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

LiDAR Surveys and Flood Mapping of Umiray River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Central Luzon State University (CLSU)

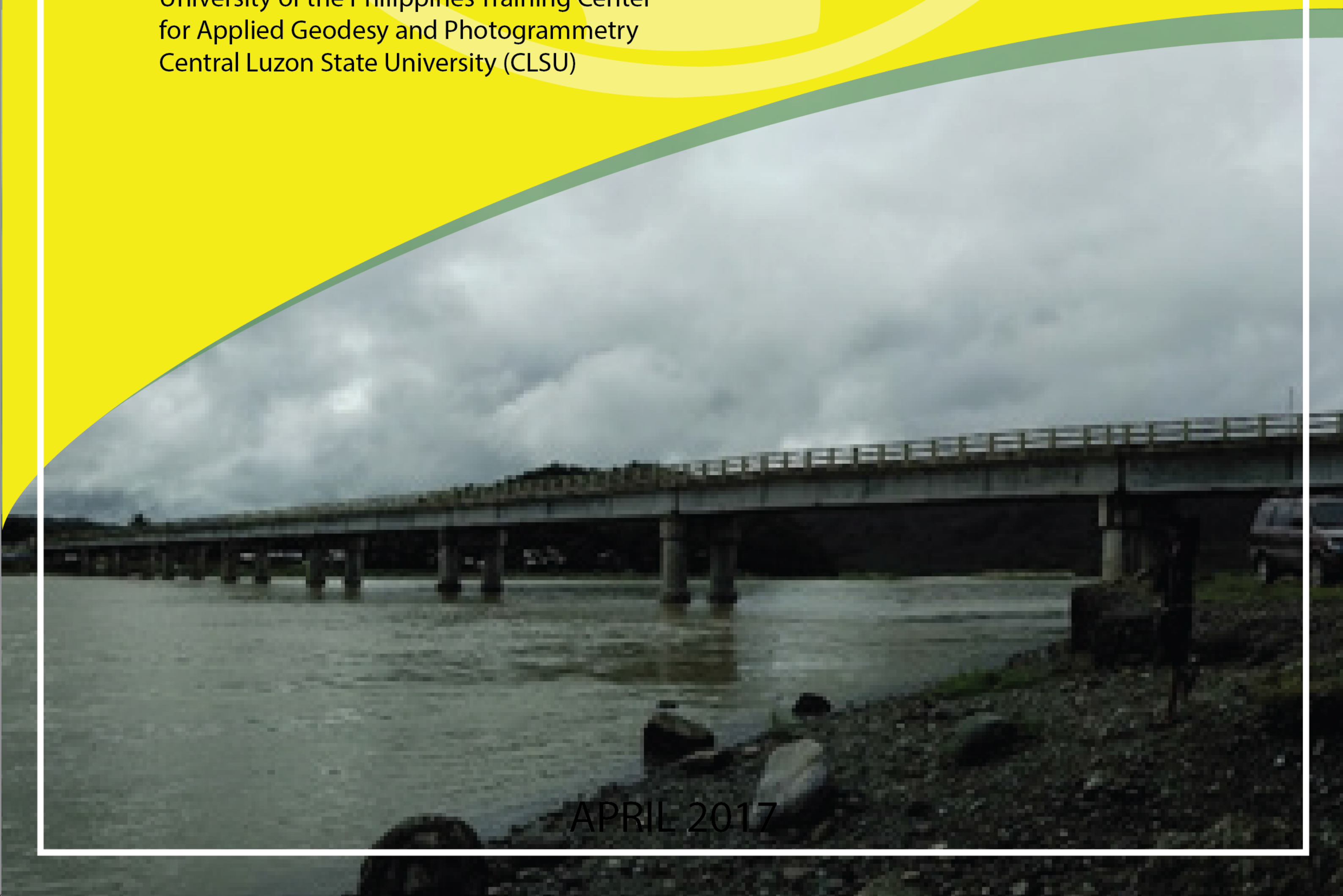

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TABLE OF CONTENTS

List of Tables .... **iv**
List of Figures .... **vi**
List of Acronyms and Abbreviations .... **viii**
CHAPTER 1: OVERVIEW OF THE PROGRAM AND UMIRAY RIVER **1**
1.1 Background of the Phil-LiDAR 1 Program 1
1.2 Overview of the Umiray River Basin 1
CHAPTER 2: LIDAR DATA ACQUISITION OF THE UMIRAY FLOODPLAIN **3**
2.1 Flight Plans 3
2.2 Ground Base Stations 6
2.3 Flight Missions 14
2.4 Survey Coverage 16
CHAPTER 3: LIDAR DATA PROCESSING OF THE UMIRAY FLOODPLAIN **19**
3.1 Overview of the LIDAR Data Pre-Processing 19
3.2 Transmittal of Acquired LiDAR Data 20
3.3 Trajectory Computation 20
3.4 LiDAR Point Cloud Computation 23
3.5 LiDAR Data Quality Checking 24
3.6 LiDAR Point Cloud Classification and Rasterization 29
3.7 LiDAR Image Processing and Orthophotograph Rectification 31
3.8 DEM Editing and Hydro-Correction 33
3.9 Mosaicking of Blocks 34
3.10 Calibration and Validation of Mosaicked LiDAR DEM 37
3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model 41
3.12 Feature Extraction 43
3.12.1 Quality Checking of Digitized Features' Boundary 43
3.12.2 Height Extraction 44
3.12.3 Feature Attribution 44
3.12.4 Final Quality Checking of Extracted Features 46
CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE UMIRAY RIVER BASIN .. **47**
4.1 Summary of Activities 47
4.2 Control Survey 49
4.3 Baseline Processing 52
4.4 Network Adjustment 53
4.5 Cross-section and Bridge As-Built Survey and Water Level Marking 55
4.6 Validation Points Acquisition Survey 60
4.7 Bathymetric Survey 62
CHAPTER 5: FLOOD MODELING AND MAPPING **65**
5.1 Data Used for Hydrologic Modeling 65
5.1.1 Hydrometry and Rating Curves 65
5.1.2 Precipitation 65
5.1.3 Rating Curves and River Outflow 66
5.2 RIDF Station 68
5.3 HMS Model 70
5.4 Cross-section Data 73
5.5 Flo 2D Model 74
5.6 Results of HMS Calibration 75
5.7 Calculated outflow hydrographs and Discharge values for different rainfall return periods 77
5.7.1 Hydrograph using the Rainfall Runoff Model 77
5.7.2 Discharge data using Dr. Horritts' recommended hydrologic method 78
5.8 River Analysis (RAS) Model Simulation 79
5.9 Flow Depth and Flood Hazard 80
5.10 Inventory of Areas Exposed to Flooding 84
5.11 Flood Validation 96
REFERENCES **98**
ANNEXES **99**
Annex 1. Technical Specifications of the LiDAR Sensors used in the Umiray Floodplain Survey 99
Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey 103
Annex 3. Baseline Processing Reports of Control Points used in the LiDAR Survey 109

Annex 4. The LiDAR Survey Team Composition 114
Annex 5. Data Transfer Sheets for the Umiray Floodplain Flights........ 116
Annex 6. Flight Logs for the Flight Missions 123
Annex 7. Flight Status Reports........ 139
Annex 8. Mission Summary Reports........ 156
Annex 9. Umiray Model Basin Parameters 251
Annex 10. Umiray Model Reach Parameters 254
Annex 11. Umiray Field Validation Points........ 255
Annex 12. Educational Institutions Affected by Flooding in Umiray Floodplain 259
Annex 13. Medical Institutions Affected by Flooding in Umiray Floodplain 260

LIST OF TABLES

Table 1. Flight planning parameters for the Pegasus LiDAR system....3
Table 2. Flight planning parameters for the Gemini LiDAR system....3
Table 3. Flight planning parameters for the Aquarius LiDAR system....4
Table 4. Flight planning parameters for the Leica LiDAR system....4
Table 5. Details of the recovered NAMRIA horizontal control point PMG-54, used as a base station for the LiDAR acquisition....7
Table 6. Details of the recovered NAMRIA horizontal control point BLN-56, used as a base station for the LiDAR acquisition....8
Table 7. Details of the recovered NAMRIA horizontal control point BLN-58, used as a base station for the LiDAR acquisition....9
Table 8. Details of the recovered NAMRIA horizontal control point PNG-66, used as a base station for the LiDAR acquisition....9
Table 9. Details of the recovered NAMRIA horizontal control point TRC-1, used as a base station for the LiDAR acquisition....10
Table 10. Details of the recovered NAMRIA horizontal control point NEJ-3060, used as a base station for the LiDAR acquisition....10
Table 11. Details of the established NAMRIA horizontal control point AAC-01 used as base station for the LiDAR acquisition....11
Table 12. Details of the established NAMRIA horizontal control point CSI-01 used as base station for the LiDAR acquisition....11
Table 13. Details of the recovered NAMRIA horizontal control point TRC-3008, used as a base station for the LiDAR acquisition....11
Table 14. Details of the recovered NAMRIA horizontal control point FMC-01, used as a base station for the LiDAR acquisition....12
Table 15. Details of the recovered NAMRIA horizontal control point BLLM-99 used as base station for the LiDAR acquisition....12
Table 16. Details of the recovered NAMRIA horizontal control point BL-142 used as base station for the LiDAR acquisition....13
Table 17. Ground control points used during the LiDAR data acquisition....13
Table 18. Flight missions for the LiDAR data acquisition in the Umiray floodplain....14
Table 19. Actual parameters used during the LiDAR data acquisition....15
Table 20. List of municipalities and cities surveyed during the Umiray floodplain LiDAR survey....16
Table 21. Self-calibration results for the Umiray flights....23
Table 22. List of LiDAR blocks for the Umiray floodplain....25
Table 23. Umiray classification results in TerraScan....29
Table 24. LiDAR blocks with their corresponding areas....33
Table 25. Shift values of each LiDAR block of the Umiray floodplain....35
Table 26. Calibration statistical measures....39
Table 27. Validation statistical measures....40
Table 28. Quality checking ratings for the Umiray building features....44
Table 29. Number of building features extracted for the Umiray floodplain....45
Table 30. Total length of extracted roads for the Umiray floodplain....46
Table 31. Number of extracted water bodies for the Umiray floodplain....46
Table 32. List of reference and control points occupied for the Umiray River Survey....49
Table 33. Baseline Processing Summary Report for the Umiray River survey....52
Table 34. Constraints applied to the adjustments of the control points....53
Table 35. Adjusted grid coordinates for the control points used in the Umiray floodplain survey....53
Table 36. Adjusted geodetic coordinates for control points used in the Umiray River floodplain validation....54
Table 37. Reference and control points used in the Umiray River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)....54
Table 38. RIDF values for the Infanta Rain Gauge, computed by PAGASA....68
Table 39. Range of calibrated values for the Umiray River Basin....75
Table 40. Summary of the Efficiency Test of the Umiray HMS Model....76
Table 41. Peak values of the Umiray HEC-HMS Model outflow using the Infanta RIDF....77
Table 42.Summary of the Umiray River (1) discharge generated in HEC-HMS....78
Table 43. Validation of river discharge estimates....78
Table 44. Municipalities affected in Umiray floodplain....80

Table 45. Affected areas in Dingalan, Aurora during a 5-year rainfall return period 84
Table 46. Affected areas in Doña Remedios Trinidad, Bulacan during a 5-year rainfall return period 85
Table 47. Affected areas in General Tinio, Nueva Ecija during a 5-year rainfall return period 86
Table 48. Affected areas in General Nakar, Quezon during a 5-year rainfall return period 86
Table 49. Affected areas in Dingalan, Aurora during a 25-year rainfall return period 87
Table 50. Affected areas in Doña Remedios Trinidad, Bulacan during a 25-year rainfall return period 88
Table 51. Affected areas in General Tinio, Nueva Ecija during a 25-year rainfall return period 89
Table 52. Affected areas in General Nakar, Quezon during a 25-year rainfall return period 90
Table 53. Affected areas in Dingalan, Aurora during a 100-year rainfall return period 91
Table 54. Affected areas in Doña Remedios Trinidad, Bulacan during a 100-year rainfall return period 92
Table 55. Affected areas in General Tinio, Nueva Ecija during a 100-year rainfall return period 93
Table 56. Affected areas in General Nakar, Quezon during a 100-year rainfall return period 94
Table 57. Areas covered by each warning level with respect to the rainfall scenarios 95
Table 58. Actual flood depth vs. Simulated flood depth in the Umiray floodplain 97
Table 59. Summary of Accuracy Assessment in the Umiray River Basin Survey 97

LIST OF FIGURES

Figure 1. Location map of the Umiray River Basin (in brown) 2
Figure 2. Flight plans and base stations used to cover the Umiray floodplain 5
Figure 3. (a) GPS set-up over PMG-54, located about 50 meters NE of Bldg. 2127 (main building) of the Clark Development Corp. and about 3 meters W of the Philippine flagpole; and (b) NAMRIA reference point PMG-54, as recovered by the field team 7
Figure 4. (a) GPS set-up over BLN-56, located within Casalat Elementary School, about 24 meters SSW of the main gate and about 0.5 meters E of the concrete fence in Barangay Casalat, San Idelfonso; and (b) NAMRIA reference point BLN-56, as recovered by the field 8
Figure 5. Actual LiDAR survey coverage of the Umiray floodplain 18
Figure 6. Schematic diagram for the Data Pre-Processing Component 20
Figure 7. Smoothed Performance Metric Parameters of a Umiray Flight 1444A 21
Figure 8. Solution Status Parameters of Umiray Flight 2302A 22
Figure 9. The best estimated trajectory conducted over the Umiray floodplain 23
Figure 10. Boundaries of the processed LiDAR data over the Umiray floodplain 24
Figure 11. Image of data overlap for the Umiray floodplain 26
Figure 12. Pulse density map of merged LiDAR data for the Umiray floodplain 27
Figure 13. Elevation difference map between flight lines for the Umiray floodplain 28
Figure 14. Quality checking for a Umiray flight 2302A using the Profile Tool of QT Modeler 29
Figure 15. (a) Tiles for the Umiray floodplain, and (b) classification results in TerraScan 30
Figure 16. Point cloud (a) before and (b) after classification 30
Figure 17. The (a) Production of last return DSM and (b) DTM, and (c) first return DSM and (d) secondary DTM in some portion of the Umiray floodplain 31
Figure 18. The Umiray floodplain with available orthophotographs 32
Figure 19. Sample orthophotograph tiles for the Umiray floodplain 32
Figure 20. Portions in the DTM of the Umiray floodplain – a bridge (a) before and (b) after manual editing; a missing tile (c) before and (d) after data retrieval; and a river data gap (e) before and (f) after manual editing 34
Figure 21. Map of processed LiDAR data for the Umiray floodplain 36
Figure 22. Map of the Umiray floodplain, with the validation survey points in green 38
Figure 23. Correlation plot between the calibration survey points and the LiDAR data 39
Figure 24. Correlation plot between the validation survey points and the LiDAR data 40
Figure 25. Map of the Umiray floodplain, with the bathymetric survey points shown in blue 42
Figure 26. Blocks (in blue) of Umiray building features that were subjected to QC 43
Figure 27. Video-tagging activity for the Umiray attribution of extracted features 44
Figure 28. Extracted features for the Umiray floodplain 46
Figure 29. Extent of the bathymetric survey (in blue line) in the Umiray River and the LiDAR data validation survey (in red) 48
Figure 30. Extent of the Umiray River Basin control survey 50
Figure 31. GNSS receiver set-up, Trimble® SPS 852, at ARA-25, located near the covered court inside the barangay complex of Barangay Ibuna, Municipality of Dingalan, Aurora 51
Figure 32. GNSS base set-up, Trimble® SPS 985, at NJ-305, located along the national road in Barangay Atate, Palayan City, Nueva Ecija 51
Figure 33. GNSS receiver set-up, Trimble® SPS 852, at UP-UMI, located at the deck of the Umiray Bridge in Barangay Umiray, Municipality of Dingalan, Aurora 52
Figure 34. The Umiray Bridge facing downstream 55
Figure 35. As-built survey of the Umiray Bridge 55
Figure 36. Umiray bridge cross-section location map 56
Figure 37. Umiray Bridge cross-section diagram 57
Figure 38. Bridge as-built form of the Umiray Bridge 58
Figure 39. Water-level markings on the Umiray Bridge 59
Figure 40. Validation points acquisition survey set-up along the Umiray River Basin 60
Figure 41. Extent of the LiDAR ground validation survey of the Umiray River Basin 61
Figure 42. Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in the Umiray River 62
Figure 43. Extent of the bathymetric survey of the Umiray River 63
Figure 44. Umiray riverbed profile 64
Figure 45. Location map of the Umiray HEC-HMS model used for calibration 66
Figure 46. Cross-section plot of the Umiray Bridge 67

Figure 48. Rainfall and outflow data at Umiray used for modeling 68
Figure 49. The Infanta RIDF station location, relative to the Umiray River Basin 69
Figure 50. Synthetic storm generated from a 24-hr period rainfall, for various return periods 69
Figure 51. Soil map of the Umiray River Basin (Source: DA) 70
Figure 52. Land cover map of the Umiray River Basin (Source: NAMRIA) 71
Figure 53. Slope map of the Umiray River Basin 72
Figure 54. Stream delineation map of the Umiray River Basin 72
Figure 55. The Umiray River basin model generated using HEC-HMS 73
Figure 56. River cross-section of the Umiray River, generated through ArcMap HEC GeoRAS tool ... 74
Figure 57. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D GDS Pro ... 74
Figure 58. Outflow hydrograph of Umiray produced by the HEC-HMS model, compared with observed outflow ... 75
Figure 59. Outflow hydrograph at the Umiray Station generated using Infanta RIDF simulated in HEC HMS ... 77
Figure 60. Umiray river generated discharge using 5-, 25-, and 100-year Infanta RIDF in HEC-HMS ... 78
Figure 61. Sample output map of Umiray RAS Model 79
Figure 62. 100-year flood hazard map for the Umiray floodplain 80
Figure 63. 100-year flow depth map for the Umiray floodplain 81
Figure 64. 25-year flood hazard map for the Umiray floodplain 81
Figure 65. 25-year flow depth map for the Umiray floodplain 82
Figure 66. 5-year flood hazard map for the Umiray floodplain 82
Figure 67. 5-year flow depth map for the Umiray floodplain 83
Figure 68. Affected Areas in Dingalan, Aurora during a 5-year rainfall return period 84
Figure 69. Affected areas in Doña Remedios Trinidad, Bulacan during a 5-year rainfall return period ... 85
Figure 70. Affected areas in General Tinio, Nueva Ecija during a 5-year rainfall return period 86
Figure 71. Affected areas in General Nakar, Quezon during a 5-year rainfall return period 87
Figure 72. Affected areas in Dingalan, Aurora during a 25-year rainfall return period 88
Figure 73. Affected areas in Doña Remedios Trinidad, Bulacan during a 25-year rainfall return period ... 89
Figure 74. Affected areas in General Tinio, Nueva Ecija during a 25-year rainfall return period 90
Figure 75. Affected areas in General Nakar, Quezon during a 25-year rainfall return period 91
Figure 76. Affected areas in Dingalan, Aurora during a 100-year rainfall return period 92
Figure 77. Affected areas in Doña Remedios Trinidad, Bulacan during a 100-year rainfall return period ... 93
Figure 78. Affected areas in General Tinio, Nueva Ecija during a 100-year rainfall return period 94
Figure 79. Affected areas in General Nakar, Quezon during a 100-year rainfall return period 95
Figure 80. Validation points for a 5-year flood depth map of the Umiray floodplain 96
Figure 81. Model flood depth vs. actual flood depth 97

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND UMIRAY RIVER

Enrico C. Paringit, Dr. Eng., Dr. Annie Melinda Paz-Alberto, and Kathrina M. Mapanao

1.1 Background of the Phil-LIDAR 1 Program

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

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through the DOST. The methods applied in this report are thoroughly described in a separate publication entitled “Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods” (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Central Luzon State University (CLSU). CLSU 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 nine (9) river basins in the Central Luzon Region. The university is located in Muñoz City in the province of Nueva Ecija.

1.2 Overview of the Umiray River Basin

The Umiray River Basin covers the Municipalities of General Nakar in the province of Quezon, and Dingalan in the province of Aurora. The Department of Environment and Natural Resource (DENR) River Basin Control Office (RBCO) identified the basin to have a drainage area of 553 km2, and an estimated annual run-off of 618 million cubic meters (MCM) (RBCO, 2015). The basin’s main stem, the Umiray River, is part of the nine (9) river systems in the Central Luzon Region.

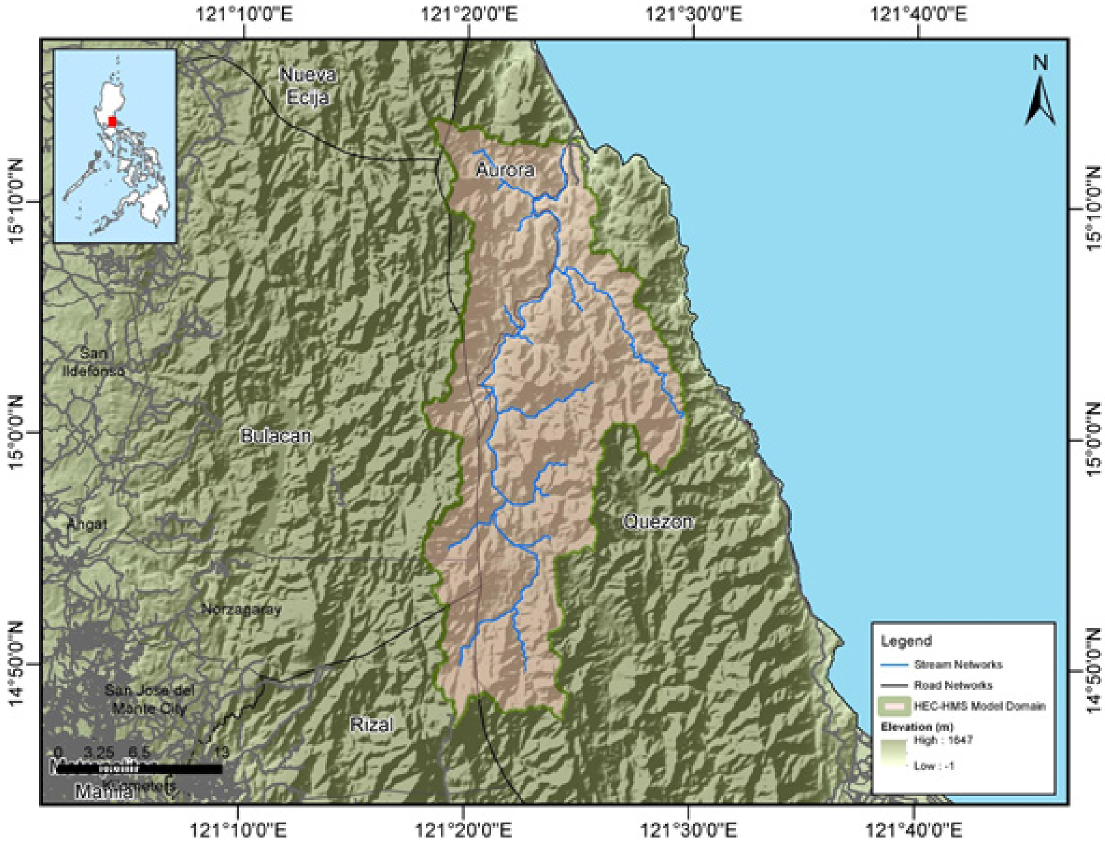

Figure 1. Location map of the Umiray River Basin (in brown)

According to the 2015 national census of the National Statistics Office (NSO), the total population of residents within the immediate vicinity of the river is 9,399, which is distributed among Barangay Umiray in Dingalan, Aurora; and Barangay Umiray in General Nakar, Quezon (NSO, 2015).

The major sources of revenue in the Municipality of General Nakar are agriculture, agro-industry, manufacturing, and commerce and trade. (http://calabarzon.dilg.gov.ph/generalnakar, 2017).

In October 2016, Typhoon Lawin (internationally known as Haima) entered the Philippine Area of Responsibility, specifically in the Municipality of Dingalan, Aurora. A total of eleven (11) barangays housing 2,074 families were directly affected by the said typhoon. (http://ndrrmc.gov.ph/attachments/article/2946/Sitrep_No_09_re_Preparedness_Measures_and_Effects_of_Super_Typhoon_LAWIN_(HAIMA)_as_of_25OCT2016_0800H.pdf, 2017).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE UMIRAY FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, and Jasmin M. Domingo

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 Umiray floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in the provinces of Aurora and Quezon. These missions were planned for fourteen (14) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Pegasus, Gemini, Aquarius, and Leica LiDAR systems were used for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR systems are found in Tables 1-4. Figure 2 illustrates the flight plans and base stations used for the Umiray floodplain survey.

Table 1. Flight planning parameters for the Pegasus LiDAR system

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

Table 2. Flight planning parameters for the Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK NEJ F	1000	30	40	125	40	130	5
PAM S1	850	30	40	100	50	130	5
	1000	30	40	100	50	130	5
	1650	30	40	70	50	130	5
PAM S3	850	30	40	100	50	130	5
	1000	30	40	100	50	130	5
	1650	30	40	70	50	130	5
PAM S8	1000	40	40	100	50	130	5
UMY A	1650	50/60	40	70/100	50	130	5
	1000	50	40	70/100	50	130	5
	700	50	40	70	50	130	5
UMY B	1650	50/60	40	70/100	50	130	5
	1000	50	40	70/100	50	130	5

Table 3. Flight planning parameters for the Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
NEJ V	600	30	36/30	50/36	50	130	5
PAM V	600	30	30	36	50	130	5
TRC V	600	30	30	36	50	130	5

Table 4. Flight planning parameters for the Leica LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
UMRY	1600	60	40	170	52	120	5

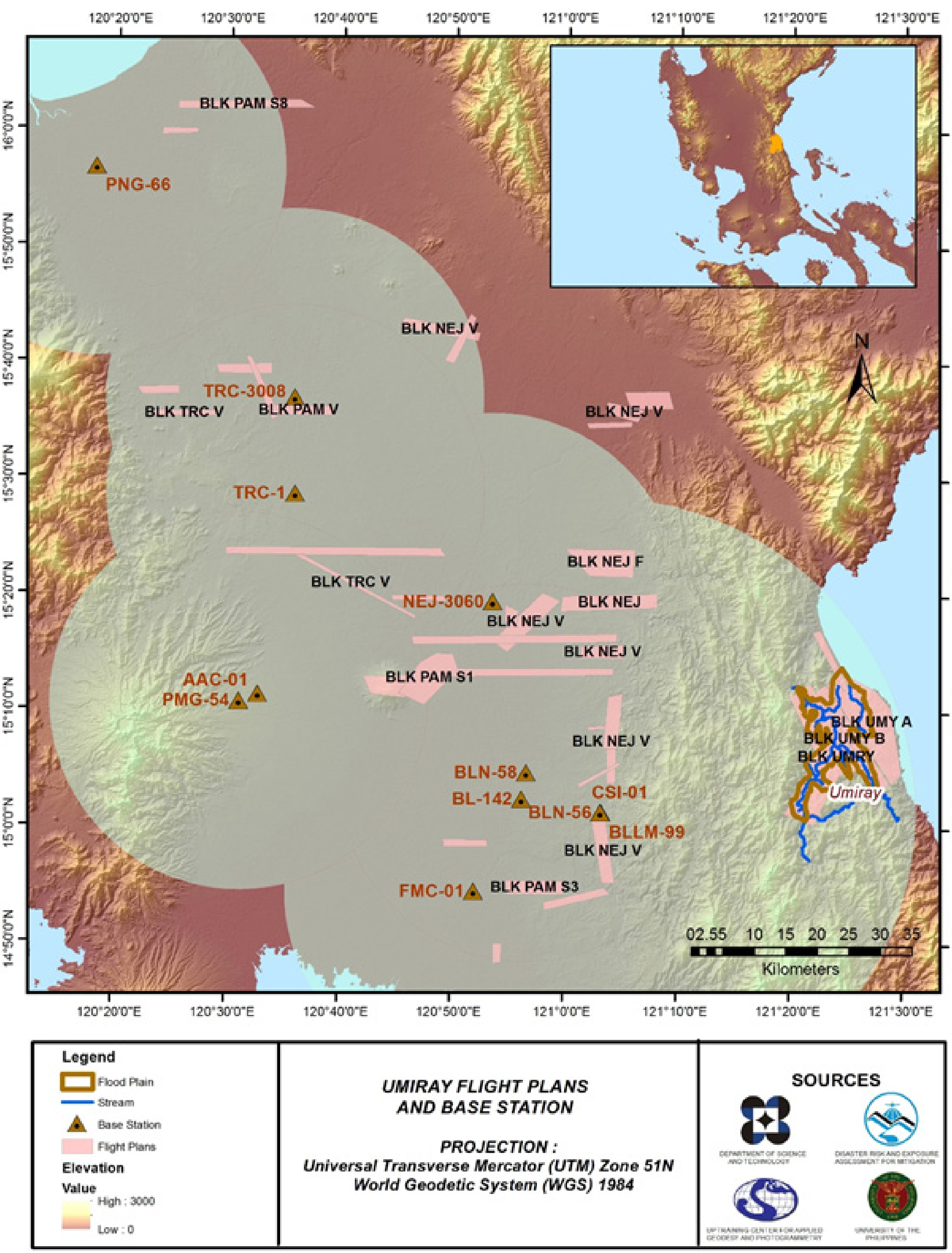

Figure 2. Flight plans and base stations used to cover the Umiray floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover five (5) NAMRIA horizontal ground control points: (i.) TRC-01, which is of first (1st) order accuracy; (ii.) BLN-56, (iii.) BLN-58, and (iv.) PNG-66, which are all of second (2nd) order accuracy; and (v.) PMG-54, which is of third (3rd) order accuracy. The project team also established three (3) ground control points – AAC-01, FMC-01, and CSI-01; and re-processed one (1) NAMRIA reference point – BLLM-99. One (1) NAMRIA benchmark was recovered: BL-142, which was used as a vertical reference point and was also established as a ground control point. The certifications for the NAMRIA reference points and benchmark are found in Annex 2, while the baseline processing reports for the ground control points are found in Annex 3. These were used as base stations during the flight operations for the entire duration of the survey, held on January 22-29, 2014; May 16-25, 2014; December 5-12, 2014; August 28-30, 2015; and July 27-28, 2016. The base stations were observed using dual frequency GPS receivers: TRIMBLE SPS852, TRIMBLE SPS985, and TOPCON GR-5. The flight plans and locations of the base stations used during the aerial LiDAR Acquisition in the Umiray floodplain are presented in Figure 2. The composition of the project team is shown in Annex 4.

Figure 3 and Figure 4 exhibit the recovered NAMRIA reference points within the area. Table 5 to Table 16 provide the details about the NAMRIA control stations and established points. Table 17 lists all of the ground control points occupied during the acquisition, with the corresponding dates of utilization.

Figure 3. (a) GPS set-up over PMG-54, located about 50 meters NE of Bldg. 2127 (main building) of the Clark Development Corp. and about 3 meters W of the Philippine flagpole; and (b) NAMRIA reference point PMG-54, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point PMG-54, used as a base station for the LiDAR acquisition

Station Name		PMG-54
Order of Accuracy		3rd
Relative Error (horizontal positioning)		1:20,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 10’ 50.24016” North 120o 31’ 8.01131” East 213.00650 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	448156.978 meters 1678845.621 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 10’ 44.64998” North 120o 31’ 8.01131” East 253.69780 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	233,266.88 meters 1,679,714.68 meters

Figure 4. (a) GPS set-up over BLN-56, located within Casalat Elementary School, about 24 meters SSW of the main gate and about 0.5 meters E of the concrete fence in Barangay Casalat, San Idelfonso; and (b) NAMRIA reference point BLN-56, as recovered by the field

Table 6. Details of the recovered NAMRIA horizontal control point BLN-56, used as a base station for the LiDAR acquisition

Station Name		BLN-56
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 1’ 26.96271” North 121o 3’ 12.22975” East 87.99600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	505742.035 meters 1661478.081 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 1’ 21.45113” North 120o 3’ 17.08731” East 130.44600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	290,711.27 meters 1,661,817.71 meters

Table 7. Details of the recovered NAMRIA horizontal control point BLN-58, used as a base station for the LiDAR acquisition

Station Name		BLN-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	15o 4’ 50.28672” North 121o 56’ 35.59715” East 24.21800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	493895.954 meters 1667726.854 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 4’ 44.75323” North 120o 56’ 40.45054” East 66.23600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	290,711.27 meters 1,661,817.71 meters

Table 8. Details of the recovered NAMRIA horizontal control point PNG-66, used as a base station for the LiDAR acquisition

Station Name		PNG-66
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 56’47.31803” North 120° 17’ 57.03550” East 10.57500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	424968.98 meters 1763650.683 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 56’ 41.53646” North 120° 18’ 1.81867” East 48.46800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	210862.35 meters 1764780.62 meters

Table 9. Details of the recovered NAMRIA horizontal control point TRC-1, used as a base station for the LiDAR acquisition

Station Name		TRC-1
Order of Accuracy		1st
Relative Error (horizontal positioning)		1 in 100,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 28’ 44.13765” North 120° 35’ 52.67202” East 46.89100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	456859.89 meters 1711833.357 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 28’ 38.48550” North 120° 35’ 57.49329” East 86.90220 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	242,278.30 meters 1,712, 636.20 meters

Table 10. Details of the recovered NAMRIA horizontal control point NEJ-3060, used as a base station for the LiDAR acquisition

Station Name		NEJ-3060
Order of Accuracy		4th
Relative Error (horizontal positioning)		1:10,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 19’ 32.78328” North 121o 53’ 29.45676” East 21.54500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	488350.739 meters 1694850.752 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 19’ 27.18854” North 120o 53’ 34.28956” East 62.72000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	273,621.71 meters 1,695,355.91 meters

Table 11. Details of the established NAMRIA horizontal control point AAC-01 used as base station for the LiDAR acquisition.

Station Name		AAC-01
Order of Accuracy		1st
Relative Error (horizontal positioning)		1:100,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 11’ 27.81685” North 120o 32’ 43.37833” East 154.260 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	2366272.483 meters 1680836.256 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Latitude Longitude Ellipsoidal Height	15o 11’ 22.22626” North 120o 32’ 48.22418” East 194.988 meters

Table 12. Details of the established NAMRIA horizontal control point CSI-01 used as base station for the LiDAR acquisition

Station Name		CSI-01
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 01’ 27.05916” North 121o 03’ 12.55894” East 87.998 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	290721.137 meters 1661820.692 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 01’ 21.54760” North 121o 03’ 17.41647” East 130.449 meters

Table 13. Details of the recovered NAMRIA horizontal control point TRC-3008, used as a base station for the LiDAR acquisition

Station Name		TRC-3008
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 37’ 01.26741” North 120° 35’ 46.76169” East 28.544 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 36’ 55.58374” North 120° 35’ 51.57129” East 68.142 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	242274.052 m 1727923.206 m

Table 14. Details of the recovered NAMRIA horizontal control point FMC-01, used as a base station for the LiDAR acquisition.

Station Name		FMC-01
Order of Accuracy		3rd
Relative Error (horizontal positioning)		1:20,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 54' 23.91904" North 120° 52' 05.23142" East 23.646 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 54' 29.41880" North 120° 52' 05.23142" East 23.646 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	270660.1554 m 1649166.271 m

Table 15. Details of the recovered NAMRIA horizontal control point BLLM-99 used as base station for the LiDAR acquisition

Station Name		BLLM-99
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 01' 27.13994" North 121° 03' 12.59033" East 88.082 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 01' 21.62838" North 121° 03' 17.44786" East 130.532 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	290722.097 m 1661823.067 m

Table 16. Details of the recovered NAMRIA horizontal control point BL-142 used as base station for the LiDAR acquisition.

Station Name		BL-142
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 02' 28.04346" North 120° 56' 11.50938" East 24.603 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 02' 22.51855" North 120° 56' 16.36612" East 66.719 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	278159.307 m 1663809.358 m

Table 17. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 22, 2014	2477P	1NEJ022A	AAC-01
January 29, 2014	7038GC	2NEJFG029A	NEJ-3060
May 16, 2014	7253G	2PAMS1S3136A	PMG-54 and FMC-1
May 24, 2014	7268GC	2PAMS8144A	PNG-66 and TRC-3008
May 25, 2014	7271GC	2PAMS1S3145B	BLN-58
December 5, 2014	2274A	3NEJV339A	AAC-01
December 6, 2014	2278A	3PAMV340A	AAC-01
December 10, 2014	2294A	3TRCV344A	AAC-01
December 11, 2014	2298A	3NEJV345A	AAC-01 and TRC-01
December 12, 2014	2302A	3NEJV346A	AAC-01
December 12, 2014	2304A	3NEJV346B	AAC-01
August 28, 2015	2662G	2UMYA240A	BLN-56 and BLLM-99
August 29, 2015	2666G	2UMYAB241A	BLN-56 and BLLM-99
August 30, 2015	2670G	2CLBUMYABS242A	BLN-56 and BL-142
July 27, 2016	10210L	4UMRY209A	BLN-56 and CSI-01
July 28, 2016	10212L	4UMRY210A	BLN-56 and CSI-01

2.3 Flight Missions

A total of sixteen (16) flight missions were conducted to complete LiDAR data acquisition in the Umiray floodplain, for a total of fifty seven hours and eight minutes (57+8) of flying time for RP-C9022, RP-C9122, RP-C9322, and RP-C9522. All missions were acquired using Pegasus, Gemini, Aquarius, and Leica LiDAR systems. The flight logs of the missions are presented in Annex 6. Table 18 indicates the total area of actual coverage and the corresponding flying hours per mission, while Table 19 outlines the actual parameters used during the LiDAR data acquisition.

Table 18. Flight missions for the LiDAR data acquisition in the Umiray 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
January 22, 2014	2477P	59.66	86.56	0.00	86.56	0	3	11
January 29, 2014	7038GC	38.66	55.98	0.00	55.98	0	3	35
May 16, 2014	7253G	178.68	97.09	0.00	97.09	0	4	7
May 24, 2014	7268GC	78.55	148.32	0.00	148.32	0	3	46
May 25, 2014	7271GC	178.68	151.23	0.00	151.23	0	3	59
December 5, 2014	2274A	157.61	27.07	0.00	27.07	0	2	53
December 6, 2014	2278A	49.02	60.40	0.00	60.40	0	3	59
December 10, 2014	2294A	28.16	37.05	0.00	37.05	0	3	11
December 11, 2014	2298A	157.61	56.23	0.00	56.23	0	4	23
December 12, 2014	2302A	157.61	31.94	0.00	31.94	0	2	53
December 12, 2014	2304A	157.61	19.37	0.00	19.37	0	2	59
August 28, 2015	2662G	89.48	51.08	11.62	39.46	401	3	59
August 29, 2015	2666G	160.55	88.82	26.94	61.89	272	3	0
August 30, 2015	2670G	160.55	129.89	51.21	78.68	466	4	10
July 27, 2016	10210L	120.43	70.61	39.08	31.53	221	3	10
July 28, 2016	10212L	120.43	125.21	73.40	51.82	429	3	53
TOTAL		1893.29	1236.85	202.25	1034.62	1789	57	08

Table 19. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2477P	1000	30	50	200	30	130	5
7038GC	1070	30	40	125	40	130	5
7253G	850	30	40	100	50	130	5
	1000	30	40	100	50	130	5
	1650	30	40	70	50	130	5
7268GC	1070	40	40	100	50	130	5
7271GC	1070	40	40	100	50	130	5
2274A	670	30	36	50	50	130	5
2278A	670	30	30	36	50	130	5
2294A	690	30	30	36	50	130	5
2298A	650	30	30	36	50	130	5
2302A	660	30	30	36	50	130	5
2304A	700	30	30	36	50	130	5
2662G	1750	50	40	70	50	130	5
	1000	50	40	70	50	130	5
	730	50	40	70	50	130	5
2666G	1650	60	40	100	50	130	5
	1200	60	40	100	50	130	5
	1100	60	40	100	50	130	5
2670G	1100	60	40	100	50	130	5
10210L	1600	60	40	170	52	120	5
10212L	1600	60	40	170	52	120	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Umiray floodplain, located in the provinces of Aurora and Quezon. Majority of the floodplain is situated in the Municipalities of Dingalan in Aurora, and General Nakar in Quezon. The Municipalities of Angat, Baliuag, Peñaranda, and San Isidro are mostly covered by the survey. The municipalities and cities surveyed, with at least one (1) square kilometer coverage, are enumerated in Table 20. The actual coverage of the LiDAR acquisition for the Umiray floodplain is presented in Figure 5. The flight status reports are found in Annex 7.

Table 20. List of municipalities and cities surveyed during the Umiray floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Aurora	Dingalan	373.11	89.81	24.07%
Bulacan	Angat	53.62	24.53	45.74%
	Baliuag	48.85	21.48	43.97%
	Bustos	43.15	15.58	36.10%
	Guiguinto	20.40	4.92	24.14%
	Pandi	41.84	8.81	21.05%
	San Miguel	272.04	54.87	20.17%
	San Ildefonso	130.48	18.16	13.92%
	Balagtas	19.21	2.66	13.85%
	San Rafael	106.34	8.38	7.88%
	Plaridel	39.17	2.03	5.19%
	Norzagaray	238.95	4.70	1.97%
	Bulacan	75.31	1.23	1.63%
	Doña Remedios Trinidad	871.20	2.43	0.28%
Nueva Ecija	Peñaranda	66.68	29.73	44.59%
	San Isidro	44.49	18.35	41.24%
	Gapan City	163.45	63.95	39.12%
	Cabiao	110.18	38.38	34.83%
	San Antonio	169.06	33.85	20.02%
	General Mamerto Natividad	114.07	14.64	12.84%
	Muñoz City	122.90	10.42	8.48%
	General Tinio	659.83	54.67	8.28%
	San Leonardo	51.79	4.20	8.10%
	Guimba	214.42	15.04	7.01%
	Talugtug	101.03	5.16	5.11%
	Palayan City	88.39	3.26	3.69%
	Bongabon	225.26	7.84	3.48%
	Jaen	93.66	3.23	3.45%
	Santa Rosa	140.49	3.18	2.26%
	Rizal	162.40	1.67	1.03%

Pampanga	Arayat	153.46	41.17	26.83%
	San Simon	50.46	9.53	18.89%
	Magalang	99.89	10.61	10.62%
	Santa Ana	52.19	3.34	6.39%
	Apalit	63.38	2.69	4.25%
	San Fernando City	72.06	1.76	2.44%
	Mexico	118.25	1.70	1.44%
	Porac	238.99	2.76	1.15%
Pangasinan	Mapandan	21.35	6.26	29.34%
	Laoac	40.70	7.50	18.43%
	Santa Barbara	64.71	9.10	14.06%
	Manaoag	42.42	4.54	10.70%
	Binalonan	78.54	6.18	7.87%
	Mangaldan	43.42	2.50	5.76%
	Asingan	65.93	1.22	1.85%
Quezon Tarlac	General Nakar	1275.55	190.93	14.97%
	Paniqui	108.69	18.94	17.42%
	Gerona	128.21	18.89	14.74%
	Concepcion	234.56	26.99	11.51%
	Pura	28.52	2.59	9.07%
	Santa Ignacia	145.32	11.84	8.15%
	La Paz	122.26	8.01	6.55%
	Mayantoc	244.09	10.53	4.32%
	Capas	467.83	16.04	3.43%
	Victoria	107.37	3.18	2.96%
	Camiling	130.78	1.17	0.89%
TOTAL		9060.71	987.14	10.89%

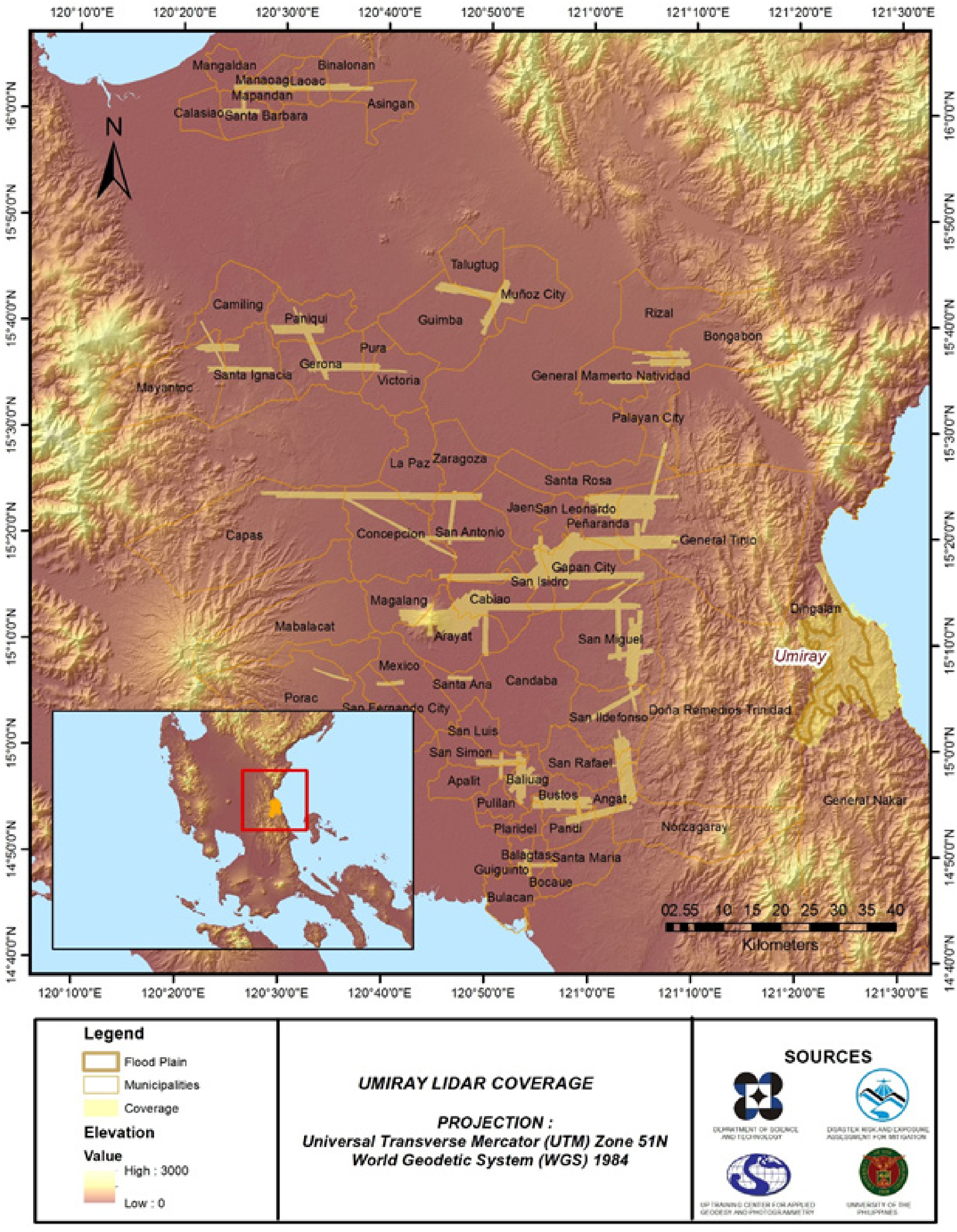

Figure 5. Actual LiDAR survey coverage of the Umiray floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE UMIRAY FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the diagram in Figure 6.

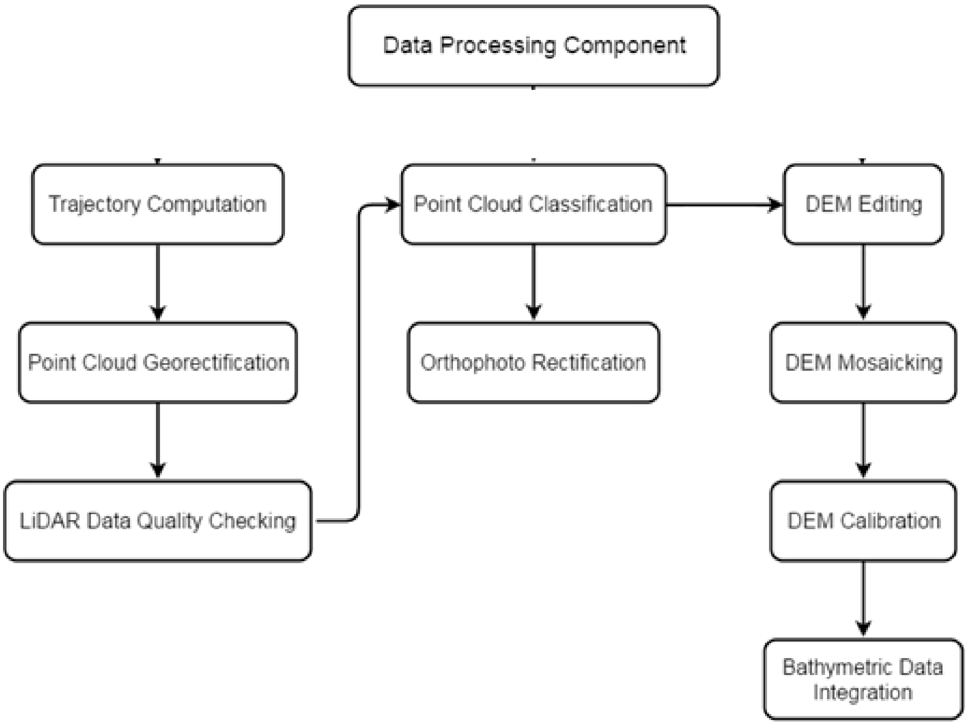


Figure 6. Schematic diagram for the Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Umiray floodplain can be found in Annex 5. Missions flown during the first survey conducted in May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system. On the other hand, missions acquired during the second survey in February 2015 were flown using the Gemini, Aquarius and Pegasus systems. Finally, the third survey was done in August 2016 using the Leica system over Dingalan, Aurora and General Nakar, Quezon. The DAC transferred a total of 131.89 Gigabytes of Range data, 2.73 Gigabytes of POS data, 189.04 Megabytes of GPS base station data, and 205.80 Gigabytes of Image data to the data server from May 26, 2014 until September 11, 2015 for the Optech LiDAR systems. Moreover, a total of 17.8 Gigabytes of RawLaser data, 818 Megabytes of GNSSIMU data, 252 Megabytes of base station data, and 47.4 Gigabytes of RCD30 raw image data were transferred on August 9, 2016 for the Leica LiDAR system. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Umiray River survey was fully transferred on August 9, 2016, as indicated on the data transfer sheets for the Umiray floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2302A, one of the Umiray flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on May 29, 2014 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

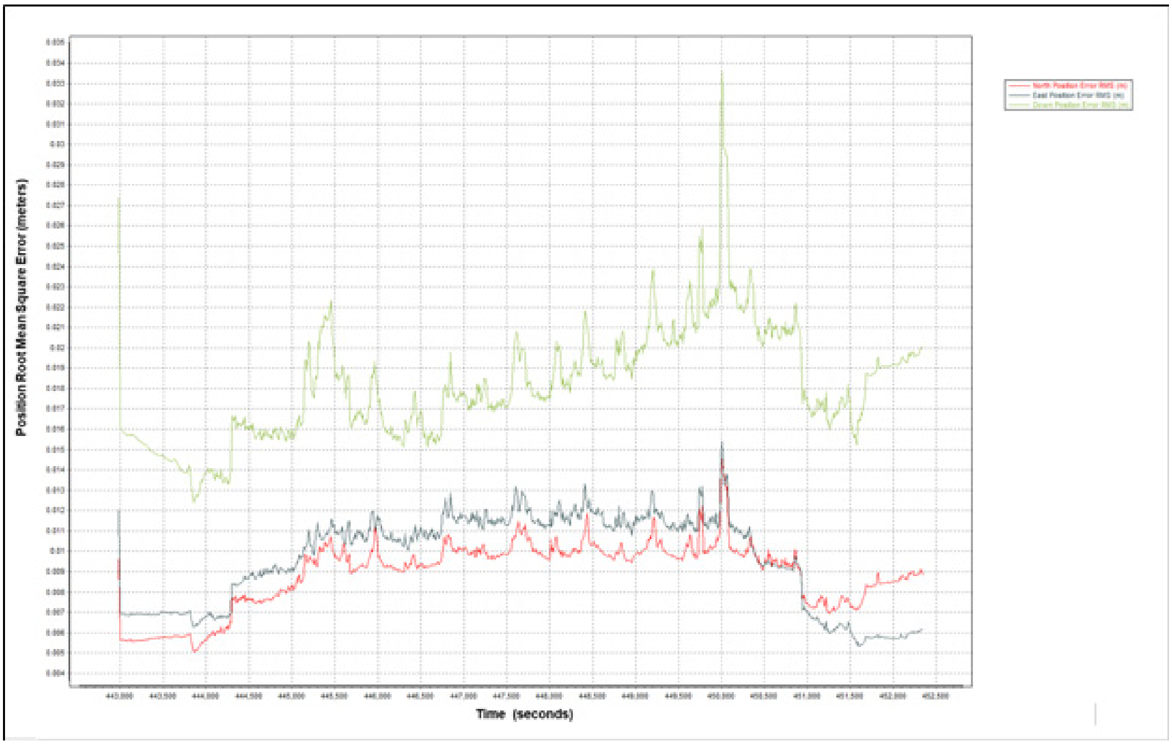


Figure 7. Smoothed Performance Metrics of Umiray Flight 1444A.

The time of flight was from 443,000 seconds to 452,500 seconds, which corresponds to the morning of May 29, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 demonstrates that the North position RMSE peaked at 1.50 centimeters, the East position RMSE peaked at 1.60 centimeters, and the Down position RMSE peaked at 3.40 centimeters, which are all within the prescribed accuracies described in the methodology.

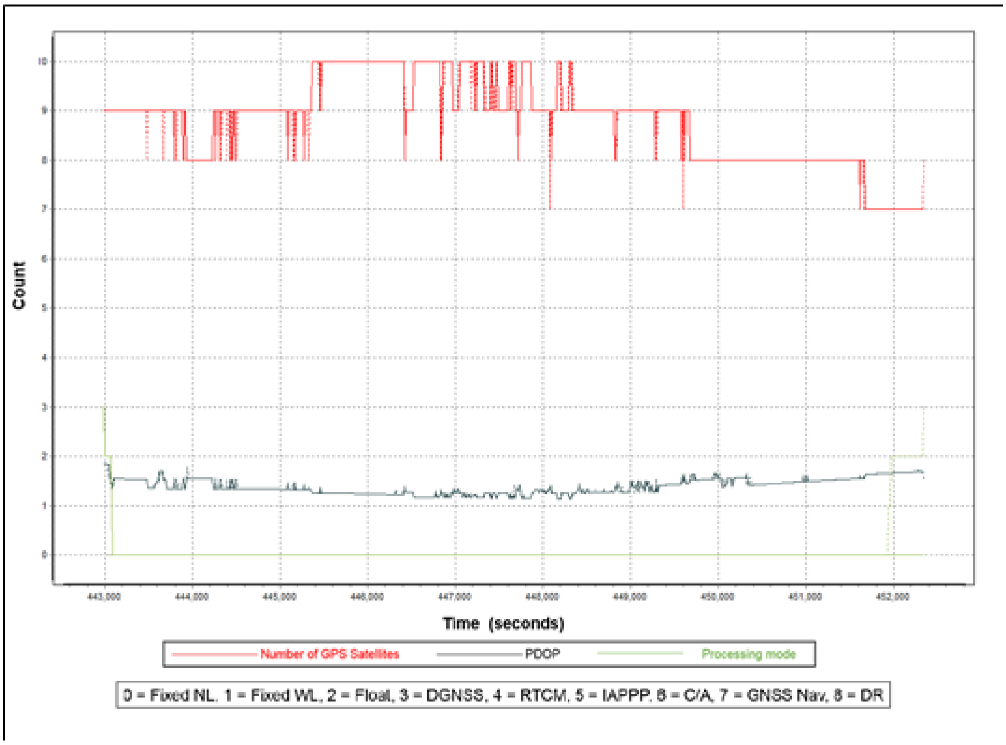


Figure 8. Solution Status Parameters of an Umiray Flight 2302A

The Solution Status parameters of flight 2302A, one of the Umiray flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are presented in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to six (6). Most of the time, the number of satellites tracked was between six (6) and ten (10). The PDOP value did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remained at zero (0) for majority of the survey with some peaks to up to one (1), attributed to the turns performed by the aircraft. The value of zero (0) represents a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Umiray flights is exhibited in Figure 9.

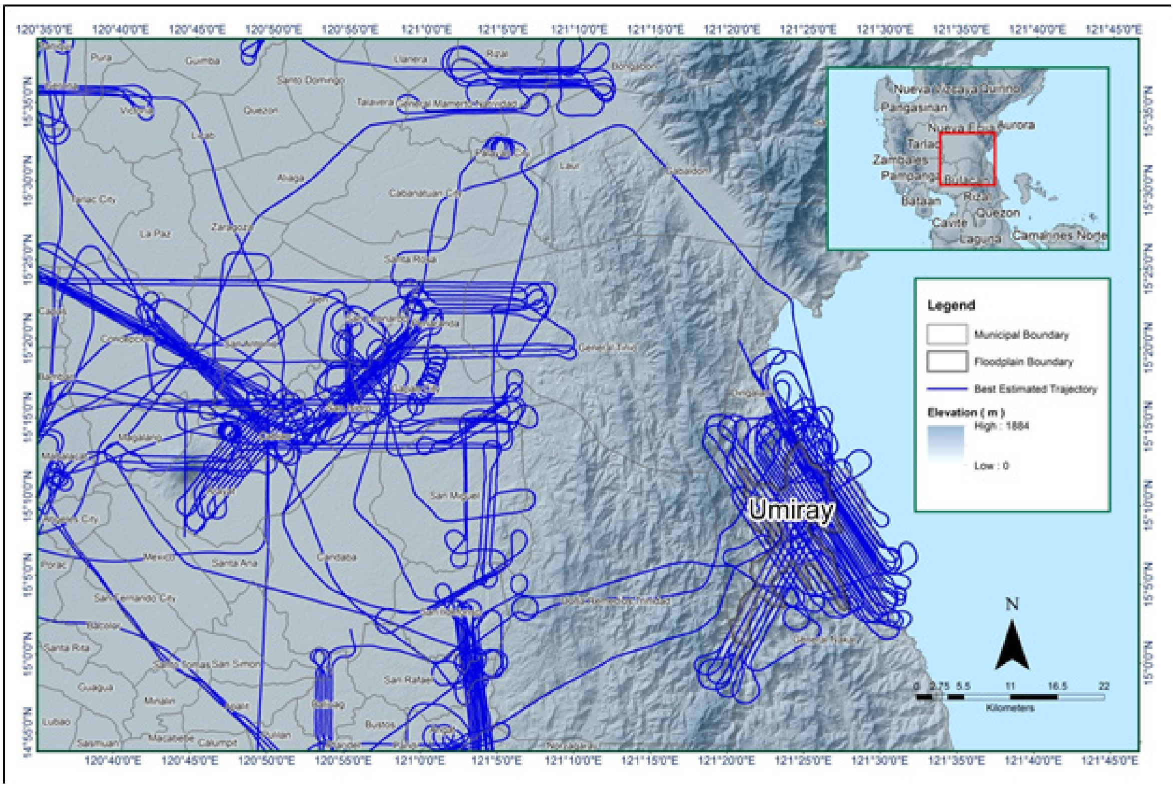


Figure 9. The best estimated trajectory conducted over the Umiray floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains one hundred and sixty-one (161) flight lines, with each flight line containing one channel for both the Gemini and Aquarius systems and two channels for both Pegasus and Leica systems. The summary of the self-calibration results for all flights over the Umiray floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 21.

Table 21. Self-calibration results for the Umiray flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000375
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000932
GPS Position Z-correction stdev (<0.01meters)	0.0017

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data are represented in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

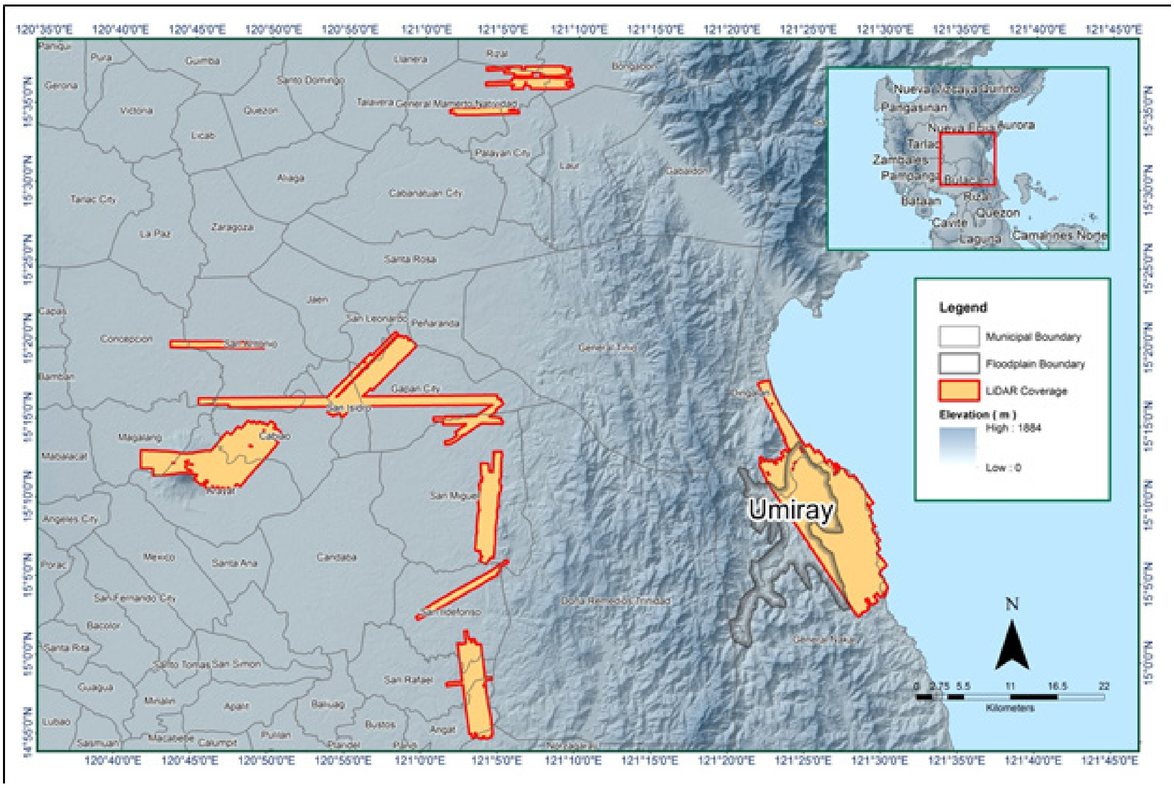


Figure 10. Boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Umiray floodplain.

The total area covered by the Umiray missions is 743.34 sq. km., comprised of sixteen (16) flight acquisitions grouped and merged into nineteen (19) blocks, as indicated in Table 22.

Table 22. List of LiDAR blocks for the Umiray floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bataan_Reflights_Pam8A_additional	2477P	26.16
Bataan_Reflights_Pam3D_additional2	2477P	42.04
Umiray_BlkA	10212L	96.45
Umiray_BlkB	10210L	56.45
Clark_Reflights_Pam3J_additional	2298A	23.75
Clark_Reflights_Pam3D_additional2	2278A	15.57
Clark_Reflights_Pam3D_additional1	2274A	25.10
Clark_Reflights_Pam3C_additional	2294A	0.01
Clark_Reflights_Pam3B_additional	2304A	11.51
Clark_Reflight_UMYAB	2666G 2670G	105.43
Clark_Reflight_UMYAB_additional	2666G	36.71
Clark_Reflights_UMYA	2662G	48.68
Clark_Reflights_Pam8D_additional	2302A	31.56
Clark_Reflights_Pam8B_additional	2304A	9.41
Pam_Agno_Reflights_PamBlk8_reflight_additional	7271GC	52.59
Pam_Agno_Reflights_PamBlk3D_reflight	7268GC	8.14
Pam_Agno_Reflights_PamBlk3C_reflight	7268GC	41.81
Pam_Agno_Reflights_PamBlk3A_reflight	7253G	64.51
NuevaEcija_Blk7038GC	7038GC	45.46
TOTAL		743.34 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 11. Since the Gemini and Aquarius systems employ one (1) channel, it is expected to have an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus and Leica systems which employ two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

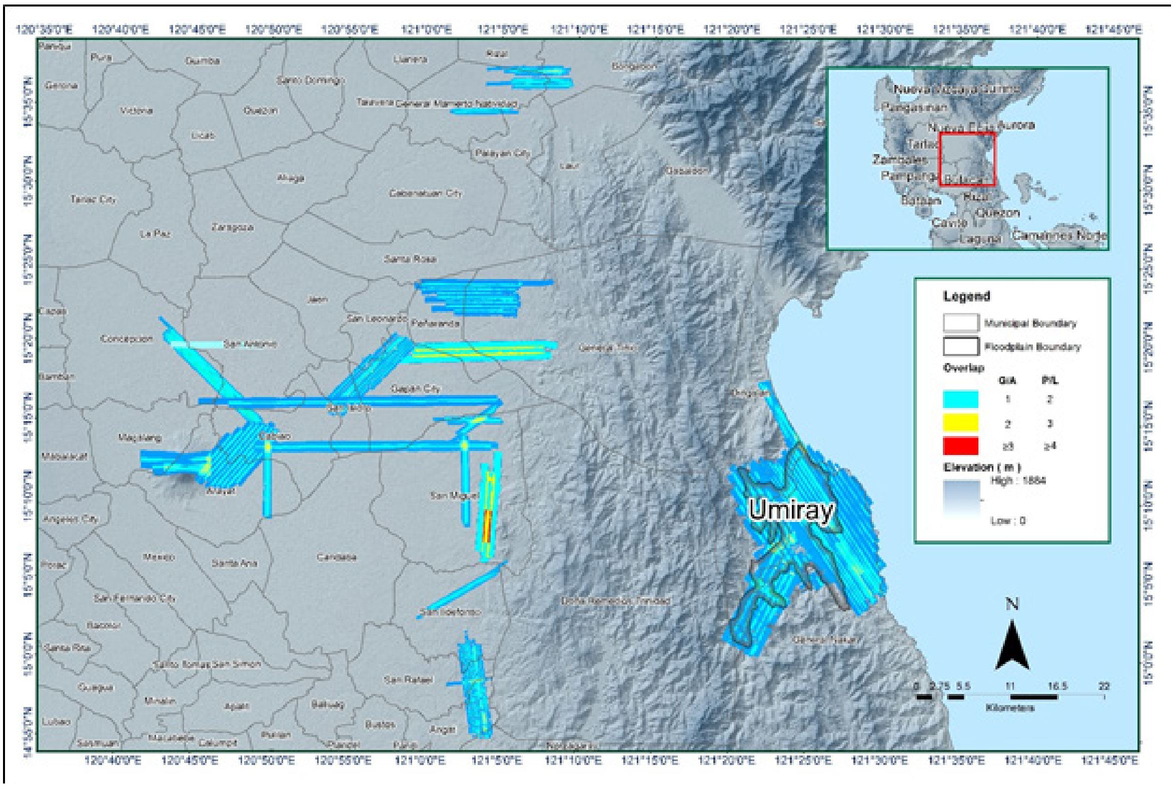


Figure 11. Image of data overlap for the Umiray floodplain

The overlap statistics per block for the Umiray floodplain can be found in Annex 8. It should be noted that one (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.02% and 46.76%, respectively, which satisfied 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 illustrated in Figure 12. It was determined that all LiDAR data for the Umiray floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.30 points per square meter.

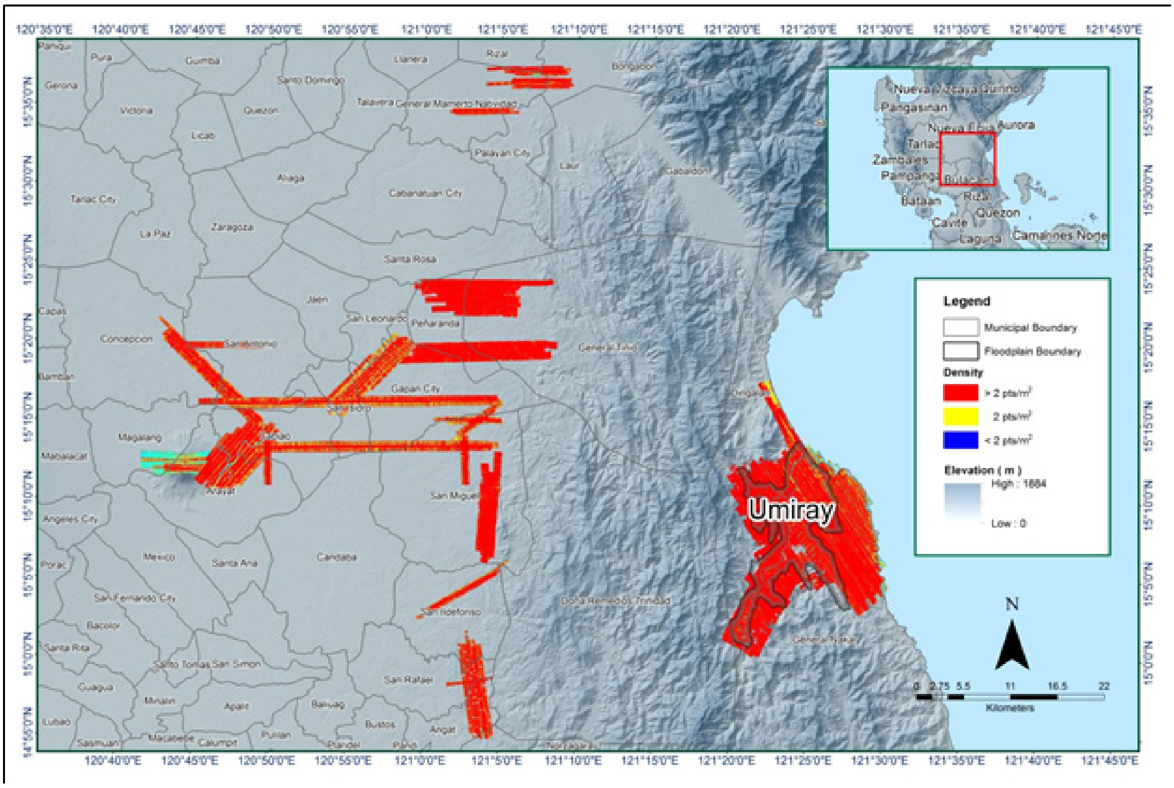


Figure 12. Pulse density map of merged LiDAR data for the Umiray floodplain

The elevation difference between overlaps of adjacent flight lines is demonstrated in Figure 13. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to elevations of its adjacent flight line. Areas with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

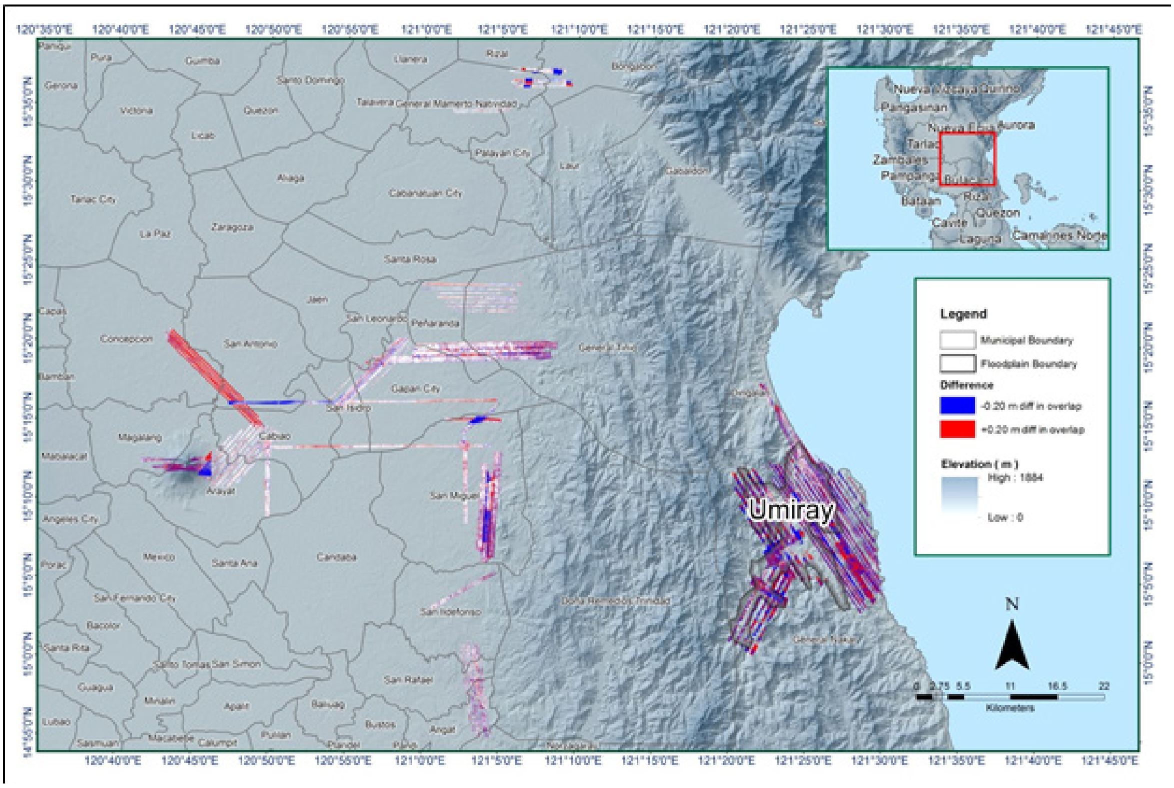


Figure 13. Elevation difference map between flight lines for the Umiray floodplain

A screen capture of the processed LAS data from an Umiray flight 2302A loaded in the QT Modeler is provided in Figure 14. The upper left image shows the elevations of the points from two (2) 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 were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

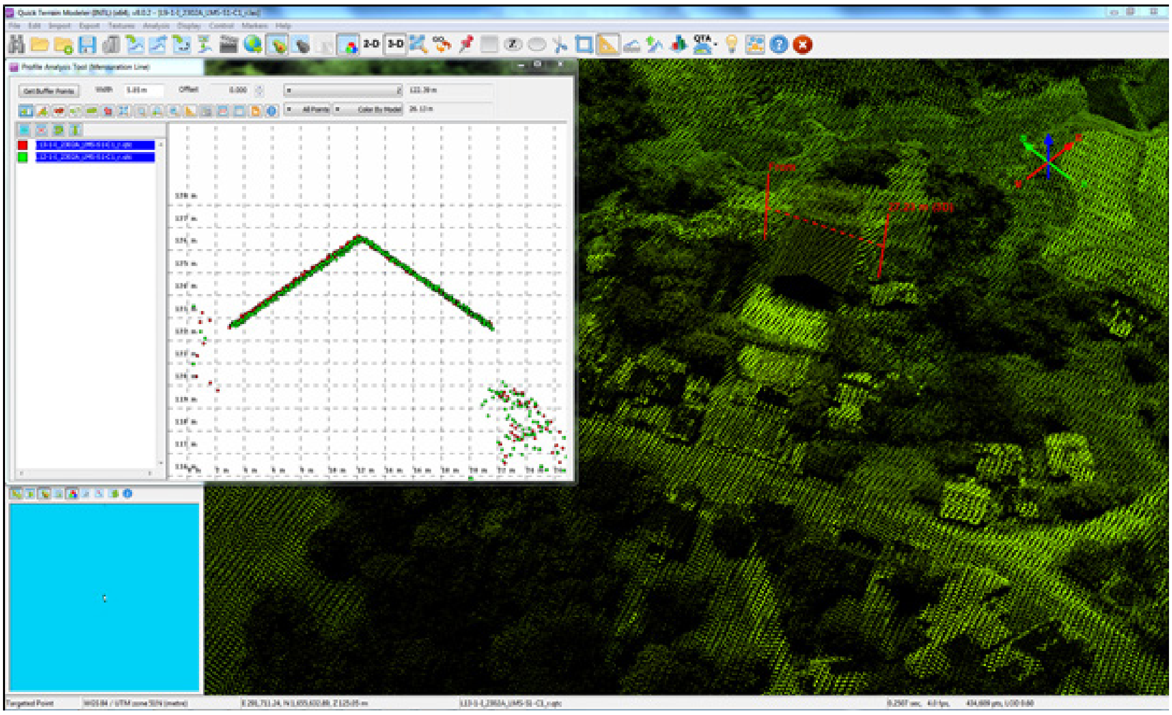


Figure 14. Quality checking for an Umiray flight 2302A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 23. Umiray classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	402,064,254
Low Vegetation	433,190,663
Medium Vegetation	506,938,249
High Vegetation	1,302,696,990
Building	175,457,092

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Umiray floodplain, are presented in Figure 15. A total of 1,273 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 23. The point cloud had a maximum and minimum height of 775.87 meters and 42.58 meters, respectively.

