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

LiDAR Surveys and Flood Mapping of Kumalarang River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mindanao State University-Iligan Institute of Technology

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND KUMALARANG RIVER

Enrico C. Paringit, Dr. Eng., Prof. Alan E. Milano, and Engr. Elizabeth Albiento

1.1 Background of the Phil-LIDAR 1 Program

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

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled 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 Mindanao State University – Iligan Institute of Technology (MSU-IIT). MSU-IIT 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 16 river basins in the Northern Mindanao Region. The university is located in Iligan City in the province of Lanao del Norte.

1.2 Overview of the Kumalarang River Basin

The Kumalarang River Basin is situated in the province of Zambanga del Sur part of Region IX of Western Mindanao, Philippine. It covers one (1) municipality in Zamboanga del Sur, namely the Municipality of Kumalarang. According to the DENR River Basin Control Office (RBCO), the Kumalarang River Basin has a drainage area of 133 km^2 and an estimated 100 cubic meter (MCM) annual run-off (RBCO, 2015).

Kumalarang river basin has an estimated area of 227.279 square kilometres while the floodplain has an estimated area of 37.840 square kilometres, which comprises the 16.65% of the whole of the river basin. The floodplain has 4,900 digitized and attributed building features, majority of which are residential type. Road networks and water bodies are also extracted and attributed based on the secondary data of the Municipal Planning and Development Office (MPDO) of Kumalarang.

The generated floodplain boundary covers the nine (9) out of eighteen (18) barangays of Kumalarang Municipality. Those enumerated barangays are susceptible in flooding which are low-lying areas and near the riverbanks. Those are small portion of barangay Boyugan West, Picanan, Diplo, Lantawan, Sicade, Gawil, Boyugan East and whole portion of barangay Poblacion and Bualan.Poblacion barangay is the center of municipality where the municipal hall is located as well as commercial establishments. The discharge point where flow measurements were obtained is located in steel bridge of barangay Boyugan East.

The municipalities covered by the delineated river basin using Synthetic Aperture Radar (SAR) data are Lakewood in the north, Tigbao and Lapuyan in the east, Dumaguilas Bay and Kumalarangon in the south, and Buug and Bayog in the west. The main river named as Kumalarang River traverses the municipality of Kumalarang, Zamboanga Del Sur. Other water bodies such as lake, small rivers and creeks located within the said river basin are Lakewood Lake, Bualan River, Dipolo, Boyugan West and Muduing Rivers and Sicade Creek.

Kumalarang River, the main stem of Kumalarang River Basin, is among the nine (9) river systems in Zamboanga Peninsula.

According to the 2015 national census of PSA, a total of 7,086 persons are residing in Brgy. Poblacion in the Municipality of Kumalarang, which is within the immediate vicinity of the river.

Kumalarang is a fourth class municipality with 28,210 population majority of which are Christians and few Muslims based on 2010 Census. On August 28, 1959, upon the recommendation of the Provincial Board of Zamboanga del Sur, Kumalarang officially became a municipality, under Executive Order No. 356 as issued by President Carlos P. Garcia. It contains 14,833.461 hectares uncontested area and 307.299 hectares contested area based on the Kumalarang Cadastre PB-09-00044 of Department of Environment and Natural Resources (DENR) Region IX data approved last April 2015. The said municipality is rich in agricultural and aquatic resources. It is known as Crab Capital of Zamboanga del Zur province. Aside from crab, the other fresh cultured seafoods in the area are tilapia, milkfish, and shrimps. Meanwhile, the economy of the province of Zamboanga del Norte largely rests on agriculture particularly fishing, and mineral extraction.

Rainy season falls from the period of June to December and smallest chances in the month of March. Last November 18, 2011, heavy flooding inundated four (4) barangays of Kumalarang. According to Vice Mayor Eugenio Salva, heavy rains struck the low-lying barangays, namely Boyugan East, Gawil, Poblacion and Sicade. Salva was shocked that almost an hour of heavy rains, the floodwaters rose very quickly and it reached up to wrist level. Five (5) houses near the river of barangay Gawil were destroyed and an estimated thirty (30) hectares of farmland had been damaged; undetermined number of animals were drowned but no casualty of persons has been reported (PhilSouth Angle 2011).

On February 16, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Kumalarang River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Southern Luzon, Visayas and Mindanao as per NDRRMC report (Source: ndrrmc.gov.ph/attachments/article/3/Advisory_GFA_No_02_for_REG_VII_No_02%20for_REG_VIII_No_03_for_REG_IX_No_04_for_REG_X_No_04_for_REG_XI_No_04_for_REG_XII_No_04_for_CARAGA_No_04_for_ARMM_16FEB2017_1800H.pdf).

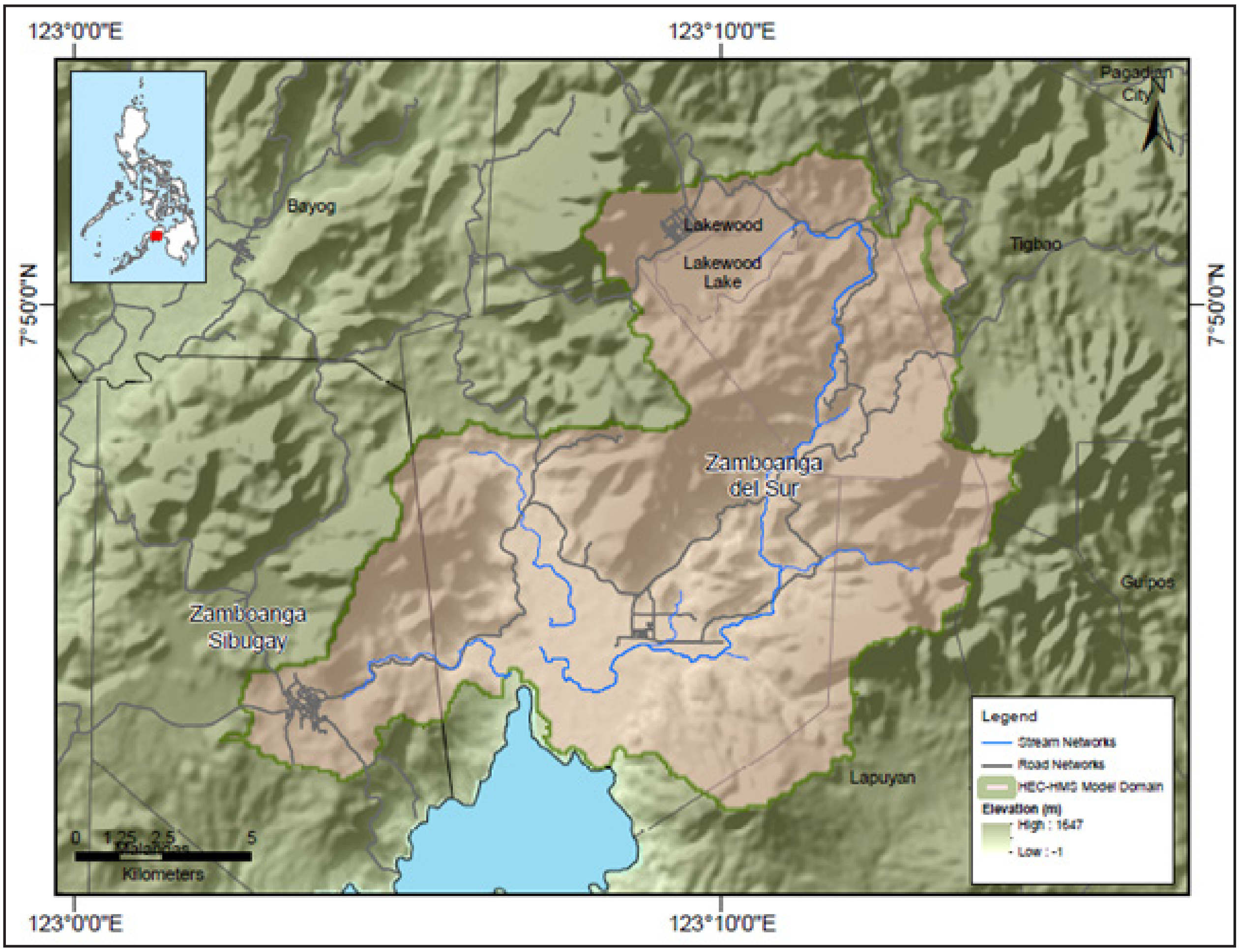

Figure 1. Map of Kumalarang River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN KUMALARANG FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Kumalarang Floodplain in Zamboanga. Each flight mission has an average of 14lines and run for at most four and a half (4.5) hours including take-off, landing and turning time. The parameter used in the LiDAR system for acquisition is found inTable1. Figure 2 shows the flight plans for Kumalarang Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK76A	1200	30	50	200	30	130	5
BLK76B	1200	30	50	200	30	130	5
BLK70A	1200	30	50	200	30	130	5
BLK71A	1200	30	50	200	30	130	5
BLK73B	1200	30	50	200	30	130	5

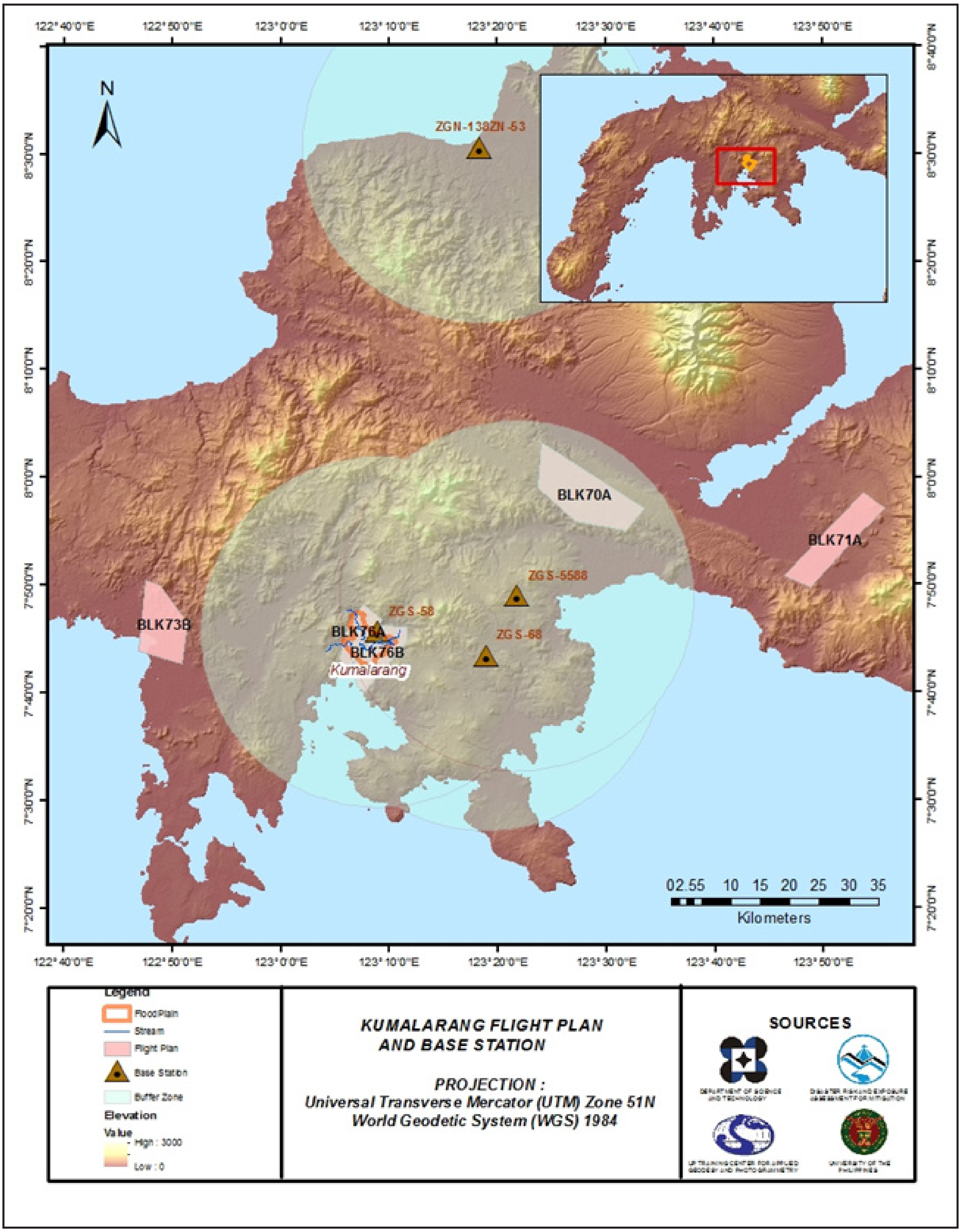


Figure 2. Flight plan used for Kumalarang Floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: ZGN-138, ZGS-68 and ZGS-58 which are of second (2nd) order accuracy and two (2) established control points: ZN-53 and ZGS-5588. The certifications for the NAMRIA reference points and processing report for the established points are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (February 4-March 4, 2016; November 18-December 2, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Kumalarang Floodplain are also shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA control stations within the area, in addition Table 2 to Table 6 show the details about the following NAMRIA control stations and established points, Table 7 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

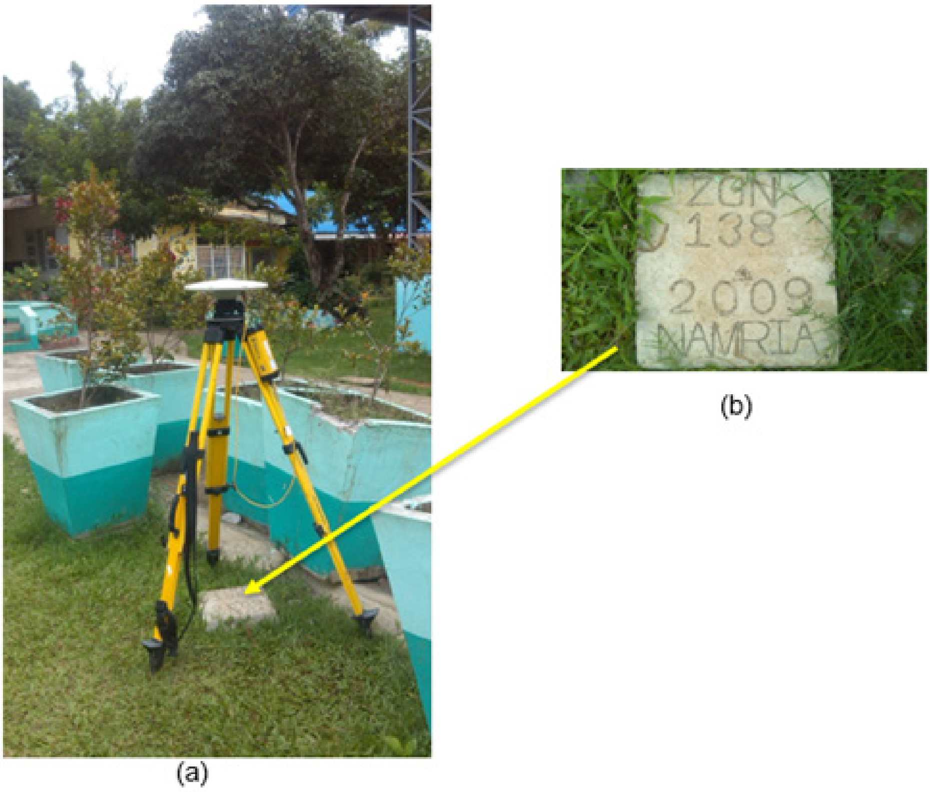


Figure 3. GPS set-up overZGN-138(a) in Katipinan Zamboanga del Norte and NAMRIA reference point ZGN-138 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGN-138 used as base station for the LiDAR Acquisition.

Station Name	**ZGN-138**	
Order of Accuracy	**2rd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°30’40.65974”North 122°18’14.44217”East 6.715 meters
GridCoordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	533471.036 meters 941106.14 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°30’36.94779” North 123°18’19.85548”East 70.925 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	533459.32 meters 940776.74 meters

(a)

Figure 4. GPS set-up over ZGNS68(a) inCERNO, Brgy. Poblacion, Guipos, Zamboanga del Sur and NAMRIA reference point ZGS-68 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-68 used as base station for the LiDAR Acquisition.

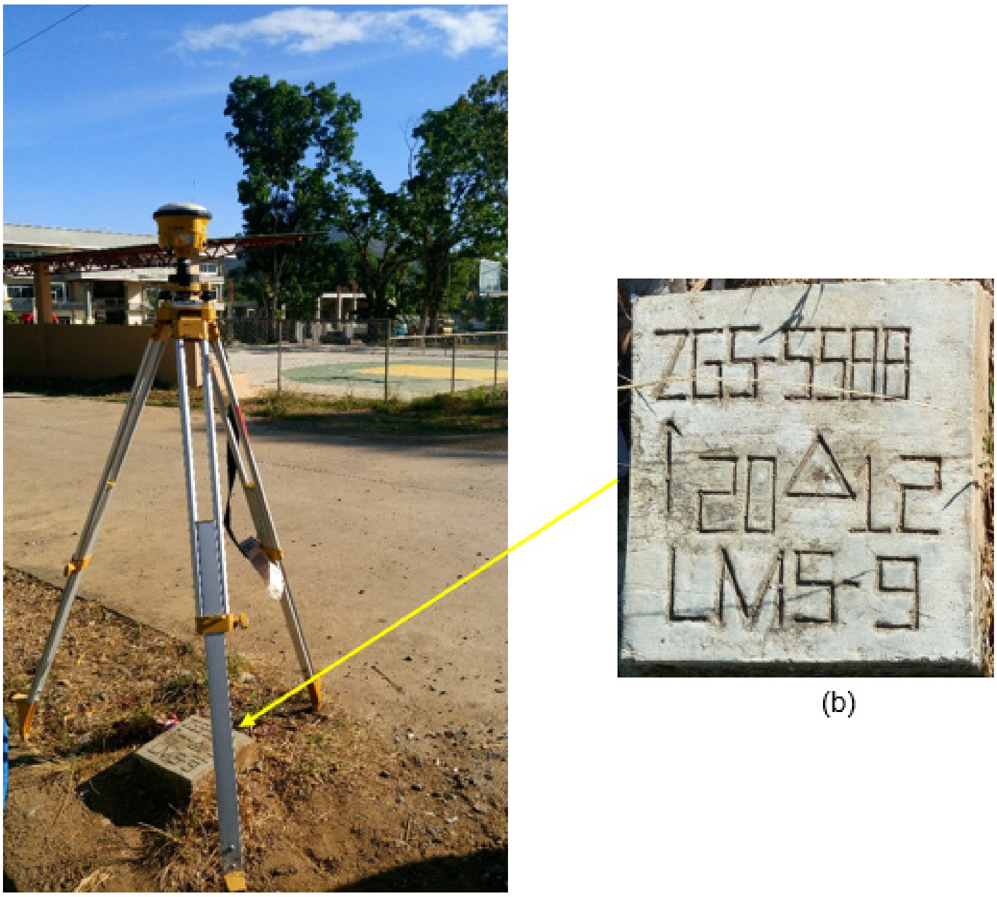
Station Name	ZGS-68	
Order of Accuracy	**2rd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°43' 33.12722"North 123°18'488.96041"East 205.941meters
GridCoordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	534593.845 meters 854250.138 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°43' 29.62251" North 123°18'54.44472" East 271.74800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	534581.74 meters 853951.14 meters

(a) (b)

Figure 5. (a) GPS set-up overZGS-58 in Brgy. Sicade, Kumaralang, Zamboanga delSurand BM reference point ZGS-58(b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ZGS-58used as base station for the LiDAR Acquisition.

Station Name	ZGS-58	
Order of Accuracy	**2rd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°45’44.20587”North 123°8’50.40994”East 31.65000 meters
GridCoordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	516245.79 meters 857966.20 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°45’40.67639” North 123°8’55.89231” East 96.97400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	516245.79 meters 857966.20 meters



(b)

(a)

Figure 6. (a) GPS set-up over ZGS-5588 in Dumalinao Municipal Hall Compound, Zamboanga del Sur and BM reference point ZGS-5588 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ZGS-5588 used as base station for the LiDAR Acquisition.

Station Name	ZGS-5588	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°49'04.07222"North 123°21'37.77947"East 259.299meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°49'00.54754"North 123°21'43.25501"East 325.044meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	539744.331meters 864117.593meters

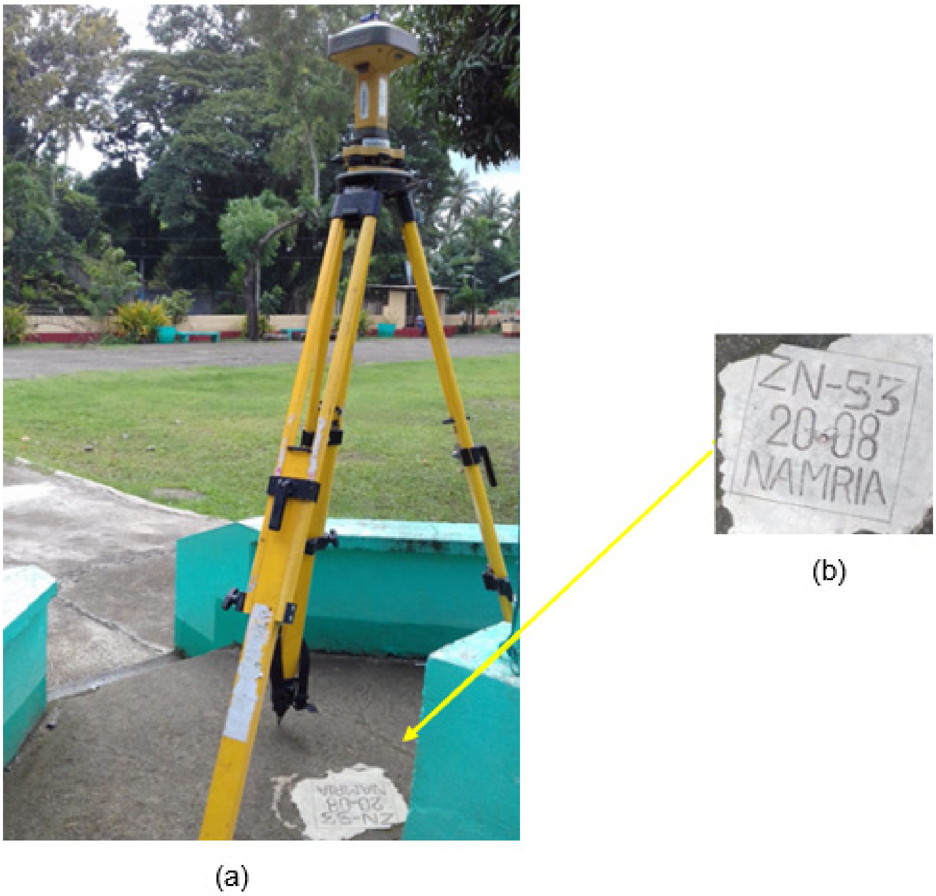


Figure 7. (a) GPS set-up overZN-53 in Brgy. Daanglungsod, Katipunan, Zamboanga del Norte and BM reference point ZN-53 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point ZN-53 used as base station for the LiDAR Acquisition.

Station Name	ZN-53	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°30'41.04428"North 123°18'14.33457"East 7.072 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°30'37.33230" North 123°18'19.74787"East 71.282 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	533456.022 meters 940788.542 meters

Table 7. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 11, 2016	23080P	1BLK76AB042A	ZGS-68 and ZGS-5588
February 26, 2016	23140P	1BLK73BS057A	ZGS-58 and ZGS-68
November 30, 2016	23598P	1BLK76A335A	ZGN-138 and ZN-53
December 1, 2016	23602P	1BLK76AB336A	ZGN-138 and ZN-53

2.3 Flight Missions

Four (4) missions were conducted to complete LiDAR data acquisition in Kumalarang Floodplain, for a total of 17 hours and 8 minutes (17+50) of flying time for RP-C9022. All missions were acquired using the Pegasus system. Table 8 shows the total area of actual coverage per mission and the flying hours per mission and Table 9 presents the actual parameters used during the LiDAR data acquisition.

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

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within the Floodplain (km²)	Area Surveyed Outside the Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 11, 2016	23080P	90.42	125.27	37.75	87.52	360	3	41
February 26, 2016	23140P	170.73	284.70	34.12	250.58	_	4	35
November 30, 2016	23598P	65.92	54.03	27.85	26.18	_	4	17
December 1, 2016	23602P	151.76	130.56	18.72	111.84	_	4	35
TOTAL		**478.83**	**594.56**	**118.44**	**476.12**	**360**	**17**	**8**

Table 9. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23080P	1200	30	50	200	30	130	5
23140P	1200	30	50	200	30	130	5
23598P	1200	30	50	200	30	130	5
23602P	1200	30	50	200	30	130	5

2.4 Survey Coverage

Kumalarang Floodplain is located in the province of Zamboanga del Sur with the floodplain situated within the municipality of Kumalarang. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage,is shown in Table 10. The actual coverage of the LiDAR acquisition for Kumalarang Floodplain is presented in Figure 8.

Table 10. List of municipalities and cities surveyed in Kumalarang Floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed =(Total Area covered/ Area of Municipality)*100
Lanao del Norte	Kapatagan	184.77	10.07	5%
	Salvador	46.46	28.96	62%
	Sapad	65.13	19.28	30%
	Tubod	121.94	16.95	14%
Zamboanga del Sur	Takuran	119.01	16.67	14%
	Aurora	162.22	26.11	16%
	Kumalarang	143.51	99.5	69%
	Lapuyan	153.28	12.53	8%
	Ramon Magsaysay	**92.84**	**46.88**	**50%**
	Sominot	**97.75**	**18.70**	**19%**
Zamboanga Sibugay	**Buug**	**134.89**	**8.64**	**6%**
	Kabasalan	**317.28**	**46.8**	**15%**
	Naga	**164.18**	**1.49**	**1%**
	Siay	**186.47**	**32.30**	**17%**
		1989.73	**384.88**	**19.34%**

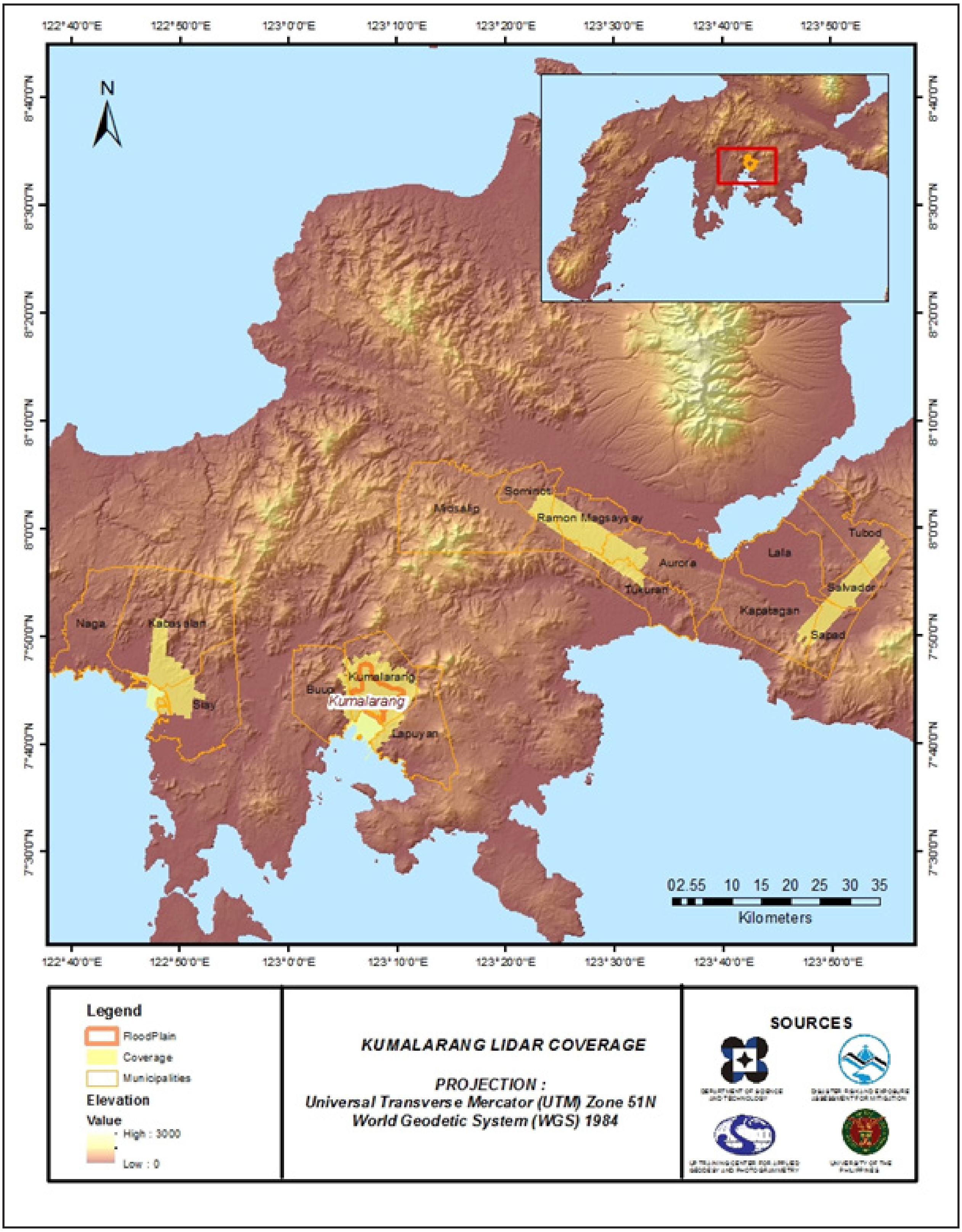


Figure 8. Actual LiDAR data acquisition for Kumalarang Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE KUMALARANG FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component 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 trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which were the minimum point density, vertical and horizontal accuracies, are met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. 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 done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 9.

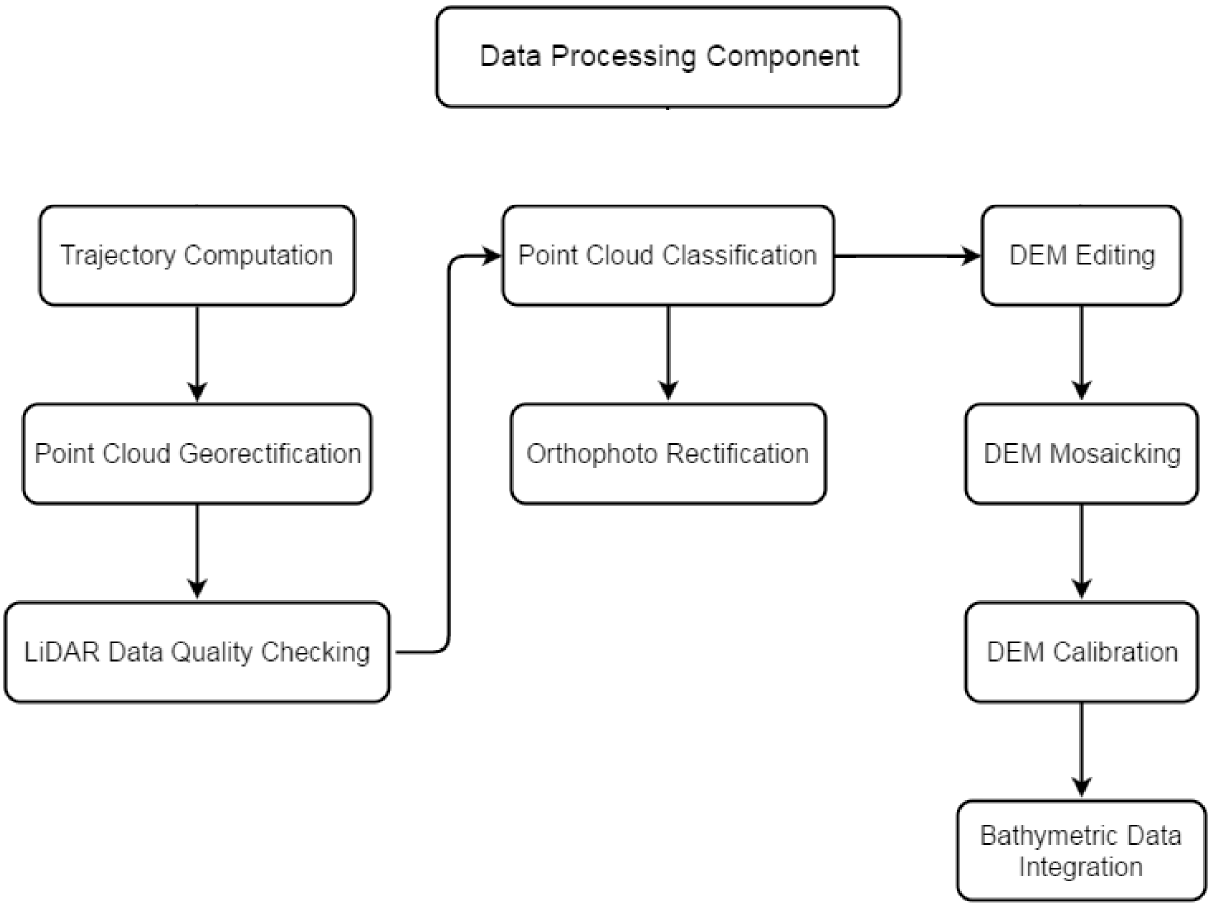


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Kumalarang Floodplain can be found in Annex 5. Missions flown during the surveys conducted in February and November 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Kumalarang, Zamboanga del Sur. The Data Acquisition Component (DAC) transferred a total of 50.85 Gigabytes of Range data, 0.831 Gigabytes of POS data, and 168 Megabytes of GPS base station data to the data server on February 19, 2016 for the first survey, March 7, 2016 for the second survey and December 8, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Kumalarang was fully transferred on December 8, 2016, as indicated in the Data Transfer Sheets for Kumalarang Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23598P, one of the Kumalarang flights, which is the North, East, and Down position RMSE values are shown 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 on that week fell on November 30, 2016 00:00 AM. The y-axis is the RMSE value for that particular position.

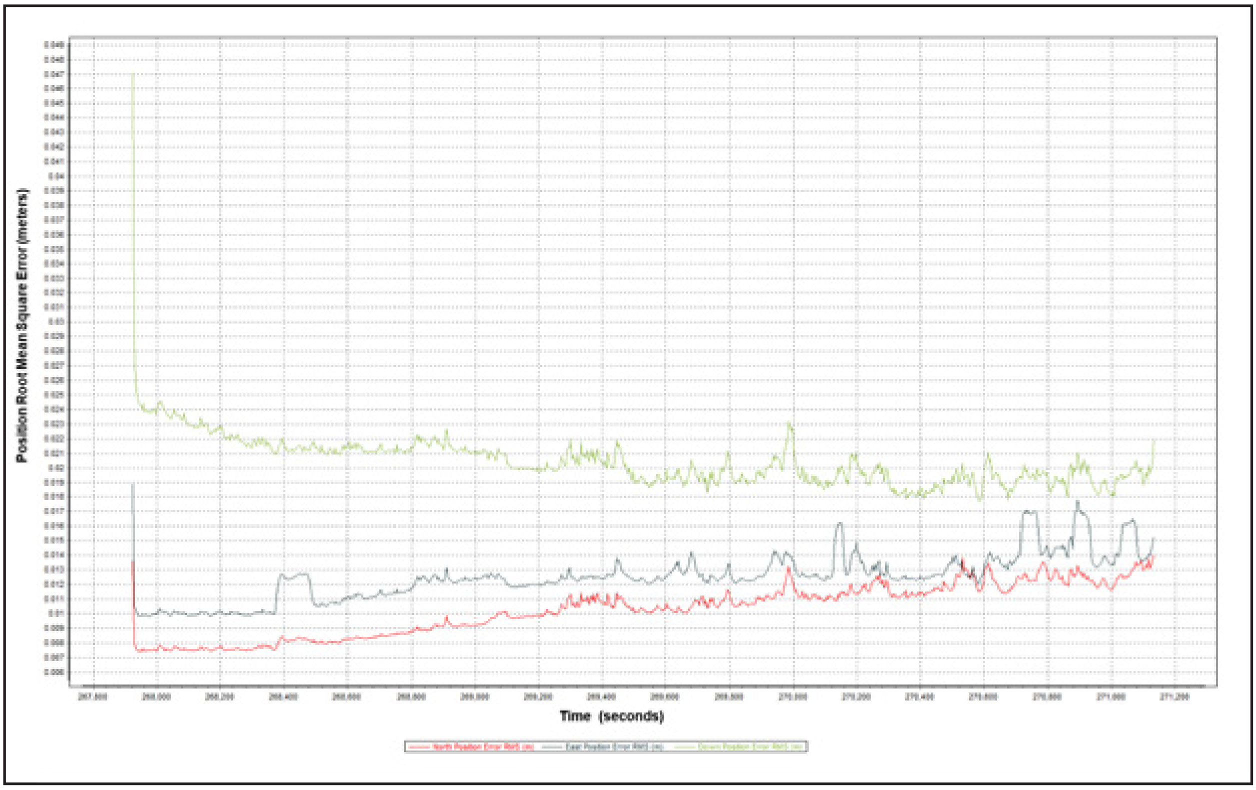


Figure 10. Smoothed Performance Metrics of Kumalarang Flight 23598P.

The time of flight was from 267800 seconds to 271200 seconds, which corresponds to morning of November 30, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.38 centimeters, the East position RMSE peaks at 1.77centimeters, and the Down position RMSE peaks at 2.32centimeters, which are within the prescribed accuracies described in the methodology.

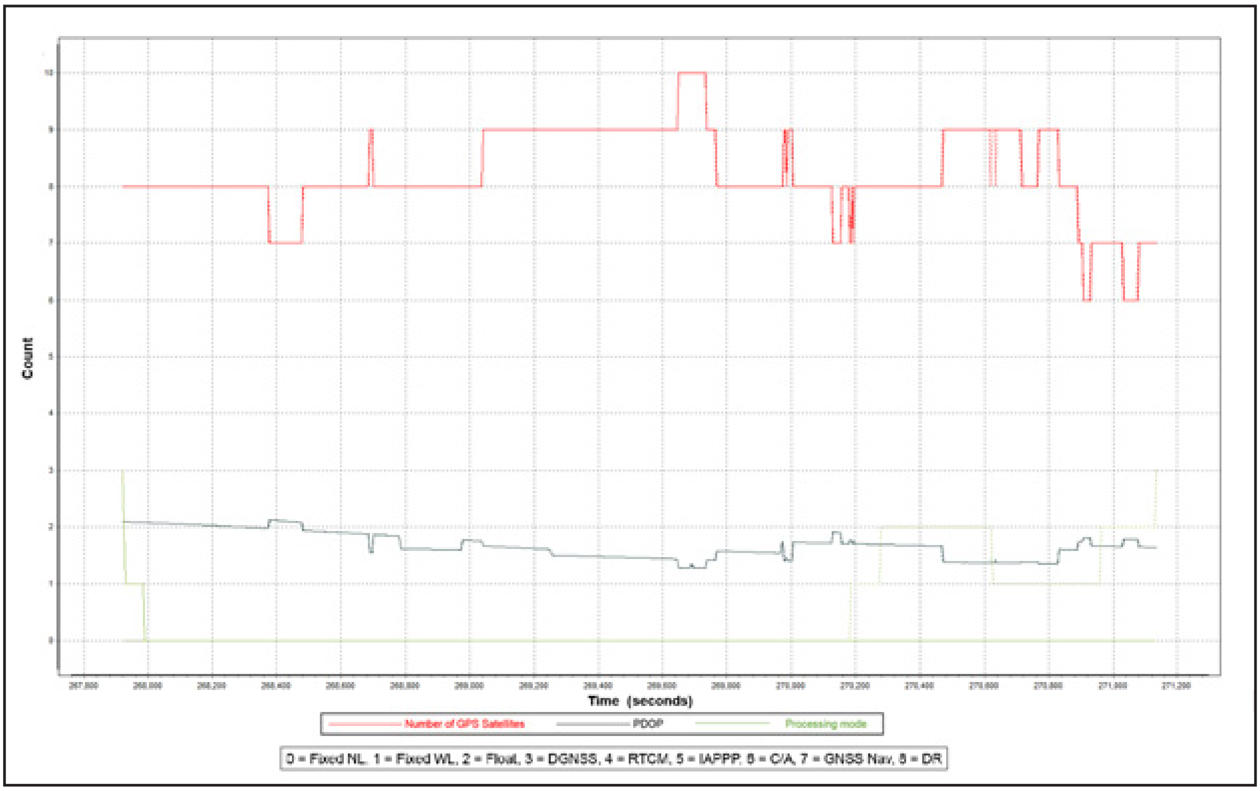


Figure 11. Solution Status Parameters of Kumalarang Flight 23598P.

The Solution Status parameters of flight 23598P, one of the Kumalarang flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Kumalarang flights is shown in Figure 12.

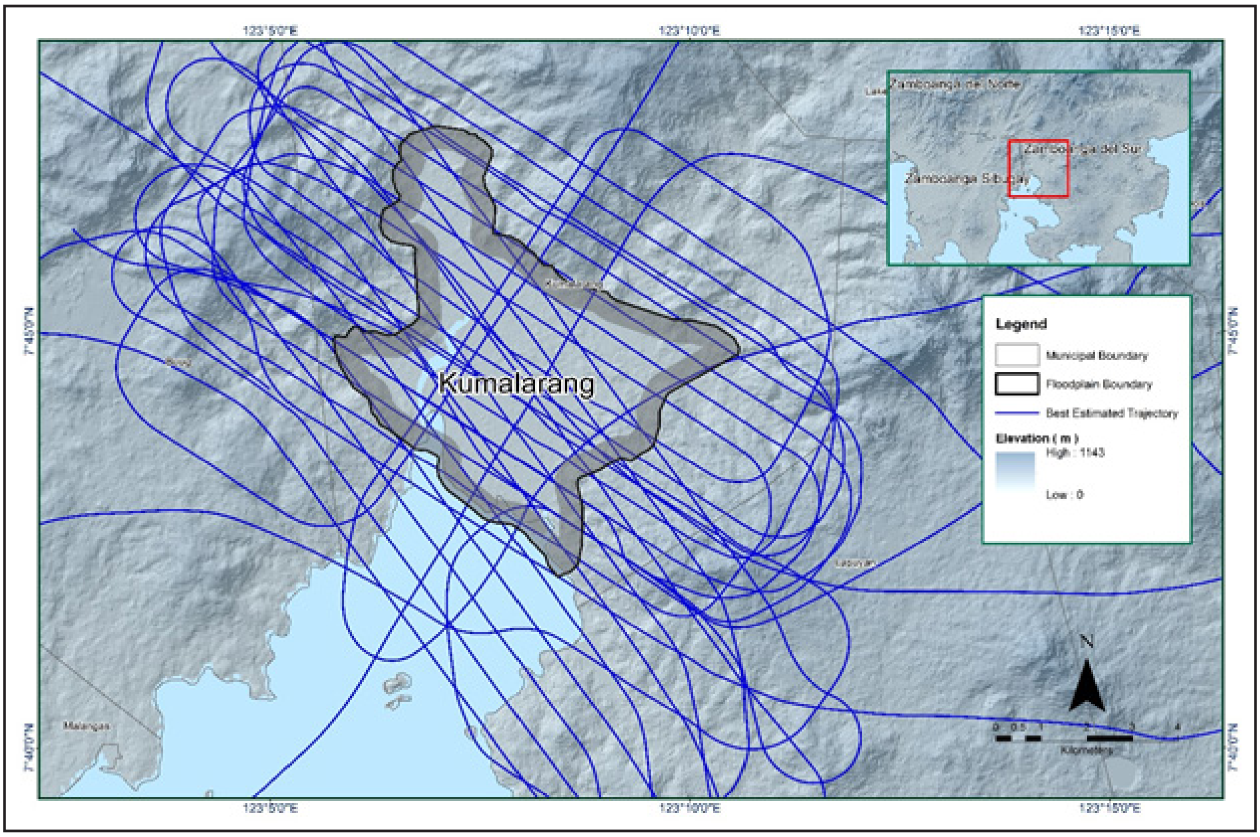


Figure 12. Figure 12. Best Estimated Trajectory for Kumalarang Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 30 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Kumalarang Floodplain are given in Table 11.

