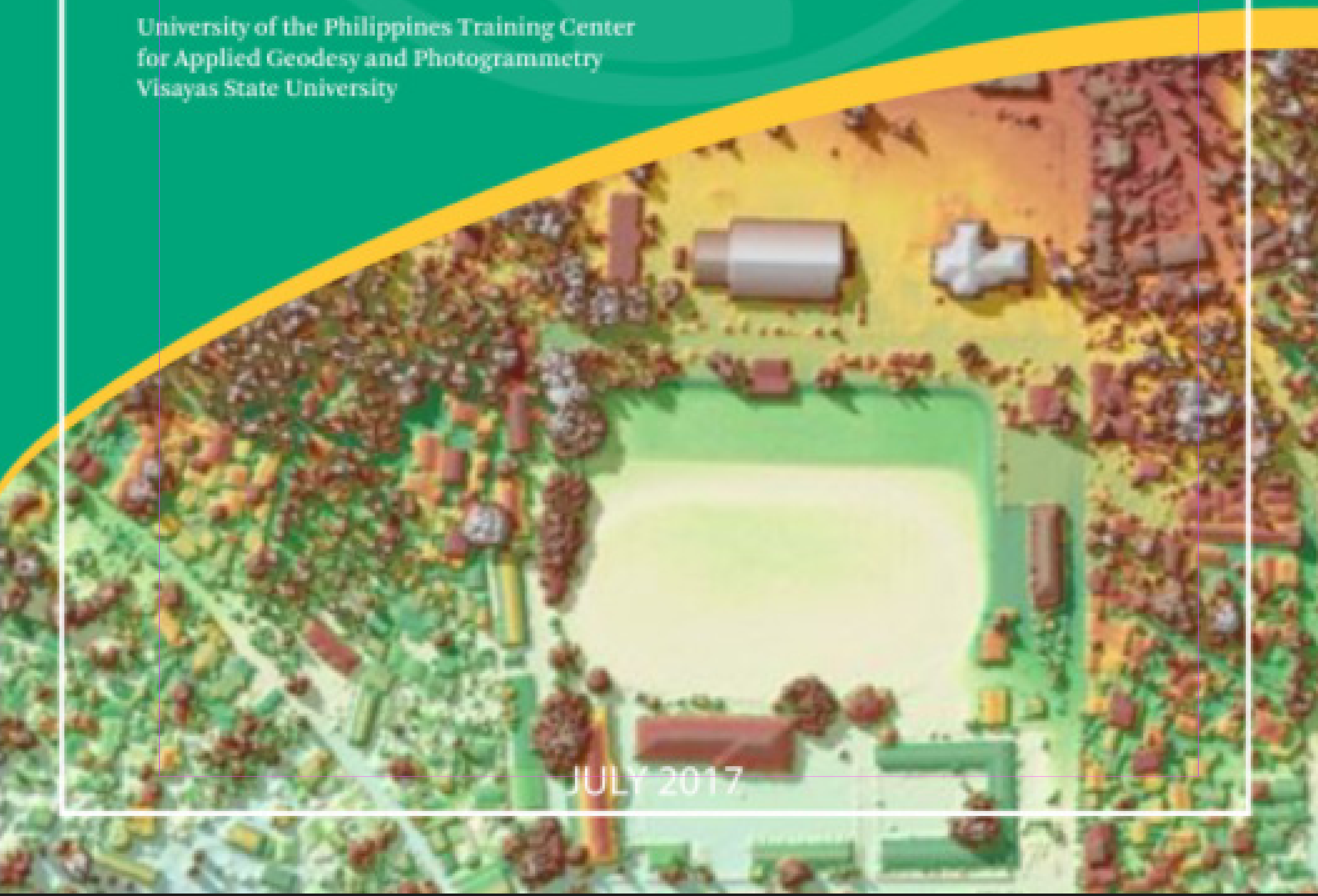
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Subangdaku River

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



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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SUBANGDAKU RIVER

Enrico C. Paringit, Dr. Eng., Dr. George Puno, and Eric Bruno

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, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at a 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 was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the twenty-eight (28)river basins in the Eastern Visayas Region. The university is located in BaybayCity in the province of Leyte.

1.2 Overview of the Subangdaku River Basin

The Subangdaku River Basin covers eight (8) barangays in the Municipality of Sogod in the province of Southern Leyte. According to the Department of Environment - River Basin Control Office (DENR-RBCO), it has a drainage area of 114 km^2, and an estimated 214 million cubic meters (MCM) in annual run-off (RCBO, 2015).

The river basin's main stem, the Subangdaku River,is part of the twenty-eight(28) river systems in the Visayas Region. It is also known locally as the Pandan River.

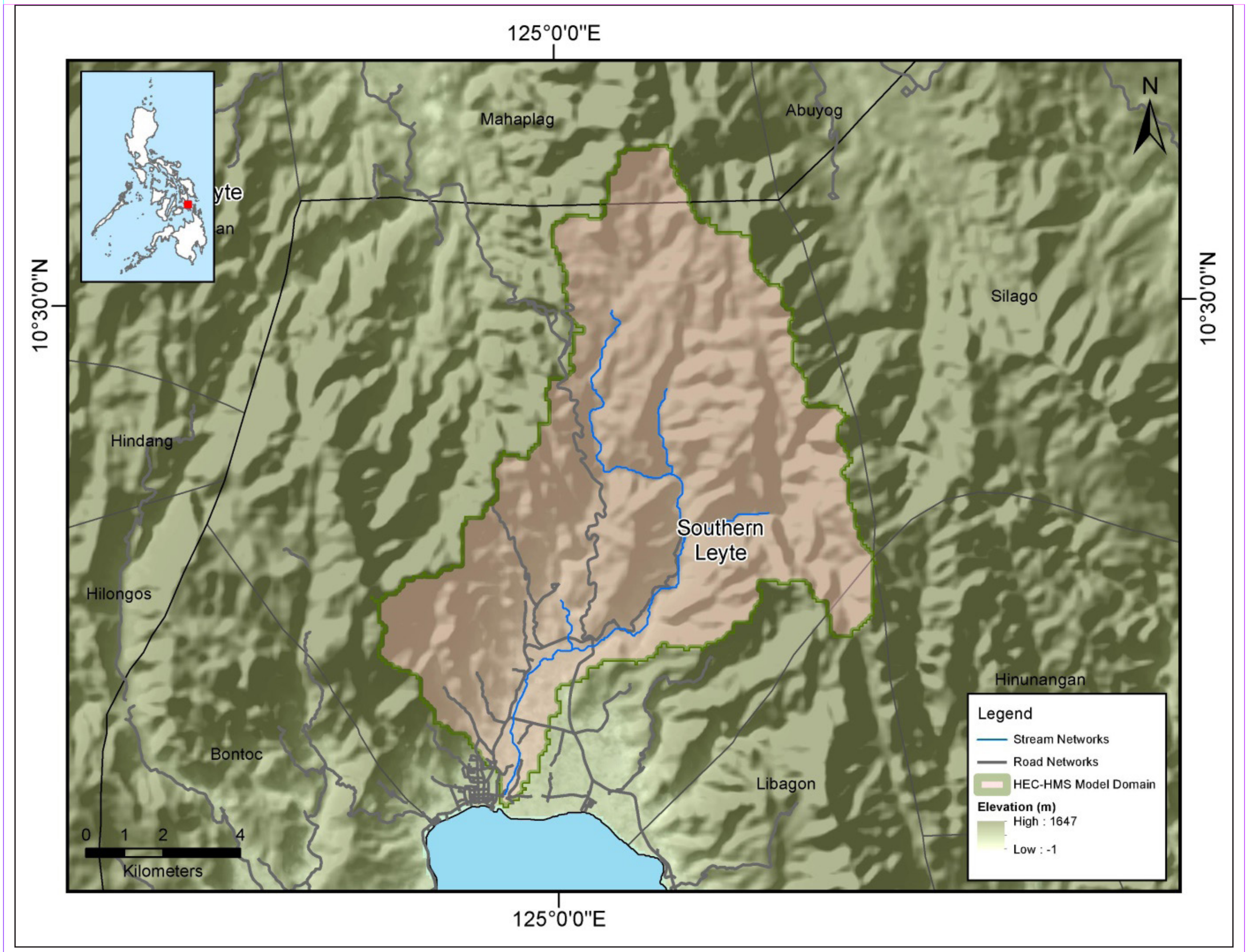

Figure 1. Location map of the Subangaku River Basin (in brown)

According to the 2010 national census of the National Statistics Office (NSO), the total population of residents within the immediate vicinity of the river is 8,936, distributed among eight (8) barangays in the Municipality of Sogod.

The river supplies irrigation to the agricultural production of rice, corn, coconuts, tobacco, abaca, and root crops, which are the primary sources of livelihood in the area. Activities of quarrying firms in the Subangdaku River greatly impact the economic performance of the Municipality of Sogod (Southern Leyte Times, 2013).

The most recent and significant flooding event in the area occurredin November 2013, which was caused by SuperTyphoon Haiyan (locally named as *Yolanda*).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SUBANGDAKUFLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Subangdakufloodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Southern Leyte. Each flight mission hadan average of seventeen (17) lines and ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Gemini and Aquarius LiDAR systems were used for the missions (See Annex 1 for the sensor specifications).The flight planning parameters for the LiDAR systems used are found in Table 1 and Table 2.Figure 2illustratesthe flight plans for theSubangdaku floodplain.

Table 1. Flight planning parameters for the 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)
BLK49A	1000	30	36	125	50	130	5
BLK49B	1000	30	36	125	50	130	5

Table 2. Flight planning parameters for the Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK49C	600	35	36	70	45	120	5
BLK49D	600	35	36	70	45	120	5

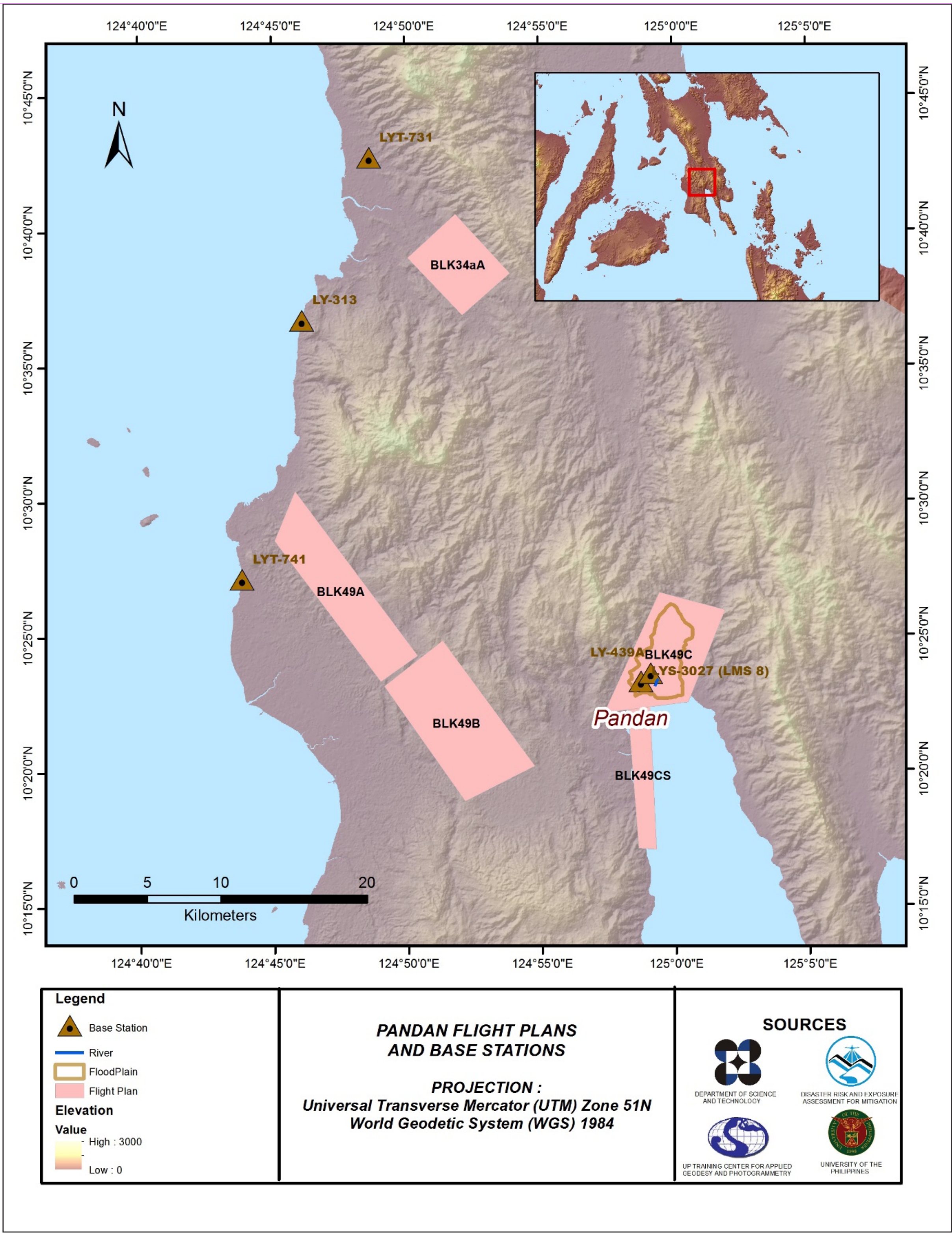
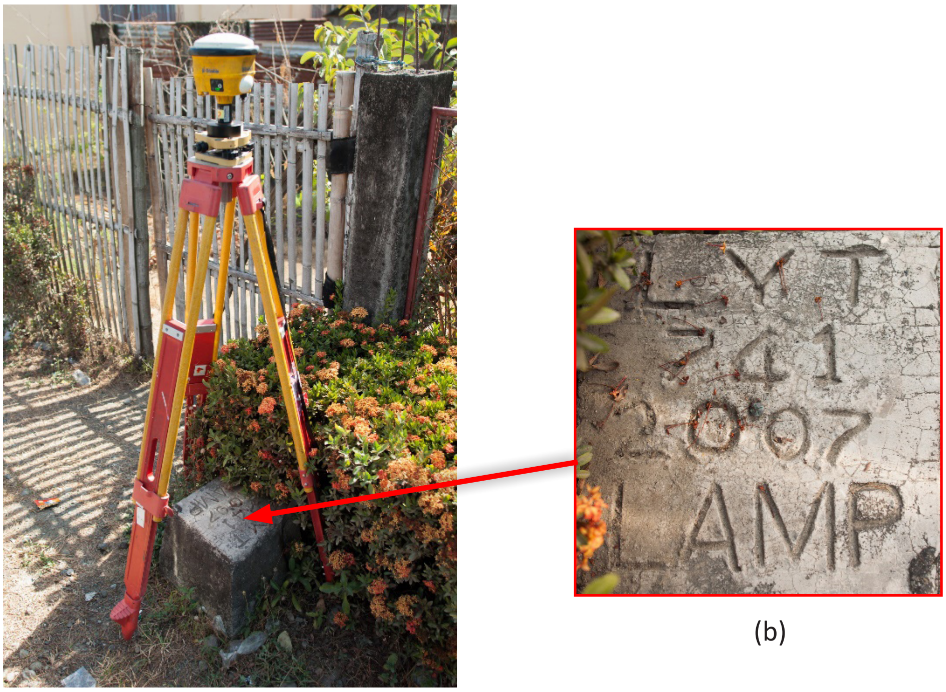


Figure 2. Flight plans and base stations used to cover the Subangdaku floodplain surve

2.2 Ground Base Stations

The field team for this undertaking was able to recover two (2) NAMRIA ground control points, LYT-741 and LYT-731, which are of second (2nd) order accuracy. The fieldteam also re-established LYS-3027, a NAMRIA reference point of fourth (4th) order accuracy. Two (2) NAMRIA benchmarks were recovered, LY-313 and LT-439A, which are of second (2nd) order accuracy. Both benchmarks were established as ground control points; andLY-313 was also used as a vertical reference point. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2;while the baseline processing reports for the established control points are found in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on January 21 – February 17, 2015; and on April 6-20, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. The flight plans and the locations of the base stations used during the aerial LiDAR acquisition in the Subangdaku floodplain are shown in Figure 2.The composition of the project team is given in Annex 4.

Figure 3 to Figure 8 exhibit the recovered NAMRIA reference points within the area. Table 3 to Table 8 provide the details on the corresponding NAMRIA control stations and established points. Table 9 lists all of the ground control points occupied during the acquisition, with the corresponding dates of utilization.



(b)

(a)

Figure 3. (a) GPS set-up over LYT-741, located on the opposite side of the road, about 36 meters away from the gate of the barangay hall of Doos Del Norte in the Municipality of Hindang; and (b) NAMRIA reference point LYT-741, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point LYT-741, used as a base station for the LiDAR acquisition

Station Name	LYT-741	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 27' 11.95722" North 124° 43' 45.08400" East 4.48300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	470351.659 meters 1155878.867 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 27' 7.86786" North 124° 43' 50.31177" East 67.94500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	689272.22 meters 1155979.90 meters

Figure 4. (a) GPS set-up over LYT-731, located in Barangay Kansungka, Baybay City, Leyte; and (b) NAMRIA reference point LYT-731, as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point LYT-731, used as a base station for the LiDAR acquisition

Station Name	LYT-731	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 42’ 47.59464” North 124° 48’ 34.34385” East 15.61000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	479165.977 meters 1184617.338 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 42’ 43.44572” North 124° 48’ 39.54791” East 78.65700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	697902.22 meters 1184777.35 meters

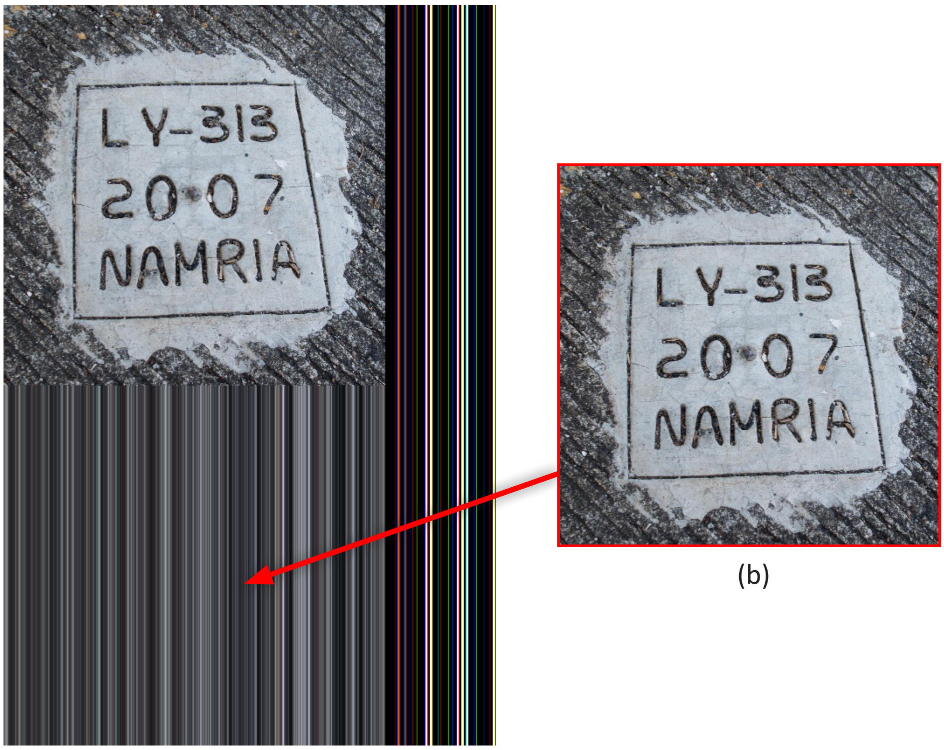
(b)

(a)

Figure 5. (a) GPS set-up over LYS-3027, located inside the campus of Sogod National High School in the Municipality of Sogod, Southern Leyte; and (b) NAMRIA reference point LYS-3027, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point LYS-3027, used as a base station for the LiDAR acquisition

Station Name	LYS-3027	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 23’ 21.51724” North
	Longitude	124° 58’ 38.32069” East
	Ellipsoidal Height	16.531000 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 23’17.46586” North 124° 58’ 43.55182” East 78.65700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	716484.590 meters 1149058.376 meters



(b)

(a)

Figure 6. (a) GPS set-up over LY-313, about 40 meters southwest of the Barangay Maitum marker, and 80 meters west of the Kilometer 1068 post in the Municipality of Baybay; and (b) NAMRIA benchmark LY-313, as recovered by the field team

Table 6. Details of the recovered NAMRIA vertical reference point LY-313, which was established as a GCP and used as a base station for the LiDAR acquisition

Station Name	LY-313	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 36' 46.67221" North
	Longitude	124° 46' 1.85493" East
	Ellipsoidal Height	9.14500 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	16° 11' 15.87355" North
	Longitude	119° 54' 15.61937" East
	Ellipsoidal Height	45.344 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	593326.992 meters
	Northing	1173661.007 meters

Figure 7. (a) GPS set-up over LY-439A; and (b) NAMRIA reference point LY-439A, as recovered by the field team

Table 7. Details of the recovered NAMRIA vertical reference point LY-439A, which was established as a ground control point and used as a base station for the LiDAR acquisition

Station Name	LY-439A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 23' 21.51652" 124° 58' 38.32154" 16.572 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 23' 17.46513" North 124° 58' 43.55267" East 80.795 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	716484.616 meters 1149058.354 meters

Table 8. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 28, 2015	7766AC	3BLK49CD028	LYS-3027, LY-439A, and LYT-731
April 10, 2016	3923G	2BLK49AB101B	LYT-741 and LY-313

2.3 Flight Missions

A total of two (2) flight missions were conducted to complete the LiDAR data acquisition in the Subangdaku floodplain, for a total of six hours and twenty nine (6+29) minutes of flying time for RP-C9322 and RP-C9022. All missions were acquired using the Aquarius and Gemini LiDAR systems. The flight logs for the missions are provided in Annex 6.Table 9indicatesthe actual coverage and flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for the LiDAR data acquisition in the Subangdaku floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
January 28, 2015	7766AC	37.5	38.172	14.330	23.842	NA	3	41
April 10, 2016	3923G	135	208.295	14.642	193.653	NA	2	48
TOTAL							6	29

Table 10. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7766AC	600	35	36	70	45	130	5
3923G	1000	35	36	125	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Subangdaku floodplain, which is located in the province of Southern Leyte, with majority of the floodplain situated within the Municipality of Sogod. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is outlined in Table 11. The actual coverage of the LiDAR acquisition for the Subangdaku floodplain is presented in Figure 8. See Annex 7 for the flight status reports.

Table 11. List of municipalities and cities surveyed during the Subangdaku floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Southern Leyte	Bato	57.55	20.34	35%
	Baybay City	404.37	39.18	10%
	Bontoc	89.135	9.39	11%
	Hilongos	156.79	55.82	36%
	Hindang	106.76	25.17	24%
	Inopacan	196.05	16.24	8%
	Matalom	110.12	2.42	2%
	Tomas Oppus	87.46	41.29	47%
	Sogod	217.20	1.92	1%
Total		1425.44	211.77	14.86%

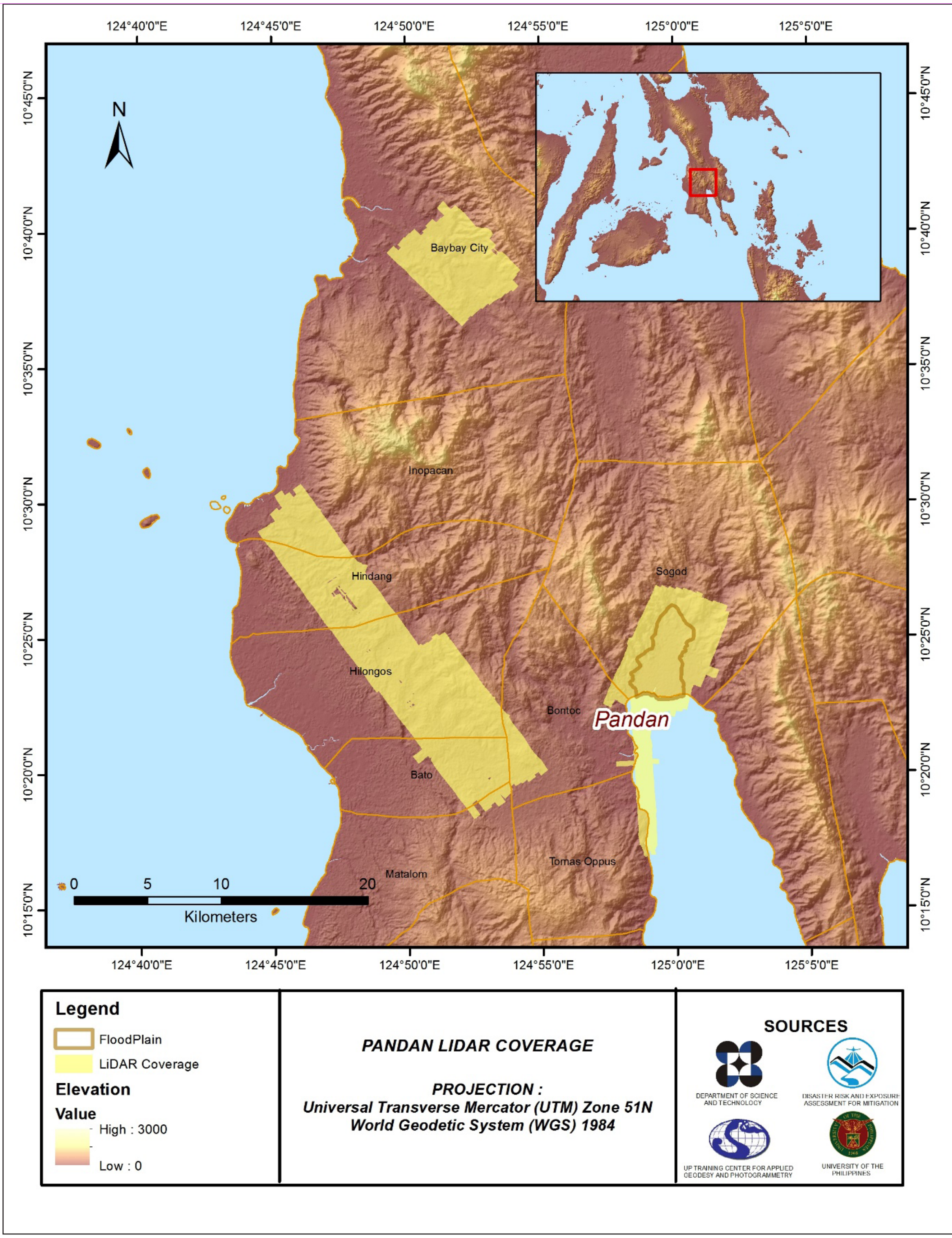


Figure 8. Actual LiDAR survey coverage of the Subangdaku floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE SUBANGDAKUFLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the diagram in Figure 9.

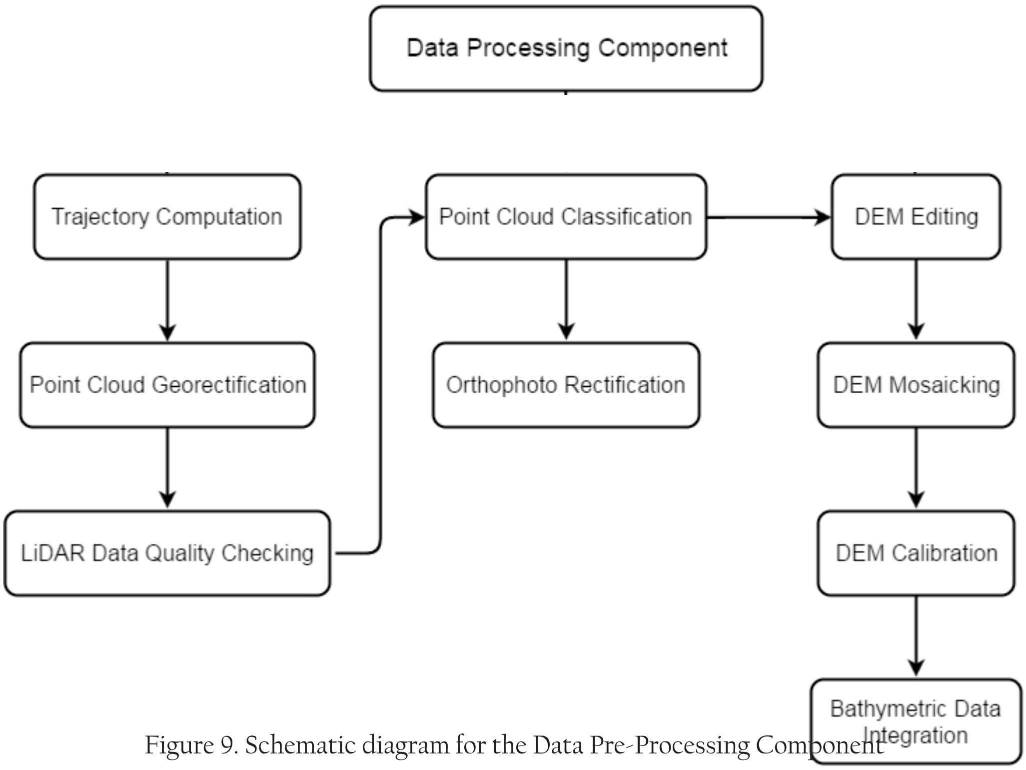


Figure 9. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Subangdaku floodplain can be found in Annex 5.Missions flown during the first survey conducted in January 2015 used the Airborne LiDAR Terrain

Mapper (ALTM™ Optech Inc.) Aquarius system; while missions acquired during the second survey in April 2016 were flown using the Gemini system over Sogod, Southern Leyte. The DAC transferred a total of 15.21 Gigabytes of Range data, 384 Megabytes of POS data, and 46.2 Megabytes of GPS base station data to the data server on January 21, 2015 for the first survey, and on April 16, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Subangdaku River survey was fully transferred on May 6, 2016, as indicated on the data transfer sheets for the Subangdaku floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7766A, one of the Subangdaku flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell onJanuary 28, 2015 at 00:00hrs. on that week. The y-axis represents the RMSE value for that particular position.

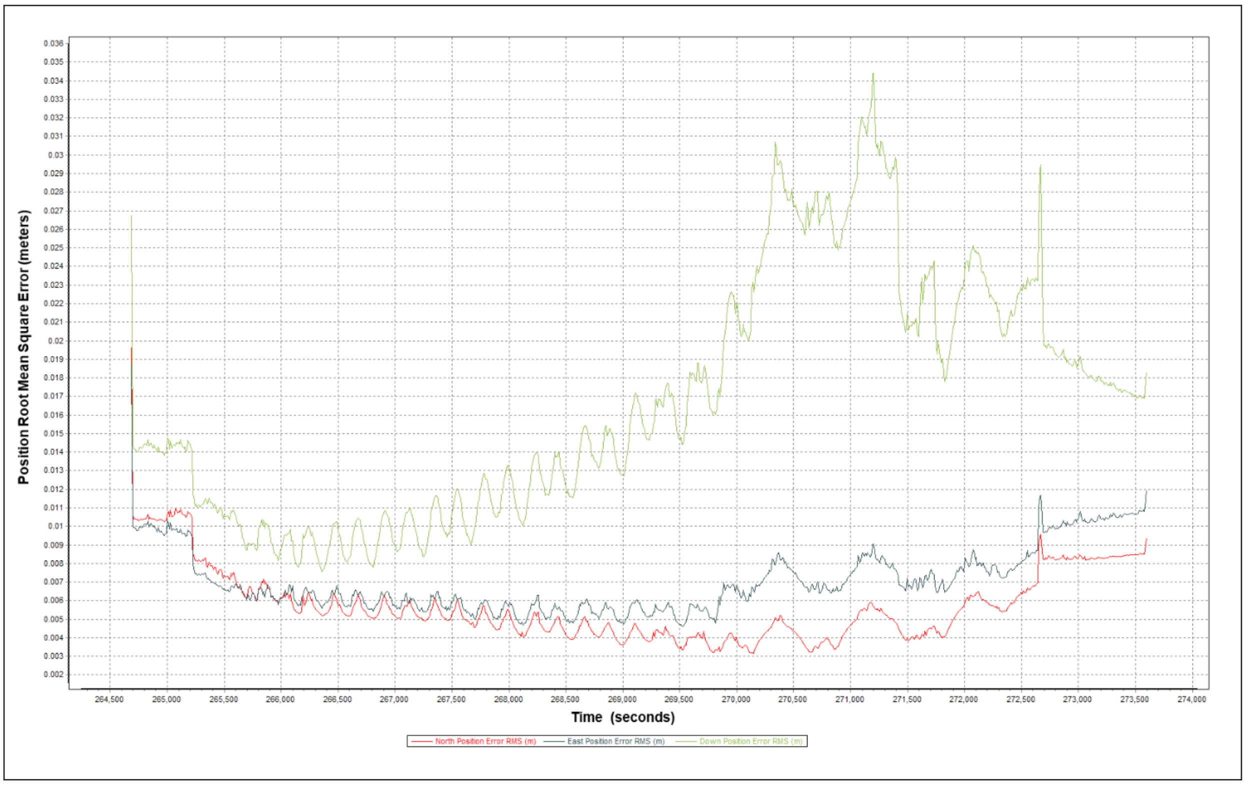


Figure 10. Smoothed Performance Metrics of Subangdaku Flight 7766A

The time of flight was from 264500 seconds to 274000 seconds, which corresponds to the morning of January 28, 2015. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute 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 set of RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10depicts that the North position RMSE peaked at 1.10 centimeters, the East position RMSE peaked at 1. 20 centimeters, and the Down position RMSE peaked at 3.50 centimeters, which are within the prescribed accuracies described in the methodology.

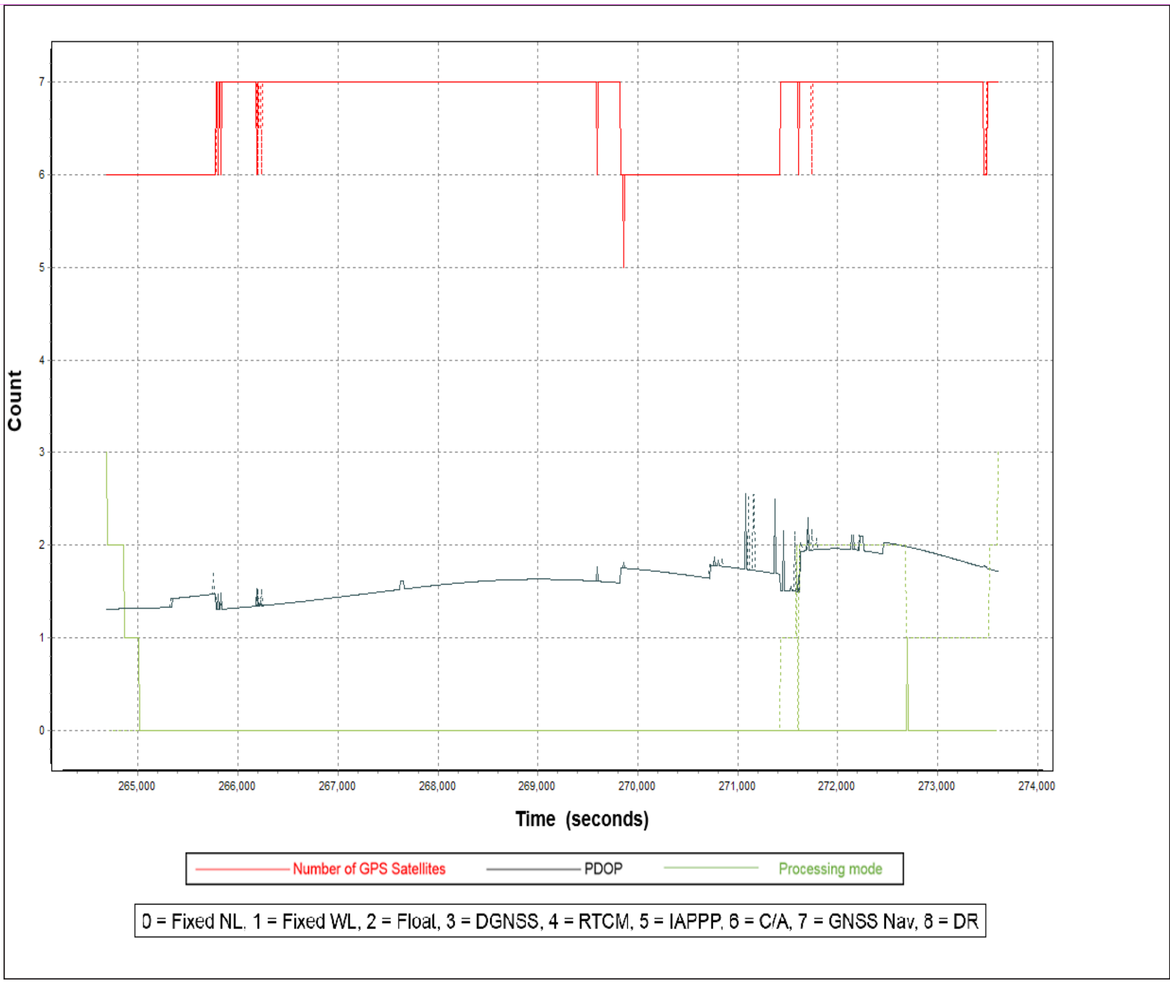


Figure 11. Solution Status Parameters of Subangdaku Flight 7766A

The Solution Status parameters of flight 7766A, one of the Subangdaku flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are demonstratedin Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down below 6. Most of the time, the number of satellites tracked was between 5 and 7. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks to up to 3, 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 satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Subangdaku flights is exhibited in Figure 12.

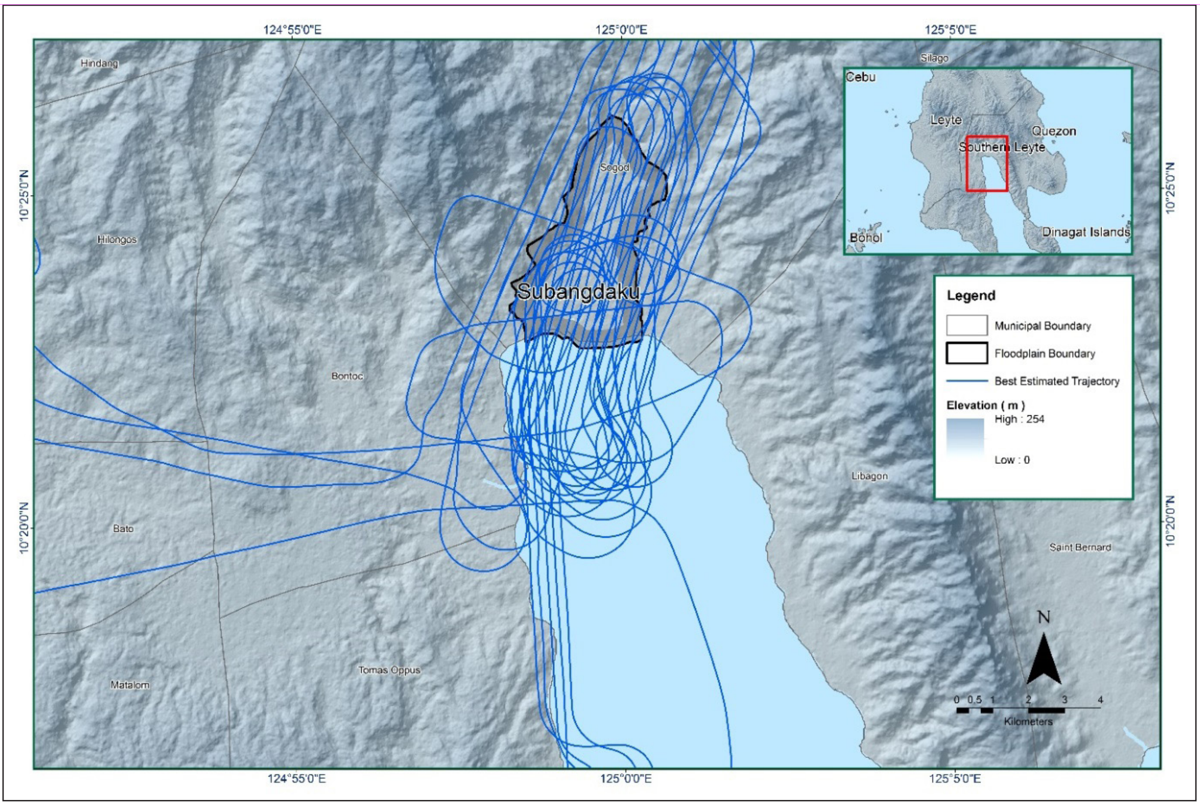


Figure 12. Best estimated trajectory conducted over the Subangdaku floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains thirty-four (34) flight lines, with each flight line containing one (1) channel, since the Gemini and Aquarius systems both contain only one (1) channel. The summary of the self-calibration results for all flights over the Subangdaku floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software,is given in Table 12.

Table 12. Self-calibration results for the Subangdaku flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000323
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.001762
GPS Position Z-correction stdev (<0.01meters)	0.0044

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data are represented in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

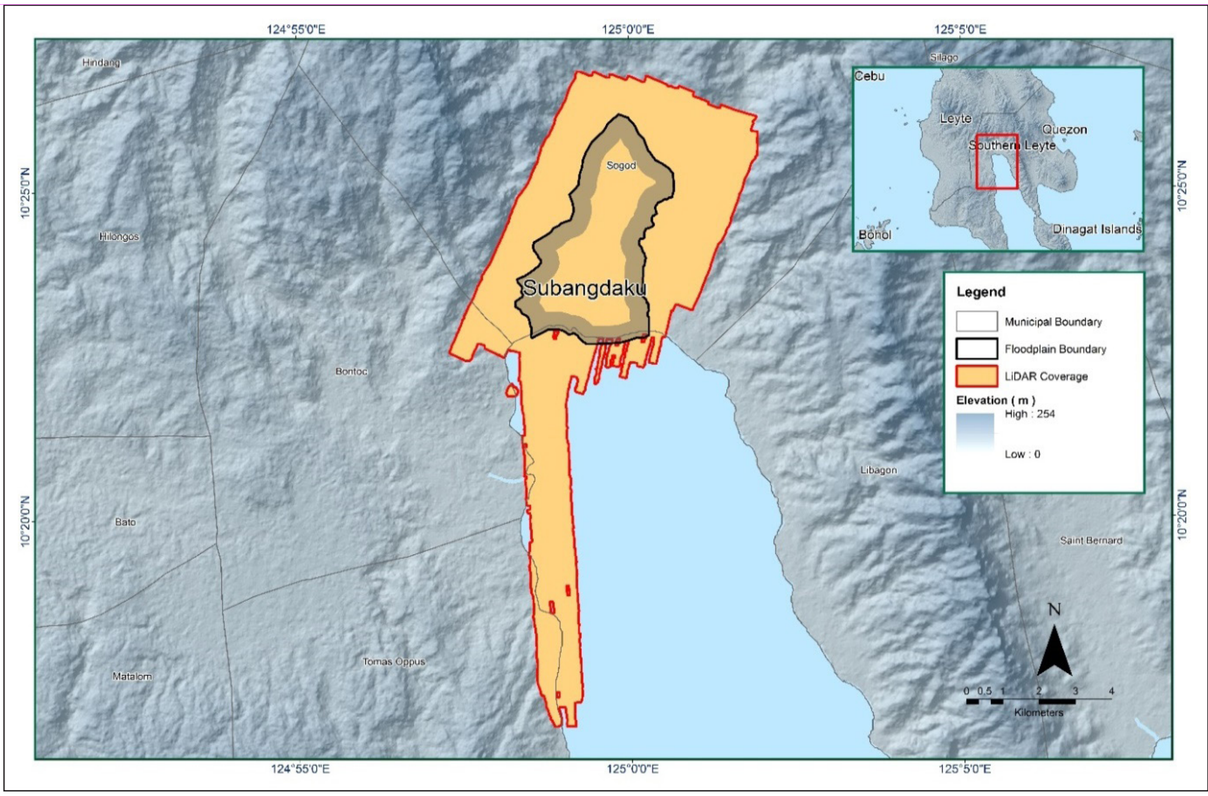


Figure 13. Boundaries of the processed LiDAR data on top of an SAR Elevation Data over the Subangdaku floodplain.

The total area covered by the Subangdaku missions is 74.70 square kilometers,comprised of two (2) flight acquisitions grouped and merged into two (2) blocks, as enumeratedin Table 13.

Table 13. List of LiDAR blocks for the Subangdaku floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Ormoc_Blk49CD	7766AC	35.00
Ormoc_South_Blk49C	3923G	39.70
TOTAL		74.70 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presentedin Figure 14. Since the Gemini and Aquarius systems both employ one (1) channel, it is expected to have an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

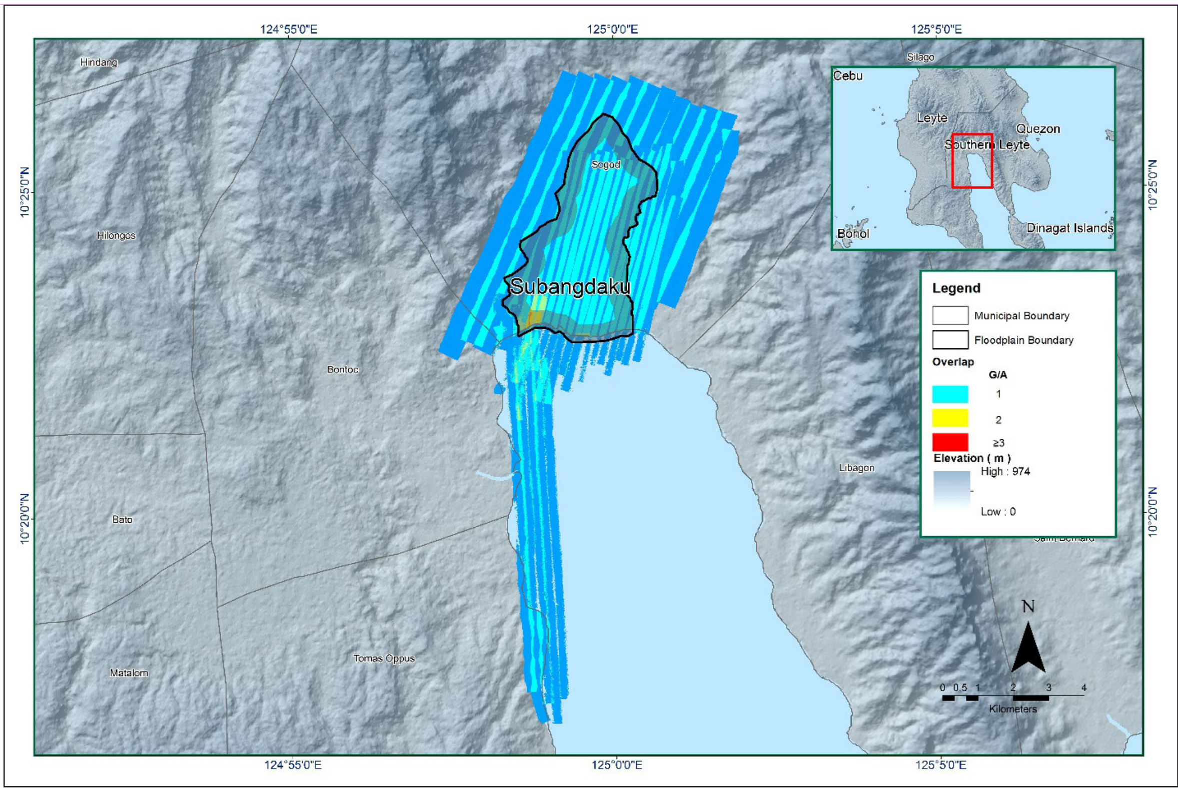


Figure 14. Image of data overlap for the Subangdaku floodplain

The overlap statistics per block for theSubangdaku floodplain can be found in Annex 8. It should be noted that one (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were31.65% and 42.31%, respectively, which satisfiedthe 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is illustratedin Figure 15. It was determined that all LiDAR data for the Subangdaku floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.495 points per square meter.

