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

# LiDAR Surveys and Flood Mapping of Palandok River


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


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

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

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# CHAPTER 1: INTRODUCTION

## 1.1 Background of the Phil-LiDAR 1 Program

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

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication 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 Ateneo de Zamboanga University (ADZU). ADZU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 18 river basins in the Zamboanga Peninsula. The university is located in Zamboanga City in the province of Zamboanga Sibugay.

## 1.2 Overview of the Palandok River Basin

Overview
The Palandok River Basin, with a total land area of 227.04 sq. km., covers four (4) municipalities in Zamboanga del Norte, namely the municipalities of Bacungan, Godod, Kabalasan, Salug, and some parts of Bayog. According to the DENR River Basin Control Office (RBCO), the river basin has a drainage area of 203 km² and an estimated 152 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Palandok River, one of the several major water bodies in Zamboanga del Norte, is part of the eighteen (18) river systems under the PHIL-LIDAR 1 Program partner HEI, Ateneo de Zamboanga University. Palandok River is one of the several major water bodies in Zamboanga del Norte. Its mouth is found between the municipalities of Salug and Leon B. Postigo. , and Tthus, it is considered as the political boundary of the two. A total of 2,024 persons are residing in Brgy. Rizon in the Municipality of Bacungan, which is within the immediate vicinity of the river, according to the 2015 national census of PSA (Source: http://www.islandsproperties.com/places/zambonor.htm).

According to legends, the river is known as the reference point in tracing and location locating Zamboanga Peninsula. It was also known as a place where sailing boats and ships dockeds when trading and sailing along the Sulu Archipelago.


Figure 1.Up-streams of Palandok River

Scenic Sights and Destination

The municipality of Leon B. Postigo is gifted with several natural resources and sights, o. One of which is the impressive and preserved and impressive beauty of Palandok River. The upstream part of the river is possessed withhas currents which could be considered for outdoor activities like such as water rafting. Aside from this, theThe municipality is also known to the local tourist for its hot spring resort which is located in Sitio Mainit, just few kilometers away from the river.

Sunset view is also very popular in the province of Zamboanga del Norte. However, it is theThe municipality that is also widely known for the its spectacular view of the sunset scene happeningwhich can be seen in from the Sindangan Bay.


Figure 2. Sunset in Leon B. Postigo

Flood and other hazards

Up to date, theThe municipality of Leon B. Postigo has still not recorded any significant flood event which happened in the area. However, in 2010, the Mines and Geosciences Bureau (MGB) Region 9 has released the Geo-hazard Map of the municipality. It was indicated in their data that areas near the mouth of the river is are highly susceptible to flooding and the waters may reach more than 1 meter in height. The agency has also identified several areas of the municipality as which are prone to landslide and storm surge.

Moreover. just recently, on February 1, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Polandok River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Mindanao as per NDRRMC report (Source: www.ndrrmc.gov.ph/attachments/article/3/ADVISORY_GFA_No.06-REGII,_No.05-REG_III,_No.01-REG_IX,_No.02-REG_X,_No.02-REG_XI,_No.02-CARAGA,_No.05-CAR,_No.01-ARMM.pdf)

In 2007, the Philippine Institute of Vulcanology and Seismology (PHILVOLCS) also identified the shorelines of the municipality as susceptible to Tsunami and have further indicated that at an 8 magnitude earthquake in the Sulu Trench, the wave of the water could reach up to 8.43 meters.
Just recently, The Polandok River Basin covers four (4) municipalities in Zamboanga del Norte; namely, the municipalities of Bacungan, Godod, Kabalasan, Salug, and some parts of Bayog. The DENR River Basin Control Office (RBCO) states that the Polandok River Basin has a drainage are of 203 km² and an estimated 152 cubic meter (MCM) annual run-off (RBCO, 2015).
Its main stem, Polandok River, is part of the eighteen (18) river systems under the PHIL-LIDAR 1 Program partner HEI, Ateneo de Zamboanga University.
According to the 2015 national census of PSA, a total of 2,024 persons are residing in Brgy. Rizon in the Municipality of Bacungan, which is within the immediate vicinity of the river. The economy of the province Zamboanga del Norte largely rests on agriculture particularly fishing, and mineral extraction (Source: ). On February 1, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Polandok River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Mindanao as per NDRRMC report (Source: www.ndrrmc.gov.ph/attachments/article/3/ADVISORY_GFA_No.06-REGII,_No.05-REG_III,_No.01-REG_IX,_No.02-REG_X,_No.02-REG_XI,_No.02-CARAGA,_No.05-CAR,_No.01-ARMM.pdf)

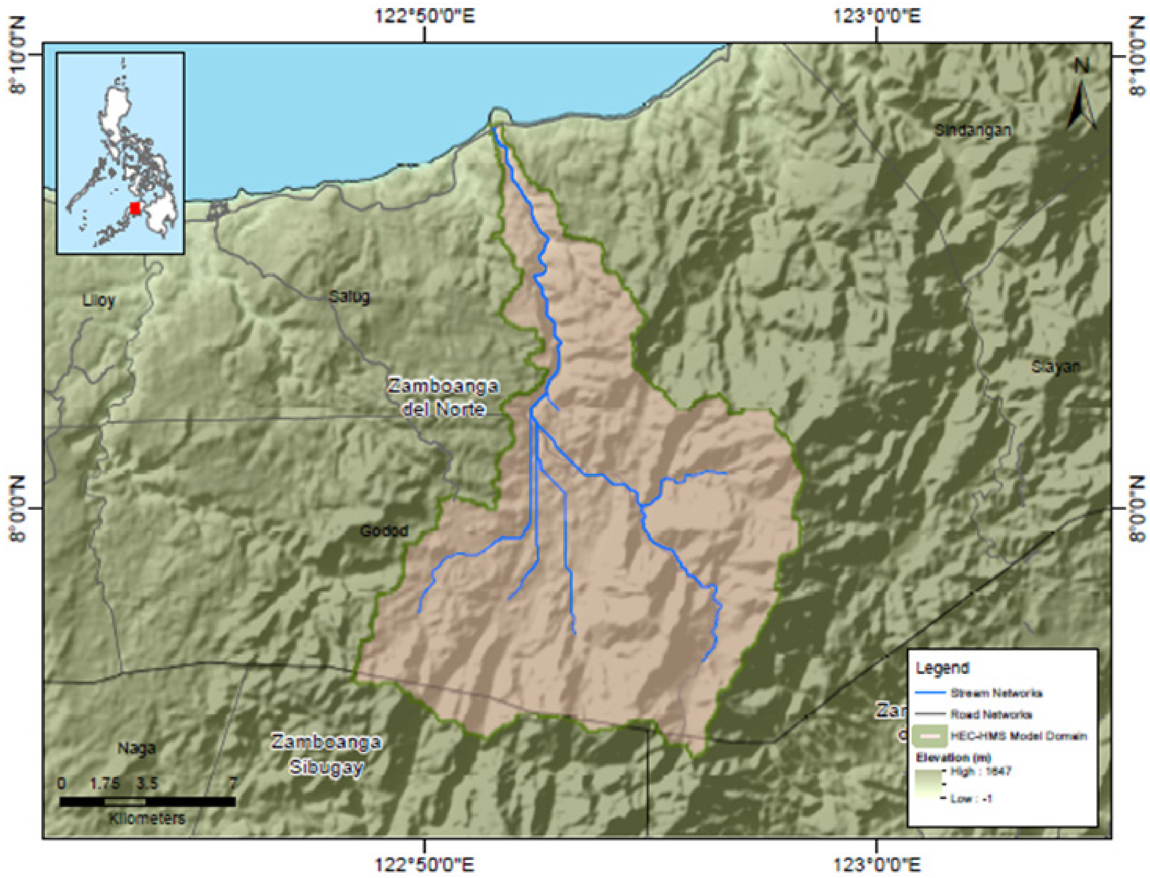


Figure 3. Map of Palandok River Basin (in brown)

# CHAPTER 2: LIDAR ACQUISITION IN PALANDOK 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 Palandok Floodplain in Zamboanga del Norte. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 4 shows the flight plan for Palandok Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR System.

| Block Name | Flying Height (AGL) | Overlap (%) | Field of View (θ) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| BLK73B | 1000 | 20 | 50 | 200 | 30 | 130 | 5 |

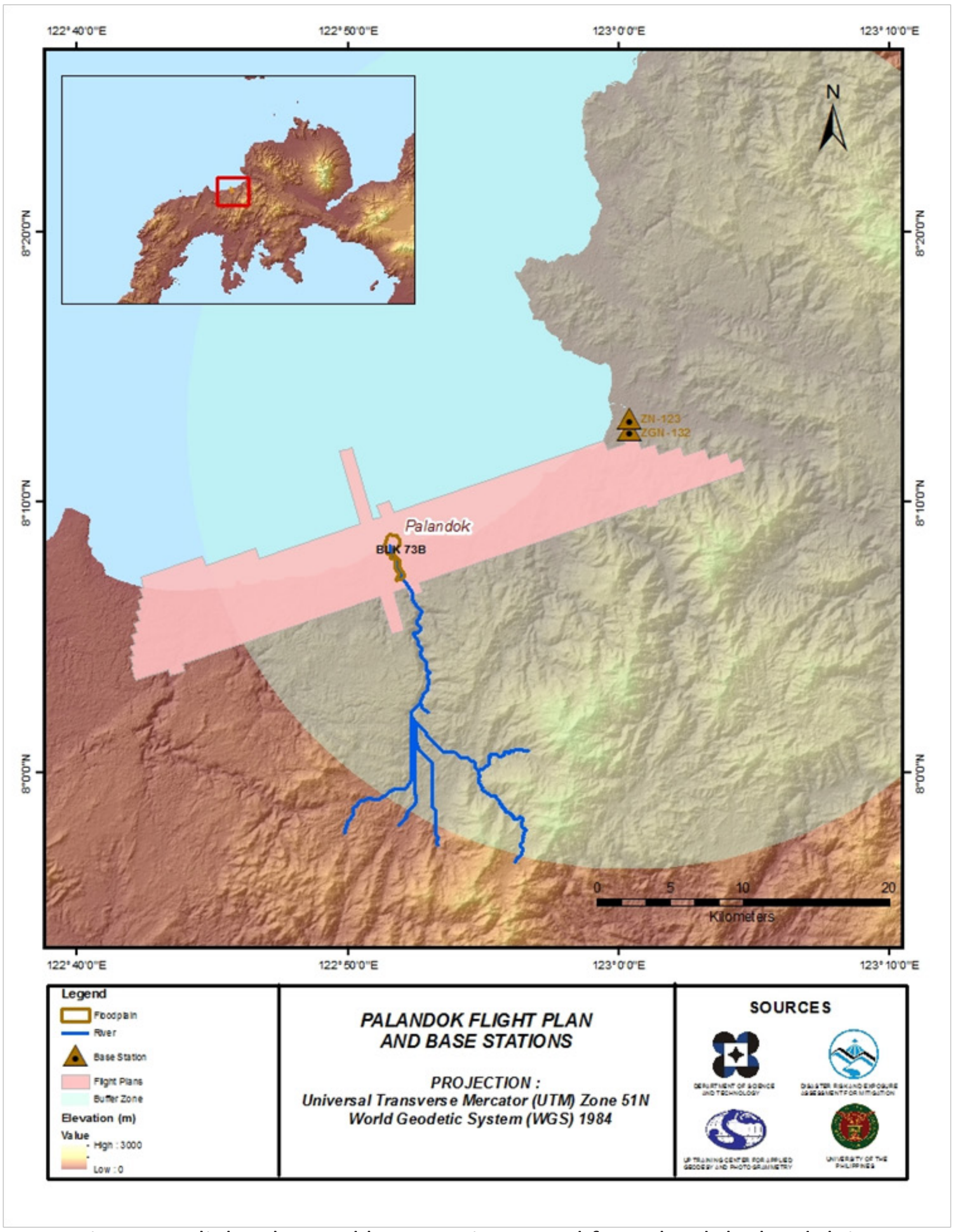


Figure 4. Flight plan and base stations used for Palandok Floodplain.

## 2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point ZGN-132 which is of second (2nd) order accuracy. The project team also recovered one (1) NAMRIA benchmark, ZN-123.The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing report for the established control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (October 8 to November 11, 2014). Base stations were observed using dual frequency GPS receivers:TRIMBLE SPS 852 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Palandok Floodplain are shown in Figure 4.

Figure 5 shows the recovered NAMRIA reference point within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations, while Table 4 shows the list oflists all ground control points occupied during the acquisition together with the corresponding dates of utilization.


Figure 5. GPS set-up over ZGN-132 at Barangay Mandih, Zambonaga del Norte (a) and NAMRIA reference point ZGN-132 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGN-132 used as base station for the LiDAR acquisition.

| Station Name | ZGN-132 | |
|---|---|---|
| Order of Accuracy | 2nd | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 8° 12’ 44.29460” North<br>123° 0’ 19.12667” East<br>11.502 meters |
| Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92) | Easting<br>Northing | 500,585.389 meters<br>908,029.029 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 8° 12’ 40.63408” North<br>123° 0’ 24.56923” East<br>75.58 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 500,751.70 meters<br>907,656.11 meters |

Table 3. Details of the recovered NAMRIA horizontal control point ZN-123 used as base station for the LiDAR acquisition.

| Station Name | ZN-123 | |
|---|---|---|
| Order of Accuracy | 1st | |
| Relative Error (horizontal positioning) | 1 in 50,000 | |
| Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92) | Latitude<br>Longitude<br>Ellipsoidal Height | 8° 13' 8.18558" North<br>123° 00' 36053" East<br>10.101 meters |
| Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84) | Latitude<br>Longitude<br>Ellipsoidal Height | 8° 13' 4.52332" North<br>123° 00' 24.80249" East<br>74.166 meters |
| Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992) | Easting<br>Northing | 500,758.82 meters<br>908,389.73 meters |

Table 4. Ground Control Points used during LiDAR data acquisition

| Date Surveyed | Flight Number | Mission Name | Ground Control Points |
|---|---|---|---|
| November 3, 2014 | 2157P | 1BLK70C307A | ZGN-132, ZN-123 |

## 2.3 Flight Missions

One (1) mission was conducted to complete the LiDAR data acquisition in Palandok Floodplain, for a total of three hours and fifty-nine minutes (3+59) of flying time for RP-9122. The mission was acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours of the mission while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight mission for LiDAR data acquisition in Palandok Floodplain.

| Date Surveyed | Flight Number | Flight Plan Area (km2) | Surveyed Area (km2) | Area Surveyed within the Floodplain (km2) | Area Surveyed Outside the Floodplain (km2) | No. of Images (Frames) | Flying Hours | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Hr | Min |
| November 3, 2014 | 2157P | 221.53 | 228.68 | 1.65 | 227.03 | 587 | 3 | 59 |
| TOTAL | | 221.53 | 228.68 | 1.65 | 227.03 | 587 | 3 | 59 |

Table 6. Actual parameters used during LiDAR data acquisition

| Flight Number | Flying Height (AGL) | Overlap (%) | Field of View (θ) | Pulse Repetition Frequency (PRF) (kHz) | Scan Frequency (Hz) | Average Speed (kts) | Average Turn Time (Minutes) |
|---|---|---|---|---|---|---|---|
| 2157P | 1100 | 20 | 50 | 200 | 30 | 130 | 5 |

## 2.4 Survey Coverage

Palandok floodplain is located along the province of Zamboanga del Norte with majority of the floodplain situated within the municipality ofSalug and Bacungan. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Palandok Floodplain is presented in Figure 63.

Table 7. List of municipalities and cities surveyed during Palandok Floodplain LiDAR survey.

| Province | Municipality/City | Area of Municipality/City (km2) | Total Area Surveyed (km2) | Percentage of Area Surveyed =(Total Area covered/ Area of Municipality)*100 |
|---|---|---|---|---|
| **Zamboanga del Norte** | Salug | 157.23 | 50.23 | 31.94% |
| | Sindangan | 295.62 | 61.55 | 20.82% |
| | Liloy | 123.94 | 23.48 | 18.95% |
| | Bacungan | 372.86 | 34.93 | 9.37% |
| | Siayan | 461.46 | 5.57 | 1.21% |
| **Total** | | 1411.11 | 175.76 | 12.46% |

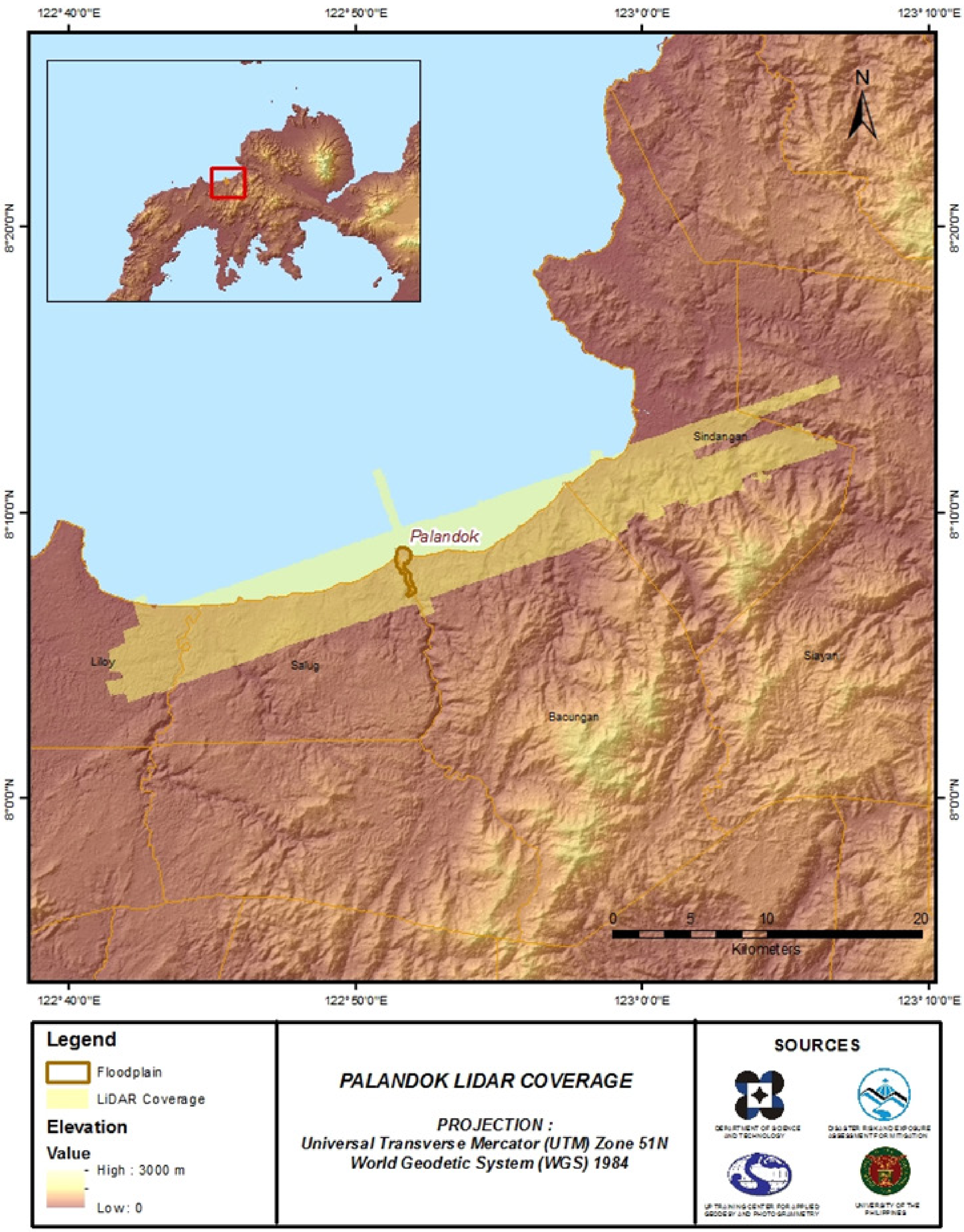


Figure 6. Actual LiDAR survey coverage for Palandok Floodplain.

# CHAPTER 3: LIDAR DATA PROCESSING FOR BATU PALANDOK FLOODPLAIN

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

Using the elevation of points gathered in the field, the LiDAR-derived digital models were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.
These processes are summarized in the flowchart shown in Figure 7.

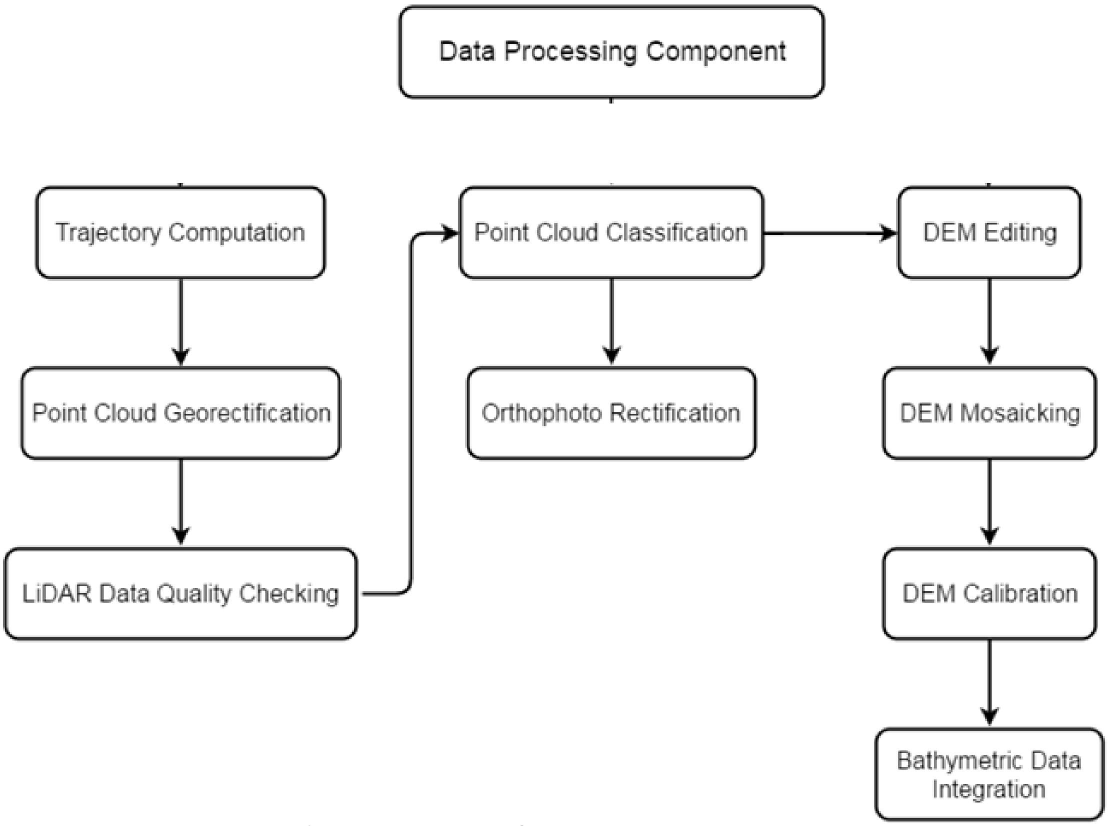



Figure 7. Schematic Diagram for Data Pre-Processing Component

## 3.2. Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Palandok floodplain can be found in Annex 5. The mission flown during the survey conducted on November 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Salug and Bacungan, Zamboanga del Norte. The Data Acquisition Component (DAC) transferred a total of 25.1 Gigabytes of Range data, 240 Megabytes of POS data, 35.5 Megabytes of GPS base station data, and 40.6 Gigabytes of raw image data to the data server on November 3, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Palandok was fully transferred on November 14, 2014, as indicated on the Data Transfer Sheets for Palandok Floodplain.

## 3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2157P, one of the Palandokflights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on November 3, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

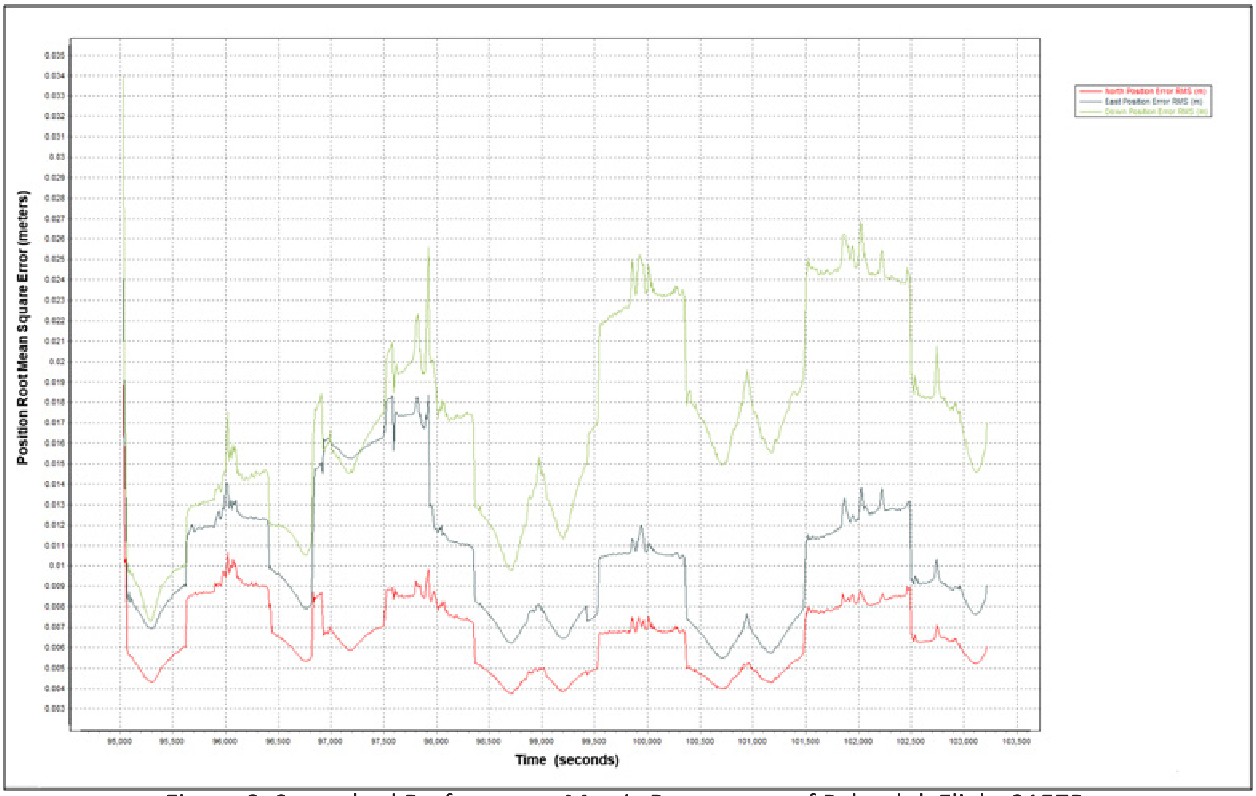



Figure 8. Smoothed Performance Metric Parameters of Palandok Flight 2157P.

The time of flight was from 95000 seconds to 103500 seconds, which corresponds to morning of November 3, 2014. 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 9 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1.90 centimeters, and the Down position RMSE peaks at 2.70 centimeters, which are within the prescribed accuracies described in the methodology.

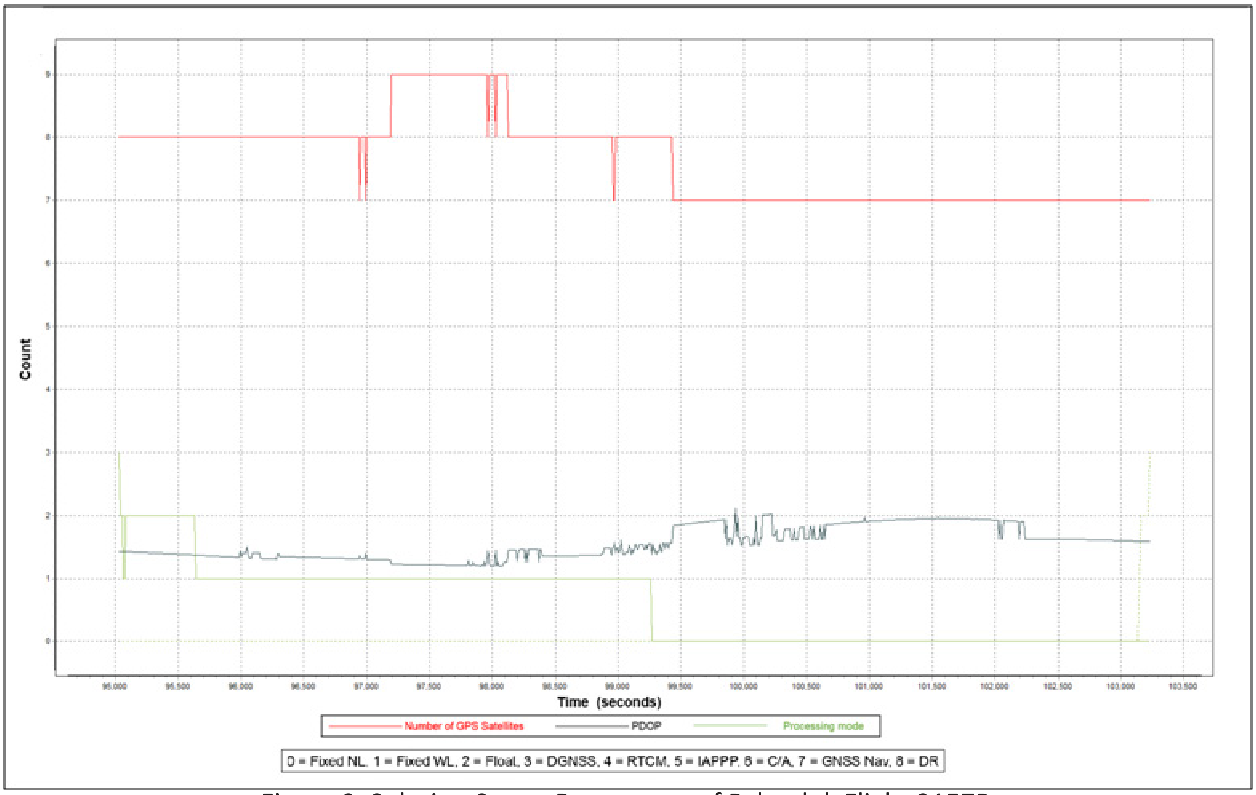


Figure 9. Solution Status Parameters of Palandok Flight 2157P.

The Solution Status parameters of flight 2157P, one of the Palandok flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. 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 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Palandok flights is shown in Figure 101.

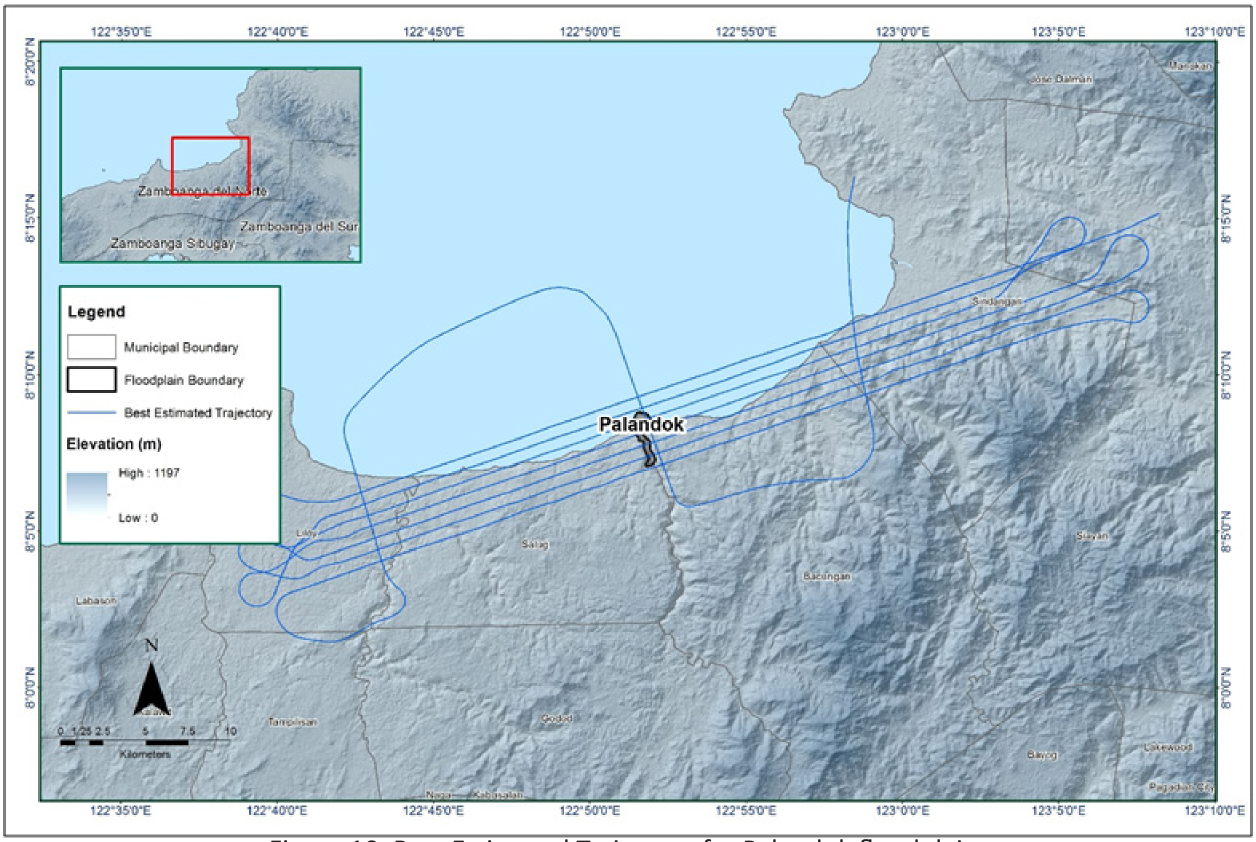



Figure 10. Best Estimated Trajectory for Palandok floodplain.

## 3.4 LiDAR Point Cloud Computation

The produced LAS data contains 10flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Palandok floodplain are given in Table B-18.

Table 8. Self-Calibration Results values for Palandok flights.

| Parameter | | Computed Value |
|---|---|---|
| Boresight Correction stdev | (<0.001degrees) | 0.000185 |
| IMU Attitude Correction Roll and Pitch Corrections stdev | (<0.001degrees) | 0.000500 |
| GPS Position Z-correction stdev | (<0.01meters) | 0.0089 |

The optimum accuracy is obtained for all Palandok 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 Palandok Floodplain is shown in Figure B-511. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

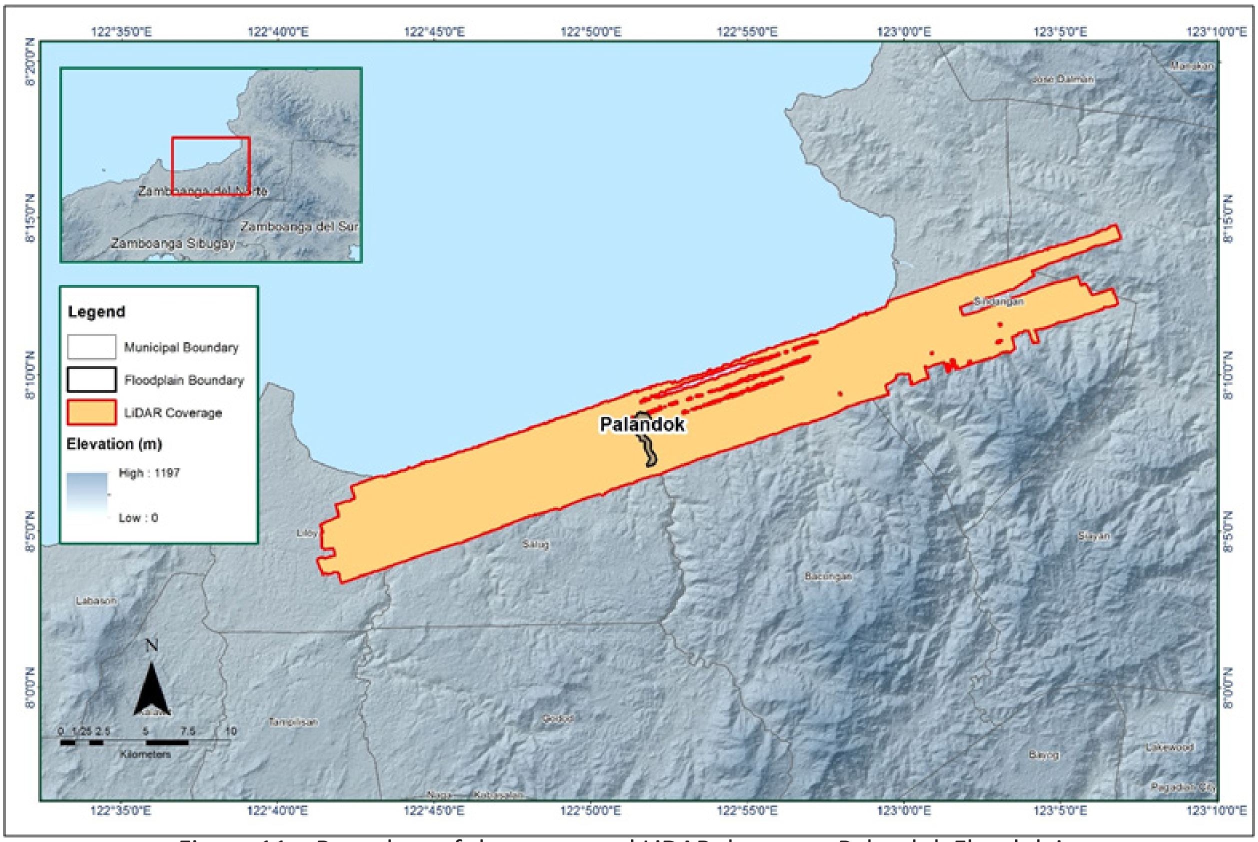



Figure 11. Boundary of the processed LiDAR data over Palandok Floodplain

The total area covered by the Palandok missions is 214.34 sq.km comprised of one (1) flight acquisition grouped and merged into one (1) block as shown in Table B-29.

Table 9. List of LiDAR blocks for Palandok floodplain.

| LiDAR Blocks | Flight Numbers | Area (sq. km) |
|---|---|---|
| Dipolog_Blk73B | 2157P | 214.34 |
| | **TOTAL** | **214.34 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 B-612. 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.

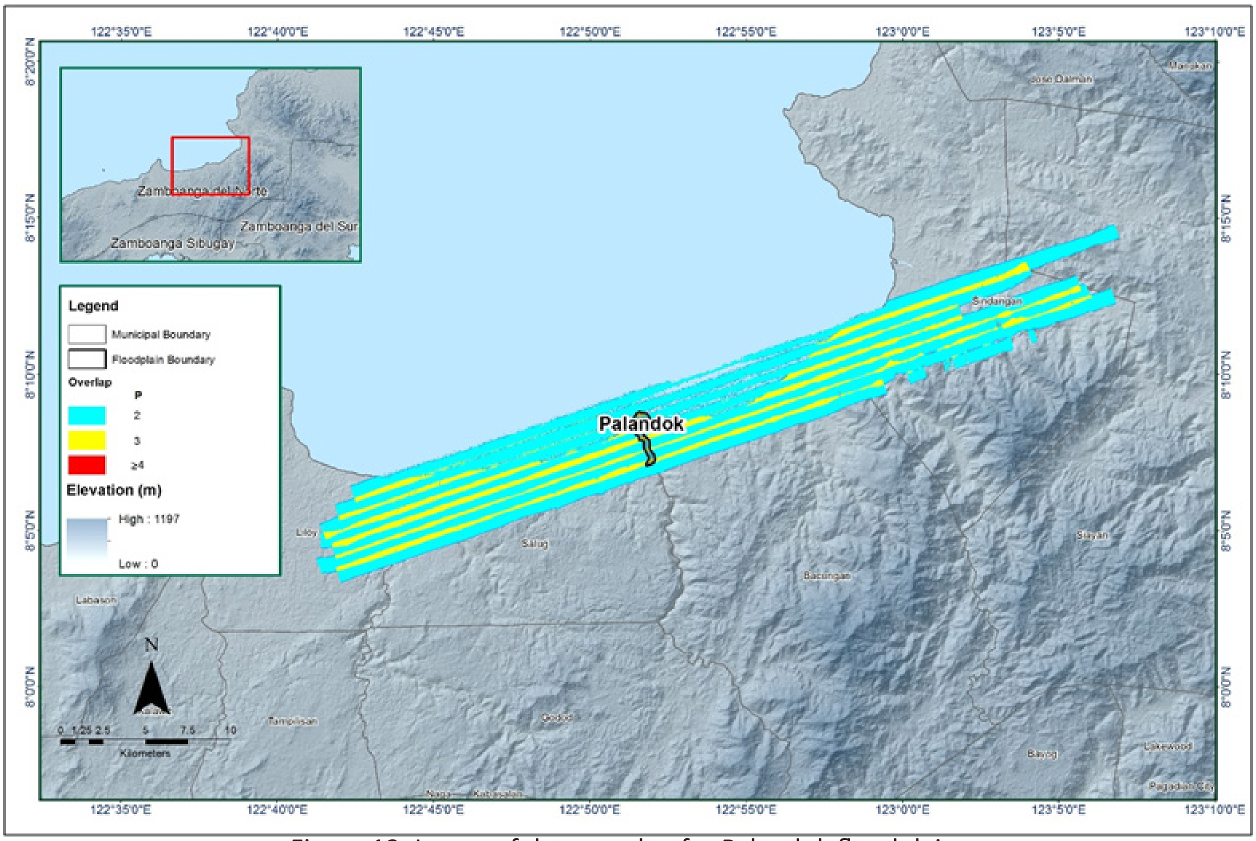



Figure 12. Image of data overlap for Palandok floodplain.

