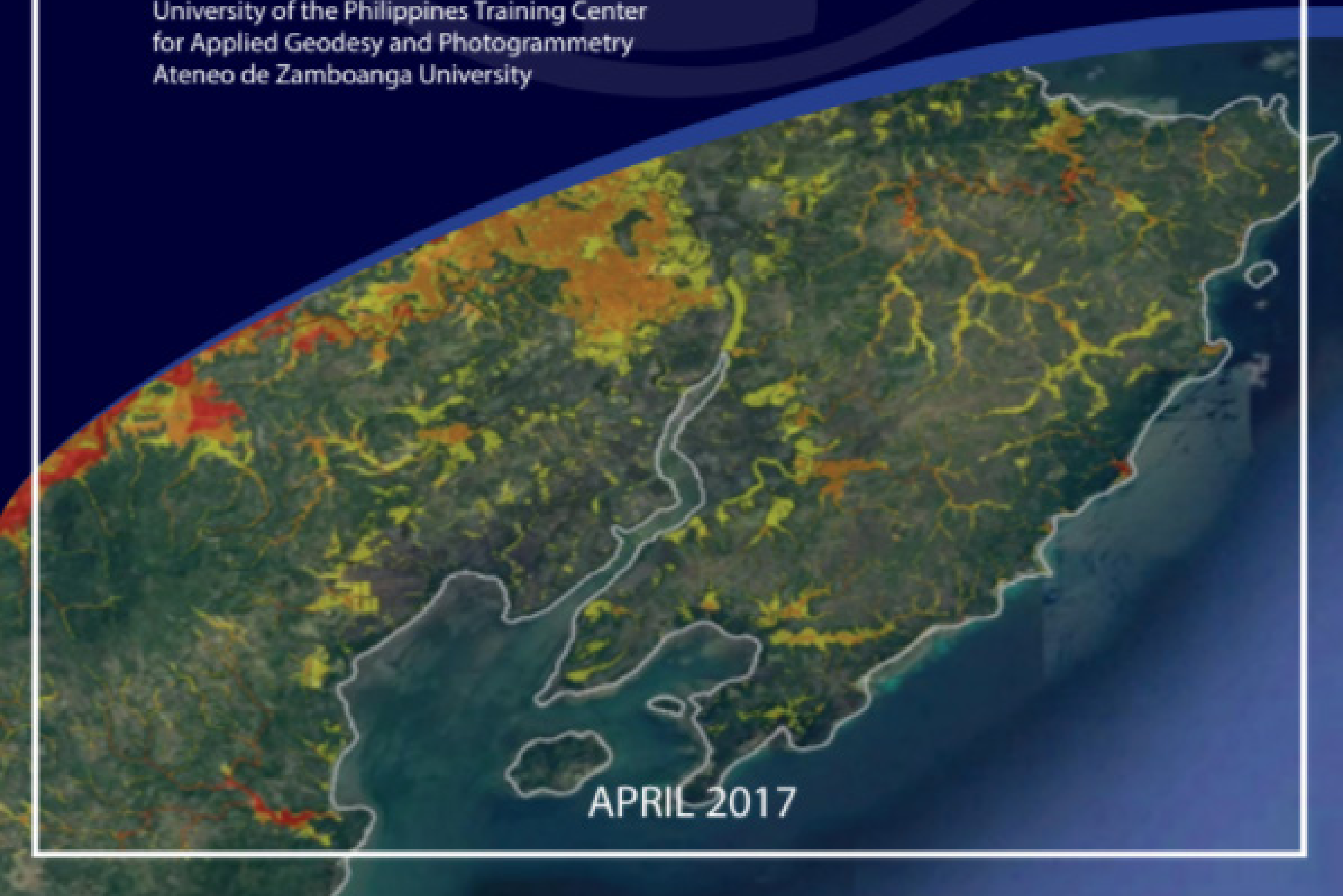
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Vitali River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Zamboanga University



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND THE VITALI RIVER

Mario S. Rodriguez   Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga University (ADZU). ADZU 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 18 river basins in the Zamboanga Peninsula. The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Vitali River Basin

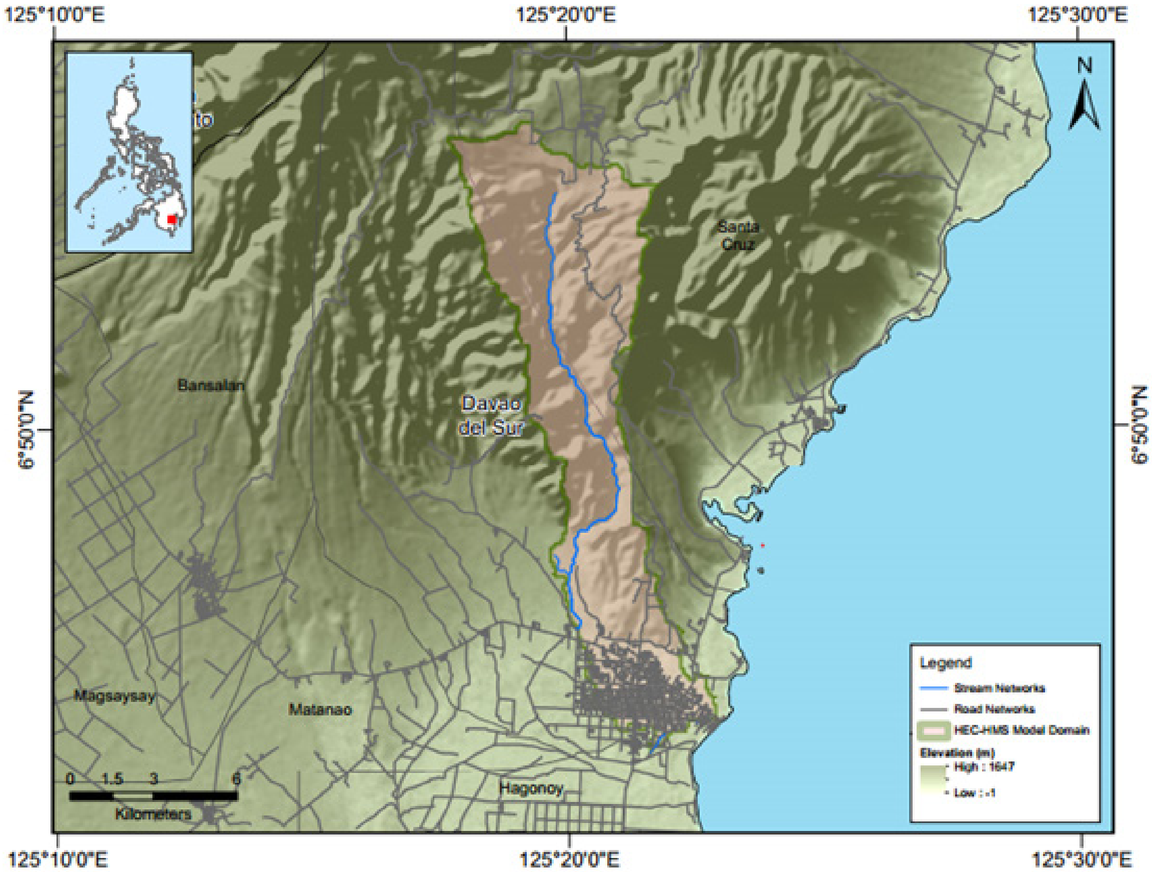


Figure 1.Map of Digos River Basin.

Vitali or Taguite River, the biggest river basin in Zamboanga City. With a catchment of approximately 211 km2based from the Flood Modelling Component and 288 MCM run-off based from the DENR-RBCO. Its main stem, the Vitali River channel has an estimated length of 10.8 km is among the river systems in Zamboanga Peninsula. It is bounded by Brgy. Tictapul in the North, Municipality of Sibuco in the West, Brgy.Curuan in the South and Moro Gulf in the East. It covers large portion of the city's mountains in the east and spans from Barangay Latuan in the southwest to Barangay Vitali in the northeast. It passes through barangays Muti, Tagasilay, Sibulao, Tigbalabag and Mangusu. . Areas in the vicinity of the Taguite River Basin, the Brgy. Vitali is classified into high susceptibility to flooding based from the Barangay Disaster Risk Reduction and Management Councils (BDRRMCs).

Producing 171,160 cubic meters per day. Its water, according to its beneficial use is categorized as Class B by the Department of Environmental Management. Its uses are for surface water recreation and drinking. It is among the rivers identified by the USAID Be Secure Project as potential alternatice sources of surface water. Other rivers on the list include Curuan, Bolong, Manicahan, Culianan and Ayala.

The name of the river was adopted from barangay Vitali. Amusingly, this name has a peculiar history. It was said that the place was named after the names of two beautiful women, Vita and Li, who migrated to the place in the Spanish times. Strange may it sound but the amazing beauty and personality of these women were kept in the place's name until now.

Flood Incidence

As a big river system, Vitali poses a great risk to the residents in the flood plains during rainy seasons. Nearby barangays especially Vitali and Mangusu were among those identified by the Office of Civil Defense 9 as six calamity-prone communities due to the regular overflows from the river. Other areas include those along Tumaga, Mercedes and San Jose. The vicinity is estimated to have population of 10,500 based from LGU Zamboanga City.

Figure 2.Vitali Bridge with the installed ARG and WLMS.

One of the biggest flood events in Vitali happened in September 2012. A three-day rain brought about by Typhoon Lawin submerged several areas of the city making the local government unit to declare a state of calamity. A lot of affected families in Vitali and Mangusu were evacuated. Two hundred families from Vitali alone were transferred. Classes were also cancelled.

In response, DPWH proposed a P53-million riprapping project in Vitali in 2013. This project was intended to protect the Vitali Elementary School from getting flooded every time the river overflows.

The community suffered flash floods due to immense rain produced by Typhoon Quedan last October 8, 2013 which put the Zamboanga City under the state of calamity affecting 2,869 families.

Vitali has also Automated Rain gauges (ARG) and Water Level Monitoring Systems (WLMS) installed at the Vitali Bridge (7.3666667N, 122.285833E) as part of DOST's nationwide Deployment of Early Warning Systems (DEWS) project.

Mining and Recreation

The uplands of Vitali is found to be rich with iron ore. Currently, mining activities are operated by the Atro Mining – VitaliInc (AMVI). Aside from mineral exploitation, AMVI also implements Adopt-a-River project as part of its Community Development Programs. Part of the project water quality management and environmental improvement program of Vitali River. But in 2014, the city council sought after the legality of AMVI's operations stating that mining should be banned in the uplands since VItali watershed has been proposed to be a protected area.

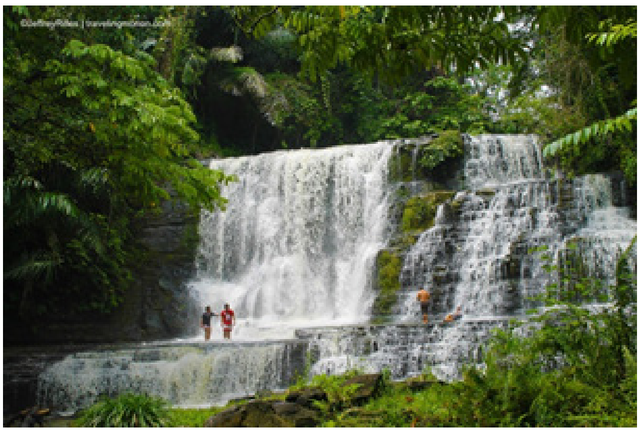


Figure 3. Merloquet Falls in Sibulao, ZC

Aside from minerals, Vitali is also gifted with the Merloquet Falls. Located at Barangay Sibulao (7.310036N, 122.213425E), this famous tourist destination has been visited by many travelers who wish to experience river trekking and bath under the refreshing drop of its pellucid waters.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE VITALI FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Julie Pearl S. Mars, Ms. Kristine Joy P. Andaya

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 Vitali floodplain in Zamboanga. These missions were planned for 16 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 4 shows the flight plan for Vitali floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK75C	1100/1200	30	50	200	30	130	5
BLK75D	1100/1200	30	50	200	30	130	5

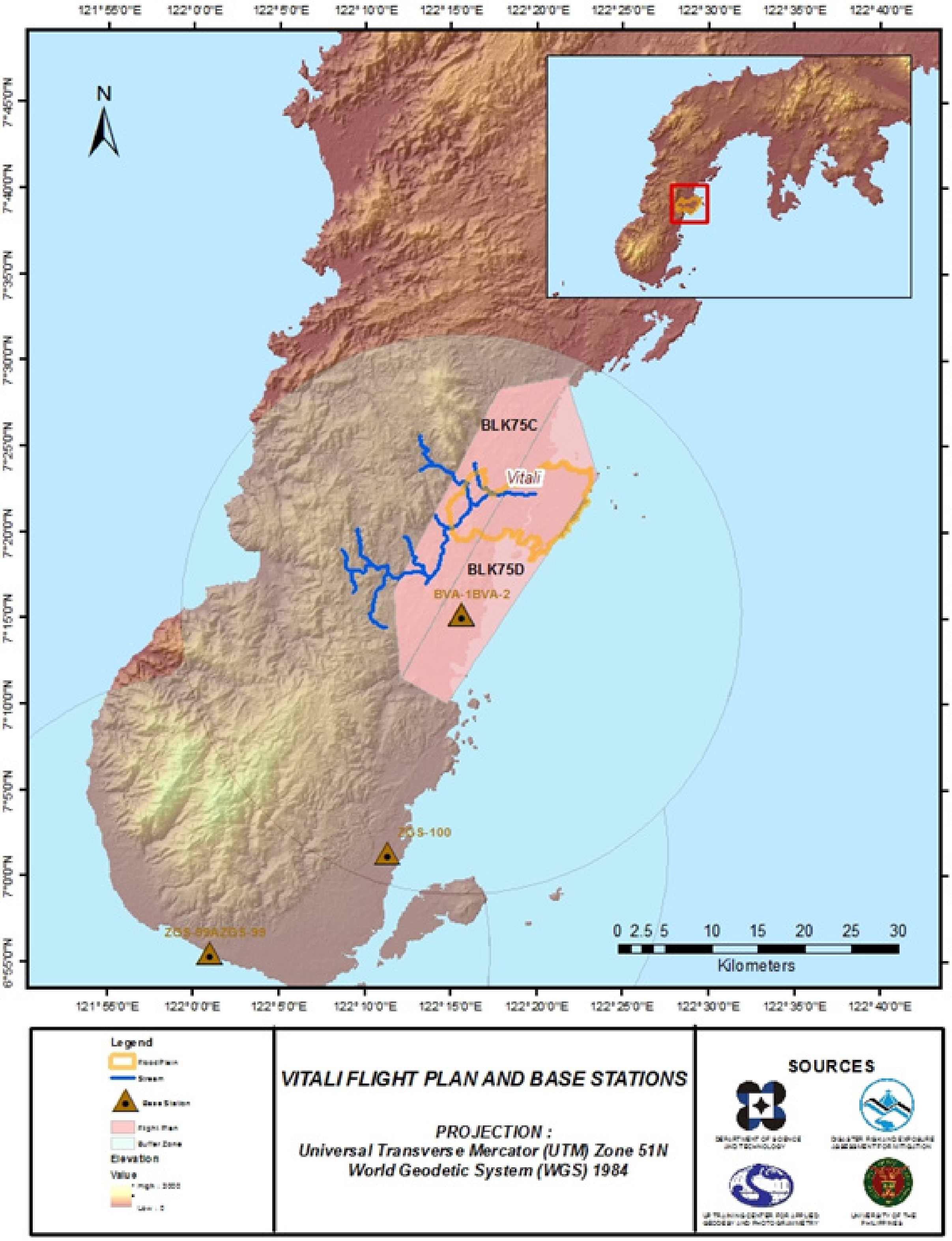
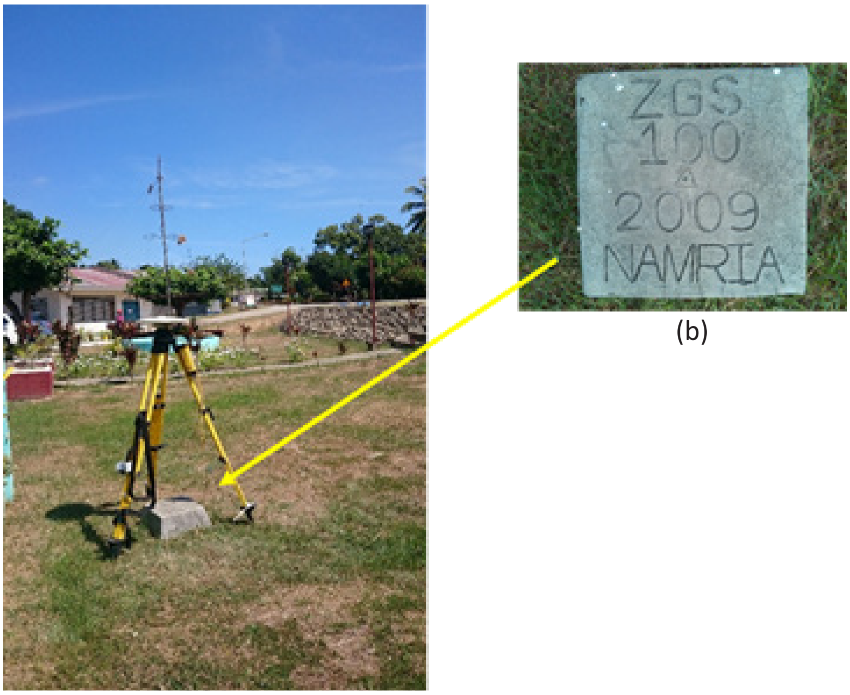


Figure 4. Flight plan and base stations used for Vitali floodplain survey.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points: ZGS-100 and ZGS-99 which are of second (2nd) order accuracy and established three (3) control points: ZG-99A, BVA-1 and BVA-2. The certifications for the NAMRIA reference points and processing report for the established points are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (January 29-Febuary 12, 2015). Base stations were observed using dual frequency GPS receivers TRIMBLE SPS 882, SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Vitali floodplain are also shown in Figure 4.

Figure 5 to Figure 8 shows the recovered NAMRIA control stations within the area, in addition Table 2 to Table 6 show the details about the following NAMRIA control stations and established points, Table 7 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.



(b)

(a)

Figure 5.GPS set-up over ZGS-100 in Brgy. Manicahan, Zamboanga del Sur (a) and NAMRIA reference point ZGS-100 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MST-28 used as base station for the LiDAR acquisition.

Station Name	ZGS-100	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 1' 26.72368" North
	Longitude	122° 11' 12.74401" East
	Ellipsoidal Height	11.27 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	410158.521 meters
	Northing	776712.542 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7° 1' 23.30149" North
	Longitude	122° 11' 18.30044" East
	Ellipsoidal Height	75.603 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	410189.97 meters
	Northing	776440.68 meters

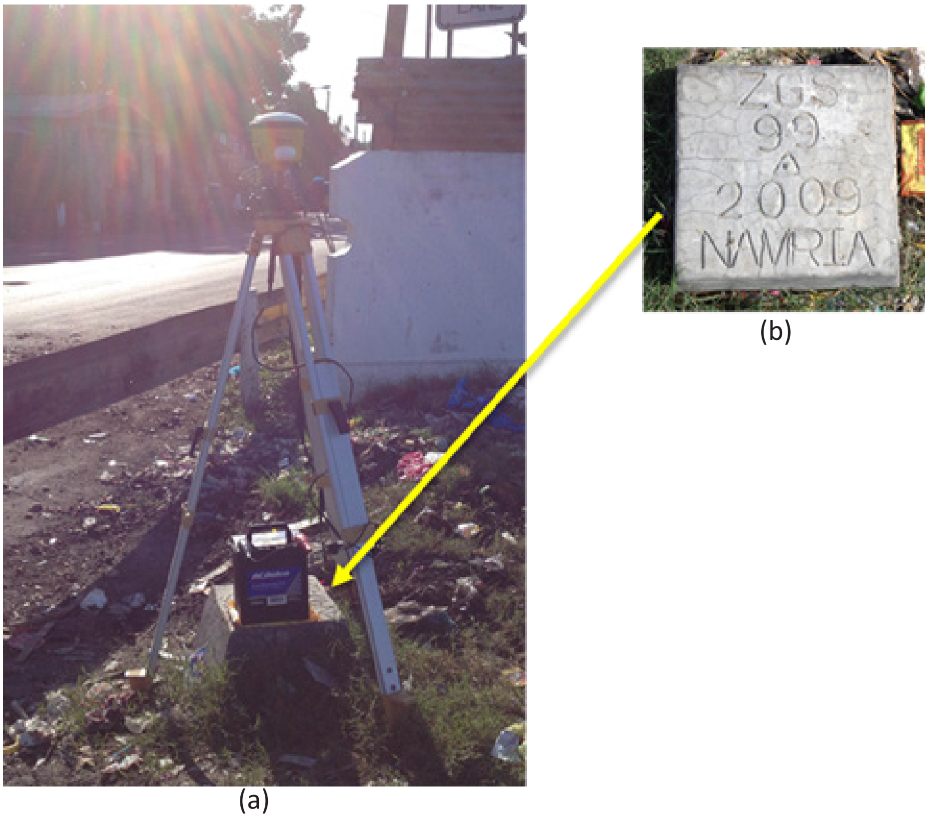
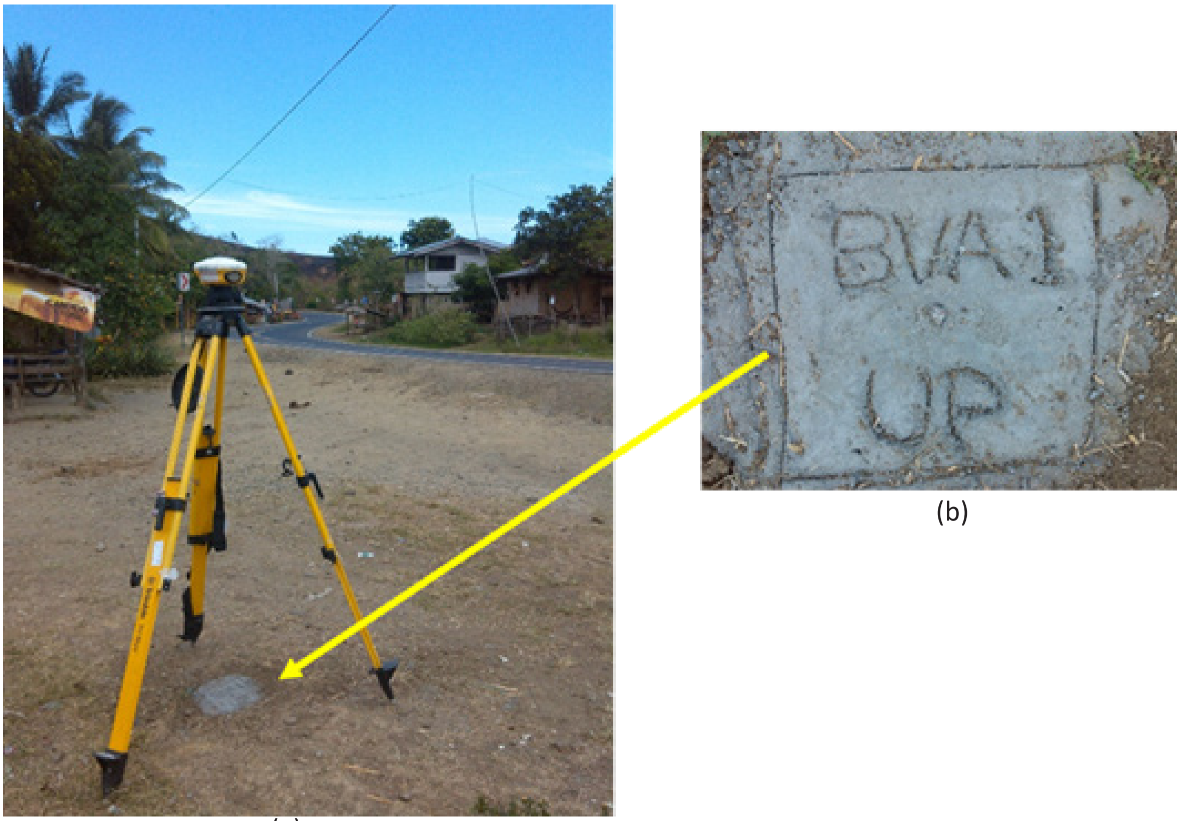


Figure 6. GPS set-up over ZGS-99 beside the seawall in Calarian, Zamboanga City (a) and NAMRIA reference point (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-99 used as base station for the LiDAR data acquisition.

Station Name	ZGS-100	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 1′ 26.72368″ North
	Longitude	122° 11′ 12.74401″ East
	Ellipsoidal Height	11.27 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	410158.521 meters
	Northing	776712.542 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7° 1′ 23.30149″ North
	Longitude	122° 11′ 18.30044″ East
	Ellipsoidal Height	75.603 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	410189.97 meters
	Northing	776440.68 meters

Station Name	ZGS-99	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	6° 55' 37.48971" North
	Longitude	122° 0' 52.66431" East
	Ellipsoidal Height	8.149 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	766020.391 meters
	Northing	391103.346 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	6° 55' 34.07737" North
	Longitude	122° 0' 59.23072" East
	Ellipsoidal Height	72.23 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	765752.27 meters
	Northing	391141.46 meters



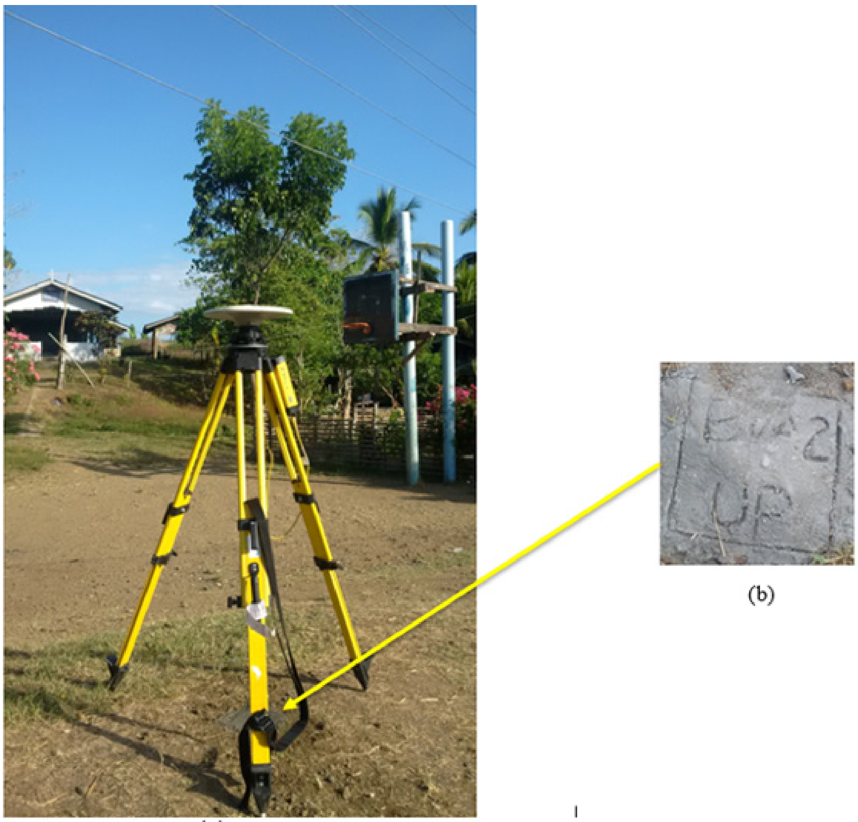
(b)

(a)

Figure 7. a) GPS set-up over BVA-1 established in Brgy. Buenavista, Zamboanga City. b) Reference point BVA-1 as established by the field team.

Table 4. Details of the established control point BVA-1 used as base station for the LiDAR data acquisition.

Station Name	BVA-1	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 15’ 19.31910”North122° 15’ 28.78738”East82.446 meters
	Longitude	417939.856 meters
	Ellipsoidal Height	802333.522 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	7° 15’ 15.84241” North122° 15’ 34.32212” East
	Northing	146.526 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 24’ 21.62786” North
	Longitude	123° 24’ 21.40082” East
	Ellipsoidal Height	83.308 meters



(a) (b)

Figure 8. GPS set-up over BVA-2 established in Brgy.Buenavista, Zamboanga City (a) and Reference point BVA-2 (b) as established by the field team.

Table 5. Details of the established control point BVA-2 used as base station for the LiDAR data acquisition.

Station Name	BVA-2	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 15’ 19.31910”North122° 15’ 28.78738”East82.446 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	417939.856 meters
	Northing	802333.522 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 15’ 15.84241” North122° 15’ 34.32212” East 146.526 meters

Table 6. Details of the established control point ZGS-99A used as base station for the LiDAR data acquisition.

Station Name	BVA-2	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	6° 55’ 37.63895”North122° 00’
	Longitude	52.48834”East
	Ellipsoidal Height	7.850 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	391136.071 meters
	Northing	765756.864 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	6° 55’ 34.22659” North
	Longitude	122° 00’ 58.05475” East
	Ellipsoidal Height	71.931 meters

Table 7. Ground control points used during LiDAR data acquisition .

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 6, 2015	2537P	1BLK75C037A	BVA-1 and BVA-2
February 6, 2015	2539P	1BLK75D037B	BVA-1 and BVA-2
February 8, 2015	2545P	1BLK75S39A	BVA-1 and ZGS-100
February 11, 2015	2557P	1BLK75S42A	ZGS-99 and ZGS-99A

2.3 Flight Missions

Four (4) missions were conducted to complete LiDAR data acquisition in Vitali Floodplain, for a total of 16 hours and 2 minutes of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Vitali floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within Floodplain (km^2)	Area Surveyed Outside Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 6, 2015	2537P	201.6	322.44	39	283.44	NA	4	23
February 6, 2015	2539P	159	165.38	33.99	131.39	715	3	05
February 8, 2015	2545P	357.52	108.98	17.28	91.7	608	4	11
February 11, 2015	2557P	234.33	228.21	7.38	220.83	474	4	23
TOTAL		1331.4	825.01	97.65	727.36	1797	16	2

Table 9. 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)
2537P	1200	30	50	200	30	130	5
2539P	1100	30	50	200	30	130	5
2545P	1100	30	50	200	30	130	5
2557P	1000/1100	30	50	200	30	130	5

2.4 Survey Coverage

Vitali floodplain is located in the provinces of Zamboanga del Sur with the floodplain situated within the City of Zamboanga. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Vitali floodplain is presented in Figure 6.

Table 10. List of municipalities and cities surveyed during Vitali floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Zamboanga Sibugay	Tungawan	441.86	246.14	56%
Zamboanga del sur	Zamboanga City	1461.05	387.72	27%
Total		1,902.91	633.86	33.31%

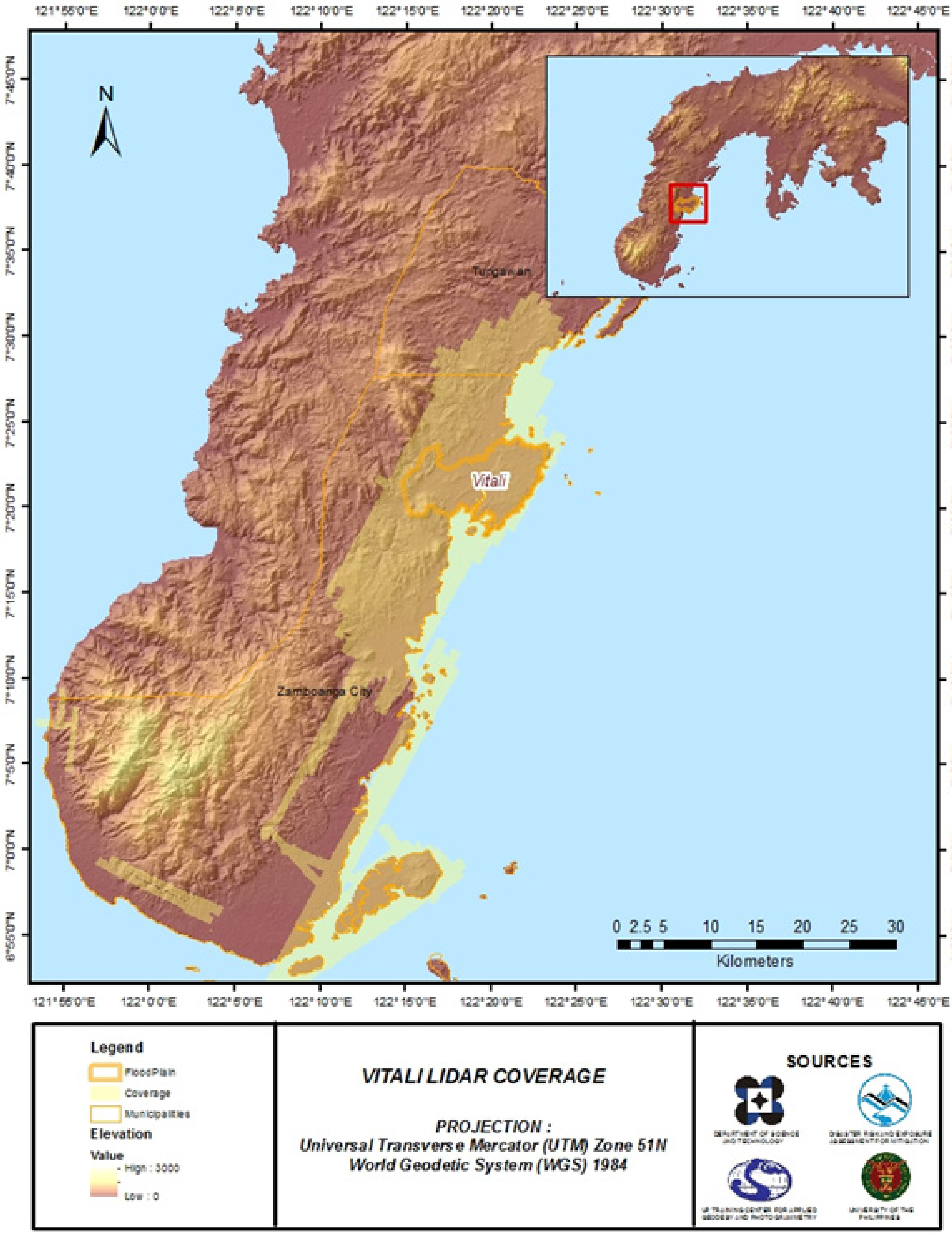


Figure 9. Actual LiDAR data acquisition for Vitali floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE VITALI FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Ma. Ailyn L. Olanda , Engr. Don Matthew B. Banatin, Aljon Rie V. Araneta, Engr. Christy Lubiano , Deane Leonard M. Bool, Eriasha Loryn C. Tong

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 10.

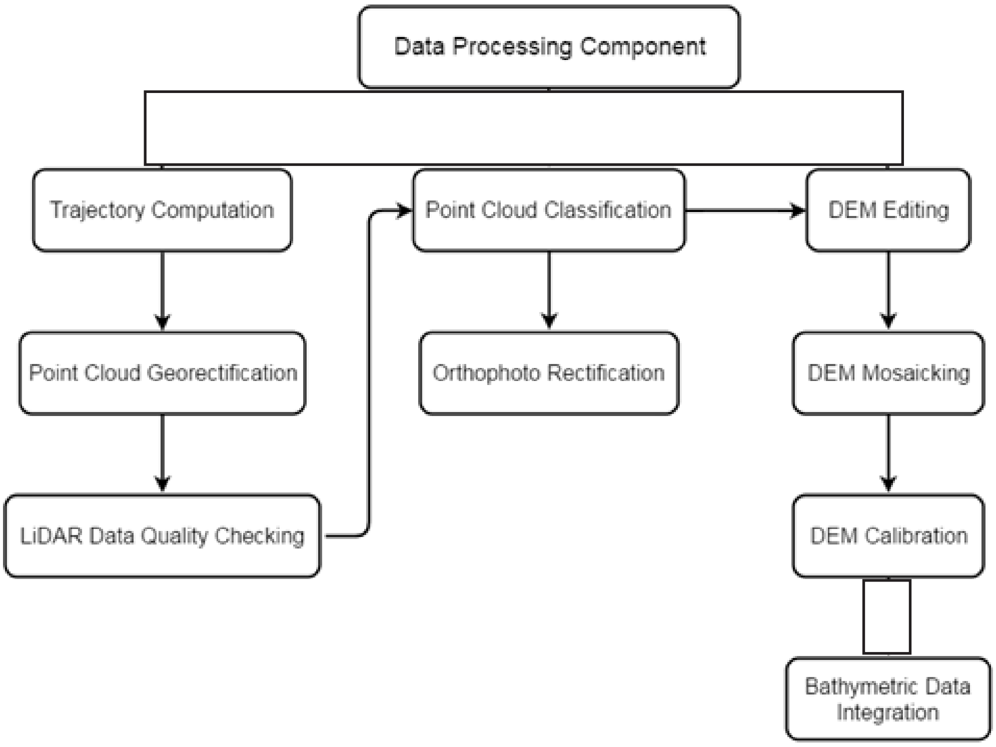


Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Vitali floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Zamboanga City. The Data Acquisition Component (DAC) transferred a total of 100.10 Gigabytes of Range data, 0.95 Gigabytes of POS data, 32.64 Megabytes of GPS base station data, and 154.20 Gigabytes of raw image data to the data server on February 24, 2015 for the first survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Vitali was fully transferred on March 13, 2015, as indicated on the Data Transfer Sheets for Vitali floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2539P, one of the Vitaliflights, which is the North, East, and Down position RMSE values are shown in Figure 11. 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 onFebruary 24, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

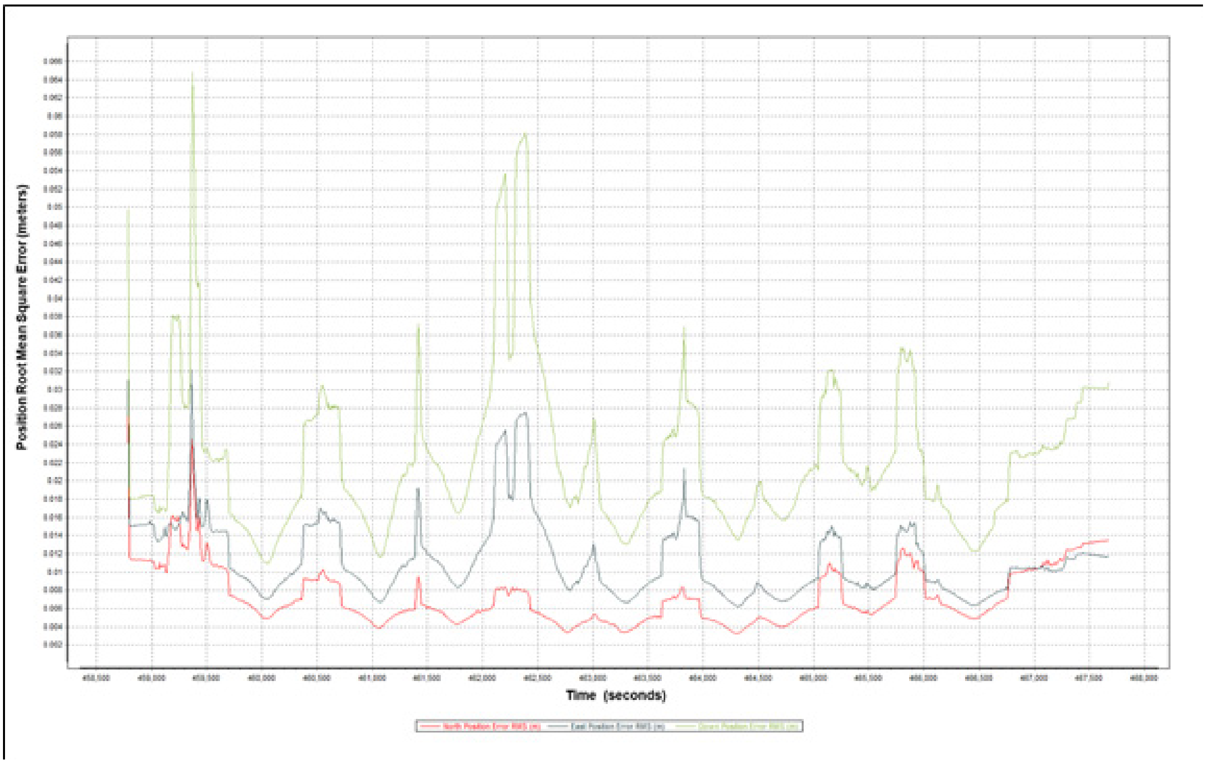


Figure 11. Smoothed Performance Metrics of a Vitali Flight 2539P.

The time of flight was from 458,500 seconds to 467,700 seconds, which corresponds to morning of February 21, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly 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 11 shows that the North position RMSE peaks at 2.40 centimeters, the East position RMSE peaks at 3.20 centimeters, and the Down position RMSE peaks at 6.50 centimeters, which are within the prescribed accuracies described in the methodology.

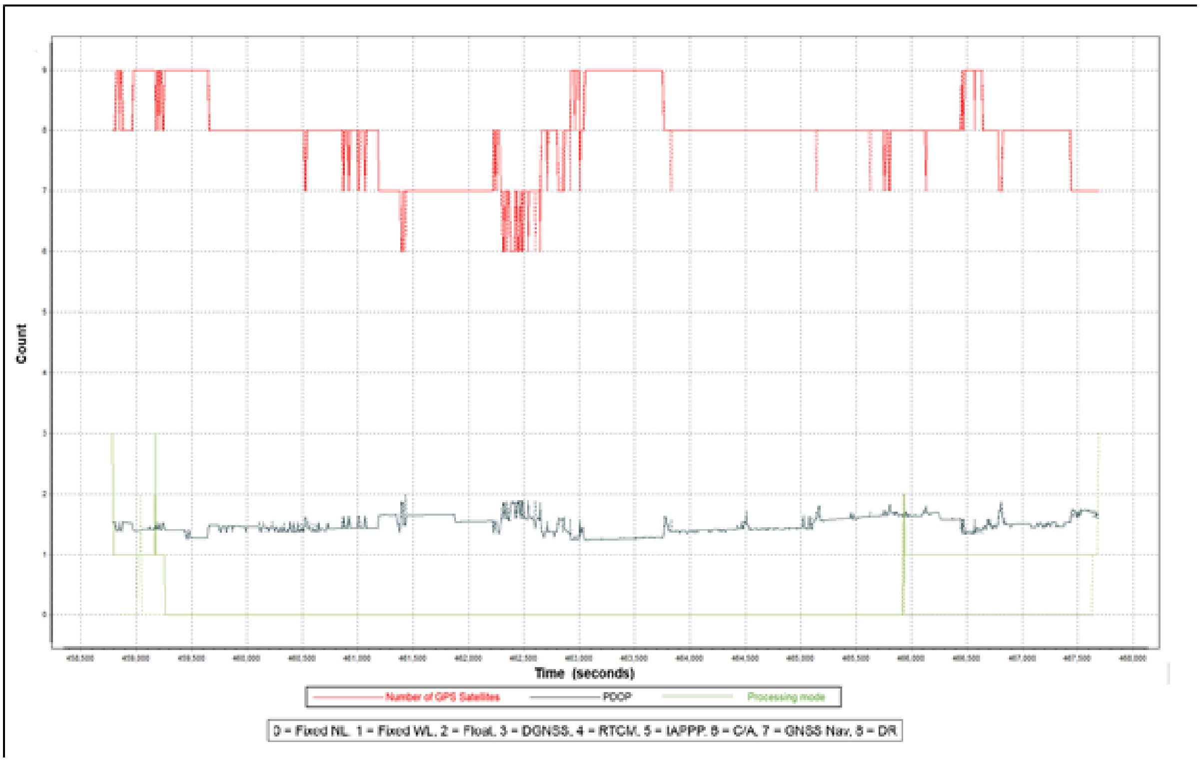


Figure 12. Solution Status Parameters of Vitali Flight 2539P.

The Solution Status parameters of flight 2539P, one of the Vitali flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not 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 Vitali flights is shown in Figure 13.

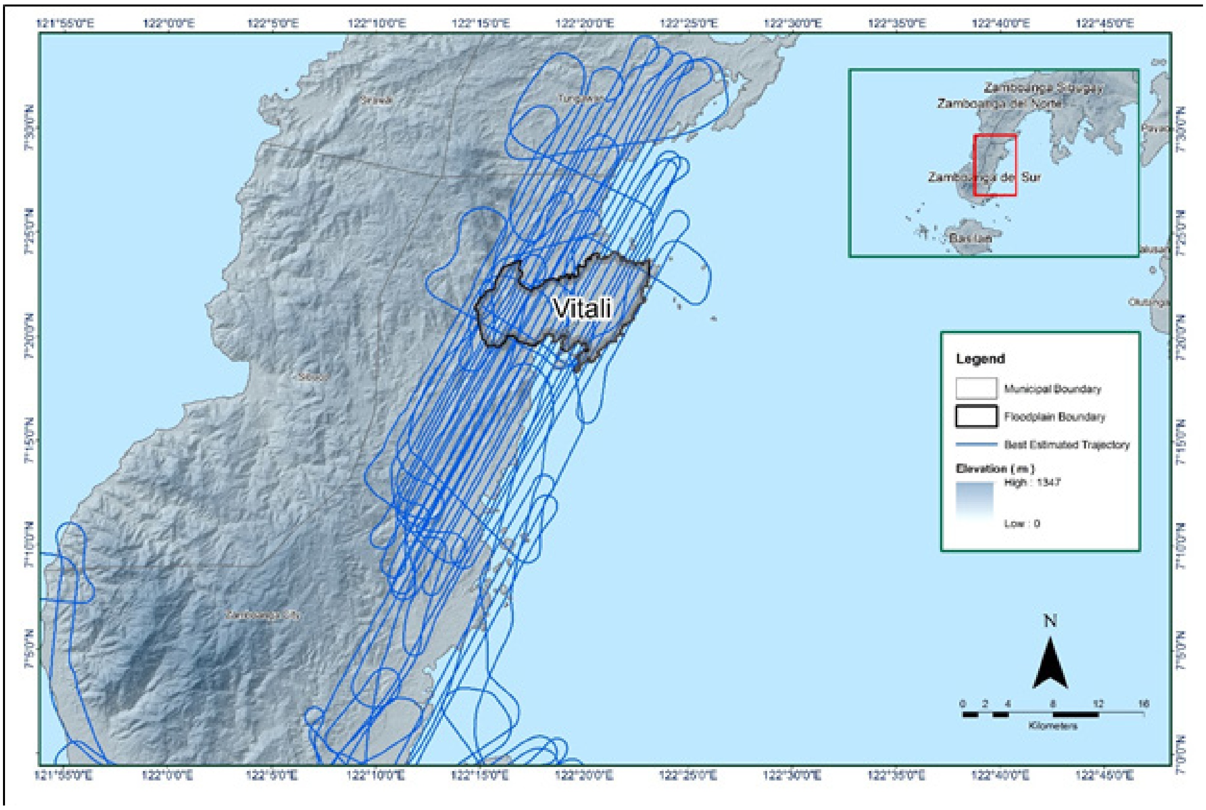


Figure 13. Best estimated trajectory of the LiDar missions conducted over the Vitali floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 40 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Vitali floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Vitali flights.

