Year	551.7	64	2206.5	9 hours, 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining 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, since only the DVC base flow was calibrated. The sample generated map of Llorente River using the calibrated HMS base flow is shown in Figure 64.

Figure 64. Sample output of Llorente RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to **Error! Reference source not found.**70 shows the 5-, 25-, and 100-year rain return scenarios of the Llorente floodplain.

The floodplain, with an area of 175.68 sq. km., covers three municipalities namely Balangkayan, Hernani, and Llorente. Table shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Llorente floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Balangkayan	170.56	32.85	19.26%
Hernani	46.44	5.62	12.11%
Llorente	344.09	136.86	39.77%

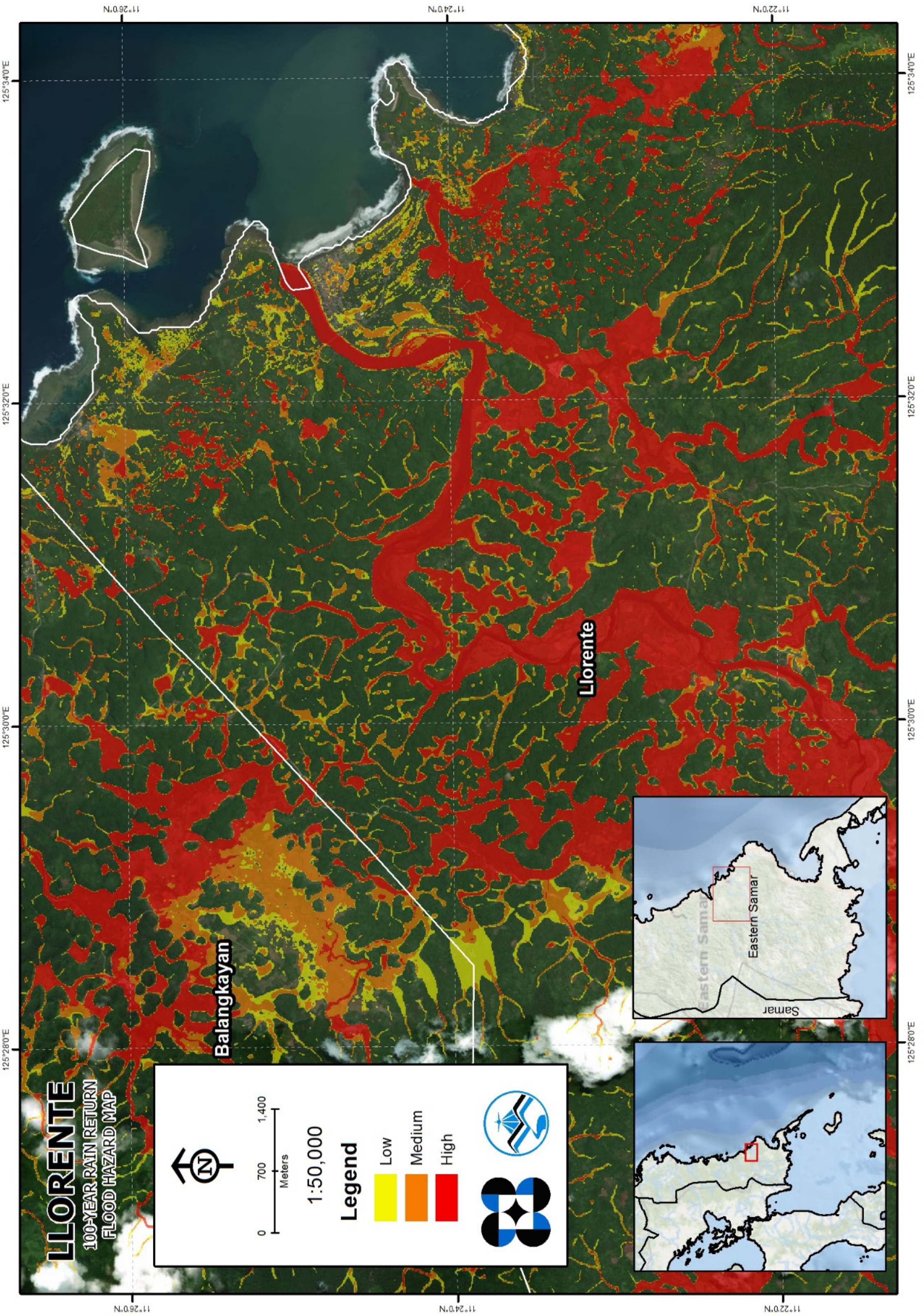


Figure 65. 100-year Flood Hazard Map for Llorente Floodplain

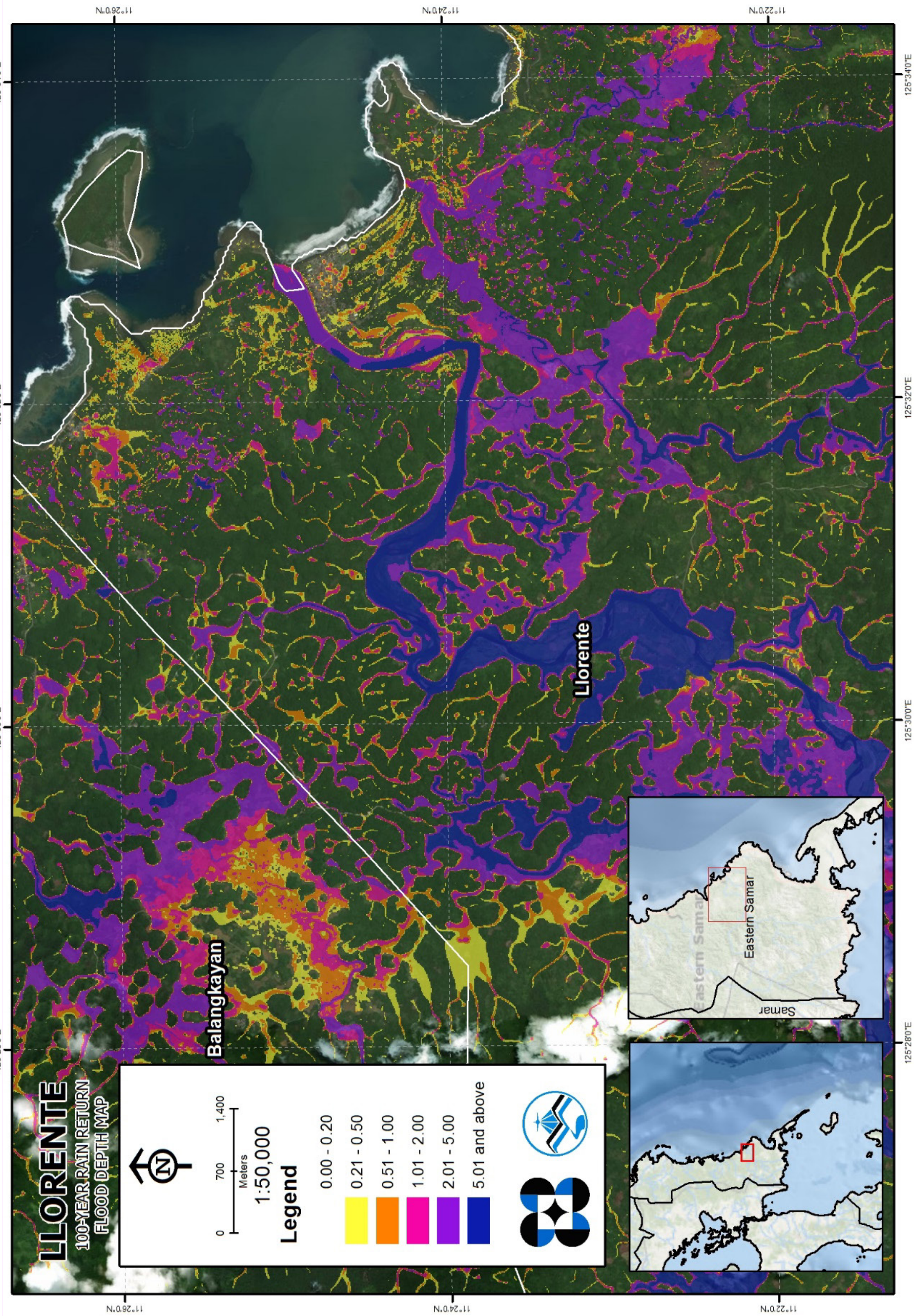


Figure 66. 100-year Flood Depth Map for Llorente Floodplain

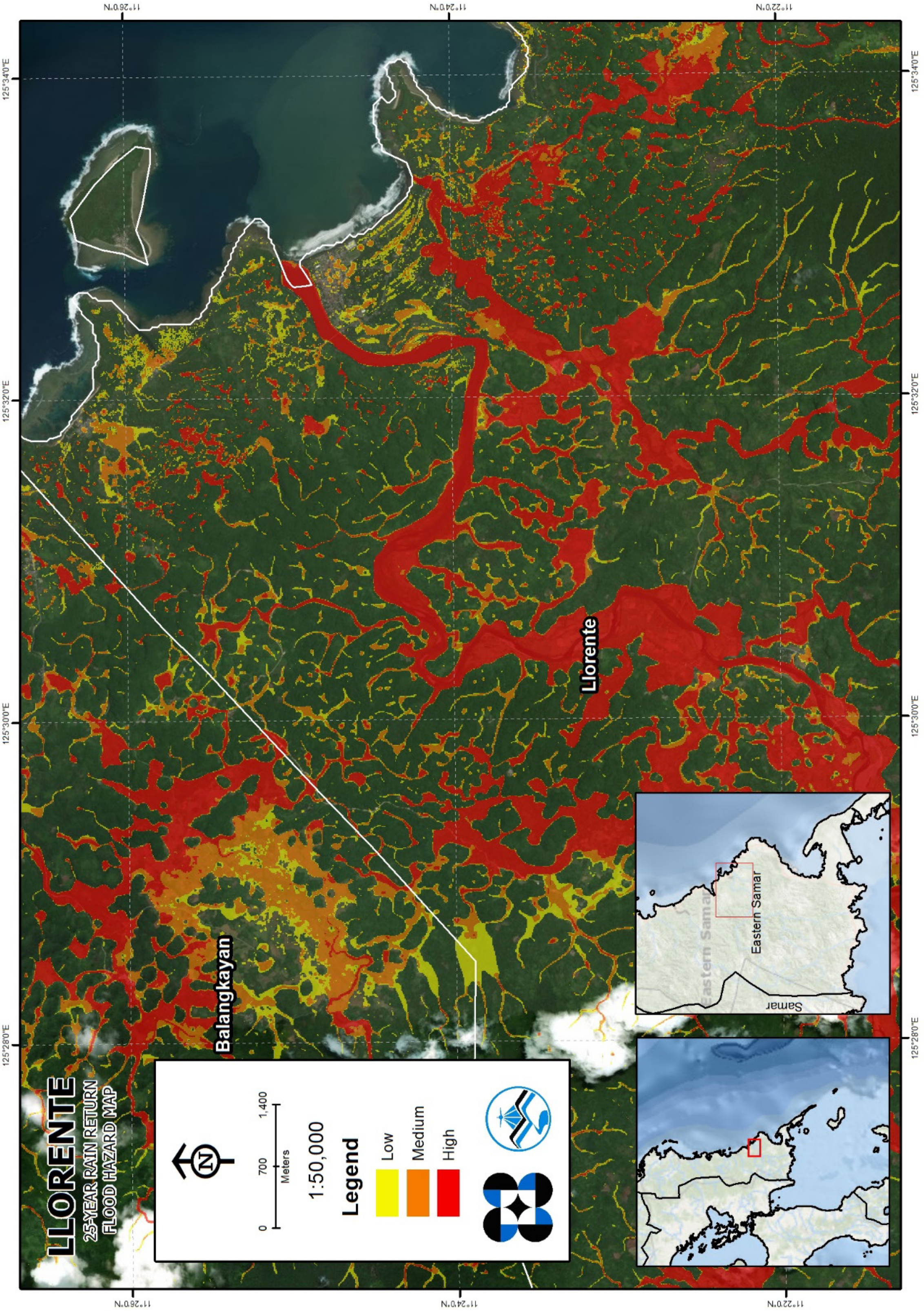


Figure 67. 25-year Flood Hazard Map for Llorente Floodplain

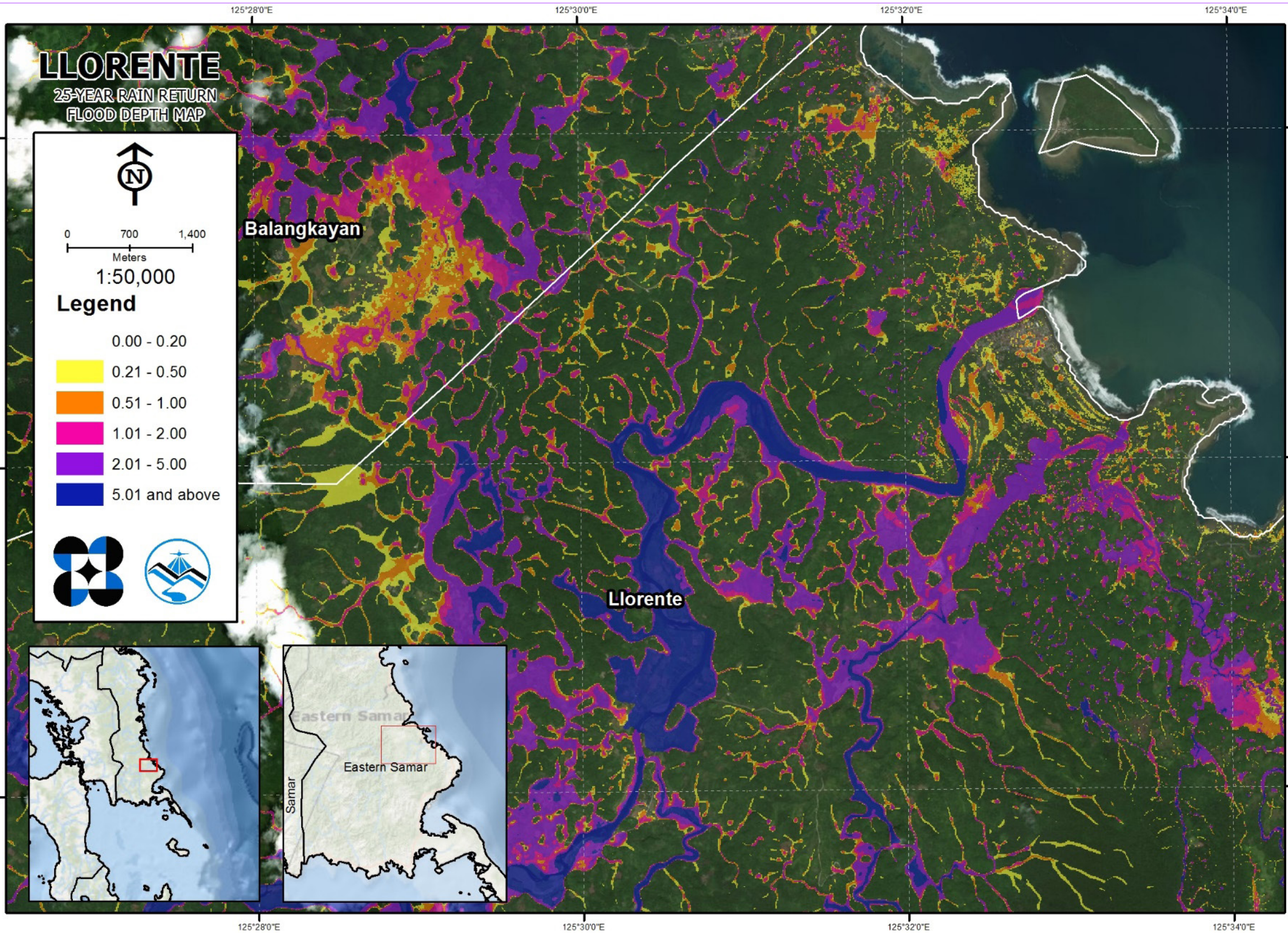


Figure 68. 25-year Flood Depth Map for Llorente Floodplain

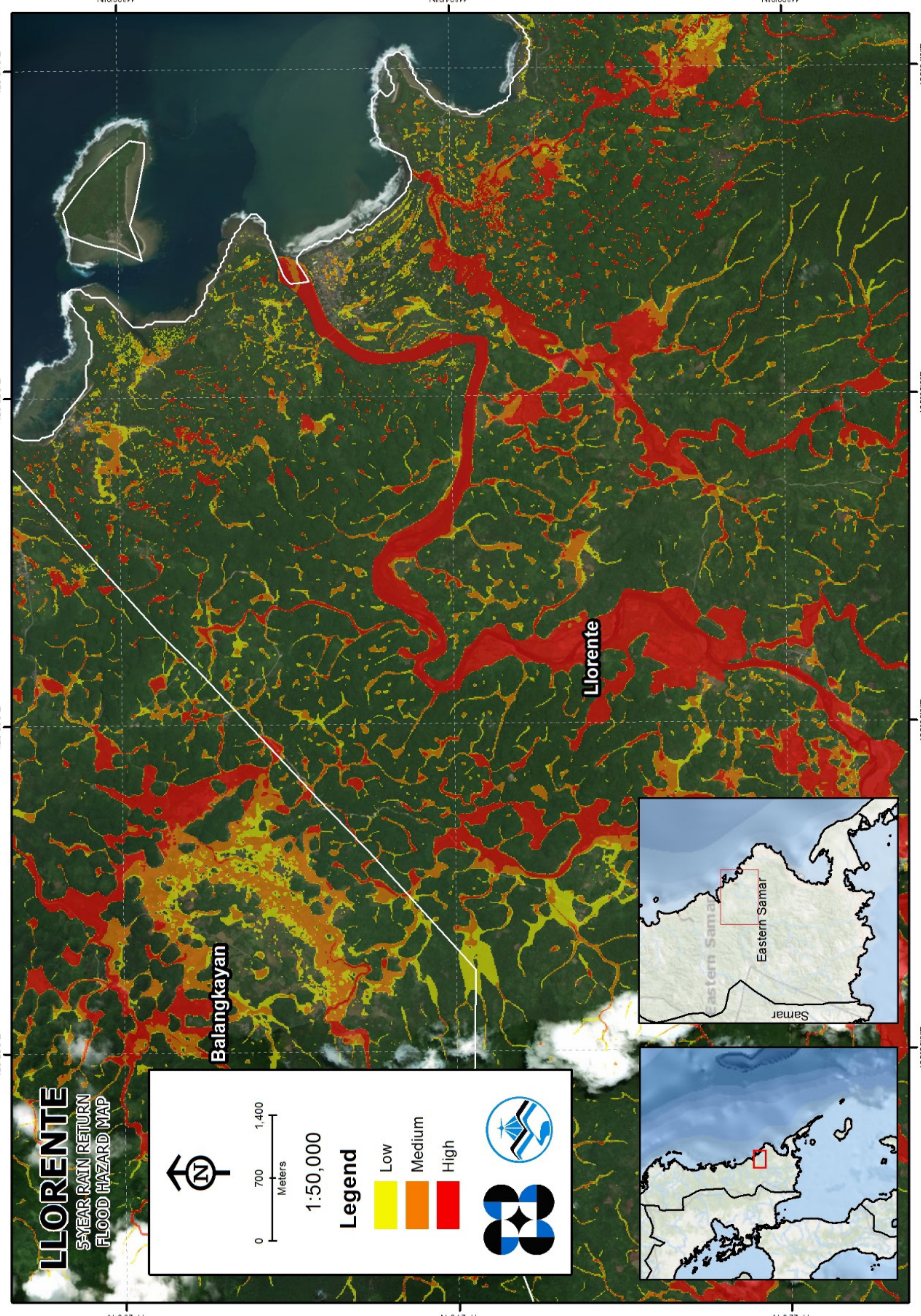


Figure 69. 5-year Flood Hazard Map for Llorente Floodplain

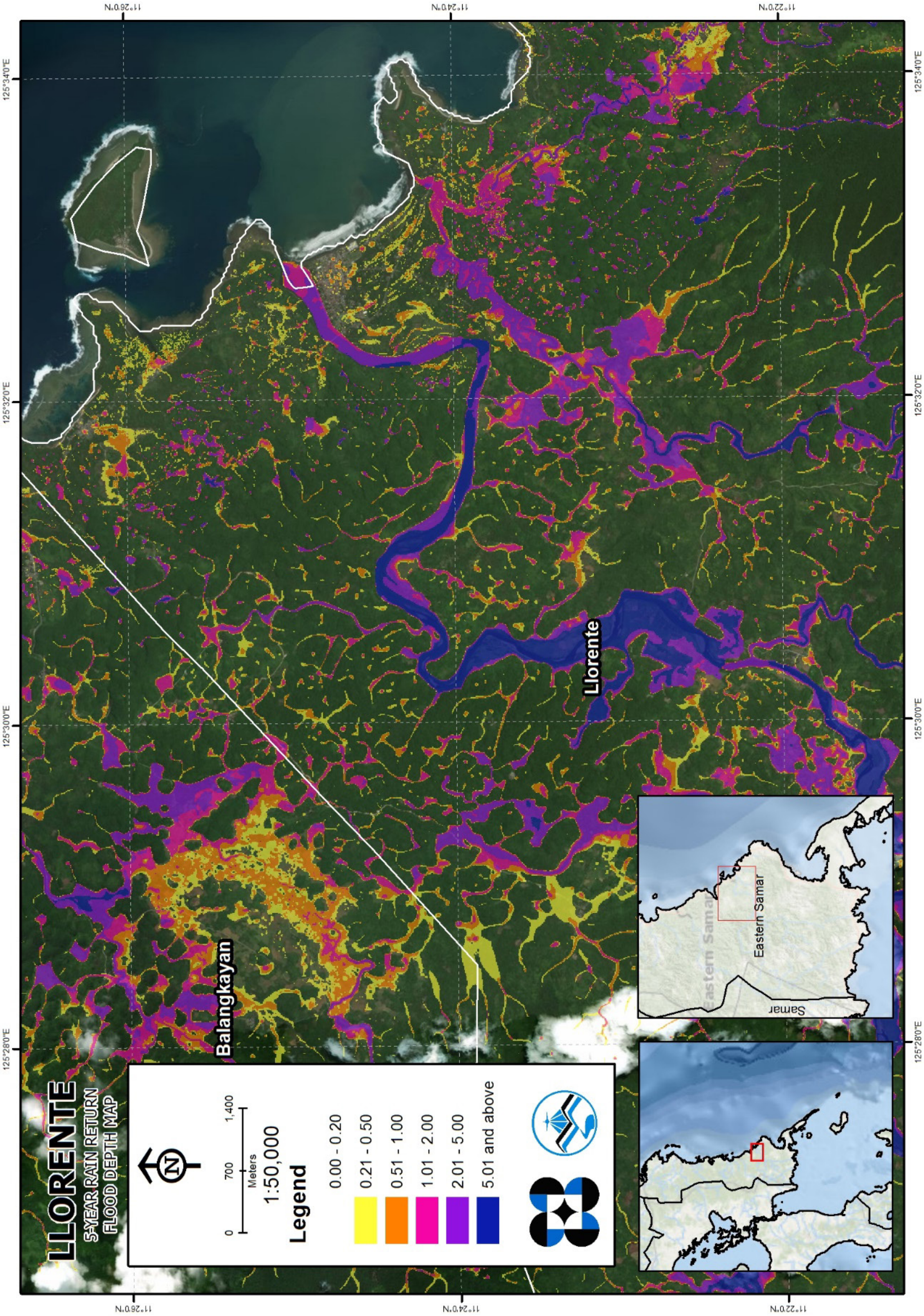


Figure 70. 5-year Flood Depth Map for Llorente Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Llorente river basin, grouped by municipality, are listed below. For the said basin, 3 municipalities consisting of 43 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 14.61% of the municipality of Balangkayan with an area of 170.563 sq. km. will experience flood levels of less 0.20 meters. 1.29% of the area will experience flood levels of 0.21 to 0.50 meters while 1.38%, 1.13%, 0.82% and 0.034% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 32 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balangkayan(in sq. km.)								
	Balogo	Llorente	Cabay	Caisawan	Cantubi	Guinpoliran	Julag	Magsaysay	Maramag
0.03-0.20	1.71	5.16	1.26	1.84	2.58	2.27	6.34	0.78	2.99
0.21-0.50	0.076	0.62	0.083	0.068	0.092	0.083	0.84	0.036	0.29
0.51-1.00	0.1	0.62	0.069	0.082	0.065	0.11	1.06	0.033	0.2
1.01-2.00	0.12	0.44	0.097	0.096	0.11	0.18	0.74	0.024	0.13
2.01-5.00	0.086	0.26	0.2	0.064	0.072	0.12	0.54	0.006	0.065
> 5.00	0	0	0.045	0	0.0003	0.0076	0	0	0.0046

