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

LiDAR Surveys and Flood Mapping of Migcanaway 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
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
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 MIGCANAWAY RIVER

Enrico C. Paringit, Dr. Eng, Prof. Alan 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 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication 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 the 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 Migcanaway River Basin

Migcanaway River Basin covers Tangub City and minor portions of Ozamiz City in the province of Misamis Occidental, Region X, in the northern part of Mindanao. The DENR River Basin Control Office identified the basin to have a drainage area of 33.952km^2(RBCO, 2015).

The basin is bounded on the North by Ozamiz City, on the East and the South surrounded by the Panguil Bay, on the Southwest by the municipality of Zamboanga Del Sur, and on the West by the Municipality of Bonifacio. Tangub City is composed of 55 barangays. Twenty-seven (27) barangays are within the river basin. Barangays prone to flooding are Aquino, Barangay I, Barangay II, Barangay III, Barangay IV, Barangay V, Barangay VI, Barangay VII, Bongabong, Caniangan, Garang, and Isidro D. Tan, Kauswagan, Labuyo, Lorenzo Tan, Maloro, Manga, Mantic, Maquilao, Migcanaway, Minsubong, Pangabuan, Prenza, San Apolinario, Sta. Cruz, Sta. Maria, and Silanga. All of these barangays are accessible by barangay, city, and national roads.

Migcanaway River Basin has an estimated area of 32.91 sq. km. The floodplain area delineated within the basin has an area of 27.937481 sq. km., which is 84.89% of the whole river basin area. A total of 8,545 features were extracted within the floodplain which belongs to the city as a flood prone area, the outlet of the basin where flow measurements were obtained specifically in Migcanaway Brige I, Barangay VII, Tangub City.

Its main stem, Migcanaway River, is part of the 16 river systems in Western Mindanao Region. According to the 2015 national census of NSO, a total of 13,813 persons distributed among ten (10) barangays from Tangub City are residing within the immediate vicinity of the river (NSO, 2015).

Tangub City is primarily agricultural, with more than 60% of the land devoted to farming while other sources of income are fishing and makinghandicrafts (http://tangubcity.gov.ph/government/about-tangub-city,2016).

Tangub City belongs to the fourth type of climate, mild and moderate where rainfall is more or less evenly distributed throughout the year. It has a generally favorable type of climate. The cool and fresh air from the south-western part in which Hoyohoy highland Resort is located, with the air from the Panguil Bay, creates an invigorating atmosphere. The topography of Tangub City consists mostly of rolling terrain with lowlands along its eastern coast facing the Panguil Bay. It has a number of waterways, rivers, small creeks, and streams which also traverse the area. Common creeks are the Manga, Kauswagan, Bongabong, Prenza, Sta. Cruz, Garang, Minsubong, Isidro D. Tan, and Dimalooc.

A flooding incident in Tangub City happened last October 7, 2011 due to heavy rains. According to the National Disaster Risk Reduction & Management Council (NDRRMC), on or before 2:00 AM – 9:00 PM in the same date, the incident occurred at Barangay Caniangan, San Antonio and Taguite in Tangub City, Misamis Occidental. Two (2) spillways were damaged—one in Barangay Caniangan and the other in Barangay Taguite which resulted in the isolation of Barangay San Antonio. According to NDRRMC through its releasing officer USEC Benito T. Ramos, Executive Director, NDRRMC and Administrator, OCD, only two (2) carabaos were considered as casualty. The action taken by the CDRRMC of Tangub City was damage assessment. This news was published by the NDRRMC on October 16, 2011.

Most recently, on December 2, 2012, Typhoon Pablo, internationally known as *Bopha*, affected approximately 700,000 families nationwide and was the worst typhoon in 2012 that hit the Mindanao region. In Misamis Occidental, two (2) people died while 320 families were affected. Pablo brought strong winds that caused flash floods and landslides.

(http://ndrrmc.gov.ph/attachments/article/1344/Effects_of_Typhoon_PABLO_(Bopha)_Situational_Report_No_38_as_of_25DEC2012_0600H.pdf).

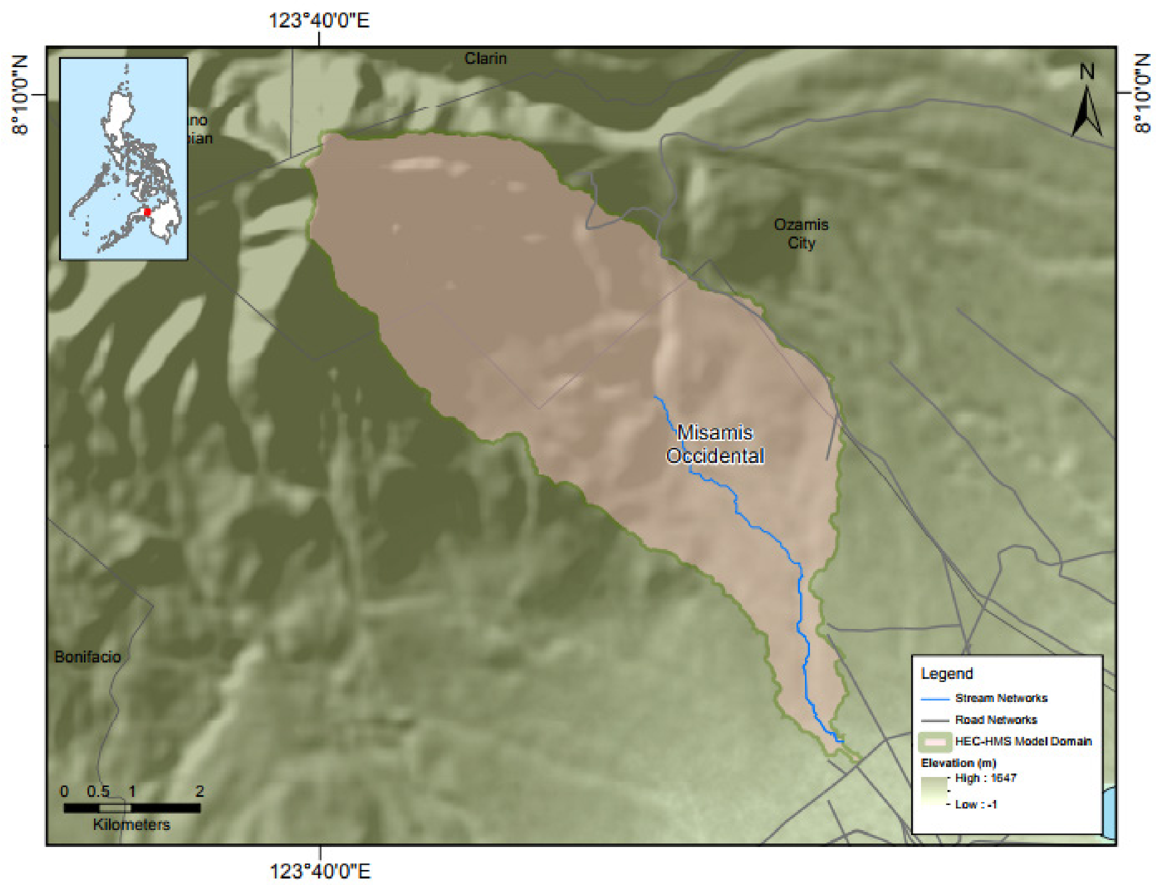

Figure 1. Map of Migcanaway River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN MIGCANAWAY 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 Migcanaway Floodplain in Northern Mindanao. The missions were planned foran average of 10 lines and ran for not more than five (5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system is found inTable 1.Figure 2shows the flight plans and base stations for Migcanaway Floodplain.

Table 1. Flight planning parameters forPegasus LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Max Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 76G	1000	25	50	200	30	130	5
BLK 76H	1000	25	50	200	30	130	5
BLK 76I	1000	25	50	200	30	130	5
BLK 76J	1000	25	50	200	30	130	5
BLK 76N	1000	25	50	200	30	130	5
BLK 71 ext	1000	30	50	200	30	130	5

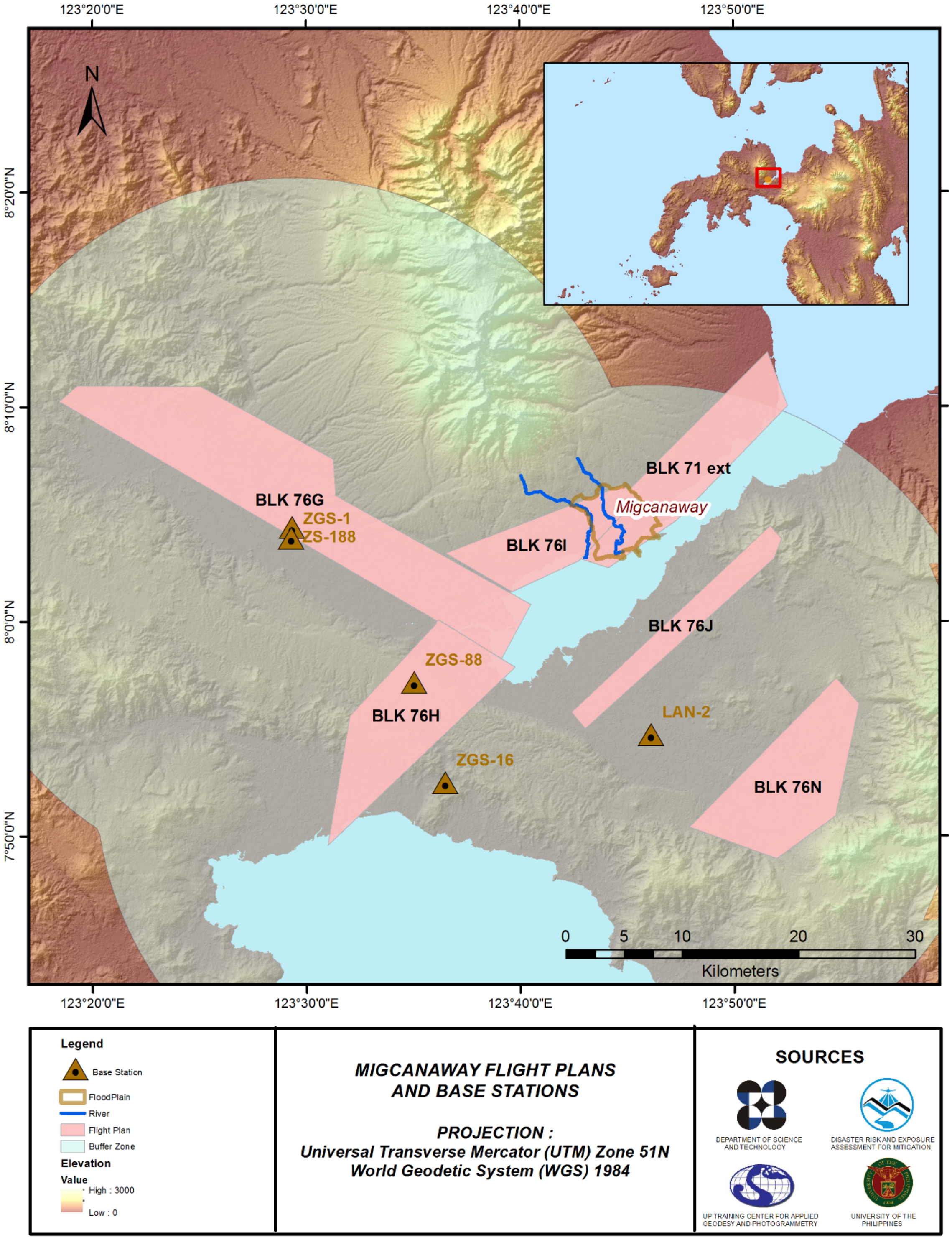


Figure 2. Flight plans and base stations used to cover Migcanaway Floodplain

2.2 Ground Base Station

The project team was able to recover four (4) NAMRIA ground control points:ZGS-1 and LAN-2 which are of first (1^{st}) order accuracy, ZGS-16 and ZGS-88 which are of second (2^{nd}) order accuracy. One (1) NAMRIA benchmark was recovered: ZS-188. This benchmark was used as vertical reference point and was also established as ground control point.The certifications for the NAMRIA reference points and benchmark are found in Annex 2 while the processing report for the NAMRIA benchmark is found in Annex 3. These were used as base stations during the flight operation for the entire duration of the survey (July 5–6, 2014, February 13–14, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 985, and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Migcanaway Floodplain are shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area. Table 2 to Table 6 show the details about the NAMRIA control points and the established control point while Table 7 lists all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a)

(b)

Figure 3. GPS set-up over LAN-2 at Brgy. Pinoyak, Lala Lanao del Norte(a) and NAMRIA reference point LAN-2 (b) as recovered by the field team.

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

Station Name	LAN-2	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 54’ 46.07859” North
	Longitude	123° 46’ 0.85333” East
	Ellipsoidal Height	17.35400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	364,025.74 meters
	Northing	875,110.149 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7° 54’ 42.56546” North
	Longitude	123° 46’ 6.31720” East
	Ellipsoidal Height	83.92120 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	584,533.45 meters
	Northing	874,680.35 meters

(b)

(a)

Figure 4. GPS set-up over ZGS-88 at Brgy. San Jose, Aurora, Zamboanga del Sur(a) and NAMRIA reference point ZGS-88(b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-88used as base station for the LiDAR Acquisition.

Station Name	ZGS-88	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 57’ 13.25316” North 123° 34’ 56.50093” East 258.34500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	564,207.26 meters 879,474.685 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 57’ 9.71271” North 123° 35’ 1.96243” East 324.37300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	564,184.79 meters 879,166.85 meters

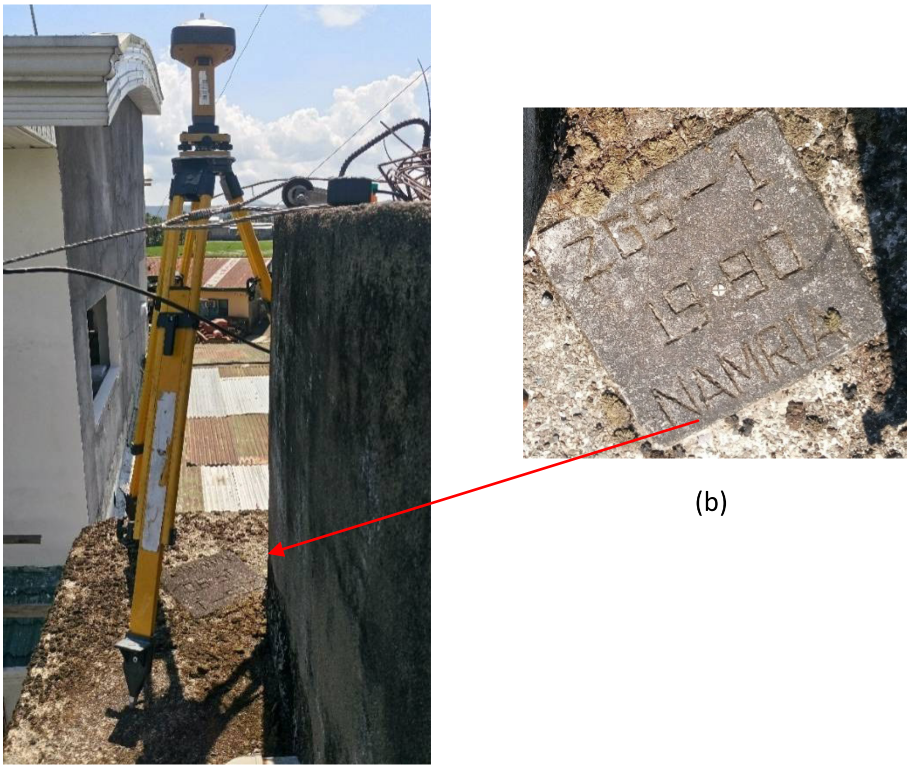
(a)

(b)

Figure 5. GPS set-up over ZGS-16 at Purok Nangka, Brgy. Baclay, Municipality of Tukuran, Zamboanga del Sur (a) and NAMRIA reference point ZGS-16 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ZGS-16 used as base station for the LiDAR Acquisition.

Station Name	ZGS-16	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 52’ 35.53106” North
	Longitude	123° 36’ 23.39905” East
	Ellipsoidal Height	18.17800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	566,881.259 meters
	Northing	870,8554.959 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	7° 52’ 29.01321” North
	Longitude	123° 36’ 28.86762” East
	Ellipsoidal Height	84.42000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	566,857.85 meters
	Northing	870,550.15 meters



(a) (b)

Figure 6. GPS set-up over ZGS-1 at National Irrigation Administration (NIA) compound, Brgy. Dipolo, Molave, Zamboanga del Sur (a) and NAMRIA reference point ZGS-1 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ZGS-1 used as base station for the LiDAR Acquisition.

Station Name	ZGS-1	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 4’ 26.98334” North 123° 29’ 14.53868” East 22.61100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	553,718.284 meters 892,784.790 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 4’ 23.40249” North 123° 29’ 19.99013” East 88.16300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	553,699.48 meters 892,472.30 meters

(a)

(b)

Figure 7. GPS set-up over ZS-188 at Brgy. Licomo, Zamboanga City, Zamboanga del Sur (a) and NAMRIA reference point ZS-188 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA vertical control point ZGS-188 used as base station for the LiDAR Acquisition with processed coordinates.

Station Name	ZS-188	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 03’ 56.69408” North
	Longitude	123° 29’ 12.15500” East
	Ellipsoidal Height	19.832 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 03’ 53.11537” North
	Longitude	123° 29’ 17.60722” East
	Ellipsoidal Height	85.400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	553,627.634meters
	Northing	891,542.089 meters

Table 7. Ground Control points using LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 5, 2014	1673P	1BLK71S186A	LAN-2, ZGS-88
July 6, 2014	1677P	1BLK71S187A	LAN-2, ZGS-88
February 13, 2016	23088P	1BLK76ILM044A	ZGS-16, ZS-188
February 14, 2016	23092P	1BLK76IG045A	ZGS-1, ZS-188

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR Data Acquisition in Migcanaway Floodplain, for a total of thirteen hours and thirty-eight minutes (13+38) of flying time for RP-C9122. The mission was acquired using the Pegasus LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight Missions for LiDAR Data Acquisition in Migcanaway Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within Floodplain (km^2)	Area Surveyed Outside Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
July 5, 2014	1673P	100.30	59.99	13.65	46.33	330	3	5
July 6, 2014	1677P	100.30	89.50	12.53	76.98	170	2	35
February 13, 2016	23088P	216.61	200.05	10.29	189.77	536	4	23
February 14, 2016	23092P	427.98	206.76	4.18	202.58	458	3	35
TOTAL		845.19	556.3	40.65	515.66	1494	13	38

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)
1673P	1000	30	50	200	30	110-130	5
1677P	1000	30	50	200	30	110-130	5
23088P	1200	30	50	200	30	110-130	5
23092P	1000	30	50	200	30	110-130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Migcanaway Floodplain (See Annex 7). Migcanaway Floodplain is located in the province of Misamis Occidental and is situated east of Migcanaway City. The list of municipalities/cities surveyed in these provinces during the LiDAR acquisition is shown in Table 10. In Figure 8, the actual coverage of the LiDAR acquisition for Migcanaway Floodplain is shown.

Table 10. List of municipalities and cities surveyed during Migcanaway Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Lanao del Norte	Salvador	46.46	25.21	54%
	Sapad	65.13	35.08	54%
	Tubod	121.95	38.09	31%
	Baroy	62.08	17.37	28%
	Lala	125.18	18.82	15%
	Nunungan	418.22	59.52	14%
	Tangcal	118.94	6.46	5%
	Kapatagan	184.76	8.45	5%
	Kolambugan	70.7	1.67	2%
	Magsaysay	83.06	0.3	0%
Misamis Occidental	Tangub City	141.82	64.21	45%
	Ozamiz City	149.44	44.52	30%
	Bonifacio	103.87	14.76	14%
	Clarin	113.99	3.22	3%
Zamboanga del Sur	Mahayag	175.97	70.24	40%
	Aurora	162.22	25.74	16%
	Tukuran	119.01	18.29	15%
	Tambulig	142.93	19.69	14%
	Dumingag	318.87	32.87	10%
	Molave	61.24	5.75	9%
	Labangan	176.44	0.94	1%
	Sominot	97.75	0.01	0%
Total		3060.03	511.21	16.71%

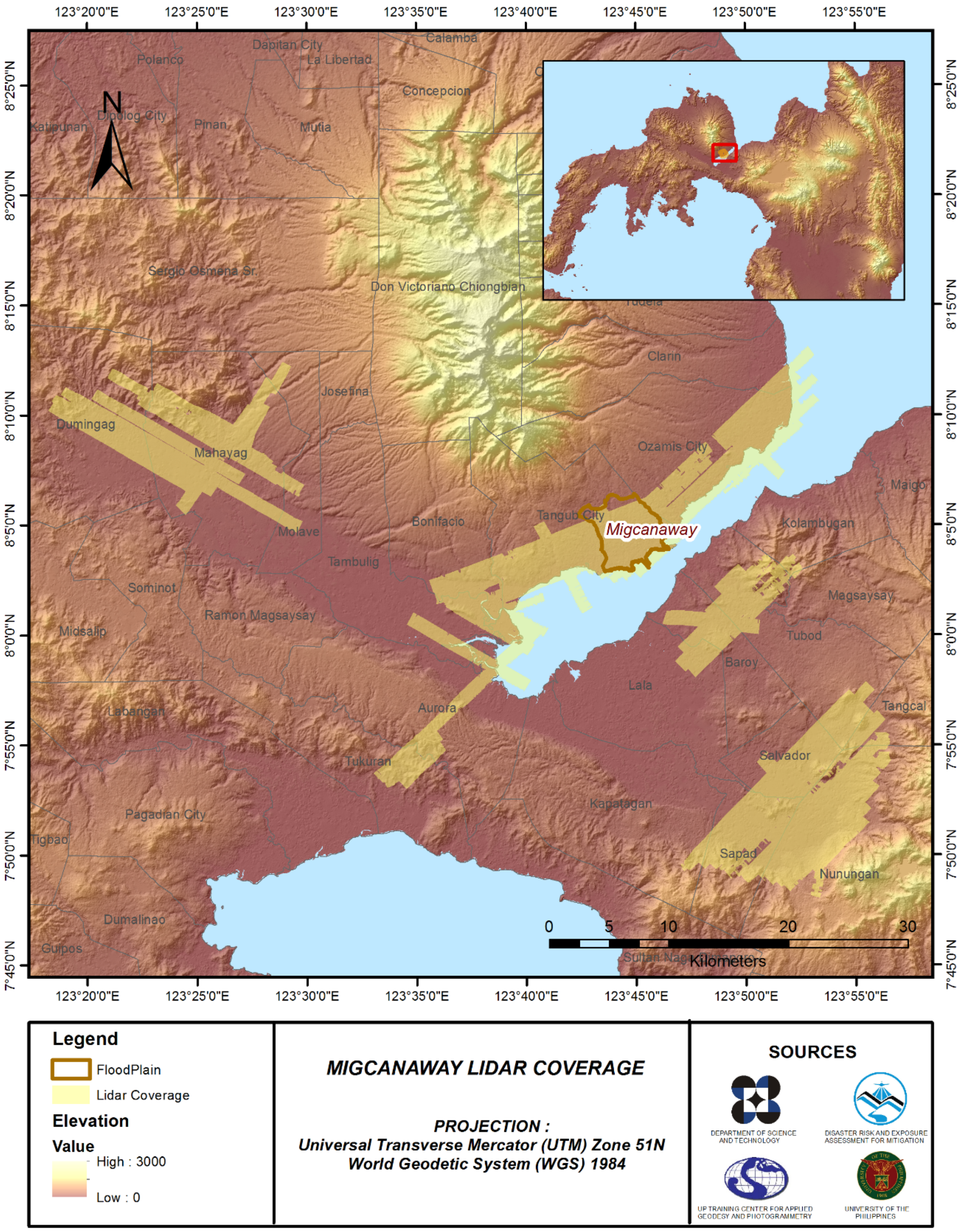


Figure 8. Actual LiDAR data acquisition for Migcanaway Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR MIGCANAWAY 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 to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected for quality checking to ensure that the required accuracies of the program,which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models 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.

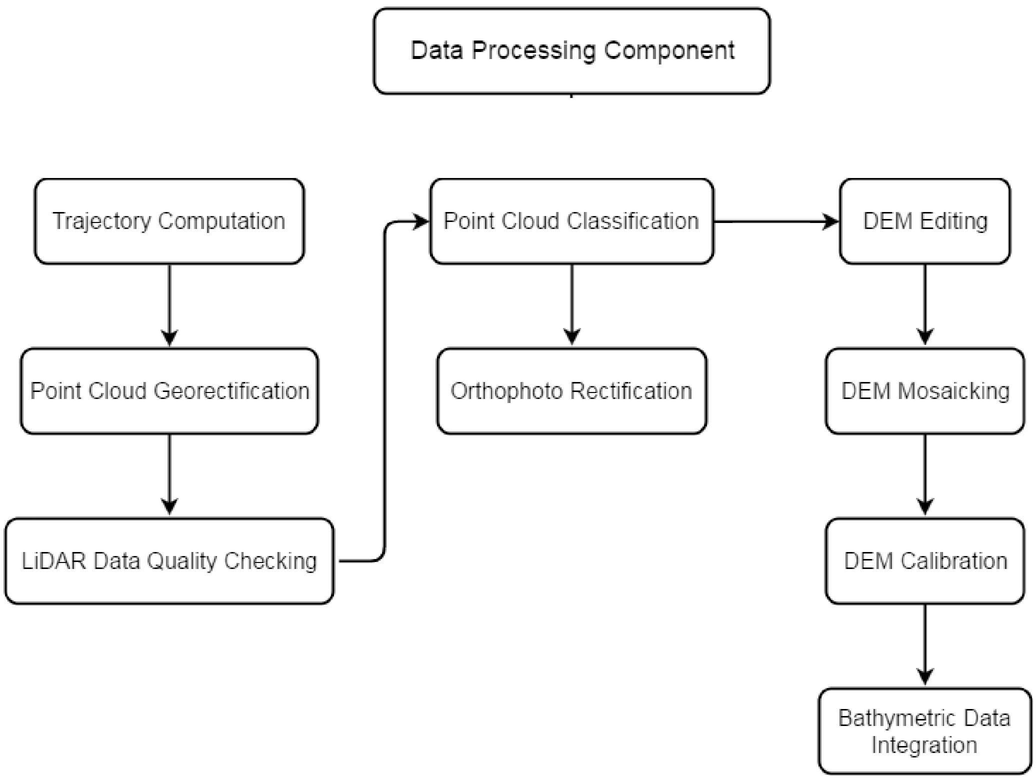


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Migcanaway floodplain can be found in Annex 5. All missions flown during the first survey and second conducted in July 2014 and February 2016 respectively used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Tangub City, Misamis Occidental. The Data Acquisition Component (DAC) transferred a total of 74.04 Gigabytes of Range data, 987.08 Megabytes of POS data, 228.98 Megabytes of GPS base station data, and 97.92 Gigabytes of raw image data to the data server on July 3, 2014 for the first survey and February 17, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Migcanaway was fully transferred on March 1, 2016, as indicated in the Data Transfer Sheets for Migcanaway Floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metric*s of the computed trajectory for flight 23092P, one of the Migcanaway 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 onFebruary 14, 2016 00:00 AM. The y-axis is the RMSE value for that particular position.

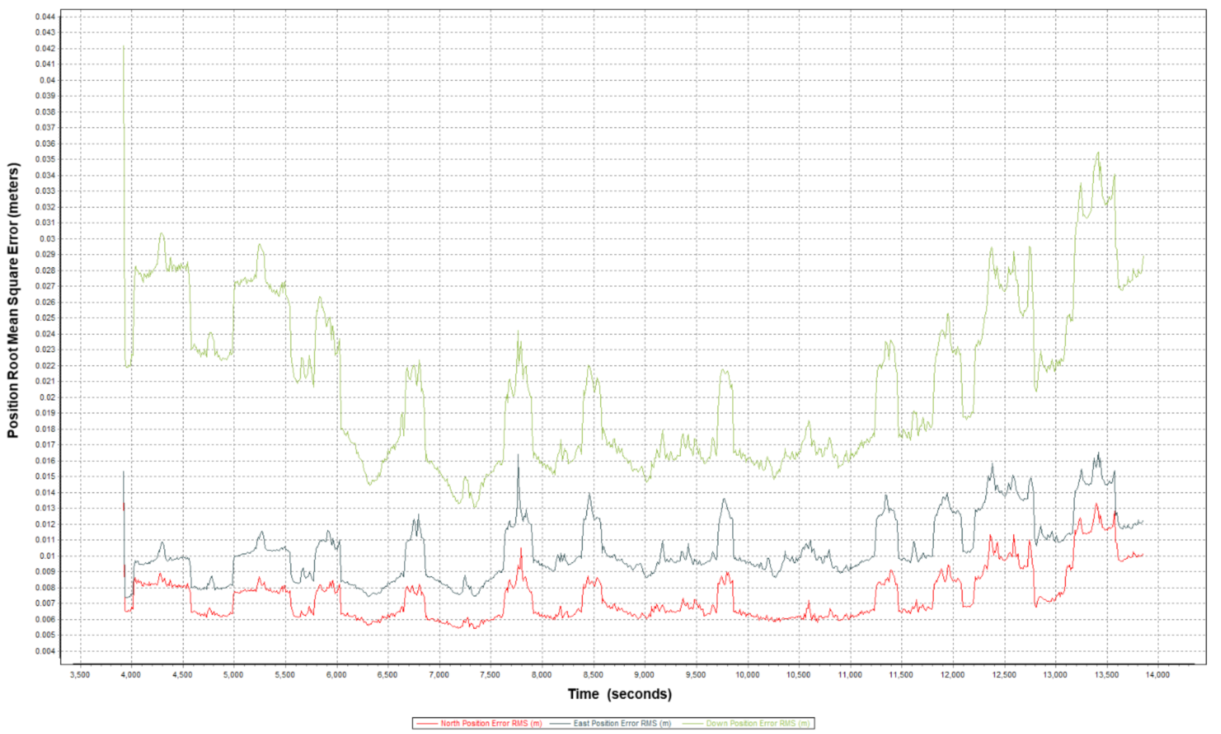


Figure 10. Smoothed Performance Metrics of Migcanaway Flight 23092P.

The time of flight was from 3500 seconds to 14000 seconds, which corresponds to morning of February 14, 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 1.40 centimeters, the East position RMSE peaks at 1.70 centimeters, and the Down position RMSE peaks at 3.60 centimeters, which are within the prescribed accuracies described in the methodology.

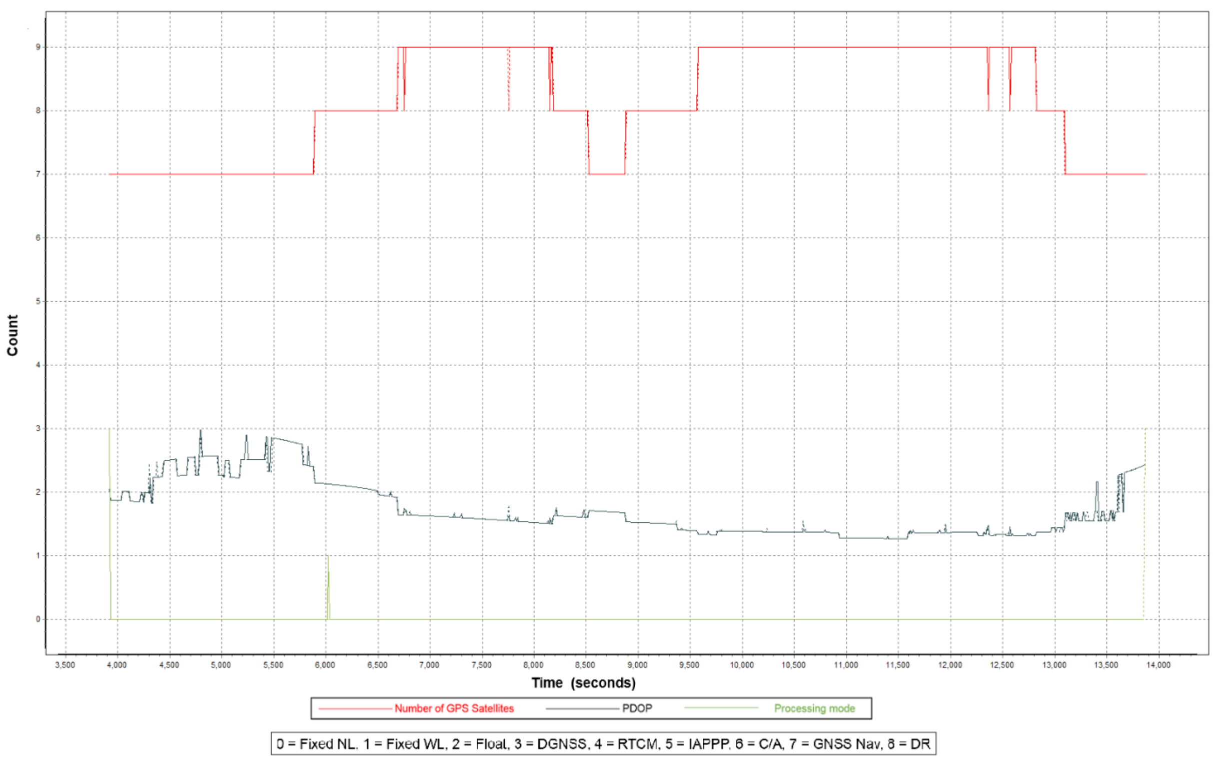


Figure 11. Solution Status Parameters of Migcanaway Flight 23092P.

The S*olution Status* parameters of flight 23092P, one of the Migcanaway 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 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Migcanaway flights is shown in Figure 12.

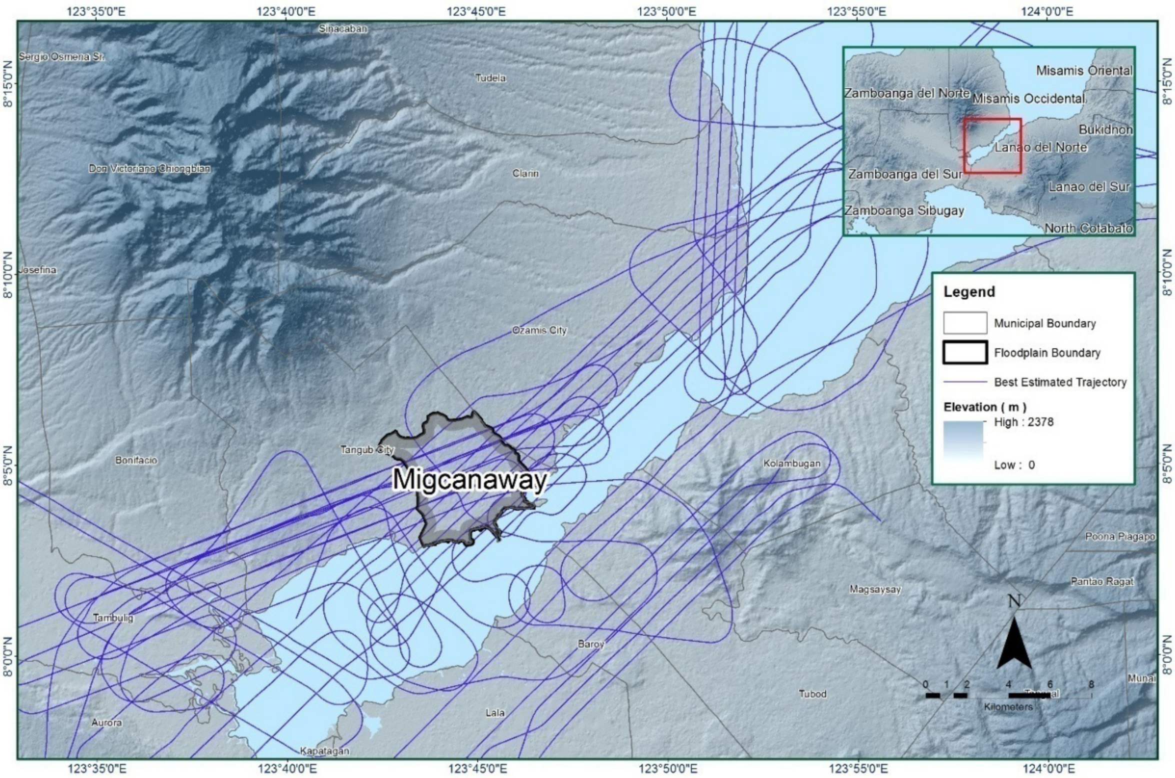


Figure 12. Best Estimated Trajectory for Migcanaway Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 28 flight lines, with each flight line containing two channels since the Pegasus system contain two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Migcanaway Floodplain are given in Table 11.

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

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000369
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000392
GPS Position Z-correction stdev	(<0.01meters)	0.0018

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

3.5 LiDAR Data Quality Checking

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

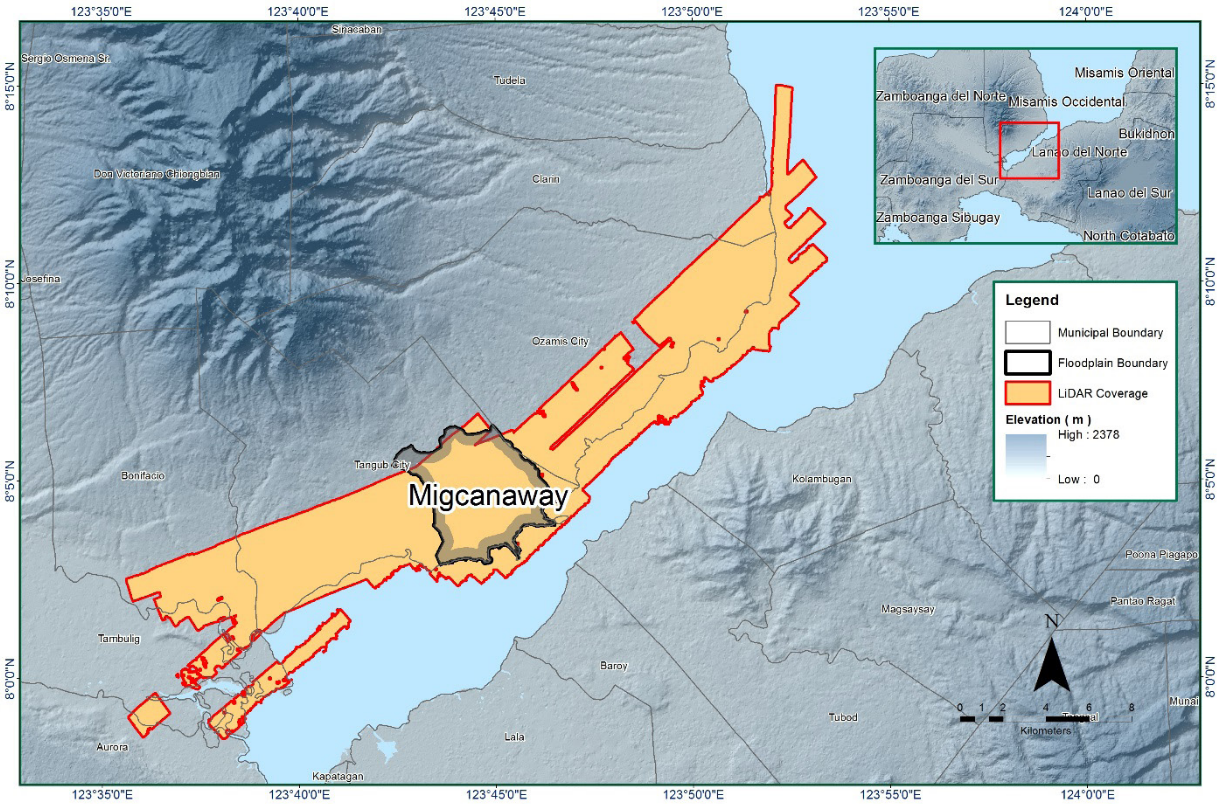


Figure 13. Boundary of the processed LiDAR data over Migcanaway Floodplain

The total area covered by the Migcanaway missions is 219.36 sq.km that is comprised of five (5) flight acquisitions grouped and merged into three (3) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Migcanaway floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Pagadian_Blk76I	23088P 23092P	37.95
Pagadian_Blk76I_additional	23088P	43.11
NorthernMindanao_Blk71_extension	1665P 1673P 1677P	138.30
TOTAL		**219.36 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Pegasus system employs two channels, 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.

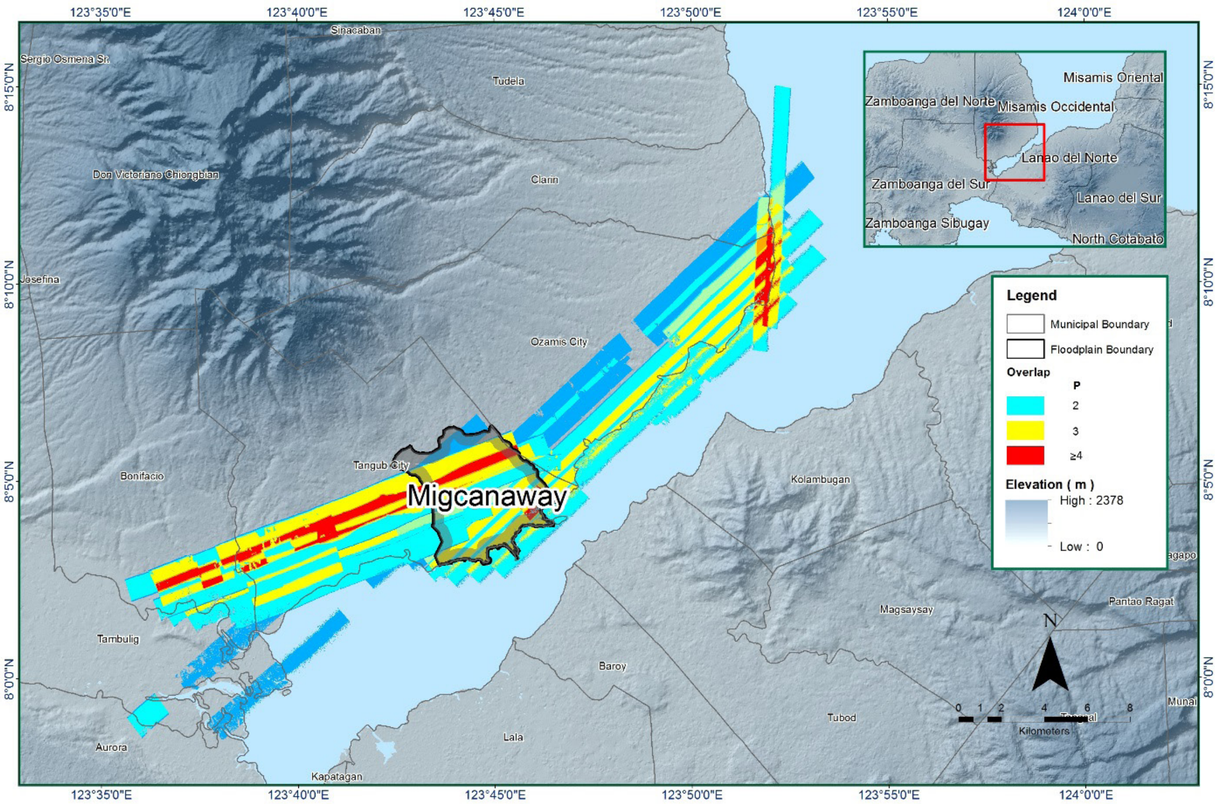


Figure 14. Image of data overlap for Migcanaway Floodplain.

The overlap statistics per block for the Migcanaway 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 overlaps are 27.83% and 52.57% 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 Migcanaway Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.20 points per square meter.

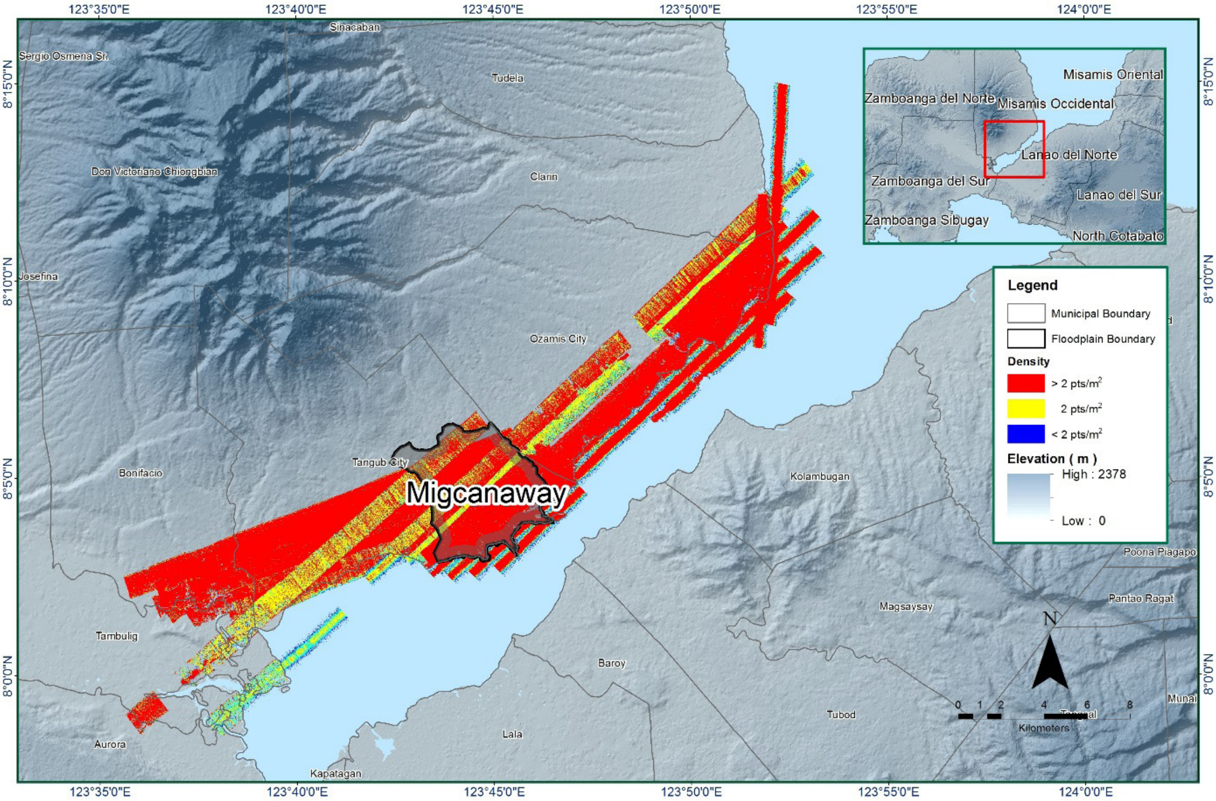


Figure 15. Pulse density map of merged LiDAR data for Migcanaway Floodplain.