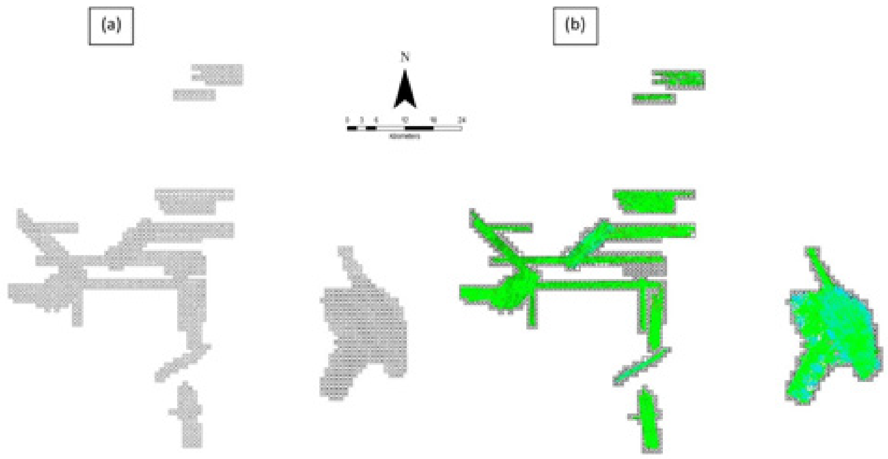


Figure 15. (a) Tiles for the Umiray floodplain, and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 16. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

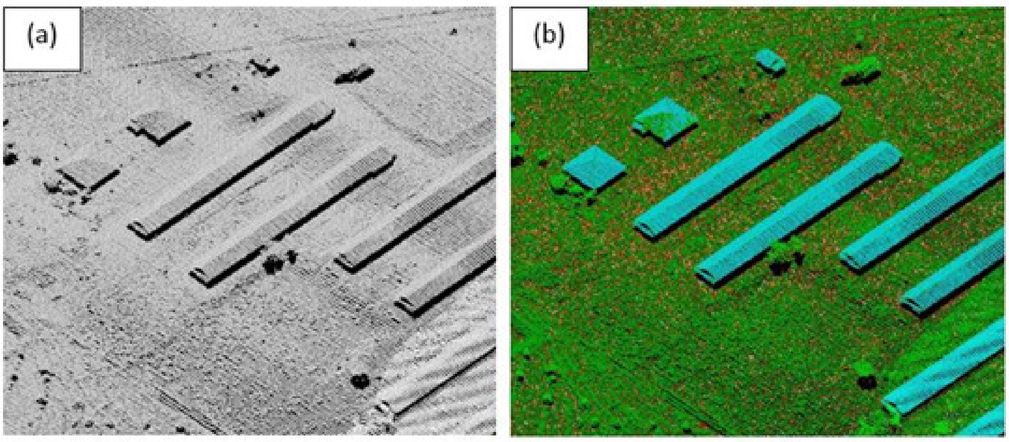


Figure 16. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 17, in top view display. The images show that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

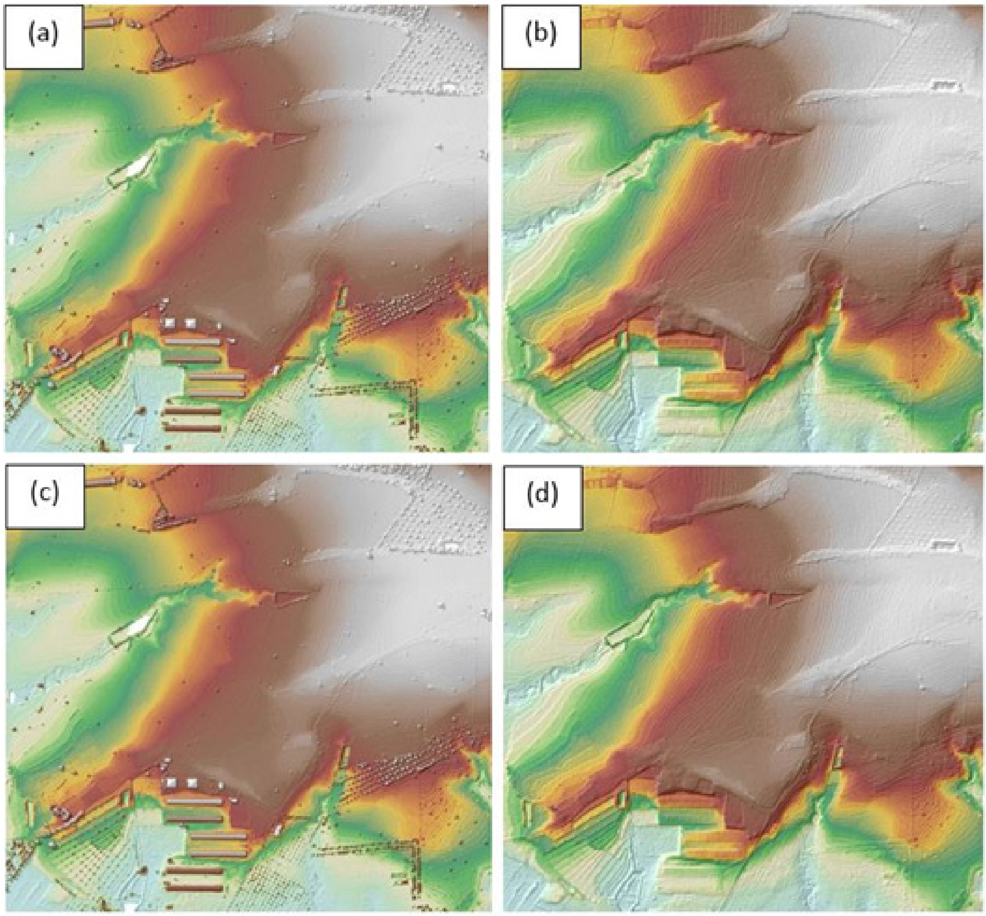


Figure 17. The (a) Production of last return DSM and (b) DTM, and (c) first return DSM and (d) secondary DTM in some portion of the Umiray floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 271 1km by 1km tiles area covered by the Umiray floodplain is presented in Figure 18. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Umiray floodplain survey attained a total of 160.25 sq. km. in orthophotographic coverage, comprised of 1,033 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 19.

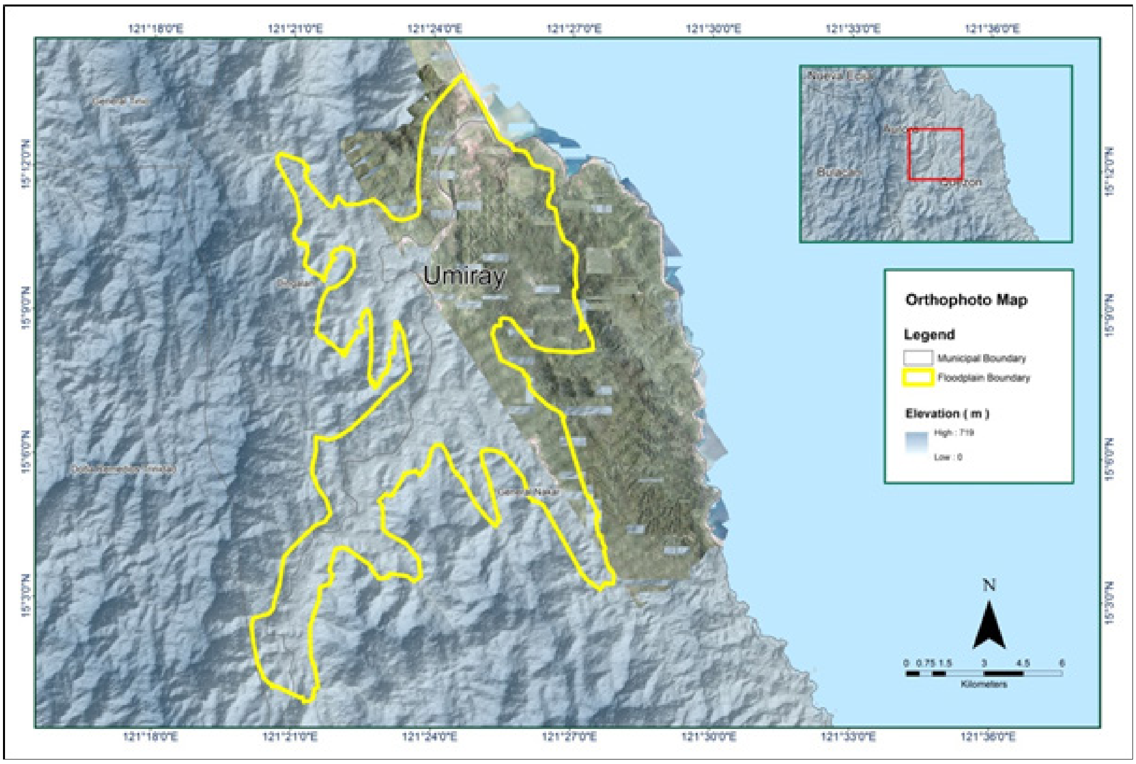


Figure 18. The Umiray floodplain with available orthophotographs

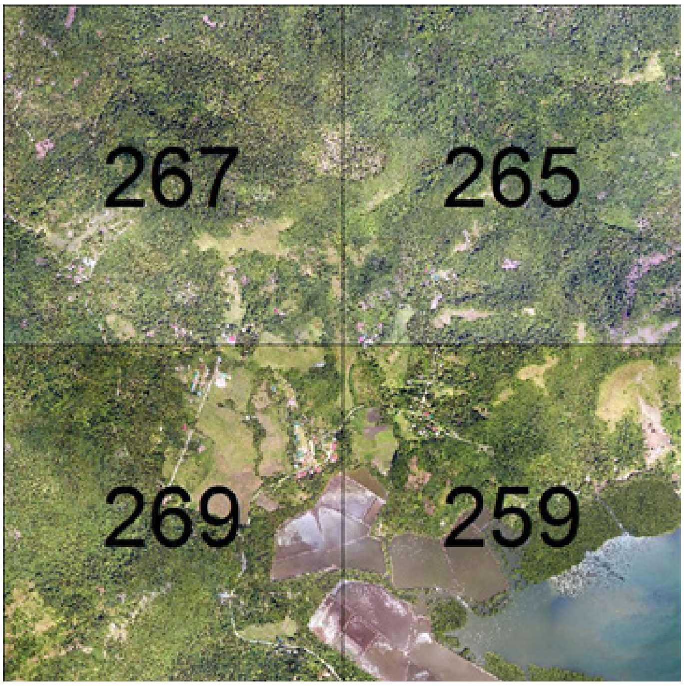


Figure 19. Sample orthophotograph tiles for the Umiray floodplain

3.8 DEM Editing and Hydro-Correction

Nineteen (19) mission blocks were processed for the Umiray floodplain. These blocks are composed of Bataan Reflights, Clark Reflights, Pam_Agno Reflights, and Umiray blocks, with a total area of 743.34 square kilometers. Table 24 enumerates the names and corresponding areas of the blocks, in square kilometers.

Table 24. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Bataan_Reflights_Pam8A_additional	26.16
Bataan_Reflights_Pam3D_additional2	42.04
Umiray_BlkA	96.45
Umiray_BlkB	56.45
Clark_Reflights_Pam3J_additional	23.75
Clark_Reflights_Pam3D_additional2	15.57
Clark_Reflights_Pam3D_additional1	25.10
Clark_Reflights_Pam3C_additional	0.01
Clark_Reflights_Pam3B_additional	11.51
Clark_Reflight_UMYAB	105.43
Clark_Reflight_UMYAB_additional	36.71
Clark_Reflights_UMYA	48.68
Clark_Reflights_Pam8D_additional	31.56
Clark_Reflights_Pam8B_additional	9.41
Pam_Agno_Reflights_PamBlk8_reflight_additional	52.59
Pam_Agno_Reflights_PamBlk3D_reflight	8.14
Pam_Agno_Reflights_PamBlk3C_reflight	41.81
Pam_Agno_Reflights_PamBlk3A_reflight	64.51
NuevaEcija_Blk7038GC	45.46
TOTAL	743.34 sq.km

Portions of the DTM before and after manual editing are illustrated in Figure 20. The bridge (Figure 20a) was misclassified and was not removed during the classification process, and had to be deleted for complete the river (Figure 20b) and to allow for the correct flow of water. There was a missing tile (Figure 20c) that had to be retrieved to complete the surface (Figure 20d) in order to correct water flow. Another case was the presence of data gaps in the river due to the limitations of the laser that cannot penetrate the water (Figure 20e), and had to be interpolated through manual editing (Figure 20f) to complete the river profile.

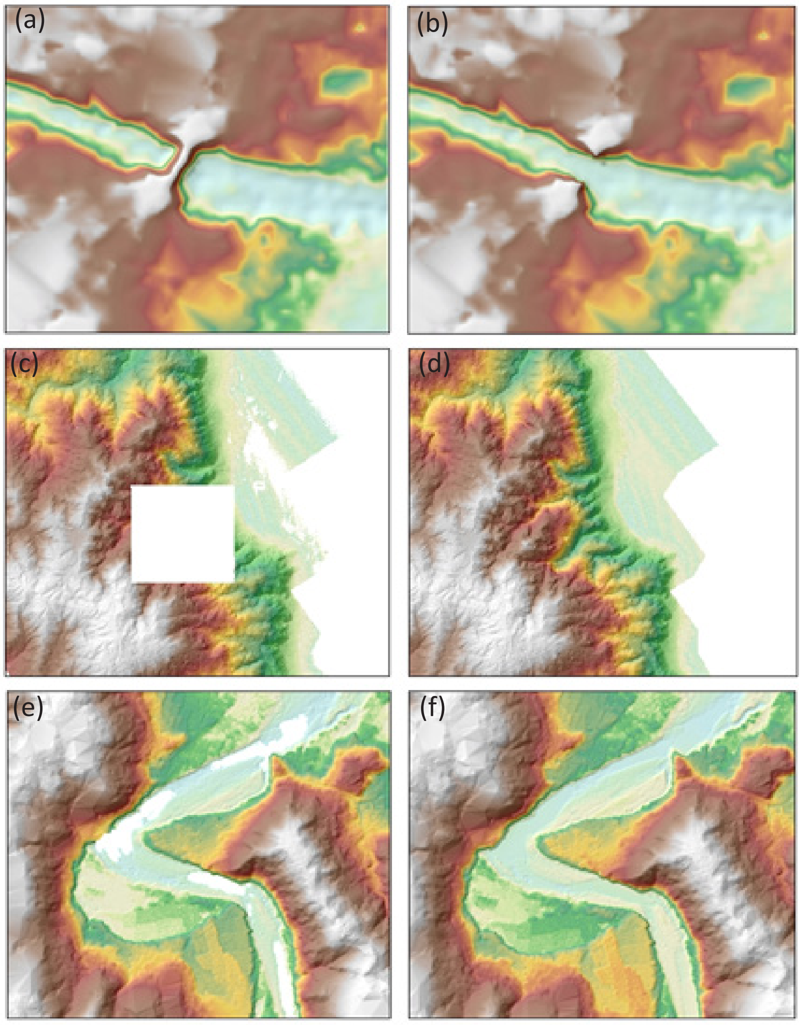


Figure 20. Portions in the DTM of the Umiray floodplain – a bridge (a) before and (b) after manual editing; a missing tile (c) before and (d) after data retrieval; and a river data gap (e) before and (f) after manual editing

3.9 Mosaicking of Blocks

The Clark_reflight_UMYA block was used as the reference block in mosaicking, since the Umiray River's main outlet is located in this block. Table 25 summarizes the shift values applied to each LiDAR block during mosaicking.

The mosaicked LiDAR DTM for the Umiray floodplain is presented in Figure 21. The entire Umiray flood plain is 90% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 25. Shift values of each LiDAR block of the Umiray floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Bataan_Reflights_ Pam8A_additional	-5.68	-3.40	-0.89
Bataan_Reflights_ Pam3D_additional2	-6.26	-0.72	-0.99
Umiray_BlkA	0.00	0.00	0.45
Umiray_BlkB	0.00	-5.00	-0.55
Clark_Reflights_Pam3J_ additional	-1.46	-1.81	0.21
Clark_Reflights_Pam3D_ additional2	-7.12	-1.03	0.21
Clark_Reflights_Pam3D_ additional1	-5.63	-459.98	0.11
Clark_Reflights_Pam3C_ additional	0.00	0.00	5.41
Clark_Reflights_Pam3B_ additional	-3.23	-0.80	2.81
Clark_Reflight_UMYAB	0.00	0.00	-1.20
Clark_Reflight_UMYAB_ additional	3.5	-6.00	-2.80
Clark_Reflights_UMYA	0.00	0.00	0.00
Clark_Reflights_Pam8D_ additional	-3.60	-0.74	0.41
Clark_Reflights_Pam8B_ additional	-4.50	1.00	0.31
Pam_Agno_Reflights_ PamBlk8_reflight_ additional	-6.00	0.30	0.91
Pam_Agno_Reflights_ PamBlk3D_reflight	-6.00	-2.00	0.01
Pam_Agno_Reflights_ PamBlk3C_reflight	-5.00	-2..00	-0.34
Pam_Agno_Reflights_ PamBlk3A_reflight	-12.50	-8.50	-0.84
NuevaEcija_Blk7038GC	-4.00	1.00	-0.45

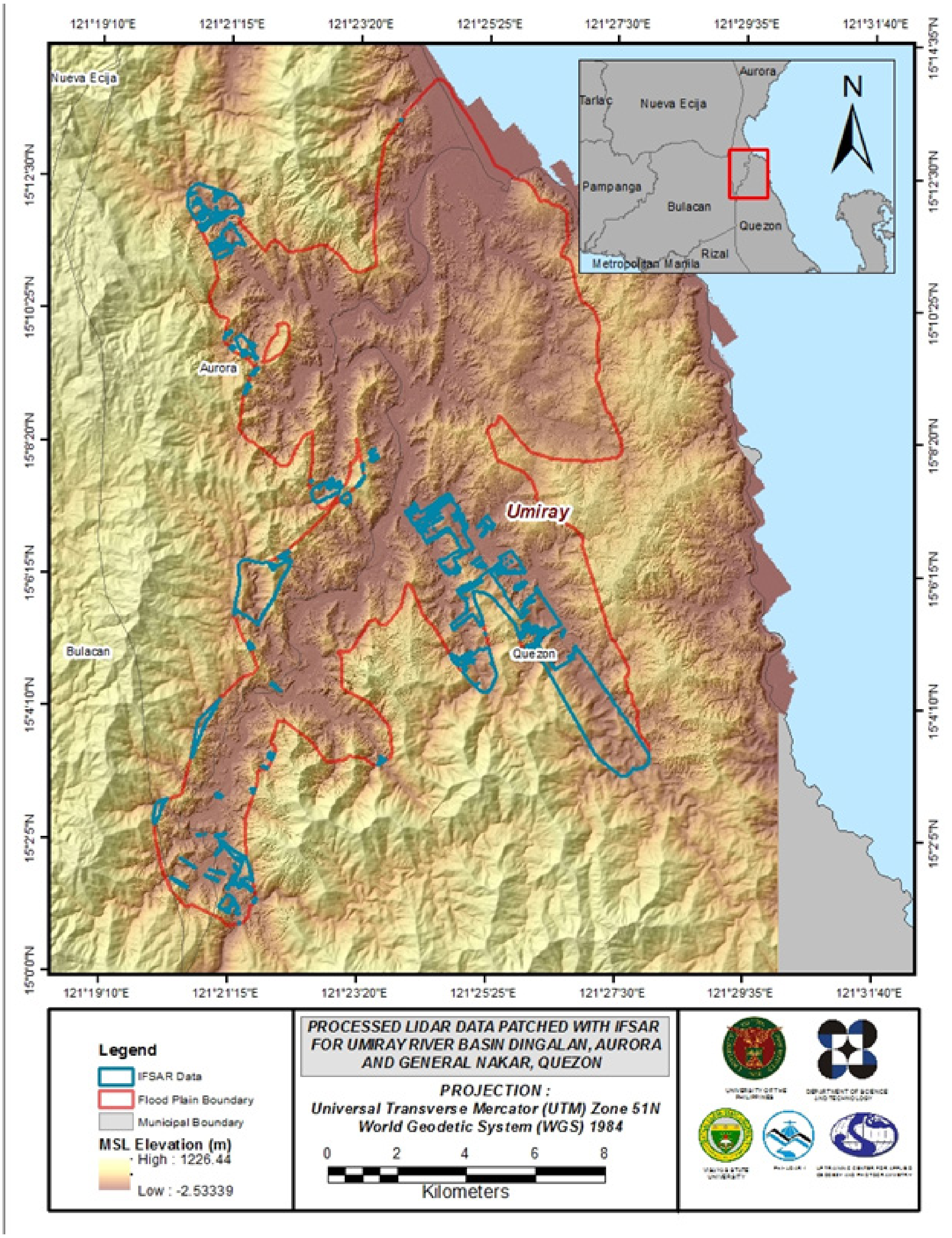


Figure 21. Map of processed LiDAR data for the Umiray floodplain

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 Umiray to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 280 survey points were used for calibration and validation of Umiray LiDAR data. Random selection of 80% of the survey points, resulting to 224 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 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.52 meters with a standard deviation of 0.19 meters. Calibration of Umiray LiDAR data was done by subtracting the height difference value, 2.52 meters, to Umiray mosaicked LiDAR data. Table 26 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

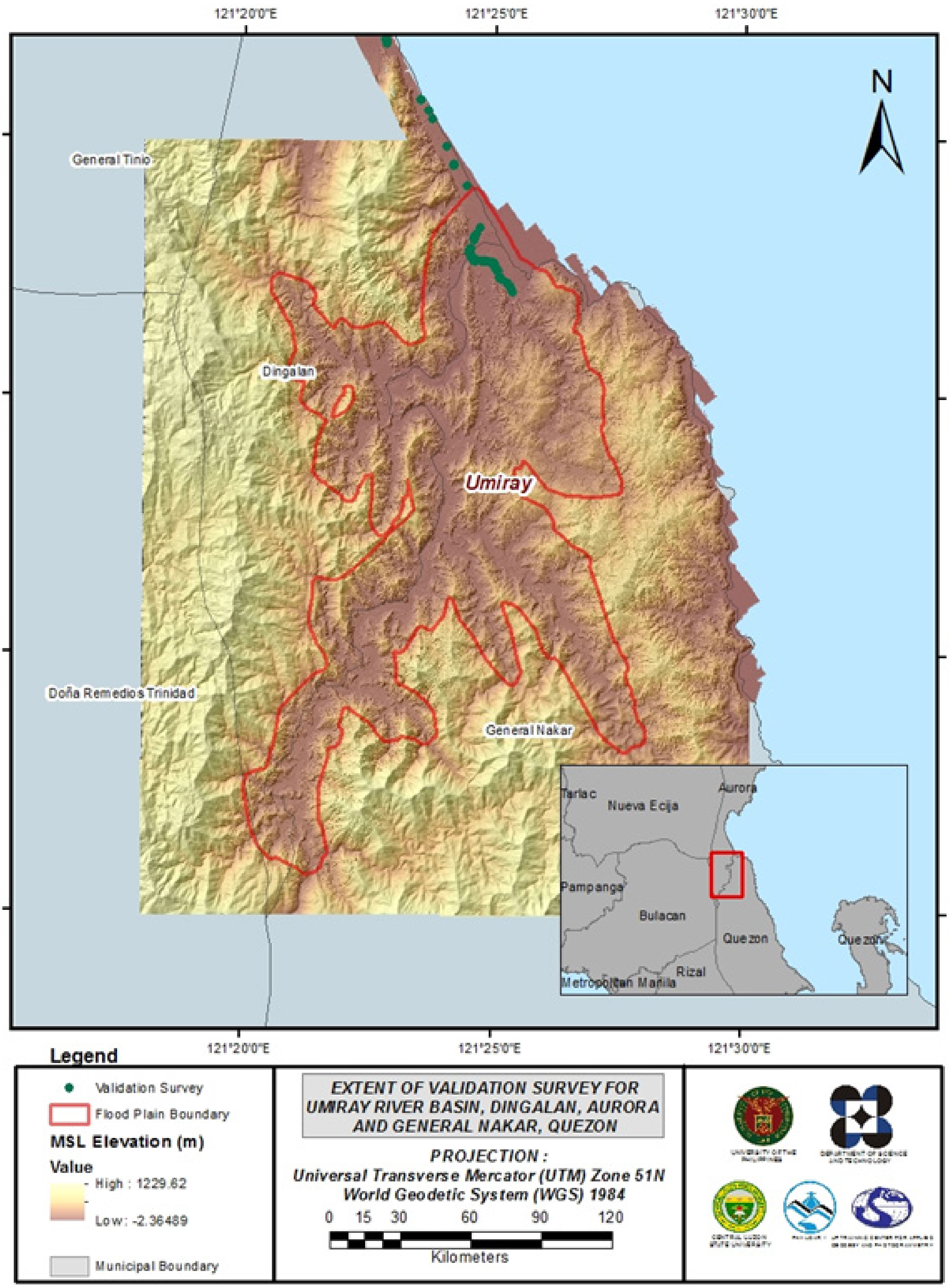


Figure 22. Map of the Umiray floodplain, with the validation survey points in green

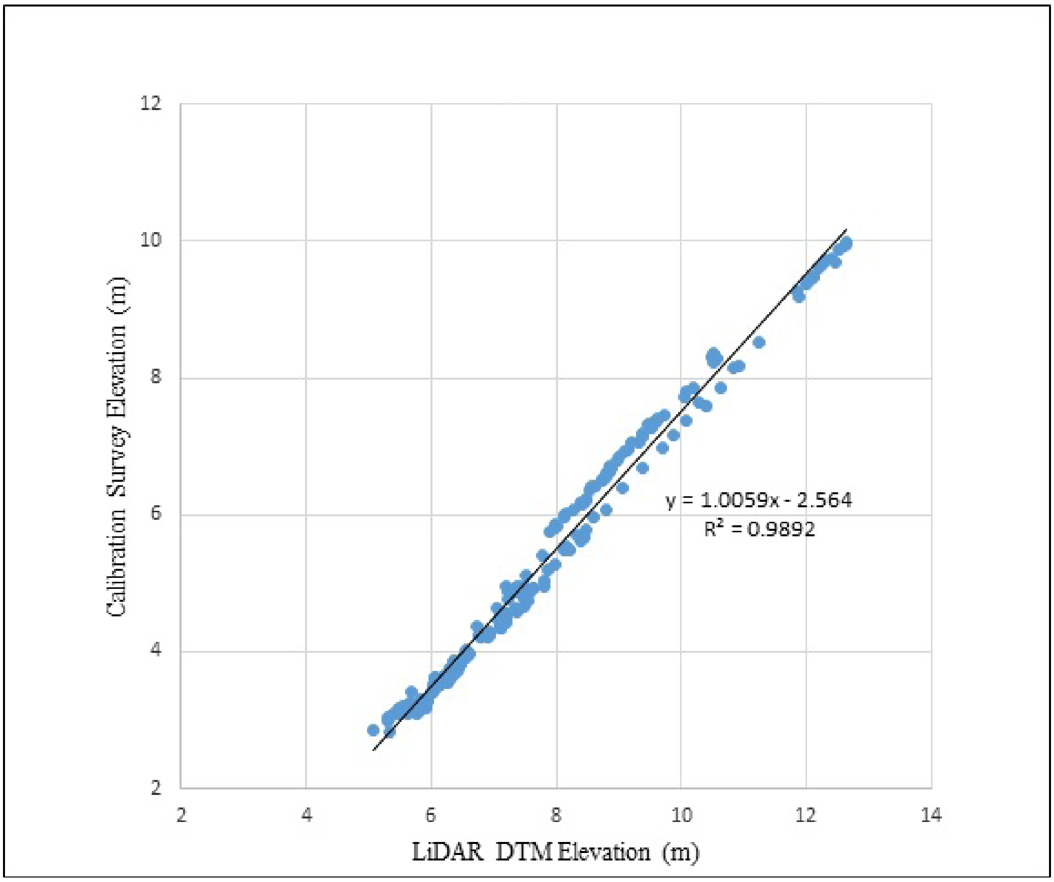


Figure 23. Correlation plot between the calibration survey points and the LiDAR data

Table 26. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.52
Standard Deviation	0.19
Average	-2.51
Minimum	-2.91
Maximum	-2.11

The remaining 20% of the total survey points, resulting in 56 points, were used for the validation of calibrated Umiray 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 demonstrated in Figure 24. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.20 meters, with a standard deviation of 0.20 meters, as shown in Table 27.

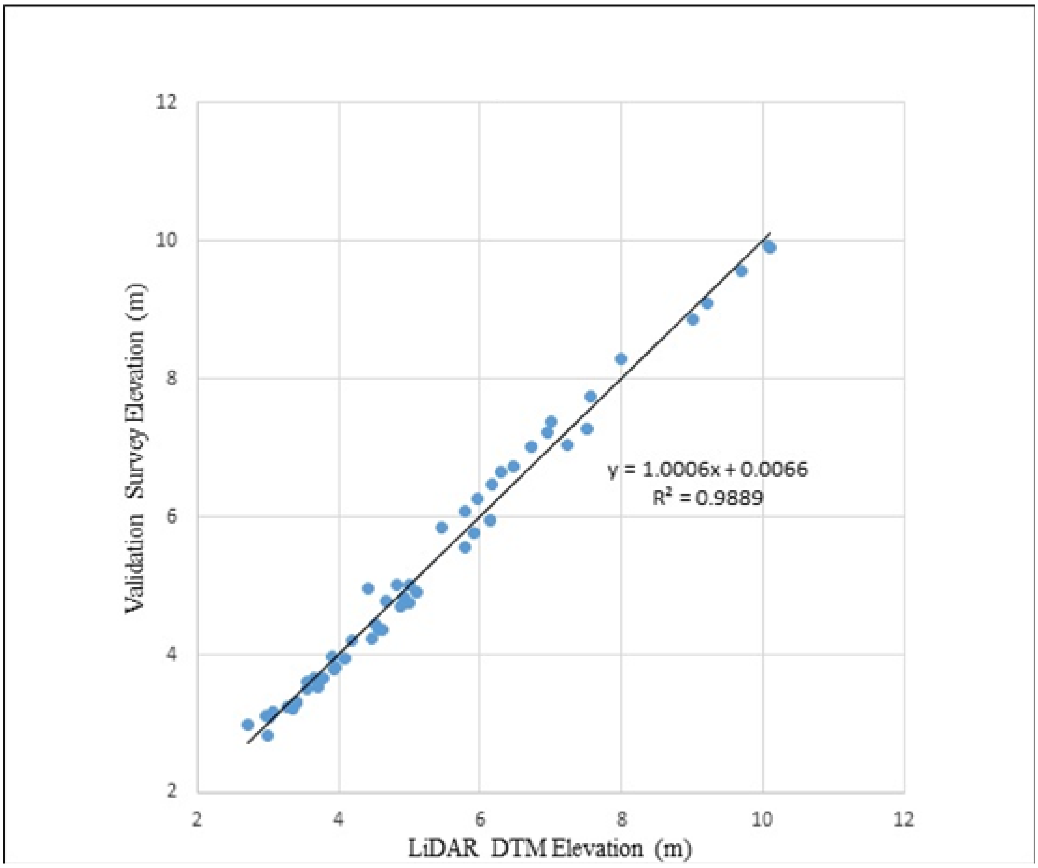


Figure 24. Correlation plot between the validation survey points and the LiDAR data

Table 27. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.20
Average	0.01
Minimum	-0.40
Maximum	-0.60

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, merged centerline and zigzag data were available for Umiray, with 6,222 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation with Barriers (KIB) method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.31 meters. The extent of the bathymetric survey executed by the DVBC in the Umiray River, integrated with the processed LiDAR DEM, is illustrated in Figure 25.

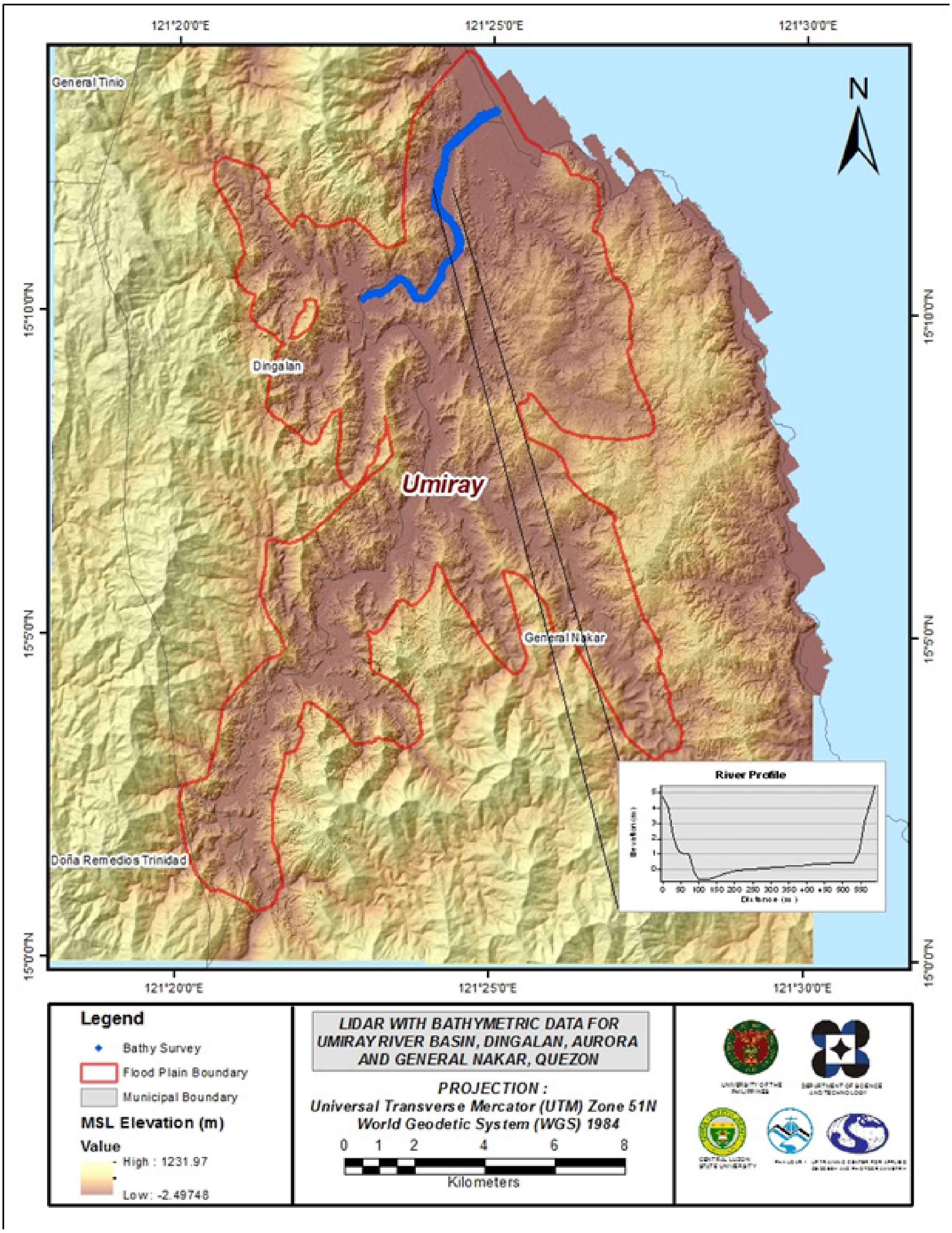


Figure 25. Map of the Umiray floodplain, with the bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Umiray floodplain, including its 200-meter buffer zone, has a total area of 155.99 sq. km. Of this area, a total of 1.0 sq. km, corresponding to a total of 167 building features, was considered for quality checking (QC). Figure 26 presents the QC blocks for the Umiray floodplain.

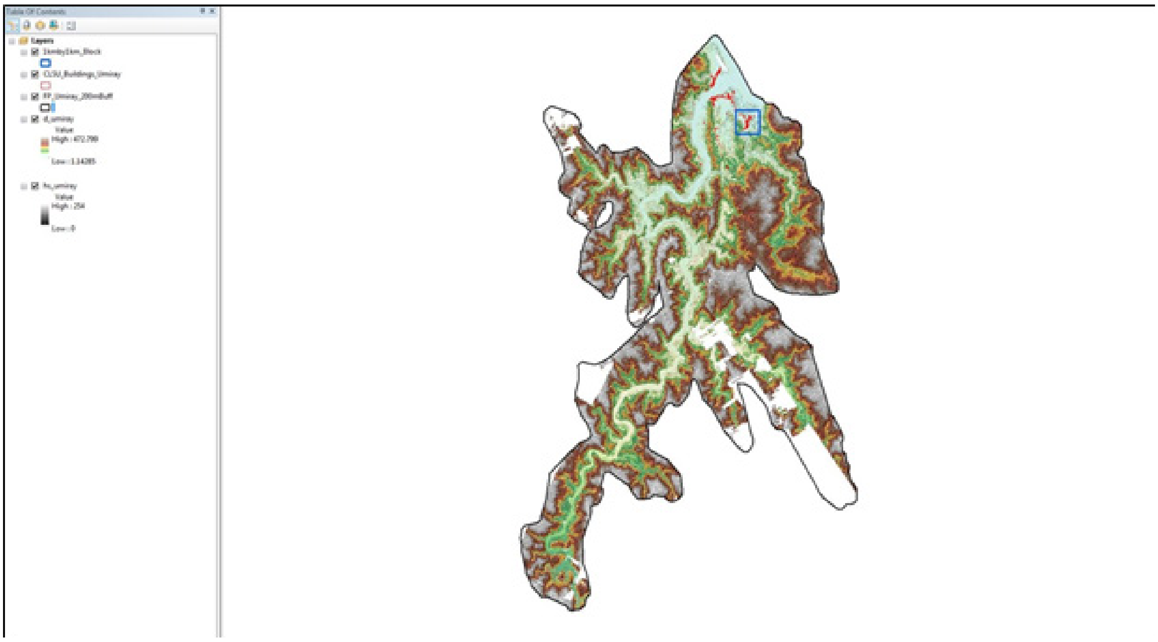


Figure 26. Blocks (in blue) of Umiray building features that were subjected to QC

Quality checking of the Umiray building features resulted in the ratings provided in Table 28.

Table 28. Quality checking ratings for the Umiray building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Umiray	99.40	100.00	96.41	PASSED

3.12.2 Height Extraction

Height extraction was done for 787 building features in the Umiray floodplain. None was filtered out after height extraction, resulting in the same amount of buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 3.64 meters.

3.12.3 Feature Attribution

Field data gathering and ground verification were conducted in order to correct and complete the information needed in the attribution of the digitized features in the floodplains of the river basin. The team used a video-tagging capture device installed in a vehicle, which trekked around the floodplain to capture information needed for the features of the buildings, bridges, and roads. Courtesy calls to the municipal officials were first conducted to request for approval before the video-tagging activity was executed. The water bodies' attributes were collected from different maps, such as the DENR, NAMRIA and MGB maps. Figure 27 depicts the activities performed during the field validation and ground verification for the attribution of extracted features.

Figure 27. Video-tagging activity for the Umiray attribution of extracted features

Table 29 summarizes the number of building features per type. Table 30 indicates the total length of each road type, and Table 31 lists the number of water features extracted per type.

Table 29. Number of building features extracted for the Umiray floodplain

Facility Type	No. of Features
Residential	733
School	21
Market	1
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	1
Barangay Hall	1
Military Institution	17
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	5
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	1
Other Commercial Establishments	4
Total	787

Table 30. Total length of extracted roads for the Umiray floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Umiray	26.12	0.00	1.17	0.00	0.00	27.29

Table 31. Number of extracted water bodies for the Umiray floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Umiray	23	0	1	0	0	24

A total of seven (7) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 28 represents the Digital Surface Model (DSM) of the Umiray floodplain, overlaid with its ground features.

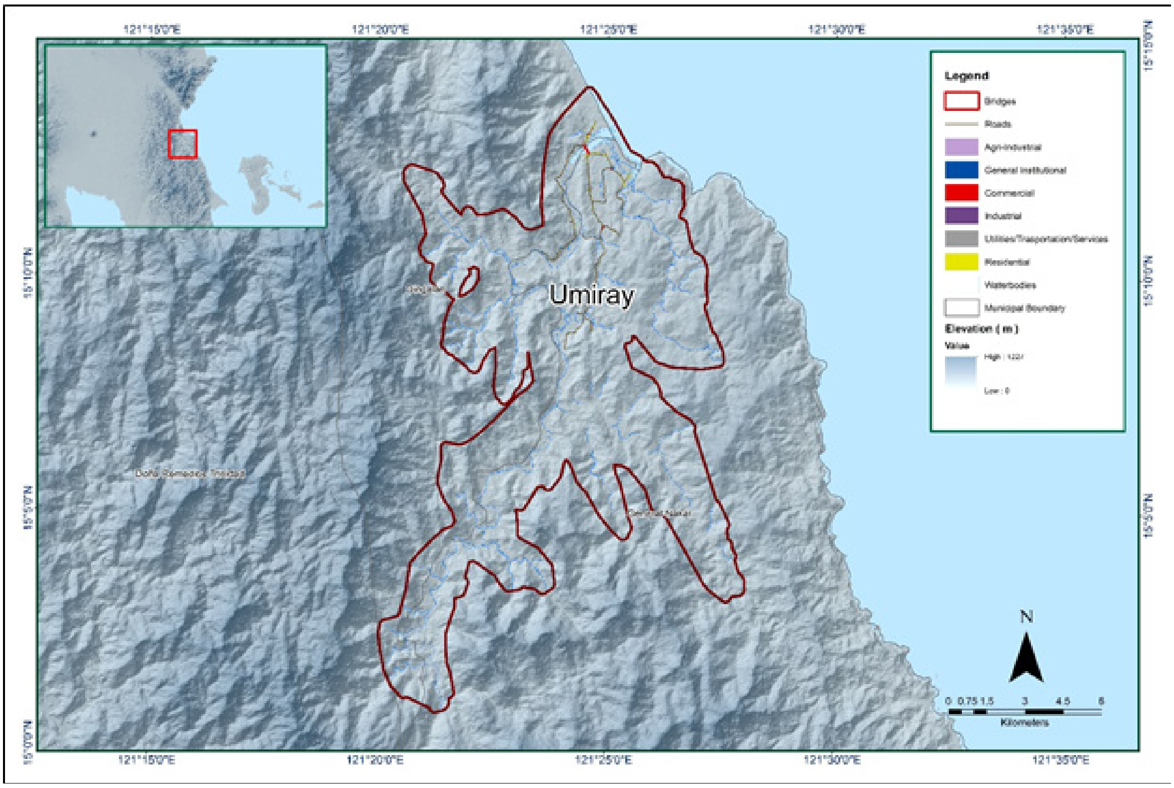


Figure 28. Extracted features for the Umiray floodplain.

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field surveys in the Umiray River on December 6-14, 2016, with the following scope of work: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built surveys at the Umiray Bridge in Barangay Umiray, Dingalan, Aurora; (iv.) validation points acquisition of about 11.8 km., covering the municipalities of Dingalan, Aurora, and General, Nakar, Quezon; and (v.) bathymetric survey from the river's upstream in Barangay Umiray, General Nakar to the mouth of the river located in Barangay Umiray, Dingalan, with an approximate length of 8.979 km. using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 29).

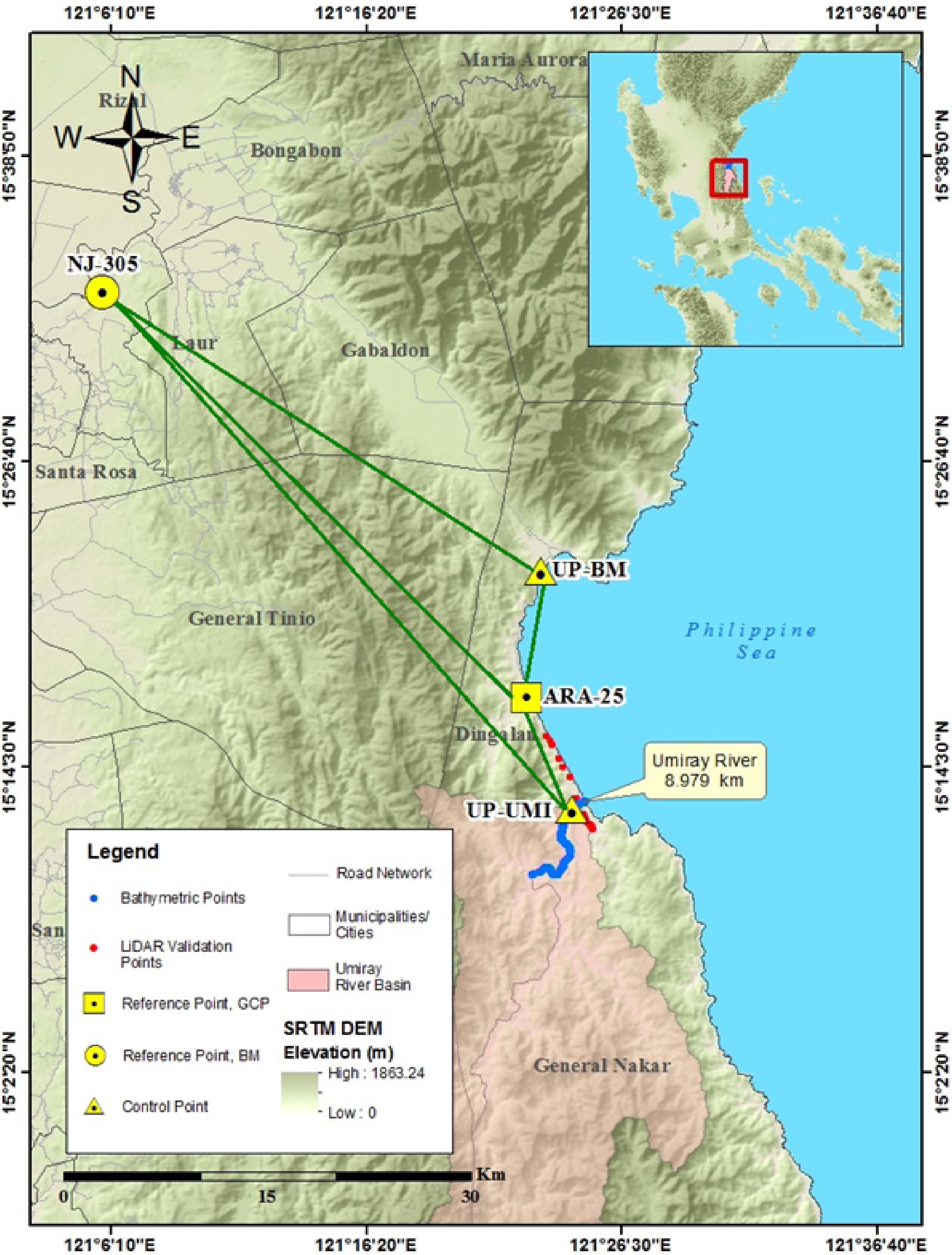


Figure 29. Extent of the bathymetric survey (in blue line) in the Umiray River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for the Umiray River Basin is composed of two (2) loops established on December 10, 2016, occupying the following reference points: (i.) ARA-25, a 2nd order NAMRIA GCP in Barangay Ibona, Municipality of Dingalan, Aurora; and (ii.) NJ-305, a 1st order BM in Barangay Ganaderia, Palayan City, Nueva Ecija.

The control points established were: (i.) UP-BM, located in front of the Family Resort guest house in Barangay Butas Na Bato, Municipality of Dingalan, Aurora; and (ii.) UP-UMI, located at the deck of the Umiray Bridge in Barangay Umiray, Municipality of Dingalan, Aurora. These established points were also occupied to serve as markers for the survey.

The summary of the reference and control points and their respective locations is given in Table 32, while the established GNSS network is illustrated in Figure 30.

Table 32. List of reference and control points occupied for the Umiray River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				Date of Establishment
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	
ARA-25	2nd Order, GCP	15°17'16.49212"	121°22'42.34563"	50.333	-	12-10-16
NJ-305	1st Order, BM	-	-	109.668	65.608	12-10-16
UP-BM	UP established	-	-	51.618	-	12-11-16

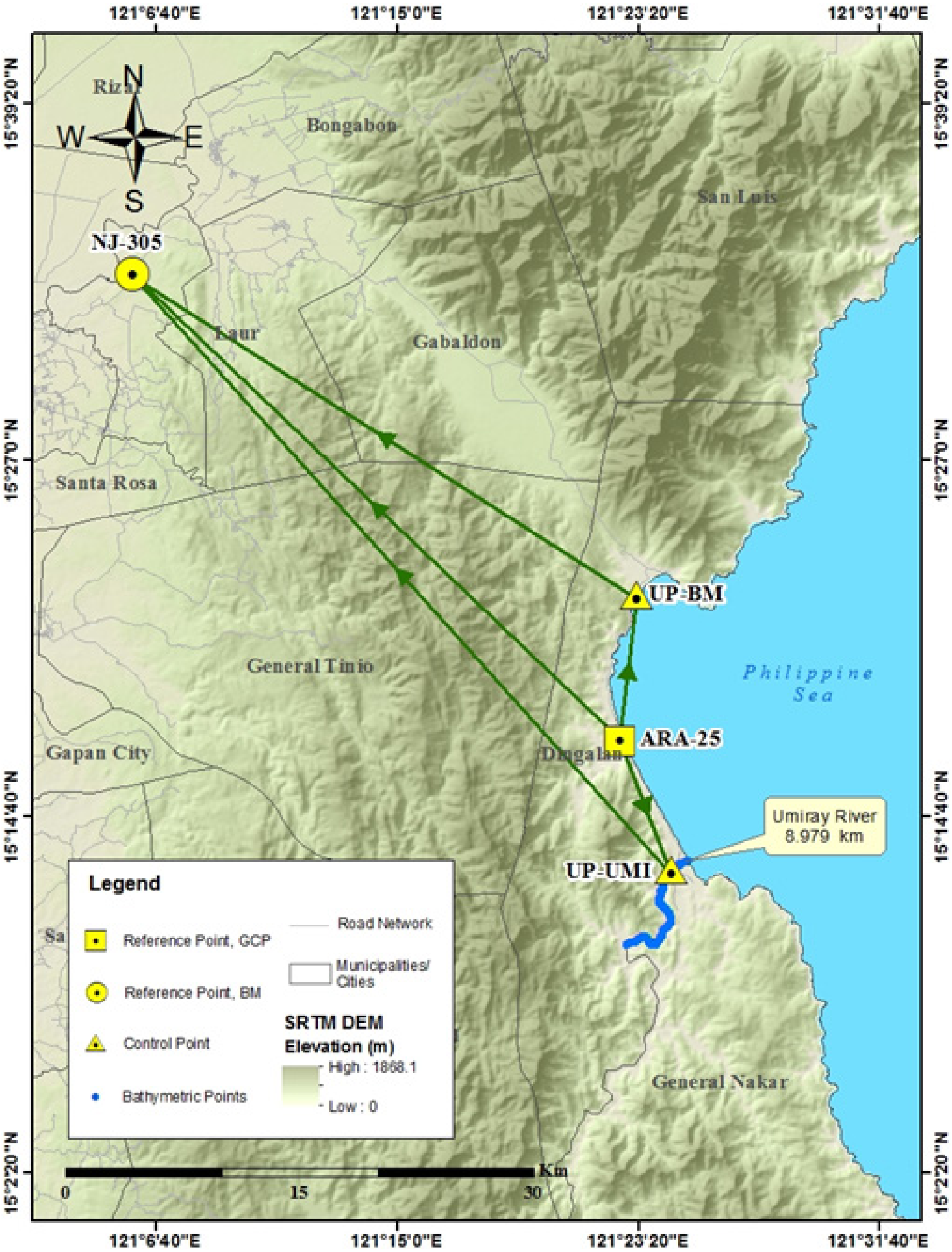


Figure 30. Extent of the Umiray River Basin control survey.

The GNSS set-ups on the recovered reference points and established control points in the Umiray River are exhibited in Figure 31 to Figure 33.

Figure 31. GNSS receiver set-up, Trimble® SPS 852, at ARA-25, located near the covered court inside the barangay complex of Barangay Ibuna, Municipality of Dingalan, Aurora.

Figure 32. GNSS base set-up, Trimble® SPS 985, at NJ-305, located along the national road in Barangay Atate, Palayan City, Nueva Ecija.

Figure 33. GNSS receiver set-up, Trimble® SPS 852, at UP-UMI, located at the deck of the Umiray Bridge in Barangay Umiray, Municipality of Dingalan, Aurora

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 of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of the control points in the Umiray River Basin, generated by the TBC software, is summarized in Table 33.

Table 33. Baseline Processing Summary Report for the Umiray River survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP-BM --- NJ-305 (B7)	12-11-16	Fixed	0.005	0.018	303°13'54"	37376.394	58.070
ARA-25 --- UP-BM (B8)	12-11-16	Fixed	0.005	0.018	6°23'24"	9377.217	1.298
ARA-25 --- UP-UMI (B5)	12-11-16	Fixed	0.003	0.015	158°51'25"	8824.411	4.340
ARA-25 --- NJ-305 (B6)	12-11-16	Fixed	0.003	0.016	314°35'55"	42442.994	59.336
ARA-25 --- NJ-305 (B4)	12-11-16	Fixed	0.004	0.020	314°35'55"	42442.994	59.301
ARA-25 --- NJ-305 (B3)	12-11-16	Fixed	0.004	0.025	314°35'55"	42443.010	59.306
UP-UMI --- NJ-305 (B1)	12-11-16	Fixed	0.007	0.025	318°42'49"	50618.256	54.970
ARA-25 --- NJ-305 (B3)	12-11-16	Fixed	0.004	0.025	314°35'55"	42443.010	59.306
UP-UMI --- NJ-305 (B1)	12-11-16	Fixed	0.007	0.025	318°42'49"	50618.256	54.970

Table 33 indicates that a total of seven (7) baselines were processed, with the coordinate values of ARA-25, and the elevation value of NJ-305 held fixed. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report presented in Table 34 to Table 37 for complete details.

The two (2) control points, UP-BM and UP-UMI, were occupied and observed simultaneously to form a GNSS loop. The coordinates of ARA-25, the elevation value of NJ-305, and the fixed values of ARA-25 were held fixed during the processing of the control points, as reflected in Table 34. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 34. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ARA-25	Local	Fixed	Fixed		
NJ-305	Grid				Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 35. All fixed control points have no values for grid and elevation errors.

Table 35. Adjusted grid coordinates for the control points used in the Umiray floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ARA-25	325884.347	?	1690820.795	?	5.739	0.048	LL
NJ-305	295887.163	0.008	1720849.660	0.007	65.608	?	e
UP-BM	326997.684	0.014	1700131.437	0.010	7.043	0.069	
UP-UMI	329005.819	0.011	1682567.205	0.010	9.998	0.073	

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

a. **ARA-25**
Horizontal Accuracy = Fixed
Vertical Accuracy = 4.8 < 10 cm

b. **NJ-305**
Horizontal Accuracy = $\sqrt{((0.8)^2 + (0.7)^2}$
= $\sqrt{(0.64 + 0.49)}$
= 1.06 < 20 cm
Vertical Accuracy = Fixed

c. **UP-BM**
Horizontal Accuracy = $\sqrt{((1.4)^2 + (1.0)^2}$
= $\sqrt{(1.96 + 1)}$
= 1.72 < 20 cm
Vertical Accuracy = 6.9 < 10 cm

d. **UP-UMI**
Horizontal Accuracy = $\sqrt{((1.1)^2 + (1.0)^2}$
= $\sqrt{(1.21 + 1)}$
= 1.49 < 20 cm
Vertical Accuracy = 7.3 < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two (2) occupied control points are within the required precision.

Table 36. Adjusted geodetic coordinates for control points used in the Umiray River floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
ARA-25	N15°17'16.49212"	E121°22'42.34563"	50.333	0.048	LL
NJ-305	N15°33'25.39479"	E121°05'48.09133"	109.668	?	e
UP-BM	N15°22'19.67894"	E121°23'17.34067"	51.618	0.069	
UP-UMI	N15°12'48.71232"	E121°24'28.99381"	54.676	0.073	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 36. 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 Umiray River GNSS Static Survey are indicated in Table 37.

Table 37. Reference and control points used in the Umiray River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	WGS 84			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	BM Ortho (m)
ARA-25	2nd Order, GCP	15°17'16.49212"	121°22'42.34563"	50.333	1690820.795	325884.347	5.739
NJ-305	1st Order, BM	15°33'25.39479"	121°05'48.09133"	109.668	1720849.66	295887.163	65.608
UP-BM	UP established	15°22'19.67894"	121°23'17.34067"	51.618	1700131.437	326997.684	7.043
UP-UMI	UP established	15°12'48.71232"	121°24'28.99381"	54.676	1682567.205	329005.819	9.998

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

The cross-section and as-built surveys were conducted on December 9 – 10, 2016 at the downstream side of the Umiray Bridge in Barangay Umiray, Municipality of Dingalan, Aurora, as depicted in Figure 34. A survey-grade GNSS receiver, Trimble® SPS 882, in PPK survey technique was utilized for this survey, as demonstrated in Figure 35.

Figure 34. The Umiray Bridge facing downstream.

Figure 35. As-built survey of the Umiray Bridge.

The length of the cross-sectional line surveyed in the Umiray Bridge is about 327.788 meters with seventy one (71) cross-sectional points, using the control points UP-UMI and ARA-25 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 36 to Figure 38.

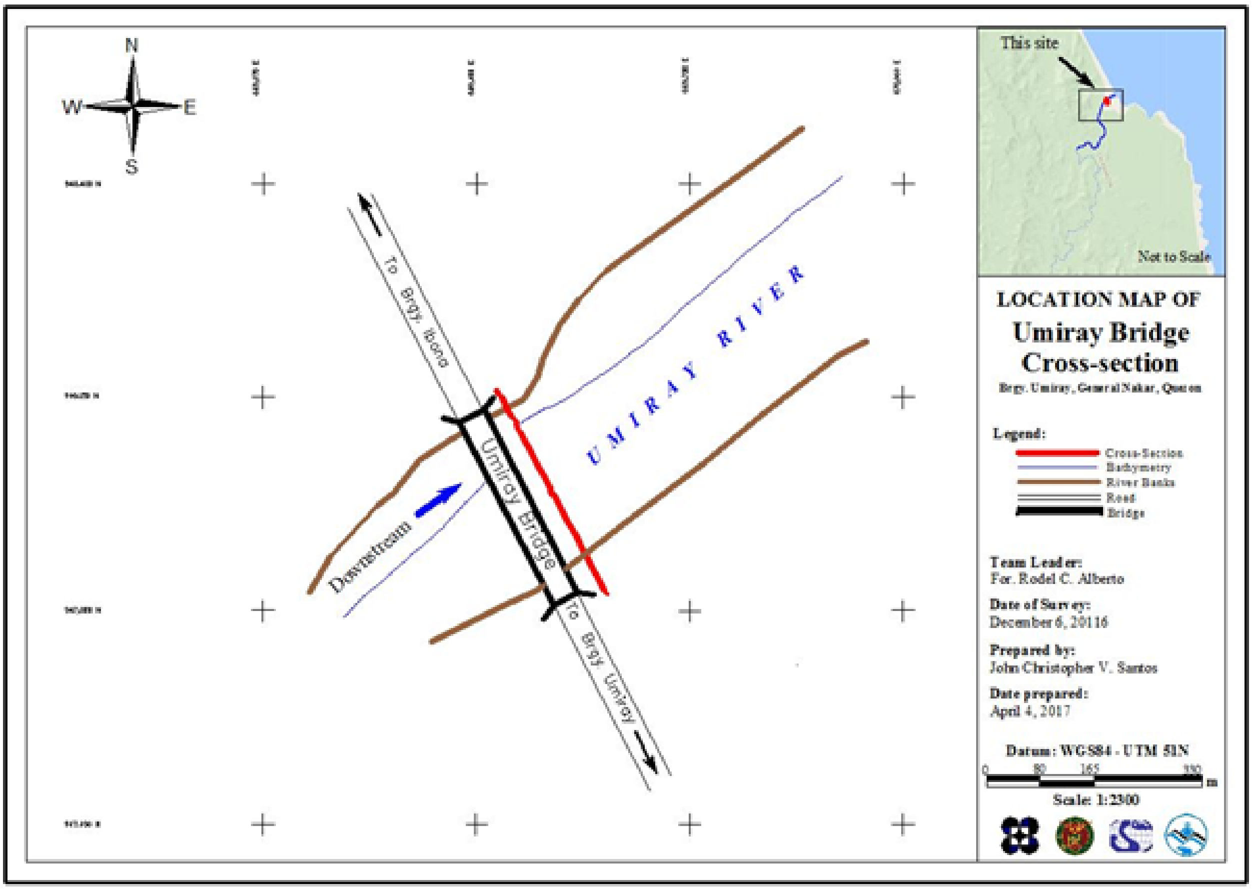


Figure 36. Umiray bridge cross-section location map.

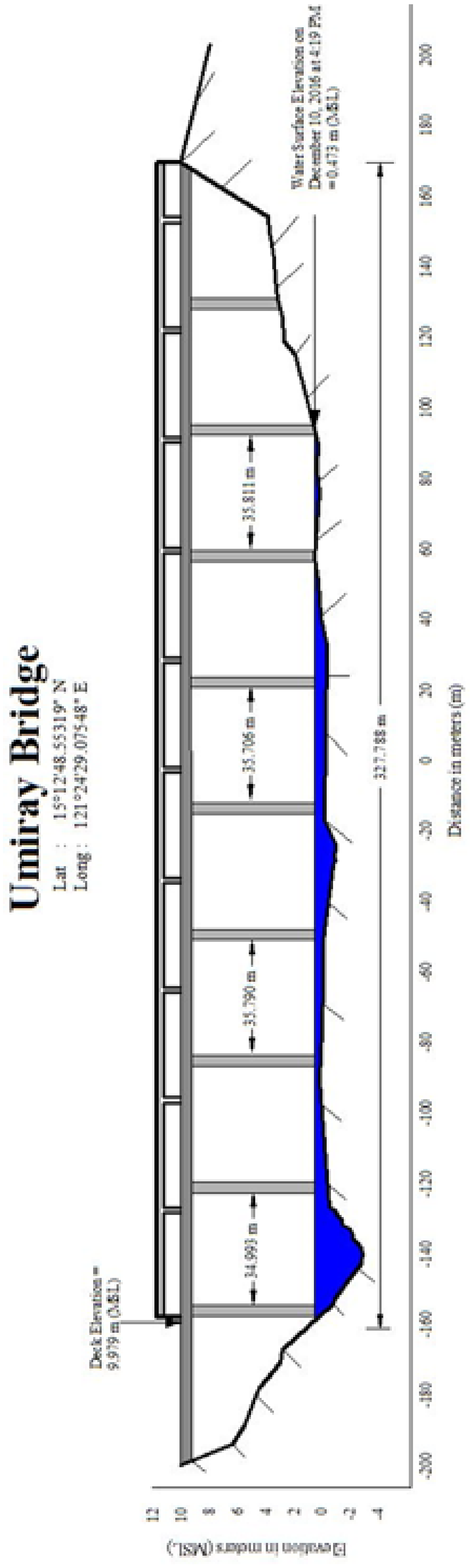
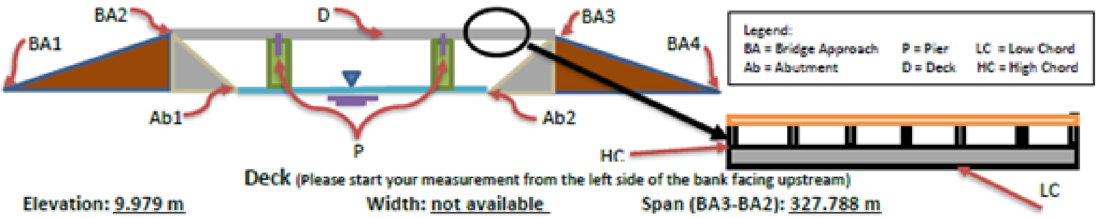


Figure 37. Umiray Bridge cross-section diagram.

Bridge Data Form

Bridge Name: Umiray Bridge | Date: December 9 and 10, 2016
River Name: Umiray River | Time: 04:19 PM
Location (Brgy, City,Region): Brgy. Umiray, Dingalan, Aurora
Survey Team: Vie Marie Rivera, Marla Tricia Morris
Flow condition: average | Weather Condition: fair
Latitude: 15°12'48.55319"N | Longitude: 121°24'29.07548"E



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

Elevation: 9.979 m Width: not available Span (BA3-BA2): 327.788 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	9.960 m	BA3	369.343 m	9.986 m
BA2	41.555 m	9.970 m	BA4	402.766 m	7.901 m

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

	Station (Distance from BA1)	Elevation
Ab1	5.728 m	6.296 m
Ab2	353. 806 m	3.811 m

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

Shape: round Number of Piers: 9 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	42.291 m	9.407 m	
Pier 2	77.284 m	9.974 m	
Pier 3	113.101 m	9.968 m	
Pier 4	148.881 m	9.971 m	
Pier 5	184.767 m	9.986 m	
Pier 6	220.473 m	10.006 m	
Pier 7	256.275 m	10.002 m	
Pier 8	292.086 m	10.007 m	
Pier 9	327.892 m	10.016 m	

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

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure 38. Bridge as-built form of the Umiray Bridge

The water surface elevation of the Umiray River was determined by a survey-grade GNSS receiver, Trimble® SPS 882, in PPK survey technique on December 10, 2016 at 16:19 hrs. at the Umiray Bridge. The elevation value obtained was 0.473 meters in MSL, as reflected in Figure 37. This was translated into markings on the bridge's deck, as illustrated in Figure 39. The markings served as a reference for flow data gathering and depth gauge deployment of the CLSU Phil-LiDAR 1 Team.

Figure 39. Water-level markings on the Umiray Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on December 11, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted in front of a vehicle, as shown in Figure 40. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.05 meters, measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with UP-BM occupied as the GNSS base station

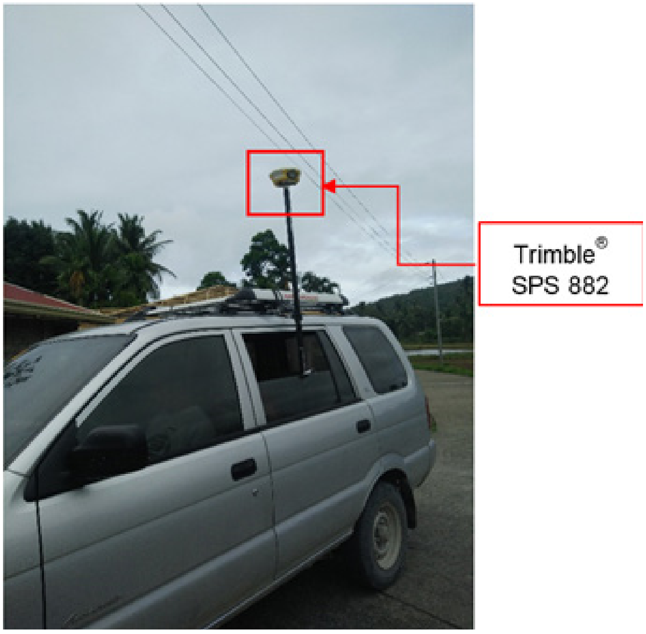


Figure 40. Validation points acquisition survey set-up along the Umiray River Basin

The survey started in Barangay Ibona in the Municipality of Dingalan, Aurora, and headed south along the national highway, covering Barangay Umiray in the Municipality of Dingalan, Aurora. The survey ended in Barangay Umiray in the Municipality of General Nakar, Quezon. A total of 3,597 points were gathered with an approximate length of 11.8 km., using UP-BM as GNSS base station for the entire extent validation points acquisition survey. This is illustrated in the map in Figure 41.