Parameter	Value	
Boresight Correction stdev	(<0.001degrees)	0.000340
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.001089
GPS Position Z-correction stdev	(<0.01meters)	0.0084

The optimum accuracy is obtained for all Vitali 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 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

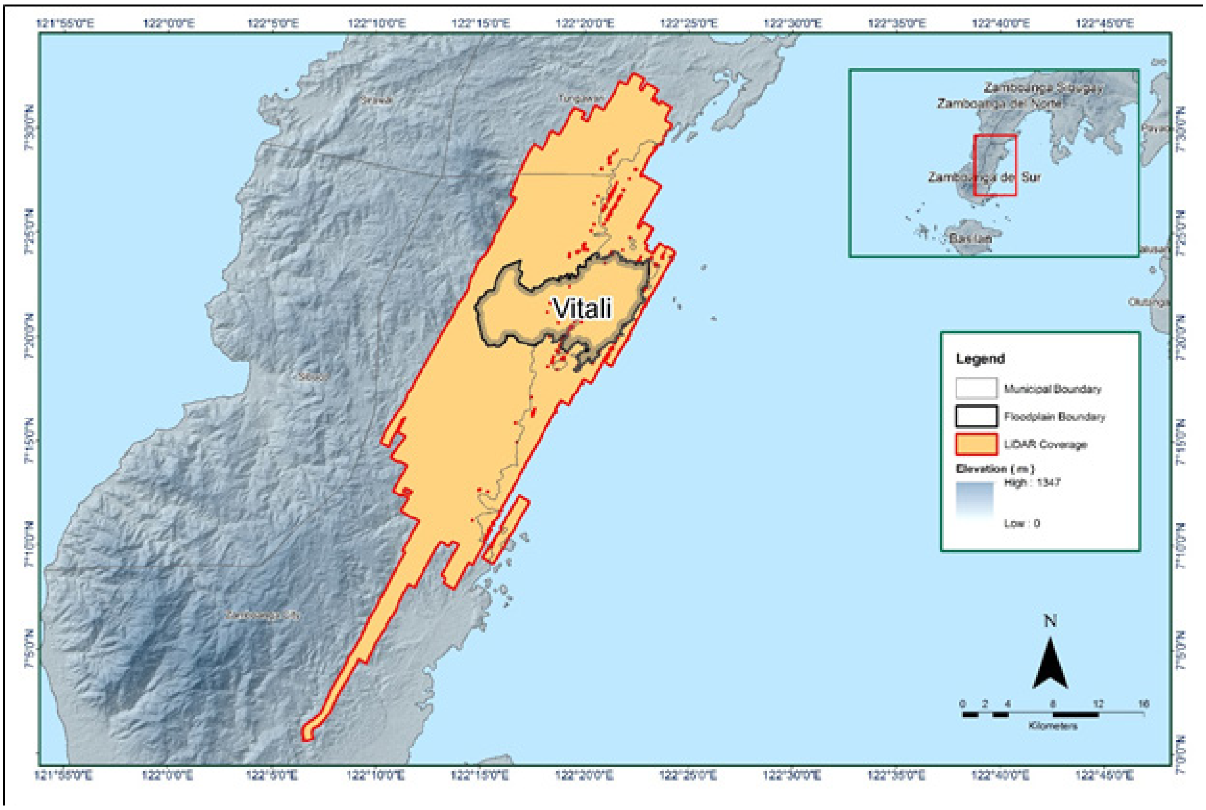


Figure 14. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Vitali Floodplain

The total area covered by the Vitali missions is 577.96 sq.km that is comprised of four (4) flight acquisitions grouped and merged into two (2) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Vitali floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75C	2537P	381.74
	2545P	
	2557P	
Zamboanga_Blk75D	2539P	166.41
	2557P	
	TOTAL	**828.67 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 15. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

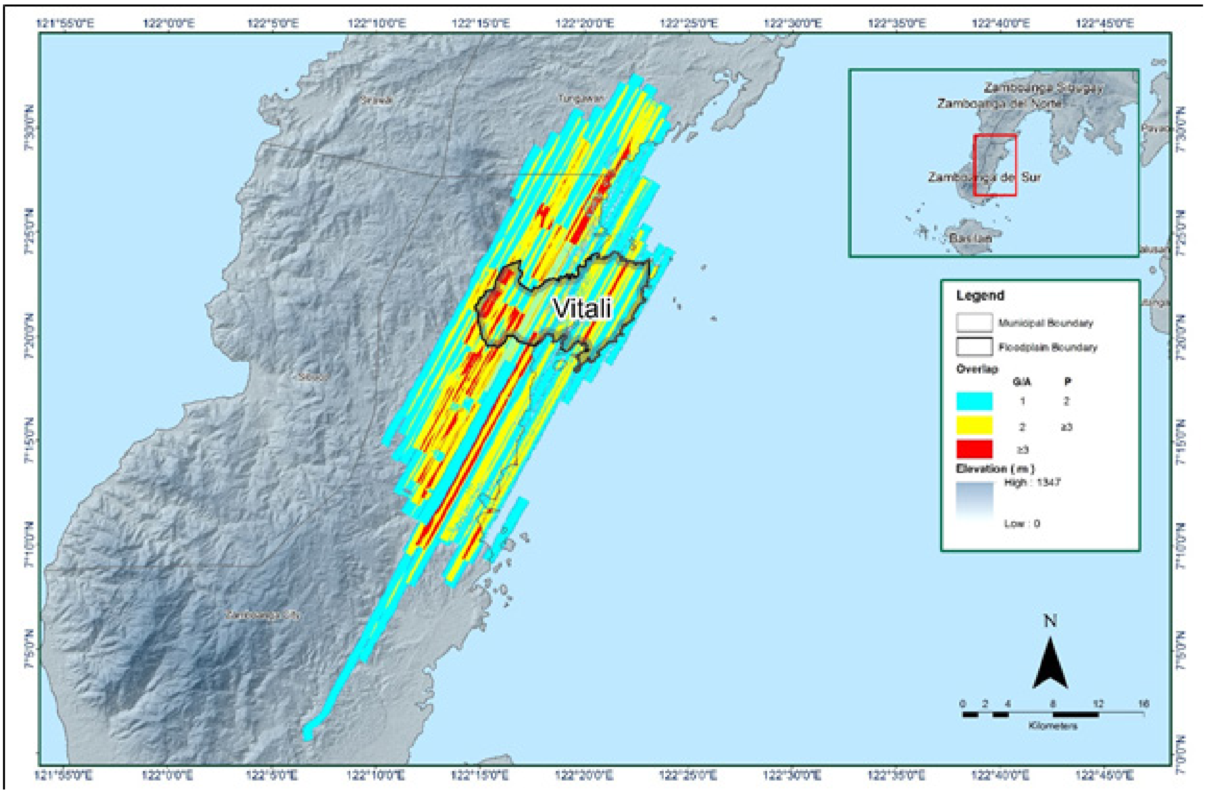


Figure 15. Image of data overlap for Vitali floodplain.

The overlap statistics per block for the Vitali 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 40.89% and 54.88% 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 16. It was determined that all LiDAR data for Vitali floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.46 points per square meter.

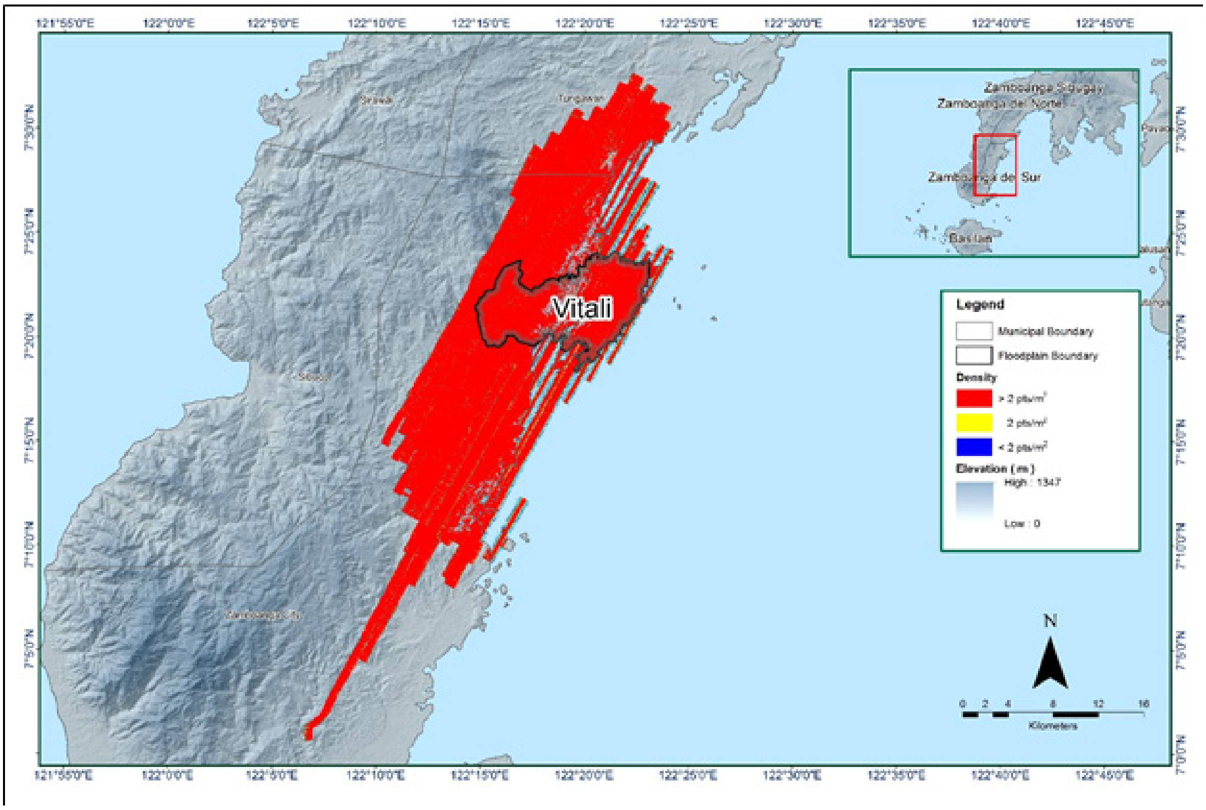


Figure 16. Density map of merged LiDAR data for Vitali floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. 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.

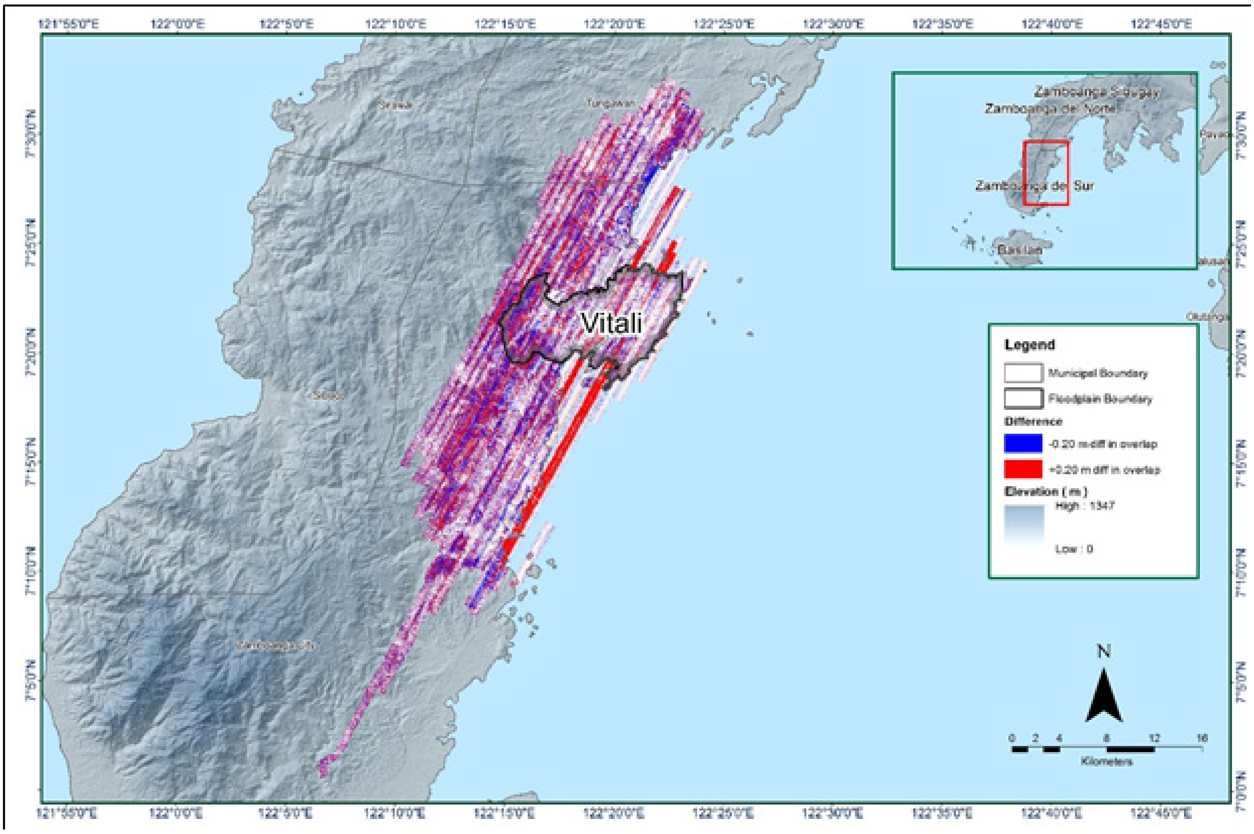


Figure 17. Elevation difference map between flight lines for Vitali floodplain.

A screen capture of the processed LAS data from a Vitali flight 2539P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there 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.

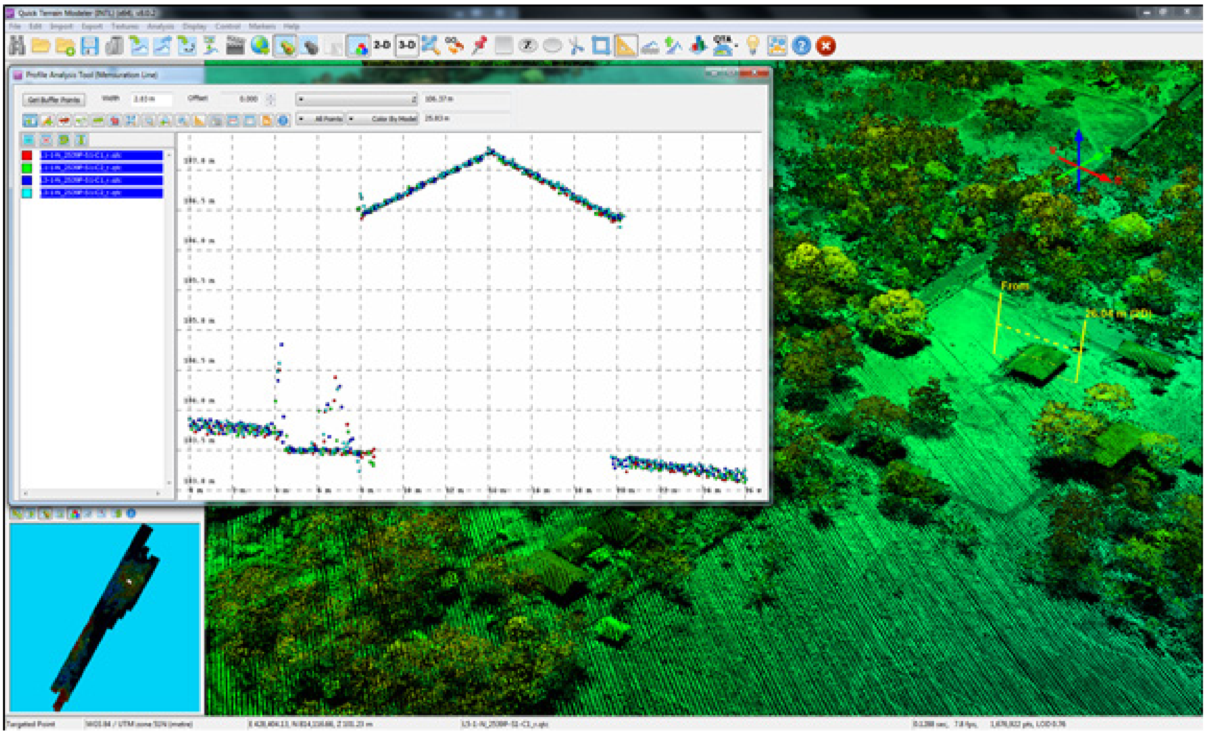


Figure 18.Quality checking for a Vitali flight 2539P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Vitali classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	634,496,404
Low Vegetation	589,517,506
Medium Vegetation	1,103,758,550
High Vegetation	1,653,188,888
Building	285,488,614

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Vitali floodplain is shown in Figure 19. A total of 784 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 578.21 meters and 67.64 meters respectively.

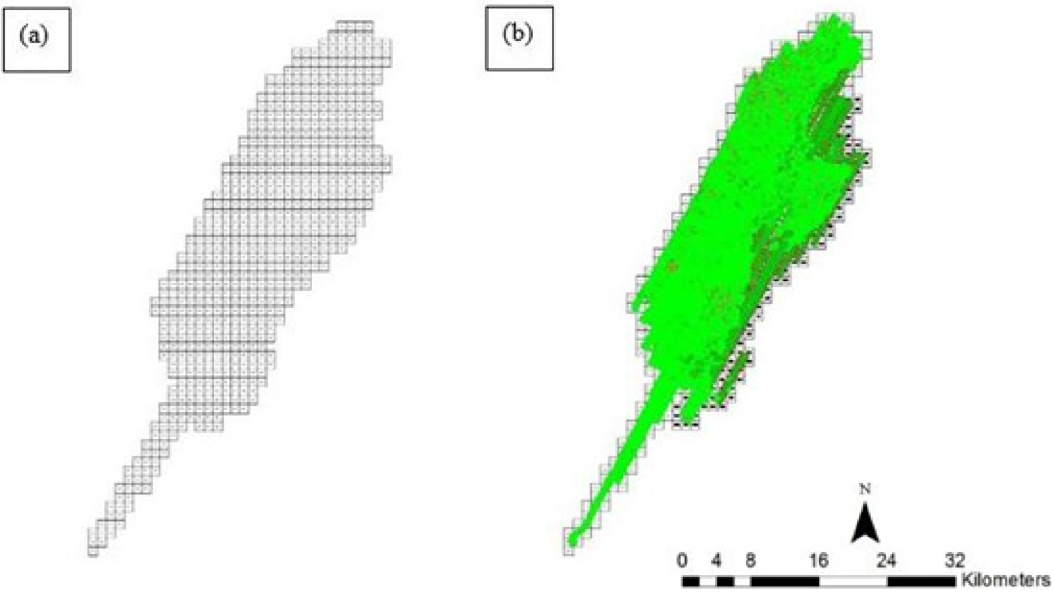


Figure 19. Tiles for Vitali floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

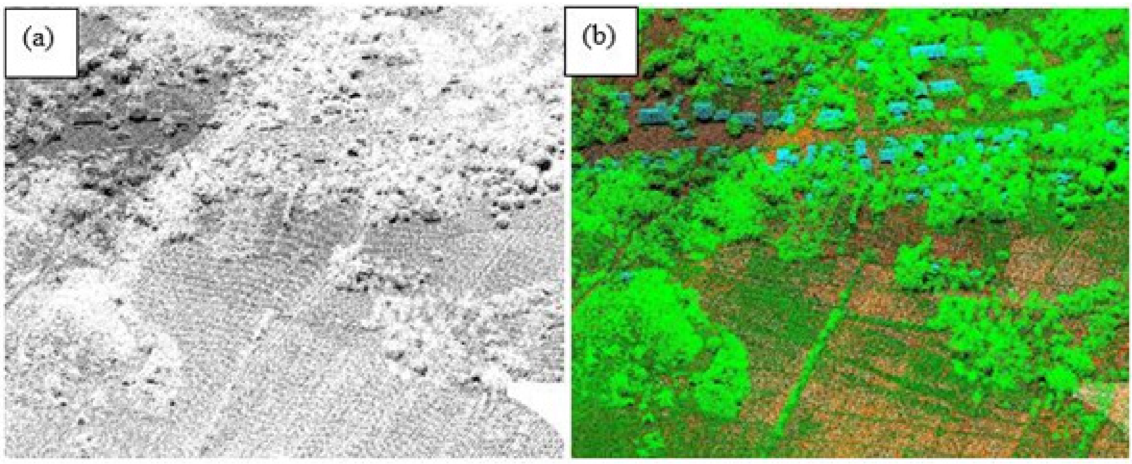


Figure 20. Point cloud before (a) and after (b) classification.

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 21. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

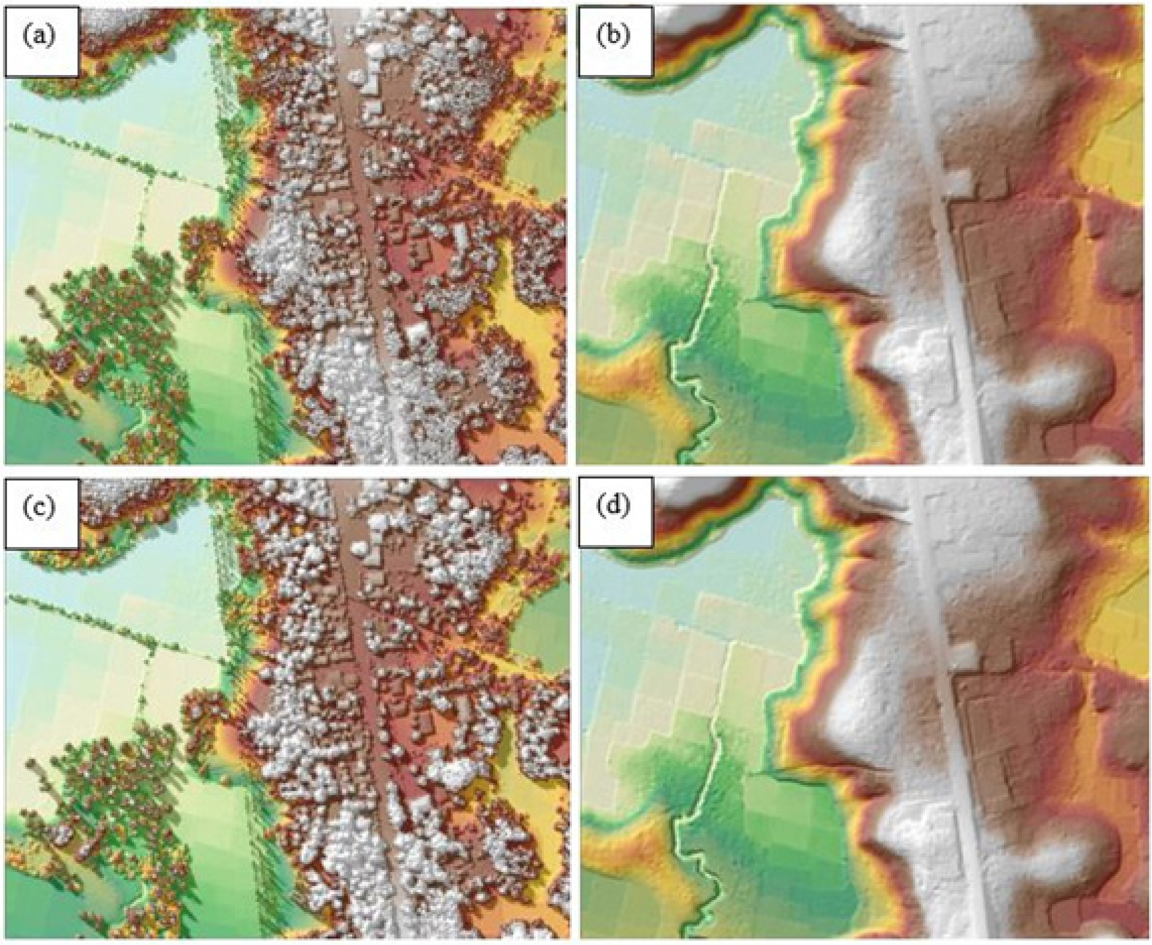


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Vitali floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 696 1km by 1km tiles area covered by Vitali floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Vitali floodplain has a total of 554.88 sq.km orthophotogaph coverage comprised of 1,728 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

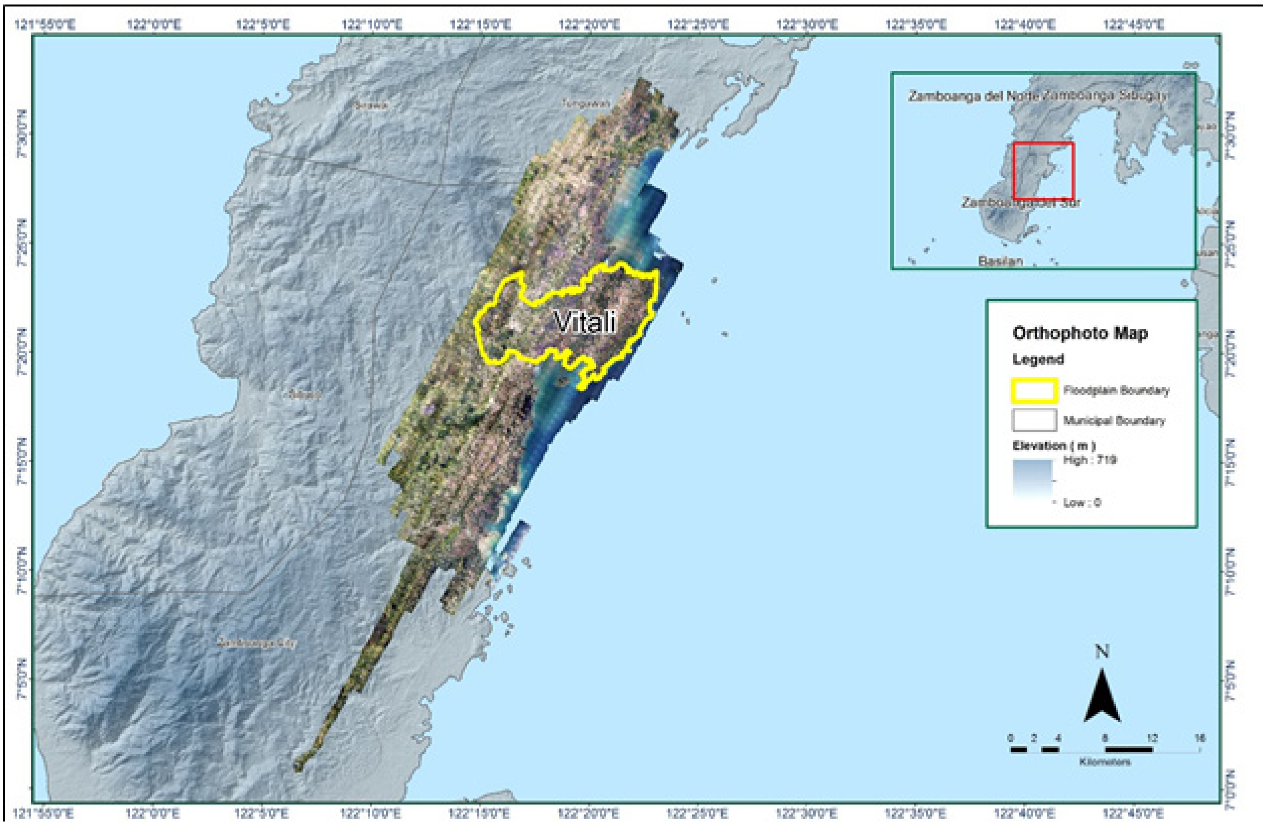


Figure 22. Vitali floodplain with available orthophotographs.

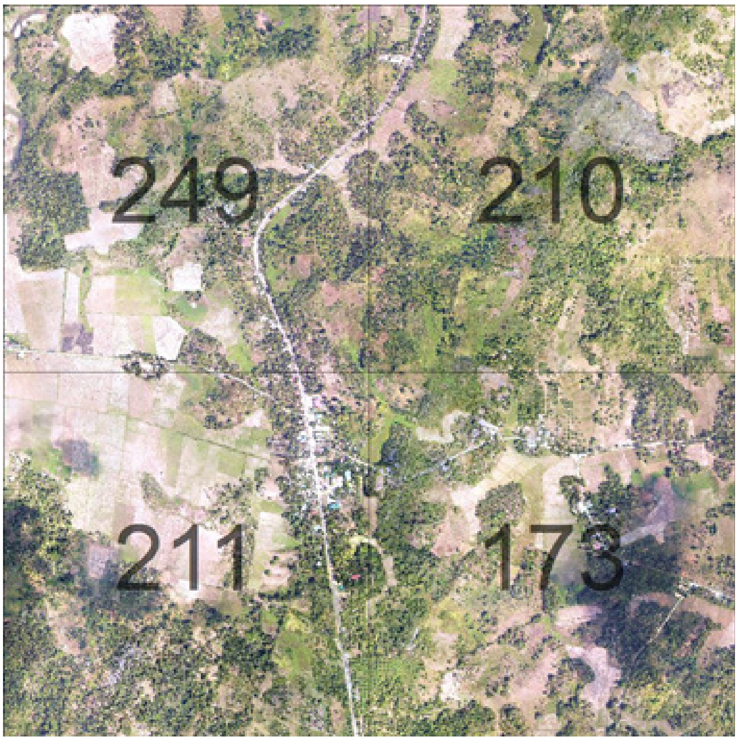


Figure 23. Sample orthophotograph tiles for Vitali floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Vitali flood plain. These blocks are composed of Zamboanga blocks with a total area of 577.96 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Zamboanga_Blk75C	381.74
Zamboanga_Blk75D	166.41
TOTAL	**577.96 sq.km**

Portions of DTM before and after manual editing are shown in Figure B-15. The rice field or fishpond embankment (Figure 24a) has been misclassified and removed during classification process and has to be retrieved to complete surface (Figure 24b) to allow the correct flow of water. The road (Figure 24c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 24d) in order to hydrologically correct the river.

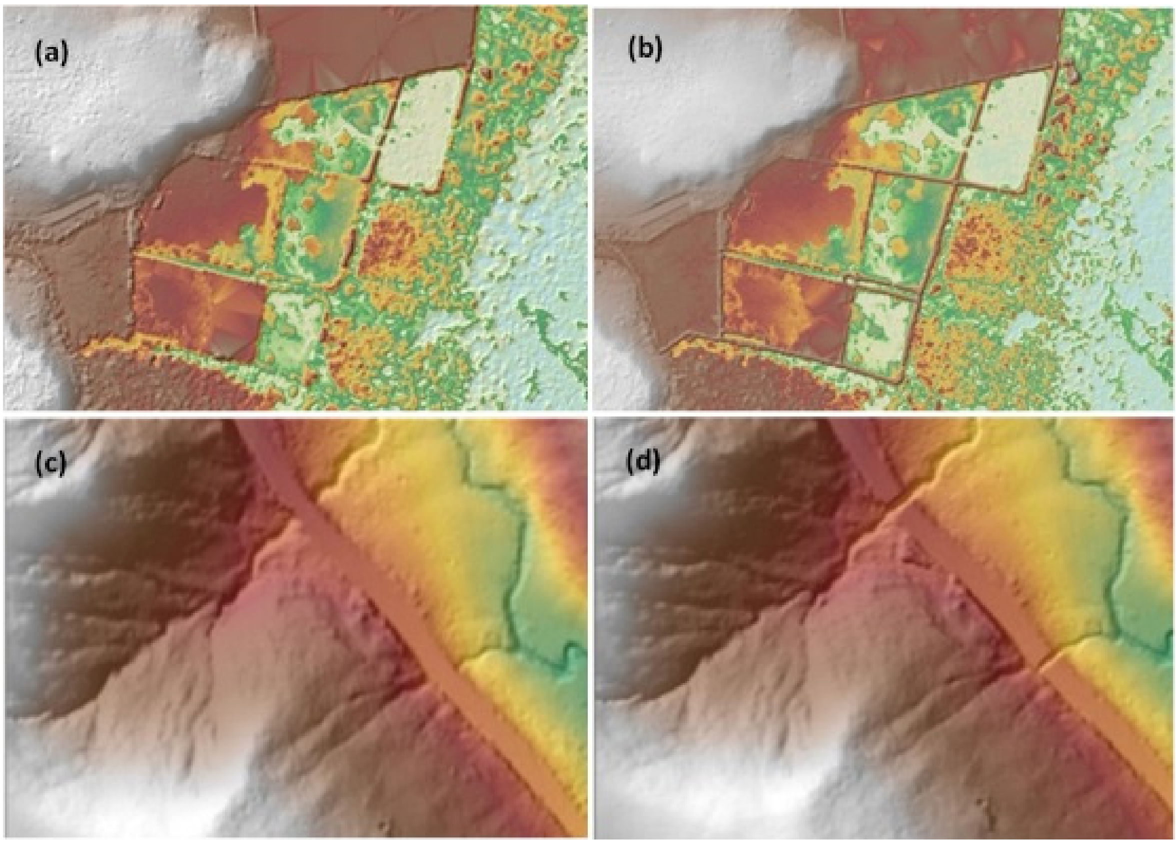


Figure 24. Portions in the DTM of Vitali floodplain – a paddy field before (a) and after (b) data retrieval; a road before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Simultaneous mosaicking was done to all the available LiDAR data (Zamboanga_Blk75G, Zamboanga_Blk75F, Zamboanga_Blk75E, Zamboanga_Blk75F_additional, Zamboanga_Blk75D, Zamboanga_Blk75C and Zamboanga_Sacol). Zamboanga_Blk75G was used as the reference block at the start of mosaicking because it is the first available LiDAR data.Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Vitali floodplain is shown in Figure 25. It can be seen that the entire Vitali floodplain is 100% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Vitali floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_Blk75C	0.00	0.00	0.47
Zamboanga_Blk75D	0.00	0.00	0.47

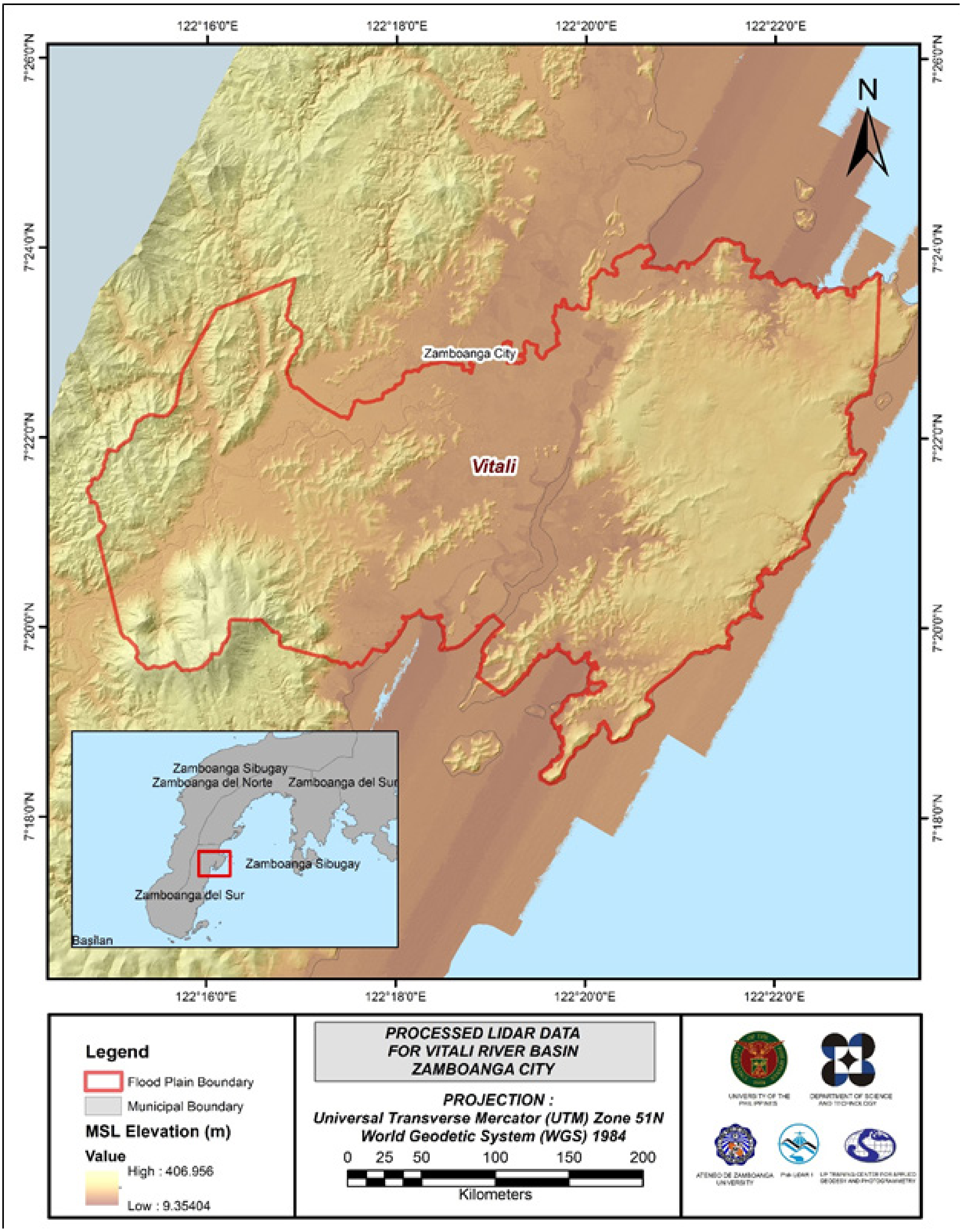


Figure 25. Map of Processed LiDAR Data for Vitali Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Vitali flood plain to collect points with which the LiDAR dataset is validated is shown in Figure 26.

Simultaneous mosaicking was done for the Zamboanga LiDAR blocks and the only available data that time was for Tumaga. The Vitali flood plain is included in the set of blocks previously mosaicked, therefore, the Tumaga calibration data and methodology was used.

A total of 1,739 survey points from Tumaga data were used for calibration and validation of all the blocks of Zamboanga LiDAR data. Random selection of 80% of the survey points, resulting to 1,391 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 8.06 meters with a standard deviation of 0.07 meters. Calibration for Zamboanga LiDAR data was done by adding the height difference value, 8.06 meters, to Zamboanga mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

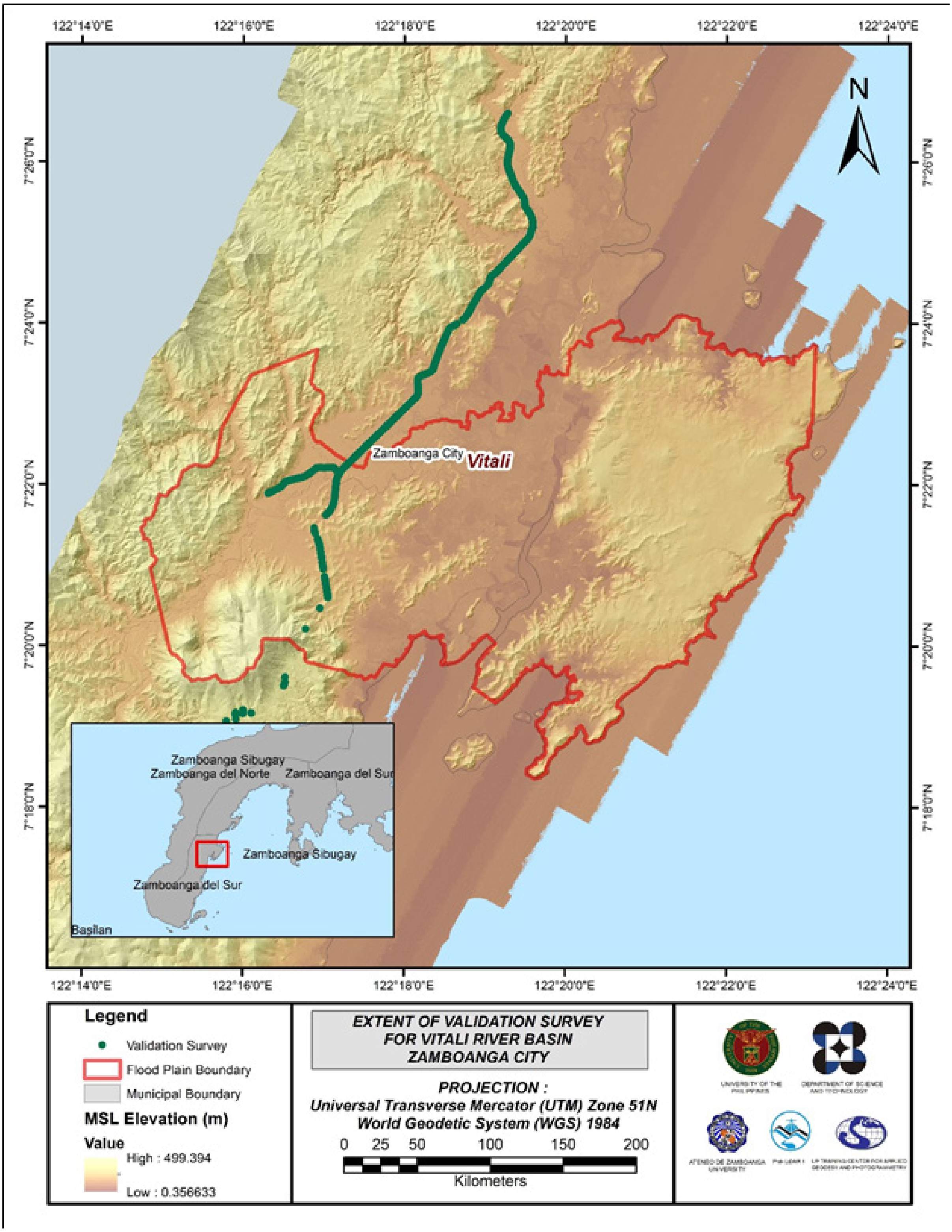


Figure 26. Map of Vitali Flood Plain with validation survey points in green.

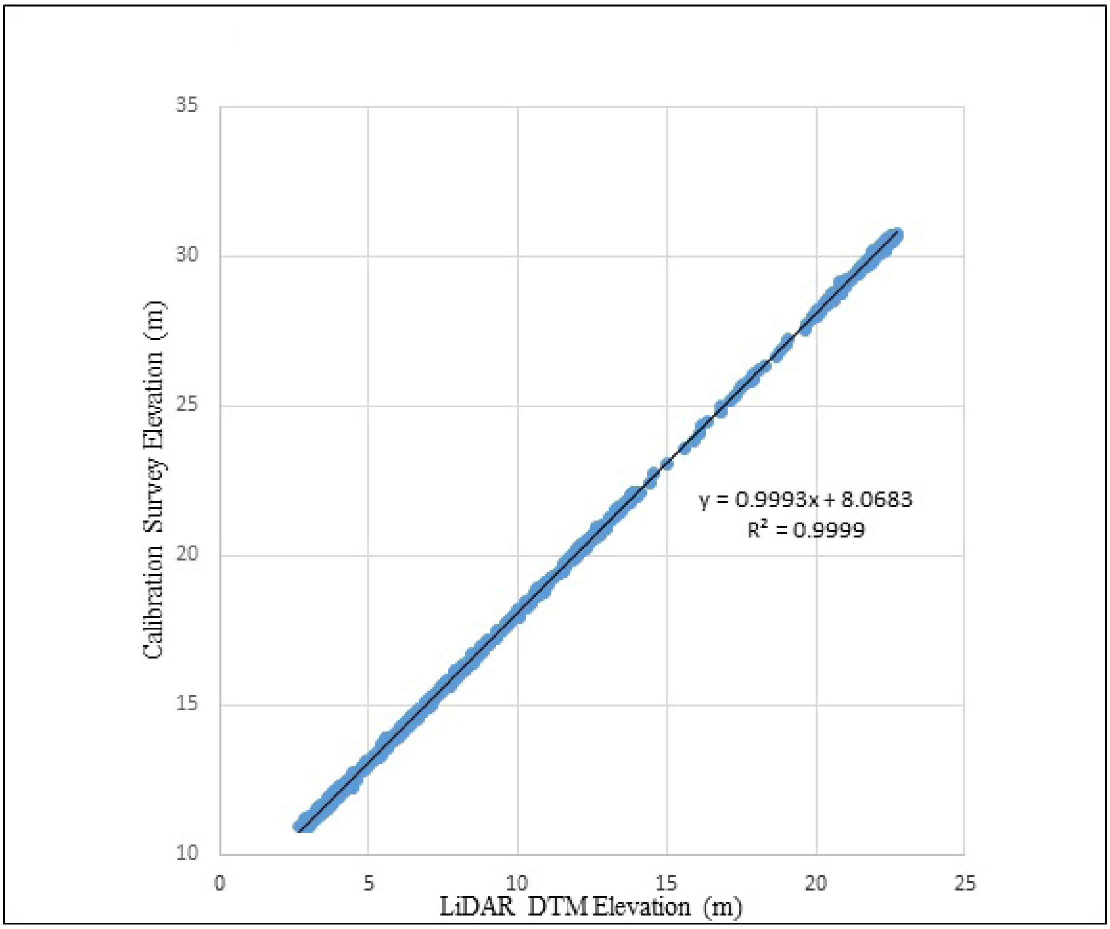


Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	8.06
Standard Deviation	0.07
Average	8.06
Minimum	7.91
Maximum	8.20

The Vitali flood plain has a total of 2564 survey points and only 20% of the total survey points, resulting to 513 points, were randomly selected and used for the validation of calibrated Vitali 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.08 meters, as shown in Table 17.

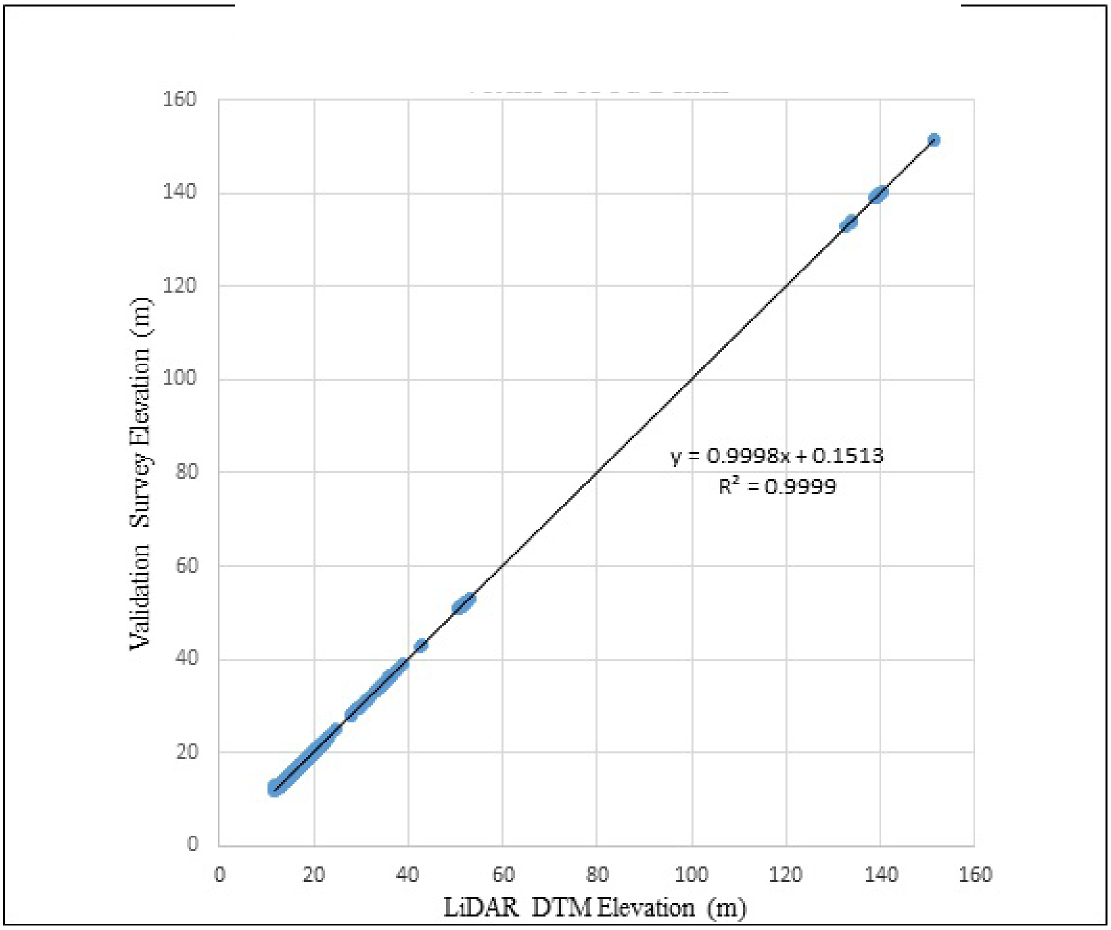


Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.08
Average	0.15
Minimum	-0.01
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Vitali with 4,840 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.44 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Vitali integrated with the processed LiDAR DEM is shown in Figure 29.