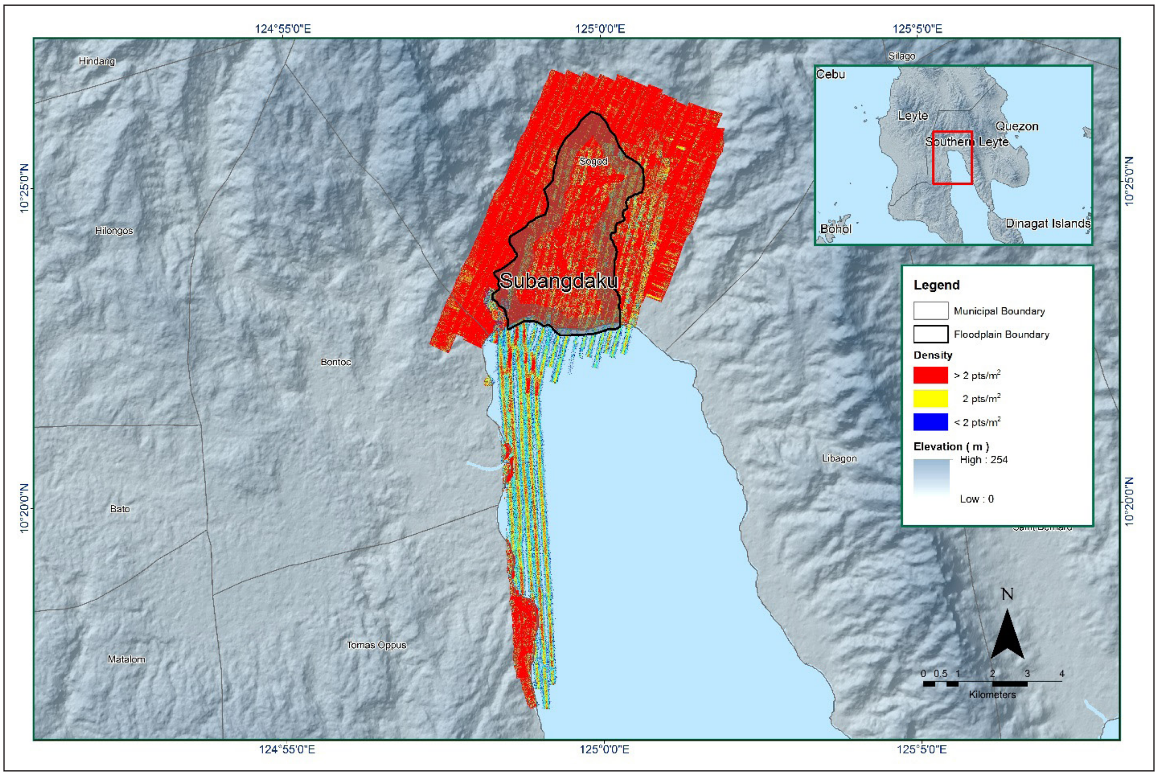


Figure 15. Pulse density map of merged LiDAR data for the Subangdaku floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red.Bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20metersrelative to the elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20metersrelative to the elevations of its adjacent flight line. Areas with bright red or bright blue colorswere investigated further using the Quick Terrain (QT) Modeler software.

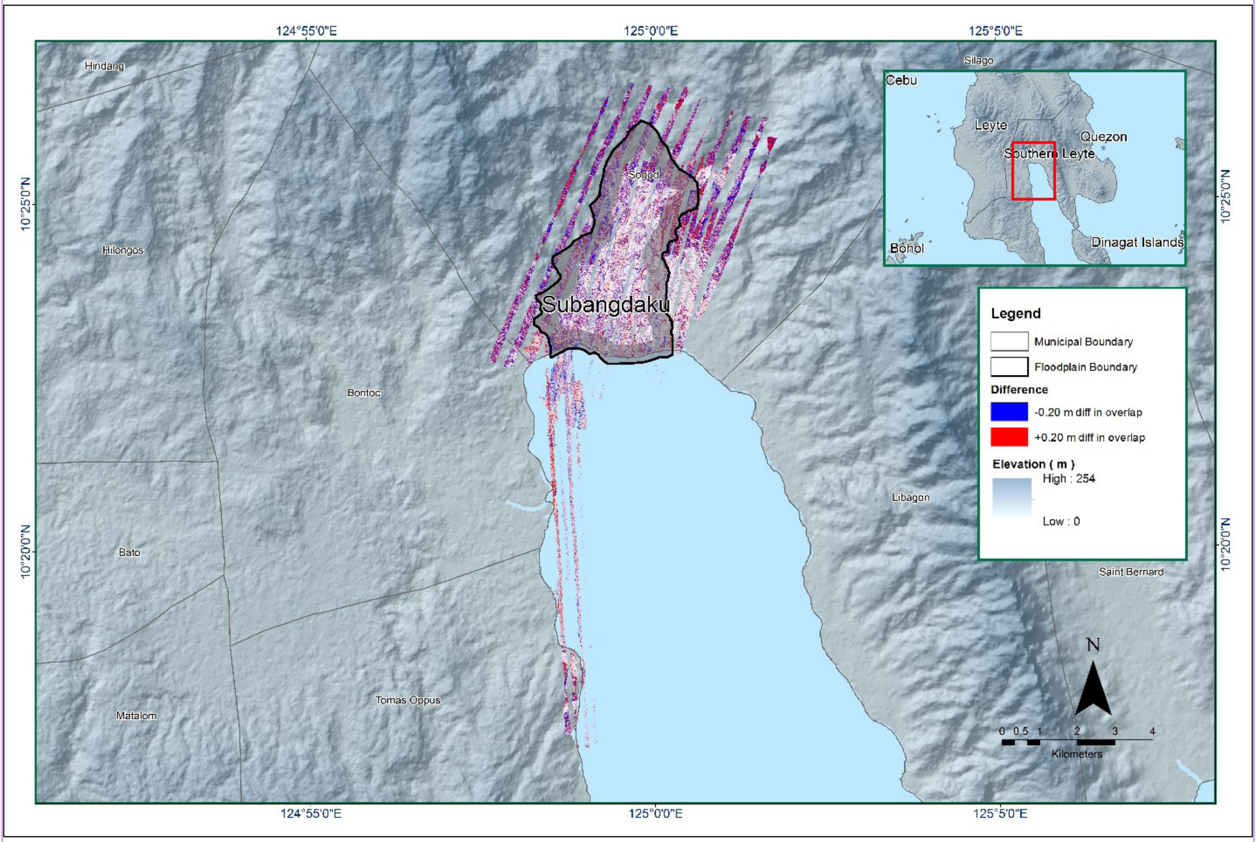


Figure 16. Elevation difference map between flight lines for the Subangdaku floodplain

A screen capture of the processed LAS data from a SubangdakuFlight 7766A loaded in the QT Modeler is providedin Figure 17. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed purple line. The x-axis corresponds to the length of the profile. It is evident that there weredifferences in elevation, but the differences didnot exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becamesatisfactory. No reprocessing was done for this LiDAR dataset.

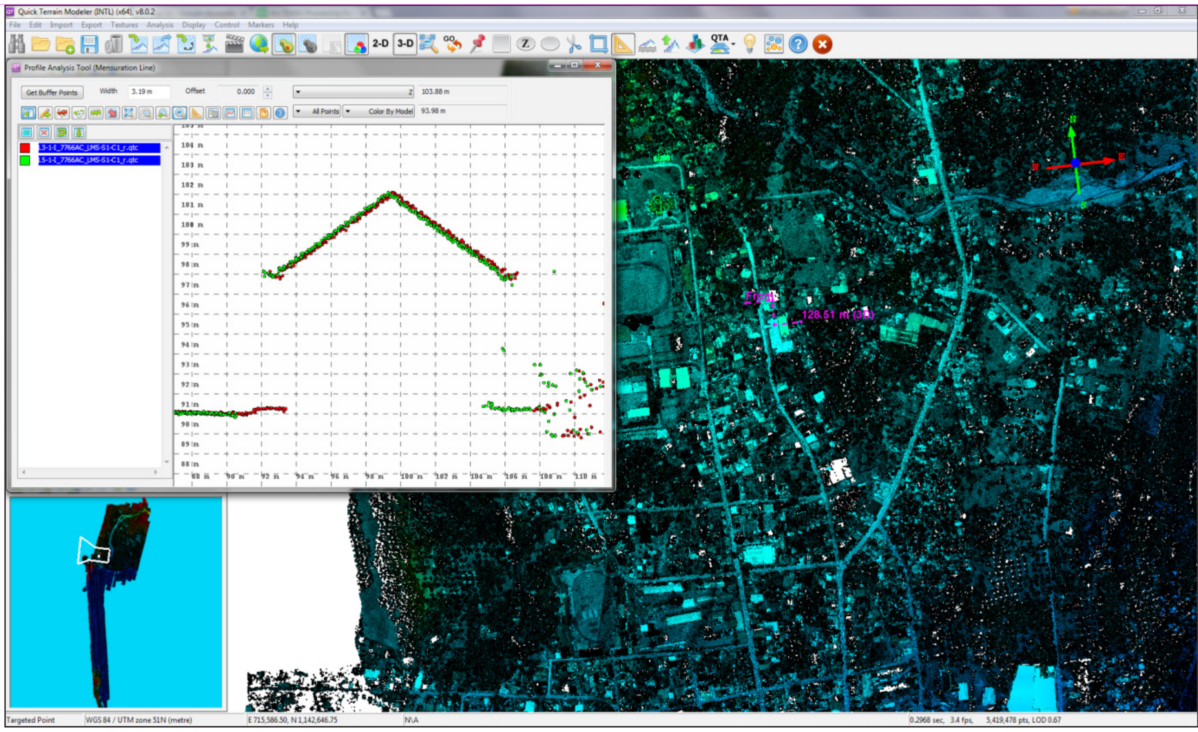


Figure 17. Quality checking for a Subangdaku flight 7766A using the Profile Tool of the QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Subangdaku classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	35,355,069
Low Vegetation	29,479,743
Medium Vegetation	57,920,618
High Vegetation	122,338,323
Building	3,359,873

The tile system that TerraScan employed for the LiDAR data,as well asthe final classification image for a block in the Subangdaku floodplain,arepresentedin Figure 18. A total of 115 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 14. The point cloud had a maximum and minimum height of 535 meters and 57.62 meters, respectively.

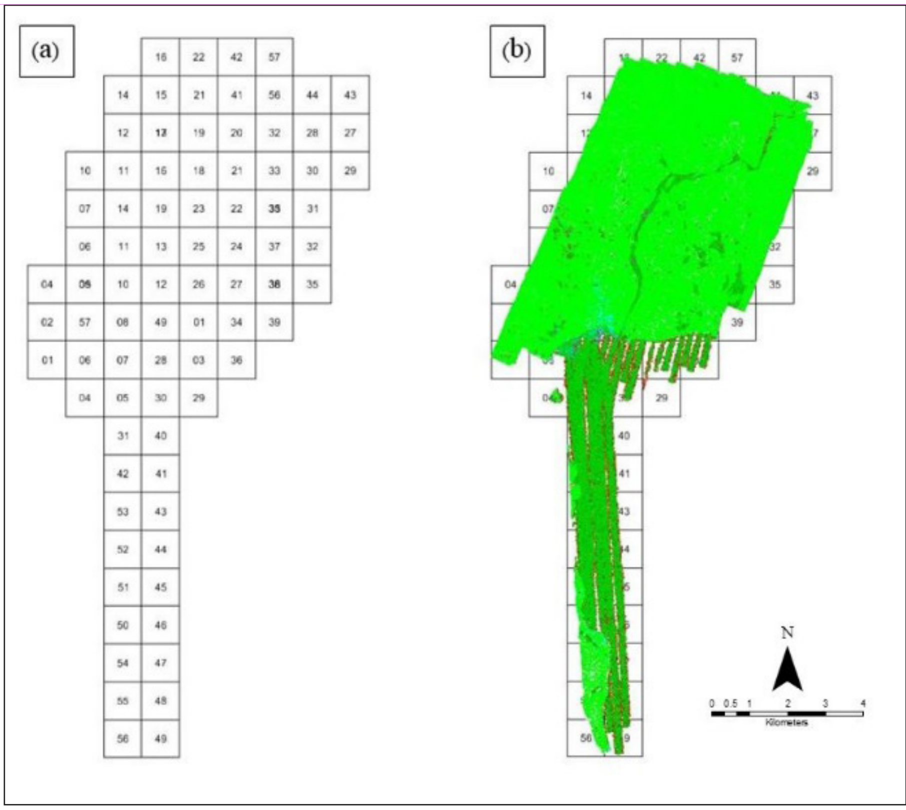


Figure 18. (a) Tiles for the Subangdaku floodplain; and (b) the classification results in TerraScan

An isometric view of an area before and after running the classification routines is presentedin Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy wereclassified correctly, due to the density of the LiDAR data.

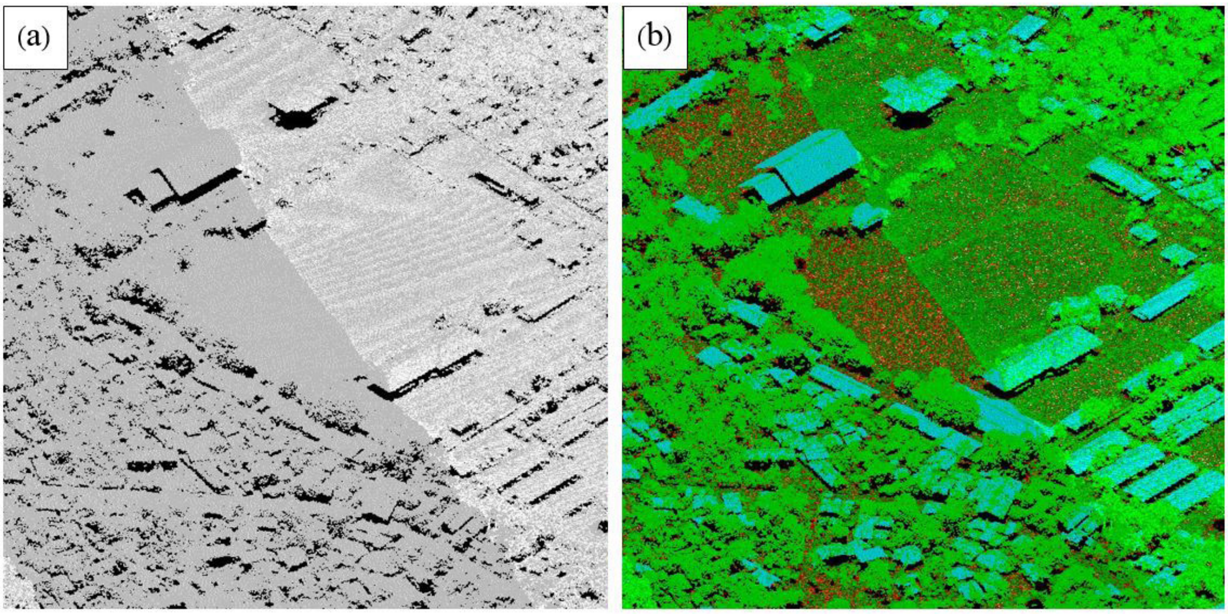


Figure 19. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the areaare illustrated in Figure 20, in top view display. The images demonstrate that the DTMs are arepresentation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

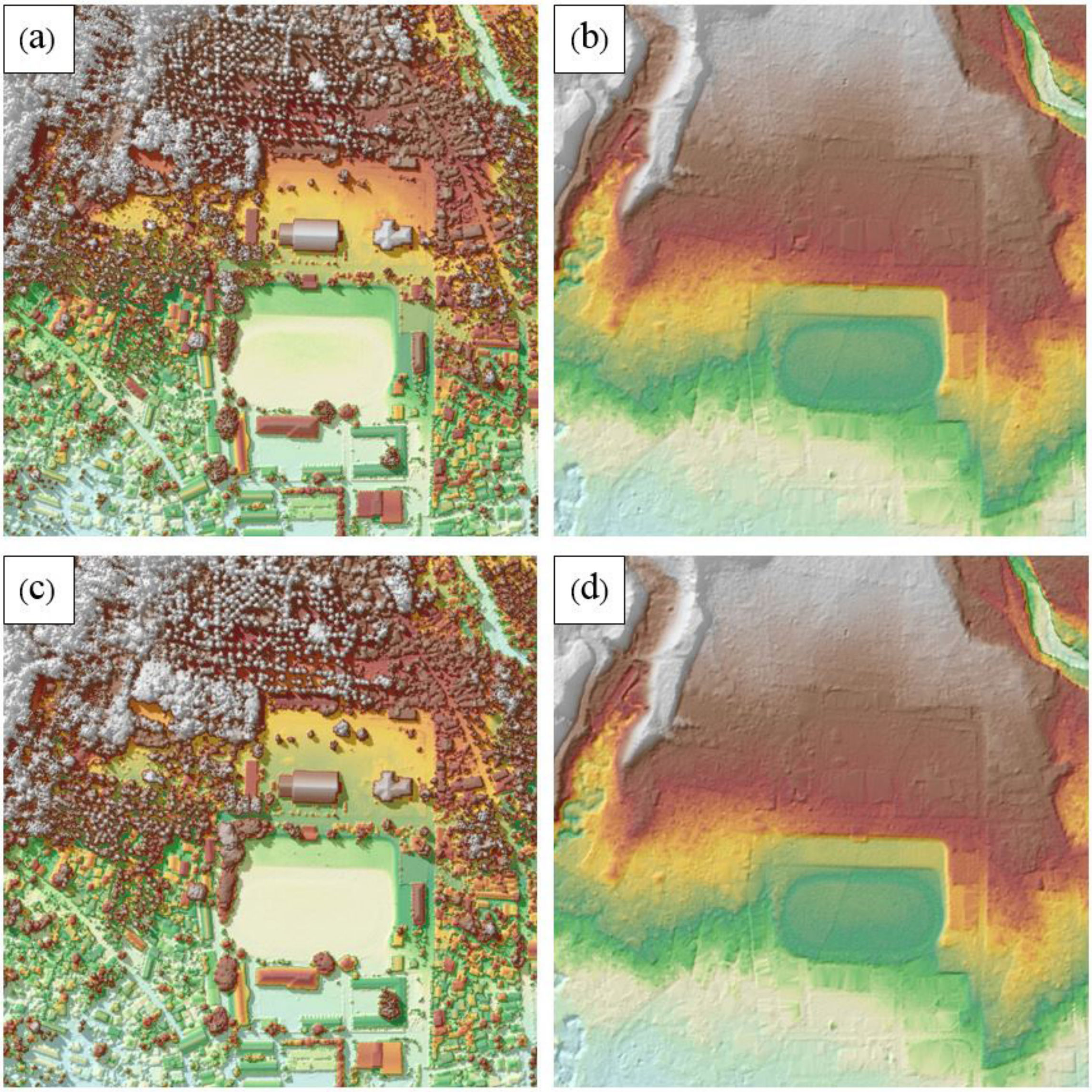


Figure 20. The (a) production of last return DSM and (b) DTM; (c) first return DSM and (d) secondary DTM, in some portion of the Subangdaku floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Subangdaku floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for the Subangdaku floodplain. These blocks are composed of Ormoc and OrmocSouth blocks, with a total area of 74.70 square kilometers. Table 15outlinesthe names and corresponding areas of theblocks, in square kilometers.

Table 15. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Ormoc_Blk49CD	35.00
Ormoc_South_Blk49C	39.70
TOTAL	74.70 sq.km

Portions of the DTM before and after manual editing are shown in Figure 21. The river embankment (Figure 21a) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 21b) in order to allow for the correct flow of water. The bridge (Figure 21c) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 21d) in order to hydrologically correct the river.

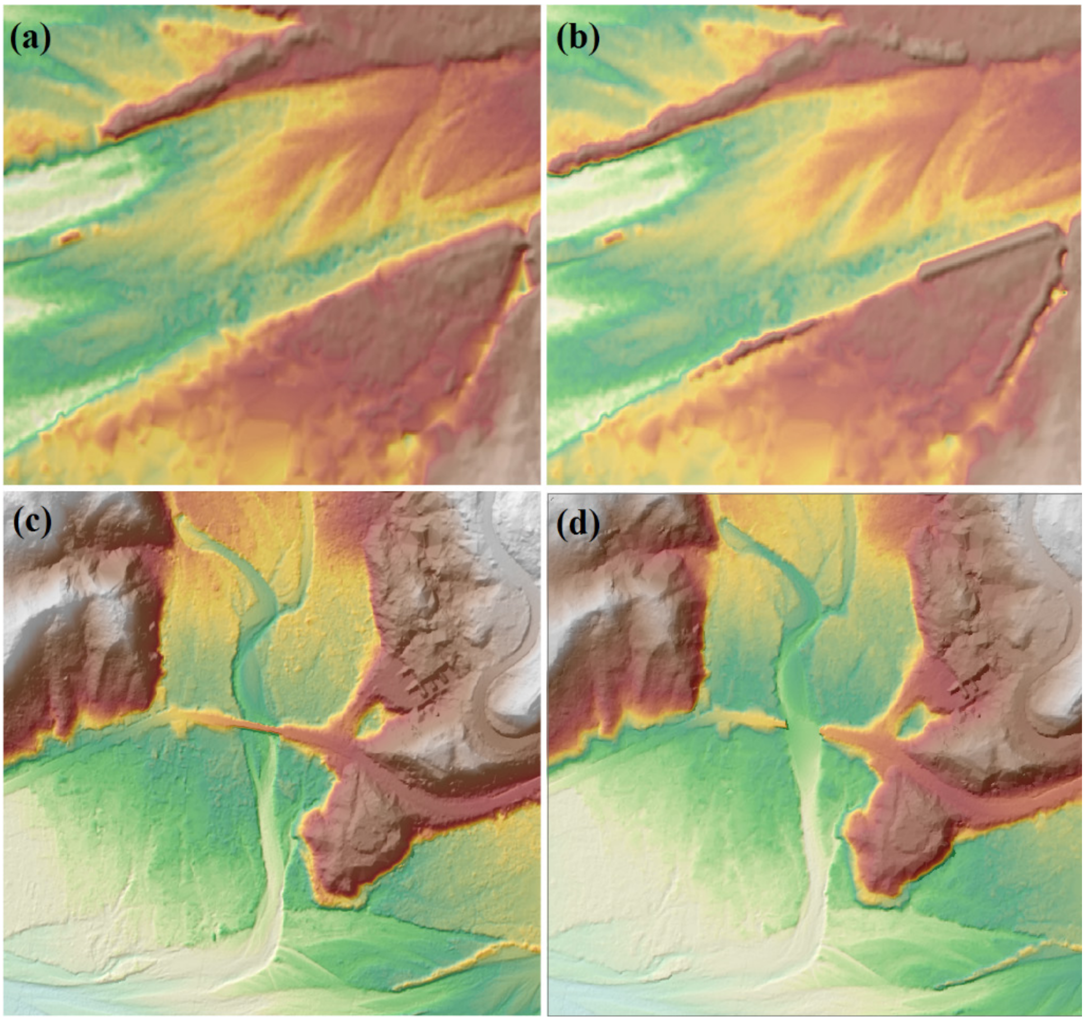


Figure 21. Portions in the DTM of the Subangdaku floodplain – a river embankment (a) before and (b) data retrieval; and a bridge (c) before and (d) after manual editing.

Examples of areas (with an average area of 167 square meters) without data in the DTM after classification and were consequently interpolated through manual editing are illustrated in Figure 22. The areas without data could cause errors in the flood simulation.

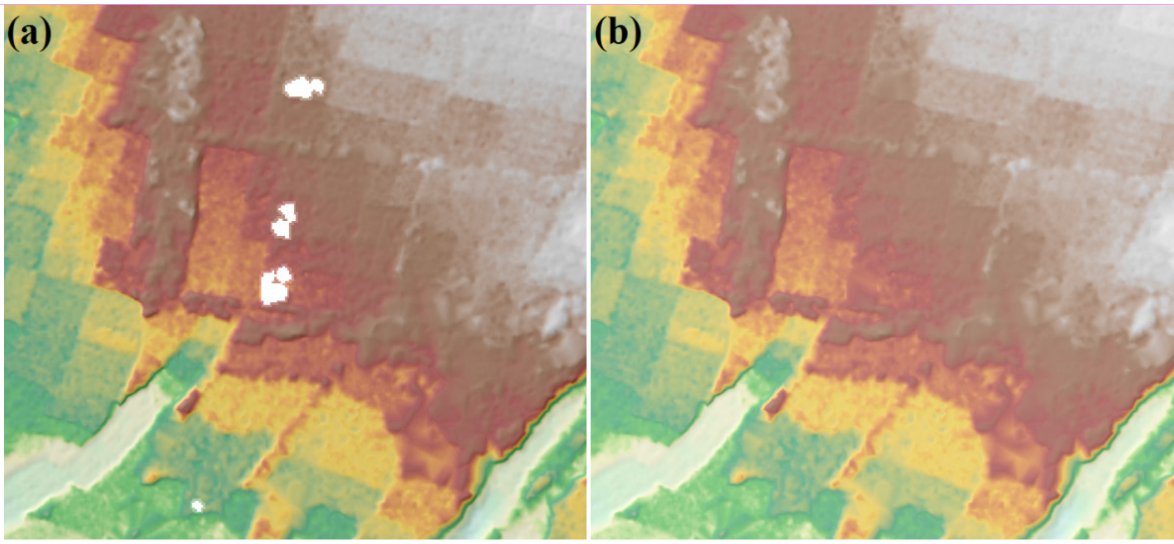


Figure 22. Portion in the DTM of the Subangdaku floodplain showing no data (a) before and (b) after manual editing

3.9 Mosaicking of Blocks

The Ormoc_49CD block was used as the reference block at the start of mosaicking, because the calibration and integration of the bathymetric data were already completed before the Ormoc_South_49C block was available for processing. Table 16 summarizes the shift values applied to each LiDAR block during mosaicking.

The mosaicked LiDAR DTM for the Subangdaku floodplain is presented in Figure 23. It demonstrates that the entire Subangdaku floodplain is 100% covered by LiDAR data.

Table 16. Shift values of each LiDAR block of the Subangdaku floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Ormoc_Blk49CD	0.00	0.00	0.00
Ormoc_South_Blk49C	0.00	0.00	-0.08

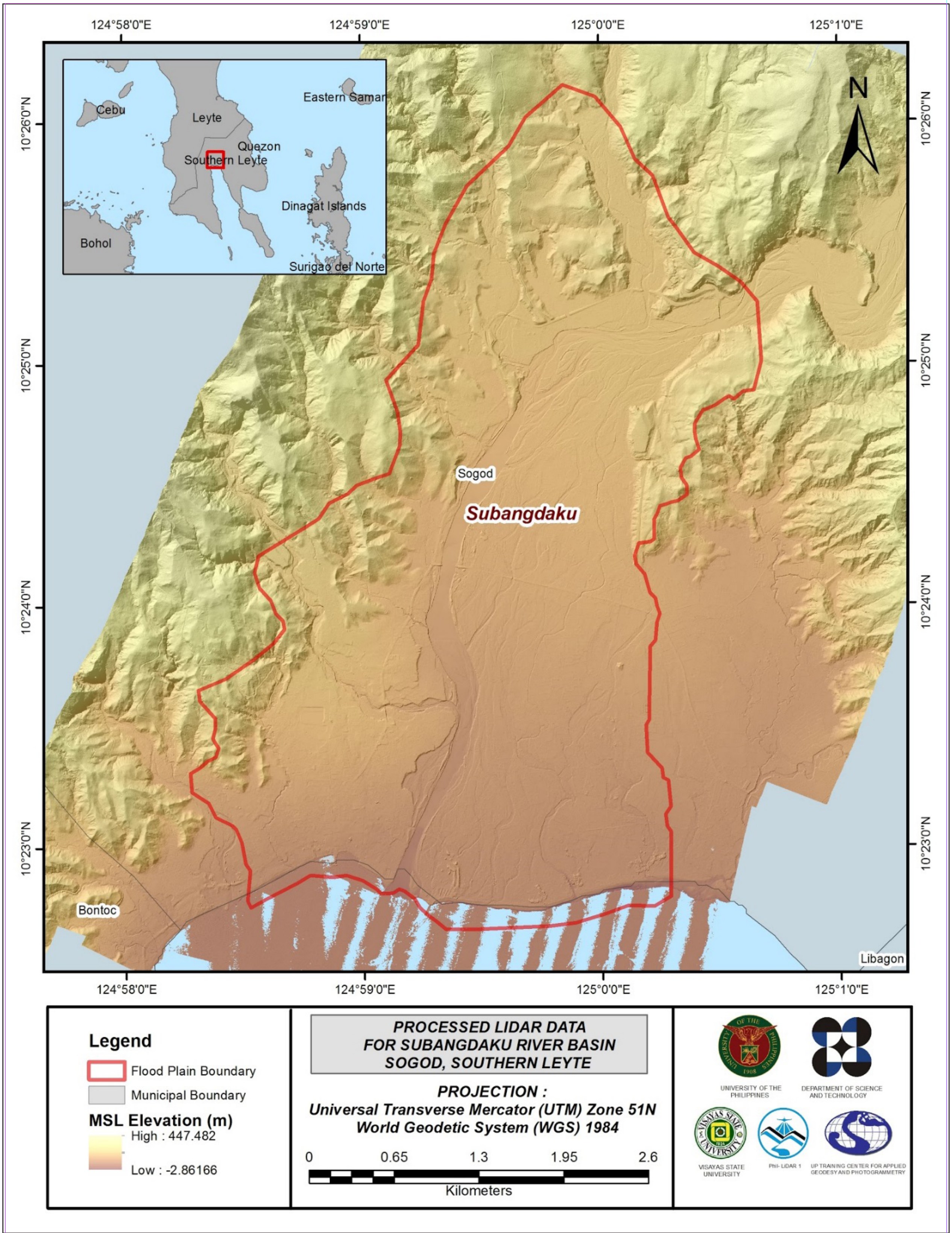


Figure 23. Map of processed LiDAR data for the Subangdaku floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Subangdaku floodplain.The extent of the validation survey in the Subangdaku River to collect points with which the LiDAR dataset wasvalidated is shown in Figure 24, with the validation survey points highlighted in green. A total of 1,038 survey points were used for the calibration and validation of

Subangdaku LiDAR data. Random selection of 80% of the survey pointsresultedin831 points, which were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflectedin Figure 25. Statistical values were computed from the extracted LiDAR values using the selected points, to assess the quality of the data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 0.25 meters, with a standard deviation of 0.07 meters. The calibration of the Subangdaku LiDAR data was performedby subtracting the height difference value, 0.07 meters, from theSubangdaku mosaicked LiDAR data. Table 17 indicatesthe statistical values of the compared elevation values between the LiDAR data and the calibration data.

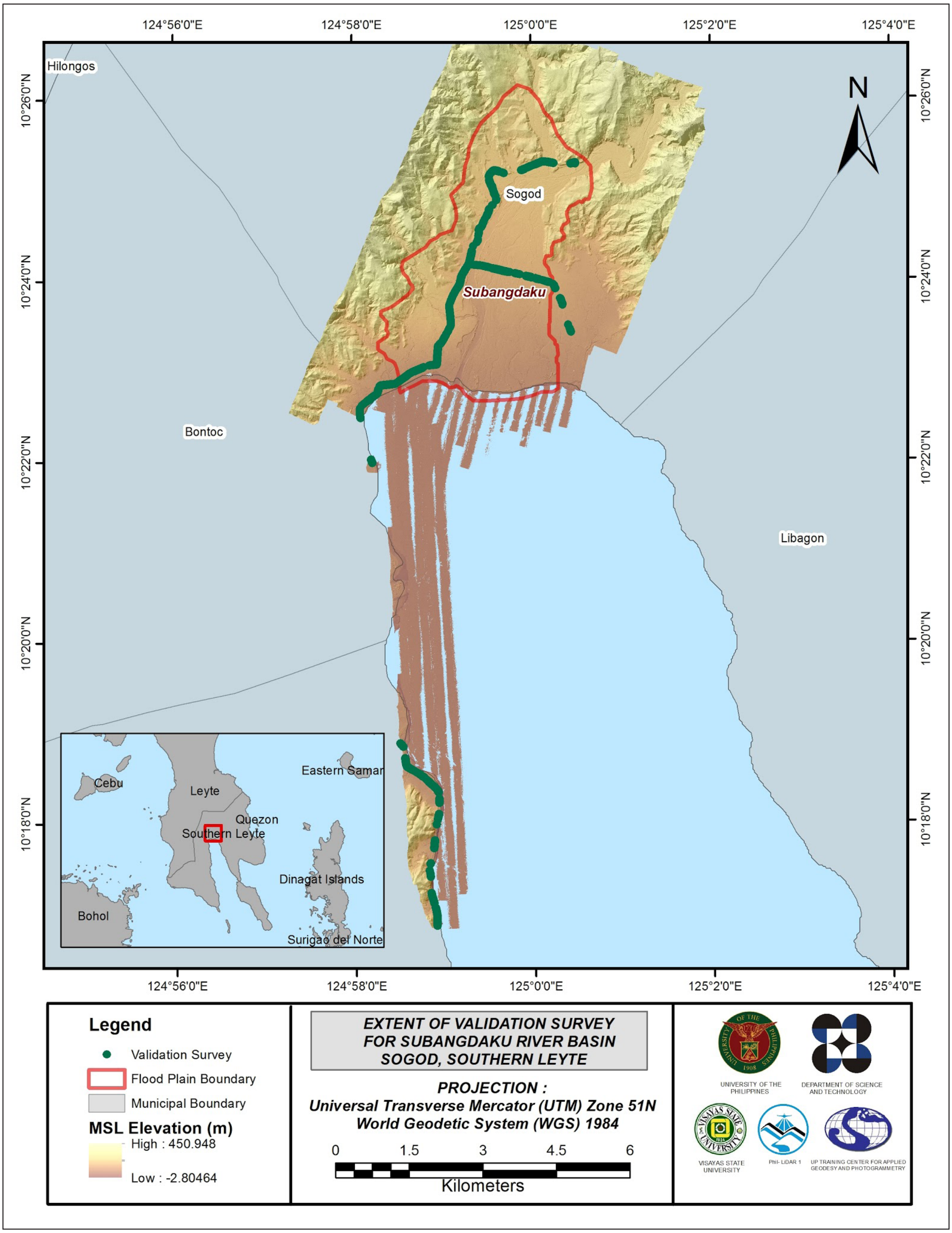


Figure 24. Map of the Subangdaku floodplain, with the validation survey points in green

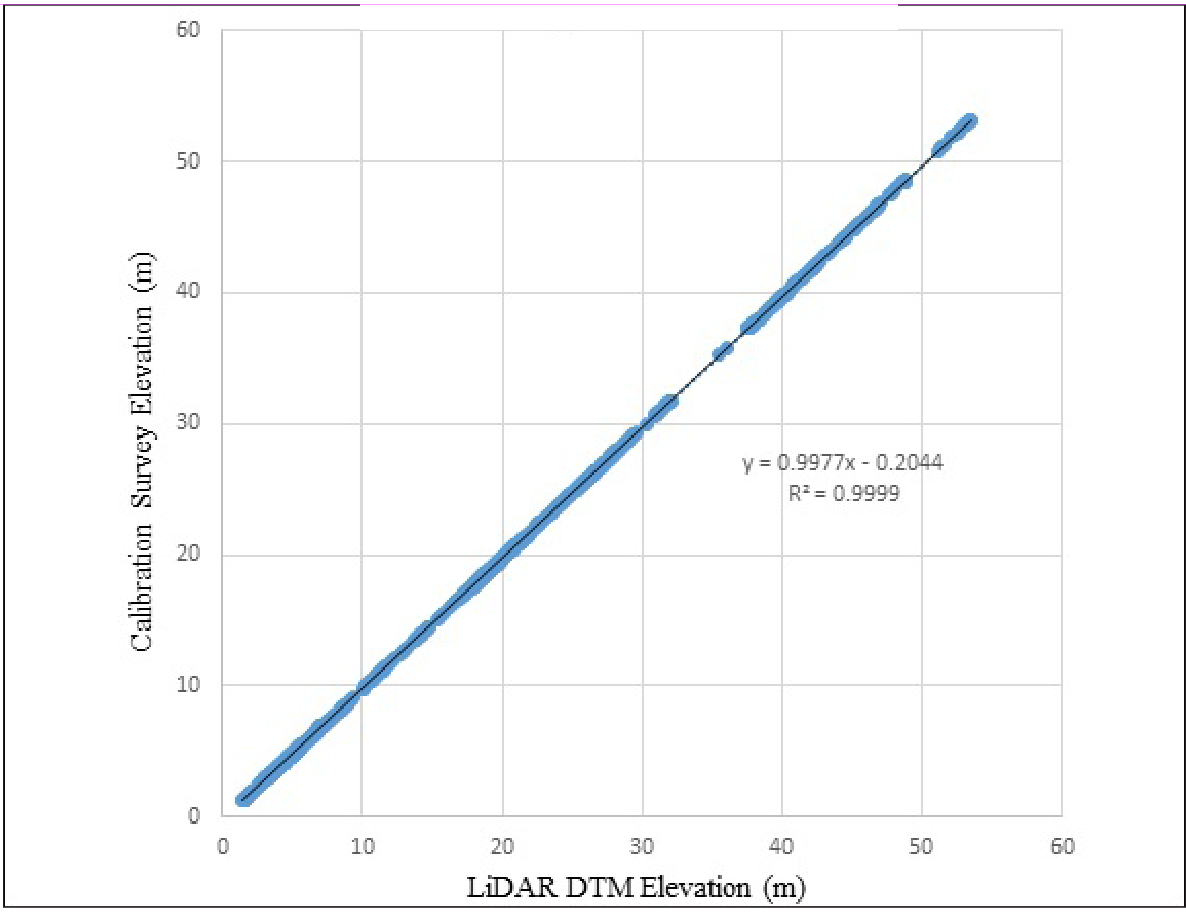


Figure 25. Correlation plot between the calibration survey points and the LiDAR data

Table 17. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.25
Standard Deviation	0.07
Average	-0.25
Minimum	-0.44
Maximum	-0.02

The remaining 20% of the total survey points, resulting in 207 points, were used for the validation of the calibrated Subangdaku 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 presentedin Figure 26. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.08 meters, with a standard deviation of 0.08 meters, as shown in Table 18.

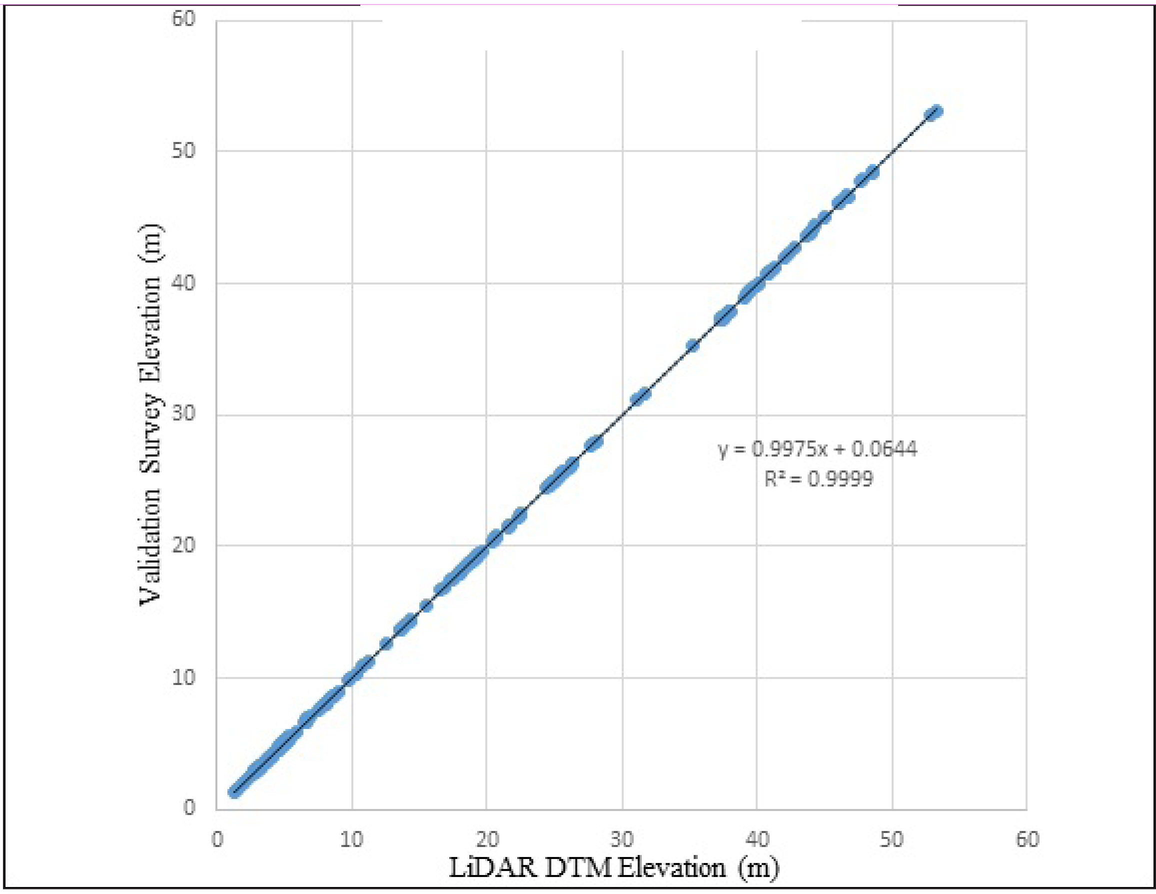


Figure 26. Correlation plot between the validation survey points and the LiDAR data

Table 18. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.08
Average	0.02
Minimum	-0.18
Maximum	0.34

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data wereavailable for Subangdaku, with 3,904 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.455 meters. The extent of the bathymetric survey executedby the DVBC in the Subangdakufloodplain, integrated with the processed LiDAR DEM, is illustratedin Figure 27.

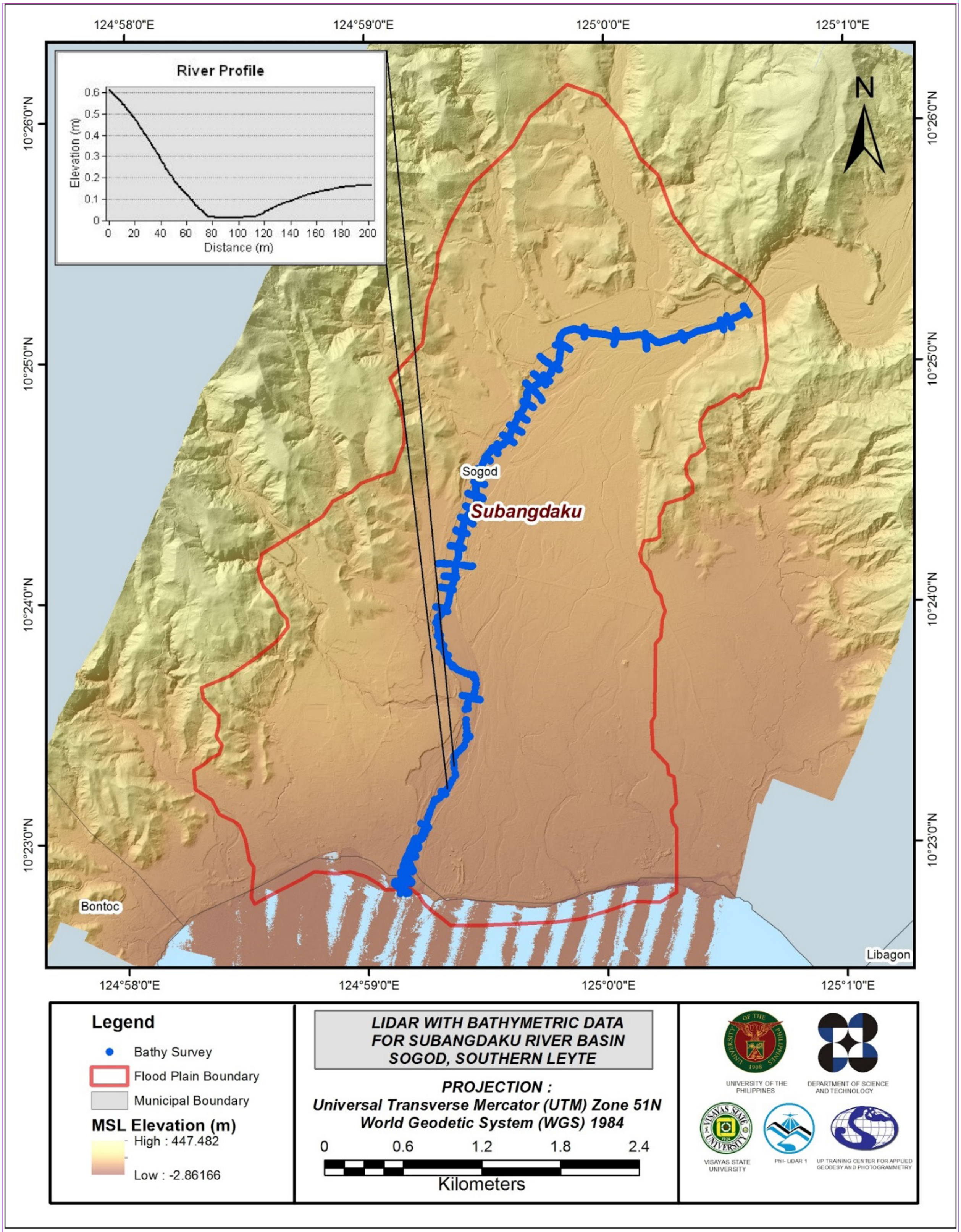


Figure 27. Map of the Subangdaku floodplain, with the bathymetric survey points shown in blue

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area, with a 200-meter buffer zone. Mosaicked LiDAR DEM with a 1-meter 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 – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Subangdaku floodplain, including its 200-meter buffer zone, has a total area of 19.91 square kilometers. Of this area, a total of 5.0 square kilometers, corresponding to a total of 2,660 building features, were considered for quality checking (QC).Figure 28depictsthe QC blocks for the Subangdaku floodplain.

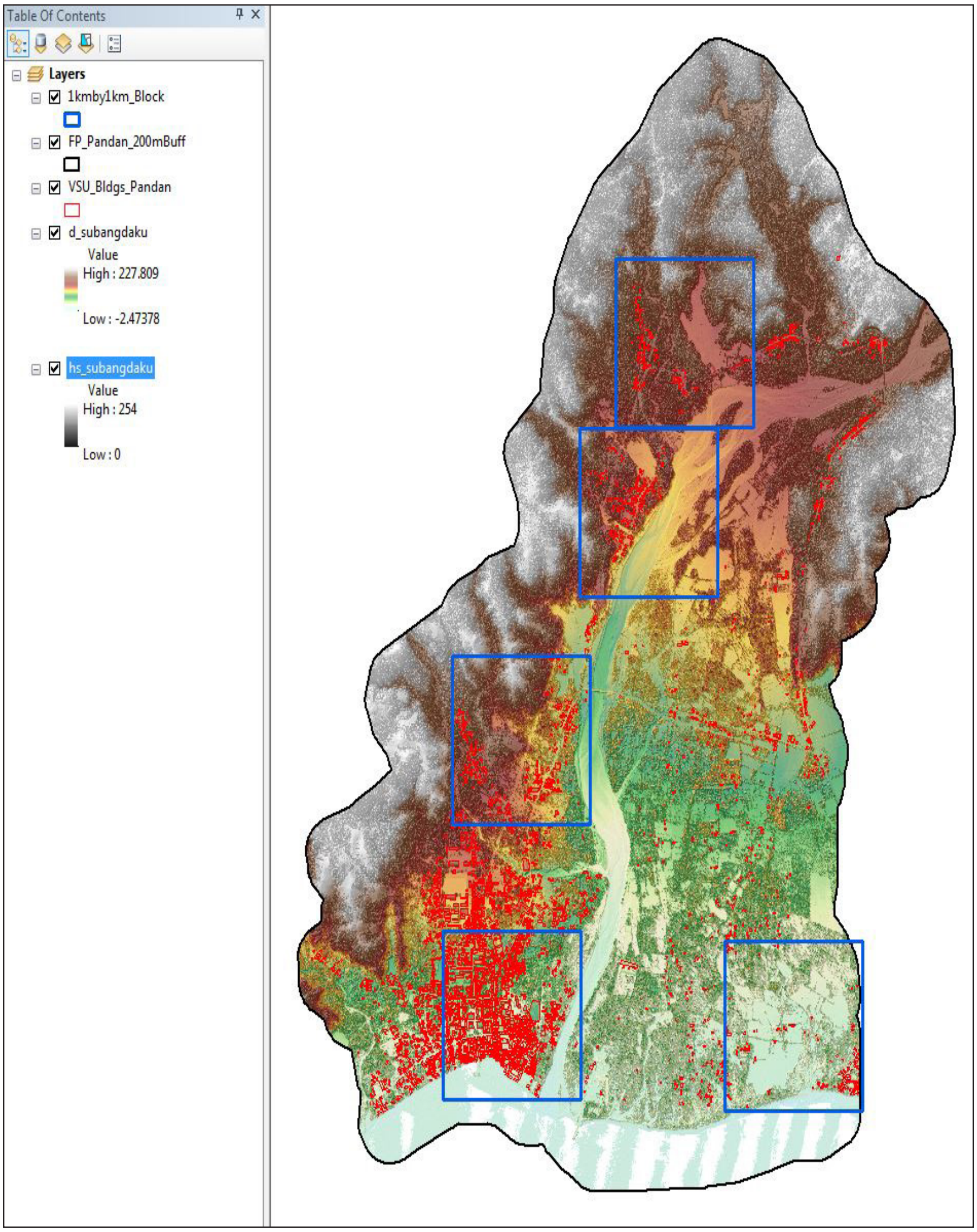


Figure 28. Blocks (in blue) of Subangdaku building features that were subjected to QC

Quality checking of the Subangdaku building features resulted in the ratings summarizedin Table 19.

Table 19. Quality checking ratings for the Subangdaku building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Subangdaku	99.92	99.66	99.06	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,866 building features in the Subangdaku floodplain. Of these building features, none was filtered out after height extraction, resulting in the same number of buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 5.92 meters.

3.12.3 Feature Attribution

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

Table 20 summarizes the number of building features per type. Table 21indicatesthe total length of each road type, andTable 22providesthe number of water features extracted per type.