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 0.20 m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

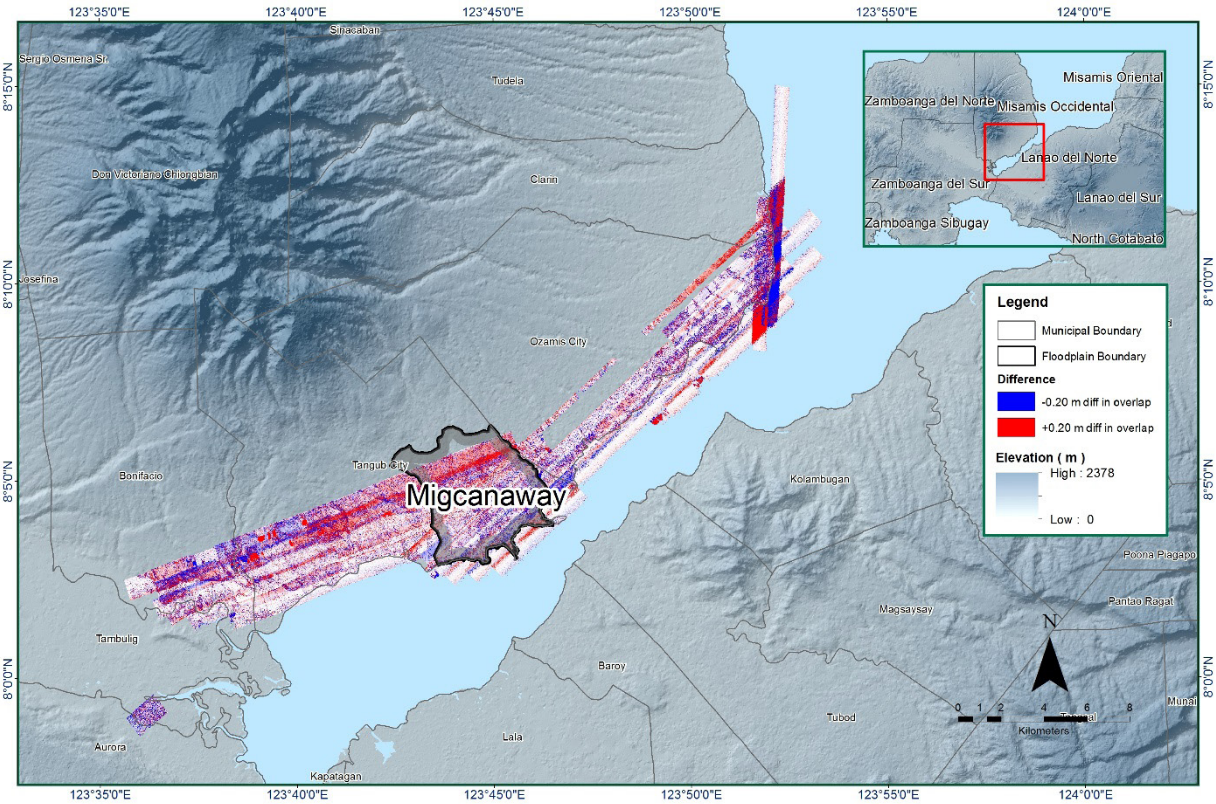


Figure 16. Elevation difference map between flight lines for Migcanaway Floodplain.

A screen capture of the processed LAS data from a Migcanaway flight 23092P 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 red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

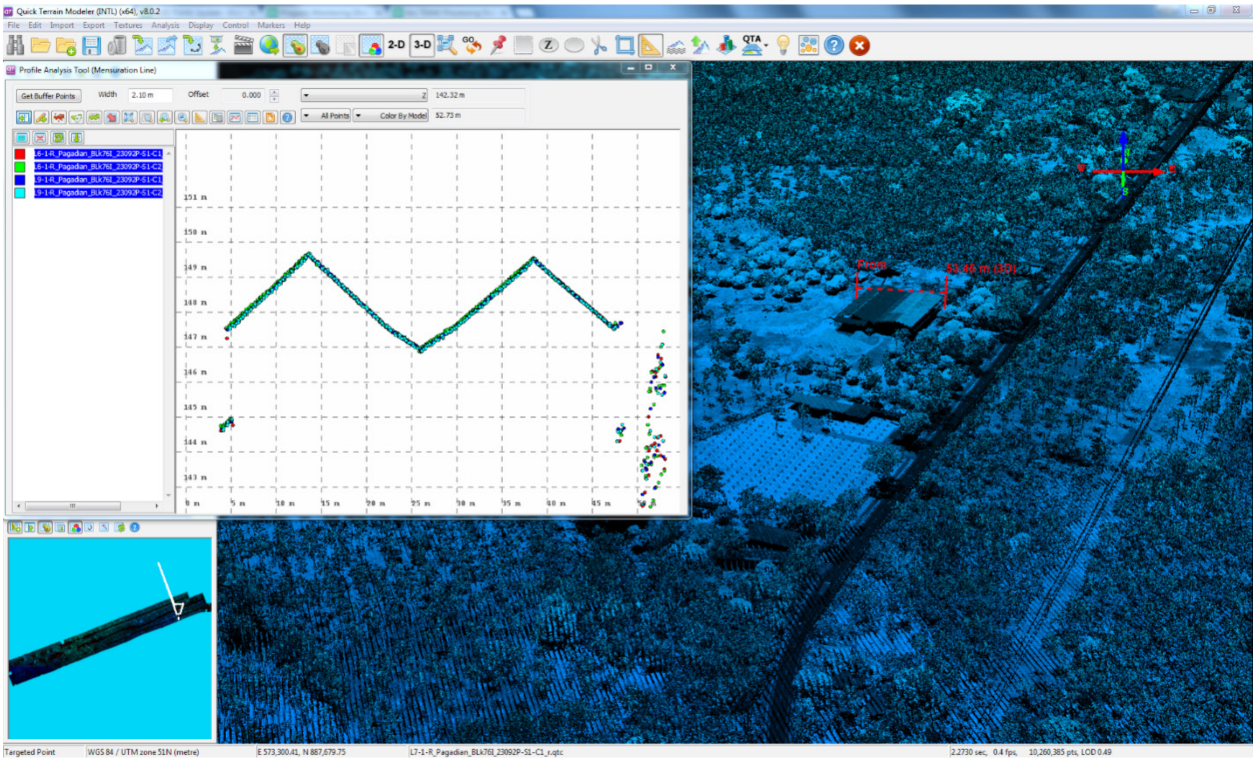


Figure 17. Quality checking for a Migcanaway flight 23092P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Migcanaway classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	246,227,810
Low Vegetation	208,105,416
Medium Vegetation	211,571,245
High Vegetation	393,497,170
Building	23,474,180

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Migcanaway Floodplain is shown in Figure 18. A total of 415 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 868.76 meters and 59.15 meters, respectively.

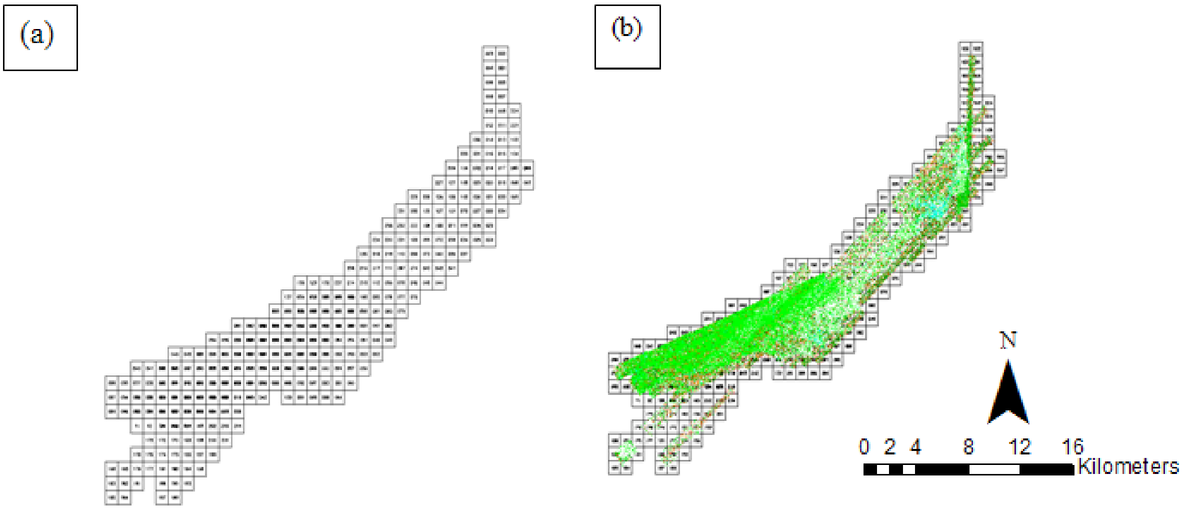


Figure 18. Tiles for Migcanaway floodplain (a) and classification results (b) in TerraScan.

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.

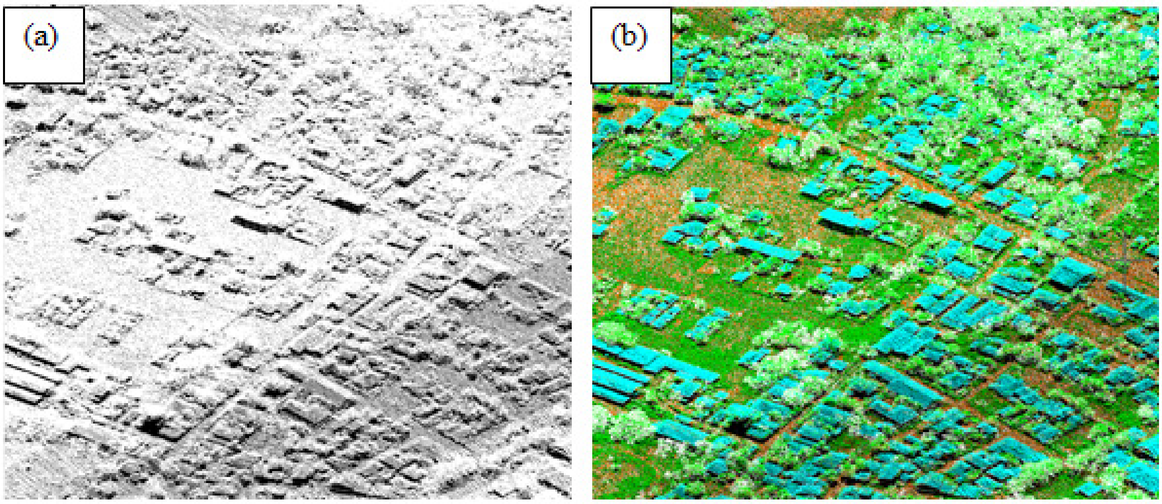


Figure 19. Point cloud before (a) and after (b) classification.

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.

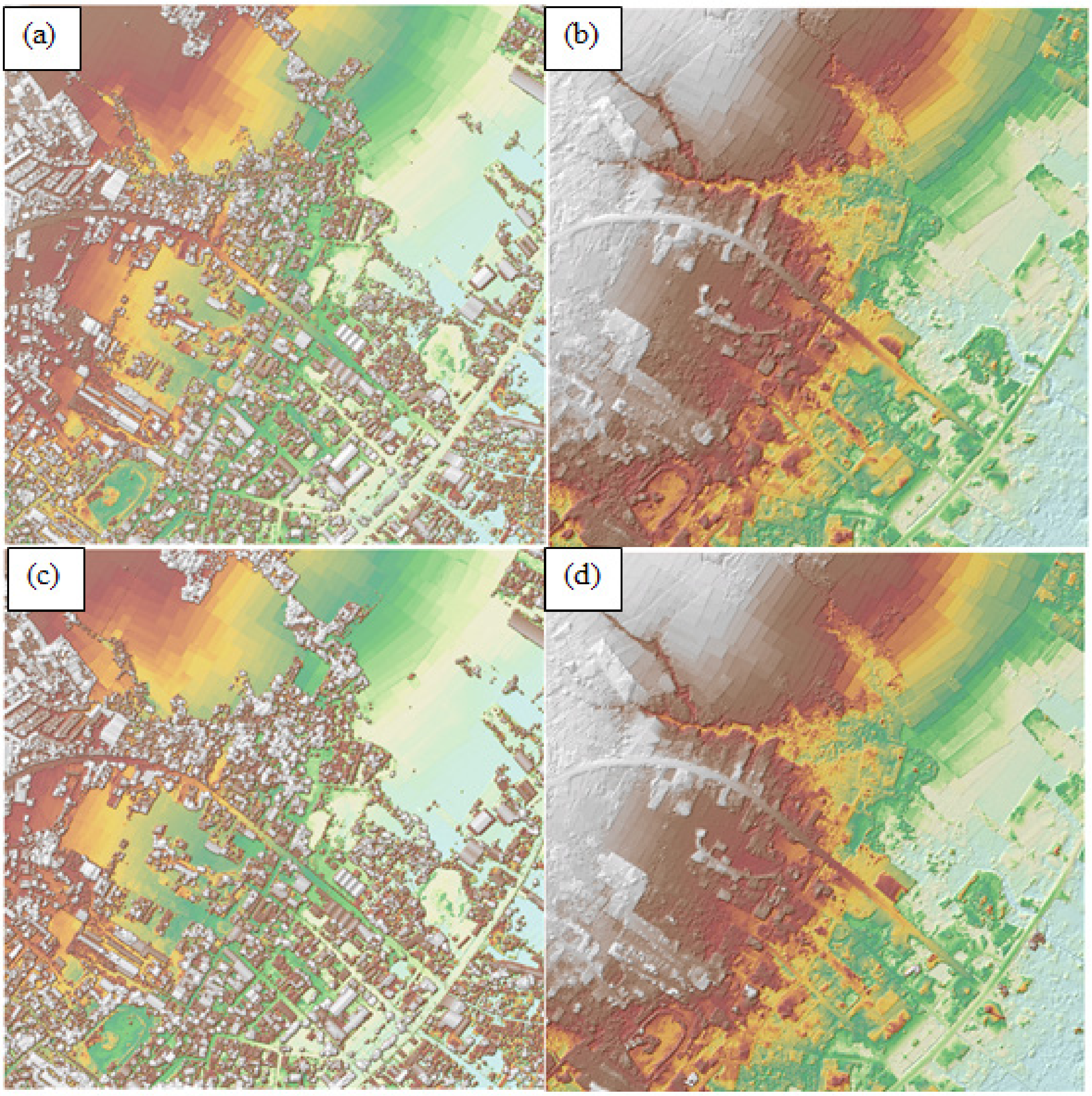


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Migcanaway floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 442 1km by 1km tiles area covered by Migcanaway 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 Migcanaway Floodplain has a total of 247.28 sq.km orthophotogaph coverage comprised of 677 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

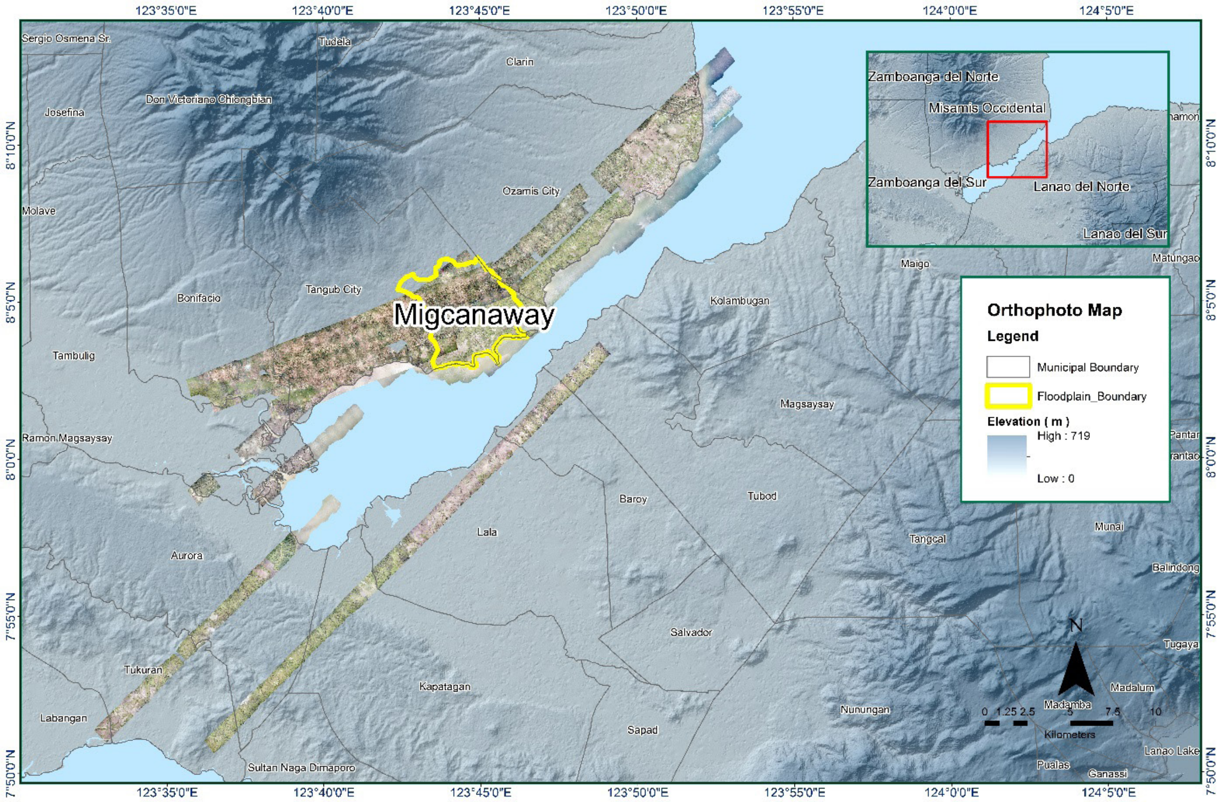


Figure 21. Migcanaway Floodplain with available orthophotographs.

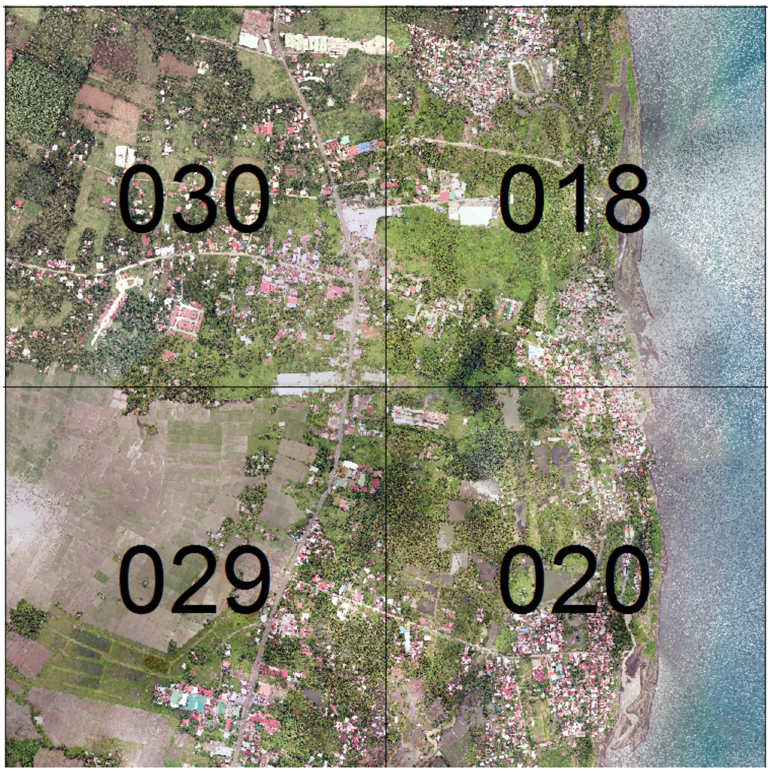


Figure 22. Sample orthophotograph tiles for Migcanaway Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Migcanaway Floodplain. These blocks are composed of Pagadian and Northern Mindanao blocks with a total area of 219.36 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_Blk76I	37.95
Pagadian_Blk76I_additional	43.11
NorthernMindanao_Blk71_extension	138.3
TOTAL	**219.36 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.

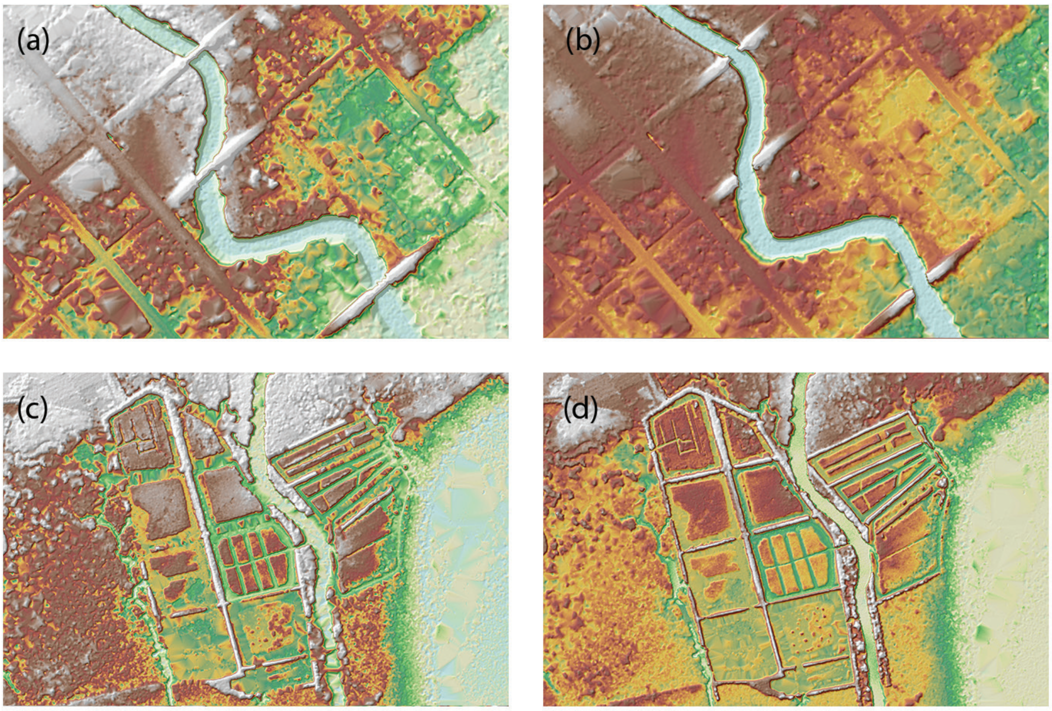


Figure 23. Portions in the DTM of Migcanaway Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

NorthernMindanao_Blk71_extension was used as the reference block at the start of mosaicking because it comprises the largest area among the mission blocks and it is already vertically calibrated to the mean sea level (MSL). Table 15 shows the shift values applied to each LiDAR block during mosaicking.

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

Mission Blocks	Shift Values (meters)		
	x	y	z
Pagadian_Blk76I	0.35	0.45	0.55
Pagadian_Blk76I_additional	0.25	-0.50	0.54
NorthernMindanao_Blk71_extension	0.00	0.00	0.00

Mosaicked LiDAR DTM for Migcanaway Floodplain is shown in Figure 24. It can be seen that the entire Migcanaway Floodplain is 94.5% covered by LiDAR data.

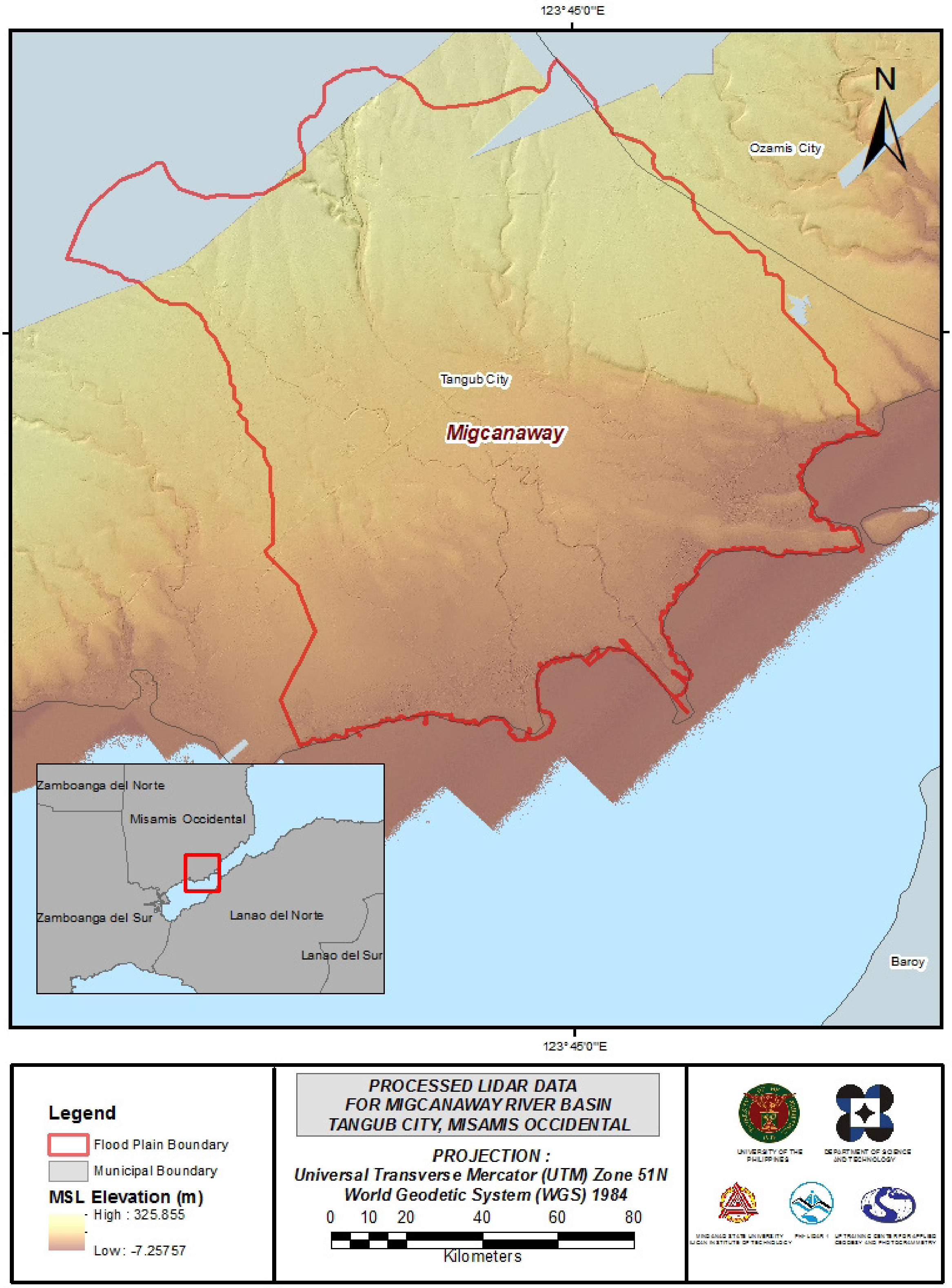


Figure 24. Map of Processed LiDAR Data for Migcanaway Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Migcanaway to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 2,003 survey points were used for calibration and validation of Migcanaway LiDAR data. Random selection of 80% of the survey points, resulting to 1,602 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values are 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 2.27meters with a standard deviation of 0.08 meters. Calibration of Migcanaway LiDAR data was done by adding the height difference value, 2.27 meters, to Migcanaway mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

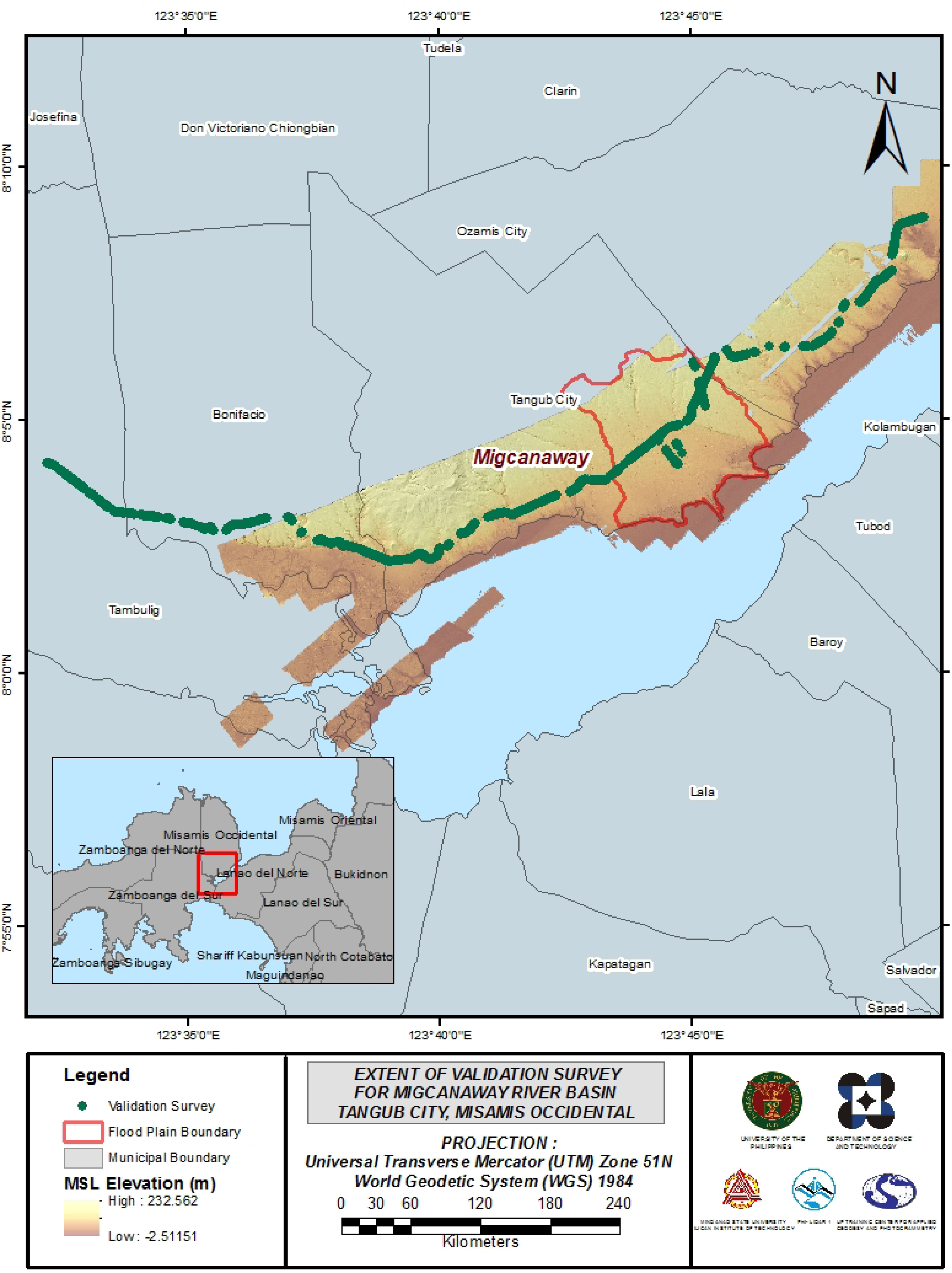


Figure 25. Map of Migcanaway Floodplain with validation survey points in green.

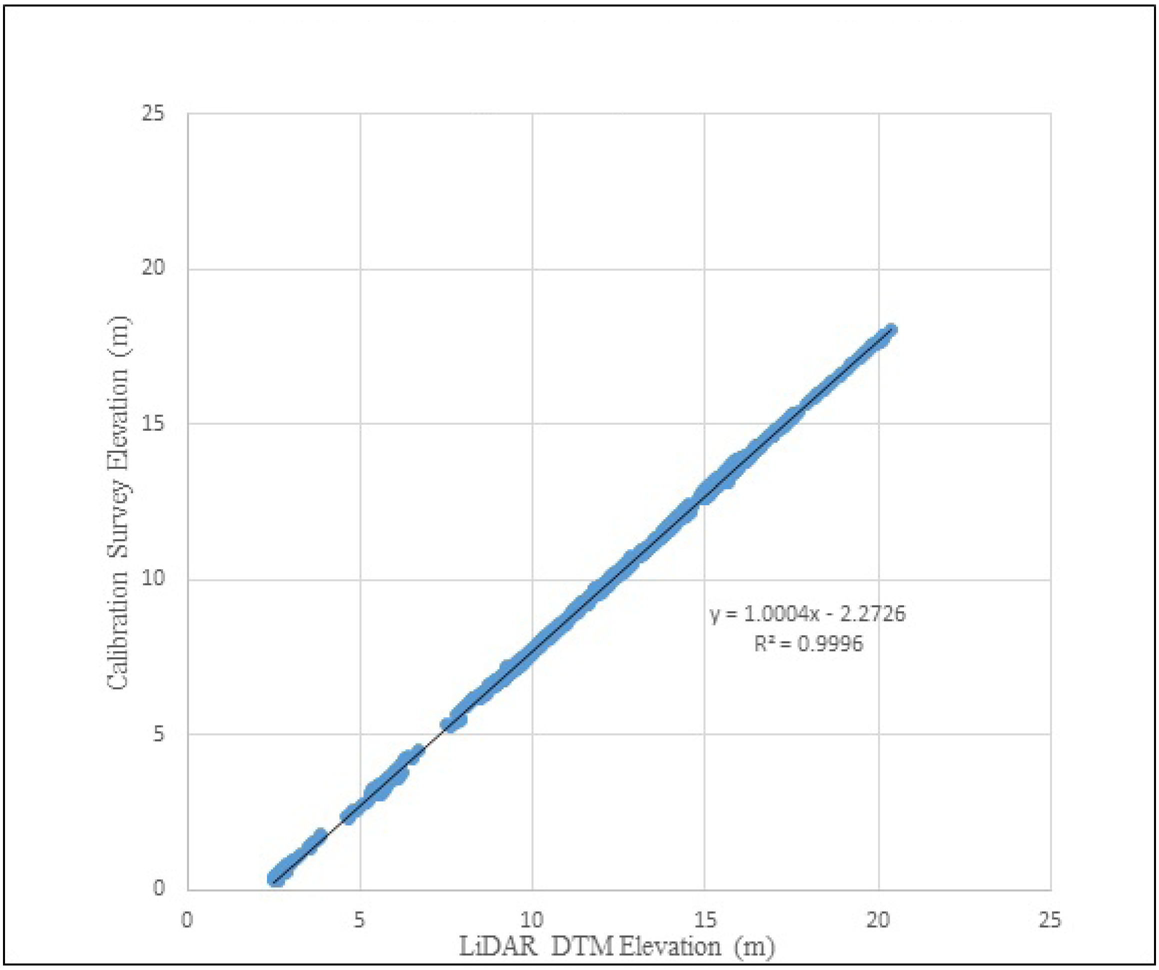


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.27
Standard Deviation	0.08
Average	2.27
Minimum	2.06
Maximum	2.52

The remaining 20% of the total survey points, resulting to 823 points, were used for the validation of calibrated Migcanaway 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 0.18 meters with a standard deviation of 0.16 meters, as shown in Table 17.

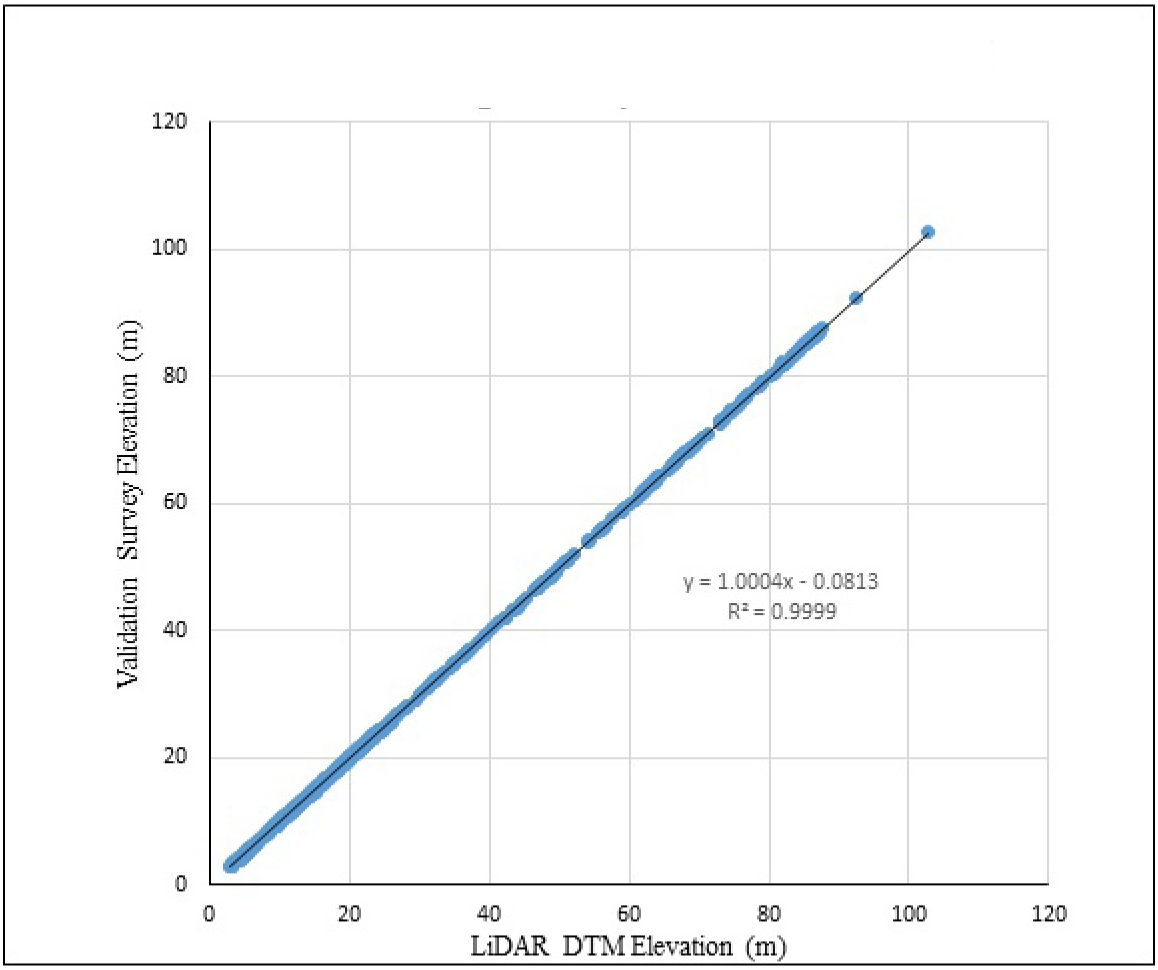


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.16
Average	0.07
Minimum	-0.33
Maximum	0.42

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline, zigzag line, and cross-section data were available for Migcanaway with 4,972 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.21 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Migcanaway integrated with the processed LiDAR DEM is shown in Figure 28.

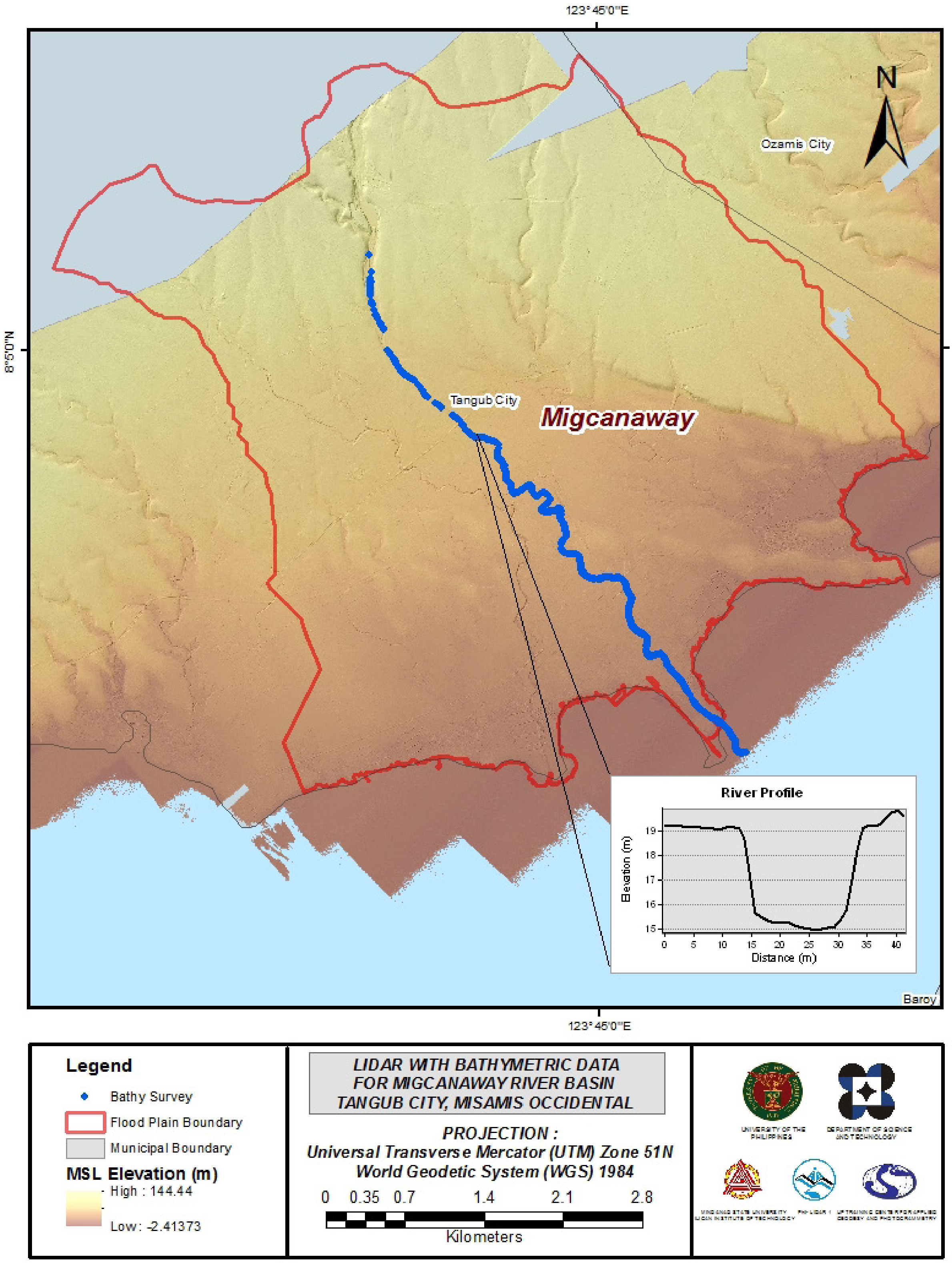


Figure 28. Map of Migcanaway Floodplain with bathymetric survey points shown in blue.

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

Migcanaway Floodplain, including its 200 m buffer, has a total area of 33.75sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1828 building features, are considered for QC. Figure 29 shows the QC blocks for Migcanaway floodplain.

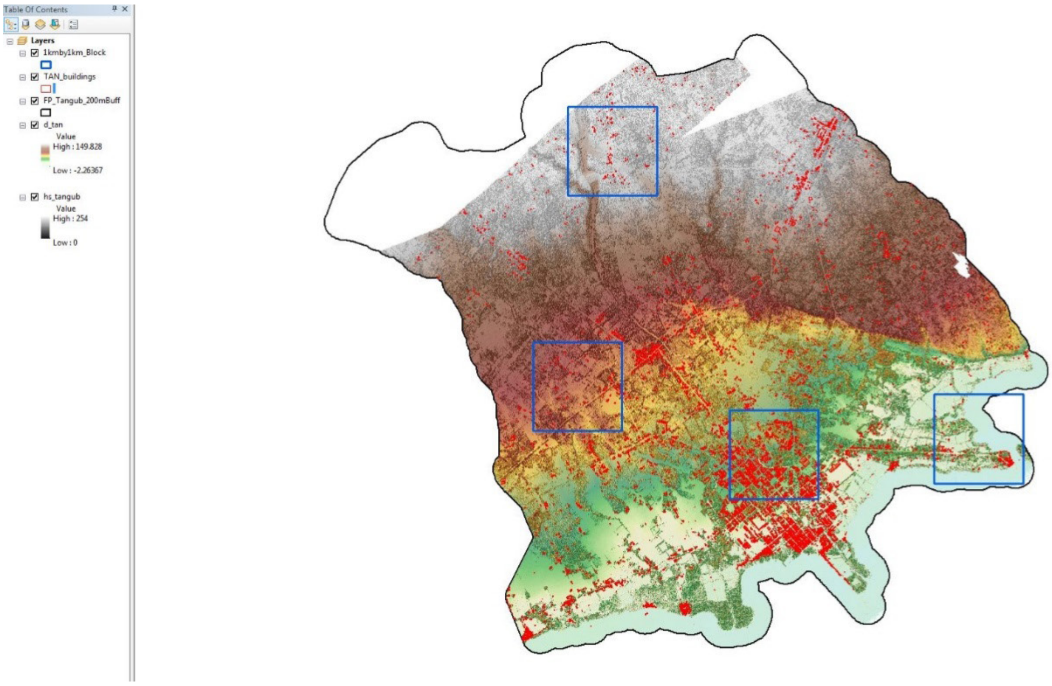


Figure 29. Blocks (in blue) of Migcanaway building features that were subjected in QC

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

Table 18. Quality Checking Ratings for Migcanaway Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Migcanaway	98.81	99.66	85.73	PASSED

3.12.2 Height Extraction

Height extraction was done for 8,657 building features in Migcanaway Floodplain. Of these building features, 112 was filtered out after height extraction, resulting in 8,545 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.34 m.

