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

LiDAR Surveys and Flood Mapping of Lian River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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
MIT	MAPUA Institute of Technology
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
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LIAN RIVER

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

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.

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

The implementing partner university for the Phil-LiDAR 1 Program is MAPUA Institute of Technology (MIT). MIT is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 26 river basins in the Southern Tagalog Region. The university is located in Intramuros, Manila.

1.1 Overview of Lian River Basin

Lian River Basin covers portions of the municipalities of Tuy and Lian in Batangas. The DENR River Basin Control Office (RBCO) identified it as one of the 140 critical watersheds in the Philippines, having a drainage area of 184 km2 and an estimated 295 million meter3 annual run-off.

Its main stem, Lian River, as it traverses the Municipality of Lian, Batangas, is part of the 23 river systems in the Southern Tagalog Region. According to the 2010 national census of NSO, a total of 16,015 locals are residing in the immediate vicinity of the river within the jurisdiction of eight (8) barangays, namely: Barangay 2, Barangay 3, Barangay 4, Barangay 5, Malaruhatan, Bagong Pook, Bungahan and Sabang.

The river was earlier found as a Safe River (Class C waters) but is now identified to be risky for recreational and industrial use and propagation of aquatic life. The project of DENR-ERDB verified that the river system contains very high level of coliform and organic pollutants way above the limit for Class C waters. Its recent flood event was on January 18, 2015 caused by the Tropical Storm "Amang" due to light with occasionally moderate rains and thunderstorms.

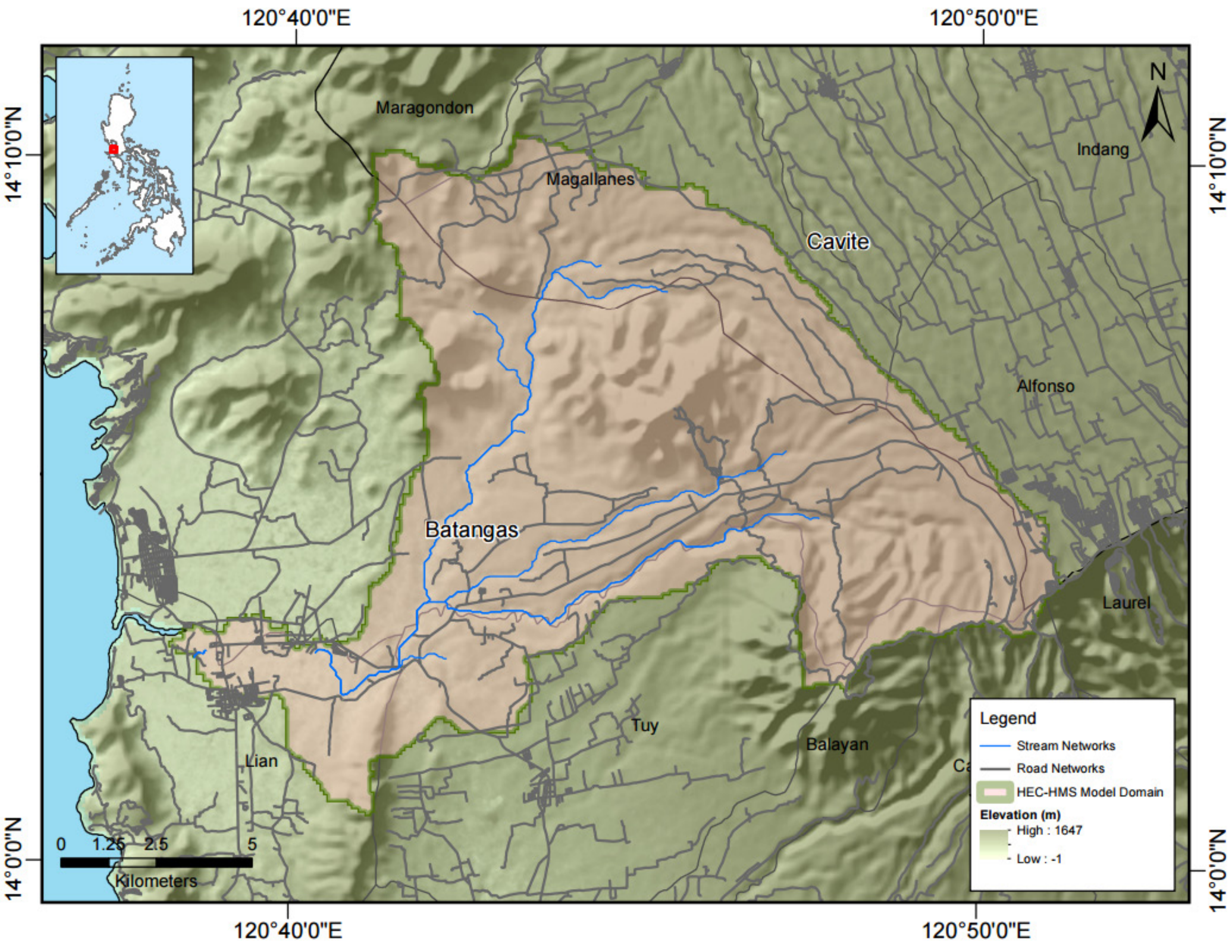

Figure 1. Map of Lian River Basin (in brown)

The Lian River Basin (also known as the Lian-Palico River) traverses from Cavite down to Nasugbu Bay and covers portion of the municipalities of Nasugbu, Lian, Tuy, Magallanes and Alfonso in the northwestern part of Batangas. Specifically, it is located to the southwest of Manila and northwest of Batangas. The main channel is the Lian-Palico River. Located in the southern part of the river basin are Mt. Talamitan and the northern part of Mt. Batulao, and the forest vegetation of the area consists mostly of secondary growth forest in steep slopes of these two mountains.

Batangas province, where the Lian River Basin is located, is frequently visited by typhoons and heavy rains every year. This causes the river tributaries to overflow, resulting in flooding of communities residing near the river or low-lying areas. Flooding is one of the most destructive natural disaster that may hit a community, causing damages to infrastructure and loss of life.

Thus, it becomes imperative to mitigate damages that are being done by these disasters. This can be done through the advancement of a highly accurate digital elevation model of the earth's surface using Light Detection and Ranging (LiDAR) technology. This is applied to flood modelling of river basins to produce high resolution flood hazard maps that can be used by local government units (LGUs) in planning, development and disaster preparedness among its people. With the use of these high-resolution flood hazard maps, it would be easy for an LGU's administrators to identify areas that are at a high risk of flooding under extreme weather conditions and make emergency plans before disasters strike.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LIAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Lian Floodplain in Batangas. These missions were planned for 18 lines that run for at most three (3) hours including take-off, landing and turning time. The flight planning parameters for Pegasus and Gemini LiDAR Systems are found in Table 1 and Table 2, respectively. 3 shows the flight plan for Lian Floodplain Survey.

Table 1. Flight Planning Parameters for Pegasus LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 18Z	1200	30	50	200	50	130	5
BLK 18OS	1000	30	50	200	50	130	5
BLK 18BCS	1000	60	50	200	32	130	5

Table 2. Flight Planning Parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 18G	750	40	50	167	40	120	5
BLK 18SD	750	40	50	167	40	120	5
BLK18SG	1000	40	40	100	50	120	5
BLK18SM	1000	40	40	100	50	120	5
BLK18SG	1000	30	40	100	50	120	5
BLK18SF	1000	30	40	100	50	120	5

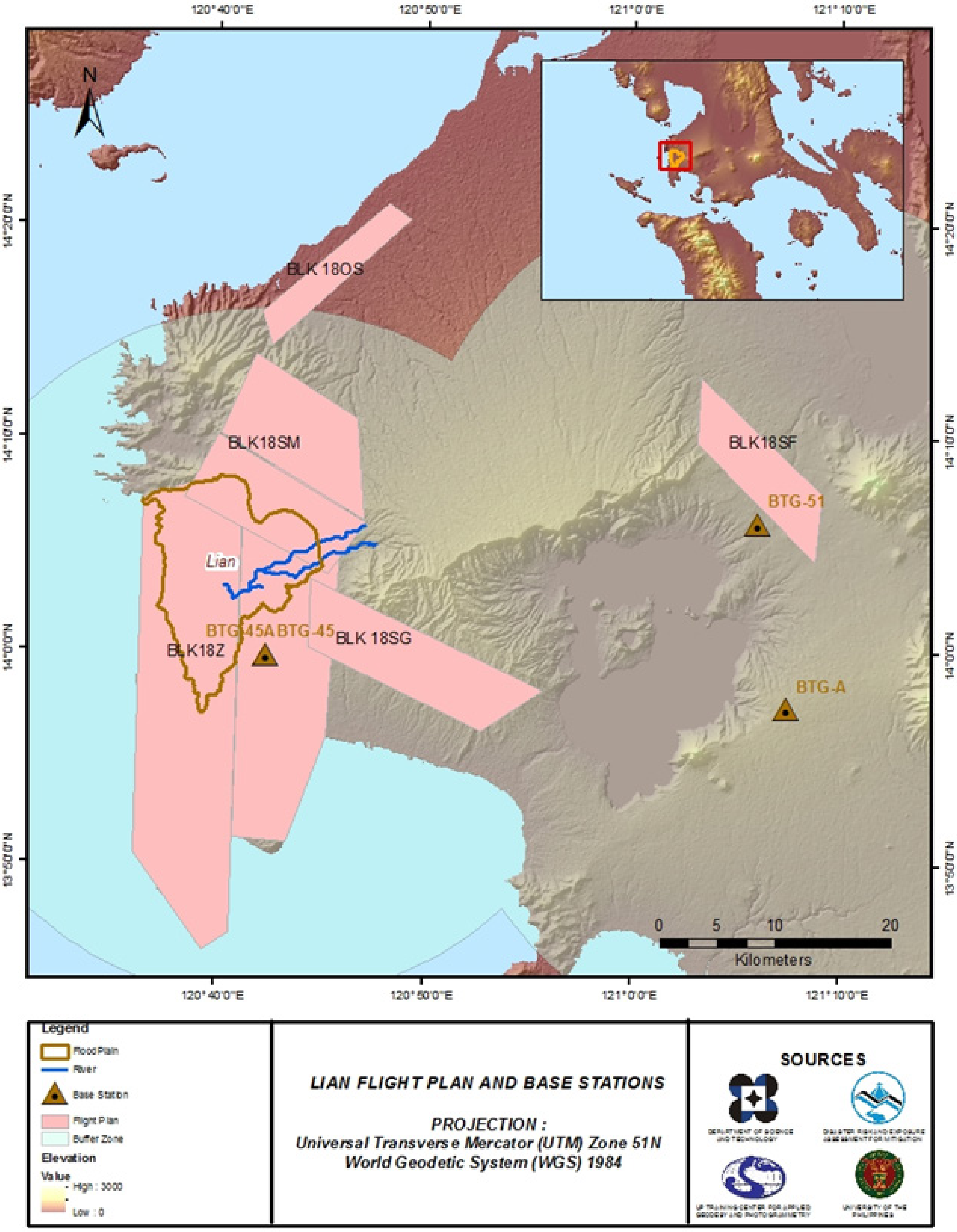

Figure 3. Flight Plan and Base Stations for Lian Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: BTG-45 and BTG-51, which are all of second (2nd) order accuracy. The project team established two (2) ground control points BTG-45A and BTG-A. The certifications for the base stations are found in Annex A-2 while the baseline processing reports for the established ground control points are found in Annex A-3. These were used as base stations during flight operations for the entire duration of the survey (February 20, 2014, September 1 - 2, 2015 and January 6 - 8, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Lian floodplain are shown in 3.

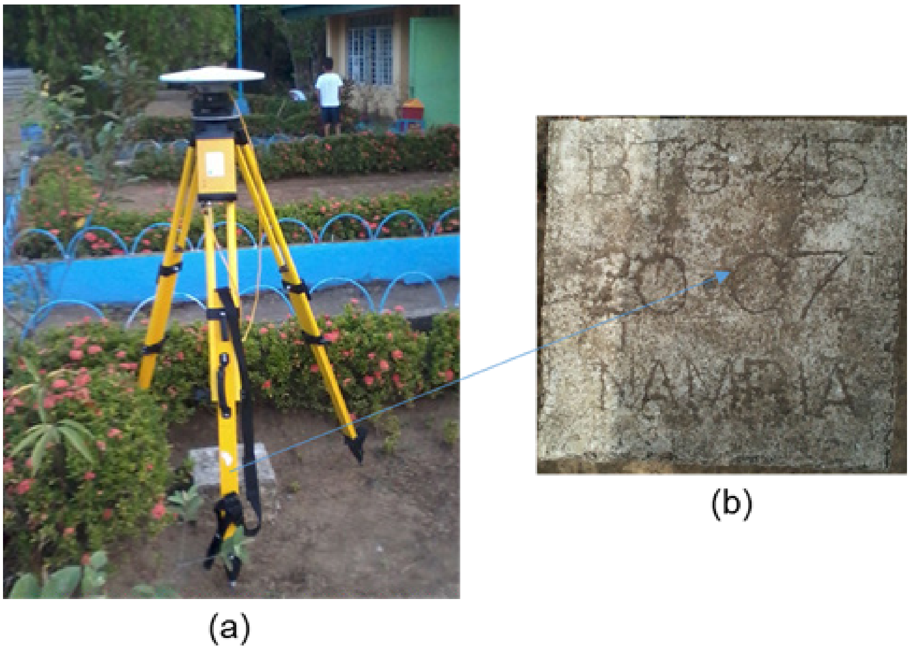

Figure 4.GPS Set-up over BTG-45 inside Santiago De Guzman Elementary School of Brgy. Malibu, Tuy, Batangas Province (a) and NAMRIA Reference Point BTG-45 (b) as recovered by the field team.

Table 3. Details of the Recovered NAMRIA Horizontal Control Point BTG-45 used as Base Station for the LiDAR Acquisition.

Station Name		BTG-45
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 59’ 52.18294”
	Longitude	120° 42’ 18.96476”
	Ellipsoidal Height	48.43000 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	468159.677 meters
	Northing	1547952.281 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 59’ 46.88216” North
	Longitude	120° 42’ 23.91169” East
	Ellipsoidal Height	92.94300 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	252125.62 meters
	Northing	1548591.80 meters

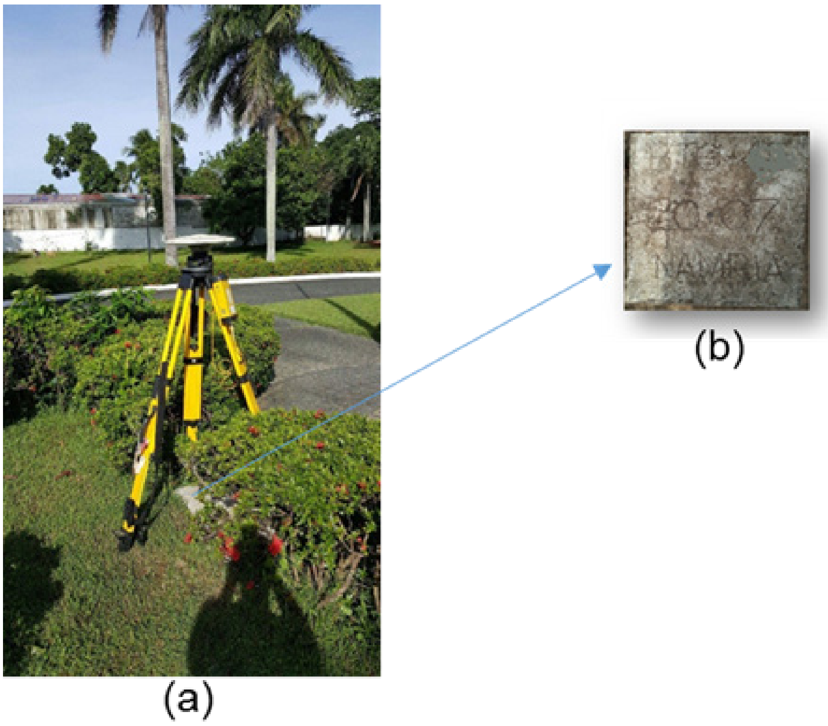

Figure 5. GPS Set-up over BTG-51 inside the vicinity of Mabini Shrine in Brgy, Talaga, Tanuan City, Batangas (a) and NAMRIA Reference Point BTG-51 (b) as recovered by the field team.

Table 4. Details of the Recovered NAMRIA Horizontal Control Point BTG-51 used as Base Station for the LiDAR Acquisition

Station Name		BTG-51
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 06’ 8.57112”
	Longitude	121° 05’ 52.31002 ”
	Ellipsoidal Height	152.36900 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	510567.544 meters
	Northing	1559501.067 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	14° 06’ 3.27790” North
	Longitude	121° 05’ 57.24592” East
	Ellipsoidal Height	197.55100 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	1559783.81 meters
	Northing	294641.94 meters

Table 5. Details of the established Ground Control Point BTG-45A used as Base Station for the LiDAR Acquisition.

Station Name		BTG-45A
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 59' 51.95603"
	Longitude	120° 42' 18.98286 "
	Ellipsoidal Height	49.08900 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	252126.100 meters
	Northing	1548584.818 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 59' 46.65526" North
	Longitude	120° 42' 23.92980" East
	Ellipsoidal Height	93.60200 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	252125.62 meters
	Northing	1548591.80 meters

Table 6. Details of the established Ground Control Point BTG-A used as Base Station for the LiDAR Acquisition.

Station Name		BTG-A
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 57' 27.65020" North
	Longitude	121° 07' 18.59698 " East
	Ellipsoidal Height	373.826 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	297103.192 meters
	Northing	1543753.102 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 57' 22.39320" North
	Longitude	121° 07' 23.54499" East
	Ellipsoidal Height	419.468 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	252125.62 meters
	Northing	1548591.80 meters

Table 7. Ground Control Points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
20 Feb 2014	1131P	1BLK18Z51A	BTG-45 and BTG-45A
20 Feb 2014	1133P	1BLK18Y51B	BTG-45 and BTG-45A
1 Sept 2015	3365P	1BLK18BCS244A	BTG-45 and BTG-45A
2 Sept 2015	3369P	1BLK18OS245A	BTG-45 and BTG-45A
6 Jan 2016	3679G	2BLK18SDG006B	BTG-51 and BTG-A
8 Jan 2016	3687G	2BLK18SGS008B	BTG-51 and BTG-A
8 Jan 2016	3685G	2BLK18SF008A	BTG-51 and BTG-A

2.3 Flight Missions

Seven (7) missions were conducted to complete the LiDAR Data Acquisition in Lian Floodplain, for a total of 22 hours and 36 minutes (22+36) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus and Gemini LiDAR systems. 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 Lian Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)			
Feb 20, 2014	1131P	567.95	242.71	71.08	71.08	171.63	471	3	41
Feb 20, 2014	1133P	567.95	159.27	59.14	59.14	100.13	281	2	53
Sept 1, 2015	3365P	164.8	155.70	34.80	34.80	120.90	NA	3	05
Sept 2, 2015	3369P	199.1	199.09	46.64	46.64	152.45	NA	4	00
Jan 6, 2016	3679G	123.65	33.28	0.21	0.21	33.07	NA	2	17
Jan 8, 2016	3687G	139.84	127.72	0.17	0.17	127.55	NA	2	59
Jan 8, 2016	3685G	139.84	184.70	NA	NA	184.70	NA	3	41
TOTAL		1903.13	1101.93	212.04	212.04	890.43	752	22	36

Table 9. Actual Parameters used during LiDAR Data Acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)	Average Turn Time (Minutes)
1133P	1200	30	50	200	30	130	5
1131P	1200	30	50	200	30	130	5
3369P	1000	30	50	200	30	130	5
3365P	1000	60	50	200	32	130	5
3679G	750	40	50	167	40	120	5
3687G	1000	40	40	100	50	120	5
3685G	1000	30	40	100	50	120	5

2.4 Survey Coverage

Lian Floodplain is located in the province of Batangas, with majority of the floodplains situated within municipality of Lian. The municipalities of Lian and Calatagan in Batangas, and Magallanes in Cavite, were mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) km2 coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Lian Floodplain is presented in Figure 6.

Table 10. List of Municipalities/Cities Surveyed during Lian Floodplain LiDAR Survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Batangas	Lian	91.27	89.23	97.77%
	Calatagan	106.33	92.44	86.94
	Nasugbu	266.83	163.82	61.39%
	Tuy	92.08	43.33	46.82%
	Calaca	117.85	49.074	41.64%
	Lemery	82.32	29.244	35.53%
	Tanauan City	111.77	34.728	31.07%
	Balayan	94.45	27.09	28.69%
	Agoncillo	39.54	4.23	10.69%
	Santo Tomas	92.08	8.58	9.31%
Cavite	Magallanes	69.07	57.67	83.49%
	Maragondon	147.39	36.98	25.09%
	Naic	76.11	5.56	7.31%
	Silang	153.10	1.81	1.18%
Laguna	Calamba City	130.68	26.48	20.26%
	Cabuyao	45.70	1.21	2.65%
Total		1716.57	671.48	36.86%

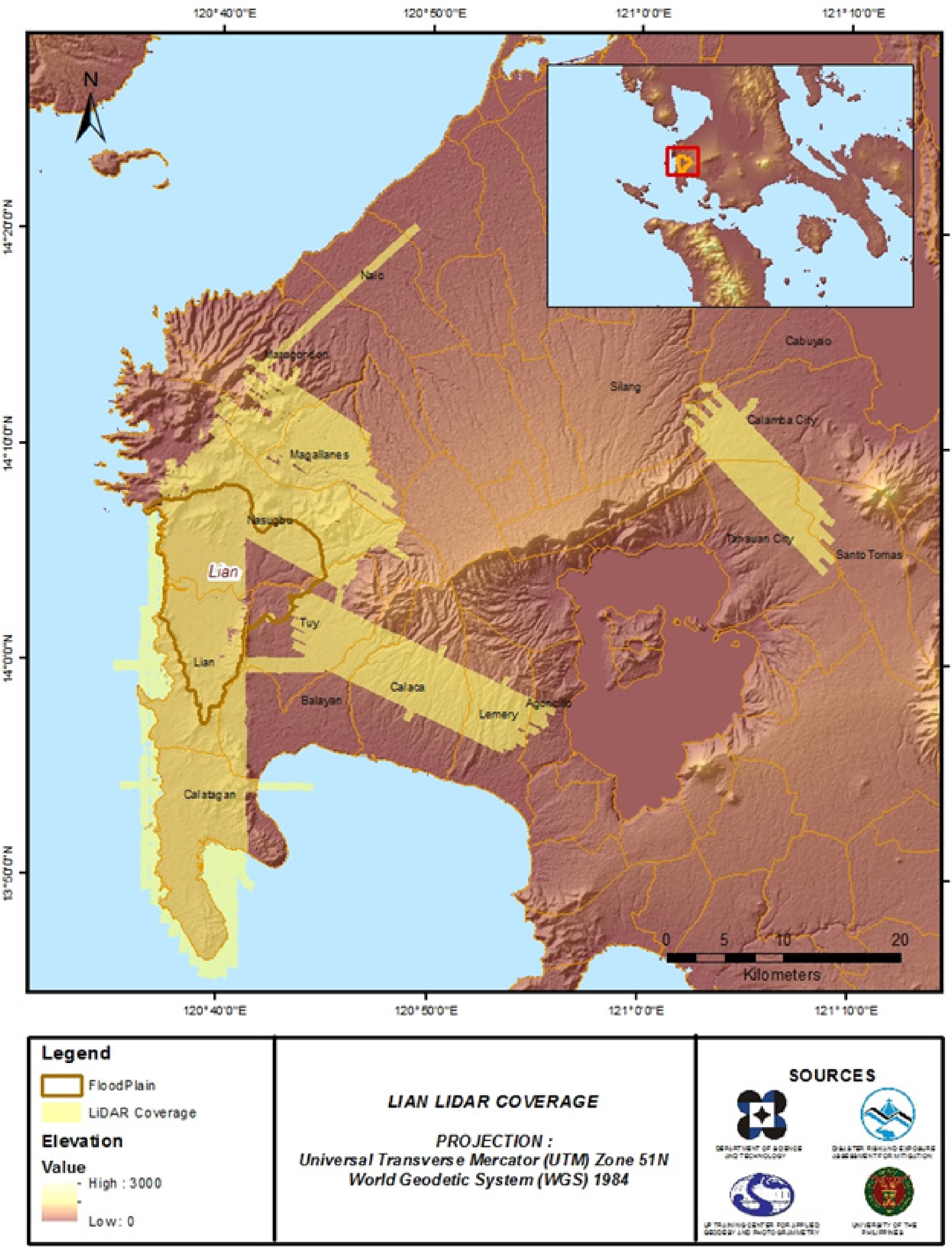

Figure 6. Actual LiDAR Survey Coverage for Lian Floodplain

Table 11:C-1 List of Rreference and Ccontrol Ppoints used in Lian River Survey
(Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
BG207	1st Order	-	-	65.606	22.502	2008
BTG-7	1st Order	13d37'19.49611"	121d04'56.32756"	66.192	-	1992
UP-ASN	UP Established	-	-	-	-	5-22-2014
UP-BTN	UP Established	-	-	-	-	5-21-2014
UP-CLG1	UP Established	-	-	-	-	5-21-2014
UP-LOBO	UP Established	-	-	-	-	5-21-2014
UP-LWY1	UP Established					5-22-2014

The GNSS set up on reference and established control points in Batangas are shown on Figure Figure C- 37 to 139.to Figure C- 9.

Figure C- 37.:. GNSS Rreceiver, Trimble® SPS 985, Sset-up at BG-207 at Palico Bridge, Brgy. Luntal, Nasugbu, Batangas

Figure C- 48.:. GNSS Rreceiver, Trimble® SPS 985, Sset-up at BTG-7 in Dela Paz Lighthouse in Brgy. Dela Paz, Batangas City, Batangas

Figure C- 59.:. GNSS Rreceiver, Trimble® SPS 882, Sset-up at UP-ASN at San Nicholas Bridge, Brgy. Poblacion, San Nicholas, Batangas

Figure C- 610.:. GNSS Bbase Rreceiver, Trimble® SPS 852, Sset-up at UP-BTN at Bantilan Bridge, Brgy. Manggalang Banitilan, Sariaya, Quezon

Figure C- 711.:. GNSS Bbase Rreceiver, Trimble® SPS 852, Sset-up at UP-CLG1 in Calumpang Bridge, Brgy. Cumintang Ibaba, Batangas City, Batangas

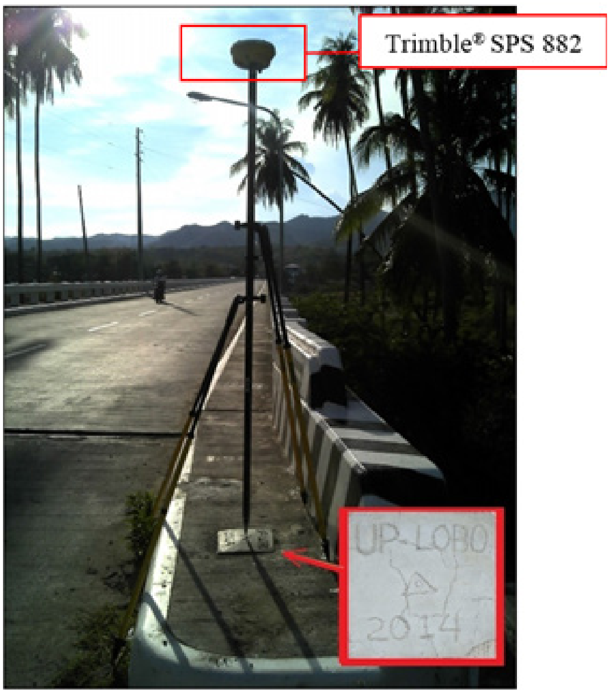

Figure C- 12.8: GNSS Bbase Rreceiver, Trimble® SPS 882, Sset-up at UP-LOBO, in Lobo Bridge, Brgy. Lagadlarin, Lobo, Batangas

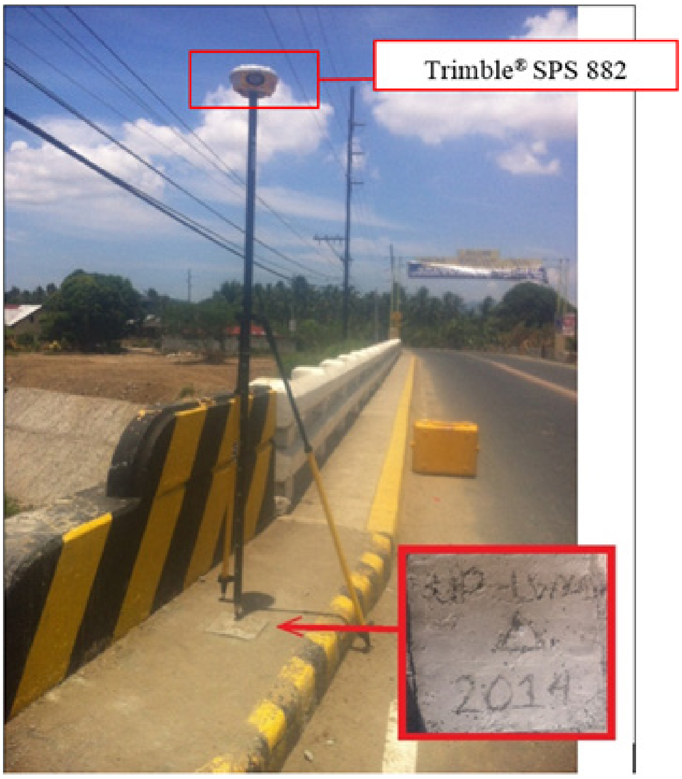

Figure C- 913.:. GNSS Rreceiver, Trimble® SPS 882, Sset-up at UP-LWY1 at Lawaye Bridge, Brgy. Calitcalit-Mabalanoy, San Juan, Batangas

CHAPTER 3: LIDAR DATA PROCESSING OF THE LIAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

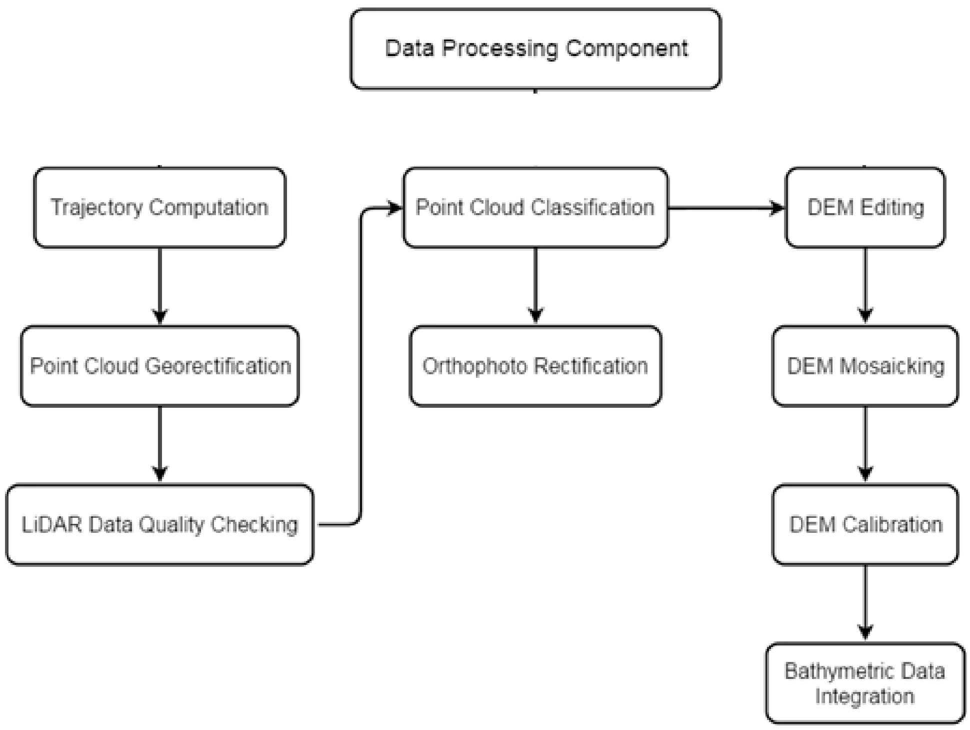


Figure 14. Schematic Diagram for Data Pre-Processing Component

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 14.

3.2.Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR Missions for Lian Floodplain can be found in Annex A-5. Missions flown during the surveys conducted on February 2014 and September 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus System while missions acquired during the third (3rd) survey on January 2016 were flown using the Gemini System over Lian, Batangas. The Data Acquisition Component (DAC) transferred a total of 118.2 gigabytes of Range Data, 1.22 gigabytes of POS data, 139.01 megabytes of GPS base station data, and 49.2 gigabytes of raw image data to the data server on February 20, 2014, September 2, 2015 and January 8, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Lian was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for Lian Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3679G, one of the Lian flights, which is the North, East, and Down position RMSE values are shown in Figure 15. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on January 6, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

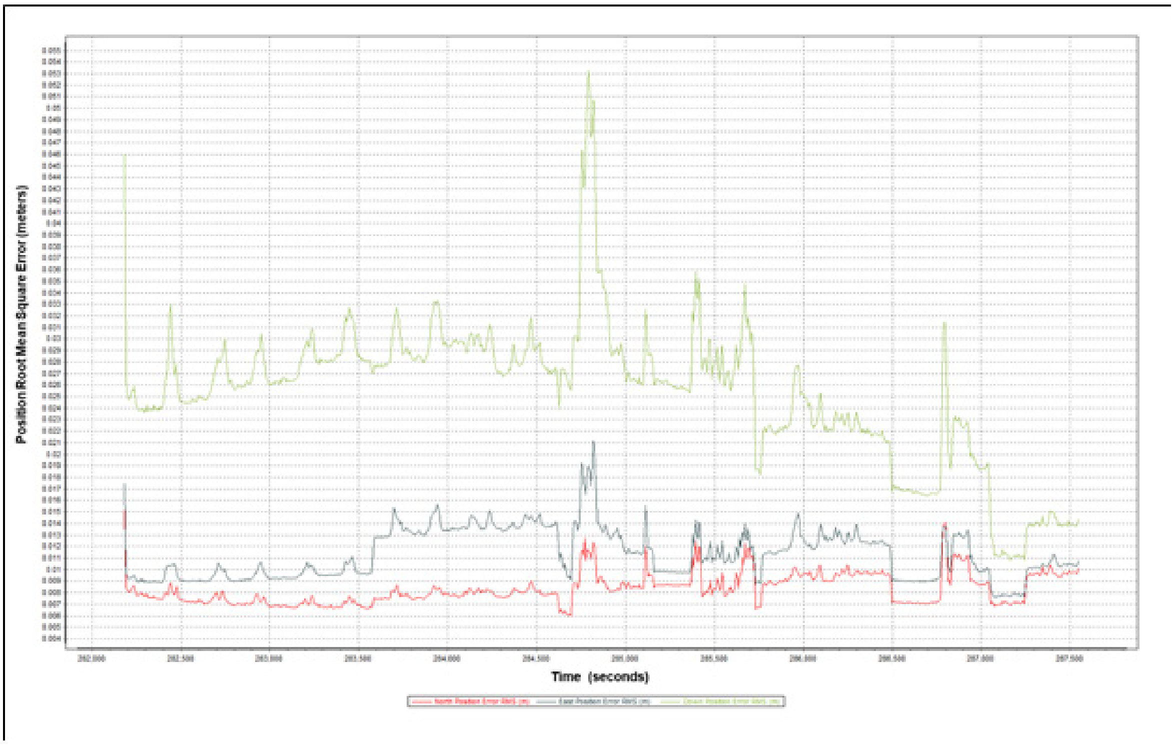


Figure 15. Smoothed Performance Metrics of a Lian Flight 3679G

The time of flight was from 282200 seconds to 287600 seconds, which corresponds to afternoon of January 6, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure B-2 shows that the North position RMSE peaks at 1.40 cm, the East position RMSE peaks at 2.10 cm, and the Down position RMSE peaks at 5.30 cm, which are within the prescribed accuracies described in the methodology.

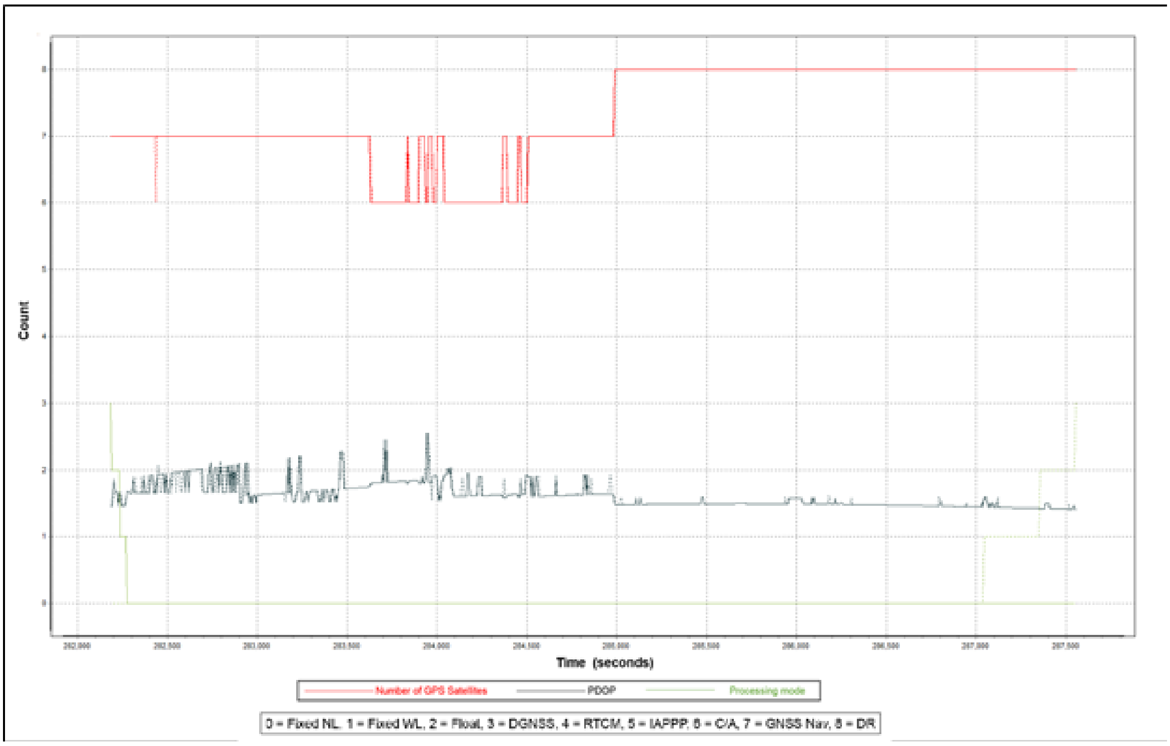


Figure 16. Solution Status Parameters of Lian Flight 3679G

The Solution Status parameters of Flight 3679G, one of the Lian flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 16. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Lian flights is shown in Figure 17.

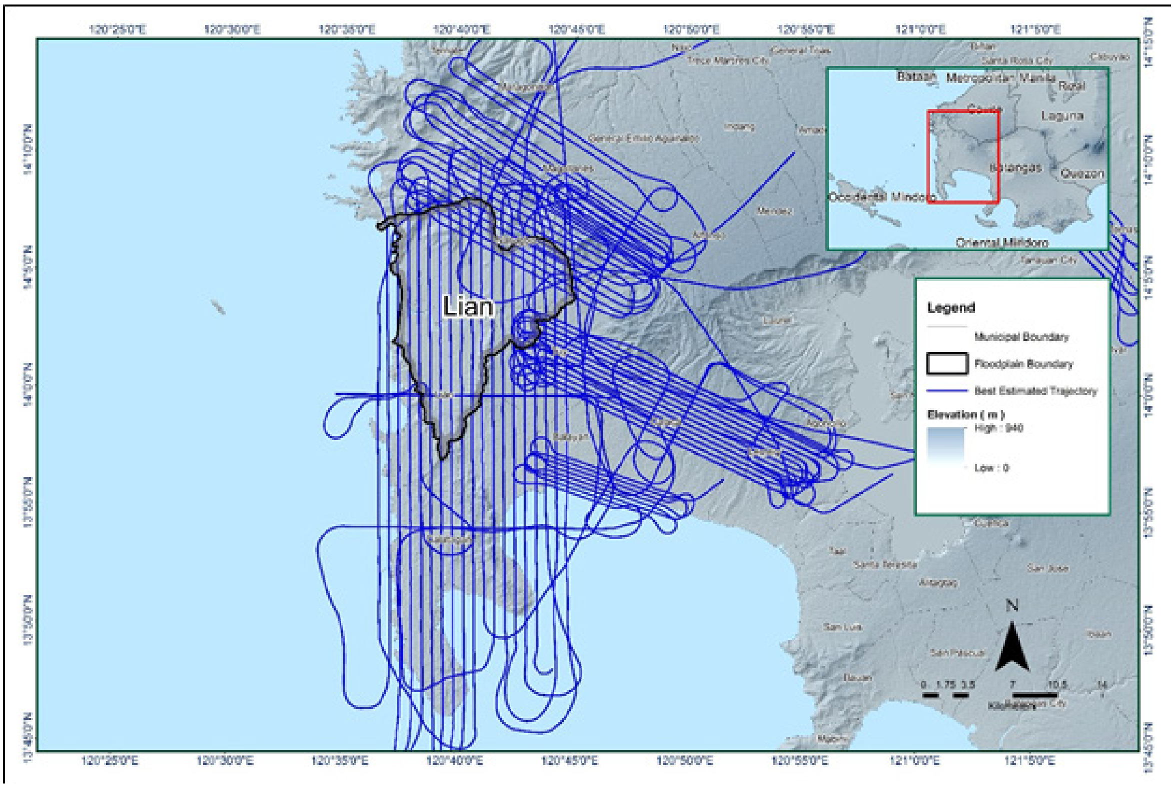


Figure 17B- 4. Best Estimated Trajectory for Lian F floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 72 flight lines, with each flight line containing one channel for the Gemini System and two channels for the Pegasus System. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Lian Floodplain are given in Table 12.

