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

LiDAR Surveys and Flood Mapping of Tanao River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Cebu

APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid Program and is to be cited as:

E.C. Paringit and J.R. Sinogaya (eds.) (2017), LiDAR Surveys and Flood Mapping of Tanao River, Quezon City: University of the Philippines Training Center on Applied Geodesy and Photogrammetry-135pp.

For questions/queries regarding this report, contact:

Jonnifer Sinogaya, PhD.
Project Leader, Phil-LiDAR 1 Program
University of the Philippines Cebu
Cebu City, Cebu, Philippines 6000
E-mail: jrsinogaya@yahoo.com

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-115-7

TABLE OF CONTENTS

LIST OF TABLES.....v
LIST OF FIGURES.....vi
LIST OF ACRONYMS AND ABBREVIATIONS.....viii
CHAPTER 1: OVERVIEW OF THE PROGRAM AND TANAO RIVER.....1
1.1 Background of the Phil-LIDAR 1 Program.....1
1.2 Overview of the Tanao River Basin.....1
CHAPTER 2: LIDAR DATA ACQUISITION OF THE TANAO FLOODPLAIN.....3
2.1 Flight Plans.....3
2.2 Ground Base Stations.....6
2.3 Flight Missions.....12
2.4 Survey Coverage.....15
CHAPTER 3: LIDAR DATA PROCESSING OF THE TANAO FLOODPLAIN.....17
3.1 Overview of the LiDAR Data Pre-Processing.....17
3.2 Transmittal of Acquired LiDAR Data.....18
3.3 Trajectory Computation.....18
3.4 LiDAR Point Cloud Computation.....20
3.5 LiDAR Data Quality Checking.....21
3.6 LiDAR Point Cloud Classification and Rasterization.....25
3.7 LiDAR Image Processing and Orthophotograph Rectification.....27
3.8 DEM Editing and Hydro-Correction.....29
3.9 Mosaicking of Blocks.....31
3.10 Calibration and Validation of Mosaicked LiDAR DEM.....33
3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model.....36
3.12 Feature Extraction.....38
3.12.1 Quality Checking of Digitized Features' Boundary.....38
3.12.2 Height Extraction.....39
3.12.3 Feature Attribution.....39
3.12.4 Final Quality Checking of Extracted Features.....40
CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE TANAO RIVER BASIN.....41
4.2 Control Survey.....42
4.3 Baseline Processing.....46
4.4 Network Adjustment.....47
4.5 Cross-section and Bridge As-Built survey and Water Level Marking.....49
4.6 Validation Points Acquisition Survey.....52
4.7 River Bathymetric Survey.....54
CHAPTER 5: FLOOD MODELING AND MAPPING.....57
5.1 Data Used for Hydrologic Modeling.....57
5.1.1 Hydrometry and Rating Curves.....57
5.1.2 Precipitation.....57
5.1.3 Rating Curves and River Outflow.....58
5.2 RIDF Station.....60
5.3 HMS Model.....62
5.4 Cross-section Data.....67
5.5 Flo 2D Model.....68
5.6 Results of HMS Calibration.....70
5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods.....71
5.7.1 Hydrograph using the Rainfall Runoff Model.....71
5.7.2 Discharge Data using Dr. Horritt's recommended hydrologic method.....73
5.8 River Analysis (RAS) Model Simulation.....77
5.9 Flow Depth and Flood Hazard.....78
5.10 Inventory of Areas Exposed to Flooding.....85
5.11 Flood Validation.....94
REFERENCES.....96
ANNEXES.....97
Annex 1. Technical Specifications of the LIDAR Sensors used in the Tanao Floodplain Survey.....97
Annex 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey.....99
Annex 3. Baseline Processing Reports of Control Points used in the LIDAR Survey.....101
Annex 4. The LIDAR Survey Team Composition.....102
Annex 5. Data Transfer Sheet for Tanao Floodplain.....103

Annex 6. Flight logs for the flight missions....105
Annex 7. Flight status reports....114
Annex 8. Mission Summary Reports....122
Annex 9. Tanao Model Basin Parameters....157
Annex 10. Tanao Model Reach Parameters....158
Annex 11. Tanao Field Validation Points....159
Annex 12. Educational Institutions Affected by flooding in Tanao Floodplain....163
Annex 13. Health Institutions affected by flooding in Tanao Floodplain....164
Annex 14. UPC Phil-LiDAR Training Team Composition....165

LIST OF TABLES

Table 1. Flight planning parameters for the Aquarius LiDAR system. 3
Table 2. Flight planning parameters for the Pegasus LiDAR system. 3
Table 3. Details of the recovered NAMRIA horizontal control point NGW-50 used as base station for the LiDAR acquisition. 7
Table 4. Details of the recovered NAMRIA horizontal control point NGW-51 used as base station for the LiDAR acquisition. 8
Table 5. Details of the recovered NAMRIA horizontal control point NGW-58 used as base station for the LiDAR acquisition. 9
Table 6. Details of the recovered NAMRIA horizontal control point NGW-63 used as base station for the LiDAR acquisition. 10
Table 7. Details of the recovered NAMRIA horizontal control point NW-123 with processed coordinates used as base station for the LiDAR acquisition. 11
Table 8. Ground control points used during the LiDAR data acquisition. 12
Table 9. Flight missions for the LiDAR data acquisition of the Tanao Floodplain. 13
Table 10. Actual parameters used during the LiDAR data acquisition of the Tanao Floodplain. 14
Table 11. The list of municipalities and cities surveyed of the Tanao Floodplain LiDAR acquisition.....15
Table 12. Self-calibration values for all Tanao flood plain flights. 20
Table 13. List of LiDAR blocks for the Tanao floodplain. 21
Table 14. Summary of point cloud classification results in TerraScan for Tanao River Floodplain. 25
Table 15. LiDAR blocks with its corresponding areas. 29
Table 16. The shift values (in meters) for each LiDAR Block of the Tanao Floodplain. 31
Table 17. The calibration statistical measures of the compared elevation values between the Tanao LiDAR data and the calibration data. 35
Table 18. Statistical measures for the Tanao River Basin DTM validation. 36
Table 19. Details of the quality checking ratings for the building features extracted for the Tanao River Basin..38
Table 20. Building features that were extracted for the Tanao Floodplain. 39
Table 21. Total length of extracted roads for Tanao floodplain. 40
Table 22. Number of extracted water bodies in the Tanao Floodplain. 40
Table 23. References used and control points established in the Tanao River Survey.........................43
Table 24. The Baseline processing report for the Tanao River GNSS static observation survey. 46
Table 25. Constraints applied to the adjustment of the control points. 47
Table 26. Adjusted grid coordinates for control points used in the Tanao River floodplain survey 47
Table 27. Adjusted geodetic coordinates for control points used in the Tanao River Floodplain validation. 48
Table 28. The reference and control points utilized in the Tanao River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP).......................................48
Table 29. RIDF values for the Tacloban Rain Gauge, as computed by PAGASA 60
Table 30. Range of calibrated values for the Tanao River Basin. 70
Table 31. Summary of the Efficiency Test of the Tanao HMS Model 71
Table 32. The peak values of the Tanao HEC-HMS Model outflow using the Mactan RIDF. 72
Table 33. Summary of Himogaan and Tanao river (1) discharge generated in HEC-HMS......................75
Table 34. Summary of Himogaan and Tanao river (2) discharge generated in HEC-HMS......................75
Table 35. Summary of Himogaan and Tanao river (3) discharge generated in HEC-HMS......................75
Table 36. Summary of Himogaan and Tanao river (4) discharge generated in HEC-HMS......................76
Table 37. Summary of Himogaan and Tanao river (5) discharge generated in HEC-HMS......................76
Table 38. Validation of river discharge estimates. 76
Table 39. Municipalities affected in Tanao floodplain 78
Table 40. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period. 85
Table 41. Affected Areas in Sagay City, Negros Occidental during 5-Year Rainfall Return Period..........86
Table 42. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period. 87
Table 43. Affected Areas in Sagay City, Negros Occidental during 25-Year Rainfall Return Period 89
Table 44. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period.......90
Table 45. Affected Areas in Sagay City, Negros Occidental during 100-Year Rainfall Return Period. 92
Table 46. Area covered by each warning level with respect to the rainfall scenario 93
Table 47. Actual Flood Depth versus Simulated Flood Depth at different levels in the Himogaan-Tanao River Basin...85
Table 48. The summary of the Accuracy Assessment in the Himogaan-Tanao River Basin Survey..95

LIST OF FIGURES

Figure 1. Map of Tanao River Basin (in brown) 2
Figure 2. Flight Plan and base stations used for the Tanao Floodplain survey using Aquarius sensor.... 4
Figure 3. Flight Plan and base stations used for the Tanao Floodplain survey using Pegasus sensor. 5
Figure 4. GPS set-up over NGW-50 on the NW sidewalk of Himoga-an bridge at km. 73+545 along the Sagay-Bacolod National Highway in Sagay, Negros Occidental (a) and NAMRIA reference point NGW-50 (b) as recovered by the field team. 7
Figure 5. GPS set-up over NGW-51 at the NW tip of a yellow headwall found at the SW of Escalante-Bacolod national road at Brgy. Had Fe, Escalante, Negros Occidental (a) and NAMRIA reference point NGW-51 (b) as recovered by the field team. 8
Figure 6. GPS set-up over NGW-58 at the NE sidewalk of Danao Bridge found at Brgy. Jonobjonob, Sitio Labarca, Escalante, Negros Occidental (a) and NAMRIA reference point MGW-58 (b) as recovered by the field team. 9
Figure 7. GPS set-up over NGW-63 at the NE end of the sidewalk of Daan-Lunsod Bridge at Brgy. Lemery, Calatrava, Negros Occidental (a) and NAMRIA reference point NGW-63 (b) as recovered by the field team. 10
Figure 8. GPS set-up over NW-123 at the right side of the bridge located in Cadiz, Negros Occidental going to San Carlos, along the national road (a) and NAMRIA reference point NW-123 (b) as recovered by the field team. 11
Figure 9. Actual LiDAR survey coverage of the Tanao Floodplain. 16
Figure 10. Schematic diagram for Data Pre-processing Component..................... 17
Figure 11. The Smoothed Performance Metric Parameters of Tanao Flight 1433P..................... 18
Figure 12. The Solution Status Parameters of Tanao Flight 1433P. 19
Figure 13. Best Estimated Trajectory of the LiDAR missions conducted over the Tanao floodplain..... 20
Figure 14. The boundaries of the processed LiDAR data over the Tanao Floodplain..................... 21
Figure 15. Data overlap between missions and flight lines for the Tanao River Floodplain Survey...... 22
Figure 16. The pulse density map of the merged LiDAR data for the Tanao Floodplain Survey. 23
Figure 17. Map of elevation difference Map between flight lines for the Tanao Floodplain Survey. ... 24
Figure 18. Screen-capture of the quality checking for Tanao Flight 1433P using the Profile Tool of QT Modeler. 25
Figure 19. The coverage of the Tanao Floodplain Survey (a) the tile system (b) depicts the classification results in TerraScan. 26
Figure 20. The images before (a) and after (b) undertaking classification. 26
Figure 21. Photo (A) features the production of the last return DSM; (B) depicts the production of the DTM; (C) portrays the production of the first return DSM; and (D) presents the generation of the secondary DTM in some portions of the Tanao Floodplain. 27
Figure 22. The Tanao Floodplain with the available orthophotographs. 28
Figure 23. Sample orthophotograph tiles for the Tanao Floodplain. 28
Figure 24. Portions in the DTM of the Tanao Floodplain showing (a) a paddy field before manual editing; (b) paddy after data retrieval; (c) a bridge before undergoing manual editing, while (d) after manual editing; (e) a building before manual editing, while (f) after manual editing. 30
Figure 27. Correlation plot between calibration survey points and LiDAR data. 35
Figure 28 Correlation plot between the validation survey points and the LiDAR data. 36
Figure 29. Map of Tanao floodplain with bathymetric survey points shown in blue. 37
Figure 30. Blocks (in blue) of Tanao building features that were subjected to QC. 38
Figure 31. Extracted features of the Tanao Floodplain. 40
Figure 32. Extent of the bathymetric survey (in blue line) in Tanao River. 41
Figure 33. The GNSS Network established in the Tanao River Survey. 42
Figure 34. The GNSS base receiver setup, Trimble® SPS 852, at NGW-50 in Himoga-An Bridge, Brgy. Paraiso, Sagay City, Negros Occidental 44
Figure 35. The GNSS (Trimble® SPS 852) receiver setup at NW-100 in Danao Bridge, Brgy. Jonobjonob, Escalante City, Negros Occidental 44
Figure 36. The GNSS (Trimble® SPS 852) receiver occupation, at NW-130 in Troso Bridge, Brgy. Daga, Cadiz City, Negros Occidental..................... 45
Figure 37. The As-Built survey at Tanao Bridge in Sagay City..................... 49
Figure 38. The Tanao Bridge cross-section survey drawn to scale 50
Figure 39. Location map of the Tanao Bridge cross-section survey..................... 50
Figure 40. The Tanao Bridge as-built survey data..................... 51
Figure 41. Water Level Mark at the pier of Tanao Bridge 52
Figure 42. (A) Occupied base station, NGW-50, in Himoga-An Bridge, Sagay City and (B) Installation of GNSS Receiver Trimble® SPS 882 on the van prior the conduct of validation points acquisition survey..................... 53

Figure 43. The extent of the LiDAR ground validation survey for Tanao River Basin 53
Figure 44. Set up of Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver on a motor boat for the bathymetric survey in Brgy. Old Sagay, Sagay City, Negros Occidental 54
Figure 45. The extent of the Tanao River Bathymetry Survey 55
Figure 46. The Tanao river bed profile 56
Figure 47. Location Map of the Tanao HEC-HMS model used for calibration 58
Figure 48. The cross-section plot of the Tanao Bridge 59
Figure 49. The rating curve of the Tanao Bridge, Poblacion II, Sagay City 59
Figure 50. Rainfall and outflow data of the Tanao River Basin, which was used for modeling. 60
Figure 51. Location of the Tacloban RIDF station relative to the Tanao River Basin. 61
Figure 52. Synthetic storm generated for a 24-hour period rainfall for various return periods 61
Figure 53. Soil Map of Tanao River Basin 62
Figure 54. Land Cover Map of Tanao River Basin 63
Figure 55. Slope Map of the Tanao River Basin.v 64
Figure 56. Stream Delineation Map of Tanao River Basin 65
Figure 57. Tanao river basin model generated in HEC-HMS 66
Figure 58. River cross-section of the Tanao River through the ArcMap HEC GeoRas tool 67
Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro) 68
Figure 60. Generated 100-year rain return hazard map from Flo-2D Mapper 70
Figure 61. Generated 100-year rain return flow depth map from Flo-2D Mapper 70
Figure 62. Outflow Hydrograph of Tanao produced by the HEC-HMS model compared with observed outflow 71
Figure 63. The Outflow hydrograph at the Tanao Station, generated using the Mactan RIDF simulated in HEC-HMS 72
Figure 64. Himogaan and Tanao river (1) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS 73
Figure 65. Himogaan and Tanao river (2) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS 73
Figure 66. Himogaan and Tanao river (3) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS 74
Figure 67. Himogaan and Tanao river (4) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS 74
Figure 68. Himogaan and Tanao river (5) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS 75
Figure 69. The sample output map of the Tanao RAS Model. 77
Figure 70. A 100-year Flood Hazard Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery. 79
Figure 71. A 100-year Flow Depth Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery. 80
Figure 72. A 25-year Flood Hazard Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery. 81
Figure 73. A 25-year Flow Depth Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery. 82
Figure 74. A 5-year Flood Hazard Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery. 83
Figure 75. A 5-year Flood Depth Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery. 84
Figure 76. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period. 85
Figure 77. Affected Areas in Sagay City, Negros Occidental during 5-Year Rainfall Return Period 87
Figure 78. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period. 88
Figure 79. Affected Areas in Sagay City, Negros Occidental during 25-Year Rainfall Return Period 90
Figure 80. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period. 91
Figure 81. Affected Areas in Sagay City, Negros Occidental during 100-Year Rainfall Return Period 93
Figure 82. The Validation Points for a 5-year Flood Depth Map of the Himogaan-Tanao Floodplain 94
Figure 83. Flood map depth versus actual flood depth 95

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND TANAO RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer R. Sinogaya, PhD.

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Cebu (UPC). UPC 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 22 river basins in the Western Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Tanao River Basin

Tanao River Basin is located in the province of Negros Occidental located at the north of Negros Island. The floodplain and drainage area of 75.57 km2 and 57.23 km2 respectively covers Toboso, Sagay City and Cadiz City. The floodplain is 100% covered with LiDAR data which compromises 7 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.06 and then bathy burned. The bathy survey conducted reached a total length of 12.46 km starting from Old Sagay, Sagay City up to the river mouth with 3807 points surveyed. There are 12444 buildings, 47.39km roads, 858 waterbodies and 6 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 11870 of them are Residential, 181 are schools and 17 are Medical Institutions.

The flood hazard map produced covers the 22.18 km2, 25.38 km2, 28 km2 for the 5-year, 25-year, and 100-year rainfall return period in Cadiz City which affects 4 barangays and in Sagay City which affects 8 barangays. A flood depth validation was conducted using 271 randomly generated points which is spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded a 0.403m RMSE.

A rating curve was developed at Tanao Bridge, Sagay City, Negros Occidental, which shows the relationship between the observed water levels at Tanao Bridge and outflow of the watershed at this location. This rating curve equation, expressed as Q = 0.0885e0.3362x, was used to compute the river outflow at Tanao Bridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

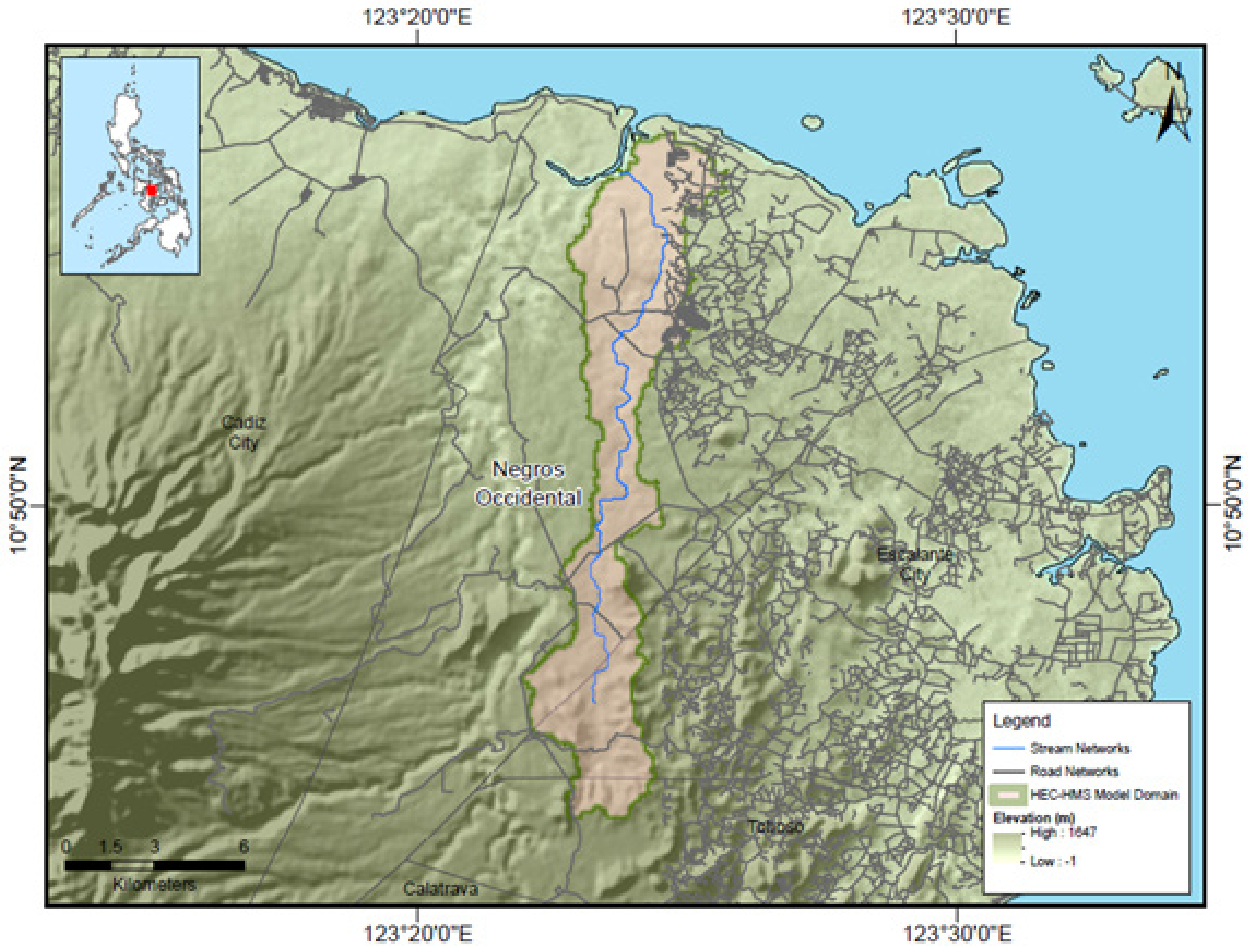


Figure 1. Map of Tanao River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE TANAO FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, and Ms. Jonalyn S. Gonzales

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Tanao floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Tanao Floodplain in Negros Occidental. Each flight mission has an average of 6 lines and ran for at most three (3) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2 and Figure 3 show the flight plan for Tanao floodplain survey.

Table 1. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK44As	500	30	18	50	45	115-130	5
BLK44ES	500	30	18	50	45	115-130	5
BLK44DS	500	30	18	50	45	115-130	5

Table 2. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK44D	1200/800	12/20/15	50	200	30	115-130	5
BLK44E	1200	12/20	50	200	30	115-130	5
BLK44H	1100/800	20/15	50	200	30	115-130	5
BLK44G	800	15	50	200	30	115-130	5

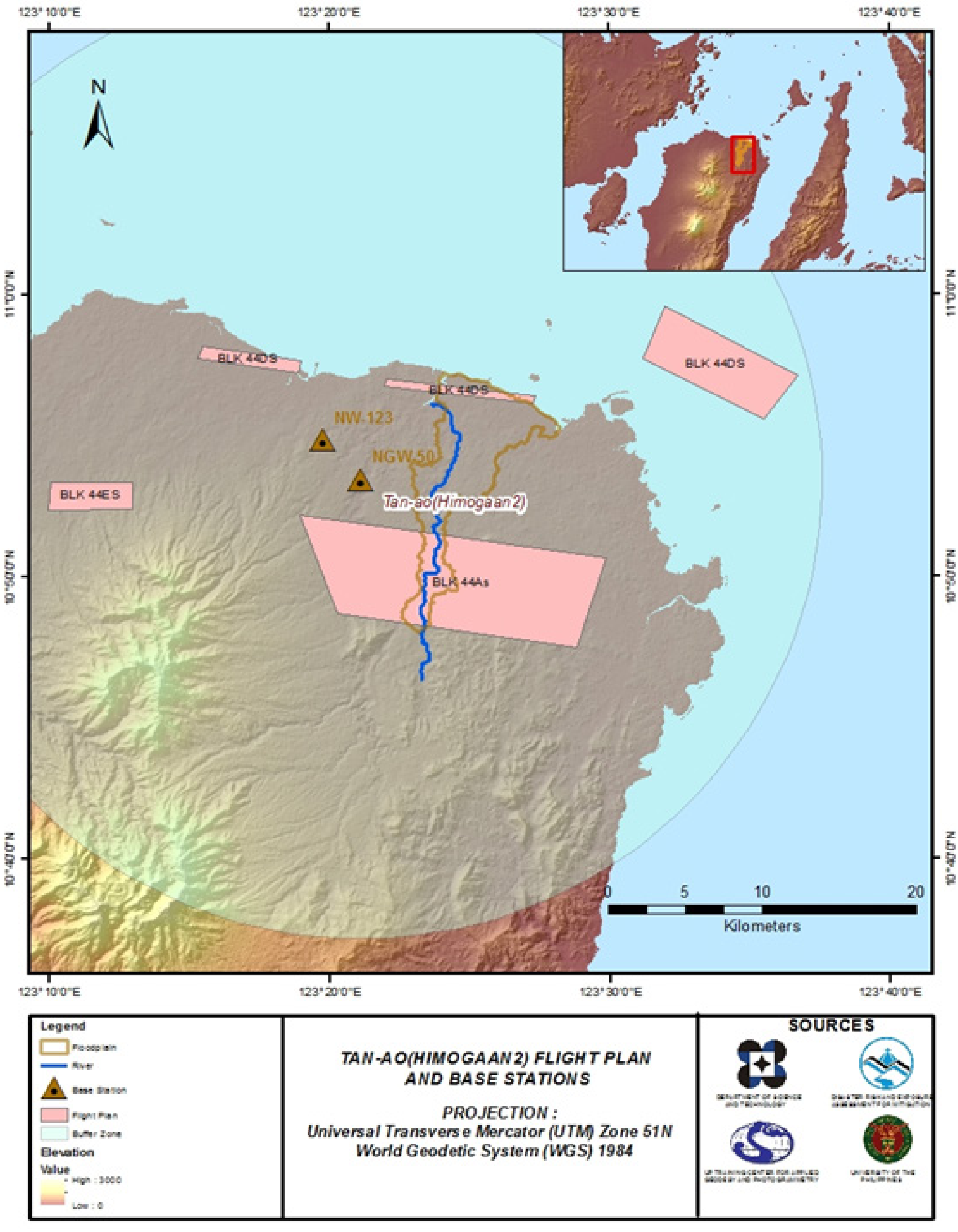


Figure 2. Flight Plan and base stations used for the Tanao Floodplain survey using Aquarius sensor.

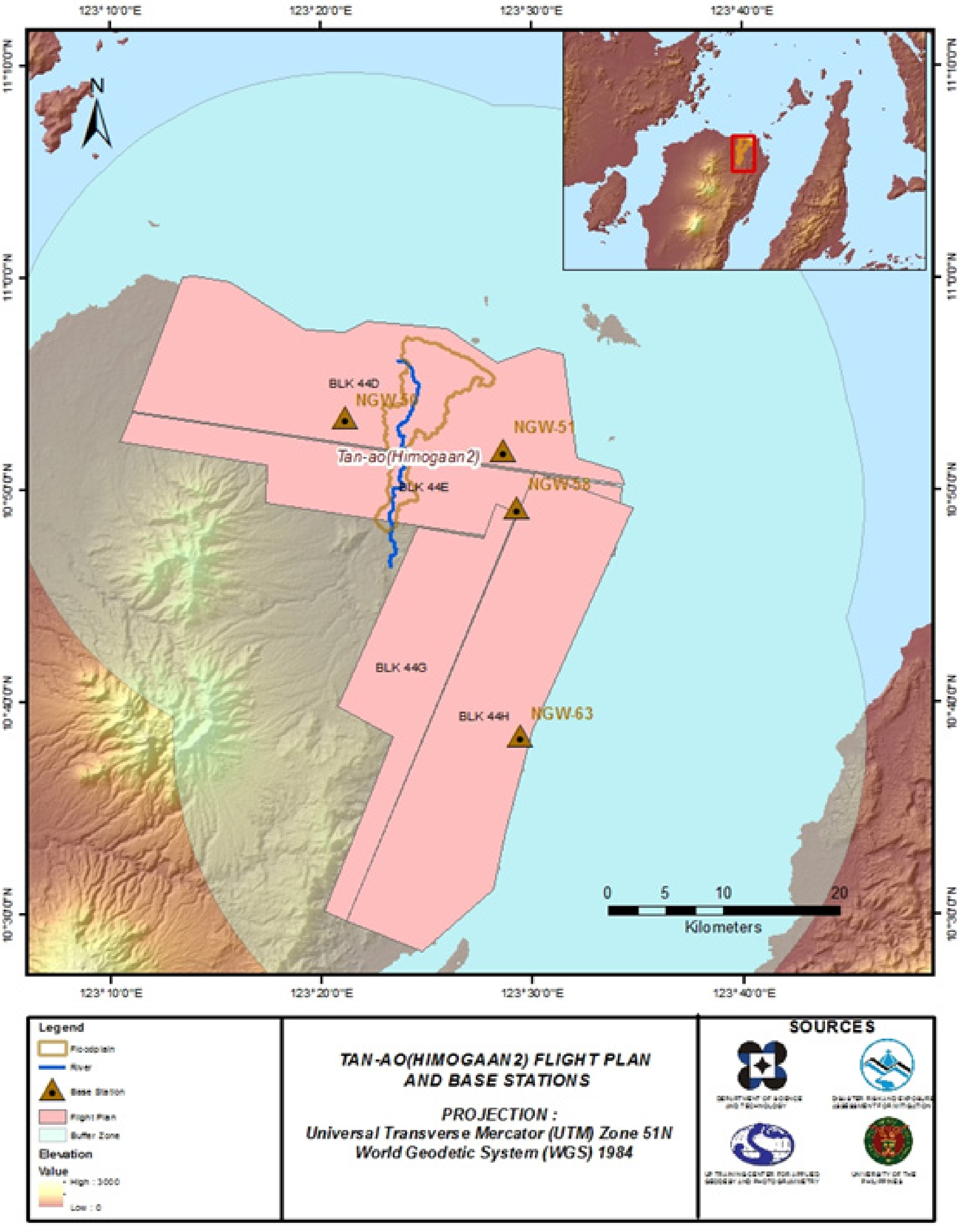


Figure 3. Flight Plan and base stations used for the Tanao Floodplain survey using Pegasus sensor.

2.2 Ground Base Stations

The field team was able to recover four (4) NAMRIA ground control points: NGW-50, NGW-51, NGW-58, and NGW-63 which are of second (2nd) order accuracy. One (1) benchmark point: NGW-123 which is of first (1st) order accuracy.

The certifications for the base stations are found in ANNEX 2 while the baseline processing report for established point is found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey from April 29 to May 7, 2014 and April 22 to 24, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Tanao (Himogaan2) floodplain are shown in Figure 2 and Figure 3.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Tanao Floodplain LiDAR Survey. Figure 4 to Figure 8 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 3 to Table 7 show the details about the following NAMRIA control stations and established points. Table 8, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

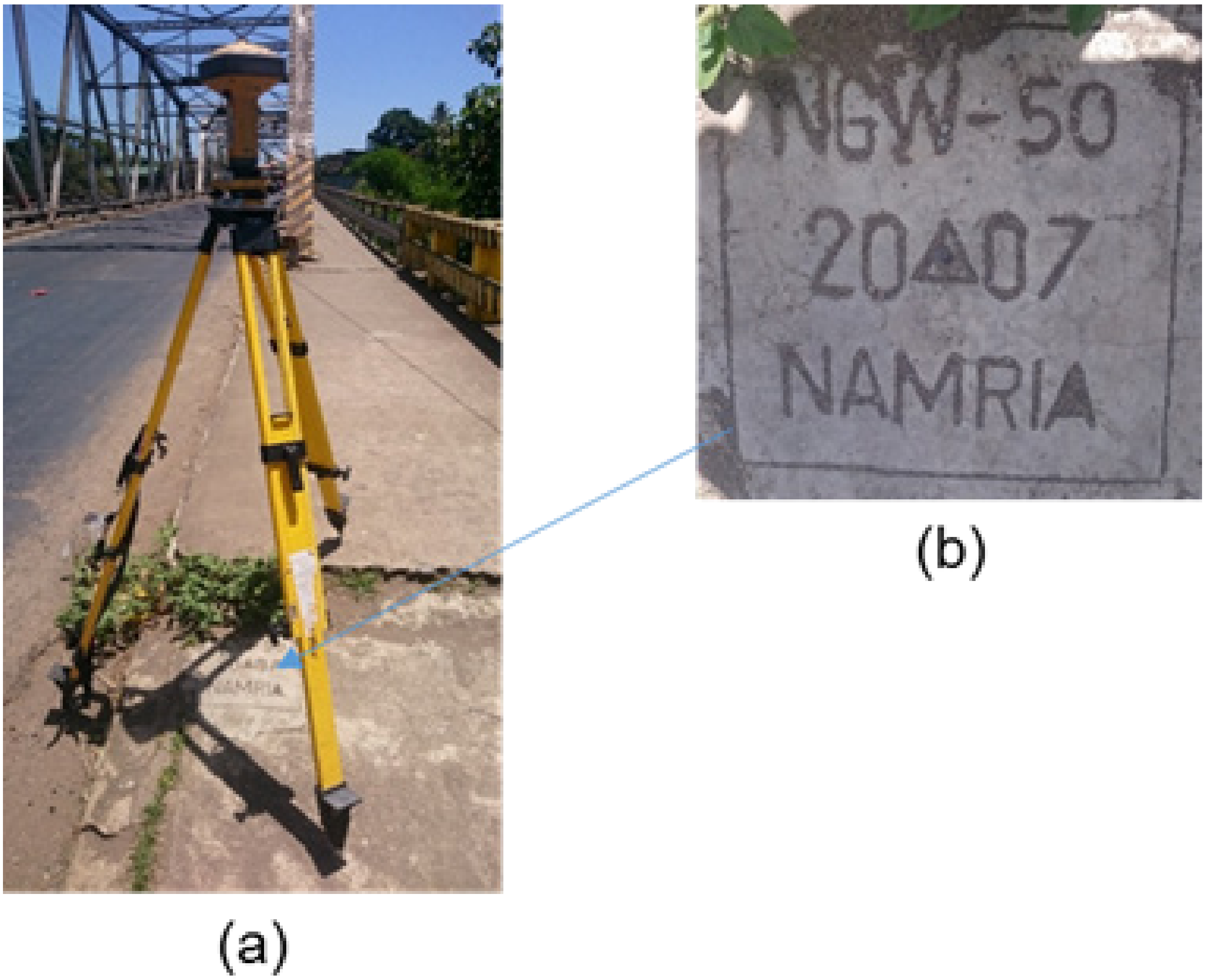


Figure 4. GPS set-up over NGW-50 on the NW sidewalk of Himoga-an bridge at km. 73+545 along the Sagay-Bacolod National Highway in Sagay, Negros Occidental (a) and NAMRIA reference point NGW-50 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGW-50 used as base station for the LiDAR

Station Name	**NGW-50**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 30’ 17.85657” North 125o 1’ 29.837339” East 26.13400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	502722.403 meters 1272180.079 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 30’ 13.52495” North 125o 1’ 34.96980” East 87.78700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	720874.14 meters 127513.40 meters

(a) (b)

Figure 5. GPS set-up over NGW-51 at the NW tip of a yellow headwall found at the SW of Escalante-Bacolod national road at Brgy. Had Fe, Escalante, Negros Occidental (a) and NAMRIA reference point NGW-51 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point NGW-51 used as base station for the LiDAR acquisition.

Station Name	**NGW-51**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 51' 58.41454" North 123° 28' 32.88028" East 32.089 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	552020.927 meters 1201574.19 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 51' 54.11167" North 123° 28' 38.08213" East 91.489 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	552002.72 meters 1201153.62 meters

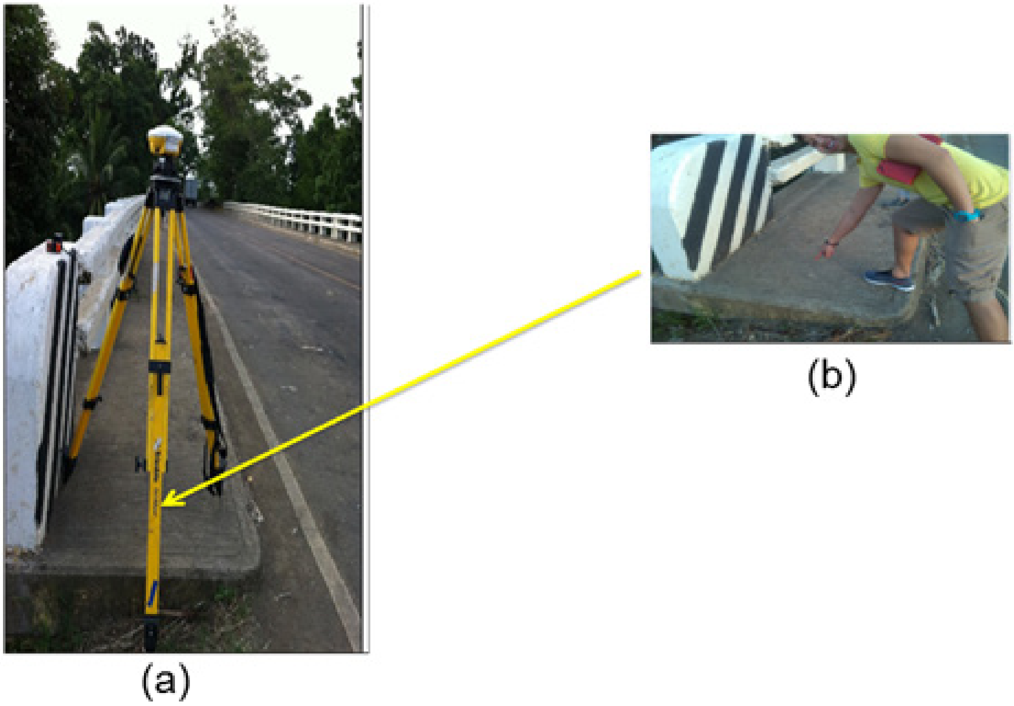


Figure 6. GPS set-up over NGW-58 at the NE sidewalk of Danao Bridge found at Brgy. Jonobjonob, Sitio Labarca, Escalante, Negros Occidental (a) and NAMRIA reference point MGW-58 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point NGW-58 used as base station for the LiDAR acquisition.

Station Name	**NGW-58**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 49' 16.43235" North 123° 29' 16.71871" East 8.722 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Latitude Longitude Ellipsoidal Height	553202.195 meters 1196599.363 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49' 12.14178" North 123° 29' 16.71871" East 68.256 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	553183.57 meters 1196180.53 meters

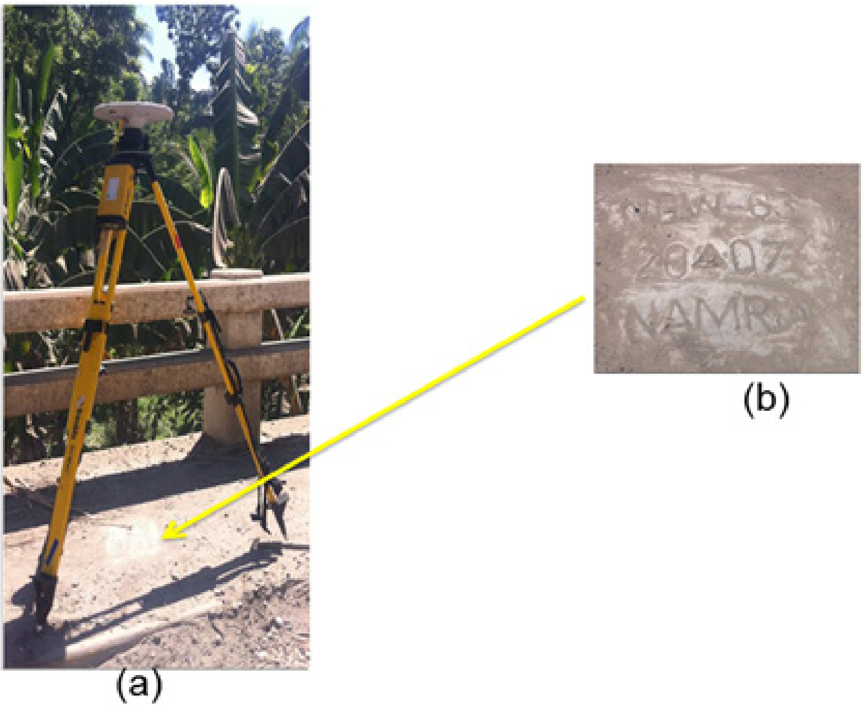
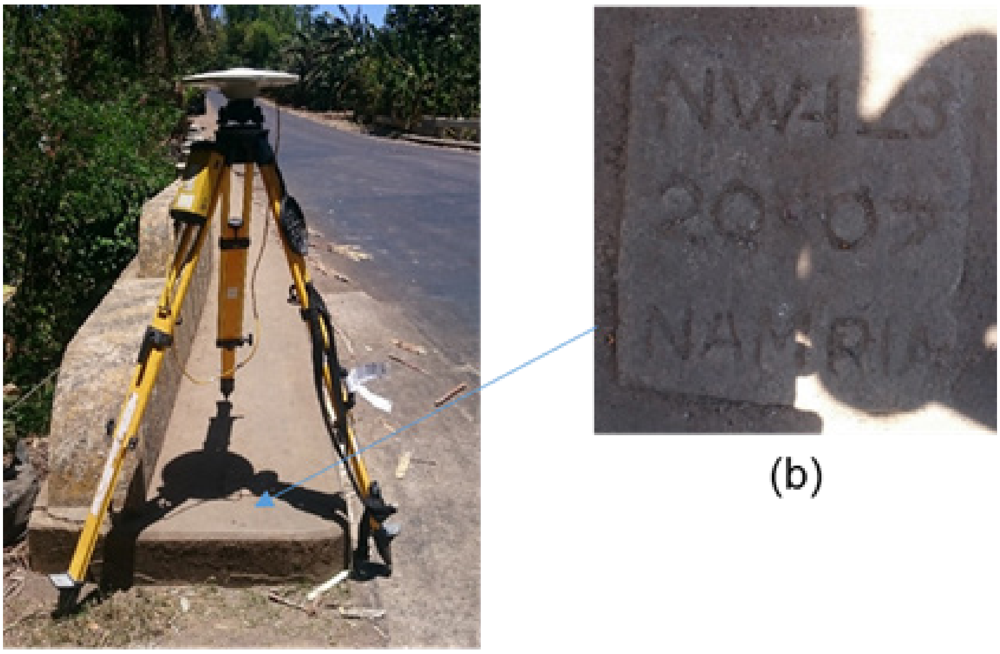


Figure 7. GPS set-up over NGW-63 at the NE end of the sidewalk of Daan-Lunsod Bridge at Brgy. Lemery, Calatrava, Negros Occidental (a) and NAMRIA reference point NGW-63 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point NGW-63 used as base station for the LiDAR acquisition.

Station Name	**NGW-63**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 38’ 30.18023” North 123° 29’ 18.57332” East 10.155 meters
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Easting Northing	553448.18 meters 1176744.618 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 38’ 25.93535” North 123° 29’ 23.79491” East 70.11800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	553429.47 meters 1176332.74 meters



(a) (b)

Figure 8. GPS set-up over NW-123 at the right side of the bridge located in Cadiz, Negros Occidental going to San Carlos, along the national road (a) and NAMRIA reference point NW-123 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point NW-123 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	**NW-123**	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 54’ 55.44193” 123° 19’ 39.85851” 29.402 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 54’ 51.11386” 123° 19’ 45.05716” 88.320 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	535814.201 meters 1206569.167 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
29 April 2014	1403P	1BLK44DE119A	NGW-51 and NGW-58
1 May 2014	1411P	1BLK44D121A	NGW-50 and NGW-58
2 May 2014	1415P	1BLK44H122A	NGW-58 and NGW-63
6 May 2014	1431P	1BLK44GHS126A	NGW-58 and NGW-63
6 May 2014	1433P	1BLK44GHS126B	NGW-58 and NGW-63
7 May 2014	1435P	1BLK44DS127A	NGW-50 and NGW-58
22-Apr-16	8453AC	3BLK44As113A	NGW-50 and NW-123
23-Apr-16	8455AC	3BLK44As114A	NGW-50 and NW-123
24-Apr-16	8457AC	3BLK44EDs115A	NGW-50 and NW-123

2.3 Flight Missions

A total of nine (9) missions were conducted to complete the LiDAR data acquisition in Tanao floodplain, for a total of one hundred ten hours and forty five minutes (110+45) of flying time for RP-C9022 and RP-C9322. All missions were acquired using the Aquarius and Pegasus LiDAR systems. Table 9 shows the total area of actual coverage per mission and the flying length for each mission and Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for the LiDAR data acquisition of the Tanao 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
29 April 2014	1403P	606.7	206.25	14.51	191.74	774	4	35
1 May 2014	1411P	606.7	360.36	41.50	318.86	519	3	47
2 May 2014	1415P	274.5	405.11	NA	405.11	686	4	23
6 May 2014	1431P	604.6	225.67	NA	225.67	728	4	41
6 May 2014	1433P	604.6	196.84	2.74	194.1	0	4	29
7 May 2014	1435P	437.8	336.42	28.06	308.34	0	4	53
22-Apr-16	8453AC	114.7	103.85	8.44	95.41	0	4	11
23-Apr-16	8455AC	50.7	60.01	5.23	54.78	0	3	53
24-Apr-16	8457AC	250.2	61.53	3.42	58.11	0	3	53
TOTAL		**3550.5**	**1956.04**	**103.9**	**1852.12**	**2707**	**110**	**45**

Table 10. Actual parameters used during the LiDAR data acquisition of the Tanao Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1403P	1200	12	50	200	30	115-130	5
1411P	1200	20	50	200	30	115-130	5
1415P	1100	20	50	200	30	115-130	5
1431P	800	15	50	200	30	115-130	5
1433P	1100	20	50	200	30	115-130	5
1435P	800	15	50	200	30	115-130	5
8453AC	500	30	18	50	45	115-130	5
8455AC	500	30	18	50	45	115-130	5
8457AC	500	30	18	50	45	115-130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Tanao floodplain (See ANNEX 7). It is located in the provinces of Negros Occidental and Negros oriental with majority of the floodplain situated within the municipality of Toboso and Escalante City. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 11. The actual coverage of the LiDAR acquisition for Tanao floodplain is presented in Figure 9.

Table 11. The list of municipalities and cities surveyed of the Tanao Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Negros Occidental	Toboso	118.52	118.51	99.99%
	Escalante City	193.40	193.31	99.96%
	Sagay City	304.62	283.99	93.23%
	Calatrava	344.54	251.56	73.01%
	Cadiz City	516.18	266.07	51.55%
	San Carlos City	408.97	84.86	20.75%
	Manapla	99.18	4.63	4.66%
Total		1985.41	1202.93	60.59%

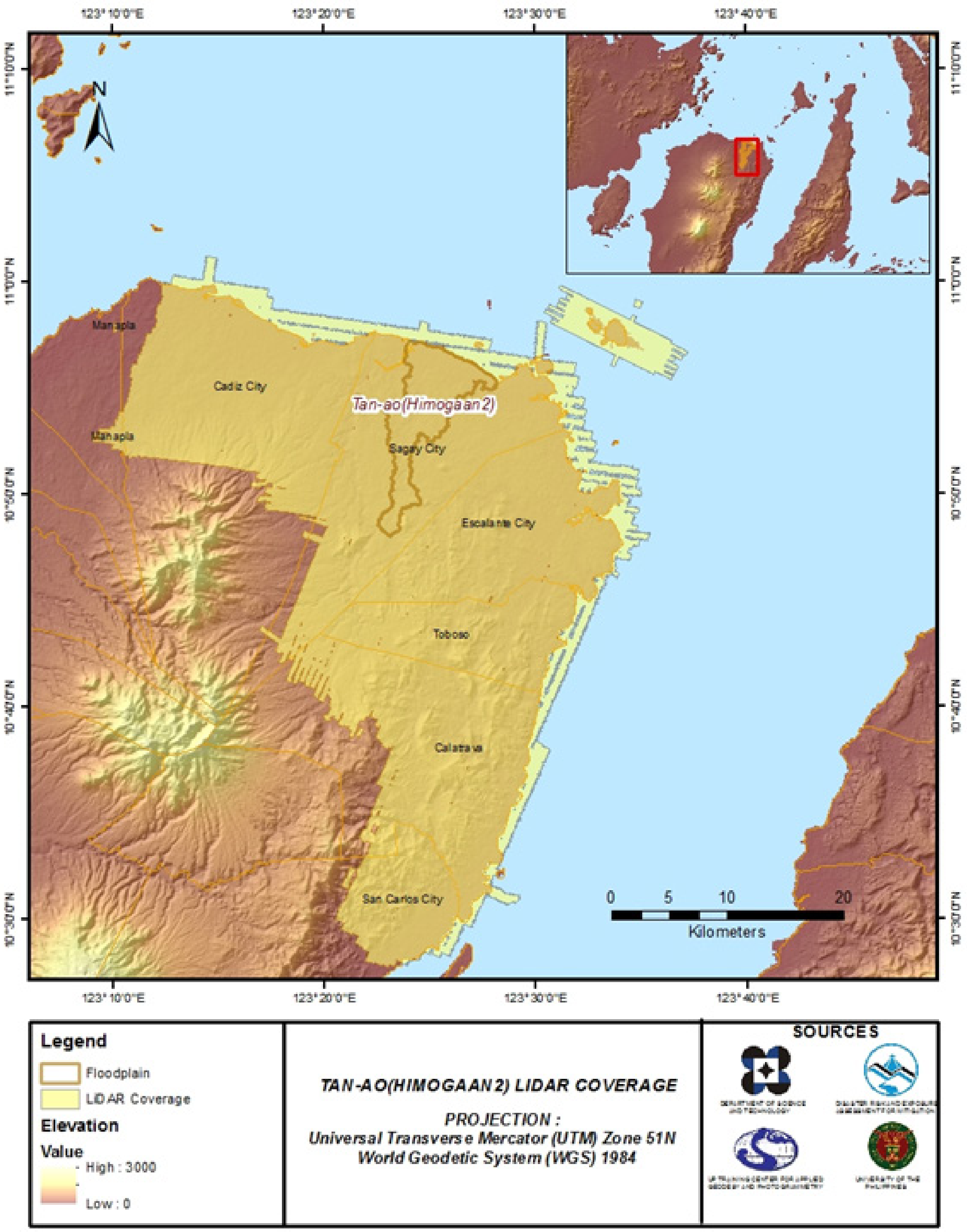


Figure 9. Actual LiDAR survey coverage of the Tanao Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE TANAO FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Joida F. Prieto , Engr. Ma. Ailyn L. Olanda, Engr. Chelou P. Prado, Eng. Czarina Jean P. Añonuevo , Franklin D. Maraya, and Chester B. de Guzman

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 10.

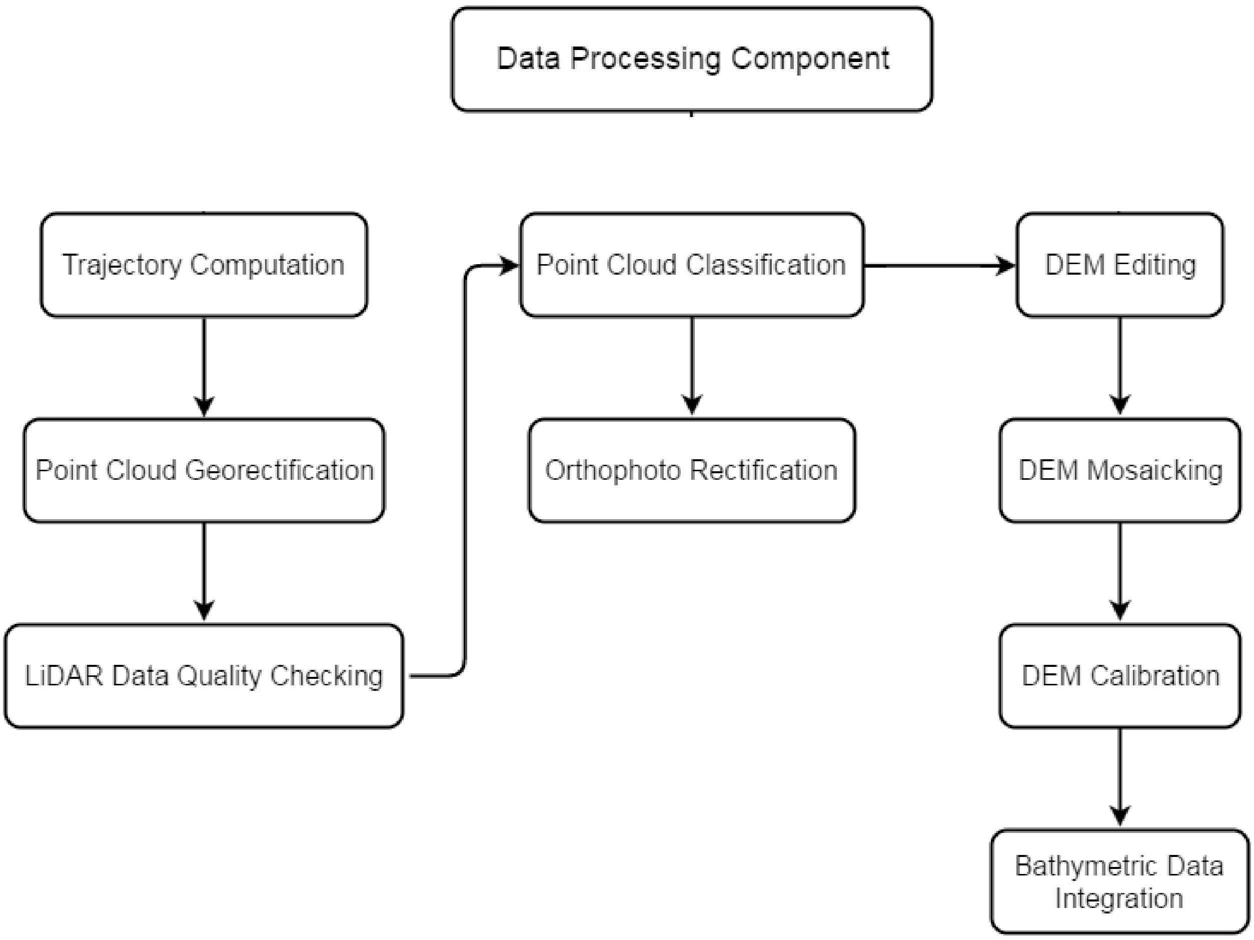


Figure 10. Schematic diagram for Data Pre-processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Tanao Floodplain can be found in ANNEX 5. The missions flown during the conduct of the first survey in May 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. Missions acquired during the second survey on April 2016 were flown using the same system over Sagay City, Negros Occidental.

The Data Acquisition Component (DAC) transferred a total of 146.14 Gigabytes of Range data, 1.99 Gigabytes of POS data, 426.78 Megabytes of GPS base station data, and 263.3 Gigabytes of raw image data to the data server on May 19, 2014 for the first survey and May 18, 2016 for the second survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Tanao Floodplain was fully transferred on May 18, 2016, as indicated on the Data Transfer Sheets for the Tanao floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 1433P, one of the Tanao flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of May 6, 2014, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

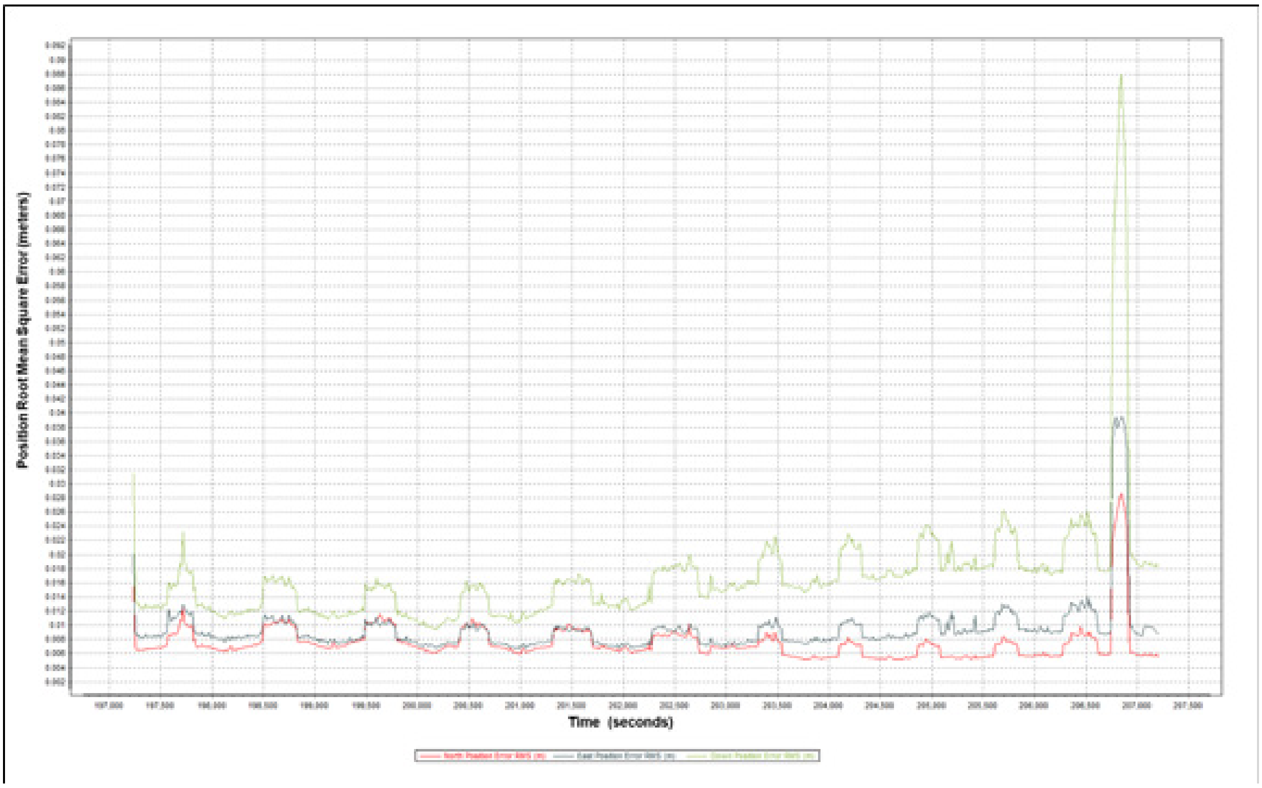


Figure 11. The Smoothed Performance Metrics of Tanao Flight 1433P.

The time of flight was from 197,500 seconds to 207,500 seconds, which corresponds to afternoon of May 6, 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 minimize 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 11 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.40 centimeters, and the Down position RMSE peaks at 2.60 centimeters, which are within the prescribed accuracies described in the methodology.

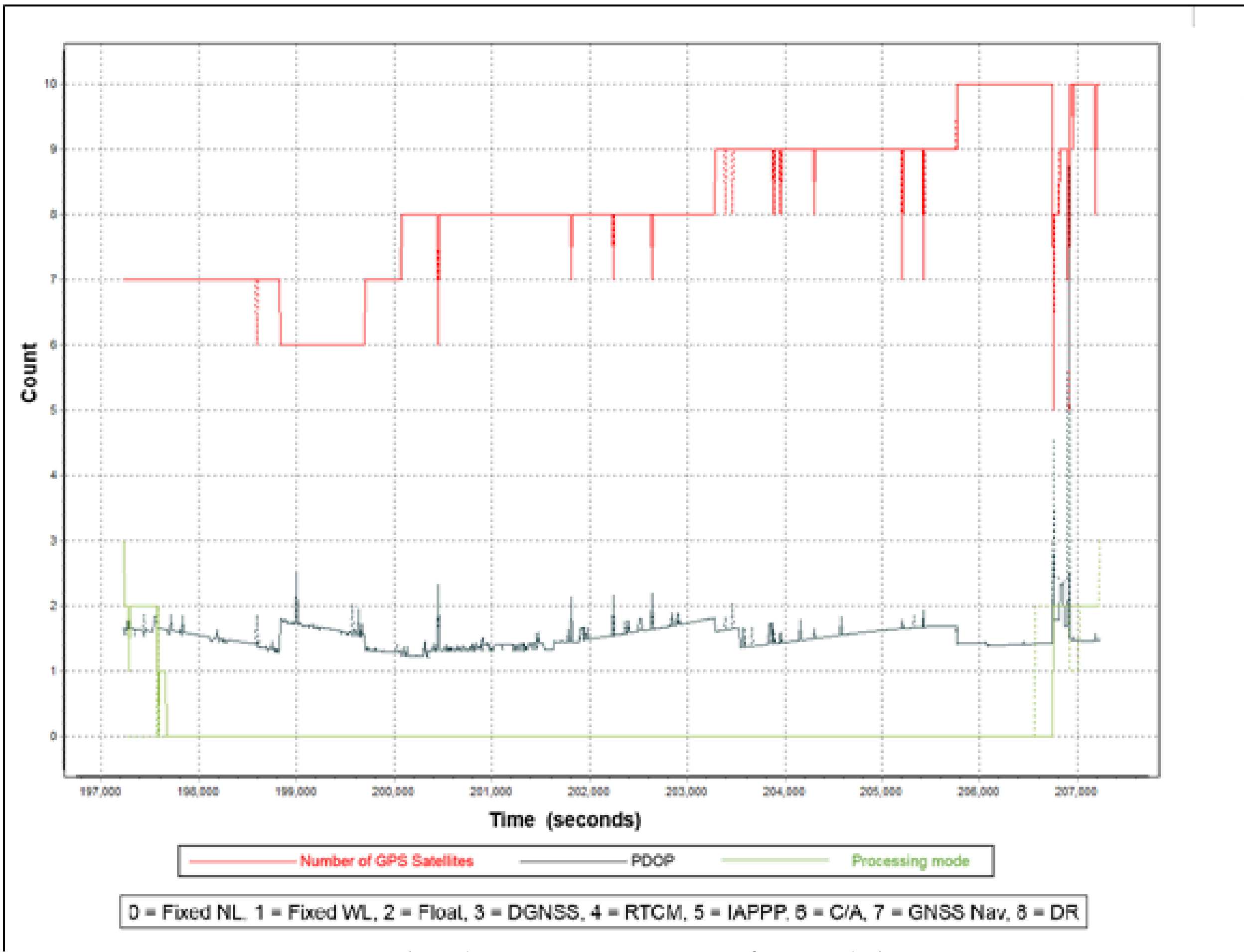


Figure 12. The Solution Status Parameters of Tanao Flight 1433P.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Tanao Flight 1433P are shown in Figure 12. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 6 and 10, not going lower than 6. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also stayed at the value of 0 for the majority of the survey stayed at the value of 0. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for the POSPAC MMS. Fundamentally, 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 Tanao flights is shown in Figure 13.