3.12.3 Feature Attribution

Migcanaway floodplain is within Tangub City. The building attribution on Tangub City 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 presents the number of water features extracted per type.

Table 19. Building Features Extracted for Migcanaway Floodplain.

Facility Type	No. of Features
Residential	7,974
School	150
Market	17
Agricultural/Agro-Industrial Facilities	14
Medical Institutions	25
Barangay Hall	22
Military Institution	1
Sports Center/Gymnasium/Covered Court	17
Telecommunication Facilities	11
Transport Terminal	4
Warehouse	17
Power Plant/Substation	0
NGO/CSO Offices	9
Police Station	1
Water Supply/Sewerage	4
Religious Institutions	58
Bank	1
Factory	3
Gas Station	4
Fire Station	2
Other Government Offices	103
Other Commercial Establishments	108
Total	**8,545**

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Migcanaway	22.06	37.22	4.76	5.93	0.00	**69.97**

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

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Migcanaway	3	0	0	0	1	**4**

A total of 14 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 Migcanaway Floodplain overlaid with its ground features.

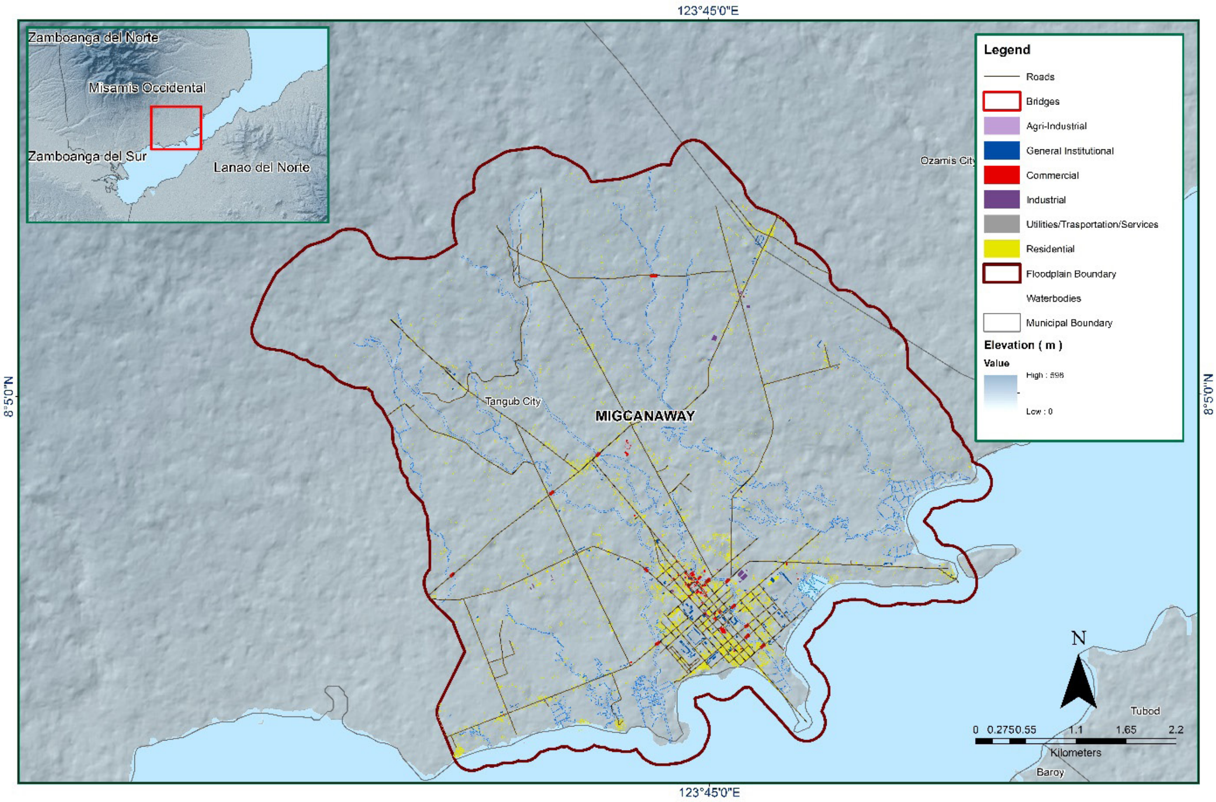


Figure 30. Extracted features for Migcanaway floodplain.

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Migcanaway River on October 23 – November 11, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Migcanaway Bridge in Brgy. Kauswagan, Tangub City; validation points acquisition of about 40 km covering the municipalities of Tambulig, Bonifacio, Tangub City and Ozamiz City in the province of Misamis Occidental; and bathymetric survey from its upstream in Brgy. Kauswagan to the mouth of the river located in Brgy. Migcanaway, Tangub City, with an approximate length of 6.833 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique.

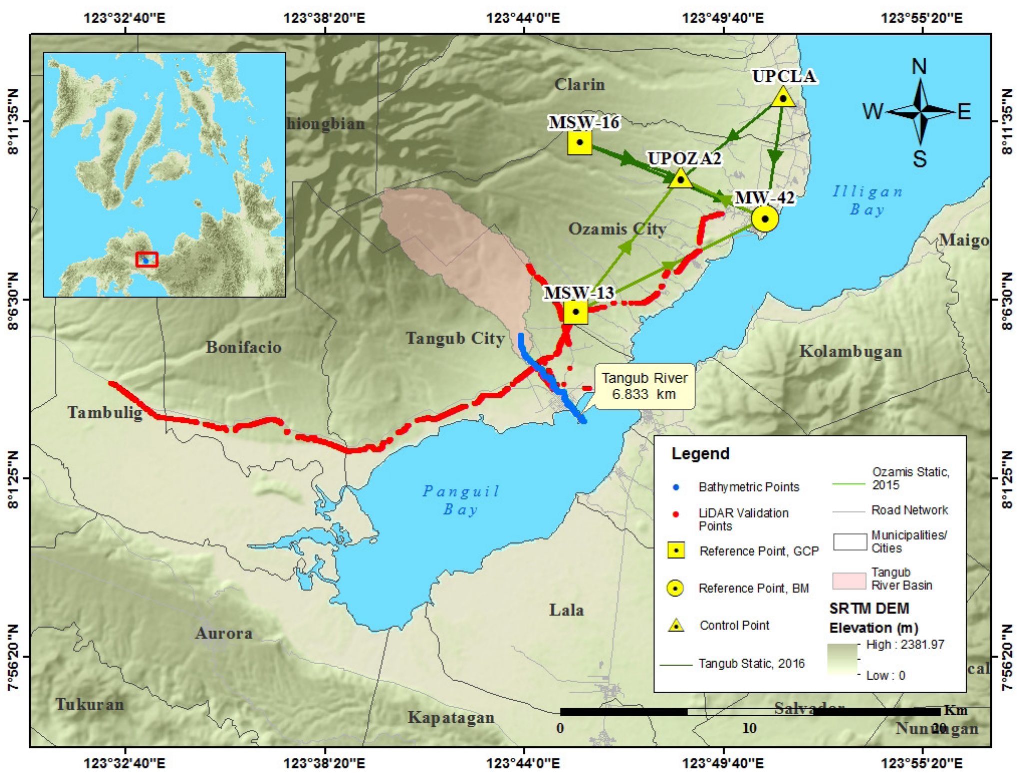


Figure 31. Extent of the bathymetric survey (in blue) in Migcanaway River and the LiDAR data validation survey

4.2 Control Survey

A GNSS network was established for a previous PHIL-LIDAR 1 DVBC fieldwork in Ozamiz River on August 21, 2016 occupying the control points MSW-13, a 2nd order GCP in Brgy. Labinay, Ozamis City;MW-42, a 1st order Benchmark in Brgy. Carmen, Ozamis City; and UP-OZA2, a UP Established control point in Brgy. Mentering, Ozamiz City, all in Misamis Occidental.

The GNSS network used for Migcanaway River Basin is composed of two (2) loops established on October 24, 2016 occupying the reference points: MSW-16, a 2nd order GCP in Brgy. Stimson Abordo, Ozamis City; and UP-CLA, a UP established control point in Brgy. Poblacion IV, Municipality of Clarin, all in Misamis Occidental.

A NAMRIA established control point namely, MW-42, a 1st order Benchmark in Brgy. Carmen, Ozamis City; and a UP established control point namely, UP-OZA2 in Brgy. Mentering, Ozamis City, all in Misamis Occidental, were also occupied to use as markers for the survey.

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

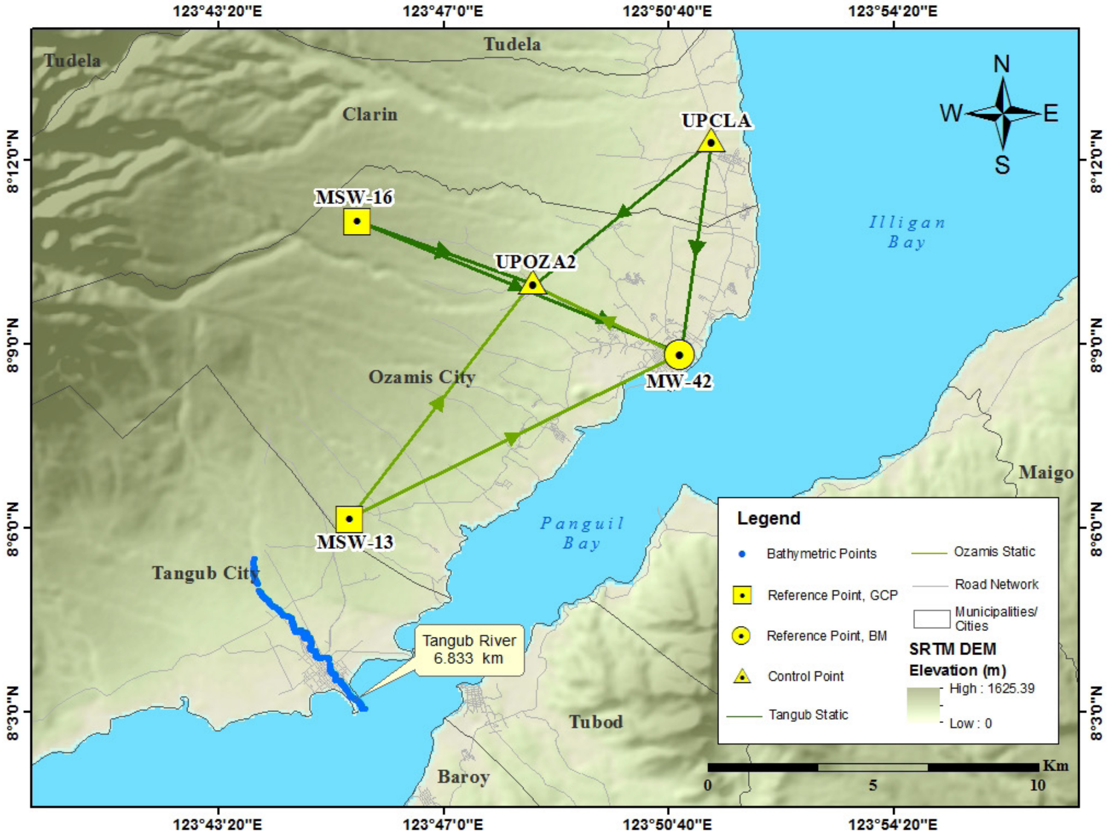


Figure 32. Migcanaway River Basin Control Survey Extent

Table 22. List of Reference and Control Points occupied for Migcanaway River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Establishment Date
Control Survey on October 24, 2016						
MSW-16	fixed	8°11’00.29163”	123°45’35.16283”	358.16	289.316	10-12-15
MW-42	Used as marker	-	-	69.691	-	2008
UP-CLA	fixed	8°12’20.32560”	123°51’20.80387”	72.796	4.138	2015
UP-OZA2	Used as marker	-	-	124.346	-	05-01-16
Control Survey on August21, 2016						
MSW-13	2nd Order, GCP	8°06’09.55249”	123°45’27.93086”	155.26	86.603	2007
MW-42	1st Order, BM	8°08’49.75314”	123°50’50.12216”	69.691	0.922	2008
UP-OZA2	Used as marker	8°10’01.18244”	123°48’26.31528”	124.809	56.066	05-01-16

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

Figure 33. GNSS receiver setup, Trimble® SPS 882, at MSW-16, located in Brgy. Stimson Abordo, Ozamis City, Misamis Occidental

Figure 34. GNSS base set up, Trimble® SPS 852, at MW-42,located in Brgy. Carmen, Ozamiz City, Misamis Occidental

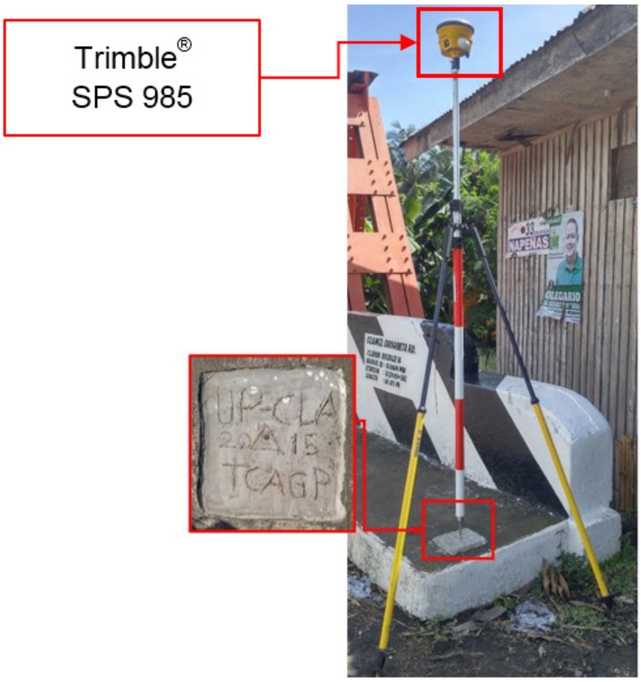


Figure 35. GNSS receiver setup, Trimble® SPS 985 at UP-CLA, located at the approach of Clarin Bridge II in Brgy. Poblacion IV, Municipality of Clarin, Misamis Occidental

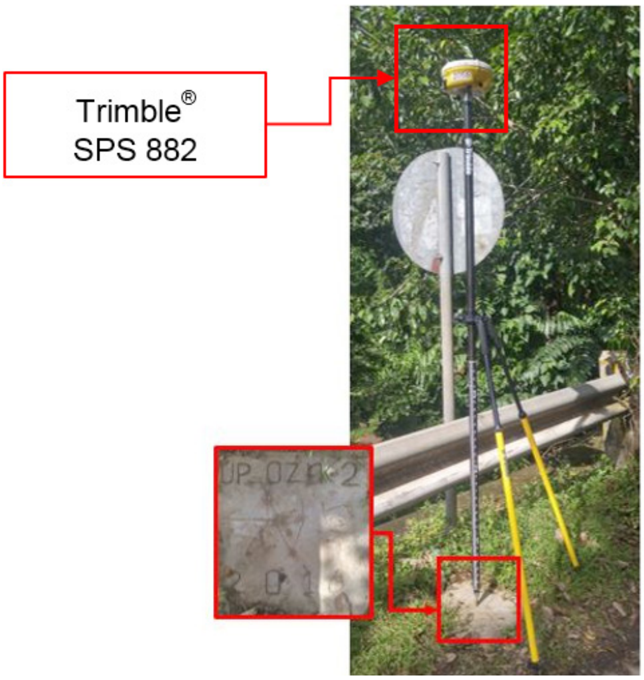


Figure 36. GNSS receiver setup, Trimble® SPS 882, at UP-OZA2, located Brgy. Mentering, Ozamiz City, Misamis Occidental

4.3 Baseline Processing

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

Table 23. Baseline Processing Summary Report for Migcanaway River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
MSW16 --- UPOZA2	10-24-16	Fixed	0.008	0.034	109°06’50”	5544.745	-233.898
UPOZA2 --- MW42	10-24-16	Fixed	0.012	0.052	116°29’34”	4918.751	-54.700
UPCLA --- UPOZA2	10-24-16	Fixed	0.009	0.051	231°19’52”	6840.944	51.696
MSW16 --- MW42	10-24-16	Fixed	0.008	0.034	112°34’45”	10441.939	-288.518
UPCLA --- MW42	10-24-16	Fixed	0.010	0.052	188°15’40”	6536.884	-2.957

As shown Table 23, a total of five (5) baselines were processed with coordinate and elevation values of MSW-16 and UP-CLA held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 24 to Table 26 for complete details.

The four (4) control points, MSW-16, MW-42, UP-CLA, and UP-OZA2 were occupied and observed simultaneously to form a GNSS loop. Coordinates of MSW-16 and MW-42; elevation value of MSW-16 and MW-42; and fixed values of MSW-16 and MW-42 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MSW-16	Grid	Fixed	Fixed		Fixed
UP-CLA	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001 (Meter)					

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

Table 25. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MSW-16	583690.278	?	904653.668	?	289.316	?	ENe
MW-42	593336.441	0.021	900663.777	0.022	0.922	0.099	
UP-CLA	594261.657	?	907132.927	?	4.138	?	ENe
UP-OZA2	588931.138	0.017	902848.507	0.013	55.604	0.098	

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

MSW-16

horizontal accuracy = Fixed
vertical accuracy = Fixed

MW-42

horizontal accuracy = $\sqrt{((2.1)^2 + (2.2)^2}$
= $\sqrt{(4.41 + 4.84)}$
= 9.25< 20 cm
vertical accuracy = 9.9< 10 cm

UP-CLA

horizontal accuracy = Fixed
vertical accuracy = Fixed

UP-OZA2

horizontal accuracy = $\sqrt{((1.7)^2 + (1.3)^2}$
= $\sqrt{(2.89 + 1.69)}$
= 4.58< 20 cm
vertical accuracy = 9.8< 10 cm

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

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
MSW-16	N8°11'00.29163"	E123°45'35.16283"	358.160	?	ENe
MW-42	N8°08'49.75314"	E123°50'50.12216"	69.691	0.099	
UP-CLA	N8°12'20.32560"	E123°51'20.80387"	72.796	?	ENe
UP-OZA2	N8°10'01.18254"	E123°48'26.31494"	124.346	0.098	

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

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

Table 27. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on October 24, 2016							
MSW-16	Fixed	8°11’00.29163”	123°45’35.16283”	358.16	904653.668	583690.278	289.316
MW-42	Used as marker	8°08’49.75314”	123°50’50.12216”	69.691	900663.777	593336.441	0.922
UP-CLA	Fixed	8°12’20.32560”	123°51’20.80387”	72.796	907132.927	594261.657	4.138
UP-OZA2	Used as marker	8°10’01.18254”	123°48’26.31494”	124.346	902848.507	588931.138	55.604
Control Survey on August 21, 2016							
MSW-13	2nd Order, GCP	8°06’09.55249”	123°45’27.93086”	155.26	895724.195	583485.71	86.603
MW-42	1st Order, BM	8°08’49.75314”	123°50’50.12216”	69.691	900663.777	593336.441	0.922
UP-OZA2	Used as marker	8°10’01.18244”	123°48’26.31528”	124.809	902848.504	588931.149	56.066

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

Cross-section and as-built surveys were conducted on October 26 and 28, 2016 at the downstream side of Migcanaway bridge in Brgy. Prenza, Tangub City as shown in Figure 37. A survey grade GNSS receiver Trimble® SPS 985 and 882 in PPK survey technique was utilized for this survey as shown in Figure 38.

Figure 37. Migcanaway Bridge facing downstream

Figure 38. As-built survey of Migcanaway Bridge

Date Surveyed: October 2016

The cross-sectional line of Migcanaway Bridge is about 31.406 m with fifty-nine (59) cross-sectional points, using the control point MW-42 as the GNSS base station. The location map, cross-section diagram, and the bridge data forms are shown in Figure 39 to Figure 41.

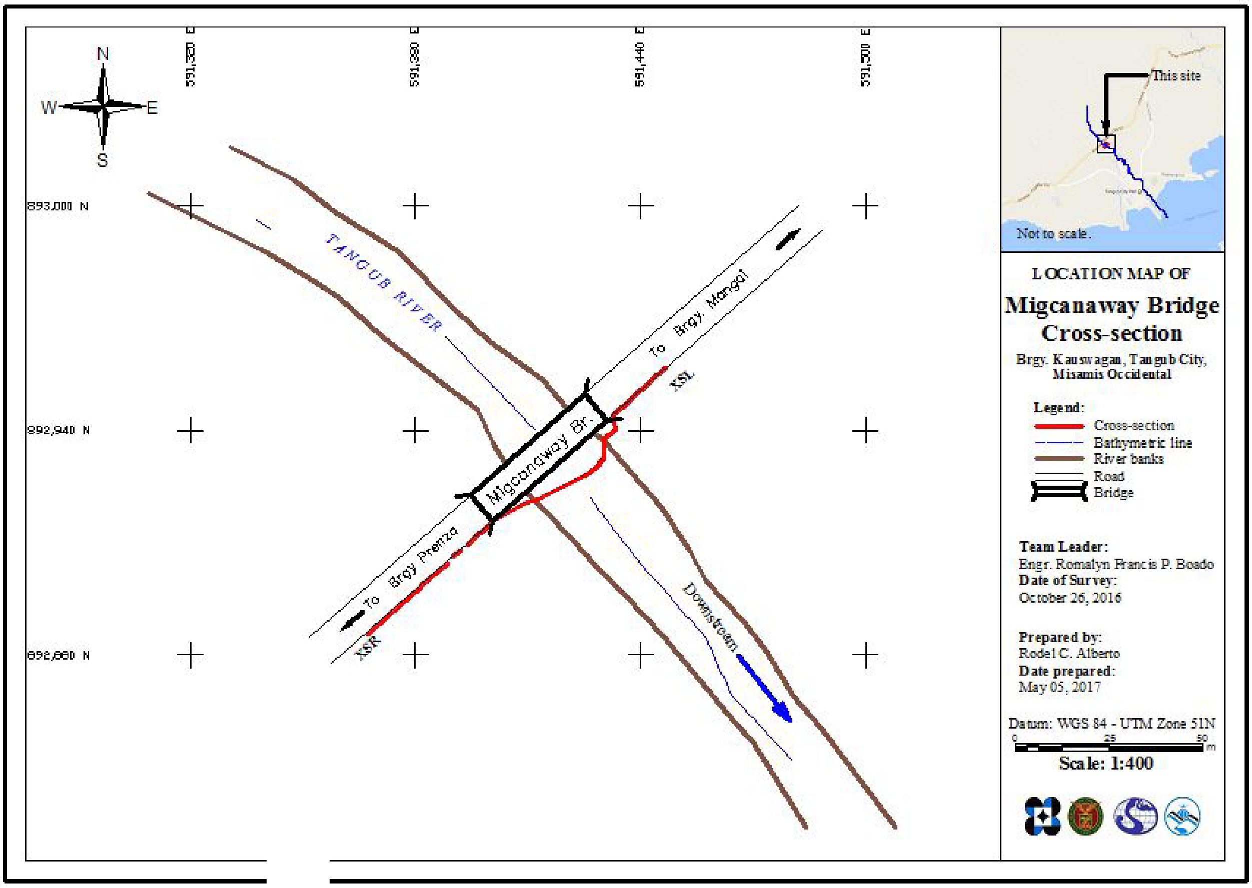


Figure 39. Migcanaway Bridge location map

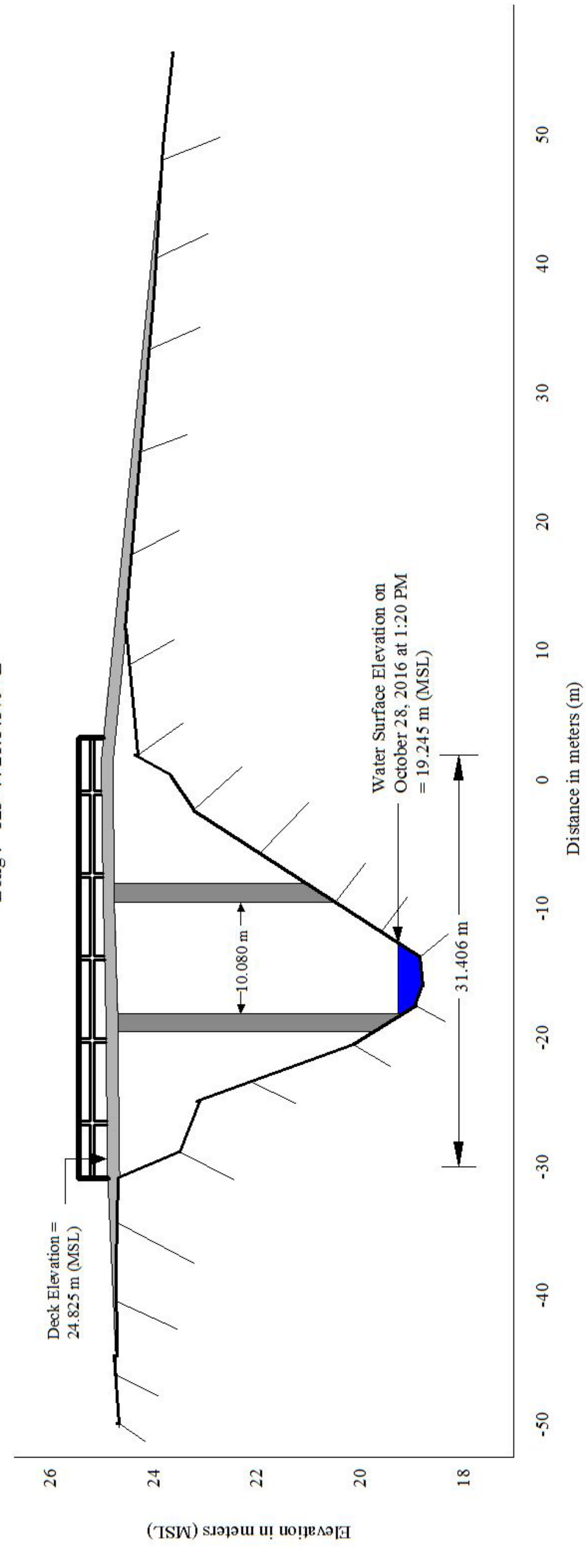


Figure 40. Migcanaway bridge cross-section location map

Bridge Data Form

Bridge Name: Migcanaway Bridge | Date: October 26 and 28, 2016

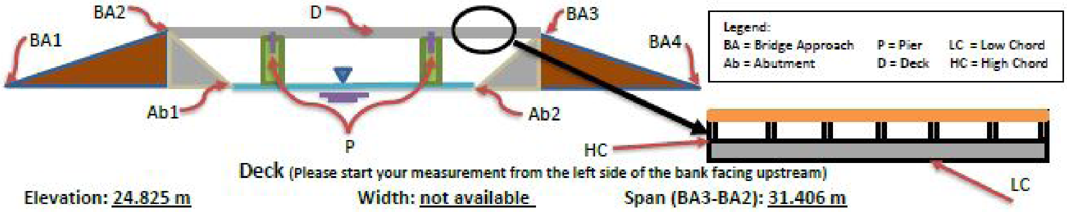
River Name: Tangub River | Time: 1:20 PM

Location (Brgy, City,Region): Brgy. Kauswagan, Tangub City, Misamis Occidental

Survey Team: Romalyn Francis Boado, Randell Pabroquez, Vie Marie Paola Rivera

Flow condition: average | Weather Condition: fair

Latitude: 8°04'39.56168"N | Longitude: 123°44'21.14379" E



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

Elevation: 24.825 m   Width: not available   Span (BA3-BA2): 31.406 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	24.670 m	BA3	51.720 m	24.844 m
BA2	20.309 m	24.825 m	BA4	106.316 m	23.591 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: rectangular   Number of Piers: 2   Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	31.078 m	24.887 m	
Pier 2	41.159 m	24.952 m	

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 41. Bridge as-built form of Migcanaway Bridge

Water surface elevation of Migcanaway River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on October 28, 2016 at1:20 PM in Brgy. Prenza with a value of 19.245 m in MSL as shown in Figure 41. This was translated into marking on the bridge's pier as shown in Figure 42. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Migcanaway River, the Mindanao State University-Iligan Institute of Technology.

Figure 42. Water-level markings on Migcanaway Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 25, 26, and 29, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted at the side of a vehicle as shown in Figure . It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.85m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with MW-42 occupied as the GNSS base station in the conduct of the survey.

Figure 43. Validation points acquisition survey set up along Migcanaway River Basin

The survey started in Brgy. Banadero, Ozamis City going south along national highway covering three (3) Cities and Municipalities in Misamis Occidental: Ozamis, Tangub and Bonifacio; as well as Municipality of Tambulig in Zamboanga del Sur. It also covered five (5) barangays in Misamis Occidental parallel to Migcanaway River namely: Salimpuno, Labinay, Villaba, Capalaran, and Santa Maria. A total of 5,310 points with approximate length of 40km using MW-42 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 44.

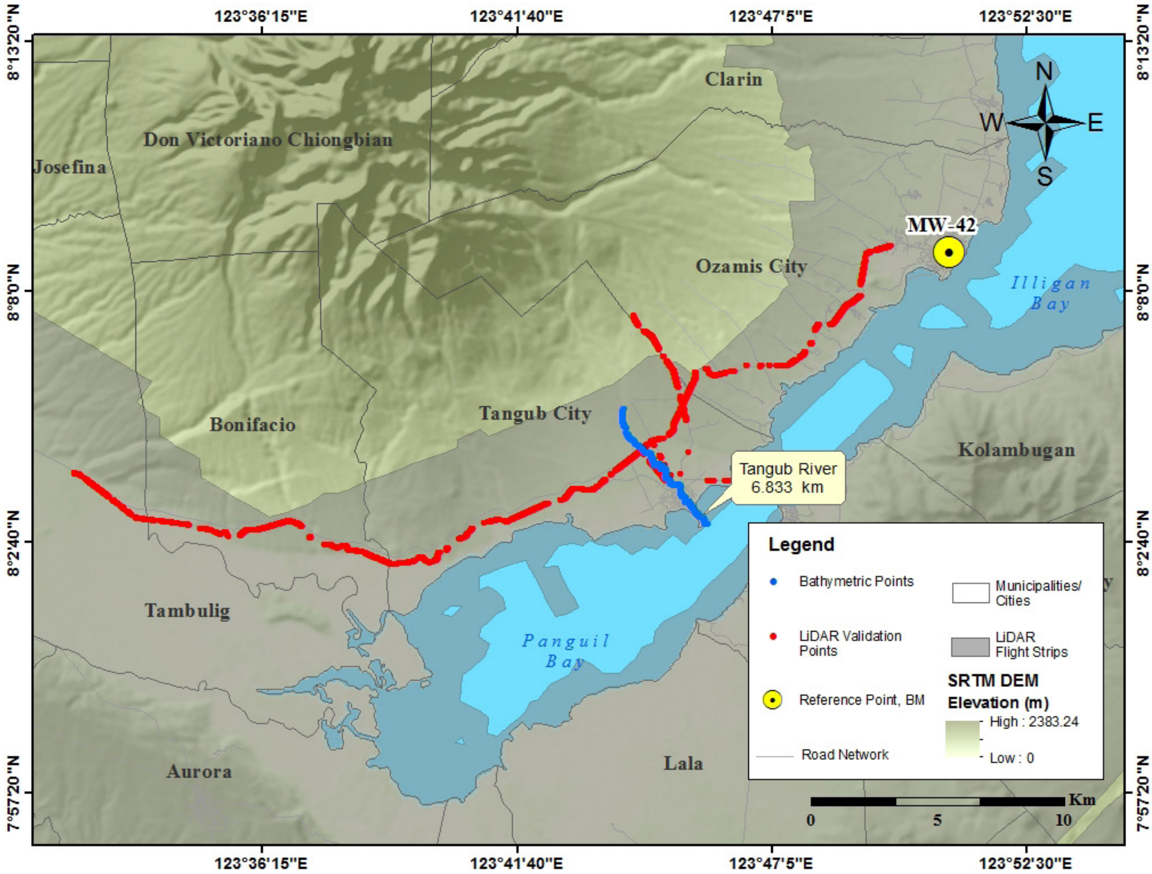


Figure 44. Validation point acquisition survey of Migcanaway River basin

4.7 Bathymetric Survey

Bathymetric survey was executed on November 7 and 9, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 45. It started in Brgy. I, Tangub City with coordinates 8°3'3.55288"N, 123°45'42.69519"E, and ended at the mouth of the river in Brgy. Migcanaway, in the same city, with coordinates 8°3'3.55288"N, 123°45'42.69519"E. The control points MSW-13 and MW-42 were used as GNSS base stations all throughout the entire survey.

Figure 45. Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in Migcanaway River

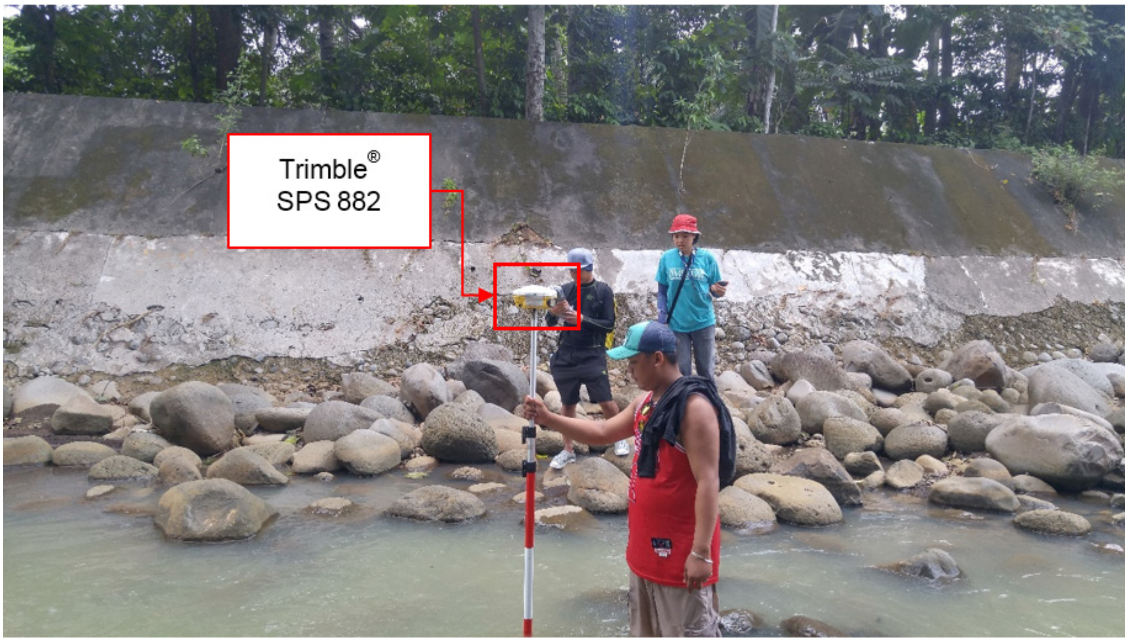


Figure 46. Manual bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in Migcanaway River

Manual Bathymetric survey on the other hand was executed simultaneously on October 25, 26, 28, and 31, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode and a Digital Total Station as illustrated in Figure 47. It started at the upstream part of the river: in Brgy. Prenza, Tangub City with coordinates 8°5'27.01181"N, 123°43'53.85938"E; and in Brgy. Isdiro D. Tan, in the same city with coordinates 8°3'57.92989"N, 123°44'54.71856"E, traversing down the river by foot and ended at the starting point of the bathymetric survey by boat. The control points MSW-13 and MW-42 were used as GNSS base station all throughout the entire survey.

The bathymetric survey for Migcanaway River gathered a total of 1,634 points covering 6.833 km of the river traversing nine (9) barangays in Tangub City in Misamis Occidental. A CAD drawing was also produced to illustrate the riverbed profile of Migcanaway River. As shown in Figure 48, the highest and lowest elevation has a 48.158-m difference. The highest elevation observed was 53.409 m above MSL located in Brgy. Kauswagan, Tangub City; while the lowest was –5.251 m below MSL located in Brgy. Migcanaway, also in Tangub City.

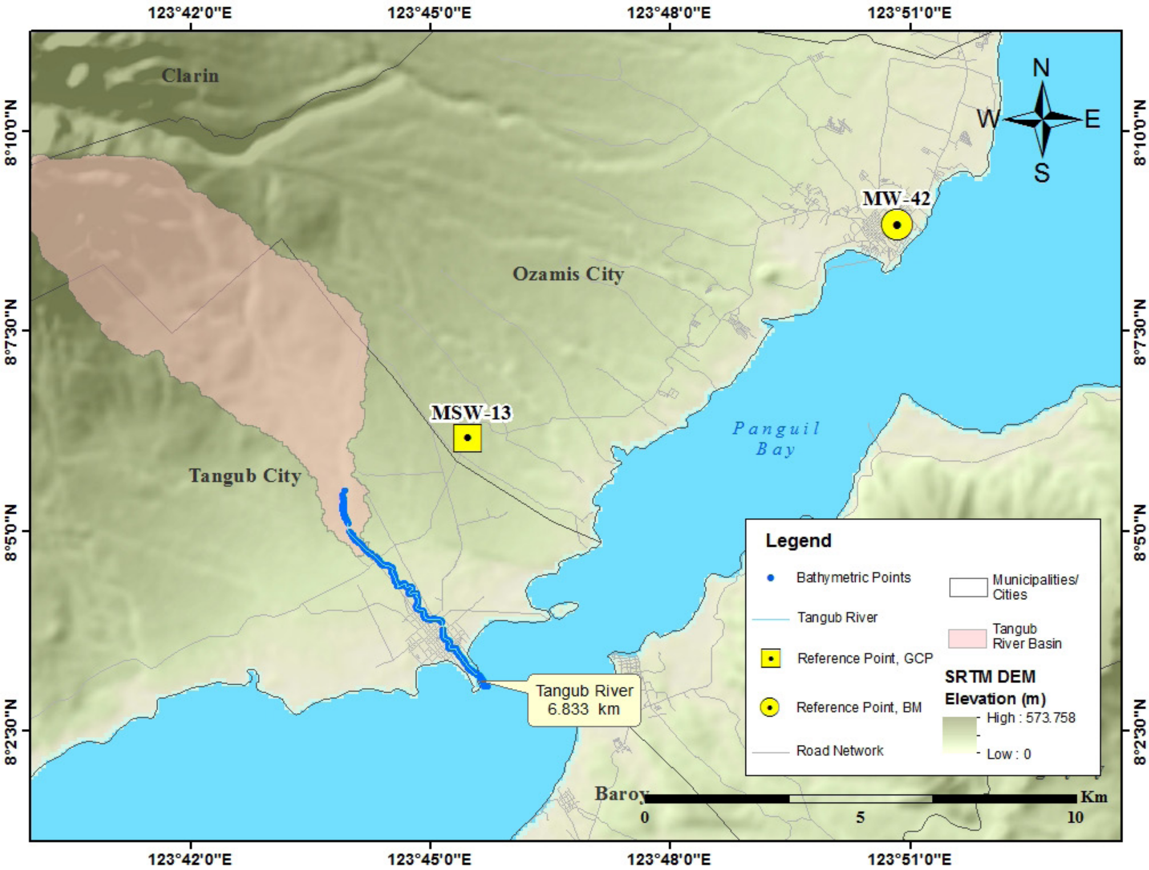


Figure 47. Bathymetric survey of Migcanaway River

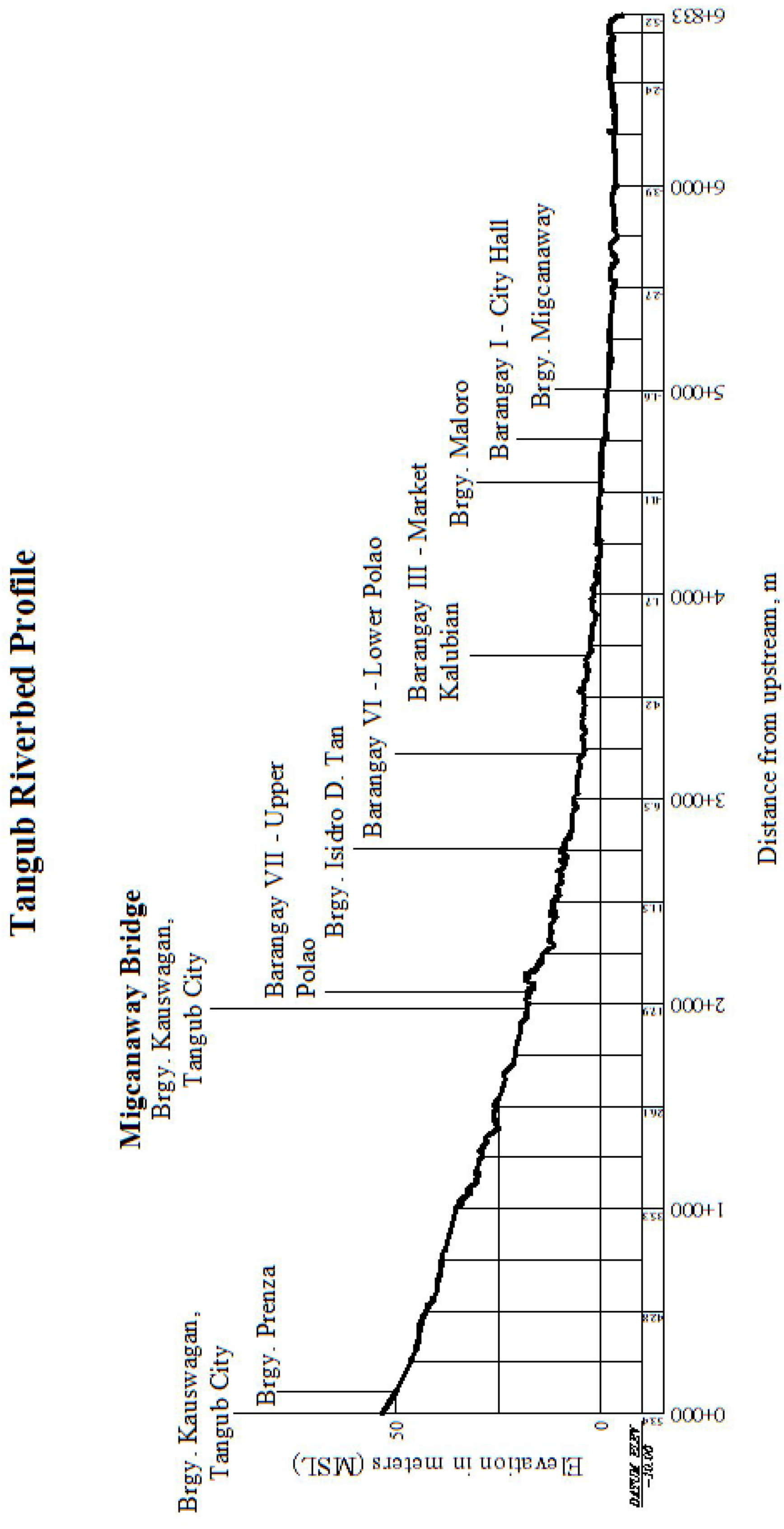


Figure 48. Migcanaway (also known as Tangub) Riverbed Profile

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 Migcanaway 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 Migcanaway 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 Department of Science and Technology (DOST). The ARG was specifically installed in the city of Tangub with coordinates 8° 9’24.37”N Latitude and 123°43’4.98”E Longitude. The location of the rain gauge is shown in Figure 49.

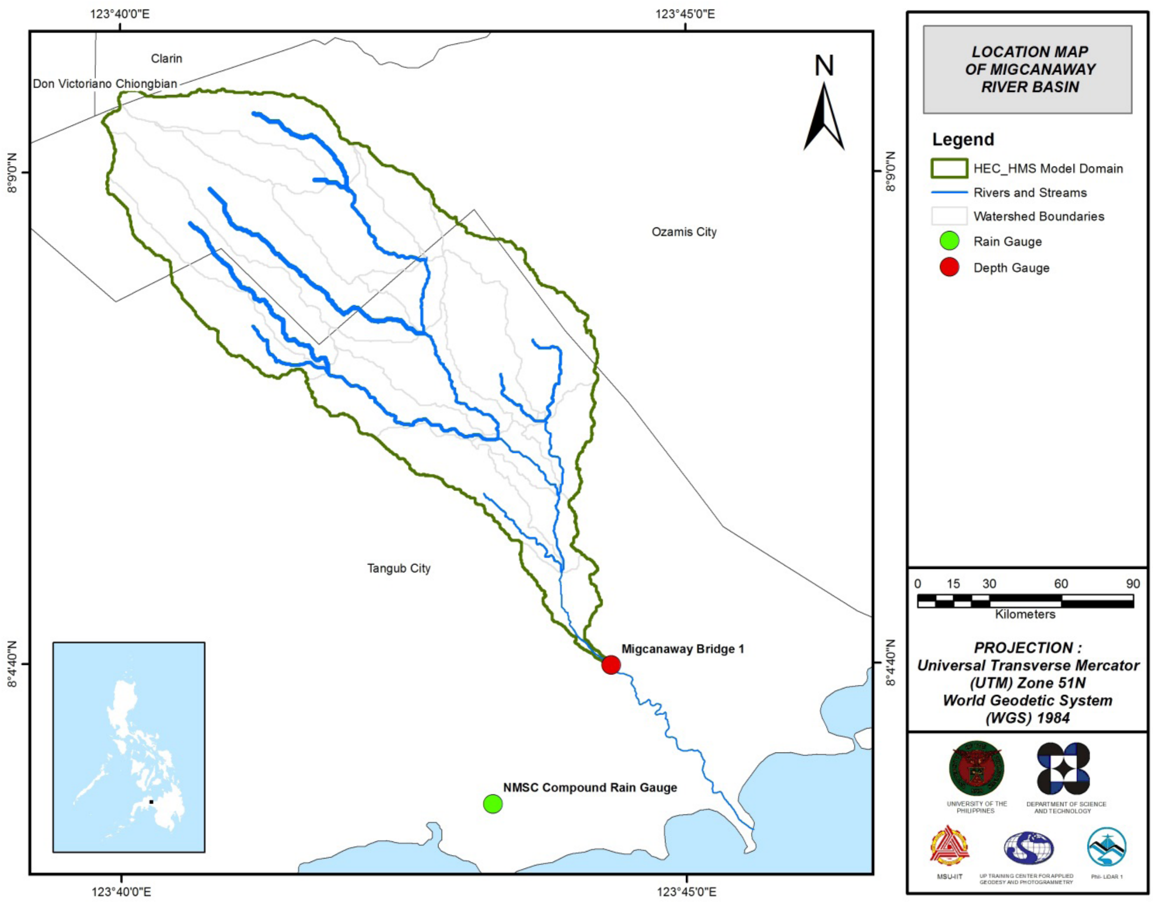


Figure 49. The location map of Migcanaway HEC-HMS model used for calibration

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 Migcanaway, base flow hydrometry was used.