Table 20. Building features extracted for the Subangdaku floodplain

Facility Type	No. of Features
Residential	4375
School	116
Market	59
Agricultural/Agro-Industrial Facilities	8
Medical Institutions	28
Barangay Hall	14
Military Institution	0
Sports Center/Gymnasium/Covered Court	13
Telecommunication Facilities	4
Transport Terminal	1
Warehouse	20
Power Plant/Substation	2
NGO/CSO Offices	3
Police Station	5
Water Supply/Sewerage	8
Religious Institutions	29
Bank	9
Factory	0
Gas Station	10
Fire Station	1
Other Government Offices	16
Other Commercial Establishments	145
Total	4866

Table 21. Total length of extracted roads for the Subangdaku floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Subangdaku	7.99	12.03	3.48	13.08	1.66	38.25

Table 22. Number of extracted water bodies for the Subangdaku floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Subangdaku	8	0	0	0	0	**8**

A total of thirteen (13) 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 comprised the flood hazard exposure database for the Subangdaku floodplain. This completes the feature extraction phase of the project.

Figure 29 illustrates the Digital Surface Model (DSM) of Subangdaku floodplain, overlaid with its ground features.

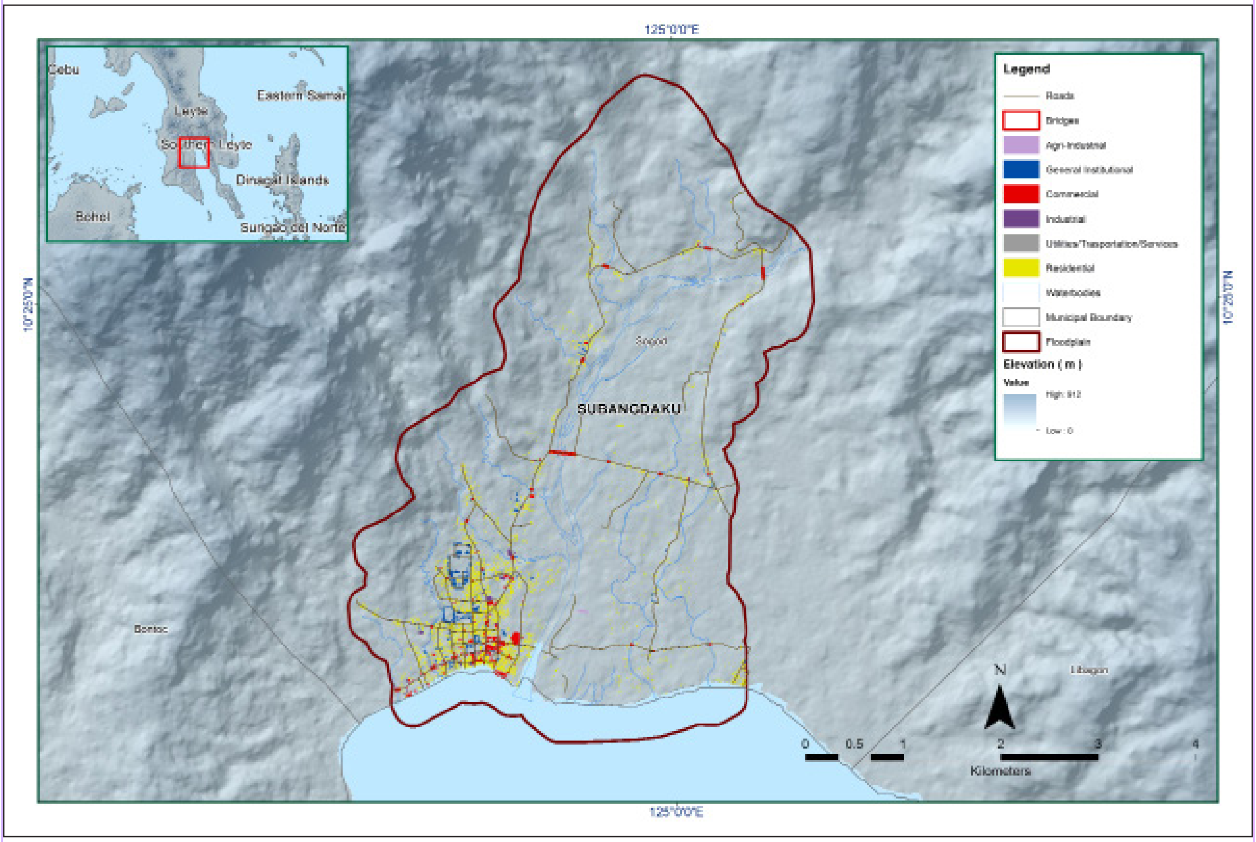


Figure 29. Extracted features for the Subangdaku floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE SUBANGDAKURIVER BASIN

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

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Subangdaku River on March 9-23, 2016. The scope of work was comprised of the following: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section, bridge as-built surveys and water level marking in MSL of the Subang-Daku Bridge in Barangay Zone V, Municipality of Sogod; (iv.) LiDAR validation points acquisition of about 73.662kilometerscovering the Subangdaku River Basin area; and (v.) bathymetric survey from theupstream side in Barangay Buac Gamay down to the mouth of the river in Barangay La Purisima Concepcion, both in the Municipality of Sogod. Thesurvey hadan approximate length of 6.514 kilometersusing an Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique.The extent of the surveys conducted is illustrated in Figure 30.

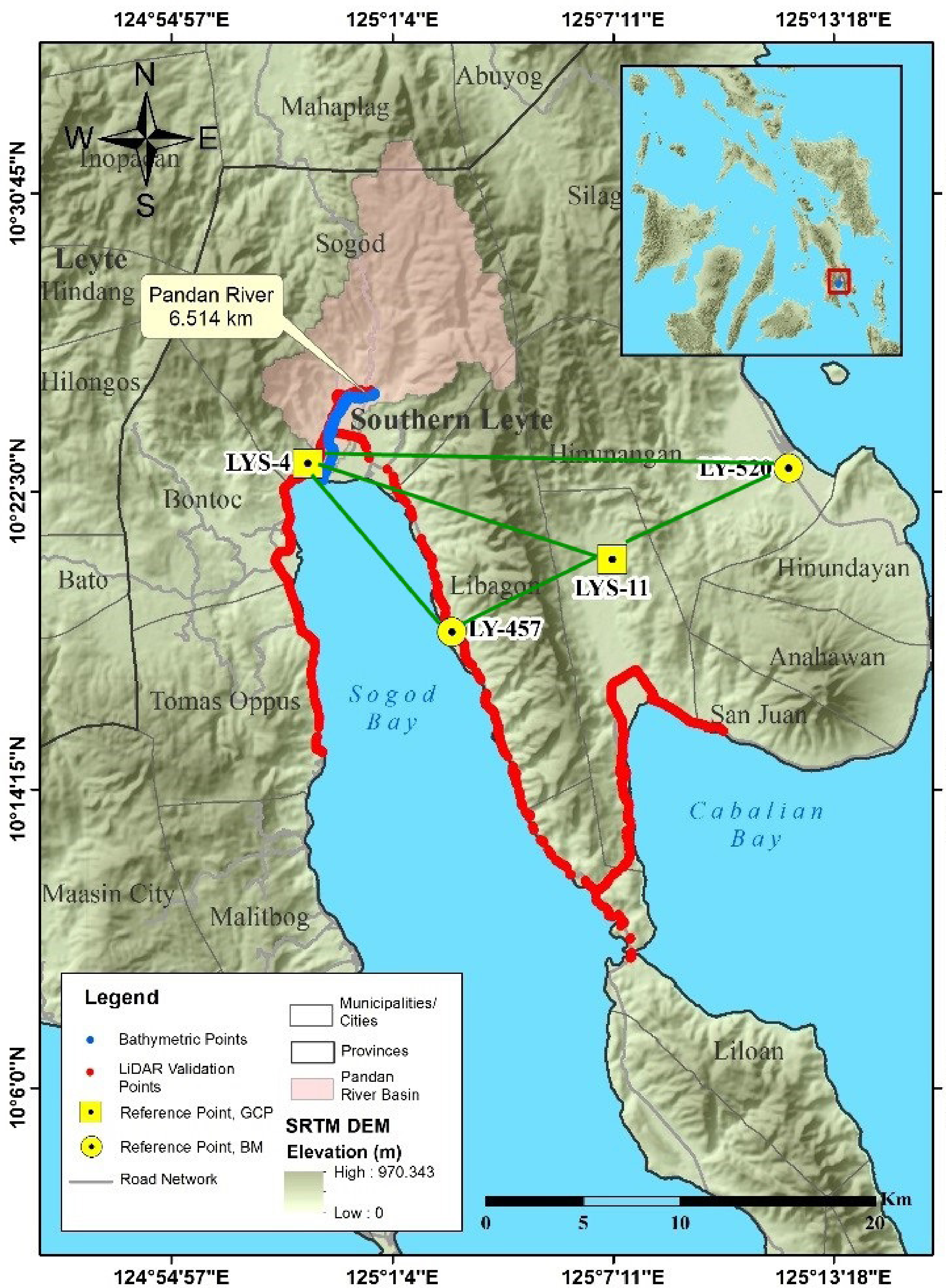


Figure 30. Extent of the bathymetric survey (in blue line) in the Subangdaku River Basin and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for theSubangdaku River Basin is composed of two (2) loops established on April 1, 2016, occupying the following reference points: (i.) LYS-4, a first-order GCP, located in Barangay Zone 1, Municipality of Sogod; (ii.) LY-457, a first-order BM, located in Barangay Bogasong, Municipality of Libagon; and (iii.) LY-520, a first-order BM, located in Barangay Labrador, Municipality of Hinunangan.

A NAMRIA established control point, LYS-11, located in Barangay Cabagawan in theMunicipality of Saint Bernard was occupied and used as a marker for the network.

The summary of reference and control points and their correspondinglocations is outlinedin Table 23; while theestablished GNSS networkis illustrated in Figure 31.

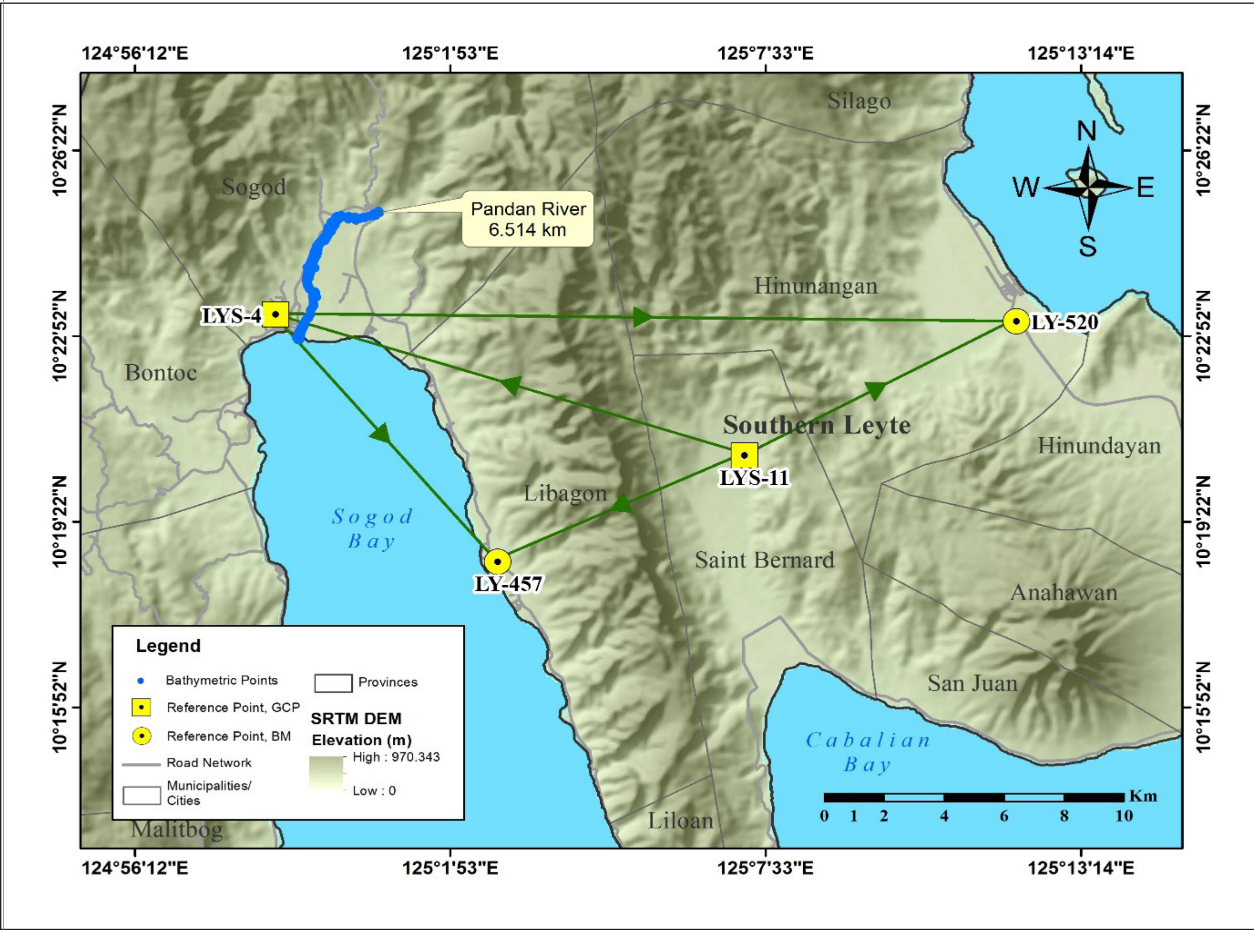


Figure 31. GNSS network of the Subangdaku River field survey

Table 23. List of reference and control points occupied for the Subangdaku River Survey (Source:NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
LYS-4	1st Order, GCP	10°23'16.14540"N	124°58'43.76469"E	79.528	-	2006
LY-457	2nd Order, BM	10°18'35.97042"N	125°02'43.63239"E	72.351	7.002	2007
LY-520	1st Order, BM	10°23'08.14105"N	125°12'03.52892"N	72.293	6.181	2008
LYS-11	Used as Marker	-	-	-	-	2007

The GNSS set-up established in the locations of the reference and control points are exhibited in Figure 32 to Figure 35.

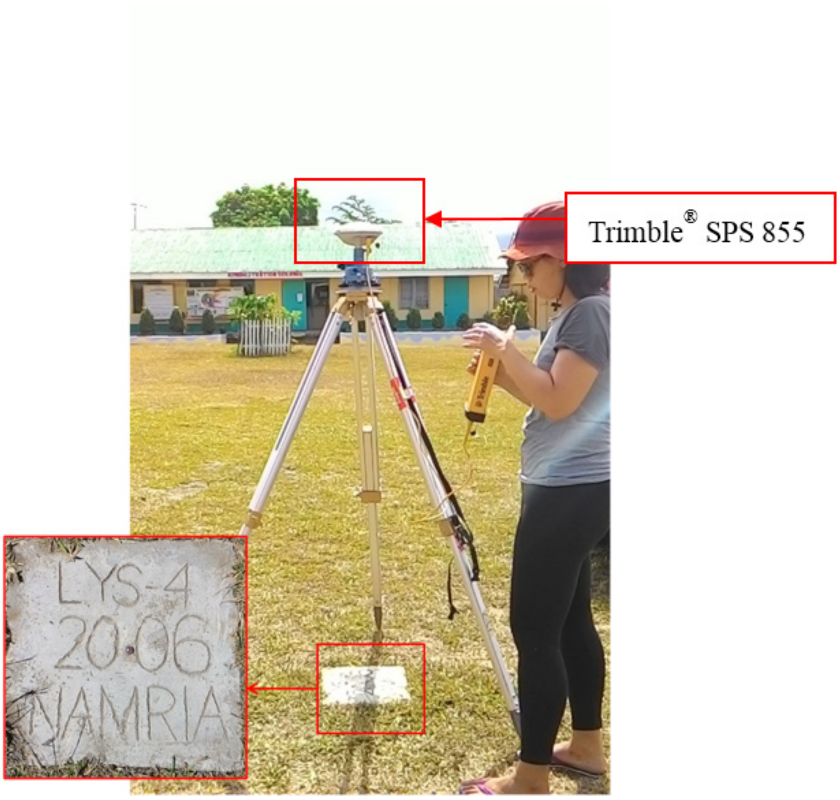


Figure 32. GNSS base set-up, Trimble® SPS 855, at LYS-4, located at the middle of the open ground of Sogod National High School in Barangay Poblacion, Sogod, Southern Leyte

Figure 33. GNSS base set-up, Trimble® SPS 855, at LY-457, located at the approach of the Tigbao-Cib Bridge 2 in Barangay Tigbao, Sogod, Southern Leyte

Figure 34. GNSS base set-up, Trimble® SPS 882, at LY-520, located along the approach of the Das-ay Bridge in Barangay Bisangon, Hinunangan, Southern Leyte

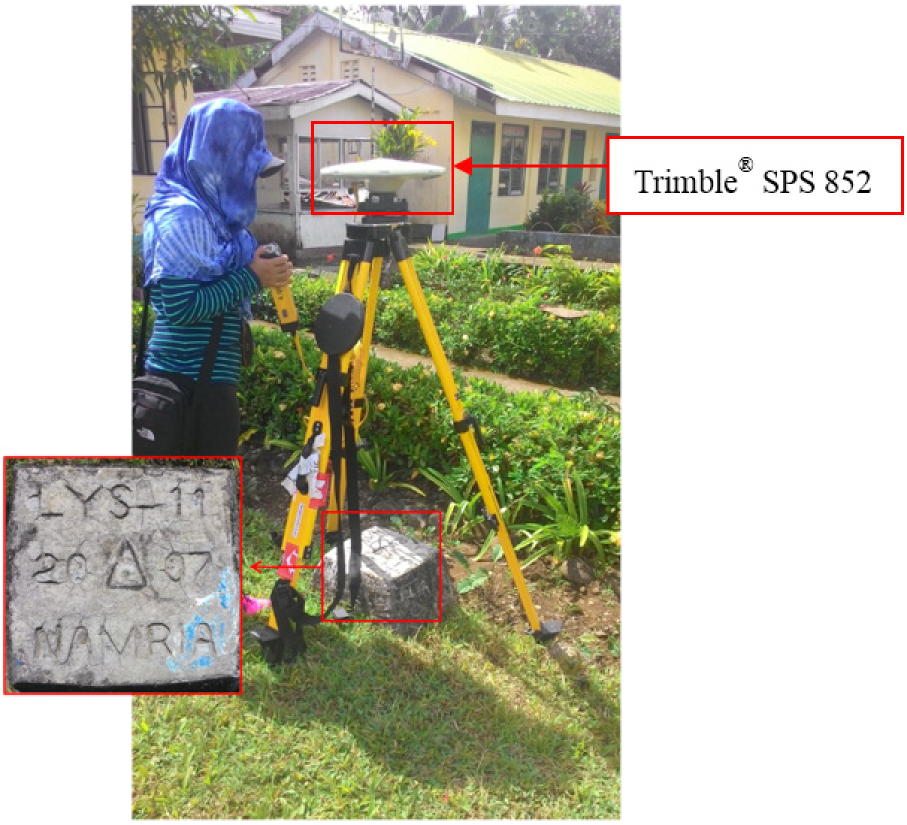


Figure 35. GNSS base set-up, Trimble® SPS 852, at LYS-11, located at the St. Bernard Elementary School Grounds, Barangay Ma. Asuncion, St. Bernard, Southern Leyte

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the+/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking wasperformed. Masking is the removal of portions of baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of control points in the Subangdaku River Basin, generated by the TBC software,aresummarized in Table 24.

Table 24. Baseline Processing Report for the Subangdaku River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
LYS-4 --- LY-520	4-1-2016	Fixed	0.003	0.021	90°33'33"	24329.003
LYS-4 --- LY-457	4-1-2016	Fixed	0.004	0.020	319°43'05"	11285.176
LYS-11 --- LYS-4	4-1-2016	Fixed	0.002	0.010	287°40'27"	16158.815
LYS-11 --- LY-520	4-1-2016	Fixed	0.007	0.024	62°27'32"	10073.109
LYS-11 --- LY-457	4-1-2016	Fixed	0.004	0.021	65°24'42"	8908.644

As reflectedin Table 24, a total of five (5) baselines were processed, with reference points LY-457 and LY-520 held fixed for elevation values; and LYS-4 held fixed for grid values. All of the baselinessatisfied the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report presentedin Table 25to Table 27 for the complete details.

The five (5) control points – LYS-4, LY-457, LY-520, and LYS-11 – were occupied and observed simultaneously to form a GNSS loop. The elevation values of LY-457 and LY-520, and the coordinates of point LYS-4 were held fixed during the processing of the control points, as demonstratedin Table 25. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 25. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LYS-4	Local	Fixed	Fixed		
LY-457	Grid				Fixed
LY-520	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 26. The fixed control points, LY-457 and LY-520, have no values for elevation errors; while LYS-4 has no values for grid errors.

Table 26. Adjusted grid coordinates for the control points used in the Subangdaku floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LYS-4	716648.623	?	1148966.313	?	14.299	0.048	LL
LY-457	724001.615	0.012	1140402.435	0.008	7.002	?	e
LY-520	740983.532	0.009	1148880.417	0.007	6.181	?	e
LYS-11	732080.501	0.008	1144162.005	0.006	35.617	0.048	

The network was heldfixed at reference points LY-457 and LY-520, with known elevation values; and LYS-4, with known coordinates. As shown in Table 26, the standard errors (x_e and y_e) of LYS-11 are 0.80 centimeters and 0.60 centimeters. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for horizontal accuracy and $z_e < 10\ cm$ for vertical accuracy, the computations for accuracy are as follows:

a. LYS-4

Horizontal Accuracy = Fixed
Vertical Accuracy = 4.80< 10 cm

b. LY-457

Horizontal Accuracy = √((1.2)² + (0.80)²
= √ (1.44 + 0.64)
= 1.44cm < 20 cm
Vertical Accuracy = Fixed

c. LY-520

Horizontal Accuracy = $\sqrt{((0.90)^2 + (0.70)^2}$

= $\sqrt{(0.81 + 0.49)}$

= 1.14 cm < 20 cm

Vertical Accuracy = Fixed

d. LYS-11

Horizontal Accuracy = $\sqrt{((0.80)^2 + (0.60)^2}$

= $\sqrt{(0.64 + 0.36)}$

= 1cm < 20 cm

Vertical Accuracy = 4.80 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the occupied control pointsarewithin the required precision.

Table 27. Adjusted geodetic coordinates for control points used in the Subangdaku River floodplain validation

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
LYS-4	N10°23'16.14540"	E124°58'43.76469"	79.528	0.048	LL
LY-457	N10°18'35.97042"	E125°02'43.63239"	72.351	?	e
LY-520	N10°23'08.14105"	E125°12'03.52892"	72.293	?	e
LYS-11	N10°20'36.58650"	E125°07'09.90652"	101.468	0.048	

The corresponding geodetic coordinates of the observed points are within the required accuracy,as presentedin Table 27. Based on the results of the computations, the accuracy conditionsaresatisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Subangdaku River GNSS Static Survey areindicated in Table 28.

Table 28. Reference and control points used in the Subangdaku River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LYS-4	1st order, GCP	10d23'16.14540"	124d58'43.76469"	79.528	1148966.313	716648.623	14.299
LY-457	1st order, BM	10d18'35.97042"	125d02'43.63239"	72.351	1140402.435	724001.615	7.002
LY-520	1st order, BM	10d23'08.14105"	125d12'03.52892"	72.293	1148880.417	740983.532	5.116
LYS-11	Used as marker	10d20'36.58650"	125d07'09.90652"	101.468	1144162.005	732080.501	35.617

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

The cross-section survey was conducted on April 4, 2016 along the upstream side of the Subangdaku Bridge 2 in Barangay Zone V in the Municipality of Sogod.The survey was performed using a GNSS receiver, Trimble® SPS 882, set in PPK survey technique, as depicted in Figure 36.

Figure 36. Cross-section survey for the Subangdaku River

The cross-sectional line surveyed in the Subangdaku Bridge 2 site is about 290.028 meters with 86 cross-sectional points acquired, using LYS-4 as the GNSS base station. The location map, cross-section diagram, and bridge as-built form are presentedin Figure 37,,Figure 38, and Figure 39, respectively.

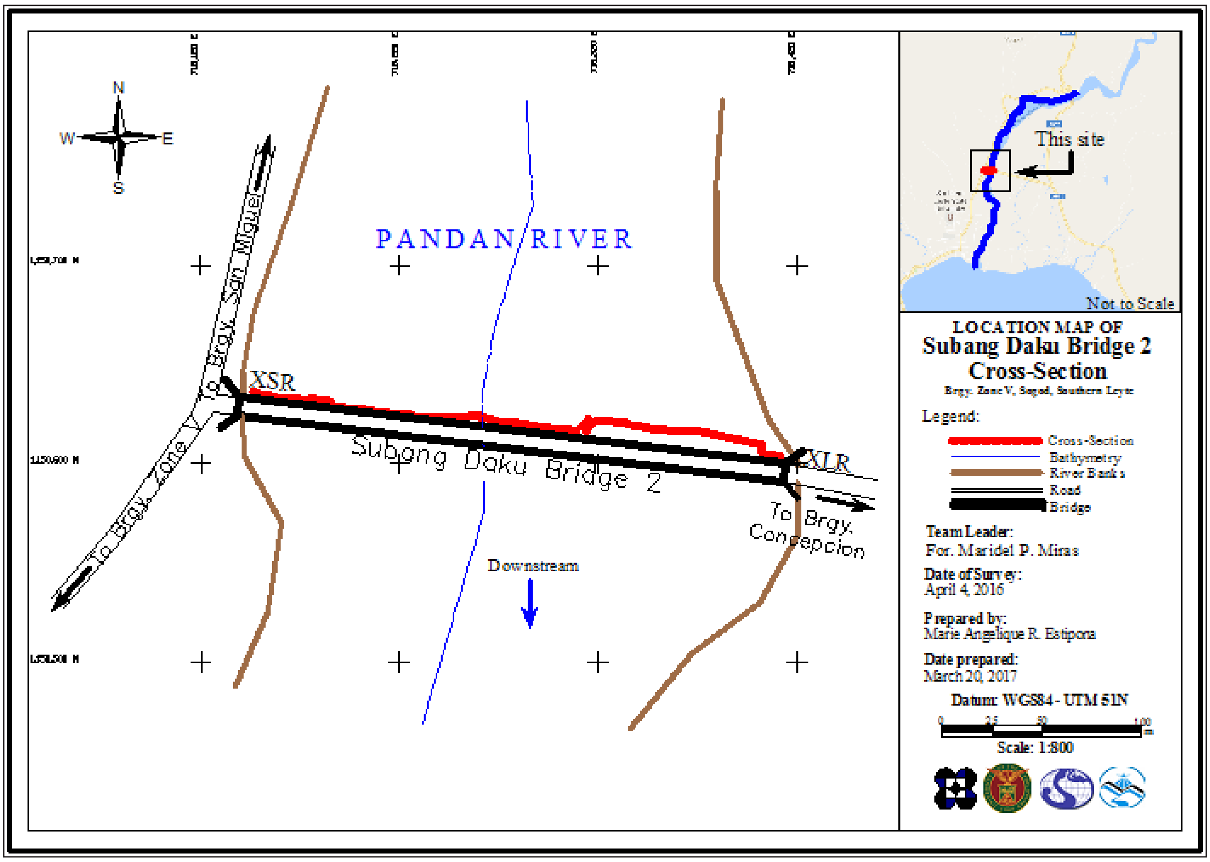


Figure 37. Subangdaku Bridge 2 cross-section location map

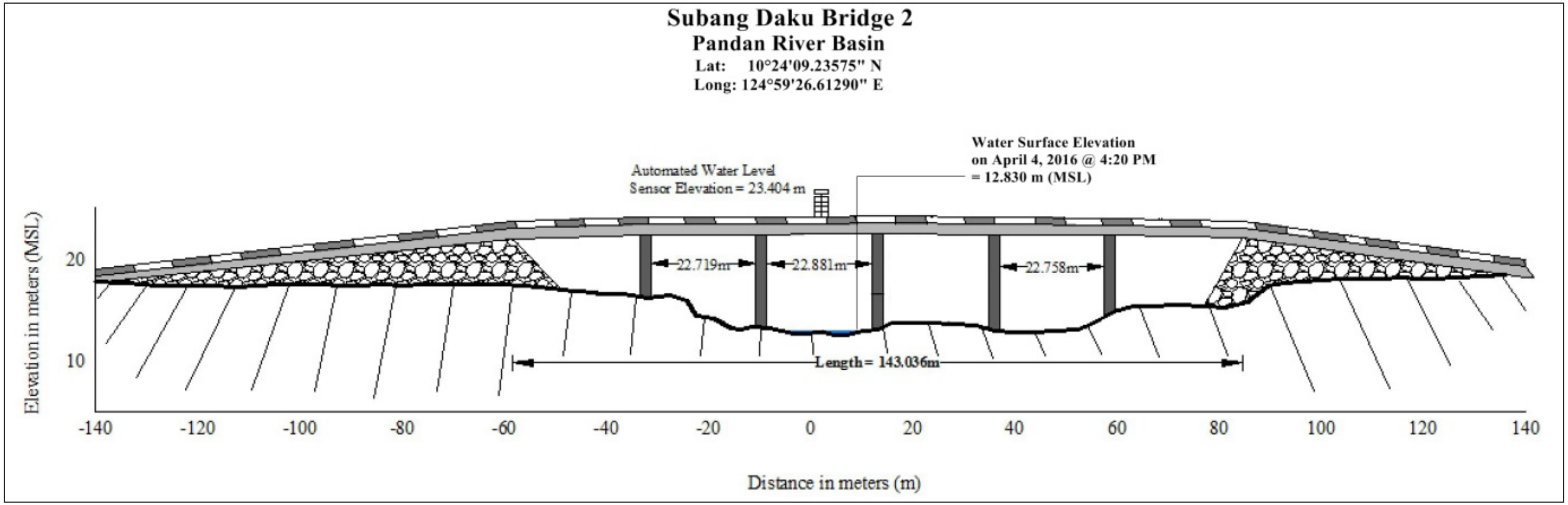


Figure 38. Subangdaku Bridge 2 cross-section diagram

Bridge Data Form

Bridge Name: Subang Daku Bridge — Date: April 4, 2016

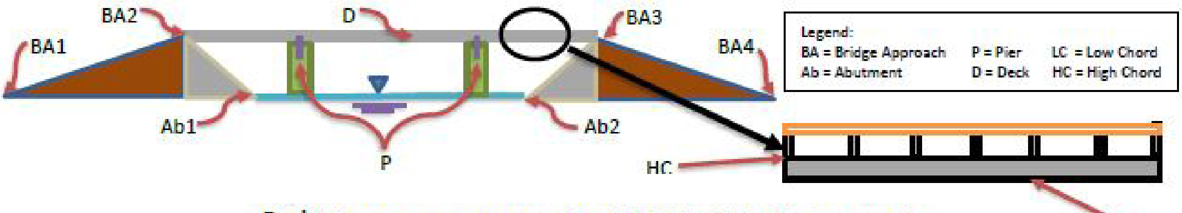
River Name: Subang Daku River — Time: 04:20 PM

Location (Brgy, City,Region): Brgy. Zone V, Municipality of Sogod

Survey Team: Mady Miras, Rodel Alberto, Caren Ordoña

Flow condition: normal — Weather Condition: fair

Latitude: 10˚24'09.57368" N — Longitude: 124˚59'24.09509" E



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

Elevation: 21.906 m — Width: 8.814 m — Span (BA3-BA2): 143.036 m

	Station	High Chord Elevation	Low Chord Elevation
1	P1	21.925	19.425

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	17.986m	BA3	220.323m	21.978m
BA2	77.300	21.906m	BA4	275.697m	18.184m

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

	Station (Distance from BA1)	Elevation
Ab1	98.144m	16.641m
Ab2	225.565m	15.660m

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

Shape: Oval — Number of Piers: 5 — Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	117.609m	21.925m	1.35m
Pier 2	140.328m	21.968m	1.35m
Pier 3	163.208m	21.954m	1.35m
Pier 4	185.889m	21.981m	1.35m
Pier 5	208.648m	21.993m	1.35m

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

Figure 39. Subangdaku Bridge 2 data form

Figure 40. Water level markings on the Subangdaku Bridge 2 railings

The water surface elevation in MSL of the Subangdaku River was determined using Trimble® SPS 882 in PPK mode technique on April 4, 2016 at 16:20 hrs. The water surface elevation value obtained was 12.830 meters in MSL. This was translated into markings on the railings of the Subangdaku Bridge 2 using digital levels. The markings, with a corresponding value of 21.937 meters in MSL illustrated in Figure 40, served as a reference for flow data gathering and depth gauge deployment for the Subangdaku River.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by two (2) separate groups on April 4, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882. The receiver wasmounted on a pole attached to the side of a vehicle, as demonstratedin Figure 41. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heightswere1.870 meters and 2.325 meters,measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with LYS-4 occupied as the GNSS base station.

Figure 41. Validation points acquisition survey set-up

The survey started inBarangay San Isidro in the Municipality of Tomas Oppus, then headedeast towards the Municipalities of Bontoc, Sogod, Libagon, Liloan, Saint Bernard, and ended in Barangay Osao in the Municipality of San Juan. This route was taken, with the aim to cut the flight strips perpendicularly. The validation points acquisition surveygathered 7,519 points with an approximate length of 73.662kilometers,using LYS-4 as the GNSS base station. The extent of the survey is illustrated in the map in Figure 42.

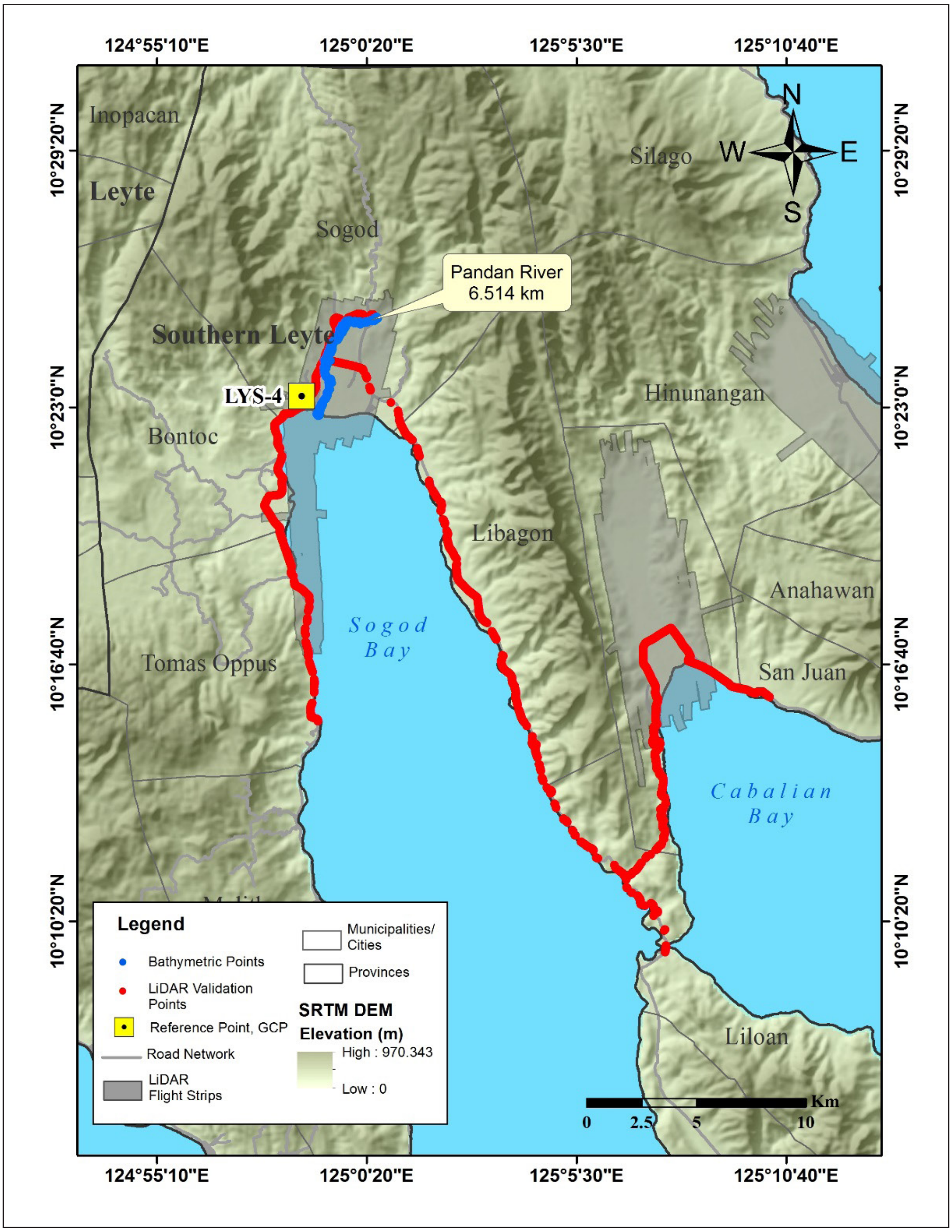


Figure 42. Extent of the LiDAR ground validation survey of the Subangdaku River Basin

4.7 Bathymetric Survey

A bathymetric survey was executed by boat on April 2, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ single beam echo sounder, as depictedin Figure 43. The survey commenced at the downstream portion of the river inBarangay La Purisima Concepcion in the Municipality of Sogod,with coordinates 10°23’04.37540”N, 124°59’14.69291”E; and extended down to the mouth of the river in the same Barangay, with coordinates 10°22’47.48176”N, 124°59’07.86828”E.

Most of the bathymetric survey was conducted manually on the same day using a Trimble® SPS 882 in GNSS PPK survey technique (Figure 44). The survey began in Barangay Buac Gamay in theMunicipality of Sogod, with coordinates 10°24’58.67361”N, 124°59’46.98050”E; and ended at the starting point of the bathymetric surveyusing the echo sounder, in the same barangay. The control point LYS-4was occupied as the GNSS base station all throughout the surveys.

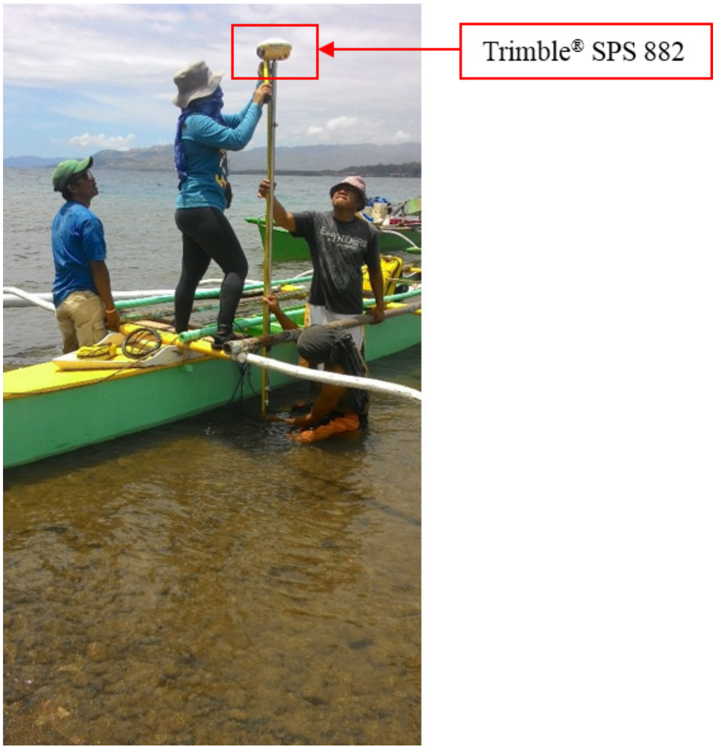


Figure 43. Bathymetry by boat set-up for the Subangdaku River survey

Figure 44. Manual bathymetry set-up for the Subangdaku River survey

A CAD drawing wasproduced to illustrate the riverbed profile of the Subangdaku River, presented in Figure 46. The profile shows thatthe highest and lowest elevation hada 51.044-meter difference. The highest elevation observed was 46.474 metersabove MSL located at the upstream portion of the river in Barangay Buac Gamay;while the lowest elevation was -4.570 metersbelow MSL located at the downstream portion of the river in Barangay La Purisima Concepcion. Both portions of the river arein the Municipality of Sogod. The bathymetric survey gathered a total of 4,030 pointscovering 6.514 kilometersof the river,traversing six (6) barangays in the Municipality of Sogod. A bathymetric line of almost 2kilometers in lengthwas not covered because the area concerned is not considered to be prone to flooding.The scope of the surveyis shown in the map in Figure 45.

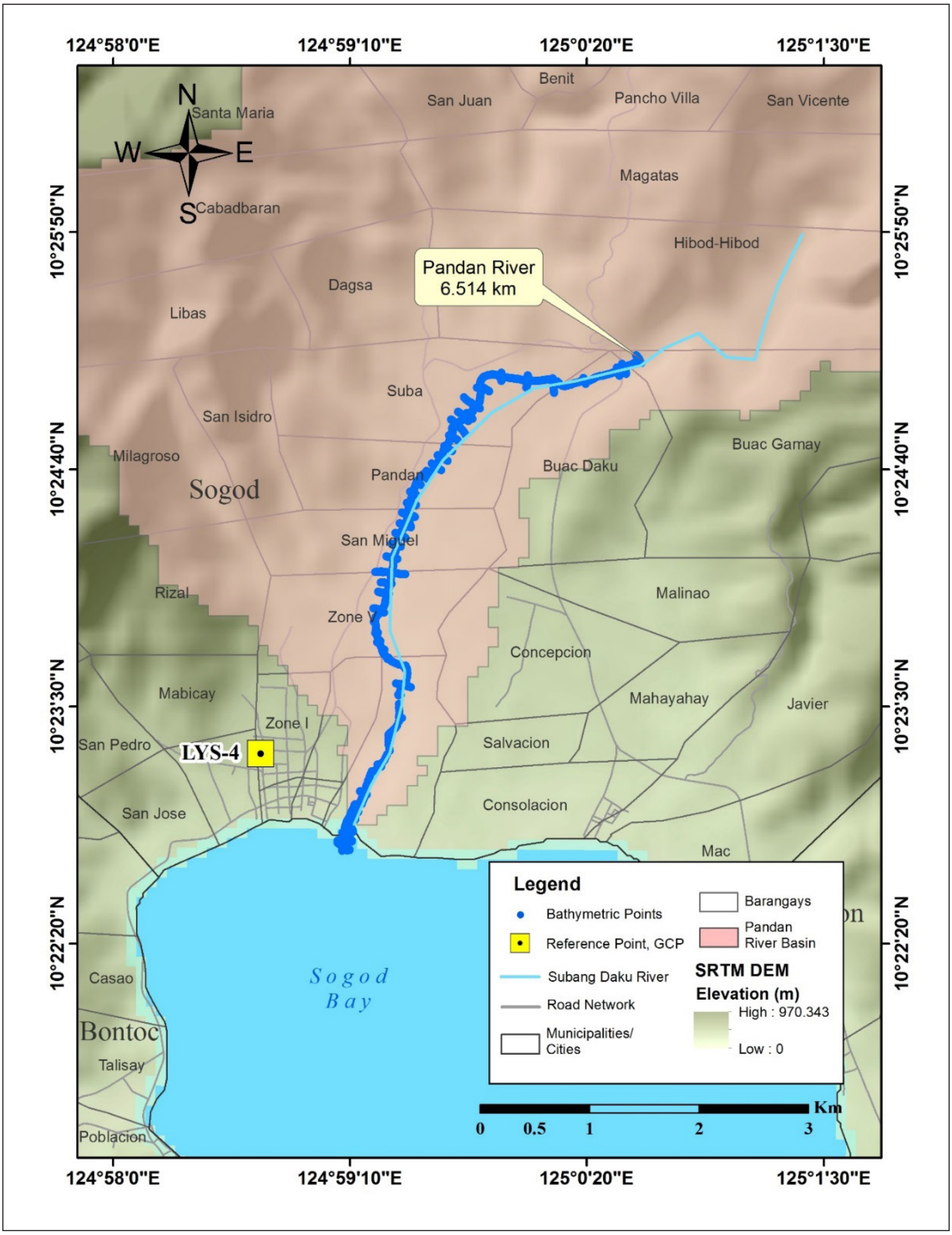


Figure 45. Extent of the bathymetric survey of the Subangdaku River

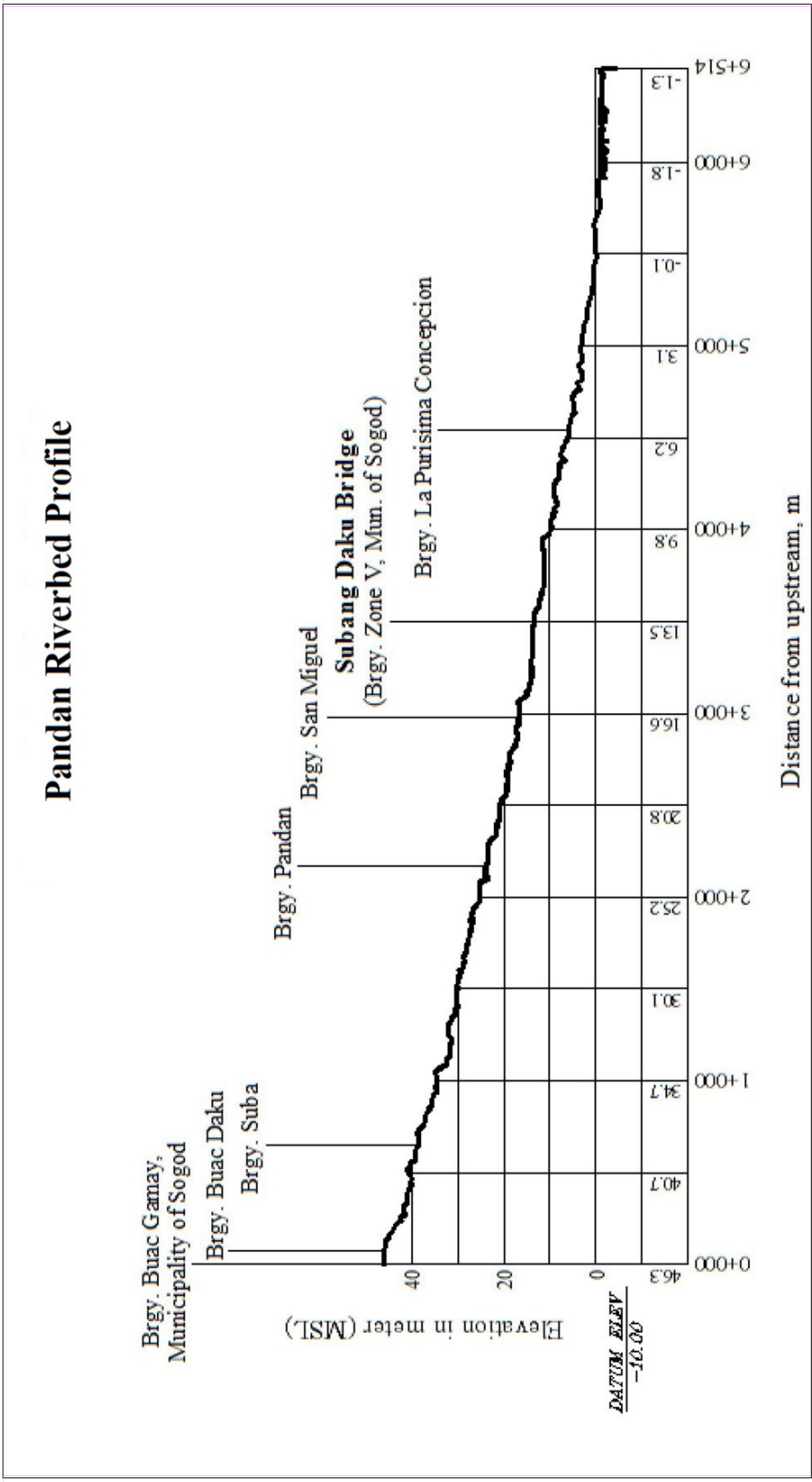


Figure 46. Riverbed profile of the Subangdaku River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which are allcomponents and data that may affect the hydrologic cycle of the Subangdaku River Basin,weremonitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from the two (2) automatic rain gauges (ARGs) deployed by the VSU Flood Modeling Component (FMC). The ARGs were installed in Magatas and in Pancho Villa – both in the Municipality of Sogod, Southern, Leyte (Figure 47). The precipitation data collection occurred on December 18, 2016 at 00:00 hrs. untilDecember 19, 2016 at 13:00 hrs., with a 10-minute recording interval.

The total precipitation in the Magatas ARG was 106 millimeters. It hada peak rainfall of 7.4 millimeters on December 19, 2015 at 04:00 hrs. The lag time between the peak rainfall and discharge was onehour and fortyminutes (1+40), as seen in Figure 50. For the Pancho Villa ARG, the total rain for this event was109.2 millimeters. A peak rainfall of 7.4 millimeters was recorded onJanuary18, 2015 at 15:10 hrs. The lag time between the peak rainfall and discharge wasfourteenhours and thirtyminutes (14+30).