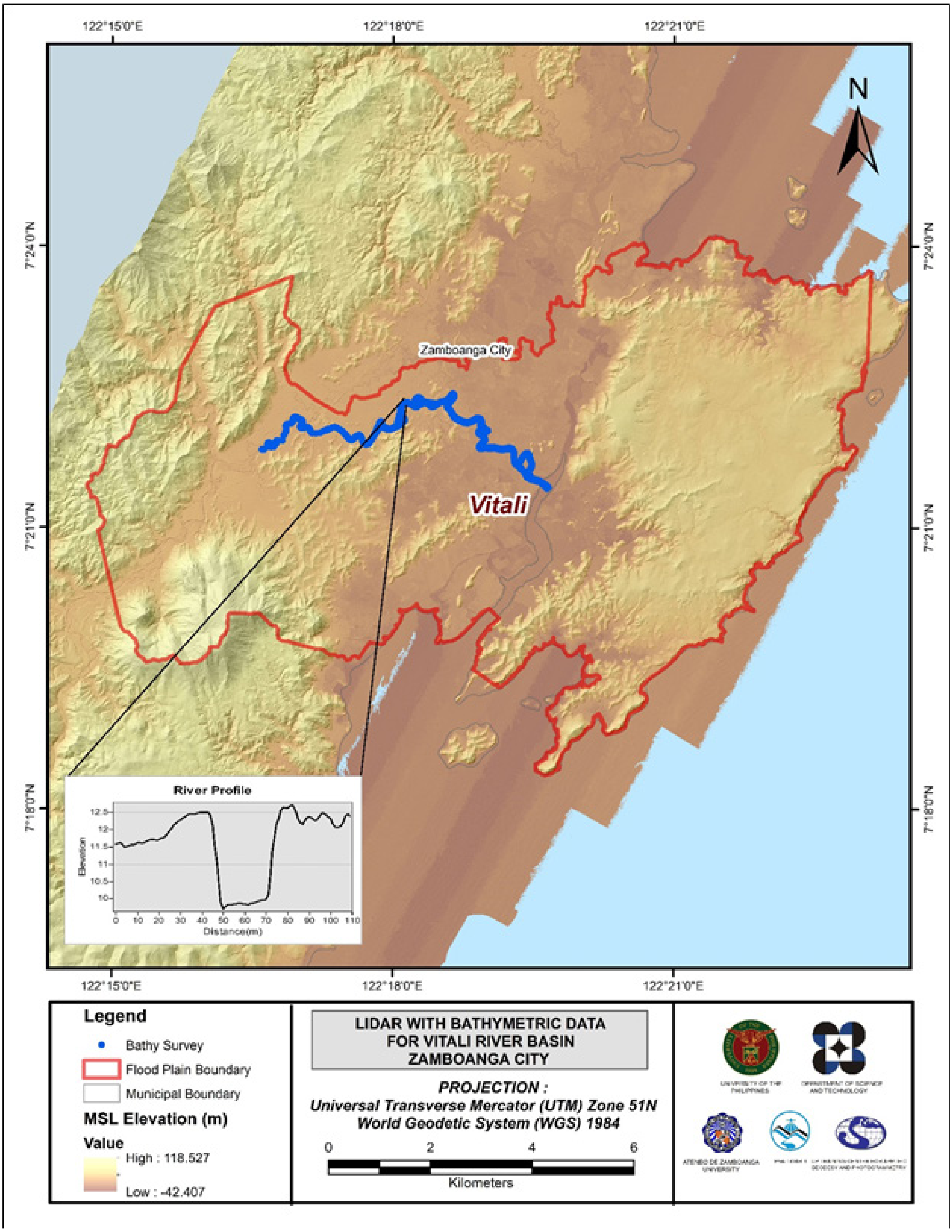


Figure 29. Extend of the bathymetric survey (in blue line) in Vitali River.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Vitali floodplain, including its 200 m buffer, has a total area of 102.14 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 820 building features, are considered for QC. Figure 30 shows the QC blocks for Vitali floodplain.

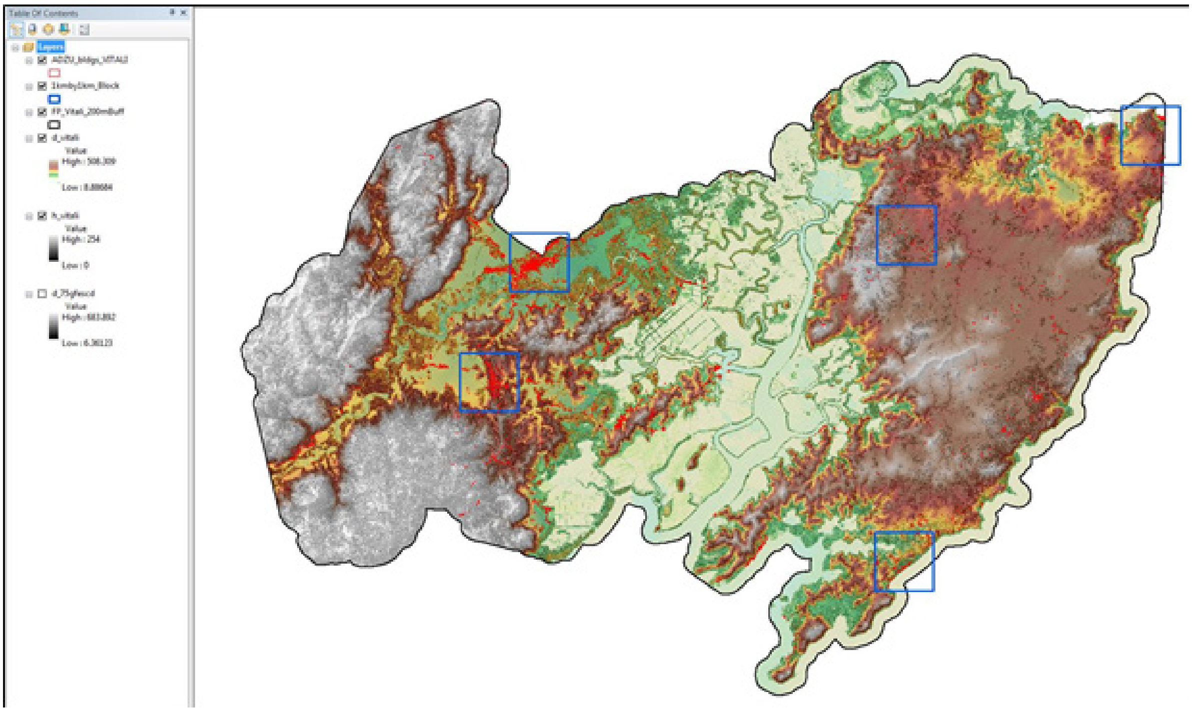


Figure 30. Blocks (in blue) of Vitali building features that were subjected to QC.

Quality checking of Vitali building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Vitali Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Vitali	99.88	99.88	99.27	PASSED

3.12.2 Height Extraction

Height extraction was done for 3486 building features in Vitali floodplain. Of these building features, none was filtered out after height extraction, resulting to 3486 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 4.72 m.

3.12.3 Feature Attribution

One of the Research Associate of ADZU Phil LiDAR 1 was able to develop GEONYT, an offline web-based application for feature attribution extracted from a LiDAR-based Digital Surface Model and which attribution is conducted by combining automatic data consolidation, geotagging and offline navigation. The app is conveniently integrated in a smart phone/ tablet. The data collected are automatically stored in database and can be viewed as CSV (or excel) and KML (can viewed via google earth). The Geonyt App was the main tool used in all feature attribution activity of the team.

The team, thru the endorsement of the Local Government Units of the Municipality/ City hired a number of enumerators who conducted the house-to-house survey of the features using the GEONYT application. The team provided the enumerators smart tablets where the GEONYT is integrated. The number of days by which the survey was conducted was dependent on the number of features of the flood plain of the river basin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the flood plain.

Table 19 summarizes the number of building features per type. On the other hand, Table B-20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building Features Extracted for Vitali Floodplain.

Facility Type	No. of Features
Residential	3,259
School	72
Market	70
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	1
Barangay Hall	3
Military Institution	4
Sports Center/Gymnasium/Covered Court	4
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	16
Power Plant/Substation	1
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	26
Bank	0
Factory	2
Gas Station	2
Fire Station	0
Other Government Offices	0
Other Commercial Establishments	9
Demolished Building	3,486
Total	1,439

Table 20. Total Length of Extracted Roads for Vitali Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Vitali	0.94	2.06	0.00	2.45	0.00	**5.45**

Table 21. Number of Extracted Water Bodies for Vitali Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Vitali	11	0	0	0	132	**143**

One (1) bridge over small channels that arepart of the river network was 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 31 shows the Digital Surface Model (DSM) of Vitali floodplain overlaid with its ground features.

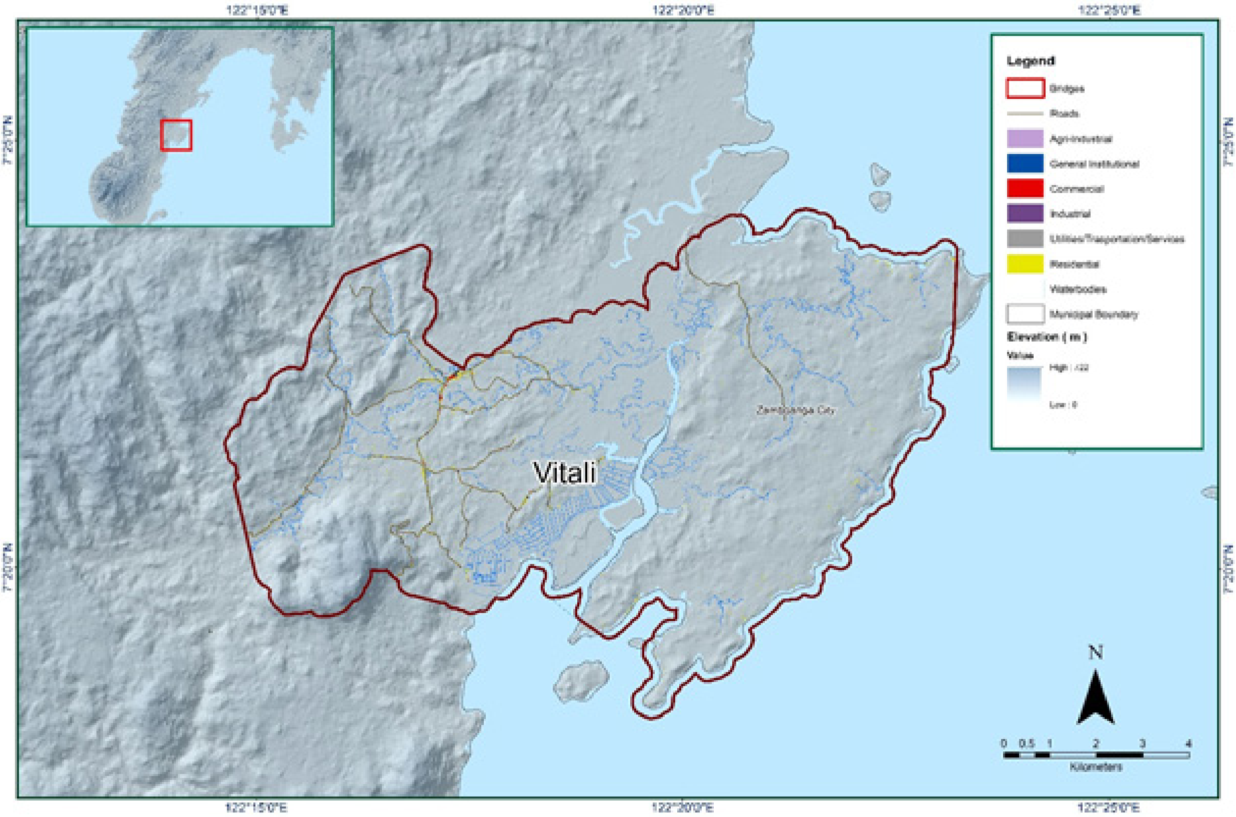


Figure 31. Extracted features for Vitali floodplain.

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

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

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

4.1 Summary of Activities

Vitali or Taguite River Basin is located in the lower area of Zamboanga City and encompasses the Municipalities of Tictapul, Vitali, Siblao, Lunday, Callabasa and Latuan as shown in Figure 32. It has a catchment area of approximately 211 km2based from the Flood Modelling Component and 288 MCM run-off based from the DENR-RBCO. Areas in the vicinity of the Taguite River Basin, the Brgy. Vitali is classified into high susceptibility to flooding based from the Barangay Disaster Risk Reduction and Management Councils (BDRRMCs).

Its main stem, the Vitali River channel has an estimated length of 10.8 km is among the river systems in Zamboanga Peninsula. It is bounded by Brgy. Tictapul in the North, Municipality of Sibuco in the West, Brgy.Curuan in the South and Moro Gulf in the East.Its water, according to its beneficial use is categorized as Class B by the Department of Environmental Management. Its uses are for surface water recreation and drinking. The vicinity is estimated to have population of 10,500 based from LGU Zamboanga City. The community suffered flash floods due to immense rain produced by Typhoon Quedan last October 8, 2013 which put the Zamboanga City under the state of calamity affecting 2,869 families.

In line with this, DVBC conducted a field survey in Vitali River on September 4 to October 8, 2015 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey; courtesy call to LGU Vitali; control survey for the establishment of control point UP-VIT at Vitali bridge approach occupied as base station for GNSS surveys; cross-section, bridge-as-built and MSL water level; validation points acquisition for LiDAR data with estimated distance of 18.3 km; and bathymetric survey of Vitali river starting from the upstreamfrom Brgy. Vitali down to Brgy. Mangusu with an approximate length of 10.76 km utilizing GNSS PPK survey technique.

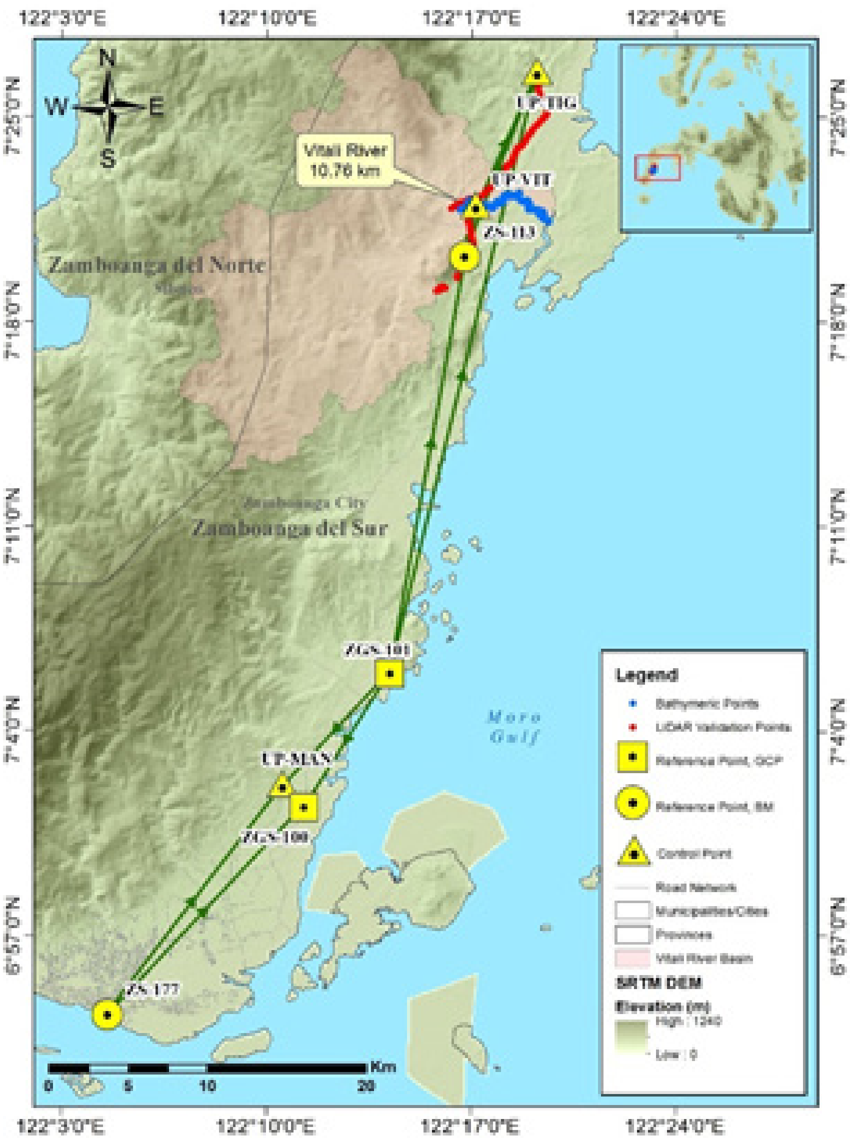


Figure 32. Vitali River Survey Extent.

4.2 Control Survey

The GNSS network used for Vitali River Basin is composed of four (4) loops established on September 26, October 3 and 8, 2015, occupying the following points: ZGS-101, a second-order GCP located within the perimeter of Bolong Elementary School; ZS-113, a first order benchmark in Brgy. Tigbalagbag, Zamboanga City; and ZS-177, a first-order benchmark on the back of the central monument at Rizal Park in front of Zamboanga City Hall.

Three control points were also established along the approach of the bridges namely: UP-MAN, situated on Manicahan Steel Bridge in Brgy. Cacap, Zamboanga City; UP-TIG, in Tigbao Bridge in Brgy.Tictapul, Zamboanga City; and UP-VIT in Vitali Bridge in Brgy.Vitali, Zamboanga City.A NAMRIA established control point namely ZGS-100, located in front of Vitali Barangay Hall, was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 22 while the GNSS network established is illustrated in Figure 33.

Figure 33. GNSS Network of Zamboanga City Field Survey.

Table 22. .List of Reference and Control points used for Control Network in Zamboanga Field Survey (Source: NAMRIA; UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84 N)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
ZGS-101	2nd Order, GCP	7°05'57.59221"	122°14'13.79610"	80.222	-	2009
ZS-177	1st Order,					
BM	-	-	80.002	12.311	2007	
ZS-113	1st Order,					
BM	-	-	219.481	151.585	2007	
ZGS-100	Used as marker	-	-	-	-	2009
UP-MAN	UP Established	-	-	-	-	October 3, 2015
UP-TIG	UP Established	-	-	-	-	August 1,
	Established					2015
UP-VIT	UP Established	-	-	-	-	August 1, 2015

The GNSS set-ups on recovered reference points and established control points in Vitali River are shown in Figure 34 to Figure 40.

Figure 34.Trimble® SPS 852 set-up at ZGS-101 located at Bolong Elementary School, Brgy. Bolong, Zamboanga City

Figure 35. Trimble® SPS 852 set-up at ZS-177 located at the stair of Rizal's Park in Brgy. Poblacion, Zamboanga City

Figure 36. Trimble SPS® 882 set-up at ZGS-100 located at Manicahan Barangay Hall, Zamboanga City.

Figure 37.Trimble SPS® 882 set-up at ZS-113 located along Tagasilay-Vitali Road, Brgy. Tigbalabag, Zamboanga City.

Figure 38. Trimble SPS® 852 set-up at UP-MAN located at the approach of Manicahan Steel Bridge in Brgy. Cacap, Zamboanga City.

Figure 39. Trimble SPS® 882 set-up at UP-TIG located at the approach of Tigbao Bridge in Brgy. Tictapul, Zamboanga City.

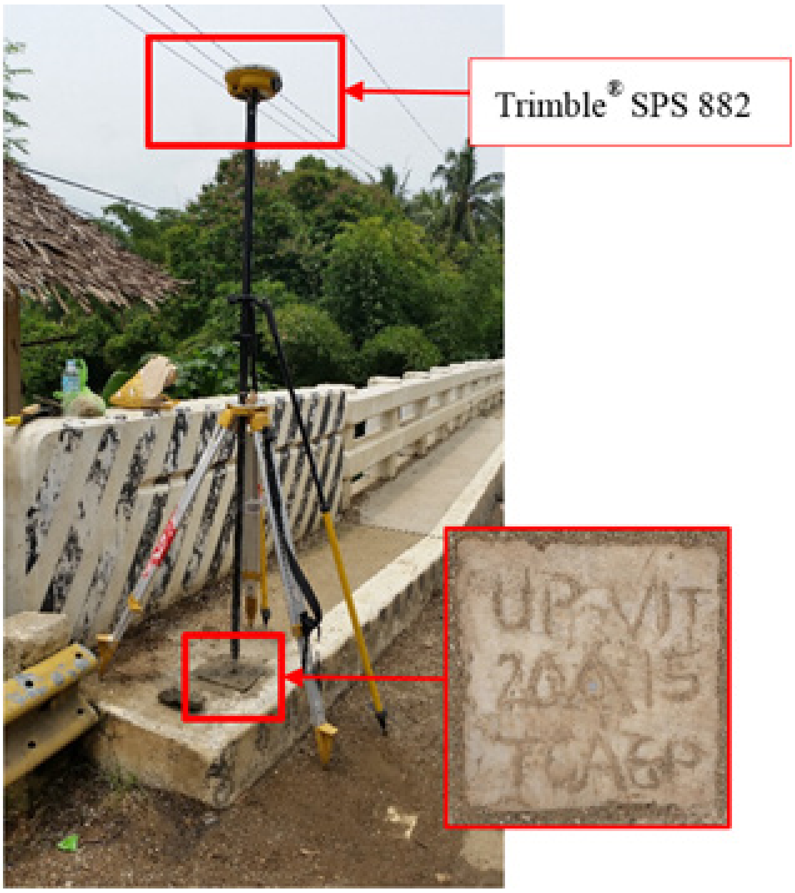


Figure 40. Trimble® SPS 882 set-up at UP-VIT located at the approach of Vitali Bridge in Brgy. Vitali, Zamboanga City.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Vitali River Basin is summarized in Table 23 generated by TBC software.

Table 23. Baseline Processing Summary Report for Vitali River Survey.

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
ZGS101 --- UPTIG	09-26-2015	Fixed	0.003	0.018	13°40'16"	39078.38	9.652
ZGS101 --- ZS113	09-26-2015	Fixed	0.003	0.023	10°06'59"	26671.69	139.258
ZGS101 --- UPVIT	09-26-2015	Fixed	0.003	0.027	10°18'43"	30022.53	6.491
ZGS101 --- UPMAN	10-03-2015	Fixed	0.006	0.026	224°10'56"	9709.698	16.669
ZGS101 --- ZGS100	10-03-2015	Fixed	0.004	0.023	212°35'19"	10000.29	4.51
UPTIG --- ZS113	09-26-2015	Fixed	0.004	0.032	201°14'35"	12567.26	129.543
UPTIG --- UPVIT	09-26-2015	Fixed	0.004	0.029	204°36'51"	9275.764	-3.206
ZS113 --- UPVIT	09-26-2015	Fixed	0.003	0.018	11°52'24"	3352.211	-132.76
ZS177 --- ZGS100	10-08-2015	Fixed	0.007	0.027	223°21'49"	18026.23	-4.678
ZGS100 --- UPMAN	10-08-2015	Fixed	0.005	0.018	316°38'30"	2011.6	12.124
ZGS100 --- UPMAN	10-03-2015	Fixed	0.005	0.023	316°38'33"	2011.599	12.107
ZS177 --- UPMAN	10-08-2015	Fixed	0.011	0.036	37°01'59"	18252.08	16.837

All baselines that formed the GNSS network for the static survey setup acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precision respectively as shown in Table 23.

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 from:

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

Where:

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

for each control point. The results of GNSS processing is shown in Table 24 to Table 26. Thecontrol point ZGS-101 was held fixed for the coordinate values, and ZS-177 and ZS-113 were held fixed for the elevation during the processing of the control point as presented in Table 24.

Table 24. Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGS101	Global	Fixed	Fixed		
ZS113	Grid				Fixed
ZS177	Grid				Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. All fixed control points have no values for grid and elevation errors.

Table 25. Adjusted grid coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UPMAN	408983.223	0.015	777849.044	0.011	28.988	0.081	
UPTIG	425056.716	0.009	822742.326	0.008	22.012	0.077	
UPVIT	421181.693	0.009	814318.080	0.008	18.825	0.067	
ZGS100	410361.342	0.013	776384.498	0.011	16.872	0.077	
ZGS101	415759.669	?	784798.916	?	12.345	0.064	LL
ZS113	420486.928	0.009	811039.756	0.008	151.585	?	e

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

a. **ZGS-101**

horizontal accuracy	=	Fixed
vertical accuracy	=	6.4 cm< 10 cm

b. **ZGS-100**

horizontal accuracy	=	$\sqrt{((1.30)^2 + (1.10)^2}$
	=	$\sqrt{(1.69 + 1.21)}$
	=	1.70 cm< 20 cm
vertical accuracy	=	7.7 cm < 10 cm

c. **ZS-113**

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm< 20 cm
vertical accuracy	=	Fixed

d. **ZS-177**

horizontal accuracy	=	$\sqrt{((2.50)^2 + (1.70)^2}$
	=	$\sqrt{(6.25 + 2.89)}$
	=	3.02 cm< 20 cm
vertical accuracy	=	Fixed

e. **UP-MAN**

horizontal accuracy	=	$\sqrt{((1.50)^2 + (1.10)^2}$
	=	$\sqrt{(2.25 + 1.21)}$
	=	1.86 cm< 20 cm
vertical accuracy	=	8.10 cm< 10 cm

f. **UP-TIG**

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm< 20 cm
vertical accuracy	=	7.70 cm< 10 cm

g. **UP-VIT**

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm< 20 cm
vertical accuracy	=	6.70 cm< 10 cm

Table 26. Adjusted geodetic coordinates.

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
UPMAN	N7°02'10.91288"	E122°10'33.30241"	96.857	0.081	
UPTIG	N7°26'33.60615"	E122°19'15.00531"	89.890	0.077	
UPVIT	N7°21'59.09413"	E122°17'09.03227"	86.709	0.067	
ZGS100	N7°01'23.30256"	E122°11'18.30194"	84.730	0.077	
ZGS101	N7°05'57.59221"	E122°14'13.79610"	80.222	0.064	LL
ZS113	N7°20'12.30776"	E122°16'46.54305"	219.481	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points is indicated in Table 27.

Table 27. References 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)
ZGS100	2nd Order, GCP	7°01'23.30256"	122°11'18.30194"	84.73	776384.5	410361.3	16.872
ZGS101	2nd Order, GCP	7°05'57.59221"	122°14'13.79610"	80.222	784798.9	415759.7	12.345
ZS177	1st Order, BM	6°54'16.64645"	122°04'35.12376"	80.002	763304.3	397965.1	12.311
ZS113	Used as marker	7°20'12.30776"	122°16'46.54305"	219.481	811039.8	420486.9	151.585
UPMAN	UP Established	7°02'10.91288"	122°10'33.30241"	96.857	777849	408983.2	28.988
UPTIG	UP Established	7°26'33.60615"	122°19'15.00531"	89.89	822742.3	425056.7	22.012

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

Cross-section and as-built survey were conducted on October 4, 2015 along the upstream side of Vitali Bridge in Brgy. Vitali, Zamboanga City as shown in Figure 41. A GNSS receiver Trimble® SPS 882 in PPK survey technique was used to acquire the cross section of the river as shown in Figure 42. The established control point, UP-VIT, was used as base station for this survey.

Figure 41. Upstream portion of Vitali Bridge for cross-section

Figure 42. Cross-section Survey at Vitali Bridge in Brgy.Vitali, Zamboanga City.

The cross-sectional line length of Vitali Bridge is about 96.120 meters with 80 cross-sectional points. The cross-section diagram, planimetric map, and collected as-built data for Vitali Bridge are displayed in Figure 43 to Figure 45, respectively.

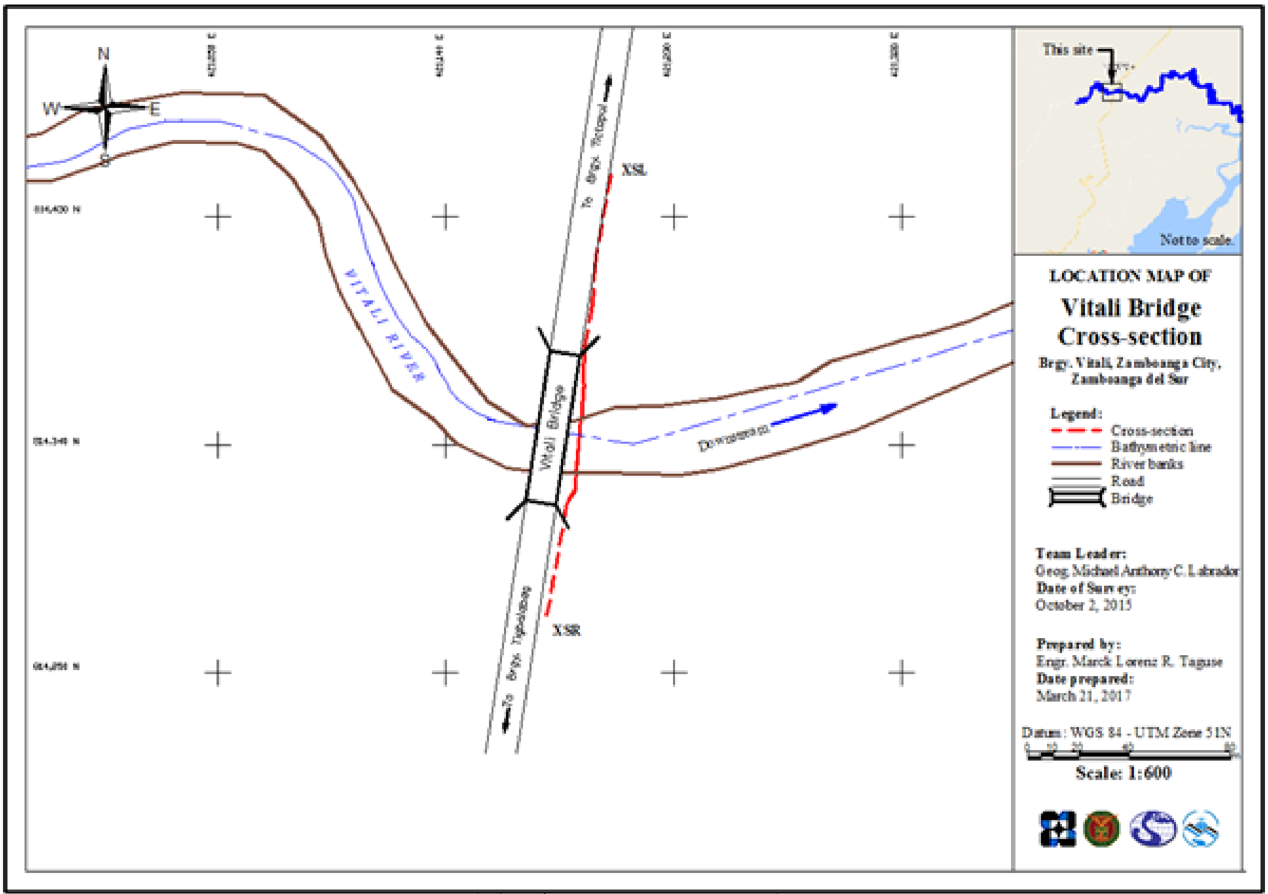


Figure 43. Vitali bridge cross-section planimetric map.

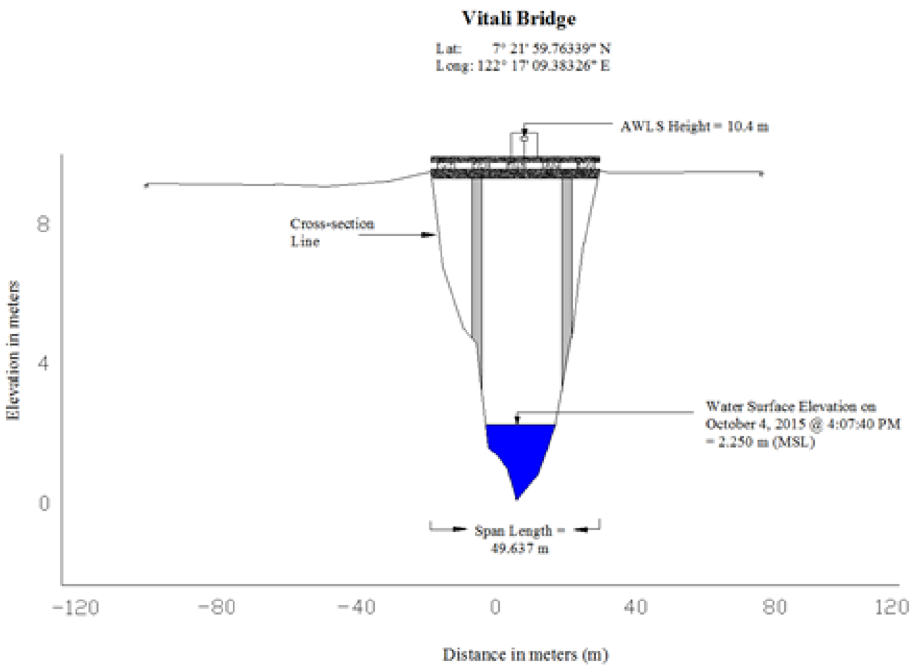


Figure 43. Vitali River cross-sectional diagram.

Bridge Data Form

Bridge Name: Vitali Bridge | Date: October 4, 2015

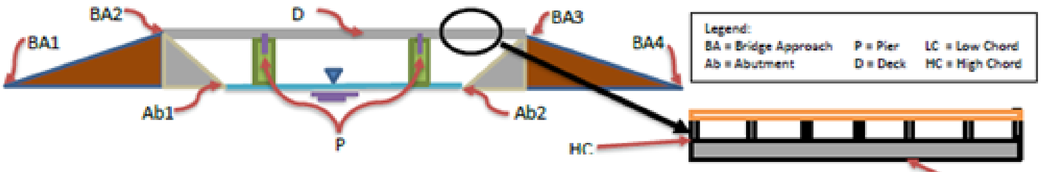
River Name: Vitali River | Time: 11:30 AM

Location (Brgy, City,Region): Bgy. Vitali, Zamboanga City, Zamboanga Peninsula

Survey Team: Michael Anthony Labrador, Precious Annie Lopez, Anthony Abogado, Kim Patrick Tort

Flow condition: low ✓ normal high | Weather Condition: fair ✓ rainy

Latitude: Longitude:



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

Elevation: Width: Span (BA3-BA2): 60.627 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	9.152	BA3	129.767	9.529
BA2	69.140	9.212	BA4	175.757	9.493

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

	Station (Distance from BA1)	Elevation
Ab1	84.88	6.769
Ab2	117.767	2.250

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

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

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	96.125	9.780	approx.
Pier 2	118.983	9.804	approx.

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

Figure 45. Vitali Bridge Data Form

Water surface elevation in MSL of Vitali River was determined using Trimble® SPS 882 in PPK mode survey on October 4, 2015 at 4:07PM. This was translated onto marking the bridge's pier using a digital level. The resulting water surface elevation data is 2.250 m above MSL. The markings on the bridge pier are shown in Figure 45. This shall serve as a reference for flow data gathering and depth gauge deployment of ADZU PHIL-LIDAR 1.

Figure 46. Water-level marking at Vitali Bridge's Footing.

4.6 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted on September 27 and October 1, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as seen in Figure 47. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 2.209 m was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous

Figure 47.Trimble® SPS 882 set-up for validation points acquisition survey.

Within the two (2) days of ground validation, the team covered the major roads of Tictapul, Vitali, Tagbalabag and Mangusu. The survey acquired 2,607 ground validation points with an approximate length of 15.8 km as presented in Figure 48. The gaps in the validation line as seen from Figure 48 were due to some difficulties in receiving satellite signals because of the presence of obstruction such as dense canopy cover of trees along the roads.

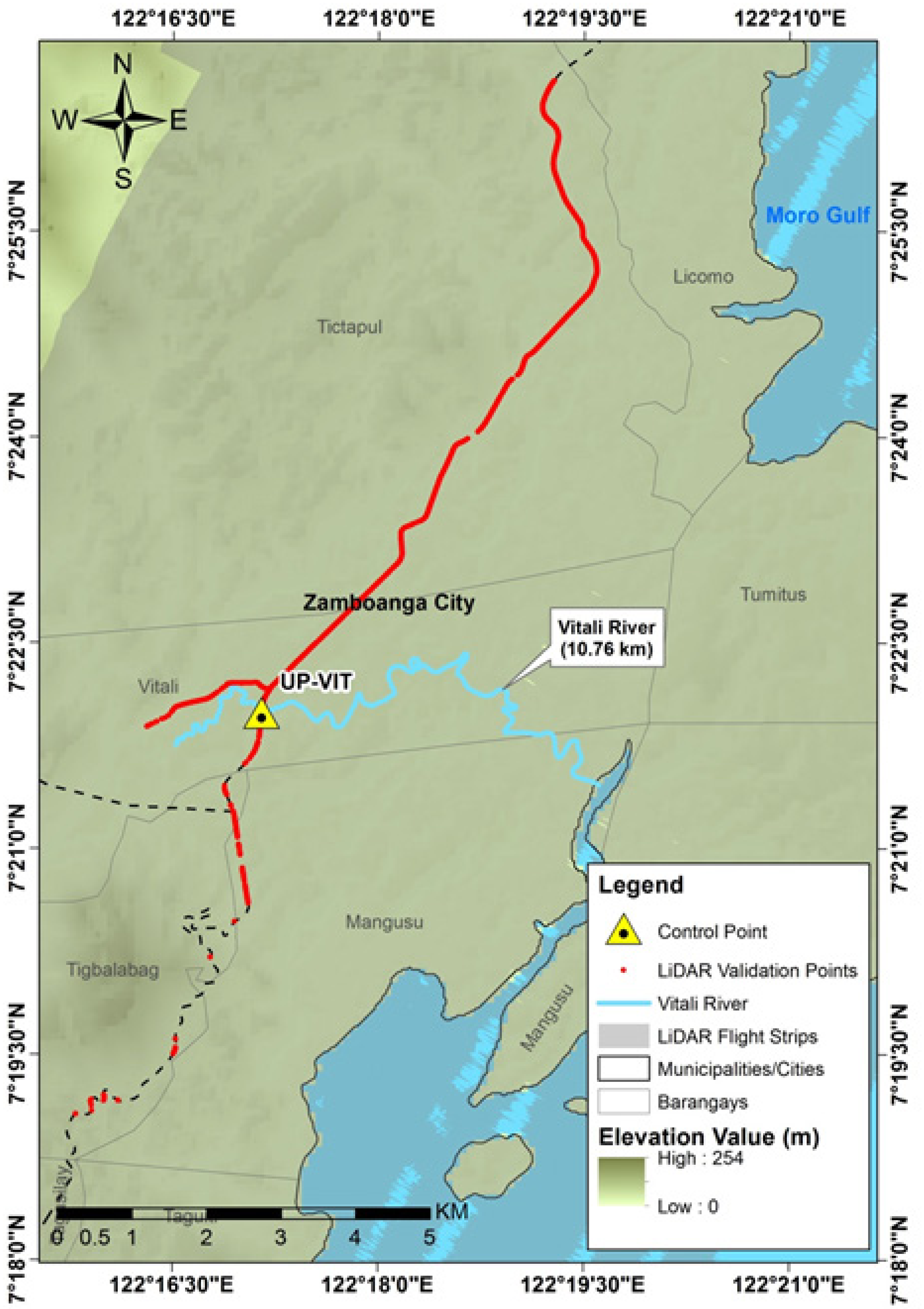


Figure 48. Ground validation points along Brgy. Cabaluay to Brgy. Sangali, Zamboanga City.

4.7 Bathymetric Survey

Bathymetric survey of Vitali River was conducted on October 1 to 2 2015 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ single beam echo sounder mounted on a boat as shown in Figure 49. The survey started in the upstream part of the river in Brgy. Vitali, Zamboanga City with coordinates 7°21'49.64726"122°16'36.12843" and ended at the mouth of the river in Brgy. Mangusu with coordinates7°21'26.31765"122°19'39.03213", also in Zamboanga City.

Figure 49. Bathymetry survey for Vitali River.

The bathymetric line length is about 10.8 km, with a total of 4,888 bathymetric points gathered using the reference point, UP-VIT as GNSS base station for the survey. The processed data were generated into map using a GIS software as shown in Figure 50.The gaps in the Bathymetric Survey of Vitali River were due to the difficulties in receiving satellite signals because of the presence of obstruction such as dense canopy cover of trees along the path during the survey.

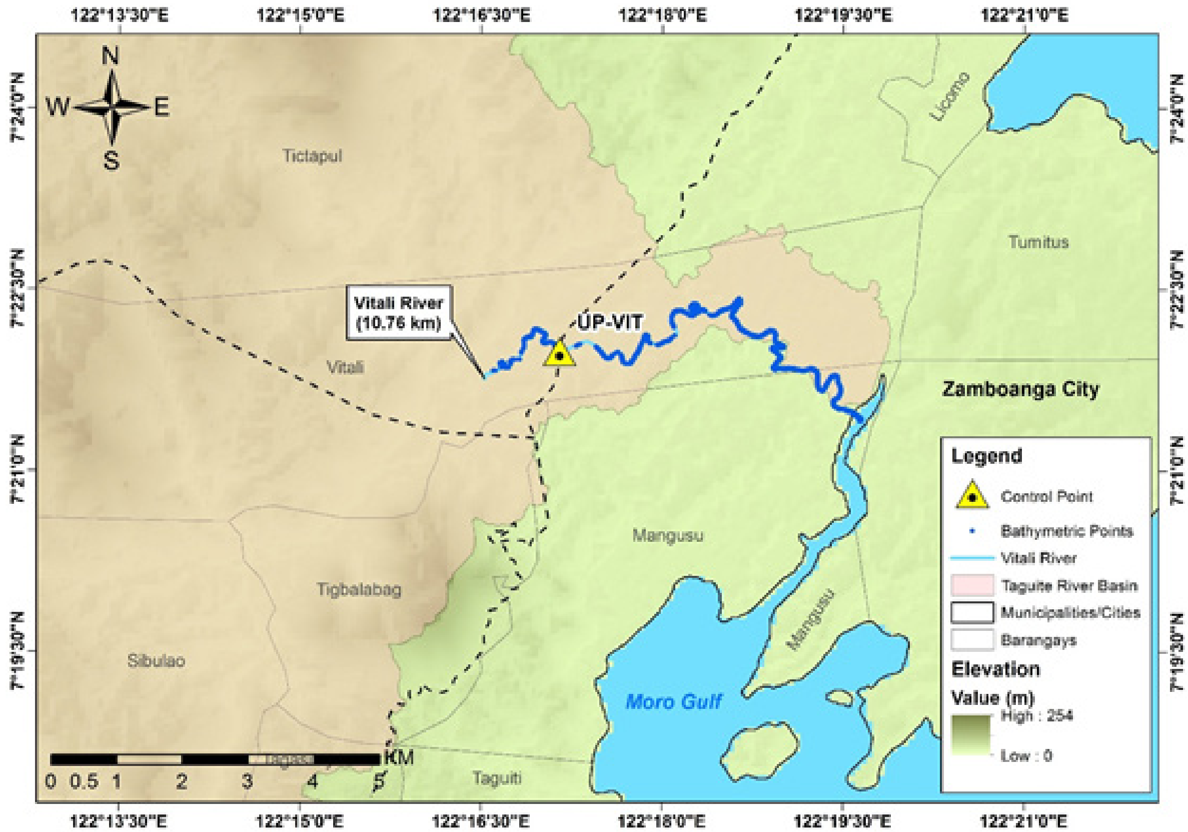


Figure 50. Bathymetric points gathered from Vitali River

A CAD drawing illustrating the Vitali riverbed profile where the highest elevation record is found in Brgy. Vitali and the lowest is after the Vitali Bridge is shown in Figure 51. An elevation drop of 2.9 meters was observed within the distance of about 10.76 km.

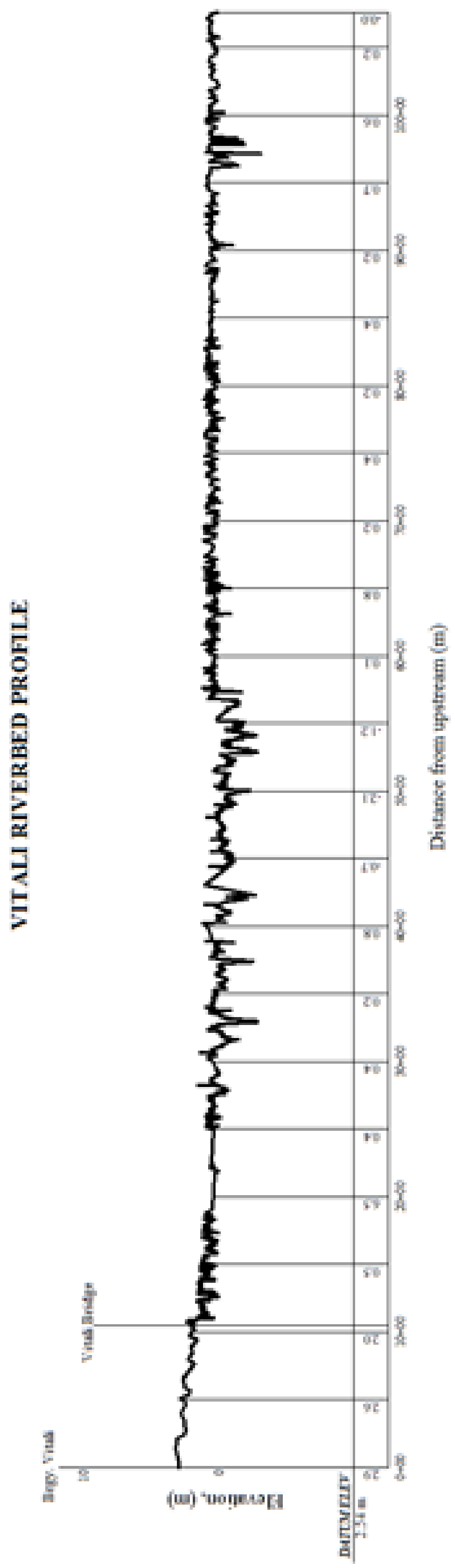


Figure 51. Vitali riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Vitaliriver were monitored, collected and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The ARG was installed in Vitali Bridge at Brgy.Vitali, Zamboanga City (Figure 1). The precipitation data collection started from November 25, 2015 at 12:00 AM to November 25, 2015 at 11:50 PM with 10 minutes recording interval.

The total precipitation for this event in Vitali Bridge ARG was 43.2 mm. It has a peak rainfall of 14.4 mm. on November 25, 2015 at 1:10 PM. The lag time between the peak rainfall and discharge is 4 hours.

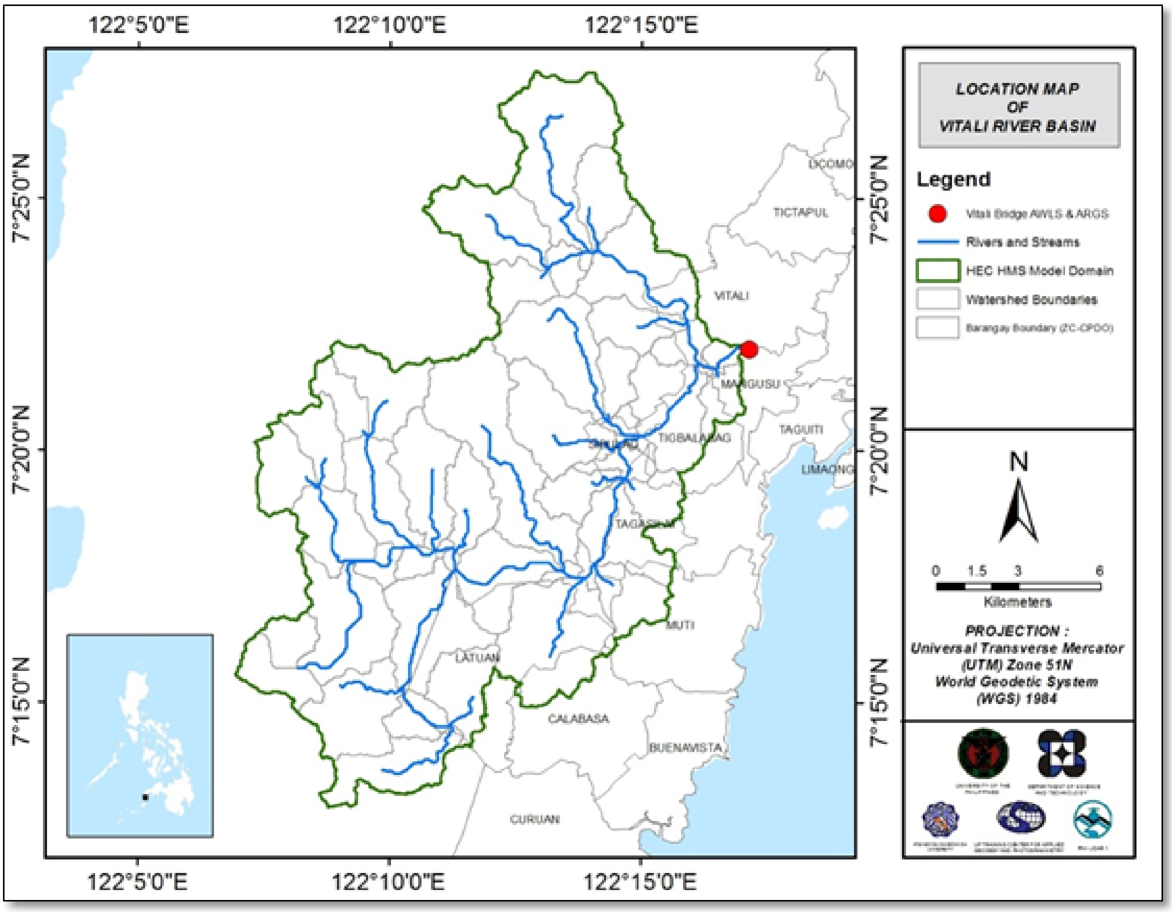


Figure 52. The location map of Vitali HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Vitali Bridge, Brgy. Vitali, Zamboanga City (7° 22’ 0.03” N, 122° 17’ 9.06” E). It gives the relationship between the observed water levels at Vitali Bridge and outflow of the watershed at this location.