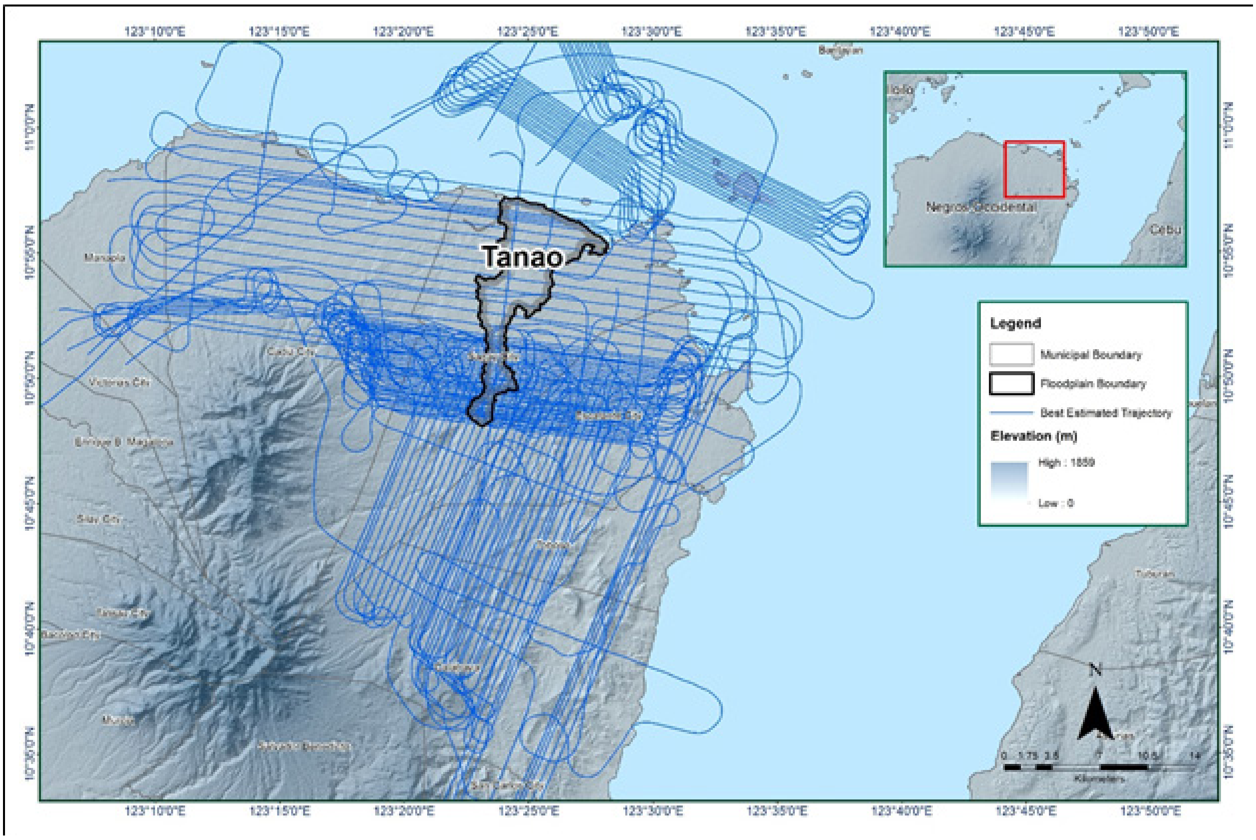


Figure 13. The Best Estimated Trajectory of the LiDAR missions conducted over the Tanao floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 142 flight lines, with each flight line contains one channel, since the Aquarius system contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Tanao floodplain are given in Table 12.

Table 12. Self-calibration values for all Tanao floodplain flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000218
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000903
GPS Position Z-correction stdev)	<0.01meters	0.0027

The optimum accuracy values for all Tanao flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (ANNEX 7).

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Tanao Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

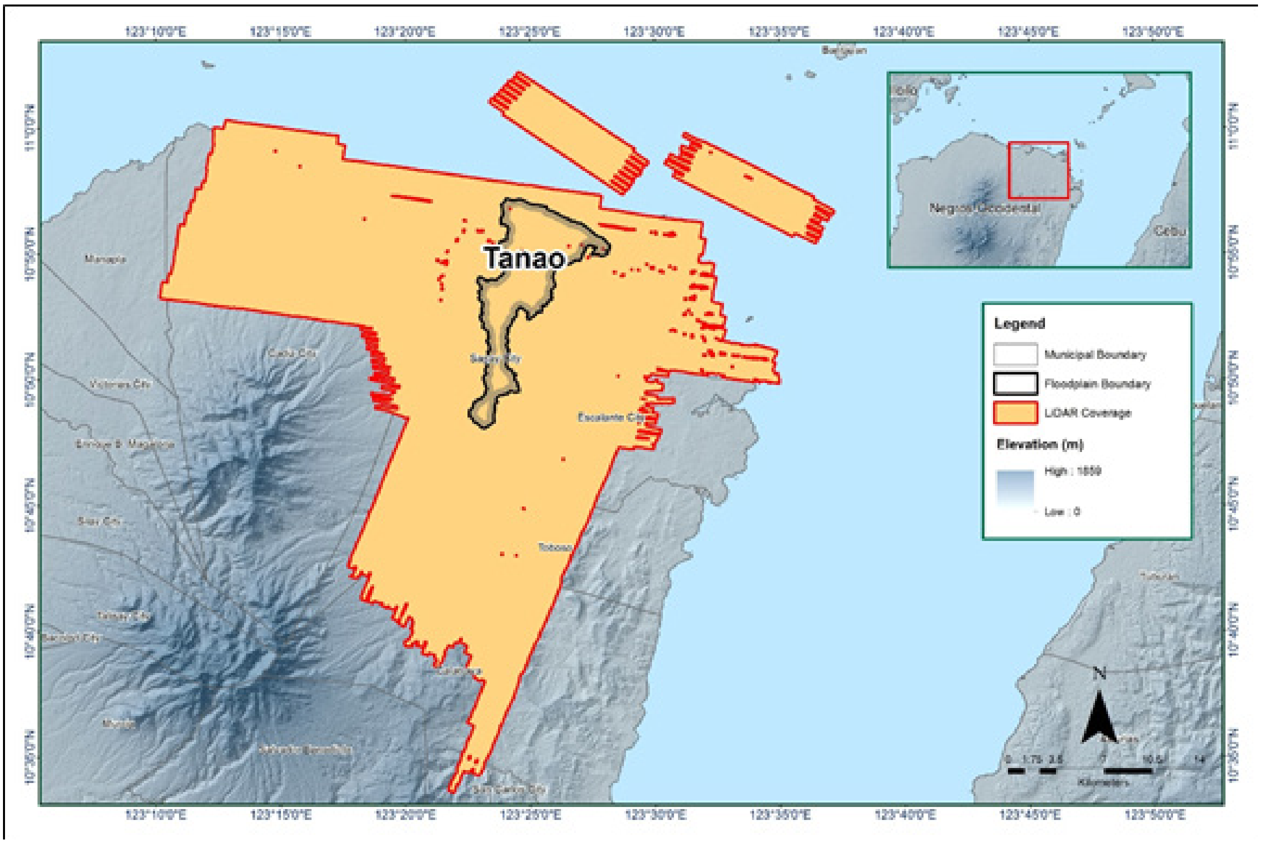


Figure 14. The boundaries of the processed LiDAR data over the Tanao Floodplain.

A total area of 980.39 square kilometers (sq. kms.) were covered by the Tanao flight missions as a result of ten (10) flight acquisitions, which were grouped and merged into seven (7) blocks accordingly, as portrayed in Table 13.

Table 13. List of LiDAR blocks for the Tanao floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Negros_Blk44D	1411P	455.2
	1435P	
Negros_Blk44FG	1433P	283.57
	1435P	
	1431P	
Bacolod_Blk44E	8453AC	101.82
Bacolod_Blk44E_additional	8455AC	54.52
Bacolod_Blk44L	8457AC	15.42
Bacolod_Blk44D	8459AC	35
Bacolod_Blk44M	8457AC	34.86
TOTAL		**980.39**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

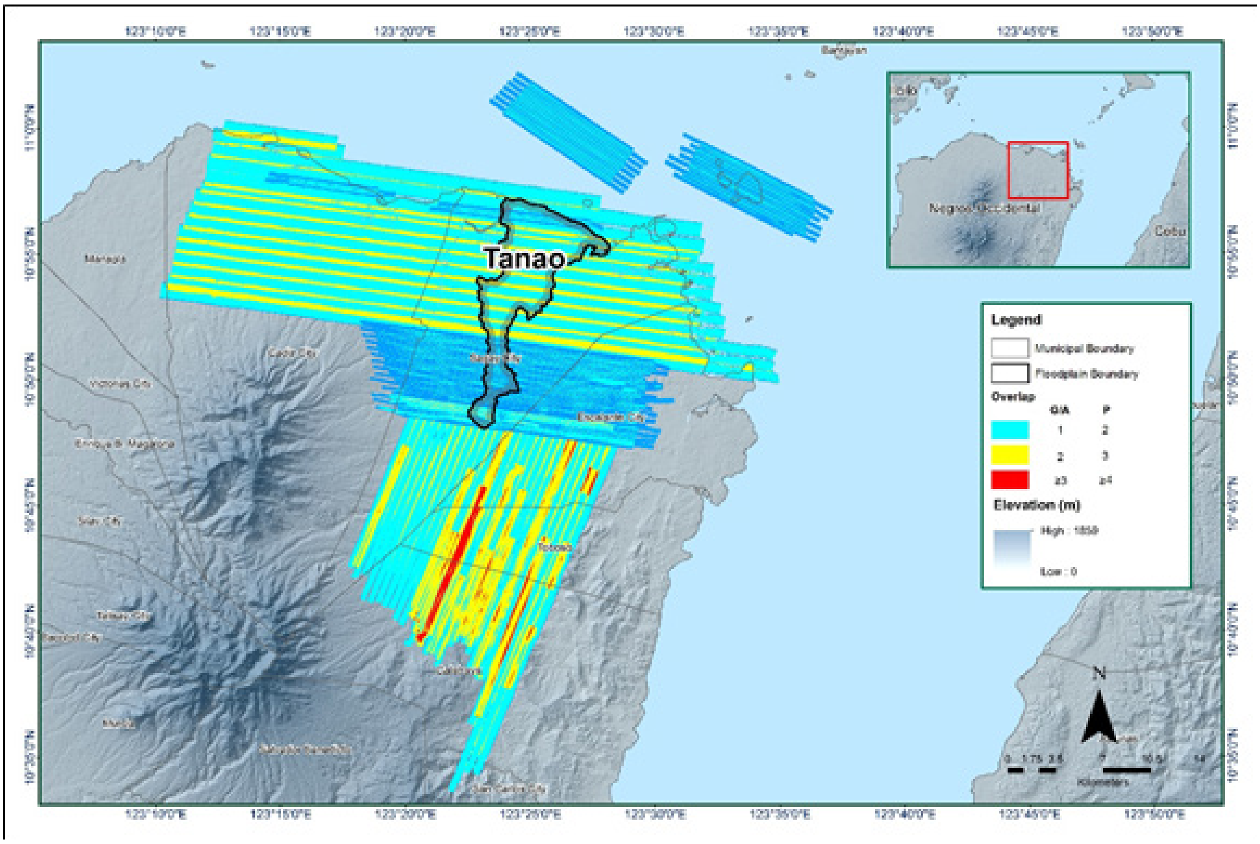


Figure 15. Data overlap between missions and flight lines for the Tanao River Floodplain Survey.

The overlap statistics per block for the Tanao Floodplain Survey can be found in the Mission Summary Reports (ANNEX 7). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.44% and 43.01% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 16. As seen in the figure below, it was determined that all LiDAR data for the Tanao Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.62 points per square meter.

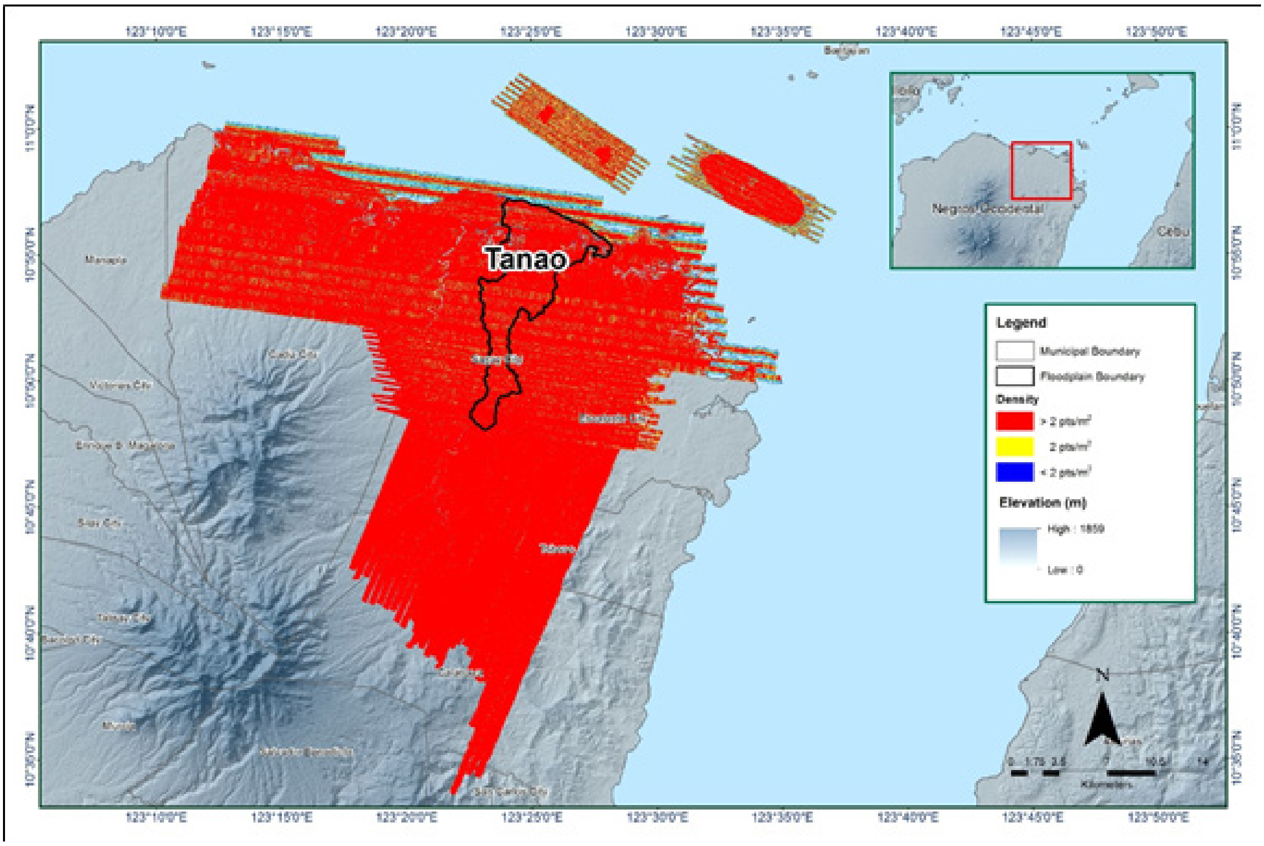


Figure 16. The pulse density map of the merged LiDAR data for the Tanao Floodplain Survey.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

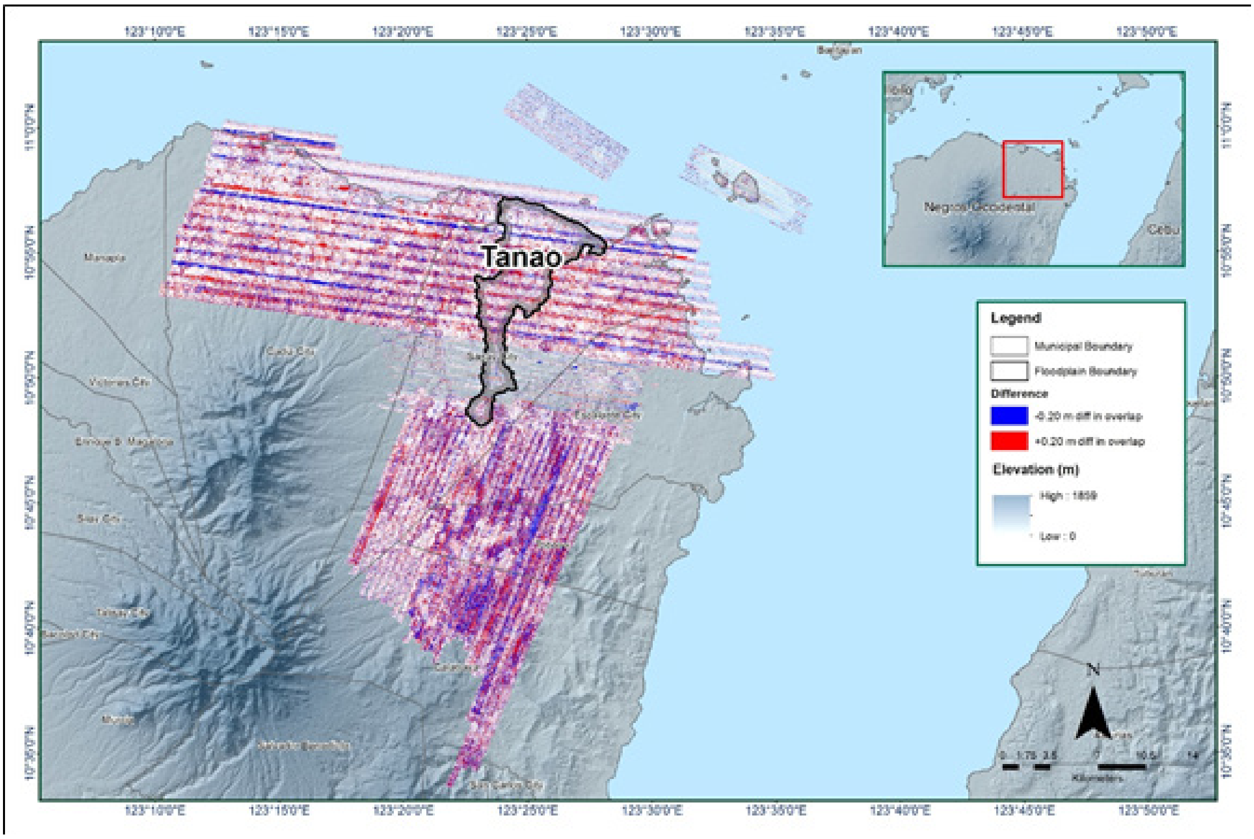


Figure 17. Map of elevation difference Map between flight lines for the Tanao Floodplain Survey.

A screen-capture of the processed LAS data from Tanao flight 1433P loaded in QT Modeler is shown in Figure 18. 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 generated satisfactory results. No reprocessing was done for this LiDAR dataset.

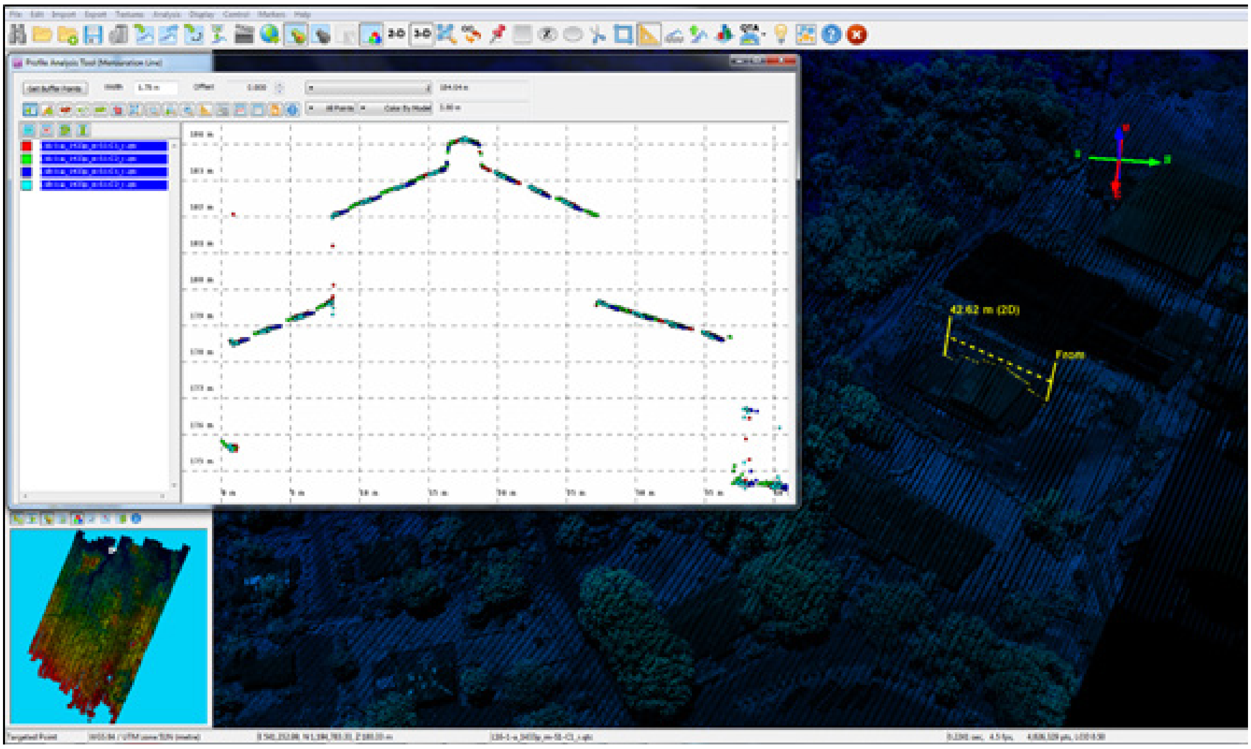


Figure 18. Screen-capture of the quality checking for Tanao Flight 1433P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Summary of point cloud classification results in TerraScan for Tanao River Floodplain.

Pertinent Class	Total Number of Points
Ground	1,043,163,716
Low Vegetation	1,018,397,531
Medium Vegetation	1,509,992,662
High Vegetation	503,124,737
Building	25,956,158

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Tanao floodplain is shown in Figure 23. A total of 1,475 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 14 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 584.11 meters and 48.75 meters respectively.

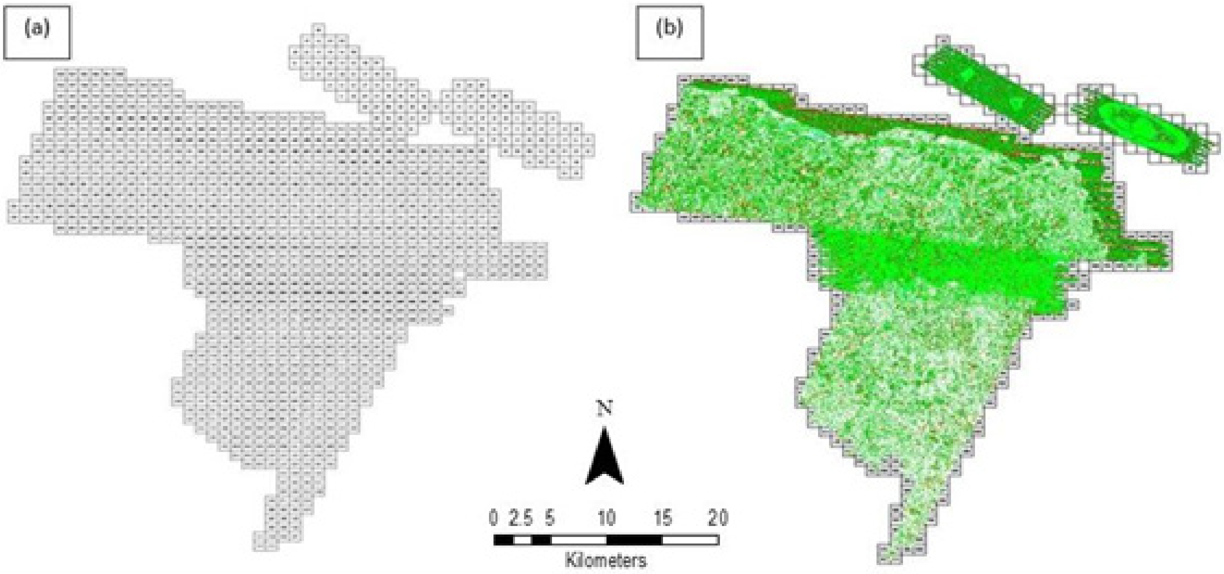


Figure 19. The coverage of the Tanao Floodplain Survey (a) the tile system (b) depicts the classification results in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are highlighted in orange, while the vegetation are in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

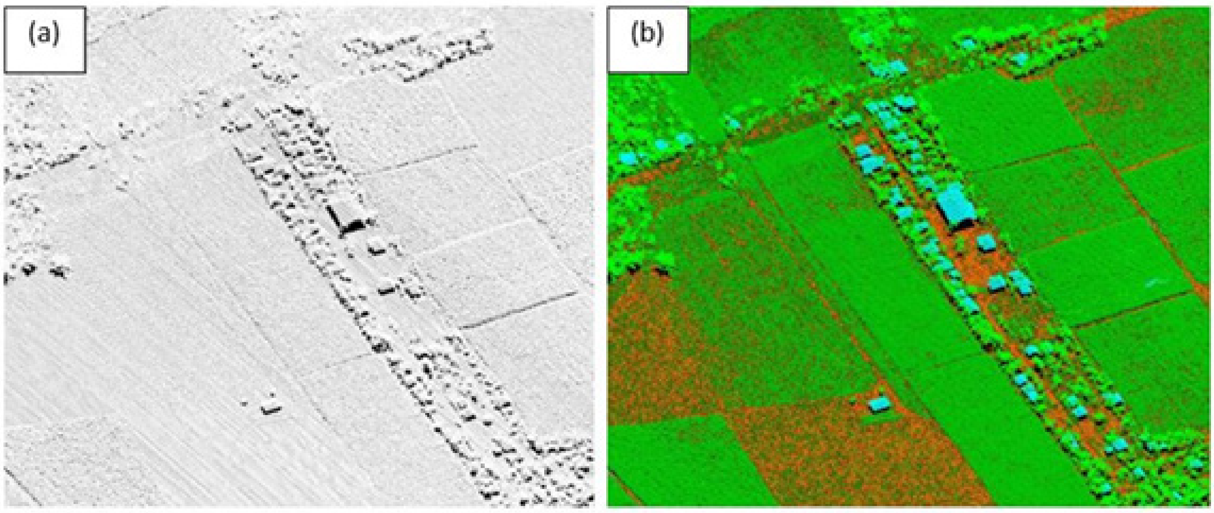


Figure 20. The images before (a) and after (b) undertaking classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show in Figure 21. As seen in the figure, the DTMs represent the bare earth, while all other features, such as buildings and vegetation, are present in the DSMs.

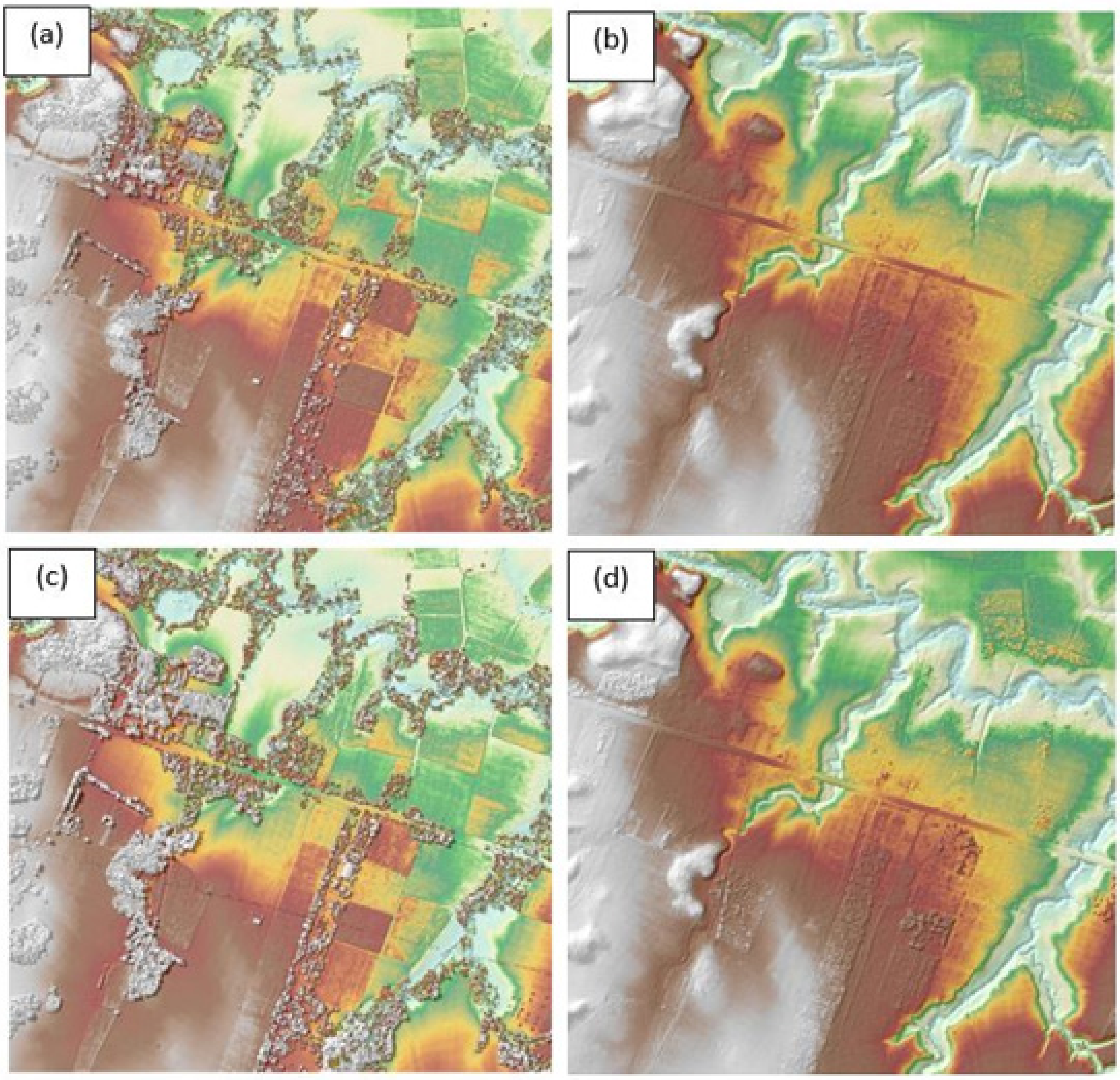


Figure 21. Photo (A) features the production of the last return DSM; (B) depicts the production of the DTM; (C) portrays the production of the first return DSM; and (D) presents the generation of the secondary DTM in some portions of the Tanao Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 685 1km by 1km tiles area covered by the Tanao floodplain is shown in Figure 22. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Tanao floodplain attained a total of 528.31 sq. kms. in orthophotograph coverage comprised of 1,624 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

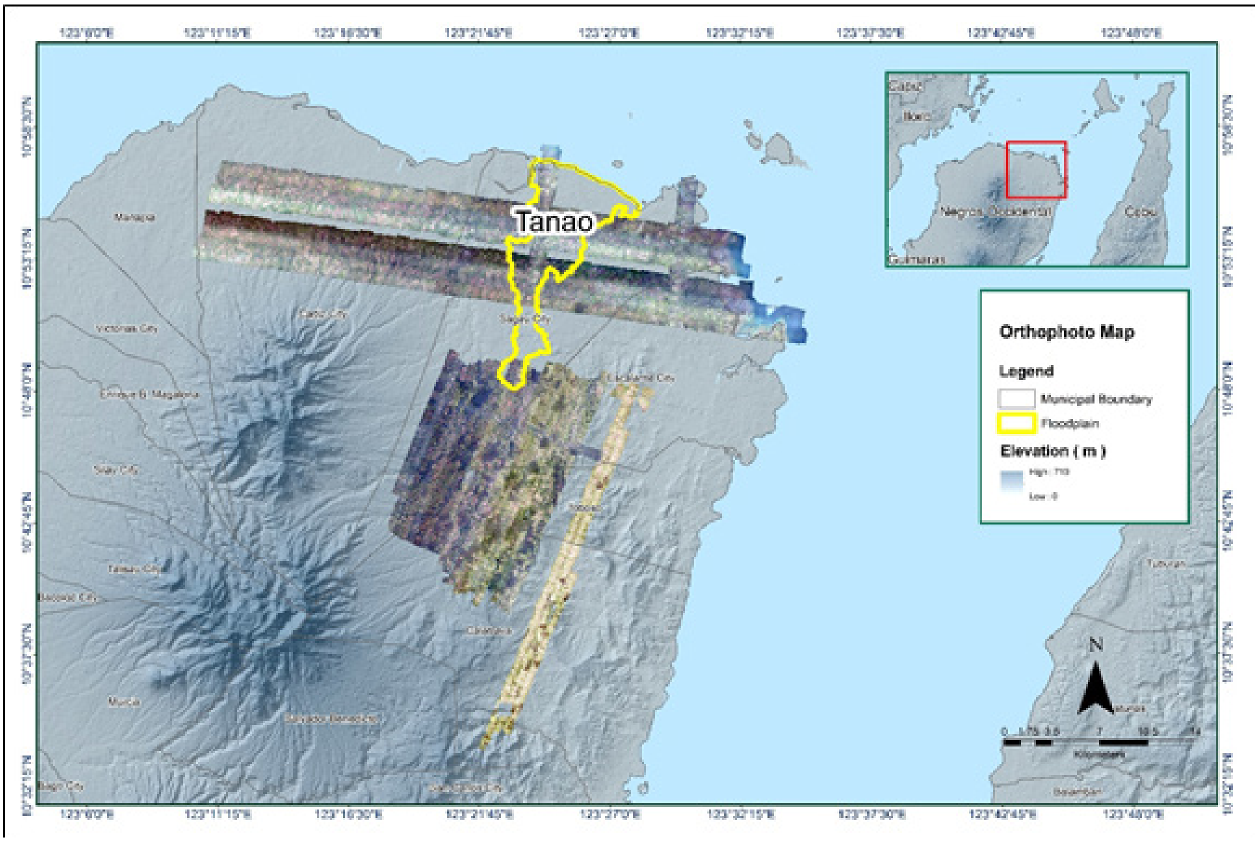


Figure 22. The Tanao Floodplain with the available orthophotographs.

Figure 23. Sample orthophotograph tiles for the Tanao Floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for the Tanao Floodplain Survey. Essentially, these blocks are composed of 'Negros' and 'Bacolod' blocks, which arrive at a total area of 998.63 sq. kms. As listed in Table 15, the name and corresponding area of each block are measured out in square kilometers (sq. kms.).

Table 15. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Negros_Blk44D	455.2
Negros_Blk44FG	283.57
Bacolod_Blk44E	101.82
Bacolod_Blk44E_additional	54.52
Bacolod_Blk44L	15.42
Bacolod_Blk44D	35
Bacolod_Blk44M	34.86
TOTAL	980.39 sq. km.

Figure 24 shows portions of a DTM before and after manual editing. As evident in the figure, the paddy field (Figure 24a) was misclassified and removed during the classification process. To complete the surface, the paddy field (Figure 24b) was retrieved and reclassified through manual editing to allow the correct water flow. Likewise, the bridge (Figure 24c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 24d). As well, a lone building (Figure 24e) was still present in the DTM after the classification process. To correct this, the building was removed through manual editing (Figure 24f).

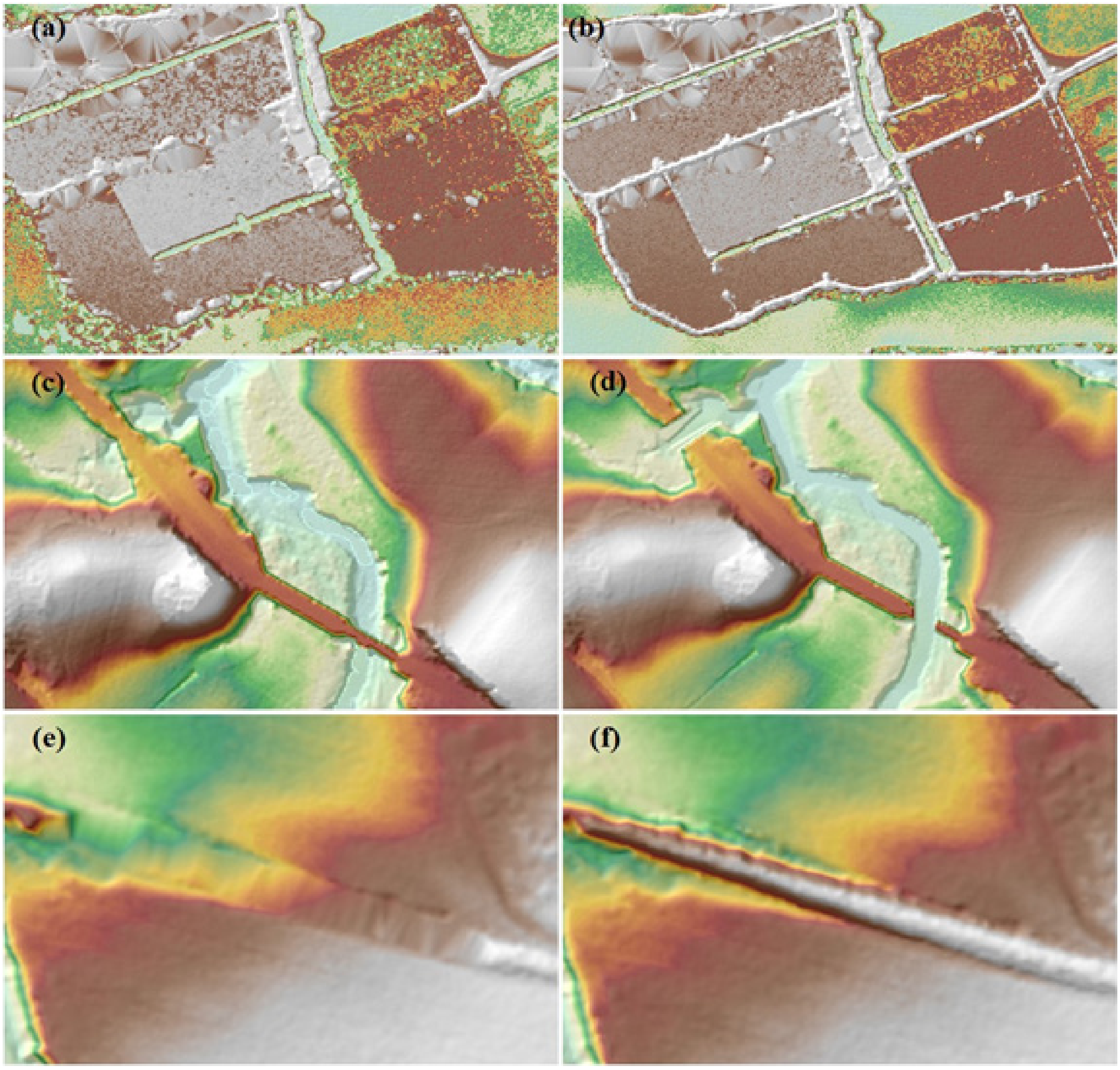


Figure 24. Portions in the DTM of the Tanao Floodplain showing (a) a paddy field before manual editing; (b) paddy after data retrieval; (c) a bridge before undergoing manual editing, while (d) after manual editing; (e) a building before manual editing, while (f) after manual editing.

3.9 Mosaicking of Blocks

Negros_Blk44AB was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Correspondingly, Table 16 shows the shifts in values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Tanao Floodplain is shown in Figure 25. It can be seen that the entire Tanao floodplain is 100% covered by LiDAR data.

Table 16. The shift values (in meters) for each LiDAR Block of the Tanao Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Negros_Blk44D	0.00	0.00	0.66
Negros_Blk44FG	0.00	0.00	0.57
Bacolod_Blk44E	0.00	0.00	1.39
Bacolod_Blk44E_additional	0.00	0.00	1.39
Bacolod_Blk44L	0.00	0.00	0.00
Bacolod_Blk44D	0.00	0.00	1.66
Bacolod_Blk44M	0.00	0.00	0.00

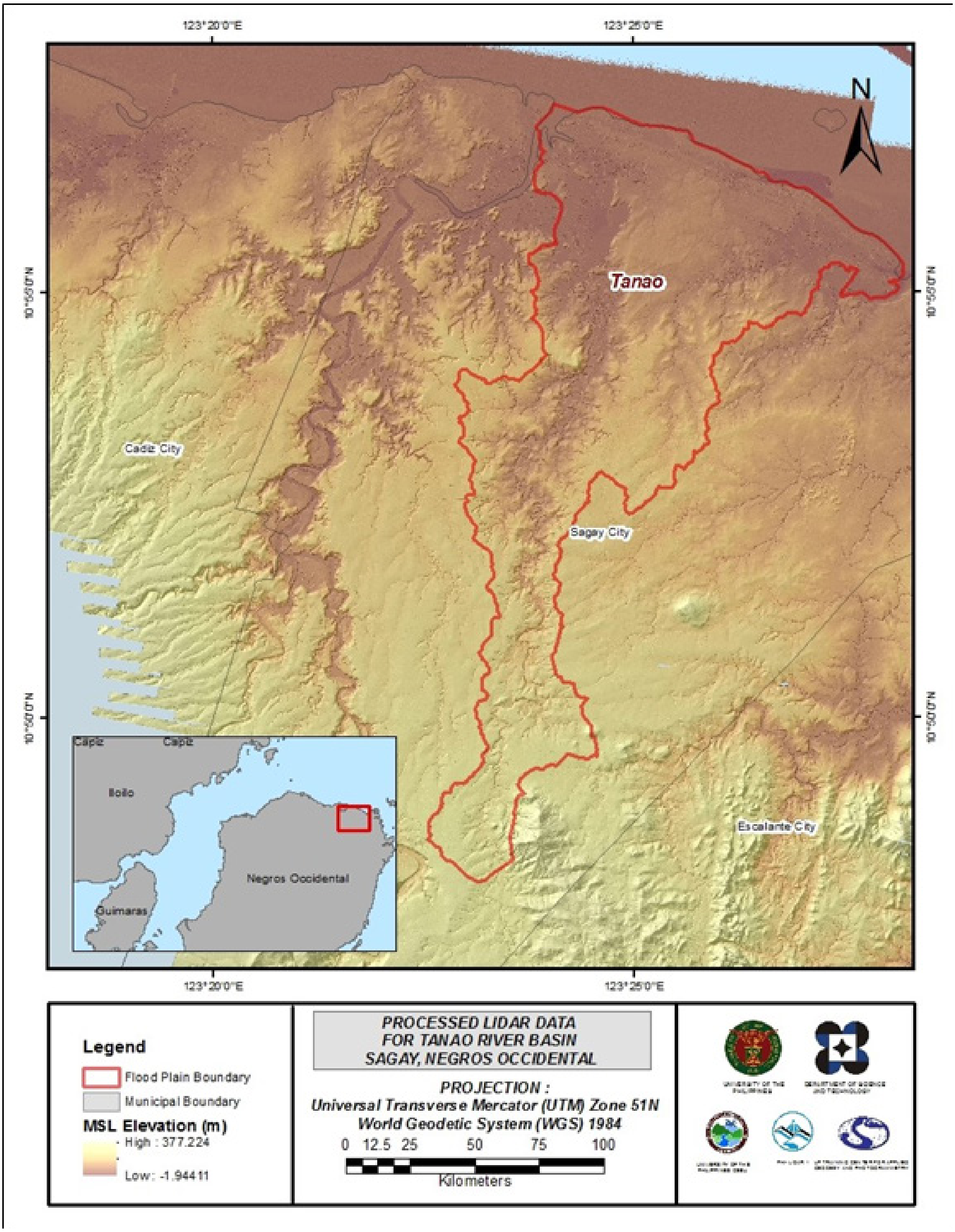


Figure 25. Map of processed LiDAR data for the Tanao Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in the Negros Island to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 39,705 points were gathered for all the floodplains within the Negros Island wherein the Tanao is located. Random selection of 80% of the survey points, resulting to 31,385 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 27. 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 0.94 meters with a standard deviation of 0.15 meters. Calibration of Tanao LiDAR data was done by subtracting the height difference value, 0.94 meters, to the mosaicked LiDAR data for Tanao. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

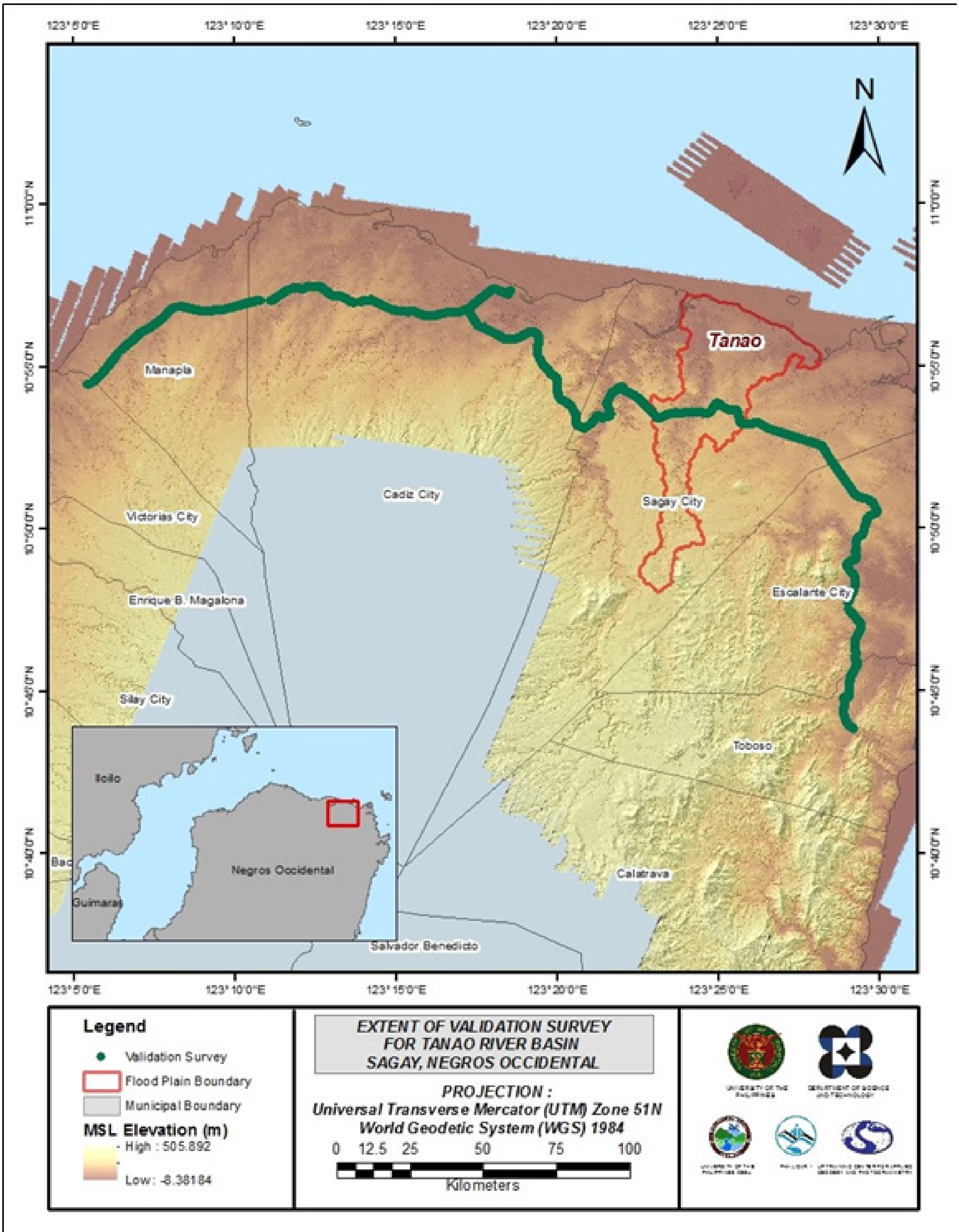


Figure 26. Map of Tanao Floodplain with validation survey points in green.

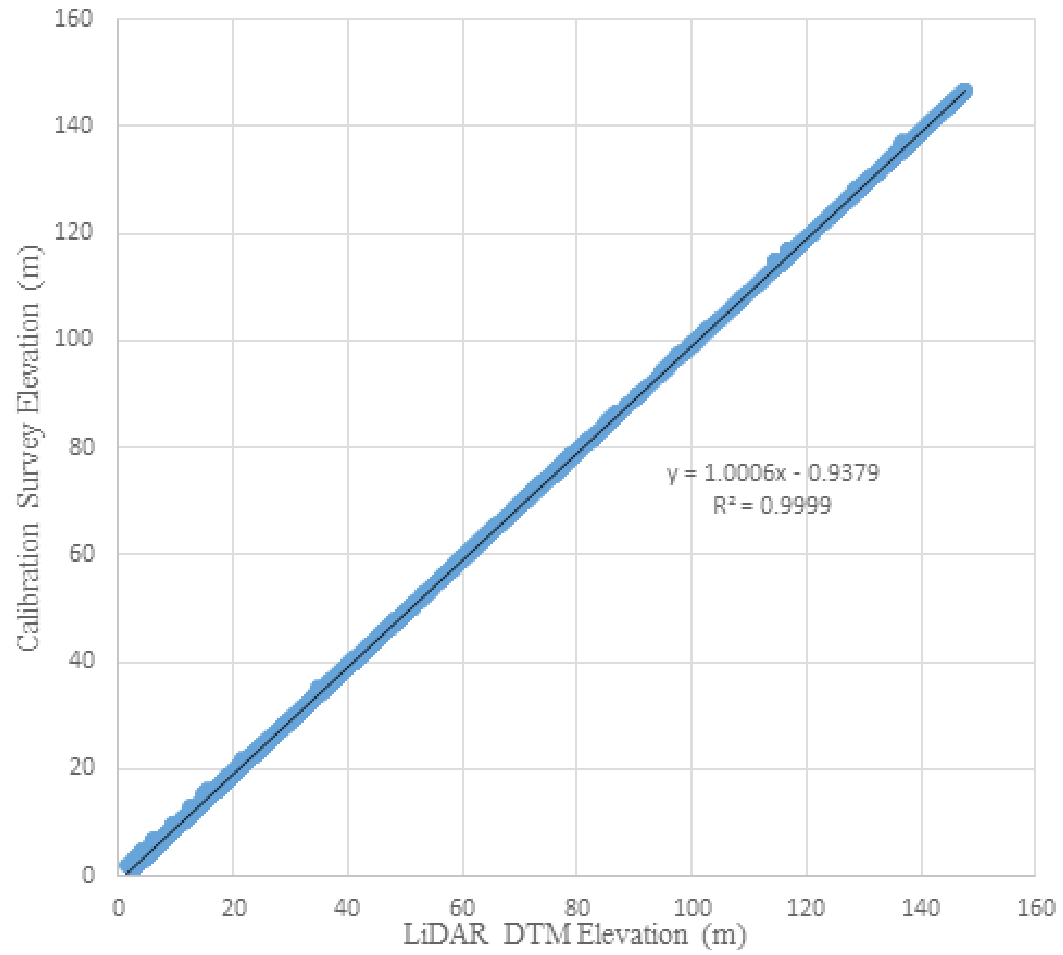


Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 17. The calibration statistical measures of the compared elevation values between the Tanao

Calibration Statistical Measures	Value (meters)
Height Difference	0.94
Standard Deviation	0.15
Average	-0.93
Minimum	-1.21
Maximum	0.89

A total of 121 survey points that are within Tanao flood plain were used for the validation of the calibrated Tanao 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.05 meters with a standard deviation of 0.05 meters, as shown in Table 18.

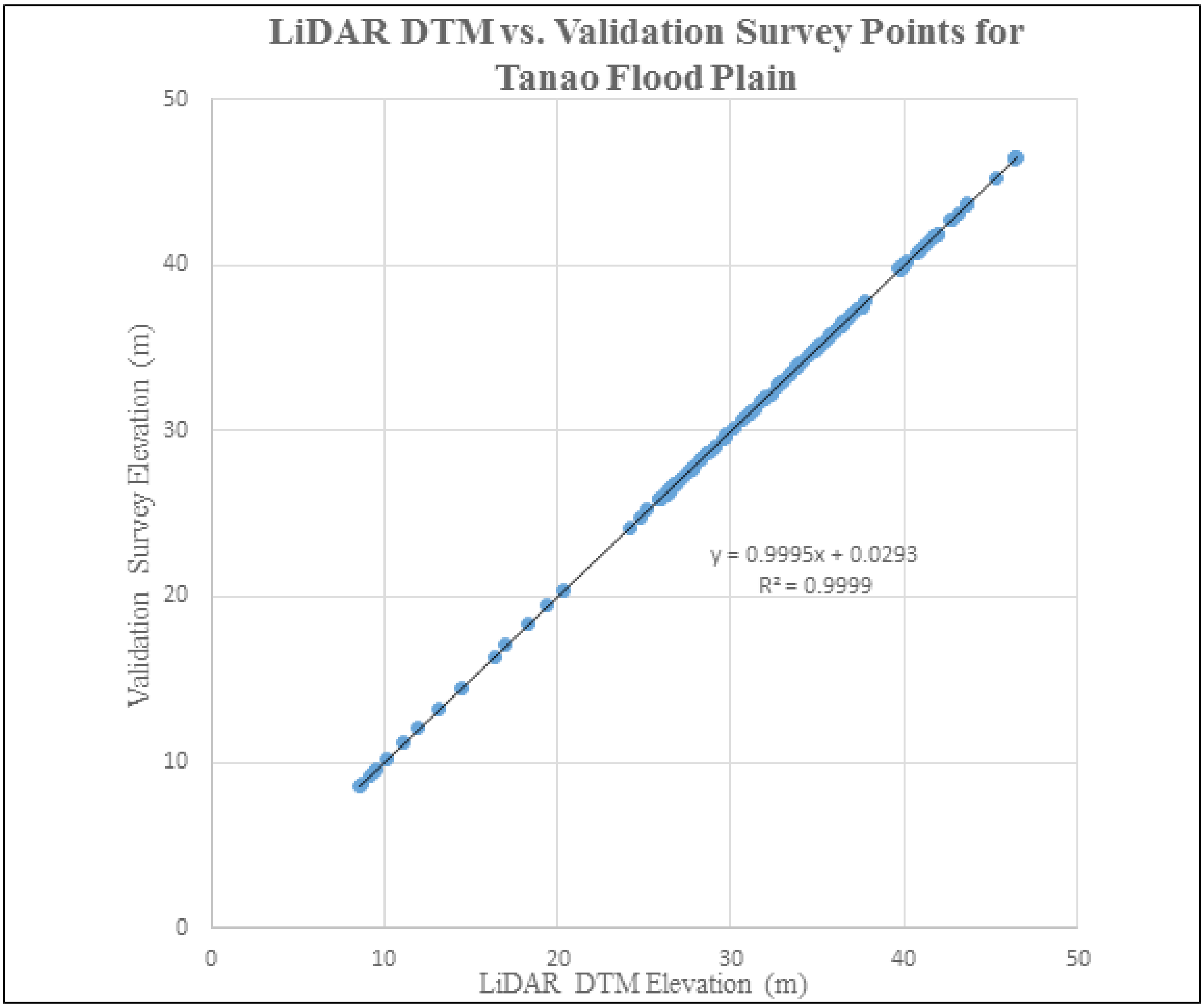


Figure 28 Correlation plot between the validation survey points and the LiDAR data.

Table 18. Statistical measures for the Tanao River Basin DTM validation.

Validation Statistical Measures	Value (meters)
RMSE	0.05
Standard Deviation	0.05
Average	0.01
Minimum	-0.15
Maximum	0.14

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Tanao with a total of 3,807 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 0.06 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Tanao integrated with the processed LiDAR DEM is shown in Figure 29.

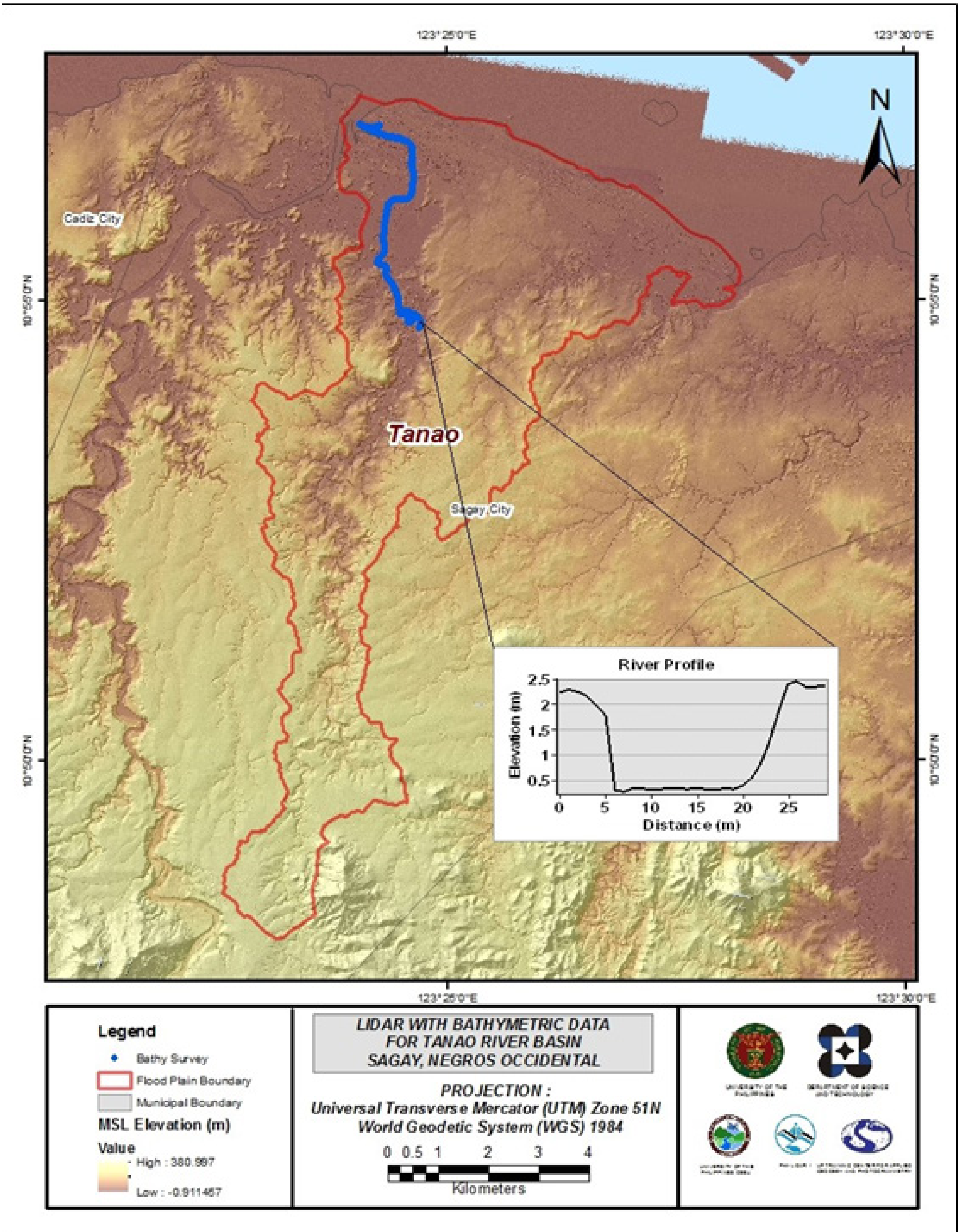


Figure 29. Map of Tanao floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Tanao floodplain, including its 200-m buffer, has a total area of 68.83 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 1,540 building features, were considered for QC. Figure 30 shows the QC blocks for the Tanao floodplain.

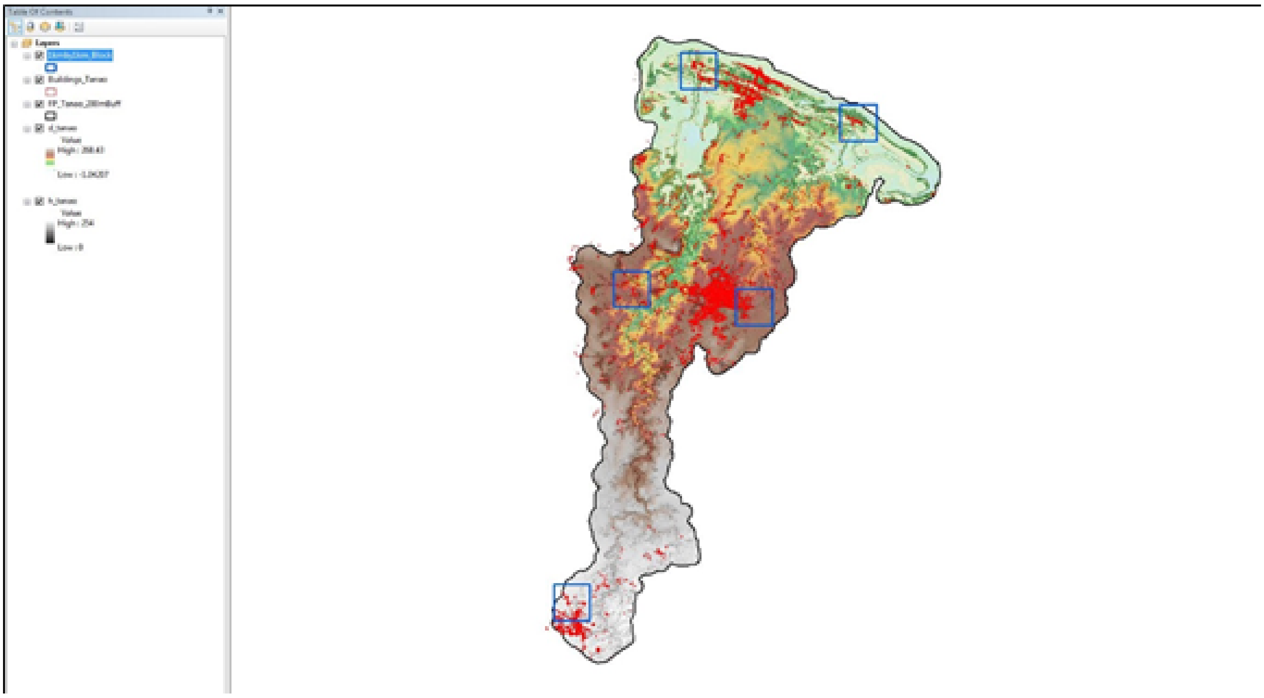


Figure 30. Blocks (in blue) of Tanao building features that were subjected to QC.

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

Table 19. Details of the quality checking ratings for the building features extracted for the Tanao River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Tanao	99.61	100.00	97.79	PASSED

3.12.2 Height Extraction

Height extraction was done for 13,083 building features in the Tanao floodplain. Of these building features, 639 was filtered out after height extraction, resulting to 12,444 building features with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 15.46 meters.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the flood plain of the river basin.

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

Table 20. Building features that were extracted for the Tanao Floodplain.

Facility Type	No. of Features
Residential	11870
School	181
Market	20
Agricultural/Agro-Industrial Facilities	27
Medical Institutions	17
Barangay Hall	3
Military Institution	30
Sports Center/Gymnasium/Covered Court	7
Telecommunication Facilities	5
Transport Terminal	10
Warehouse	4
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	1
Water Supply/Sewerage	3
Religious Institutions	3
Bank	6
Factory	40
Gas Station	6
Fire Station	1
Other Government Offices	31
Other Commercial Establishments	152
Others	1
Total	12,444

Table 21. Total length of extracted roads for Tanao floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Tanao	31.33	4.60	0	11.46	0.00	47.39

Table 22. Number of extracted water bodies in the Tanao Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Tanao	55	0	0	0	803	858

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 31 shows the completed Digital Surface Model (DSM) of the Tanao Floodplain, with all its ground features.