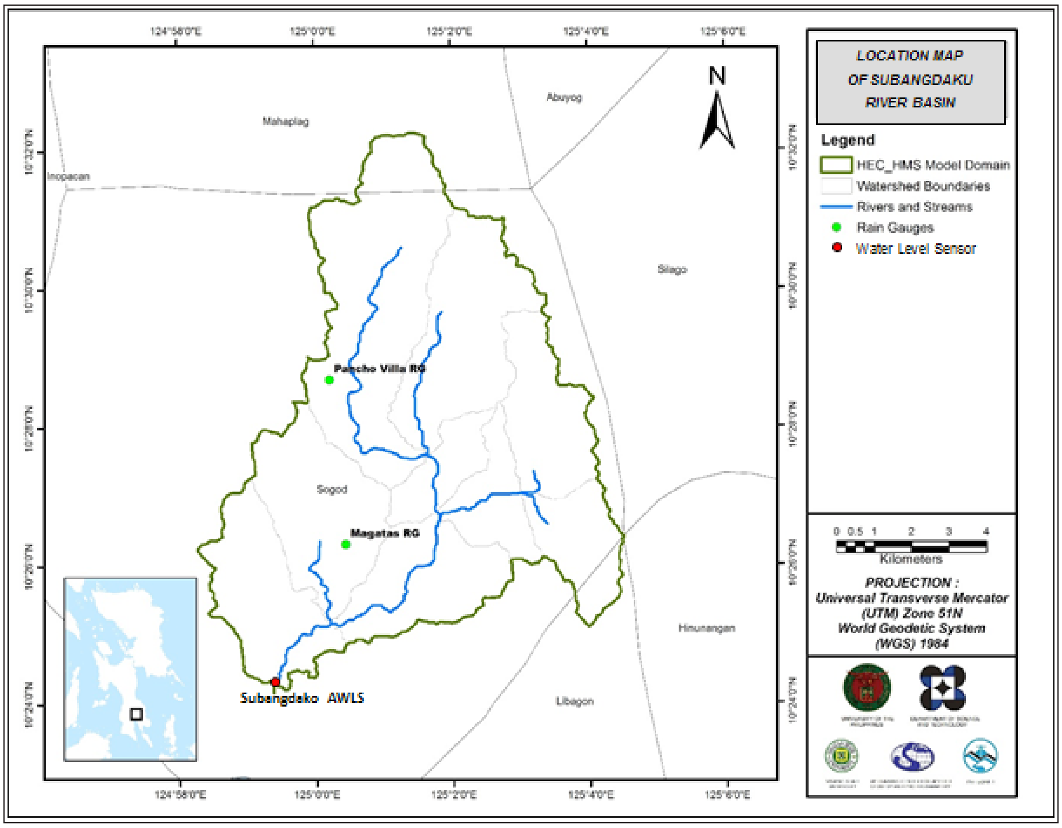


Figure 47. Location map of the Subangdaku HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48)at the SubangdakuBridge, Sogod, Southern Leyte (10°24'9.82"N, 124°59'22.77"E)to establish the relationship between the observed water levels (H) from the Subangdaku Bridge Automated Water Level Sensor (AWLS) and the outflow (Q) of the watershed at this location.

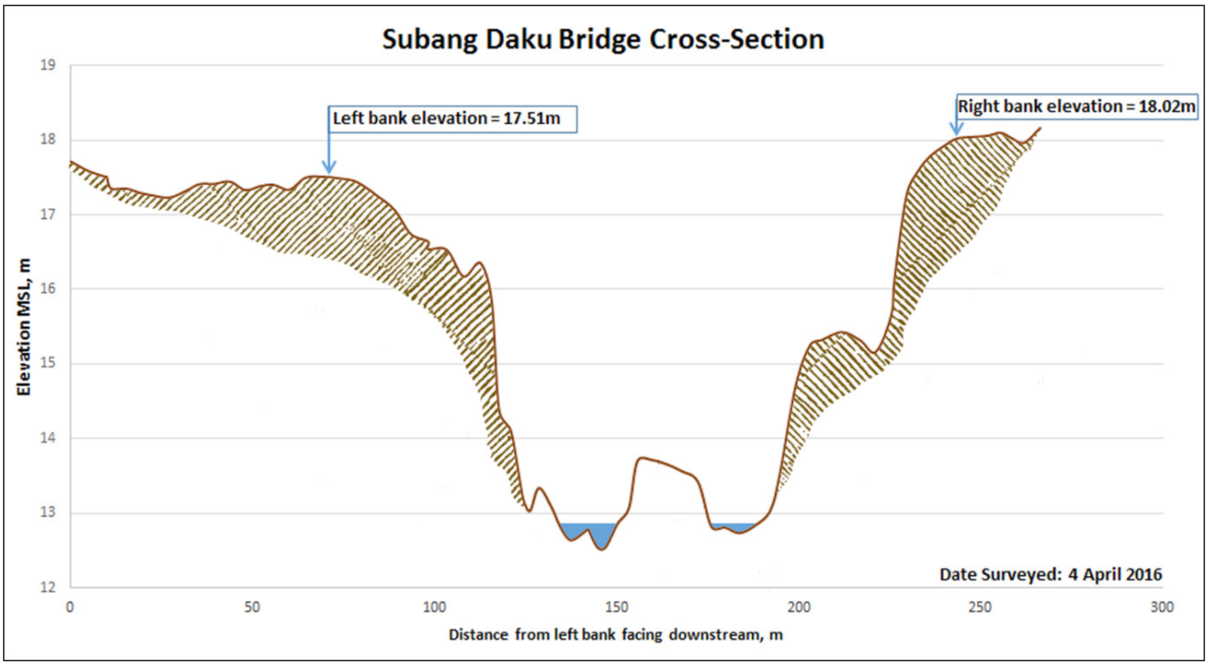


Figure 48. Cross-section plot of the Subangdaku Bridge

For the Subangdaku Bridge, the rating curve is expressed as $H = 12.326e^{0.0004Q}$,as reflectedin Figure 49.

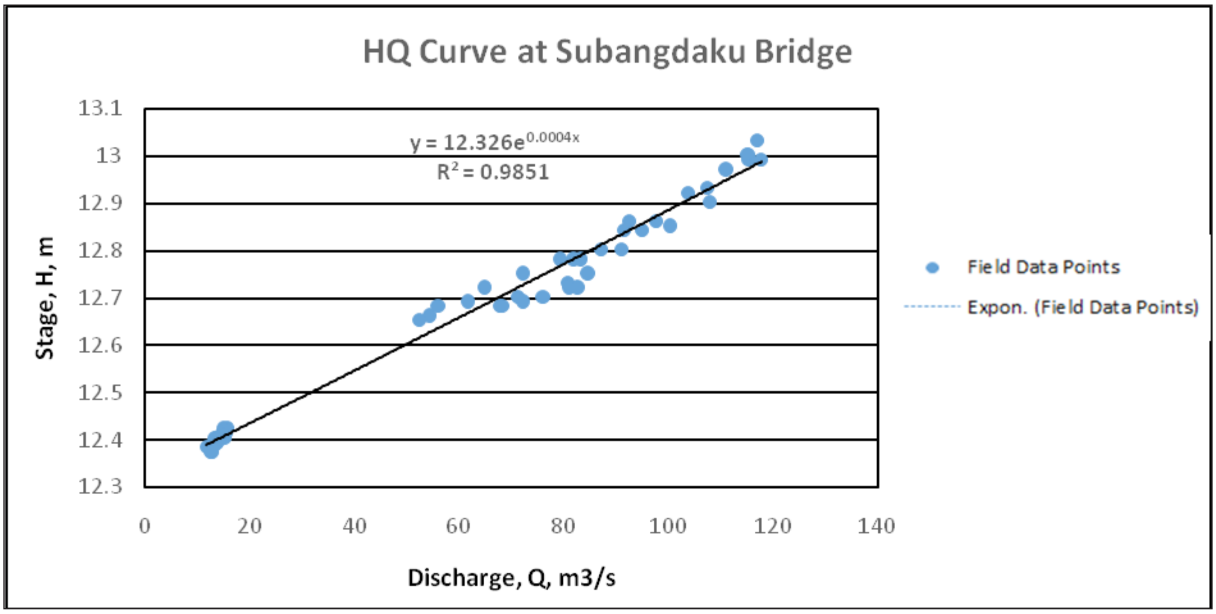


Figure 49. Rating curve at the Subangdaku Bridge

The resulting rating curve equation was used to compute for the river outflow at the Subangdaku Bridge, for the calibration of the HEC-HMS model exhibitedin Figure 50. The peak discharge was285.6 centimeters on December 19, 2015at 05:40 hrs.

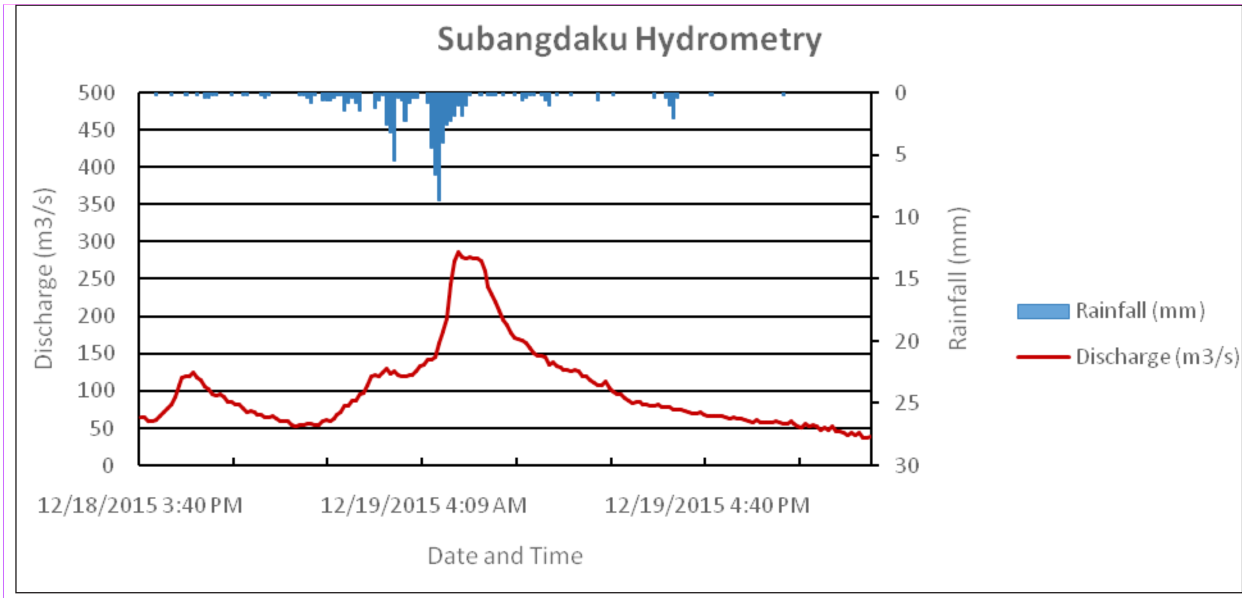


Figure 50. Rainfall and outflow data at the Subangdaku Bridge, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Maasin Rain Gauge (Table 29). This station was selected based on its proximity to the Subangdaku watershed (Figure 51). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the valuessuch that certain peak valueswere attained at a certain time.The extreme values for this watershed were computed based on a 16-year record.

Table 29. RIDF values for the Maasin 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	18.5	28.1	35.6	48.1	68	82.1	104.6	124.9	145
5	25.9	38.3	63.8	63.8	90.4	108.8	137.5	165.2	190.8
10	30.8	45	74.2	74.2	105.3	126.5	159.3	191.9	221.2
15	33.5	48.8	80.1	80.1	113.7	136.5	171.5	206.9	238.4
20	35.5	51.5	84.2	84.2	119.6	143.5	180.1	217.5	250.4
25	37	53.6	87.3	87.3	124.1	148.9	186.7	225.6	259.6
50	41.5	59.9	97.1	97.1	138.1	165.5	207.1	250.6	288.1
100	46.1	66.2	106.8	106.8	151.9	181.9	227.4	275.4	316.3

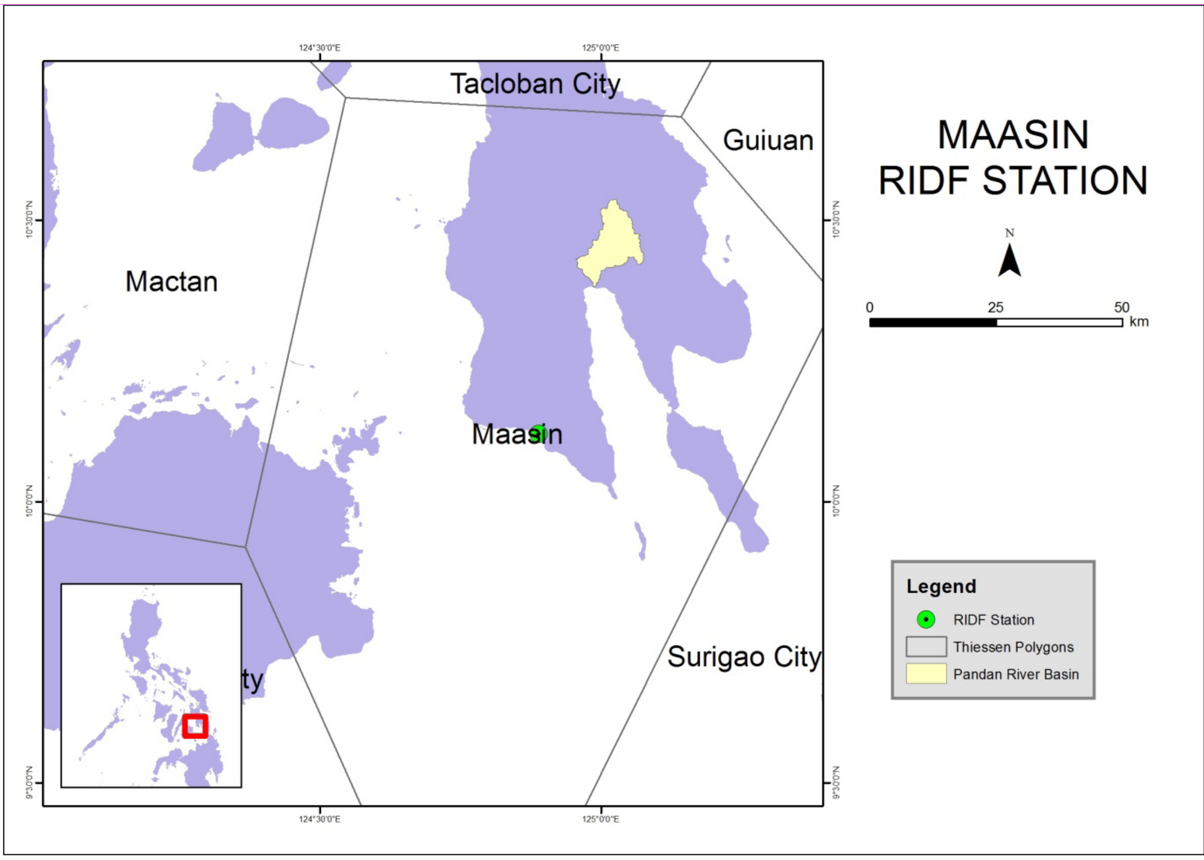


Figure 51. Location of the Maasin RIDF station relative to the Subangdaku River Basin

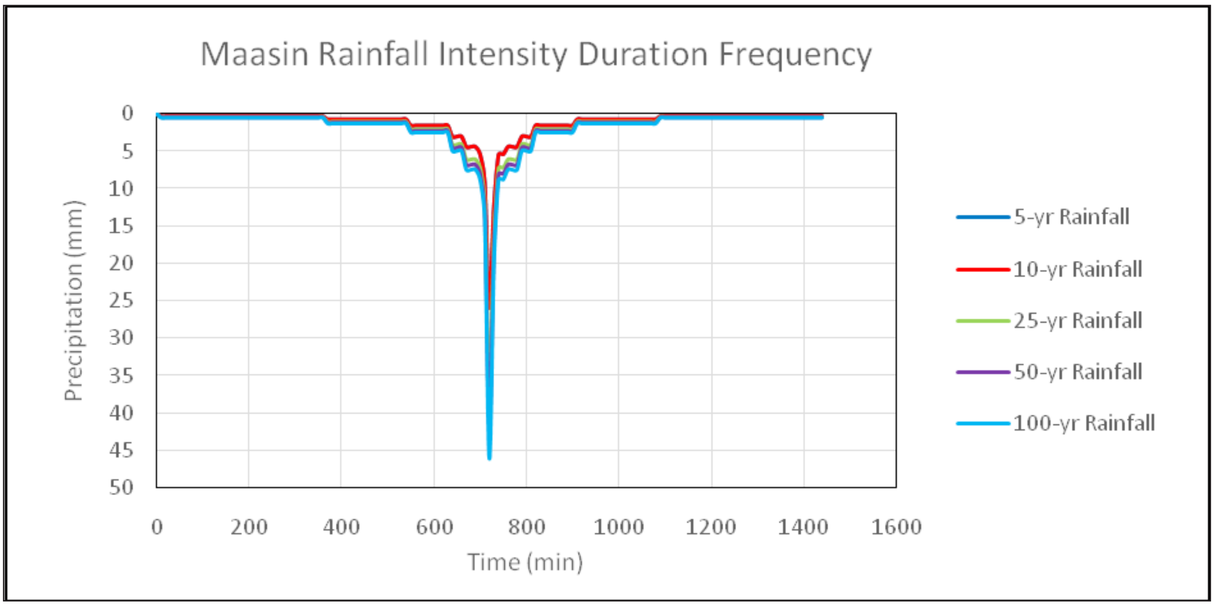


Figure 52. Synthetic storm generated from a 24-hr. period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Subangdaku River Basin are presentedin Figures 53 and 54, respectively.

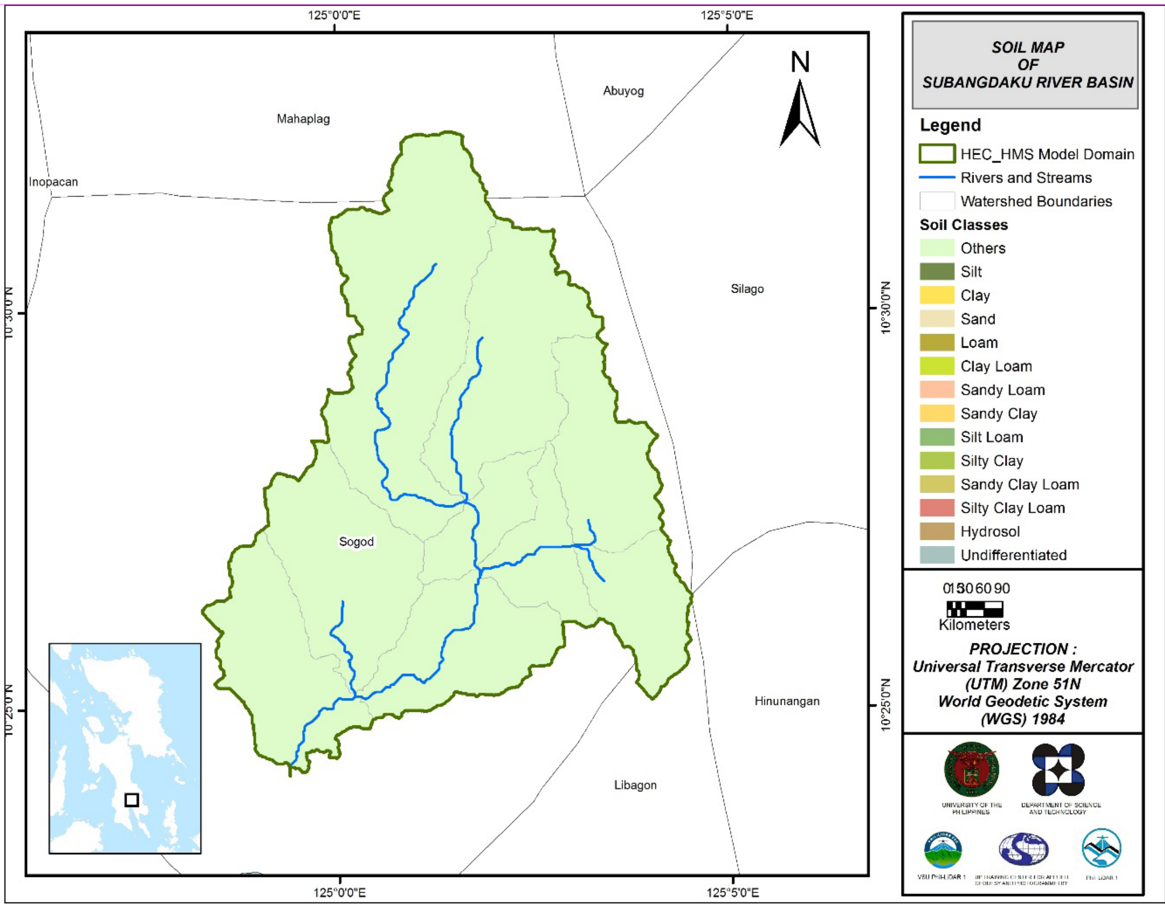


Figure 53. Soil map of the Subangdaku River Basin (Source: DA)

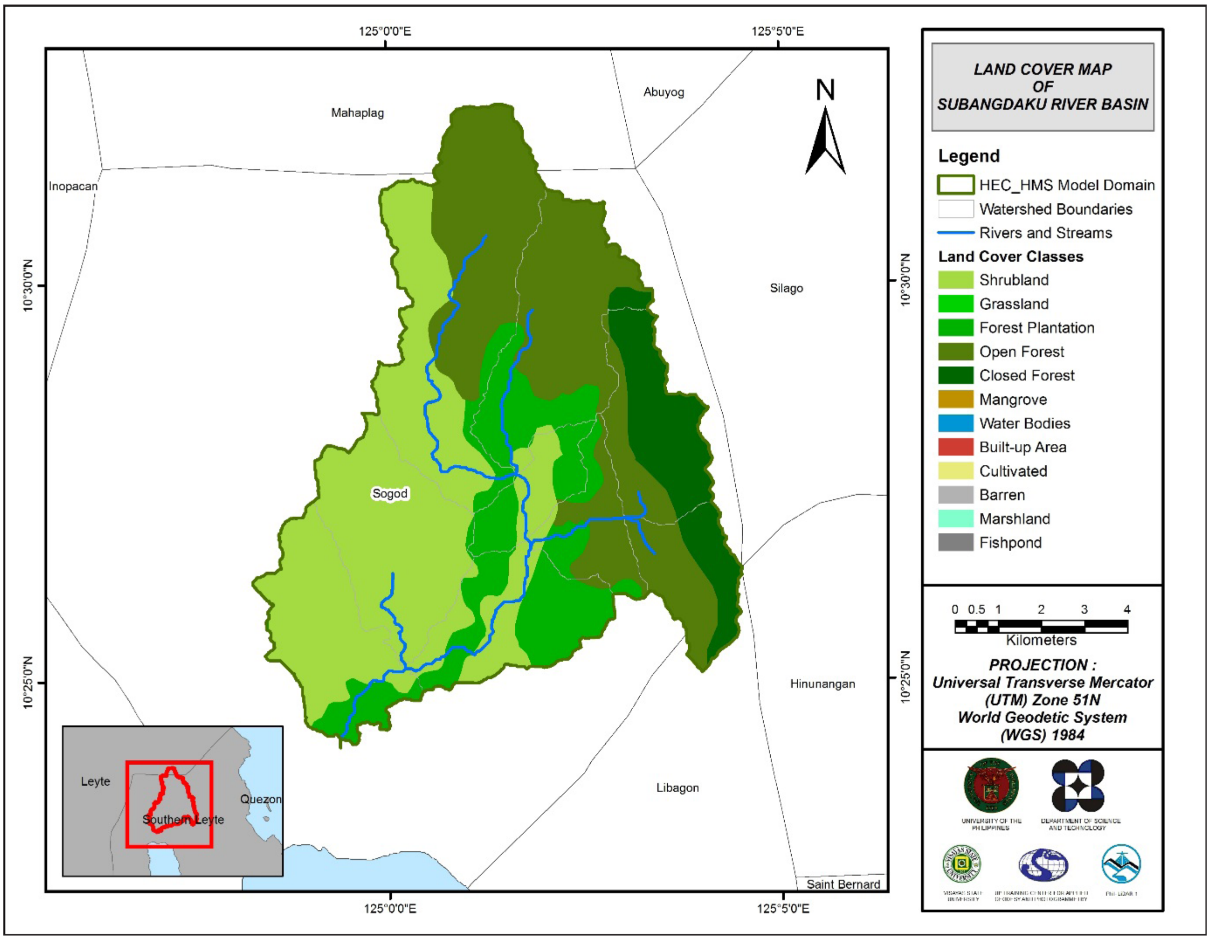


Figure 54. Land cover map of the Subangdaku River Basin (Source: NAMRIA)

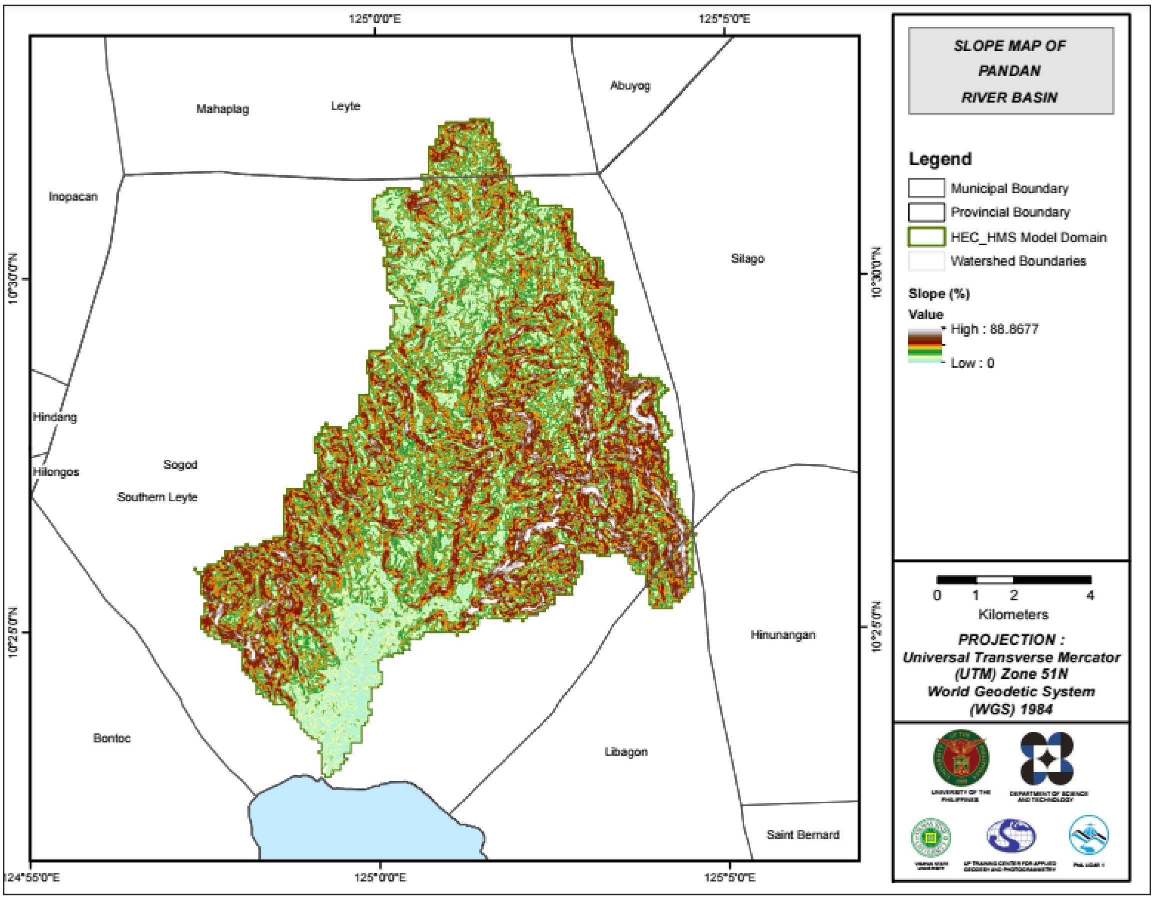


Figure 55. Slope map of the Subangdaku River Basin

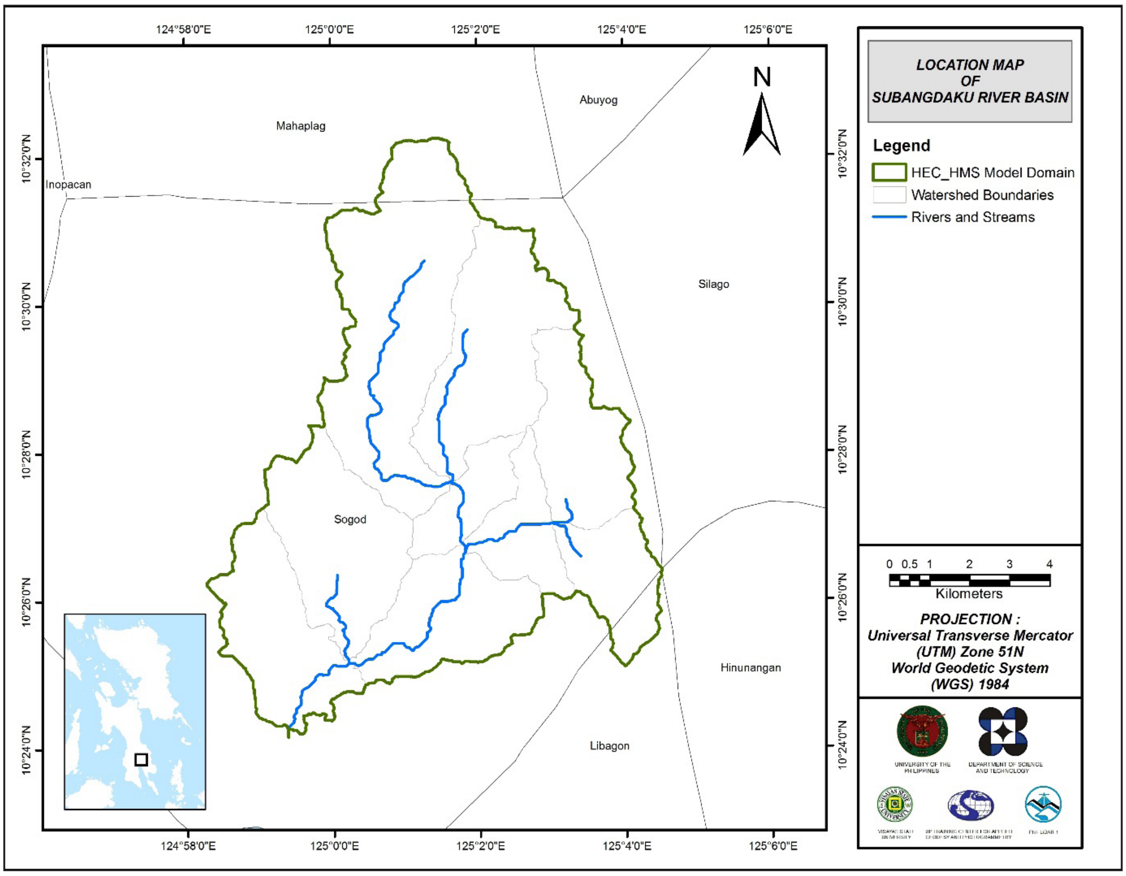


Figure 56. Stream delineation map of the Subangdaku River Basin

The model generation of the Subangdaku basin was carried out using the HEC-GeoHMS – an ArcGIS extension of the HEC-HMS. The input data were the SAR DEM (in a 10-meter resolution), and the soil and land cover maps of the basin. The resulting Subangdaku basin model consists of nine (9) sub-basins, four (4) reaches, and four (4) junctions, as illustrated in Figure 57. The Subangdaku basin's main outlet is in the Subangdaku Bridge, located near the town center of Sogod, Southern Leyte. The Subangdaku basin model was calibrated using the actual river discharge at the Subangdaku Bridge during the occurrence of Typhoon Onyok on December 18 – 20, 2015. The precipitation data on the same datesweretaken from the two (2) rain gauges deployed in the river basin. The Subangdaku Model Reach Parameters are available in Annex 10.

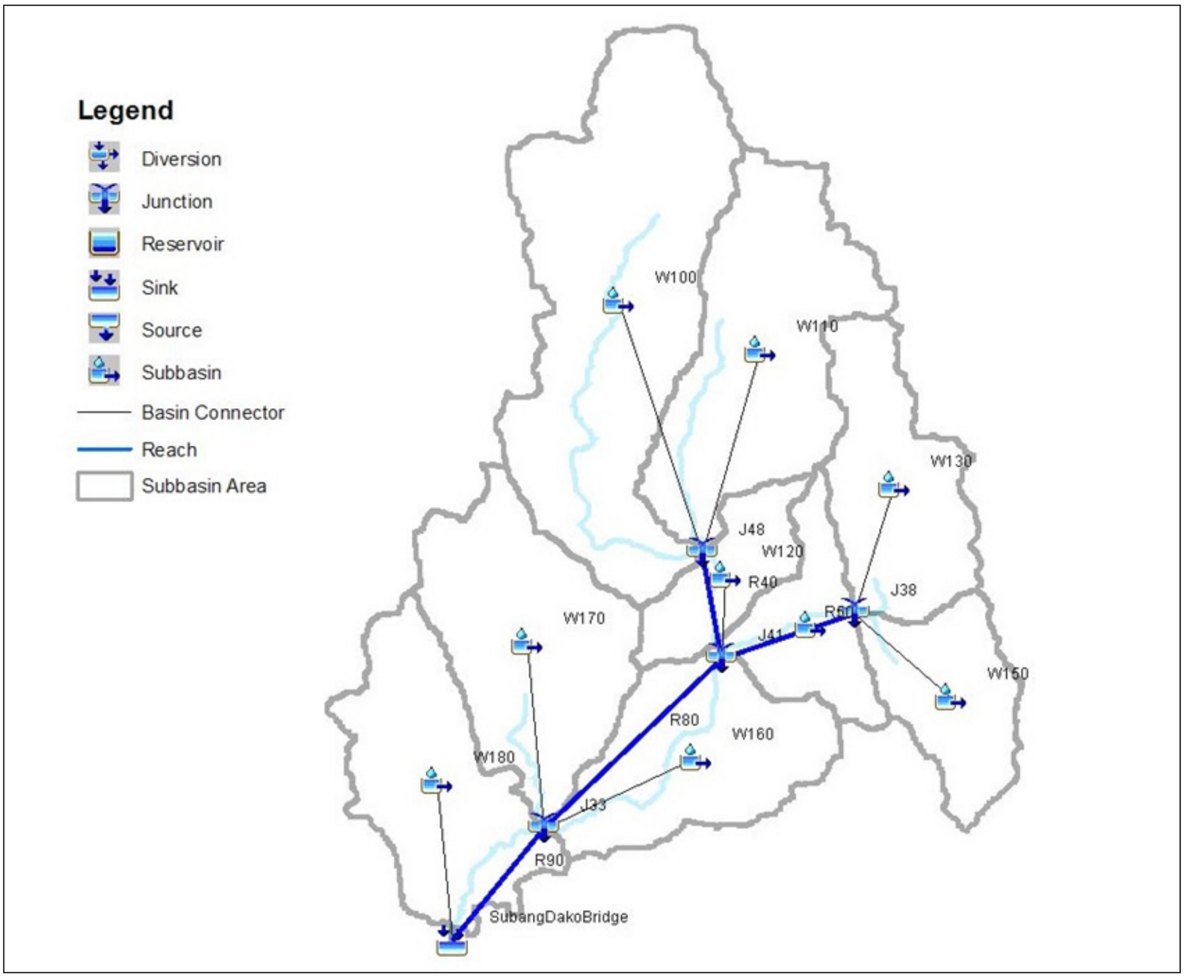


Figure 57. The Subangdaku River Basin model, generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model werederived fromthe LiDAR DEM data. The data were defined using the Arc GeoRAS tool, and post-processed in ArcGIS (Figure 58).

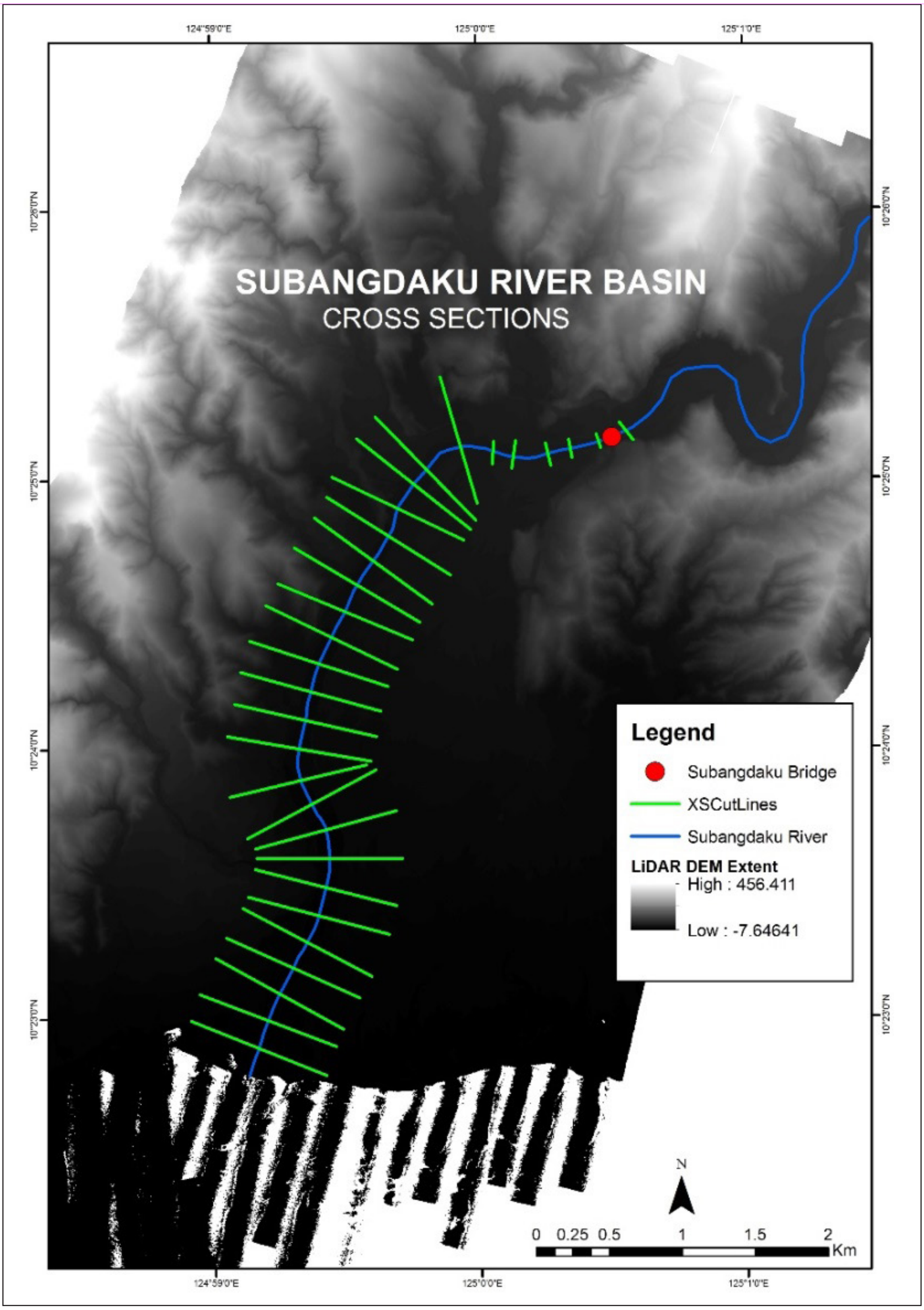


Figure 58. River cross-section of the Subangdaku River, generated through the ArcMap HEC

5.5 Flo 2D Model\

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

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

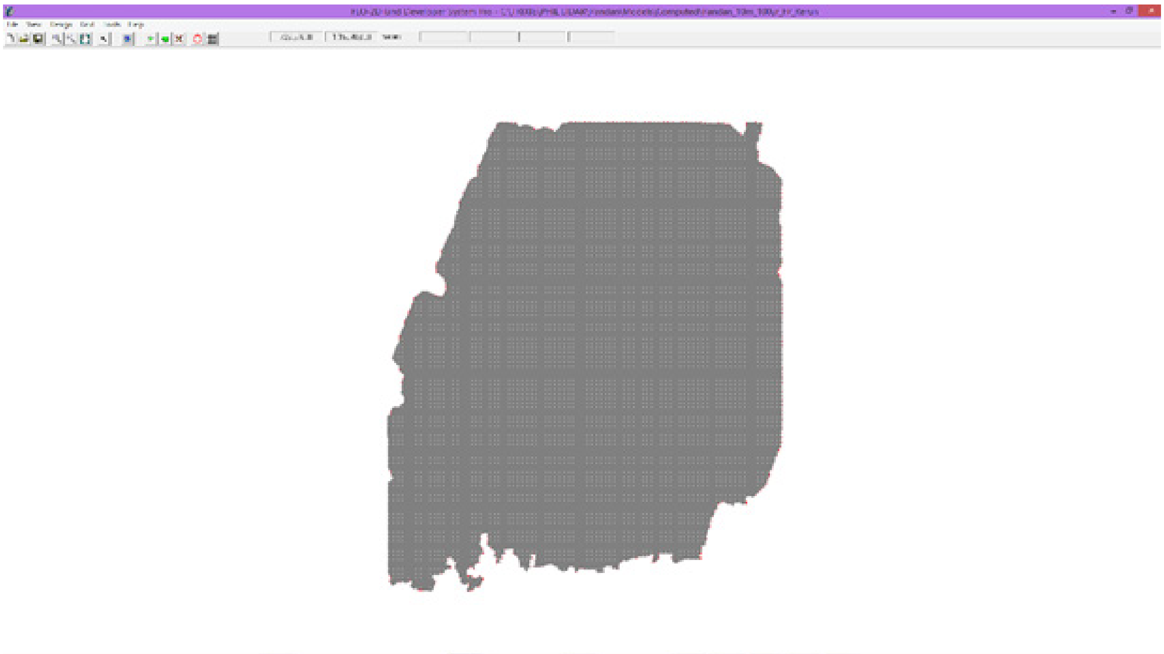


Figure 59. A screenshot of a sub-catchment, with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 21.63574 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 31 541 300.00 m2.

There is a total of 25 724 292.73 m3 of water entering the model. Of this amount, 9 668 003.15 m3 is due to rainfall while 16 056 289.58 m3 is inflow from other areas outside the model. 2 559 059.00 m3 of this water is lost to infiltration and interception, while 1 316 930.65 m3 is stored by the flood plain. The rest, amounting up to 21 848 303.14 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Subangdaku HEC-HMS River Basin model, its accuracy was measured against the observed values. Figure 60shows the comparison between the two (2) discharge data. The Subangdaku Model Basin Parameters are found in Annex 9.

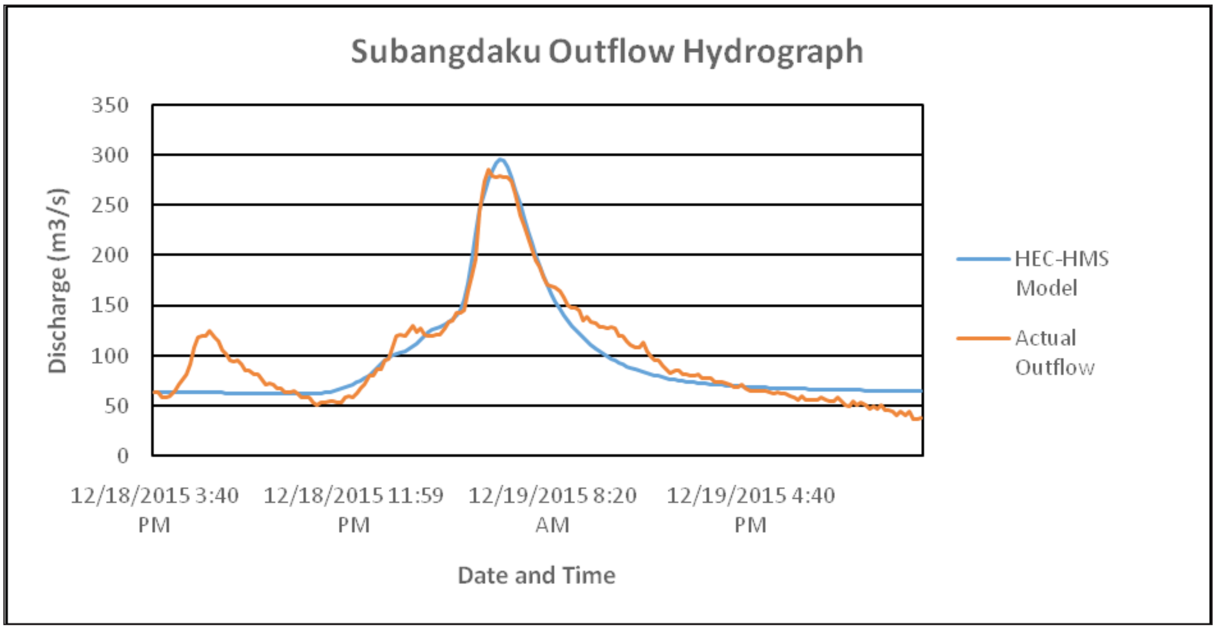


Figure 60. Outflow hydrograph of the Subangdaku River Basin produced by the HEC-HMS model, compared with the observed outflow

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 the Subangdaku River Basin Model

Basin/Reach Characteristic	Method	Parameter	Range of Calibrated Values
Loss	SCS Curve number	Initial Abstraction (mm)	4 - 20
		Curve Number	72 - 92
Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.8 - 3
		Storage Coefficient (hr)	0.8 - 3
Baseflow	Recession	Recession Constant	0.9
		Ratio to Peak	0.38
Routing	Muskingum-Cunge	Manning's n	0.04

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values from 4 to 20millimeters for the initial abstractionmeans that there is a minimal to average amount of infiltration or rainfall interception by vegetation.

The 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 the curve number increases. The range of 72 to 92 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.8 to 3 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.9 indicates that the basin is unlikely to quickly return to its original discharge, and will be higherinstead. A ratio to peak of 0.38representsa steeper receding limb of the outflow hydrograph.

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

Table 31. Efficiency Test of the Subangdaku HMS Model

RMSE	17.90
r^2	0.99
NSE	0.90
PBIAS	2.17
RSR	0.31

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified as17.9 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.99.

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 0.90.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is 2.17.

The Observation Standard Deviation Ratio(RSR) is an error index. A perfect model attains a value of 0 when the error units of the valuesare quantified. The model has an RSR value of 0.31.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

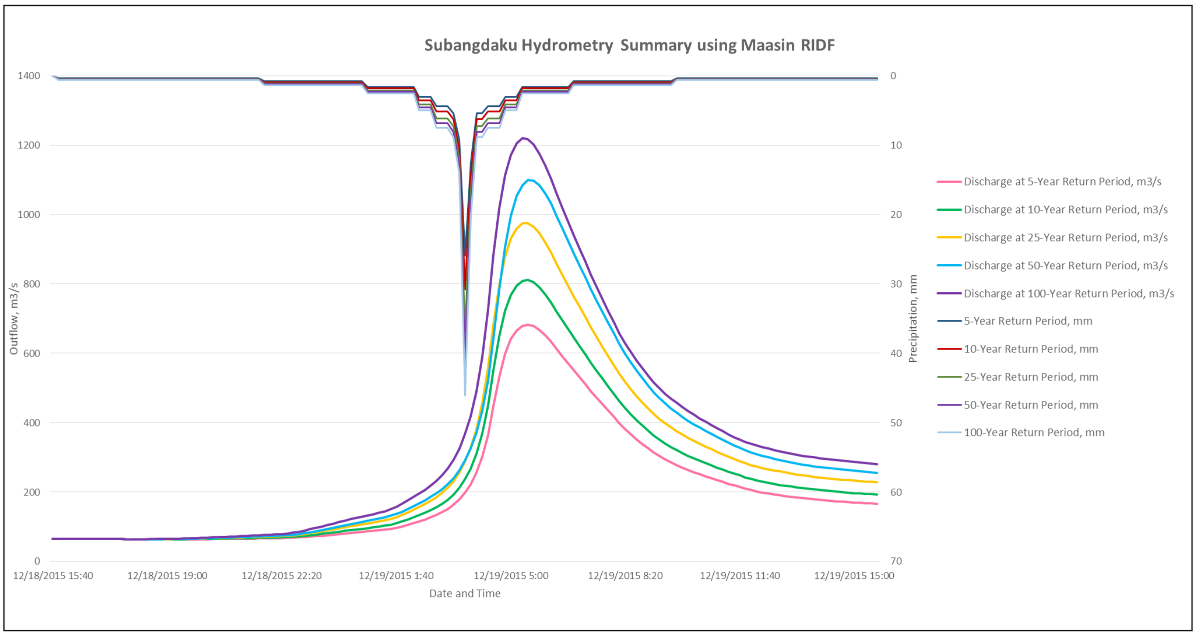


Figure 61. Outflow hydrograph at the Subangdaku Station generated using the Maasin RIDF, simulated in HEC-HMS

The summary graph (Figure 61) depicts the Subangdaku outflow using the MaasinRIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Subangdaku discharge using the MaasinRIDF curves in five (5) different return periods is provided in Table 32.