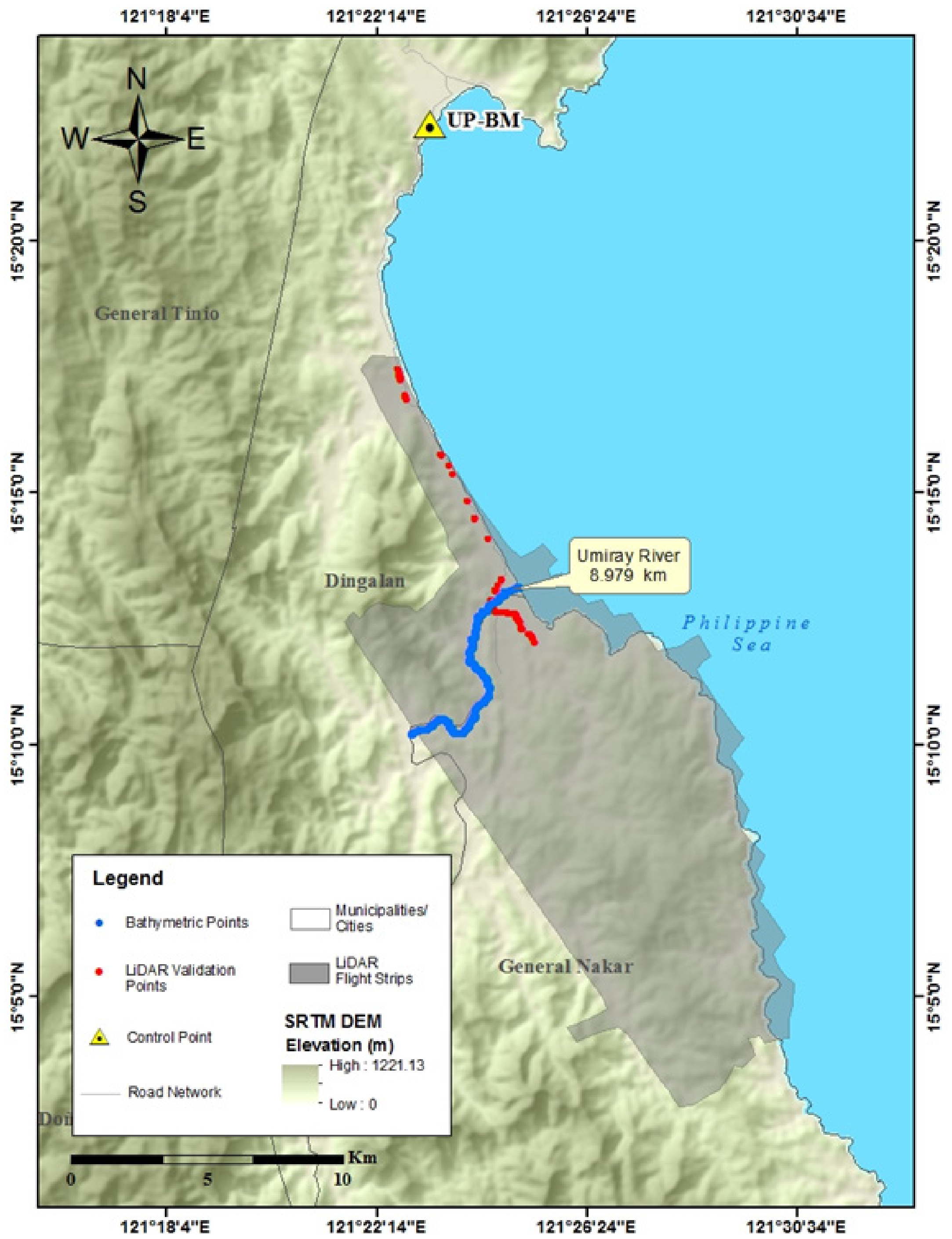


Figure 41. Extent of the LiDAR ground validation survey of the Umiray River Basin

4.7 Bathymetric Survey

A manual bathymetric survey was executed on December 8 – 9, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode, as depicted in Figure 42. It started in Barangay Umiray in the Municipality of General Nakar, Quezon, with coordinates 15°10’11.69191”N, 121°22’55.06733”E. The survey then traversed down the river by boat and ended at the mouth of the river in Barangay Umiray in the Municipality of Dingalan, Aurora, with coordinates 15°13’07.41701”N, 121°25’03.31695”E. The control point UP-UMI was used as the GNSS base station all throughout the survey.

Figure 42. Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in the Umiray River

The bathymetric survey for the Umiray River gathered a total of 5,854 points covering 8.979 km. of the river, traversing Barangay Umiray in the Municipality of General Nakar, Quezon to Barangay Umiray in the Municpality of Dingalan, Aurora. A length of 7.5 km. was not covered due to a few communities that were present in the upstream side of the river. A CAD drawing was also produced to illustrate the riverbed profile of Umiray River, presented in Figure 44. The profile shows that the highest and lowest elevation had an 11.258-meter difference. The highest elevation observed was 7.27 meters below MSL, located at the upstream part of the river; while the lowest elevation was –3.988 meters below MSL, located in the middle the river.

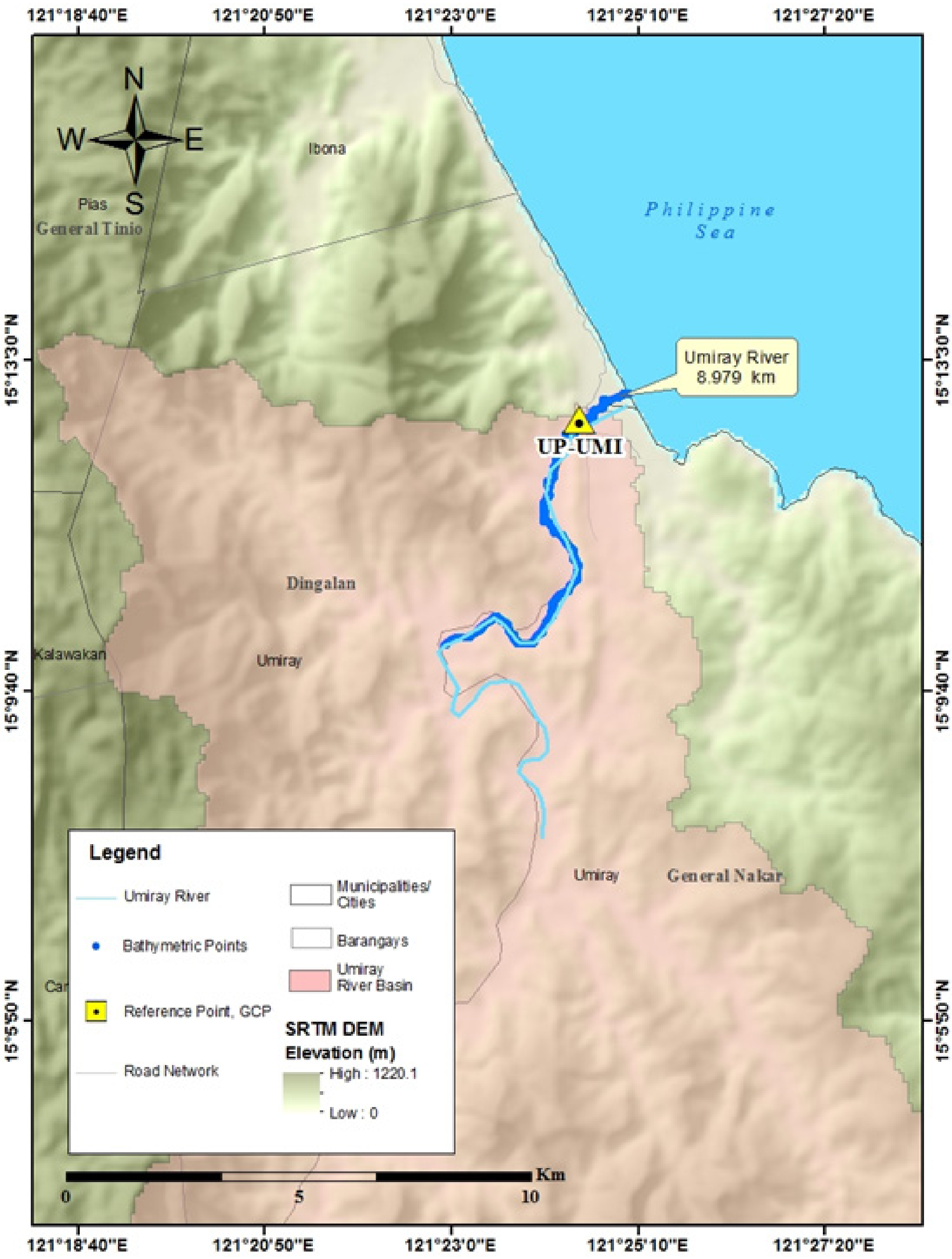


Figure 43. Extent of the bathymetric survey of the Umiray River

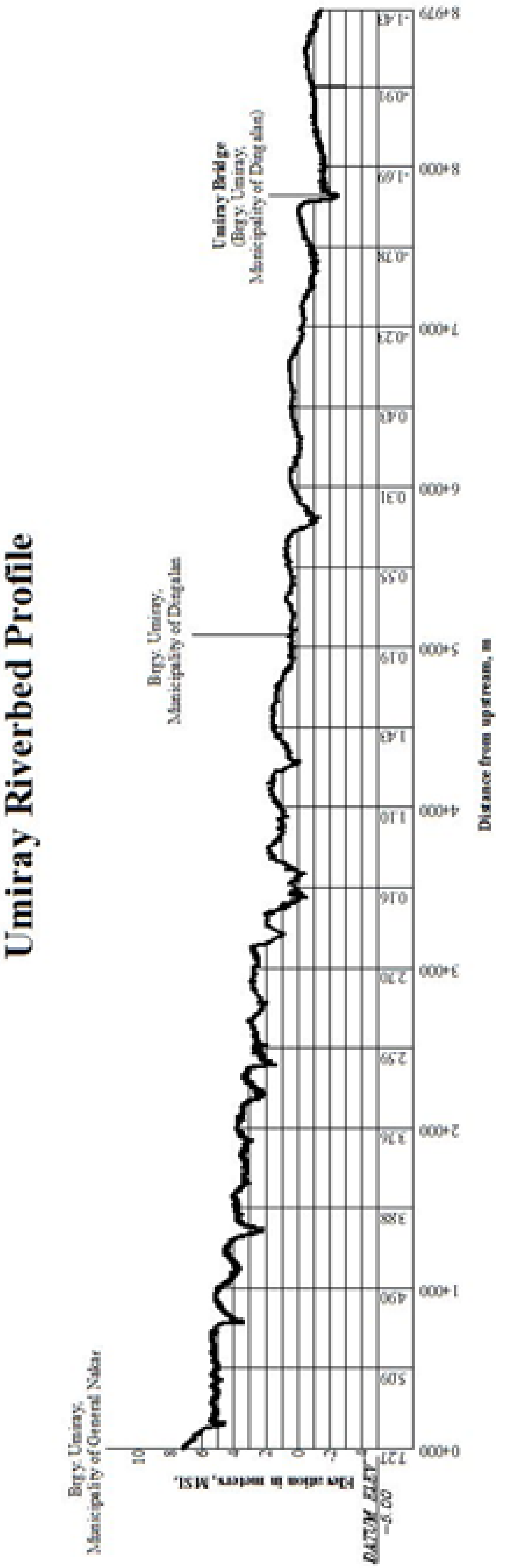


Figure 44. Umiray riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Girlie David, Mariel Monteclaro, Eleazar Raneses, Jr. and Jose T. Gavino

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Due to the absence of an automatic rain gauge in Umiray, precipitation data was recorded through manual reading in an 8-inch standard rain gauge installed in the study area. The rain gauge was installed one (1) kilometer upstream from the flow measurement site.

The total rain recorded for this event from the rain gauge was 59.25 mm. It peaked at 11.56 mm. on October 6, 2016 at 14:50 hrs. The lag time between the peak rainfall and discharge was five (5) hours and ten (10) minutes.

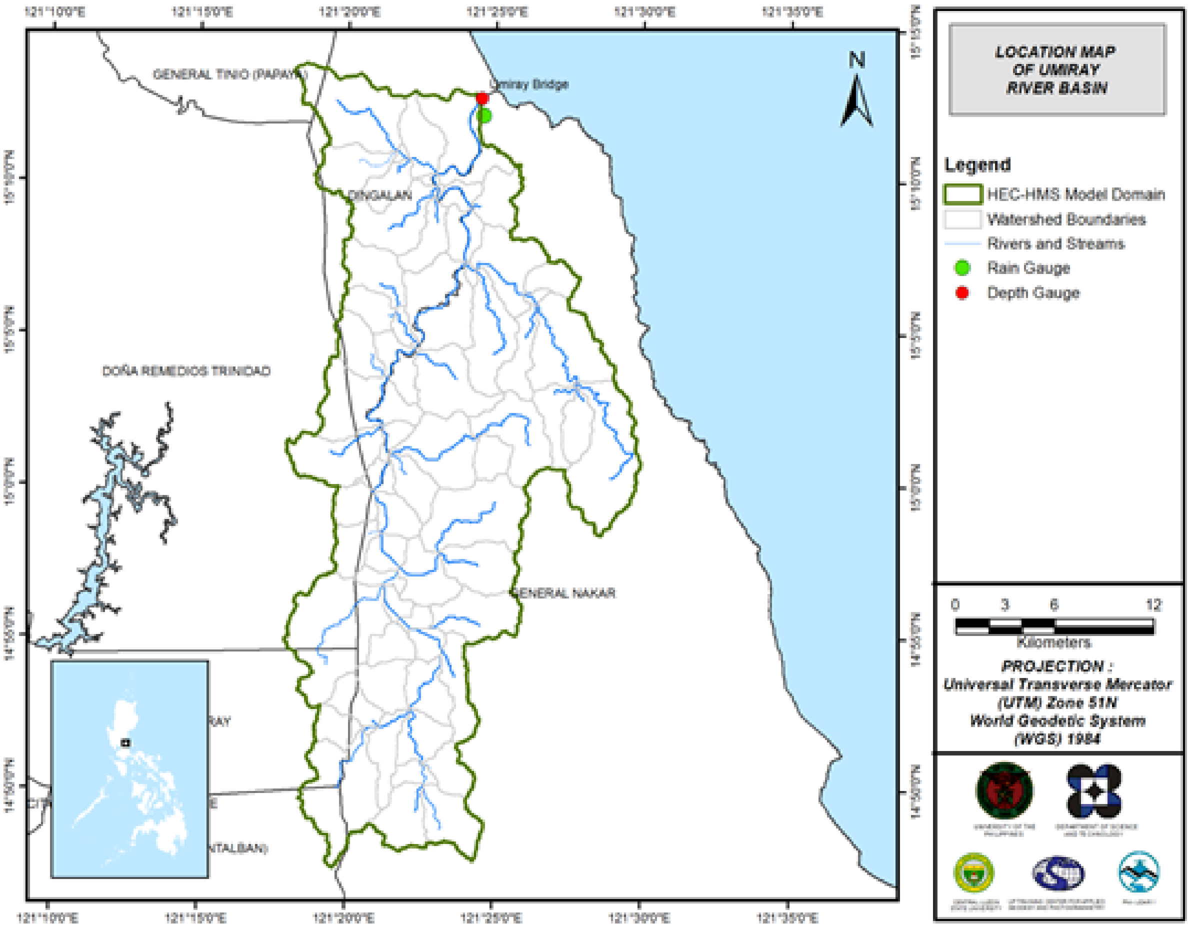


Figure 45. Location map of the Umiray HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed at the prevailing cross-section (Figure 46) at the Umiray Bridge in Dingalan, Aurora (15°12’ 43.26”N, 121°24’ 31.91”E) to establish the relationship between the observed water levels (H) at the Umiray Bridge and the outflow (Q) of the watershed at this location.

For the Umiray Bridge, the rating curve is expressed as Q = 91.454e1.253h, as presented in Figure 47.

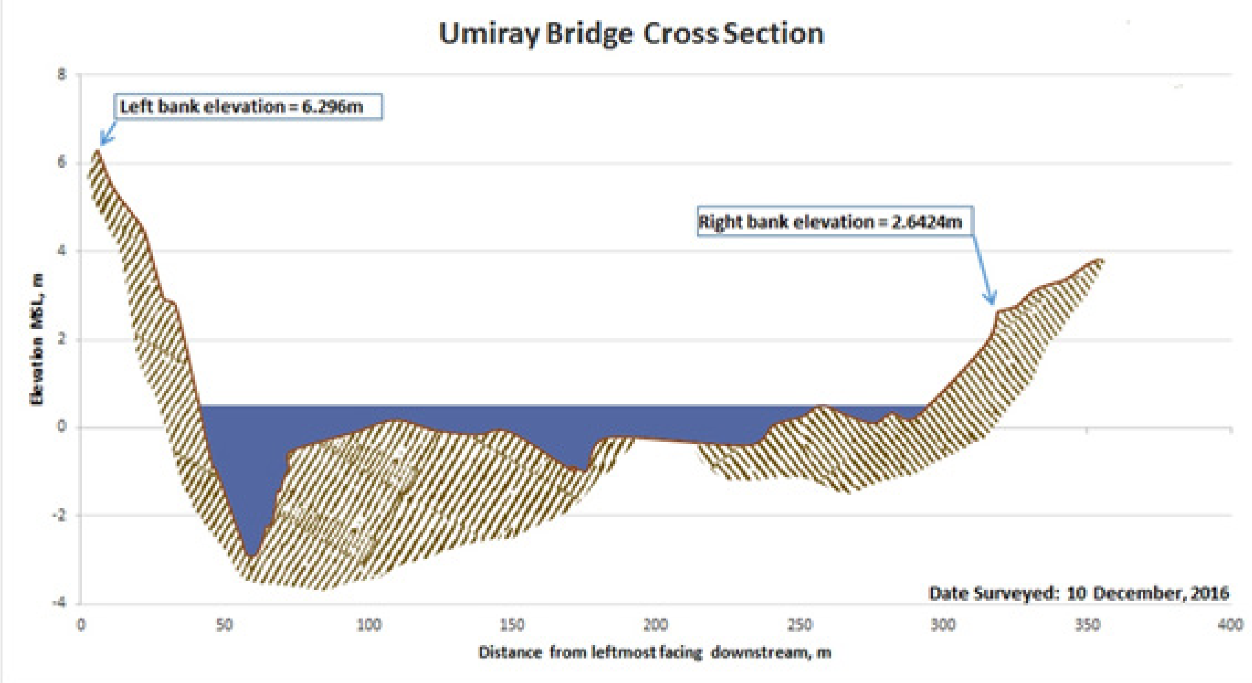


Figure 46. Cross-section plot of the Umiray Bridge.

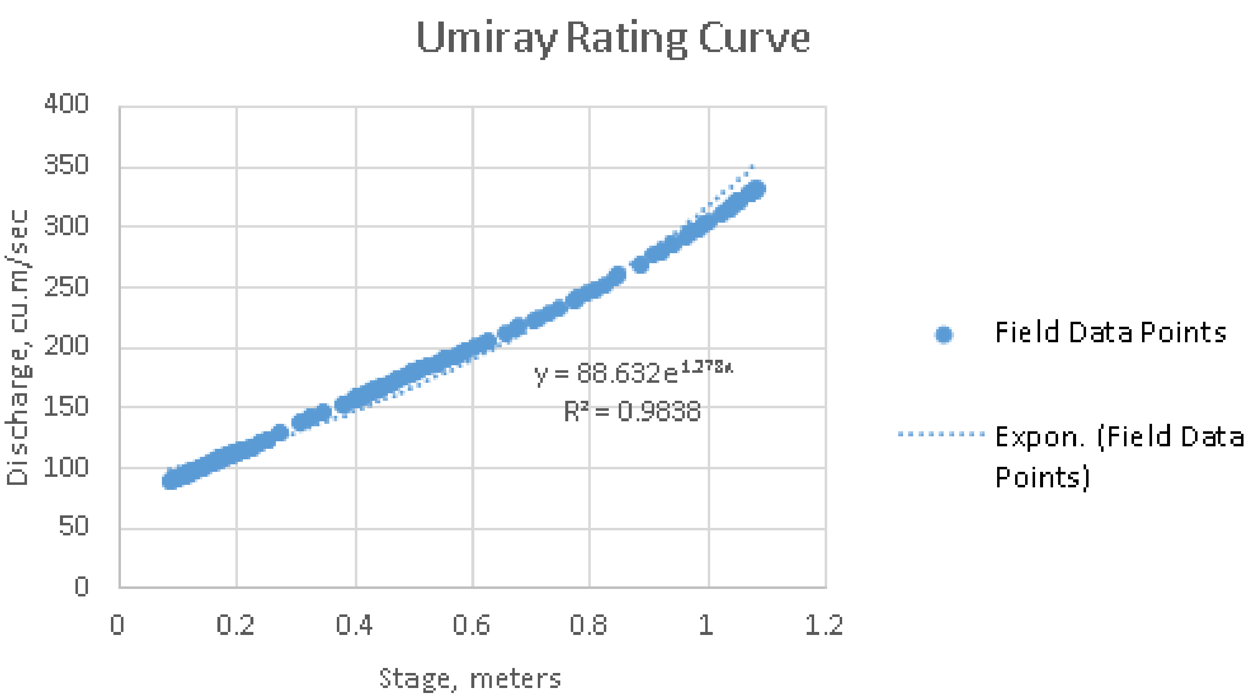


Figure 47. Rating curve at the Umiray Bridge, Dingalan, Aurora.

This rating curve equation was used to compute for the river outflow at the Umiray Bridge, for the calibration of the HEC-HMS model illustrated in Figure 48. The peak discharge was 331.6 cm. on October 6, 2016 at 20:50 hrs.

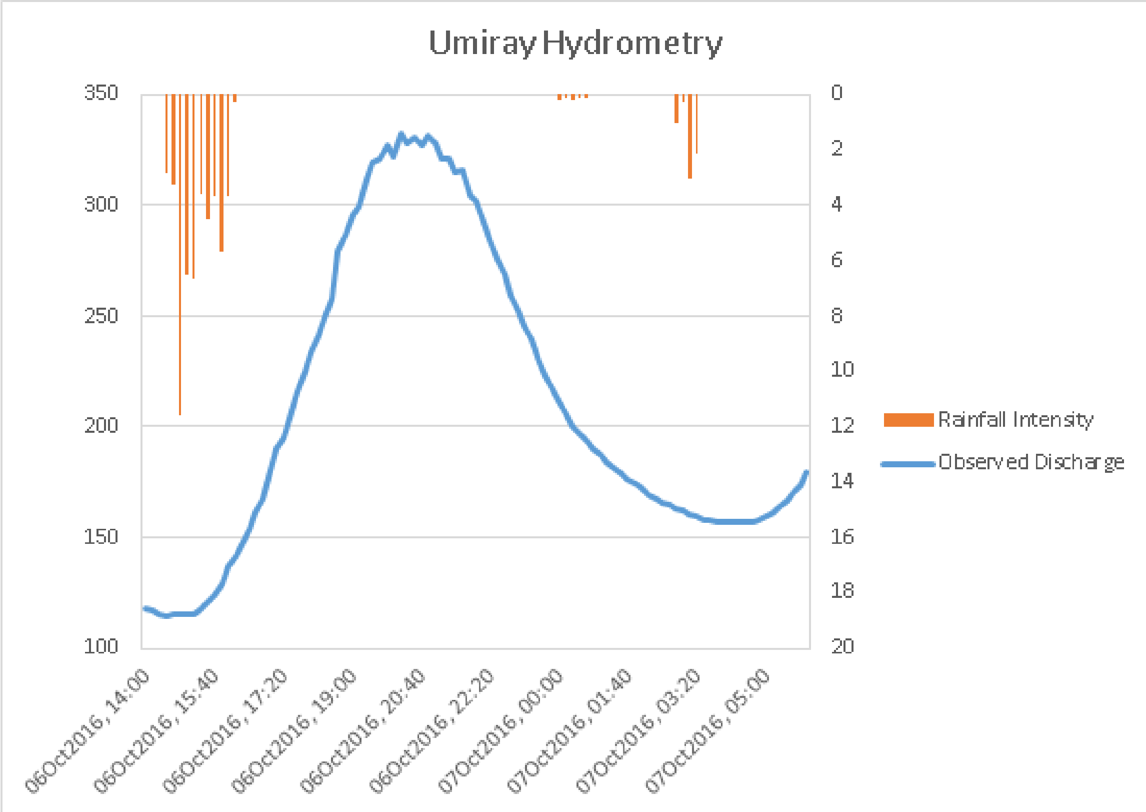


Figure 48. Rainfall and outflow data at Umiray used for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Infanta Rain Gauge (Table 38). . This station was selected based on its proximity to the Umiray watershed (Figure 49). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 26-year record.

Table 38. RIDF values for the Infanta Rain Gauge, computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	20.4	30.7	39.2	57	79.5	93	121.9	151.2	192.9
5	25.7	38.3	49.3	75.4	112.9	133.1	175.3	212.7	249.6
10	29.2	43.4	56	87.6	135	159.6	210.7	253.4	287.1
15	31.2	46.2	59.8	94.5	147.4	174.5	230.7	276.4	308.2
20	32.6	48.2	62.4	99.4	156.2	185	244.6	292.4	323
25	33.7	49.7	64.4	103.1	162.9	193.1	255.4	304.8	334.4
50	37	54.5	70.7	114.5	183.6	217.9	288.6	343	369.6
100	40.3	59.2	76.9	125.9	204.2	242.6	321.5	380.9	404.4

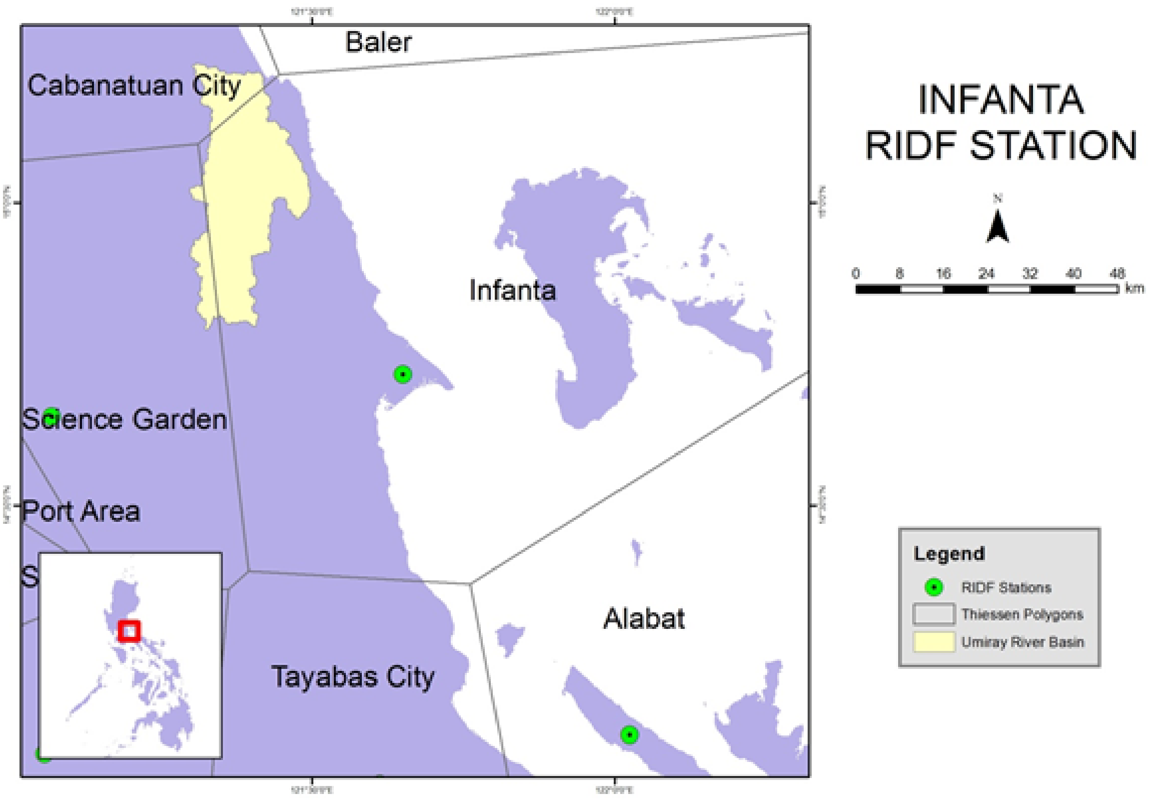


Figure 49. The Infanta RIDF station location, relative to the Umiray River Basin.

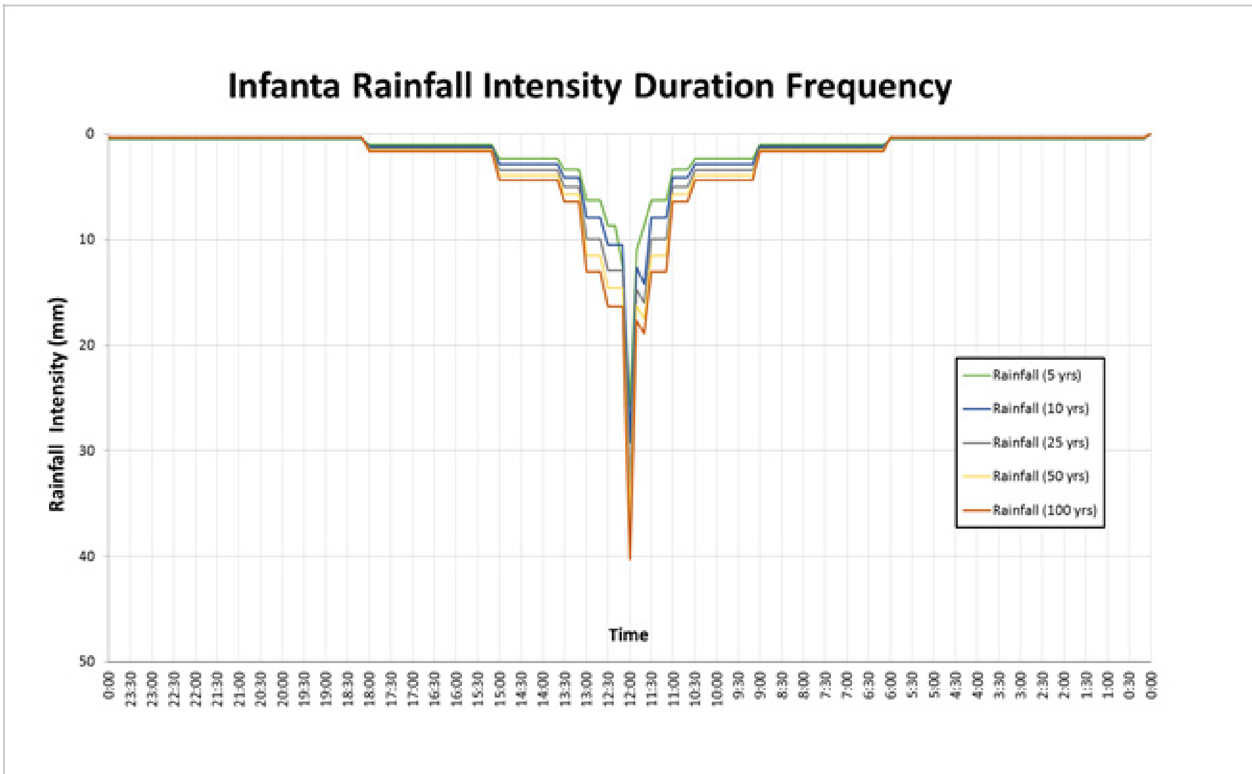


Figure 50. Synthetic storm generated from a 24-hr period rainfall, for various return periods.

5.3 HMS Model

The soil dataset was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004.The soil and land cover maps of the Umiray River Basin are presented in Figures 51 and 52, respectively.

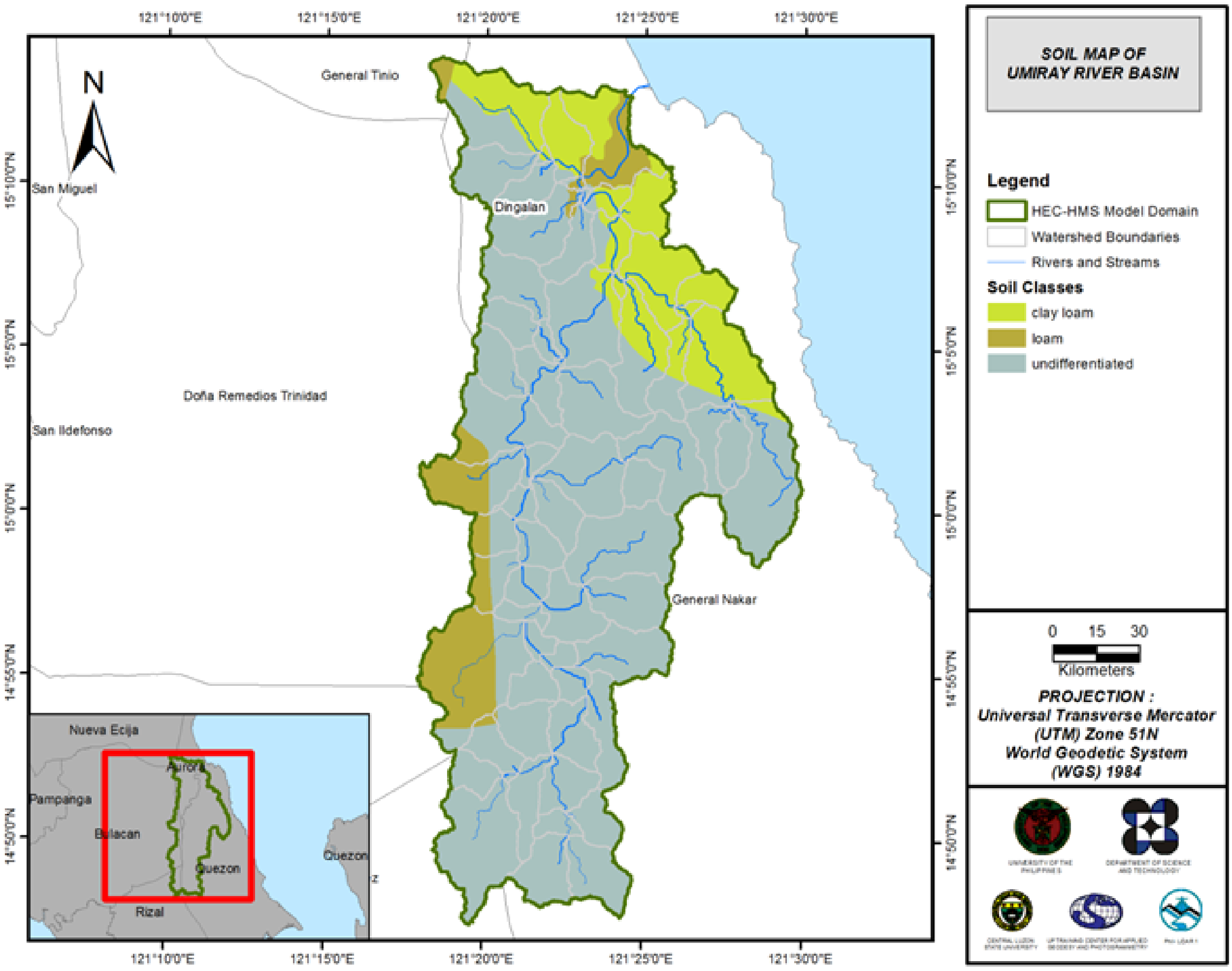


Figure 51. Soil map of the Umiray River Basin (Source: DA)

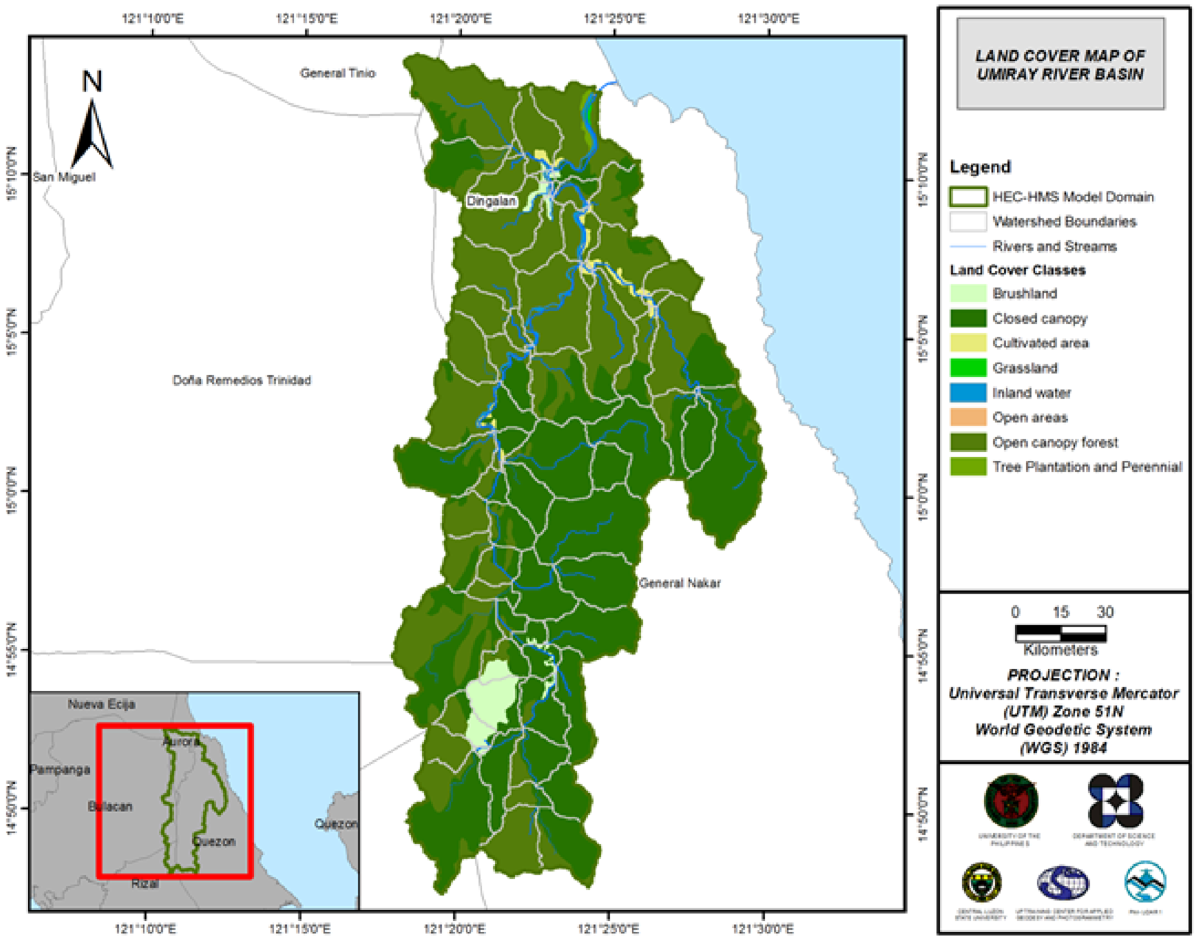


Figure 52. Land cover map of the Umiray River Basin (Source: NAMRIA).

Three (3) soil classes were identified in the Umiray River Basin. These are clay loam, loam, and undifferentiated soil. Moreover, eight (8) land cover classes were identified. These are brushlands, closed canopy, cultivated areas, grasslands, inland water, open areas, open canopy forests, and tree plantations and perennials.

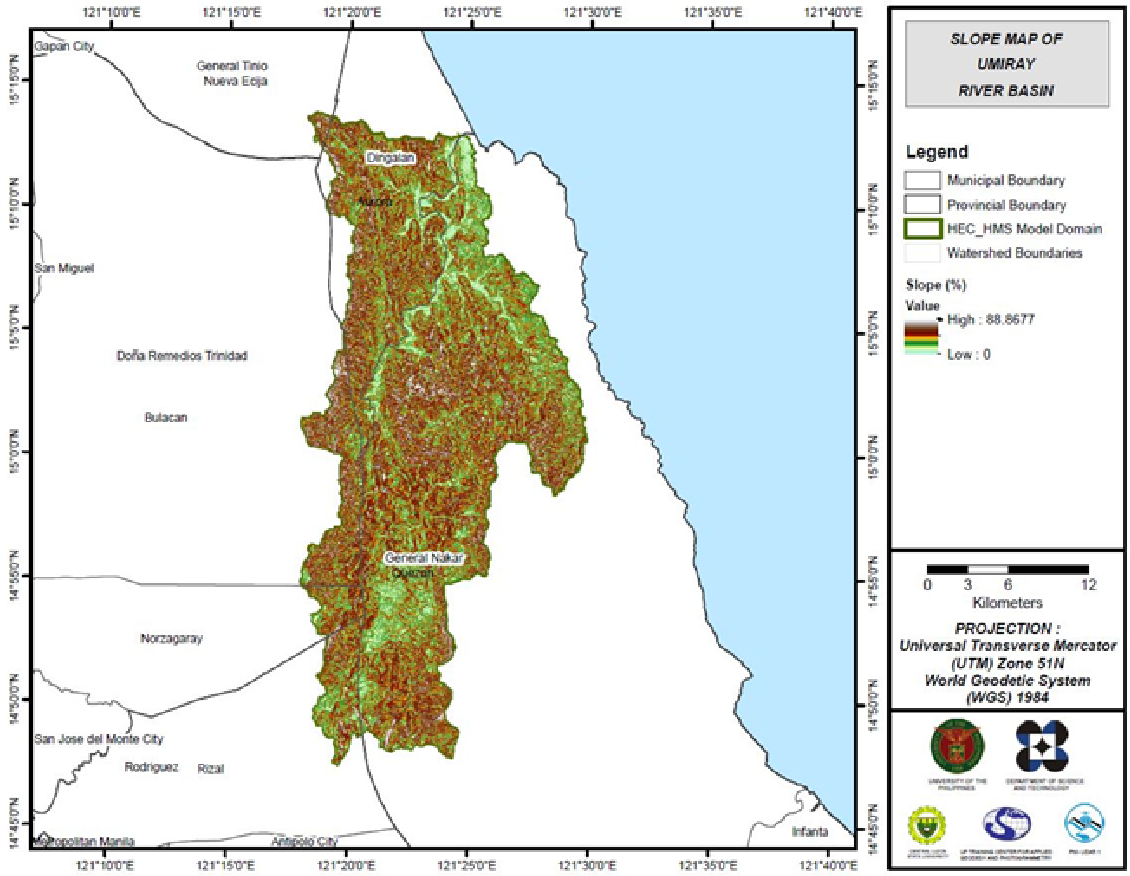


Figure 53. Slope map of the Umiray River Basin.

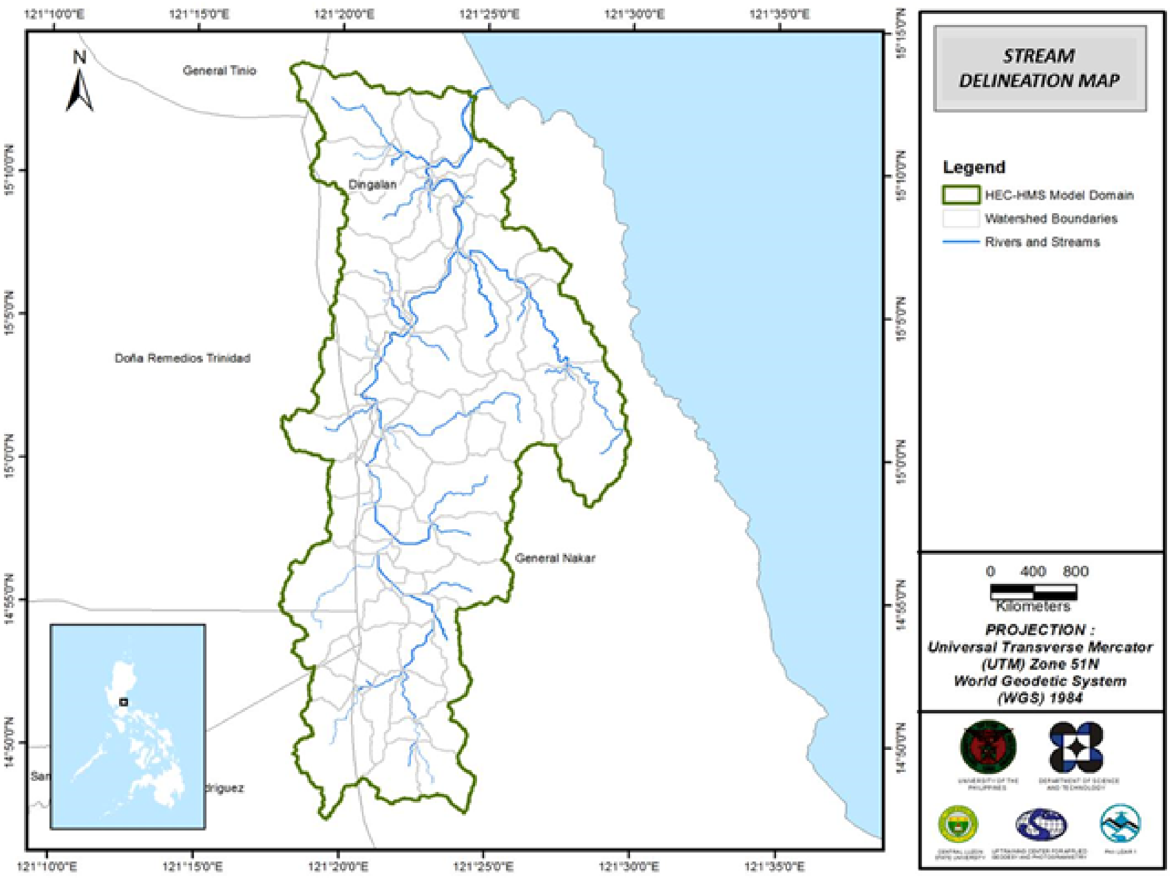


Figure 54. Stream delineation map of the Umiray River Basin.

Using the SAR-based DEM, the Umiray basin was delineated and further subdivided into sub-basins. The Umiray basin model consists of sixty-nine (69) sub-basins, thirty-four (34) reaches, and thirty-four (34) junctions, as demonstrated in Figure 55. Finally, it was calibrated using a depth gauge installed at the Umiray Bridge. See Annex 10 for the Umiray Model Reach Parameters.

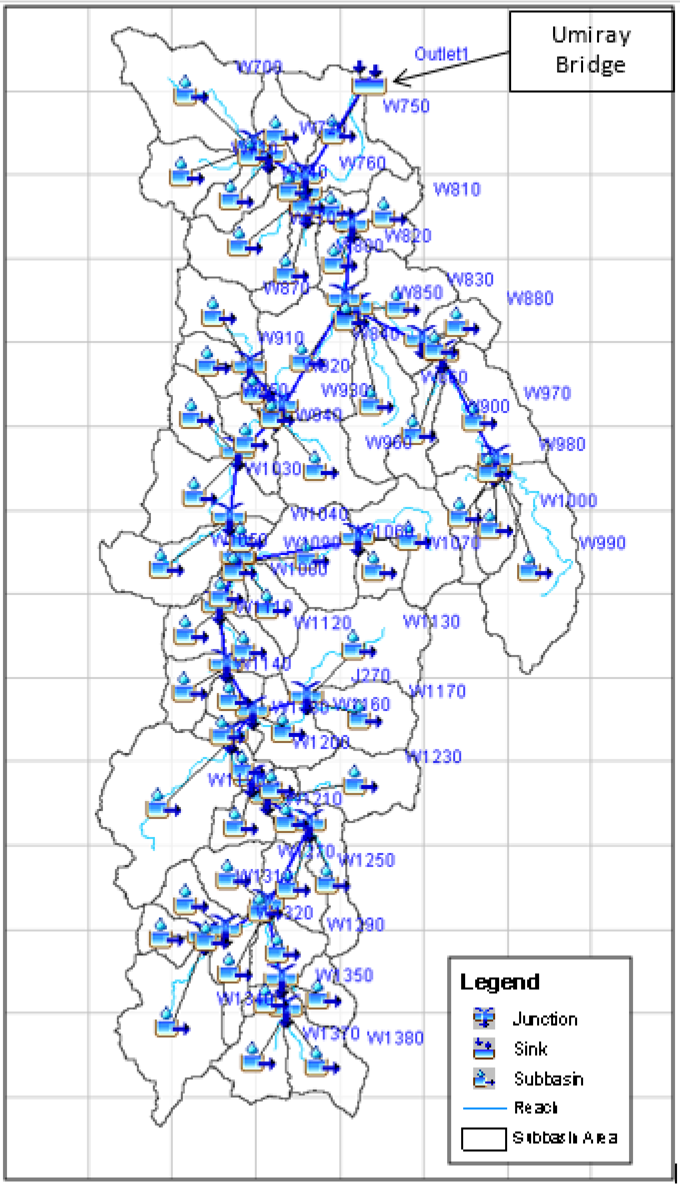


Figure 55. The Umiray River basin model generated using HEC-HMS.

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model were derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcMap (Figure 56).

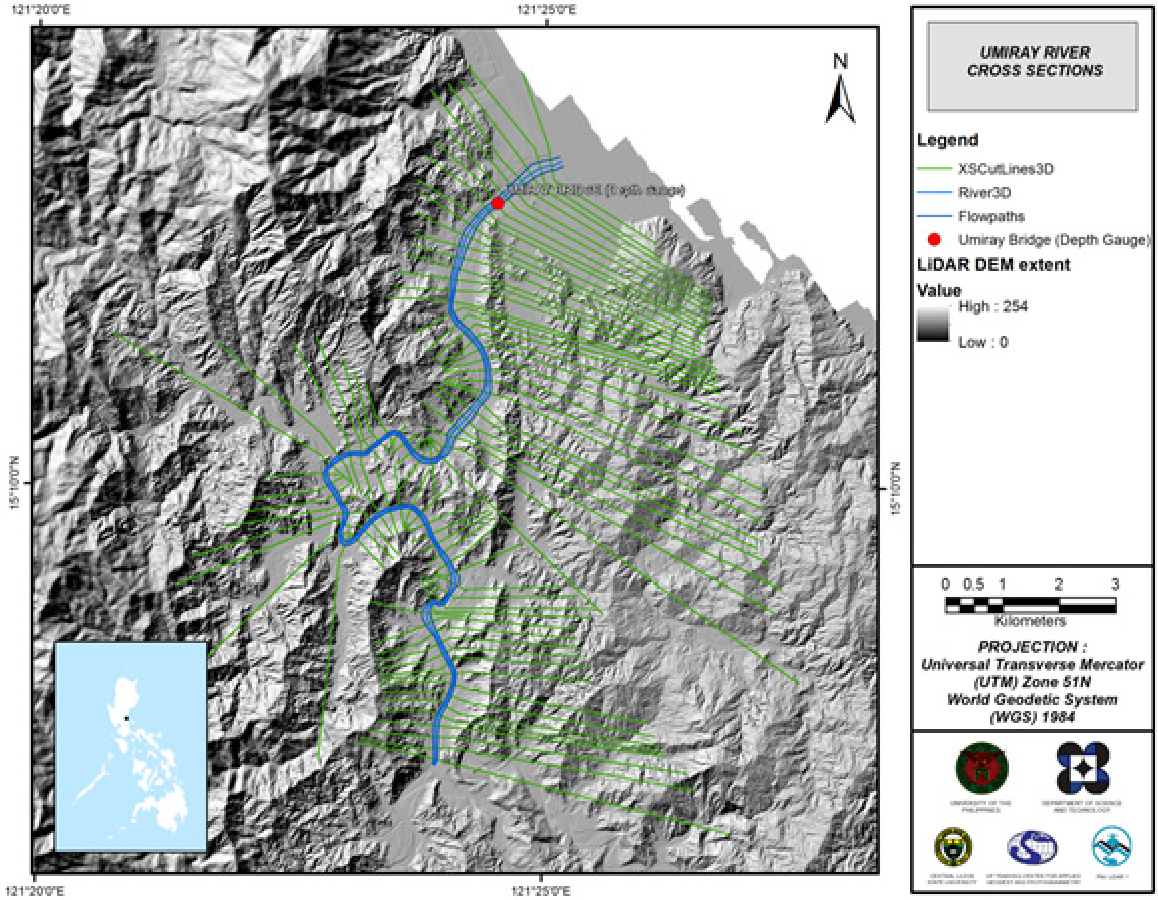


Figure 56. River cross-section of the Umiray River, generated through the ArcMap HEC GeoRAS tool.

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 southwest 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.

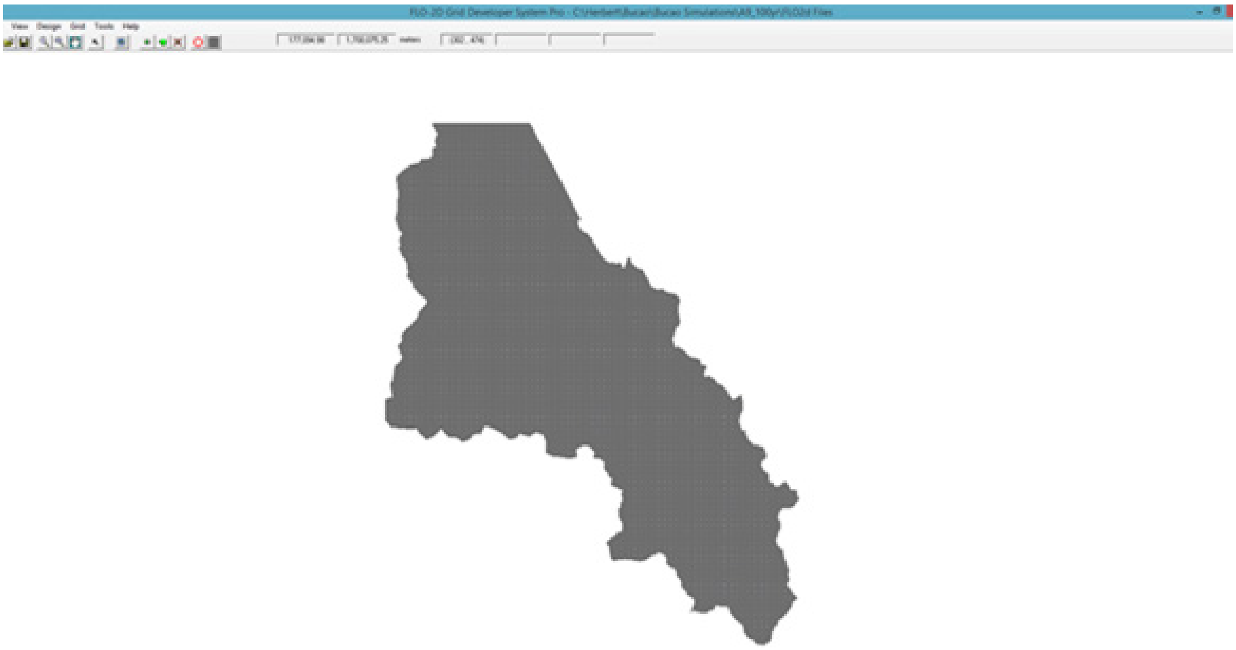


Figure 62. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 263.53613 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 74388960.00 m2.

There is a total of 196462972.67 m3 of water entering the model. Of this amount, 37302731.97 m3 is due to rainfall while 159160240.70 m3 is inflow from other areas outside the model. 7448690.50 m3 of this water is lost to infiltration and interception, while 82222857.44 m3 is stored by the flood plain. The rest, amounting up to 106791522.36 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Umiray HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 58 illustrates the comparison between the two (2) discharge data. Annex 9 presents the Umiray Model Basin Parameters.

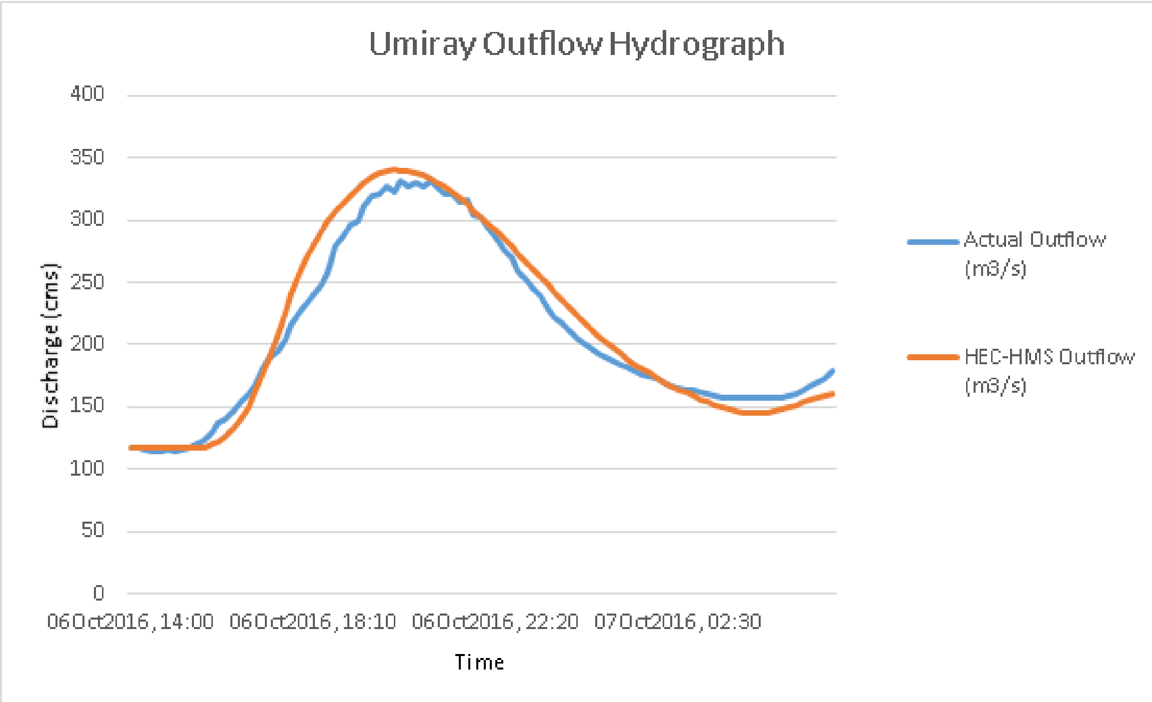


Figure 58. Outflow hydrograph of Umiray produced by the HEC-HMS model, compared with observed outflow.

Table 39 outlines the adjusted ranges of values of the parameters used in calibrating the model.

Table 39. Range of calibrated values for the Umiray River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	4.8 – 26
			Curve Number	59 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2 – 8.1
			Storage Coefficient (hr)	0.3 – 12
	Baseflow	Recession	Recession Constant	0.5
			Ratio to Peak	0.1 – 0.15
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.01 – 0.02

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values from 4.8mm to 26mm for initial abstraction signifies that there is a minimal amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range for the curve number of the Umiray River Basin is 59 to 999. The Umiray basin mostly consists of closed canopy and open canopy forests, and the soil mostly consists of undifferentiated soil.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 hours to 12 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which baseflow recedes between storm events; while ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.50 indicates that the basin is likely to quickly return to its original discharge. A ratio to peak of 0.1 – 0.15 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.01 - 0.02 corresponds to the common roughness in the Umiray watershed, which is determined to be cultivated but without crops (Brunner, 2010).

Table 40. Summary of the Efficiency Test of the Umiray HMS Model.

Accuracy measure	Value
RMSE	14.6
r2	0.98
NSE	0.96
PBIAS	-2.24
RSR	0.21

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed at 14.6 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC-HMS model. A value of r2 = 0.98 was computed for this model. This means that the degree of collinearity between the simulated and measured data is relatively high.

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 0.96, which signifies that the model obtained a very good performance rating in simulating discharge.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -2.24, which implies that the model was overestimated with a 2.24 percent difference in streamflow volume between the simulated and measured data for a particular period.

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 59) shows the Umiray outflow using the Infanta RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

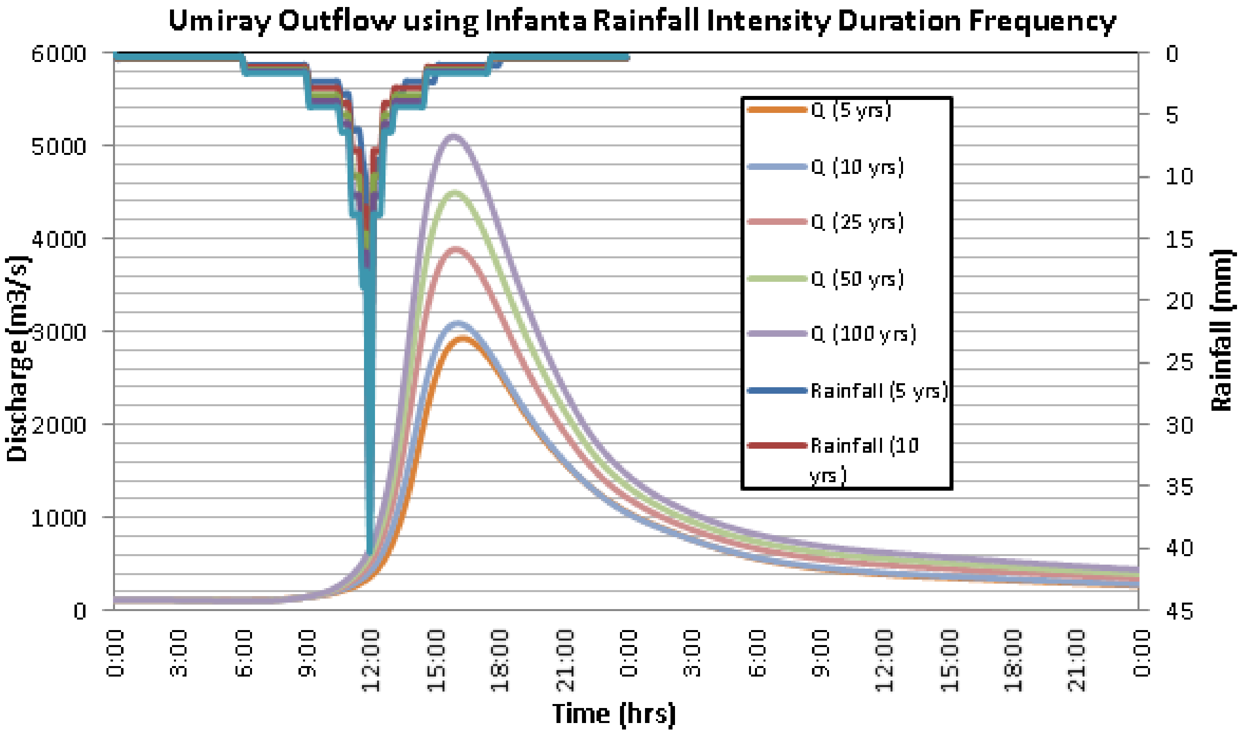


Figure 59. Outflow hydrograph at the Umiray Station generated using Infanta RIDF simulated in HEC HMS.

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Umiray discharge using the Infanta RIDF curves in five (5) different return periods is given in Table 41.

Table 41. Peak values of the Umiray HEC-HMS Model outflow using the Infanta RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	249.6	25.7	2927.7	4 hours 20 minutes
10-Year	287.1	29.2	3088.7	4 hours 10 minutes
25-Year	334.4	33.7	3885.8	4 hours
50-Year	369.6	37.0	4492.9	4 hours
100-Year	404.4	40.3	5097.3	3 hours 50 minutes

5.7.2 Discharge data using Dr. Horritts' recommended hydrologic method

The river discharge values entering the Umiray floodplain is illustrated in Figure 60, and the peak values are enumerated in Table 42.

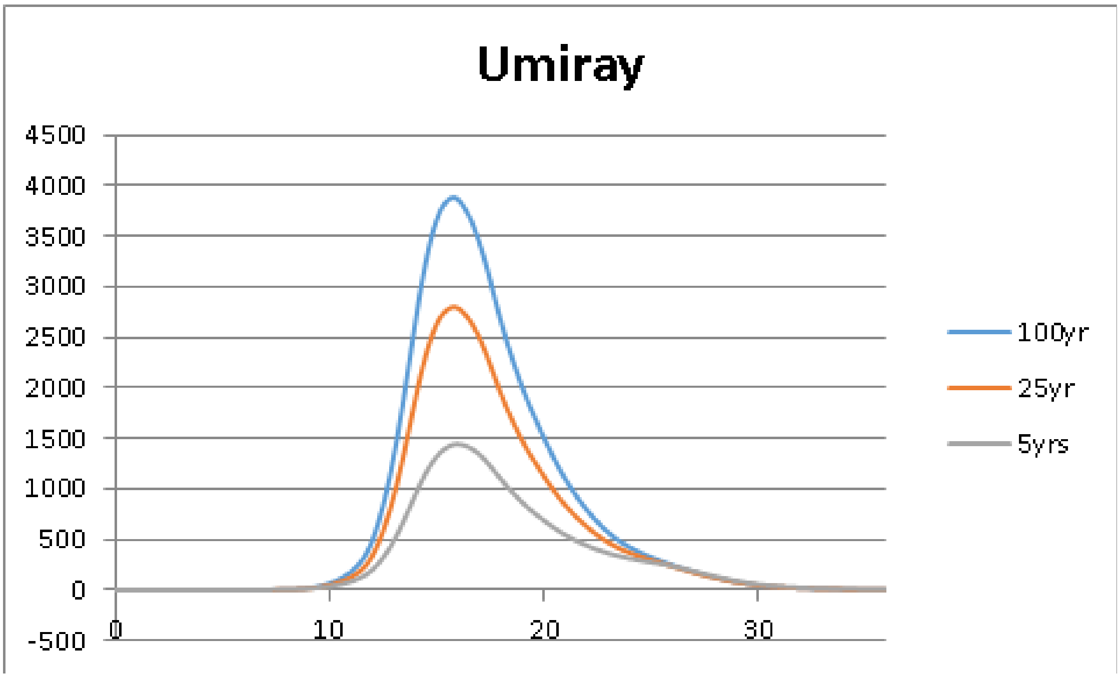


Figure 60. Umiray River generated discharge using 5-, 25-, and 100-year Infanta RIDF in HEC-HMS.

Table 42.Summary of the Umiray River (1) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time to Peak
100-Year	3884.2	15 hours, 50 minutes
25-Year	2801.4	15 hours, 50 minutes
5-Year	1441.7	16 hours

The comparison of the discharge results using Dr. Horritts' recommended hydrological method against the bankful and specific discharge estimates is presented in Table 43.

Table 43. Validation of river discharge estimates.

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Umiray	1268.696	438.095	1044.289	Fail	Pass

The results from the HEC-HMS river discharge estimates were not able to satisfy the conditions for validation using the bankful and specific discharge methods. One value did not pass and will need further recalculation. The passing values are based on theory but are supported by other discharge computation methods, so they were appropriate for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain the actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the extent of real-time flood inundation of the river, after it has been automated and uploaded on the DREAM website.

The Umiray model had a minimum and maximum flow discharge of 117 m3/s and 332.6 m3/s, respectively. This information was needed for unsteady flow analysis, as an input file. The simulation results showed that there were no occurremces of overflows along the banks of the river due to low discharge, which clearly indicates that the bank heights of most of the river sections are higher than the water surface level. The sample output 1D flood hazard map using the calibrated discharge of the Umiray River from the HMS model is presented in Figure 61.

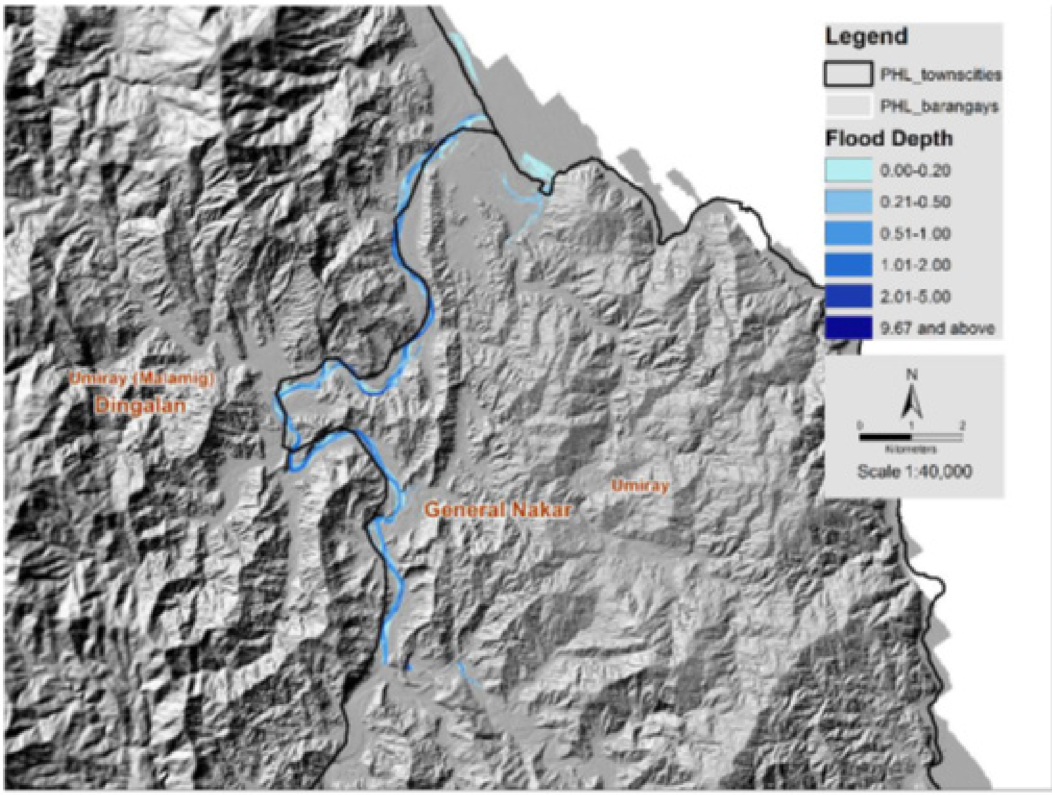


Figure 61. Sample output map of Umiray RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10-meter resolution. Figure 62 to Figure 67 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Umiray floodplain. The floodplain, with an area of 403.95 sq. km., covers four (4) municipalities: Dingalan, Doña Remedios Trinidad, General Tinio, and General Nakar. Table 44 outlines the percentage of area affected by flooding per municipality.

Table 44. Municipalities affected in Umiray floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Dingalan	373.11	137.52	37%
Doña Remedios Trinidad	871.20	19.01	2%
General Tinio	659.83	2.92	0.4%
General Nakar	1275.55	244.50	19%

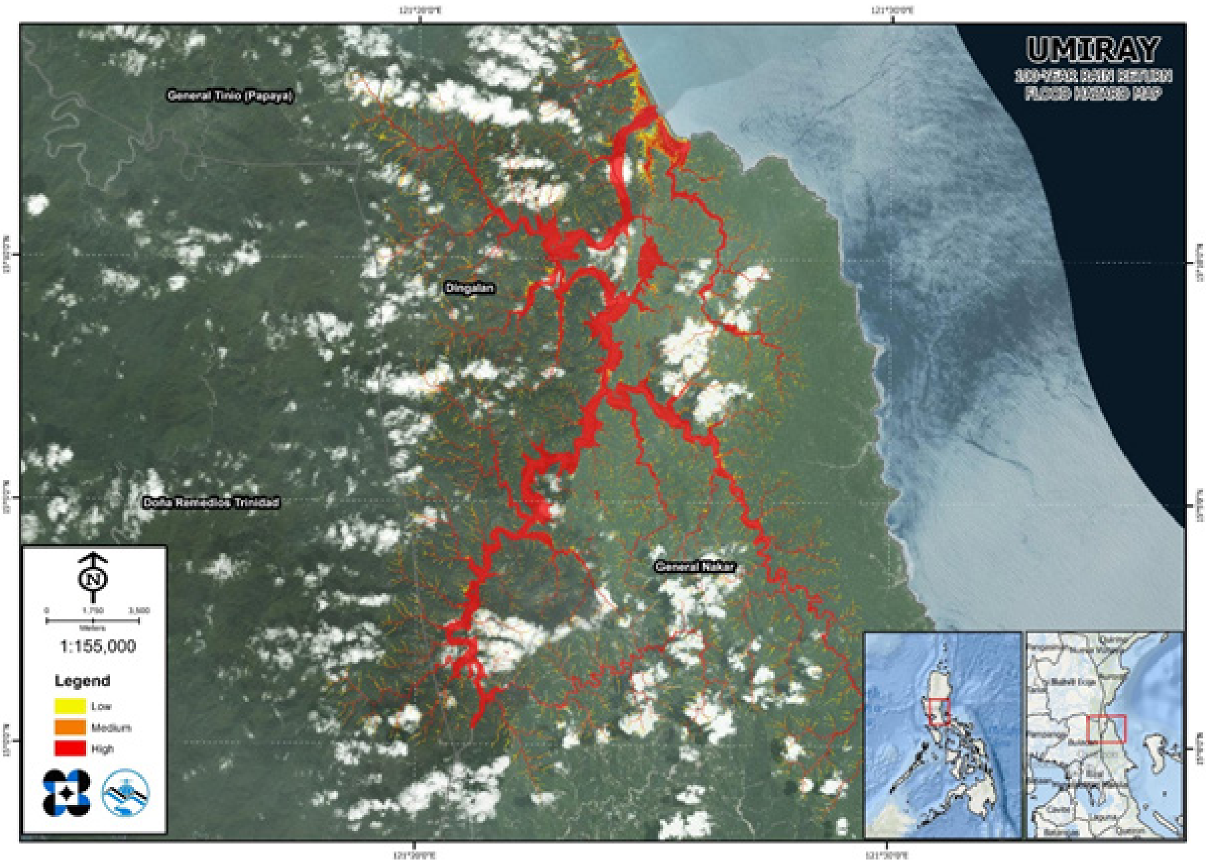


Figure 62. 100-year flood hazard map for the Umiray floodplain.