Figure 51 shows the highest R-Squared value of 0.986 compared to the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

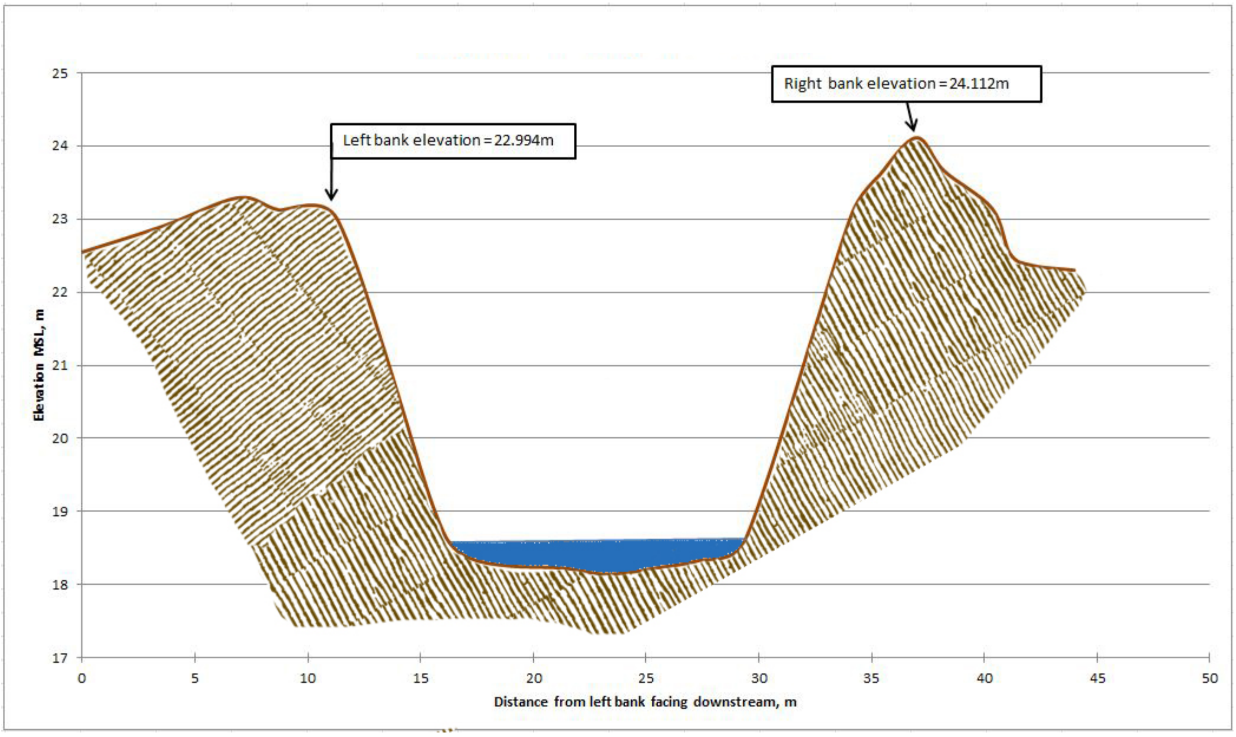


Figure 50. Cross-Section Plot of Migcanaway Bridge

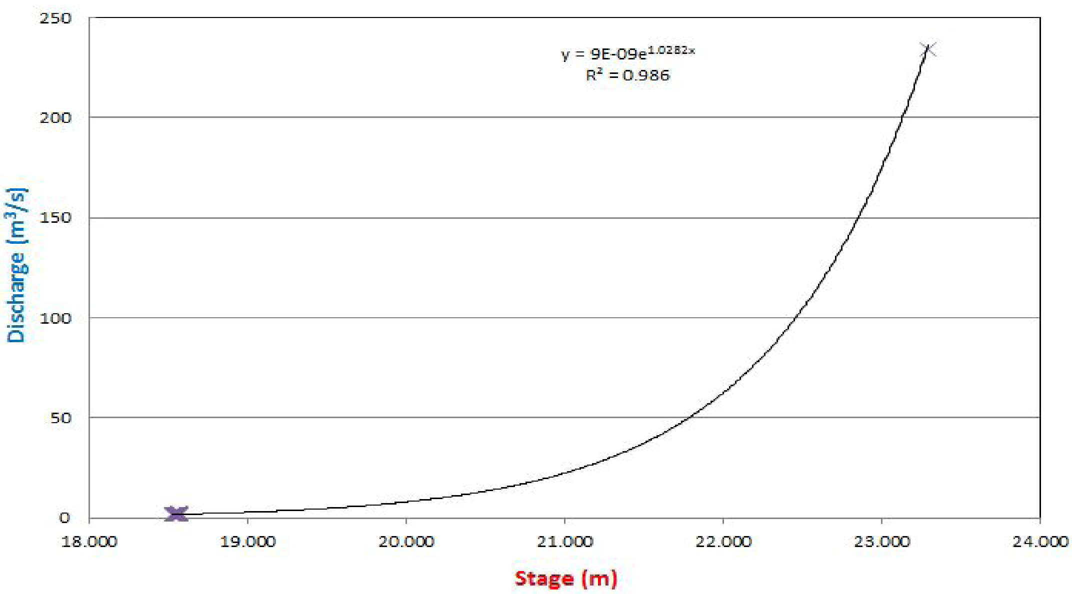


Figure 51. Rating Curve at Migcanaway Bridge

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

Total rainfall taken from the ARG at Labuyo, Tangub City was 65.6 mm. It peaked to 11.8 mm on 15 August 2016, 16:45. The lag time between the peak rainfall and discharge is 35 minutes.

(This image is not available for this floodplain)

Figure 52. Rainfall and outflow data at Migcanaway 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 chosen based on its proximity to the Migcanaway 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

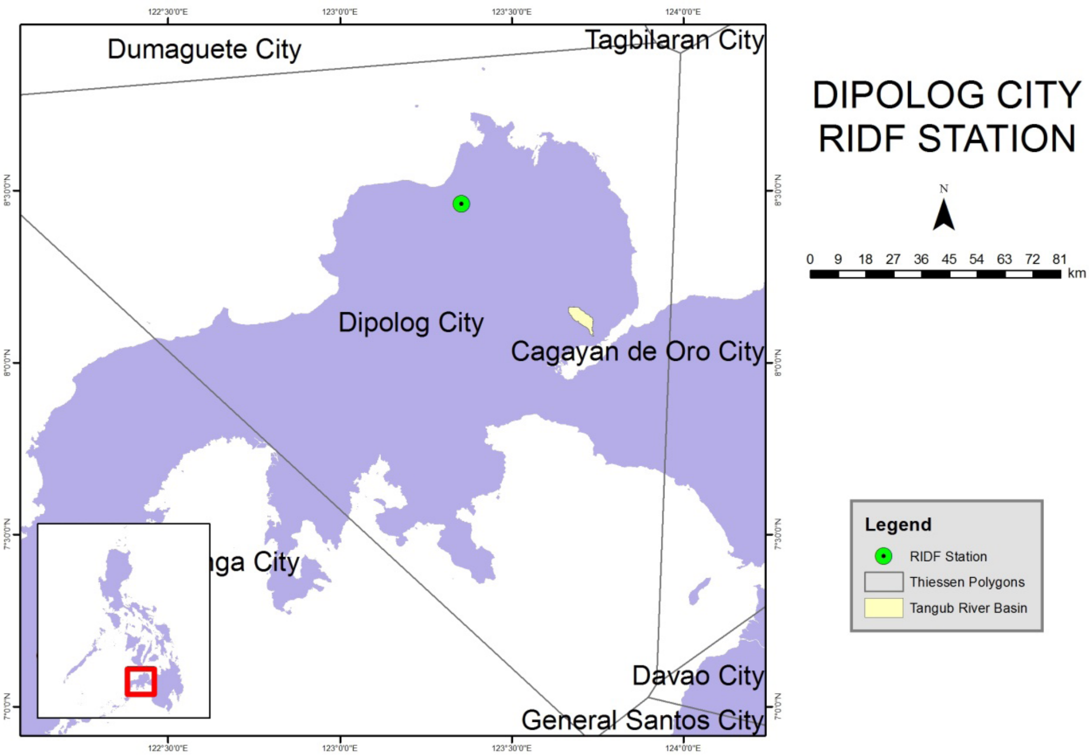


Figure 53. Location of Dipolog RIDF station relative to Migcanaway (Tangub) River Basin

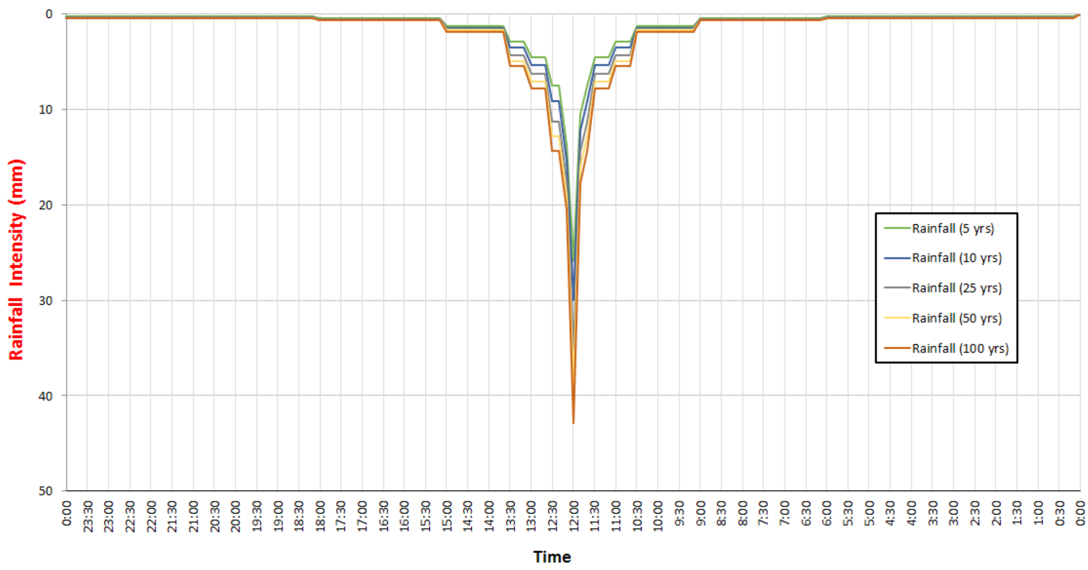


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil texture map (Figure 55) of the Migcanaway River basin was used as one of the factors for the estimation of the CN parameter.

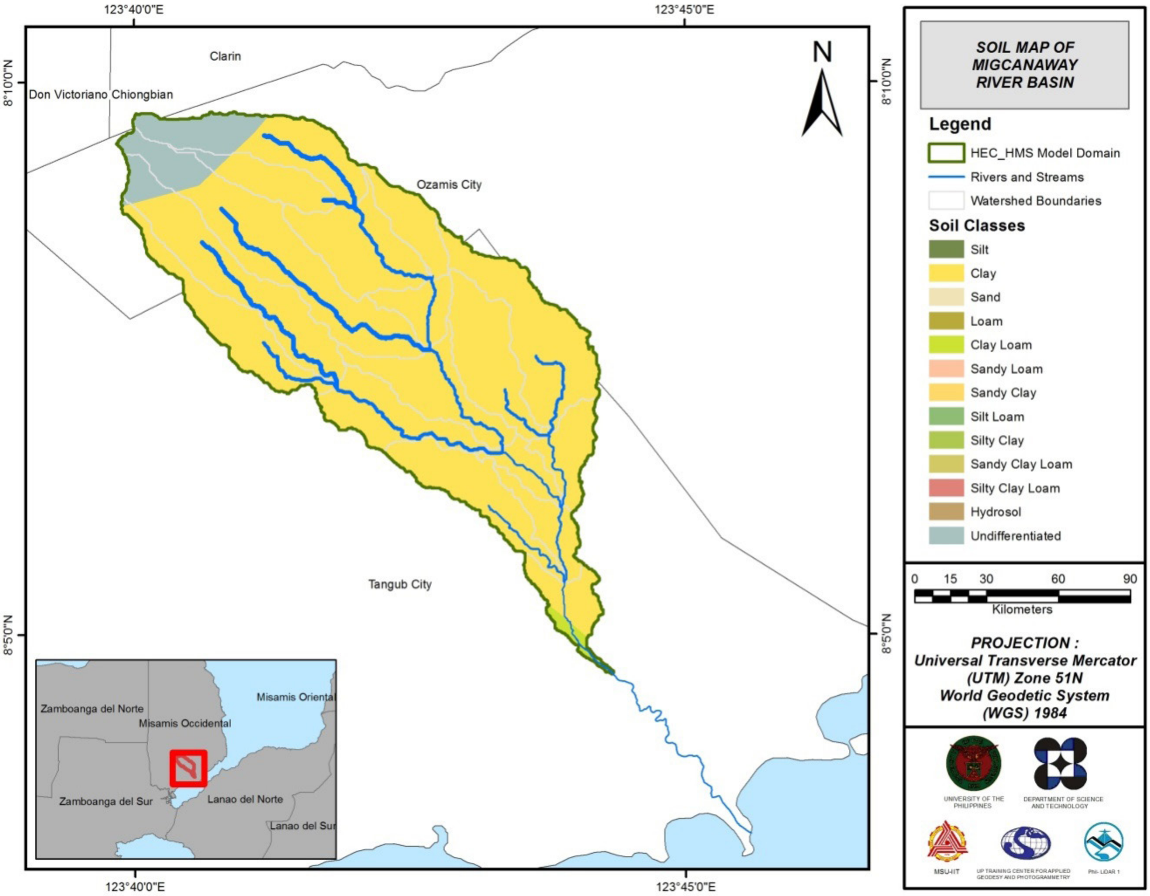


Figure 55. Soil Map of Migcanaway River Basin

The land cover data was generated in 2003 from the National Mapping and Resource information Authority (NAMRIA), DENR. Figure 3 shows the Land Cover inside Migcanaway River Basin. The land cover map of Migcanaway River Basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

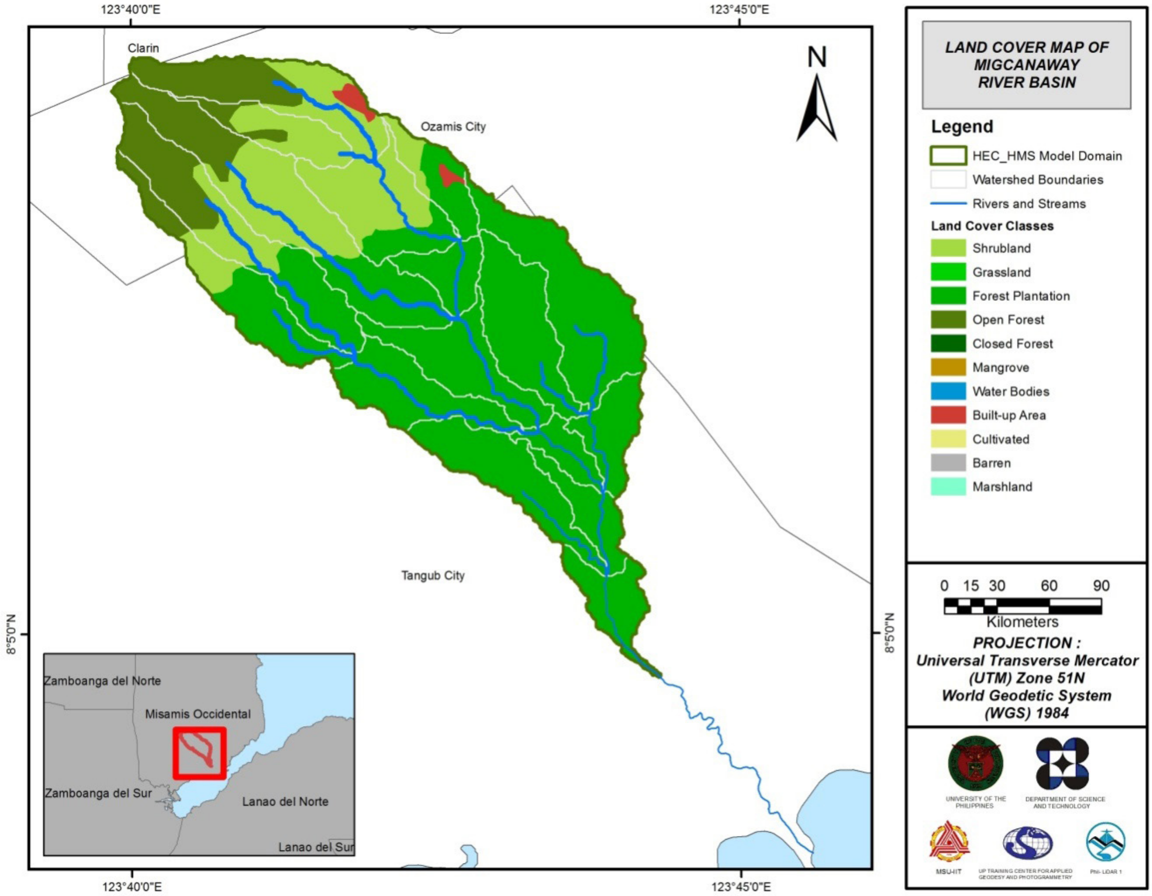


Figure 56. Land Cover Map of Migcanaway River Basin

For Migcanaway, the soil classes identified were clay, and undifferentiated. The land cover types identified were shrubland, forest plantation, open forest, and built-up areas.

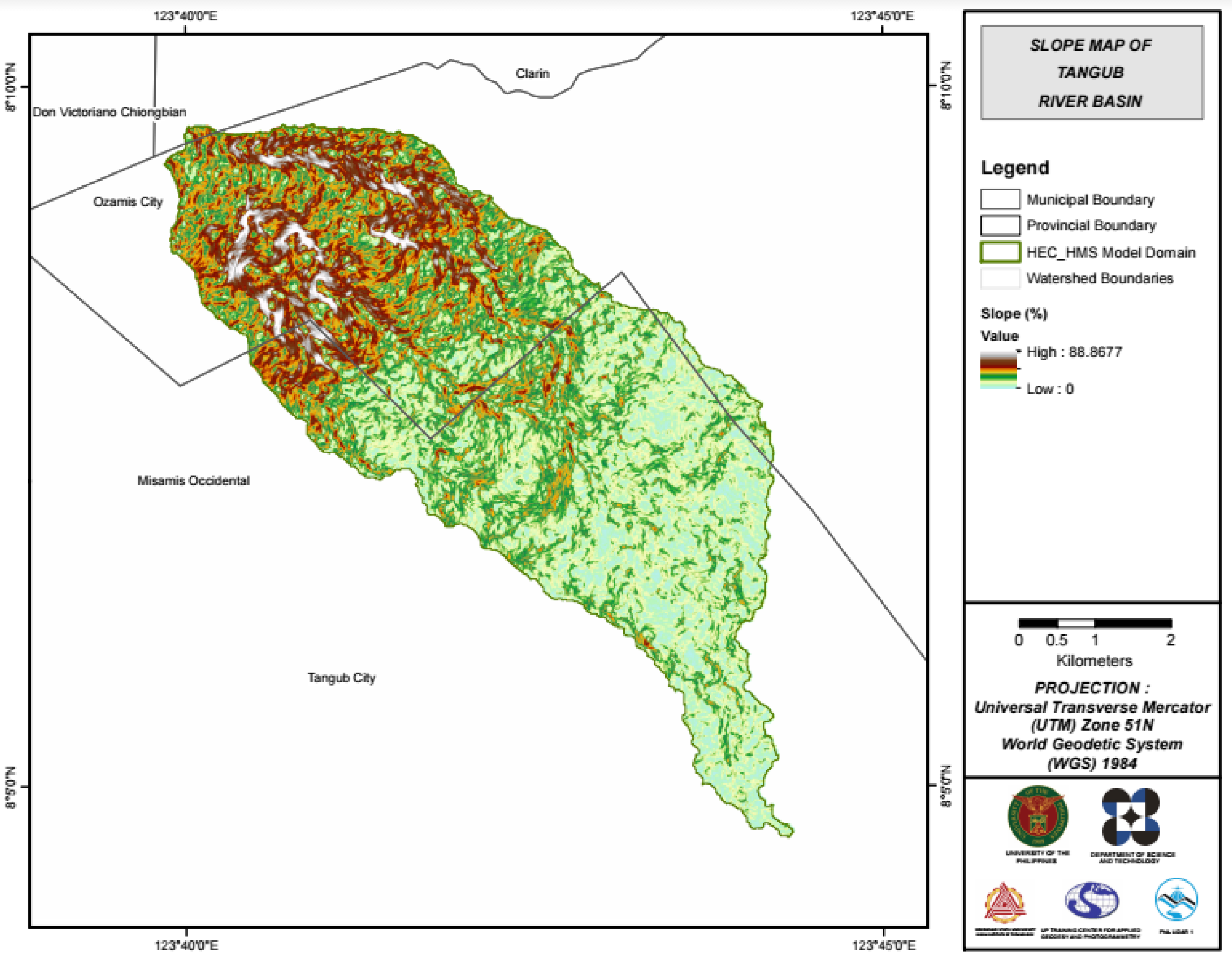


Figure 57. Slope Map of the Migcanaway River Basin

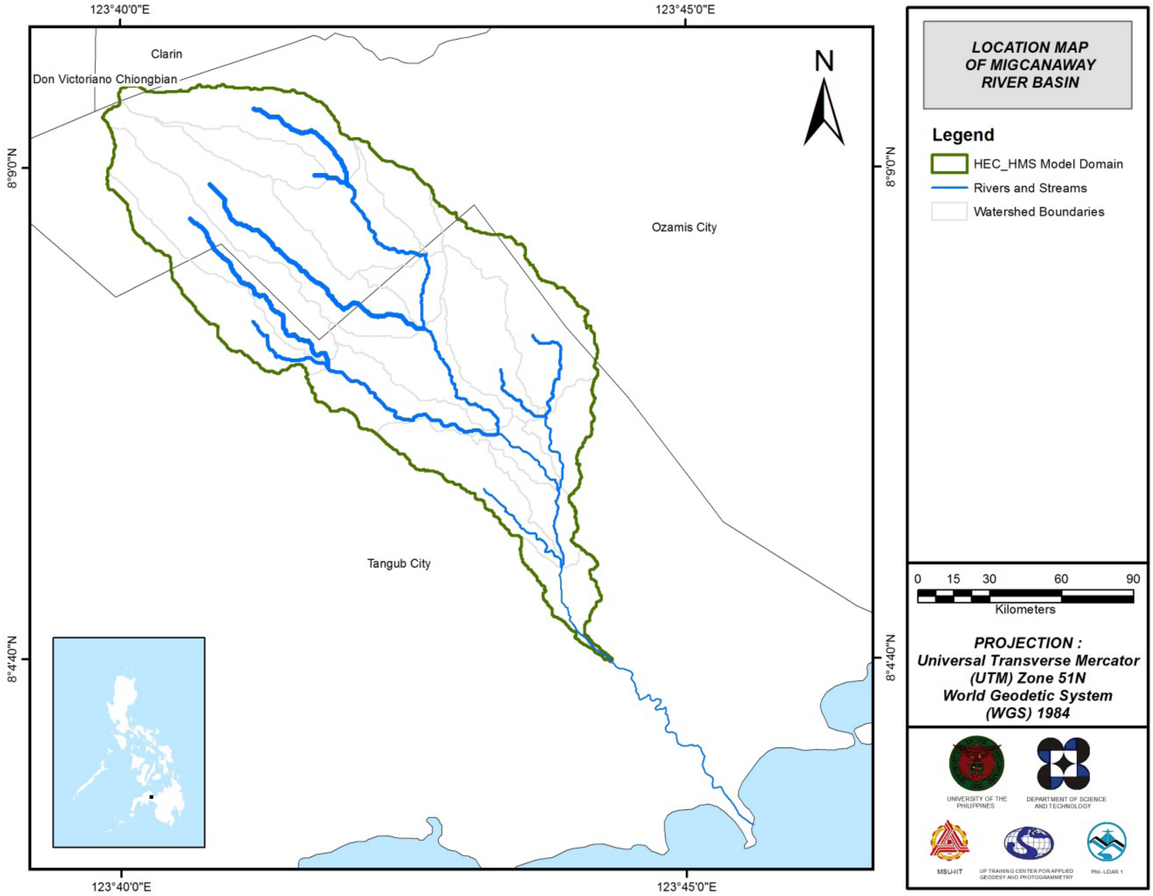


Figure 58. Stream Delineation Map of the Migcanaway River Basin

Using the SAR-based DEM, the Migcanaway basin was delineated and further subdivided into subbasins. The model consists of 17 sub basins, 8 reaches, and 8 junctions (See Annex 10). The main outlet is located at Migcanaway Bridge, Migcanaway. This basin model is illustrated in Figure 59. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Migcanaway Bridge.

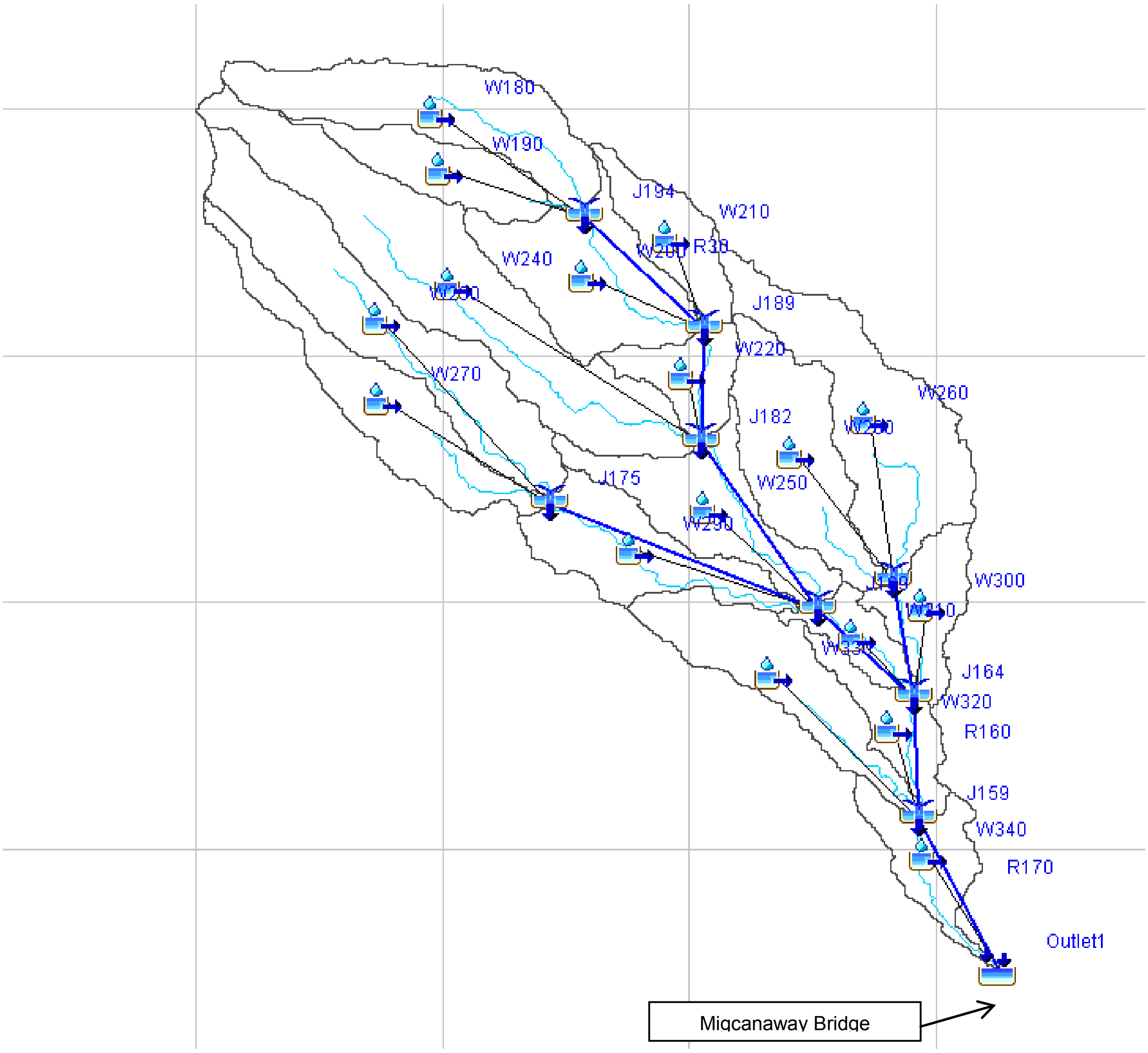


Figure 59. The Migcanaway Hydrologic Model generated in HEC-GeoHMS

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.

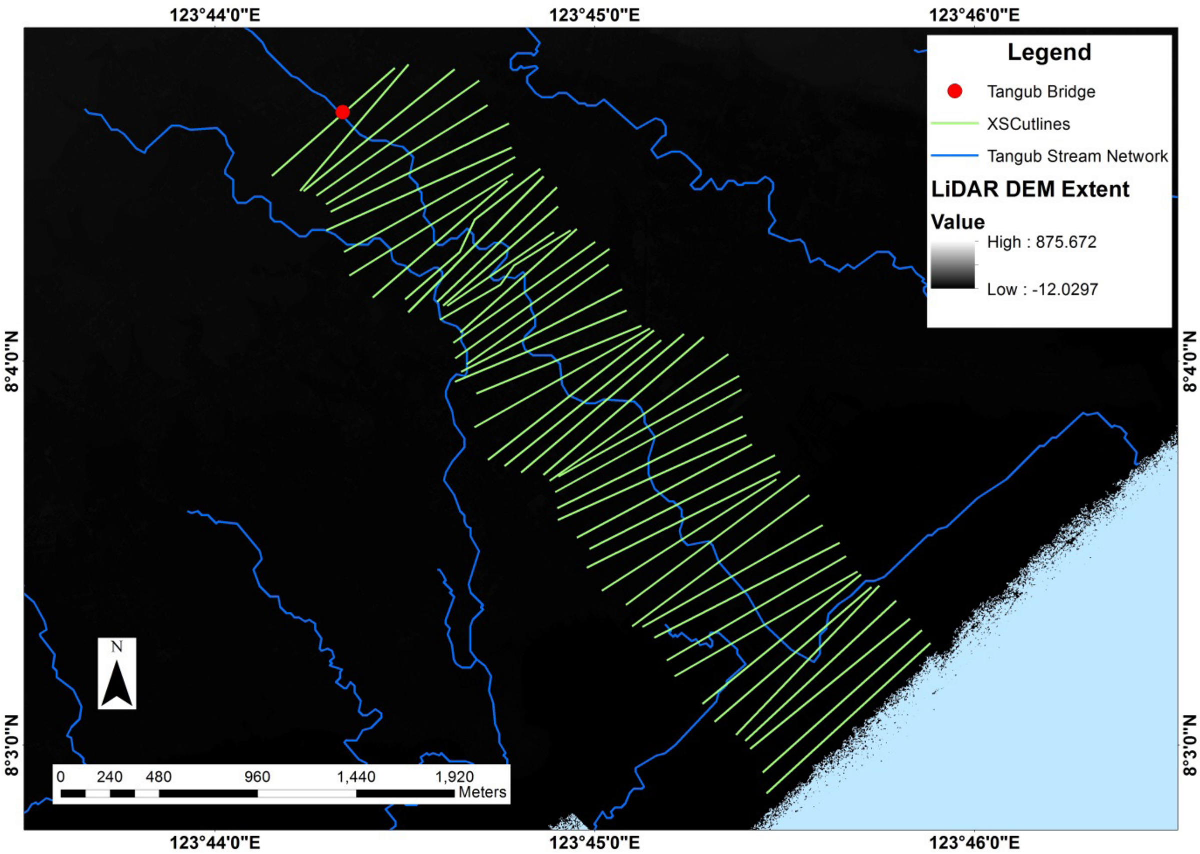


Figure 60. River cross-section of Migcanaway River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

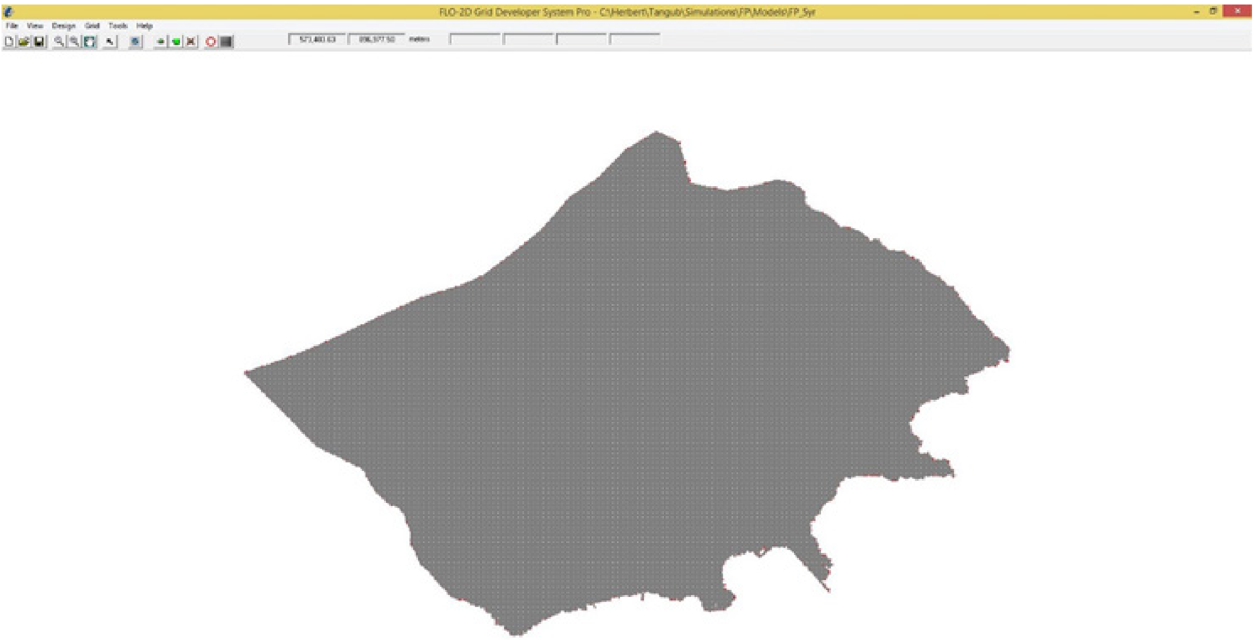


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 17.69318 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 36,855,400.00 m^2.

There is a total of 19,785,923.23 m^3 of water entering the model. Of this amount, 8,909,319.72 m^3 is due to rainfall while 10,876,603.51 m3 is inflow from other areas outside the model. 2,852,752.25 m^3 of this water is lost to infiltration and interception, while 1,751,733.38 m3 is stored by the flood plain. The rest, amounting up to 15,181,435.24 m^3, is outflow.

5.6 Results of HMS Calibration

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

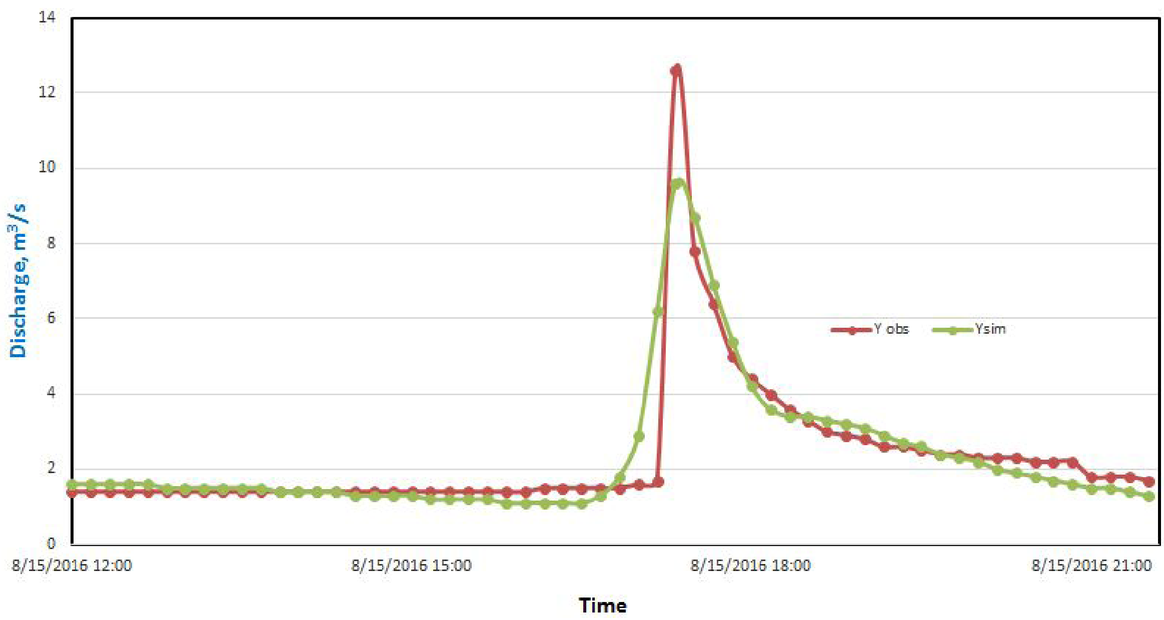


Figure 62. Outflow Hydrograph of Migcanaway Bridge generated in HEC-HMS model compared with observed outflow

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 Migcanaway

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 - 37
			Curve Number	38 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.04 - 0.1
			Storage Coefficient (hr)	0.1 - 3
	Baseflow	Recession	Recession Constant	0.02 – 0.08
			Ratio to Peak	0.001
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.04

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 5 to 37mm 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 38 to 99 for curve number depends on the soil and land cover of the area. For Migcanaway, the basin mostly consists of shrubland and forest plantation, and the soil mostly consists of clay.

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 0.04 to 3 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 0.02 to 0.08 indicates that the basin is likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.001 indicates a steeper receding limb of the outflow hydrograph.

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

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

RMSE	0.78
r^2	0.98
NSE	0.82
PBIAS	-0.15
RSR	0.42

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as0.78(m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.98.

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 0.82.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.15.

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 0.42.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

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

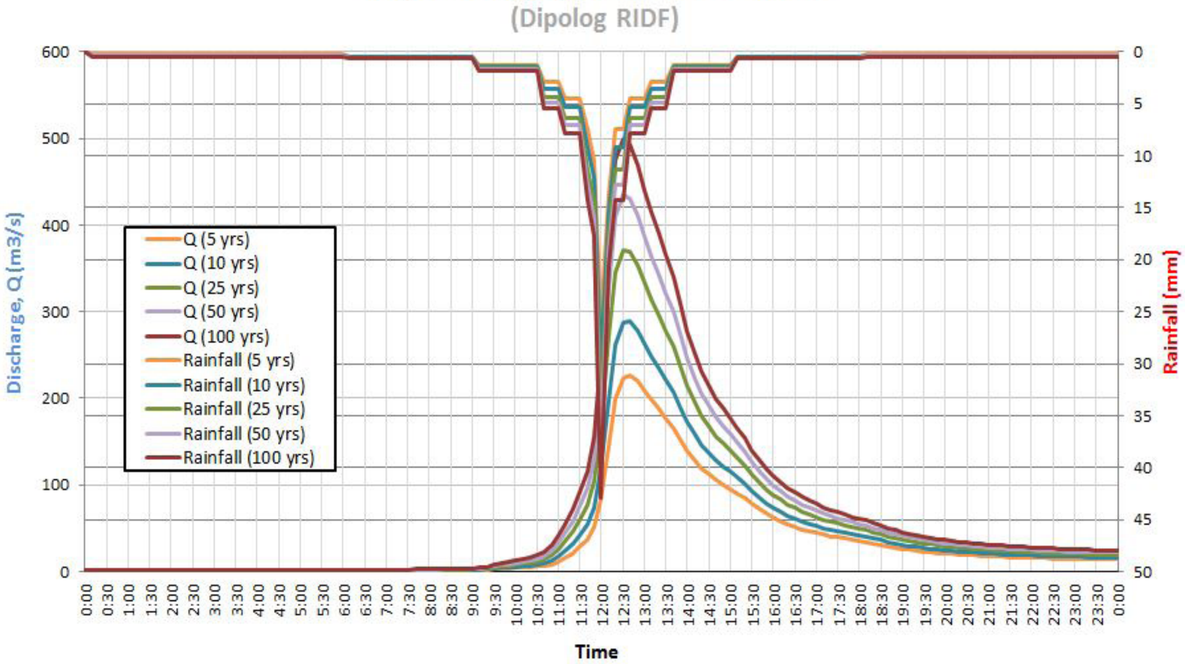


Figure 63. Outflow hydrograph at Migcanaway Station generated using Dipolog RIDF simulated in HEC-HMS

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

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

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	178.32	25.9	226.3	12 hours 40 mins
10-Year	206.37	30	288.3	12 hours 40 mins
25-Year	241.91	35.2	371.4	12 hours 30 mins
50-Year	268.14	39	435.2	12 hours 30 mins
100-Year	294.55	42.9	500.1	12 hours 30 mins

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 was 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 Migcanaway River using the calibrated HMS base flow is shown in Figure 64.