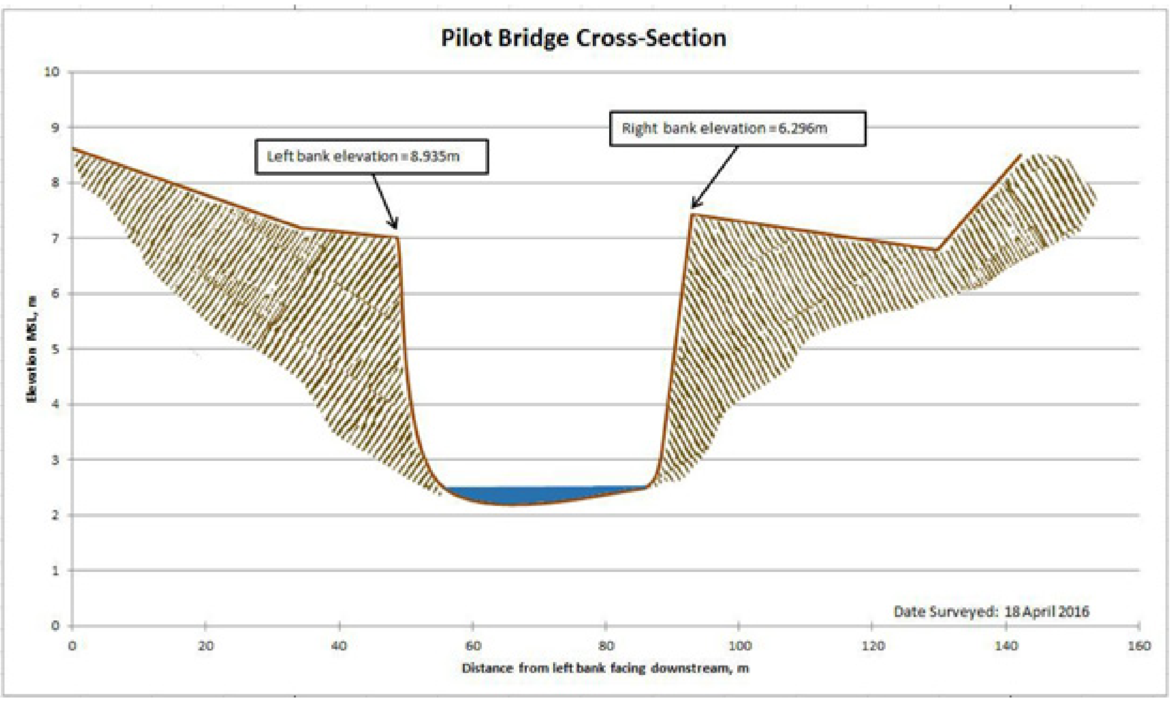


Figure 53. Cross-Section Plot of Vitali Bridge.

For Vitali Bridge, the rating curve is expressed as Q = 9E-05e1.0428h as shown in Figure 54.

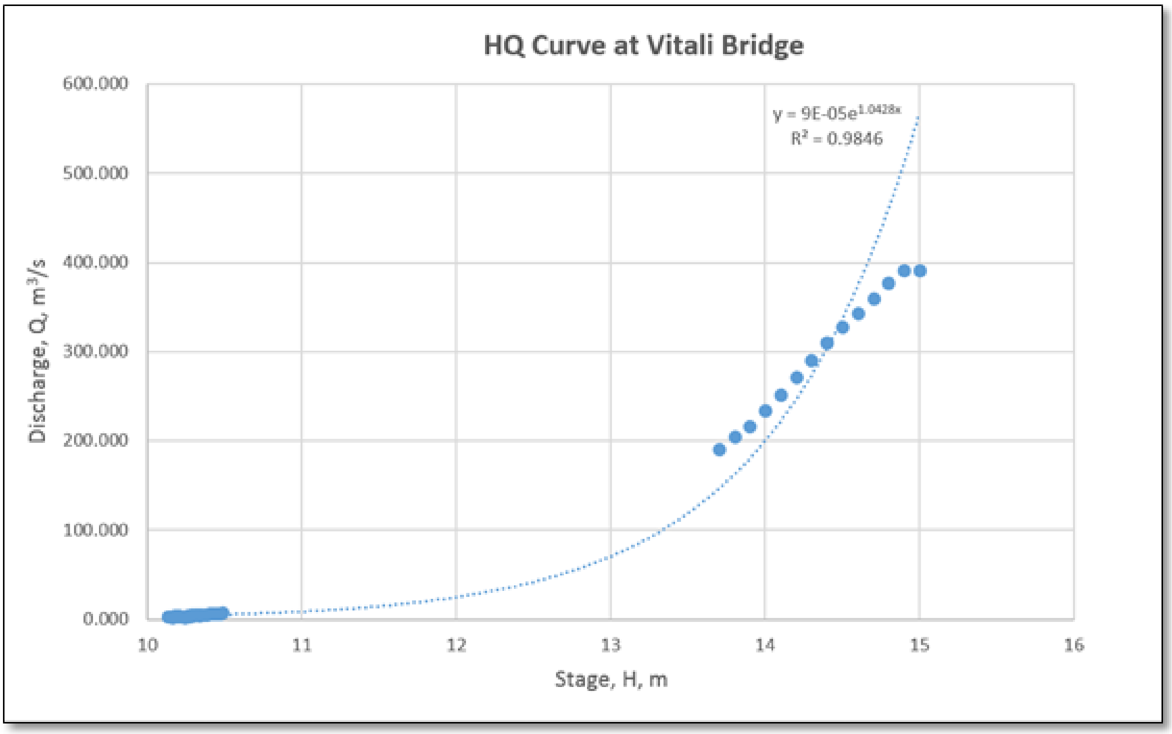


Figure 54. Rating Curve at Vitali Bridge, Brgy. Vitali, Zamboanga.

This rating curve equation was used to compute the river outflow at Vitali Bridge for the calibration of the HEC-HMS model shown in Figure 55. Peak discharge is 23.3 cubic meters per second at November 25, 2015 at 5:00PM.

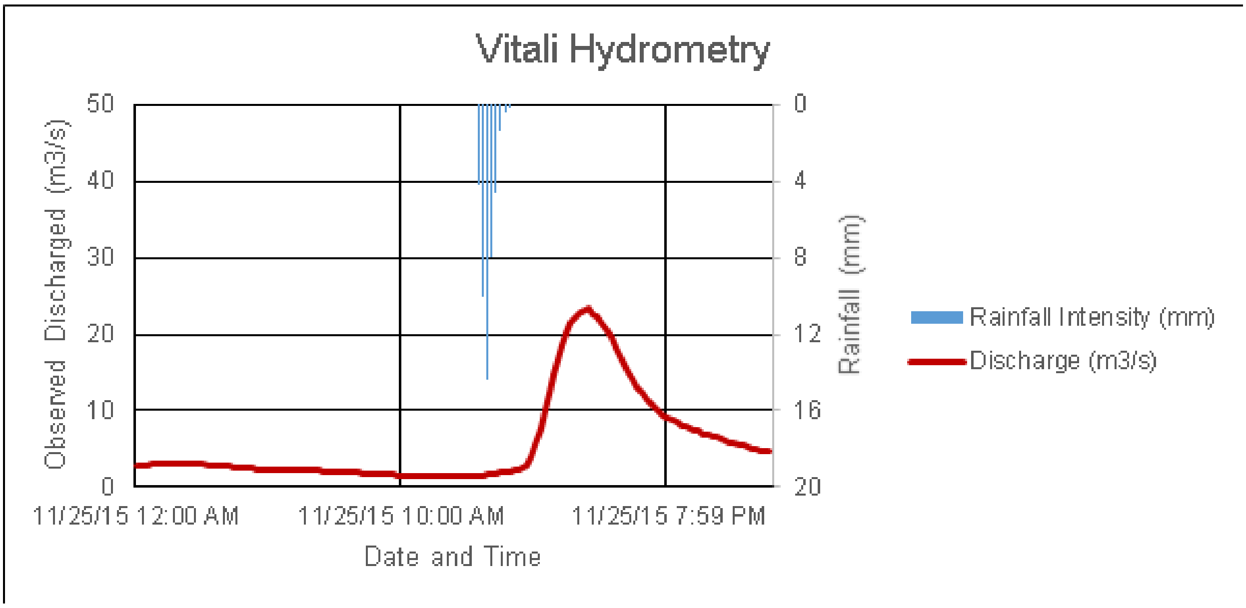


Figure 55. Rainfall and outflow data at Vitali Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City 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 Vitali watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 28. RIDF values for Zamboanga City 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	15.5	23.3	28.4	36.9	45.6	50.7	60	66.1	77.3
5	21.4	31.6	38.3	50.4	61.2	38.2	82.5	91.5	107.8
10	25.3	37.1	44.8	59.4	71.6	79.8	97.5	108.3	127.9
15	27.5	40.2	48.5	64.4	77.4	86.4	105.9	117.8	139.3
20	29	42.3	51.1	68	81.5	91	111.8	124.4	147.3
25	30.2	44	53.1	70.7	84.7	94.5	116.3	129.5	153.4
50	33.9	49.1	59.2	79.1	94.4	105.4	130.4	145.3	172.3
100	37.5	54.2	65.3	87.4	104	116.2	144.3	161	191.1

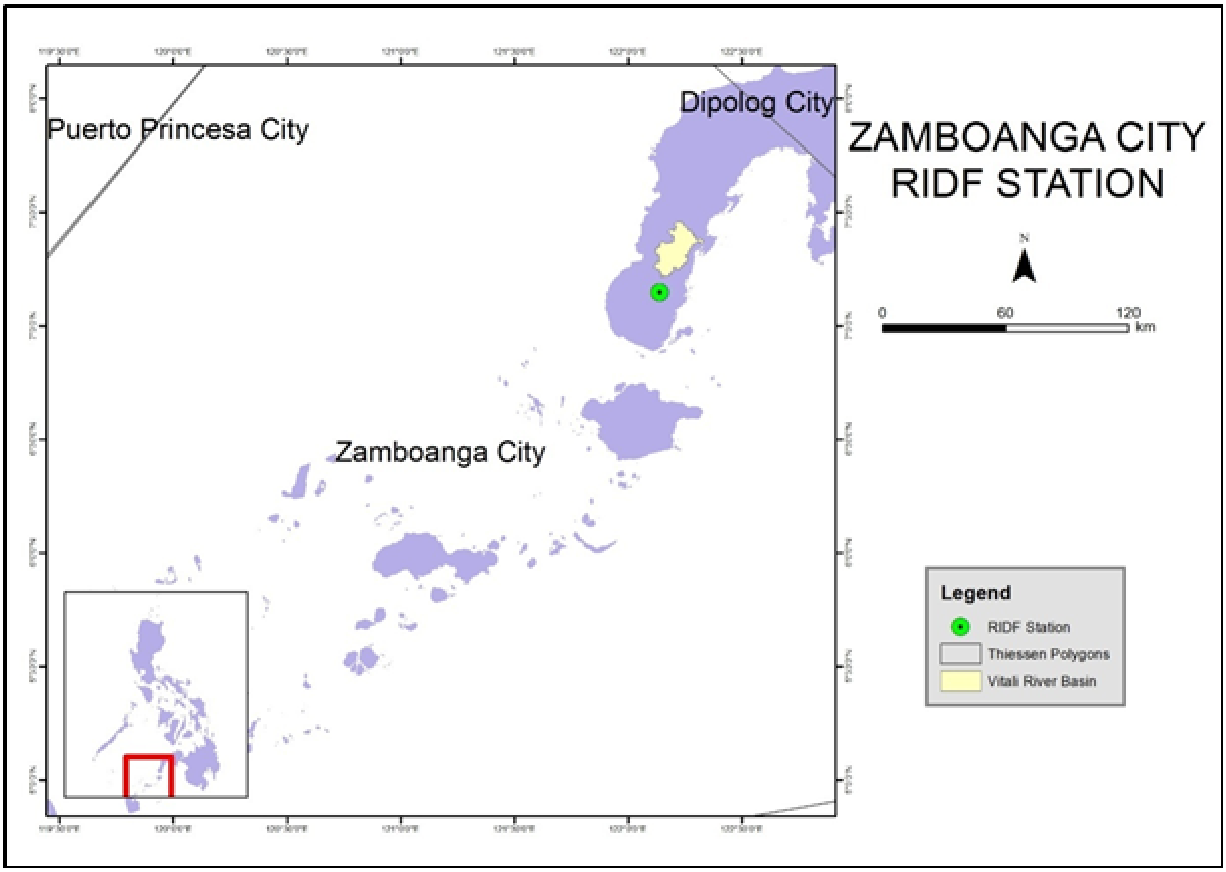


Figure 56. Zamboanga City RIDF location relative to Vitali River Basin.

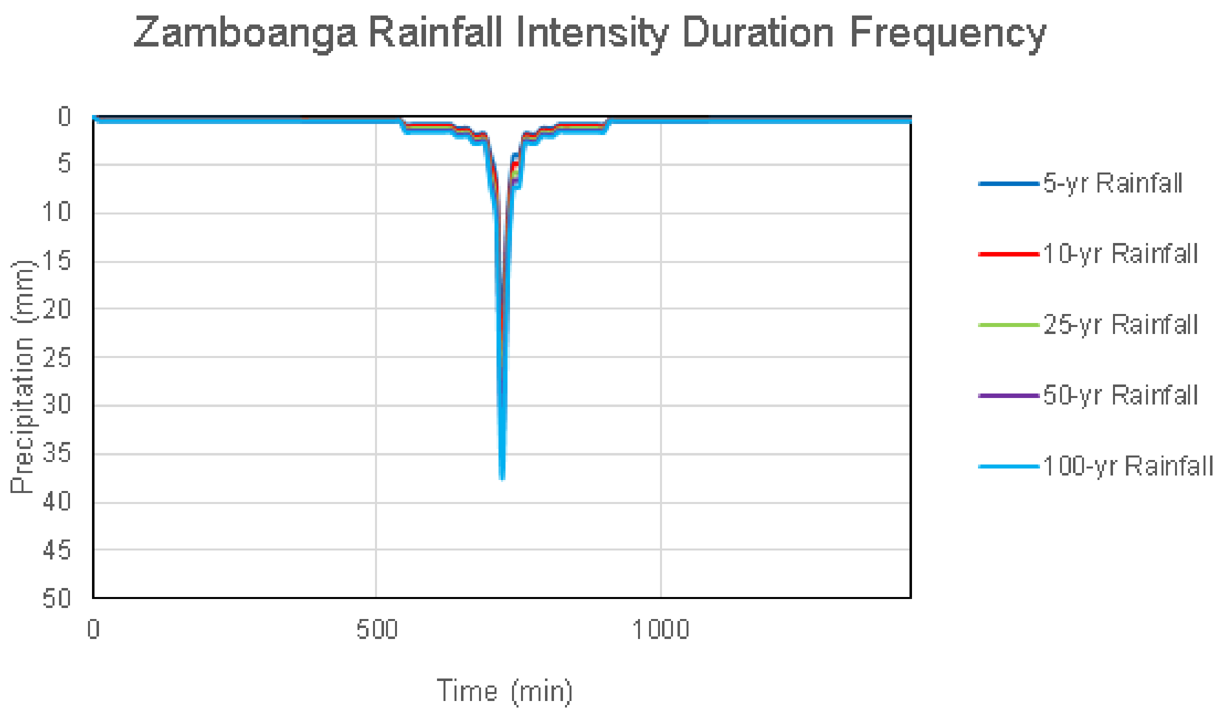


Figure 57. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils and Water Management. It is under the Department of Agriculture. The land cover data set is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Vitali River Basin are shown in Figures 58 and 59, respectively.

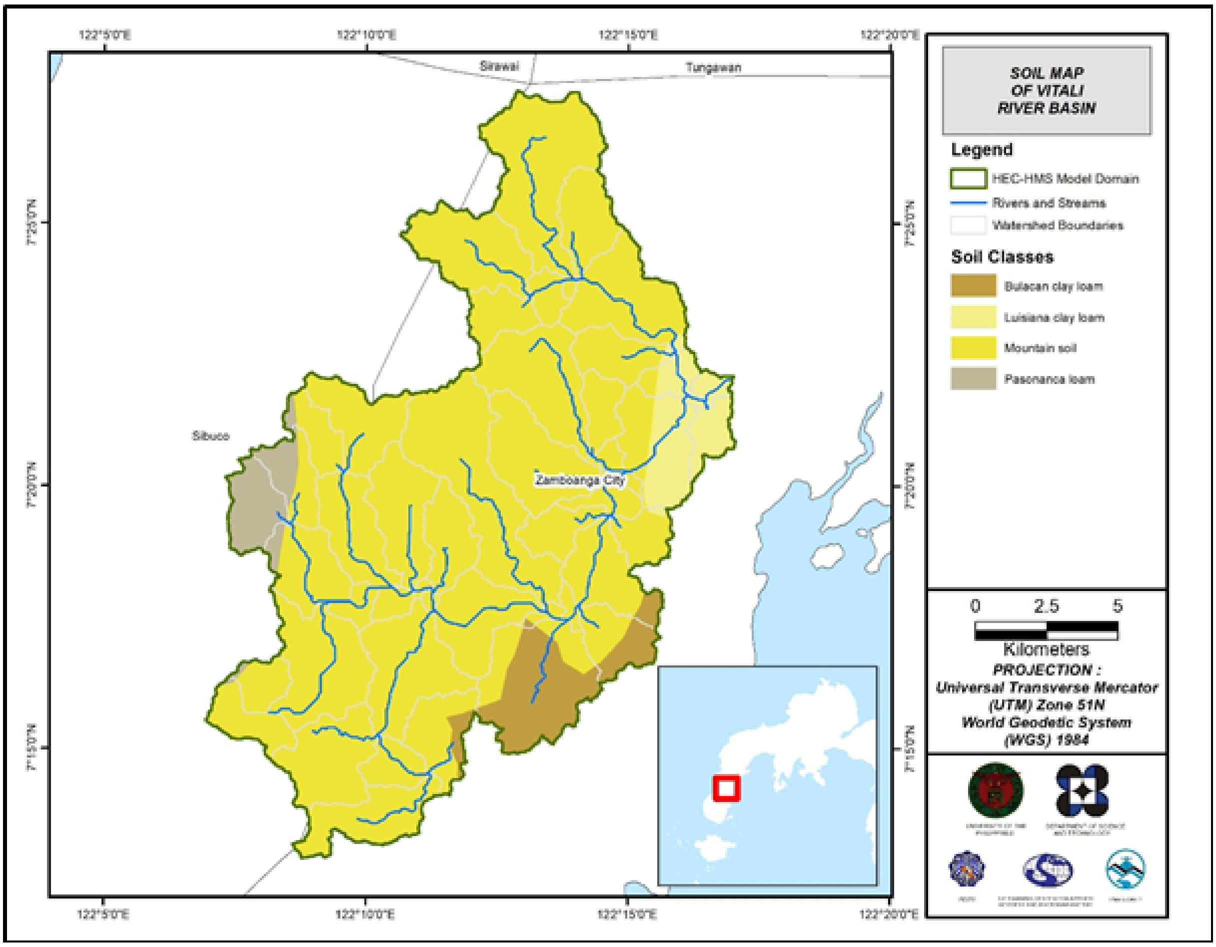


Figure 58.Soil Map of Vitali River Basin (Source: NAMRIA)

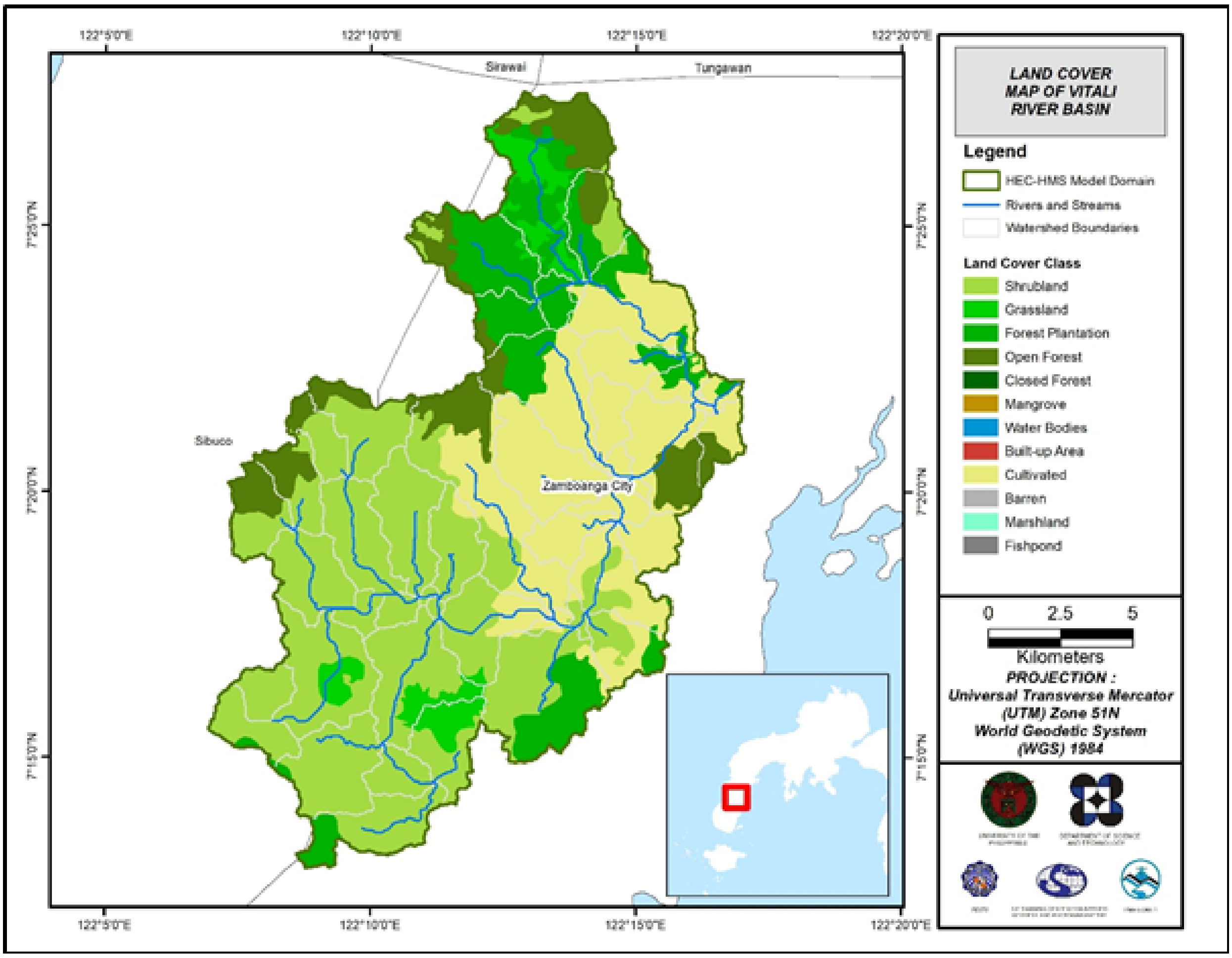


Figure 59. Land Cover Map of Vitali River Basin (Source: NAMRIA)

For Vitali, the soil classes identified were loam, clay loam and undifferentiated mountain soil. The land cover types identified were cultivated areas, shrubland, open and closed canopy forests and forest plantations.

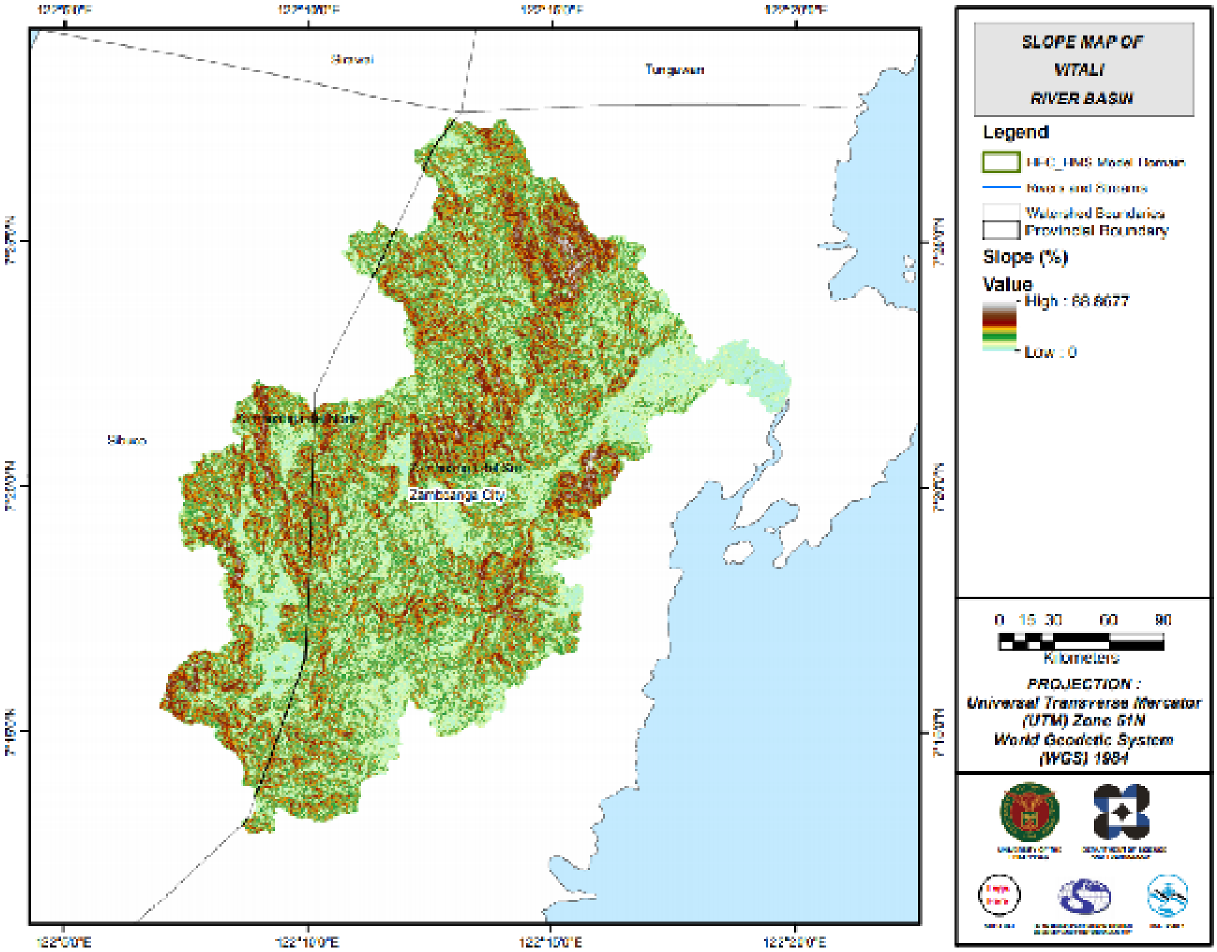


Figure 60. Slope Map of Vitali river basin

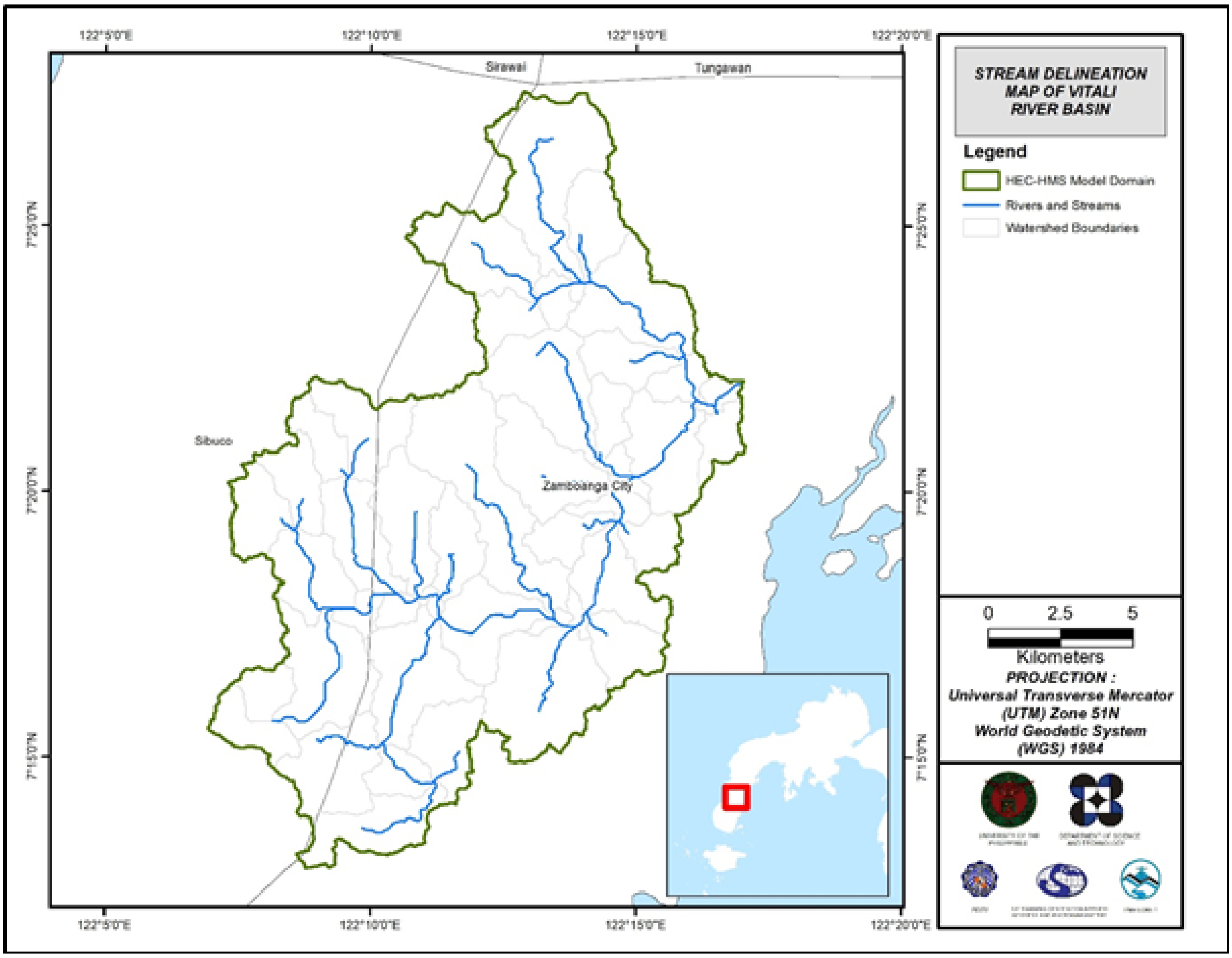


Figure 61. Stream delineation map of Vitali river basin

Using the SAR-based DEM, the Vitali basin was delineated and further subdivided into subbasins. The model consists of 49 sub basins, 24 reaches, and 24 junctions as shown in Figure 32. The main outlet is at Vitali Bridge.

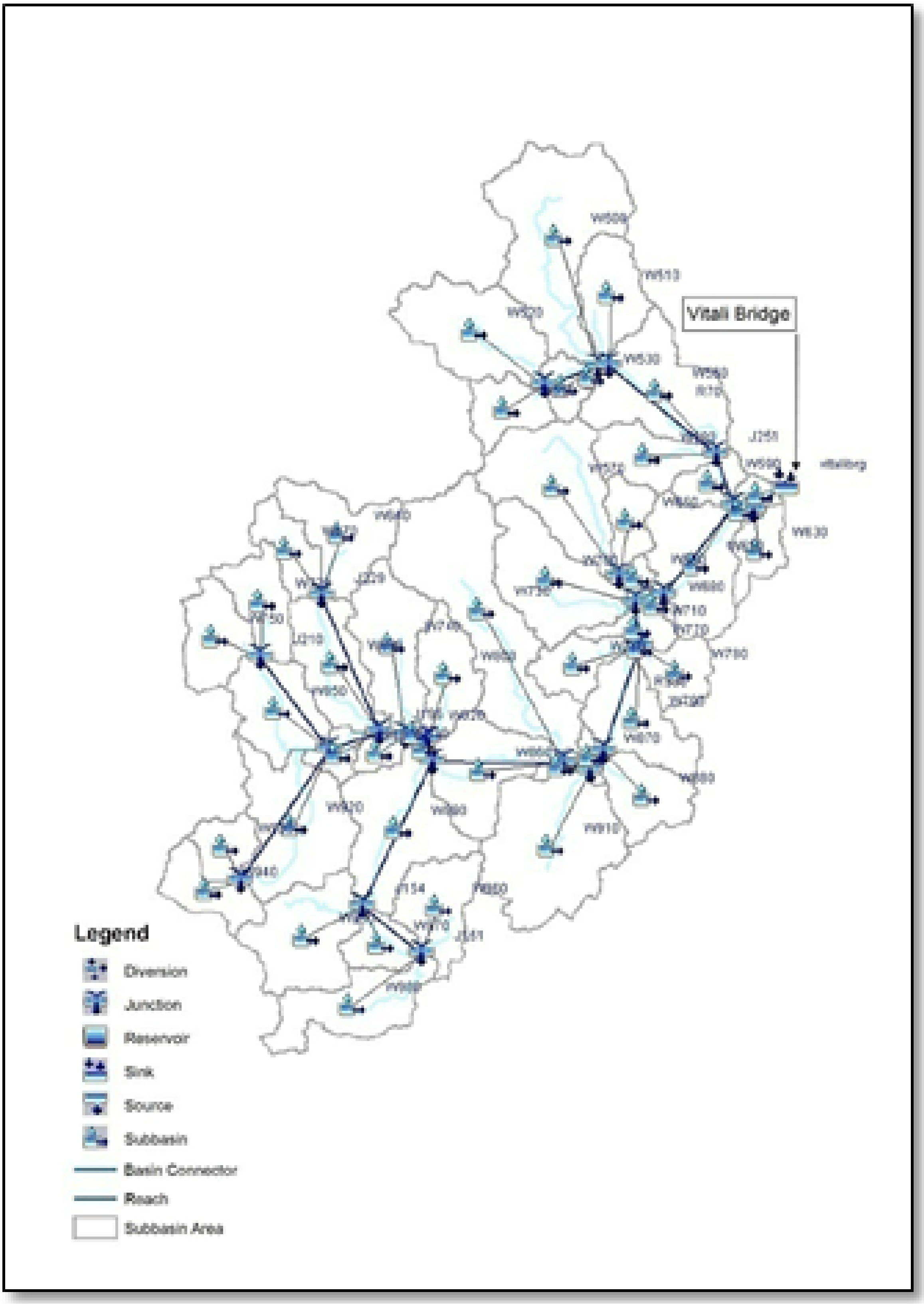


Figure 62. The Vitali river basin model generated using HEC-HMS

5.4 Cross-section Data

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

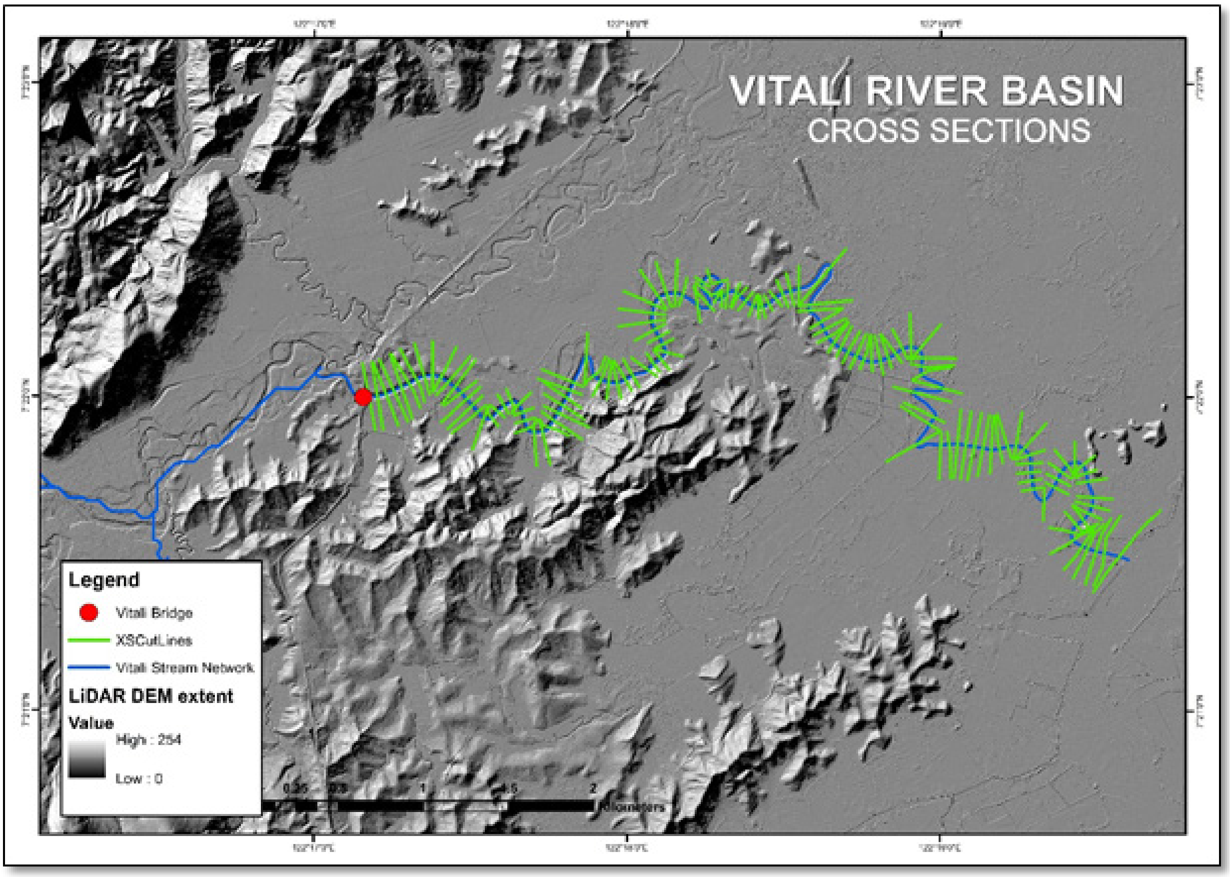


Figure 63. River cross-section of Vitali River generated through Arcmap HEC GeoRAS tool

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

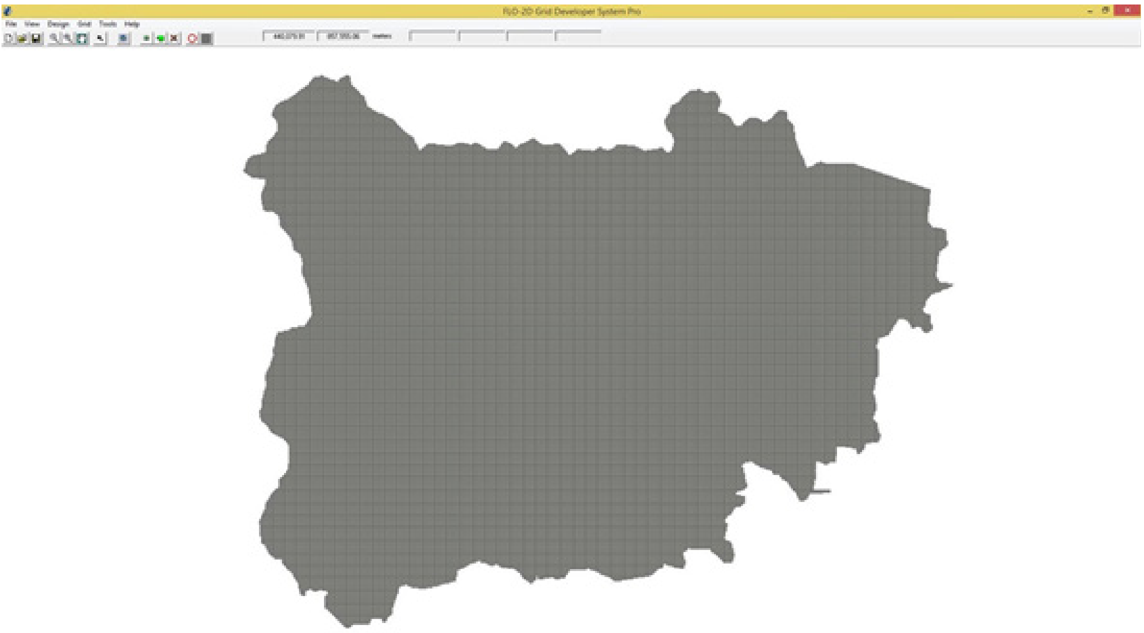


Figure 64. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 10.40424 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.

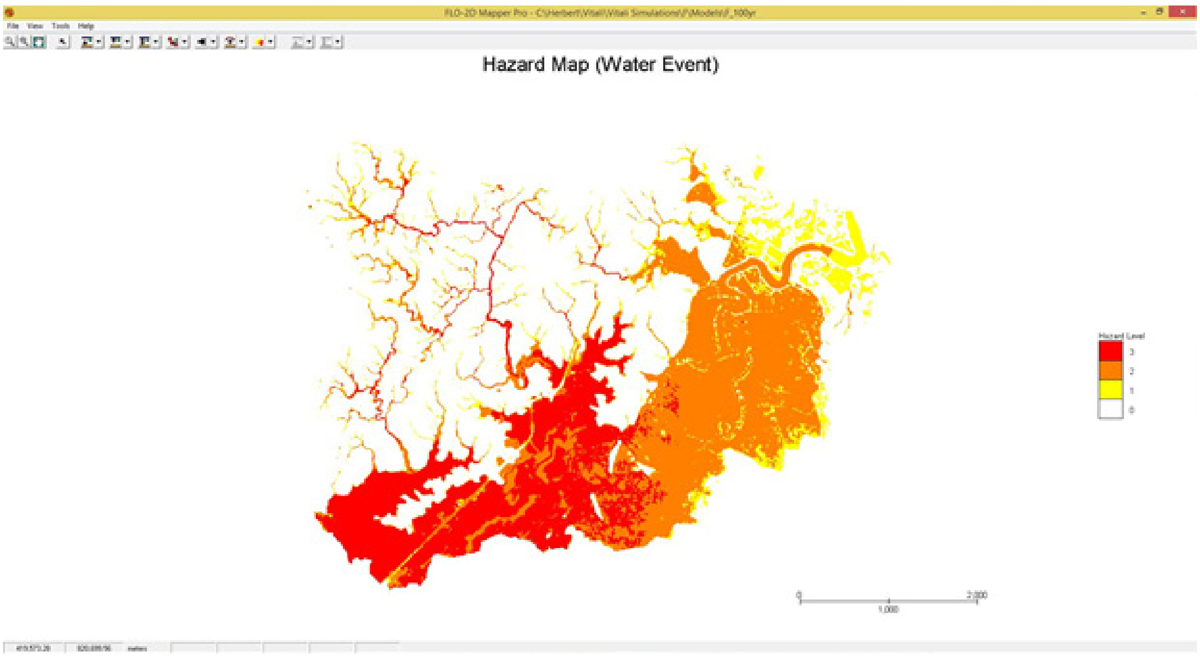


Figure 65. Generated 100-year rain return hazard map from FLO-2D Mapper.

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 23,962,900.00 m2.

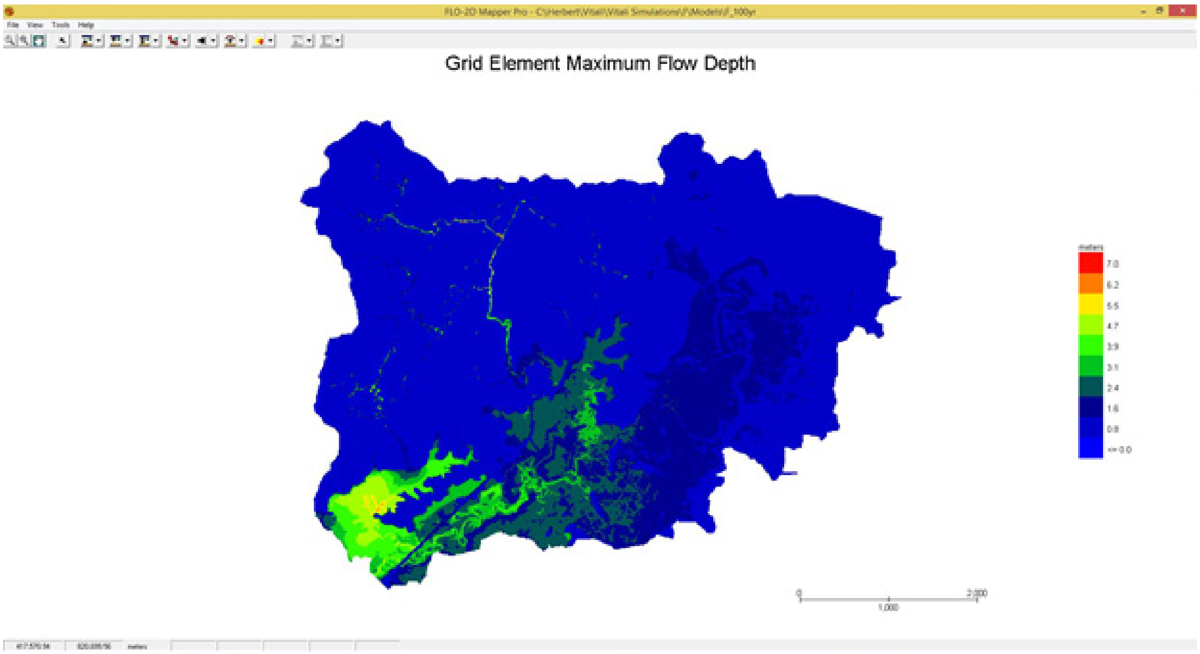


Figure 66. Generated 100-year rain return flow depth map from FLO-2D Mapper.

There is a total of 27,331,265.67 m3 of water entering the model. Of this amount, 4,613,095.60 m3 is due to rainfall while 22,718,170.07 m3 is inflow from other areas outside the model. 3,270,871.50 m3 of this water is lost to infiltration and interception, while 7,935,769.15 m3 is stored by the flood plain. The rest, amounting up to 16,124,616.29m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Vitali HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 37 shows the comparison between the two discharge data.

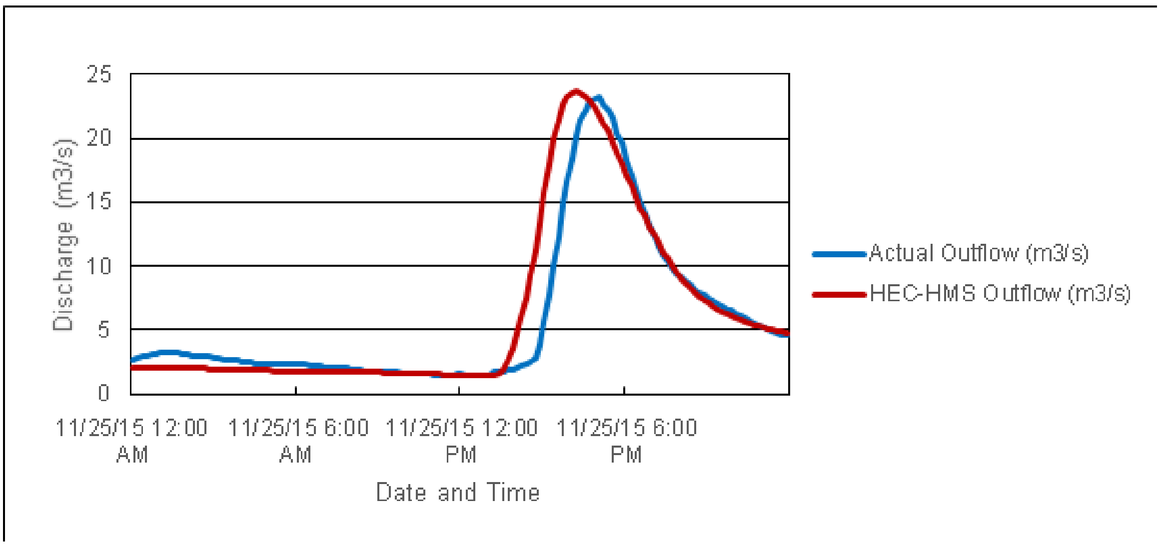


Figure 67. Outflow Hydrograph of Vitali produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for Vitali

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.080 – 1.74
			Curve Number	12 – 22.23
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.18 – 10.01
			Storage Coefficient (hr)	0.046 – 2.53
	Baseflow	Recession	Recession Constant	0.5
			Ratio to Peak	0.01
Reach	Routing	Muskingum-Cunge	Slope	0.01
			Manning's n	0.0001-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.080mm to 1.74mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. For Vitali, the basin mostly consists of cultivated and tree plantation areas and open and closed canopy forests and the soil consists of loam, clay loam and undifferentiated mountain soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.046 hours to 10.01 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 0.5 indicates that the basin is moderately likely to go back to its original discharge. Ratio to peak of 0.01 indicates a steep receding limb of the outflow hydrograph.

Table 30. Summary of the Efficiency Test of Vitali HMS Model

Accuracy Measure	Value
RMSE	29.13778
r2	0.09846
NSE	29.13778
PBIAS	-5.98667
RSR	0.402172

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 29.13778 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.09846.

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 0.838258.

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 -5.98667.

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 0.402172.