Table 12. Self-Calibration Results Values for Lian Flight

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000166
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000640
GPS Position Z-correction stdev (<0.01meters)	0.0026

The optimum accuracy is obtained for all Lian 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 B-1. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Lian Floodplain is shown in Figure 18. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

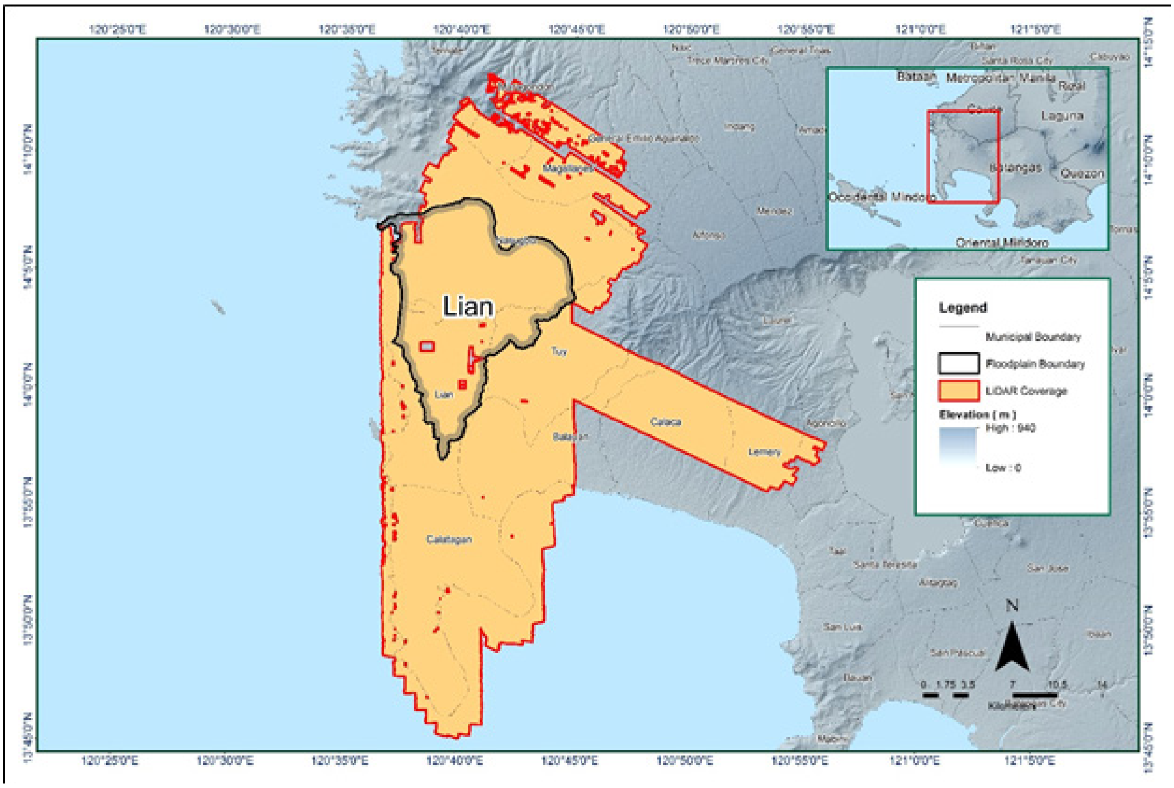


Figure 18B- 5. Boundary of the Pprocessed LiDAR Ddata over Lian Floodplain

The total area covered by the Lian missions is 913.65 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 13.

Table 13. List of LiDAR Blocks for Lian Floodplain

LiDAR Blocks	Flight Numbers	Area (km2)
CALABARZON_Blk18BC_ supplement	3365P	181.08
	3369P	
Batangas_Blk18SG_additional	3679G	30.84
Batangas_Blk18SGa	3687G	98.42
Batangas_Blk18SGb	3685G	91.14
Batangas_Blk18Y	1131P	285.15
	1133P	
Batangas_Blk18Z	1131P	217.74
	1133P	
Batangas_Blk18Z_additional	1133P	9.28
TOTAL		913.65 km2

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 19. Since the Gemini System employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines, while 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.

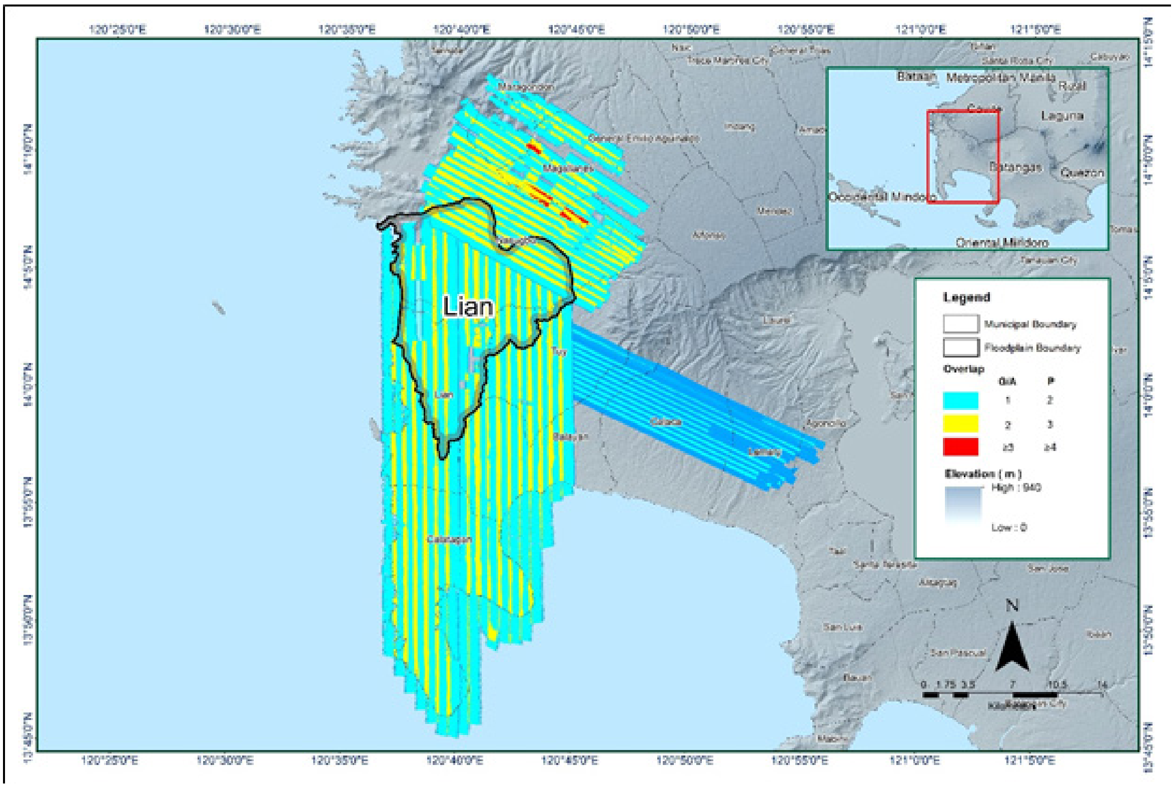


Figure 19. Image of Data Overlap for Lian Floodplain

The overlap statistics per block for the Lian Floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.93% and 39.24% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 20. It was determined that all LiDAR data for Lian Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.43 points per m2.

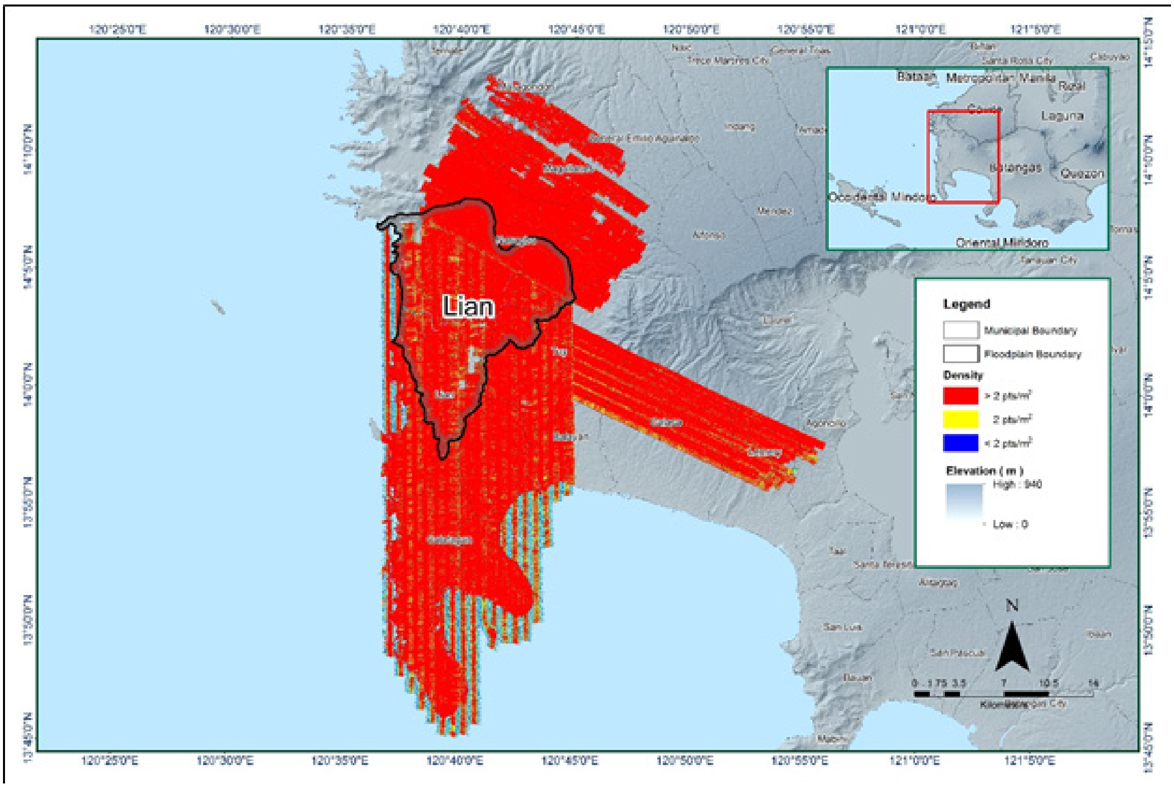


Figure 20. Pulse density Map of Merged LiDAR Data for Lian Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 21. 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 0.20 m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m 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.

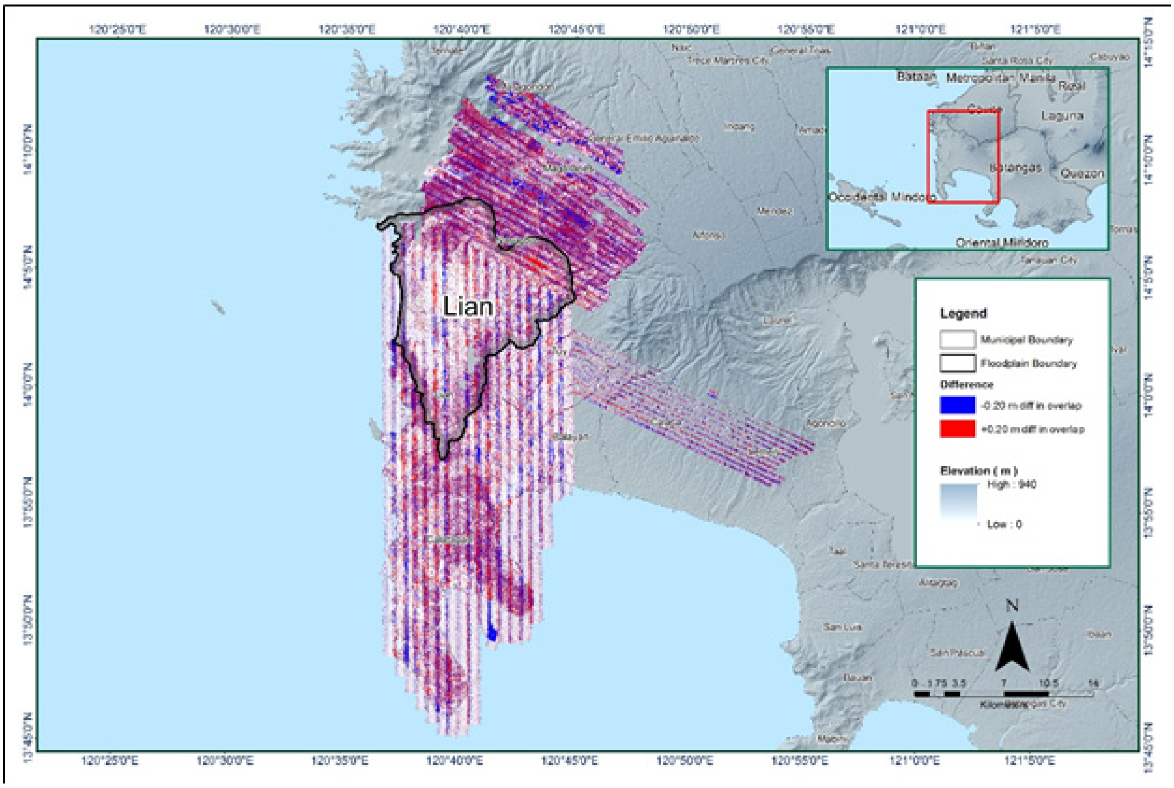


Figure 21. Elevation Difference Map between Flight Lines for Lian Floodplain

A screen capture of the processed LAS data from a Lian Flight 3679G loaded in QT Modeler is shown in Figure 21. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20 cm mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

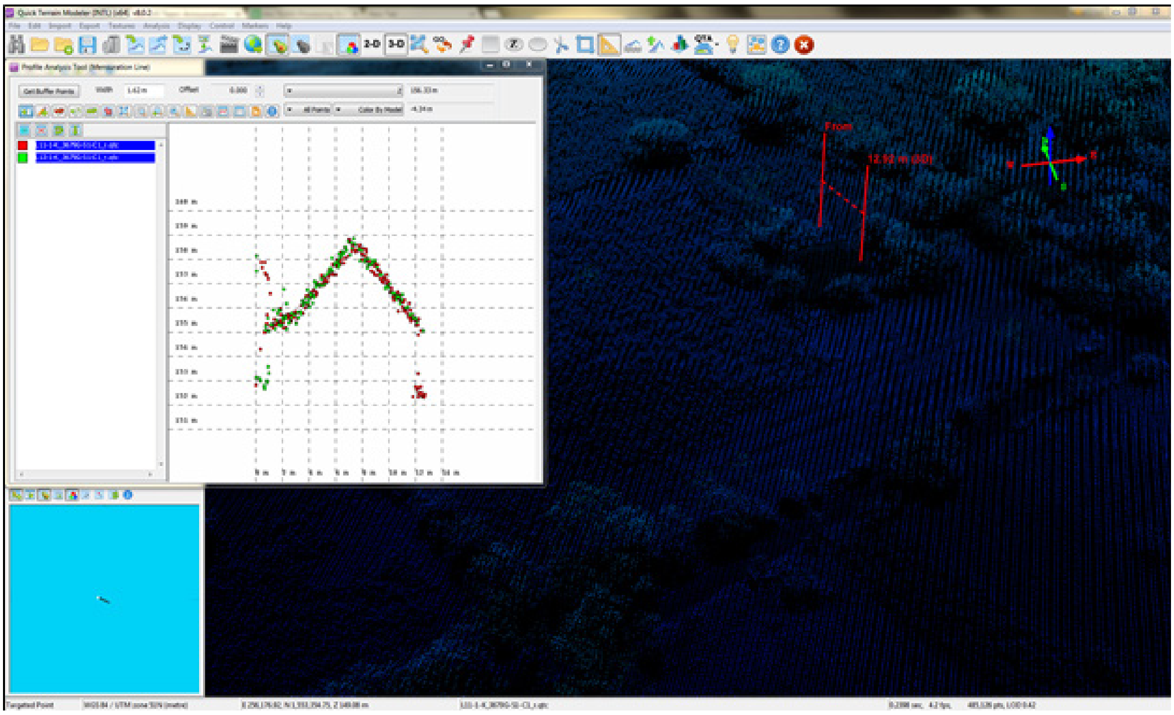


Figure 22. Quality Checking for a Lian Flight 3679G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Lian Classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	699,190,907
Low Vegetation	483,399,367
Medium Vegetation	1,037,915,801
High Vegetation	933,207,412
Building	35,514,975

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Lian Floodplain is shown in Figure 22. A total of 1,254 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 689.99 m and 44.37 m respectively.

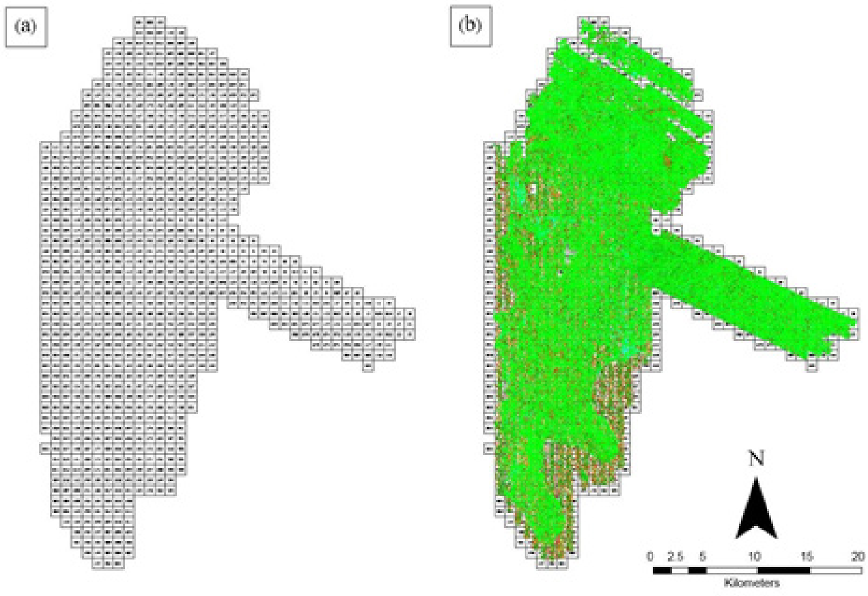


Figure 23B- 10. Tiles for Lian Ffloodplain (a) and Cclassification Rresults (b) in TerraScann.

An isometric view of an area before and after running the classification routines is shown in Figure 23. 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.

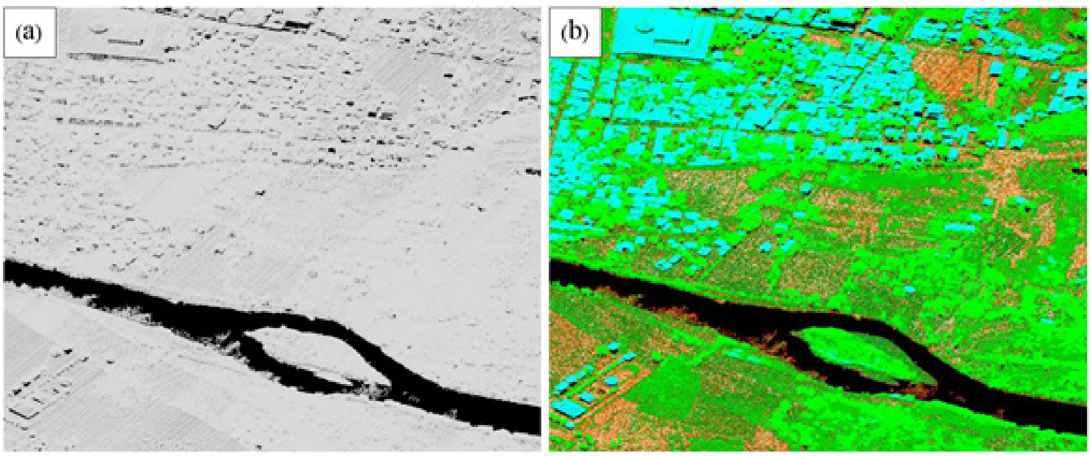


Figure 24. Point Cloud Before (a) and After (b) Classification

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

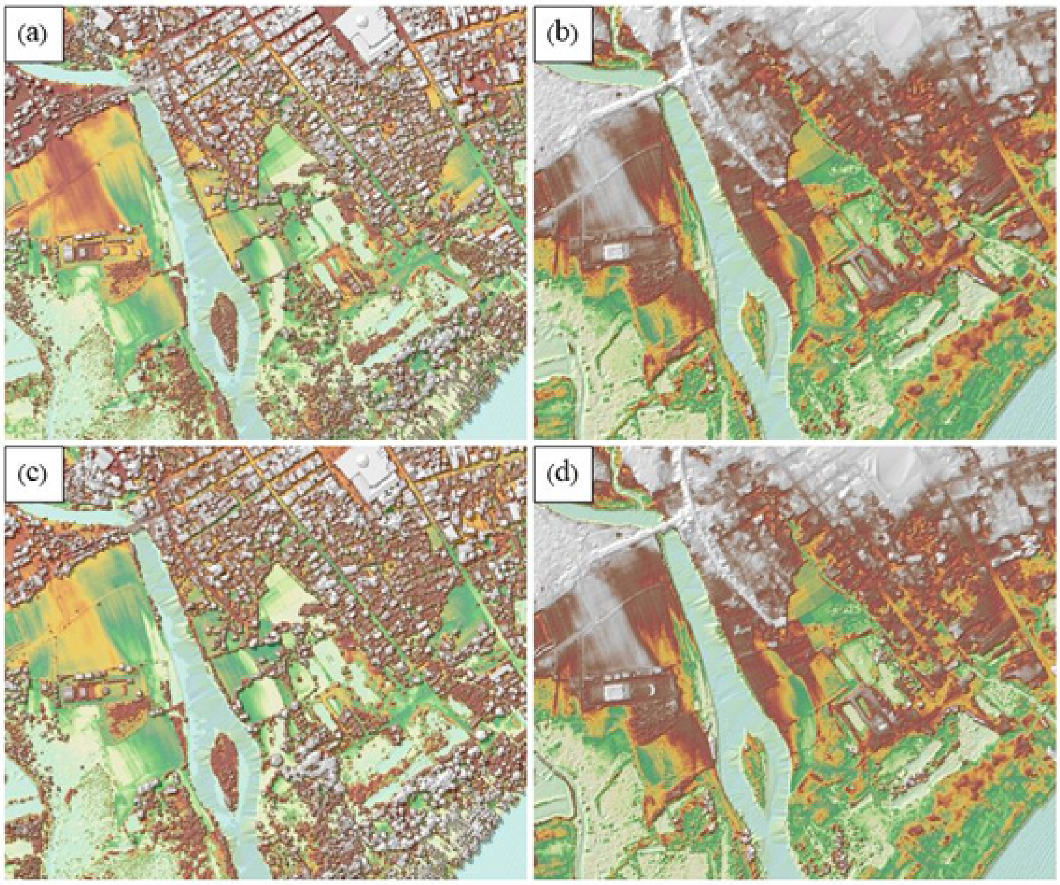


Figure 25. The Production of Last Return DSM (a) and DTM (b), First Return DSM (c) and Secondary DTM (d) in some portion of Lian Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,438 1km by 1km tiles area covered by Lian Floodplain is shown in Figure 25. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Lian Floodplain has a total of 265.97 km2 orthophotogaph coverage comprised of 728 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 26.

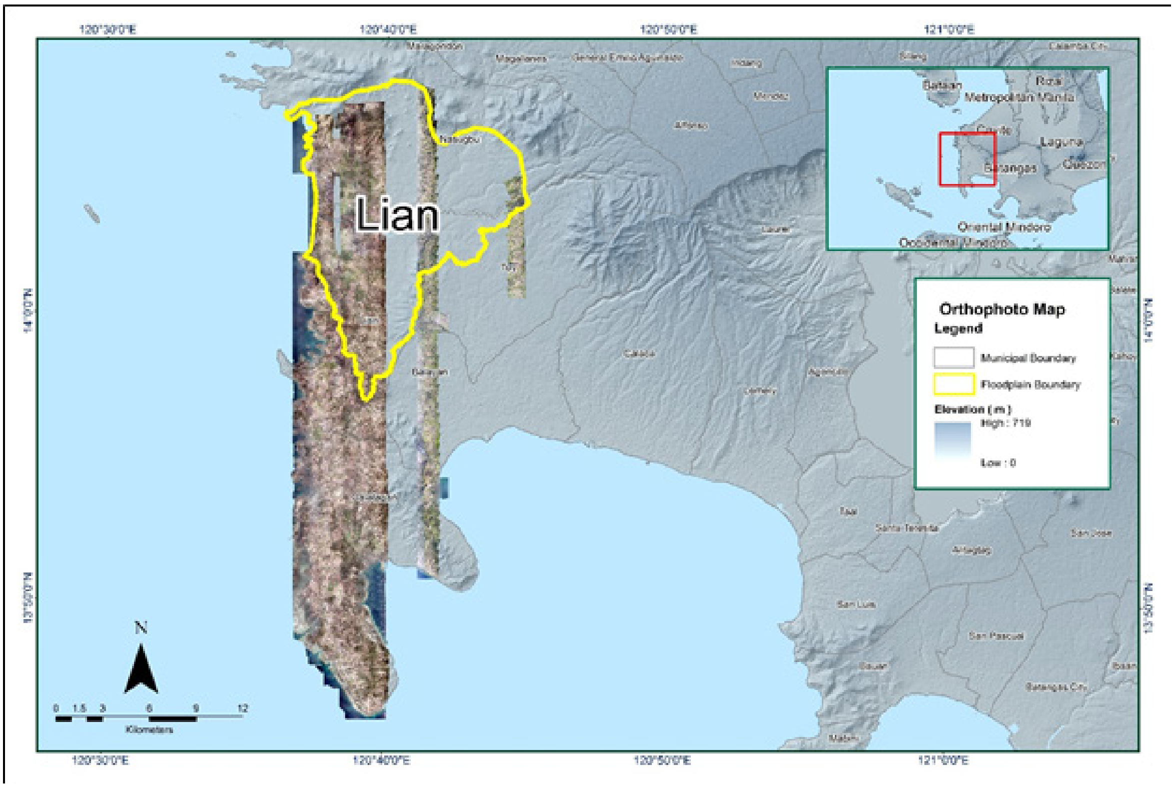


Figure 26. Lian Floodplain with available Orthophotographs

Figure 27. Sample Orthophotograph Tiles for Lian Floodplain

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Lian Floodplain. These blocks are composed of CALABARZON and Batangas blocks with a total area of 913.65 km2. Table 15 shows the name and corresponding area of each block in km2.

Table 15. LiDAR Blocks with its Corresponding Area

LiDAR Blocks	Area (km2)
CALABARZON_Blk18BC_supplement	181.08
Batangas_Blk18SG_additional	30.84
Batangas_Blk18SGa	98.42
Batangas_Blk18SGb	91.14
Batangas_Blk18Y	285.15
Batangas_Blk18Z	217.74
Batangas_Blk18Z_additional	9.28
TOTAL	913.65 km2

Portions of DTM before and after manual editing are shown in Figure 27. The bridge (Figure 27a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 27b) in order to hydrologically correct the river. The paddy field (Figure 27c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure B 27d) to allow the correct flow of water. Another example is a pit that is present in the DTM after classification (Figure 27e) and has to be filled through manual editing (Figure 27f).

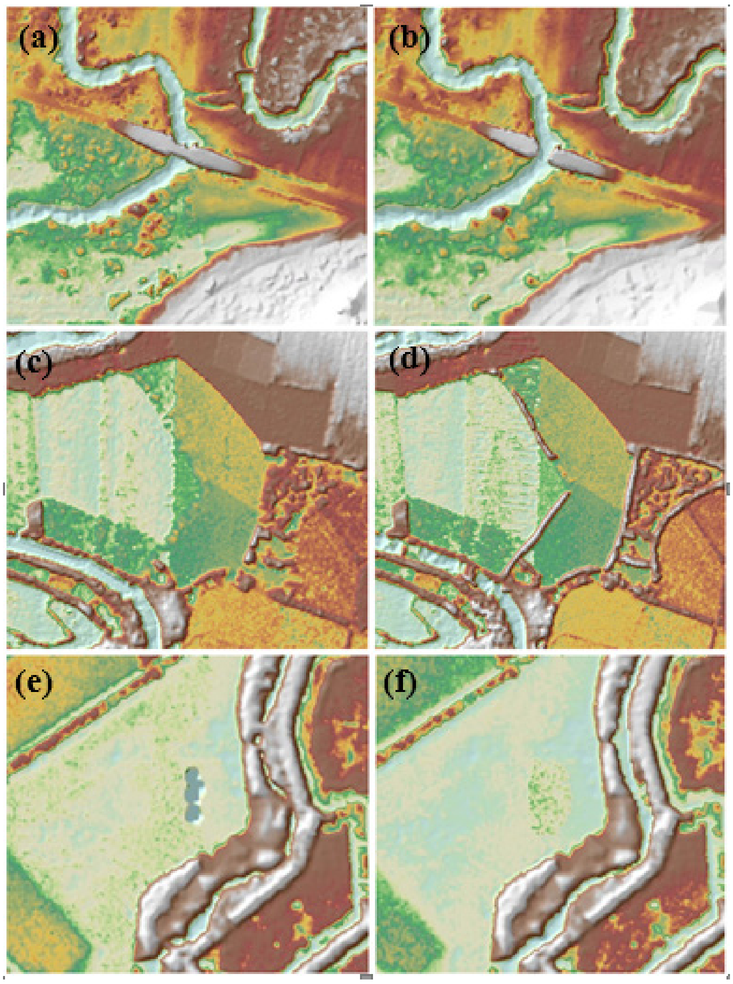


Figure 28. Portions in the DTM of Lian Floodplain – a Bridge Before (a) and After (b) Manual Editing; a Paddy Field Before (c) and After (d) Data Retrieval; and a Pit Before (e) and After (f) Manual Editing

3.9 Mosaicking of Blocks

Batangas_Blk18Z was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Lian Floodplain is shown in Figure 28. It can be seen that the entire Lian Floodplain is 94.27% covered by LiDAR data.

Table 16. Shift Values of each LiDAR Block of Lian Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_Blk18BC_ supplement	0.00	0.00	0.00
Batangas_Blk18SG_ additional	0.00	0.00	0.00
Batangas_Blk18SGa	0.00	0.00	0.00
Batangas_Blk18SGb	-0.65	-3.95	0.11
Batangas_Blk18Y	0.00	0.00	0.16
Batangas_Blk18Z	0.00	0.00	0.00
Batangas_Blk18Z_ additional	0.00	0.00	0.00

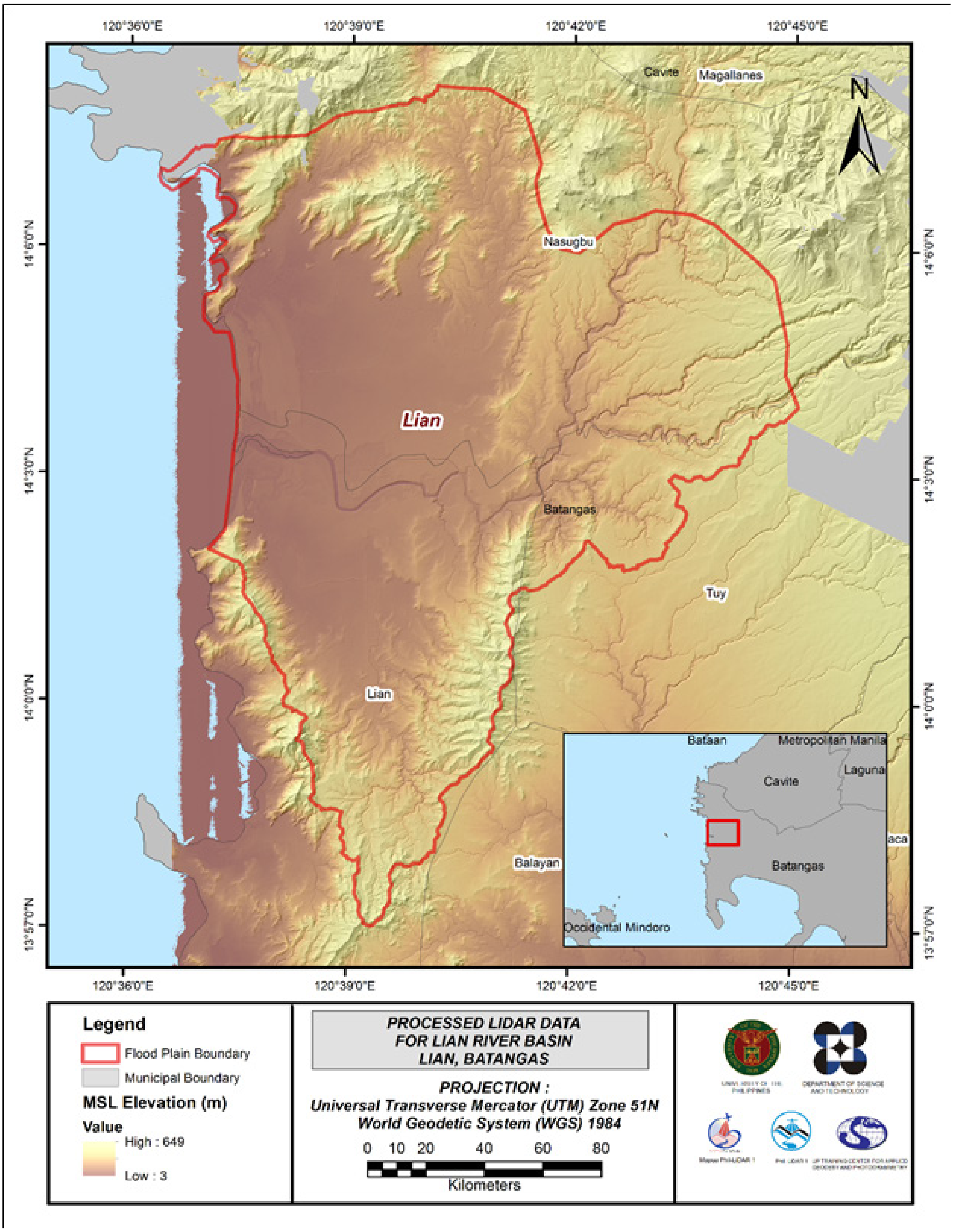


Figure 29. Map of Processed LiDAR Data for Lian Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Lian to collect points with which the LiDAR dataset is validated is shown in Figure 30. A total of 24,251 survey points were gathered for all the flood plains within the provinces of CALABARZON wherein the Lian floodplain is located. Random selection of 80% of the survey points, resulting to 19,401 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 31. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 2.97 meters with a standard deviation of 0.20 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 2.97 meters, to the mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

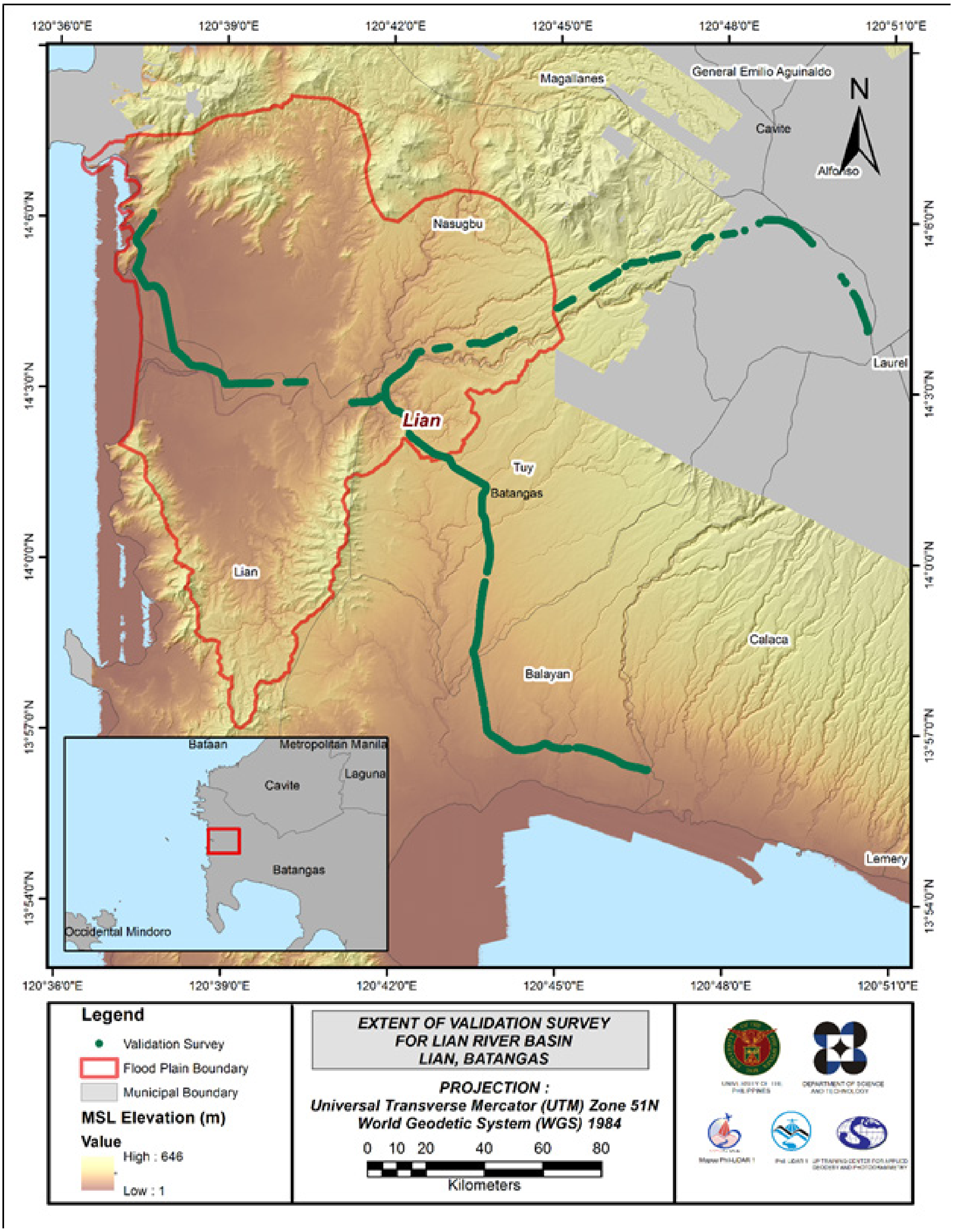


Figure 30. Map of Lian Flood Plain with Validation Survey Points in Green

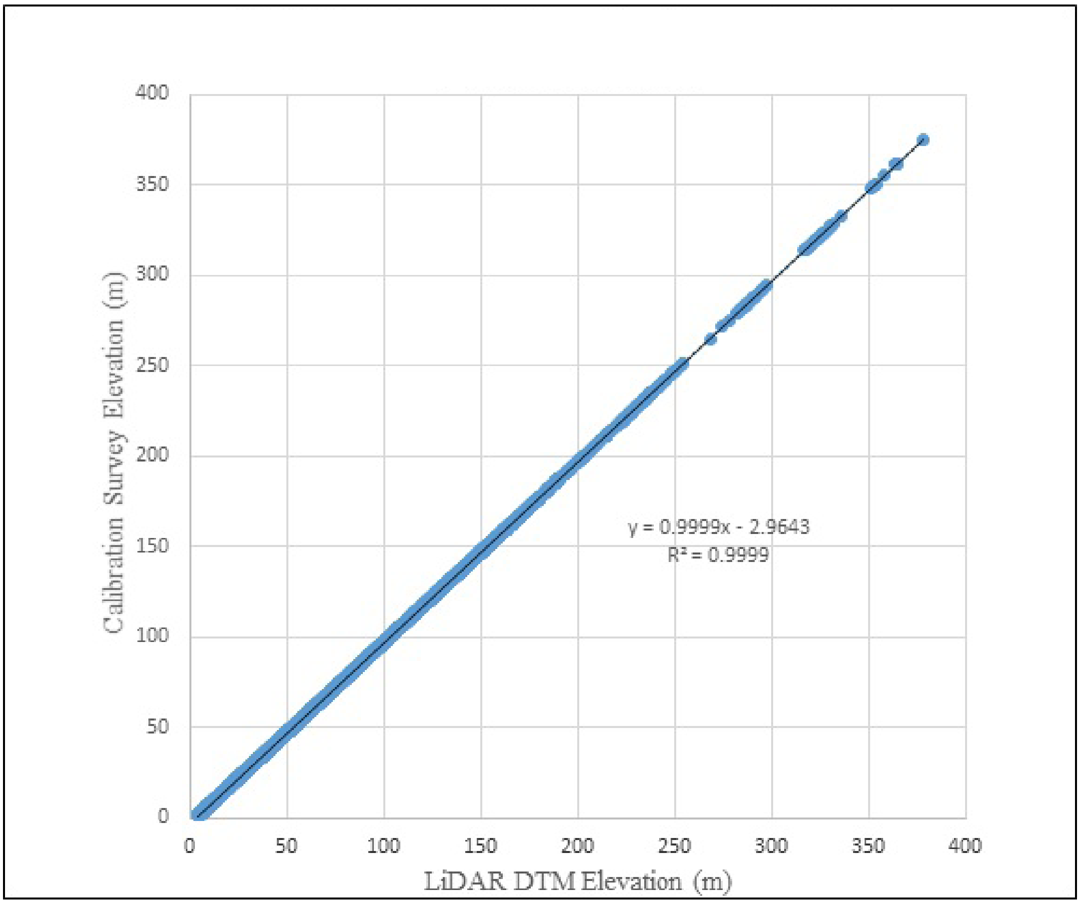


Figure 31. Correlation Plot Between Calibration Survey Points and LiDAR Data

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.97
Standard Deviation	0.20
Average	-2.97
Minimum	-3.48
Maximum	-2.40

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 314 points, were used for the validation of calibrated Lian 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 32. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.07 meters with a standard deviation of 0.07 meters, as shown in Table 18.

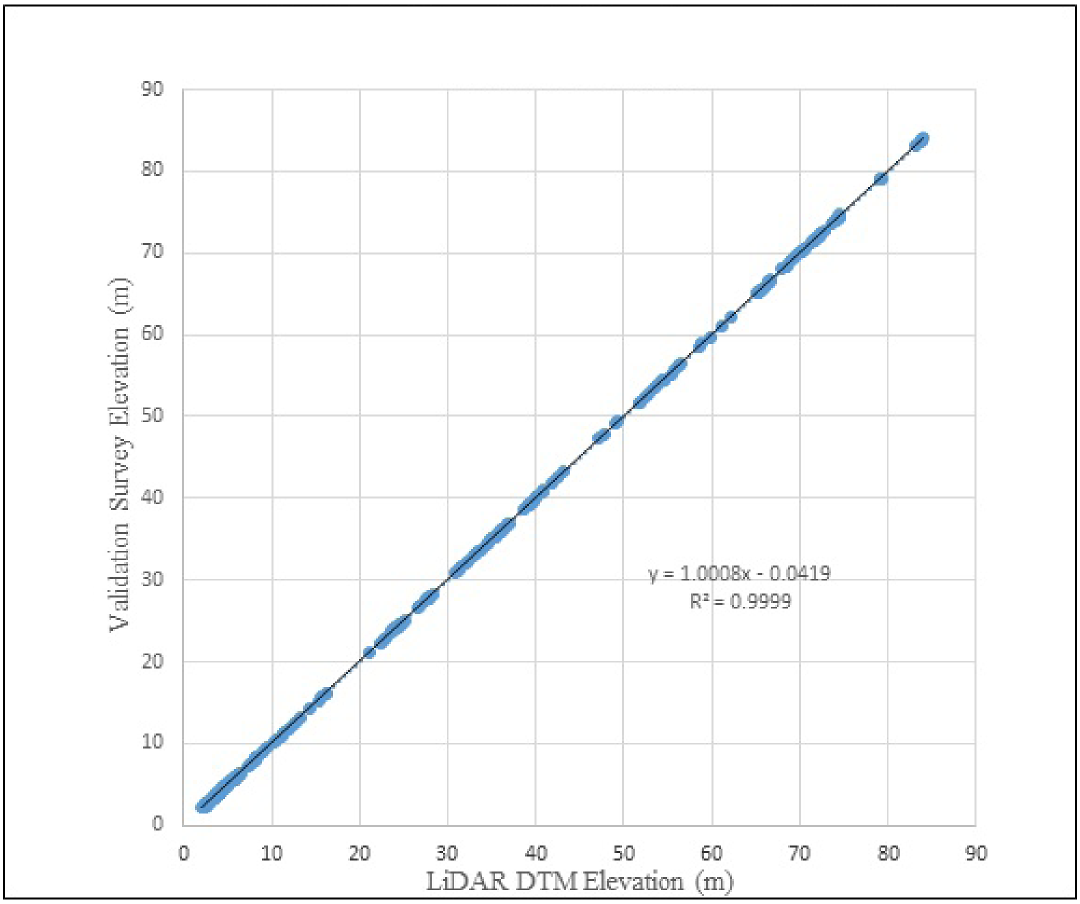


Figure 32. Correlation Plot Between Validation Survey Points and LiDAR Data

Table 18. Validation Statistical Measure

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.07
Average	-0.02
Minimum	-0.19
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Lian with 5,100 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 0.21 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Lian integrated with the processed LiDAR DEM is shown in Figure 32.