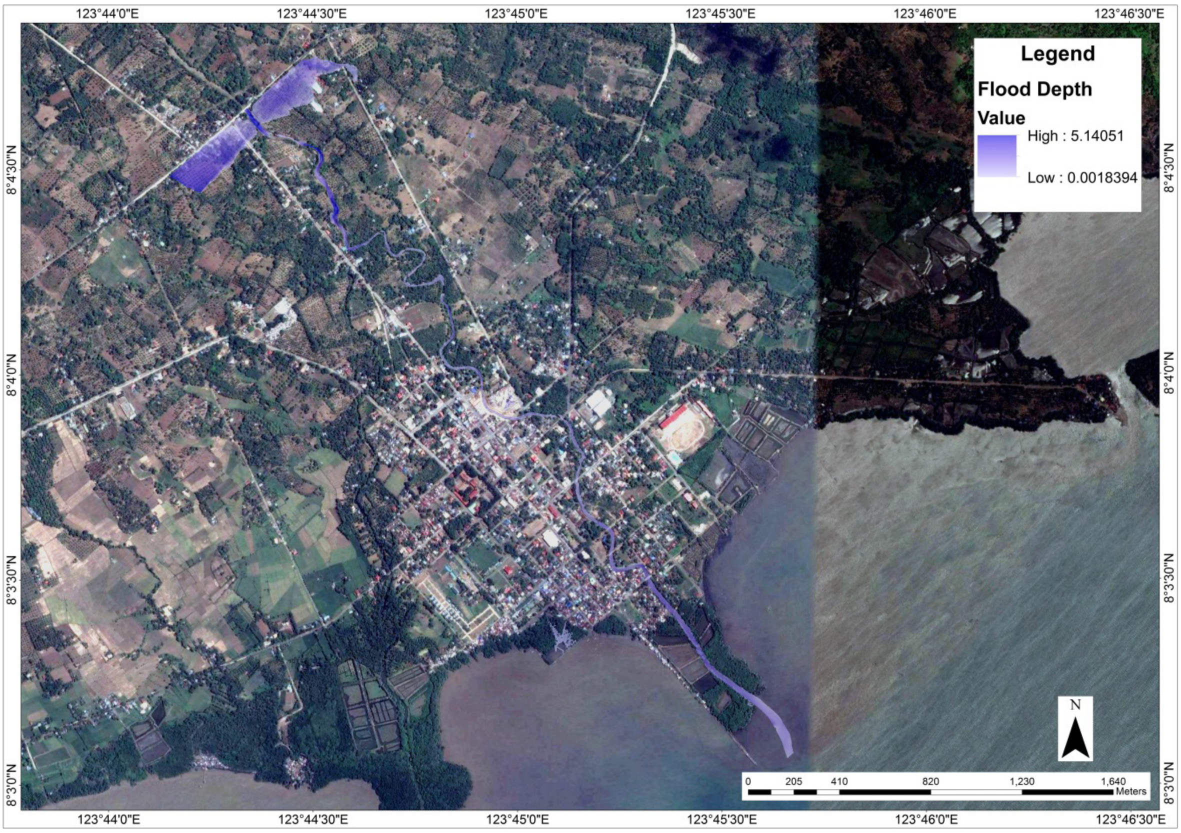


Figure 64. Sample output of Migcanaway RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 100-, 25-, and 5-year rain return scenarios of the Migcanaway Floodplain.The floodplain, with an area of 38.55 sq. km., covers Tangub City and Ozamis City. Table 32 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Migcanaway floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Tangub City	141.82	37.97	27%
Ozamiz City	149.437	0.40	0.3%

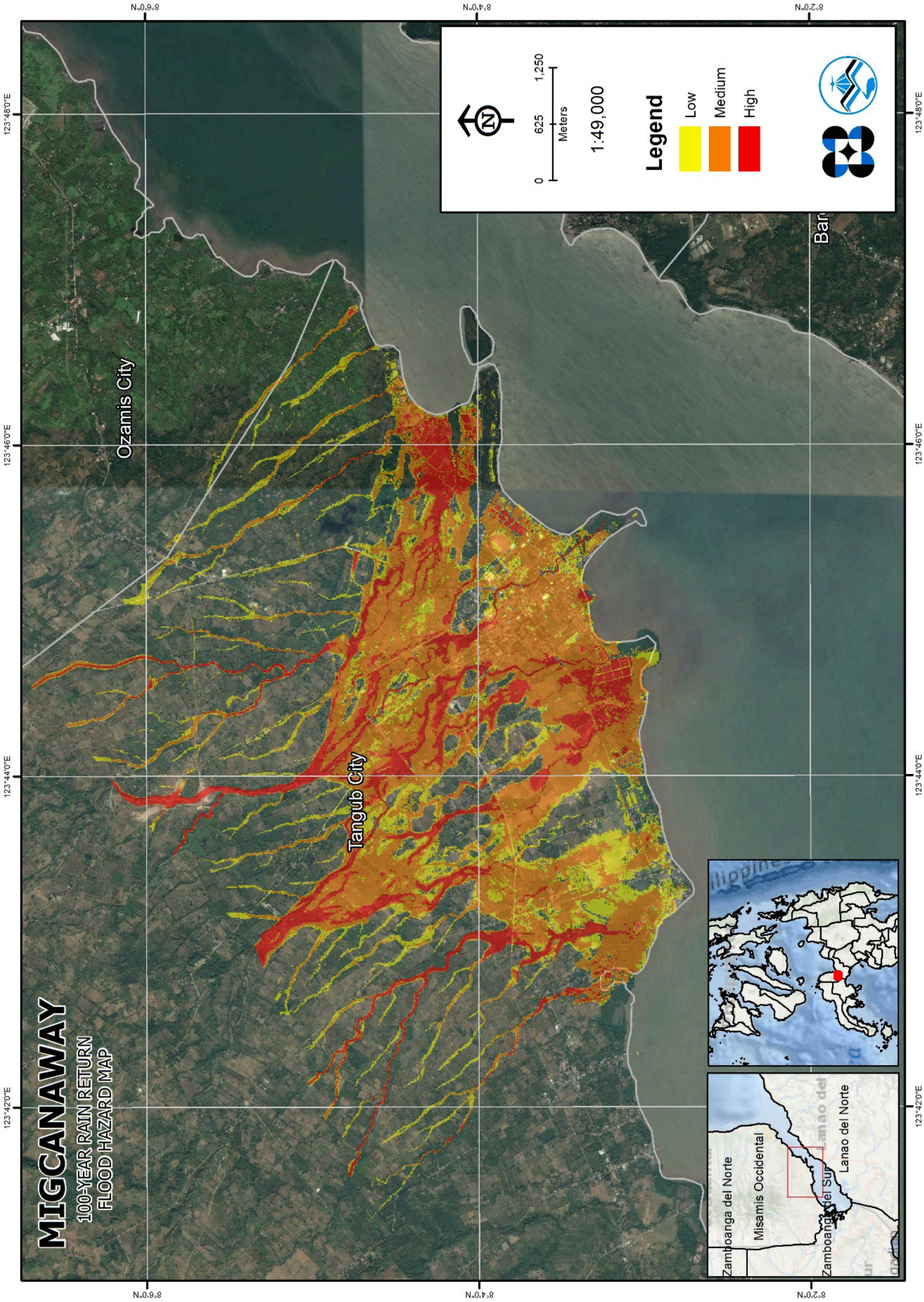


Figure 65. 100-year Flood Hazard Map for Migcanaway Floodplain overlaid on Google Earth imagery

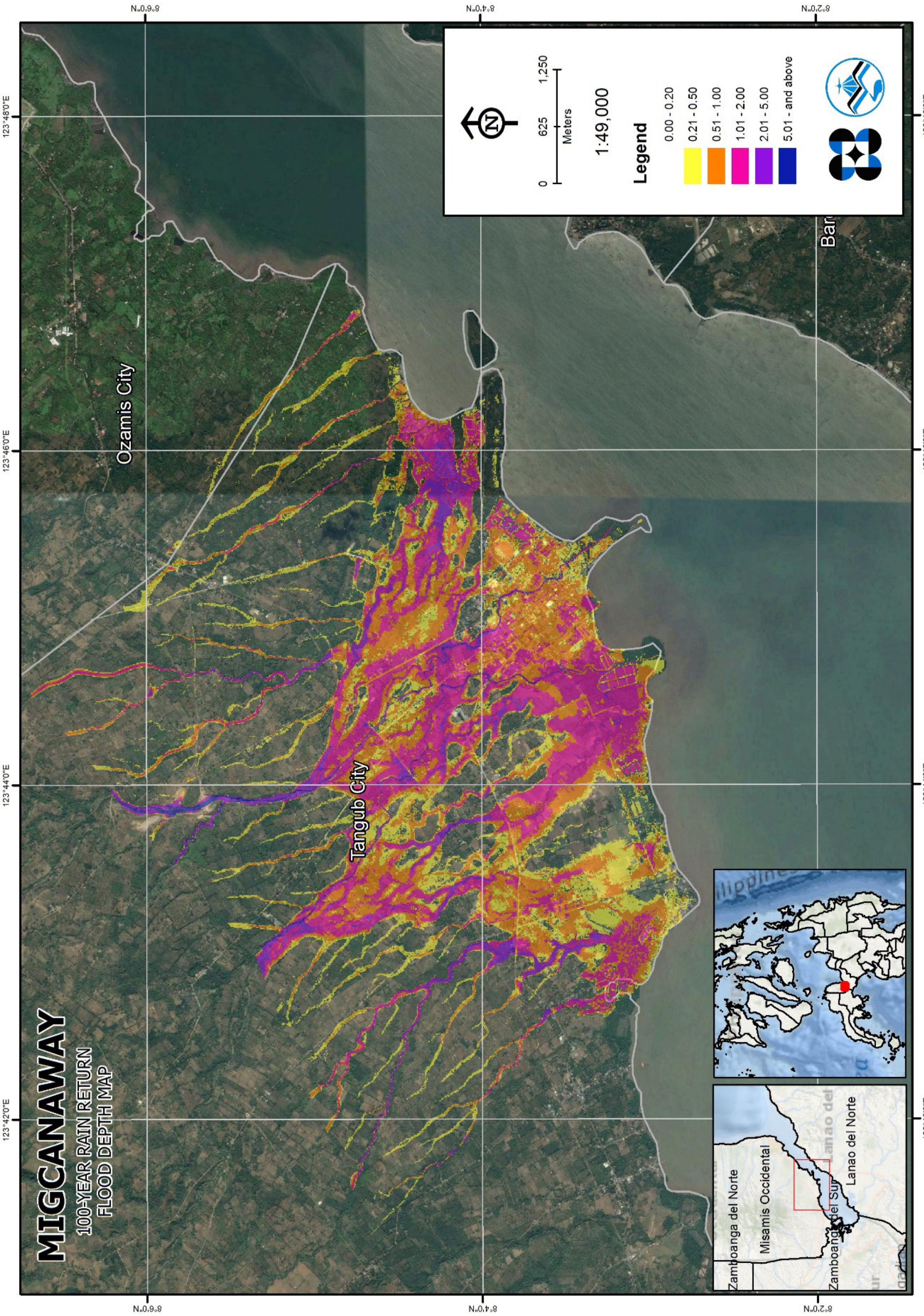


Figure 66. 100-year Flood Depth Map for Migcanaway Floodplainoverlaid on Google Earth imagery

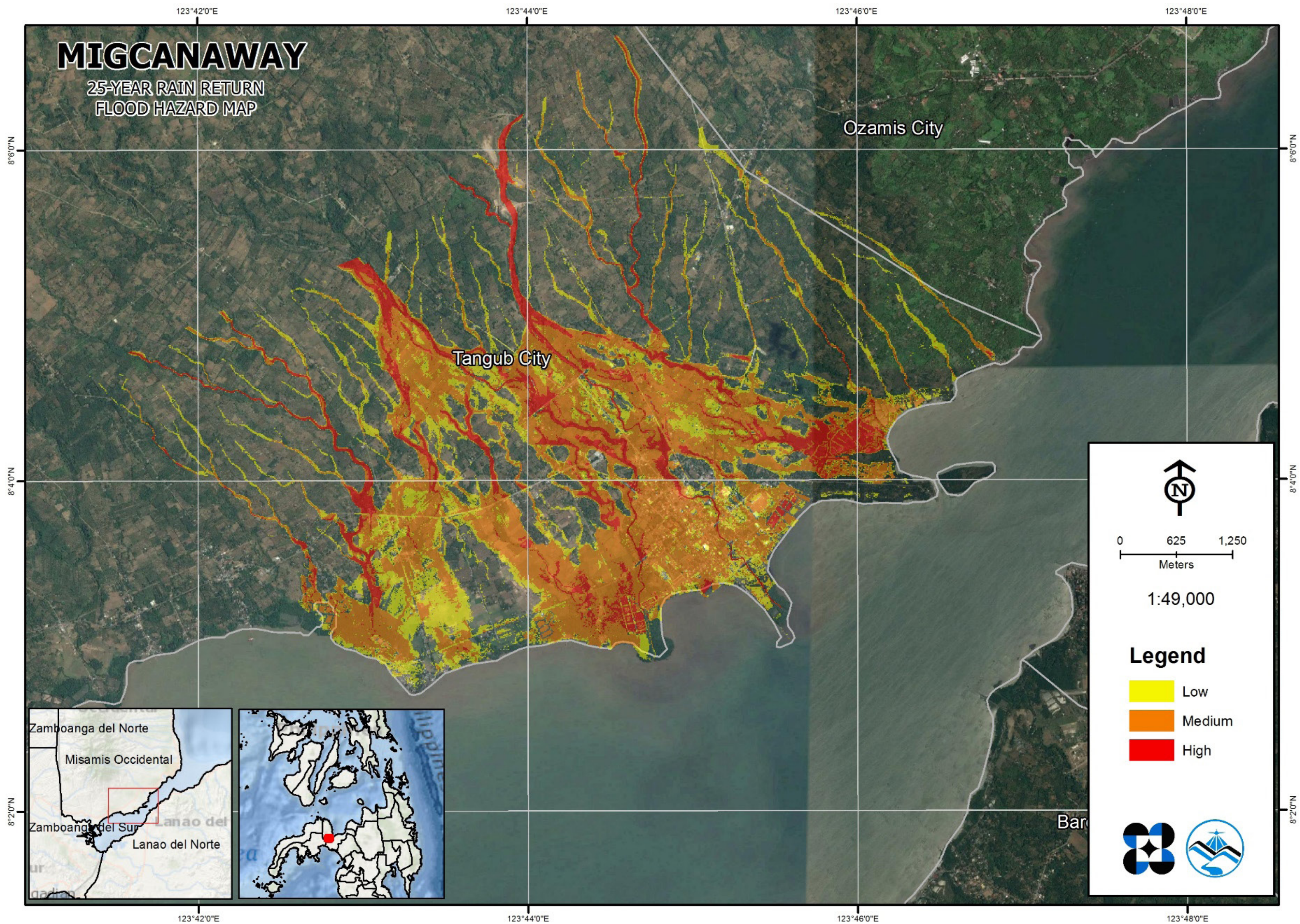


Figure 67. 25-year Flood Hazard Map for Migcanaway Floodplainoverlaid on Google Earth imagery

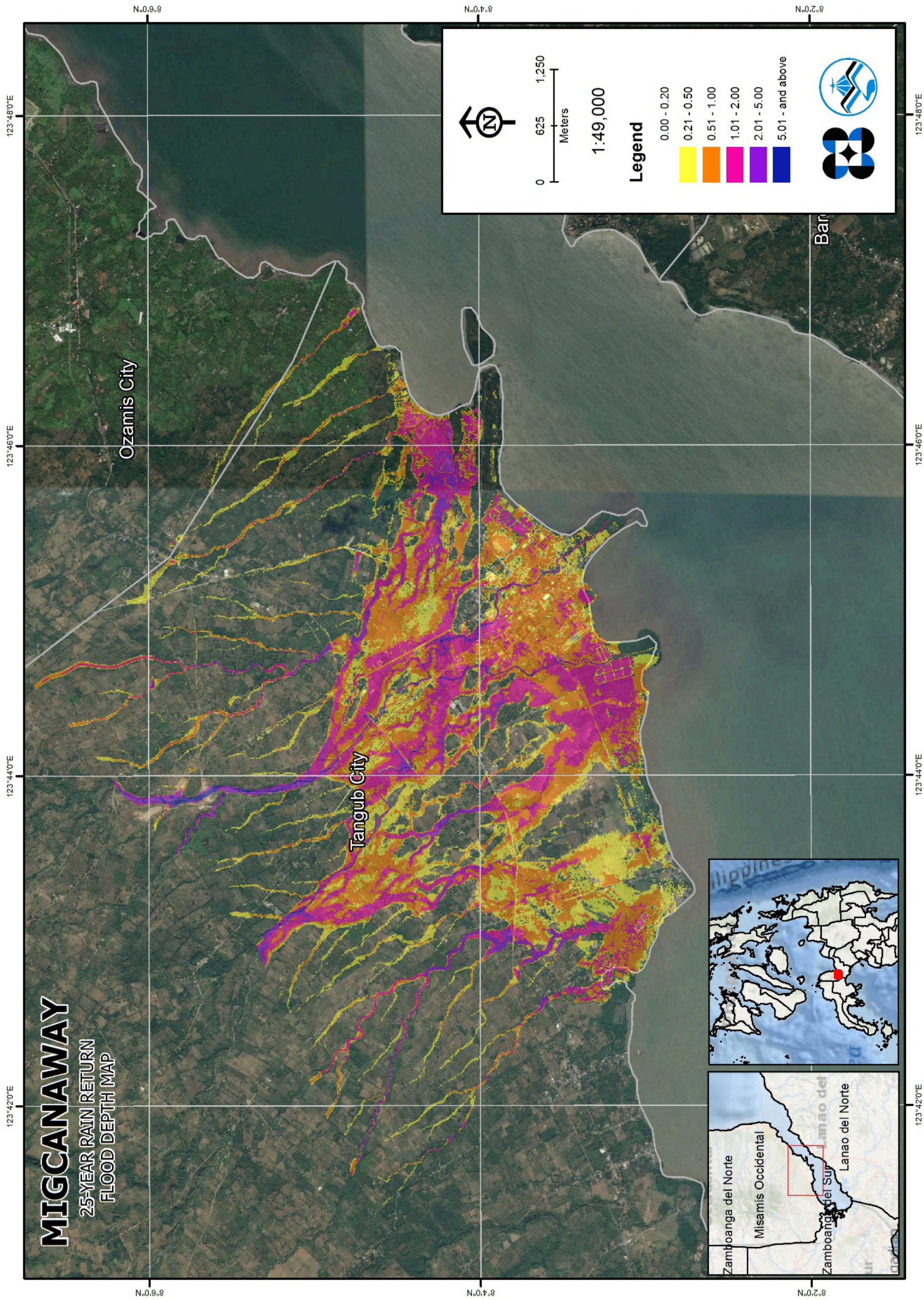


Figure 68. 25-year Flood Depth Map for Migcanaway Floodplainoverlaid on Google Earth imagery

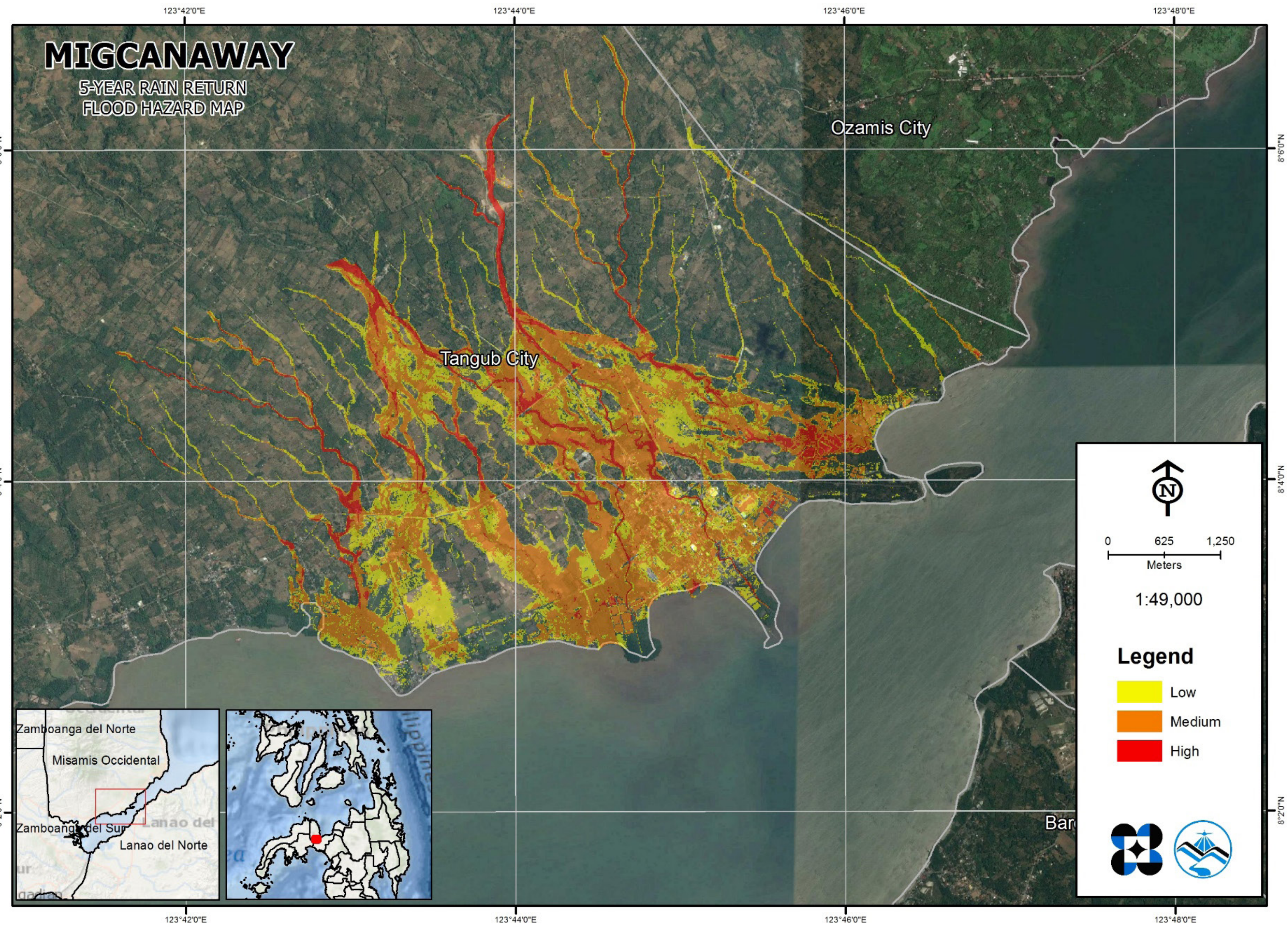


Figure 69. 5-year Flood Hazard Map for Migcanaway Floodplainoverlaid on Google Earth imagery

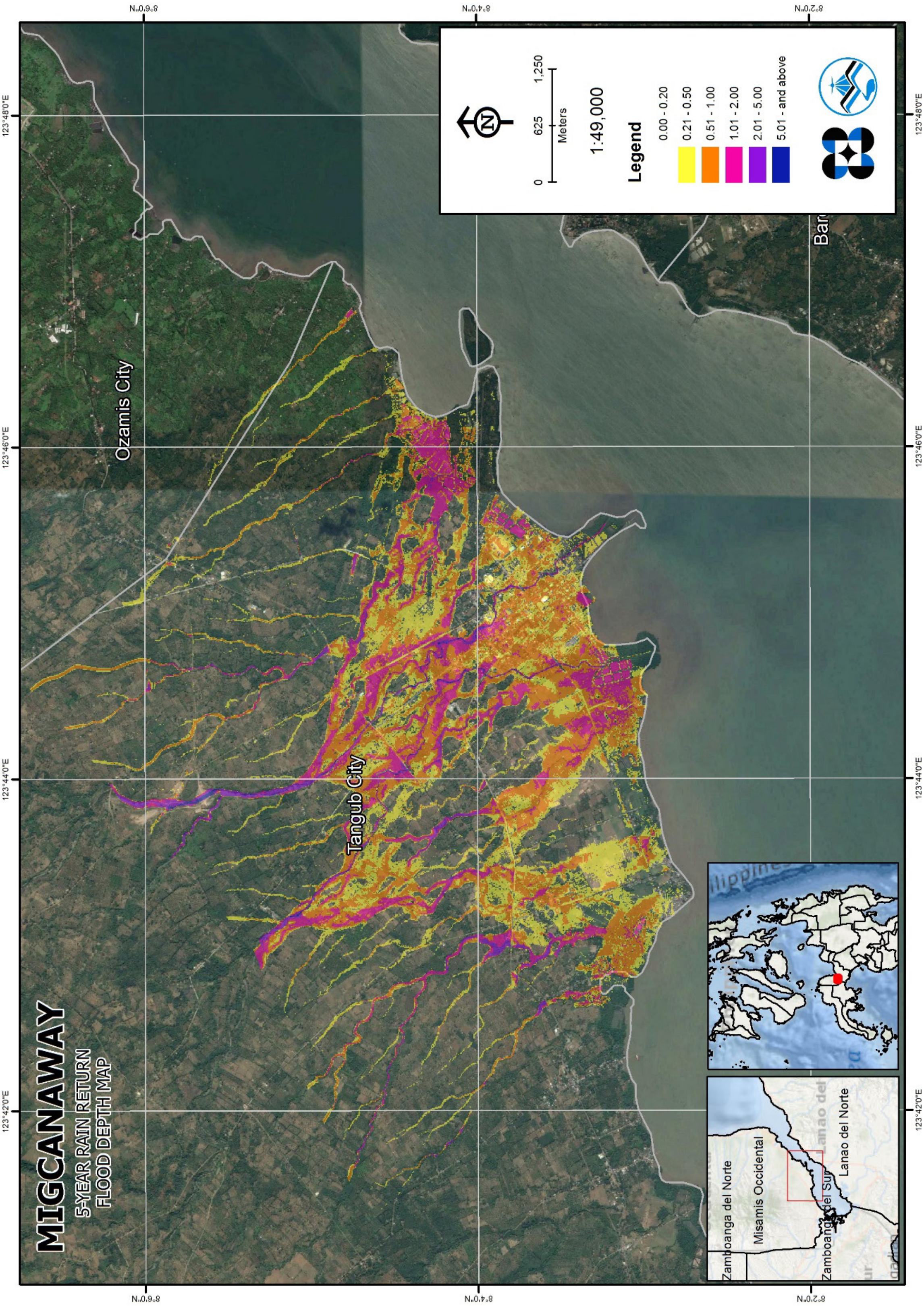


Figure 70. 5-year Flood Depth Map for Migcanaway Floodplainoverlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Migcanaway river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 31 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 17.79% of the city of Tangub with an area of 141.82 sq. km. will experience flood levels of less 0.20 meters; 3.40% of the area will experience flood levels of 0.21 to 0.50 meters while 3.54%, 1.71%, 0.32%, and 0.03% 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 33 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Tangub City, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Tangub City (in sq. km.)														
	Aquino	Baran-gay I - City Hall	Baran-gay II - Marilou	Baran-gay III - Market	Baran-gay IV - St. Mic	Baran-gay V - Malubog	Baran-gay VI - Lower P	Baran-gay VII - Upper	Bintana	Bonga-bong	Canian-gan	Capalar-an	Garang	Isidro D. Tan	Kauswa-gan
0.03-0.20	0.28	0.0089	0.0042	0.0048	0.0015	0.0046	0.009	0.052	2.24	0.41	3.3	1.15	1.16	4.38	1.07
0.21-0.50	0.33	0.05	0.035	0.018	0.043	0.025	0.023	0.095	0.095	0.01	0.53	0.043	0.38	0.79	0.052
0.51-1.00	0.21	0.075	0.066	0.072	0.16	0.044	0.11	0.11	0.031	0.011	0.47	0.035	0.37	0.68	0.015
1.01-2.00	0.041	0.0024	0.0012	0.047	0.021	0.0033	0.074	0.049	0.025	0.025	0.27	0.011	0.069	0.46	0.0065
2.01-5.00	0.0001	0.0019	0	0.011	0.0017	0.00092	0.014	0.0094	0.011	0.062	0.049	0.0017	0.0057	0.047	0.014
> 5.00	0	0	0	0.002	0	0	0.0035	0.0016	0.0001	0.017	0.0032	0	0	0.0033	0.00017

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Tangub City (in sq. km.)													
	Labuyo	Lorenzo Tan	Maloro	Manga	Mantic	Maqui-lao	Migcanaway	Minsub-ong	Prenza	San Apo-linario	Santa Cruz	Santa Maria	Silanga	Villaba
0.03-0.20	0.88	1.1	0.31	2.53	0.1	0.44	0.16	1.23	1.11	0.1	0.7	1.67	0.45	0.37
0.21-0.50	0.43	0.11	0.22	0.19	0.093	0.2	0.1	0.17	0.28	0.18	0.18	0.093	0.041	0.016
0.51-1.00	0.34	0.18	0.22	0.25	0.14	0.054	0.093	0.16	0.3	0.45	0.27	0.029	0.04	0.024
1.01-2.00	0.14	0.085	0.064	0.14	0.033	0.011	0.009	0.18	0.16	0.31	0.14	0.0033	0.036	0
2.01-5.00	0.049	0.039	0.0046	0.024	0	0.0002	0.0057	0.006	0.069	0.0042	0.022	0	0.0018	0
> 5.00	0.0013	0.0001	0.0004	0.00011	0	0	0	0	0.0044	0	0.0016	0	0	0

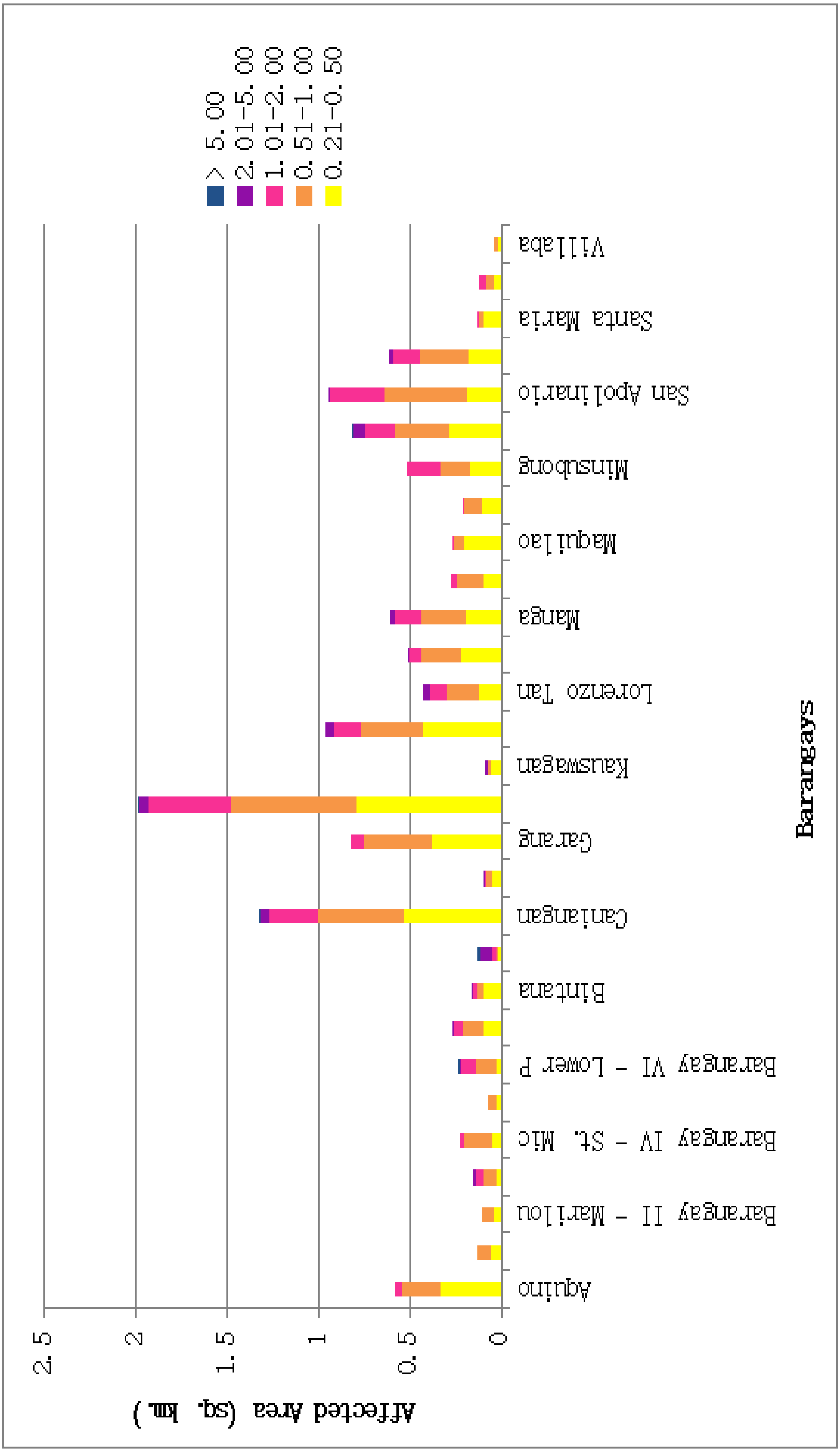


Figure 71. Affected Areas in Tangub City, Misamis Occidental during 5-Year Rainfall Return Period

For the city of Ozamis, with an area of 149.44 sq. km., 0.24% will experience flood levels of less 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.002%, and 0.0003% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 34 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Ozamis City, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Ozamis City (in sq. km.)	
	Labinay	Sinuza
0.03-0.20	0.06	0.31
0.21-0.50	0.0008	0.032
0.51-1.00	0	0.0033
1.01-2.00	0	0.0005
2.01-5.00	0	0
> 5.00	0	0

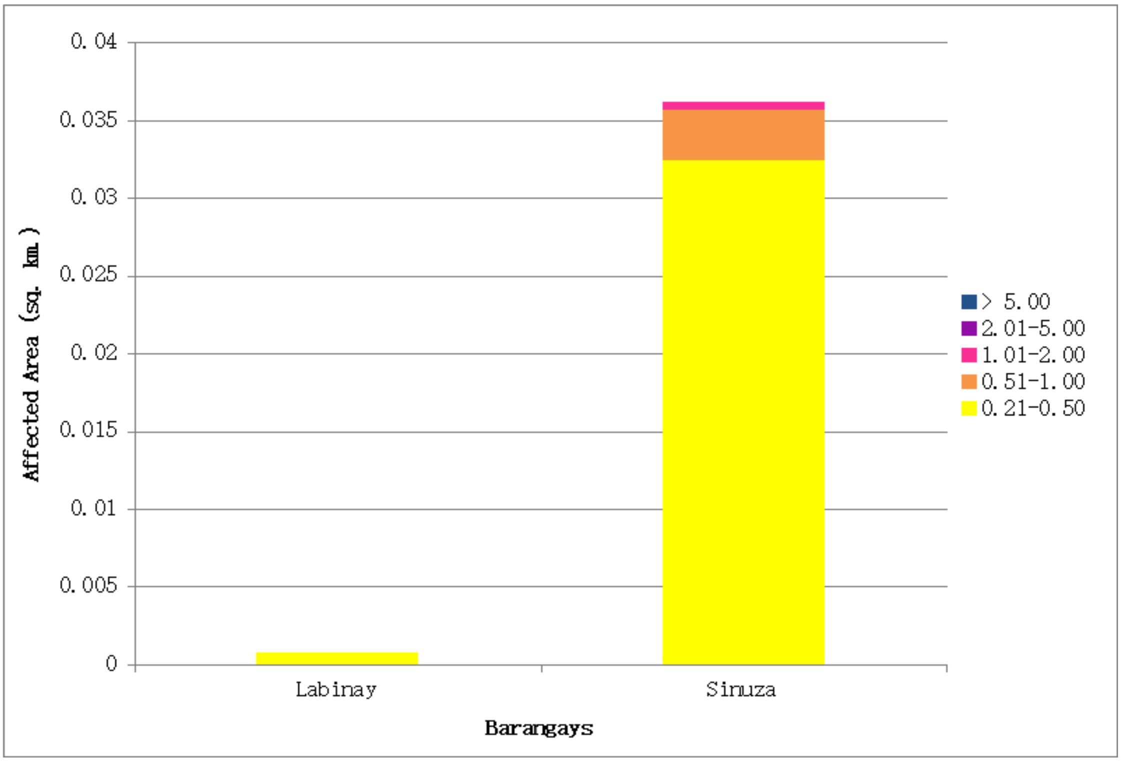


Figure 72. Affected Areas in Ozamis City, Misamis Occidental during 5-Year Rainfall Return Period

For the 25-Year return period, 16.19% of the city of Tangub with an area of 141.82 sq. km. will experience flood levels of less 0.20 meters. 3.05% of the area will experience flood levels of 0.21 to 0.50 meters while 4.02%, 2.87%, 0.60%, 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 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Tangub City, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tangub City (in sq. km.)														
	Aquino	Barangay I - City Hall	Barangay II - Marilou	Barangay III - Market	Barangay IV - St. Mic	Barangay V - Malubog	Barangay VI - Lower P	Barangay VII - Upper	Bintana	Bongabong	Caniangan	Capalaran	Garang	Isidro D. Tan	Kauswagan
0.03-0.20	0.15	0.0046	0.0022	0.0025	0.0001	0.0023	0.0041	0.029	2.19	0.39	3.02	1.13	0.95	3.98	1.05
0.21-0.50	0.36	0.028	0.019	0.0075	0.0074	0.0064	0.011	0.081	0.13	0.011	0.5	0.043	0.32	0.68	0.058
0.51-1.00	0.26	0.097	0.081	0.058	0.15	0.059	0.063	0.1	0.044	0.0079	0.56	0.036	0.47	0.93	0.024
1.01-2.00	0.081	0.0076	0.0037	0.071	0.07	0.0092	0.14	0.095	0.023	0.015	0.43	0.029	0.23	0.62	0.0076
2.01-5.00	0.004	0.0019	0	0.012	0.0021	0.00092	0.017	0.012	0.025	0.069	0.11	0.002	0.012	0.15	0.017
> 5.00	0	0.0001	0	0.0024	0	0	0.004	0.0017	0.0002	0.037	0.0054	0	0	0.0044	0.0014

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tangub City (in sq. km.)													
	Labuyo	Lorenzo Tan	Maloro	Manga	Mantic	Maquilao	Migcanaway	Minsubong	Prenza	San Apolinario	Santa Cruz	Santa Maria	Silanga	Villaba
0.03-0.20	0.65	1.02	0.24	2.44	0.076	0.37	0.13	1.16	1.01	0.032	0.57	1.62	0.37	0.36
0.21-0.50	0.4	0.11	0.19	0.19	0.056	0.24	0.1	0.14	0.24	0.07	0.14	0.12	0.045	0.012
0.51-1.00	0.49	0.2	0.28	0.23	0.15	0.083	0.12	0.17	0.32	0.34	0.26	0.042	0.053	0.029
1.01-2.00	0.2	0.13	0.095	0.22	0.083	0.017	0.016	0.24	0.26	0.59	0.28	0.0073	0.085	0.0095
2.01-5.00	0.093	0.066	0.0078	0.045	0.0001	0.0003	0.0074	0.033	0.088	0.01	0.045	0	0.018	0
> 5.00	0.0018	0.00072	0.0005	0.00033	0	0	0	0	0.014	0	0.0028	0	0	0

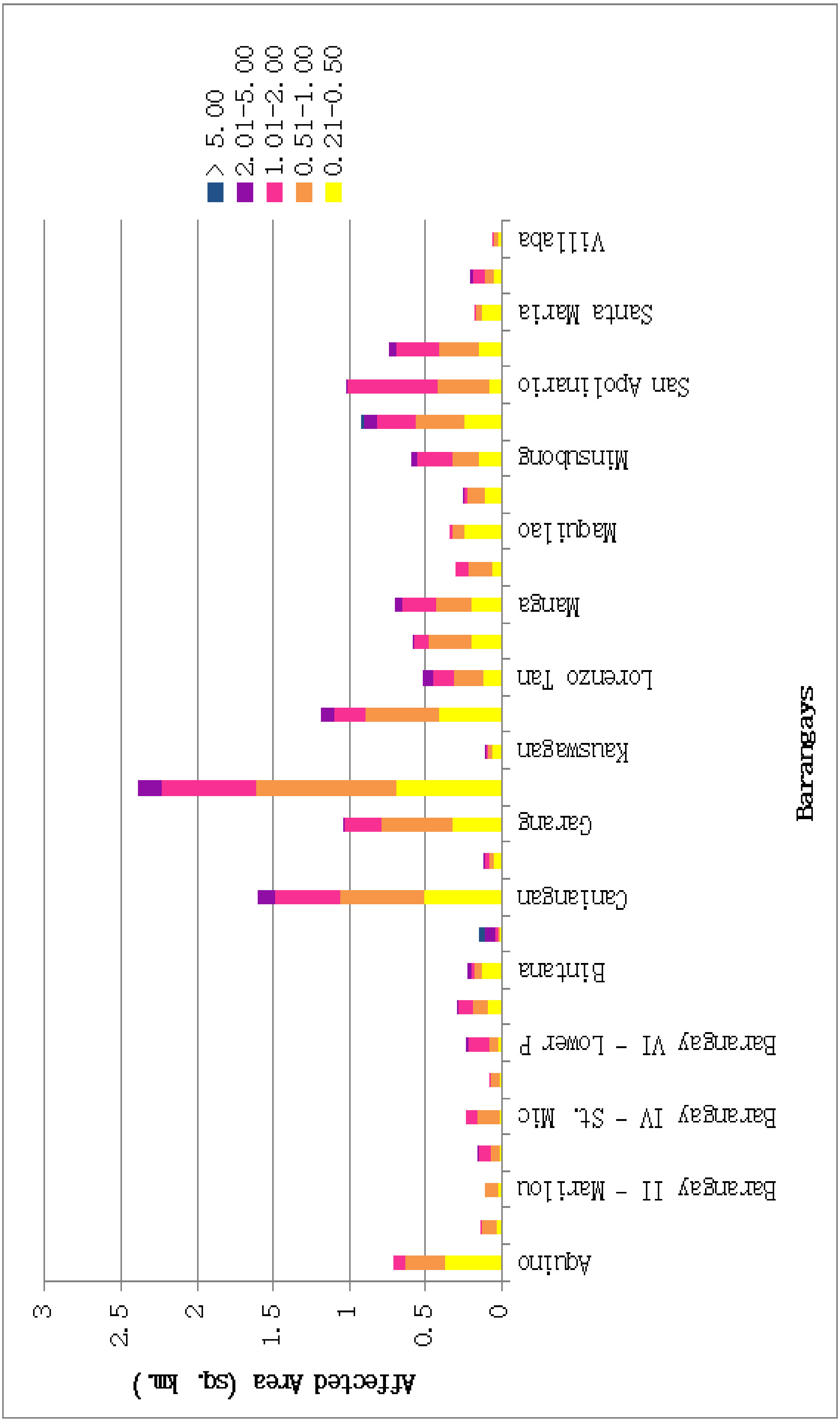


Figure 73. Affected Areas in Tangub City, Misamis Occidental during 25-Year Rainfall Return Period

For the city of Ozamis, with an area of 149.44 sq. km., 0.24% will experience flood levels of less 0.20 meters; 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.007%, and 0.0005% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Ozamis City, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Ozamis City (in sq. km.)	
	Labinay	Sinuza
0.03-0.20	0.059	0.29
0.21-0.50	0.0011	0.039
0.51-1.00	0	0.011
1.01-2.00	0	0.0007
2.01-5.00	0	0
> 5.00	0	0

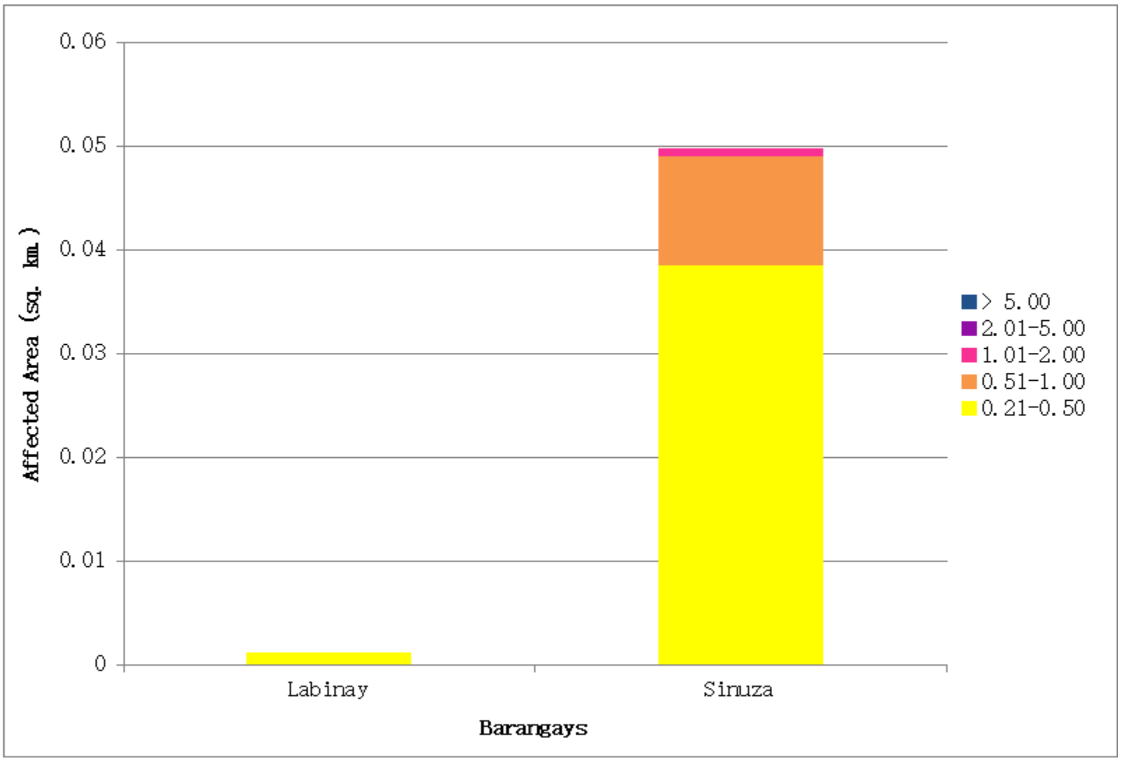


Figure 74. Affected Areas in Ozamis City, Misamis Occidental during 25-Year Rainfall Return Period

For the 100-year return period, 15.29% of the city of Tangub with an area of 141.82 sq. km. will experience flood levels of less 0.20 meters. 2.88% of the area will experience flood levels of 0.21 to 0.50 meters while 4.01%, 3.68%, 0.85%, and 0.08% 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 Tangub City, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tangub City (in sq. km.)														
	Aquino	Barangay I - City Hall	Barangay II - Marilou	Barangay III - Market	Barangay IV - St. Mic	Barangay V - Malubog	Barangay VI - Lower P	Barangay VII - Upper	Bintana	Bongabong	Caniangan	Capalaran	Garang	Isidro D. Tan	Kauswagan
0.03-0.20	0.099	0.003	0.0018	0.0015	0	0.0021	0.0022	0.02	2.14	0.39	2.86	1.11	0.82	3.77	1.04
0.21-0.50	0.33	0.019	0.013	0.0051	0.0022	0.0017	0.0074	0.07	0.15	0.011	0.48	0.046	0.29	0.66	0.065
0.51-1.00	0.28	0.1	0.084	0.048	0.11	0.053	0.046	0.088	0.054	0.0082	0.57	0.038	0.47	0.96	0.028
1.01-2.00	0.13	0.013	0.0076	0.085	0.11	0.02	0.16	0.12	0.024	0.014	0.54	0.038	0.39	0.76	0.011
2.01-5.00	0.013	0.002	0	0.013	0.0027	0.00092	0.019	0.015	0.034	0.062	0.18	0.004	0.017	0.21	0.018
> 5.00	0	0.0001	0	0.0024	0	0	0.0044	0.0019	0.00053	0.054	0.0076	0	0.0002	0.0046	0.0036

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tangub City (in sq. km.)													
	Labuyo	Lorenzo Tan	Maloro	Manga	Mantic	Maquilao	Migcanaway	Minsubong	Prenza	San Apolinario	Santa Cruz	Santa Maria	Silanga	Villaba
0.03-0.20	0.52	0.95	0.22	2.38	0.064	0.33	0.11	1.12	0.96	0.016	0.5	1.58	0.33	0.36
0.21-0.50	0.35	0.11	0.17	0.2	0.042	0.25	0.091	0.13	0.21	0.039	0.14	0.15	0.055	0.011
0.51-1.00	0.58	0.17	0.3	0.22	0.15	0.11	0.13	0.17	0.32	0.24	0.24	0.05	0.054	0.023
1.01-2.00	0.26	0.21	0.12	0.27	0.12	0.024	0.025	0.24	0.32	0.72	0.36	0.012	0.099	0.021
2.01-5.00	0.12	0.083	0.012	0.067	0.0002	0.0003	0.0076	0.08	0.11	0.029	0.073	0	0.028	0
> 5.00	0.0042	0.00092	0.0005	0.00094	0	0	0	0	0.019	0	0.0031	0	0	0

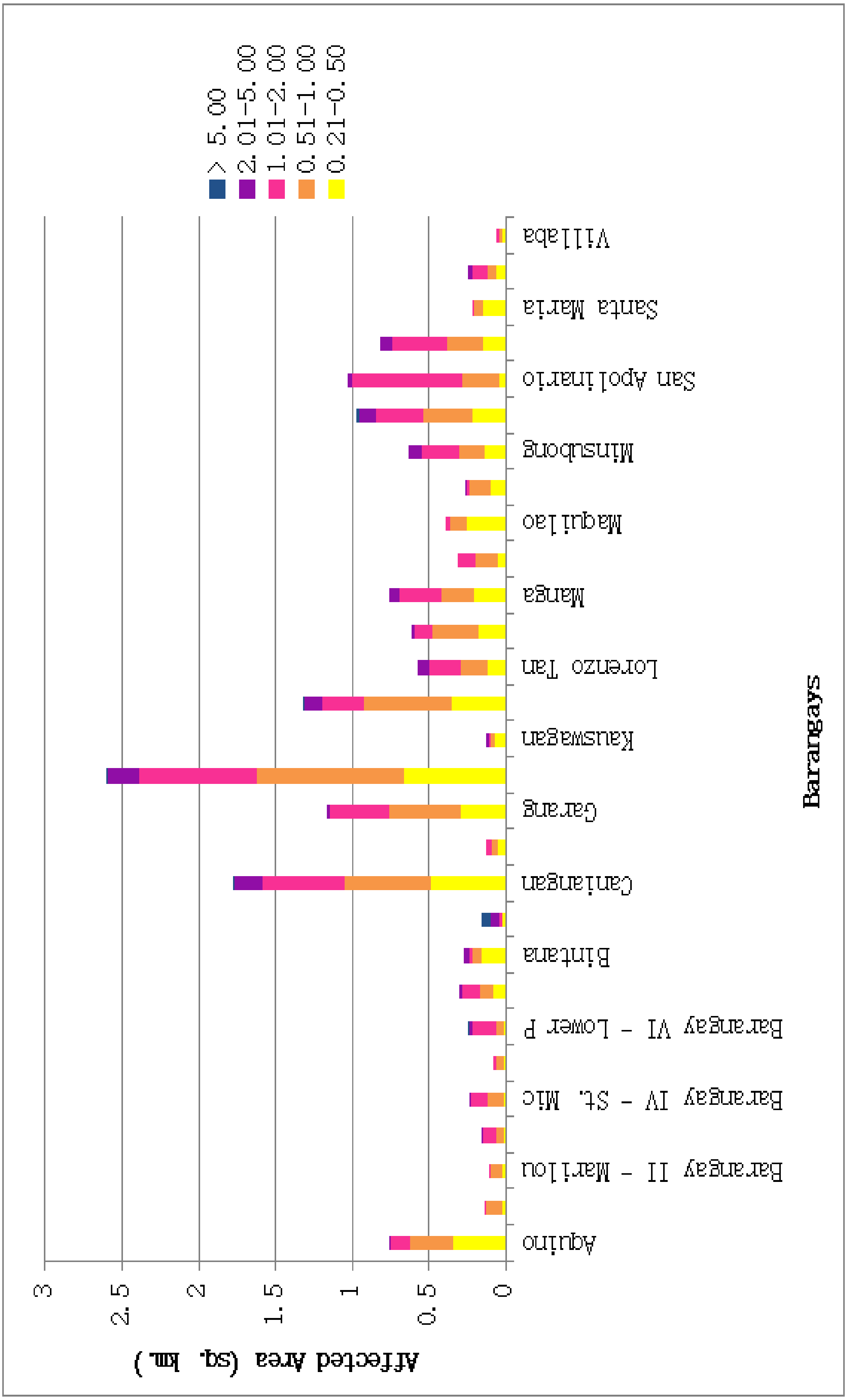


Figure 75. Affected Areas in Tangub City, Misamis Occidental during 100-Year Rainfall Return Period

For the city of Ozamis, with an area of 149.44 sq. km., 0.23% will experience flood levels of less 0.20 meters; 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% and 0.0005% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Ozamis City, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Ozamis City (in sq. km.)	
	Labinay	Sinuza
0.03-0.20	0.059	0.28
0.21-0.50	0.0013	0.042
0.51-1.00	0	0.017
1.01-2.00	0	0.0008
2.01-5.00	0	0
> 5.00	0	0

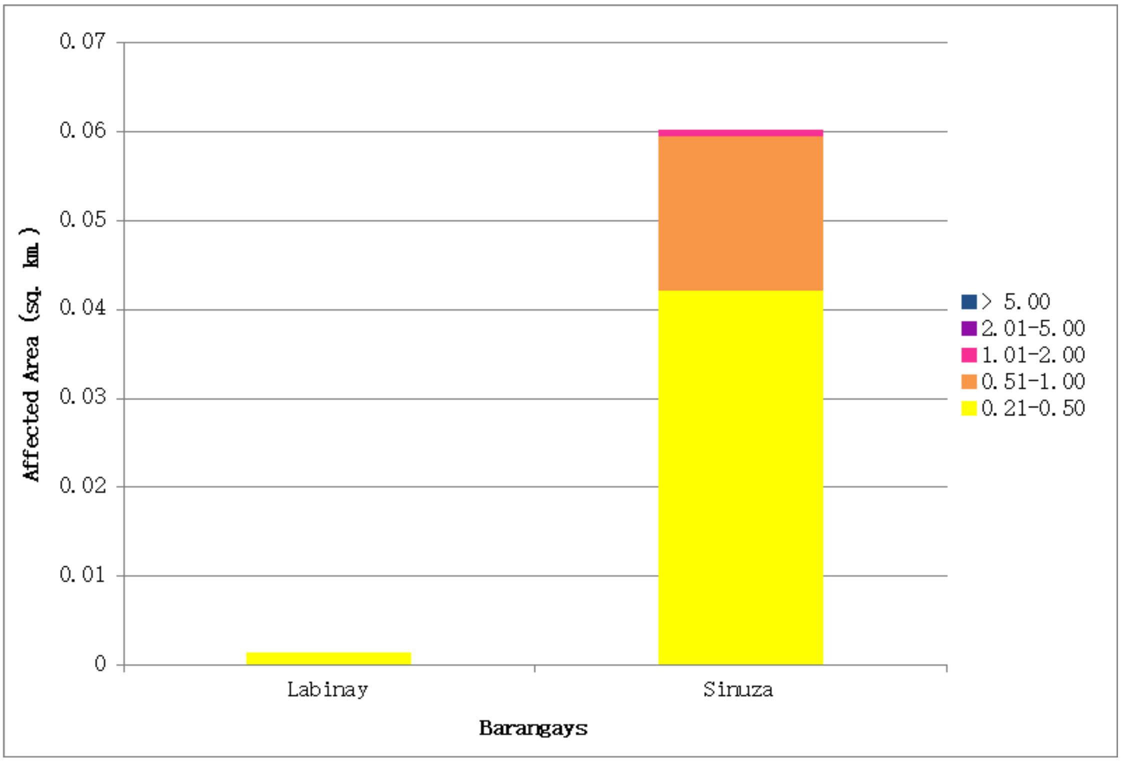


Figure 76. Affected Areas in Ozamis City, Misamis Occidental during 100-Year Rainfall Return Period

Among the barangays in the city of Tangub, Isidro D. Tan is projected to have the highest percentage of area that will experience flood levels at 4.49%. Meanwhile, Caniangan posted the second highest percentage of area that may be affected by flood depths at 3.26%.