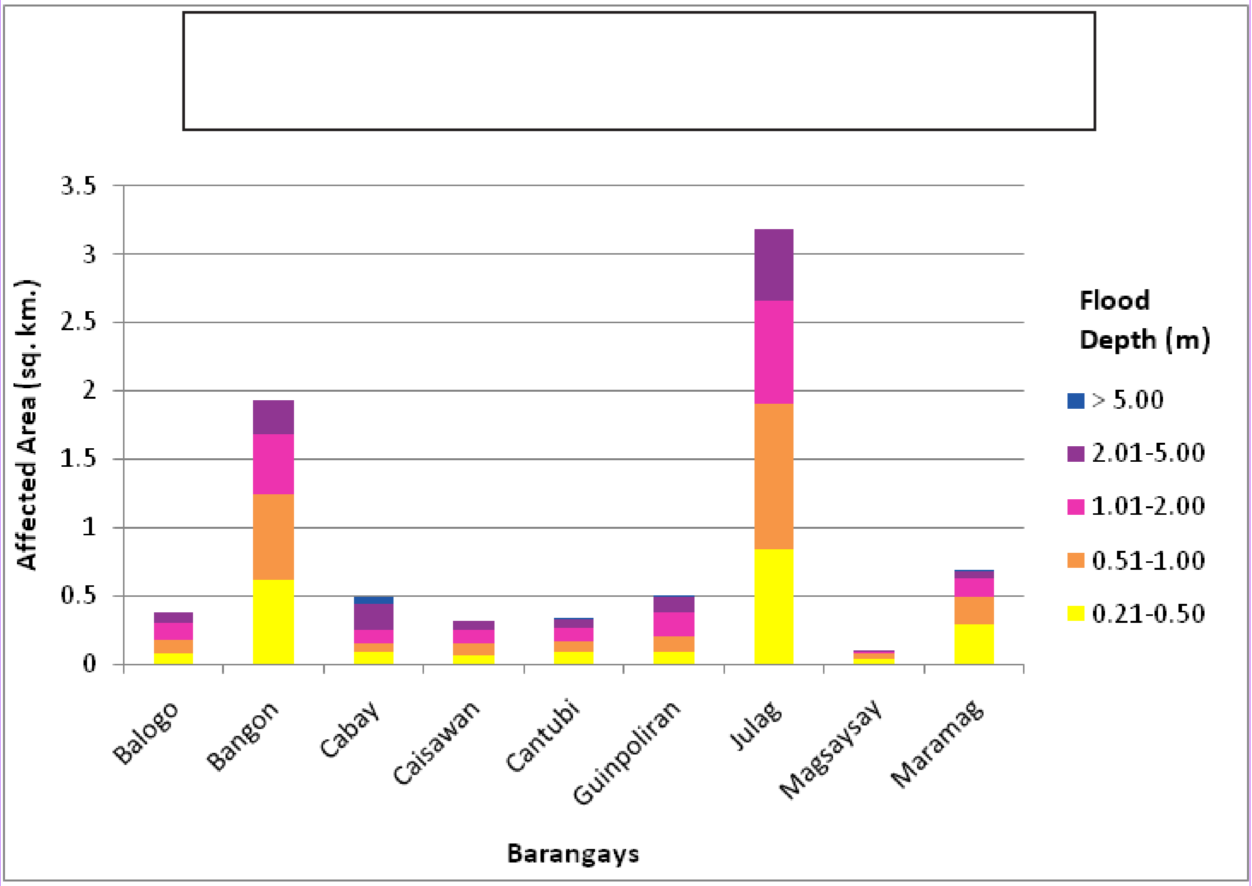


Figure 71. Affected Areas in Balangkayan, Eastern Samar during 5-Year Rainfall Return Period

For the municipality of Hernani, with an area of 46.444 sq. km., 7.57% will experience flood levels of less 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.15%, 0.12% and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Hernani(in sq. km.)					
	Cacatmonan	Canciledes	Garawon	Padang	San Isidro	San Miguel
0.03-0.20	0.93	0.35	0.15	1.2	0.88	0.0011
0.21-0.50	0.029	0.0091	0.0008	0.052	0.026	0
0.51-1.00	0.018	0.0053	0	0.035	0.014	0
1.01-2.00	0.015	0.0079	0	0.03	0.017	0
2.01-5.00	0.011	0.011	0	0.018	0.02	0
> 5.00	0	0.0003	0	0.00073	0	0

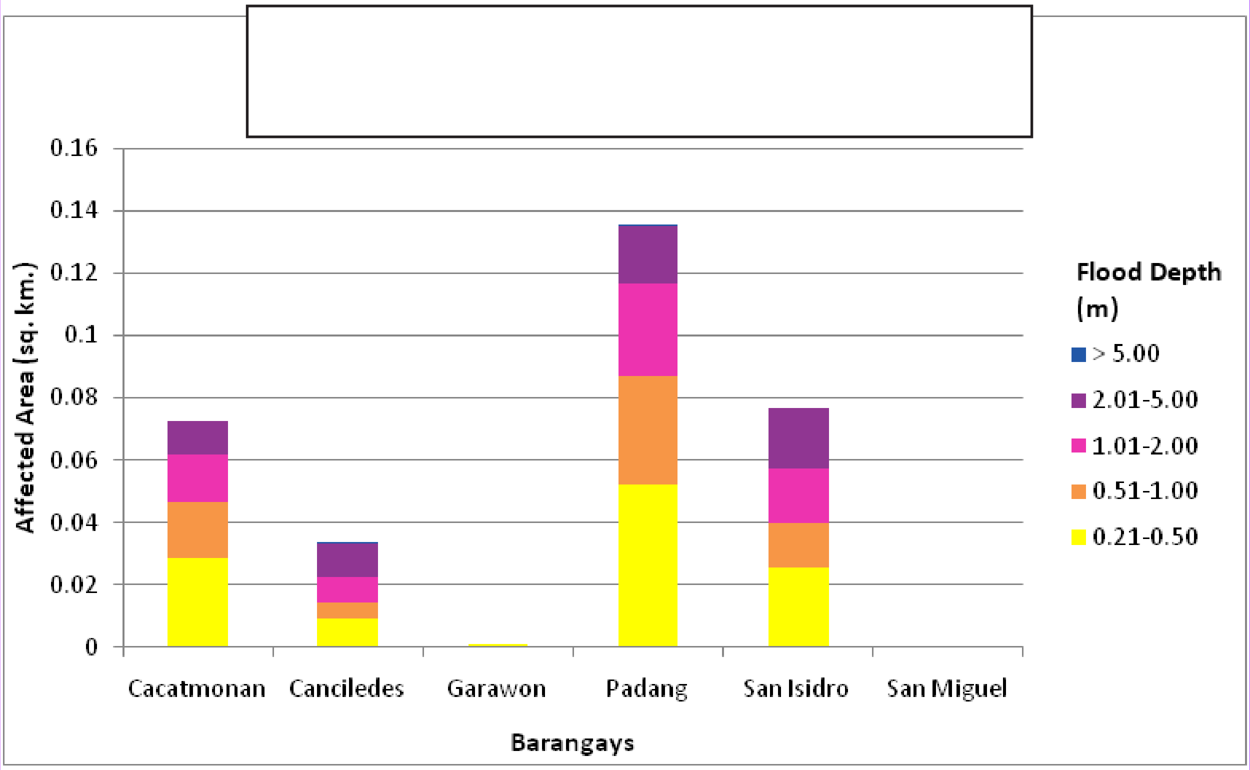


Figure 72. Affected Areas in Hernani, Eastern Samar during 5-Year Rainfall Return Period

For the municipality of Llorente, with an area of 344.086 sq. km., 31.72% will experience flood levels of less 0.20 meters. 1.70% of the area will experience flood levels of 0.21 to 0.50 meters while 1.31%, 1.55%, 1.72%, and 1.42% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)								
	Antipolo	Babanikhon	Bacayawan	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 2	Barangay 3
0.03-0.20	16.48	4.74	11.16	1.31	0.034	0.065	0.12	0.034	0.038
0.21-0.50	0.75	0.28	0.44	0.2	0.0088	0.0045	0.0086	0.0063	0.0054
0.51-1.00	0.71	0.23	0.23	0.1	0.0023	0.0039	0.0044	0.0037	0.0026
1.01-2.00	0.85	0.24	0.2	0.043	0.00078	0.01	0.0082	0.0015	0
2.01-5.00	1.32	0.074	0.2	0.14	0	0.035	0.048	0	0
> 5.00	1.62	0.0004	0.073	0.076	0	0.0003	0.0005	0	0

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)								
	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Barobo	Canliwag	Cantomco
0.03-0.20	0.037	0.046	0.012	0.042	0.31	0.026	2.18	3.13	11.9
0.21-0.50	0.0039	0.0021	0.00064	0.0045	0.041	0.0019	0.036	0.13	0.77
0.51-1.00	0.0013	0.0004	0.0007	0.0023	0.024	0.0011	0.025	0.14	0.72
1.01-2.00	0	0	0.0051	0.013	0.018	0.0048	0.027	0.3	0.97
2.01-5.00	0	0	0.019	0.031	0.0021	0.016	0.056	0.25	1.07
> 5.00	0	0	0	0	0	0	0.33	0.025	0.91

Table 36. Affected Areas in Llorente, Eastern Samar during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)									
	Hugpa	Maca-Anga	Naubay	Piliw	San Jose	San Miguel	San Roque	So-Ong	Tabok	Waso
0.03-0.20	16.12	8.84	3.59	4.92	3.37	2.36	2.54	1.83	4.59	9.29
0.21-0.50	0.65	0.58	0.22	0.37	0.12	0.14	0.24	0.21	0.27	0.33
0.51-1.00	0.49	0.31	0.3	0.29	0.11	0.14	0.16	0.1	0.16	0.23
1.01-2.00	0.69	0.26	0.64	0.26	0.11	0.097	0.075	0.095	0.12	0.28
2.01-5.00	0.98	0.14	0.57	0.18	0.083	0.044	0.075	0.058	0.091	0.43
> 5.00	0.28	0	0.0026	0.021	0.027	0.0034	0.01	0.006	0.011	1.49

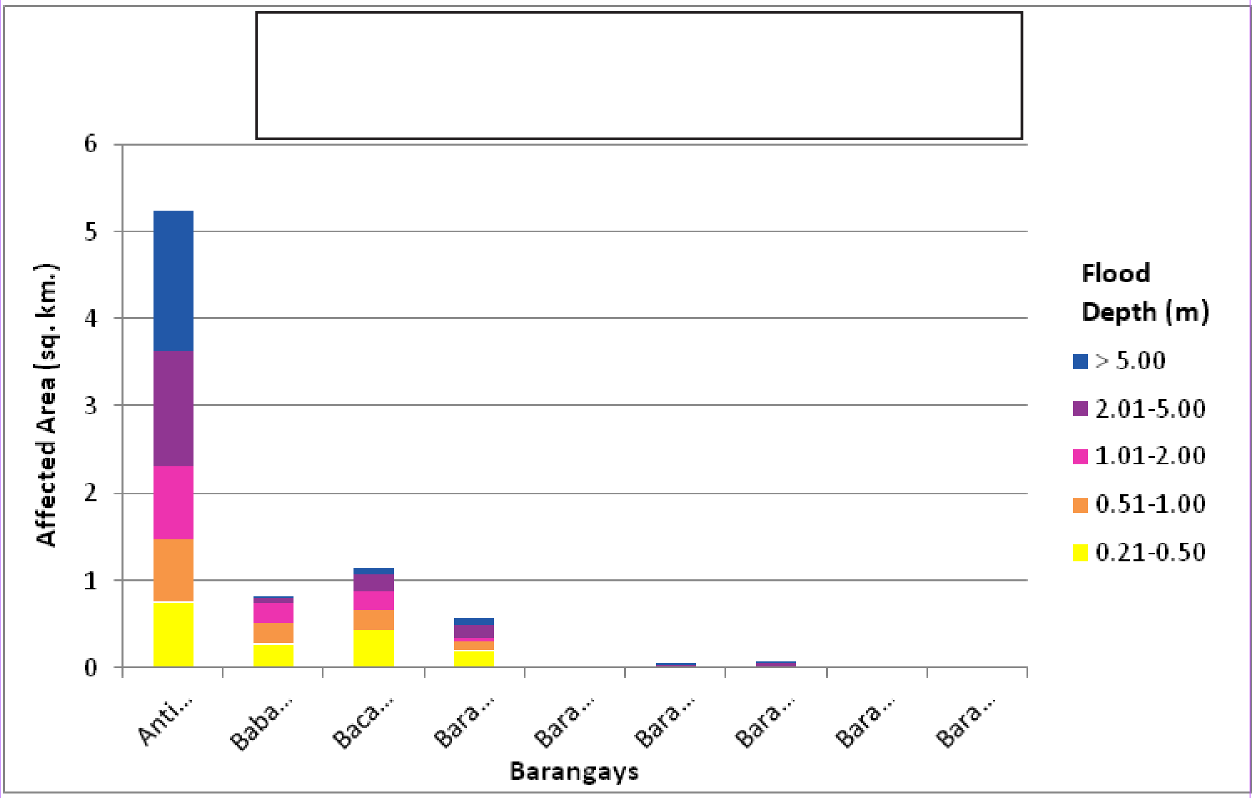


Figure 73. *Affected Areas in Llorente, Eastern Samar during 5-Year Rainfall Return Period*

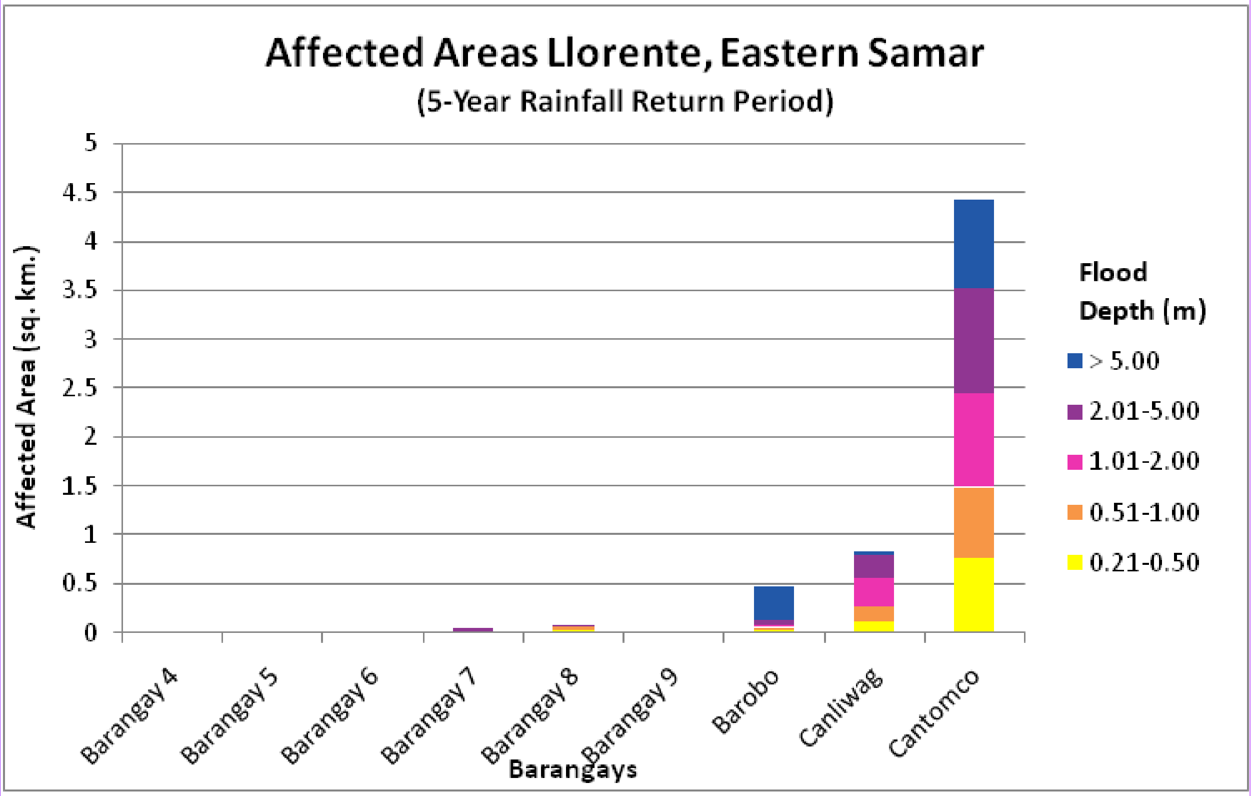


Figure 74. Affected Areas in Llorente, Eastern Samar during 5-Year Rainfall Return Period

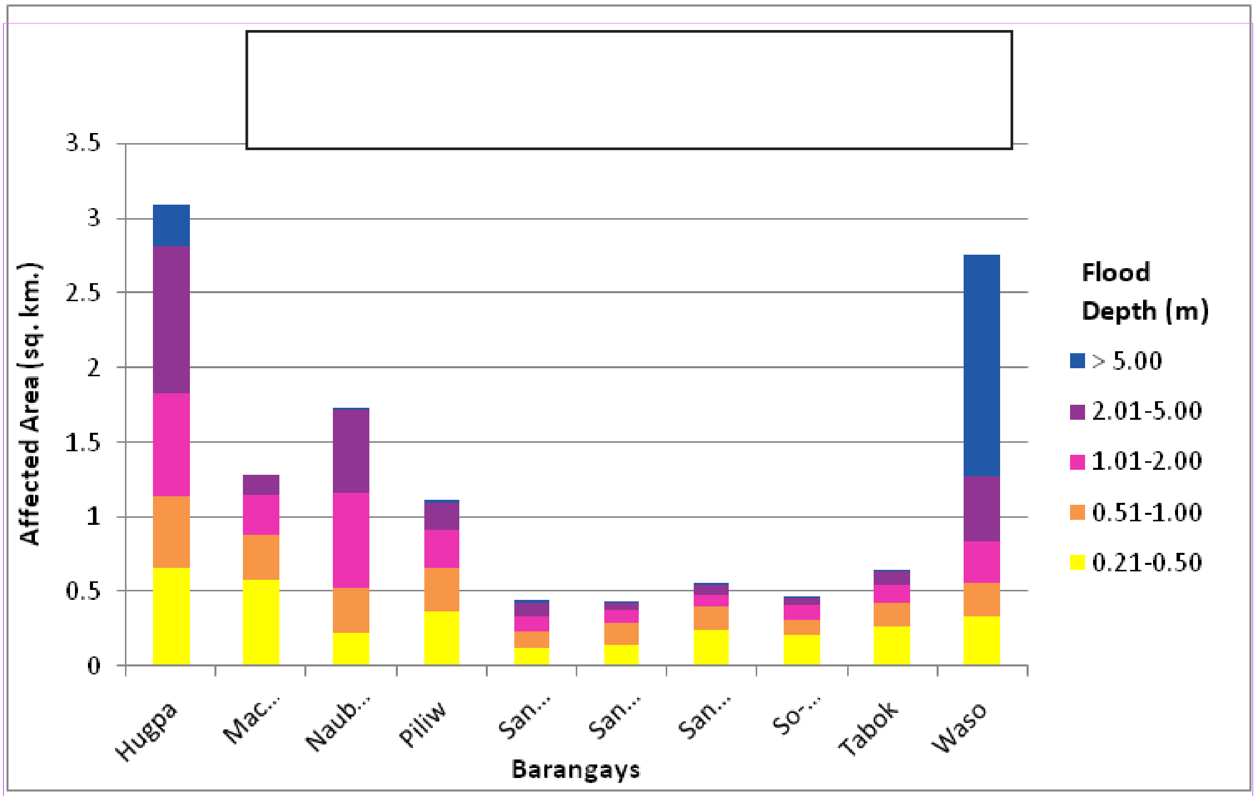


Figure 75. *Affected Areas in Llorente, Eastern Samar during 5-Year Rainfall Return Period*

For the 25-year return period, 13.89% of the municipality of Balangkayan with an area of 170.563 sq. km. will experience flood levels of less 0.20 meters. 1.14% of the area will experience flood levels of 0.21 to 0.50 meters while 1.38%, 1.36%, 1.39% and 0.097% 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 kilometres by flood depth per barangay.

Table 37. Affected Areas in Balangkayan, Eastern Samarduring 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balangkayan(in sq. km.)								
	Balogo	Llorente	Cabay	Caisawan	Cantubi	Guinpoliran	Julag	Magsaysay	Maramag
0.03-0.20	1.65	4.81	1.2	1.78	2.52	2.19	5.94	0.76	2.84
0.21-0.50	0.074	0.55	0.089	0.067	0.1	0.079	0.67	0.037	0.27
0.51-1.00	0.09	0.53	0.076	0.091	0.066	0.099	1.08	0.035	0.28
1.01-2.00	0.14	0.71	0.1	0.11	0.079	0.15	0.83	0.032	0.17
2.01-5.00	0.13	0.5	0.16	0.1	0.13	0.24	0.99	0.01	0.11
> 5.00	0	0.0015	0.12	0	0.0054	0.017	0.01	0	0.012

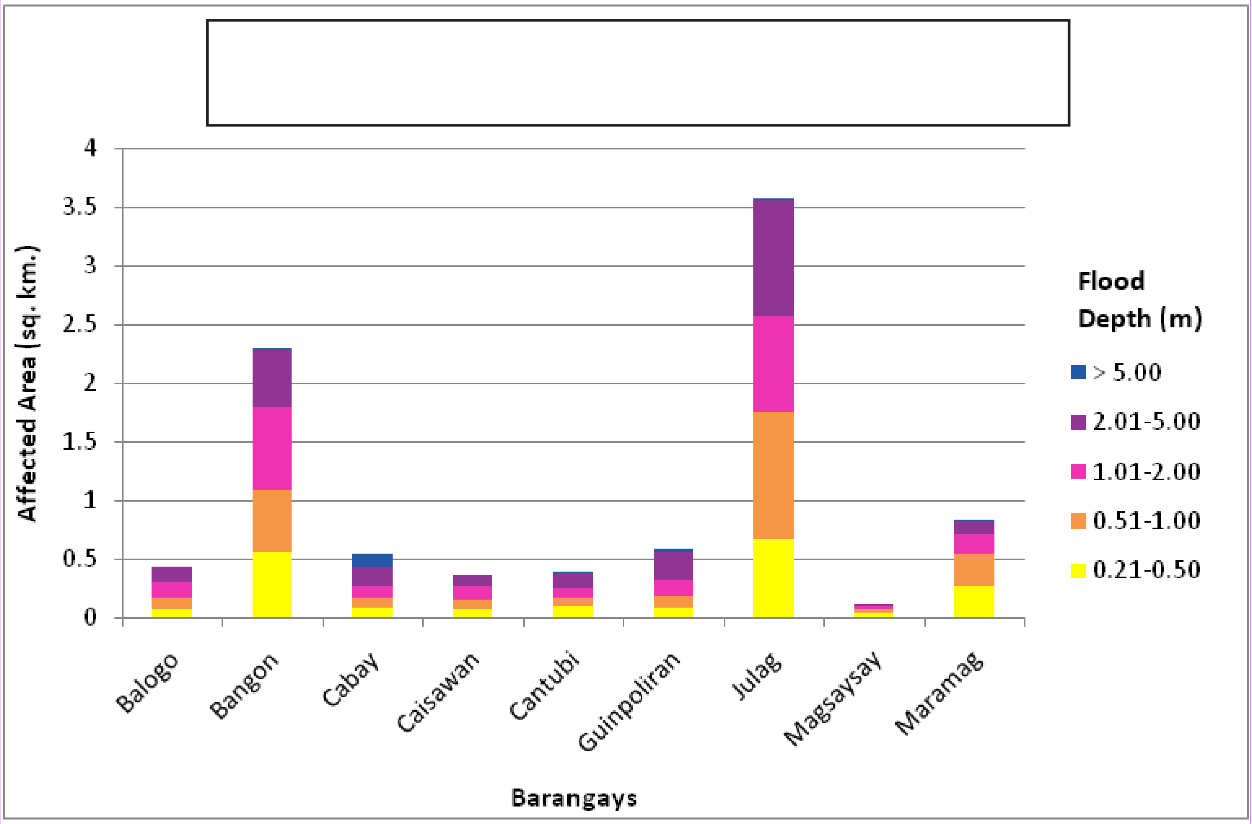


Figure 76. *Affected Areas in Balangkayan, Eastern Samarduring 25-Year Rainfall Return Period*

For the municipality of Hernani, with an area of 46.444 sq. km., 7.44% will experience flood levels of less 0.20 meters. 0.29% of the area will experience flood levels of 0.21 to 0.50 meters while 0.18%, 0.17%, 0.16% and 0.009% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Hernani, Eastern Samarduring 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Hernani(in sq. km.)					
	Cacatmonan	Cancildedes	Garawon	Padang	San Isidro	San Miguel
0.03-0.20	0.92	0.34	0.15	1.18	0.87	0.00073
0.21-0.50	0.032	0.012	0.002	0.061	0.03	0
0.51-1.00	0.02	0.0055	0	0.04	0.018	0
1.01-2.00	0.018	0.0079	0	0.036	0.017	0
2.01-5.00	0.015	0.014	0	0.024	0.025	0
> 5.00	0	0.0013	0	0.0016	0.0012	0

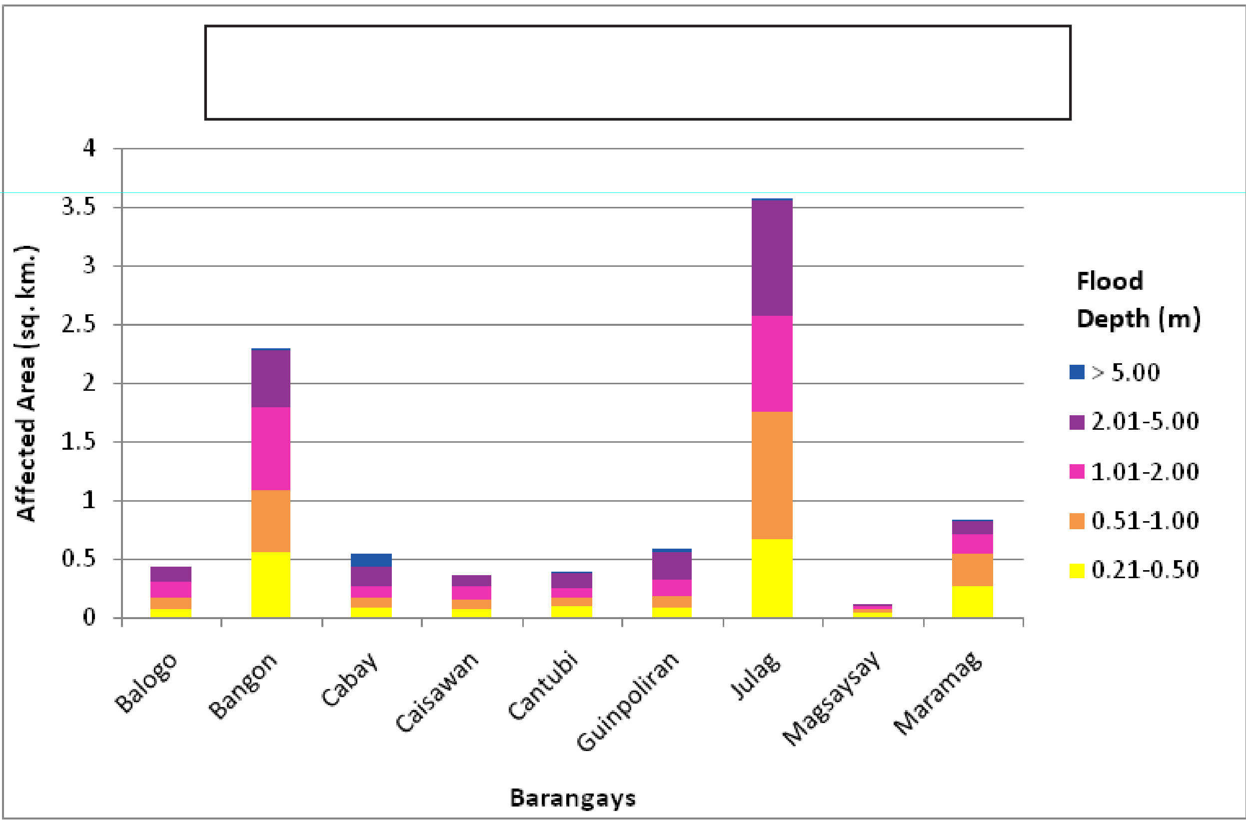


Figure 77. Affected Areas in Hernani, Eastern Samarduring 25-Year Rainfall Return Period

For the municipality of Llorente, with an area of 344.086 sq. km., 30% will experience flood levels of less 0.20 meters. 1.73% of the area will experience flood levels of 0.21 to 0.50 meters while 1.32%, 1.56%, 2.74%, and 2.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively.