The overlap statistics per block for the Palandok Floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap computed between flight lines is 24.96.

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 B-713. It was determined that all LiDAR data for Palandok Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.15 points per square meter.

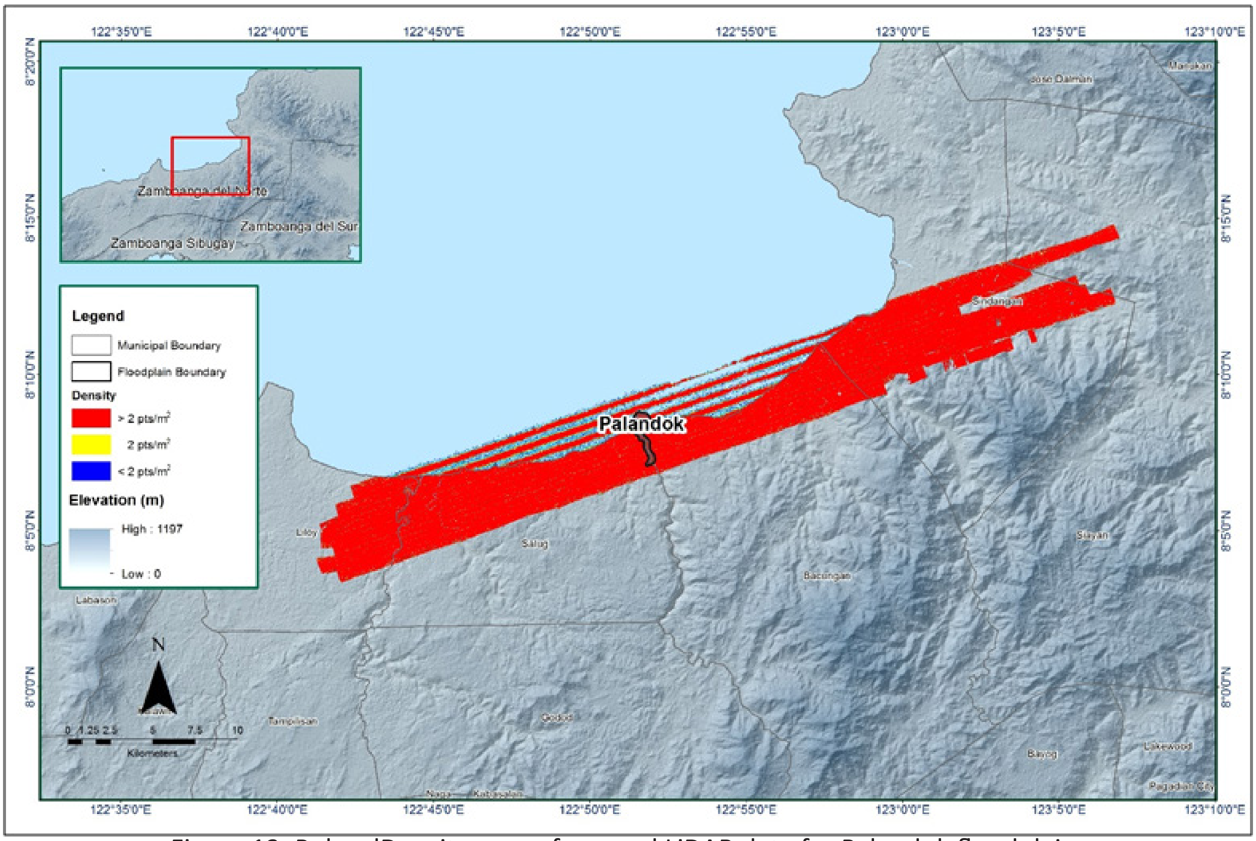



Figure 13. Pulse dDensity map of merged LiDAR data for Palandok floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure B-814. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

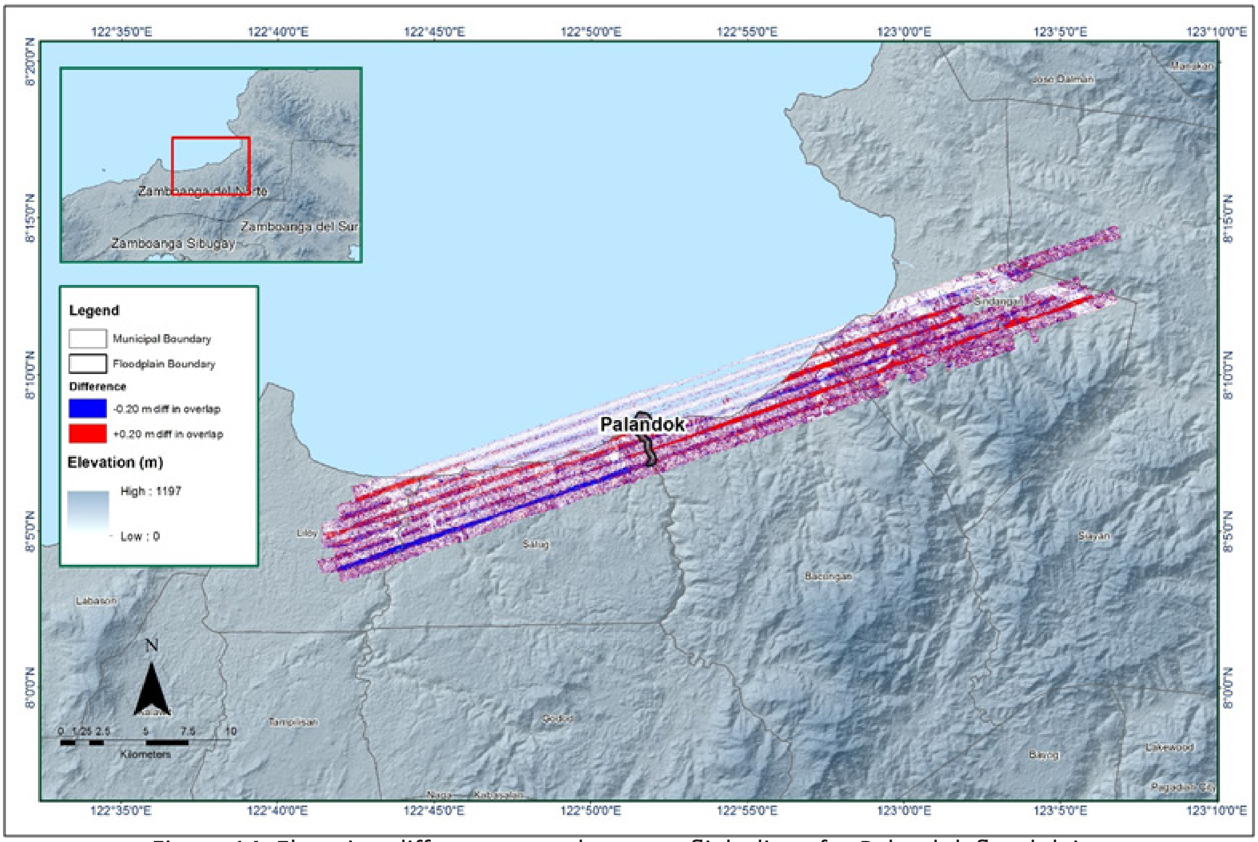


Figure 14. Elevation difference map between flight lines for Palandok floodplain.

A screen capture of the processed LAS data from a Palandok flight 2157P loaded in QT Modeler is shown in Figure B-915. 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.

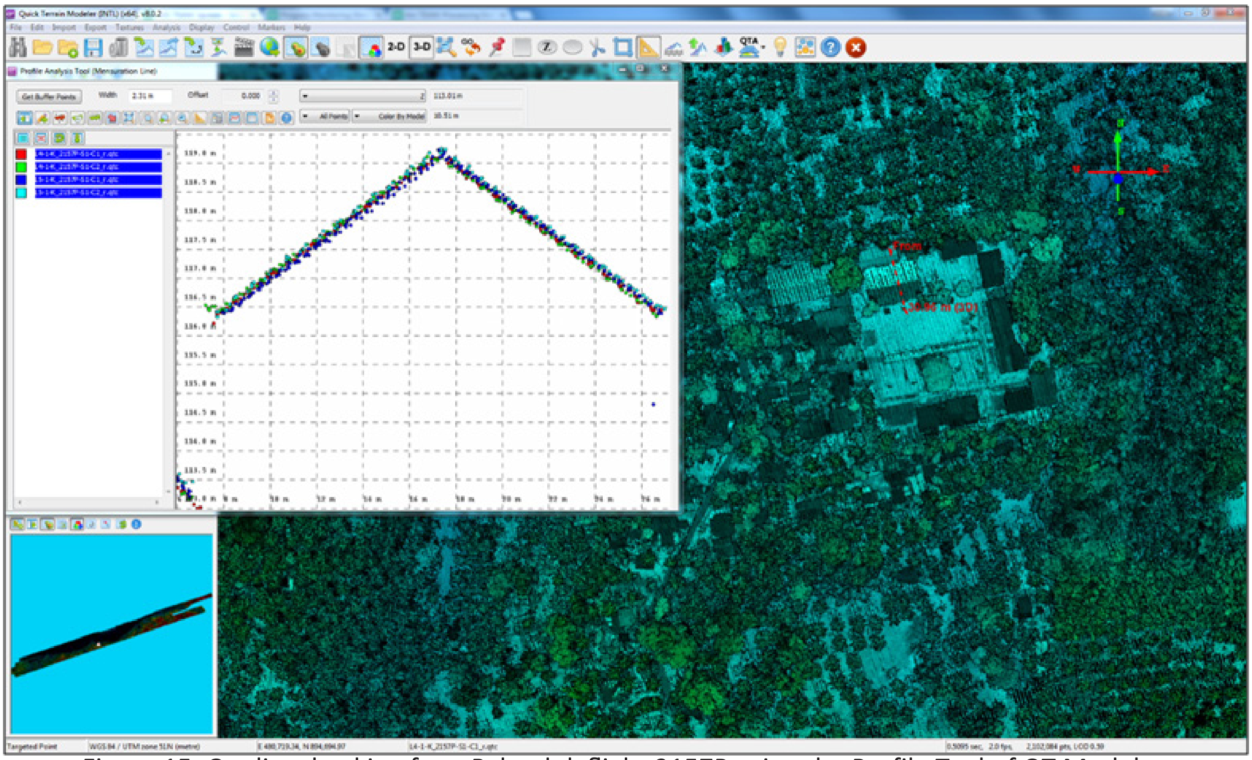


Figure 15. Quality checking for a Palandok flight 2157P using the Profile Tool of QT Modeler.

## 3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Table B- 3. Palandok classification results in TerraScan.

| Pertinent Class | Total Number of Points |
|---|---|
| Ground | 221,447,994 |
| Low Vegetation | 167,724,982 |
| Medium Vegetation | 312,332,327 |
| High Vegetation | 222,386,814 |
| Building | 4,523,324 |

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Palandok Floodplain floodplain is shown in Figure B-1016. A total of 306 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table B-310. The point cloud has a maximum and minimum height of 537.22 meters and 62.35 meters, respectively.

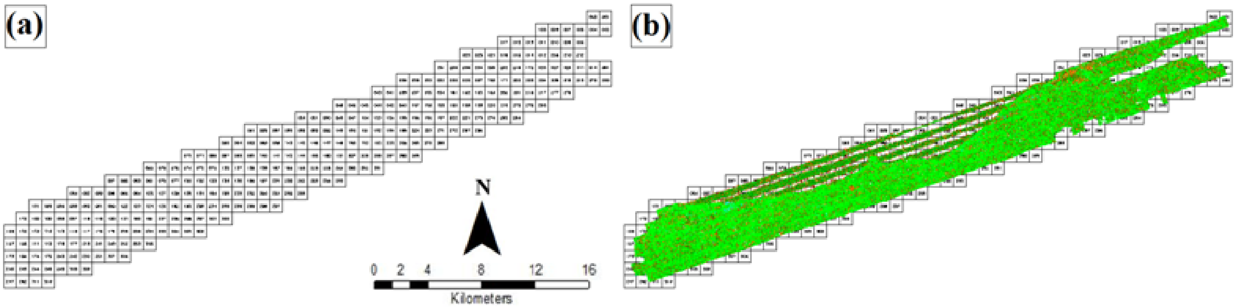



Figure 16. Tiles for Palandok floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure B-1117. 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.

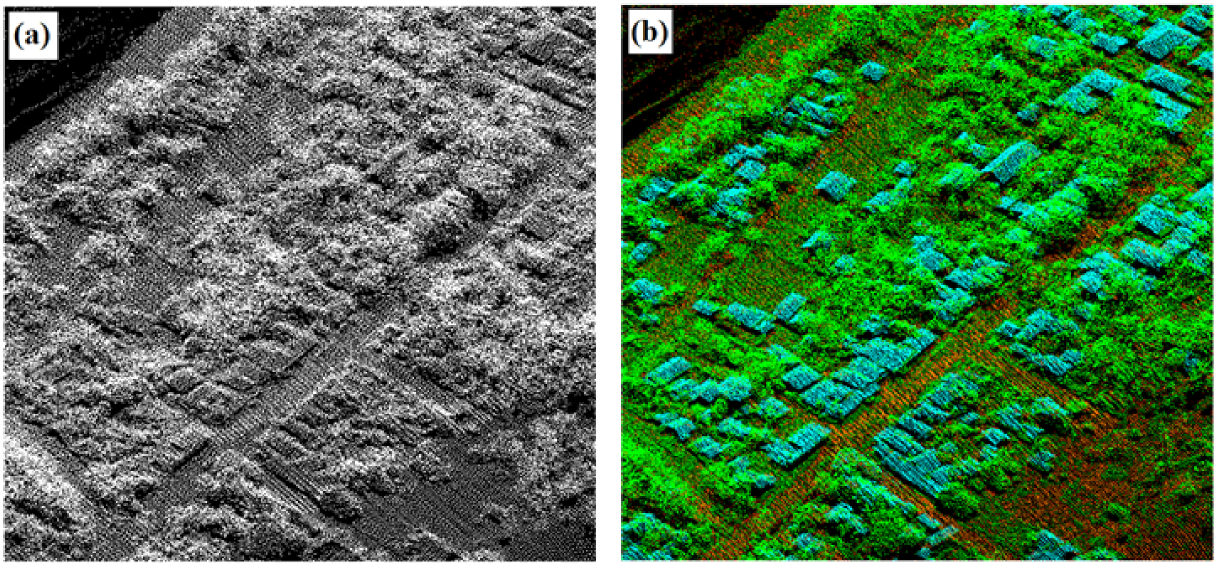



Figure 17. Point cloud before (a) and after (b) classification.

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 B-1218. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

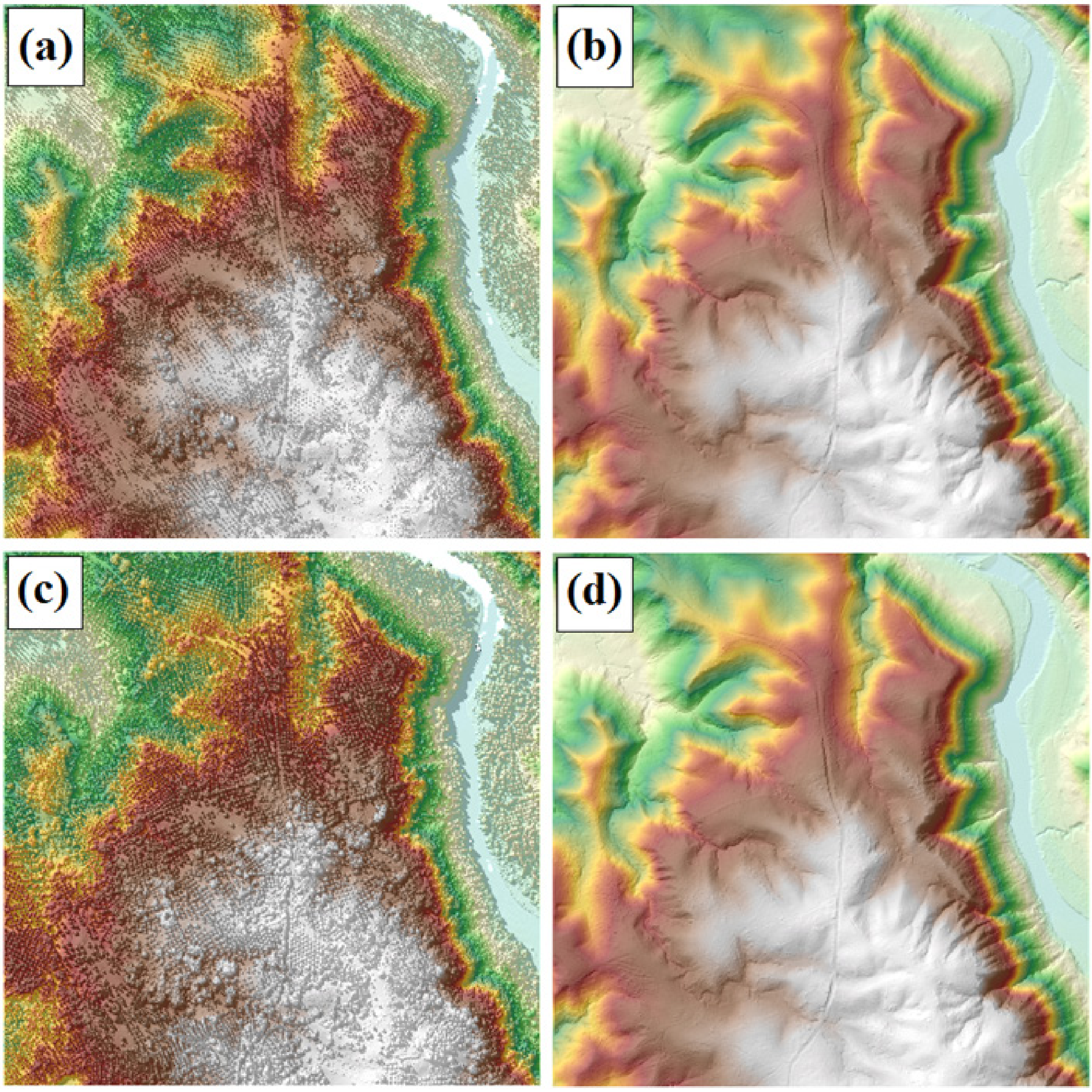



Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Palandok Floodplainfloodplain.

## 3.7 LiDAR Image Processing and Orthophotograph Rectification

The 297 1km by 1km tiles area covered by Palandok floodplain is shown in Figure B-1319. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Palandok Floodplain floodplain has a total of 223.00 sq.km orthophotograph coverage comprised of 570 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure B-1420.

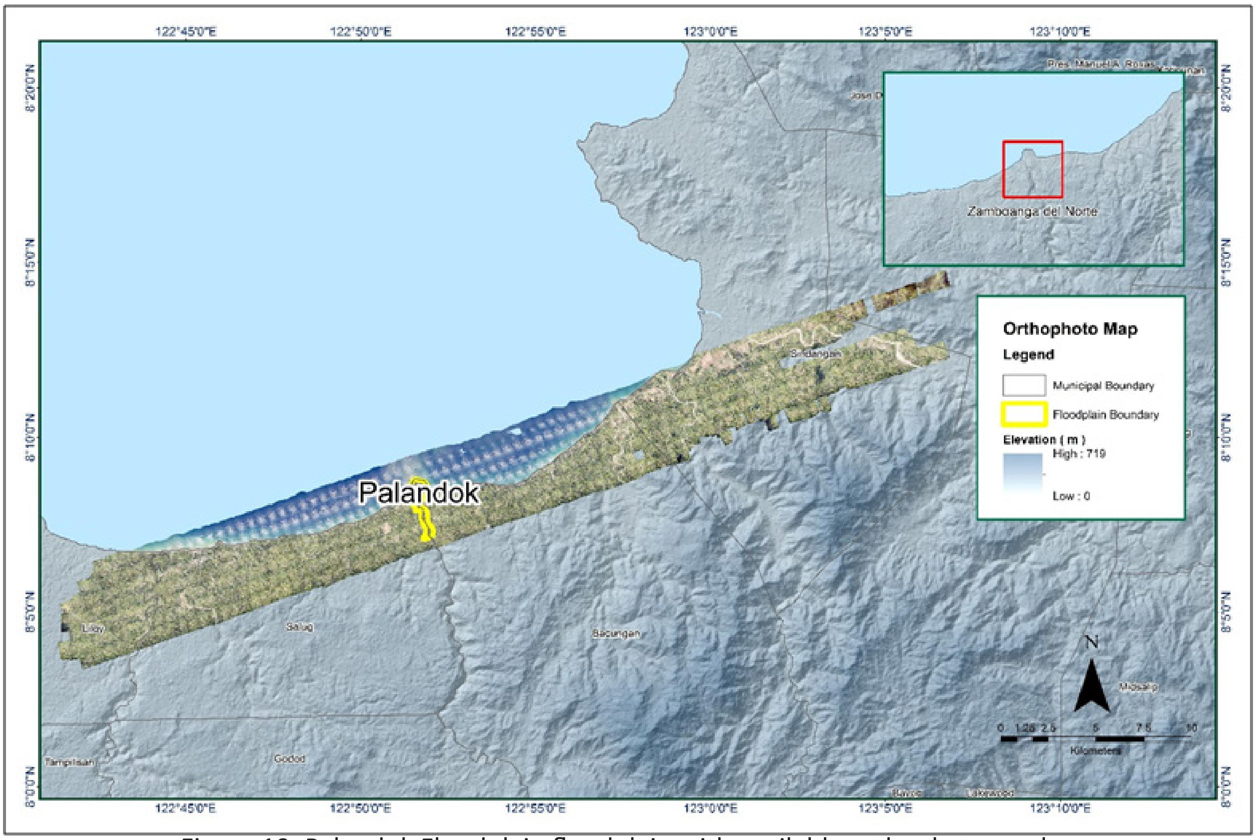



Figure 19. Palandok Floodplain floodplain with available orthophotographs.

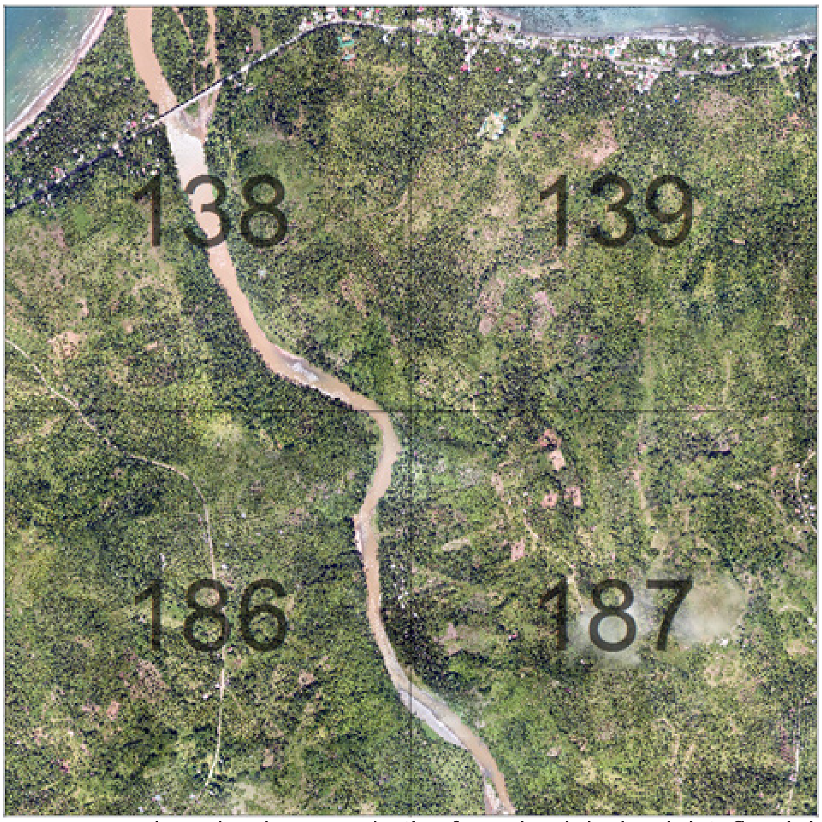



Figure 20. Sample orthophotograph tiles for Palandok Floodplainfloodplain.

## 3.8 DEM Editing and Hydro-Correction

One (1) mission block was processed for Palandok Floodplain flood plain which is Dipolog_Blk73B. Table B-411 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

| LiDAR Blocks | Area (sq.km) |
|---|---|
| Dipolog_Blk73B | 214.34 |
| **TOTAL** | **214.34 sq.km** |

Portions of DTM before and after manual editing are shown in Figure B-1521. The portion of the mountain (Figure B-15a21a) has been removed during classification process and has to be retrieved to complete the surface (Figure B-15b21b) to allow the correct flow of water. The bridge (Figure B-15c21c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure B-15d21d) in order to hydrologically correct the river.

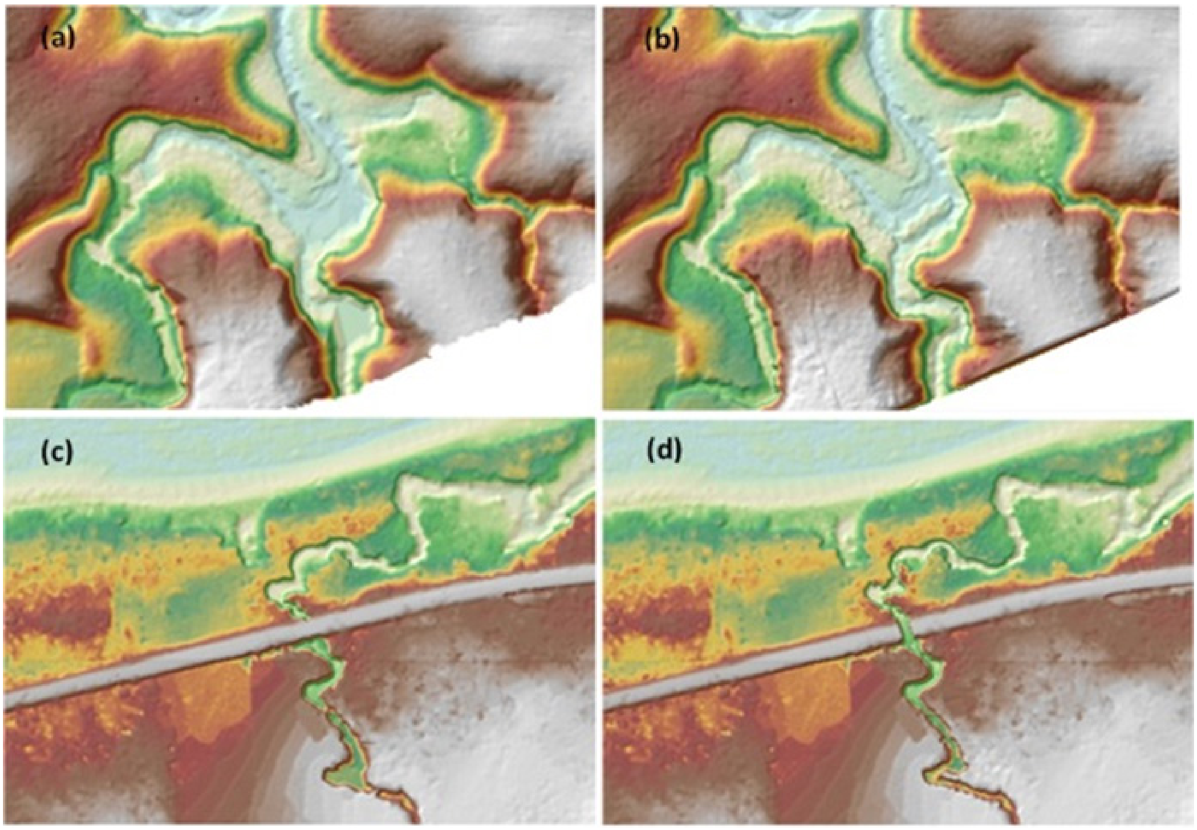



Figure 21. Portions in the DTM of Palandok floodplain – a cut portion of the mountain before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

## 3.9 Mosaicking of Blocks

Dipolog_Blk73B fully covered the Palandok floodplain. Thus, no mosaicking of blocks was performed. Moreover, Dipolog_Blk73B was used as reference in mosaicking adjacent LiDAR blocks of Dipolog. Table B-512 shows the shift values applied to the LiDAR block covering Palandok floodplain.

Table 12. Shift Values of each LiDAR Block of Palandok floodplain.

| Mission Blocks | Shift Values (meters) | | |
|---|---|---|---|
| | x | y | z |
| Dipolog_Blk73B | 0.00 | 0.00 | 0.00 |

The LiDAR DTM for Palandok Floodplain floodplain is shown in Figure B-1622. It can be seen that the entire Palandok Floodplain floodplain is 100% covered by LiDAR data.

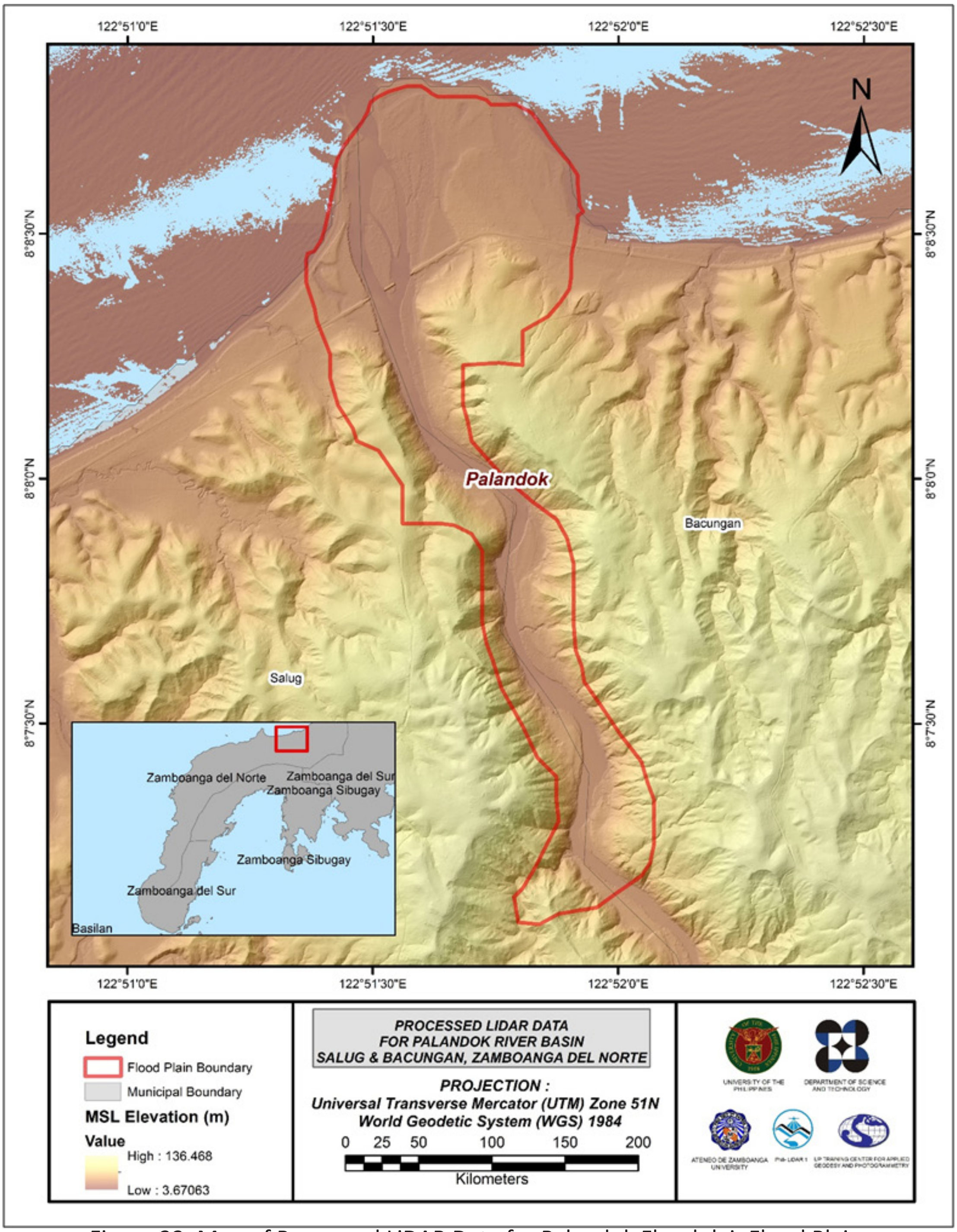



Figure 22. Map of Processed LiDAR Data for Palandok FloodplainFlood Plain.

## 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 Palandok to collect points with which the LiDAR dataset is validated is shown in Figure B-1723. A total of 5,856 survey points were used for calibration and validation of Palandok LiDAR data. Random selection of 80% of the survey points, resulting to in 4,685 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure B-1824. 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 4.62 meters with a standard deviation of 0.16 meters. Calibration of Palandok LiDAR data was done by adding the height difference value, 4.62 meters, to Palandok mosaicked LiDAR data. Table B-613 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

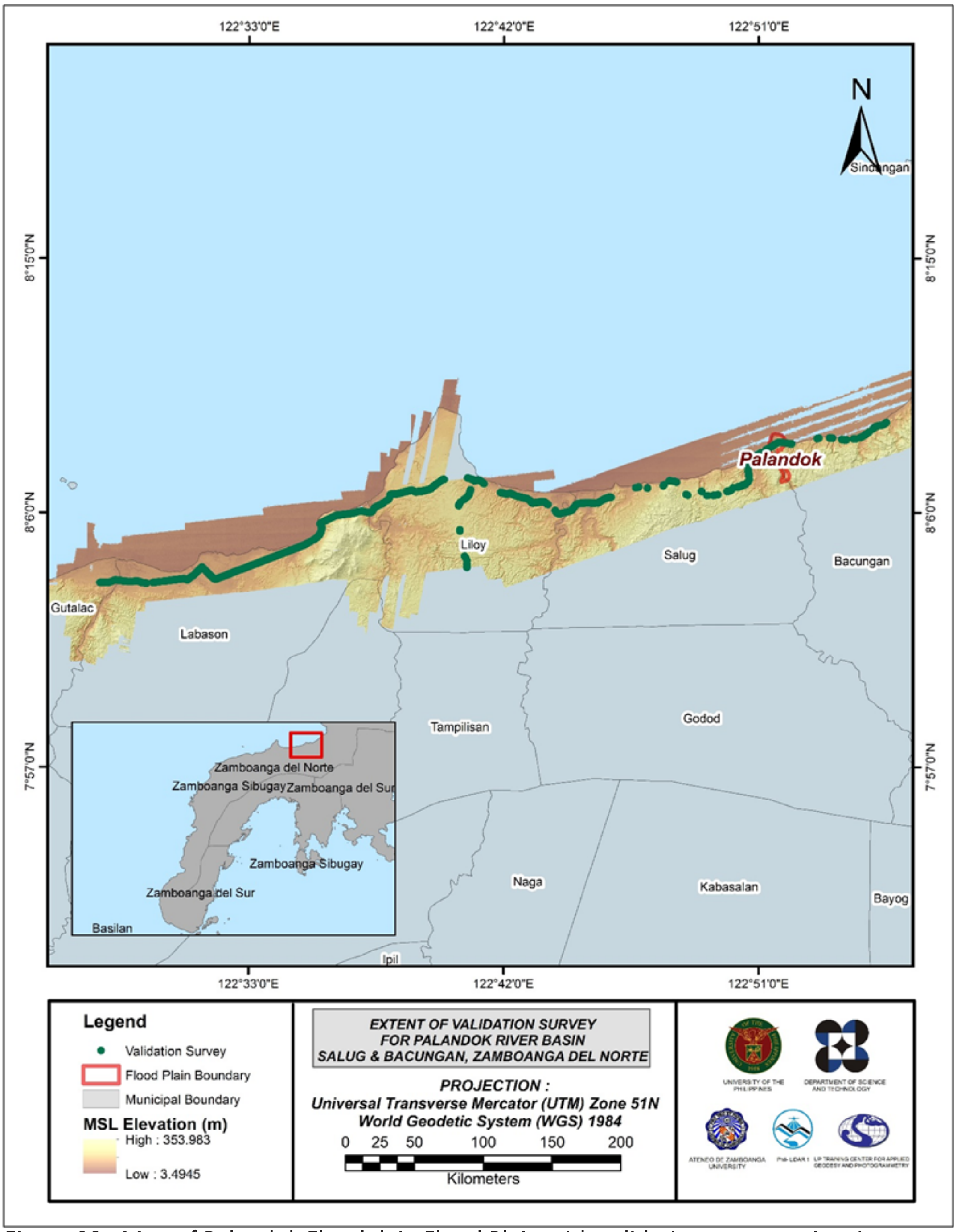



Figure 23. Map of Palandok Floodplain Flood Plain with validation survey points in green.

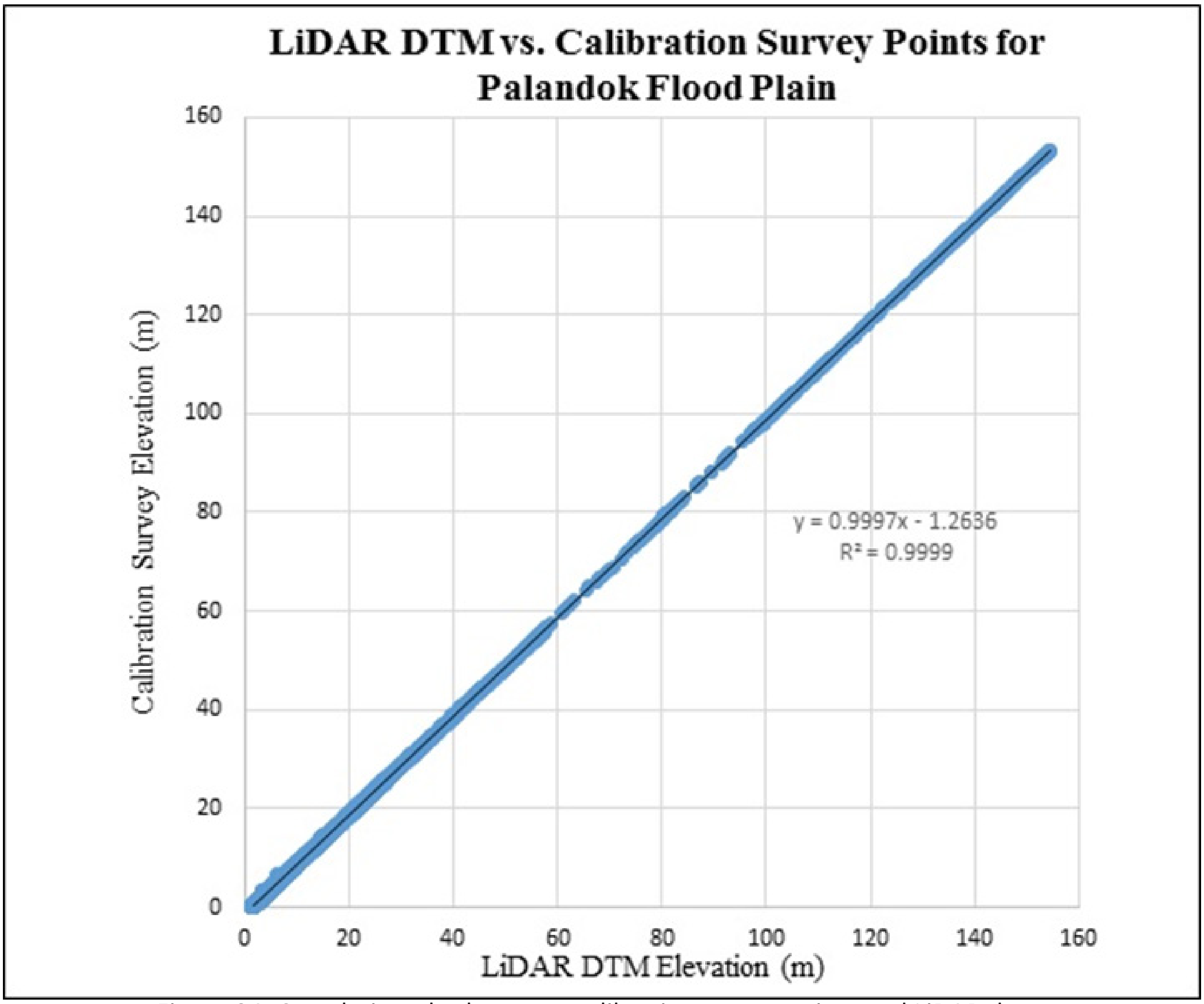



Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures.

| Calibration Statistical Measures | Value (meters) |
|---|---|
| Height Difference | 4.62 |
| Standard Deviation | 0.16 |
| Average | 4.62 |
| Minimum | 4.30 |
| Maximum | 4.93 |

The remaining 20% of the total survey points is equivalent to 1,171. Fourteen (14) of the said points lie within the Palandok Floodplain flood plain and were used for the validation of calibrated Palandok 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 B-1925. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.06 meters with a standard deviation of 0.02 meters, as shown in Table B-714.