Among the barangays in the city of Ozamis, Sinuza is projected to have the highest percentage of area that will experience flood levels at 0.23%. Meanwhile, Labinayposted the second highest percentage of area that may be affected by flood depths at 0.04%.

Moreover, the generated flood hazard maps for the Migcanaway 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 39. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	4.89	4.40	4.18
Medium	6.78	8.48	9.05
High	1.36	2.43	3.38

Of the 46 identified Education Institutions in Migcanaway Flood plain, 11 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 17 schools were assessed to be exposed to Medium level flooding. In the 25 year scenario, 4 schools were assessed to be exposed to the Low level flooding while 28 schools were assessed to be exposed to Medium level flooding and 1 school was assessed to be exposed to High level flooding in the same scenario. For the 100 year scenario, 3 schools were assessed for Low level flooding and 29 schools for Medium level flooding. In the same scenario, 1 school was assessed to be exposed to High level flooding. See Annex 12 for a detailed enumeration of schools inside Migcanaway floodplain.

Of the 14 identified Medical Institutions in Migcanaway Flood plain, 1 was assessed to be exposed to the Low level flooding during a 5 year scenario while 9 were assessed to be exposed to Medium level flooding in the same scenario. In the 25 year scenario, 10 were assessed to be exposed to the Medium level flooding. For the 100 year scenario, 1 school was assessed for Low level flooding and 10 for Medium level flooding. See Annex 13 for a detailed enumeration of medical insitutions inside Migcanaway Floodplain.

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5.11 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.The points in the flood map versus its corresponding validation depths are shown in Figure77.

The flood validation consists of 301 points randomly selected all over the Migcanaway flood plain. It has an RMSE value of 0.92.

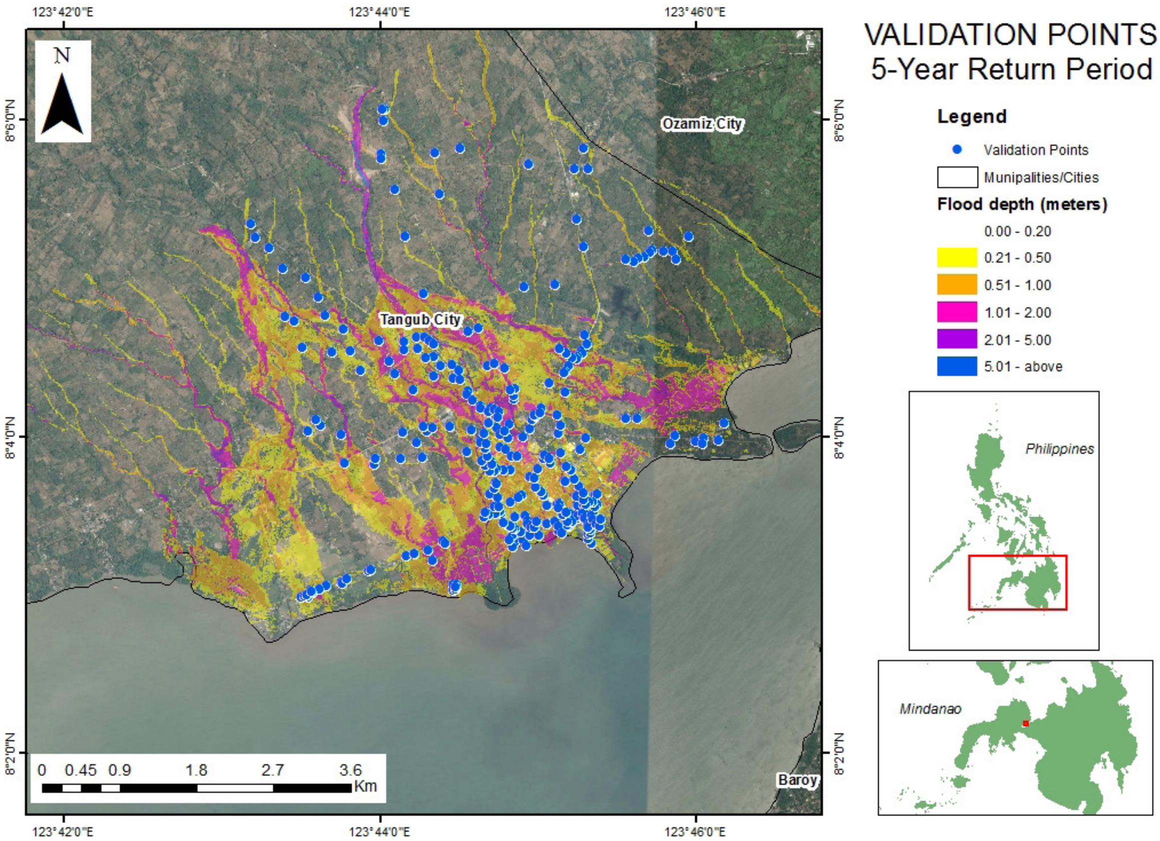

Figure 77. Validation points for 5-year Flood Depth Map of Migcanaway Floodplain

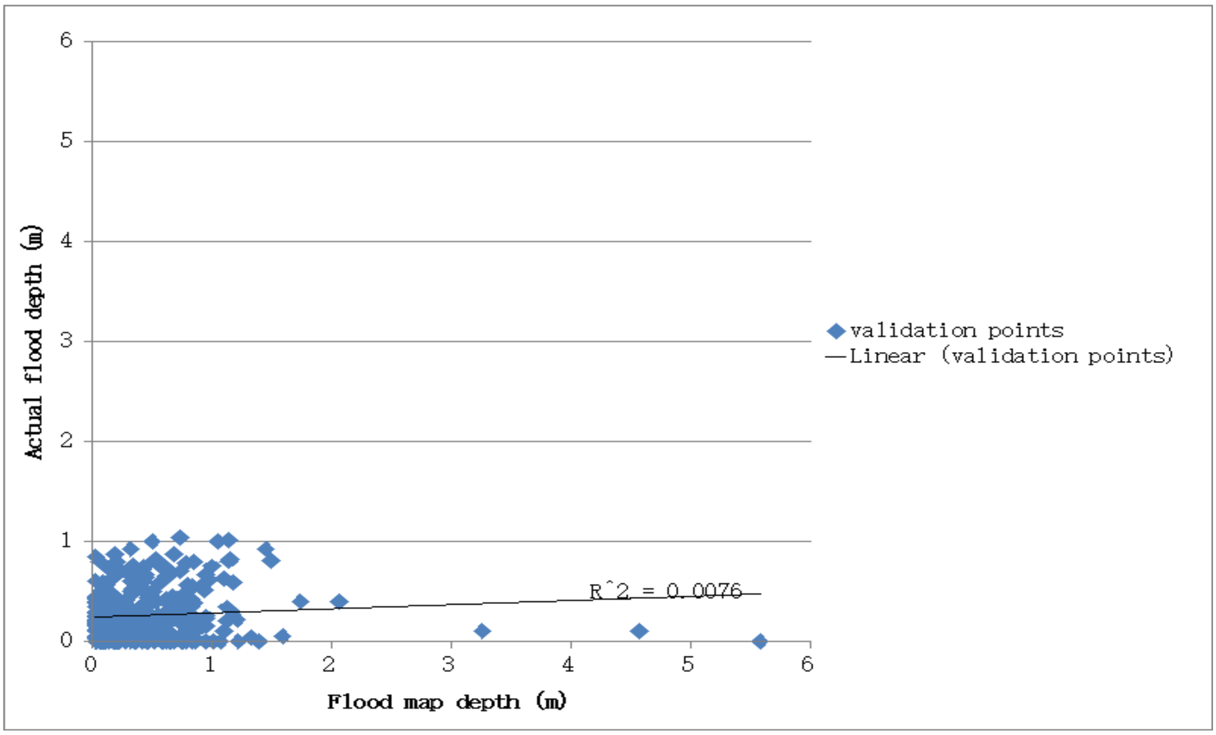

Figure 78. Flood map depth vs actual flood depth

Table 40. Actual Flood Depth vs Simulated Flood Depth in Migcanaway

Actual Flood Depth (m)	**Modeled Flood Depth (m)**						
	0.21-0.50	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**	
0-0.20	67	33	46	8	2	1	157
0.21-0.50	27	24	32	4	1	0	88
0.51-1.00	13	16	18	7	0	0	54
1.01-2.00	0	0	1	1	0	0	2
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	107	73	97	20	3	1	301

The overall accuracy generated by the flood model is estimated at 36.54%, with 110 points correctly matching the actual flood depths. In addition, there were 116 points estimated one level above and below the correct flood depths while there were 63 points and 12 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 134 points were overestimated while a total of 57 points were underestimated in the modelled flood depths of Migcanaway.

Table 41. Summary of Accuracy Assessment in Migcanaway

	No. of Points	%
Correct	110	**36.54**
Overestimated	134	44.52
Underestimated	57	18.94
Total	301	100

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors Used in the Migcanaway Floodplain Survey

PEGASUS SENSOR

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

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

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

LAN-2

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

June 24, 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: **LANAO DEL NORTE**
Station Name: **LAN-2**
Order: **1st**

Island: **MINDANAO**
Municipality: **LALA**
Barangay: **PINOYAK**

	PRS92 Coordinates	
Latitude: **7º 54' 46.07859"**	Longitude: **123º 46' 0.85333"**	Ellipsoidal Hgt: **17.35400 m.**
	WGS84 Coordinates	
Latitude: **7º 54' 42.56546"**	Longitude: **123º 46' 6.31720"**	Ellipsoidal Hgt: **83.92120 m.**
	PTM Coordinates	
Northing: **875110.149 m.**	Easting: **364025.74 m.**	Zone: **5**
	UTM Coordinates	
Northing: **874,680.35**	Easting: **584,533.45**	Zone: **51**

Location Description

LAN-2
From Iligan City, travel southwest along the National highway for 74.5 kilometers to the municipality of Lala. Travel farther along the national highway for 1.4 kilometers up to Maranding junction. Thence from the junction travel southeast along the national highway for another 1.3 kilometers to a dirt road going to Pinoyak barangay proper. Turn right on the dirt road and national highway intersection and continue travelling westward for 400 meters up to the irrigation canal. Station is located on top of the concrete irrigation canal water gate. Station mark is 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in a drill hole on top of the concrete irrigation canal water gate; centered in cement patty and inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in drill holes on top of the concrete irrigation canal water gate; centered in cement patty and inscribed with the reference mark numbers and arrow pointing to the station.

Requesting Party:	**Engr. Cruz**
Pupose:	**Reference**
OR Number:	**8796376 A**
T.N.:	**2014-1441**

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

9 9 0 6 2 4 2 0 1 4 1 1 1 6 5 8

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

ZGS-1

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-1**			
		Order: **1st**			
Island: **MINDANAO**		Barangay: **DIPOLO**			
Municipality: **MOLAVE**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**8° 4' 26.98334"**	Longitude:	**123° 29' 14.53868"**	Ellipsoidal Hgt:	**22.61100 m.**
		WGS84 Coordinates			
Latitude:	**8° 4' 23.40249"**	Longitude:	**123° 29' 19.99013"**	Ellipsoidal Hgt:	**88.16300 m.**
		PTM / PRS92 Coordinates			
Northing:	**892784.79 m.**	Easting:	**553718.284 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**892,472.30**	Easting:	**553,699.48**	Zone:	**51**

Location Description

ZGS-1
From Iligan City, travel SW along the national highway for 138 km., about 2 hrs. and 5 min., passing through the towns of Kolambugan, Tubod, and Salvador, Lanao del Norte. Then turn right, travel NW direction passing by Aurora town, 138 km. about 2 hrs. and 52 min. drive. About 5.4 km. going W direction before the junction to Molave proper proceed to the junction going E direction to Pagadian City, 3.2 km. to National Irrigation Administration (NIA) compound. Station is located at the top S corner of the concrete water tank 6 m. high beside the NIA building. Station mark is a cross cut on top of a 0.15 m. x 0.01 m. in dia. brass rod, set in a drill hole, centered in a 0.30 m. x 0.30 m. cement patty with inscription of the station name.

*Note: Reported EXISTING by FNSP-DENR Region IX (By: Engr. Fermin Enero - 06 August 2003)

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0332**

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

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

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CIP/4701/12/09/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

ZGS-16

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-16**			
		Order: **2nd**			
Island:	**MINDANAO**	Barangay:	**BACLAY**		
Municipality:	**TUKURAN**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**7° 52' 32.53106"**	Longitude:	**123° 36' 23.39905"**	Ellipsoidal Hgt:	**18.17800 m.**
		WGS84 Coordinates			
Latitude:	**7° 52' 29.01321"**	Longitude:	**123° 36' 28.86762"**	Ellipsoidal Hgt:	**84.42000 m.**
		PTM / PRS92 Coordinates			
Northing:	**870854.959 m.**	Easting:	**566881.259 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**870,550.15**	Easting:	**566,857.85**	Zone:	**51**

Location Description

ZGS-16
Is located at Purok Nangka, Brgy. Baclay. It is situated 1 m. NE of Km. Post # 1644 and about 50 m. SW of the chapel, approx. 3 km. from the road junction leading to Aurora town. Mark is the head of a 3 in. concrete nail embedded and centered on a 30 cm. x 30 cm. x 58 cm. concrete monument, with inscriptions "ZGS-16 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0334**

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

9902102016122213

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

ZGS-88

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

July 11, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-88**
Order: **2nd**

Island: **MINDANAO**
Municipality: **AURORA**
Barangay: **SAN JOSE**
MSL Elevation:

PRS92 Coordinates

Latitude: **7° 57' 13.25316"**	Longitude: **123° 34' 56.50093"**	Ellipsoidal Hgt: **258.34500 m.**

WGS84 Coordinates

Latitude: **7° 57' 9.71271"**	Longitude: **123° 35' 1.96243"**	Ellipsoidal Hgt: **324.37300 m.**

PTM / PRS92 Coordinates

Northing: **879474.685 m.**	Easting: **564207.26 m.**	Zone: **4**

UTM / PRS92 Coordinates

Northing: **879,166.85**	Easting: **564,184.79**	Zone: **51**

Location Description

ZGS-88
Is located on the S end of the W wedge-shaped island in Purok Saray, Brgy. San Jose, Aurora. It is about 500 m. N of the municipal hall, 30 m. W of the Seaoil Gasoline Station and 5 m. E of the W side of the road. Mark is the head of a 3 in. copper nail embedded and centered on a 27 cm. x 26 cm. x cement putty, with inscriptions "ZGS-88 2005 NAMRIA LEP IX".

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1601**

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

9907112014150154

NAMRIA OFFICES:
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CIP/4701/12/09/814

ZS-188

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: **ZS-188**

Island: **Mindanao**	Municipality: **ZAMBOANGA CITY**	Barangay: **LICOMO**
Elevation: **22.1396 +/- 0.16 m.**	Accuracy Class at 95% C.L: **2 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

ZS-188 is located in Sitio Simoropan Purok 1 Brgy. Licomo Vital District Zamboanga City The BM established in hedawall of Pipe Culvert, about 4 m from the cneterline of the road leftside going to Maria Clara lobgegat Hi-way.

Mark is the head of a 4" copper nail on a drilled hole and cemented flushed on top of a 15x15cm cement putty with inscription "ZS-188, 2008, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0337**

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

9902102016122745

NAMRIA OFFICES:
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Annex 3. Baseline Processing Reports of Reference Points Used

ZS-188

Vector Components (Mark to Mark)

From:	ZGS-1				
Grid		Local		Global	
Easting	553699.482 m	Latitude	N8°04'26.98335"	Latitude	N8°04'23.40249"
Northing	892472.300 m	Longitude	E123°29'14.53868"	Longitude	E123°29'19.99013"
Elevation	20.051 m	Height	22.611 m	Height	88.163 m

To:	ZS-188A				
Grid		Local		Global	
Easting	553627.634 m	Latitude	N8°03'56.69408"	Latitude	N8°03'53.11537"
Northing	891542.089 m	Longitude	E123°29'12.15500"	Longitude	E123°29'17.60722"
Elevation	17.277 m	Height	19.832 m	Height	85.400 m

Vector					
ΔEasting	-71.848 m	NS Fwd Azimuth	184°29'06"	ΔX	-9.705 m
ΔNorthing	-930.211 m	Ellipsoid Dist.	933.322 m	ΔY	146.900 m
ΔElevation	-2.773 m	ΔHeight	-2.778 m	ΔZ	-921.644 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.004 m	σ ΔHeight	0.004 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000013603		
Y	0.0000026352	0.0000296273	
Z	0.0000004069	0.0000057486	0.0000013978

2

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		GEROME HIPOLITO	UP-TCAGP
FIELD TEAM			
LiDAR Operation, Ground Survey, Data Download and Transfer	Supervising Science Research Specialist (Supervising SRS)	GEROME HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (Senior SRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	GEF SORIANO	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	IRO ROXAS	UP-TCAGP
	RA	LANCE CINCO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. JAYCO S. MANZANO	PHILIPPINE AIR FORCE (PAF)
	Airborne Security	SSG. LEE JAY PUNZALAN	PAF
	Pilot	CAPT. SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JERICHO JECIEL	AAC
	Pilot	CAPT. C. ALFONSO	AAC
	Pilot	CAPT. J. LIM	AAC

Annex 5. Data Transfer Sheet for Migcanaway Floodplain

DATA TRANSFER SHEET
08/05/2014(Northern Mindanao - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	SHP	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	
7/3/2014	1665P	1BLK71ES184A	Pegasus	606	93	4.69	94.5	169	NA	NA	6.77	NA	6.94	1KB	1KB	35	NA	Z:\Airborne_Raw
7/5/2014	1673P	1BLK71ES186A	Pegasus	1.05	379	7.58	335	190	22.4	167	12.5	27.8	5.09	1KB	1KB	92/84	NA	Z:\Airborne_Raw
7/6/2014	1677P	1BLK71S187A	Pegasus	695	68	5.33	188	141	11.2	86	7.79	NA	4.94	1KB	1KB	130	NA	Z:\Airborne_Raw
7/8/2014	1685P	1BLK71S189A	Pegasus	2.31	515	11	578	242	37	288	22.4	47.4	4.39	1KB	1KB	184	NA	Z:\Airborne_Raw
7/8/2014	1687P	1BLK71S189B	Pegasus	749	79	4.81	176	136	NA	NA	7.47	NA	4.39	1KB	1KB	NA	NA	Z:\Airborne_Raw
7/9/2014	1689P	1BLK71S190A	Pegasus	2.56	156	12.6	740	257	NA	NA	27.1	NA	3.68	1KB	1KB	196/207	NA	Z:\Airborne_Raw
7/10/2014	1693P	1RXES191A	Pegasus	1.78	551	8.11	448	175	NA	NA	16.9	NA	4.08	1KB	1KB	53	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
8/6/14

DATA TRANSFER SHEET
PAGADIAN 2/29/16

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	
2016-02-17	23104P	1BLK76DLM48A	Pegasus	1.81 GB	NA	10.09 MB	287.01 MB	25.87 GB	193.97 KB	18.3 GB	0 B	116.78 MB	133 B	1.08 KB	0 B	NA	Z:\DAC\RAW DATA\23104P
2016-02-16	23100P	1BLK76G047A	Pegasus	2.83 GB	NA	12.33 MB	285.96 MB	38 GB	297.52 KB	27.31 GB	0 B	103.23 MB	132 B	341B	0 B	NA	Z:\DAC\RAW DATA\23100P
2016-02-15	23096P	1BLK76NO46A	Pegasus	665.91 MB	NA	4.64 MB	164.2 MB	9.7 GB	82.64 KB	7.07 GB	0 B	90.32 MB	133 B	603 B	0 B	NA	Z:\DAC\RAW DATA\23096P
2016-02-14	23092P	1BLK76IG045A	Pegasus	2.19 GB	NA	10.66 MB	203.46 MB	28.87 GB	230.75 KB	22.33 GB	0 B	110.72 MB	132 B	279 B	0 B	NA	Z:\DAC\RAW DATA\23092P
2016-02-13	23088P	1BLK76ILM044A	Pegasus	2.48 GB	NA	11.64 MB	283.62 MB	35.45 GB	263.38 KB	24.65 GB	0 B	101.29 MB	133 B	889 B	0 B	NA	Z:\DAC\RAW DATA\23088P
2016-02-12	23084P	1BLK76KJLM043A	Pegasus	3.01 GB	NA	13.36 MB	276.9 MB	44.56 GB	332.83 KB	29.36 GB	0 B	129.73 MB	133 B	362 B	0 B	NA	Z:\DAC\RAW DATA\23084P

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/1/16

Annex 6. Flight Logs for the Flight Missions

Flight Log for **1673P** Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 167:

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK71ES/S6A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 5, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0933H	14 Engine Off: 1238H	15 Total Engine Time: 3+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Very cloudy					

20 Remarks:

Attempted to survey Lanao and Pagadian but transferred to Tangub and Ozamis due to heavy build up in the previous areas

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
V. [illegible]	W. Punzalan	Cesar Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for **1677P** Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23088P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: 1BLK76ILM044A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecrel	9 Route:			
10 Date: 13 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0720 H	14 Engine Off: 1143H	15 Total Engine Time: 4+23	16 Take off: 0725H	17 Landing: 1138H	18 Total Flight Time: 4H3
19 Weather	Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK76 I, L and M- with voids due to clouds.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G.H. Pocito	A1C Jayed S. Marano PAF	C. Alfonso III	J. Almalvez	N/A
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

Flight Log for 23092P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23092P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK76GHI049A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecrel	9 Route:			
10 Date: 14 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0835H	14 Engine Off: 1210H	15 Total Engine Time: 3+35	16 Take off: 0840H	17 Landing: 1205H	18 Total Flight Time: 3+25
19 Weather: Cloudy					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
☑ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: ______	○ Phil-LiDAR Admin Activities
○ Calibration Flight		

21 Remarks

Surveyed voids over BLK76 G, H and I.

22 Problems and Solutions

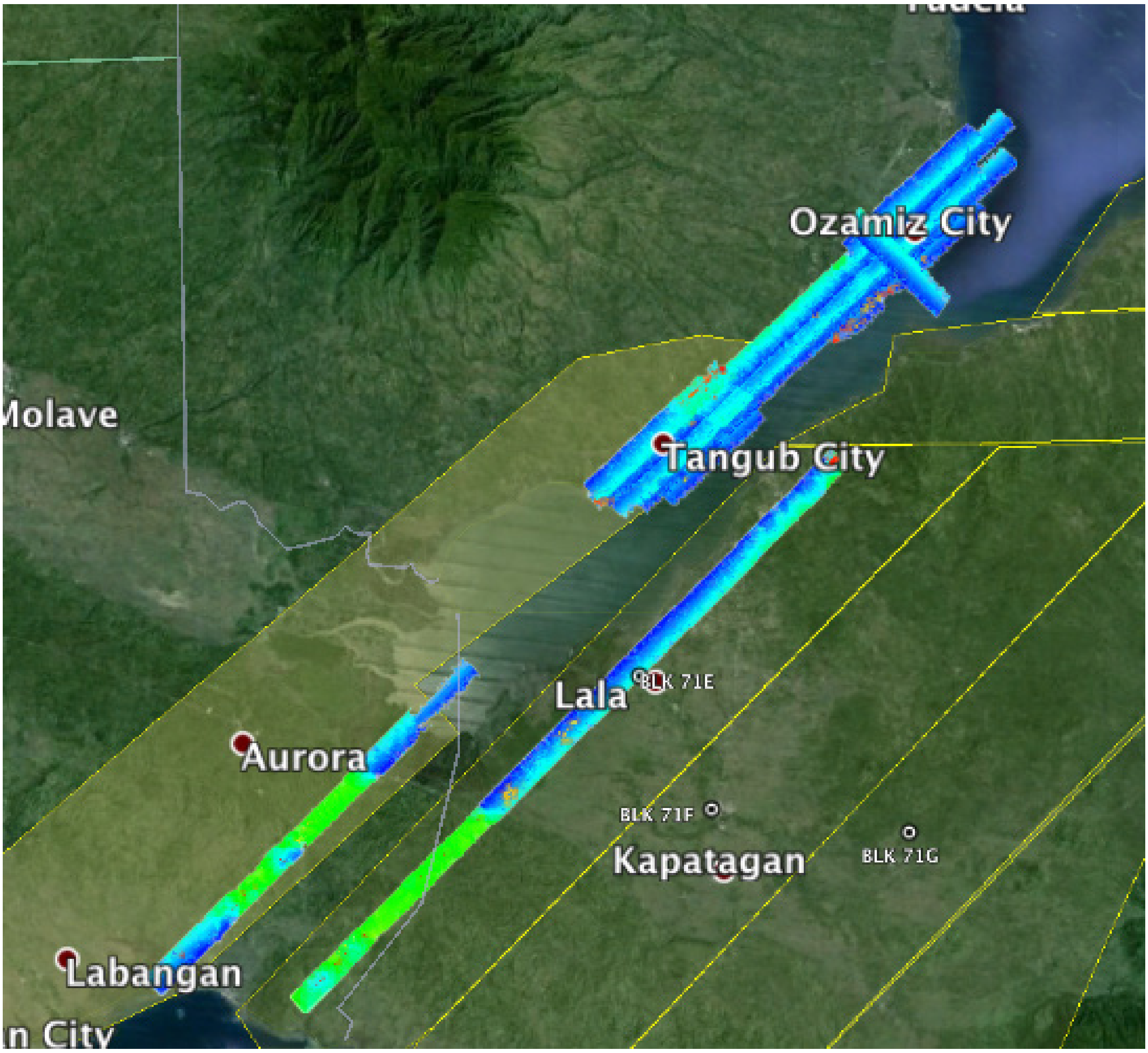
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ______

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G. Hipolito	MC Jaudo B. Manzano PAF	C. Alfonso III	I. Roxas	N/A
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

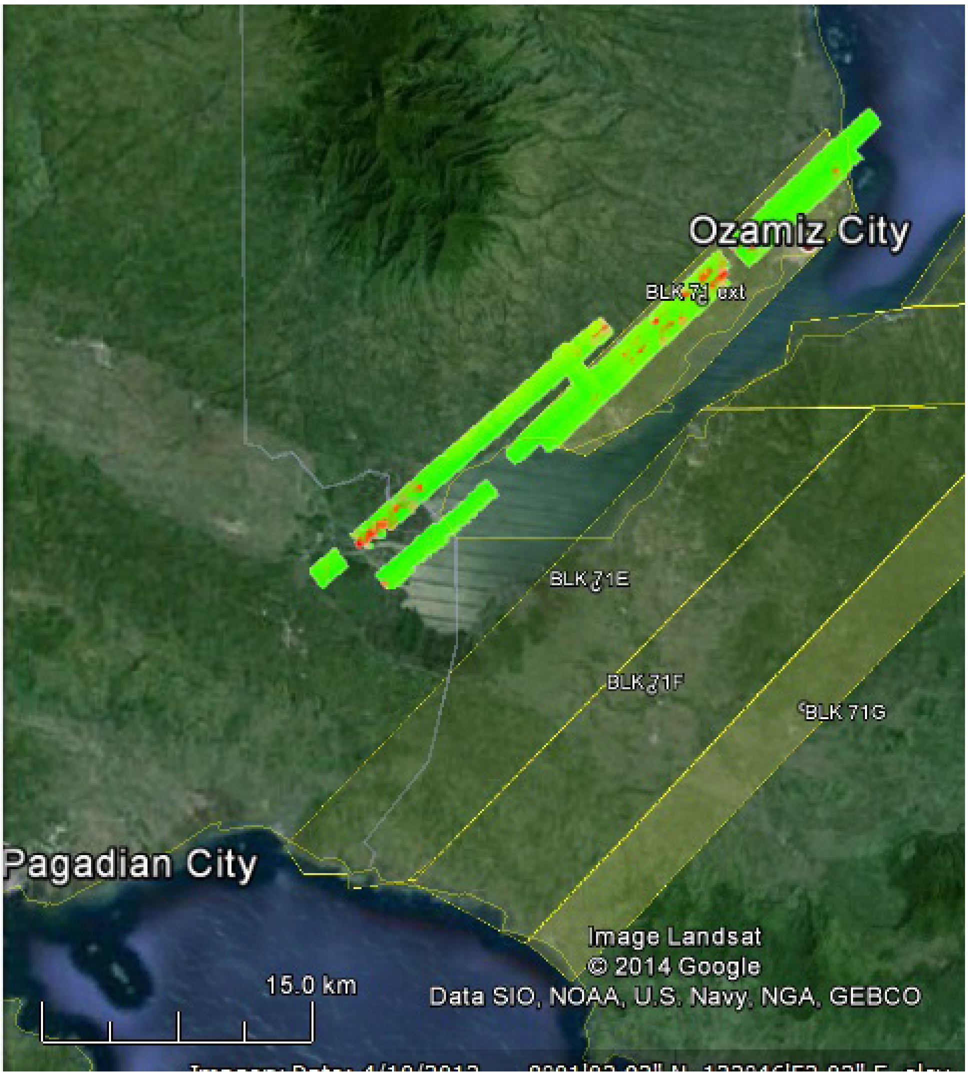
Annex 7. Flight Status Reports

FLIGHT STATUS REPORT NORTHERN MINDANAO (July 5-6, 2014)					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
1673P	BLK 71 ext	1BLK71ES186A	I.Roxas	July 5	Attempted to survey Lanao and Pagadian but transferred to Migcanaway and Ozamis due to heavy build up in the previous areas; 63.7 sq.km
1677P	BLK 71 ext	1BLK71S187A	G. Sinadjan	July 6	Heavy build over all remaining survey areas; surveyed supplementary lines to BLK 71ext; 89.67 sq.km

Flight No. :	1673P		
Area:	BLK 71		
Mission Name:	1BLK71ES186A		
Parameters:	Altitude:	1000m;	Scan Frequency: 30Hz;
Scan Angle:	25deg;	Overlap: 25%	



Flight No. :	1677P		
Area:	BLK 71 ext		
Mission Name:	1BLK71S187A		
Parameters:	Altitude:	1000m;	Scan Frequency: 30Hz;
Scan Angle:	25deg;	Overlap: 25%	

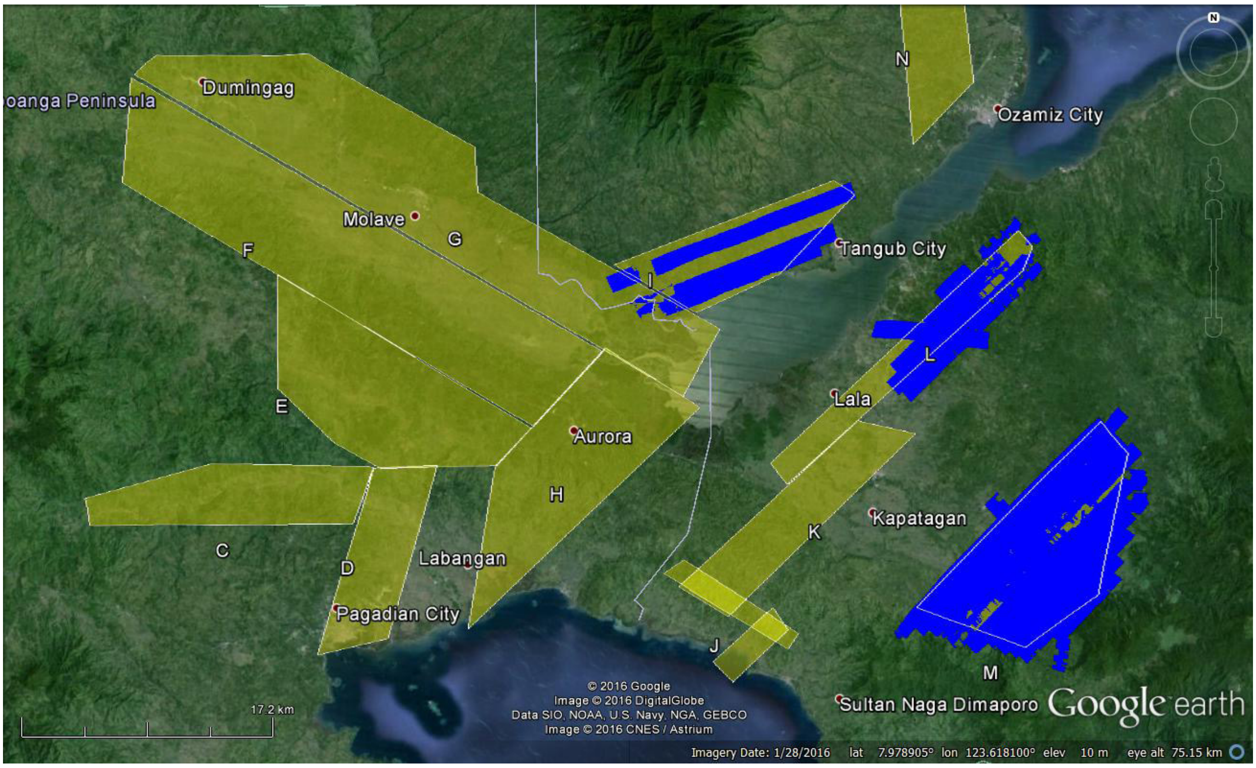


PAGADIAN (BLK 76) WITH REFLIGHTS PEGASUS (9122) FLIGHT STATUS REPORT

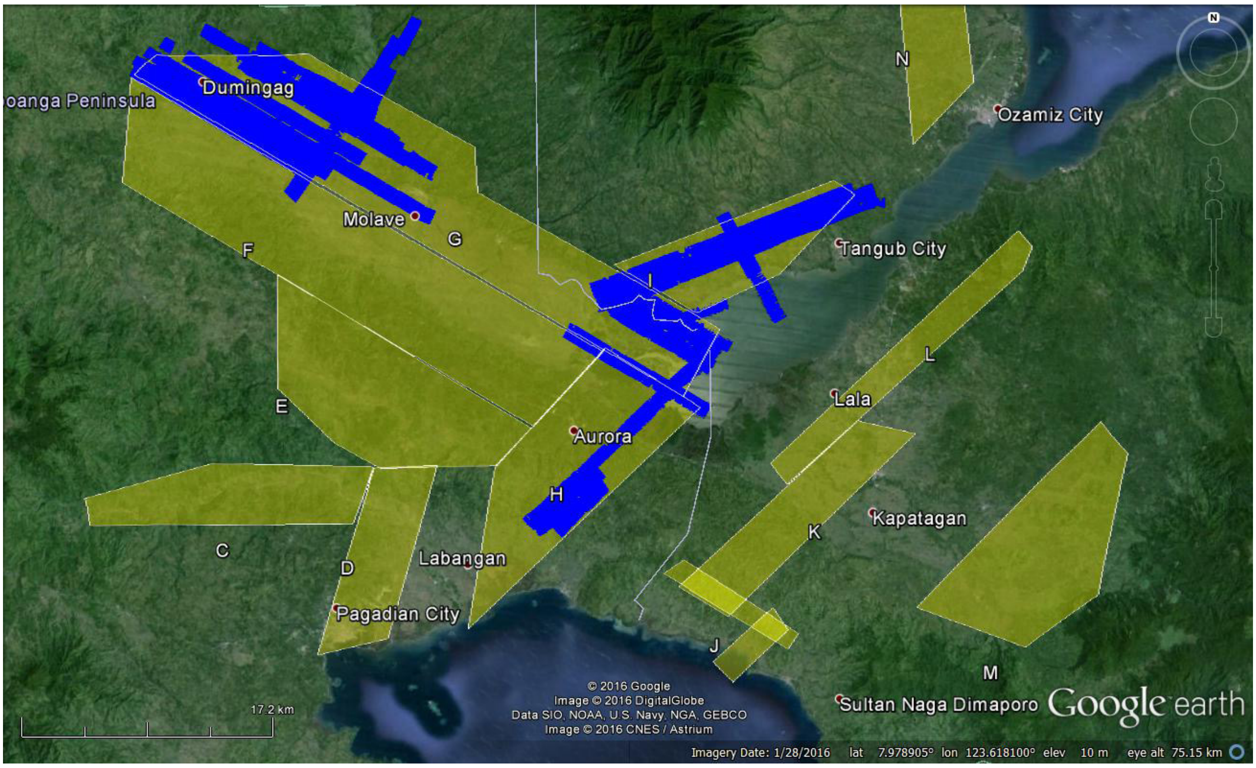
FEBRUARY 13–14, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23088	BLK I,L,M	1BLK76ILM044A	JM ALMALVEZ	FEB 13, 2016	Cloudy over L & M. Pegasus problem encountered so no tie lines over I; please use 23078's and 23092's tie line
23092	BLK G,H,I	1BLK76GHI045A	IN ROXAS	FEB 14, 2016	Cloudy w/ some rain. Surveyed voids over G & H; completed I; please also process tie lines especially in 76G as they also cover voids and flood plain

Flight No. :	23088P		
Area:	BLK I, L, M		
Mission Name:	1BLK76ILM044A		
Parameters:	Altitude:	1000m;	Scan Frequency: 30Hz;
Scan Angle:	25deg;	Overlap: 30%	



Flight No. :	23092P		
Area:	BLK G, H, I		
Mission Name:	1BLK76GHI045A		
Parameters:	Altitude:	1200m;	Scan Frequency: 30Hz;
Scan Angle:	25deg;	Overlap: 30%	



Annex 8. Mission Summary Reports

Flight Area	Pagadian
Mission Name	**Blk76I**
Inclusive Flights	23088P, 23092P
Range data size	46.98 GB
POS data size	487.08 MB
Base data size	211.99 MB
Image	64.32 GB
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000369
IMU attitude correction stdev (<0.001deg)	0.001254
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	52.57
Ave point cloud density per sq.m. (>2.0)	4.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	100
Maximum Height	326.08
Minimum Height	59.15
Classification (# of points)	
Ground	74,430,912
Low vegetation	88,671,219
Medium vegetation	93,736,117
High vegetation	225,713,168
Building	4,653,764
Orthophoto	Yes
Processed By	Engr. Regis Guhiting, Engr. Edgardo Gubatanga Jr., Marie Denise Bueno