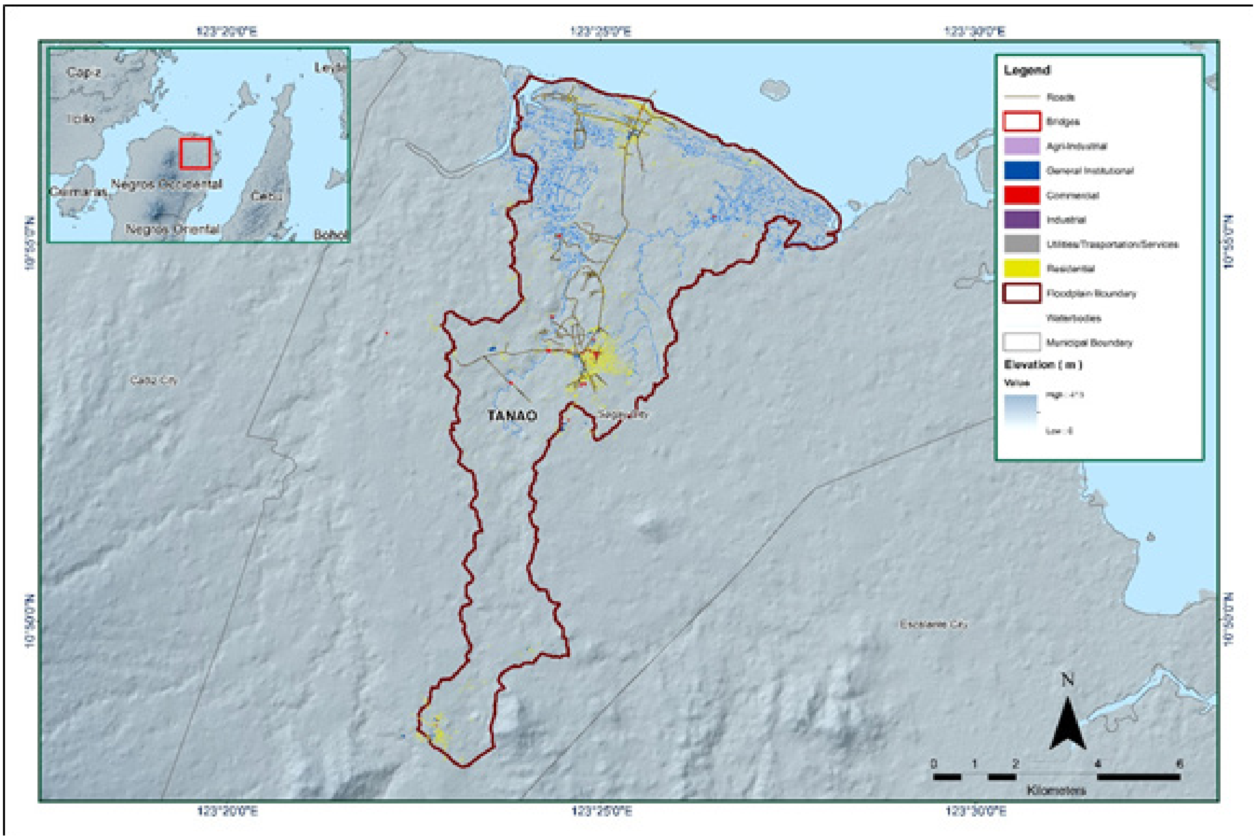


Figure 31. Extracted features of the Tanao Floodplain.

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted Phase I field survey in Tanao River from September 10 to 24, 2014 with the following scope of work: reconnaissance; courtesy call to the barangays near the survey area for information dissemination of the team's activities and to ask for a boat and a local aide's assistance; control survey for the establishment of a control point; cross-section and bridge as-built and water level marking in MSL of Tanao Bridge; ground validation data acquisition survey of about 106.70 km. On December 4 to 16, 2014, DVBC conducted Phase II field survey in Tanao River for the bathymetric survey from Brgy. Poblacion II, Sagay City down to the mouth of the river in Brgy. Old Sagay, Sagay City using Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 utilizing GNSS PPK survey technique. UP Cebu also conducted supplemental bathymetric survey on October 1, 2016.

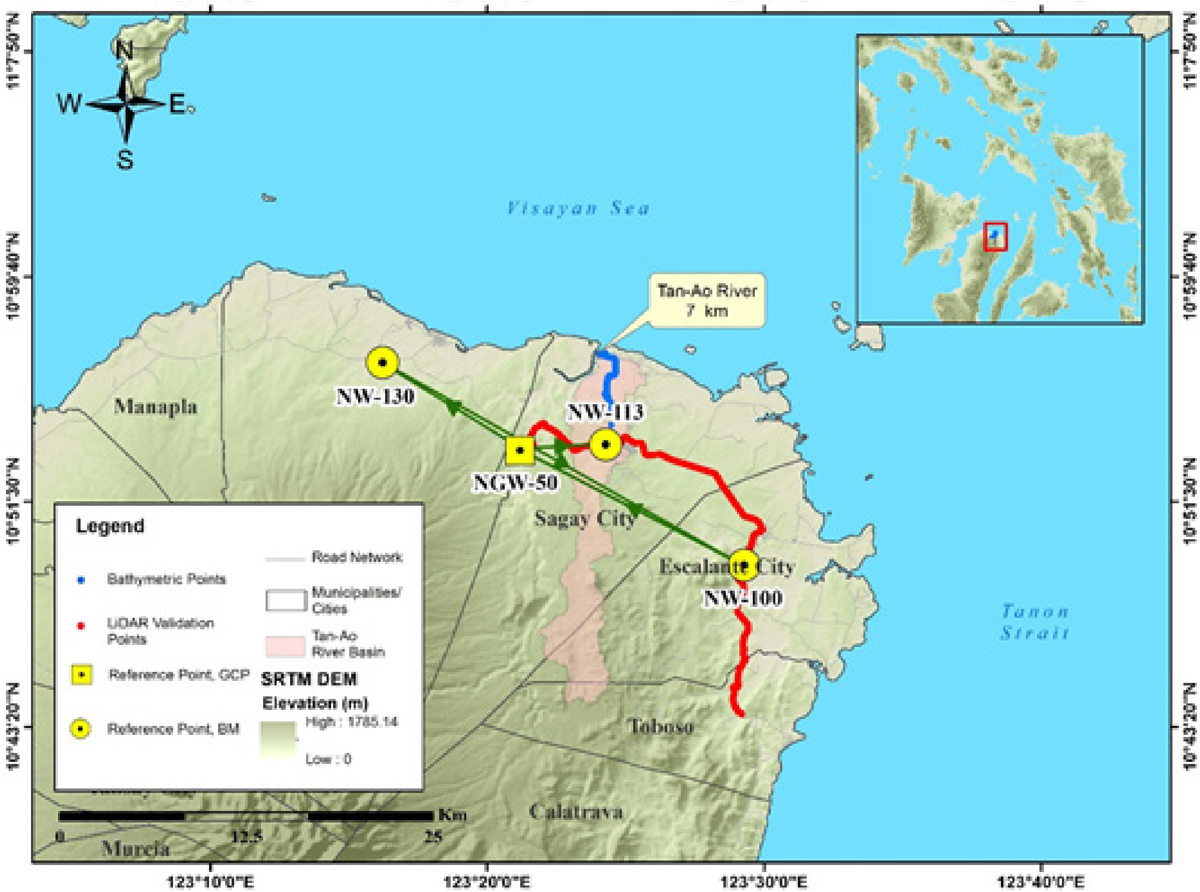


Figure 32. Extent of the bathymetric survey (in blue line) in Tanao River.

4.2 Control Survey

The GNSS network used for Tanao River survey is composed of a single loop established on September 9, 2014 occupying the following reference points: NGW-50, a second order GCP in Brgy. Paraiso, Sagay City; and NW-100, a first order BM in Brgy. Jonobjonob, Escalante City, Negros Occidental.

The point NW-130, a NAMRIA established control point, along the approach of Trozo Bridge in Brgy. Daga, Cadiz City, was also occupied to use by the DVBC survey team as marker during the survey.

Table 23 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 33 shows the GNSS network established in the Tanao River Survey.

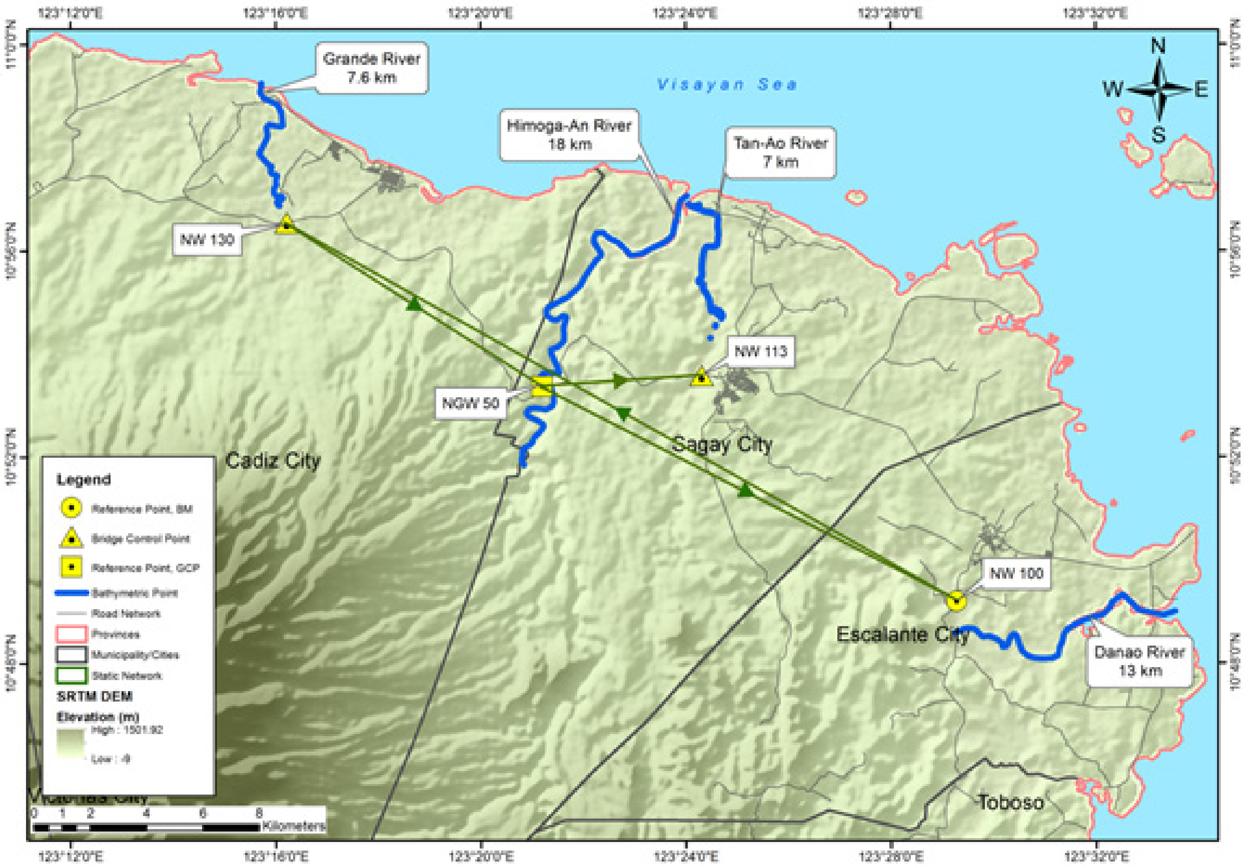


Figure 33. The GNSS Network established in the Tanao River Survey.

Table 23. References used and control points established in the Tanao River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
NGW-50	2nd order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	13.0512	2013
NW-100	1st order, BM	-	-	68.325	7.2272	2007
NW-130	Used as Marker	-	-	-	-	2017

Figure 34 to Figure 36 depict the setup of the GNSS on recovered reference points and established control points in the Occidental Mindoro Survey.

Figure 34. The GNSS base receiver setup, Trimble® SPS 852, at NGW-50 in Himoga-An Bridge, Brgy. Paraiso, Sagay City, Negros Occidental

Figure 35. The GNSS (Trimble® SPS 852) receiver setup at NW-100 in Danao Bridge, Brgy. Jonobjonob, Escalante City, Negros Occidental

Figure 36. The GNSS (Trimble® SPS 852) receiver occupation, at NW-130 in Troso Bridge, Brgy. Daga, Cadiz City, Negros Occidental

4.3 Baseline Processing

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

Table 24. The Baseline processing report for the Tanao River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NGW 50 --- NW 130 (B4)	09-11-2014	Fixed	0.005	0.008	302°49'33"	10801.487	-2.613
NW 130 --- NW 100 (B5)	09-11-2014	Fixed	0.185	0.037	119°37'31"	27388.571	-3.542
NGW 50 --- NW 100 (B6)	09-11-2014	Fixed	0.004	0.006	117°34'16"	16614.558	-6.178

As shown in Table 24, a total of three (3) baselines were processed with the coordinates of NGW-50, and the elevation value of reference points NW-100 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 26 to Table 29.

The three (3) control points: NGW-50, NW-100, and NW-130 were occupied and observed simultaneously to form a GNSS loop. Coordinates of NGW-50; and elevation value of NW-100 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed. An offset of 0.0188 m between geoid (EGM2008) and MSL values of the benchmark NW-100 from September 10 to 24, 2014 was applied for referring the elevation of the control points to MSL because the direct processing to BMOrtho will give a low accuracy level.

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

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGW 50	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 26. The fixed control NGW-50 has no values for grid and elevation errors.

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

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGW 50	538610.026	?	1203793.905	?	13.070	?	LLh
NW 100	553341.183	0.013	1196123.819	0.007	7.170	0.020	
NW 130	529529.956	0.017	1209636.397	0.008	10.639	0.024	

The results of the computation for accuracy are as follows:

a. NGW-50
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. NW-100
horizontal accuracy = $\sqrt{((1.3)^2 + (0.7)^2}$
= $\sqrt{(1.69 + 0.49)}$
= 1.48 < 20 cm
vertical accuracy = 2.0 cm < 10 cm

c. NW-130
horizontal accuracy = $\sqrt{((1.7)^2 + (0.8)^2}$
= $\sqrt{(2.89 + 0.64)}$
= 1.88 < 20 cm
vertical accuracy = 2.4 cm < 10 cm

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

Table 27. Adjusted geodetic coordinates for control points used in the Tanao River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
NGW 50	N10°53'22.52478"	E123°21'11.86863"	74.422	?	LLh
NW 130	N10°56'33.04992"	E123°16'12.93293"	71.819	0.024	
NW 100	N10°49'12.14033"	E123°29'16.71793"	68.325	0.020	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Tanao River GNSS Static Survey are seen in Table 28.

Table 28. The reference and control points utilized in the Tanao River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
NGW-50	2nd order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	1203793.905	538610.026	13.051
NW-100	1st order BM	10°49'12.14033"	123°29'16.71793"	68.325	1196123.819	553341.183	7.227
NW-130	Used as Marker	10°56'33.04992"	123°16'12.93293"	71.819	1209636.397	529529.956	10.643

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

The bridge cross-section and as-built surveys were conducted on September 12, 18 and 19, 2014 along the downstream side of Tanao Bridge in Brgy. Poblacion II, Sagay City using the GNSS receiver Trimble® SPS 882 in PPK Survey Technique (Figure 37).

Figure 37. The As-Built survey at Tanao Bridge in Sagay City

The cross-sectional line of Tanao Bridge is about 830 meters with eighty-one (81) points acquired using NGW-50 and NW-113. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 38 to Figure 40.

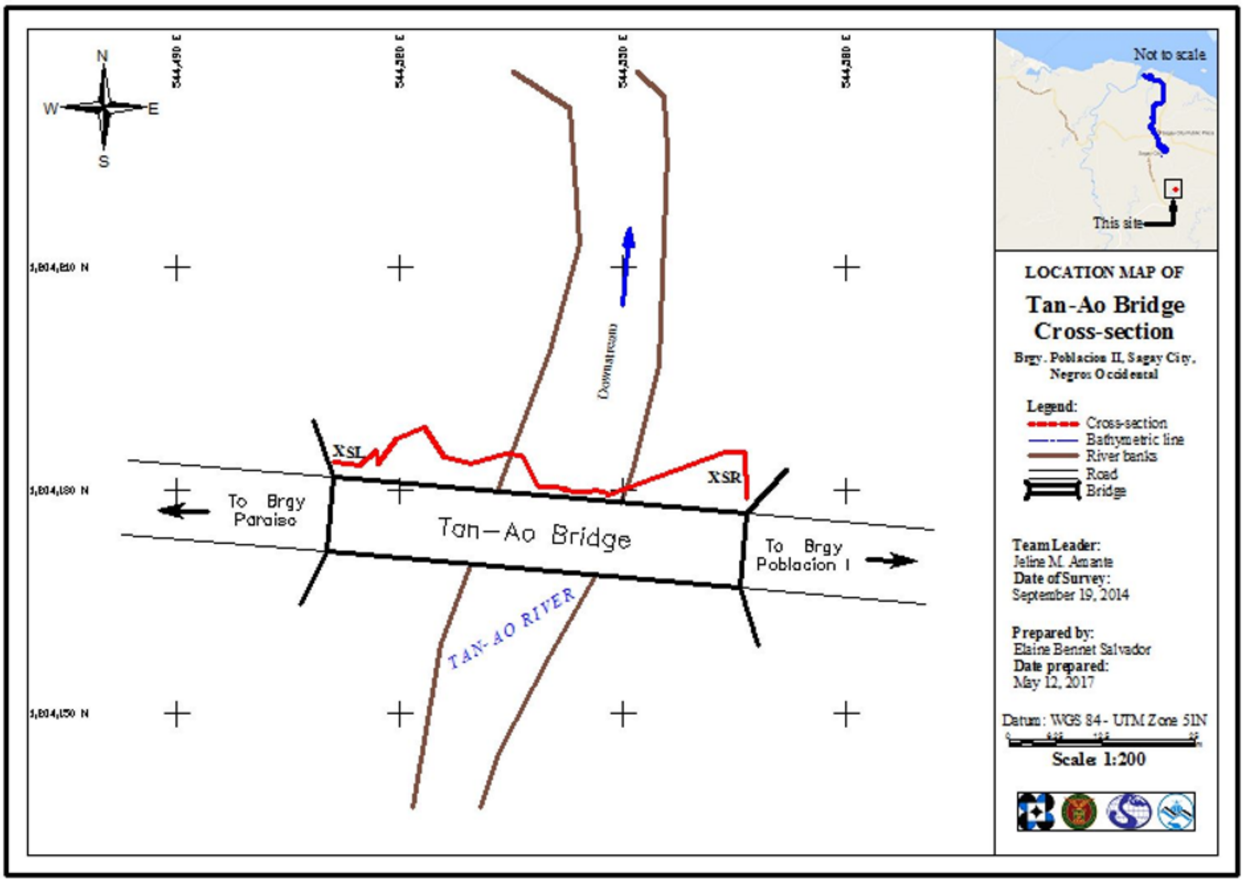


Figure 39. Location map of the Tanao Bridge cross-section survey.

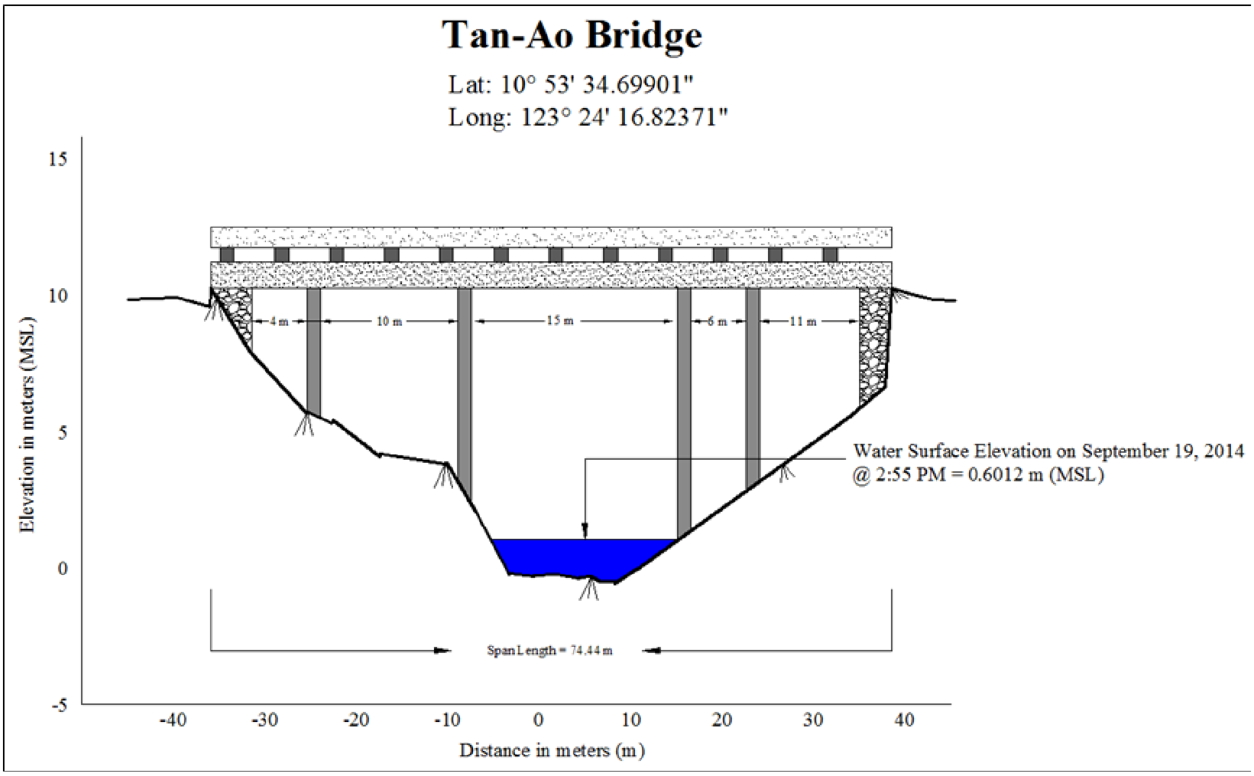


Figure 38. The Tanao Bridge cross-section survey drawn to scale

Bridge Data Form

Bridge Name: Tan-Ao Bridge **Date:** September 12 & 18, 2014

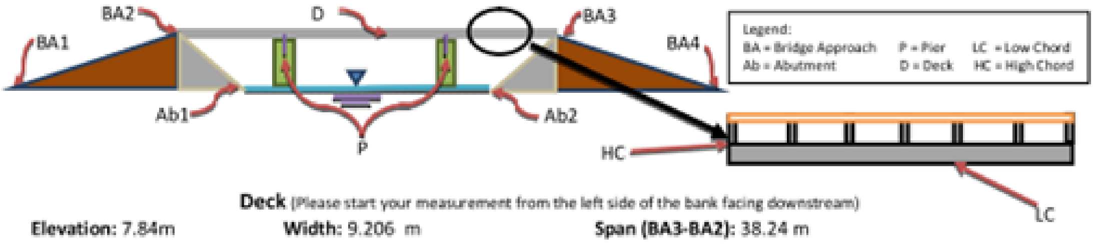
River Name: Tan-Ao River **Time:** 3:00 PM

Location (Brgy, City,Region): Brgy. Poblacion II, Sagay City, Negros Occidental

Survey Team: Negros Occidental Survey Team

Flow condition: low normal high **Weather Condition:** fair rainy

Latitude: 10d53'34.69901"N **Longitude:** 123d24'16.82371" E



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

Elevation: 7.84m **Width:** 9.206 m **Span (BA3-BA2):** 38.24 m

	Station	High Chord Elevation	Low Chord Elevation
1	-	-	-
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	n/a	BA3	38.24 m	7.4043 m
BA2	44.29 m	10.9652 m	BA4	44.29 m	9.8122 m

Abutment: Is the abutment sloping? Yes No; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	14.93 m	5.4142 m
Ab2	113.328 m	5.5492 m

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

Shape: cylinder **Number of Piers:** 4 **Height of column footing:** _______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	73.2431 m	7.6853 m	
Pier 2	85.5644 m	7.6483 m	
Pier 3	100.513 m	7.6523 m	
Pier 4	115.444 m	7.5823 m	
Pier 5			
Pier 6			

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

Figure 40. The Tanao Bridge as-built survey data

The water surface elevation of Tanao River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on September 19, 2014 at 2:55 PM at Tanao Bridge area with a value of 0.6012 m in MSL as shown in Figure 38. This was translated into marking on the bridge's pier as shown in Figure 41. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Tanao River, the University of the Philippines Cebu.

Figure 41. Water Level Mark at the pier of Tanao Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 12 and 13, 2014 using a survey grade GNSS rover receiver Trimble® SPS 882 mounted on a pole, which was attached in front of the vehicle as shown in Figure 42. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height of 2.10 was measured from the ground up to the bottom of the notch of the GNSS rover receiver. Points were gathered along concrete roads so that data to be acquired will have a relatively minimal change in elevation, observing vehicle speed of 10 to 20 kph.

Figure 42. (A) Occupied base station, NGW-50, in Himoga-An Bridge, Sagay City and (B) Installation of GNSS Receiver Trimble® SPS 882 on the van prior the conduct of validation points acquisition survey

The base was set up at NAMRIA established reference point, NGW-50, in Himoga-an Bridge on September 12, 2014 and gathered validation points from Brgy. Poblacion, Toboso to Himoga-An Bridge, Sagay City. On September 13, 2014, the base was set up at established control point, NW 130, in Troso Bridge, Brgy. Bayabas, Sitio Troso, Cadiz City and gathered validation points from Himoga-An Bridge, Sagay City to Brgy. VI Manapla. The ground validation line is approximately 106.70 km in length and with overall gathered points of 8,887. Figure 43 shows the validation points acquisition survey coverage.

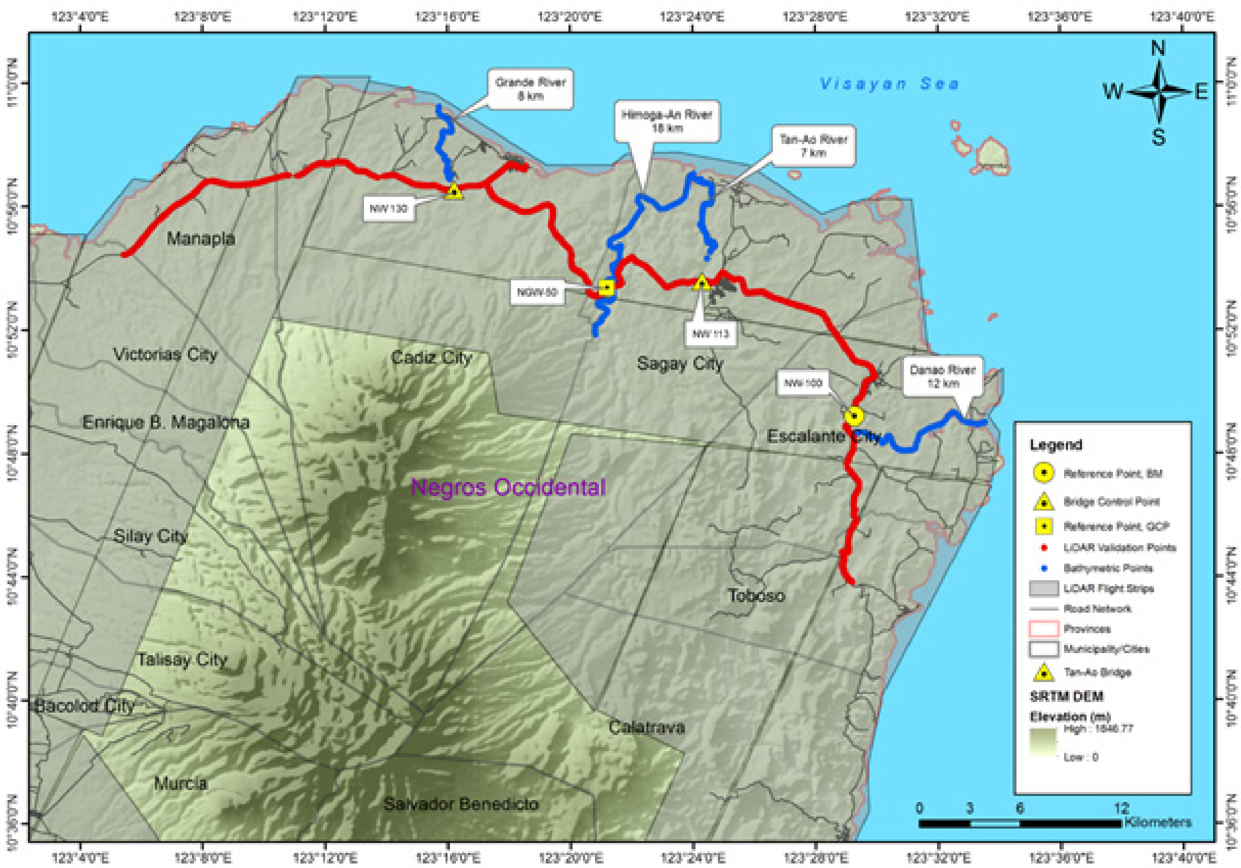


Figure 43. The extent of the LiDAR ground validation survey for Tanao River Basin

4.7 River Bathymetric Survey

A bathymetric survey was performed on December 9 and 10, 2014 and October 1, 2016 using Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 in GNSS PPK survey technique, installed on the boat as shown in Figure 44. The survey began the upstream part of the river in Brgy. Poblacion II, Sagay City with coordinates 10°53’35.04268” 123°24’17.79037”, down to the mouth of the river in Brgy. Old Sagay, Sagay City with coordinates 10°56’53.25488” 123°24’04.89364”. The reference point NGW-50, located in Himoga-An Bridge in Brgy. Fabrica, Sagay City, served as the base station in conducting the bathymetric survey.

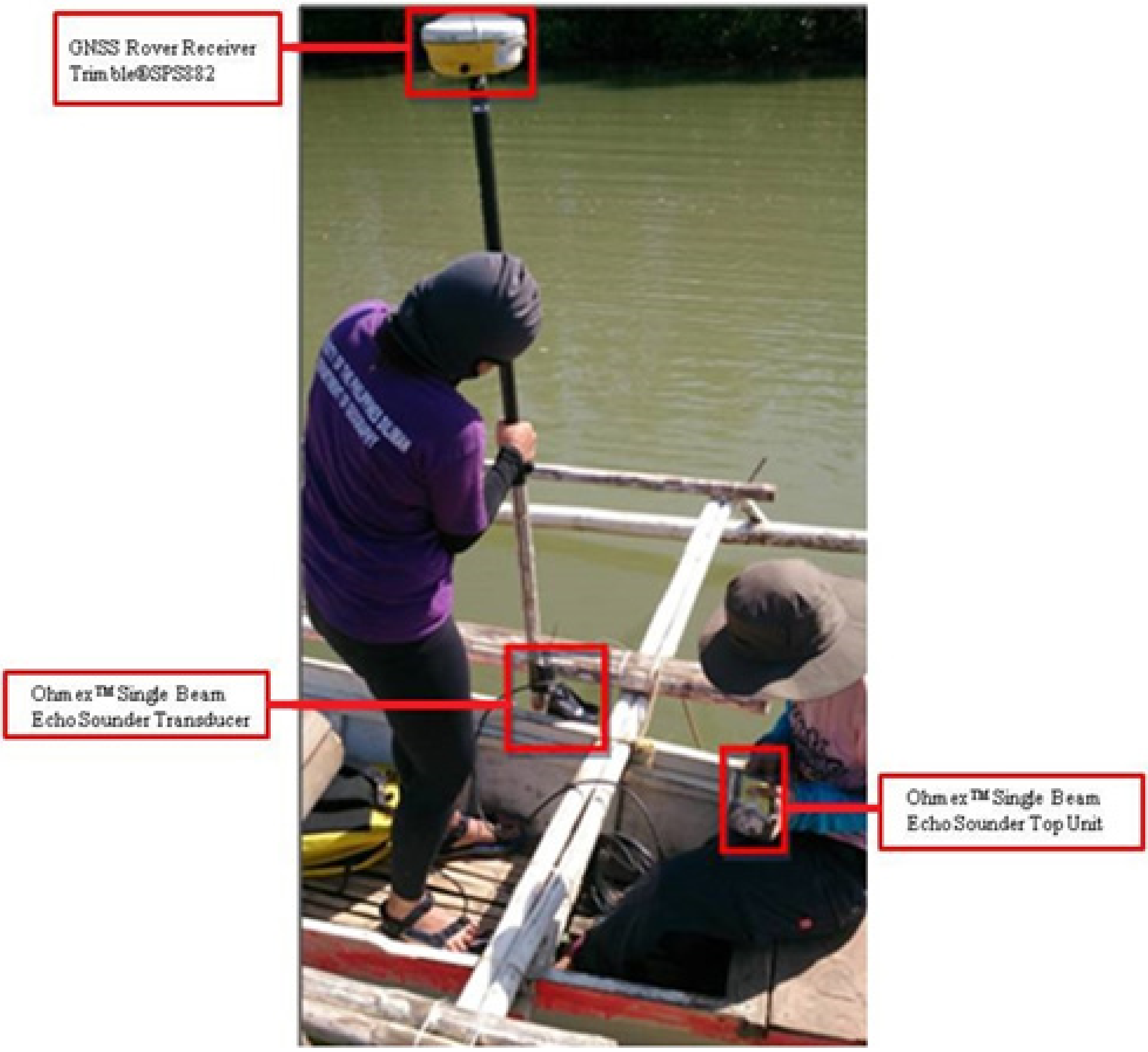


Figure 44. Set up of Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver on a motor boat for the bathymetric survey in Brgy. Old Sagay, Sagay City, Negros Occidental

The entire bathymetric data coverage for Tanao River is illustrated in the map in Figure 45. The bathymetric line is approximately 7 km in length with 7,455 bathymetric points starting from Brgy. Old Sagay, Sagay City going upstream in Brgy. Poblacion II, Sagay City. A CAD diagram was also produced to illustrate the Tanao riverbed profile as shown in Figure 46. The lowest elevation was recorded at -3.4188 m (MSL), approximately 3,000 m from Tanao Bridge, while the highest elevation observed was 0.791 m in MSL located in the upstream.

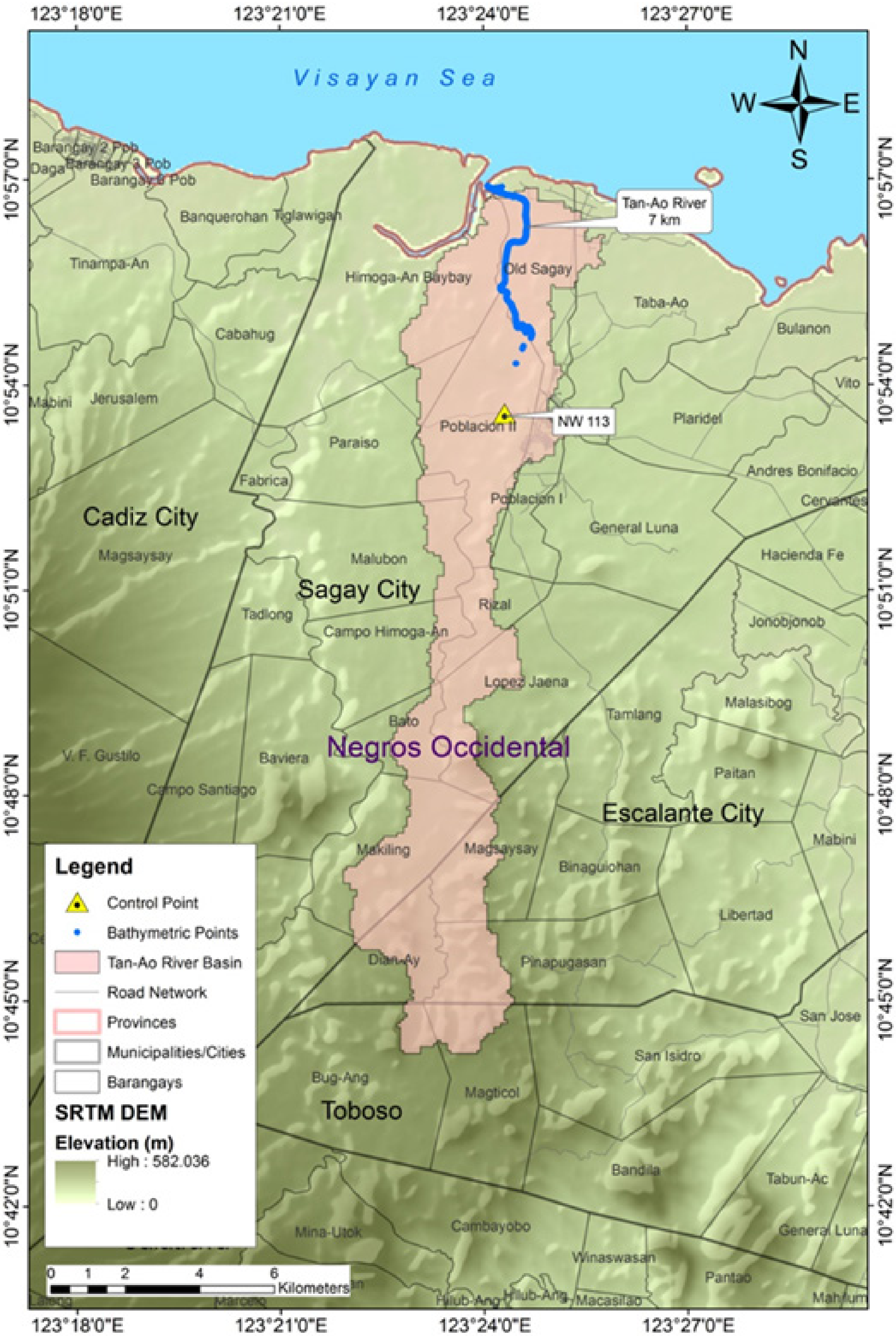


Figure 45. The extent of the Tanao River Bathymetry Survey

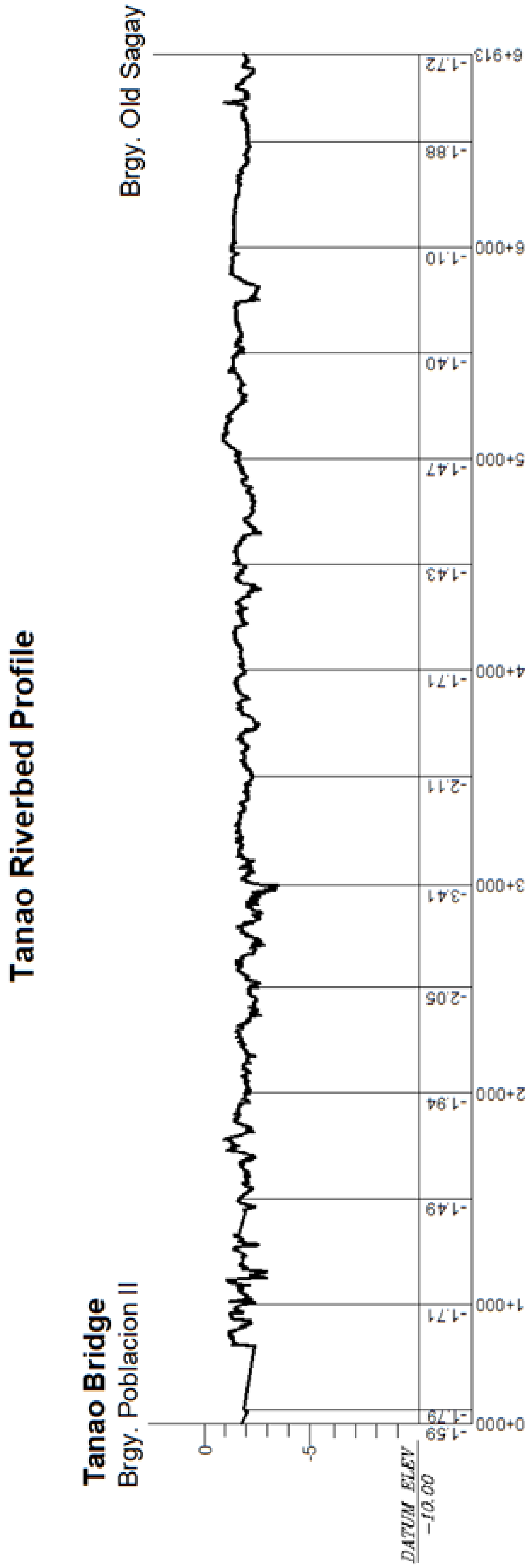


Figure 46. TheTanao river bed profile.

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, Narvin Clyd Tan, and Marvin Arias

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

All components and data that affect the hydrologic cycle of the Tanao River Basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Tanao River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Puey, Sagay City, Negros Occidental as illustrated in Figure 47. The precipitation data collection started from January 10, 2017 at 4:30 AM to at 2:55 with a recording interval of 5 minutes.

The total precipitation for this event in Brgy Puey ARG was 6.8 mm. It has a peak rainfall of 0.80 mm. on January 10, 2017 at 10:50 in the morning. The lag time between the peak rainfall and discharge is 6 hours and 15 minutes.

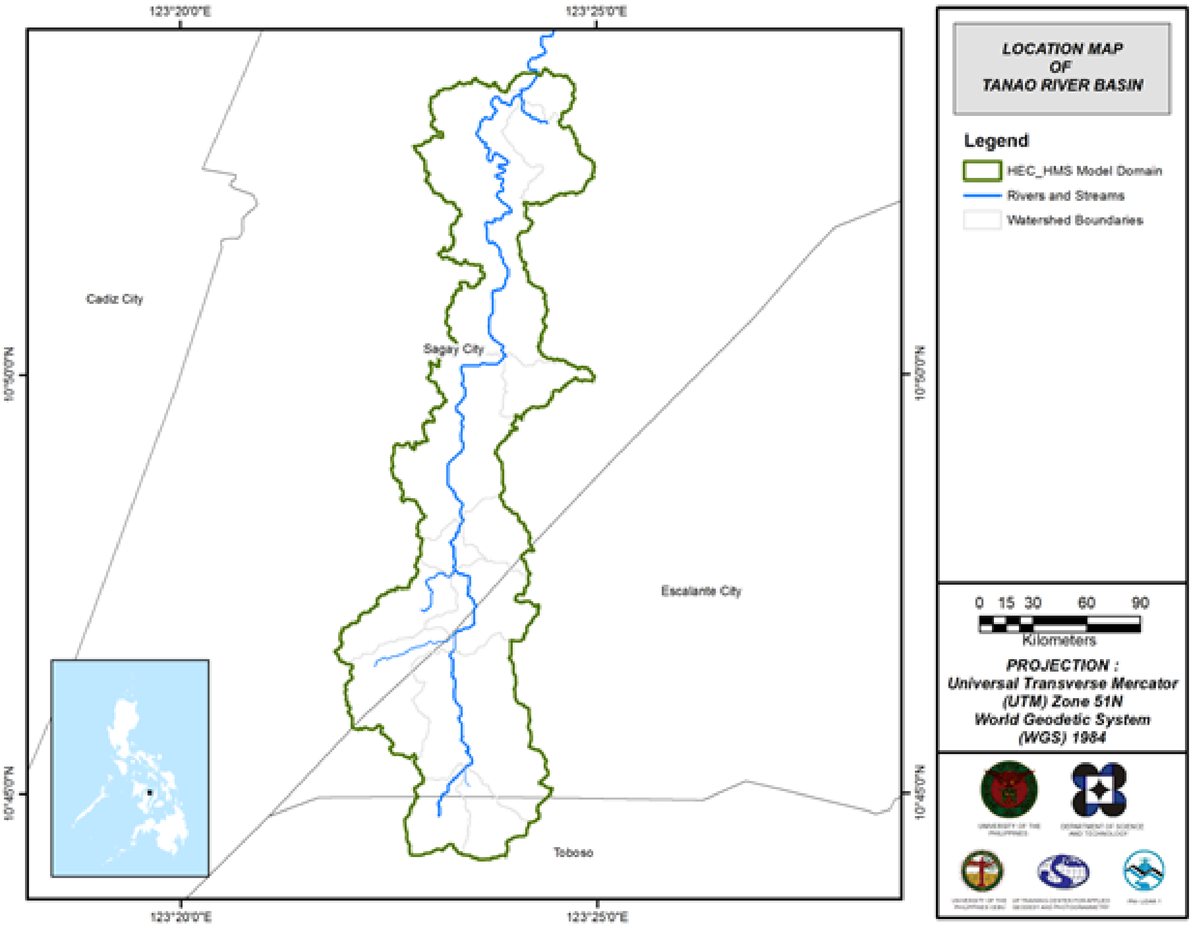


Figure 47. Location Map of the Tanao HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Tanao Bridge, Sagay City, Negros Occidental (10°53'34.75"N, 123°24'17.59"E) to establish the relationship between the observed water levels (H) at Tanao Bridge and outflow (Q) of the watershed at this location.

For Tanao Bridge, the rating curve is expressed as Q = 0.0885ev0.3362x as shown in Figure 49.

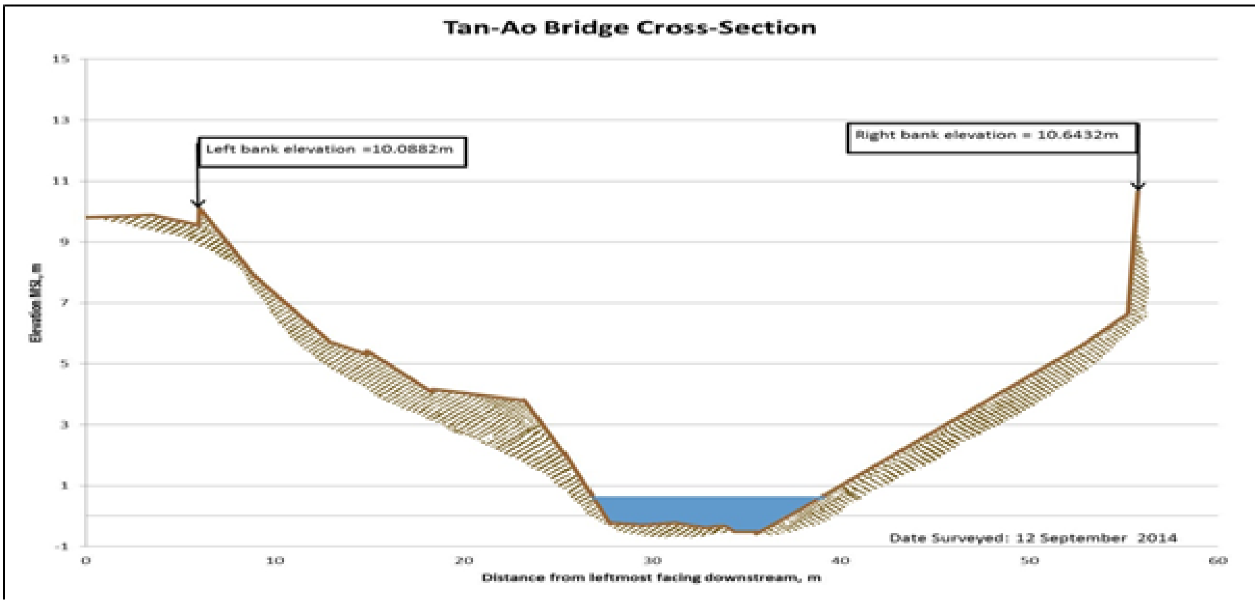


Figure 48. The cross-section plot of the Tanao Bridge

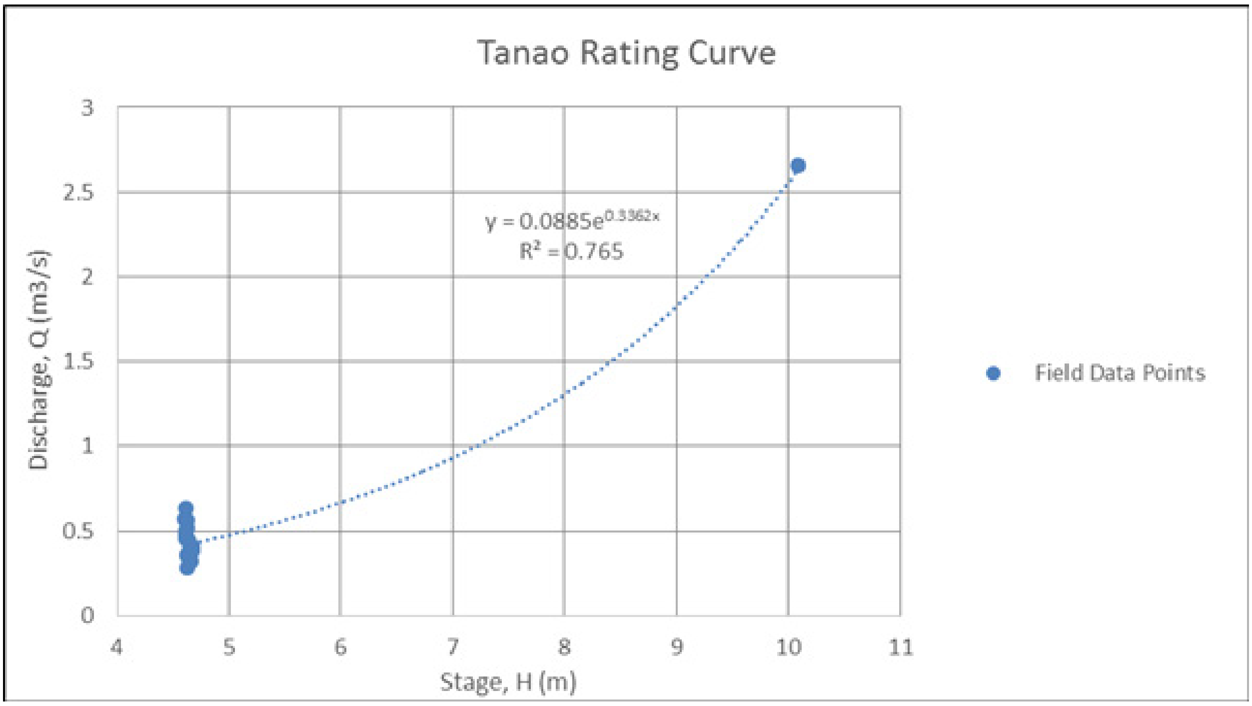


Figure 49. The rating curve of the Tanao Bridge, Poblacion II, Sagay City

This rating curve equation was used to compute the river outflow at Tanao Bridge for the calibration of the HEC-HMS model shown in Figure 50. The peak discharge is 0.9959 m3 at 5:10 in the afternoon, January 10, 2017.

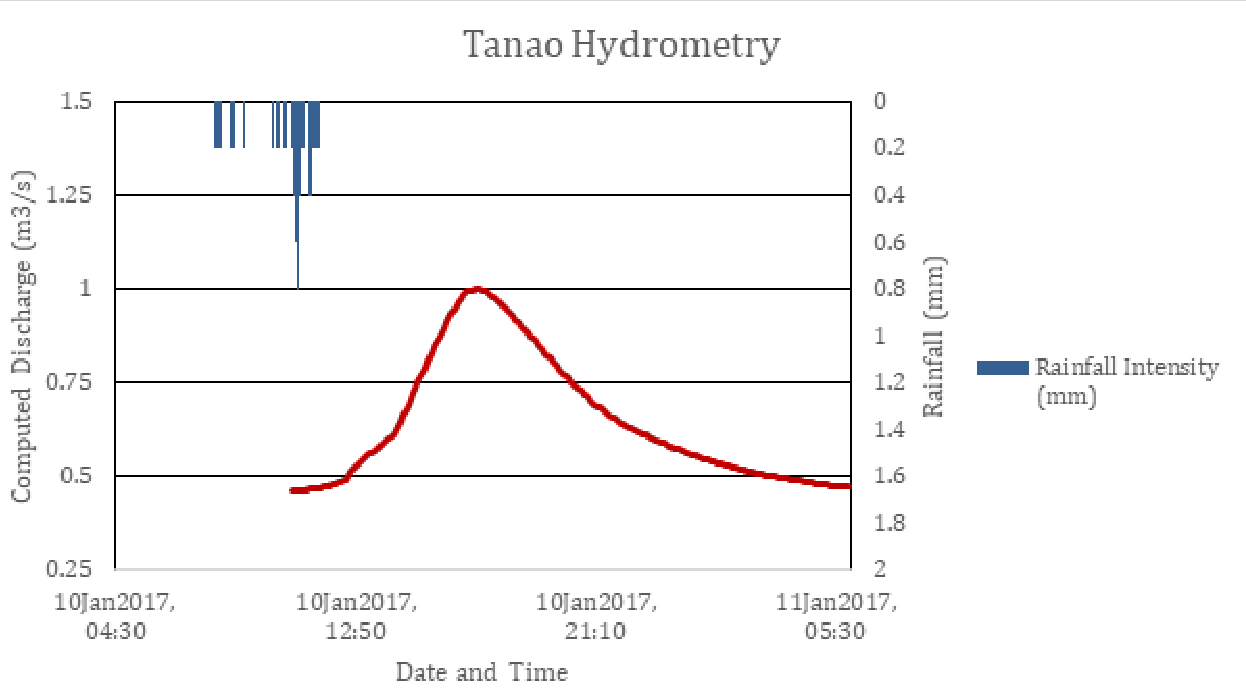


Figure 50. Rainfall and outflow data of the Tanao River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Mactan Rain Gauge (Table 29). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 52). This station was selected based on its proximity to the Tanao watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 29. RIDF values for the Mactan Rain Gauge as 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**
5	21.9	34	43.2	58.4	74.9	84	105.2	122.6	139.1
10	25.8	40.2	51.1	69.7	88.9	99.6	126.3	148.6	169.7
25	30.9	48	61	83.9	106.6	119.3	153.1	181.4	208.5
50	34.6	53.8	68.3	94.4	119.7	133.9	173	205.8	237.2
100	38.3	59.5	75.6	104.9	132.7	148.4	192.7	237.2	265.7

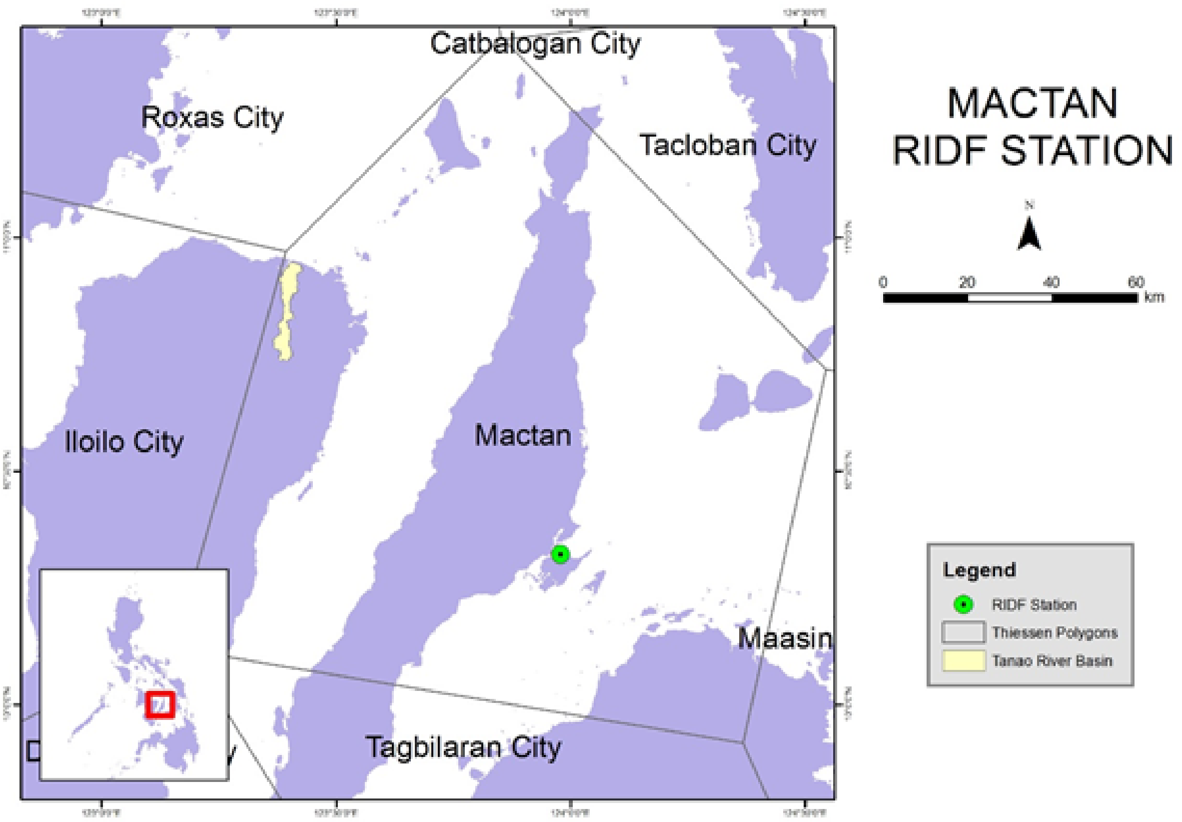


Figure 51. Location of the Tacloban RIDF station relative to the Tanao River Basin.

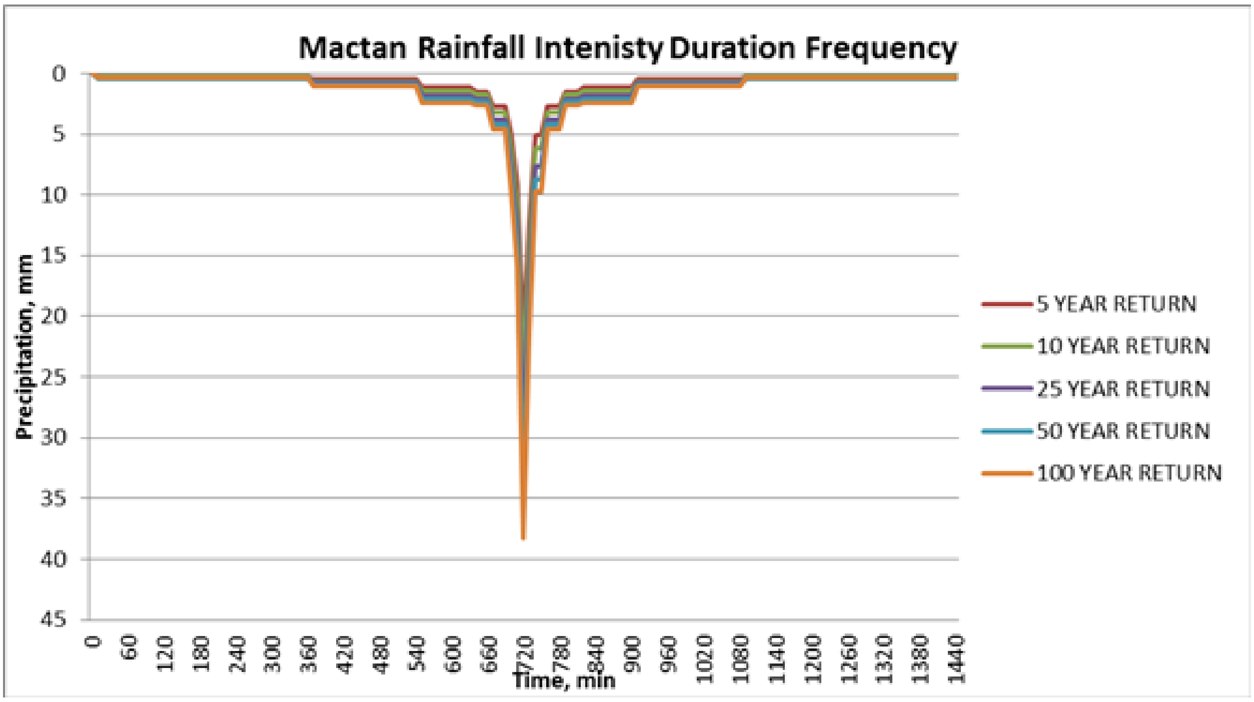


Figure 52. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is under the Department of Environment and Natural Resources Management (DENR). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Tanao River Basin are shown in Figure 53 and Figure 54, respectively.

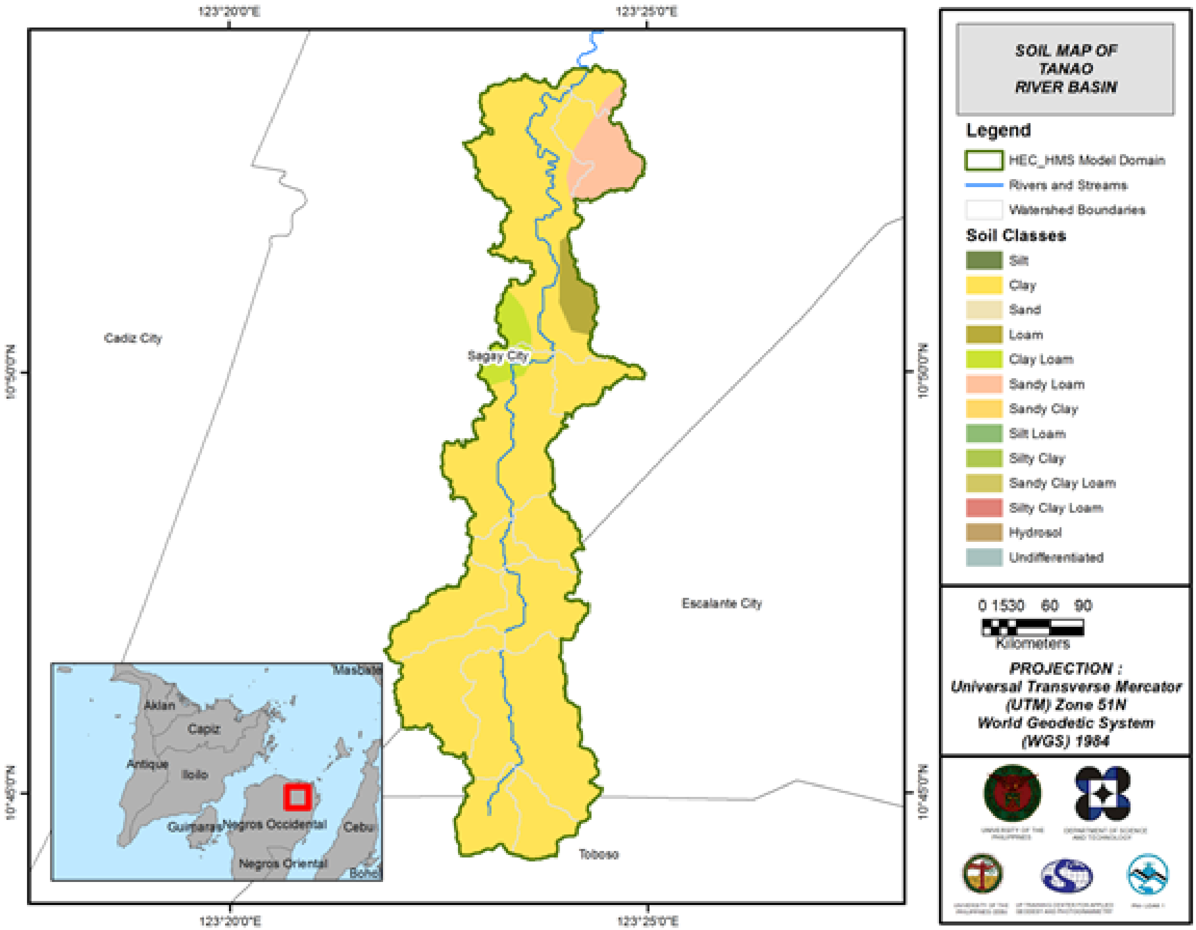


Figure 53. Soil Map of Tanao River Basin.