Table 39. Affected Areas in Llorente, Eastern Samarduring 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)								
	Antipolo	Babanikhon	Bacayawan	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 2	Barangay 3
0.03-0.20	15.16	4.57	10.87	1.14	0.03	0.063	0.12	0.031	0.035
0.21-0.50	0.68	0.3	0.54	0.23	0.012	0.0048	0.012	0.0085	0.0064
0.51-1.00	0.6	0.25	0.28	0.17	0.0037	0.0037	0.0073	0.0044	0.0041
1.01-2.00	0.94	0.25	0.23	0.08	0.0011	0.0031	0.0037	0.0016	0.00014
2.01-5.00	2.06	0.2	0.27	0.13	0	0.044	0.05	0	0
> 5.00	2.3	0.0015	0.11	0.13	0	0.00063	0.0059	0	0

Table 40. Affected Areas in Llorente, Eastern Samarduring 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)								
	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Barobo	Canliwag	Cantomco
0.03-0.20	0.035	0.044	0.0084	0.039	0.29	0.024	2.12	3.02	10.54
0.21-0.50	0.0059	0.0032	0.002	0.0055	0.048	0.0027	0.041	0.12	0.67
0.51-1.00	0.0017	0.00055	0.00093	0.0044	0.031	0.0018	0.022	0.11	0.64
1.01-2.00	0.00021	0	0.0017	0.0048	0.013	0.0016	0.029	0.23	0.86
2.01-5.00	0	0	0.024	0.039	0.014	0.02	0.056	0.44	2.07
> 5.00	0	0	0	0	0	0	0.38	0.04	1.56

Table 41. Affected Areas in Llorente, Eastern Samarduring 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)									
	Hugpa	Maca-Anga	Naubay	Piliw	San Jose	San Miguel	San Roque	So-Ong	Tabok	Waso
0.03-0.20	15.6	8.56	3.35	4.71	3.28	2.26	2.44	1.7	4.43	8.76
0.21-0.50	0.74	0.59	0.2	0.32	0.13	0.13	0.25	0.25	0.31	0.33
0.51-1.00	0.5	0.34	0.23	0.33	0.11	0.18	0.2	0.13	0.18	0.23
1.01-2.00	0.61	0.29	0.5	0.35	0.13	0.13	0.096	0.1	0.16	0.35
2.01-5.00	1.26	0.26	1.05	0.29	0.11	0.073	0.11	0.11	0.13	0.62
> 5.00	0.52	0.071	0.01	0.04	0.046	0.0073	0.015	0.012	0.038	1.74

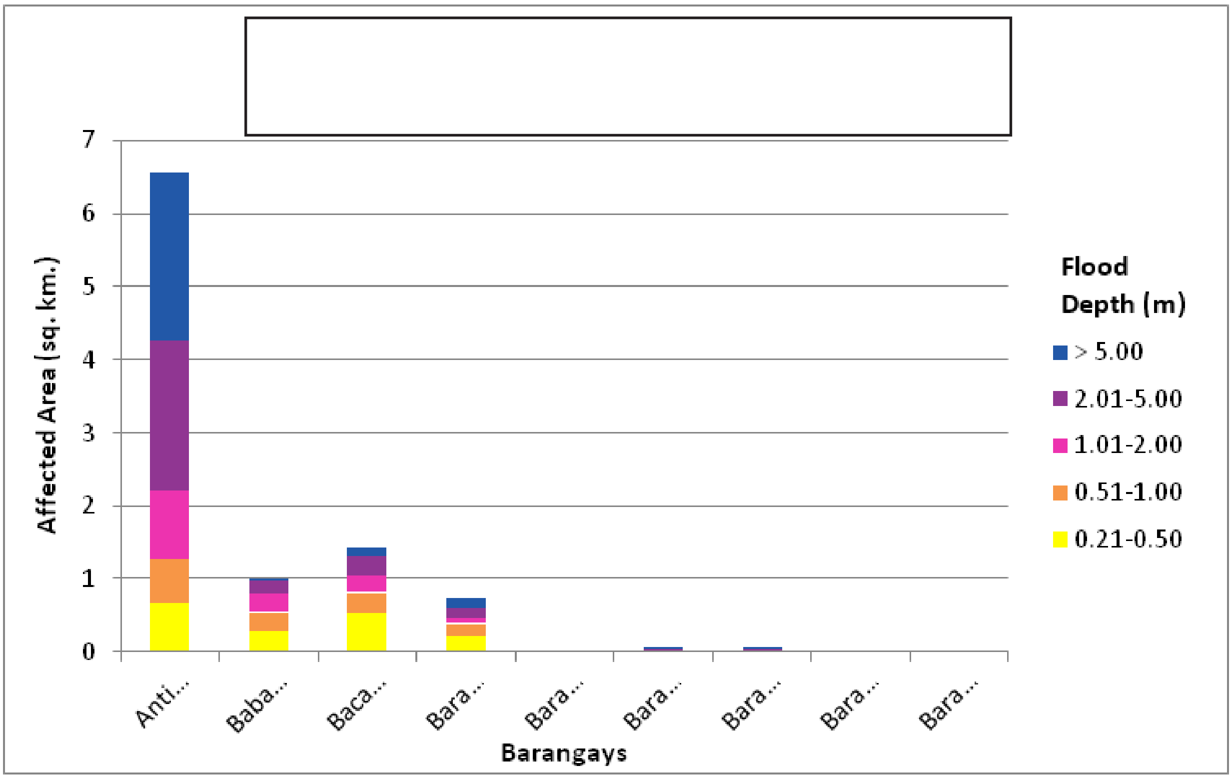


Figure 78. *Affected Areas in Llorente, Eastern Samarduring 25-Year Rainfall Return Period*

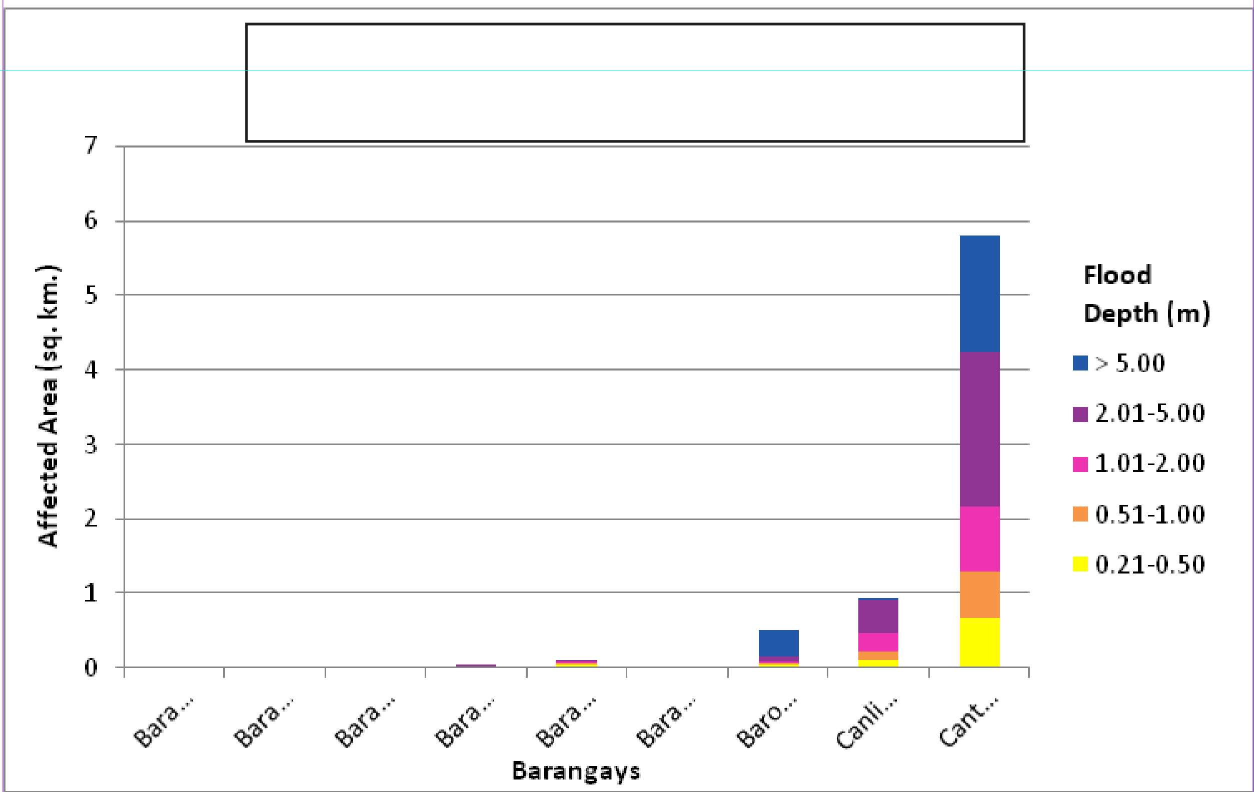


Figure 79. Affected Areas in Llorente, Eastern Samarduring 25-Year Rainfall Return Period

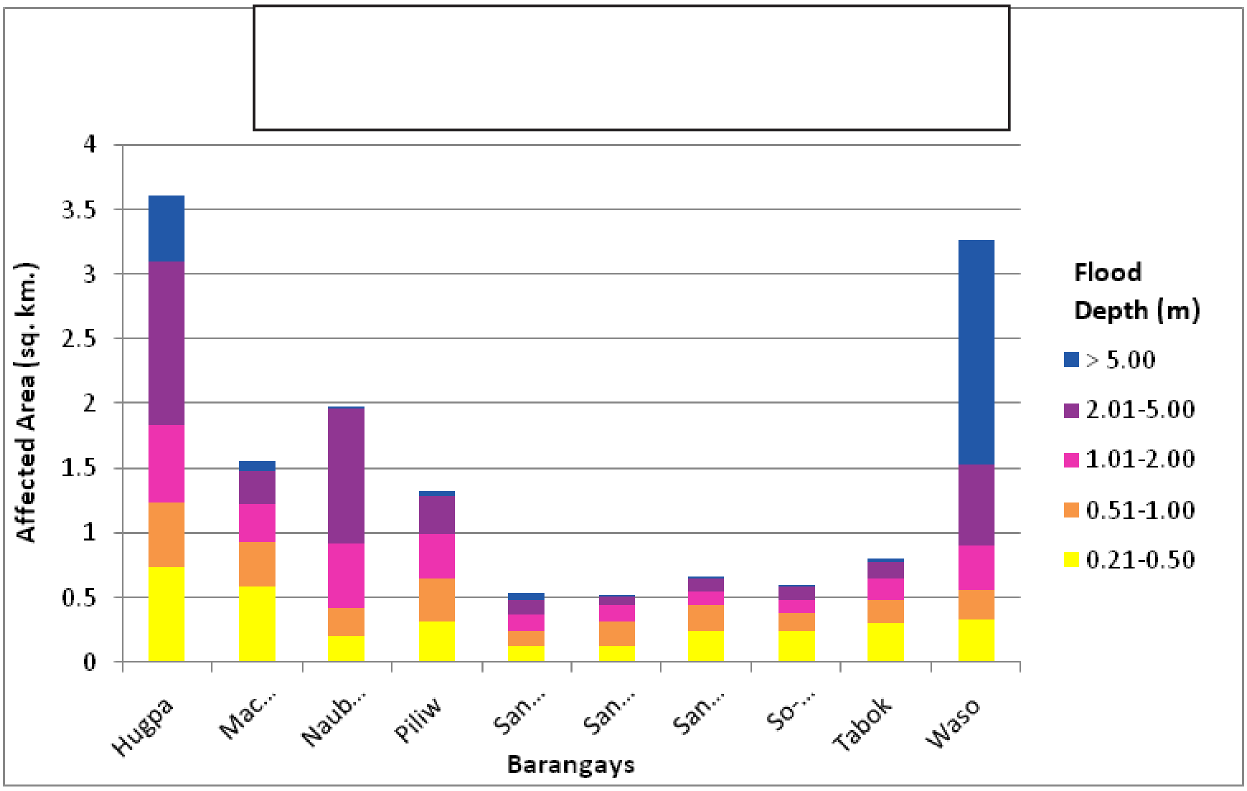


Figure *80. Affected Areas in Llorente, Eastern Samarduring 25-Year Rainfall Return Period*

For the 100-year return period, 13.49% of the municipality of Balangkayan with an area of 170.563 sq. km. will experience flood levels of less 0.20 meters. 1.08% of the area will experience flood levels of 0.21 to 0.50 meters while 1.3%, 1.44%, 1.75% and 0.19% 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 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Balangkayan, Eastern Samarduring 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balangkayan(in sq. km.)								
	Balogo	Llorente	Cabay	Caisawan	Cantubi	Guinpoliran	Julag	Magsaysay	Maramag
0.03-0.20	1.62	4.6	1.17	1.75	2.49	2.15	5.72	0.75	2.76
0.21-0.50	0.073	0.56	0.081	0.065	0.12	0.077	0.59	0.039	0.25
0.51-1.00	0.085	0.49	0.087	0.084	0.071	0.1	0.95	0.035	0.31
1.01-2.00	0.15	0.65	0.1	0.13	0.071	0.14	0.98	0.038	0.19
2.01-5.00	0.15	0.79	0.15	0.12	0.16	0.27	1.19	0.015	0.14
> 5.00	0	0.0052	0.16	0	0.011	0.035	0.094	0	0.02

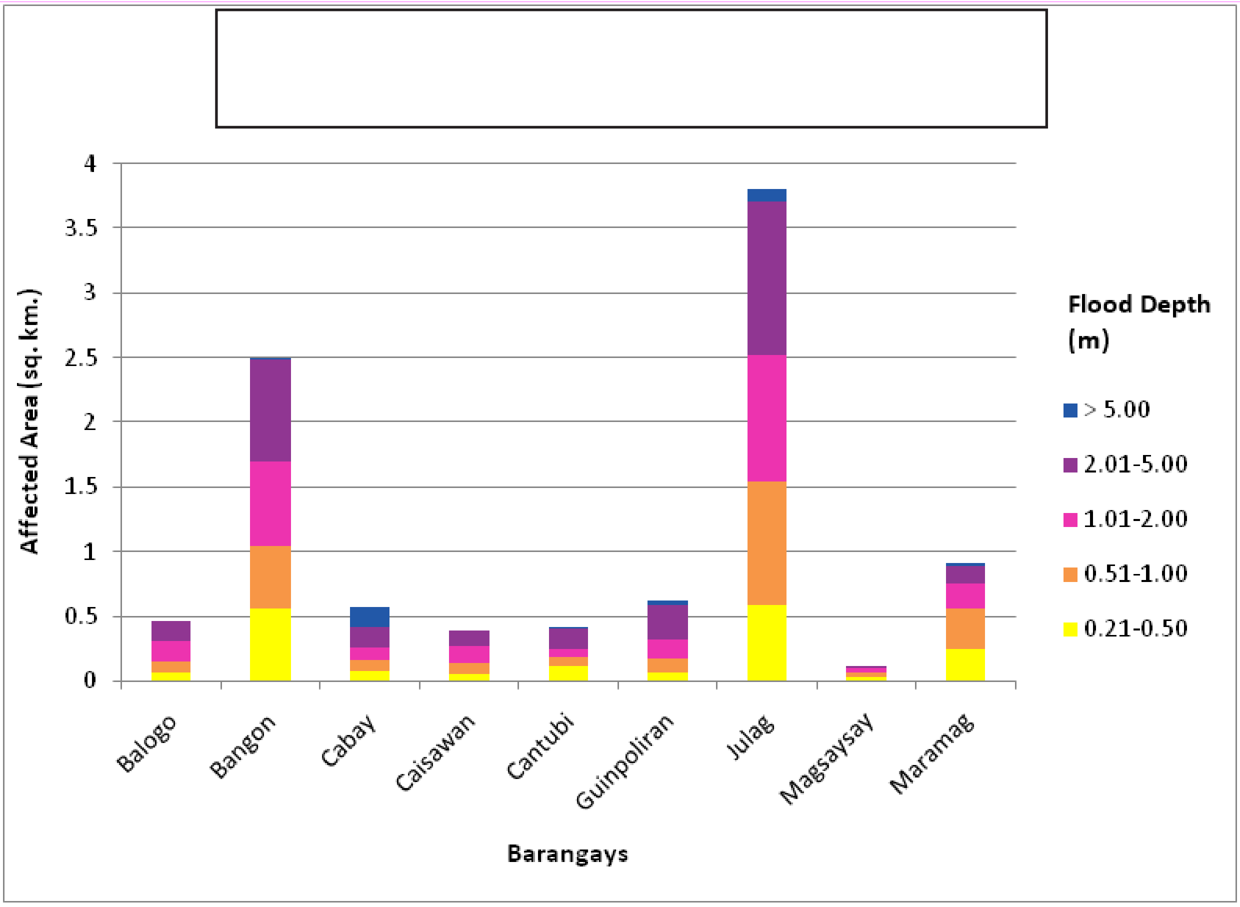


Figure *81. Affected Areas in Balangkayan, Eastern Samarduring 100-Year Rainfall Return Period*

For the municipality of Hernani, with an area of 46.444 sq. km., 7.34% will experience flood levels of less 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters while 0.2%, 0.18%, 0.19% and 0.019% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Hernani, Eastern Samarduring 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Hernani(in sq. km.)					
	Cacatmonan	Canciledes	Garawon	Padang	San Isidro	San Miguel
0.03-0.20	0.91	0.34	0.15	1.16	0.86	0.00073
0.21-0.50	0.036	0.013	0.003	0.068	0.033	0
0.51-1.00	0.021	0.0068	0	0.044	0.02	0
1.01-2.00	0.018	0.008	0	0.039	0.018	0
2.01-5.00	0.019	0.016	0	0.028	0.028	0
> 5.00	0.0002	0.0023	0	0.003	0.0031	0

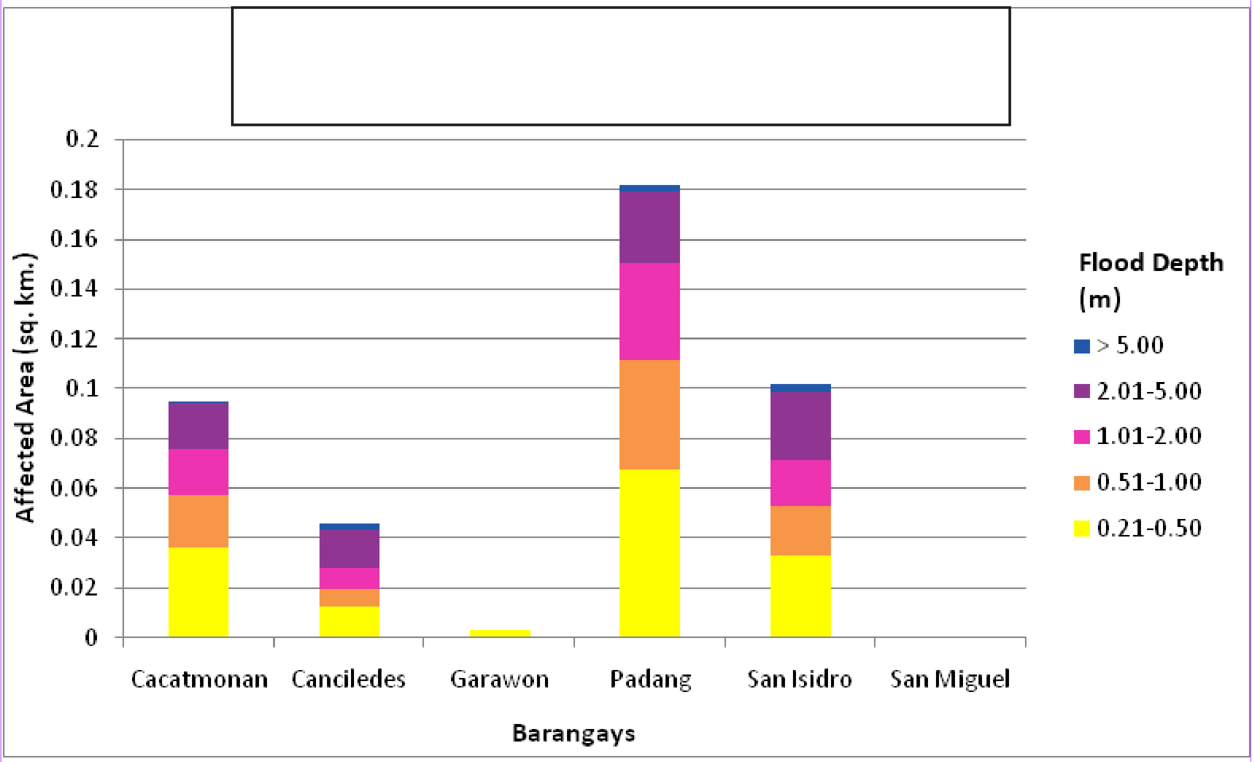


Figure 82. Affected Areas in Hernani, Eastern Samarduring 100-Year Rainfall Return Period

For the municipality of Llorente, with an area of 344.086 sq. km., 28.98% will experience flood levels of less 0.20 meters. 1.8% of the area will experience flood levels of 0.21 to 0.50 meters while 1.34%, 1.52%, 3.13%, and 2.63% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively.