Table 32. Peak values of the Subangdaku HEC-HMS Model outflow using the Maasin RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m ^{3}/s)	Time to Peak
5-Year	190.8	25.9	682.6	1 hour,50 minutes
10-Year	221.2	30.8	811.3	1 hour, 50 minutes
25-Year	259.6	37	974.9	1 hour, 50 minutes
50-Year	288.1	41.5	1098.5	1 hour, 50 minutes
100-Year	316.3	46.1	1219.7	1 hour, 40 minutes

5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method

Thegenerated values for the river discharge entering the Subangdaku floodplain in various return periodsare exhibitedin Figure 62,and the peak values are summarized in Table 33.

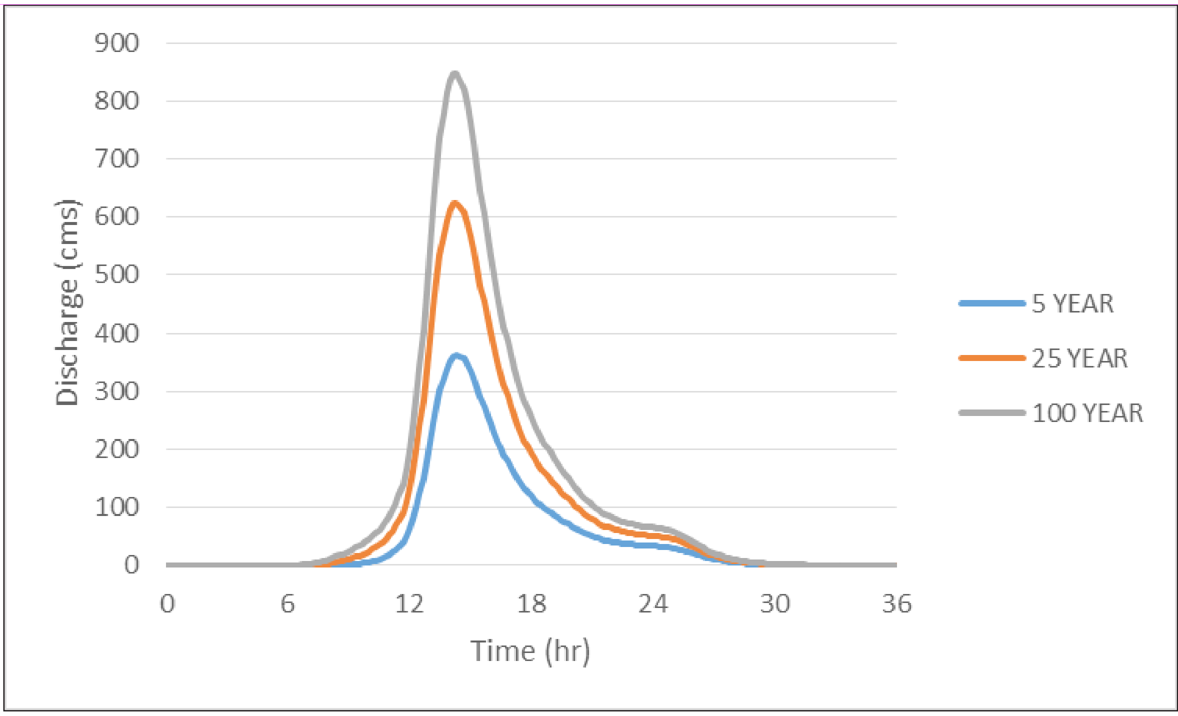


Figure 62. Generated discharge of the Subangdaku River, using interpolated 5-yr., 25-yr., and 100-yr. RIDF in HEC-HMS

Table 33. Summary of the Subangdaku River discharge, generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak (minutes)
100-Year	847.2	134.48
25-Year	624.3	134.48
5-Year	362.7	134.48

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the estimates from the bankful and specific discharge methodis shown in Table 34.

Table 34. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Subangdaku	319.176	0.243	191.918	FALSE	FALSE

The values generated from the HEC-HMS river discharge estimates using the bankful discharge and specific discharge methods were not able to satisfy the required conditions for validation. The calculated values werebased on theory, but weresupported byother discharge computation methods;hence,thesewere appropriateto be applied for flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain the actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the extent of real-time flood inundation of the river, after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is presented, since only the VSU-FMC base flow was calibrated. The sample generated map of the Subangdaku River using the calibrated HMS base flow is shown in Figure 63.

Figure 63. Sample output map of the Subangdaku RAS model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps for the 5-year, 25-year, and 100-year rain return scenarios forthe Subangdaku floodplain are presentedin Figure 64 to Figure 69.

The floodplain, with an area of 31.12 square kilometers, covers two (2) municipalities; namely,Bontoc and Sogod. Table 35indicatesthe percentage of area affected by flooding, per municipality.

Table 35. Municipalities affected in the Subangdaku floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Bontoc	89.13	0.03	0.04%
Sogod	217.2	31.06	14%

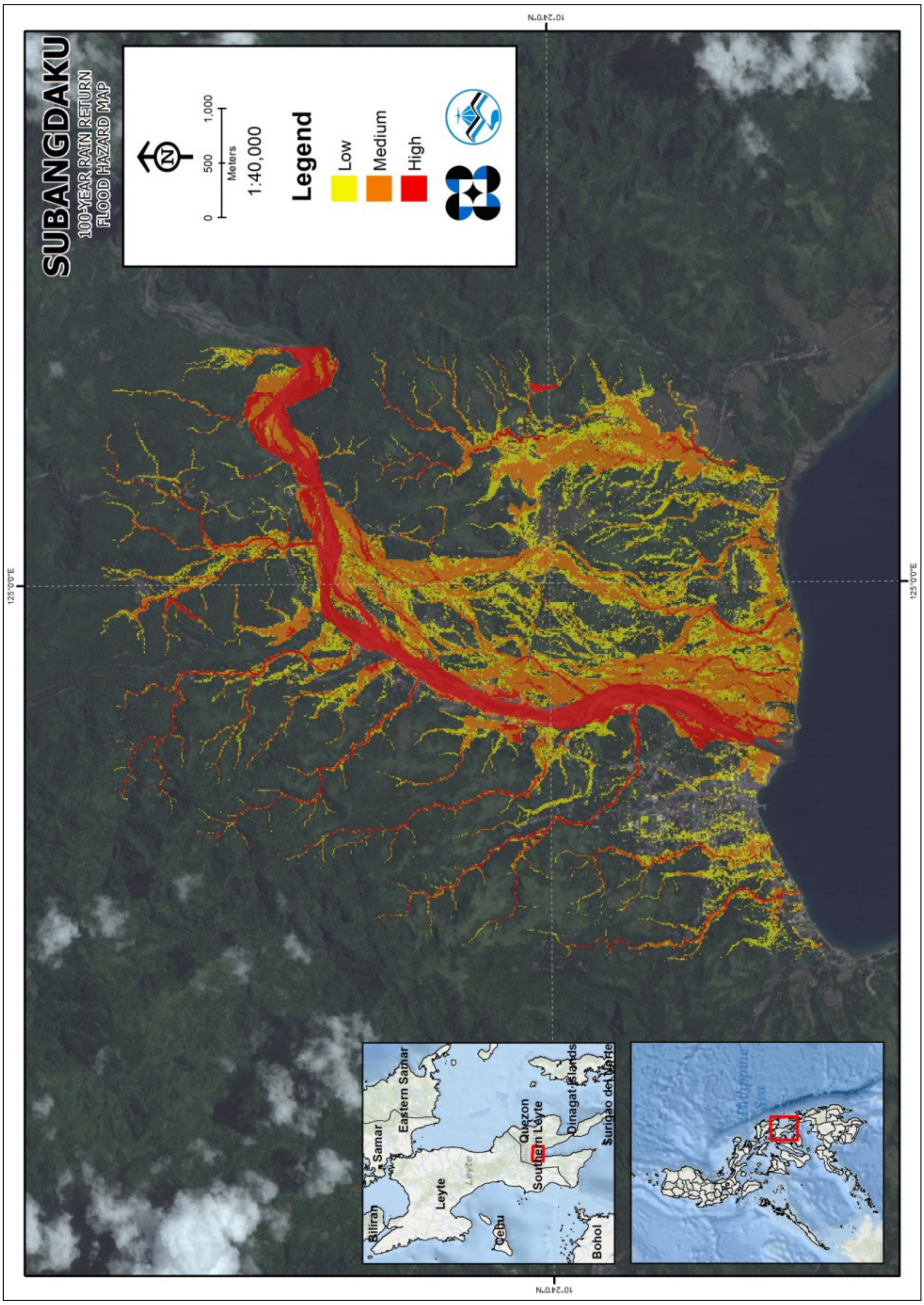


Figure 64. 100-year flood hazard map for the Subangdaku floodplain

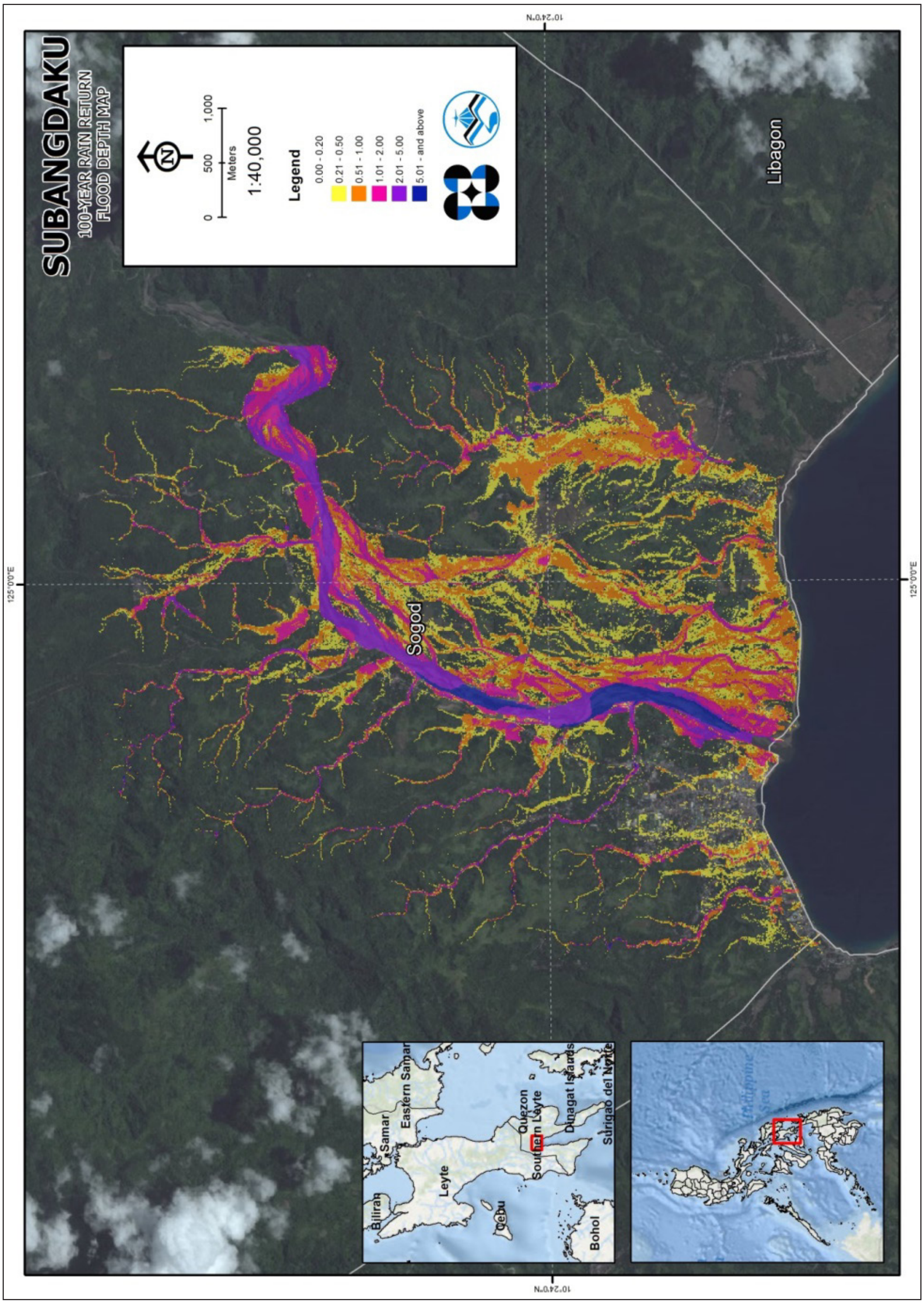


Figure 65. 100-year flow depth map for the Subangdaku floodplain

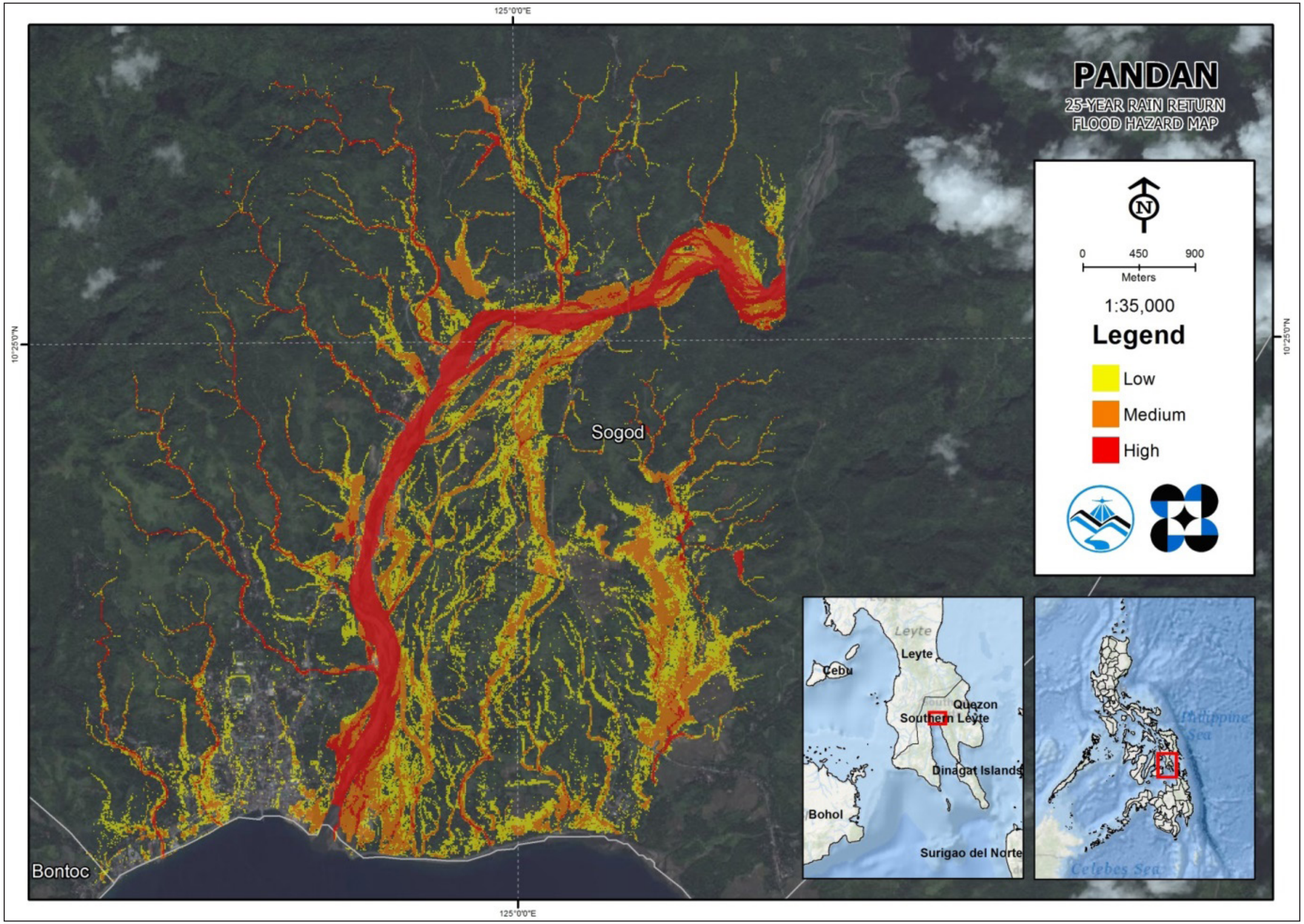


Figure 66. 25-year flood hazard map for the Subangdaku floodplain

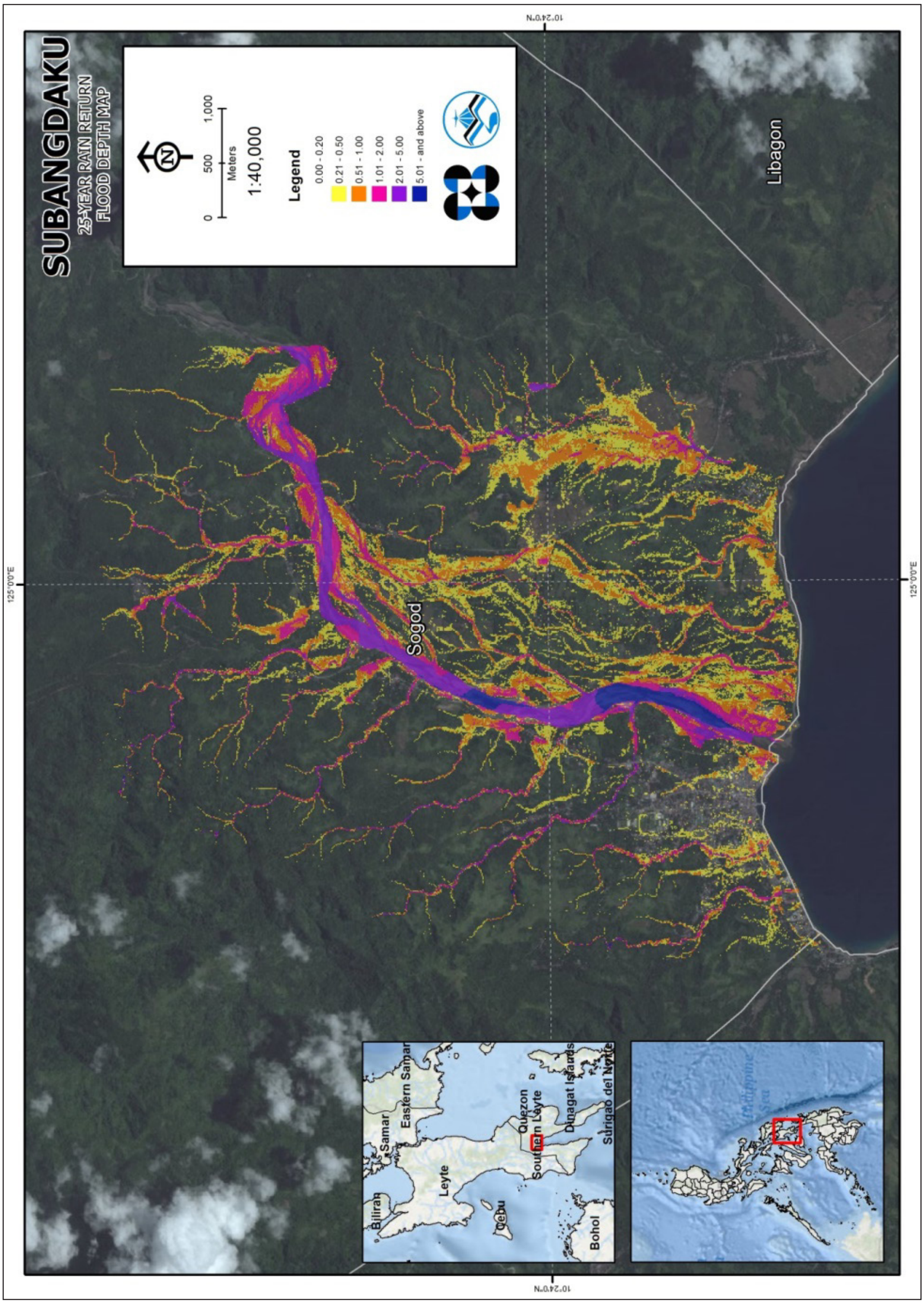


Figure 67. 25-year flow depth map for the Subangdaku floodplain

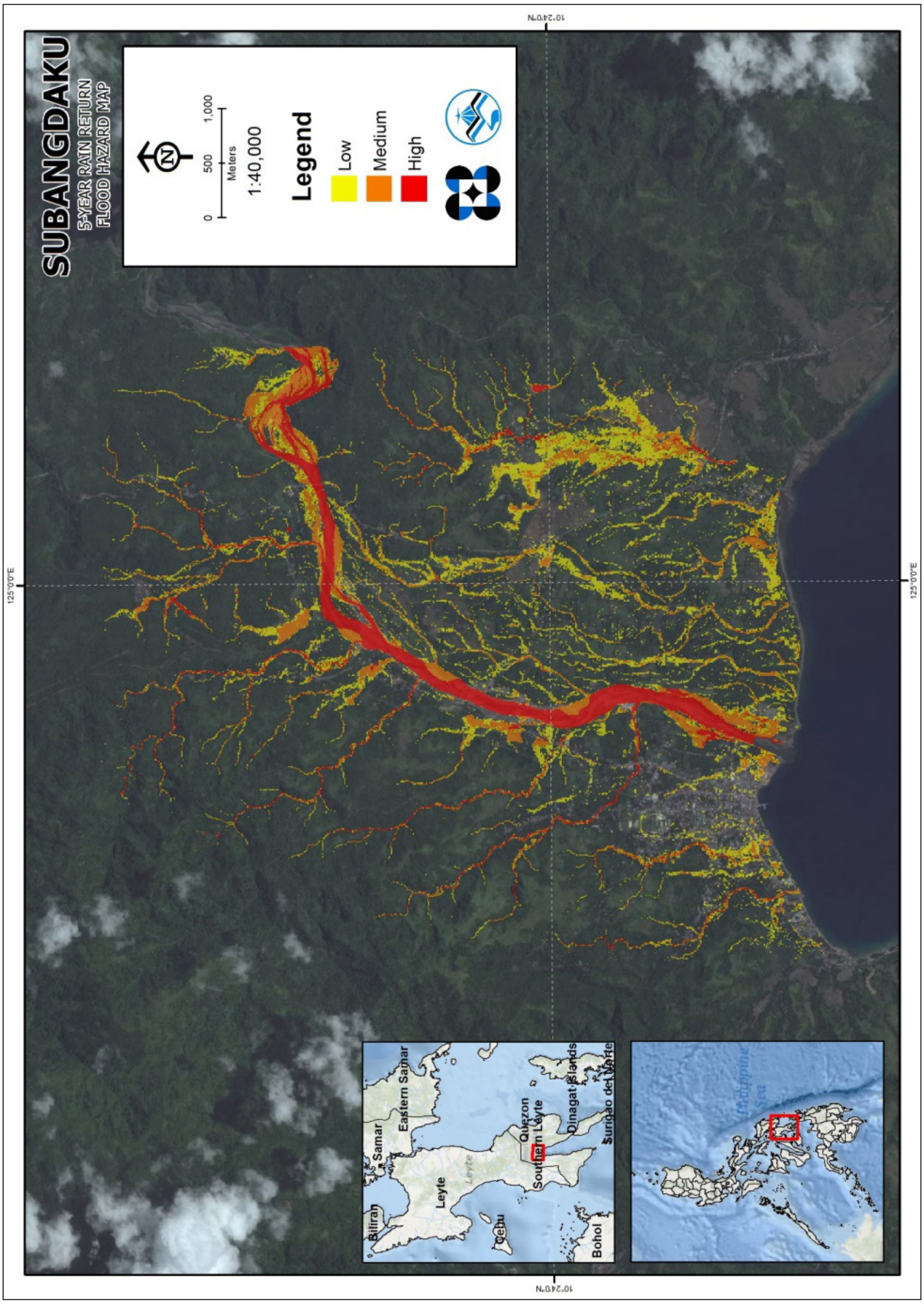


Figure 68. 5-year flood hazard map for the Subangdaku floodplain

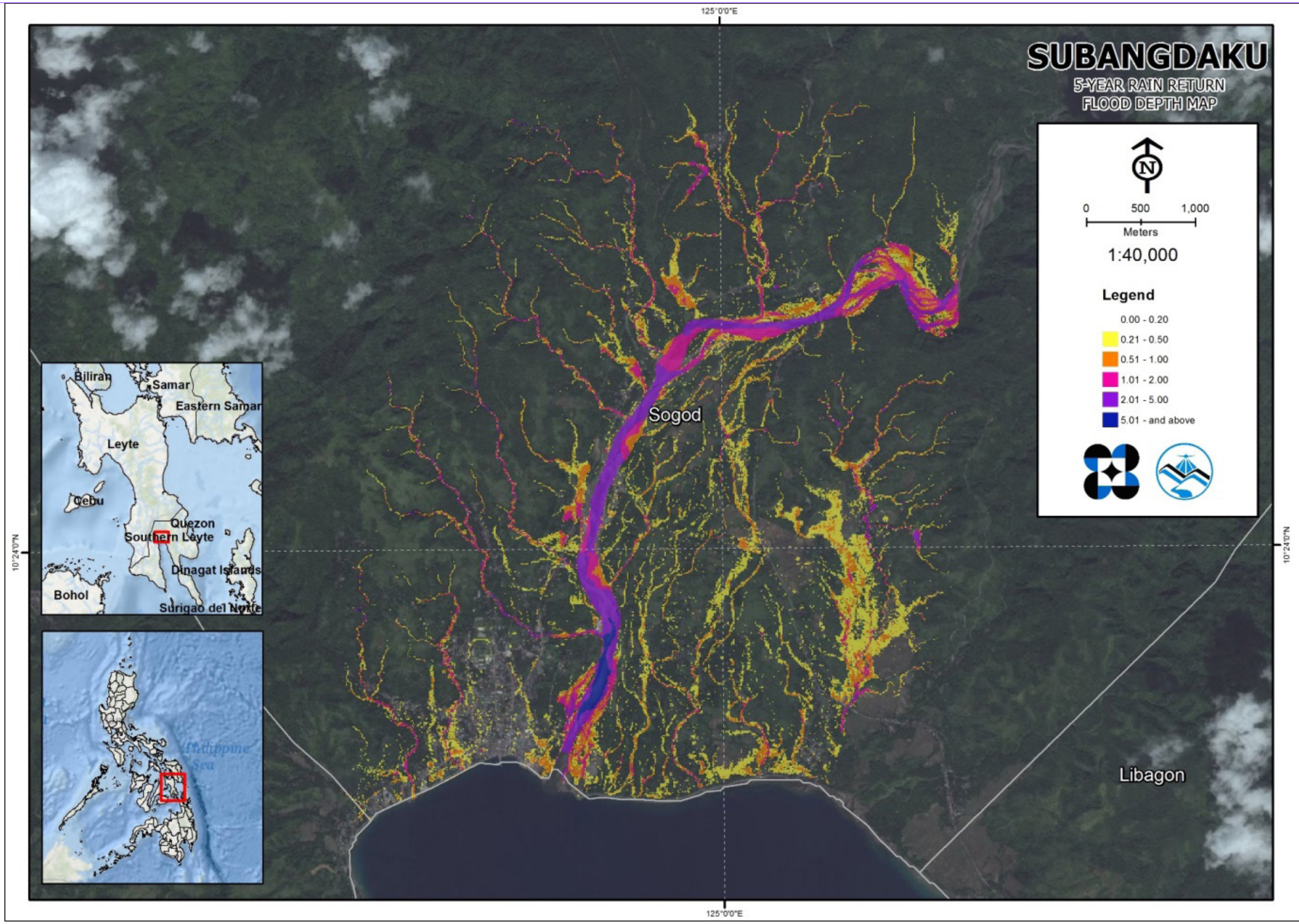


Figure 69. 5-year flow depth map for the Subangdaku floodplain

5.10 Inventory of Areas Exposed to Flooding

The affected barangays in the Subangdaku River Basin, grouped by municipality, are listed in this section. For the said basin, two (2) municipalities consisting of thirty-two (32) barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 0.04% of the Municipality of Bontoc, with an area of 89.13 square kilometers, will experience flood levels of less than 0.20 meters. 0.002% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.001% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected Areas in Bontoc, Southern Leyte during a 5-Year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Bontoc
		Santa Cruz
Affected Area (sq. km.)	0.03-0.20	0.032
	0.21-0.50	0.0021
	0.51-1.00	0.0009
	1.01-2.00	0
	2.01-5.00	0
	> 5.00	0

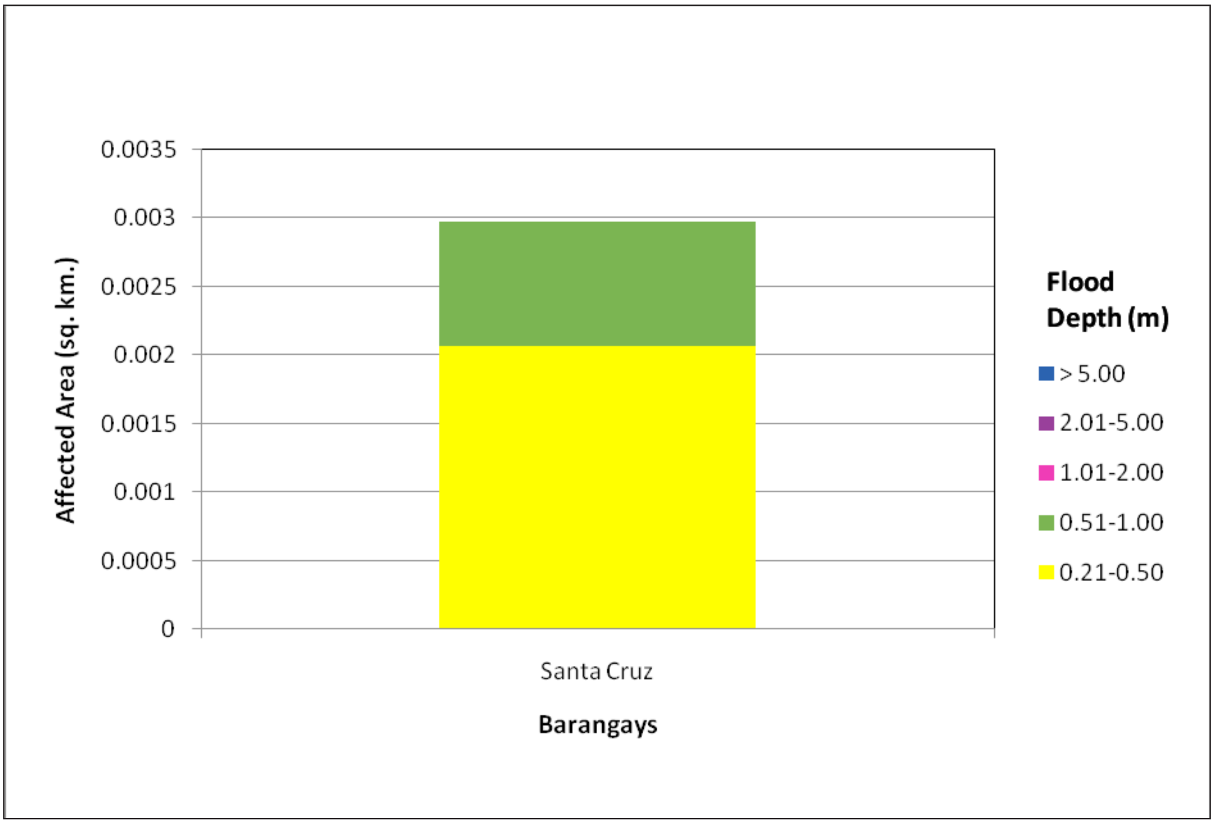


Figure 70. Affected Areas in Bontoc, Southern Leyte during a 5-Year rainfall return period

For the Municipality of Sogod, with an area of 217.20 square kilometers, 11.94% will experience flood levels of less than 0.20 meters. 1.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.53%, 0.37%, 0.31%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 37-39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Sogod, Southern Leyte during a 5-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte										
		Buac Daku	Buac Gamay	Cabadbaran	Concepcion	Consolacion	Dagsa	Hibod-Hibod	Javier	La Purisima	Libas	Mabicay
Affected Area (sq. km.)	0.03-0.20	1.81	1.58	0.75	1.6	0.99	1.26	2.92	0.18	0.67	0.41	0.76
	0.21-0.50	0.21	0.083	0.0098	0.24	0.19	0.041	0.21	0.02	0.16	0.0072	0.03
	0.51-1.00	0.081	0.088	0.0094	0.063	0.072	0.018	0.15	0.0058	0.13	0.0044	0.018
	1.01-2.00	0.037	0.092	0.0045	0.0067	0.022	0.013	0.14	0.0005	0.085	0.0031	0.012
	2.01-5.00	0.048	0.056	0.0046	1.00E-04	0.002	0.0035	0.056	0	0.13	0.0024	0.0032
	> 5.00	0.0001	0	0.0011	0	0	0.0003	0	0	0.077	0.0002	0.0008

Table 38. Affected areas in Sogod, Southern Leyte during a 5-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte									
		Mac	Magatas	Mahayahay	Malinao	Milagroso	Pandan	Rizal	Salvacion	San Isidro	San Jose
Affected Area (sq. km.)	**0.03-0.20**	0.017	1.51	0.75	0.94	0.57	1.01	1.16	0.45	0.75	0.51
	0.21-0.50	0.0019	0.04	0.25	0.18	0.012	0.052	0.022	0.05	0.011	0.041
	0.51-1.00	0.00054	0.024	0.078	0.063	0.0061	0.036	0.016	0.015	0.0075	0.014
	1.01-2.00	0	0.0089	0.023	0.014	0.0048	0.03	0.013	0.0043	0.0072	0.01
	2.01-5.00	0	0.0007	0.0034	0.014	0.0026	0.065	0.0054	0	0.0027	0.0001
	> 5.00	0	0	0	0	1.00E-04	0	0.0007	0	0.0003	0

Table 39. Affected areas in Sogod, Southern Leyte during a 5-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte									
		San Miguel	San Pedro	Santa Maria	Suba	Tampoong	Zone I	Zone II	Zone III	Zone IV	Zone V
Affected Area (sq. km.)	**0.03-0.20**	0.98	0.058	0.00023	1.7	0.41	0.52	0.074	0.1	0.44	1.08
	0.21-0.50	0.088	0.0044	0	0.15	0.086	0.028	0.0078	0.014	0.026	0.13
	0.51-1.00	0.056	0.0029	0	0.11	0.025	0.002	0.0005	0.0032	0.012	0.054
	1.01-2.00	0.024	0.00091	0	0.16	0.015	0.0017	0.0004	0	0.0085	0.066
	2.01-5.00	0.077	0	0	0.095	0.0038	0.0028	0	0	0.0016	0.091
	> 5.00	0.0009	0	0	0	0	0	0	0	0	0

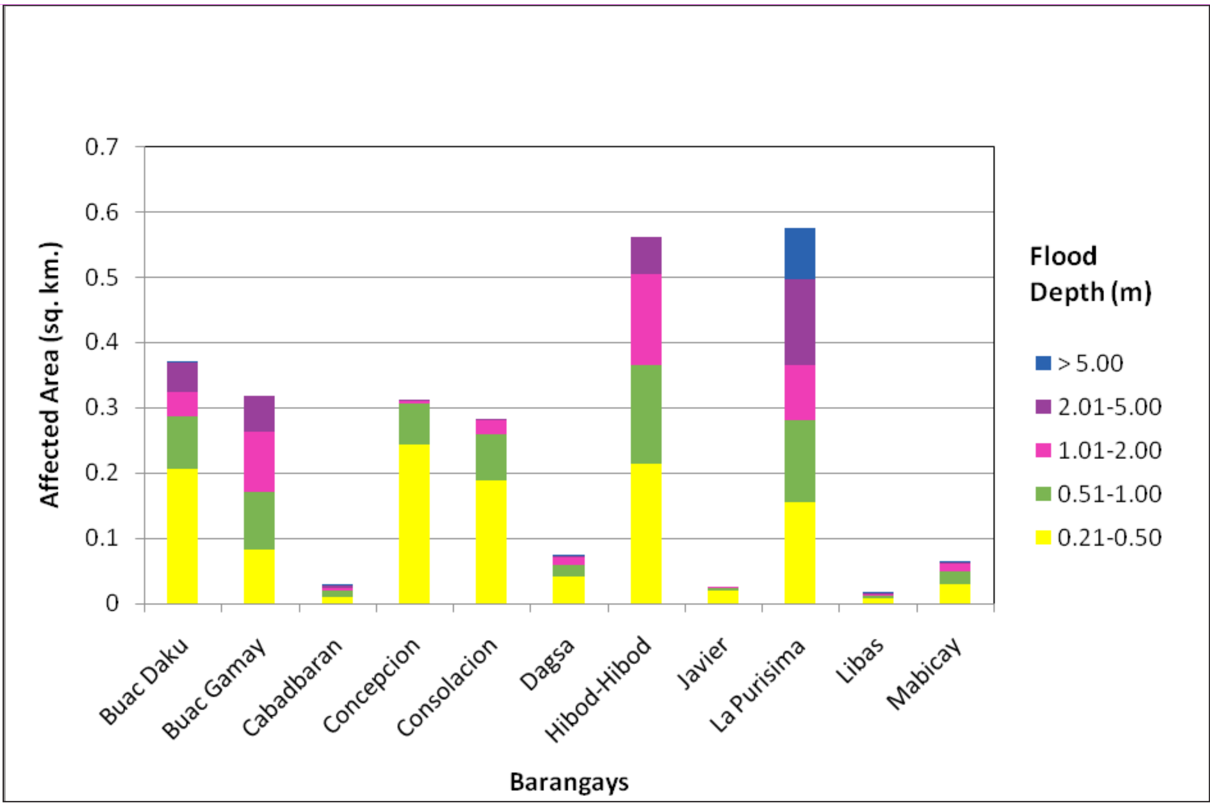


Figure 71. Affected areas in Sogod, Southern Leyte during a 5-year rainfall return period

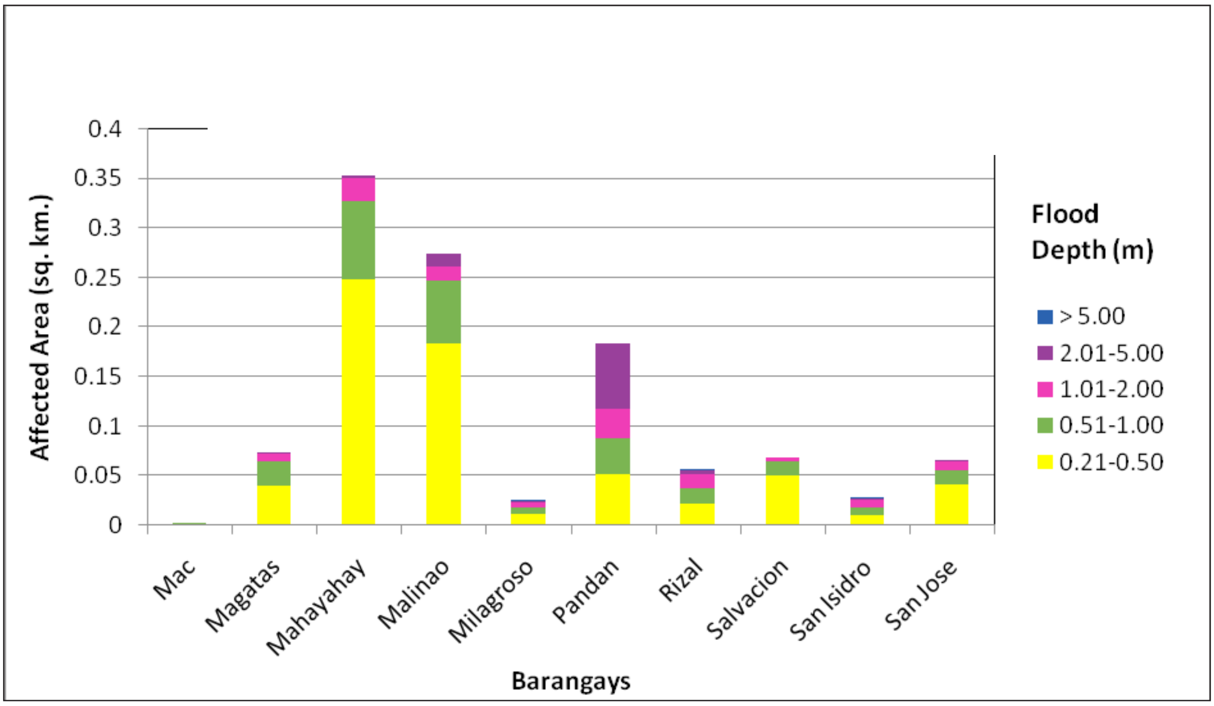


Figure 72. Affected areas in Sogod, Southern Leyte during a 5-year rainfall return period

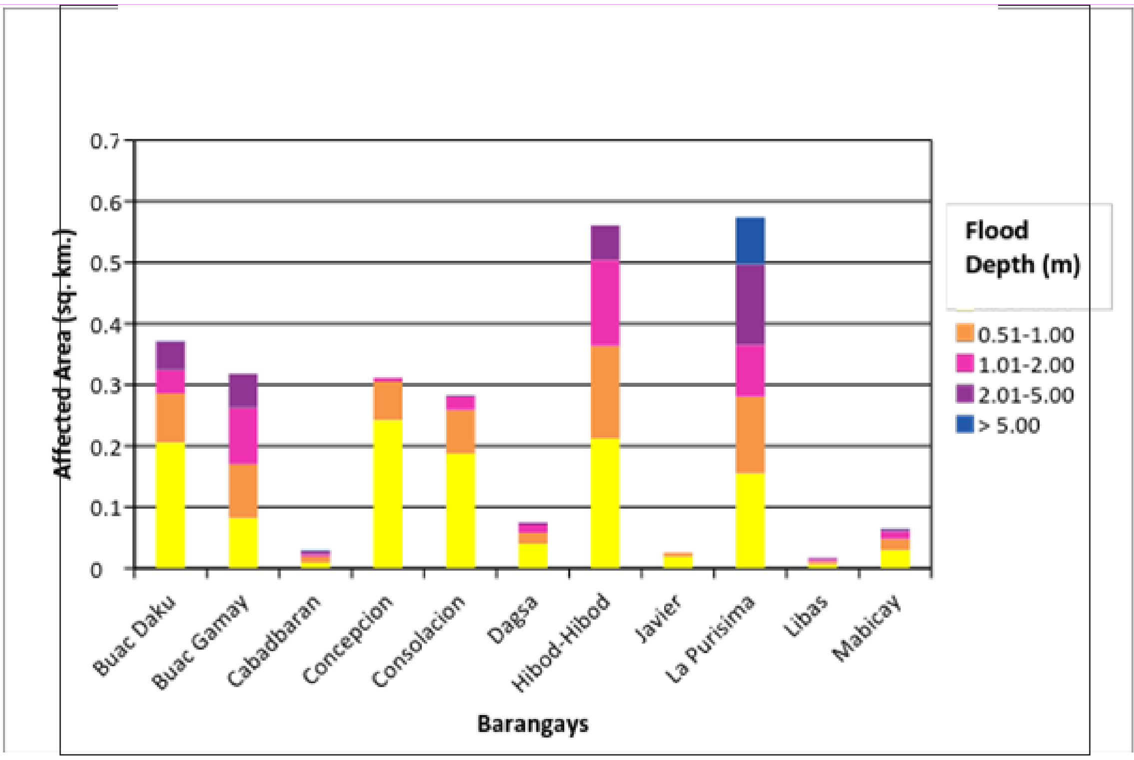


Figure 73. Affected areas in Sogod, Southern Leyte during a 5-year rainfall return period

For the 25-year return period, 0.03% of the Municipality of Bontoc, with an area of 89.13 square kilometers, will experience flood levels of less than 0.20 meters. 0.003% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 0.001% and 0.001% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Bontoc, Southern Leyte during a 25-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Bontoc, Southern Leyte
		Santa Cruz
Affected Area (sq. km.)	0.03-0.20	0.031
	0.21-0.50	0.003
	0.51-1.00	0.0011
	1.01-2.00	0.0001
	2.01-5.00	0
	> 5.00	0

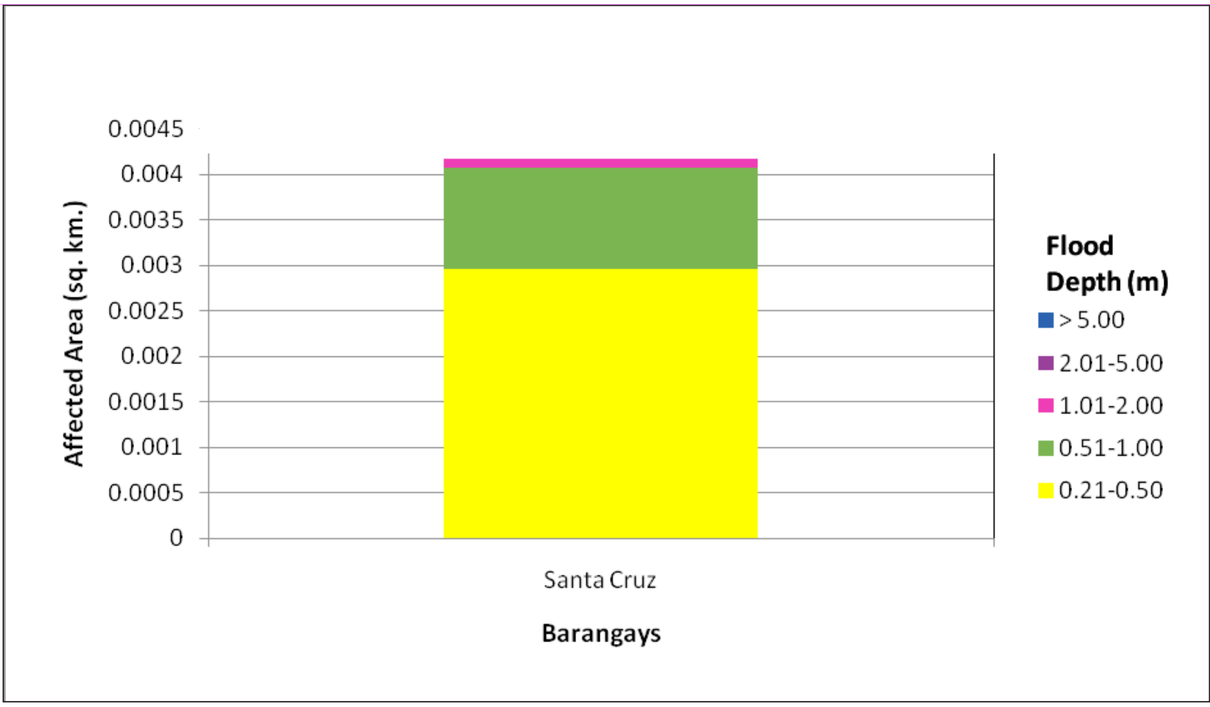


Figure 74. Affected areas in Bontoc, Southern Leyte during a 25-year rainfall return period

For the Municipality of Sogod, with an area of 217.20 square kilometers, 10.84% will experience flood levels of less than 0.20 meters. 1.45% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.93%, 0.56%, 0.42%, and 0.10% 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 Tables 41-43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Sogod, Southern Leyte during a 25-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte										
		Buac Daku	Buac Gamay	Cabadbaran	Concepcion	Consolacion	Dagsa	Hibod-Hibod	Javier	La Purisima Concepcion	Libas	Mabicay
Affected Area (sq. km.)	0.03-0.20	1.5	1.54	0.74	1.38	0.83	1.24	2.77	0.17	0.28	0.4	0.74
	0.21-0.50	0.3	0.068	0.01	0.36	0.27	0.052	0.22	0.025	0.24	0.0074	0.039
	0.51-1.00	0.21	0.084	0.01	0.15	0.13	0.024	0.19	0.013	0.26	0.0051	0.023
	1.01-2.00	0.11	0.12	0.007	0.024	0.042	0.018	0.19	0.0008	0.21	0.0045	0.017
	2.01-5.00	0.06	0.093	0.0056	1.00E-04	0.0049	0.0067	0.11	0	0.097	0.0032	0.005
	> 5.00	0.0001	0	0.0016	0	0	0.0006	0	0	0.16	0.0003	0.0012

Table 42. Affected areas in Sogod, Southern Leyte during a 25-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte									
		Mac	Magatas	Mahayahay	Malinao	Milagroso	Pandan	Rizal	Salvacion	San Isidro	San Jose
Affected Area (sq. km.)	0.03-0.20	0.016	1.49	0.62	0.82	0.56	0.92	1.15	0.39	0.74	0.47
	0.21-0.50	0.0029	0.05	0.25	0.22	0.013	0.083	0.027	0.088	0.013	0.063
	0.51-1.00	0.00059	0.028	0.17	0.14	0.0076	0.047	0.018	0.029	0.008	0.023
	1.01-2.00	0	0.015	0.045	0.021	0.0063	0.047	0.016	0.008	0.0081	0.014
	2.01-5.00	0	0.0011	0.0063	0.02	0.0045	0.091	0.0088	0	0.005	0.0015
	> 5.00	0	0	0	0	0.0001	0.0017	0.001	0	0.0005	0