5.7 Calculated outflow hydrographs and Discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph in Figure 68 shows the Vitali outflow using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

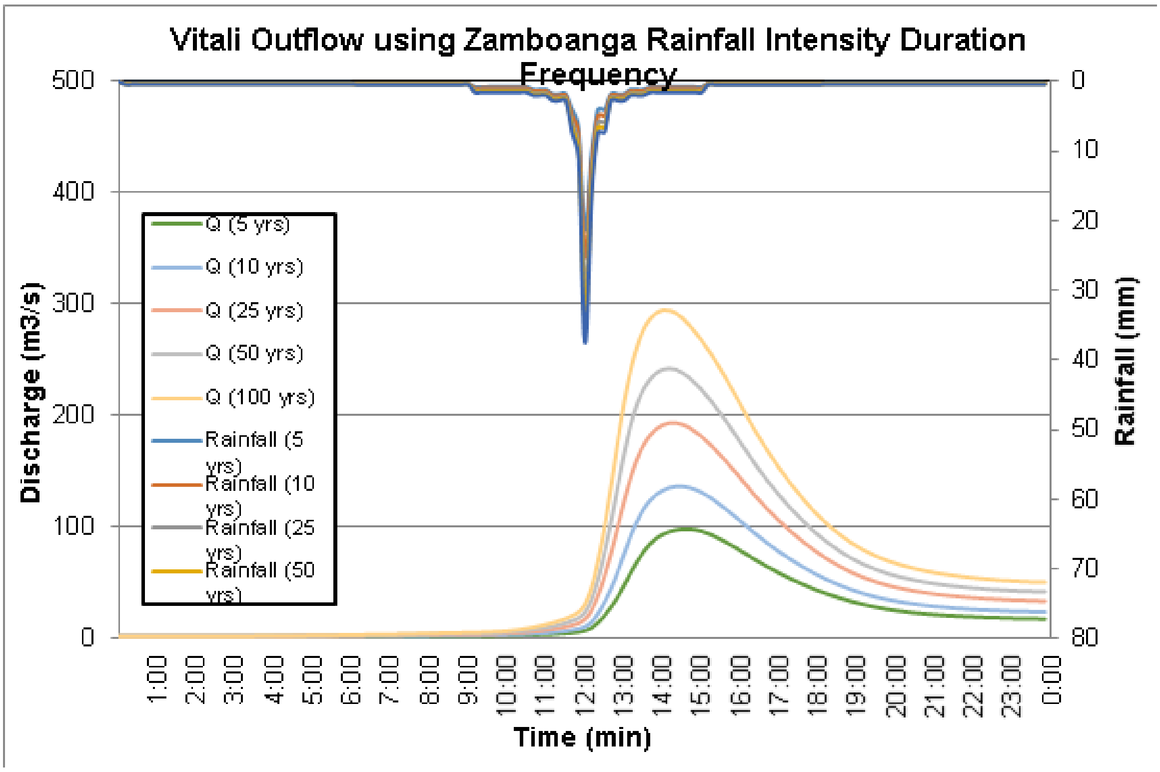


Figure 68. .Outflow hydrograph at Vitali Bridge Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Vitali discharge using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Vitali HECHMS Model outflow using the Zamboanga City RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	91.5	21.40	72.9	2 hours, 50 minutes
10-Year	108.3	25.30	100.9	2 hours, 20 minutes
25-Year	129.5	30.20	142.2	2 hours, 10 minutes
50-Year	145.3	33.90	176.7	2 hours, 10 minutes
100-Year	161	37.50	214.7	2 hours

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Vitali River using the calibrated HMS base flow is shown in Figure 69.

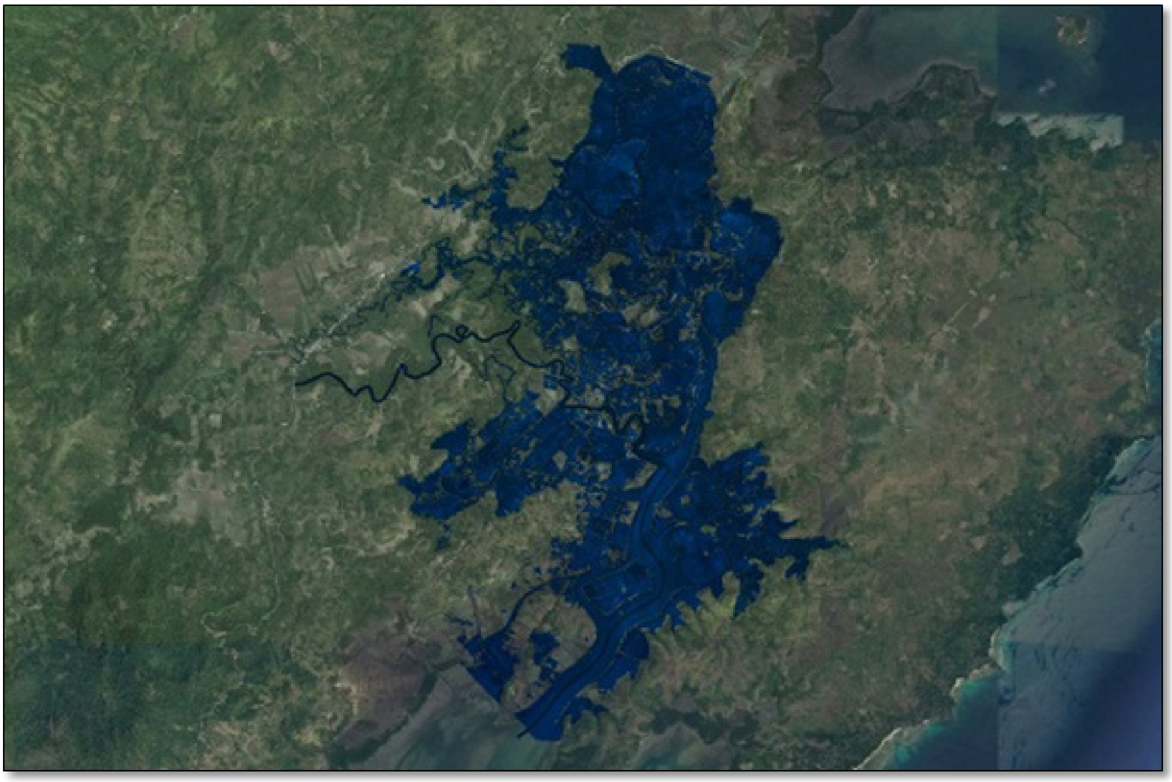


Figure 69. Sample output of Vitali RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 70 to Figure 75 shows the 5-, 25-, and 100-year rain return scenarios of the Vitali floodplain.

The generated flood hazard maps for the Vitali 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 32. Municipalities affected in Vitali-Tigbao floodplain.

Municipality	Total Area (km2)	Area Flooded (km2)	% Flooded
Zamboanga City	1496.29	195.07	13%
Tungawan	344.02	5.25	2%

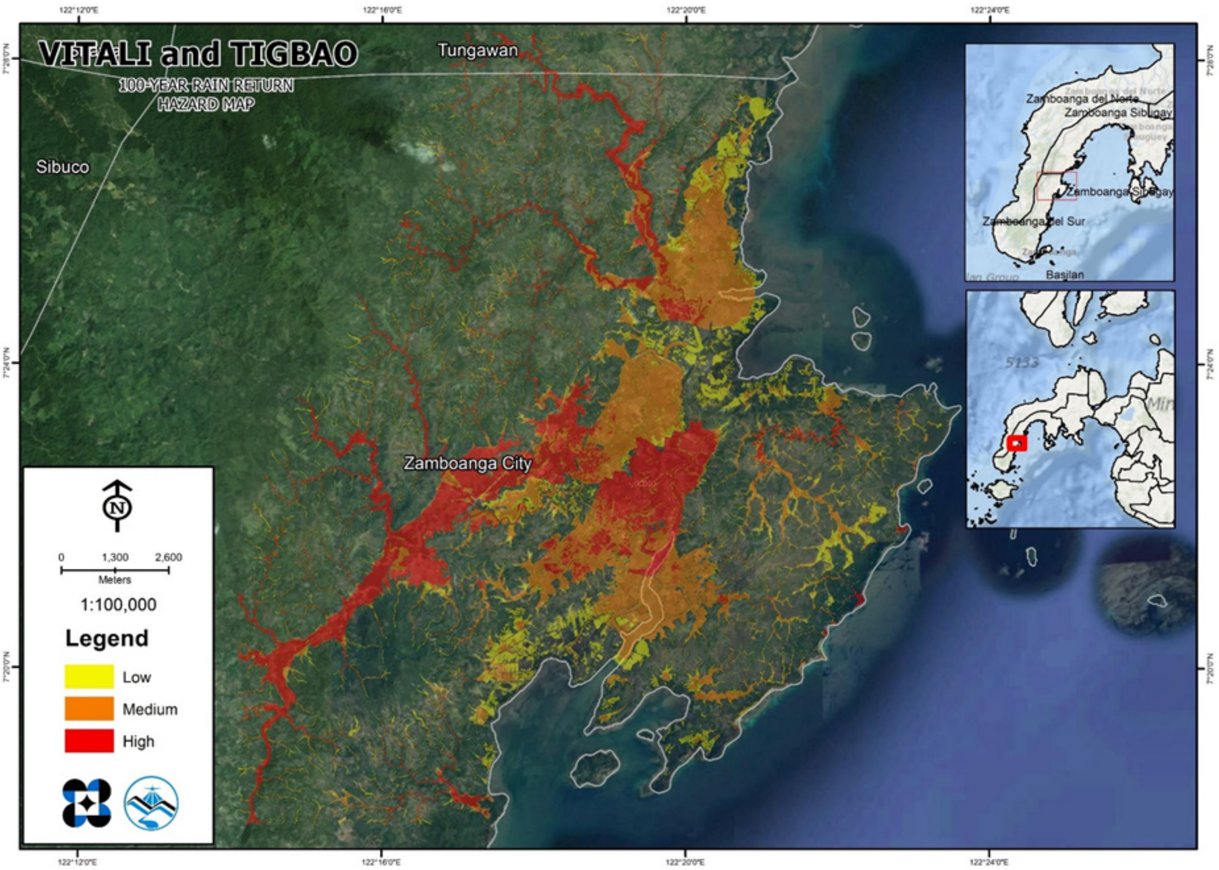


Figure 70. 100-year Flood Hazard Map for Vitali Floodplain.

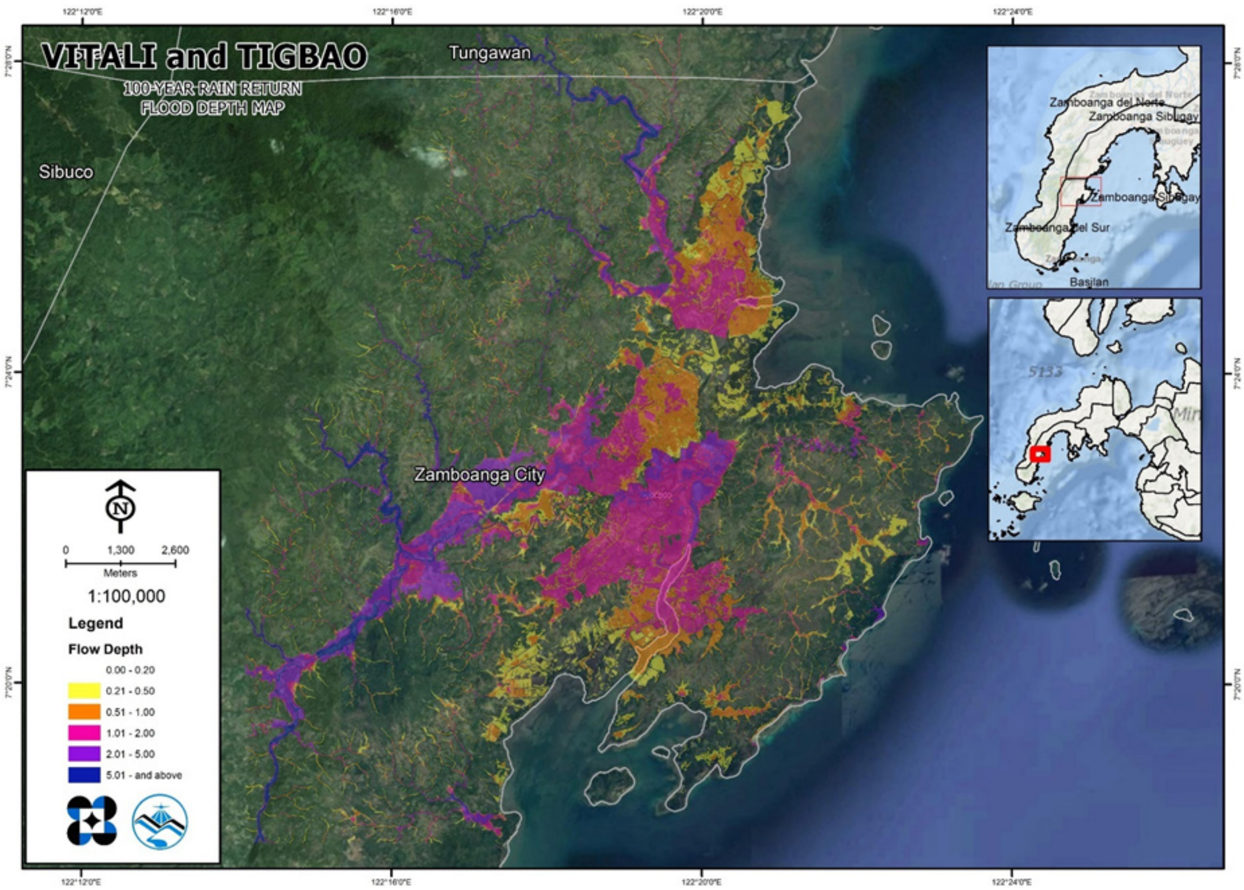


Figure 71. 100-year Flow Depth Map for Vitali Floodplain.

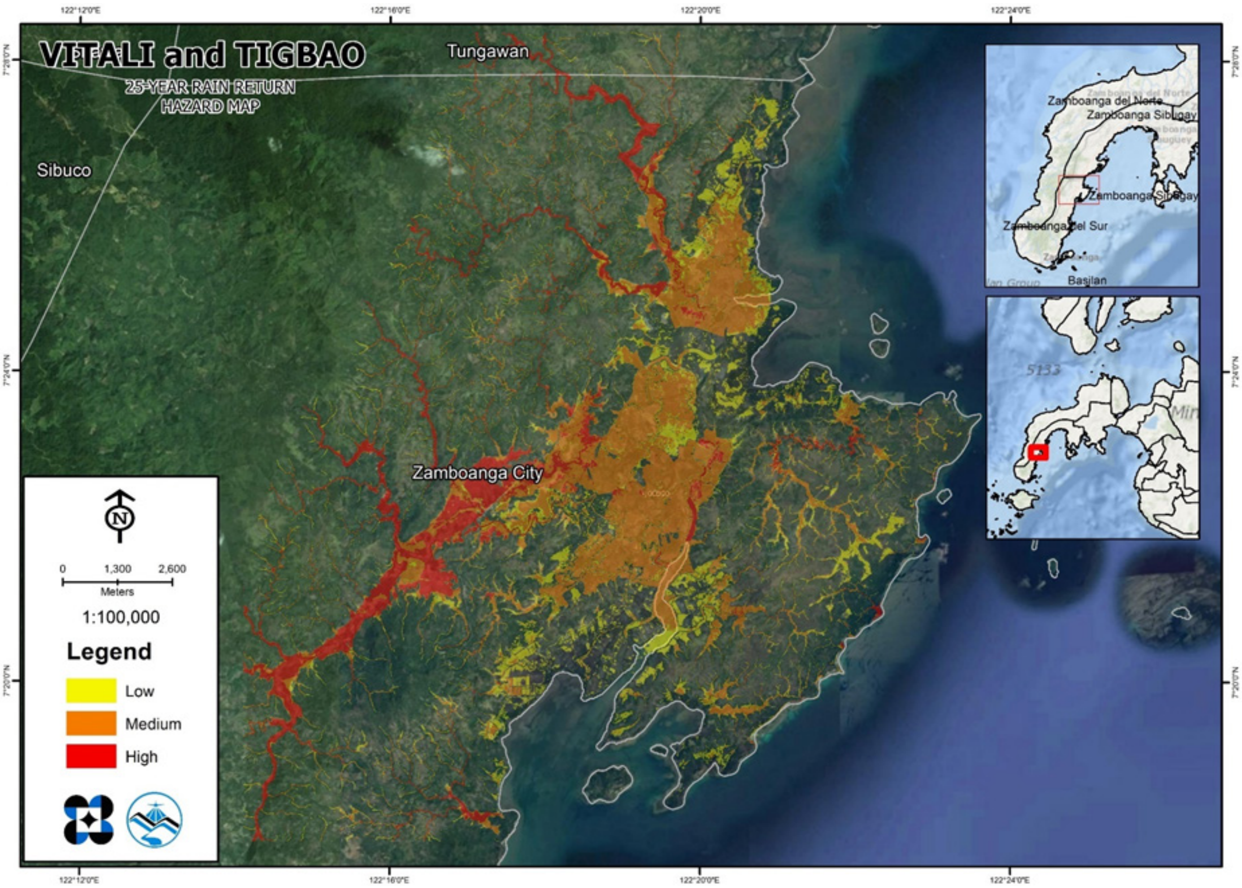


Figure 72. 25-year Flood Hazard Map for Vitali Floodplain

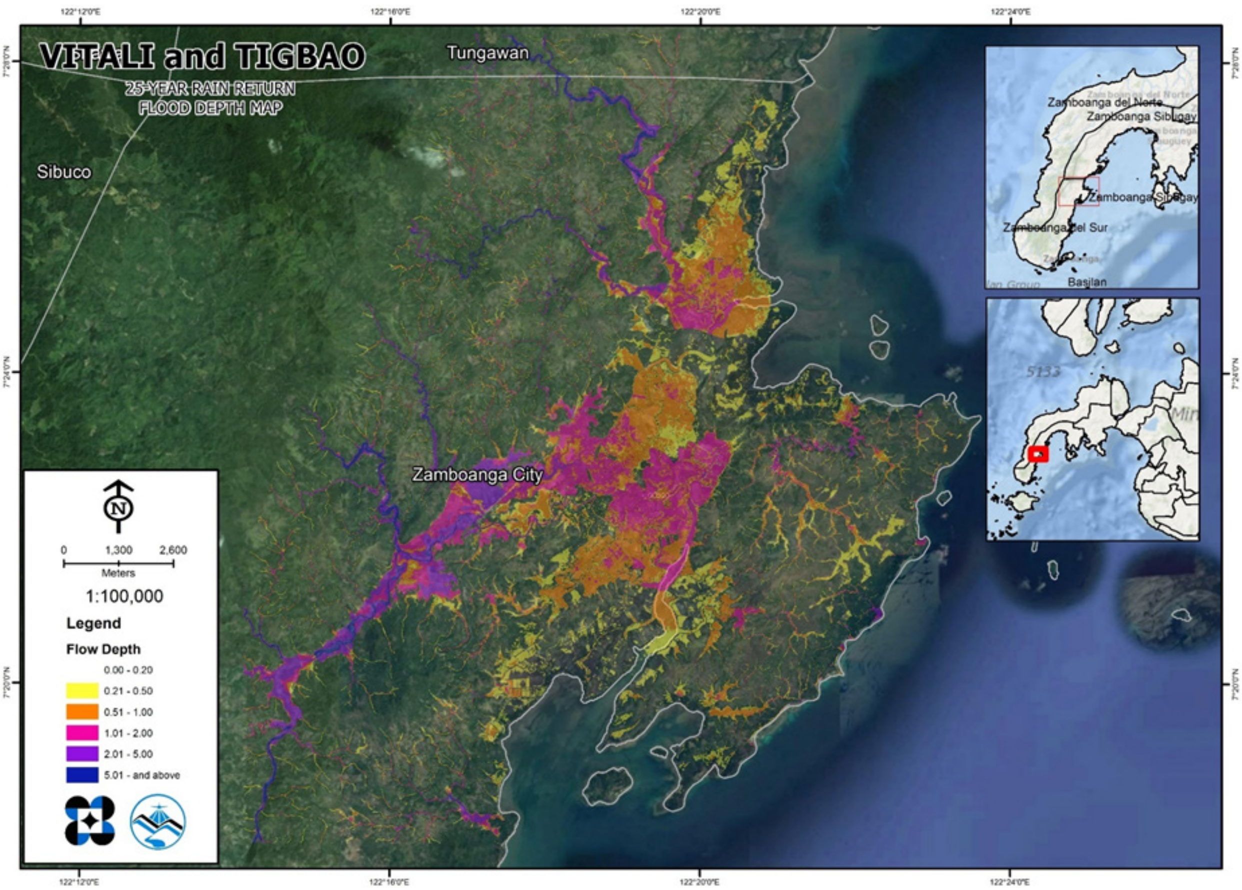


Figure 73. 25-year Flow Depth Map for Vitali Floodplain.

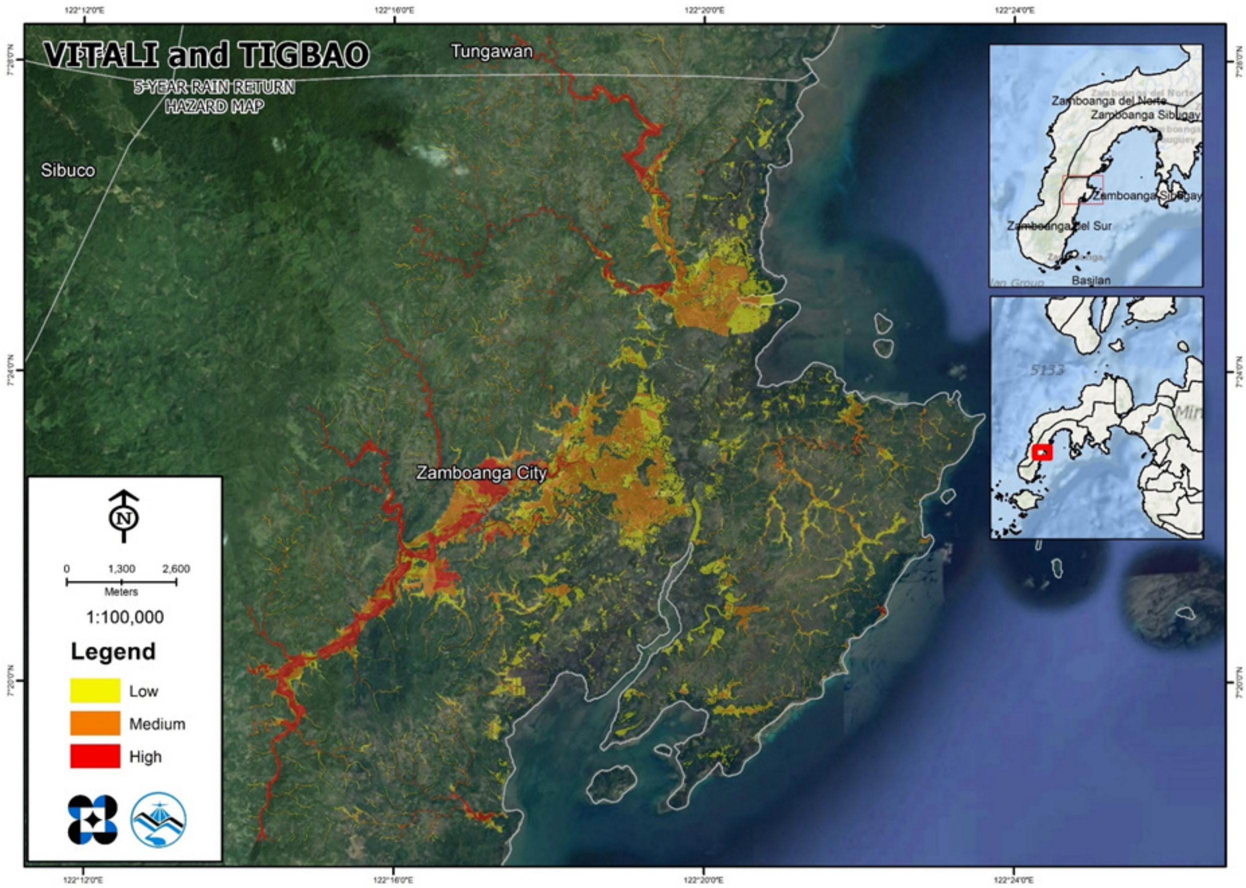


Figure 74. 5-year Flood Hazard Map for Vitali Floodplain

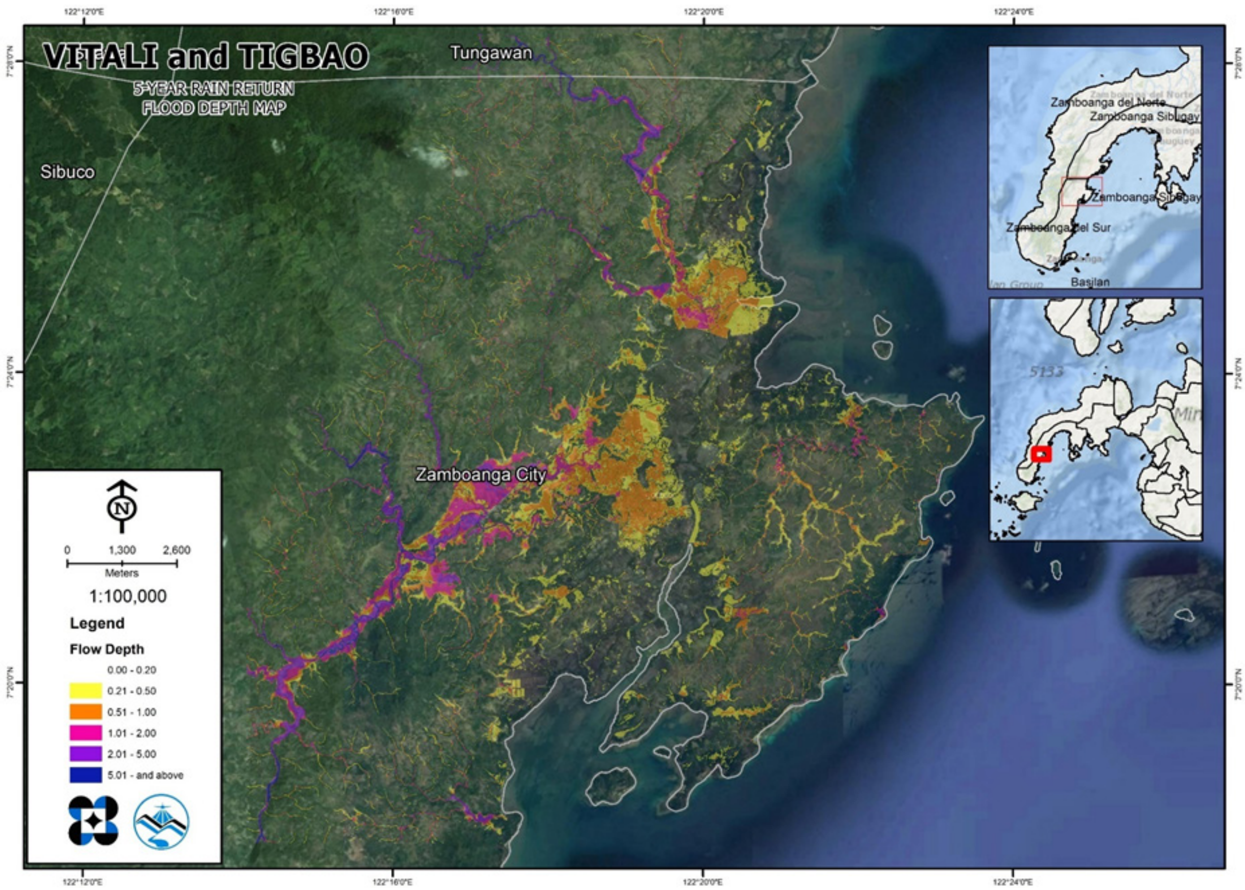


Figure 75. 5-year Flood Depth Map for VitaliFloodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Tigbao river basin, grouped by municipality, are listed below. For the said basin, 11 barangays in two municipalities are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 10.82% of the municipality of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.96% of the area will experience flood levels of 0.21 to 0.50 meters while 0.67%, 0.34%, 0.21%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Zamboanga City (in sq. km.)				
	Licomo	Limaong	Mangusu	Tagasilay	Taguiti
0.03-0.20	10.7	18.48	19.79	3.61	3.65
0.21-0.50	2.05	1.73	1.96	0.13	0.14
0.51-1.00	0.89	0.64	0.43	0.056	0.1
1.01-2.00	0.084	0.14	0.11	0.015	0.11
2.01-5.00	0.031	0.017	0.0066	0.0002	0.098
> 5.00	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Zamboanga City (in sq. km.)				
	Tictapul	Tigbalabag	Tumitus	Vitali	
0.03-0.20	59.16	12.34	16.09	18.01	
0.21-0.50	3.54	0.54	1.46	2.85	
0.51-1.00	3.16	0.37	0.63	3.77	
1.01-2.00	1.89	0.44	0.27	2	
2.01-5.00	1.43	0.4	0.022	1.1	
> 5.00	0.32	0.054	0	0.16	

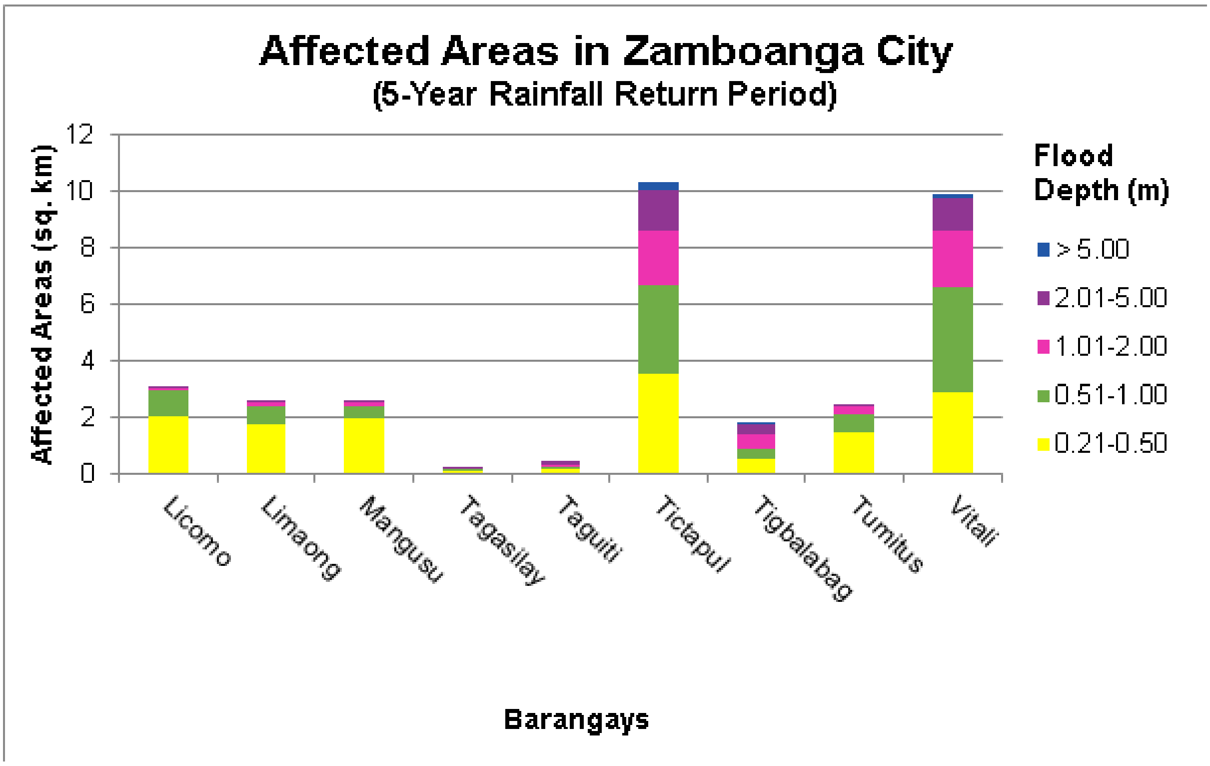


Figure 76. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

For the 5-year return period, 1.42% of the municipality of Tungawan with an area of 344.0154 sq. km. will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.01%, 0.03%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Tungawan, Zamboanga Sibugay during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tungawan (in sq. km.)
	San Pedro
0.03-0.20	4.87
0.21-0.50	0.084
0.51-1.00	0.065
1.01-2.00	0.049
2.01-5.00	0.1
> 5.00	0.074

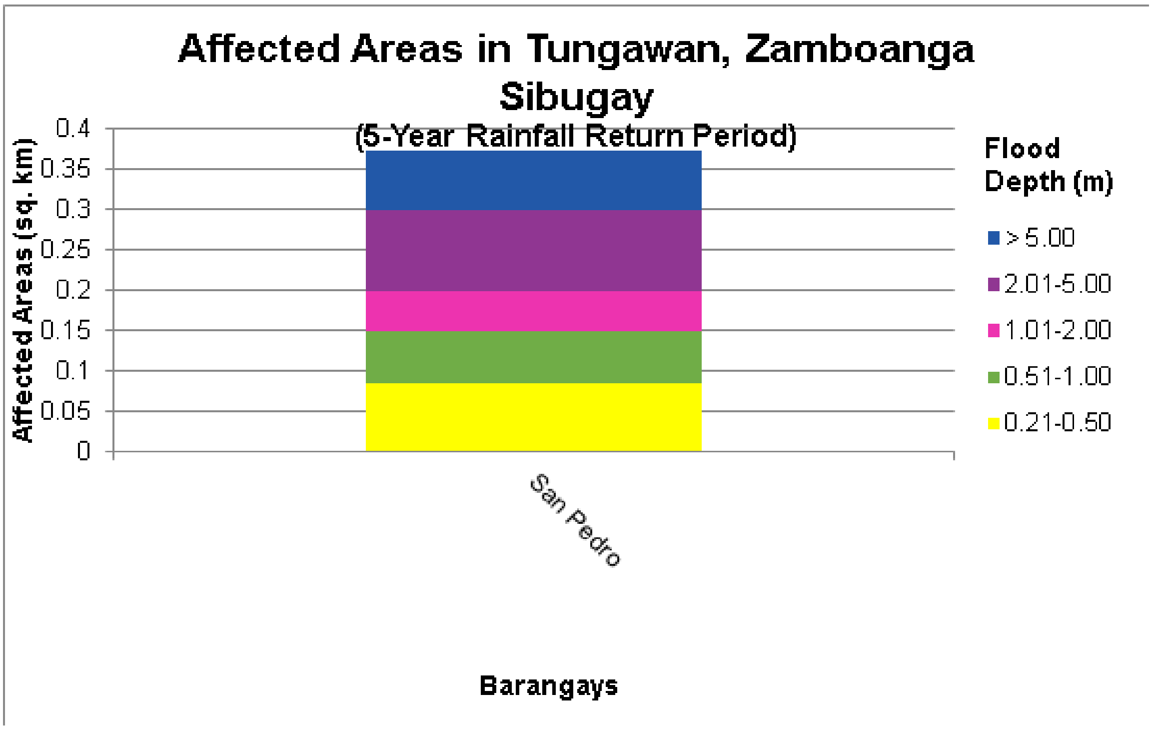


Figure 77. Affected Areas in Tungawan, Zamboanga Sibugay during 5-Year Rainfall Return Period.

For the 25-year return period, 9.72% of the municipality of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.96% of the area will experience flood levels of 0.21 to 0.50 meters while 1.08%, 0.83%, 0.36%, and 0.09% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Zamboanga City (in sq. km.)				
	Licomo	Limaong	Mangusu	Tagasilay	Taguiti
0.03-0.20	8.01	17.06	15.97	3.56	3.53
0.21-0.50	2.54	2.25	2.92	0.14	0.12
0.51-1.00	2.63	1.3	2.76	0.082	0.12
1.01-2.00	0.53	0.34	0.62	0.028	0.16
2.01-5.00	0.063	0.051	0.023	0.0018	0.15
> 5.00	0	0.0001	0	0	0.013

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Zamboanga City (in sq. km.)				
	Tictapul	Tigbalabag	Tumitus	Vitali	
0.03-0.20	55.27	12.05	14.99	15.07	
0.21-0.50	2.96	0.5	1.52	1.43	
0.51-1.00	4.81	0.32	1.04	3.07	
1.01-2.00	3.67	0.39	0.8	5.88	
2.01-5.00	2.04	0.76	0.12	2.13	
> 5.00	0.77	0.12	0	0.37	

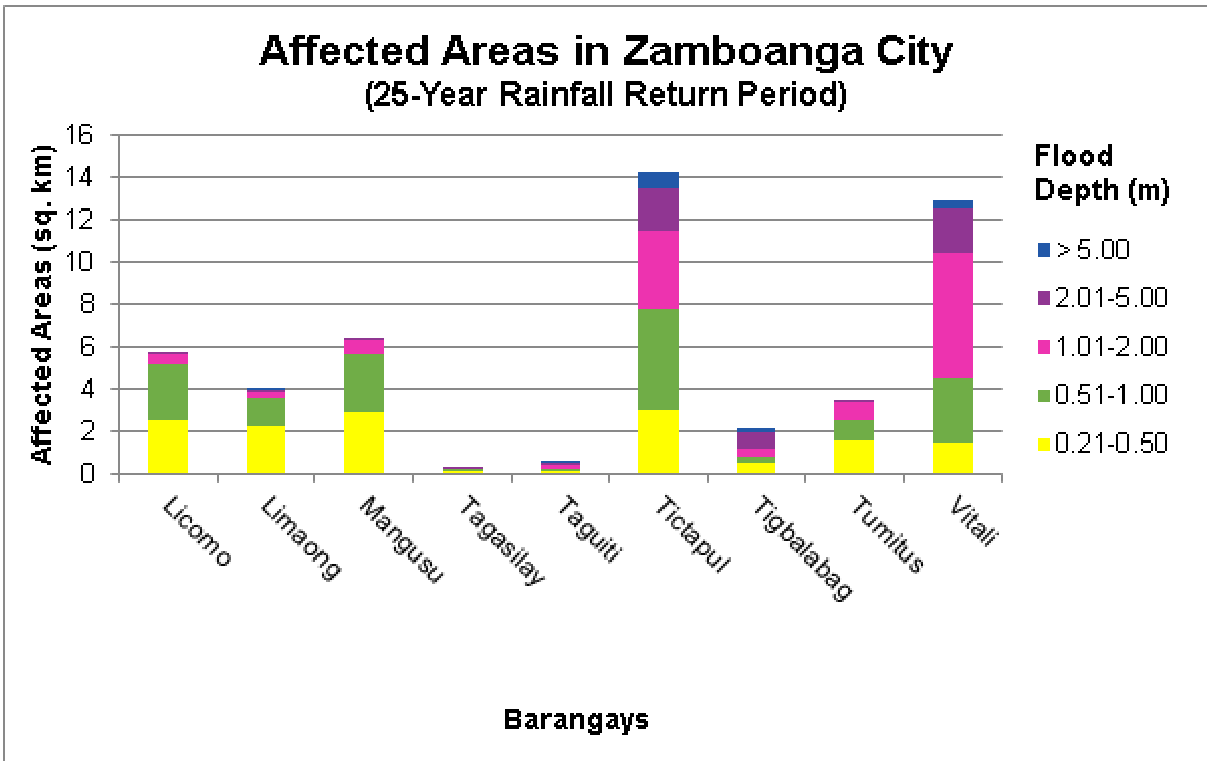


Figure 78. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period.

For the 25-year return period, 1.39% of the municipality of Tungawan with an area of 344.0154 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.02%, 0.03%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Tungawan, Zamboanga Sibugay during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tungawan (in sq. km.)
	San Pedro
0.03-0.20	4.77
0.21-0.50	0.1
0.51-1.00	0.066
1.01-2.00	0.064
2.01-5.00	0.1
> 5.00	0.14

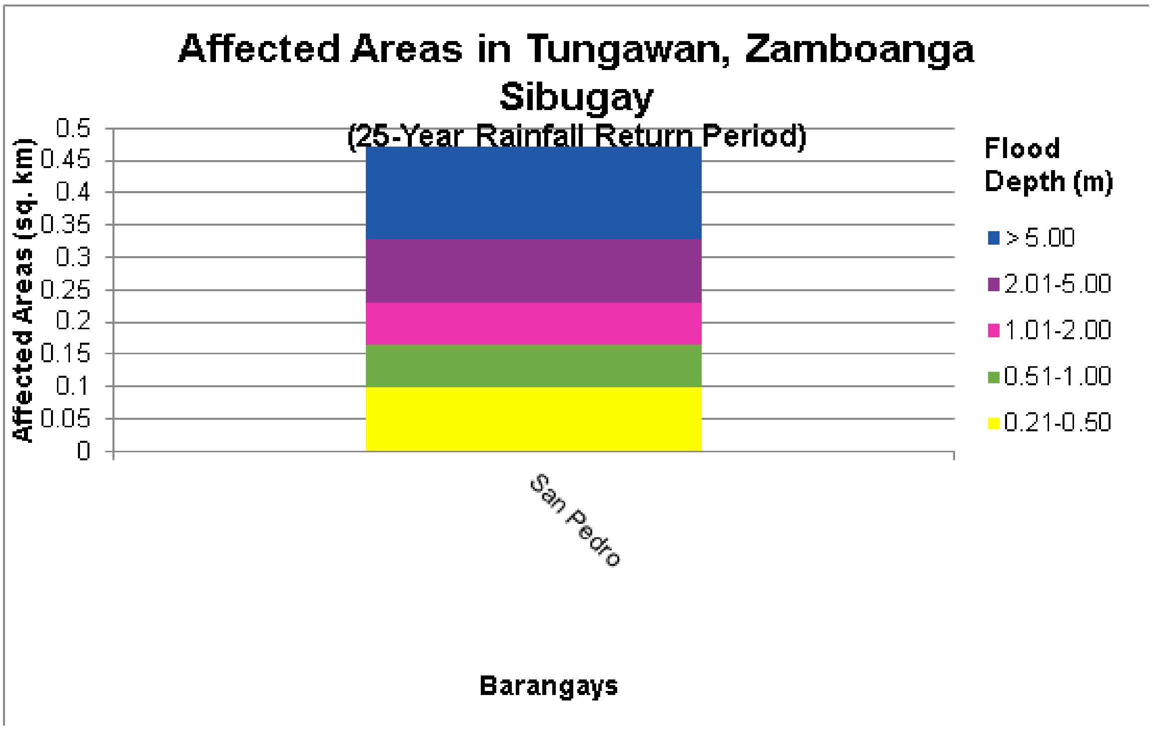


Figure 79. Affected Areas in Tungawan, Zamboanga Sibugay during 25-Year Rainfall Return Period.

For the 100-year return period, 9.26% of the municipality of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.86% of the area will experience flood levels of 0.21 to 0.50 meters while 0.97%, 1.23%, 0.59%, and 0.13% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Zamboanga City (in sq. km.)				
	Licomo	Limaong	Mangusu	Tagasilay	Taguiti
0.03-0.20	6.77	16.08	13.73	3.52	3.47
0.21-0.50	2.47	1.61	2.87	0.15	0.13
0.51-1.00	3.03	1.7	2.29	0.098	0.1
1.01-2.00	1.41	1.52	3.32	0.035	0.18
2.01-5.00	0.088	0.096	0.081	0.0044	0.2
> 5.00	0.0027	0.0026	0	0	0.027

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Zamboanga City (in sq. km.)				
	Tictapul	Tigbalabag	Tumitus	Vitali	
0.03-0.20	54.15	11.89	14.5	14.45	
0.21-0.50	2.46	0.5	1.53	1.1	
0.51-1.00	4.17	0.33	1.13	1.62	
1.01-2.00	4.91	0.3	0.84	5.95	
2.01-5.00	2.71	0.9	0.47	4.26	
> 5.00	1.12	0.23	0.0021	0.56	

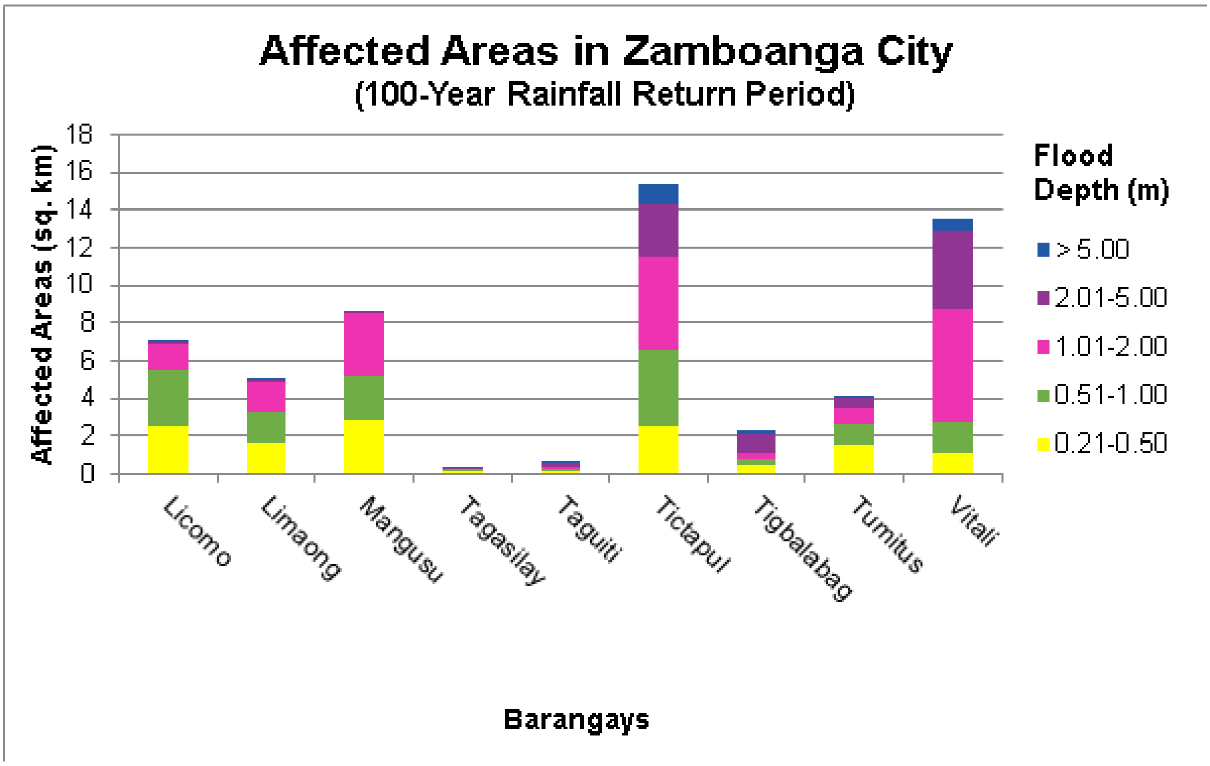


Figure 80. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

For the 100-year return period, 1.37% of the municipality of Tungawan with an area of 344.0154 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.02%, 0.03%, and 0.06% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Tungawan, Zamboanga Sibugay during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tungawan (in sq. km.)
	San Pedro
0.03-0.20	4.71
0.21-0.50	0.11
0.51-1.00	0.07
1.01-2.00	0.067
2.01-5.00	0.099
> 5.00	0.19

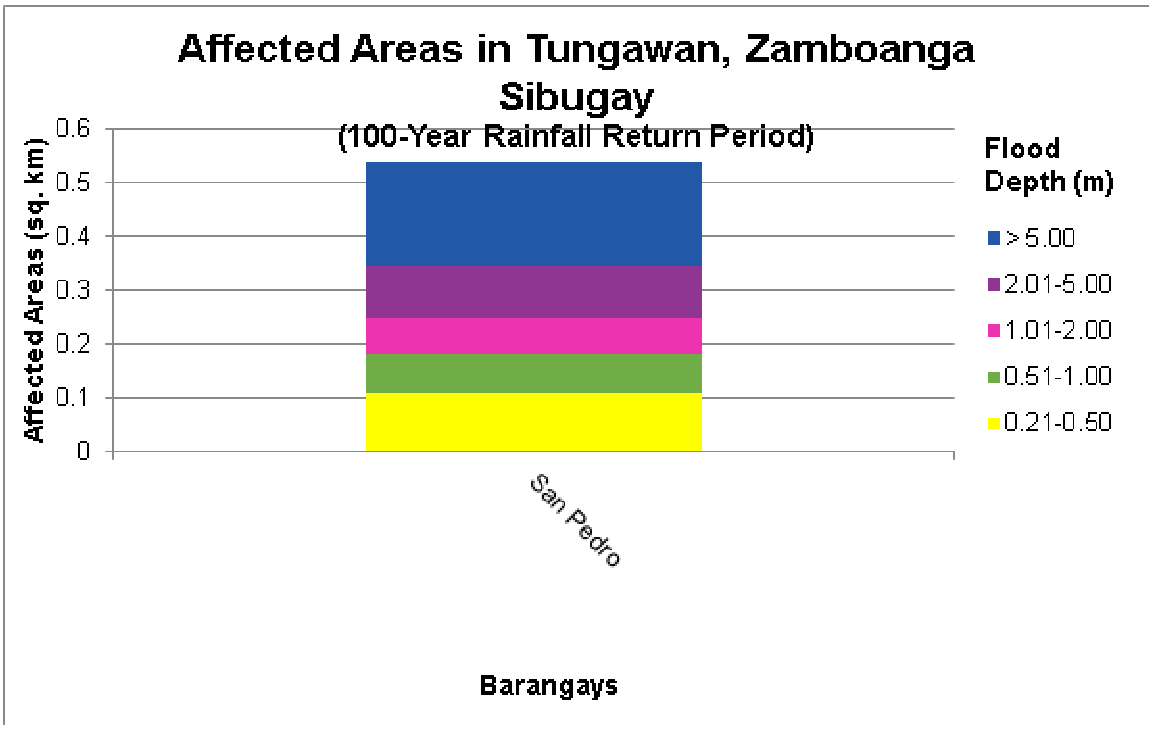


Figure 81. Affected Areas in Tungawan, Zamboanga Sibugay during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Vitali-Tigbaofloodplain 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 39. 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	15.05757	14.9967	13.16983
Medium	13.81369	26.18549	26.31082
High	6.630025	11.53816	20.41189

Of the 30 identified educationalinstitutes in Vitali-Tigbaofloodplain, 3 were exposed to medium flood hazard levels while 10 were exposed to high flood hazard levels in the 5-year rain return period. The same 13 identified institutes were exposed to high flood hazard levels in the 25-year rain return period. For the 100-year rain return period, the same structures were exposed to the same hazard level while an additional 5 and 3 institutes were exposed to low and medium flood hazard levels, respectively.