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

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000514
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000618
GPS Position Z-correction stdev)	<0.01meters	0.0047

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Kumalarang Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

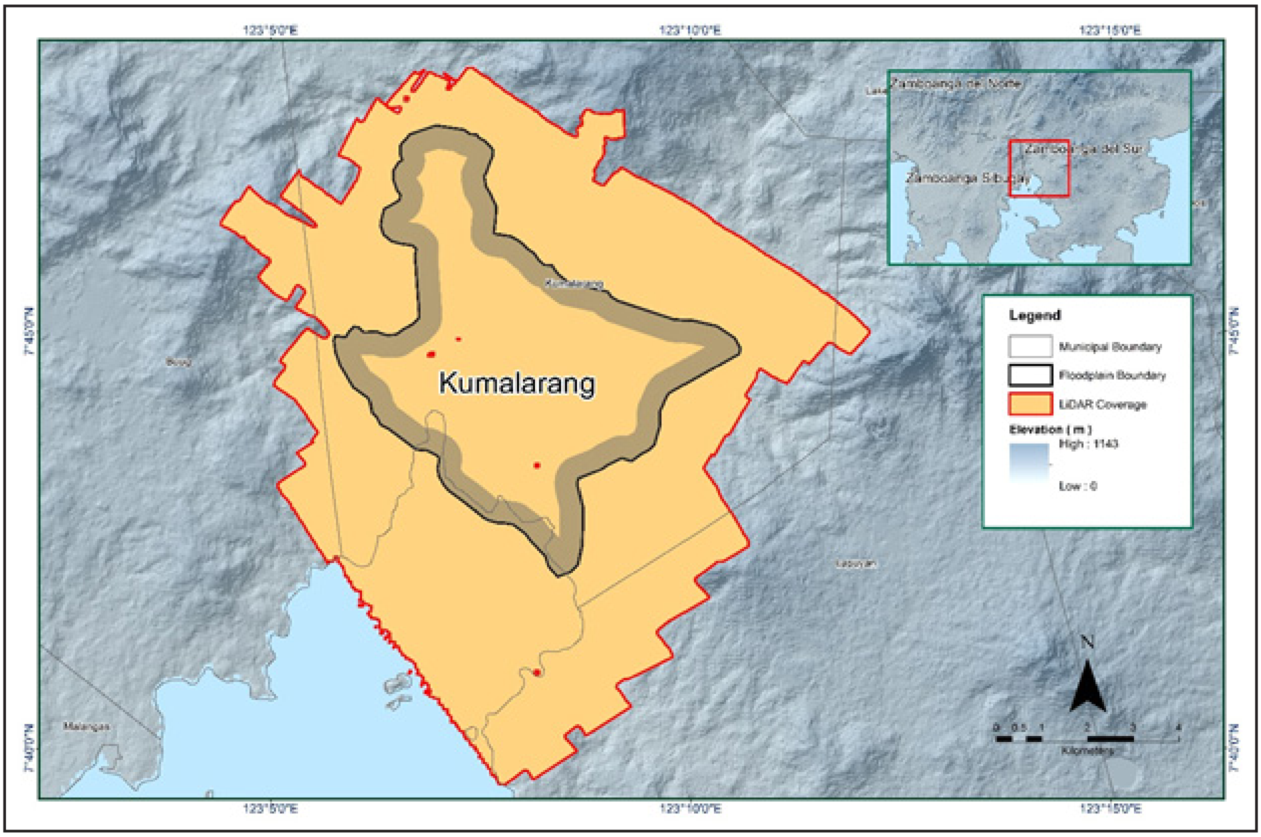


Figure 13. Boundary of the processed LiDAR data over Kumalarang Floodplain

The total area covered by the Kumalarang missions is 183.24 sq.km that is comprised of three (3) flight acquisitions grouped and merged into three (3) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Kumalarang floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Pagadian_Blk76AB	23140P	81.99
Dipolog_Reflights_Blk76A	23598P	50.23
Dipolog_Reflights_Blk76B	23602P	51.02
TOTAL		**183.24**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Pegasus system employs two channel, an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines are expected.

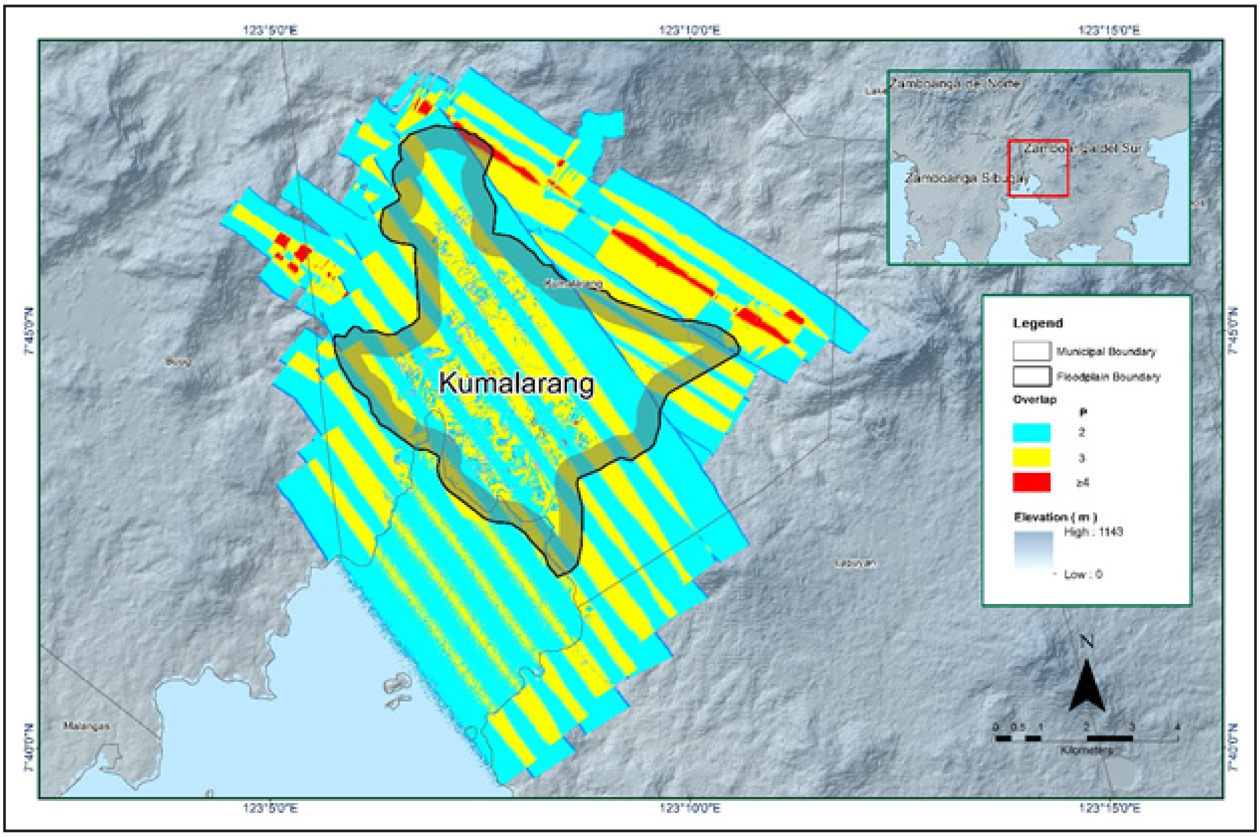


Figure 14. Image of data overlap for Kumalarang Floodplain.

The overlap statistics per block for the Kumalarang Floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlapsare38.45% and 51.32% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Kumalarang Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.27 points per square meter.

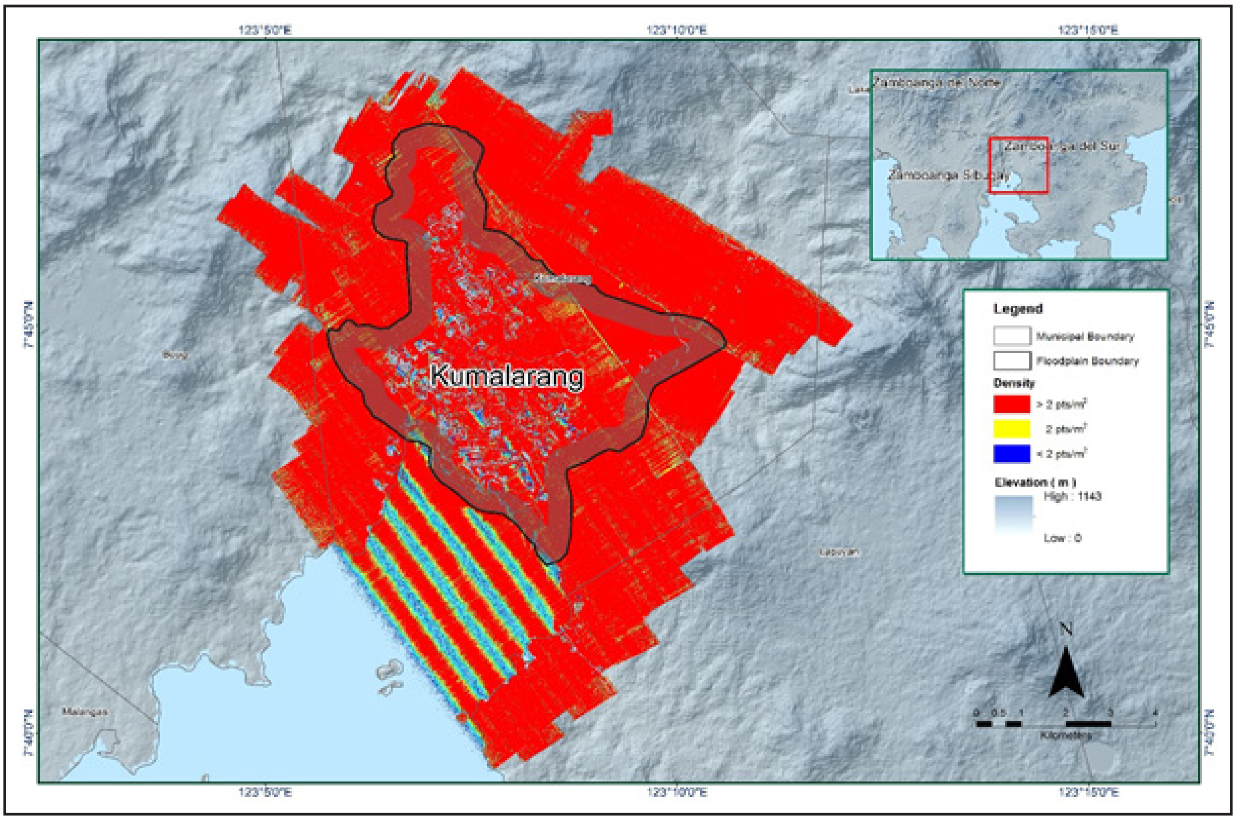


Figure 15. Pulse density map of merged LiDAR data for Kumalarang Floodplain.

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

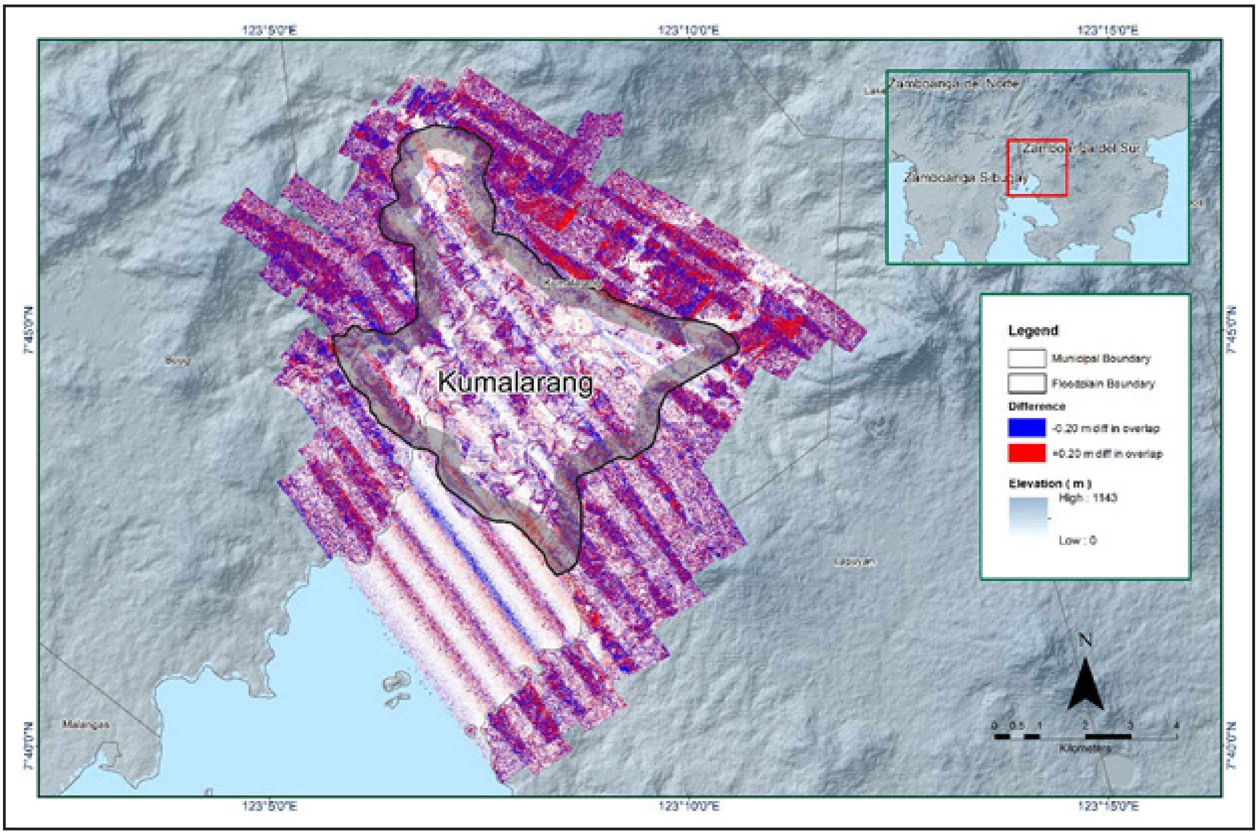


Figure 16. Elevation difference map between flight lines for Kumalarang Floodplain.

A screen capture of the processed LAS data from a Kumalarang flight 23598P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

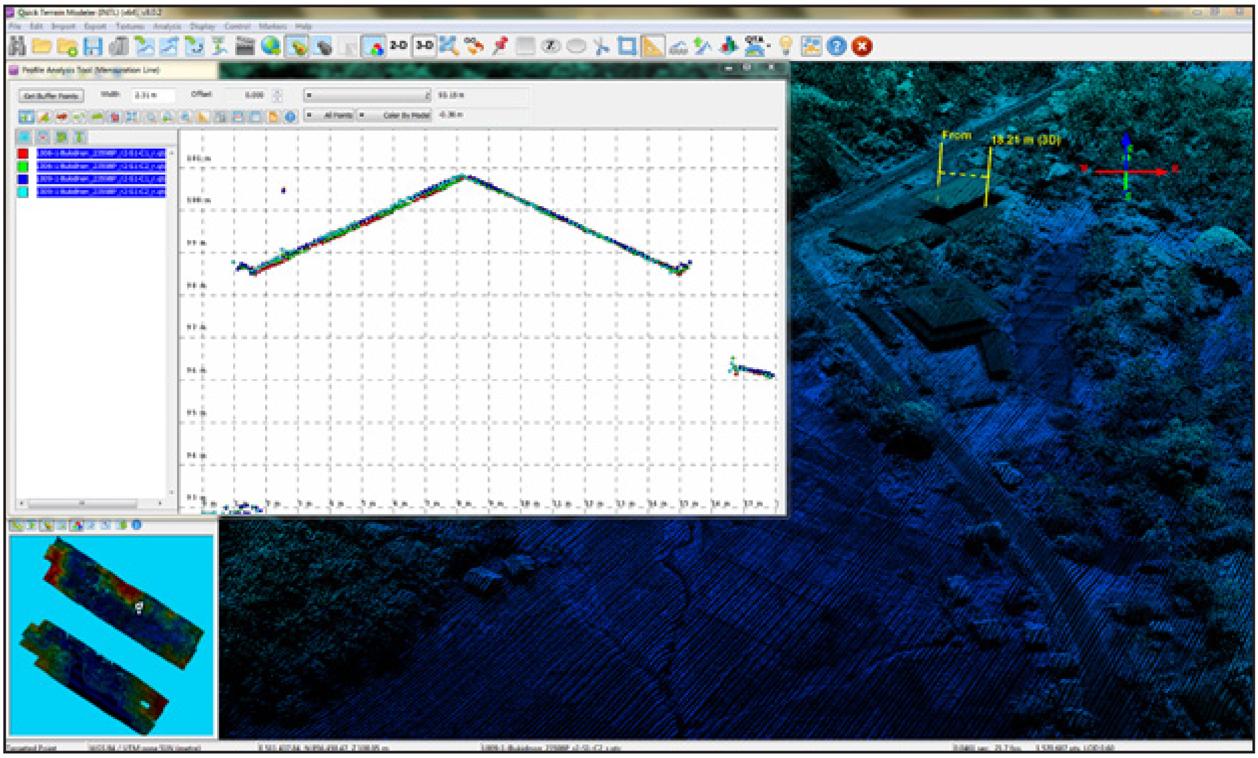


Figure 17. Quality checking for a Kumalarang flight 23598P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Kumalarang classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	165,513,711
Low Vegetation	113,479,017
Medium Vegetation	226,429,329
High Vegetation	501,159,073
Building	10,693,080

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Kumalarang Floodplain is shown in Figure 18. A total of 293 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 737.39 meters and 59.13 meters respectively.

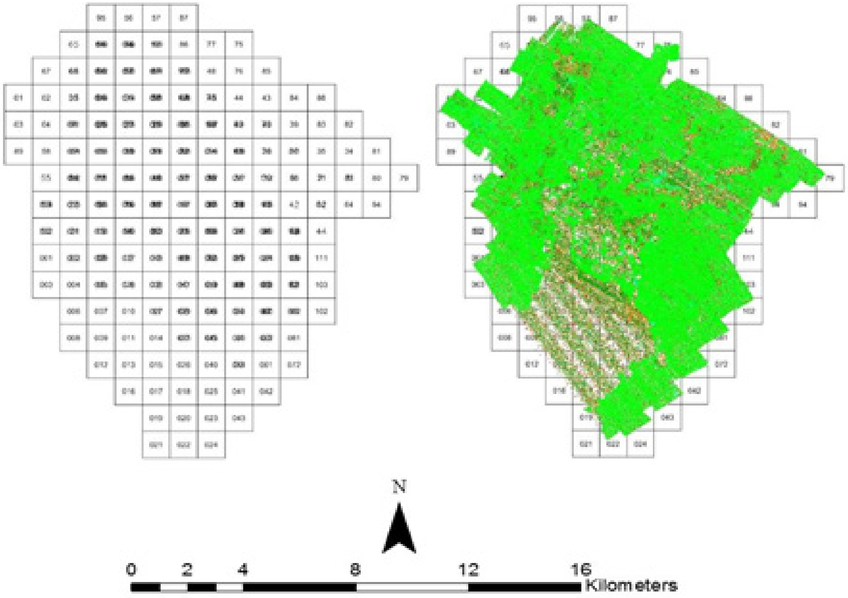


Figure 18. Tiles for Kumalarang floodplain (a) and classification results (b) in TerraScan.

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

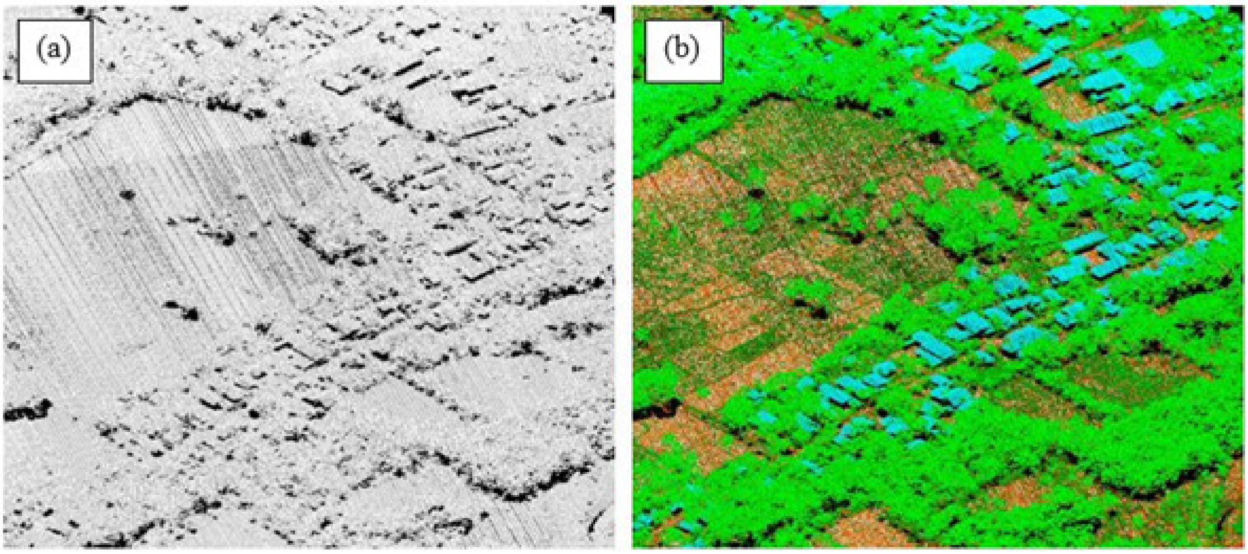


Figure 19. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

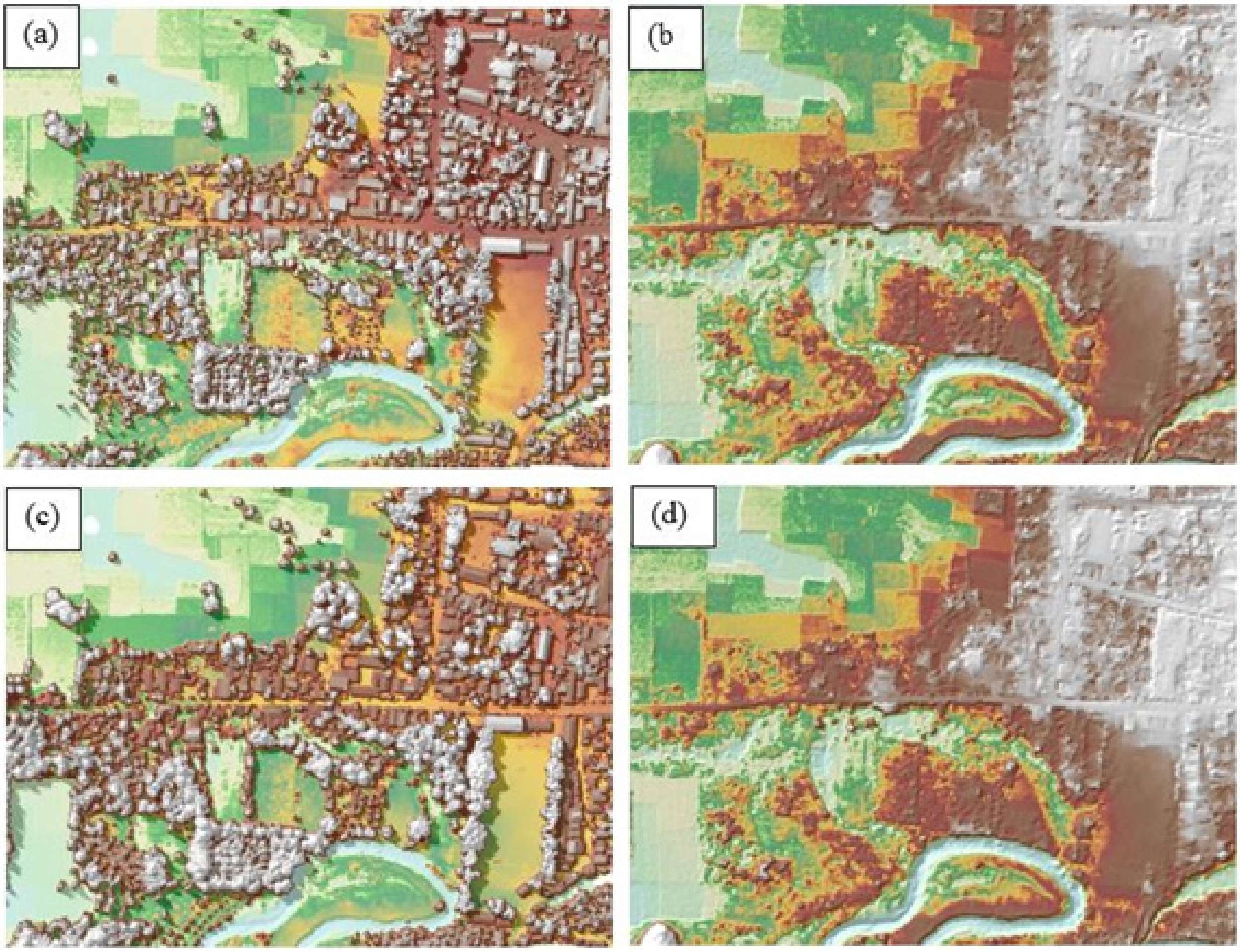


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Kumalarang Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 108 1km by 1km tiles area covered by Kumalarang Floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Kumalarang Floodplain has a total of 78.55 sq.km orthophotogaph coverage comprised of 186 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

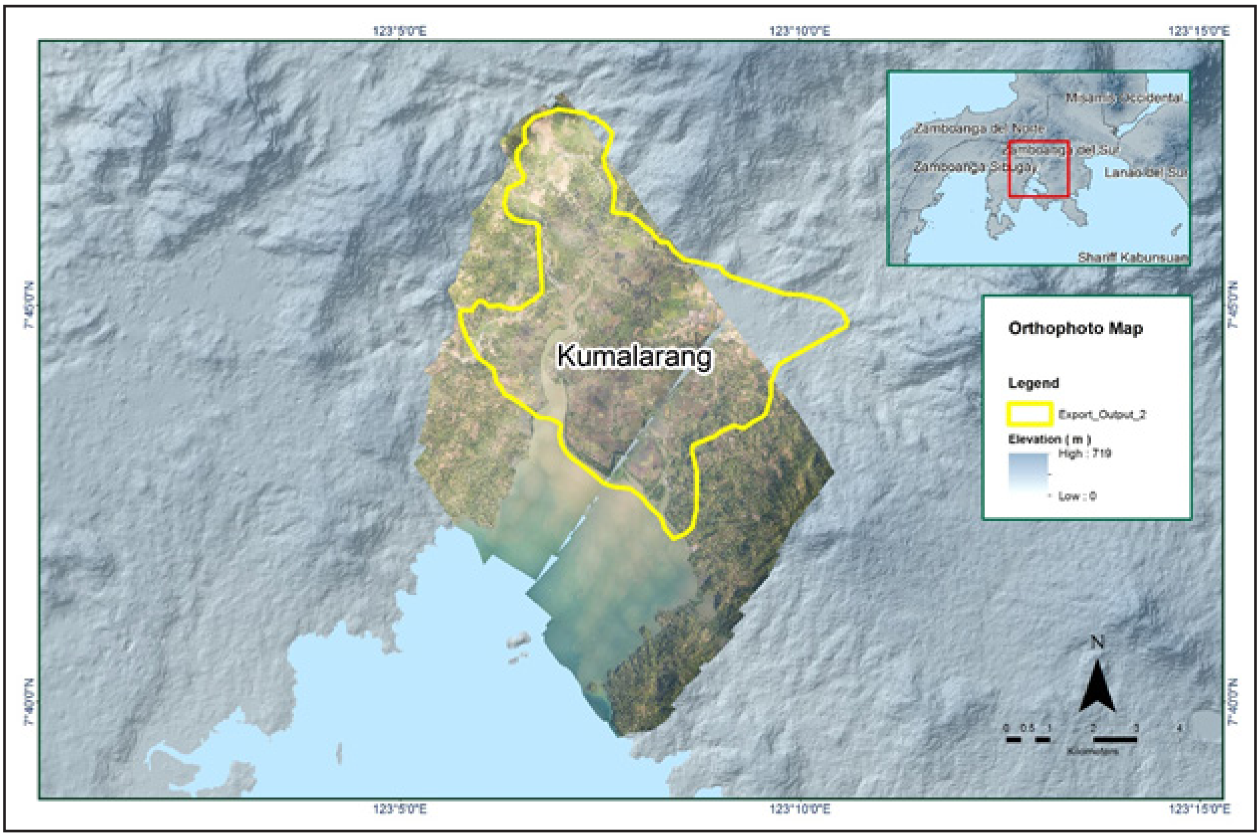


Figure 21. Kumalarang Floodplain with available orthophotographs.

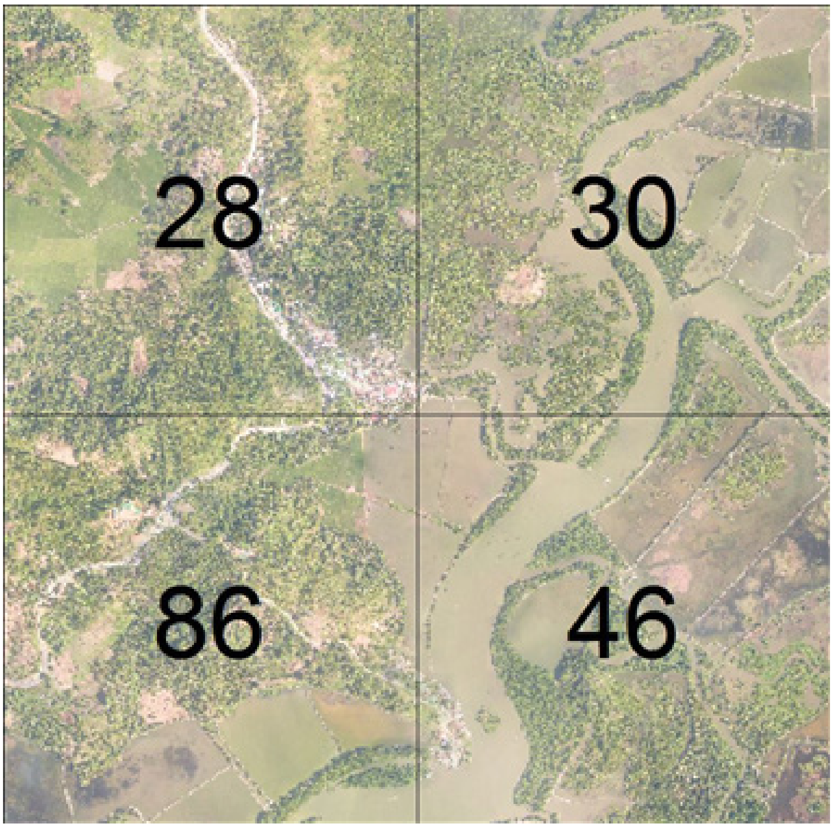


Figure 22. Sample orthophotograph tiles for Kumalarang Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Kumalarang Floodplain. These blocks are composed of Pagadian and Dipolog reflights with a total area of 183.24 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Pagadian_Blk76AB	81.99
Dipolog_Reflights_Blk76A	50.23
Dipolog_Reflights_Blk76B	51.02
TOTAL	**183.24 sq.km**

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. The river embankment (Figure 23c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23d) to allow the correct flow of water.

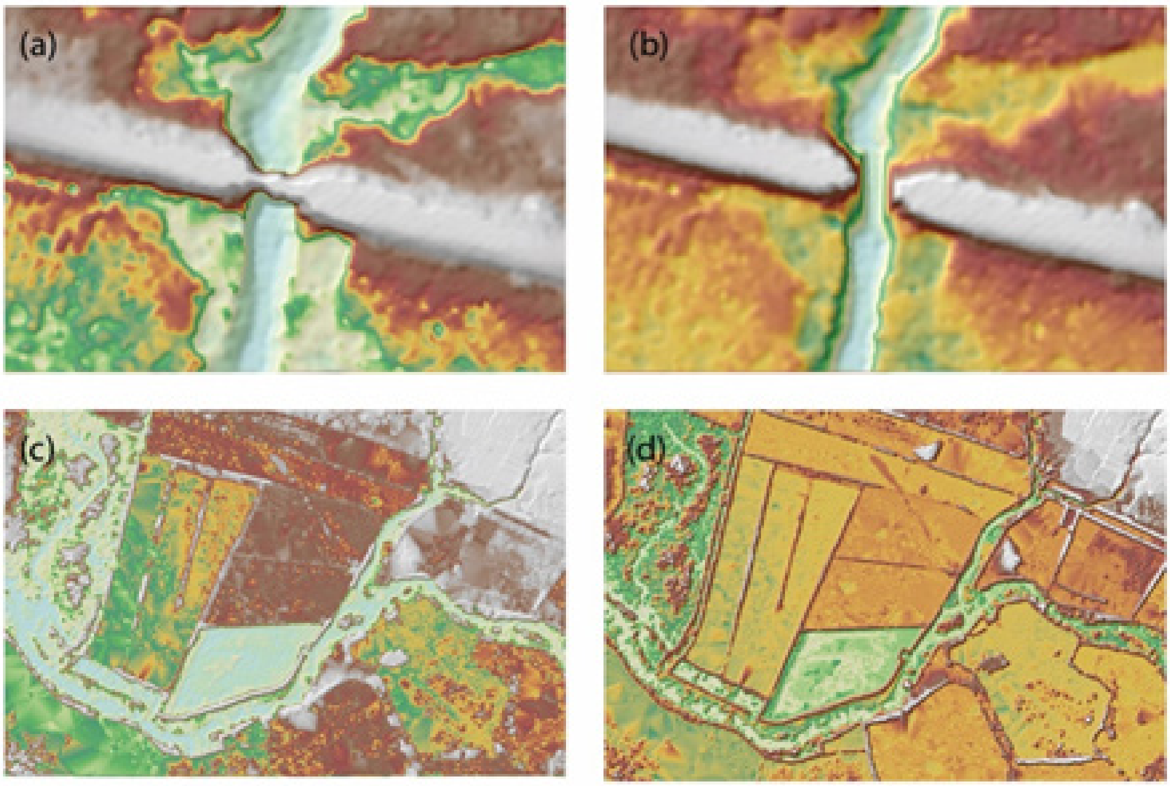


Figure 23. Portions in the DTM of Kumalarang floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Pagadian_Blk76AB was used as the reference block at the start of mosaicking because it comprises the largest area among the missions blocks. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Kumalarang Floodplain is shown in Figure 24. It can be seen that the entire Kumalarang Floodplain is 100% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Kumalarang Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Pagadian_Blk76AB	0.00	0.00	0.00
Dipolog_Reflights_Blk76A(Southern)	0.60	1.60	0.43
Dipolog_Reflights_Blk76A(Northern)	-2.00	-0.20	-0.09
Dipolog_reflights_Blk76B	-0.60	0.10	-0.32

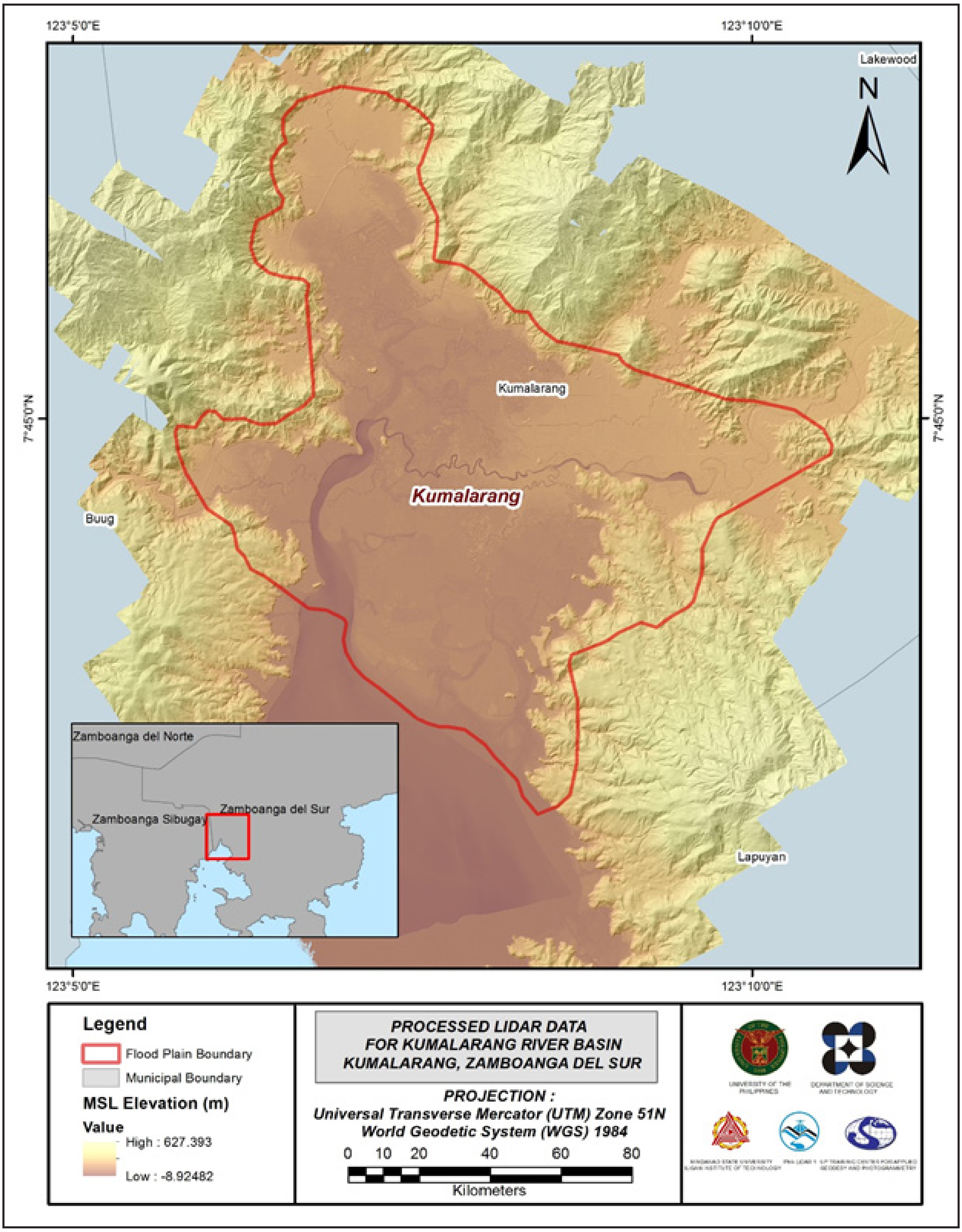


Figure 24. Map of Processed LiDAR Data for Kumalarang Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Kumalarang to collect points with which the LiDAR dataset was validated is shown in Figure 25. A total of 1,558 survey points were used for calibration and validation of Kumalarang LiDAR data. Random selection of 80% of the survey points, resulting in 1,246 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.72 meters with a standard deviation of 0.06 meters. Calibration of Kumalarang LiDAR data was done by adding the height difference value, 2.72 meters, to Kumalarang mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

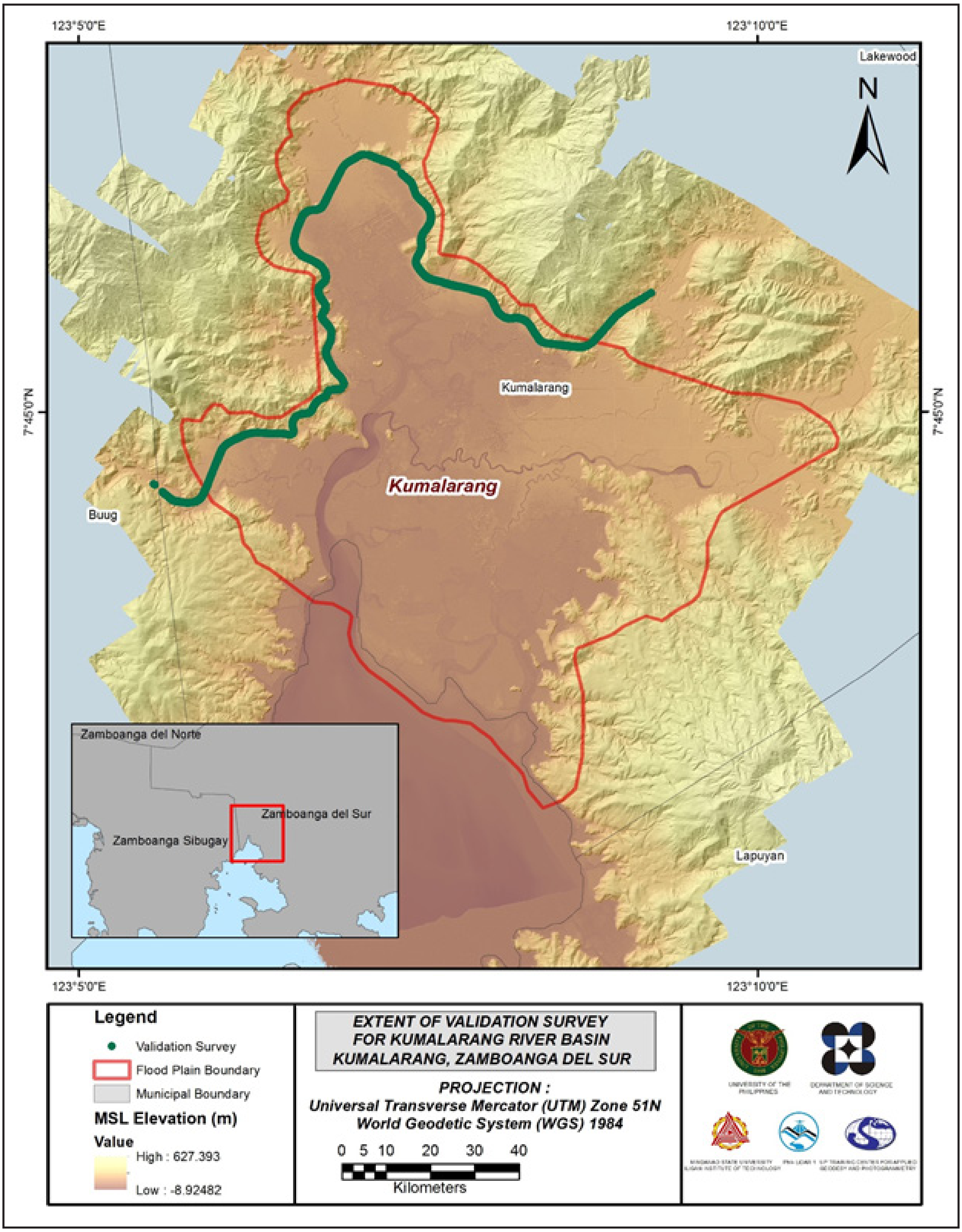


Figure 25. Map of Kumalarang Floodplain with validation survey points in green.