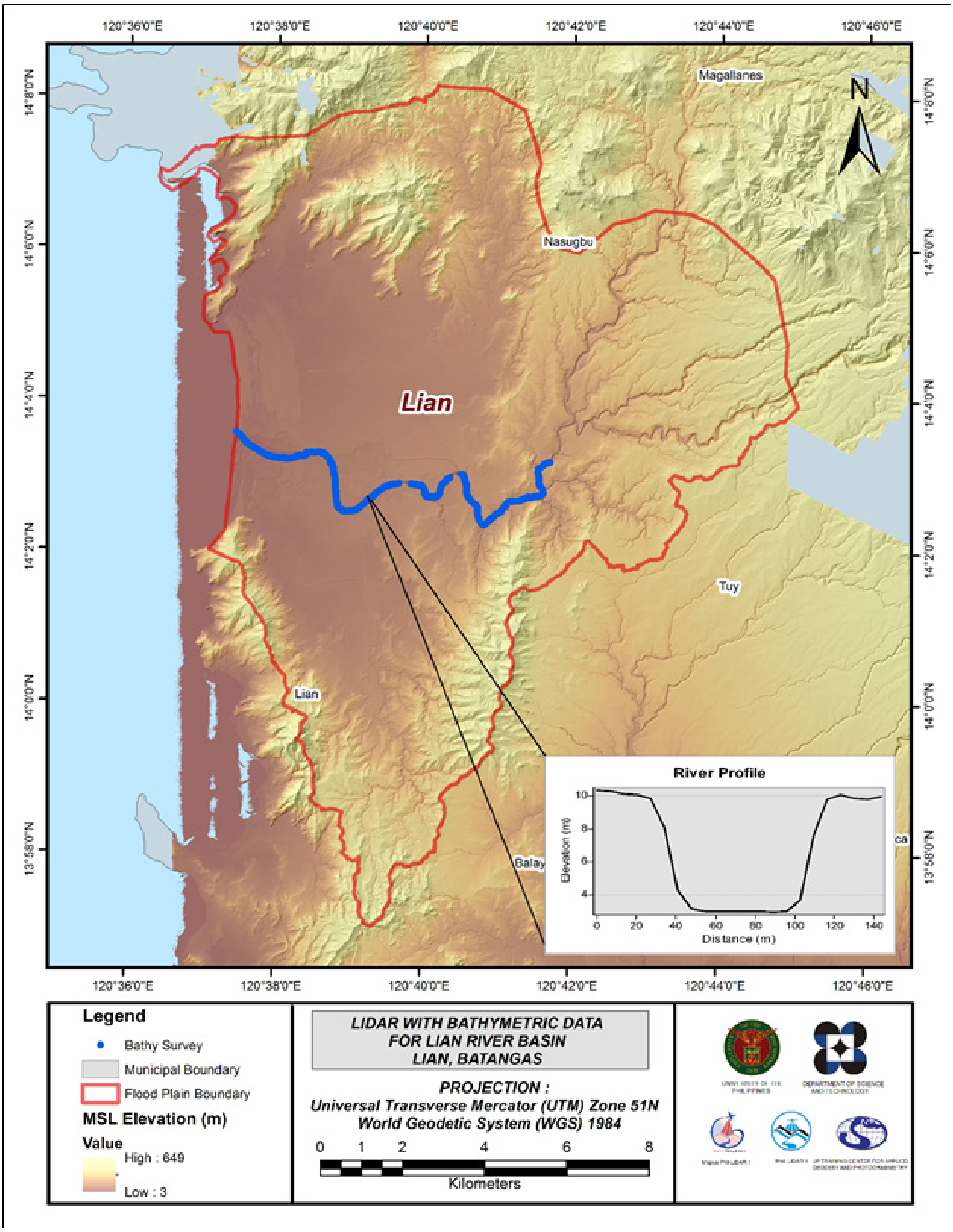


Figure 33. Map of Lian Floodplain with Bathymetric Survey Points shown in Blue

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 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, 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

Lian Floodplain, including its 200 m buffer, has a total area of 175.48 km2. For this area, a total of 5.0 km2, corresponding to a total of 4,048 building features, are considered for QC. Figure 33 shows the QC blocks for Lian Floodplain.

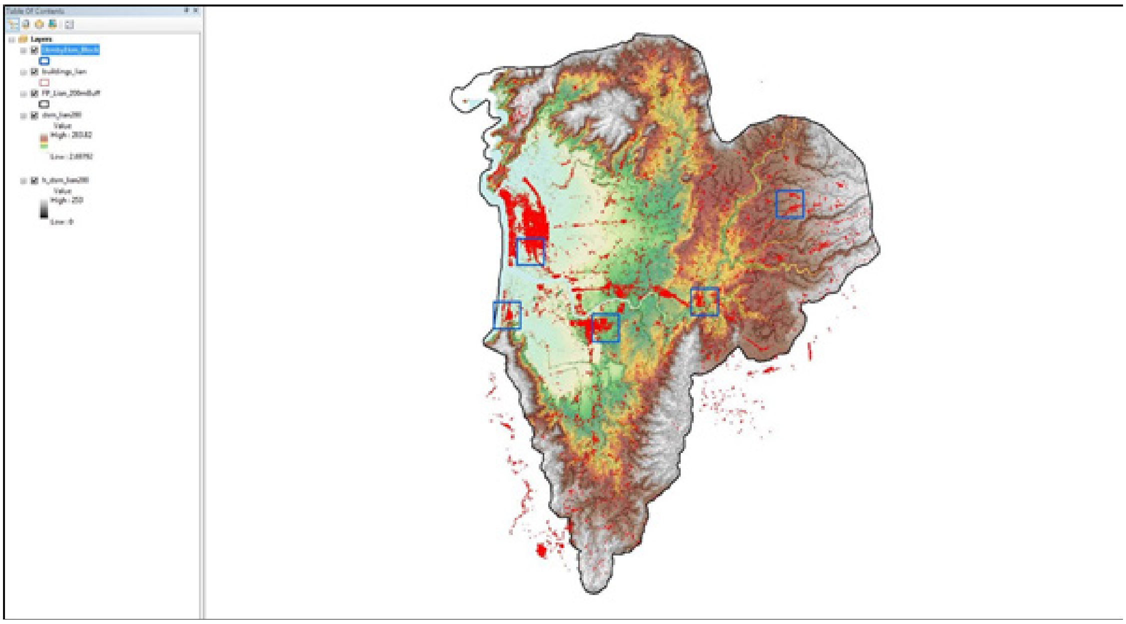


Figure 34. QC Blocks for Lian Building Features

Quality checking of Lian building features resulted in the ratings shown in Table 19.

Table 19. Quality Checking Ratings for Lian Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Lian	99.25	99.97	98.17	PASSED

3.12.2 Height Extraction

Height extraction was done for 26,585 building features in Lian Floodplain. Of these building features, 1,333 were filtered out after height extraction, resulting to 25,252 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 22.64 m.

3.12.3 Feature Attribution

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

Table 20 summarizes the number of building features per type. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Building Features Extracted for Lian Floodplain

Facility Type	No. of Features
Residential	24,781
School	149
Market	22
Agricultural/Agro-Industrial Facilities	240
Medical Institutions	2
Barangay Hall	14
Military Institution	1
Sports Center/Gymnasium/Covered Court	4
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	26
Bank	2
Factory	0
Gas Station	7
Fire Station	0
Other Government Offices	3
Other Commercial Establishments	0
Total	25,252

Table 21. Total Length of Extracted Roads for Lian Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Lian	240.07	120.06	23.75	12.44	0.00	396.32

Table 22. Number of Extracted Water Bodies for Lian Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Lian	20	2	1	0	35	58

A total of 76 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 34 shows the Digital Surface Model (DSM) of Lian Floodplain overlaid with its ground features.

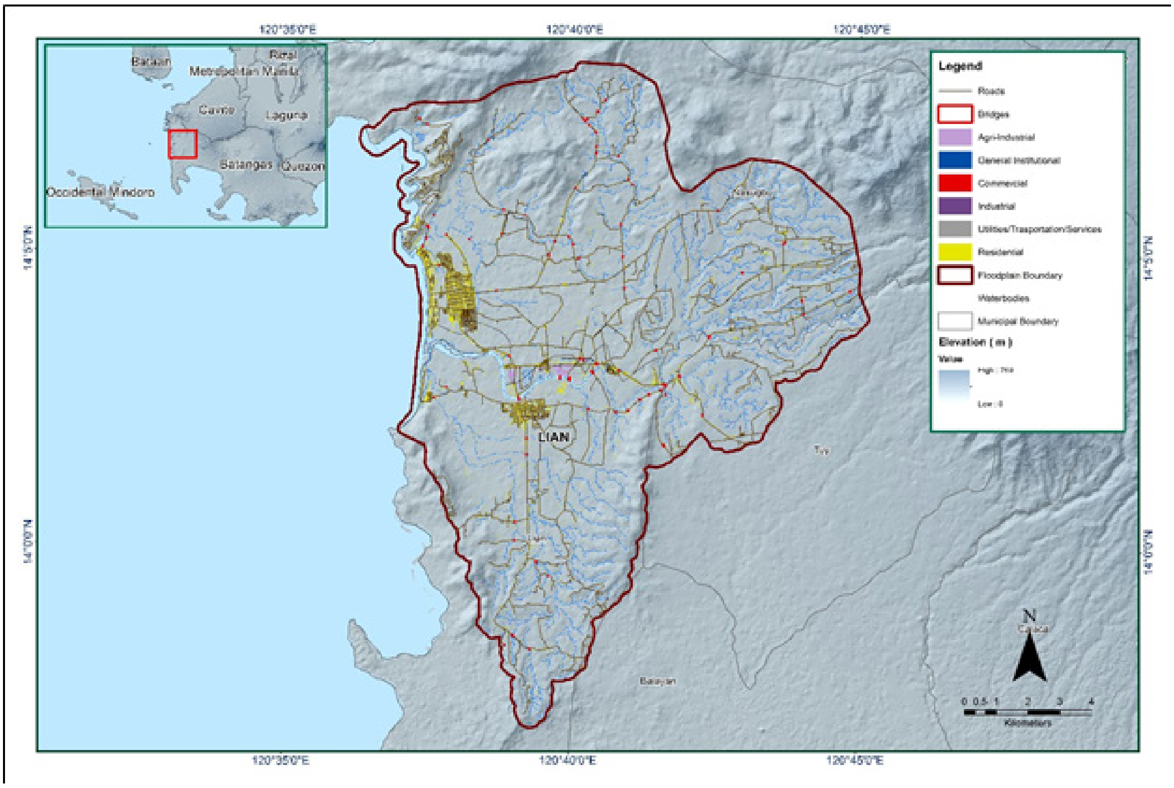


Figure 35. Extracted Features for Lian Floodplain

CHAPTER 4: SURVEY AND MEASUREMENTS IN THE LIAN RIVER BASIN SURVEY

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted two field surveys in Lian River. The first one was conducted on May 14 - 22, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; and bridge cross-section. The second one was conducted on August 26 - 30, 2014 with the following scope of work: water level marking in MSL of Palico Bridge pier; ground validation data acquisition of about 58 km; and bathymetric survey from Brgy. Sabang down to the mouth of the river in Brgy. Bungahan, with an estimated length of 11.80 km using an OHMEX™ Single Beam Echo Sounder and GNSS PPK survey technique.

4.2 Control Survey

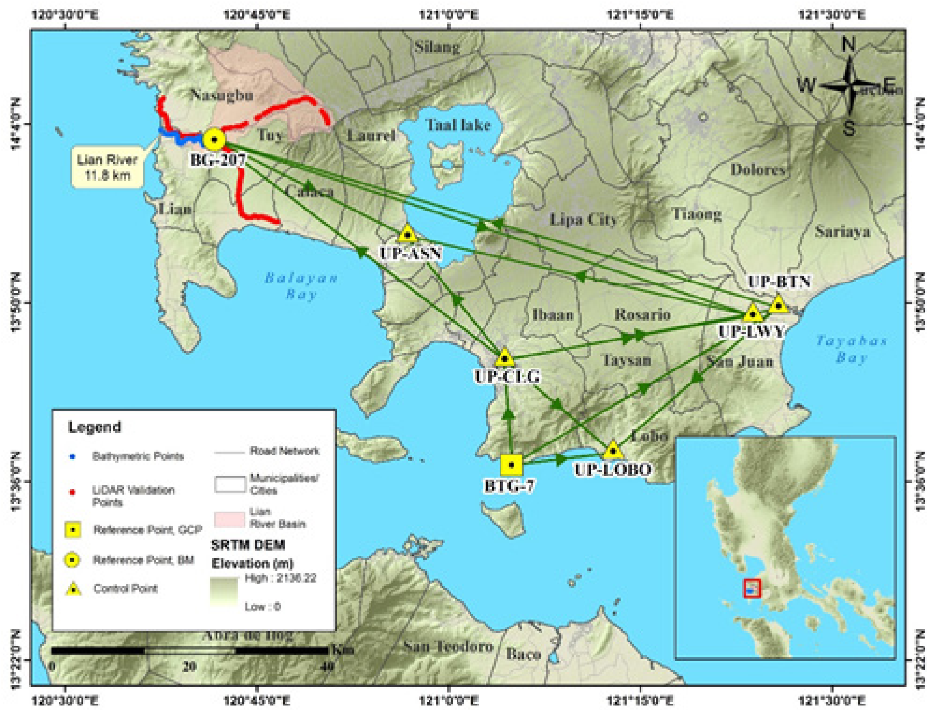


Figure 1: Survey Extent for Lian River Basin

The GNSS network for this survey is composed of six (6) loops established on May 14 – 22, 2014, occupying the following reference points: BG-207, a first order BM in Brgy. Sabang, Municipality of Tuy; and BTG-7, a first order GCP located in Brgy. Dela Paz, Batangas City.

Five (5) control points were established at the approach of bridges namely UP-BTN at Bantilan Bridge in Brgy. UP-LOBO at Lobo Bridge in Brgy. Lagadlarin, Municipality of Lobo; UP-ASN at San Nicholas Bridge in Brgy. Poblacion, Municipality of San Nicholas, UP-CLG at Calumpang Bridge in Brgy. Kumintang Ibaba, Batangas City and UP-LWY at Lawaye Bridge in Brgy. Calitcalit, Municipality of San Juan.

The summary of reference and control points and its location is summarized in Table 1, while the GNSS network established is illustrated in Figure 2.

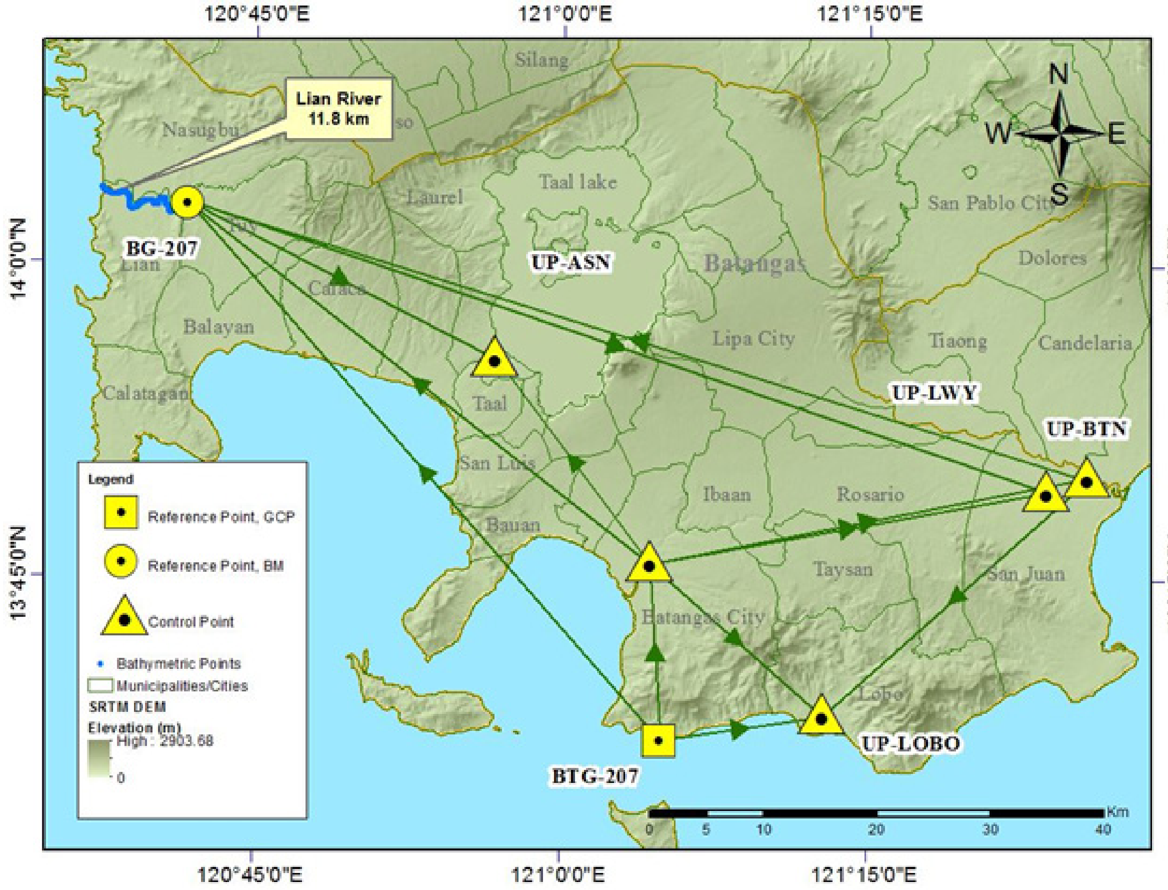


Figure 2: GNSS Network of Lian River Field Survey

4.3 Baseline Processing

Table 23. Baseline Processing Report for Lian River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UPCLG --- BTG7 (B11)	5-22-2014	Fixed	0.003	0.013	356°25'22"	15777.353	-8.962
BTG7 --- UPLOBO (B14)	5-22-2014	Fixed	0.008	0.037	80°16'20"	14501.810	-9.895
UPCLG --- UPBTN (B8)	5-21-2014	Fixed	0.004	0.018	78°44'11"	39325.812	-1.938
UPCLG --- UPBTN (B10)	5-22-2014	Fixed	0.023	0.082	78°44'11"	39325.931	-1.993
UPCLG --- UPBTN (B9)	5-21-2014	Fixed	0.018	0.032	78°44'11"	39326.011	-1.988
UPCLG --- BMBG207 (B7)	5-21-2014	Fixed	0.008	0.021	307°20'38"	51500.583	8.348
UPCLG --- UPLWY (B15)	5-22-2014	Fixed	0.004	0.015	79°31'48"	35577.341	6.690
UPCLG --- UPASN (B6)	5-21-2014	Fixed	0.005	0.020	322°34'54"	22553.641	-5.613
UPCLG --- UPLOBO (B12)	5-22-2014	Fixed	0.006	0.026	131°01'52"	20253.372	-0.954
UPBTN --- BMBG207 (B2)	5-21-2014	Fixed	0.066	0.086	286°35'24"	82928.558	10.191
BTG7 --- UPBTN (B5)	5-21-2014	Fixed	0.004	0.018	58°03'54"	44287.329	-10.884
BTG7 --- UPBTN (B3)	5-21-2014	Fixed	0.017	0.070	58°03'54"	44287.367	-10.925
BTG7 --- UPBTN (B4)	5-21-2014	Fixed	0.011	0.024	58°03'54"	44287.360	-10.823
UPBTN --- UPLOBO (B13)	5-22-2014	Fixed	0.011	0.045	228°04'35"	31344.157	0.983
BMBG207 --- UPLWY (B17)	5-22-2014	Fixed	0.015	0.033	107°58'47"	79868.067	-1.689
BMBG207 --- UPASN (B1)	5-21-2014	Fixed	0.005	0.022	115°58'50"	30324.834	-14.030
UPLWY --- UPASN (B16)	5-22-2014	Fixed	0.011	0.021	283°18'29"	50016.834	-12.285

As shown in Table 23, a total of 17 baselines were processed with reference elevation of point BG-207 and coordinates of BTG-7 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

For each complete details, see the Network Adjustment Report shown in Table 24 to 27.

The seven (7) control points, BG-207, BTG-7, UP-ASN, UP-BTN, UP-CLG, UP-LOBO and UP-LWY were occupied and observed simultaneously to form a GNSS loop. Coordinates of point BTG-7 and elevation value of BG-207 were held fixed during the processing of the control points as presented in Table 24 Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
BG-207	Grid				Fixed
BTG-7	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. The fixed control point BG-207 and BTG-7, have no values for standard elevation and coordinates error, respectively.

Table 25. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MBG207	250979.768	0.014	1554083.399	0.009	22.502	?	e
BTG7	292538.897	?	1506749.028	?	20.801	0.072	LL
UPASN	278117.299	0.013	1540530.569	0.008	7.619	0.060	
UPBTN	330309.700	0.008	1529876.941	0.006	9.361	0.075	
UPCLG	291679.224	0.007	1522505.093	0.005	12.287	0.058	
UPLOBO	306852.492	0.014	1509086.720	0.008	10.498	0.094	
UPLWY	326716.786	0.013	1528689.759	0.008	18.019	0.064	

The network is fixed at reference points BG-207 and BTG-7 for elevation and coordinate values, respectively. 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 for the controls are as follows:

a. **BG-207**
Horizontal Accuracy = $\sqrt{(1.4)^2 + (0.9)^2}$
= $\sqrt{1.96 + 0.81}$
= 1.66 cm < 20 cm
Vertical Accuracy = Fixed

b. **BTG-7**
Horizontal Accuracy = Fixed
Vertical Accuracy = 7.2 cm

c. **UP-ASN**
Horizontal Accuracy = $\sqrt{(1.3)^2 + (0.8)^2}$
= $\sqrt{1.69 + 0.64}$
= 1.53 cm < 20 cm
Vertical Accuracy = 6.0 cm

d. **UP-BTN**
Horizontal Accuracy = $\sqrt{(0.8)^2 + (0.6)^2}$
= $\sqrt{0.64 + 0.36}$
= 1.0 cm < 20 cm
Vertical Accuracy = 7.5 cm

e. **UP-CLG**
Horizontal Accuracy = $\sqrt{(0.7)^2 + (0.5)^2}$
= $\sqrt{0.49 + 0.25}$
= 0.86 cm < 20 cm
Vertical Accuracy = 5.8 cm

f. **UP-LOB**
Horizontal Accuracy = $\sqrt{(1.4)^2 + (0.8)^2}$
= $\sqrt{1.96 + 0.64}$
= 1.48 cm < 20 cm
Vertical Accuracy = 9.4 cm

g. **UP-LWY**

Horizontal Accuracy = $\sqrt{((1.3)^2 + (0.8)^2}$
= $\sqrt{(1.69 + 0.64)}$
= 1.52 cm < 20 cm

Vertical Accuracy = 6.4 cm

Following the given formula, the horizontal and vertical accuracy result of the seven (7) occupied control points are within the required precision of the project.

Table 26. Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Ellipsoidal Height	Height Error (Meter)	Constraint
BMBG207	N14°02'47.32674"	E120°41'38.93608"	65.606	?	e
BTG7	N13°37'19.49611"	E121°04'56.32756"	66.192	0.072	LL
UPASN	N13°55'34.60792"	E120°56'47.03882"	51.610	0.060	
UPBTN	N13°50'00.87917"	E121°25'47.84870"	55.321	0.075	
UPCLG	N13°45'51.87502"	E121°04'23.55781"	57.236	0.058	
UPLOBO	N13°38'39.10157"	E121°12'51.89916"	56.291	0.094	
UPLWY	N13°49'21.47536"	E121°23'48.47095"	63.917	0.064	

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 equation is satisfied; hence, the required accuracy for the program was met.

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

Table 27. Reference and Control Points and its Location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	Elevation in MSL (m)
BG207	1st Order	14°02'47.32674"	120°41'38.93608"	65.606	1554083	250979.8	22.502
BTG-7	1st Order	13°37'19.49611"	121°04'56.32756"	66.192	1506749	292538.9	20.801
UP-ASN	UP Established	13°55'34.60792"	120°56'47.03882"	51.61	1540531	278117.3	7.619
UP-BTN	UP Established	13°50'00.87917"	121°25'47.84870"	55.321	1529877	330309.7	9.361
UP-CLG1	UP Established	13°45'51.87502"	121°04'23.55781"	57.236	1522505	291679.2	12.287

4.5 Cross-section and Water Level Marking

A GNSS receiver Trimble® SPS 882 using PKKK survey technique was utilized to get the cross-section of Palico Bridge, Brgy. Bagong Pook, Municipality of Lian, Batangas on May 19, 2014, as shown in Figure 35.

Figure 36. (a) Cross Section Survey using Trimble® SPS 882 at Palico Bridge in Municipality of Lian and (b) Acquisition of Water Surface Elevation

The cross-sectional line length of the Palico Bridge is about 168.65 m with 18 cross-sectional points acquired using BG-207 as the GNSS base station. The location map and cross section diagram are shown in Figure 36 and 37, respectively.

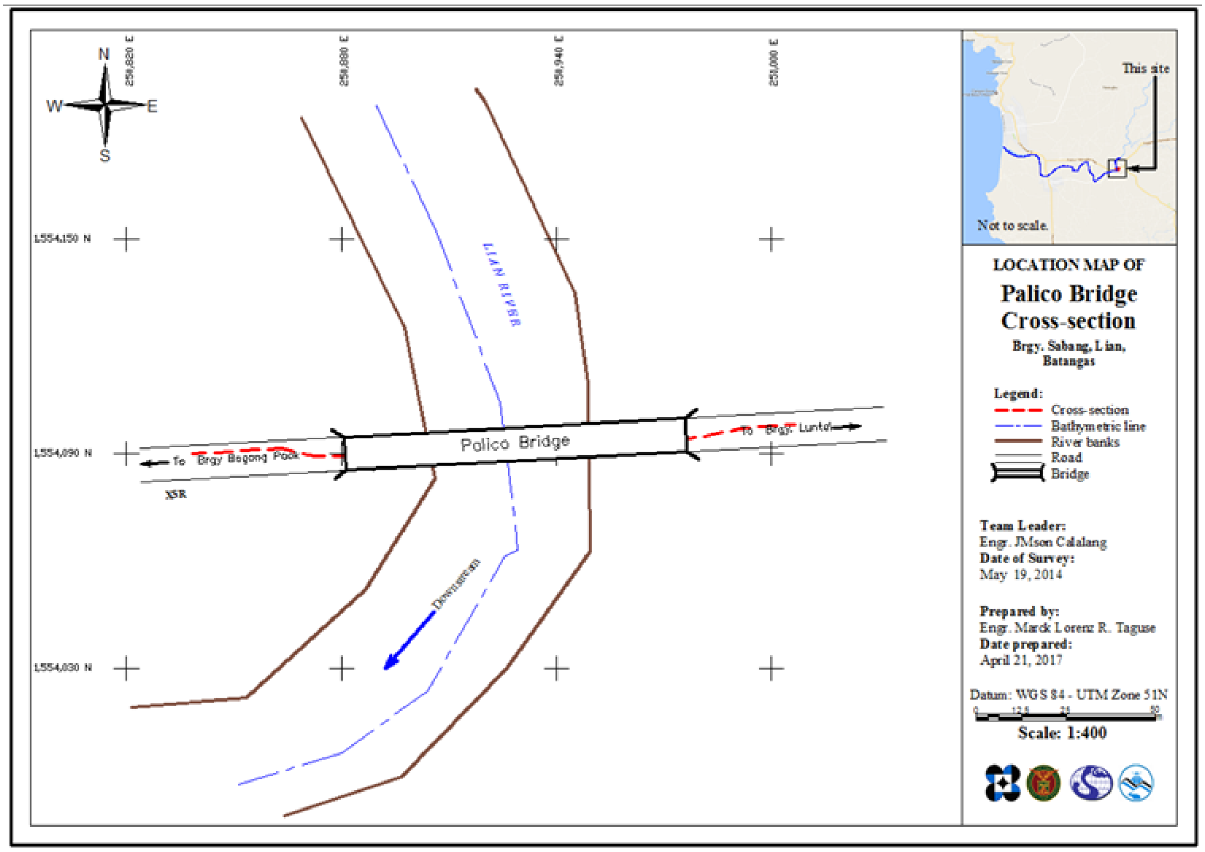


Figure 38. Palico Bridge Cross-section Planimetric Map

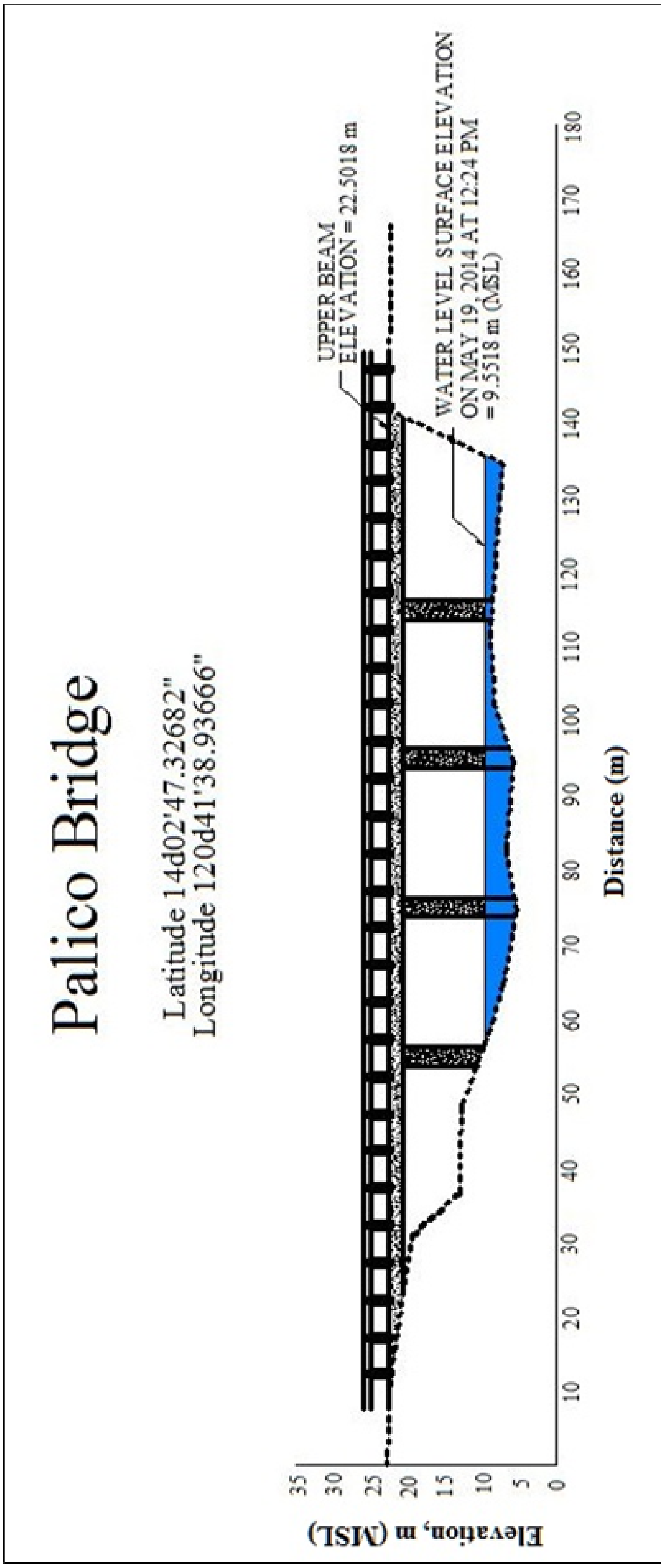


Figure 37. Palico Bridge Cross-section Diagram

The water surface elevation of Lian River at the left bank was acquired using PPK survey technique on May 19, 2014 at 12:24 PM. The resulting water surface elevation data of 9.5518 m above MSL was translated and marked on the piers of Palico Bridge using a Digital Level, as shown in Figure 38. The marking on the bridge pier will serve as a reference for flow data gathering and depth gauge deployment of Mapúa Institute of Technology PHIL-LiDAR 1.

Figure 39. Using a Digital Level to Translate Water Surface Elevation Data to the Bridge Pier (a) and Marking of Bridge Pier (b) for Lian River

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on August 30, 2014. In this survey, Trimble® SPS 882 was attached on the top of a vehicle, as shown in Figure 39, to measure points utilizing continuous topography method in a PPK Survey Technique. The height of the instrument was measured and noted a 1.53 m distance from the ground up to the bottom of the notch. Points were gathered along major concrete roads with the aid of a vehicle which moved at a speed of 20 to 40 kph, cutting across the flight strips of the DAC, with the aid of available topographic maps and Google Earth™ images.

The ground validation started from the Municipality of Nasugbu, traversing the major roads eastward and ended in the Municipality of Alfonso. Another major road was validated, traversing from Palico Bridge, Municipality of Lian up to the Municipality of Balayan.

Figure 40. (a) Validation Points Acquisition Survey Setup: A Trimble® SPS 882 is attached on Top of a Vehicle and (b) Trimble® SPS 895 setup at BG-207, at Palico Bridge

The map in Figure 40 shows the extent of the ground validation survey, which acquired 4,202 ground validation points, with an approximate length of 58 km using the base station BG-207.

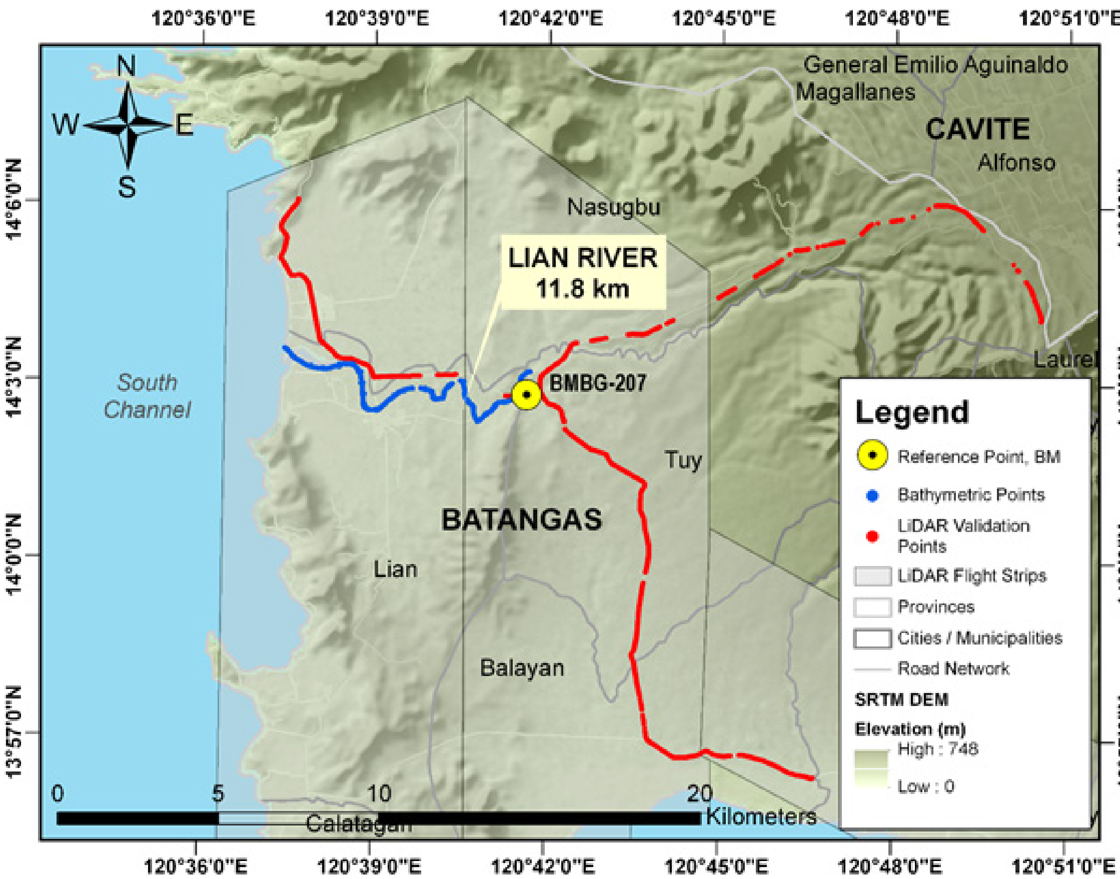


Figure 41. Validation Points Acquisition Survey along Lian River Basin

4.7 Bathymetric Survey

The Bathymetric survey was conducted on August 29, 2014 using Trimble® SPS 882 in GNSS PPK survey technique, utilizing continuous topo mode and Hi-Target™ Single Beam Echo Sounder, mounted on a rubber boat as shown in Figure 41. A GPS receiver, Trimble® SPS 985, was setup at BG-207, which served as the base station. The survey began in the upstream in Brgy. Sabang, Municipality of Tuy with coordinates 14°03’11.03047” 120°41’42.68966” and ended at the mouth of the river in Brgy. Bungahan, Municipality of Lian with coordinates 14°03’32.42660” 120°37’29.15550.

Figure 42. Bathymetry Setup using OHMEX™ Single Beam Echo Sounder with a Trimble® SPS 882.

The bathymetric line length of Lian River is 11.8 km, with 5,108 acquired bathymetric points covering 8 barangays as shown in . A CAD drawing was also produced to illustrate the Lian Riverbed Profile. As shown in Figure 42, the change in elevation is gradual with a 6 m (MSL) difference between the upstream in Brgy. Bagong Pook to its downstream in Brgy. Bungahan (mouth of the river). The highest elevation observed was 8.165 m in MSL, located in Brgy. Bagong Pook, while the lowest elevation observed was -7.98 m below MSL, located in Brgy. Malaruhatan, both in Municipality of Lian.

Figure 43. Bathymetric Points gathered along Lian River.

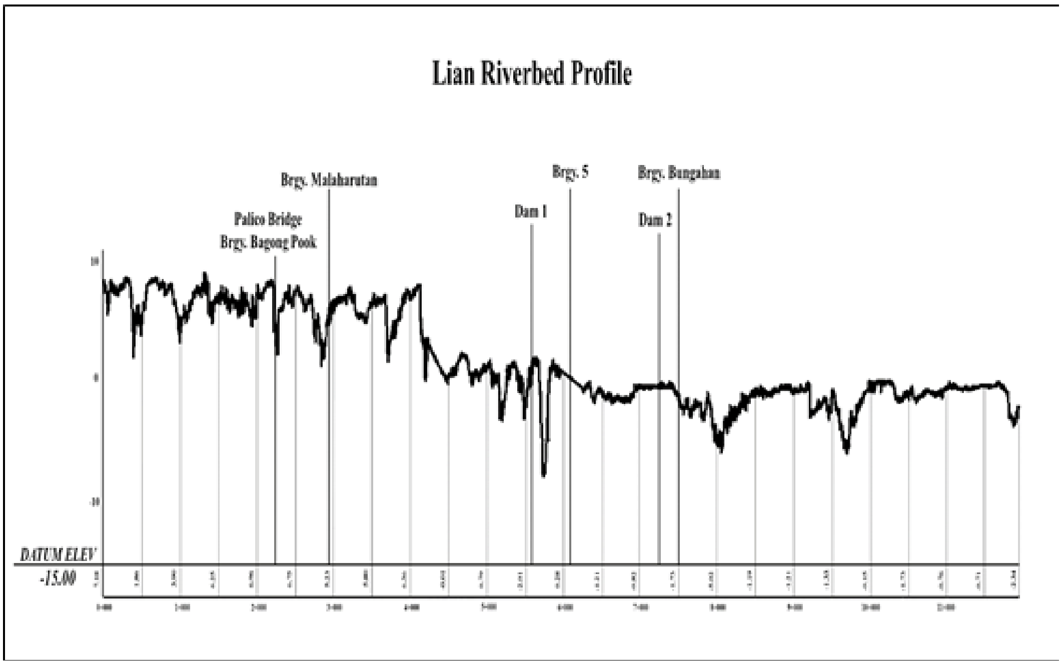


Figure 44. Riverbed Profile of Lian River.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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. These include the rainfall, water level, and flow in a certain period of time.

5.1.2. Precipitation

Precipitation data was taken from automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These are the Dayap Itaas Rain Gauge (14° 3'19.26"N, 120°51'6.80"E), Toong Rain Gauge (14°3'0.00"N, 120°45'36.00"E) and Mataas na Pulo Rain Gauge (14°5'16.55"N, 120°43'42.89"E). The location of the rain gauges is seen in Figure 44. The precipitation data collection started from September 20, 2016 at 0:00 to September 21, 2016 at 23:50 with a 15 minute recording interval for Dayap Itaas Rain Gauge and a 10 minute recording interval for both Toong and Mataas na Pulo Rain Gauge.

Total precipitation from Mataas na Pulo Rain Gauge is 17 mm. It peaked to 5.5 mm on September 20, 2016 16:30. The lag time between the peak rainfall and discharge is 2 hours and 29 minutes. For Dayap Itaas Rain Gauge, the total amount of rainfall recorded during the event is 5.4 mm and it peaked to 4.2 mm on September 20, 2016 16:15. The lag time between the peak rainfall and discharge is 2 hours and 44 minutes. And lastly Toong Rain Gauge recorded a 13.5 mm of precipitation with a peak of 8.5 mm on September 20, 2016 16:10 and a lag time of 2 hours and 49 minutes.

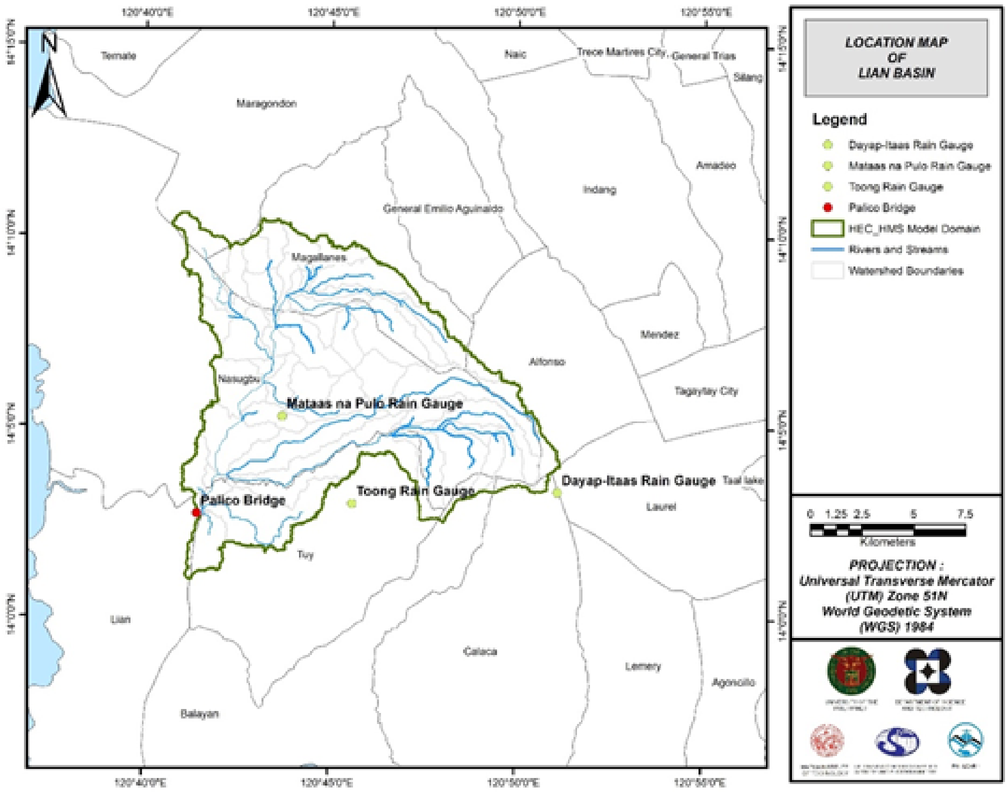


Figure 45. The Location Map of Rain Gauges used for the Calibration of the Lian HEC-HMS Model

5.1.3. Rating Curves and River Outflow

A rating curve was developed at Palico, Lian, Batangas (14° 2'47.26"N, 120°41'36.80"E). It gives the relationship between the observed water levels from the Palico Bridge using depth gage and outflow of the watershed using the flow meter at this location. It is expressed in the form of the following equation:

Q=anh

where, Q	:	Discharge (m3/s),
h	:	Gauge height, and
a and n	:	Constants.