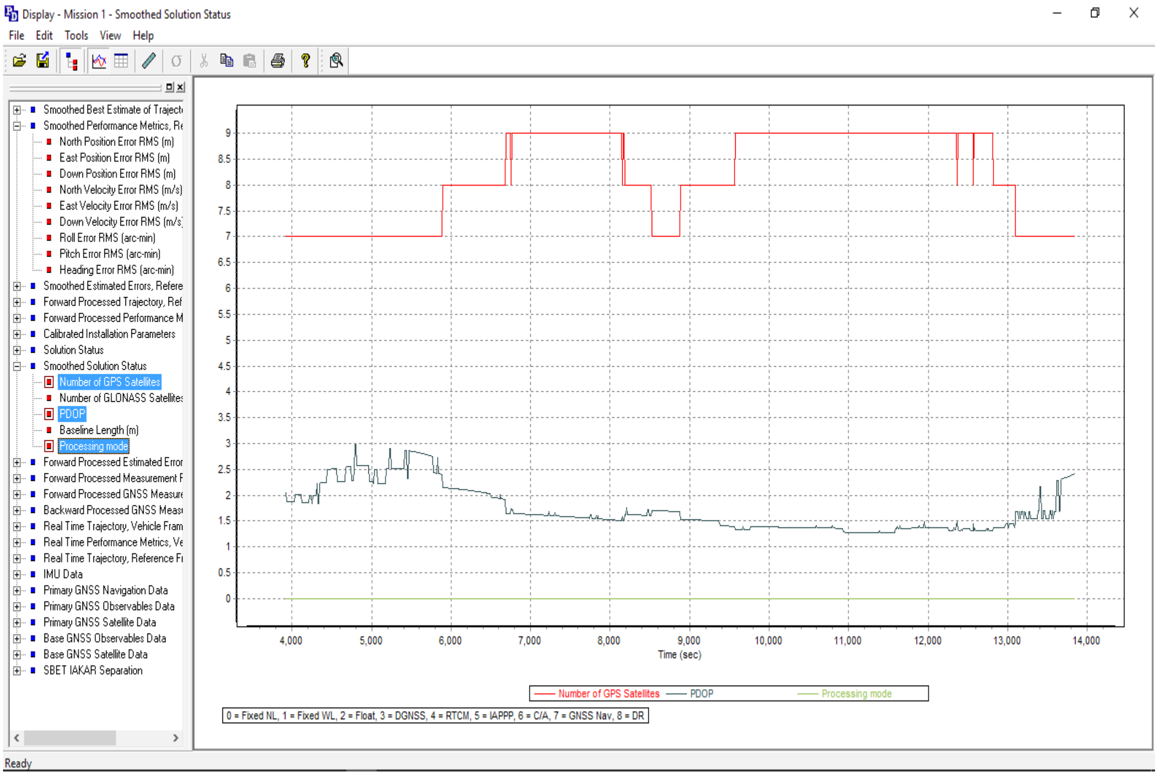


Figure 1.1.1. Solution Status

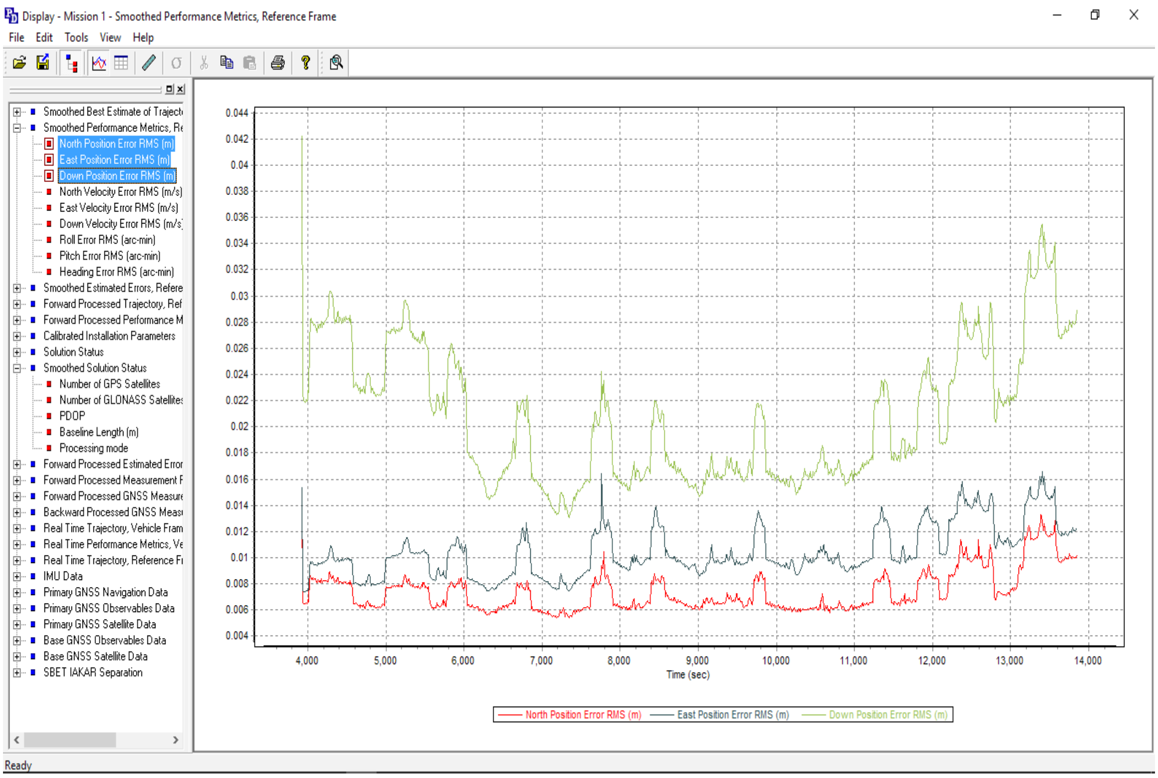


Figure 1.1.2. Smoothed Performance Metric Parameters

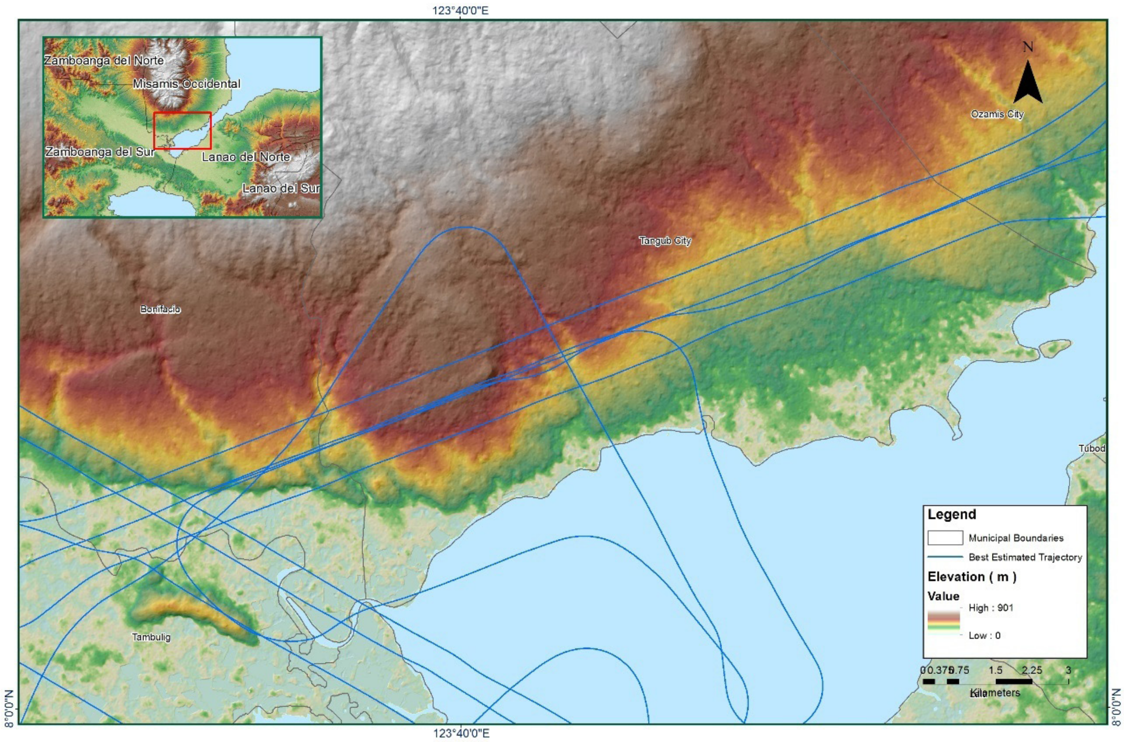


Figure 1.1.3. Best Estimated Trajectory

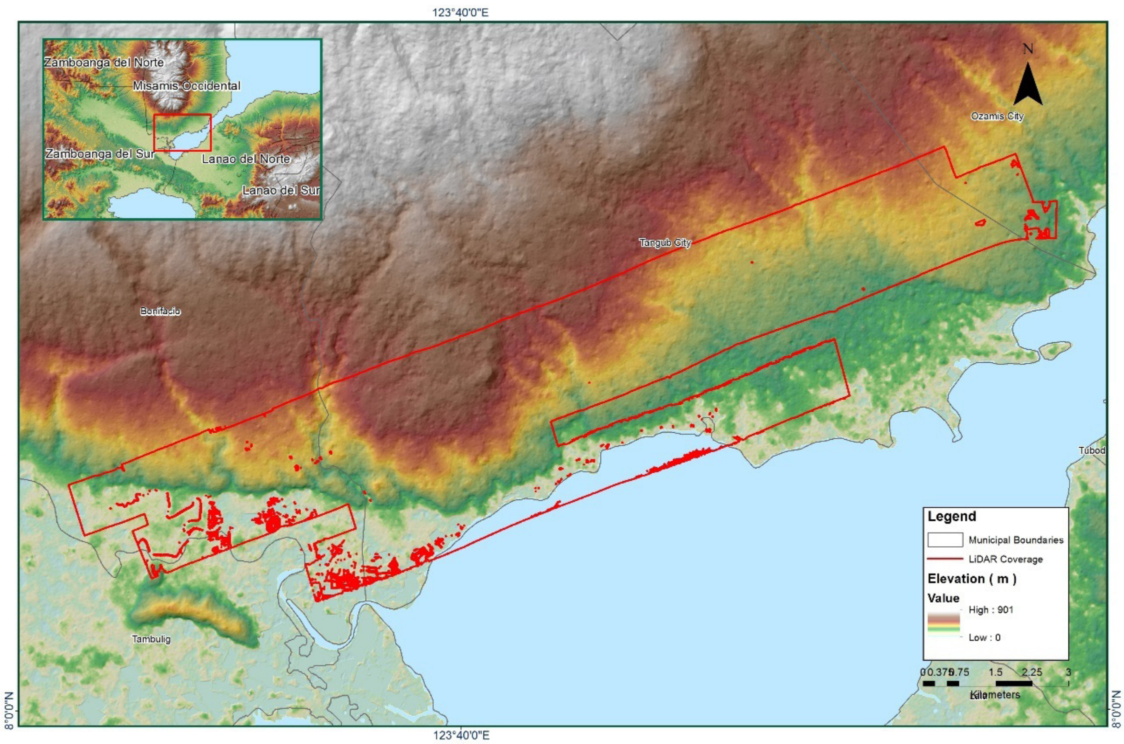


Figure 1.1.4. Coverage of LiDAR Data

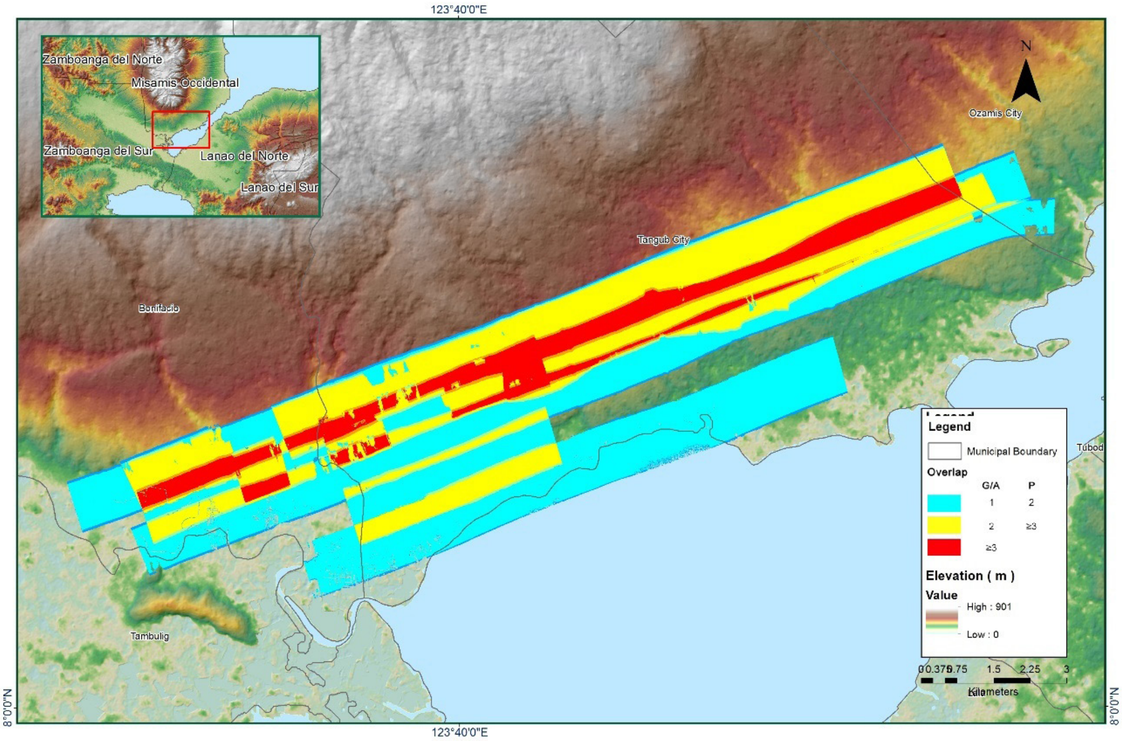


Figure 1.1.5. Image of data overlap

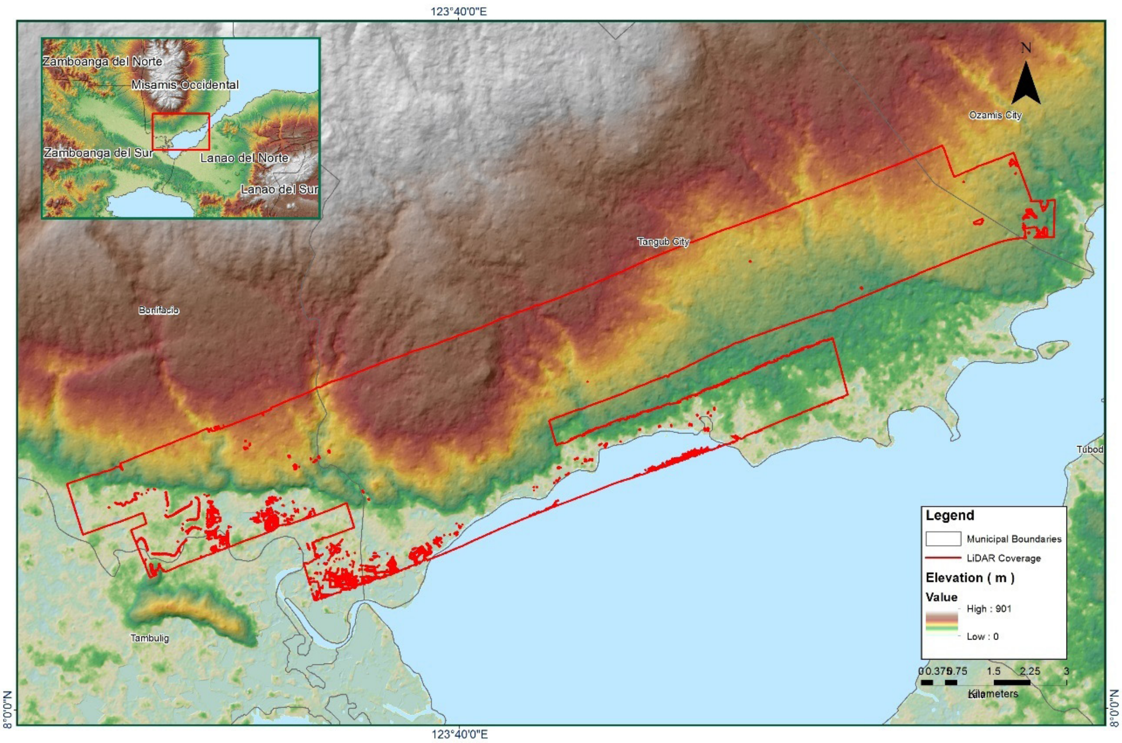


Figure 1.1.6. Density map of merged LiDAR data

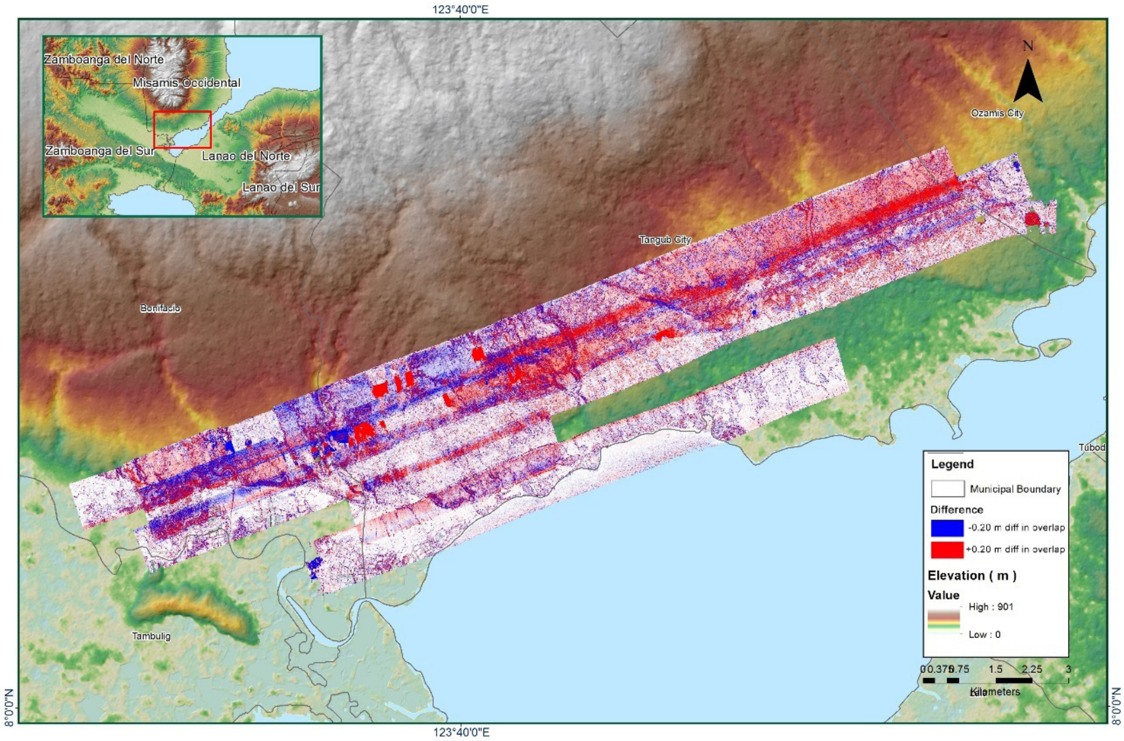


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	**Blk76I_additional**
Inclusive Flights	23088P
Range data size	24.65 GB
POS data size	283.62 MB
Base data size	101.29 MB
Image	35.45 GB
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.24
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.22
Boresight correction stdev (<0.001deg)	0.000139
IMU attitude correction stdev (<0.001deg)	0.000082
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	24.77
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	72
Maximum Height	321.08
Minimum Height	67.52
Classification (# of points)	
Ground	63889750
Low vegetation	23205040
Medium vegetation	21659026
High vegetation	87182655
Building	1567242
Orthophoto	No
Processed By	Engr. Regis Guhiting, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

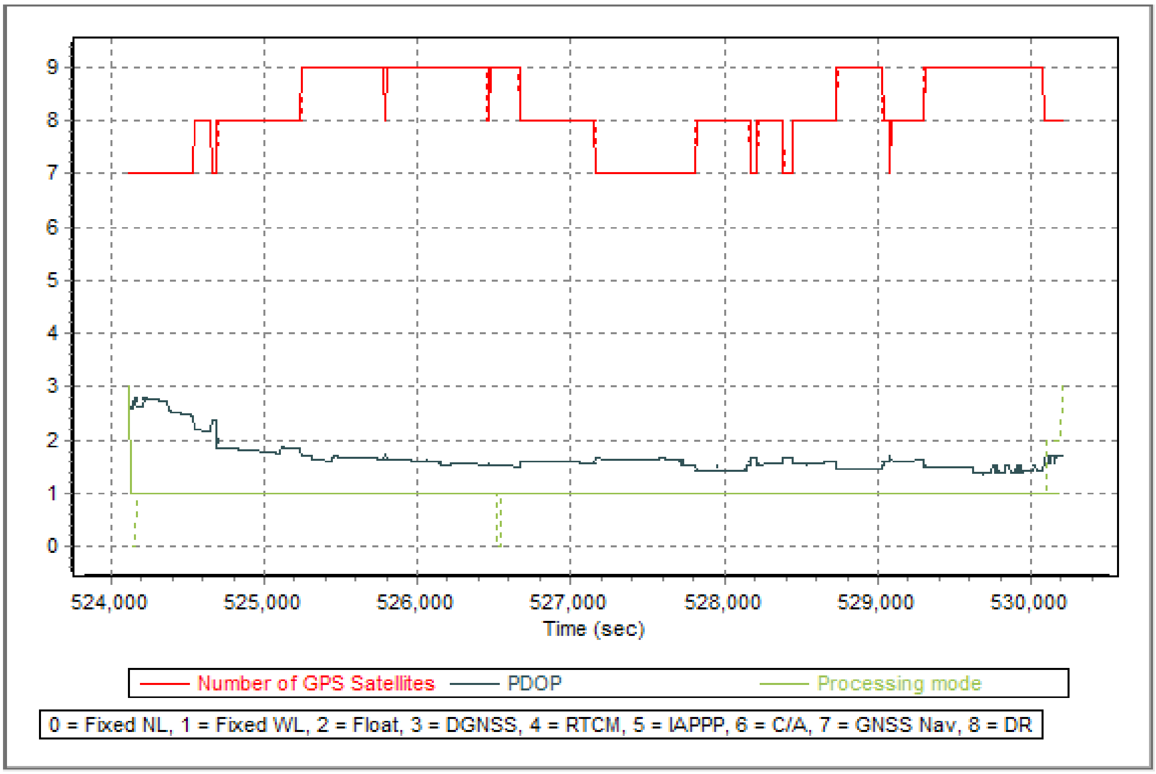


Figure 1.2.1. Solution Status

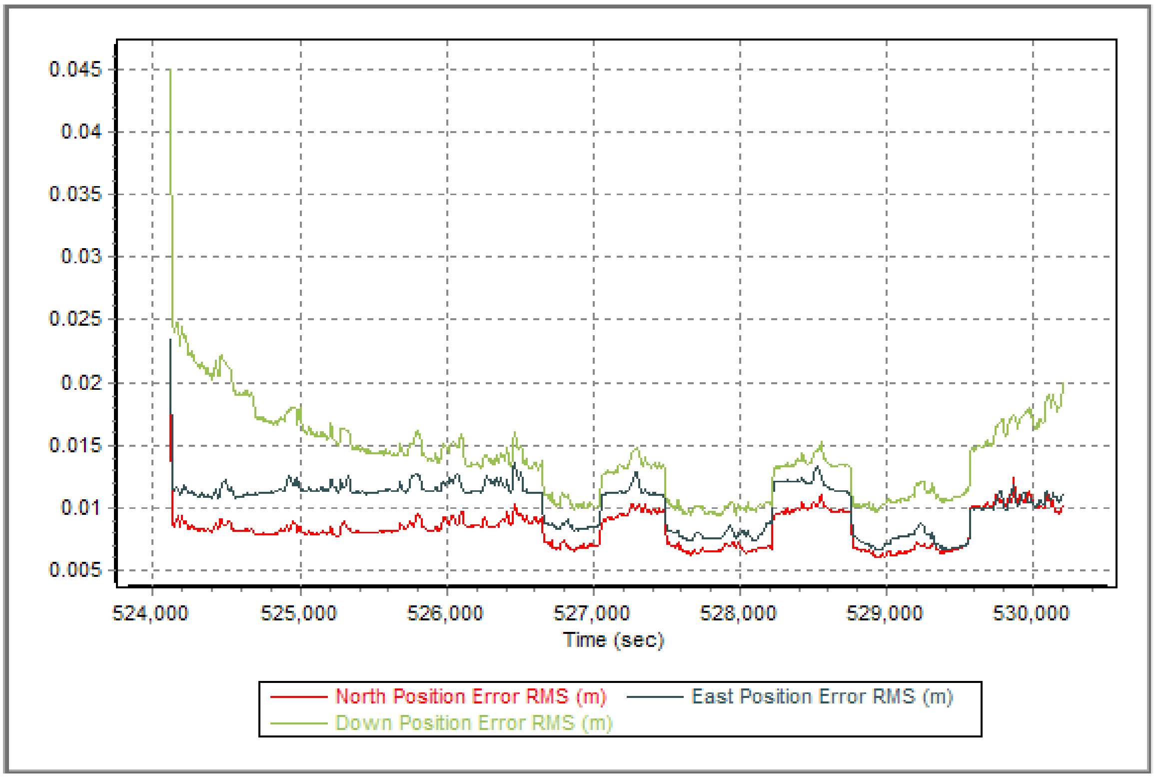


Figure 1.2.2. Smoothed Performance Metric Parameters

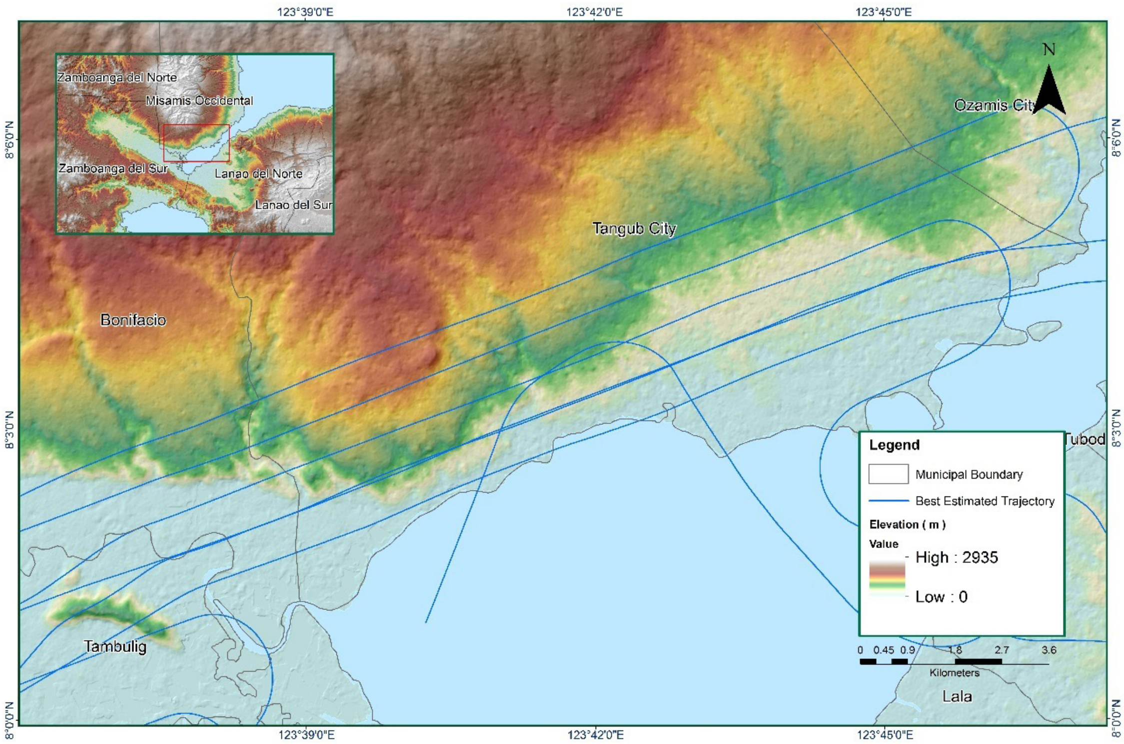


Figure 1.2.3. Best Estimated Trajectory

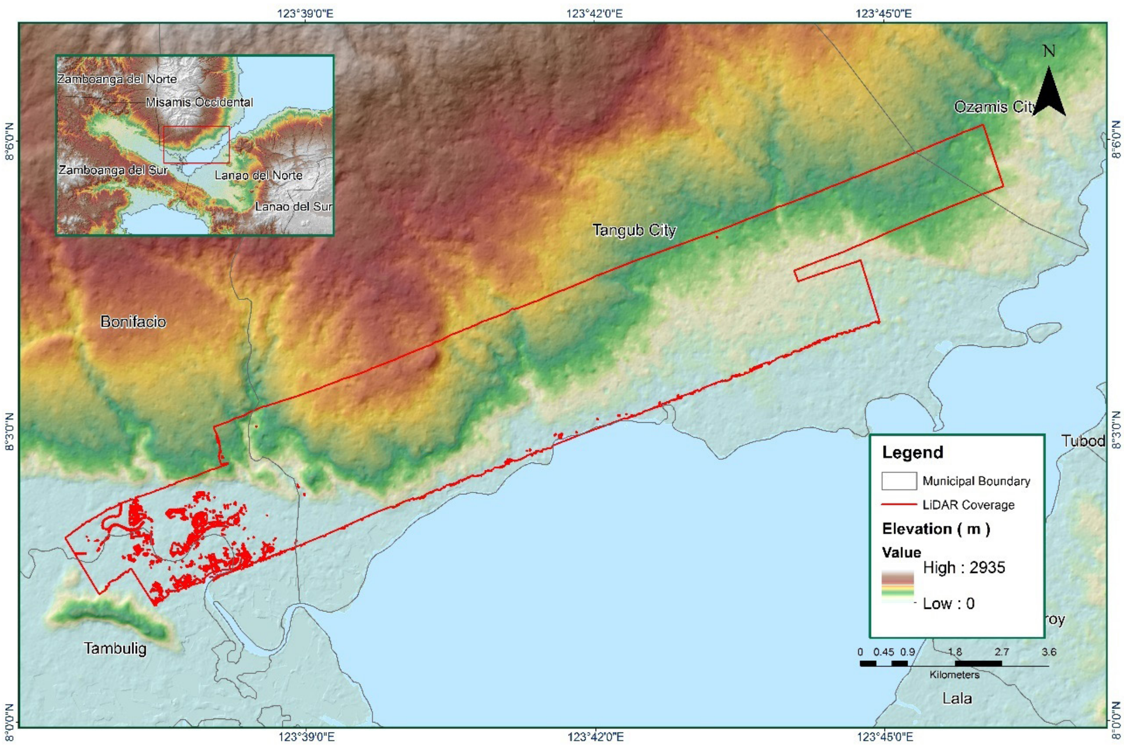


Figure 1.2.4. Coverage of LiDAR Data

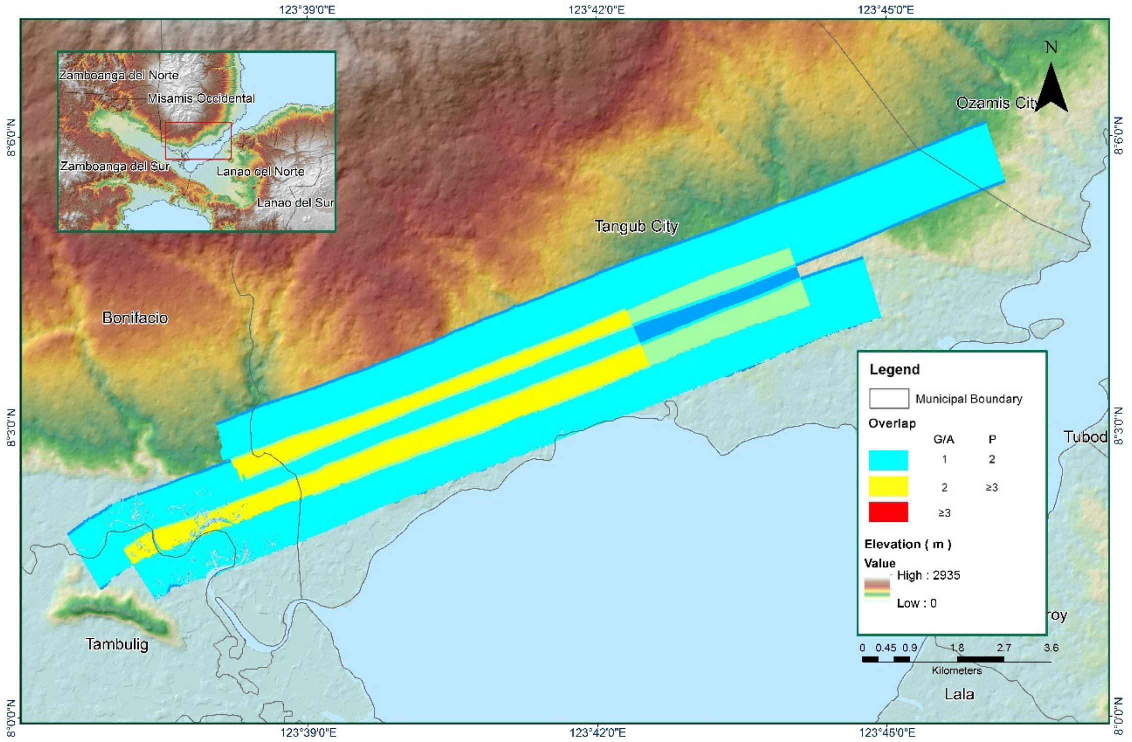


Figure 1.2.5. Image of data overlap

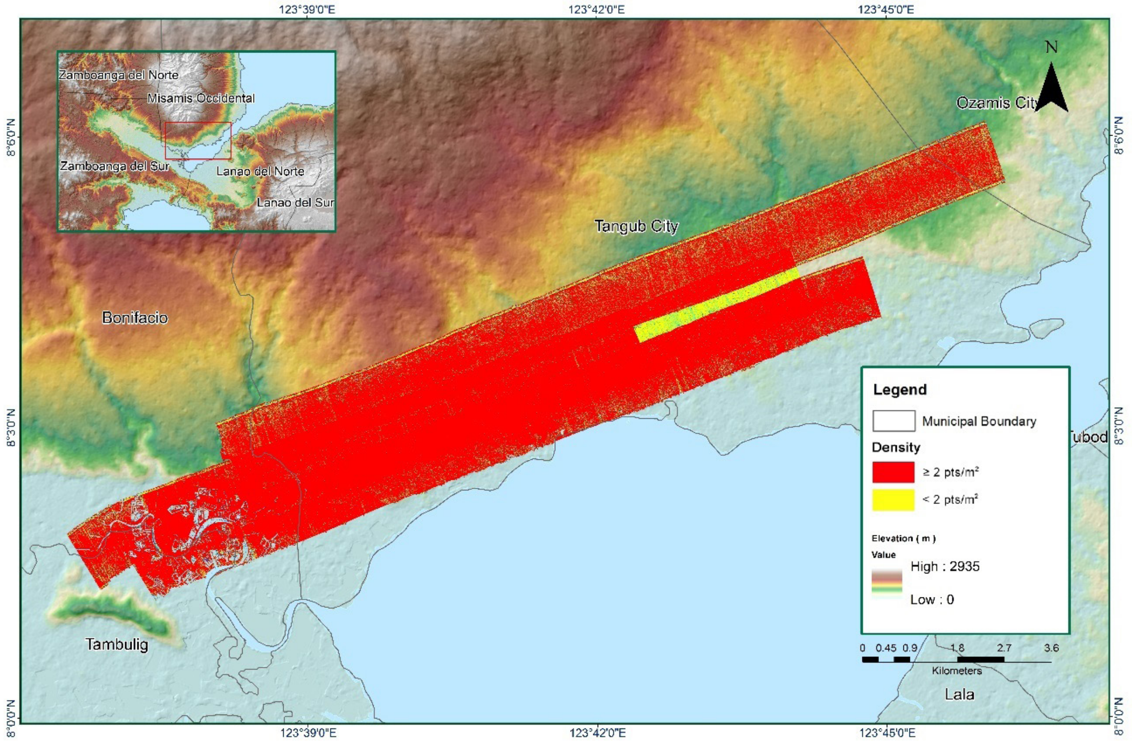


Figure 1.2.6. Density map of merged LiDAR data

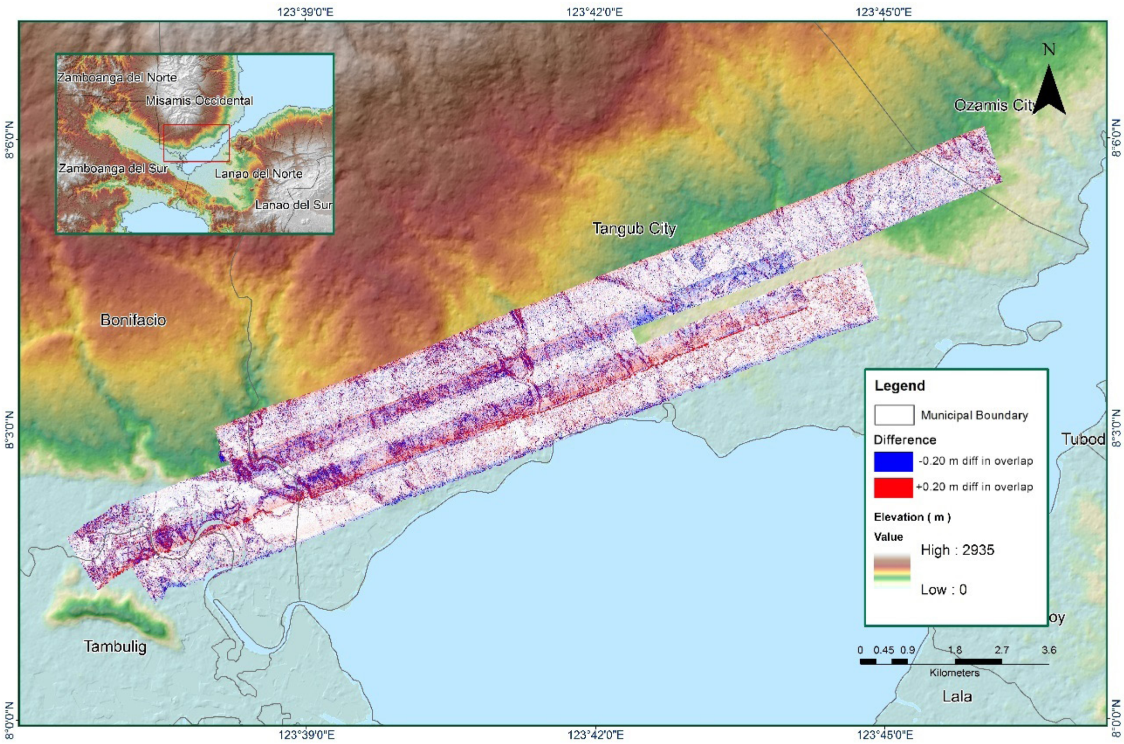


Figure 1.2.7. Elevation difference between flight lines

Flight Area	**Northern Mindanao**
Mission Name	**Blk71_Extension**
Inclusive Flights	1665P, 1673P, 1677P
Range data size	27.06 GB
Base data size	16.97 MB
POS	500 MB
Image	33.6 GB
Transfer date	August 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.0
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000243
IMU attitude correction stdev (<0.001deg)	0.001298
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	27.83%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	868.76 m
Minimum Height	63.2 m
Classification (# of points)	
Ground	107,907,148
Low vegetation	96,229,157
Medium vegetation	96,176,102
High vegetation	80,601,347
Building	17,253,174
Orthophoto	Yes
Processed By	Engr. Analyn Naldo, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