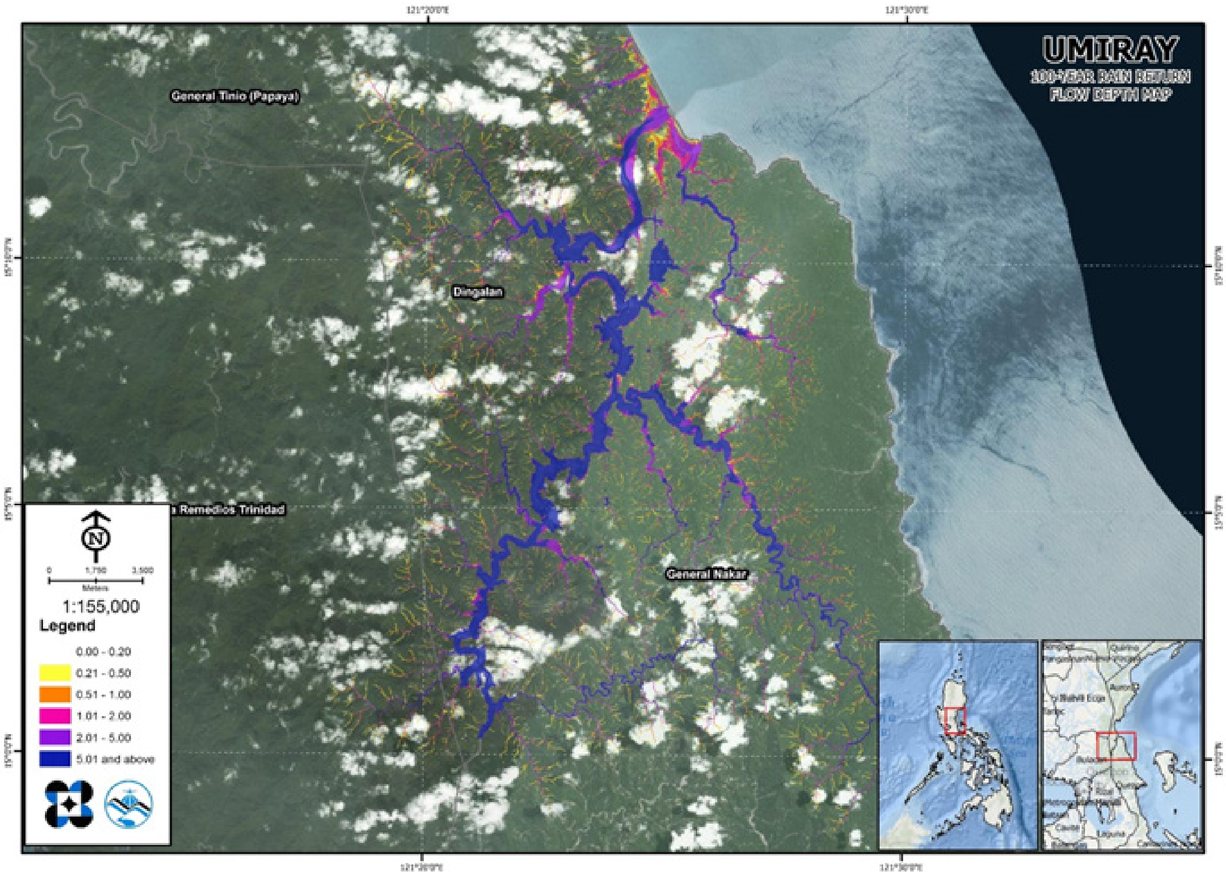


Figure 63. 100-year flow depth map for the Umiray floodplain.

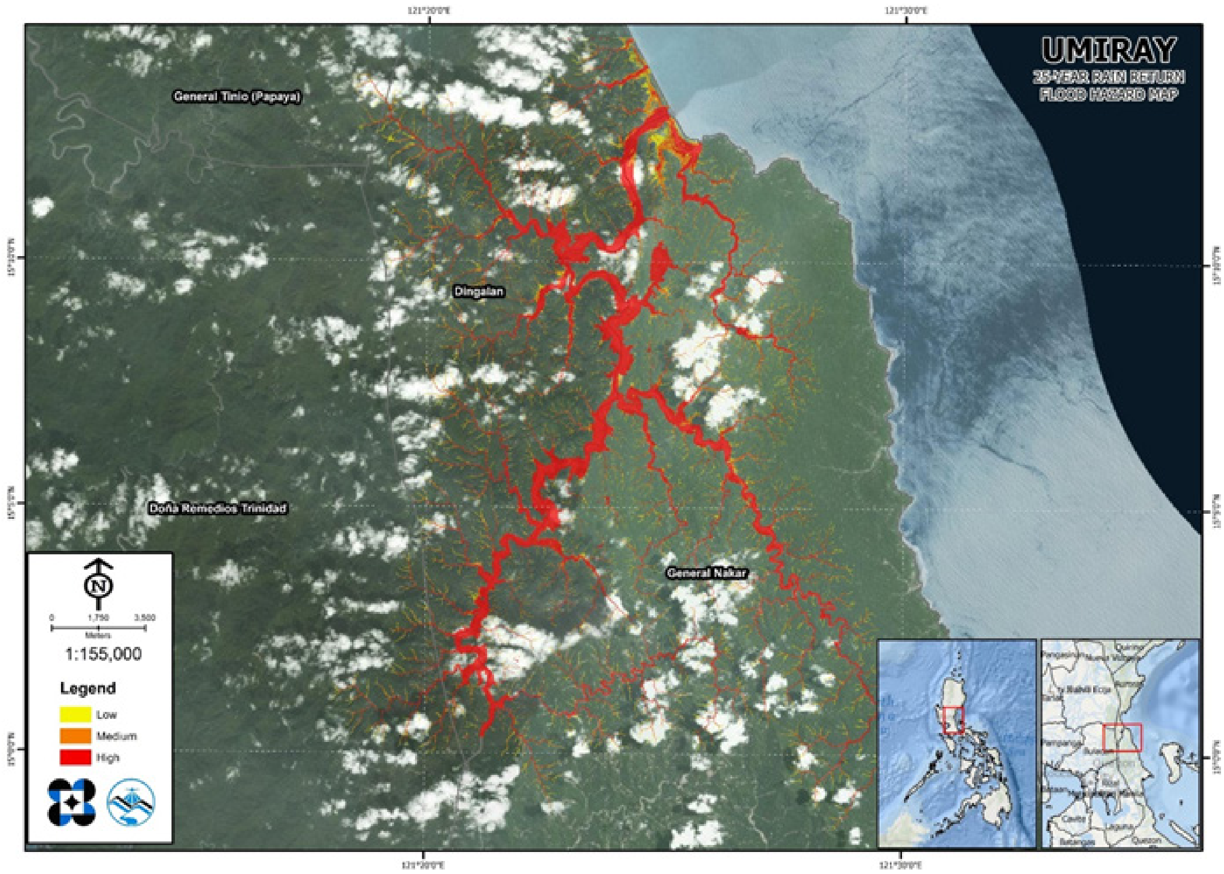


Figure 64. 25-year flood hazard map for the Umiray floodplain

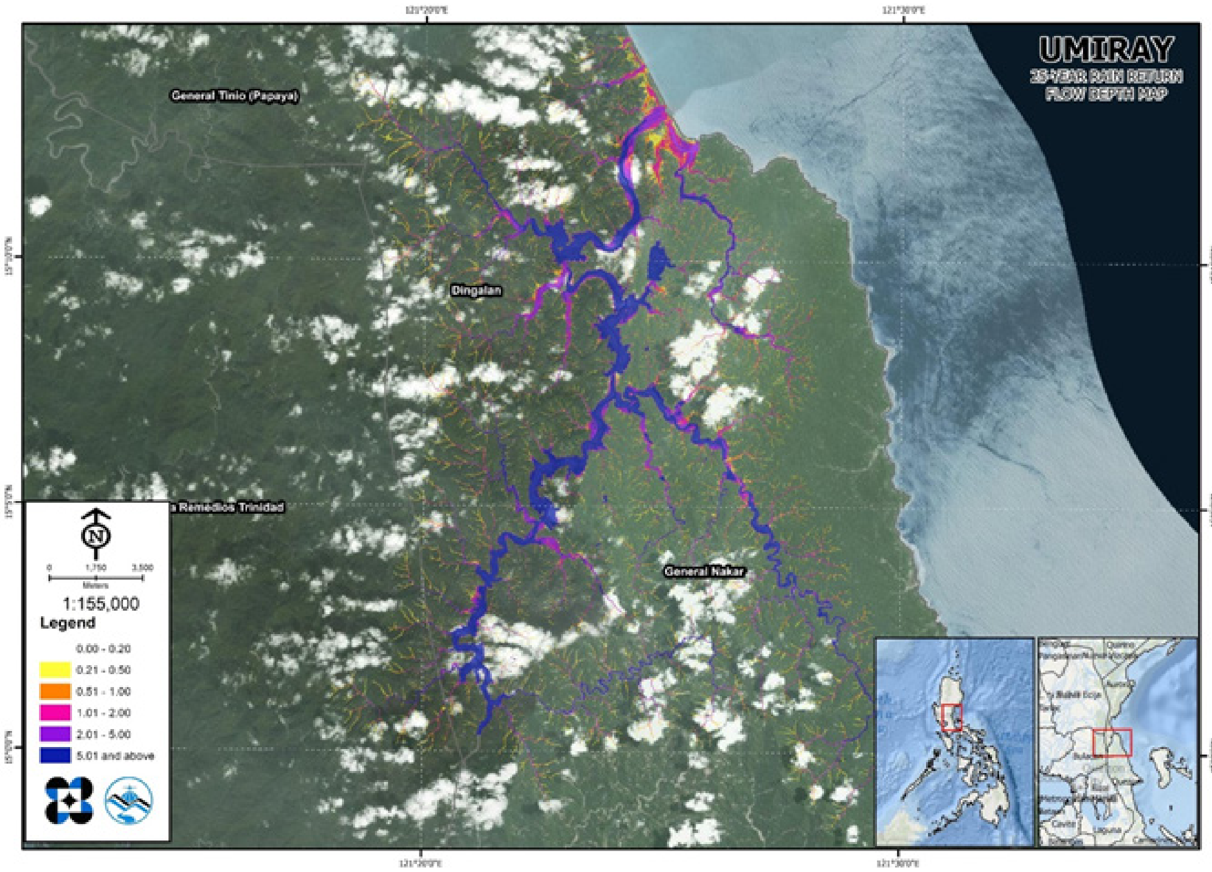


Figure 65. 25-year flow depth map for the Umiray floodplain.

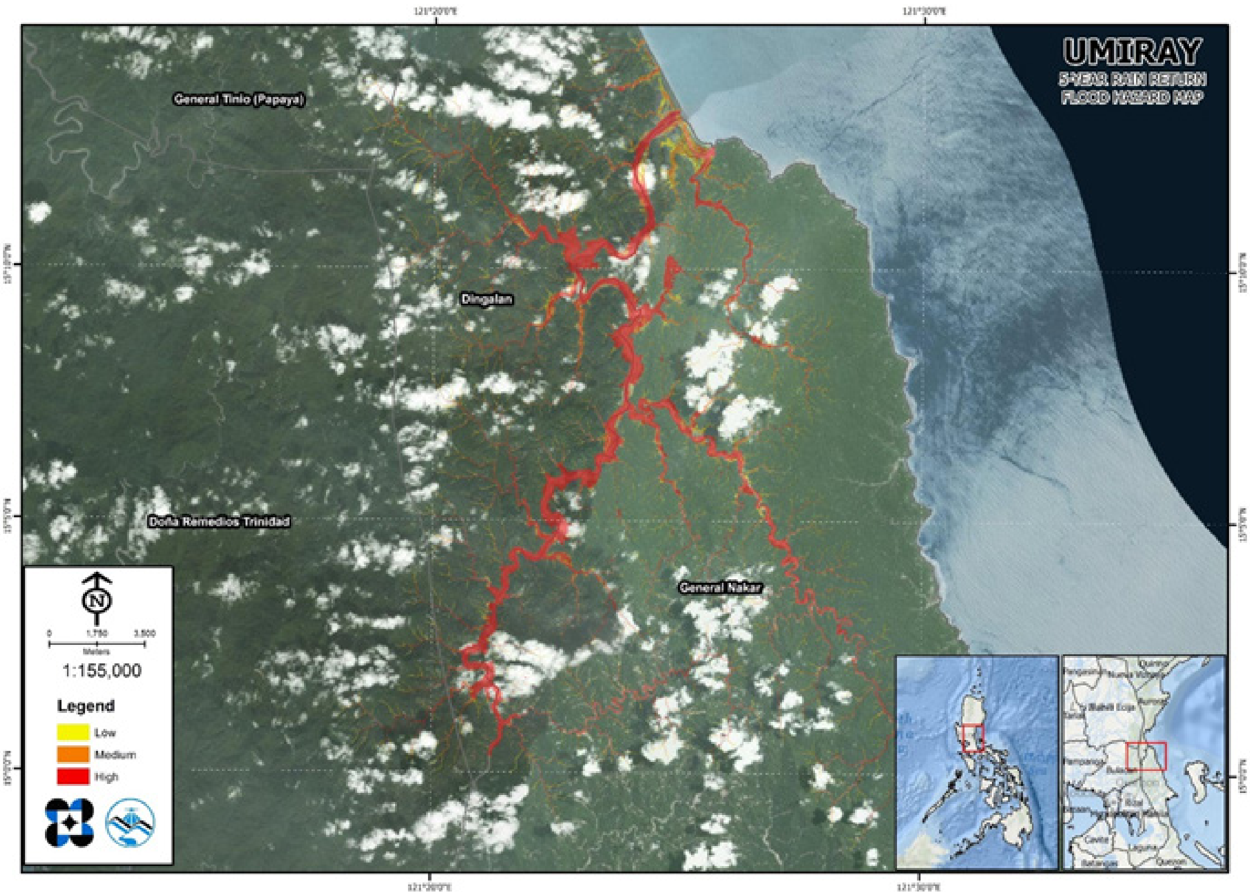


Figure 66. 5-year flood hazard map for the Umiray floodplain.

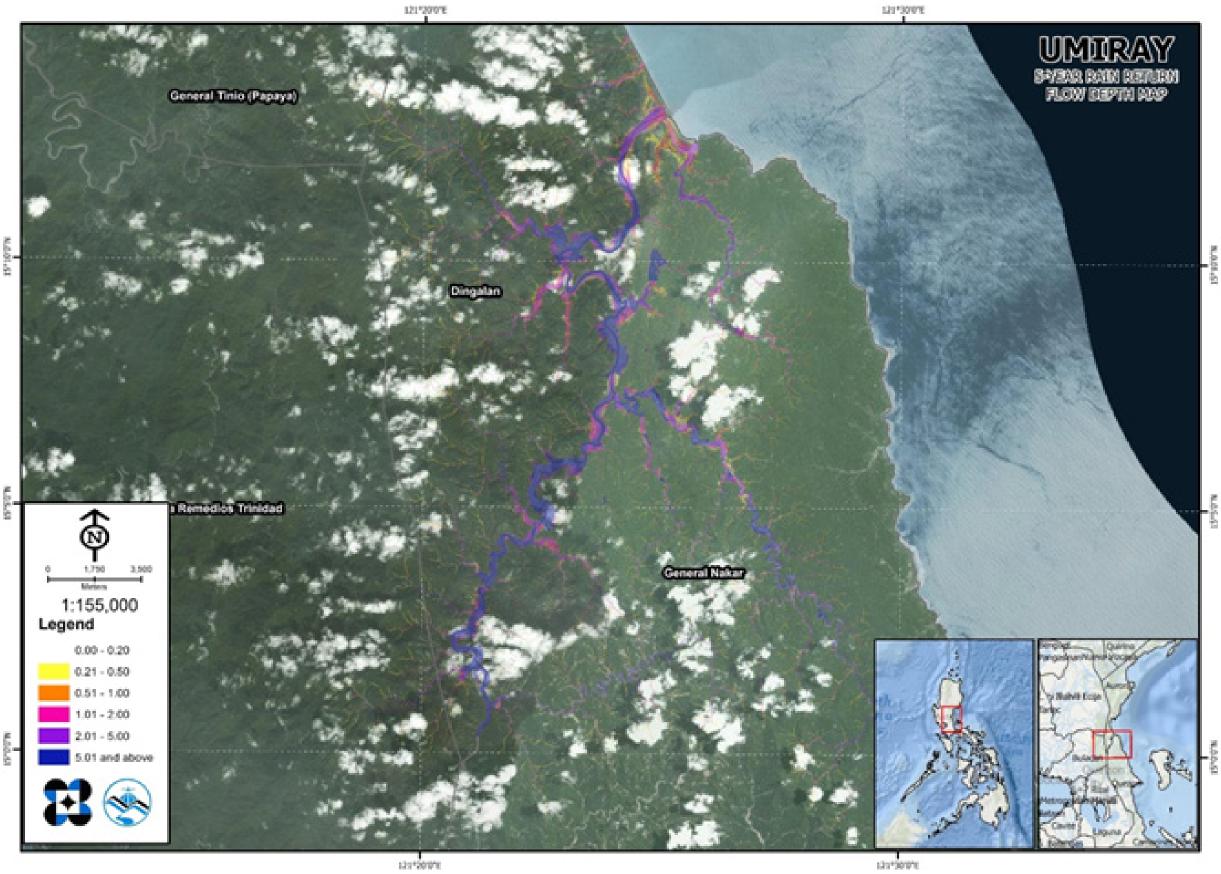


Figure 67. 5-year flow depth map for the Umiray floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Umiray River Basin, grouped by municipality, are listed below. For the said basin, four (4) municipalities consisting of six (6) barangays are expected to experience flooding when subjected to the 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 33.30% of the Municipality of Dingalan, with an area of 373.109657 sq. km., will experience flood levels of less than 0.20 meters. 1.01% of the area will experience flood levels of 0.21 to 0.50 meters, Meanwhile, 0.60%, 0.61%, 0.78%, and 0.56% 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 Dingalan, Aurora during a 5-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dingalan (in sq. km)
	Umiray
0.03-0.20	124.23
0.21-0.50	3.76
0.51-1.00	2.24
1.01-2.00	2.28
2.01-5.00	2.92
> 5.00	2.09

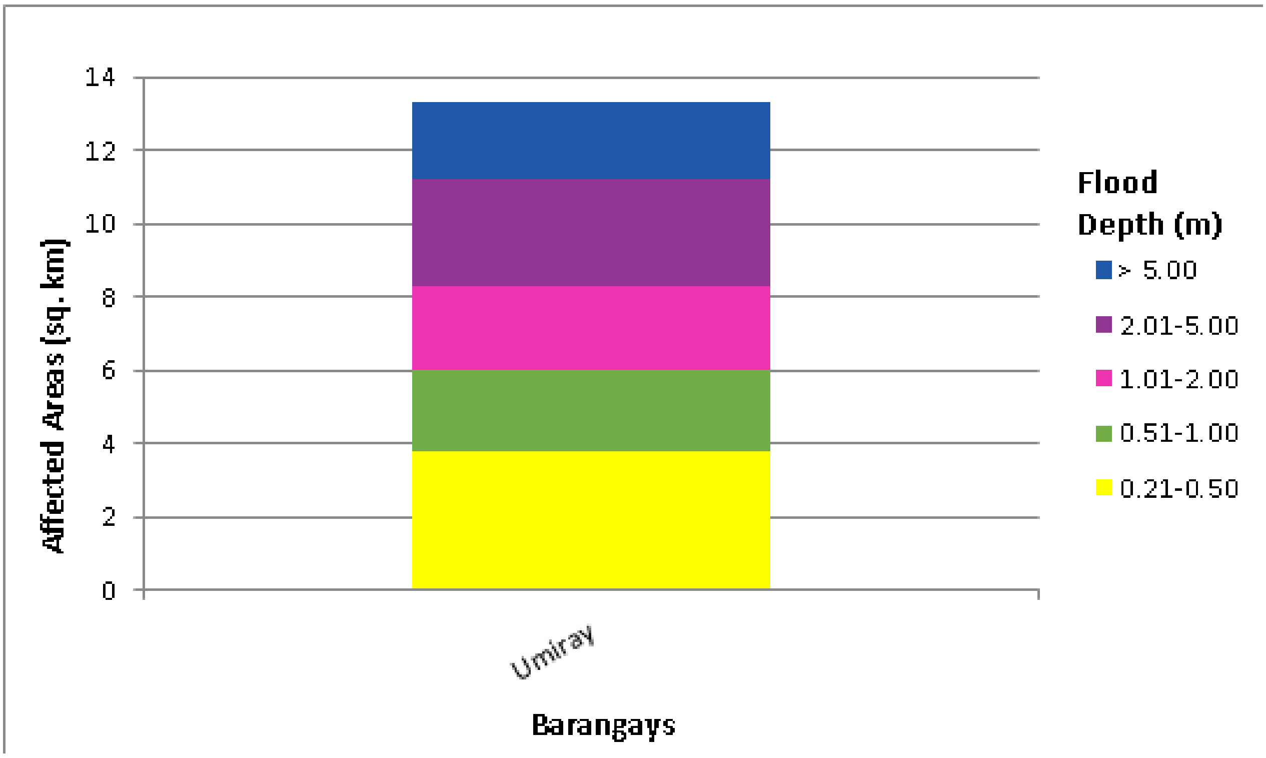


Figure 68. Affected Areas in Dingalan, Aurora during a 5-year rainfall return period.

For the 5-year return period, 2.09% of the Municipality of Doña Remedios Trinidad, with an area of 871.198841 sq. km., will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.02%, 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Doña Remedios Trinidad, Bulacan during a 5-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Doña Remedios Trinidad (in sq. km)	
	Camachin	Kalawakan
0.03-0.20	18.05	0.17
0.21-0.50	0.41	0.0002
0.51-1.00	0.16	0
1.01-2.00	0.092	0
2.01-5.00	0.099	0
> 5.00	0.016	0

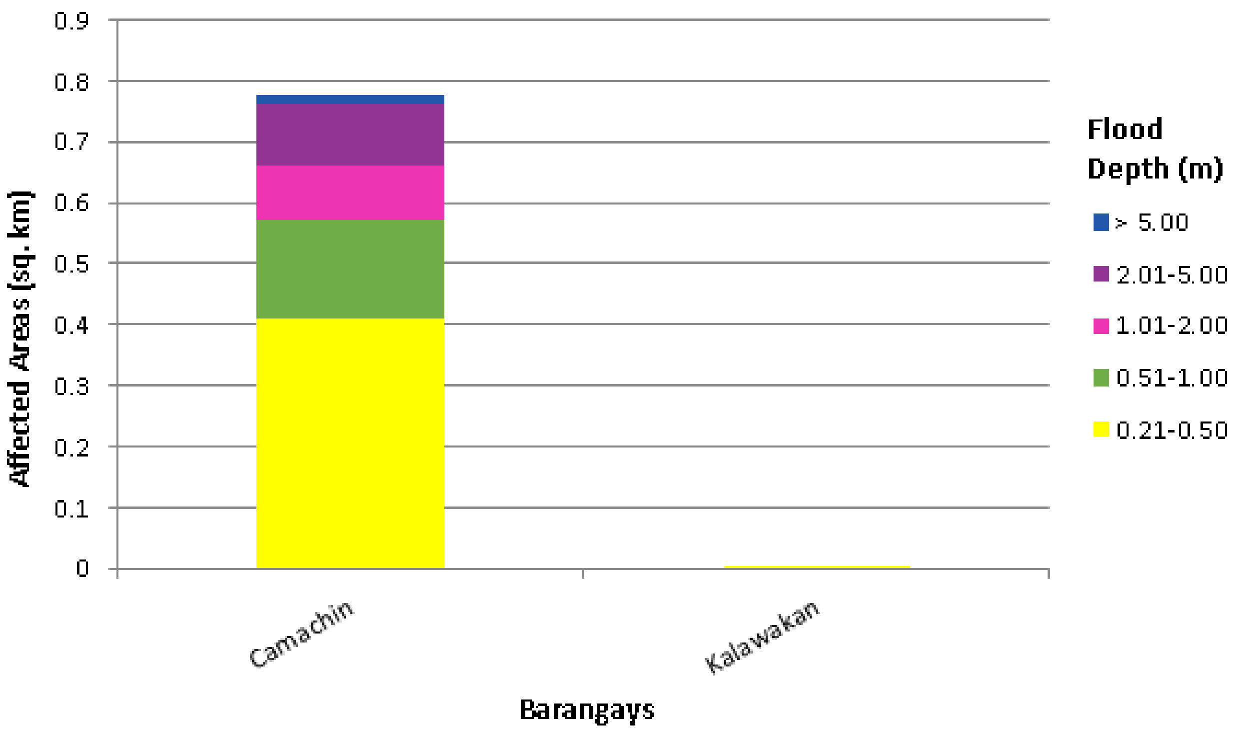


Figure 69. Affected areas in Doña Remedios Trinidad, Bulacan during a 5-year rainfall return period.

For the 5-year return period, 0.42% of the Municipality of General Tinio, with an area of 659.833412 sq. km., will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in General Tinio, Nueva Ecija during a 5-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Tinio (in sq. km)
	Pias
0.03-0.20	2.8
0.21-0.50	0.08
0.51-1.00	0.032
1.01-2.00	0.0054
2.01-5.00	0
> 5.00	0

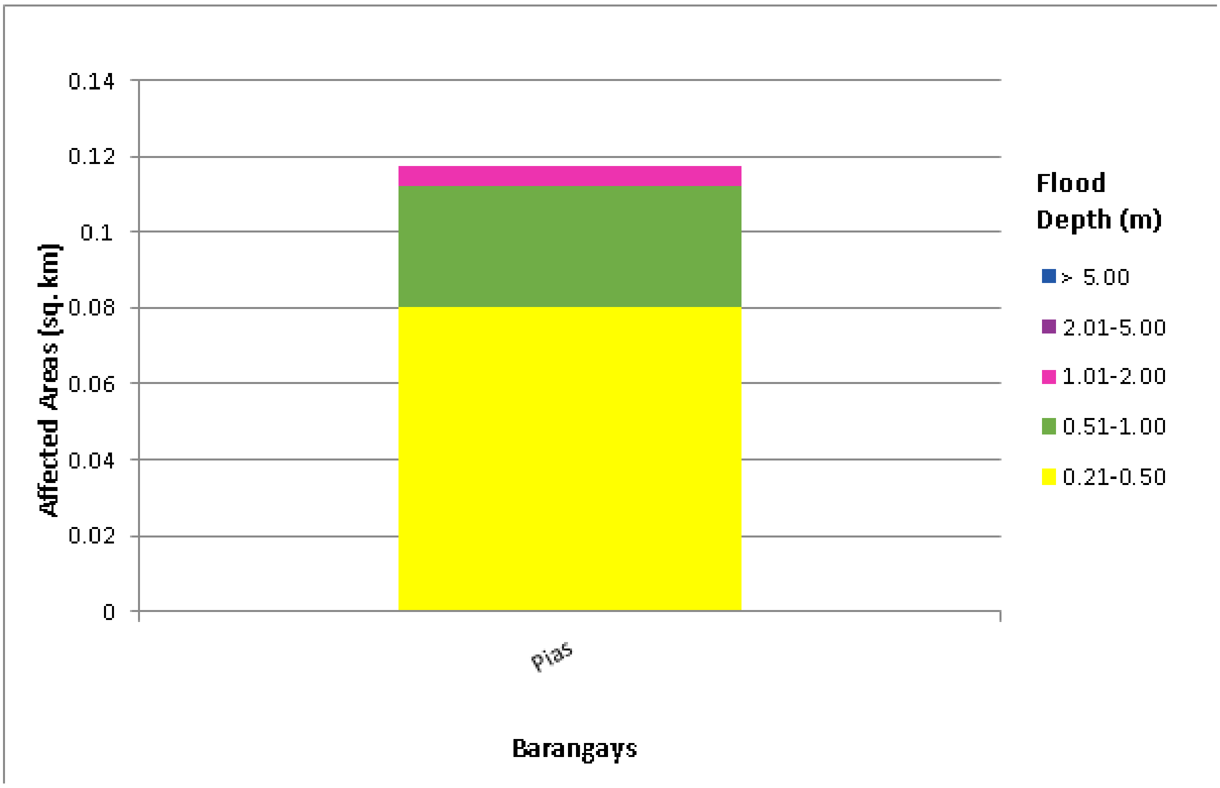


Figure 70. Affected areas in General Tinio, Nueva Ecija during a 5-year rainfall return period.

For the 5-year return period, 16.69% of the Municipality of General Nakar, with an area of 1275.549305 sq. km., will experience flood levels of less than 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.31%, 0.33%, 0.51%, and 0.84% 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 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in General Nakar, Quezon during a 5-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Nakar (in sq. km)	
	Canaway	Umiray
0.03-0.20	61.31	151.52
0.21-0.50	1.25	4.94
0.51-1.00	0.59	3.38
1.01-2.00	0.57	3.69
2.01-5.00	0.75	5.78
> 5.00	0.89	9.78

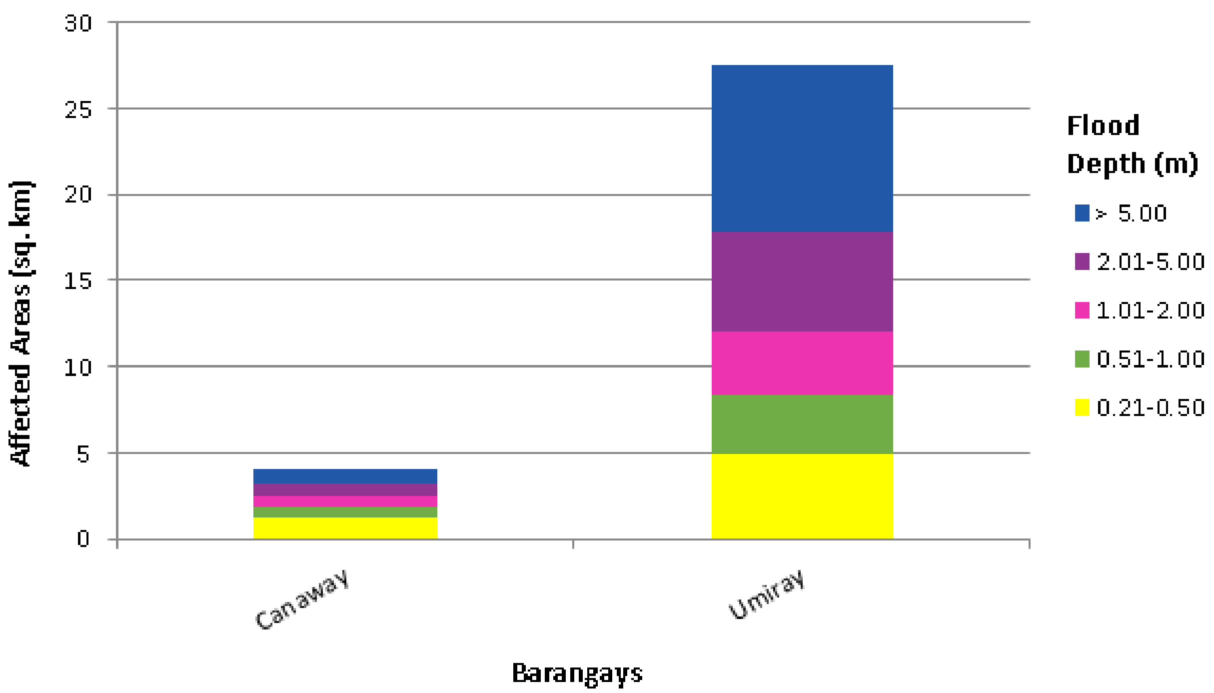


Figure 71. Affected areas in General Nakar, Quezon during a 5-year rainfall return period.

For the 25-year return period, 32.07% of the Municipality of Dingalan, with an area of 373.109657 sq. km., will experience flood levels of less than 0.20 meters. 1.33% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.70%, 0.64%, 1.03%, and 1.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Dingalan, Aurora during a 25-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dingalan (in sq. km)
	Umiray
0.03-0.20	119.64
0.21-0.50	4.96
0.51-1.00	2.63
1.01-2.00	2.39
2.01-5.00	3.85
> 5.00	4.04

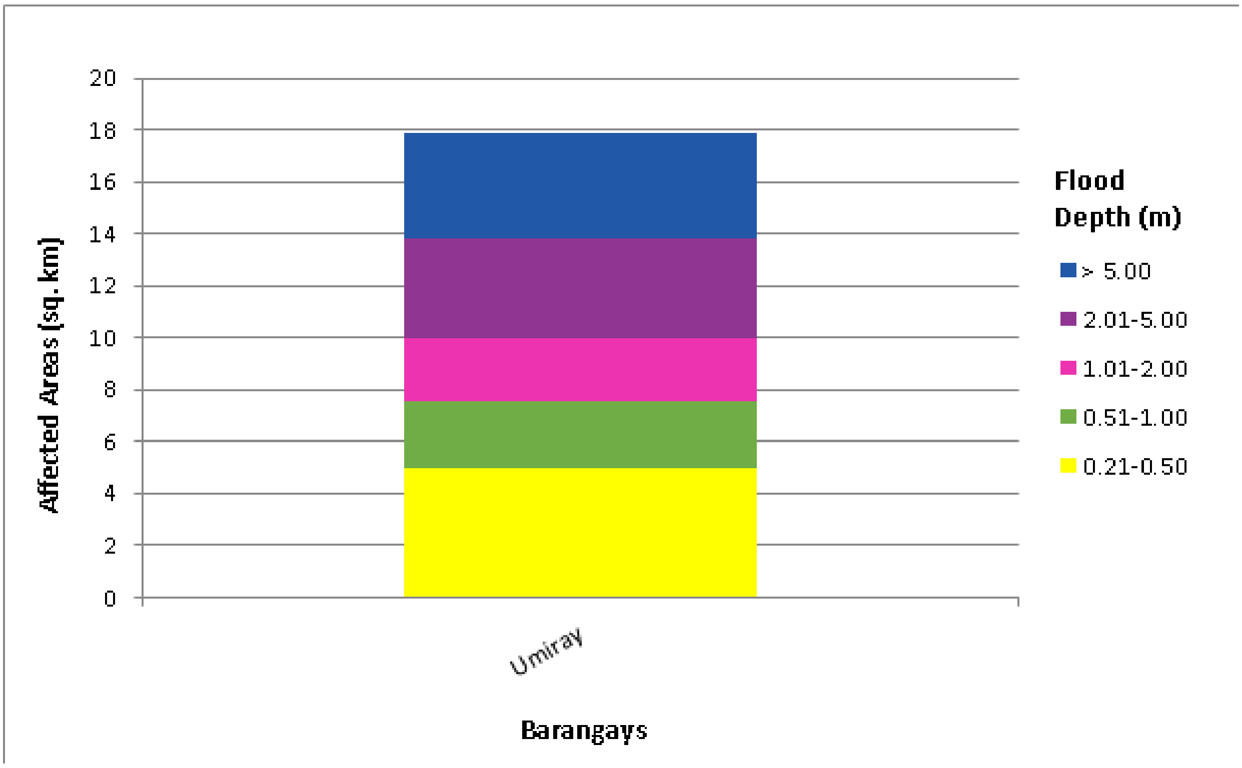


Figure 72. Affected areas in Dingalan, Aurora during a 25-year rainfall return period.

For the 25-year return period, 2.05% of the Municipality of Doña Remedios Trinidad, with an area of 871.198841 sq. km., will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03%, 0.01%, 0.01%, and 0.01% 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 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Doña Remedios Trinidad, Bulacan during a 25-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dingalan (in sq. km)	
	Camachin	Kalawakan
0.03-0.20	17.66	0.17
0.21-0.50	0.58	0.00011
0.51-1.00	0.24	0.0001
1.01-2.00	0.13	0
2.01-5.00	0.13	0
> 5.00	0.081	0

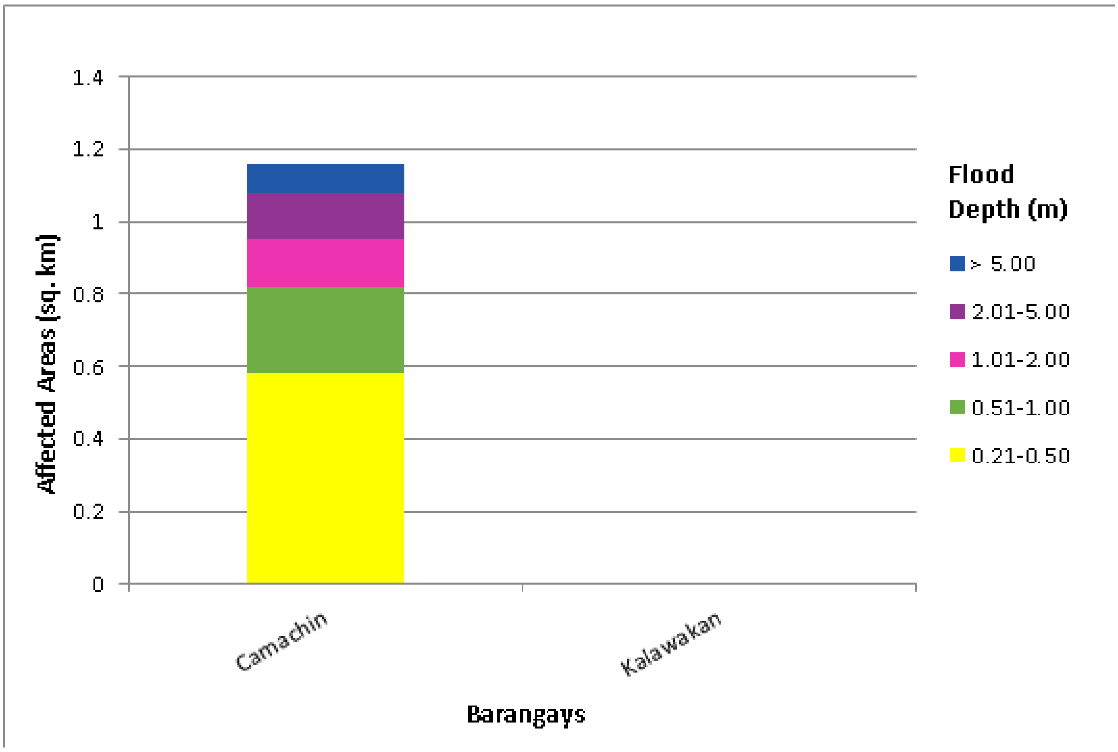


Figure 73. Affected areas in Doña Remedios Trinidad, Bulacan during a 25-year rainfall return

For the 25-year return period, 0.41% of the Municipality of General Tinio, with an area of 659.833412 sq. km., will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.01% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in General Tinio, Nueva Ecija during a 25-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Tinio (in sq. km)
	Pias
0.03-0.20	2.73
0.21-0.50	0.12
0.51-1.00	0.046
1.01-2.00	0.025
2.01-5.00	0.00051
> 5.00	0

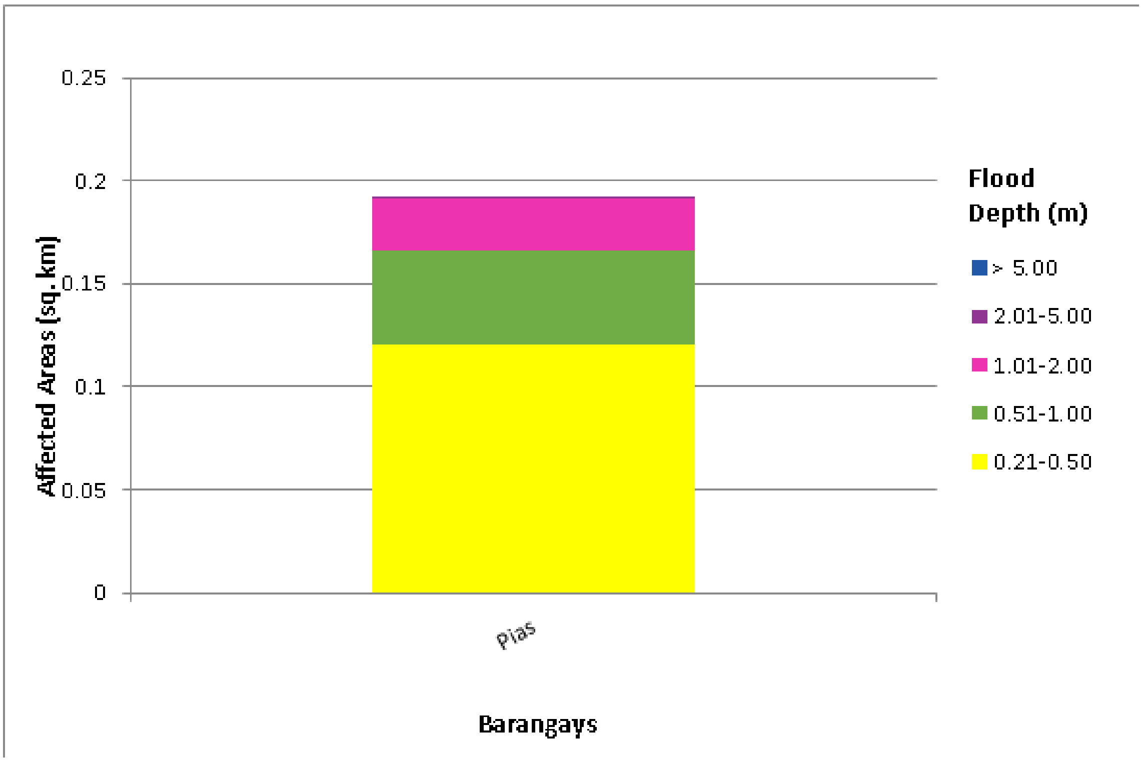


Figure 74. Affected areas in General Tinio, Nueva Ecija during a 25-year rainfall return period.

For the 25-year return period, 16.00% of the Municipality of General Nakar, with an area of 1275.549305 sq. km., will experience flood levels of less than 0.20 meters. 0.61% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.34%, 0.35%, 0.59%, and 1.28% 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 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in General Nakar, Quezon during a 25-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Nakar (in sq. km)	
	Canaway	Umiray
0.03-0.20	59.51	144.61
0.21-0.50	1.92	5.9
0.51-1.00	0.77	3.52
1.01-2.00	0.58	3.9
2.01-5.00	0.96	6.51
> 5.00	1.63	14.65

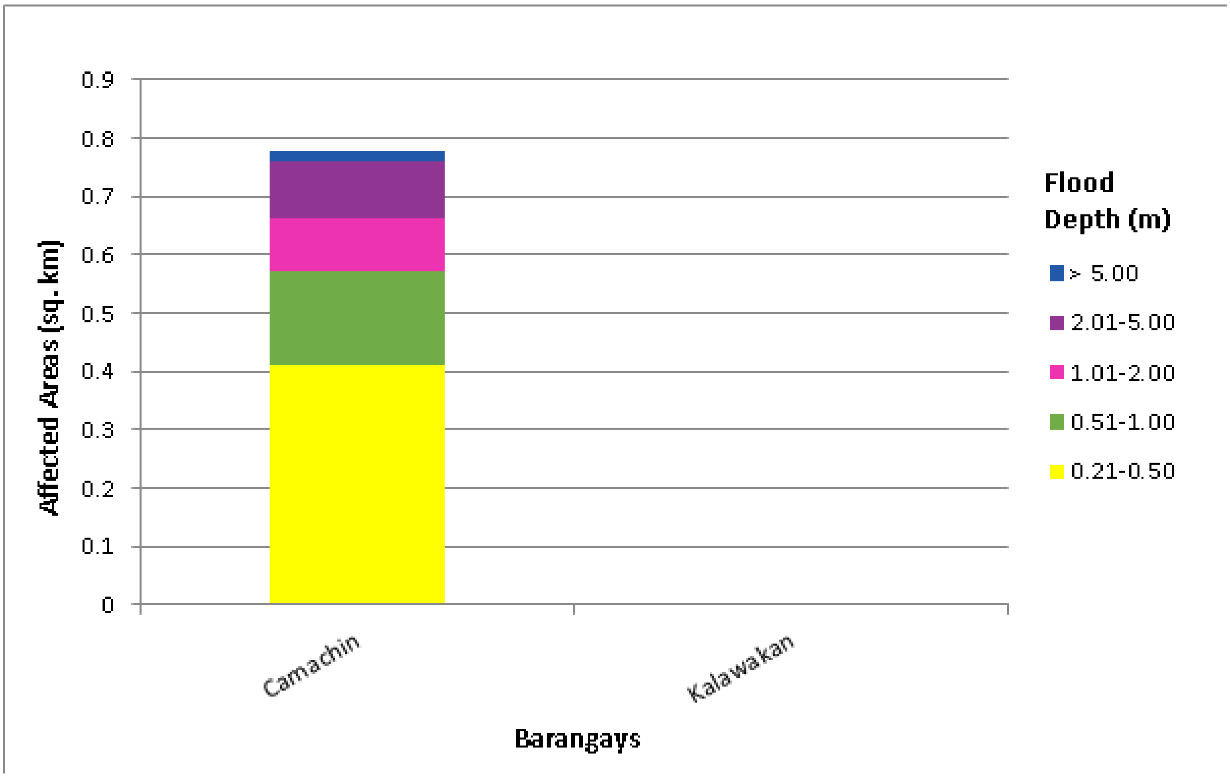


Figure 75. Affected areas in General Nakar, Quezon during a 25-year rainfall return period.

For the 100-year return period, 31.49% of the Municipality of Dingalan, with an area of 373.109657 sq. km., will experience flood levels of less than 0.20 meters. 1.47% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.76%, 0.65%, 1.10%, and 1.39% 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 53 are the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Dingalan, Aurora during a 100-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dingalan (in sq. km)
	Umiray
0.03-0.20	117.51
0.21-0.50	5.5
0.51-1.00	2.83
1.01-2.00	2.42
2.01-5.00	4.09
> 5.00	5.17

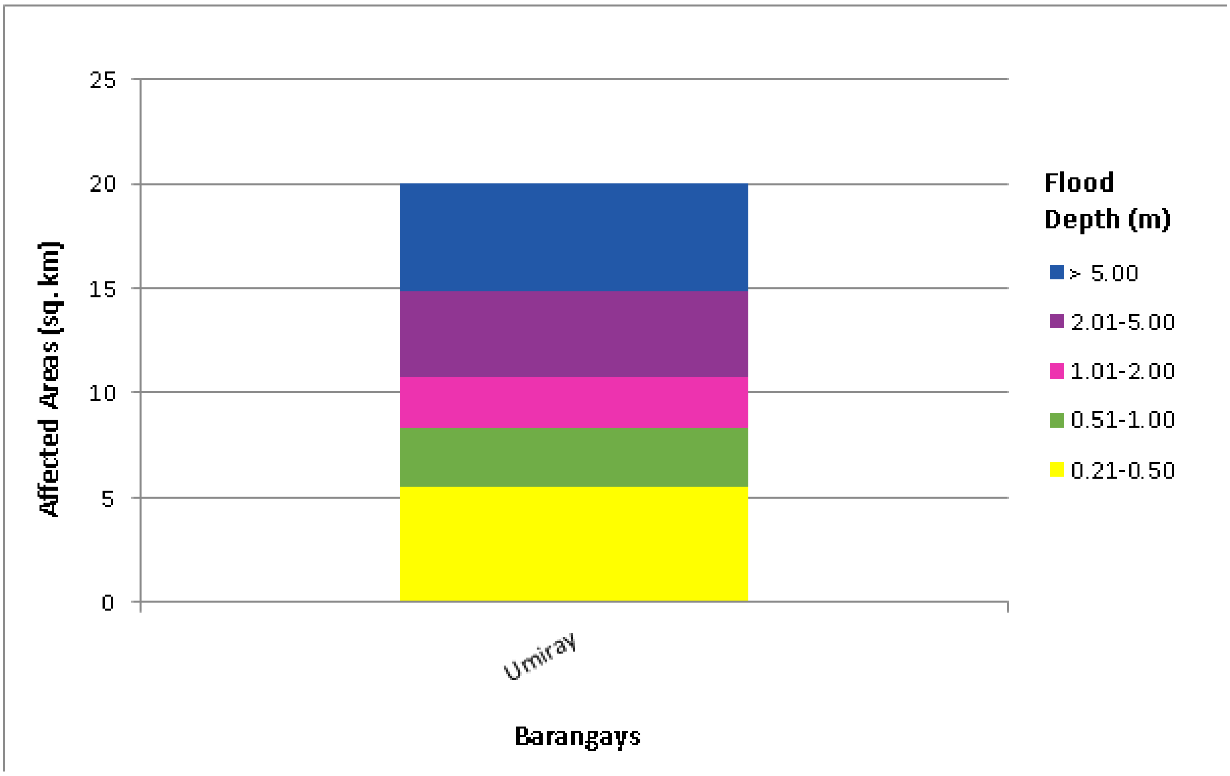


Figure 76. Affected areas in Dingalan, Aurora during a 100-year rainfall return period.

For the 100-year return period, 2.03% of the Municipality of Doña Remedios Trinidad, with an area of 871.198841 sq. km., will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03%, 0.02%, 0.02%, and 0.01% 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 54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 54. Affected areas in Doña Remedios Trinidad, Bulacan during a 100-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Doña Remedios Trinidad (in sq. km)	
	Camachin	Kalawakan
0.03-0.20	17.48	0.17
0.21-0.50	0.67	0.00025
0.51-1.00	0.29	0.0001
1.01-2.00	0.15	0
2.01-5.00	0.15	0
> 5.00	0.1	0

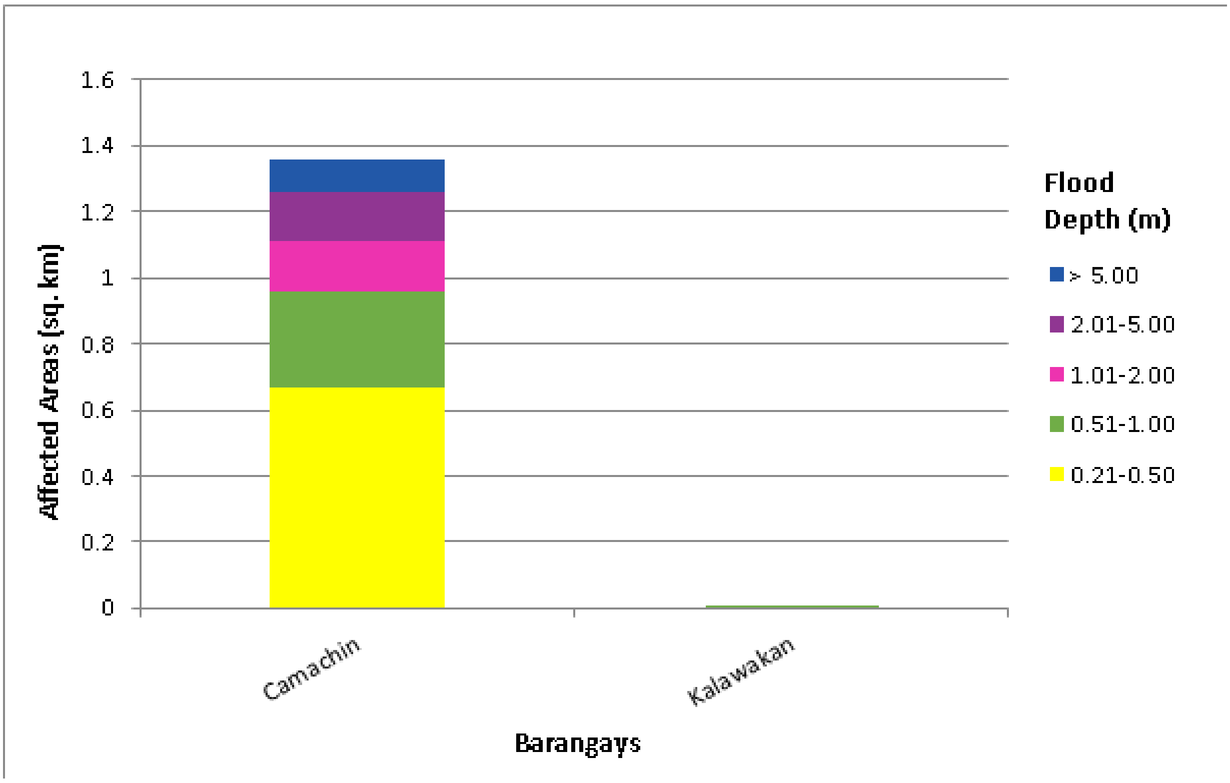


Figure 77. Affected areas in Doña Remedios Trinidad, Bulacan during a 100-year rainfall return period.

For the 100-year return period, 0.41% of the municipality of General Tinio, with an area of 659.833412 sq. km., will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.01% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 55 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in General Tinio, Nueva Ecija during a 100-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Tinio (in sq. km)
	Pias
0.03-0.20	2.69
0.21-0.50	0.14
0.51-1.00	0.054
1.01-2.00	0.03
2.01-5.00	0.0067
> 5.00	0

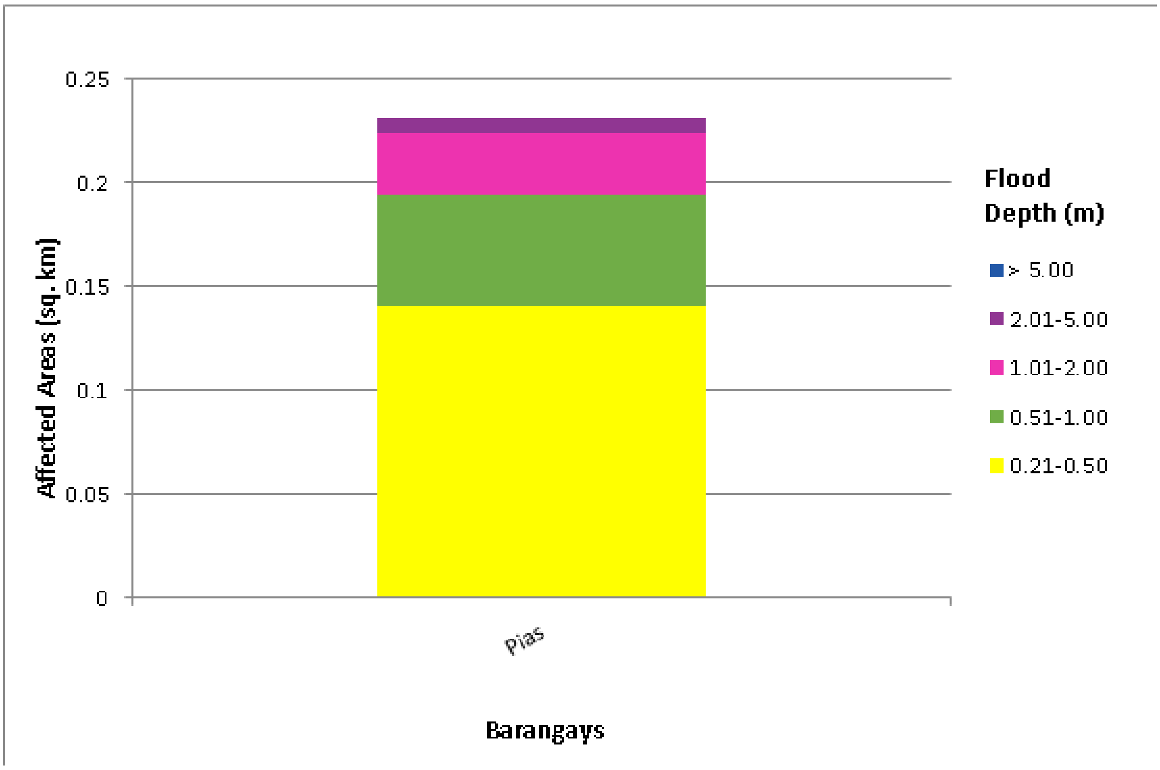


Figure 78. Affected areas in General Tinio, Nueva Ecija during a 100-year rainfall return period.

For the 100-year return period, 22.97% of the Municipality of General Nakar, with an area of 871.198841 sq. km., will experience flood levels of less than 0.20 meters. 1.00% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.51%, 0.50%, 0.86%, and 2.22% 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 56 are the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in General Nakar, Quezon during a 100-year rainfall return period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dingalan (in sq. km)	
	Camachin	Kalawakan
0.03-0.20	17.66	0.17
0.21-0.50	0.58	0.00011
0.51-1.00	0.24	0.0001
1.01-2.00	0.13	0
2.01-5.00	0.13	0

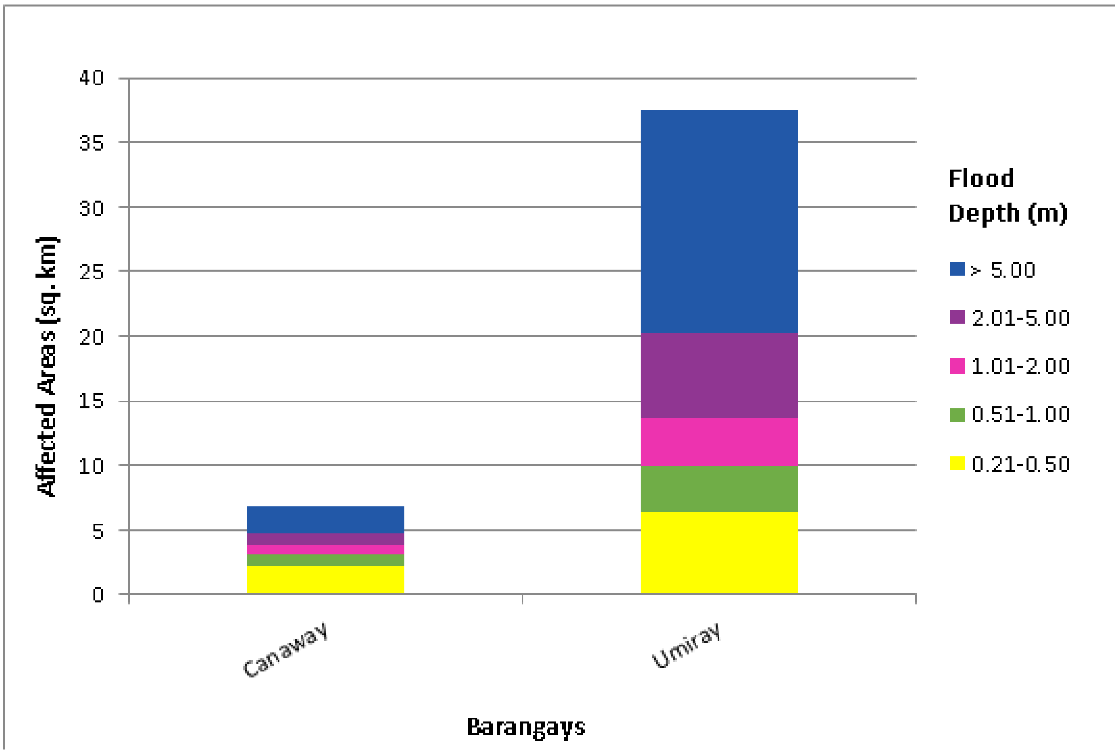


Figure 79. Affected areas in General Nakar, Quezon during a 100-year rainfall return period.

Barangay Umiray is the only barangay in the Municipality of Dingalan in the province of Aurora. The barangay is projected to experience flooding in 36.86% of the area.

Among the barangays in the Municipality of Doña Remedios Trinidad in the province of Bulacan, Camachin is projected to have the highest percentage of area that will experience flood levels, at 5.05%. Meanwhile, Kalawakan posted the second highest percentage of area that may be affected by flood depths, at 0.05%.

Barangay Pias is the only barangay in the Municipality of General Tinio in the province of Nueva Ecija. The barangay is projected to experience flooding in 0.78% of the area.

Among the barangays in the Municipality of General Nakar in the province of Quezon, Umiray is projected to have the highest percentage of area that will experience flood levels, at 48.01%. Meanwhile, Canaway posted the second highest percentage of area that may be affected by flood depths, at 17.52%

The generated flood hazard maps for the Umiray floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the hazard maps – "Low", "Medium", and "High" – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 10-year). Annex 12 and Annex 13 enumerate the educational and health institutions exposed to flooding, respectively.

Table 57. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	6.12	6.13	6.22
Medium	3.45	9.68	10.47
High	0.41	3.73	4.58
Total	**9.98**	**19.54**	**21.27**

Of the twenty-one (21) identified educational institutions in the Umiray floodplain, no school buildings were discovered to be exposed to any warning level during a 5-year scenario. For the 25-year scenario, three (3) school buildings were assessed to be exposed to Low-level flooding. For the 100-year scenario, four (4) school buildings were discovered to be exposed to Low-level flooding.

One (1) medical institution was identified in the Umiray floodplain, which was assessed to be exposed to Low-level flooding during the 5-year, 25-year and 100-year scenarios.

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. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

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

After which, the actual data from the field were compared with 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 the corresponding validation depths are illustrated in Figure 81.

The flood validation consists of one hundred and eighty (180) points, randomly selected all over the Umiray floodplain. It has an RMSE value of 0.61. Table 58 shows a contingency matrix of the comparison. The field validation points are found in Annex 11.

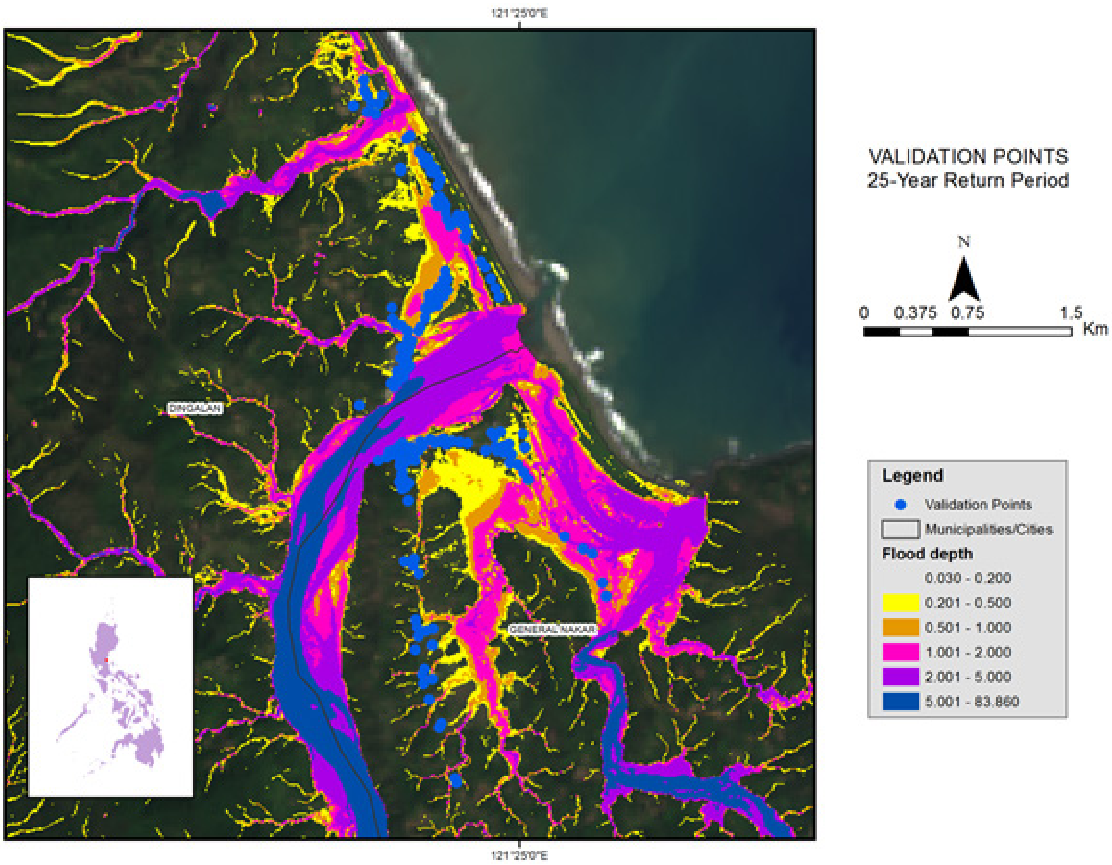


Figure 80. Validation points for a 5-year flood depth map of the Umiray floodplain.

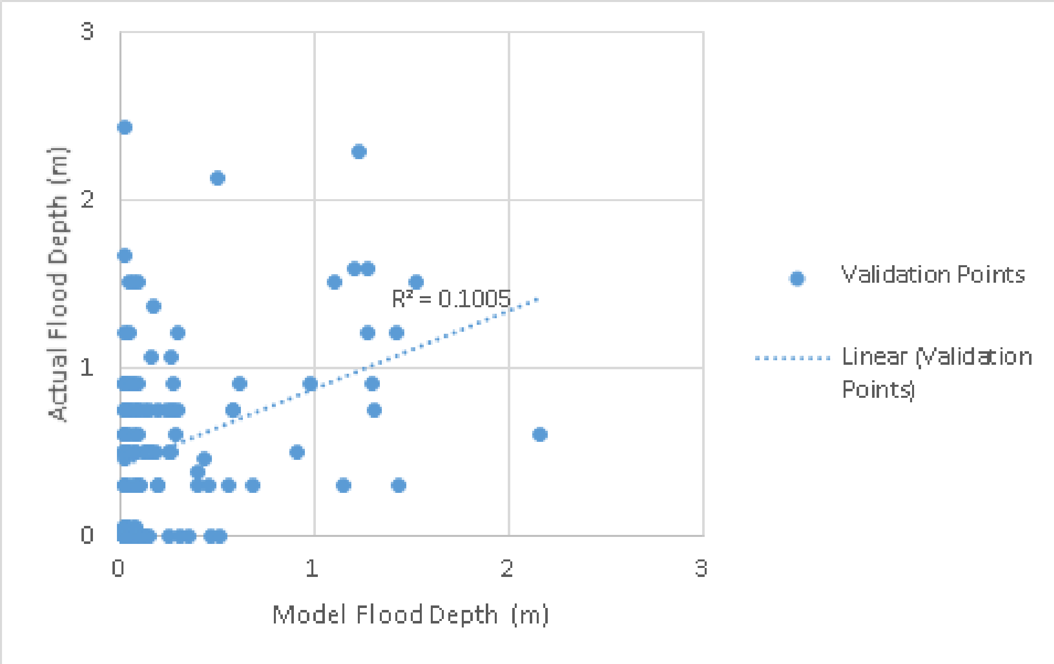


Figure 81. Model flood depth vs. actual flood depth.

Table 58. Actual flood depth vs. simulated flood depth in the Umiray floodplain.

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	54	4	1	0	0	0	59
0.21-0.50	44	6	3	2	0	0	55
0.51-1.00	33	6	4	2	1	0	46
1.01-2.00	8	2	0	6	0	0	16
2.01-5.00	2	1	0	1	0	0	4
> 5.00	0	0	0	0	0	0	0
Total	141	19	8	11	1	0	180

The overall accuracy generated by the flood model is estimated at 38.89%, with seventy (70) points correctly matching the actual flood depths. In addition, there were fifty-four (54) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were thirty-nine (39) points and eleven (11) points estimated two (20) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of ninety-seven (97) points were underestimated in the modeled flood depths of the Umiray floodplain.

Table 59. Summary of Accuracy Assessment in the Umiray River Basin Survey.

	No. of Points	%
Correct	70	38.89
Overestimated	13	7.22
Underestimated	97	53.89
Total	180	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.

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

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

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

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

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

ANNEXES

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

Figure A-1.1. Pegasus Sensor

Table A-1.1. Specifications of the Pegasus sensor

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

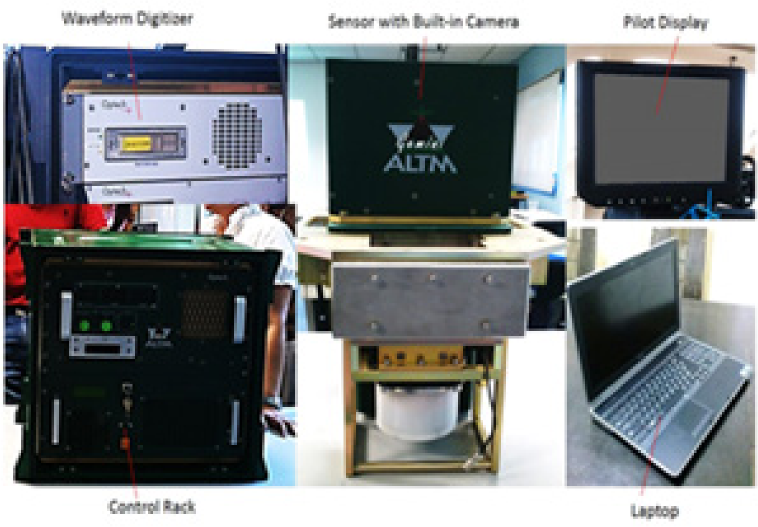

Figure A-1.2. Gemini Sensor

Table A-1.2. Specifications of the Gemini sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);
220-channel dual frequency GPS/ GNSS/Galileo/L-Band receiver	Programmable, 0-75 ˚
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

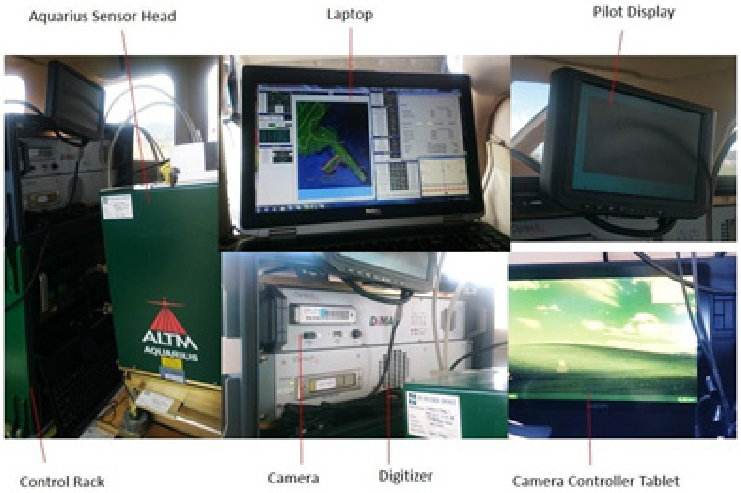

Figure A-1.3. Aquarius Sensor

Table A-1.3. Specifications of the Aquarius sensor

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

Figure A-1.4. Leica Sensor

Table A-1.4. Specifications of the Leica sensor

Parameter	Specification
Operational altitude	100 to 3500 m max AGL
Maximum measurement rate	1000 kHz
Maximum scan rate	200 Hz for sine; 158 for triangle;120 for raster
Field of view (degrees, full angle, user-adjustable)	0 to 72
Roll Stabilization(automatic adaptive, degrees)	72 – active FOV
Number of returns	unlimited
Number of intensity measurements	3(first, second and third)
Data Storage	ALS80: removable SSD hard disk (800GB each volume)
Power Consumption	922 W @ 22.0-30.3 VDC
Dimensions and weight	Scanner:37 W x 68 L x 26 H cm; 47 kg; Control Electronics: 45 W x 47 D x 25 H cm; 33 kg
Operating temperature	0-40˚C

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

1. BLN-56

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

September 04, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **BULACAN**	
	Station Name: **BLN-56**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **CASALAT**	
Municipality: **SAN ILDEFONSO**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **15° 1' 26.96271"**	Longitude: **121° 3' 12.22975"**	Ellipsoidal Hgt: **87.99600 m.**
	WGS84 Coordinates	
Latitude: **15° 1' 21.45113"**	Longitude: **121° 3' 17.08731"**	Ellipsoidal Hgt: **130.44600 m.**
	PTM / PRS92 Coordinates	
Northing: **1661478.081 m.**	Easting: **505742.035 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,661,817.71**	Easting: **290,711.27**	Zone: **51**

Location Description

BLN-56
From San Ildefonos municipal hall travel for about 15 km SE towards Brgy. Casalat via Brgys. Alagao and Akle. Station is located within Casalat Elementary School, about 24 m SSW of the main gate and about 0.5 m E of the concrete fence. Mark is the head of a 4 inches copper nail centered on a 30 cm x 30 cm concrete monument protruding about 20 cm above the ground with inscriptions BLN-56 2007 NAMRIA.

Requesting Party:	**Christopher Cruz**
Purpose:	**Reference**
OR Number:	**8087193 I**
T.N.:	**2015-2549**

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

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CIP/4701/12/09/814

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. BLN-56

2. BLN-58

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

May 29, 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: **BULACAN**
Station Name: **BLN-58**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN ILDEFONSO**
Barangay: **POBLACION**

	PRS92 Coordinates	
Latitude: **15° 4' 50.28672"**	Longitude: **120° 56' 35.59715"**	Ellipsoidal Hgt: **24.21800 m.**
	WGS84 Coordinates	
Latitude: **15° 4' 44.75323"**	Longitude: **120° 56' 40.45054"**	Ellipsoidal Hgt: **66.23600 m.**
	PTM Coordinates	
Northing: **1667726.854 m.**	Easting: **493895.954 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,668,175.07**	Easting: **278,919.72**	Zone: **51**

Location Description

BLN-58
The station is located in San Ildefonso Elementary School North District, about 10 m S of Gusaling Gabaldon and about 6 m NE of the SW corner of Math area. Mark is the head of a 4" copper nail centered on a 0.30 m x 0.30 m x 1 m concrete monument flushed on the ground with inscriptions BLN-58 2007 NAMRIA.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8796226 A**
T.N.: **2014-1187**

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Director, Mapping And Geodesy Branch

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Figure A-2.2. BLN-58

3. PMG-54

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

January 20, 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: **PAMPANGA**	
	Station Name: **PMG-54**	
Island: **LUZON**	Order: **3rd**	Barangay: **C.S.E.Z.**
Municipality: **CLARK DEV'T. CORP.**		
	PRS92 Coordinates	
Latitude: **15° 10' 50.24016"**	Longitude: **120° 31' 3.16452"**	Ellipsoidal Hgt: **213.00650 m.**
	WGS84 Coordinates	
Latitude: **15° 10' 44.64998"**	Longitude: **120° 31' 8.01131"**	Ellipsoidal Hgt: **253.69780 m.**
	PTM Coordinates	
Northing: **1678845.621 m.**	Easting: **448156.978 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,679,714.68**	Easting: **233,266.88**	Zone: **51**

Location Description

PMG-54
Is located about 50 m. NE of Bldg. 2127 (Main Bldg.) of Clark Development Corp. and about 3 m. W of the Phil. flagpole. Mark is the head of a 1 in. concrete nail driven on the marbled tiled footing of a historical mark commemorating the turnover of the U.S. Military Base to the Philippine Gov't.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-96**

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

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Figure A-2.3. PMG-54

4. PNG-66

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

May 29, 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: **PANGASINAN**
Station Name: **PNG-66**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN CARLOS**
Barangay: **CALOMBOYAN**

PRS92 Coordinates

Latitude: **15° 56' 47.31803"** Longitude: **120° 17' 57.03550"** Ellipsoidal Hgt: **10.57500 m.**

WGS84 Coordinates

Latitude: **15° 56' 41.53646"** Longitude: **120° 18' 1.81867"** Ellipsoidal Hgt: **48.46800 m.**

PTM Coordinates

Northing: **1763650.683 m.** Easting: **424968.98 m.** Zone: **3**

UTM Coordinates

Northing: **1,764,780.62** Easting: **210,862.35** Zone: **51**

Location Description

PNG-66

From San Carlos Mun. Hall, travel along the highway going to Binmaley. Then turn left to the brgy. road going to Brgy. Pangalangan. Station is located inside the compound of Calomboyan Elem. School. It is situated along and beside the SE side of the concrete base of the flagpole, which is about 20 m. NW of the gate. Mark is the head of a 4 in. copper nail centered and embedded in a 30 cm. x 30 cm. concrete block protruding 20 cm. iabove ground surface, with inscriptions "PNG-66 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8796226 A**
T.N.: **2014-1185**

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

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Figure A-2.4. PNG-66

5. TRC-01

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

May 10, 2013

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: **TARLAC**
Station Name: **TRC-1**
Order: **1st**

Island: **LUZON** Municipality: **TARLAC**		Barangay: **SAN ROQUE**
	PRS92 Coordinates	
Latitude: **15° 28' 44.13765"**	Longitude: **120° 35' 52.67202"**	Ellipsoidal Hgt: **46.89100 m.**
	WGS84 Coordinates	
Latitude: **15° 28' 38.48550"**	Longitude: **120° 35' 57.49329"**	Ellipsoidal Hgt: **86.90220 m.**
	PTM Coordinates	
Northing: **1711833.357 m.**	Easting: **456859.89 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,712,636.20**	Easting: **242,278.30**	Zone: **51**

Location Description

TRC-1
Is located in a NIA irrigation canal concrete floodgate 300 m. E of the natl. highway, 1.5 km. SE of Tarlac town proper. From Manila, travel along MacArthur Highway to Tarlac. A small bridge, 10 m. NW of Sombrero Food Center along the irrigation canal bank to the railroad. It is 2 m. W of the railroad on the eastern floodgate wall, which is 5 min. walk from highway. Mark is a 0.15 m. x 0.01 m. dia. brass rod set on a drilled hole in a standard concrete block with cement putty, 0.03 m. above the top of the concrete railing, inscribed with station name. Reference marks (RM): RM's 1, 2 & 3 are 0.15 m. x 0.01 m. dia. brass rods set in a drilled hole with cement putties. RM-2 is a 0.15 m. x 0.01 m. dia. brass rod set on concrete block, 0.6 m. below ground level; Sub-RM is a 0.15 m. x 0.01 m. dia. brass rod set on a drilled hole on top of the concrete railing.