Table 44. Affected Areas in Llorente, Eastern Samarduring 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)								
	Antipolo	Babanikhon	Bacayawan	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 2	Barangay 3
0.03-0.20	14.44	4.44	10.67	0.99	0.027	0.061	0.11	0.029	0.034
0.21-0.50	0.68	0.31	0.61	0.23	0.013	0.0056	0.013	0.0094	0.007
0.51-1.00	0.56	0.27	0.32	0.18	0.0046	0.0033	0.011	0.005	0.0046
1.01-2.00	0.81	0.25	0.26	0.15	0.0014	0.0032	0.0053	0.002	0.00029
2.01-5.00	2.4	0.27	0.3	0.13	0	0.044	0.044	0	0
> 5.00	2.85	0.025	0.15	0.19	0	0.0023	0.014	0	0

Table 45. Affected Areas in Llorente, Eastern Samarduring 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)								
	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Barobo	Canliwag	Cantomco
0.03-0.20	0.033	0.044	0.0042	0.036	0.28	0.021	2.08	2.94	9.72
0.21-0.50	0.007	0.0036	0.0029	0.0062	0.056	0.0046	0.043	0.14	0.64
0.51-1.00	0.0021	0.00095	0.0034	0.006	0.033	0.0025	0.021	0.096	0.65
1.01-2.00	0.00038	0	0.0017	0.0014	0.012	0.0019	0.03	0.18	0.87
2.01-5.00	0	0	0.025	0.044	0.018	0.02	0.054	0.54	2.12
> 5.00	0	0	0	0	0	0	0.41	0.066	2.34

Table 46. Affected Areas in Llorente, Eastern Samarduring 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Llorente (in sq. km.)									
	Hugpa	Maca-Anga	Naubay	Piliw	San Jose	San Miguel	San Roque	So-Ong	Tabok	Waso
0.03-0.20	15.27	8.39	3.2	4.59	3.23	2.21	2.37	1.61	4.32	8.55
0.21-0.50	0.83	0.61	0.21	0.31	0.14	0.13	0.26	0.26	0.34	0.33
0.51-1.00	0.5	0.39	0.2	0.31	0.11	0.17	0.22	0.16	0.19	0.18
1.01-2.00	0.6	0.3	0.39	0.37	0.14	0.18	0.1	0.098	0.18	0.3
2.01-5.00	1.35	0.3	1.27	0.4	0.14	0.092	0.13	0.16	0.16	0.75
> 5.00	0.68	0.13	0.055	0.065	0.059	0.012	0.024	0.017	0.05	1.92

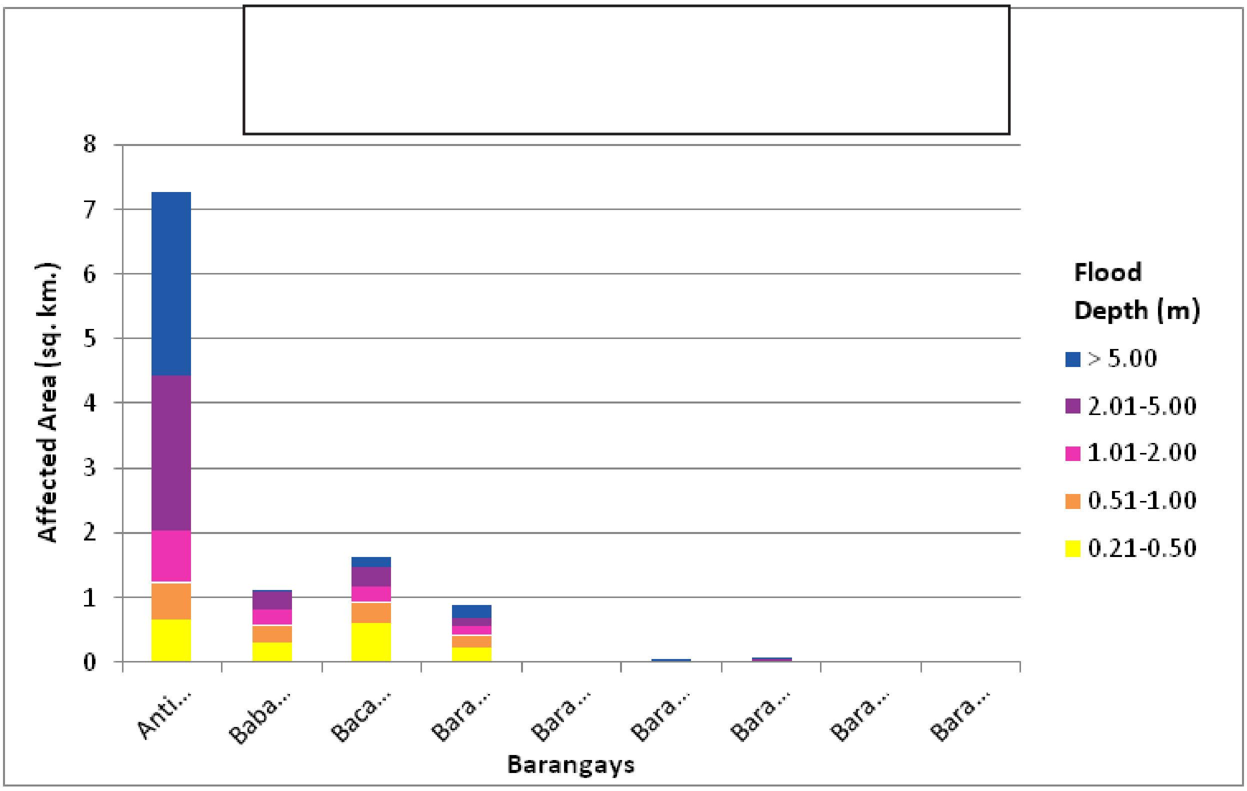


Figure 83. Affected Areas in Llorente, Eastern Samarduring 100-Year Rainfall Return Period

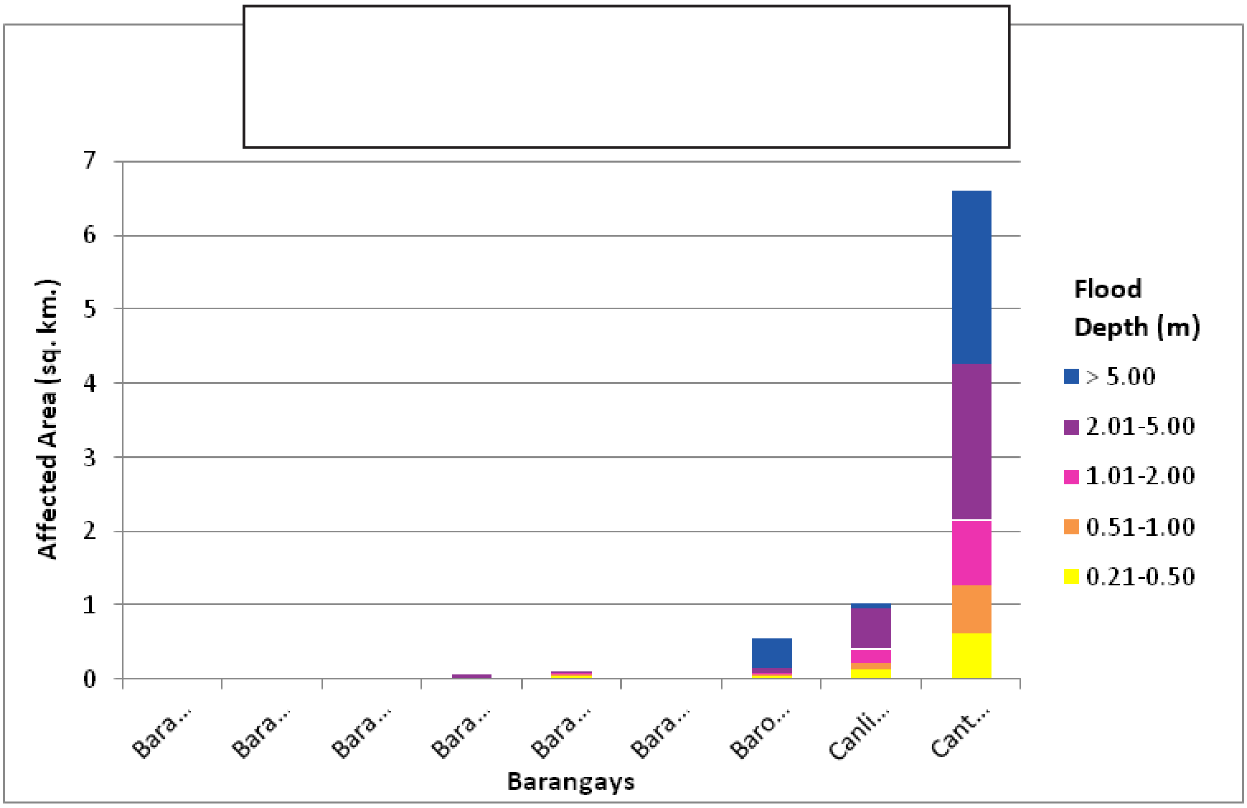


Figure 84. Affected Areas in Llorente, Eastern Samarduring 100-Year Rainfall Return Period

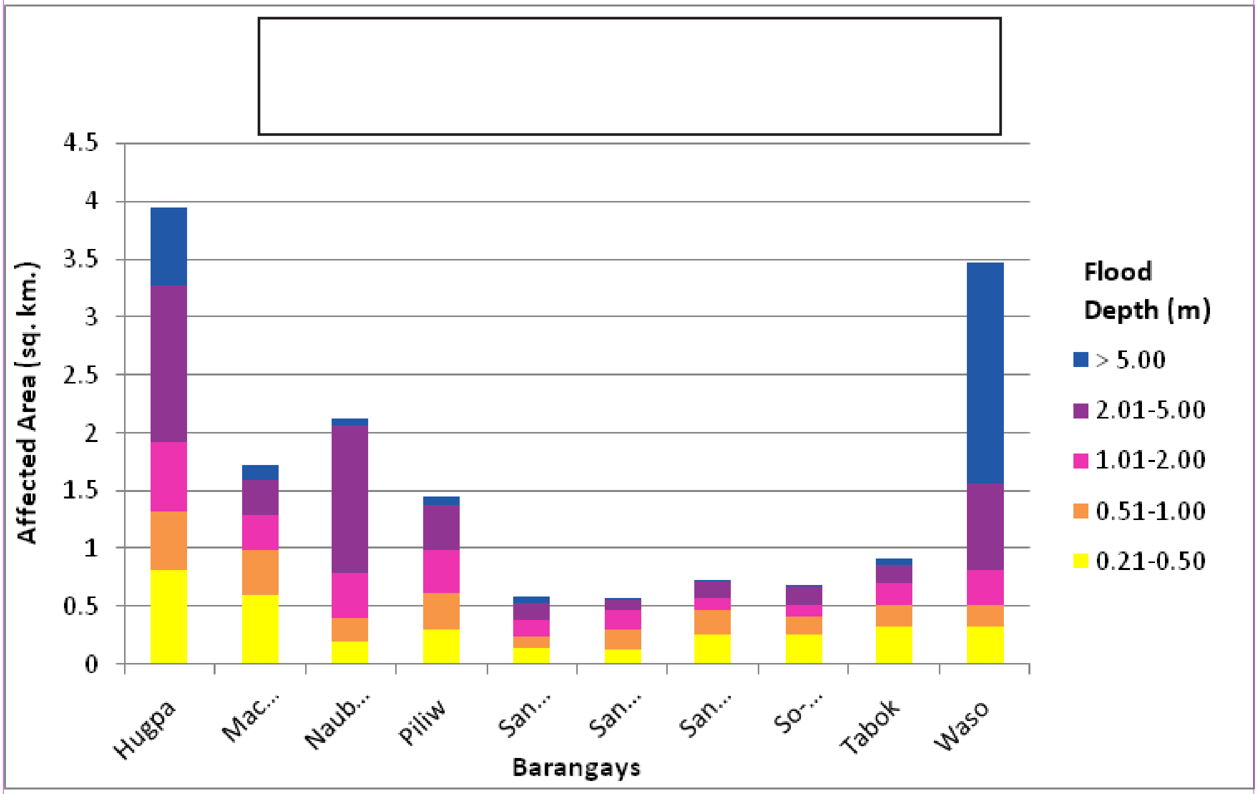


Figure 85. Affected Areas in Llorente, Eastern Samar during 100-Year Rainfall Return Period

Among the barangays in the municipality of Balangkayan, Julag is projected to have the highest percentage of area that will experience flood levels at 5.59%. Meanwhile, Bangon posted the second highest percentage of area that may be affected by flood depths at 4.16%.

Among the barangays in the municipality of Hernani, Padang is projected to have the highest percentage of area that will experience flood levels at 2.88%. Meanwhile, Cacatmonan posted the second highest percentage of area that may be affected by flood depths at 2.16%.

Among the barangays in the city of Llorente, Antipolo is projected to have the highest percentage of area that will experience flood levels of at 6.32%. Meanwhile, Hugpa posted the second highest percentage of area that may be affected by flood depths of at 5.59%.

Moreover, the generated flood hazard maps for the Llorente 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 47. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	8.28	8.17	8.35
Medium	11.08	11.26	11.14
High	15.85	22.91	27.14
Total	35.21	42.35	46.63

Of the 18 identified Education Institutions in Llorente Flood plain, 7 schools were assessed to be exposed to the Low level flooding during 5 year. For the 25 year scenario, 7 schools were assessed to be exposed to the Low level flooding and 1 for Medium level flooding. For the 100 year scenario, 8 schools were assessed for Low level flooding and 2 for Medium level flooding. See Appendix D for a detailed enumeration of schools inside Llorente floodplain.

Of the 3 identified Medical Institutions in Llorente Flood plain, 2 were assessed to be exposed to the Low level flooding during a 5 year scenario. In the 25 and 100 year scenario, 1 was assessed to be exposed to the Low level flooding while 1 was assessed to be exposed to the Medium level flooding. See Appendix E for a detailed enumeration of medical insitutions inside Llorente floodplain.

5.11 Flood Validation

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

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios are identified for validation.

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 273 points randomly selected all over the Llorente flood plain. It has an RMSE value of 0.83.

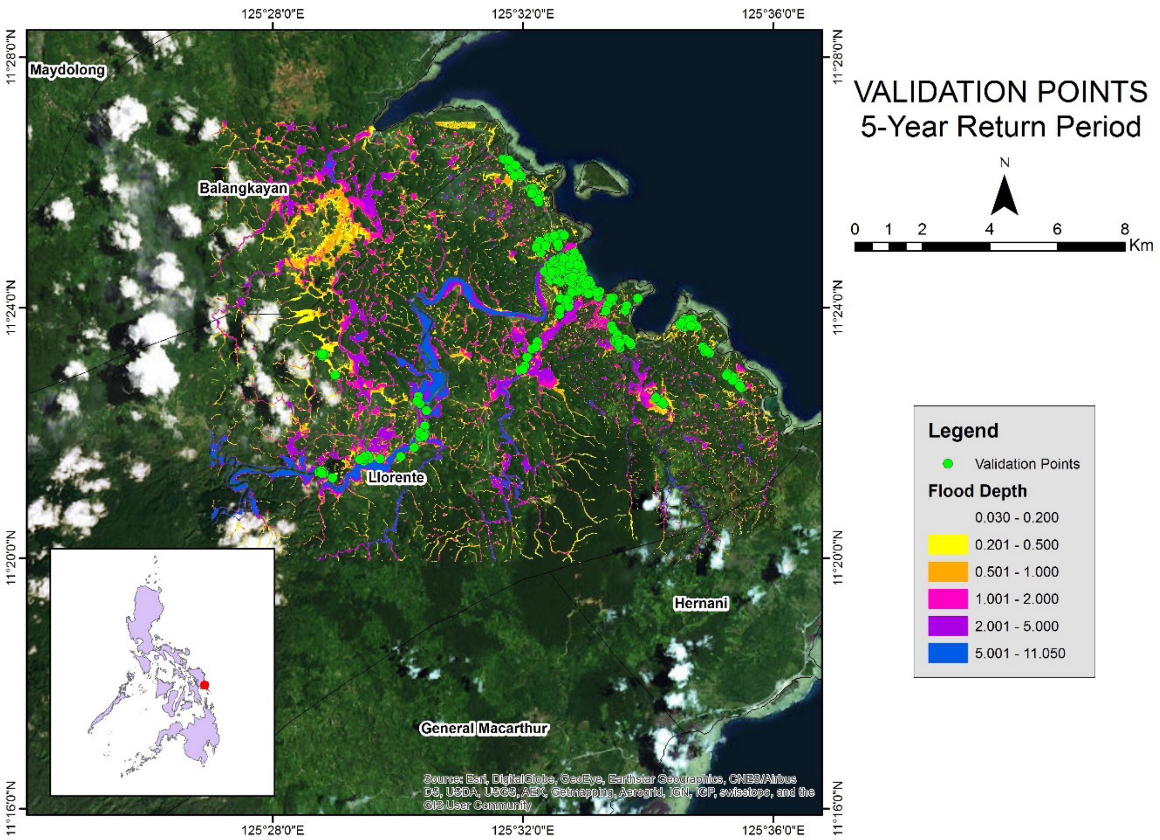


Figure 86. Validation points for 5-year Flood Depth Map of Llorente Floodplain

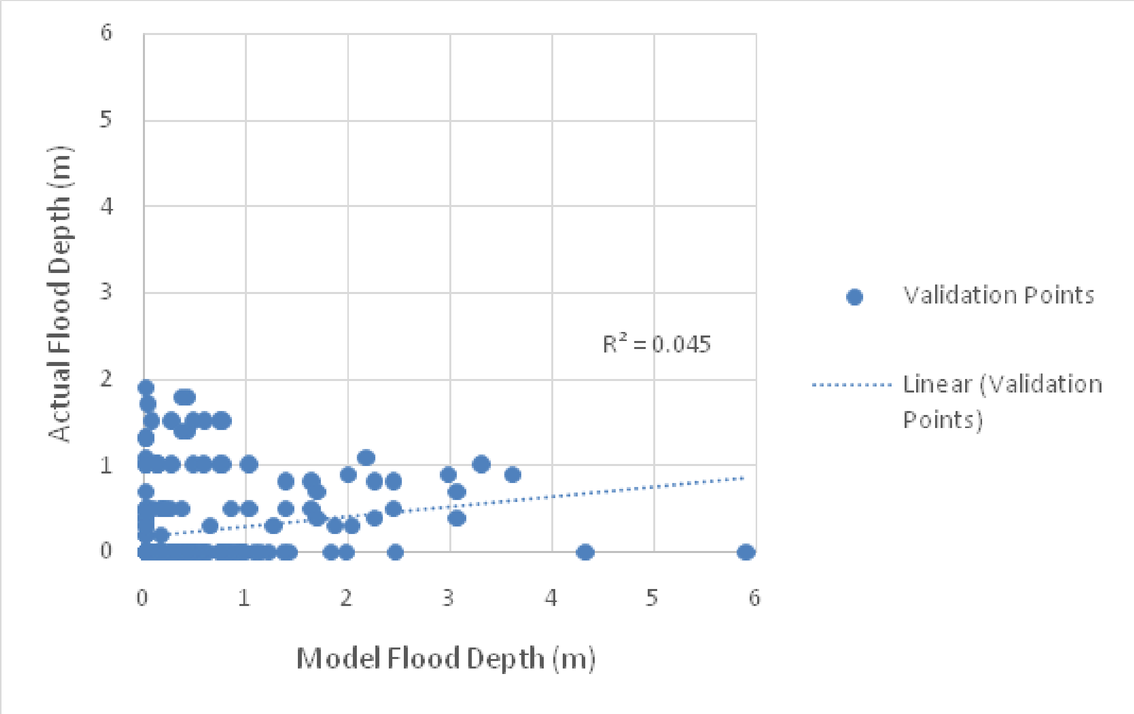


Figure 87. Flood map depth vs actual flood depth

Table 48. Actual Flood Depth vs Simulated Flood Depth in Llorente

LLORENTE 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	147	22	23	7	2	1	202
	0.21-0.50	15	4	2	6	4	0	31
	0.51-1.00	8	2	3	5	6	0	24
	1.01-2.00	6	6	3	0	1	0	16
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	176	34	31	18	13	1	273

The overall accuracy generated by the flood model is estimated at 56.41%, with 154 points correctly matching the actual flood depths. In addition, there were 50 points estimated one level above and below the correct flood depths while there were 49 points and 20 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 79 points were overestimated while a total of 40 points were underestimated in the modelled flood depths of Llorente.

Table 49. Summary of Accuracy Assessment in Llorente

	No. of Points	%
Correct	154	**56.41**
Overestimated	79	28.94
Underestimated	40	14.65
Total	273	100

REFERENCES:

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

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

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

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

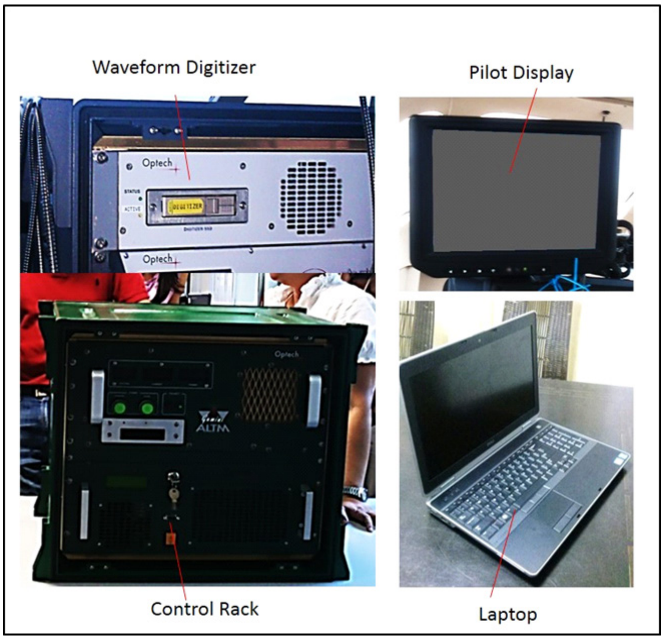
Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

ANNEXES

ANNEX 1. OPTECH TECHNICAL SPECIFICATION OF THE AQUARIUS SENSOR



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

ANNEX 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. SME - 3117

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **EASTERN SAMAR**
Station Name: **SME-3117**
Order: **4th**

Island: **VISAYAS** Municipality: **MAYDOLONG**		Barangay: **BARANGAY POBLACION 4**
	PRS92 Coordinates	
Latitude: **11° 30' 19.94572"**	Longitude: **125° 29' 48.45875"**	Ellipsoidal Hgt: **-0.71500 m.**
	WGS84 Coordinates	
Latitude: **11° 30' 15.65415"**	Longitude: **125° 29' 53.58658"**	Ellipsoidal Hgt: **62.09300 m.**
	PTM Coordinates	
Northing: **1272291.016 m.**	Easting: **554197.385 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,272,983.11**	Easting: **772,367.30**	Zone: **51**

Location Description

SME-3117

From Tacloban City, travel about 70 Km. NE towards the junction of Buena Vista, Quinapondan. Then travel about 80 Km. N pass Gen. Mc Arthur, Hernani, Llorente and Balangkayan towards Poblacion 4, Maydolong until reaching Maydolong Nat'l High School. Station is located inside the compound of school about 2 m S of the flagpole. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument with inscriptions, "SME-3117, 2008, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1304**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. SE - 37

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

May 02, 2014

CERTIFICATION

To whom it may concern:

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

Province: **EASTERN SAMAR**
Station Name: **SE-37**

Island: **VISAYAS**	Municipality: **QUINAPONDAN**	Barangay: **SANTO NIÑO**
Elevation: **1.3583 m.**	Order: **1st Order**	Datum:

Location Description

SE-37 is in the Province of Eastern Samar, town of Quinapondan, Brgy. Sto Nino along right side of the National highway. It is located beside Km 995, positioned approximately 1.00m S and 4.90m from the centerline of the national highway. Station mark is the head of 4" copper nail centered on a 0.30m x 0.30m concrete block and mark with "SE-37, 2007, NAMRIA."

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8796083 A**
T.N.:	**2014-1028**

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

9 9 0 5 0 2 2 0 1 4 1 5 4 8 0 8

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

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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

3. SE - 102

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **EASTERN SAMAR**
Station Name: **SE-102**

Island: **VISAYAS**	Municipality: **MAYDOLONG**	Barangay: **BARANGAY**
Elevation: **2.5962 m.**	Order: **1st Order**	Datum:

Location Description

SE-102 is in the Province of Eastern Samar, town of Maydolong, Brgy. 4 along right side of the National highway going to Borongan. It is located in front of Maydolong National High School near the gate, and about 8.50m from the centerline of the national highway. Station mark is the head of 4" copper nail centered on a 0.30m x 0.30m concrete block and mark with
"SE-102, 2007, NAMRIA."