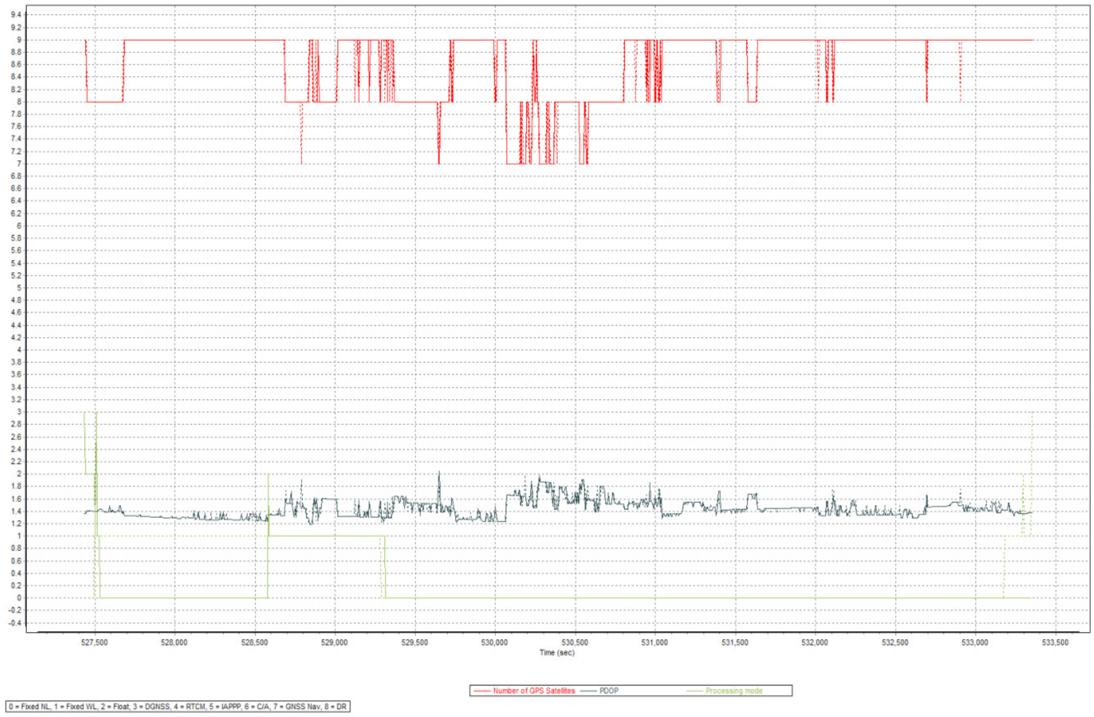


Figure 1.3.1 Solution Status

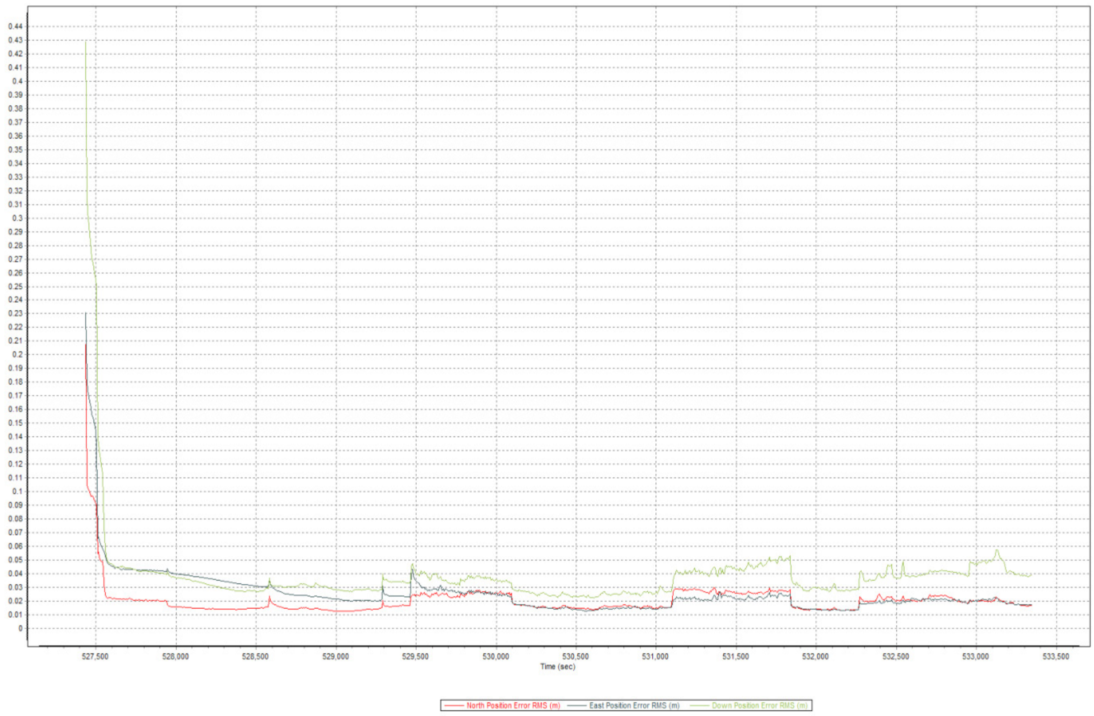


Figure 1.3.2 Smoothed Performance Metric Parameters

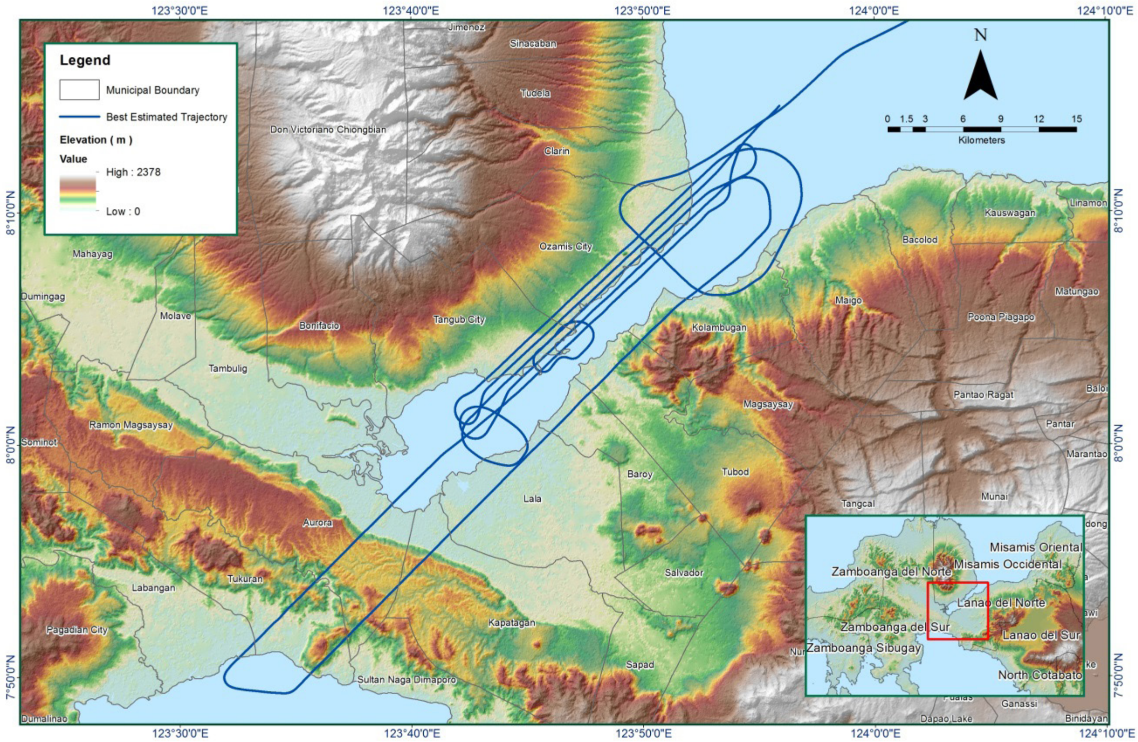


Figure 1.3.3 Best Estimated Trajectory

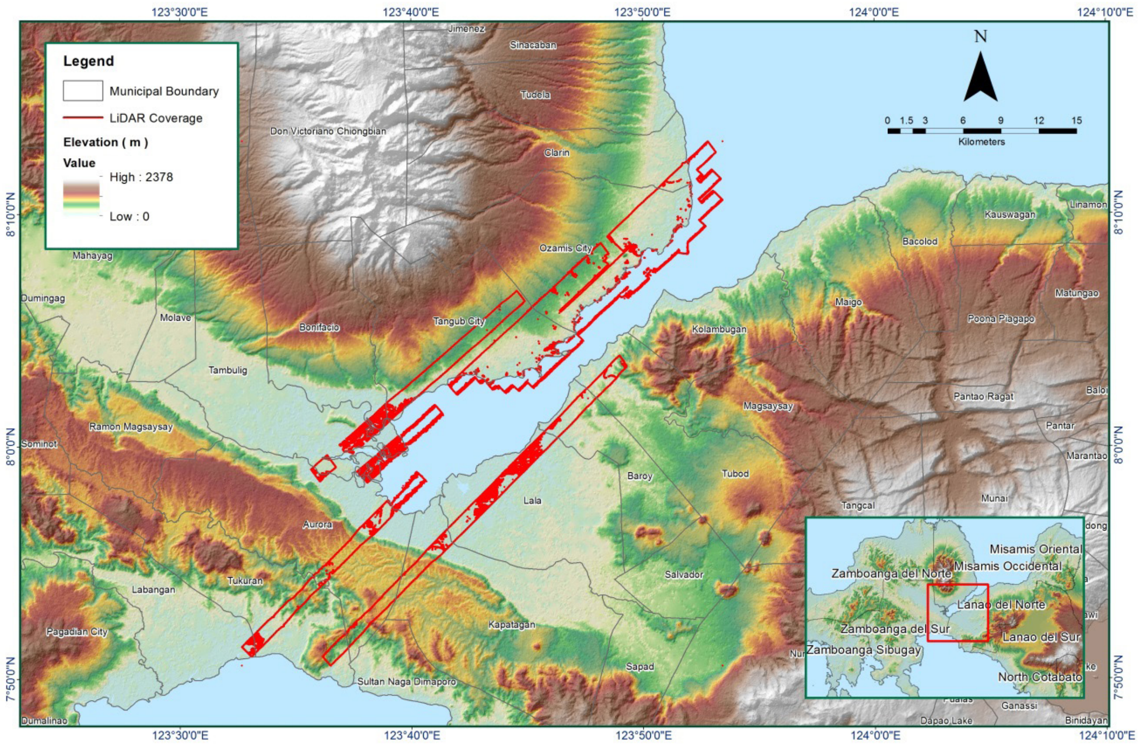


Figure 1.3.4 Coverage of LiDAR data

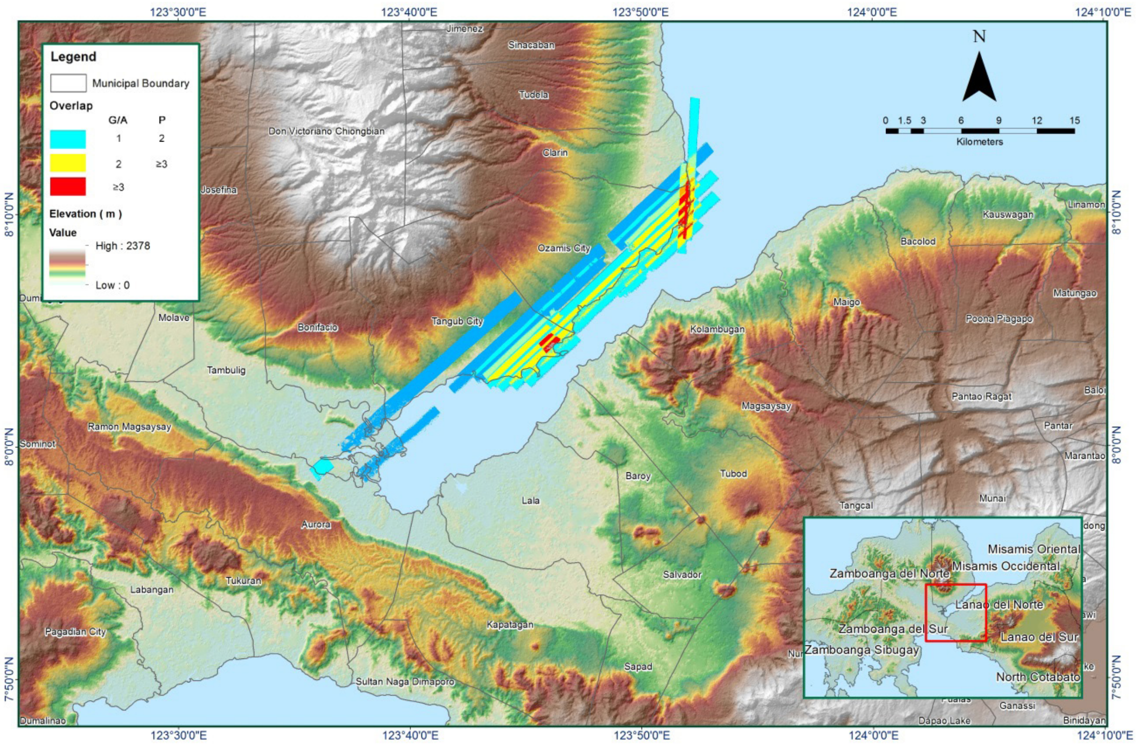


Figure 1.3.5 Image of data overlap

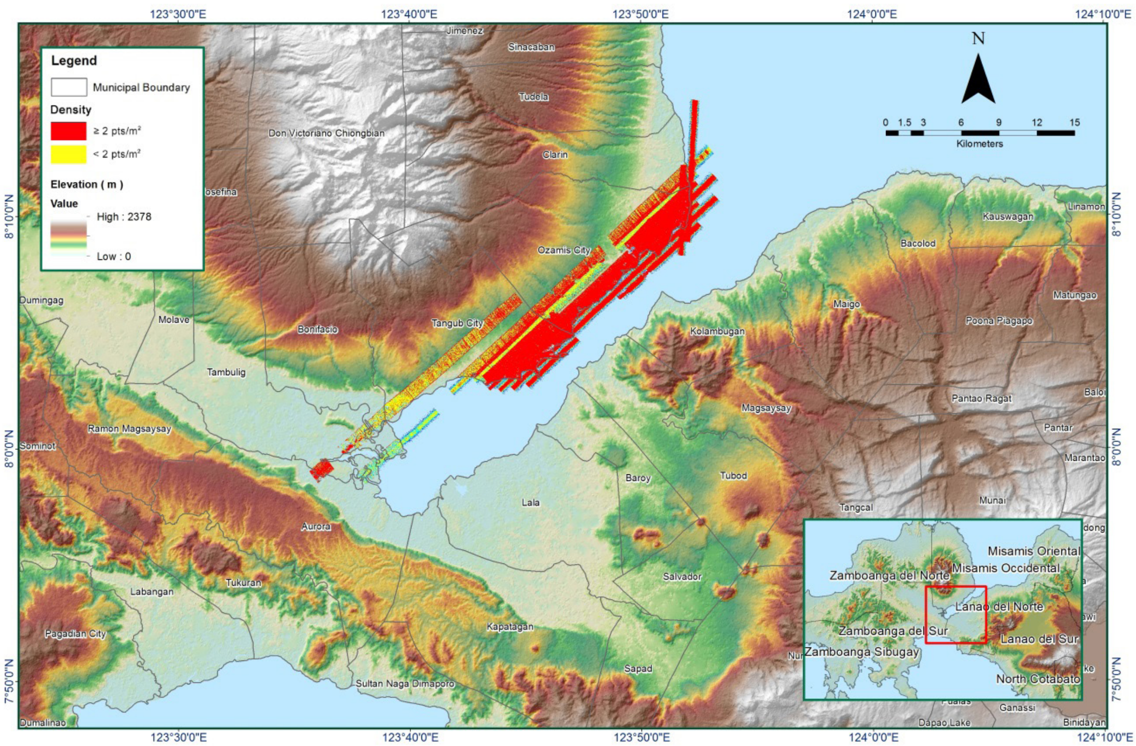


Figure 1.3.6 Density map of merged LiDAR data

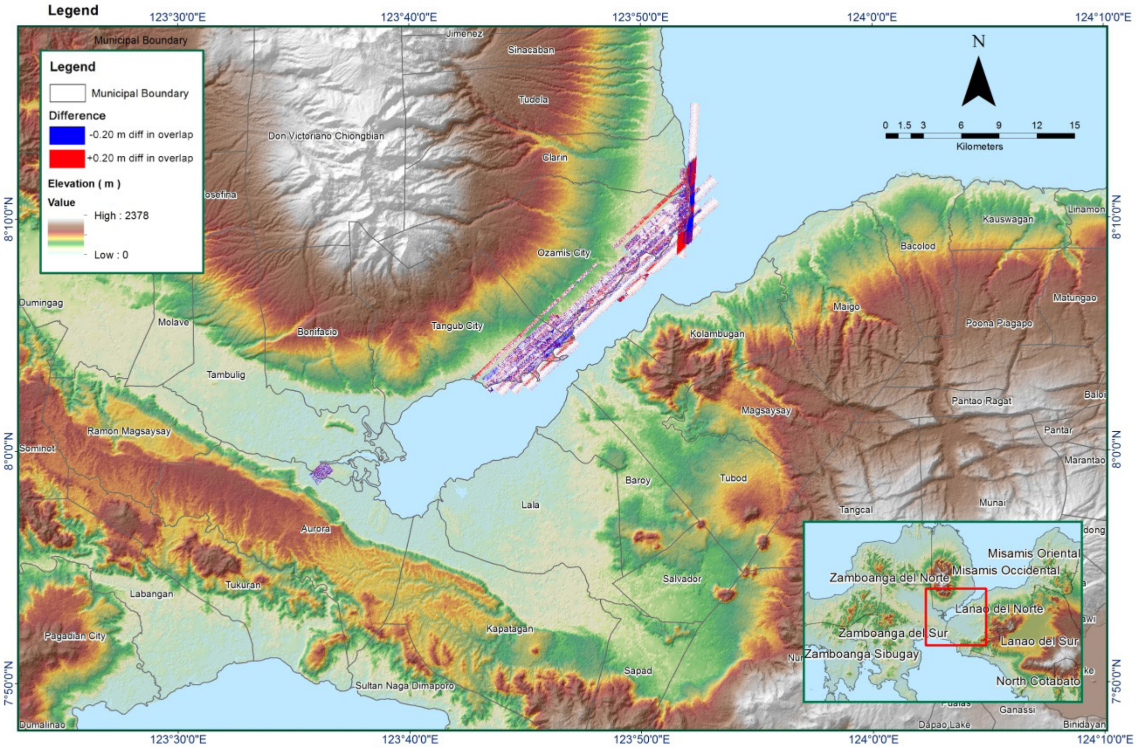


Figure 1.3.7 Elevation difference between flight lines

Annex 9. Migcanaway 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
W180	30.003	79.306	0.0	0.092293	0.62021	Discharge	0.1172	0.0728243	Ratio to Peak	0.001
W190	24.243	89.077	0.0	0.0650626	0.6705	Discharge	0.0593421	0.0768718	Ratio to Peak	0.001
W200	36.769	52.871	0.0	0.0660688	0.99895	Discharge	0.11544	0.0514928	Ratio to Peak	0.001
W210	20.377	92.47	0.0	0.0527347	1.8207	Discharge	0.051068	0.0590201	Ratio to Peak	0.001
W220	20.265	74.814	0.0	0.0392318	1.3597	Discharge	0.0436294	0.0589326	Ratio to Peak	0.001
W230	31.363	54.27	0.0	0.0918675	1.389	Discharge	0.11051	0.0334628	Ratio to Peak	0.001
W240	18.8	89.23	0.0	0.1179	2.7154	Discharge	0.22814	0.0769657	Ratio to Peak	0.001
W250	31.866	48.324	0.0	0.0917601	0.41388	Discharge	0.0923301	0.0341664	Ratio to Peak	0.001
W260	5.7319	52.696	0.0	0.11849	0.0985735	Discharge	0.18348	0.0275758	Ratio to Peak	0.001
W270	26.491	99	0.0	0.0791274	3.1015	Discharge	0.0694619	0.0228042	Ratio to Peak	0.001
W280	6.803	68.343	0.0	0.0921797	1.8259	Discharge	0.11259	0.0307824	Ratio to Peak	0.001
W290	32.22	44.126	0.0	0.0855176	1.9727	Discharge	0.091718	0.0336462	Ratio to Peak	0.001
W300	8.6374	85.07	0.0	0.0790532	0.50679	Discharge	0.0541231	0.0341656	Ratio to Peak	0.001
W310	10.187	86.449	0.0	0.0638575	0.18899	Discharge	0.0322135	0.034166	Ratio to Peak	0.001
W320	9.6361	42.418	0.0	0.0903145	0.27114	Discharge	0.0515516	0.0772514	Ratio to Peak	0.001
W330	6.422	38.054	0.0	0.1144	0.35072	Discharge	0.10173	0.0772461	Ratio to Peak	0.001
W340	9.5347	57.991	0.0	0.0932976	0.4234	Discharge	0.0522447	0.0772496	Ratio to Peak	0.001

Annex 10. Migcanaway Model Reach Parameters

Reach Number	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	2600.4	0.0448013	0.04	Trapezoid	17.088	1
R120	Automatic Fixed Interval	3566.3	0.0729865	0.04	Trapezoid	10.078	1
R130	Automatic Fixed Interval	1531.0	0.0329250	0.04	Trapezoid	20.152	1
R140	Automatic Fixed Interval	1463.3	0.0328286	0.04	Trapezoid	11.446	1
R160	Automatic Fixed Interval	1427.4	0.0216510	0.04	Trapezoid	24.2925	1
R170	Automatic Fixed Interval	1978.4	0.0167806	0.04	Trapezoid	14.732	1
R30	Automatic Fixed Interval	2123.1	0.0997929	0.04	Trapezoid	10.0275	1
R60	Automatic Fixed Interval	1311.8	0.0628153	0.04	Trapezoid	16.36	1

Annex 11. Migcanaway Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	8.055488	123.755582	0.03	0	0.03	December 17, 2013	5 - Year
2	8.055955	123.755149	0.03	0.25	-0.22	December 17, 2013	5 - Year
3	8.056381	123.755176	0.15	0.28	-0.13	December 17, 2013	5 - Year
4	8.056557	123.755493	0.18	0.75	-0.57	December 17, 2013	5 - Year
5	8.056912	123.755417	0.2	0.80	-0.60	December 17, 2013	5 - Year
6	8.058297	123.755083	0.32	0.92	-0.60	December 17, 2013	5 - Year
7	8.058532	123.754879	0.45	0.50	-0.05	December 17, 2013	5 - Year
8	8.058023	123.755291	0.03	0.40	-0.37	December 17, 2013	5 - Year
9	8.057703	123.75505	0.21	0.68	-0.47	December 17, 2013	5 - Year
10	8.057554	123.755512	0.03	0.45	-0.42	December 17, 2013	5 - Year
11	8.058837	123.755768	0.24	0.70	-0.46	December 17, 2013	5 - Year
12	8.059499	123.756129	0.85	0.38	0.47	December 17, 2013	5 - Year
13	8.060458	123.755974	0.28	0	0.28	December 17, 2013	5 - Year
14	8.06068	123.756198	0.17	0	0.17	December 17, 2013	5 - Year
15	8.059723	123.755132	0.71	0.43	0.28	December 17, 2013	5 - Year
16	8.059975	123.754424	0.51	0.50	0.01	December 17, 2013	5 - Year
17	8.05937	123.754744	0.57	0.75	-0.18	December 17, 2013	5 - Year
18	8.059476	123.75409	0.03	0.10	-0.07	December 17, 2013	5 - Year
19	8.060397	123.754034	0.06	0.80	-0.74	December 17, 2013	5 - Year
20	8.061507	123.754263	0.42	0	0.42	December 17, 2013	5 - Year
21	8.062169	123.753716	0.34	0.50	-0.16	December 17, 2013	5 - Year
22	8.061927	123.752728	0.51	0.43	0.08	December 17, 2013	5 - Year
23	8.063155	123.753364	0.59	0	0.59	December 17, 2013	5 - Year
24	8.065276	123.754394	0.03	0	0.03	December 17, 2013	5 - Year
25	8.06356	123.752894	0.5	1	-0.50	December 17, 2013	5 - Year
26	8.064994	123.752318	0.1	0	0.10	December 17, 2013	5 - Year
27	8.066994	123.752016	0.03	0.15	-0.12	December 17, 2013	5 - Year
28	8.055665	123.747637	0.77	0.30	0.47	December 17, 2013	5 - Year
29	8.055847	123.74835	0.56	0.20	0.36	December 17, 2013	5 - Year
30	8.056335	123.747202	0.76	0.45	0.31	December 17, 2013	5 - Year
31	8.057217	123.74684	0.03	0.35	-0.32	December 17, 2013	5 - Year
32	8.056311	123.749058	0.07	0	0.07	December 17, 2013	5 - Year
33	8.056317	123.749964	0.23	0	0.23	December 17, 2013	5 - Year
34	8.0568	123.75203	0.31	0.45	-0.14	December 17, 2013	5 - Year
35	8.057688	123.751762	0.61	0.15	0.46	December 17, 2013	5 - Year
36	8.051379	123.729126	0.03	0.21	-0.18	December 17, 2013	5 - Year
37	8.051249	123.729287	0.14	0.24	-0.10	December 17, 2013	5 - Year
38	8.051034	123.727577	0.09	0.59	-0.50	December 17, 2013	5 - Year
39	8.050617	123.726854	0.98	0.61	0.37	December 17, 2013	5 - Year
40	8.050258	123.726174	0.26	0.30	-0.04	December 17, 2013	5 - Year
41	8.049761	123.725644	1.21	0.22	0.99	December 17, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
42	8.049836	123.724974	0.78	0.78	0	December 17, 2013	5 - Year
43	8.049864	123.72531	0.27	0.33	-0.06	December 17, 2013	5 - Year
44	8.050056	123.725553	0.32	0.46	-0.14	December 17, 2013	5 - Year
45	8.050359	123.725968	0.31	0.12	0.19	December 17, 2013	5 - Year
46	8.051748	123.72972	0.35	0	0.35	December 17, 2013	5 - Year
47	8.052521	123.732075	0.13	0.22	-0.09	December 17, 2013	5 - Year
48	8.052729	123.732325	0.41	0.51	-0.10	December 17, 2013	5 - Year
49	8.054156	123.735992	0.46	0.44	0.02	December 17, 2013	5 - Year
50	8.054311	123.736865	0.16	0.18	-0.02	December 17, 2013	5 - Year
51	8.05471	123.738277	0.65	0.43	0.22	December 17, 2013	5 - Year
52	8.053677	123.738742	0.95	0.59	0.36	December 17, 2013	5 - Year
53	8.055687	123.739862	0.74	0.40	0.34	December 17, 2013	5 - Year
54	8.055475	123.740074	0.41	0.28	0.13	December 17, 2013	5 - Year
55	8.051128	123.740969	0.95	0.23	0.72	December 17, 2013	5 - Year
56	8.051075	123.74137	0.94	0.51	0.43	December 17, 2013	5 - Year
57	8.050543	123.740925	0.82	0.34	0.48	December 17, 2013	5 - Year
58	8.050682	123.741213	0.76	0.20	0.56	December 17, 2013	5 - Year
59	8.050891	123.741326	0.56	0.58	-0.02	December 17, 2013	5 - Year
60	8.050854	123.741224	0.62	0.42	0.20	December 17, 2013	5 - Year
61	8.06053	123.748181	0.19	0	0.19	December 17, 2013	5 - Year
62	8.060248	123.747791	0.6	0.27	0.33	December 17, 2013	5 - Year
63	8.059821	123.746985	0.76	0.16	0.60	December 17, 2013	5 - Year
64	8.058615	123.746026	0.7	0.40	0.30	December 17, 2013	5 - Year
65	8.058655	123.745699	0.61	0.24	0.37	December 17, 2013	5 - Year
66	8.058825	123.745861	0.42	0.36	0.06	December 17, 2013	5 - Year
67	8.058605	123.745376	0.67	0.25	0.42	December 17, 2013	5 - Year
68	8.058461	123.744735	0.03	0.12	-0.09	December 17, 2013	5 - Year
69	8.058208	123.744196	1.39	0	1.39	December 17, 2013	5 - Year
70	8.058692	123.744377	0.7	0.03	0.67	December 17, 2013	5 - Year
71	8.059465	123.745413	0.8	0.56	0.24	December 17, 2013	5 - Year
72	8.059295	123.745319	1.18	0.59	0.59	December 17, 2013	5 - Year
73	8.060617	123.744814	0.67	0.06	0.61	December 17, 2013	5 - Year
74	8.060286	123.745623	0.65	0.38	0.27	December 17, 2013	5 - Year
75	8.061268	123.745261	0.41	0.04	0.37	December 17, 2013	5 - Year
76	8.061861	123.745436	0.76	0	0.76	December 17, 2013	5 - Year
77	8.061769	123.74556	0.66	0	0.66	December 17, 2013	5 - Year
78	8.063109	123.747017	0.75	0	0.75	December 17, 2013	5 - Year
79	8.063164	123.746262	0.74	0.33	0.41	December 17, 2013	5 - Year
80	8.063229	123.745518	0.75	0.18	0.57	December 17, 2013	5 - Year
81	8.063017	123.745356	0.66	0.04	0.62	December 17, 2013	5 - Year
82	8.063023	123.744847	0.69	0.26	0.43	December 17, 2013	5 - Year
83	8.063587	123.744343	0.75	0.07	0.68	December 17, 2013	5 - Year
84	8.064133	123.744019	0.71	0.03	0.68	December 17, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
85	8.064127	123.744918	0.83	0	0.83	December 17, 2013	5 - Year
86	8.063798	123.745018	0.77	0.04	0.73	December 17, 2013	5 - Year
87	8.064594	123.744566	0.78	0.06	0.72	December 17, 2013	5 - Year
88	8.065473	123.744376	1.12	0.34	0.78	December 17, 2013	5 - Year
89	8.077387	123.754863	0.03	0.04	-0.01	December 17, 2013	5 - Year
90	8.076377	123.75505	0.11	0.42	-0.31	December 17, 2013	5 - Year
91	8.075746	123.754526	0.36	0.08	0.28	December 17, 2013	5 - Year
92	8.075442	123.754631	0.21	0.29	-0.08	December 17, 2013	5 - Year
93	8.075067	123.754154	0.53	0.82	-0.29	December 17, 2013	5 - Year
94	8.07485	123.753946	0.95	0.67	0.28	December 17, 2013	5 - Year
95	8.074947	123.753883	1.15	0.82	0.33	December 17, 2013	5 - Year
96	8.074822	123.754007	0.85	0.79	0.06	December 17, 2013	5 - Year
97	8.074982	123.753469	0.65	0.66	-0.01	December 17, 2013	5 - Year
98	8.075463	123.752939	1.49	0.81	0.68	December 17, 2013	5 - Year
99	8.075898	123.752172	0.41	0.04	0.37	December 17, 2013	5 - Year
100	8.074124	123.753187	0.84	0.05	0.79	December 17, 2013	5 - Year
101	8.07357	123.752805	0.19	0.06	0.13	December 17, 2013	5 - Year
102	8.073418	123.75262	0.03	0.24	-0.21	December 17, 2013	5 - Year
103	8.072271	123.751076	0.33	0.32	0.01	December 17, 2013	5 - Year
104	8.071369	123.752808	0.12	0.08	0.04	December 17, 2013	5 - Year
105	8.069005	123.751906	0.47	0.04	0.43	December 17, 2013	5 - Year
106	8.067868	123.752245	0.58	0	0.58	December 17, 2013	5 - Year
107	8.067488	123.748998	0.03	0.19	-0.16	December 17, 2013	5 - Year
108	8.068505	123.74928	0.03	0	0.03	December 17, 2013	5 - Year
109	8.068768	123.749618	0.04	0	0.04	December 17, 2013	5 - Year
110	8.068999	123.749506	0.04	0.42	-0.38	December 17, 2013	5 - Year
111	8.069625	123.750197	0.82	0.11	0.71	December 17, 2013	5 - Year
112	8.069206	123.750124	0.87	0.19	0.68	December 17, 2013	5 - Year
113	8.07066	123.74741	0.61	0.41	0.2	December 17, 2013	5 - Year
114	8.071012	123.747359	1.14	1.01	0.13	December 17, 2013	5 - Year
115	8.071685	123.747433	0.82	0.42	0.40	December 17, 2013	5 - Year
116	8.071632	123.747005	0.82	0.09	0.73	December 17, 2013	5 - Year
117	8.073912	123.746347	1.1	0.63	0.47	December 17, 2013	5 - Year
118	8.074162	123.744529	0.79	0	0.79	December 17, 2013	5 - Year
119	8.074369	123.745307	0.89	0.12	0.77	December 17, 2013	5 - Year
120	8.078133	123.743591	0.34	0.52	-0.18	December 17, 2013	5 - Year
121	8.077697	123.742555	1.33	0.04	1.29	December 17, 2013	5 - Year
122	8.08636	123.76201	0.05	0.06	-0.01	December 17, 2013	5 - Year
123	8.088361	123.76164	0.03	0.04	-0.01	December 17, 2013	5 - Year
124	8.086192	123.763112	0.03	0	0.03	December 17, 2013	5 - Year
125	8.086237	123.764082	0.04	0.44	-0.40	December 17, 2013	5 - Year
126	8.087728	123.765819	0.03	0.12	-0.09	December 17, 2013	5 - Year
127	8.085338	123.764494	0.03	0.03	0	December 17, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
128	8.08608	123.761694	0.03	0.28	-0.25	December 17, 2013	5 - Year
129	8.085632	123.76114	0.05	0.18	-0.13	December 17, 2013	5 - Year
130	8.085458	123.760457	0.18	0.46	-0.28	December 17, 2013	5 - Year
131	8.085117	123.760064	0.09	0	0.09	December 17, 2013	5 - Year
132	8.08538	123.759172	0.03	0	0.03	December 17, 2013	5 - Year
133	8.086631	123.754709	0.14	0.21	-0.07	December 17, 2013	5 - Year
134	8.059495	123.754709	0.48	0.43	0.05	December 17, 2013	5 - Year
135	8.059575	123.751921	0.19	0.87	-0.68	December 17, 2013	5 - Year
136	8.059678	123.752165	0.44	0.66	-0.22	December 17, 2013	5 - Year
137	8.058695	123.753177	0.73	1.04	-0.31	December 17, 2013	5 - Year
138	8.058267	123.753185	0.7	0.43	0.27	December 17, 2013	5 - Year
139	8.058352	123.753631	0.4	0.14	0.26	December 17, 2013	5 - Year
140	8.058099	123.754087	0.25	0.18	0.07	December 17, 2013	5 - Year
141	8.058298	123.754092	0.17	0.28	-0.11	December 17, 2013	5 - Year
142	8.058617	123.75463	0.38	0.56	-0.18	December 17, 2013	5 - Year
143	8.058082	123.754769	0.34	0.76	-0.42	December 17, 2013	5 - Year
144	8.058051	123.754799	0.48	0.48	0	December 17, 2013	5 - Year
145	8.057402	123.755248	0.08	0.55	-0.47	December 17, 2013	5 - Year
146	8.057111	123.755222	0.3	0.29	0.01	December 17, 2013	5 - Year
147	8.066567	123.754906	0.79	0	0.79	December 17, 2013	5 - Year
148	8.066766	123.764403	0.11	0	0.11	December 17, 2013	5 - Year
149	8.065894	123.763821	0.03	0.10	-0.07	December 17, 2013	5 - Year
150	8.066176	123.766897	0.03	0.12	-0.09	December 17, 2013	5 - Year
151	8.066223	123.766578	0.03	0.10	-0.07	December 17, 2013	5 - Year
152	8.06656	123.767334	0.22	0.28	-0.06	December 17, 2013	5 - Year
153	8.065985	123.767285	0.03	0.05	-0.02	December 17, 2013	5 - Year
154	8.066329	123.768952	0.04	0.03	0.01	December 17, 2013	5 - Year
155	8.068075	123.769533	0.17	0.28	-0.11	December 17, 2013	5 - Year
156	8.06856	123.759148	0.03	0.16	-0.13	December 17, 2013	5 - Year
157	8.068571	123.760371	0.03	0.22	-0.19	December 17, 2013	5 - Year
158	8.057223	123.75319	0.45	0.64	-0.19	December 17, 2013	5 - Year
159	8.057412	123.753053	0.61	0.74	-0.13	December 17, 2013	5 - Year
160	8.05773	123.753477	0.12	0.56	-0.44	December 17, 2013	5 - Year
161	8.057767	123.753082	0.43	0.31	0.12	December 17, 2013	5 - Year
162	8.058493	123.752589	0.53	0.12	0.41	December 17, 2013	5 - Year
163	8.059561	123.752174	0.68	0.87	-0.19	December 17, 2013	5 - Year
164	8.059183	123.75208	0.14	0.31	-0.17	December 17, 2013	5 - Year
165	8.059472	123.750871	0.55	0.26	0.29	December 17, 2013	5 - Year
166	8.060549	123.750441	0.52	0	0.52	December 17, 2013	5 - Year
167	8.060867	123.75025	0.42	0	0.42	December 17, 2013	5 - Year
168	8.061294	123.749601	0.5	0.25	0.25	December 17, 2013	5 - Year
169	8.062451	123.749077	0.2	0	0.20	December 17, 2013	5 - Year
170	8.062368	123.749574	0.6	0	0.60	December 17, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
171	8.063831	123.75125	0.19	0.10	0.09	December 17, 2013	5 - Year
172	8.064353	123.750444	0.32	0	0.32	December 17, 2013	5 - Year
173	8.064772	123.750602	0.35	0	0.35	December 17, 2013	5 - Year
174	8.064424	123.751125	0.07	0.15	-0.08	December 17, 2013	5 - Year
175	8.063295	123.749843	0.84	0.20	0.64	December 17, 2013	5 - Year
176	8.09538	123.748898	0.06	0	0.06	December 17, 2013	5 - Year
177	8.089023	123.719671	0.03	0	0.03	December 17, 2013	5 - Year
178	8.087632	123.720116	0.03	0	0.03	December 17, 2013	5 - Year
179	8.086596	123.721572	0.14	0	0.14	December 17, 2013	5 - Year
180	8.084408	123.723036	0.03	0	0.03	December 17, 2013	5 - Year
181	8.083421	123.725441	0.03	0	0.03	December 17, 2013	5 - Year
182	8.081365	123.726713	0.03	0	0.03	December 17, 2013	5 - Year
183	8.077964	123.72938	0.44	0.20	0.24	December 17, 2013	5 - Year
184	8.076815	123.733171	1.45	0.92	0.53	December 17, 2013	5 - Year
185	8.076622	123.735787	0.45	0.40	0.05	December 17, 2013	5 - Year
186	8.079442	123.727511	1.1	0.10	1	December 17, 2013	5 - Year
187	8.079343	123.723284	0.75	0.20	0.55	December 17, 2013	5 - Year
188	8.078884	123.724192	0.51	0.15	0.36	December 17, 2013	5 - Year
189	8.076113	123.725002	0.56	0.25	0.31	December 17, 2013	5 - Year
190	8.075529	123.728222	0.11	0.75	-0.64	December 17, 2013	5 - Year
191	8.075704	123.730168	3.26	0.10	3.16	December 17, 2013	5 - Year
192	8.073683	123.731193	0.19	0.70	-0.51	December 17, 2013	5 - Year
193	8.101137	123.733784	0.03	0.40	-0.37	December 17, 2013	5 - Year
194	8.101172	123.733532	0.03	0.18	-0.15	December 17, 2013	5 - Year
195	8.099877	123.733614	0.03	0.05	-0.02	December 17, 2013	5 - Year
196	8.096382	123.733395	0.03	0.60	-0.57	December 17, 2013	5 - Year
197	8.095919	123.733411	0.03	0	0.03	December 17, 2013	5 - Year
198	8.096507	123.738997	0.08	0	0.08	December 17, 2013	5 - Year
199	8.092203	123.739468	0.64	0	0.64	December 17, 2013	5 - Year
200	8.092718	123.734841	0.03	0	0.03	December 17, 2013	5 - Year
201	8.087746	123.735952	0.03	0.30	-0.27	December 17, 2013	5 - Year
202	8.081678	123.737834	0.75	0.35	0.40	December 17, 2013	5 - Year
203	8.097003	123.741648	0.06	0.15	-0.09	December 17, 2013	5 - Year
204	8.09705	123.754689	0.04	0	0.04	December 17, 2013	5 - Year
205	8.094812	123.755155	0.06	0	0.06	December 17, 2013	5 - Year
206	8.094881	123.753727	0.28	0	0.28	December 17, 2013	5 - Year
207	8.089592	123.754043	0.22	0	0.22	December 17, 2013	5 - Year
208	8.082657	123.751722	0.17	0	0.17	December 17, 2013	5 - Year
209	8.082423	123.748442	0.07	0.35	-0.28	December 17, 2013	5 - Year
210	8.066616	123.748361	4.57	0.10	4.47	December 17, 2013	5 - Year
211	8.066437	123.743844	1.16	0.30	0.86	December 17, 2013	5 - Year
212	8.066973	123.744171	0.32	0.05	0.27	December 17, 2013	5 - Year
213	8.066046	123.743903	5.58	0	5.58	December 17, 2013	5 - Year
214	8.065049	123.74242	0.03	0	0.03	December 17, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
215	8.067351	123.742887	0.03	0.05	-0.02	December 17, 2013	5 - Year
216	8.067695	123.740662	0.03	0.03	0	December 17, 2013	5 - Year
217	8.067233	123.738247	0.75	0	0.75	December 17, 2013	5 - Year
218	8.0676	123.738823	0.39	0.22	0.17	December 17, 2013	5 - Year
219	8.066078	123.737107	0.03	0.15	-0.12	December 17, 2013	5 - Year
220	8.064496	123.737703	0.03	0	0.03	December 17, 2013	5 - Year
221	8.067691	123.737897	1.12	0.20	0.92	December 17, 2013	5 - Year
223	8.067183	123.735619	0.49	0.15	0.34	December 17, 2013	5 - Year
224	8.064389	123.735472	0.03	0	0.03	December 17, 2013	5 - Year
225	8.063778	123.732646	0.03	0.05	-0.02	December 17, 2013	5 - Year
226	8.064416	123.732792	0.03	0.85	-0.82	December 17, 2013	5 - Year
227	8.063944	123.729572	1.05	1	0.05	December 17, 2013	5 - Year
228	8.066886	123.729161	0.03	0.38	-0.35	December 17, 2013	5 - Year
229	8.06729	123.725661	0.03	0	0.03	December 17, 2013	5 - Year
230	8.067869	123.727031	0.03	0	0.03	December 17, 2013	5 - Year
231	8.068501	123.726557	0.03	0	0.03	December 17, 2013	5 - Year
232	8.071622	123.736775	0.8	0.50	0.30	December 17, 2013	5 - Year
233	8.073245	123.734801	0.47	0	0.47	December 17, 2013	5 - Year
234	8.074633	123.734163	1.59	0.05	1.54	December 17, 2013	5 - Year
235	8.075869	123.735844	0.33	0.65	-0.32	December 17, 2013	5 - Year
236	8.075955	123.737245	0.63	0.30	0.33	December 17, 2013	5 - Year
237	8.077205	123.737078	0.43	0.75	-0.32	December 17, 2013	5 - Year
238	8.077137	123.737998	0.73	0.70	0.03	December 17, 2013	5 - Year
239	8.07674	123.738401	0.32	0.50	-0.18	December 17, 2013	5 - Year
240	8.076447	123.738878	0.37	0.58	-0.21	December 17, 2013	5 - Year
241	8.075076	123.73888	0.39	0.15	0.24	December 17, 2013	5 - Year
242	8.074187	123.739636	0.29	0.05	0.24	December 17, 2013	5 - Year
243	8.073073	123.738897	0.23	0	0.23	December 17, 2013	5 - Year
244	8.07498	123.738073	0.2	0.40	-0.20	December 17, 2013	5 - Year
245	8.074238	123.740829	0.31	0.30	0.01	December 17, 2013	5 - Year
246	8.073604	123.741554	1.01	0	1.01	December 17, 2013	5 - Year
247	8.072806	123.740995	0.28	0.15	0.13	December 17, 2013	5 - Year
248	8.072657	123.741659	0.14	0	0.14	December 17, 2013	5 - Year
249	8.071451	123.742578	0.03	0.40	-0.37	December 17, 2013	5 - Year
250	8.071121	123.742425	0.49	0.20	0.29	December 17, 2013	5 - Year
251	8.070569	123.743067	2.06	0.40	1.66	December 17, 2013	5 - Year
252	8.069944	123.743821	0.95	0.25	0.70	December 17, 2013	5 - Year
253	8.06965	123.743888	1.14	0.80	0.34	December 17, 2013	5 - Year
254	8.069709	123.744973	1.22	0	1.22	December 17, 2013	5 - Year
255	8.069081	123.745312	0.34	0.25	0.09	December 17, 2013	5 - Year
256	8.069286	123.744714	0.84	0.55	0.29	December 17, 2013	5 - Year
257	8.069585	123.745307	1	0.75	0.25	December 17, 2013	5 - Year
258	8.069299	123.745776	0.67	0.45	0.22	December 17, 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
259	8.067999	123.746861	1.74	0.40	1.34	December 17, 2013	5 - Year
260	8.067664	123.745575	0.68	0.30	0.38	December 17, 2013	5 - Year
261	8.066925	123.745887	0.36	0	0.36	December 17, 2013	5 - Year
262	8.06659	123.746814	0.79	0	0.79	December 17, 2013	5 - Year
263	8.067269	123.746444	0.95	0.15	0.80	December 17, 2013	5 - Year
264	8.068674	123.745675	0.68	0	0.68	December 17, 2013	5 - Year
265	8.068143	123.744719	0.62	0	0.62	December 17, 2013	5 - Year
266	8.065989	123.744516	1.07	0	1.07	December 17, 2013	5 - Year
267	8.065633	123.745962	0.35	0	0.35	December 17, 2013	5 - Year
268	8.065279	123.746527	0.74	0	0.74	December 17, 2013	5 - Year
269	8.064582	123.747154	0.86	0	0.86	December 17, 2013	5 - Year
270	8.064609	123.747685	0.95	0.25	0.70	December 17, 2013	5 - Year
271	8.055258	123.748679	0.24	0.20	0.04	December 17, 2013	5 - Year
272	8.055041	123.747274	0.51	0.05	0.46	December 17, 2013	5 - Year
273	8.05576	123.746896	0.45	0	0.45	December 17, 2013	5 - Year
274	8.056664	123.748069	0.74	0	0.74	December 17, 2013	5 - Year
275	8.056953	123.747486	0.03	0	0.03	December 17, 2013	5 - Year
276	8.057044	123.747284	0.03	0	0.03	December 17, 2013	5 - Year
277	8.05724	123.746949	0.06	0.40	-0.34	December 17, 2013	5 - Year
278	8.057575	123.746324	0.14	0.60	-0.46	December 17, 2013	5 - Year
279	8.059311	123.745767	0.21	0	0.21	December 17, 2013	5 - Year
280	8.05817	123.747481	0.46	0	0.46	December 17, 2013	5 - Year
281	8.058362	123.748608	0.75	0	0.75	December 17, 2013	5 - Year
282	8.057861	123.74881	0.36	0	0.36	December 17, 2013	5 - Year
283	8.05746	123.748808	0.66	0	0.66	December 17, 2013	5 - Year
284	8.05708	123.749183	0.84	0.20	0.64	December 17, 2013	5 - Year
285	8.057138	123.749479	0.31	0.30	0.01	December 17, 2013	5 - Year
286	8.057741	123.749721	0.84	0.25	0.59	December 17, 2013	5 - Year
287	8.057489	123.750914	0.95	0	0.95	December 17, 2013	5 - Year
288	8.05769	123.75165	0.59	0	0.59	December 17, 2013	5 - Year
289	8.057214	123.75204	0.53	0.40	0.13	December 17, 2013	5 - Year
290	8.056558	123.752393	0.32	0.60	-0.28	December 17, 2013	5 - Year
291	8.058732	123.75287	0.62	0.65	-0.03	December 17, 2013	5 - Year
292	8.058378	123.755503	0.03	0.05	-0.02	December 17, 2013	5 - Year
293	8.058018	123.75574	0.11	0.30	-0.19	December 17, 2013	5 - Year
294	8.057476	123.756034	0.03	0	0.03	December 17, 2013	5 - Year
295	8.057241	123.756367	0.17	0.70	-0.53	December 17, 2013	5 - Year
296	8.057925	123.7565	0.03	0	0.03	December 17, 2013	5 - Year
297	8.059351	123.755867	0.45	0.75	-0.3	December 17, 2013	5 - Year
298	8.059755	123.755707	0.47	0	0.47	December 17, 2013	5 - Year
299	8.059783	123.75529	0.49	0.40	0.09	December 17, 2013	5 - Year
300	8.059537	123.754943	0.54	0.80	-0.26	December 17, 2013	5 - Year
301	8.059993	123.754722	0.39	0.70	-0.31	December 17, 2013	5 - Year

Annex 12. Educational Institutions Affected by Flooding in Migcanaway Floodplain

MISAMIS OCCIDENTAL				
OZAMIS CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sta. Maria Central School	Labinay			
Sta. Maria National High School	Labinay			

MISAMIS OCCIDENTAL				
TANGUB CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Tangub City Central School	Barangay I - City Hall	Medium	Medium	Medium
St. Michael High School	Barangay II - Marilou	Medium	Medium	Medium
Tangub City Central School	Barangay II - Marilou	Medium	Medium	Medium
Sweet Honey Day Care Center	Barangay III- Market	Medium	High	High
St. Michael High School	Barangay IV - St. Mic	Medium	Medium	Medium
Brgy III Elementary School	Barangay VI - Lower P	Medium	Medium	Medium
Montesorri Elementary School	Barangay VI - Lower P	Medium	Medium	Medium
TNJMC Montesorri Elementary School	Barangay VI - Lower P	Medium	Medium	Medium
Shekinnah Learning Center	Garang	Low	Low	Low
Shekinnah Learning Center Guard House	Garang			
Day Care Center	Isidro D. Tan	Low	Medium	Medium
Isidro D. Tan Elementary School	Isidro D. Tan		Low	Medium
Minsubong Elementary School	Isidro D. Tan			
GADTC	Maloro	Medium	Medium	Medium
Gopherwood School	Maloro	Low	Medium	Medium
Maloro Elementary School	Maloro	Low	Low	Low
Sibol Day Care Center	Maloro	Medium	Medium	Medium
Day Care Center	Manga			
Manga Elementary School	Manga			
Mantic Day Care Center 2	Mantic	Medium	Medium	Medium
Tangub City Central School	Mantic	Medium	Medium	Medium
Tangub City National High School	Mantic	Low	Medium	Medium
Garang Elementary School	Maquilao	Low	Low	Low
Day Care Center 1	Migcanaway	Medium	Medium	Medium
Our Lady of Triumph and Institute of Technology	Migcanaway	Medium	Medium	Medium
Day Care Center	Prenza			
Kauswagan Elementary School	Prenza			
Polao Elementary School	Prenza	Low	Medium	Medium
Day Care Center	San Apolinario	Medium	Medium	Medium
Day Care Center 2	San Apolinario	Low	Medium	Medium
San Apolinario Elementary School	San Apolinario	Medium	Medium	Medium
Day Center	Santa Cruz	Low	Medium	Medium

MISAMIS OCCIDENTAL				
TANGUB CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sta. Cruz Elementary School	Santa Cruz	Medium	Medium	Medium
Day Care Center	Santa Maria			
Sta. Maria Central School	Santa Maria			
Sta. Maria National High School	Santa Maria			
Day Care Center	Silanga			
Silanga Elementary School Bldg 1-3	Silanga	Low	Medium	Medium
Silanga Elementary School Bldg 4-6	Silanga		Medium	Medium
Silanga Elementary School Canteen	Silanga		Medium	Medium
Silanga Elementary School Home Economics Bldg	Silanga		Medium	Medium
Silanga Elementary School Mess Hall	Silanga		Medium	Medium
Silanga Elementary School Pre-School	Silanga	Low	Medium	Medium
Silanga Elementary School Principals Office	Silanga	<Null>	<Null>	<Null>

Annex 13. Health Institutions Affected by Flooding in Migcanaway Floodplain

MISAMIS OCCIDENTAL				
TANGUB CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
City Health Center	Barangay I - City Hall	Low	Medium	Medium
Lying-in Clinic	Barangay I - City Hall	Medium	Medium	Medium
Aruelo General Hospital	Barangay III- Market	Medium	Medium	Medium
Sha Pharmacy	Barangay III- Market	Medium	Medium	Medium
Shy-Nna Pharmacy	Barangay III- Market	Medium	Medium	Medium
St. Vicente Hospital	Barangay III- Market	Medium	Medium	Medium
Tangub Pharmacy	Barangay III- Market	Medium	Medium	Medium
Minsubong Health Center	Isidro D. Tan			
Brgy Mantic Health Center	Mantic	Medium	Medium	Medium
Doña Maria D. Tan Memorial Hospital	Mantic	Medium	Medium	Medium
Health Center	Maquilao			Low
Health Center	Prenza	Medium	Medium	Medium
Health Center	Santa Maria			
BotikangBrgy	Silanga			