Requesting Party: **Christopher Cruz**
Pupose: **Reference**
OR Number: **3943636B**
T.N.: **2013-0420**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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

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Figure A-2.5. TRC-01

6. NEJ-3060

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

May 10, 2013

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: **NUEVA ECIJA**
Station Name: **NEJ-3060**
Order: **4th**

Island: **LUZON**
Municipality: **JAEN**
Barangay: **NIYUGAN**

	PRS92 Coordinates	
Latitude: **15° 19' 32.78238"**	Longitude: **120° 53' 29.45676"**	Ellipsoidal Hgt: **21.54500 m.**
	WGS84 Coordinates	
Latitude: **15° 19' 27.18854"**	Longitude: **120° 53' 34.28956"**	Ellipsoidal Hgt: **62.72000 m.**
	PTM Coordinates	
Northing: **1694850.752 m.**	Easting: **488350.739 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,695,355.91**	Easting: **273,621.71**	Zone: **51**

Location Description

NEJ-3060

Station is located at Brgy. Niyugan, Jaen, Nueva Ecija. Situated infront of the brgy. hall and brgy. chapel. about 4 m W of waiting shed. To reach the station, from the town of Jaen travel NW for about 4.2 Km. until reaching Brgy. Niyugan. Station mark is the head of a 4 in. concrete nail centered on a 0.20 m x 0.20 m concrete block and mark with, "NEJ-3060, 2008, NAMRIA".

Requesting Party: **Christopher Cruz**
Pupose: **Reference**
OR Number: **3943636B**
T.N.: **2013-0418**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

9905102013160315

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

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www.namria.gov.ph

Figure A-2.6. NEJ-3060

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

1. AAC-01

Table A-3.1. AAC-01

Vector Components (Mark to Mark)

From:	TRC-01				
Grid		Local		Global	
Easting	242278.307 m	Latitude	N15°28'44.13767"	Latitude	N15°28'38.48550"
Northing	1712636.202 m	Longitude	E120°35'52.67202"	Longitude	E120°35'57.49329"
Elevation	44.420 m	Height	46.891 m	Height	86.902 m

To:	AAC-01				
Grid		Local		Global	
Easting	236272.483 m	Latitude	N15°11'27.81685"	Latitude	N15°11'22.22626"
Northing	1680836.256 m	Longitude	E120°32'43.37833"	Longitude	E120°32'48.22418"
Elevation	151.882 m	Height	154.260 m	Height	194.988 m

Vector					
ΔEasting	-6005.824 m	NS Fwd Azimuth	190°03'34"	ΔX	523.697 m
ΔNorthing	-31799.946 m	Ellipsoid Dist.	32347.854 m	ΔY	10213.192 m
ΔElevation	107.461 m	ΔHeight	107.369 m	ΔZ	-30689.417 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.011 m
σ ΔElevation	0.013 m	σ ΔHeight	0.013 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000413905		
Y	-0.0000661260	0.0001225849	
Z	-0.0000191610	0.0000334556	0.0000154812

2. CSI-01

Table A-3.2. CSI-01

Vector Components (Mark to Mark)

From:	BLN-56				
Grid		Local		Global	
Easting	290711.278 m	Latitude	N15°01'26.96269"	Latitude	N15°01'21.45113"
Northing	1661817.714 m	Longitude	E121°03'12.22978"	Longitude	E121°03'17.08731"
Elevation	86.405 m	Height	87.996 m	Height	130.446 m

To:	CSI-01				
Grid		Local		Global	
Easting	290721.137 m	Latitude	N15°01'27.05915"	Latitude	N15°01'21.54760"
Northing	1661820.592 m	Longitude	E121°03'12.55894"	Longitude	E121°03'17.41647"
Elevation	86.407 m	Height	87.998 m	Height	130.449 m

Vector					
ΔEasting	9.860 m	NS Fwd Azimuth	73°13'15"	ΔX	-8.028 m
ΔNorthing	2.878 m	Ellipsoid Dist.	10.270 m	ΔY	-5.729 m
ΔElevation	0.001 m	ΔHeight	0.002 m	ΔZ	2.864 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'08"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000004740		
Y	-0.0000003786	0.0000006509	
Z	-0.0000001087	0.0000001868	0.0000002004

3. BL-142

Table A-3.3. BL-142

Vector Components (Mark to Mark)

From:	BLN-56				
Grid		Local		Global	
Easting	290711.278 m	Latitude	N15°01'26.96269"	Latitude	N15°01'21.45113"
Northing	1661817.713 m	Longitude	E121°03'12.22979"	Longitude	E121°03'17.08731"
Elevation	89.692 m	Height	91.282 m	Height	133.732 m

To:	BL-142				
Grid		Local		Global	
Easting	278159.307 m	Latitude	N15°02'28.04346"	Latitude	N15°02'22.51855"
Northing	1663809.358 m	Longitude	E120°56'11.50938"	Longitude	E120°56'16.36612"
Elevation	23.946 m	Height	24.603 m	Height	66.719 m

Vector					
ΔEasting	-12551.970 m	NS Fwd Azimuth	278°30'39"	ΔX	11056.864 m
ΔNorthing	1991.644 m	Ellipsoid Dist.	12706.774 m	ΔY	5999.287 m
ΔElevation	-65.745 m	ΔHeight	-66.679 m	ΔZ	1795.387 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.008 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.011 m
σ ΔElevation	0.014 m	σ ΔHeight	0.014 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000611462		
Y	-0.0000767156	0.0001278991	
Z	-0.0000288607	0.0000438236	0.0000188133

4. BLLM-99

Table A-3.4. BLLM-99

Vector Components (Mark to Mark)

From:	BLN-56				
Grid		Local		Global	
Easting	290711.278 m	Latitude	N15°01'26.96269"	Latitude	N15°01'21.45113"
Northing	1661817.714 m	Longitude	E121°03'12.22978"	Longitude	E121°03'17.08731"
Elevation	86.405 m	Height	87.996 m	Height	130.446 m

To:	BLLM-99				
Grid		Local		Global	
Easting	290722.097 m	Latitude	N15°01'27.13994"	Latitude	N15°01'21.62838"
Northing	1661823.067 m	Longitude	E121°03'12.59033"	Longitude	E121°03'17.44785"
Elevation	86.490 m	Height	88.082 m	Height	130.532 m

Vector					
ΔEasting	10.819 m	NS Fwd Azimuth	63°10'09"	ΔX	-8.541 m
ΔNorthing	5.353 m	Ellipsoid Dist.	12.070 m	ΔY	-6.695 m
ΔElevation	0.085 m	ΔHeight	0.086 m	ΔZ	5.284 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'04"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.000 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002702		
Y	-0.0000001252	0.0000002337	
Z	-0.0000000656	0.0000000570	0.0000000747

5. FMC-01

Table A-3.5. FMC-01

Vector Components (Mark to Mark)

From:	PMG-54				
Grid		Local		Global	
Easting	233266.879 m	Latitude	N15°10'50.24034"	Latitude	N15°10'44.64998"
Northing	1679714.686 m	Longitude	E120°31'03.16450"	Longitude	E120°31'08.01131"
Elevation	220.332 m	Height	223.018 m	Height	263.709 m

To:	FMC-1				
Grid		Local		Global	
Easting	270660.154 m	Latitude	N14°54'29.41880"	Latitude	N14°54'23.91904"
Northing	1649166.271 m	Longitude	E120°52'05.23142"	Longitude	E120°52'10.09982"
Elevation	23.745 m	Height	23.646 m	Height	65.981 m

Vector					
ΔEasting	37393.275 m	NS Fwd Azimuth	128°36'08"	ΔX	-36313.138 m
ΔNorthing	-30548.415 m	Ellipsoid Dist.	48267.727 m	ΔY	-12679.923 m
ΔElevation	-196.587 m	ΔHeight	-199.372 m	ΔZ	-29162.699 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.009 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.012 m
σ ΔElevation	0.015 m	σ ΔHeight	0.015 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000868373		
Y	-0.0000999365	0.0001486951	
Z	-0.0000311237	0.0000462768	0.0000158611

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	SSRS	ENGR. GEROME HIPOLITO	UP-TCAGP
	SSRS	JULIE PEARL MARS	UP-TCAGP
	SSRS	PAULINE JOANNE ARCEO	UP-TCAGP
	SSRS	AUBREY PAGADOR	UP-TCAGP
	SUP SRS	ENGR. LOVELYN ASUNCION	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	FOR. VERLINA TONGA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	FOR. MA. REMEDIOS VILLANUEVA	UP-TCAGP
	RA	FOR. REGINA AEDRIANNE FELISMINO	UP-TCAGP
	RA	JONALYN GONZALES	UP-TCAGP

LiDAR Operation/ Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
	RA	ENGR. IRO ROXAS	UP-TCAGP
	RA	ENGR. GEF SORIANO	UP-TCAGP
	RA	ENGR. KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG DIOSCORO SOBERANO	PHILIPPINE AIR FORCE (PAF)
		SSG LEE JAY PUNZALAN	PAF
		SSG GERONIMO BALICAO	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AERO-SPACE CORPO-RATION (AAC)
		CAPT. JEFFREY JEREMY ALAJAR	AAC
		CAPT. JERICHO JECIEL	AAC
		CAPT. ALBERT LIM	AAC
		CAPT. BRIAN DONGINES	AAC
		CAPT. SHERWIN ALFONSO III	AAC
		CAPT. MARK LAWRENCE TAN-GONAN	AAC
		CAPT. DANTHONY LOGRONIO	AAC

Annex 5. Data Transfer Sheets for the Umiray Floodplain Flights

15-13

DATA TRANSFER SHEET
03/09/2015(Clark)

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	
20-Jan	2471P	1BUC020A	pegasus	847	na	7.8	192	25.1	217	15.5	na	5.41	1KB	1KB	50	na	Z:\DAC\RAW DATA
21-Jan	2473P	1BUC021A	pegasus	1.69	na	10.3	252	31	208	16	na	4.14	1KB	1KB	44	na	Z:\DAC\RAW DATA
22-Jan	2477P	1NEJ022A	pegasus	1.04	na	7.5	197	na	na	10.2	na	4.16	1KB	1KB	na	na	Z:\DAC\RAW DATA
23-Jan	2481P	1BTN023A	pegasus	2.44	na	11.7	273	na	na	24.4	na	2.82	1KB	1KB	113	na	Z:\DAC\RAW DATA
26-Jan	2493P	1BUC026A	pegasus	2.44	na	11.7	273	18.7/11.1	13682.4q	6.71	na	8.56	1KB	1KB	113	na	Z:\DAC\RAW DATA
27-Jan	2497P	1BUC027A	pegasus	631	na	6.73	195	21	170	7.47	na	2.41	1KB	1KB	63	na	Z:\DAC\RAW DATA
28-Jan	2501P	1BUC028A	pegasus	1.9	na	8.65	184	22.5	161	20.7	na	5.3	1KB	1KB	89	na	Z:\DAC\RAW DATA

Received from

Name C JOAQUIN
Position
Signature

Received by

Name AC Bongat 3/9/15
Position CSRS
Signature

Figure A-5.1. Data Transfer Sheet for Umiray Floodplain - A

DATA TRANSFER SHEET
6/17/2014 (Missing Flights - NEJ, CAG, Arayat)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Oct 21, 2013	669G	2CAG161BC294A	GEMINI	NA	NA	NA	161MB	38.9	64/139	20	79.3	7.33	1KB	1KB	5	NA	X:\Airborne_Raw\669G
Jan 20, 2014	1009P	1NEJA020A	PEGASUS	3.49	NA	9.13	241	41.8	361	31.2	149	5.57	1KB	1KB	42/47	NA	X:\Airborne_Raw\1009P
Jan 21, 2014	1011P	1NEJ1B021A	PEGASUS	NA	88	8.56	185	15.3	NA	18.5	93.4	8.24	1KB	1KB	36	NA	X:\Airborne_Raw\1011P
Jan 21, 2014	1013P	1NEJ1B021B	PEGASUS	NA	NA	6.13	150	NA	NA	11.3	53.8	8.24	1KB	1KB	NA	NA	X:\Airborne_Raw\1013P
Jan 26, 2014	7032G	2NEJ1C026A	GEMINI	NA	122	NA	158	NA	NA	9.77	NA	8.03	1KB	1KB	5	NA	X:\Airborne_Raw\7032G
Jan 28, 2014	7036G	2NEJ1CS028A	GEMINI	NA	259	262	185	NA	NA	11.1	NA	2.56	1KB	1KB	5	NA	X:\Airborne_Raw\7036G
Jan 29, 2014	7038G	2NEJFG029A	GEMINI	NA	TO FOLLOW					8.65	NA	3.77	1KB	1KB		NA	X:\Airborne_Raw\7038G
Feb 2, 2014	7047G	2MtAS033A	GEMINI	NA	105	188	138	30.4(casi)	NA	3.64	NA	2.42	1KB	1KB	4	NA	X:\Airborne_Raw\7047G

Received from
Name C. JOAQUIN
Position RA
Signature

Received by
Name JOIDA PRIETO
Position SSRS
Signature 6/17/2014

14-42

Figure A-5.2. Data Transfer Sheet for Umiray Floodplain - B

DATA TRANSFER SHEET
5/22/2014(PAMPANGA REFLIGHTS)

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	
5/16/2014	7253GC	2PAMS1S3136A	GEMINI	na	140	350	228	NA	NA	10.8	NA	11.7	1KB	1KB	93	30	Z:\Airborne_Raw\7253GC
5/17/2014	7254GC	2BLK15S1S2137A	GEMINI	na	59.7	141	191	NA	NA	5.17	NA	7.17	1KB	1KB	40	NA	Z:\Airborne_Raw\7254GC
5/17/2014	7255GC	2PAMS2137B	GEMINI	na	78.4	167	121	NA	NA	6.45	NA	7.17	1KB	1KB	53	5	Z:\Airborne_Raw\7255GC
5/18/2014	7256GC	2PAMS5138A	GEMINI	na	245	486	227	NA	NA	18.9	NA	18.7	1KB	1KB	216	NA	Z:\Airborne_Raw\7256GC
5/18/2014	7257GC	2PAMS7138B & 2NEJS1138B	GEMINI	na	318	197	146	NA	NA	6.22	NA	18.7	1KB	1KB	216	32	Z:\Airborne_Raw\7257GC
5/20/2014	7260GC	2BLK17S1140A	GEMINI	na	209	301	183	NA	NA	14.5	NA	10.7	1KB	1KB	241	NA	Z:\Airborne_Raw\7260GC

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Name C. Joaquin
Position RA
Signature

Received by

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

14-21

Figure A-5.3. Data Transfer Sheet for Umiray Floodplain - C

DATA TRANSFER SHEET
5/29/2014(Pampanga Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
5/22/2014	7264GC	2BLK15S142A	GEMINI	NA	89.2	276	205	NA	NA	8.92	NA	6.63	1KB	1KB	187	24	Z:\Airborne_Raw\7264GC
5/23/2014	7266GC	2BLK15S143A	GEMINI	NA	168	374	220	NA	NA	14.4	NA	13.2	1KB	1KB	13	18	Z:\Airborne_Raw\7266GC
5/24/2014	7268GC	2PAMS8144A	GEMINI	NA	192	364	223	NA	NA	14.7	NA	11.3	1KB	1KB	23	26	Z:\Airborne_Raw\7268GCA
5/24/2014	7269GC	2PAMS8144B	GEMINI	NA	236	197	140	NA	NA	7.93	NA	11.3	1KB	1KB	18	NA	Z:\Airborne_Raw\7269GC
5/25/2014	7271GC	2PAMS1S3145B	GEMINI	NA	91.8	383	233	NA	NA	15.5	NA	3.68	1KB	1KB	17	na	Z:\Airborne_Raw\7271GC

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Name C.Joaquin
Position RA
Signature

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Name JOIDA PRIETO
Position SSRS
Signature 5/29/14

14-217

Figure A-5.4. Data Transfer Sheet for Umiray Floodplain - D

DATA TRANSFER SHEET
02/09/2015(CLARK)

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-Dec-14	2270A	3PAMV338A	AQUARIUS	NA	173	352	201	NA	NA	7.79	14.8	23.7	1KB	1KB	NA	48	Z:\DAC\RAW DATA
5-Dec-14	2274A	3NEJV339A	AQUARIUS	NA	70	180	163	NA	NA	3.8	473MB	17.2	1KB	1KB	23	23	Z:\DAC\RAW DATA
6-Dec-14	2278A	3PAMV340A	AQUARIUS	NA	181	425	238	NA	NA	8.18	NA	26.5	1KB	1KB	23	NA	Z:\DAC\RAW DATA
10-Dec-14	2294A	3TRCV344A	AQUARIUS	NA	128	266	174	NA	NA	5.02	652	28.9	1KB	1KB	23	48	Z:\DAC\RAW DATA
11-Dec-14	7670GC	2TRCV345A	GEMINI	NA	301	1.89	256	NA	NA	13.4	NA	8.41	1KB	1KB	1.15MB		Z:\DAC\RAW DATA
11-Dec-14	2298A	3NEJV345A	AQUARIUS	NA	301	455	216	NA	NA	8.18	NA	19.3	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
12-Dec-14	2302A	3NEJV346A	AQUARIUS	NA	113	259	169	NA	NA	5.17	NA	31.1	1KB	1KB	29	57	Z:\DAC\RAW DATA
12-Dec-14	2304A	3NEJV346B	AQUARIUS	NA	NA	515	173	NA	NA	4.2	NA	31.1	1KB	1KB	29	NA	Z:\DAC\RAW DATA

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Name [illegible]
Position
Signature

Received by

Name AC Bongat 2/12/15
Position SSRS
Signature

Figure A-5.5. Data Transfer Sheet for Umiray Floodplain - E

DATA TRANSFER SHEET
~~Dalabarzon~~ 9/10/15 CLARK

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	
26-Aug-15	2656G	2BTNAB238B	gemini	na	202	385	185	9.17/1.8/361	81/15/4	9.15	1.22	175	1KB	1KB	8	7	Z:\DAC\RAW DATA
27-Aug-15	2658G	2BTNCD239A	gemini	na	298	623	232	11.6/9.83	1/1/1	13.3	537	94.8	1KB	1KB	10	17	Z:\DAC\RAW DATA
28-Aug-15	2662G	2UMYA240A	gemini	na	273	482	231	134/25.1	2/198	8.59	0	137	1KB	1KB	12	30	Z:\DAC\RAW DATA
29-Aug-15	2666G	2UMYAB241A	gemini	na	301	554	238	17.6	139	12.5	673	104	1KB	1KB	12	na	Z:\DAC\RAW DATA
30-Aug-15	2670G	2CLBUMYABS242A	gemini	na	379	635	247	29.1	233	16.4	321	84.5	1KB	1KB	5	7	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature [signature]

Received by

Name AC Bongat 9/11/15 Calib: 10/5/15
Position SSRS
Signature ABongat

15-26

Figure A-5.6. Data Transfer Sheet for Umiray Floodplain - F

DATA TRANSFER SHEET
UMIRAY 8/3/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	GnssImu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S)		SERVER LOCATION
													BASE STATION(S)	Base Info (.txt)	
27-Jul-16	10210L	4UMRY209A	ALS 80	NA	358	102	20.3	5.6	4.5	NA	76.4	16.9	129	1KB	Z:\DAC\RAW DATA
28-Jul-16	10212L	4UMRY210A	ALS 80	NA	460	121	35.3	12.2	8.27	NA	137	30.5	123	1KB	Z:\DAC\RAW DATA
29-Jul-16	10214L	4BLK15A211A	ALS 80	NA	382	100	20.2	2.72	1.64	NA	54.4	14.2	130	1KB	Z:\DAC\RAW DATA

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Name R. PUNTO
Position RA
Signature

Received by

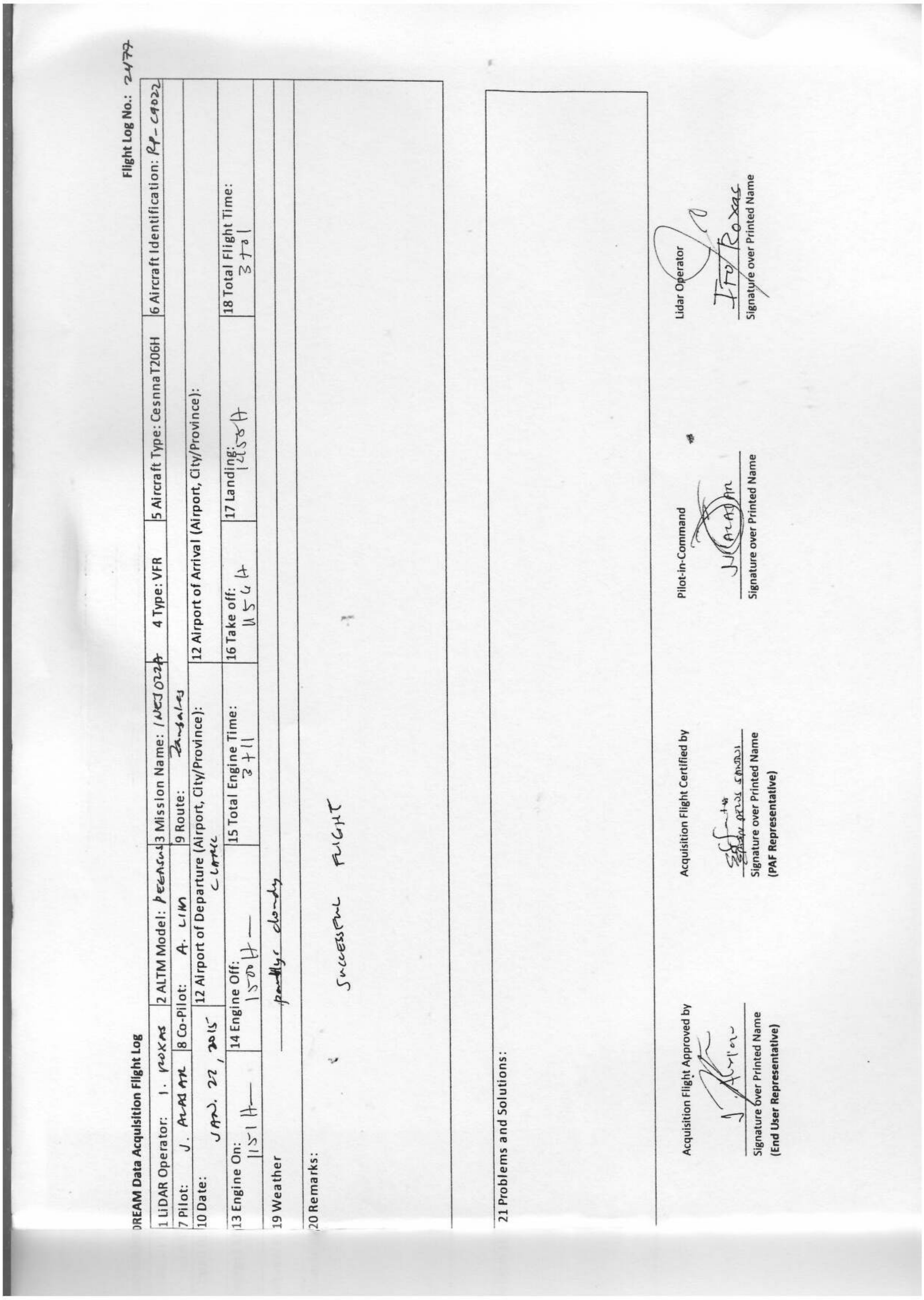
Name AC Bongat
Position SSRS
Signature ACBongat 8/9/16

16-44

Figure A-5.7. Data Transfer Sheet for Umiray Floodplain - G

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 2477P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 2477

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1NES022A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: Zambales			
10 Date: Jan. 22, 2015	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1151H	14 Engine Off: 1502H	15 Total Engine Time: 3+11	16 Take off: 1154H	17 Landing: 1258H	18 Total Flight Time: 3+01

19 Weather: partly cloudy

20 Remarks: Successful flight

21 Problems and Solutions:

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

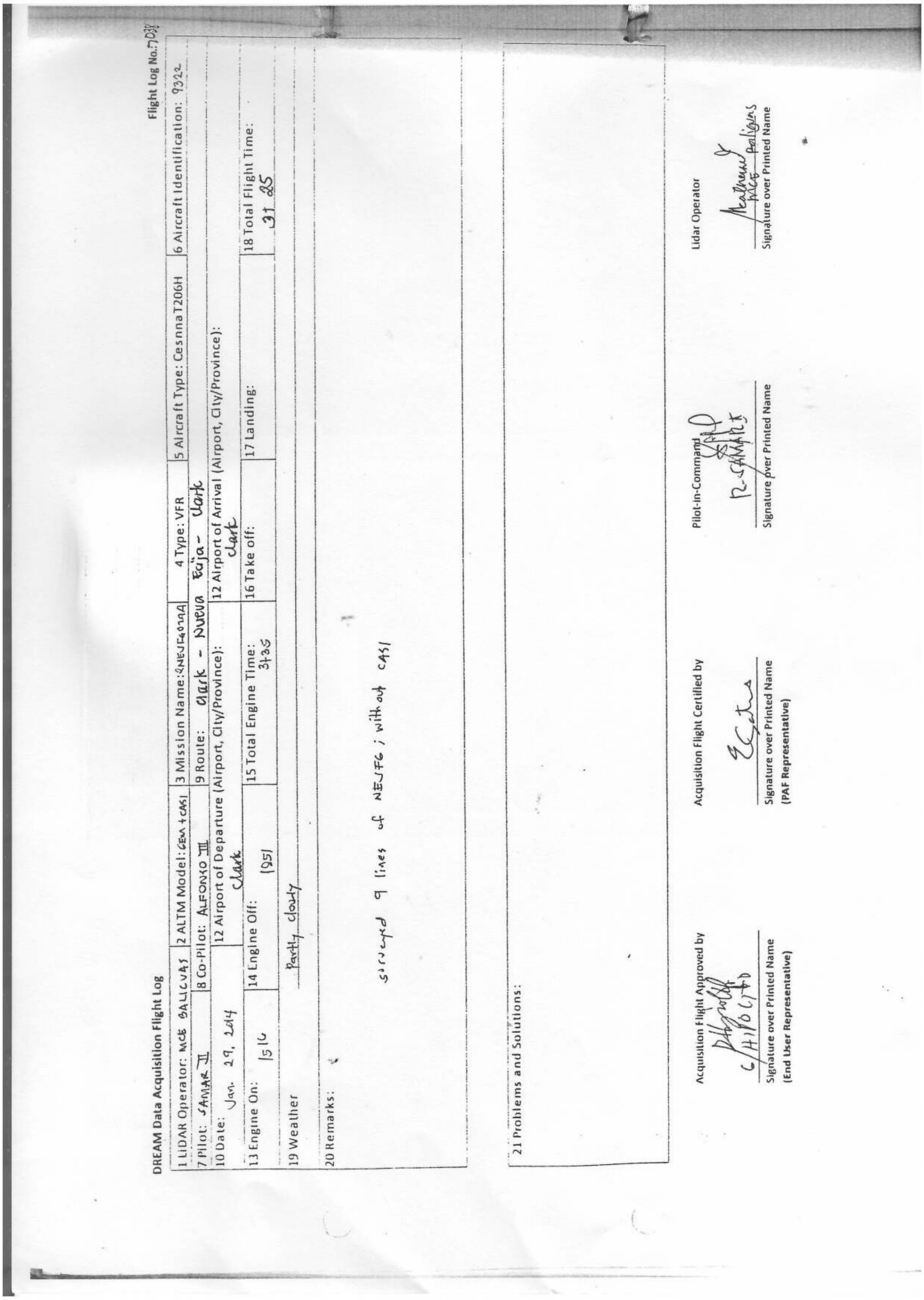
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — J. Alajar — Signature over Printed Name

Lidar Operator — I. Roxas — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2477P

2. Flight Log for 7038GC Mission



Flight Log No.: 7038

DREAM Data Acquisition Flight Log

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: GEM + CASI	3 Mission Name: 2NEJF6029A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: SAMAR II	8 Co-Pilot: ALFONSO III	9 Route: Clark - Nueva Ecija - Clark			
10 Date: Jan. 29, 2014	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 1516	14 Engine Off: 1951	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time: 3+25
19 Weather: Partly cloudy					

20 Remarks:

surveyed 9 lines of NEJF6 ; without CASI

21 Problems and Solutions:

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

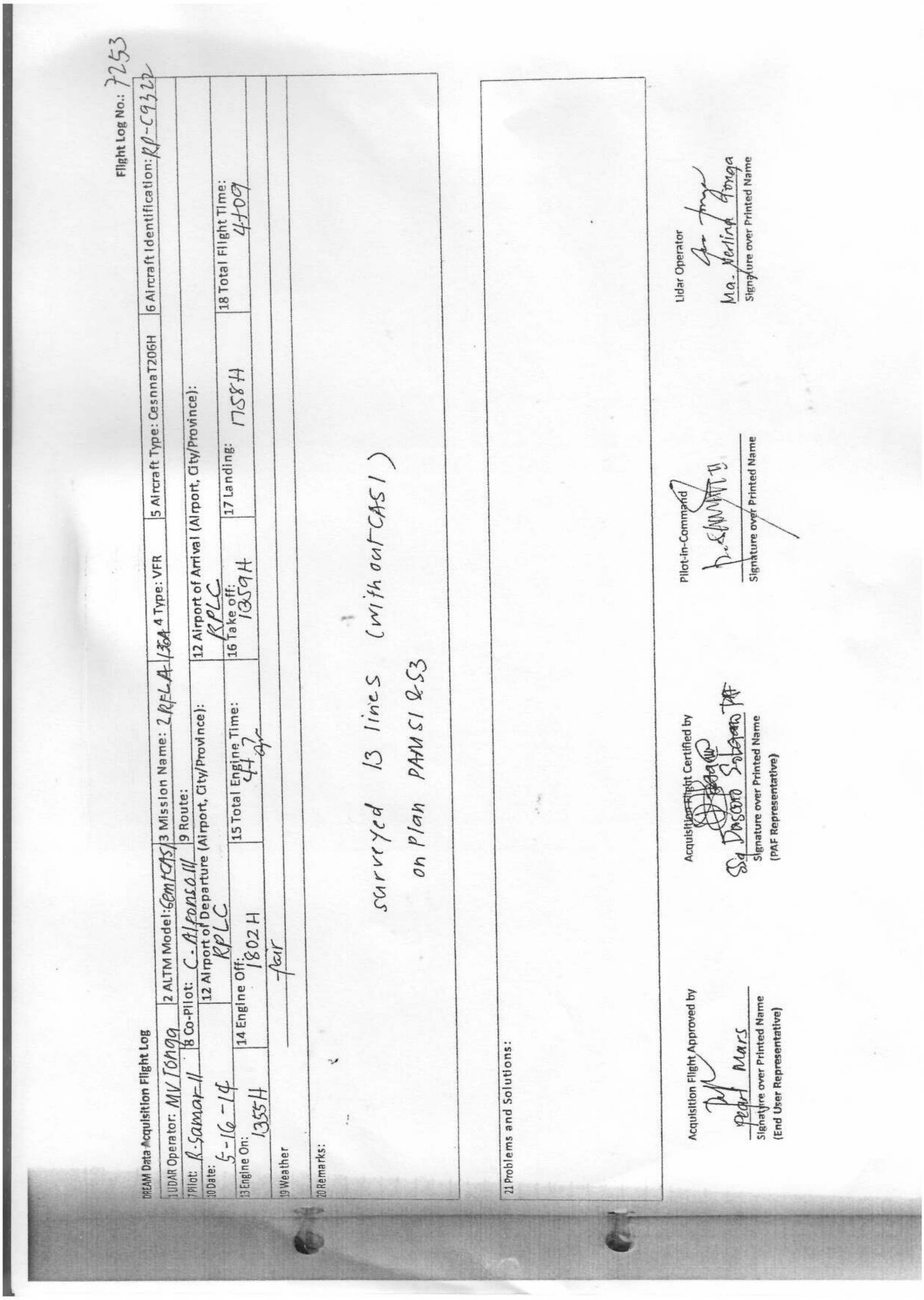
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — R. SAMAR II — Signature over Printed Name

Lidar Operator — MCE Baliguas — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 7038GC

3. Flight Log for 7253G Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7253

1 LIDAR Operator: MV Tonga	2 ALTM Model: Gemini/CAS	3 Mission Name: 2RFLA136A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso II	9 Route:			
10 Date: 5-16-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 1355H	14 Engine Off: 1802H	15 Total Engine Time: 4+07	16 Take off: 1359H	17 Landing: 1758H	18 Total Flight Time: 4+09
19 Weather: fair					

20 Remarks:

surveyed 13 lines (without CAS1) on plan PAMS1 & S3

21 Problems and Solutions:

Acquisition Flight Approved by: Pearl Mars — Signature over Printed Name (End User Representative)

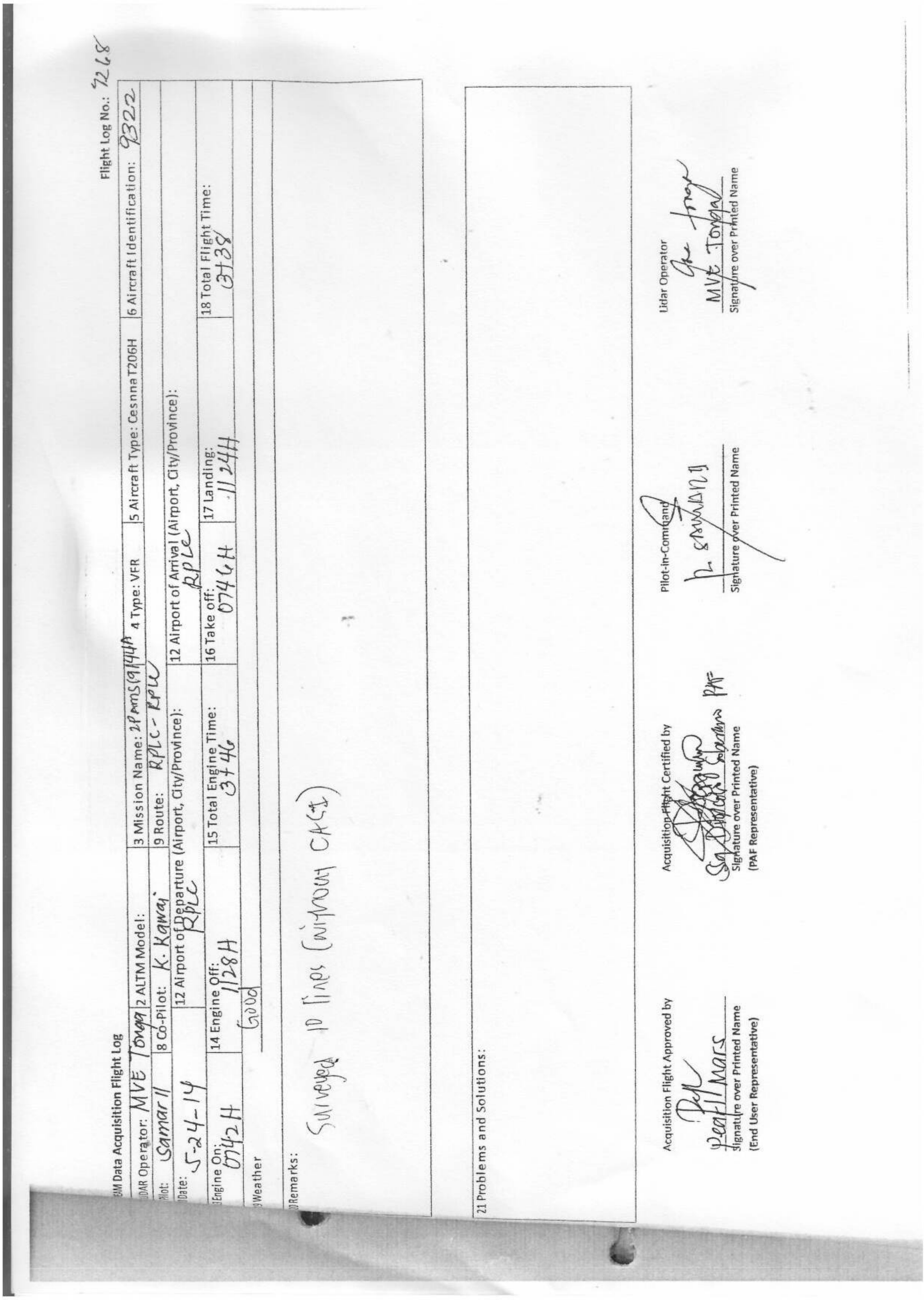
Acquisition Flight Certified by: SSg Dascoro Sobejano PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: Ma. Verlina Tonga — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 7253G

4. Flight Log for 7268GC Mission


Data Acquisition Flight Log

Flight Log No.: 7268

1 LiDAR Operator: MVE Tongga
2 ALTM Model:
3 Mission Name: 2PAMS191144A
4 Type: VFR
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9322

7 Pilot: Samar II
8 Co-Pilot: K. Kawai
9 Route: RPLC - RPLC

10 Date: 5-24-14
12 Airport of Departure (Airport, City/Province): RPLC
12 Airport of Arrival (Airport, City/Province): RPLC

13 Engine On: 0742H
14 Engine Off: 1128H
15 Total Engine Time: 3+46
16 Take off: 0746H
17 Landing: 1124H
18 Total Flight Time: 3+38

19 Weather: Good

20 Remarks: Surveyed 10 lines (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by: Pearl Mars — Signature over Printed Name (End User Representative)

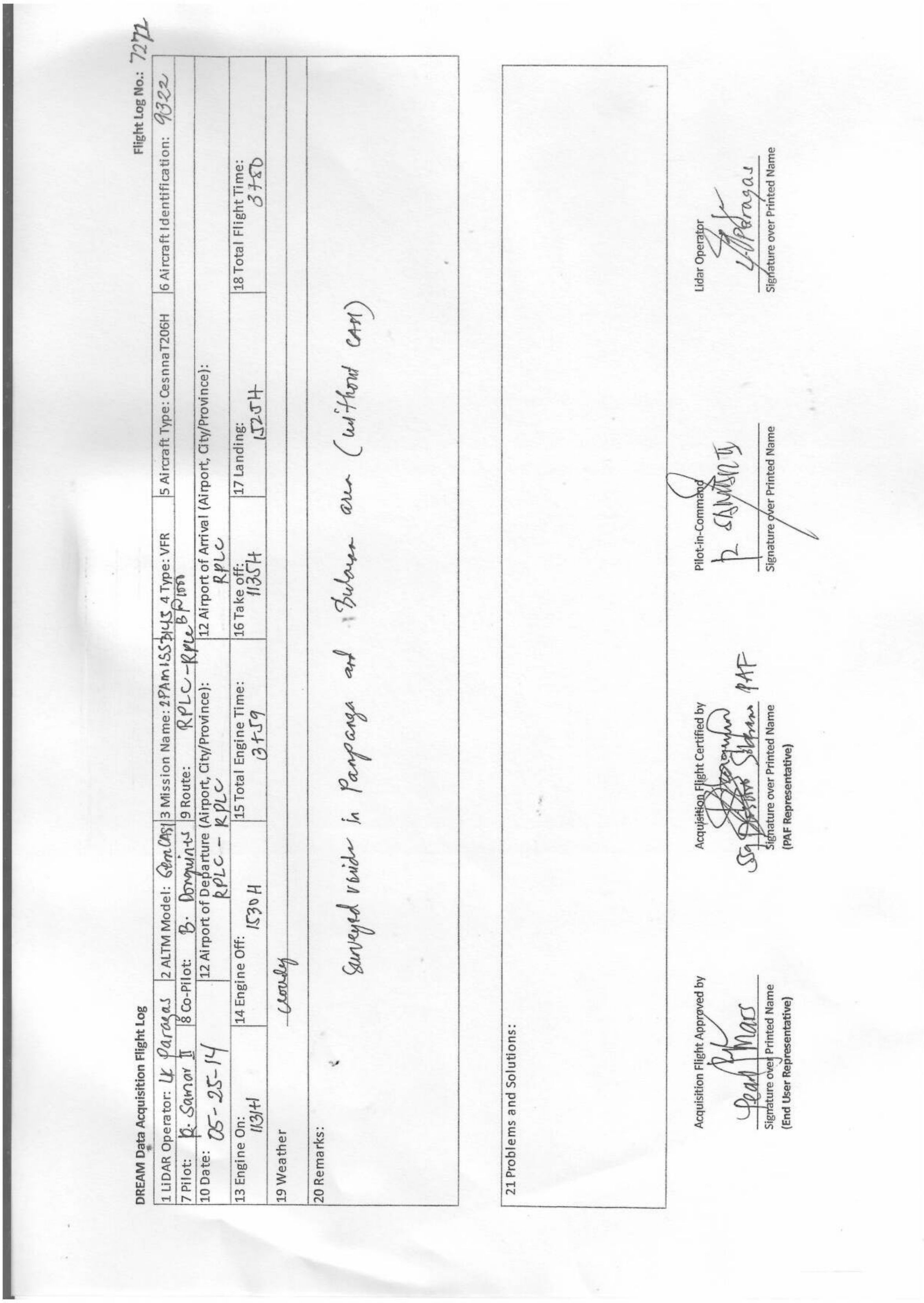
Acquisition Flight Certified by: PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: L. Samar II — Signature over Printed Name

Lidar Operator: MVE Tongga — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 7268GC

5. Flight Log for 7271GC Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 7272

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini	3 Mission Name: 2PAM155B145	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samson II	8 Co-Pilot: B. Donguines	9 Route: RPLC-RPLC-BPinn			
10 Date: 05-25-14	12 Airport of Departure (Airport, City/Province): RPLC - RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 1131H	14 Engine Off: 1530H	15 Total Engine Time: 3+59	16 Take off: 1135H	17 Landing: 1525H	18 Total Flight Time: 3+50
19 Weather: cloudy					
20 Remarks: Surveyed voids in Pampanga and Bulacan area (without CAM)					

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — LK Paragas — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 7271GC

6. Flight Log for 2274A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2274

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3BLK13S9A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Clark			
10 Date: 5 DEC 2014	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 15:48	14 Engine Off: 18:41	15 Total Engine Time: 2+53	16 Take off: 15+53	17 Landing: 18+36	18 Total Flight Time: 2+43

19 Weather: Fair

20 Remarks: Surveyed 7 line of void over Nueva Ecija

21 Problems and Solutions:

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

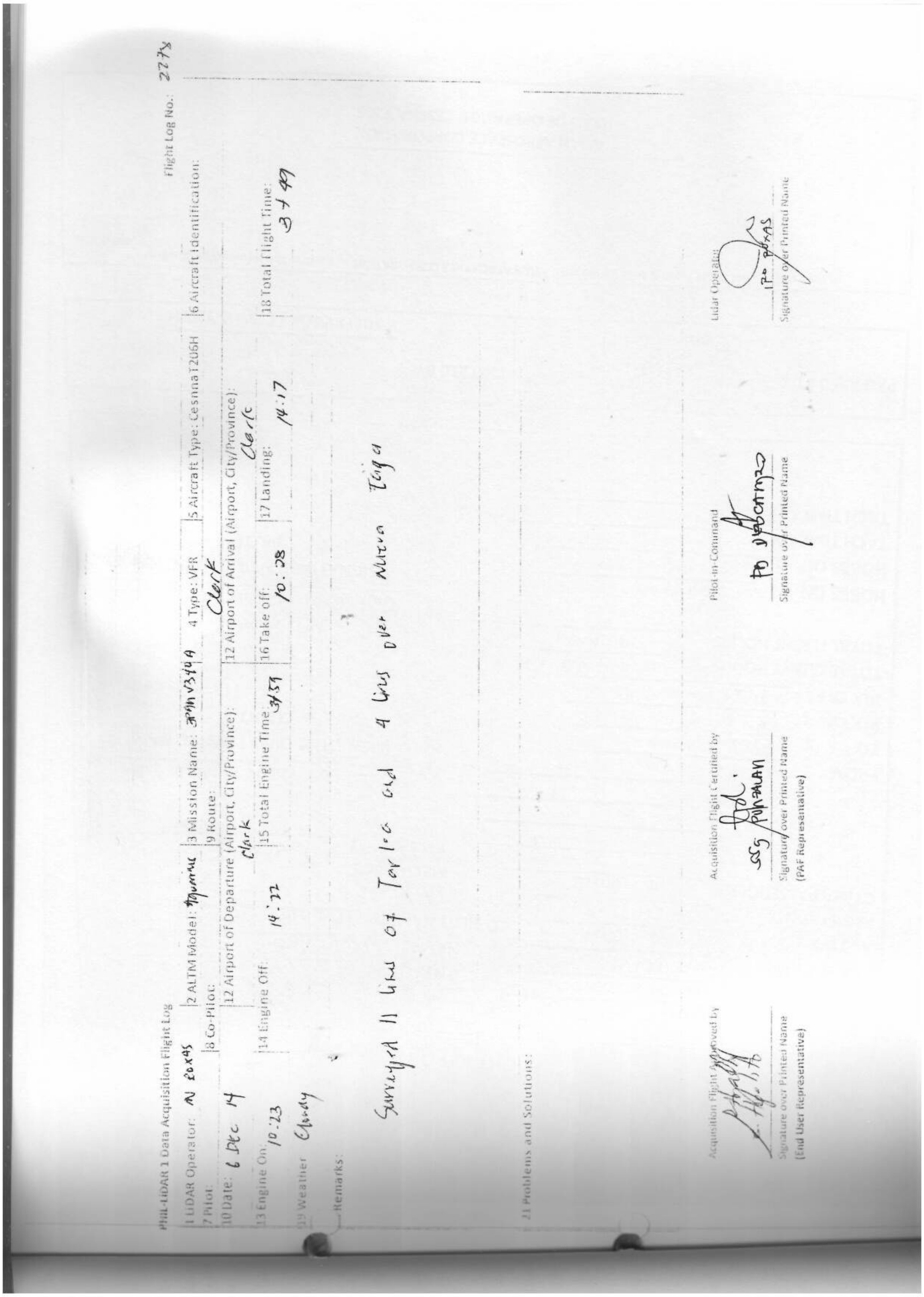
Acquisition Flight Certified by: SSG Pornaval — Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: MR Villanueva — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 2274A

7. Flight Log for 2278A Mission


Phil-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2278

1 LIDAR Operator: N Roxas	2 ALTM Model: Pegasus	3 Mission Name: 3PYN V349A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:	Clark		
10 Date: 6 Dec 14		12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark	
13 Engine On: 10:23	14 Engine Off: 14:22	15 Total Engine Time: 3+59	16 Take off: 10:28	17 Landing: 14:17	18 Total Flight Time: 3+49
19 Weather: Cloudy					

Remarks:

Surveyed 11 lines of Tarlac and 4 lines over Nueva Ecija

21 Problems and Solutions:

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

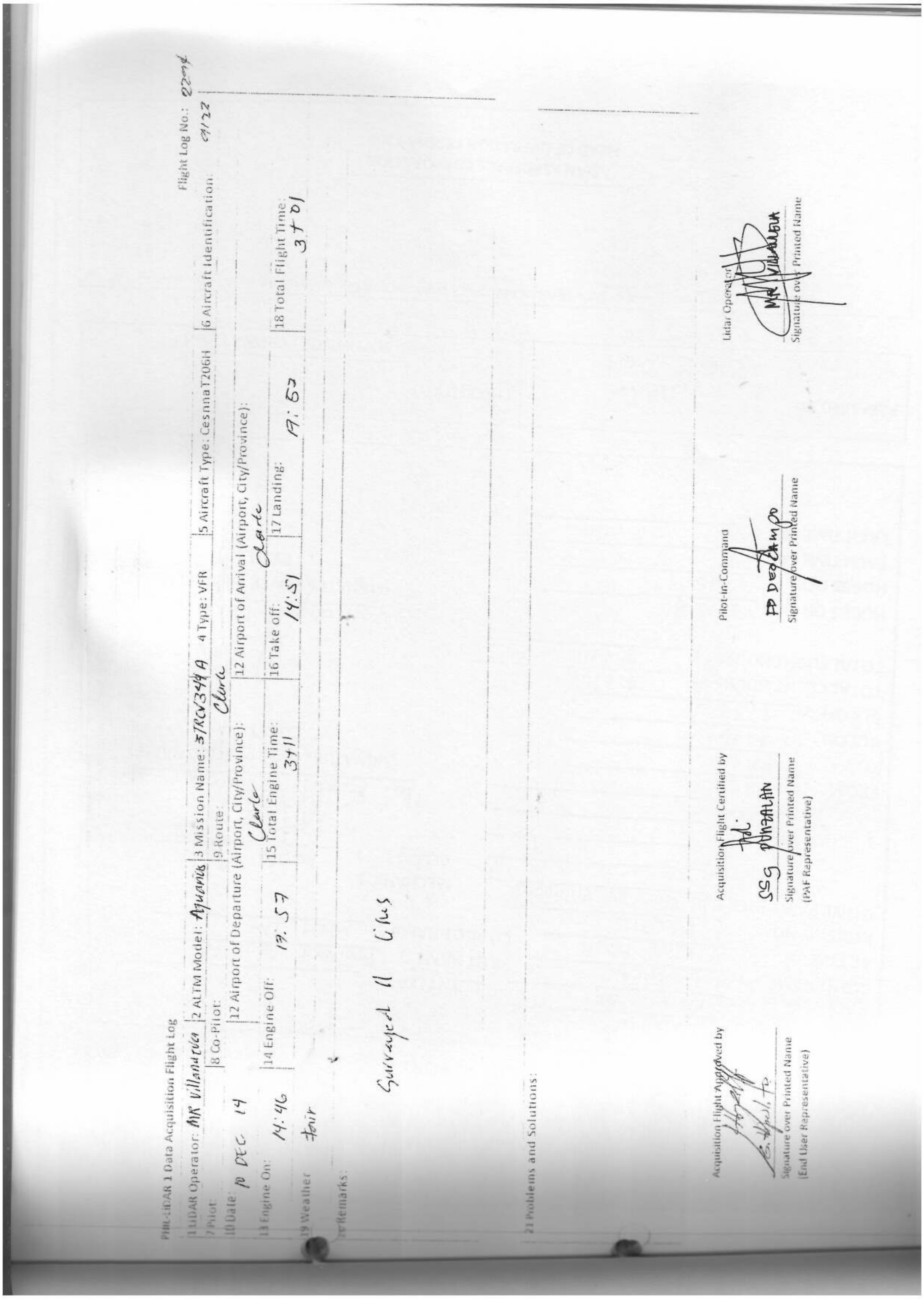
Acquisition Flight Certified by — SSg Pujalan — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — I²O Roxas — Signature over Printed Name

Figure A-6.7. Flight Log for Mission 2278A

8. Flight Log for 2294A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2294

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3RCV349A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Clark			
10 Date: 10 DEC 14	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 14:46	14 Engine Off: 17:57	15 Total Engine Time: 3+11	16 Take off: 14:51	17 Landing: 17:52	18 Total Flight Time: 3+01
19 Weather: fair					

20 Remarks:

Surveyed 11 lines

21 Problems and Solutions:

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

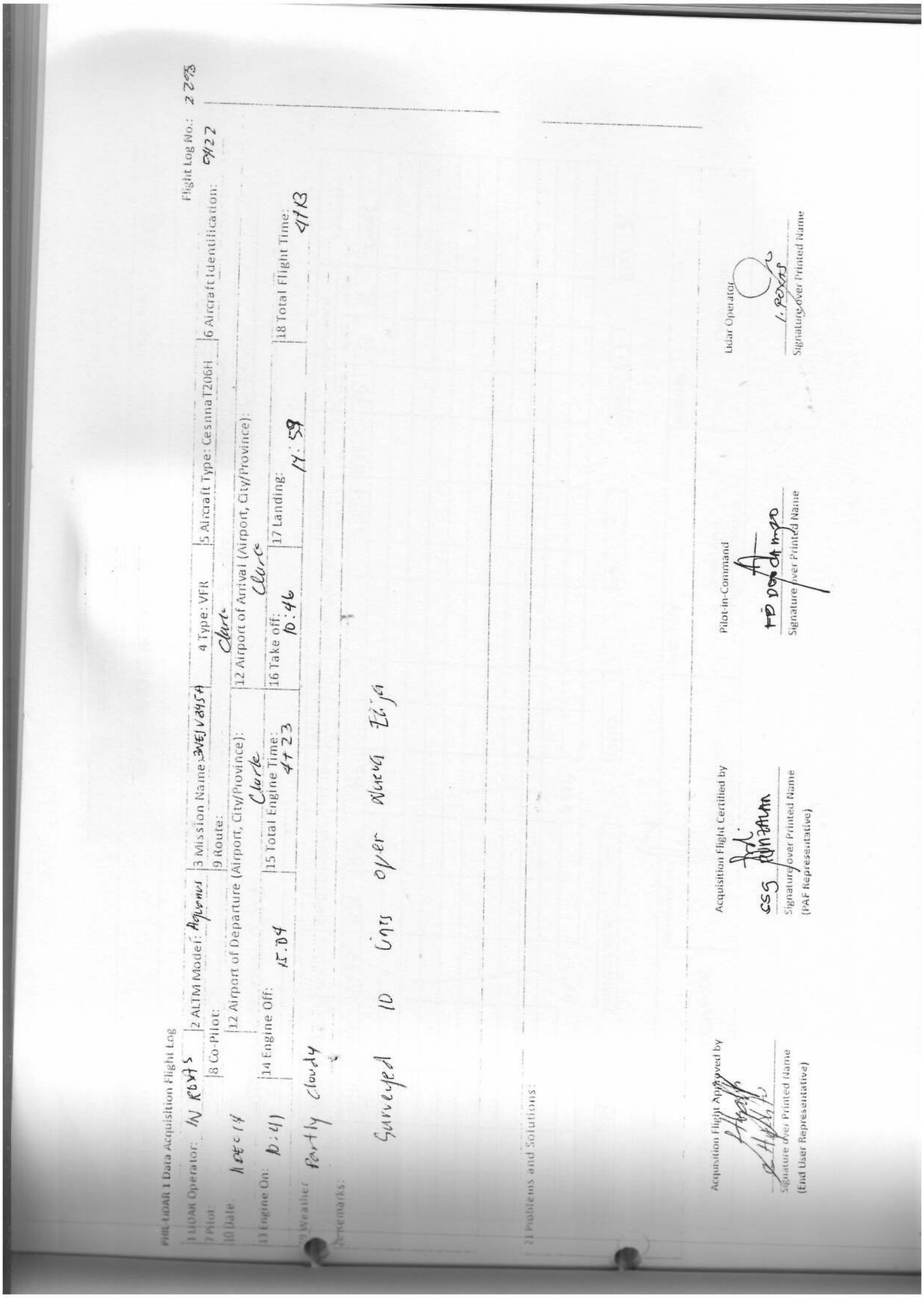
Acquisition Flight Certified by — SSG PUHALAN — Signature over Printed Name (PAF Representative)

Pilot-in-Command — FP DEOCAMPO — Signature over Printed Name

Lidar Operator — MR VILLANUEVA — Signature over Printed Name

Figure A-6.8. Flight Log for Mission 2294A

9. Flight Log for 2298A Mission


PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 2298

1 LiDAR Operator: N Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3NEJV345A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Clark			
10 Date: Dec 14	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 10:41	14 Engine Off: 15:04	15 Total Engine Time: 4+23	16 Take off: 10:46	17 Landing: 14:59	18 Total Flight Time: 4+13

19 Weather: Partly cloudy

20 Remarks: Surveyed 10 lines over Nueva Ecija

21 Problems and Solutions:

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

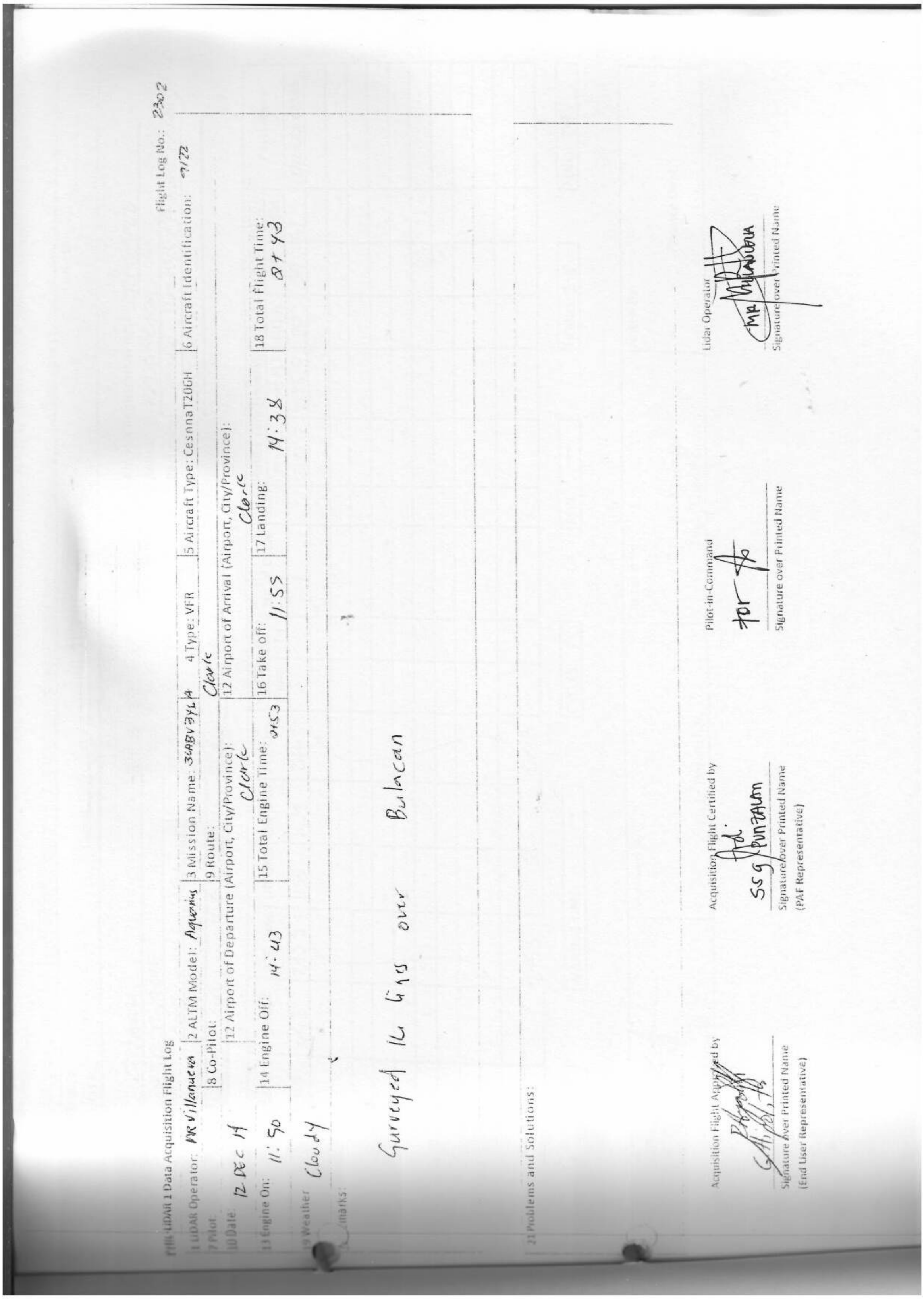
Acquisition Flight Certified by — CSG — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — N. Roxas — Signature over Printed Name

Figure A-6.9. Flight Log for Mission 2298A

10. Flight Log for 2302A Mission


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2302

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Aquarius	3 Mission Name: 3BLBV3YLA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Clark			
10 Date: 12 Dec 14	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 11:50	14 Engine Off: 14:43	15 Total Engine Time: 2+53	16 Take off: 11:55	17 Landing: 14:38	18 Total Flight Time: 2+43

19 Weather: Cloudy

20 Remarks: Surveyed 1L Gaps over Bulacan

21 Problems and Solutions:

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

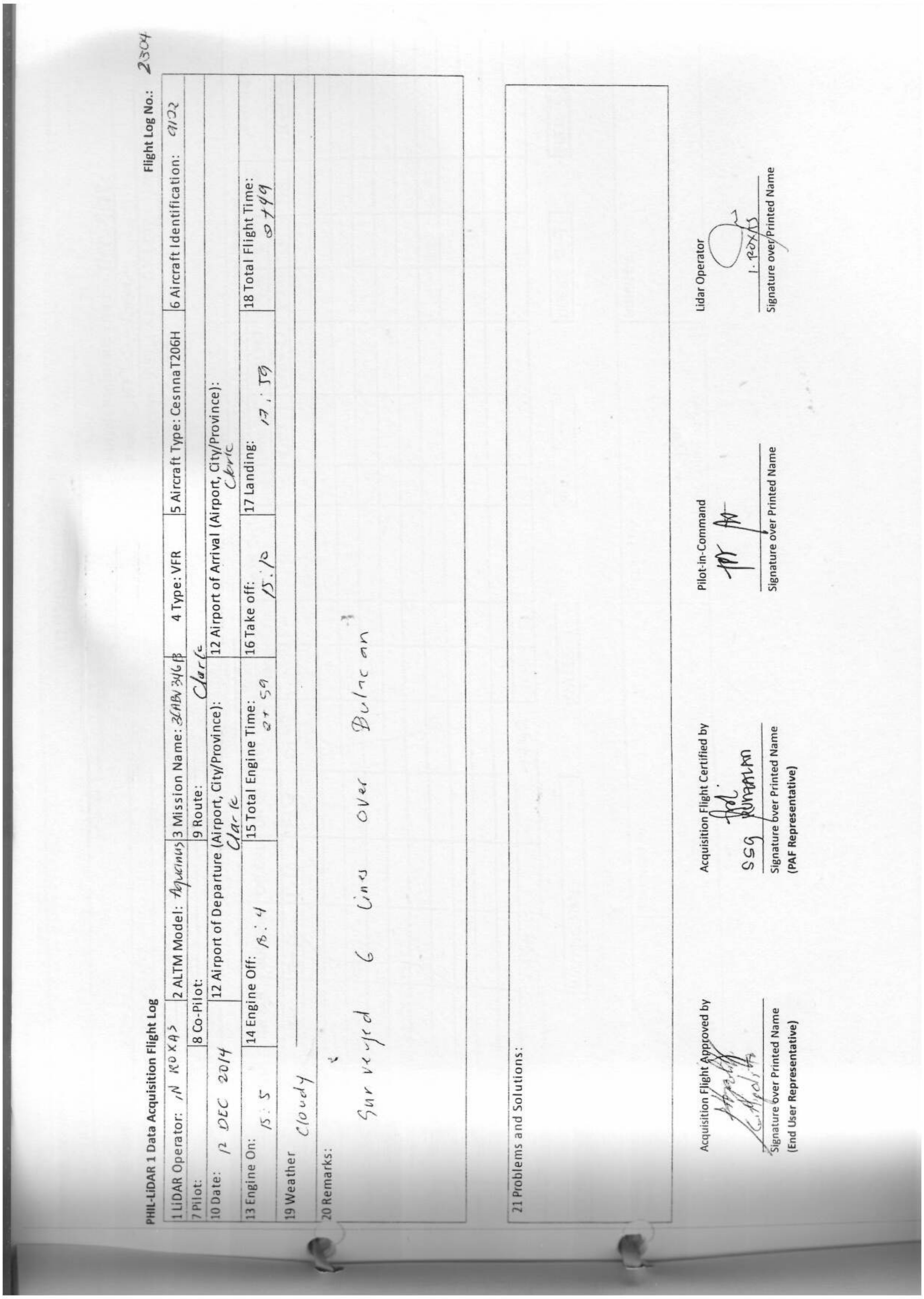
Acquisition Flight Certified by — SSG Punzalan — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — MR Villanueva — Signature over Printed Name

Figure A-6.10. Flight Log for Mission 2302A

11. Flight Log for 2304A Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2304

1 LiDAR Operator: I. ROXAS	2 ALTM Model: Aquarius	3 Mission Name: 3CABN346B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Clark			
10 Date: 12 DEC 2014	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 15:5	14 Engine Off: 18:4	15 Total Engine Time: 2+59	16 Take off: 15:10	17 Landing: 17:59	18 Total Flight Time: 2+49

19 Weather: Cloudy

20 Remarks:

Surveyed 6 lines over Bulacan

21 Problems and Solutions:

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

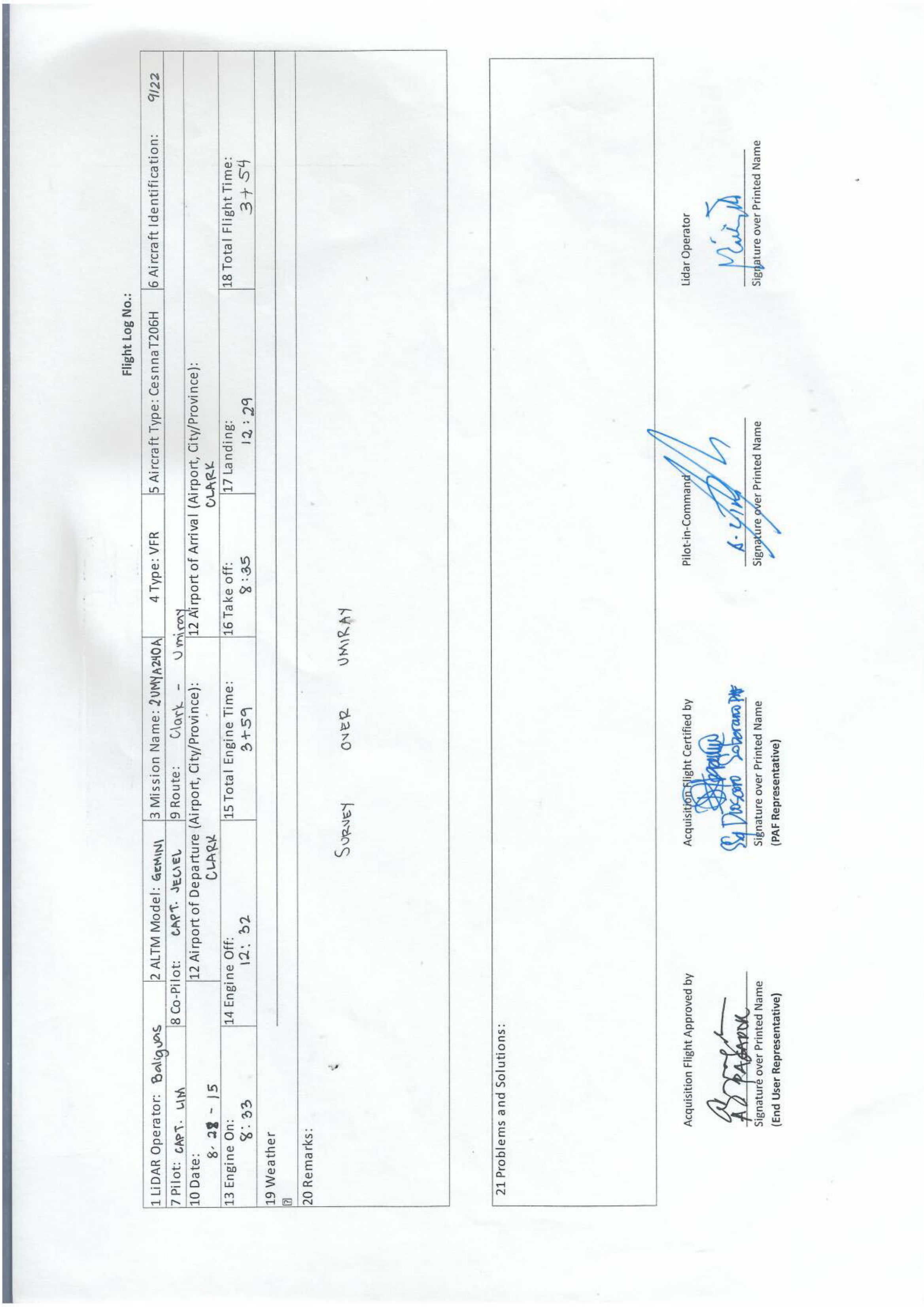
Acquisition Flight Certified by: SSG [signature] Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: I. Roxas Signature over Printed Name

Figure A-6.11. Flight Log for Mission 2304A

12. Flight Log for 2662G Mission


Flight Log No.:

1 LiDAR Operator: Balguas	2 ALTM Model: GEMINI	3 Mission Name: 2UMYA240A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: CAPT. LIM	8 Co-Pilot: CAPT. JECIEL	9 Route: Clark - Umiray			
10 Date: 8-28-15	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province): CLARK		
13 Engine On: 8:33	14 Engine Off: 12:32	15 Total Engine Time: 3+59	16 Take off: 8:35	17 Landing: 12:29	18 Total Flight Time: 3+54
19 Weather					
20 Remarks: SURVEY OVER UMIRAY					

21 Problems and Solutions:

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

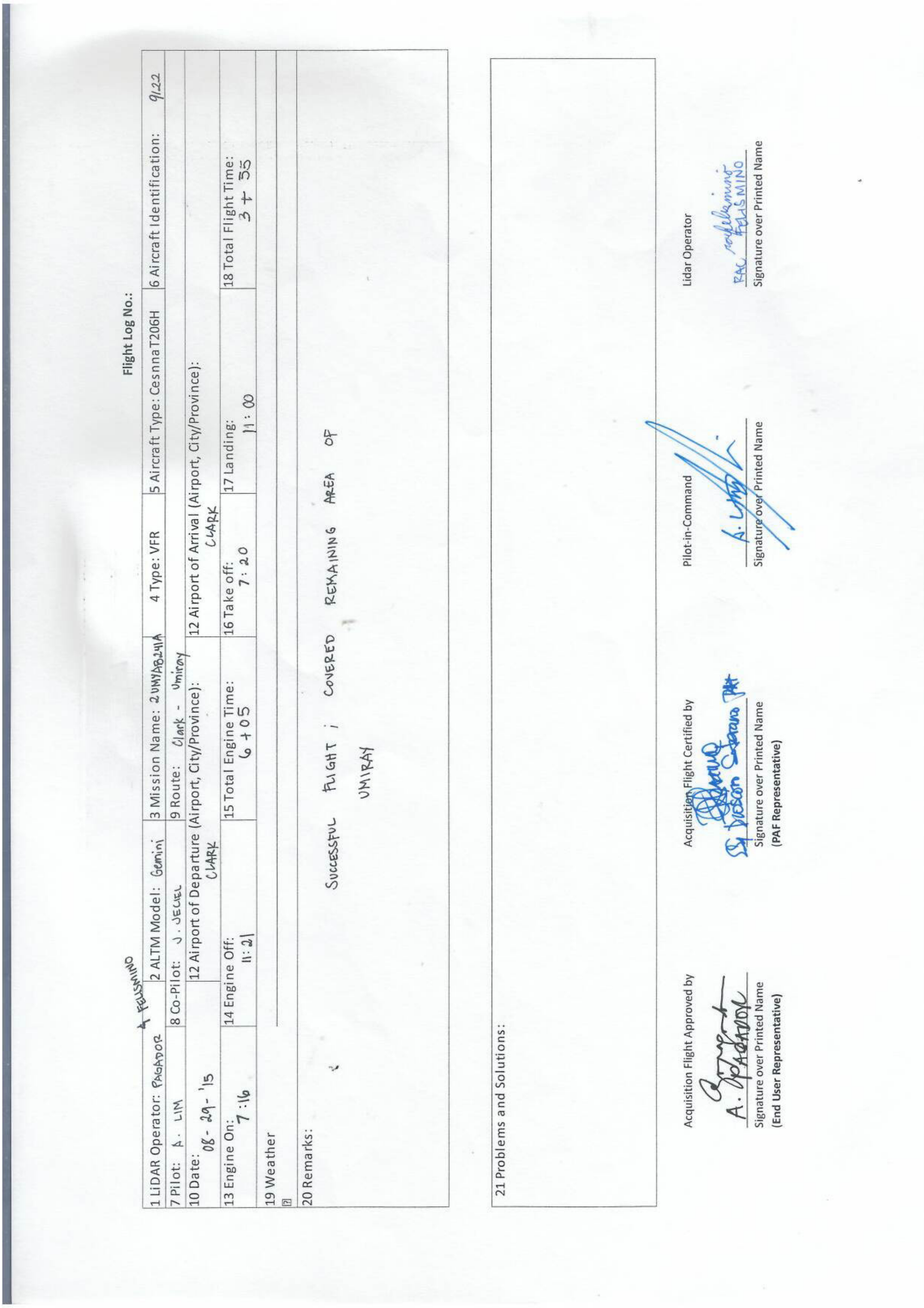
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.12. Flight Log for Mission 2662G