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**8796290 A**
T.N.:	**2014-1305**

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

9906062014164701

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

ANNEX 3. BASELINE PROCESSING REPORT

1. SME – 3074

SME3074 - PTAC (7:59:44 AM-11:59:43 AM) (S6)

Baseline observation:	SME3074 --- PTAC (B6)
Processed:	7/2/2014 12:08:00 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.008 m
Vertical precision:	0.020 m
RMS:	0.014 m
Maximum PDOP:	2.117
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	6/2/2014 7:59:44 AM (Local: UTC+8hr)
Processing stop time:	6/2/2014 11:59:43 AM (Local: UTC+8hr)
Processing duration:	03:59:59
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME3074				
Grid		Local		Global	
Easting	774710.019 m	Latitude	N11°07'59.28294"	Latitude	N11°07'55.08754"
Northing	1231788.008 m	Longitude	E125°30'54.00701"	Longitude	E125°30'59.16732"
Elevation	5.509 m	Height	5.541 m	Height	69.310 m

To:	SE37				
Grid		Local		Global	
Easting	774710.109 m	Latitude	N11°07'59.24685"	Latitude	N11°07'55.05146"
Northing	1231786.899 m	Longitude	E125°30'54.00964"	Longitude	E125°30'59.16995"
Elevation	5.446 m	Height	5.478 m	Height	69.247 m

Vector					
ΔEasting	0.089 m	NS Fwd Azimuth	175°52'59"	ΔX	-0.154 m
ΔNorthing	-1.109 m	Ellipsoid Dist.	1.112 m	ΔY	0.078 m
ΔElevation	-0.063 m	ΔHeight	-0.063 m	ΔZ	-1.100 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°08'25"	σ ΔX	0.003 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

2. SE - 37

SME3074 - SE37 (7:47:33 AM-12:39:00 PM) (S5)

Baseline observation:	SME3074 --- SE37 (B5)
Processed:	7/2/2014 12:10:17 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.007 m
Vertical precision:	0.003 m
RMS:	0.000 m
Maximum PDOP:	2.118
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/2/2014 7:48:10 AM (Local: UTC+8hr)
Processing stop time:	6/2/2014 12:39:00 PM (Local: UTC+8hr)
Processing duration:	04:50:50
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME3074				
Grid		Local		Global	
Easting	774710.019 m	Latitude	N11°07'59.28294"	Latitude	N11°07'55.08754"
Northing	1231788.008 m	Longitude	E125°30'54.00701"	Longitude	E125°30'59.16732"
Elevation	5.509 m	Height	5.541 m	Height	69.310 m

To:	SE37				
Grid		Local		Global	
Easting	774710.109 m	Latitude	N11°07'59.24685"	Latitude	N11°07'55.05146"
Northing	1231786.899 m	Longitude	E125°30'54.00964"	Longitude	E125°30'59.16995"
Elevation	5.446 m	Height	5.478 m	Height	69.247 m

Vector					
ΔEasting	0.089 m	NS Fwd Azimuth	175°52'59"	ΔX	-0.154 m
ΔNorthing	-1.109 m	Ellipsoid Dist.	1.112 m	ΔY	0.078 m
ΔElevation	-0.063 m	ΔHeight	-0.063 m	ΔZ	-1.100 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°08'25"	σ ΔX	0.003 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

3. SE – 102

SME-3117 - SE-102 A (6:47:42 AM-11:17:03 AM) (S2)

Baseline observation:	SME-3117 --- SE-102 A (B2)
Processed:	6/17/2014 10:44:29 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.004 m
RMS:	0.000 m
Maximum PDOP:	2.769
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/8/2014 6:47:51 AM (Local: UTC+8hr)
Processing stop time:	6/8/2014 11:17:03 AM (Local: UTC+8hr)
Processing duration:	04:29:12
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME-3117				
Grid		Local		Global	
Easting	772367.303 m	Latitude	N11°30'19.94572"	Latitude	N11°30'15.65415"
Northing	1272983.110 m	Longitude	E125°29'48.45876"	Longitude	E125°29'53.68668"
Elevation	1.116 m	Height	-0.714 m	Height	62.093 m

To:	SE-102 A				
Grid		Local		Global	
Easting	772214.094 m	Latitude	N11°30'18.33686"	Latitude	N11°30'14.04528"
Northing	1272932.317 m	Longitude	E125°29'43.39146"	Longitude	E125°29'48.61933"
Elevation	2.196 m	Height	0.393 m	Height	63.198 m

Vector					
ΔEasting	-153.209 m	NS Fwd Azimuth	252°09'24"	ΔX	118.669 m
ΔNorthing	-50.793 m	Ellipsoid Dist.	161.326 m	ΔY	98.078 m
ΔElevation	1.081 m	ΔHeight	1.107 m	ΔZ	-48.223 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.002 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

ANNEX 4. THE SURVEY TEAM

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	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
LiDAR Operation	Research Associate (RA)	PAULINE JOANNE ARCEO	
		FAITH JOY SABLE	
		MARY CATHERINE ELIZABETH BALIGUAS	
		ENGR. IRO NIEL ROXAS	
Ground Survey, Data Download and Transfer		JERIEL PAUL ALAMBAN	
LiDAR Operation	Airborne Security	SGT. RANDY SISON	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JACKSON RHOD JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	

ANNEX 5. DATA TRANSFER SHEETS FOR LLORENTE FLOODPLAIN FLIGHTS

DATA TRANSFER SHEET
6/19/2014 (Samar - Leyte)

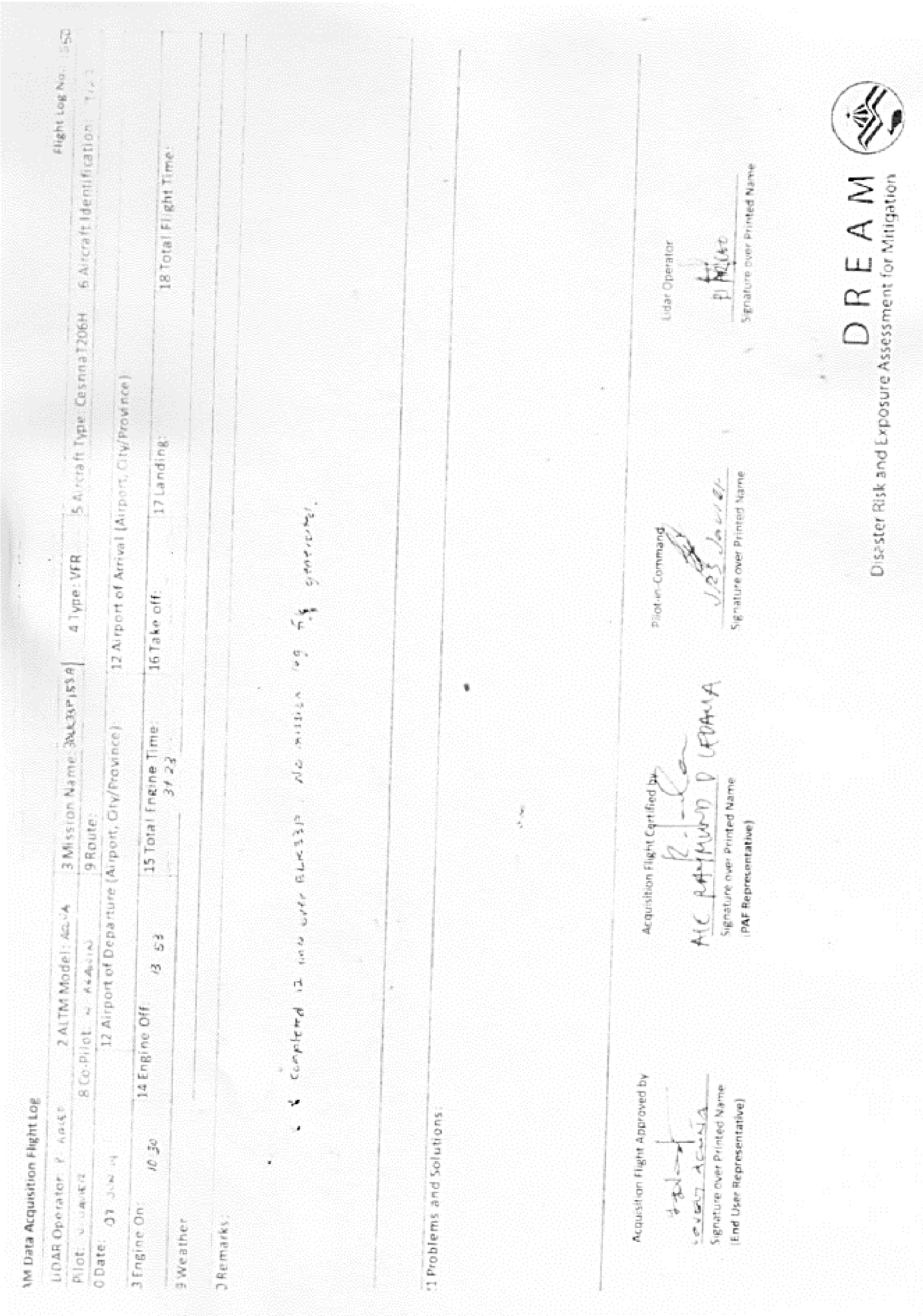
DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
30-May-14	1520A	3BLK33VSS150A	Aquarius	NA	424/602	1.48	289	88.5	748	14	164	10.5	1KB	1KB	4	NA	X:\Airborne_Raw\1520A
31-May-14	1522A	3BLK33SS151A	Aquarius	NA	288	469KB	112	9.78/21	164/69	4.87	59.1	4.53	1KB	1KB	5	NA	X:\Airborne_Raw\1522A
1-Jun-14	1526A	3BLK33SSR152A	Aquarius	NA	456/784	1.68	277	119	403	15.5	204	8.36	1KB	1KB	6	NA	X:\Airborne_Raw\1526A
2-Jun-14	1530A	3BLK33RSQ153A	Aquarius	NA	353/605	1.48	254	30.9/80.2	555/246	15.6	165	7.88	1KB	1KB	3	NA	X:\Airborne_Raw\1530A
3-Jun-14	1534A	3BLK33QS154A	Aquarius	NA	1175	1.49	250	56.9/35.1	399/154	14.5	114/95.5	6.6	1KB	1KB	7	NA	X:\Airborne_Raw\1534A
7-Jun-14	1550A	3BLK33P158A	Aquarius	NA	657	1.03	199	52.9	na	10.8	149	7	1KB	1KB	3	NA	X:\Airborne_Raw\1550A
8-Jun-14	1554A	3BLK33PSM159A	Aquarius	NA	533/1012	1.78	257	99.8	695	14.5	27.2/59/32.2	16.4	1KB	1KB	3	NA	X:\Airborne_Raw\1554A
8-Jun-14	1556A	3BLK33MS159B	Aquarius	NA	982	1.52	291	97.2	477	15.9	216	16.4	1KB	1KB	5	NA	X:\Airborne_Raw\1556A
9-Jun-14	1558A	3BLK33J160A	Aquarius	NA	833	1.27	277	95.7	452	14.2	95.6/80.5	16.1	1KB	1KB	4	NA	X:\Airborne_Raw\1558A
9-Jun-14	1560A	3BLK33J	Aquarius	NA	1583	1.67	223	72.2	357	12.1	123	16.1	1KB	1KB	5	NA	X:\Airborne_Raw\1560A

Received from
Name: O. JOAQUIN
Position: DA
Signature:

Received by
Name: JOIDA PRIETO
Position: SSRS
Signature:
6/19/14

ANNEX 6. FLIGHT LOGS

1. Flight Log for 1550 A Mission



M Data Acquisition Flight Log

Flight Log No.: 1550

LIDAR Operator: P. Arceo | 2 ALTM Model: AQUA | 3 Mission Name: 3BLK33P153A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9123

Pilot: J. Javier | 8 Co-Pilot: N. Adawan | 9 Route:

0 Date: 01 Jun 14 | 12 Airport of Departure (Airport, City/Province) | 12 Airport of Arrival (Airport, City/Province)

3 Engine On: 10 30 | 14 Engine Off: 13 53 | 15 Total Engine Time: 3+23 | 16 Take off: | 17 Landing: | 18 Total Flight Time:

9 Weather

0 Remarks:

Completed 12 lines over BLK33P. No mission log file generated.

1 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

A1C Raymund P. Lerama

Signature over Printed Name (PAF Representative)

Pilot-in-Command

J.R.B. Javier

Signature over Printed Name

Lidar Operator

P. Arceo

Signature over Printed Name

DREAM

Disaster Risk and Exposure Assessment for Mitigation

2. Flight Log for 1554 A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1554

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: AQUA	3 Mission Name: 5BLK33PSM159A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. BLAWIN	9 Route:			
10 Date: 08 JUN 10	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0649	14 Engine Off: 1130	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK33P and surveyed 7 lines BLK33M					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	MC RAYMUND D CEPAMA	JRS Javier	CATH BALICUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1556 A Mission

DREAM Data Acquisition Flight Log | **Flight Log No.:** 1556

1 LIDAR Operator: P. ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK33MS159B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALAWIN	9 Route:			
10 Date: 08 JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1247	14 Engine Off: 1734	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: COMPLETED MISSION FOR BLK 33M					
21 Problems and Solutions:					

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

Acquisition Flight Certified by
A1C RAYMUND D LEDAMA
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
PJ Arceo
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

ANNEX 7. FLIGHT STATUS REPORT

SOUTHERN SAMAR – NORTHERN LEYTE FLIGHT LOGS (April 15 – June 11, 2014)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1550A	BLK33P	3BLK33P158A	PJ ARCEO	7 JUN 14	Completed 12 lines over BLK33P. No mission log file generated.
1554A	BLK33P BLK33M	3BLK33PSM159A	MCE BALIGUAS	8 JUN 14	Completed mission over BLK33P and surveyed 7 lines over BLK33M
1556A	BLK33M	3BLK33MS159B	PJ ARCEO	8 JUN 14	Completed mission over BLK33M

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	1550 A		
Area:	BLK33P		
Mission Name:	3BLK33P158A		
Parameters:	PRF: 50 kHz	SF: 45 Hz	FOV: 44 Degrees
Flying Height:	600 m		

Flight No. : 1554 A
Area: BLK33P and BLK33M
Mission Name: 3BLK33PSM159A
Parameters: PRF: 50 kHz SF: 45 Hz FOV: 44 Degrees
Flying Height: 600 m

LAS/SWATH

Flight No. :	1556 A		
Area:	BLK33P and BLK33M		
Mission Name:	3BLK33PSM159A		
Parameters:	PRF: 50 kHz	SF: 45 Hz	FOV: 44 Degrees
Flying Height:	600 m		

LAS/SWATH

ANNEX 8: Mission Summary Reports

Flight Area	Samar-Leyte
Mission Name	Blk33M
Inclusive Flights	1554A,1556A
Range data size	30.4 GB
POS	548 MB
Image	197 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000680
IMU attitude correction stdev (<0.001deg)	0.000100
GPS position stdev (<0.01m)	0.0052
Minimum % overlap (>25)	41.81%
Ave point cloud density per sq.m. (>2.0)	2.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	246
Maximum Height	306.43 m
Minimum Height	50.90 m
Classification (# of points)	
Ground	61,298,470
Low vegetation	48,684,831
Medium vegetation	90,178,182
High vegetation	164,585,214
Building	2,711,407
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Velina Angela Bemida, Engr. Jommer Medina

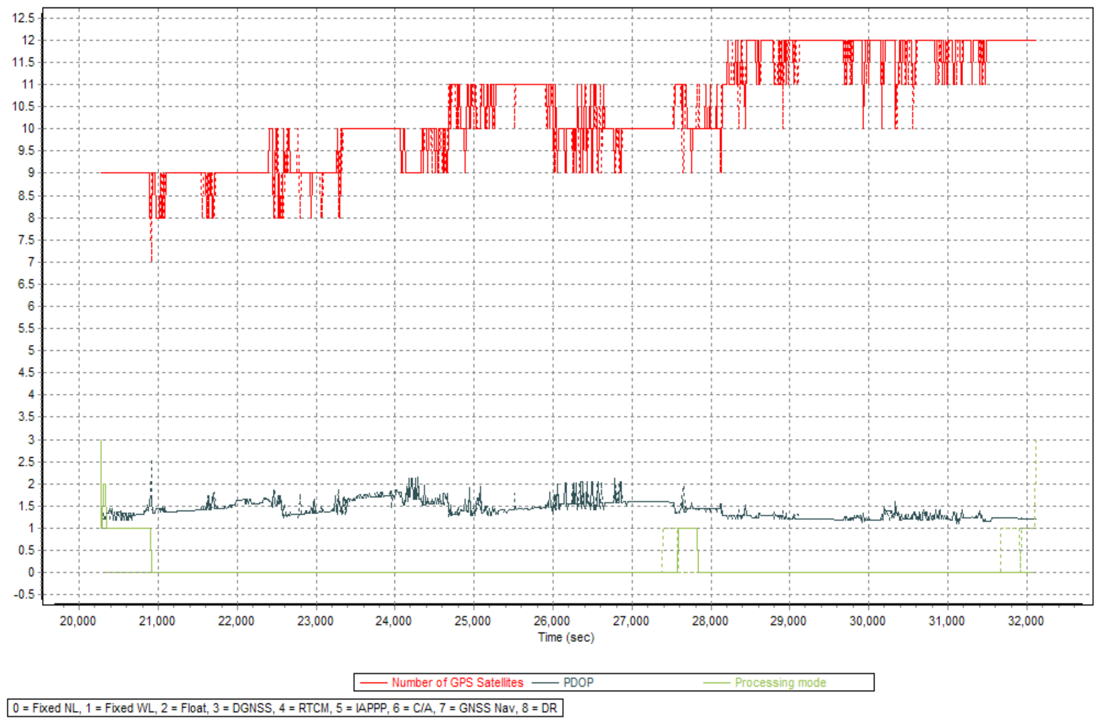


Figure 1.1.1. Solution Status

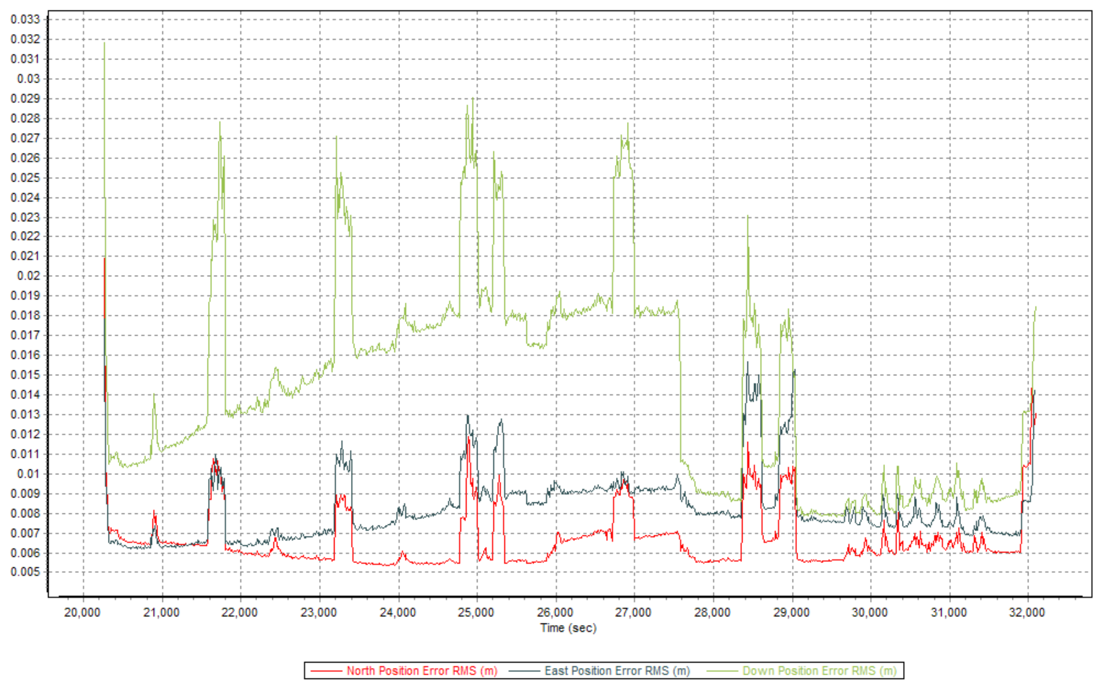


Figure 1.1.2. Smoothed Performance Metrics Parameters

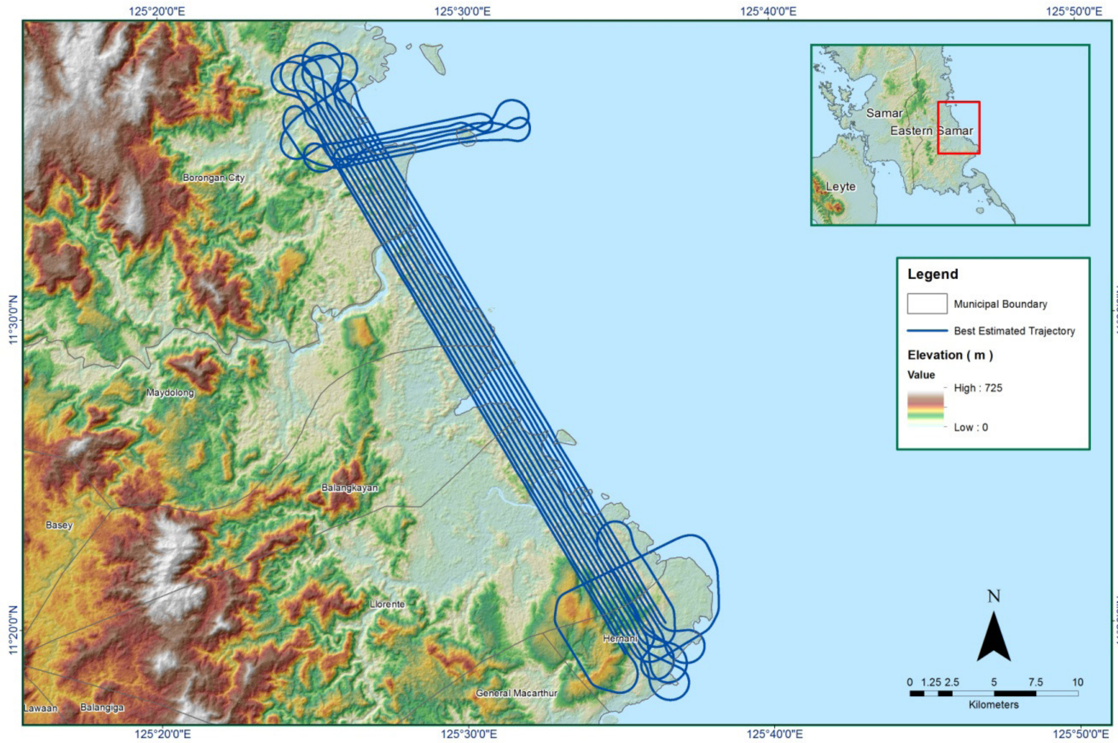


Figure 1.1.3. Best Estimated Trajector

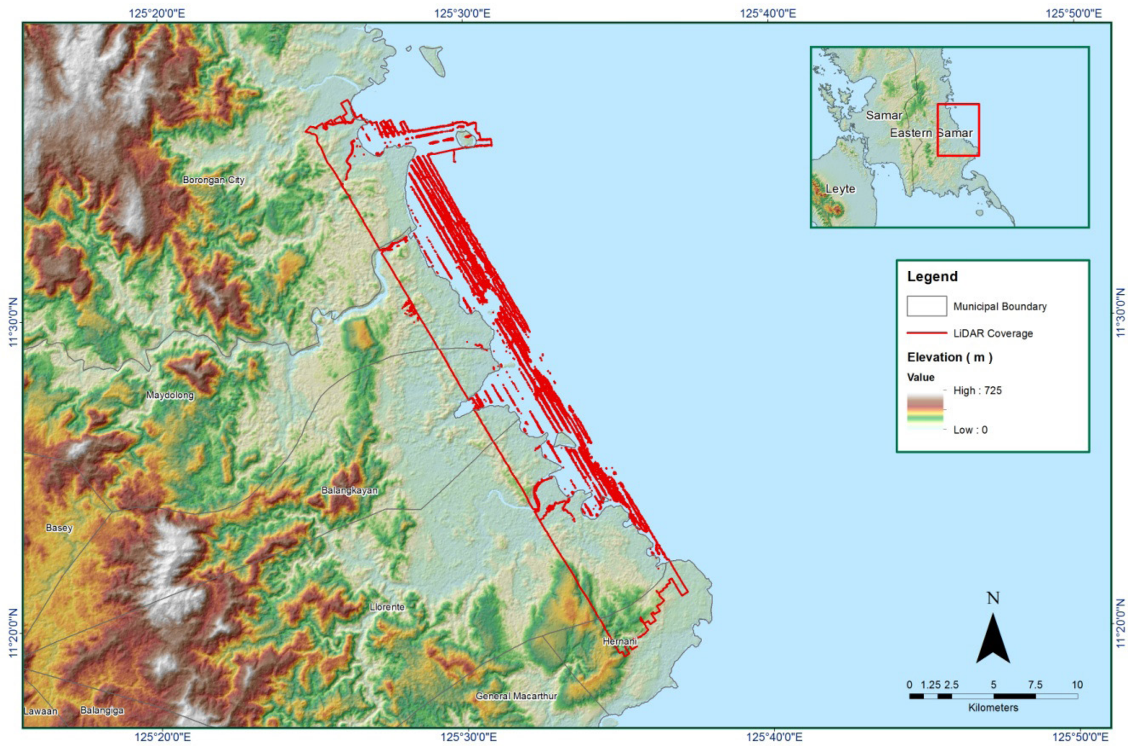


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Figure 1.1.4. Coverage of LiDAR data