Table 43. Affected areas in Sogod, Southern Leyte during a 25-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte									
		San Miguel	San Pedro	Santa Maria	Suba	Tampoong	Zone I	Zone II	Zone III	Zone IV	Zone V
Affected Area (sq. km.)	0.03-0.20	0.86	0.056	0.00023	1.52	0.36	0.5	0.068	0.091	0.42	0.92
	0.21-0.50	0.13	0.0051	0	0.19	0.12	0.049	0.013	0.019	0.033	0.2
	0.51-1.00	0.094	0.0037	0	0.17	0.04	0.0039	0.0009	0.0075	0.012	0.1
	1.01-2.00	0.053	0.0017	0	0.15	0.017	0.0014	0.0005	0.0001	0.016	0.061
	2.01-5.00	0.044	0.0005	0	0.19	0.007	0.0041	0	0	0.0048	0.14
	> 5.00	0.044	0	0	0.0001	0	0	0	0	0.0003	0.0094

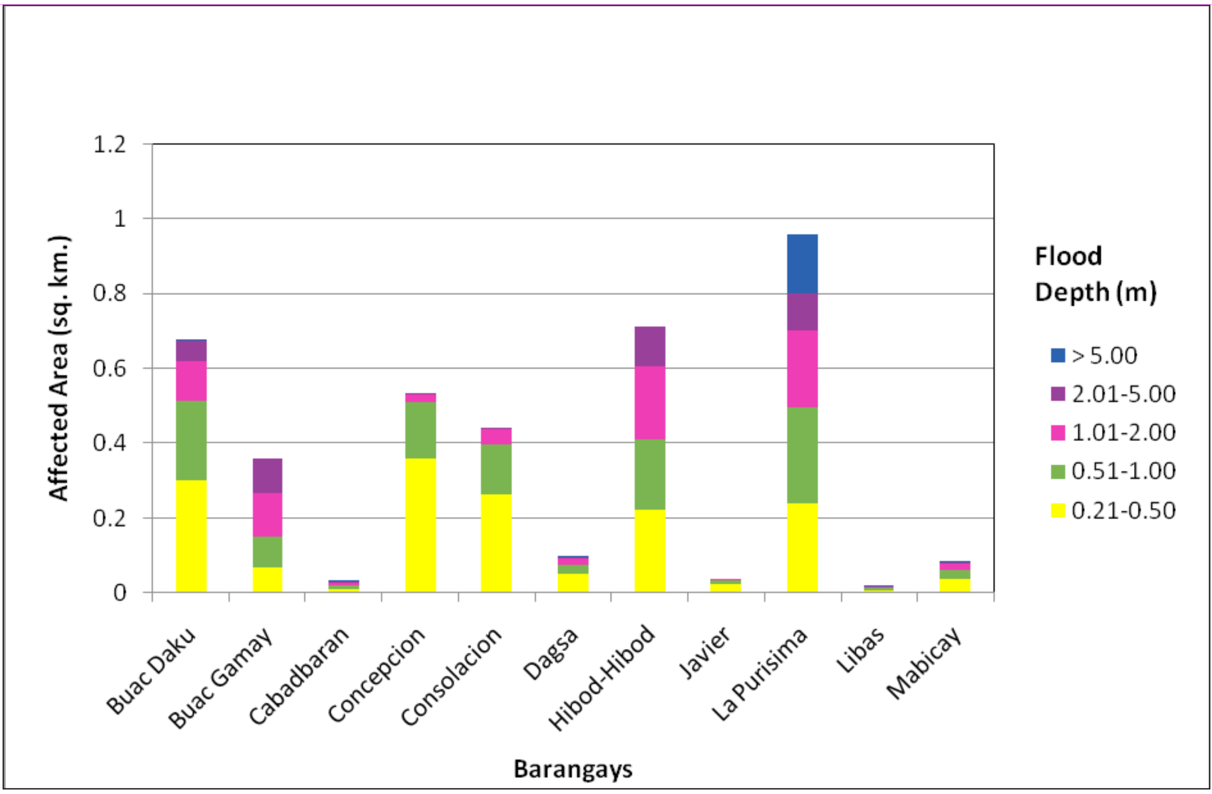


Figure 75. Affected areas in Sogod, Southern Leyte during a 25-year rainfall return period

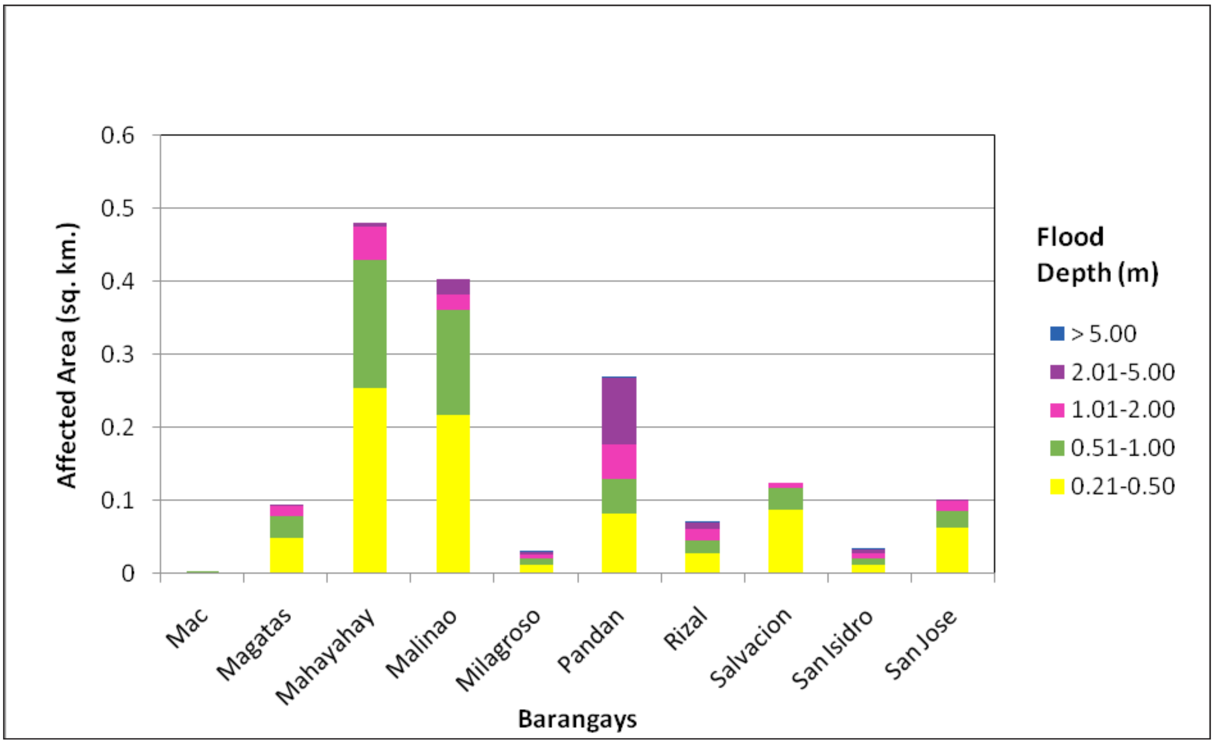


Figure 76. Affected areas in Sogod, Southern Leyte during a 25-year rainfall return period

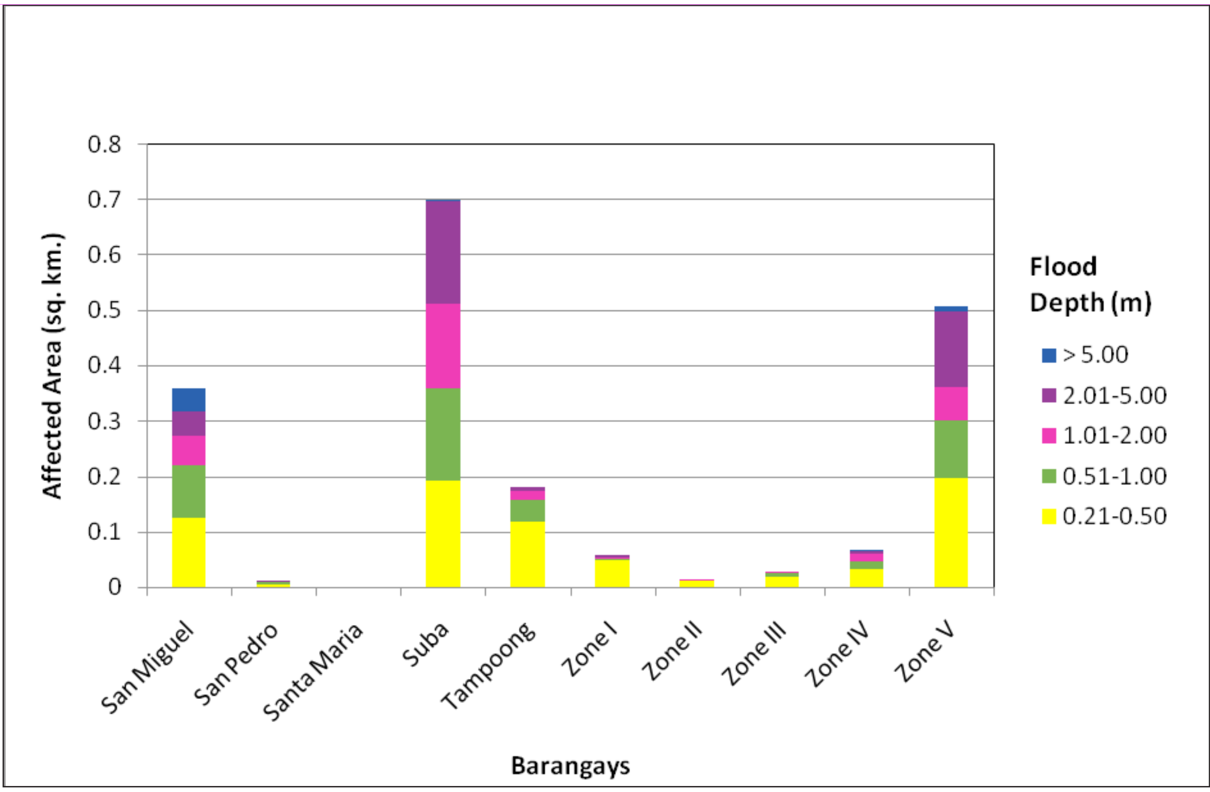


Figure 77. Affected areas in Sogod, Southern Leyte during a 25-year rainfall return period

For the 100-year return period, 0.03% of the Municipality of Bontoc,with an area of 89.13 square kilometers, will experience flood levels of less than 0.20 meters. 0.003% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 0.002% and 0.0002% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Bontoc Southern Leyte during a 100-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Bontoc, Southern Leyte
		Santa Cruz
Affected Area (sq. km.)	0.03-0.20	0.03
	0.21-0.50	0.003
	0.51-1.00	0.0015
	1.01-2.00	0.0002
	2.01-5.00	0
	> 5.00	0

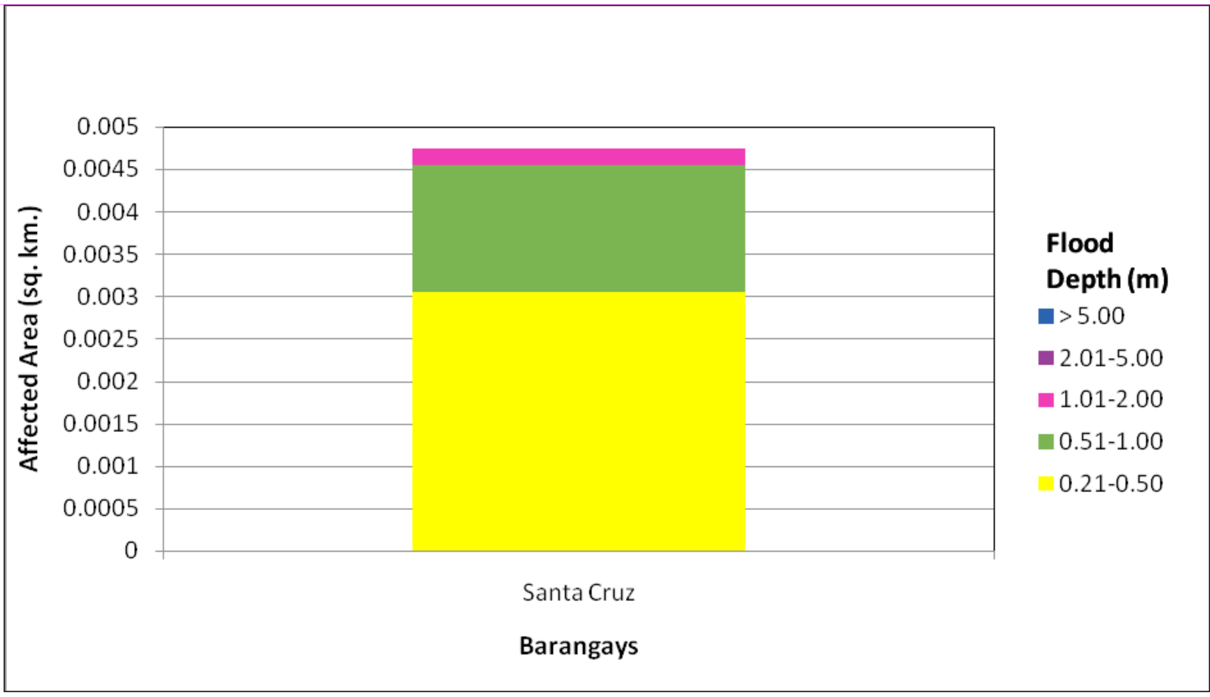


Figure 78. Affected areas in Bontoc Southern Leyte during a 100-year rainfall return period

For the Municipality of Sogod, with an area of 217.20 square kilometers, 10.00% will experience flood levels of less than 0.20 meters. 1.56% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.29%, 0.81%, 0.51%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively.Listed in Tables 45-47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Sogod, Southern Leyte during a 100-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte										
		Buac Daku	Buac Gamay	Cabadbaran	Concepcion	Consolacion	Dagsa	Hibod-Hibod	Javier	La Purisima Concepcion	Libas	Mabicay
Affected Area (sq. km.)	0.03-0.20	1.38	1.51	0.74	1.18	0.54	1.22	2.68	0.16	0.13	0.4	0.73
	0.21-0.50	0.26	0.067	0.011	0.44	0.33	0.061	0.22	0.03	0.14	0.0088	0.043
	0.51-1.00	0.3	0.07	0.01	0.24	0.31	0.028	0.19	0.018	0.35	0.0051	0.027
	1.01-2.00	0.18	0.12	0.008	0.05	0.08	0.02	0.22	0.001	0.33	0.0044	0.019
	2.01-5.00	0.075	0.12	0.0064	0.0001	0.015	0.0099	0.16	0	0.12	0.0042	0.0064
	> 5.00	0.0001	0	0.0019	0	0	0.0008	0.0001	0	0.17	0.0003	0.0014

Table 46. Affected areas in Sogod, Southern Leyte during a 100-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte									
		Mac	Magatas	Mahayahay	Malinao	Milagroso	Pandan	Rizal	Salvacion	San Isidro	San Jose
Affected Area (sq. km.)	0.03-0.20	0.015	1.47	0.56	0.73	0.56	0.83	1.13	0.28	0.74	0.45
	0.21-0.50	0.0029	0.058	0.24	0.23	0.014	0.11	0.031	0.14	0.014	0.074
	0.51-1.00	0.0015	0.029	0.22	0.2	0.0088	0.075	0.02	0.076	0.0093	0.03
	1.01-2.00	0.0001	0.019	0.073	0.03	0.0072	0.066	0.018	0.024	0.0079	0.017
	2.01-5.00	0	0.0023	0.0093	0.022	0.0052	0.1	0.012	0.0009	0.0066	0.0049
	> 5.00	0	0	0	0.0032	0.0001	0.011	0.0011	0	0.0007	0

Table 47. Affected areas in Sogod, Southern Leyte during a 100-year rainfall return period

SUBANGDAKU BASIN		Affected Barangays in Sogod, Southern Leyte									
		San Miguel	San Pedro	Santa Maria	Suba	Tampoong	Zone I	Zone II	Zone III	Zone IV	Zone V
Affected Area (sq. km.)	**0.03-0.20**	0.74	0.055	0.00023	1.41	0.33	0.47	0.063	0.083	0.41	0.74
	0.21-0.50	0.14	0.0049	0	0.22	0.13	0.072	0.018	0.024	0.039	0.22
	0.51-1.00	0.14	0.0041	0	0.18	0.055	0.0068	0.0011	0.01	0.013	0.17
	1.01-2.00	0.11	0.0022	0	0.19	0.018	0.0014	0.0005	0.0005	0.016	0.12
	2.01-5.00	0.034	0.0006	0	0.22	0.0098	0.0049	0	0	0.01	0.14
	> 5.00	0.061	0	0	0.0002	0	0.00012	0	0	0.00048	0.032

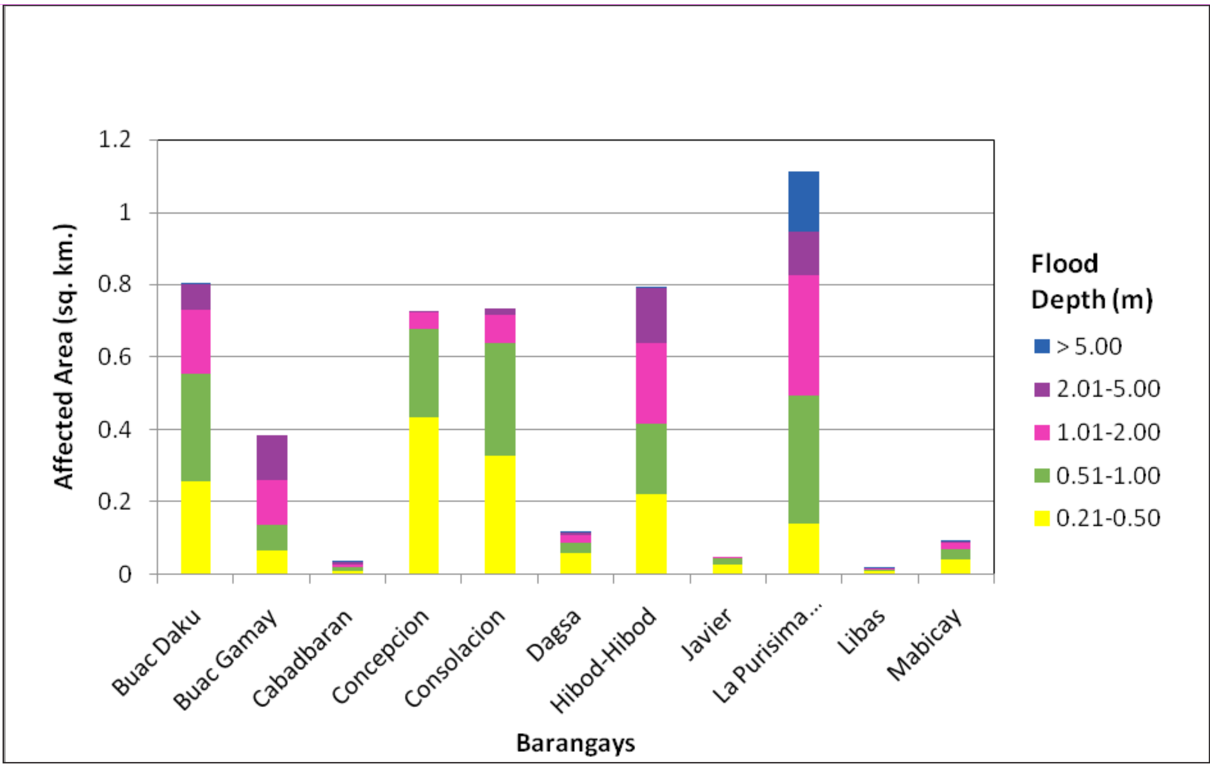


Figure 79. Affected areas in Sogod, Southern Leyte during a 100-year rainfall return period

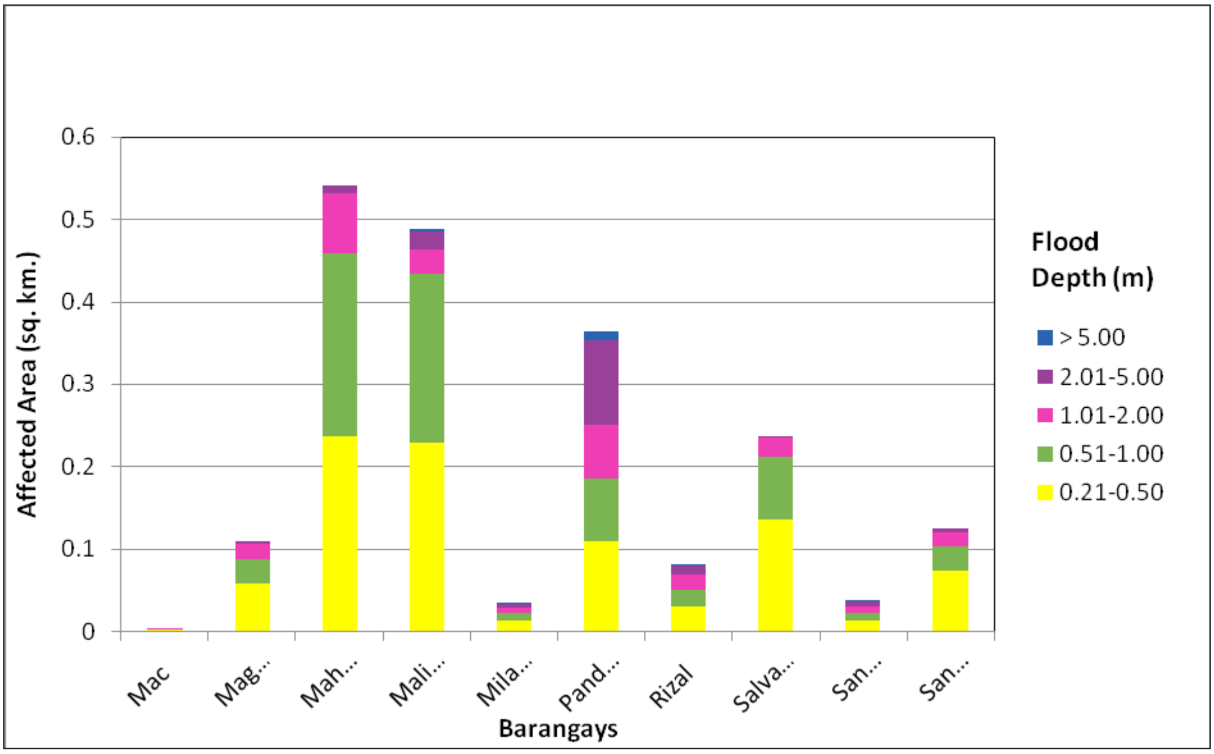


Figure 80. Affected areas in Sogod, Southern Leyte during a 100-year rainfall return period

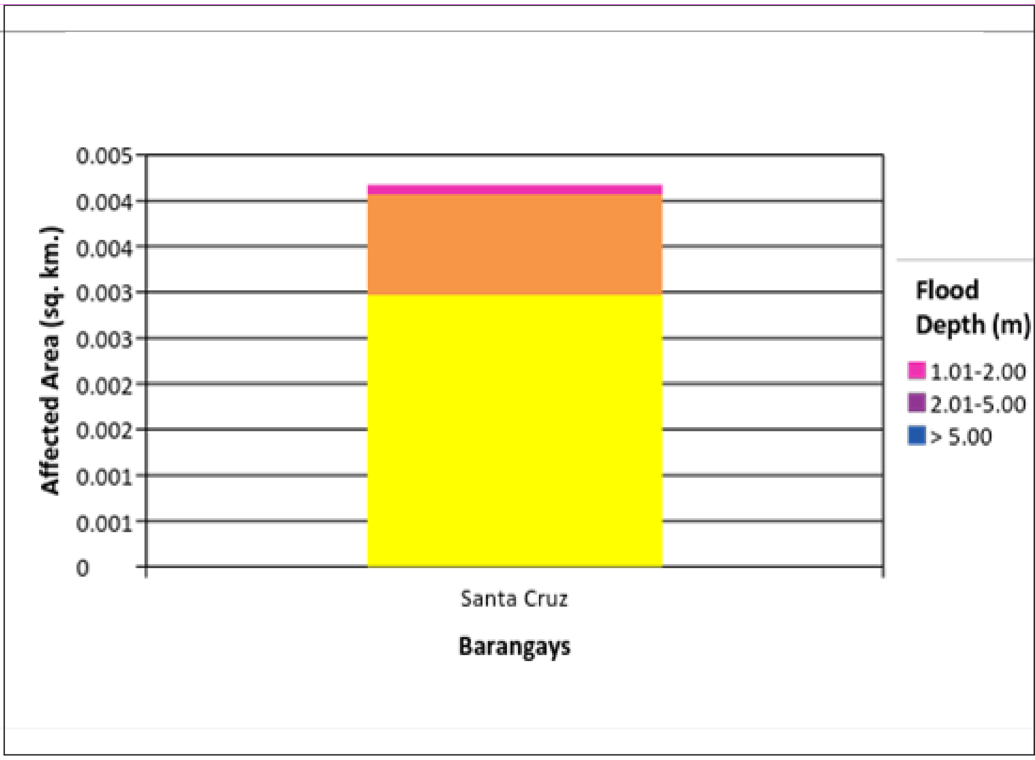


Figure 81. Affected areas in Sogod, Southern Leyte during a 100-year rainfall return period

In the Municipality of Bontoc, the only barangay, Barangay Sta. Cruz, is projected to have0.04% of its area to experience flood levels

Among the barangays in the Municipality of Sogod, Hibod-Hibod is projected to have the highest percentage of area that will experience flood levels, at 1.60%. Meanwhile, Suba posted the second highest percentage of area that may be affected by flood depths, at 1.02%.

The generated flood hazard maps for the Subangdaku floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood hazard maps – "Low", "Medium", and "High" – the affected institutions were given anindividual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year).

Table 48. Area covered by each warning level, with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	2.47	3.21	3.42
Medium	1.62	2.76	3.95
High	1.17	1.71	2.14

Of the seventy-three (73) identified educationalinstitutions in the Subangdakufloodplain, eleven (11) were assessed to be exposed to Low-level flooding during a 5-year scenario.On the other hand,three (3) schools were assessed to be exposed to Medium-level flooding, and one (1) to High-level flooding, in the same scenario. In the 25-year scenario, eighteen (18) schools were assessed to be exposed to Low-level flooding,fourteen (14) schools to Medium-level flooding, and two (2) to High-level flooding. For the 100-year scenario, twenty-three (23) schools werediscovered to be exposed to Low-level flooding, and six (6) schools toMedium-level flooding. In the same scenario, two (2) schools wereprojectedto be subjectedto High-level flooding. See Annex 12 for a detailed enumeration and assessment of the schools within theSubangdaku floodplain.

Of the twenty-eight (28) identified medical institutions in theSubangdakufloodplain, seven (7) were assessed to be exposed to Low-level flooding during a 5-year scenario; while five (5) were assessed to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, seven (7) institutions were assessed to be exposed to Low-level flooding,and another seven (7)to Medium-level flooding. Inthe

100-year scenario, nine (9)institutionswere assessed to be exposed toLow-level flooding, and seven (7) were discovered to be exposed toMedium-level flooding. See Annex 13 for a detailed enumeration and assessment of the medical institutions within the Subangdaku floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in the different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in theriver basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared withthe simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths, for each rainfall return scenario, are illustrated in Figures85-87.

The flood validation consists of two hundred and eighty (280) points, randomly selected all over the Subangdaku flood plain. The points were grouped according to the RIDF return period of the event. Table 50, Table 52, and Table 54 showthe contingency matrices of the comparison for every return scenario. The field validation points for the return scenarios are found in Annex 11.

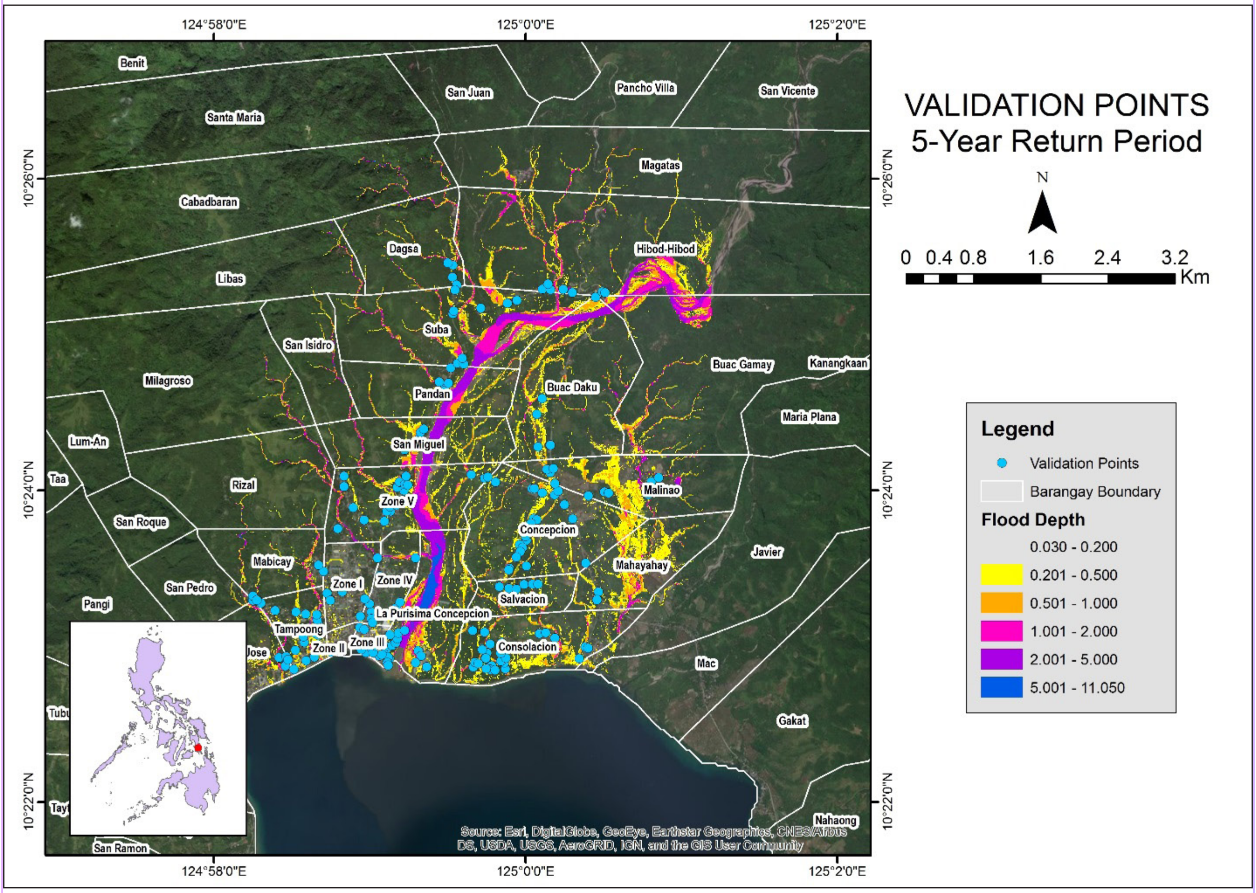


Figure 82. Validation points for a 5-year flood depth map of the Subangdaku floodplain

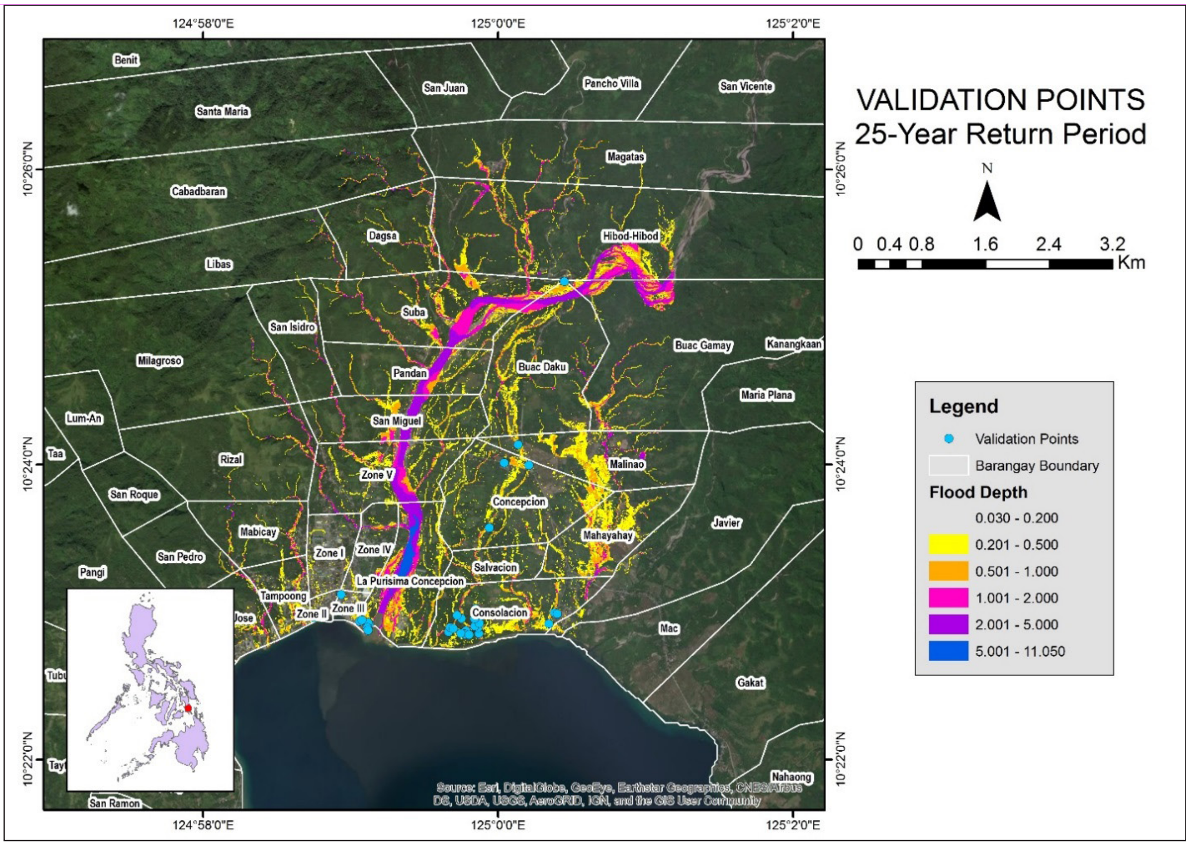


Figure 83. Validation points for a 5-year flood depth map of the Subangdaku floodplain

The RMSE values for the different flood depth mapsare listed in Table 49 below:

Table 49. RMSE values for each return period of the flood depth map

Return Period	RMSE
5-year	0.42
25-year	1.36
100-year	0.51

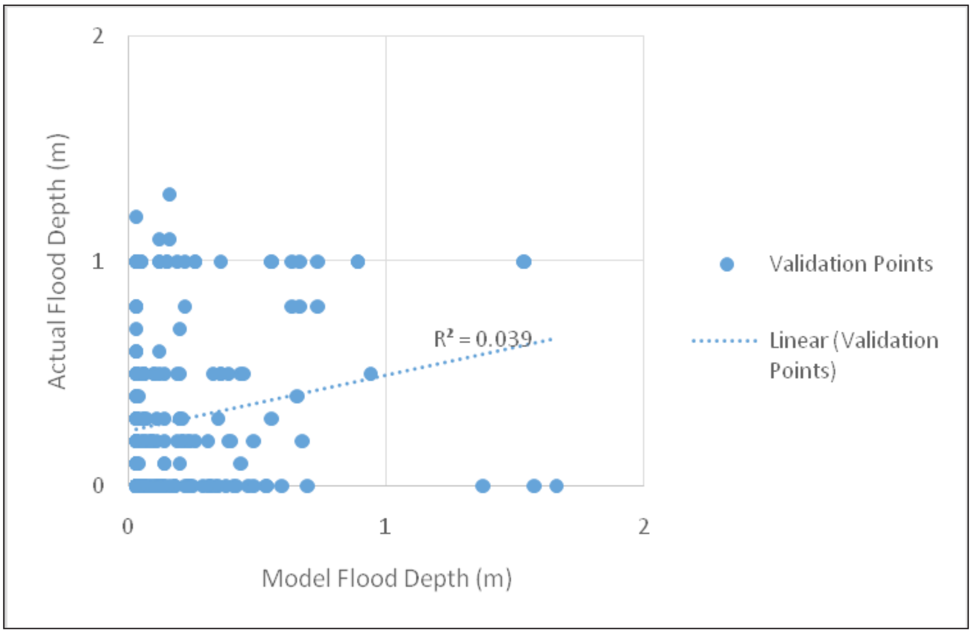


Figure 84. Flood map depth vs. actual flood depth for the 5-year return period

Table 50. Actual flood depth vs. simulated flood depth in Subangdaku, for the 5-year return period

SUBANGDAKU 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	97	27	5	3	0	0	132
	0.21-0.50	35	8	3	0	0	0	46
	0.51-1.00	21	5	10	2	0	0	38
	1.01-2.00	4	0	0	0	0	0	4
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	157	40	18	5	0	0	220

The overall accuracy generated by the flood modelfor the 5-year return scenario is estimated at 52.27%, with one hundred and fifteen (115) points correctly matching the actual flood depths. In addition, there were sixty-seven (67) points estimated one (1) level above and below the correct flood depths.Meanwhile, there were twenty-six (26) points and seven (7) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of sixty-five (65) points were underestimated in the modeled flood depths of the Subangdaku floodplain.

Table 51. Summary of the Accuracy Assessment in Subangdaku, for the 5-year return period

No. of Points		%
Correct	115	52.27
Overestimated	40	18.18
Underestimated	65	29.55
Total	220	**100.00**

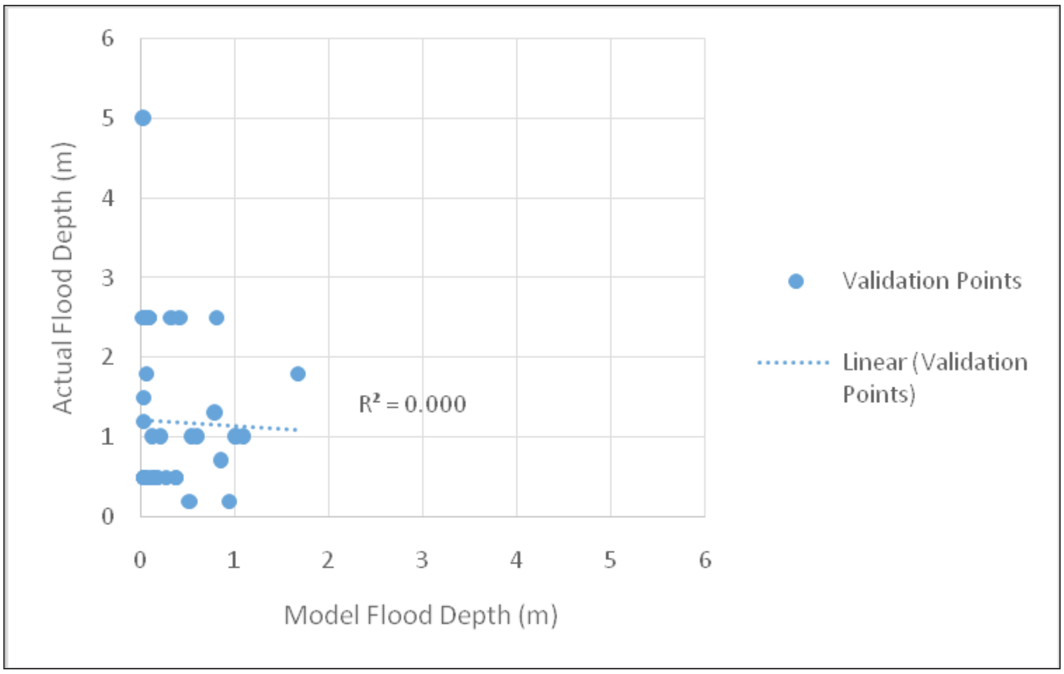


Figure 85. Flood map depth vs. actual flood depth for the 25-year return period

Table 52. Actual flood depth vs. simulated flood depth in Subangdaku, for the 25-year return period

SUBANGDAKU 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	0	0	2	0	0	0	2
	0.21-0.50	13	3	0	0	0	0	16
	0.51-1.00	1	1	4	2	0	0	8
	1.01-2.00	3	0	1	1	0	0	5
	2.01-5.00	5	2	1	0	0	0	8
	> 5.00	0	0	0	0	0	0	0
	Total	22	6	8	3	0	0	39

The overall accuracy generated by the flood model for the 25-year scenario is estimated at 20.51%, with eight (8) points correctly matching the actual flood depths. There were sixteen (16) points estimated one (1) level above and below the correct flood depths.On the other hand,there were four (4) points and ten (10) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of twenty-seven (27) points were underestimated in the modeled flood depths of the Subangdaku floodplain.

Table 53. Summary of the Accuracy Assessment in Subangdaku, for the 25-year return period

No. of Points		%
Correct	8	20.51
Overestimated	4	10.26
Underestimated	27	69.23
Total	39	**100.00**

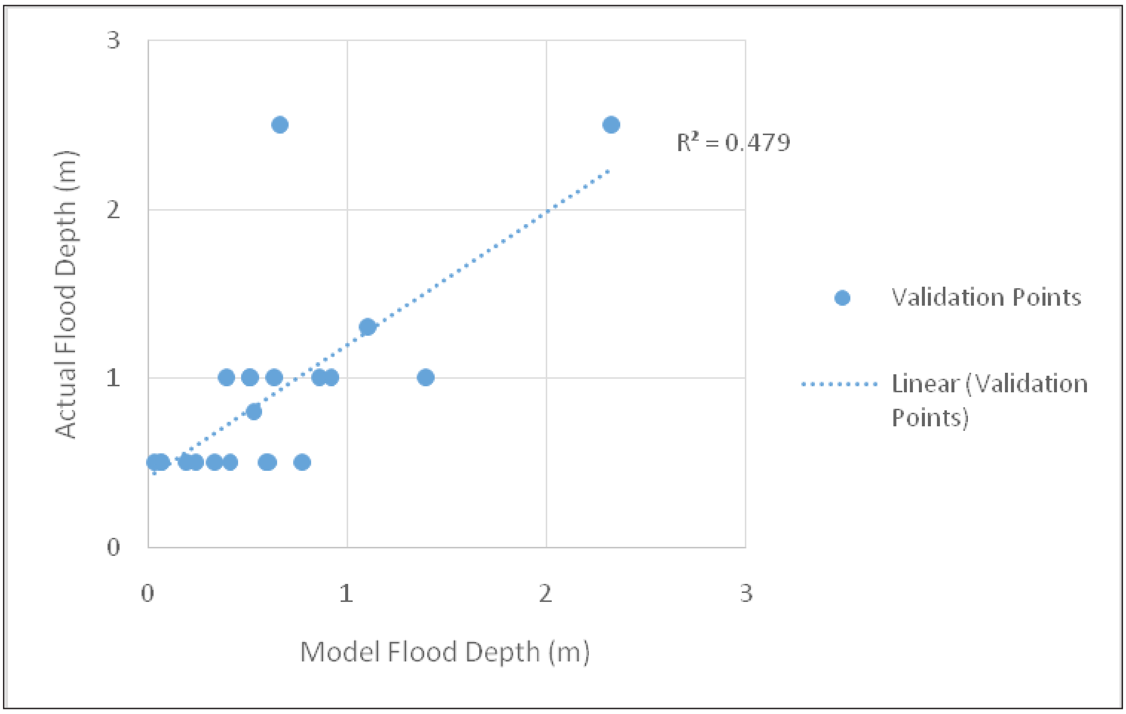


Figure 86. Flood map depth vs. actual flood depth for the 100-year return period

Table 54. Actual flood depth vs. simulated flood depth in Subangdaku, for the 100-year return period

SUBANGDAKU 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	0	0	0	0	0	0	0
	0.21-0.50	4	3	3	0	0	0	10
	0.51-1.00	0	1	6	1	0	0	8
	1.01-2.00	0	0	0	1	0	0	1
	2.01-5.00	0	0	1	0	1	0	2
	> 5.00	0	0	0	0	0	0	0
	Total	4	4	10	2	1	0	21

The overall accuracy generated by the flood model for the 100-year return scenario is estimated at 52.38%, with eleven (11) points correctly matching the actual flood depths. In addition, there were eight (8) points estimated one (1) level above and below the correct flood depths.Meanwhile, there wasone (1) point and zero (0) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of six (6) points were underestimated in the modeled flood depths of Subangdaku.

Table 55. Summary of Accuracy Assessment in Subangdaku, for the 100-year return period

No. of Points		%
Correct	11	52.38
Overestimated	4	19.05
Underestimated	6	28.57
Total	21	**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.

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

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

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

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

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

ANNEXES

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

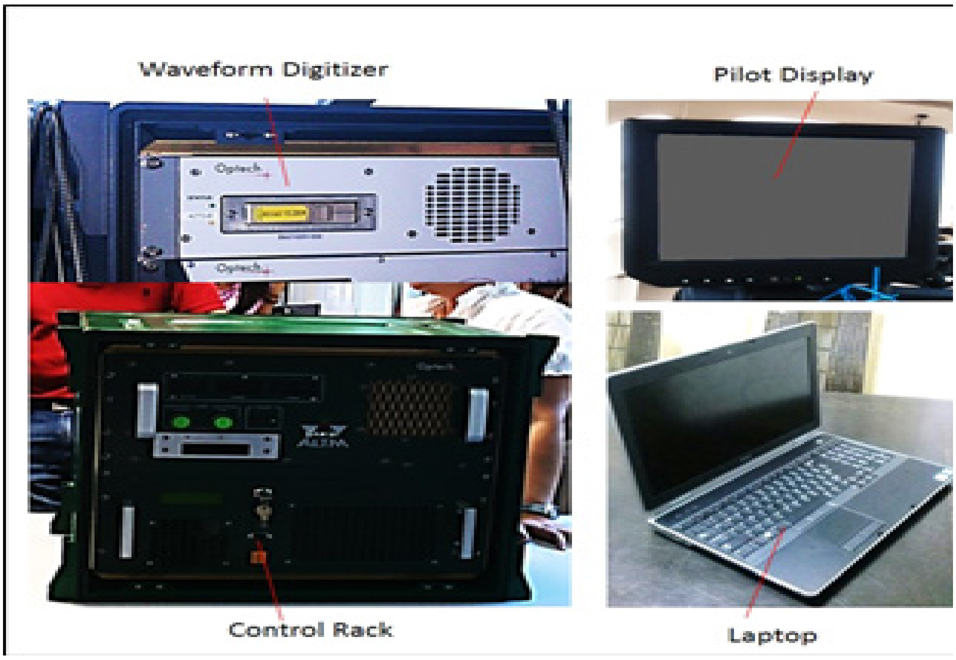


Figure A-1.1. Aquarius sensor

Table A-1.1. Specifications of the Aquarius sensor

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

Figure A-1.2. Gemini sensor

Table A-1.2. Specifications of the Gemini sensor

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

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

1. LYT-741

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

April 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LYT-741**
Order: **2nd**

Island: **VISAYAS**
Municipality: **HINDANG**
Barangay: **DOOS DEL NORTE**
MSL Elevation:

PRS92 Coordinates

Latitude:	10° 27' 11.95722"	Longitude:	124° 43' 45.08400"	Ellipsoidal Hgt:	4.48300 m.

WGS84 Coordinates

Latitude:	10° 27' 7.86786"	Longitude:	124° 43' 50.31177"	Ellipsoidal Hgt:	67.94500 m.

PTM / PRS92 Coordinates

Northing:	1155878.867 m.	Easting:	470351.659 m.	Zone:	5

UTM / PRS92 Coordinates

Northing:	1,155,979.90	Easting:	689,272.22	Zone:	51

Location Description

LYT-741
Brgy. doos del norte is about 2.6 km. from the poblacion pf hindang taking the national road to babay. upon reaching the said barangay, locate the brgy. hall, The LYT-741 is located on the opposite side of the road for about 36 m. far from the gate of the brgy hall.30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-741, 2007, LAMP".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0916**

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

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

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

CIP/4701/12/09/814

Figure A-2.1. LYT-741

2. LY-731

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

February 05, 2015

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: **LEYTE**
Station Name: **LYT-731**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**KANSUNGKA**		
Municipality:	**BAYBAY**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**10° 42' 47.59464"**	Longitude:	**124° 48' 34.34385"**	Ellipsoidal Hgt:	**15.61000 m.**
		WGS84 Coordinates			
Latitude:	**10° 42' 43.44572"**	Longitude:	**124° 48' 39.54791"**	Ellipsoidal Hgt:	**78.65700 m.**
		PTM / PRS92 Coordinates			
Northing:	**1184617.338 m.**	Easting:	**479165.977 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**1,184,777.35**	Easting:	**697,902.97**	Zone:	**51**

Location Description

LYT-731
From Babay City going to municipality of Albuera, from a bridge near babay city, Brgy. Kansungka is located on the 3rd junction on the right side of the highway, then passing thru Brgy. Candadau straight to a steel bridge near brgy. San Isidro then left to Brgy. Kasungka the control point is located near the house of ex-brgy. captain aring. The mark is a 3 inches cocnrete nail, embedded on a 40x40x100 cm. cocnrete monument having 40 cm height above the ground and is marked with LYT-731, 2007, LAMP.