13. Flight Log for 2666G Mission



Flight Log No.:

1 LiDAR Operator: PAGADOR + FELISMINO	2 ALTM Model: Gemini	3 Mission Name: 2UMYAB241A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route: Clark - Umiray			
10 Date: 08-29-'15	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province): CLARK		
13 Engine On: 7:16	14 Engine Off: 11:21	15 Total Engine Time: 6+05	16 Take off: 7:20	17 Landing: 11:00	18 Total Flight Time: 3+55
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT ; COVERED REMAINING AREA OF UMIRAY					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. PAGADOR	SSg Dobson Serrano PAF	A. LIM	RAC FELISMINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.13. Flight Log for Mission 2666G

14. Flight Log for 2670G Mission

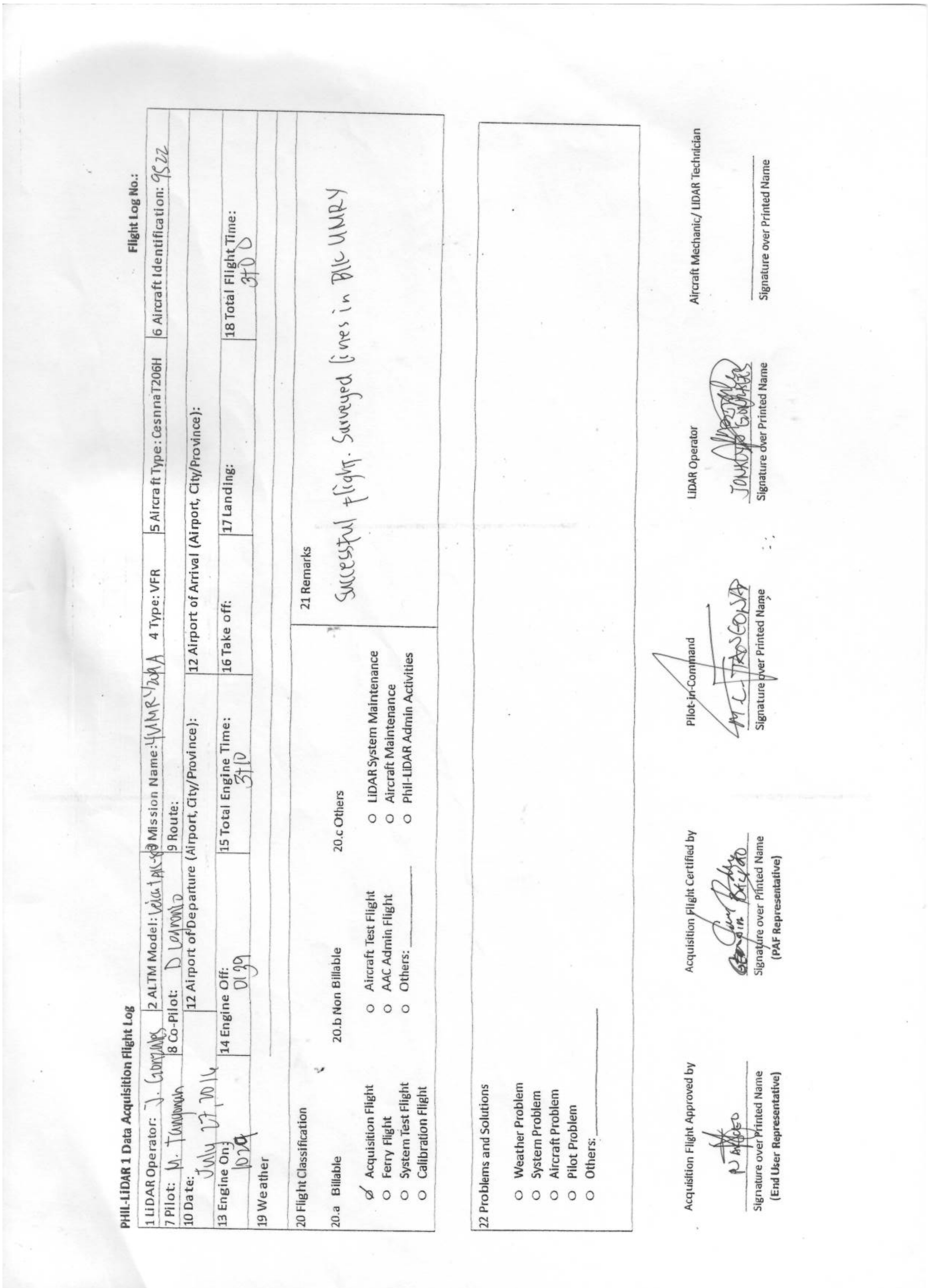
Flight Log No.:

1 LiDAR Operator: Pauline Arceo	2 ALTM Model: Gemini	3 Mission Name: 2UMA242A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: Capt. Lim	8 Co-Pilot: Capt. Jeciel	9 Route: Umiray			
10 Date: 8/30/15	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:57	14 Engine Off: 11:07	15 Total Engine Time: 4+10	16 Take off: 7:02	17 Landing: 11:02	18 Total Flight Time: 4+00
19 Weather					
20 Remarks: Successful flight over Umiray & Calib flight over Baliuag					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Asuncion	SSg Dioscoro Sg Dioscoro PAF	B. Lim	Pauline Arceo
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.14. Flight Log for Mission 2670G

15. Flight Log for 10210L Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: J. Gonzales	2 ALTM Model: Leica ALS-80	3 Mission Name: 4UMRV209A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9522
7 Pilot: M. Tangonan	8 Co-Pilot: D Legronio	9 Route:			
10 Date: July 27, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1029	14 Engine Off: 0139	15 Total Engine Time: 3+10	16 Take off:	17 Landing:	18 Total Flight Time: 3+00
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

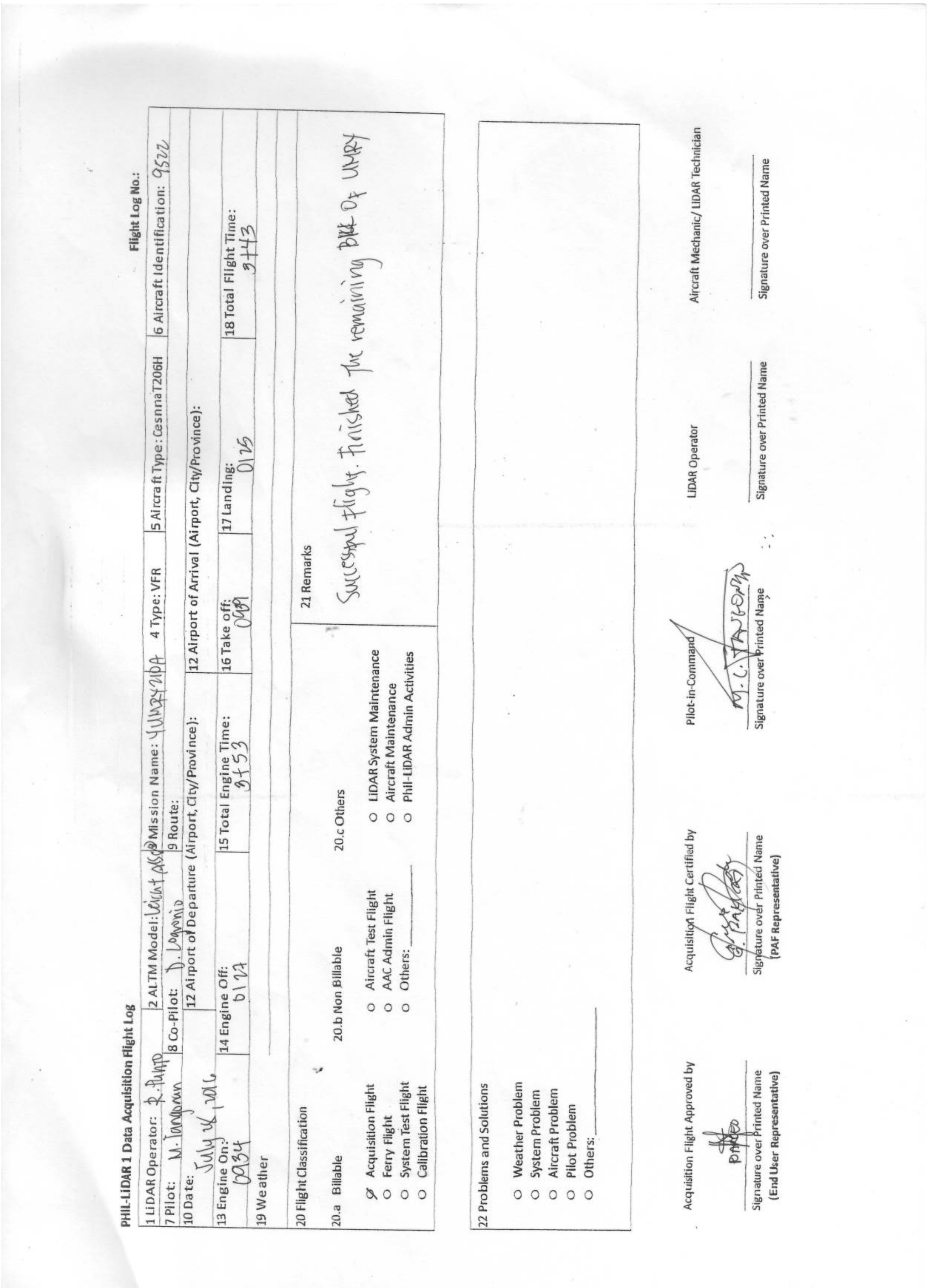
Successful flight. Surveyed lines in BLK UMRY

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.15. Flight Log for Mission 10210L

16. Flight Log for 20212L Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: R. Punto	2 ALTM Model: Leica ALS	3 Mission Name: 4UMRY21DA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9522
7 Pilot: M. Tangonan	8 Co-Pilot: D. Logronio	9 Route:			
10 Date: July 18, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0934	14 Engine Off: 0127	15 Total Engine Time: 3+53	16 Take off: 0939	17 Landing: 0125	18 Total Flight Time: 3+43
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Successful flight. Finished the remaining BLK of UMRY

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

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

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

Pilot-in-Command — M. C. Tangonan — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.16. Flight Log for Mission 20212L

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
Zambales, Umiray, Clark Reflights
(January 22-29, 2014; May 16-25, 2014; December 5-12, 2014; August 28-30, 2015; and July 27-28, 2016)

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2477P	NUEVA ECIJA	1NEJ022A	I.ROXAS	JANUARY 22, 2014	FILLED UP GAPS IN NUEVA ECIJA, CALIBRATION FLIGHT BUT BASE USED WAS IN AAC
7038GC	NEJ F	2NEJFG029A	MCE BALIGUAS	JANUARY 29, 2014	SURVEYED NEJ F
7253G	PAMS1, PAMS3	2PAMS1S3136A	MVE TONGA	MAY 16, 2014	MT. ARAYAT FLOWN AT 1650M (PAMS3); BULACAN AREA AT 850M(PAMS1)
7268GC	PAMS8	2PAMS8144A	MVE TONGA	MAY 24, 2014	COMPLETED 10 LINES AT 1000M
7271GC	PAMS1, S3	2PAMS1S3145B	LK PARAGAS	MAY 25, 2014	COMPLETED 15 LINES AT 1000M
2274A	NEJ	3NEJV339A	MR VILLANUEVA	DECEMBER 5, 2014	SURVEYED 8 LINES
2278A	PAM	3PAMV340A	I ROXAS	DECEMBER 6, 2014	NO DIGITIZER
2294A	TRC	3TRCV344A	MR VILLANUEVA	DECEMBER 10, 2014	SURVEYED 11 LINES
2298A	NEJ	3NEJV345A	I ROXAS	DECEMBER 11, 2014	NO DIGITIZER
2302A	NEJ	3NEJV346A	MR VILLANUEVA	DECEMBER 12, 2014	MISSION COMPLETED (WITH-OUT CASI). 12 LINES
2304A	NEJ	3NEJV346B	I ROXAS	DECEMBER 12, 2014	SURVEYED 11 LINES
2662G	UMYA	2UMYA240A	MCE BALIGUAS	AUGUST 28, 2015	CLOUDY ON SURVEY AREA, SUR-VEYED 4 LINES OVER UMYA
2666G	UMYAB	2UMYAB241A	AM PAGADOR AND R FELISMINO	AUGUST 29, 2015	SUPPLEMENTARY FLIGHT FOR UMYA AND SURVEYED 2 LINES OVER UMYB
2670G	UMYAB & BALIUAG, BULACAN	2CLBUMYAB-S242A	PJ ARCEO	AUGUST 30, 2015	LMS CALIBRATION OVER BALIUAG BULACAN, SUPPLEMENTARY FLIGHT FOR UMYA AND SURVEYED 7 LINES OVER UMYB
10210L	UMIRAY FLOODPLAIN	4UMRY209A	J GONZALES	JULY 27, 2016	4UMRY209A
10212L	UMIRAY FLOODPLAIN	4UMRY210A	R. PUNTO	JULY 28, 2016	SURVEYED UMIRAY AND SOME VOIDS FROM YESTERDAY'S FLIGHT

SWATH/LAS PER MISSION

Flight No. : 2477P
Area: NEJ
Mission Name: 1NEJ022A
Parameters: Altitude: 1000 Scan Frequency: 30
Scan Angle: 25 Overlap: 30

SWATH

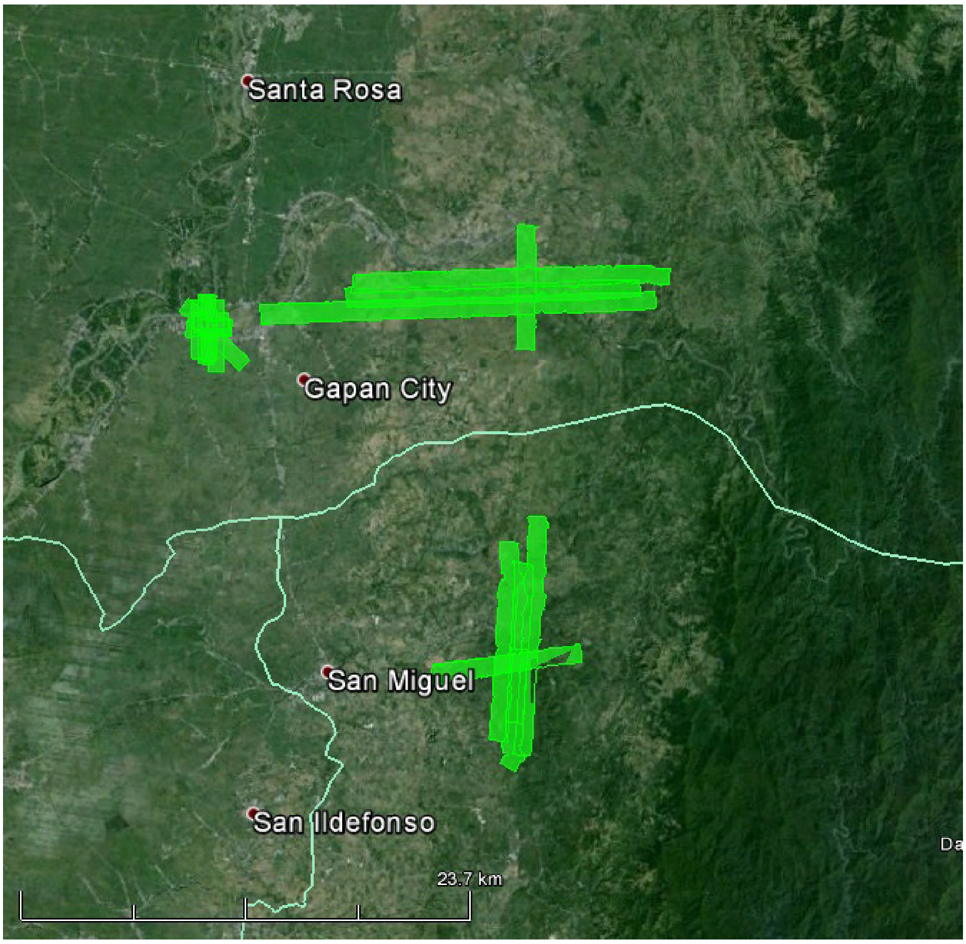


Figure A-7.1. Swath for Flight No. 2477P

Flight No. : 7038GC
Area: NEJ F
Mission Name: 2NEJFG029A
Parameters: Altitude: 1000 Scan Frequency: 40
Scan Angle: 20 Overlap: 30

SWATH

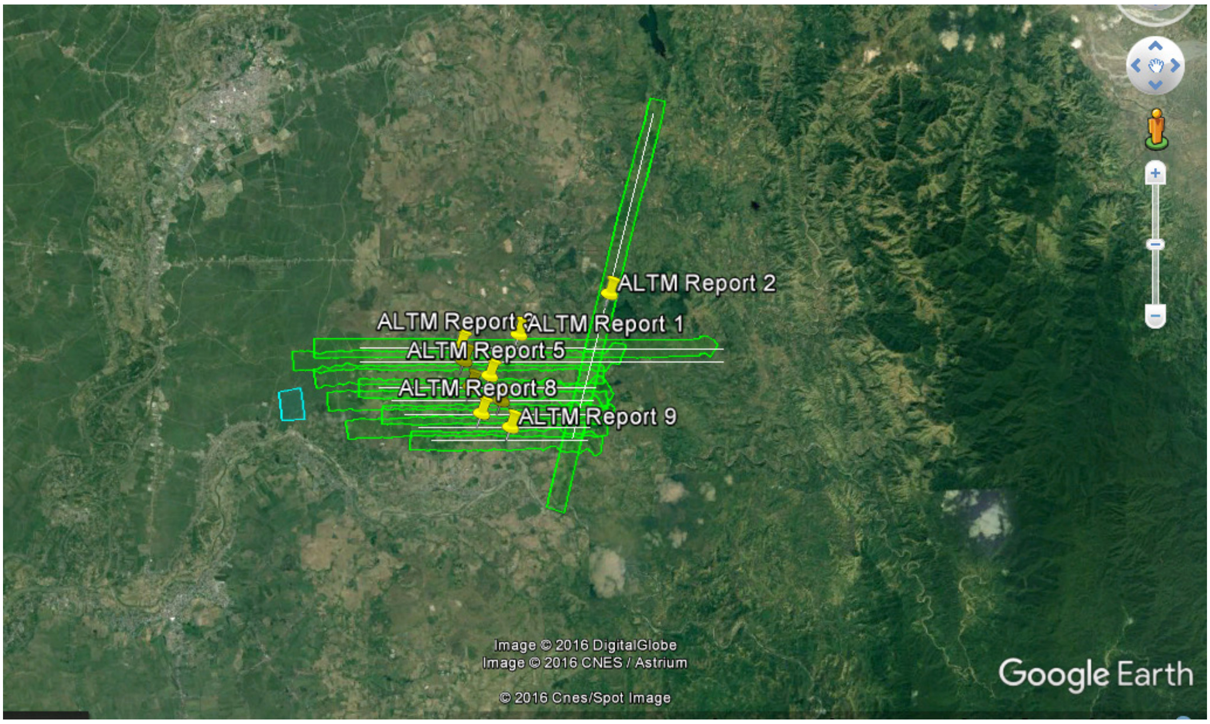


Figure A-7.2. Swath for Flight No. 7038GC

Flight No. : 7253G
Area: PAM S1, PAM
Mission Name: 2PAMS1S3136A
Parameters: Altitude: 1650-800
Scan Frequency: 50
Scan Angle: 20
Overlap: 30

SWATH

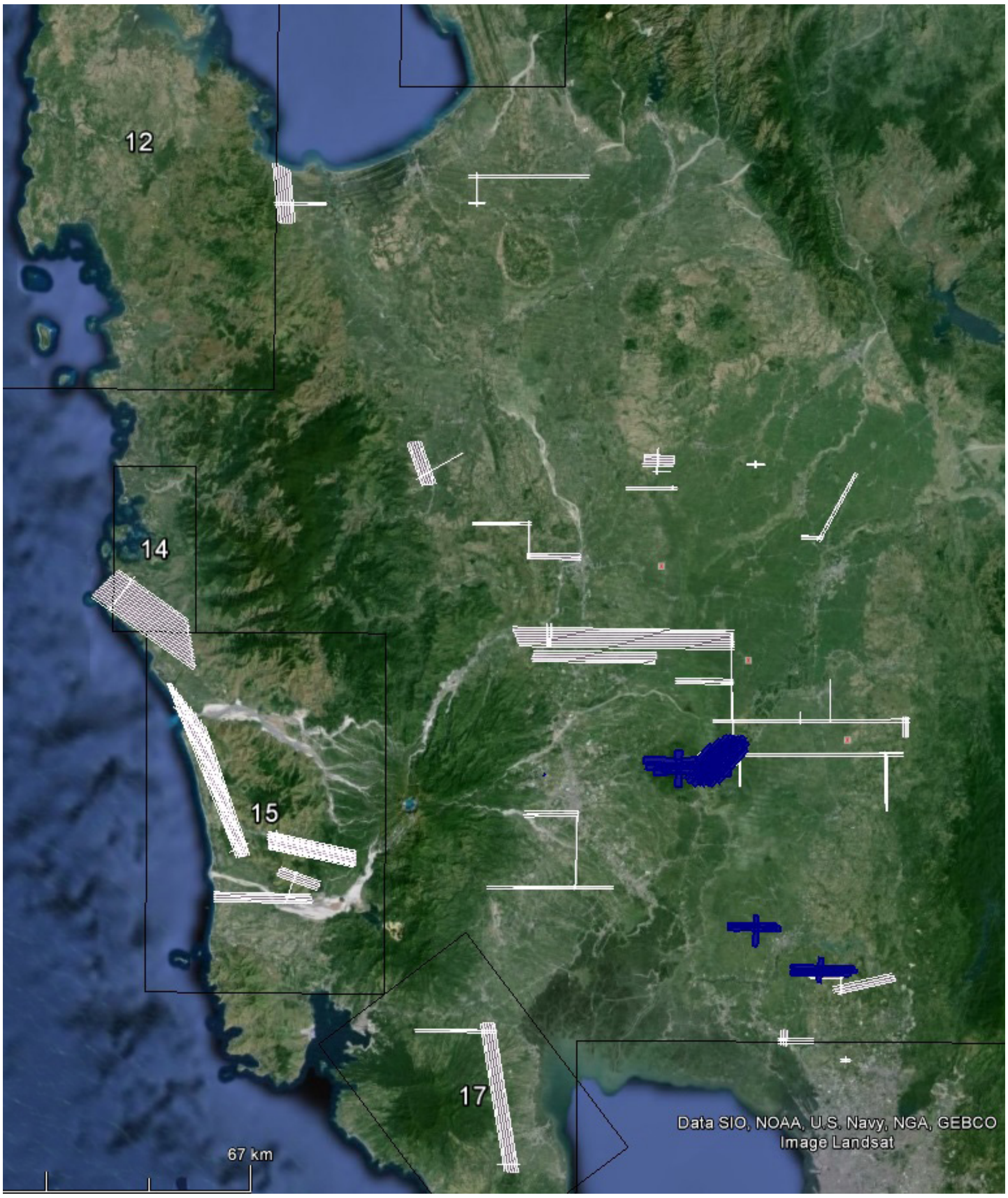


Figure A-7.3. Swath for Flight No. 7253G

Flight No. : 7268GC
Area: PAM S8
Mission Name: 2PAMS8144A
Parameters: Altitude: 1000 Scan Frequency: 50
Scan Angle: 20 Overlap: 40

SWATH

Figure A-7.4. Swath for Flight No. 7268GC

Flight No. : 7271GC
Area: PAM S1, S3
Mission Name: 2PAMS1S3145B
Parameters: Altitude: 1000 Scan Frequency: 50
Scan Angle: 20 Overlap: 40

SWATH

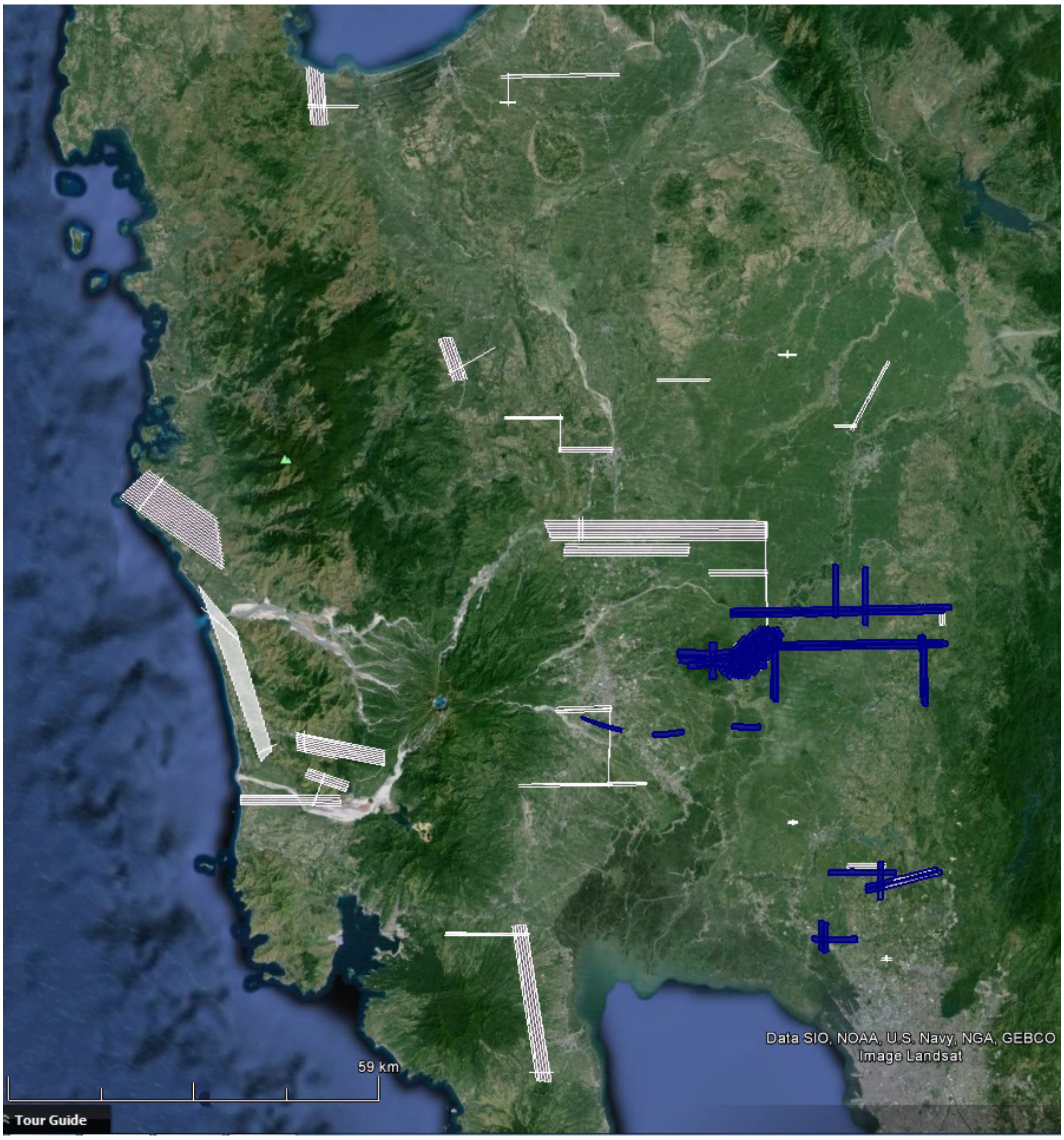


Figure A-7.5. Swath for Flight No. 7271GC

Flight No. : 2274A
Area: NEJ V
Mission Name: 3NEJV339A
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 18 Overlap: 30

SWATH

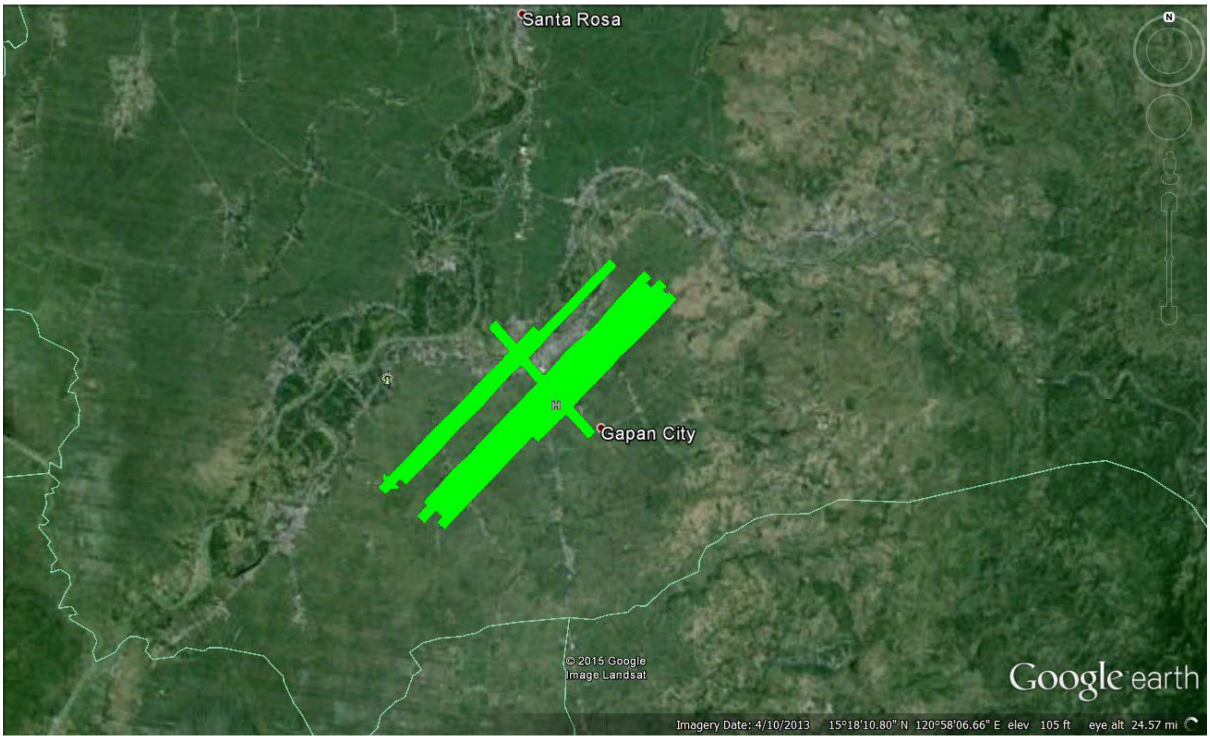


Figure A-7.6. Swath for Flight No. 2274A

Flight No. : 2278A
Area: PAM V
Mission Name: 3PAMV340A
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 18 Overlap: 30

SWATH

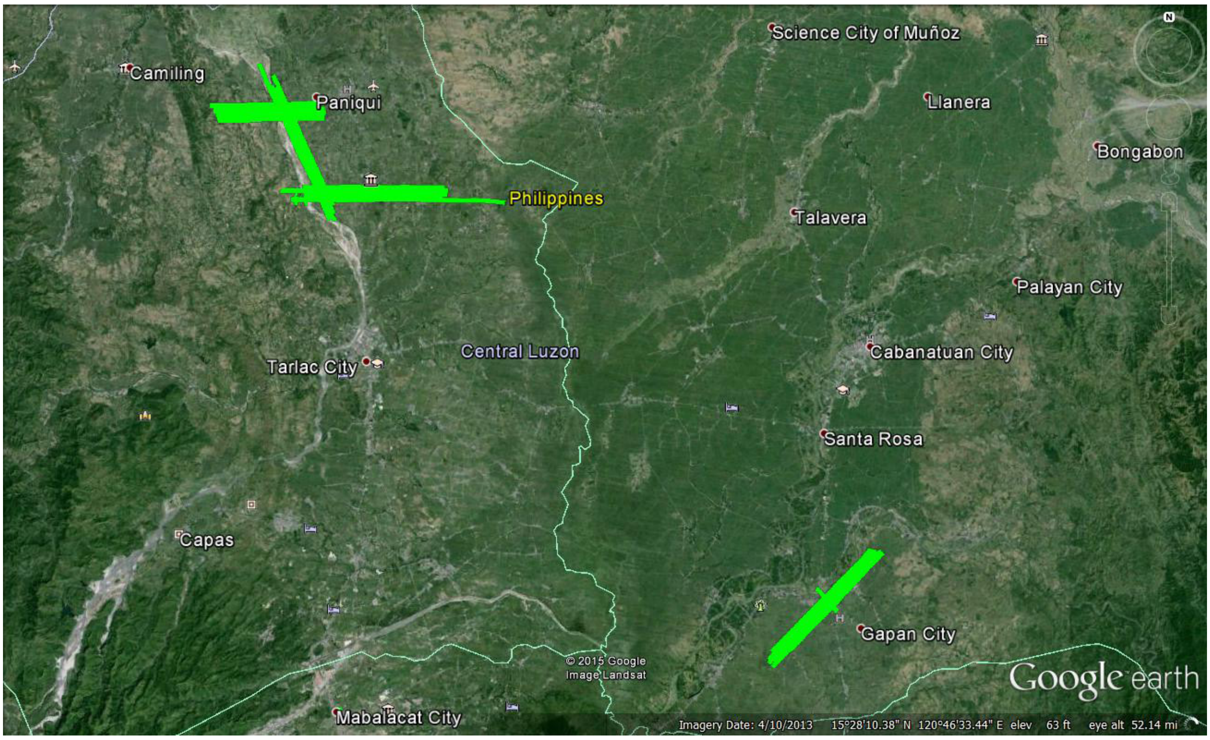


Figure A-7.7. Swath for Flight No. 2278A

Flight No. : 2294A
Area: TRC V
Mission Name: 3TRCV344A
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 18 Overlap: 30

SWATH

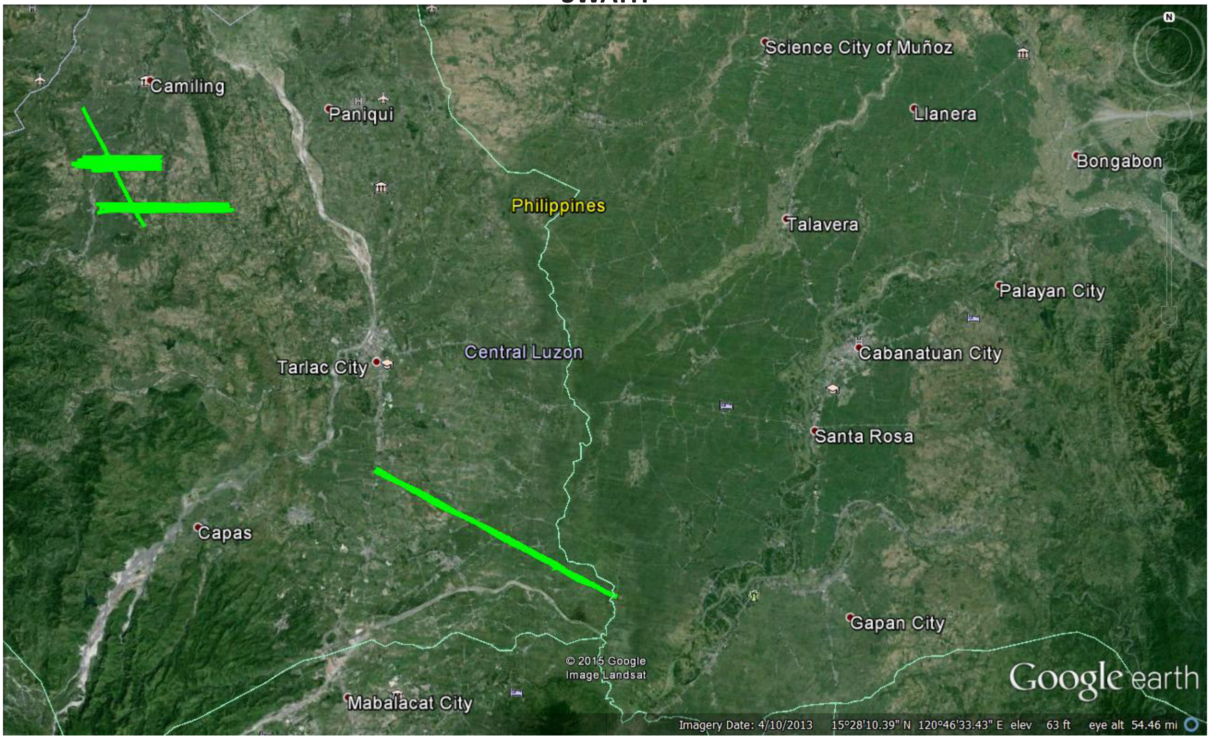


Figure A-7.8. Swath for Flight No. 2294A

Flight No. : 2298A
Area: NEJ
Mission Name: 3NEJV345A
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 18 Overlap: 30

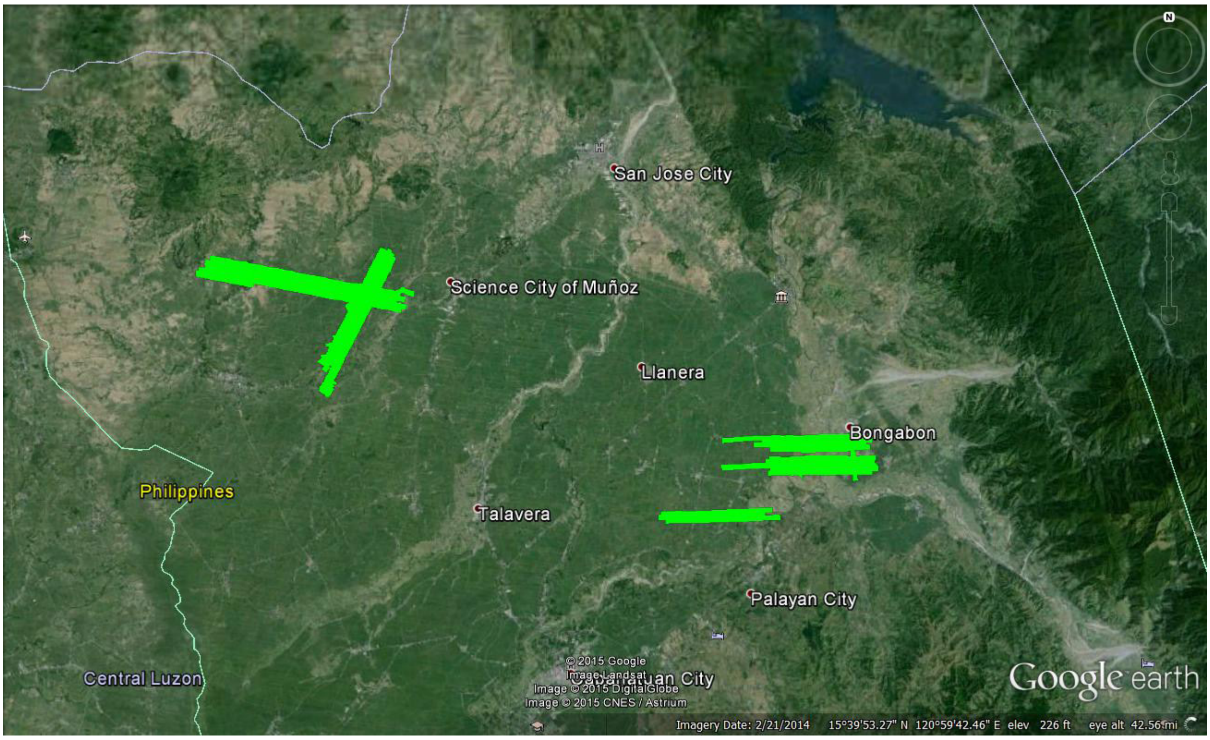


Figure A-7.9. Swath for Flight No. 2298A

Flight No. : 2302A
Area:
Mission Name: 3NEJV346A
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 18 Overlap: 30

SWATH

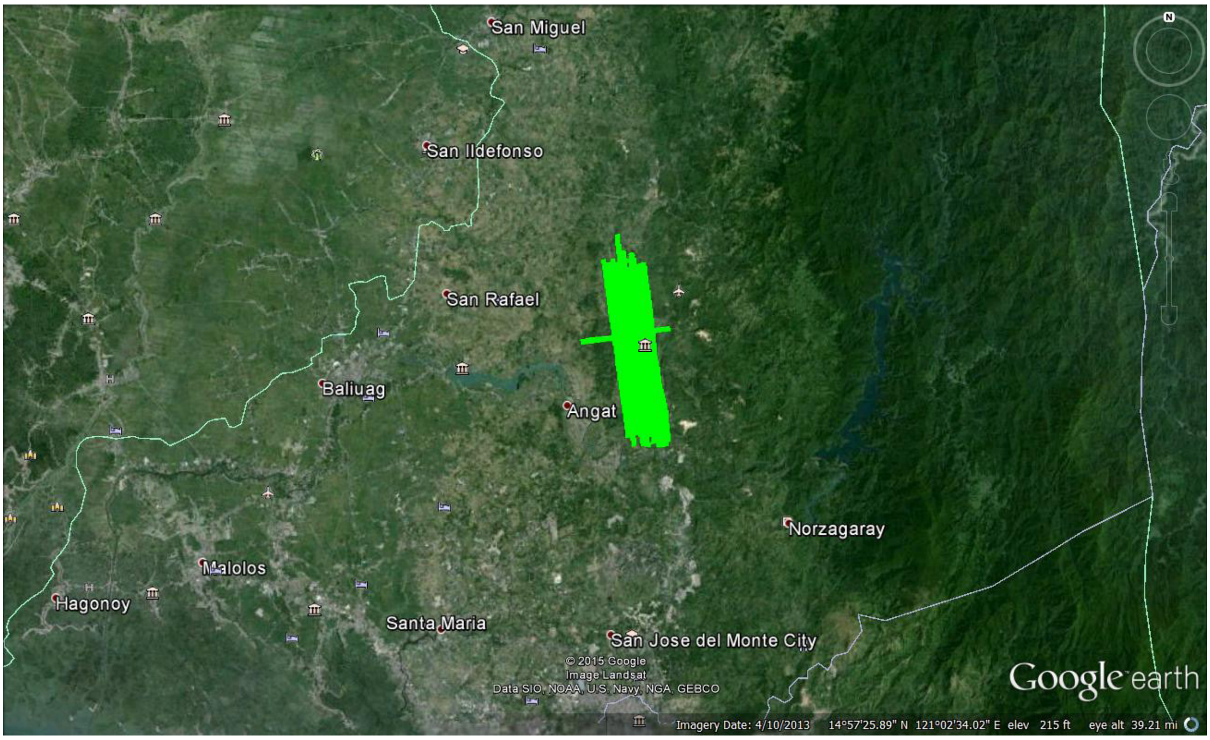


Figure A-7.10. Swath for Flight No. 2302A

Flight No. : 2304A
Area: NEJ V
Mission Name: 3NEJV346B
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 18 Overlap: 30

SWATH

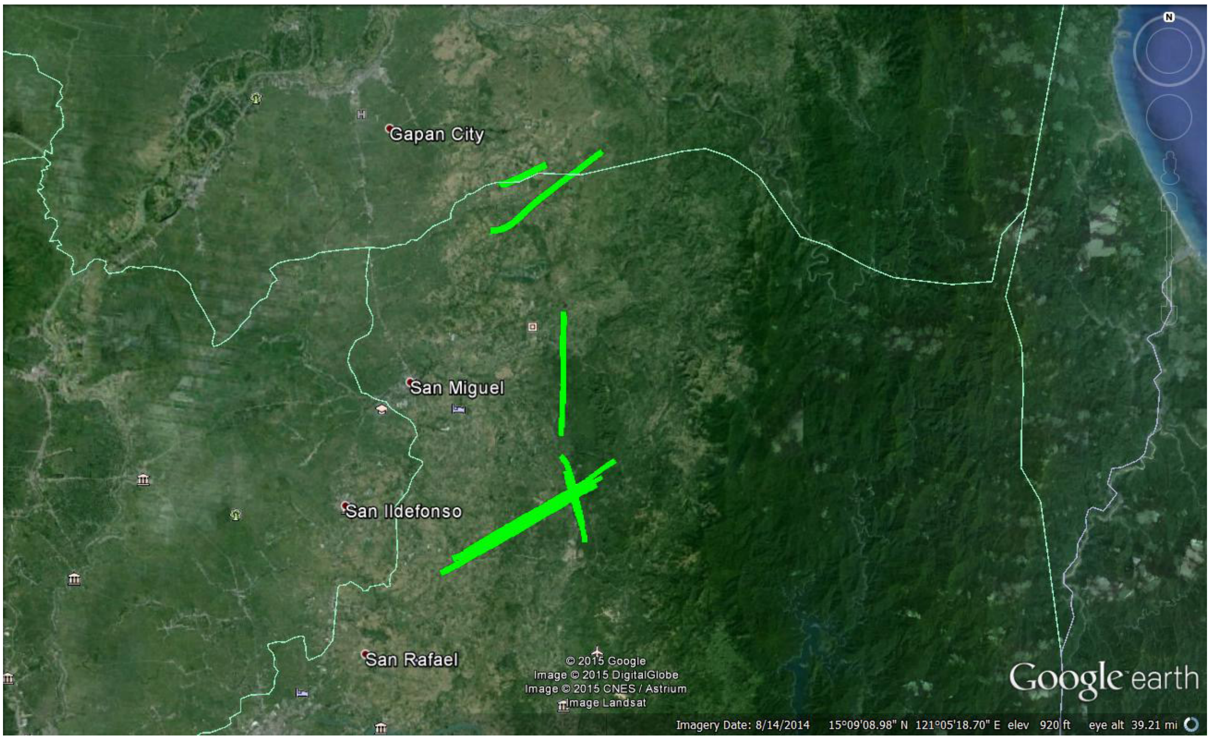


Figure A-7.11. Swath for Flight No. 2304A

Flight No. : 2662G
Area: UMYA
Mission Name: 2UMYA240A
Parameters: Altitude: 1000 Scan Frequency: 50
Scan Angle: 20 Overlap: 50

SWATH

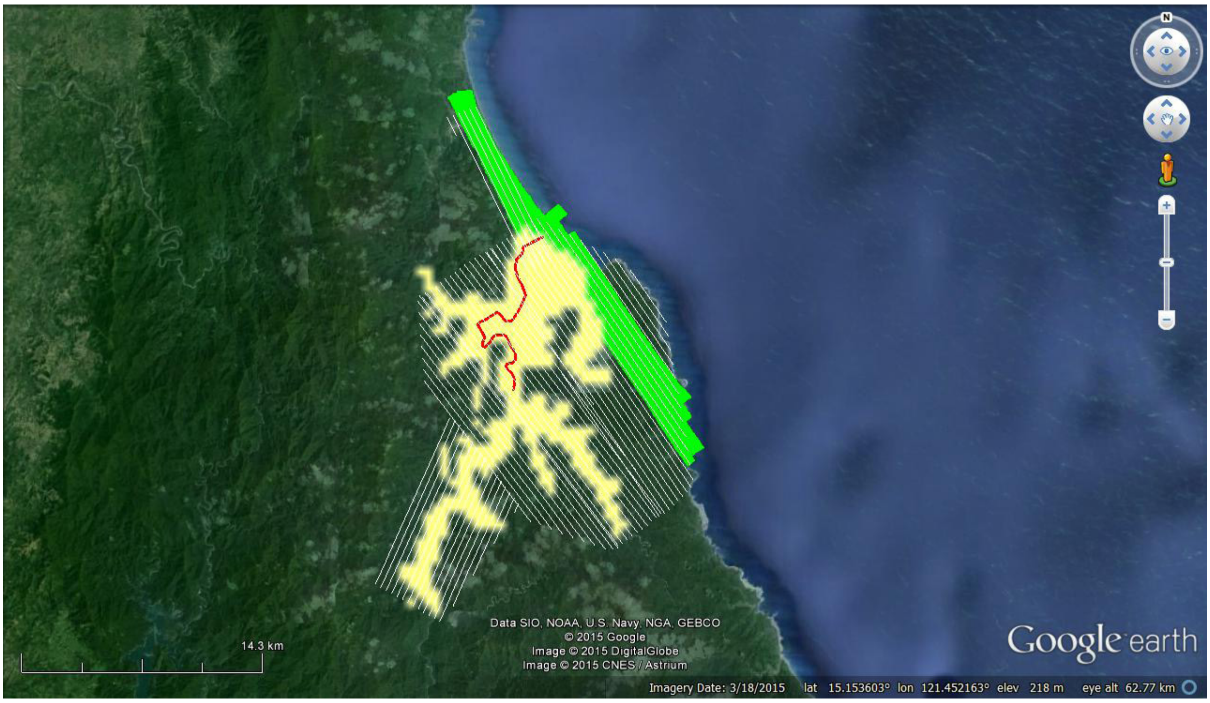


Figure A-7.12. Swath for Flight No. 2662G

Flight No. : 2666G
Area: UMY A, B
Mission Name: 2UMYAB241A
Parameters: Altitude: 1000 Scan Frequency: 50
Scan Angle: 20 Overlap: 60

SWATH

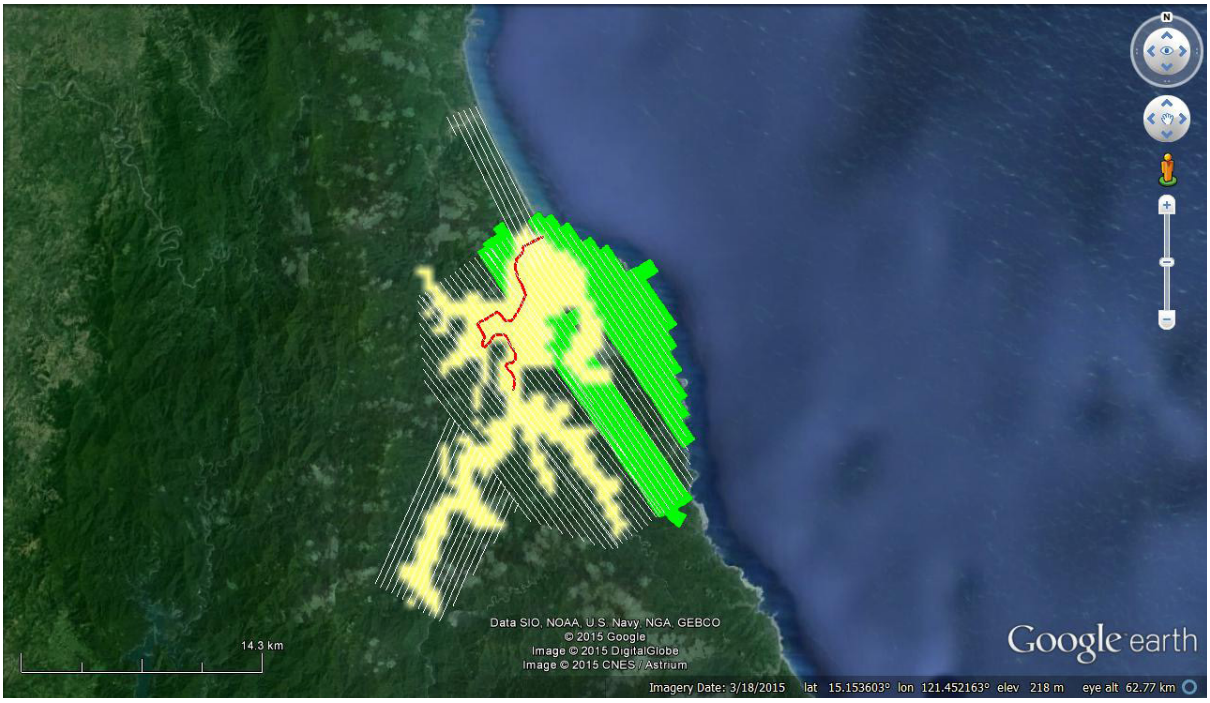


Figure A-7.13. Swath for Flight No. 2666G

Flight No. : 2670G
Area: UMY A, B & BALIUAG, BULACAN
Mission Name: 2CLBUMYABS242A
Parameters: Altitude: 1000 Scan Frequency: 50
Scan Angle: 20 Overlap: 60

SWATH

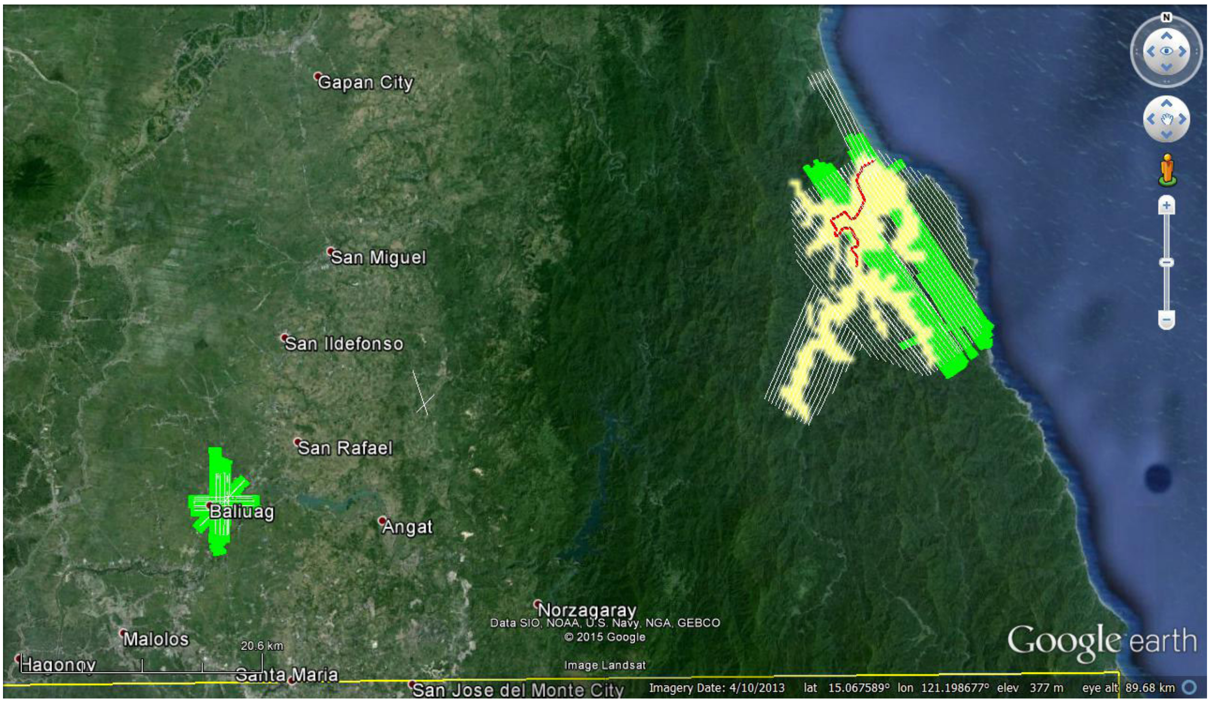


Figure A-7.14. Swath for Flight No. 2670G

Flight No. : 10210L
Area: UMRY
Mission Name: 4UMRY209A
Parameters: Altitude: 1600 Scan Frequency: 52
Scan Angle: 20 Overlap: 30

SWATH

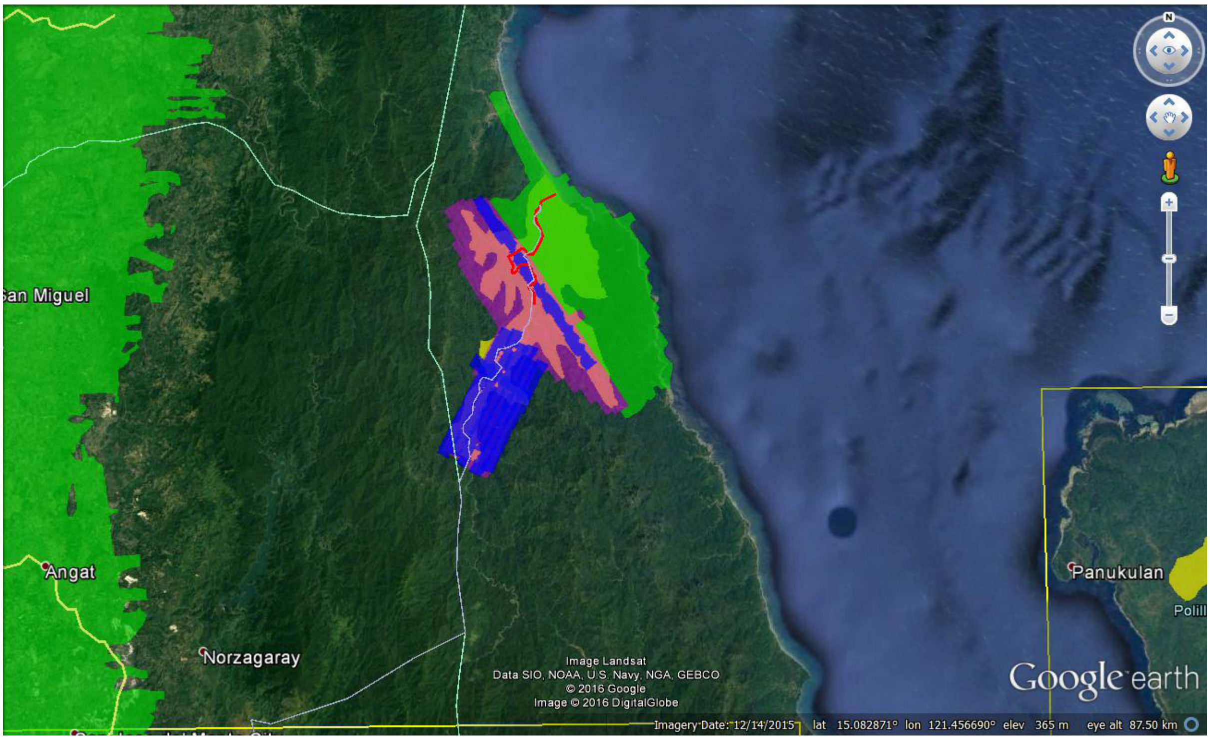


Figure A-7.15. Swath for Flight No. 10210L

Flight No. : 10212L
Area: UMRY
Mission Name: 4UMRY210A
Parameters: Altitude: 1600 Scan Frequency: 52
Scan Angle: 20 Overlap: 30

SWATH

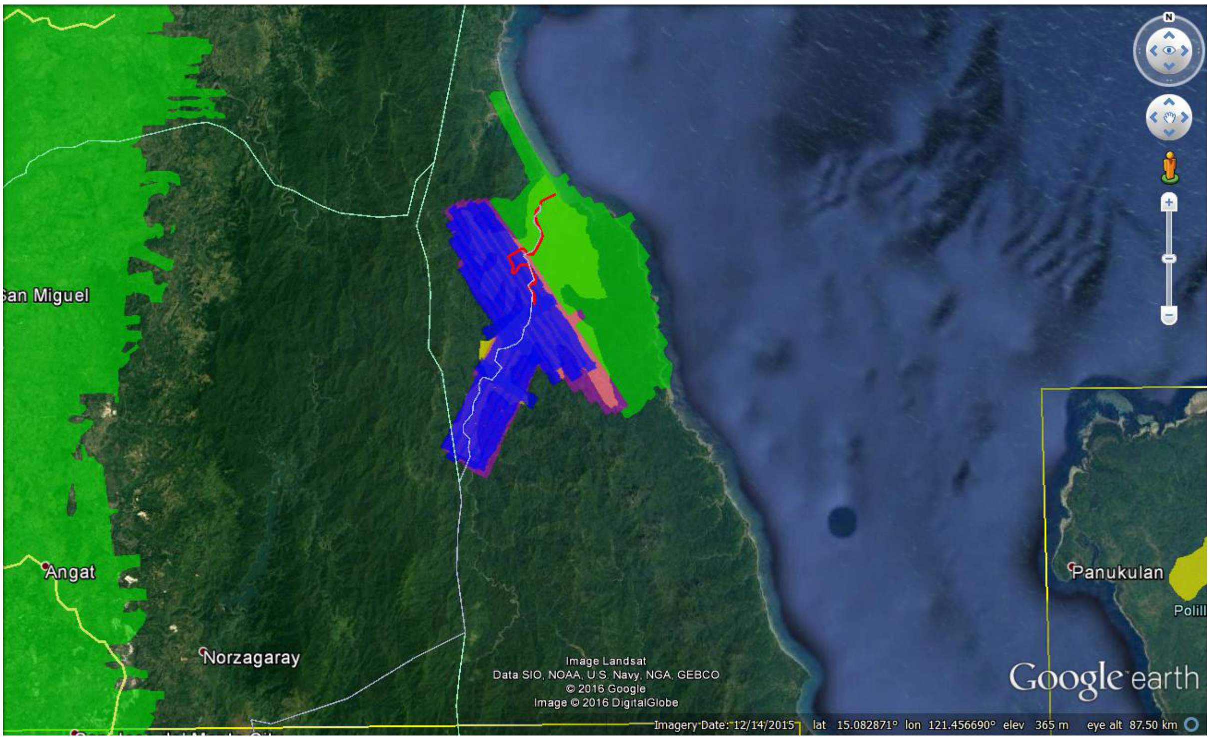


Figure A-7.16. Swath for Flight No. 10212L

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Pam_8A_Additional

Flight Area	Bataan_Reflights
Mission Name	Pam_8A_Additional
Inclusive Flights	2477P
Range data size	10.2 GB
POS data size	197 MB
Base data size	4.16 MB
Image	NA
Transfer date	March 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.02
RMSE for East Position (<4.0 cm)	1.81
RMSE for Down Position (<8.0 cm)	4.29
Boresight correction stdev (<0.001deg)	0.000435
IMU attitude correction stdev (<0.001deg)	0.000453
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	27.02
Ave point cloud density per sq.m. (>2.0)	3.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	48
Maximum Height	350 m
Minimum Height	75.12 m
Classification (# of points)	
Ground	2,877,749
Low vegetation	16,623,507
Medium vegetation	45,168,090
High vegetation	33,072,391
Building	1,587,329
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Mark Joshua Salvacion, Ryan James Nicholai Dizon

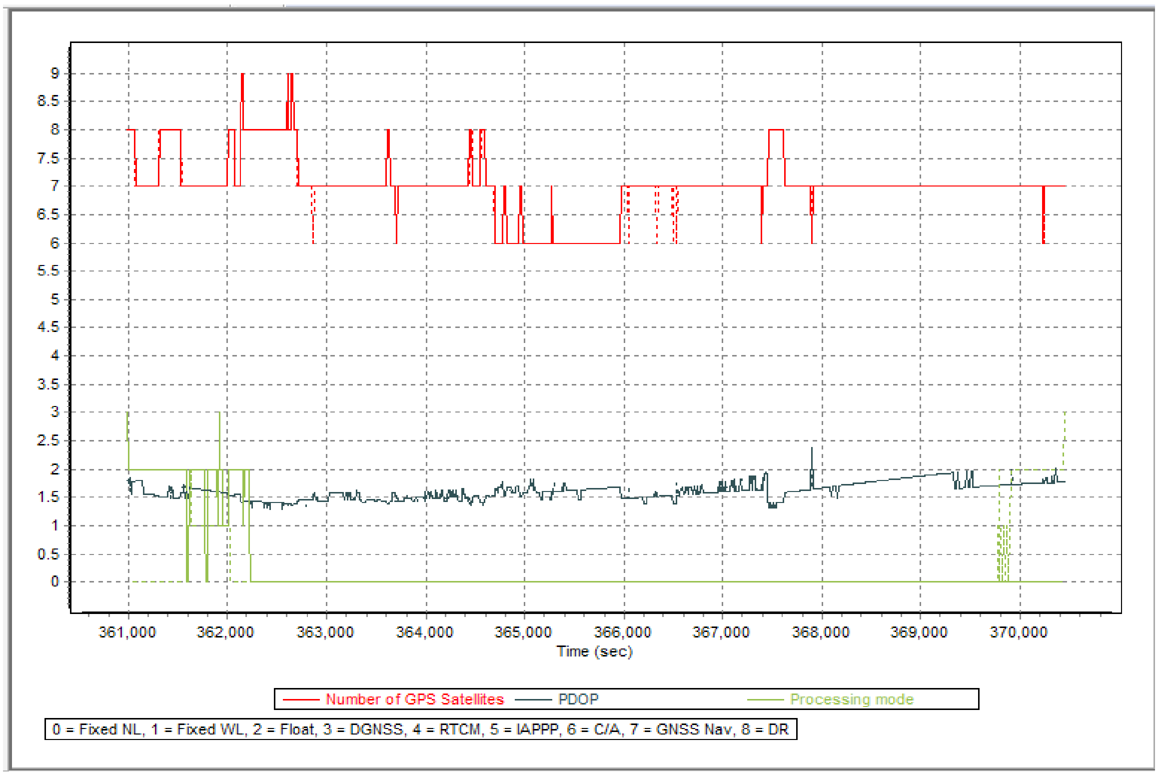


Figure A-8.1. Solution Status

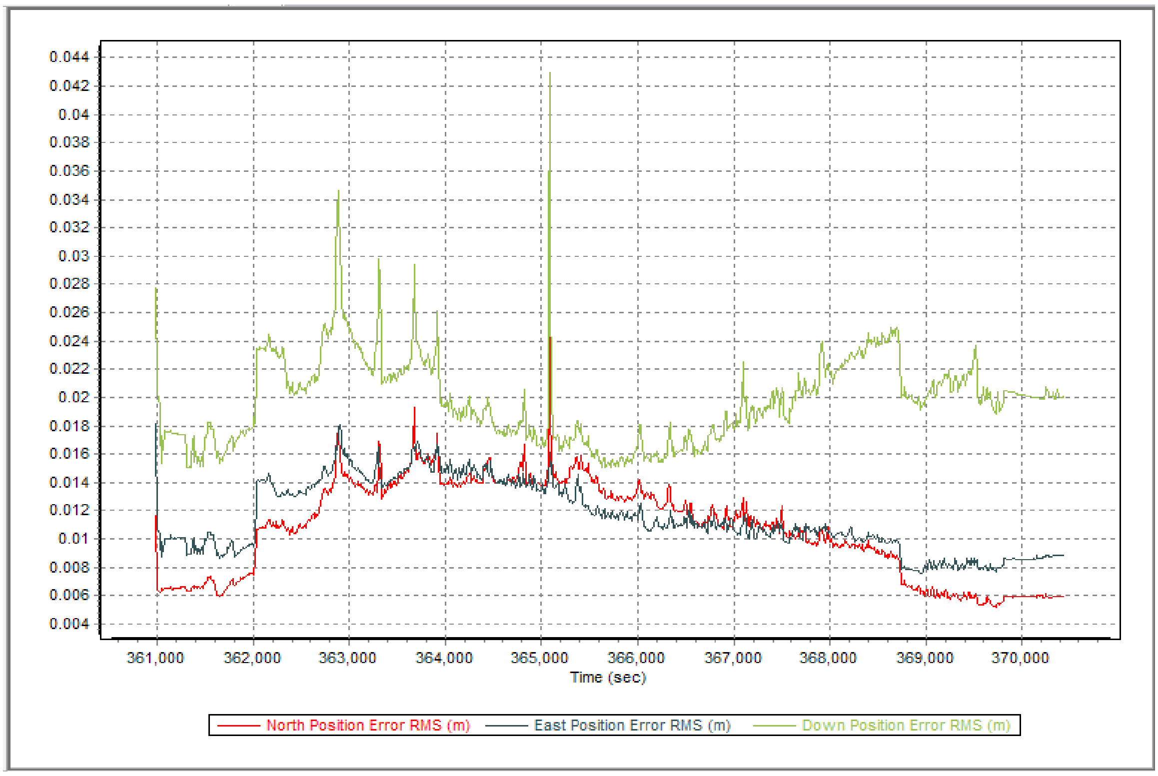


Figure A-8.2. Smoothed Performance Metric Parameters

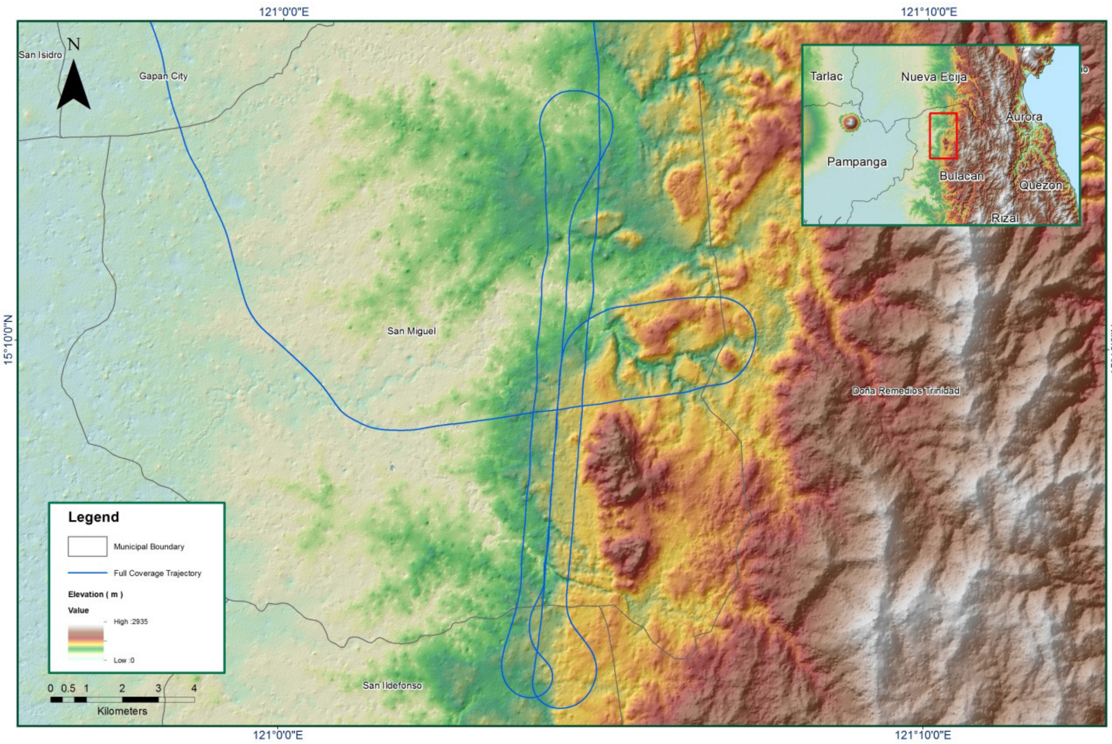


Figure A-8.3. Best Estimate Trajectory

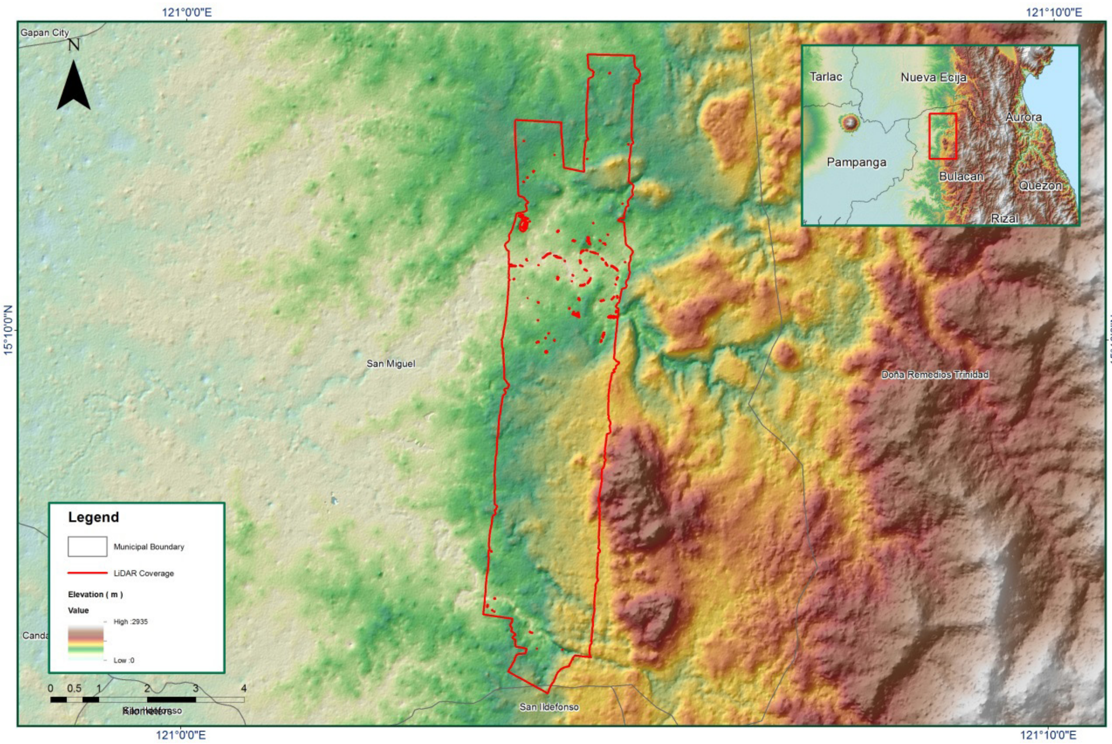


Figure A-8.4. Coverage of LiDAR data

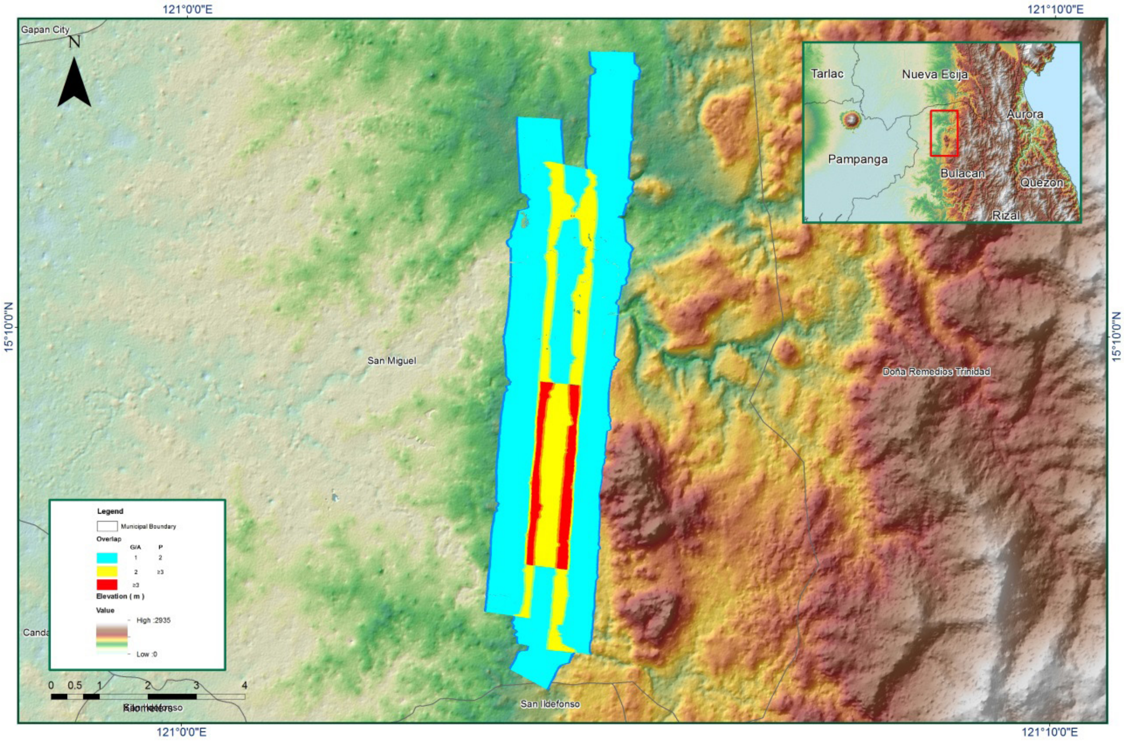


Figure A-8.5 Image of data overlap

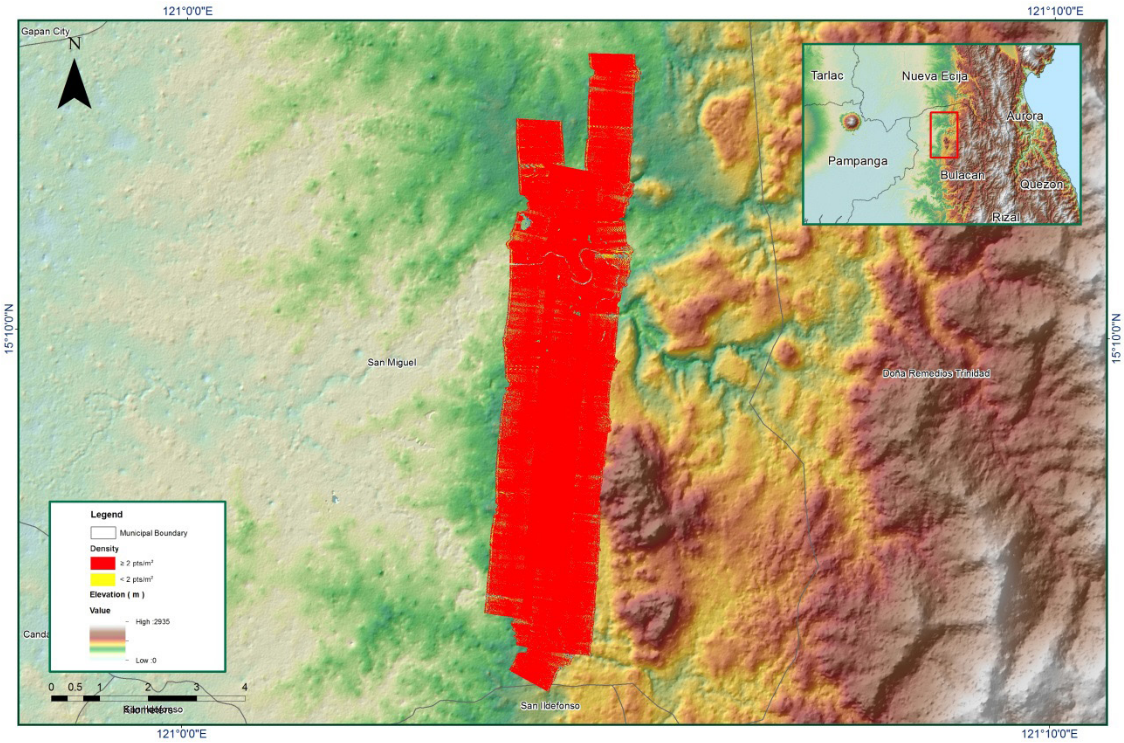


Figure A-8.6. Density Map of merged LiDAR data

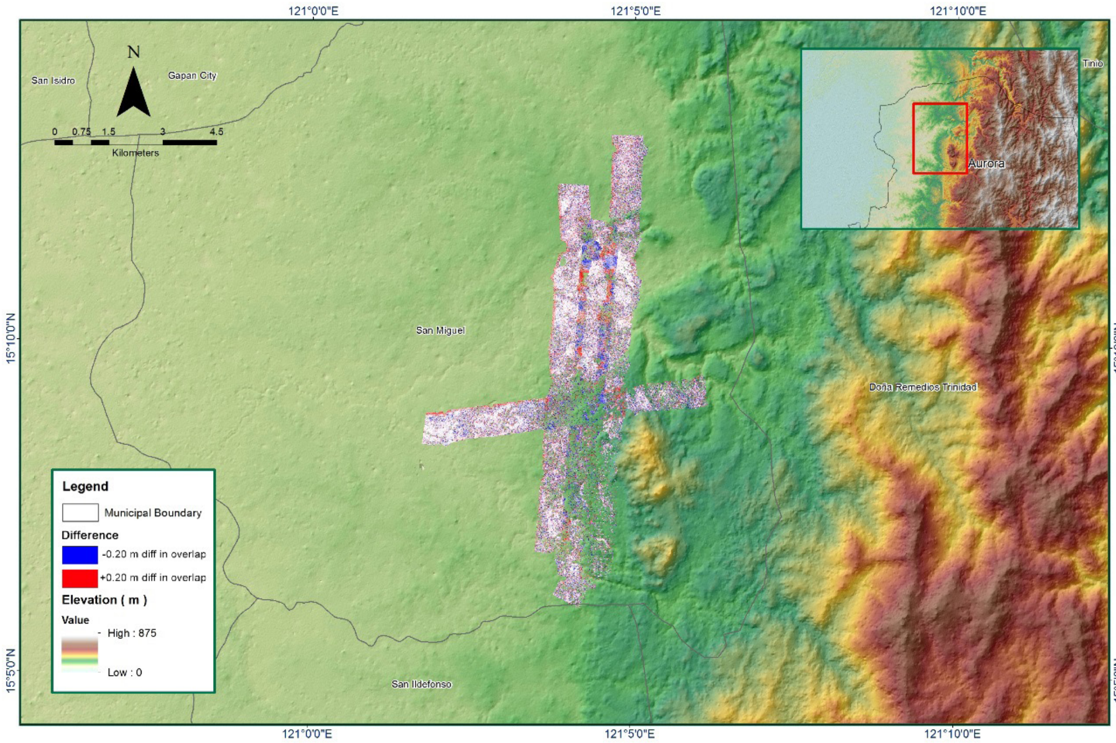


Figure A-8.7. Elevation Difference Between flight lines

Table A-8.2. Mission Summary Report for Mission Pam3D_Additional2

Flight Area	Bataan_Reflights
Mission Name	Pam3D_Additional2
Inclusive Flights	2477P
Range data size	3.8 GB
POS data size	163 MB
Base data size	17.2 MB
Image	N/A
Transfer date	December 5, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.018
RMSE for East Position (<4.0 cm)	1.809
RMSE for Down Position (<8.0 cm)	4.293
Boresight correction stdev (<0.001deg)	0.000375
IMU attitude correction stdev (<0.001deg)	0.000932
GPS position stdev (<0.01m)	0.00170
Minimum % overlap (>25)	21.6.5
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	72
Maximum Height	289.56 m
Minimum Height	56.79 m
Classification (# of points)	
Ground	58,455,490
Low vegetation	36,067,151
Medium vegetation	50,813,166
High vegetation	34,107,389
Building	2,486,259
Orthophoto	None
Processed by	Engr. Angelo Carlo Bongat, Aljon Rie Araneta, Engr. Gladys Mae Apat