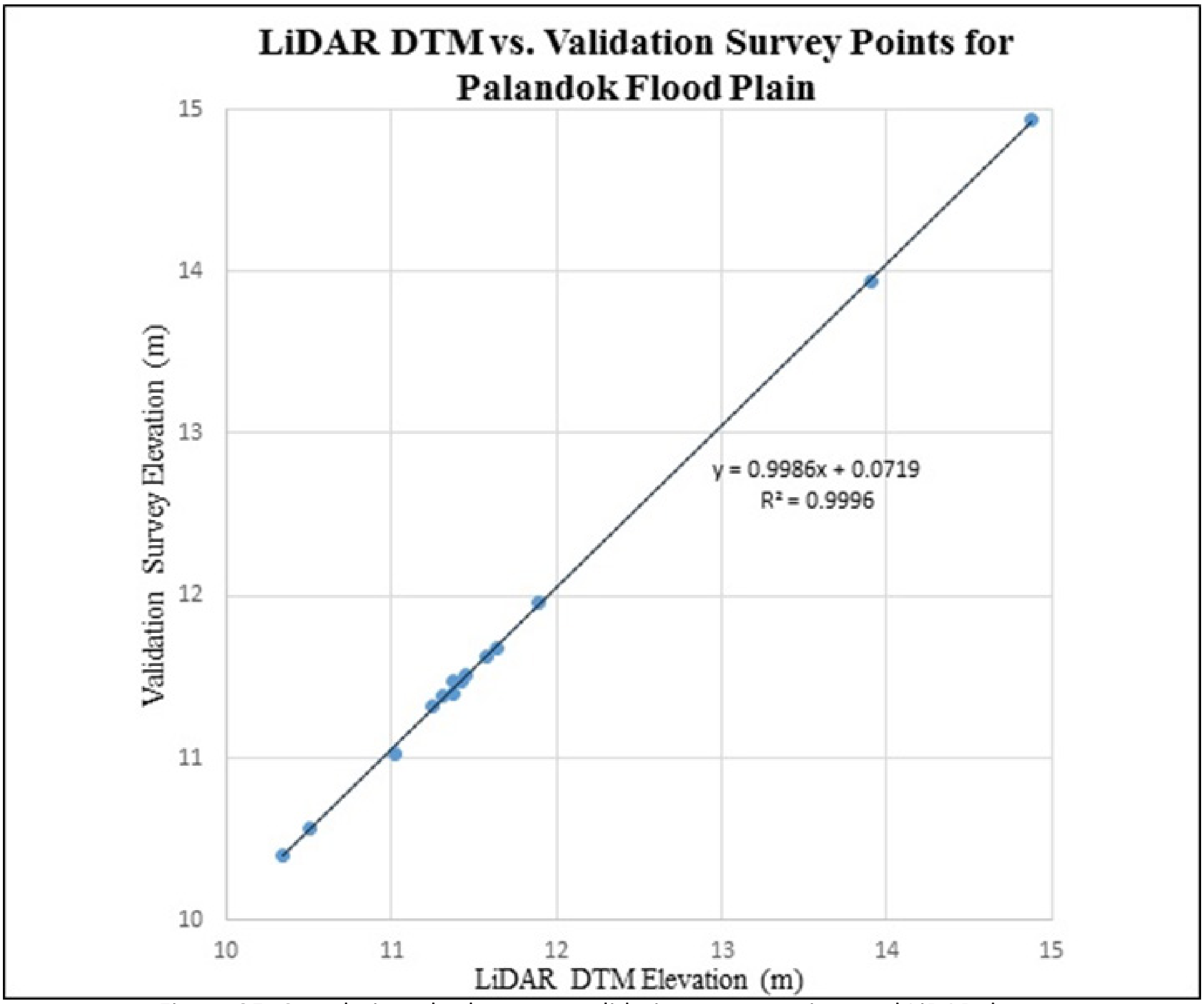



Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

| Validation Statistical Measures | Value (meters) |
|---|---|
| RMSE | 0.06 |
| Standard Deviation | 0.02 |
| Average | -0.05 |
| Minimum | -0.10 |
| Maximum | -0.00 |

## 3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross section data was available for Palandok with 1,299 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.56 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Palandok integrated with the processed LiDAR DEM is shown in Figure B-2026.

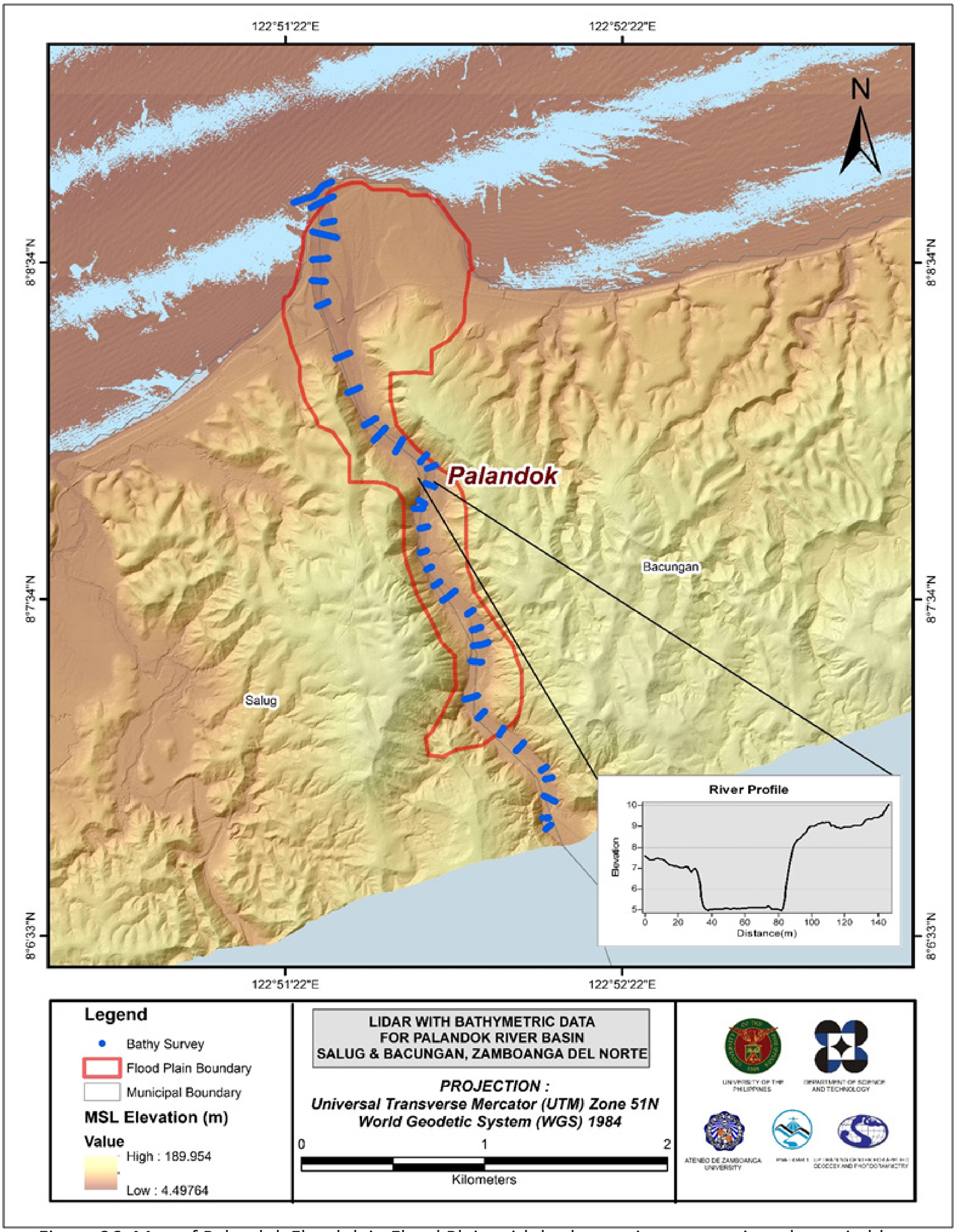



Figure 26. Map of Palandok Floodplain Flood Plain with bathymetric survey points shown in blue.

## 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

Palandok floodplain, including its 200 m buffer, has a total area of 3.42 sq km. For this area, a total of 1.0 sq km, corresponding to a total of 264 building features, are considered for QC. Figure B-2127 shows the QC blocks for Palandok Floodplainfloodplain.

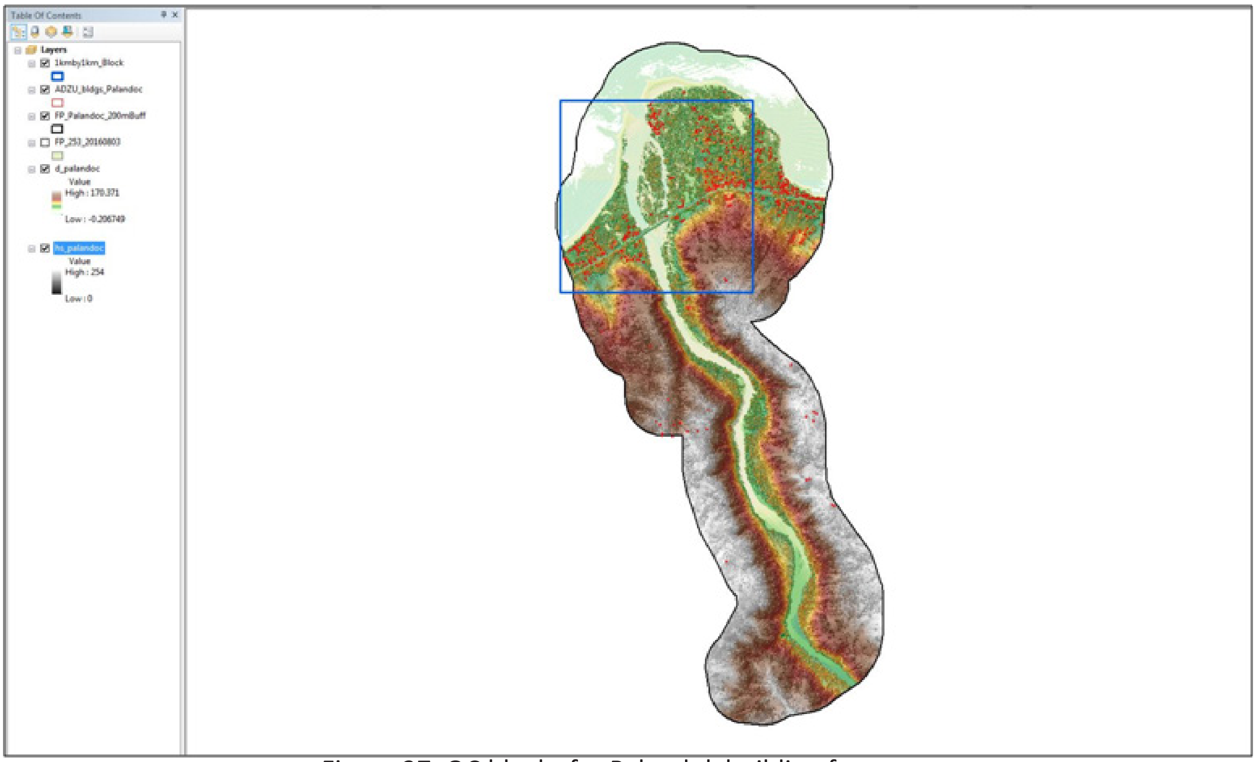



Figure 27. QC blocks for Palandok building features.

Quality checking of Palandok building features resulted in the ratings shown in Figure27.

Table 15. Quality Checking Ratings for Palandok Building Features.

| FLOODPLAIN | COMPLETENESS | CORRECTNESS | QUALITY | REMARKS |
|---|---|---|---|---|
| Palandok | 100.00 | 94.70 | 89.39 | PASSED |

### 3.12.2 Height Extraction

Height extraction was done for 501 building features in Palandok Floodplainfloodplain. Of these building features, none was filtered out after height extraction, resulting to 501 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 5.67 m.

### 3.12.3 Feature Attribution

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

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

Table B-916 summarizes the number of building features per type. On the other hand, Table B-1017 shows the total length of each road type, while Table B-1118 shows the number of water features extracted per type.

Table 16. Building Features Extracted for Palandok Floodplain.

| Facility Type | No. of Features |
|---|---|
| Residential | 455 |
| School | 13 |
| Market | 4 |
| Agricultural/Agro-Industrial Facilities | 7 |
| Medical Institutions | 1 |
| Barangay Hall | 1 |
| Military Institution | 0 |
| Sports Center/Gymnasium/Covered Court | 1 |
| Telecommunication Facilities | 0 |
| Transport Terminal | 0 |
| Warehouse | 8 |
| Power Plant/Substation | 0 |
| NGO/CSO Offices | 0 |
| Police Station | 0 |
| Water Supply/Sewerage | 0 |
| Religious Institutions | 7 |
| Bank | 0 |
| Factory | 0 |
| Gas Station | 0 |
| Fire Station | 0 |
| Other Government Offices | 1 |
| **Other Commercial Establishments** | **3** |
| **Total** | **501** |

Table 17. Total Length of Extracted Roads for Palandok Floodplain.

| Floodplain | Road Network Length (km) | | | | | Total |
|---|---|---|---|---|---|---|
| | Barangay Road | City/Municipal Road | Provincial Road | National Road | Others | |
| Palandok | 0.66 | 0.00 | 0.00 | 1.45 | 0.00 | 2.11 |

Table 18. Number of Extracted Water Bodies for Palandok Floodplain.

| Floodplain | Water Body Type | | | | | Total |
|---|---|---|---|---|---|---|
| | Fish Pen | City/Municipal Road | Provincial Road | National Road | Others | |
| Palandok | 3 | 0 | 0 | 0 | 0 | 3 |

One (1) bridge over small channels that are part of the river network was also extracted for the floodplain.

### 3.12.4 Final Quality Checking of Extracted Features

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

Figure B-2228 shows the Digital Surface Model (DSM) of Palandok Floodplain floodplain overlaid with its ground features.

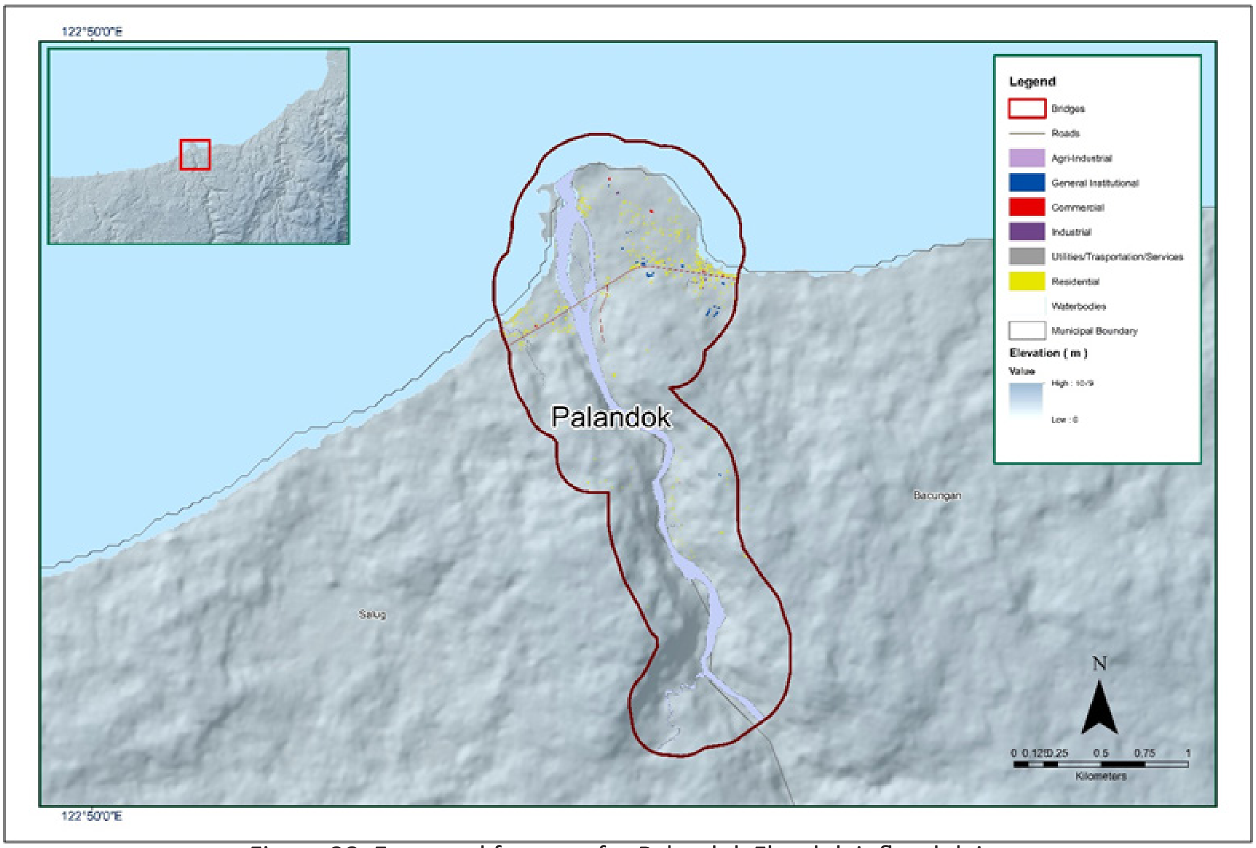



Figure 28. Extracted features for Palandok Floodplainfloodplain.

# CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BATU PALANDOK RIVER BASIN

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

The methods applied in this cChapter 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

In line with this,The AB Surveying and Development (ABSD) conducted a field survey in Polandok Palandok River April 9, 12, 14, 15, 18, 19, 21, 23, 28, and May 2, 2016 with the following scope of work: cross-section, bridge as-built and water level marking in MSL of Polandok Bridge and manual bathymetric survey from the mouth of the river in Brgy. Rizon to the upstream in Brgy. Morob in the Municipality of Bacungan using GNSS survey technique and Total Station and bathymetry data were gathered by DVC on August 21-31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Polandok Palandok River Basin area. The entire survey extent is illustrated in Figure C-129.

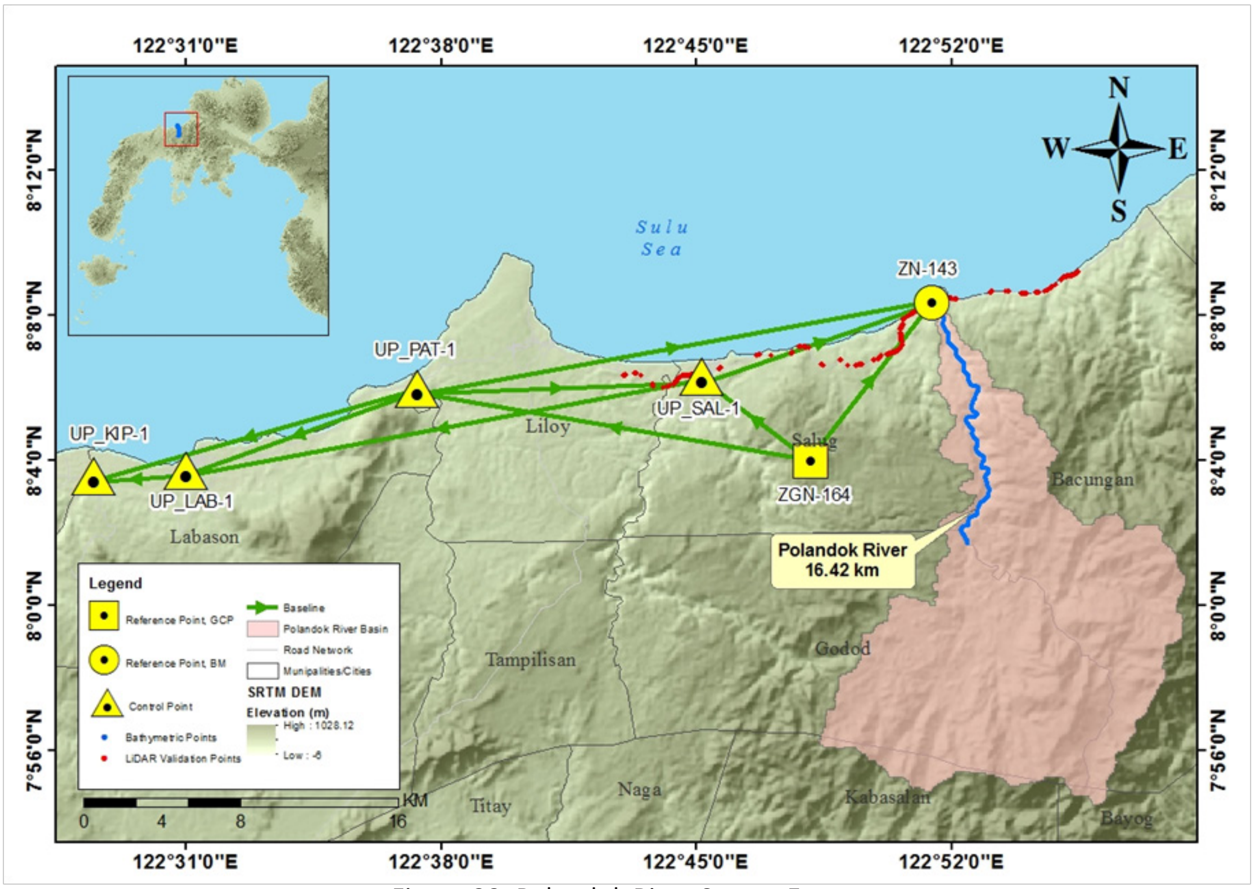



Figure 29. Polandok River Survey Extent

## 4.2 Control Survey

The GNSS network used for Polandok River is composed of five (5) loops established on August 24, 2016 occupying the following occupying the following reference points: ZGN-164, a second-order GCP, situated inside the barangay hall compound beside basketball court in Brgy. Caracol, Salug, Province of Zamboanga Del Norte; and ZN-143, a first-order BM, located at Brgy.Ramon Magsaysay, Salug, Province of Zamboanga Del Norte.

Four (4) control points established in the area by ABSD: UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, UP_LAB-1 inat Labason Bridge in Brgy. Antonio, Municipality of Labason, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, and UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac. The summary of reference and control points and its location is summarized in Table C-119 while GNSS network established is illustrated in Figure C-230.

Figure 71.Table 19. Table C-1 List of reference and control points used during the survey in Polandok Palandok River. (Source: NAMRIA, UP-TCAGP)

| Control Point | Order of Accuracy | Geographic Coordinates (WGS 84) | | | | |
|---|---|---|---|---|---|---|
| | | Latitude | Longitude | Ellipsoidal Height (m) | MSL Elevation (m) | Date Established |
| ZGN-164 | 2nd Order GCP | 8°03'58.80475" N | E122°48'08.60698" E | 296.130 | 229.325 | 2004 |
| ZN-143 | 1st Order BM | 8°08'21.39646" N | | 22°51' 28.86114" E | 11.526 | 2009 |
| UP_KIP-1 | Established | 8°03'35.83524" N | 122°28'26.48383"E | 78.022 | 12.435 | 08-24-16 |
| UP_LAB-1 | Established | 8°03'44.29109" N | 122°30'59.74333"E | 75.708 | 9.889 | 08-24-16 |
| UP_PAT-1 | Established | 8°06'00.79142" N | 122°37'19.54470" E | 76.488 | 10.835 | 08-24-16 |
| UP_SAL-1 | Established | 8°06'20.46964"N | 122°45'09.85390"E | 76.124 | 10.080 | 08-24-16 |

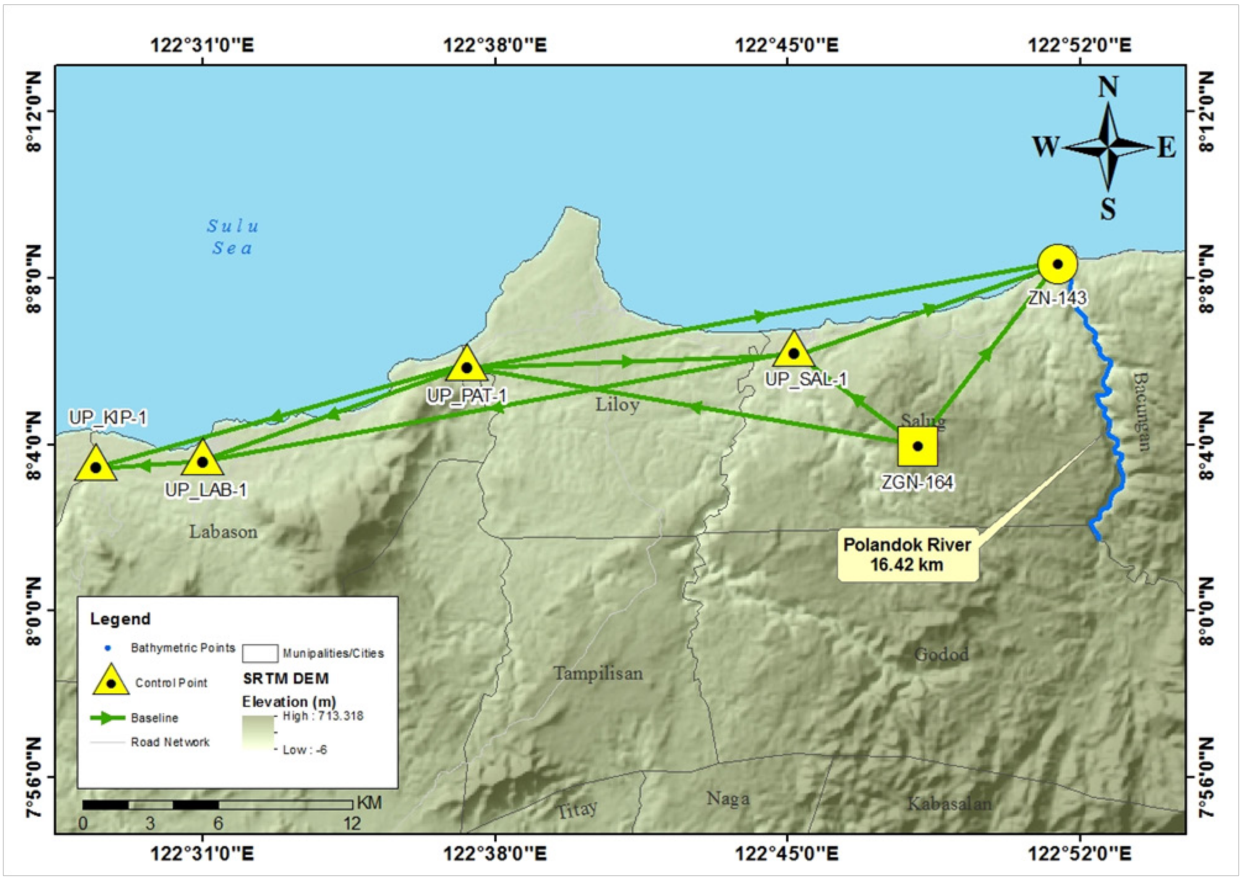



Figure 30. Polandok River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Polandok Palandok River are shown from Figure C-331 to Figure C-836.


Figure 31. GNSS rover, Hi-Target™ V30, ZGN-164, situated inside the barangay hall compound beside basketball court in Brgy. Caracol, Salug, Province of Zamboanga del Norte


Figure 32. GNSS rover, Hi-Target™ V30, at ZN-143, an established control point, located at the right side walk going to Brgy. Rizon direction of Polandok Bridge in Brgy.Ramon Magsaysay, Salug, Province of Zamboanga del Norte


Figure 33. Figure C-5UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, Province of Zamboanga del Norte


Figure 34. Figure C-6 GNSS receiver set up, Hi-Target™ V30, at UP_LAB-1 at Labason Bridge in Brgy. Antonio, Municipality of Labason, Province of Zamboanga del Norte

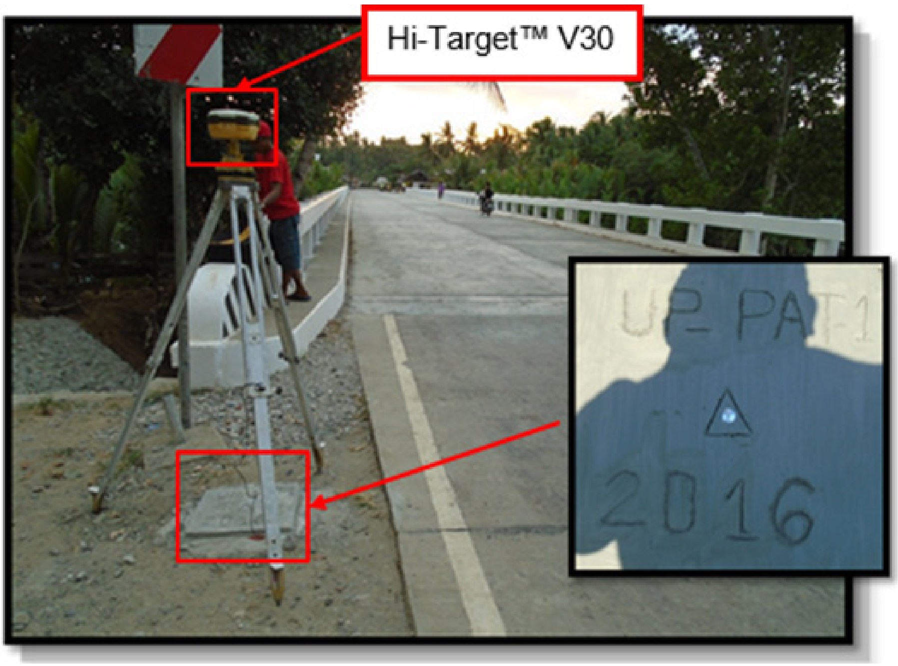



Figure 35. GNSS receiver set up, Hi-Target™ V30, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, Province of Zamboanga del Norte

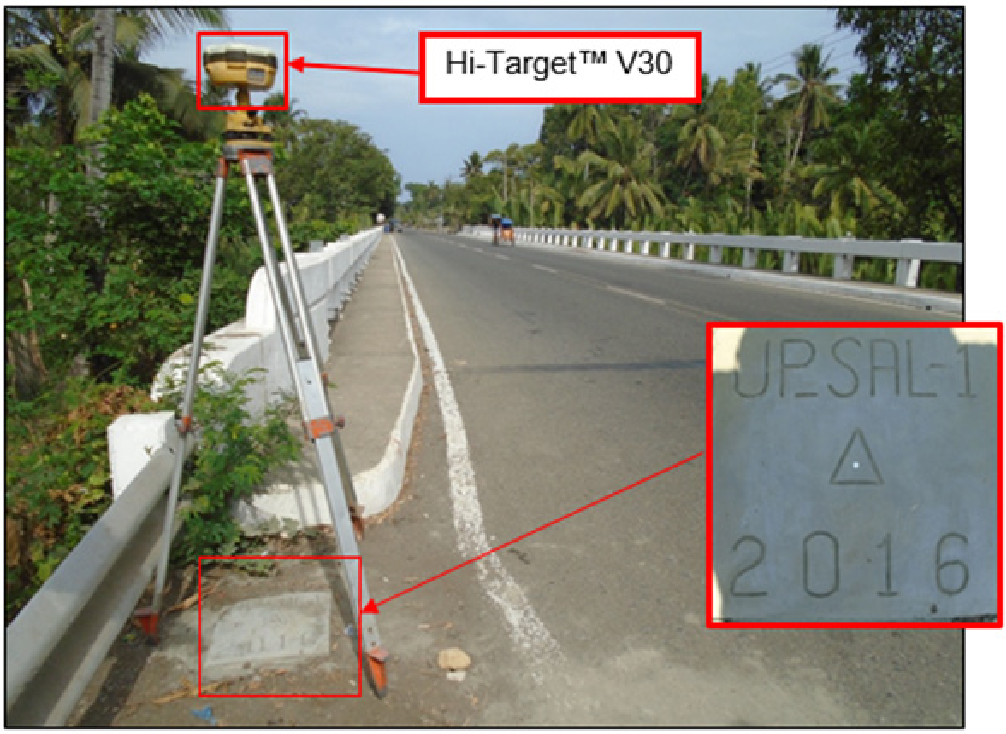



Figure 36. GNSS receiver set up, Hi-Target™ V30, UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac, Province of Zamboanga del Norte

## 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 was 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 Polandok River Basin is summarized in Table C-220 generated by TBC software.

Table 20.Baseline Processing Report for Polandok River Static Survey (First Network)

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| UP_KIP-1 --- UP_PAT-1 | 8-27-2016 | Fixed | 0.006 | 0.035 | 254°44'54" | 16917.407 | 1.523 |
| UP_LAB-1 --- UP_SAL-1 | 8-27-2016 | Fixed | 0.005 | 0.054 | 259°34'18" | 26466.198 | -0.410 |
| UP_LAB-1 --- UP_KIP-1 | 8-27-2016 | Fixed | 0.006 | 0.033 | 266°50'03" | 4699.763 | 2.326 |
| UP_SAL-1 --- UPPAT1 | 8-27-2016 | Fixed | 0.006 | 0.040 | 87°35'11" | 14411.370 | -0.290 |
| UP_LAB-1 --- UP_PAT-1 | 8-27-2016 | Fixed | 0.013 | 0.081 | 250°10'37" | 12361.399 | -0.729 |

As shown Table C-220 a total of five (5) baselines were processed with coordinate and ellipsoidal height values of UP_PAT-1 and UP_SAL-1 held fixed. All of them passed the required accuracy.

Table 21. Baseline Processing Report for Polandok River Static Survey (Second Network)

| Observation | Date of Observation | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|---|---|---|---|---|---|---|---|
| UP_PAT-1 --- ZGN-164 | 8-27-2016 | Fixed | 0.006 | 0.029 | 280°41'32" | 20222.545 | -219.677 |
| ZGN-164 --- UP_SAL-1 | 8-27-2016 | Fixed | 0.004 | 0.030 | 308°29'46" | 6992.329 | -219.983 |
| ZGN-164 --- ZN-143 | 8-27-2016 | Fixed | 0.005 | 0.021 | 37°13'49" | 10132.429 | -218.798 |
| UP_PAT-1 --- UP_SAL-1 | 8-27-2016 | Fixed | 0.009 | 0.047 | 87°35'12" | 14411.385 | -0.393 |
| UP_PAT-1 --- ZN-143 | 8-27-2016 | Fixed | 0.008 | 0.042 | 80°33'03" | 26357.443 | 0.785 |
| UP_SAL-1 --- ZN-143 | 8-27-2016 | Fixed | 0.006 | 0.035 | 72°14'19" | 12183.132 | 1.211 |

As shown in Table C-321, a total of six (6) baselines were processed with coordinate and ellipsoidal height values of ZGN-164 and ZN-143 held fixed. All of them passed the required accuracy.

## 4.4 Network Adjustment

After the baseline processing procedure, network adjustment is was 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 squares of x and y must be less than 20 cm and z less than 10 cm in equation form:
$\sqrt{(x_e)^2 + (y_e)^2} < 20$ cm 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 from Table C-322 to Table C-5Table 24 for the complete details. Refer to Annex A for the computation for the accuracy of ABSD.

The four (4) control points, UP_KIP-1, UP_LAB-1, UP_PAT-1, UP_SAL-1 were occupied and observed simultaneously to form a GNSS loop. For the second network, the four (4) control points ZGN-164, ZN-143, UP_PAT-1, and UP_SAL-1. The coordinates and ellipsoidal height of UP_PAT-1 and UP_SAL-1, and ZGN-164 and ZN-143 were held fixed during the processing of the control points as presented in Tables C-422 and C-523. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 22. Control Point Constraints (First Network)

| Point ID | Type | East σ (Meter | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| UP_PAT-1 | Local | Fixed | Fixed | Fixed | |
| UP_SAL-1 | Local | Fixed | Fixed | Fixed | |
| **Fixed = 0.000001(Meter)** | | | | | |

Table 23. Control Point Constraints (Second Network)

| Point ID | Type | East σ (Meter | North σ (Meter) | Height σ (Meter) | Elevation σ (Meter) |
|---|---|---|---|---|---|
| ZGN-164 | Local | Fixed | Fixed | | |
| ZN-143 | Grid | | | | Fixed |
| **Fixed = 0.000001(Meter)** | | | | | |

The lists of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network are indicated in Tables C-624 and C-725. All fixed control points have no values for grid errors and elevation error.

Table 24. Adjusted Grid Coordinated (First Network)

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Constraint |
|---|---|---|---|---|---|---|---|
| UP_KIP-1 | 442045.506 | 0.011 | 890963.192 | 0.011 | 12.435 | 0.053 | |
| UP_LAB-1 | 446736.710 | 0.011 | 891217.077 | 0.011 | 9.889 | 0.058 | |
| UP_PAT-1 | 458365.200 | ? | 895396.684 | ? | 10.835 | ? | LLh |
| UP_SAL-1 | 472758.821 | ? | 895989.921 | ? | 10.080 | ? | LLh |

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

UP_KIP-1
horizontal accuracy = $\sqrt{((0.1)^2 + (1.1)^2}$
= $\sqrt{(0.01 + 1.21)}$
= 1.10 < 20 cm
vertical accuracy = 5.3 < 10 cm

UP_LAB-1
horizontal accuracy = $\sqrt{((0.1)^2 + (1.1)^2}$
= $\sqrt{(0.01 + 1.21)}$
= 1.10 < 20 cm
vertical accuracy = 5.8 < 10 cm

UP_PAT-1
horizontal accuracy = Fixed
vertical accuracy = Fixed

UP_SAL-1
horizontal accuracy = Fixed
vertical accuracy = Fixed

Table 25. Adjusted Grid Coordinated

| Point ID | Easting (Meter) | Easting Error (Meter) | Northing (Meter) | Northing Error (Meter) | Elevation (Meter) | Elevation Error (Meter) | Cons traint |
|---|---|---|---|---|---|---|---|
| ZGN-164 | 478227.123 | ? | 891636.530 | ? | 229.325 | 0.040 | LL |
| ZN-143 | 484358.928 | 0.006 | 899697.912 | 0.006 | 11.526 | ? | e |
| UP_PAT-1 | 458365.200 | 0.007 | 895396.684 | 0.006 | 10.835 | 0.054 | |
| UP_SAL-1 | 472758.821 | 0.006 | 895989.921 | 0.005 | 10.080 | 0.051 | |

a. ZGN-164
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. ZN-143
horizontal accuracy = Fixed
vertical accuracy = Fixed

c. UP_PAT-1
horizontal accuracy = $\sqrt{((0.7)^2 + (0.6)^2}$
= $\sqrt{(0.49 + 0.36)}$
= 0.85 < 20 cm
vertical accuracy = 5.4 < 10 cm

d. UP_SAL-1
horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$
= $\sqrt{(0.36 + 0.25)}$
= 0.61 < 20 cm
vertical accuracy = 5.1 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the six (6) occupied control points are within the required precision.

Table 26. Adjusted Geodetic Coordinates (First Network)

| Point ID | Latitude | Longitude | Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| UP_KIP-1 | 8°03'35.83524" N | 122°28'26.48383"E | 78.022 | 0.053 | |
| UP_LAB-1 | 8°03'44.29109" N | 122°30'59.74333"E | 75.708 | 0.058 | |
| UP_PAT-1 | 8°06'00.79142" N | 122°37'19.54470" E | 76.488 | ? | LLh |
| UP_SAL-1 | 8°06'20.46964"N | 122°45'09.85390"E | 76.124 | ? | LLh |

Table 27. Adjusted Geodetic Coordinates (Second Network)

| Point ID | Latitude | Longitude | Height (Meter) | Height Error (Meter) | Constraint |
|---|---|---|---|---|---|
| ZGN-164 | 8°03'58.80475" N | 122°48'08.60698" E | 296.130 | 0.040 | LL |
| ZN-143 | 8°08'21.39646" N | 122°51'28.86114" E | 77.323 | ? | e |
| UP_PAT-1 | 8°06'00.79142" N | 122°37'19.54470" E | 76.488 | 0.054 | |
| UP_SAL-1 | 8°06'20.46964" N | 122°45'09.85390" E | 76.124 | 0.051 | |

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Tables C-826 and Table C-927. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summaries of reference control points used are indicated in Tables C-1028 and C-1129.