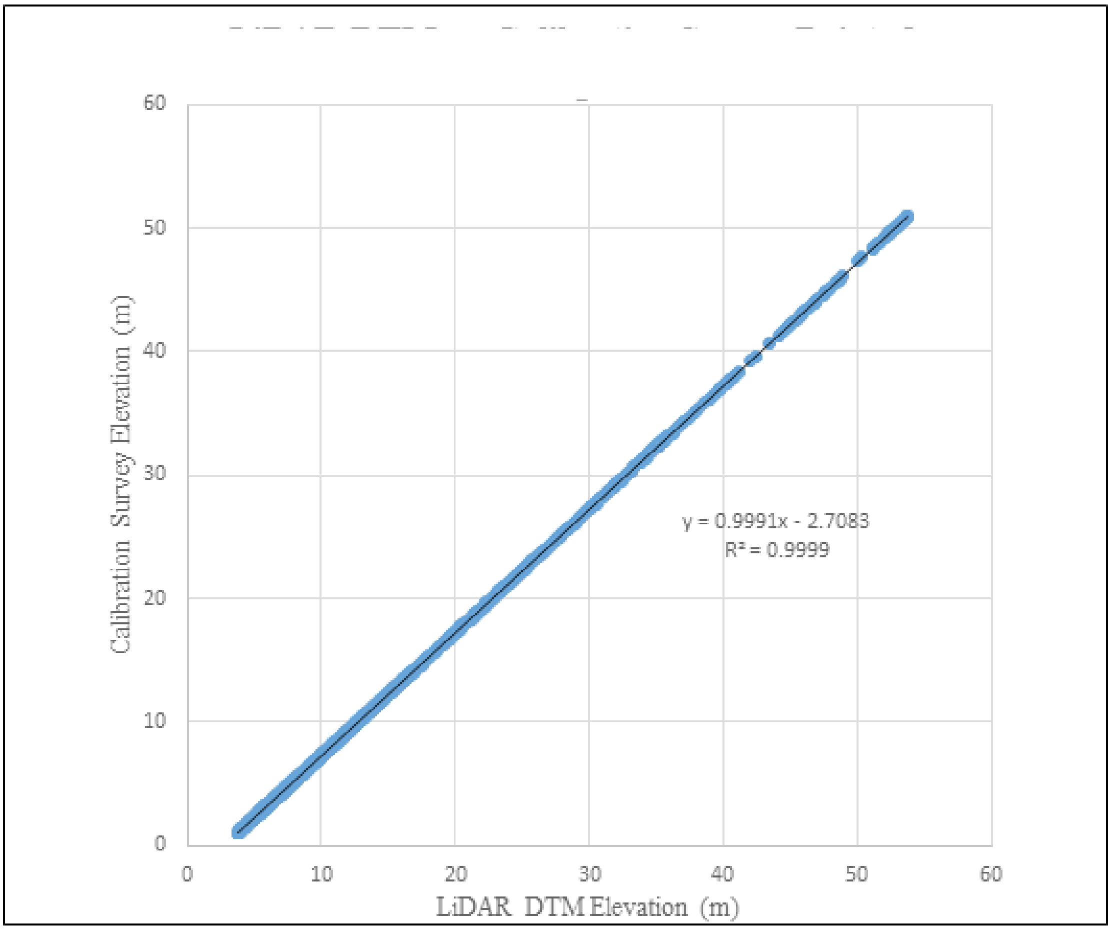


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.72
Standard Deviation	0.06
Average	2.72
Minimum	2.61
Maximum	2.83

The remaining 20% of the total survey points, resulting to 311 points, were used for the validation of calibrated Kumalarang DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.06 meters with a standard deviation of 0.06 meters, as shown in Table 17.

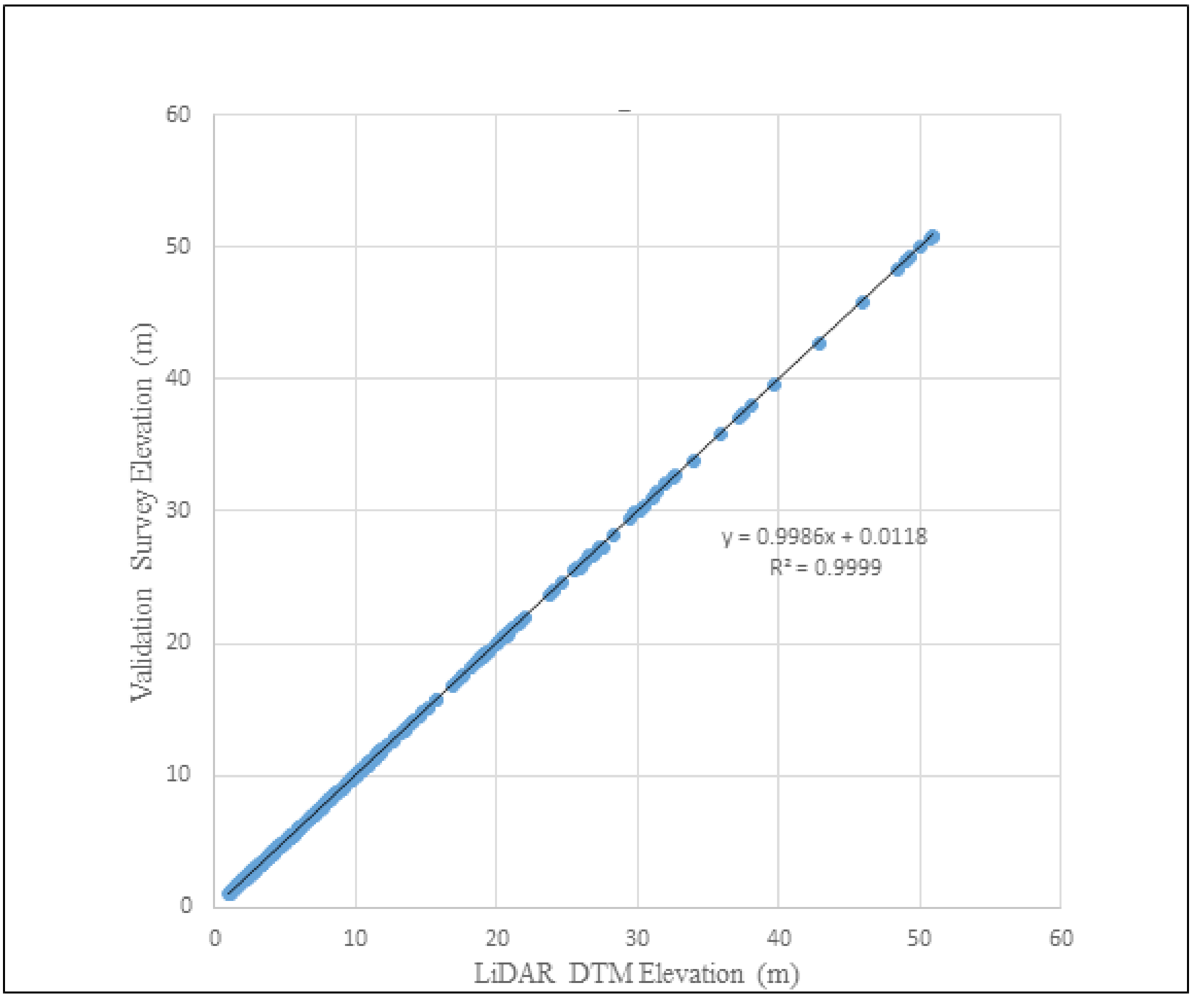


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.06
Standard Deviation	0.06
Average	0.00
Minimum	-0.11
Maximum	0.27

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Kumalarang with 13,004 bathymetric survey points. The resulting raster surface produced was done by 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 0.37 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Kumalarang integrated with the processed LiDAR DEM is shown in Figure 28.

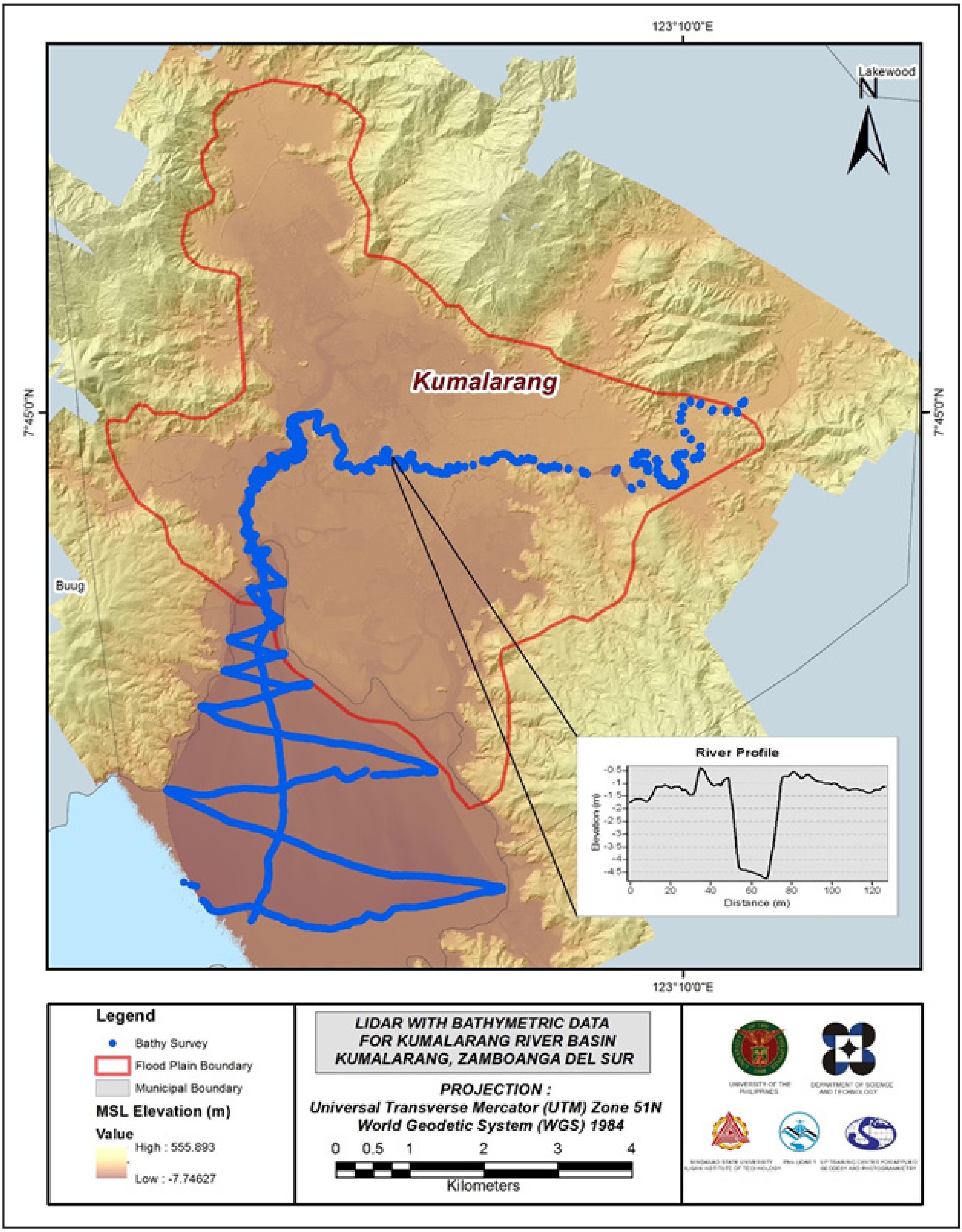


Figure 28. Map of Kumalarang Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Kumalarang floodplain, including its 200 m buffer, has a total area of 44.44sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1101 building features, are considered for QC. Figure 29 shows the QC blocks for Kumalarang Floodplain.

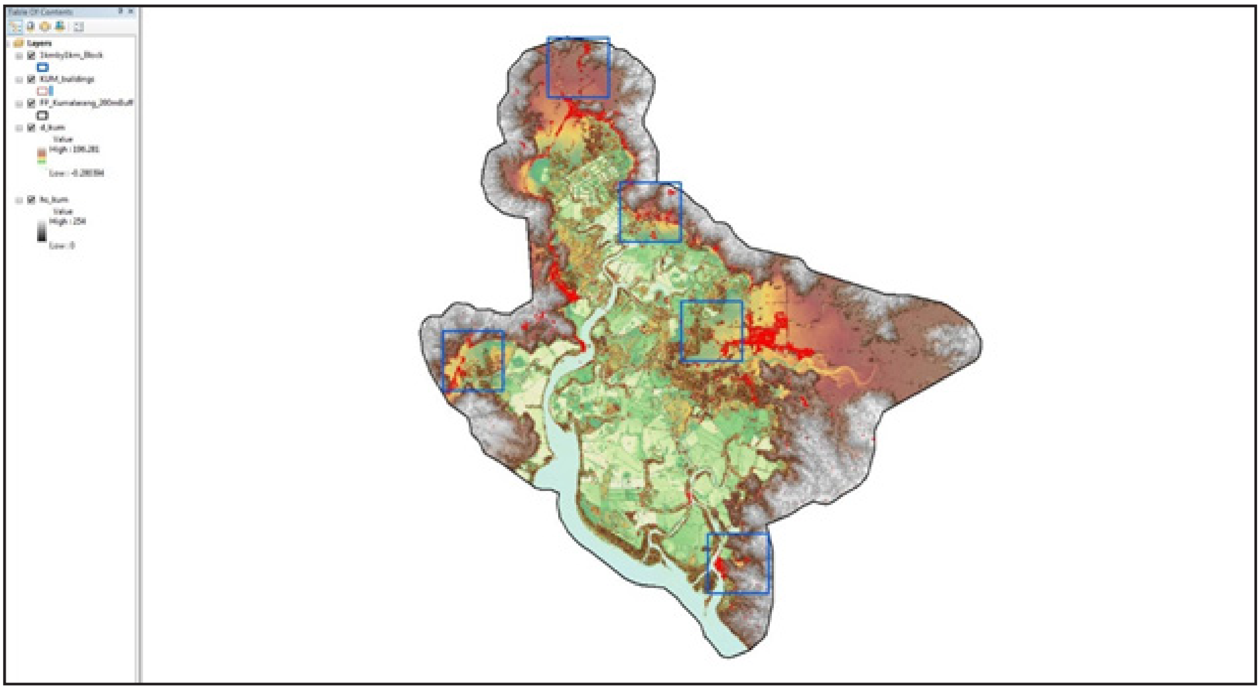


Figure 29. Blocks (in blue) for Kumalarang building features subjected to QC.

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

Table 18. Quality Checking Ratings for Kumalarang Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Kumalarang	98.37	99.18	80.47	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,938 building features in Kumalarang floodplain. Of these building features, 38 were filtered out after height extraction, resulting to 4,900 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 11.17 m.

3.12.3 Feature Attribution

Kumalarang Floodplain is within the municipality of Kumalarang. The building attribution on the municipality of Kumalarang was done with the Google Earth approach. In Google Earth approach, aid from Purok representatives were sought for participatory mapping over the Google Earth software. The attributions of road, bridge and water body features were done using NAMRIA maps, municipal and city records, and participatory mapping of municipals and cities.

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

Table 19. Building Features Extracted for Kumalarang Floodplain.

Facility Type	No. of Features
Residential	4,751
School	77
Market	9
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	7
Barangay Hall	12
Military Institution	0
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	2
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	24
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	11
Other Commercial Establishments	4
Total	**4,900**

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Kumalarang	22.33	5.88	0.00	13.99	0.00	**42.20**

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

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Kumalarang	5	0	0	0	385	**390**

A total of 42 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of Kumalarang Floodplain overlaid with its ground features.

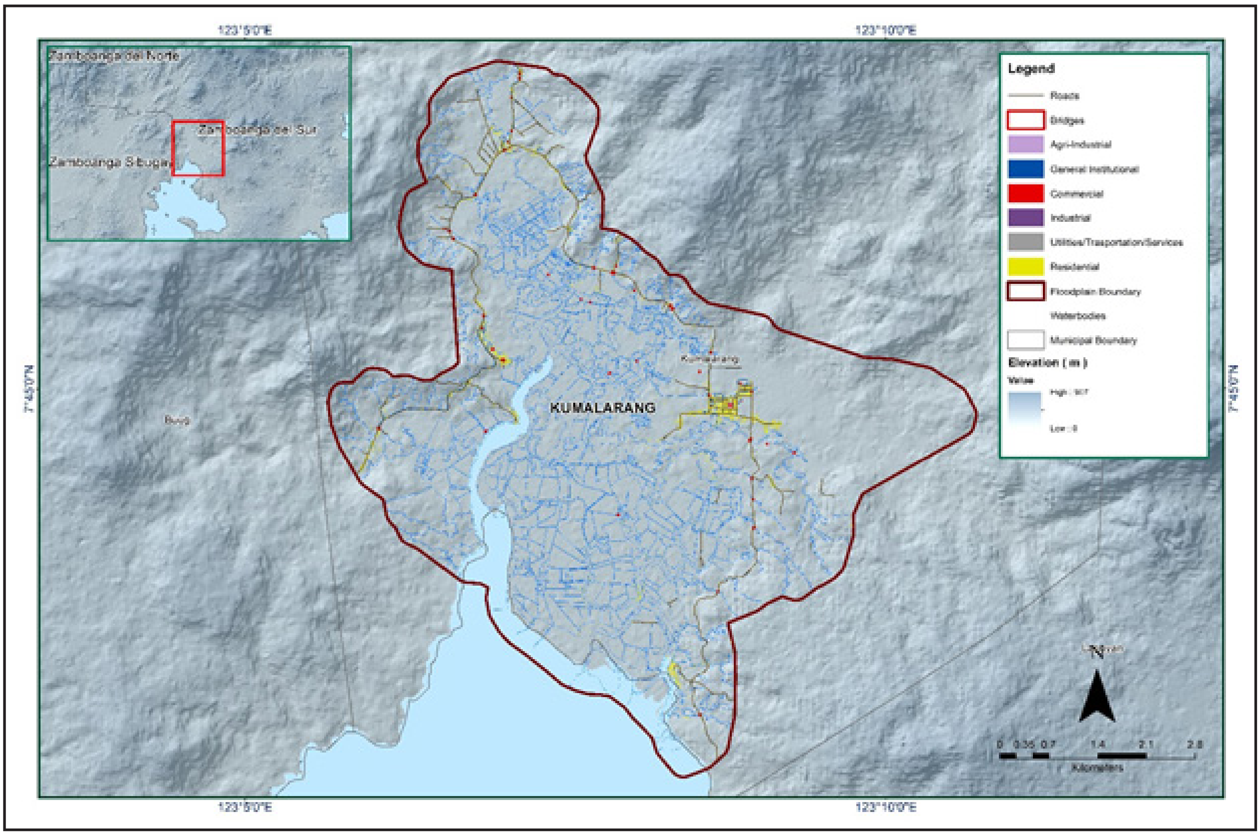


Figure 30. Extracted features for Kumalarang Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, and Vie Marie Paola M. Rivera

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 AB Surveying and Development (ABSD) conducted a field survey in Kumalarang River on April 23 to 29, 2016 and March 23, 28 and 29, 2016,with the following scope: reconnaissance; cross-section, bridge as-built and water level marking in MSL of Kumalarang Bridge and bathymetric survey from the mouth of the river in Brgy. Gusom to upstream in Brgy. Secade in the Municipality of Kumalarang using GNSS survey technique, Hi-Target™ echo sounder and Hi-Target™ Total Station. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVC on August 16-25, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Kumalarang River Basin area. The entire survey extent is illustrated in Figure 31.

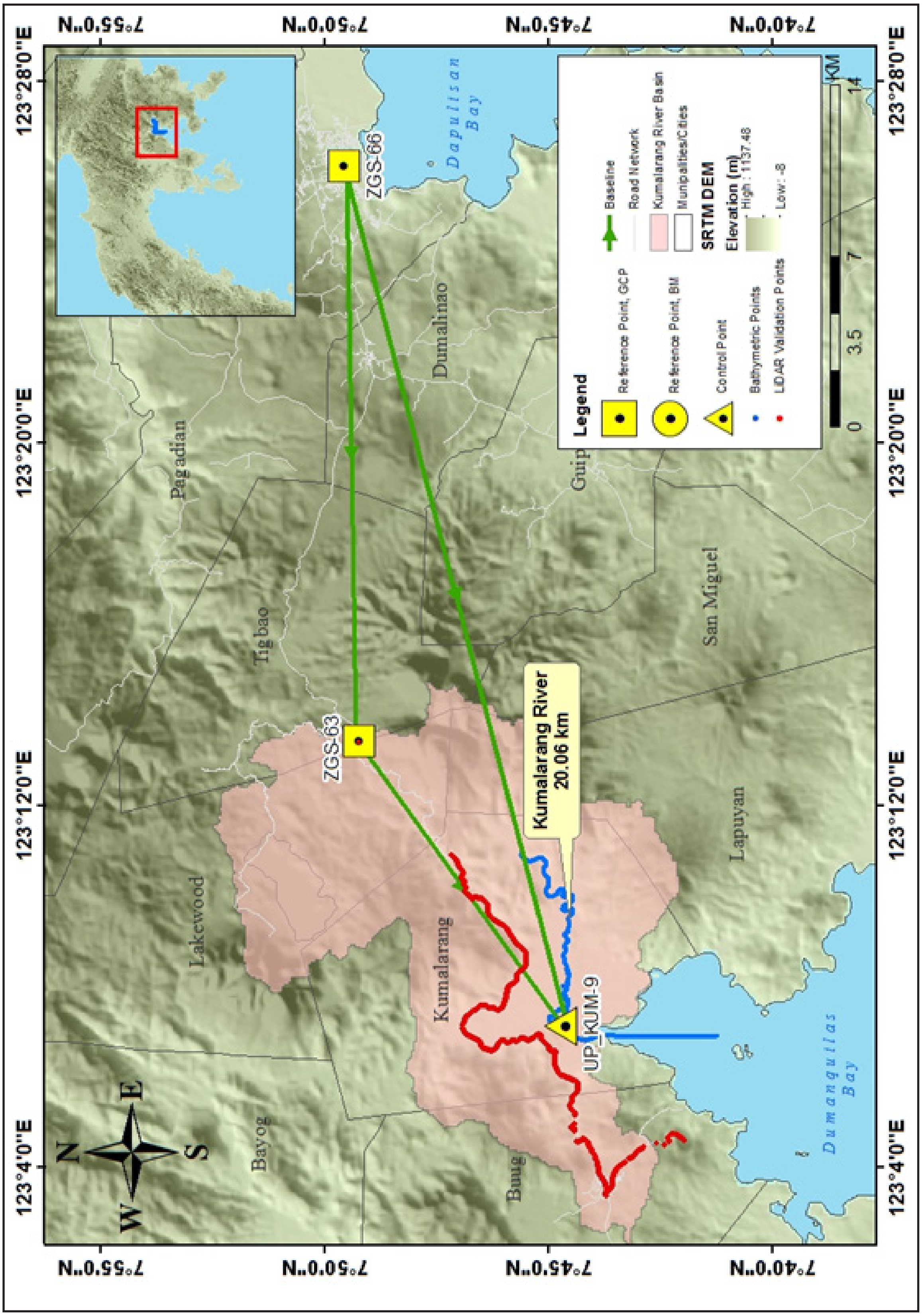


Figure 31. Extent of the bathymetric survey (in blue) in Kumalarang River and the LiDAR data validation (in red)

4.2 Control Survey

The GNSS network used for Kumalarang River is composed of three (3) loops established on December 11 and 15, 2015 occupying the following reference point: ZGS-63, a second-order GCP, in Brgy. Poblacion, Brgy. Tigbao, Zamboanga Del Sur, and ZGS-66, a second-order GCP, in Brgy. Gatas,Pagadian City, Zamboanga del Sur.image: UP_KUM-9 in Brgy. Bogayo, Kumalarang, Zamboanga del Sur.

The summary of reference and control points and its location is summarized in Table 22 while GNSS network established is illustrated in Figure 32.

Table 22. List of reference and control points used during the survey in Kumalarang River (Source: NAMRIA)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date of Establishment
ZGS-63	2nd order, GCP	7°49’14.46774”N	123°13’24.08162”E	379.687	310.923	2005
ZGS-66	2nd order, GCP	7°49’33.63372”N	123°26’07.29815”E	106.847	38.050	2005
UP_ KUM-9	Established	7°44’44.20174”N	123°07’07.10666”E	72.338	3.743	August 2016

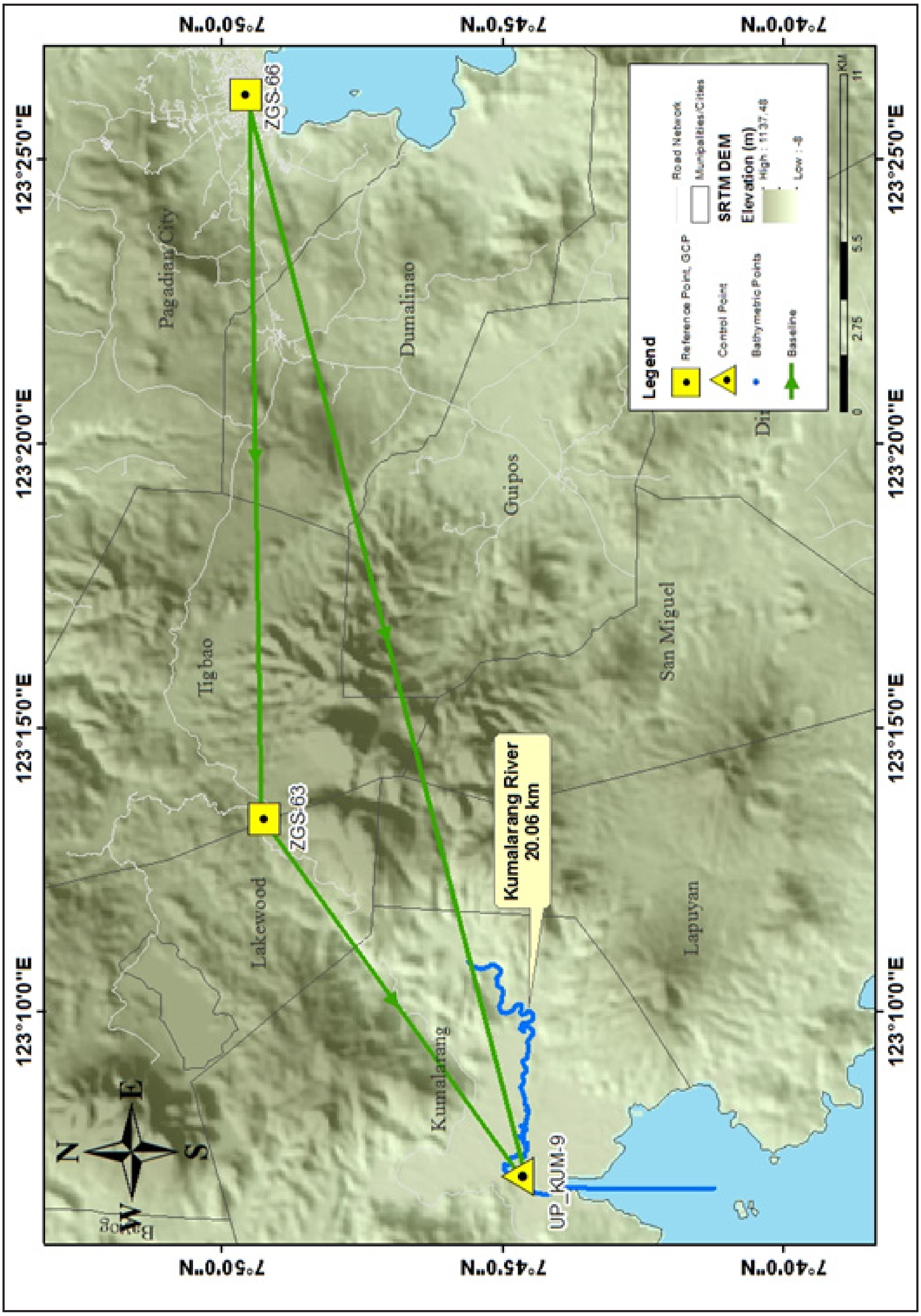


Figure 32. Kumalarang River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Kumalarang River are shown from Figure 33 to Figure 35.

Figure 33. GNSS receiver set up, Trimble® SPS 985, at ZGS-63, is located on the cement riprap of the Public Plaza, south of the Municipal Hall of Tigbao, in Brgy. Poblacion, Tigbao, Province of Zamboanga del Sur

Figure 34. GNSS receiver set up, Trimble® SPS 985, at ZGS-66, is located in Brgy. Gatas, Pagadian City, Province of Zamboanga del Sur

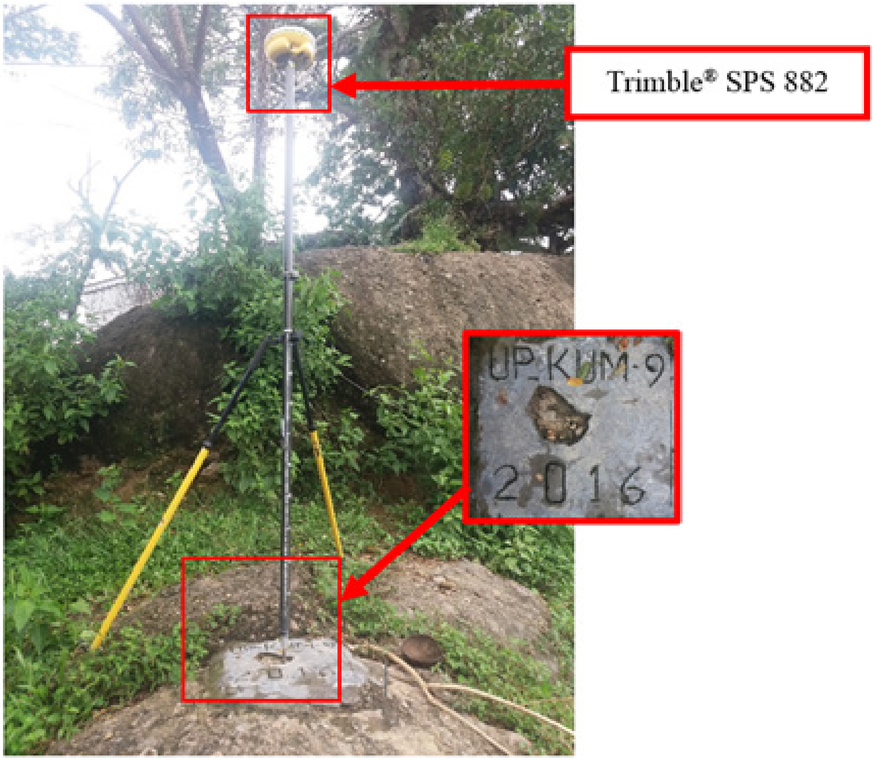


Figure 35. GNSS base set up, Trimble® SPS 882, at UP_KUM-9, located at the side of house near the pier at Brgy. Bogayo, Kumalarang., Province of Zamboanga del Sur

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 of the baselines did not meet all of these criteria, masking was performed. 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 the control points in the Kumalarang River Basin, generated by the TBC software, are summarized in Table 23.

Table 23. Baseline Processing Report for Kumalarang River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_KUM-9 --- ZGS-66	8-21-2016	Fixed	0.006	0.018	255°44'30"	36047.874	-34.513
ZGS-63 --- ZGS-66	8-21-2016	Fixed	0.005	0.020	268°34'19"	23389.351	272.843
UP_KUM-9 --- ZGS-63	8-21-2016	Fixed	0.005	0.019	234°17'49"	14224.655	-307.343

As shown in Table 23, a total of six (6) baselines were processed with coordinate and ellipsoidal height values of ZGS-63 and ZGS-66 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown from Table 24 to Table 26 for the complete details. Refer to Annex A for the computation for the accuracy of ABSD.

The three (3) control points, ZGS-63, ZGS-66, and UP_KUM-9 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal heights of ZGS-63 and ZGS-66 were held fixed during the processing of the control points as presented in Table 24. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGS-63	Local	Fixed	Fixed		
ZGS-66	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001 (Meter)					

Table 25. Adjusted Grid Coordinated

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ZGS-63	524624.346	?	864480.970	?	310.923	0.023	LL
ZGS-66	547996.953	?	865087.828	?	38.050	?	ENe
UP_KUM-9	513082.098	0.005	856176.816	0.004	3.743	0.022	

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

a. ZGS-63
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. ZGS-66
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

c. UP_KUM-9
Horizontal Accuracy = √((0.5)² + (0.4)²
= √ (0.25 + 0.16)
= 0.25 + 0.16 cm
Vertical Accuracy = 2.2< 10 cm

Following the given formula, the horizontal and vertical accuracy result of the three (3) occupied control points are within the required precision.

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
ZGS-63	N7°49'14.46774"	E123°13'24.08162"	379.687	0.023	LL
ZGS-66	N7°49'33.63372"	E123°26'07.29815"	106.847	?	ENe
UP_KUM-9	N7°44'44.20174"	E123°07'07.10666"	72.338	0.022	

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

Table 27. Reference and control points used in the Kumalarang 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)
ZGS-63	2nd order, GCP	7°49'14.46774"N	123°13'24.08162"E	379.687	864480.970	524624.346	310.923
ZGS-66	2nd order, GCP	7°49'33.63372"N	123°26'07.29815"E	106.847	865087.828	547996.953	38.050
UP_KUM-9	Established	7°44'44.20174"N	123°07'07.10666"E	72.338	856176.816	513082.098	3.743

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

Cross-section and as-built surveys were conducted on April 26, 2016 at the upstream side of Kumalarang Bridge in Brgy. Boyugan East, Municipality of Kumalarang as shown in Figure 36. A Horizon® Total Station was utilized for this survey as shown in Figure 37.

Figure 36. Downstream side of Kumalarang (also known as Boyugan East) Bridge

Figure 37. As-built survey of Kumalarang (also known as Boyugan East) Bridge

The cross-sectional line of Kumalarang Bridge is about 116.591 m with ninety (90) cross-sectional points using the control points UP_KUM-1 and UP_KUM-2as the GNSS base stations. The location map, cross-section diagram, and the bridge-as-built data form are shown in Figures 38 to Figure 40.

Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 22, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.9848 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value 0.10543 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

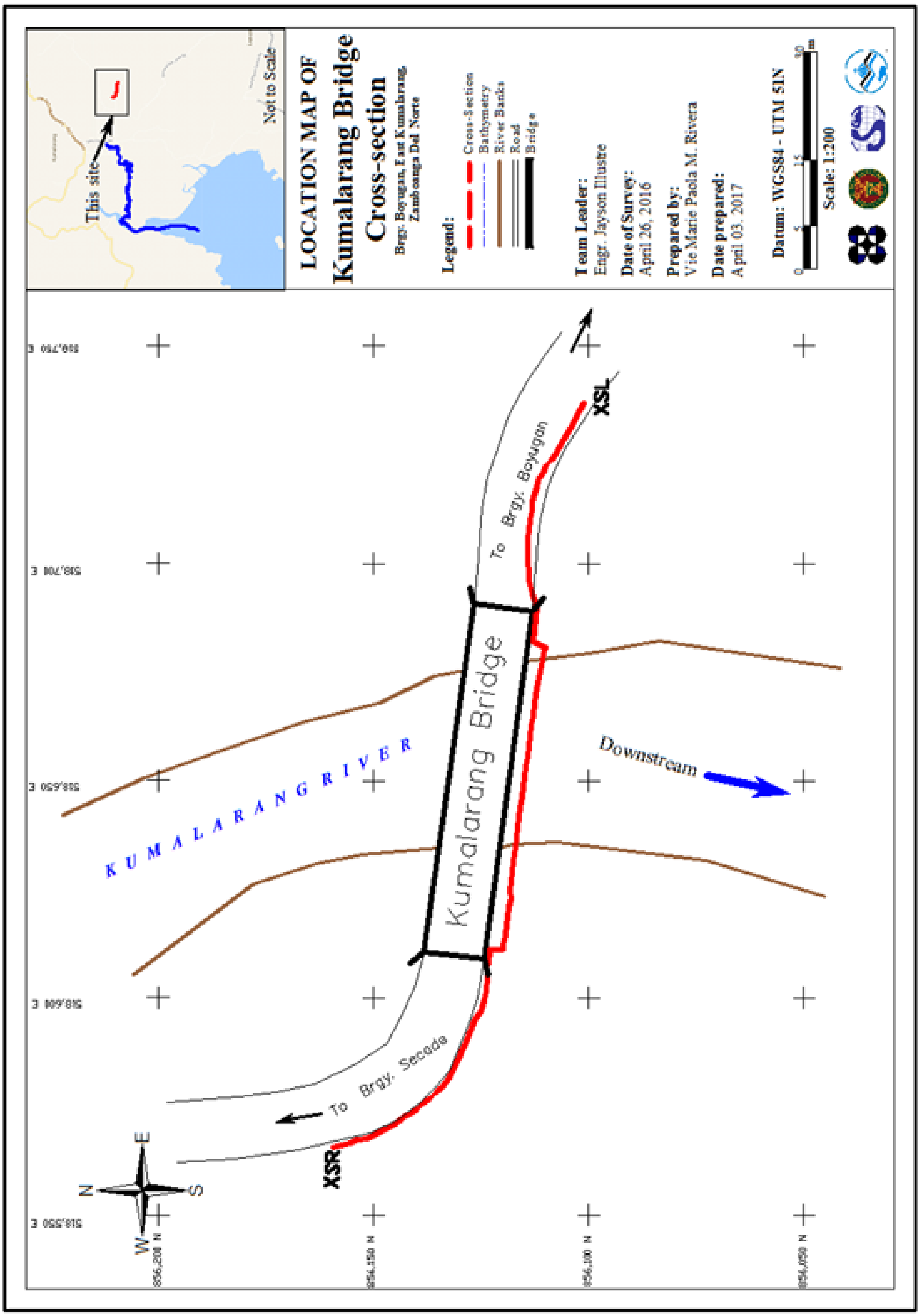


Figure 38. Location Map of Kumalarang (also known as Boyugan East) Bridge Cross-Section

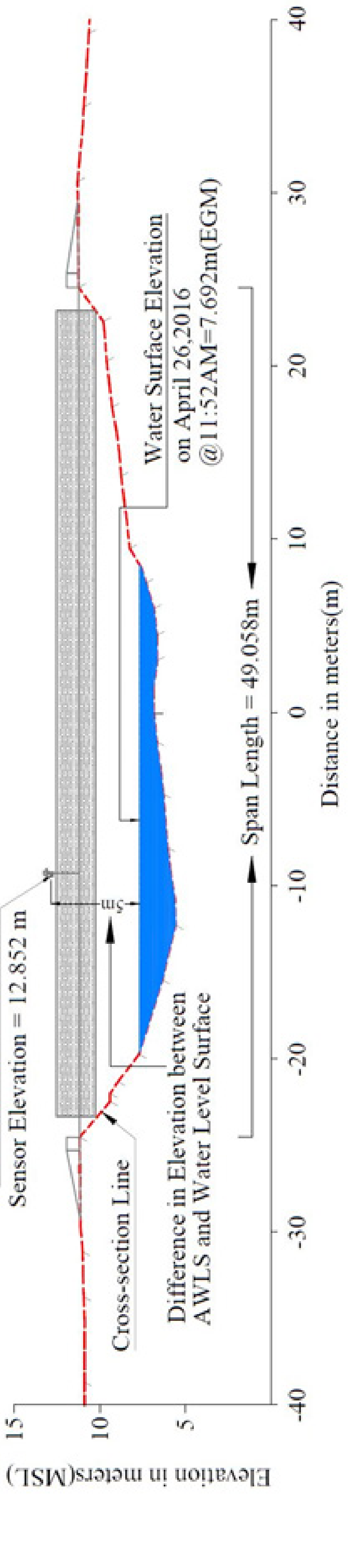


Figure 39. Kumalarang (also known as Boyugan East) Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Kumalarang Bridge

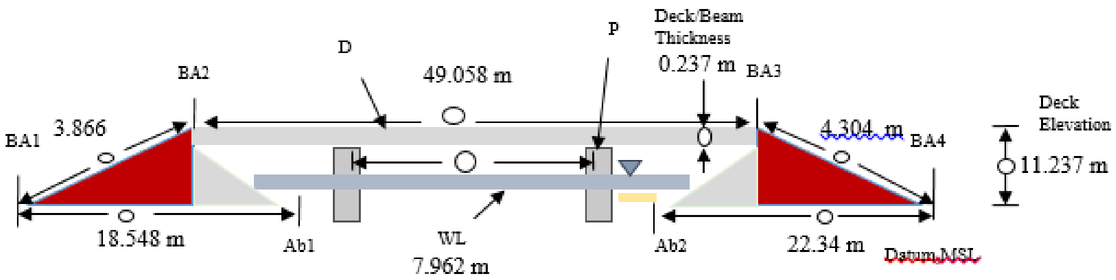
River Name: Kumalarang River
Location (Brgy,City,Region): Brgy. Boyugan, East Kumalarang, Zamboanga Del Sur

Survey Team: Jayson Ilustre, Ryan Artenio (Local Aide)
Date and Time: April 26, 2016, 11:52 A.M.

Flow Condition: low ✔ normal high

Weather Condition: ✔ fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
○ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	3.866 m	
2. BA2-BA3	49.058 m	
3. BA3-BA4	4.304 m	
4. BA1-Ab1	18.584 m	
5. Ab2-BA4	22.34 m	
6. Deck/beam thickness	0.237 m	
7. Deck elevation	11.237 m	

Note: Observer should be facing downstream

Figure 40. Kumalarang (also known as Boyugan East) Bridge Data Sheet

The water surface elevation of Kumalarang River was determined by a Nikon® Total Station on April 26, 2016 at 11:52 AM at Kumalarang Bridge area with a value of 7.692 min MSL as shown in Figure 38. This was translated into marking on the bridge's pier as shown in Figure 41. The marking served as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Kumalarang River, the Mindanao State University-Iligan Institute of Technology.

Figure 41. Water-level markings on Kumalarang (Boyugan East) Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 16-25, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 42. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.4 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZGS-63 occupied as the GNSS base station in the conduct of the survey.

Figure 42. Validation points acquisition survey set-up for Kumalarang River

The survey started from Brgy. Lantawan, Municipality of Buug, Zamboanga Sibugay going northeast along the national high way covering two (7) barangays in the Municipality of Buug and six (6) barangays in the Municipality of Kumalarang, and ended in Brgy. Bayugan West, Municipality of Kumalarang, Zamboanga del Sur. The survey gathered a total of 4,084 points with approximate length of 27.50 km using ZGS-63 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 43.

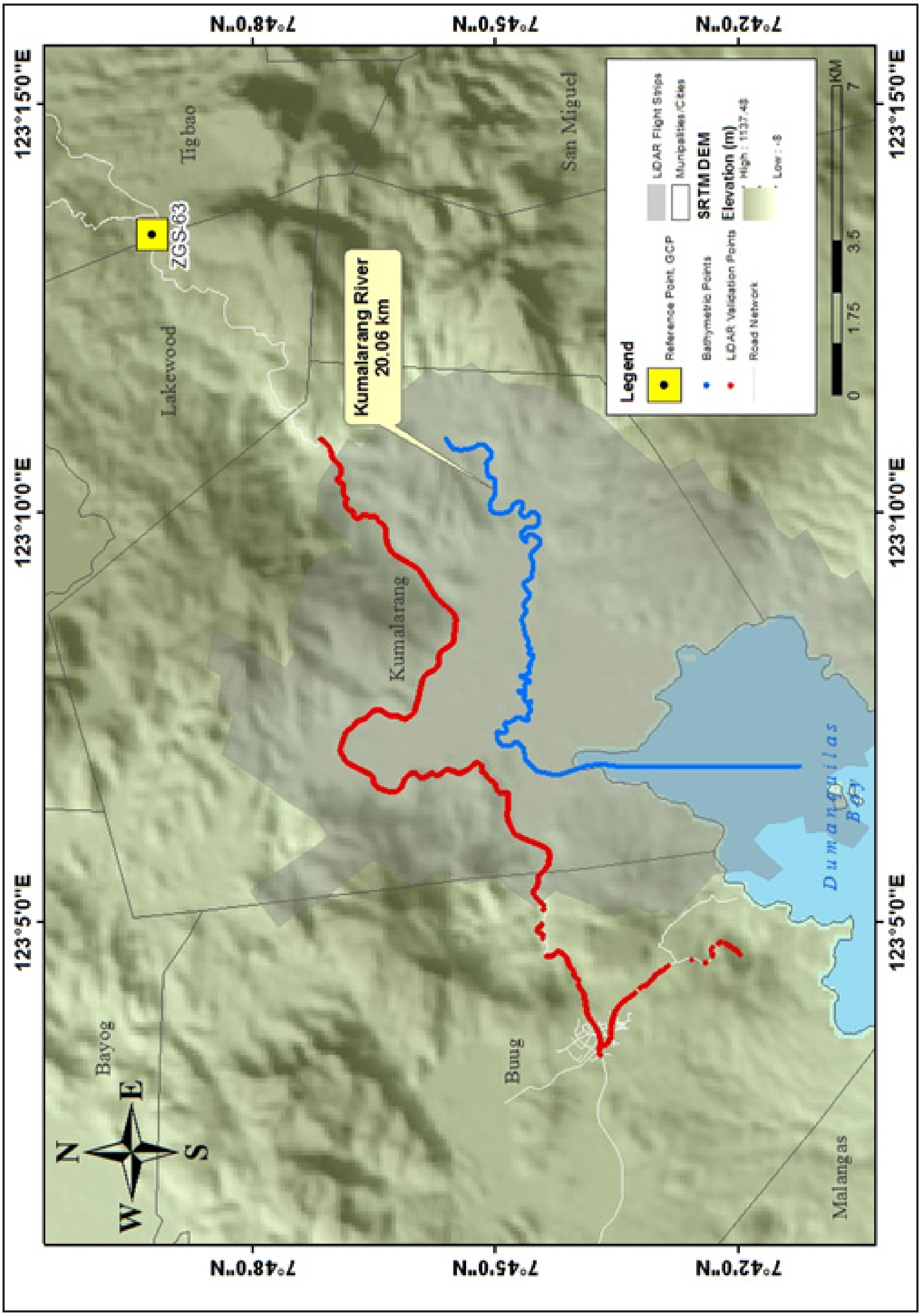


Figure 43. Validation points acquisition covering the Kumalarang River Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed on March 23, and 28-29, 2016 using a Hi-Target™ Echo Sounder as illustrated in Figure 44. The survey started in Brgy. Secade, Municipality of Kumalarang, Zamboanga del Sur with coordinates 7°54'37.54515"N, 123°10.56.40877"E and ended in Dumanquilas Bay as well, with coordinates 7°44'33381"N, 123°8'20.48568"E. The control points UP_KUM-8 and UP_KUM-9 were used as GNSS base stations all throughout the entire survey.