For Palico Bridge, the rating curve is expressed as Q = 2E-16e4.5145x as shown in Figure 45.

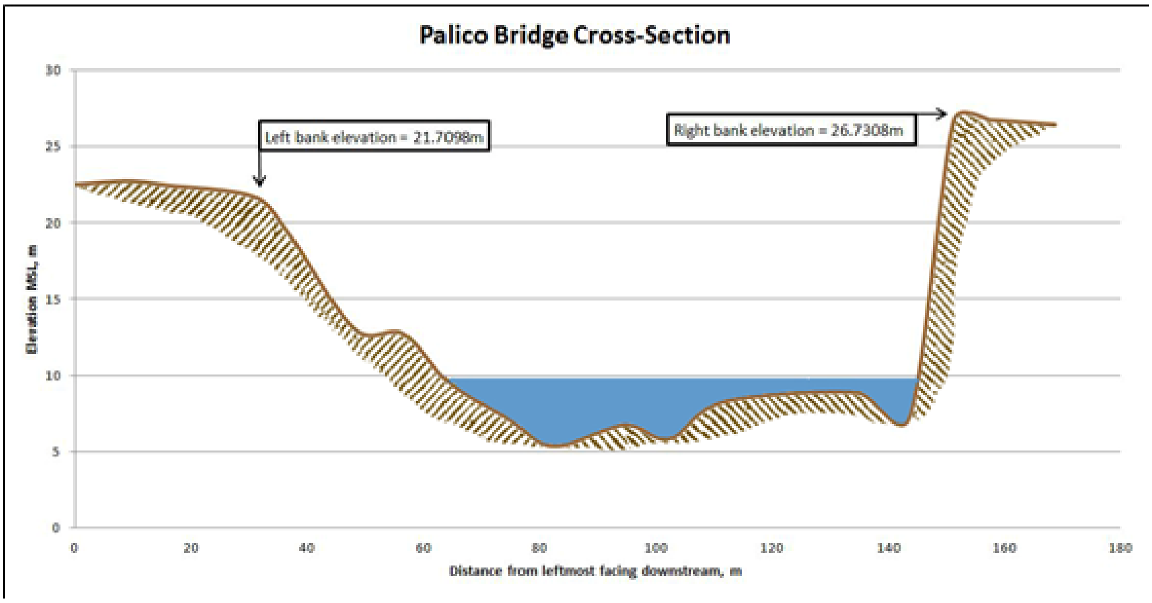


Figure 46. Cross-Section Plot of Palico Bridge

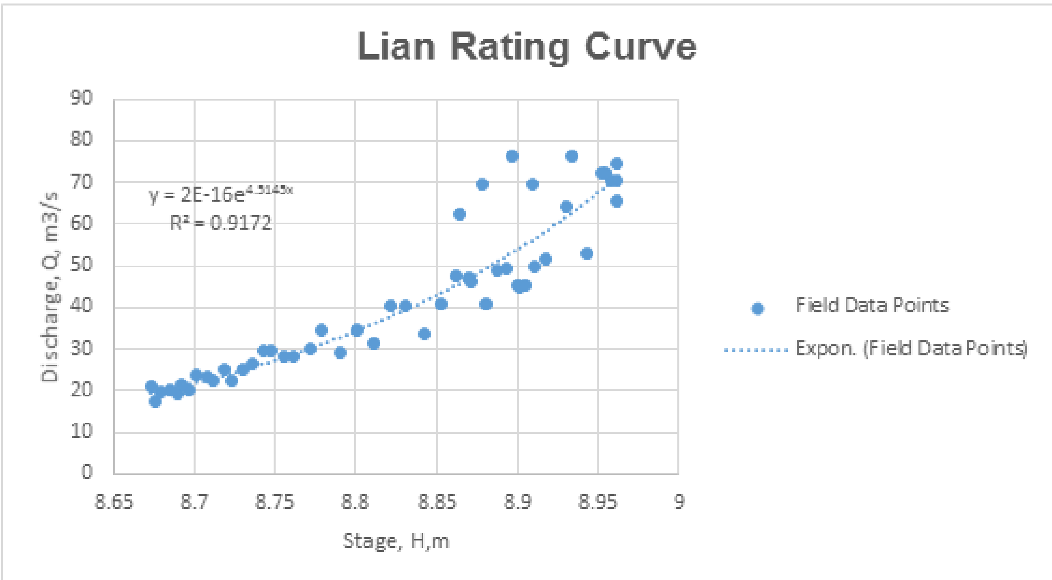


Figure 47. Rating Curve at Palico Bridge Batangas Province.

This rating curve equation was used to compute the river outflow at Palico for the calibration of the HEC-HMS model shown in Figure 46. Peak discharge is 76.5 m3/s at 19:00 PM, September 20, 2016.

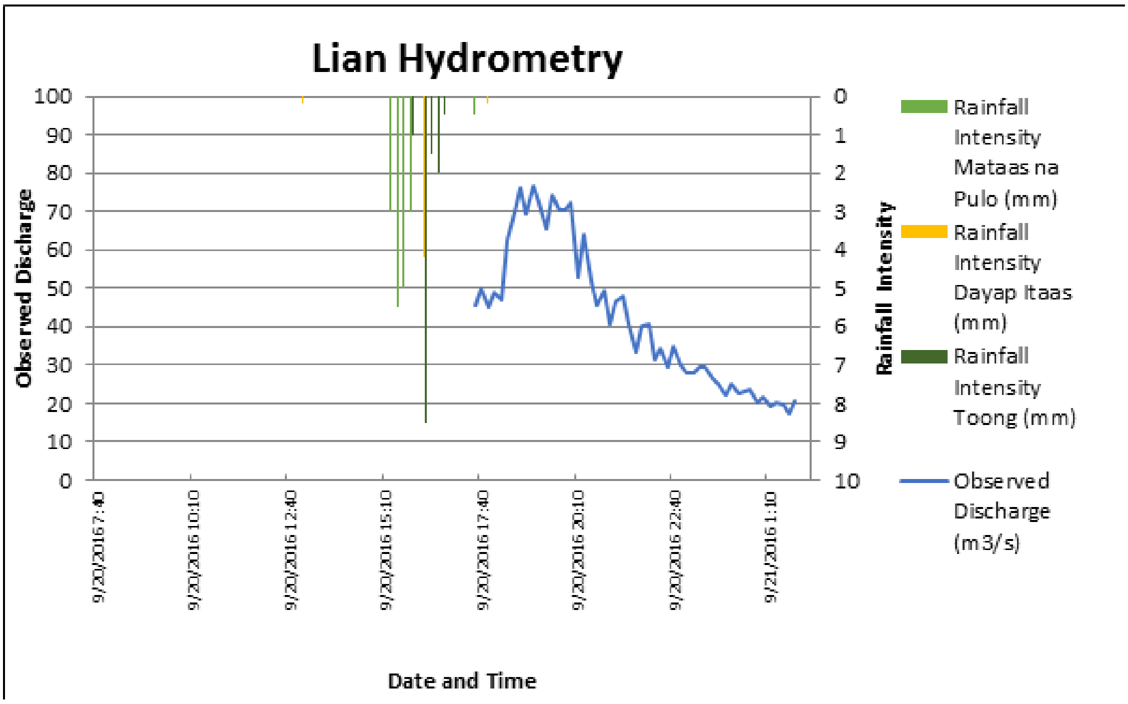


Figure 48. Rainfall and outflow data at Lian used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Ambulong Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station is chosen based on its proximity to the Lian watershed. The extreme values for this watershed were computed based on a 54-year record.

Table 28. RIDF values for Ambulong Rain Gauge computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	22.7	35.5	36.3	50.2	68.2	80.1	104.1	125.7	150.8
5	27.9	45.5	53.8	74.2	103.4	122.5	159.7	192.9	226.7
10	34.2	52.1	65.4	90.1	126.7	150.6	196.5	237.3	276.9
15	37.8	57.4	71.9	99	139.8	166.4	217.3	262.4	305.3
20	40.3	61	76.5	105.3	149	177.5	231.9	280	325.1
25	42.2	63.9	80	110.1	156.1	186	243.1	293.5	340.4
50	48.1	72.6	90.9	125	178	212.3	277.6	335.2	387.5
100	54	81.2	101.6	139.8	199.7	238.4	311.8	376.6	434.3

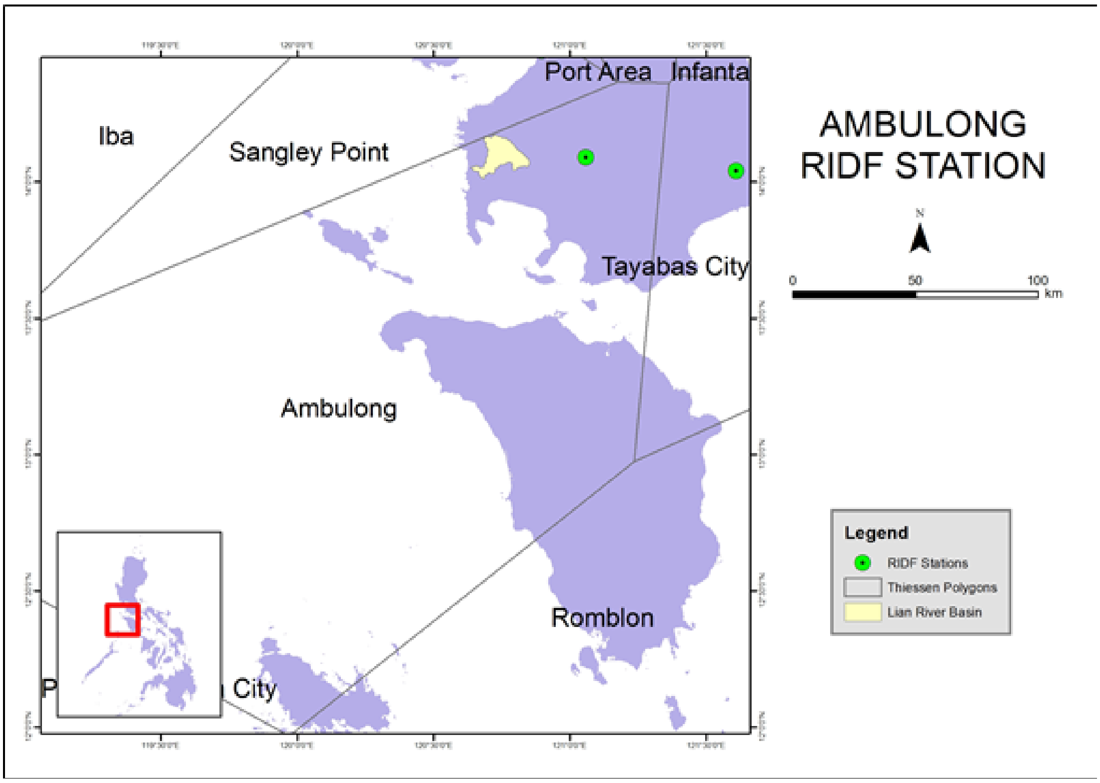


Figure 49. Location of Ambulong RIDF Station Relative to Lian River Basin

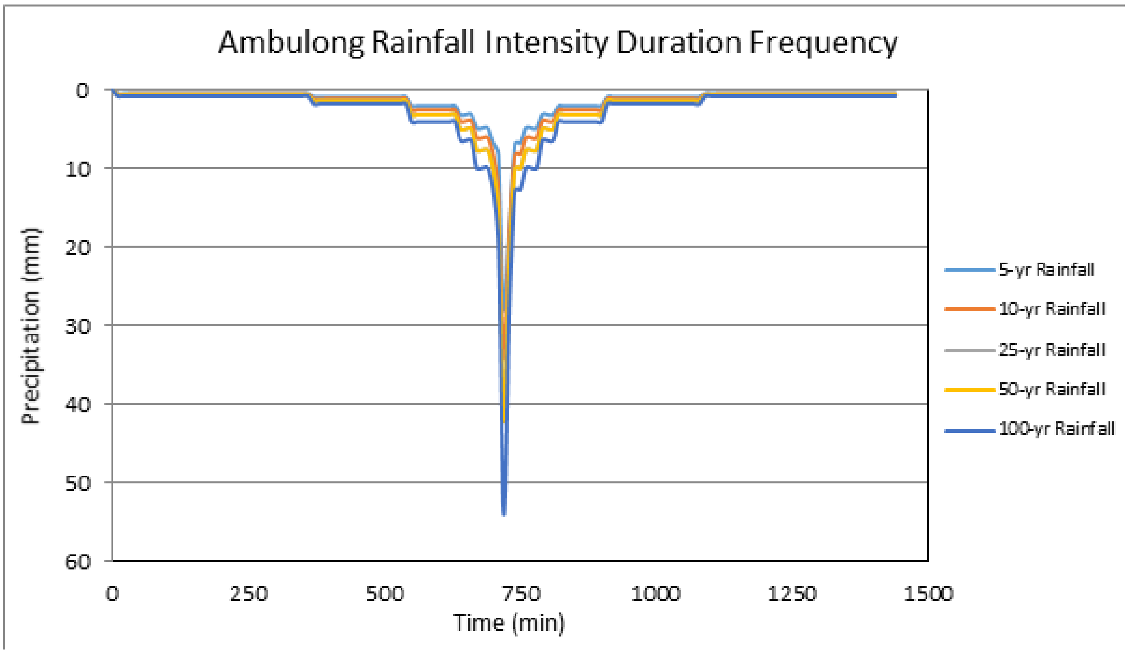


Figure 50. Synthetic Storm Generated for a 24-hr period Rainfall for various Return Periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover data set is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Lian River Basin are shown in Figures 50 and 51, respectively.

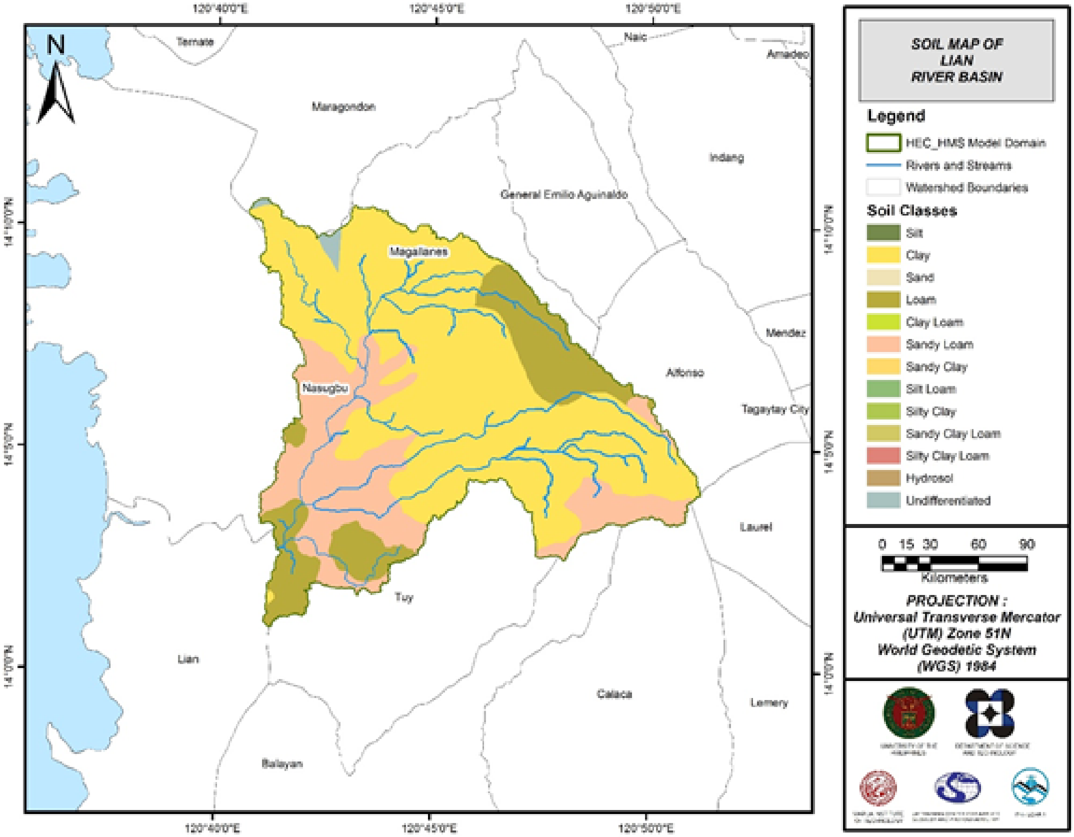


Figure 51. Soil Map of Lian River Basin.

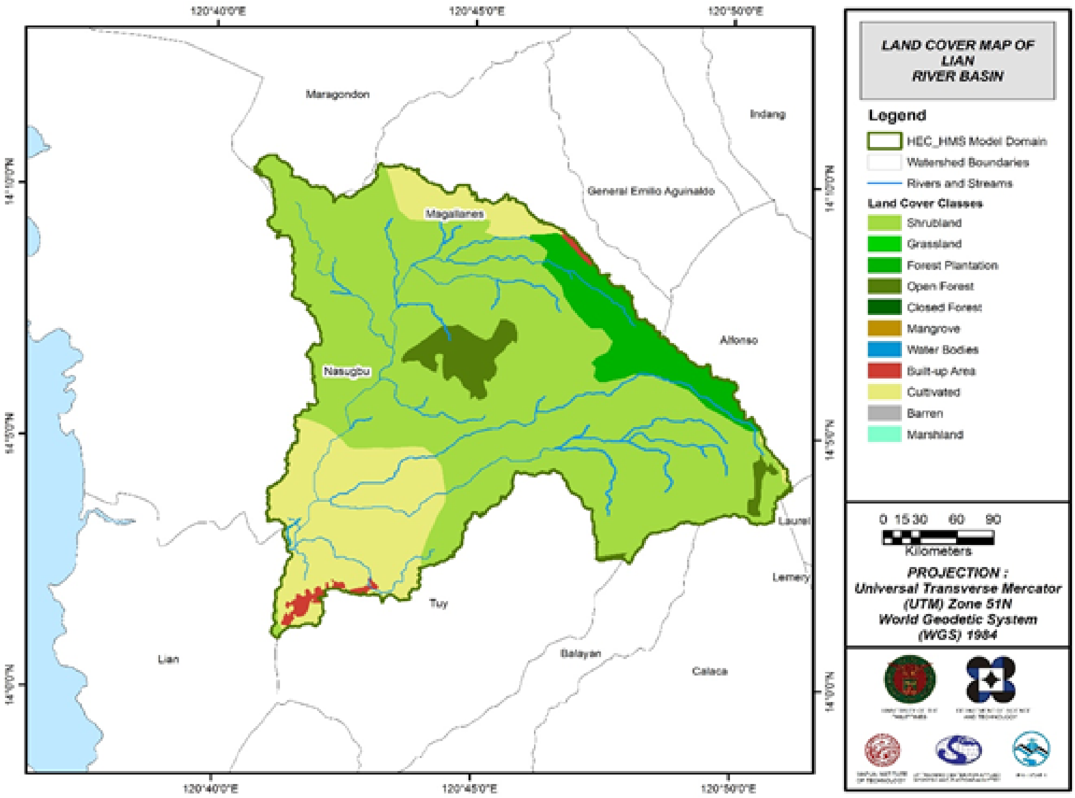


Figure 52. Land Cover Map of Lian River Basin

For Lian, the soil classes identified were clay, loam, sandy loam, and mountain soil. The land cover types identified were built-up areas, cultivated areas, shrubland, forest plantations and open canopy forests.

[insert Slope Map]

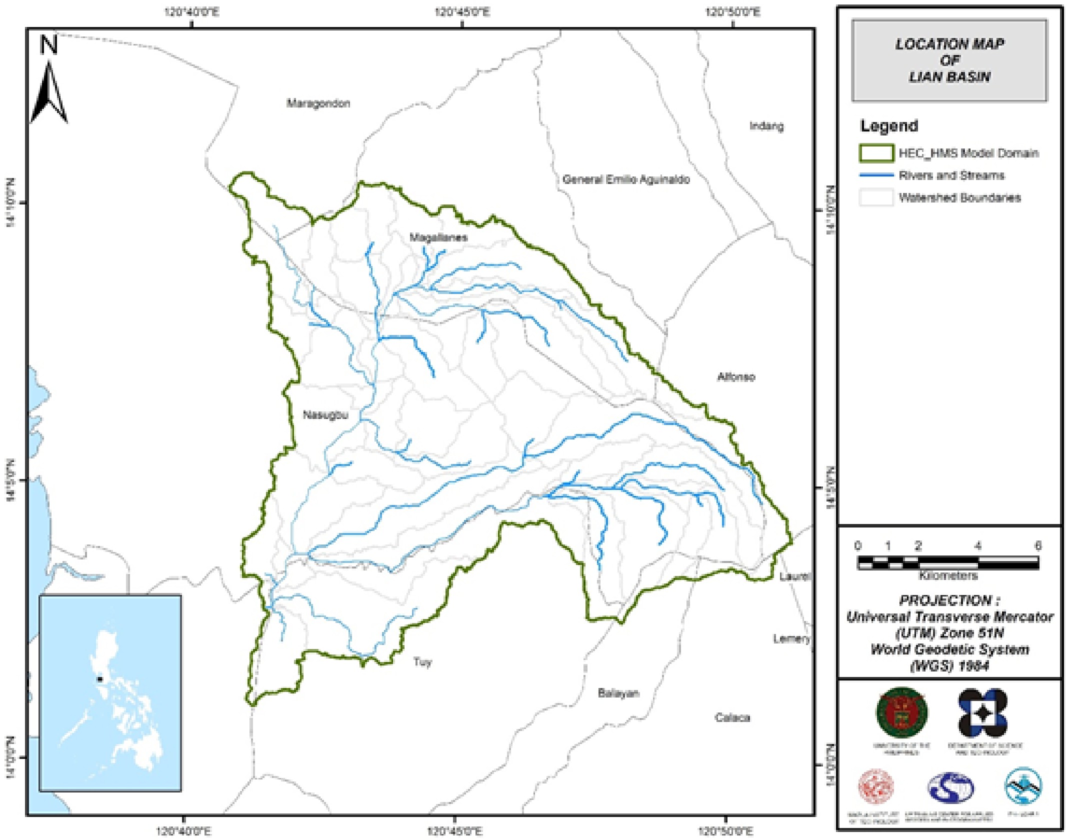


Figure 53. Stream Delineation Map of Lian River Basin.

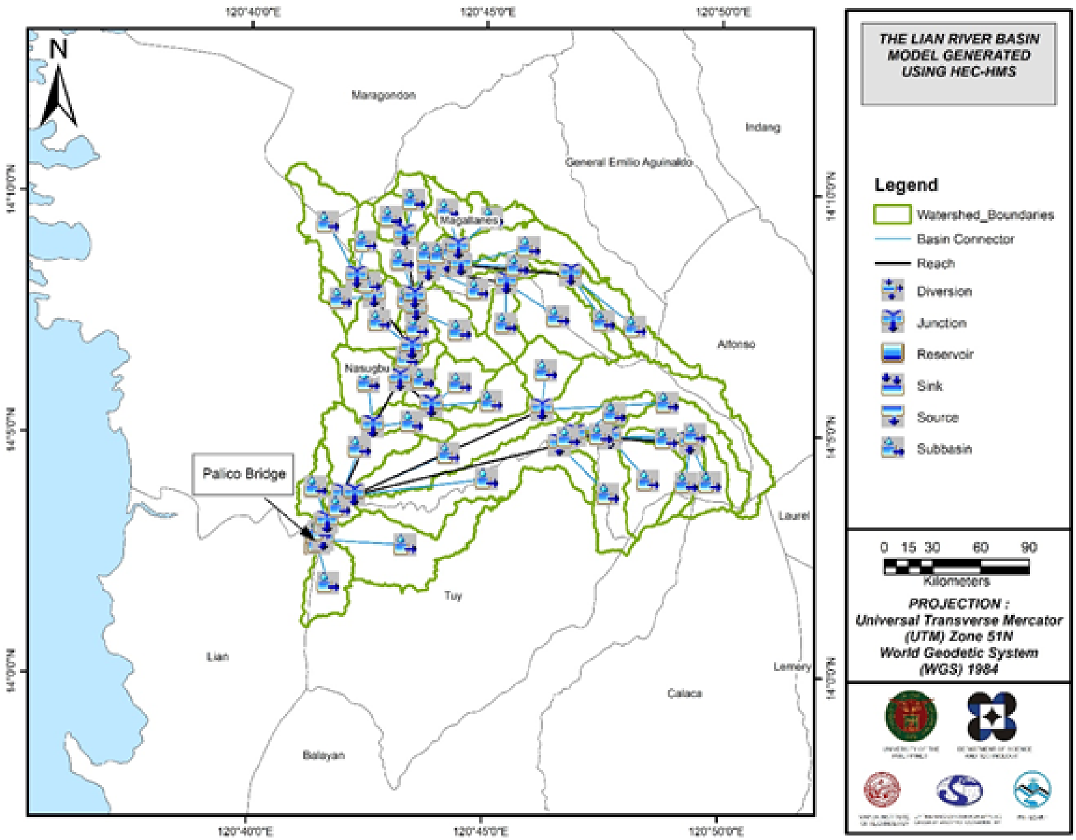


Figure 54. The Lian River Basin Model Domain generated by HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 54).

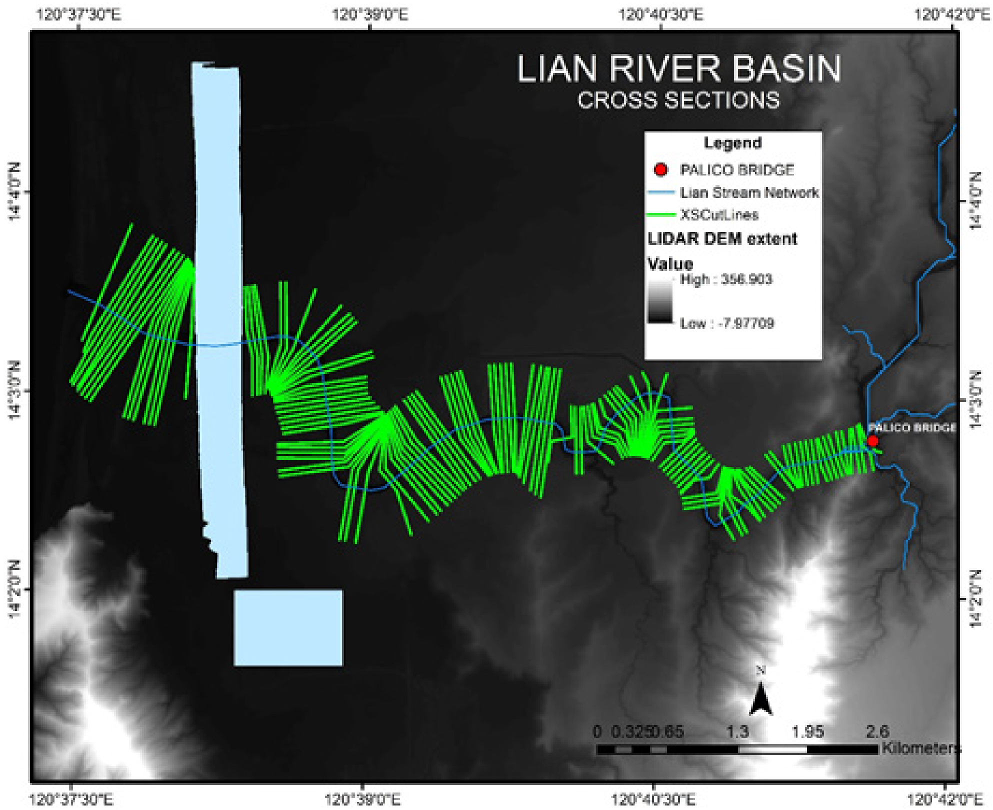


Figure 55. River cross-section of Lian River generated through Arcmap HEC GeoRAS Tool.

5.5 Manning's n

The Manning's n is a constant value that depends on the nature of the channel and its surface. Determining the roughness coefficient of the channel is important in determining the water flow. Appropriate selection of Manning's n values is based on the land cover type of the watershed area. A look-up table was derived to have a standardized Manning's n value for the HEC-RAS model (Table 29).

Table 29. Look-up table for Manning's n values (Source: Brunner, 2010)

Land-cover Class	Corresponding Manning's *n* Class	Manning's *n*
Barren Land	Cultivated areas, no crop	0.030
Built-up Area	Concrete, float finished	0.015
Cultivated land, annual crop	Cultivated areas, mature field crops	0.040
Cultivated land, perennial crop	Cultivated areas, mature row crops	0.035
Fishpond	Excavated, earth, straight and uniform	0.018
Inland Water	Main channel, clean, straight, no rifts or deep pools	0.030
Grassland	Pasture, no brush, short grass	0.030
Mangrove Forest	Trees, heavy stand, flow into branches	0.120
Shrub land	Medium to dense brush	0.100

5.6 Flo 2D Model

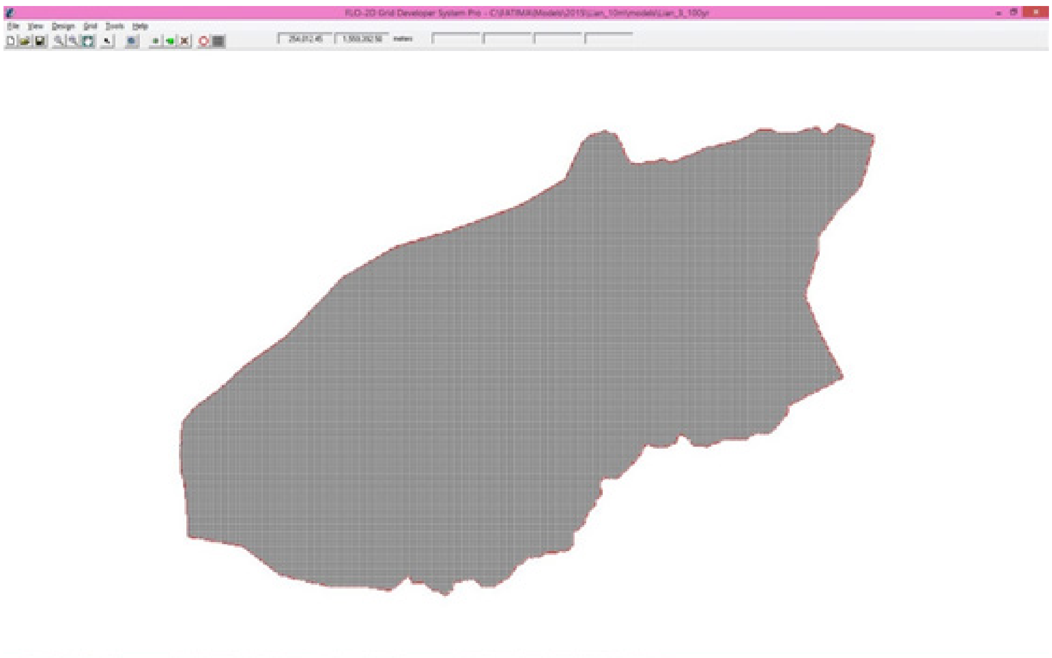


Figure 56. Screenshot of Subcatchment with the Computational Area to be modeled in FLO-2D GDS Pro.

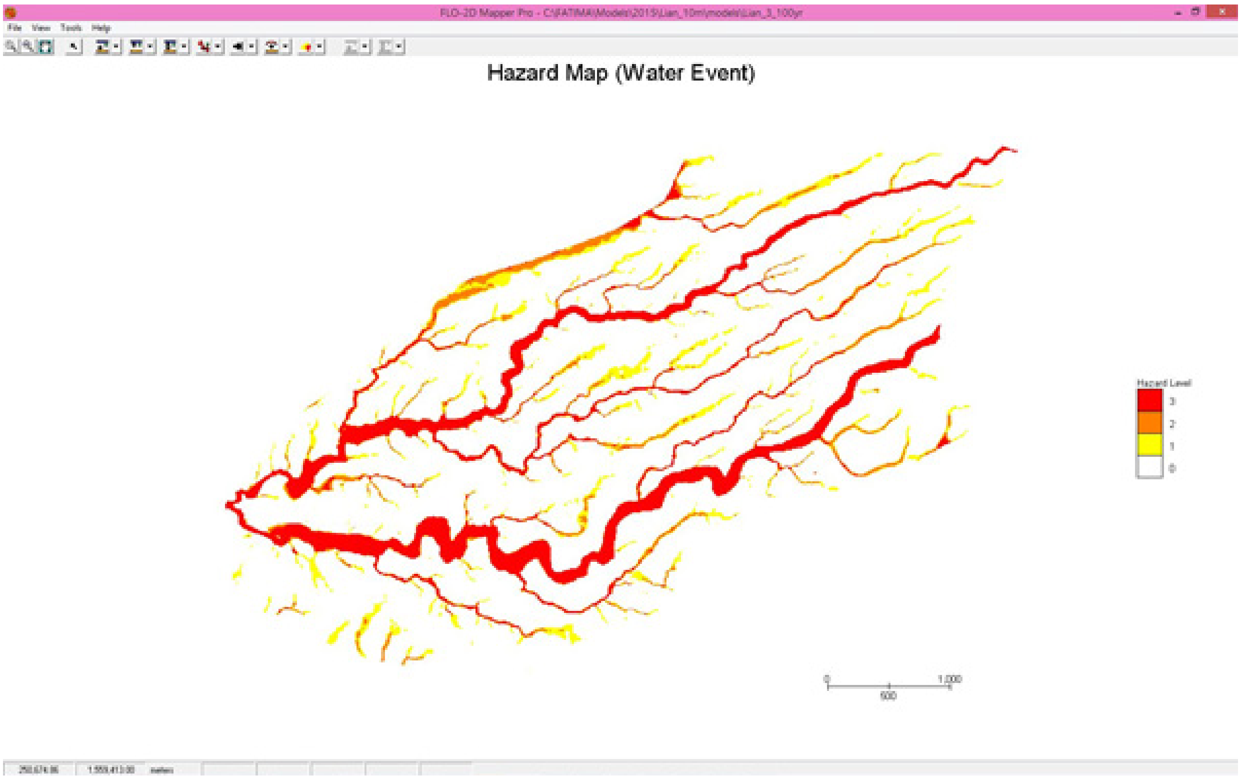


Figure 57. Generated 100-year Rain Return Hazard Map from FLO-2D Mapper.

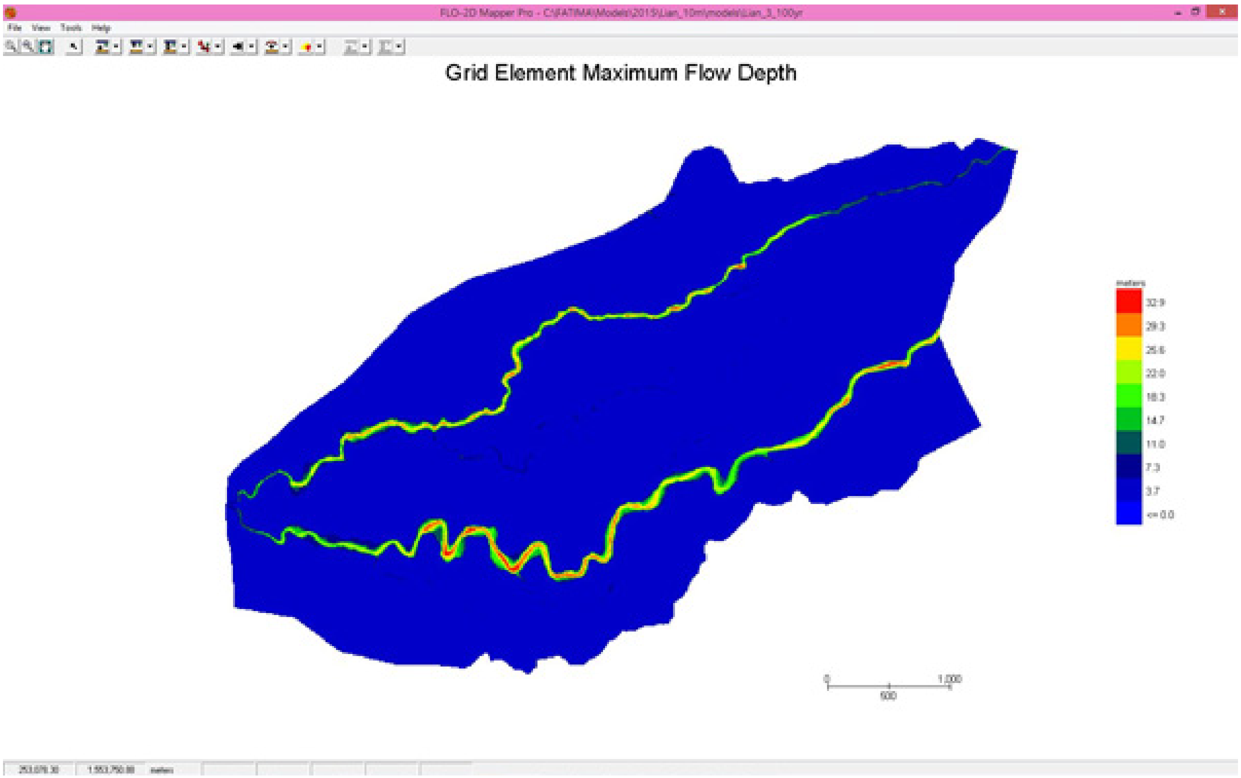


Figure 58. Generated 100-year Rain Return Hazard Map from FLO-2D Mapper.

5.7 Results of HMS Calibration

After calibrating the Lian HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 58 shows the comparison between the two (2) discharge data.

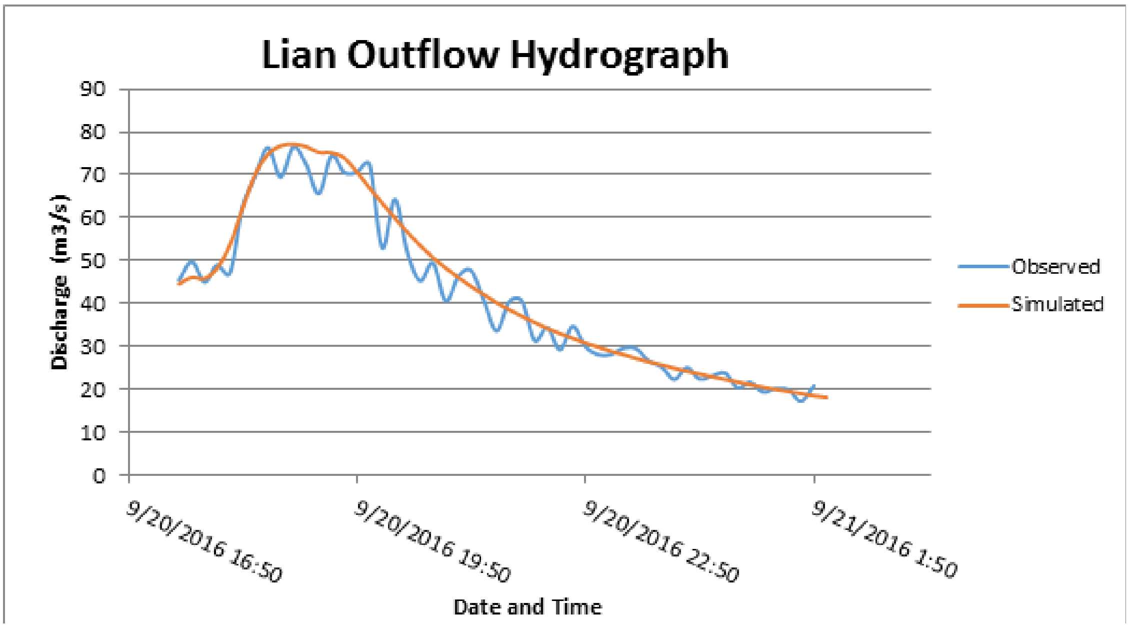


Figure 59. Outflow Hydrograph of Lian produced by the HEC-HMS Model Compared with Observed Outflow

Enumerated in Table 30 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of Calibrated Values for Lian

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.0071 – 28.028
			Curve Number	35.30 – 99.00
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.017 – 17.32
			Storage Coefficient (hr)	0.017 – 15.11
	Baseflow	Recession	Recession Constant	0.0002 – 0.57
			Ratio to Peak	0.056 – 1.00
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001 – 0.34

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 1.0071 mm to 28.028 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35.30 to 99.00 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.017 hours to 17.32 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 0.0002 to 0.57 indicates that the basin is moderately likely to quickly go back to its original discharge. Ratio to peak of 0.056 to 1.00 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001 to 0.34 corresponds to the common roughness in Lian Watershed.

Table 31. Summary of the Efficiency Test of Lian HMS Model

RMSE	3.7
r2	0.9172
NSE	0.96
PBIAS	-2.49
RSR	0.16

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 3.7 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 0.9172.

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

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -2.49.

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 0.16.

5.8 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.8.1. Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 59) shows the Lian outflow using the Ambulong Rainfall Intensity-Duration-F quency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall t series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-A data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases a range of durations and return periods.

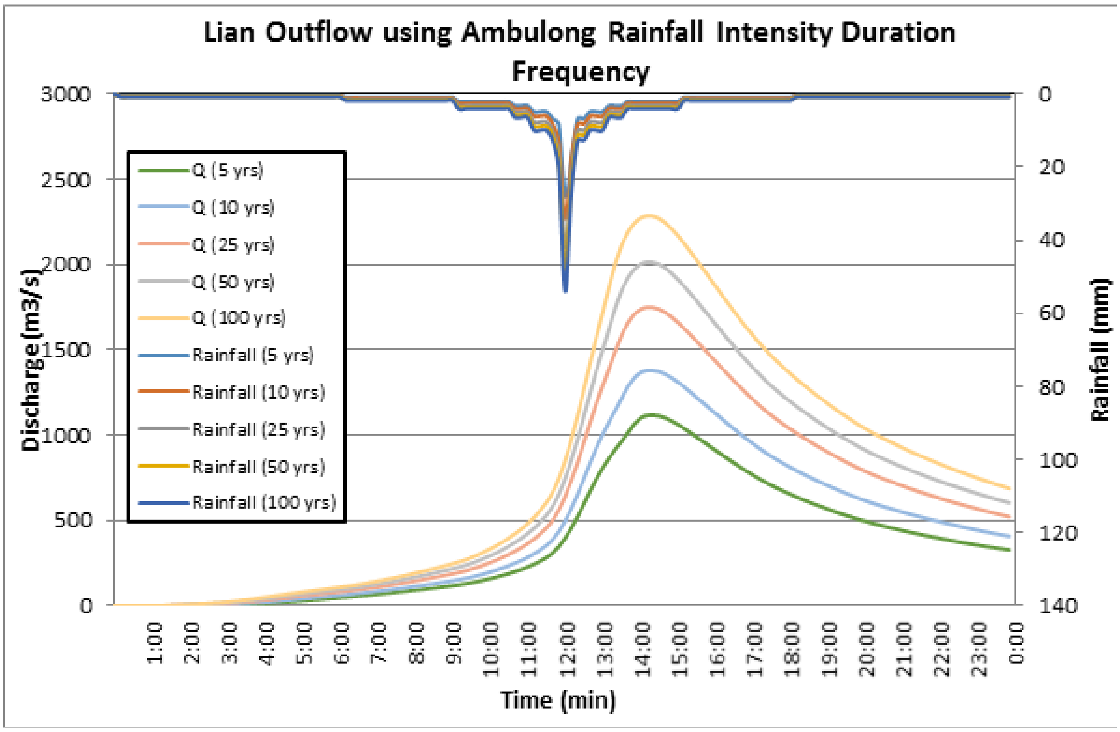


Figure 60. Outflow Hydrograph at Palico Bridge generated using Ambulong RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Lian River discha using the Ambulong Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return period shown in Table 32.