Table 28. 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 (Meter) | Northing (m) | Easting (m) | BM Ortho (m) |
| UP_KIP-1 | Established | 8°03'35.83524" N | 122°28'26.48383"E | 78.022 | 890963.192 | 442045.506 | 12.435 |
| UP_LAB-1 | Established | 8°03'44.29109" N | 122°30'59.74333"E | 75.708 | 891217.077 | 446736.710 | 9.889 |
| UP_PAT-1 | Established | 8°06'00.79142" N | 122°37'19.54470" E | 76.488 | 895396.684 | 458365.200 | 10.835 |
| UP_SAL-1 | Established | 8°06'20.46964"N | 122°45'09.85390"E | 76.124 | 895989.921 | 472758.821 | 10.080 |

Table 29. 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 (Meter) | Northing (m) | Easting (m) | BM Ortho (m) |
| ZGN-164 | 2nd Order GCP | 8°03'58.80475" N | 122°48'08.60698" E | 296.130 | 891636.530 | 478227.123 | 229.325 |
| ZN-143 | 1st Order BM | 8°08'21.39646" N | 122°51'28.86114" E | 77.323 | 899697.912 | 484358.928 | 11.526 |
| UP_PAT-1 | Established | 8°06'00.79142" N | 122°37'19.54470" E | 76.488 | 895396.684 | 458365.200 | 10.835 |
| UP_SAL-1 | Established | 8°06'20.46964" N | 122°45'09.85390" E | 76.124 | 895989.921 | 472758.821 | 10.080 |

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

Network Adjustment

Cross-section and as-built surveys were conducted on April 9, 2016 at the upstream side of Polandok Palandok Bridge in Brgy., Ramon Magsaysay, Municipality of Salug, Province of Zamboanga del Norte, as shown in Figure C-9Figure 37. A Nikon® Total Station was utilized for this survey as shown in Figure C-1038.

Figure 37. Figure C-9 Polandok Bridge facing upstream


Figure 38. As-built survey of Polandok Bridge

The cross-sectional line of Polandok Palandok Bridge is about 362.221 m with two hundred fifteen (215) cross-sectional points using the control points UP_PAL-1 and UP_PAL-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure C-1139 to Figure C-13Figure 41.

No bridge cross-section or bridge points checking data were gathered for Polandok Palandok Bridge because the contractor's data passed the quality assessment.

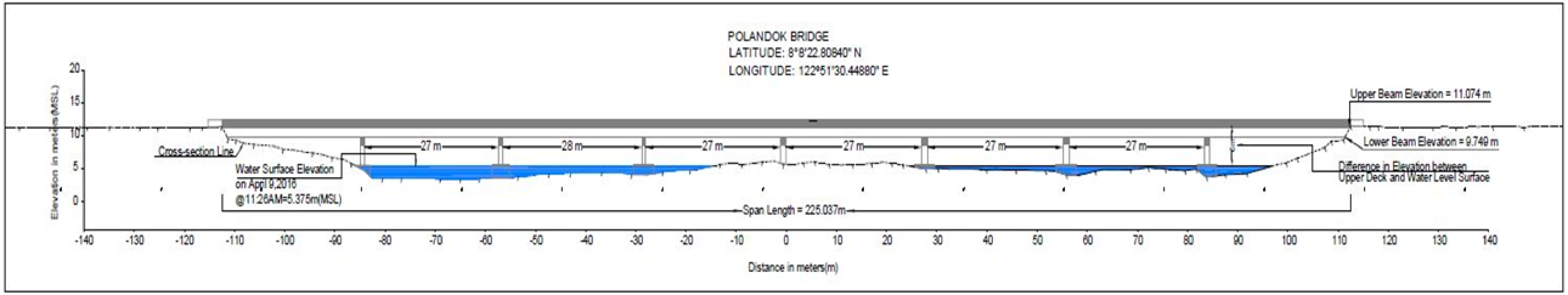



Figure 39. PolandokPalandok Bridge Cross-section Diagram

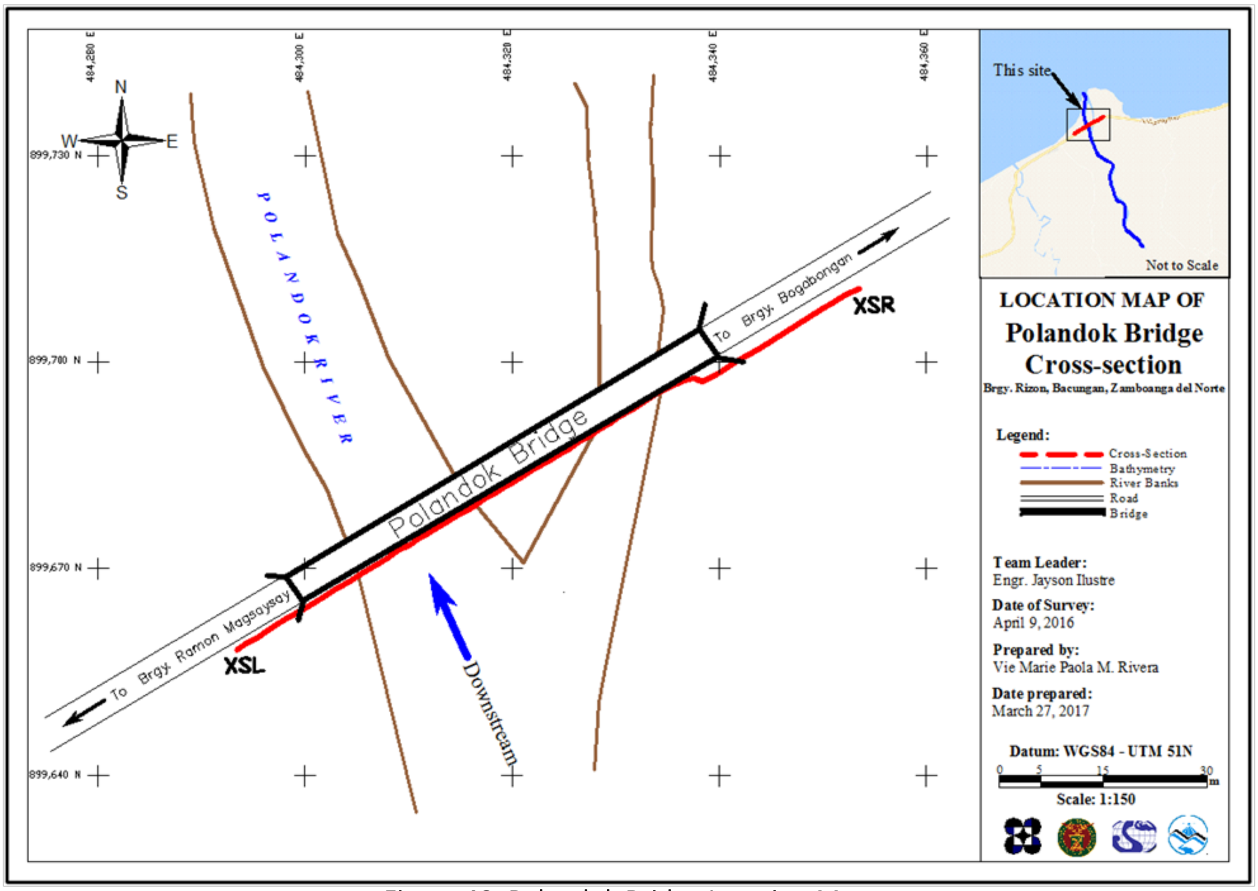
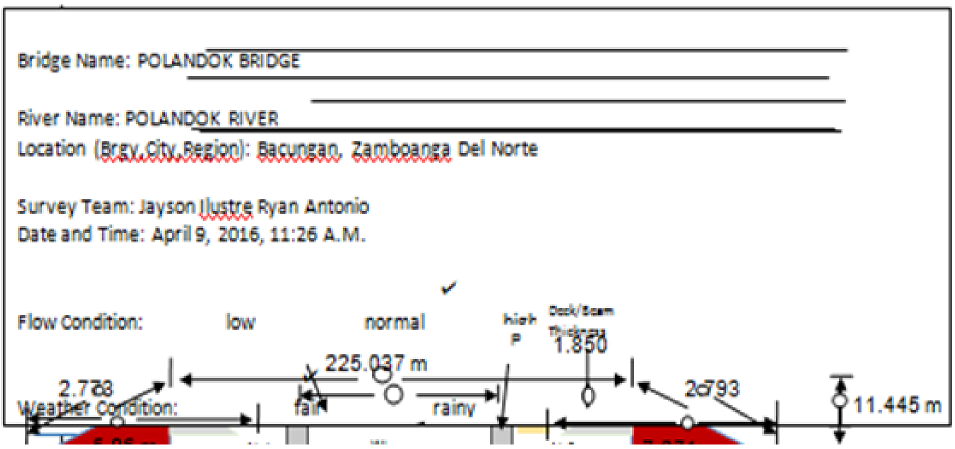



Figure 40. Polandok Bridge Location Map

Bridge Data Form


Bridge Name: POLANDOK BRIDGE

River Name: POLANDOK RIVER

Location (Brgy.City.Region): Bacungan, Zamboanga Del Norte

Survey Team: Jayson Ilustre Ryan Antonio

Date and Time: April 9, 2016, 11:26 A.M.

Flow Condition: low normal high

Weather Condition: fair rainy



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

| Line Segment | Measurement (m) | Remarks |
|---|---|---|
| 1. BA1-BA2 | 2.773 | |
| 2. BA2-BA3 | 225.037 m | |
| 3. BA3-BA4 | 2.793 m | |
| 4. BA1-Ab1 | 5.86 m | |
| 5. Ab2-BA4 | 7.271 m | |
| 6. Deck/beam thickness | 1.850 m | |
| 7. Deck elevation | 11.445 m | |

Note: Observer should be facing downstream

Figure 41. PolandokPalandok Bridge Data Sheet

Water surface elevation of Polandok Palandok River was determined by a Nikon® Total Station on April 9, 2016 at 11:26 AM at Polandok Palandok Bridge area with a value of 5.375 m in MSL as shown in Figure C-11Figure 39. This was translated into marking on the bridge's pier as shown in Figure C-14Figure 42. The marking will serveserved as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Polandok Palandok River, the Ateneo de Zamboanga University.


Figure 42. Water-level markings on Polandok Palandok Bridge

## 4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 27, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 43.Figure C-15. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.278 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZN-143 occupied as the GNSS base station in the conduct of the survey.


Figure 43. Validation points acquisition survey set-up for Polandok River

The survey started from Brgy. Bacungan, Municipality of Bacungan, Zamboanga del Norte going west along the national highway covering thirteen (13) barangays in three (3) municipalities, namely, the municipalities of Bacungan, Salug, and Liloy, and ending in Brgy. Kayok, Municipality of Liloy, Zamboanga del Norte. The survey gathered a total of 993 points with approximate length of 24 km using ZN-143 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 44Figure C-16.

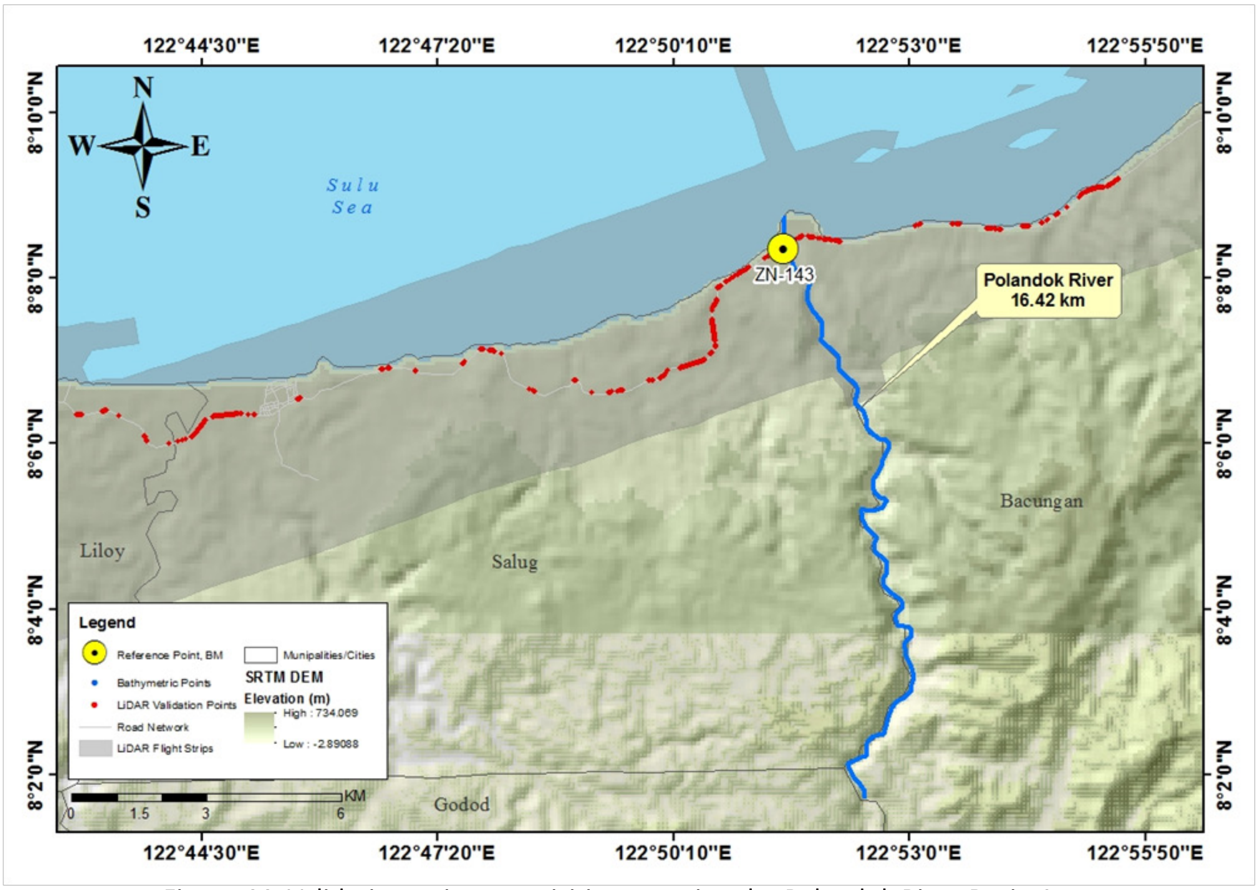



Figure 44. Validation points acquisition covering the Polandok River Basin Area

## 4.7 River Bathymetric Survey

Bathymetric survey was executed on April 15, 18, 19, 23, 28, and May 2, 2016 at Polandok Palandok River using a Nikon® Total Station as illustrated in Figures C-17Figure 45. The survey started from the mouth of the river at Brgy. Rizon, Bacungan, Zamboanga del Norte with coordinates 8°9'11.80343"N, 122°55'30.86879"E and ended in Brgy. Morob, Bacungan, Zamboanga Del Norte as well, with coordinates 8°6'20.92905"N, 122°43'00.12187"E. The control points UP_POL-1 and UP-POL-2 were used as GNSS base stations all throughout the entire survey.


Figure 45. Manual bathymetric survey at Polandok River using Nikon® Total Station

The bathymetric survey for Polandok Palandok River gathered a total of 4,806 points covering 16.484 km of the river traversing Brgy. Rizon to Brgy. Morob, along the boundary between the municipalities of Bacungan and Salug. A CAD drawing was also produced to illustrate the riverbed profile of Palandok Polandok River. As shown in Figure C-20Figure 48, elevation drop of 148.22 m of the river bed was recorded. An elevation drop of 178.36 m was observed within the distance of approximately 16.484 km.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 21-31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. A map showing the DVC bathymetric checking points is shown in Figure C-1947.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.87 was obtained was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.154 which is within the accuracy required by the program.

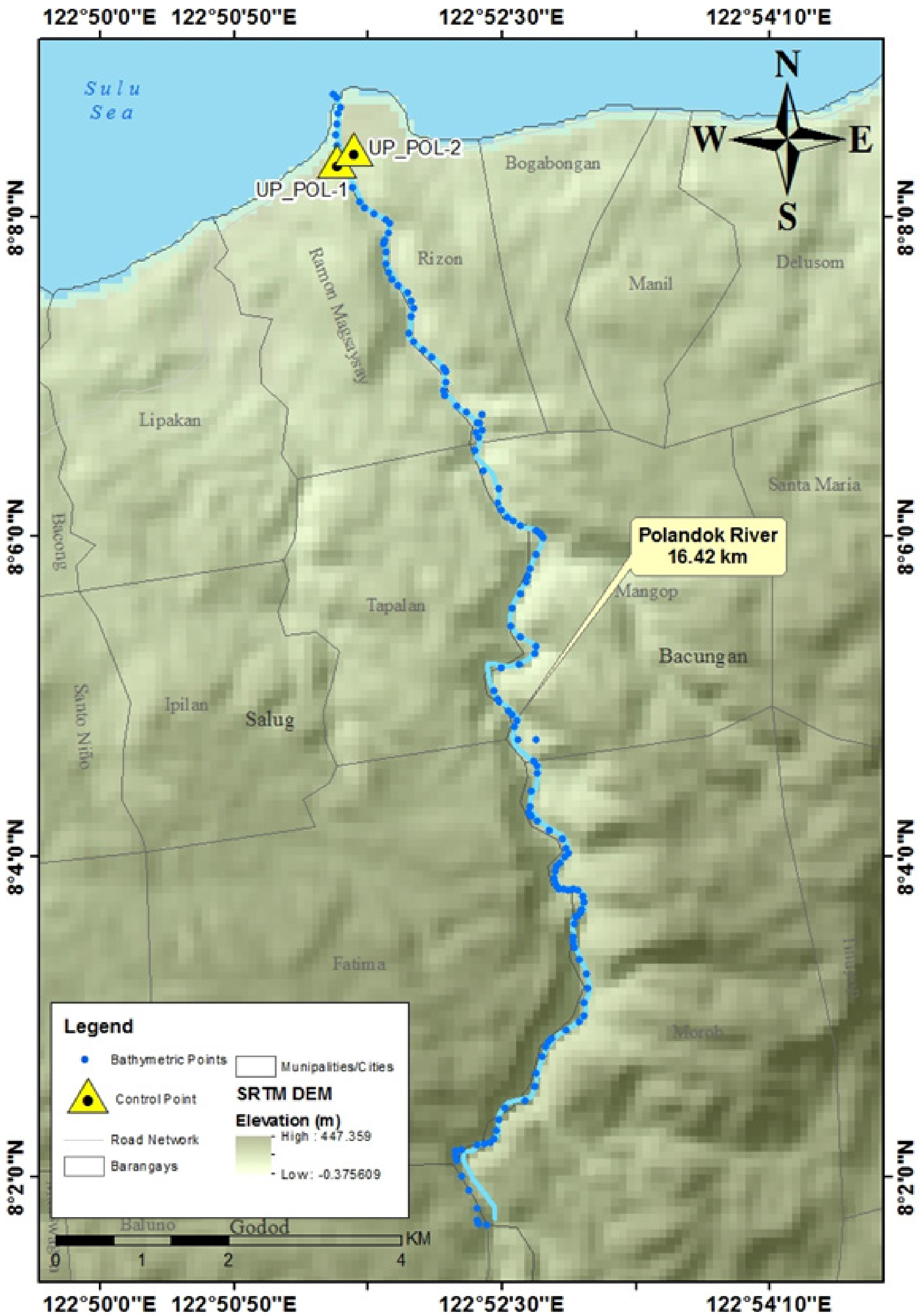


Figure 46. Figure C-18 Bathymetric survey of Polandok River

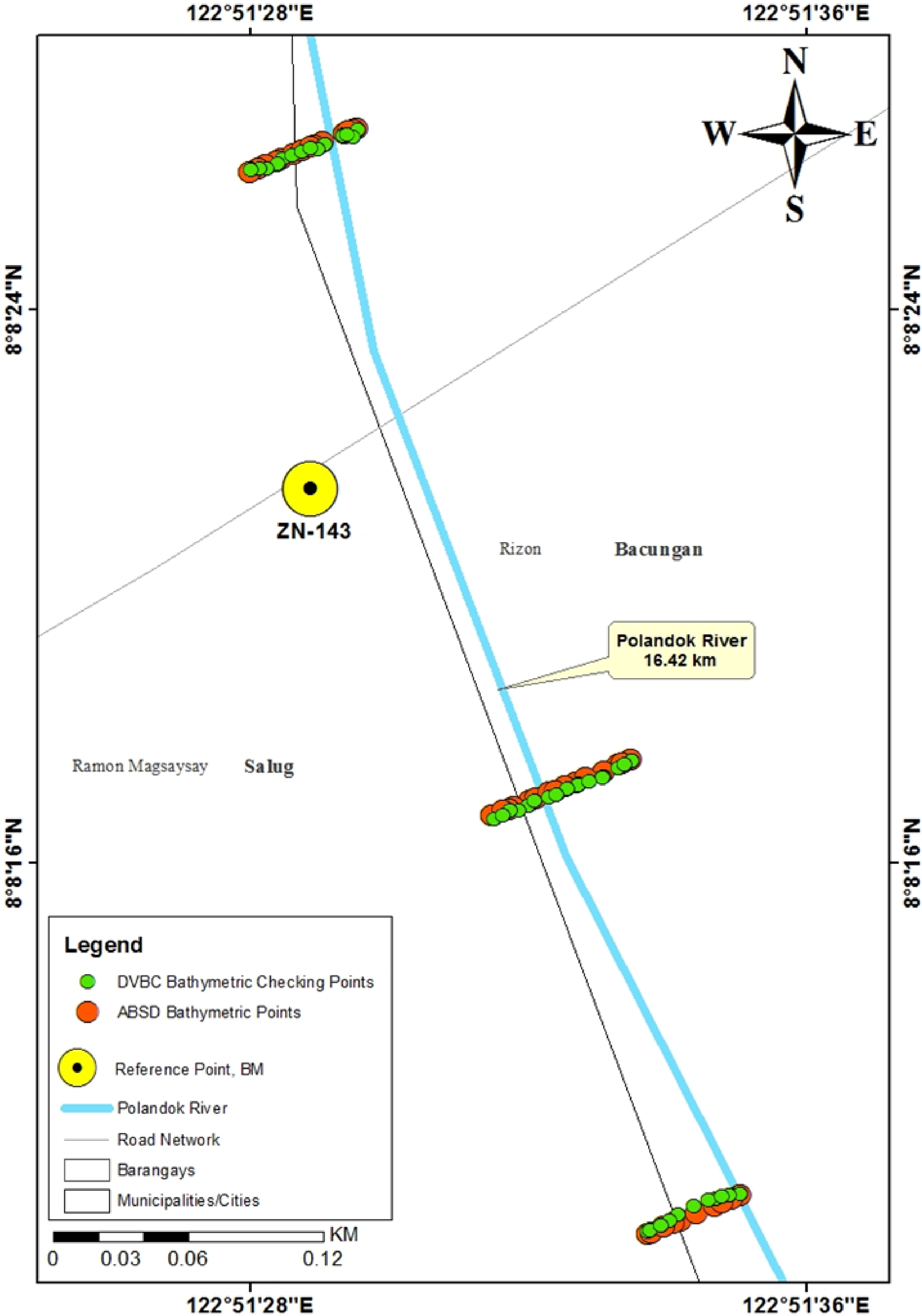



Figure 47. Quality checking points gathered along Polandok River by DVBC

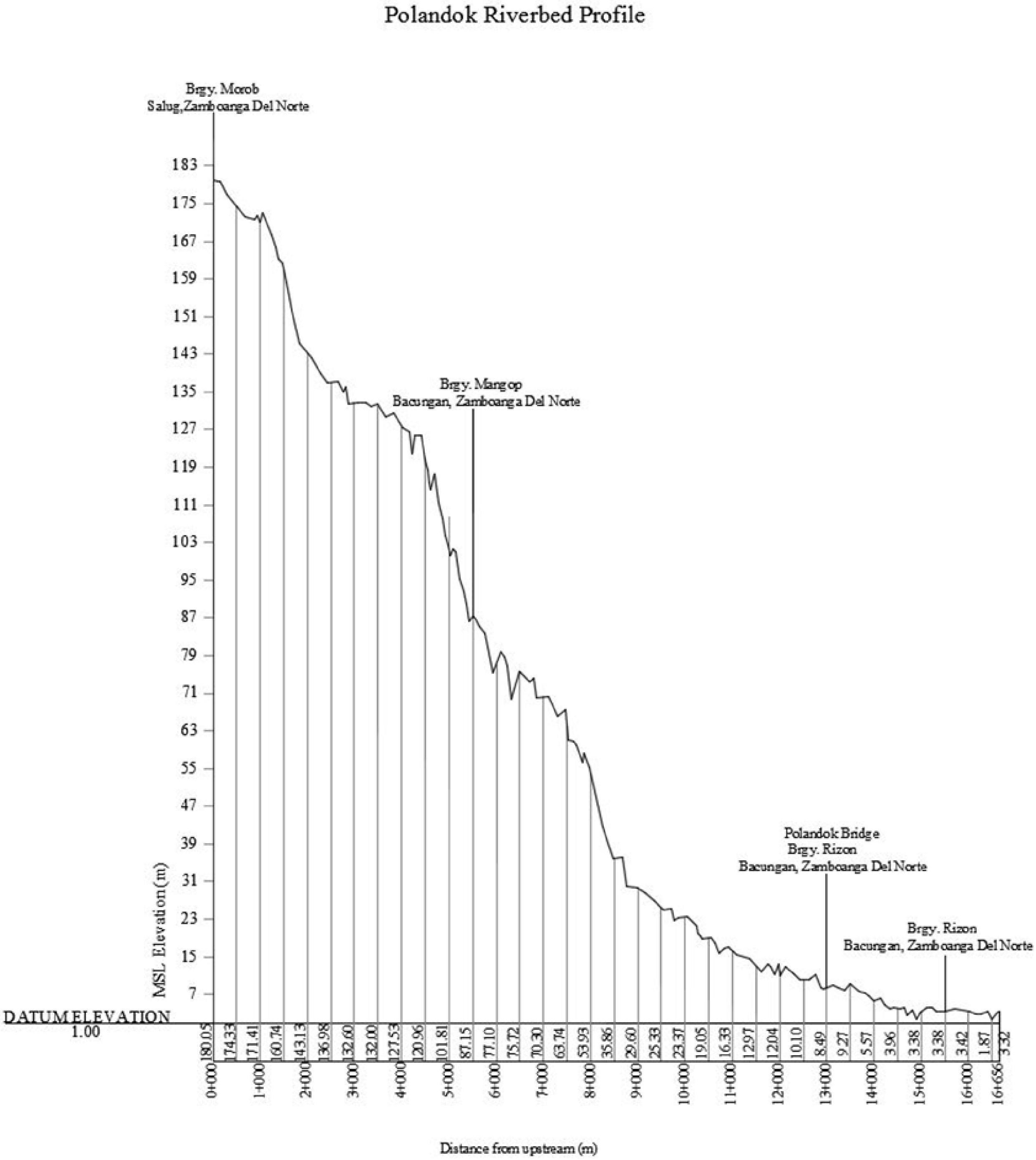



Figure 48. Figure C-20 Polandok Riverbed Profile

# CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

## 5.1 Data Used for Hydrologic Modeling

### 5.1.1 Hydrometry and Rating Curves

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

### 5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. Morob, Leon B. Postigo, Zamboanga del Norte (8° 4' 33.10" N, 122° 22' 44.00" E). (Figure 491). The precipitation data collection started from July 27, 2016 at 09:00 AM to July 28, 2016 at 7:00AM with 10 minutes recording interval.

The total precipitation for this event in Brgy. Morob was 100.8 mm. It has a peak rainfall of 18.4 mm. on July 27, 2016 at 4:30 PM. The lag time between the peak rainfall and discharge is 2 hours.

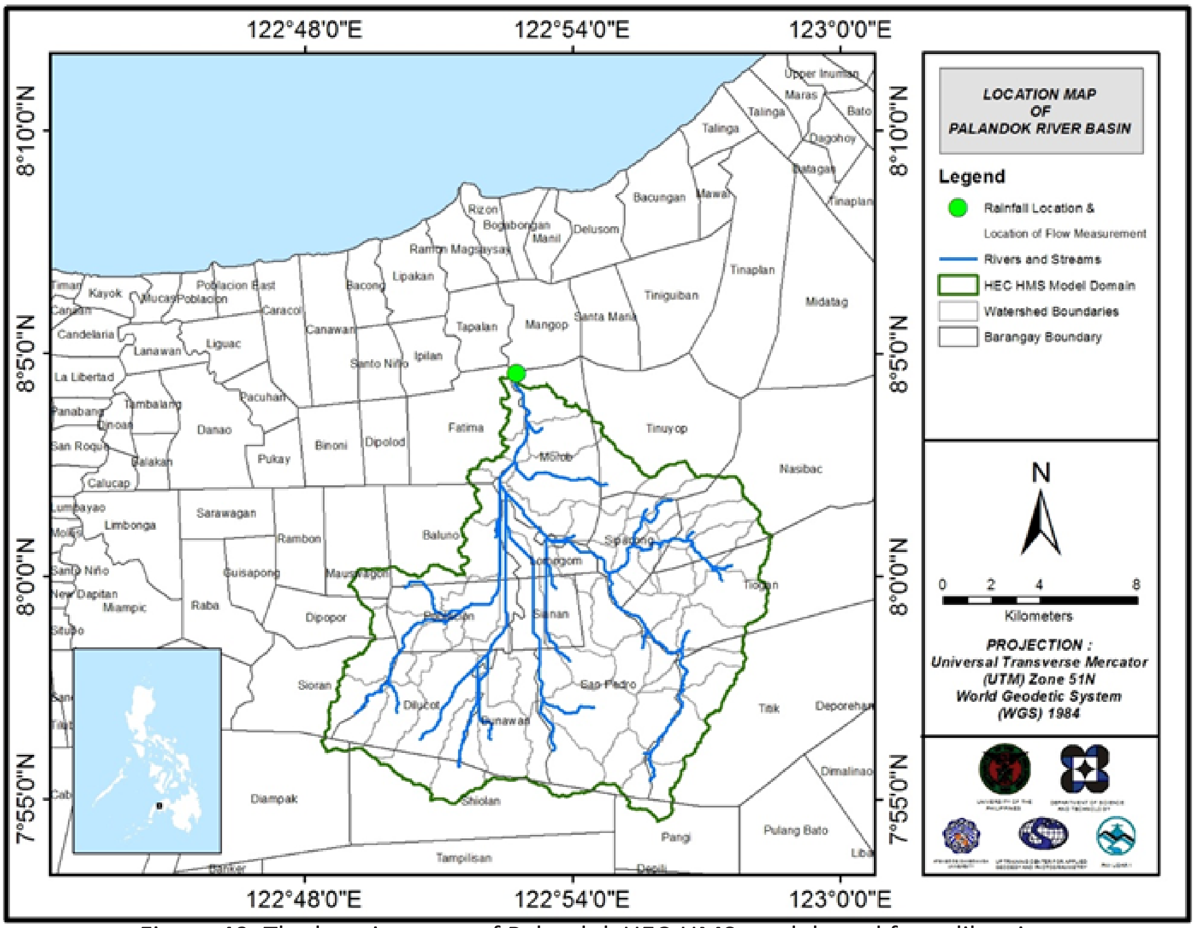


Figure 49. The location map of Palandok HEC-HMS model used for calibration

### 5.1.3 Rating Curves and River Outflow

A rating curve was developed at Brgy. Morob, Leon B. Postigo, Zamboanga del Norte(7° 59' 30.43" N, 122° 52' 49.33" E). It gives the relationship between the observed water levels at Brgy. Morob and outflow of the watershed at this location.
For Brgy. Morob, the rating curve is expressed as Q = 2E-136e2.2412h as shown in Figure 513.

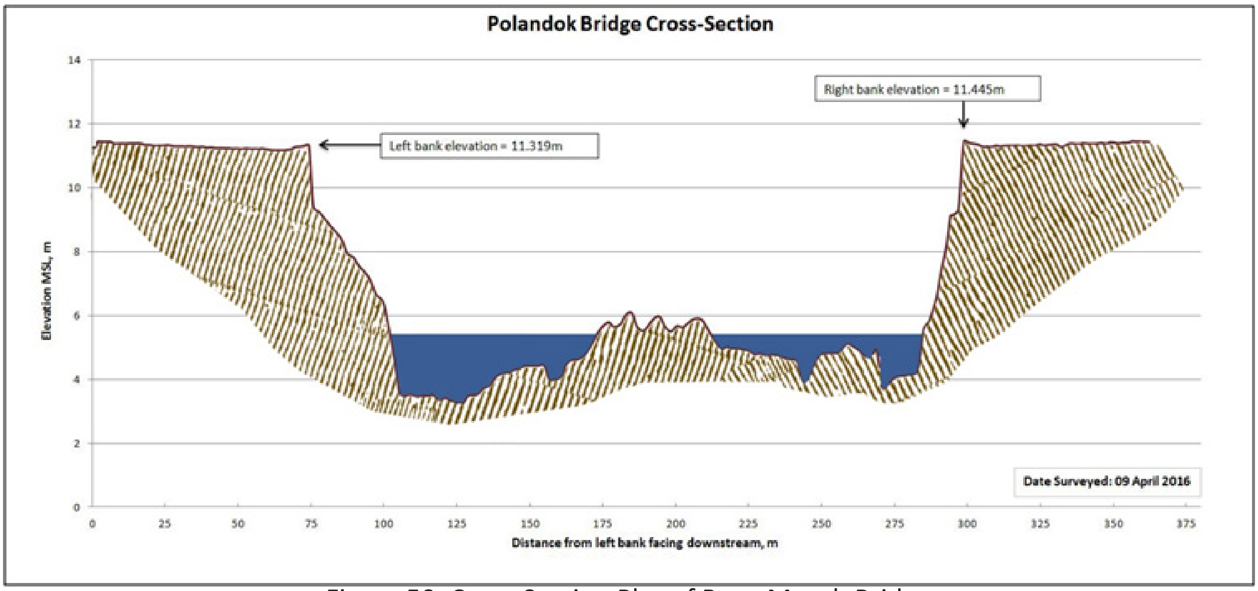



Figure 50. Cross-Section Plot of Brgy. Morob Bridge

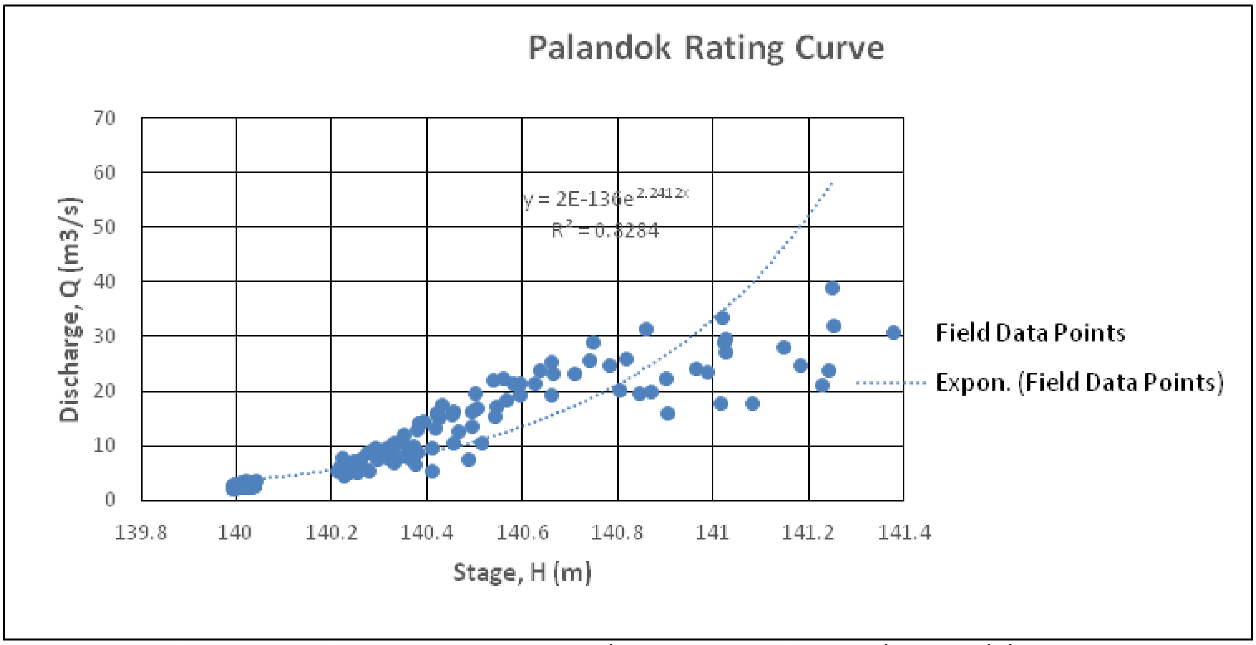



Figure 51. Rating Curve at Brgy. Morob, Leon B. Postigo, Zamboanga del Norte

This rating curve equation was used to compute the river outflow at Brgy. Morob for the calibration of the HEC-HMS model shown in Figure 351. Peak discharge is 39 cubic meters per second at 6:30 PM, July 27, 2016.