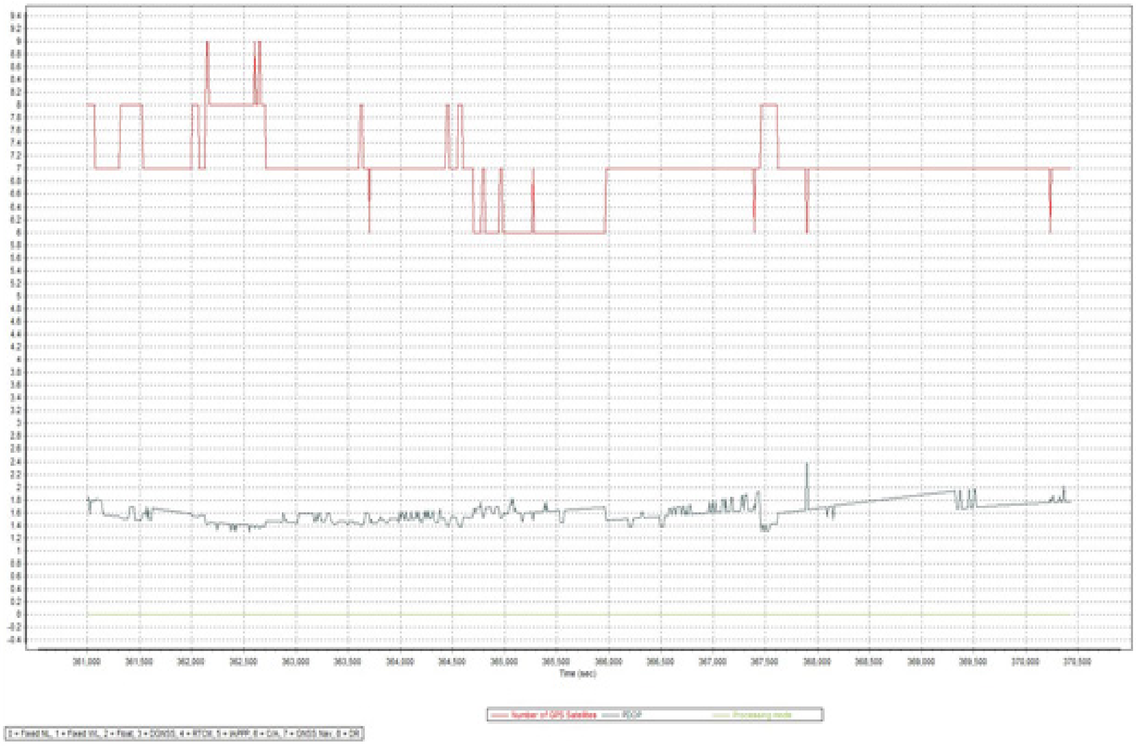


Figure A-8.8. Solution Status

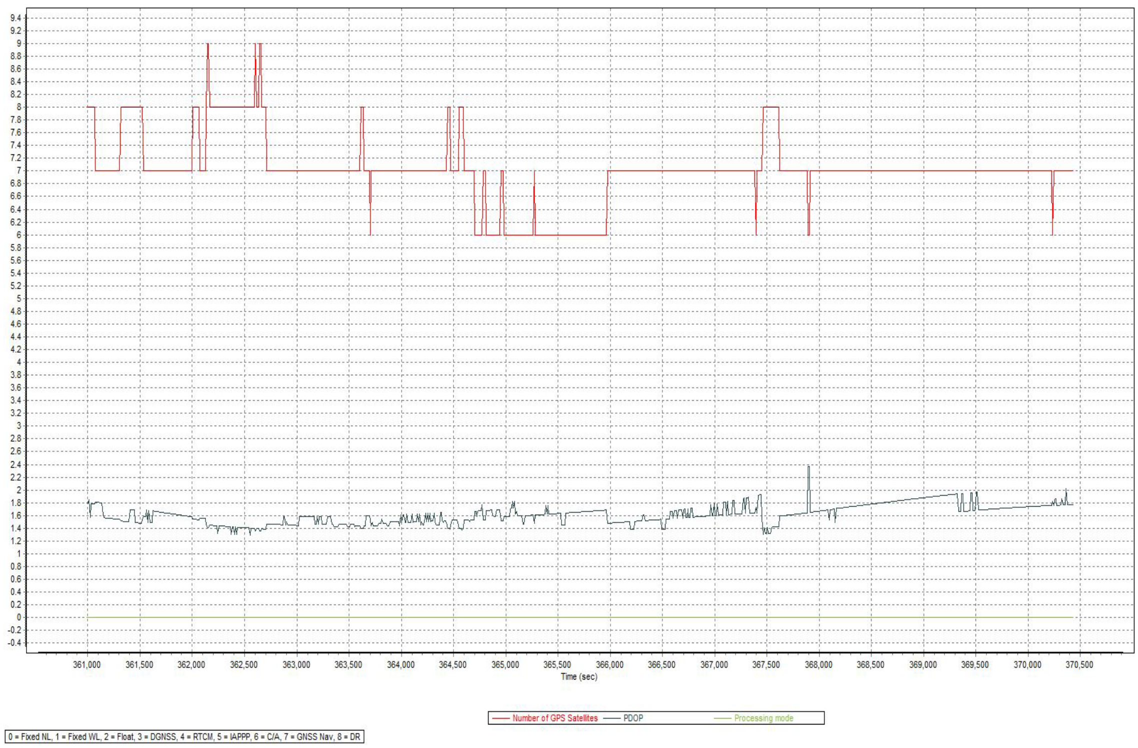


Figure A-8.9. Smoothed Performance Metric Parameters

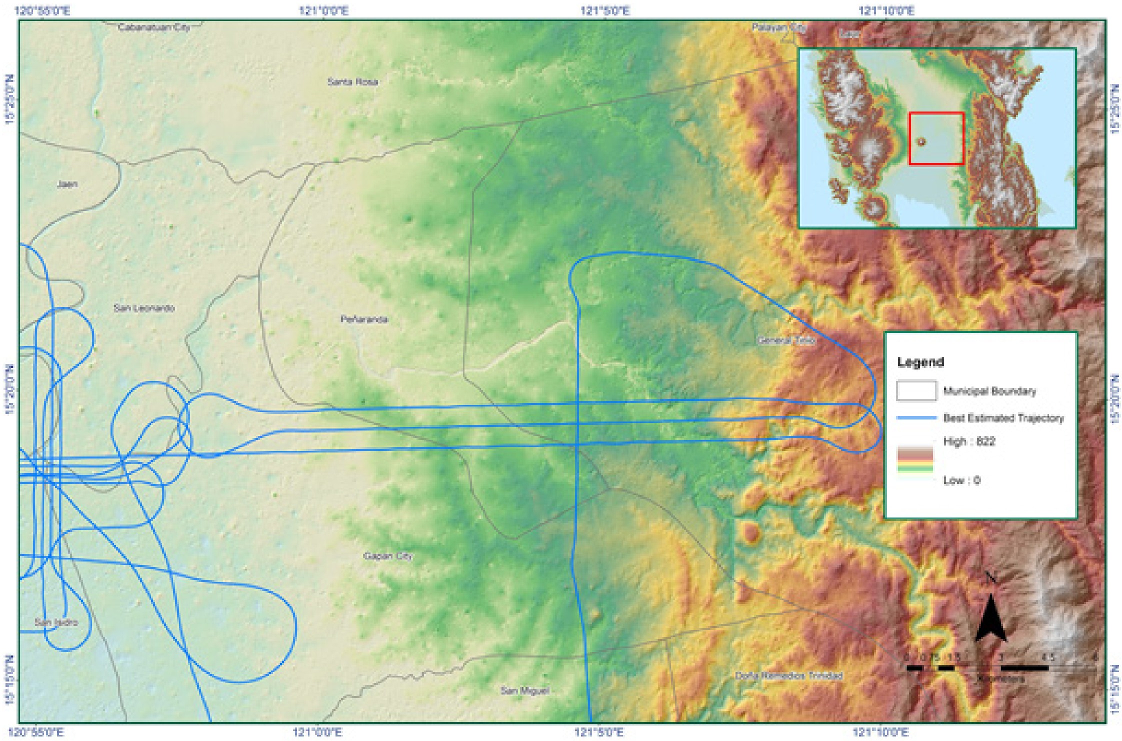


Figure A-8.10. Best Estimate Trajectory

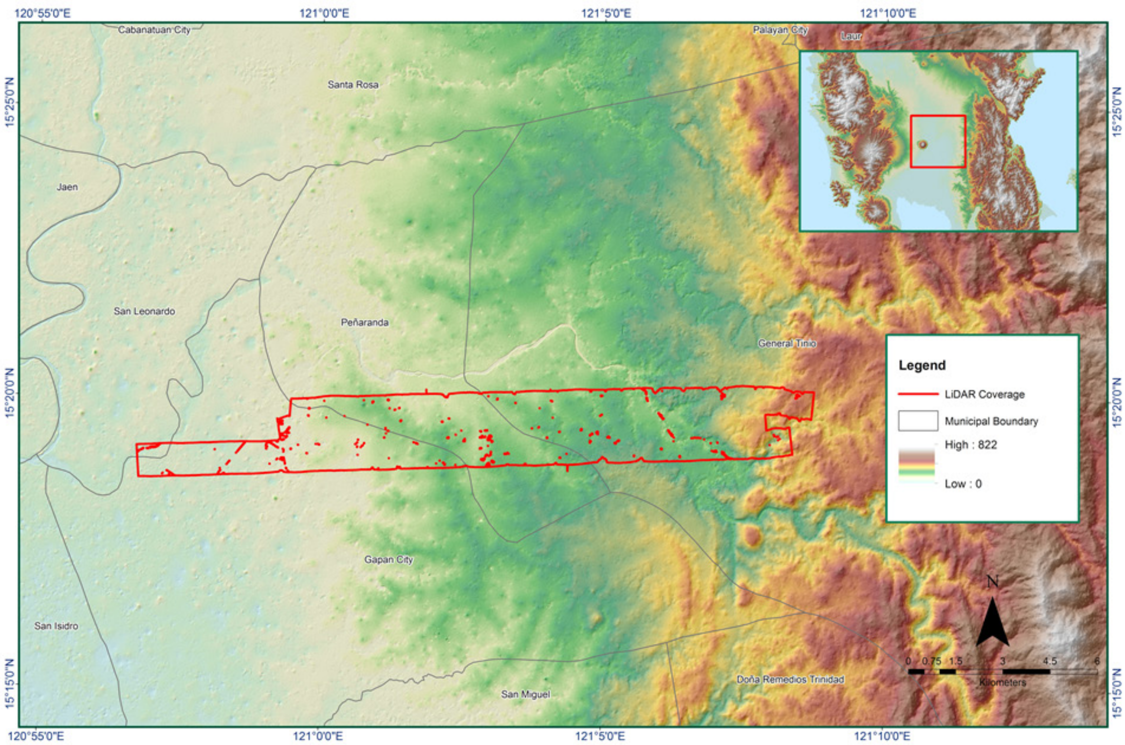


Figure A-8.11. Coverage of LiDAR data

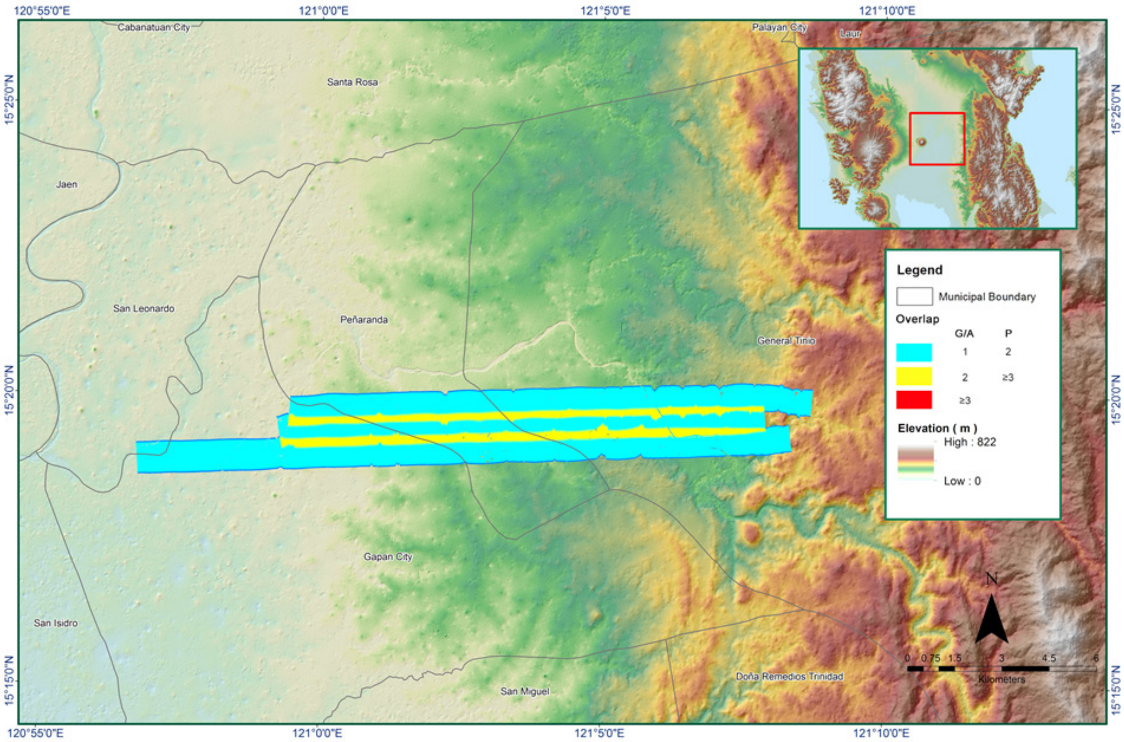


Figure A-8.12. Image of data overlap

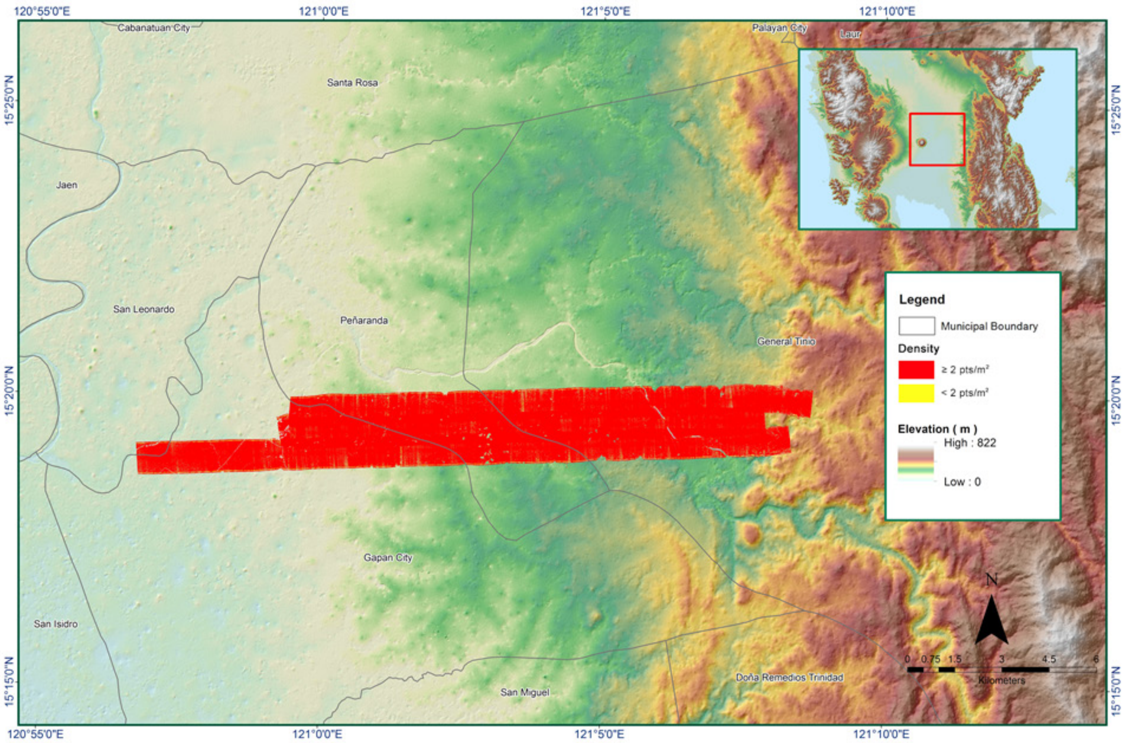
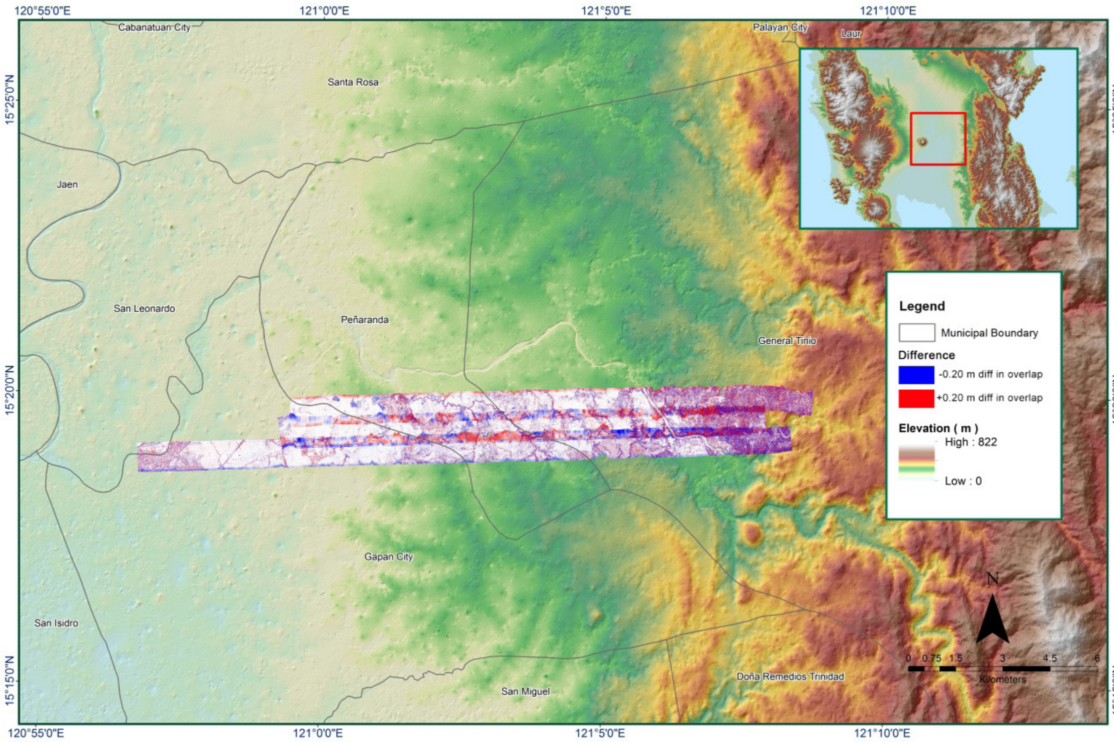


Figure A-8.13. Density Map of merged LiDAR data



FigureA-8.14. Elevation Difference Between flight lines

Table A-8.3. Mission Summary Report for Mission BlkA

Flight Area	Umiray
Mission Name	BlkA
Inclusive Flights	10212L
Range data size	8.27 GB
POS data size	121 MB
Base data size	1.23 MB
Image	30.5 GB
Transfer date	July 28, 2016
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)	6.00
RMSE for East Position (<4.0 cm)	5.55
RMSE for Down Position (<8.0 cm)	3.60
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	39.24
Ave point cloud density per sq.m. (>2.0)	4.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	175
Maximum Height	698.75 m
Minimum Height	20.13 m
Classification (# of points)	
Ground	20,471,624
Low vegetation	11,296,669
Medium vegetation	56,551,922
High vegetation	567,080,856
Building	44,391,241
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Engr. Gladys Mae Apat

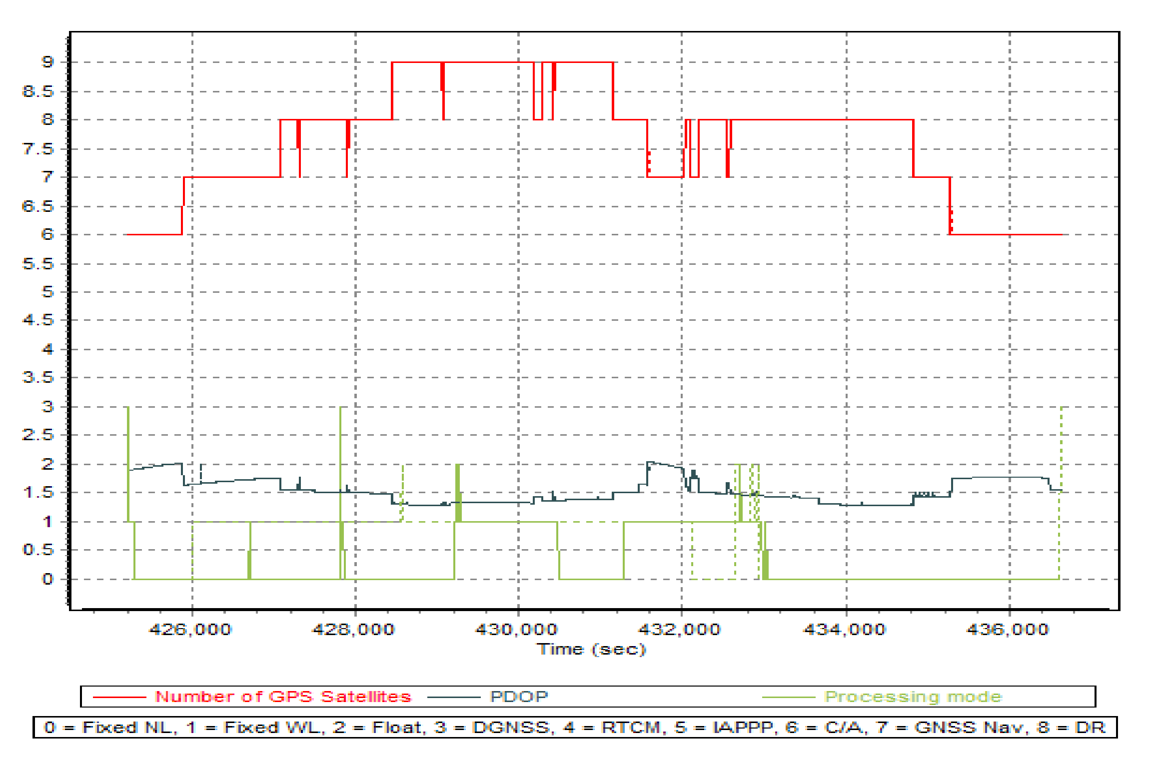


Figure A-8.15. Solution Status

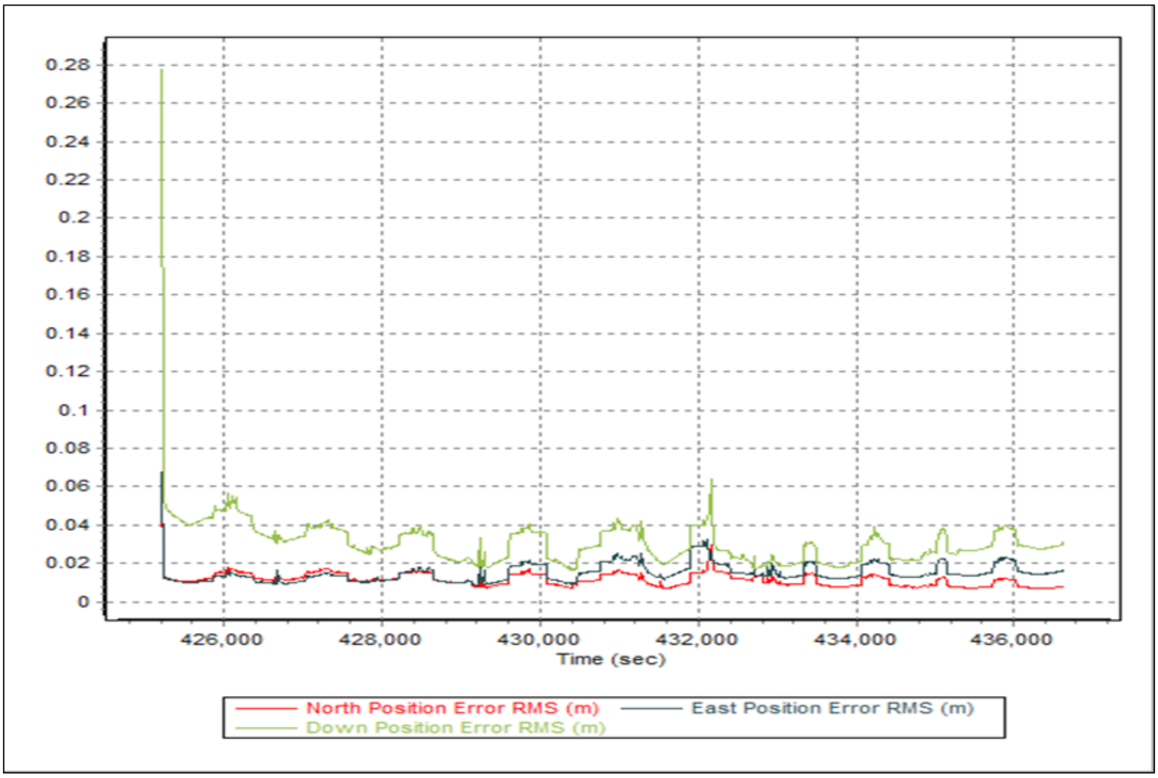


Figure A-8.16. Smoothed Performance Metric Parameters

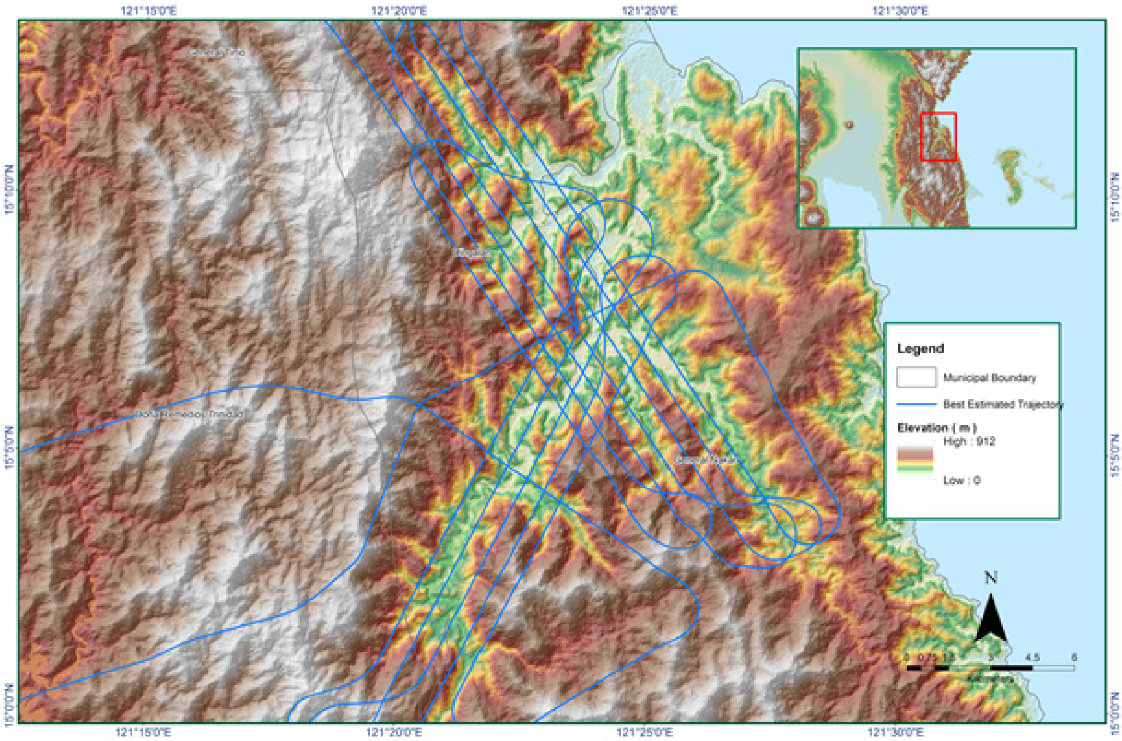


Figure A-8.17. Best Estimate Trajectory

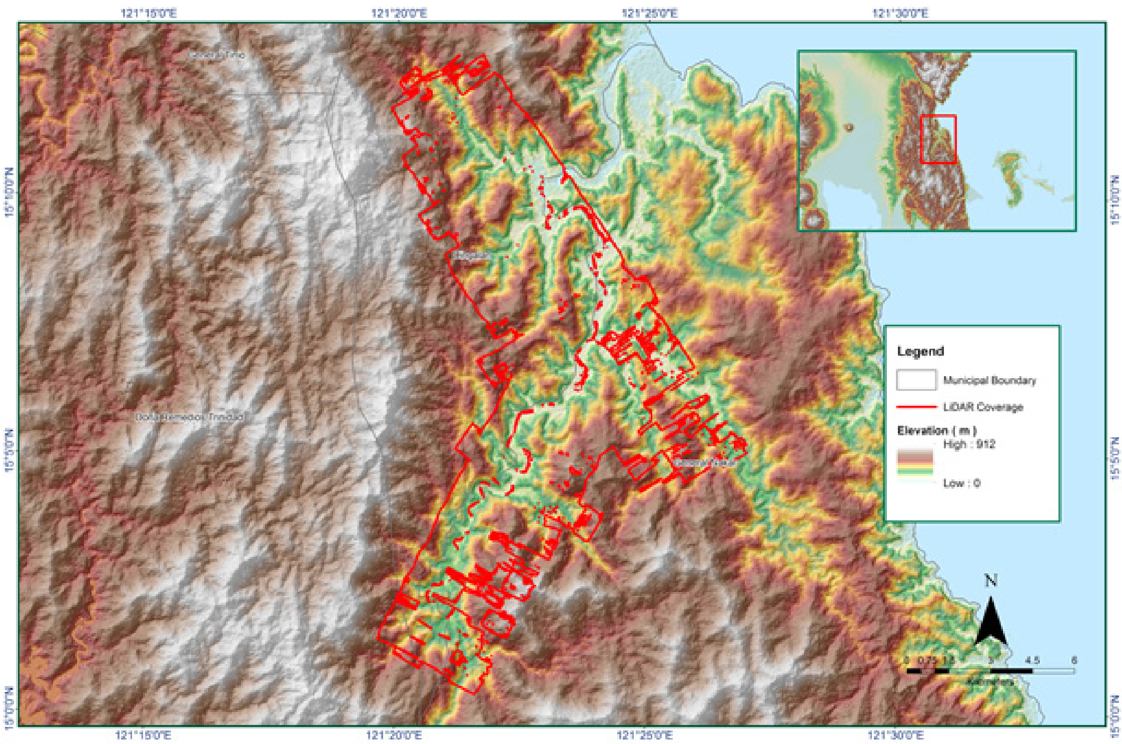


Figure A-8.18. Coverage of LiDAR data

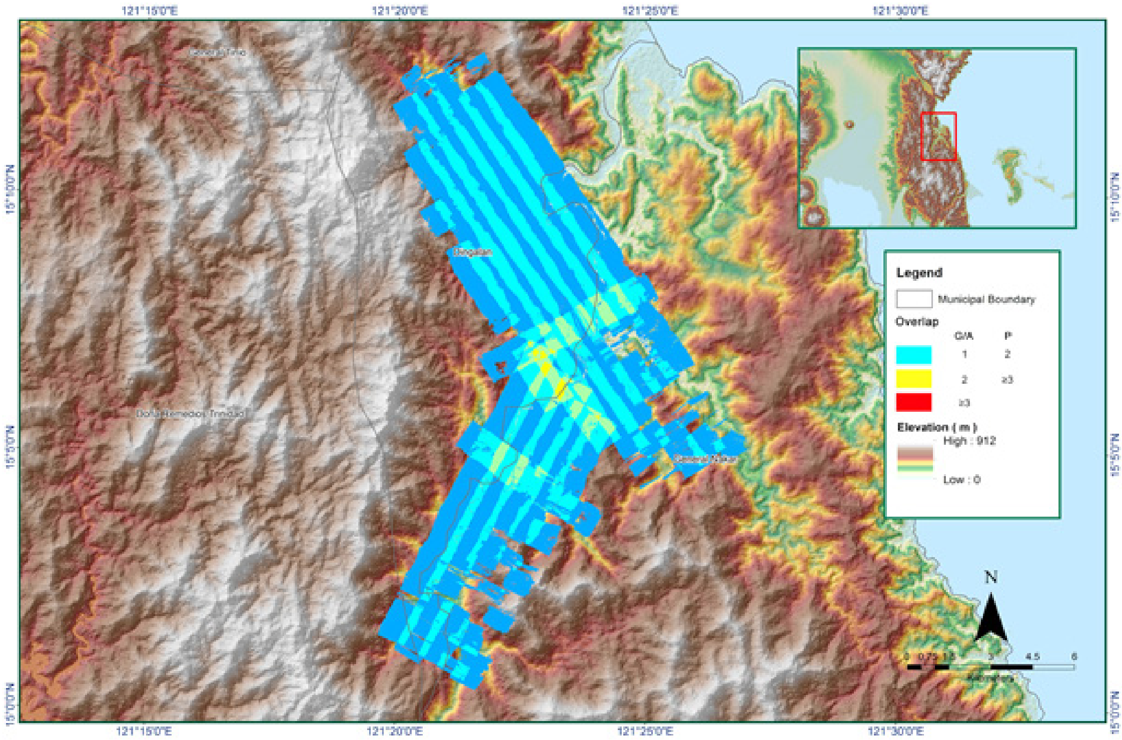


Figure A-8.19. Image of data overlap

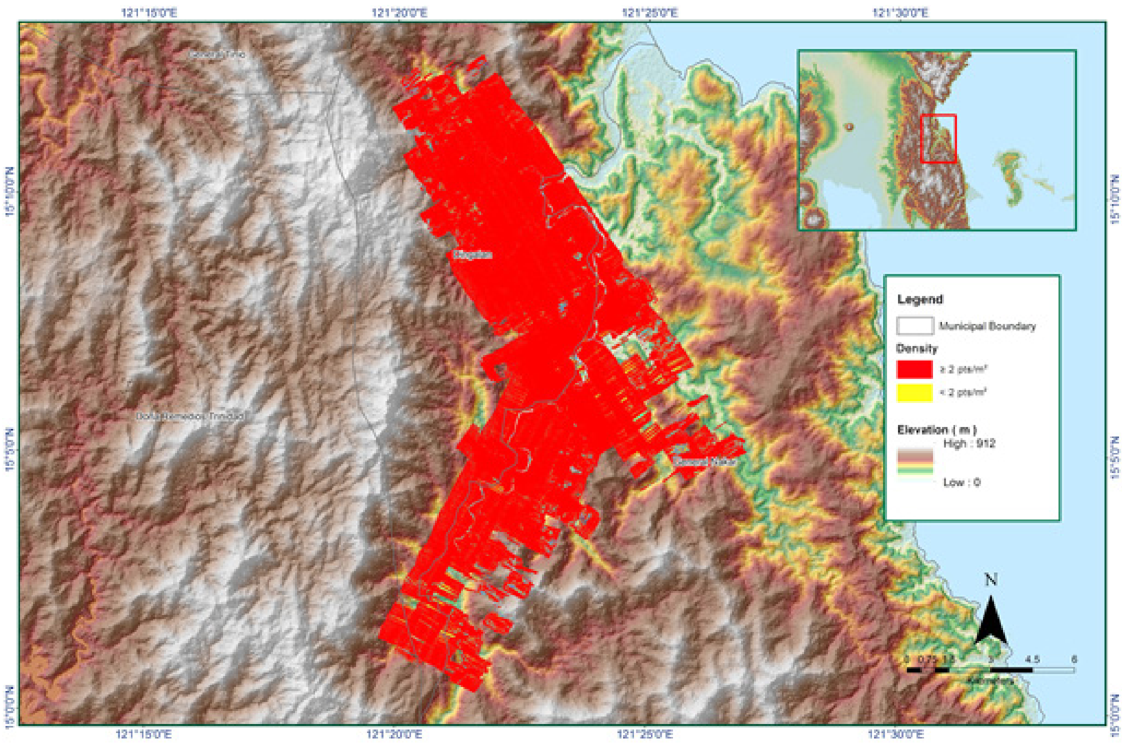


Figure A-8.20. Density Map of merged LiDAR data

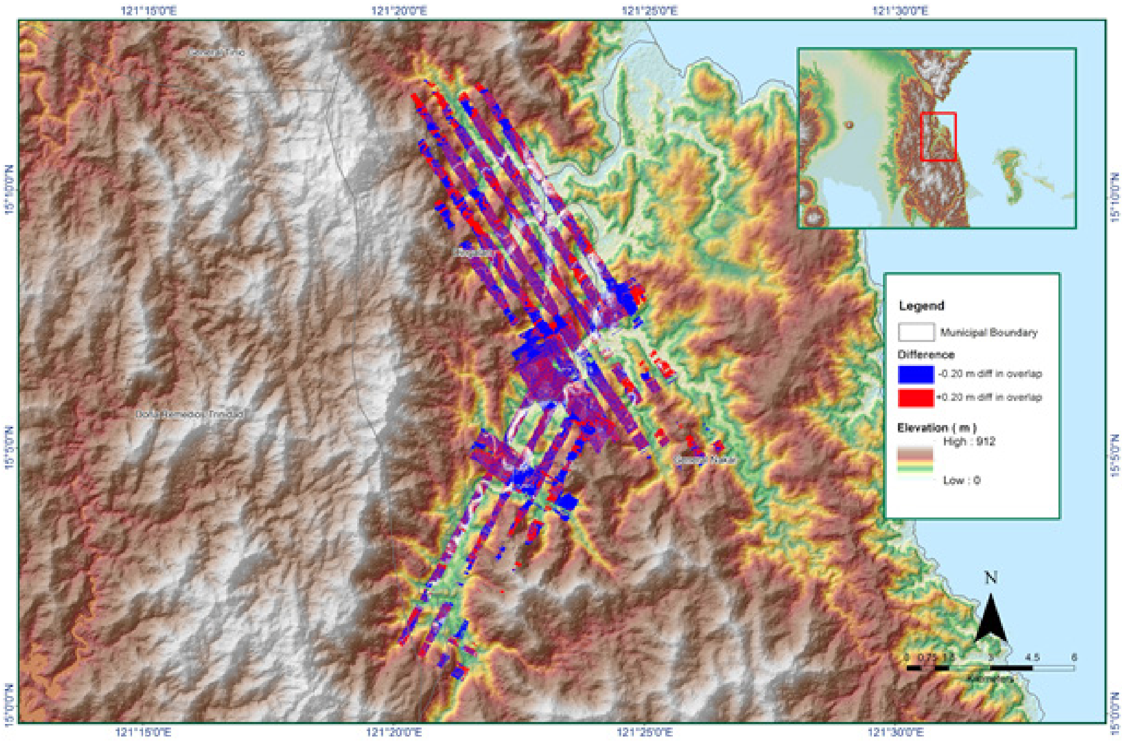


Figure A-8.21. Elevation Difference Between flight lines

Table A-8.4. Mission Summary Report for Mission BlkB

Flight Area	Umiray
Mission Name	BlkB
Inclusive Flights	10210L
Range data size	4.5 GB
POS data size	102 MB
Base data size	1.29 MB
Image	NA
Transfer date	July 27, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	2.50
RMSE for North Position (<4.0 cm)	3.10
RMSE for East Position (<4.0 cm)	3.00
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	23.32
Ave point cloud density per sq.m. (>2.0)	4.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	118
Maximum Height	775.87 m
Minimum Height	53.01 m
Classification (# of points)	
Ground	12,168,883
Low vegetation	2,354,273
Medium vegetation	22,710,957
High vegetation	317,797,524
Building	14,315,386
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Chelou Prado, Engr. Gladys Mae Apat

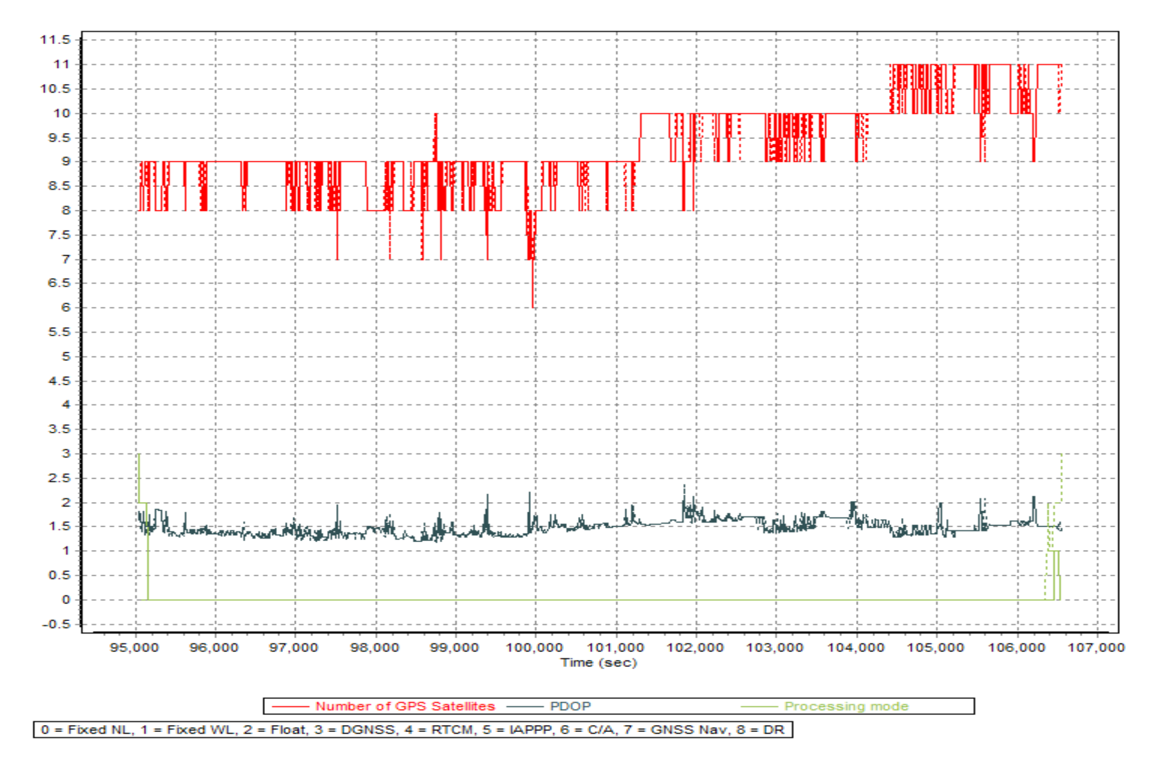


Figure A-8.22. Solution Status

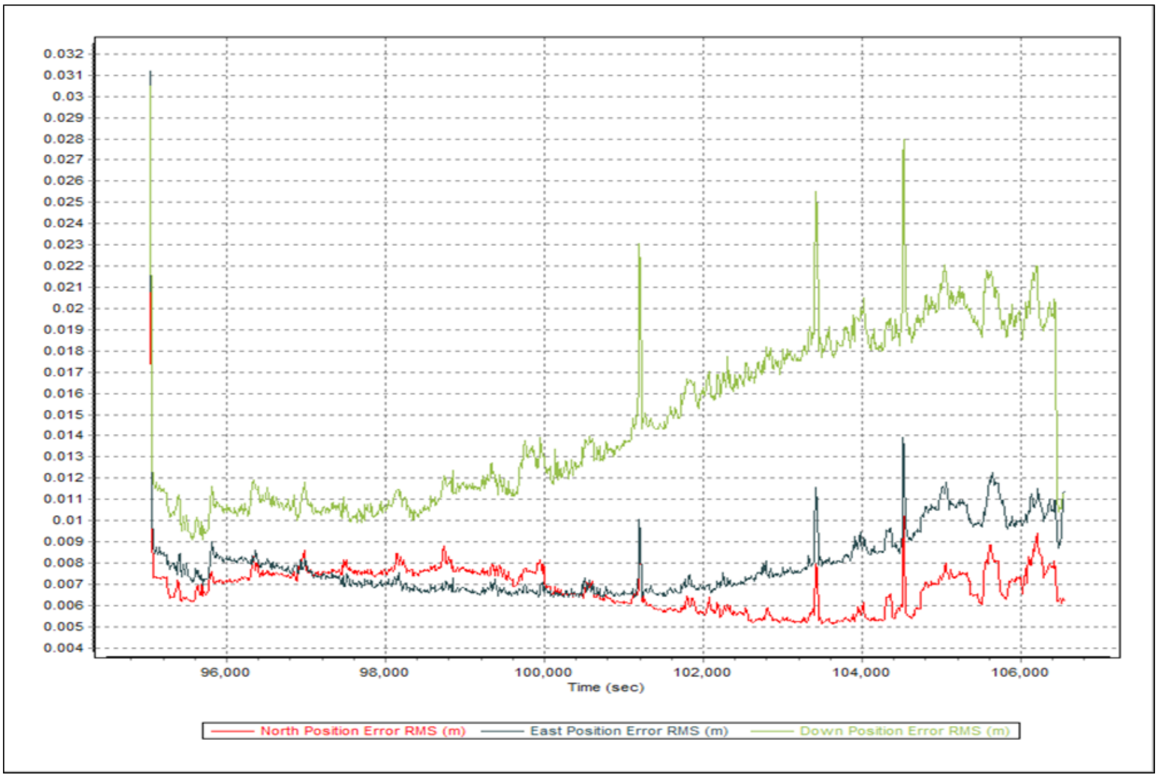


Figure A-8.23. Smoothed Performance Metric Parameters

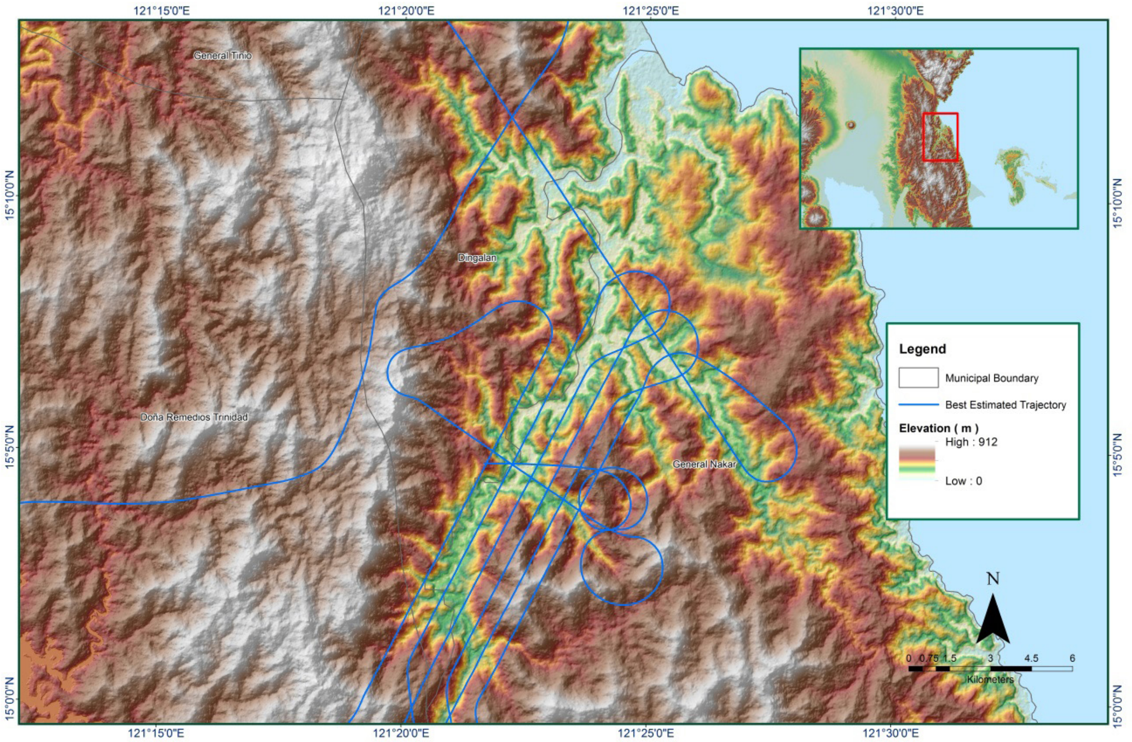


Figure A-8.24. Best Estimate Trajectory

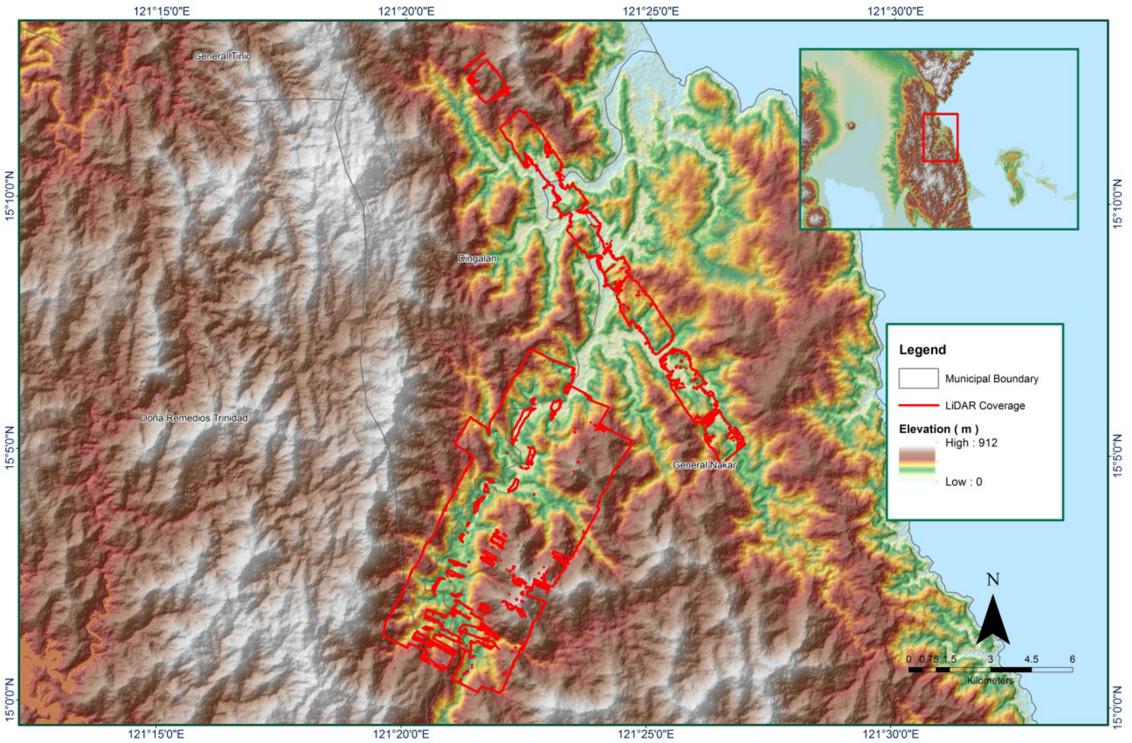


Figure A-8.25. Coverage of LiDAR data

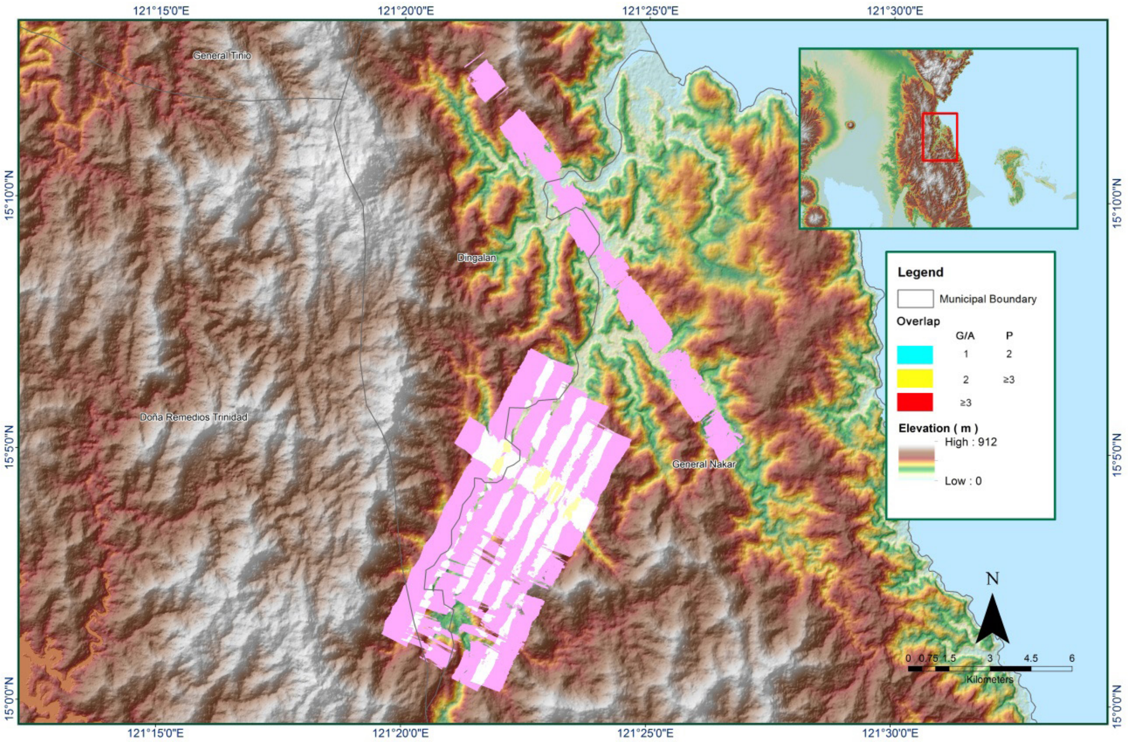


Figure A-8.26. Image of data overlap

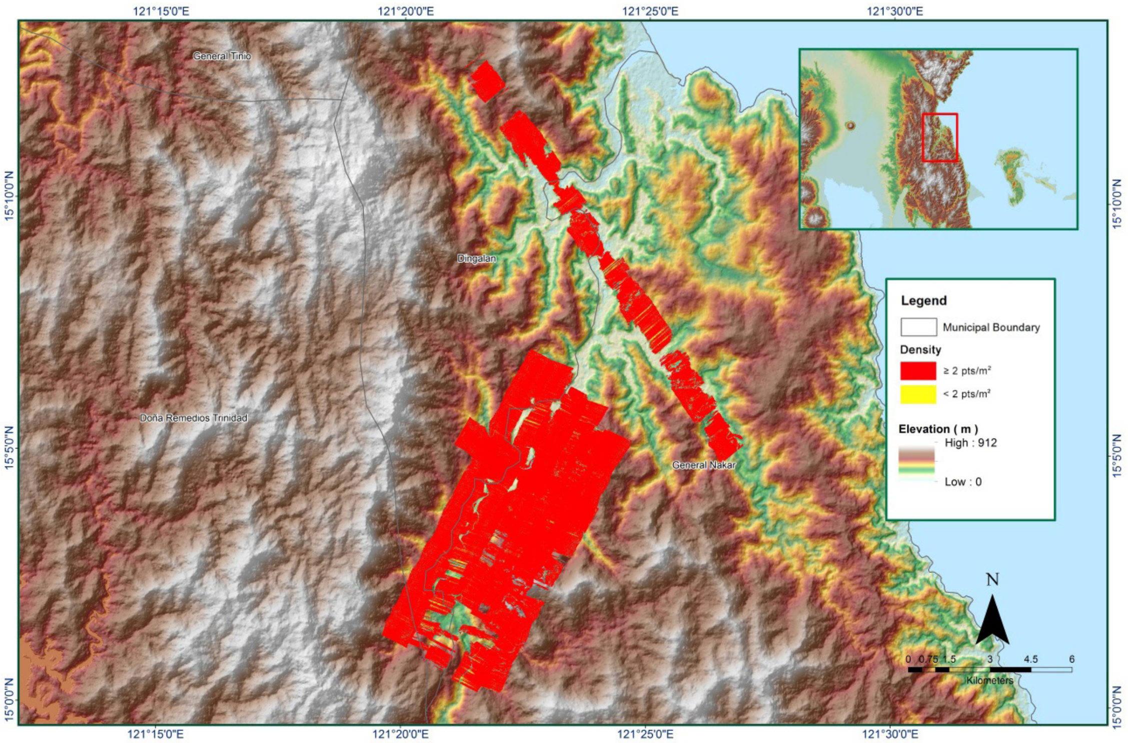


Figure A-8.27. Density Map of merged LiDAR data

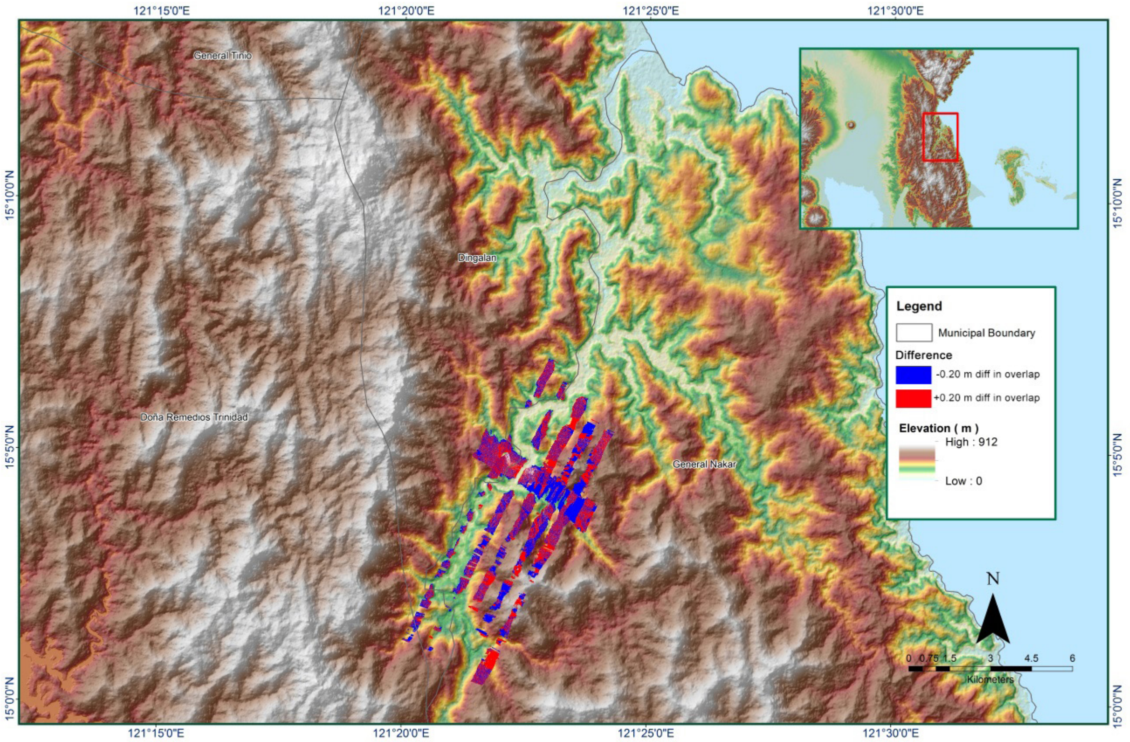


Figure A-8.28. Elevation Difference Between flight lines

Table A-8.5. Mission Summary Report for Mission Pam3J_additional

Flight Area	Clark Reflights
Mission Name	Pam3J_additional
Inclusive Flights	2298A
Range data size	8.18 GB
POS data size	216 MB
Base data size	19.3 MB
Image	n/a
Transfer date	December 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.428
RMSE for East Position (<4.0 cm)	2.315
RMSE for Down Position (<8.0 cm)	4.577
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	36.23
Ave point cloud density per sq.m. (>2.0)	3.11
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	161.27 m
Minimum Height	88.62 m
Classification (# of points)	
Ground	22,413,762
Low vegetation	27,510,930
Medium vegetation	8,927,950
High vegetation	2,569,451
Building	1,130,400
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Chelou Prado, Jovy Narisma