Table 32. Peak Values of the Lian HEC-HMS Model outflow using the Ambulong RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
			1118.2	14 hours and 20 min
10-Year	276.9	34.2	1380	14 hours and 20 min
25-Year	340.4	42.2	1748.7	14 hours and 20 min
50-Year	387.5	48.1	2013.6	14 hours and 10 min
100-Year	434.3	54	2284.3	14 hours and 10 min

5.9 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map

Figure 61. Sample Output of Lian RAS Model

5.10 Flow Depth and Floor Hazard Maps

The resulting hazard and flow depth maps have a 10 m resolution. Figure 61 to 66 shows the 5-, 25-, and 100-year rain return scenarios of the Lian floodplain.

Table 33. Municipalities Affected in Lian Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Nasugbu	266.54	60.36	23%
Tuy	266.54	8.72	9%
Liam	83.48	68.55	82%

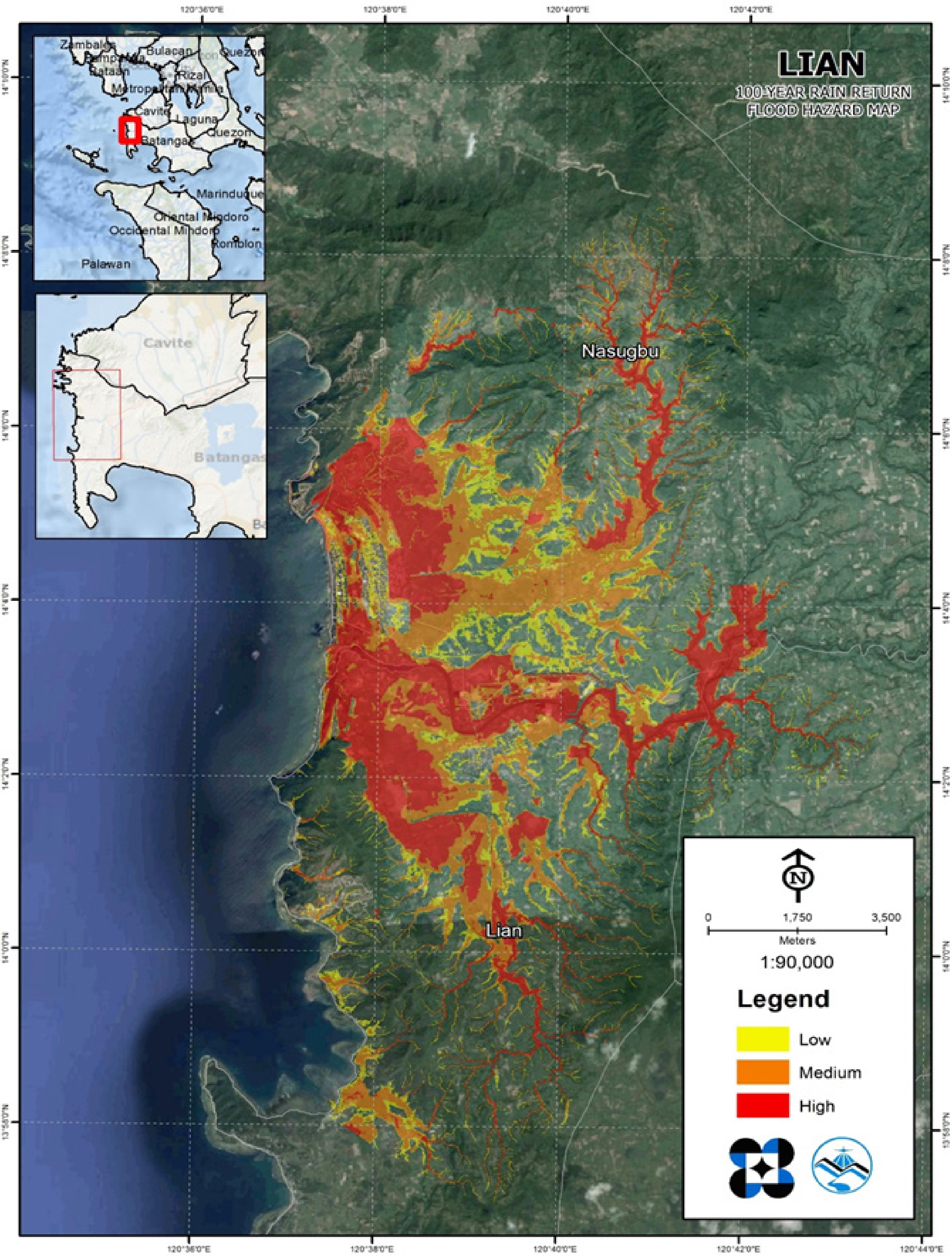


Figure 62. A 100-year Flood Hazard Map for Lian Floodplain

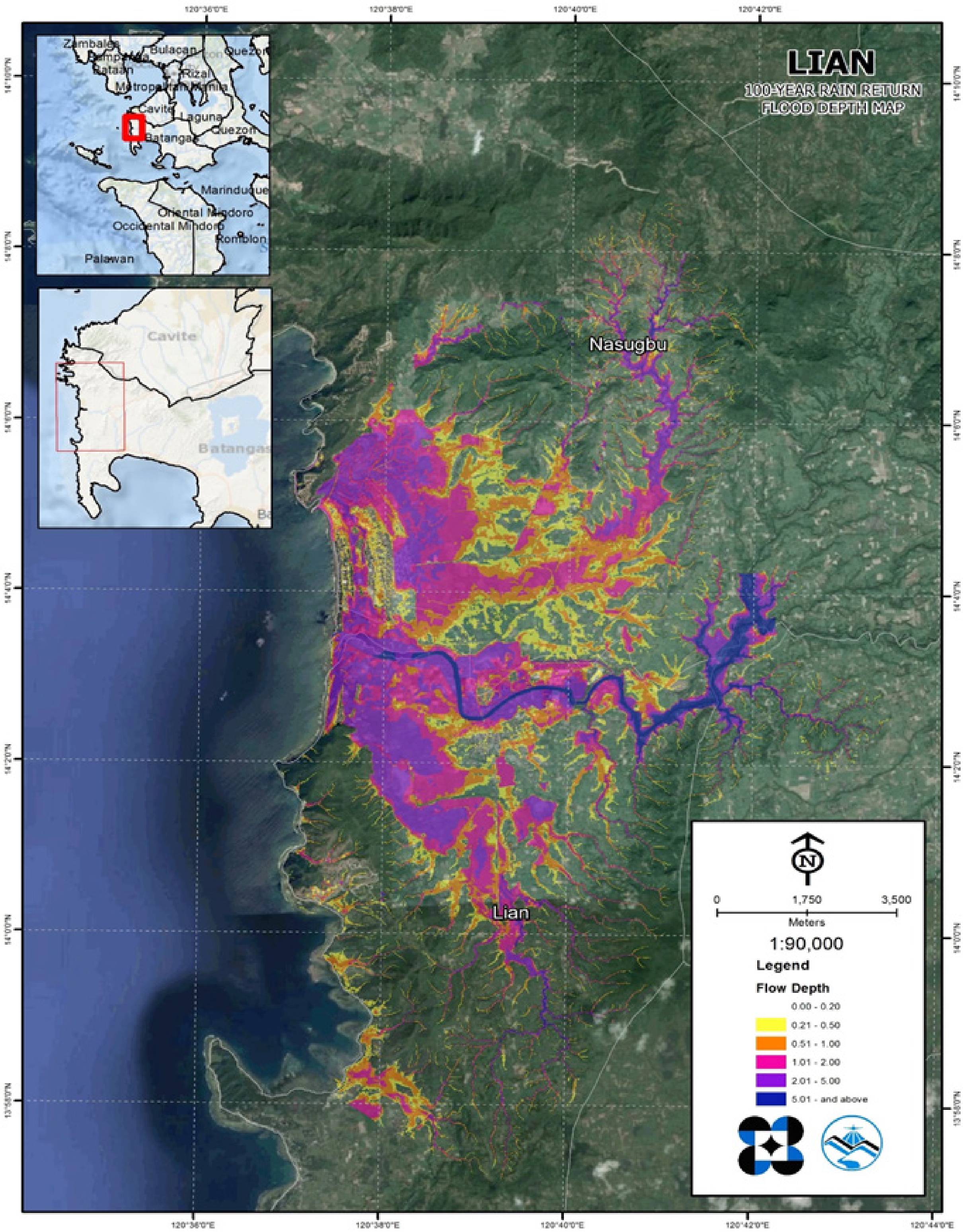


Figure 63. A 100-year Flow Depth Map for Lian Floodplain

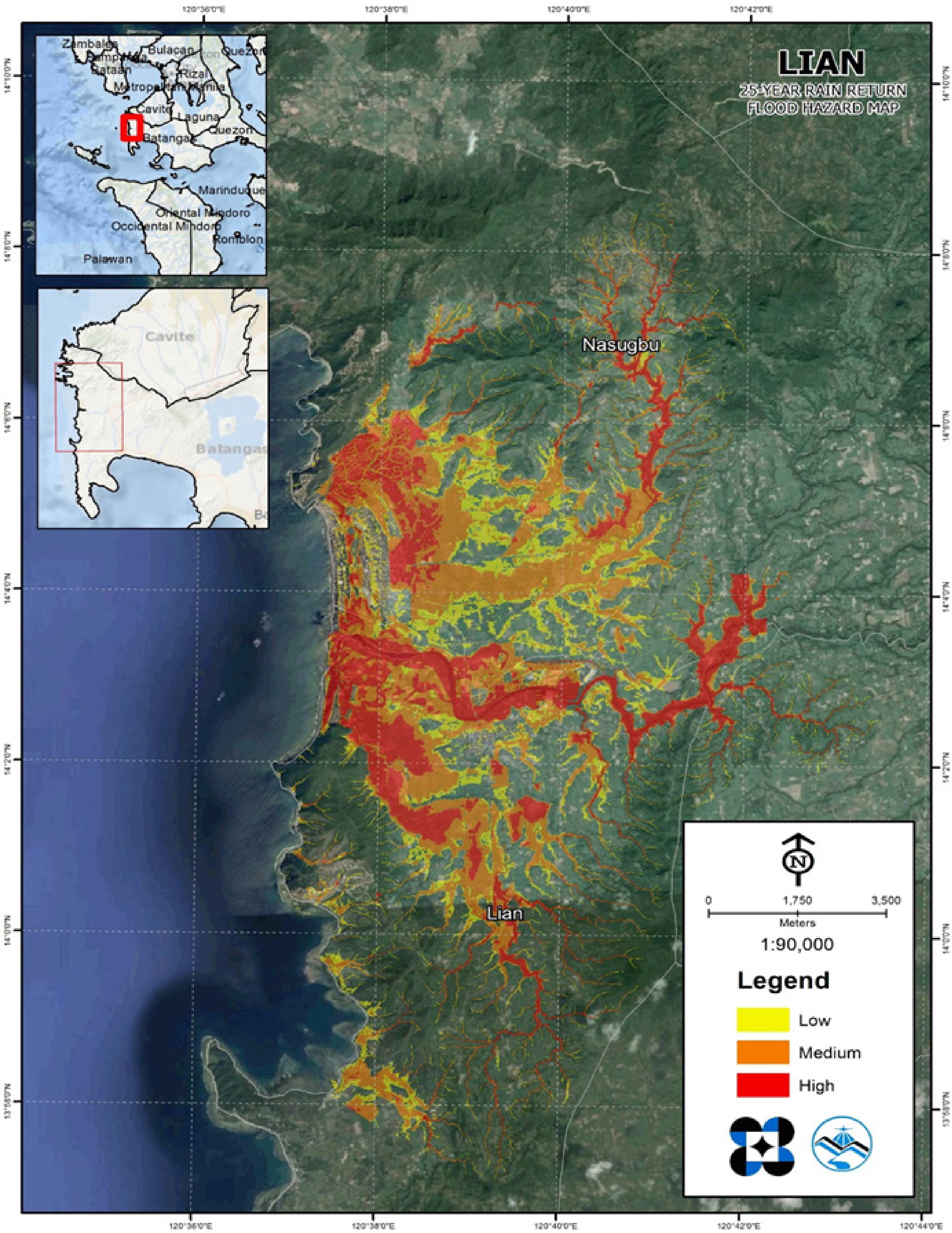


Figure 64. A 25-year Flood Hazard Map for Lian Floodplain

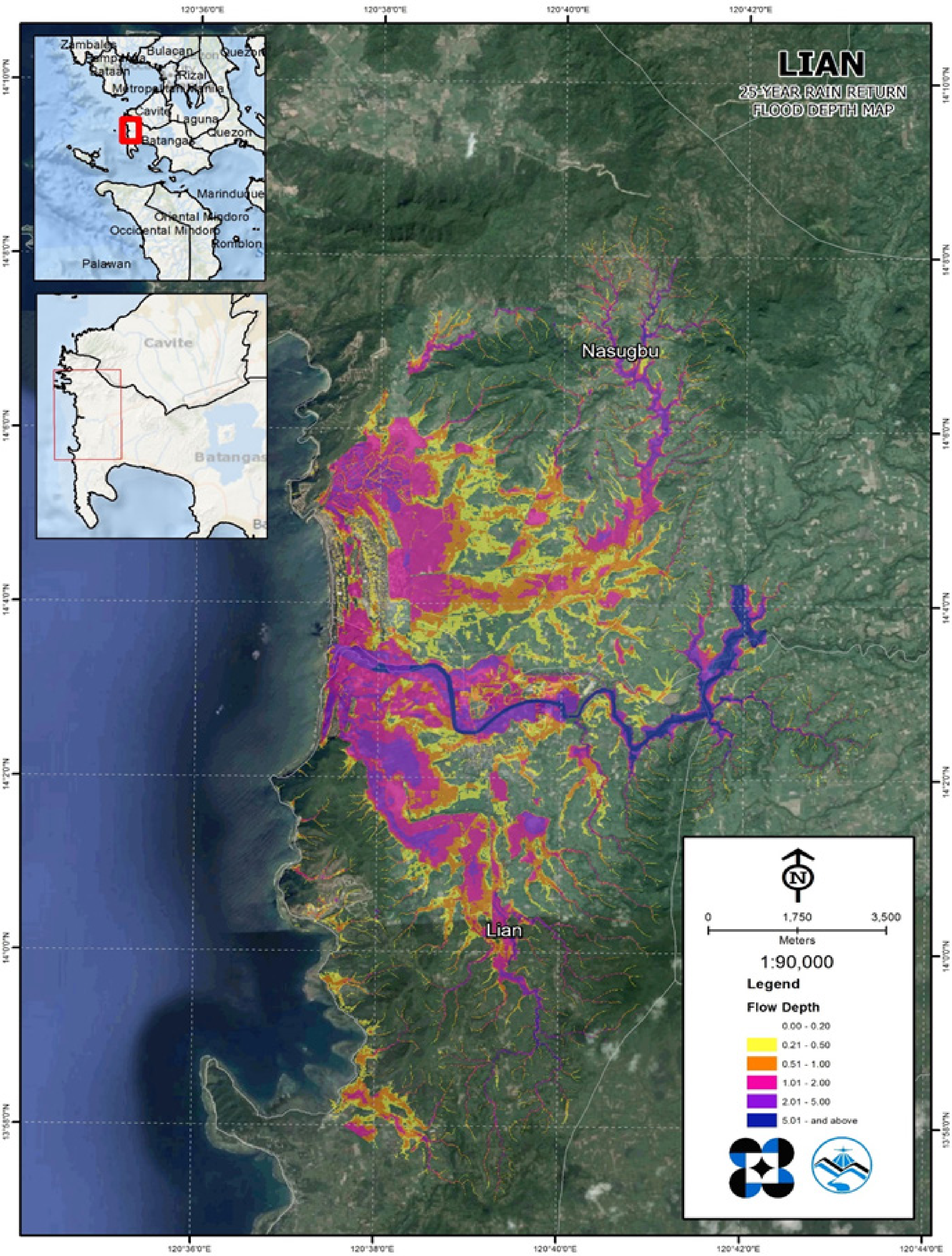


Figure 65. A 25-year Flow Depth Map for Lian Floodplain

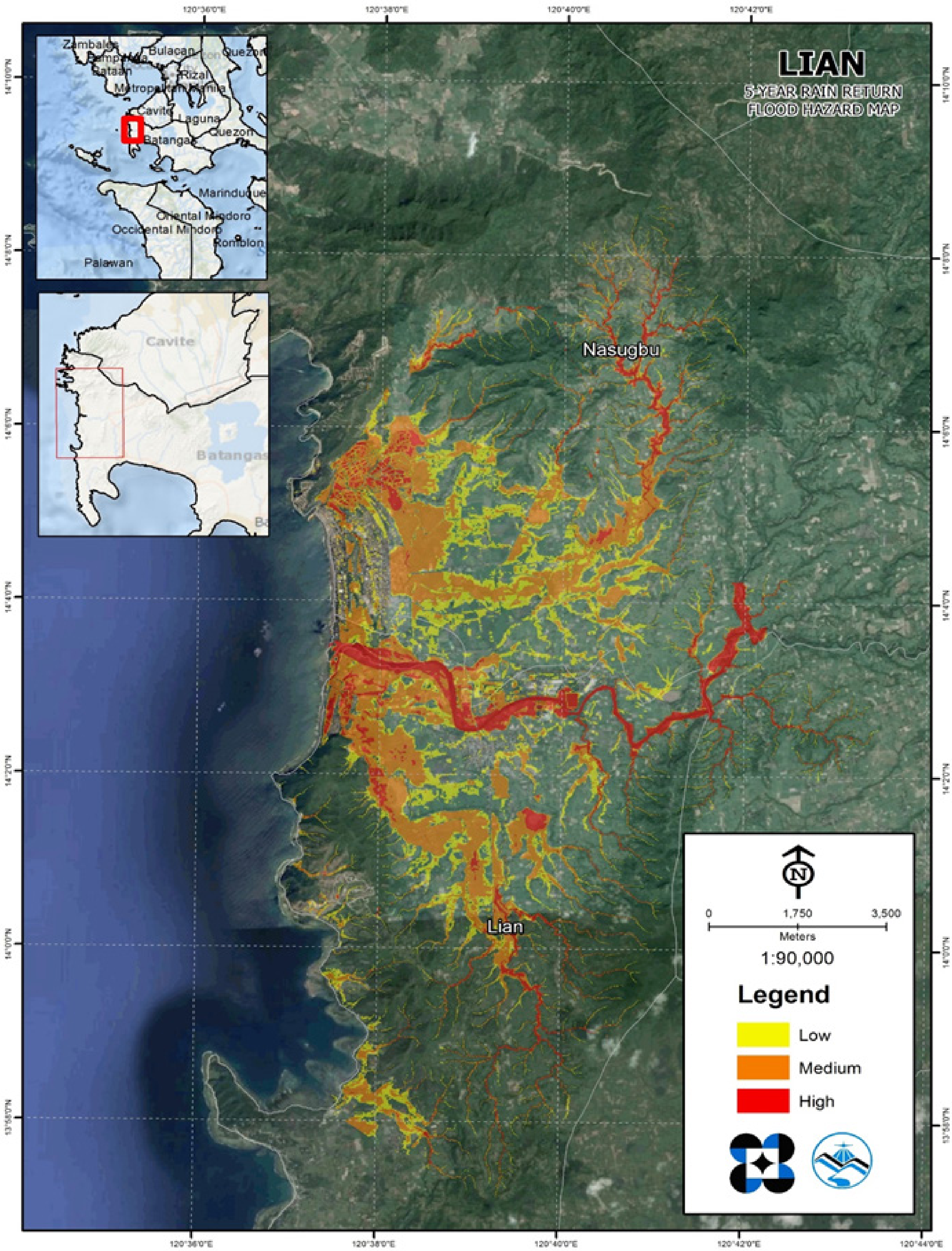


Figure 66. A 5-year Flood Hazard Map for Lian Floodplain.

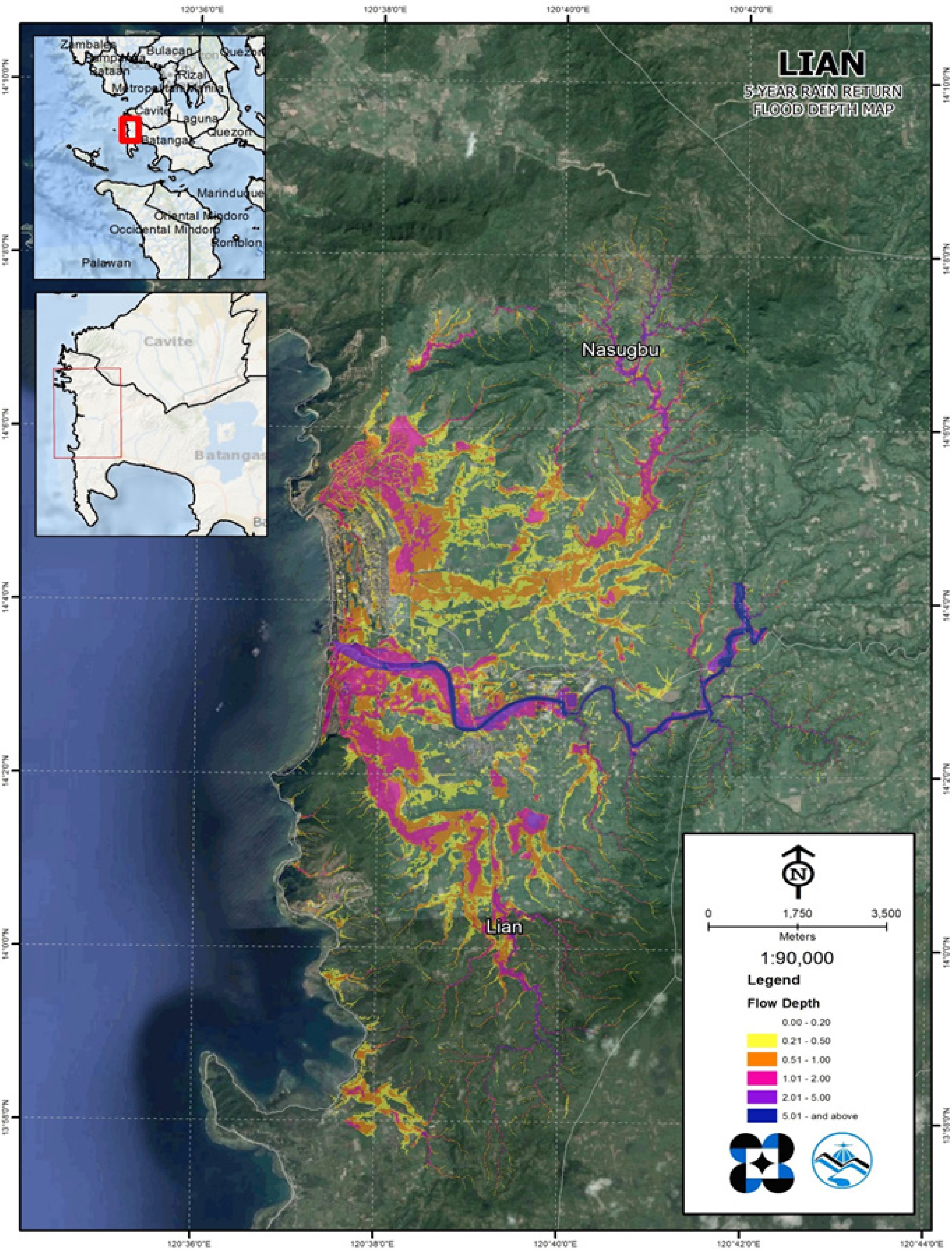


Figure 67. A 5-year Flow Depth Map for Lian Floodplain

5.11 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Lian River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 56 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 15.62% of the municipality of Nasugbu with an area of 266.54 km2. will experience flood levels of less than 0.20 meters. 2.76% of the area will experience flood levels of 0.21 to 0.50 meters while 2.45%, 1.41%, 0.27%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 34 are the affected areas in km2 by flood depth per barangay.

Table 34. Affected areas in Nasugbu, Batangas during a 5-Year Rainfall Return Period

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Nasugbu (in km2)										
		Banilad	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7
Affected Area (km2)	1	0.26	0.048	0.062	0.063	0.093	0.052	0.069	0.068	0.03	0.032	0.052
	2	0.0077	0.02	0.016	0.018	0.0099	0.015	0.012	0.021	0.013	0.014	0.0028
	3	0.0075	0.006	0.019	0.0004	0.0079	0	0.0024	0.0038	0.012	0.053	0.0043
	4	0.0067	0.00055	0.01	0	0	0	0.0071	0.0022	0.0057	0.069	0
	5	0.0054	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Nasugbu (in km2)										
		Barangay 8	Barangay 9	Bilaran	Bucana	Bunducan	Butucan	Catandaan	Cogunan	Dayap	Lumbangan	Malapad na Bato
Affected Area (km2)	1	0.049	0.047	1.16	1.36	5.08	5.14	2.08	3.26	1.69	2.42	3.75
	2	0.0068	0.0099	0.16	0.29	0.5	0.22	0.5	2.01	0.082	0.73	0.2
	3	0	0	0.073	0.45	0.36	0.18	0.59	2.1	0.047	0.24	0.2
	4	0	0	0.036	0.11	0.43	0.14	0.41	0.11	0.048	0.11	0.23
	5	0	0	0.016	0	0.015	0.14	0.015	0	0.011	0.0037	0.24
	6	0	0	0	0	0	0	0	0	0	0	0

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Nasugbu (in km2)										
		Maugat	Munting Indan	Natipunan	Pantalan	Putat	Reparo	Talangan	Tumalim	Utod	Wawa	Barangay 7
Affected Area (km2)	1	2.69	3.36	0	0.39	2.74	3.05	0.074	0.069	2.05	0.35	0.052
	2	0.15	0.11	0	0.25	1.46	0.17	0.043	0.0028	0.22	0.086	0.0028
	3	0.14	0.054	0	0.42	1.03	0.13	0.14	0.0009	0.15	0.12	0.0043
	4	0.27	0.034	0	0.74	0.36	0.11	0.18	0	0.16	0.19	0
	5	0.095	0.0045	0	0.0053	0	0.15	0	0	0.025	0.0003	0
	6	0.0012	0	0	0	0	0.29	0	0	0	0	0

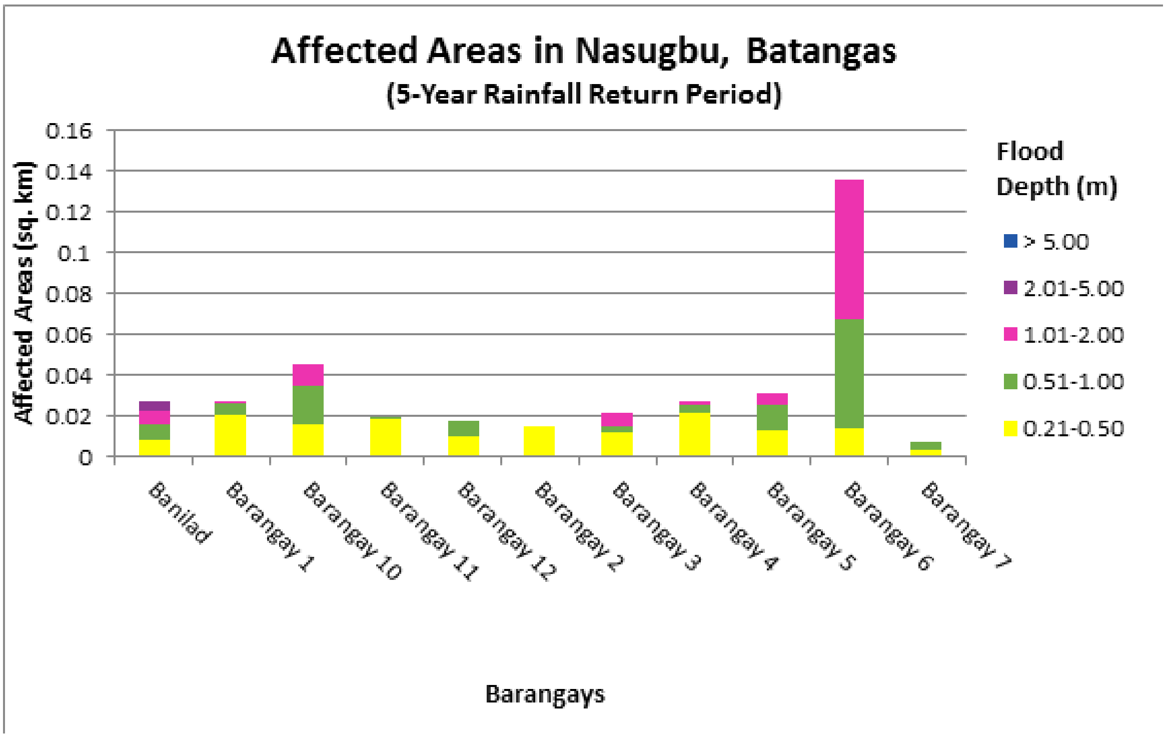


Figure 68. Affected Areas in Nasugbu, Batangas during a 5-year Rainfall Return Period

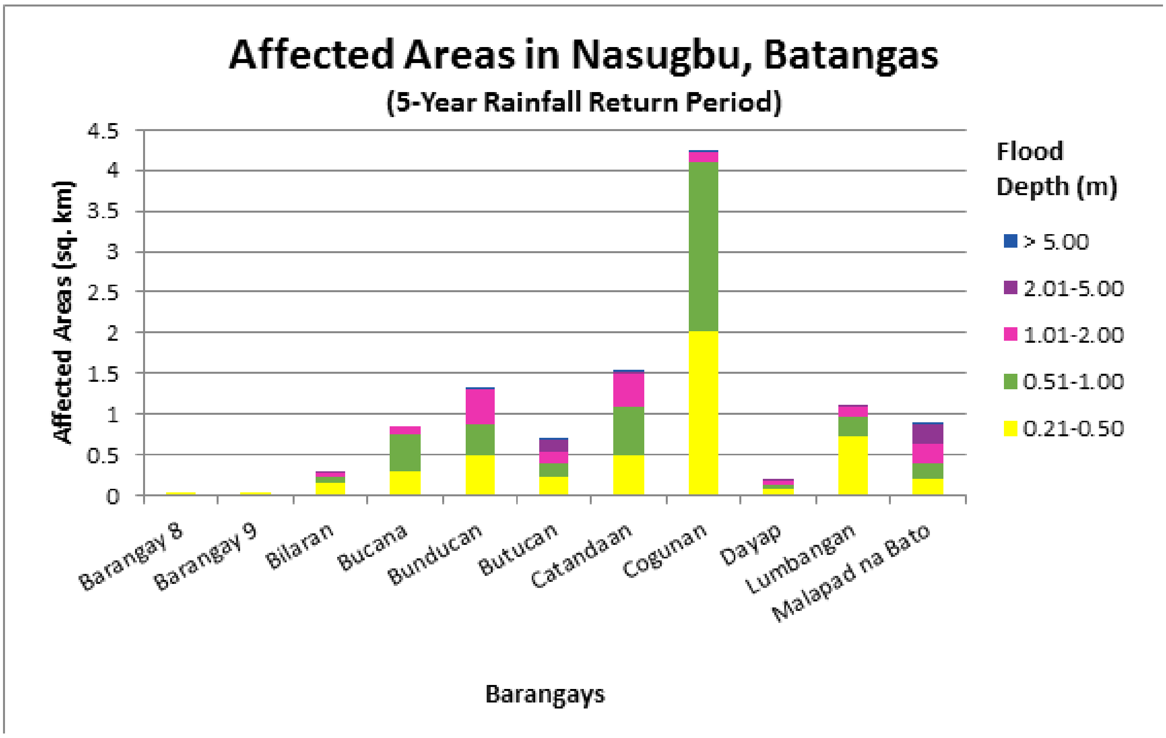


Figure 69. Affected Areas in Nasugbu, Batangas during a 5-year Rainfall Return Period

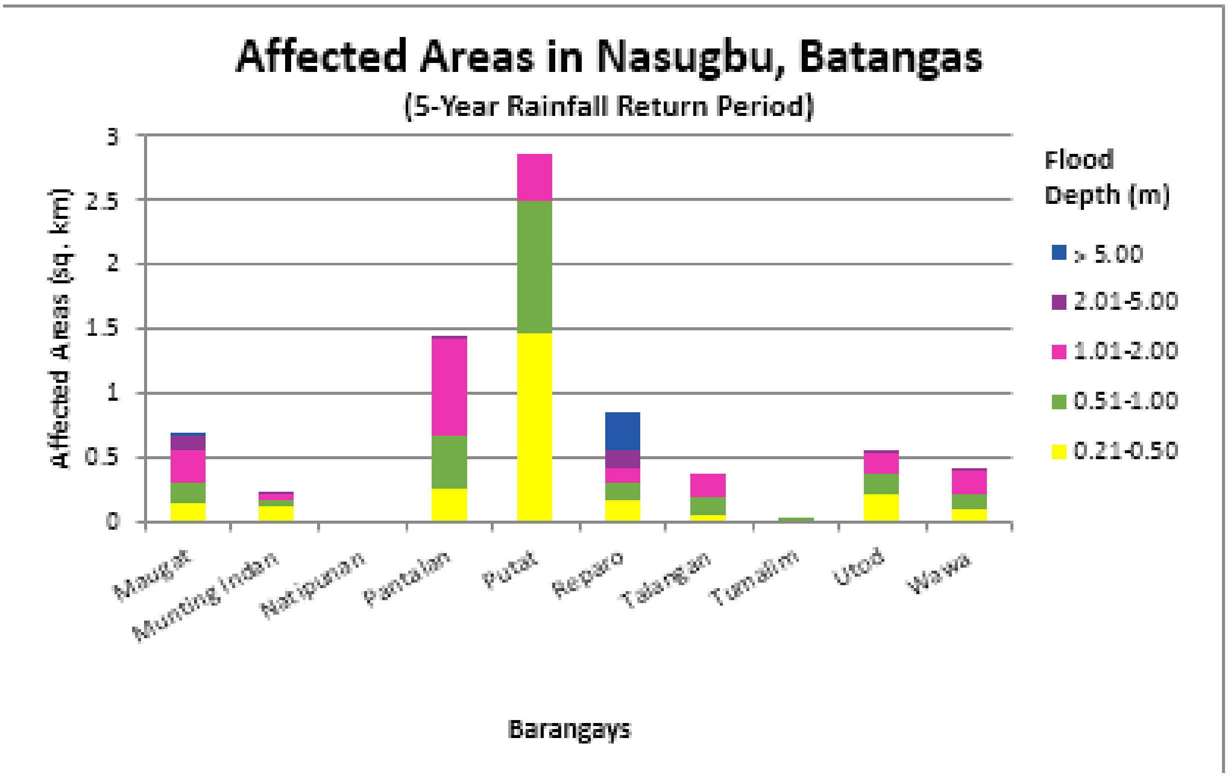


Figure 70. Affected Areas in Nasugbu, Batangas during a 5-year Rainfall Return Period

For the 5-year return period, 8.28% of the municipality of Tuy with an area of 93.6 km2. will experience flood levels of less than 0.20 meters. 0.26% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.16%, 0.22%, and 0.23% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in km2 by flood depth per barangay.

Table 35. Affected areas in Tuy, Batangas during a 5-Year Rainfall Return Period

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Tuy (km2)					
		Bayudbud	Dalima	Luntal	Palincaro	Sabang	Talon
Affected Area (km2)	1	0.85	1.27	2.78	0.0026	2.85	0.000038
	2	0.02	0.046	0.079	0	0.1	0
	3	0.0064	0.023	0.047	0	0.063	0
	4	0.0063	0.017	0.043	0	0.082	0
	5	0.0036	0.01	0.059	0	0.13	0
	6	0.0007	0.0007	0.035	0	0.18	0

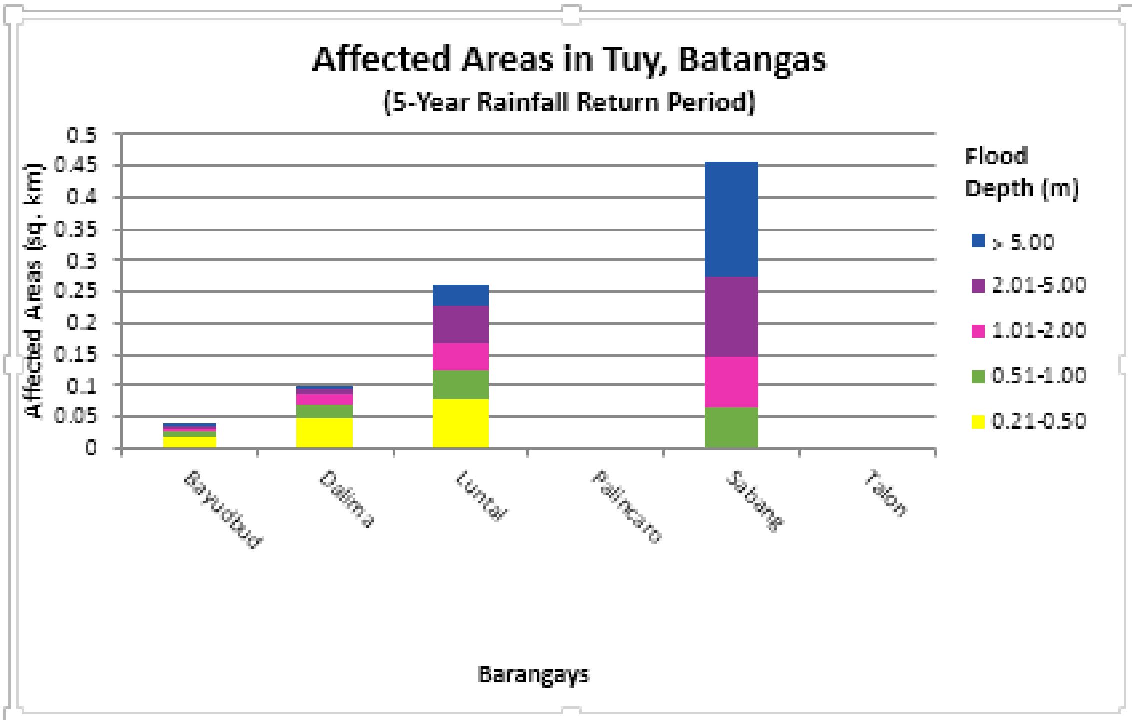


Figure 71. Areas affected by Flooding in Tuy, Batangas for a 5-Year Rainfall Return Period

For the 5-year return period, 60.06% of the municipality of Lian with an area of 83.48 km2. will experience flood levels of less than 0.20 meters. 6.98% of the area will experience flood levels of 0.21 to 0.50 meters while 6.45%, 6.10%, 1.71%, and 0.82% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in km2 by flood depth per barangay.

Table 36. Affected areas in Lian, Batangas during a 5-Year Rainfall Return Period

Affected Area km2)by flood depth (in m.)		Area of affected barangays in Lian (km2)							
		Bagong Pook	Balibago	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Binubusan
Affected Area km2)	1	0.9	0.89	0.19	0.016	0.068	0.079	0.21	4.96
	2	0.051	0.028	0.022	0.031	0.015	0.0052	0.059	0.74
	3	0.019	0.017	0.0011	0.012	0.02	0.011	0.085	0.49
	4	0.028	0.012	0	0.023	0.057	0.038	0.05	0.12
	5	0.067	0.0016	0	0.033	0.037	0.05	0.078	0.026
	6	0.088	0	0	0.036	0.0011	0.0023	0.049	0

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Lian (km2)									
		Bungahan	Cumba	Humayingan	Kapito	Lumaniag	Luyahan	Malaruhatan	Prenza	Puting-Kahoy	San Diego
Affected Area km2)	1	1.96	4.71	6.14	7.91	3.75	0.0043	3.9	6.59	4.4	3.46
	2	0.86	0.12	0.2	0.73	0.21	0.0042	0.46	1.22	0.48	0.59
	3	1.26	0.087	0.14	0.64	0.088	0.036	0.23	1.23	0.55	0.47
	4	1.75	0.091	0.13	0.44	0.016	0.02	0.29	0.68	0.35	1
	5	0.33	0.097	0.086	0.13	0.0015	0	0.3	0.013	0.16	0.019
	6	0.18	0.018	0.0012	0.0003	0	0	0.3	0.0001	0.0069	0

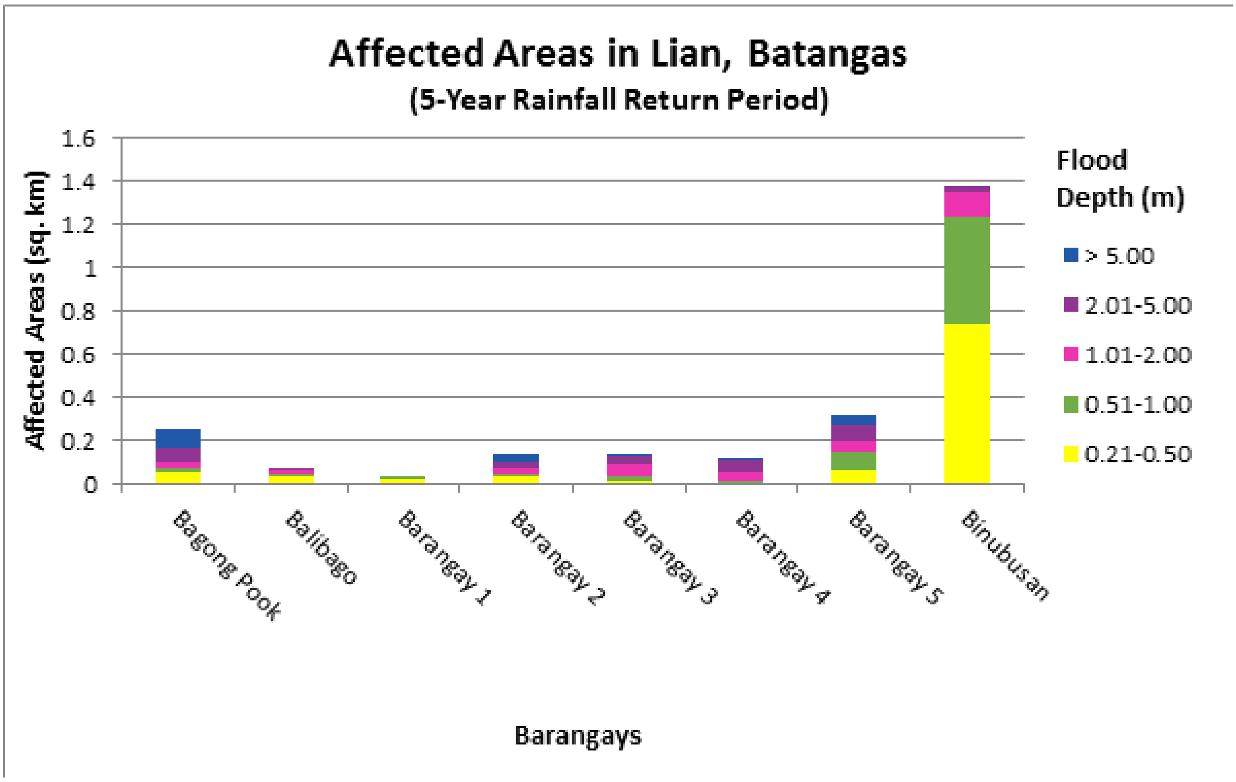


Figure 72. Affected Areas in Lian, Batangas during a 5-Year Rainfall Return Period

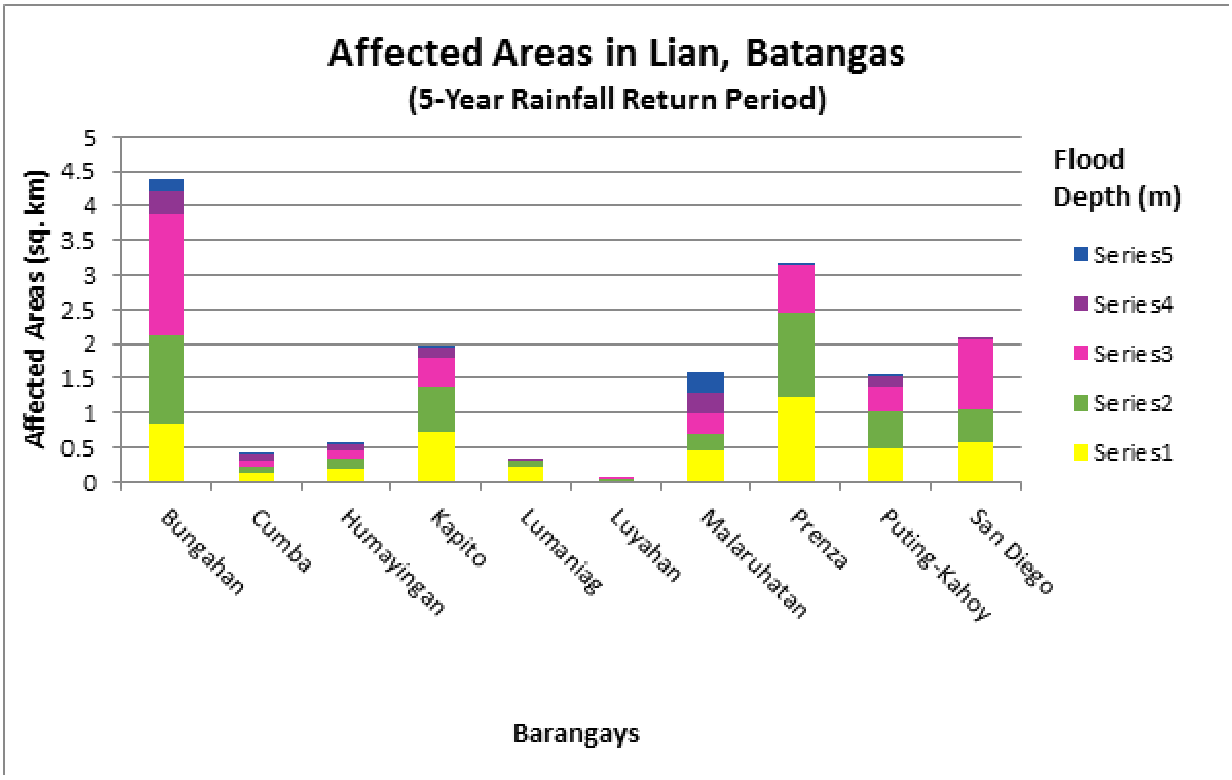


Figure 73. Affected Areas in Lian, Batangas during a 5-Year Rainfall Return Period

For the 25-year return period, 13.55% of the municipality of Nasugbu with an area of 266.54 sq. km. will experience flood levels of less than 0.20 meters. 2.62% of the area will experience flood levels of 0.21 to 0.50 meters while 2.54%, 2.88%, 0.87%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in km2 by flood depth per barangay.