Requesting Party:	**PHIL-LIDAR I**
Purpose:	**Reference**
OR Number:	**8077605 I**
T.N.:	**2015-0216**

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

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

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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Figure A-2.2. LY-731

3. LY-313

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

April 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LY-313**

Island: **Visayas** | Municipality: **BAYBAY** | Barangay:

Elevation: **5.0757 +/- 0.0678 m.** | Accuracy Class at 95% C.L: **7 cm** | Datum: **Mean Sea Level**

Latitude: | Longitude:

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

(RECOMPUTED MARCH 2014)
Mark is head of a 4" copper nail set and centered on a 10 x 10 cm. cement putty with inscriptions "LY-313, 2007, NAMRIA".

It is located in the Municipality of Leyte, Baybay Brgy. Pandan.
Located at the footwalk, W corner of 20 m. long bridge, 40 m. SW of Brgy. Maitum marker and 80 m. W of KM post 1068. It is 400 m. NE of the Basketball court and Church at the boundary of BRgy. Pandan and Maitum marker.
It can be reached approx. by 7 min. drive from Baybay going to South to Maasin.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0917**

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

9904142016153453

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

CIP/4701/12/09/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. LY-313

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

1. LYS-3027

Table A-3.1. LYS-3027

LYS-3027 - LYT-731 (10:42:33 AM-3:12:40 PM) (S1)	
Baseline observation:	LYS-3027 --- LYT-731 (B1)
Processed:	2/11/2015 7:20:06 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.013 m
RMS:	0.002 m
Maximum PDOP:	5.130
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	2/1/2015 10:42:33 AM (Local: UTC+8hr)
Processing stop time:	2/1/2015 3:12:40 PM (Local: UTC+8hr)
Processing duration:	04:30:07
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYT-731				
Grid		Local		Global	
Easting	697902.966 m	Latitude	N10°42'47.59464"	Latitude	N10°42'43.44572"
Northing	1184777.350 m	Longitude	E124°48'34.34385"	Longitude	E124°48'39.54791"
Elevation	14.266 m	Height	15.609 m	Height	78.657 m

To:	LYS-3027				
Grid		Local		Global	
Easting	716484.590 m	Latitude	N10°23'21.51724"	Latitude	N10°23'17.46586"
Northing	1149058.376 m	Longitude	E124°58'38.32069"	Longitude	E124°58'43.55182"
Elevation	15.525 m	Height	16.531 m	Height	80.754 m

Vector					
ΔEasting	18581.624 m	NS Fwd Azimuth	152°50'50"	ΔX	-18815.522 m
ΔNorthing	-35718.975 m	Ellipsoid Dist.	40257.860 m	ΔY	-5123.452 m
ΔElevation	1.259 m	ΔHeight	0.922 m	ΔZ	-35219.611 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 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

2. LY-313

Table A-3.2. LY-313

LY-313 - LYT-741 (9:21:42 AM-1:52:00 PM) (S3)	
Baseline observation:	LY-313 --- LYT-741 (B3)
Processed:	4/15/2016 6:17:08 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.014 m
RMS:	0.005 m
Maximum PDOP:	2.723
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	4/10/2016 9:21:57 AM (Local: UTC+8hr)
Processing stop time:	4/10/2016 1:52:00 PM (Local: UTC+8hr)
Processing duration:	04:30:03
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYT-741				
Grid		Local		Global	
Easting	689272.210 m	Latitude	N10°27'11.95721"	Latitude	N10°27'07.86786"
Northing	1155979.897 m	Longitude	E124°43'45.08400"	Longitude	E124°43'50.31177"
Elevation	3.600 m	Height	4.482 m	Height	67.945 m

To:	LY-313				
Grid		Local		Global	
Easting	693326.992 m	Latitude	N10°36'46.67221"	Latitude	N10°36'42.54525"
Northing	1173661.007 m	Longitude	E124°46'01.67926"	Longitude	E124°46'06.89257"
Elevation	5.229 m	Height	6.279 m	Height	69.460 m

Vector					
ΔEasting	4054.782 m	NS Fwd Azimuth	13°13'57"	ΔX	-1573.287 m
ΔNorthing	17681.110 m	Ellipsoid Dist.	18139.132 m	ΔY	-5017.663 m
ΔElevation	1.629 m	ΔHeight	1.796 m	ΔZ	17360.172 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

3. LY-439A

Table A-3.3. LY-439A

LYS-3027 - LY-439A (8:40:42 AM-12:23:20 PM) (S1)	
Baseline observation:	LYS-3027 --- LY-439A (B1)
Processed:	2/11/2015 11:55:01 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.003 m
RMS:	0.001 m
Maximum PDOP:	2.351
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	1/28/2015 8:40:42 AM (Local: UTC+8hr)
Processing stop time:	1/28/2015 12:23:20 PM (Local: UTC+8hr)
Processing duration:	03:42:38
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	LYS-3027				
Grid		Local		Global	
Easting	716484.616 m	Latitude	N10°23'21.51652"	Latitude	N10°23'17.46513"
Northing	1149058.354 m	Longitude	E124°58'38.32154"	Longitude	E124°58'43.55267"
Elevation	15.566 m	Height	16.572 m	Height	80.795 m

To:	LY-439A				
Grid		Local		Global	
Easting	717145.997 m	Latitude	N10°23'39.44046"	Latitude	N10°23'35.38833"
Northing	1149613.271 m	Longitude	E124°59'00.17361"	Longitude	E124°59'05.40423"
Elevation	25.960 m	Height	27.012 m	Height	91.238 m

Vector					
ΔEasting	661.381 m	NS Fwd Azimuth	50°21'33"	ΔX	-493.553 m
ΔNorthing	554.918 m	Ellipsoid Dist.	863.185 m	ΔY	-454.045 m
ΔElevation	10.394 m	ΔHeight	10.439 m	ΔZ	543.552 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	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

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	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
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
		MA. VERLINA E. TONGA	
		JONATHAN ALMALVEZ	
		KRISTINE JOY ANDAYA	
		ENGR. GRACE SINADJAN	
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
		FRANK NICOLAS ILEJAY	
LiDAR Operation	Airborne Security	SSG. RANDY SISON JR.	PHILIPPINE AIR FORCE (PAF)
		SSG. RAYMUND DOMINE	
	Pilot	CAPT. JEROME MOONEY	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. ANTON RETSE DAYO	AAC
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. FERDINAND DE OCAMPO	AAC

Annex 5. Data Transfer Sheets for the SubangdakuFloodplain Flights

DATA TRANSFER SHEET
02/13/2015(ORMOC)

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-Jan-15	7753AC	3BLK35B21A	AQUARIUS	NA	270	527	167	NA	NA	11.1	NA	29.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
22-Jan-15	7754AC	3BLK49B022A	AQUARIUS	NA	280	566	258	NA	NA	12	NA	66.1	1KB	1KB	4	NA	Z:\DAC\RAW DATA
23-Jan-15	7756AC	3BLK49A023A	AQUARIUS	NA	279	548	231	NA	NA	11.9	NA	34	1KB	1KB	3	NA	Z:\DAC\RAW DATA
25-Jan-15	7760AC	3BLK35A025A	AQUARIUS	NA	289	671	243	NA	NA	12.3	223	26.4	1KB	1KB	4	NA	Z:\DAC\RAW DATA
27-Jan-15	7764AC	3BLK35CD027A	GEMINI	NA	169/107	611	228	NA	NA	11.7	207	37.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7766AC	3BLK49CD028A	AQUARIUS	NA	136	366	216	NA	NA	6.71	185MB	27.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7767AC	3BLK35X028B	AQUARIUS	NA	123	310	148	NA	NA	6.4	98.6	18.5	1KB	1KB	3	NA	Z:\DAC\RAW DATA
29-Jan-15	7768AC	3BLK50A029A	AQUARIUS	NA	152	360	234	NA	NA	7.39	111	40.2	1KB	1KB	3	NA	Z:\DAC\RAW DATA

Received from
Name C. Joaquin
Position
Signature

Received by
Name AC Bongat 2/13/15
Position SSRS
Signature

Figure A-5.1. Data Transfer Sheet for Subangdaku Floodplain – A

DATA TRANSFER SHEET
ORMOC(SOUTH LEYTE) 5/2/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
April 10,2016	3921G	2BLK34a101A	GEMINI	NA	270	673	275	NA	NA	20.5	NA	19.1	1KB	1KB	23	NA	Z:\DAC\RAW DATA
April 10,2016	3923G	2BLK49AB101B	GEMINI	NA	375	377	168	NA	NA	8.5	NA	19.1	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 11,2016	3925G	2BLK49DE102A	GEMINI	NA	138	570	252	NA	NA	9.56	NA	6.82	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 13,2016	3933G	2BLK50ABC104A	GEMINI	NA	581	474	262	NA	NA	16.2	NA	17.4	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 14,2016	3937G	2BLK50DS105A	GEMINI	NA	763	557	292	NA	NA	14.7	NA	10.5	1KB	1KB	28	NA	Z:\DAC\RAW DATA
April 16,2016	3945G	2BLK35AB107A	GEMINI	NA	216	940	267	NA	NA	17.1	NA	19.5	1KB	1KB	6	NA	Z:\DAC\RAW DATA
April 16,2016	3947G	2BLK35CS107B	GEMINI	NA	492	1.03	278	NA	NA	21	NA	19.5	1KB	1KB	10	NA	Z:\DAC\RAW DATA

Received from

Name: R. PUNTO
Position: RA
Signature: [signature]

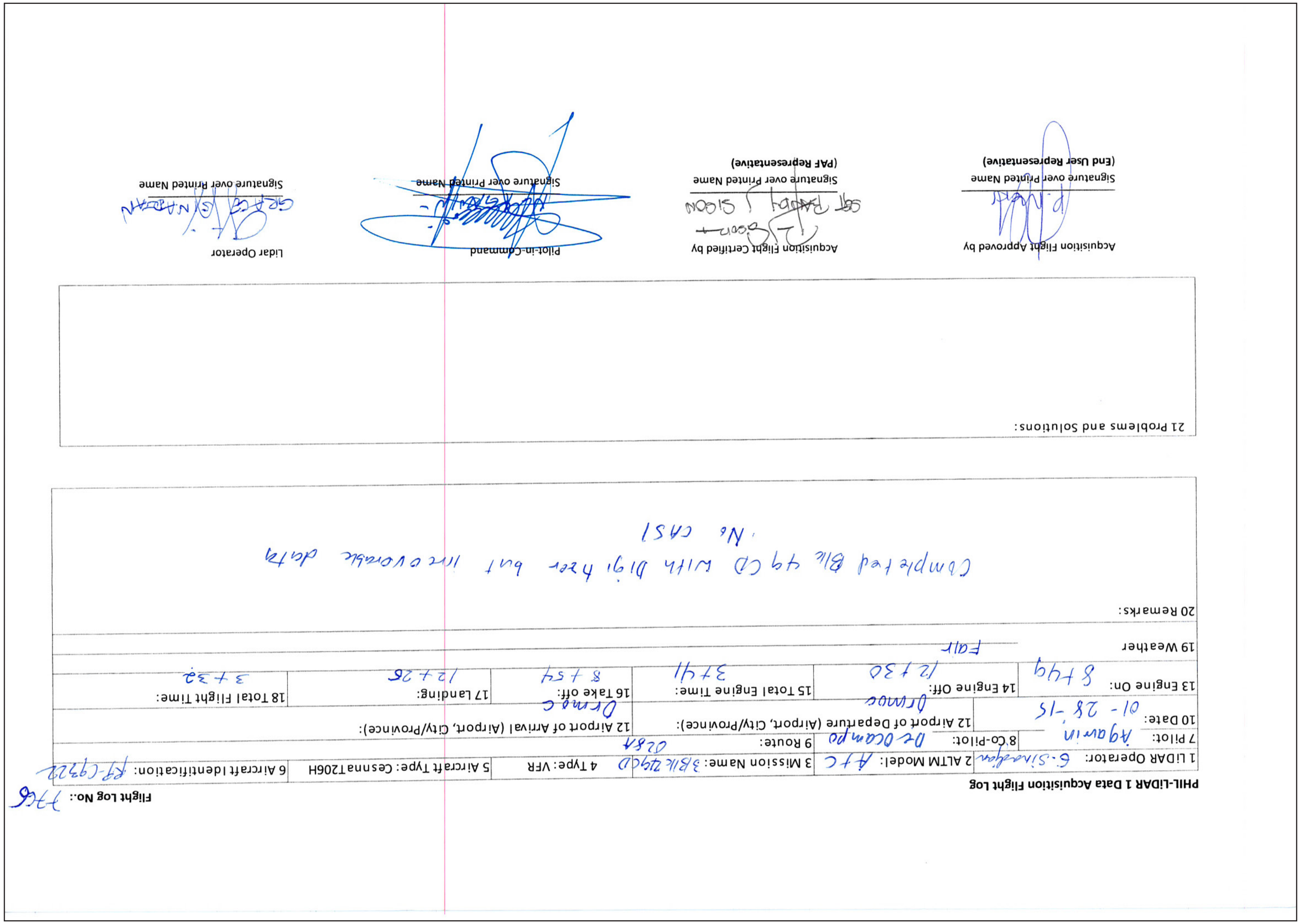
Received by

Name: AC Bongat
Position: SSRS
Signature: [signature] 5/6/16

Figure A-5.2. Data Transfer Sheet for Subangdaku Floodplain – B

Annex 6. Flight Logs for the Flight Missions

Flight Log for 7766GC Mission



PHIL-LiDAR 1 Data Acquisition Flight Log — **Flight Log No.:** 7766

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: A+C	3 Mission Name: 3BLK49CD 028A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: Agawin	8 Co-Pilot: De Ocampo	9 Route:			
10 Date: 01-28-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 8+49	14 Engine Off: 12+30	15 Total Engine Time: 3+41	16 Take off: 8+54	17 Landing: 12+26	18 Total Flight Time: 3+32
19 Weather: Fair					
20 Remarks: Completed Blk 49CD with Digitizer but incoverable data. No CASI					
21 Problems and Solutions:					

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

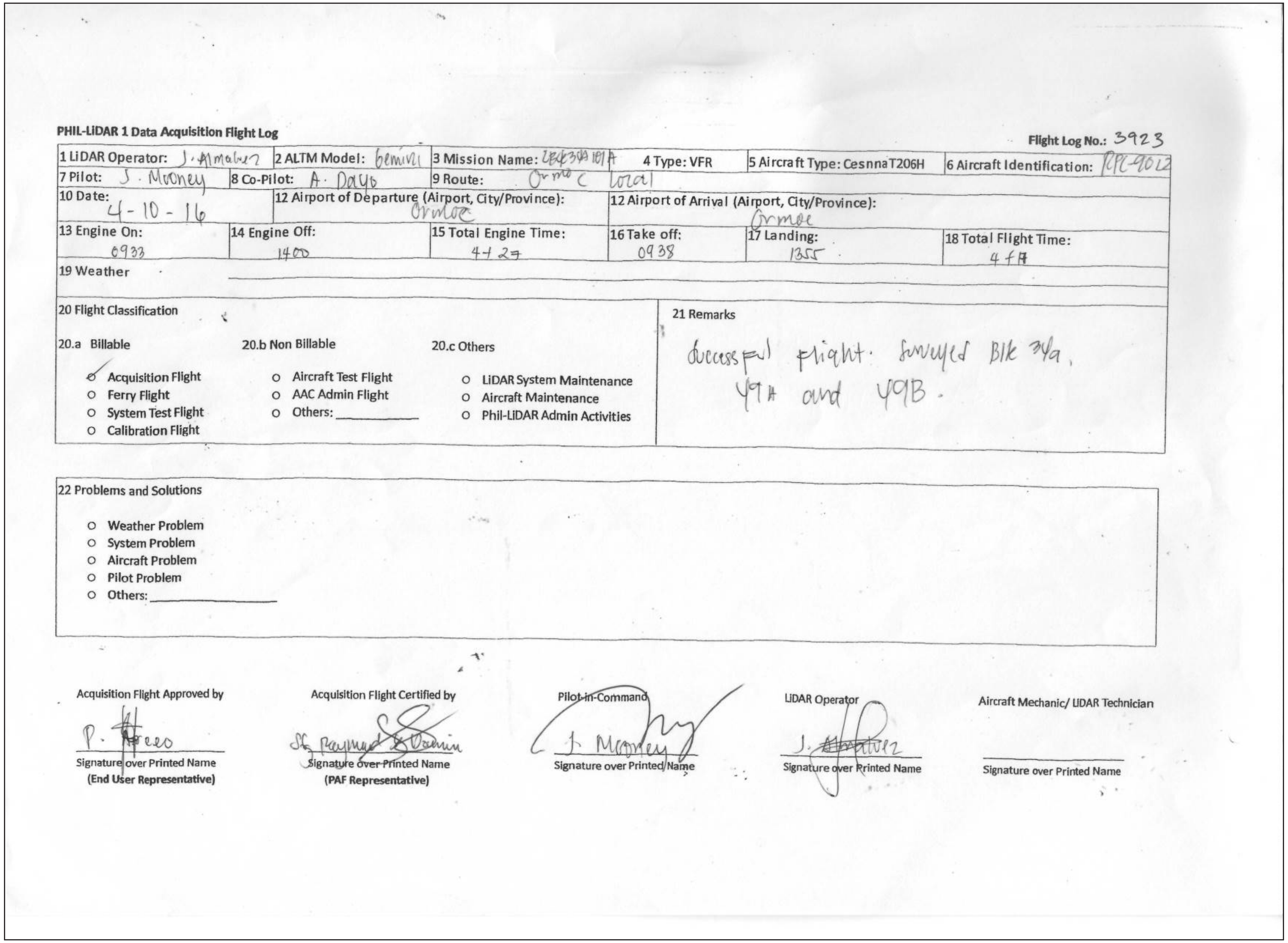
Acquisition Flight Certified by: SGT Paddy J Sioson — Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: G. Sinadjan — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 7766GC

Flight Log for 3923G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3923

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9022
7 Pilot: J. Mooney	8 Co-Pilot: A. Dayo	9 Route: Ormoc Local			
10 Date: 4-10-16	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 0933	14 Engine Off: 1400	15 Total Engine Time: 4+27	16 Take off: 0938	17 Landing: 1355	18 Total Flight Time: 4+17
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

Successful flight. Surveyed Blk 39a, 49A and 49B.

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
P. Arceo	SSg Raymund S. Damian	J. Mooney	J. Almalvez	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 3923G

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
SOUTHERN LEYTE
January 28, 2015; April 10, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7766AC	BLK49CD	3BLK49CD028A	G. SINADJAN	January 28, 2015	COMPLETED BLK49CD WITH DIGITIZER BUT IRRECOVERABLE DATA. LESS NUMBER OF FRAMES FOR A 4-HR FLIGHT. NO CASI
3923G	BLK49AB	2BLK49AB101B	J. ALMALVEZ	April 10, 2016	SURVEYED VOIDS OVER BLK 49A AND 49B

LAS/SWATH BOUNDARIES PER FLIGHT

Flight No.: 7766AC
Area: 49CD
Mission Name: 3BLK49CD028A
Parameters: Altitude: 600m; Scan Frequency: 45; Scan Angle: 18

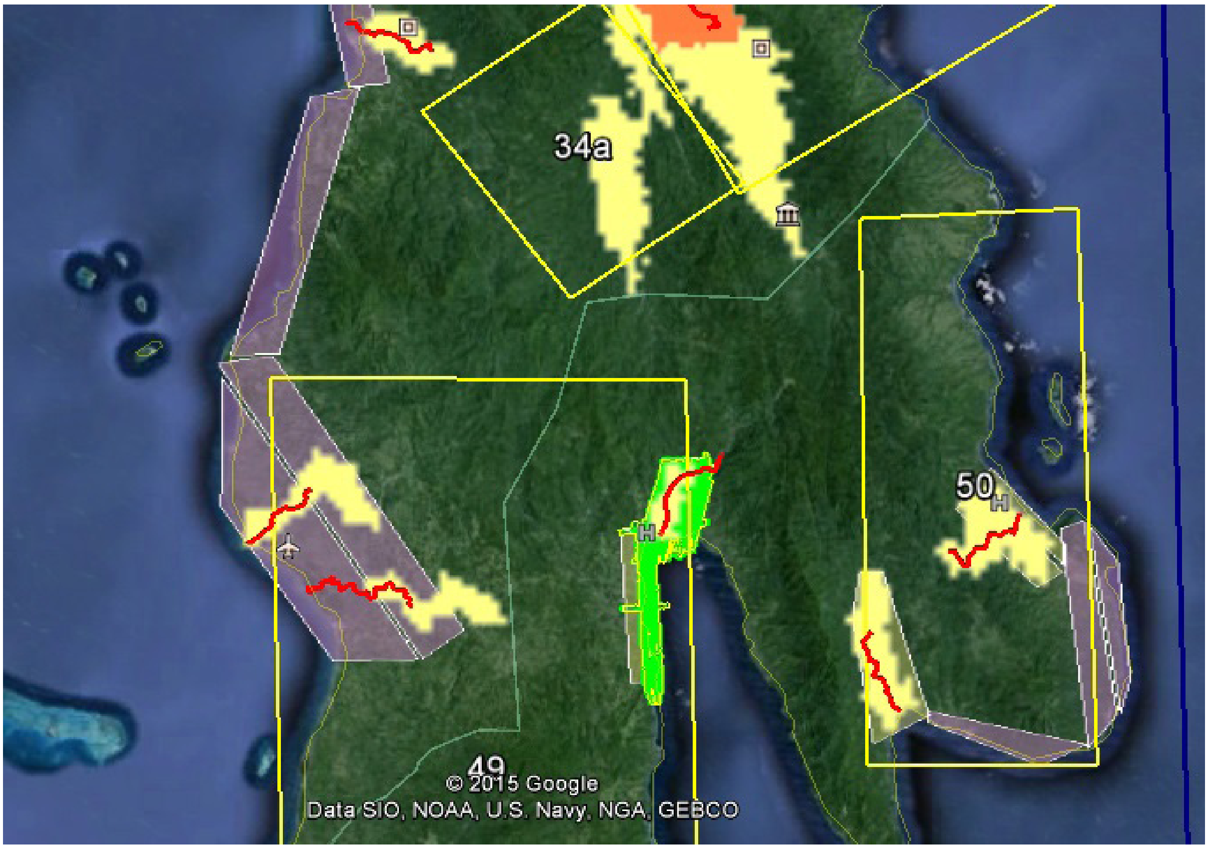


Figure A-7.1. Swath for Flight No. 7766AC

Flight No.: 3923
Area: 49AB
Mission Name: 2BLK49AB101B
Parameters: Altitude: 1000m; Scan Frequency: 50; Scan Angle: 18

Figure A-7.2. Swath for Flight No. 3923

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk49CD

Flight Area	Ormoc
Mission Name	Blk49CD
Inclusive Flights	7766AC
Range data size	6.71 GB
POS	216 MB
Base data size	27.1 MB
Image	0 GB
Transfer date	March 9 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.95
RMSE for East Position (<4.0 cm)	1.17
RMSE for Down Position (<8.0 cm)	3.45
Boresight correction stdev (<0.001deg)	0.000323
IMU attitude correction stdev (<0.001deg)	0.001762
GPS position stdev (<0.01m)	0.0044
Minimum % overlap (>25)	42.31
Ave point cloud density per sq.m. (>2.0)	2.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	407.97 m
Minimum Height	57.62 m
Classification (# of points)	
Ground	15,583,995
Low vegetation	17,762,369
Medium vegetation	17,566,518
High vegetation	17,922,788
Building	2,116,918
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Alex John Escobido