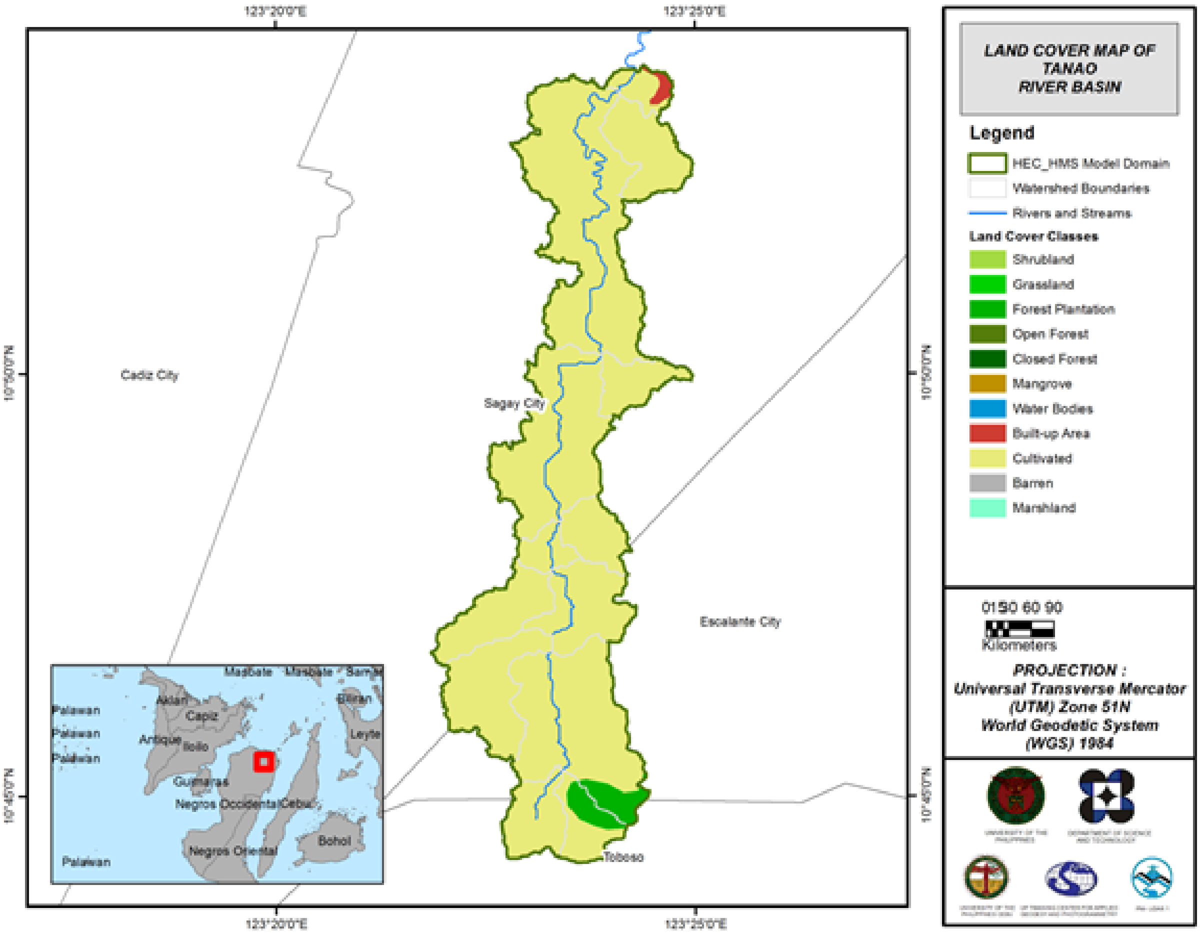


Figure 54. Land Cover Map of Tanao River Basin

For Tanao, four (4) soil classes were identified. These are are clay loam, clay, hydrosol, and sandyloam. Moreover, three land cover classes were identified. These are shrubland, forest plantation, and built-up area.

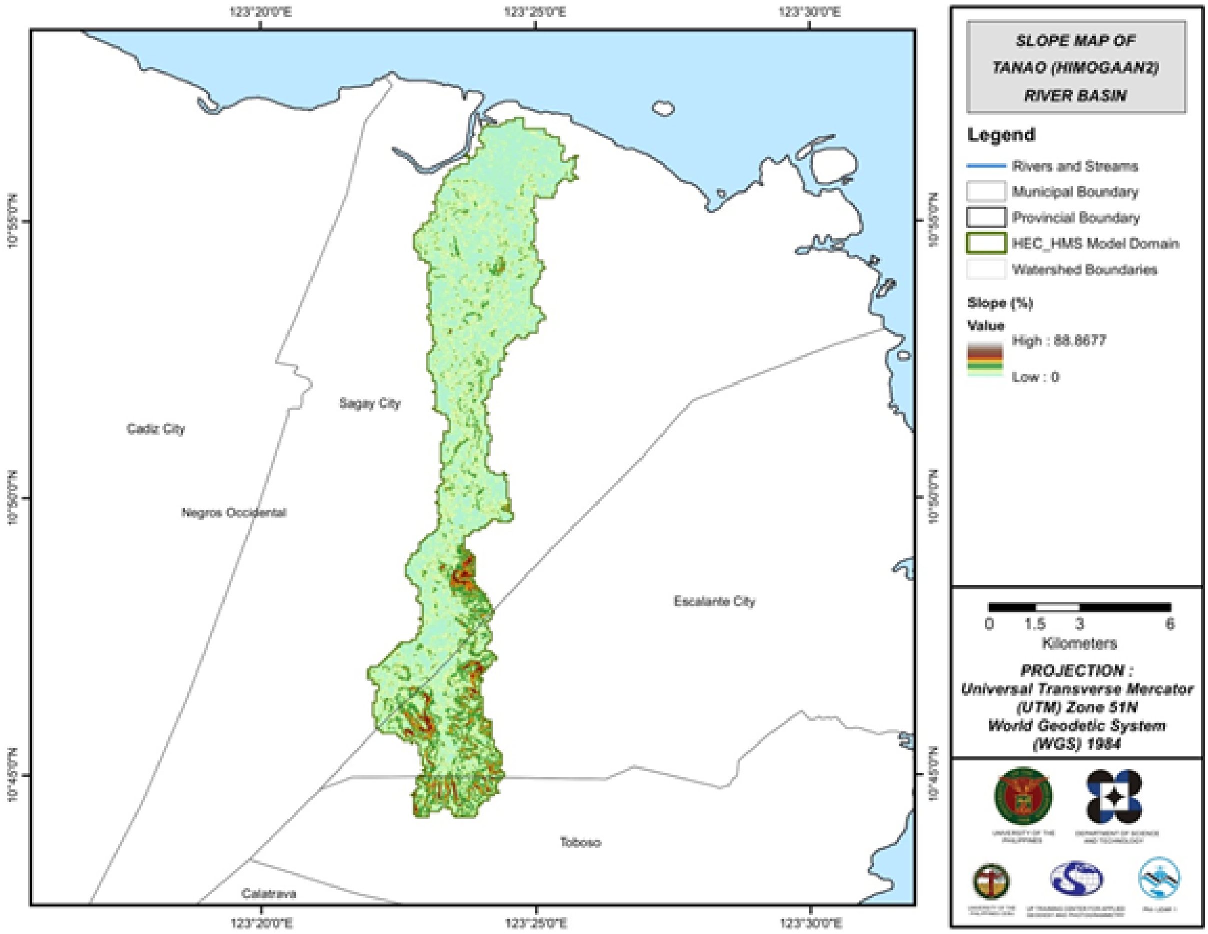


Figure 55. Slope Map of the Tanao River Basin.v

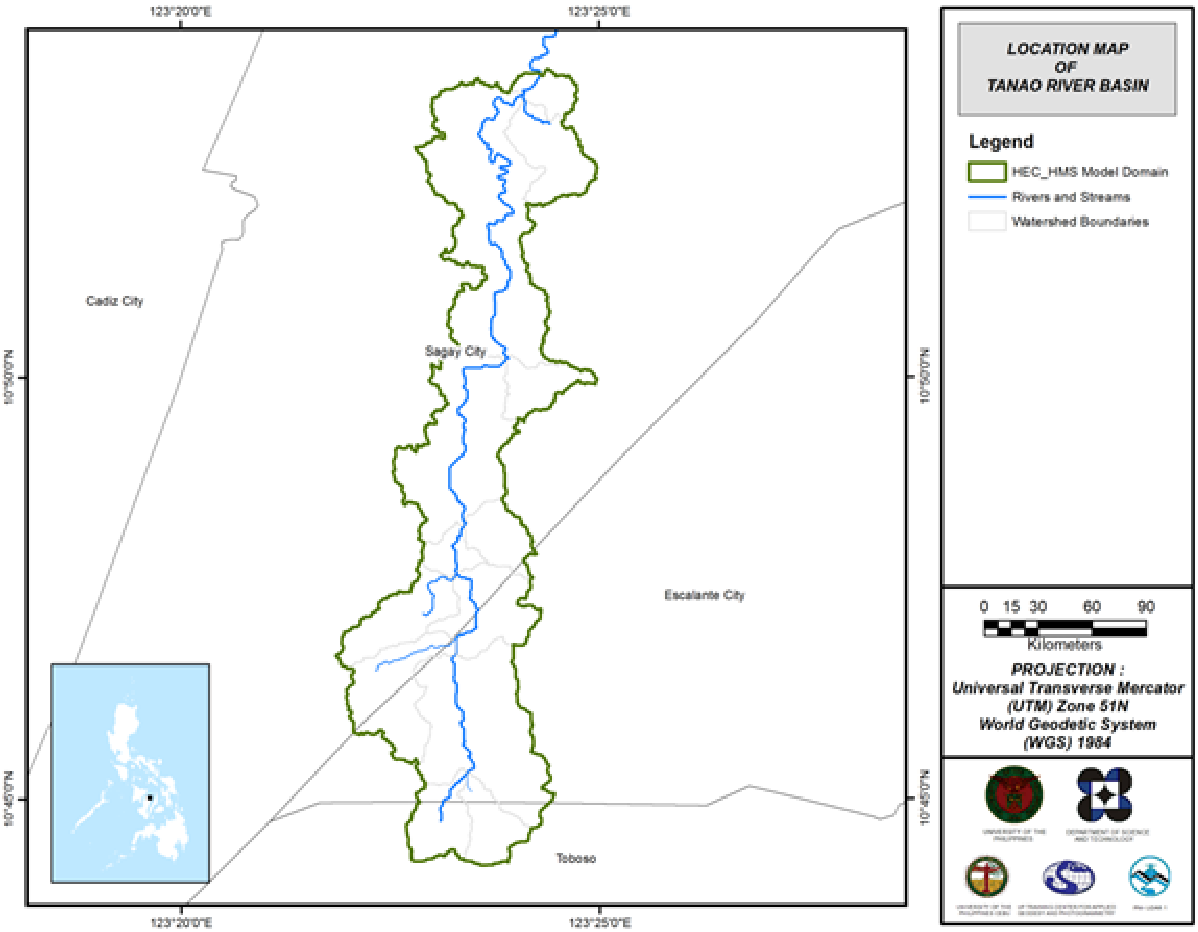


Figure 56. Stream Delineation Map of Tanao River Basin

Using the SAR-based DEM, the Tanao basin was delineated and further subdivided into subbasins. The model consists of 13 sub basins, 6 reaches, and 6 junctions as shown in Figure 57. The main outlet is at Tanao Bridge.

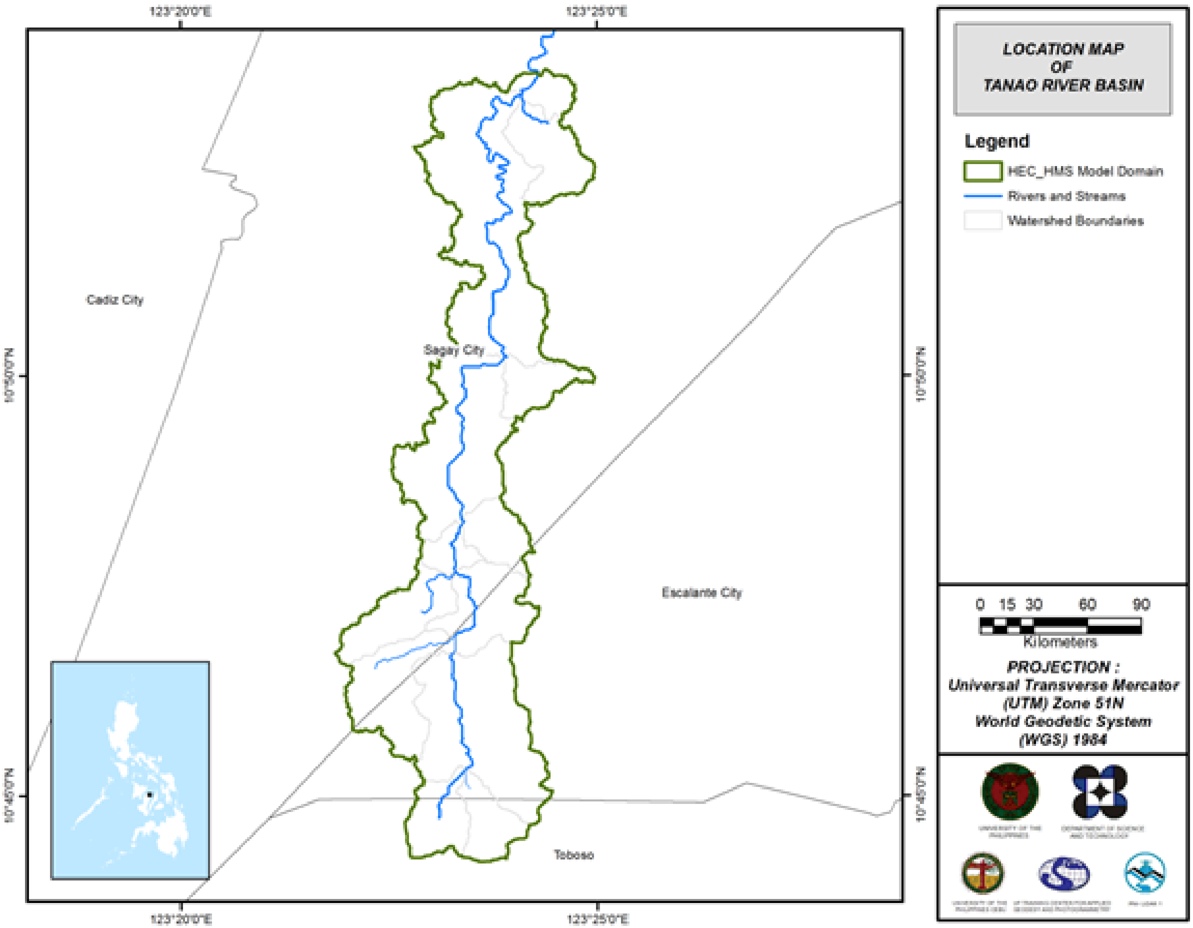


Figure 57. Silaga river basin model generated in HEC-HMS

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 58).

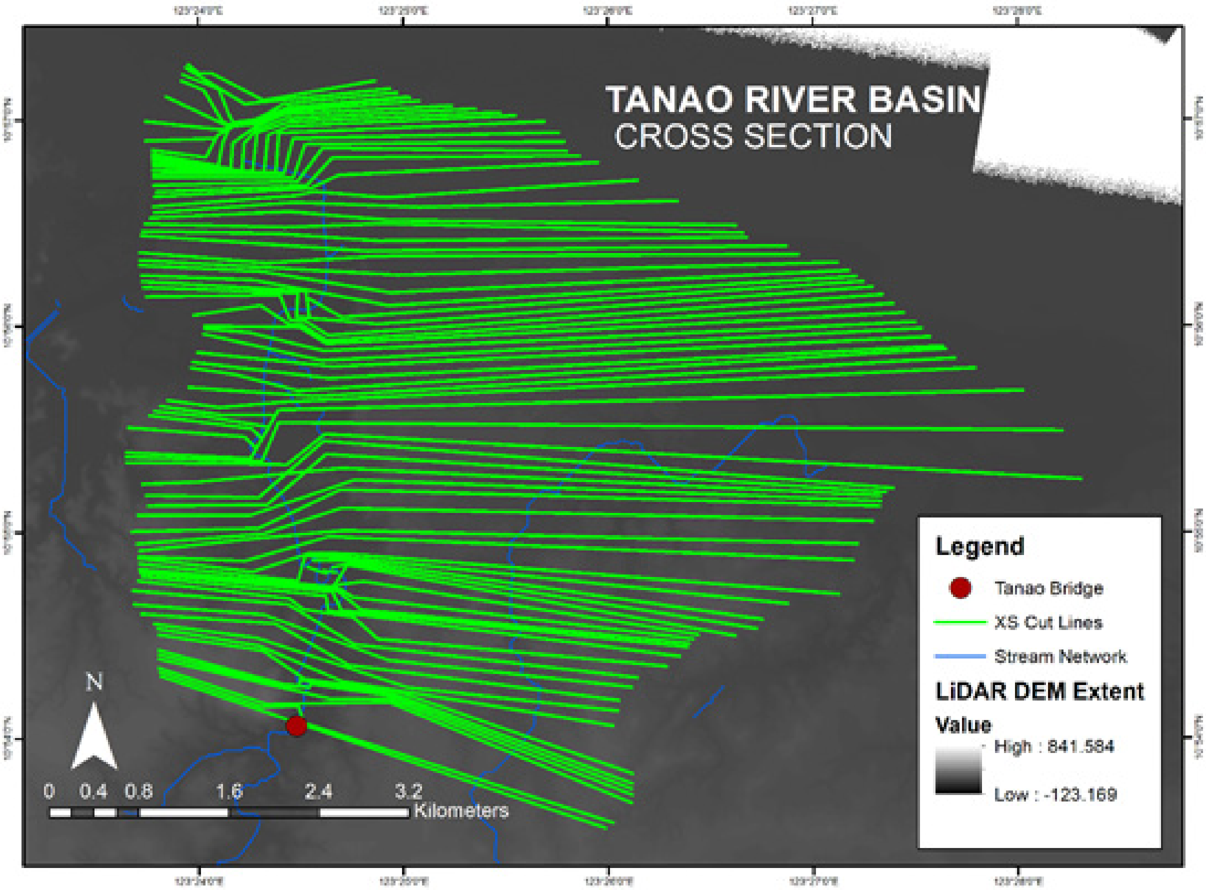


Figure 58. River cross-section of the Tanao River through the ArcMap HEC GeoRas tool

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

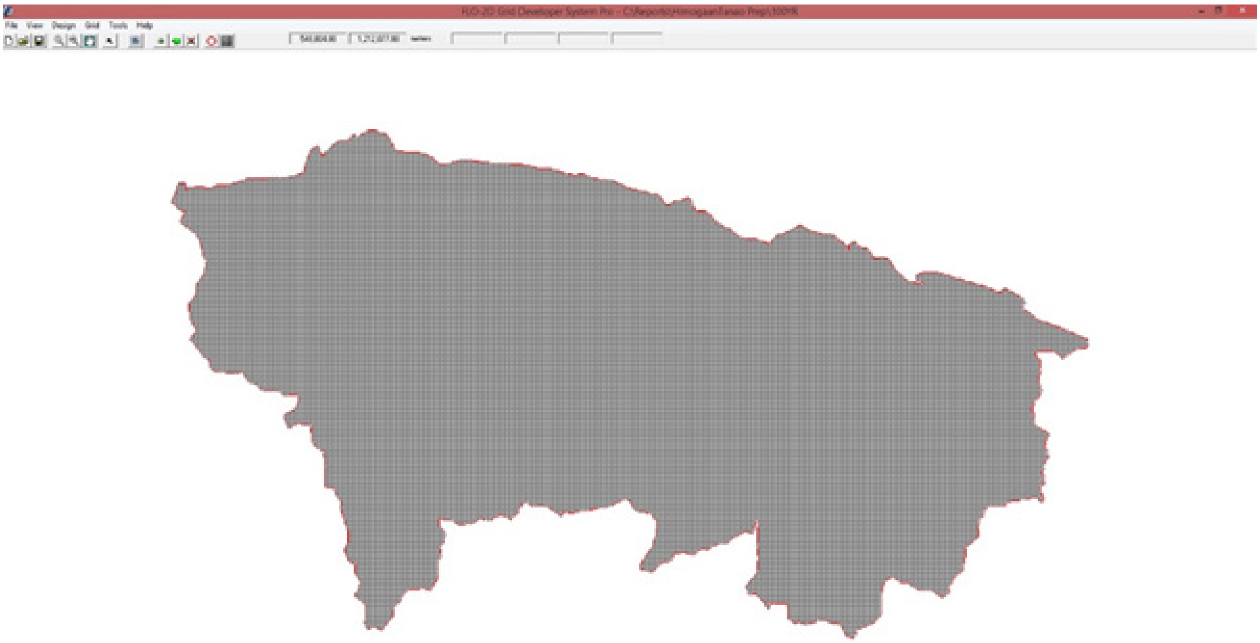


Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 22.20007 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Tanao are in Figures 70, 72, and 74.

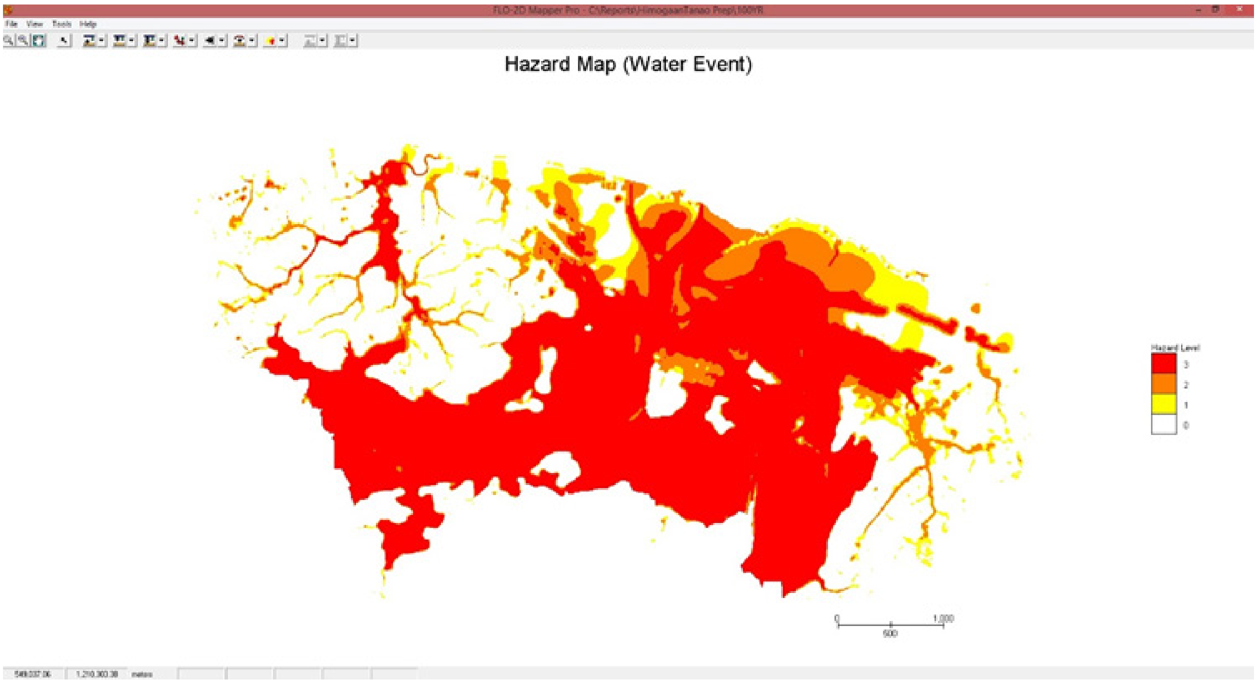


Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper

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 22958400.00 m2. The generated flood depth maps for Tanao are in Figures 71, 73, and 75.

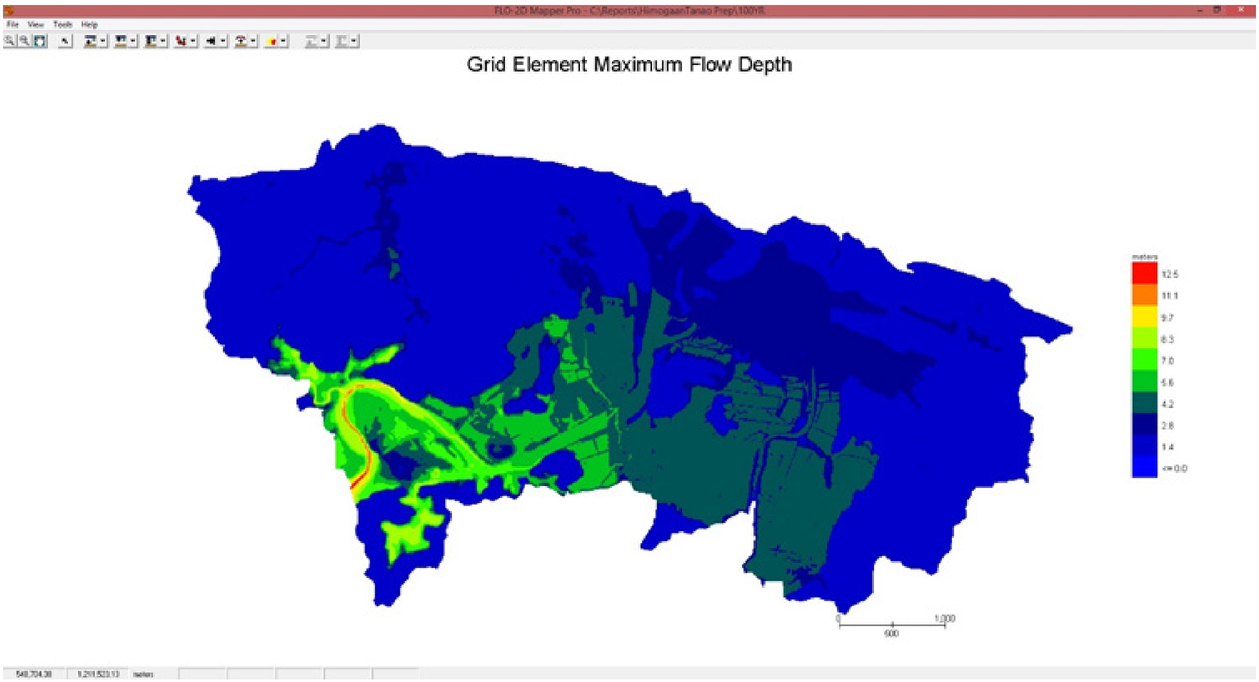


Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 61783670.89 m3 of water entering the model. Of this amount, 6072171.66 m3 is due to rainfall while 55711499.22 m3 is inflow from other areas outside the model 4363573.50 m3 of this water is lost to infiltration and interception, while 33831397.31 m3 is stored by the flood plain. The rest, amounting up to 23588699.98 m3, is outflow.

5.6 Results of HMS Calibration

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

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

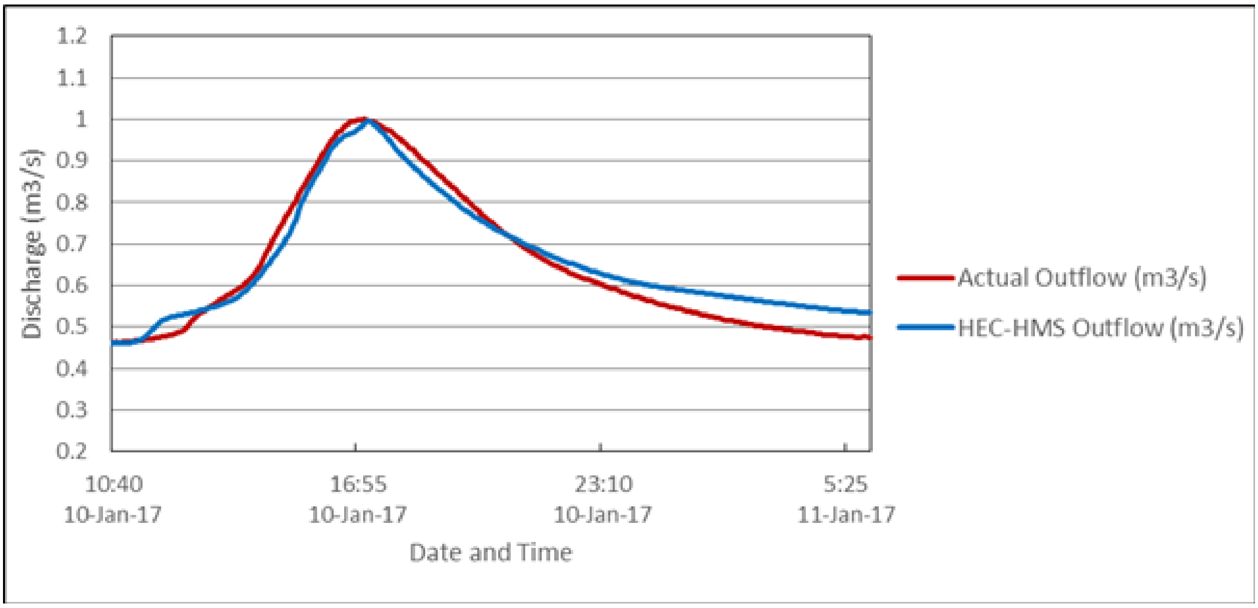


Figure 62. Outflow Hydrograph of Tanao produced by the HEC-HMS model compared with observed outflow

Table 30. Range of calibrated values for the Tanao River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.1-2.4
			Curve Number	83-98
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.73-5.9
			Storage Coefficient (hr)	1.1-9.6
	Baseflow	Recession	Recession Constant	0.75
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.015

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 1.1 mm to 2.4 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 83 to 98 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).. For Tanao, the basin mostly consists of shrublands, forest plantations and urban area, and the soil consists of clay, loam, clay loam, and sandy loam.

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 0.73 hours to 5.9 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 0.75 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.5 indicates a gradual receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.015 corresponds to the common roughness in the Tanao watershed, which is determined to be concrete, and float finished (Brunner, 2010).

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

Accuracy measure	Value
RMSE	0.3790
r2	0.9877
NSE	0.95
PBIAS	-1.95
RSR	0.22

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.03790 (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 0.9877.

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 0.95.

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 -1.95.

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 0.22.

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 66) shows the Tanao outflow using the Mactan Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

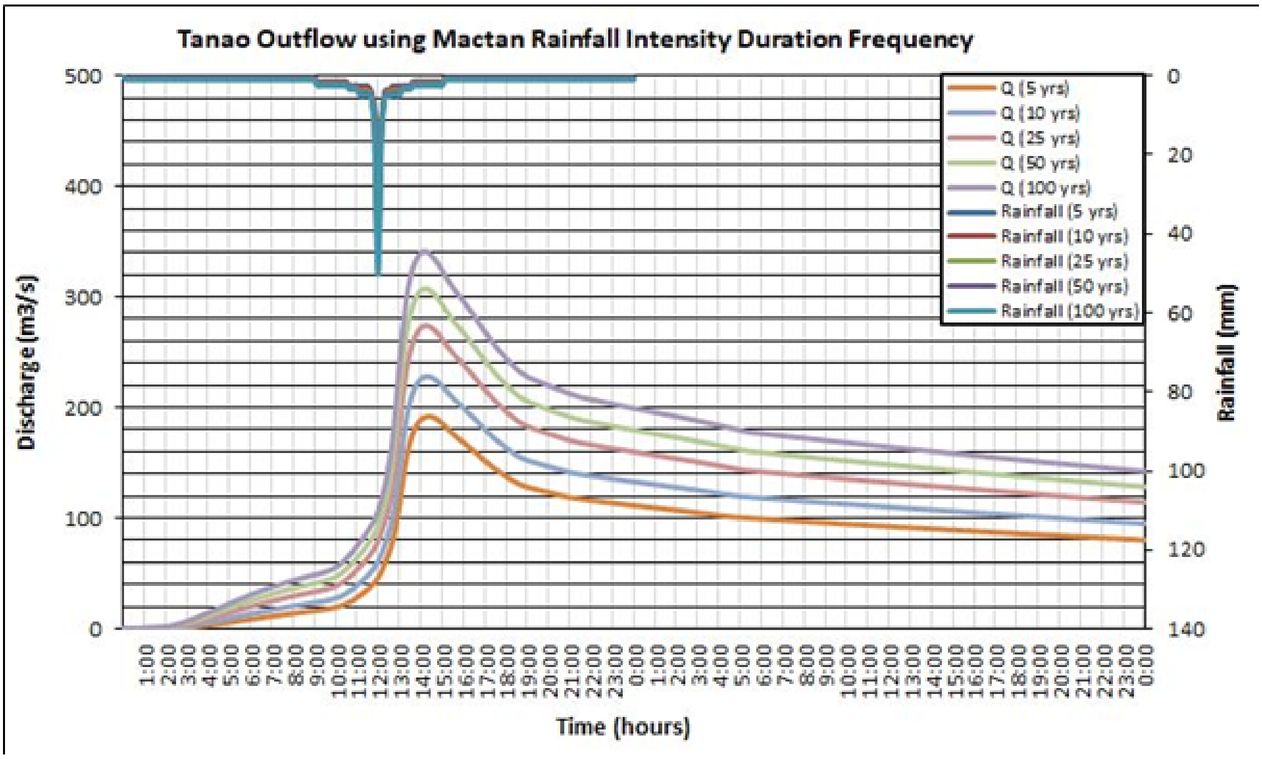


Figure 63. The Outflow hydrograph at the Tanao Station, generated using the Mactan RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Tanao discharge using the Mactan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 32.

Table 32. The peak values of the Tanao HEC-HMS Model outflow using the Mactan RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	139.1	21.9	174.41505	2 hours, 20 minutes
10-Year	169.7	25.8	214.41972	2 hours, 20 minutes
25-Year	208.5	30.9	264.85068	2 hours, 10 minutes
50-Year	237.2	34.6	302.08635	2 hours, 10 minutes
100-Year	265.7	38.3	339.91187	2 hours, 10 minutes

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

The river discharges entering the floodplain are shown in Figure 64 to Figure 68 and the peak values are summarized in Table 33 to Table 37.

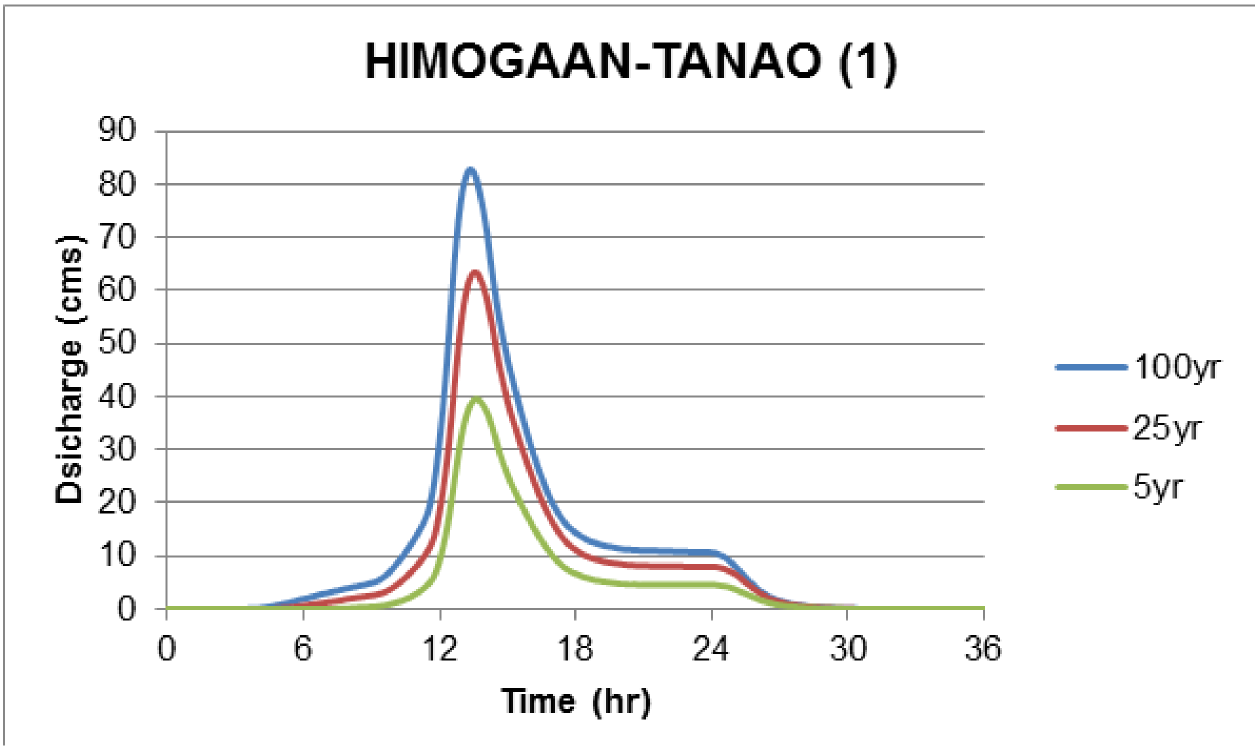


Figure 64. Himogaan and Tanao river (1) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

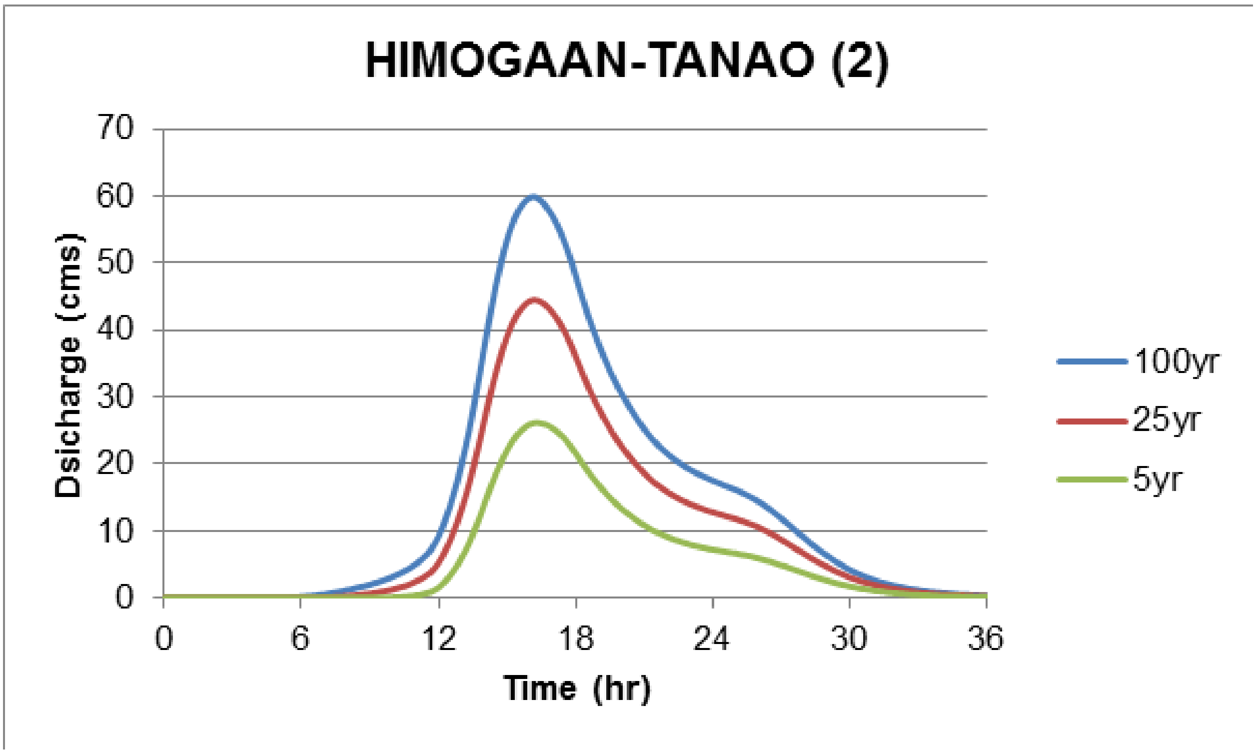


Figure 65. Himogaan and Tanao river (2) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

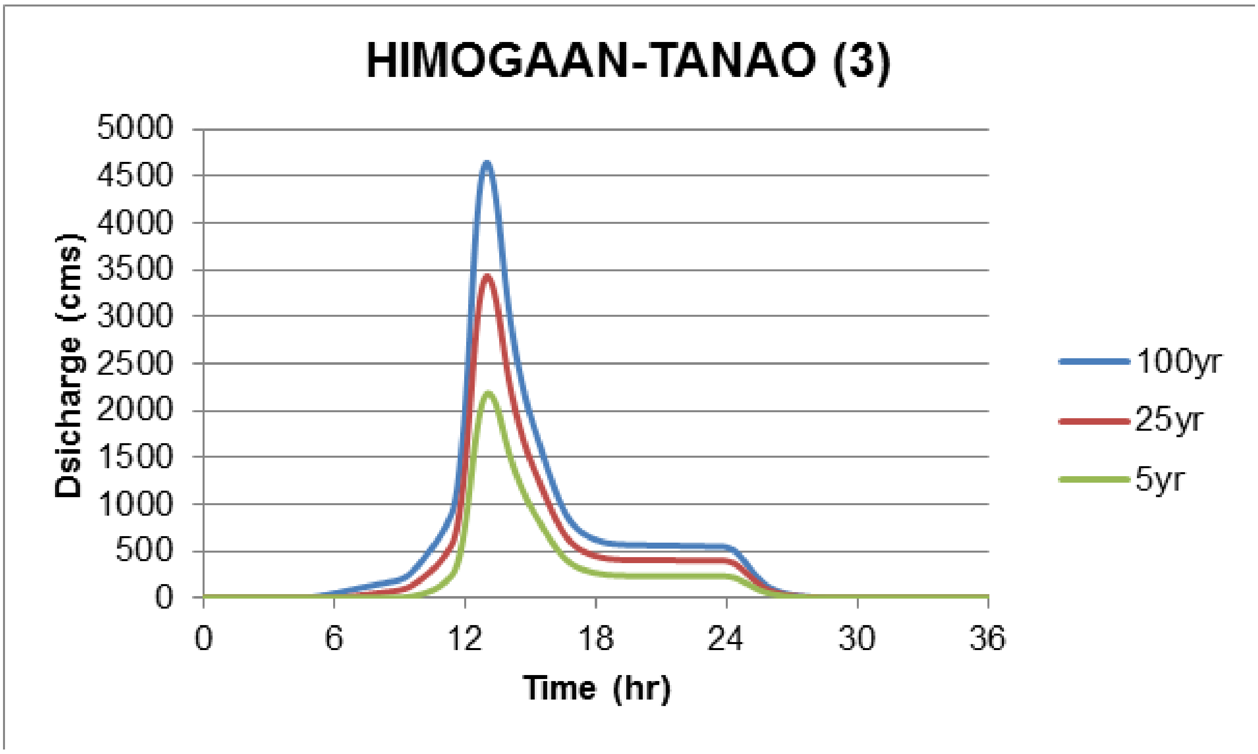


Figure 66. Himogaan and Tanao river (3) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

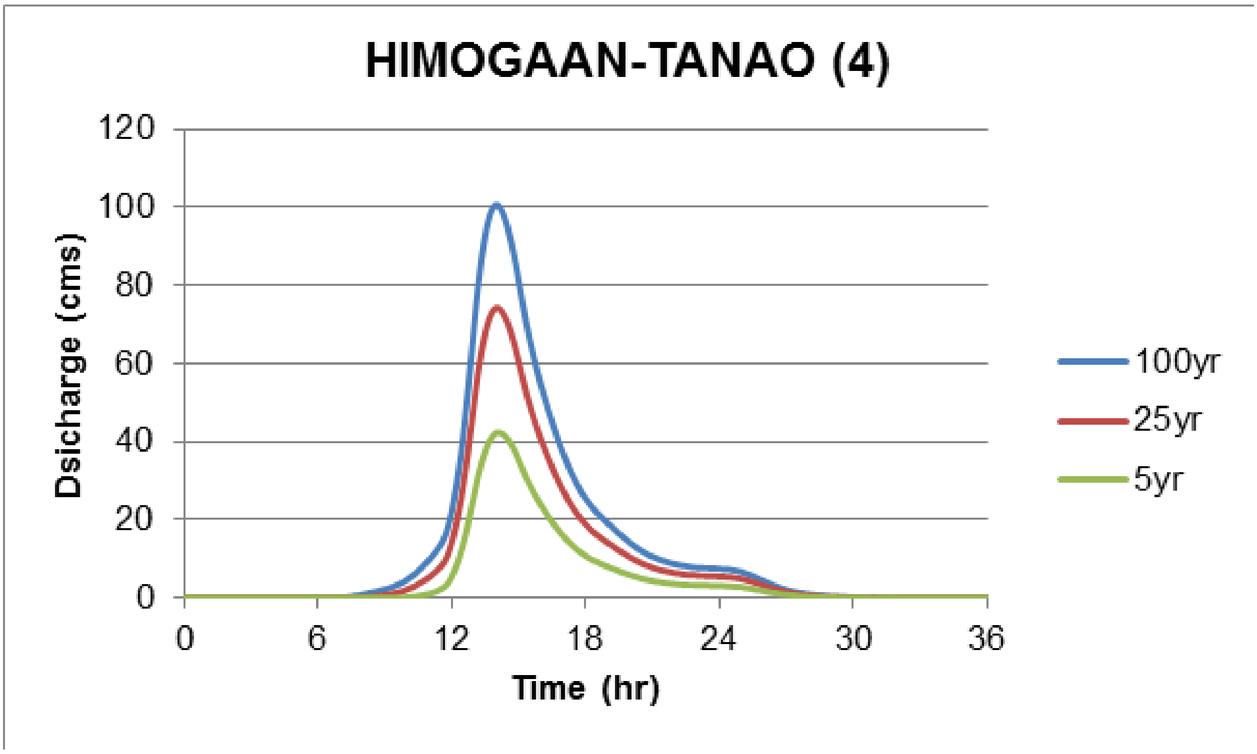


Figure 67. Himogaan and Tanao river (4) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

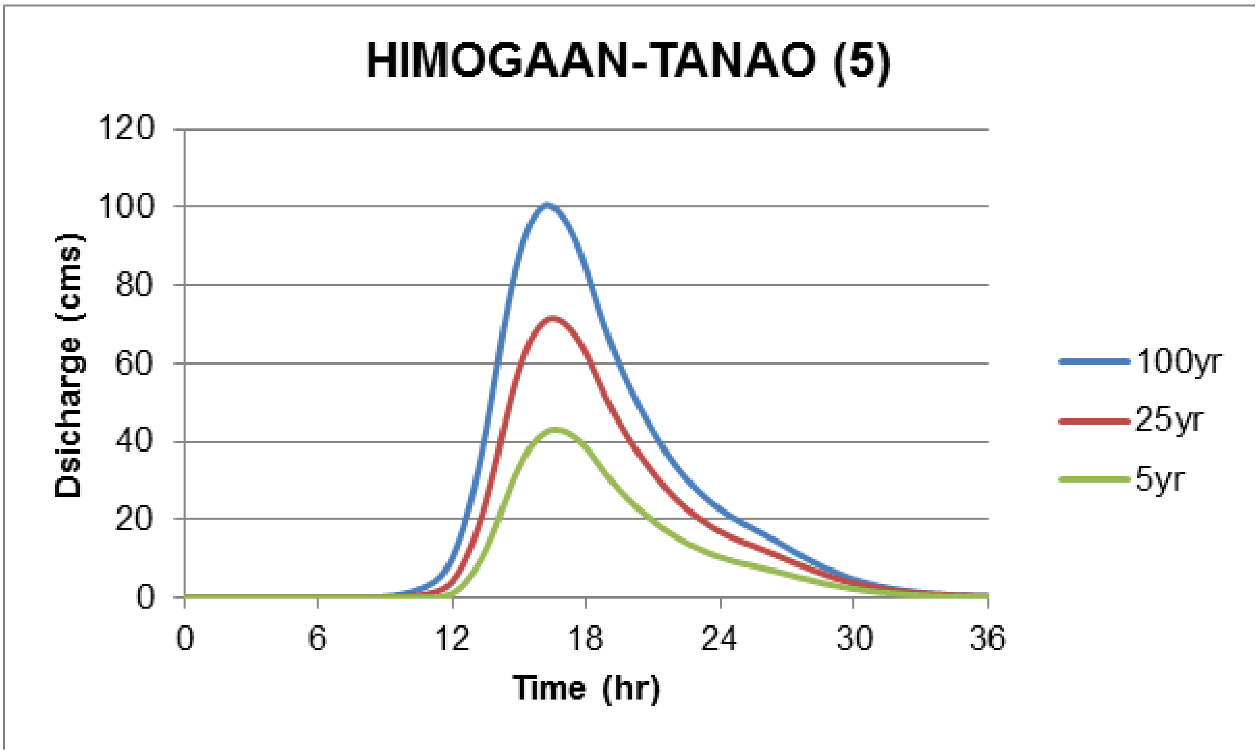


Figure 68. Himogaan and Tanao river (5) generated discharge using 5-, 25-, and 100-year Iloilo and Mactan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 33. Summary of Himogaan and Tanao river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	396.8	13 hours, 50 minutes
25-Year	307.5	13 hours, 50 minutes
5-Year	196.8	13 hours, 50 minutes

Table 34. Summary of Himogaan and Tanao river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	589.8	14 hours, 30 minutes
25-Year	444.1	14 hours, 30 minutes
5-Year	267.2	14 hours, 30 minutes

Table 35. Summary of Himogaan and Tanao river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	189.7	12 hours, 30 minutes
25-Year	147.3	12 hours, 30 minutes
5-Year	94.8	12 hours, 30 minutes

Table 36. Summary of Himogaan and Tanao river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	55.4	12 hours, 20 minutes
25-Year	43.2	12 hours, 20 minutes
5-Year	27.8	12 hours, 20 minutes

Table 37. Summary of Himogaan and Tanao river (5) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	55.4	12 hours, 20 minutes
25-Year	43.2	12 hours, 20 minutes
5-Year	27.8	12 hours, 20 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 38.

Table 38. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Himogaan-Tanao (1)	34.760	51.930	34.649	Pass	Pass
Himogaan-Tanao (2)	23.056	29.710	75.694	Pass	Fail
Himogaan-Tanao (3)	1915.584	3471.490	529.417	Pass	Fail
Himogaan-Tanao (4)	37.224	58.830	45.224	Pass	Pass
Himogaan-Tanao (5)	37.928	66.320	118.887	Pass	Fail

All five values from the HEC-HMS river discharge estimates were able to satisfy at least one of the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 62 shows a generated sample map of the Tanao River using the calibrated HMS base flow.

Figure 69. The sample output map of the Tanao RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 70 to Figure 75 shows the 5-, 25-, and 100-year rain return scenarios of the Himogaan-Tanao floodplain. The floodplain, with an area of 82.421898 sq. km., covers two municipalities namely Cadiz and Sagay. Table 39 shows the percentage of area affected by flooding per municipality.

Table 39. Municipalities affected in Tanao floodplain

Municipality	Total Area	Area Flooded	% Flooded
Cadiz	516.18	11.54	2.24%
Sagay	304.62	69.97	22.97%

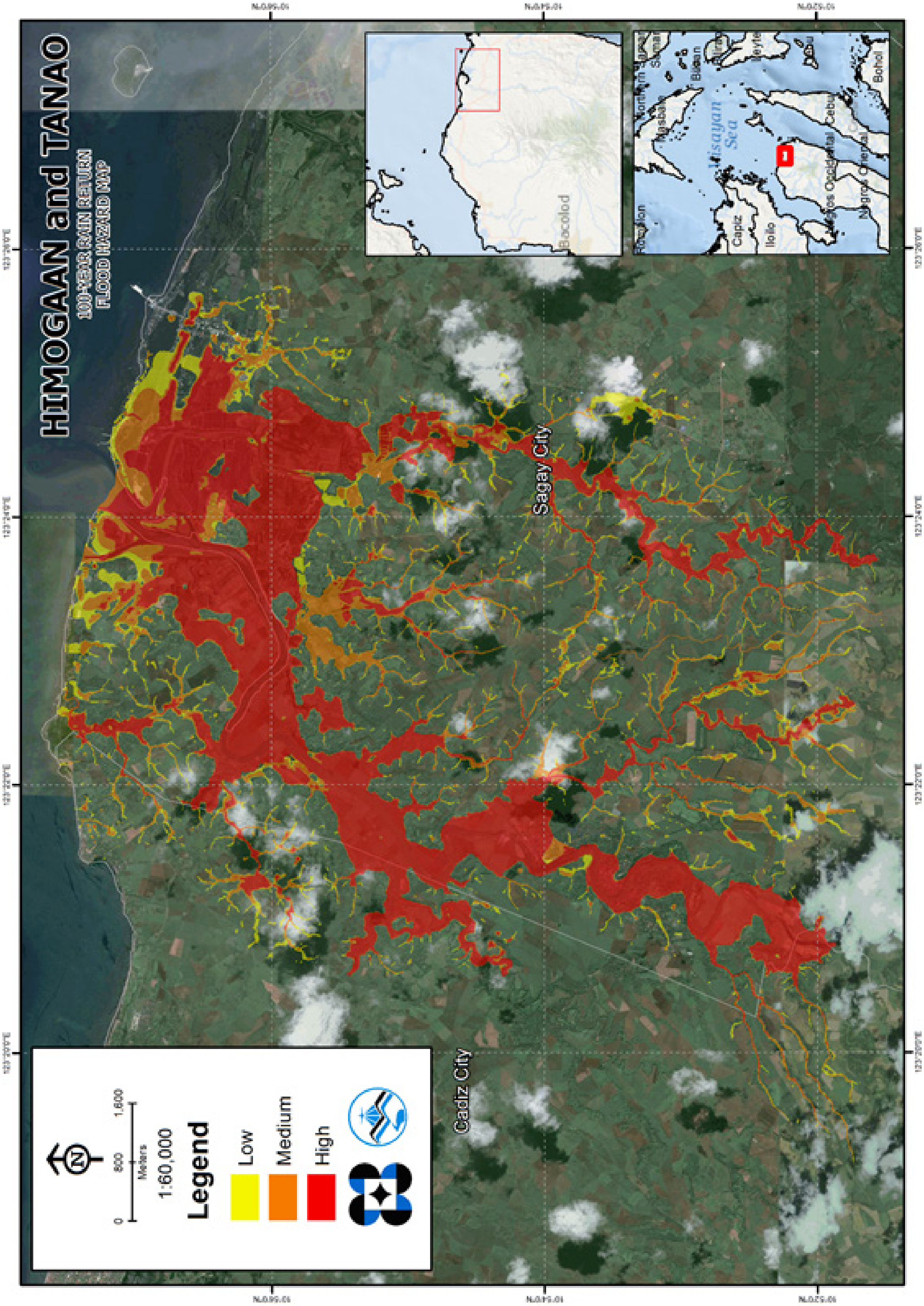


Figure 70. A 100-year Flood Hazard Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery.

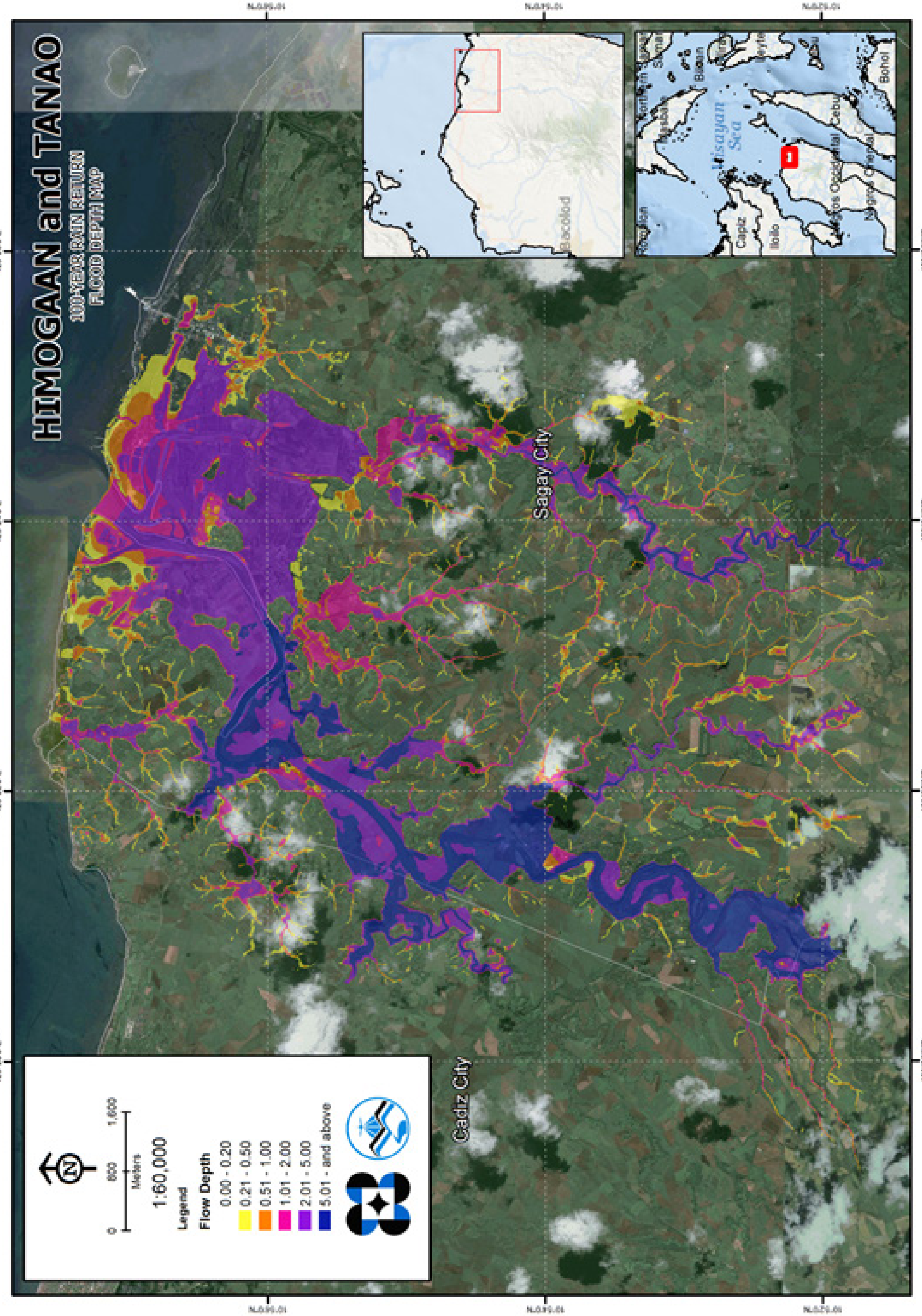


Figure 71. A 100-year Flow Depth Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery.

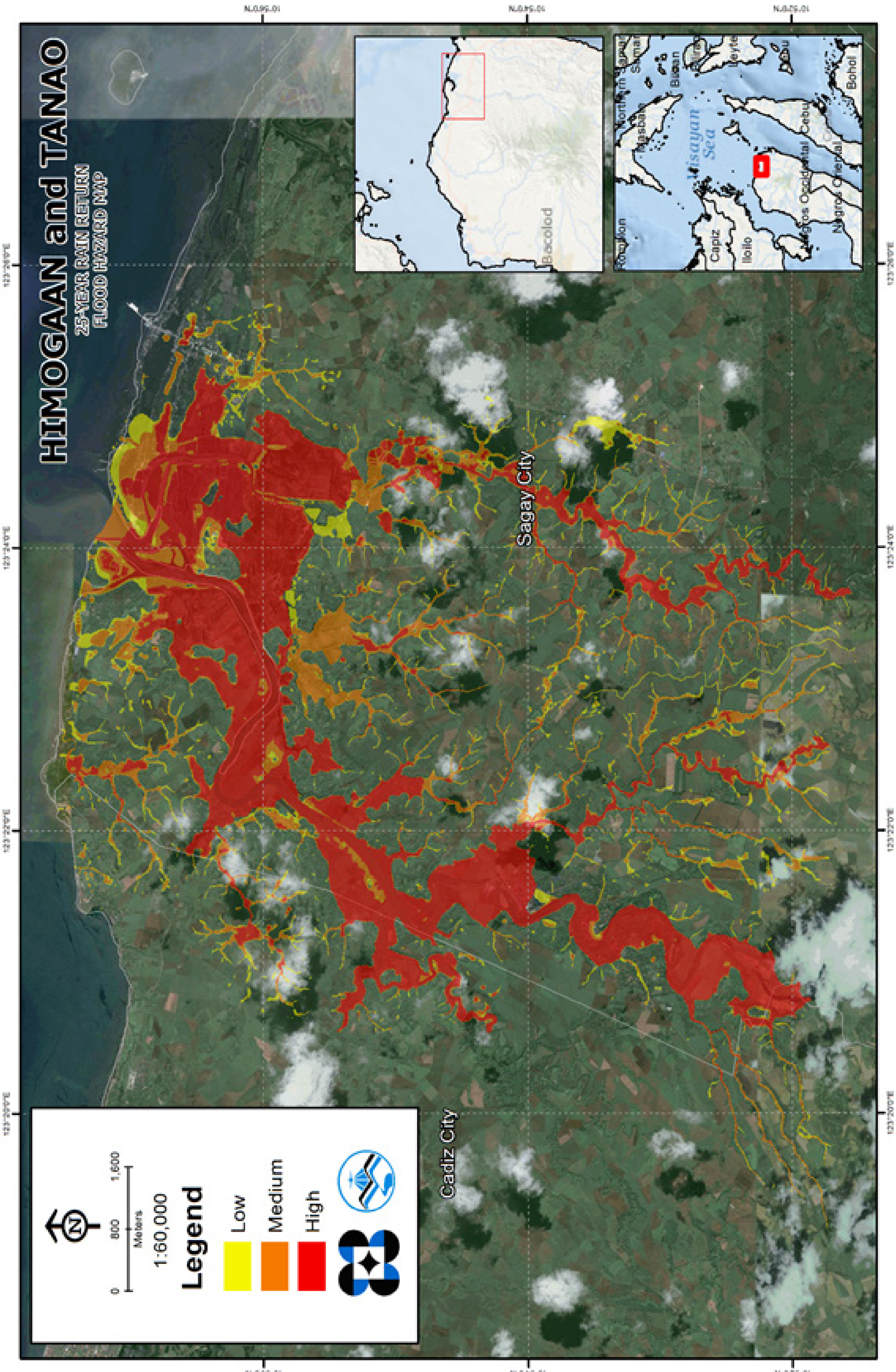


Figure 72. A 25-year Flood Hazard Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery.