Figure 44. Bathymetric survey of ABSD at Kumalarang River using Hi-Target™ Echo Sounder (upstream)

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets. The computed R2 value of 0.9874 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.1971 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Kumalarang River gathered a total of 16,206 points covering 20.6 km of the river traversing barangays of Secade, Boyugan East, Poblacion, Gawil, and Bogayo, all in the Municipality ofKumalarang as seen in the map in Figure 45. A CAD drawing was also produced to illustrate the river bed profile of Kumalarang River. As shown in Figure 47, the highest and lowest elevation has a 10-m difference. The highest elevation observed was 19.5 m MSL while the lowest was -4.94m below MSL located in Brgy. Bogayo, Municipality of Kumalarang.

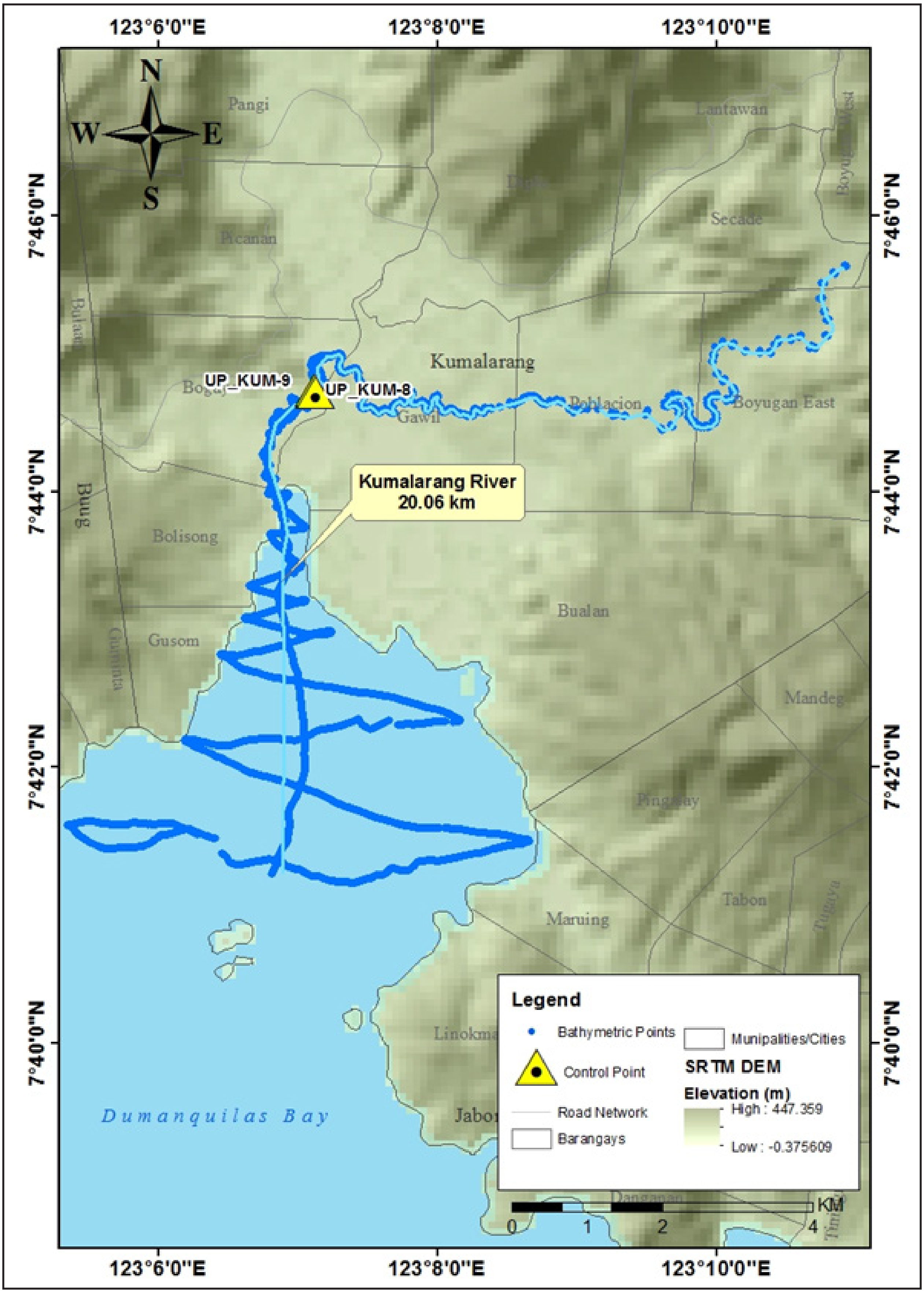


Figure 45. Bathymetric survey of Kumalarang River

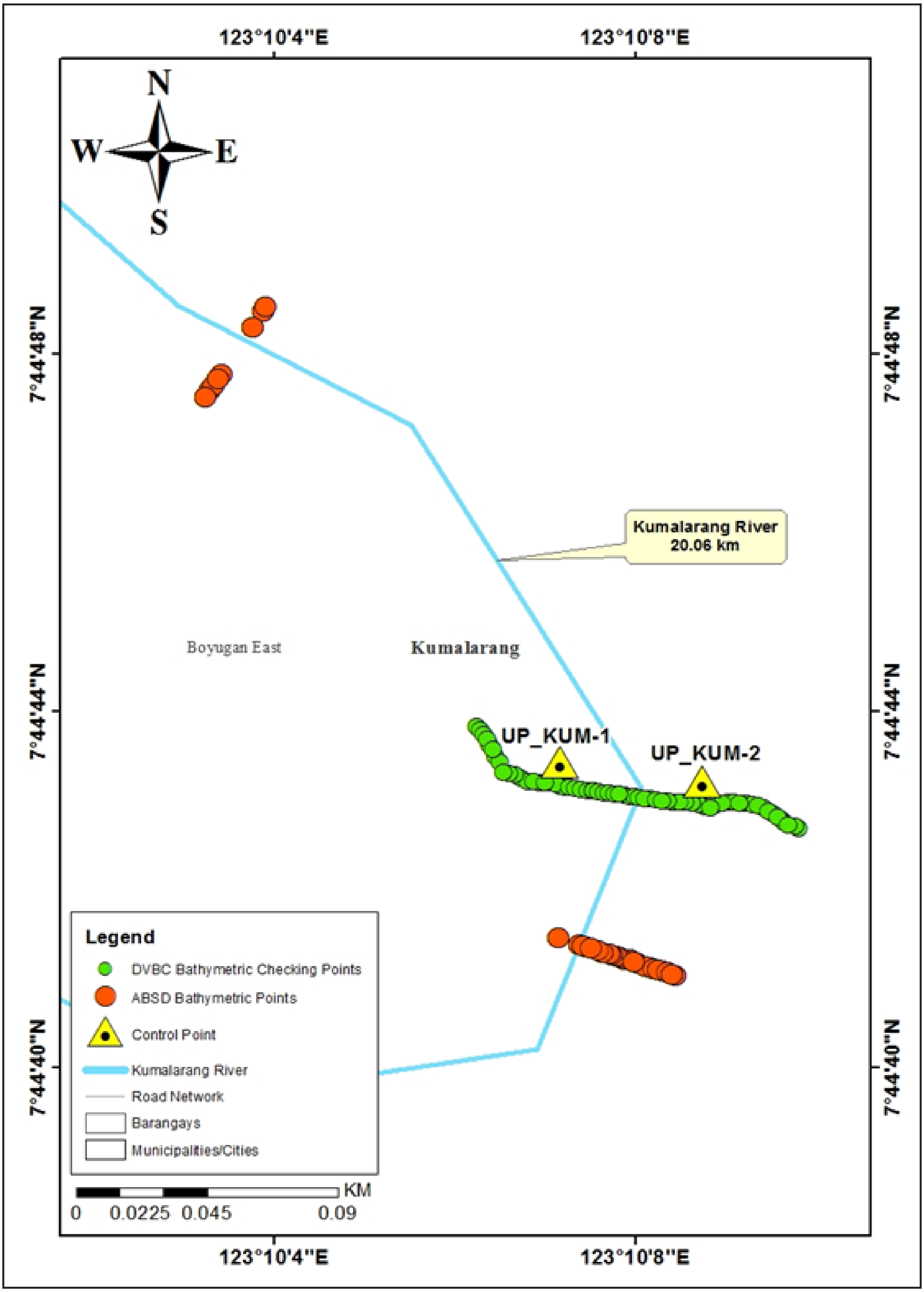


Figure 46. Bathymetric survey of Kumalarang River

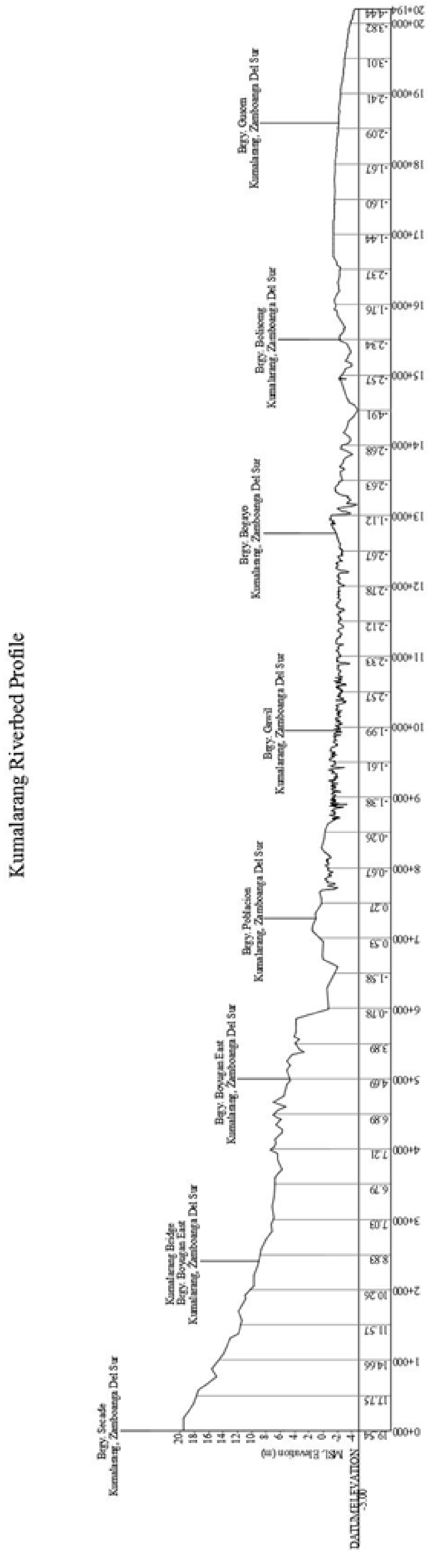


Figure 47. Kumalarang Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the Automatic Rain Gauge (ARG) installed upstream by the DOST. The ARG was specifically installed in the municipality of Kumalarang with coordinates 7°44’43.20”N Latitude and 123°10’8.10”E Longitude. The location of the rain gauge is shown in Figure 48 below.

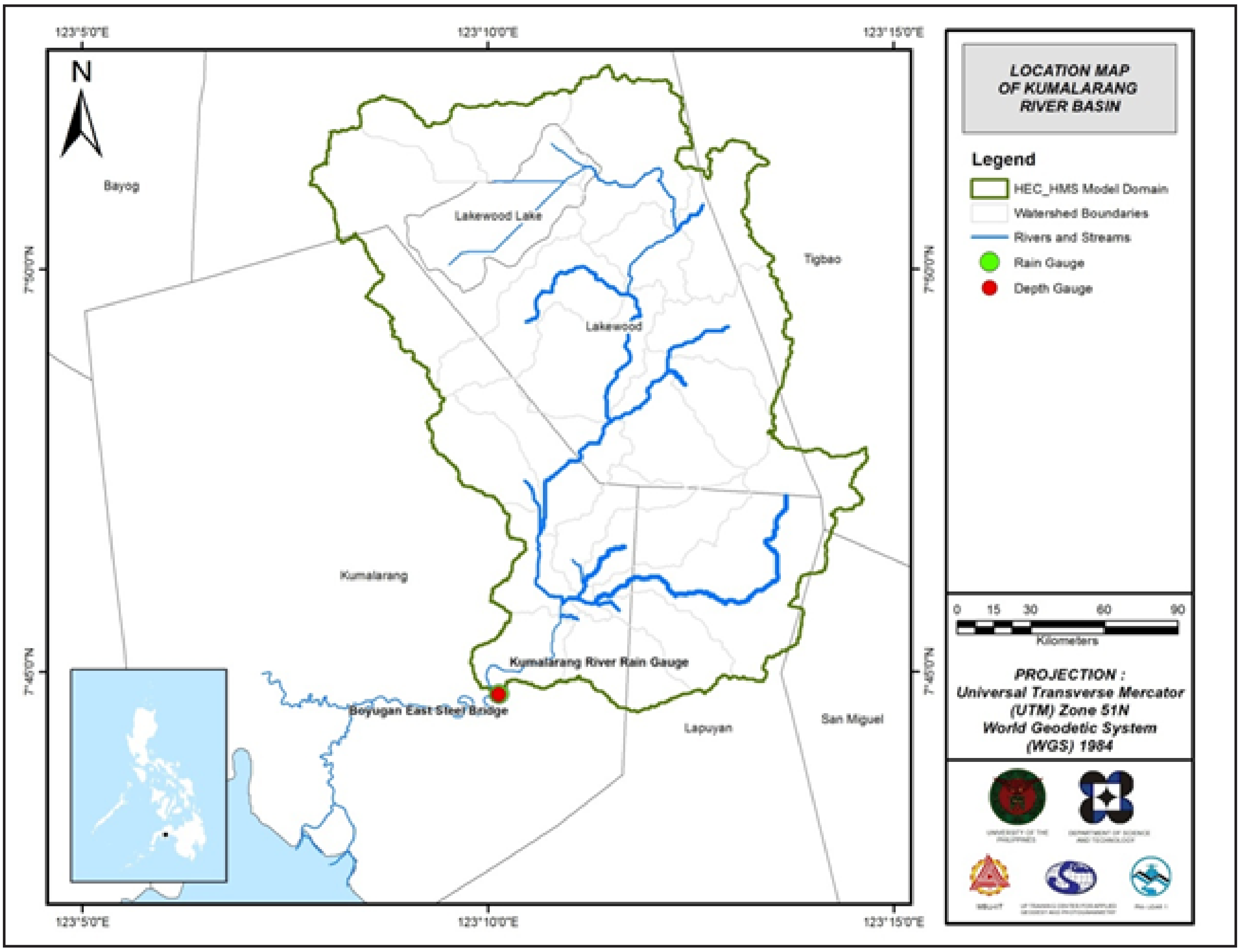


Figure 48. The location map of Kumalarang HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

HQ curve analysis is important in determining the equation to be used in establishing Q values with R-Squared values closer to 1. A trendline is more accurate if the R-Squared value is closer or at 1. For Kumalarang, base flow hydrometry was used.

Figure 50 shows the highest R-Squared value of 0.9623 compared to the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

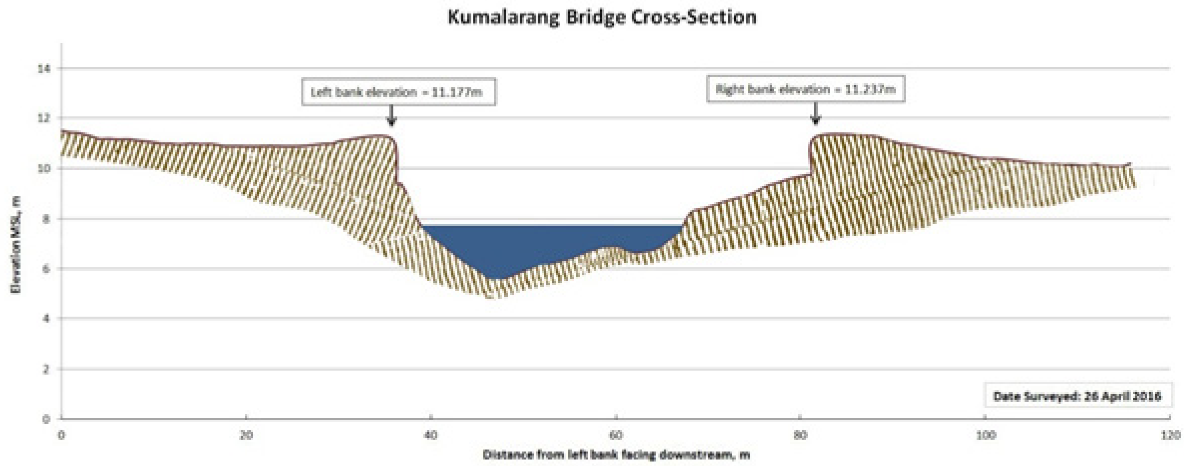


Figure 49. Cross-Section Plot of Boyugan East Steel Bridge

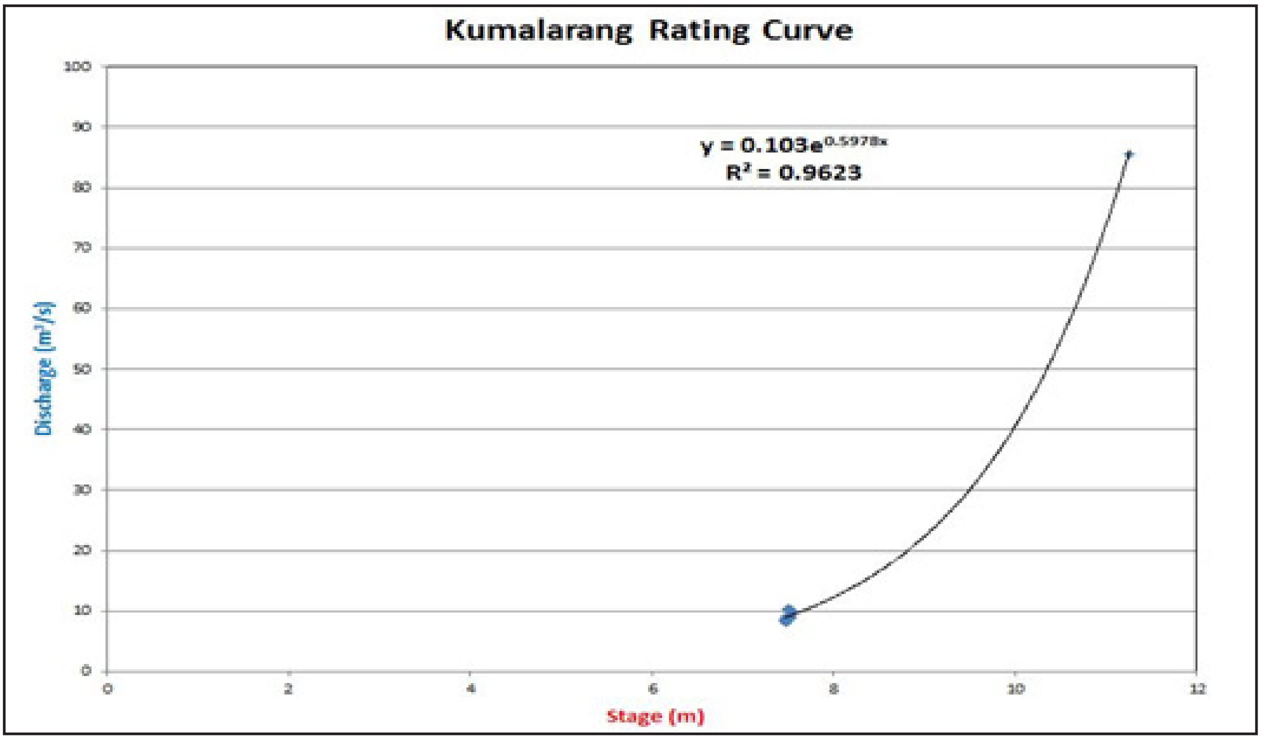


Figure 50. Rating Curve at Boyugan East Steel Bridge

This rating curve equation was used to compute the river outflow at Boyugan East Steel Bridge for the calibration of the HEC-HMS model.

Total rainfall taken from the ARG at Boyugan East, Kumalarang was 35 mm. It peaked to 16.5 mm on 22 July 2016, 15:00. The peak discharge is 29.4 cmson 22 July 2016, 16:50. The lag time between the peak rainfall and discharge is 1 hour and 50 minutes.

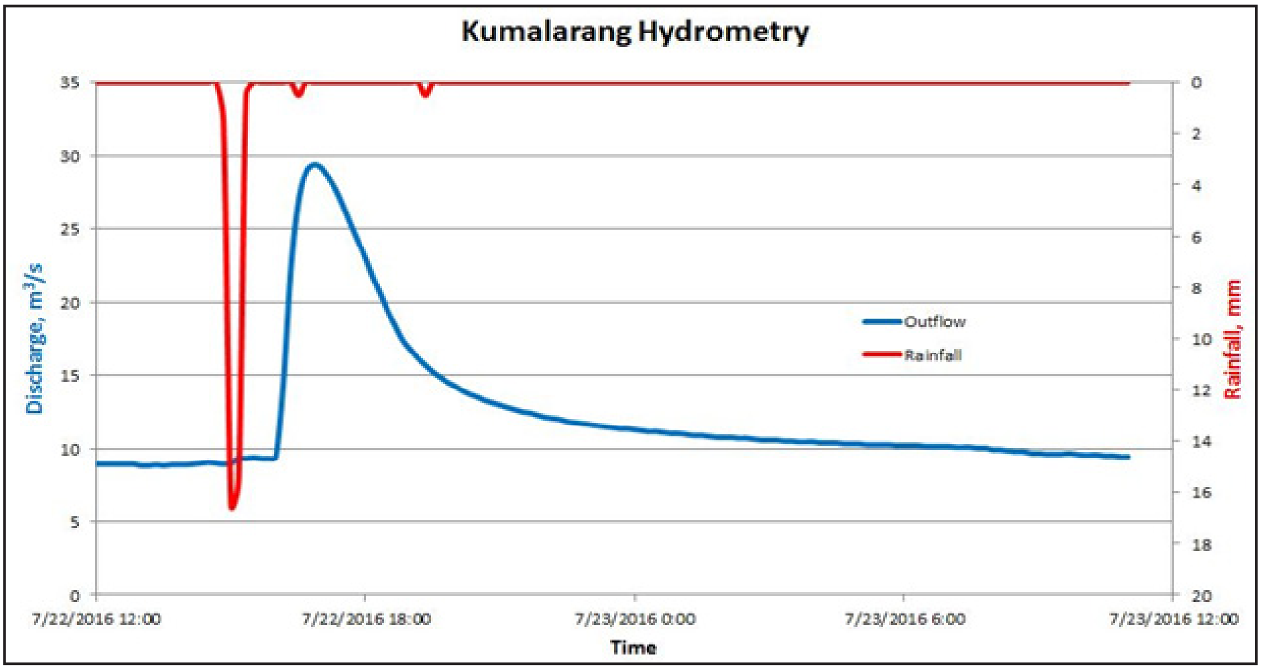


Figure 51. Rainfall and outflow data at Boyugan East Steel Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Dipolog Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Kumalarang watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 28. RIDF values for Dipolog 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	19.7	30.9	38.7	53.8	73.6	85.5	105.7	120.3	136.2
5	25.9	39.6	50.1	72.6	99.7	117.3	140.9	158.3	178.5
10	30	45.4	57.6	85.1	117	138.3	164.3	183.4	206.5
15	32.3	48.6	61.8	92.1	126.8	150.2	177.4	197.6	222.4
20	34	50.9	64.8	97.1	133.6	158.5	186.6	207.6	233.4
25	35.2	52.7	67.1	100.9	138.9	164.9	193.7	215.2	242
50	39	58.1	74.1	112.5	155.1	184.6	215.6	238.8	268.3
100	42.9	63.4	81.1	124.1	171.2	204.2	237.3	262.1	294.4

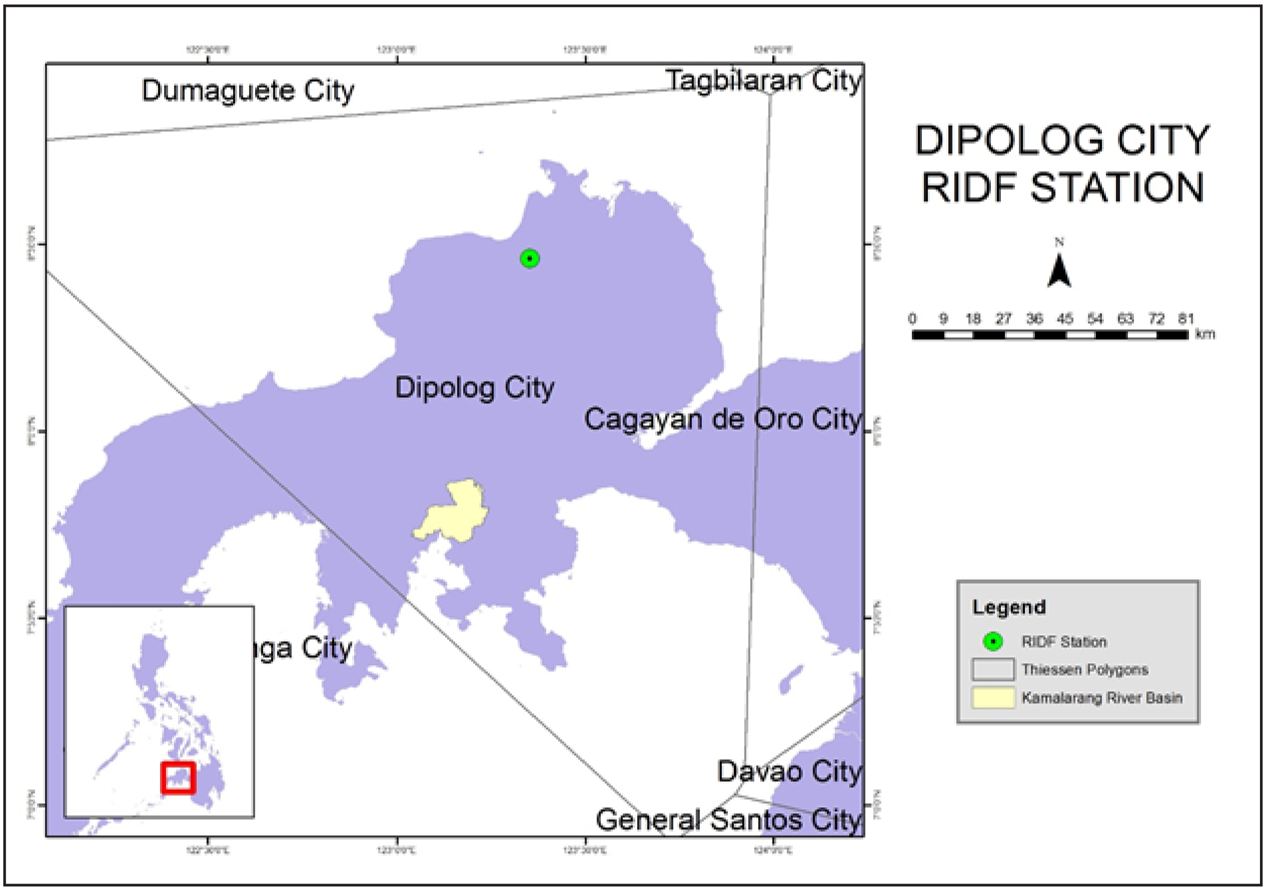


Figure 52. Location of Dipolog RIDF station relative to Kumalarang River Basin

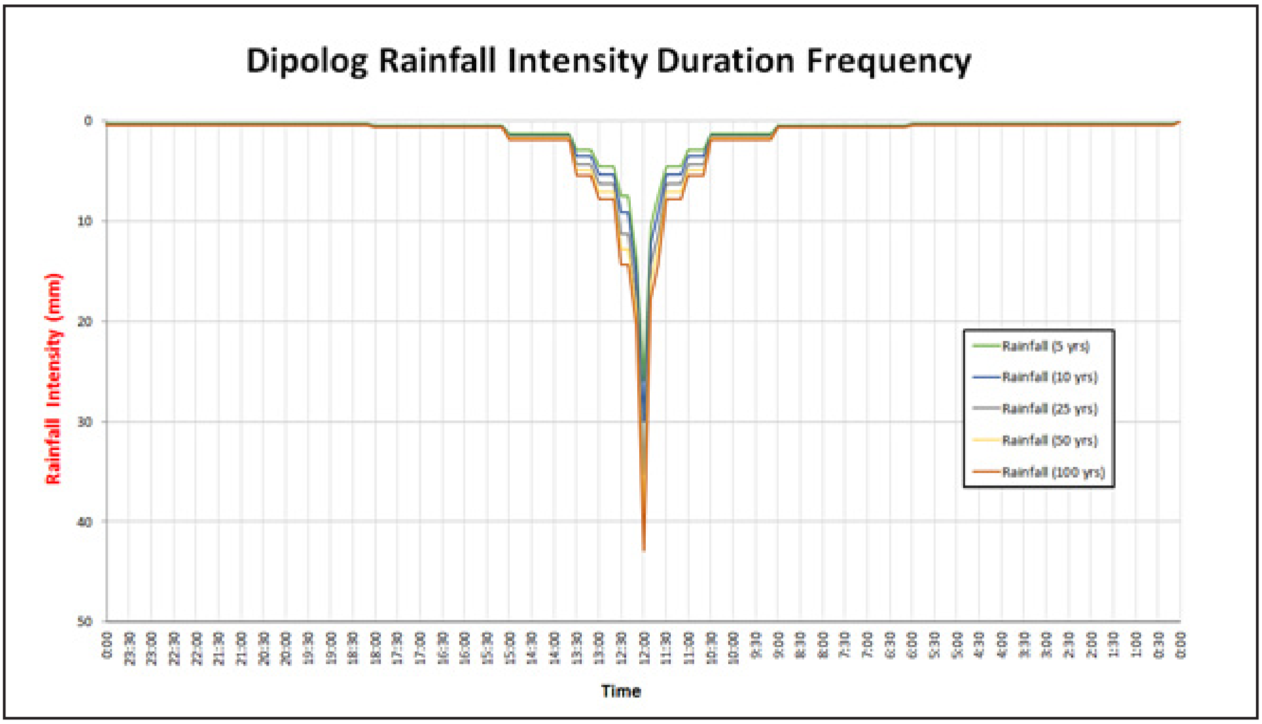


Figure 53. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil texture map (Figure 54) of the Kumalarang River basin was used as one of the factors for the estimation of the CN parameter.

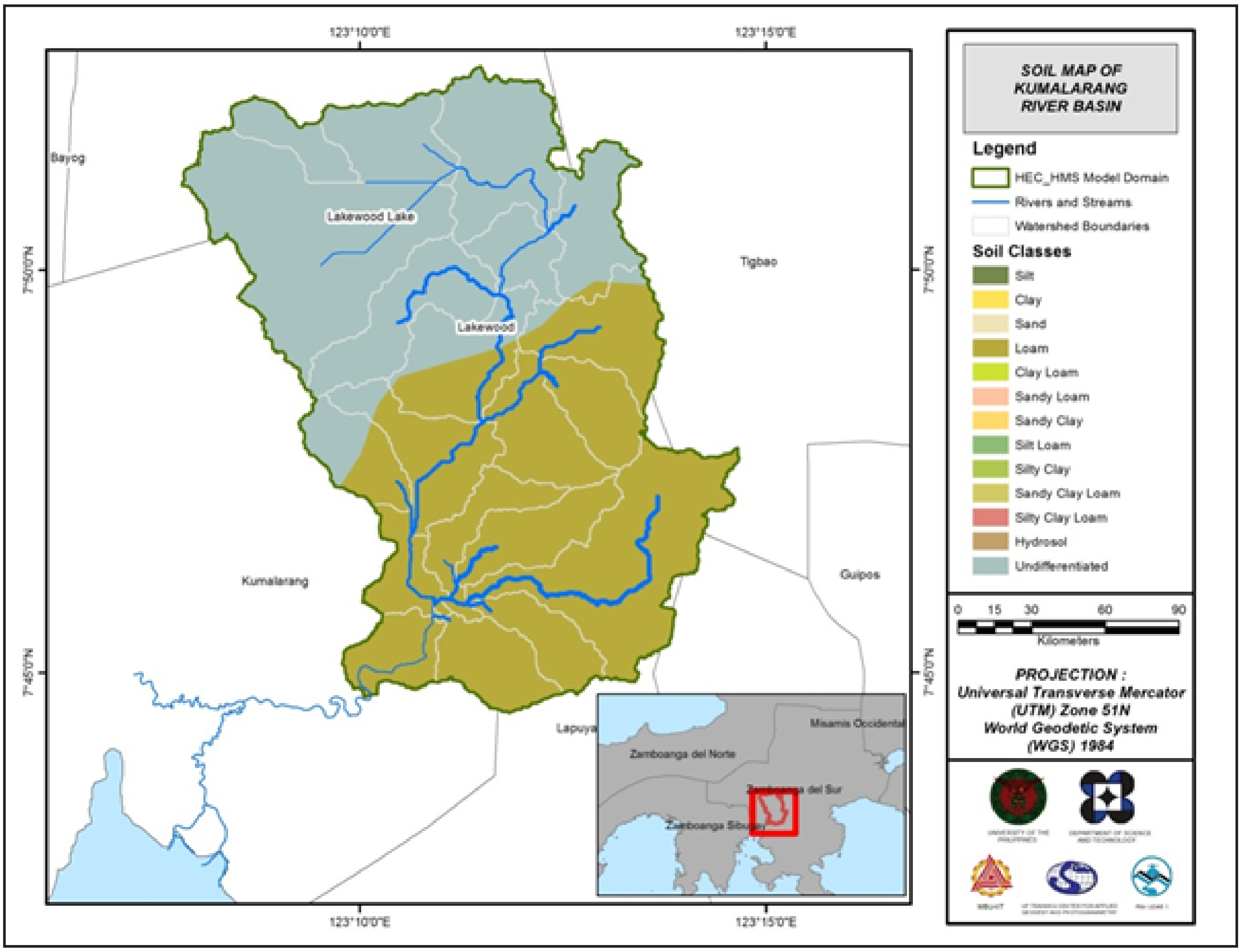


Figure 54. Soil Map of Kumalarang River Basin

The land cover data was generated in 2003 from the National Mapping and Resource Information Authority (NAMRIA), DENR. Figure 55 shows the Land Cover inside Kumalarang River Basin. The land cover map of Kumalarang River Basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

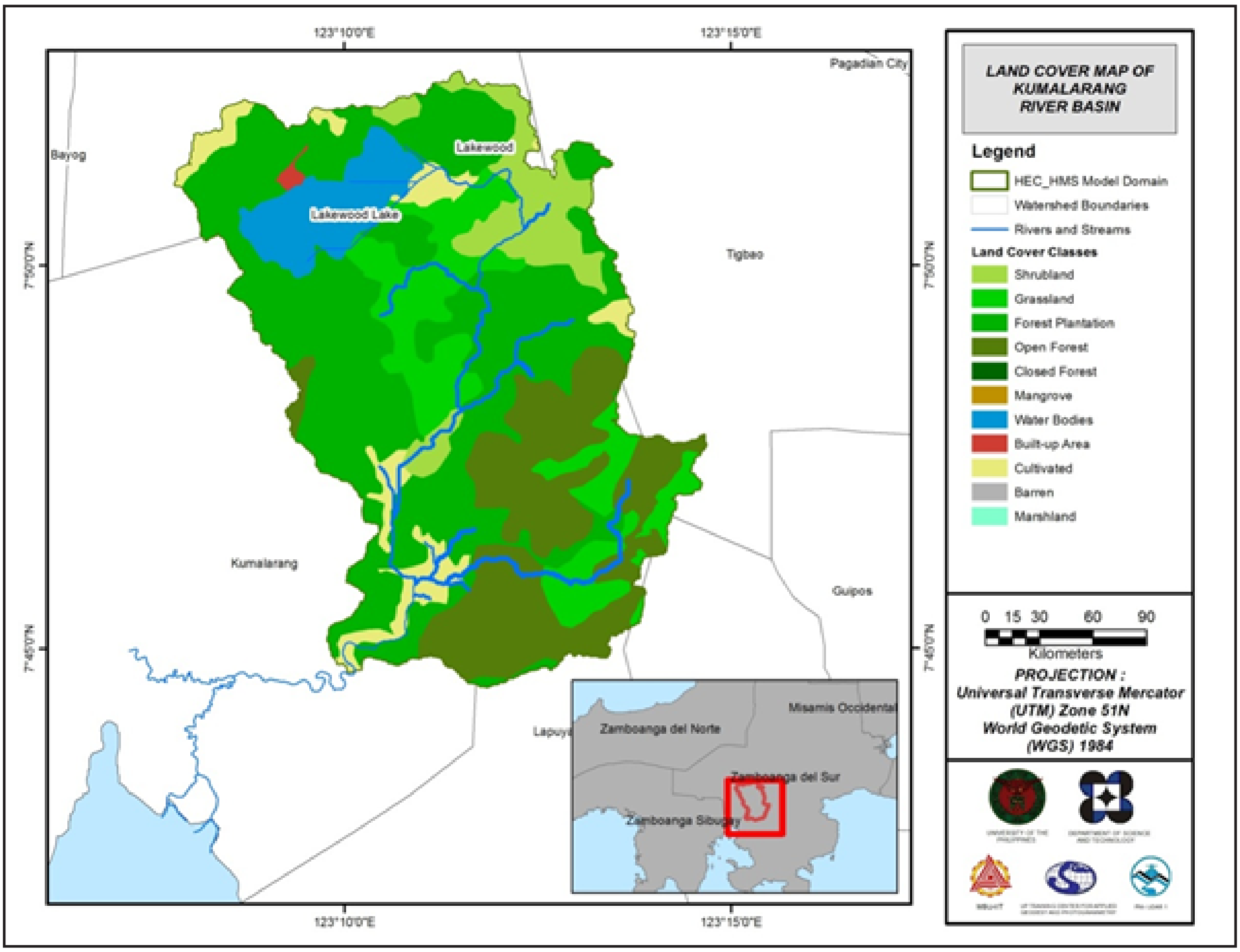


Figure 55. Land Cover Map of Kumalarang River Basin

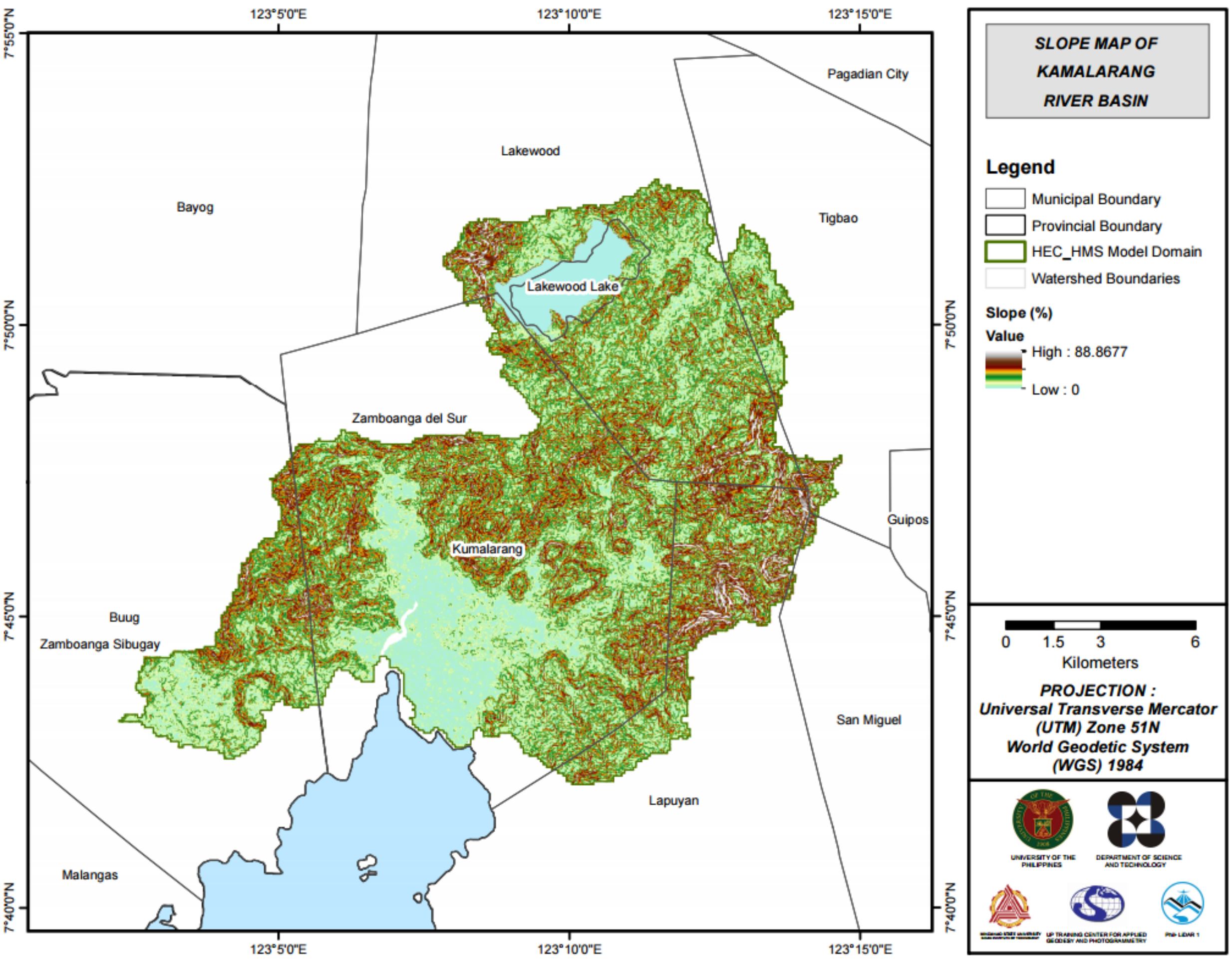


Figure 56. Slope Map of Kumalarang River Basin

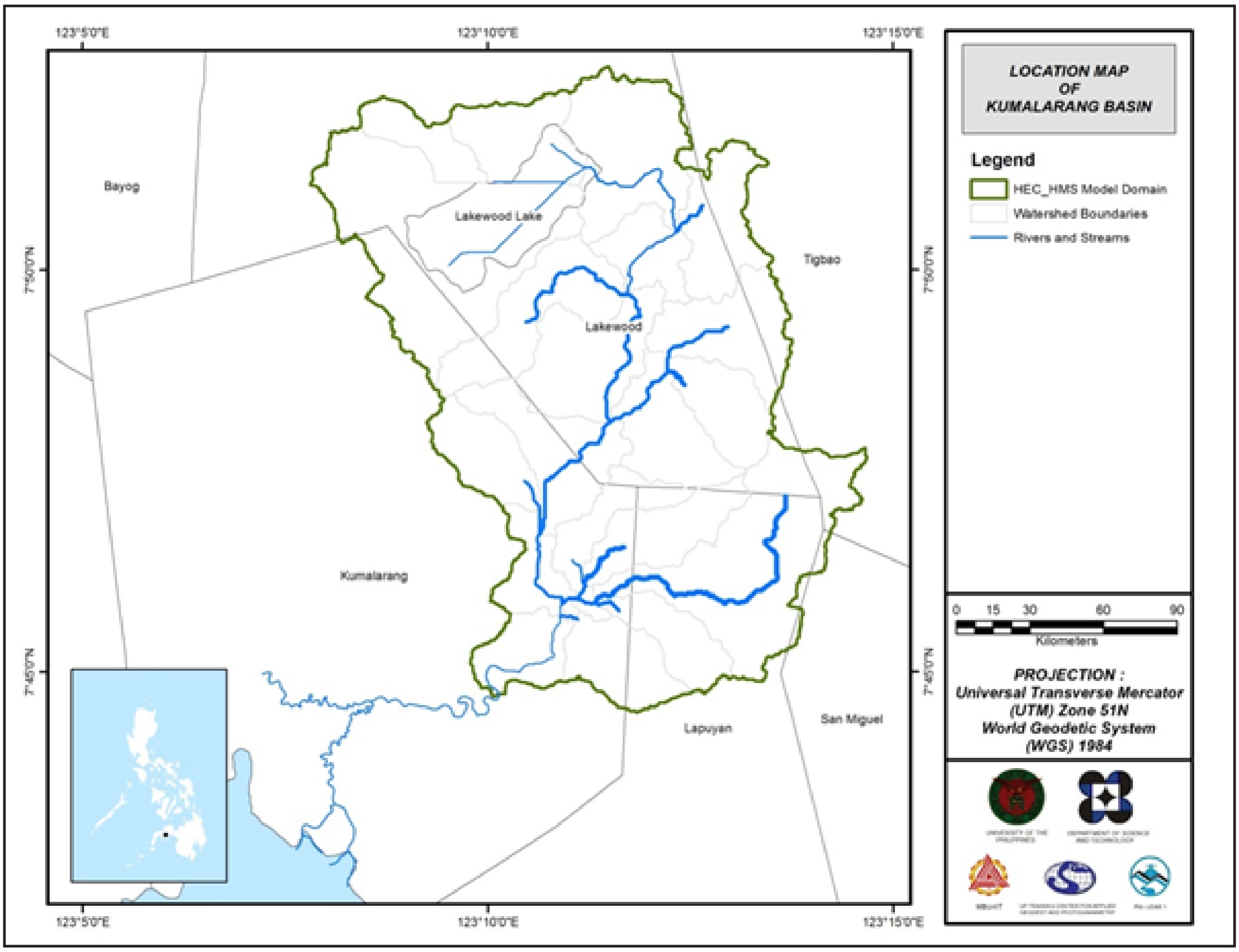


Figure 57. Stream Delineation Map of the Kumalarang River Basin

Using the SAR-based DEM, the Kumalarang basin was delineated and further subdivided into subbasins. The model consists of 20 sub basins, 12 reaches, and 12 junctions. The main outlet is located at Boyugan East Bridge, Kumalarang. This basin model is illustrated in Figure 58. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Boyugan East Bridge.