The sole medical institution identified in the flood plain is the Health Center in Brgy. Vitali in Zamboanga City. It was assessed to be exposed to high level flooding for all flood hazard scenarios.

5.11 Flood Validation

The flood validation consists of 351 points randomly selected all over the Vitaliflood plain. It has an RMSE value of 0.35.

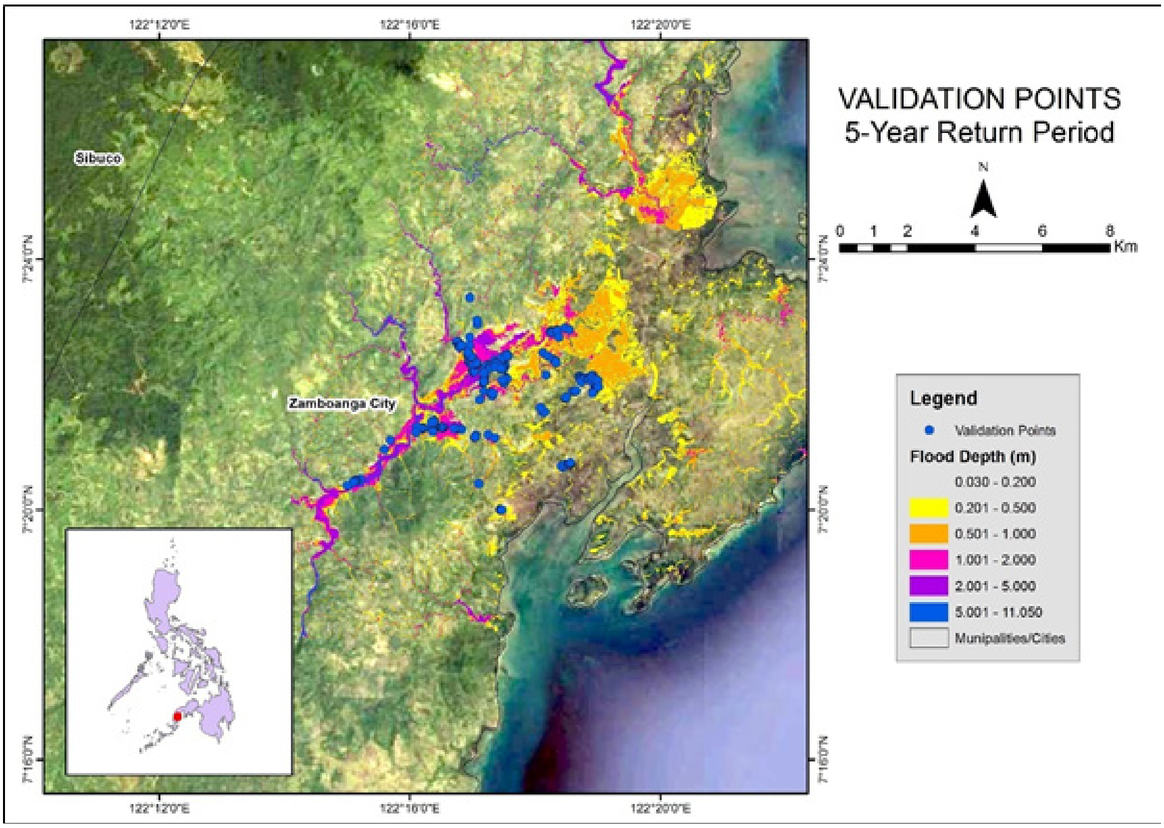


Figure 82. Validation points for 5-year Flood Depth Map of Vitali Floodplain.

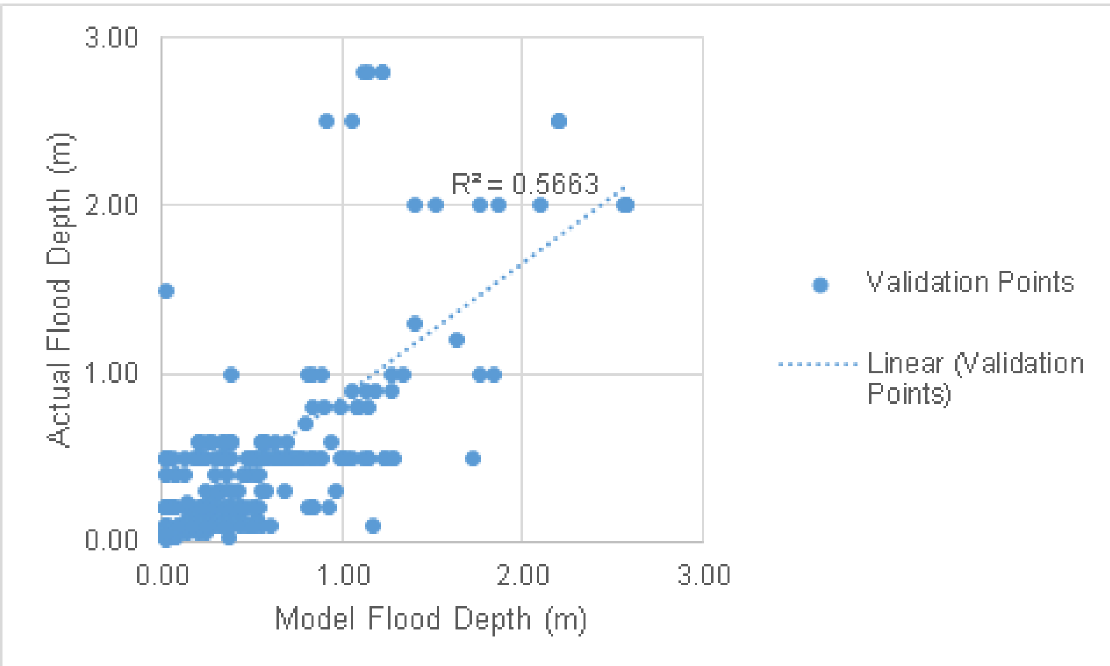


Figure 83. Flood map depth vs actual flood depth

Table 40. Actual flood vs. Simulated flood depth in the Lanang River Basin.

VITALI		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	121	56	13	1	0	0	191
	0.21-0.50	19	29	42	11	0	0	101
	0.51-1.00	1	12	15	11	0	0	39
	1.01-2.00	1	0	0	6	4	0	11
	2.01-5.00	0	0	1	5	3	0	9
	> 5.00	0	0	0	0	0	0	0
	Total	142	97	71	34	7	0	351

The overall accuracy generated by the flood model is estimated at 57.84%, with 107 points correctly matching the actual flood depths. In addition, there were 38 points estimated one level above and below the correct flood depths while there were 24 points and 11 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 27 points were overestimated while a total of 51 points were underestimated in the modelled flood depths of Vitali.

Table 41. Summary of Accuracy Assessment in Vitali.

VITALI	No. of Points	%
Correct	174	**49.57**
Overestimated	138	39.32
Underestimated	39	11.11
Total	351	100.00

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ANNEXES

Annex 1. OPTECH TECHNICAL SPECIFICATION OF THE PEGASUS SENSOR

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

OPTECH TECHNICAL SPECIFICATION OF THE D-8900 AERIAL DIGITAL CAMERA

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embed-ded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

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

1. ZGS-100

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

August 29, 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: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-100**
Order: **2nd**

Island:	**MINDANAO**	Barangay:	**MANICAHAN**		
Municipality:	**ZAMBOANGA CITY**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**7° 1' 26.72368"**	Longitude:	**122° 11' 12.74401"**	Ellipsoidal Hgt:	**11.27000 m.**
		WGS84 Coordinates			
Latitude:	**7° 1' 23.30149"**	Longitude:	**122° 11' 18.30044"**	Ellipsoidal Hgt:	**75.60300 m.**
		PTM / PRS92 Coordinates			
Northing:	**776712.542 m.**	Easting:	**410158.521 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**776,440.68**	Easting:	**410,189.97**	Zone:	**51**

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGS-100, 2009 NAMRIA".Located at Manicahan Barangay Hal 7 meters South from the flag pole 7 meters km post 1916-ZC22

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1902**

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/854

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. ZGS-99

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

August 29, 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: ZAMBOANGA DEL SUR
Station Name: ZGS-99
Order: 2nd

Island: MINDANAO
Municipality: ZAMBOANGA CITY
Barangay: CALARIAN
MSL Elevation:

PRS92 Coordinates

Latitude: 6° 55' 37.48971" Longitude: 122° 0' 52.66431" Ellipsoidal Hgt: 8.14900 m.

WGS84 Coordinates

Latitude: 6° 55' 34.07737" Longitude: 122° 0' 58.23072" Ellipsoidal Hgt: 72.23000 m.

PTM / PRS92 Coordinates

Northing: 766020.391 m. Easting: 391103.346 m. Zone: 4

UTM / PRS92 Coordinates

Northing: 765,752.27 Easting: 391,141.46 Zone: 51

Location Description

ZGS-99

The station is located beside a seawall, 10 m from the centerline and 50 m from the Airforce Beach, in Brgy. Upper Calarian. It is marked by a 4" copper nail flushed at the center of a cement putty on a concrete open canal with inscriptions " ZGS-99, 2009, NAMRIA".

Requesting Party: ENGR. CHRISTOPHER CRUZ
Purpose: Reference
OR Number: 8799780 A
T.N.: 2014-1901

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. BVA-1

BVA-1 - BVA-2 (2:54:04 PM-5:12:34 PM) (S1)

Baseline observation:	BVA-1 --- BVA-2 (B1)
Processed:	3/6/2015 3:31:41 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.093
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/6/2015 2:54:04 PM (Local: UTC+8hr)
Processing stop time:	2/6/2015 5:12:34 PM (Local: UTC+8hr)
Processing duration:	02:18:30
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	BVA-1				
Grid		**Local**		**Global**	
Easting	418087.142 m	**Latitude**	N7°15'19.31910"	**Latitude**	N7°15'15.84241"
Northing	801995.112 m	**Longitude**	E122°15'28.78739"	**Longitude**	E122°15'34.32212"
Elevation	78.652 m	**Height**	82.446 m	**Height**	146.526 m

To:	BVA-2				
Grid		**Local**		**Global**	
Easting	418085.472 m	**Latitude**	N7°15'19.25198"	**Latitude**	N7°15'15.77529"
Northing	801993.053 m	**Longitude**	E122°15'28.73303"	**Longitude**	E122°15'34.26776"
Elevation	78.729 m	**Height**	82.524 m	**Height**	146.603 m

Vector					
ΔEasting	-1.670 m	**NS Fwd Azimuth**	218°57'49"	**ΔX**	1.230 m
ΔNorthing	-2.059 m	**Ellipsoid Dist.**	2.652 m	**ΔY**	1.175 m
ΔElevation	0.077 m	**ΔHeight**	0.077 m	**ΔZ**	-2.036 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	**σ NS fwd Azimuth**	0°00'28"	**σ ΔX**	0.001 m
σ ΔNorthing	0.000 m	**σ Ellipsoid Dist.**	0.000 m	**σ ΔY**	0.001 m
σ ΔElevation	0.001 m	**σ ΔHeight**	0.001 m	**σ ΔZ**	0.000 m

4. BVA-2

BVA-1 - BVA-2 (2:54:04 PM-5:12:34 PM) (S1)

Baseline observation:	BVA-1 --- BVA-2 (B1)
Processed:	3/6/2015 3:31:41 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.093
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/6/2015 2:54:04 PM (Local: UTC+8hr)
Processing stop time:	2/6/2015 5:12:34 PM (Local: UTC+8hr)
Processing duration:	02:18:30
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	BVA-1				
Grid		**Local**		**Global**	
Easting	418087.142 m	**Latitude**	N7°15'19.31910"	**Latitude**	N7°15'15.84241"
Northing	801995.112 m	**Longitude**	E122°15'28.78739"	**Longitude**	E122°15'34.32212"
Elevation	78.652 m	**Height**	82.446 m	**Height**	146.526 m

To:	BVA-2				
Grid		**Local**		**Global**	
Easting	418085.472 m	**Latitude**	N7°15'19.25198"	**Latitude**	N7°15'15.77529"
Northing	801993.053 m	**Longitude**	E122°15'28.73303"	**Longitude**	E122°15'34.26776"
Elevation	78.729 m	**Height**	82.524 m	**Height**	146.603 m

Vector					
ΔEasting	-1.670 m	**NS Fwd Azimuth**	218°57'49"	**ΔX**	1.230 m
ΔNorthing	-2.059 m	**Ellipsoid Dist.**	2.652 m	**ΔY**	1.175 m
ΔElevation	0.077 m	**ΔHeight**	0.077 m	**ΔZ**	-2.036 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	**σ NS fwd Azimuth**	0°00'28"	**σ ΔX**	0.001 m
σ ΔNorthing	0.000 m	**σ Ellipsoid Dist.**	0.000 m	**σ ΔY**	0.001 m
σ ΔElevation	0.001 m	**σ ΔHeight**	0.001 m	**σ ΔZ**	0.000 m

5. ZGS-99A

ZGS-99 - ZGS-99A (9:00:34 AM-1:46:19 PM) (S1)

Baseline observation:	ZGS-99 --- ZGS-99A (B1)
Processed:	3/6/2015 1:27:43 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.000 m
Maximum PDOP:	4.130
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/11/2015 9:00:34 AM (Local: UTC+8hr)
Processing stop time:	2/11/2015 1:46:19 PM (Local: UTC+8hr)
Processing duration:	04:45:45
Processing interval:	5 seconds

1

Vector Components (Mark to Mark)

From:	ZGS-99				
Grid		Local		Global	
Easting	391141.462 m	Latitude	N6°55'37.48971"	Latitude	N6°55'34.07737"
Northing	765752.270 m	Longitude	E122°00'52.66432"	Longitude	E122°00'58.23072"
Elevation	4.653 m	Height	8.149 m	Height	72.230 m

To:	ZGS-99A				
Grid		Local		Global	
Easting	391136.071 m	Latitude	N6°55'37.63895"	Latitude	N6°55'34.22659"
Northing	765756.864 m	Longitude	E122°00'52.48834"	Longitude	E122°00'58.05475"
Elevation	4.354 m	Height	7.850 m	Height	71.931 m

Vector					
ΔEasting	-5.391 m	NS Fwd Azimuth	310°19'07"	ΔX	5.031 m
ΔNorthing	4.594 m	Ellipsoid Dist.	7.085 m	ΔY	2.144 m
ΔElevation	-0.299 m	ΔHeight	-0.299 m	ΔZ	4.515 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'11"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002239		
Y	-0.0000001250	0.0000004533	
Z	-0.0000000277	0.0000000071	0.0000000770

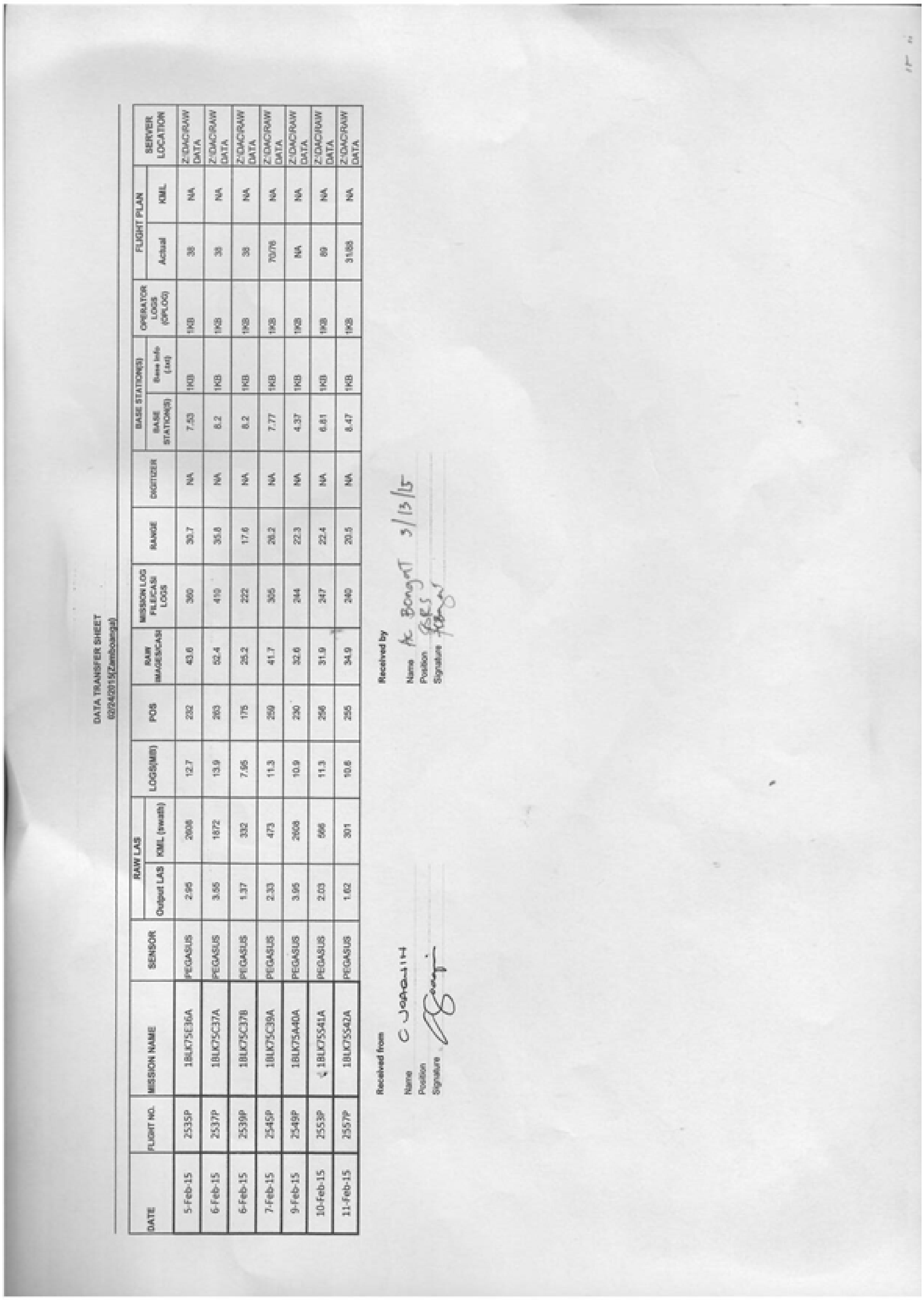
Annex 3. Base Processing Reports of Control Points used in the LiDAR Survey

This river basin has no Baseline Processing Report

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising-Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. RENAN PUNTO	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KRISTINE JOY ANDAYA	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERWIN DELOS SANTOS	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. BRYAN DOMINGUEZ	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. SHERWIN CESAR ALFONSO	AAC

Annex 5. Data Transfer Sheet for Vitali Floodplain



DATA TRANSFER SHEET
02/24/2015(Zamboanga)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Feb-15	2535P	1BLK75E36A	PEGASUS	2.95	2608	12.7	232	43.6	360	30.7	NA	7.53	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2537P	1BLK75C37A	PEGASUS	3.55	1872	13.9	263	52.4	410	35.8	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2539P	1BLK75C37B	PEGASUS	1.37	332	7.95	175	25.2	222	17.6	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
7-Feb-15	2545P	1BLK75C39A	PEGASUS	2.33	473	11.3	259	41.7	305	26.2	NA	7.77	1KB	1KB	70/76	NA	Z:\DAC\RAW DATA
9-Feb-15	2549P	1BLK75A40A	PEGASUS	3.95	2608	10.9	230	32.6	244	22.3	NA	4.37	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
10-Feb-15	2553P	1BLK75S41A	PEGASUS	2.03	566	11.3	256	31.9	247	22.4	NA	6.61	1KB	1KB	89	NA	Z:\DAC\RAW DATA
11-Feb-15	2557P	1BLK75S42A	PEGASUS	1.62	301	10.6	255	34.9	240	20.5	NA	8.47	1KB	1KB	31/88	NA	Z:\DAC\RAW DATA

Received from
Name C JOAQUIN
Position
Signature

Received by
Name AC BONGAT 3/13/15
Position SSRS
Signature

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 2537P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 2537

1 LIDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK2P37B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Dongiines	9 Route: Zambo - Zambo			
10 Date: Feb. 4 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zambo		
13 Engine On: 1509 H	14 Engine Off: 1814 H	15 Total Engine Time: 3+05	16 Take off: 1514 H	17 Landing: 1809 H	18 Total Flight Time: 2+55
19 Weather: Partly Cloudy					

20 Remarks:

Surveyed BLK 75-D

21 Problems and Solutions:

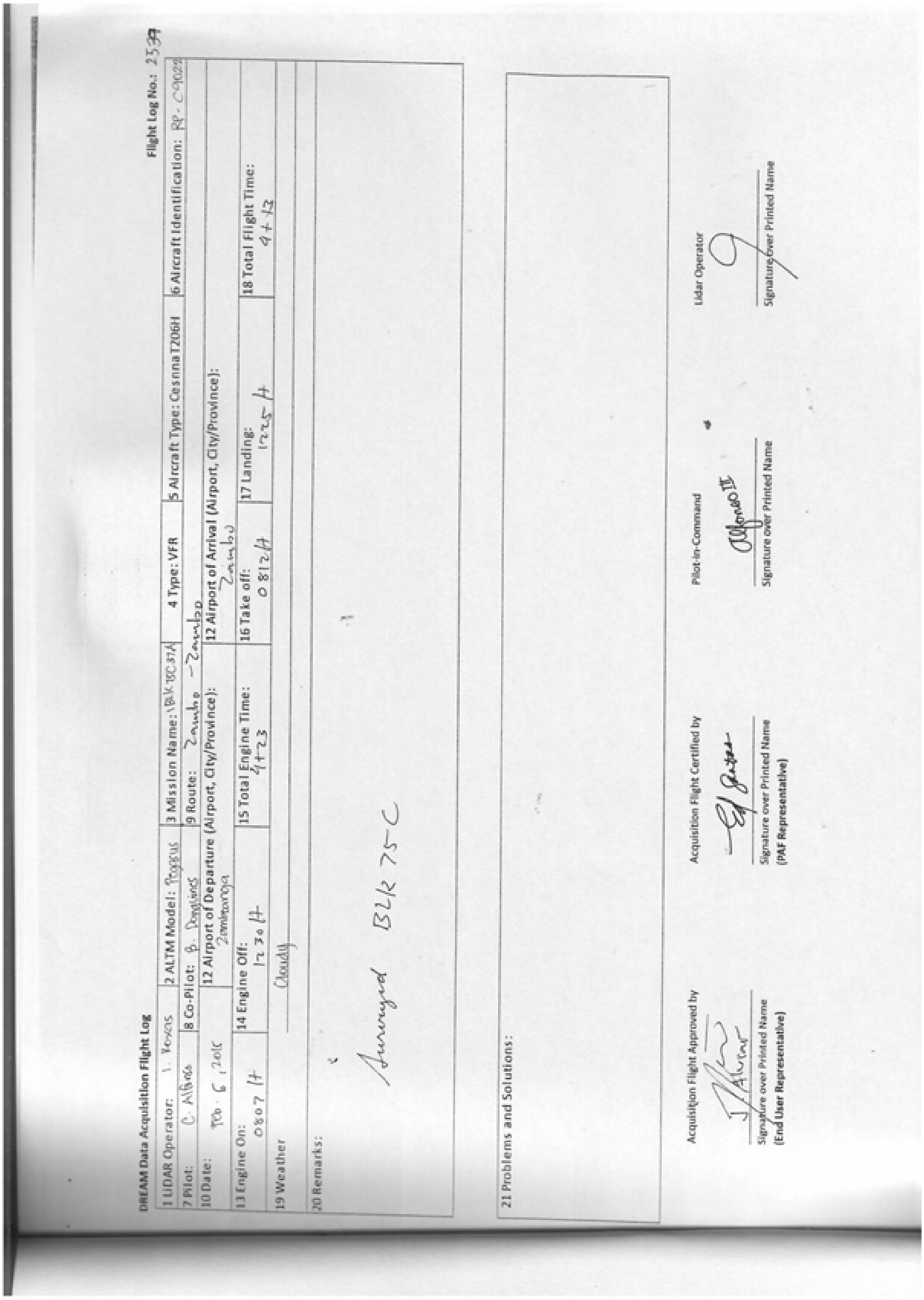
Acquisition Flight Approved by: J. Alviar — Signature over Printed Name (End User Representative)

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

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

Lidar Operator: J. Alviar — Signature over Printed Name

2. Flight Log for2539P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 2539

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK75C37A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route: Zambo - Zambo			
10 Date: Feb. 6, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zambo		
13 Engine On: 0807 H	14 Engine Off: 1230 H	15 Total Engine Time: 4+23	16 Take off: 0812H	17 Landing: 1225 H	18 Total Flight Time: 4+13
19 Weather: Cloudy					

20 Remarks:

Surveyed BLK 75C

21 Problems and Solutions:

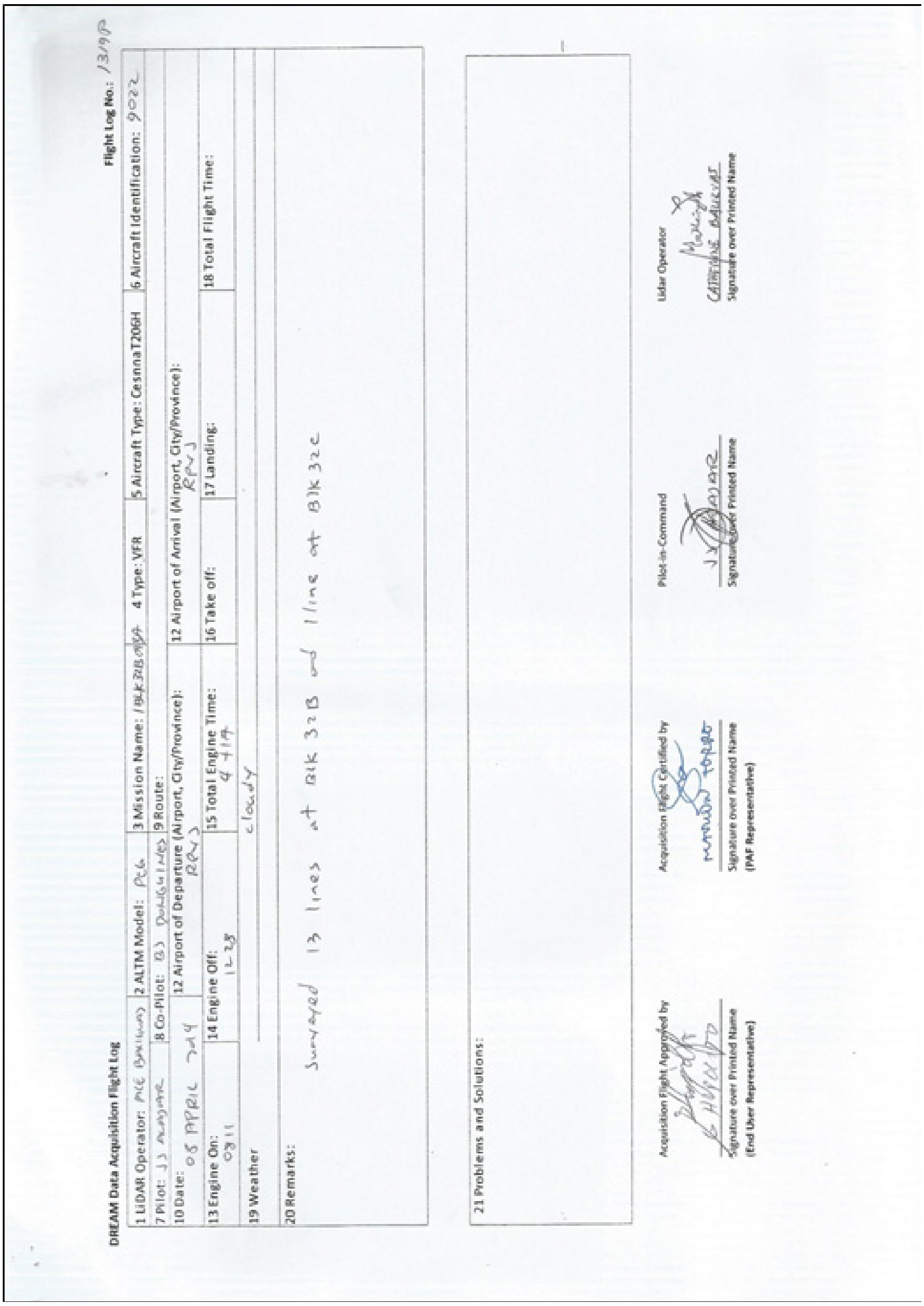
Acquisition Flight Approved by: J. Alviar, Signature over Printed Name (End User Representative)

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

Pilot-in-Command: Alfonso III, Signature over Printed Name

Lidar Operator: Signature over Printed Name

3. Flight Log for 1BLK32B098A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1319P

1 LiDAR Operator:	2 ALTM Model: Pe6	3 Mission Name: 1BLK32B098A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: 08 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0711	14 Engine Off: 1125	15 Total Engine Time: 4+14	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				
20 Remarks:	Surveyed 13 lines at BLK 32B and 1 line at BLK 32C				
21 Problems and Solutions:					

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

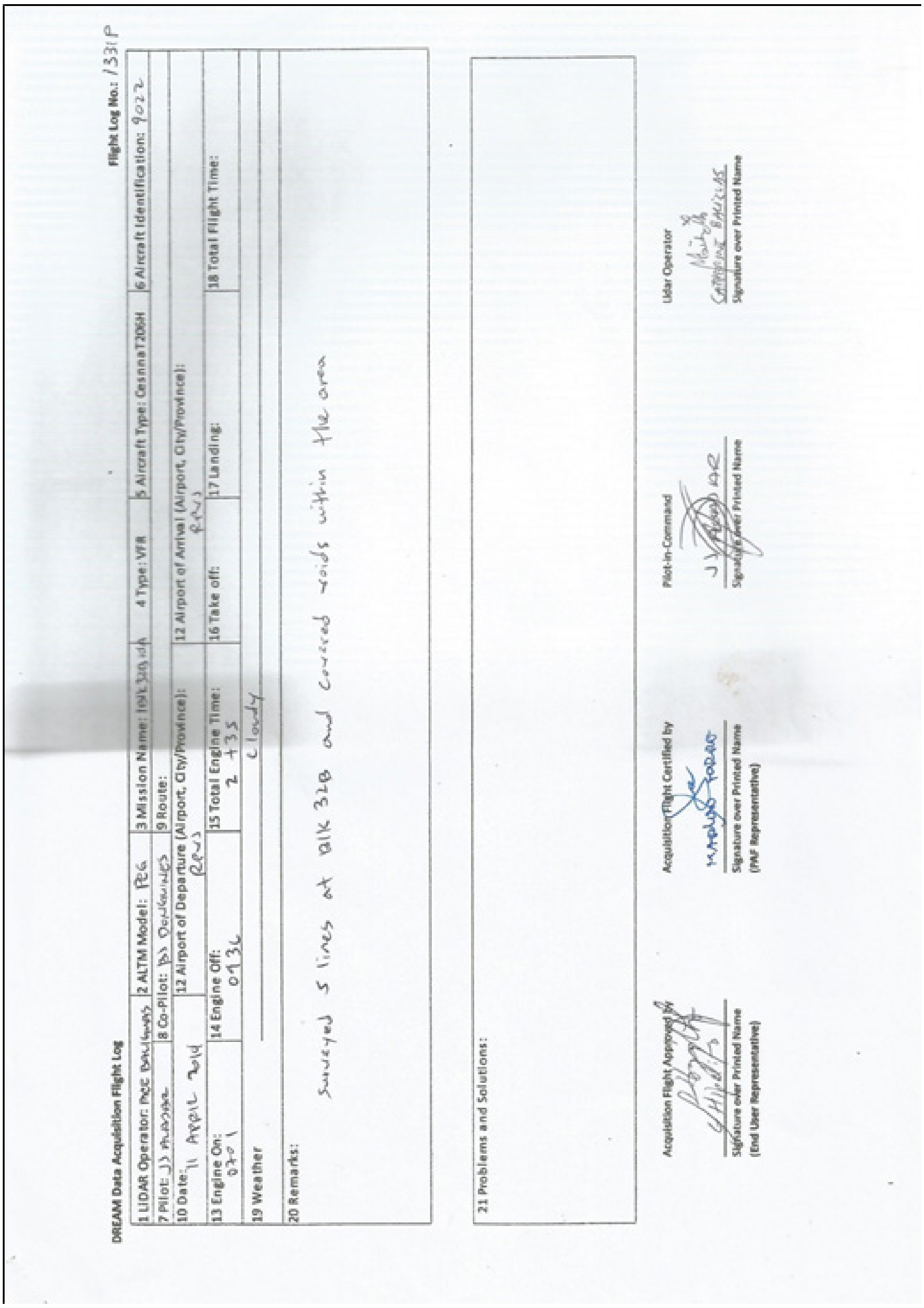
Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

4. Flight Log for 1BLK32B101A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1331P

1 LIDAR Operator: PGC [illegible]	2 ALTM Model: PEG	3 Mission Name: 1BLK32B101A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ [illegible]	8 Co-Pilot: BJ [illegible]	9 Route:			
10 Date: 11 April 2016	12 Airport of Departure (Airport, City/Province): Revs		12 Airport of Arrival (Airport, City/Province): Revs		
13 Engine On: 0701	14 Engine Off: 0936	15 Total Engine Time: 2+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

Surveyed 5 lines at BLK 32B and covered voids within the area

21 Problems and Solutions:

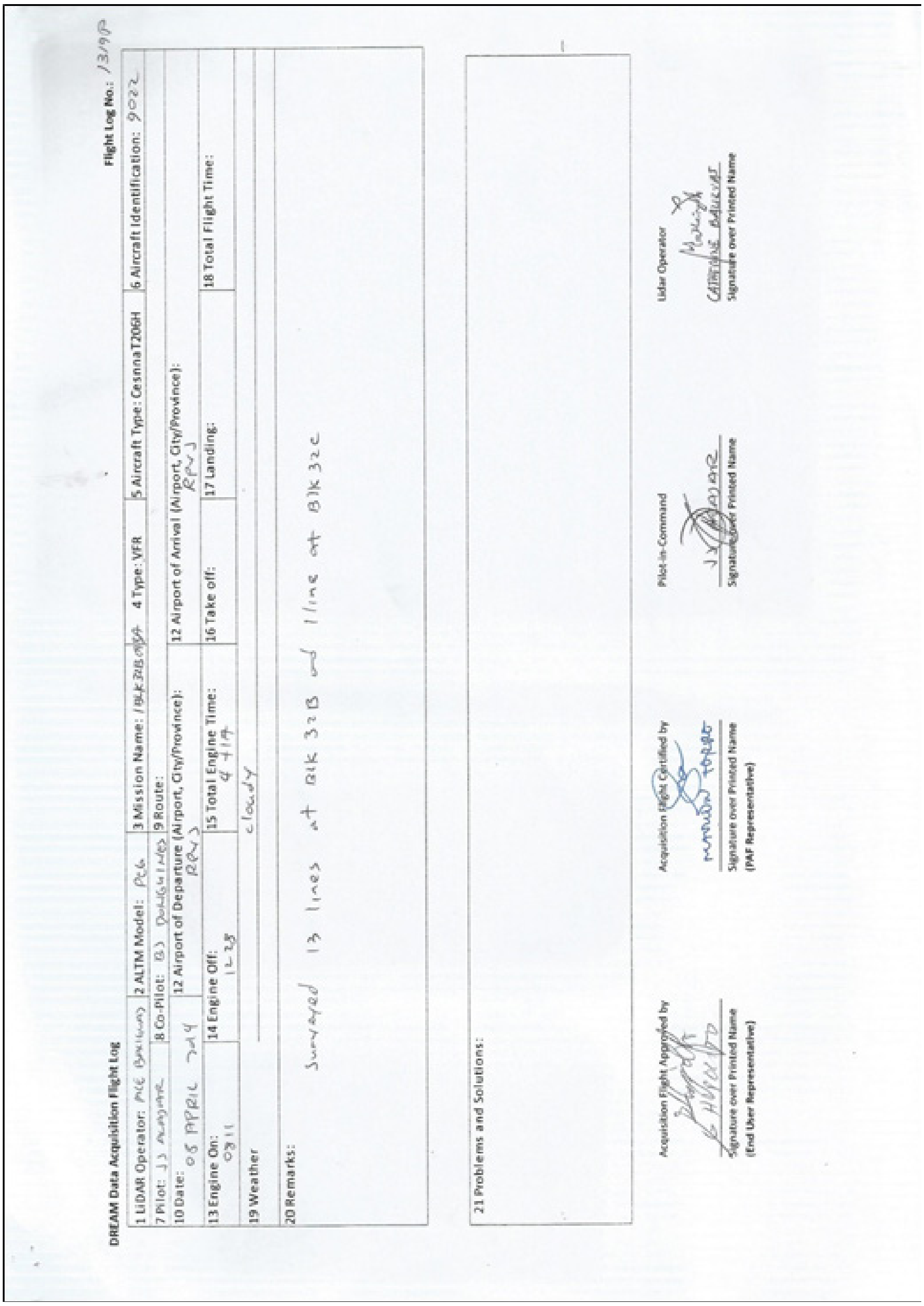
Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

3. Flight Log for 2545P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1319P

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32B098A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 08 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0811	14 Engine Off: 1228	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

Surveyed 13 lines at BLK 32B and 1 line at BLK 32C

21 Problems and Solutions:

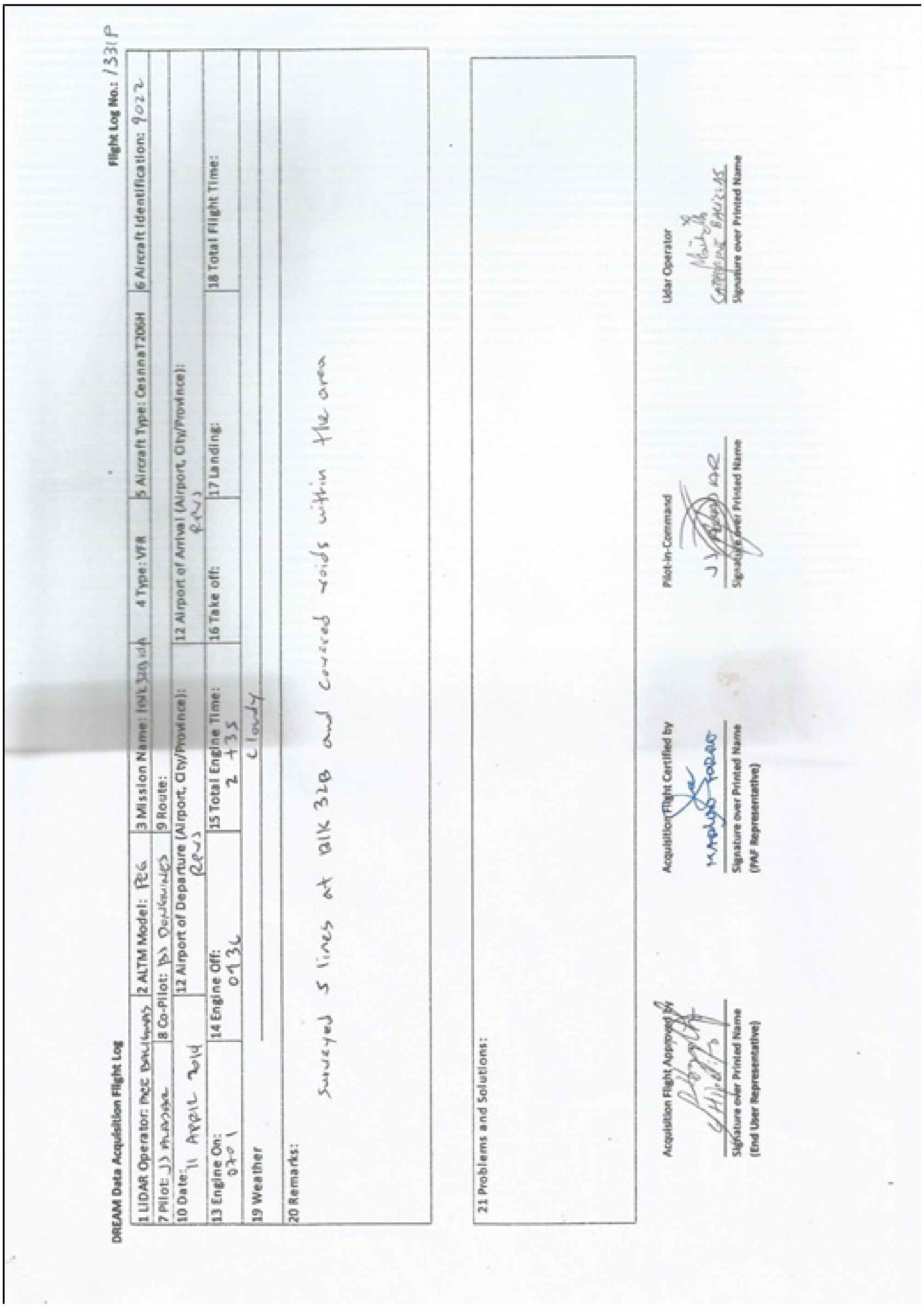
Acquisition Flight Approved by
E. HUTAC(?)
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
JJ ALAJAR
Signature over Printed Name

Lidar Operator
CATHERINE BALICUAS
Signature over Printed Name

4. Flight Log for 1BLK32B101A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1331P

1 LIDAR Operator: PCC Bauzas	2 ALTM Model: PEG	3 Mission Name: 1BLK32B101A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alasar	8 Co-Pilot: BJ Dongluines	9 Route:			
10 Date: 11 April 2014	12 Airport of Departure (Airport, City/Province): Revs		12 Airport of Arrival (Airport, City/Province): Revs		
13 Engine On: 0701	14 Engine Off: 0936	15 Total Engine Time: 2+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Surveyed 5 lines at BLK 32B and covered voids within the area

21 Problems and Solutions:

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

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

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

Lidar Operator — Catherine Bauzas — Signature over Printed Name

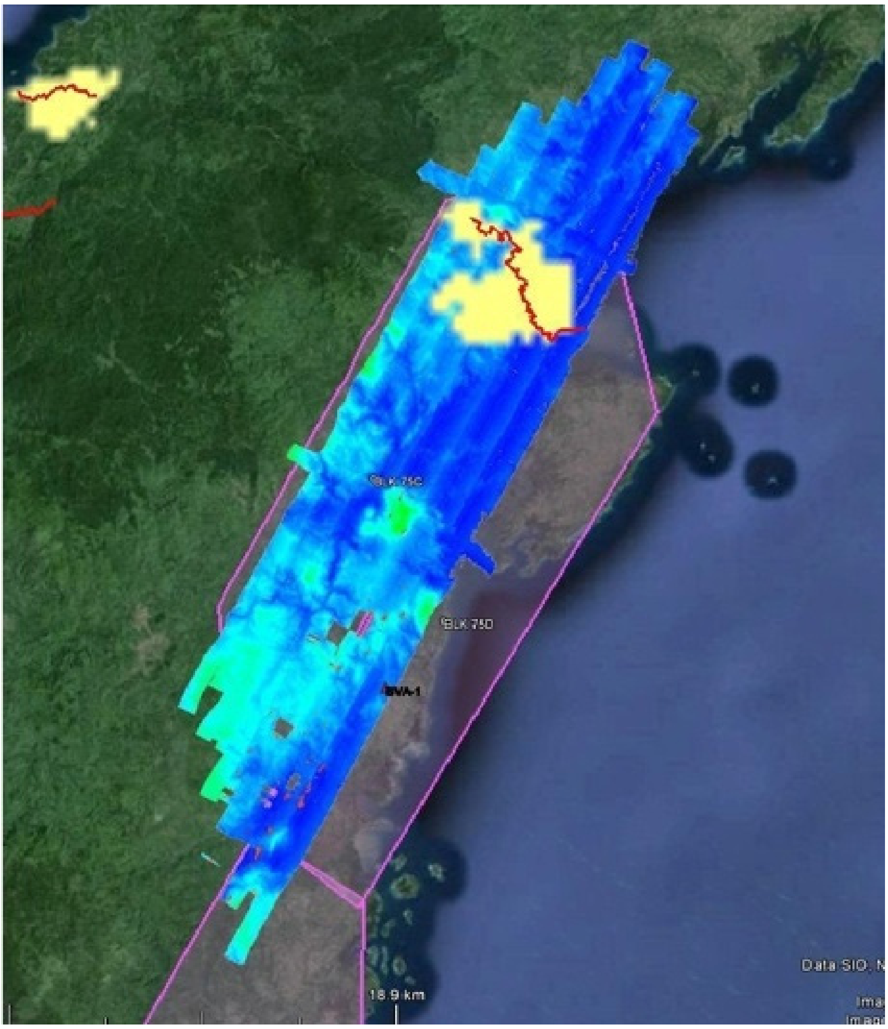
Annex 7. Flight Status Reports

FLIGHT STATUS REPORT
Zamboanga-Zamboanga Sibugay

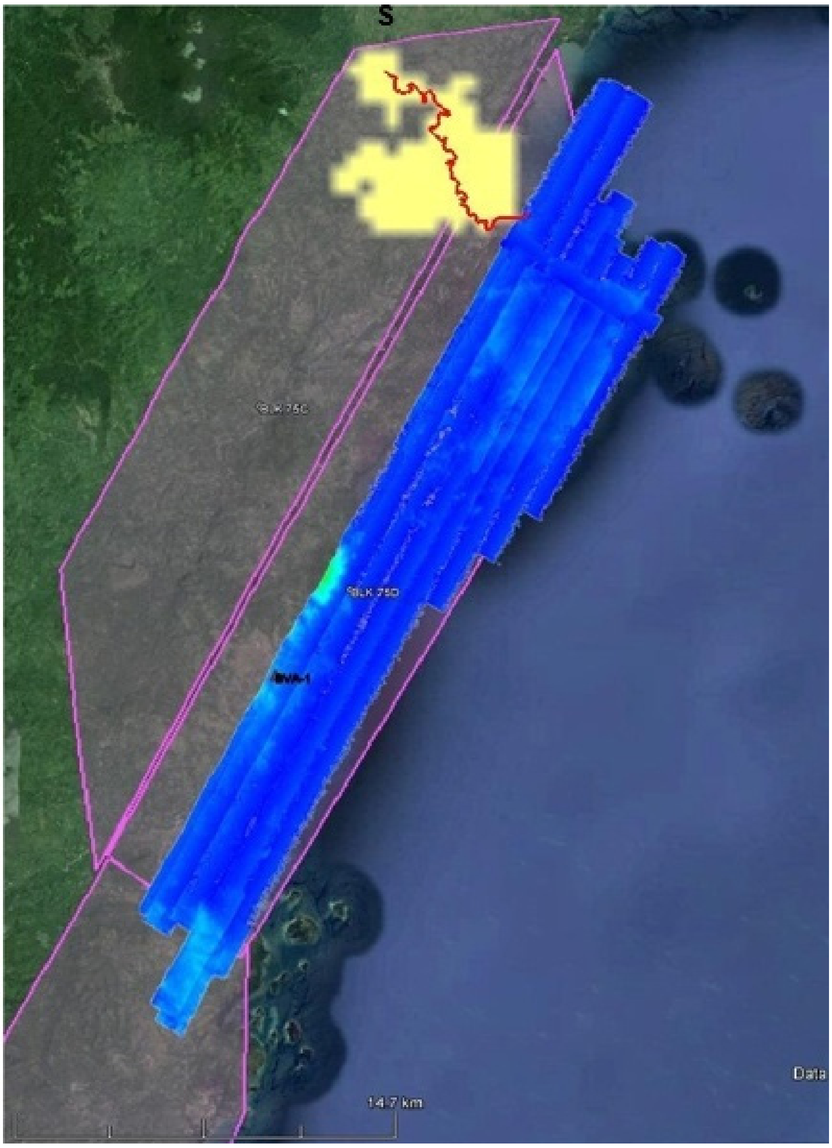
FLIGHT NO	AREA	MISSION	OPERA-TOR	DATE FLOWN	REMARKS
2537P	BLK75C	1BLK75C37A	I. ROXAS	Feb. 6, 2015	FMS NAV LOST COM WITH POS; AVPOS STILL LOGGING
2539P	BLK75D	1BLK75C37B	J. ALVIAR	Feb. 6, 2015	COMPLETED 165.38 sq.km
2545P	BLK75C BLK75D BLK75E BLK75FS	1BLK75C39A	J. ALVIAR	Feb. 8, 2015	ABNORMAL PROGRAM TERMINATION (AVPOS)
2557P	BLK75C BLK75D	1BLK75S42A	J. ALVIAR	Feb. 11, 2015	SURVEY 6 DESCENDED TO 1000 DUE TO CLOUDS; RETURNED TO 1100M FOR SURVEY OVER SACOL;GAPS DUE TO CLOUDS, DESCENDED TO 1000M TO FILL UP VOIDS IN SACOL AND BLK 75 EFG;ADDED 1 SMALL LINE (CORRIDOR 18), DESCENDED TO 800M;CORRIDOR 16 WHICH SHOULD COVER GAP IN BLK75E, UP TO ALL