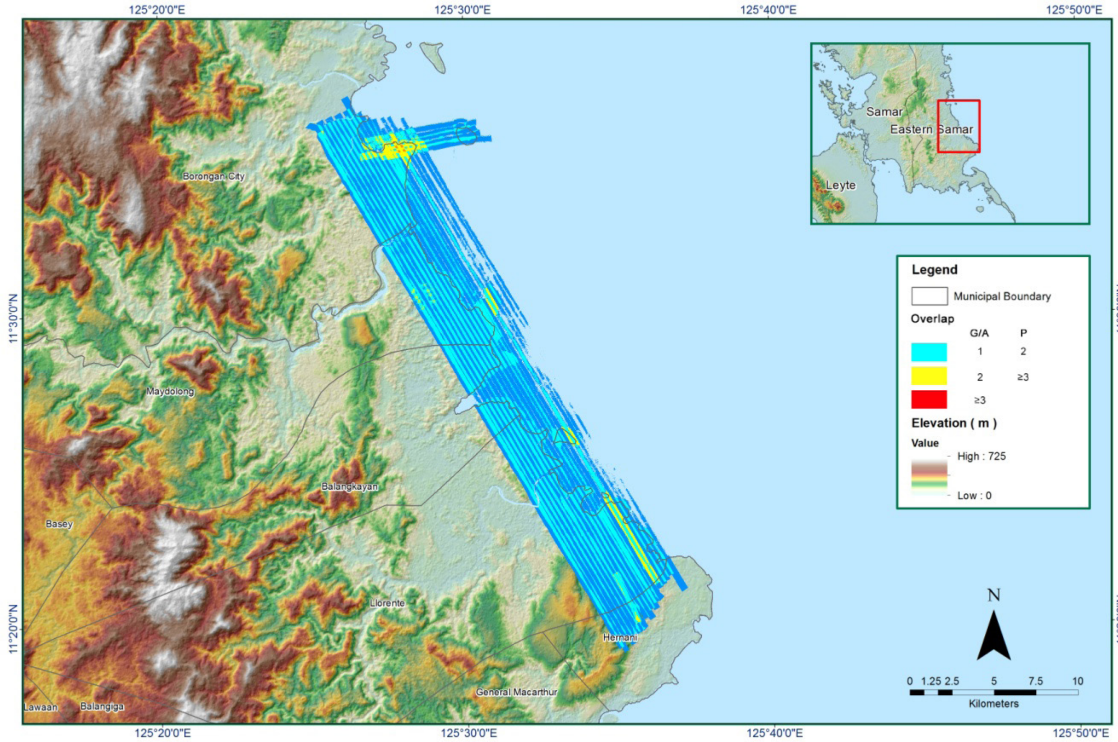

Figure 1.1.5. Image of data overlap

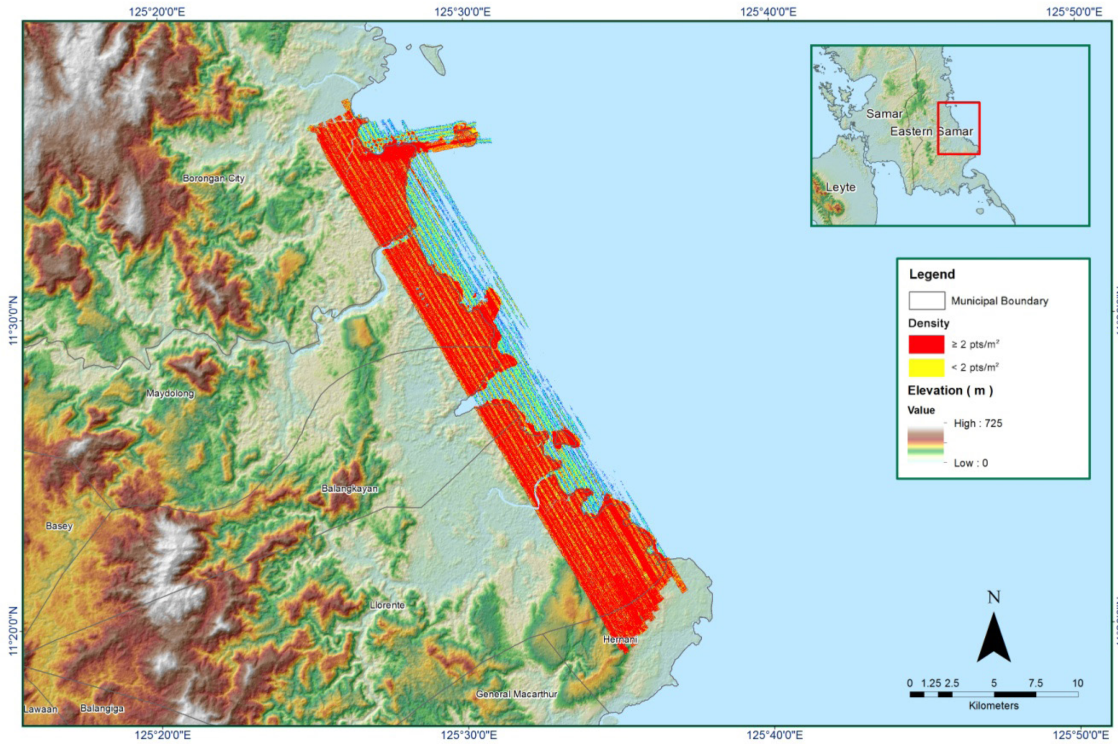

Figure 1.1.6. Density map of merged LiDAR data

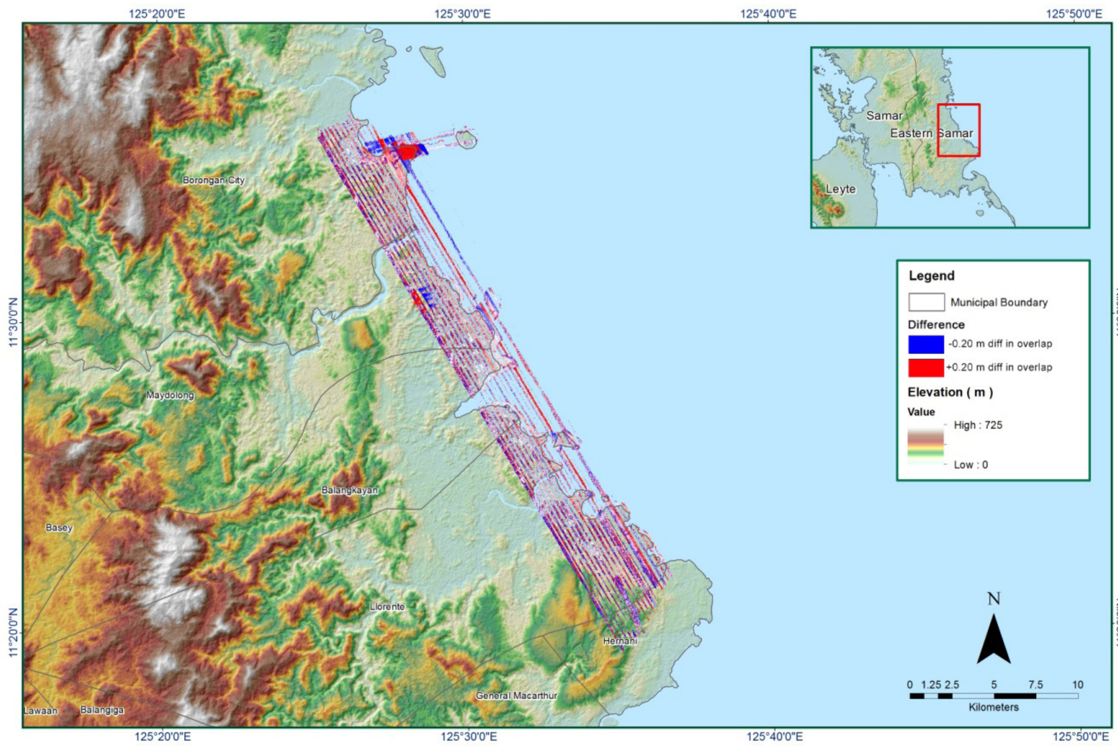

Figure 1.1.7. Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk33P
Inclusive Flights	1550A, 1554A
Range data size	25.3 GB
POS	456 MB
Image	152.7 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	6.0
Boresight correction stdev (<0.001deg)	0.000508
IMU attitude correction stdev (<0.001deg)	0.032438
GPS position stdev (<0.01m)	0.0037
Minimum % overlap (>25)	47.89%
Ave point cloud density per sq.m. (>2.0)	3.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	162
Maximum Height	350.43 m
Minimum Height	50.38 m
Classification (# of points)	
Ground	50,223,810
Low vegetation	41,963,655
Medium vegetation	113,119,809
High vegetation	118,313,645
Building	1,208,494
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Jovelle Anjeanette Canlas, Engr. Elainne Lopez