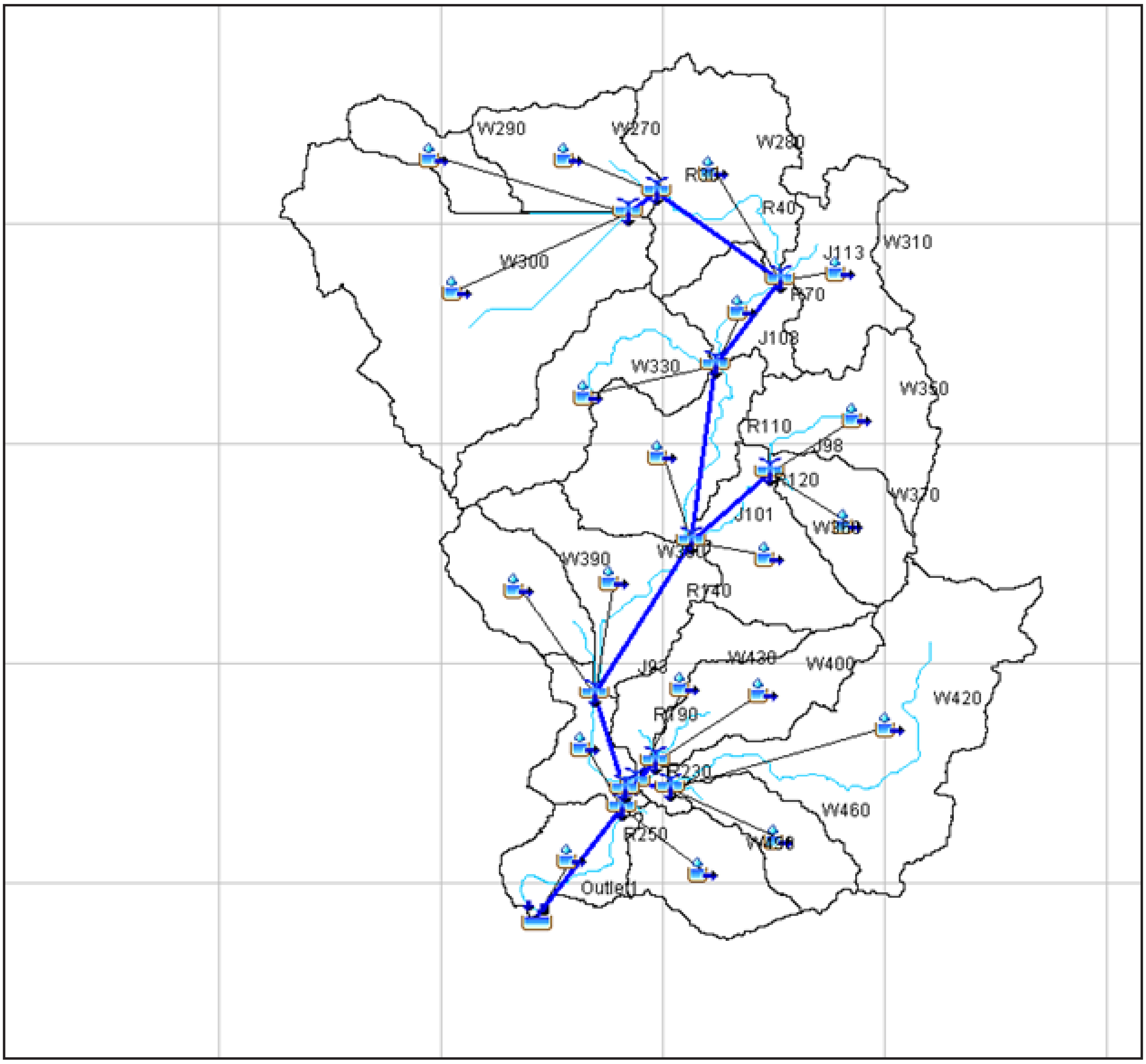


Figure 58. The Kumalarang Hydrologic Model generated in HEC-GeoHMS

5.4 Cross-section Data

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

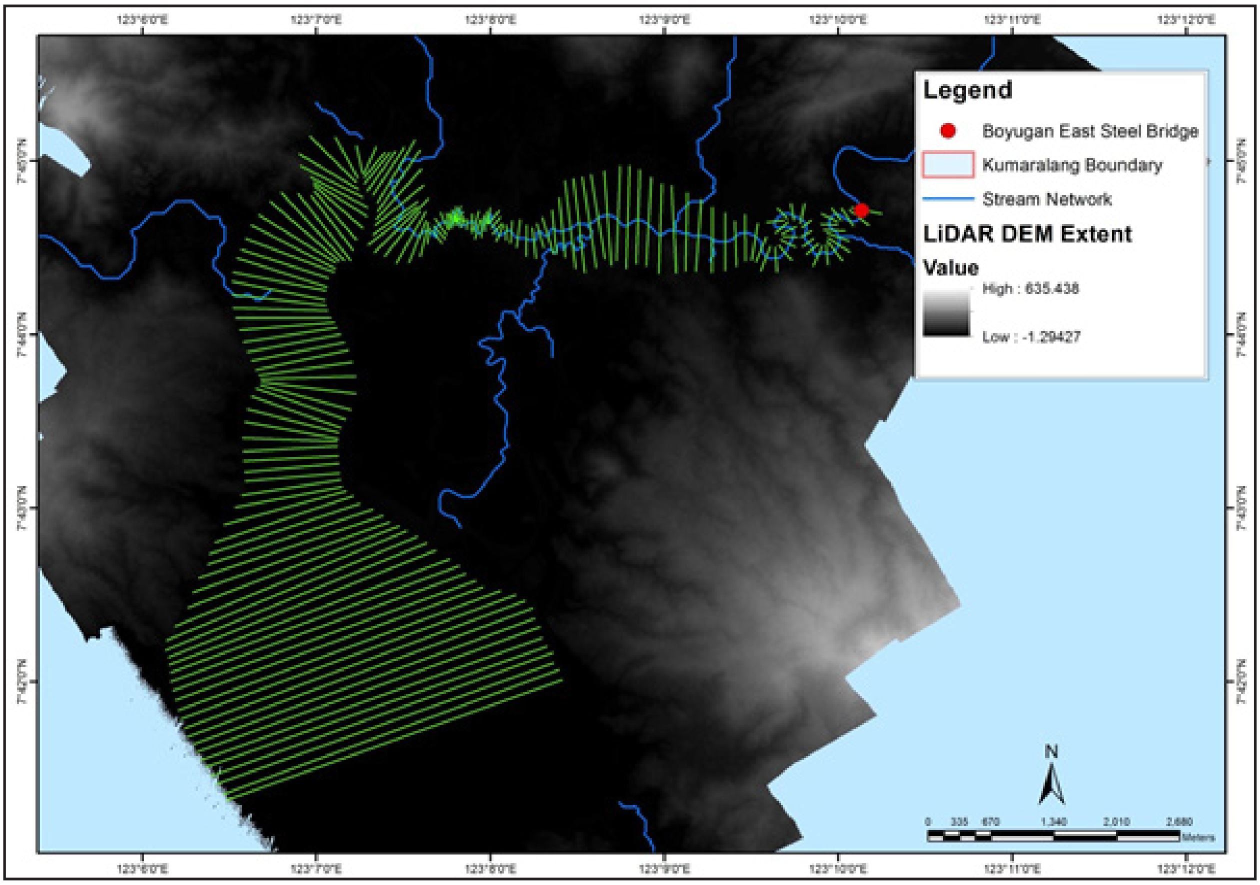


Figure 59. River cross-section of Kumalarang River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element as assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y- coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it was determined that the water will generally flow from the southwest side of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively.

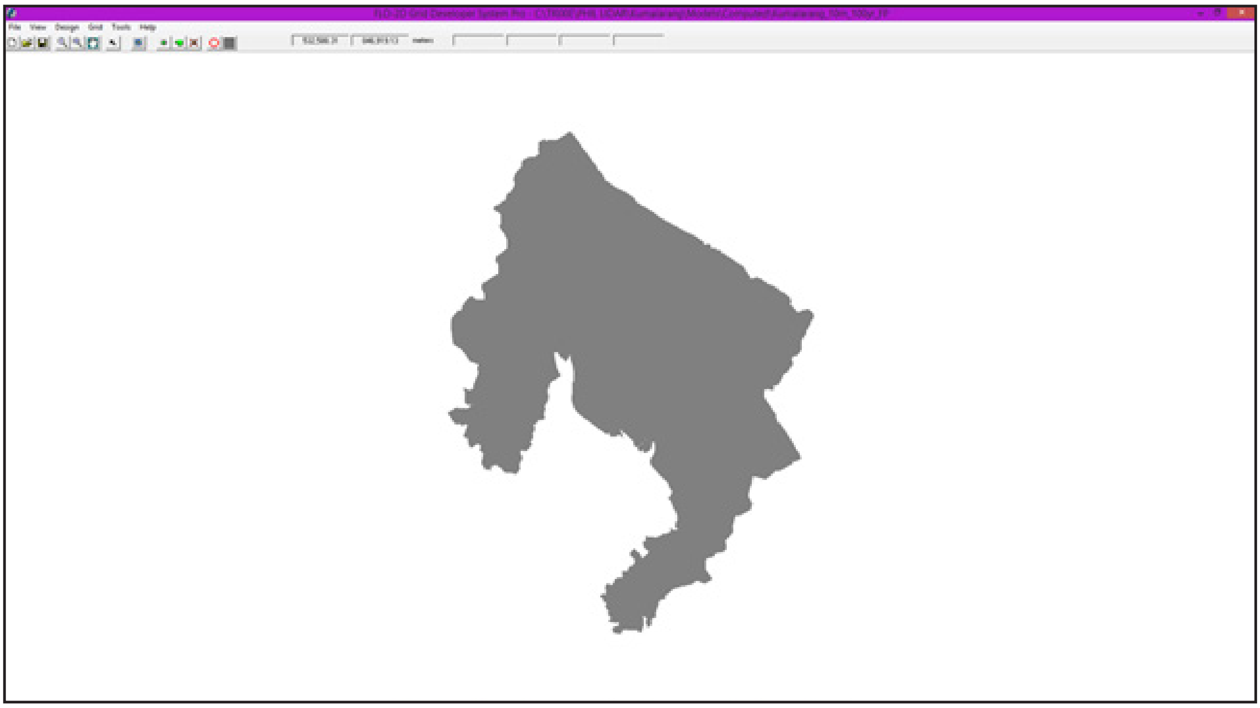


Figure 60. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

5.6 Results of HMS Calibration

After calibrating the Kumalarang HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data.

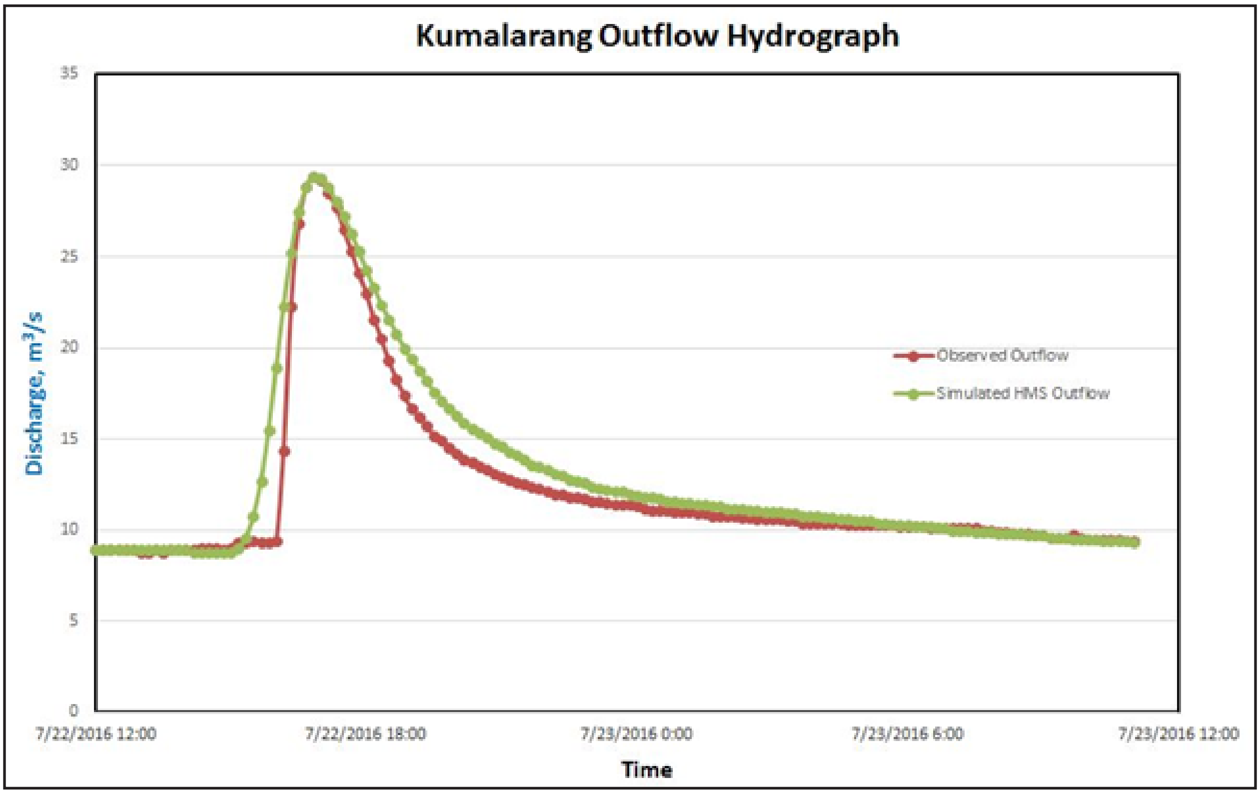


Figure 61. Outflow Hydrograph of Kumalarang Bridge generated in HEC-HMS model compared with observed outflow

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

Table 29. Range of Calibrated Values for Kulamarang River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	8 - 40
			Curve Number	70 - 80
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 12
			Storage Coefficient (hr)	0.3 - 5
	Baseflow	Recession	Recession Constant	0.72
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.015

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 8 to 40mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation per subbasin.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 70 to 80 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area(M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 to 12 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.72 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.2 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.015 is lower than the common roughness of Philippine watersheds.

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

Accuracy measure	Value
RMSE	1.54
r^2	0.96
NSE	0.90
PBIAS	-5.76
RSR	0.32

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.54 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.96.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.90.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -5.76.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.32.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 13) shows the Kumalarang outflow using the Kumalarang RIDF curves in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

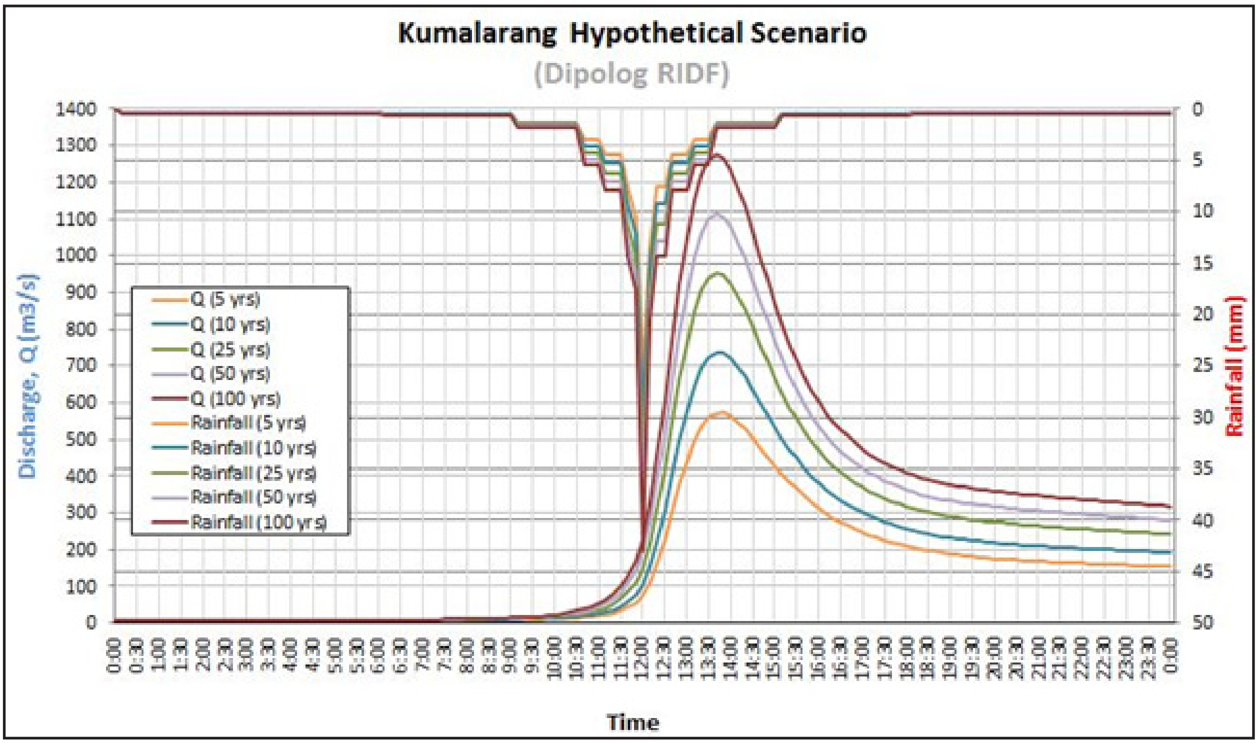


Figure 62. Outflow hydrograph at Kumalarang Station generated using Dipolog RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Kumalarang discharge using the Kumalarang RIDF curves in five different return periods is shown in Table 31.

Table 31. Peak values of the Kumalarang HECHMS Model outflow using Kumalarang RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	178.32	25.9	573.2	13 hours 50 mins
10-Year	206.37	30	736.5	13 hours 40 mins
25-Year	241.91	35.2	952.4	13 hours 40 mins
50-Year	268.14	39	1112.3	13 hours 40 mins
100-Year	294.55	42.9	1276.8	13 hours 40 mins

5.7.2 Discharge data using Dr. Horritts'srecommended hydrologic method

The river discharge values for the two rivers entering the floodplain are shown in Figure 63 to Figure 64 and the peak values are summarized in Table 32 to 33.

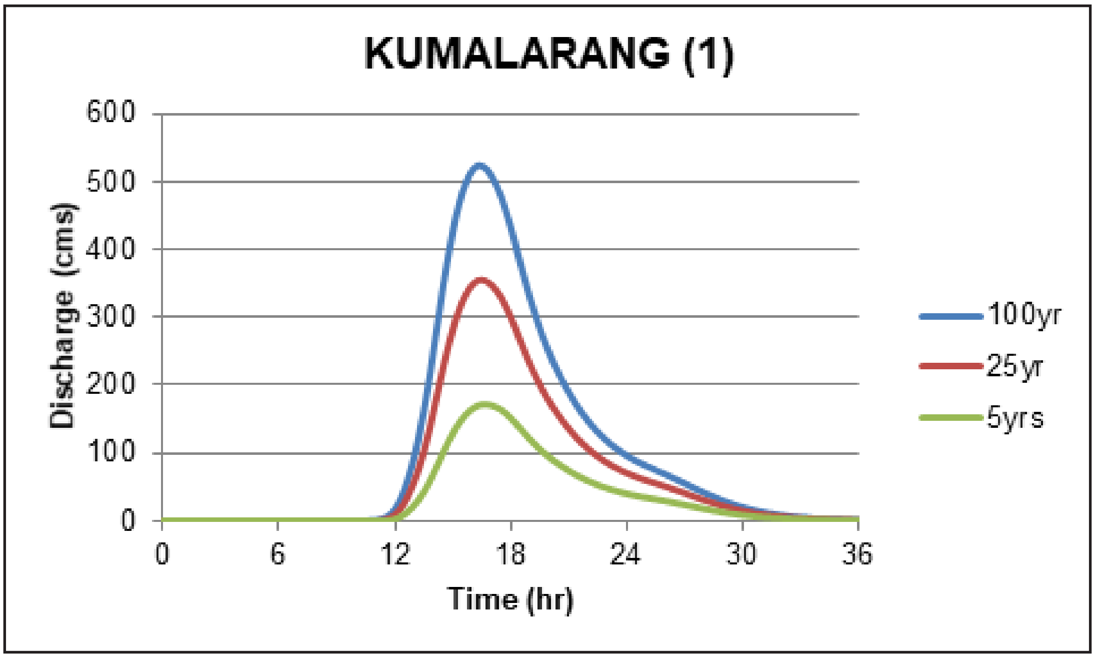


Figure 63. Kumalarang river (1) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

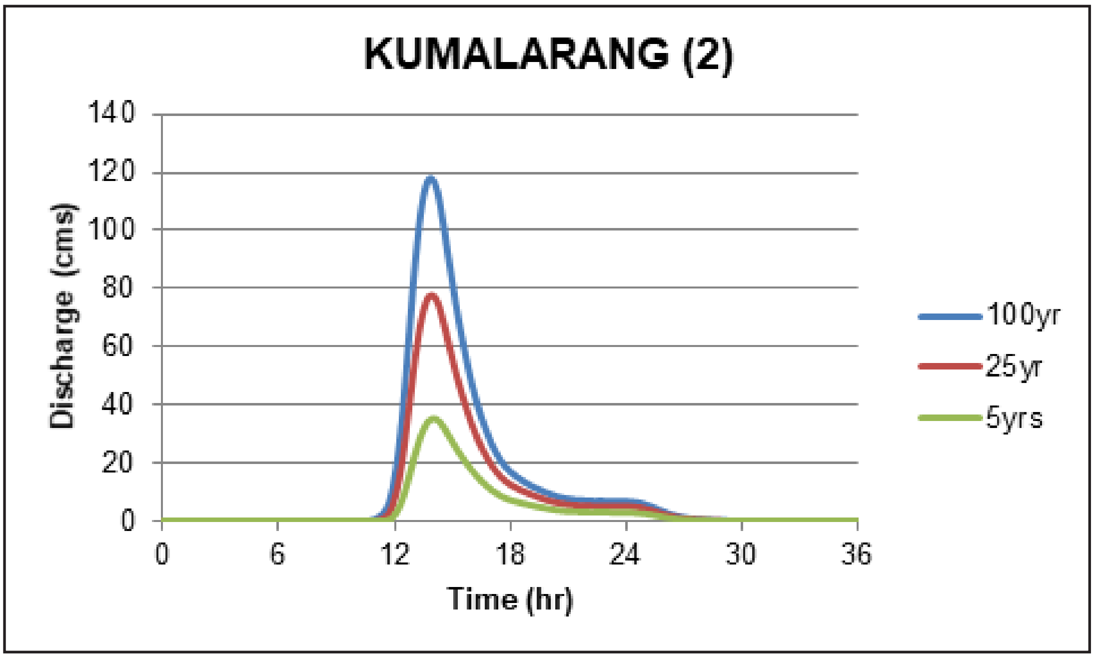


Figure 64. Kumalarang river (2) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 32. Summary of Kumalarang river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	524.1	245.09 minutes
25-Year	355.2	245.09 minutes
5-Year	171.6	245.09 minutes

Table 33. Summary of Kumalarang river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	117.9	103.14 minutes
25-Year	77.5	103.14 minutes
5-Year	35.2	103.14 minutes

Table 34. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Kumalarang (1)	151.008	290.190	341.367	Pass	Fail
Kumalarang (2)	30.976	42.288	85.051	Pass	Fail

The HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful discharge method. The passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain 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 was used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Kumalarang River using the calibrated HMS base flow is shown in Figure 65.

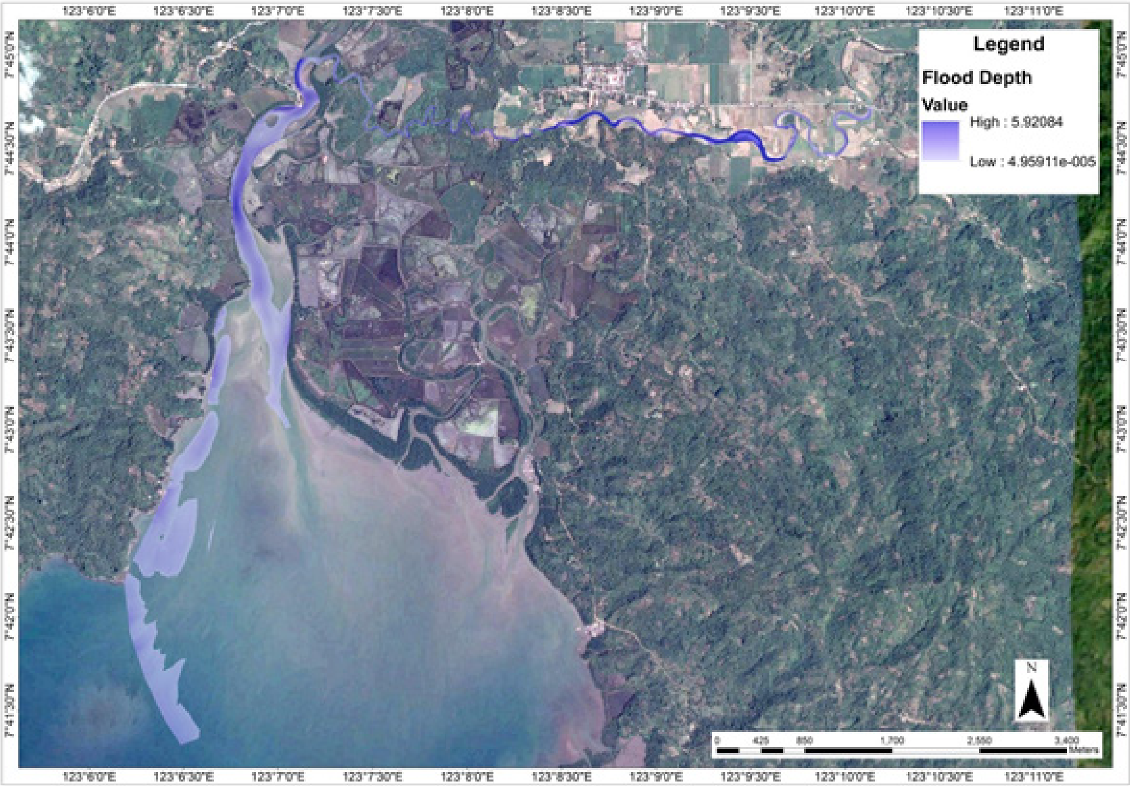


Figure 65. Sample output of Kumalarang RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 shows the 100-, 25-, and 5-year rain return scenarios of the Kumalarang Floodplain.The floodplain, with an area of 74.39 sq. km., covers three municipalities Buug, Kumalarang, and Lapuyan. Table 35 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Kumalarang Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Buug	134.89	2.98	2%
Kumalarang	143.51	61.34	43%
Lapuyan	153.28	9.76	6%

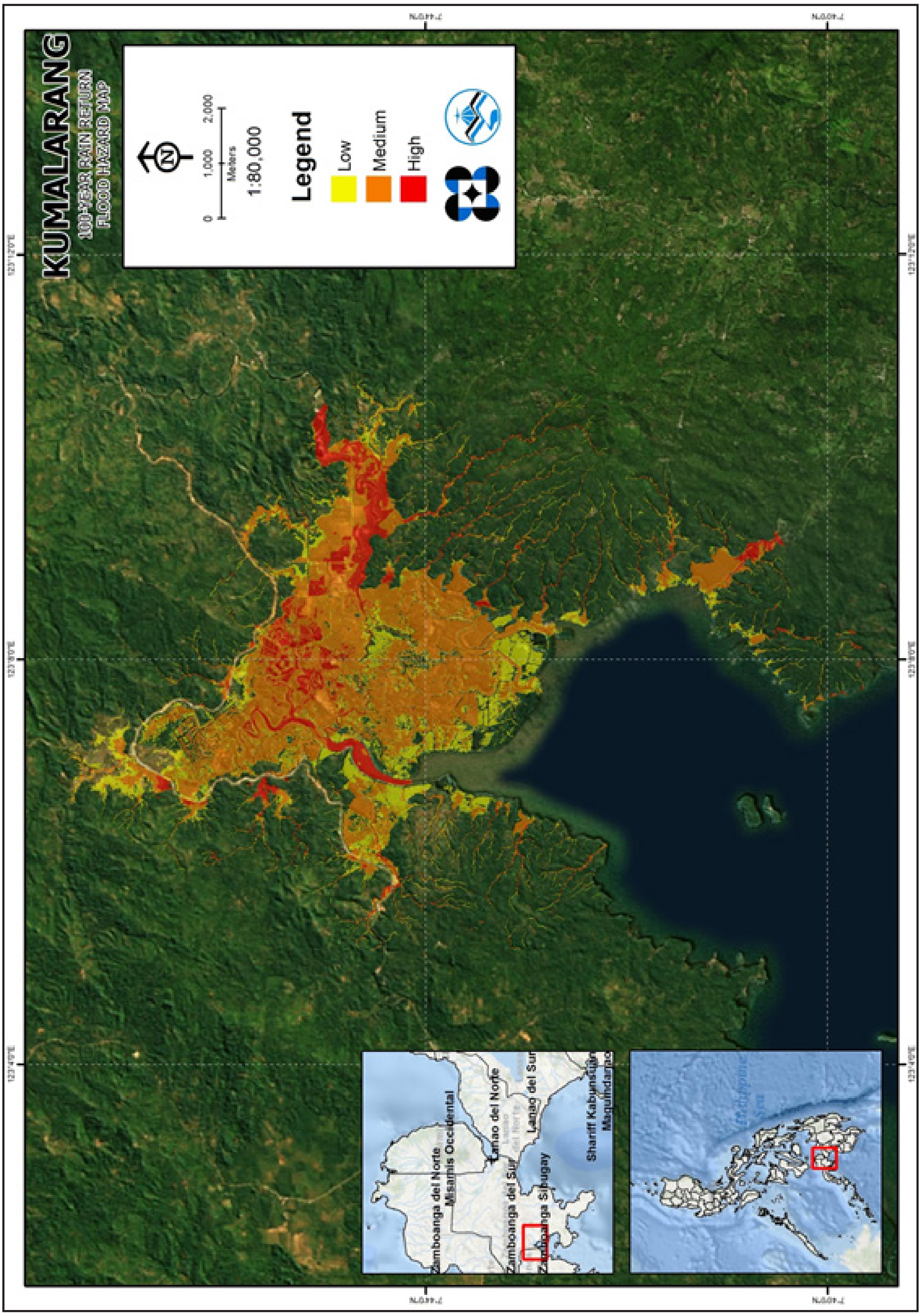


Figure 66. 100-year Rain Return Flood Hazard Map for Kumalarang Floodplain overlaid in Google Earth imagery

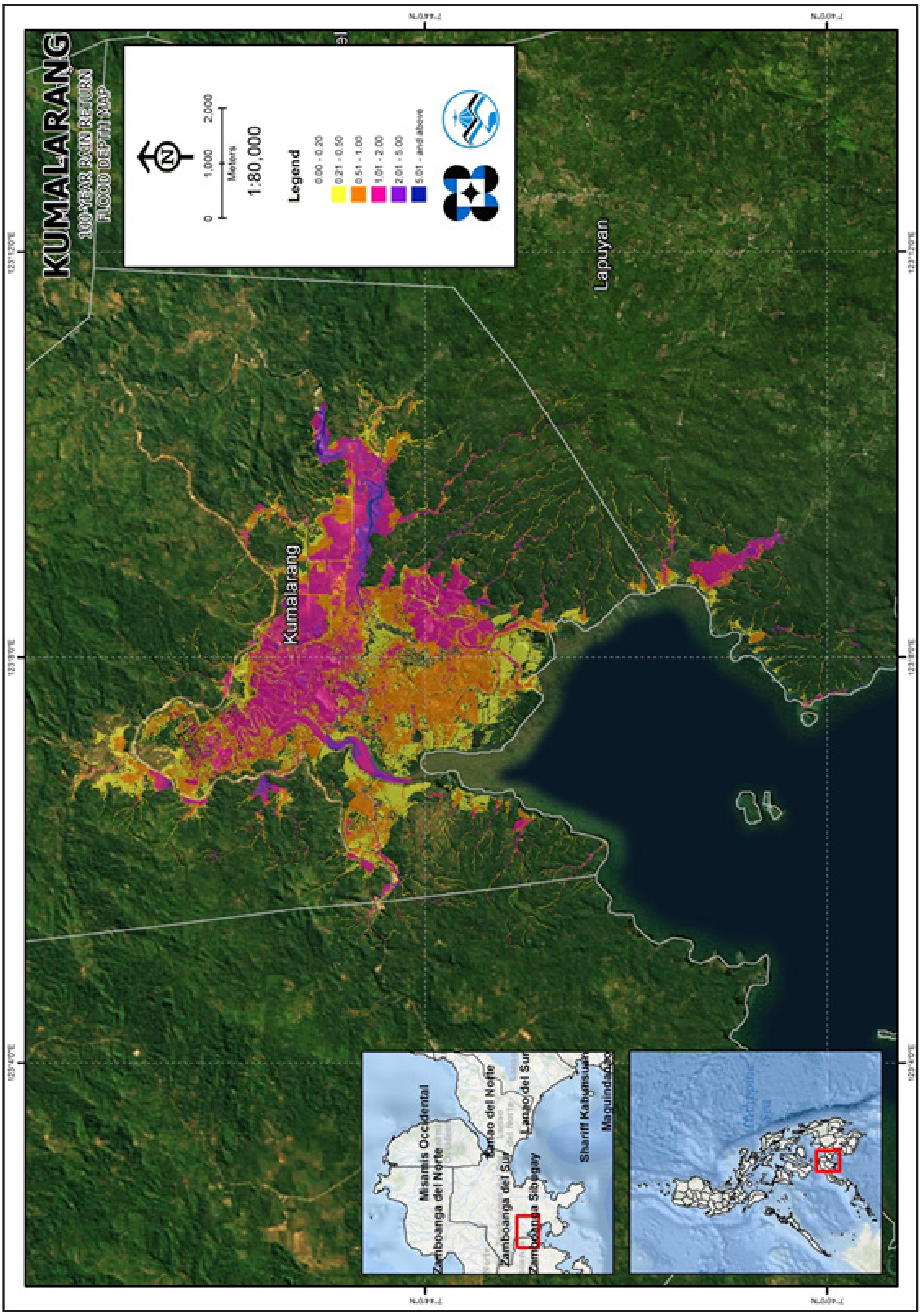


Figure 67. 100-year Rain Return Flood Depth Map for Kumalarang Floodplain overlaid in Google Earth imagery

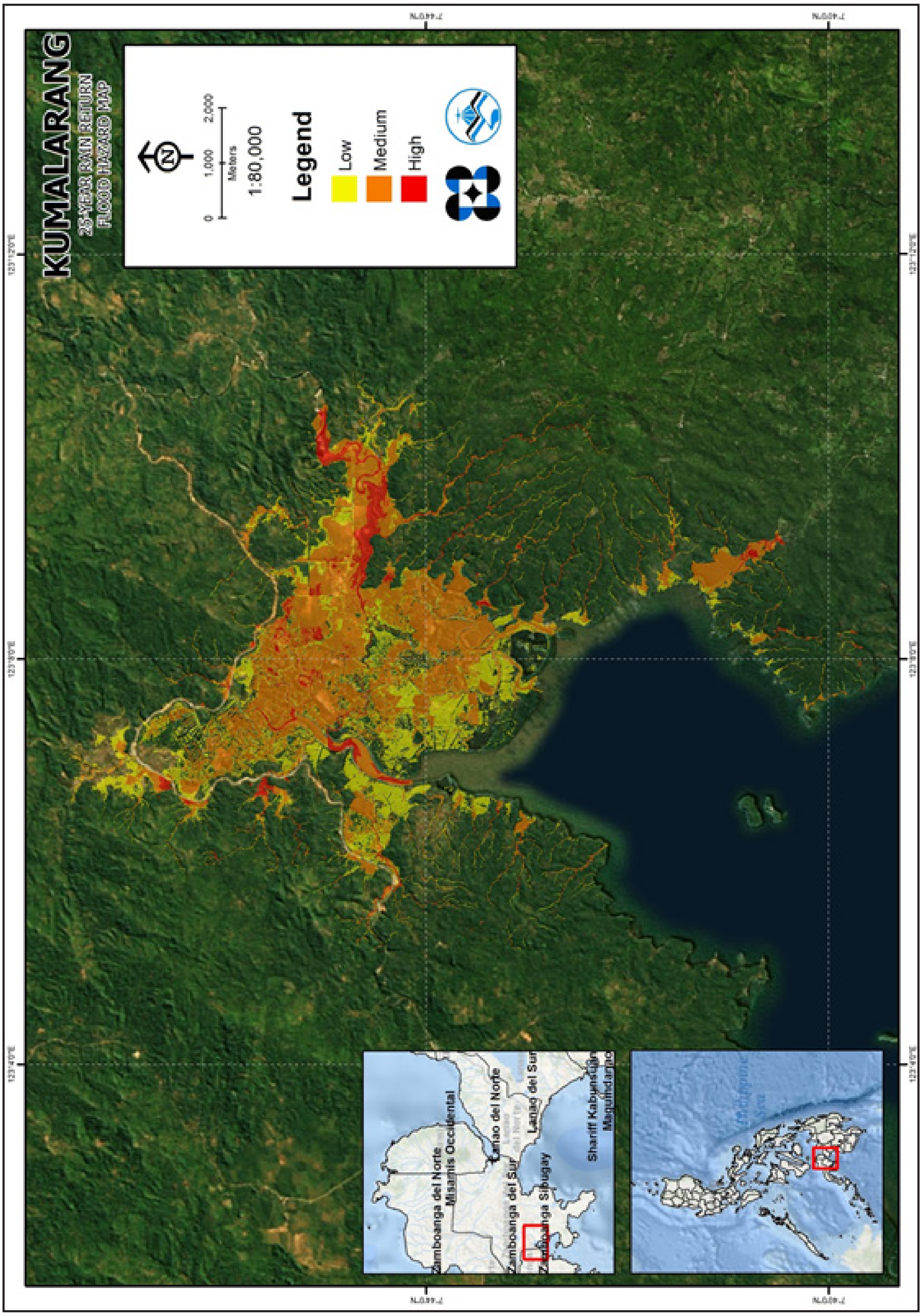


Figure 68. 25-year Rain Return Flood Hazard Map for Kumalarang Floodplain overlaid in Google Earth imagery

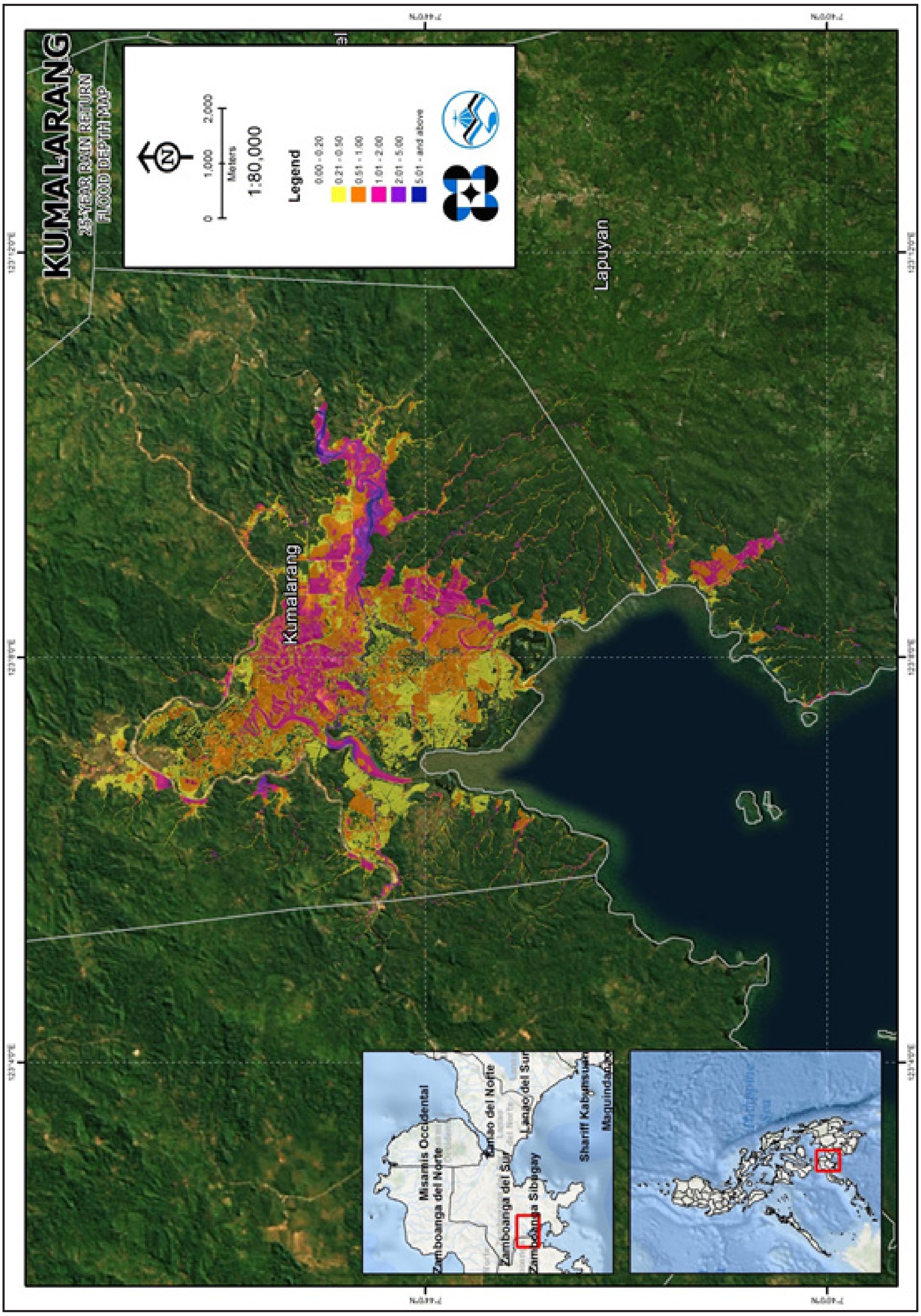


Figure 69. 25-year Rain Return Flood Depth Map for Kumalarang Floodplain overlaid in Google Earth imagery