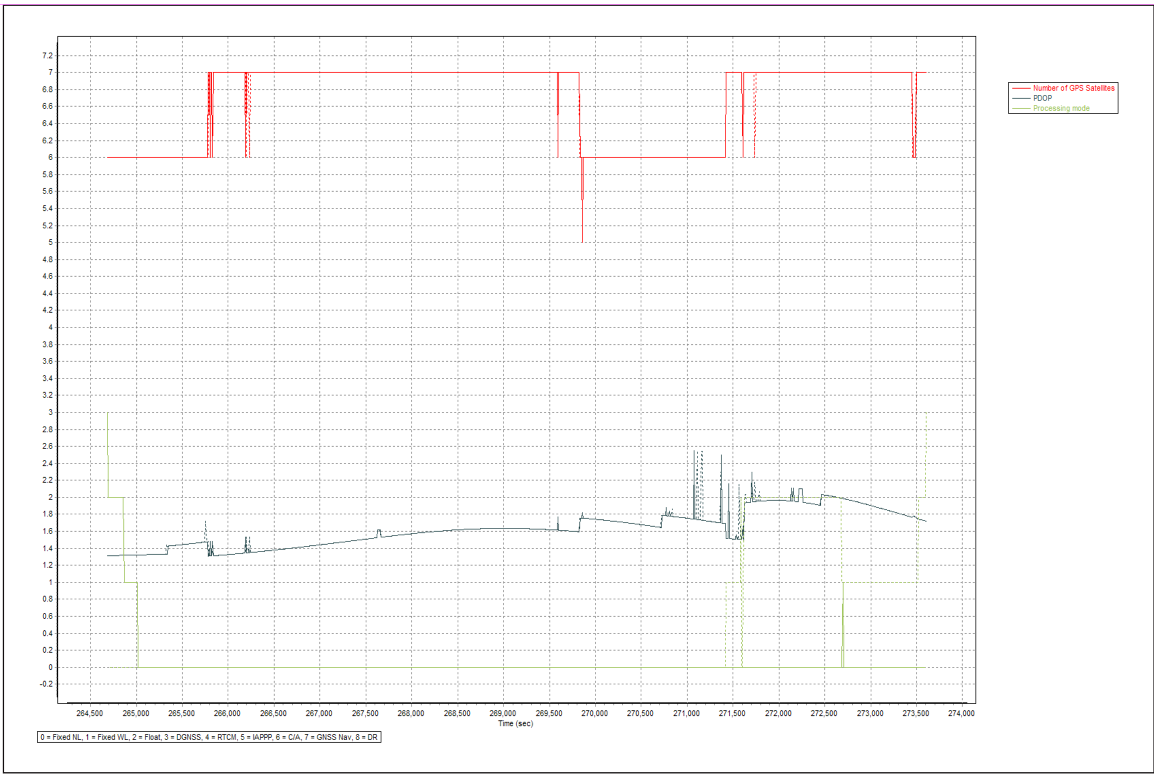


Figure A-8.1. Solution Status

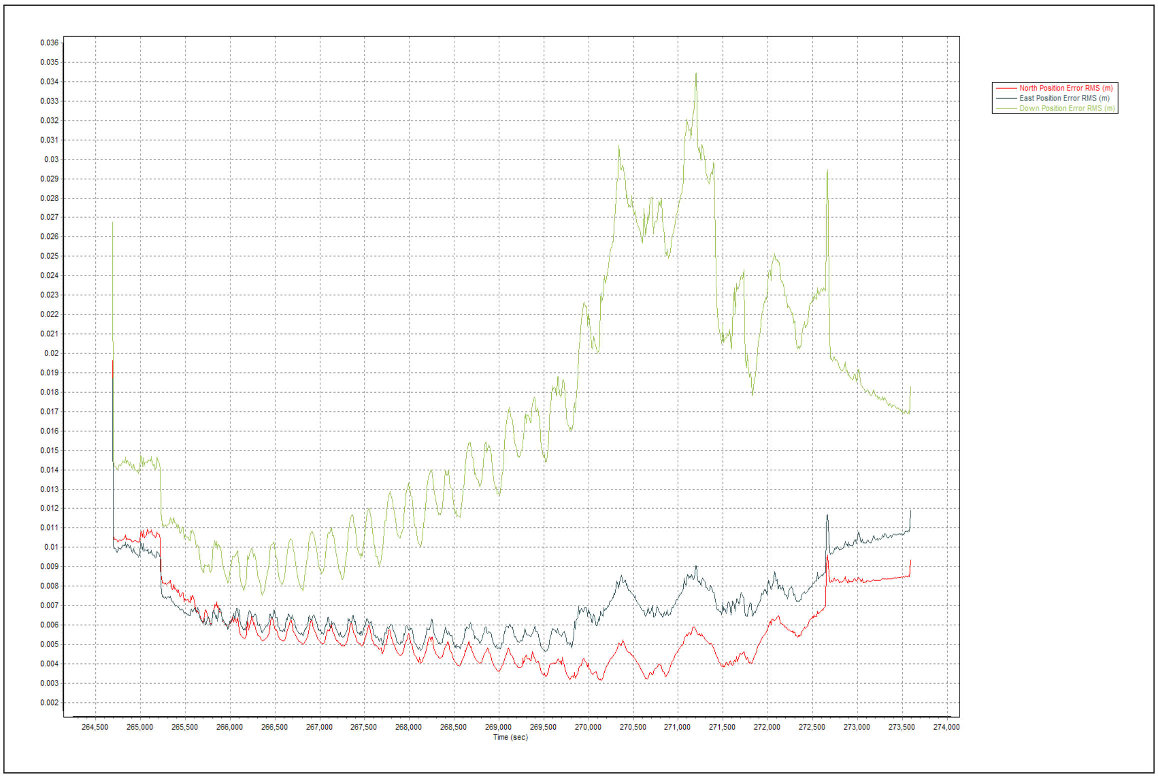


Figure A-8.2. Smoothed Performance Metric Parameters

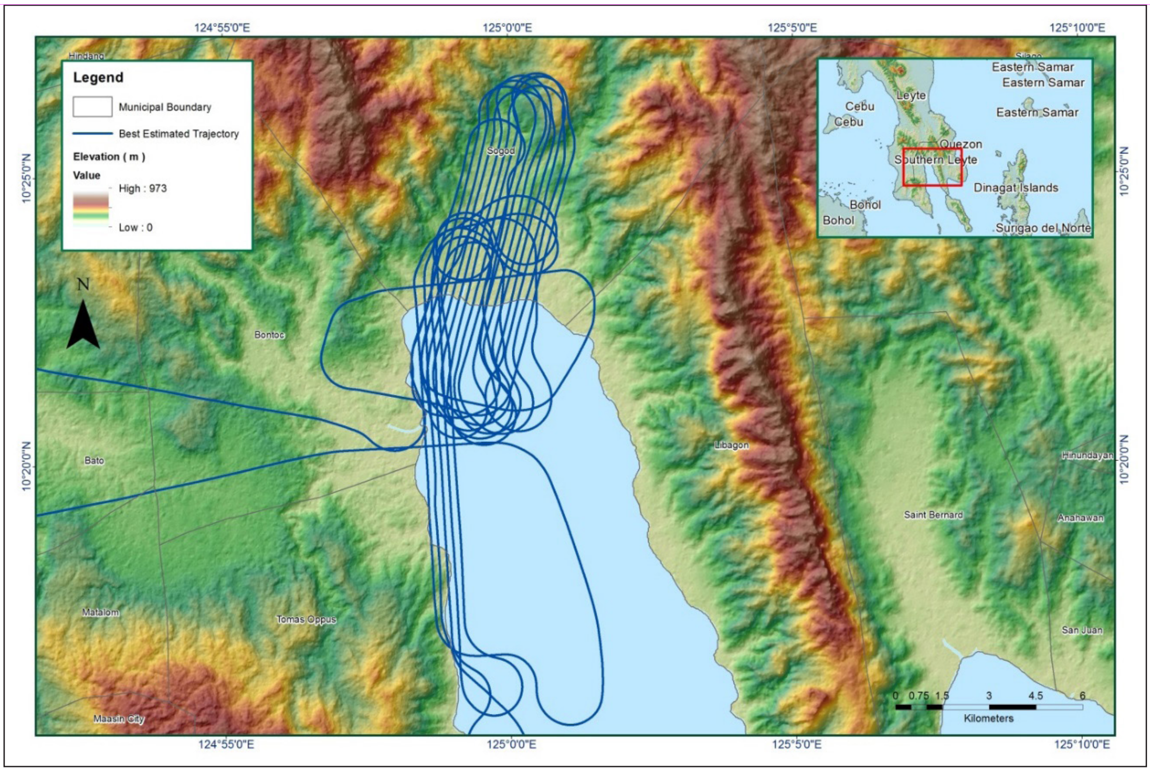


Figure A-8.3. Best Estimated Trajectory

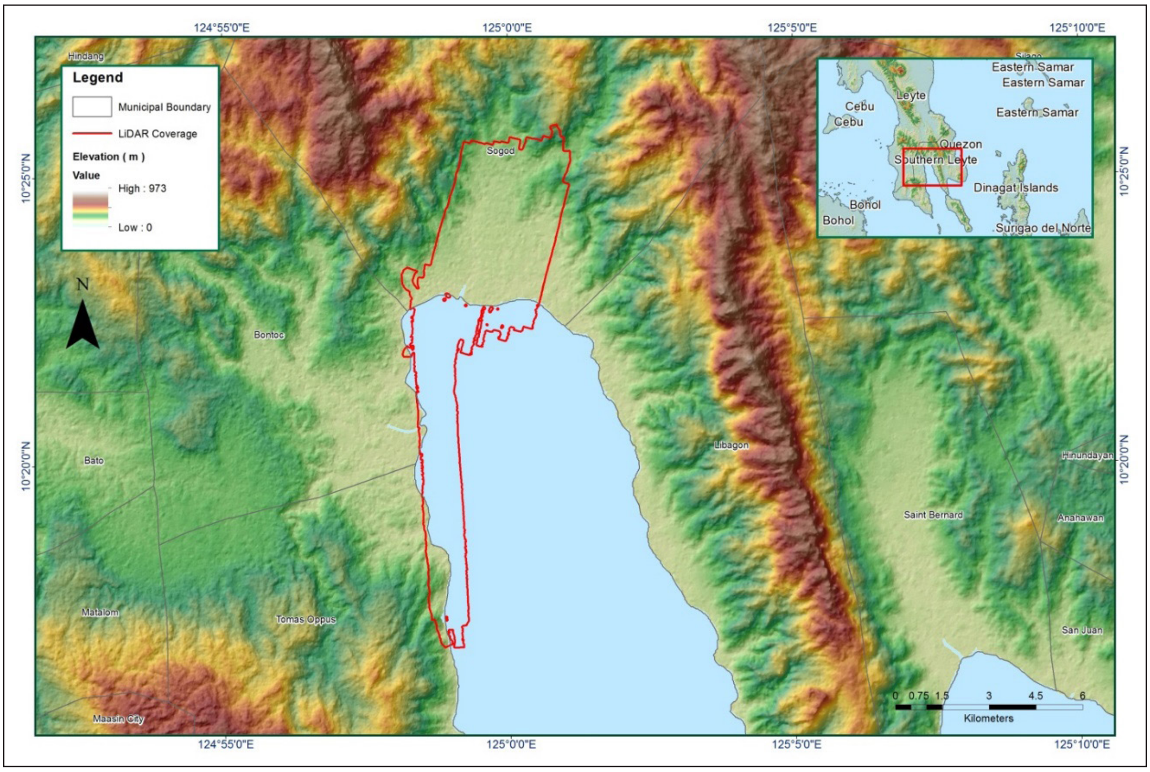


Figure A-8.4.Coverage of LiDAR data

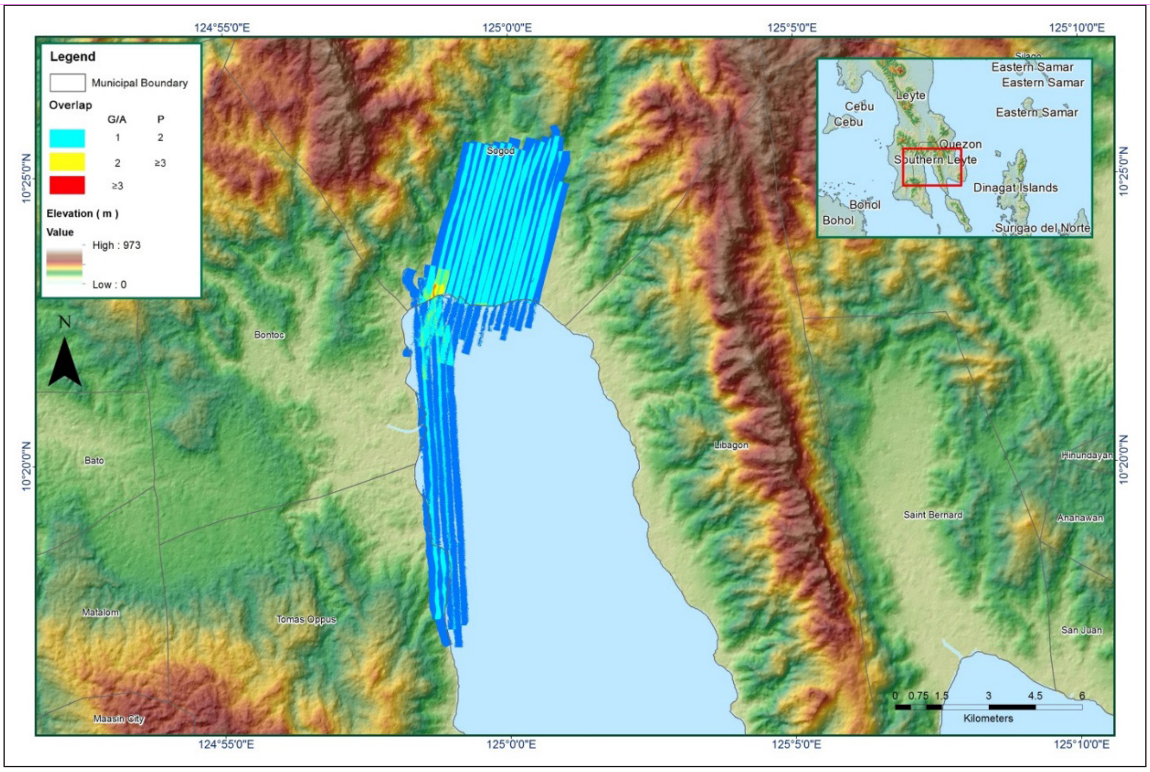


Figure A-8.5.Image of data overlap

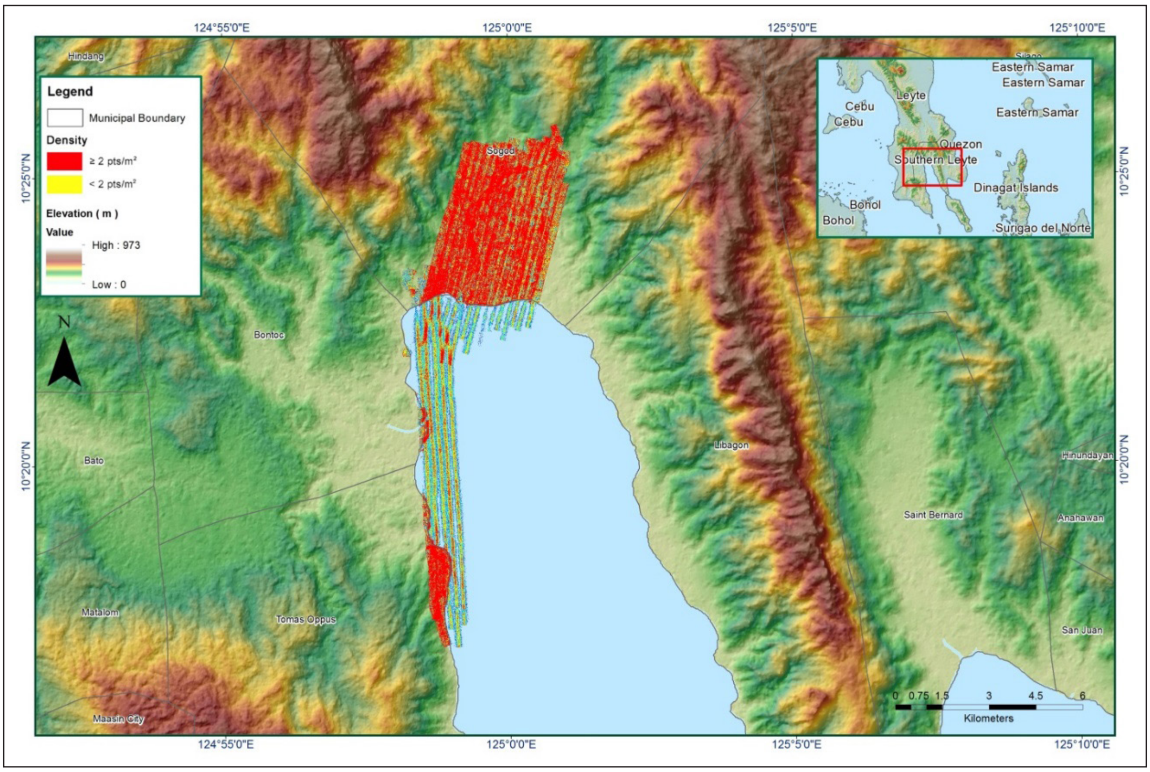


Figure A-8.6. Density map of merged LiDAR data

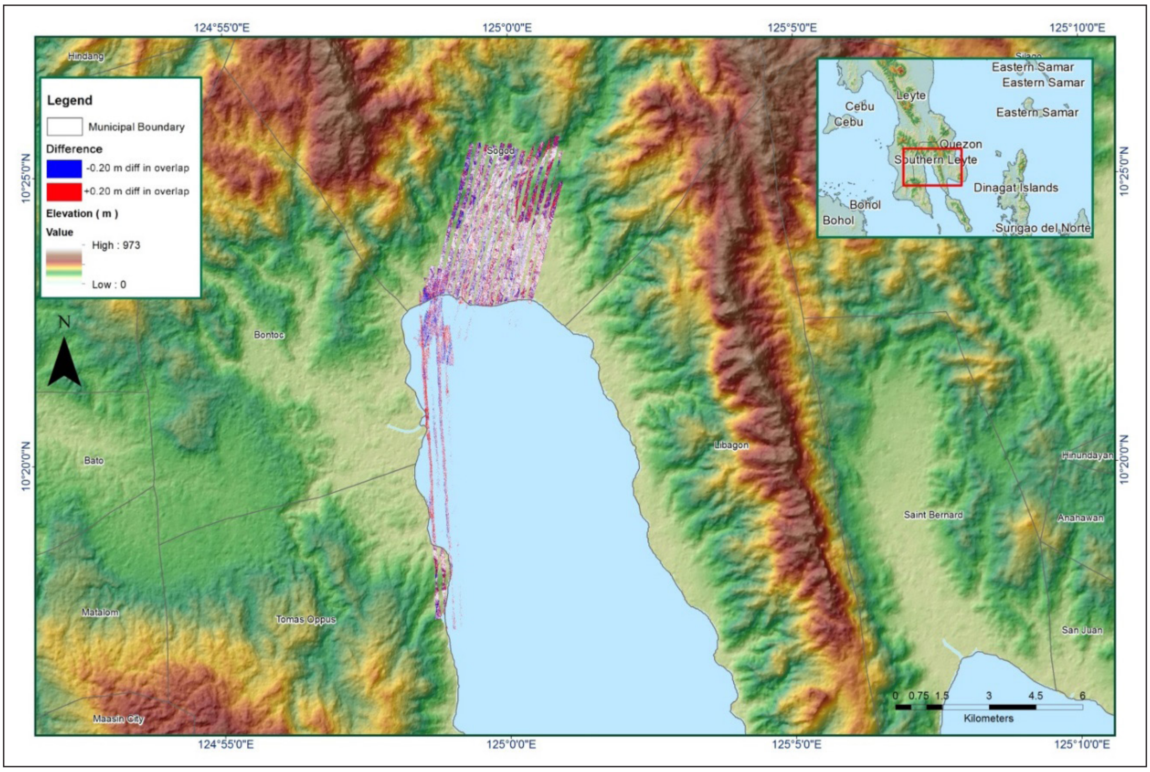


Figure A-8.7. Elevation difference between flight lines

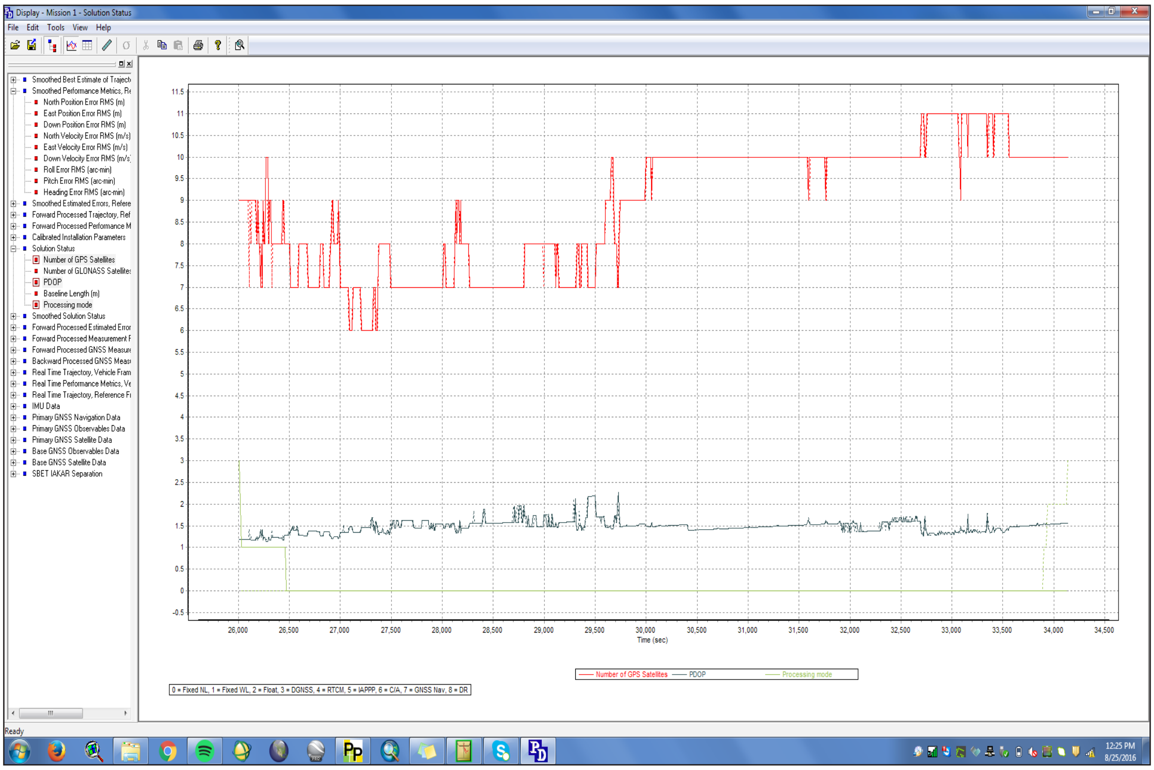


Figure A-8.8. Solution Status

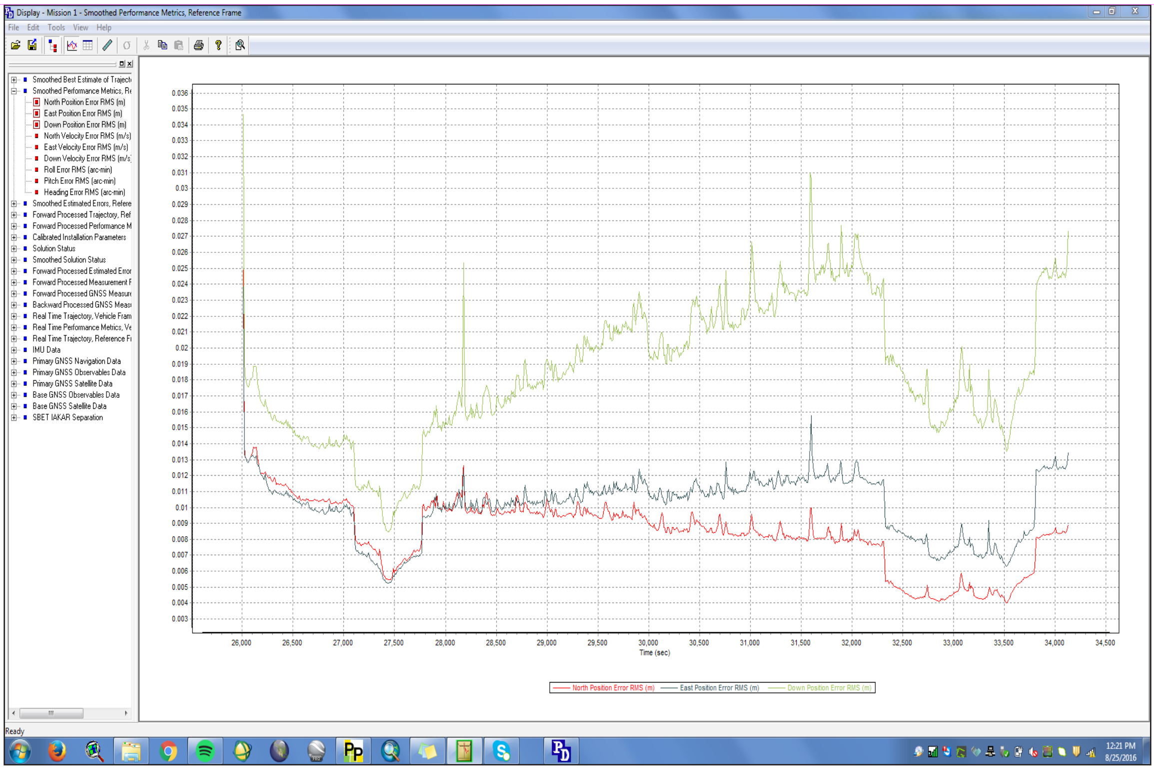


Figure A-8.9. Smoothed Performance Metric Parameters

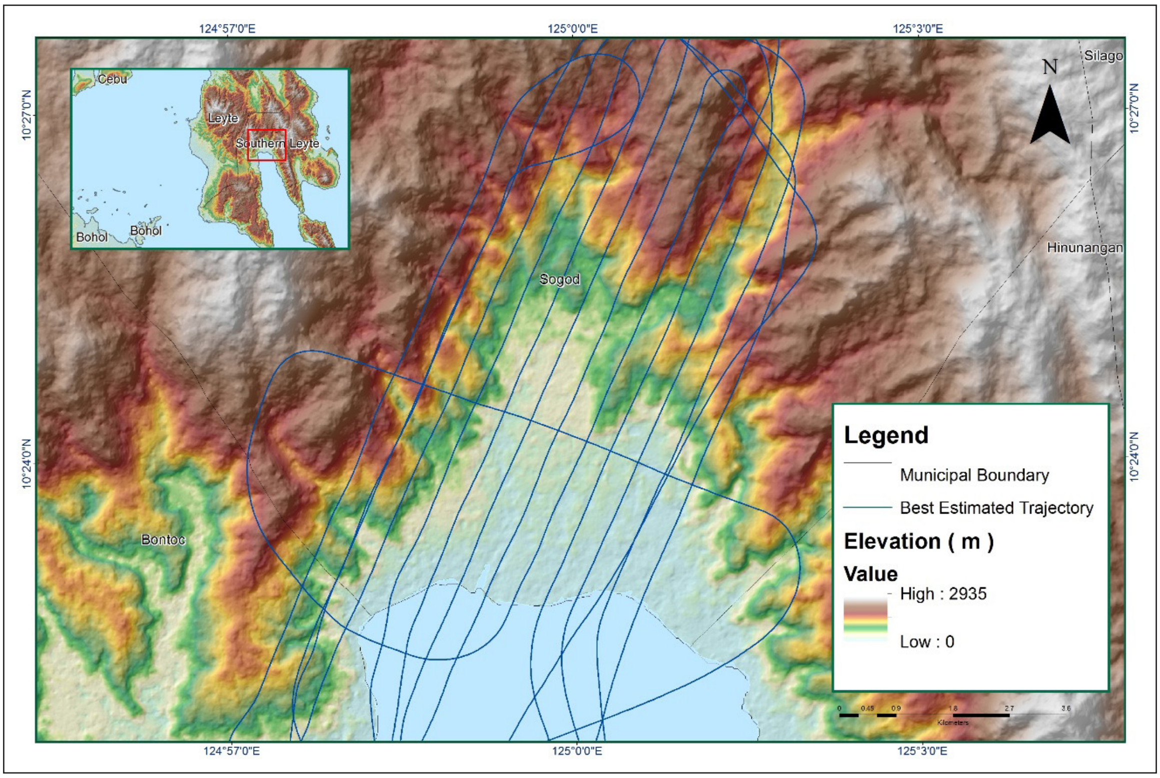


Figure A-8.10. Best Estimated Trajectory

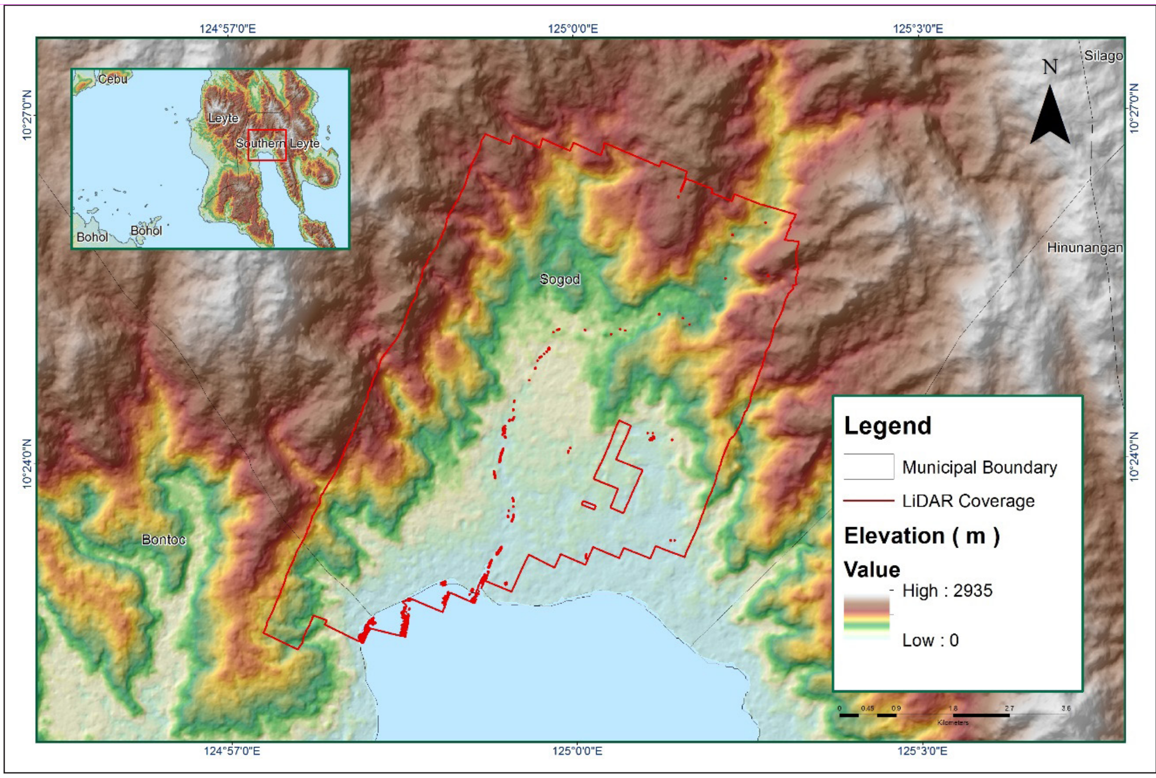


Figure A-8.11. Coverage of LiDAR Data

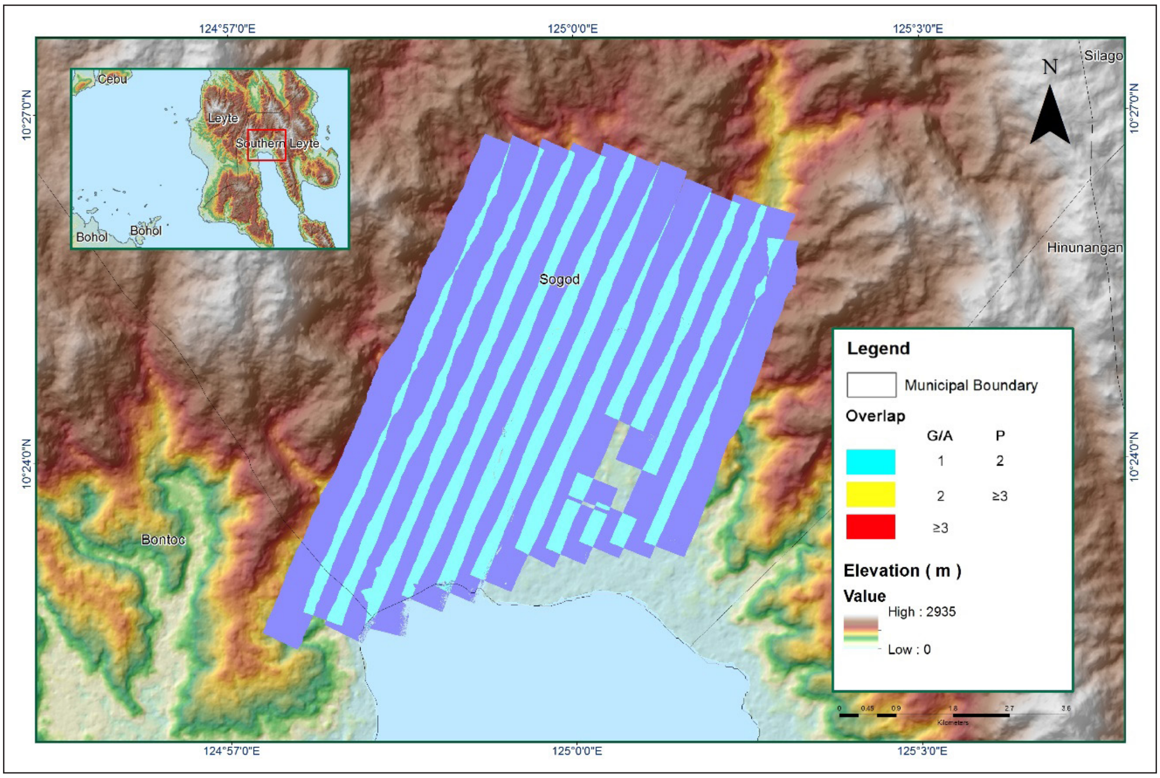


Figure A-8.12. Image of data overlap

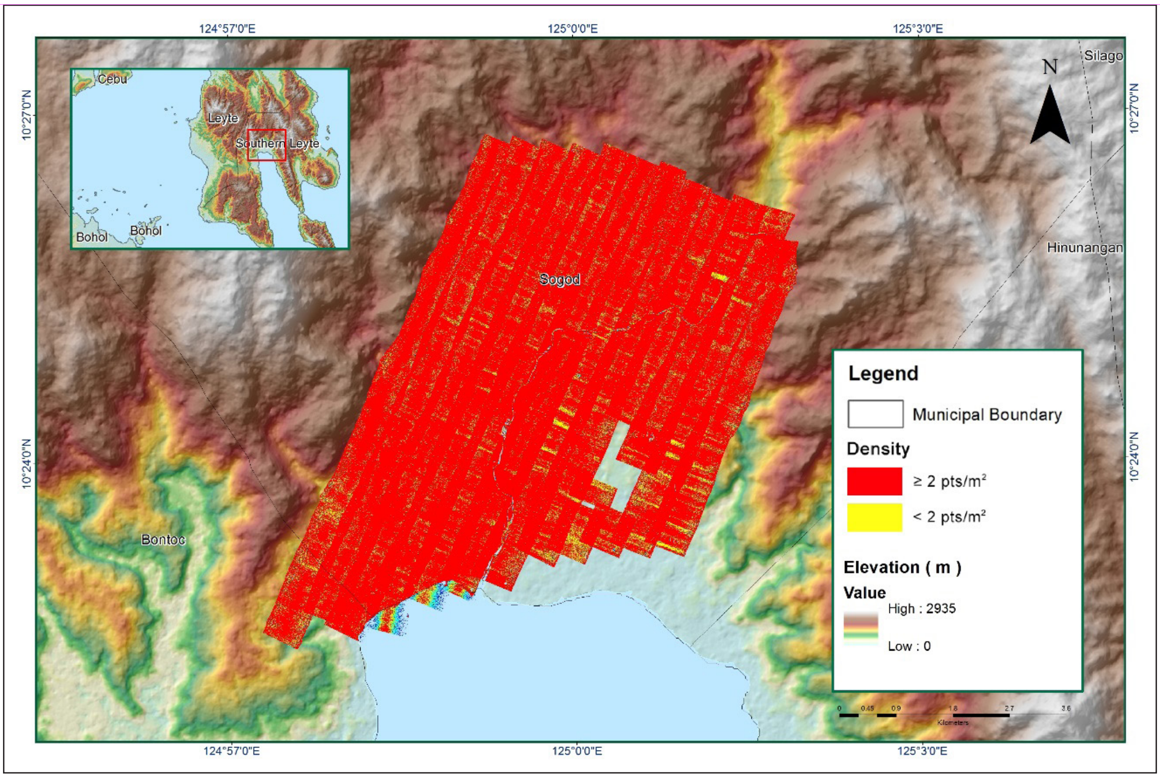


Figure A-8.13. Density map of merged LiDAR data

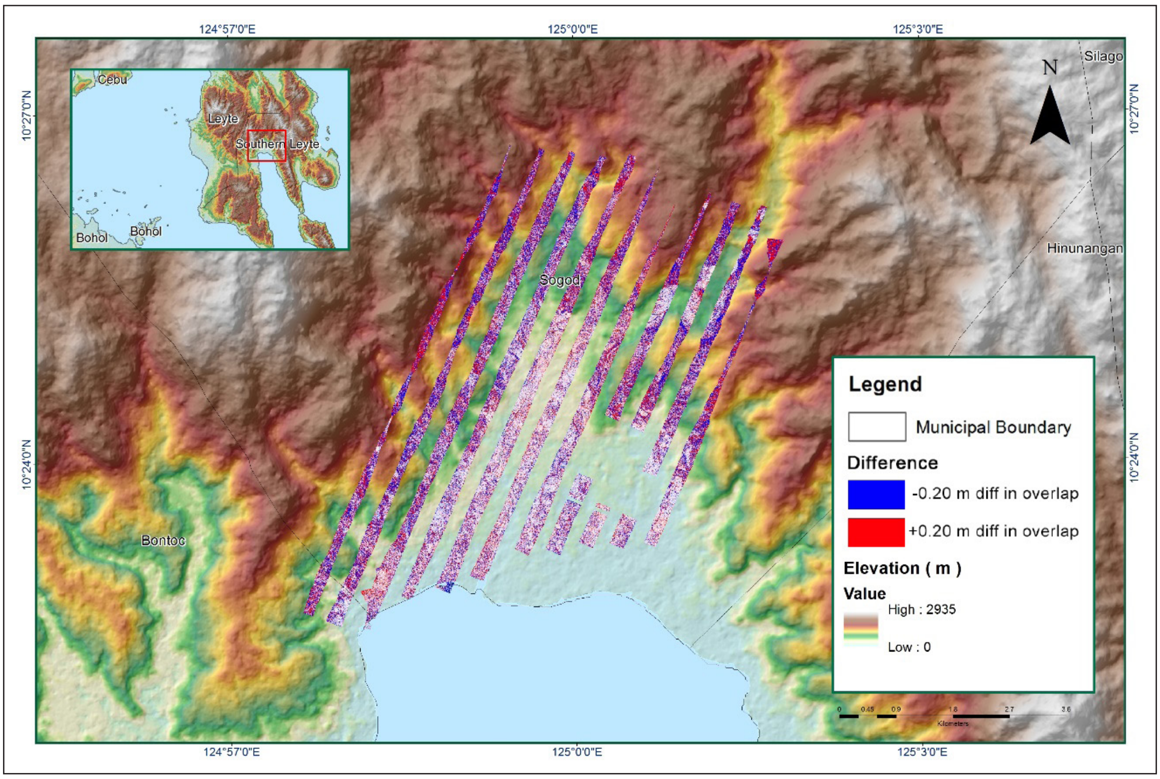


Figure A-8.14. Elevation difference between flight lines

Annex 9. Subangdaku Model Basin Parameters

Table A-9.1.Subangdaku Model Basin Parameters

	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
Sub-basin	Initial Abstraction	Curve Number	Impervious %	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge (m^3/s)	Recession Constant	Threshold Type	Ratio to Peak
W100	11.857	81.0765	0	3.0848	3.0207	Discharge	3.1876	0.9	Ratio to Peak	0.38
W110	4.2498	92.28	0	1.7406	1.7044	Discharge	1.9530703	0.9	Ratio to Peak	0.38
W120	7.4192	87.2565	0	0.83042	0.81314	Discharge	0.58237	0.9	Ratio to Peak	0.38
W130	8.3124	85.938	0	1.38	1.3513	Discharge	1.1944	0.9	Ratio to Peak	0.38
W140	4.6809	91.563	0	0.93561	0.91615	Discharge	0.71237	0.9	Ratio to Peak	0.38
W150	6.9791	87.921	0	1.0673	1.0451	Discharge	0.84181	0.9	Ratio to Peak	0.38
W160	8.0045	86.388	0	1.2308	1.2052	Discharge	1.3394	0.9	Ratio to Peak	0.38
W170	19.756	72	0	2.1028	2.0591	Discharge	1.722	0.9	Ratio to Peak	0.38
W180	17.046	74.8755	0	1.8373	1.799	Discharge	1.467	0.9	Ratio to Peak	0.38

Annex 10. Subangdaku Model Reach Parameters

Table A-10.1. Subangdaku Model Reach Parameters

Reach	Time Step Method	Length	Slope	Manning's n	Shape	Width	Side Slope
R40	Automatic Fixed Interval	2069.5	0.035738	0.04	Trapezoid	17.774	1
R50	Automatic Fixed Interval	2641.0	0.06171	0.04	Trapezoid	37.342	1
R80	Automatic Fixed Interval	5282.4	0.016848	0.04	Trapezoid	101.208	1
R90	Automatic Fixed Interval	2923.4	0.016848	0.04	Trapezoid	188.86	1

Annex 11. SubangdakuField Validation Points

Table A-11.1.Subangdaku Field Validation Points for the 5-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
3	10.3838	124.9763	0.09	0.2	-0.11	Yolanda	November 08, 2013	5-YR
4	10.3844	124.9762	0.20	0.5	-0.3	Ruby	December 06, 2014	5-YR
5	10.3829	124.9754	0.11	0.0	0.11			5-YR
6	10.3845	124.9779	0.07	0.3	-0.23	Yolanda	November 08, 2013	5-YR
7	10.3859	124.9778	0.11	0.3	-0.19	Yolanda	November 08, 2013	5-YR
8	10.3868	124.9765	0.09	0.2	-0.11	Yolanda	November 08, 2013	5-YR
9	10.3872	124.9732	0.03	0.0	0.03			5-YR
10	10.3881	124.9715	0.05	0.0	0.05			5-YR
11	10.3882	124.9709	0.38	0.0	0.38			5-YR
12	10.4013	124.9956	0.03	1.2	-1.17	Yolanda	November 08, 2013	5-YR
13	10.4013	124.9956	0.03	1.0	-0.97	Ruby	December 06, 2014	5-YR
14	10.4014	124.996	0.16	1.3	-1.14	Ruby	December 06, 2014	5-YR
15	10.4014	124.996	0.16	1.1	-0.94	Yolanda	November 08, 2013	5-YR
16	10.4009	124.9968	0.04	0.4	-0.36	Ruby	December 06, 2014	5-YR
19	10.4002	125.001	0.03	0.6	-0.57	Yolanda	November 08, 2013	5-YR
20	10.3998	125.0084	0.03	0.3	-0.27	Yolanda	November 08, 2013	5-YR
21	10.3998	125.0084	0.03	0.5	-0.47	Ruby	December 06, 2014	5-YR
22	10.3997	125.0089	0.03	0.3	-0.27	Yolanda	November 08, 2013	5-YR
23	10.3997	125.0089	0.03	0.5	-0.47	Ruby	December 06, 2014	5-YR
24	10.3994	125.0067	0.03	0.3	-0.27	Yolanda	November 08, 2013	5-YR
25	10.3994	125.0067	0.03	0.5	-0.47	Ruby	December 06, 2014	5-YR
26	10.4009	125.0134	0.04	0.0	0.04			5-YR
27	10.4001	125.0131	0.03	0.0	0.03			5-YR
28	10.3996	125.0131	0.07	0.2	-0.13	Yolanda	November 08, 2013	5-YR
29	10.4014	125.0142	0.03	0.0	0.03			5-YR
30	10.3995	125.0031	0.12	1.1	-0.98	Yolanda	November 08, 2013	5-YR
31	10.3995	125.0031	0.12	1.0	-0.88	Ruby	December 06, 2014	5-YR
32	10.3997	125.0018	0.03	0.0	0.03			5-YR
33	10.397	125.0008	0.03	0.0	0.03			5-YR
34	10.3969	125.0012	0.03	0.6	-0.57	Yolanda	November 08, 2013	5-YR
35	10.3969	125.0012	0.03	0.1	-0.07	Ruby	December 06, 2014	5-YR
36	10.3965	125.0006	0.03	0.6	-0.57	Yolanda	November 08, 2013	5-YR
37	10.3965	125.0006	0.03	0.1	-0.07	Ruby	December 06, 2014	5-YR
38	10.3947	125.0001	0.04	0.5	-0.46	Yolanda	November 08, 2013	5-YR
39	10.3947	125.0001	0.04	0.3	-0.26	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
40	10.3953	124.9999	0.14	0.5	-0.36	Yolanda	November 08, 2013	5-YR
41	10.3953	124.9999	0.14	0.3	-0.16	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
42	10.3951	125	0.03	0.5	-0.47	Yolanda	November 08, 2013	5-YR
43	10.3951	125	0.03	0.3	-0.27	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
44	10.3942	124.9994	0.12	1.0	-0.88	Yolanda	November 08, 2013	5-YR
46	10.3939	124.9997	0.14	0.0	0.14			5-YR
47	10.3934	124.9994	0.03	0.8	-0.77	Basyang	Jan. 30 - Feb. 1, 2014	5-YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
48	10.3919	125.0001	0.03	0.0	0.03			5-YR
49	10.3929	124.999	0.39	0.5	-0.11	Ruby	December 06, 2014	5-YR
50	10.3929	124.999	0.39	0.2	0.19	Yolanda	November 08, 2013	5-YR
53	10.3917	124.9983	0.03	0.0	0.03			5-YR
54	10.3915	124.9982	0.03	0.5	-0.47	Yolanda	November 08, 2013	5-YR
55	10.3897	124.9972	0.03	0.0	0.03			5-YR
56	10.3895	124.9982	0.03	0.1	-0.07	Yolanda	November 08, 2013	5-YR
57	10.3895	124.999	0.66	0.4	0.26	Yolanda	November 08, 2013	5-YR
58	10.39	124.9998	0.11	0.2	-0.09	Yolanda	November 08, 2013	5-YR
59	10.39	125.0008	0.25	0.0	0.25			5-YR
60	10.39	125.0013	0.03	0.0	0.03			5-YR
61	10.3886	124.9978	0.47	0.0	0.47			5-YR
65	10.3816	124.9977	0.03	0.4	-0.37	Yolanda	November 08, 2013	5-YR
81	10.3836	124.9962	0.03	0.0	0.03			5-YR
84	10.383	124.9954	0.03	0.1	-0.07	Yolanda	November 08, 2013	5-YR
87	10.3821	124.9957	0.03	0.0	0.03			5-YR
88	10.3813	124.9964	0.03	0.2	-0.17	Yolanda	November 08, 2013	5-YR
91	10.3809	124.9962	0.05	0.2	-0.15	Yolanda	November 08, 2013	5-YR
94	10.3809	124.9958	0.31	0.2	0.11	Yolanda	November 08, 2013	5-YR
97	10.3808	124.9967	0.09	0.2	-0.11	Yolanda	November 08, 2013	5-YR
100	10.3811	124.9944	0.09	0.2	-0.11	Yolanda	November 08, 2013	5-YR
103	10.3816	124.9946	0.03	0.2	-0.17	Yolanda	November 08, 2013	5-YR
106	10.3815	124.995	0.68	0.2	0.48	Yolanda	November 08, 2013	5-YR
109	10.3849	124.9956	0.05	0.0	0.05			5-YR
110	10.385	124.9943	0.13	0.0	0.13			5-YR
111	10.3828	124.9885	1.58	0.0	1.58			5-YR
112	10.3823	124.9888	0.03	0.0	0.03			5-YR
113	10.3816	124.9882	1.38	0.0	1.38			5-YR
114	10.3811	124.9894	0.23	0.0	0.23			5-YR
115	10.3847	125.0015	0.29	0.0	0.29			5-YR
116	10.3848	125.0022	0.32	0.0	0.32			5-YR
117	10.3842	125.0031	0.26	0.2	0.06	Yolanda	November 08, 2013	5-YR
124	10.3892	125.0078	0.03	0.2	0.17	Ruby	December 06, 2014	5-YR
125	10.3892	125.0078	0.03	0.2	0.17	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
126	10.3883	125.0076	0.03	0.2	0.17	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
127	10.3883	125.0076	0.03	0.2	0.17	Ruby	December 06, 2014	5-YR
128	10.3922	125.0064	0.03	0.0	-0.03			5-YR
129	10.3969	125.005	0.03	0.0	-0.03			5-YR
130	10.3985	125.0041	0.03	0.0	-0.03			5-YR
131	10.4017	124.9942	0.03	0.0	-0.03			5-YR
132	10.3828	124.985	0.70	0.0	-0.7			5-YR
133	10.3833	124.9854	0.19	1.0	0.81	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
134	10.3833	124.9854	0.19	0.5	0.31	Yolanda	November 08, 2013	5-YR
135	10.3834	124.9857	0.04	0.0	-0.04			5-YR
136	10.3837	124.9861	0.18	0.0	-0.18			5-YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
137	10.3842	124.9863	0.42	0.0	-0.42			5-YR
138	10.3847	124.9864	0.22	0.0	-0.22			5-YR
139	10.385	124.987	1.66	0.0	-1.66			5-YR
140	10.3845	124.9855	0.08	0.0	-0.08			5-YR
141	10.382	124.9854	0.67	1.0	0.33	Yolanda	November 08, 2013	5-YR
142	10.382	124.9854	0.67	0.8	0.13	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
144	10.3822	124.9853	0.74	1.0	0.26	Yolanda	November 08, 2013	5-YR
145	10.3822	124.9853	0.74	0.8	0.06	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
147	10.3816	124.9852	0.22	1.0	0.78	Yolanda	November 08, 2013	5-YR
148	10.3816	124.9852	0.22	0.8	0.58	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
150	10.3813	124.9853	0.03	1.0	0.97	Yolanda	November 08, 2013	5-YR
151	10.3813	124.9853	0.03	0.8	0.77	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
153	10.3823	124.9844	0.03	1.0	0.97	Yolanda	November 08, 2013	5-YR
154	10.3823	124.9844	0.03	0.8	0.77	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
156	10.3824	124.9846	0.64	1.0	0.36	Yolanda	November 08, 2013	5-YR
157	10.3824	124.9846	0.64	0.8	0.16	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
159	10.3827	124.9829	0.03	1.0	0.97	Ruby	December 06, 2014	5-YR
160	10.3827	124.9829	0.03	1.0	0.97	Yolanda	November 08, 2013	5-YR
161	10.383	124.9824	0.15	1.0	0.85	Ruby	December 06, 2014	5-YR
162	10.383	124.9824	0.15	1.0	0.85	Yolanda	November 08, 2013	5-YR
163	10.383	124.9836	0.56	1.0	0.44	Ruby	December 06, 2014	5-YR
164	10.383	124.9836	0.56	1.0	0.44	Yolanda	November 08, 2013	5-YR
165	10.3827	124.9837	0.05	1.0	0.95	Ruby	December 06, 2014	5-YR
166	10.3827	124.9837	0.05	1.0	0.95	Yolanda	November 08, 2013	5-YR
167	10.3833	124.984	0.26	1.0	0.74	Ruby	December 06, 2014	5-YR
168	10.3833	124.984	0.26	1.0	0.74	Yolanda	November 08, 2013	5-YR
169	10.387	124.9835	0.40	0.2	-0.2	Yolanda	November 08, 2013	5-YR
170	10.3863	124.9835	0.23	0.2	-0.03	Yolanda	November 08, 2013	5-YR
171	10.3859	124.9836	0.24	0.2	-0.04	Yolanda	November 08, 2013	5-YR
172	10.3879	124.9833	0.32	0.0	-0.32			5-YR
173	10.3865	124.9823	0.04	0.0	-0.04			5-YR
175	10.3853	124.9823	0.49	0.2	-0.29	Yolanda	November 08, 2013	5-YR
176	10.3851	124.9827	0.19	0.2	0.01	Yolanda	November 08, 2013	5-YR
178	10.3822	124.9774	0.60	0.0	-0.6			5-YR
179	10.3818	124.9765	0.13	0.0	-0.13			5-YR
180	10.3809	124.9752	0.03	0.0	-0.03			5-YR
181	10.3812	124.9743	0.10	0.5	0.4	Yolanda	November 08, 2013	5-YR
182	10.3812	124.9743	0.10	0.5	0.4	Ruby	December 06, 2014	5-YR
183	10.3821	124.9736	0.06	0.5	0.44	Ruby	December 06, 2014	5-YR
184	10.3821	124.9736	0.06	0.5	0.44	Basyang	Jan. 30 - Feb. 1, 2014	5-YR
185	10.3821	124.9736	0.06	0.5	0.44	Yolanda	November 08, 2013	5-YR
186	10.3821	124.9736	0.06	0.5	-0.44	Seniang	December 28, 2014	5-YR
187	10.3823	124.9744	0.03	0.0	0.03			5-YR
188	10.3819	124.9746	0.07	0.0	0.07			5-YR
189	10.3847	124.9776	0.06	0.3	-0.24	Ruby	December 06, 2014	5-YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
190	10.3861	124.9777	0.04	0.1	-0.06	Yolanda	November 08, 2013	5-YR
191	10.3867	124.9777	0.13	0.0	0.13			5-YR
192	10.387	124.9754	0.12	0.0	0.12			5-YR
193	10.3879	124.9717	0.03	0.0	0.03			5-YR
194	10.3887	124.9708	0.06	0.0	0.06			5-YR
195	10.3883	124.9713	0.04	0.0	0.04			5-YR
196	10.3959	124.9799	0.03	0.0	0.03			5-YR
197	10.4004	124.9806	0.03	0.0	0.03			5-YR
198	10.4015	124.9806	0.10	0.0	0.1			5-YR
199	10.3981	124.9816	0.03	0.0	0.03			5-YR
200	10.3968	124.9828	0.18	0.0	0.18			5-YR
201	10.3967	124.9849	0.35	0.0	0.35			5-YR
202	10.3978	124.9855	0.54	0.0	0.54			5-YR
203	10.3978	124.9852	0.12	0.0	0.12			5-YR
204	10.3983	124.9855	0.34	0.0	0.34			5-YR
205	10.3984	124.9862	0.03	0.0	0.03			5-YR
206	10.4	124.987	0.20	0.3	-0.1	Ruby	December 06, 2014	5-YR
207	10.4	124.987	0.20	0.3	-0.1	Seniang	December 28, 2014	5-YR
208	10.4	124.987	0.20	0.7	-0.5	Yolanda	November 08, 2013	5-YR
209	10.4003	124.9863	0.36	1.0	-0.64	Yolanda	November 08, 2013	5-YR
210	10.4003	124.9863	0.36	0.5	-0.14	Ruby	December 06, 2014	5-YR
211	10.4003	124.9863	0.36	0.5	-0.14	Seniang	December 28, 2014	5-YR
212	10.4009	124.9865	0.94	0.5	0.44	Yolanda	November 08, 2013	5-YR
213	10.4007	124.9871	0.03	0.7	-0.67	Yolanda	November 08, 2013	5-YR
214	10.4007	124.9871	0.03	0.4	-0.37	Ruby	December 06, 2014	5-YR
215	10.4007	124.9871	0.03	0.4	-0.37	Seniang	December 28, 2014	5-YR
216	10.4006	124.9874	0.21	0.3	-0.09	Yolanda	November 08, 2013	5-YR
217	10.4006	124.9874	0.21	0.2	0.01	Ruby	December 06, 2014	5-YR
218	10.4006	124.9874	0.21	0.2	0.01	Seniang	December 28, 2014	5-YR
219	10.4015	124.9872	0.03	0.0	0.03			5-YR
220	10.4043	124.9871	0.12	0.5	-0.38	Yolanda	November 08, 2013	5-YR
221	10.4043	124.9871	0.12	0.6	-0.48	Ruby	December 06, 2014	5-YR
222	10.4056	124.9886	0.09	0.0	0.09			5-YR
223	10.4062	124.9888	0.18	0.0	0.18			5-YR
224	10.4066	124.9891	0.03	0.0	0.03			5-YR
225	10.4104	124.9909	0.06	0.0	0.06			5-YR
226	10.411	124.9914	0.03	0.0	0.03			5-YR
227	10.4107	124.9914	0.03	0.0	0.03			5-YR
228	10.4116	124.9908	1.54	1.0	0.54	Ruby	December 06, 2014	5-YR
229	10.4116	124.9908	1.54	1.0	0.54	Seniang	December 28, 2014	5-YR
230	10.4115	124.9917	0.03	0.0	0.03			5-YR
231	10.4131	124.992	0.20	0.1	0.1	Yolanda	November 08, 2013	5-YR
232	10.4136	124.9927	0.06	0.2	-0.14	Yolanda	November 08, 2013	5-YR
233	10.4135	124.9934	0.44	0.5	-0.06	Yolanda	November 08, 2013	5-YR
234	10.4135	124.9934	0.44	0.1	0.34	Ruby	December 06, 2014	5-YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
235	10.4141	124.9932	0.06	0	0.06			5-YR
236	10.4189	124.9922	0.06	0.3	-0.24	Yolanda	November 08, 2013	5-YR
237	10.4192	124.9923	0.03	0.3	-0.27	Yolanda	November 08, 2013	5-YR
238	10.4241	124.9922	0.16	0	0.16			5-YR
239	10.4243	124.9917	0.11	0	0.11			5-YR
240	10.4228	124.9922	0.23	0	0.23			5-YR
241	10.422	124.9927	0.33	0.5	-0.17	Yolanda	November 08, 2013	5-YR
242	10.4214	124.9925	0.06	0	0.06			5-YR
243	10.4195	124.9952	0.41	0	0.41			5-YR
244	10.42	124.9981	0.03	0.3	-0.27	Yolanda	November 08, 2013	5-YR
245	10.42	124.9981	0.03	0.3	-0.27	Seniang	December 28, 2014	5-YR
246	10.4203	124.9991	0.05	0	0.05			5-YR
247	10.4215	125.0018	0.05	0	0.05			5-YR
248	10.4211	125.005	0.03	0	0.03			5-YR
249	10.4207	125.0075	0.14	0.2	-0.06	Yolanda	November 08, 2013	5-YR
251	10.4207	125.0075	0.14	0.1	0.04	Ruby	December 06, 2014	5-YR
252	10.4207	125.0075	0.14	0.1	0.04	Seniang	December 28, 2014	5-YR
253	10.4213	125.0082	0.12	0	0.12			5-YR
254	10.4212	125.0085	0.03	0	0.03			5-YR
255	10.4215	125.004	0.03	0	0.03			5-YR
256	10.4215	125.0027	0.03	0.1	-0.07	Ruby	December 06, 2014	5-YR
257	10.4215	125.0027	0.03	0.1	-0.07	Yolanda	November 08, 2013	5-YR
258	10.4221	125.0024	0.24	0	0.24			5-YR
260	10.3999	125.0035	0.45	0.5	-0.05	Yolanda	November 08, 2013	5-YR
261	10.4007	125.0031	0.35	0.3	0.05	Seniang	December 28, 2014	5-YR
262	10.4019	125.0026	0.89	1	-0.11	Ruby	December 06, 2014	5-YR
263	10.4019	125.0026	0.89	1	-0.11	Seniang	December 28, 2014	5-YR
265	10.4024	125.003	0.03	0	0.03			5-YR
266	10.4049	125.0027	0.03	0	0.03			5-YR
267	10.4098	125.0018	0.03	0	0.03			5-YR
268	10.4082	125.0012	0.49	0	0.49			5-YR
269	10.4047	125.0013	0.03	0.2	-0.17	Yolanda	November 08, 2013	5-YR
270	10.3928	124.9842	0.12	0	0.12			5-YR
271	10.3928	124.9882	0.04	0	0.04			5-YR
272	10.3874	124.9861	0.56	0.3	0.26	Yolanda	November 08, 2013	5-YR
273	10.3881	124.9866	0.31	0	0.31			5-YR
274	10.3908	124.9844	0.54	0	0.54			5-YR
275	10.3884	124.9828	0.24	0	0.24			5-YR
276	10.3892	124.9804	0.03	0	0.03			5-YR
277	10.389	124.9788	0.12	0	0.12			5-YR
278	10.3913	124.9784	0.14	0	0.14			5-YR
279	10.392	124.9779	0.05	0	0.05			5-YR
280	10.3882	124.9791	0.03	0	0.03			5-YR

Table A-11.2. Subangdaku Field Validation Points for the 25-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
2	10.3834	124.9819	0.05	0.5	-0.45	Bising	March 22-29, 1982	25-YR
17	10.4002	125.0007	0.03	1.5	-1.47	Amy	December 10, 1951	25-YR
18	10.4002	125.0007	0.03	1.2	-1.17	Bising	March 22-29, 1982	25-YR
51	10.3929	124.999	0.80	1.3	-0.5	Bising	March 22-29, 1982	25-YR
62	10.3809	124.9978	0.03	0.5	-0.47	Amy	December 10, 1951	25-YR
64	10.3809	124.9978	0.03	0.5	-0.47	Bising	March 22-29, 1982	25-YR
66	10.3816	124.9977	0.03	0.5	-0.47	Amy	December 10, 1951	25-YR
67	10.3816	124.9977	0.03	0.5	-0.47	Bising	March 22-29, 1982	25-YR
69	10.3817	124.9974	0.03	0.5	-0.47	Amy	December 10, 1951	25-YR
71	10.3817	124.9974	0.03	0.5	-0.47	Bising	March 22-29, 1982	25-YR
72	10.3821	124.9979	0.16	0.5	-0.34	Amy	December 10, 1951	25-YR
74	10.3821	124.9979	0.16	0.5	-0.34	Bising	March 22-29, 1982	25-YR
75	10.3826	124.9973	0.38	0.5	-0.12	Amy	December 10, 1951	25-YR
77	10.3826	124.9973	0.38	0.5	-0.12	Bising	March 22-29, 1982	25-YR
78	10.3837	124.9975	0.19	0.5	-0.31	Amy	December 10, 1951	25-YR
80	10.3837	124.9975	0.19	0.5	-0.31	Bising	March 22-29, 1982	25-YR
83	10.3826	124.9959	1.67	1.8	-0.13	Bising	March 22-29, 1982	25-YR
86	10.383	124.9954	0.06	1.8	-1.74	Bising	March 22-29, 1982	25-YR
89	10.3813	124.9964	0.03	2.5	-2.47	Bising	March 22-29, 1982	25-YR
92	10.3809	124.9962	0.10	2.5	-2.4	Bising	March 22-29, 1982	25-YR
95	10.3809	124.9958	0.34	2.5	-2.16	Bising	March 22-29, 1982	25-YR
98	10.3808	124.9967	0.43	2.5	-2.07	Bising	March 22-29, 1982	25-YR
101	10.3811	124.9944	0.10	2.5	-2.4	Bising	March 22-29, 1982	25-YR
104	10.3816	124.9946	0.04	2.5	-2.46	Bising	March 22-29, 1982	25-YR
107	10.3815	124.995	0.81	2.5	-1.69	Bising	March 22-29, 1982	25-YR
118	10.382	125.0057	0.27	0.5	-0.23	Bising	March 22-29, 1982	25-YR
121	10.3833	125.0064	0.11	0.5	-0.39	Bising	March 22-29, 1982	25-YR
123	10.3831	125.0067	0.06	0.5	0.44	Bising	March 22-29, 1982	25-YR
143	10.382	124.9854	1.02	1.0	-0.02	Bising	March 22-29, 1982	25-YR
146	10.3822	124.9853	1.09	1.0	-0.09	Bising	March 22-29, 1982	25-YR
149	10.3816	124.9852	0.54	1.0	0.46	Bising	March 22-29, 1982	25-YR
152	10.3813	124.9853	0.21	1.0	0.79	Bising	March 22-29, 1982	25-YR
155	10.3823	124.9844	0.12	1.0	0.88	Bising	March 22-29, 1982	25-YR
158	10.3824	124.9846	1.00	1.0	0	Bising	March 22-29, 1982	25-YR
174	10.3853	124.9823	0.53	0.2	-0.33	Bising	March 22-29, 1982	25-YR
177	10.3827	124.9792	0.04	5.0	4.96	Bising	March 22-29, 1982	25-YR
250	10.4207	125.0075	0.94	0.2	0.74	Bising	March 22-29, 1982	25-YR
259	10.3999	125.0035	0.60	1	-0.4	Bising	March 22-29, 1982	25-YR
264	10.4022	125.0023	0.85	0.7	0.15	Amy	December 10, 1951	25-YR

Table A-11.3. Subangdaku Field Validation Points for the 100-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
1	10.3834	124.98191	0.06	0.5	-0.44	Ruping	November 5-18, 1990	100-YR
45	10.3942	124.99936	0.53	0.8	-0.27	Ruping	November 5-18, 1990	100-YR
52	10.3929	124.99903	1.11	1.3	-0.19	Ruping	November 5-18, 1990	100-YR
63	10.3809	124.99785	0.03	0.5	-0.47	Ruping	November 5-18, 1990	100-YR
68	10.3816	124.99775	0.41	0.5	-0.09	Ruping	November 5-18, 1990	100-YR
70	10.3817	124.99735	0.59	0.5	0.09	Ruping	November 5-18, 1990	100-YR
73	10.3821	124.99789	0.61	0.5	0.11	Ruping	November 5-18, 1990	100-YR
76	10.3826	124.99732	0.78	0.5	0.28	Ruping	November 5-18, 1990	100-YR
79	10.3837	124.99747	0.24	0.5	-0.26	Ruping	November 5-18, 1990	100-YR
82	10.3826	124.99586	2.33	2.5	-0.17	Ruping	November 5-18, 1990	100-YR
85	10.383	124.99537	0.67	2.5	-1.83	Ruping	November 5-18, 1990	100-YR
90	10.3813	124.9964	0.52	1.0	-0.48	Ruping	November 5-18, 1990	100-YR
93	10.3809	124.99623	0.64	1.0	-0.36	Ruping	November 5-18, 1990	100-YR
96	10.3809	124.99579	0.86	1.0	-0.14	Ruping	November 5-18, 1990	100-YR
99	10.3808	124.99673	0.92	1.0	-0.08	Ruping	November 5-18, 1990	100-YR
102	10.3811	124.99441	0.40	1.0	-0.6	Ruping	November 5-18, 1990	100-YR
105	10.3816	124.99461	0.51	1.0	-0.49	Ruping	November 5-18, 1990	100-YR
108	10.3815	124.99496	1.40	1.0	0.4	Ruping	November 5-18, 1990	100-YR
119	10.382	125.00573	0.34	0.5	-0.16	Ruping	November 5-18, 1990	100-YR
120	10.3833	125.00638	0.20	0.5	-0.3	Ruping	November 5-18, 1990	100-YR
122	10.3831	125.0067	0.07	0.5	-0.43	Ruping	November 5-18, 1990	100-YR

Annex 12. Educational Institutions Affected by Flooding in Subangdaku Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Subangdaku Floodplain

SOUTHERN LEYTE				
SOGOD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Suba Day Care Center	Buac Daku			
Barangay Concepcion Day Care Center	Concepcion	Medium	Medium	Medium
Hibod-hibod Day Care Center	Hibod-Hibod			
San Isidro Elementary School Classroom	Pandan			
San Isidro Elementary School Nursery	Pandan			
San Isidro Elementary School Stage	Pandan			
San Isidro Elementary School Watsan	Pandan			
Concepcion Elementary School Canteen	Salvacion		Low	Medium
Concepcion Elementary School Classroom	Salvacion		Low	Medium
Concepcion Elementary School Comfort Room	Salvacion	Low	Medium	Medium
Concepcion Elementary School Library	Salvacion			Low
Concepcion Elementary School Office and Classroom	Salvacion	Low	Medium	Medium
Concepcion Elementary School Stage	Salvacion			Low
B.A.T.A Learning Center -CFC FFL	Tampoong	Medium	High	High
Grace Christian School of Leyte Inc	Tampoong		Low	Low
Royal Waldorf Integrated Academy	Tampoong			
Sogod National High School A.P Department	Tampoong		Low	Low
Sogod National High School Canteen	Tampoong	High	High	High
Sogod National High School Classroom	Tampoong			
Sogod National High School Library and Computer Laboratory	Tampoong			
Creative Minds Learning Center	Zone I			
Merryhills Academy of Sogod	Zone I			
Rizal Primary School	Zone I			
Royal Waldorf Integrated Academy	Zone I			
San Roque Day Care Center	Zone I	Low	Low	Low
SLSU AACUP COA Office	Zone I			
SLSU Administration Building	Zone I			
SLSU Canteen	Zone I			
SLSU Covered Court	Zone I			
SLSU Diagnostic Tissue Culture Laboratory	Zone I			
SLSU Dormitory	Zone I			
SLSU Drafting Building	Zone I			Low

SOUTHERN LEYTE				
SOGOD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
SLSU DYSL Office	Zone I			
SLSU Extension Service Building	Zone I		Low	Low
SLSU Food Tech Lab Building	Zone I			Low
SLSU Graduate Studies Building	Zone I			
SLSU Guardpost	Zone I	Low	Low	Low
SLSU High School Building	Zone I	Low	Low	Low
SLSU HRTM OJT Building	Zone I	Low	Low	Low
SLSU Info Tech Building	Zone I			
SLSU Livelihood Training center	Zone I			
SLSU Management Building	Zone I		Low	Low
SLSU New Engineering Building	Zone I		Low	Low
SLSU Old Engineering Building	Zone I	Low	Low	Low
SLSU Physical Education Building/Stage	Zone I			
SLSU Physical Plant Office	Zone I	Low	Low	Low
SLSU Power Plant	Zone I			
SLSU Social Services Center	Zone I			
SLSU Technology Building	Zone I			
SLSU Technology Building 1	Zone I			Low
SLSU Technology Building 2	Zone I			
SLSU Technology Building 3	Zone I			
SLSU Technology Building 4	Zone I			
SLSU U Shaped Building	Zone I			
Sogod Central School Canteen	Zone I			
Sogod Central School Classroom	Zone I			
Sogod Central School Clinic	Zone I			
Sogod Central School Faculty Room	Zone I			
Sogod Central School Guardpost	Zone I			
Sogod Central School National Development Center	Zone I	Medium	Medium	Medium
Sogod National High School Canteen	Zone I		Low	Low
Sogod National High School Classroom	Zone I			
Sogod National High School H.E Building	Zone I	Low	Low	Low
Sogod National High School Office	Zone I	Low	Low	Low
Southern Leyte State University (SLSU) Dept. of Education Building	Zone I			
St. Thomas Aquinas College	Zone I			
Zone 1 Barangay Day Care Center	Zone I	Low	Low	Low
St. Thomas Aquinas College	Zone II			Low

SOUTHERN LEYTE				
SOGOD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Pandan-San Miguel Elementary School Classroom	Zone V			
Pandan-San Miguel Elementary School Stage	Zone V			Low
Pandan Day Care Center	Zone V			
SLSU Dormitory	Zone V			
SLSU Physical Plant Office	Zone V		Low	Low

Annex 13. Medical Institutions Affected by Flooding in Subangdaku Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Subangdaku Floodplain

SOUTHERN LEYTE				
SOGOD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Suba Health Center	Buac Daku			
Barangay Concepcion Health Center	Concepcion	Medium	Medium	Medium
Hibod-hibod Health Center	Hibod-Hi-bod			
Hibod-hibod Health Center	Suba			
City Health Sogod	Tampoong	Medium	Medium	Medium
Consuelo Tan Memorial Medical Center	Tampoong	Low	Low	Low
Corpus Christi Pharmacy	Tampoong		Low	Low
Dental Clinic (Dr. Acero)	Tampoong			
Divine Rays	Tampoong	Low	Medium	Medium
Medical Center	Tampoong			Low
Riel's Pharmacy	Tampoong	Low	Low	Low
Sogod Distict Hospital Botica	Tampoong	Medium	Medium	Medium
Consuelo Tan Memorial Medical Center	Zone II	Low	Low	Low
Consuelo Tan Memorial Medical Center Building	Zone II		Low	Low
D & ES Pharmacy	Zone II			
Dental Clinic (Dr. Acero)	Zone II			Low
Sogod RHU Birthing Facility	Zone II			
VCS Pharmacy	Zone II	Low	Low	Low
Eye Aces Optical	Zone III			
Generika Drugstore	Zone III			
Mercury Drugstore	Zone III			
Prime/ OB Gyne Clinic	Zone III			
Zone 3 Barangay Health Center	Zone III			
Corrompido Specialty Hospital	Zone IV	Low	Low	Low
Corrompido Specialty Hospital Botica	Zone IV	Medium	Medium	Medium
Zone 5 Health Center	Zone IV			
Dr. Jadoc Eye & Hearing Aid Center	Zone V	Medium	Medium	Medium
Pudpud Polyclinic& Specialty Hospital	Zone V	Low	Medium	Medium

Table A-8.2. Mission Summary Report for Mission Blk49C

Flight Area	Ormoc South
Mission Name	**Blk49C**
Inclusive Flights	3923G
Range data size	8.5 GB
POS data size	168 MB
Base data size	19.1 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.26
RMSE for East Position (<4.0 cm)	1.57
RMSE for Down Position (<8.0 cm)	3.10
Boresight correction stdev (<0.001deg)	0.001094
IMU attitude correction stdev (<0.001deg)	0.002630
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	31.65
Ave point cloud density per sq.m. (>2.0)	4.62
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	58
Maximum Height	535.33 m
Minimum Height	63.51 m
Classification (# of points)	
Ground	19,771,074
Low vegetation	11,717,374
Medium vegetation	40,354,100
High vegetation	104,415,535
Building	1,242,955
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Melanie Hingpit, Engr. Czarina Jean Añonuevo