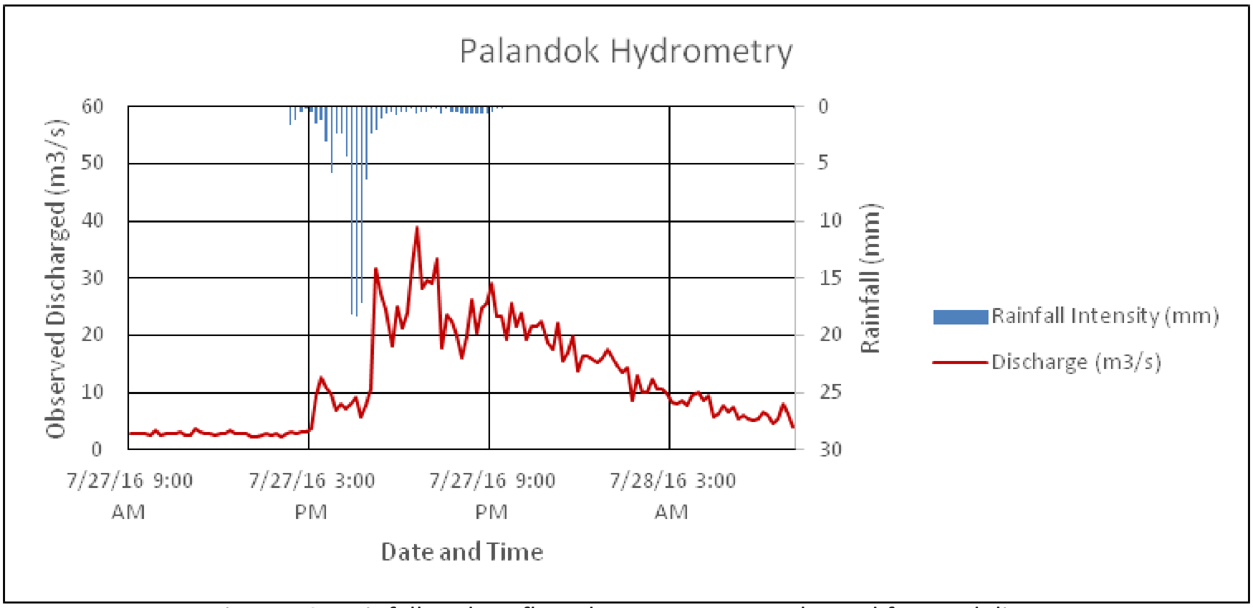



Figure 52. Rainfall and outflow data at Brgy. Morob used for modeling

## 5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Palandok watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 30. RIDF values for Zamboanga City Rain Gauge computed by PAGASA

| COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T (yrs) | 10 mins | 20 mins | 30 mins | 1 hr | 2 hrs | 3 hrs | 6 hrs | 12 hrs | 24 hrs |
| 2 | 15.5 | 23.3 | 28.4 | 36.9 | 45.6 | 50.7 | 60 | 66.1 | 77.3 |
| 5 | 21.4 | 31.6 | 38.3 | 50.4 | 61.2 | 38.2 | 82.5 | 91.5 | 107.8 |
| 10 | 25.3 | 37.1 | 44.8 | 59.4 | 71.6 | 79.8 | 97.5 | 108.3 | 127.9 |
| 15 | 27.5 | 40.2 | 48.5 | 64.4 | 77.4 | 86.4 | 105.9 | 117.8 | 139.3 |
| 20 | 29 | 42.3 | 51.1 | 68 | 81.5 | 91 | 111.8 | 124.4 | 147.3 |
| 25 | 30.2 | 44 | 53.1 | 70.7 | 84.7 | 94.5 | 116.3 | 129.5 | 153.4 |
| 50 | 33.9 | 49.1 | 59.2 | 79.1 | 94.4 | 105.4 | 130.4 | 145.3 | 172.3 |
| 100 | 37.5 | 54.2 | 65.3 | 87.4 | 104 | 116.2 | 144.3 | 161 | 191.1 |

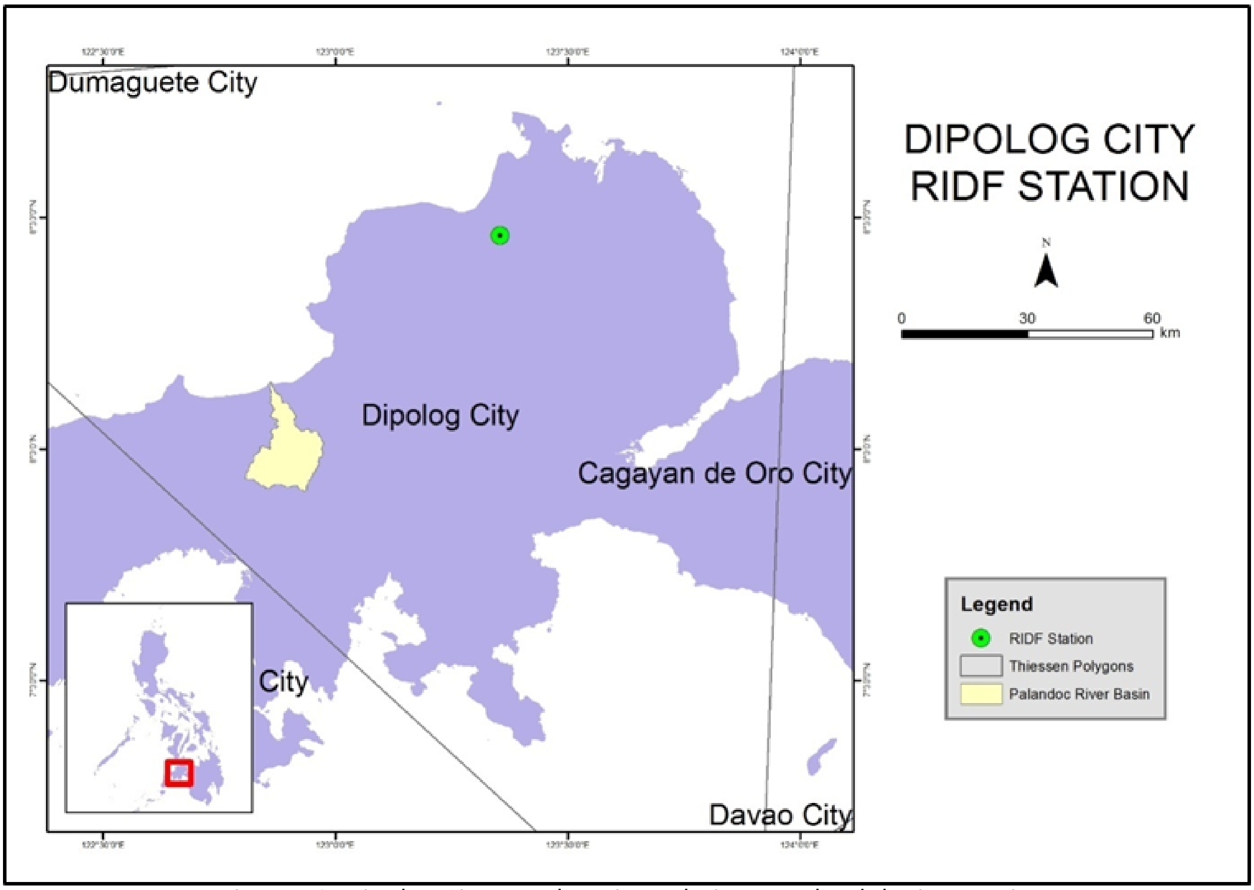



Figure 53. Dipolog City RIDF location relative to Palandok River Basin

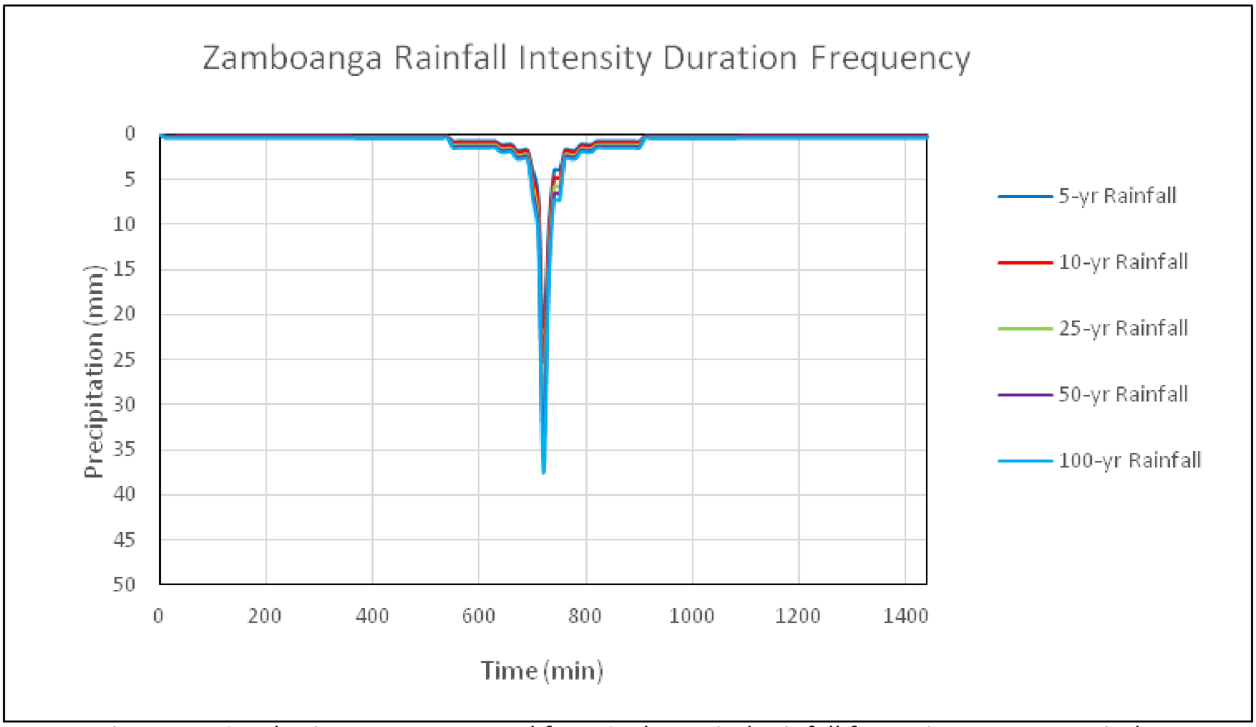



Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

## 5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Palandok River Basin are shown in Figures 59 55 and 6056, respectively.

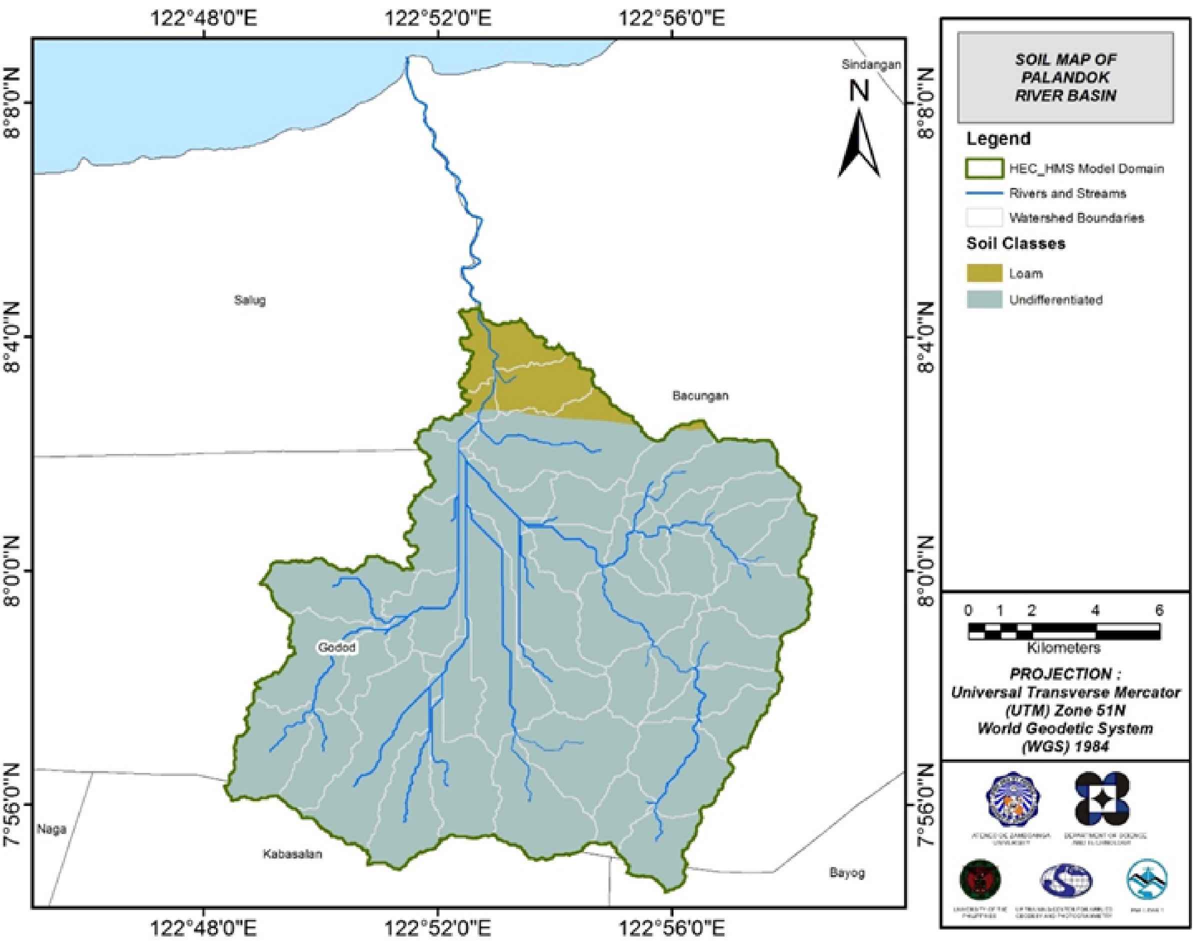



Figure 55. Soil Map of Palandok River Basin

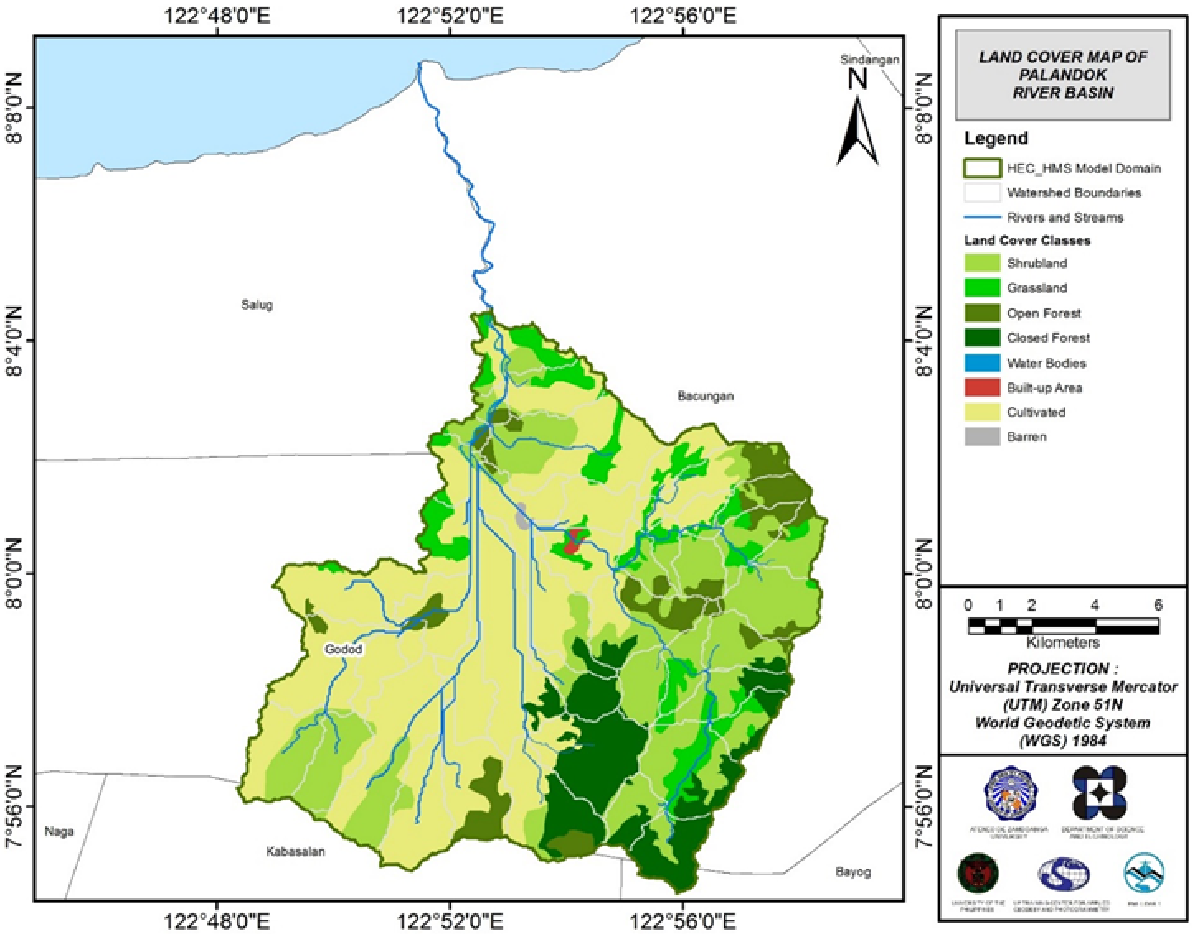



Figure 56. Land Cover Map of Palandok River Basin

For Palandok, the soil classes identified were loam and undifferentiated mountain soil. The land cover types identified were shrubland, grassland, open and closed canopy forests, built-up areas and cultivated areas.

# Figure 57. [insert Slope Map]

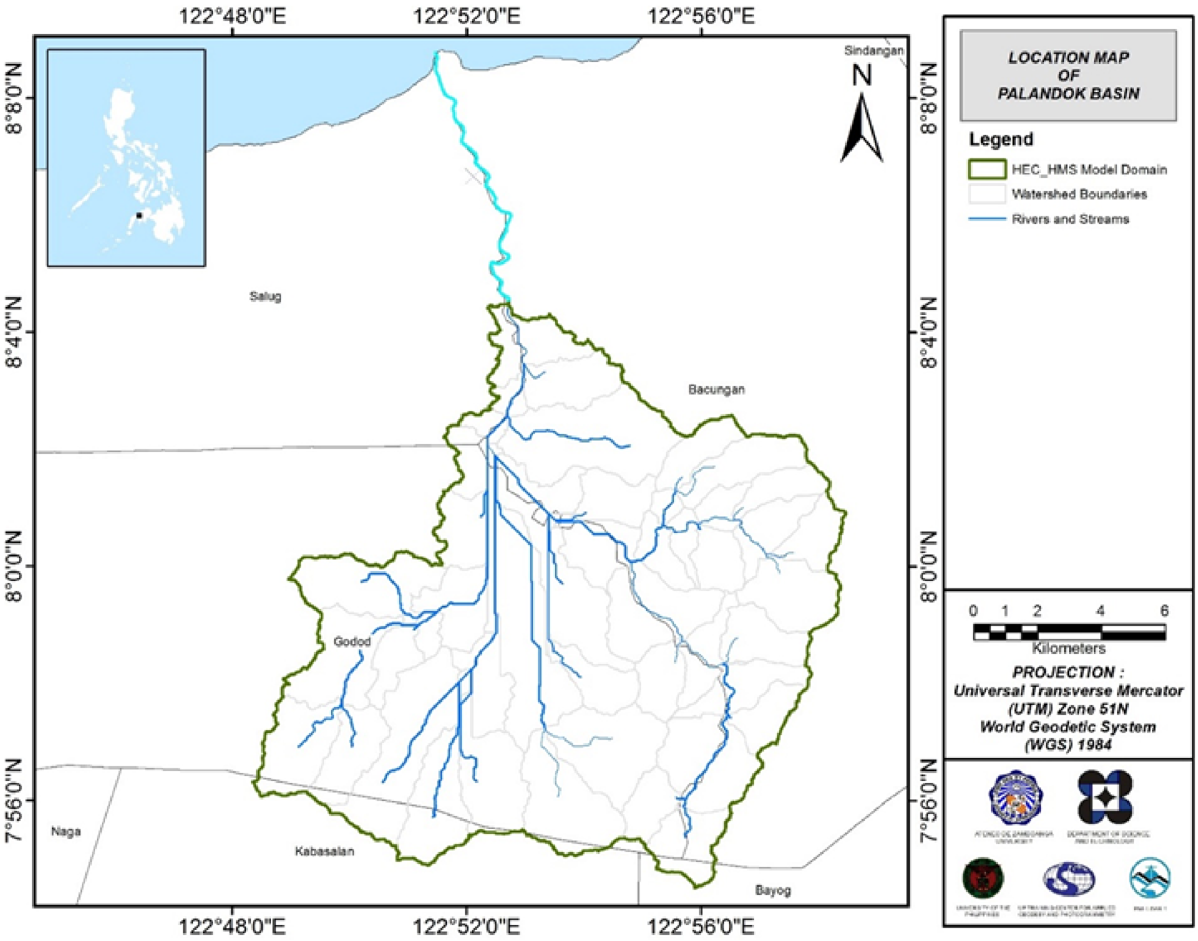



Figure 58. Stream delineation map of Palandok river basin

Using the SAR-based DEM, the Palandok basin was delineated and further subdivided into subbasins. The model consists of 51 sub basins, 25 reaches, and 25 junctions as shown in Figure 597. The main outlet is at Brgy. Morob, Leon B. Postigo, Zamboanga del Norte.

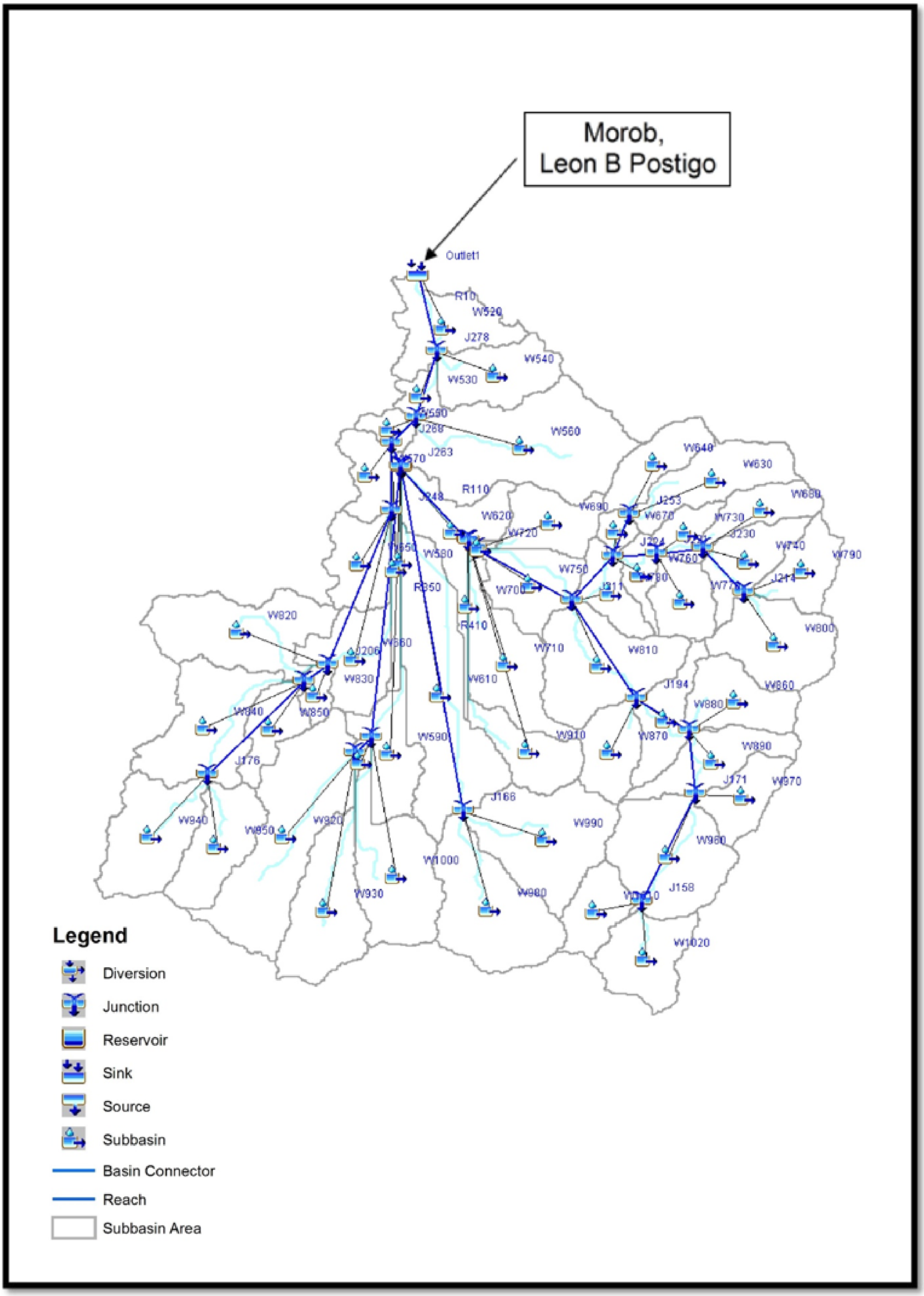



Figure 59. The Palandok river basin model generated using HEC-HMS

## 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 Arc GeoRAS tool and was post-processed in ArcGIS.

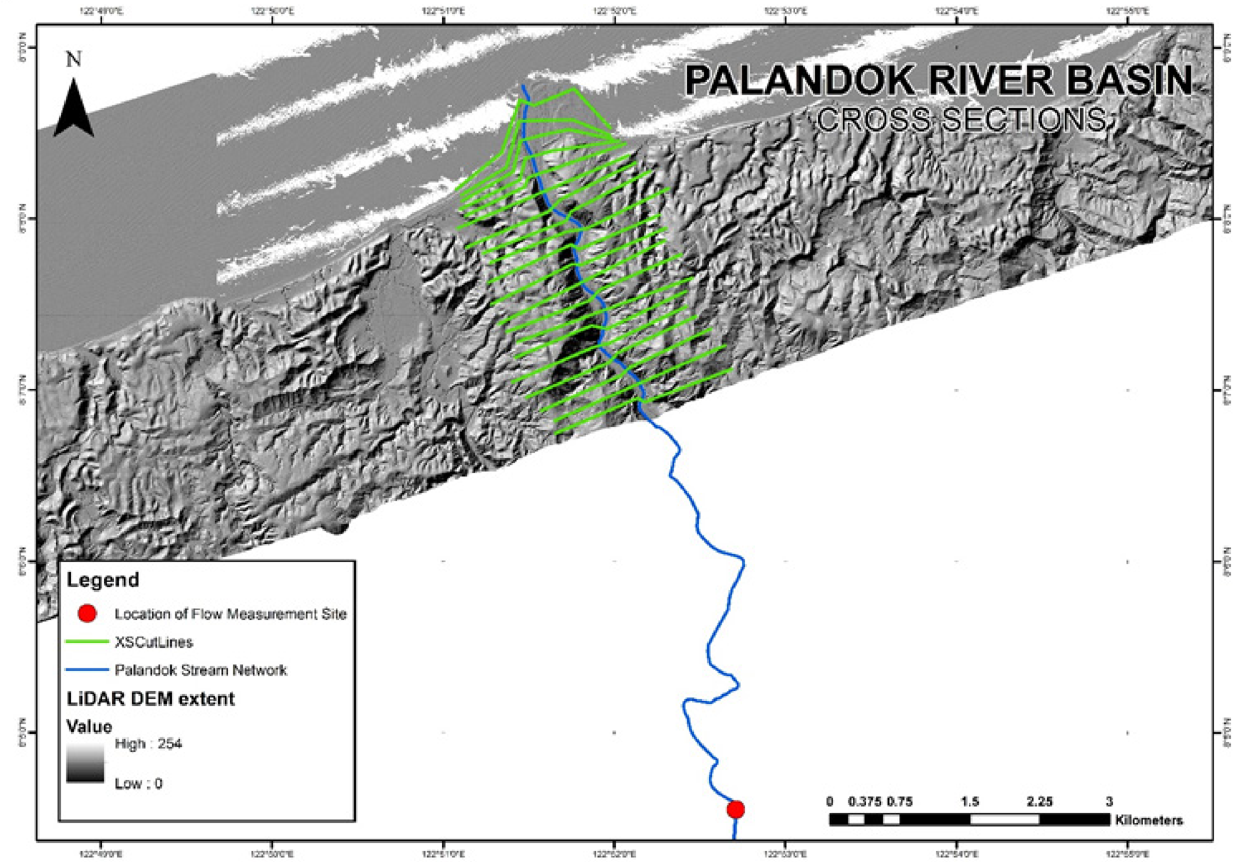



Figure 60. River cross-section of Palandok River generated through Arcmap HEC GeoRAS tool

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

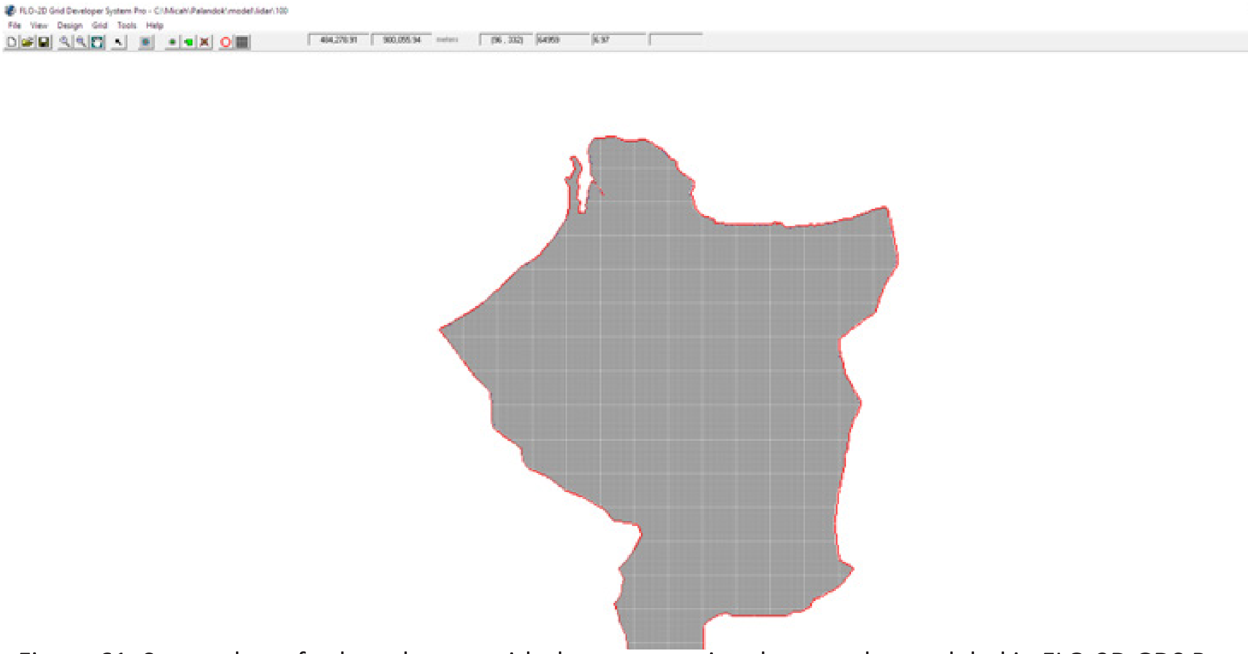


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 4.57031 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

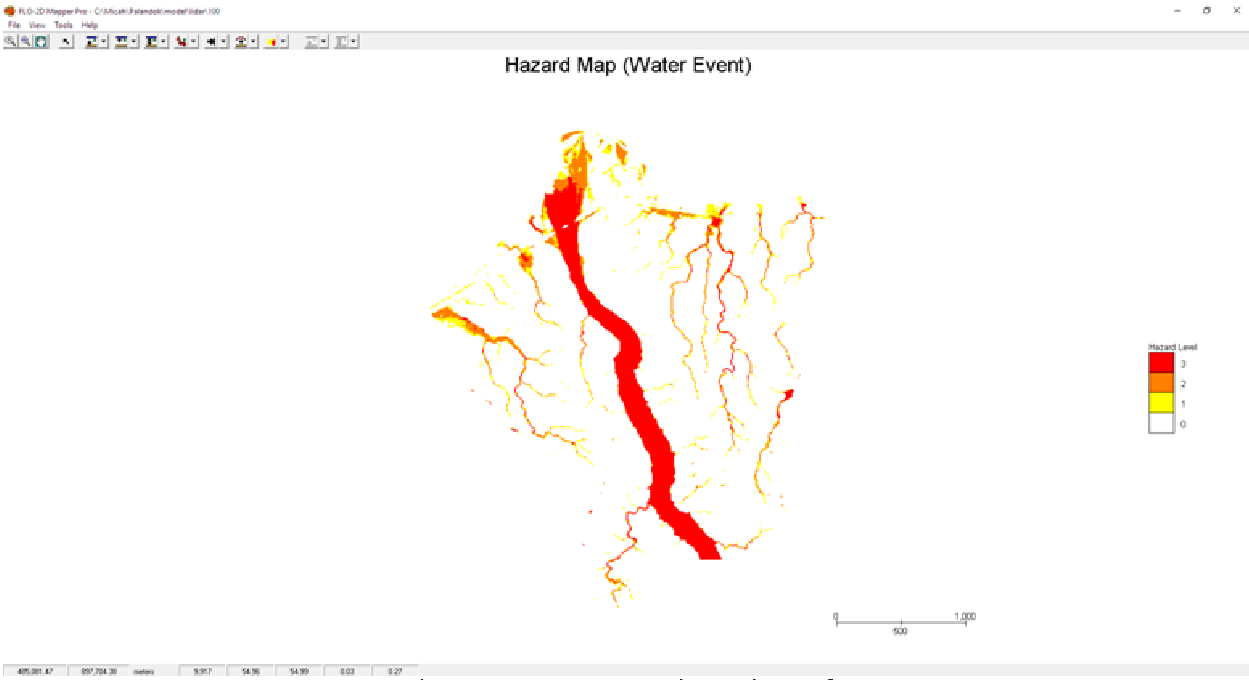



Figure 62. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element.The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 6818900.00 m2.

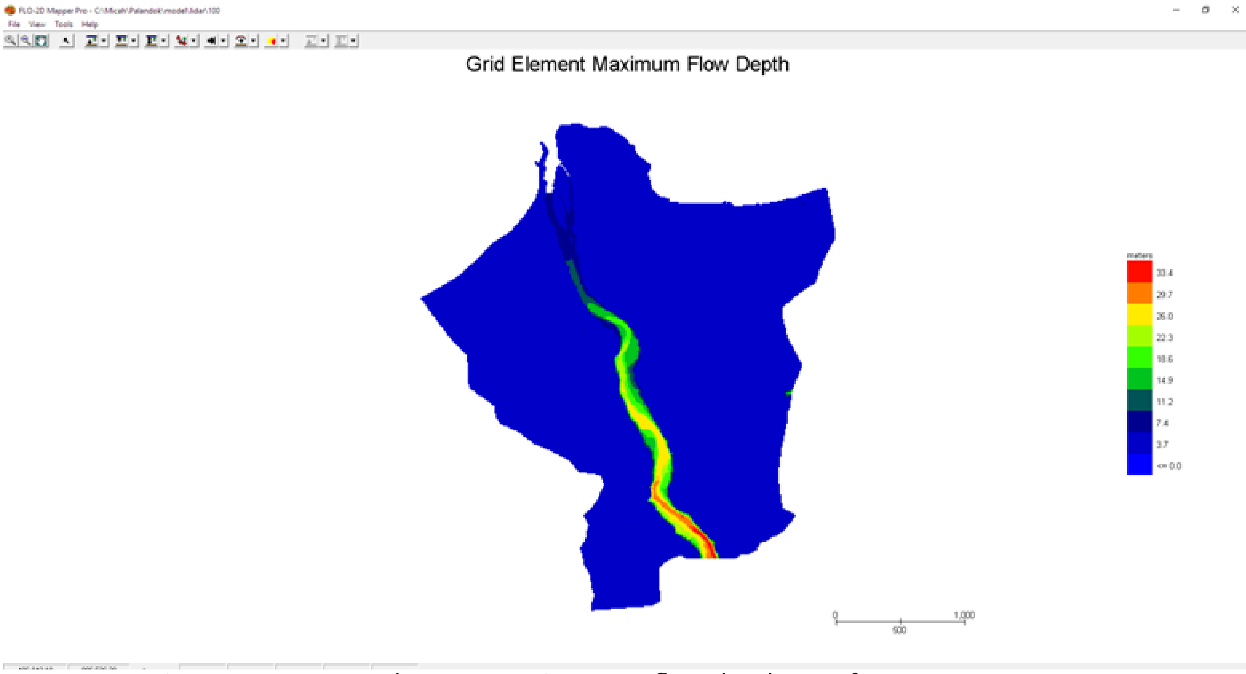


Figure 63. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 32116000.86 m3 of water entering the model. Of this amount, 1407591.65 m3 is due to rainfall while 30708409.22 m3 is inflow from other areas outside the model. 512356.75 m3 of this water is lost to infiltration and interception, while 399268.01 m3 is stored by the flood plain. The rest, amounting up to 31204376.06 m3,is outflow.

## Discharge data using Dr. Horritts's recommended hydrologic method

The river discharge values for the river entering the floodplain are shown in and the peak values are summarized in Table 314.

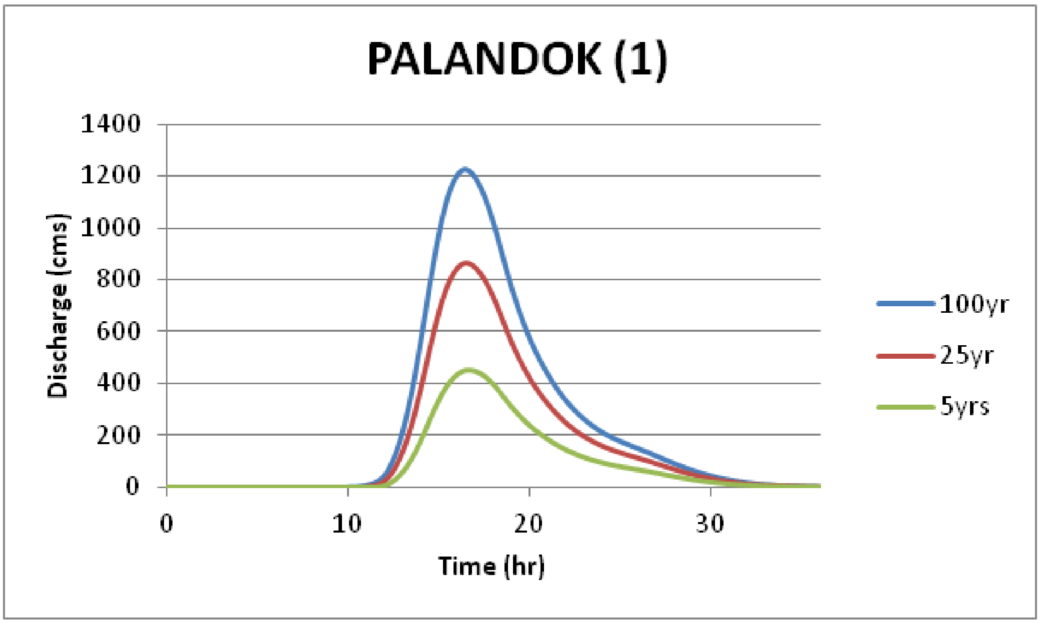



Figure 64. Palandok Rriver (1) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Palandok river (1) discharge generated in HEC-HMS

| RIDF Period | Peak discharge (cms) | Time-to-peak |
|---|---|---|
| 100-Year | 1223.3 | 16 hours, 30 minutes |
| 25-Year | 868.6 | 16 hours, 30 minutes |
| 5-Year | 455 | 16 hours, 40 minutes |

Table 32. Validation of river discharge estimates

| Discharge Point | QMED(SCS), cms | QBANKFUL, cms | QMED(SPEC), cms | VALIDATION | |
|---|---|---|---|---|---|
| | | | | Bankful Discharge | Specific Discharge |
| Palandok (1) | 400.400 | 379.442 | 521.954 | Pass | Pass |

The HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful method and specific discharge methods. The passing values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

## 5.6 Results of HMS Calibration

Table 7. After calibrating the Palandok HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 12 65 shows the comparison between the two discharge data.

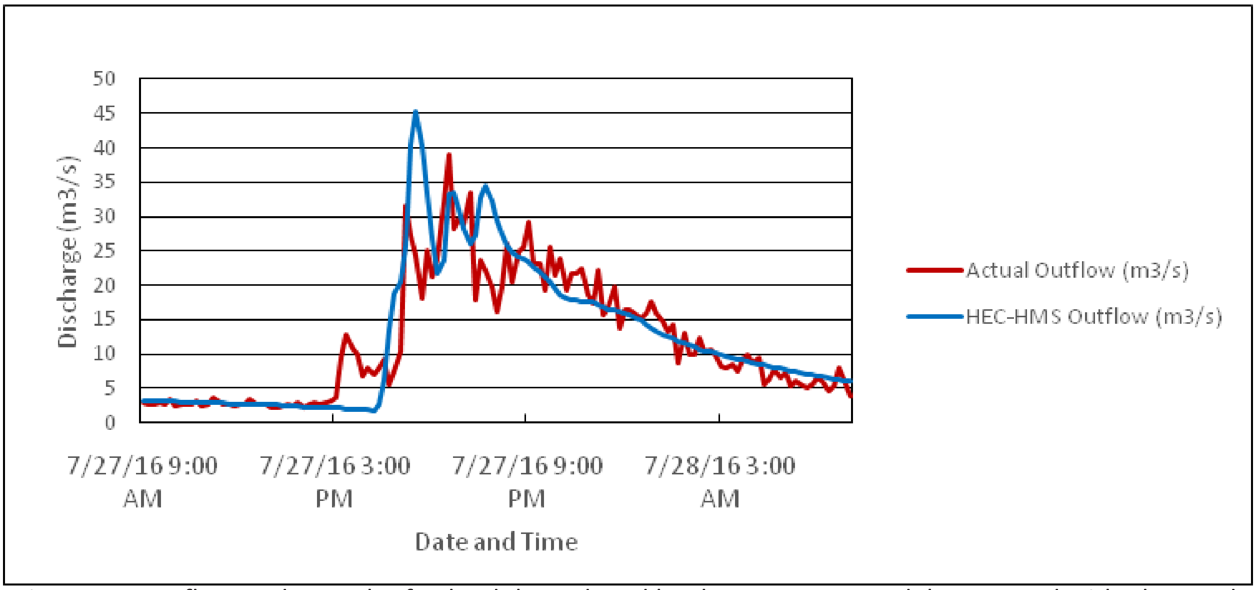



Figure 65. Outflow Hydrograph of Palandok produced by the HEC-HMS model compared with observed outflow

Table 9. Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of Calibrated Values for Palandok

| Hydrologic Element | Calculation Type | Method | Parameter | Range of Calibrated Values |
|---|---|---|---|---|
| Basin | Loss | SCS Curve Number | Initial Abstraction (mm) | 22.66 – 101.27 |
| | | | Curve Number | 15.13 – 27.92 |
| | Transform | Clark Unit Hydrograph | Time of Concentration (hr) | 0.44 – 1.70 |
| | | | Storage Coefficient (hr) | 0.017 – 0.66 |
| | Baseflow | Recession | Recession Constant | 0.05 |
| | | | Ratio to Peak | 0.1 |
| Reach | Routing | Muskingum-Cunge | Manning's Coefficient | 0.044 |

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 22.66mm to 101.27mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The range of curve numbers in this area is 15.13 – 27.92.The magnitude of the outflow hydrograph increases as curve number increases. For Palandok, the soil classes identified were loam and undifferentiated mountain soil. The land cover types identified were shrubland, grassland, open and closed canopy forests, built-up areas and cultivated areas.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.017 hours to 1.70 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 0.05 indicates that the basin is not likely to quickly go back to its original discharge. Ratio to peak of 0.1 indicates a shallower receding limb of the outflow hydrograph.

Table 34. Summary of the Efficiency Test of Palandok HMS Model

| | |
|---|---|
| RMSE | 0.552075 |
| r2 | 0.8284 |
| NSE | 0.695213 |
| PBIAS | -3.27858 |
| RSR | 0.551759 |

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.552075 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8284.

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 0.695213.

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 -3.27858.

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 0.551759.

## 5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

### 5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 1266) shows the Palandok outflow using the Zamboanga City Rainfall Intensity-Duration-FrequencyRIDF 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.