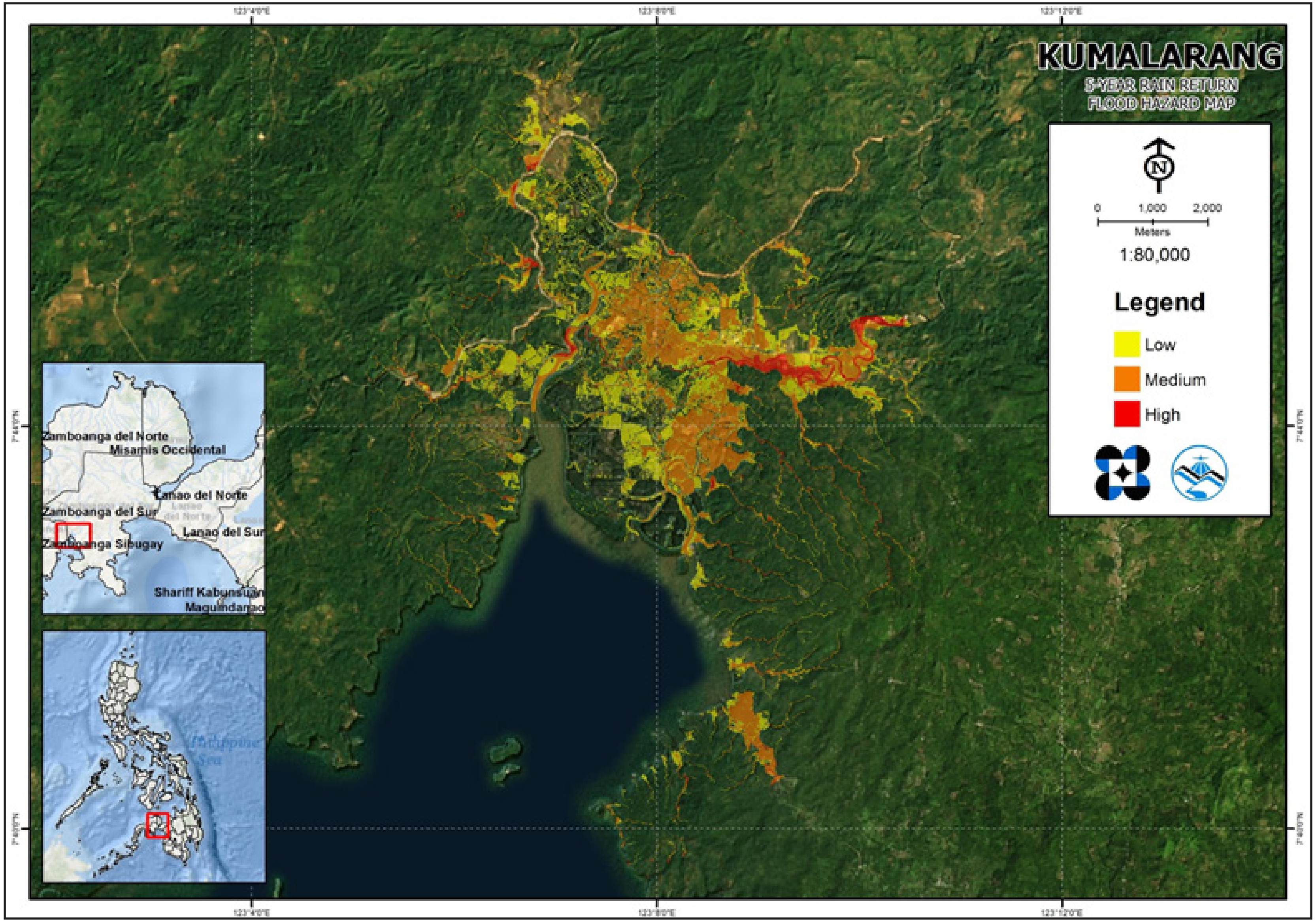


Figure 70. 5-year Rain Return Flood Hazard Map for Kumalarang Floodplain overlaid in Google Earth imagery

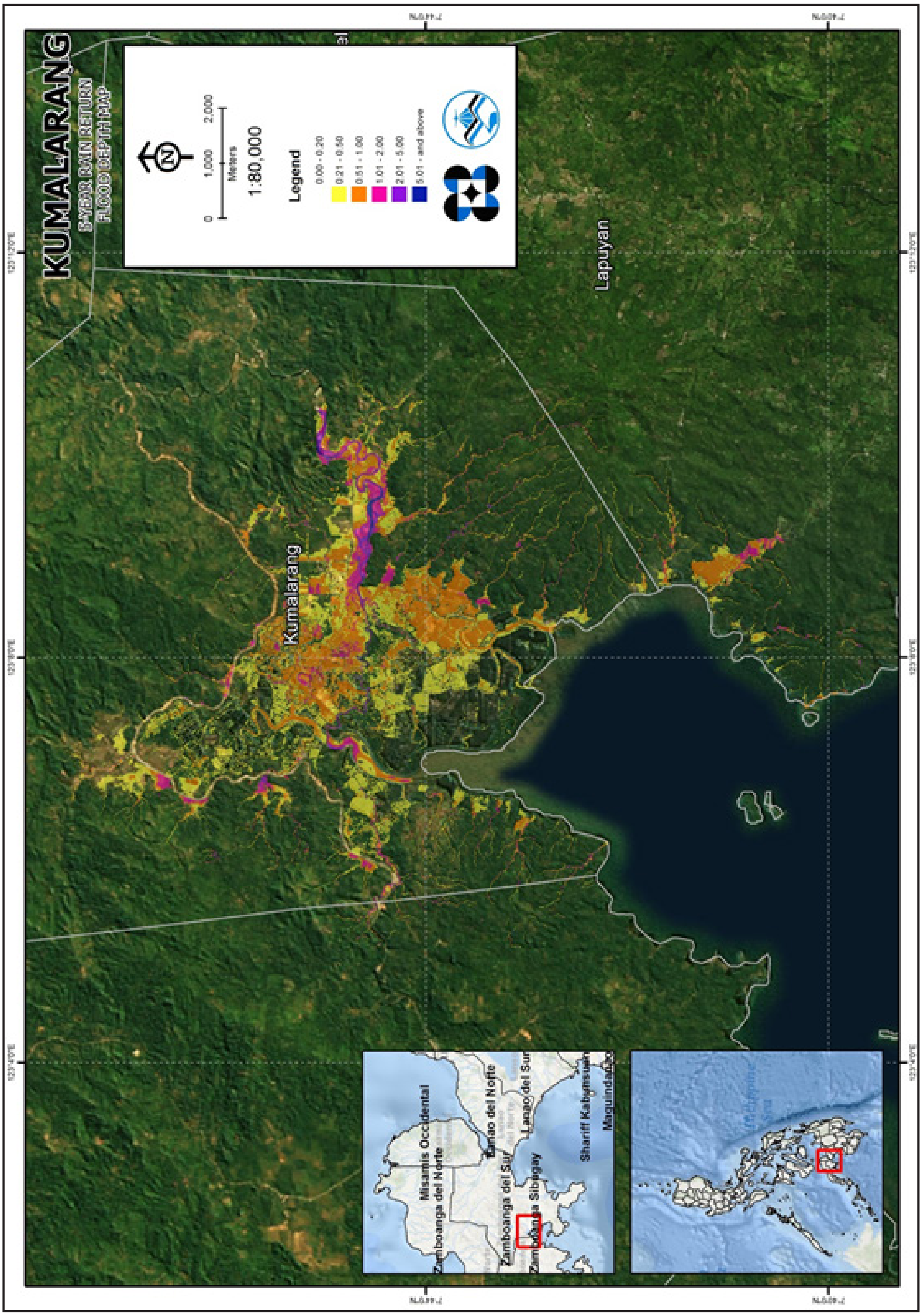


Figure 71. 5-year Rain Return Flood Depth Map for Kumalarang Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Kumalarang river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 19 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 2.12% of the municipality of Buug with an area of 134.89 sq. km. will experience flood levels of less 0.20 meters; 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.01%, and 0.005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Buug, Zamboanga Sibugay during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Buug (in sq. km)		
	Basalem	Bulaan	Guminta
0.03-0.20	0.63	0.5	1.72
0.21-0.50	0.012	0.014	0.036
0.51-1.00	0.0098	0.0095	0.019
1.01-2.00	0.0039	0.0069	0.0086
2.01-5.00	0.0006	0.0038	0.0023
> 5.00	0	0	0

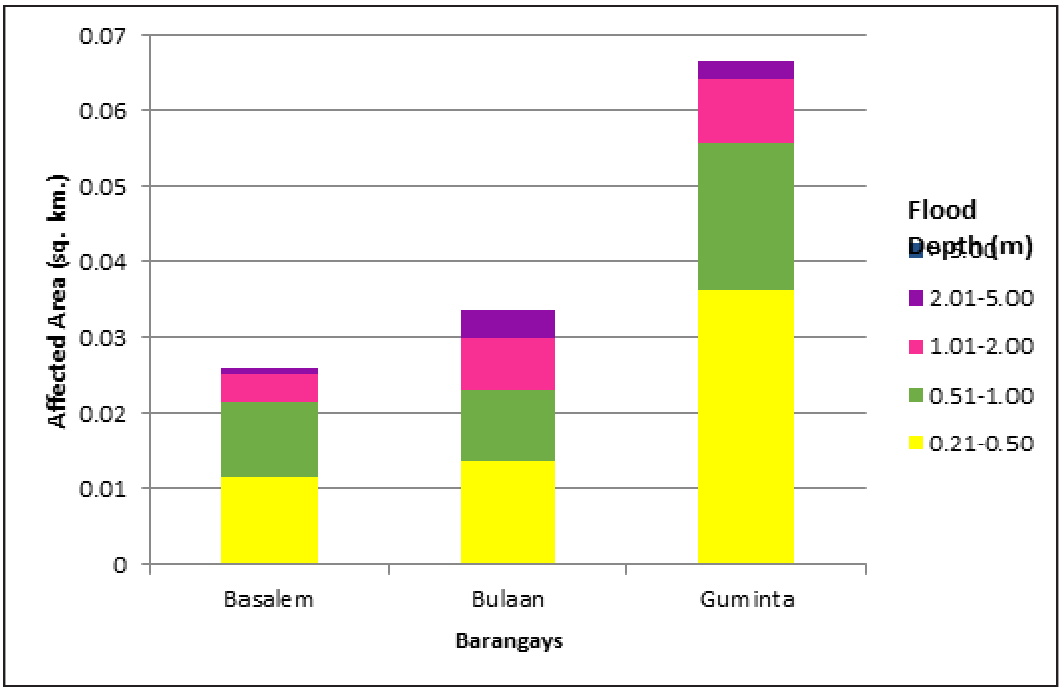


Figure 72. Affected Areas in Buug, Zamboanga Sibugay during 5-Year Rainfall Return Period

For the municipality of Kumalarang, with an area of 143.51 sq. km., 32.15% will experience flood levels of less 0.20 meters; 5.22% of the area will experience flood levels of 0.21 to 0.50 meters while 4.02%, 0.97%, 0.34%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Kumalarang, Zamboanga del Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kumalarang (in sq. km)											
	Bogayo	Bolisong	Boyugan East	Bualan	Diplo	Gawil	Gusom	Lantawan	Pangi	Picanan	Poblacion	Secade
0.03-0.20	4.54	3.19	2.82	12.77	3.55	2.93	1.65	0.0072	4.83	5.61	3.92	0.33
0.21-0.50	0.92	0.22	0.34	1.05	0.45	1.92	0.073	0.0041	0.59	0.87	0.99	0.065
0.51-1.00	0.32	0.08	0.28	1.17	0.45	1.83	0.073	0.00094	0.12	0.3	1.12	0.025
1.01-2.00	0.14	0.022	0.15	0.13	0.052	0.2	0.026	0.00085	0.07	0.1	0.5	0.0055
2.01-5.00	0.033	0.003	0.12	0.023	0.0061	0.066	0.0047	0.00031	0.0034	0.027	0.2	0.0032
> 5.00	0	0	0.015	0	0.0001	0	0	0	0	0.0001	0.059	0

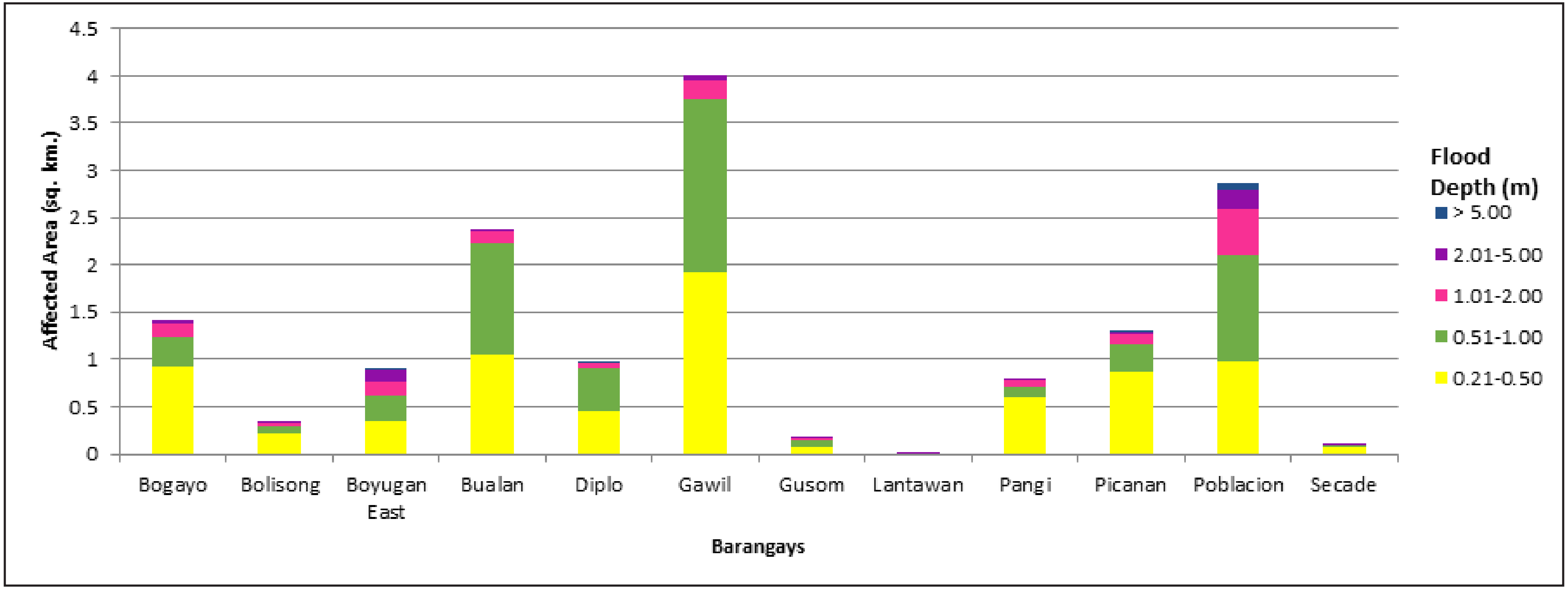


Figure 73. Affected Areas in Kumalarang, Zamboanga del Sur during 5-Year Rainfall Return Period

For the municipality of Lapuyan, with an area of 153.28 sq. km., 5.96% will experience flood levels of less 0.20 meters; 0.32% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.09%, 0.01%, and 0.0001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Lapuyan, Zamboangadel Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lapuyan (in sq. km)			
	Linokmadalum	Mandeg	Maruing	Pingalay
0.03-0.20	3.14	0.52	1.59	3.32
0.21-0.50	0.14	0.011	0.21	0.13
0.51-1.00	0.057	0.0058	0.39	0.08
1.01-2.00	0.02	0.0041	0.083	0.026
2.01-5.00	0.007	0.0016	0.0063	0.0025
> 5.00	0.0002	0	0	0

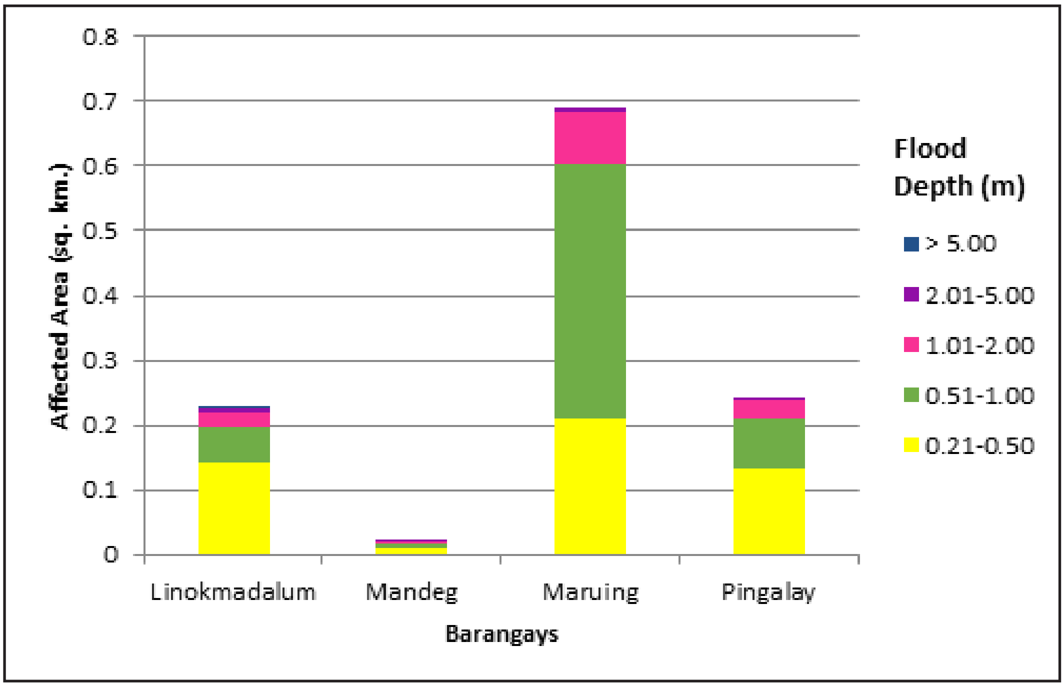


Figure 74. Affected Areas in Lapuyan, Zamboanga del Sur during 5-Year Rainfall Return Period

For the 25-year return period, 2.09% of the municipality of Buug with an area of 134.89 sq. km. will experience flood levels of less 0.20 meters; 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.008%, and 0.00003%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Buug, ZamboangaSibugay during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Buug (in sq. km)		
	Basalem	Bulaan	Guminta
0.03-0.20	0.62	0.49	1.7
0.21-0.50	0.015	0.018	0.043
0.51-1.00	0.011	0.0097	0.021
1.01-2.00	0.0065	0.009	0.012
2.01-5.00	0.001	0.006	0.0038
> 5.00	0	0	0.000034

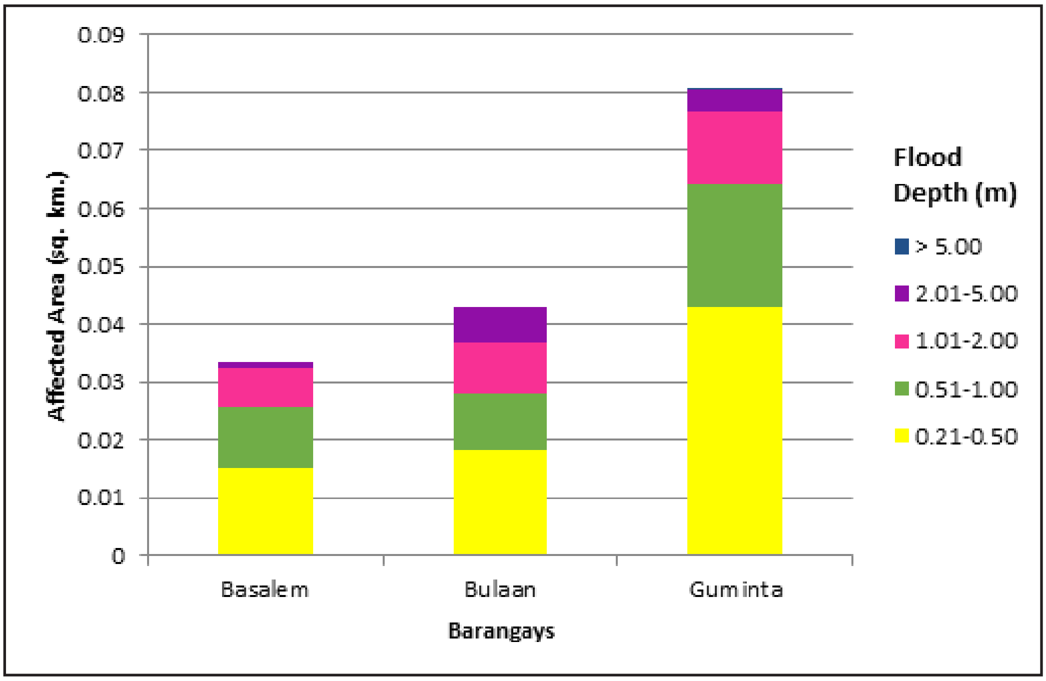


Figure 75. Affected Areas in Buug, Zamboanga Sibugay during 25-Year Rainfall Return Period

For the municipality of Kumalarang, with an area of 143.51 sq. km., 27.36% will experience flood levels of less 0.20 meters; 5.26% of the area will experience flood levels of 0.21 to 0.50 meters while 6.11%, 3.35%, 0.59%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Kumalarang, Zamboangadel Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kumalarang (in sq. km)											
	Bogayo	Bolisong	Boyugan East	Bualan	Diplo	Gawil	Gusom	Lantawan	Pangi	Picanan	Poblacion	Secade
0.03-0.20	3.78	3.08	2.62	11.31	3.11	1.35	1.62	0.0034	4.45	4.42	3.23	0.29
0.21-0.50	1.11	0.27	0.28	1.6	0.29	1.72	0.061	0.0052	0.73	0.83	0.59	0.07
0.51-1.00	0.6	0.11	0.28	1.62	0.57	2.51	0.092	0.0036	0.33	1.27	1.34	0.049
1.01-2.00	0.37	0.037	0.33	0.57	0.55	1.28	0.045	0.00085	0.094	0.34	1.19	0.013
2.01-5.00	0.091	0.0049	0.17	0.047	0.0084	0.077	0.009	0.00031	0.011	0.057	0.37	0.0044
> 5.00	0.0001	0	0.038	0.0001	0.0001	0	0	0	0.0002	0.0001	0.067	0

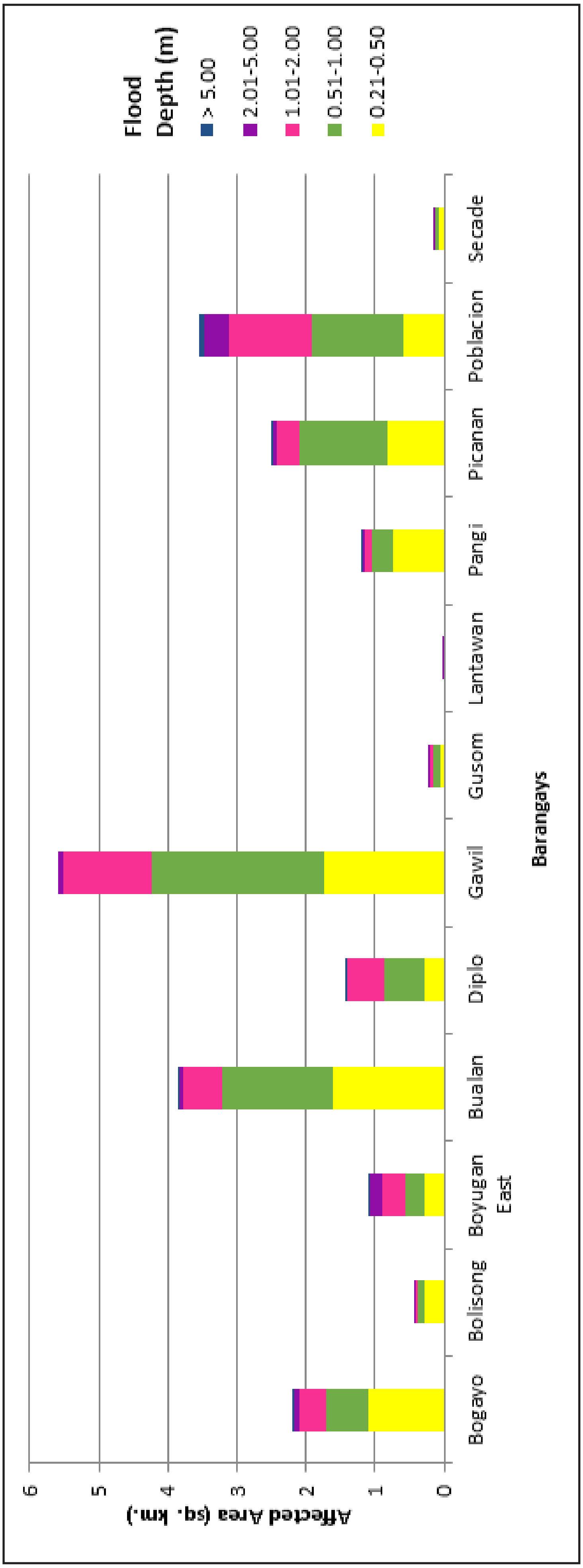


Figure 76. Affected Areas in Kumalarang, Zamboanga del Sur during 25-Year Rainfall Return Period

For the municipality of Lapuyan, with an area of 153.28 sq. km., 5.45% will experience flood levels of less 0.20 meters; 0.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.25%, 0.02%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Lapuyan, Zamboanga del Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lapuyan (in sq. km)			
	Linokmadalum	Mandeg	Maruing	Pingalay
0.03-0.20	3.08	0.52	1.49	3.27
0.21-0.50	0.15	0.013	0.16	0.13
0.51-1.00	0.081	0.0063	0.34	0.11
1.01-2.00	0.039	0.0048	0.28	0.053
2.01-5.00	0.014	0.0027	0.014	0.005
> 5.00	0.0021	0.0001	0	0

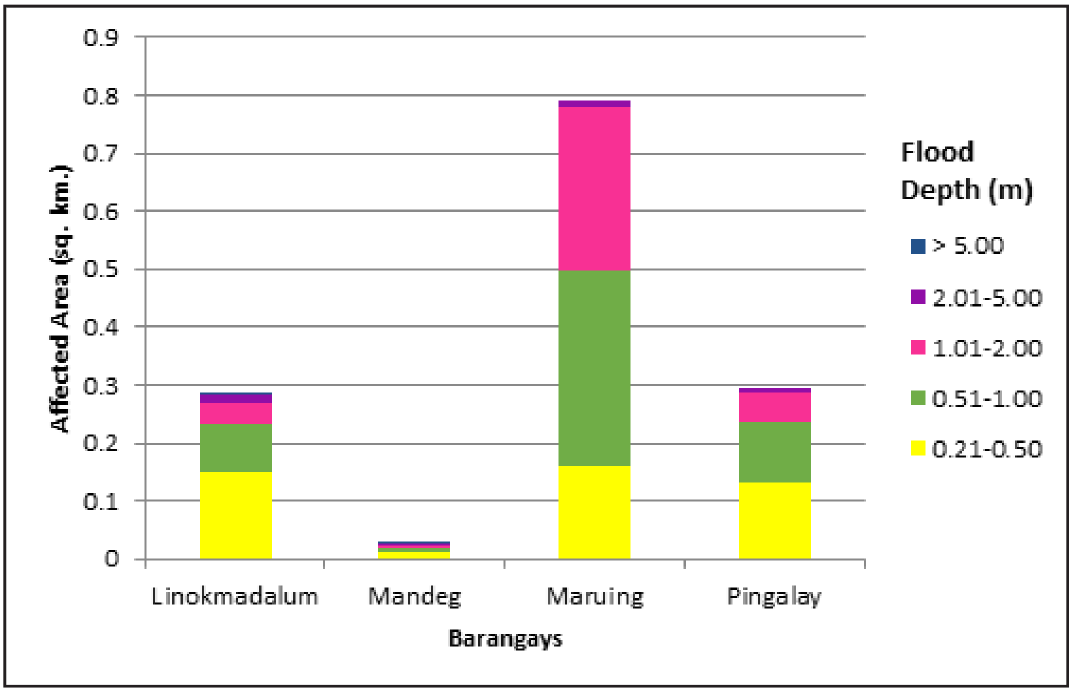


Figure 77. Affected Areas in Lapuyan, Zamboanga del Sur during 25-Year Rainfall Return Period

For the 100-Year return period, 2.08% of the municipality of Buug with an area of 134.89 sq. km. will experience flood levels of less 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.01%, and 0.00003%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Buug, Zamboanga Sibugay during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Buug (in sq. km)		
	Basalem	Bulaan	Guminta
0.03-0.20	0.62	0.49	1.69
0.21-0.50	0.017	0.021	0.047
0.51-1.00	0.011	0.011	0.023
1.01-2.00	0.0079	0.0099	0.016
2.01-5.00	0.0017	0.0077	0.0051
> 5.00	0	0	0.000034

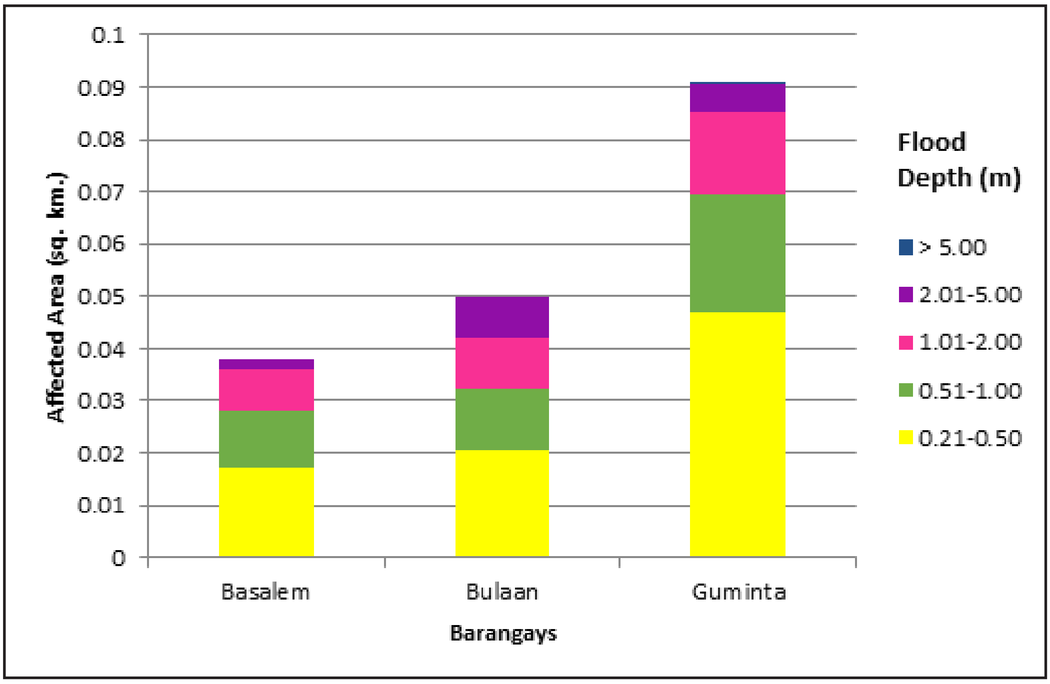


Figure 78. Affected Areas in Buug, Zamboanga Sibugay during 100-Year Rainfall Return Period

For the municipality of Kumalarang, with an area of 143.51 sq. km., 25.54% will experience flood levels of less 0.20 meters; 4.34% of the area will experience flood levels of 0.21 to 0.50 meters while 6.25%, 5.60%, 0.91%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Kumalarang, Zamboangadel Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Kumalarang (in sq. km)											
	Bogayo	Bolisong	Boyugan East	Bualan	Diplo	Gawil	Gusom	Lantawan	Pangi	Picanan	Poblacion	Secade
0.03-0.20	3.51	3.02	2.51	10.61	3.02	0.85	1.6	0.0019	4.22	3.99	3.04	0.27
0.21-0.50	0.93	0.28	0.27	1.54	0.22	1.11	0.056	0.0053	0.77	0.63	0.4	0.051
0.51-1.00	0.87	0.15	0.28	1.88	0.33	2.71	0.074	0.005	0.49	1.11	1	0.073
1.01-2.00	0.44	0.051	0.36	1.03	0.89	2.15	0.077	0.00085	0.12	1.09	1.8	0.024
2.01-5.00	0.21	0.0067	0.24	0.083	0.058	0.12	0.013	0.00041	0.018	0.087	0.46	0.0045
> 5.00	0.0035	0	0.043	0.0007	0.0001	0	0	0	0.0007	0.0006	0.078	0

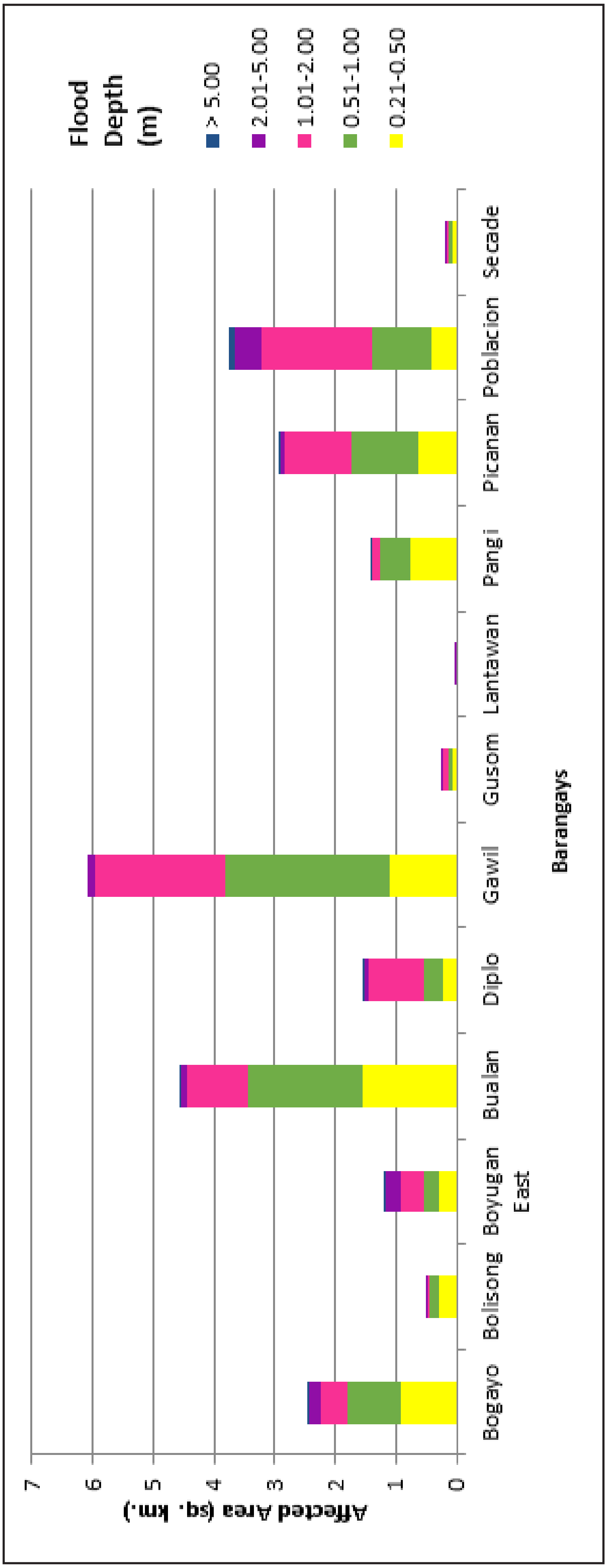


Figure 79. Affected Areas in Kumalarang, Zamboanga del Sur during 100-Year Rainfall Return Period

For the municipality of Lapuyan, with an area of 153.28 sq. km., 5.38% will experience flood levels of less 0.20 meters; 0.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.26%, 0.38%, 0.05%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected Areas in Lapuyan, Zamboanga del Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lapuyan (in sq. km)			
	Linokmadalum	Mandeg	Maruing	Pingalay
0.03-0.20	3.05	0.51	1.44	3.24
0.21-0.50	0.15	0.015	0.16	0.13
0.51-1.00	0.095	0.0077	0.18	0.11
1.01-2.00	0.048	0.0051	0.46	0.07
2.01-5.00	0.018	0.0035	0.045	0.0089
> 5.00	0.0033	0.0001	0	0

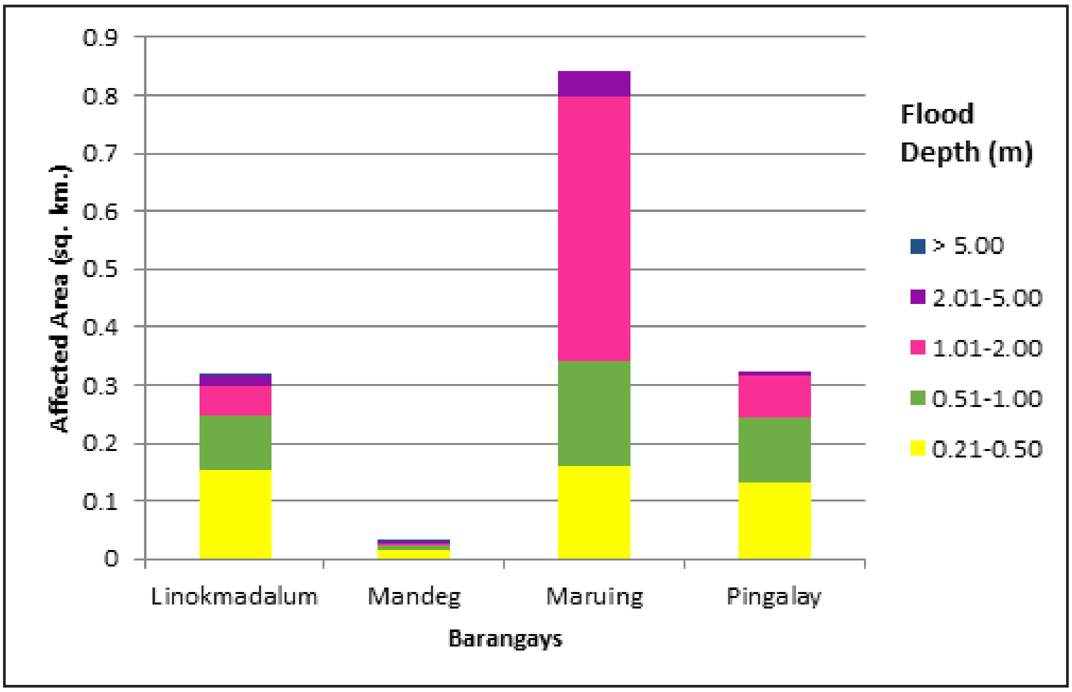


Figure 80. Affected Areas in Lapuyan, Zamboanga del Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Buug, Guminta is projected to have the highest percentage of area that will experience flood levels at 1.32%. Meanwhile, Basalem posted the second highest percentage of area that may be affected by flood depths at 0.49%.

Among the barangays in the municipality of Kumalarang, Bualan is projected to have the highest percentage of area that will experience flood levels at 10.55%. Meanwhile, Gawil posted the second highest percentage of area that may be affected by flood depths at 4.83%.

Among the barangays in the municipality of Lapuyan, Pingalay is projected to have the highest percentage of area that will experience flood levels of at 2.33%. Meanwhile, Linokmadalum posted the percentage of area that may be affected by flood depths of at 2.20%.

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

Table 45. 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	5 year	25 year	100 year
Medium	8.19	8.06	6.80
High	7.60	13.68	15.93
TOTAL	**1.14**	**2.22**	**3.98**

Of the 22 identified education institutions in Kumalarang Flood plain, 6 schools were assessed to be exposed to the Low level flooding during a 5-year scenario while 2 schools were assessed to be exposed to Medium level flooding. In the 25-year scenario, 3 schools were assessed to be exposed to the Low level flooding while 8 schools were assessed to be exposed to Medium level flooding. For the 100-year scenario, 2 schools were assessed for Low level flooding and 9 schools for Medium level flooding. See Annex 12 for a detailed enumeration of schools inside Kumalarang Floodplain.

Of the 5 identified medical institutions in Kumalarang Floodplain, none were assessed to be exposed to the any level of flooding during a 5 year scenario. In the 25 and 100 year scenario, 2 were assessed to be exposed to the Low level flooding while one was assessed to be exposed to Medium level flooding. See Apppendix E for a detailed enumeration of medical institutions inside Kumalarang Floodplain.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.The points in the flood map versus its corresponding validation depths are shown in Figure 82.