Table 37. Affected Areas in Nasugbu, Batangas during 25-Year Rainfall Return Period.

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Nasugbu (km2)										
		Banilad	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7
Affected Area (km2)	1	0.25	0.034	0.044	0.051	0.081	0.041	0.057	0.04	0.015	0.017	0.035
	2	0.01	0.02	0.024	0.028	0.02	0.0098	0.019	0.018	0.0098	0.0054	0.0089
	3	0.011	0.012	0.0097	0.0015	0.0023	0.0082	0.0055	0.03	0.016	0.015	0.0095
	4	0.0088	0.0081	0.024	0	0.0079	0.0089	0.0069	0.0064	0.019	0.11	0.0057
	5	0.0079	0.000016	0.0044	0	0	0	0.0018	0	0	0.024	0
	6	0.00052	0	0	0	0	0	0	0	0	0	0

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Nasugbu (km2)										
		Barangay 8	Barangay 9	Bilaran	Bucana	Bunducan	Butucan	Catandaan	Cogunan	Dayap	Lumbangan	Malapad na Bato
Affected Area (km2)	1	0.045	0.035	1.02	1.02	4.87	4.97	1.83	2.08	1.63	1.79	3.51
	2	0.011	0.022	0.19	0.33	0.45	0.26	0.44	1.71	0.1	0.71	0.24
	3	0	0.00005	0.079	0.19	0.42	0.2	0.51	2.2	0.062	0.45	0.2
	4	0	0	0.084	0.65	0.58	0.19	0.71	1.49	0.055	0.4	0.28
	5	0	0	0.065	0.015	0.051	0.18	0.11	0.0018	0.027	0.16	0.37
	6	0	0	0.015	0	0.0018	0.024	0.0012	0.004	0	0.0002	0.019

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Nasugbu (km2)										
		Maugat	Munting Indan	Natipunan	Pantalan	Putat	Reparo	Talangan	Tumalim	Utod	Wawa	Malapad na Bato
Affected Area (km2)	1	2.56	3.3	0	0.13	1.79	2.59	0.02	0.065	1.95	0.24	3.51
	2	0.15	0.14	0	0.099	1.49	0.18	0.024	0.0029	0.2	0.055	0.24
	3	0.14	0.069	0	0.32	1.22	0.19	0.065	0.0038	0.19	0.13	0.2
	4	0.2	0.041	0	0.83	1.08	0.22	0.27	0.0011	0.18	0.21	0.28
	5	0.28	0.013	0	0.43	0.02	0.29	0.062	0	0.083	0.12	0.37
	6	0.005	0	0	0	0	0.44	0	0	0	0	0.019

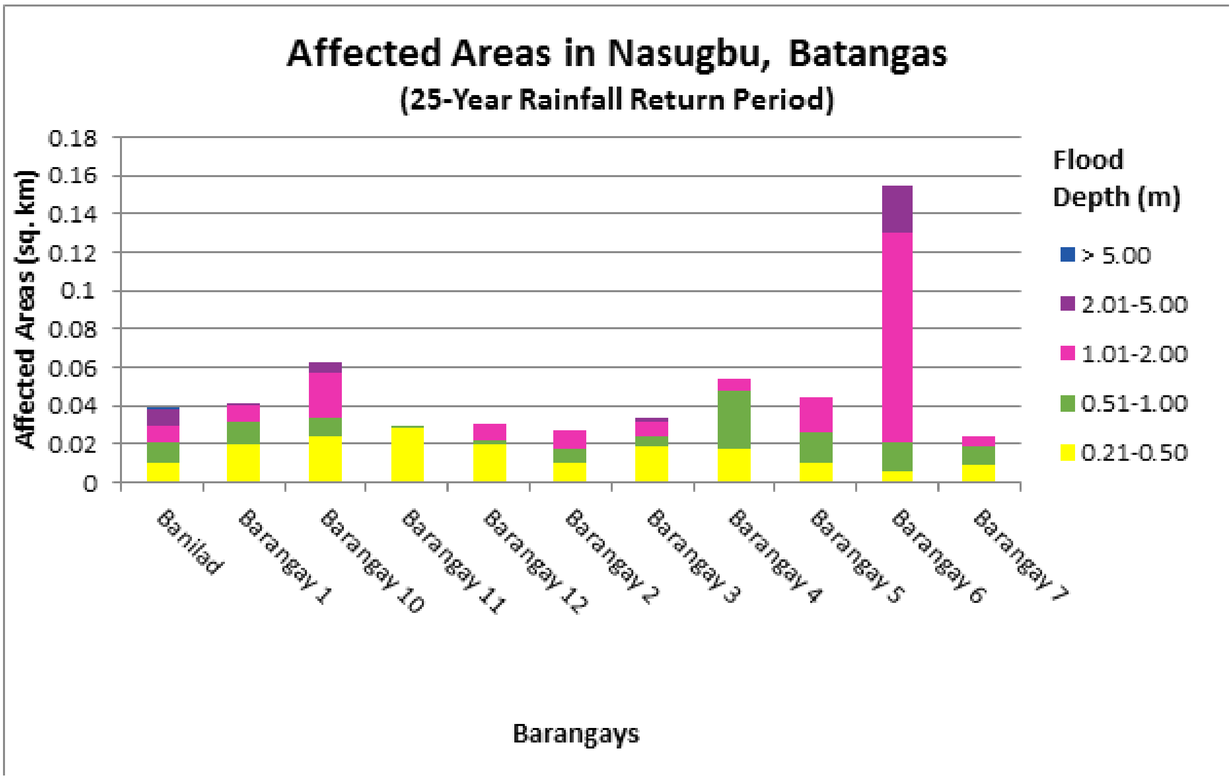


Figure 74. Affected Areas in Nasugbu, Batangas during a 25-year Rainfall Return Period

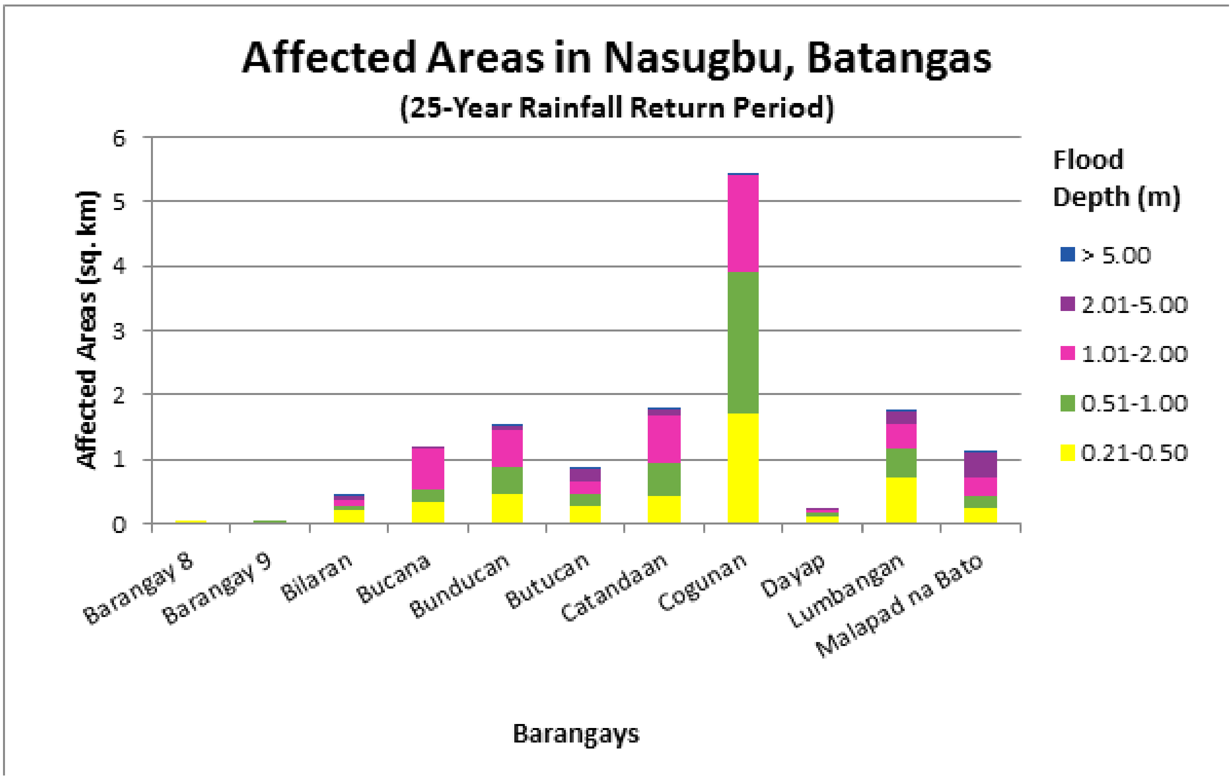


Figure 75. Affected Areas in Nasugbu, Batangas during a 25-year Rainfall Return Period

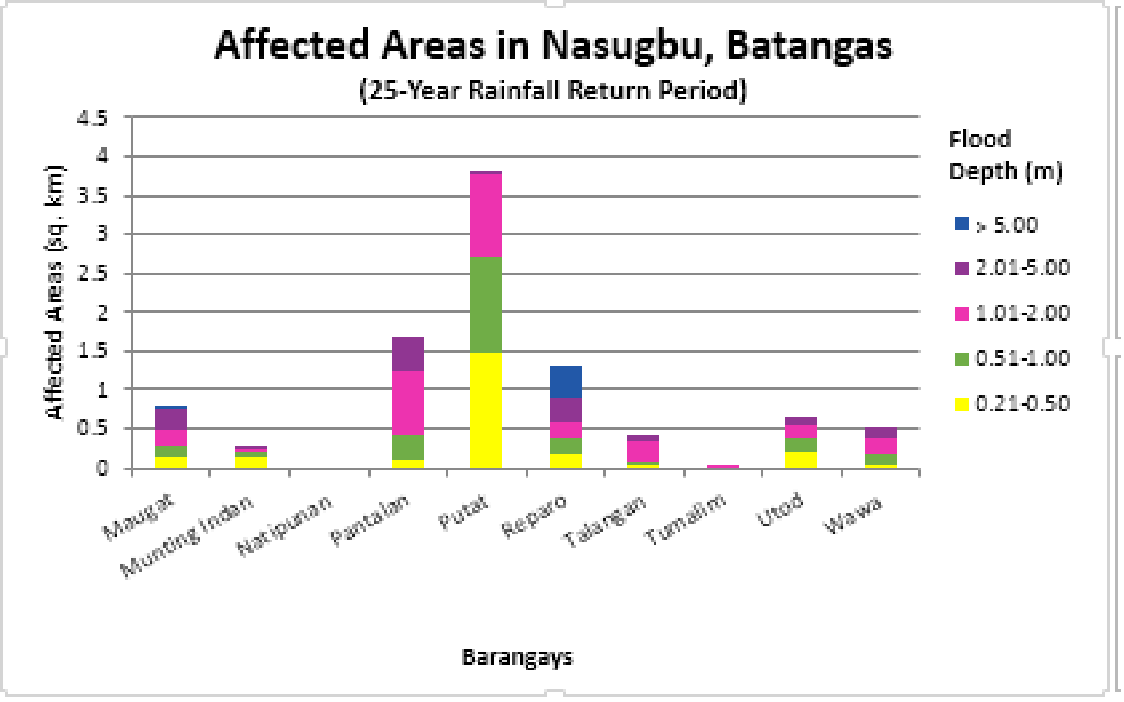


Figure 76. Affected Areas in Nasugbu, Batangas during a 25-year Rainfall Return Period

For the 25-year return period, 7.75% of the municipality of Tuy with an area of 93.6 sq. km. will experience flood levels of less than 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.26%, 0.35%, and 0.38% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in km2 by flood depth per barangay.

Table 38. Affected Areas in Tuy, Batangas during a 25-Year Rainfall Return Period

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Tuy (km2)					
		Bayudbud	Dalima	Luntal	Palincaro	Sabang	Talon
Affected Area (km2)	1	0.84	1.24	2.62	0.0026	2.55	0.000038
	2	0.027	0.06	0.11	0	0.12	0
	3	0.0079	0.03	0.064	0	0.11	0
	4	0.0073	0.02	0.073	0	0.14	0
	5	0.0048	0.016	0.1	0	0.21	0
	6	0.001	0.0013	0.071	0	0.28	0

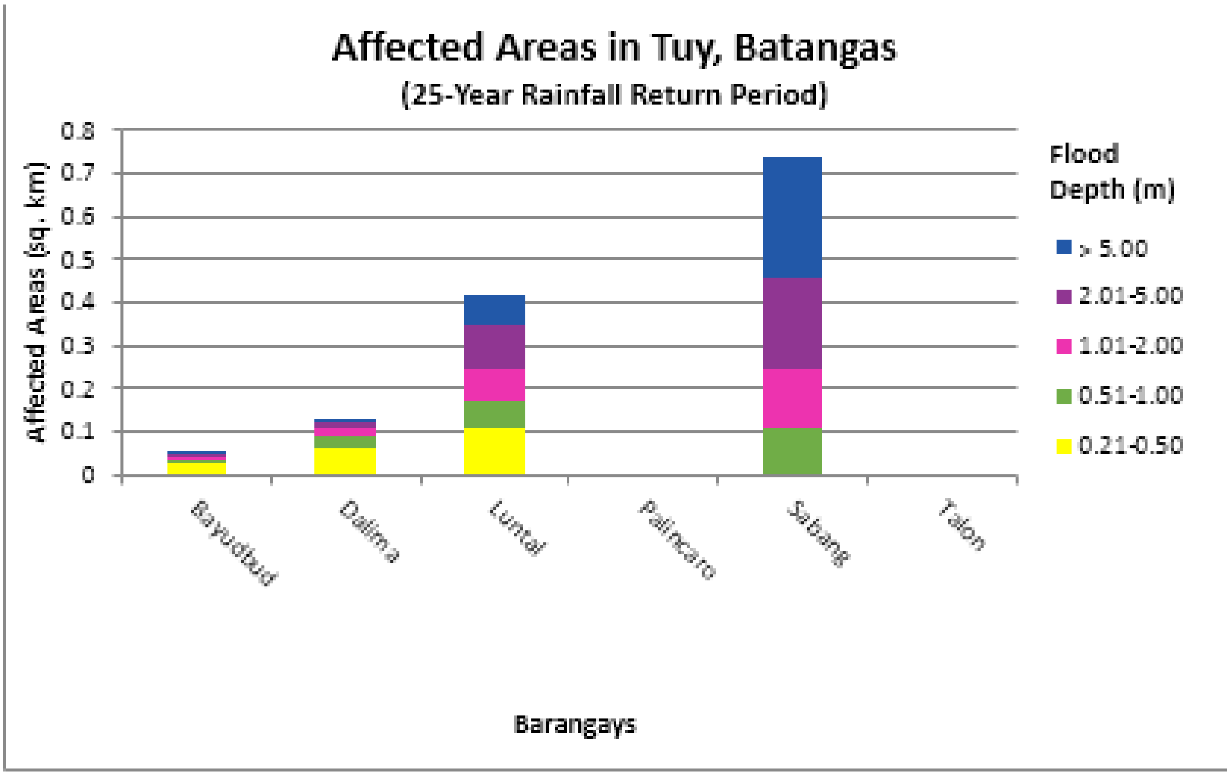


Figure 77. Affected Areas in Tuy, Batangas during a 25-year Rainfall Return Period

For the 25-year return period, 53.81% of the municipality of Lian with an area of 83.48 sq. km. will experience flood levels of less than 0.20 meters. 6.53% of the area will experience flood levels of 0.21 to 0.50 meters while 6.83%, 8.70%, 5.06%, and 1.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in km2 by flood depth per barangay.

Table 39. Affected Areas in Lian, Batangas during 25-Year Rainfall Return Period

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Lian (km2)							
		Bagong Pook	Balibago	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Binubusan
Affected Area (km2)	1	0.75	0.87	0.14	0.0023	0.046	0.055	0.066	4.67
	2	0.051	0.033	0.048	0.00098	0.012	0.0078	0.044	0.7
	3	0.033	0.02	0.025	0.023	0.023	0.013	0.083	0.68
	4	0.035	0.016	0.0028	0.039	0.044	0.018	0.17	0.24
	5	0.1	0.0032	0	0.047	0.073	0.088	0.11	0.04
	6	0.18	0	0	0.039	0.0011	0.0026	0.053	0.0001

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Lian (km2)									
		Bungahan	Cumba	Humayingan	Kapito	Lumaniag	Luyahan	Malaruhatan	Prenza	Puting-Kahoy	San Diego
Affected Area (km2)	1	0.78	4.62	6.03	7.57	3.66	0.0034	2.75	5.79	4.15	2.97
	2	0.81	0.15	0.22	0.71	0.25	0.00083	0.66	1.03	0.37	0.35
	3	0.97	0.094	0.16	0.7	0.13	0.0071	0.63	1.11	0.58	0.42
	4	2.32	0.11	0.16	0.63	0.025	0.053	0.42	1.44	0.55	0.99
	5	1.25	0.13	0.13	0.23	0.0039	0	0.6	0.36	0.26	0.8
	6	0.21	0.031	0.0045	0.0037	0	0	0.44	0.0025	0.025	0

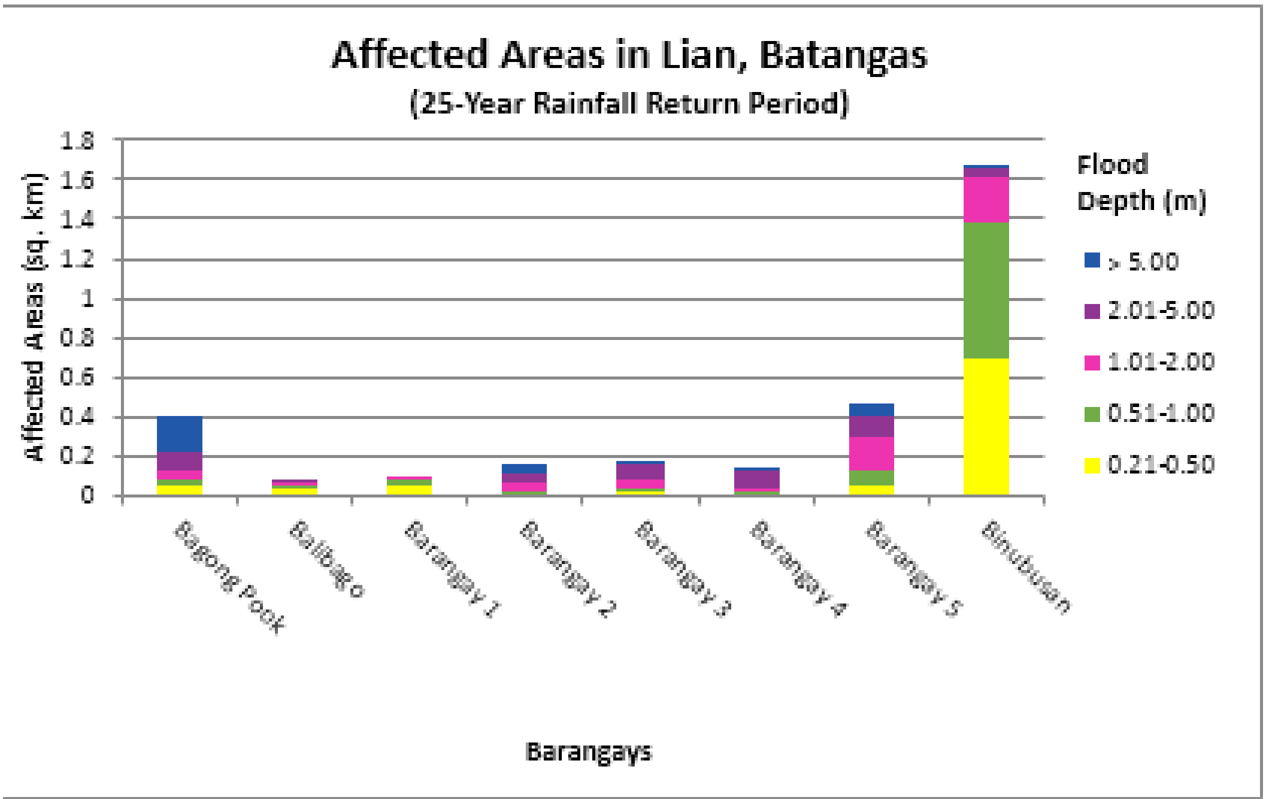


Figure 78. Affected Areas in Lian, Batangas during a 25-year Rainfall Return Period

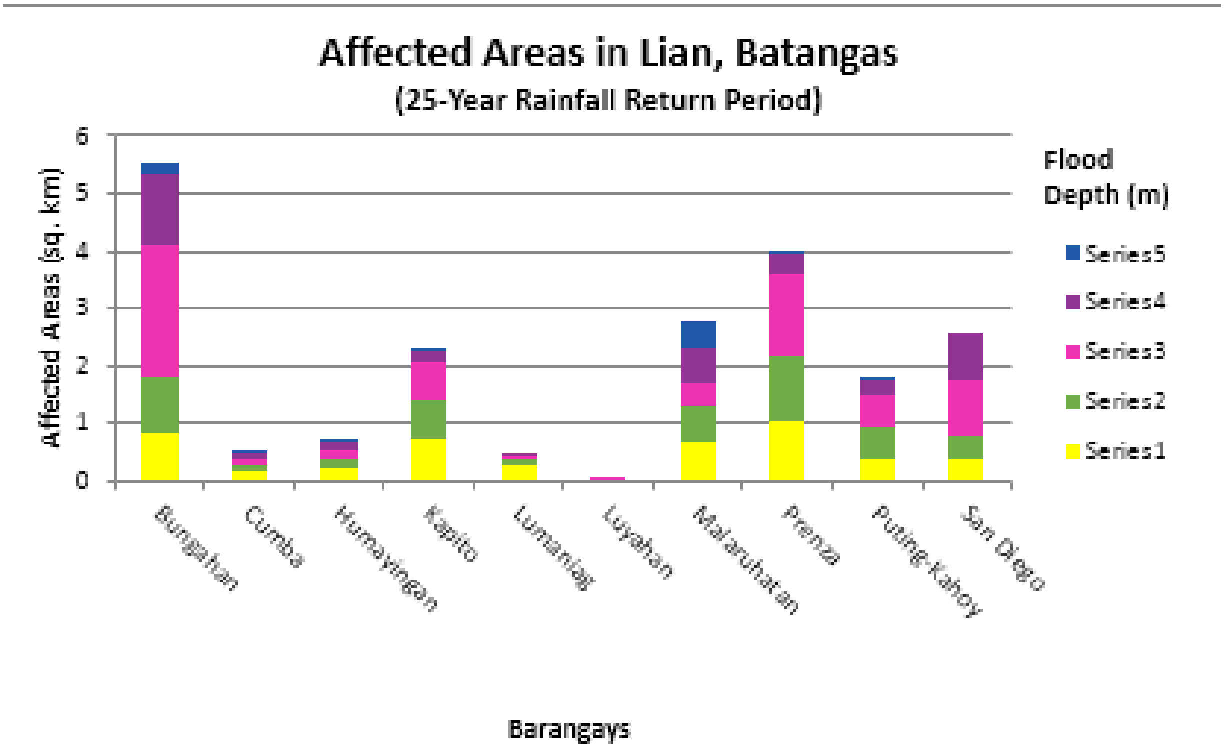


Figure 79. Affected Areas in Lian, Batangas during a 25-year Rainfall Return Period

For the 100-year return period, 12.37% of the municipality of Nasugbu with an area of 266.54 km2. will experience flood levels of less than 0.20 meters. 2.39% of the area will experience flood levels of 0.21 to 0.50 meters while 2.45%, 3.21%, 1.96%, and 0.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in km2 by flood depth per barangay.

Table 40. Affected Areas in Nasugbu, Batangas during a 100-Year Rainfall Return Period

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Nasugbu (km2)										
		Banilad	Barangay 1	Barangay 10	Barangay 11	Barangay 12	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7
Affected Area (sq. km.)	1	0.24	0.0077	0.025	0.041	0.071	0.017	0.014	0.011	0.0022	0.0005	0.021
	2	0.0095	0.016	0.018	0.037	0.029	0.012	0.033	0.024	0.0044	0.013	0.01
	3	0.01	0.029	0.02	0.0029	0.00056	0.021	0.027	0.018	0.017	0.013	0.012
	4	0.016	0.018	0.022	0.000086	0.003	0.019	0.0086	0.039	0.03	0.054	0.016
	5	0.015	0.0028	0.022	0	0.0071	0	0.0068	0.0027	0.0071	0.087	0
	6	0.0015	0	0	0	0	0	0	0	0	0	0

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Nasugbu (km2)										
		Barangay 8	Barangay 9	Bilaran	Bucana	Bunducan	Butucan	Catandaan	Cogunan	Dayap	Lumbangan	Malapad na Bato
Affected Area (km2)	1	0.041	0.018	0.95	0.75	4.79	4.85	1.7	1.6	1.6	1.42	3.36
	2	0.015	0.036	0.19	0.33	0.39	0.28	0.4	1.37	0.11	0.83	0.24
	3	0.00072	0.0028	0.11	0.24	0.42	0.22	0.49	2.08	0.072	0.31	0.22
	4	0	0	0.069	0.43	0.49	0.23	0.78	2.18	0.061	0.63	0.29
	5	0	0	0.08	0.45	0.29	0.21	0.24	0.25	0.031	0.33	0.47
	6	0	0	0.049	0	0.0027	0.037	0.0012	0.004	0	0.0042	0.039

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Nasugbu (km2)									
		Maugat	Munting Indan	Natipunan	Pantalan	Putat	Reparo	Talangan	Tumalim	Utod	Wawa
Affected Area (km2)	1	2.48	3.26	0	0.07	1.34	2.3	0.0007	0.062	1.88	0.058
	2	0.16	0.16	0	0.029	1.2	0.16	0.0055	0.0049	0.19	0.064
	3	0.14	0.077	0	0.1	1.36	0.15	0.032	0.0036	0.23	0.09
	4	0.17	0.049	0	0.73	1.36	0.22	0.2	0.0026	0.19	0.24
	5	0.37	0.021	0	0.87	0.33	0.5	0.2	0	0.11	0.31
	6	0.0094	0	0	0	0	0.58	0	0	0.00011	0

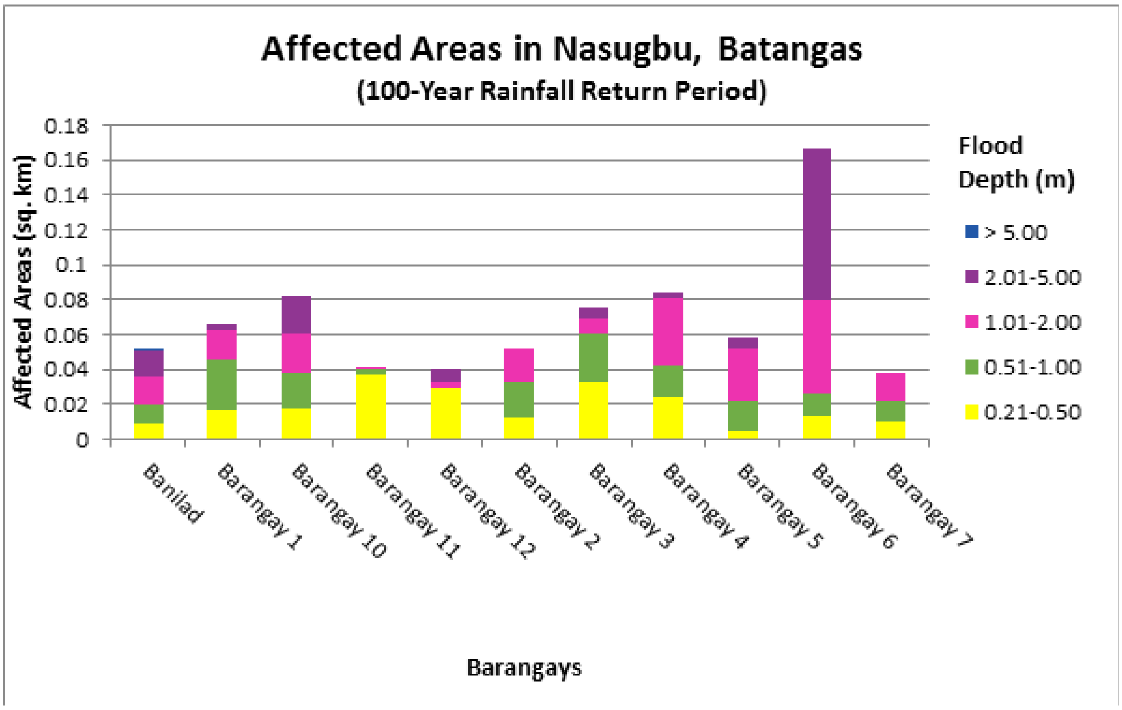


Figure 80. Affected Areas in Nasugbu, Batangas during a 100-year Rainfall Return Period

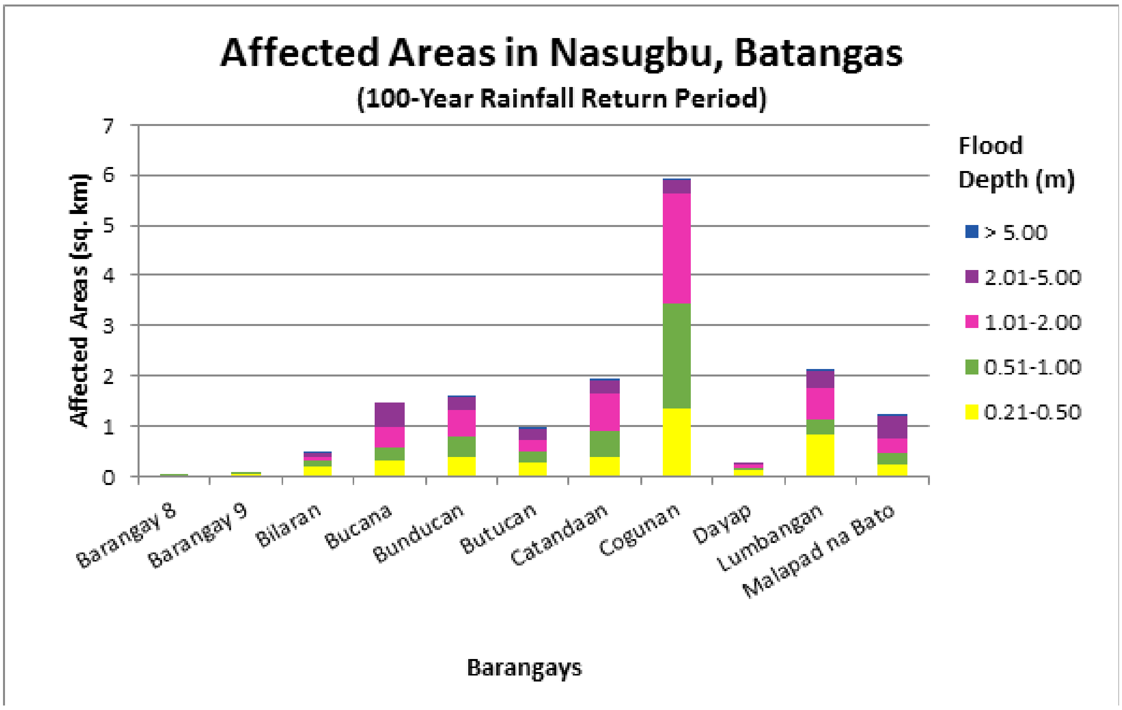


Figure 81. Affected Areas in Nasugbu, Batangas during a 100-year Rainfall Return Period

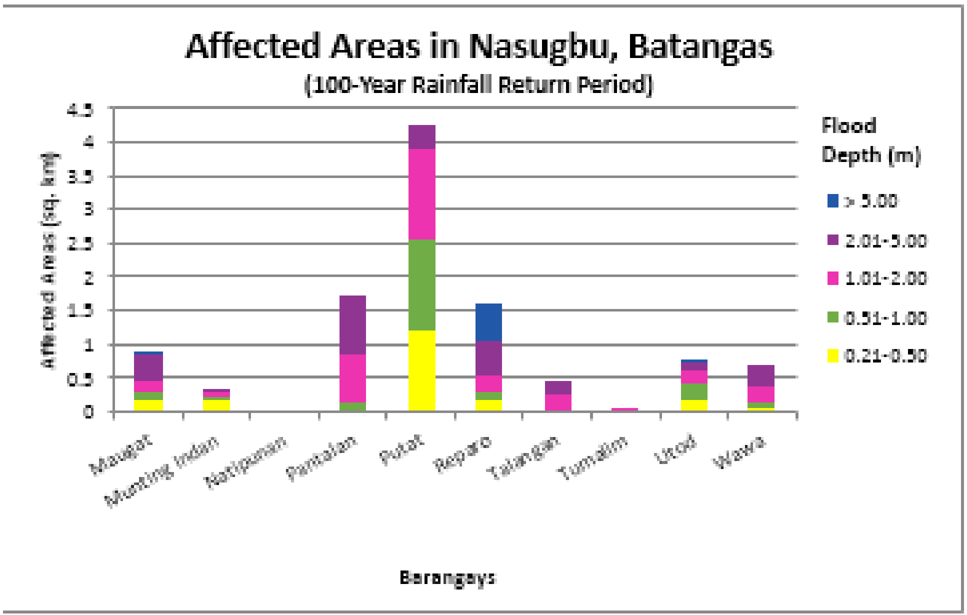


Figure 82. Affected Areas in Nasugbu, Batangas during a 100-year Rainfall Return Period

For the 100-year return period, 7.37% of the municipality of Tuy with an area of 93.6 km2 will experience flood levels of less than 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.29%, 0.51%, and 0.52% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in km2 by flood depth per barangay.

Table 41. Affected Areas in Tuy, Batangas during a 100-Year Rainfall Return Period

Affected Area (km2)by flood depth (in m.)		Area of affected barangays in Tuy (km2)					
		Bayudbud	Dalima	Luntal	Palincaro	Sabang	Talon
Affected Area (km2)	1	0.83	1.21	2.51	0.0026	2.35	0.000038
	2	0.033	0.069	0.14	0	0.12	0
	3	0.0087	0.034	0.063	0	0.11	0
	4	0.0075	0.023	0.074	0	0.17	0
	5	0.0057	0.025	0.15	0	0.3	0
	6	0.0013	0.0026	0.11	0	0.37	0

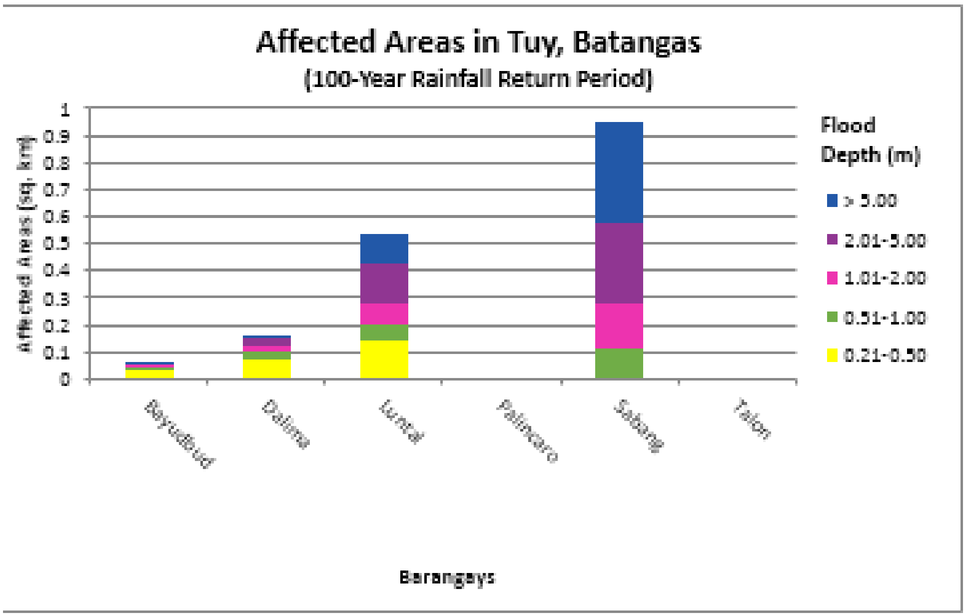


Figure 83. Affected Areas in Tuy, Batangas during a 100-Year Rainfall Return Period

For the 100-year return period, 50.85% of the municipality of Lian with an area of 83.48 km2. will experience flood levels of less than 0.20 meters. 5.54% of the area will experience flood levels of 0.21 to 0.50 meters while 6.65%, 9.17%, 8.49%, and 1.42% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas in km2 by flood depth per barangay.

Table 42. Affected Areas in Lian, Batangas during a 100-Year Rainfall Return Period

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Lian (km2)							
		Bagong Pook	Balibago	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Binubusan
Affected Area (km2)	1	0.68	0.86	0.1	0.0014	0.034	0.039	0.046	4.51
	2	0.055	0.036	0.056	0.0011	0.013	0.012	0.018	0.66
	3	0.039	0.022	0.045	0.007	0.02	0.015	0.069	0.74
	4	0.037	0.018	0.011	0.05	0.042	0.019	0.17	0.38
	5	0.11	0.0054	0.000062	0.051	0.089	0.097	0.17	0.052
	6	0.24	0	0	0.04	0.0013	0.0028	0.057	0.0002

Affected Area (km2) by flood depth (in m.)		Area of affected barangays in Lian (km2)									
		Bunga-han	Cumba	Hu-mayin-gan	Kapito	Luma-niag	Luyah-an	Ma-laruha-tan	Prenza	Put-ing-Ka-hoy	San Diego
Affected Area (km2)	1	0.42	4.55	5.95	7.38	3.6	0.0024	2.07	5.44	4.03	2.74
	2	0.38	0.17	0.22	0.69	0.27	0.0011	0.55	0.86	0.32	0.31
	3	0.91	0.1	0.17	0.73	0.15	0.0014	0.73	1.02	0.49	0.29
	4	2	0.11	0.18	0.72	0.034	0.06	0.89	1.5	0.7	0.73
	5	2.41	0.14	0.16	0.32	0.006	0	0.73	0.92	0.35	1.48
	6	0.22	0.045	0.0084	0.0076	0	0	0.52	0.0028	0.04	0

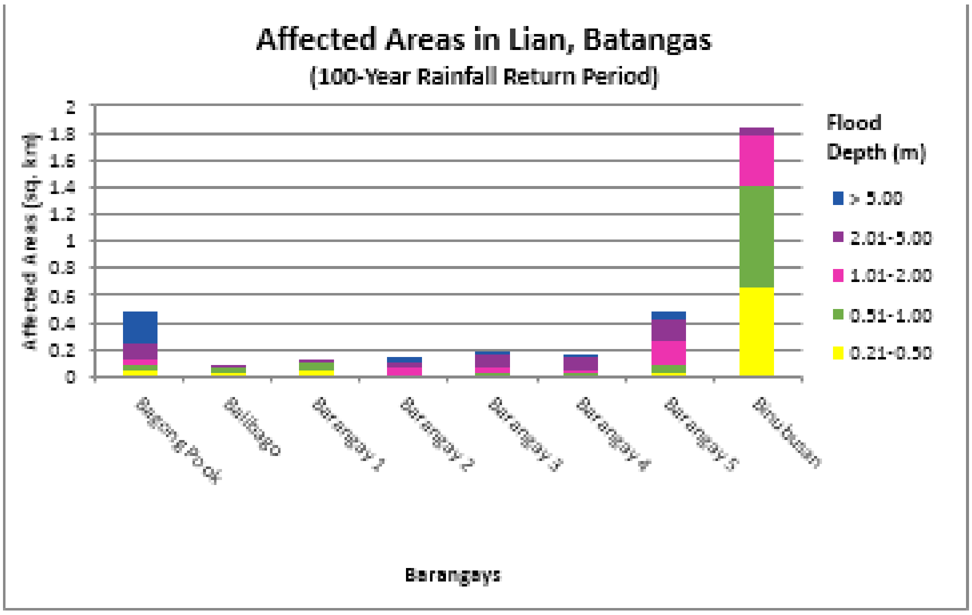


Figure 84. Affected Areas in Lian, Batangas during a 100-Year Rainfall Return Period

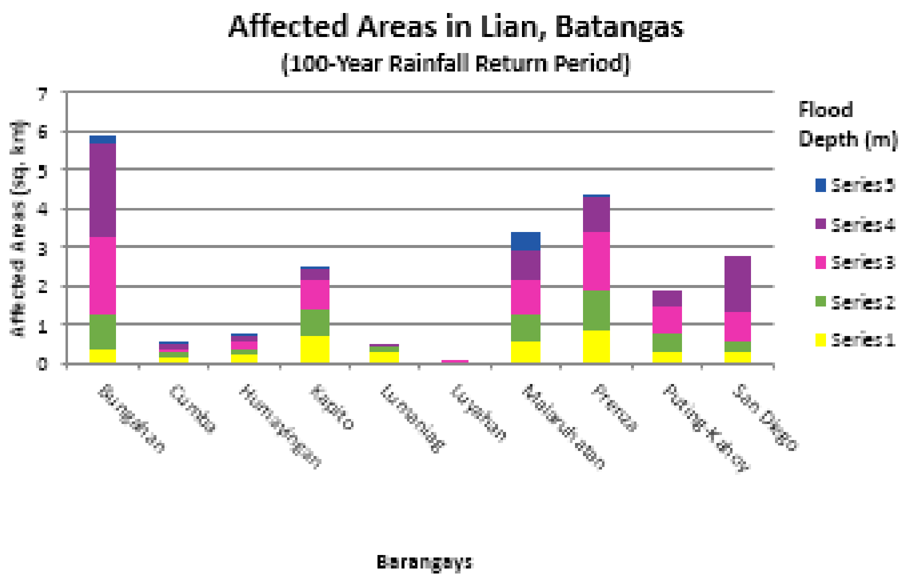


Figure 85. Affected Areas in Lian, Batangas during a 100-Year Rainfall Return Period

Table 43. Areas Covered by Each Warning Level with Respect to the Rainfall Scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	13.78	12.98	11.55
Medium	18.61	21.58	21.30
High	6.79	15.83	23.54
TOTAL	39.18	50.39	56.39

Of the 14 identified Education Institutes in Lian Flood plain, one (1) school was discovered exposed to medium-level flooding during a 5-year scenario.
In the 25-year scenario, two (2) schools were found exposed to Low-level flooding, while one (1) school was discovered exposed to Medium-level flooding.
For the 100-year scenario, three (3) schools were discovered exposed to Low-level flooding, while two (2) schools were exposed to Medium-level flooding.
Apart from this, one (1) Medical Institution was identified in the Lian Floodplain, the Health Center in Brgy. Dayap, Nasugbu, which was exposed to low-level flooding for all scenarios.