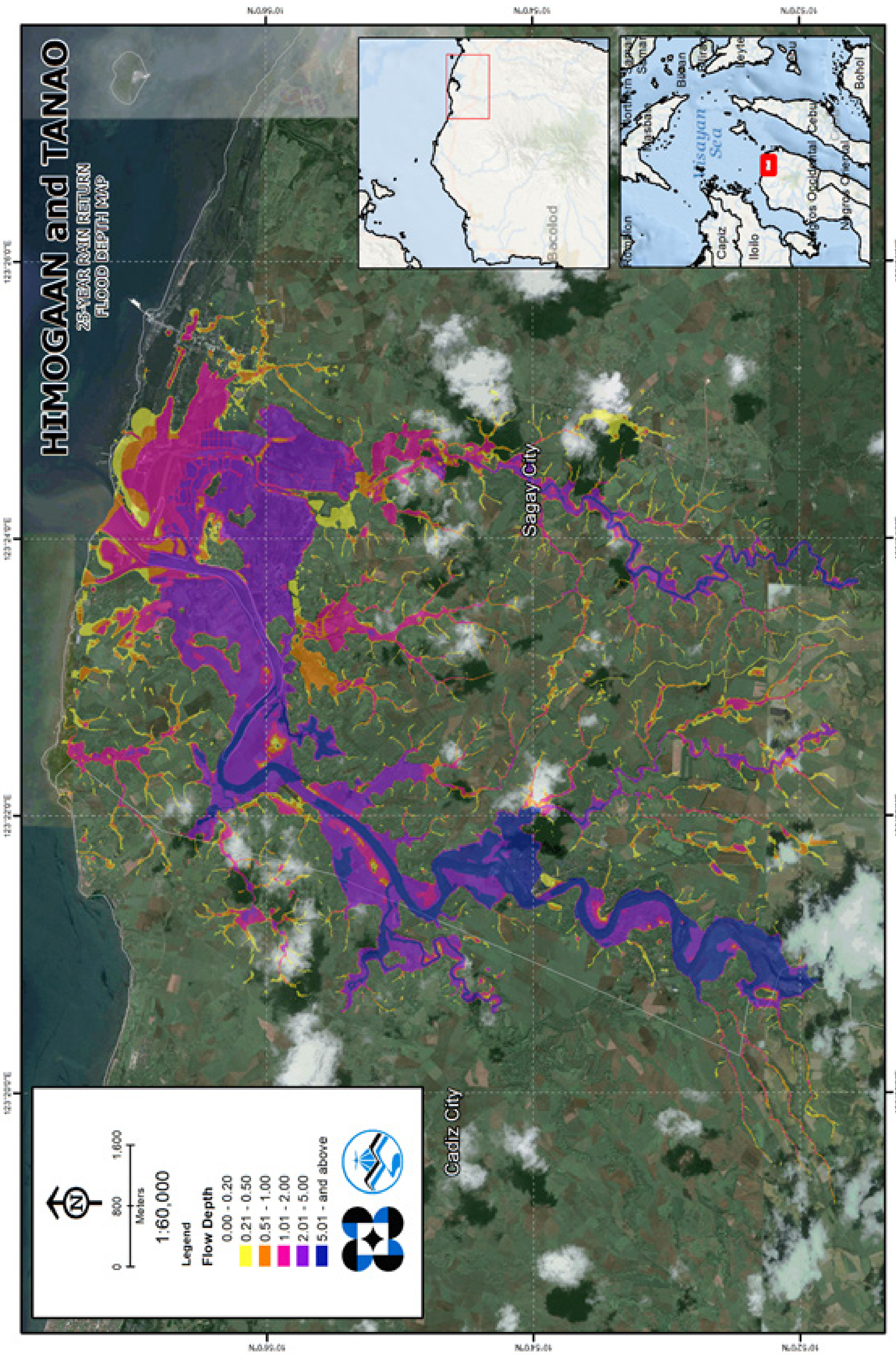


Figure 73. A 25-year Flow Depth Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery.

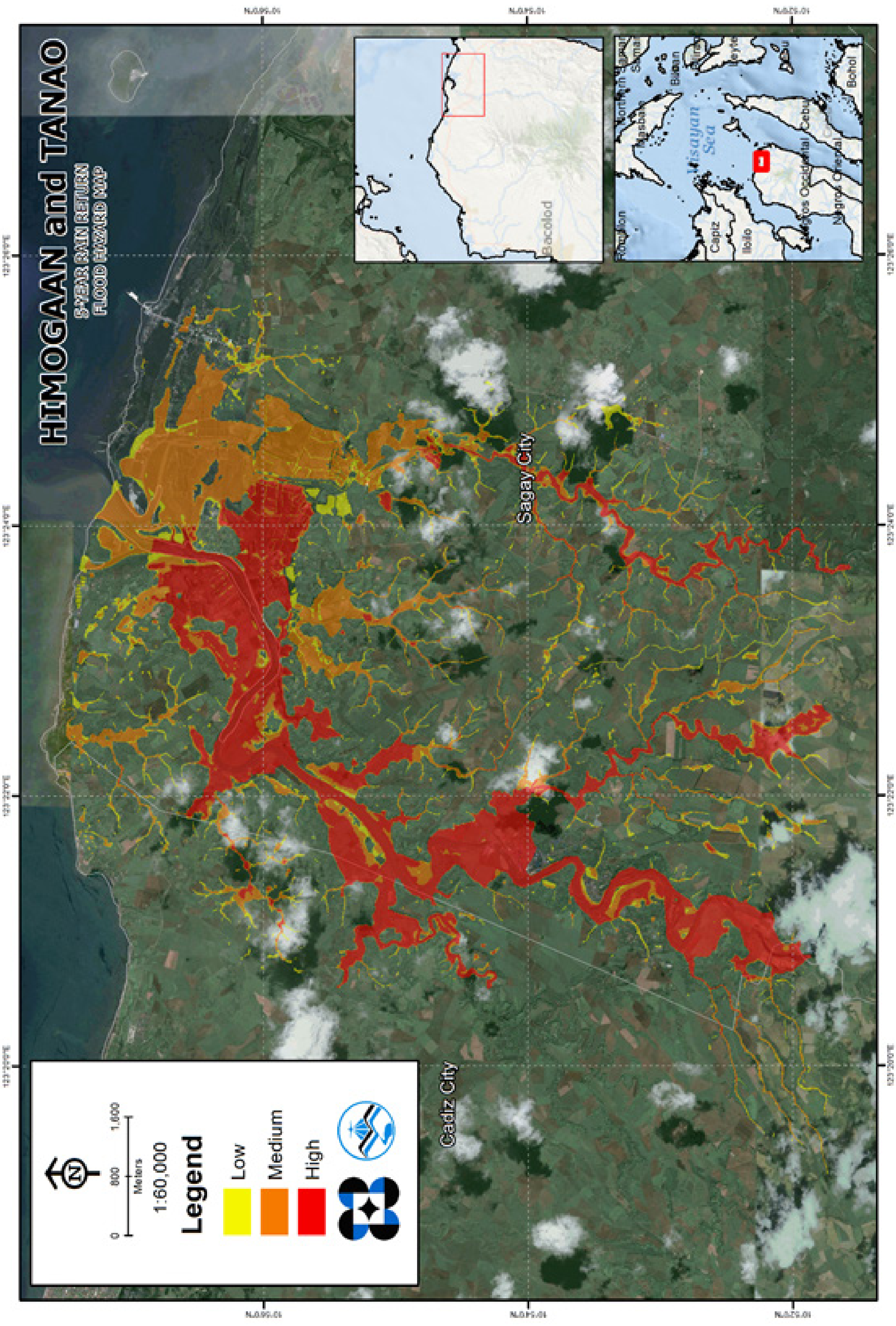


Figure 74. A 5-year Flood Hazard Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery.

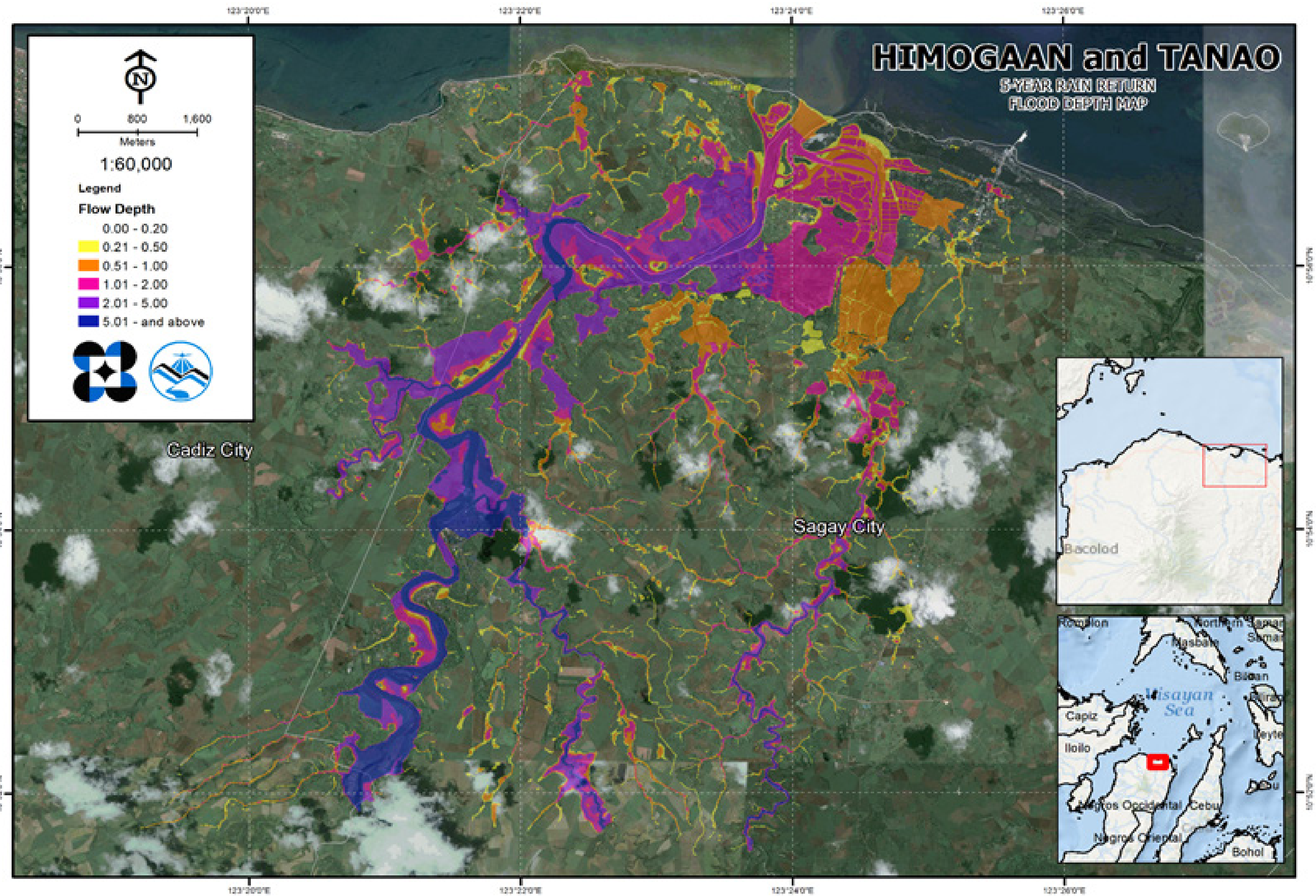


Figure 75. A 5-year Flood Depth Map for Himogaan-Tanao Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Tanao River Basin, grouped accordingly by municipality. For the said basin, two municipalities consisting of 12 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 1.88% of the city of Cadiz with an area of 516.18 sq. km. will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.06%, 0.12%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (m.)	Affected Barangays in Cadiz City (sq. km.)			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.55	2.42	2.91	3.8
0.21-0.50	0.024	0.07	0.093	0.2
0.51-1.00	0.0048	0.078	0.096	0.14
1.01-2.00	0.0024	0.15	0.059	0.12
2.01-5.00	0	0.59	0.026	0.0092
> 5.00	0	0.086	0.11	0

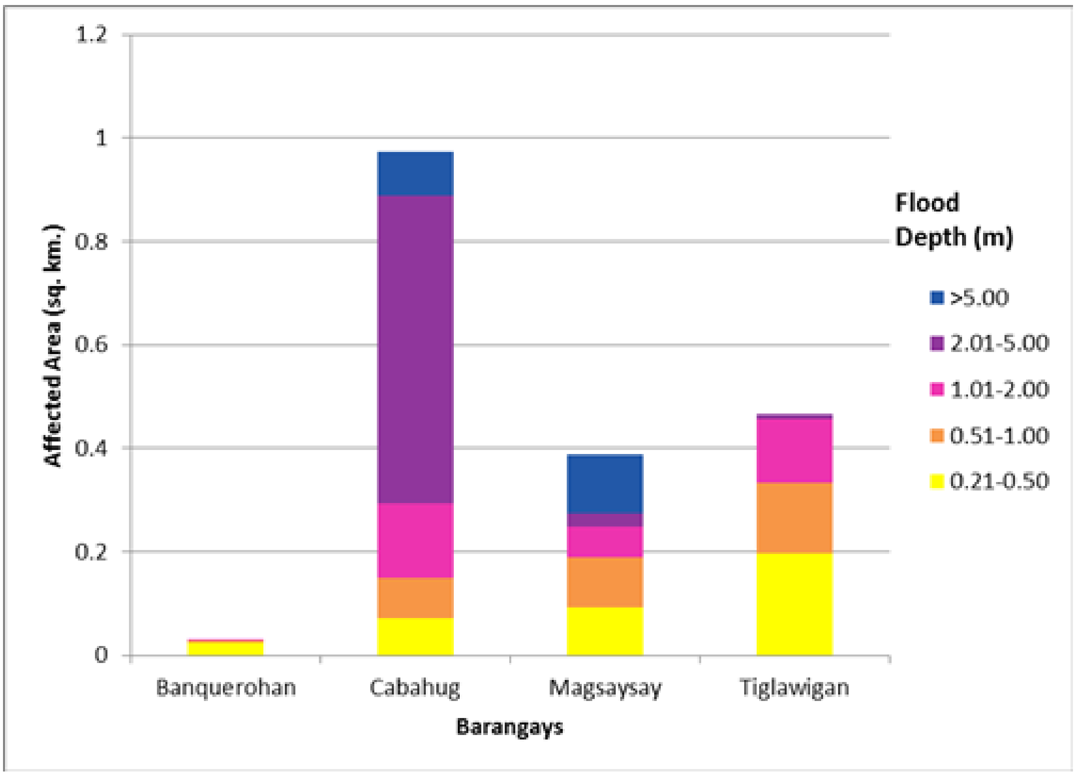


Figure 76. Affected Areas in Cadiz City, Negros Occidental during 5-Year Rainfall Return Period.

For the city of Sagay, with an area of 304.62 sq. km., 16.36% will experience flood levels of less 0.20 meters. 1% of the area will experience flood levels of 0.21 to 0.50 meters while 1.57%, 1.72%, 1.49%, and 0.82% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Sagay City, Negros Occidental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (m.)	Affected Barangays in Sagay City (sq.km.)							
	Fabrica	Himoga-An Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.28	17.44	4	4.24	10.4	0.75	10.34	1.38
0.21-0.50	0.041	1.25	0.17	0.49	0.48	0.081	0.47	0.062
0.51-1.00	0.035	1.77	0.14	1.98	0.4	0.011	0.41	0.042
1.01-2.00	0.052	2.95	0.14	1.26	0.37	0.0011	0.46	0.016
2.01-5.00	0.11	3.49	0.22	0	0.37	0	0.35	0
> 5.00	0.27	1.3	0.25	0	0.56	0	0.13	0

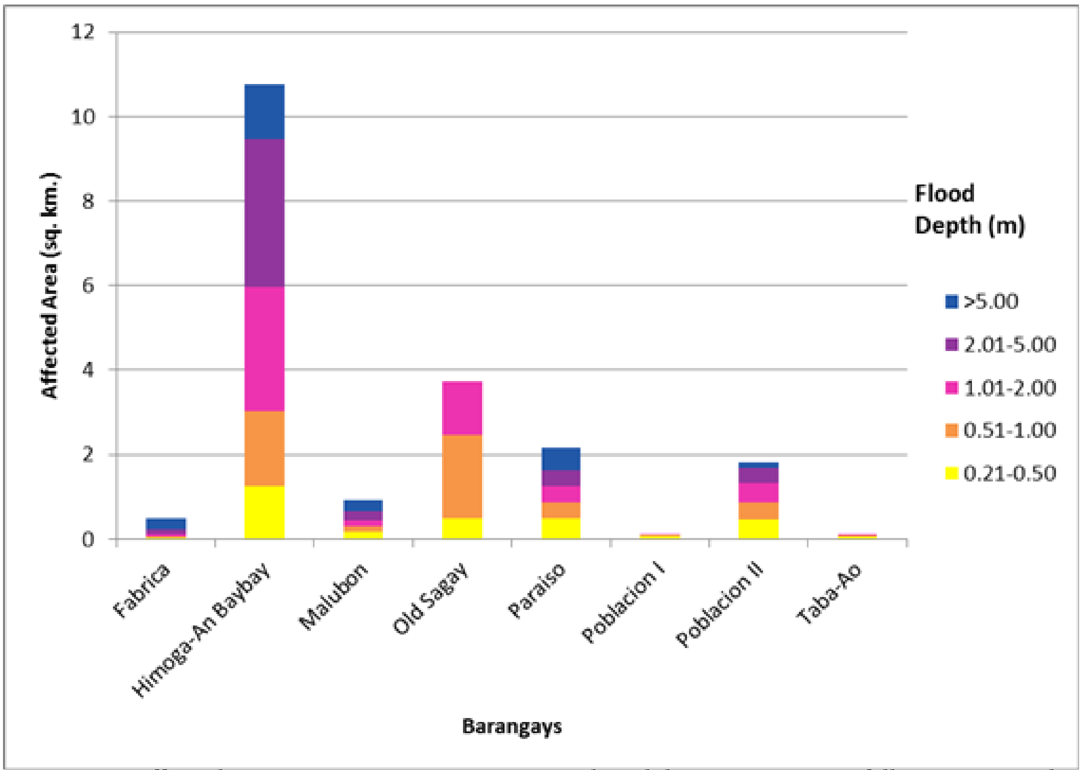


Figure 77. Affected Areas in Sagay City, Negros Occidental during 5-Year Rainfall Return Period.

For the 25-year return period, 1.81% of the city of Cadiz with an area of 516.18 sq. km. will experience flood levels of less 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.07%, 0.13%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (m.)	Affected Barangays in Cadiz City (sq. km.)			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.54	2.32	2.84	3.69
0.21-0.50	0.037	0.076	0.096	0.22
0.51-1.00	0.0055	0.07	0.1	0.16
1.01-2.00	0.0052	0.12	0.073	0.15
2.01-5.00	0	0.58	0.049	0.049
> 5.00	0	0.23	0.13	0

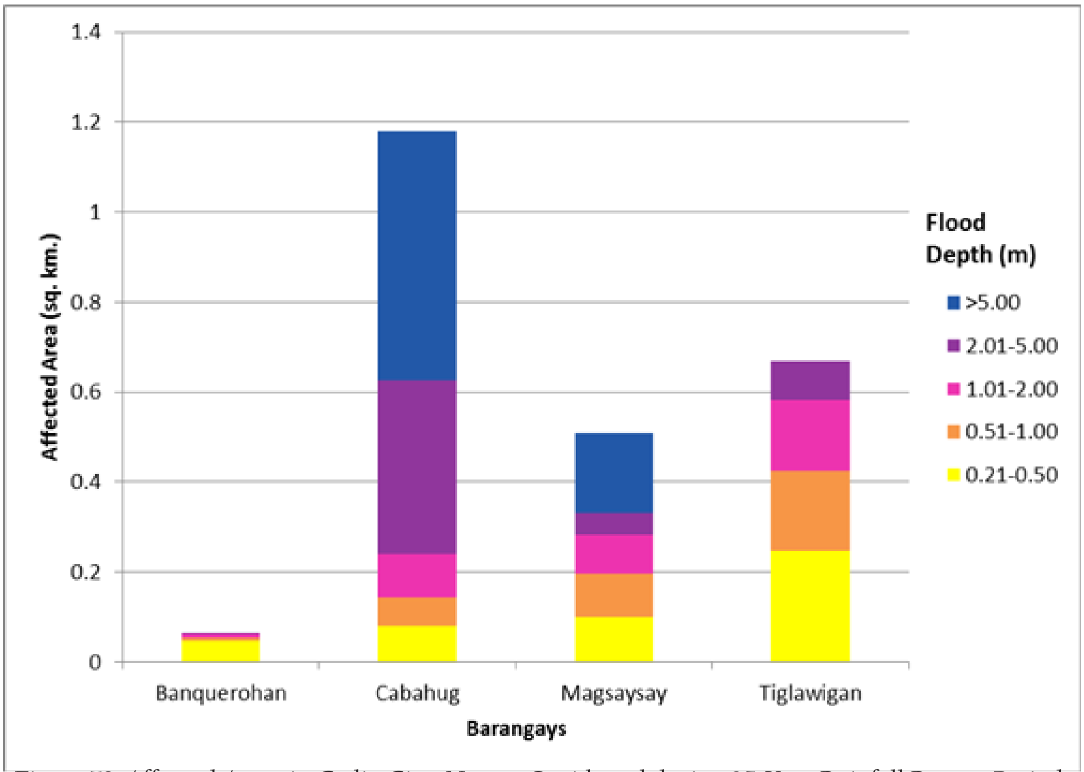


Figure 78. Affected Areas in Cadiz City, Negros Occidental during 25-Year Rainfall Return Period.

For the city of Sagay, with an area of 304.62 sq. km., 15.41% will experience flood levels of less 0.20 meters. 1.1% of the area will experience flood levels of 0.21 to 0.50 meters while 1%, 1.7%, 2.7%, and 1.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Sagay City, Negros Occidental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (m.)	Affected Barangays in Sagay City (sq. km.)							
	Fabrica	Himoga-An Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.22	16.18	4.04	3.41	10.26	0.66	9.84	1.32
0.21-0.50	0.043	1.24	0.23	0.58	0.53	0.16	0.5	0.082
0.51-1.00	0.03	1.42	0.17	0.55	0.4	0.018	0.41	0.054
1.01-2.00	0.049	2.21	0.11	1.86	0.35	0.0019	0.56	0.036
2.01-5.00	0.11	5.3	0.11	1.58	0.54	0	0.58	0
> 5.00	0.34	1.87	0.26	0	0.49	0	0.26	0

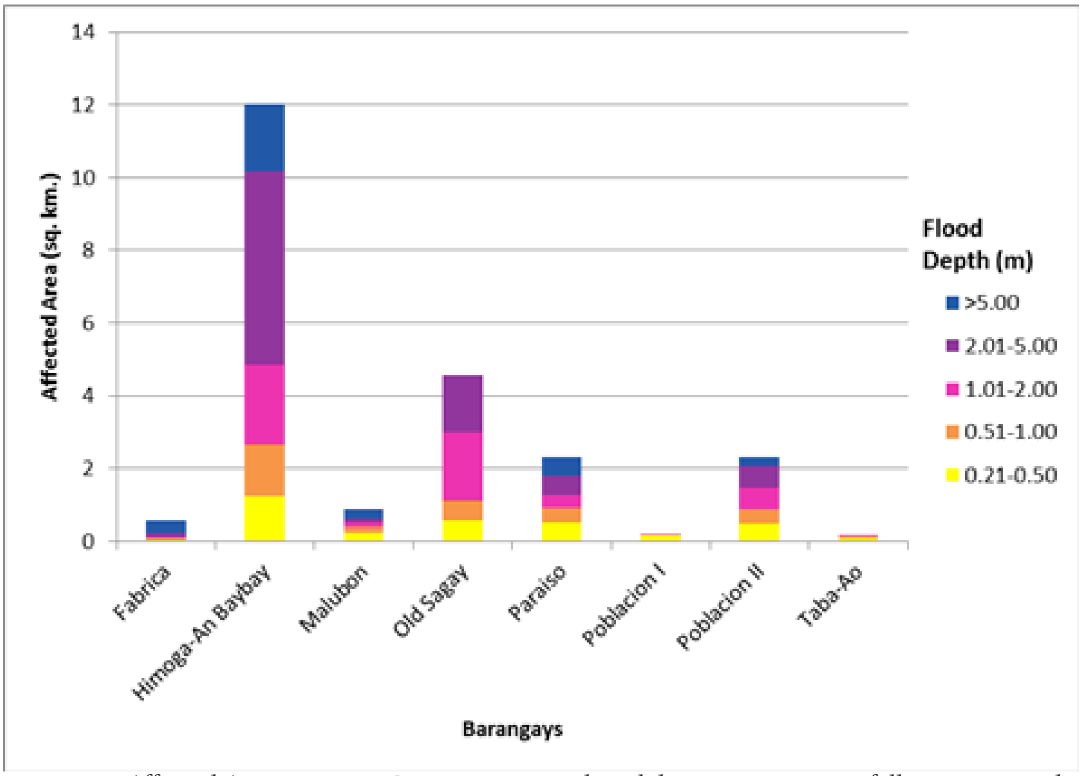


Figure 79. Affected Areas in Sagay City, Negros Occidental during 25-Year Rainfall Return Period.

For the 100-year return period, 1.77% of the city of Cadiz with an area of 516.18 sq. km. will experience flood levels of less 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.07%, 0.1%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (m.)	Affected Barangays in Cadiz City (sq. km.)			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.52	2.22	2.78	3.6
0.21-0.50	0.048	0.079	0.099	0.25
0.51-1.00	0.0074	0.064	0.096	0.18
1.01-2.00	0.0057	0.098	0.088	0.16
2.01-5.00	0.0015	0.39	0.047	0.087
> 5.00	0	0.55	0.18	0

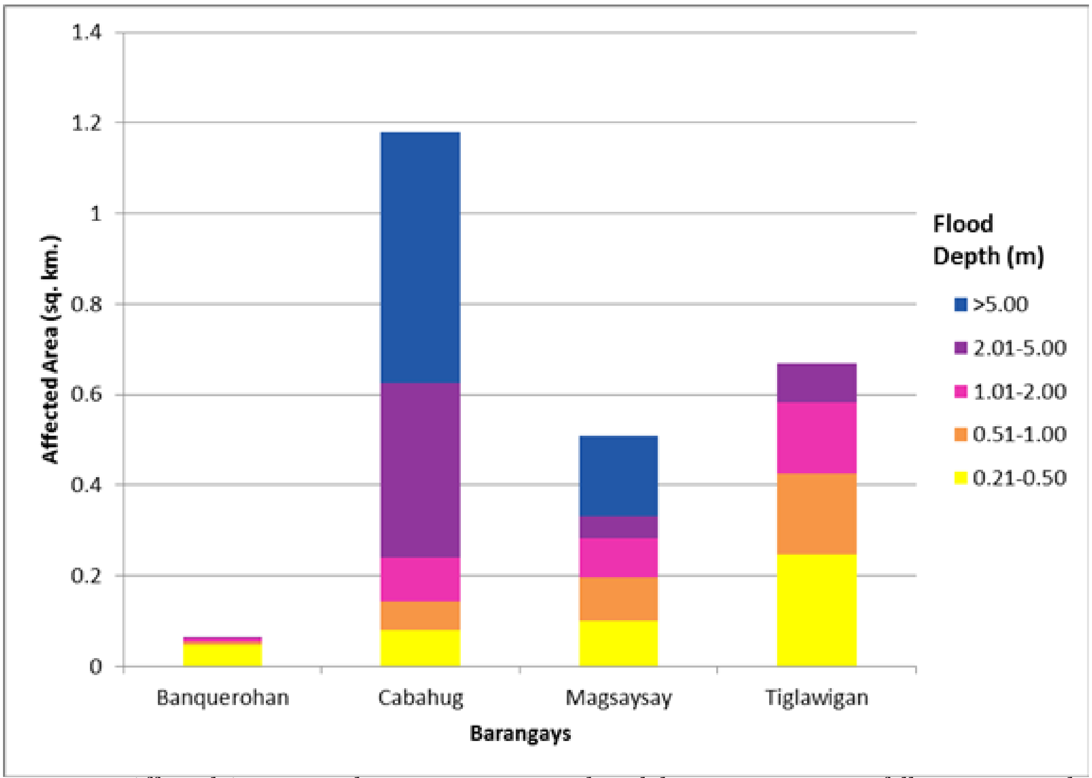


Figure 80. Affected Areas in Cadiz City, Negros Occidental during 100-Year Rainfall Return Period.

For the city of Sagay, with an area of 304.62 sq. km., 14.65% will experience flood levels of less 0.20 meters. 1.15% of the area will experience flood levels of 0.21 to 0.50 meters while 1%, 1.35%, 3.24%, and 1.6% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Sagay City, Negros Occidental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (m.)	Affected Barangays in Sagay City (sq. km.)							
	Fabrica	Himoga-An Baybay	Malubon	Old Sagay	Paraiso	Poblacion I	Poblacion II	Taba-Ao
0.03-0.20	1.18	15.11	3.91	2.88	10.06	0.62	9.58	1.28
0.21-0.50	0.043	1.24	0.24	0.64	0.55	0.2	0.49	0.1
0.51-1.00	0.024	1.22	0.18	0.64	0.44	0.024	0.4	0.061
1.01-2.00	0.04	2.03	0.15	0.92	0.36	0.0027	0.55	0.046
2.01-5.00	0.076	5.53	0.14	2.91	0.45	0	0.78	0.0034
> 5.00	0.43	3.09	0.31	0	0.72	0	0.35	0

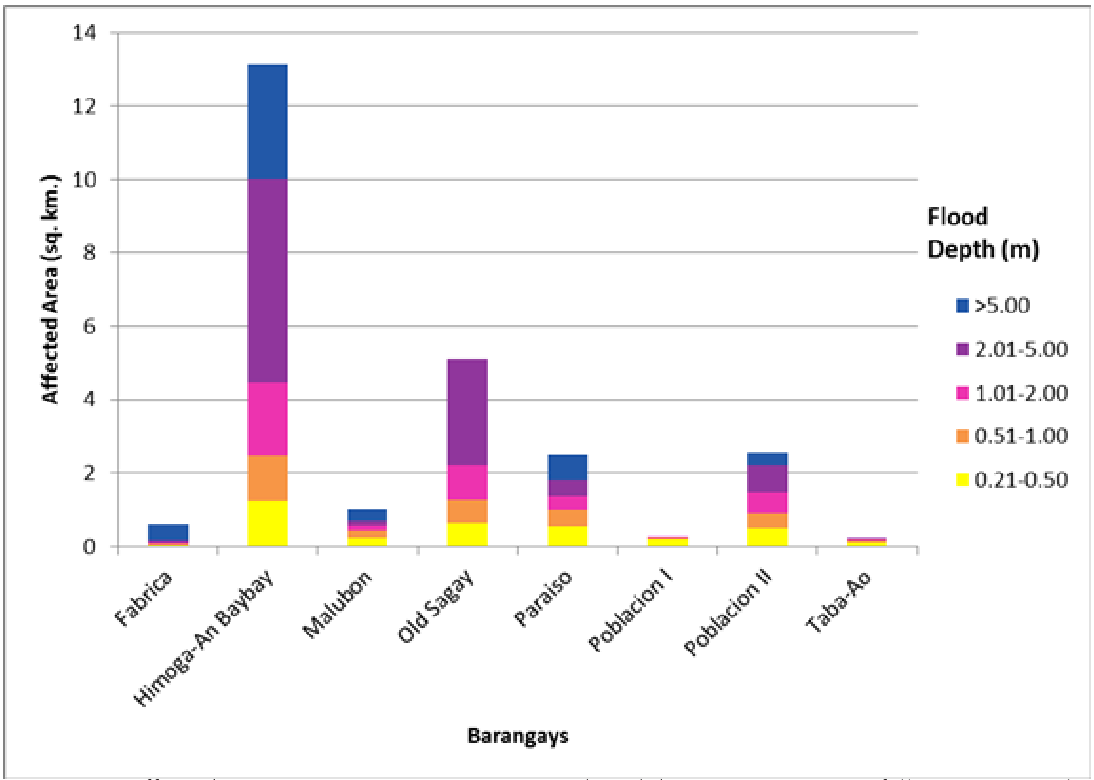


Figure 81. Affected Areas in Sagay City, Negros Occidental during 100-Year Rainfall Return Period.

Among the barangays in the city of Cadiz, Tiglawigan is projected to have the highest percentage of area that will experience flood levels at 4.27%. Meanwhile, Cabahug posted the second highest percentage of area that may be affected by flood depths at 3.4%.

Among the barangays in the city of Sagay, Himoga-An Baybay is projected to have the highest percentage of area that will experience flood levels at 28.21%. Meanwhile, Paraiso posted the second highest percentage of area that may be affected by flood depths at 12.57%.

Moreover, the generated flood hazard maps for the Tanao (Himogaan-Tanao) 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 46. 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	3.56	3.92	4.12
Medium	8.84	6.22	5.91
High	10.65	16.22	18.89
Total	**23.05**	**26.36**	**28.92**

Of the twenty (20) identified Education Institute in Himogaan-Tanao Flood plain, 1 school was assessed to be exposed to the medium level flooding during a 25 year scenario while 2 schools were assessed to be exposed to high level flooding in the same scenario. In the 100 year scenario, 3 schools were assessed to be exposed to the high level flooding scenario. See Annex 12 for a detailed enumeration of schools in the HImogaan-Tanao floodplain.

Two (2) Medical Institutions were identified in Himogaan-Tanao Floodplain, only 1 was assessed to be exposed to high level flooding in two different scenarios, medium and high, in Barangay Himoga-An Baybay. See Annex 13 for a detailed enumeration of schools in the Himogaan-Tanao floodplain.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 83.

The flood validation consists of 152 points randomly selected all over the Tanao (Himogaan-Tanao) flood plain (Figure 82). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.40302m. Table 47 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

The validation data were obtained on November 6, 2015.

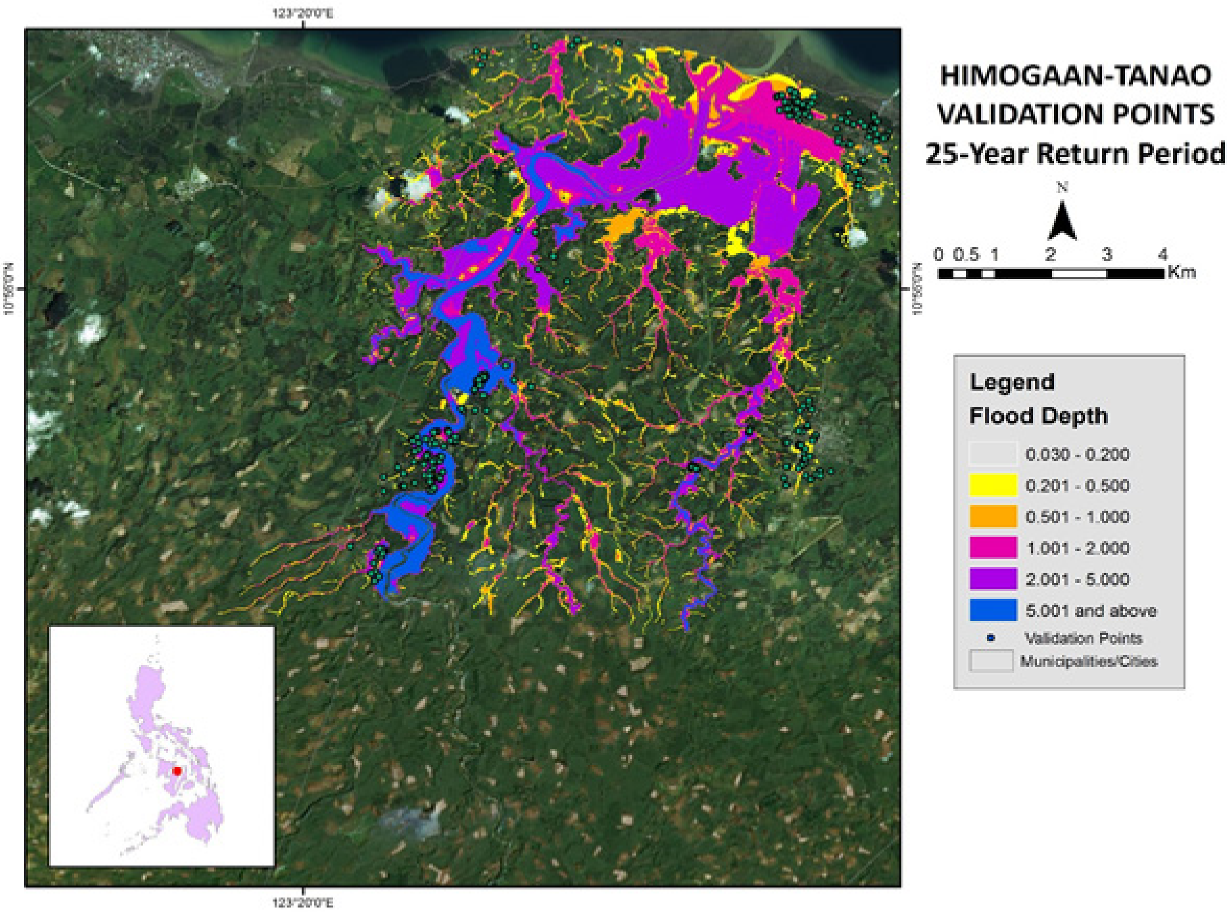


Figure 82. The Validation Points for a 5-year Flood Depth Map of the Himogaan-Tanao Floodplain.

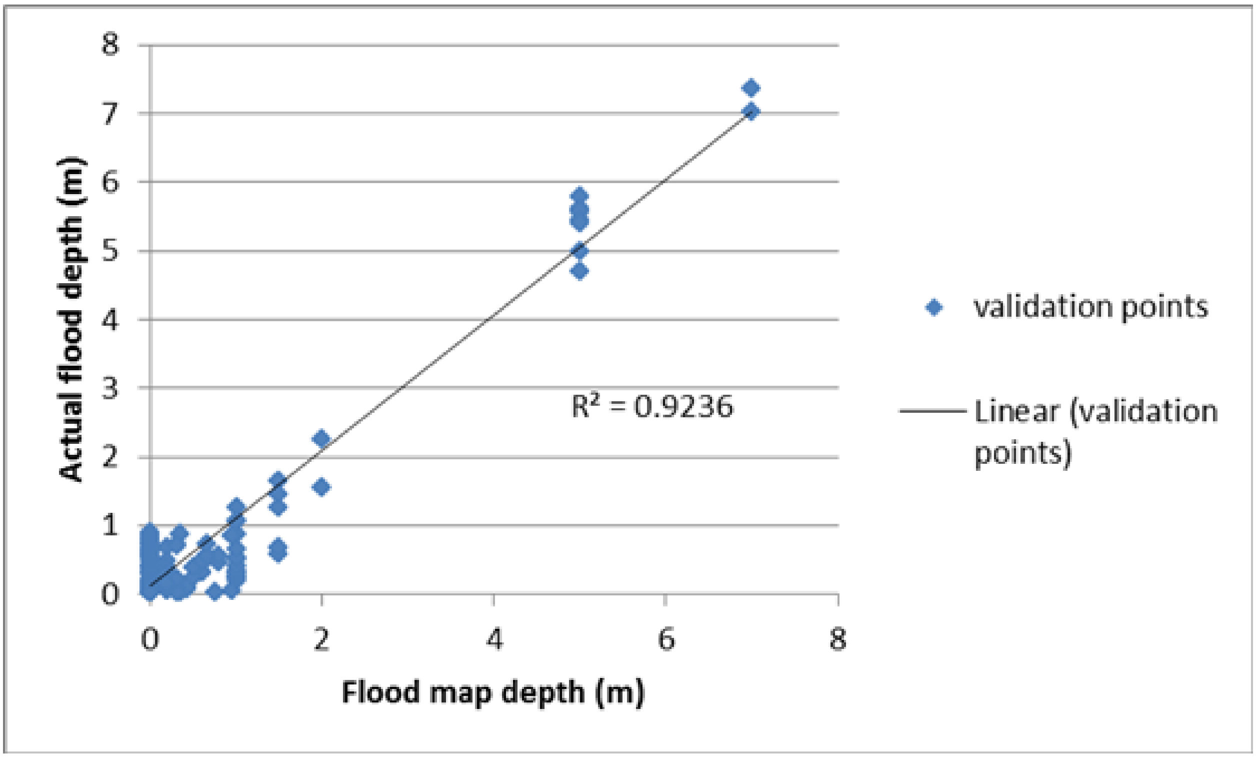


Figure 83. Flood map depth versus actual flood depth

Table 47. Actual flood vs simulated flood depth at differnent levels in the Tanao River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	59	16	23	0	0	0	98
0.21-0.50	4	3	3	0	0	0	10
0.51-1.00	3	11	8	3	0	0	25
1.01-2.00	0	0	2	4	1	0	7
2.01-5.00	0	0	0	0	2	6	8
> 5.00		0	0	0	2	2	4
Total	66	30	36	7	5	8	152

On the whole, the overall accuracy generated by the flood model is estimated at 51.32%, with 78 points correctly matching the actual flood depths. In addition, there were 48 points estimated one level above and below the correct flood depths while there were 26 points estimated two levels above and below. A total of 52 points were overestimated while a total of 22 points were underestimated in the modelled flood depths of Himogaan-Tano. Table 48 depicts the summary of the Accuracy Assessment in the Himogaan-Tanao River Basin Flood Depth Map.

Table 48. The Summary of the Accuracy Assessment in the Himogaan-Tanao River Basin Survey.

	No. of Points	%
Correct	78	51.32
Overestimated	52	34.21
Underestimated	22	14.47
Total	152	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

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

1. PEGASUS SENSOR

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

2. AQUARIUS SENSOR

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

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

1. NGW-50

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

May 09, 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: **NEGROS OCCIDENTAL**
Station Name: **NGW-50**
Order: **2nd**

Island:	**VISAYAS**			Barangay:	**FABRICA**
Municipality:	**SAGAY**				
		PRS92 Coordinates			
Latitude:	**10° 53' 26.84456"**	Longitude:	**123° 21' 6.66799"**	Ellipsoidal Hgt:	**15.38600 m.**
		WGS84 Coordinates			
Latitude:	**10° 53' 22.52478"**	Longitude:	**123° 21' 11.86863"**	Ellipsoidal Hgt:	**74.42200 m.**
		PTM Coordinates			
Northing:	**1204272.594 m.**	Easting:	**538465.927 m.**	Zone:	**4**
		UTM Coordinates			
Northing:	**1,203,851.08**	Easting:	**538,452.46**	Zone:	**51**

Location Description

NGW-50
The station is on the NW sidewalk of Himoga-an bridge at km. 73+545 along the Sagay-Bacolod national highway. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete sidewalk with inscriptions "NGW-50; 2007; NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8796117 A**
T.N.:	**2014-1064**

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

9905092014100502

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. NGW-51v

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

May 09, 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: **NEGROS OCCIDENTAL**
Station Name: **NGW-51**
Order: **2nd**

Island: **VISAYAS**
Municipality: **ESCALANTE**
Barangay: **HAD. FE**

PRS92 Coordinates

Latitude: **10º 51' 58.41454"** Longitude: **123º 28' 32.88028"** Ellipsoidal Hgt: **32.08900 m.**

WGS84 Coordinates

Latitude: **10º 51' 54.11167"** Longitude: **123º 28' 38.08213"** Ellipsoidal Hgt: **91.48900 m.**

PTM Coordinates

Northing: **1201574.19 m.** Easting: **552020.927 m.** Zone: **4**

UTM Coordinates

Northing: **1,201,153.62** Easting: **552,002.72** Zone: **51**

Location Description

Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete headwall with inscriptions "NGW-51; 2007; NAMRIA". The station is located SW of the Escalante-Bacolod national highway, on the NW tip of the headwall.

The station is about 110 m. from Vito wharf junction and about 3.9 km. from Escalante City proper.

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1065**

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

9 9 0 5 0 9 2 0 1 4 1 0 0 5 3 8

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

1. NW=123

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\NW-123.vce	Name:	UTM
Size:	752 KB	Datum:	PRS 92
Modified:	4/22/2016 8:06:07 PM (UTC:8)	Zone:	51 North (123E)
Time zone:	China Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NGW-50 --- NW-123 (B1)	NGW-50	NW-123	Fixed	0.021	0.057	315°55'13"	3789.388	13.992
NGW-50 --- NW-123 (B2)	NGW-50	NW-123	Fixed	0.019	0.064	315°55'14"	3789.385	14.045

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

NGW-50 - NW-123 (8:46:55 AM-2:12:55 PM) (S1)

Baseline observation:	NGW-50 --- NW-123 (B1)
Processed:	4/22/2016 8:33:29 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.021 m
Vertical precision:	0.057 m
RMS:	0.008 m
Maximum PDOP:	4.126
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/22/2016 8:46:55 AM (Local: UTC+8hr)
Processing stop time:	4/22/2016 2:12:55 PM (Local: UTC+8hr)
Processing duration:	05:26:00
Processing interval:	1 second

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	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
		LOVELY GRACIA ACUÑA	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVAR	UP-TCAGP
		ENGR. CHRISTOPHER JOAQUIN	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
		JONALYN GONZALES	UP-TCAGP
LiDAR Operation / Ground Survey	Research Associate (RA)	RENAN PUNTO	UP-TCAGP
		DAN ALDOVINO	UP-TCAGP
Ground Survey	Research Associate (RA)	LANCE CINCO	UP-TCAGP
		KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG LEEJAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG RAYMUND DOMINE	PAF
	Pilot	CAPT. JEFFREY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RANDY LAGCO	AAC
		CAPT. BRYAN DONGUINES	AAC
		CAPT. JERICO JECIEL	AAC

Annex 5. Data Transfer Sheet for Tanao Floodplain

DATA TRANSFER SHEET
5/19/2014(Bacolod Ready)

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	
4/29/2014	1403P	1BLK44DE119A	PEGASUS	2.89GB	2078KB	13.3	550	54.5	431	57.1	NA	7.14MB	1KB	1KB	92/75/52/56	NA	Z:\Airborne_Raw\1403P
5/1/2014	1411P	1BLK44D121A	PEGASUS	NA	88KB	10.9	221	31.5	264	26.5	NA	6.74MB	1KB	1KB	82/69/56	NA	Z:\Airborne_Raw\1411P
5/2/2014	1415P	1BLK44H122A	PEGASUS	3.27GB	2121KB	14.1	266	40.3	346	32.8	NA	7.32MB	1KB	1KB	37/38/46	NA	Z:\Airborne_Raw\1415P
5/5/2014	1427P	1BLK45E125A	PEGASUS	2.73GB	661KB	10.6	219	NA	NA	25.7	NA	6.12	1KB	1KB	30.9	NA	Z:\Airborne_Raw\1427P
5/6/2014	1431P	1BLK44GHS126A	PEGASUS	3.11	1612KB	13	254	51.3	370	29.2	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1431P
5/6/2014	1433P	1BLK44FGS126B	PEGASUS	3.04	1652	12.8	271	59	495	27.8	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1433P
5/7/2014	1435P	1BLK44DS127A	PEGASUS	2.94	712	14	285	NA	NA	19.6	NA	7.14	1KB	1KB	114	NA	Z:\Airborne_Raw\1435P
5/10/2014	1447P	1BLK45FG130A	PEGASUS	3.45	1382	14.4	294	NA	NA	32.3	NA	6.21	1KB	1KB	43	NA	Z:\Airborne_Raw\1447P
5/11/2014	1451P	1BLK45S132A	PEGASUS	2.42	500	11.5	243	NA	NA	27.2	NA	11.4	1KB	1KB	53	NA	Z:\Airborne_Raw\1451P
5/11/2014	1453P	1BLK45DFGS133A	PEGASUS	1.8	581	7.34	170	21.5	171	16.6	NA	11.4	1KB	1KB	49.3	NA	Z:\Airborne_Raw\1453P
5/12/2014	1455P	1IHLS134A	PEGASUS	3.05	530	13.2	298	NA	NA	26.3	NA	8.9	1KB	1KB	81/82/33/23	NA	Z:\Airborne_Raw\1455P
5/13/2014	1459P	1IHLS136A	PEGASUS	3.23	577	14.6	287	NA	NA	31.1	NA	7.18	1KB	1KB	88	NA	Z:\Airborne_Raw\1459P
5/14/2014	1463P	1IHLX137A	PEGASUS	782MB	249	5.69	148	NA	NA	8.26	NA	6.42	1KB	1KB	119	NA	Z:\Airborne_Raw\1463P

Received from

Name C - Jeronimo
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 5/26/2014

DATA TRANSFER SHEET
BACOLOD 5/18/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
April 22,2016	8453AC	3BLK44AS113A	AQUA/CASI	NA	343	769	246	NA	NA	13.9	101	99.1	1KB	1KB	6	14	Z:\DAC\RAW DATA
April 23,2016	8455AC	3BLK44AS114A	AQUA/CASI	NA	247	663	233	38.5	43	10.2	85.3	91	1KB	1KB	20	30	Z:\DAC\RAW DATA
April 24,2016	8457AC	3BLK44EDS115A	AQUA/CASI	NA	197	544	222	39.6	221	8.64	66.9	94	1KB	1KB	40	22	Z:\DAC\RAW DATA
April 25,2016	8459AC	3BLK44IJS116A	AQUA/CASI	NA	240	603	262	43.4	248	10.3	66.5	100	1KB	1KB	18	38	Z:\DAC\RAW DATA
April 26,2016	8462AC	3BLK46AS117B	AQUA/CASI	NA	194	502	229	37.4	187	8.59	67.4	107	1KB	1KB	8	20	Z:\DAC\RAW DATA
April 27,2016	8464AC	3BLK46AS118B	AQUA/CASI	NA	81	209	143	9.78	3.23	4	23.9	158	1KB	1KB	8	20	Z:\DAC\RAW DATA
May 1,2016	8471AC	3BLK44FGHS122A	AQUA/CASI	NA	191	541	241	45.3	263	8.33	139	90.5	1KB	1KB	10	22	Z:\DAC\RAW DATA
May 2,2016	8473AC	3BLK46AS123A	AQUA/CASI	NA	88	320	206	5.45	3.7	4.59	55.3	64.6	1KB	NA	16	22	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 5/20/16

Annex 6. Flight logs for the flight missions

1. Flight Log for 1403P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1403P

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK49DE119A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Dongoires	9 Route: Bacolod			
10 Date: April 29, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 0738H	14 Engine Off: 1213H	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Data acquired but with voids due to clouds; changed plan several times to lower altitude					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	David Bhmban	JJ Alajar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

2. Flight Log for 1411P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1411P

1 LiDAR Operator: D. Aldovino	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44D121A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: May 1, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1505 H	14 Engine Off: 1852 H	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

Mission successful at 1200 m ; surveyed BLK 44D and parts of BLK 44E

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alajar	Dave Gumban	J J Alajar	Dan Aldovino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1415P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1415P

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44H124A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: May 2, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1446H	14 Engine Off: 1909H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

Mission successful at 1200m; surveyed BLK 44H; gap in the middle

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

4. Flight Log for 1431P Mission

DREAM Data Acquisition Flight Log | **Flight Log No.:** 1431P

1 LiDAR Operator: D. ALDOVINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK44GH46A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCC.			
10 Date: MAY 6, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 8+10	14 Engine Off: 12+51	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	very cloudy				
20 Remarks:	Mission successful @ 800 m; filled gaps in BLK44H + BLK44G				

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Bumban	J. ALAJAR	DAN ALDOVINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight log for 1433P Mission

DREAM Data Acquisition Flight Log | **Flight Log No.: 1433P**

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK44B126A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCC.			
10 Date: MAY 6, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 14+4	14 Engine Off: 18+33	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					
20 Remarks: Mission successful @ 800 m; gaps due to diminished overlap, high terrain. low cloud ceiling					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alvior	Dave Gabalan	J. ALAJAR	RENAN PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 1435P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1435P

1 LiDAR Operator: D. Alcovindo	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44PS129A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. Alajar	8 Co-Pilot: B. Dolomines	9 Route: Negros Occidental			
10 Date: May 7, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 13+7	14 Engine Off: 18+0	15 Total Engine Time: 4+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					
20 Remarks: Mission successful in BLK44D @ 1200m + filled up gaps in BLK44 @ 800m					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Bunban	J. Alajar	Dan Alcovindo
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

7. Flight log for 8453AC Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8453

1 LiDAR Operator: JW Tong	2 ALTM Model: Aqua 1CAS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Laujo	8 Co-Pilot: Jeciel	9 Route:			
10 Date: April 22, 2016	12 Airport of Departure (Airport, City/Province): Baguio		12 Airport of Arrival (Airport, City/Province): Baguio		
13 Engine On: 9:40	14 Engine Off: 13:51	15 Total Engine Time: 4+11	16 Take off: 9:45	17 Landing: 13:46	18 Total Flight Time: 4+01
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered parts of BLK44AS

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

Acquisition Flight Approved by: CHRIS [illegible] — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: LEE JAY E. PUNZALAN — Signature over Printed Name (PAF Representative)

Pilot-in-Command: [illegible] — Signature over Printed Name

Lidar Operator: [illegible] E. [illegible] — Signature over Printed Name

Aircraft Mechanic/ Technician: — Signature over Printed Name

8. Flight log for 8455AC Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8455

1 LiDAR Operator: J. Gamalao	2 ALTM Model: Aqua 1CAS	3 Mission Name: 3BLK44AKLYA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Layco	8 Co-Pilot: Pucal	9 Route:			
10 Date: April 23, 2016	12 Airport of Departure (Airport, City/Province): Bacolod-Silay		12 Airport of Arrival (Airport, City/Province): Bacolod-Silay		
13 Engine On: 1020	14 Engine Off: 1410	15 Total Engine Time: 3+53	16 Take off: 1025	17 Landing: 1408	18 Total Flight Time: 3+43
19 Weather: fair					

20 Flight Classification

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

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

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

21 Remarks

Completed BLK 44A and some voids

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[signature]	LEE JAY A. PUNZALAN		[signature]	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

9. Flight log for 8457AC Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8457

1 LiDAR Operator: Tonga, MV	2 ALTM Model: Aqua 4CA1	3 Mission Name: 3BLK44V115A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Lagyo	8 Co-Pilot: Jedel	9 Route:			
10 Date: April 24, 2014	12 Airport of Departure (Airport, City/Province): Buulud - Silay		12 Airport of Arrival (Airport, City/Province): Buulud - Silay		
13 Engine On: 1002	14 Engine Off: 1359	15 Total Engine Time: 3+53	16 Take off: 1007	17 Landing: 1350	18 Total Flight Time: 3+43
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed voids over BLK 44

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[signature]	LEE JAY PUNZALAN	[signature]	[signature]	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

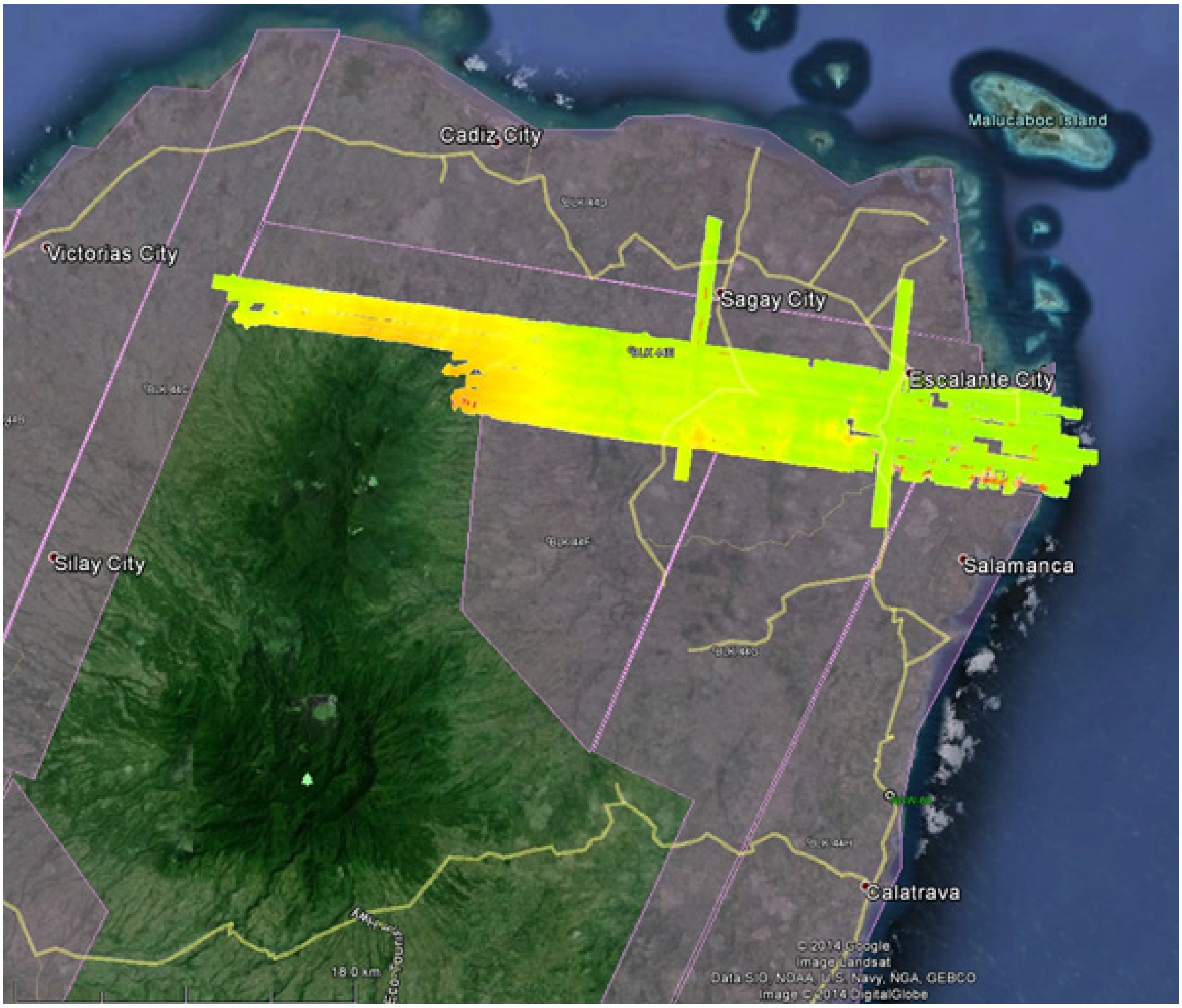
Annex 7. Flight Status Reports

NEGROS OCCIDENTAL
(April 29 to May 7, 2014 and April 22 to 24, 2016)

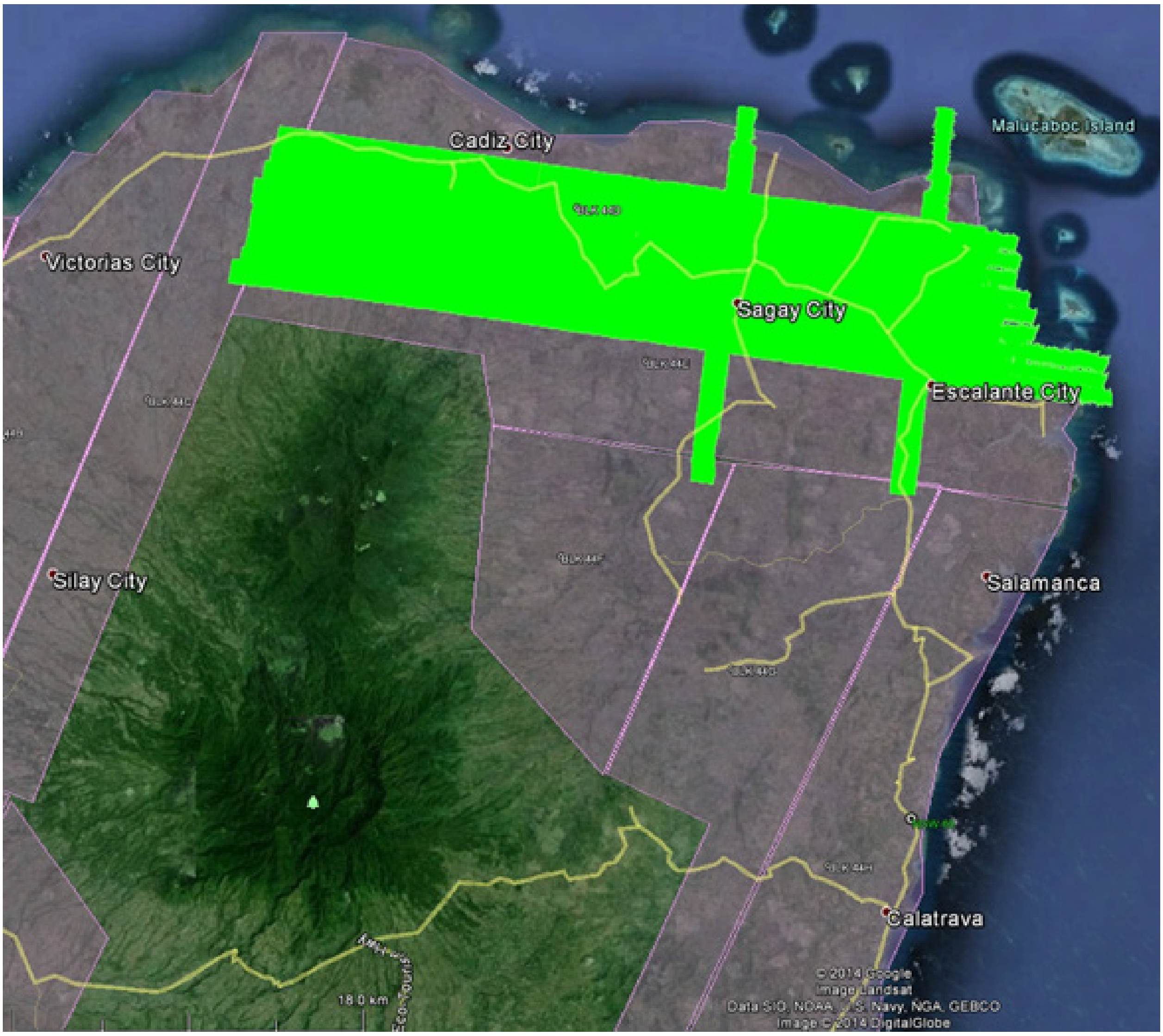
FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1403P	BLK44D & E	1BLK44DE119A	R. PUNTO	29 April 2014	Data acquired but with voids due to clouds; changed plan several times to lower altitude
1411P	BLK 44DE	1BLK44D121A	D. ALDOVINO	1 May 2014	Mission successful at 1200m; surveyed BLK 44D and parts of BLK 44E
1415P	BLK44H	1BLK44H122A	R. PUNTO	2 May 2014	Mission successful at 1200m; 2-3 lines gap in the middle
1431P	BLK 44G, BLK 44H, BLK 44F	1BLK44GHS126A	D. ALDOVINO	6 May 2014	Mission successful at 800m; filled gaps in BLK 44H and BLK 44G and some parts of BLK 44F
1433P	BLK 44 F	1BLK44F126B	R. PUNTO	6 May 2014	Mission successful at 800m; gaps due to diminished overlap, high terrain, low cloud ceiling
1435P	BLK44D	1BLK44DS127A	D. ALDOVINO	7 May 2014	Mission successful in BLK 44D at 1200m and filled up gaps in BLK 44 at 800m.
8453AC	BLK44As Danao, Himogaan FP	3BLK44As113A	V. TONGA	22 APR 2016	SURVEYED PARTS OF BLK44AS
8455AC	BLK44As Danao, Himogaan FP	3BLK44As114A	J. GONZALES	23 APR 2016	SURVEYED REST OF BLK44AS
8457AC	BLK44ES, BLK44DS	3BLK44EDs115A	V. TONGA	24 APR 2016	SURVEYED BLKES AND BLK44DS

SWATH PER FLIGHT MISSION

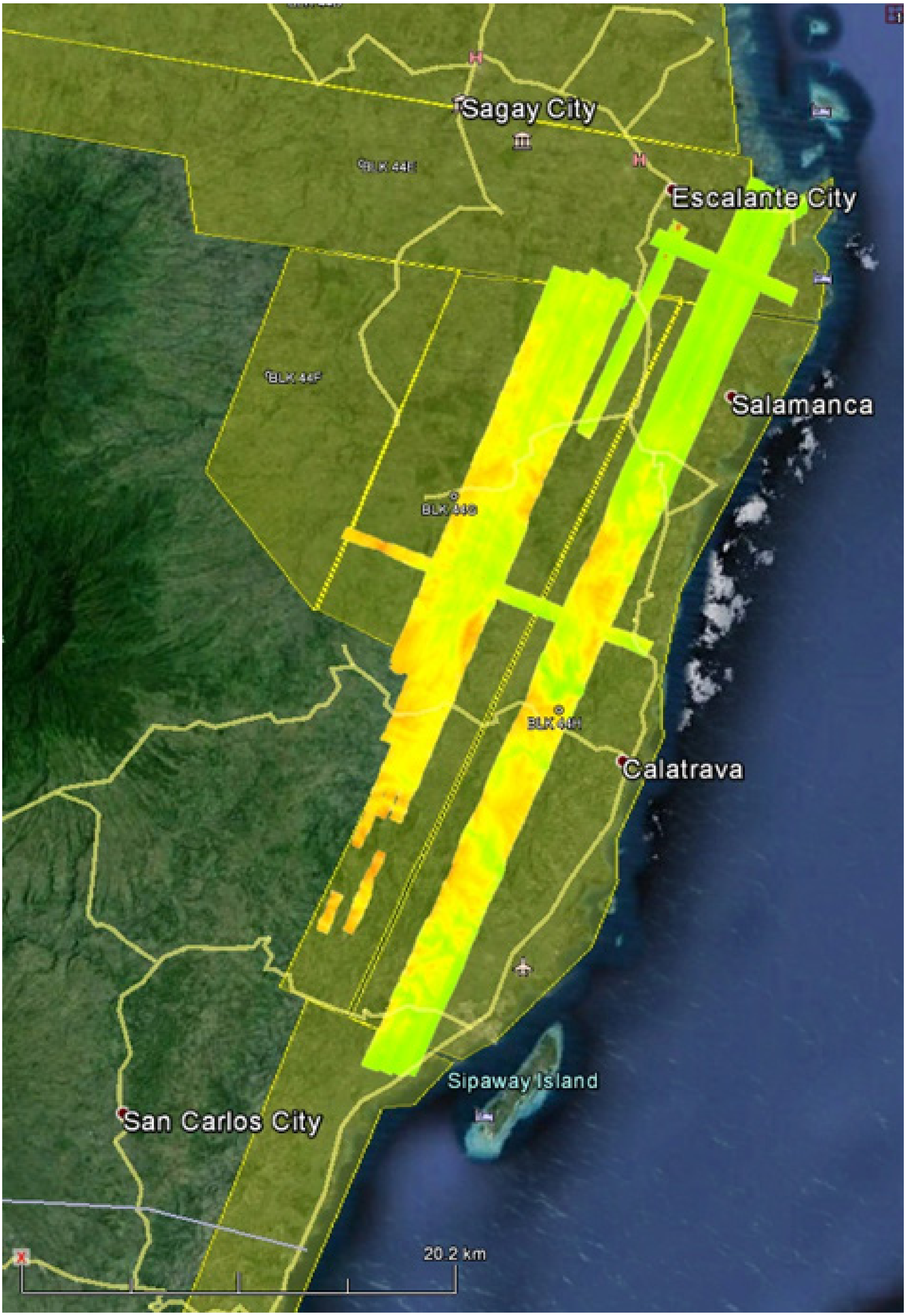
Flight No. :	1403P
Area:	BLK 44E
Mission Name:	1BLK44DE119A
Area Surveyed:	213.78 sq.km.