LAS BOUNDARIES PER FLIGHT

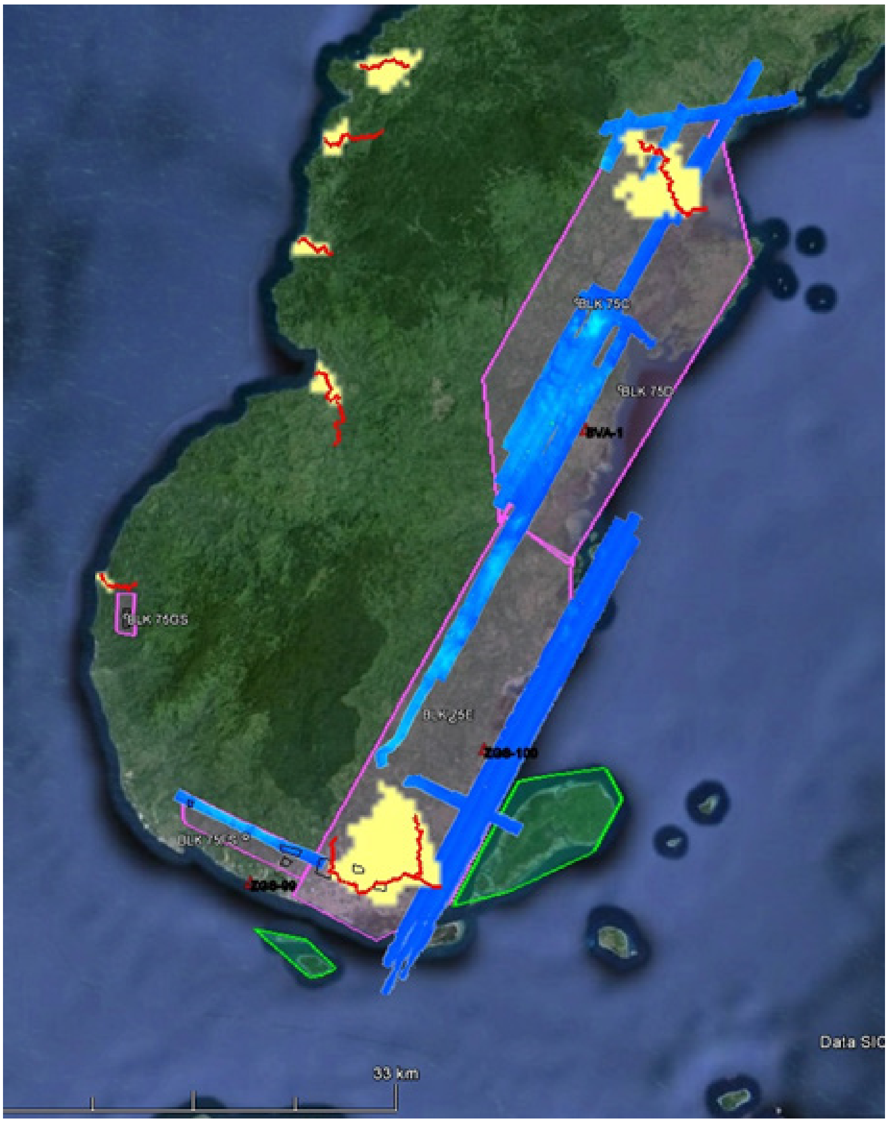
Flight No.:	2537P
Area:	BLK75C
Mission Name:	1BLK75C37A
Parameters:	Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50



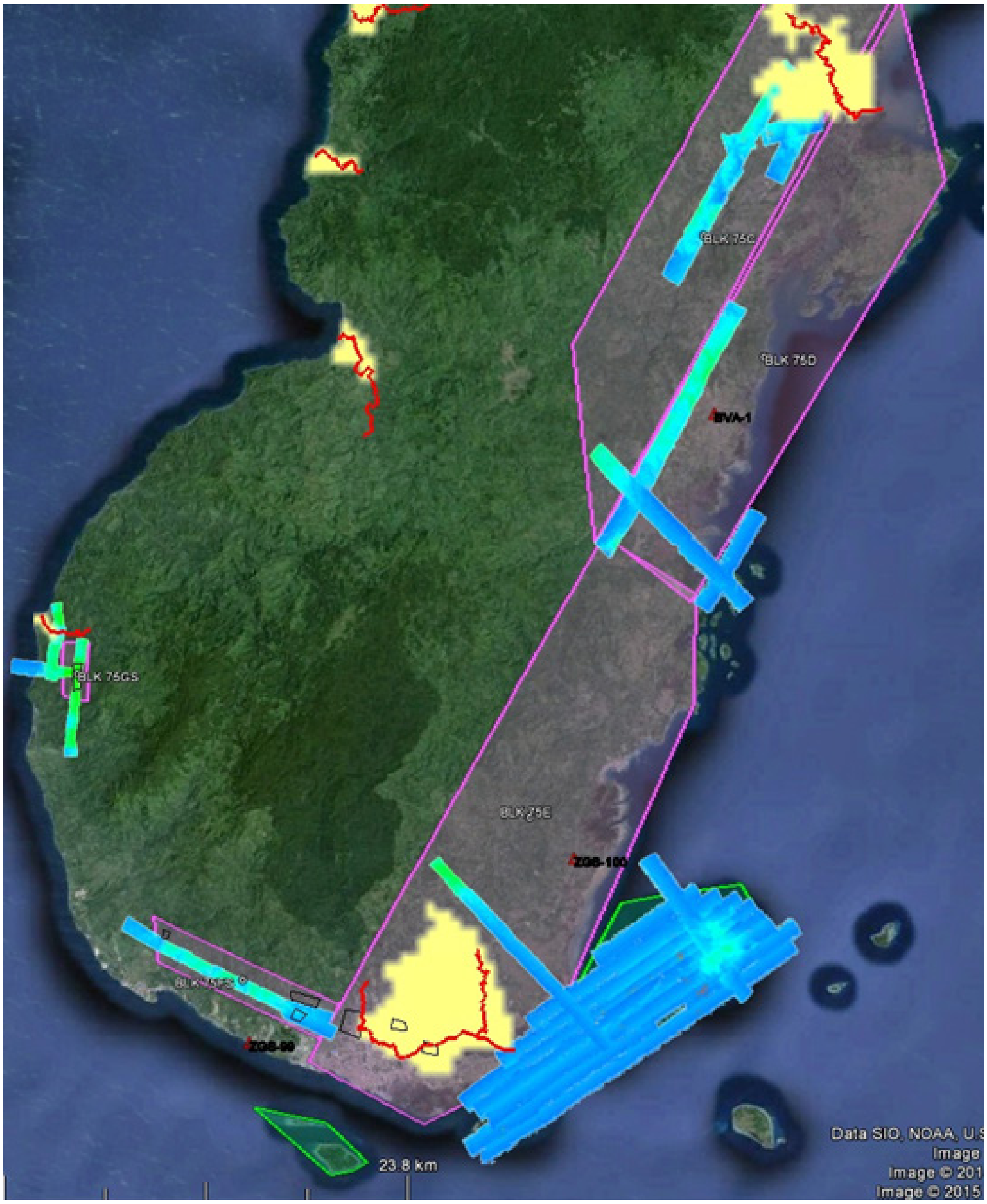
Flight No.: 2539P
Area: BLK75D
Mission Name: 1BLK75C37B
Parameters: Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50



Flight No. :	2545P
Area:	BLK 75C
Mission Name:	1BLK75C39A
Parameters:	Altitude: 1100m; Scan Frequency: 30; Scan Angle: 50



Flight No. : 2557P
Area: BLK 75C, D, E, GS, FS, Sacol island
Mission Name: 1BLK75S42A
Parameters: Altitude: 1100-1000m; Scan Frequency: 30; Scan Angle: 50



Annex 8. Mission Summary Reports

Flight Area	Zamboanga
Mission Name	**Blk75C**
Inclusive Flights	2537P, 2545P, 2557P
Range data size	77.4 GB
POS data size	777 MB
Base data size	24.44 MB
Image	129 GB
Transfer date	February 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.14
RMSE for East Position (<4.0 cm)	1.74
RMSE for Down Position (<8.0 cm)	3.62
Boresight correction stdev (<0.001deg)	0.000178
IMU attitude correction stdev (<0.001deg)	0.000672
GPS position stdev (<0.01m)	0.0042
Minimum % overlap (>25)	54.88%
Ave point cloud density per sq.m. (>2.0)	4.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	490
Maximum Height	578.21 m
Minimum Height	67.64 m
Classification (# of points)	
Ground	462,127,429
Low vegetation	431,469,791
Medium vegetation	831,710,835
High vegetation	1,470,249,193
Building	16,154,276
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Engr. Krisha Marie Bautista

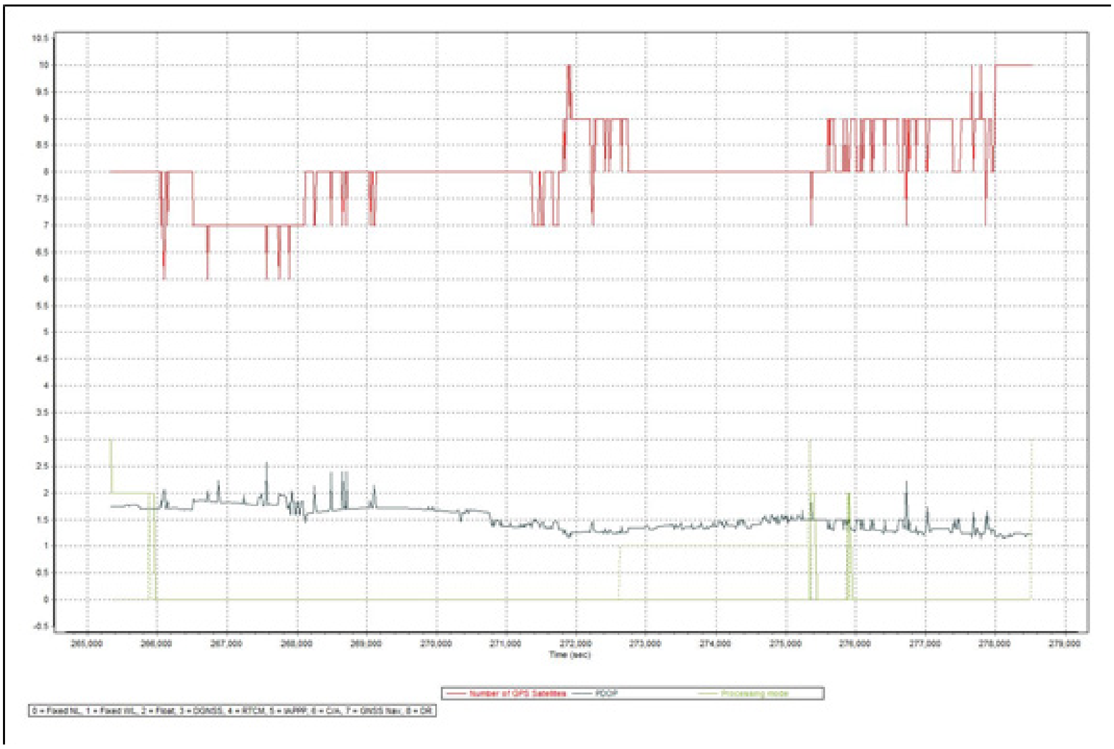


Figure 1.1.1. Solution Status

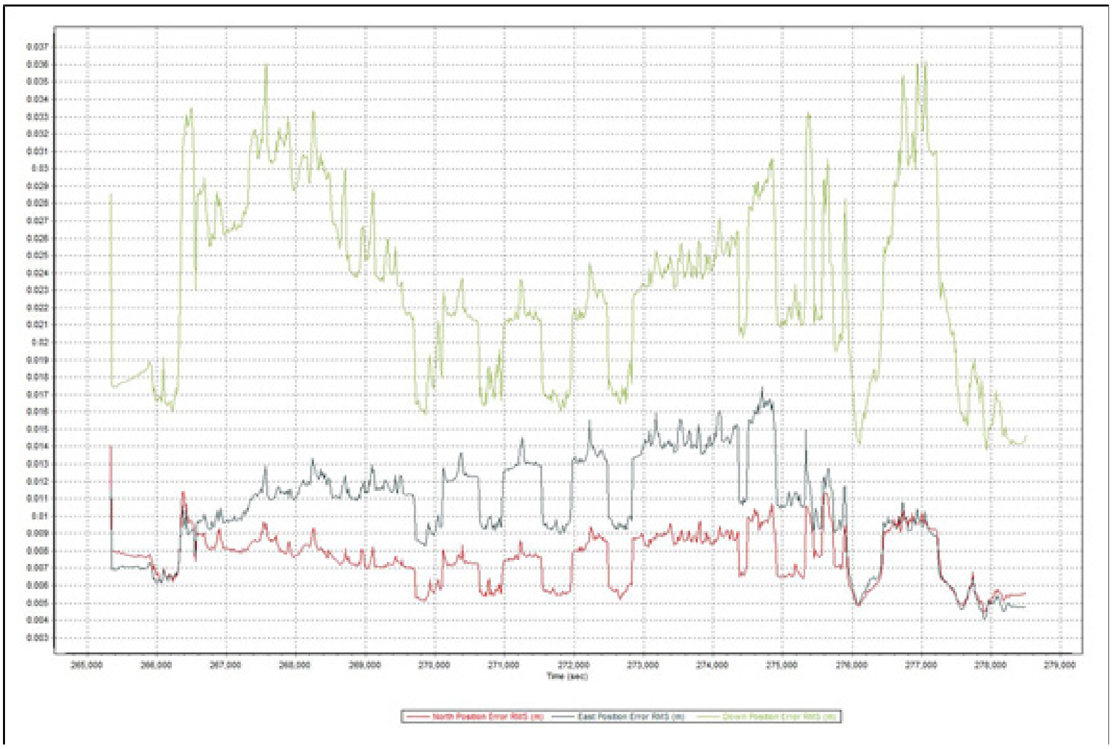


Figure 1.1.2. Smoothed Performance Metric Parameters

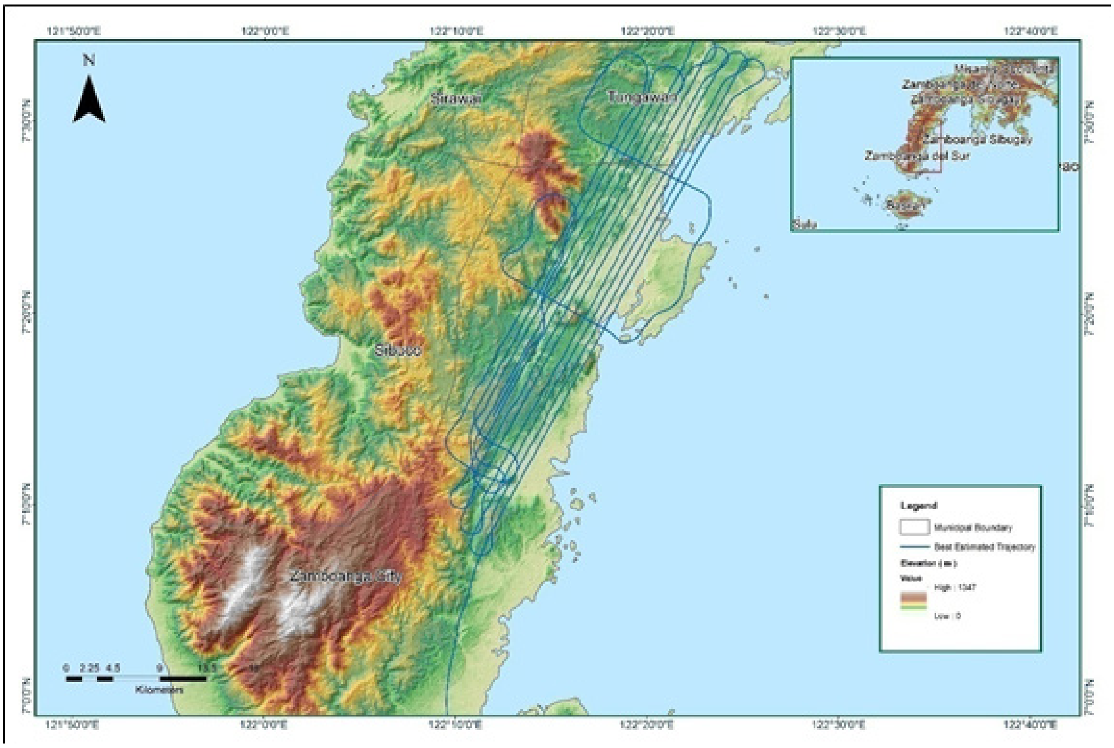


Figure 1.1.3. Best Estimated Trajectory

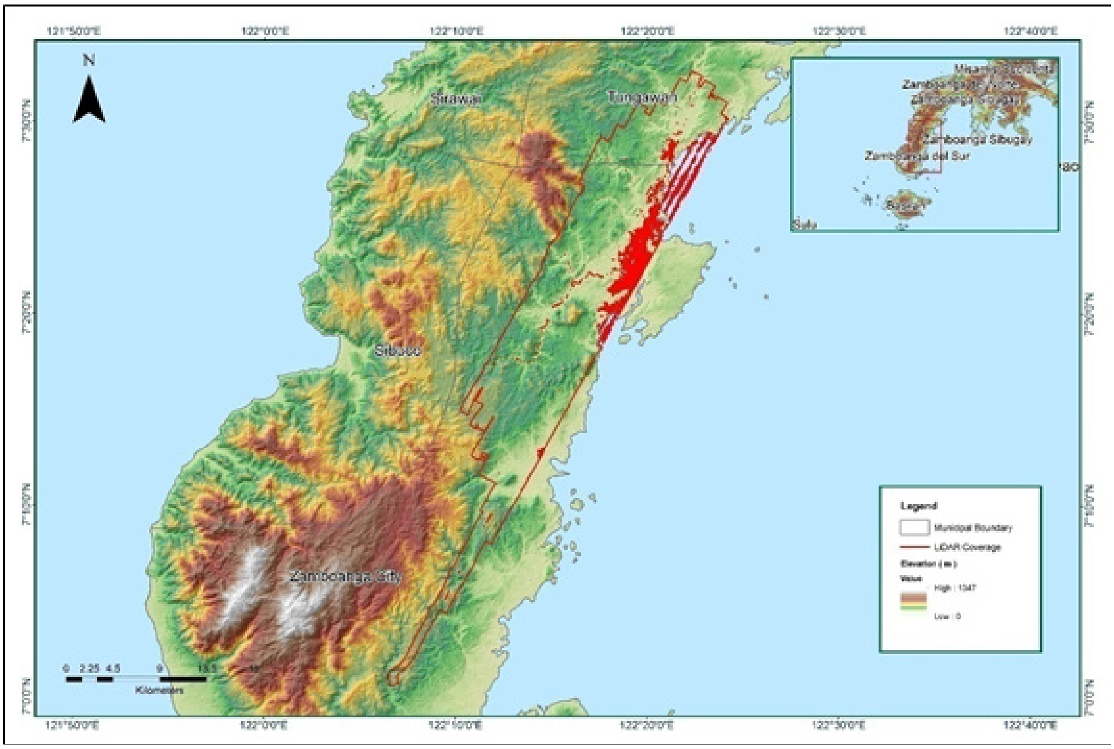


Figure 1.1.4. Coverage of LiDAR Data

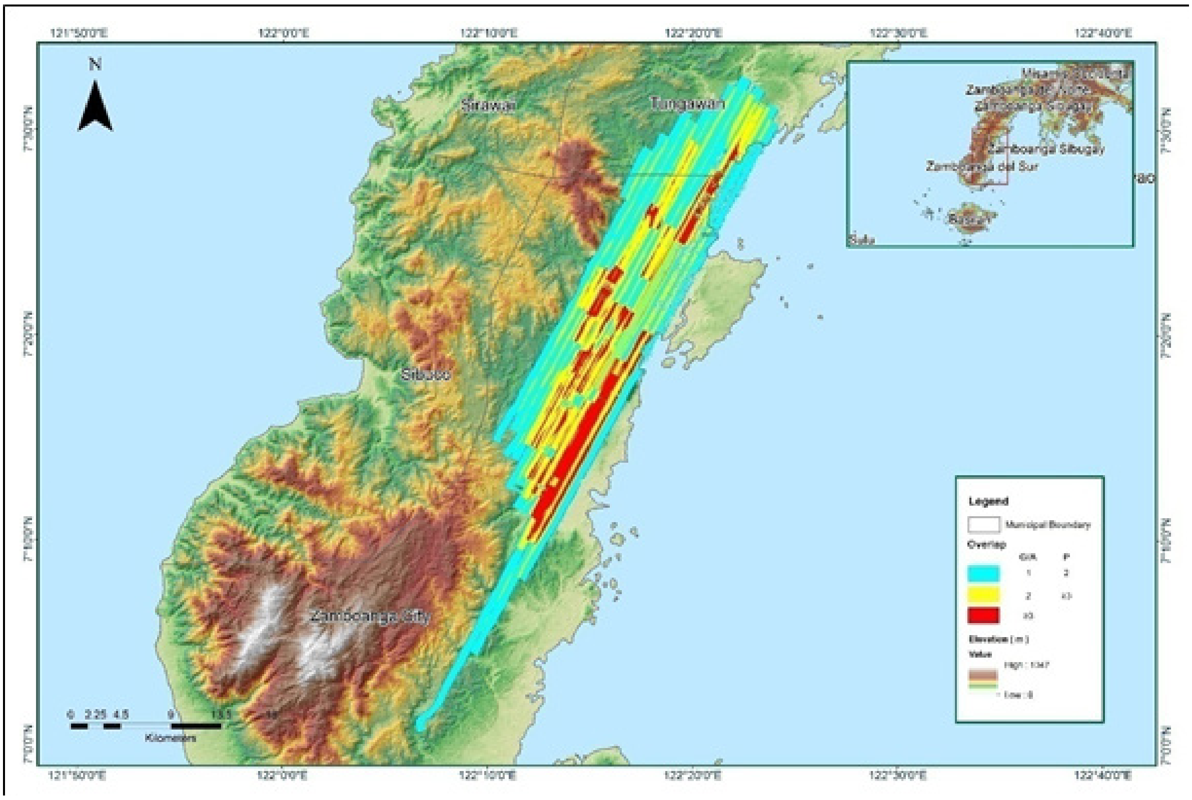


Figure 1.1.5 Image Data Overlap

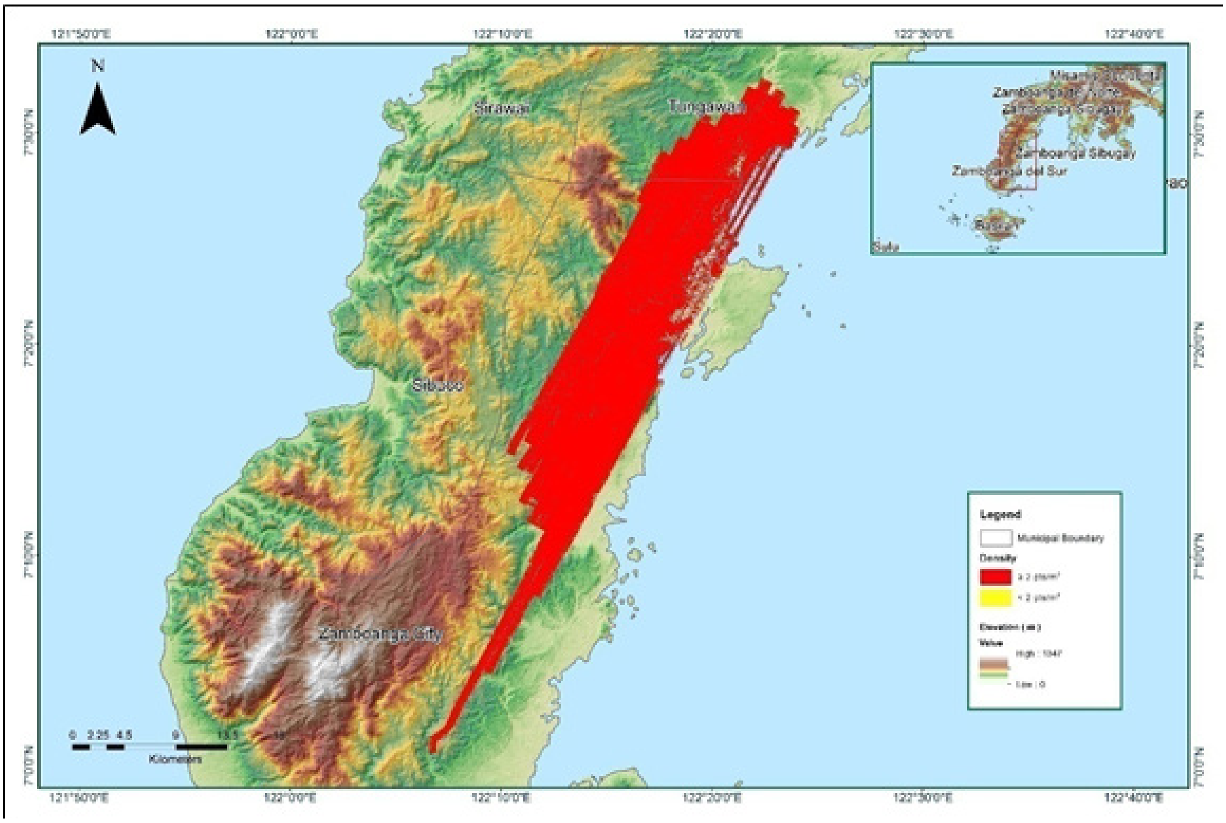


Figure 1.1.6 Density Map

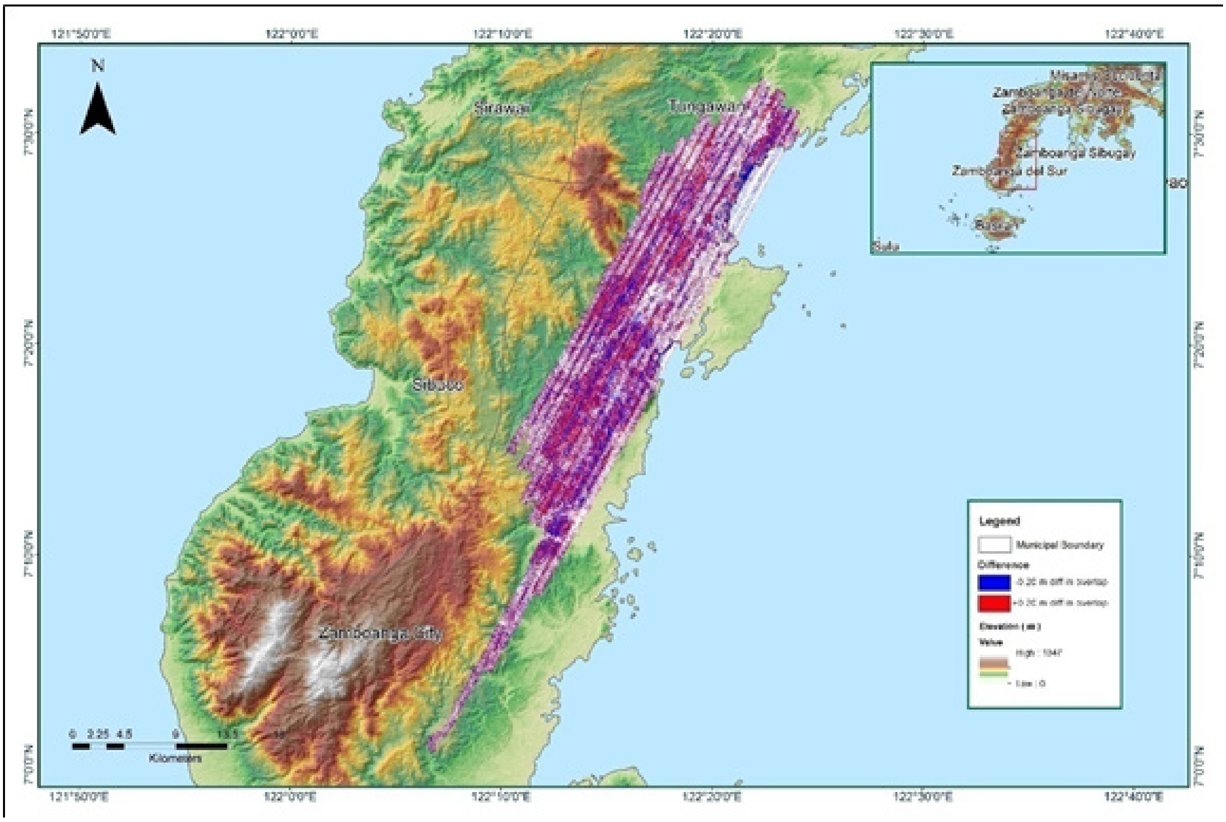


Figure 1.1.7 Elevation difference between flight

Flight Area	Zamboanga
Mission Name	Blk75D
Inclusive Flights	2539P, 2557P
Range data size	38.1 GB
POS data size	430 MB
Base data size	16.67 MB
Image	60.1 GB
Transfer date	February 27 2015
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)	2.10
RMSE for East Position (<4.0 cm)	2.40
RMSE for Down Position (<8.0 cm)	8.50
Boresight correction stdev (<0.001deg)	0.000340
IMU attitude correction stdev (<0.001deg)	0.000781
GPS position stdev (<0.01m)	0.0081
Minimum % overlap (>25)	94.25%
Ave point cloud density per sq.m. (>2.0)	4.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	294
Maximum Height	477.12 m
Minimum Height	67.95 m
Classification (# of points)	
Ground	172,368,975
Low vegetation	158,047,715
Medium vegetation	182,939,695
High vegetation	269,334,338
Building	2,718,053
Orthophoto	YES
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Alex John Escobido

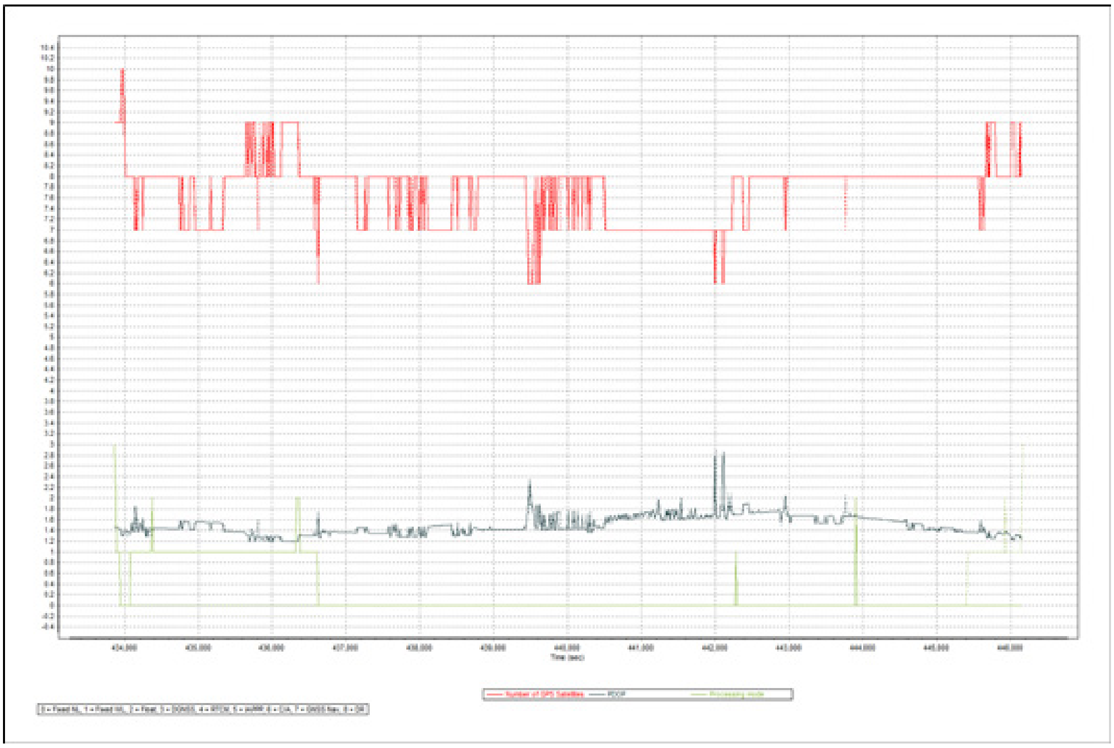


Figure 1.2.1 Solution Status

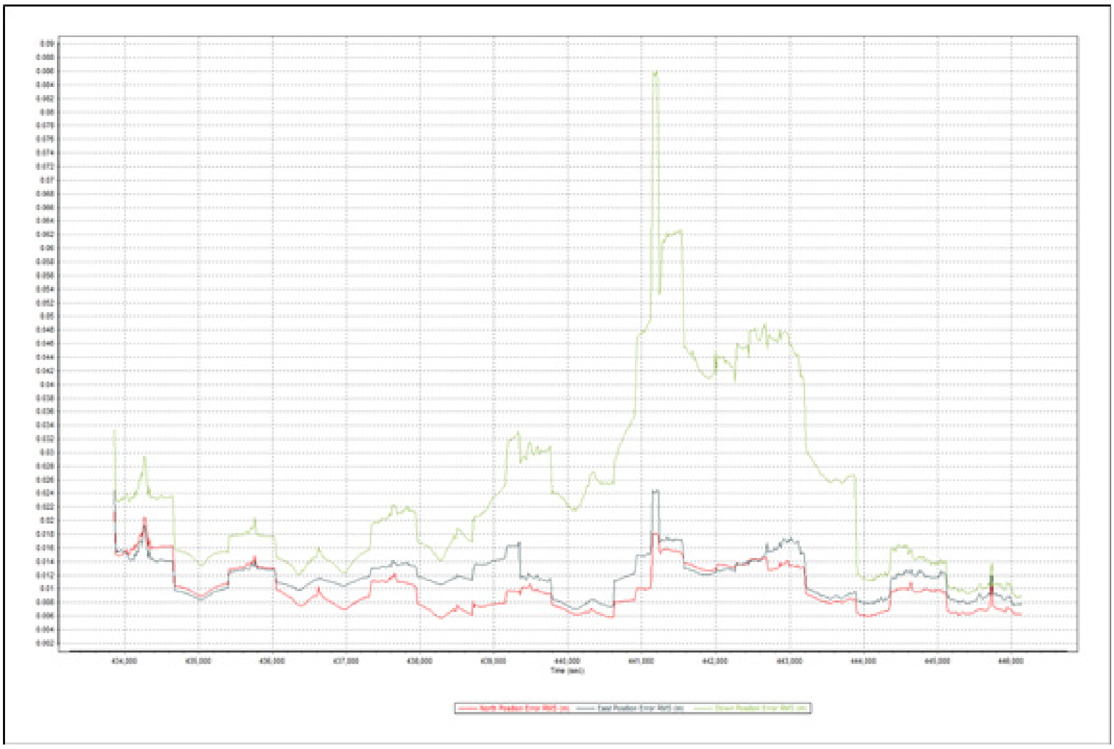


Figure 1.2.2 Smoothed Performance Metric Parameters

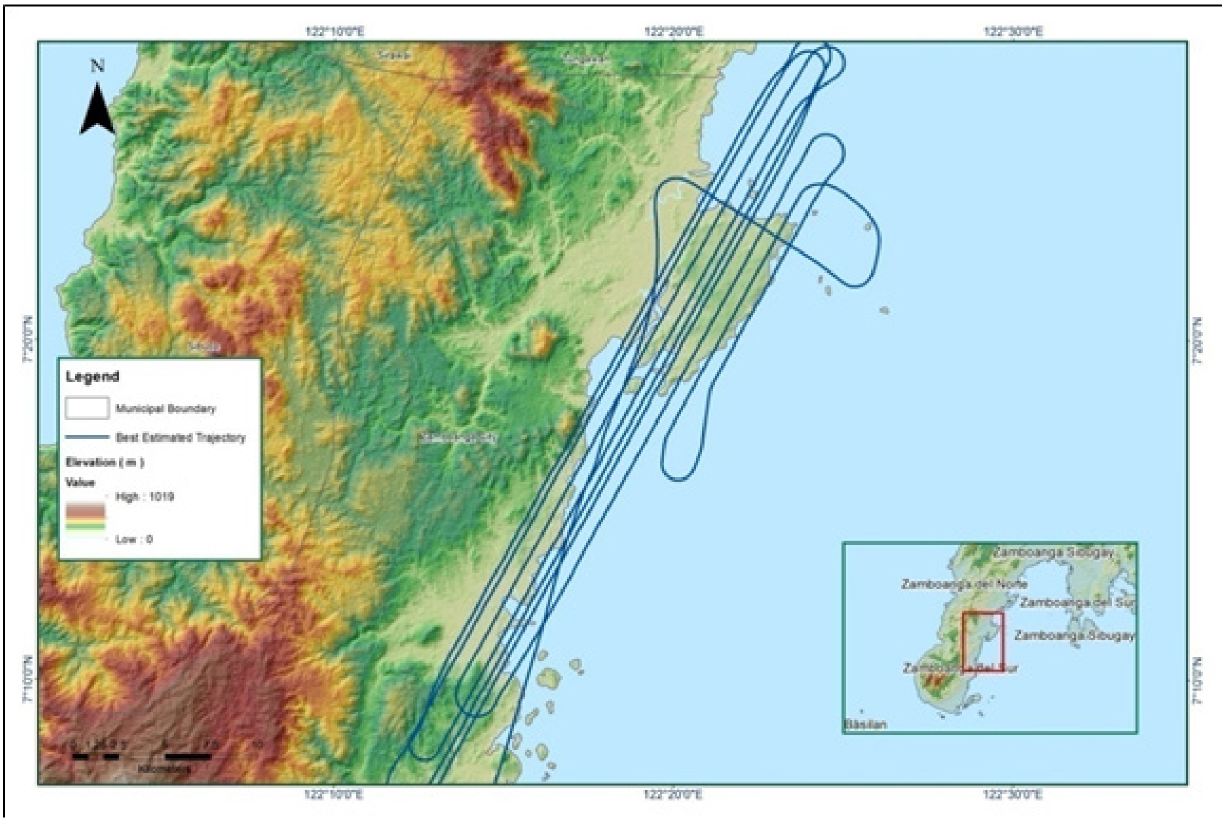


Figure 1.2.3. Best Estimated Trajectory

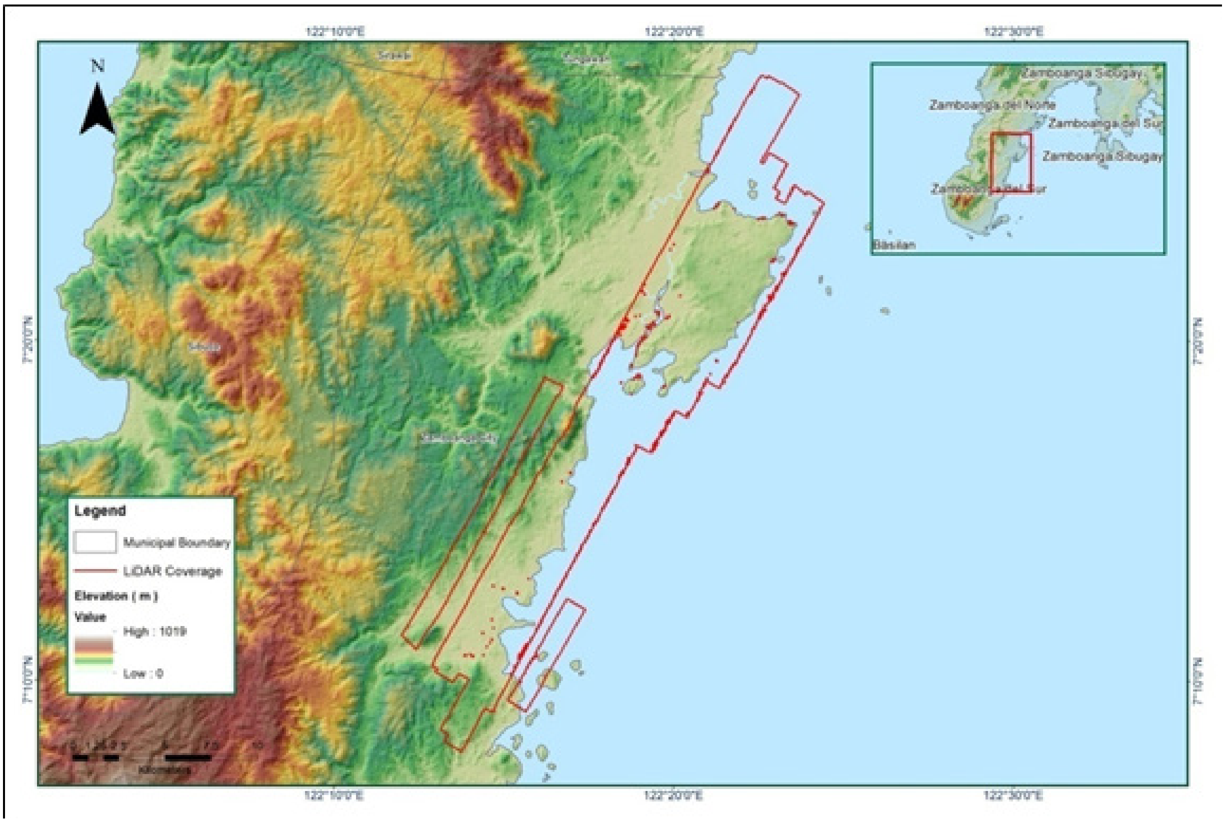


Figure 1.2.4 Coverage of LiDAR Data

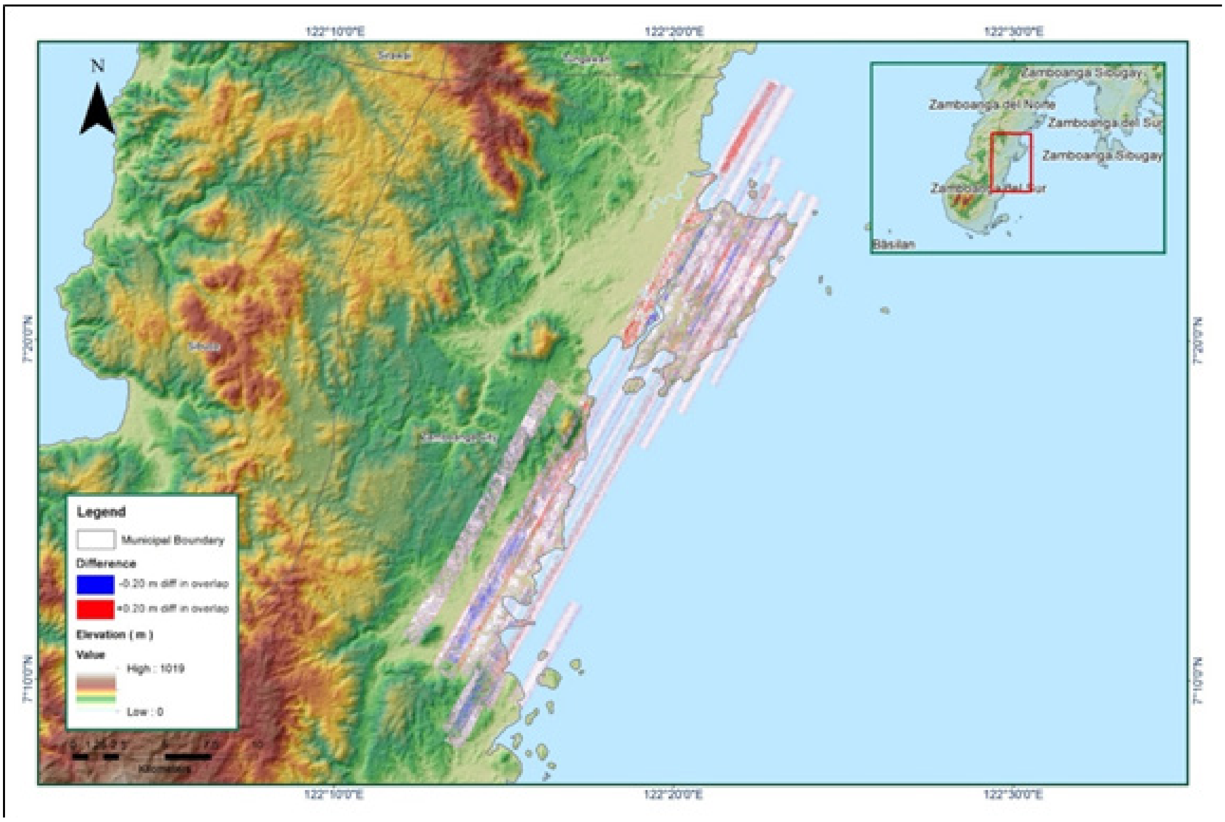


Figure 1.2.5 Image Data Overlap

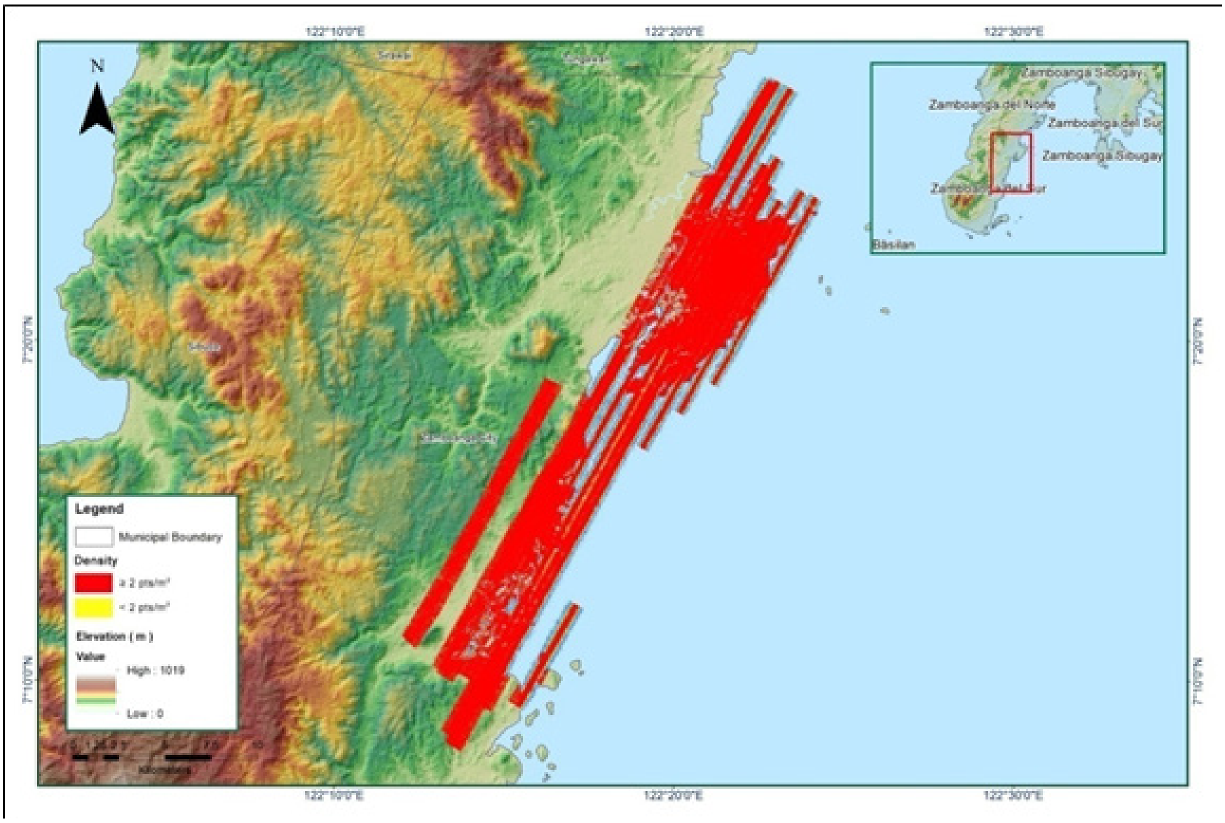


Figure 1.2.6 Density Map

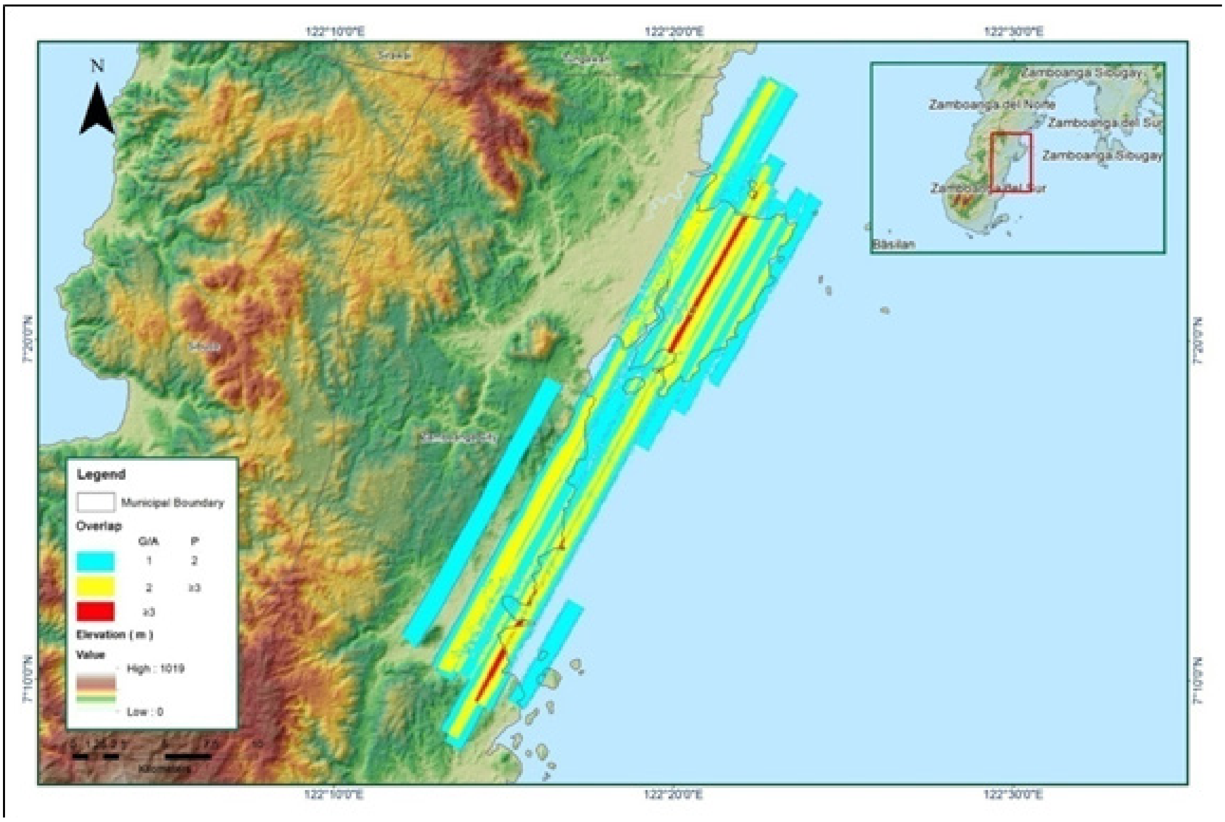


Figure 1.2.7 Elevation difference between flight lines

Annex 9. Vitali Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W500	0.88185	13.0175	0	4.8685	1.1078315	Discharge	0.12265	0.5	Ratio to Peak	0.01
W510	1.03935	12	0	2.6468	0.534905	Discharge	0.0420482	0.5	Ratio to Peak	0.01
W520	1.06615	14.3245	0	3.6969	0.8274985	Discharge	0.0738715	0.5	Ratio to Peak	0.01
W530	1.01145	12.16025	0	4.1495	0.162285	Discharge	0.0022706	0.5	Ratio to Peak	0.01
W540	1.36565	12.124	0	1.6866	0.42284	Discharge	0.0153408	0.5	Ratio to Peak	0.01
W550	1.03185	12	0	1.9737	0.352594	Discharge	0.0279847	0.5	Ratio to Peak	0.01
W560	0.97395	12.4165	0	10.005	0.525729	Discharge	0.0792369	0.5	Ratio to Peak	0.01
W570	0.25286	17.95275	0	2.9838	0.834334	Discharge	0.0829255	0.5	Ratio to Peak	0.01
W580	0.16839	19.82175	0	0.70966	0.408549	Discharge	0.0352877	0.5	Ratio to Peak	0.01
W590	0.67295	12.20675	0	4.0974	0.2062585	Discharge	0.0183751	0.5	Ratio to Peak	0.01
W600	0.28019	17.41975	0	1.827	0.175987	Discharge	0.0088390	0.5	Ratio to Peak	0.01
W610	0.5187	16.24225	0	0.54894	0.343418	Discharge	0.0686294	0.5	Ratio to Peak	0.01
W620	0.54495	13.535	0	4.9598	0.10334625	Discharge	0.0020188	0.5	Ratio to Peak	0.01
W630	1.0406	12	0	3.4104	0.1890535	Discharge	0.0221954	0.5	Ratio to Peak	0.01
W640	0.6982	12	0	0.89866	0.663245	Discharge	0.0530652	0.5	Ratio to Peak	0.01
W650	1.0421	12	0	1.52	0.27869	Discharge	0.0226346	0.5	Ratio to Peak	0.01
W660	0.69475	12	0	1.2263	0.2048325	Discharge	0.0071622	0.5	Ratio to Peak	0.01
W670	1.55515	12	0	2.3333	0.568416	Discharge	0.0258832	0.5	Ratio to Peak	0.01
W680	0.9729	12.42975	0	3.6947	0.09672775	Discharge	0.0050149	0.5	Ratio to Peak	0.01
W690	0.25675	17.8785	0	3.4063	0.947608	Discharge	0.0548674	0.5	Ratio to Peak	0.01
W700	0.178765	19.572	0	0.93694	0.481678	Discharge	0.0735800	0.5	Ratio to Peak	0.01
W710	0.181805	19.5	0	0.1811	0.267995	Discharge	0.0159721	0.5	Ratio to Peak	0.01