5.12 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.
The flood validation consists of 180 points randomly selected all over the Lian flood plain. It has an RMSE value of 1.990012 (Figure 84).

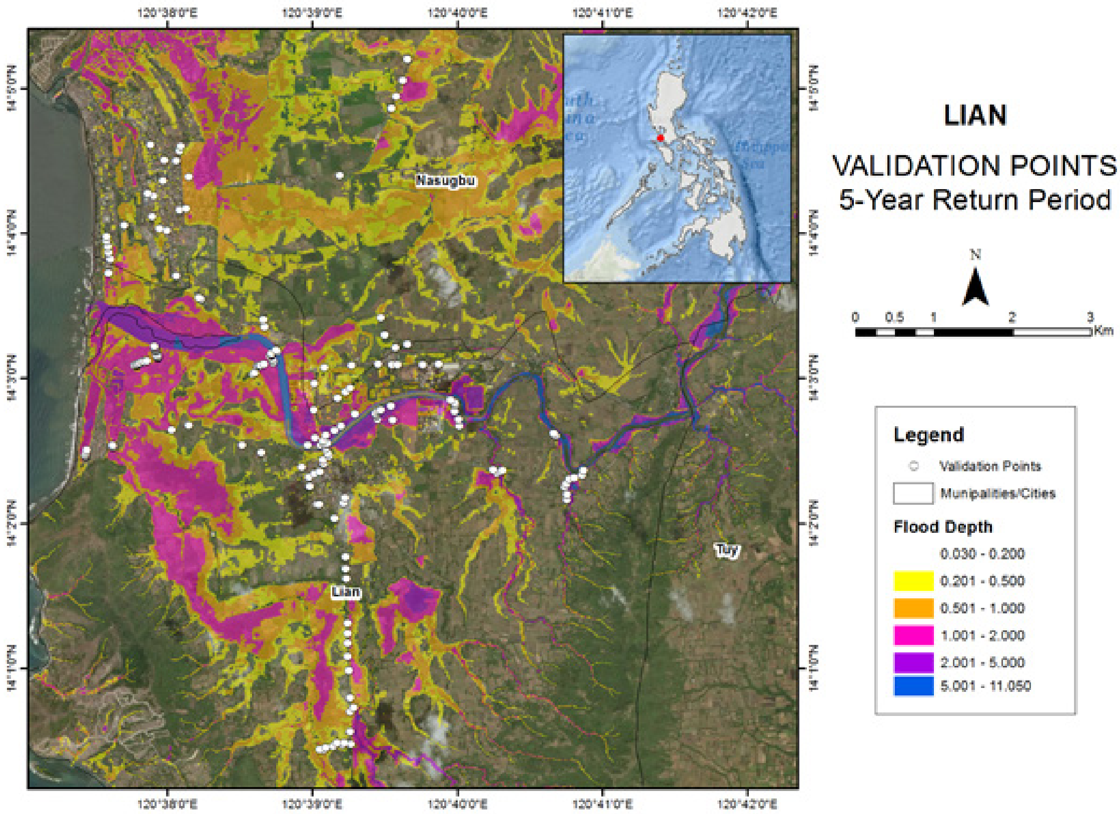


Figure 86. Flood Validation Points of Lian River Basin

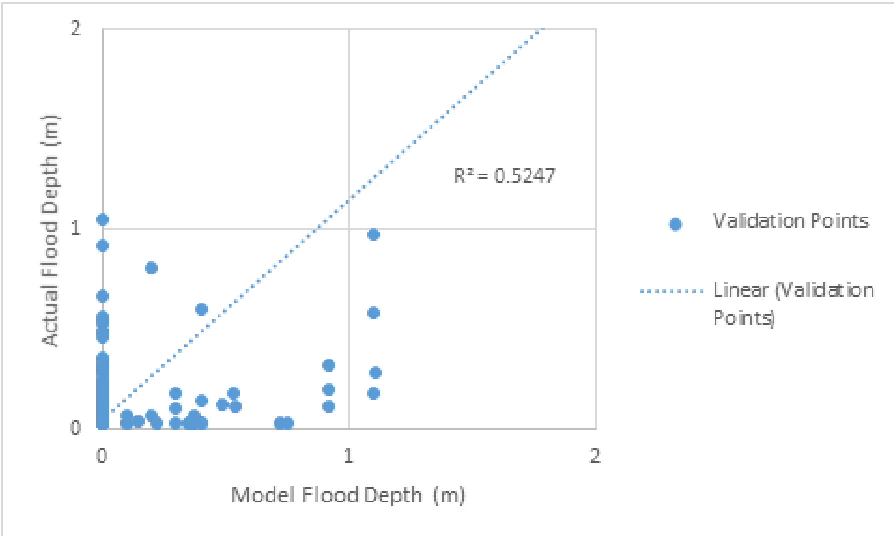


Table 44. Actual Flood Depth vs Simulated Flood Depth in Lian

LIAN BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	63	7	5	0	0	0	75
	0.21-0.50	39	4	9	1	0	0	53
	0.51-1.00	34	7	6	3	0	0	50
	1.01-2.00	40	5	3	0	0	0	48
	2.01-5.00	6	2	1	0	0	0	9
	> 5.00	0	0	0	0	0	0	0
	Total	182	25	24	4	0	0	235

The overall accuracy generated by the flood model is estimated at 72.99% with 154 points correctly matching the actual flood depths. In addition, there were 41 points estimated one level above and below the correct flood depths while there were 13 points and 2 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 32 points were underestimated in the modelled flood depths of Lian (Table 45).

Table 45. Summary of Accuracy Assessment in Lian

	No. of Points	%
Correct	154	72.99
Overestimated	25	11.85
Underestimated	32	15.17
Total	211	100.00

REFERENCES

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

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

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

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

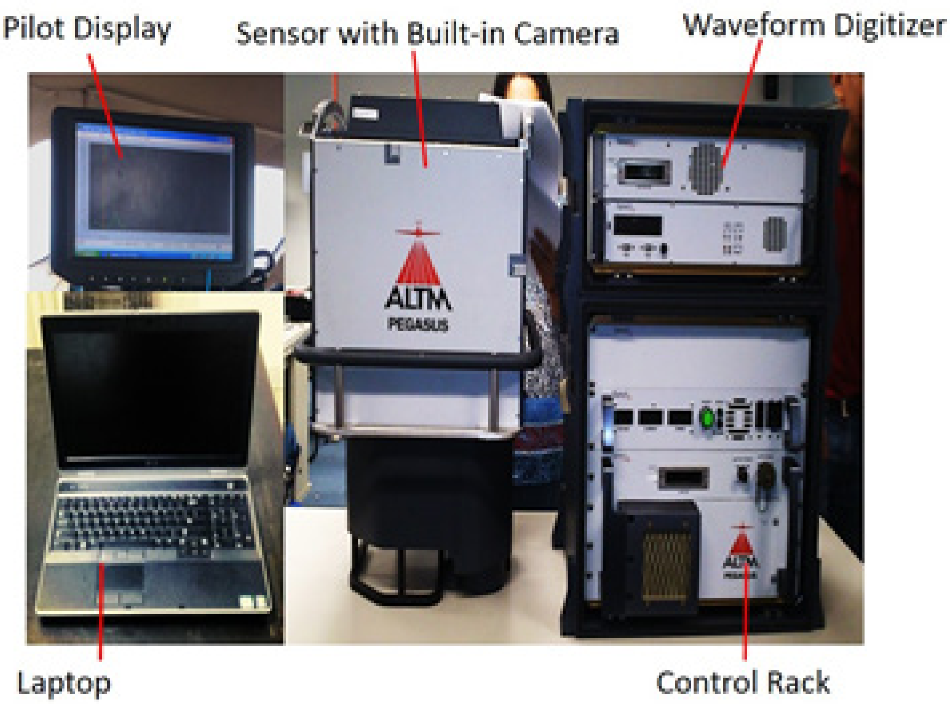
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Lian Floodplain Survey

PEGASUS



Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);
220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver	
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)

Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg
Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg	
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

GEMINI

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)

Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certification of Reference Points Used in the

BTG-51

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

January 05, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **BATANGAS**	
	Station Name: **BTG-51**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **TALAGA**	
Municipality: **TANAUAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **14° 6' 8.57112"**	Longitude: **121° 5' 52.31002"**	Ellipsoidal Hgt: **152.36900 m.**
	WGS84 Coordinates	
Latitude: **14° 6' 3.27790"**	Longitude: **121° 5' 57.24592"**	Ellipsoidal Hgt: **197.55100 m.**
	PTM / PRS92 Coordinates	
Northing: **1559501.067 m.**	Easting: **510567.544 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,559,783.81**	Easting: **294,641.94**	Zone: **51**

Location Description

BTG-51
From Star Expressway Exit, Tanauan City, turn right to Talisay and continue traveling W until reaching the Y-road. Station is located inside the Mabini Shrine, approx. 100 m. from the right side of the road. It is situated approx. 2 m. S of the flagpole, about 15 m. N from the gate of the said shrine. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. concrete block flushed on the ground, with inscriptions "BTG-51 2007 NAMRIA".

Requesting Party: **DOST-PCIEERD**
Purpose: **Reference**
OR Number: **8089513 I**
T.N.: **2016-0018**

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

9 9 0 1 0 5 2 0 1 6 1 5 0 5 1 0

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

1. BTG-45

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

March 04, 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: **BATANGAS**
Station Name: **BTG-45**
Order: **2nd**

Island: **LUZON** Municipality: **TUY**		Barangay: **MALIBU**
	PRS92 Coordinates	
Latitude: **13° 59' 52.18294"**	Longitude: **120° 42' 18.96476"**	Ellipsoidal Hgt: **48.43000 m.**
	WGS84 Coordinates	
Latitude: **13° 59' 46.88216"**	Longitude: **120° 42' 23.91169"**	Ellipsoidal Hgt: **92.94300 m.**
	PTM Coordinates	
Northing: **1547952.281 m.**	Easting: **468159.677 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,548,591.80**	Easting: **252,125.62**	Zone: **51**

Location Description

BTG-45
From Tuy Town Proper, travel S on the road going to Balayan, then turn right to the road going to Brgy. Malibu. Station is located on the NW side of a fenced garden and about 10 m. W of the school bldg. of Santiago De Guzman Elem. School. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "BTG-45 2007 NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-444**

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

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

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

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

Annex 3. Baseline Procesing Reports of Control Points Used in

1. BTG-A

Project Information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
BTG-51 --- BTG-A (B1)	BTG-51	BTG-A	Fixed	0.003	0.013	170°48'36"	16216.677	221.457
BTG-51 --- BTG-A (B2)	BTG-51	BTG-A	Fixed	0.004	0.017	170°48'36"	16216.637	221.577
BTG-51 --- BTG-A (B3)	BTG-51	BTG-A	Fixed	0.003	0.012	170°48'36"	16216.621	221.544
TGT-1 --- BTG-A (B4)	BTG-A	TGT-1	Fixed	0.008	0.017	315°18'50"	24750.750	239.384
BTG-51 --- TGT-1 (B5)	BTG-51	TGT-1	Fixed	0.009	0.018	276°06'46"	14901.801	460.990
BTG-A --- TGT-1 (B6)	BTG-A	TGT-1	Fixed	0.005	0.019	315°18'50"	24750.733	239.429
BTG-51 --- TGT-1 (B7)	BTG-51	TGT-1	Fixed	0.005	0.017	276°06'46"	14901.814	461.001
TGT-2 --- TGT-1 (B8)	TGT-2	TGT-1	Fixed	0.005	0.008	183°02'45"	3.316	0.124
BTG-A --- TGT-2 (B9)	TGT-2	BTG-A	Fixed	0.006	0.017	135°16'50"	24752.968	-239.298
BTG-51 --- TGT-2 (B10)	BTG-51	TGT-2	Fixed	0.007	0.017	276°07'32"	14901.989	460.964
TGT-1 --- TGT-2 (B11)	TGT-2	TGT-1	Fixed	0.003	0.004	182°17'41"	3.293	0.187
BTG-A --- TGT-2 (B12)	TGT-2	BTG-A	Fixed	0.004	0.017	135°16'50"	24752.942	-239.320
BTG-51 --- TGT-2 (B13)	BTG-51	TGT-2	Fixed	0.005	0.017	276°07'32"	14901.994	460.970
BTG-51 --- BTG-A (B14)	BTG-51	BTG-A	Fixed	0.020	0.025	170°48'36"	16216.661	221.703
TGT-2 --- BTG-A (B15)	TGT-2	BTG-A	Fixed	0.065	0.038	135°16'50"	24753.003	-239.177
BTG-51 --- TGT-2 (B16)	BTG-51	TGT-2	Fixed	0.004	0.013	276°07'31"	14901.990	460.994

1

Acceptance Summary

Processed	Passed	Flag	Fail
16	16	0	0

BTG-51 - BTG-A (10:17:13 AM-4:00:13 PM) (S1)

Baseline observation:	BTG-51 --- BTG-A (B1)
Processed:	1/6/2016 4:11:57 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.013 m
RMS:	0.003 m
Maximum PDOP:	1.859
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/21/2015 10:17:33 AM (Local: UTC+8hr)
Processing stop time:	12/21/2015 4:00:13 PM (Local: UTC+8hr)
Processing duration:	05:42:40
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BTG-51				
Grid		Local		Global	
Easting	294641.947 m	Latitude	N14°06'08.57113"	Latitude	N14°06'03.27790"
Northing	1559783.810 m	Longitude	E121°05'52.31001"	Longitude	E121°05'57.24592"
Elevation	152.867 m	Height	152.369 m	Height	197.551 m

To:	BTG-A				
Grid		Local		Global	
Easting	297103.192 m	Latitude	N13°57'27.65020"	Latitude	N13°57'22.39320"
Northing	1543753.102 m	Longitude	E121°07'18.59698"	Longitude	E121°07'23.54499"
Elevation	374.449 m	Height	373.826 m	Height	419.468 m

Vector					
ΔEasting	2461.246 m	NS Fwd Azimuth	170°48'36"	ΔX	-4333.540 m
ΔNorthing	-16030.708 m	Ellipsoid Dist.	16216.677 m	ΔY	2168.834 m
ΔElevation	221.582 m	ΔHeight	221.457 m	ΔZ	-15477.964 m

2

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000115832		
Y	-0.0000161070	0.0000283548	
Z	-0.0000056707	0.0000090452	0.0000037943

Occupations

	From	To
Point ID:	BTG-51	BTG-A
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(1)\12-21 -15 BTG - 51 1.355m.T02	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(1)\12-21 -15 BTG - A 1.39m.T02
Receiver type:	SPS852	SPS852
Receiver serial number:	5217K84538	5203K81512
Antenna type:	Zephyr Geodetic 2	Zephyr Geodetic 2
Antenna serial number:	--------	--------
Antenna height (measured):	1.355 m	1.390 m
Antenna method:	Bottom of notch	Bottom of notch

Tracking Summary

2. BTG-45A

Project Information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
BTG-45 --- BTG-45A (B1)	BTG-45	BTG-45A	Fixed	0.001	0.001	175°32'41"	6.995	0.659

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

BTG-45 - BTG-45A (7:15:33 AM-11:52:39 AM) (S1)

Baseline observation:	BTG-45 --- BTG-45A (B1)
Processed:	9/2/2015 11:37:56 AM
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:	2.331
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	9/1/2015 7:15:33 AM (Local: UTC+8hr)
Processing stop time:	9/1/2015 11:52:39 AM (Local: UTC+8hr)
Processing duration:	04:37:06
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BTG-45				
Grid		Local		Global	
Easting	252125.624 m	Latitude	N13°59'52.18294"	Latitude	N13°59'46.88216"
Northing	1548591.799 m	Longitude	E120°42'18.96476"	Longitude	E120°42'23.91169"
Elevation	49.818 m	Height	48.430 m	Height	92.943 m

To:	BTG-45A				
Grid		Local		Global	
Easting	252126.100 m	Latitude	N13°59'51.95603"	Latitude	N13°59'46.65526"
Northing	1548584.818 m	Longitude	E120°42'18.98286"	Longitude	E120°42'23.92980"
Elevation	50.478 m	Height	49.089 m	Height	93.602 m

Vector					
ΔEasting	0.476 m	NS Fwd Azimuth	175°32'41"	ΔX	-1.655 m
ΔNorthing	-6.981 m	Ellipsoid Dist.	6.995 m	ΔY	1.723 m
ΔElevation	0.659 m	ΔHeight	0.659 m	ΔZ	-6.607 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'12"	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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002866		
Y	-0.0000001658	0.0000003931	
Z	-0.0000000756	0.0000000861	0.0000001315

Annex 4. The LiDAR Survery Team Composition

Data Acquisition Component Sub-team	Designation	Name	Agency/Affiliation
Program Leader	Program Leader –I	ENRICO C. PARINGIT, D. Eng.	UP TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. LOUIE P. BALICANTA	UP TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		ENGR. LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP TCAGP
		JULIE PEARL MARS	UP TCAGP
	Research Associate	ENGR. LARAH PARAGAS	UP TCAGP
		PAULINE JOANNE ARCEO	UP TCAGP
		FAITH JOY SABLE	UP TCAGP
		Mary CATHERINE ELIZABETH BALIGUAS	UP TCAGP
		ENGR. IRO NIEL ROXAS	UP TCAGP
		ENGR. GRACE SINADJAN	UP TCAGP
		JONALYN GONZALES	UP TCAGP
		ENGR. RENAN PUNTO	UP TCAGP
Ground Survey, Data Download and Transfer	Research Associate	ENGR. KENNETH QUISADO	UP TCAGP
		ENGR. CHRISTOPHER JOAQUIN	UP TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		TSG. JULIUS RENDON	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORP (AAC)
		CAPT. FRANCO JESUS PEPITO	ASIAN AEROSPACE CORP (AAC)
		CAPT. ARNEL BAYANI, JR.	ASIAN AEROSPACE CORP (AAC)
		CAPT. JUSTINE JOYA	ASIAN AEROSPACE CORP (AAC)
		CAPT. ALBERT PAUL LIM	ASIAN AEROSPACE CORP (AAC)
		CAPT. RANDY LAGCO	ASIAN AEROSPACE CORP (AAC)

Annex 5. Data Transfer Sheet for Tumaga Floodplain

Feb 15,2014	1111P	1BLK18RS46A	PEGASUS	1.39GB	1.74MB	6.22MB	194MB	19.7GB	172KB	14.7GB	N/A	10.9MB	216B	569B	71KB	N/A	Z:\Airborne_Raw\1111P
Feb 17,2014	1119P	1BLK18O48A	PEGASUS	1.02GB	1.95MB	8.25MB	250MB	21.5GB	195KB	16.8GB	N/A	11.7MB	213MB	520B	41KB	N/A	Z:\Airborne_Raw\1119P
Feb 18, 2014	1123P	1BLK18OS49A	PEGASUS	1.36GB	1.81MB	6.46MB	193MB	N/A	N/A	14.7GB	N/A	12.5MB	213B	504B	43KB	N/A	Z:\Airborne_Raw\1123P
Feb 18,2014	1125P	1BLK18S49B	PEGASUS	374MB	665KB	4.21MB	144MB	N/A	N/A	5.57GB	N/A	12.6MB	213B	282B	79.7KB	N/A	Z:\Airborne_Raw\1125P
Feb 19, 2014	1127P	1BLK18S50A	PEGASUS	985MB	1.54MB	5.26MB	190MB	N/A	N/A	12.1GB	N/A	6.85MB	213B	507B	67.1KB	N/A	Z:\Airborne_Raw\1127P
Feb 20, 2014	1131P	1BLK18Z51A	PEGASUS	1.84GB	2.39MB	7.83MB	219MB	33.3GB	254KB	20GB	90.4GB	13.2MB	133B	310B	91.9KB	N/A	Z:\Airborne_Raw\1131P
Feb 20,2014	1133P	1BLK18Z51B	PEGASUS	1.06GB	1.41MB	4.71MB	169MB	18.9GB	140KB	12.1GB	N/A	13.2MB	133B	265B	91.5KB	N/A	Z:\Airborne_Raw\1133P
Feb 21, 2014	1135P	1BLK18V52A	PEGASUS	1.54GB	2.04MB	7.95MB	235MB	7.41GB	117KB	17.4GB	33.9GB	7.52MB	133B	335B	91.9KB	N/A	Z:\Airborne_Raw\1135P
Feb 22,2014	1139P	1BLK18X53A	PEGASUS	2.19GB	2.45MB	7.52MB	238MB	29.3GB	238KB	213B	N/A	6.71MB	133B	0B	147KB	N/A	Z:\Airborne_Raw\1139P
Feb 22, 2014	1141P	1BLK18S53B	PEGASUS	1.05GB	1.80MB	7.25MB	219MB	24GB	176KB	15.4GB	N/A	6.25MB	157B	410B	171KB	N/A	Z:\Airborne_Raw\1141P
28-Jan	1039P	1BLK18B029A	PEGASUS	2.06	36KB	11.8	185	NA	NA	19.1	NA	7.43	141B	242B	40.5	NA	Z:\Airborne_Raw\1039P

Received from
Name
Position
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature

DATA TRANSFER SHEET
CALABARZON 9/7/2015

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	
15-Aug	3299P	1BLK18KS227A	PEGASUS	535	614	5.45	143	na	na	10.4	na	3.73	1KB	1KB	222	NA	Z:\DAC\RAW DATA
26-Aug	3341P	1BLK18AbS238A	PEGASUS	1.49	NA	10.1	240	na	na	16.1	na	7.02	1KB	1KB	69	NA	Z:\DAC\RAW DATA
26-Aug	3343P	1BLK18AcS238B	PEGASUS	1.84	NA	9.44	214	na	na	17.9	na	5.96	1KB	1KB	59	NA	Z:\DAC\RAW DATA
27-Aug	3345P	1BLK18TS239A	PEGASUS	2.5	NA	7.11	177	na	na	22.5	na	5.99	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
27-Aug	3347P	1BLK18TS239B	PEGASUS	0.99	NA	6.27	152	na	na	9.85	na	4.13	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
29-Aug	3353P	1BLK18QRS241A	PEGASUS	1.91	NA	10.3	246	na	na	18.8	na	7.19	1KB	1KB	87.1	NA	Z:\DAC\RAW DATA
1-Sep	3365P	1BLK18BCS244A	PEGASUS	1.92	NA	8.57	192	na	na	18.2	na	8.61	1KB	1KB	41	NA	Z:\DAC\RAW DATA
2-Sep	3369P	1BLK18CS245A	PEGASUS	1.34	NA	7.43	154	na	na	13.5	na	35	1KB	1KB	54	NA	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRA
Signature
9/8/15

IC-2

DATA TRANSFER SHEET
Batangas 1/13/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
21-Dec 1	3000P	1BLK18SB355A	pegasus	736	656	3.8	107	11.1	85	7.11	na	11.1	1KB	1KB	100	na	Z:\DAC\RAW DATA
6-Jan 6	3677G	2BLK18SK006A	GEMINI	NA	322	699	157	NA	NA	38.7	na	27.2	0KB	1KB	11	na	Z:\DAC\RAW DATA
6-Jan 7	3679G	2BLK18SDG006B	GEMINI	NA	60	401	131	NA	NA	12.8	na	27.2	0KB	1KB	5/3	na	Z:\DAC\RAW DATA
7-Jan 8	3681G	2BLK18SM007A	GEMINI	NA	226	0	209	NA	NA	24	na	18.5	0KB	1KB	NA	na	Z:\DAC\RAW DATA
8-Jan 9	3685G	2BLK18SF008A	GEMINI	NA	99	786	185	NA	NA	24.4	na	20.9	0KB	1KB	4/2	na	Z:\DAC\RAW DATA
8-Jan 10	3687G	2BLK18SGS008B	GEMINI	NA	214	0	172	NA	NA	17.2	na	20.9	0KB	1KB	4/20	na	Z:\DAC\RAW DATA
9-Jan 11	3689G	2BLK18SV009A	GEMINI	NA	201	1.54	219	NA	NA	16.3	na	12.9	0KB	1KB	23	na	Z:\DAC\RAW DATA
9-Jan 12	3691G	2BLK18SVV009B	GEMINI	NA	12.8	440	124	NA	NA	6.93	na	12.9	0KB	1KB	10	na	Z:\DAC\RAW DATA

Received from
Name C. Joaquin
Position
Signature

Received by
Name KBongat
Position SSRA
Signature KBongat 1/15/16

Annex 6. Flight logs for the flight missions

1. Flight Log for Flight Log for 1131P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1131P

1 LIDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18B51A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: C9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: FEB. 20, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0720	14 Engine Off: 1101	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time: 3+29
19 Weather: partly cloudy					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Sgt. Das Ramirez PAF	M.L. TANGONAN	ROMAN PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 1133P Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1137P

1 LiDAR Operator: J. ALVIAR	2 ALTM Model: PEG	3 Mission Name: 1BLK16A57B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: F. PEPITO	9 Route:			
10 Date: FEB. 20, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 1314	14 Engine Off: 1607	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time: 2+40
19 Weather	partly cloudy				
20 Remarks:	SUCCESSFUL FLIGHT				

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Sgt. Ray Ramirez PAF	M.A. TANGONAN	Jasmine Alviar
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 3369P Mission

Data Acquisition Flight Log

Flight Log No.: 3369P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18OS245A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Mooney	9 Route: NAIA - NAIA			
10 Date: SEPT. 2, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0632H	14 Engine Off: 1032H	15 Total Engine Time: 4+00	16 Take off: 0637H	17 Landing: 1027H	18 Total Flight Time: 3+50
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Jasmine Alviar	LEE JAY PUNZALAN	M.L. TANGONAN	I. ROXAS	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 3365PMission

Data Acquisition Flight Log

Flight Log No.: 3365P

1 LiDAR Operator: LK PARAGAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18BCS 244A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Mooney	9 Route: NAIA - NAIA			
10 Date: SEPT. 1, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0624H	14 Engine Off: 0931H	15 Total Engine Time: 3+05	16 Take off: 0631H	17 Landing: 0926H	18 Total Flight Time: 2+55
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Alviar	Lee Jay Punzalan	M.L. Tangonan	L.K. Paragas	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

5. Flight Log for 3679GMission

Data Acquisition Flight Log

Flight Log No.: 3479

1 LiDAR Operator: Mars, P	2 ALTM Model: Gemini	3 Mission Name: 2BLK18D006B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: Lim	8 Co-Pilot: Lagu	9 Route: Lipa - Lipa			
10 Date: Jan. 6, 2016	12 Airport of Departure (Airport, City/Province): Lipa City, Batangas		12 Airport of Arrival (Airport, City/Province): Lipa City, Batangas		
13 Engine On: 1400	14 Engine Off: 1617	15 Total Engine Time: 2+17	16 Take off: 1405 H	17 Landing: 1602 H	18 Total Flight Time: 2+07
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 18SD

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
J. Alviar		L. Lim	P. Mars	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 3687G Mission

Data Acquisition Flight Log

Flight Log No.: 3687

1 LiDAR Operator: R. Punto	2 ALTM Model: Gemini	3 Mission Name: 2BLK1856 008A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: Lim	8 Co-Pilot: Laguo	9 Route: Lipa – Lipa			
10 Date: Jan. 6, 2016	12 Airport of Departure (Airport, City/Province): Lipa		12 Airport of Arrival (Airport, City/Province): Lipa		
13 Engine On: 1432	14 Engine Off: 1742	15 Total Engine Time: 3+10	16 Take off: 1437H	17 Landing: 1737H	18 Total Flight Time: 3+00
19 Weather: Cloudy					

20 Flight Classification

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

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

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

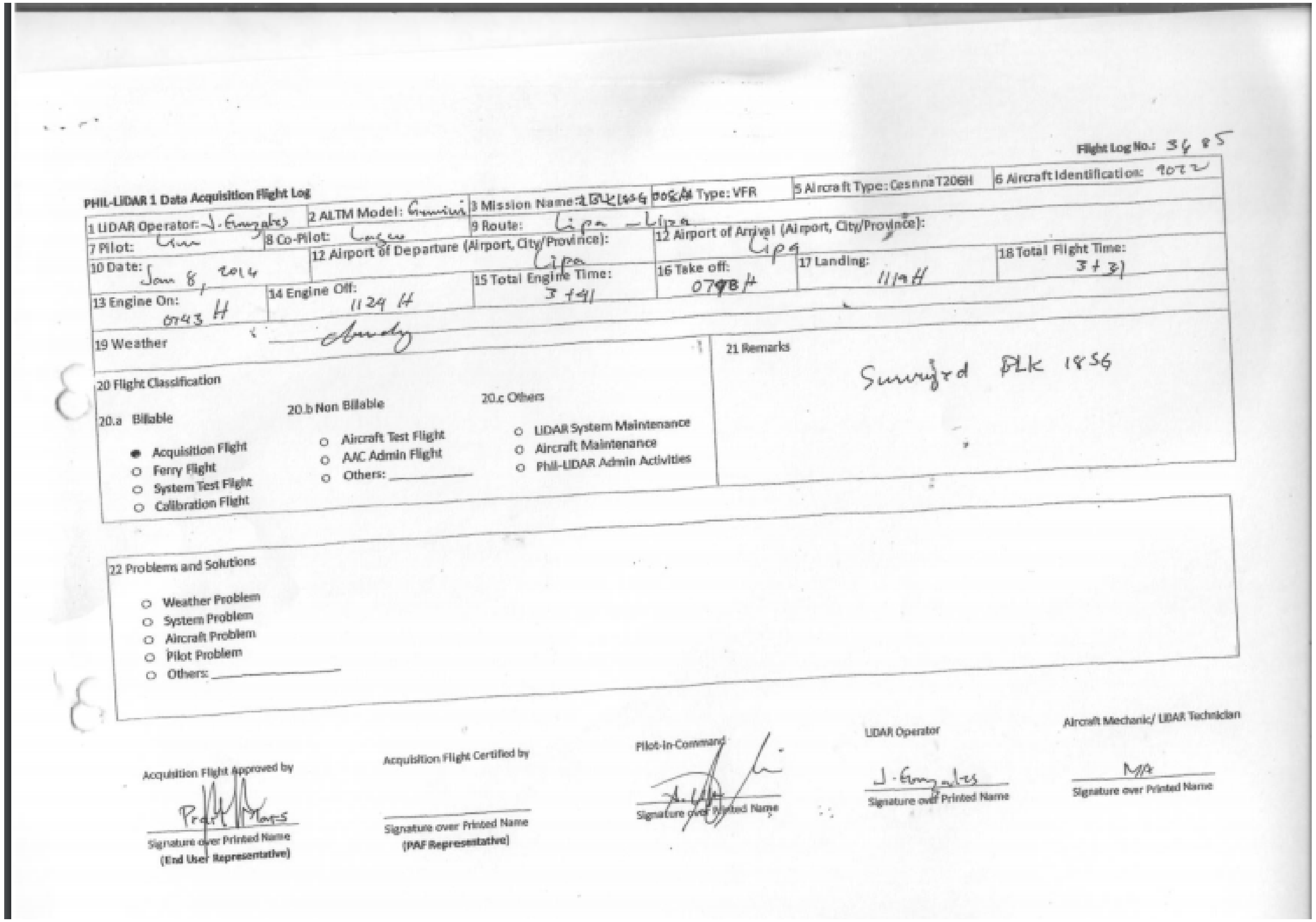
21 Remarks

Surveyed BLK 1856

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Prof. ... Mours		A. Lim	R. Punto	G. Antonio
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

7. Flight Log for 3685G Mission



Flight Log No.: 3685

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: J. Gonzales	2 ALTM Model: Gemini	3 Mission Name: 1BLK18S6 006A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot:	8 Co-Pilot:	9 Route: Lipa – Lipa			
10 Date: Jan 8, 2014	12 Airport of Departure (Airport, City/Province): Lipa		12 Airport of Arrival (Airport, City/Province): Lipa		
13 Engine On: 0743 H	14 Engine Off: 1129 H	15 Total Engine Time: 3+41	16 Take off: 0748 H	17 Landing: 1119 H	18 Total Flight Time: 3+31
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 18S6

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	J. Gonzales Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status Report

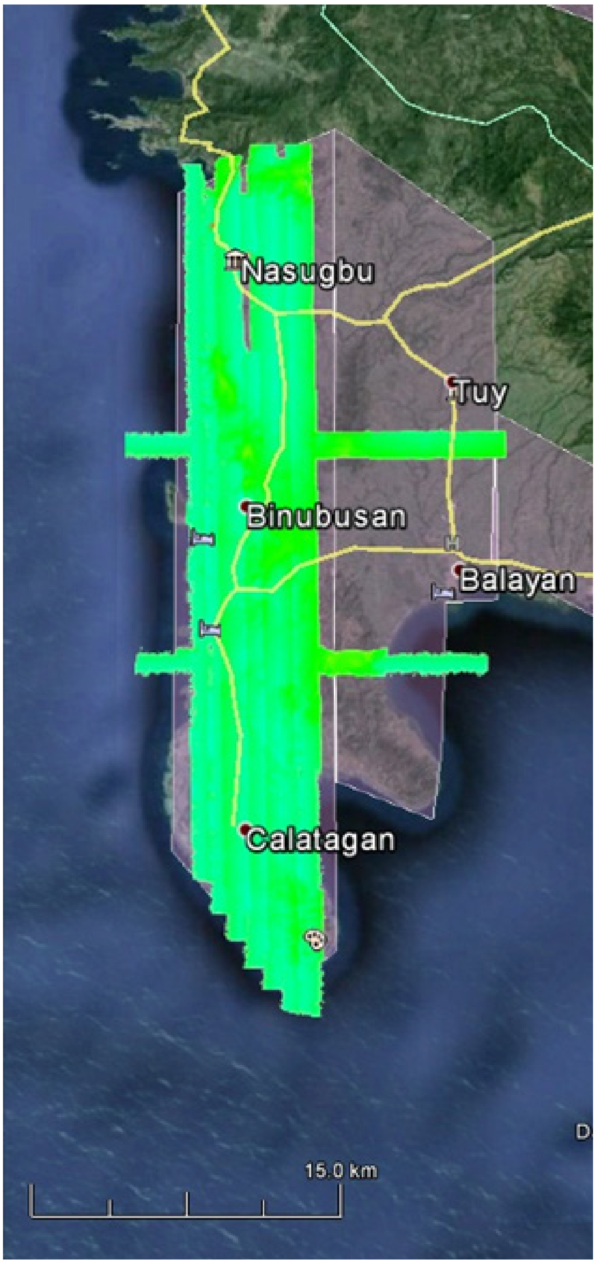
CALABARZON
(February 20, 2014, September 1-2, 2015 and January 6-8, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1131P	BLK 18Z	1BLK18Z51A	R. Punto	Feb 20 2014	Surveyed at 1200m flying height
1133P	BLK 18Zs	1BLK18Z51B	J. Alviar	Feb 20 2014	Completed remaining lines in BLK 18Zand 2 lines in BLK 18Y at 1200m flying height
3365P	BLK 18BCS	1BLK18BCS244A	LK PARAGAS	SEPT 1 2015	Mission Aborted due to clouds Experienced POS error Without Digitizer and Camera
3369P	BLK 18OS	1BLK18OS245A	I ROXAS	SEPT 2 2015	Laser off due to Clouds Experienced POSAV error Without Digitizer and Camera
3679G	BLK 18G, SD CALACA BALAYAN	2BLK18SDG006B	P.MARS	JAN 6 2016	SURVEYED BLK 18SGJ; 56.811SQ.KM
3687G	BLK18SG, SM	2BLK18SGS008B	R.PUNTO	JAN 8 2016	SURVEYED BLK 18SG GAPS IN BLK 18SM 86.12 SQ.KM.
3685G	BLK 18SG, SF CALAMBA CALACA	2BLK18SF008A	J.GONZALES	JAN 8 2016	SURVEYED BLK 18SF, 18SG 105.99SQ.KM

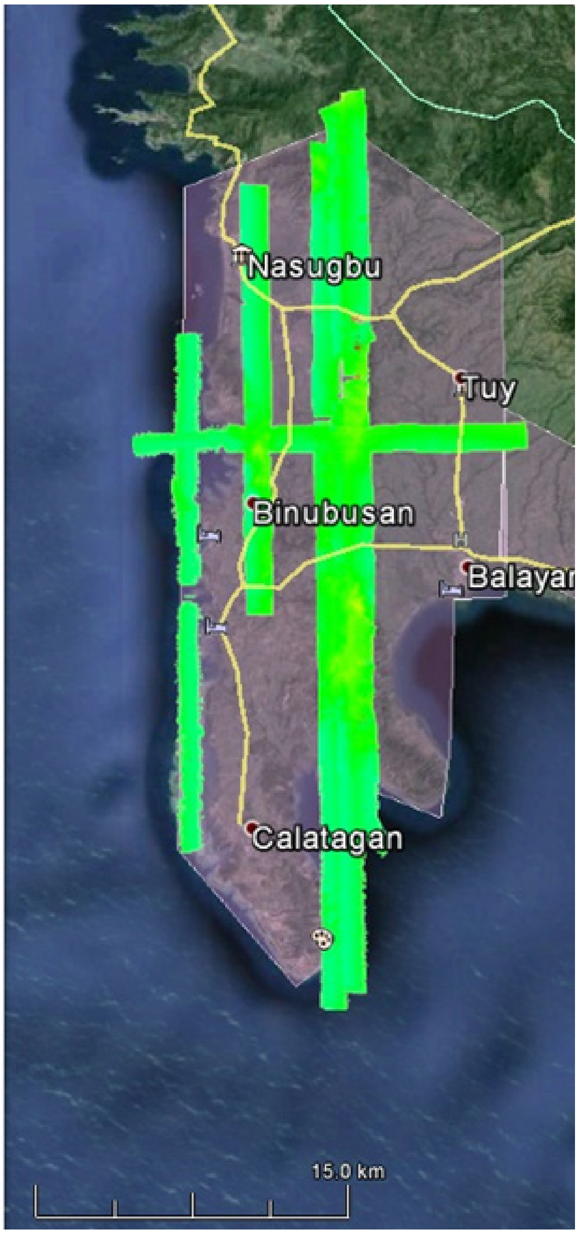
LAS BOUNDARIES PER FLIGHT

Flight No. : 1131P (renamed from 1129P)
Area: BLK 18Z
Mission Name: 1BLK18Z51A
Parameters: Altitude: 1000; Scan Frequency: 30; Overlap: 30%

LAS

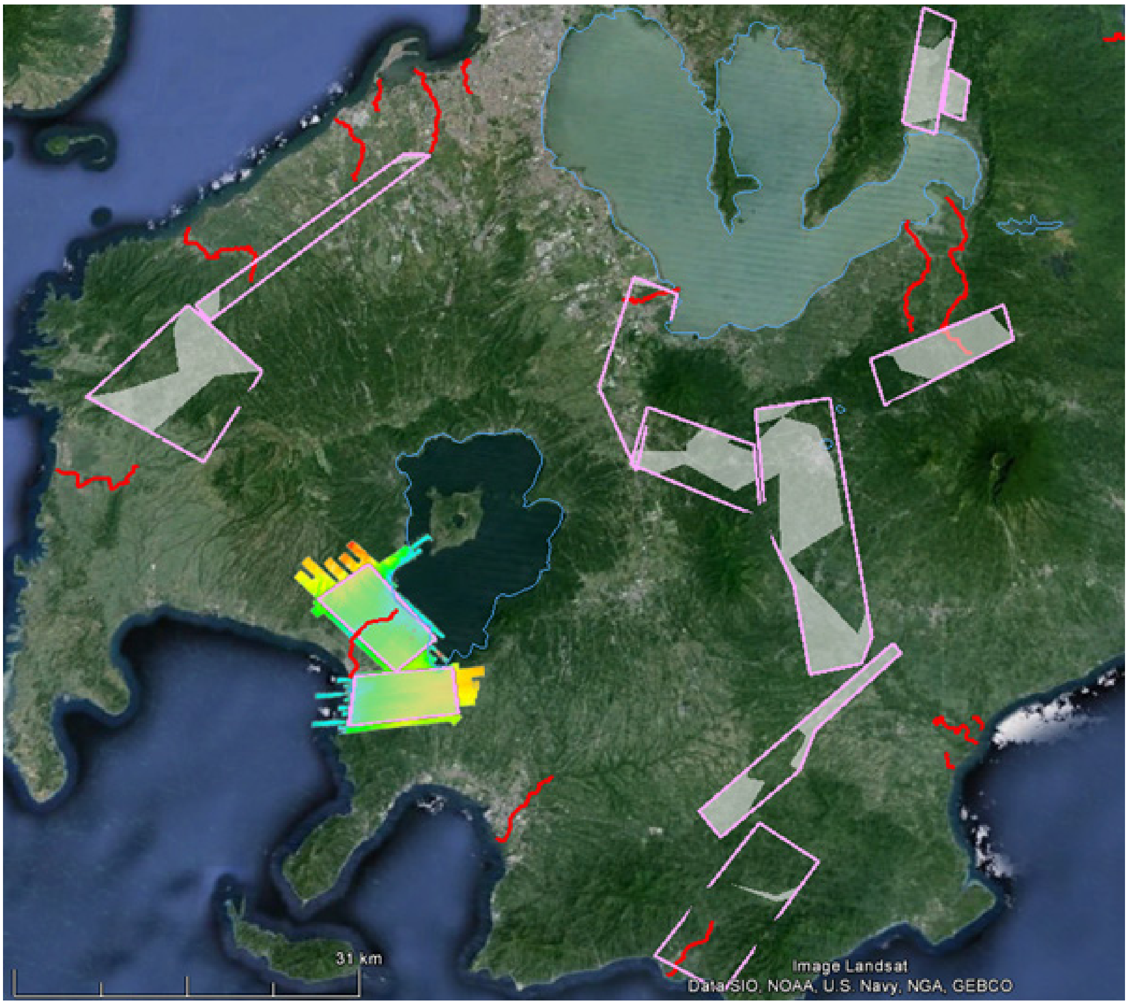


Flight No. : 1133P (renamed from 1131P)
Area: BLK 18Zs
Mission Name: 1BLK18Z51B
Parameters: Altitude: 1000; Scan Frequency: 30; Overlap: 30%