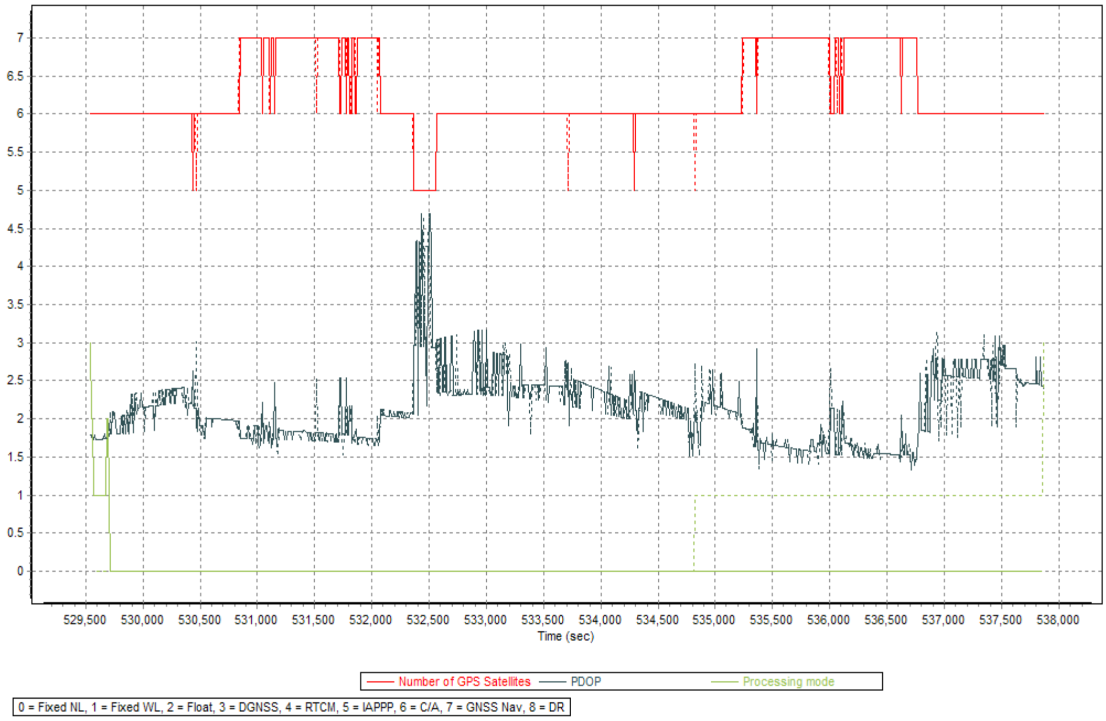

Figure 1.2.1. Solution Status

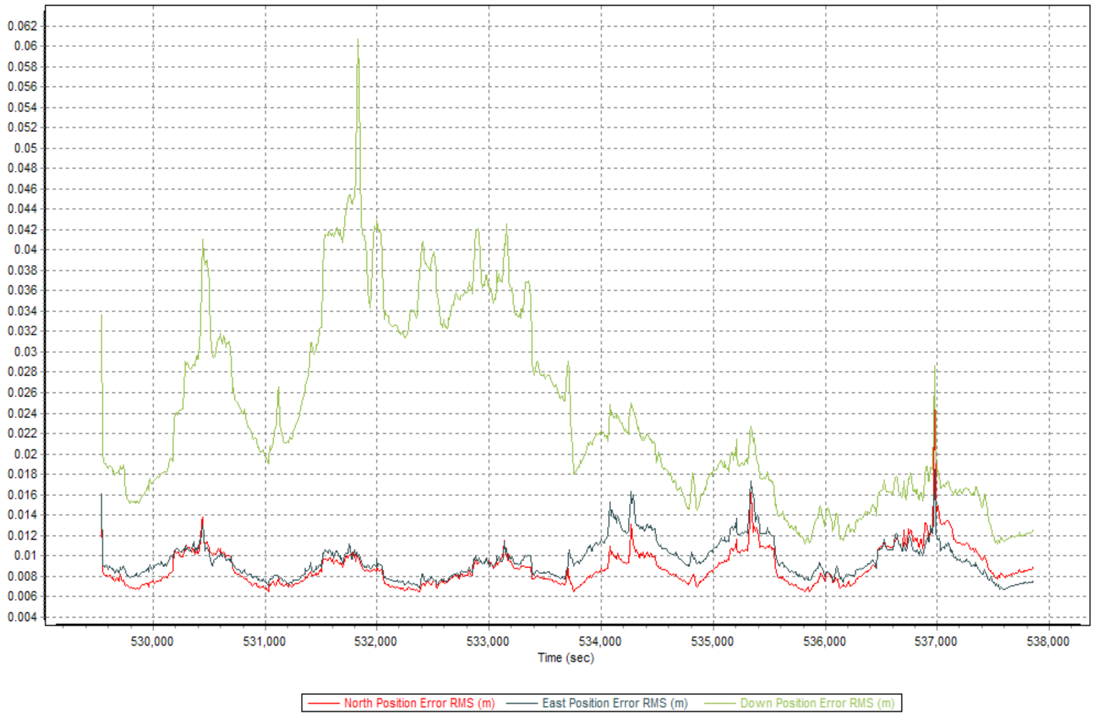

Figure 1.2.2. Smoothed Performance Metrics Parameters

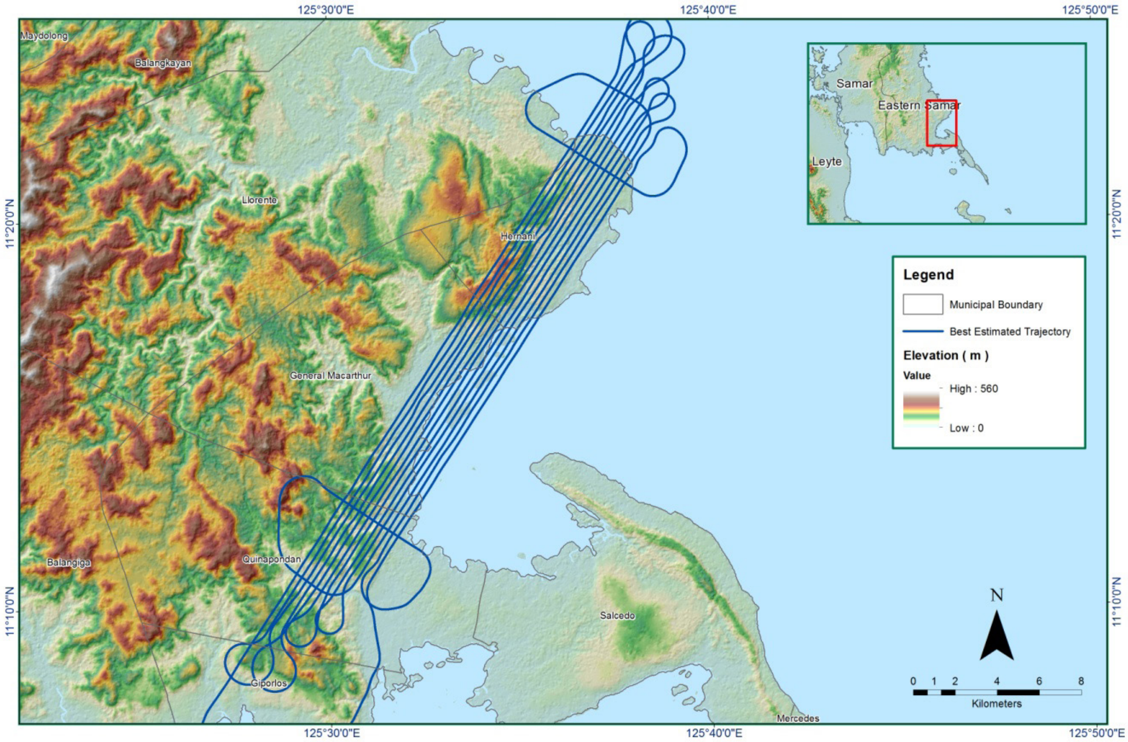

Figure 1.2.3. Best Estimated Trajectory

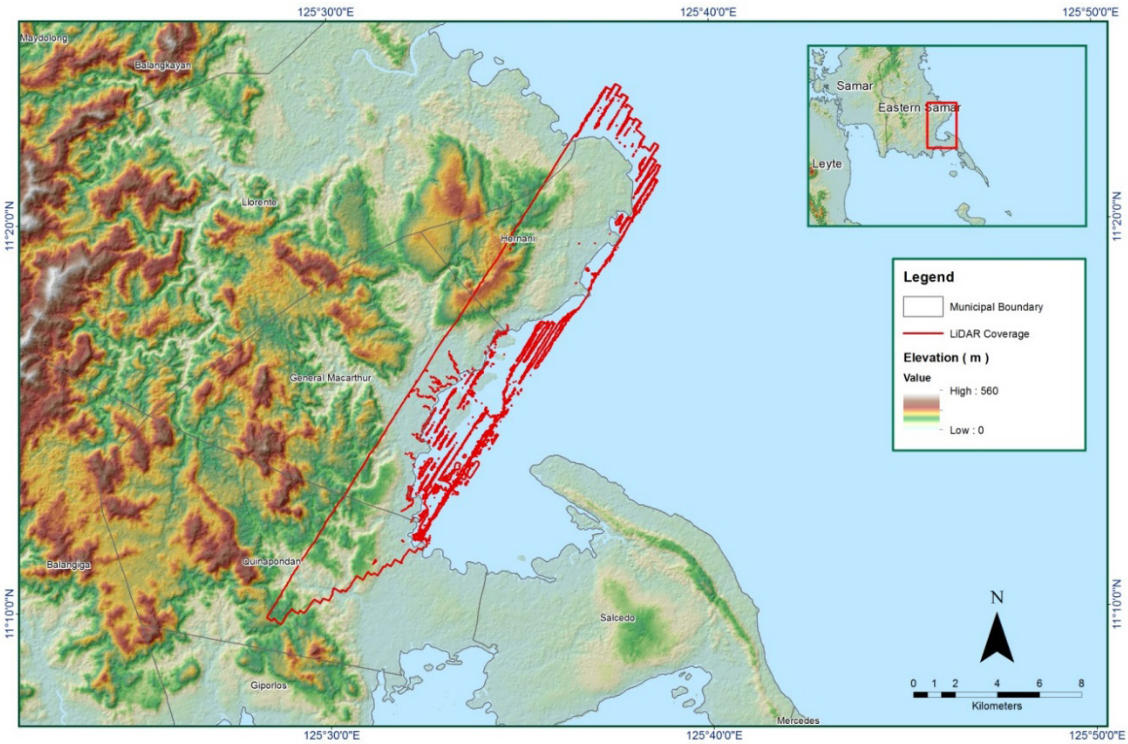

Figure 1.2.4. Coverage of LiDAR data

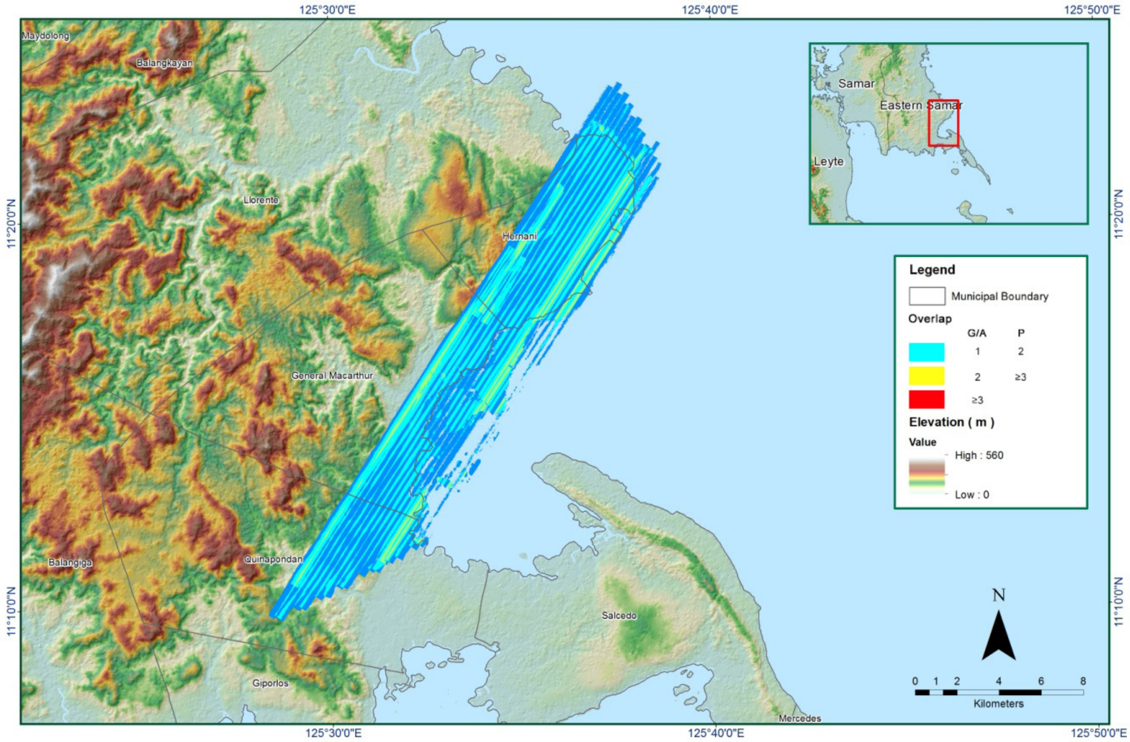

Figure 1.2.5. Image of data overlap

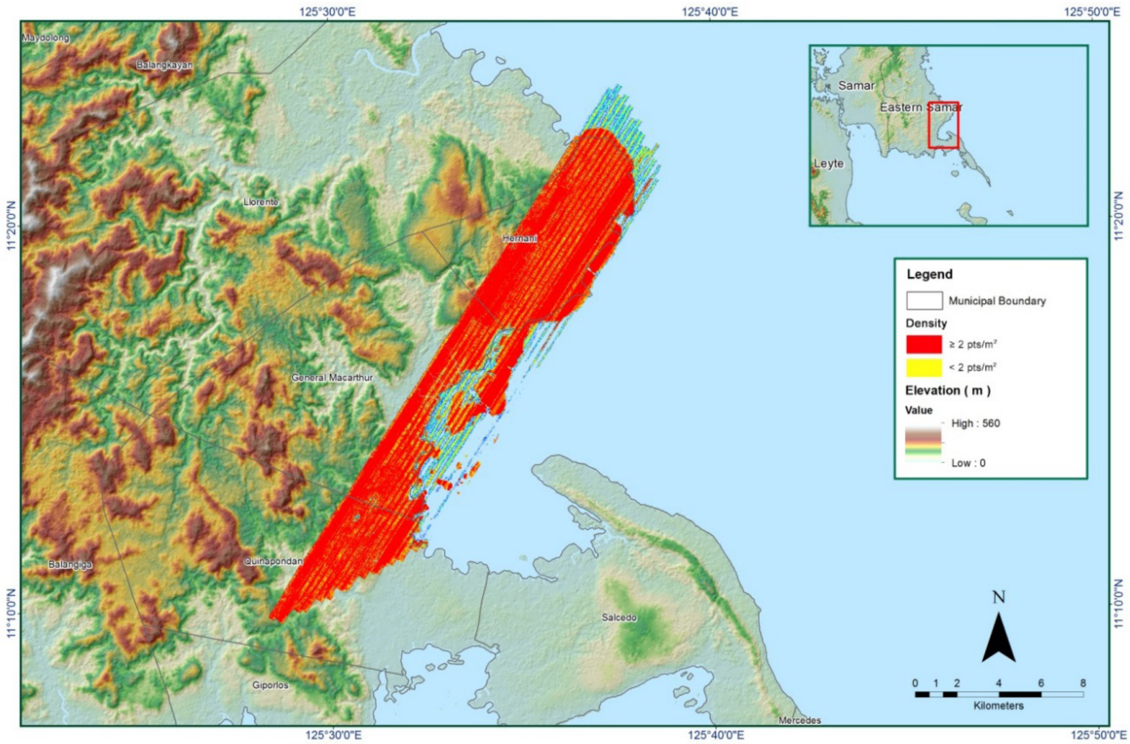

Figure 1.2.6. Density map of merged LiDAR data

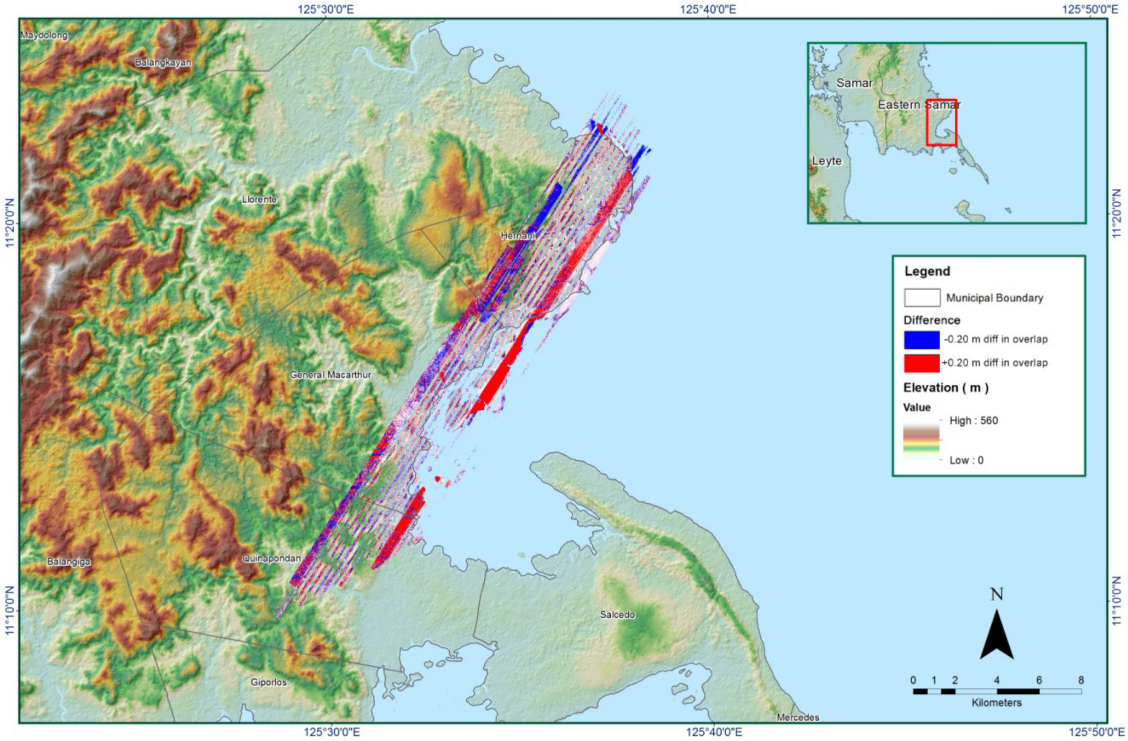

Figure 1.2.7. Elevation difference between flight lines

Flight Area	Samar-Leyte
Mission Name	Blk33P_additional
Inclusive Flights	1554A
Range data size	14.5 GB
POS	257 MB
Image	99.8 MB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.0
RMSE for East Position (<4.0 cm)	5.8
RMSE for Down Position (<8.0 cm)	9.0
Boresight correction stdev (<0.001deg)	0.000508
IMU attitude correction stdev (<0.001deg)	0.032438
GPS position stdev (<0.01m)	0.0037
Minimum % overlap (>25)	9.26
Ave point cloud density per sq.m. (>2.0)	4.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	13
Maximum Height	349.68
Minimum Height	123.82
Classification (# of points)	
Ground	2463923.0
Low vegetation	943991.0
Medium vegetation	3600838.0
High vegetation	6463073.0
Building	3484.0
Orthophoto	No
Processed by	Engr. Angelo Carlo B. Bongat, Engr. Velina Angela S. Bemida, Engr. Gladys Mae Apat

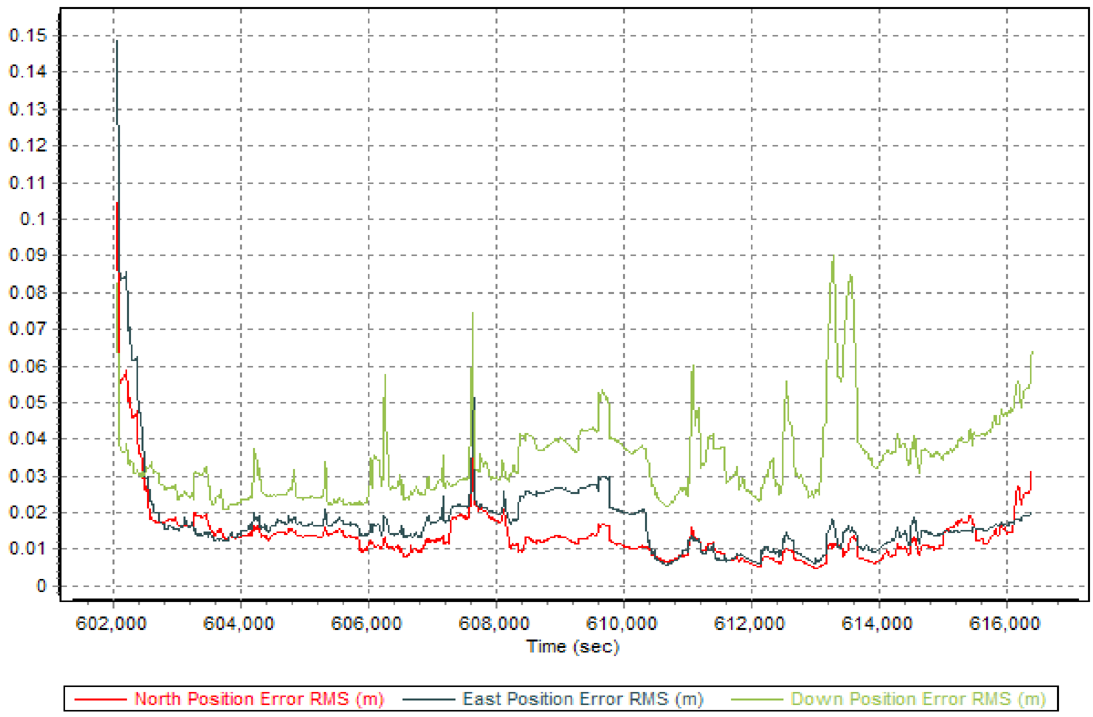

Figure 1.3.1. Solution Status

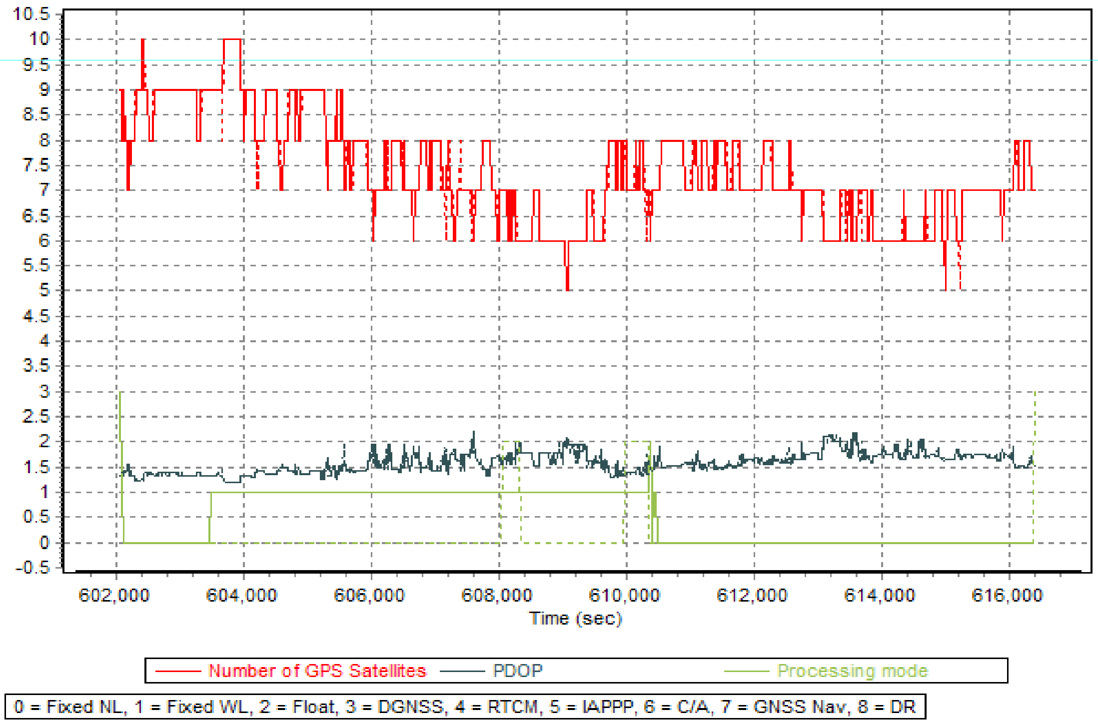

Figure 1.3.2. Smoothed Performance Metrics Parameters

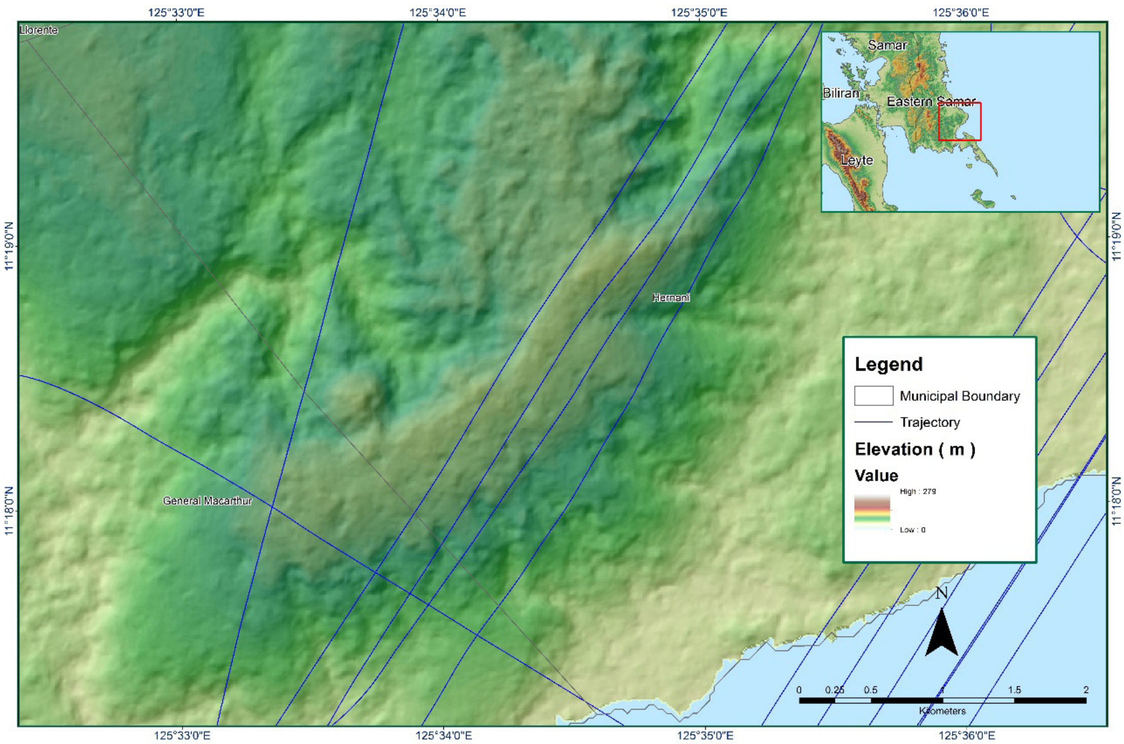

Figure 1.3.3. Best Estimated Trajectory

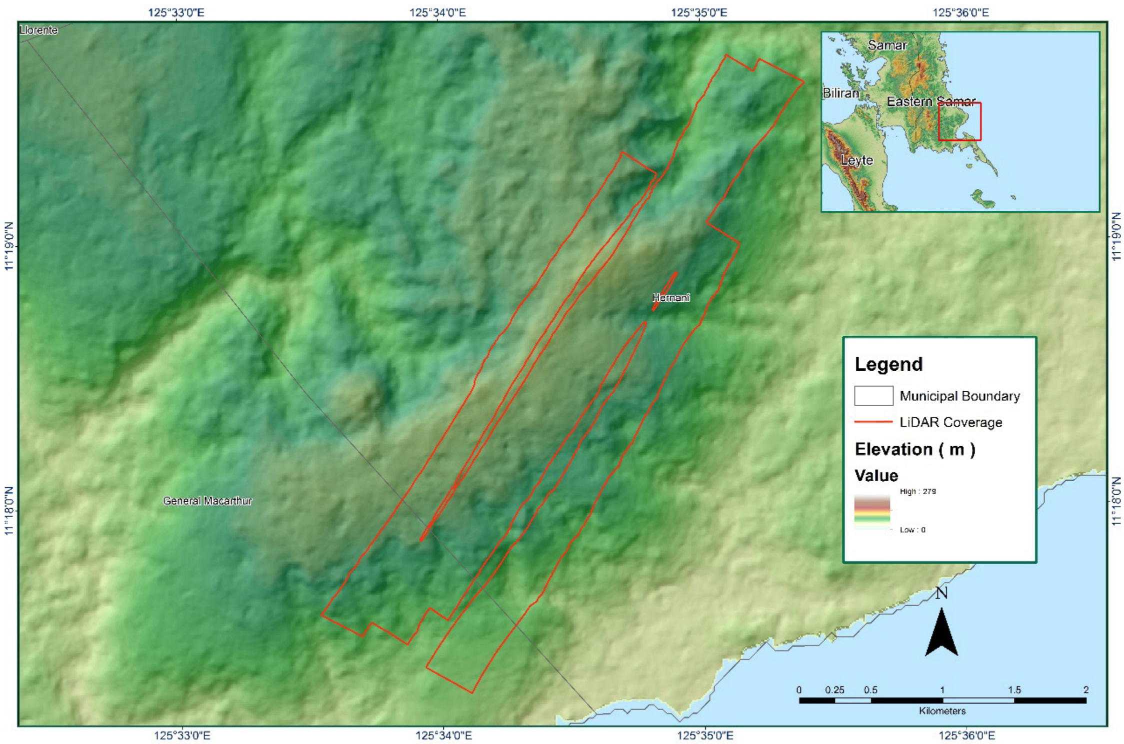

Figure 1.3.4. Coverage of LiDAR data

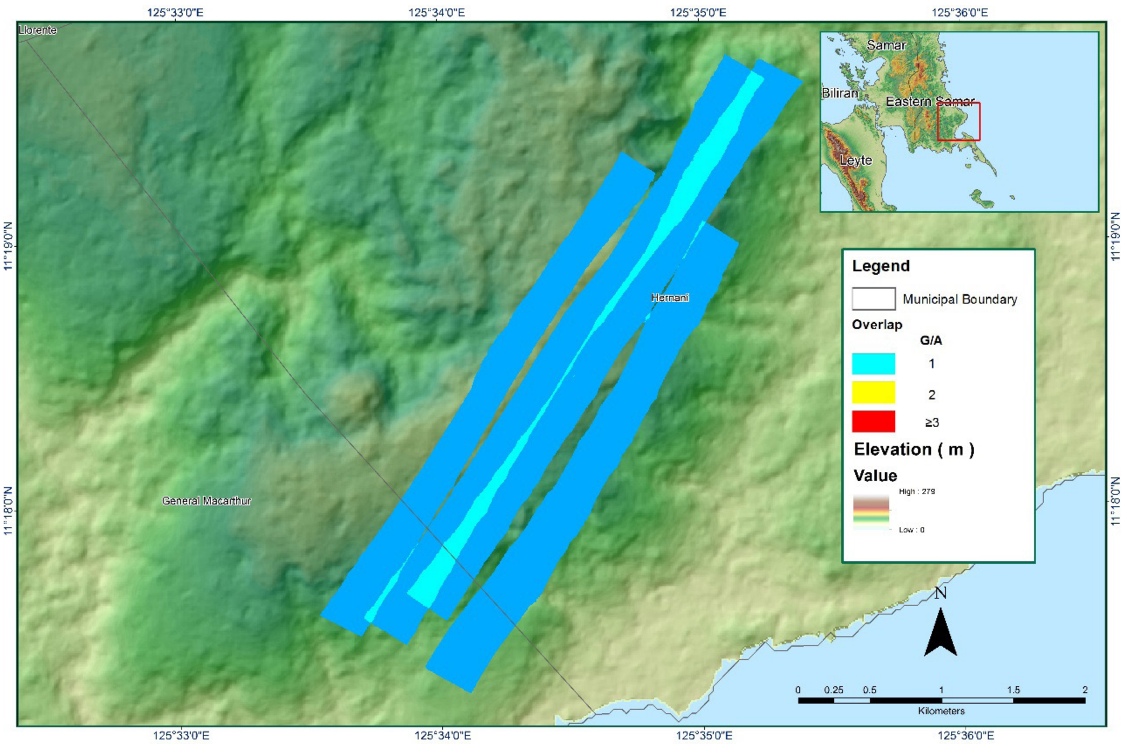

Figure 1.3.5. Image of data overlap

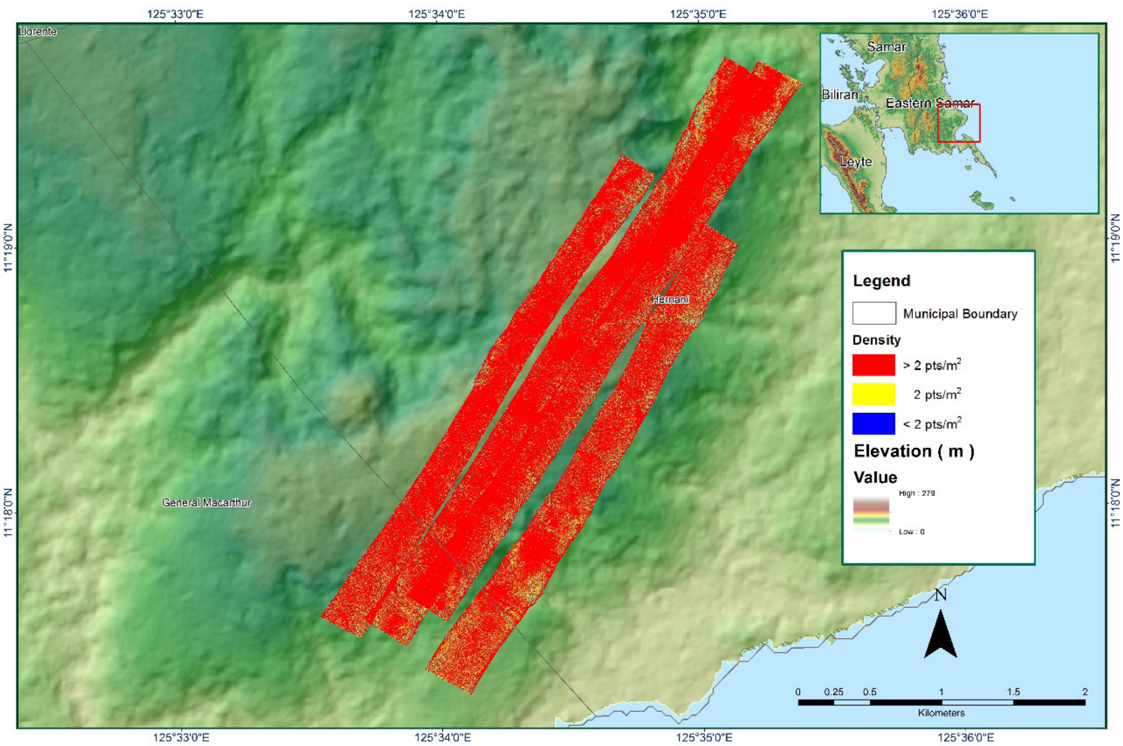

Figure 1.3.6. Density map of merged LiDAR data

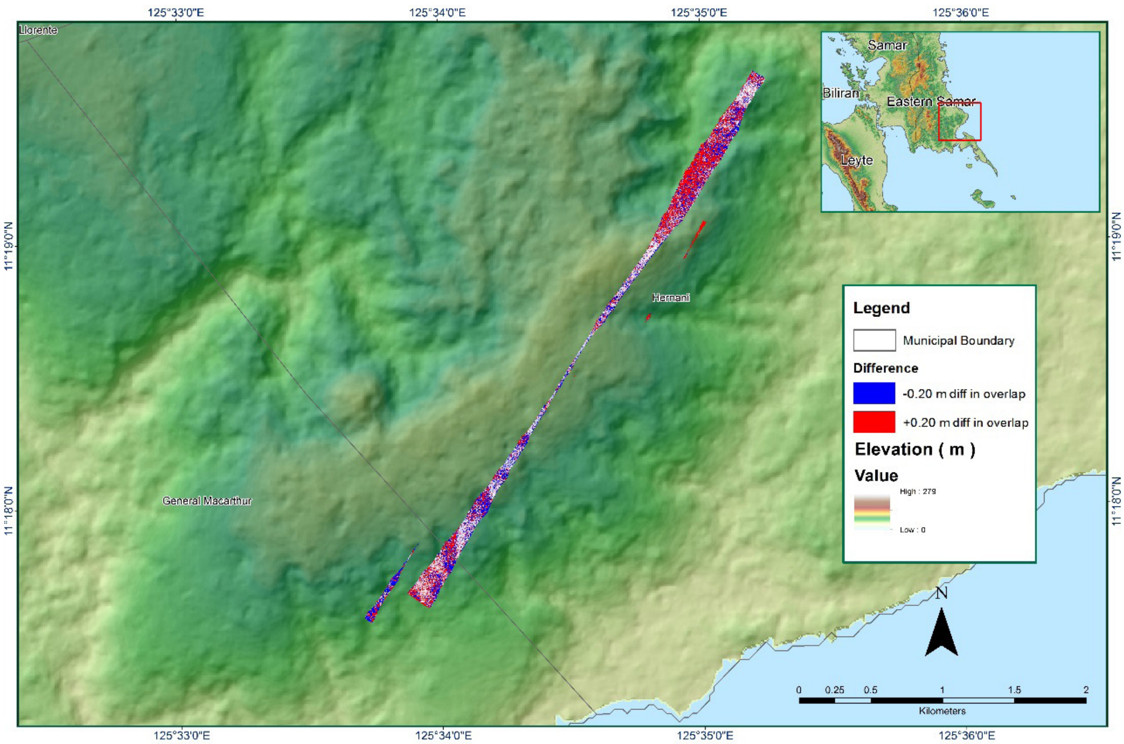

Figure 1.3.7. Elevation difference between flight lines

ANNEX 9. LLORENTE MODEL BASIN PARAMETERS

Subbasin	SCS Curve Number			Clark Unit Hydropgraph		Recession Baseflow				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W300	25.637	66.46	0	11.97135	26.04948	Discharge	1.9196	0.9	Ratio to Peak	0.1
W310	15.834	76.237	0	1.742034	3.790724	Discharge	0.25553	0.9	Ratio to Peak	0.1
W320	14.81	77.427	0	1.185258	2.579196	Discharge	0.12887	0.9	Ratio to Peak	0.1
W330	18.7890411	73	0	1.281273	2.788024	Discharge	0.0744619	0.9	Ratio to Peak	0.1
W340	17.17	74.739	0	4.222551	9.188284	Discharge	1.0739	0.9	Ratio to Peak	0.1
W350	14.739	77.511	0	1.741812	3.790132	Discharge	0.27012	0.9	Ratio to Peak	0.1
W360	18.7223758	73.07	0	1.833387	3.989488	Discharge	0.10214	0.9	Ratio to Peak	0.1
W370	18.1271516	73.701	0	4.496055	9.783392	Discharge	0.5931	0.9	Ratio to Peak	0.1
W380	16.246	75.769	0	2.455209	5.342652	Discharge	0.35863	0.9	Ratio to Peak	0.1
W390	13.504	79	0	1.387833	3.01994	Discharge	0.12245	0.9	Ratio to Peak	0.1
W400	17.846	74.003	0	4.480848	9.750388	Discharge	0.86032	0.9	Ratio to Peak	0.1
W410	37.614	57.457	0	3.152955	6.860836	Discharge	0.3278	0.9	Ratio to Peak	0.1
W420	47.062	51.91	0	5.531241	12.036	Discharge	0.53173	0.9	Ratio to Peak	0.1
W430	15.912	76.148	0	3.244197	7.059452	Discharge	0.71642	0.9	Ratio to Peak	0.1
W440	15.481	76.643	0	2.891106	6.291184	Discharge	0.66948	0.9	Ratio to Peak	0.1
W450	43.89	53.649	0	13.36662	29.08496	Discharge	1.4271	0.9	Ratio to Peak	0.1
W460	13.95	78.455	0	3.12465	6.799268	Discharge	0.43614	0.9	Ratio to Peak	0.1
W470	16.424	75.568	0	2.316237	5.04014	Discharge	0.43807	0.9	Ratio to Peak	0.1
W480	20.209	71.54	0	5.649012	12.292288	Discharge	0.76273	0.9	Ratio to Peak	0.1
W490	18.264	73.555	0	2.454987	5.341912	Discharge	0.32524	0.9	Ratio to Peak	0.1
W500	17.997	73.84	0	1.965588	4.277052	Discharge	0.20837	0.9	Ratio to Peak	0.1
W510	18.7890411	73	0	0.315462	0.6864536	Discharge	0.0030497	0.9	Ratio to Peak	0.1
W520	17.074	74.845	0	3.371736	7.336804	Discharge	0.53477	0.9	Ratio to Peak	0.1