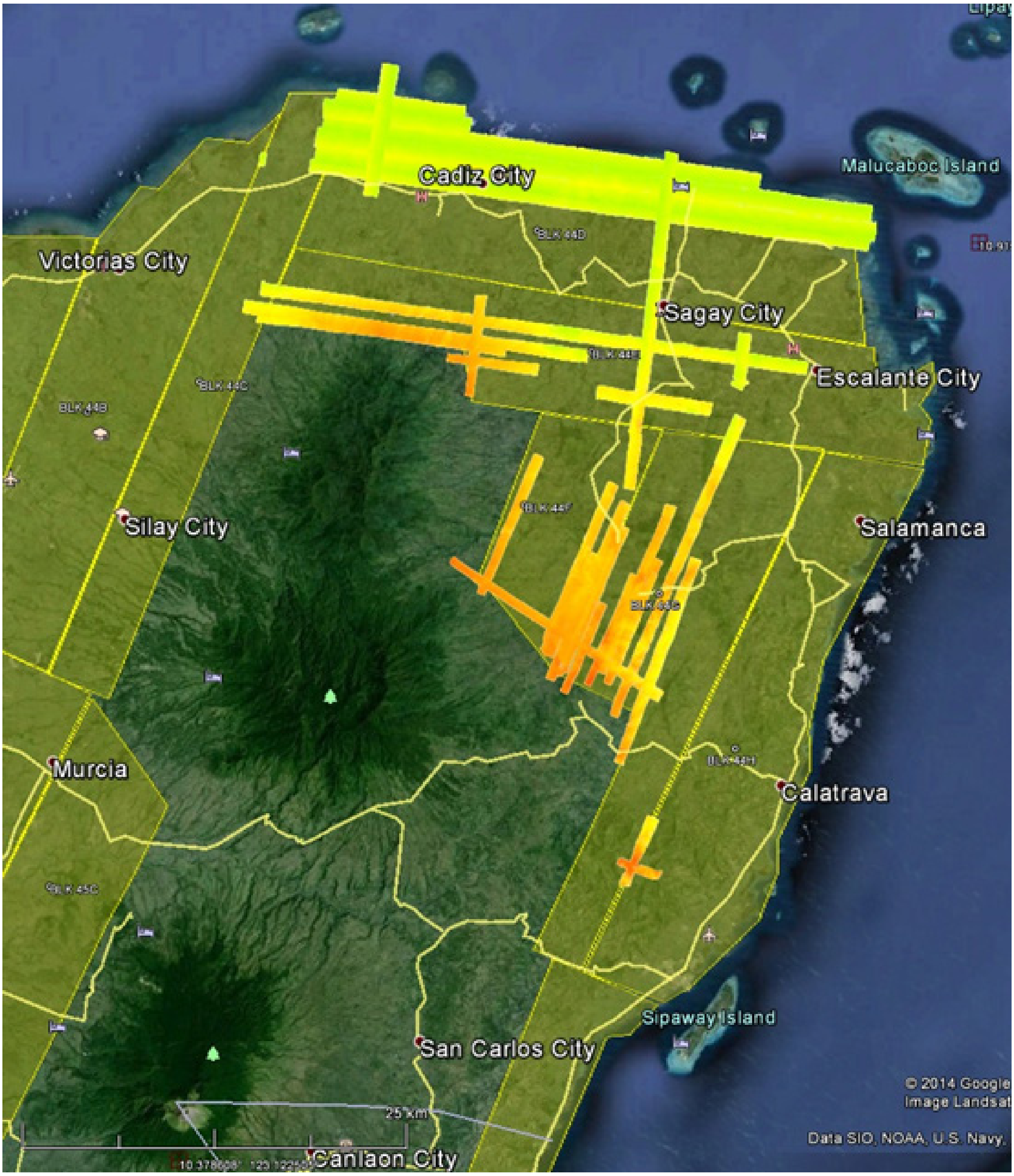
Flight No. :	1411P
Area:	BLK 44DE
Mission Name:	1BLK44D121A
Area Surveyed:	356.01 sq.km.



Flight No. : 1431P
Area: BLK 44G, 44H, 44F
Mission Name: 1BLK44GHS126A
Area Surveyed: 230.5 sq.km



Flight No. : 1435P
Area: BLK 44D, 44E, 44F, 44G
Mission Name: 1BLK44DS127A
Area Surveyed: 139.55 sq.km new area; 131.307 gap filling



Flight No. :	8453AC
Area:	BLK44AS
Mission Name:	3BLK44As113A
Parameters:	PRF 50 SF 45 SCAN ANGLE 18
Flying Height:	500 M

Flight No. :	8455AC
Area:	BLK44AS
Mission Name:	3BLK44AS114A
Parameters:	PRF 50 SF 45 SCAN ANGLE 18
Flying height:	500M

Flight No. :	8457AC
Area:	BLK44ES, BLK44DS
Mission Name:	3BLK44EDs115A
Parameters:	PRF 50 SF 45 SCAN ANGLE 18
Flying Height:	500 M

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk44D

Flight Area	Samar-Leyte
Mission Name	Blk44D
Inclusive Flights	1411P, 1435P
Range data size	75.2 GB
POS	728 MB
Image	31.5 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.26
RMSE for Down Position (<8.0 cm)	2.51
Boresight correction stdev (<0.001deg)	0.000446
IMU attitude correction stdev (<0.001deg)	0.005774
GPS position stdev (<0.01m)	0.0134
Minimum % overlap (>25)	27.44%
Ave point cloud density per sq.m. (>2.0)	3.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	552
Maximum Height	395.70 m
Minimum Height	50.84 m
Classification (# of points)	
Ground	387,844,370
Low vegetation	324,638,606
Medium vegetation	458,253,579
High vegetation	120,361,293
Building	9,453,151
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

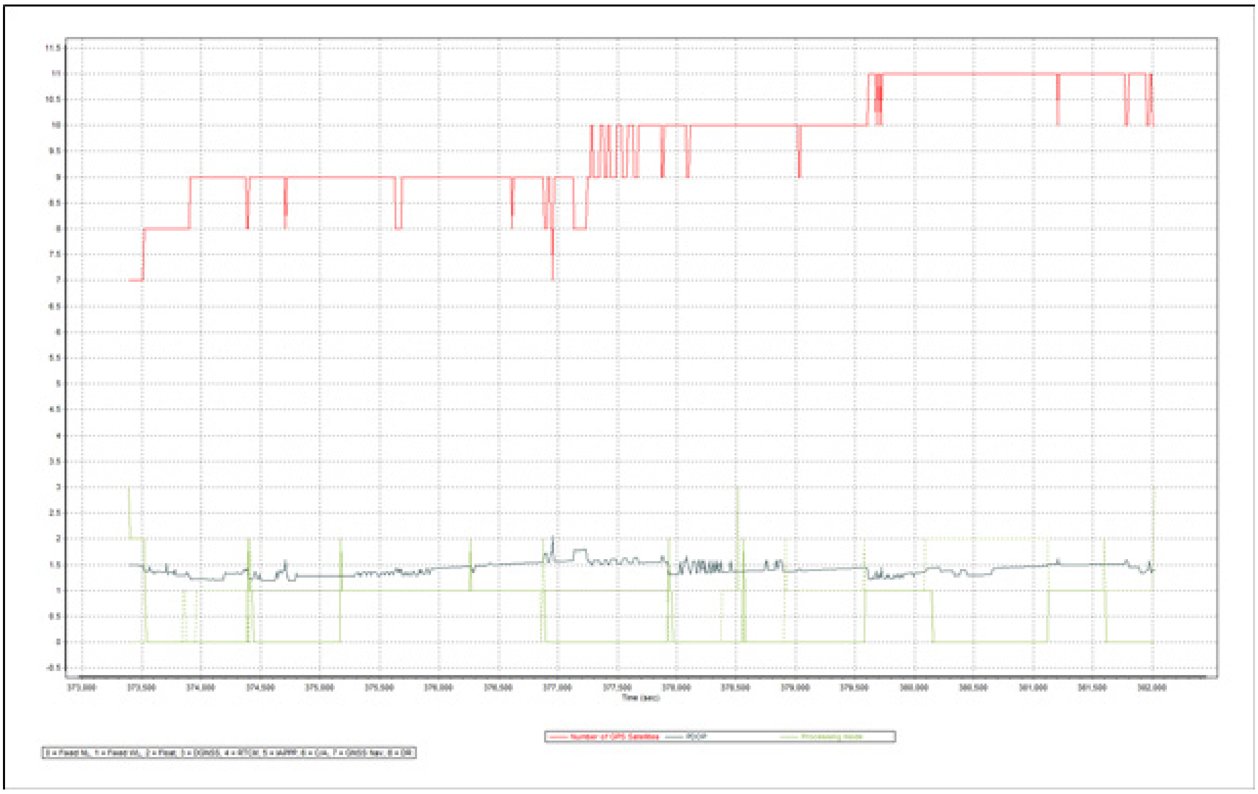


Figure A-8.1 Solution Status

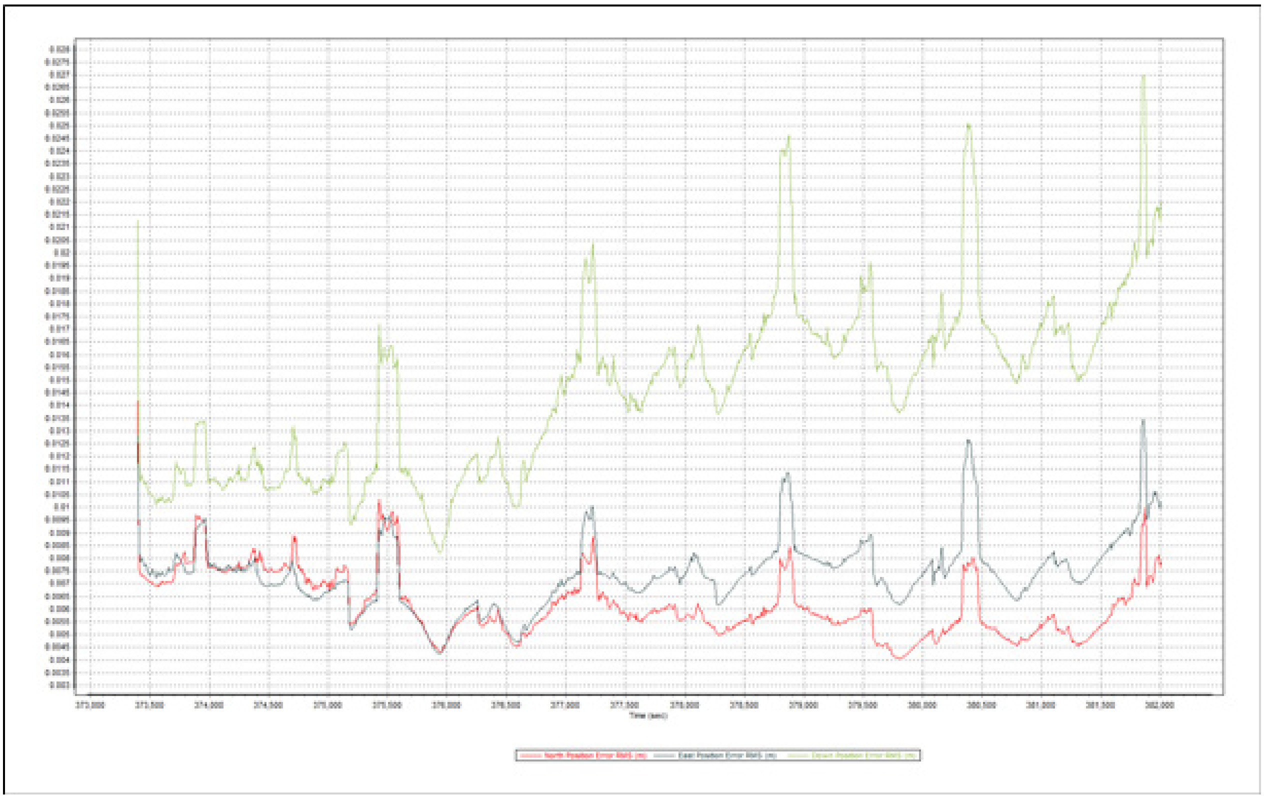


Figure A-8.2 Smoothed Performance Metric Parameters

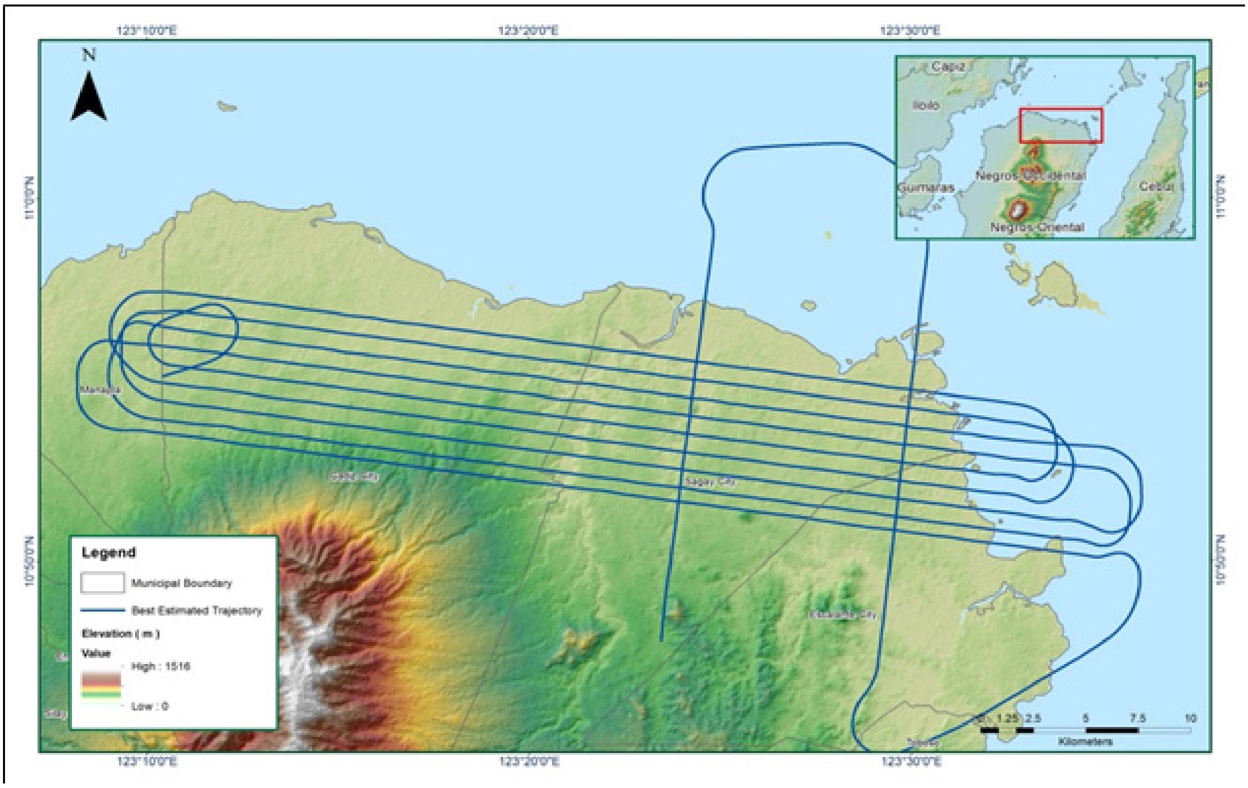


Figure A-8.3 Best Estimated Trajectory

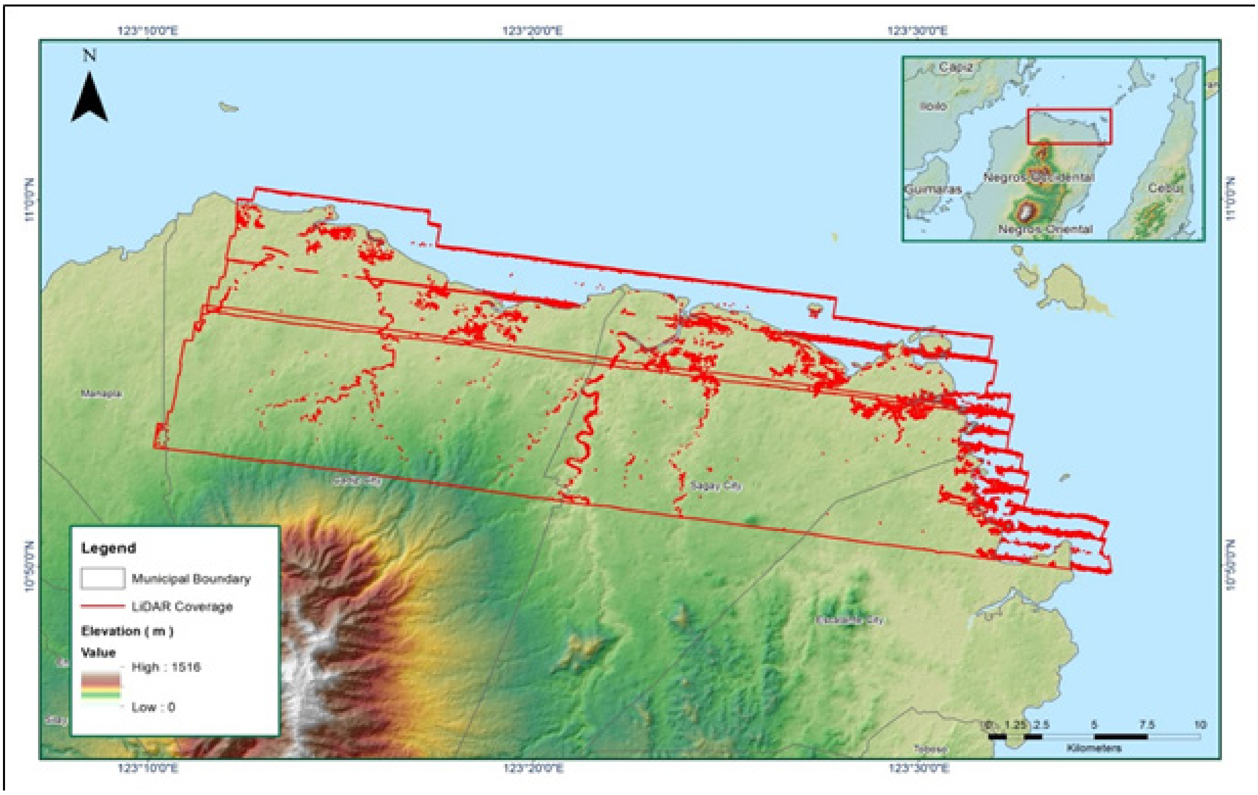


Figure A-8.4 Coverage of LiDAR data

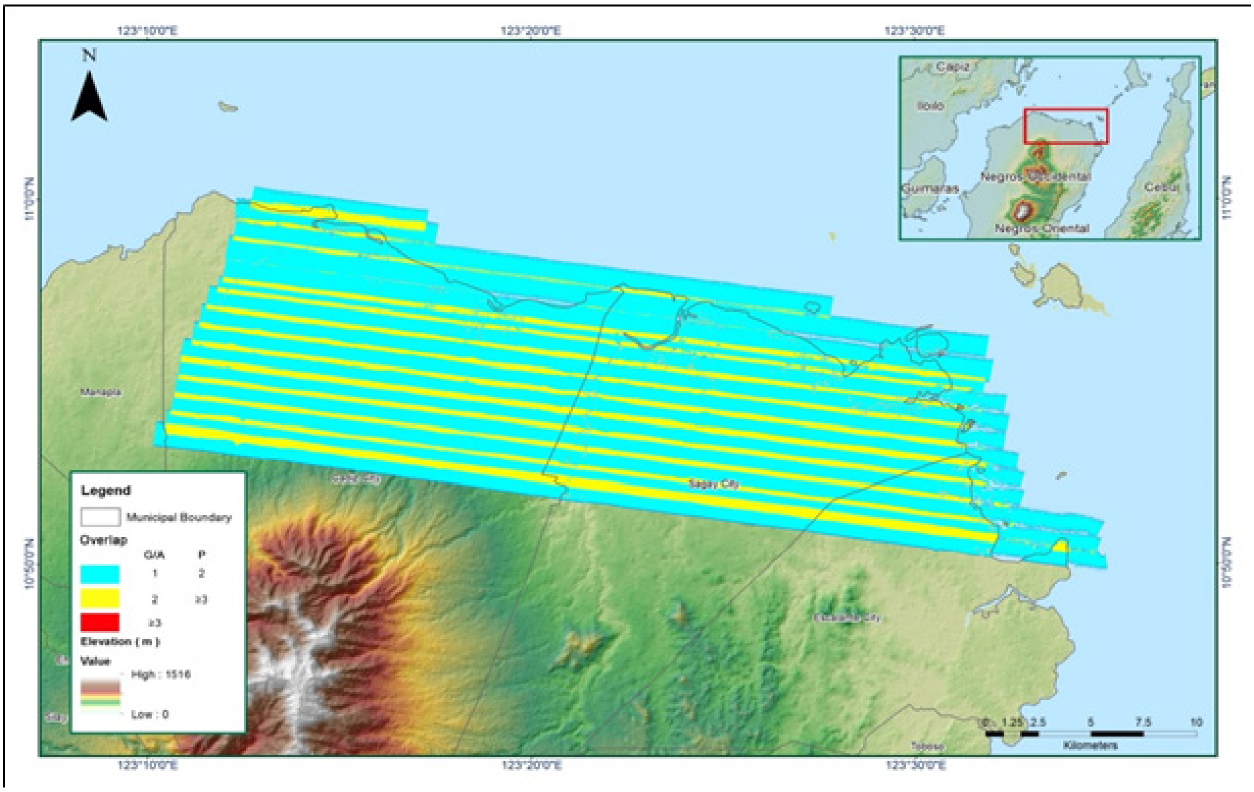


Figure A-8.5 Image of Data Overlap

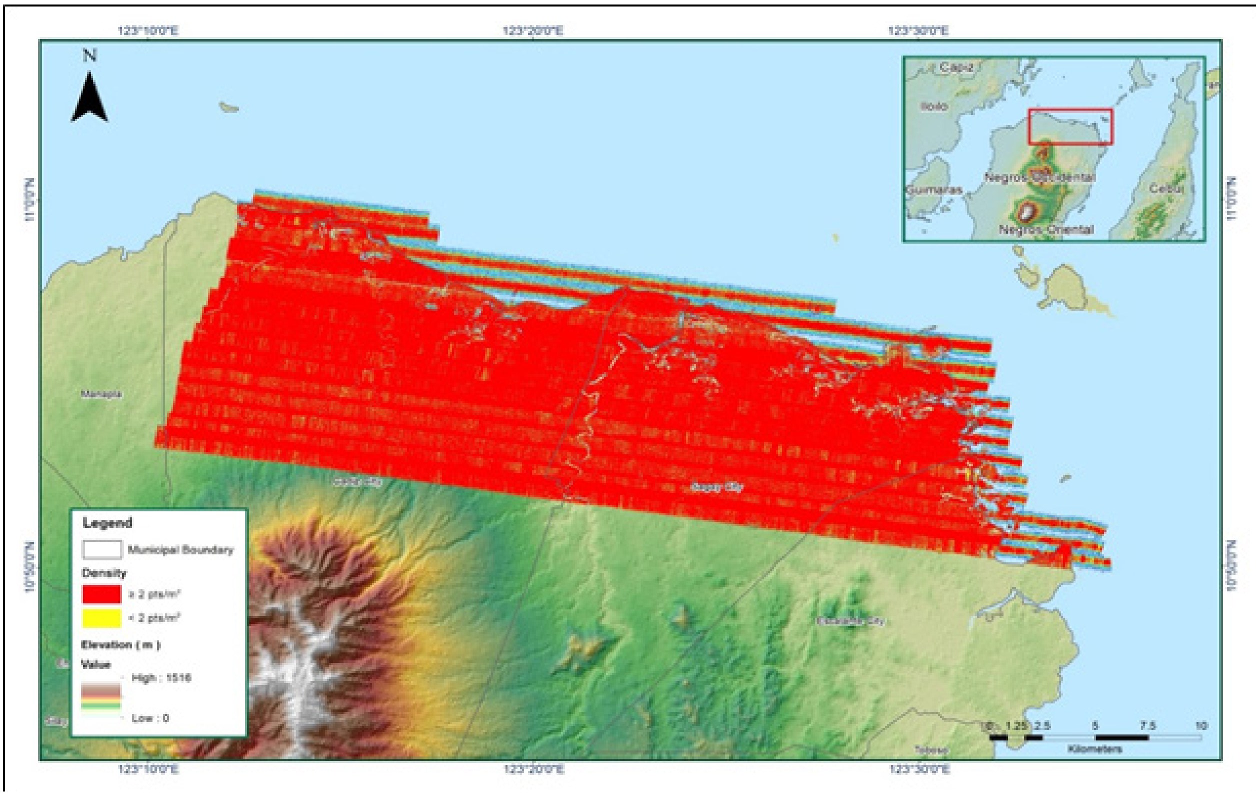


Figure A-8.6 Density map of merged LiDAR data

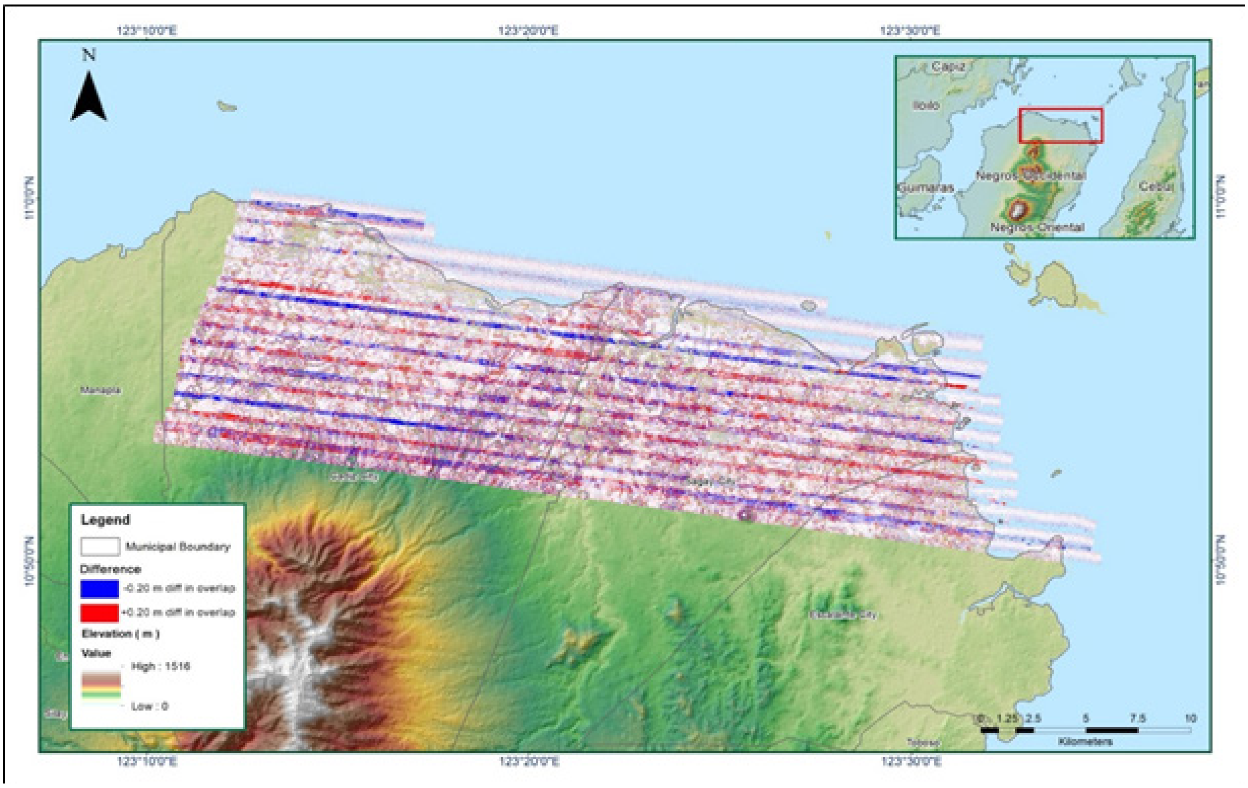


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk44FG

Flight Area	Samar-Leyte
Mission Name	Blk44FG
Inclusive Flights	1431P, 1433P, 1435P
Range data size	105.7 GB
POS	810 MB
Image	110.3 GB
Transfer date	May 26, 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)	1.24
RMSE for East Position (<4.0 cm)	1.41
RMSE for Down Position (<8.0 cm)	2.62
Boresight correction stdev (<0.001deg)	0.000248
IMU attitude correction stdev (<0.001deg)	0.001112
GPS position stdev (<0.01m)	0.0062
Minimum % overlap (>25)	43.01%
Ave point cloud density per sq.m. (>2.0)	9.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	347
Maximum Height	584.11 m
Minimum Height	72.76 m
Classification (# of points)	
Ground	445,025,694
Low vegetation	463,475,098
Medium vegetation	838,129,177
High vegetation	234,468,284
Building	6,471,602
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

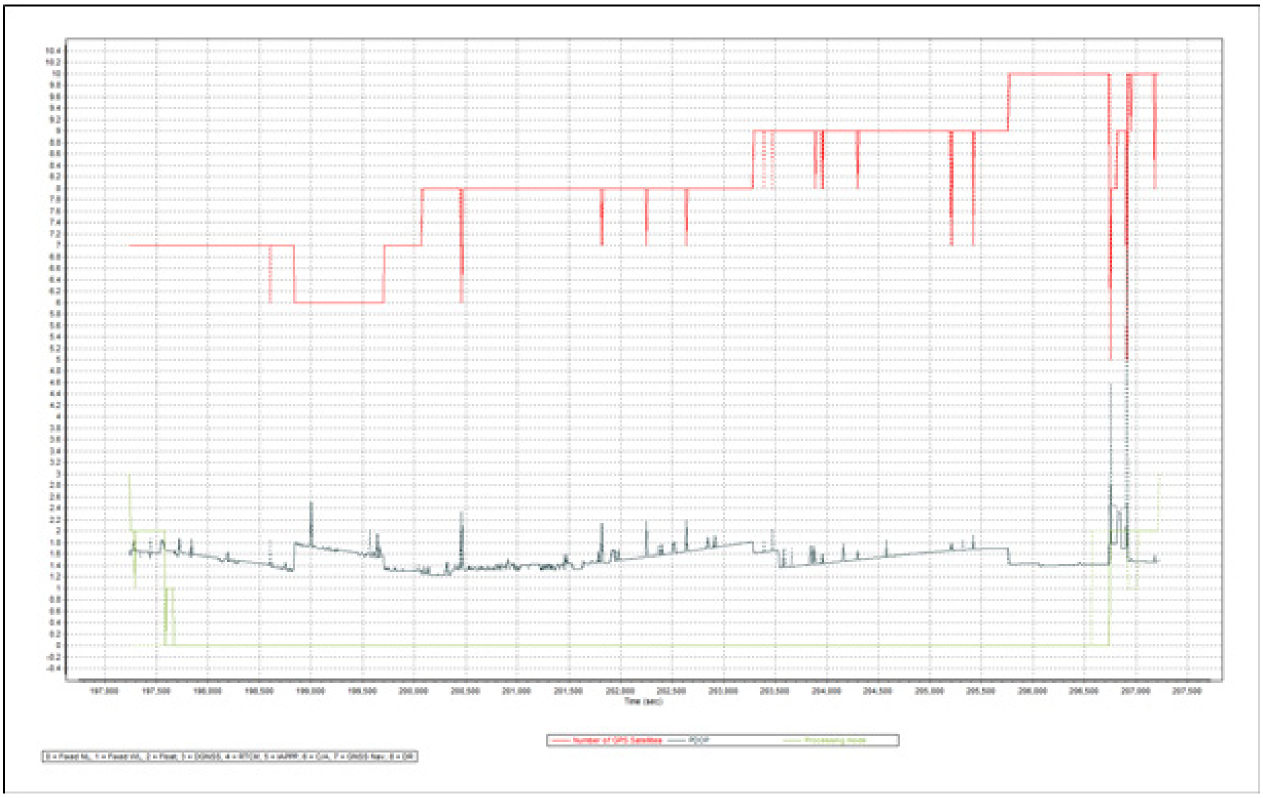


Figure A-8.8 Solution Status Parameters

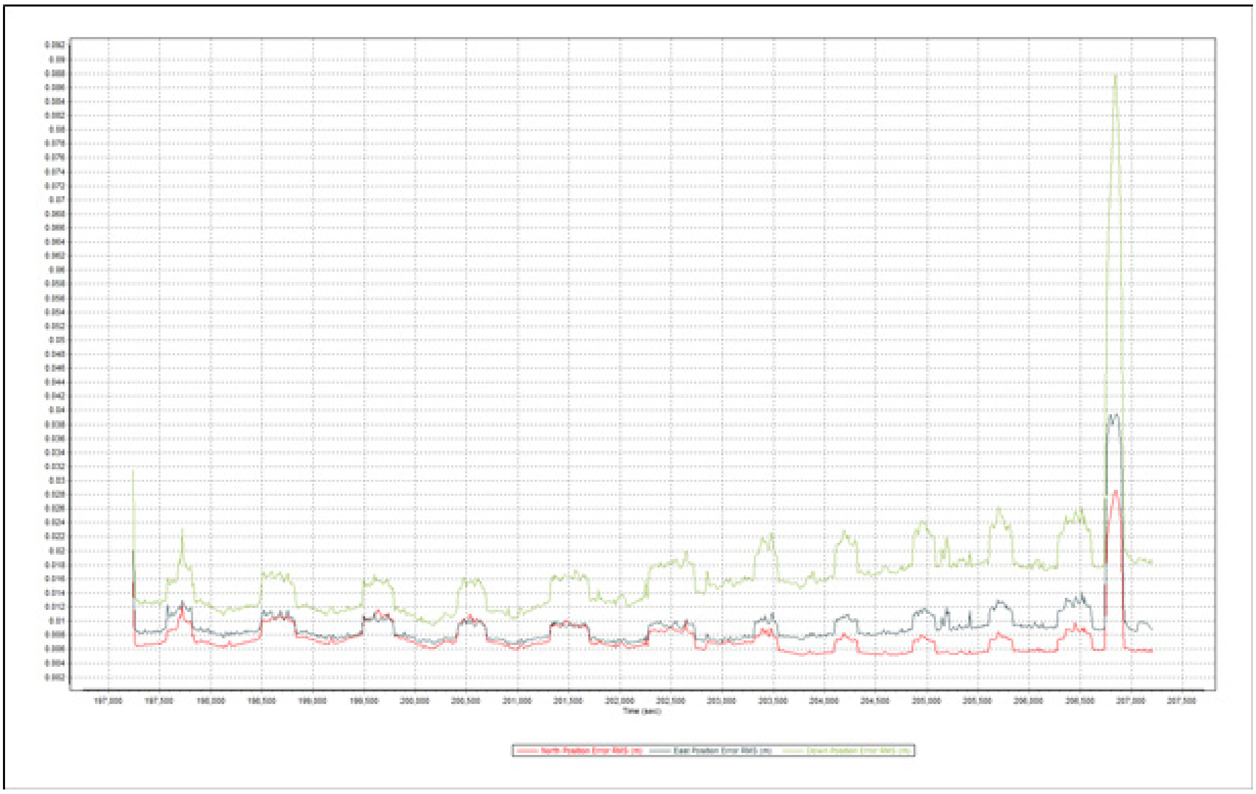


Figure A-8.9 Smoothed Performance Metrics Parameters

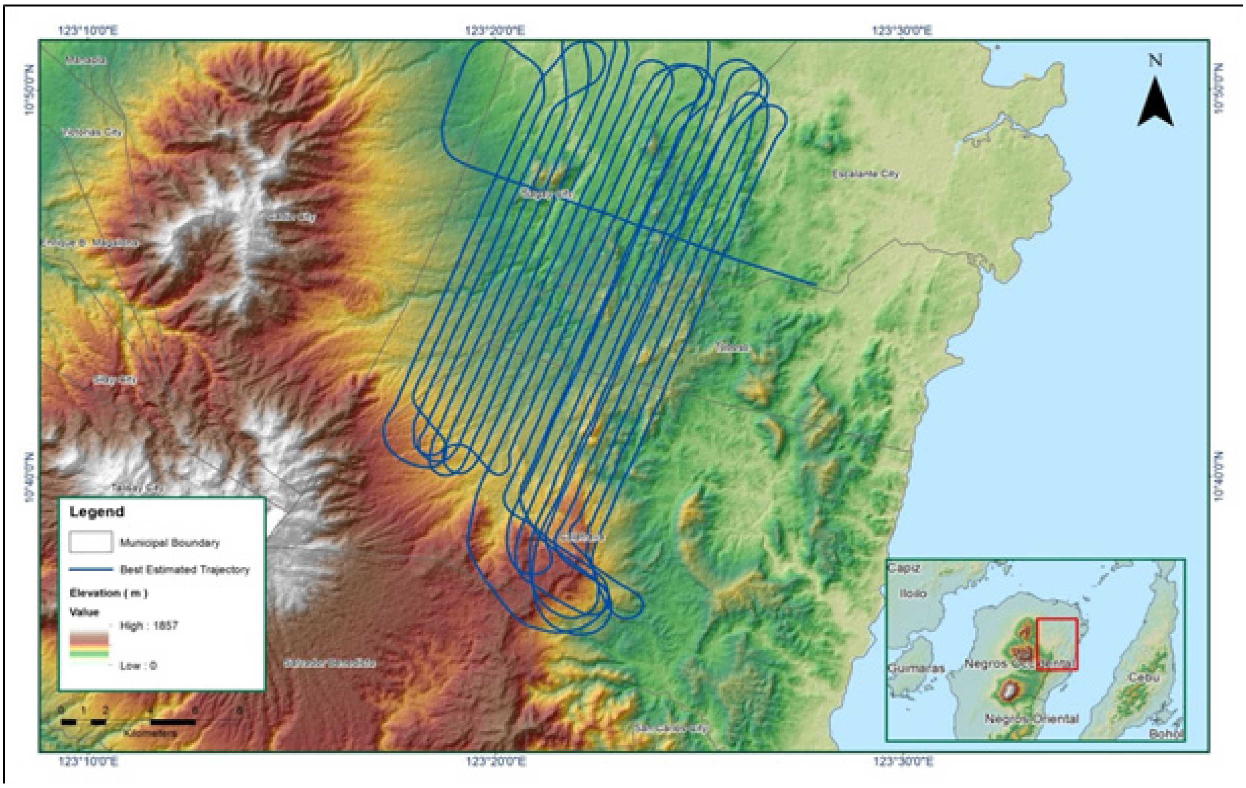


Figure A-8.10 Best Estimated Trajectory

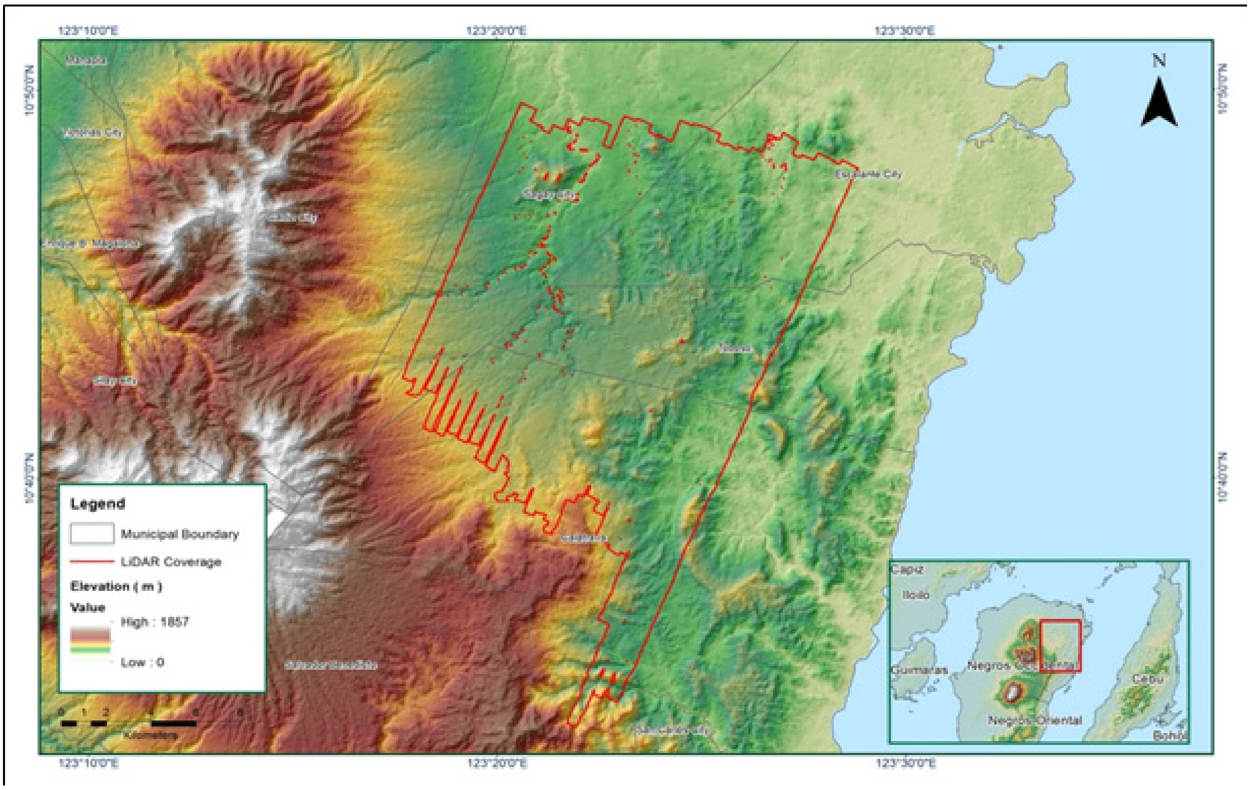


Figure A-8.11 Coverage of LiDAR data

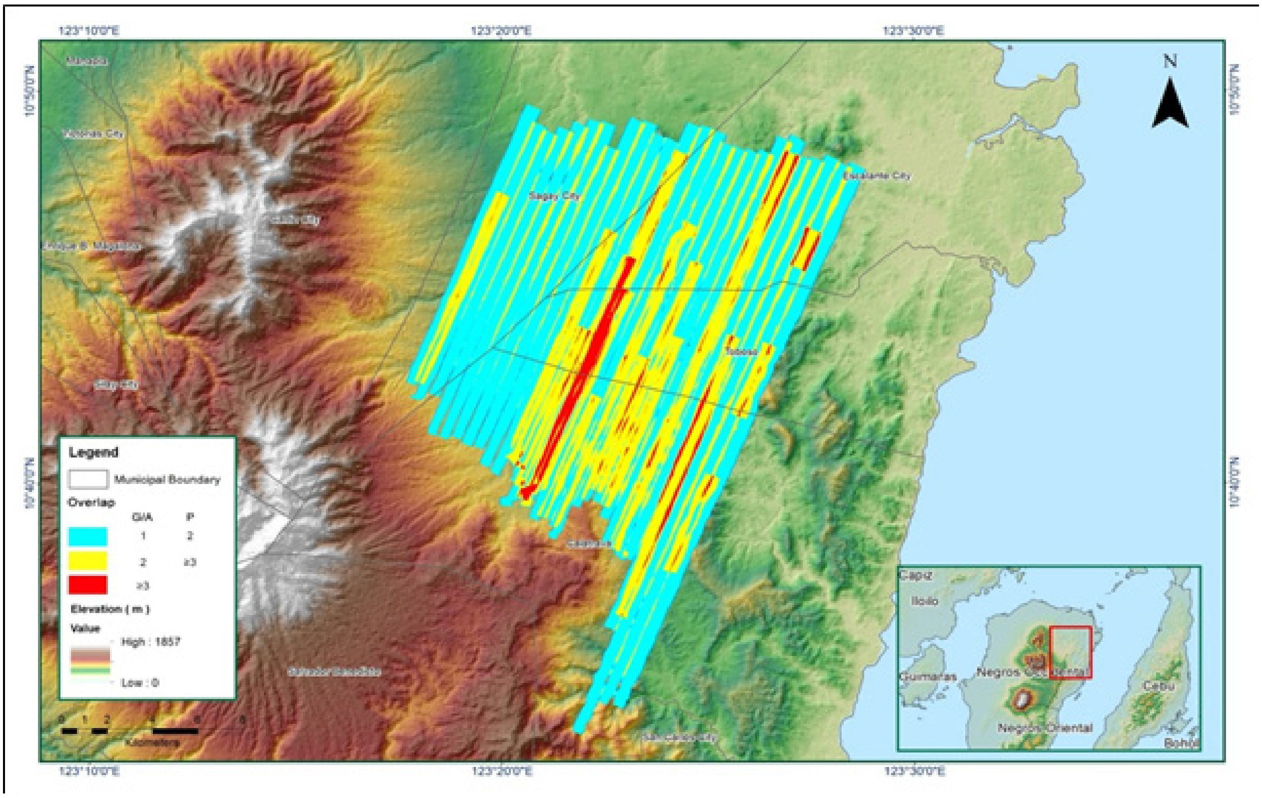


Figure A-8.12 Image of Data Overlap

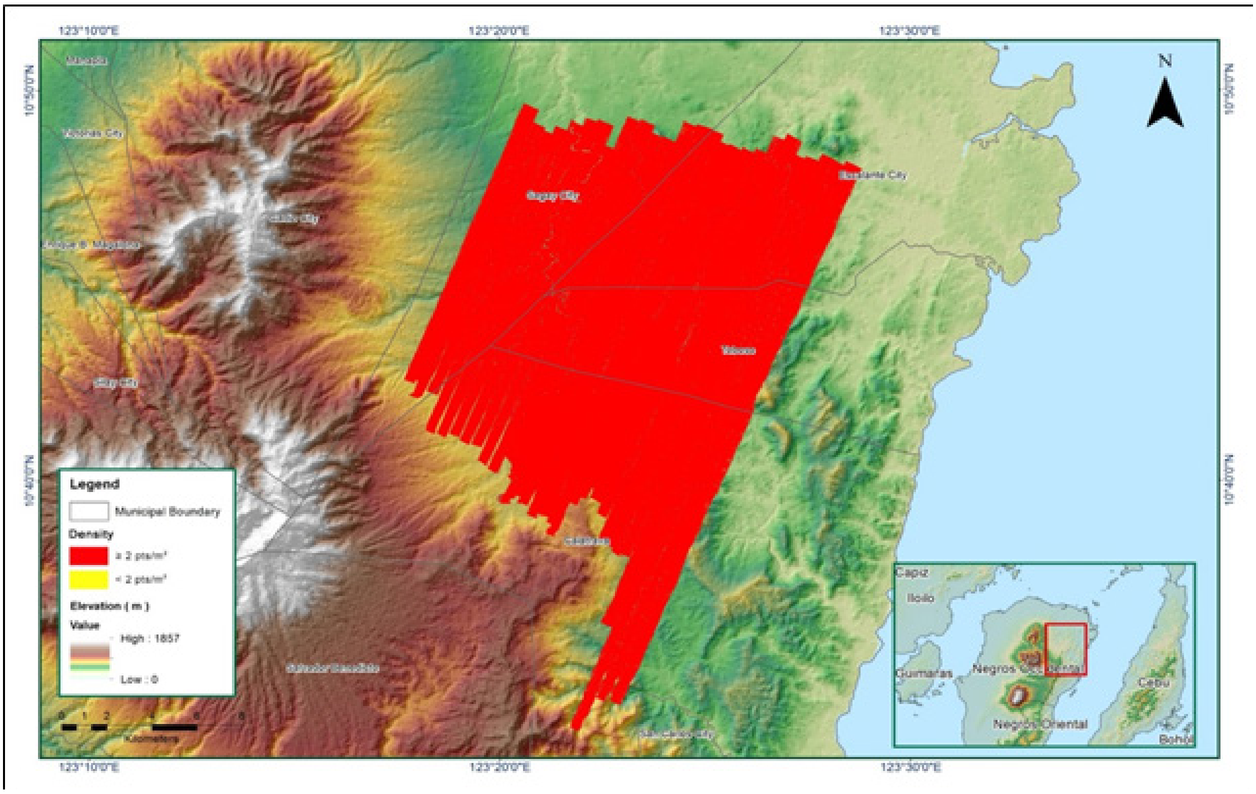


Figure A-8.13 Density map of merged LiDAR data

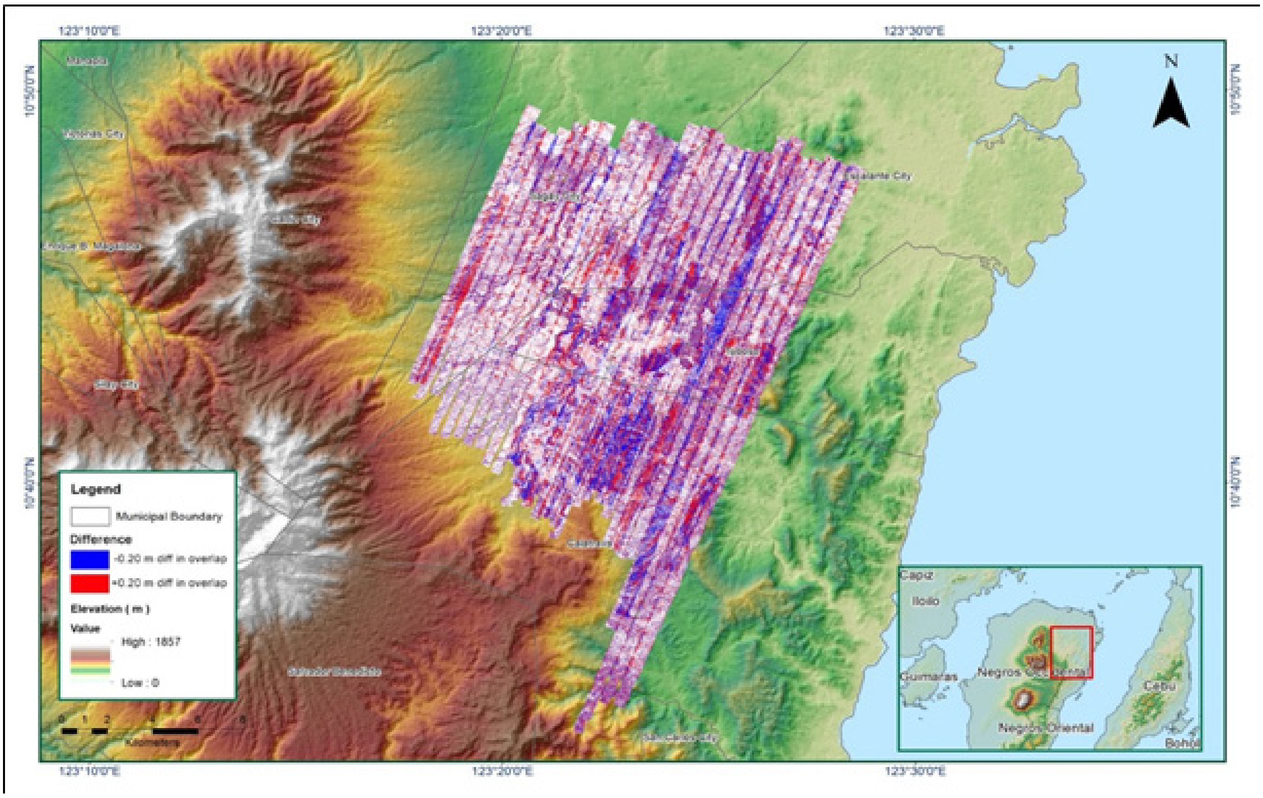


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Block 44E

Flight Area	Leyte
Mission Name	Block 44E
Inclusive Flights	8453AC
Range data size	13.9 GB
POS data size	246 MB
Base data size	99.1
Image	n/a
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.002
RMSE for East Position (<4.0 cm)	1.603
RMSE for Down Position (<8.0 cm)	5.037
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000791
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	30.04
Ave point cloud density per sq.m. (>2.0)	3.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	139
Maximum Height	578.38
Minimum Height	60.03
Classification (# of points)	
Ground	93,527,454
Low vegetation	98,324,857
Medium vegetation	111,788,117
High vegetation	66,668,017
Building	3,363,991
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Engr. Elainne Lopez, Engr. Merven Matthew Natino