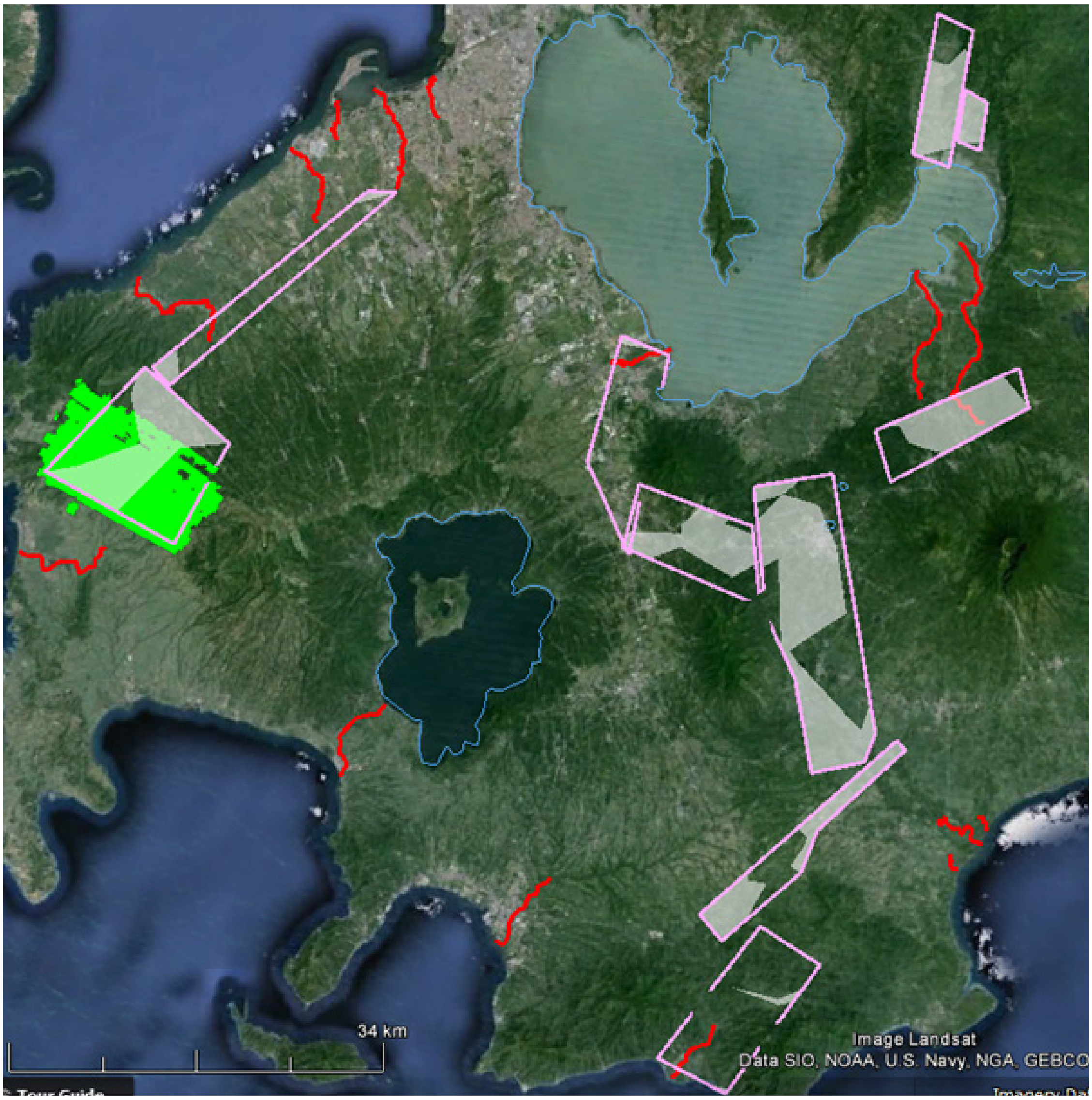
Flight No. : 3369P
Area: BLK 18OS
Mission Name: 1BLK18OS245A
Parameters: Altitude: 1000; Scan Frequency: 30; Overlap: 30%

LAS



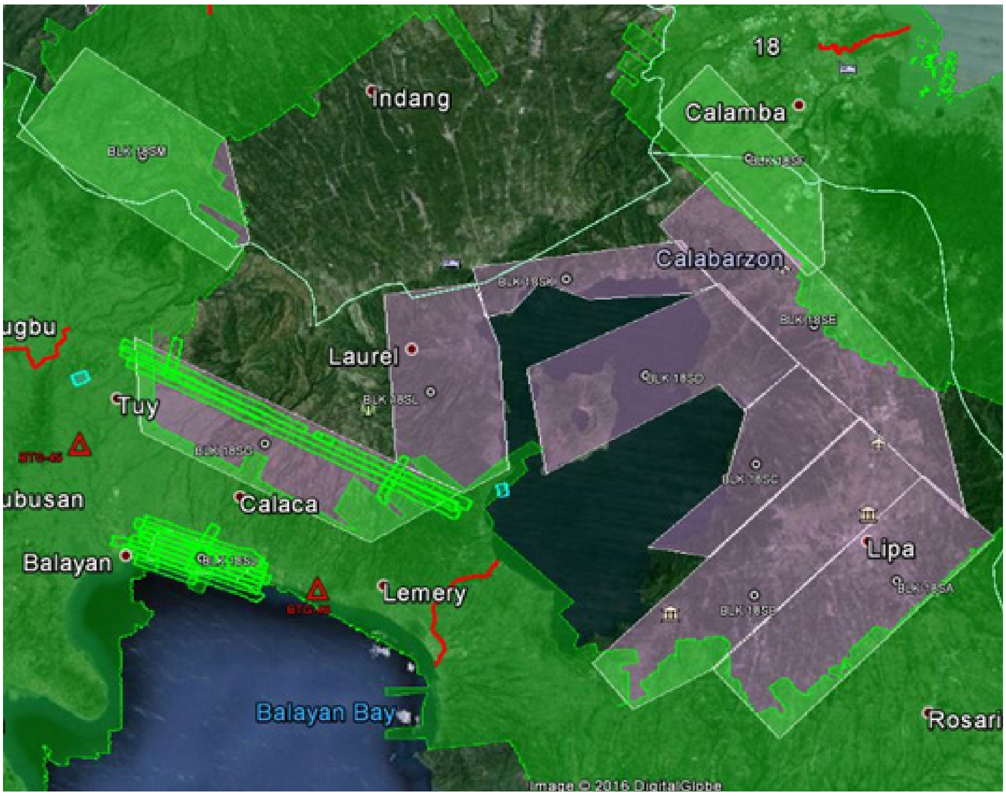
Flight No. : 3365P
Area: BLK 18BCS
Mission Name: 1BLK18BCS244A
Parameters: Altitude: 1000; Scan Frequency: 30; Overlap: 60%

LAS



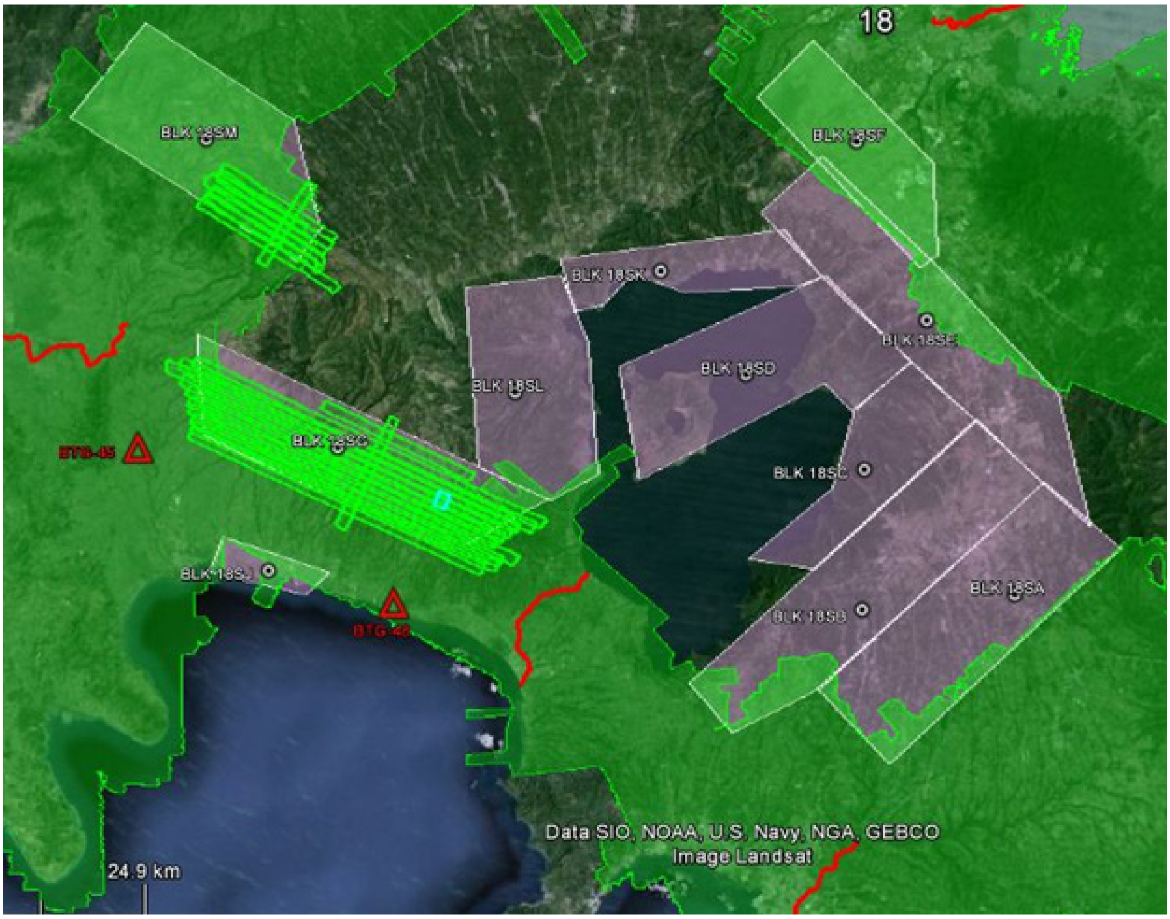
Flight No. : 3679G
Area: BLK 18G, SD
Mission Name: 2BLK18SDG006B
Parameters: Altitude: 750; Scan Frequency: 50 ; Overlap: 40%

LAS/ SWATH



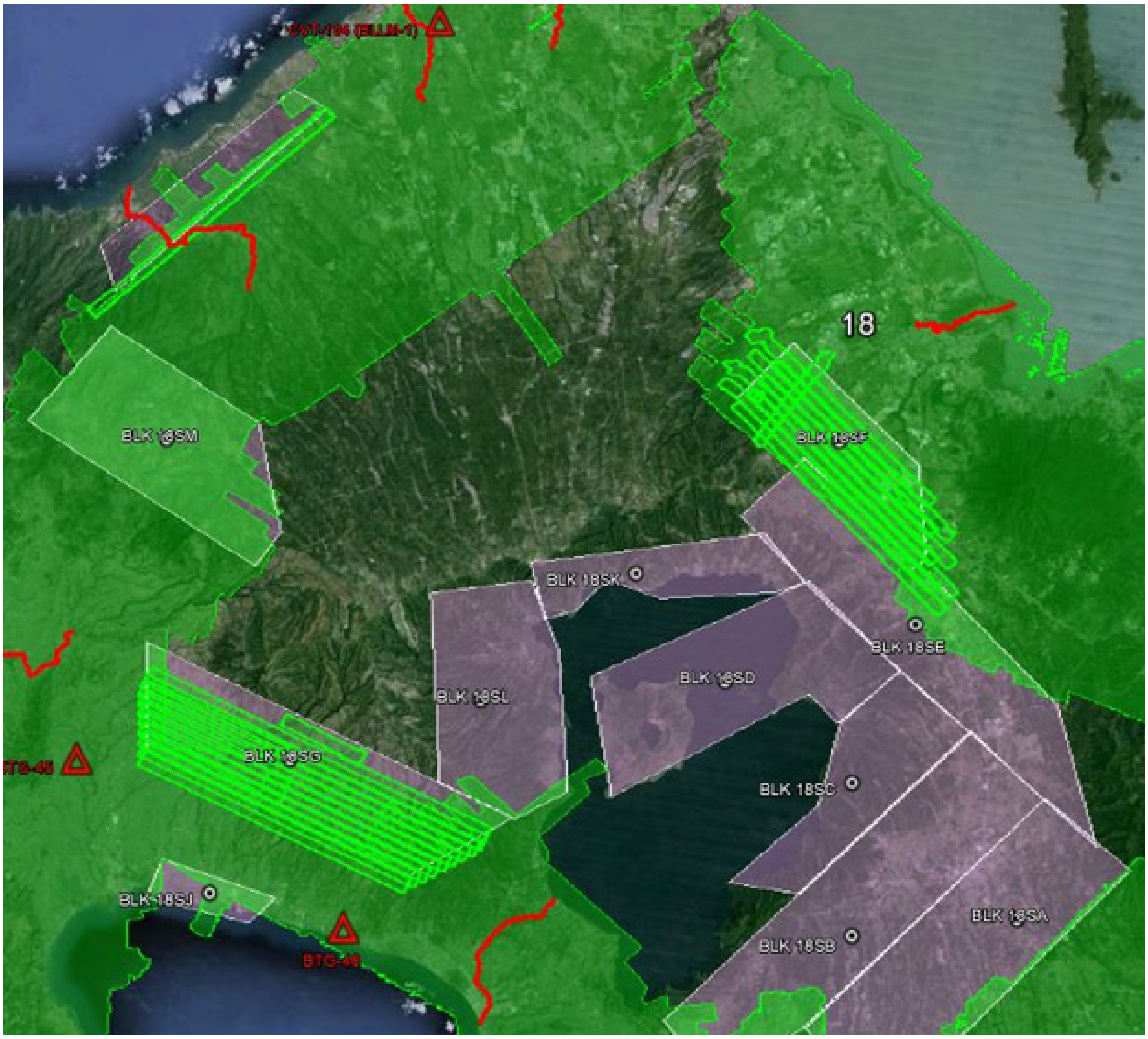
Flight No. : 3687G
Area: BLK18SG, SM
Mission Name: 2BLK18SGS008B
Parameters: Altitude: 1000; Scan Frequency: 40 ; Overlap: 40%

LAS/SWATH



Flight No. : 3685G
Area: BLK 18SG, SF
Mission Name: 2BLK18SF008A:
Parameters: Altitude: 1000; Scan Frequency: 40; Overlap: 30%

LAS/SWATH



Annex 9. Lian Model Basin Parameters

Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious	Time of Concentation (HR)	Storage Coefficient (HR)	Initial type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W1000	1.8077	99	0	0.78887	0.26403	Discharge	3.19E-06	0.00046	Ratio to Peak	0.05633
W1010	2.2571	98.995	0	2.0024	1.2651	Discharge	0.0016	0.00485	Ratio to Peak	0.0879
W1020	2.0453	99	0	0.96043	0.29792	Discharge	6.43E-05	0.00046	Ratio to Peak	0.13883
W1030	2.6216	99	0	1.0365	0.47893	Discharge	0.00023	0.00232	Ratio to Peak	0.69178
W1040	5.1688	98.674	0	3.1902	5.0158	Discharge	0.008	0.06887	Ratio to Peak	0.06197
W1050	3.6911	99	0	0.144	0.08689	Discharge	2.38E-05	0.0002	Ratio to Peak	0.30581
W1060	2.6871	99	0	1.1153	0.4701	Discharge	0.00306	0.00686	Ratio to Peak	0.69178
W540	2.9963	58.427	0	2.5705	0.24535	Discharge	0.00148	0.00461	Ratio to Peak	0.3028
W550	1.8364	99	0	0.11434	2.7224	Discharge	0.00169	0.00915	Ratio to Peak	0.30745
W560	1.0071	99	0	2.8799	2.7562	Discharge	0.00183	0.01638	Ratio to Peak	0.33947
W570	8.5918	99	0	0.78409	2.1055	Discharge	0.00136	0.01697	Ratio to Peak	0.44303
W580	1.9545	99	0	0.36129	0.85604	Discharge	0.00205	0.05367	Ratio to Peak	0.5513
W590	3.3484	99	0	2.6394	2.776	Discharge	0.00398	0.03844	Ratio to Peak	0.38813
W600	4.4463	99	0	2.3568	1.4303	Discharge	0.00471	0.01095	Ratio to Peak	0.33857
W610	3.0557	97.889	0	0.14497	0.9685	Discharge	0.00027	0.0048	Ratio to Peak	0.73569
W620	6.6529	99	0	2.7111	2.7684	Discharge	0.00139	0.00066	Ratio to Peak	0.33117
W630	6.2404	99	0	2.282	2.1826	Discharge	0.00162	0.01613	Ratio to Peak	0.49894
W640	2.668	99	0	0.44409	0.27867	Discharge	0.00045	0.00456	Ratio to Peak	0.50275
W650	2.7823	99	0	0.43676	0.17704	Discharge	0.00013	0.00489	Ratio to Peak	0.49
W660	3.7683	99	0	3.0221	2.6827	Discharge	0.00113	0.00228	Ratio to Peak	0.33844
W670	4.2611	49.517	0	12.502	0.01667	Discharge	0.00305	0.09715	Ratio to Peak	0.5
W680	1.3163	46.213	0	0.01667	1.7215	Discharge	0.00139	0.17157	Ratio to Peak	0.75735
W690	4.3574	99	0	0.1609	0.59035	Discharge	0.00059	0.01016	Ratio to Peak	0.47464
W700	10.694	99	0	2.7217	6.6188	Discharge	0.00281	0.05879	Ratio to Peak	0.47169
W710	4.9635	99	0	0.96524	2.0565	Discharge	0.00192	0.08459	Ratio to Peak	0.09099
W720	6.4798	98.45	0	1.0148	3.0085	Discharge	0.0058	0.08233	Ratio to Peak	0.06197
W730	6.3714	98.854	0	2.6681	3.3435	Discharge	0.00138	0.03916	Ratio to Peak	0.26062
W740	4.4356	99	0	0.20189	0.52684	Discharge	0.0002	0.01531	Ratio to Peak	0.98237
W750	7.338	99	0	1.5144	2.7078	Discharge	0.0032	0.00424	Ratio to Peak	0.06319
W760	2.27	99	0	2.7372	1.1589	Discharge	0.00365	0.03768	Ratio to Peak	0.31423
W770	9.8074	99	0	0.32071	0.67835	Discharge	0.00107	0.02057	Ratio to Peak	0.75
W780	27.301	47.624	0	1.9815	3.2337	Discharge	0.00079	0.02338	Ratio to Peak	0.21342

W790	5.9731	58.397	0	17.322	3.694	Discharge	0.0092	0.56505	Ratio to Peak	0.22222
W800	28.028	47.955	0	3.2889	5.3675	Discharge	0.00385	0.10288	Ratio to Peak	0.32666
W810	5.3631	98.593	0	0.76682	1.9641	Discharge	0.00275	0.01583	Ratio to Peak	0.21523
W820	7.7657	96.911	0	0.92526	1.833	Discharge	0.00259	0.0569	Ratio to Peak	0.3785
W830	11.621	99	0	2.9603	1.4621	Discharge	0.00167	0.01766	Ratio to Peak	0.49692
W840	4.9908	99	0	2.1117	3.0404	Discharge	0.00644	0.07481	Ratio to Peak	0.32959
W850	4.7072	99	0	1.0476	4.1288	Discharge	0.00302	0.10188	Ratio to Peak	0.68246
W860	9.1152	99	0	3.0213	3.4604	Discharge	0.00195	0.0096	Ratio to Peak	0.21847
W870	5.8347	68.52	0	3.4506	5.6314	Discharge	0.00376	0.11143	Ratio to Peak	0.32667
W880	7.4382	35.301	0	0.17958	0.82318	Discharge	0.0017	0.17643	Ratio to Peak	0.52789
W890	14.223	98.912	0	2.9033	15.113	Discharge	0.00469	0.02638	Ratio to Peak	0.50475
W900	1.2201	41.828	0	0.01667	0.80804	Discharge	0.001	0.27321	Ratio to Peak	0.22222
W910	8.7013	48.509	0	0.52483	0.01667	Discharge	0.00018	0.3803	Ratio to Peak	0.75
W920	8.7076	36.488	0	0.80073	0.01667	Discharge	0.00039	0.27888	Ratio to Peak	0.8625
W930	1.155	99	0	0.02288	0.03734	Discharge	2.83E-07	0.08452	Ratio to Peak	0.33391
W940	12.518	50.361	0	3.1173	5.0875	Discharge	0.00212	0.43451	Ratio to Peak	0.48695
W950	11.727	51.992	0	2.5023	4.0838	Discharge	0.00157	0.49799	Ratio to Peak	0.49
W960	2.7838	63.208	0	1.6222	0.01667	Discharge	0.00396	0.27607	Ratio to Peak	1
W970	4.5541	99	0	2.5028	2.8757	Discharge	0.0097	0.03787	Ratio to Peak	0.33905
W980	10.636	54.422	0	3.3951	5.5408	Discharge	0.00444	0.09487	Ratio to Peak	0.45
W990	4.0051	98.249	0	0.90414	2.6748	Discharge	0.001	0.09076	Ratio to Peak	0.33292

Annex 10. Lian Model Reach Parameters

Reach	Muskingum Cunge Channel Routing								
	Time Step method	Length	Slope	Manning's n	Invert	Shape	Diameter	Width	Side Slope
R130	Automatic Fixed Interval	3575	0.01792	0.0428954		Trapezoid		40	1
R150	Automatic Fixed Interval	1109.5	0.03782	0.3395		Trapezoid		40	1
R160	Automatic Fixed Interval	2728.9	0.01972	0.036082		Trapezoid		40	1
R170	Automatic Fixed Interval	1307.1	0.00178	0.0097709		Trapezoid		40	1
R180	Automatic Fixed Interval	503.14	0.02301	0.0001		Trapezoid		40	1
R230	Automatic Fixed Interval	3084.6	0.00943	0.003983		Trapezoid		40	1
R240	Automatic Fixed Interval	1697.8	0.00439	0.0001		Trapezoid		40	1
R250	Automatic Fixed Interval	1488.1	0.00599	0.000329049		Trapezoid		40	1
R260	Automatic Fixed Interval	2147.9	0.01708	0.0929482		Trapezoid		40	1
R300	Automatic Fixed Interval	2521.5	0.00432	0.0062153		Trapezoid		40	1
R330	Automatic Fixed Interval	14.142	0.16555	0.0497919		Trapezoid		40	1
R340	Automatic Fixed Interval	1411.1	0.04351	0.0059266		Trapezoid		40	1
R360	Automatic Fixed Interval	3516.2	0.03357	0.0001		Trapezoid		40	1
R370	Automatic Fixed Interval	786.69	0.04989	0.0049655		Trapezoid		40	1
R420	Automatic Fixed Interval	3379.5	0.00109	0.0029165		Trapezoid		40	1
R430	Automatic Fixed Interval	440	0.00076	0.012332		Trapezoid		40	1
R440	Automatic Fixed Interval	9186.5	0.01903	0.0388799		Trapezoid		40	1
R460	Automatic Fixed Interval	9673.1	0.01386	0.12718		Trapezoid		40	1
R480	Automatic Fixed Interval	1337.8	0.0004	0.0017571		Trapezoid		40	1
R490	Automatic Fixed Interval	743.85	0.00646	0.0001		Trapezoid		40	1
R50	Automatic Fixed Interval	734.26	0.02032	0.0001		Trapezoid		40	1
R500	Automatic Fixed Interval	263.14	0.00111	0.0001		Trapezoid		40	1
R510	Automatic Fixed Interval	71.569	0.0004	0.001557		Trapezoid		40	1
R70	Automatic Fixed Interval	608.7	0.01621	0.0698318		Trapezoid		40	1
R80	Automatic Fixed Interval	874.97	0.02313	0.0001		Trapezoid		40	1
R90	Automatic Fixed Interval	4974.2	0.0278	0.15031		Trapezoid		40	1

Annex 11. Lian Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	14.007258	120.651335	0.48	0.55	-0.07	Ondoy/Sept 24, 2009	5-year
2	14.007387	120.650914	0.65	0.95	-0.3	Ondoy/Sept 24, 2009	5-year
3	14.007596	120.65159	0.54	0.95	-0.41	Ondoy/Sept 24, 2009	5-year
4	14.007726	120.652381	0.11	0.5	-0.39	Ondoy/Sept 24, 2009	5-year
5	14.007888	120.653537	0.03	0.5	-0.47	Ondoy/Sept 24, 2009	5-year
6	14.008006	120.654471	0.1	0.3	-0.2	Ondoy/Sept 24, 2009	5-year
7	14.00812	120.652856	0.13	0.95	-0.82	Ondoy/Sept 24, 2009	5-year
8	14.00812	120.653693	0.1	0.95	-0.85	Ondoy/Sept 24, 2009	5-year
9	14.009407	120.654389	0.27	0.5	-0.23	Ondoy/Sept 24, 2009	5-year
10	14.011736	120.654383	0.65	0.3	0.35	Ondoy/Sept 24, 2009	5-year
11	14.012143	120.654778	0.52	0	0.52	Ondoy/Sept 24, 2009	5-year
12	14.013314	120.654386	0.05	0.5	-0.45	Ondoy/Sept 24, 2009	5-year
13	14.016484	120.654242	0.28	0.1	0.18	Ondoy/Sept 24, 2009	5-year
14	14.018084	120.654124	0.2	0.5	-0.3	Ondoy/Sept 24, 2009	5-year
15	14.019619	120.654112	0.14	0.5	-0.36	Ondoy/Sept 24, 2009	5-year
16	14.020715	120.654098	0.26	0.55	-0.29	Ondoy/Sept 24, 2009	5-year
17	14.02188	120.654064	0.12	0.5	-0.38	Ondoy/Sept 24, 2009	5-year
18	14.027009	120.653908	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
19	14.028171	120.653856	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
20	14.029481	120.653864	0.03	0.6	-0.57	Ondoy/Sept 24, 2009	5-year
21	14.033929	120.652601	0.32	0.5	-0.18	Ondoy/Sept 24, 2009	5-year
22	14.035522	120.650602	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
23	14.03558	120.650835	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
24	14.035734	120.653627	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
25	14.036063	120.67932	0.05	3	-2.95	Ondoy/Sept 24, 2009	5-year
26	14.036351	120.653765	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
27	14.0367	120.679268	0.04	3	-2.96	Ondoy/Sept 24, 2009	5-year
28	14.037543	120.679083	0.03	3	-2.97	Ondoy/Sept 24, 2009	5-year
29	14.03765	120.649739	0.05	0.15	-0.1	Ondoy/Sept 24, 2009	5-year
30	14.037893	120.679188	0.03	3	-2.97	Ondoy/Sept 24, 2009	5-year
31	14.038467	120.679593	4.04	3	1.04	Ondoy/Sept 24, 2009	5-year
32	14.038607	120.680144	2.1	2.5	-0.4	Ondoy/Sept 24, 2009	5-year
33	14.038721	120.649696	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
34	14.038915	120.681074	2.32	2.5	-0.18	Ondoy/Sept 24, 2009	5-year
35	14.03904	120.650313	0.04	0	0.04	Ondoy/Sept 24, 2009	5-year
36	14.039135	120.671315	1.15	4	-2.85	Ondoy/Sept 24, 2009	5-year
37	14.039276	120.650898	0.05	0	0.05	Ondoy/Sept 24, 2009	5-year
38	14.039293	120.67169	6.16	5.5	0.66	Ondoy/Sept 24, 2009	5-year
39	14.039481	120.671924	6.28	3	3.28	Ondoy/Sept 24, 2009	5-year
40	14.039485	120.681239	13.15	5.5	7.65	Ondoy/Sept 24, 2009	5-year
41	14.039529	120.670856	0.17	0	0.17	Ondoy/Sept 24, 2009	5-year
42	14.039806	120.648793	0.29	0	0.29	Ondoy/Sept 24, 2009	5-year
43	14.040242	120.651338	0.04	0	0.04	Ondoy/Sept 24, 2009	5-year
44	14.040641	120.651236	0.48	0	0.48	Ondoy/Sept 24, 2009	5-year
45	14.04103	120.623894	0.78	1.5	-0.72	Ondoy/Sept 24, 2009	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
46	14.041051	120.623939	0.03	0.95	-0.92	Ondoy/Sept 24, 2009	5-year
47	14.041097	120.623948	0.18	0.95	-0.77	Ondoy/Sept 24, 2009	5-year
48	14.041112	120.651927	0.41	4	-3.59	Ondoy/Sept 24, 2009	5-year
49	14.041115	120.623883	1.1	1.5	-0.4	Ondoy/Sept 24, 2009	5-year
50	14.0413	120.623937	0.71	1.5	-0.79	Ondoy/Sept 24, 2009	5-year
51	14.041436	120.651813	0.58	4	-3.42	Ondoy/Sept 24, 2009	5-year
52	14.041517	120.644186	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
53	14.041542	120.623975	1.45	2	-0.55	Ondoy/Sept 24, 2009	5-year
54	14.041847	120.624095	1.17	1.5	-0.33	Ondoy/Sept 24, 2009	5-year
55	14.042	120.65152	12.76	5.5	7.26	Ondoy/Sept 24, 2009	5-year
56	14.042095	120.627066	0.53	1.5	-0.97	Ondoy/Sept 24, 2009	5-year
57	14.042106	120.627058	0.03	5.1	-5.07	Ondoy/Sept 24, 2009	5-year
58	14.042206	120.627107	0.03	0.95	-0.92	Ondoy/Sept 24, 2009	5-year
59	14.042254	120.650938	4.58	5.5	-0.92	Ondoy/Sept 24, 2009	5-year
60	14.042318	120.651041	4.88	5.5	-0.62	Ondoy/Sept 24, 2009	5-year
61	14.04234	120.627086	0.08	1.5	-1.42	Ondoy/Sept 24, 2009	5-year
62	14.042347	120.649512	4.27	5.5	-1.23	Ondoy/Sept 24, 2009	5-year
63	14.042365	120.641976	0.05	0	0.05	Ondoy/Sept 24, 2009	5-year
64	14.042436	120.651383	3.71	5.5	-1.79	Ondoy/Sept 24, 2009	5-year
65	14.042461	120.651534	4.44	5.5	-1.06	Ondoy/Sept 24, 2009	5-year
66	14.042579	120.651705	4.58	5.5	-0.92	Ondoy/Sept 24, 2009	5-year
67	14.042865	120.651284	0.97	3	-2.03	Ondoy/Sept 24, 2009	5-year
68	14.043199	120.650385	1.47	2.8	-1.33	Ondoy/Sept 24, 2009	5-year
69	14.043404	120.678101	4	0.9	3.1	Ondoy/Sept 24, 2009	5-year
70	14.043466	120.65156	1.69	3	-1.31	Ondoy/Sept 24, 2009	5-year
71	14.043495	120.677962	4.31	0.9	3.41	Ondoy/Sept 24, 2009	5-year
72	14.04372	120.677748	8.22	5.5	2.72	Ondoy/Sept 24, 2009	5-year
73	14.044014	120.652534	2.1	3.5	-1.4	Ondoy/Sept 24, 2009	5-year
74	14.044121	120.633881	0.7	1.5	-0.8	Ondoy/Sept 24, 2009	5-year
75	14.044552	120.666933	1.5	3	-1.5	Ondoy/Sept 24, 2009	5-year
76	14.044573	120.653335	2.41	3.5	-1.09	Ondoy/Sept 24, 2009	5-year
77	14.044606	120.635822	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
78	14.045281	120.659297	2.16	3	-0.84	Ondoy/Sept 24, 2009	5-year
79	14.045329	120.657527	2.83	0.95	1.88	Ondoy/Sept 24, 2009	5-year
80	14.045341	120.666833	3.14	3	0.14	Ondoy/Sept 24, 2009	5-year
81	14.045683	120.657402	2.8	2	0.8	Ondoy/Sept 24, 2009	5-year
82	14.045851	120.657358	3.17	1.5	1.67	Ondoy/Sept 24, 2009	5-year
83	14.045933	120.654915	1.29	4	-2.71	Ondoy/Sept 24, 2009	5-year
84	14.046002	120.657314	3.33	2	1.33	Ondoy/Sept 24, 2009	5-year
85	14.046212	120.666407	0.71	3	-2.29	Ondoy/Sept 24, 2009	5-year
86	14.046255	120.657501	3.27	3	0.27	Ondoy/Sept 24, 2009	5-year
87	14.046347	120.65778	3.04	3	0.04	Ondoy/Sept 24, 2009	5-year
88	14.046407	120.650235	0.12	0.15	-0.03	Ondoy/Sept 24, 2009	5-year
89	14.046424	120.657941	3.25	3	0.25	Ondoy/Sept 24, 2009	5-year
90	14.046832	120.659077	2.69	3	-0.31	Ondoy/Sept 24, 2009	5-year
91	14.047022	120.666447	8.270001	5.5	2.770001	Ondoy/Sept 24, 2009	5-year
92	14.047264	120.666407	11.82	5.5	6.32	Ondoy/Sept 24, 2009	5-year
93	14.047572	120.665967	21.9	5.5	16.4	Ondoy/Sept 24, 2009	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
94	14.047739	120.652983	0.15	0.15	0	Ondoy/Sept 24, 2009	5-year
95	14.048445	120.653844	0.54	4	-3.46	Ondoy/Sept 24, 2009	5-year
96	14.048902	120.654372	0.68	4	-3.32	Ondoy/Sept 24, 2009	5-year
97	14.049426	120.650312	0.21	0.4	-0.19	Ondoy/Sept 24, 2009	5-year
98	14.050554	120.643238	0.49	0.5	-0.01	Ondoy/Sept 24, 2009	5-year
99	14.050698	120.643398	0.64	0.5	0.14	Ondoy/Sept 24, 2009	5-year
100	14.051312	120.65143	0.31	0	0.31	Ondoy/Sept 24, 2009	5-year
101	14.051409	120.643705	1.8	1.5	0.3	Ondoy/Sept 24, 2009	5-year
102	14.051473	120.643811	1.91	2	-0.09	Ondoy/Sept 24, 2009	5-year
103	14.051486	120.654528	0.03	0.4	-0.37	Ondoy/Sept 24, 2009	5-year
104	14.051518	120.62977	1.21	2	-0.79	Ondoy/Sept 24, 2009	5-year
105	14.05152	120.629596	1.08	2	-0.92	Ondoy/Sept 24, 2009	5-year
106	14.05152	120.643959	2	0.85	1.15	Ondoy/Sept 24, 2009	5-year
107	14.051522	120.644014	1.98	2	-0.02	Ondoy/Sept 24, 2009	5-year
108	14.051546	120.644097	1.94	0.3	1.64	Ondoy/Sept 24, 2009	5-year
109	14.051569	120.629743	1.3	1.5	-0.2	Ondoy/Sept 24, 2009	5-year
110	14.051589	120.659215	0.22	0.3	-0.08	Ondoy/Sept 24, 2009	5-year
111	14.051613	120.659828	0.19	0.25	-0.06	Ondoy/Sept 24, 2009	5-year
112	14.051625	120.662752	0.03	0.1	-0.07	Ondoy/Sept 24, 2009	5-year
113	14.051628	120.629891	1.32	1.5	-0.18	Ondoy/Sept 24, 2009	5-year
114	14.051646	120.644483	1.36	0.3	1.06	Ondoy/Sept 24, 2009	5-year
115	14.051665	120.629952	1.28	0.9	0.38	Ondoy/Sept 24, 2009	5-year
116	14.051672	120.657585	0.11	4	-3.89	Ondoy/Sept 24, 2009	5-year
117	14.051687	120.664555	0.03	0.55	-0.52	Ondoy/Sept 24, 2009	5-year
118	14.051754	120.630104	1.26	0.9	0.36	Ondoy/Sept 24, 2009	5-year
119	14.051836	120.630286	1.33	1.5	-0.17	Ondoy/Sept 24, 2009	5-year
120	14.05186	120.64551	1.62	1.5	0.12	Ondoy/Sept 24, 2009	5-year
121	14.051945	120.630484	1.25	0.9	0.35	Ondoy/Sept 24, 2009	5-year
122	14.052006	120.63075	1.15	0.95	0.2	Ondoy/Sept 24, 2009	5-year
123	14.052027	120.631014	1.08	0.5	0.58	Ondoy/Sept 24, 2009	5-year
124	14.052044	120.645524	1.55	2	-0.45	Ondoy/Sept 24, 2009	5-year
125	14.05226	120.645388	1.5	1.5	0	Ondoy/Sept 24, 2009	5-year
126	14.052358	120.632268	1.16	0.9	0.26	Ondoy/Sept 24, 2009	5-year
127	14.052405	120.632276	1.12	1.5	-0.38	Ondoy/Sept 24, 2009	5-year
128	14.052531	120.632251	1.06	1.5	-0.44	Ondoy/Sept 24, 2009	5-year
129	14.052618	120.64517	1.53	1.5	0.03	Ondoy/Sept 24, 2009	5-year
130	14.052637	120.632218	1.01	0.9	0.11	Ondoy/Sept 24, 2009	5-year
131	14.052732	120.645291	2.2	2	0.2	Ondoy/Sept 24, 2009	5-year
132	14.052741	120.63211	0.76	1.5	-0.74	Ondoy/Sept 24, 2009	5-year
133	14.052785	120.64537	4.96	0.9	4.06	Ondoy/Sept 24, 2009	5-year
134	14.052802	120.64531	2.99	2	0.99	Ondoy/Sept 24, 2009	5-year
135	14.052894	120.645321	5.25	3	2.25	Ondoy/Sept 24, 2009	5-year
136	14.053095	120.631994	0.63	0.9	-0.27	Ondoy/Sept 24, 2009	5-year
137	14.053122	120.645965	8.35	5.5	2.85	Ondoy/Sept 24, 2009	5-year
138	14.053143	120.632034	0.61	0.85	-0.24	Ondoy/Sept 24, 2009	5-year
139	14.053237	120.632002	0.68	1.5	-0.82	Ondoy/Sept 24, 2009	5-year
140	14.05325	120.645865	8.49	5.5	2.99	Ondoy/Sept 24, 2009	5-year
141	14.053368	120.631966	0.97	0.9	0.07	Ondoy/Sept 24, 2009	5-year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
142	14.053469	120.631937	0.92	1.5	-0.58	Ondoy/Sept 24, 2009	5-year
143	14.05353	120.631843	1.05	2	-0.95	Ondoy/Sept 24, 2009	5-year
144	14.053565	120.659608	0.1	0.4	-0.3	Ondoy/Sept 24, 2009	5-year
145	14.053637	120.631903	1.37	1.5	-0.13	Ondoy/Sept 24, 2009	5-year
146	14.053736	120.631887	3.7	2	1.7	Ondoy/Sept 24, 2009	5-year
147	14.053941	120.660996	0.05	0.15	-0.1	Ondoy/Sept 24, 2009	5-year
148	14.055068	120.658334	0.03	0.4	-0.37	Ondoy/Sept 24, 2009	5-year
149	14.055957	120.64453	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
150	14.056803	120.644374	0.08	0.15	-0.07	Ondoy/Sept 24, 2009	5-year
151	14.057033	120.657946	0.23	0.55	-0.32	Ondoy/Sept 24, 2009	5-year
152	14.059153	120.637237	0.04	0.6	-0.56	Ondoy/Sept 24, 2009	5-year
153	14.059272	120.636973	0.03	0.4	-0.37	Ondoy/Sept 24, 2009	5-year
154	14.061867	120.634402	0.03	0.55	-0.52	Ondoy/Sept 24, 2009	5-year
155	14.062119	120.626577	0.13	0.15	-0.02	Ondoy/Sept 24, 2009	5-year
156	14.063731	120.62684	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
157	14.064534	120.626599	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
158	14.065162	120.626492	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
159	14.065894	120.626387	0.03	0.3	-0.27	Ondoy/Sept 24, 2009	5-year
160	14.066361	120.626363	0.06	0.15	-0.09	Ondoy/Sept 24, 2009	5-year
161	14.067038	120.633322	0.03	0.6	-0.57	Ondoy/Sept 24, 2009	5-year
162	14.067291	120.632507	0.14	0.25	-0.11	Ondoy/Sept 24, 2009	5-year
163	14.067646	120.628422	0.04	0.6	-0.56	Ondoy/Sept 24, 2009	5-year
164	14.068635	120.631637	0.15	0.05	0.1	Ondoy/Sept 24, 2009	5-year
165	14.069367	120.63476	0.07	0.25	-0.18	Ondoy/Sept 24, 2009	5-year
166	14.069552	120.635568	0.93	0	0.93	Ondoy/Sept 24, 2009	5-year
167	14.070984	120.631819	0.21	0.1	0.11	Ondoy/Sept 24, 2009	5-year
168	14.07127	120.631116	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
169	14.072719	120.632829	0.11	0	0.11	Ondoy/Sept 24, 2009	5-year
170	14.073248	120.635815	0.98	0.25	0.73	Ondoy/Sept 24, 2009	5-year
171	14.073399	120.653155	0.03	0.3	-0.27	Ondoy/Sept 24, 2009	5-year
172	14.075031	120.634396	0.05	0	0.05	Ondoy/Sept 24, 2009	5-year
173	14.075125	120.63302	0.18	0.15	0.03	Ondoy/Sept 24, 2009	5-year
174	14.076208	120.634734	0.03	0.3	-0.27	Ondoy/Sept 24, 2009	5-year
175	14.076748	120.634916	0.07	0.1	-0.03	Ondoy/Sept 24, 2009	5-year
176	14.076853	120.631371	0.03	0.35	-0.32	Ondoy/Sept 24, 2009	5-year
177	14.081106	120.659126	0.03	0.15	-0.12	Ondoy/Sept 24, 2009	5-year
178	14.082489	120.659651	0.06	0.05	0.01	Ondoy/Sept 24, 2009	5-year
179	14.084299	120.660413	0.03	0	0.03	Ondoy/Sept 24, 2009	5-year
180	14.086702	120.660967	0.22	0.25	-0.03	Ondoy/Sept 24, 2009	5-year
				RMSE	1.990012		

Annex 12. Educational Institutions Affected in Lian Flood Plain

Batangas				
Lian				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
SMARTKIDS of Mary Mediatrix School, Inc.	Barangay 1		Low	Medium
Lumbangan National High School	Barangay 5			Low
Divine Mercy Daycare Center	Malaruhatan			Low
Yale Children's School	San Diego			

Batangas				
Nasugbu				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bunducan Elementary School	Bunducan	Medium	Medium	Medium
Balokbalok Elementary School	Catandaan		Low	Low
Catandaan Elementary School	Catandaan			
Catandaan National High School	Catandaan			
Patnubay Daycare Center	Cogunan			
Dayap Elementary School	Dayap			
Malapad Na Bato National High School	Malapad Na Bato			
Tala National High School	Munting Indan			
Pingkian Elementary School	Reparo			
Utod Elementary School	Utod			

Annex 13. Medical Institutions Affected in Lian Flood Plain

Batangas				
Nasugbu				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Dayap	Low	Low	Low