Subbasin	SCS Curve Number			Clark Unit Hydropgraph		Recession Baseflow				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W530	51.212129	49.798	0	4.954596	10.781208	Discharge	0.33632	0.9	Ratio to Peak	0.1
W540	21.318	70.44	0	3.535461	7.693188	Discharge	0.369	0.9	Ratio to Peak	0.1
W550	14.921	77.296	0	2.526804	5.498348	Discharge	0.35336	0.9	Ratio to Peak	0.1
W560	17.367	74.523	0	1.949826	4.242716	Discharge	0.25457	0.9	Ratio to Peak	0.1
W570	14.88	77.345	0	3.236316	7.042284	Discharge	0.58429	0.9	Ratio to Peak	0.1
W580	15.317	76.834	0	2.85159	6.205196	Discharge	0.41369	0.9	Ratio to Peak	0.1

ANNEX 10. LLORENTE MODEL REACH PARAMETERS

Reach	Time Step Method	Length	Slope	Manning's n	Shape	Width	Side Slope
R20	Automatic Fixed Interval	2316.5	0.0053003	0.03	Trapezoid	25.512	1
R30	Automatic Fixed Interval	1247.8	0.0228157	0.03	Trapezoid	21.528	1
R50	Automatic Fixed Interval	1893	0.0014766	0.03	Trapezoid	33.438	1
R60	Automatic Fixed Interval	4375.3	0.0014766	0.03	Trapezoid	12.956	1
R90	Automatic Fixed Interval	4577.2	0.0014766	0.03	Trapezoid	26.506	1
R100	Automatic Fixed Interval	11523	0.0144538	0.03	Trapezoid	46.82	1
R120	Automatic Fixed Interval	2874.5	0.003801	0.03	Trapezoid	36.792	1
R150	Automatic Fixed Interval	5374.6	0.0014766	0.03	Trapezoid	25.082	1
R160	Automatic Fixed Interval	4914.9	0.0040921	0.03	Trapezoid	33.344	1
R170	Automatic Fixed Interval	5669	0.011986	0.03	Trapezoid	27.18	1
R190	Automatic Fixed Interval	365.56	0.0228157	0.03	Trapezoid	41.02	1
R220	Automatic Fixed Interval	9613.9	0.0103922	0.03	Trapezoid	21.614	1
R240	Automatic Fixed Interval	3244.9	0.011512	0.03	Trapezoid	24.048	1
R270	Automatic Fixed Interval	2764.9	0.0078758	0.03	Trapezoid	24.756	1

ANNEX 11. LLORENTE FIELD VALIDATION

Validation Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
1	11.43962287	125.5280605	0	0.06	-0.06		
2	11.43915047	125.5289642	0	0.03	-0.03		
3	11.43885895	125.5298576	0	0.03	-0.03		
4	11.43826325	125.5301619	0	0.03	-0.03		
5	11.43766394	125.5301835	0	0.97	-0.97		
6	11.43740896	125.5309223	0.5	0.03	0.47	Ruby/December 6, 2014	5-year
7	11.43740896	125.5309223	0.2	0.03	0.17	Yolanda/November 8, 2013	5-year
8	11.43659466	125.5304891	1	0.13	0.87	Ruby/December 6, 2014	5-year
9	11.43659466	125.5304891	1	0.13	0.87	Yolanda/November 8, 2013	5-year
10	11.43690387	125.5313668	0.5	0.03	0.47	Ruby/December 6, 2014	5-year
11	11.43690387	125.5313668	0.2	0.03	0.17	Yolanda/November 8, 2013	5-year
12	11.43649316	125.5315512	0.5	0.17	0.33	Ruby/December 6, 2014	5-year
13	11.43649316	125.5315512	0.2	0.17	0.03	Yolanda/November 8, 2013	5-year
14	11.43589276	125.5318405	0	0.03	-0.03		
15	11.43496614	125.5329175	0	0.07	-0.07		
16	11.43160206	125.5353623	0	0.27	-0.27		
17	11.4309181	125.5358495	0	0.18	-0.18		
18	11.43099295	125.536692	0	0.28	-0.28		
19	11.43022643	125.5365938	0	0.03	-0.03		
20	11.42986835	125.5371983	1	0.79	0.21	Ruby/December 6, 2014	5-year
21	11.42986835	125.5371983	1.5	0.79	0.71	Yolanda/November 8, 2013	5-year
22	11.43009089	125.5377598	0.5	1.05	-0.55	Ruby/December 6, 2014	5-year
23	11.43009089	125.5377598	1	1.05	-0.05	Yolanda/November 8, 2013	5-year
24	11.42919906	125.5369934	0	0.03	-0.03		
25	11.43013255	125.5361514	0	0.03	-0.03		
26	11.43177373	125.5361539	1.5	0.08	1.42	Yolanda/November 8, 2013	5-year
27	11.42821049	125.5376445	0	0.12	-0.12		
28	11.4196576	125.5434431	1.3	0.03	1.27	Ruby/December 6, 2014	5-year
29	11.4196576	125.5434431	1	0.03	0.97	Yolanda/November 8, 2013	5-year

Validation Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
30	11.41848824	125.5429643	1.5	0.49	1.01	Ruby/December 6, 2014	5-year
31	11.41848824	125.5429643	1	0.49	0.51	Yolanda/November 8, 2013	5-year
32	11.41631926	125.5428794	1.8	0.43	1.37	Ruby/December 6, 2014	5-year
33	11.41631926	125.5428794	1.4	0.43	0.97	Yolanda/November 8, 2013	5-year
34	11.41472477	125.5381847	0	0.34	-0.34		
35	11.41199973	125.5419555	0	0.12	-0.12		
36	11.41227214	125.5427687	0	0.04	-0.04		
37	11.41215345	125.5445026	0	0.33	-0.33		
38	11.41187651	125.5459028	0	0.61	-0.61		
39	11.41076155	125.5484719	0	0.06	-0.06		
40	11.40904795	125.5418708	0	0.13	-0.13		
41	11.40928734	125.5468424	0	0.03	-0.03		
42	11.41097797	125.5454331	0	0.03	-0.03		
43	11.41354443	125.5462372	0	0.03	-0.03		
44	11.40734039	125.546846	0	0.03	-0.03		
45	11.4085877	125.5494753	0	0.03	-0.03		
46	11.41125114	125.5401462	0	0.03	-0.03		
47	11.40466439	125.5523811	0	0.03	-0.03		
48	11.40331498	125.5458376	0	0.03	-0.03		
49	11.39830118	125.5431998	0	0.03	-0.03		
50	11.40178663	125.5571156	0	0.03	-0.03		
51	11.40731307	125.5407189	0	0.49	-0.49		
52	11.39176229	125.5581109	0	1.84	-1.84		
53	11.39067985	125.5588944	0	2.47	-2.47		
54	11.38924445	125.5592436	0	0.56	-0.56		
55	11.39008926	125.5622029	0	0.60	-0.60		
56	11.39558452	125.5756246	0	0.64	-0.64		
57	11.39617243	125.5776817	0	0.04	-0.04		
58	11.39529451	125.5792023	0	0.49	-0.49		
59	11.38958249	125.5813422	0	0.03	-0.03		
60	11.38796646	125.5831184	0	0.14	-0.14		
61	11.38245125	125.5878791	0	0.08	-0.08		
62	11.38067161	125.5900588	0	0.18	-0.18		
63	11.3786597	125.5916093	0	0.07	-0.07		
64	11.37557415	125.5697641	0	0.29	-0.29		
65	11.37507208	125.5698018	0	0.27	-0.27		
66	11.3743519	125.5708142	0	0.11	-0.11		
67	11.38901403	125.5358588	0.5	1.40	-0.90	Ruby/December 6, 2014	5-year

Valida-tion Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
68	11.38901403	125.5358588	0.8	1.40	-0.60	Low Pressure/ January 9, 2017	2-year
69	11.39086652	125.5372243	0.5	1.66	-1.16	Ruby/December 6, 2014	5-year
70	11.39086652	125.5372243	0.8	1.66	-0.86	Low Pressure/ January 9, 2017	2-year
71	11.38449971	125.5339883	0.4	0.03	0.37	Ruby/December 6, 2014	5-year
72	11.38449971	125.5339883	0.7	0.03	0.67	Low Pressure/ January 9, 2017	2-year
73	11.3834166	125.5326428	0.4	3.09	-2.69	Ruby/December 6, 2014	5-year
74	11.3834166	125.5326428	0.7	3.09	-2.39	Low Pressure/ January 9, 2017	2-year
75	11.37631537	125.5055124	0.9	3.62	-2.72	Low Pressure/ January 9, 2017	2-year
76	11.37260914	125.5077694	1	3.33	-2.33	Low Pressure/ January 9, 2017	2-year
77	11.36850561	125.5072799	1	0.61	0.39	Low Pressure/ January 9, 2017	2-year
78	11.36640854	125.5072424	1	0.03	0.97	Low Pressure/ January 9, 2017	2-year
79	11.36549743	125.5059173	1	0.14	0.86	Low Pressure/ January 9, 2017	2-year
80	11.36282486	125.5044707	1.9	0.03	1.87	Low Pressure/ January 9, 2017	2-year
81	11.3603584	125.50086	1.1	2.20	-1.10	Low Pressure/ January 9, 2017	2-year
82	11.35970897	125.4923884	0.3	0.03	0.27	Low Pressure/ January 9, 2017	2-year
83	11.36001248	125.4904171	0.3	1.29	-0.99	Low Pressure/ January 9, 2017	2-year
84	11.36071807	125.4920205	0.3	2.04	-1.74	Low Pressure/ January 9, 2017	2-year
85	11.35917722	125.4909857	0.3	0.03	0.27	Low Pressure/ January 9, 2017	2-year
86	11.35970797	125.4910766	0.3	0.65	-0.35	Low Pressure/ January 9, 2017	2-year
87	11.41769908	125.5426782	1.5	0.29	1.21	Ruby/December 6, 2014	5-year
88	11.41769908	125.5426782	1	0.29	0.71	Yolanda/November 8, 2013	5-year
89	11.41870248	125.5402248	0	0.20	-0.20		
90	11.41768115	125.5378467	0	0.06	-0.06		
91	11.41653685	125.5394161	0	0.03	-0.03		
92	11.4135606	125.543857	0	1.99	-1.99		
93	11.41308082	125.5451039	0	0.03	-0.03		
94	11.41266391	125.5482653	0	0.03	-0.03		

Validation Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
95	11.41174961	125.5487237	0	0.03	-0.03		
96	11.41406939	125.5470702	0	0.11	-0.11		
97	11.41111158	125.5433868	0	0.03	-0.03		
98	11.40948608	125.542994	0	0.03	-0.03		
99	11.40944534	125.5447517	0	0.03	-0.03		
100	11.40539604	125.5479269	0	0.03	-0.03		
101	11.40472993	125.5492584	0	0.03	-0.03		
102	11.40277997	125.5534893	0	0.03	-0.03		
103	11.40624915	125.5465272	0	0.60	-0.60		
104	11.40685869	125.5433965	0	0.09	-0.09		
105	11.41154501	125.5469335	0	0.96	-0.96		
106	11.41268528	125.5473465	0	0.03	-0.03		
107	11.40073336	125.5448021	0	0.03	-0.03		
108	11.39517565	125.556995	0	0.75	-0.75		
109	11.41602153	125.5369241	0	0.07	-0.07		
110	11.4128406	125.5421815	0	1.44	-1.44		
111	11.40695172	125.549037	0	0.04	-0.04		
112	11.39166414	125.5606464	0	0.10	-0.10		
113	11.39102058	125.5577666	0	0.93	-0.93		
114	11.39485379	125.5764401	0	0.03	-0.03		
115	11.39590639	125.5767939	0	0.03	-0.03		
116	11.395638	125.5775003	0	0.07	-0.07		
117	11.39683091	125.5763808	0	0.58	-0.58		
118	11.39700517	125.578397	0	0.89	-0.89		
119	11.40250052	125.5639998	0	0.03	-0.03		
120	11.39920157	125.5606705	0	0.03	-0.03		
121	11.40056807	125.561038	0	0.03	-0.03		
122	11.40634521	125.5514279	0	0.38	-0.38		
123	11.40766217	125.5455778	0	0.04	-0.04		
124	11.40967878	125.5391452	0	0.03	-0.03		
125	11.35632914	125.479048	0	4.35	-4.35		
126	11.3559346	125.4803673	0	1.23	-1.23		
127	11.35663223	125.4797336	0	5.92	-5.92		
128	11.35587148	125.4798003	0	0.03	-0.03		
129	11.35469483	125.4826765	0	0.03	-0.03		
130	11.38779698	125.4793241	0.5	0.38	0.12		
131	11.38759649	125.4795516	0.5	0.27	0.23		
132	11.38753614	125.4805643	0.5	0.07	0.43		
133	11.38715618	125.4799879	0.5	0.22	0.28		
134	11.3744524	125.5059576	0.9	2.99	-2.09		
135	11.37518213	125.5052482	0.9	2.00	-1.10		
136	11.38365599	125.533505	0.4	1.72	-1.32	Ruby/December 6, 2014	5-year

Valida-tion Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
137	11.38365599	125.533505	0.7	1.72	-1.02	Low Pressure/ January 9, 2017	2-year
138	11.38952558	125.5367796	0.5	2.45	-1.95	Ruby/December 6, 2014	5-year
139	11.38952558	125.5367796	0.8	2.45	-1.65	Low Pressure/ January 9, 2017	2-year
140	11.40147222	125.5457286	0	0.03	-0.03		
141	11.40489296	125.546544	0	0.03	-0.03		
142	11.41108191	125.5472886	0	0.03	-0.03		
143	11.41000995	125.5410616	0	0.03	-0.03		
144	11.41412739	125.5456403	0	0.31	-0.31		
145	11.40360156	125.5536552	0.5	0.20	0.30		
146	11.40266011	125.5574612	0.5	0.23	0.27		
147	11.40247847	125.5433428	0	0.03	-0.03		
148	11.36672898	125.5059186	0.5	0.03	0.47	Low Pressure/ January 9, 2017	2-year
149	11.39195566	125.5587629	0	0.83	-0.83		
150	11.37974734	125.5908539	0	0.33	-0.33		
151	11.38152799	125.5892938	0	0.74	-0.74		
152	11.38832663	125.5818487	0	0.14	-0.14		
153	11.3954308	125.5761662	0	0.03	-0.03		
154	11.39617084	125.5771599	0	0.03	-0.03		
155	11.3955453	125.576732	0	0.03	-0.03		
156	11.38971535	125.5588323	0	0.55	-0.55		
157	11.39118813	125.5585057	0	0.51	-0.51		
158	11.40434051	125.5477895	0	0.03	-0.03		
159	11.40752999	125.5494871	0	0.03	-0.03		
160	11.41056567	125.5461407	0	0.85	-0.85		
161	11.4113373	125.5462458	0	0.04	-0.04		
162	11.41195379	125.5478648	0	0.11	-0.11		
163	11.41274605	125.5438529	0	0.06	-0.06		
164	11.41144996	125.5408405	0	0.03	-0.03		
165	11.41853686	125.5413732	0	0.30	-0.30		
166	11.38681647	125.5344784	0.4	2.26	-1.86	Ruby/December 6, 2014	5-year
167	11.38681647	125.5344784	0.8	2.26	-1.46	Yolanda/November 8, 2013	5-year
168	11.37489815	125.570408	0	0.39	-0.39		
169	11.37599157	125.5688023	0	0.40	-0.40		
170	11.38068326	125.5893157	0	0.03	-0.03		
171	11.38889535	125.5819297	0	0.05	-0.05		
172	11.3949993	125.5797808	1	0.14	0.86	Ruby/December 6, 2014	5-year
173	11.39595291	125.5764055	0	0.04	-0.04		

Validation Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
174	11.4037459	125.5509132	0	0.04	-0.04		
175	11.40725456	125.5509833	0	0.35	-0.35		
176	11.41071302	125.5449122	0	0.99	-0.99		
177	11.40744148	125.5423942	0	0.03	-0.03		
178	11.41175196	125.5431801	0	0.04	-0.04		
179	11.41232771	125.5435646	0	0.05	-0.05		
180	11.41313153	125.5431903	0	0.13	-0.13		
181	11.4142532	125.5463362	0	0.07	-0.07		
182	11.41360712	125.5456766	0	0.08	-0.08		
183	11.41087253	125.540839	0	0.03	-0.03		
184	11.41248353	125.5416674	0	0.05	-0.05		
185	11.41260322	125.5445082	0	0.03	-0.03		
186	11.41151383	125.54514	0	0.12	-0.12		
187	11.41215236	125.5451393	0	0.03	-0.03		
188	11.41225772	125.5457259	0	0.22	-0.22		
189	11.41244162	125.5463858	0.4	0.03	0.37		
190	11.41244162	125.5463858	0.4	0.03	0.37		
191	11.41296289	125.5459384	0	0.03	-0.03		
192	11.41223777	125.5484137	0	0.03	-0.03		
193	11.41052954	125.5492413	0	0.03	-0.03		
194	11.40432593	125.5538172	0	0.19	-0.19		
195	11.40033379	125.5456381	0	0.03	-0.03		
196	11.39960675	125.5432578	0	0.04	-0.04		
197	11.40851604	125.5405377	0	0.41	-0.41		
198	11.43801405	125.5309509	0.5	0.03	0.47	Ruby/December 6, 2014	5-year
199	11.43801405	125.5309509	0.2	0.03	0.17	Yolanda/November 8, 2013	5-year
200	11.38769891	125.479965	0.5	0.11	0.39	Low Pressure/ January 9, 2017	2-year
201	11.38207398	125.4834134	0.5	0.86	-0.36	Low Pressure/ January 9, 2017	2-year
202	11.36039972	125.4910577	0.3	1.87	-1.57	Low Pressure/ January 9, 2017	2-year
203	11.36585324	125.5070654	1.7	0.04	1.66	Low Pressure/ January 9, 2017	2-year
204	11.35972314	125.495339	1.1	0.03	1.07	Low Pressure/ January 9, 2017	2-year
205	11.35954519	125.4898722	0.3	0.03	0.27	Low Pressure/ January 9, 2017	2-year
206	11.41919986	125.5417797	0	0.20	-0.20		
207	11.43557022	125.5323908	0	0.88	-0.88		
208	11.43752053	125.5297213	0	0.03	-0.03		
209	11.43045978	125.5371502	1	0.74	0.26	Ruby/December 6, 2014	5-year

Validation Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
210	11.43045978	125.5371502	1.5	0.74	0.76	Yolanda/November 8, 2013	5-year
211	11.42890837	125.5374648	0	0.76	-0.76		
212	11.41338542	125.547941	0	0.03	-0.03		
213	11.41021807	125.5450097	0	0.03	-0.03		
214	11.39416857	125.5574165	0	0.49	-0.49		
215	11.41928109	125.5444317	1.3	0.03	1.27	Ruby/December 6, 2014	5-year
216	11.41928109	125.5444317	1	0.03	0.97	Yolanda/November 8, 2013	5-year
217	11.40883011	125.5411709	0	0.05	-0.05		
218	11.41139589	125.5440618	0	0.03	-0.03		
219	11.40858946	125.5473298	0	0.16	-0.16		
220	11.40082623	125.5559593	0	0.03	-0.03		
221	11.39559123	125.5788789	0	0.15	-0.15		
222	11.38831691	125.5825843	0	0.04	-0.04		
223	11.38200911	125.5877029	0	0.05	-0.05		
224	11.43733948	125.5305302	0	0.03	-0.03		
225	11.43133041	125.5361734	1.5	0.60	0.90	Yolanda/November 8, 2013	5-year
226	11.4305928	125.5362761	0	0.14	-0.14		
227	11.41108132	125.5466711	0	0.46	-0.46		
228	11.41258369	125.543162	0	0.05	-0.05		
229	11.41333513	125.5447026	0	0.03	-0.03		
230	11.41218362	125.5469076	0	0.03	-0.03		
231	11.41111099	125.548266	0	0.07	-0.07		
232	11.40408369	125.5530672	0	0.13	-0.13		
233	11.39064255	125.5619011	0	0.03	-0.03		
234	11.390144	125.5588936	0	1.11	-1.11		
235	11.39138242	125.5582536	0	1.16	-1.16		
236	11.39276066	125.558634	0	0.03	-0.03		
237	11.41007918	125.5471203	0	0.46	-0.46		
238	11.41001548	125.5418867	0	0.10	-0.10		
239	11.41166244	125.5423327	0	0.14	-0.14		
240	11.41104419	125.5429043	0	0.03	-0.03		
241	11.41207256	125.5440247	0	0.03	-0.03		
242	11.41112457	125.5458884	0	0.03	-0.03		
243	11.4070166	125.5461231	0	0.17	-0.17		
244	11.4100796	125.5435114	0	0.06	-0.06		
245	11.39909436	125.5555321	0	0.03	-0.03		
246	11.39554664	125.5751944	0	0.85	-0.85		
247	11.396127	125.5759788	0	0.76	-0.76		
248	11.39676696	125.5777895	0	0.03	-0.03		
249	11.40409031	125.546437	0	0.31	-0.31		

Validation Point	Validation Coordinates		Actual Flood Depth	Flood Depth based on Model	Error	Event/Date	Return Period of Event
	Latitude	Longitude					
250	11.41707463	125.5426449	1.8	0.37	1.43	Ruby/December 6, 2014	5-year
251	11.41707463	125.5426449	1.4	0.37	1.03	Yolanda/November 8, 2013	5-year
252	11.40221603	125.545124	0	0.03	-0.03		
253	11.40618042	125.5502699	0	0.03	-0.03		
254	11.41105408	125.548926	0	0.08	-0.08		
255	11.39123532	125.5588441	0	0.99	-0.99		
256	11.41464455	125.5470936	0	0.03	-0.03		
257	11.41275929	125.5454432	0	0.03	-0.03		
258	11.41160729	125.5460575	0	0.20	-0.20		
259	11.41315567	125.5465819	0	0.03	-0.03		
260	11.43948013	125.5285643	0	0.43	-0.43		
261	11.43925491	125.5296534	0	0.03	-0.03		
262	11.43784759	125.5314901	0	0.03	-0.03		
263	11.43513101	125.5312307	0	0.08	-0.08		
264	11.43042642	125.5357673	0	0.05	-0.05		
265	11.39522745	125.5781962	0	0.76	-0.76		
266	11.37913747	125.5911851	0	0.03	-0.03		
267	11.40248761	125.5567969	0	0.09	-0.09		
268	11.39062705	125.5591769	0	1.38	-1.38		
269	11.40955288	125.5420751	0	0.03	-0.03		
270	11.41310463	125.5442812	0.45	0.03	0.42	Ruby/December 6, 2014	5-year
271	11.40958356	125.5410544	0	0.03	-0.03		
272	11.41143185	125.547956	0	0.03	-0.03		
273	11.40821798	125.5466888	0	0.03	-0.03		

ANNEX 12. EDUCATIONAL INSTITUTIONS AFFECTED IN LLORENTE FLOOD PLAIN

EASTERN SAMAR				
LLORENTE				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Mother Ignacia Learning Center	Barangay 1	Low	Low	Low
Banika Elementary School	Barangay 10			
Llorente National High School	Barangay 10			Low
Banika Elementary School	Barangay 11		Low	Low
Mother Ignacia Learning Center	Barangay 2	Low	Low	Low
Llorente National High School	Barangay 3	Low	Low	Medium
Llorente National High School	Barangay 4	Low	Low	Low
Llorente National High School	Barangay 5			
Llorente Central Elementary School	Barangay 8			
St. Anthony’s Academy	Barangay 8			Low
Banika Elementary School	Barangay 9			
Llorente National High School	Barangay 9			
Canliwag Elementary School	Canliwag	Low	Low	Low
Piliw Elementary School	Piliw			
San Miguel Elementary School	San Miguel			
San Roque Elementary School	San Roque	Low	Medium	Medium
So-ong Elementary School	So-Ong			
Tabok Elementary School	Tabok	Low	Low	Low

ANNEX 13. MEDICAL INSTITUTIONS AFFECTED IN LLORENTE FLOOD PLAIN

EASTERN SAMAR				
LLORENTE				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Llorente Municipal Hospital	Barangay 4			
Brgy. Canliwag Health Center	San Roque	Low	Low	Low
Brgy. So-ong Health Center	So-Ong	Low	Medium	Medium