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W720	0.1818	19.5	0	1.5045	0.663586	Discharge	0.0346732	0.5	Ratio to Peak	0.01
W730	0.52965	13.69775	0	1.94	1.34199	Discharge	0.13819	0.5	Ratio to Peak	0.01
W740	0.69815	12	0	4.5619	1.153975	Discharge	0.0610156	0.5	Ratio to Peak	0.01
W750	0.356885	16.08275	0	5.3052	0.4907455	Discharge	0.0383083	0.5	Ratio to Peak	0.01
W760	0.51325	13.85225	0	2.6233	0.3805715	Discharge	0.0271551	0.5	Ratio to Peak	0.01
W770	0.405	19.5	0	1.0594	0.0458118	Discharge	6.19875E-5	0.5	Ratio to Peak	0.01
W780	0.191435	19.27525	0	1.9042	0.2370105	Discharge	0.0255259	0.5	Ratio to Peak	0.01
W790	1.5523	12.01075	0	3.7461	0.861645	Discharge	0.0534998	0.5	Ratio to Peak	0.01
W800	0.181805	19.5	0	0.38238	0.9346035	Discharge	0.0395366	0.5	Ratio to Peak	0.01
W810	1.28455	13.1945	0	2.247	0.59024	Discharge	0.0126347	0.5	Ratio to Peak	0.01
W820	0.1818	19.5	0	0.80972	0.310217	Discharge	0.0022423	0.5	Ratio to Peak	0.01
W830	0.27135	19.5	0	1.1017	0.3845085	Discharge	0.0108670	0.5	Ratio to Peak	0.01
W840	1.3322	12.94175	0	2.6219	0.227323	Discharge	0.0027053	0.5	Ratio to Peak	0.01
W850	0.10956	21.368	0	0.74738	0.8626835	Discharge	0.0505015	0.5	Ratio to Peak	0.01
W860	0.08039	22.22775	0	0.40855	1.2546165	Discharge	0.0589662	0.5	Ratio to Peak	0.01
W870	0.13801	20.59125	0	1.3576	0.1388614	Discharge	0.0059355	0.5	Ratio to Peak	0.01
W880	0.097715	21.709	0	0.69574	0.4621635	Discharge	0.0370777	0.5	Ratio to Peak	0.01
W890	0.12828	20.86775	0	0.81537	1.0364695	Discharge	0.0808960	0.5	Ratio to Peak	0.01
W900	0.19214	19.281	0	1.6151	0.179521	Discharge	0.0052261	0.5	Ratio to Peak	0.01
W910	0.26452	17.73925	0	3.2983	0.754788	Discharge	0.11091	0.5	Ratio to Peak	0.01
W920	0.23496	18.34575	0	2.0783	2.53084	Discharge	0.0842036	0.5	Ratio to Peak	0.01
W930	1.7444	16.206	0	1.3939	0.499255	Discharge	0.0220010	0.5	Ratio to Peak	0.01
W940	0.33627	16.43575	0	1.6715	0.4266375	Discharge	0.0301045	0.5	Ratio to Peak	0.01
W950	0.329215	16.57575	0	0.64157	1.04966	Discharge	0.0665800	0.5	Ratio to Peak	0.01

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W960	1.29495	15.60575	0	3.2713	0.935161903	Discharge	0.0443701	0.5	Ratio to Peak	0.01
W970	0.42036	15.1405	0	2.1146	0.6695225	Discharge	0.0229277	0.5	Ratio to Peak	0.01
W980	0.9397	15.14	0	4.0337	1.231537	Discharge	0.0550243	0.5	Ratio to Peak	0.01

Annex 10. Vitali Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	338.99	0.0323520	0.01	Trapezoid	30	1
R40	Automatic Fixed Interval	1839.5	0.0080315	0.01	Trapezoid	30	1
R70	Automatic Fixed Interval	5546.1	0.0192946	0.01	Trapezoid	30	1
R90	Automatic Fixed Interval	1774.4	0.0068555	0.01	Trapezoid	30	1
R100	Automatic Fixed Interval	1432.9	0.0001176	0.01	Trapezoid	30	1
R110	Automatic Fixed Interval	666.98	0.0002527	0.01	Trapezoid	30	1
R150	Automatic Fixed Interval	1704.3	0.0118110	0.01	Trapezoid	30	1
R160	Automatic Fixed Interval	3899.7	0.0012973	0.01	Trapezoid	30	1
R190	Automatic Fixed Interval	953.55	0.0014112	0.01	Trapezoid	30	1
R210	Automatic Fixed Interval	1530.2	0.0049649	0.01	Trapezoid	30	1
R220	Automatic Fixed Interval	42.426	0.0359668	0.01	Trapezoid	30	1
R270	Automatic Fixed Interval	5221.7	0.0084161	0.01	Trapezoid	30	1
R290	Automatic Fixed Interval	900.42	0.0152785	0.01	Trapezoid	30	1
R310	Automatic Fixed Interval	992.25	0.0212994	0.01	Trapezoid	30	1
R320	Automatic Fixed Interval	4651.2	0.0036009	0.01	Trapezoid	30	1
R330	Automatic Fixed Interval	3635.3	0.0079066	0.01	Trapezoid	30	1
R340	Automatic Fixed Interval	2192.0	0.0418606	0.01	Trapezoid	30	1
R350	Automatic Fixed Interval	720.42	0.0412070	0.01	Trapezoid	30	1
R370	Automatic Fixed Interval	863.55	0.0023482	0.01	Trapezoid	30	1
R380	Automatic Fixed Interval	750.83	0.0299190	0.01	Trapezoid	30	1
R390	Automatic Fixed Interval	4694.2	0.0068035	0.01	Trapezoid	30	1
R440	Automatic Fixed Interval	6684.0	0.0023247	0.01	Trapezoid	30	1
R450	Automatic Fixed Interval	5511.4	0.0194273	0.01	Trapezoid	30	1
R480	Automatic Fixed Interval	2614.9	0.0109734	0.01	Trapezoid	30	1

Annex 11. Vitali Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
1	Abdu sauban	419737.8423	812953.0251	0.03	0.20	-0.17	5 -Year
2	Abdul Bansalan	419917.054	813083.1338	0.84	0.20	0.64	5 -Year
3	Abdurahman Hack	419958.1419	813076.8938	0.30	0.20	0.10	5 -Year
4	Adoracion Ramos	420978.2472	815001.3904	0.89	1.00	-0.11	5 -Year
5	Agustine Bides Jr.	424439.908	814412.6783	0.26	0.20	0.06	5 -Year
6	Aida Fernando	420453.1091	815572.9121	1.15	0.50	0.65	5 -Year
7	Aida lamanilaw	421778.5693	815075.1185	0.03	0.06	-0.03	5 -Year
8	Aimee Ann Salvador	420507.5486	815453.2762	0.93	0.20	0.73	5 -Year
9	airene cando	421943.1781	815182.4491	0.16	0.20	-0.04	5 -Year
10	Alberto ferrer	421773.89	815109.074	0.03	0.05	-0.02	5 -Year
11	Alex Alfaro	424228.5843	814505.8002	0.03	0.10	-0.07	5 -Year
12	Alex nolepaniola	421606.6556	814881.8176	0.03	0.03	0.00	5 -Year
13	Alexander Vidad	420528.6693	815431.602	0.83	0.20	0.63	5 -Year
14	Alfredo S. Nulo	420899.7389	814716.6503	0.58	0.30	0.28	5 -Year
15	Aliya Bayan	420020.8662	813070.7327	0.48	0.20	0.28	5 -Year
16	Alphame Gonzales	423750.5989	811980.2965	0.33	0.50	-0.17	5 -Year
17	Alvin ampo	421740.769	814815.0642	0.06	0.03	0.03	5 -Year
18	Alvin belantes	421571.1412	814841.9767	0.14	0.06	0.08	5 -Year
19	Amnilla hack	419995.6362	813050.8233	0.33	0.30	0.03	5 -Year
20	Amy Jane Francisco	421218.4875	814395.0946	0.22	0.20	0.02	5 -Year
21	Anabella Hipolito	424305.3391	814495.3004	0.20	0.50	-0.30	5 -Year
22	Analie Condeno	420787.0583	815259.8109	0.27	0.60	-0.33	5 -Year
23	Analie Cuasito	421455.5052	814080.2221	0.25	0.20	0.05	5 -Year
24	Analiza Vilasis	423562.7526	811924.4235	0.03	0.50	-0.47	5 -Year
25	Andarang Pangkalan	420574.6692	813016.8285	0.03	0.10	-0.07	5 -Year
26	Andres Caputilla	421416.1254	814104.5321	0.25	0.20	0.05	5 -Year
27	Angelina Palasangga	420871.5787	815038.5721	0.48	0.50	-0.02	5 -Year
28	Angelito Fuentes	421725.4971	814920.8815	0.03	0.02	0.01	5 -Year
29	Anita Angeles	420845.2265	815183.7026	0.51	0.20	0.31	5 -Year
30	Antonia C. Torres	423377.7792	815923.8862	0.38	0.11	0.27	5 -Year
31	Antonia T. Acejas	417217.5246	811368.7295	0.03	1.50	-1.47	5 -Year
32	antonio angeles	421764.748	814902.682	0.03	0.07	-0.04	5 -Year
33	Antonio falcasantos	421852.7127	814855.1808	0.17	0.10	0.07	5 -Year
34	Anwar Kumalarng	420006.2313	813092.0711	0.15	0.20	-0.05	5 -Year
35	Aracelie Ancheta	422971.7277	815270.8407	0.35	0.50	-0.15	5 -Year

Point Number	Validation Coordinates			Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long						
36	Aracelie Sanchez	420991.8601	814930.2261	1.23	0.50	0.73	5 -Year
37	Arcy Manalo	421014.7787	814981.2353	0.84	0.80	0.04	5 -Year
38	Arlene Delos Reyes	423057.2176	814613.2692	0.78	0.50	0.28	5 -Year
39	Arlene Fernando	420820.3974	815725.151	0.06	0.50	-0.44	5 -Year
40	Arlito Limen	424144.3899	814527.1809	0.57	0.50	0.07	5 -Year
41	Arlyn Perez	422893.5526	813648.0587	0.03	0.10	-0.07	5 -Year
42	Armando Arias	421231.2821	814461.5957	0.08	0.40	-0.32	5 -Year
43	Armando Miñosa	423553.22	811893.6426	0.06	0.20	-0.14	5 -Year
44	Arnel Angeles	421616.5542	814943.878	0.03	0.02	0.01	5 -Year
45	Arnold Feliciano	421462.8027	814068.3679	0.03	0.20	-0.17	5 -Year
46	Arturo Dayday	421551.8949	812766.4697	0.03	0.20	-0.17	5 -Year
47	Asma Amsani	419806.3952	813088.5083	0.51	0.40	0.11	5 -Year
48	Asniri kisalan	419399.789	813066.4599	0.38	0.60	-0.22	5 -Year
49	Aurora Sagdi	421013.8083	814953.8774	0.83	0.50	0.33	5 -Year
50	Baby Deslate	420992.3426	815011.9548	0.81	1.00	-0.19	5 -Year
51	Bobong Francisco	421339.8953	814926.4955	0.82	0.50	0.32	5 -Year
52	Carlos Comisas	421217.2682	814453.1677	0.05	0.20	-0.15	5 -Year
53	Carmelita Alfonso	420941.0484	815041.9801	0.65	0.50	0.15	5 -Year
54	Carolyn T. Ituralde	423401.5084	815927.0628	0.44	0.13	0.31	5 -Year
55	Cecile Guevara	421613.1812	815006.4983	1.76	2.00	-0.24	5 -Year
56	Celina Sanson	421405.4679	814854.8397	1.18	0.90	0.28	5 -Year
57	Cerelina Basalo	420757.3932	815233.5045	0.49	0.50	-0.01	5 -Year
58	Cesar Nones	423025.7368	813527.1044	0.03	0.10	-0.07	5 -Year
59	Charity Aizon	421219.5722	814464.1534	0.03	0.40	-0.37	5 -Year
60	Chester Cudia	421245.6593	814582.9998	2.10	2.00	0.10	5 -Year
61	Corazon Francisco Perez	420961.4861	812771.3819	0.14	0.20	-0.06	5 -Year
62	Danilo Fernando	420492.274	815565.7991	1.12	2.80	-1.68	5 -Year
63	Dante Perez	420952.7375	812778.3612	0.14	0.20	-0.06	5 -Year
64	Darya Santis	424189.1002	814493.933	0.23	0.20	0.03	5 -Year
65	David buayan	421677.6507	814889.9831	0.07	0.04	0.03	5 -Year
66	Delia Borce	424426.3466	814079.6245	0.58	0.50	0.08	5 -Year
67	Dolcisima Garcia	421375.0388	814860.6196	0.89	0.50	0.39	5 -Year
68	Dolores Bitay	424135.4228	814513.2834	0.03	0.02	0.01	5 -Year
69	Dolores cagurin	421755.3607	815083.7007	0.04	0.07	-0.03	5 -Year
70	Edna Gregorio	420494.7836	815469.9633	0.81	0.20	0.61	5 -Year
71	Eduardo Angeles	420818.8428	815231.7106	0.23	0.50	-0.27	5 -Year
72	Edwin Cuevas	421363.2659	814889.6477	1.10	0.80	0.30	5 -Year
73	Edwin Manalansan	420926.1396	815058.3158	0.52	0.50	0.02	5 -Year

Point Number	Validation Coordinates			Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long						
74	Edwina Sanson	421021.3474	814946.1762	0.64	0.50	0.14	5 -Year
75	Efren guevarra	421781.5498	814927.9569	0.03	0.02	0.01	5 -Year
76	Elena Perano	421033.3403	814945.1326	0.74	0.50	0.24	5 -Year
77	Elena T. Torres	423396.3326	815915.8093	0.34	0.12	0.22	5 -Year
78	Elensia Lana	421827.7864	814370.5428	0.57	0.50	0.07	5 -Year
79	Elizabeth esmires	421938.5974	815172.7027	0.25	0.15	0.10	5 -Year
80	Elizabeth f. Arcillas	421913.5196	815232.1954	0.21	0.20	0.01	5 -Year
81	Elizabeth Taglucop	423612.5106	811979.2192	0.35	0.50	-0.15	5 -Year
82	Elmer Limen	421319.761	814900.0401	1.15	0.50	0.65	5 -Year
83	Elmer P. Ziton	417447.1039	811496.115	0.47	0.40	0.07	5 -Year
84	Eloisa Vergara	424473.5509	814171.2884	0.27	0.10	0.17	5 -Year
85	Ema	420809.3161	814997.177	0.72	0.50	0.22	5 -Year
86	Emalyn Llanita	420952.3944	815024.4233	0.83	1.00	-0.17	5 -Year
87	Emelia Liogan	423775.6115	811995.1678	0.37	0.50	-0.13	5 -Year
88	Emilia Midel	420866.5586	814949.3989	0.90	0.80	0.10	5 -Year
89	Emillia Francisco	421758.2267	814781.9585	0.30	0.50	-0.20	5 -Year
90	Encarnacion Guevara	424030.8529	814582.7533	0.03	0.10	-0.07	5 -Year
91	Enocencia estrellas	421916.6952	815180.0732	0.56	0.50	0.06	5 -Year
92	Enrique Alvarez	421395.7132	814848.8982	1.28	0.90	0.38	5 -Year
93	Erlinda Eden	422970.6977	813508.3942	0.03	0.10	-0.07	5 -Year
94	Erlinda F. Alam	424201.2861	814525.9356	0.21	0.05	0.16	5 -Year
95	Ermelita T. Casimiro	420956.7283	814717.9525	0.68	0.30	0.38	5 -Year
96	Ernesto Dela Mer-cednmarine Product	421553.491	814884.5555	0.03	0.05	-0.02	5 -Year
97	Erwin Arcillas	420926.929	814959.0716	0.99	0.80	0.19	5 -Year
98	Erwin L. Eugenio	423274.0011	815868.3605	0.60	0.10	0.50	5 -Year
99	Ester Angeles	420982.0502	814990.9332	1.34	1.00	0.34	5 -Year
100	Evangeline Catamisan	424599.3618	814258.217	0.37	0.20	0.17	5 -Year
101	Expedito Angeles	420856.3711	815173.9239	0.53	0.50	0.03	5 -Year
102	Expedito Midel	420829.3998	816889.6353	0.03	0.50	-0.47	5 -Year
103	Fast food of Estela Abella	421426.7166	814819.2903	0.80	0.70	0.10	5 -Year
104	Fatima Midel	420884.6207	814921.5993	0.87	0.50	0.37	5 -Year
105	Fe Alejo	421609.7307	814939.534	0.03	0.02	0.01	5 -Year
106	Fe Manalo	420911.5794	815051.8808	0.73	0.50	0.23	5 -Year
107	Fedelina Perez	421356.9611	812861.4411	0.03	0.50	-0.47	5 -Year
108	Federico Salahug	423742.2799	815944.2127	0.28	0.15	0.13	5 -Year
109	Felixberto Salvador	420510.509	815441.5104	0.83	0.20	0.63	5 -Year
110	Flordelisa Bides	424442.841	814527.8519	0.27	0.20	0.07	5 -Year
111	Frechie Perez	423709.1895	811986.7566	0.21	0.50	-0.29	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
112	Fredie Gegone	424221.0197	814493.6183	0.19	0.10	0.09	5 -Year
113	Genaro Vergara	424215.0559	814528.1188	0.37	0.20	0.17	5 -Year
114	Georgina Cabiles	420582.942	815473.2877	1.40	2.00	-0.60	5 -Year
115	Georgina F. Delante	417482.2107	811518.1977	0.14	0.10	0.04	5 -Year
116	Gerlie Ramos	424075.0719	814565.145	0.19	0.10	0.09	5 -Year
117	Gina Angeles	420938.2081	815046.0584	0.68	0.50	0.18	5 -Year
118	Gisell delacruz	421735.9771	814826.213	0.05	0.03	0.02	5 -Year
119	Gomersindo Belarde	420465.0797	815583.2673	1.15	2.80	-1.65	5 -Year
120	Haji Pangkalan	420481.5184	813033.5672	0.09	0.10	-0.01	5 -Year
121	Hassan Kumalarang	420001.7964	813074.8666	0.54	0.20	0.34	5 -Year
122	Helen saavedra	424164.6814	814508.8584	0.05	0.04	0.01	5 -Year
123	Herendito Angeles Jr.	420817.053	815197.6545	0.41	0.20	0.21	5 -Year
124	Hilaria angeles	421827.6453	814920.9422	0.03	0.05	-0.02	5 -Year
125	HTipa danial	419443.3746	813064.8573	0.35	0.50	-0.15	5 -Year
126	Ignacia Napalcruz	423624.1397	813929.0221	0.03	0.05	-0.02	5 -Year
127	Imie Hipolito	420797.039	815006.9929	0.52	0.50	0.02	5 -Year
128	Isidro Goron	421714.9337	810642.5794	0.03	0.20	-0.17	5 -Year
129	Isnaura sauban	419372.5285	813064.8415	0.33	0.60	-0.27	5 -Year
130	Jackka Mohammad	419788.4495	813099.9307	0.45	0.40	0.05	5 -Year
131	Jaime Delos Reyes	424416.2826	814530.6811	0.13	0.10	0.03	5 -Year
132	James Vergara	424179.9153	814522.7887	0.19	0.10	0.09	5 -Year
133	Jamil samson	419392.5046	813025.8557	0.24	0.50	-0.26	5 -Year
134	Jane Christy Rey	421080.3108	811415.0516	0.06	0.20	-0.14	5 -Year
135	Jay Marvin F. Sotto	423232.691	815902.9209	0.32	0.10	0.22	5 -Year
136	Jeanette batuigas	424501.7214	814263.6882	0.16	0.10	0.06	5 -Year
137	Jeanilyn Hipolito	424296.4989	814493.2628	0.19	0.10	0.09	5 -Year
138	Jeany Napalcruz	424037.1191	814557.889	0.34	0.10	0.24	5 -Year
139	Jennlyn Maywila	421905.4808	814527.4975	0.03	0.02	0.01	5 -Year
140	Jennlyn Niño Nuevo	423359.8332	814981.7922	0.14	0.20	-0.06	5 -Year
141	Jenny Faustino	424091.0794	814407.7354	0.12	0.10	0.02	5 -Year
142	Jerimar F. Sotto	423225.1566	815894.1801	0.27	0.10	0.17	5 -Year
143	Jerry Guevara	424173.9468	814507.8641	0.05	0.04	0.01	5 -Year
144	Jerwin Calva	423347.229	815019.0443	0.31	0.20	0.11	5 -Year
145	Jessa B. Arcillas	423200.2056	815912.6327	0.20	0.10	0.10	5 -Year
146	Jesselyn berdon	421768.6294	814831.5346	0.07	0.02	0.05	5 -Year
147	Jessica alberto	421929.2493	815178.5363	0.15	0.15	0.00	5 -Year
148	Jesus Goron	421725.1188	810644.128	0.03	0.20	-0.17	5 -Year
149	Jesus Ramos	424047.3574	814515.9272	0.04	0.03	0.01	5 -Year
150	Jhonrey Pagasita	421452.3738	814100.2565	0.39	1.00	-0.61	5 -Year
151	Jimroy C. Iba	421224.7604	814696.049	1.28	1.00	0.28	5 -Year
152	Jinnul Usan	419772.4924	813250.1622	0.58	0.60	-0.02	5 -Year
153	Jobert Taripe	421210.9765	814419.7641	0.25	0.20	0.05	5 -Year
154	Jocel DeLos Reyes	424149.7225	814508.9456	0.05	0.04	0.01	5 -Year

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	Lat	Long						
155	Jocelyn Bodce	424444.6686	814130.8913	0.37	0.15	0.22	5 -Year
156	Jocelyn Tibor	421257.7209	814432.5732	0.38	0.50	-0.12	5 -Year
157	Jodel Taglucop	423745.955	812009.0708	0.04	0.50	-0.46	5 -Year
158	Joel Lorenzo	420806.6191	815238.9073	0.22	0.50	-0.28	5 -Year
159	Joerey Basalo	421363.2337	814799.9565	1.27	0.50	0.77	5 -Year
160	John Kumalarang	420010.0956	813076.8998	0.51	0.20	0.31	5 -Year
161	Jojo bansalan	419446.8741	813036.1627	0.20	0.60	-0.40	5 -Year
162	Jomar Falcasantos	421491.866	814059.5003	0.03	0.20	-0.17	5 -Year
163	Jorel Buendia	424140.5825	814513.217	0.22	0.10	0.12	5 -Year
164	Josefine gayon	421779.9755	814775.7937	0.29	0.11	0.18	5 -Year
165	Joselito guevarra	421768.7834	814921.0323	0.62	0.50	0.12	5 -Year
166	Joselito Taglucop	423760.2908	812009.236	0.03	0.50	-0.47	5 -Year
167	Joselito Vidad	420564.4132	815506.5187	1.06	2.50	-1.44	5 -Year
168	Joseph Vidad	423501.8415	811921.529	0.03	0.10	-0.07	5 -Year
169	Joven Pesalbon	424429.3737	814514.701	0.18	0.10	0.08	5 -Year
170	Judith apillas	421690.4061	814896.1629	0.03	0.02	0.01	5 -Year
171	Julhani Amsani	419795.0976	813091.0813	0.13	0.40	-0.27	5 -Year
172	Julie ann paragas	421883.3314	815204.5762	0.75	0.50	0.25	5 -Year
173	Juliet Custodio	421113.1076	813882.3945	0.03	0.20	-0.17	5 -Year
174	Julieta B. Araneta	420934.2919	814715.2184	1.84	1.00	0.84	5 -Year
175	Julio Taglucop	423766.0833	811999.2731	0.20	0.50	-0.30	5 -Year
176	Kambad Pangkalan	420377.0987	813038.4408	0.39	0.10	0.29	5 -Year
177	Kennette Cuenca	424465.8014	814417.0916	0.20	0.10	0.10	5 -Year
178	Kitchen	418313.0367	812427.2042	0.11	0.10	0.01	5 -Year
179	Kitchen	423374.6615	815936.0741	0.53	0.13	0.40	5 -Year
180	Laning amsani	419738.5912	812966.8179	0.03	0.20	-0.17	5 -Year
181	Leonarda araneta	421870.6575	815197.7752	0.83	0.50	0.33	5 -Year
182	Leonora Condeno	421259.8219	814598.8695	2.58	2.00	0.58	5 -Year
183	Lilia L. Torres	423314.0505	815887.0106	0.47	0.10	0.37	5 -Year
184	Lilia Ramos	424116.0595	814531.0588	0.03	0.03	0.00	5 -Year
185	Lilian Gonzales	421217.2347	814411.5108	0.24	0.20	0.04	5 -Year
186	Lilian Muta	421550.7004	815046.2165	1.72	0.50	1.22	5 -Year
187	Lita mangilum	424294.9412	814476.4141	0.42	0.30	0.12	5 -Year
188	Lita Paredes	423730.334	812003.4363	0.33	0.50	-0.17	5 -Year
189	Lito Villacura	421920.7884	814496.9709	0.03	0.01	0.02	5 -Year
190	Lorenzo Espinosa	421232.6467	814135.6957	0.48	0.50	-0.02	5 -Year
191	Lorna Ladraso	421501.8818	814072.941	0.03	0.20	-0.17	5 -Year
192	Lorna Vergara	424469.2848	814161.2267	0.36	0.50	-0.14	5 -Year
193	Luci Bustamante	420962.7936	812791.9462	0.14	0.20	-0.06	5 -Year
194	Lucia	423900.8551	814122.4033	0.04	0.05	-0.01	5 -Year
195	Ludivina lanipa	421771.3316	814762.6934	0.26	0.10	0.16	5 -Year
196	Luvisminda Martinez	421435.0987	814094.1938	0.25	0.20	0.05	5 -Year
197	Manaoag Chapel	421234.935	814468.9032	0.07	0.40	-0.33	5 -Year
198	Maria balucos	421698.126	814918.1273	0.03	0.02	0.01	5 -Year

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	Lat	Long					
199	Maria belen lianeta	421659.426	814921.856	0.03	0.04	-0.01	5 -Year
200	Marian Amsani	419787.4713	813091.6691	0.29	0.40	-0.11	5 -Year
201	Maricel Gil	421720.5794	814873.1396	0.03	0.02	0.01	5 -Year
202	Marichu Dolete	421243.3375	814414.81	0.32	0.50	-0.18	5 -Year
203	Maricor Marquez	420949.204	815032.5354	0.69	0.50	0.19	5 -Year
204	Marilou Falcasantos	421838.2535	814919.4334	0.03	0.04	-0.01	5 -Year
205	Marilyn Tose	421620.8461	814951.0683	0.03	0.02	0.01	5 -Year
206	Mario Perez	420985.1787	812802.5334	0.03	0.02	0.01	5 -Year
207	Marisa Goron	421708.963	810656.8803	0.06	0.20	-0.14	5 -Year
208	Marisa Guevarra	423834.4439	814130.7341	0.07	0.05	0.02	5 -Year
209	Marivic Aguila	420918.2657	814961.4818	1.08	0.80	0.28	5 -Year
210	Marlon Fernando	420523.3222	815542.9556	2.20	2.50	-0.30	5 -Year
211	Marlyn angeles	421722.7743	814827.0276	0.06	0.03	0.03	5 -Year
212	Marlyn falec	421752.841	814875.8339	0.14	0.07	0.07	5 -Year
213	Marlyn Fernandez	420985.0539	814962.4704	0.74	0.50	0.24	5 -Year
214	Marlyn paleg	421803.8567	814870.3532	0.03	0.05	-0.02	5 -Year
215	Marvin Ramillano	421484.3687	814036.3894	0.03	0.20	-0.17	5 -Year
216	Marvin Villarcampo	423555.4695	811900.126	0.05	0.20	-0.15	5 -Year
217	Mary cris malubay	424448.6858	814585.0656	0.17	0.12	0.05	5 -Year
218	Mary jane Falcasantos	421845.824	814915.7357	0.03	0.07	-0.04	5 -Year
219	Mary Jane Impas	420796.6459	815023.1989	0.70	0.50	0.20	5 -Year
220	Matilde P. Aqua	423200.0494	815888.8589	0.94	0.60	0.34	5 -Year
221	Melanio Hermosilla	421218.5688	814432.5438	0.03	0.20	-0.17	5 -Year
222	Melisa S. Delosreyes	421233.5011	814682.8113	1.41	1.30	0.11	5 -Year
223	Melven Saavedra	424573.719	814456.7613	0.12	0.10	0.02	5 -Year
224	Melvin Macario	420935.6223	815049.9834	0.56	0.50	0.06	5 -Year
225	Mercelino entrina	421754.9709	815119.1284	2.56	2.00	0.56	5 -Year
226	Mercham nurilla	419699.5372	813056.5051	0.24	0.30	-0.06	5 -Year
227	Merly Villarcampo	423771.7475	811983.8113	0.20	0.50	-0.30	5 -Year
228	Michael Flores	421361.5604	814856.6547	1.03	0.50	0.53	5 -Year
229	Mikael P. Bucoy	417380.1112	811474.1582	0.55	0.30	0.25	5 -Year
230	Milagrosa Bakilar	424517.3931	814245.5899	0.28	0.10	0.18	5 -Year
231	Mining Lacastesantos	423249.2143	815861.1867	0.35	0.10	0.25	5 -Year
232	Mirna Bueno	424092.5393	814546.1031	0.35	0.20	0.15	5 -Year
233	Mirna Hermosilla	421222.6968	814471.8676	0.03	0.40	-0.37	5 -Year
234	Mishel Mancio	420825.0534	815116.4615	0.72	0.50	0.22	5 -Year
235	Mubin Kumalang	420030.1698	813071.0015	0.43	0.20	0.23	5 -Year
236	Munib jaani	419232.4683	812927.3065	0.03	0.10	-0.07	5 -Year
237	Najan A. Masangka	418479.9045	812701.4502	0.69	0.60	0.09	5 -Year
238	Nalun Kainding	419775.9292	813215.6033	0.38	0.60	-0.22	5 -Year
239	Nanang panglima	419377.6781	813027.7675	0.21	0.50	-0.29	5 -Year

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	Lat	Long					
240	Nardo Macario	421474.21	814000.05	0.38	0.20	0.18	5 -Year
241	Nasser Abdul	419818.35	813104.96	0.36	0.40	-0.04	5 -Year
242	Nelbin M. Atilano	417457.37	811514.22	0.14	0.10	0.04	5 -Year
243	Nelson hillario	421784.12	814769.02	0.28	0.25	0.03	5 -Year
244	Nene Carza	420999.43	812836.49	0.03	0.20	-0.17	5 -Year
245	Nimfa Cuartocruz	421267.36	814608.49	2.58	2.00	0.58	5 -Year
246	Nini Mohammad	419769.94	813105.59	0.70	0.50	0.20	5 -Year
247	Nobeth Macario	421467.23	814009.06	0.38	0.20	0.18	5 -Year
248	Noimi Samson	420985.16	814978.25	0.76	0.50	0.26	5 -Year
249	Nora Suarez	424413.41	814482.7	0.13	0.10	0.03	5 -Year
250	Nora Suarez	424439.41	814120.34	0.55	0.10	0.45	5 -Year
251	Norberto Buendia Batuigas	424134.45	814527.65	0.37	0.03	0.34	5 -Year
252	Norita Desaca	423767.36	812029.01	0.03	0.50	-0.47	5 -Year
253	Norma aping	421789.78	815095.51	0.19	0.07	0.12	5 -Year
254	Normina Ramos	423434.43	815721.01	0.52	0.10	0.42	5 -Year
255	Norvin arcillas	421718.94	814888.96	0.03	0.03	0.00	5 -Year
256	Nurkiya maad	419268.58	813089.79	0.03	0.20	-0.17	5 -Year
257	Ofelia Gregorio	420543.75	815518.68	2.20	2.50	-0.30	5 -Year
258	Ofelito Guevara	420875.96	815166.38	0.54	0.50	0.04	5 -Year
259	Orlando Balan	420444.4	815610.05	1.22	2.80	-1.58	5 -Year
260	Orlando Valencia	423920.91	814129.47	0.03	0.05	-0.02	5 -Year
261	Oscar Salazar	420804.84	815021.77	0.77	0.50	0.27	5 -Year
262	Oyong Usan	419972.28	813078.18	0.43	0.20	0.23	5 -Year
263	Palusong Amsani	419815.92	813083.77	0.54	0.40	0.14	5 -Year
264	Pananjung Mon-tong	419659.36	813056.32	0.21	0.60	-0.39	5 -Year
265	Paulita Vegas	423110.72	815168.93	0.21	0.10	0.11	5 -Year
266	Percibal penaranda	421714.77	814820.93	0.06	0.03	0.03	5 -Year
267	Perlan Mateo	419779.47	813204.37	0.56	0.60	-0.04	5 -Year
268	Pilar dela cruz	421742.39	815072.62	0.03	0.06	-0.03	5 -Year
269	Porpirio Empeñado	420948.71	814717.12	1.76	1.00	0.76	5 -Year
270	Prospero Clemente	420792.13	815243.98	0.25	0.60	-0.35	5 -Year
271	Prudencio Malinis	420430.34	815593.8	1.12	0.50	0.62	5 -Year
272	Puring Hilario	421001.77	814937.2	1.06	0.50	0.56	5 -Year
273	Ramil	421731.89	814885.89	0.14	0.24	-0.10	5 -Year
274	Ramil Guevara	420873.79	815158.52	0.50	0.50	0.00	5 -Year
275	Ramon Maywila	421773.75	814467.67	0.03	0.05	-0.02	5 -Year
276	Raymond Delos Reyes	424288.45	814512.71	0.31	0.30	0.01	5 -Year
277	Regie Angeles	420829.54	815180.94	0.26	0.20	0.06	5 -Year
278	Regine Delos Reyes	423649.6	813948.26	0.07	0.05	0.02	5 -Year
279	Reynalda A. Paragas	421919.05	815214.81	0.23	0.20	0.03	5 -Year
280	Reynaldo Angeles Jr.	420767.96	815181.56	0.35	0.20	0.15	5 -Year
281	Reynaldo Espiritu	420449.68	815604.02	1.22	2.80	-1.58	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
282	Reynaldo Salvador	420508.05	815446.18	0.83	0.20	0.63	5 -Year
283	Reynante Midel	420817.6	815484.53	0.97	0.30	0.67	5 -Year
284	Reynante Porras	421008.67	814933.37	1.00	0.50	0.50	5 -Year
285	Reynerio T. Galvez	423228.72	815863.88	0.23	0.10	0.13	5 -Year
286	Ricarda A. Lacastesan-tos	417596.99	811563.97	1.17	0.10	1.07	5 -Year
287	Richinel L. Torres	423294.45	815879.1	0.49	0.10	0.39	5 -Year
288	Rito Delos Reyes	420766.33	815283.69	0.26	0.20	0.06	5 -Year
289	Rizza A.Alam	424200.81	814518.1	0.24	0.05	0.19	5 -Year
290	Rodolfo Buan	421206.91	814384.38	0.03	0.20	-0.17	5 -Year
291	Rodolfo Delos Reyes	424314.77	814472.91	0.13	0.10	0.03	5 -Year
292	Rodrigo Estrada	421619.9	814995.65	1.52	2.00	-0.48	5 -Year
293	Rodrigo Sabido	424412.59	814454.79	0.08	0.05	0.03	5 -Year
294	Roel G. Pelayo	423254.6	815875.88	0.43	0.10	0.33	5 -Year
295	Roel panasantos	421840.92	815079.11	0.22	0.19	0.03	5 -Year
296	Roger bolutano	421650.5	814831.32	0.03	0.04	-0.01	5 -Year
297	Roger Guevara	420527.12	815530.16	2.20	2.50	-0.30	5 -Year
298	Roger Napalcruz	423641.63	813938.22	0.04	0.05	-0.01	5 -Year
299	Rolando C. Morales	423609.08	815993.29	0.50	0.10	0.40	5 -Year
300	Romel Maywila	421781.44	814450.59	0.03	0.04	-0.01	5 -Year
301	Romulo Cuenca	424458.72	814406.28	0.20	0.10	0.10	5 -Year
302	Ronald P. Bucoy	417431.87	811476.62	1.24	0.50	0.74	5 -Year
303	Ronald Suarez	424311.37	814480.98	0.13	0.50	-0.37	5 -Year
304	Ronel nagrama	421761.17	815089.6	0.03	0.06	-0.03	5 -Year
305	Ronni Vergara	424399	814594.77	0.23	0.16	0.07	5 -Year
306	Rosalinda Goron	421738.33	810640.12	0.03	0.20	-0.17	5 -Year
307	Rosalio Salazar	420835.34	814960.65	1.01	0.50	0.51	5 -Year
308	Rosario hillario	421756.72	814799.12	0.03	0.03	0.00	5 -Year
309	Rosella Dianan	421786.66	814930.62	0.03	0.03	0.00	5 -Year
310	Rosemary Falcasantos	421049.37	816115.04	0.03	0.50	-0.47	5 -Year
311	Rosemary Midel	420806.34	815478.06	0.63	0.50	0.13	5 -Year
312	Ryan Resurrecssion	424324.65	814460.55	0.16	0.10	0.06	5 -Year
313	Samson Bides	424423.66	814402.2	0.20	0.10	0.10	5 -Year
314	Sandra Taglucop	423761.87	811979.26	0.18	0.50	-0.32	5 -Year
315	Sara Barera	423941.87	814147.72	0.03	0.05	-0.02	5 -Year
316	Sarabil Halon	420041.37	813070.85	0.38	0.20	0.18	5 -Year
317	School building	419733.44	813106.56	0.63	0.60	0.03	5 -Year
318	School building	419690.91	813104.46	0.57	0.60	-0.03	5 -Year
319	School building	419696.86	813087.46	0.22	0.60	-0.38	5 -Year
320	School Cr	419683.53	813082.69	0.28	0.60	-0.32	5 -Year
321	Serapin Goron	421754.33	810642.93	0.08	0.20	-0.12	5 -Year
322	Service garage	423193.16	815901.09	0.16	0.10	0.06	5 -Year
323	Sherly bongganay	424412.14	814505.13	0.38	0.30	0.08	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
324	Sitti S. Ramos	424035.55	814538.39	0.09	0.10	-0.01	5 -Year
325	Slaughterhouse of Awring Chong	421429.28	814872.76	1.13	0.90	0.23	5 -Year
326	Steffanie ando	421792.37	814891.55	0.05	0.03	0.02	5 -Year
327	Taguan Najan	419695.66	813244.64	0.55	0.60	-0.05	5 -Year
328	Telma B Escala	424461.28	814156.08	0.57	0.50	0.07	5 -Year
329	Telma Bayona	421400.59	814819.19	0.99	0.50	0.49	5 -Year
330	Telma bides	424453.98	814420.08	0.43	0.20	0.23	5 -Year
331	Teresita B.Fernando	420766.04	815242.61	0.55	0.60	-0.05	5 -Year
332	Teresita Manalansan	420924.01	815032.39	0.64	0.50	0.14	5 -Year
333	Tereso Libres	423280.36	815066.17	0.20	0.10	0.10	5 -Year
334	Tony Sala	419760.61	813198.49	0.39	0.60	-0.21	5 -Year
335	Tuti Buendia	424111.69	814514.23	0.03	0.02	0.01	5 -Year
336	Valentine	421464.2	814093.02	1.63	1.20	0.43	5 -Year
337	Valentine Falcasantos	421253.26	814587.25	1.87	2.00	-0.13	5 -Year
338	Vicente Ebuña	424071.02	814486.25	0.17	0.10	0.07	5 -Year
339	victorino falcasantos	421790.41	815115.03	0.03	0.03	0.00	5 -Year
340	Vincent Gacer	420891.81	815138.87	0.57	0.50	0.07	5 -Year
341	Vincent Guevara	421043.36	816223.95	0.03	0.20	-0.17	5 -Year
342	Vitali Central School	421534.63	814941.16	1.29	0.50	0.79	5 -Year
343	Vitali Square cock fighting	421289.28	814871.96	0.22	0.20	0.02	5 -Year
344	Wali Pangkalan	420358.8	813040.89	0.24	0.10	0.14	5 -Year
345	Wall I Tahil	419775.17	813264.69	0.35	0.60	-0.25	5 -Year
346	Walter Ignacio	421376.69	814906.55	1.14	0.80	0.34	5 -Year
347	Weweng mohammad	419757.01	813208.4	0.34	0.60	-0.26	5 -Year
348	Wilfredo Francisco	424235.1	814487.15	0.03	0.06	-0.03	5 -Year
349	Wilfrido Pajarito	421423.24	814842.18	1.06	0.90	0.16	5 -Year
350	Zenaida Alviar	424493.89	814494.99	0.03	0.05	-0.02	5 -Year
351	Zenaida Lacastesantos	420583.55	815486.28	0.91	2.50	-1.59	5 -Year
				RMSE	0.35		

ANNEX 12. Educational Institutions Affected by flooding in Vitali Floodplain

ZAMBOANGA CITY				
		Rainfall Event		
Barangay	Building	5-year	25-year	100-year
Mangusu	Manggusu Integrated School			Low
Mangusu	Day care Center			Low
Mangusu	Dr.manuel S. DIAZ MEMORIAL ELEM. SCHOOL			Low
Mangusu	TRIBU DAY CARE CENTER			Low
Mangusu	Sibuktuk Elementary school			Low
Tumitus	Day care			Medium
Tumitus	Limaong national high school			Medium
Tumitus	Matarling Elementary School			Medium
Tictapul	Tictapul elementary school	Medium	High	High
Tictapul	TICTAPUL NATIONAL HIGH SCHOOL	Medium	High	High
Tictapul	Tamion Elementary School	Medium	High	High
Vitali	VITALI CENTRAL SCHOOL	High	High	High
Vitali	VITALI NATIONAL HIGH SCHOOL	High	High	High
Vitali	ZAMBOANGA CITY STATE POLYTECHNIC COLLEGE	High	High	High
Vitali	Tamion Daycare	High	High	High
Vitali	Asma Amsani	High	High	High
Vitali	School building	High	High	High
Vitali	Pananjung Montong	High	High	High
Vitali	TES ROOM	High	High	High
Vitali	TINDALO ELEMENTARY SCHOOL	High	High	High
Vitali	Vitali care center	High	High	High
Licomo	LICUMO CENTRAL SCHOOL			
Licomo	DAY CARE CENTER			
Licomo	Talaga elementary school			
Licomo	Dre care center			
Limaong	Limaong national high school			
Limaong	Matiti elementary school			
Tigbalabag	Day Care Center			
Tigbalabag	Day Care School			
Tigbalabag	Day care			

ANNEX 13. Health Institutions Affected by flooding in Vitali Floodplain

ZAMBOANGA CITY				
Barangay	**Building**	**Rainfall Scenario**		
		5-year	**25-year**	**100- year**
Vitali	Vitali Center	High	High	High