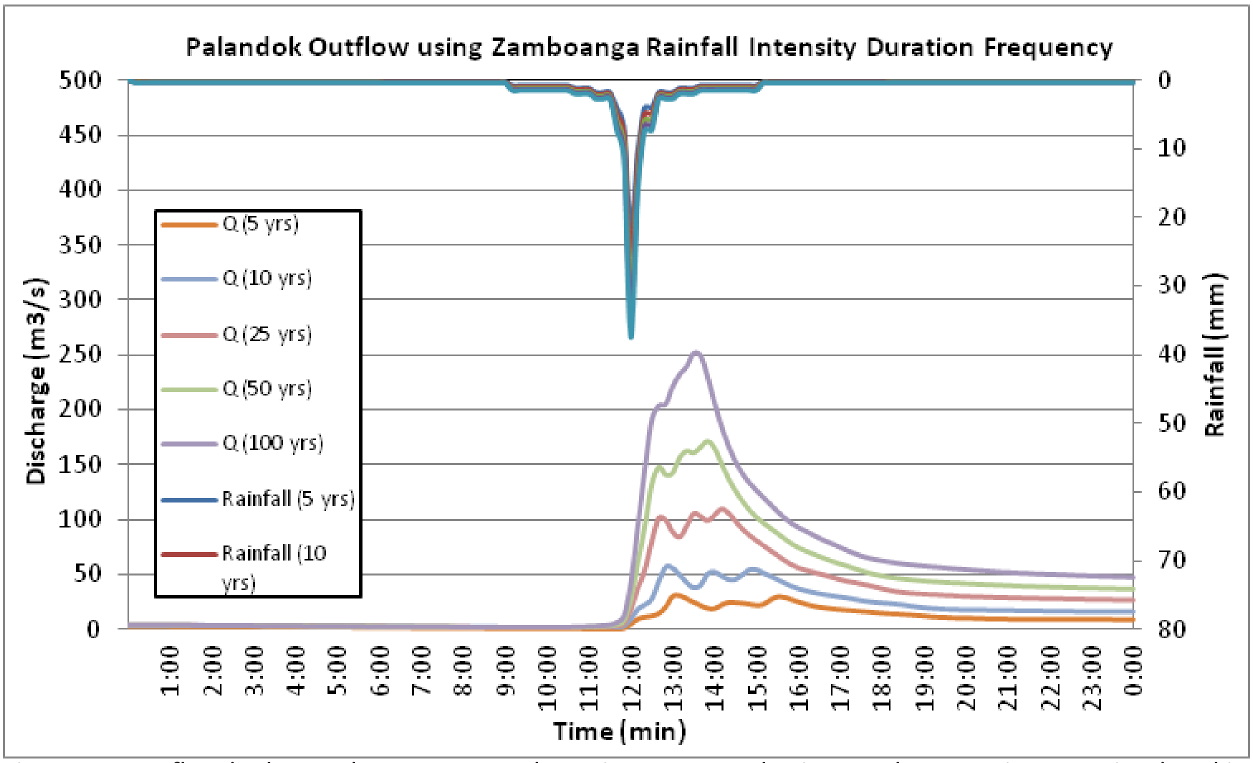



Figure 66. Outflow hydrograph at Brgy. Morob Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Palandok discharge using the Zamboanga City Rainfall Intensity-Duration-FrequencyRIDF curves (RIDF) in five different return periods is shown in Table 35.

Table 35. Peak values of the Palandok HECHMS Model outflow using the Zamboanga City RIDF

| RIDF Period | Total Precipitation (mm) | Peak Rainfall (mm) | Peak Outflow (m3/s) | Time to Peak |
|---|---|---|---|---|
| 5-year RIDF | 107.80 | 21.40 | 30.50 | 13 hours and 10 minutes |
| 10-year RIDF | 127.90 | 25.30 | 56.40 | 12 hours and 50 minutes |
| 25-year RIDF | 153.40 | 30.20 | 110.20 | 14 hours and 10 minutes |
| 50-year RIDF | 172.30 | 33.90 | 171.50 | 13 hours and 50 minutes |
| 100-year RIDF | 191.10 | 37.50 | 251.70 | 13 hours and 30 minutes |

## 5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will bewas used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Palandok River using the calibrated HMS base flow is shown in Figure 67.

Figure 67. Sample output of Palandok RAS Model

## 5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 14 to Figure 19 shows the 1005-, 25-, and 5100-year rain return scenarios of the Palandok floodplainFloodplain.

The generated flood hazard maps for the Palandok 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 36. Municipalities affected in Palandok floodplainFloodplain

| Municipality | Total Area | Area Flooded | % Flooded |
|---|---|---|---|
| Bacungan | 250.41 | 4.11 | 1.64% |
| Salug | 144.44 | 2.62 | 1.81% |

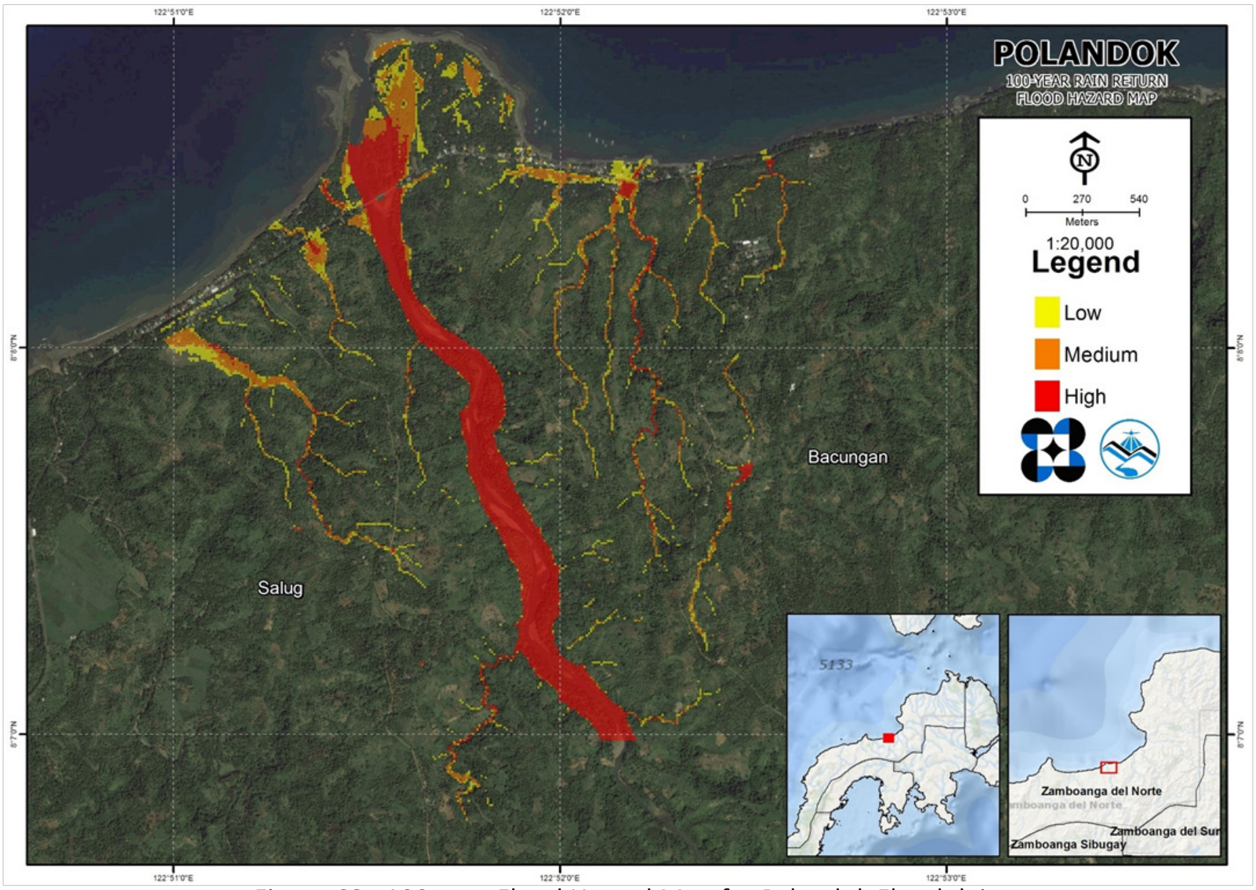



Figure 68. 100-year Flood Hazard Map for Palandok Floodplain

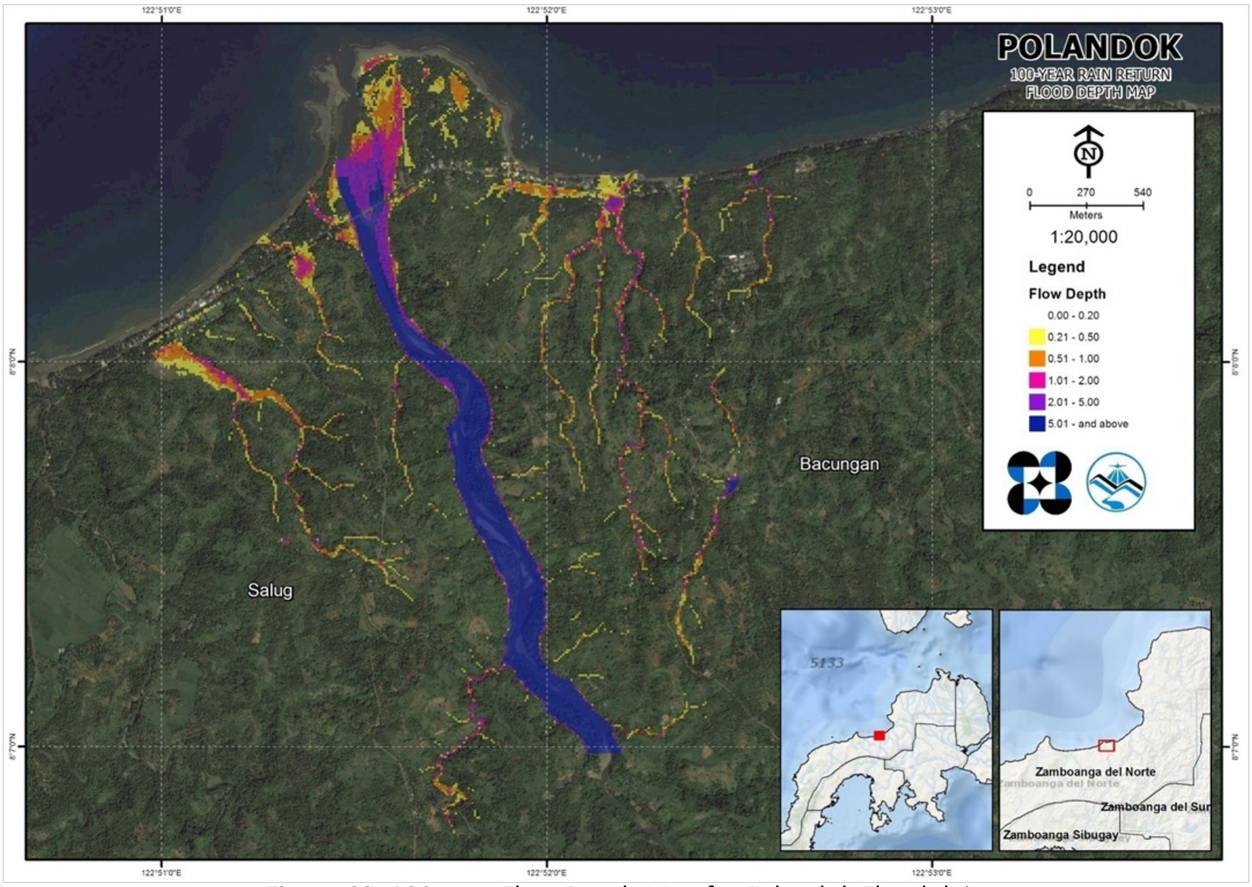



Figure 69. 100-year Flow Depth Map for Palandok Floodplain

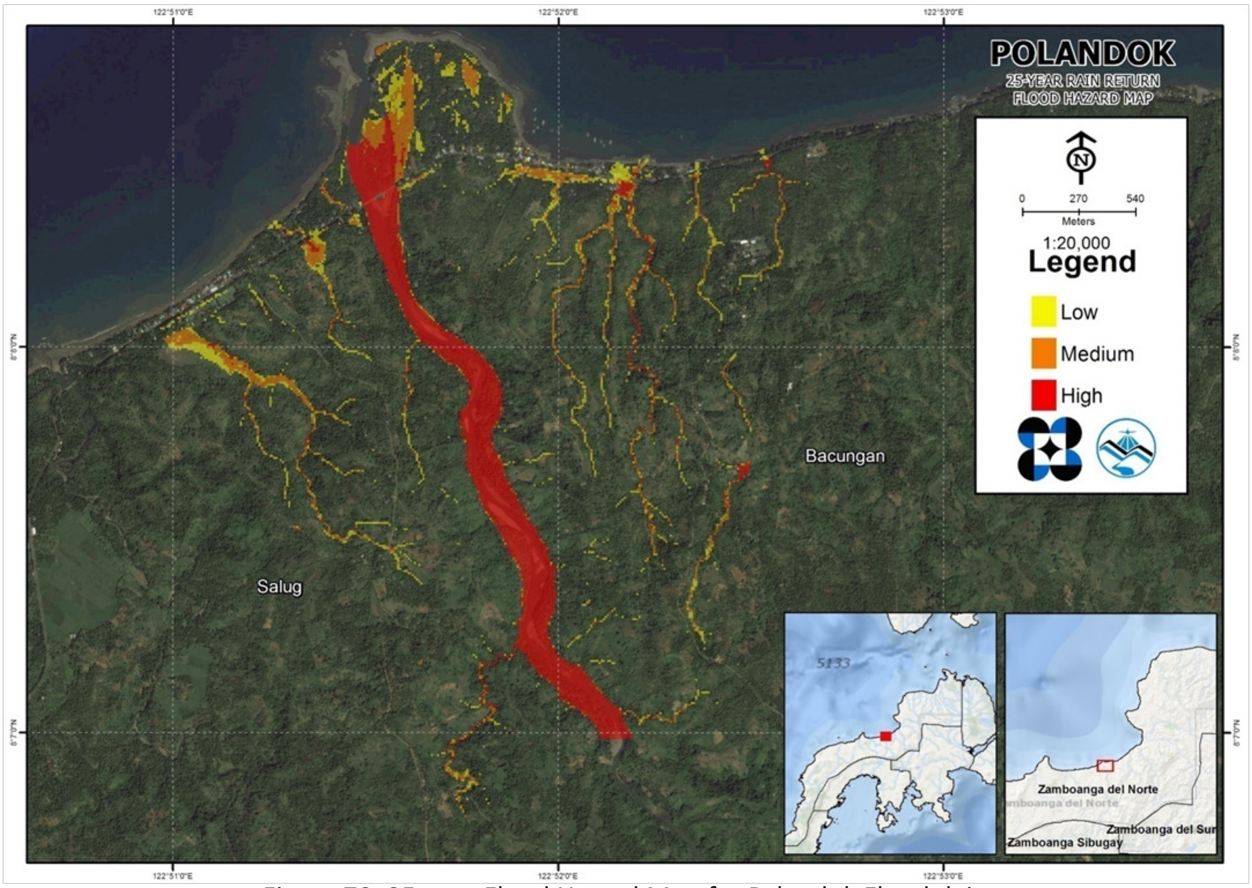



Figure 70. 25-year Flood Hazard Map for Palandok Floodplain

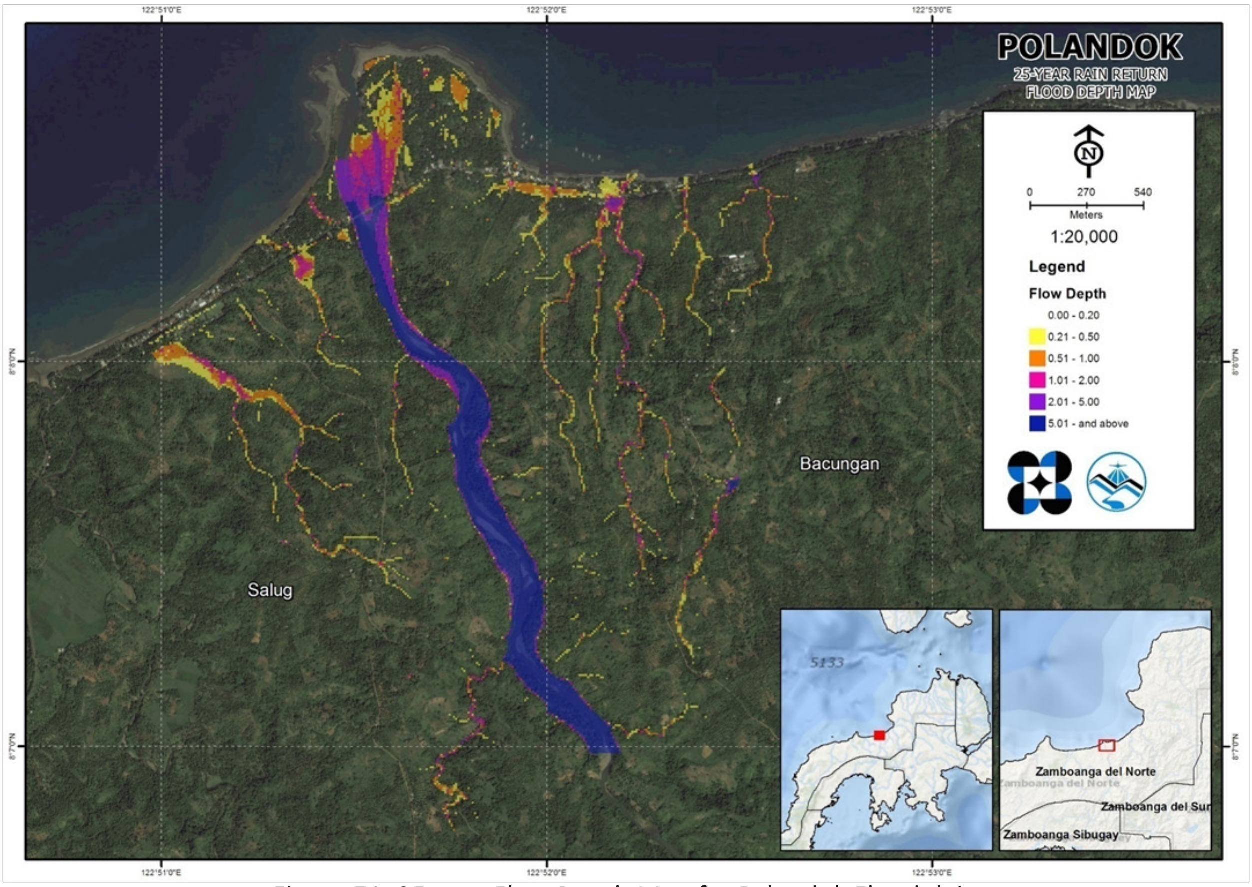



Figure 71. 25-year Flow Depth Map for Palandok Floodplain

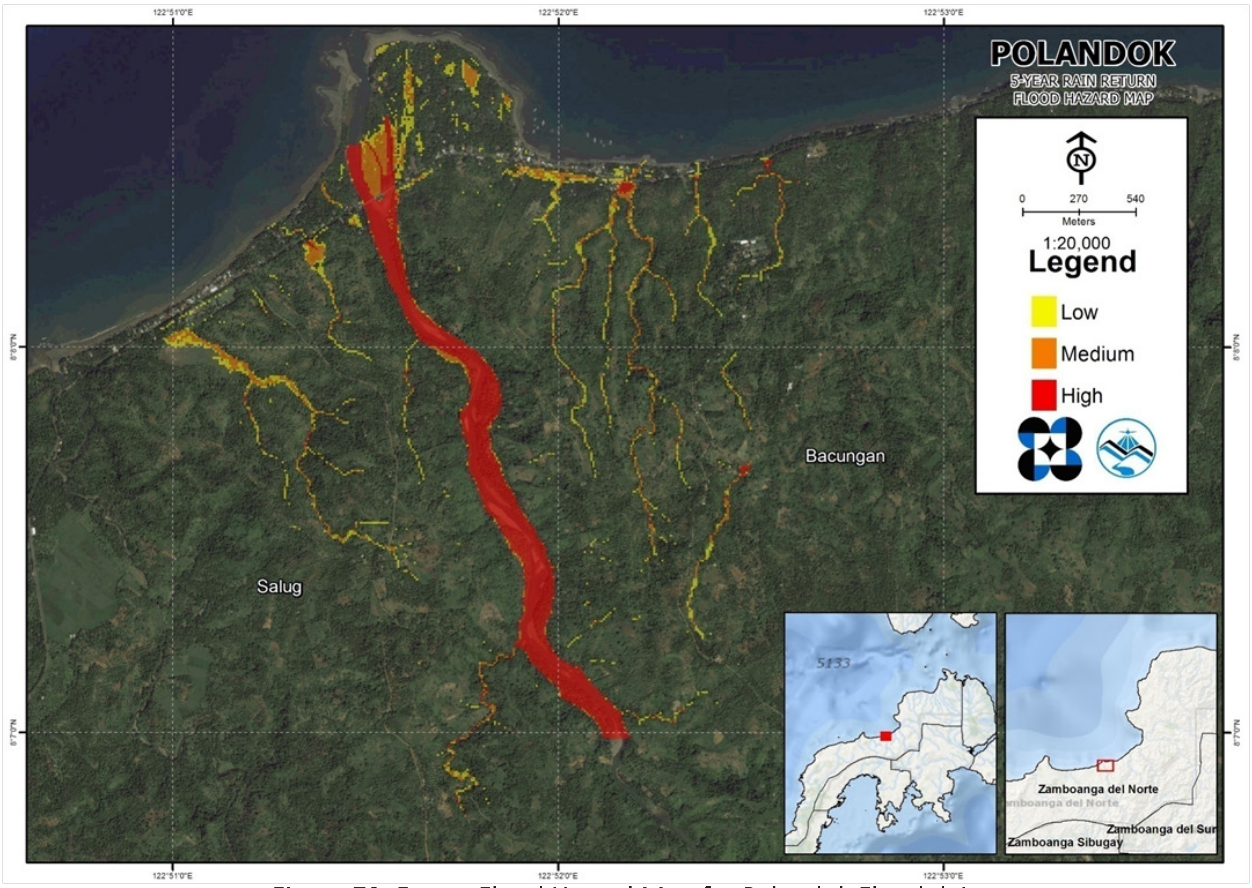



Figure 72. 5-year Flood Hazard Map for Palandok Floodplain

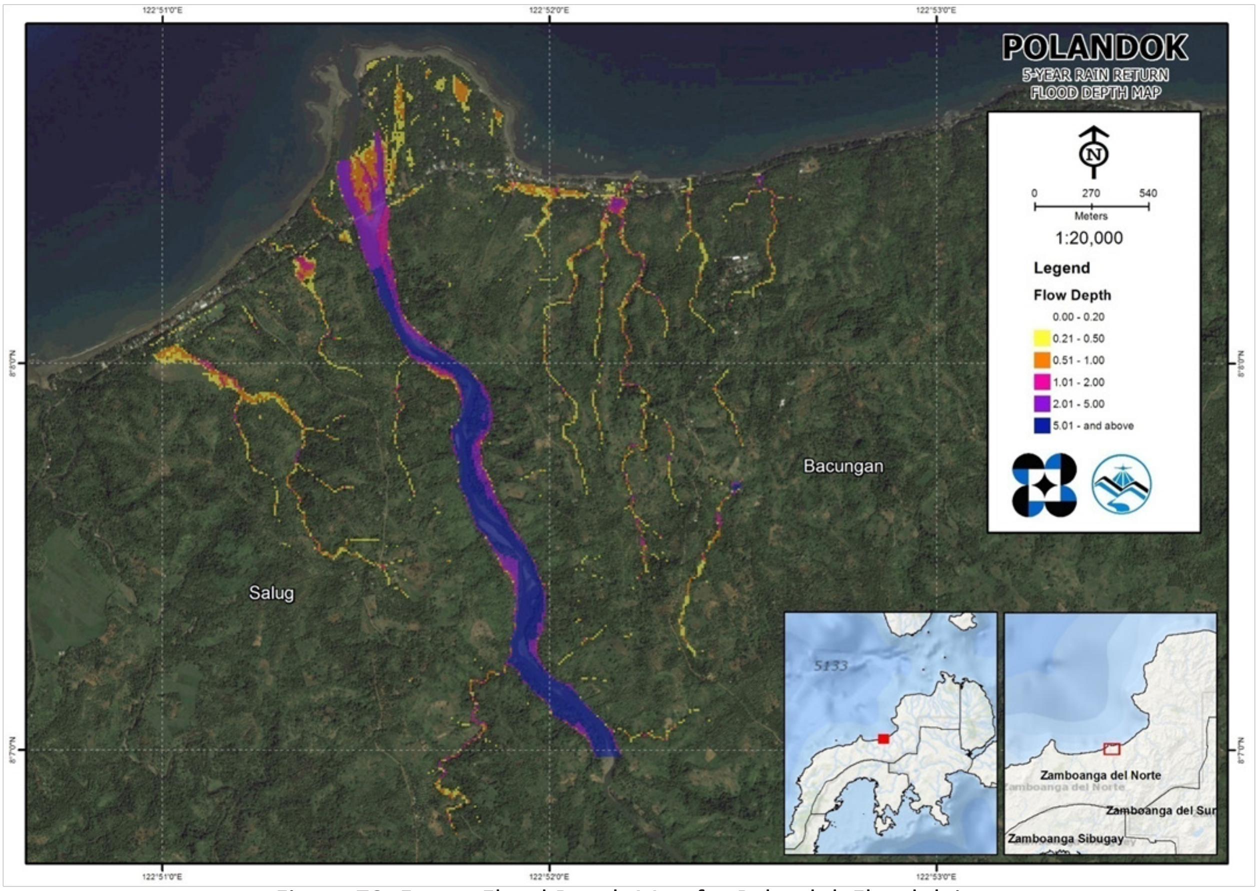



Figure 73. 5-year Flood Depth Map for Palandok Floodplain

## 5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Palandok River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 3 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 1.43% of the municipality of Bacungan with an area of 250.41 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.04%, 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 the table 37 are the affected areas in square kilometers by flood depth per barangay.

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

| Affected area (sq. km.) by flood depth ( in m.) | | Area of affected barangays in Roseller Lim (in sq. km.) | |
|---|---|---|---|
| | | Bogabongan | Rizon |
| Affected Area (sq. km.) | 1 | 0.38 | 3.19 |
| | 2 | 0.011 | 0.11 |
| | 3 | 0.0049 | 0.082 |
| | 4 | 0.0011 | 0.043 |
| | 5 | 0.0012 | 0.092 |
| | 6 | 0.00025 | 0.19 |

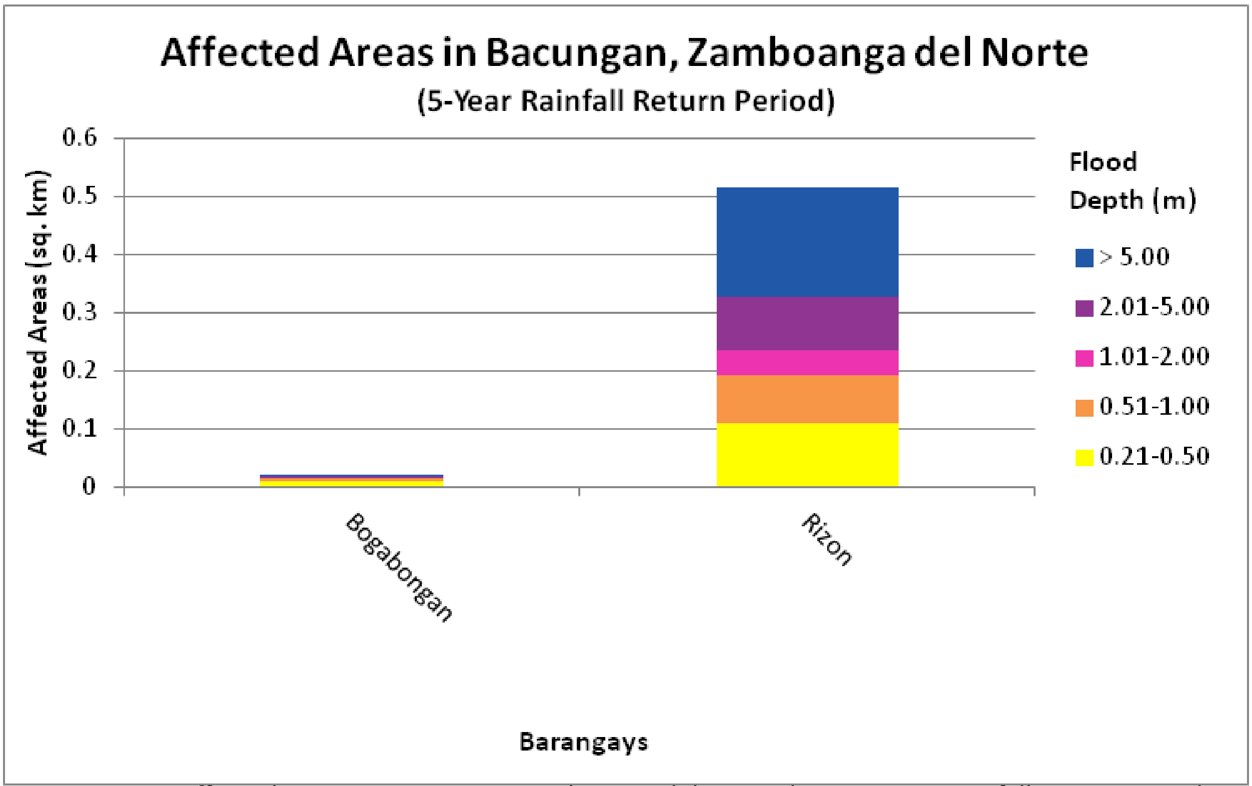



Figure 74. Affected Areas in Bacungan, Zamboanga del Norte during 5-Year Rainfall Return Period

For the 5-year return period, 1.65% of the municipality of Salug with an area of 144.44 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.02%, 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 the table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Salug, Zamboanga del Norte during 5-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | | Area of affected barangays in Roseller Lim (in sq. km.) |
|---|---|---|
| | | Ramon Magsaysay |
| Affected Area (sq. km.) | 1 | 2.39 |
| | 2 | 0.064 |
| | 3 | 0.043 |
| | 4 | 0.022 |
| | 5 | 0.03 |
| | 6 | 0.067 |

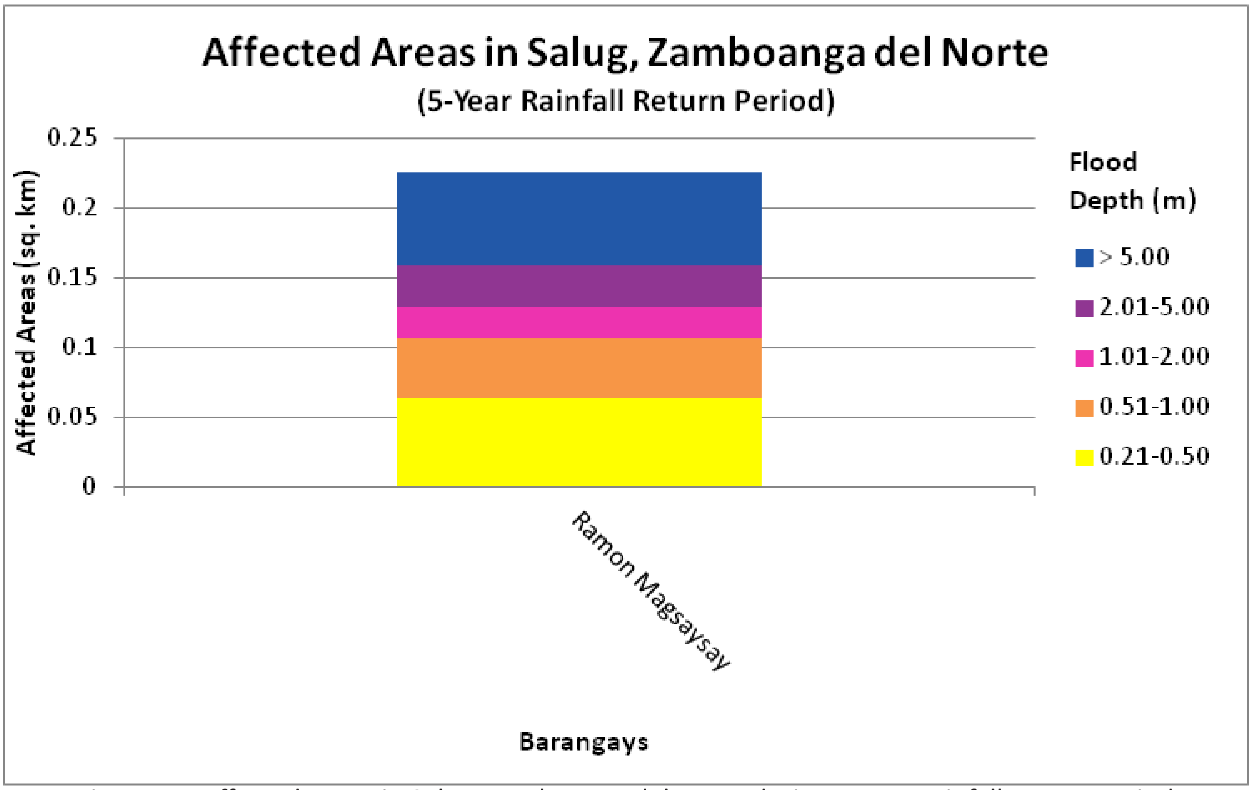


Figure 75. Affected Areas in Salug, Zamboanga del Norte during 5-Year Rainfall Return Period

For the 25-year return period, 1.39% of the municipality of Bacungan with an area of 250.41 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.03%, 0.03%, and 0.10% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Bacungan, Zamboanga del Norte during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | | Area of affected barangays in Roseller Lim (in sq. km.) | |
|---|---|---|---|
| | | Bogabongan | Rizon |
| Affected Area (sq. km.) | 1 | 0.38 | 3.09 |
| | 2 | 0.011 | 0.12 |
| | 3 | 0.0076 | 0.1 |
| | 4 | 0.0018 | 0.065 |
| | 5 | 0.0014 | 0.073 |
| | 6 | 0.00036 | 0.26 |

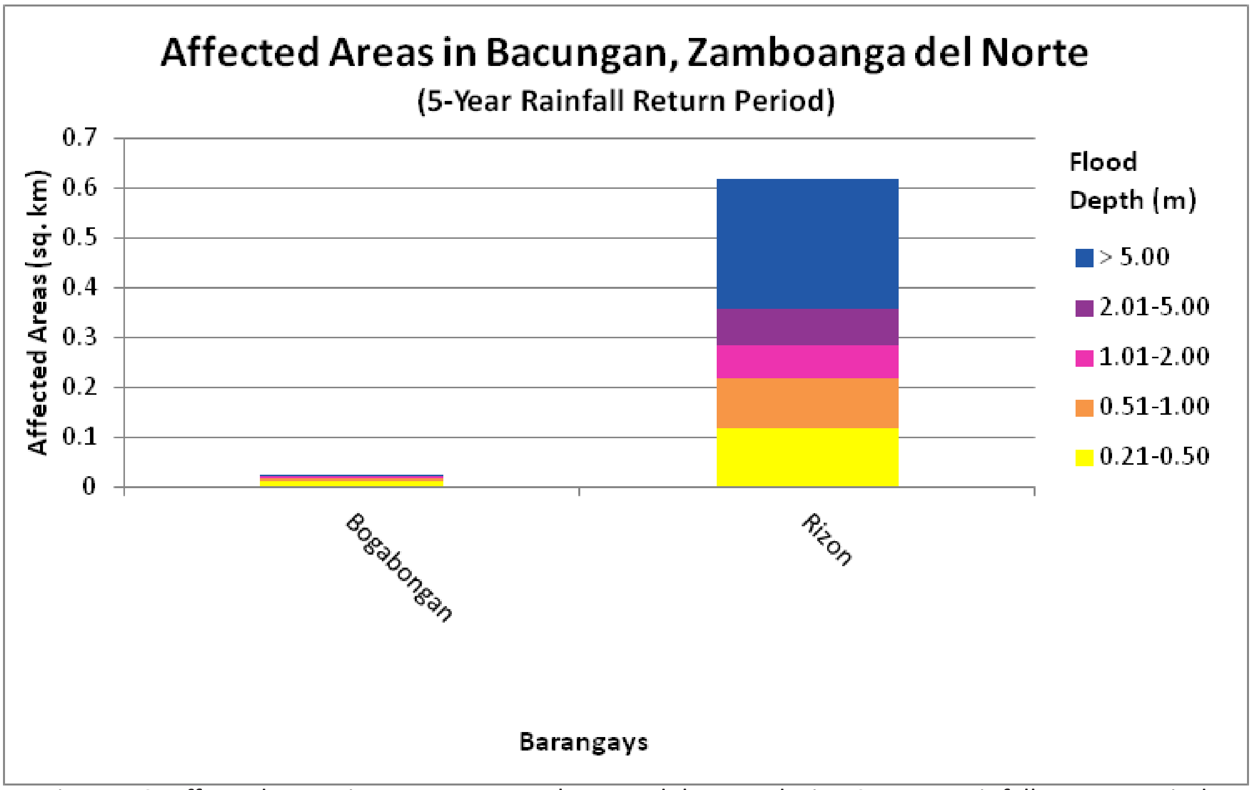



Figure 76. Affected Areas in Bacungan, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 25-year return period, 1.61% of the municipality of Salug with an area of 144.44 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.02%, 0.02%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Salug, Zamboanga del Norte during 25-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | | Area of affected barangays in Roseller Lim (in sq. km.) |
|---|---|---|
| | | Ramon Magsaysay |
| Affected Area (sq. km.) | 1 | 2.33 |
| | 2 | 0.075 |
| | 3 | 0.054 |
| | 4 | 0.031 |
| | 5 | 0.029 |
| | 6 | 0.095 |

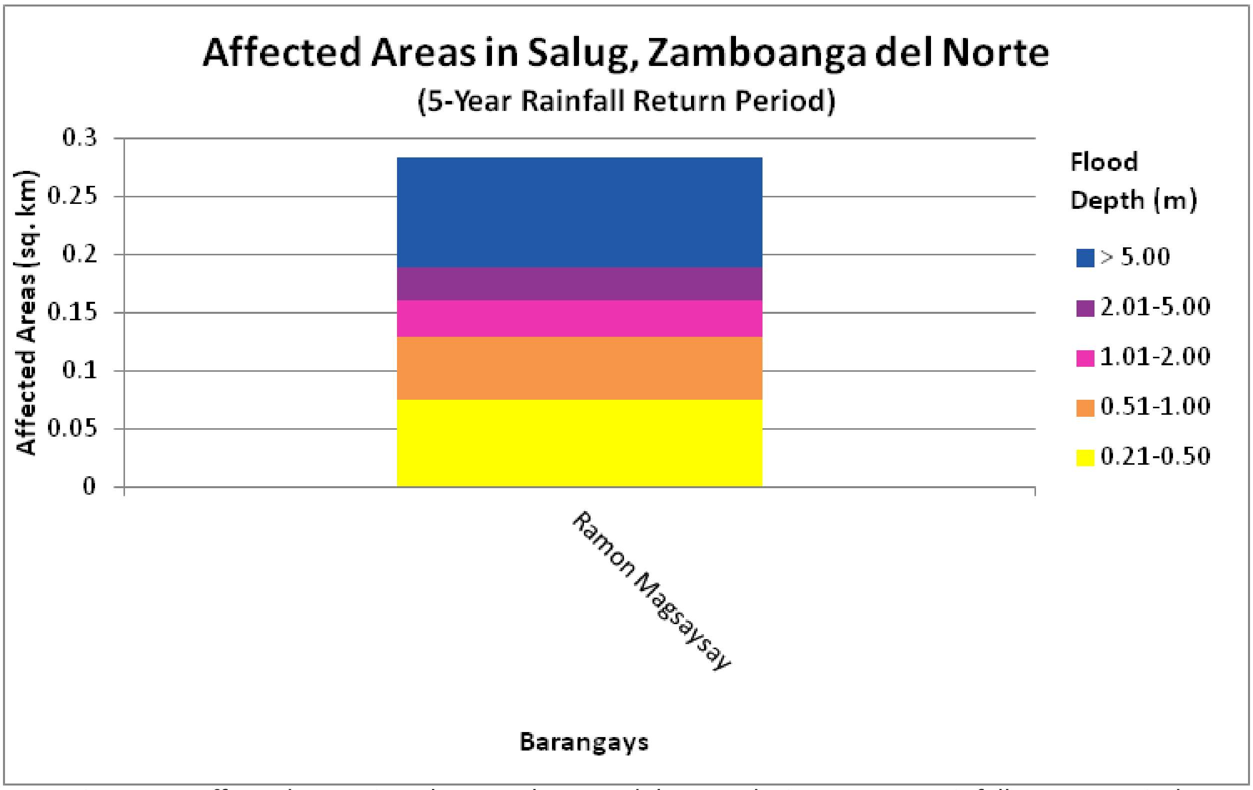



Figure 77. Affected Areas in Salug, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 100-year return period, 1.36% of the municipality of Bacungan with an area of 250.41 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.03%, 0.03%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Bacungan, Zamboanga del Norte during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | | Area of affected barangays in Roseller Lim (in sq. km.) | |
|---|---|---|---|
| | | Bogabongan | Rizon |
| Affected Area (sq. km.) | 1 | 0.38 | 3.02 |
| | 2 | 0.011 | 0.13 |
| | 3 | 0.0087 | 0.11 |
| | 4 | 0.003 | 0.079 |
| | 5 | 0.0013 | 0.079 |
| | 6 | 0.00052 | 0.29 |