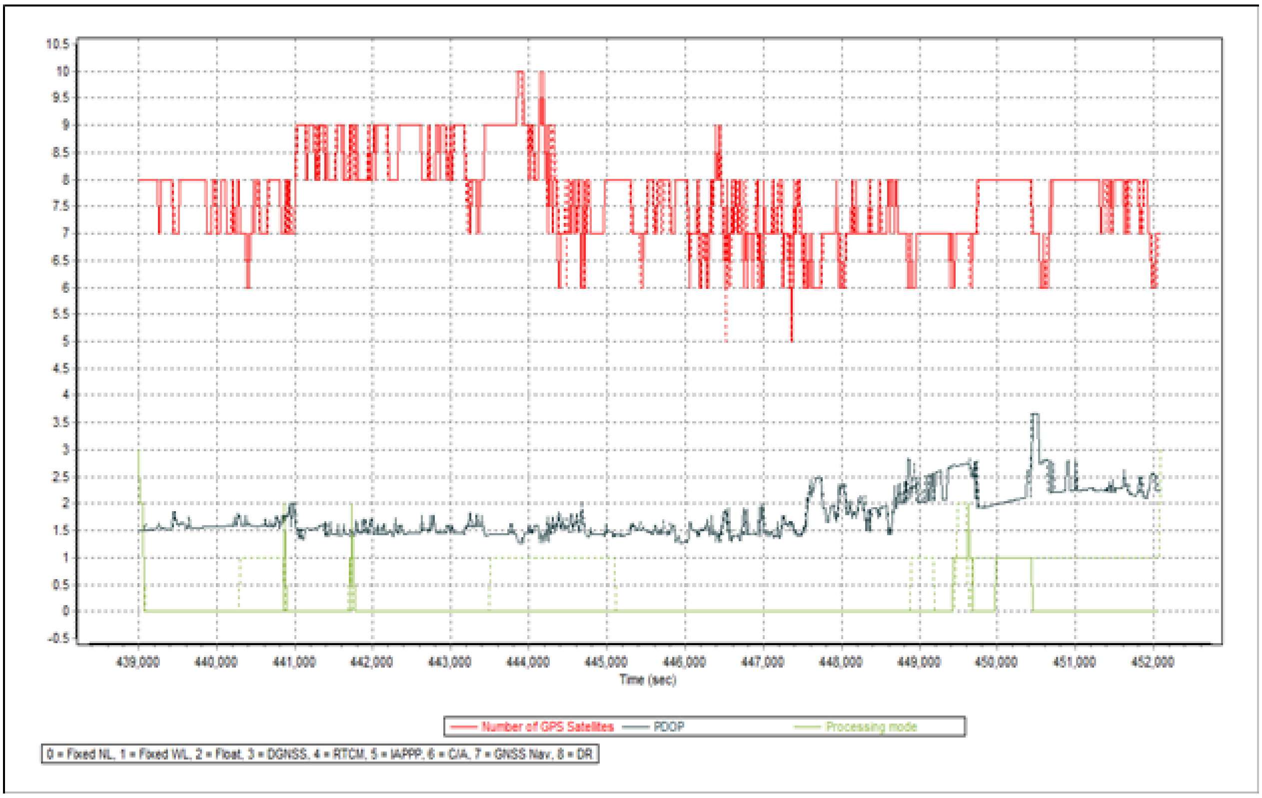


Figure A-8.15 Solution Status

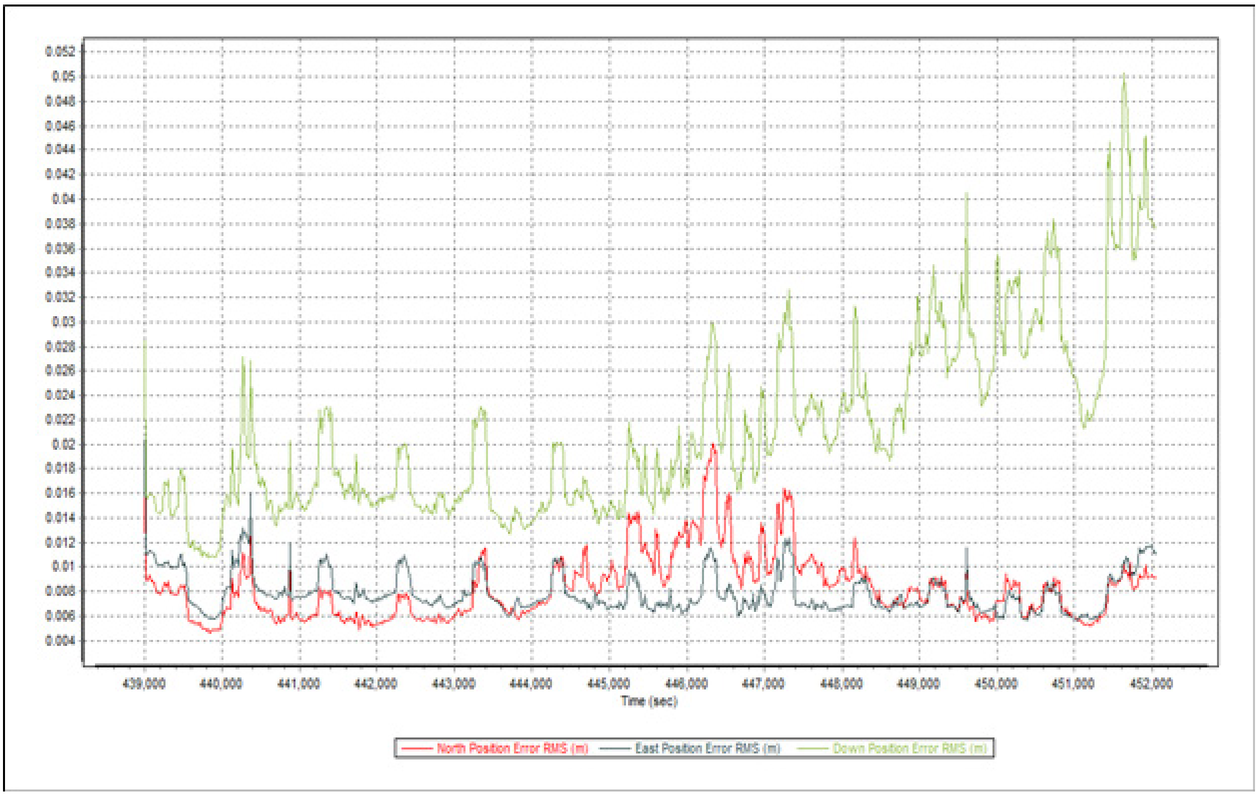


Figure A-8.16 Smoothed Performance Metric Parameters

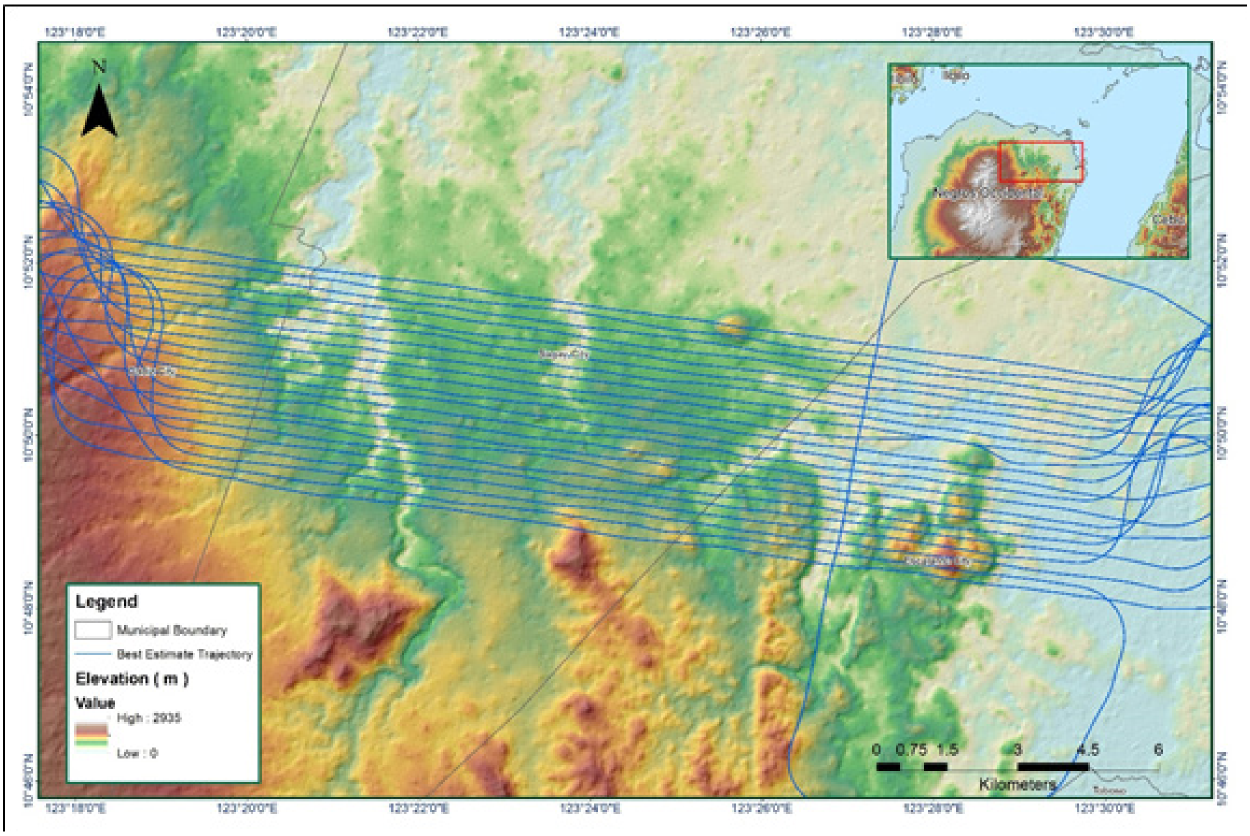


Figure A-8.17 Best Estimated Trajectory

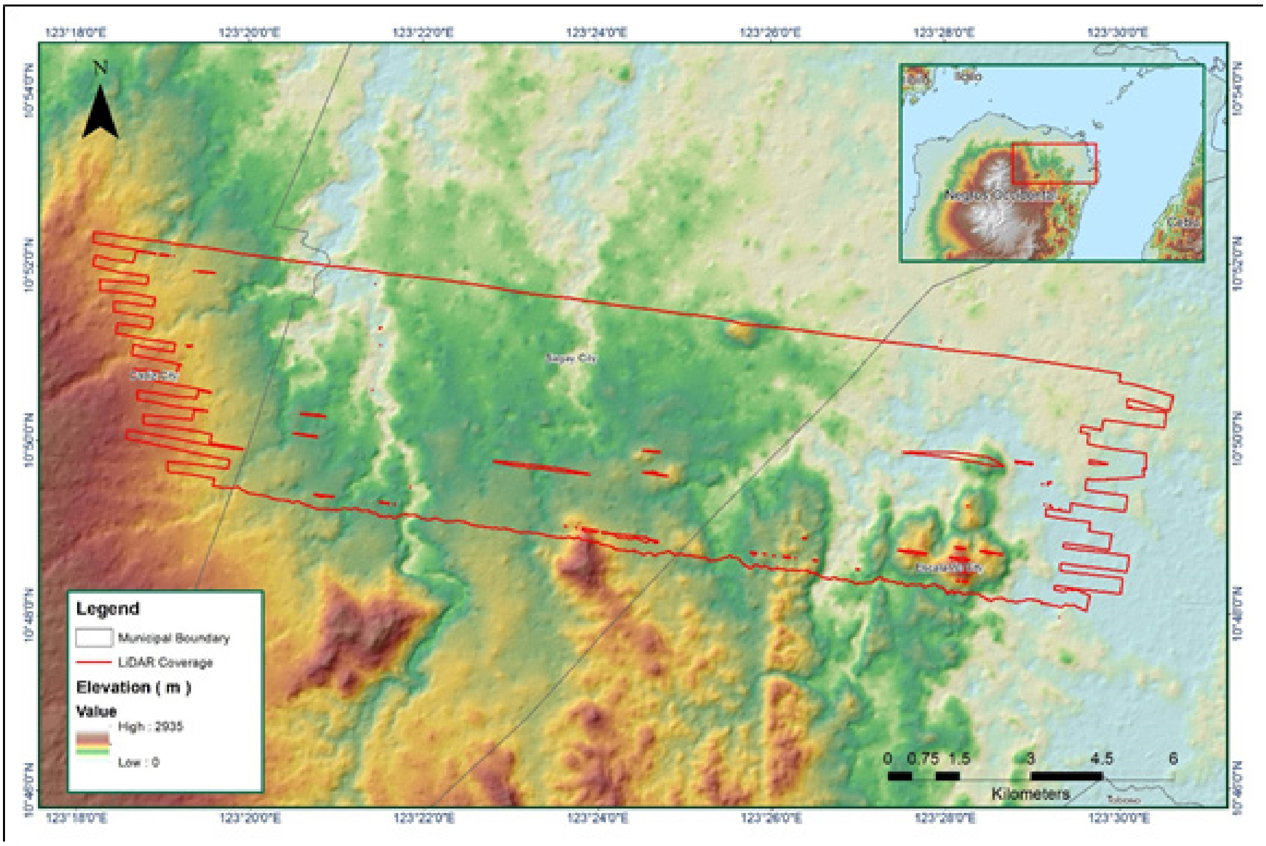


Figure A-8.18 Coverage of LiDAR data

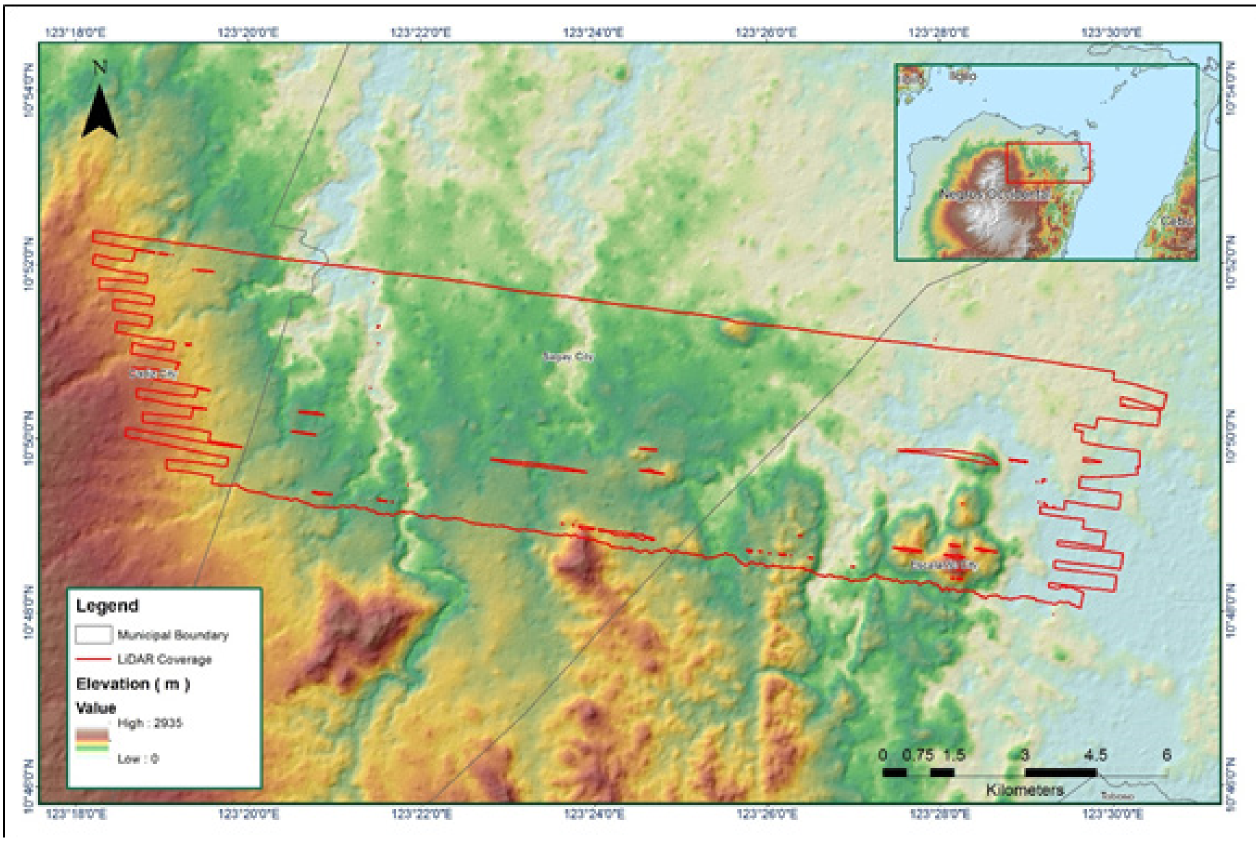


Figure A-8.19 Image of Data Overlap

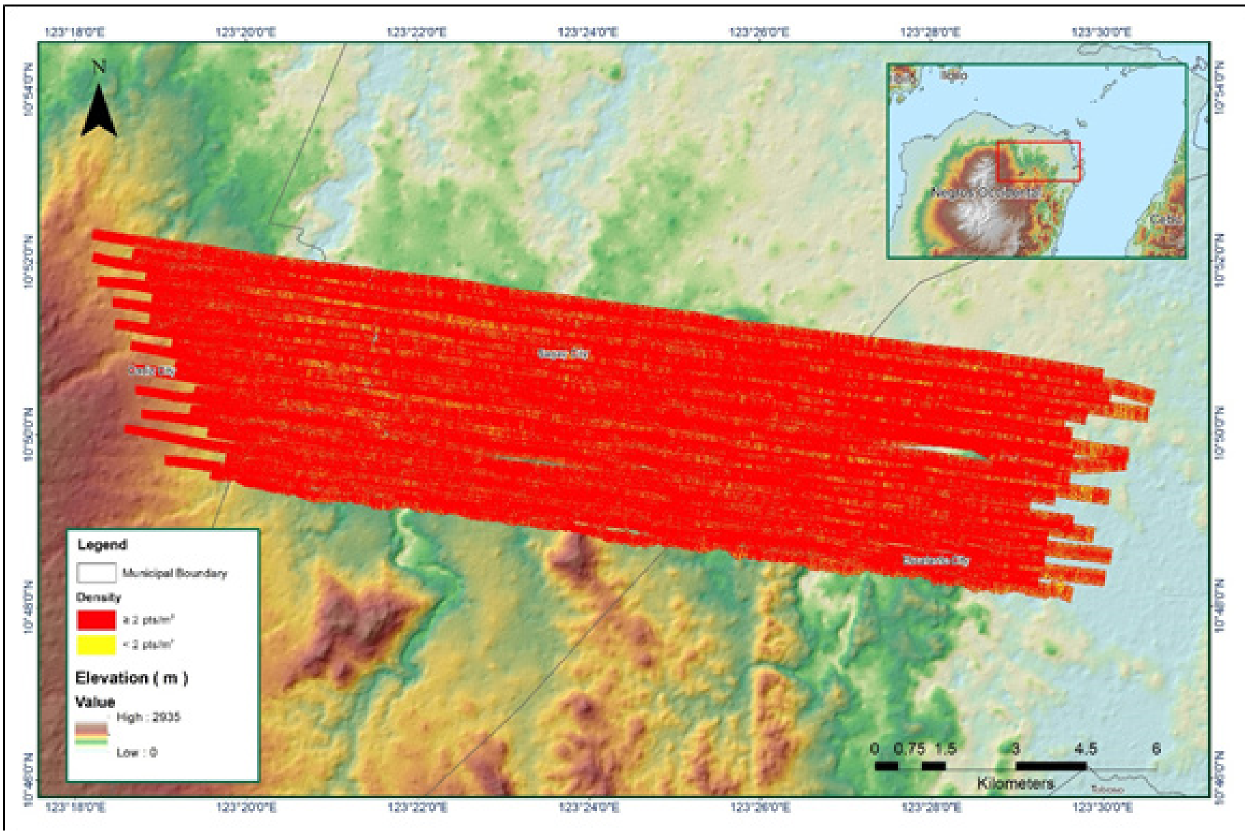


Figure A-8.20 Density map of merged LiDAR data

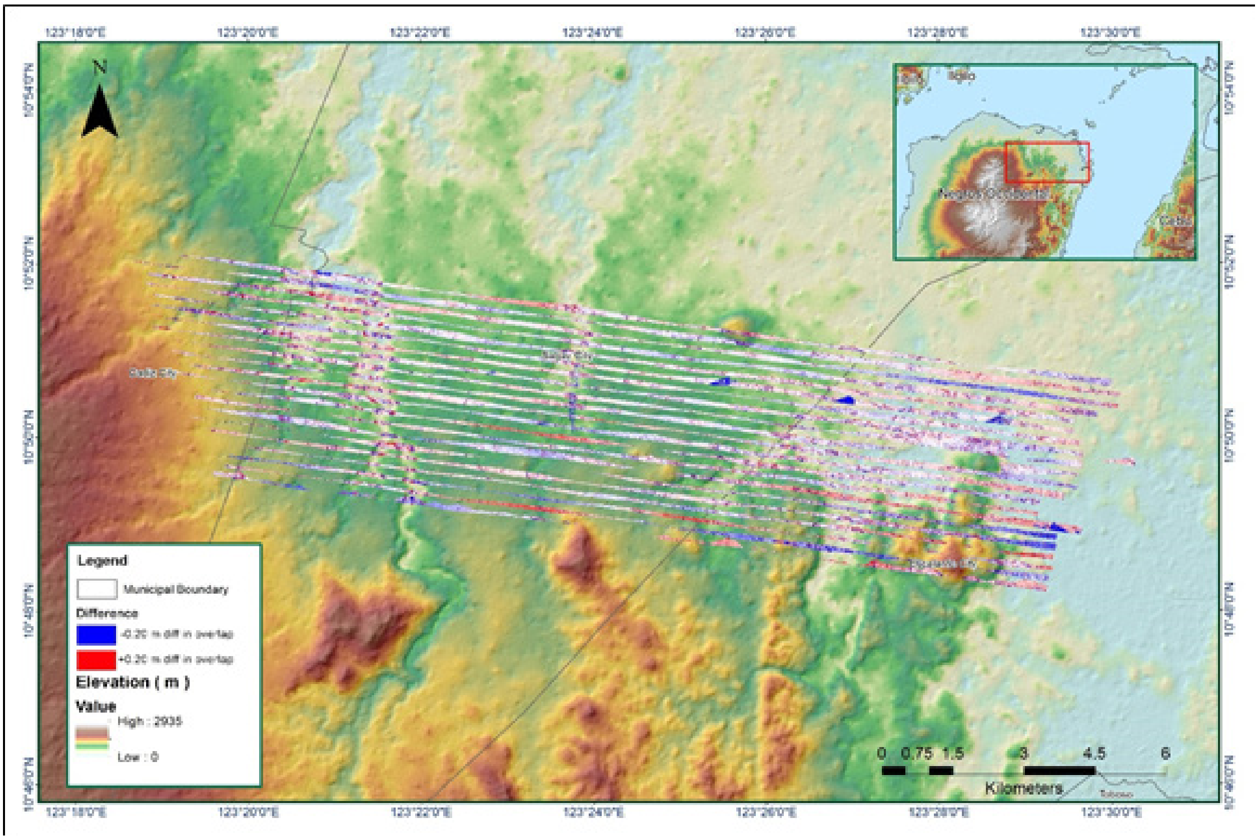


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Block 44E additional

Flight Area	Samar-Leyte
Mission Name	Block 44E additional
Inclusive Flights	8455AC
Range data size	10.2 GB
POS data size	233 MB
Base data size	91
Image	38.5
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.245
RMSE for East Position (<4.0 cm)	1.87
RMSE for Down Position (<8.0 cm)	4.065
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.004166
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	41.20
Ave point cloud density per sq.m. (>2.0)	4.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	387.49
Minimum Height	59.77
Classification (# of points)	
Ground	53,625,771
Low vegetation	63,815,686
Medium vegetation	72,382,824
High vegetation	55,860,054
Building	2,859,236
Orthophoto	None
Processed by	Engr. Sheila Maye Santillan, Engr. Edgardo Gubatanga Jr., Engr. Melissa Fernandez

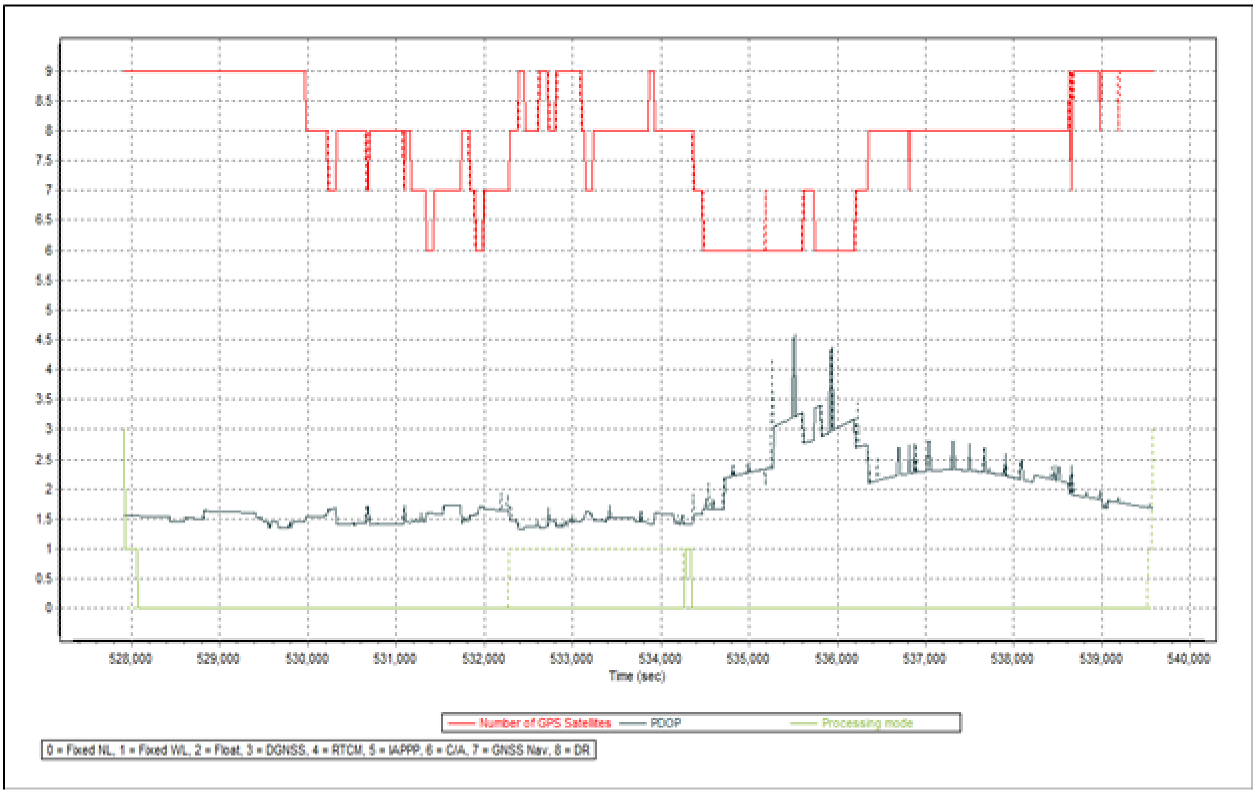


Figure A-8.22 Solution Status

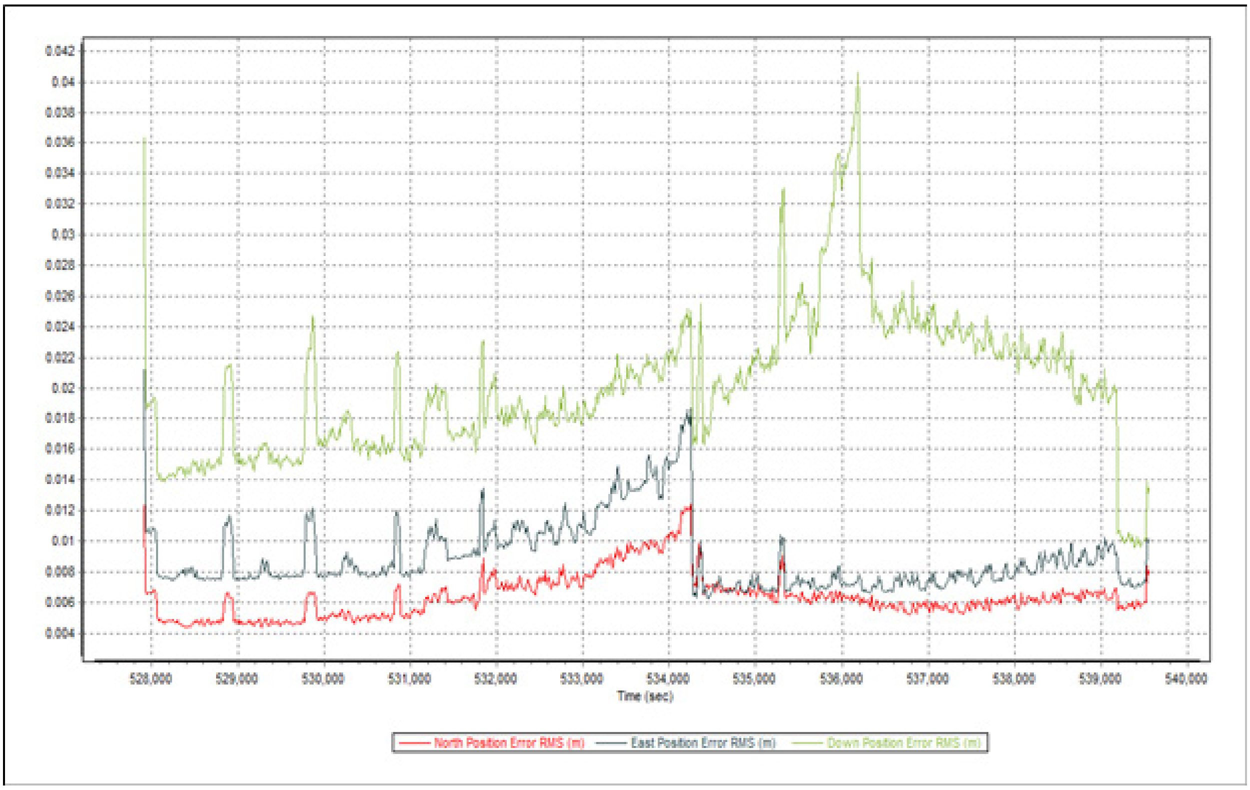


Figure A-8.23 Smoothed Performance Metric Parameters

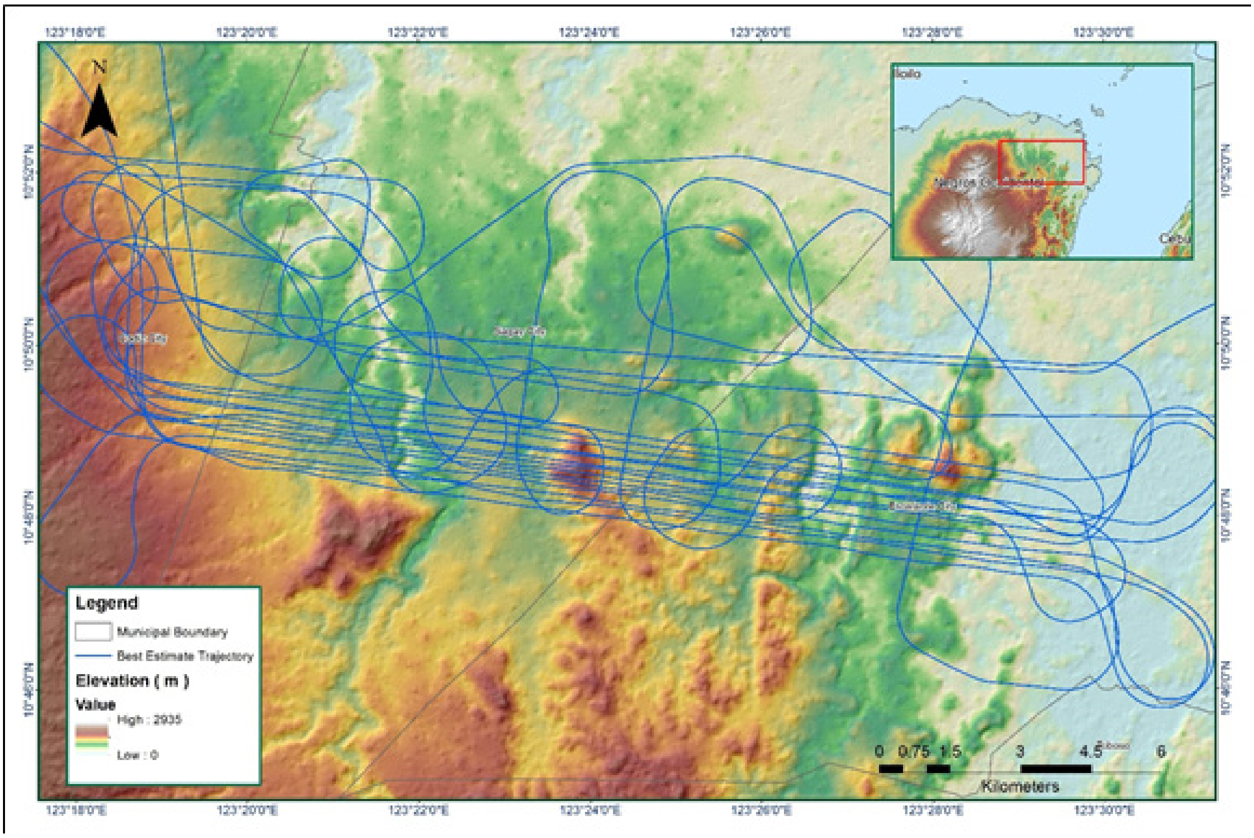


Figure A-8.24 Best Estimated Trajectory

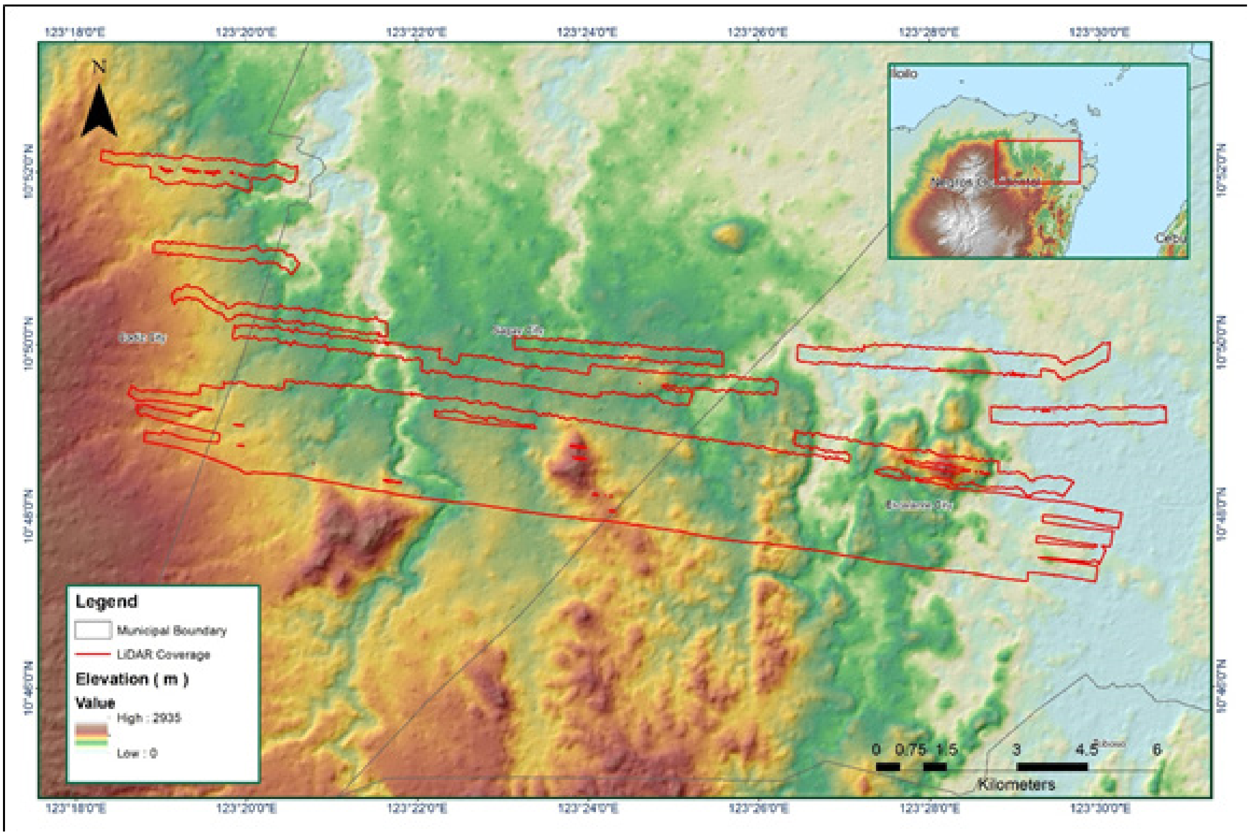


Figure A-8.25 Coverage of LiDAR data

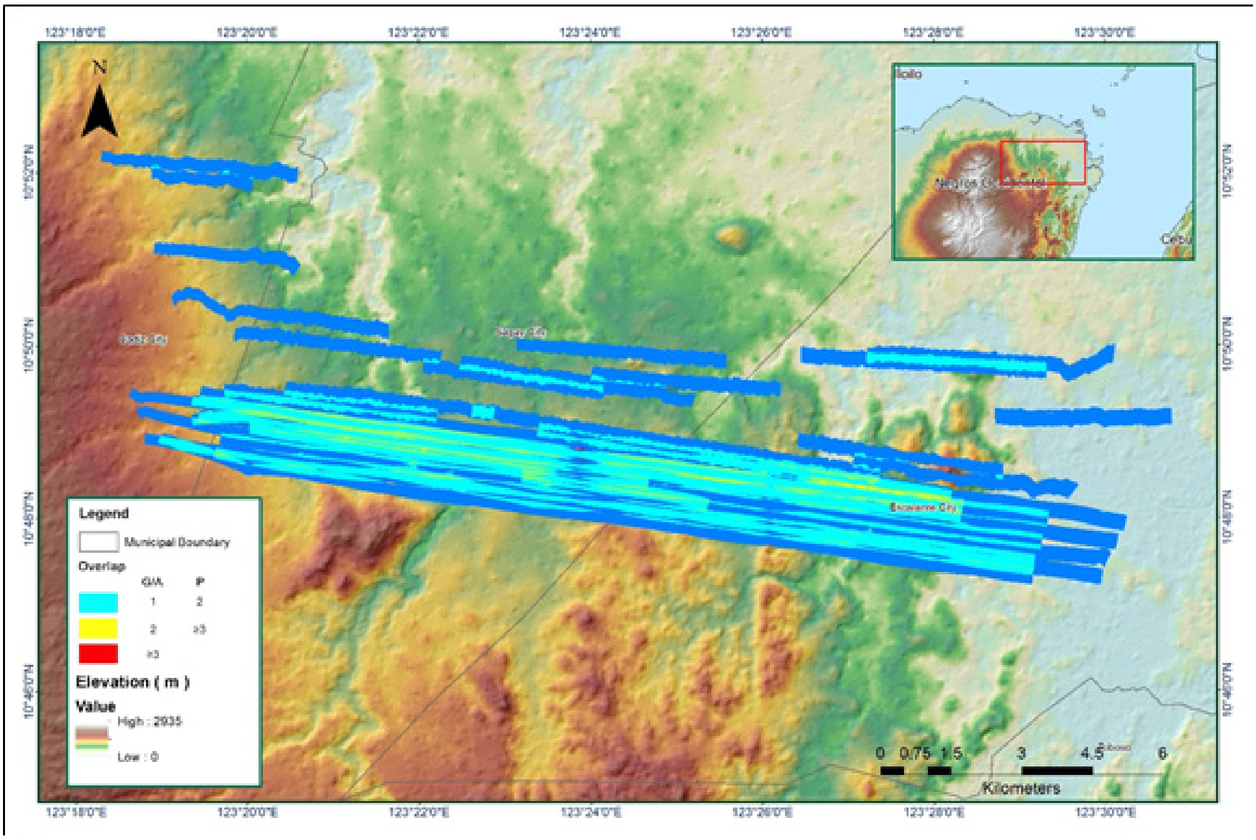


Figure A-8.26 Image of Data Overlap

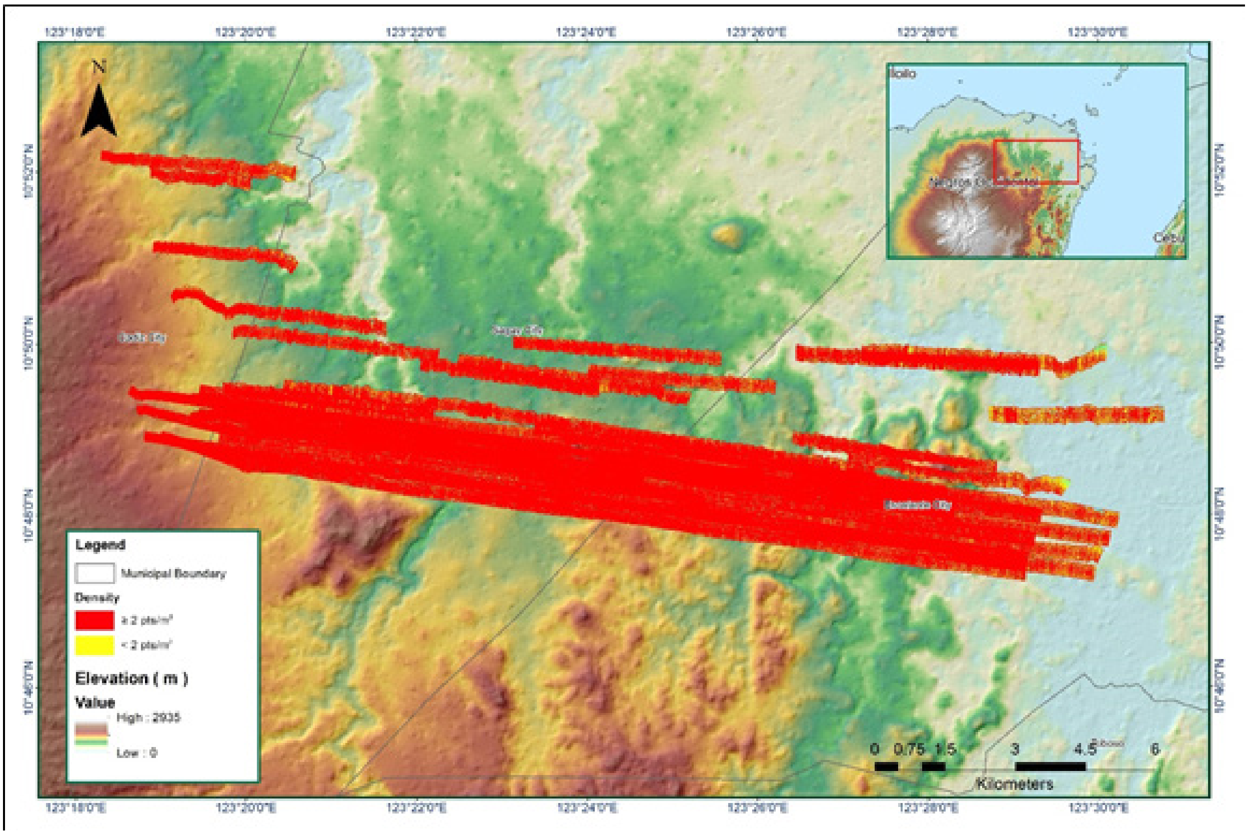


Figure A-8.27 Density map of merged LiDAR data

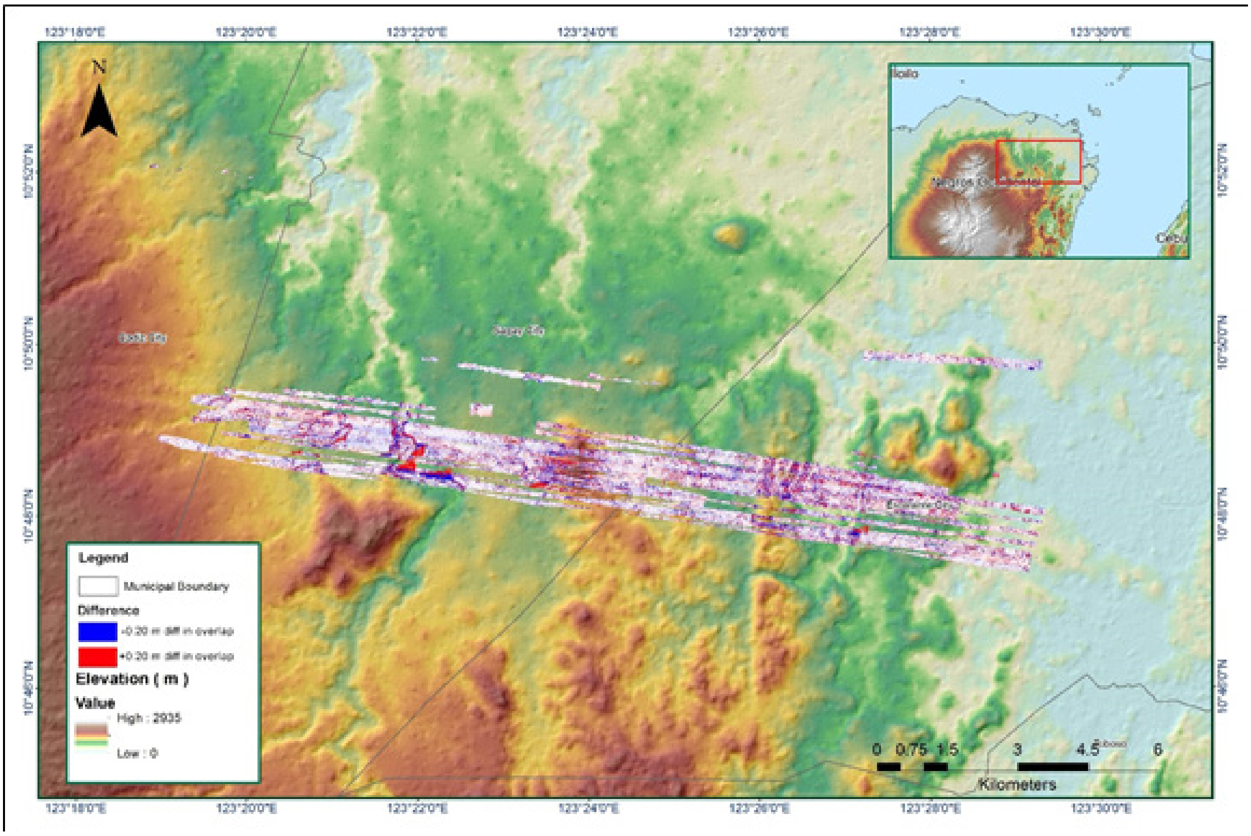


Figure A-8.28 Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Block 44L

Flight Area	Samar-Leyte
Mission Name	Block 44L
Inclusive Flights	8459AC
Range data size	10.3 GB
POS data size	262 MB
Base data size	100
Image	43.4
Transfer date	May 20, 2016
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)	1.220
RMSE for East Position (<4.0 cm)	1.058
RMSE for Down Position (<8.0 cm)	1.755
Boresight correction stdev (<0.001deg)	0.002388
IMU attitude correction stdev (<0.001deg)	0.038047
GPS position stdev (<0.01m)	0.0301
Minimum % overlap (>25)	36.87
Ave point cloud density per sq.m. (>2.0)	2.05
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	70.2
Minimum Height	48.75
Classification (# of points)	
Ground	23,074,394
Low vegetation	22,928,655
Medium vegetation	8,012,527
High vegetation	2,553,739
Building	597,128
Orthophoto	None
Processed by	Engr. Analyn Naldo, Engr. Melanie Hingpit, Engr. Monalyne Rabino

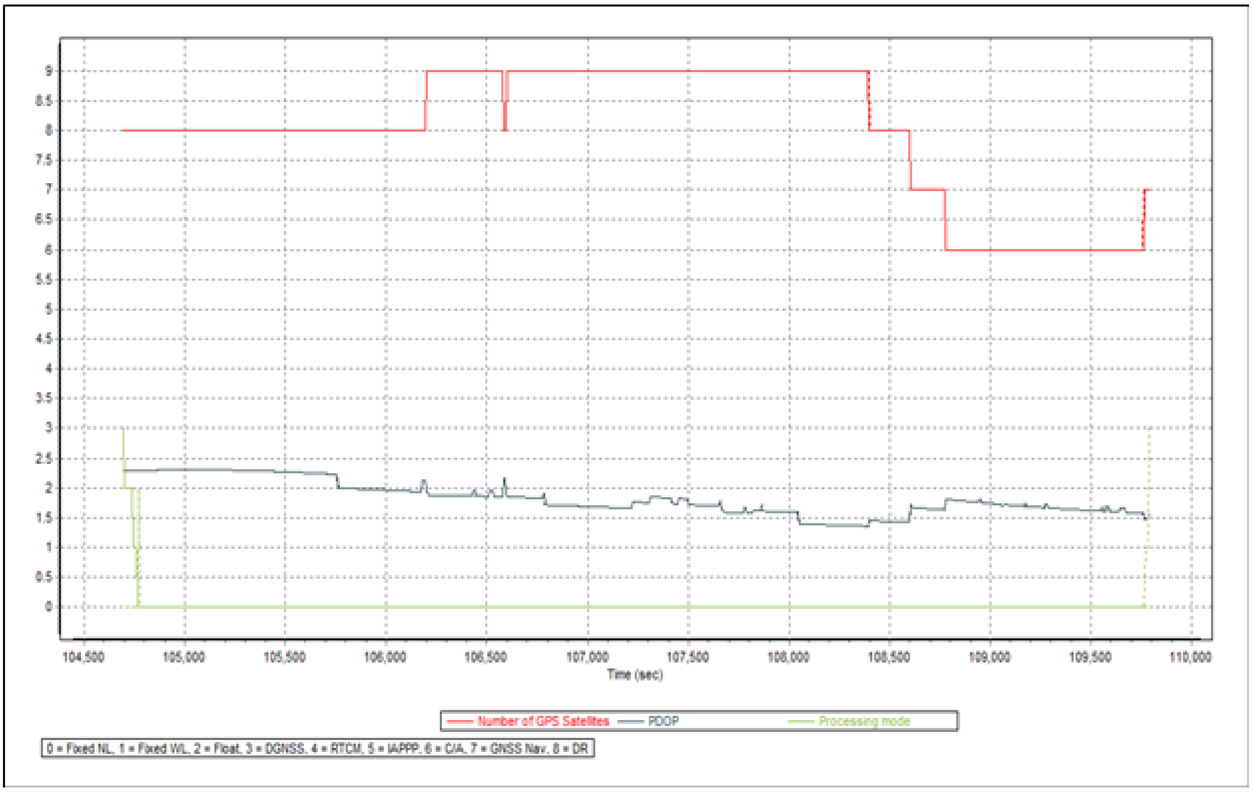


Figure A-8.29 Solution Status

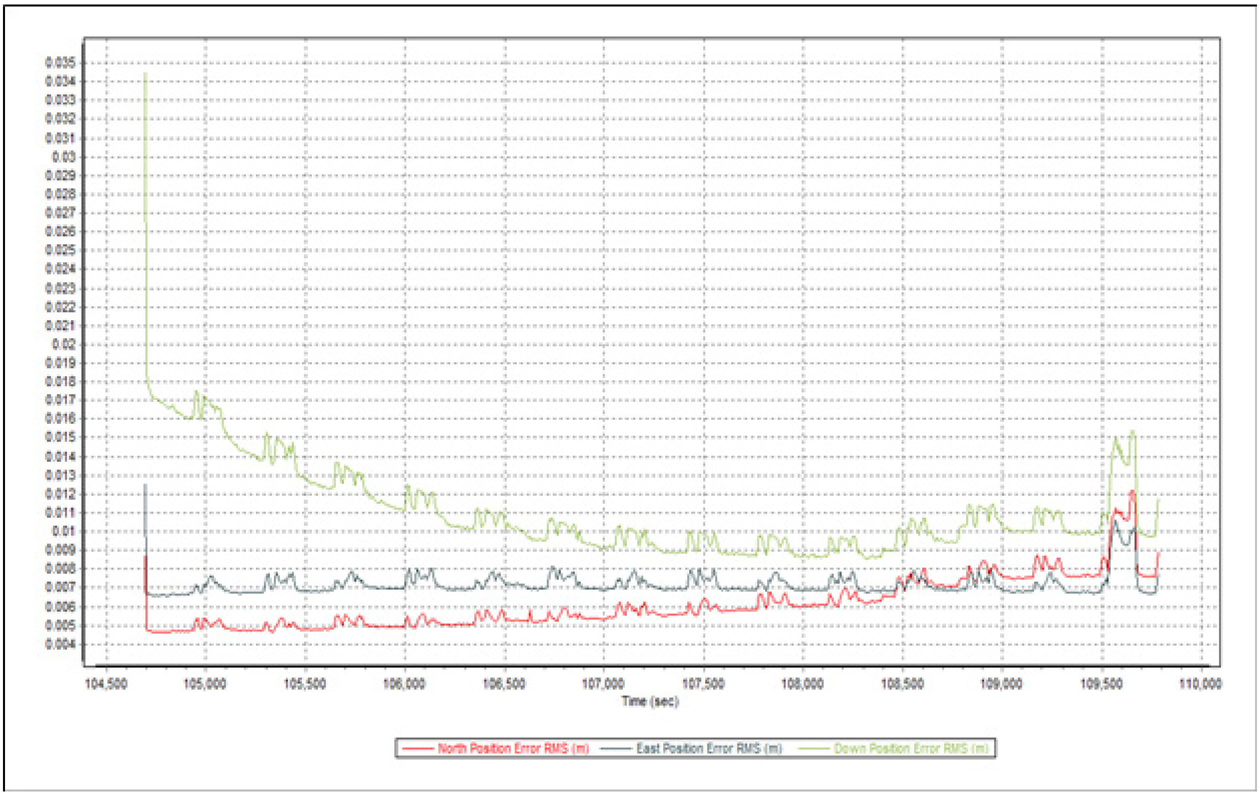


Figure A-8.30 Smoothed Performance Metric Parameters

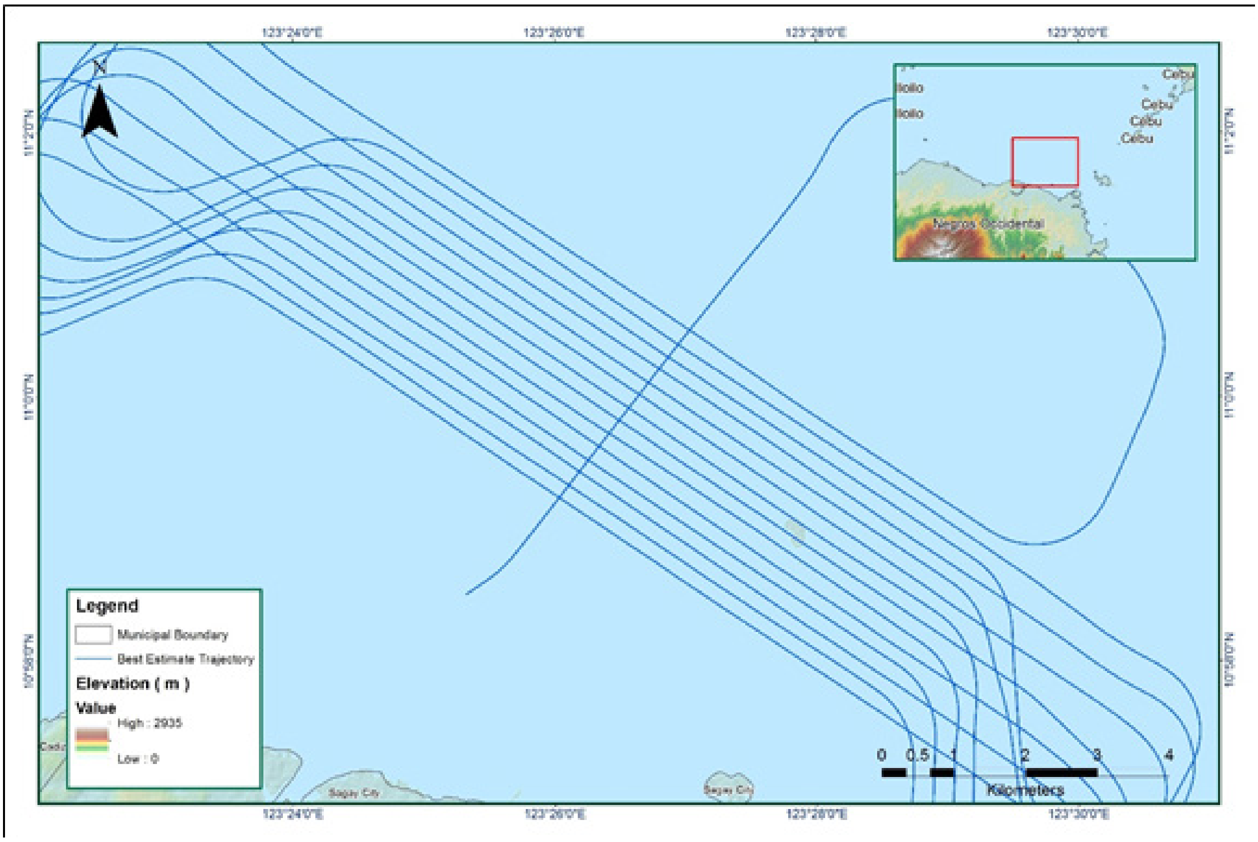


Figure A-8.31 Best Estimated Trajectory

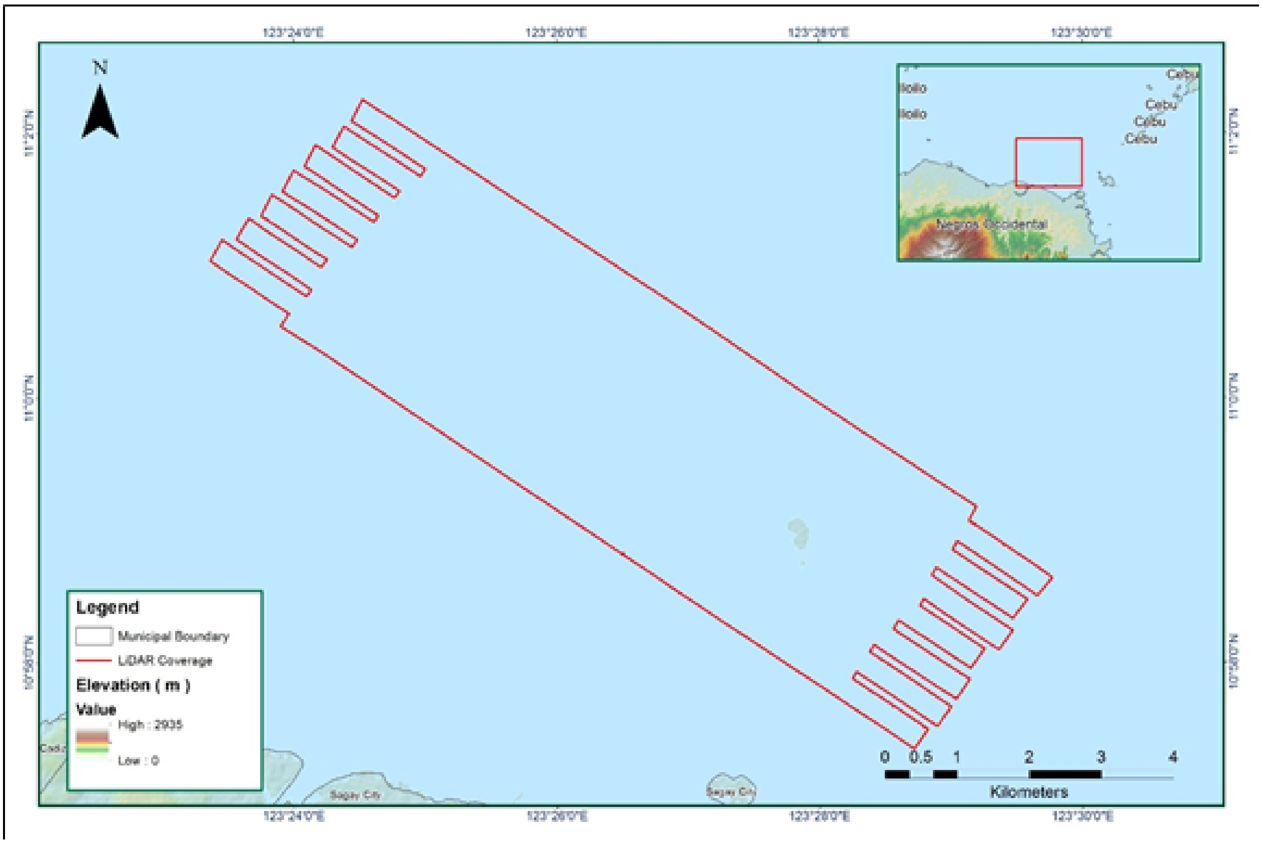


Figure A-8.32 Coverage of LiDAR data

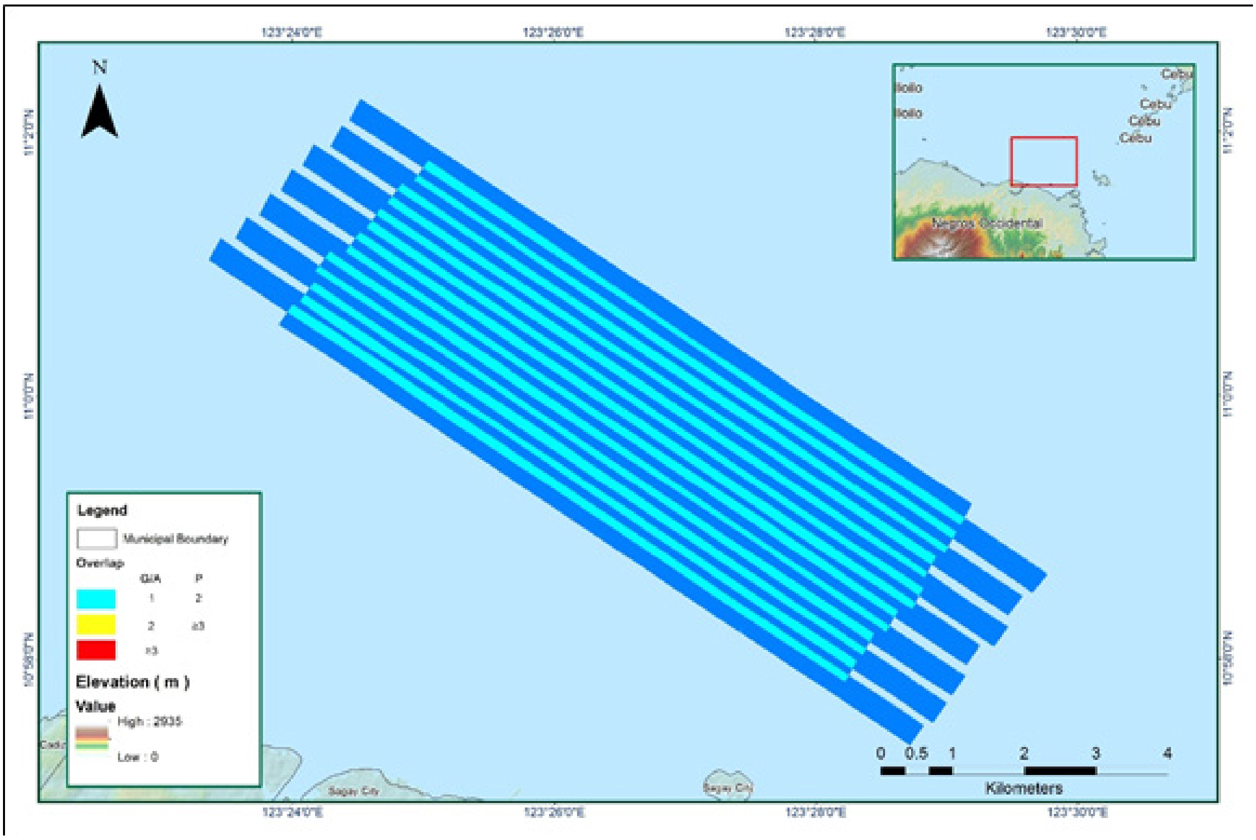


Figure A-8.33 Image of Data Overlap

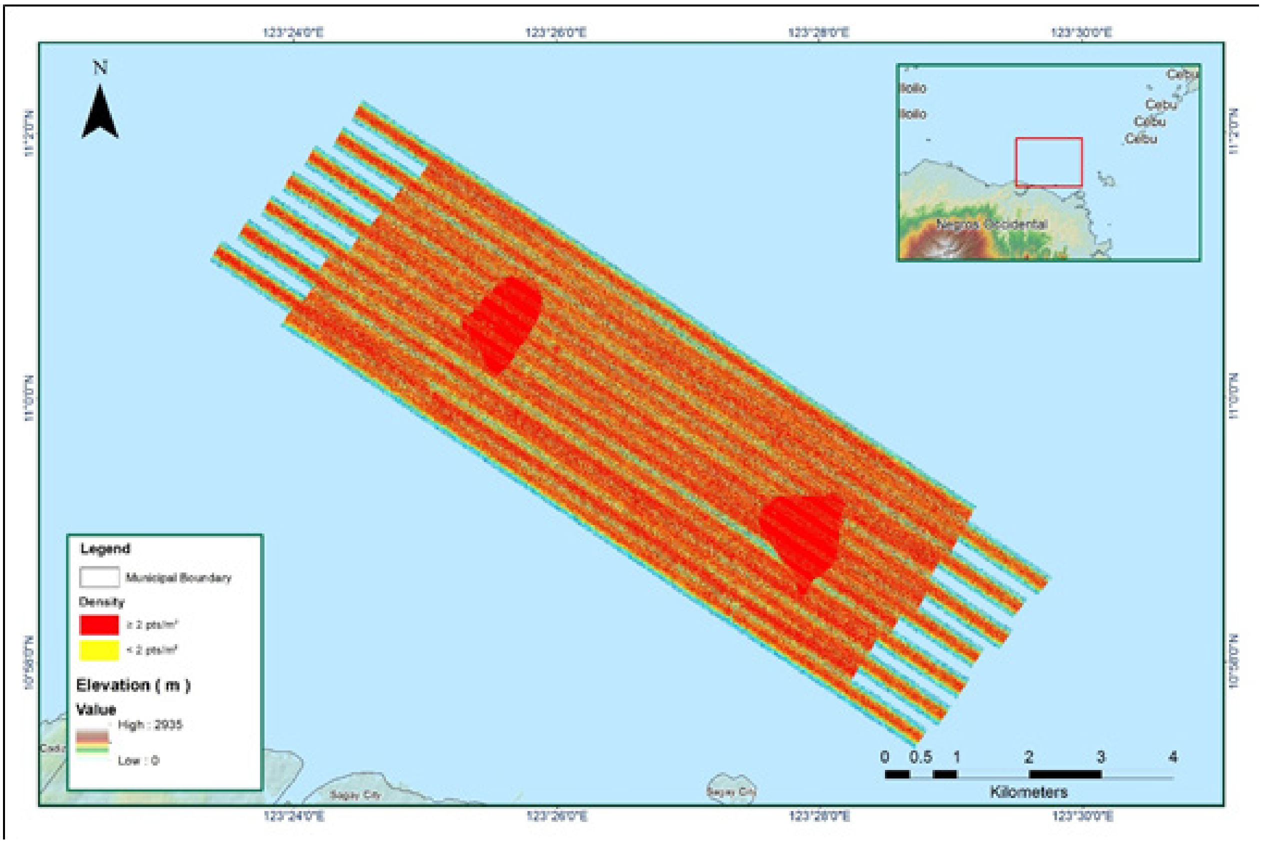


Figure A-8.34 Density map of merged LiDAR data

Figure A-8.35 Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Block 44D

Flight Area	Leyte
Mission Name	Block 44D
Inclusive Flights	8457AC
Range data size	8.64 GB
POS data size	222 MB
Base data size	94
Image	39.6
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.204
RMSE for Down Position (<8.0 cm)	5.78
Boresight correction stdev (<0.001deg)	0.000478
IMU attitude correction stdev (<0.001deg)	0.000940
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	30.10
Ave point cloud density per sq.m. (>2.0)	3.33
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	48
Maximum Height	106.51
Minimum Height	57.85
Classification (# of points)	
Ground	11,374,042
Low vegetation	10,746,942
Medium vegetation	12,511,682
High vegetation	8,971,525
Building	2,031,597
Orthophoto	None
Processed by	Engr. Irish Cortez, Aljon Rei Araneta, Engr. Melissa Fernandez