The flood validation consists of 215 points randomly selected all over the Kumalarang Floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.52m. Table 46 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

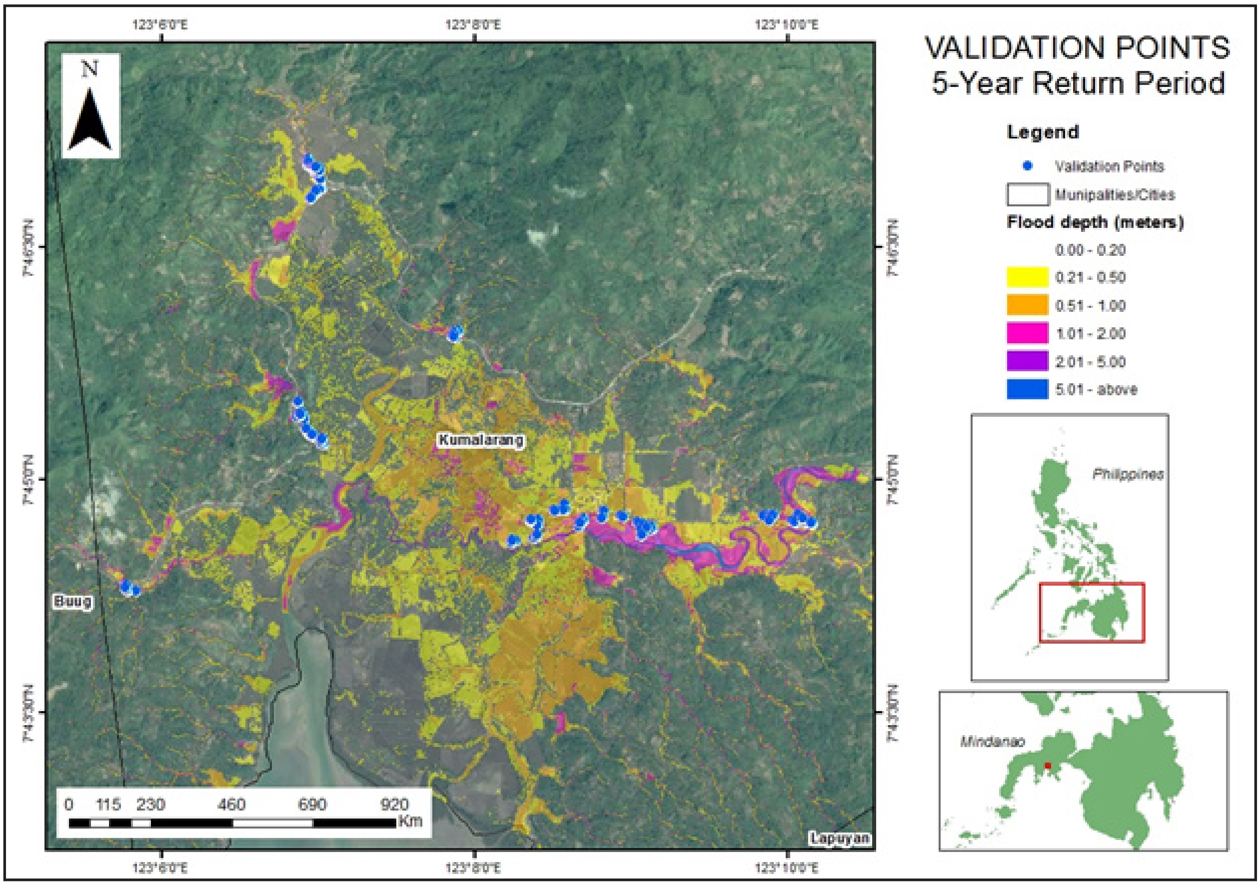


Figure 81. Validation points for 5-year Flood Depth Map of Kumalarang Floodplain

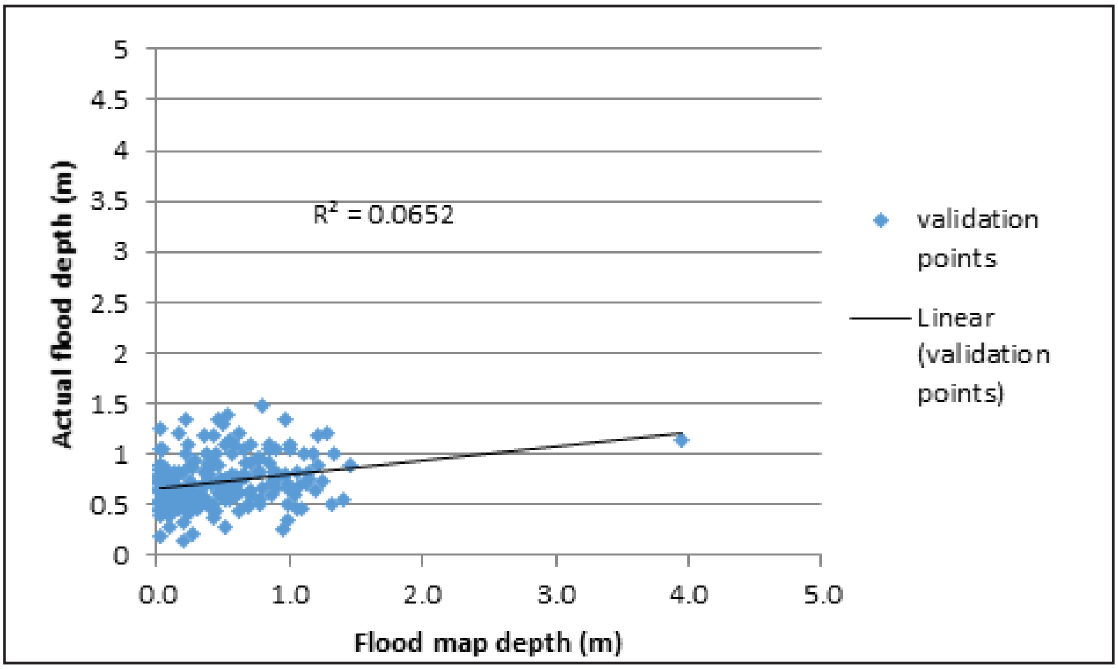


Figure 82. Flood map depth vs actual flood depth

Table 46. Actual flood depth vs. simulated flood depth in the Kumalarang River Basin

Actual Flood Depth (m)	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
0-0.20	2	0	0	0	0	0	2
0.21-0.50	17	11	8	3	0	0	39
0.51-1.00	55	35	43	14	0	0	147
1.01-2.00	4	6	14	2	1	0	27
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	78	52	65	19	1	0	215

The overall accuracy generated by the flood model is estimated at 26.98%, with 58 points correctly matching the actual flood depths. In addition, there were 89 points estimated one level above and below the correct flood depths while there were 64 points and 4 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 26 points were overestimated while a total of 131 points were underestimated in the modelled flood depths of Kumalarang.

Table 47. Summary of Accuracy Assessment in the Kumalarang RIver Basin Survey

	No. of Points	%
Correct	58	26.98
Overestimated	26	12.09
Underestimated	131	60.93
Total	215	100

REFERENCES

Ang M.C., 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.C., Lagmay, A.F., 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.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition 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 Kumalarang Floodplain Survey

Table 1: Technical Specifications of the LiDAR Sensors Used in the Kumalarang Floodplain Survey

Figure A-1.1. Pegasus Sensor

Table A-1.1 Parameters and Specifications

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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20˚

4 Target size ≥ laser footprint5 Dependent on system configuration

Table A-1.2. Technical specifications of the D-8900 Aerial Digital Camera

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

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

1. ZGN-138

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

October 30, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL NORTE**
Station Name: **ZGN-138**
Order: **2nd**

Island: **MINDANAO**	Barangay:	
Municipality: **KATIPUNAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 30' 40.65974"**	Longitude: **123° 18' 14.44217"**	Ellipsoidal Hgt: **6.71500 m.**
	WGS84 Coordinates	
Latitude: **8° 30' 36.94779"**	Longitude: **123° 18' 19.85548"**	Ellipsoidal Hgt: **70.92500 m.**
	PTM / PRS92 Coordinates	
Northing: **941106.14 m.**	Easting: **533471.036 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **940,776.74**	Easting: **533,459.32**	Zone: **51**

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGN-138, 2009 NAMRIA".Located at brgy. Taga katipunan zamboanga del norte. The monument is situated inside taga central school 10 meters from the main gate going north west 6 meters from the flag pole going south east.

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2584**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 ZGN-138

2. ZGS-58

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

February 24, 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: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-58**
Order: **2nd**

Island: **MINDANAO**	Barangay: **SICADE**	
Municipality: **KUMALARANG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **7° 45' 44.20587"**	Longitude: **123° 8' 50.40994"**	Ellipsoidal Hgt: **31.65000 m.**
	WGS84 Coordinates	
Latitude: **7° 45' 40.67639"**	Longitude: **123° 8' 55.89231"**	Ellipsoidal Hgt: **96.97400 m.**
	PTM / PRS92 Coordinates	
Northing: **858266.608 m.**	Easting: **516251.478 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **857,966.20**	Easting: **516,245.79**	Zone: **51**

Location Description

ZGS-58
Is located about 200 m. NNE of the intersection of the national highway and the road going to Poblacion, Kumalarang. It is about 190 m. NE of the PNP Checkpoint and Collection post, 190 m. NNE of a waiting shed and 400 m. NNE of ZGS-59. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-58 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0411**

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

9902242016140321

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 ZGS-58

3. ZGS-68

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

February 10, 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: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-68**
Order: **2nd**

Island: **MINDANAO**	Barangay: **POBLACION**		
Municipality: **GUIPOS**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **7° 43' 33.12722"**	Longitude: **123° 18' 48.96041"**	Ellipsoidal Hgt:	**205.94100 m.**
	WGS84 Coordinates		
Latitude: **7° 43' 29.62251"**	Longitude: **123° 18' 54.44472"**	Ellipsoidal Hgt:	**271.74800 m.**
	PTM / PRS92 Coordinates		
Northing: **854250.138 m.**	Easting: **534593.845 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **853,951.14**	Easting: **534,581.74**	Zone:	**51**

Location Description

ZGS-68
Is located on the lot of the CENRO of Guipos. It is on the E end of the S sidewalk along the entrance way of CENRO from the national road, 15 m. E of the said office and 2.5 m. from the centerline of the driveway. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-68 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0335**

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

9902102016122229

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. ZGS-68

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

1. ZGS-5588

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZGS-68 --- ZGS-5588A (B2)	ZGS-68	ZGS-5588A	Fixed	0.048	0.096	26°57'51"	11406.526	53.359
ZGS-68 --- ZGS-5588B (B1)	ZGS-68	ZGS-5588B	Fixed	0.025	0.077	26°57'52"	11406.521	53.410

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	ZGS-68				
Grid		Local		Global	
Easting	534581.737 m	Latitude	N7°43'33.12723"	Latitude	N7°43'29.62251"
Northing	853951.136 m	Longitude	E123°18'48.96041"	Longitude	E123°18'54.44472"
Elevation	202.869 m	Height	206.940 m	Height	271.748 m

To:	ZGS-5588A				
Grid		Local		Global	
Easting	539744.331 m	Latitude	N7°49'04.07222"	Latitude	N7°49'00.54754"
Northing	864117.593 m	Longitude	E123°21'37.77947"	Longitude	E123°21'43.25601"
Elevation	256.251 m	Height	259.299 m	Height	325.044 m

Vector					
ΔEasting	5162.594 m	NS Fwd Azimuth	26°57'51"	ΔX	-3594.901 m
ΔNorthing	10166.457 m	Ellipsoid Dist.	11406.526 m	ΔY	-3947.104 m
ΔElevation	53.392 m	ΔHeight	53.359 m	ΔZ	10080.574 m

Standard Errors

Vector errors:					
σ ΔEasting	0.019 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.033 m
σ ΔNorthing	0.012 m	σ Ellipsoid Dist.	0.012 m	σ ΔY	0.040 m
σ ΔElevation	0.048 m	σ ΔHeight	0.048 m	σ ΔZ	0.015 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0010645478		
Y	-0.0009257641	0.0015799237	
Z	-0.0001544829	0.0003190727	0.0002122076

Figure A-3.1 ZGS-5588

2. ZN-53

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
zgn 138 --- zn 53 am (B1)	zgn 138	zn 53 am	Fixed	0.001	0.002	344°25'59"	12.263	0.357
zgn 138 --- zn 53 pm (B2)	zgn 138	zn 53 pm	Fixed	0.003	0.004	344°25'44"	12.270	0.372

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	zgn 138				
Grid		Local		Global	
Easting	533459.321 m	Latitude	N8°30'40.65974"	Latitude	N8°30'36.94779"
Northing	940776.736 m	Longitude	E123°18'14.44217"	Longitude	E123°18'19.85548"
Elevation	5.484 m	Height	6.715 m	Height	70.925 m

To:	zn 53 am				
Grid		Local		Global	
Easting	533456.022 m	Latitude	N8°30'41.04428"	Latitude	N8°30'37.33230"
Northing	940788.542 m	Longitude	E123°18'14.33457"	Longitude	E123°18'19.74787"
Elevation	5.842 m	Height	7.072 m	Height	71.282 m

Vector					
ΔEasting	-3.299 m	NS Fwd Azimuth	344°25'59"	ΔX	3.517 m
ΔNorthing	11.806 m	Ellipsoid Dist.	12.263 m	ΔY	0.641 m
ΔElevation	0.358 m	ΔHeight	0.357 m	ΔZ	11.736 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'09"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000005629		
Y	-0.0000004033	0.0000010310	
Z	-0.0000000776	0.0000001462	0.0000001693

Figure A-3.2 ZN-53

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader - I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="6">LiDAR Operation</td><td rowspan="2">Senior Science Research Specialist (SSRS)</td><td>ENGR. GEROME HIPOLITO</td><td>UP-TCAGP</td></tr>
<tr><td>PAULINE JOANNE ARCEO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="4">Research Associate (RA)</td><td>ENGR. KENNETH QUISADO</td><td>UP-TCAGP</td></tr>
<tr><td>ENGR. GRACE SINADJAN</td><td>UP-TCAGP</td></tr>
<tr><td>ENGR. GEF SORIANO</td><td>UP-TCAGP</td></tr>
<tr><td>JERIEL PAUL ALAMBAN,GEOL.</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Ground Survey, Data Download and Transfer</td><td rowspan="2">RA</td><td>JASMIN DOMINGO</td><td>UP-TCAGP</td></tr>
<tr><td>MERLIN FERNANDO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="6">LiDAR Operation</td><td rowspan="2">Airborne Security</td><td>SSG. LEEJAY PUNZALAN</td><td rowspan="2">PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td>SSG. GERONIMO BALICOW III</td></tr>
<tr><td rowspan="4">Pilot</td><td>CAPT. SHERWIN CESAR ALFONSO</td><td rowspan="4">ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. JERICO JECIEL</td></tr>
<tr><td>CAPT. ERNESTO SAYSAY</td></tr>
<tr><td>CAPT. ANTON DAYO</td></tr>
</table>

Annex 5. Data Transfer Sheet Kumalarang Floodplain

DATA TRANSFER SHEET
Pagadian 2/19/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6-Feb	23062	1BLK76F037A	PEGASUS	268	NA	4.12	143	11.9	96.9	6.97	NA	57.2	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
7-Feb	23064	1BLK76EF038A	PEGASUS	1.95	NA	10.2	270	12.1	92.1	20.2	NA	5.13	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
7-Feb	23066	1BLK76F038B	PEGASUS	750	NA	4.63	99.8	2.76	20.5	7.2	NA	5.13	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
9-Feb	23072	1BLK76EF040A	PEGASUS	2.84	NA	12.5	208	38.7	291	26.6	NA	146	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
9-Feb	23074	1BLK76EFH040B	PEGASUS	1.56	NA	6.64	163	20.6	167	15.4	NA	145	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
10-Feb	23076	1BLK76GH041A	PEGASUS	3.3	NA	14.4	278	49.7	376	32.7	NA	152	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
10-Feb	23078	1BLK76DI041B	PEGASUS	1.33	NA	6.57	159	17.8	151	13	NA	152	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
11-Feb	23080	1BLK76AB042A	PEGASUS	1.2	NA	9.56	233	22.1	177	16	NA	100	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
11-Feb	23082	1BLK76CDs042B	PEGASUS	990	NA	5.11	144	12.9	111	9.66	NA	100	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA

Received from

Name C. J. Sayson-Lili
Position
Signature

Received by

Name AC Bongat
Position SSRS
Signature 2/22/16

16-12

Figure A-5.1. Transfer Sheet for Kumalarang Floodplain (A)

DATA TRANSFER SHEET
DIPOLOG 12/8/2016

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	
November 28, 2016	23590P	1BLK73DEF333A	PEGASUS	1.56	NA	7.69	203	32.6	298	16.6	NA	42.3	1KB	1KB	1.19	NA	Z:\DAC\RAW DATA
November 30, 2016	23598P	1BLK76A335A	PEGASUS	600	NA	6.93	239	NA	NA	7.85	NA	48.2	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA
December 01, 2016	23602P	1BLK76AB336A	PEGASUS	1.56	NA	9.08	287	NA	NA	16.5	NA	53.9	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

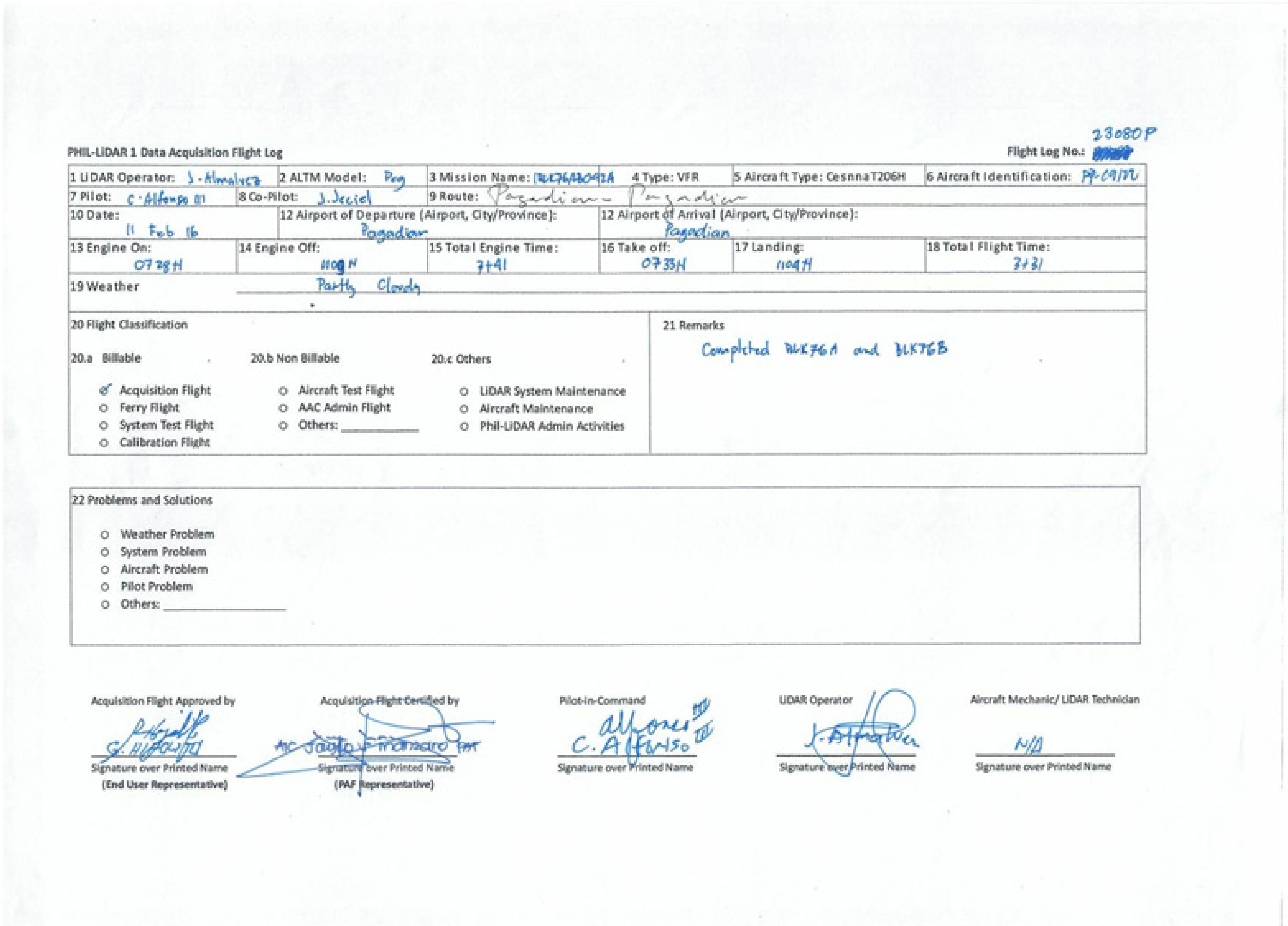
Received by

Name AC Bongat
Position SSRS
Signature 12/8/16

Figure A-5.2. Transfer Sheet for Kumalarang Floodplain (B)

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 23080PMission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23080P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: 1BLK76AB042A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jeciel	9 Route: Pagadian – Pagadian			
10 Date: 11 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0728H	14 Engine Off: 1109H	15 Total Engine Time: 3+41	16 Take off: 0733H	17 Landing: 1104H	18 Total Flight Time: 3+31
19 Weather	Partly Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Completed BLK76A and BLK76B

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	C. Alfonso III — Signature over Printed Name	J. Almalvez — Signature over Printed Name	N/A — Signature over Printed Name

Figure A-6.1 Flight Log for 23080PMission

2. Flight Log for 23140P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: K Quisado	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/26/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del sur		
13 Engine On: 9:15	14 Engine Off: 13:50	15 Total Engine Time: 4+35	16 Take off: 9:20	17 Landing: 13:45	18 Total Flight Time: 4+25
19 Weather	Fair to Partly Cloudy				

20 Flight Classification

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

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

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

21 Remarks

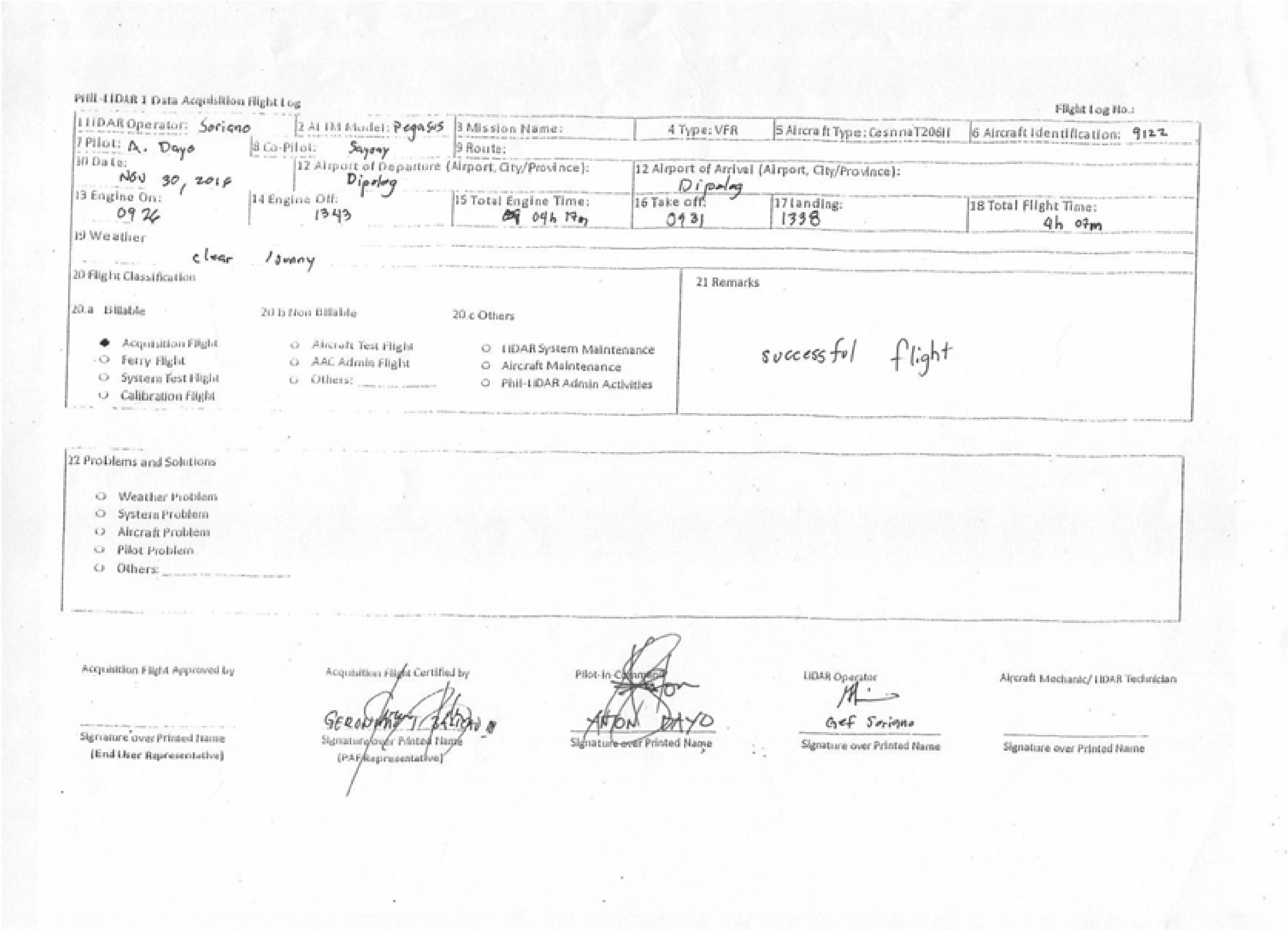
Successful flight

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. [illegible]	LEE J. [illegible]	C. Alonso III	Kenneth Quisado	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for 23140P Mission

3. Flight Log for 23598PMission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: Soriano	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. Dayo	8 Co-Pilot: Sayoay	9 Route:			
10 Date: NOV 30, 2016	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 0926	14 Engine Off: 1343	15 Total Engine Time: 04h 17m	16 Take off: 0931	17 Landing: 1338	18 Total Flight Time: 4h 07m
19 Weather: clear / sunny					

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

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
	GERONIMO T. BALLON III	ANTON DAYO	Gef Soriano	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for 23598PMission

4. Flight Log for 23602P Mission

Phil-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LIDAR Operator: RJ ARCEO | 2 ALTM Model: PEGASUS | 3 Mission Name: | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9122

7 Pilot: A DAYO | 8 Co-Pilot: E CAYSAY JR | 9 Route:

10 Date: 12/09/2016 | 12 Airport of Departure (Airport, City/Province): DIPOLOG | 12 Airport of Arrival (Airport, City/Province): DIPOLOG

13 Engine On: 0839H | 14 Engine Off: 1314H | 15 Total Engine Time: 4+35 | 16 Take off: 0844H | 17 Landing: 1309H | 18 Total Flight Time: 4+25

19 Weather: CLOUDY

20 Flight Classification

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

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

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

21 Remarks

COMPLETED BLK 76A AND BLK 71A OVER KUMALARANG AND KAPATAGAN.

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

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

Acquisition Flight Certified by
GERONIMO BALICAO III
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
ANTON DAYO
Signature over Printed Name

LIDAR Operator
RJ ARCEO
Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name

Figure A-6.4 Flight Log for 23602P Mission

Annex 7. Flight Status Report

FLIGHT STATUS REPORT
Zamboanga-Zamboanga Sibugay
February 4-March 4, 2016; November 18-December 2, 2016

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23080P	BLK76A, B	1BLK76AB042A	J. ALMALVEZ	Feb. 11, 2015	COMPLETED BLK76A AND 76B; SOUTHERN PART IS WATER
23140P	BLK 73B, 72A, 70A	1BLK73BS057A	K QUISADO	FEB 26, 2016	ENCOUNTERED LOST CHANNEL A. COMPLETED BLK73B AND VOIDS OVER BLK72A AND 70A
23598P	KUMALARANG BLK 76A	1BLK76A335A	G. SORIANO	NOV.30, 2016	SURVEYED KUMALARANG FLOODPLAIN
23602P	KUMALARANG KAPATAGAN BLK 76A, 71A	1BLK76AB336A	PJ ARCEO	DEC.1, 2016	COMPLETED KUMALARANG FLOODPLAIN AND VOIDS OVER KAPATAGAN FLOODPLAIN

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No.: 23080P
Area: BLK A, B
Mission Name: 1BLK76AB042A
Parameters: Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50

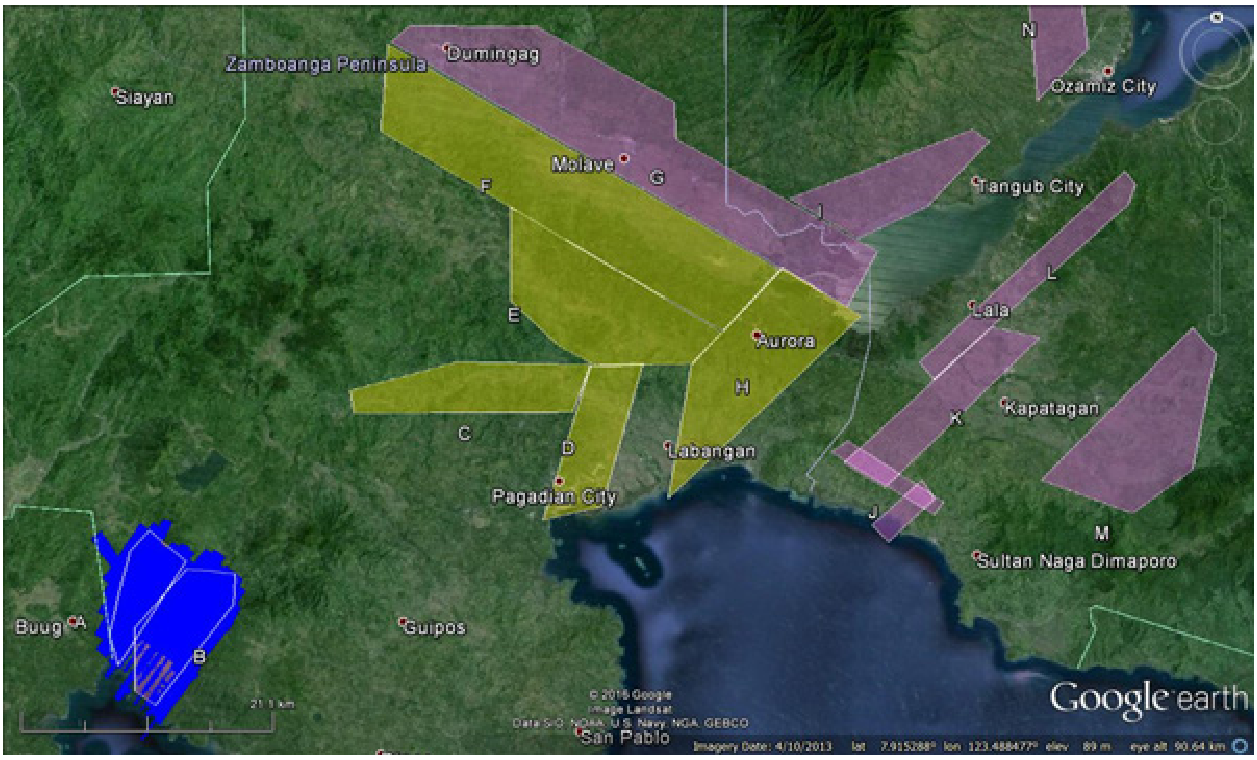


Figure A-7.1. Swath Coverage of Mission 1BLK76AB042A

Flight No.:	23080P
Area:	BLK A, B
Mission Name:	1BLK76AB042A
Parameters:	Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50

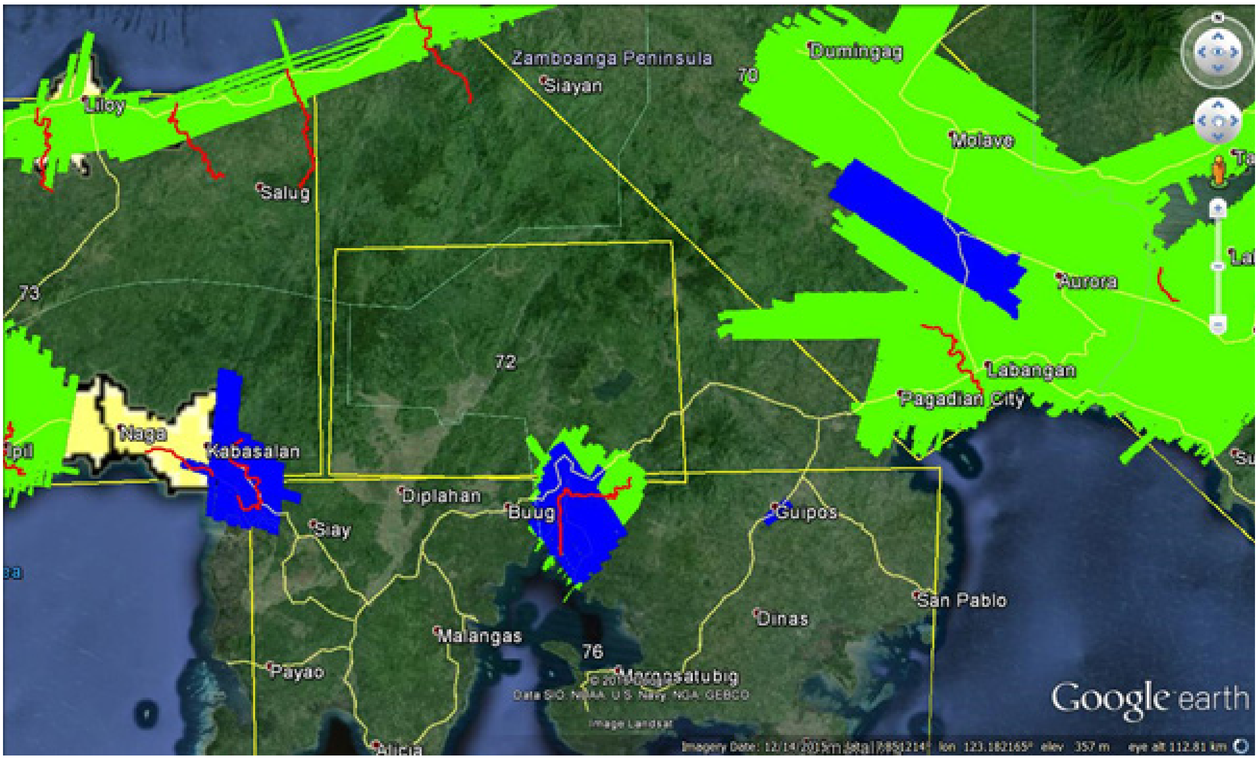


Figure A-7.2. Swath Coverage of Mission 1BLK73BS057A

Flight No. :	23598P
Area:	KUMALARANG;BLK 76A
Mission Name:	1BLK76A335A
Parameters:	Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50

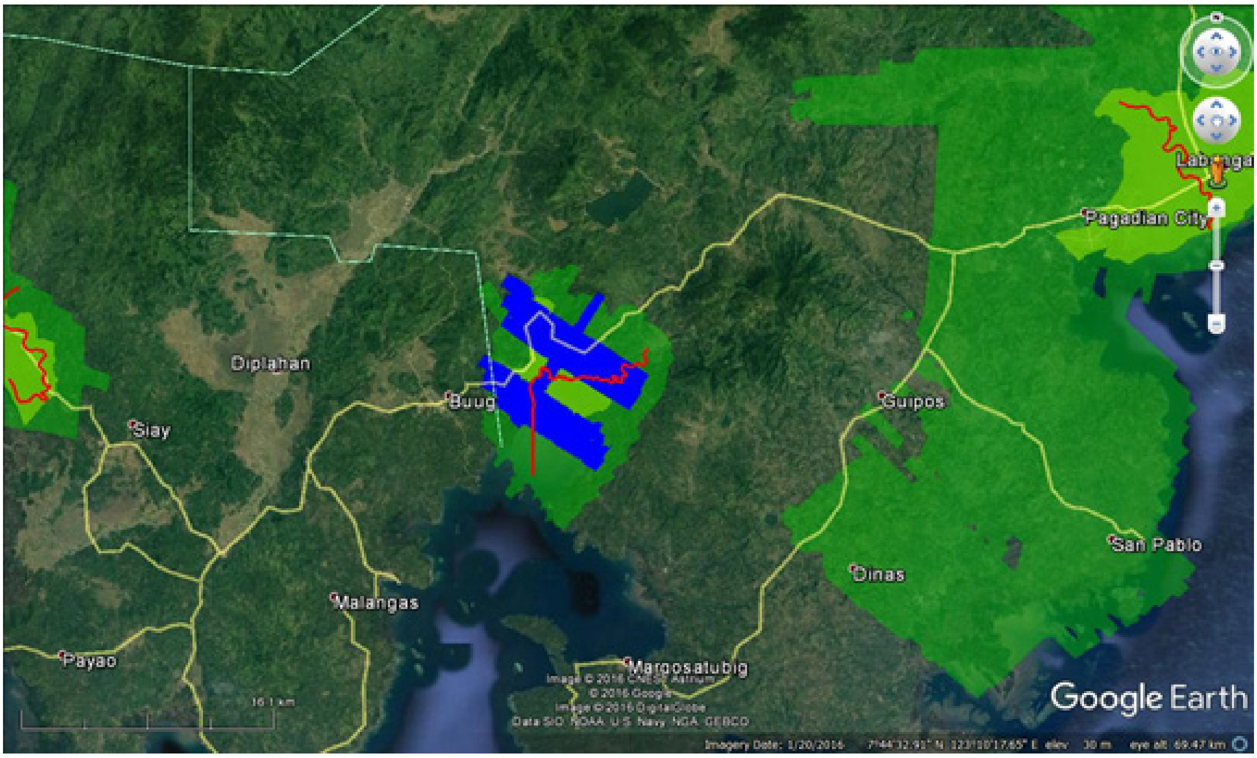


Figure A-7.3. Swath Coverage of Mission 1BLK76A335A

Flight No. :	235602P
Area:	KUMALARANG, KAPATAGAN,BLK 76A, 71A
Mission Name:	1BLK76AB336A
Parameters:	Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50

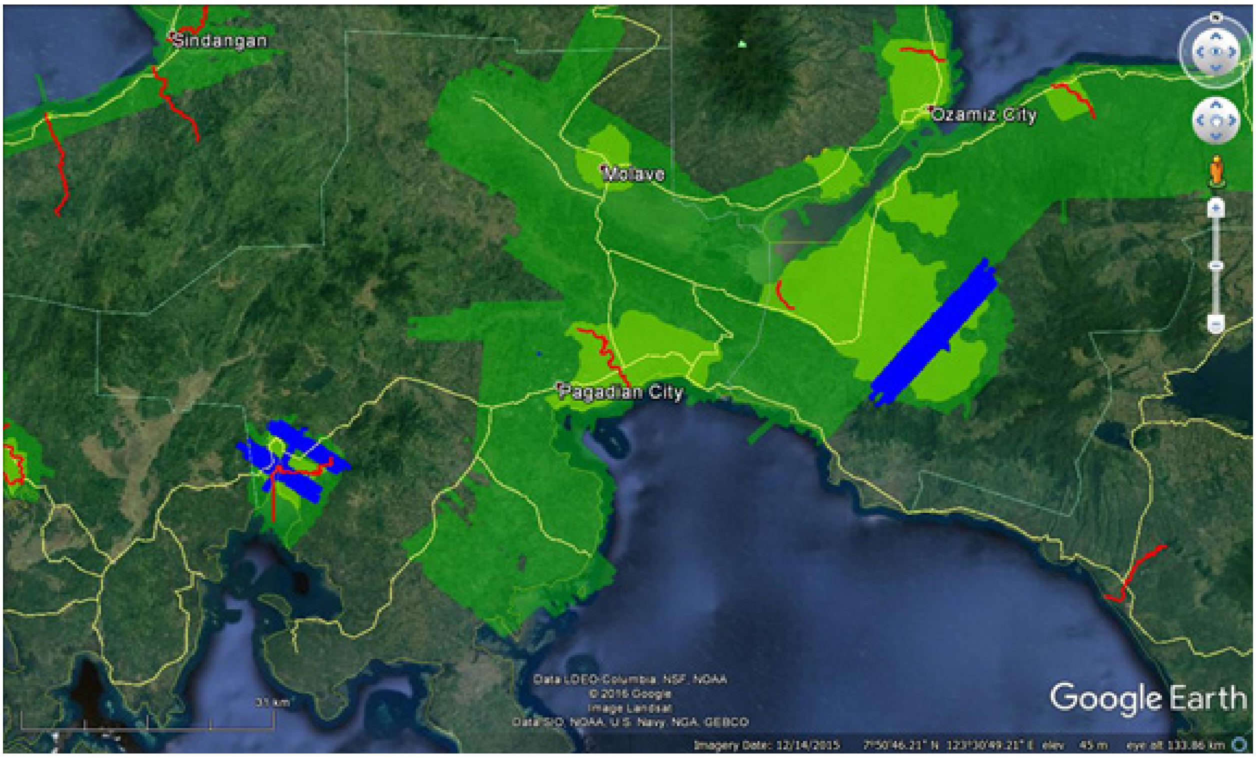


Figure A-7.4. Swath Coverage of Mission 1BLK76AB336A

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission 76AB

Flight Area	Pagadian
Mission Name	76AB
Inclusive Flights	23140P
Range data size	26.5
POS data size	305
Base data size	65.9
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	8.4
RMSE for East Position (<4.0 cm)	6.9
RMSE for Down Position (<8.0 cm)	1.6
Boresight correction stdev (<0.001deg)	0.000264
IMU attitude correction stdev (<0.001deg)	0.000999
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	38.45
Ave point cloud density per sq.m. (>2.0)	2.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	113
Maximum Height	581.36 m
Minimum Height	67.58 m
Classification (# of points)	
Ground	66,486,516
Low vegetation	49,707,693
Medium vegetation	79,888,737
High vegetation	165,544,331
Building	1,581,356
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Jovelle Anjeanette Canlas, Jovy Narisma