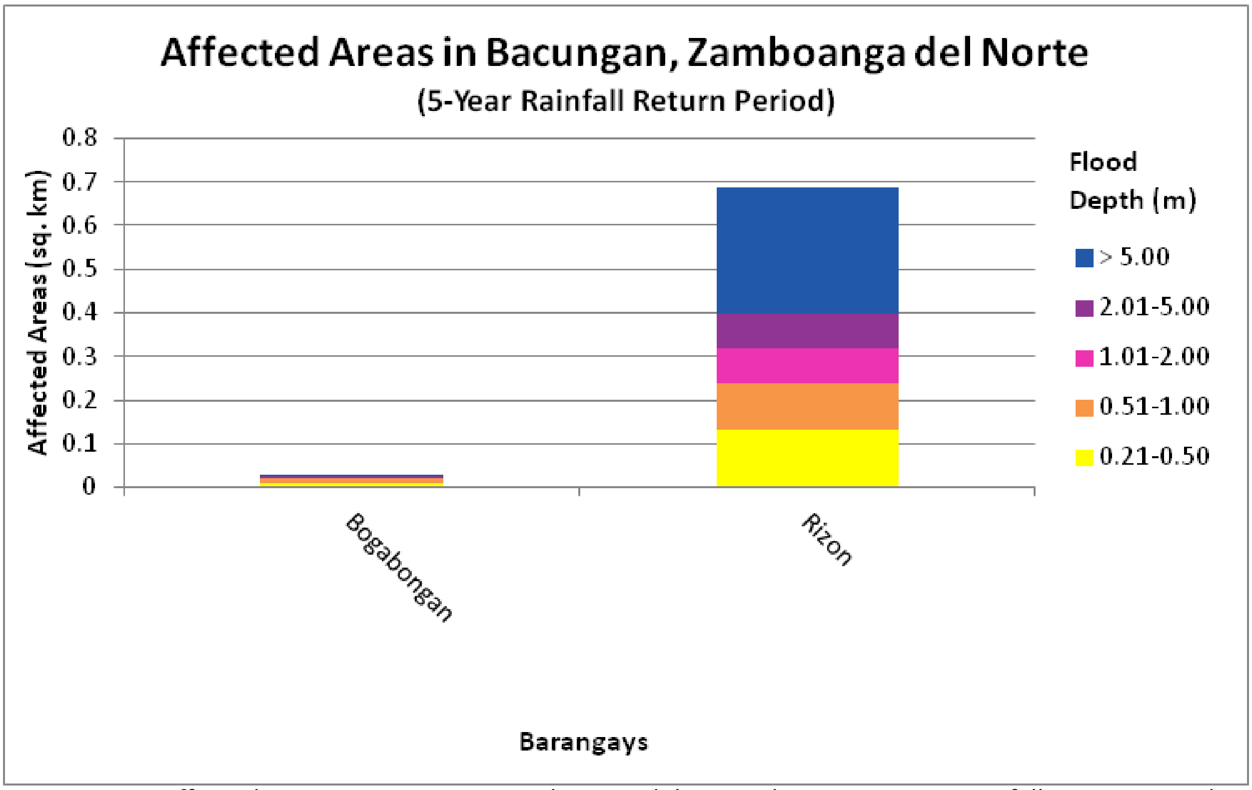



Figure 78. Affected Areas in Bacungan, Zamboanga del Norte during 100-Year Rainfall Return Period

For the 100-year return period, 1.58% of the municipality of Salug with an area of 144.44 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.03%, 0.02%, 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 the table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Salug, Zamboanga del Norte during 100-Year Rainfall Return Period

| Affected area (sq. km.) by flood depth ( in m.) | | Area of affected barangays in Roseller Lim (in sq. km.) |
|---|---|---|
| | | Ramon Magsaysay |
| Affected Area (sq. km.) | 1 | 2.28 |
| | 2 | 0.085 |
| | 3 | 0.068 |
| | 4 | 0.037 |
| | 5 | 0.025 |
| | 6 | 0.12 |

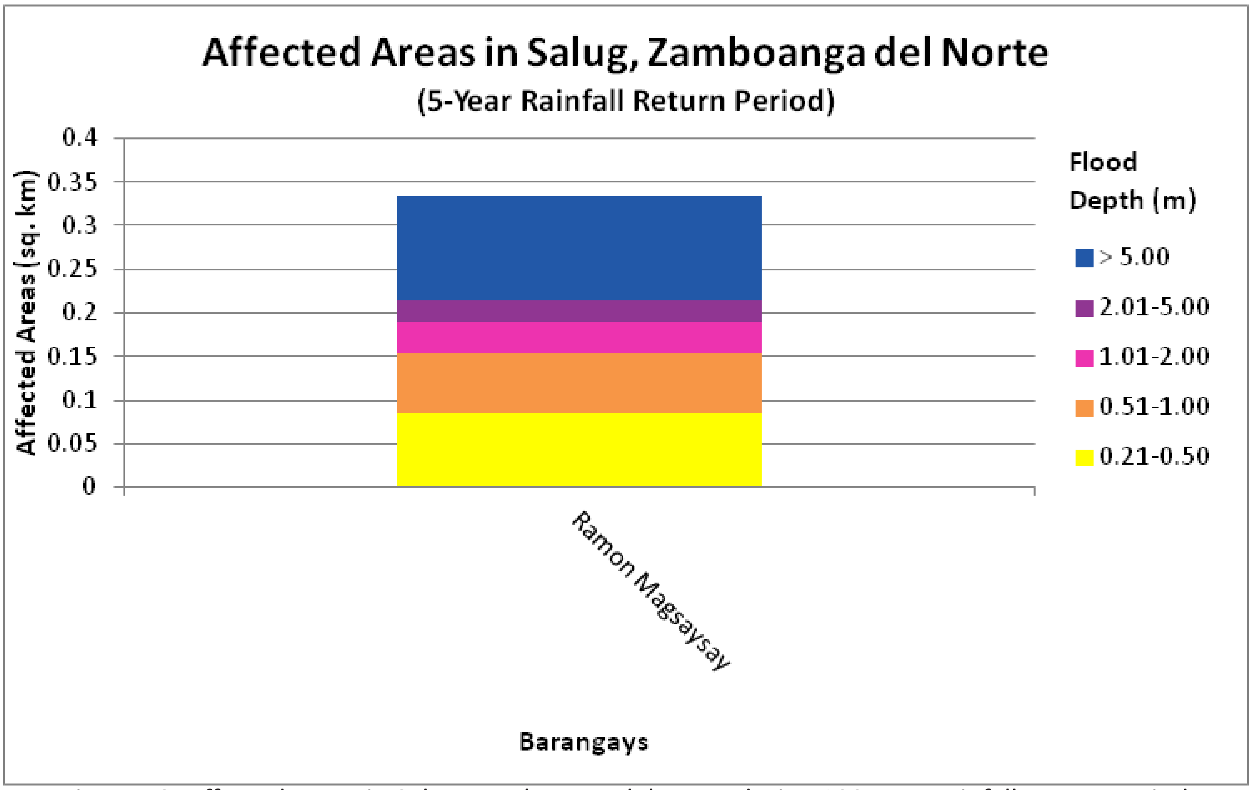



Figure 79. Affected Areas in Salug, Zamboanga del Norte during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Palandok 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 43. 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 | 0.18 | 0.20 | 0.22 |
| Medium | 0.17 | 0.22 | 0.26 |
| High | 0.40 | 0.50 | 0.57 |
| TOTAL | 0.75 | 0.92 | 1.05 |

Of the 6 identified educational and medical institutions and buildings, none were assessed to be exposed to any flood hazard level for any rain return scenario.
See Appendix Annex D 12 and E Annex 13 for a detailed enumeration of schools, hospitals and clinics in the Palandok floodplainFloodplain.

## 5.11 Flood Validation

The flood validation consists of 189 points randomly selected all over the Palandok flood plainFloodplain. It has an RMSE value of 1.66.

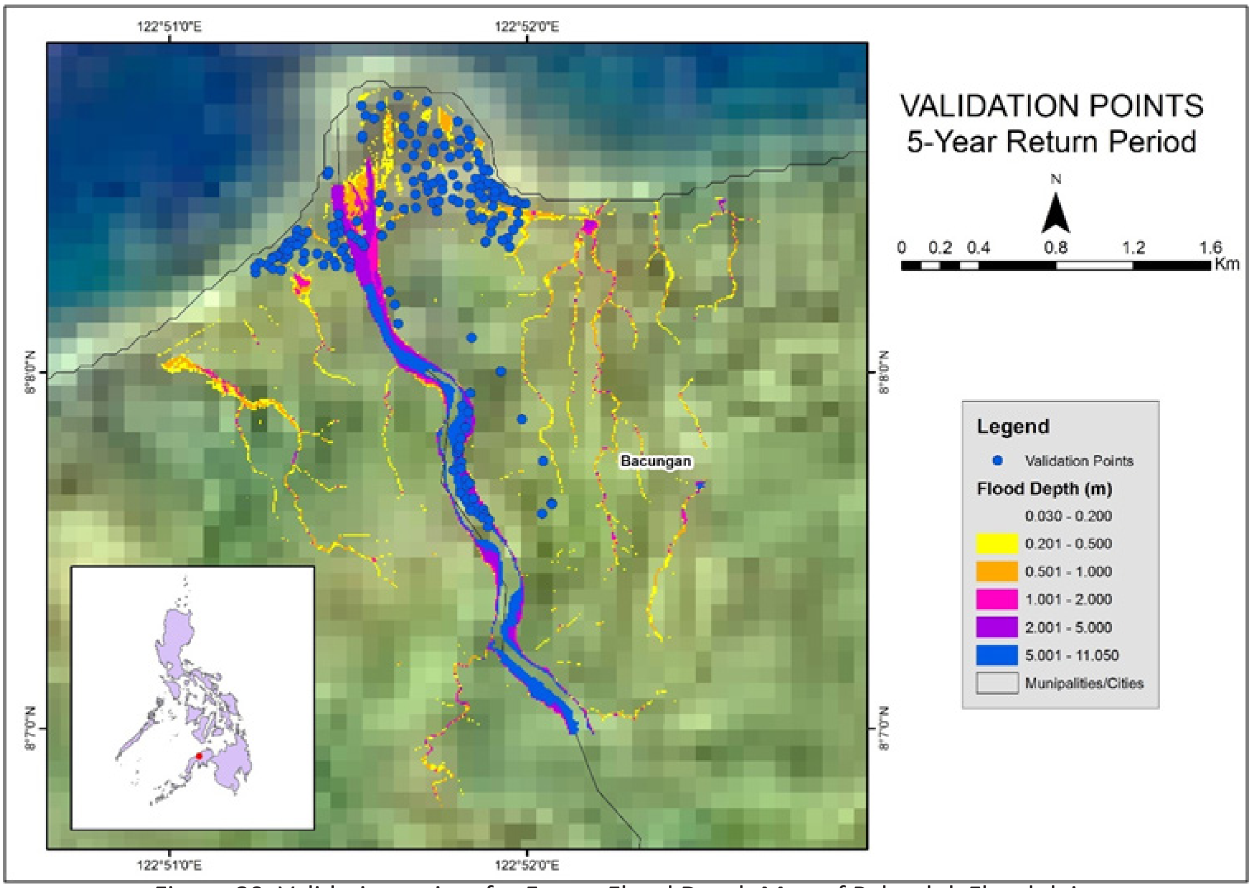



Figure 80. Validation points for 5-year Flood Depth Map of Palandok Floodplain

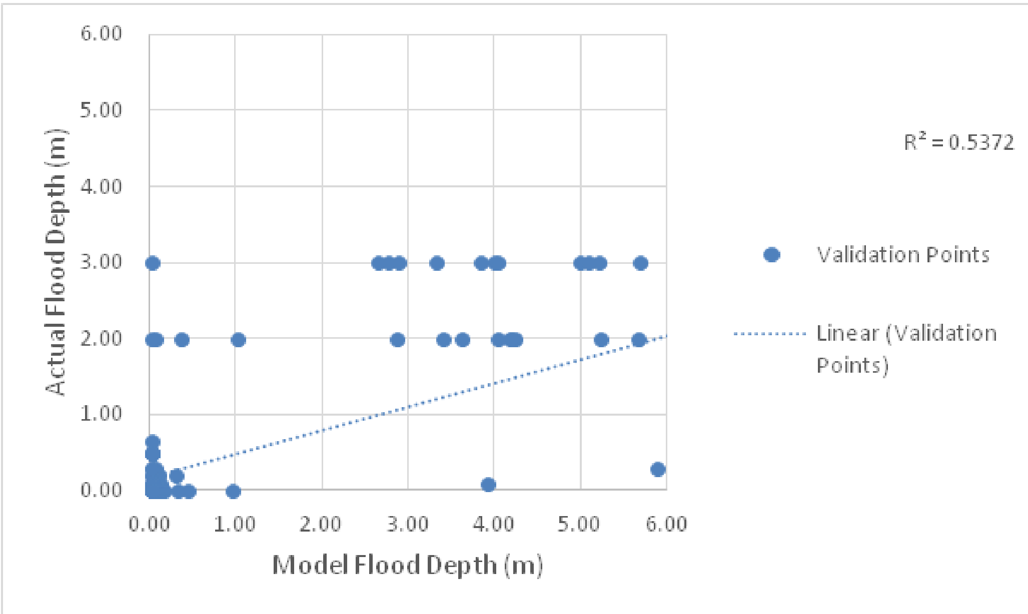



Figure 81. Flood map depth vs actual flood depth

Table 45. Actual Flood Depth vs Simulated Flood Depth in Palandok

| PALANDOK BASIN | | Modeled Flood Depth (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **0-0.20** | **0.21-0.50** | **0.51-1.00** | **1.01-2.00** | **2.01-5.00** | **> 5.00** | **Total** |
| **Actual Flood Depth (m)** | 0-0.20 | 143 | 3 | 1 | 0 | 1 | 0 | 148 |
| | 0.21-0.50 | 8 | 0 | 0 | 0 | 0 | 1 | 9 |
| | 0.51-1.00 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 1.01-2.00 | 2 | 1 | 0 | 1 | 7 | 7 | 18 |
| | 2.01-5.00 | 1 | 0 | 0 | 0 | 7 | 5 | 13 |
| | > 5.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | **155** | 4 | 1 | 1 | 15 | 13 | 189 |

The overall accuracy generated by the flood model is estimated at 79.89% with 151 points correctly matching the actual flood depths. In addition, there were 23 points estimated one level above and below the correct flood depths while there were 10 points and 5 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 13 points were underestimated in the modelled flood depths of PalandocPalandok.

Table 46. Summary of Accuracy Assessment in Palandok

| | No. of Points | % |
|---|---|---|
| Correct | 151 | 79.89 |
| Overestimated | 25 | 13.23 |
| Underestimated | 13 | 6.88 |
| Total | 189 | 100.00 |

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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.

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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.

http://www.islandsproperties.com/places/zambonor.htm).

*Sources:*

*Municipal Profile of Leon B. Postigo*

*Mines and Geosciences Bureau*

*Philippine Institute of Vulcanology and Seismology*

# ANNEXES

## Annex 1. Technical Specifications of the LIDAR Sensors used in the Palandok Floodplain Survey

Table A-1.1 Parameters and Specifications


| Parameter | Specification |
|---|---|
| Operational envelope (1,2,3,4) | 150-4000 m AGL, nominal |
| Laser wavelength | 1064 nm |
| Horizontal accuracy (2) | 1/5,500 x altitude, (m AGL) |
| Elevation accuracy (2) | <5-35 cm, 1 σ |
| Effective laser repetition rate | Programmable, 33-167 kHz |
| Position and orientation system | POS AV™ AP50 (OEM);<br>220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver |
| Scan width (WOV) | Programmable, 0-50˚ |
| Scan frequency (5) | Programmable, 0-70 Hz (effective) |
| Sensor scan product | 1000 maximum |
| Beam divergence | Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal |
| Roll compensation | Programmable, ±5˚ (FOV dependent) |
| Range capture | Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns |
| Intensity capture | Up to 4 intensity returns for each pulse, including last (12 bit) |
| Video Camera | Internal video camera (NTSC or PAL) |
| Image capture | Compatible with full Optech camera line (optional) |
| Full waveform capture | 12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional) |
| Data storage | Removable solid state disk SSD (SATA II) |
| Power requirements | 28 V; 900 W;35 A(peak) |

| | |
|---|---|
| Dimensions and weight | Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg<br>Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg |
| Operating temperature | -10˚C to +35˚C (with insulating jacket) |
| Relative humidity | 0-95% no-condensing |

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

ZGN-132

Figure A-2.1 ZGN-132

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

October 30, 2014

**CERTIFICATION**

To whom it may concern:

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

Province: **ZAMBOANGA DEL NORTE**
Station Name: **ZGN-132**
Order: **2nd**

| | | | | | |
|---|---|---|---|---|---|
| Island: | **MINDANAO** | Barangay: | **MANDIH** | | |
| Municipality: | **SINDANGAN** | MSL Elevation: | | | |
| | | ***PRS92 Coordinates*** | | | |
| Latitude: | **8° 12' 44.29460"** | Longitude: | **123° 0' 19.12667"** | Ellipsoidal Hgt: | **11.50200 m.** |
| | | ***WGS84 Coordinates*** | | | |
| Latitude: | **8° 12' 40.63408"** | Longitude: | **123° 0' 24.56923"** | Ellipsoidal Hgt: | **75.58000 m.** |
| | | ***PTM / PRS92 Coordinates*** | | | |
| Northing: | **908029.029 m.** | Easting: | **500585.389 m.** | Zone: | **4** |
| | | ***UTM / PRS92 Coordinates*** | | | |
| Northing: | **907,711.20** | Easting: | **500,585.18** | Zone: | **51** |

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGN-132, 2009 NAMRIA".Located at brgy. Mandih sindangan zamboanga del norte. The monument is situated inside mandih central school 30 meters from the gate going east.

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2585**

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

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

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

ZN-123

Vector Components (Mark to Mark)

| From: | ZGN 132 | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 500585.184 m | Latitude | N8°12'44.29460" | Latitude | N8°12'40.63408" |
| Northing | 907711.203 m | Longitude | E123°00'19.12667" | Longitude | E123°00'24.56923" |
| Elevation | 10.036 m | Height | 11.502 m | Height | 75.580 m |

| To: | ZN 123 AM | | | | |
|---|---|---|---|---|---|
| Grid | | Local | | Global | |
| Easting | 500592.329 m | Latitude | N8°13'08.18558" | Latitude | N8°13'04.52332" |
| Northing | 908444.828 m | Longitude | E123°00'19.36053" | Longitude | E123°00'24.80249" |
| Elevation | 8.704 m | Height | 10.101 m | Height | 74.166 m |

| Vector | | | | | |
|---|---|---|---|---|---|
| ΔEasting | 7.145 m | NS Fwd Azimuth | 0°33'32" | ΔX | 51.898 m |
| ΔNorthing | 733.625 m | Ellipsoid Dist. | 733.953 m | ΔY | -93.002 m |
| ΔElevation | -1.333 m | ΔHeight | -1.401 m | ΔZ | 726.187 m |

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

| | X | Y | Z |
|---|---|---|---|
| X | 0.0000005039 | | |
| Y | -0.0000002536 | 0.0000007702 | |
| Z | -0.0000000601 | 0.0000000520 | 0.0000001616 |

Figure A-3.1 ZN-123

# Annex 4. The LIDAR Survey Team Composition

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

Table A-4.1. The LiDAR Survey Team Composition

# Annex 5. Data Transfer Sheet Palandok Floodplain

DATA TRANSFER SHEET
11/17/2014(dipolog)

| 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 | |
| 19-Oct | 2099P | 1BLK69CALIB292A | PEGASUS | 106 | na | 3.84 | 113 | 9.11 | 83 | 3.84 | na | 4.08 | 1KB | 1KB | 47/23 | na | Z:\DAC\RAW DATA |
| 22-Oct | 2111P | 1BLK69B295A | PEGASUS | 2.01 | 453 | 12.4 | 236 | 29.5 | 292 | 22.2 | na | 7.59 | 1KB | 1KB | 292/48/58 | na | Z:\DAC\RAW DATA |
| 23-Oct | 2113P | 1BLK69B296A | PEGASUS | 1.62 | 394 | 10 | 216 | 36.4 | 260 | 19.4 | na | 15.1 | 1KB | 1KB | 48/51/44/61 | na | Z:\DAC\RAW DATA |
| 23-Oct | 2115P | 1BLK6970A296B | PEGASUS | 754 | 171 | 6.26 | 105 | 13.6 | 115 | 8.18 | na | 15.1 | 1KB | 1KB | 40/51/25 | na | Z:\DAC\RAW DATA |
| 24-Oct | 2117P | 1BLK69B297A | PEGASUS | 1.24 | 237 | 5.73 | 113 | 18.6 | 164 | 12.4 | na | 7.64 | 1KB | 1KB | 48/51/50 | na | Z:\DAC\RAW DATA |
| 26-Oct | 2125P | 1BLK69C299A | PEGASUS | 1.5 | 267 | 8.41 | 211 | 32 | 239 | 15.4 | na | 37.4 | 1KB | 1KB | 48/51/50/41/ 56/43/22 | na | Z:\DAC\RAW DATA |
| 26-Oct | 2127P | 1BLK6970A299B | PEGASUS | 2.64 | na | 5.91 | 114 | 16 | 1 | 12.9 | na | 37.4 | 1KB | 1KB | 27/1 | na | Z:\DAC\RAW DATA |
| 28-Oct | 2133P | 1BLK69FE301A | PEGASUS | 2.05 | 244/454 | 10.2 | 225 | 57.4 | 343 | na | na | 37.3 | 1KB | 1KB | 73/51/81/39 | na | Z:\DAC\RAW DATA |
| 28-Oct | 2135P | 1BLK69F301B | PEGASUS | 268 | 1701/87 | 3.42 | 94.6 | na | na | 5.4 | na | 37.3 | 1KB | 1KB | 92 | na | Z:\DAC\RAW DATA |
| 29-Oct | 2137P | 1BLK70D302A | PEGASUS | 1.05 | 453/220 | 7.37 | 190 | 28.3 | 181 | 11.2 | na | 19.4 | 1KB | 1KB | 106/93/82/75 | na | Z:\DAC\RAW DATA |
| 31-Oct | 2145P | 1BLK69C304A | PEGASUS | 2.33 | 1118/434 | 9.11 | 182 | 48.6 | 342 | 22.8 | na | 6.52 | 1KB | 1KB | 74 | na | Z:\DAC\RAW DATA |
| 1-Nov | 2149P | 1BLK70B305A | PEGASUS | 1.79 | 338 | 7.39 | 192 | 32.1 | 227 | 20.3 | na | 29.2 | 1KB | 1KB | 54/79 | na | Z:\DAC\RAW DATA |
| 3-Nov | 2157P | 1BLK70C307A | PEGASUS | 2.26 | 198 | 11.3 | 240 | 40.6 | 295 | 25.1 | na | 35.5 | 1KB | 1KB | 33 | na | Z:\DAC\RAW DATA |
| 6-Nov | 2169P | 1BLK73A310A | PEGASUS | 3.01 | 523 | 12.1 | 240 | 62.9 | na | 26.9 | na | 21.3 | 1KB | 1KB | 80 | na | Z:\DAC\RAW DATA |
| 8-Nov | 2177P | 1BLK70C312A | PEGASUS | 1.75 | 327 | 8.89 | 199 | 23.1 | na | 17.5 | na | 17.8 | 1KB | 1KB | 60/53/57 | na | Z:\DAC\RAW DATA |
| 9-Nov | 2181P | 1BLK69F313A | PEGASUS | 1.46 | 291 | 8.11 | 182 | 22.4 | 182 | 15.2 | na | 17 | 1KB | 1KB | 65/62/51 | na | Z:\DAC\RAW DATA |

Received from

Name C. JOAQUIN
Position RA
Signature [signature]

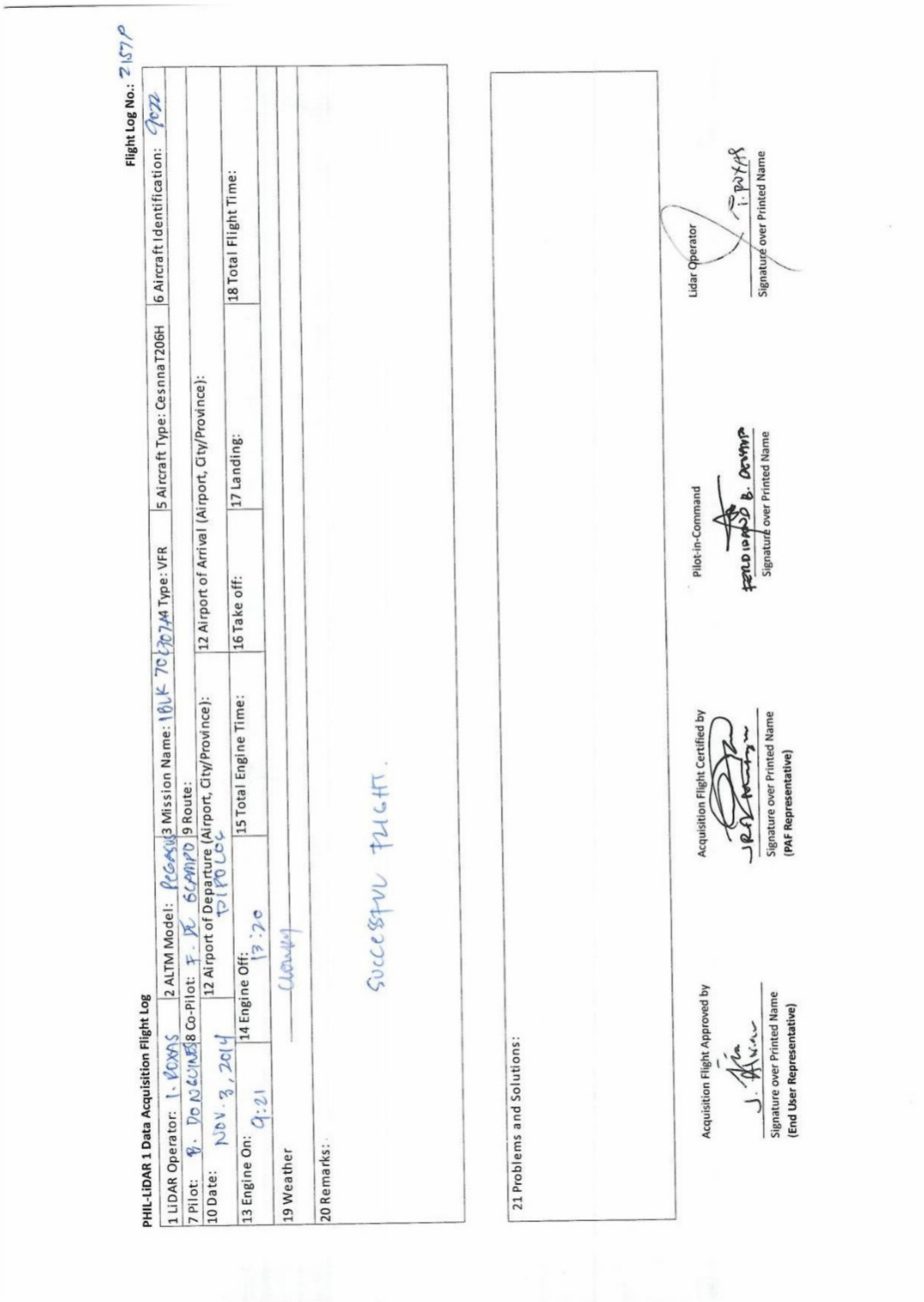
Received by

Name Angelo Carlo Bongat
Position SSRS
Signature [signature] 11/19/2014

Figure A-5.1. Transfer Sheet for Palandok Floodplain

# Annex 6. Flight Logs for the Flight Missions

Flight Log for 1BLK70C307A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2157P

| | | | | | |
|---|---|---|---|---|---|
| 1 LiDAR Operator: I. Roxas | 2 ALTM Model: Pegasus | 3 Mission Name: 1BLK70C307A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022 |
| 7 Pilot: B. Donguines | 8 Co-Pilot: F. de Ocampo | 9 Route: | | | |
| 10 Date: Nov. 3, 2014 | 12 Airport of Departure (Airport, City/Province): Dipolog | | 12 Airport of Arrival (Airport, City/Province): | | |
| 13 Engine On: 9:21 | 14 Engine Off: 13:20 | 15 Total Engine Time: | 16 Take off: | 17 Landing: | 18 Total Flight Time: |
| 19 Weather: Cloudy | | | | | |
| 20 Remarks: Successful flight. | | | | | |

21 Problems and Solutions:

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

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

Pilot-in-Command: Bernard B. Donguines — Signature over Printed Name

Lidar Operator: I. Roxas — Signature over Printed Name

Figure A-6.1 Flight Log for 1BLK70C307A Mission

# Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

| DIPOLOG-ZAMBOANGA DEL NORTE (October 8 to November 11, 2014) | | | | | |
|---|---|---|---|---|---|
| **FLIGHT NO** | **AREA** | **MISSION** | **OPERATOR** | **DATE FLOWN** | **REMARKS** |
| 2157P | BLK 75A | 1BLK70C307A | I. Roxas | November 3, 2014 | Surveyed BLK 73B; Clouds caused gaps |

**LAS BOUNDARIES PER FLIGHT**

Flight No.: 2157P

Area: BLK 73B

Mission Name: 1BLK70C307A

Parameters: Altitude: 1000 m; Scan Frequency: 30 Hz;

Scan Angle: 25 deg; Overlap: 20%

**LAS**

# ANNEX 8. MISSION SUMMARY REPORT

Table A-8.1. Mission Summary Report for Mission Blk73B

| | |
|---|---|
| Flight Area | Dipolog |
| Mission Name | Blk73B |
| Inclusive Flights | 2157P |
| Mission Name | 1BLK70C307A |
| Range data size | 25.1 GB |
| POS | 240MB |
| Base data size | 35.5 |
| Image | 40.6 GB |
| Transfer date | November 19, 2014 |
| | |
| *Solution Status* | |
| Number of Satellites (>6) | Yes |
| PDOP (<3) | Yes |
| Baseline Length (<30km) | Yes |
| Processing Mode (<=1) | Yes |
| | |
| *Smoothed Performance Metrics*(in cm) | |
| RMSE for North Position (<4.0 cm) | 1.05 |
| RMSE for East Position (<4.0 cm) | 1.85 |
| RMSE for Down Position (<8.0 cm) | 2.85 |
| | |
| Boresight correction stdev (<0.001deg) | 0.000185 |
| IMU attitude correction stdev (<0.001deg) | 0.000500 |
| GPS position stdev (<0.01m) | 0.0089 |
| | |
| Minimum % overlap (>25) | 24.96% |
| Ave point cloud density per sq.m. (>2.0) | 3.15 |
| Elevation difference between strips (<0.20m) | Yes |
| | |
| Number of 1km x 1km blocks | 306 |
| Maximum Height | 537.22 m |
| Minimum Height | 62.35 m |
| | |
| *Classification (# of points)* | |
| Ground | 221,447,994 |
| Low vegetation | 167,724,982 |
| Medium vegetation | 312,332,327 |
| High vegetation | 222,386,814 |
| Building | 4,523,324 |
| | |
| Orthophoto | Yes |
| Processed by | Engr. Angelo Carlo Bongat, Engr. Antonio Chua Jr., AilynBiñas |