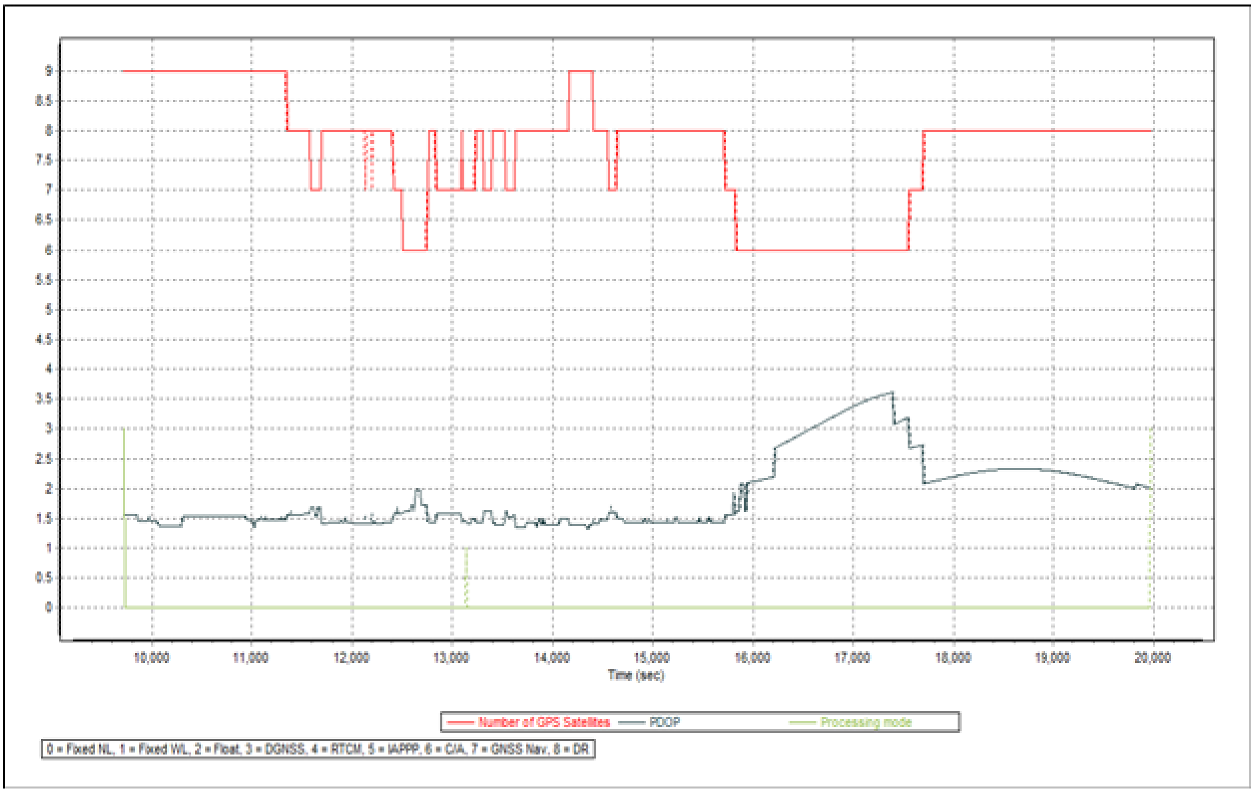


Figure A-8.36 Solution Status

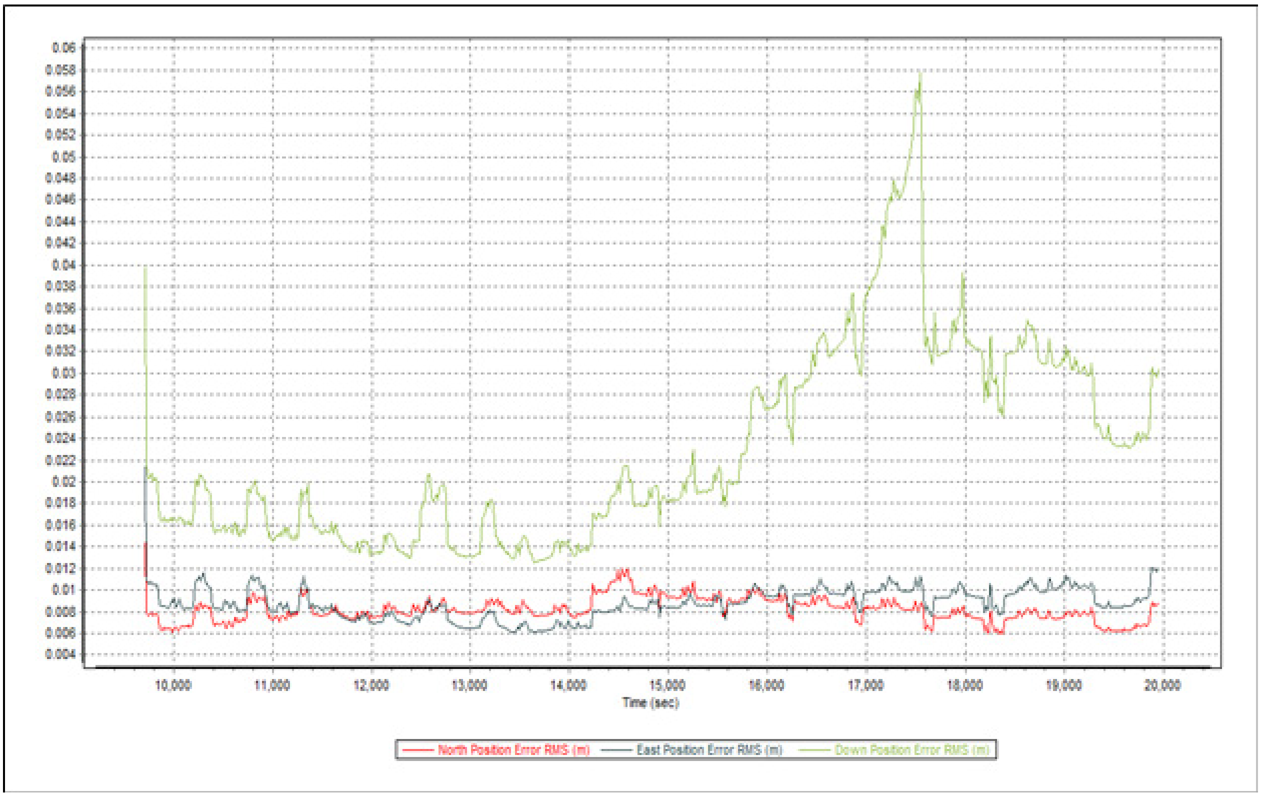


Figure A-8.37 Smoothed Performance Metric Parameters

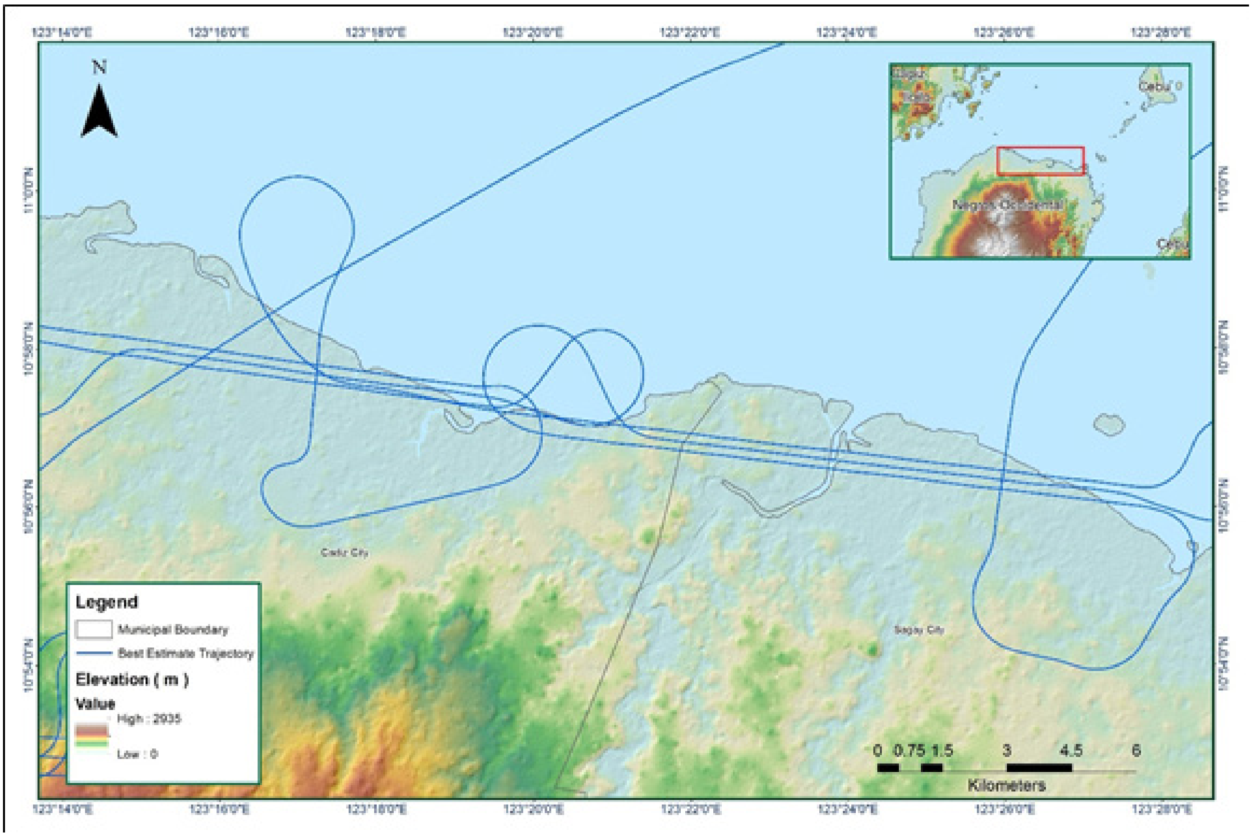


Figure A-8.38 Best Estimated Trajectory

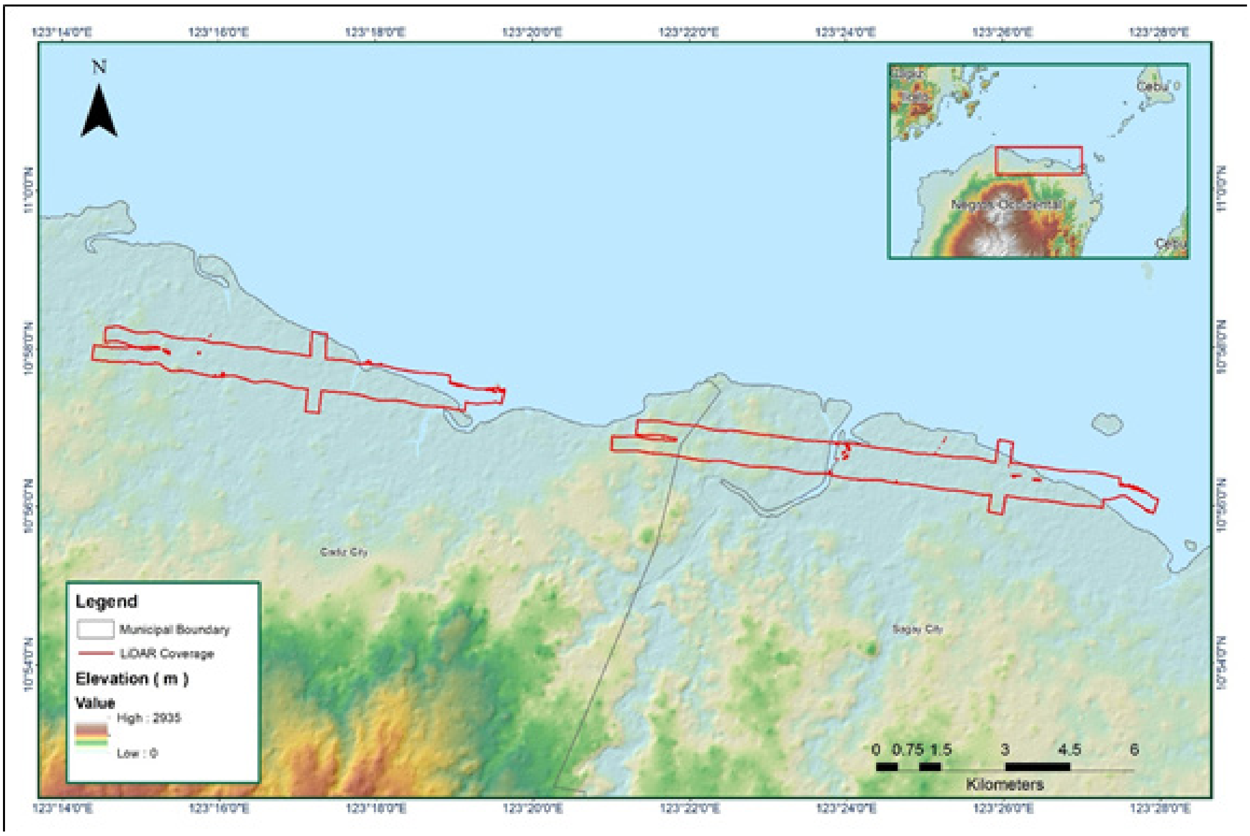


Figure A-8.39 Coverage of LiDAR data

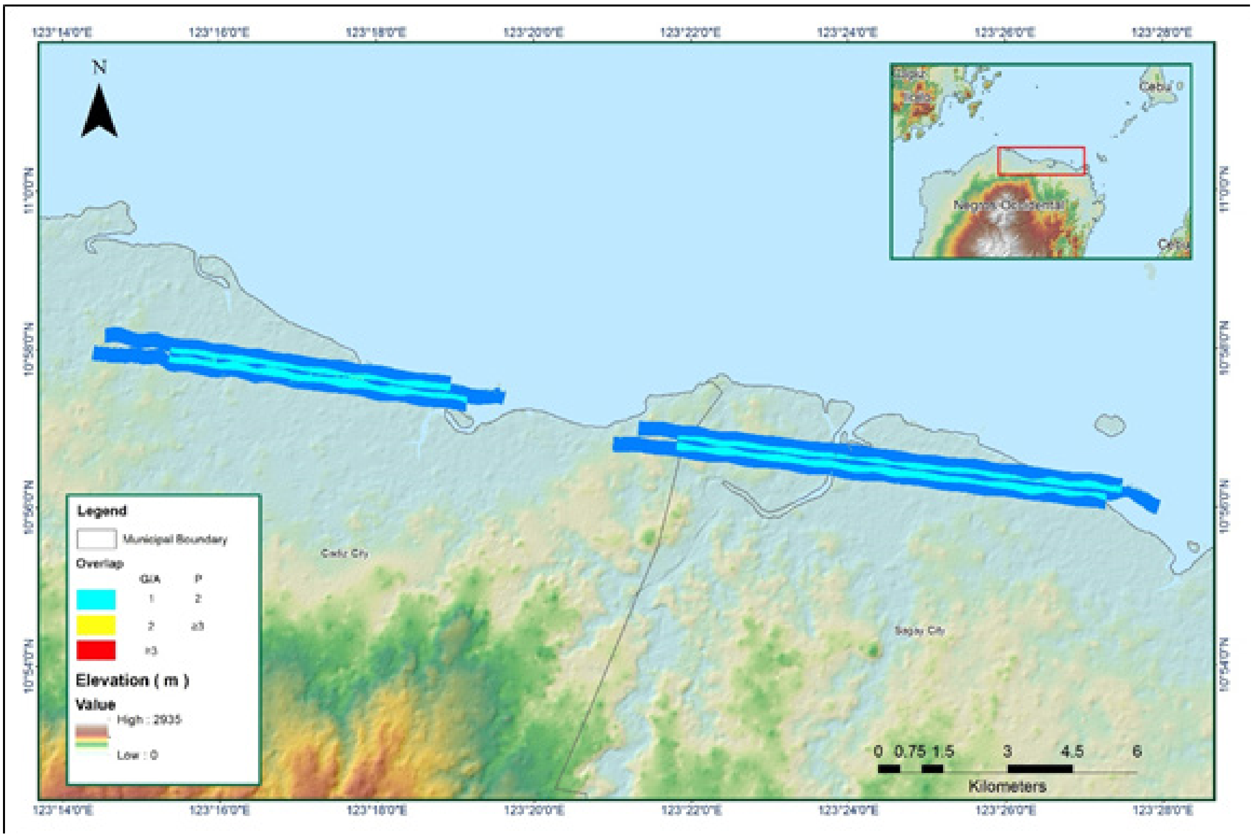


Figure A-8.40 Image of Data Overlap

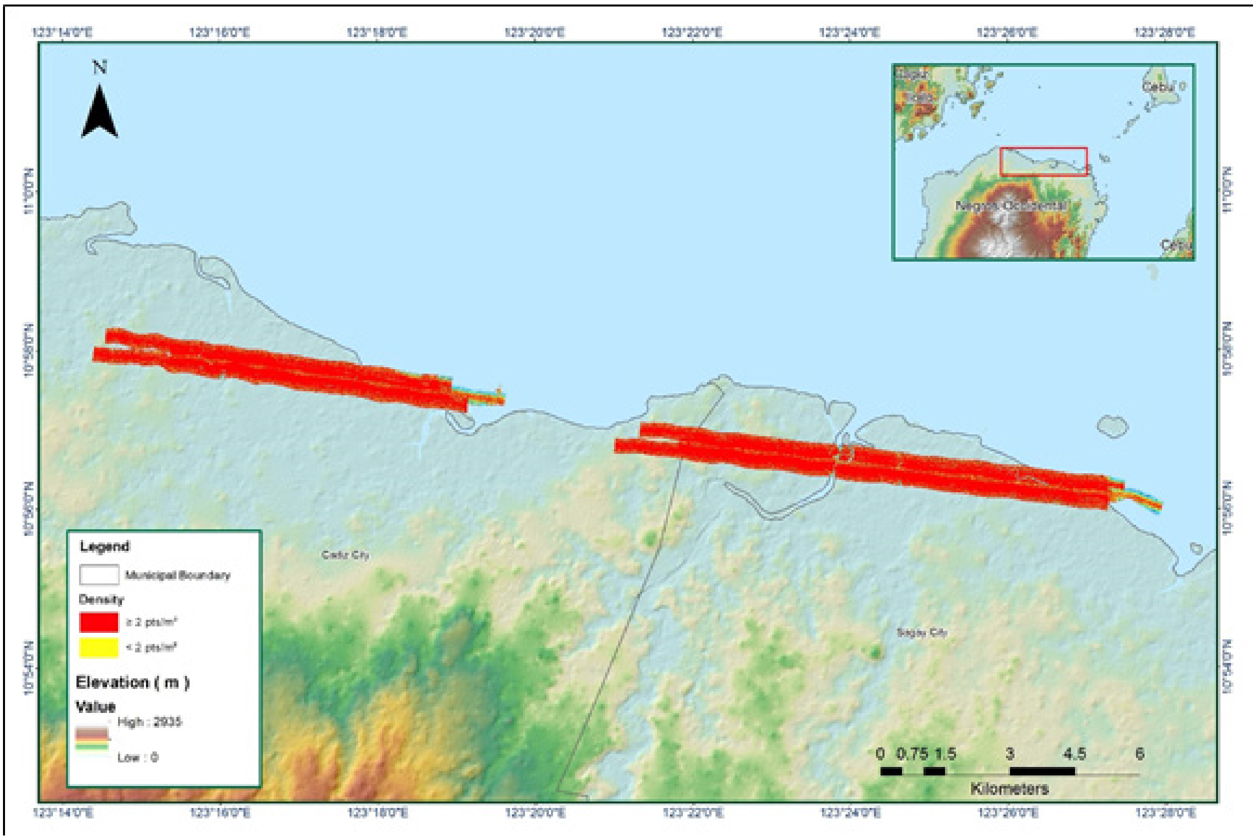


Figure A-8.41 Density map of merged LiDAR data

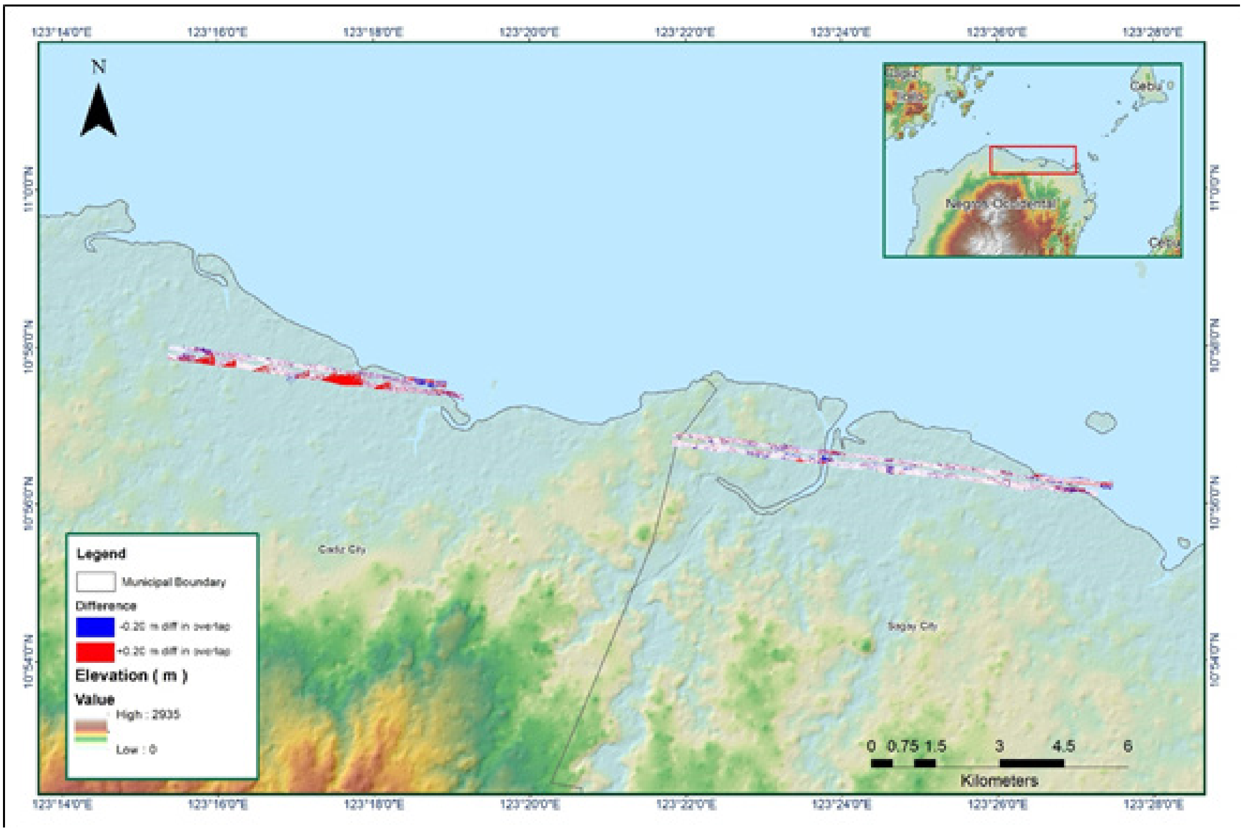


Figure A-8.42 Elevation difference between flight lines

Table A-8.7 Mission Summary Report for Mission Block 44M

Flight Area	Leyte
Mission Name	Block 44M
Inclusive Flights	8457AC
Range data size	8.64 GB
POS data size	222 MB
Base data size	94
Image	39.6
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.203
RMSE for East Position (<4.0 cm)	1.13
RMSE for Down Position (<8.0 cm)	5.8
Boresight correction stdev (<0.001deg)	0.000918
IMU attitude correction stdev (<0.001deg)	0.003627
GPS position stdev (<0.01m)	0.0078
Minimum % overlap (>25)	28.02
Ave point cloud density per sq.m. (>2.0)	2.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	63
Maximum Height	80.99
Minimum Height	41.71
Classification (# of points)	
Ground	28,691,991
Low vegetation	34,467,687
Medium vegetation	8,914,756
High vegetation	14,241,825
Building	1,179,453
Orthophoto	None
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew Natino, Engr. Elainne Lopez

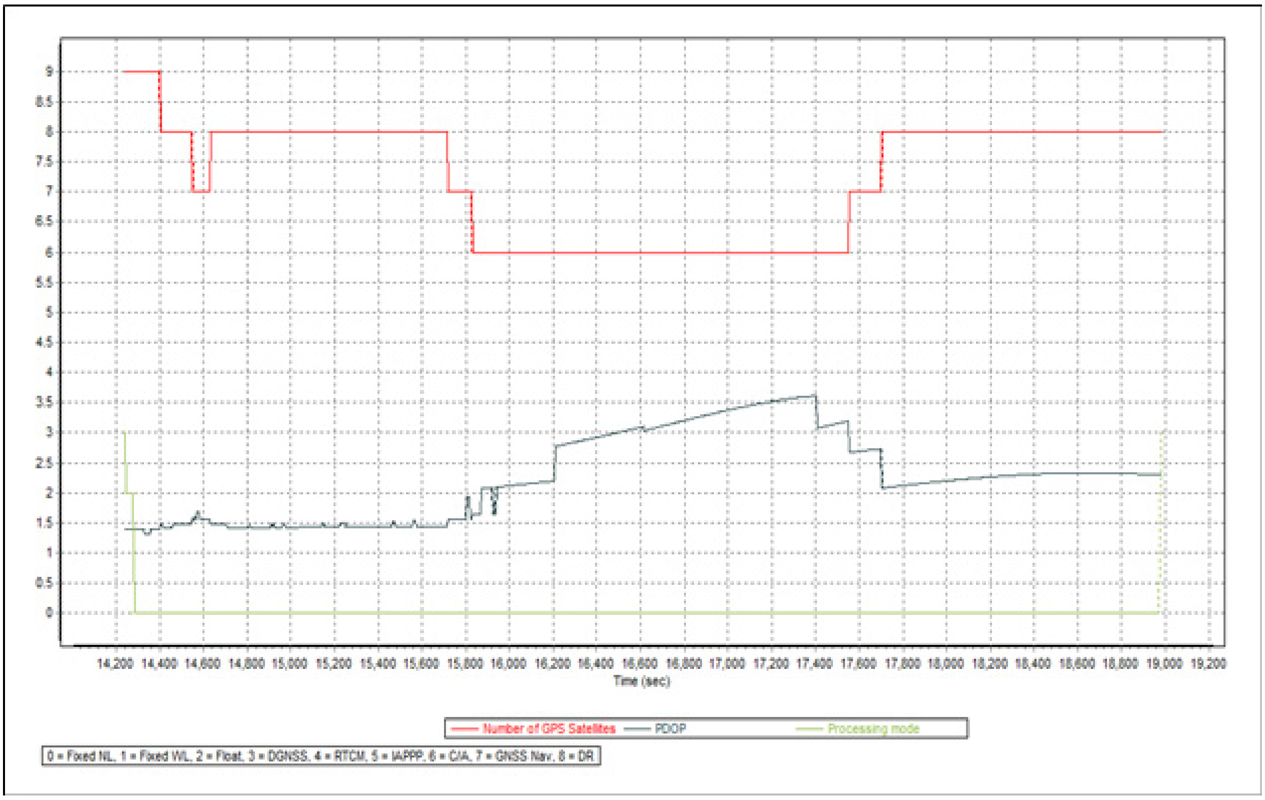


Figure A-8.43 Solution Status

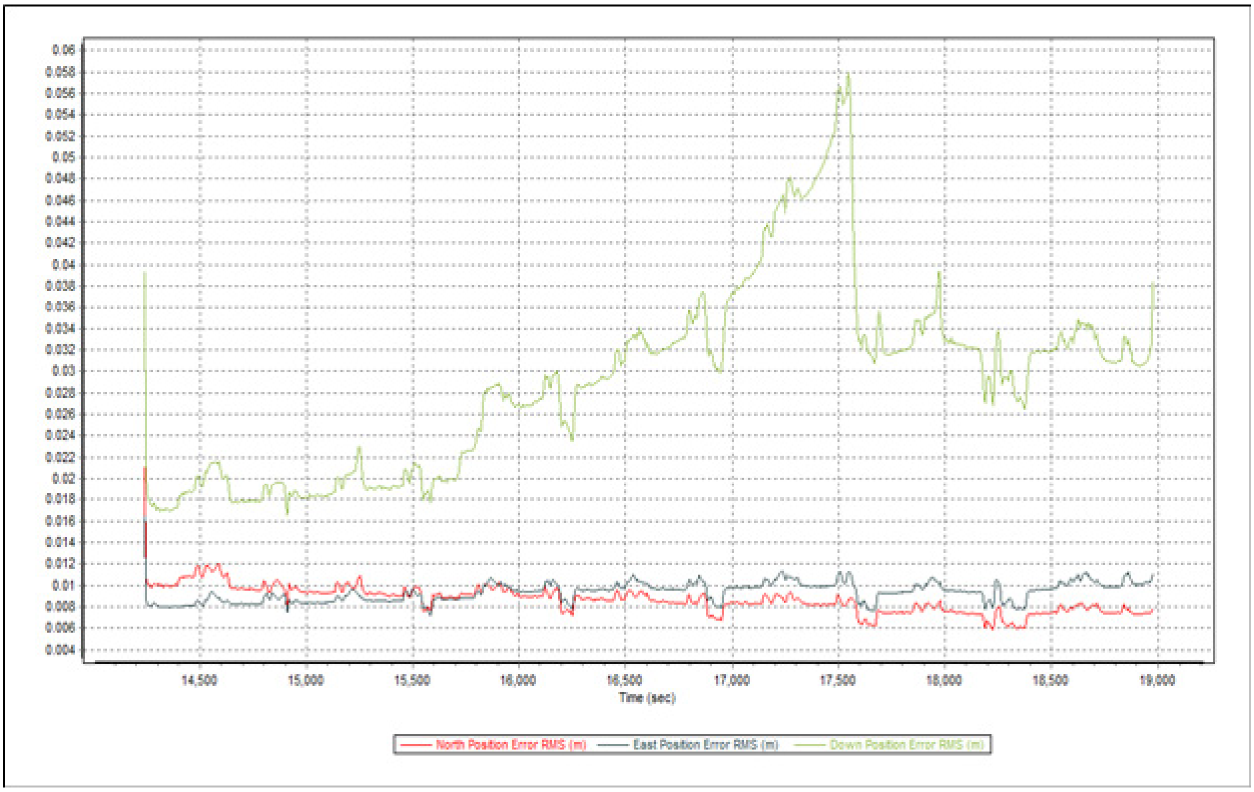


Figure A-8.44 Smoothed Performance Metric Parameters

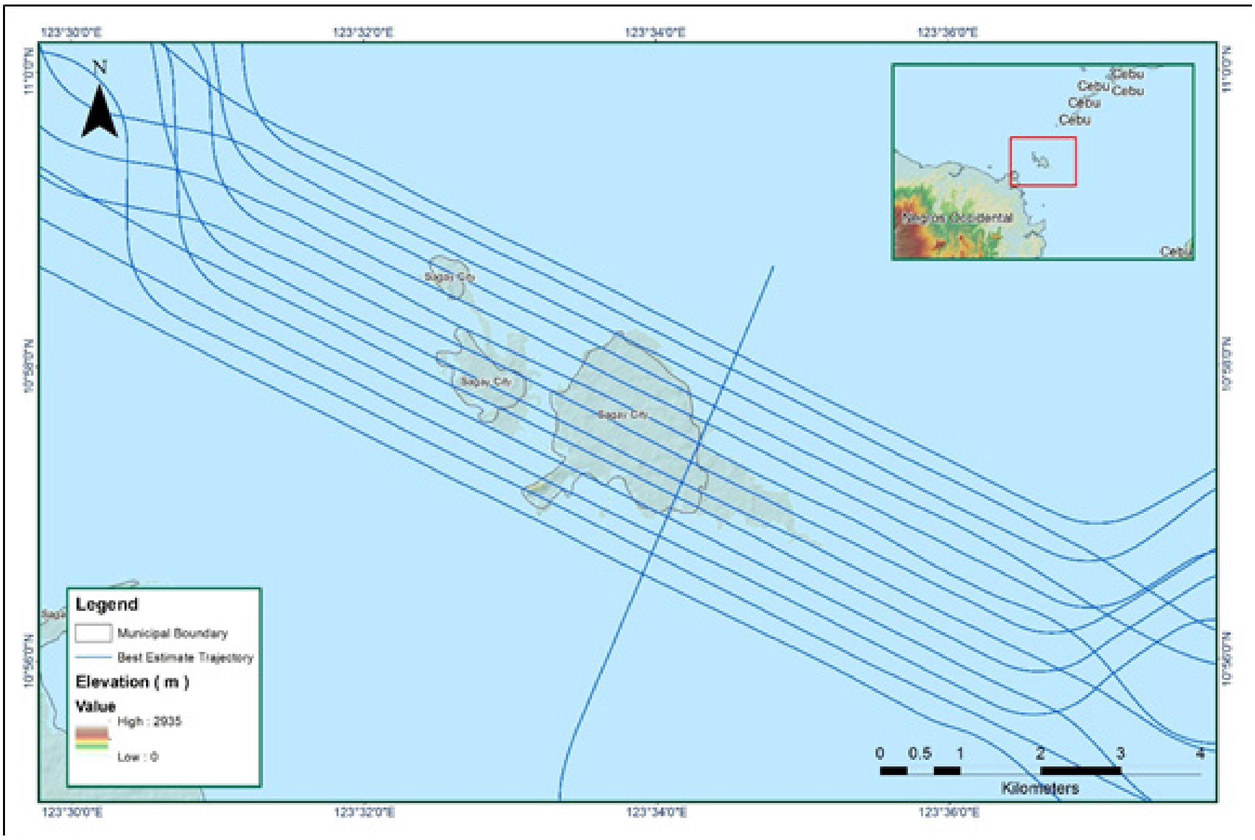


Figure A-8.45 Best Estimated Trajectory

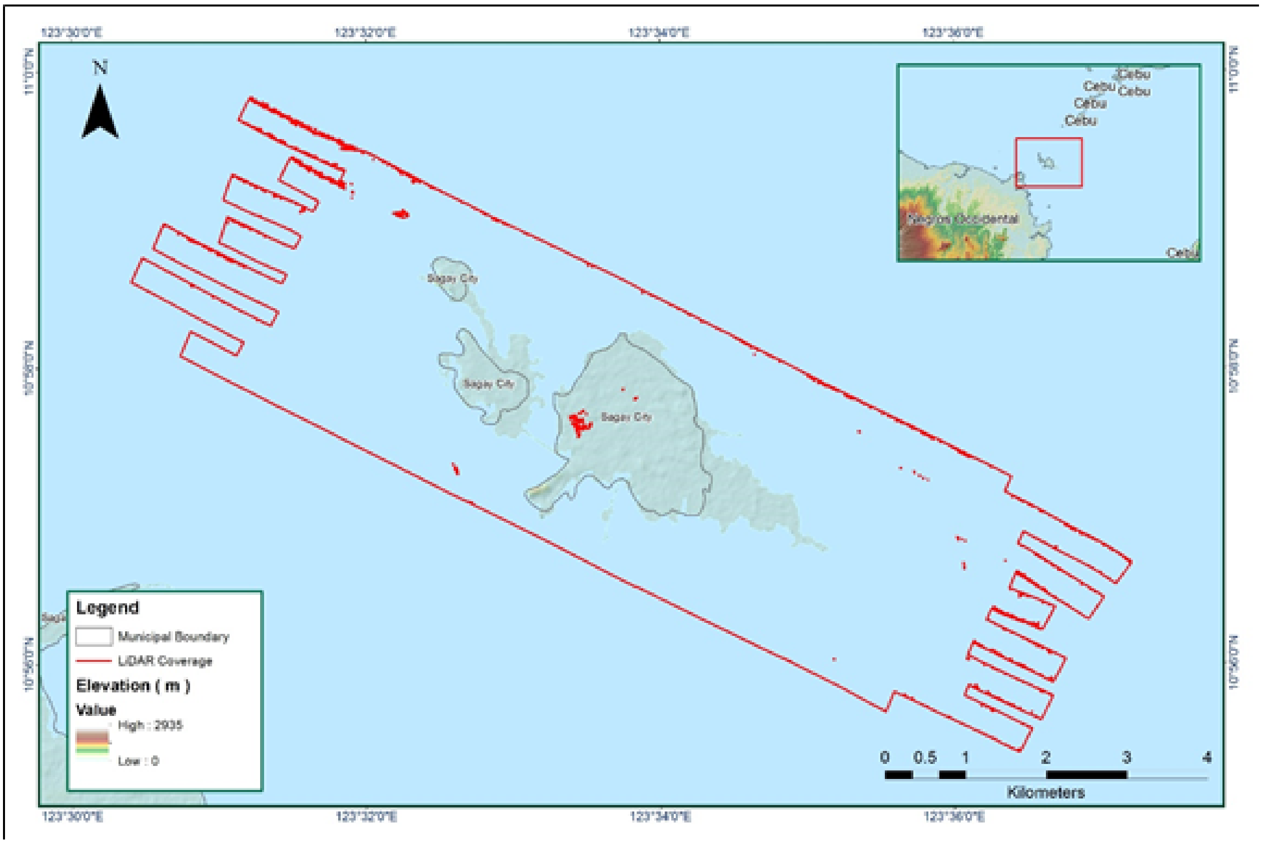


Figure A-8.46 Coverage of LiDAR data

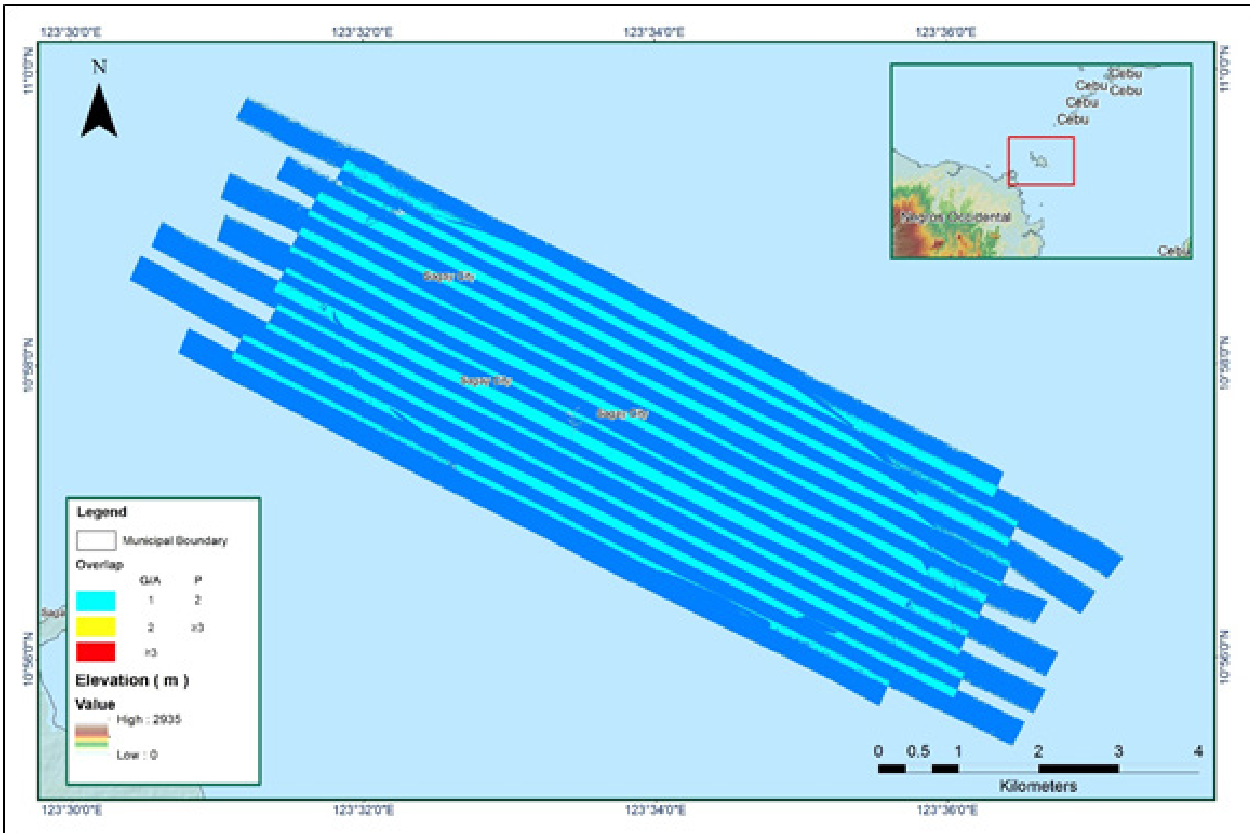


Figure A-8.47 Image of Data Overlap

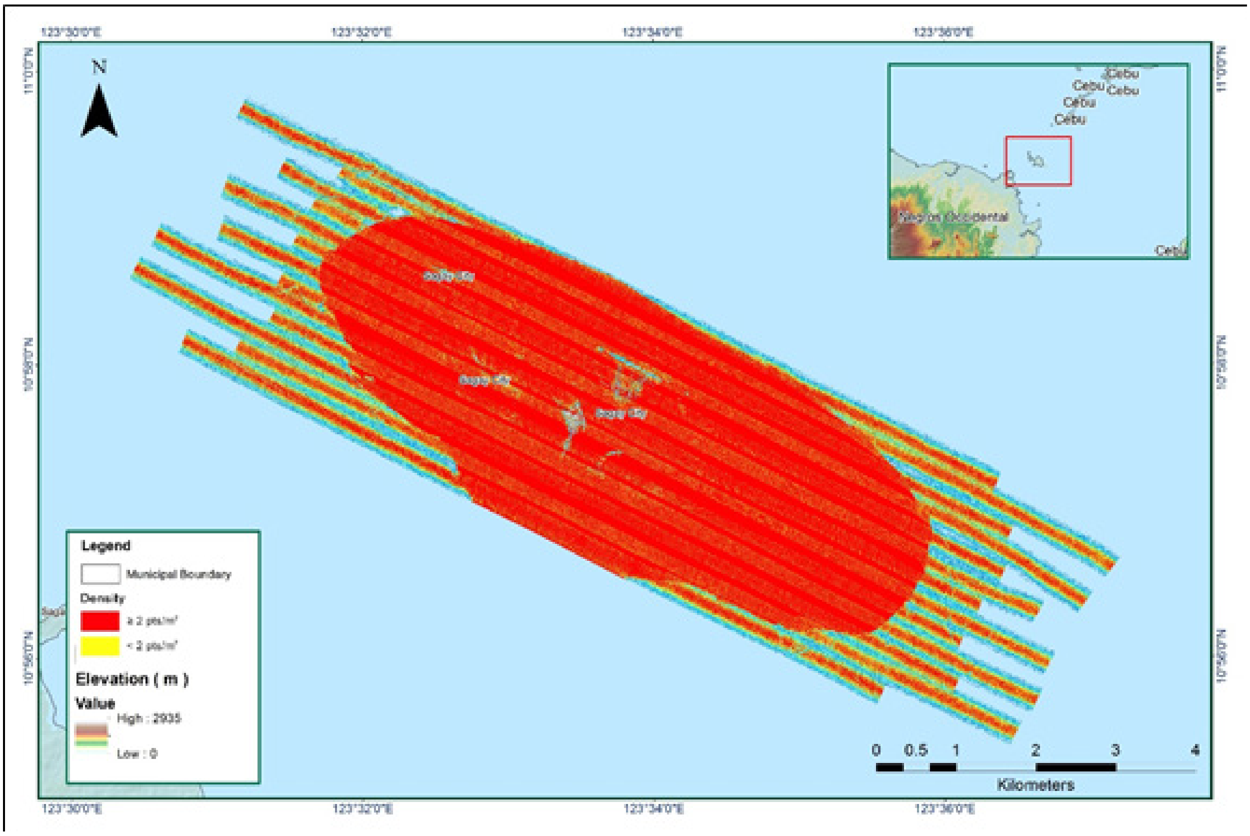


Figure A-8.48 Density map of merged LiDAR data

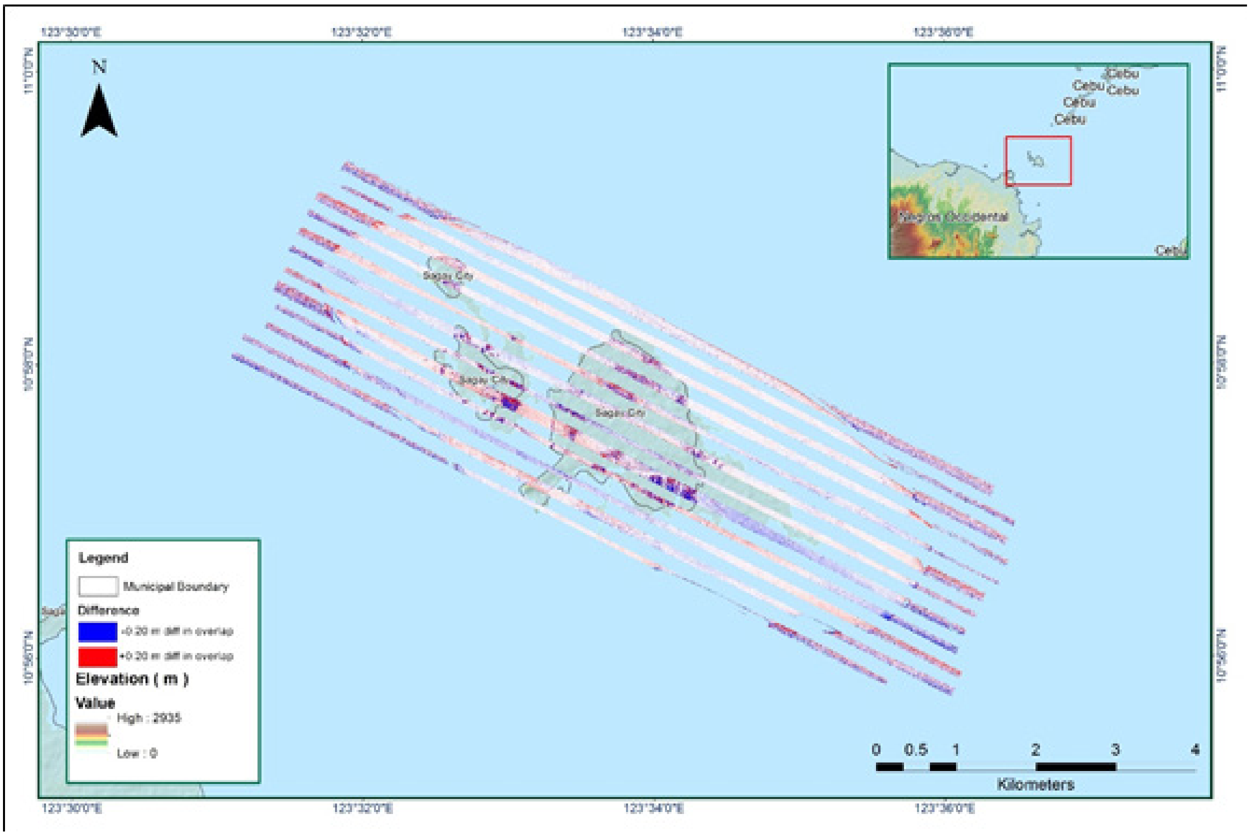


Figure A-8.49 Elevation difference between flight lines

Annex 9. Tanao 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
W140	1.5218	93.783	0	0.731106	1.193165	Discharge	0.0098694	0.75	Ratio to Peak	0.5
W150	1.323	97.593	0	5.860626	9.564542	Discharge	0.1085	0.75	Ratio to Peak	0.5
W160	2.3799	94.21	0	1.830382	2.987184	Discharge	0.0261105	0.75	Ratio to Peak	0.5
W170	1.191	93.097	0	2.946682	4.808985	Discharge	0.0692642	0.75	Ratio to Peak	0.5
W180	1.2308	94.774	0	1.677836	2.738229	Discharge	0.0156626	0.75	Ratio to Peak	0.5
W190	1.264	91.125	0	1.12951	1.84336	Discharge	0.0092623	0.75	Ratio to Peak	0.5
W200	1.2634	88.462	0	0.880072	1.436279	Discharge	0.0165697	0.75	Ratio to Peak	0.5
W210	1.2624	89.612	0	1.957839	3.195194	Discharge	0.0269084	0.75	Ratio to Peak	0.5
W220	1.2575	88.056	0	1.384417	2.259369	Discharge	0.0304784	0.75	Ratio to Peak	0.5
W230	1.2566	90.148	0	1.871367	3.054072	Discharge	0.0367359	0.75	Ratio to Peak	0.5
W240	1.4958	91.906	0	2.077028	3.38971	Discharge	0.0759145	0.75	Ratio to Peak	0.5
W250	1.2427	84.858	0	0.793341	1.294734	Discharge	0.0200285	0.75	Ratio to Peak	0.5
W260	1.7394	83.148	0	0.85995	1.403438	Discharge	0.0169452	0.75	Ratio to Peak	0.5

Annex 10. Tanao 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	701.335	0.021871	0.015	Trapezoid	9.89	1
R30	Automatic Fixed Interval	9938.33	0.004417	0.015	Trapezoid	9.89	1
R50	Automatic Fixed Interval	5166.88	6.92E-03	0.015	Trapezoid	9.89	1
R70	Automatic Fixed Interval	1287.4	0.00532	0.015	Trapezoid	9.89	1
R90	Automatic Fixed Interval	2141.67	0.006278	0.015	Trapezoid	9.89	1
R110	Automatic Fixed Interval	3508.36	0.008403	0.015	Trapezoid	9.89	1

Annex 11. Tanao Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	10.89304	123.4049171	3.49	5	2.2801	Undang/November 5-7, 1985	100-Year
2	10.88665	123.3956462	1.08	5	15.3664	Undang/November 5-7, 1986	100-Year
3	10.88706	123.3956749	0.95	5	16.4025	Undang/November 5-7, 1987	100-Year
4	10.88671	123.3956508	3.17	5	3.3489	Undang/November 5-7, 1988	100-Year
5	10.88675	123.3961603	0.00	3	9	Ruping/November 13-18, 1990	100-Year
6	10.89284	123.4048072	4.03	5	0.9409	Undang/November 5-7, 1989	100-Year
7	10.8866	123.3956406	1.97	5	9.1809	Undang/November 5-7, 1990	100-Year
8	10.88644	123.3964139	0.30	5	22.09	Undang/November 5-7, 1991	100-Year
9	10.88685	123.3961504	1.78	3	1.4884	Ruping/November 13-18, 1991	100-Year
10	10.89264	123.4047981	0.05	5	24.5025	Undang/November 5-7, 1992	100-Year
11	10.88679	123.395619	0.24	5	22.6576	Undang/November 5-7, 1993	100-Year
12	10.88678	123.395511	1.84	5	9.9856	Undang/November 5-7, 1994	100-Year
13	10.88679	123.3957428	1.98	3	1.0404	Ruping/November 13-18, 1992	100-Year
14	10.89333	123.4049507	1.62	3	1.9044	Ruping/November 13-18, 1993	100-Year
15	10.89323	123.4049247	0.03	3	8.8209	Ruping/November 13-18, 1994	100-Year
16	10.89268	123.4047117	0.39	3	6.8121	Ruping/November 13-18, 1995	100-Year
17	10.89289	123.4048491	0.59	5	19.4481	Undang/November 5-7, 1995	100-Year
18	10.88686	123.3957575	0.26	5	22.4676	Undang/November 5-7, 1996	100-Year
19	10.88656	123.3963104	0.74	5	18.1476	Undang/November 5-7, 1997	100-Year
20	10.88494	123.4104032	0.59	0.75	0.0256	Yolanda/ November 2-11, 2013	5-Year
21	10.89096	123.357543	0.6	3	5.76	Yolanda/ November 2-11, 2013	5-Year
22	10.88607	123.4179368	1.39	0	1.9321		5-Year
23	10.89276	123.4133247	2.46	0	6.0516		5-Year
24	10.8828	123.3463334	0.00	0	0		5-Year
25	10.89703	123.4134465	2.17	0	4.7089		5-Year
26	10.89627	123.3590016	0.03	0	0.0009		5-Year
27	10.8868	123.3485264	0.00	0	0		5-Year
28	10.88362	123.3492893	0.00	0	0		5-Year
29	10.89705	123.4145236	0.00	0.2	0.04	Yolanda/ November 2-11, 2013	5-Year
30	10.88689	123.4107982	0.23	0	0.0529	Yolanda/ November 2-11, 2013	5-Year
31	10.88372	123.4107134	10.23	0	104.6529		5-Year
32	10.88471	123.4146668	5.62	0	31.5844		5-Year
33	10.88612	123.4161576	5.67	0	32.1489		5-Year
34	10.89088	123.4108827	0.14	0	0.0196		5-Year
35	10.88573	123.3495022	5.37	0	28.8369		5-Year
36	10.89633	123.3609441	0.04	0	0.0016		5-Year
37	10.89118	123.3577763	1.08	3	3.6864	Yolanda/ November 2-11, 2013	5-Year
38	10.89884	123.3622023	0.03	0	0.0009		5-Year
39	10.89628	123.3627223	0.06	0	0.0036		5-Year
40	10.89005	123.4133036	5.23	0.3	24.3049	Yolanda/ November 2-11, 2013	5-Year
41	10.94794	123.4139833	0.05	0	0.0025		5-Year
42	10.88898	123.4135544	0.00	0	0		5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
43	10.93673	123.4201519	0.76	0.6	0.0256	Marce/November 24 -28, 2016	5-Year
44	10.89043	123.4125809	6.5	0.2	39.69	Yolanda/ November 2-11, 2013	5-Year
45	10.89063	123.4128556	5.71	0.2	30.3601	Yolanda/ November 2-11, 2013	5-Year
46	10.88668	123.4128659	2.58	0	6.6564		5-Year
47	10.89215	123.4154028	4.75	0	22.5625		5-Year
48	10.93655	123.4206146	0.03	0.6	0.3249	Marce/November 24 -28, 2016	5-Year
49	10.88829	123.4136962	5.62	0	31.5844		5-Year
50	10.89798	123.4144229	5.71	0.2	30.3601	Yolanda/ November 2-11, 2013	5-Year
51	10.89053	123.4130661	6.06	0.2	34.3396	Yolanda/ November 2-11, 2013	5-Year
52	10.93826	123.4266992	0.14	0	0.0196		5-Year
53	10.88767	123.3510572	0.03	0.5	0.2209	Yolanda/ November 2-11, 2013	5-Year
54	10.94281	123.4271363	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
55	10.94779	123.4144961	0.54	0	0.2916		5-Year
56	10.89166	123.4150796	1.37	0	1.8769		5-Year
57	10.88746	123.4138217	4.44	0	19.7136		5-Year
58	10.88362	123.3495837	0.00	0	0		5-Year
59	10.88819	123.4135659	4.95	0	24.5025		5-Year
60	10.94931	123.4117194	0.1	1	0.81	Yolanda/ November 2-11, 2013	5-Year
61	10.94866	123.415151	0.72	0	0.5184		5-Year
62	10.94504	123.419977	0.03	0.3	0.0729	Yolanda/ November 2-11, 2013	5-Year
63	10.89353	123.4142786	0.03	0	0.0009		5-Year
64	10.88829	123.4137663	2.73	0	7.4529		5-Year
65	10.94956	123.4118795	0.05	1.5	2.1025	Yolanda/ November 2-11, 2013	5-Year
66	10.94901	123.4124439	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
67	10.88985	123.4138047	0.00	0.5	0.25	Yolanda/ November 2-11, 2013	5-Year
68	10.89388	123.4141792	5.12	0	26.2144		5-Year
69	10.94486	123.4127808	0.1	2	3.61	Yolanda/ November 2-11, 2013	5-Year
70	10.9471	123.4128954	0.21	1	0.6241	Yolanda/ November 2-11, 2013	5-Year
71	10.94125	123.4250748	0.03	0	0.0009		5-Year
72	10.93804	123.4228981	0.03	0.8	0.5929	Marce/November 24 -28, 2016	5-Year
73	10.89136	123.3540596	0.03	2.5	6.1009	Senyang/December 28-30, 2014	5-Year
74	10.94379	123.4243637	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
75	10.94798	123.4126136	0.00	1.5	2.25	Yolanda/ November 2-11, 2013	5-Year
76	10.94448	123.4226574	0.12	1	0.7744	Yolanda/ November 2-11, 2013	5-Year
77	10.94873	123.411936	0.56	0	0.3136		5-Year
78	10.94538	123.4124247	0.37	0.35	0.0004	Yolanda/ November 2-11, 2013	5-Year
79	10.89627	123.4128828	0.03	0	0.0009		5-Year
80	10.94769	123.4121133	0.16	1.5	1.7956	Yolanda/ November 2-11, 2013	5-Year
81	10.88862	123.4145798	3.45	0.15	10.89	Yolanda/ November 2-11, 2013	5-Year
82	10.93814	123.4265406	0.09	0	0.0081		5-Year
83	10.88516	123.3463296	0.00	0	0		5-Year
84	10.93711	123.4205947	0.55	0.6	0.0025	Marce/November 24 -28, 2016	5-Year
85	10.93403	123.4220335	0.04	0.65	0.3721	Yolanda/ November 2-11, 2013	5-Year
86	10.93393	123.4223241	1.18	0.65	0.2809	Yolanda/ November 2-11, 2013	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
87	10.94984	123.411379	0.05	1	0.9025	Yolanda/ November 2-11, 2013	5-Year
88	10.88415	123.3511928	0.00	0	0		5-Year
89	10.9476	123.413034	0.03	1.5	2.1609	Yolanda/ November 2-11, 2013	5-Year
90	10.88392	123.353926	0.67	1.5	0.6889	Ruby/December 6-7, 2014	5-Year
91	10.93823	123.4230217	0.03	0.8	0.5929	Marce/November 24 -28, 2016	5-Year
92	10.94181	123.4262827	0.09	1	0.8281	Yolanda/ November 2-11, 2013	5-Year
93	10.94222	123.4269669	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
94	10.94785	123.4121691	0.25	1.5	1.5625	Yolanda/ November 2-11, 2013	5-Year
95	10.94717	123.4133356	0.04	0	0.0016		5-Year
96	10.94743	123.4133695	0.31	0	0.0961		5-Year
97	10.94449	123.4205476	0.00	0.3	0.09	Yolanda/ November 2-11, 2013	5-Year
98	10.8908	123.3542476	4.66	2	7.075599	Ruping/November 13-18, 1996	100-Year
99	10.94782	123.4125584	0.24	0	0.0576		5-Year
100	10.94669	123.4109516	0.30	2	2.89	Sig #3/November 5-7, 1984	5-Year
101	10.94582	123.4137397	0.03	0	0.0009		5-Year
102	10.94898	123.4101126	0.03	0	0.0009		5-Year
103	10.94556	123.414017	0.06	0	0.0036		5-Year
104	10.94657	123.4102076	0.67	0	0.4489		5-Year
105	10.94168	123.4191304	0.26	2	3.0276	Yolanda/ November 2-11, 2013	5-Year
106	10.94083	123.4202902	0.47	2	2.3409	Yolanda/ November 2-11, 2013	5-Year
107	10.89189	123.3577537	1.21	3	3.2041	Yolanda/ November 2-11, 2013	5-Year
108	10.9455	123.4114517	0.64	0	0.4096		5-Year
109	10.94693	123.4125658	1.12	0	1.2544		5-Year
110	10.94939	123.4121342	0.68	1	0.1024	Yolanda/ November 2-11, 2013	5-Year
111	10.94532	123.4145939	0.03	0	0.0009		5-Year
112	10.94217	123.4266381	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
113	10.94568	123.4247056	0.03	1	0.9409	Marce/November 24 -28, 2016	5-Year
114	10.88547	123.3529407	0.00	0	0		5-Year
115	10.94778	123.4110035	0.03	0.6	0.3249	Yolanda/ November 2-11, 2013	5-Year
116	10.94503	123.4194403	0.47	0.3	0.0289	Yolanda/ November 2-11, 2013	5-Year
117	10.94869	123.4091837	1.09	0	1.1881		5-Year
118	10.9408	123.4198035	0.03	2	3.8809	Yolanda/ November 2-11, 2013	5-Year
119	10.94689	123.4135927	0.03	1	0.9409	Yolanda/ November 2-11, 2013	5-Year
120	10.9431	123.4242639	0.76	1	0.0576	Marce/November 24 -28, 2016	5-Year
121	10.94663	123.4141144	1.23	1	0.0529	Yolanda/ November 2-11, 2013	5-Year
122	10.88535	123.3536215	0.00	0	0		5-Year
123	10.94103	123.4205604	0.85	2	1.3225	Yolanda/ November 2-11, 2013	5-Year
124	10.94587	123.4126984	0.03	0.35	0.1024	Yolanda/ November 2-11, 2013	5-Year
125	10.88297	123.3536586	3.19	1.5	2.8561	Ruby/December 6-7, 2014	5-Year
126	10.9455	123.4112715	0.51	0	0.2601		5-Year
127	10.947	123.4134435	0.73	1	0.0729	Yolanda/ November 2-11, 2013	5-Year
128	10.94695	123.4143944	0.8	1	0.04	Yolanda/ November 2-11, 2013	5-Year
129	10.94077	123.4209853	0.97	2	1.0609	Yolanda/ November 2-11, 2013	5-Year
130	10.89127	123.3507638	0.06	0	0.0036	Frank/June 18-23, 2008	100-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
131	10.94646	123.409658	1.09	0	1.1881		5-Year
132	10.94662	123.4123274	0.84	0	0.7056		5-Year
133	10.94694	123.4114504	1.08	1.5	0.1764	Yolanda/ November 2-11, 2013	5-Year
134	10.94881	123.4094301	0.67	0	0.4489		5-Year
135	10.94613	123.4142009	0.97	1	0.0009	Yolanda/ November 2-11, 2013	5-Year
136	10.94109	123.4190218	0.89	2	1.2321	Yolanda/ November 2-11, 2013	5-Year
137	10.89125	123.3570098	3.07	3	0.0049	Yolanda/ November 2-11, 2013	5-Year
138	10.8848	123.3539152	0.51	1.5	0.9801	Ruby/December 6-7, 2014	5-Year
139	10.88527	123.3551674	0.47	0	0.2209		5-Year
140	10.8866	123.354211	1.36	0	1.8496		5-Year
141	10.89279	123.3549387	0.03	0.2	0.0289	Yolanda/ November 2-11, 2013	5-Year
142	10.88906	123.3534196	1.37	0	1.8769		5-Year
143	10.88613	123.3536963	0.11	0	0.0121		5-Year
144	10.88834	123.3536729	3.16	0	9.985601		5-Year
145	10.89299	123.3564838	0.05	0.2	0.0225	Yolanda/ November 2-11, 2013	5-Year
146	10.88535	123.3545947	0.00	0.3	0.09	Ondoy/September 24-30, 2009	5-Year
147	10.89117	123.3509395	0.04	0	0.0016	Frank/June 18-23, 2008	100-Year
148	10.88769	123.3547796	1.69	2	0.0961		5-Year
149	10.89275	123.3545688	0.04	0.2	0.0256	Yolanda/ November 2-11, 2013	5-Year
150	10.8828	123.3540693	0.92	1.5	0.3364	Ruby/December 6-7, 2014	5-Year
151	10.87203	123.3459072	0.21	5	22.9441	Yolanda/ November 2-11, 2013	5-Year
152	10.88474	123.3552168	2.02	0	4.0804		5-Year

Annex 12. Educational Institutions Affected by flooding in Tanao Flood Plain

Negros Occidental				
Sagay City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Fabrica	Faraon Institute			
Fabrica	Gil Lopez Elementary School			
Fabrica	TLRC Building			
Himoga-An Baybay	Fabrica Elementary School			
Himoga-An Baybay	Himogaan Integrated School			
Himoga-An Baybay	Holy Family School			
Himoga-An Baybay	Josebio Gonzaga Elementary School		High	High
Himoga-An Baybay	Paraiso Day Care		High	High
Malubon	Filomeno Pascual Elementary School		Medium	High
Malubon	Uychiat Elementary School			
Paraiso	Eusebio Lopez Integrated School			
Paraiso	Josebio Lopez Gonzaga Memorial Extension			

Annex 13. Health Institutions affected by flooding in Tanao Floodplain

Negros Occidental				
Sagay City				
Barangay	Building Name	Rainfall Scenario		
		5-year	25-year	100-year
Himoga-An Baybay	Paraiso Health Center		High	High

Annex 14. UPC Phil-LiDAR 1 Team Composition

Project Leader
Jonnifer R. Sinogaya, PhD.

Chief Science Research Specialist
Chito Patiño

Senior Science Research Specialists
Christine Coca
Jared Kislev Vicentillo

Research Associates
Isabella Pauline Quijano
Jarlou Valenzuela
Rey Sidney Carredo
Mary Blaise Obaob
Rani Dawn Olavides
Sabrina Maluya
Naressa Belle Saripada
Jao Hallen Bañados
Michael Angelo Palomar
Glory Ann Jotea