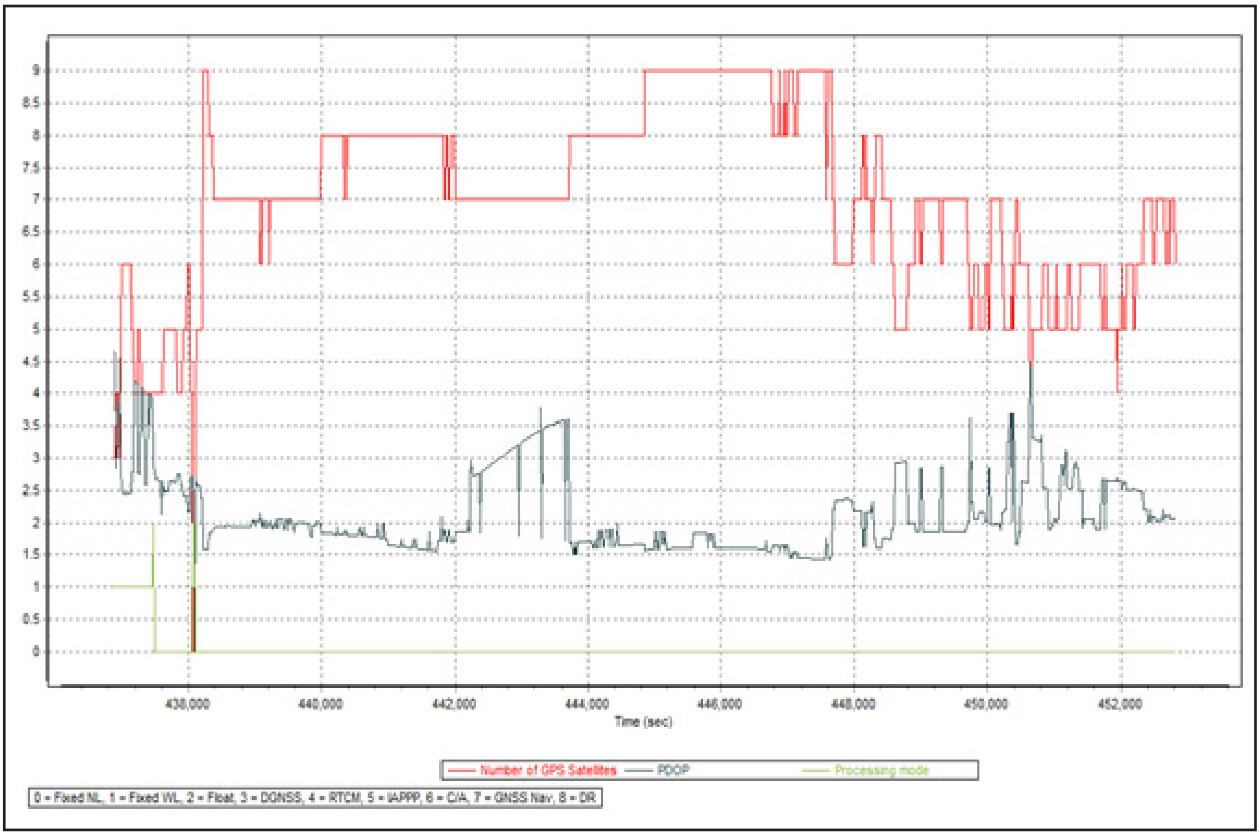


Figure A-8.1 Solution Status

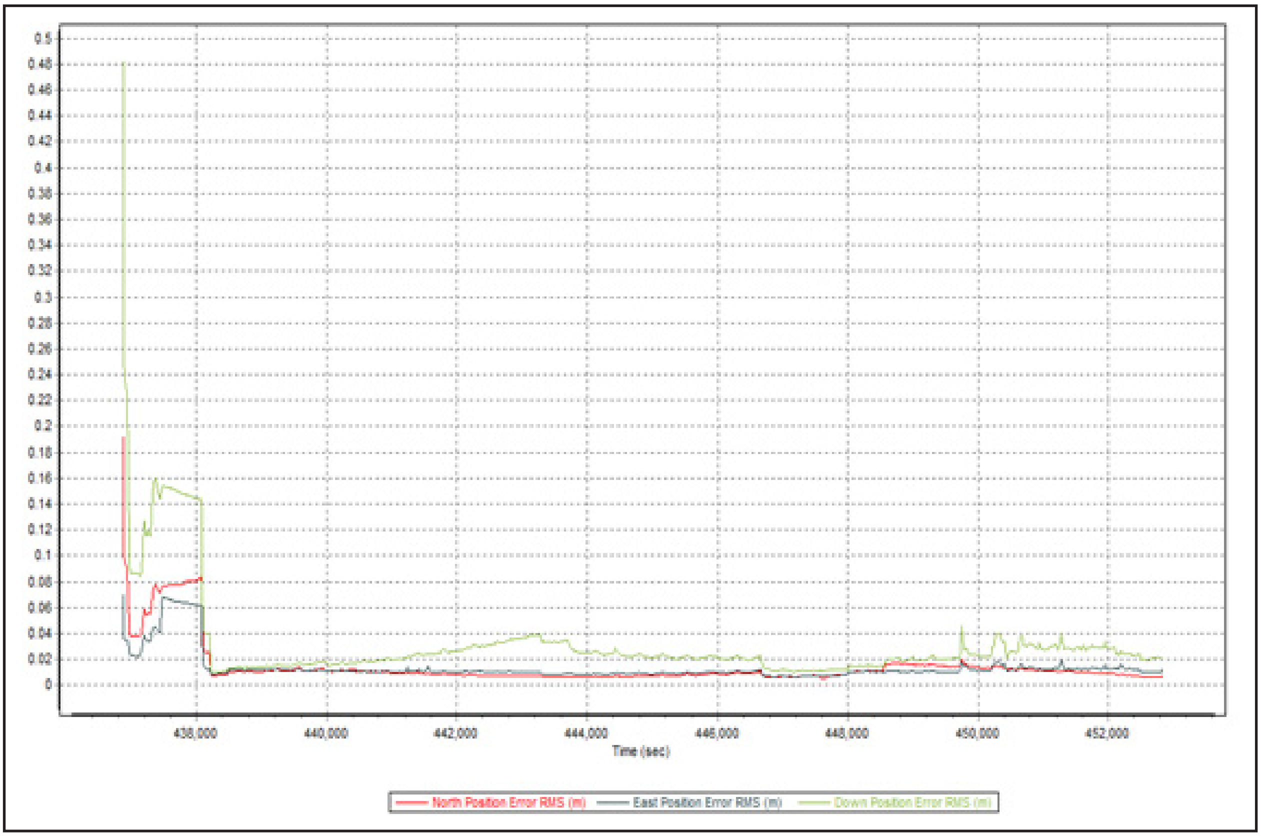


Figure A-8.2 Smoothed Performance Metric Parameters

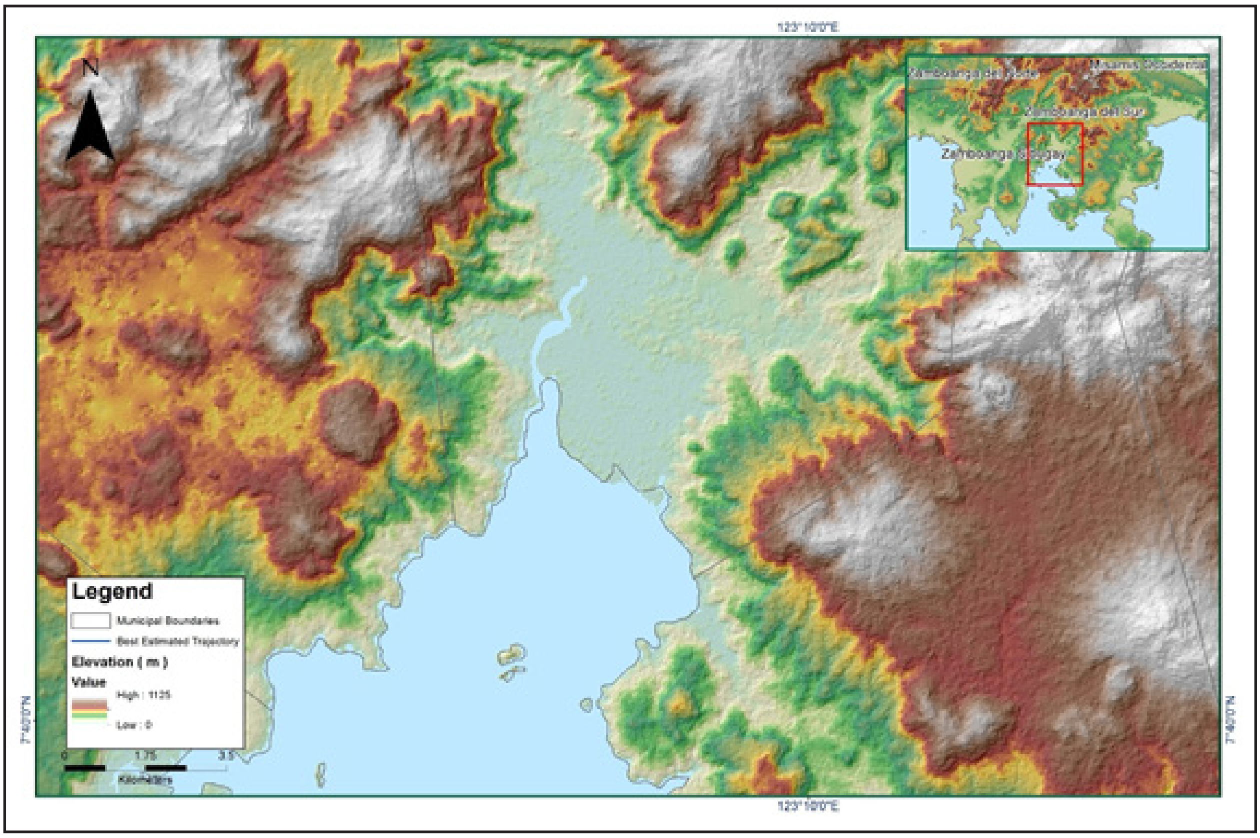


Figure A-8.3 Best Estimated Trajectory

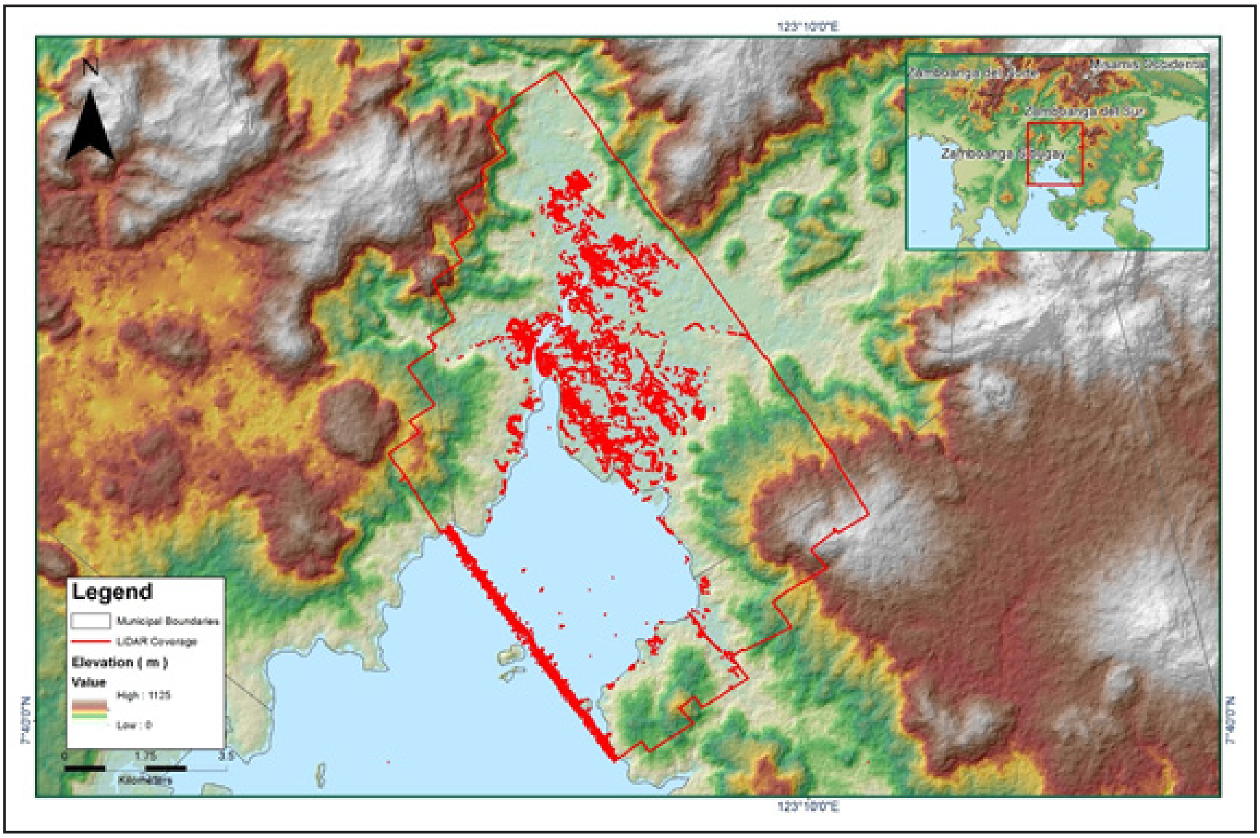


Figure A-8.4 Coverage of LiDAR Data

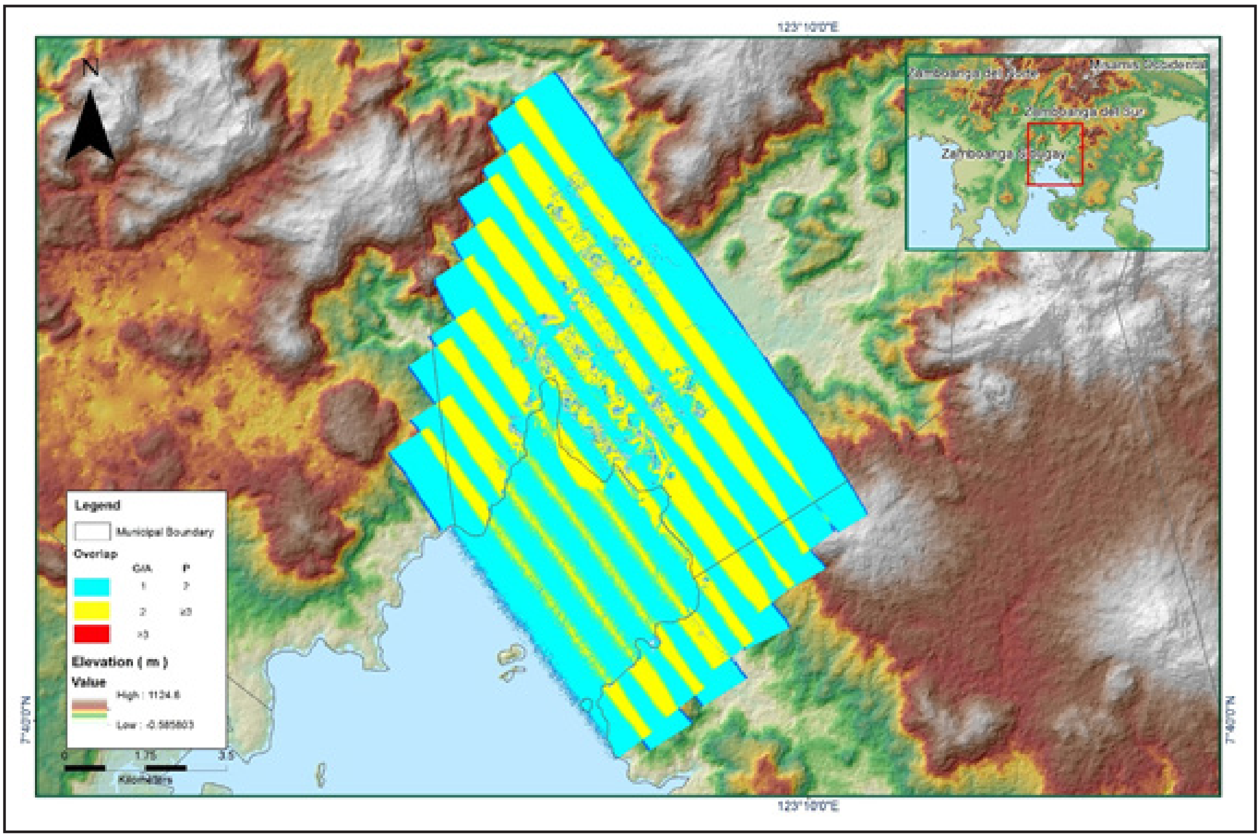


Figure A-8.5 Image of data overlap

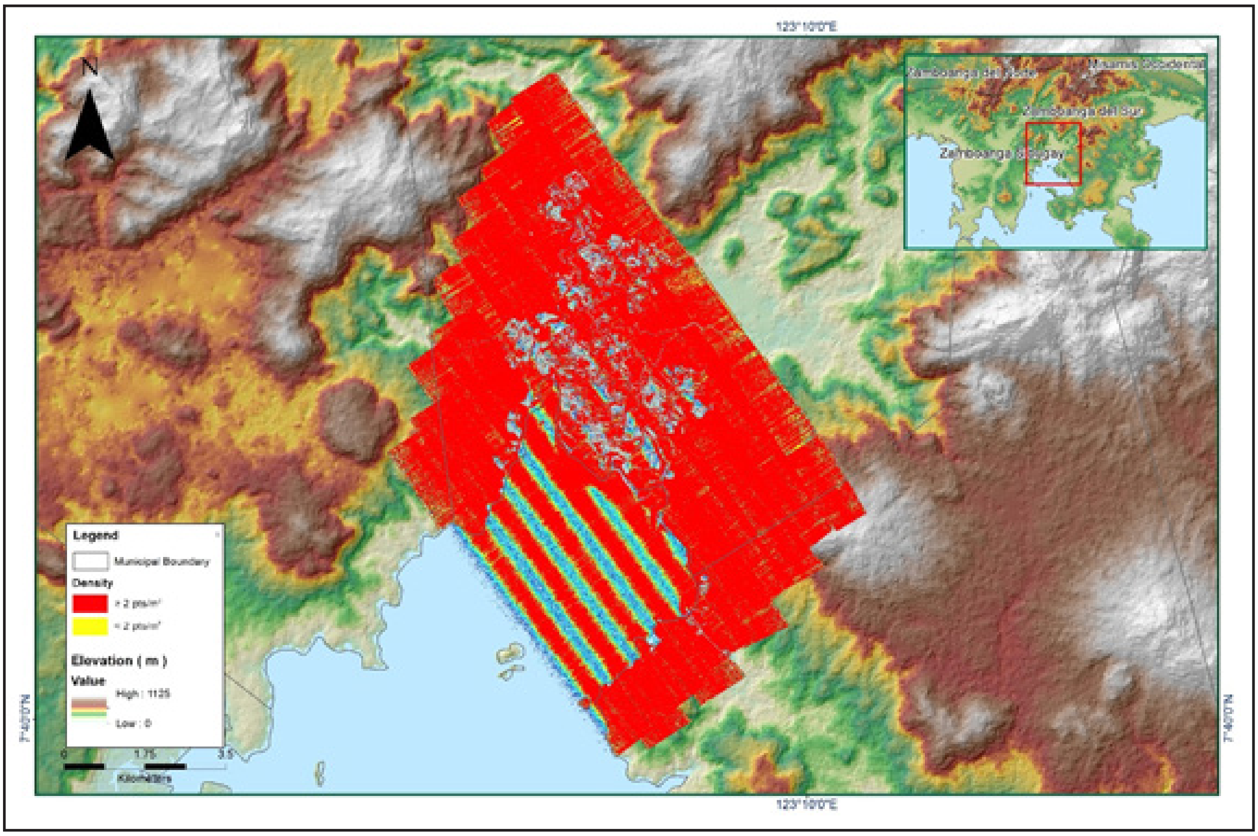


Figure A-8.6 Density map of merged LiDAR data

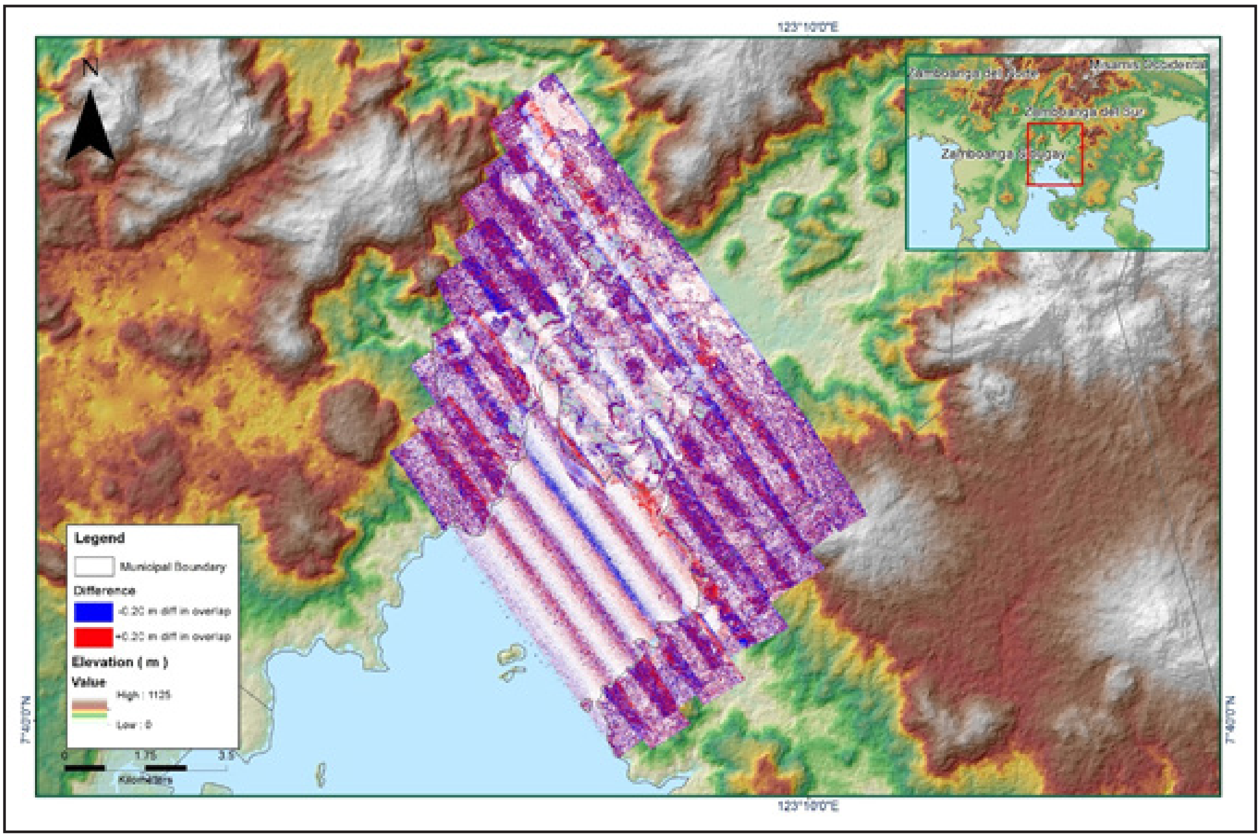


Figure A-8.7 Elevation difference between flight lines

Annex 9. Kumalarang Model Basin Parameters

Table A-9.1. Kumalarang Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W270	10.619	70.218	0.0	0.98578	4.82751	Discharge	0.37276	0.72	Ratio to Peak	0.2
W280	17.970	70.353	0.0	11.753	3.3876	Discharge	0.65007	0.72	Ratio to Peak	0.2
W290	18.523359	70.351	0.0	0.28595	1.3365	Discharge	0.20434	0.72	Ratio to Peak	0.2
W300	40.508	75.105	0.0	2.0182	1.48797	Discharge	1.4220	0.72	Ratio to Peak	0.2
W310	37.703	78.598	0.0	2.5106	2.34135	Discharge	0.39174	0.72	Ratio to Peak	0.2
W320	36.589	79.695	0.0	4.4229	2.76336	Discharge	0.24095	0.72	Ratio to Peak	0.2
W330	16.7631282	71.598	0.0	1.0478	2.25351	Discharge	0.51914	0.72	Ratio to Peak	0.2
W340	17.468	72.307	0.0	1.5577	0.679617	Discharge	0.50160	0.72	Ratio to Peak	0.2
W350	10.812	73.018	0.0	1.0937	2.21544	Discharge	0.44780	0.72	Ratio to Peak	0.2
W360	11.5404279	71.3	0.0	0.66333	1.41237	Discharge	0.38939	0.72	Ratio to Peak	0.2
W370	17.362	71.093	0.0	0.9553	0.675207	Discharge	0.29882	0.72	Ratio to Peak	0.2
W380	16.352	70.352	0.0	1.4098	0.829719	Discharge	0.46002	0.72	Ratio to Peak	0.2
W390	15.066	78.931	0.0	1.566	1.02312	Discharge	0.30190	0.72	Ratio to Peak	0.2
W400	11.309	71.711	0.0	1.8211	0.799803	Discharge	0.34681	0.72	Ratio to Peak	0.2
W420	12.693	70.006	0.0	1.976	1.26306	Discharge	1.0833	0.72	Ratio to Peak	0.2
W430	15.4702455	75.29	0.0	2.3602	0.383985	Discharge	0.24000	0.72	Ratio to Peak	0.2
W450	9.2361	78.928	0.0	1.4589	0.815643	Discharge	0.20516	0.72	Ratio to Peak	0.2
W460	16.667	71.643	0.0	1.3745	1.09053	Discharge	0.27533	0.72	Ratio to Peak	0.2
W490	11.283	71.773	0.0	2.7968	0.288891	Discharge	0.32530	0.72	Ratio to Peak	0.2
W500	8.3979	70.351	0.0	1.9486	0.762876	Discharge	0.26007	0.72	Ratio to Peak	0.2

Annex 10. Kumalarang Model Reach Parameters

Table 10. Kumalarang Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	3756.8	0.0250285	0.015	Trapezoid	20.065	1
R120	Automatic Fixed Interval	2012.8	0.0256722	0.015	Trapezoid	10.072	1
R140	Automatic Fixed Interval	3689.1	0.0300081	0.015	Trapezoid	17.27	1
R170	Automatic Fixed Interval	631.13	0.0230798	0.015	Trapezoid	6.432	1
R190	Automatic Fixed Interval	2156.8	0.0158146	0.015	Trapezoid	20.724	1
R200	Automatic Fixed Interval	252.13	0.0271847	0.015	Trapezoid	17.2752	1
R210	Automatic Fixed Interval	642.13	0.0254440	0.015	Trapezoid	8.268	1
R230	Automatic Fixed Interval	306.57	0.0189222	0.015	Trapezoid	27.866	1
R250	Automatic Fixed Interval	3509.9	0.0001	0.015	Trapezoid	32.942	1
R30	Automatic Fixed Interval	606.69	0.0057196	0.015	Trapezoid	30	1
R40	Automatic Fixed Interval	3996.8	0.0119184	0.015	Trapezoid	10.8725	1
R70	Automatic Fixed Interval	2135.9	0.0125710	0.015	Trapezoid	11.328	1

Annex 11. Kumalarang Field Validation Points

Table 11. Kumalarang Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Return Period of Event
	Lat	Long					
1	7.758320	123.114358	0.03	0.54	-0.51	June 1, 2016	5 - Year
2	7.755235	123.115441	0.03	0.81	-0.78	June 1, 2016	5 - Year
3	7.784545	123.115491	0.03	0.65	-0.62	June 1, 2016	5 - Year
4	7.784484	123.115521	0.03	0.50	-0.47	June 1, 2016	5 - Year
5	7.784449	123.115501	0.03	0.74	-0.71	June 1, 2016	5 - Year
6	7.784533	123.115483	0.03	0.45	-0.42	June 1, 2016	5 - Year
7	7.780834	123.116058	0.03	0.5	-0.47	June 1, 2016	5 - Year
8	7.780678	123.116028	0.03	0.50	-0.47	June 1, 2016	5 - Year
9	7.780332	123.115739	0.03	0.72	-0.69	June 1, 2016	5 - Year
10	7.746311	123.164950	0.03	0.70	-0.67	June 1, 2016	5 - Year
11	7.765377	123.131279	0.03	1.25	-1.22	June 1, 2016	5 - Year
12	7.781451	123.116905	0.03	0.40	-0.37	June 1, 2016	5 - Year
13	7.781431	123.116868	0.03	0.43	-0.40	June 1, 2016	5 - Year
14	7.766062	123.131558	0.05	0.80	-0.75	June 1, 2016	5 - Year
15	7.766002	123.131548	0.05	0.58	-0.53	June 1, 2016	5 - Year
16	7.781063	123.116405	0.03	0.47	-0.44	June 1, 2016	5 - Year
17	7.783487	123.116749	0.03	0.90	-0.87	June 1, 2016	5 - Year
18	7.782746	123.116397	0.03	0.63	-0.6	June 1, 2016	5 - Year
19	7.783887	123.115518	0.03	0.67	-0.64	June 1, 2016	5 - Year
20	7.781763	123.116791	0.04	0.52	-0.48	June 1, 2016	5 - Year
21	7.755003	123.115553	0.06	0.71	-0.65	June 1, 2016	5 - Year
22	7.784001	123.115397	0.03	0.74	-0.71	June 1, 2016	5 - Year
23	7.755107	123.115542	0.04	0.58	-0.54	June 1, 2016	5 - Year
24	7.783223	123.116214	0.03	0.84	-0.81	June 1, 2016	5 - Year
25	7.758355	123.114405	0.03	0.84	-0.81	June 1, 2016	5 - Year
26	7.758361	123.114384	0.03	0.53	-0.50	June 1, 2016	5 - Year
27	7.753936	123.117261	0.03	0.78	-0.75	June 1, 2016	5 - Year
28	7.782648	123.116536	0.04	0.60	-0.56	June 1, 2016	5 - Year
29	7.782009	123.116842	0.06	0.46	-0.40	June 1, 2016	5 - Year
30	7.784396	123.115480	0.03	0.78	-0.75	June 1, 2016	5 - Year
31	7.784226	123.115419	0.03	0.90	-0.87	June 1, 2016	5 - Year
32	7.783298	123.116658	0.03	0.65	-0.62	June 1, 2016	5 - Year
33	7.783183	123.116322	0.03	0.70	-0.67	June 1, 2016	5 - Year
34	7.783891	123.115684	0.03	0.70	-0.67	June 1, 2016	5 - Year
35	7.783656	123.116497	0.03	0.74	-0.71	June 1, 2016	5 - Year
36	7.781479	123.116647	0.09	0.57	-0.48	June 1, 2016	5 - Year
37	7.758439	123.114417	0.04	0.64	-0.60	June 1, 2016	5 - Year
38	7.783130	123.116509	0.06	0.87	-0.81	June 1, 2016	5 - Year
39	7.781394	123.116594	0.06	0.54	-0.48	June 1, 2016	5 - Year

40	7.783544	123.115984	0.05	0.84	-0.79	June 1, 2016	5 - Year
41	7.781264	123.116551	0.13	0.53	-0.40	June 1, 2016	5 - Year
42	7.754800	123.115767	0.06	0.46	-0.40	June 1, 2016	5 - Year
43	7.783678	123.116580	0.06	0.81	-0.75	June 1, 2016	5 - Year
44	7.784248	123.115579	0.03	0.90	-0.87	June 1, 2016	5 - Year
45	7.782325	123.116789	0.13	0.58	-0.45	June 1, 2016	5 - Year
46	7.782507	123.116794	0.10	0.54	-0.44	June 1, 2016	5 - Year
47	7.782614	123.116648	0.13	0.62	-0.49	June 1, 2016	5 - Year
48	7.783811	123.115781	0.10	0.70	-0.60	June 1, 2016	5 - Year
49	7.783163	123.116631	0.12	0.65	-0.53	June 1, 2016	5 - Year
50	7.782397	123.116866	0.15	0.47	-0.32	June 1, 2016	5 - Year
51	7.781275	123.116638	0.19	0.56	-0.37	June 1, 2016	5 - Year
52	7.783649	123.116659	0.11	0.75	-0.64	June 1, 2016	5 - Year
53	7.754672	123.116000	0.08	0.42	-0.34	June 1, 2016	5 - Year
54	7.783695	123.115868	0.14	0.66	-0.52	June 1, 2016	5 - Year
55	7.743722	123.139542	0.13	0.70	-0.57	June 1, 2016	5 - Year
56	7.783689	123.116048	0.13	0.70	-0.57	June 1, 2016	5 - Year
57	7.783199	123.116611	0.14	0.83	-0.69	June 1, 2016	5 - Year
58	7.754103	123.116914	0.22	0.53	-0.31	June 1, 2016	5 - Year
59	7.743583	123.137311	0.17	1.20	-1.03	June 1, 2016	5 - Year
60	7.783389	123.116752	0.21	0.83	-0.62	June 1, 2016	5 - Year
61	7.754923	123.115754	0.16	0.65	-0.49	June 1, 2016	5 - Year
62	7.754561	123.117028	0.23	0.5	-0.27	June 1, 2016	5 - Year
63	7.738074	123.097177	0.05	0.8	-0.75	June 1, 2016	5 - Year
64	7.754311	123.116942	0.26	0.7	-0.44	June 1, 2016	5 - Year
65	7.780566	123.115937	0.09	0.4	-0.31	June 1, 2016	5 - Year
66	7.743533	123.137650	0.22	1.00	-0.78	June 1, 2016	5 - Year
67	7.743261	123.137069	0.22	1.35	-1.13	June 1, 2016	5 - Year
68	7.743253	123.137097	0.22	0.64	-0.42	June 1, 2016	5 - Year
69	7.781132	123.116331	0.09	0.46	-0.37	June 1, 2016	5 - Year
70	7.783700	123.116370	0.25	0.73	-0.48	June 1, 2016	5 - Year
71	7.783719	123.116170	0.27	0.88	-0.61	June 1, 2016	5 - Year
72	7.746197	123.148892	0.04	1.05	-1.01	June 1, 2016	5 - Year
73	7.756900	123.115024	0.23	0.42	-0.19	June 1, 2016	5 - Year
74	7.738045	123.097143	0.03	0.77	-0.74	June 1, 2016	5 - Year
75	7.746131	123.149050	0.04	0.70	-0.66	June 1, 2016	5 - Year
76	7.757257	123.114734	0.09	0.28	-0.19	June 1, 2016	5 - Year
77	7.746172	123.148842	0.10	0.67	-0.57	June 1, 2016	5 - Year
78	7.780471	123.115828	0.17	0.46	-0.29	June 1, 2016	5 - Year
79	7.745828	123.139986	0.29	0.6	-0.31	June 1, 2016	5 - Year
80	7.755009	123.115643	0.27	0.65	-0.38	June 1, 2016	5 - Year
81	7.756831	123.114865	0.24	0.42	-0.18	June 1, 2016	5 - Year
82	7.756507	123.115013	0.29	0.94	-0.65	June 1, 2016	5 - Year
83	7.754781	123.115875	0.30	0.59	-0.29	June 1, 2016	5 - Year
84	7.783721	123.116198	0.35	0.68	-0.33	June 1, 2016	5 - Year

85	7.745291	123.169189	0.03	0.76	-0.73	June 1, 2016	5 - Year
86	7.754472	123.117106	0.38	0.54	-0.16	June 1, 2016	5 - Year
87	7.745439	123.151050	0.03	0.55	-0.52	June 1, 2016	5 - Year
88	7.743461	123.137300	0.37	0.80	-0.43	June 1, 2016	5 - Year
89	7.756770	123.114325	0.26	0.89	-0.63	June 1, 2016	5 - Year
90	7.755387	123.115561	0.36	0.82	-0.46	June 1, 2016	5 - Year
91	7.754183	123.116828	0.42	0.50	-0.08	June 1, 2016	5 - Year
92	7.745282	123.169229	0.03	0.20	-0.17	June 1, 2016	5 - Year
93	7.746072	123.149086	0.14	0.66	-0.52	June 1, 2016	5 - Year
94	7.746781	123.142203	0.36	1.18	-0.82	June 1, 2016	5 - Year
95	7.756758	123.114285	0.31	0.46	-0.15	June 1, 2016	5 - Year
96	7.746769	123.141961	0.40	0.90	-0.50	June 1, 2016	5 - Year
97	7.745536	123.139308	0.41	0.70	-0.29	June 1, 2016	5 - Year
98	7.746808	123.142497	0.38	1.00	-0.62	June 1, 2016	5 - Year
99	7.756890	123.114500	0.33	0.48	-0.15	June 1, 2016	5 - Year
100	7.755310	123.115594	0.46	0.89	-0.43	June 1, 2016	5 - Year
101	7.745247	123.140075	0.51	1.10	-0.59	June 1, 2016	5 - Year
102	7.743839	123.139731	0.51	0.55	-0.04	June 1, 2016	5 - Year
103	7.746767	123.142664	0.44	1.00	-0.56	June 1, 2016	5 - Year
104	7.745639	123.139242	0.48	0.67	-0.19	June 1, 2016	5 - Year
105	7.745703	123.139208	0.48	0.75	-0.27	June 1, 2016	5 - Year
106	7.743906	123.139853	0.53	0.6	-0.07	June 1, 2016	5 - Year
107	7.745689	123.139961	0.54	0.65	-0.11	June 1, 2016	5 - Year
108	7.745436	123.150731	0.17	0.82	-0.65	June 1, 2016	5 - Year
109	7.746289	123.164400	0.41	0.90	-0.49	June 1, 2016	5 - Year
110	7.756868	123.114323	0.41	0.46	-0.05	June 1, 2016	5 - Year
111	7.745528	123.139925	0.56	0.66	-0.10	June 1, 2016	5 - Year
112	7.745786	123.167917	0.10	0.50	-0.40	June 1, 2016	5 - Year
113	7.746306	123.164253	0.43	1.18	-0.75	June 1, 2016	5 - Year
114	7.747017	123.142786	0.47	1.35	-0.88	June 1, 2016	5 - Year
115	7.745600	123.140042	0.60	0.70	-0.10	June 1, 2016	5 - Year
116	7.745139	123.139908	0.61	0.60	0.01	June 1, 2016	5 - Year
117	7.745514	123.150564	0.24	1.10	-0.86	June 1, 2016	5 - Year
118	7.745475	123.150575	0.24	0.60	-0.36	June 1, 2016	5 - Year
119	7.747367	123.142881	0.40	0.80	-0.40	June 1, 2016	5 - Year
120	7.757164	123.114571	0.44	0.44	0	June 1, 2016	5 - Year
121	7.746842	123.141694	0.60	0.77	-0.17	June 1, 2016	5 - Year
122	7.746183	123.163983	0.57	1.00	-0.43	June 1, 2016	5 - Year
123	7.745832	123.168016	0.20	0.15	0.05	June 1, 2016	5 - Year
124	7.745892	123.167983	0.20	0.32	-0.12	June 1, 2016	5 - Year
125	7.746689	123.146922	0.32	0.60	-0.28	June 1, 2016	5 - Year
126	7.756983	123.114673	0.52	0.29	0.23	June 1, 2016	5 - Year
127	7.745578	123.139225	0.65	1.05	-0.40	June 1, 2016	5 - Year
128	7.746825	123.142922	0.61	0.64	-0.03	June 1, 2016	5 - Year
129	7.746100	123.164781	0.51	0.65	-0.14	June 1, 2016	5 - Year

130	7.746833	123.142689	0.62	1.20	-0.58	June 1, 2016	5 - Year
131	7.745655	123.167318	0.29	0.54	-0.25	June 1, 2016	5 - Year
132	7.746703	123.147011	0.35	0.70	-0.35	June 1, 2016	5 - Year
133	7.757113	123.114601	0.55	0.56	-0.01	June 1, 2016	5 - Year
134	7.765860	123.131232	0.62	0.63	-0.01	June 1, 2016	5 - Year
135	7.765882	123.131153	0.62	0.43	0.19	June 1, 2016	5 - Year
136	7.755380	123.115386	0.71	0.91	-0.20	June 1, 2016	5 - Year
137	7.746642	123.141775	0.77	0.82	-0.05	June 1, 2016	5 - Year
138	7.746167	123.167808	0.25	0.43	-0.18	June 1, 2016	5 - Year
139	7.765892	123.131097	0.69	0.49	0.20	June 1, 2016	5 - Year
140	7.765842	123.131079	0.69	0.50	0.19	June 1, 2016	5 - Year
141	7.738392	123.096106	0.03	1.05	-1.02	June 1, 2016	5 - Year
142	7.746031	123.146933	0.54	1.40	-0.86	June 1, 2016	5 - Year
143	7.746086	123.164825	0.58	0.60	-0.02	June 1, 2016	5 - Year
144	7.746273	123.167761	0.27	0.21	0.06	June 1, 2016	5 - Year
145	7.745716	123.167704	0.39	0.91	-0.52	June 1, 2016	5 - Year
146	7.745583	123.167140	0.43	0.38	0.05	June 1, 2016	5 - Year
147	7.745350	123.150739	0.50	0.70	-0.20	June 1, 2016	5 - Year
148	7.755541	123.115245	0.85	1.04	-0.19	June 1, 2016	5 - Year
149	7.745695	123.167455	0.46	0.62	-0.16	June 1, 2016	5 - Year
150	7.744911	123.151961	0.48	0.60	-0.12	June 1, 2016	5 - Year
151	7.745711	123.139306	0.84	1.10	-0.26	June 1, 2016	5 - Year
152	7.744064	123.139961	0.88	0.82	0.06	June 1, 2016	5 - Year
153	7.754953	123.115997	0.84	0.92	-0.08	June 1, 2016	5 - Year
154	7.745053	123.144403	0.77	0.55	0.22	June 1, 2016	5 - Year
155	7.753936	123.116889	0.95	0.26	0.69	June 1, 2016	5 - Year
156	7.744797	123.152186	0.51	0.75	-0.24	June 1, 2016	5 - Year
157	7.745953	123.144858	0.79	0.67	0.12	June 1, 2016	5 - Year
158	7.745484	123.169181	0.35	0.58	-0.23	June 1, 2016	5 - Year
159	7.746061	123.146914	0.66	0.78	-0.12	June 1, 2016	5 - Year
160	7.738556	123.096150	0.16	0.79	-0.63	June 1, 2016	5 - Year
161	7.745437	123.167433	0.42	0.92	-0.50	June 1, 2016	5 - Year
162	7.745534	123.167363	0.58	0.62	-0.04	June 1, 2016	5 - Year
163	7.746236	123.165117	0.58	0.75	-0.17	June 1, 2016	5 - Year
164	7.746203	123.165108	0.58	1.10	-0.52	June 1, 2016	5 - Year
165	7.744947	123.152097	0.61	0.70	-0.09	June 1, 2016	5 - Year
166	7.745717	123.144847	0.86	0.60	0.26	June 1, 2016	5 - Year
167	7.745722	123.144917	0.86	0.70	0.16	June 1, 2016	5 - Year
168	7.765442	123.130888	0.90	0.75	0.15	June 1, 2016	5 - Year
169	7.755546	123.115301	1.00	1.04	-0.04	June 1, 2016	5 - Year
170	7.745639	123.164678	0.88	0.77	0.11	June 1, 2016	5 - Year
171	7.745597	123.164650	0.89	0.82	0.07	June 1, 2016	5 - Year
172	7.744947	123.151889	0.67	0.77	-0.10	June 1, 2016	5 - Year
173	7.745814	123.144917	0.90	1.05	-0.15	June 1, 2016	5 - Year
174	7.745922	123.146836	0.79	1.48	-0.69	June 1, 2016	5 - Year

175	7.745628	123.144864	0.90	0.66	0.24	June 1, 2016	5 - Year
176	7.754347	123.116739	1.09	0.46	0.63	June 1, 2016	5 - Year
177	7.744997	123.151053	0.70	0.60	0.10	June 1, 2016	5 - Year
178	7.765798	123.131121	0.98	0.70	0.28	June 1, 2016	5 - Year
179	7.765800	123.131142	0.98	0.66	0.32	June 1, 2016	5 - Year
180	7.765743	123.131130	0.98	0.50	0.48	June 1, 2016	5 - Year
181	7.765527	123.130896	0.99	0.35	0.64	June 1, 2016	5 - Year
182	7.744947	123.152053	0.71	0.65	0.06	June 1, 2016	5 - Year
183	7.745444	123.168519	0.54	0.75	-0.21	June 1, 2016	5 - Year
184	7.744803	123.152056	0.71	1.10	-0.39	June 1, 2016	5 - Year
185	7.754961	123.115903	1.08	0.68	0.40	June 1, 2016	5 - Year
186	7.745458	123.144672	1.00	1.10	-0.10	June 1, 2016	5 - Year
187	7.765602	123.130909	1.05	0.46	0.59	June 1, 2016	5 - Year
188	7.745560	123.168409	0.55	1.15	-0.60	June 1, 2016	5 - Year
189	7.745550	123.144733	1.03	0.60	0.43	June 1, 2016	5 - Year
190	7.745400	123.144558	1.06	0.82	0.24	June 1, 2016	5 - Year
191	7.783760	123.116328	1.25	0.74	0.51	June 1, 2016	5 - Year
192	7.745817	123.168269	0.65	0.80	-0.15	June 1, 2016	5 - Year
193	7.745336	123.144506	1.12	0.70	0.42	June 1, 2016	5 - Year
194	7.765490	123.130996	1.15	0.75	0.40	June 1, 2016	5 - Year
195	7.754097	123.116789	1.31	0.50	0.81	June 1, 2016	5 - Year
196	7.765428	123.131015	1.17	1.00	0.17	June 1, 2016	5 - Year
197	7.738283	123.096084	0.50	1.30	-0.80	June 1, 2016	5 - Year
198	7.744489	123.151039	0.97	0.80	0.17	June 1, 2016	5 - Year
199	7.744536	123.151061	0.97	1.35	-0.38	June 1, 2016	5 - Year
200	7.745747	123.168320	0.76	0.83	-0.07	June 1, 2016	5 - Year
201	7.745846	123.168193	0.78	0.50	0.28	June 1, 2016	5 - Year
202	7.738032	123.096305	0.57	0.80	-0.23	June 1, 2016	5 - Year
203	7.754458	123.116986	1.46	0.90	0.56	June 1, 2016	5 - Year
204	7.744567	123.151408	1.10	1.00	0.10	June 1, 2016	5 - Year
205	7.738656	123.096097	0.76	0.95	-0.19	June 1, 2016	5 - Year
206	7.737993	123.096217	0.67	0.92	-0.25	June 1, 2016	5 - Year
207	7.744678	123.151811	1.14	0.82	0.32	June 1, 2016	5 - Year
208	7.744797	123.151000	1.20	0.64	0.56	June 1, 2016	5 - Year
209	7.744819	123.151617	1.21	0.90	0.31	June 1, 2016	5 - Year
210	7.744878	123.151550	1.21	1.18	0.03	June 1, 2016	5 - Year
211	7.738145	123.096105	0.78	0.95	-0.17	June 1, 2016	5 - Year
212	7.743989	123.150939	1.29	1.20	0.09	June 1, 2016	5 - Year
213	7.744122	123.151050	1.34	1.00	0.34	June 1, 2016	5 - Year
214	7.745410	123.169134	1.41	0.56	0.85	June 1, 2016	5 - Year
215	7.738391	123.096032	3.94	1.15	2.79	June 1, 2016	5 - Year

Annex 12. Educational Institutions affected by flooding in Kumalarang Floodplain

Table 12. Educational Institutions affected by flooding in Kumalarang Floodplain

ZAMBOANGA DEL SUR				
KUMALARANG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Arabic School	Bogayo			Low
Boyugan West Elem. School	Bogayo			
Day Care Center	Bogayo			
Graciano Primary School	Bogayo			
Picanan National High School	Bogayo			
Picanan National High School Outdoor Stage	Bogayo			
Bualan Day Care Center	Bualan			
Bualan Elem. School	Bualan			
Day Care Center	Pangi	Low	Low	Low
Diplo Elem. School	Pangi		Low	Low
MCSM National High School	Pangi			
Day Care Center	Picanan			
Lantawan Day Care Center	Picanan			
Picanan Elem. School	Picanan	Low	Medium	Medium
Medium-StoreyKumalarang Central Elem. School	Poblacion	Medium	Medium	Medium
Medium-StoreyKumalarang National High School	Poblacion		Medium	Medium
Arabic School	Poblacion	Low	Medium	Medium
Kumalarang Central Elem. School	Poblacion	Medium	Medium	Medium
Kumalarang National High School	Poblacion		Low	Medium
Poblacion Day Care Center	Poblacion	Low	Medium	Medium
Sacred Heart School Building	Poblacion	Low	Medium	Medium
Sacred Heart School Multi-purpose Building	Poblacion	Low	Medium	Medium

Annex 13. Health Institutions affected by flooding in Kumalarang Floodplain

Table 13. Health Institutions affected by flooding in Kumalarang Floodplain

ZAMBOANGA DEL SUR				
KUMALARANG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bualan Health Station	Bualan			
Health Center	Pangi		Low	Low
Health Center	Picanan		Low	Low
Health Station	Picanan			
Health Center	Poblacion		Medium	Medium