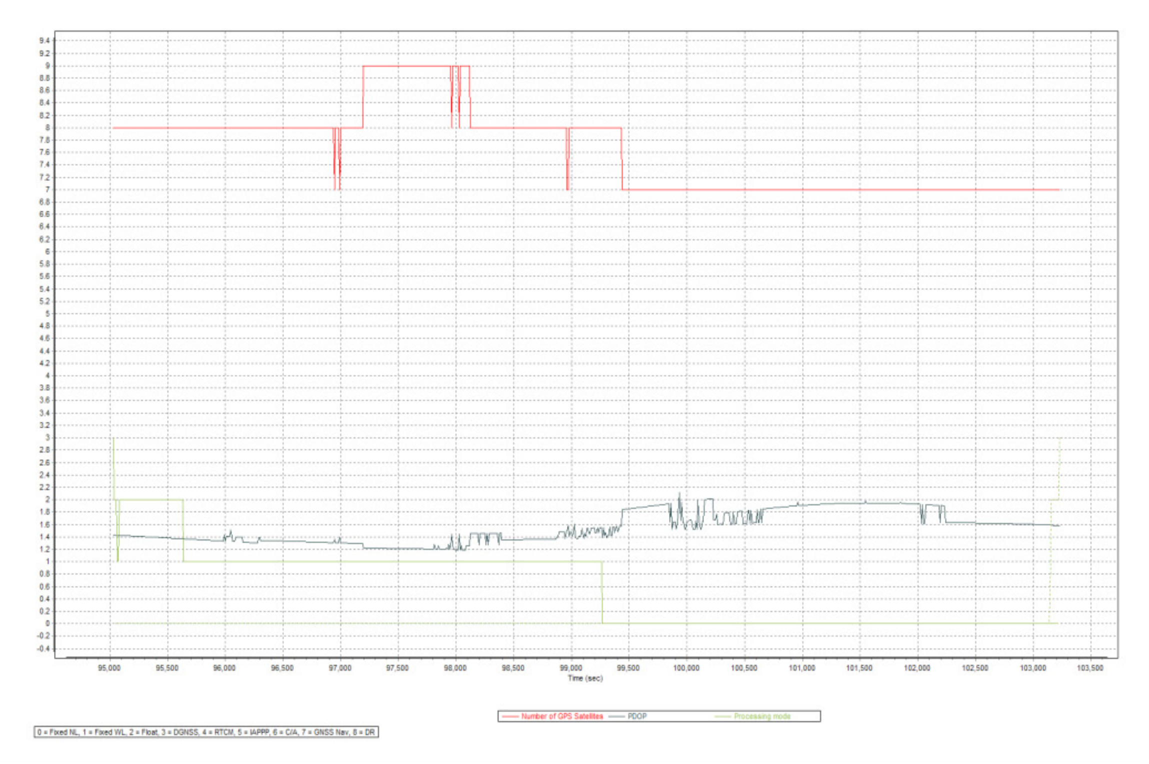



Figure A-8.1 ***Solution Status***

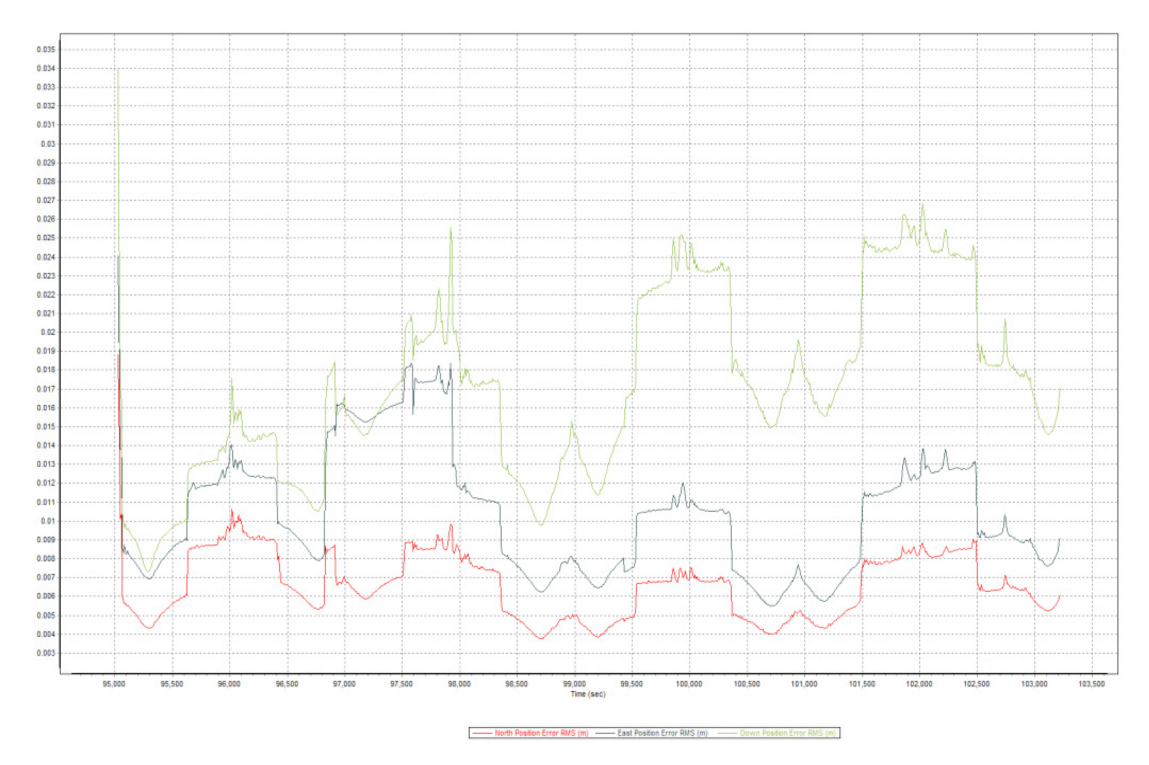



Figure A-8.2 ***Smoothed Performance Metric Parameters***

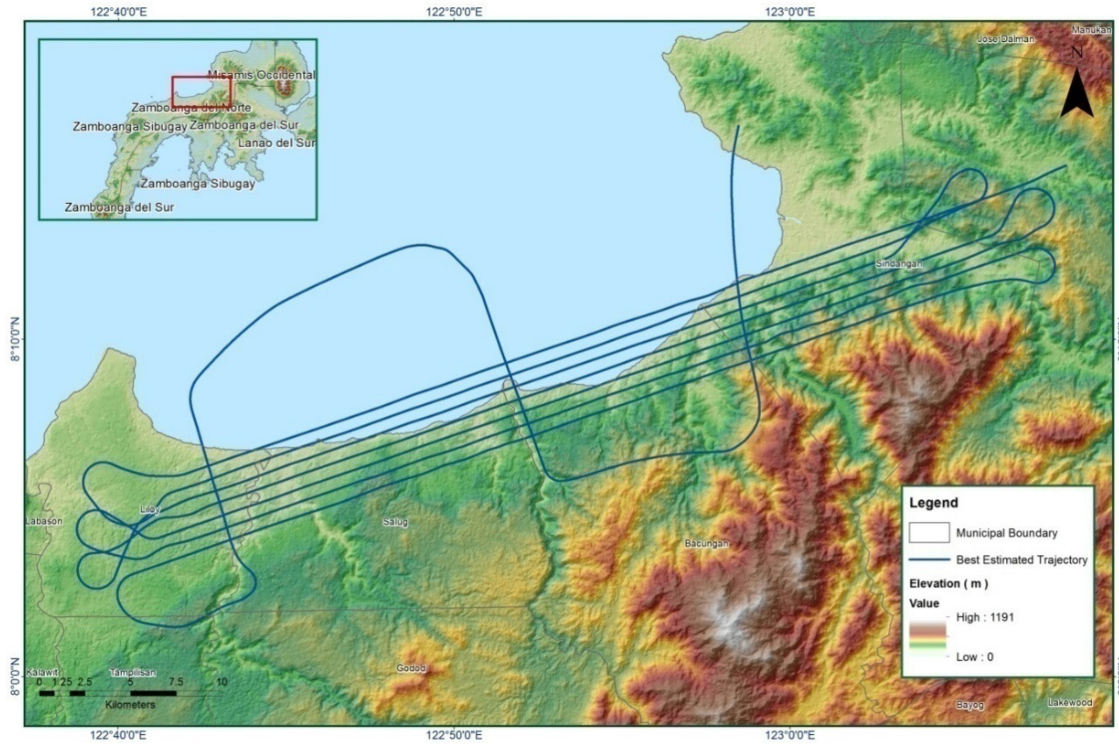



Figure A-8.3 ***Best Estimated Trajectory***

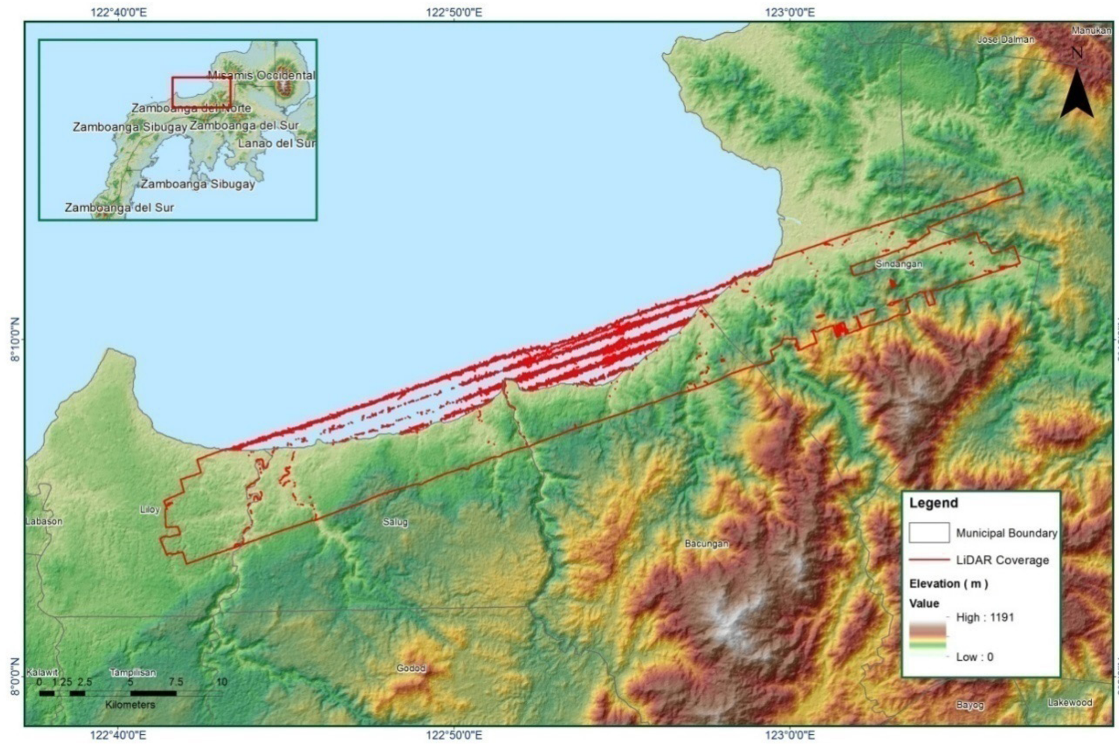



Figure A-8.4 ***Coverage of LiDAR Data***

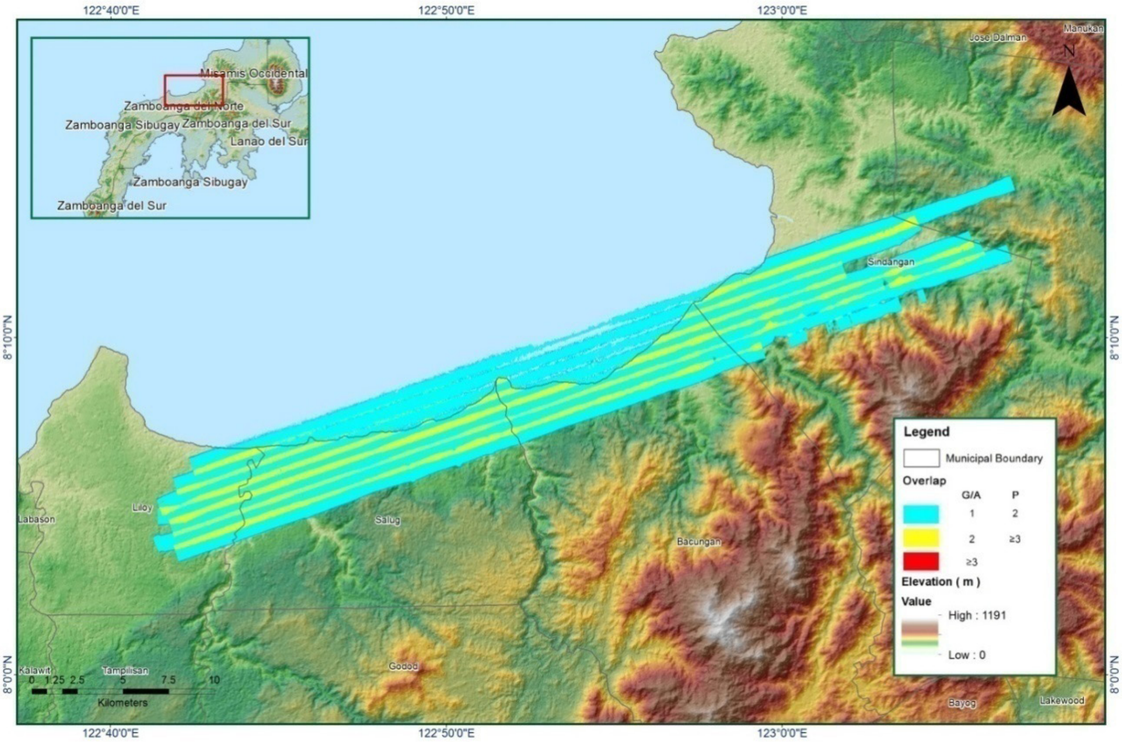



Figure A-8.5 ***Image of Data Overlap***

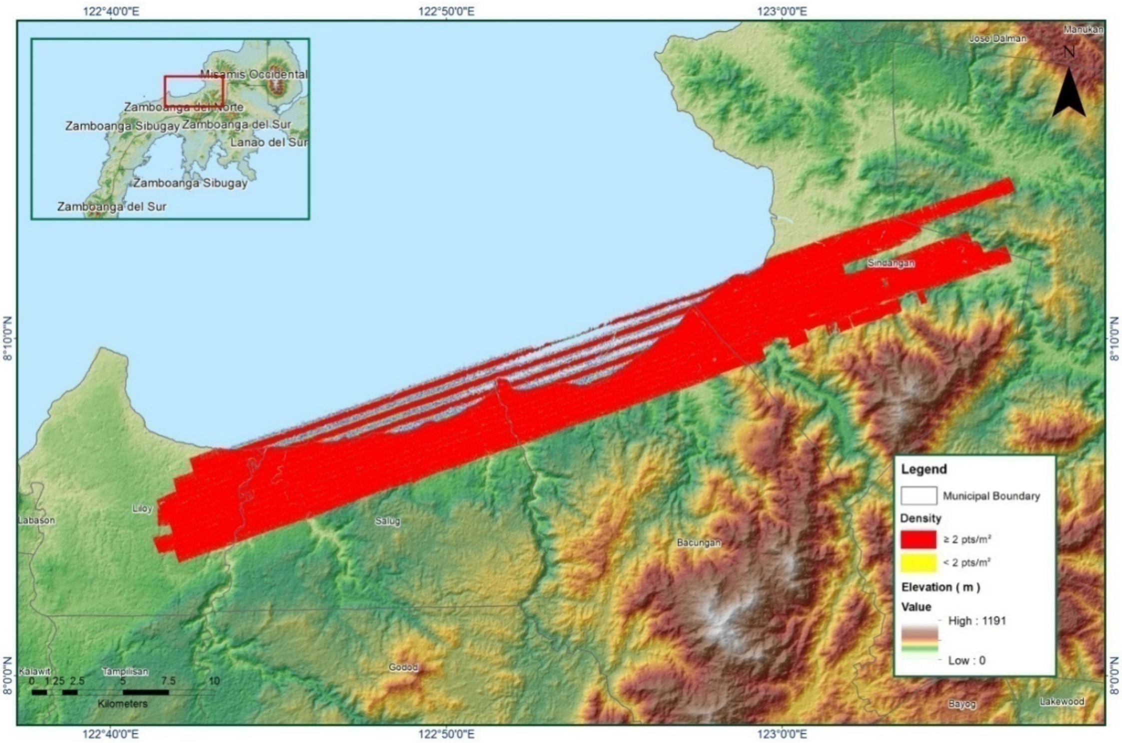



Figure A-8.6 ***Density map of merged LiDAR data***

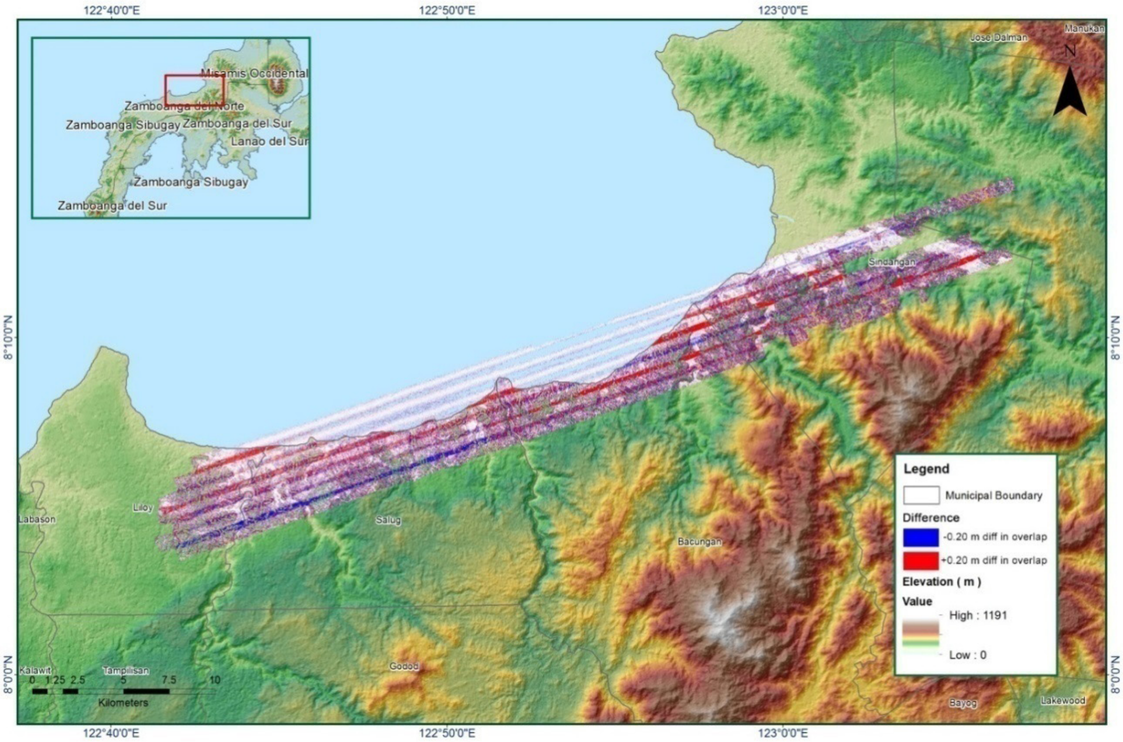



Figure A-8.7 Elevation difference between flight lines

# Annex 9. Palandok Model Basin Parameters

Table A-9.1. Palandok 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 |
| W520 | 29.214 | 23.8204 | 0 | 0.17777 | 0.0454376 | Discharge | 0.0660664 | 0.05 | Ratio to Peak | 0.1 |
| W530 | 40.331 | 18.0064 | 0 | 0.1606 | 0.0410470 | Discharge | 0.0162005 | 0.05 | Ratio to Peak | 0.1 |
| W540 | 31.380 | 22.3078 | 0 | 0.15986 | 0.0408591 | Discharge | 0.0636676 | 0.05 | Ratio to Peak | 0.1 |
| W550 | 41.089 | 17.4478 | 0 | 0.1296 | 0.0331256 | Discharge | 0.0154366 | 0.05 | Ratio to Peak | 0.1 |
| W560 | 50.568 | 21.118 | 0 | 0.35707 | 0.0912628 | Discharge | 0.17635 | 0.05 | Ratio to Peak | 0.1 |
| W570 | 29.176 | 23.3116 | 0 | 0.1603 | 0.0409718 | Discharge | 0.0330883 | 0.05 | Ratio to Peak | 0.1 |
| W580 | 41.605 | 24.5722 | 0 | 0.44246 | 0.25444 | Discharge | 0.0222793 | 0.05 | Ratio to Peak | 0.1 |
| W590 | 38.268 | 25.5934 | 0 | 0.88125 | 0.33924 | Discharge | 0.0577924 | 0.05 | Ratio to Peak | 0.1 |
| W600 | 41.670 | 24.4618 | 0 | 1.7038 | 0.65640 | Discharge | .000805202 | 0.05 | Ratio to Peak | 0.1 |
| W610 | 58.100 | 25.3246 | 0 | 0.5036 | 0.19345 | Discharge | 0.16801 | 0.05 | Ratio to Peak | 0.1 |
| W620 | 40.722 | 24.8026 | 0 | 0.93477 | 0.53756 | Discharge | 0.0705608 | 0.05 | Ratio to Peak | 0.1 |
| W630 | 47.355 | 22.0252 | 0 | 0.20889 | 0.12013 | Discharge | 0.0691341 | 0.05 | Ratio to Peak | 0.1 |
| W640 | 39.400 | 25.0228 | 0 | 0.1258 | 0.0321531 | Discharge | 0.0447454 | 0.05 | Ratio to Peak | 0.1 |
| W650 | 67.623 | 22.5814 | 0 | 0.20606 | 0.0526660 | Discharge | 0.0517335 | 0.05 | Ratio to Peak | 0.1 |
| W660 | 39.801 | 24.9124 | 0 | 0.40485 | 0.23282 | Discharge | 0.0638008 | 0.05 | Ratio to Peak | 0.1 |
| W670 | 38.689 | 24.9898 | 0 | 0.073444 | 0.0275933 | Discharge | 0.0125801 | 0.05 | Ratio to Peak | 0.1 |
| W680 | 71.712 | 21.6382 | 0 | 0.12683 | 0.0729370 | Discharge | 0.0375338 | 0.05 | Ratio to Peak | 0.1 |
| W690 | 37.706 | 25.4212 | 0 | 0.19349 | 0.0494547 | Discharge | 0.0505364 | 0.05 | Ratio to Peak | 0.1 |
| W700 | 36.825 | 26.407 | 0 | 0.32345 | 0.12152 | Discharge | .000913889 | 0.05 | Ratio to Peak | 0.1 |
| W710 | 39.484 | 23.4736 | 0 | 0.24841 | 0.0634910 | Discharge | 0.0841528 | 0.05 | Ratio to Peak | 0.1 |
| W720 | 22.661 | 27.919 | 0 | 0.044448 | 0.0167 | Discharge | 0.0028320 | 0.05 | Ratio to Peak | 0.1 |
| W730 | 58.194 | 25.2844 | 0 | 0.093445 | 0.0351083 | Discharge | 0.0250914 | 0.05 | Ratio to Peak | 0.1 |
| W740 | 60.621 | 17.3434 | 0 | 0.12926 | 0.0495557 | Discharge | 0.0513156 | 0.05 | Ratio to Peak | 0.1 |
| W750 | 25.478 | 25.9642 | 0 | 0.13807 | 0.0352892 | Discharge | 0.0594457 | 0.05 | Ratio to Peak | 0.1 |
| W760 | 78.659 | 20.1472 | 0 | 0.1104 | 0.0414816 | Discharge | 0.0216440 | 0.05 | Ratio to Peak | 0.1 |
| W770 | 64.365 | 16.1692 | 0 | 0.14161 | 0.0535070 | Discharge | 0.0420114 | 0.05 | Ratio to Peak | 0.1 |
| W780 | 75.356 | 21.028 | 0 | 0.11213 | 0.0421300 | Discharge | 0.0349697 | 0.05 | Ratio to Peak | 0.1 |
| W790 | 87.062 | 18.1222 | 0 | 0.13824 | 0.0795005 | Discharge | 0.0441330 | 0.05 | Ratio to Peak | 0.1 |
| W800 | 99 | 15.5734 | 0 | 0.18143 | 0.0698525 | Discharge | 0.0811310 | 0.05 | Ratio to Peak | 0.1 |
| W810 | 77.144 | 20.6212 | 0 | 0.19339 | 0.0494288 | Discharge | 0.10794 | 0.05 | Ratio to Peak | 0.1 |
| W820 | 38.596 | 25.5274 | 0 | 0.27774 | 0.15972 | Discharge | 0.10837 | 0.05 | Ratio to Peak | 0.1 |
| W830 | 39.695 | 24.9592 | 0 | 0.13592 | 0.0522408 | Discharge | 0.0149866 | 0.05 | Ratio to Peak | 0.1 |
| W840 | 38.674 | 25.4104 | 0 | 0.34394 | 0.19780 | Discharge | 0.10155 | 0.05 | Ratio to Peak | 0.1 |
| W850 | 38.246 | 25.6 | 0 | 0.19419 | 0.0748186 | Discharge | 0.0378369 | 0.05 | Ratio to Peak | 0.1 |
| W860 | 63.789 | 16.3798 | 0 | 0.18944 | 0.10895 | Discharge | 0.0576761 | 0.05 | Ratio to Peak | 0.1 |
| W870 | 97.964 | 15.724 | 0 | 0.14479 | 0.0832639 | Discharge | 0.0461292 | 0.05 | Ratio to Peak | 0.1 |
| W880 | 64.146 | 16.1656 | 0 | 0.17589 | 0.10115 | Discharge | 0.0471763 | 0.05 | Ratio to Peak | 0.1 |
| W890 | 66.107 | 15.5788 | 0 | 0.20343 | 0.11699 | Discharge | 0.0573990 | 0.05 | Ratio to Peak | 0.1 |
| W900 | 38.057 | 25.6 | 0 | 0.25578 | 0.0980613 | Discharge | 0.0053532 | 0.05 | Ratio to Peak | 0.1 |
| W910 | 50.206 | 20.0866 | 0 | 0.34022 | 0.19565 | Discharge | 0.0505900 | 0.05 | Ratio to Peak | 0.1 |
| W920 | 46.769 | 22.5676 | 0 | 0.3163 | 0.18190 | Discharge | 0.16196 | 0.05 | Ratio to Peak | 0.1 |
| W930 | 45.975 | 22.8514 | 0 | 0.34311 | 0.13154 | Discharge | 0.0936698 | 0.05 | Ratio to Peak | 0.1 |
| W940 | 69.871 | 22.5688 | 0 | 0.24602 | 0.0943214 | Discharge | 0.0874288 | 0.05 | Ratio to Peak | 0.1 |
| W950 | 101.2685089 | 15.1252 | 0 | 0.25458 | 0.0977113 | | 0.0668134 | 0.05 | Ratio to Peak | 0.1 |
| W960 | 66.163 | 15.4846 | 0 | 0.26294 | 0.15121 | | 0.11058 | 0.05 | Ratio to Peak | 0.1 |
| W970 | 97.815 | 15.7588 | 0 | 0.14743 | 0.0567301 | | 0.0416394 | 0.05 | Ratio to Peak | 0.1 |
| W980 | 47.1673079 | 22.0138 | 0 | 0.20811 | 0.11968 | | 0.11541 | 0.05 | Ratio to Peak | 0.1 |
| W990 | 50.272 | 20.6044 | 0 | 0.18845 | 0.10837 | | 0.11720 | 0.05 | Ratio to Peak | 0.1 |
| W1000 | 40.0029865 | 24.7828 | 0 | 0.2451 | 0.14095 | | 0.0975443 | 0.05 | Ratio to Peak | 0.1 |
| W1010 | 94.024 | 16.5028 | 0 | 0.14203 | 0.0816806 | | 0.0415261 | 0.05 | Ratio to Peak | 0.1 |
| W1020 | 86.422 | 18.004 | 0 | 0.18719 | 0.0716896 | | 0.0632574 | 0.05 | Ratio to Peak | 0.1 |

# Annex 10. Palandok  Model Reach Parameters

Table A-10.1. Palandok Model Reach Parameters

| Reach Number | Muskingum Cunge Channel Routing | | | | | | |
|---|---|---|---|---|---|---|---|
| | Time Step Method | Length (m) | Slope | Manning's n | Shape | Width | Side Slope |
| R10 | Automatic Fixed Interval | 2411.5 | 0.0404465 | 0.044 | Trapezoid | 30 | 0.01 |
| R30 | Automatic Fixed Interval | 1877.1 | 0.0223902 | 0.044 | Trapezoid | 30 | 0.01 |
| R40 | Automatic Fixed Interval | 892.67 | 0.0138171 | 0.044 | Trapezoid | 30 | 0.01 |
| R60 | Automatic Fixed Interval | 695.27 | 0.0836177 | 0.044 | Trapezoid | 30 | 0.01 |
| R70 | Automatic Fixed Interval | 38.284 | 0.0029422 | 0.044 | Trapezoid | 30 | 0.01 |
| R80 | Automatic Fixed Interval | 1694.1 | 0.0332265 | 0.044 | Trapezoid | 30 | 0.01 |
| R110 | Automatic Fixed Interval | 2473.5 | 0.0158731 | 0.044 | Trapezoid | 30 | 0.01 |
| R120 | Automatic Fixed Interval | 28.284 | 0.11095 | 0.044 | Trapezoid | 30 | 0.01 |
| R140 | Automatic Fixed Interval | 268.70 | 0.0218626 | 0.044 | Trapezoid | 30 | 0.01 |
| R170 | Automatic Fixed Interval | 1363.3 | 0.0455737 | 0.044 | Trapezoid | 30 | 0.01 |
| R180 | Automatic Fixed Interval | 1252.3 | 0.0235759 | 0.044 | Trapezoid | 30 | 0.01 |
| R200 | Automatic Fixed Interval | 1504.3 | 0.0351911 | 0.044 | Trapezoid | 30 | 0.01 |
| R210 | Automatic Fixed Interval | 1824.1 | 0.0443836 | 0.044 | Trapezoid | 30 | 0.01 |
| R230 | Automatic Fixed Interval | 3103.5 | 0.0094950 | 0.044 | Trapezoid | 30 | 0.01 |
| R240 | Automatic Fixed Interval | 1866.8 | 0.0133855 | 0.044 | Trapezoid | 30 | 0.01 |
| R270 | Automatic Fixed Interval | 5038.9 | 0.0040137 | 0.044 | Trapezoid | 30 | 0.01 |
| R290 | Automatic Fixed Interval | 759.83 | 0.0073660 | 0.044 | Trapezoid | 30 | 0.01 |
| R310 | Automatic Fixed Interval | 3550.9 | 0.0408339 | 0.044 | Trapezoid | 30 | 0.01 |
| R340 | Automatic Fixed Interval | 1952.4 | 0.0755265 | 0.044 | Trapezoid | 30 | 0.01 |
| R350 | Automatic Fixed Interval | 7073.8 | 0.0019376 | 0.044 | Trapezoid | 30 | 0.01 |
| R370 | Automatic Fixed Interval | 565.69 | 0.0178275 | 0.044 | Trapezoid | 30 | 0.01 |
| R380 | Automatic Fixed Interval | 4188.5 | 0.0081160 | 0.044 | Trapezoid | 30 | 0.01 |
| R390 | Automatic Fixed Interval | 2085.8 | 0.0109545 | 0.044 | Trapezoid | 30 | 0.01 |
| R410 | Automatic Fixed Interval | 9262.4 | 0.0049640 | 0.044 | Trapezoid | 30 | 0.01 |
| R490 | Automatic Fixed Interval | 3389.6 | 0.0060254 | 0.044 | Trapezoid | 30 | 0.01 |

# Annex 11. Palandok Field Validation Points

Table A-11.1. Palandok Field Validation

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 1 | 8.145988 | 122.862 | 0.03 | 0.50 | -0.47 | Amihan | 5 -Year |
| 2 | 8.14466 | 122.8639 | 0.03 | 0.30 | -0.27 | Amihan | 5 -Year |
| 3 | 8.142812 | 122.86477 | 0.03 | 0.65 | -0.62 | Amihan | 5 -Year |
| 4 | 8.142165 | 122.86497 | 0.03 | 0.50 | -0.47 | Amihan | 5 -Year |
| 5 | 8.131745 | 122.86362 | 5.88 | 0.30 | 5.58 | Typhoon Lawin | 5 -Year |
| 6 | 8.130237 | 122.86358 | 5.21 | 3.00 | 2.21 | Typhoon Lawin | 5 -Year |
| 7 | 8.129563 | 122.86342 | 4.24 | 2.00 | 2.24 | Typhoon Lawin | 5 -Year |
| 8 | 8.128729 | 122.86322 | 10.16 | 2.00 | 8.16 | Typhoon Lawin | 5 -Year |
| 9 | 8.127672 | 122.86354 | 9.15 | 2.00 | 7.15 | Typhoon Lawin | 5 -Year |
| 10 | 8.127386 | 122.86384 | 8.04 | 2.00 | 6.04 | Typhoon Lawin | 5 -Year |
| 11 | 8.12686 | 122.86402 | 8.93 | 2.00 | 6.93 | Typhoon Lawin | 5 -Year |
| 12 | 8.126106 | 122.86483 | 14.25 | 2.00 | 12.25 | Typhoon Lawin | 5 -Year |
| 13 | 8.129765 | 122.86344 | 2.86 | 2.00 | 0.86 | Typhoon Lawin | 5 -Year |
| 14 | 8.139233 | 122.85906 | 4.18 | 2.00 | 2.18 | Typhoon Lawin | 5 -Year |
| 15 | 8.139584 | 122.85872 | 4.05 | 2.00 | 2.05 | Typhoon Lawin | 5 -Year |
| 16 | 8.14039 | 122.85871 | 1.02 | 2.00 | -0.98 | Typhoon Lawin | 5 -Year |
| 17 | 8.139148 | 122.85813 | 0.06 | 2.00 | -1.94 | Typhoon Lawin | 5 -Year |
| 18 | 8.140008 | 122.85792 | 0.03 | 2.00 | -1.97 | Typhoon Lawin | 5 -Year |
| 19 | 8.140699 | 122.85786 | 3.63 | 2.00 | 1.63 | Typhoon Lawin | 5 -Year |
| 20 | 8.139924 | 122.85592 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 21 | 8.139382 | 122.8555 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 22 | 8.139 | 122.85526 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 23 | 8.138734 | 122.85497 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 24 | 8.138612 | 122.85534 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 25 | 8.138357 | 122.85457 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 26 | 8.138706 | 122.85482 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 27 | 8.139616 | 122.85603 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 28 | 8.141612 | 122.86547 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 29 | 8.14168 | 122.86557 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 30 | 8.141361 | 122.86611 | 0.10 | 0.00 | 0.10 | Amihan | 5 -Year |
| 31 | 8.14183 | 122.8651 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 32 | 8.141525 | 122.86505 | 0.08 | 0.00 | 0.08 | Amihan | 5 -Year |
| 33 | 8.142033 | 122.86471 | 0.07 | 0.00 | 0.07 | Amihan | 5 -Year |
| 34 | 8.14355 | 122.86435 | 0.05 | 0.00 | 0.05 | Amihan | 5 -Year |
| 35 | 8.142393 | 122.86454 | 0.08 | 0.00 | 0.08 | Amihan | 5 -Year |
| 36 | 8.14294 | 122.8639 | 0.05 | 0.00 | 0.05 | Amihan | 5 -Year |
| 37 | 8.145053 | 122.86342 | 0.03 | 0.00 | 0.03 | Typhoon Lawin | 5 -Year |
| 38 | 8.143843 | 122.86393 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 39 | 8.142382 | 122.86425 | 0.08 | 0.00 | 0.08 | Typhoon Lawin | 5 -Year |
| 40 | 8.144156 | 122.86353 | 0.07 | 0.00 | 0.07 | Amihan | 5 -Year |
| 41 | 8.143556 | 122.86351 | 0.08 | 0.00 | 0.08 | Amihan | 5 -Year |
| 42 | 8.144261 | 122.85897 | 0.11 | 0.20 | -0.10 | Typhoon lawin | 5 -Year |
| 43 | 8.14439 | 122.85898 | 0.31 | 0.20 | 0.11 | Typhoon Lawin | 5 -Year |
| 44 | 8.146264 | 122.86065 | 0.03 | 0.50 | -0.47 | Amihan | 5 -Year |
| 45 | 8.144363 | 122.86403 | 0.03 | 0.50 | -0.47 | Amihan | 5 -Year |
| 46 | 8.143174 | 122.86444 | 0.03 | 0.50 | -0.47 | Amihan | 5 -Year |
| 47 | 8.142722 | 122.86487 | 0.03 | 0.20 | -0.17 | Amihan | 5 -Year |
| 48 | 8.142176 | 122.86487 | 0.03 | 0.20 | -0.17 | Amihan | 5 -Year |
| 49 | 8.137098 | 122.86026 | 0.07 | 0.30 | -0.23 | Typhoon lawin | 5 -Year |
| 50 | 8.13559 | 122.86066 | 0.03 | 0.30 | -0.27 | Typhoon Lawin | 5 -Year |
| 51 | 8.132351 | 122.86401 | 0.03 | 3.00 | -2.97 | Typhoon lawin | 5 -Year |
| 52 | 8.13146 | 122.86392 | 5.69 | 3.00 | 2.69 | Typhoon Lawin | 5 -Year |
| 53 | 8.13075 | 122.86378 | 5.23 | 2.00 | 3.23 | Typhoon lawin | 5 -Year |
| 54 | 8.129712 | 122.8635 | 2.89 | 3.00 | -0.11 | Typhoon Lawin | 5 -Year |
| 55 | 8.129138 | 122.86361 | 3.41 | 2.00 | 1.41 | Typhoon lawin | 5 -Year |
| 56 | 8.128817 | 122.86358 | 3.84 | 3.00 | 0.84 | Typhoon Lawin | 5 -Year |
| 57 | 8.128299 | 122.86381 | 4.00 | 3.00 | 1.00 | Typhoon Lawin | 5 -Year |
| 58 | 8.127986 | 122.86384 | 5.68 | 2.00 | 3.68 | Typhoon lawin | 5 -Year |
| 59 | 8.12812 | 122.864 | 3.32 | 3.00 | 0.32 | Typhoon Lawin | 5 -Year |
| 60 | 8.127424 | 122.86416 | 5.00 | 3.00 | 2.00 | Typhoon Lawin | 5 -Year |
| 61 | 8.12691 | 122.86461 | 4.04 | 3.00 | 1.04 | Typhoon Lawin | 5 -Year |
| 62 | 8.126683 | 122.86467 | 5.09 | 3.00 | 2.09 | Typhoon lawin | 5 -Year |
| 63 | 8.126509 | 122.8646 | 8.29 | 3.00 | 5.29 | Typhoon lawin | 5 -Year |
| 64 | 8.126426 | 122.86489 | 2.78 | 3.00 | -0.22 | Typhoon Lawin | 5 -Year |
| 65 | 8.129846 | 122.86352 | 2.65 | 3.00 | -0.35 | Typhoon | 5 -Year |
| 66 | 8.139414 | 122.85893 | 4.20 | 2.00 | 2.20 | Typhoon Lawin | 5 -Year |
| 67 | 8.141637 | 122.85986 | 0.36 | 2.00 | -1.64 | Typhoon lawin | 5 -Year |
| 68 | 8.139764 | 122.85843 | 3.93 | 0.10 | 3.83 | Typhoon Lawin | 5 -Year |
| 69 | 8.138678 | 122.85822 | 0.09 | 0.10 | -0.01 | Typhoon lawin | 5 -Year |
| 70 | 8.138458 | 122.85841 | 0.03 | 0.10 | -0.07 | Typhoon | 5 -Year |
| 71 | 8.139845 | 122.85792 | 0.03 | 0.10 | -0.07 | Typhoon Lawin | 5 -Year |
| 72 | 8.140263 | 122.85784 | 0.03 | 0.10 | -0.07 | Typhoon Lawin | 5 -Year |
| 73 | 8.142562 | 122.85735 | 0.03 | 0.10 | -0.07 | Typhoon lawin | 5 -Year |
| 74 | 8.142706 | 122.8574 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 75 | 8.139873 | 122.85641 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 76 | 8.139971 | 122.85596 | 0.03 | 0.05 | -0.02 | Amihan | 5 -Year |
| 77 | 8.139638 | 122.8559 | 0.03 | 0.05 | -0.02 | Amihan | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 78 | 8.139441 | 122.85565 | 0.03 | 0.10 | -0.07 | Amihan | 5 -Year |
| 79 | 8.139217 | 122.85541 | 0.03 | 0.05 | -0.02 | Amihan | 5 -Year |
| 80 | 8.139029 | 122.85531 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 81 | 8.138782 | 122.85504 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 82 | 8.138771 | 122.855 | 0.03 | 0.07 | -0.04 | Amihan | 5 -Year |
| 83 | 8.138616 | 122.85479 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 84 | 8.138442 | 122.85419 | 0.14 | 0.10 | 0.04 | Amihan | 5 -Year |
| 85 | 8.137985 | 122.854 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 86 | 8.138224 | 122.85399 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 87 | 8.14121 | 122.86658 | 0.04 | 0.10 | -0.06 | Typhoon lawin | 5 -Year |
| 88 | 8.141187 | 122.86637 | 0.04 | 0.00 | 0.04 | Amihan | 5 -Year |
| 89 | 8.141254 | 122.86622 | 0.04 | 0.00 | 0.04 | Amihan | 5 -Year |
| 90 | 8.141363 | 122.86613 | 0.10 | 0.05 | 0.05 | Amihan | 5 -Year |
| 91 | 8.141341 | 122.86597 | 0.07 | 0.04 | 0.03 | Amihan | 5 -Year |
| 92 | 8.141363 | 122.86583 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 93 | 8.141479 | 122.8656 | 0.03 | 0.06 | -0.03 | Amihan | 5 -Year |
| 94 | 8.141928 | 122.8654 | 0.10 | 0.05 | 0.05 | Amihan | 5 -Year |
| 95 | 8.141498 | 122.86516 | 0.04 | 0.00 | 0.04 | Amihan | 5 -Year |
| 96 | 8.142022 | 122.86518 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 97 | 8.141794 | 122.86517 | 0.03 | 0.06 | -0.03 | Amihan | 5 -Year |
| 98 | 8.142803 | 122.86461 | 0.03 | 0.00 | 0.03 | Amihan | 5 -Year |
| 99 | 8.141639 | 122.86146 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 100 | 8.141256 | 122.86225 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 101 | 8.141319 | 122.86254 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 102 | 8.143002 | 122.86196 | 0.05 | 0.00 | 0.05 | | 5 -Year |
| 103 | 8.127181 | 122.86779 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 104 | 8.127149 | 122.86782 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 105 | 8.143483 | 122.86138 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 106 | 8.144744 | 122.8609 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 107 | 8.145779 | 122.85985 | 0.16 | 0.00 | 0.16 | | 5 -Year |
| 108 | 8.145327 | 122.85914 | 0.07 | 0.00 | 0.07 | | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 109 | 8.145788 | 122.85894 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 110 | 8.141932 | 122.86405 | 0.06 | 0.00 | 0.06 | | 5 -Year |
| 111 | 8.142024 | 122.86446 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 112 | 8.141418 | 122.86321 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 113 | 8.141272 | 122.86347 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 114 | 8.140536 | 122.86457 | 0.14 | 0.00 | 0.14 | | 5 -Year |
| 115 | 8.140298 | 122.86625 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 116 | 8.139604 | 122.86576 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 117 | 8.139489 | 122.86551 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 118 | 8.141082 | 122.86507 | 0.96 | 0.00 | 0.96 | | 5 -Year |
| 119 | 8.138168 | 122.85481 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 120 | 8.138797 | 122.85552 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 121 | 8.139213 | 122.85571 | 0.08 | 0.00 | 0.08 | | 5 -Year |
| 122 | 8.138892 | 122.85628 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 123 | 8.138507 | 122.85623 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 124 | 8.138877 | 122.85687 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 125 | 8.138771 | 122.85738 | 0.07 | 0.00 | 0.07 | | 5 -Year |
| 126 | 8.139397 | 122.85766 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 127 | 8.138974 | 122.858 | 0.07 | 0.00 | 0.07 | | 5 -Year |
| 128 | 8.143975 | 122.86149 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 129 | 8.140854 | 122.86245 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 130 | 8.144483 | 122.8625 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 131 | 8.139721 | 122.85988 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 132 | 8.139715 | 122.85989 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 133 | 8.133365 | 122.86543 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 134 | 8.133363 | 122.86544 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 135 | 8.131118 | 122.86641 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 136 | 8.142253 | 122.86137 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 137 | 8.142871 | 122.86103 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 138 | 8.143971 | 122.86084 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 139 | 8.145191 | 122.85952 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 140 | 8.143929 | 122.8628 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 141 | 8.141207 | 122.86399 | 0.07 | 0.00 | 0.07 | | 5 -Year |
| 142 | 8.142041 | 122.86341 | 0.06 | 0.00 | 0.06 | | 5 -Year |
| 143 | 8.142564 | 122.8632 | 0.07 | 0.00 | 0.07 | | 5 -Year |
| 144 | 8.140459 | 122.86414 | 0.12 | 0.00 | 0.12 | | 5 -Year |
| 145 | 8.139878 | 122.86497 | 0.05 | 0.00 | 0.05 | | 5 -Year |
| 146 | 8.140386 | 122.86512 | 0.04 | 0.00 | 0.04 | | 5 -Year |
| 147 | 8.140639 | 122.86552 | 0.05 | 0.00 | 0.05 | | 5 -Year |
| 148 | 8.139175 | 122.86584 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 149 | 8.141465 | 122.86461 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 150 | 8.1381 | 122.8552 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 151 | 8.13904 | 122.85552 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 152 | 8.138338 | 122.85717 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 153 | 8.138517 | 122.85767 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 154 | 8.138292 | 122.85775 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 155 | 8.138204 | 122.85839 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 156 | 8.139776 | 122.85767 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 157 | 8.140158 | 122.85758 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 158 | 8.141297 | 122.85977 | 0.45 | 0.00 | 0.45 | | 5 -Year |
| 159 | 8.140192 | 122.86028 | 0.03 | 0.00 | 0.03 | | 5 -Year |

| Point Number | Validation Coordinates | | Model Var (m) | Validation Points (m) | Error | Event/Date | Rain Return / Scenario |
|---|---|---|---|---|---|---|---|
| | Lat | Long | | | | | |
| 160 | 8.141078 | 122.8602 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 161 | 8.136484 | 122.8605 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 162 | 8.141006 | 122.86147 | 0.08 | 0.00 | 0.08 | | 5 -Year |
| 163 | 8.141797 | 122.86203 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 164 | 8.142081 | 122.86202 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 165 | 8.142167 | 122.86228 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 166 | 8.142377 | 122.86259 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 167 | 8.142149 | 122.86271 | 0.05 | 0.00 | 0.05 | | 5 -Year |
| 168 | 8.134936 | 122.86408 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 169 | 8.129169 | 122.8674 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 170 | 8.126708 | 122.86735 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 171 | 8.142464 | 122.86179 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 172 | 8.144464 | 122.86115 | 0.05 | 0.00 | 0.05 | | 5 -Year |
| 173 | 8.145272 | 122.86093 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 174 | 8.14483 | 122.8618 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 175 | 8.144585 | 122.86175 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 176 | 8.143788 | 122.86227 | 0.06 | 0.00 | 0.06 | | 5 -Year |
| 177 | 8.143592 | 122.8623 | 0.09 | 0.00 | 0.09 | | 5 -Year |
| 178 | 8.143391 | 122.86306 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 179 | 8.141691 | 122.86444 | 0.05 | 0.00 | 0.05 | | 5 -Year |
| 180 | 8.14185 | 122.86271 | 0.04 | 0.00 | 0.04 | | 5 -Year |
| 181 | 8.140692 | 122.86405 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 182 | 8.139419 | 122.86472 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 183 | 8.139423 | 122.86473 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 184 | 8.140242 | 122.865 | 0.06 | 0.00 | 0.06 | | 5 -Year |
| 185 | 8.140772 | 122.86621 | 0.32 | 0.00 | 0.32 | | 5 -Year |
| 186 | 8.139985 | 122.866 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 187 | 8.140953 | 122.86093 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 188 | 8.139502 | 122.85618 | 0.03 | 0.00 | 0.03 | | 5 -Year |
| 189 | 8.139272 | 122.85599 | 0.04 | 0.00 | 0.04 | | 5 -Year |
| | | | | RMSE | 1.66 | | |

# Annex 12. Educational Institutions affected by flooding in Palandok Floodplain

Table A-12.1. Educational Institutions affected by flooding in Palandok Floodplain

| Bacungan | | | | |
|---|---|---|---|---|
| | | Rainfall Scenario | | |
| Barangay | Buildings | 5-year | 25-year | 100-year |
| Rizon | Arabic center | None | None | None |
| Rizon | Palandok Elementary School | None | None | None |
| Rizon | Palandok National High School | None | None | None |
| Rizon | Palandok Day care center | None | None | None |
| Rizon | PALANDOK SCHOOL | None | None | None |

# Annex 13. Health Institutions affected by flooding in Palandok Floodplain

Table A-13.1. Health Institutions affected by flooding in Palandok Floodplain

| Bacungan | | | | |
|---|---|---|---|---|
| | | Rainfall Scenario | | |
| Barangay | Buildings | 5-year | 25-year | 100-year |
| Rizon | Brgay. Health Center | None | None | None |