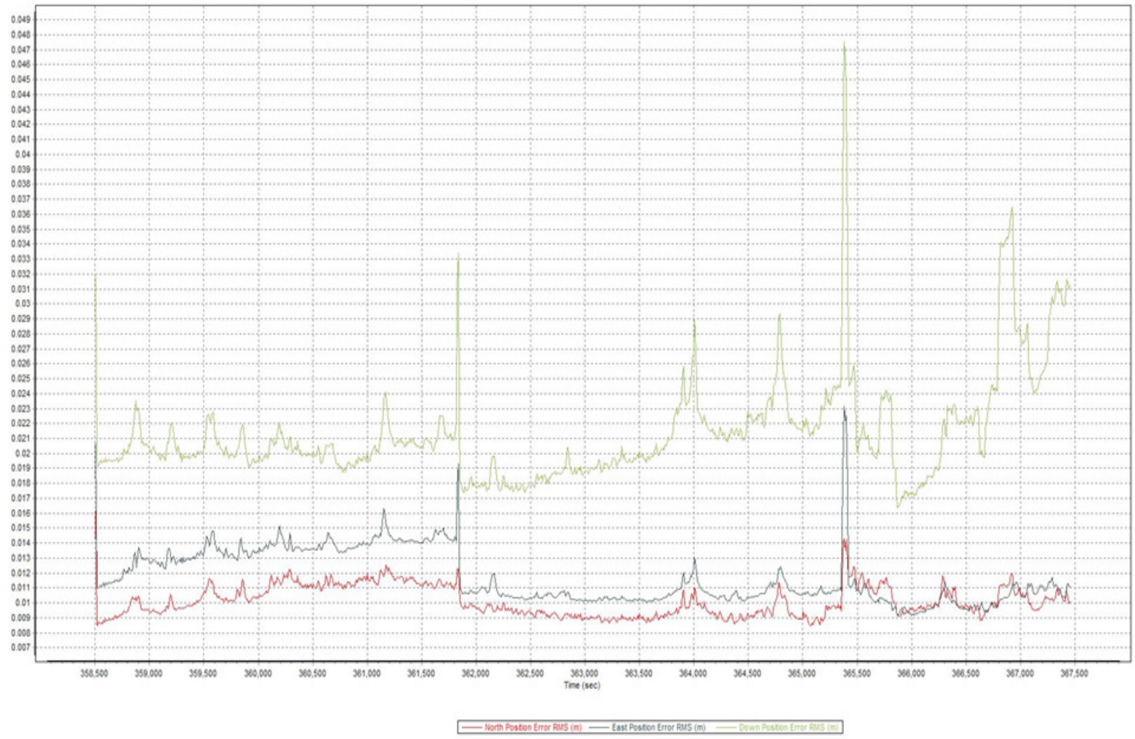


Figure A-8.29. Solution Status

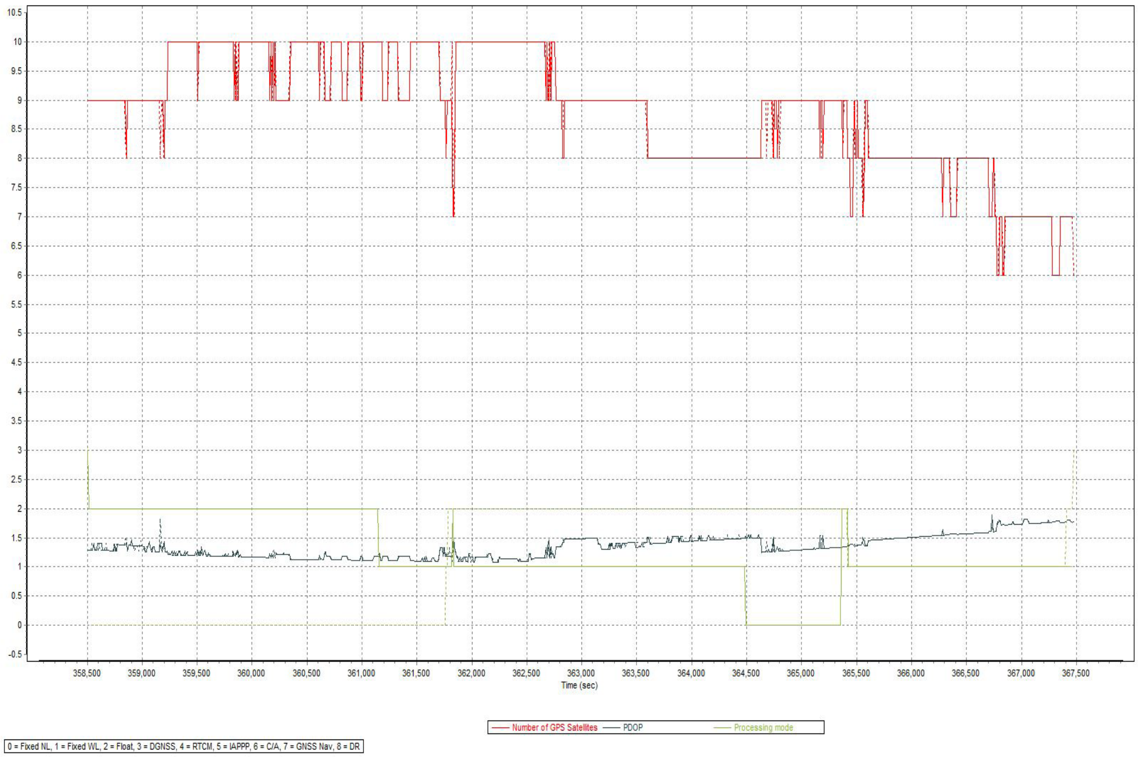


Figure A-8.30. Smoothed Performance Metric Parameters

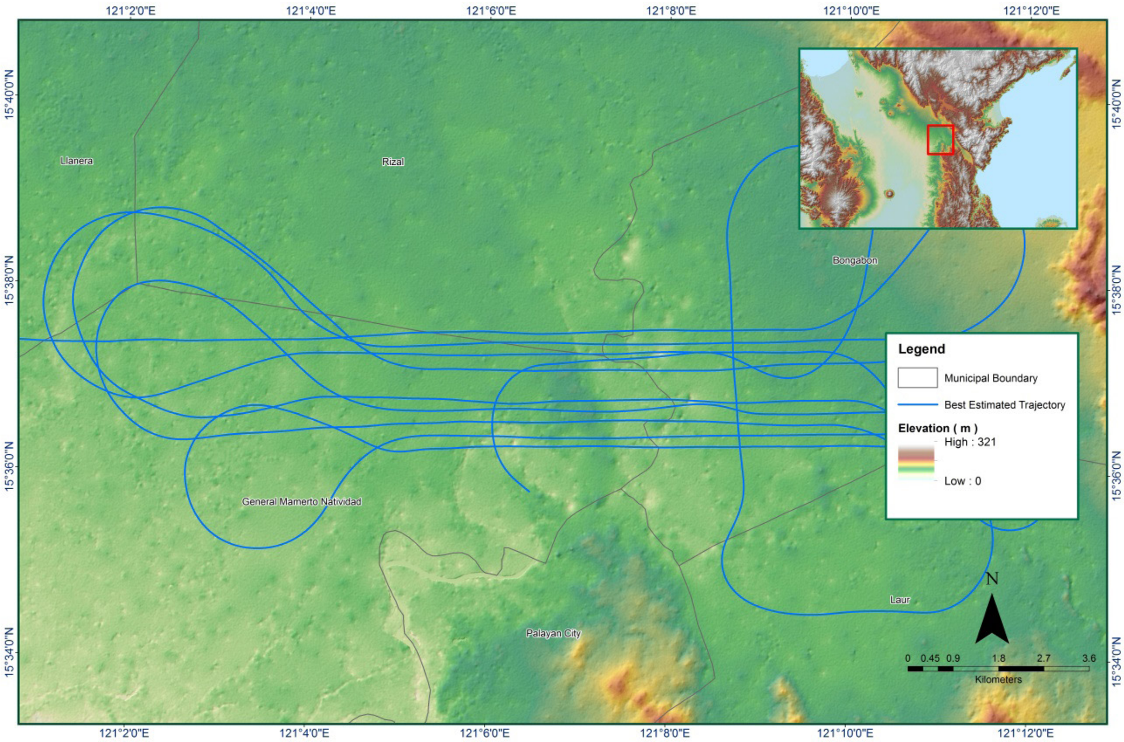


Figure A-8.31. Best Estimate Trajectory

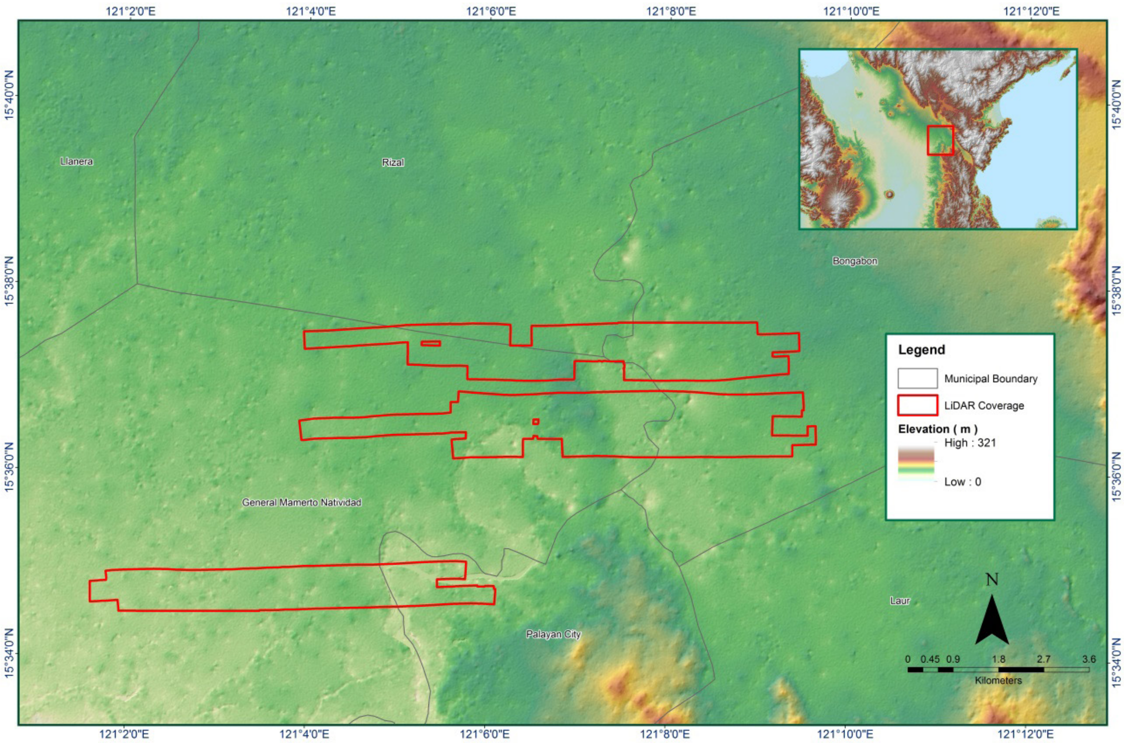


Figure A-8.32. Coverage of LiDAR data

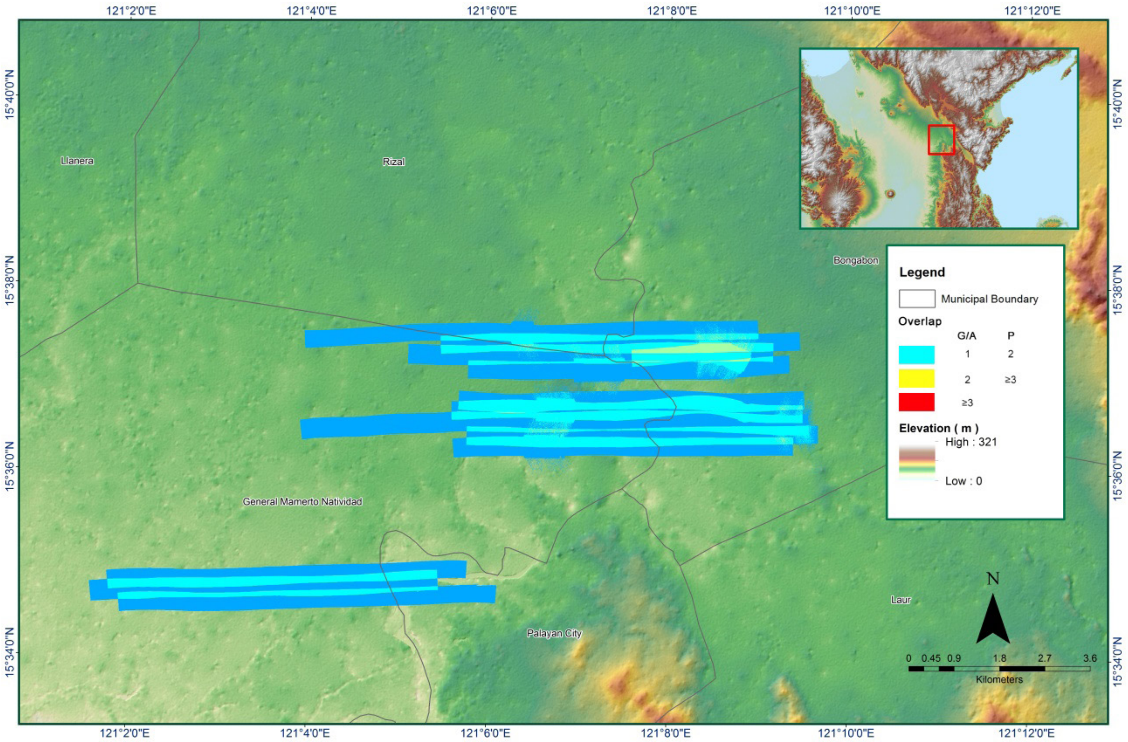


Figure A-8.33. Image of data overlap

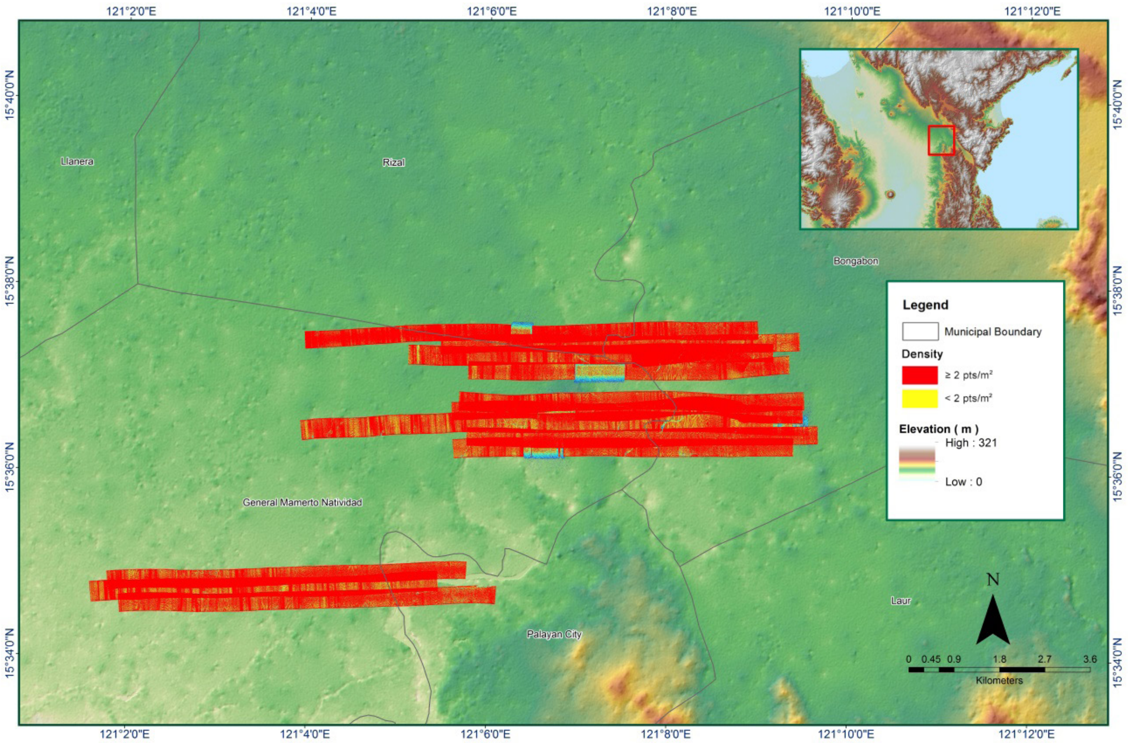


Figure A-8.34. Density Map of merged LiDAR data

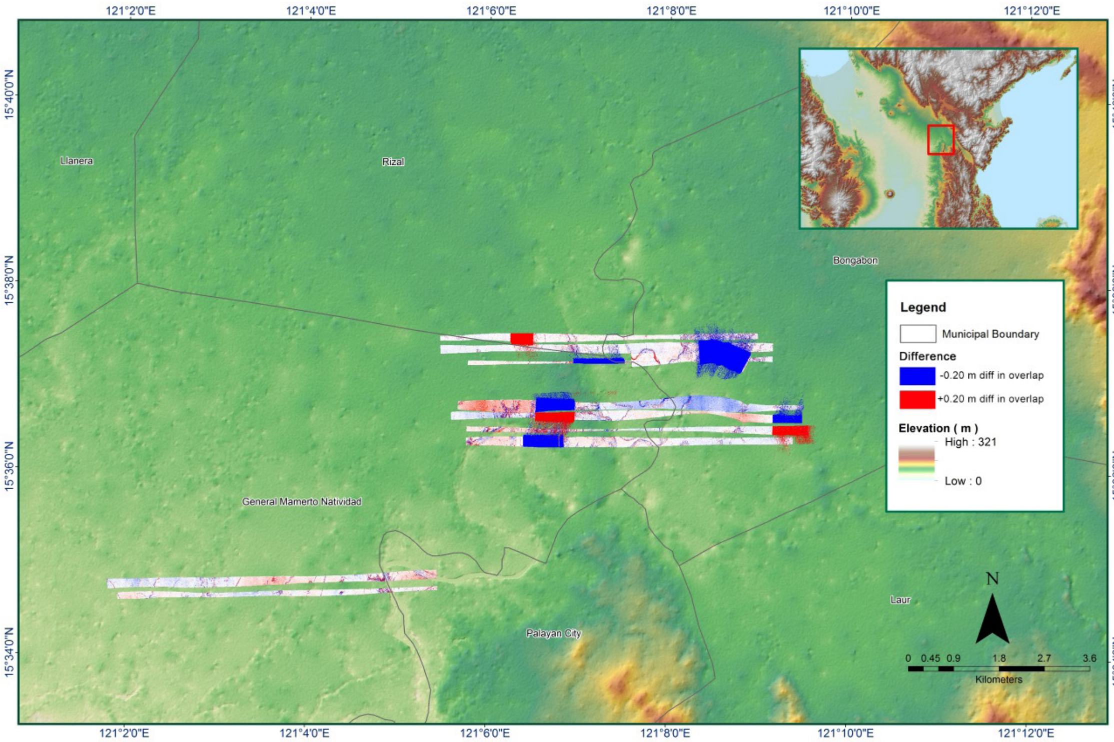


Figure A-8.35. Elevation Difference Between flight lines

Table A-8.6. Mission Summary Report for Mission Pam3D_additional2

Flight Area	Clark Reflights
Mission Name	Pam3D_additional2
Inclusive Flights	2278A
Range data size	8.18 GB
POS data size	238 MB
Base data size	26.5 MB
Image	n./a
Transfer date	December 6, 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)	1.08
RMSE for East Position (<4.0 cm)	1.42
RMSE for Down Position (<8.0 cm)	2.94
Boresight correction stdev (<0.001deg)	0.000223
IMU attitude correction stdev (<0.001deg)	0.000328
GPS position stdev (<0.01m)	0.0061
Minimum % overlap (>25)	70.38
Ave point cloud density per sq.m. (>2.0)	3.1
Elevation difference between strips (<0.20 m)	No
Number of 1km x 1km blocks	38
Maximum Height	114.75 m
Minimum Height	52.83 m
Classification (# of points)	
Ground	11,720,858
Low vegetation	17,395,354
Medium vegetation	12,269,532
High vegetation	3,883,846
Building	1,854,437
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

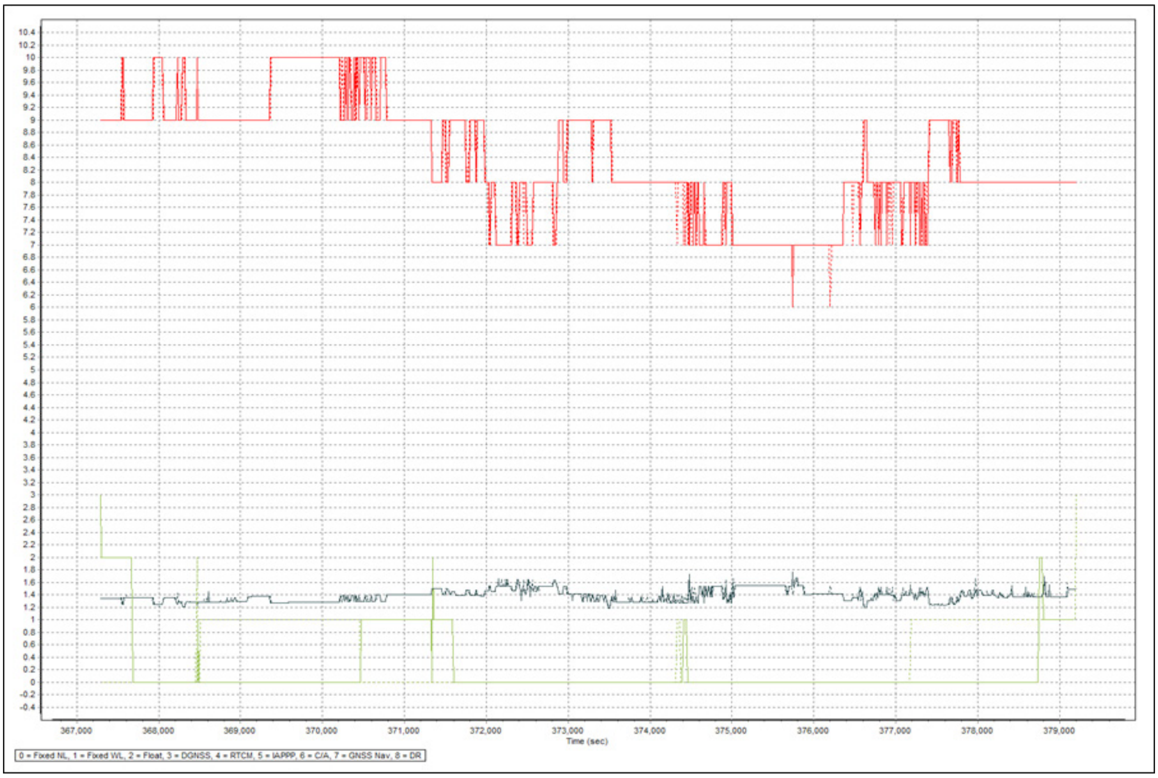


Figure A-8.36. Solution Status

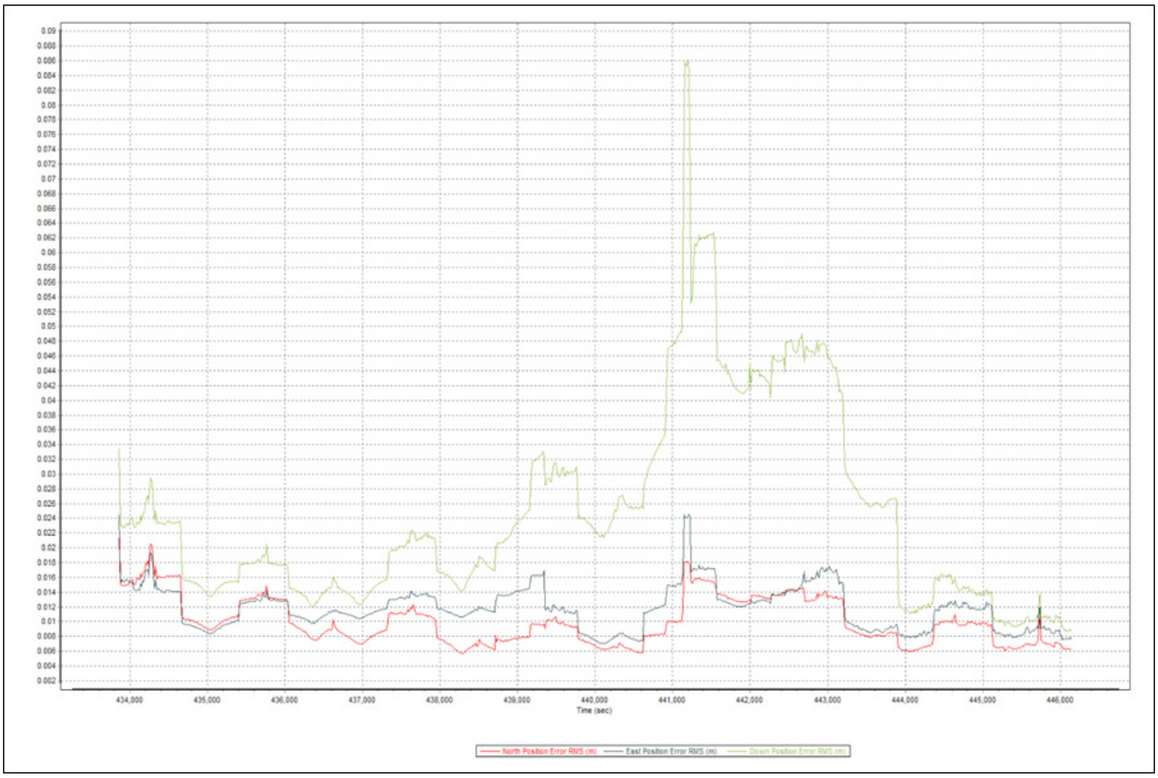


Figure A-8.37. Smoothed Performance Metric Parameters

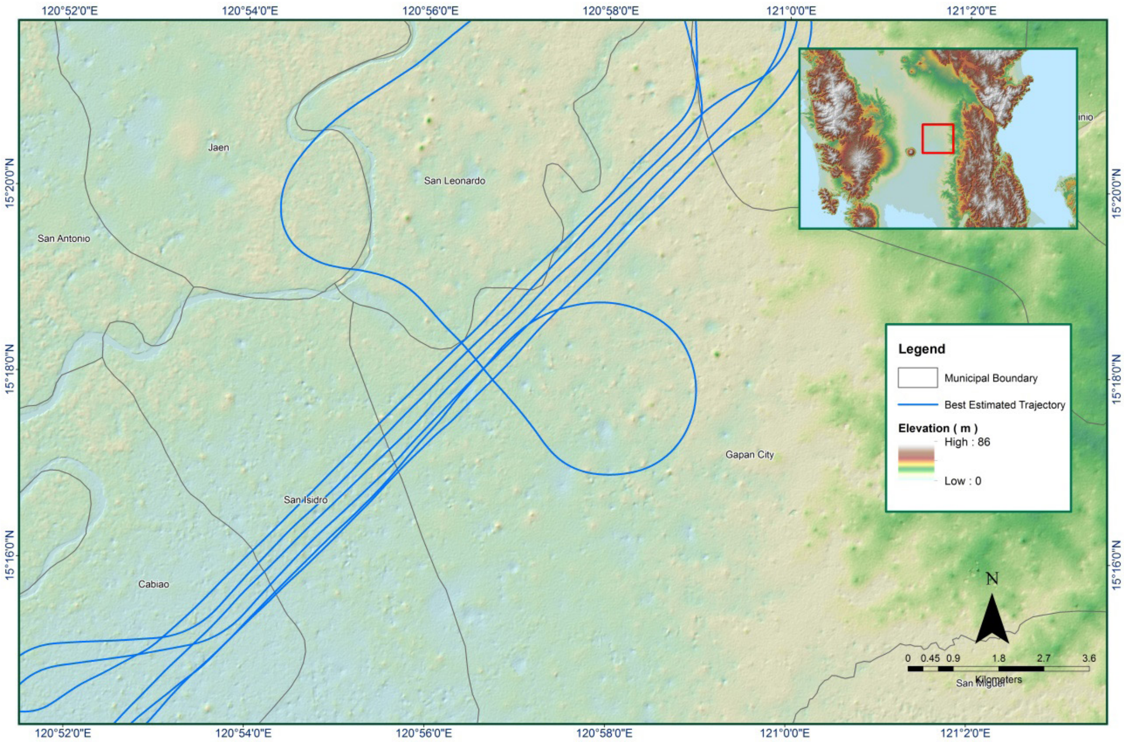


Figure A-8.38. Best Estimate Trajectory

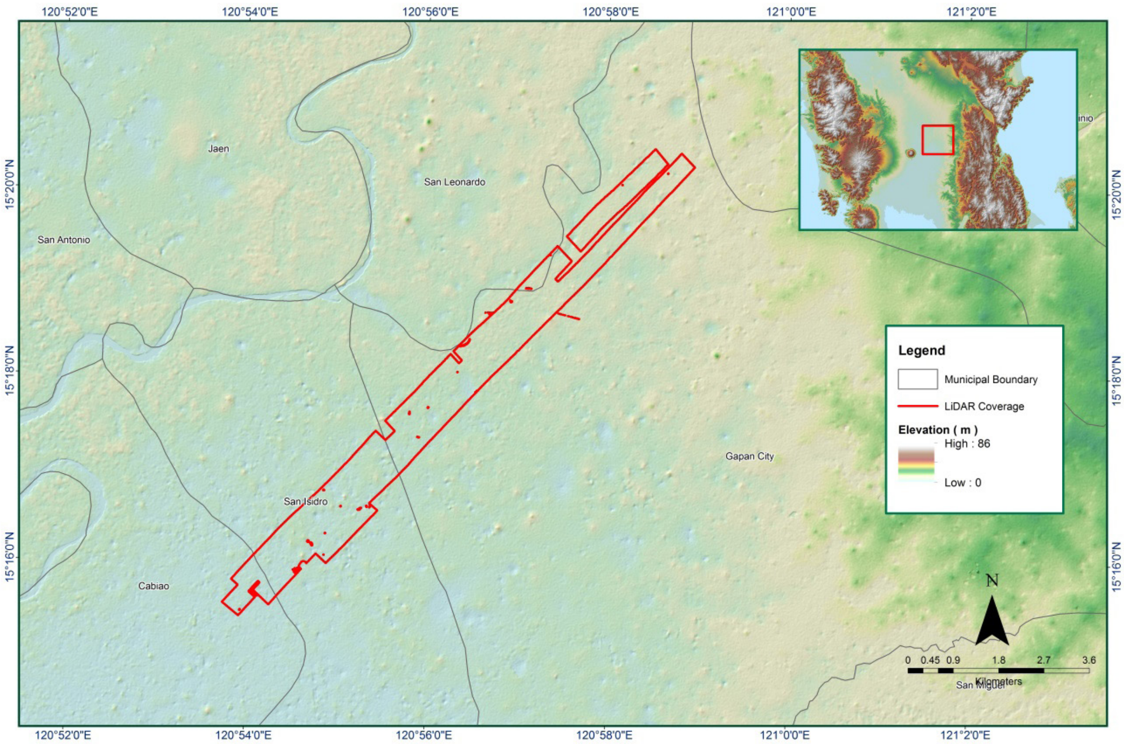


Figure A-8.39. Coverage of LiDAR data

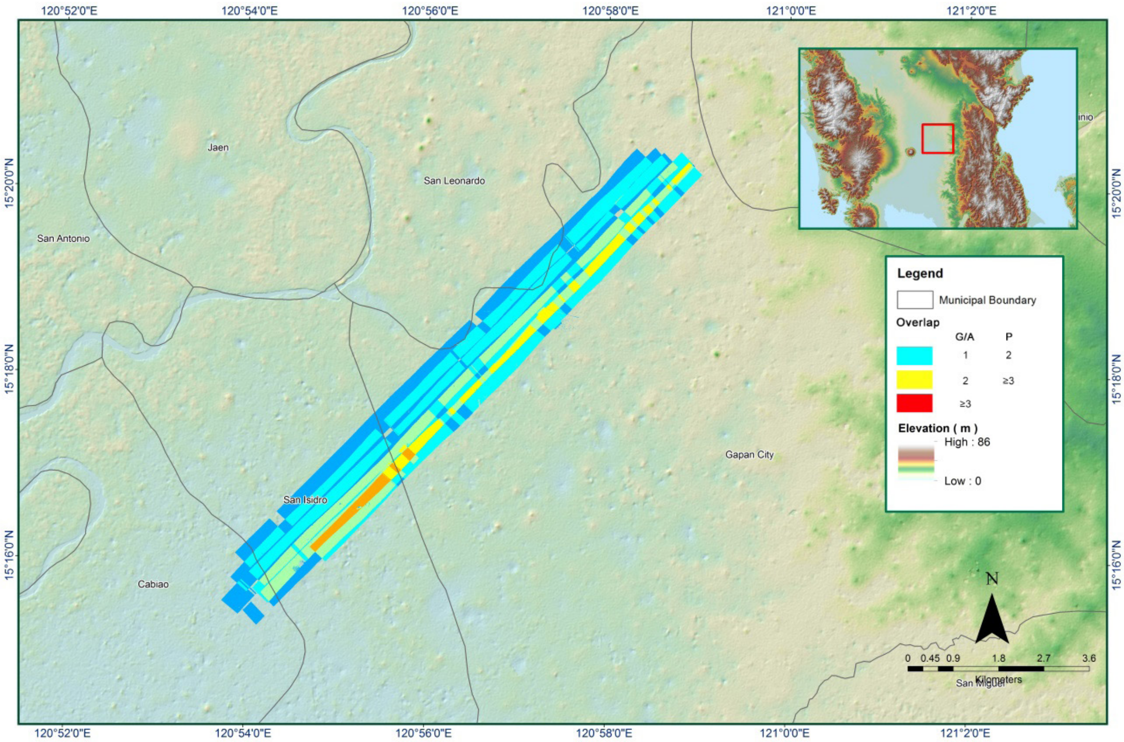


Figure A-8.40. Image of data overlap

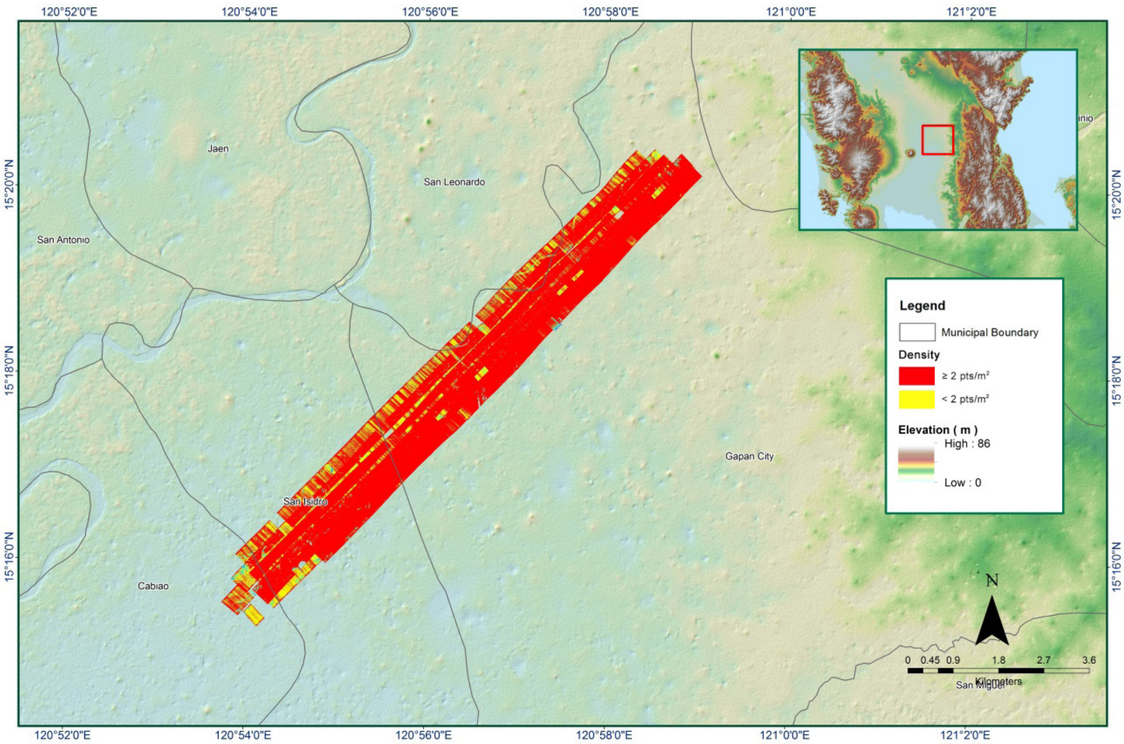


Figure A-8.41. Density Map of merged LiDAR data

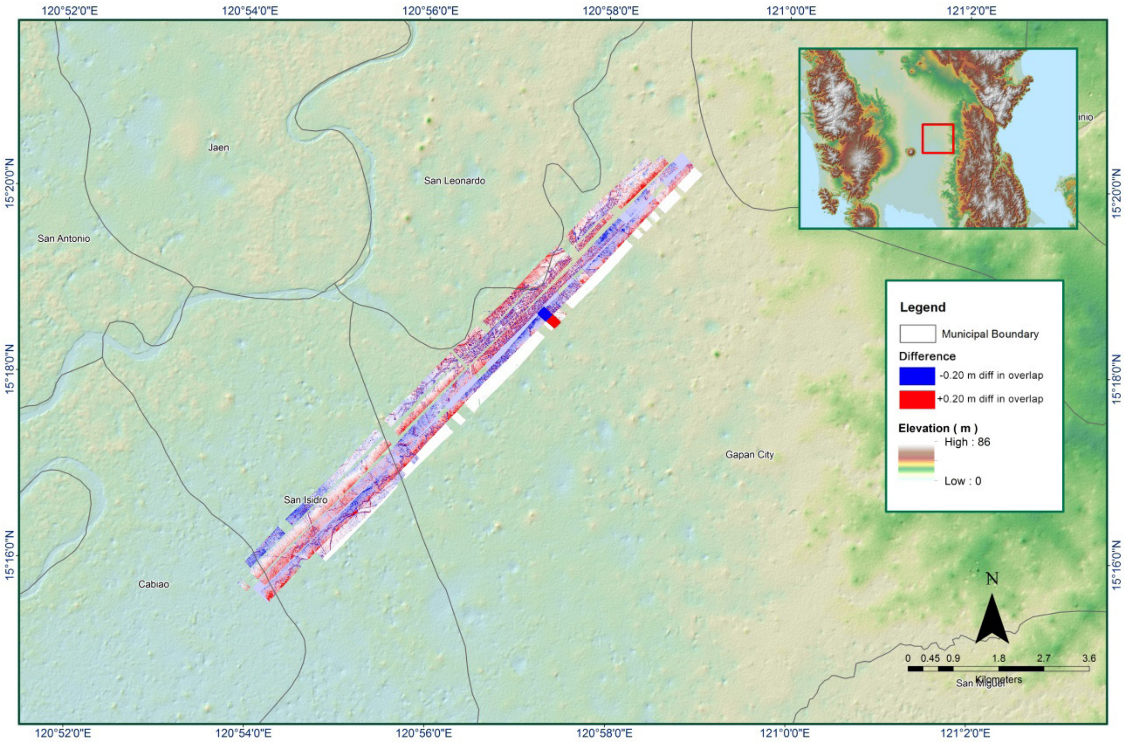


Figure A-8.42. Elevation Difference Between flight lines

Table A-8.7. Mission Summary Report for Mission Pam3D_additional1

Flight Area	**Clark Reflights**
Mission Name	**Pam3D_additional1**
Inclusive Flights	2274A
Range data size	3.8 GB
POS data size	163 MB
Base data size	17.2 MB
Image	n/a
Transfer date	December 5, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.55
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.000869
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	22.86
Ave point cloud density per sq.m. (>2.0)	2.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	121.45
Minimum Height	53.81
Classification (# of points)	
Ground	14,860,147
Low vegetation	15,895,852
Medium vegetation	6,250,228
High vegetation	1,347,962
Building	1,010,155
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Gladys Mae Apat

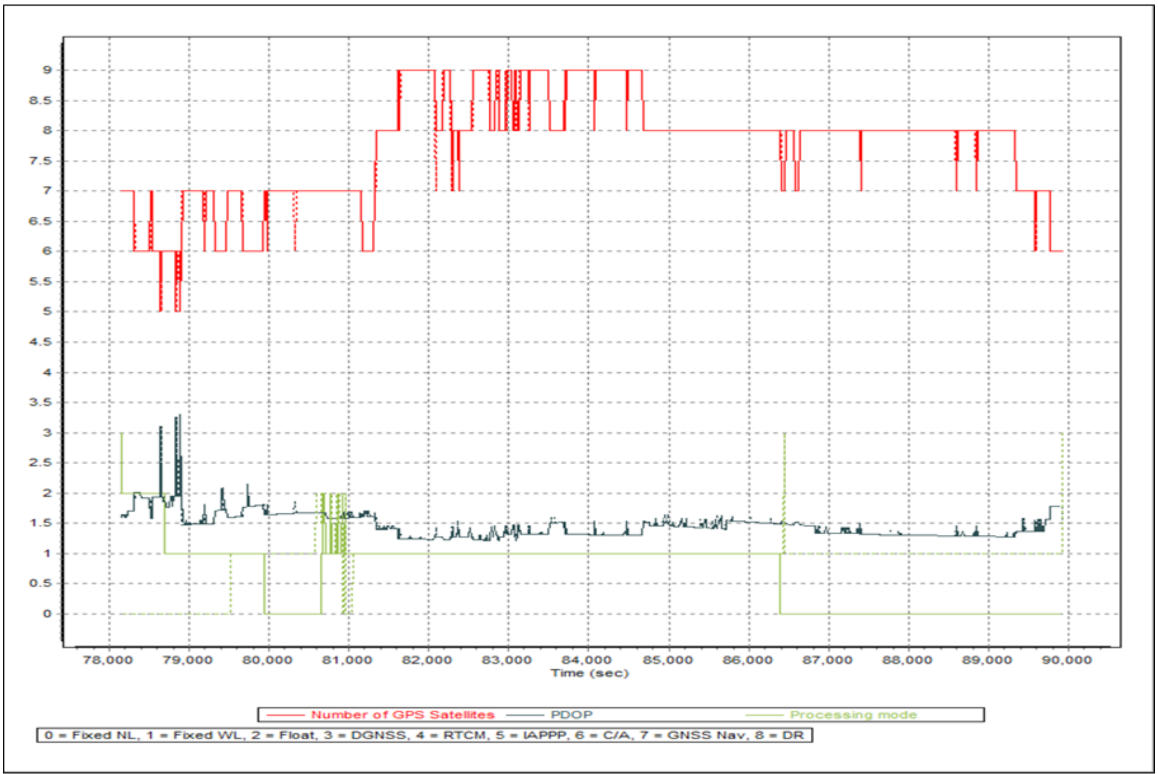


Figure A-8.43. Solution Status

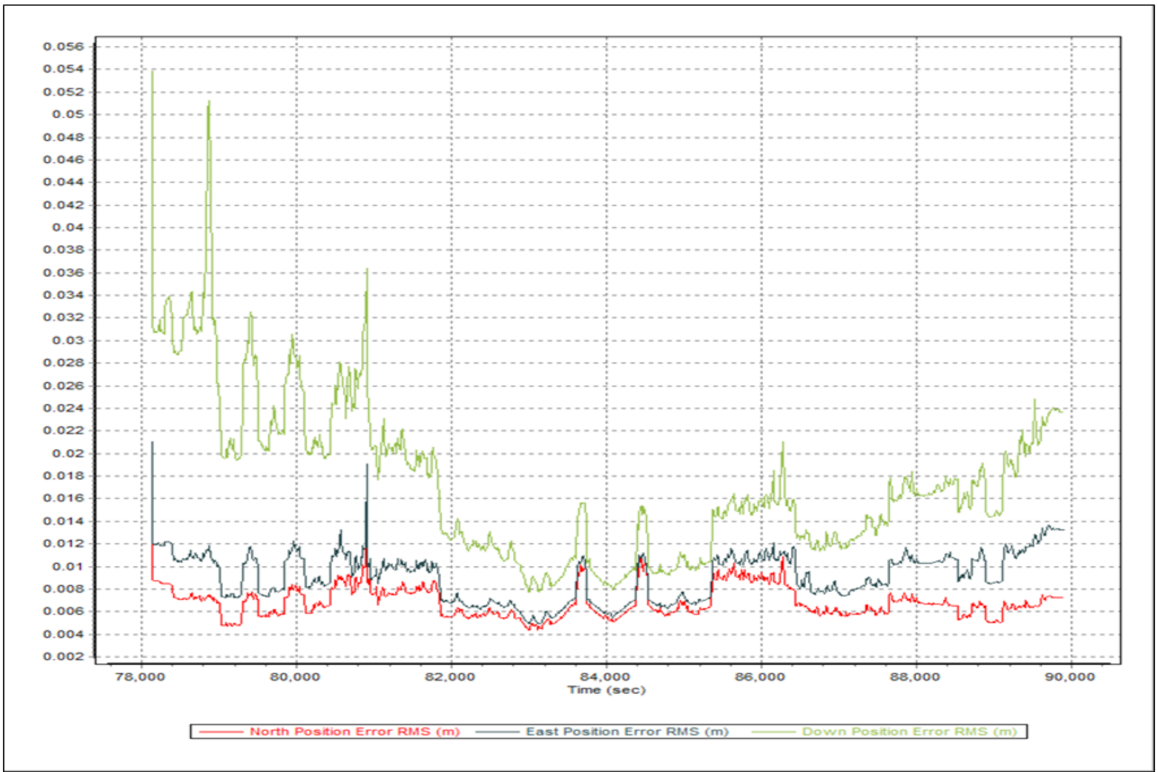


Figure A-8.44. Smoothed Performance Metric Parameters

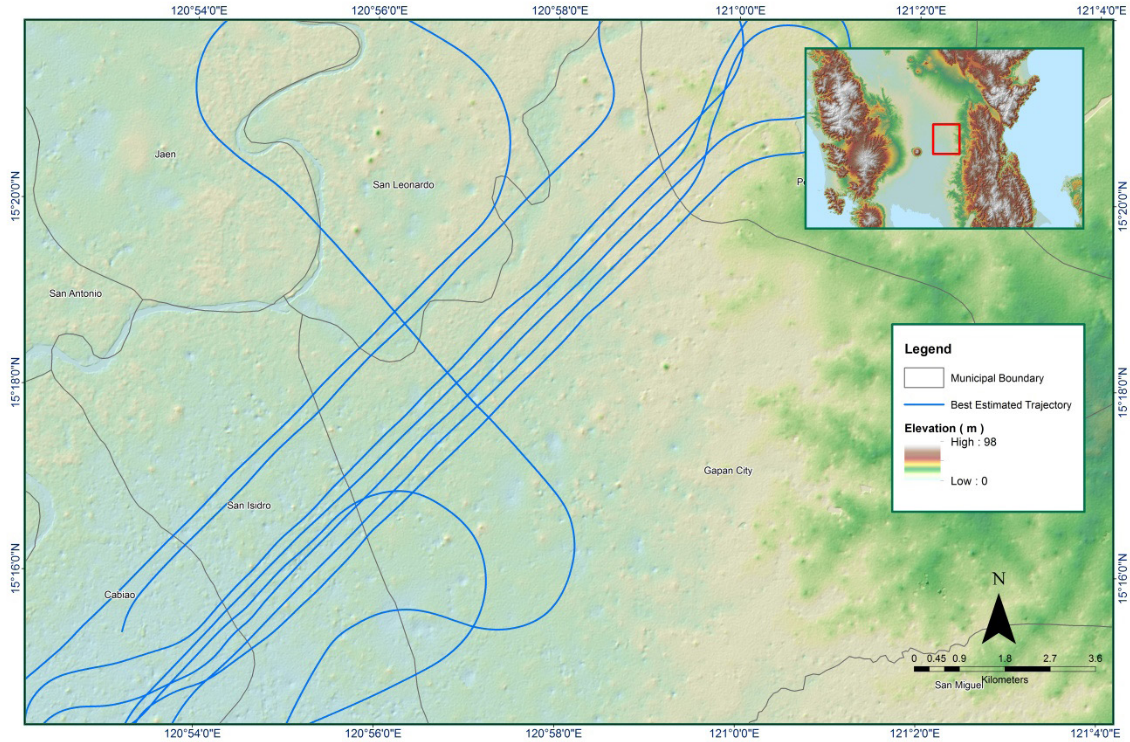


Figure A-8.45. Best Estimate Trajectory

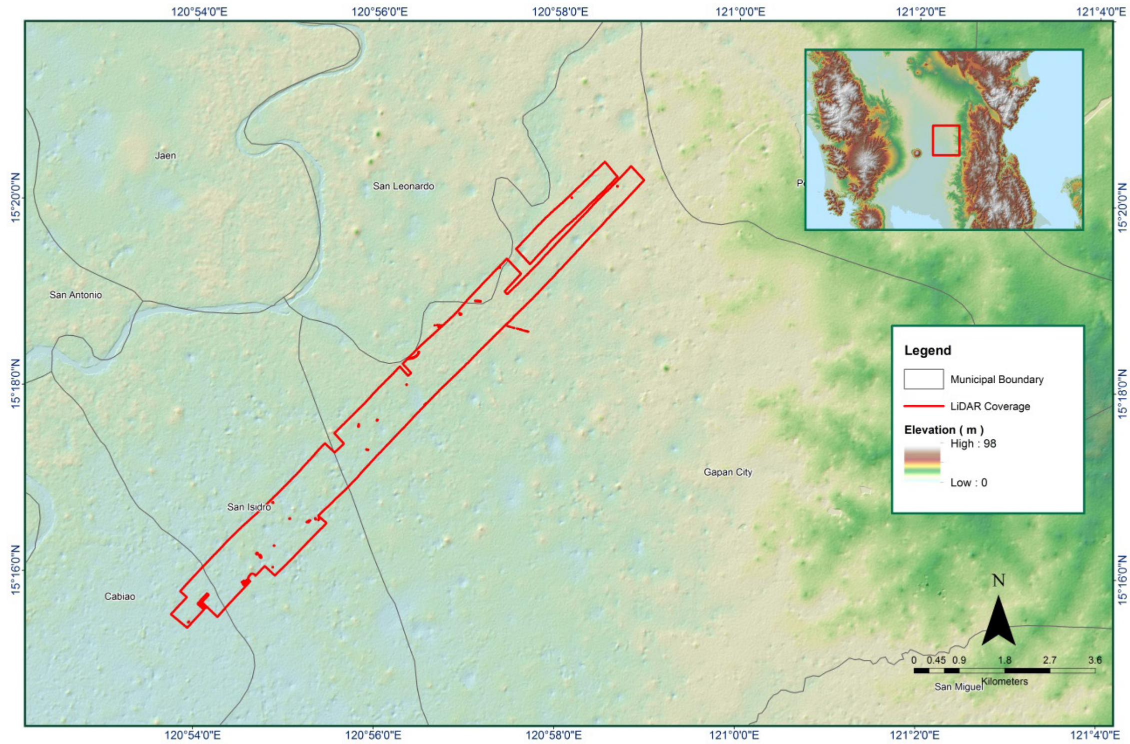


Figure A-8.46. Coverage of LiDAR data

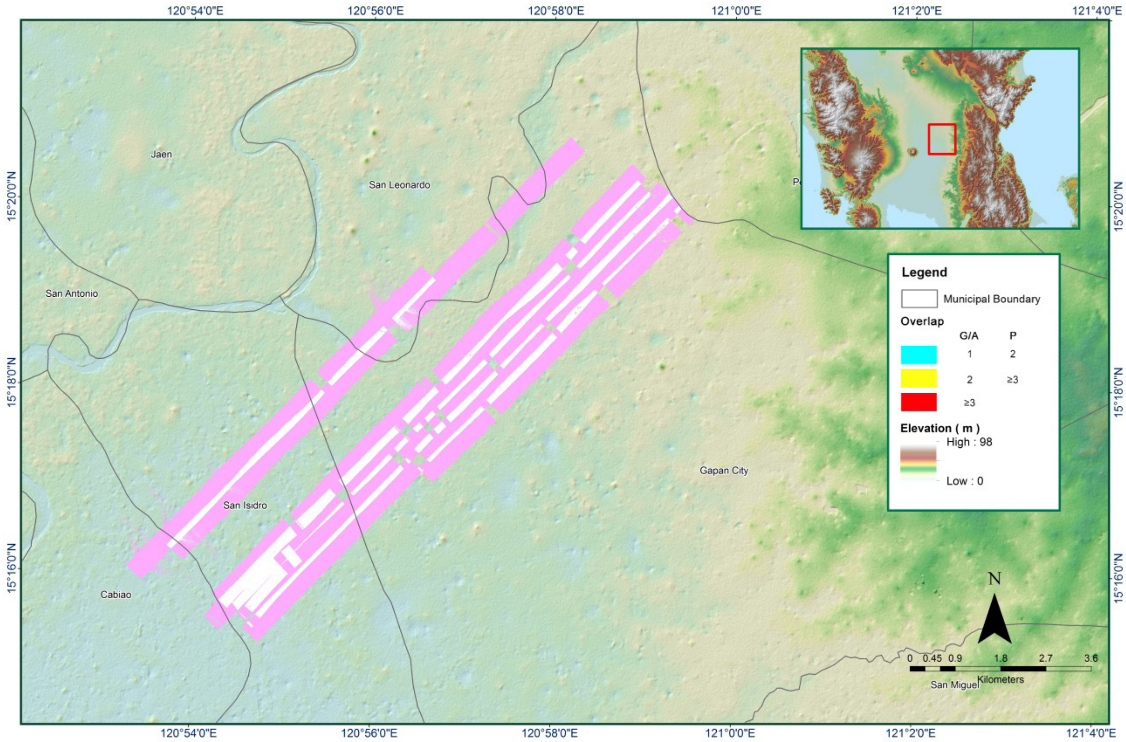


Figure A-8.47. Image of data overlap

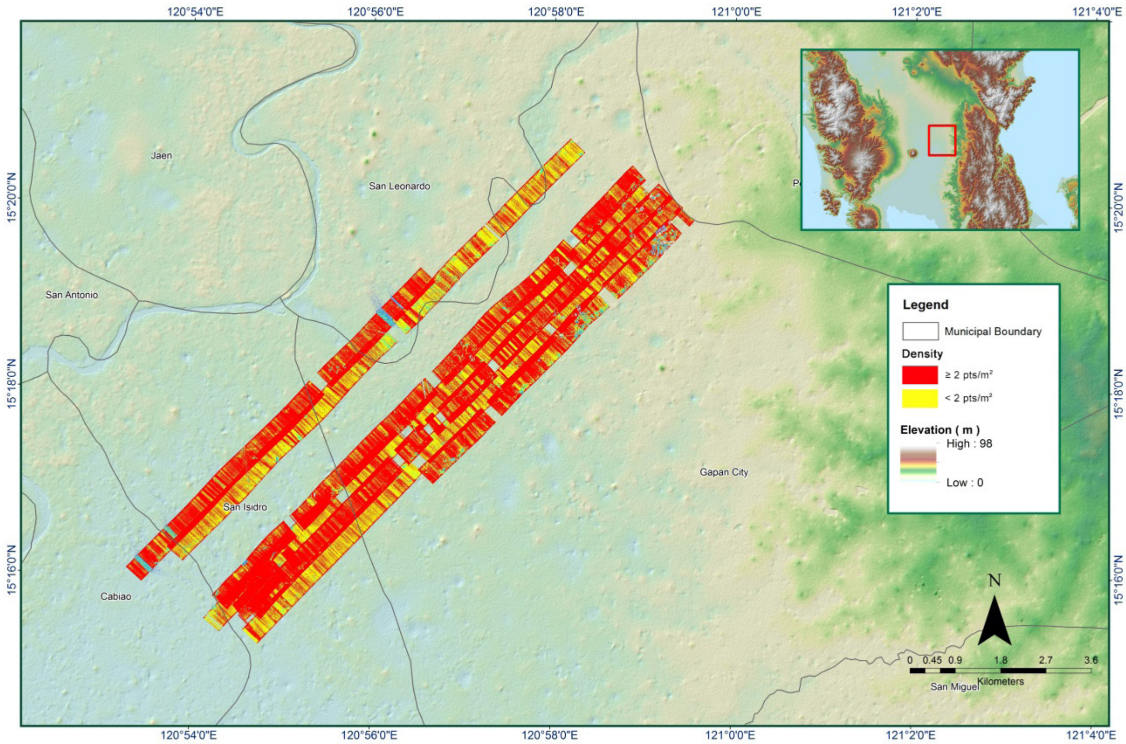


Figure A-8.48. Density Map of merged LiDAR data

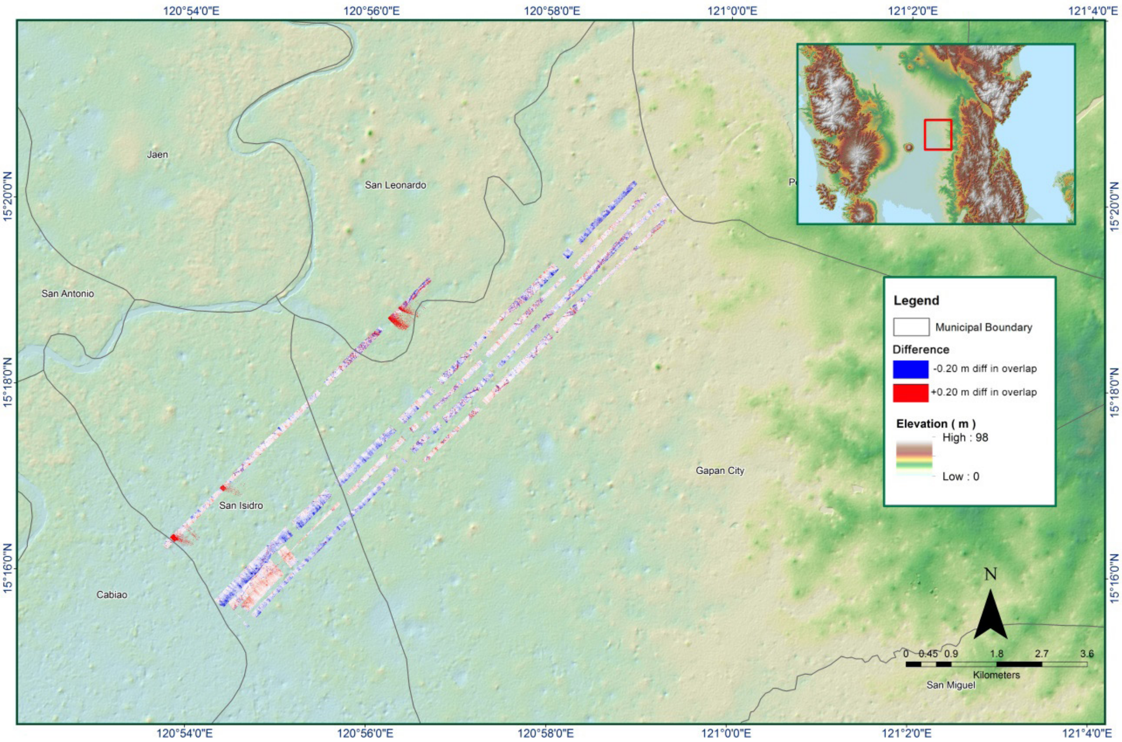


Figure A-8.49. Elevation Difference Between flight lines

Table A-8.8. Mission Summary Report for Mission Pam3C_additional

Flight Area	**Clark Reflights**
Mission Name	**Pam3C_additional**
Inclusive Flights	2294A
Range data size	5.02 GB
POS data size	174 MB
Base data size	28.9 MB
Image	n/a
Transfer date	December 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.334
RMSE for East Position (<4.0 cm)	1.437
RMSE for Down Position (<8.0 cm)	3.941
Boresight correction stdev (<0.001deg)	0.000375
IMU attitude correction stdev (<0.001deg)	0.000932
GPS position stdev (<0.01m)	0.00170
Minimum % overlap (>25)	71.82
Ave point cloud density per sq.m. (>2.0)	3.1
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	57
Maximum Height	81.19 m
Minimum Height	44.44 m
Classification (# of points)	
Ground	21,539,378
Low vegetation	30,642,898
Medium vegetation	18,514,374
High vegetation	1,531,471
Building	248,001
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Alex John Escobido

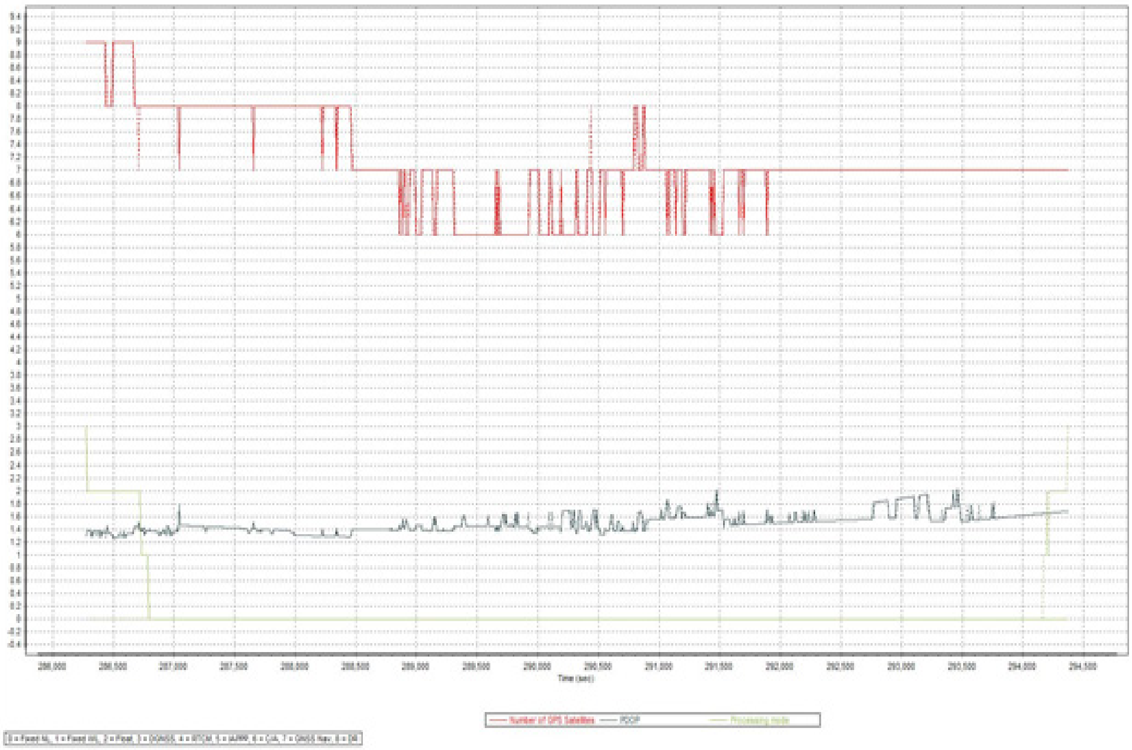


Figure A-8.50. Solution Status

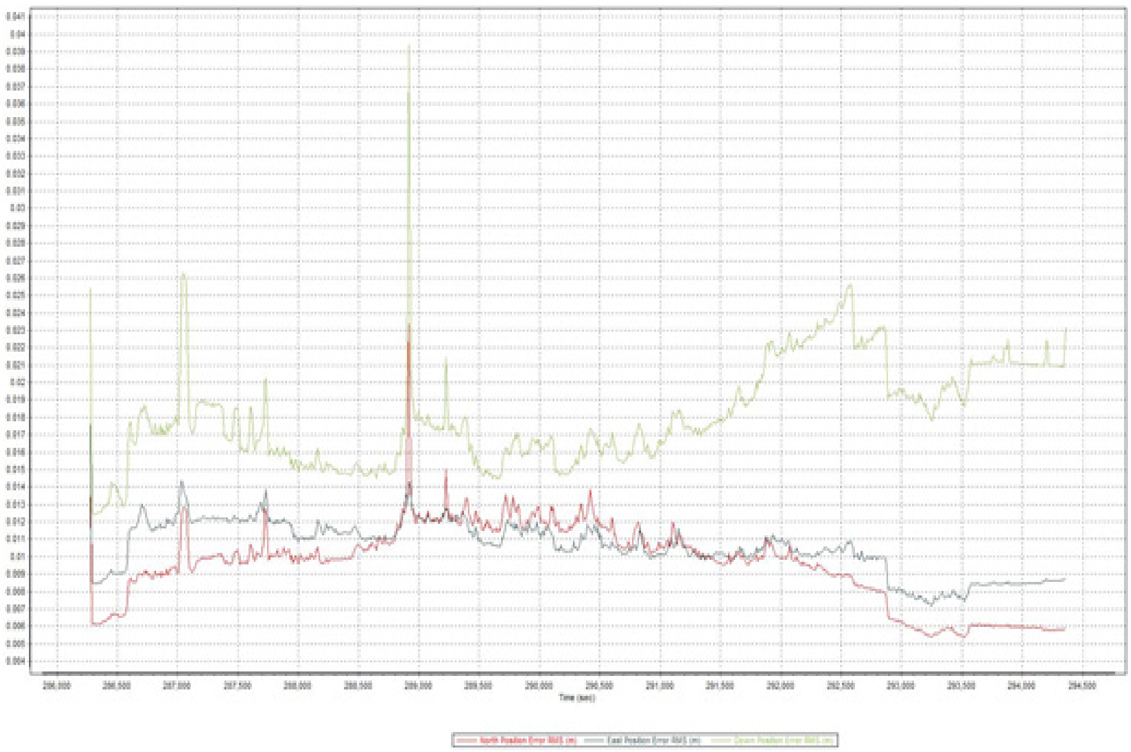


Figure A-8.51. Smoothed Performance Metric Parameters

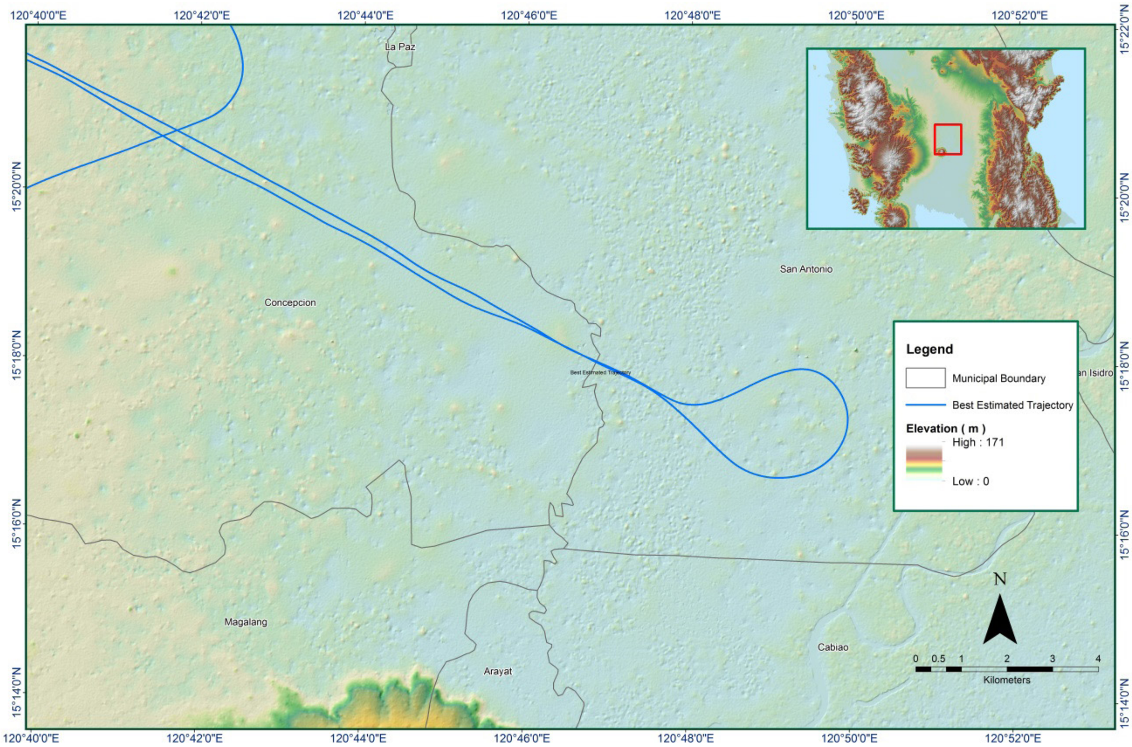


Figure A-8.52. Best Estimate Trajectory

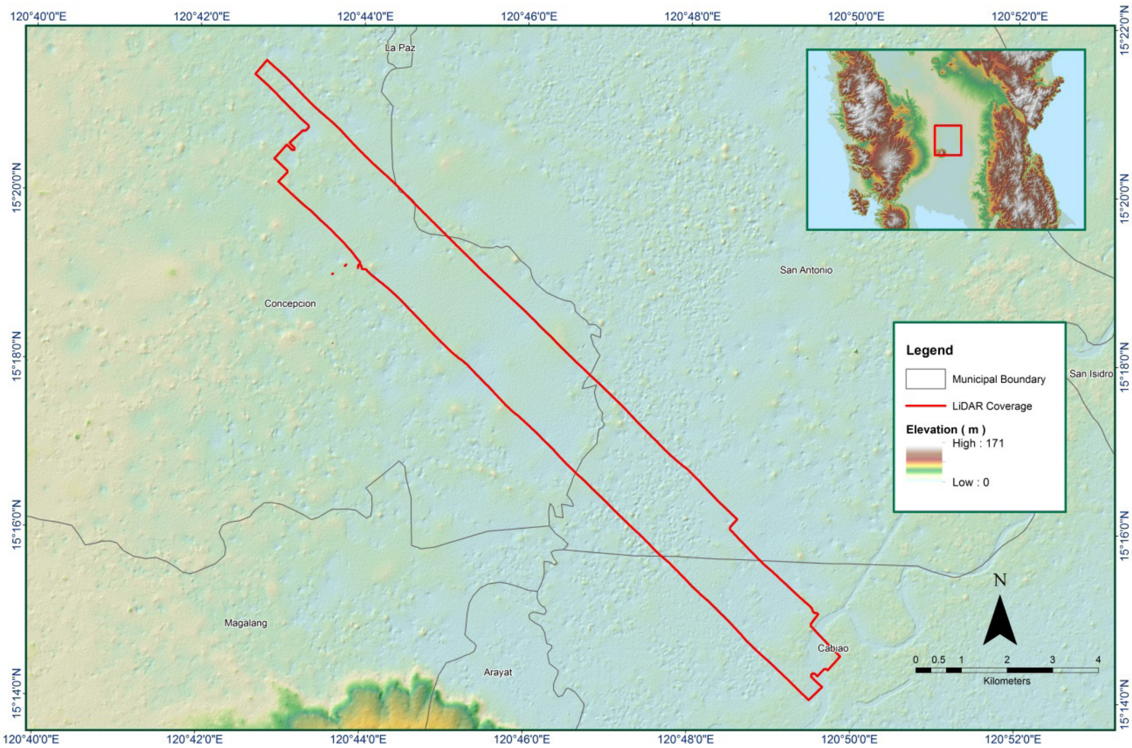


Figure A-8.53. Coverage of LiDAR data

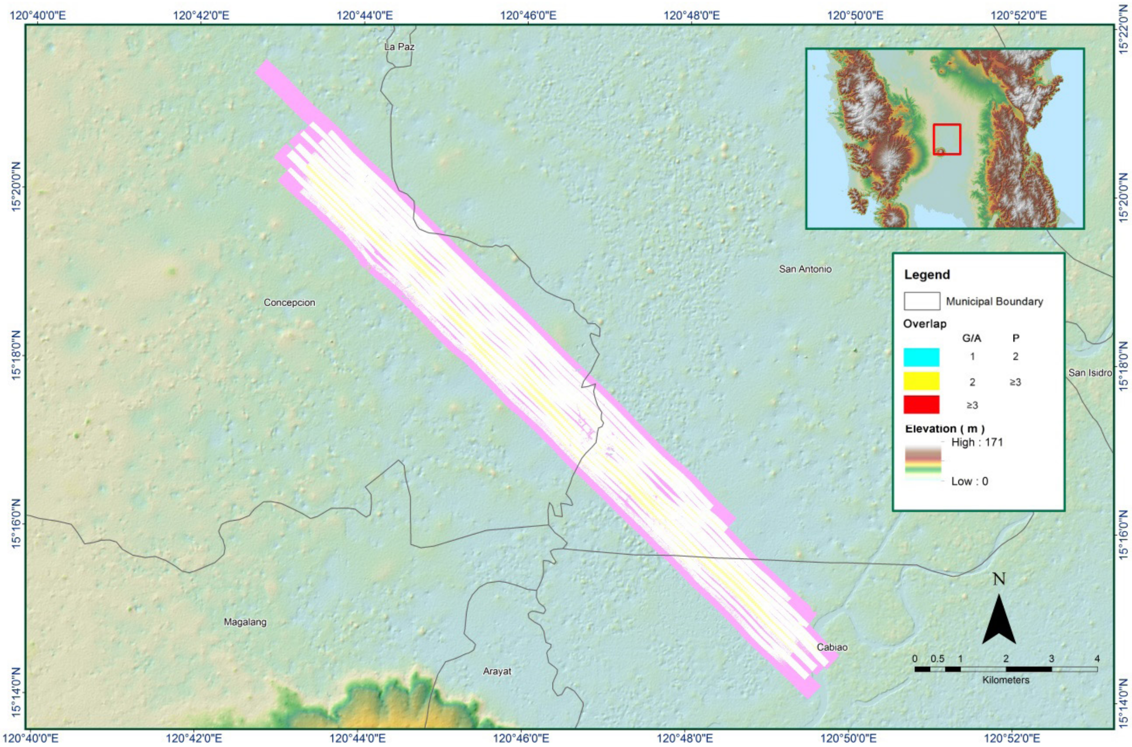


Figure A-8.54. Image of data overlap

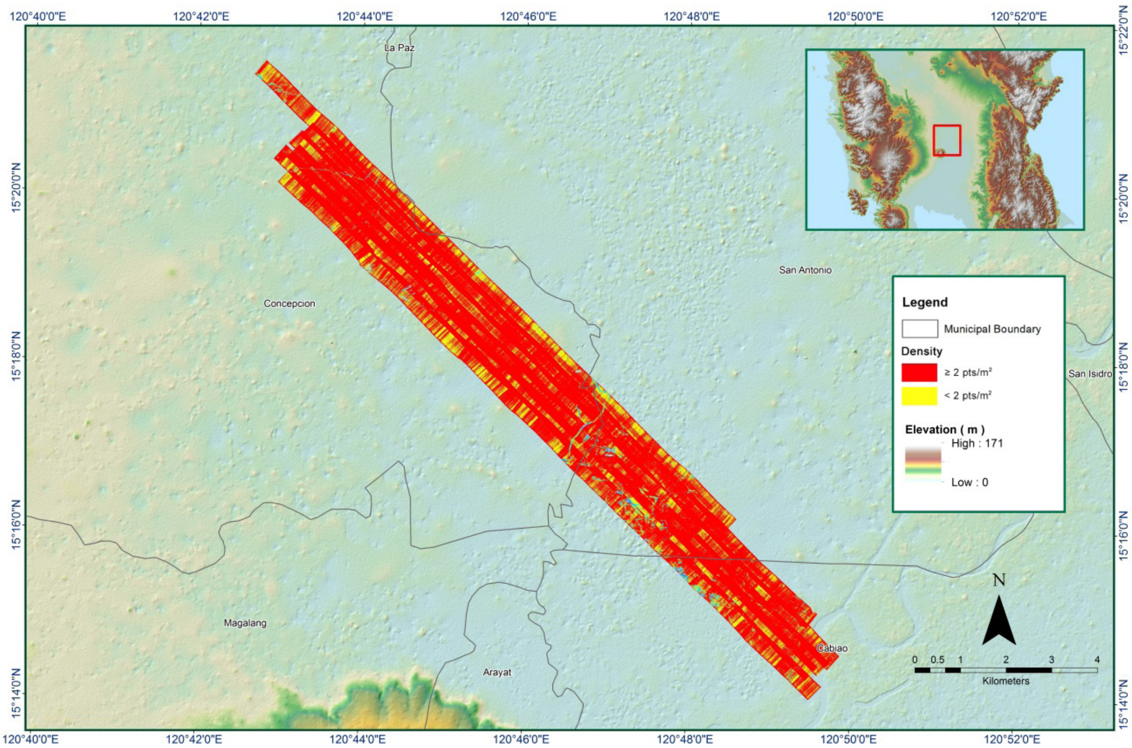


Figure A-8.55. Density Map of merged LiDAR data

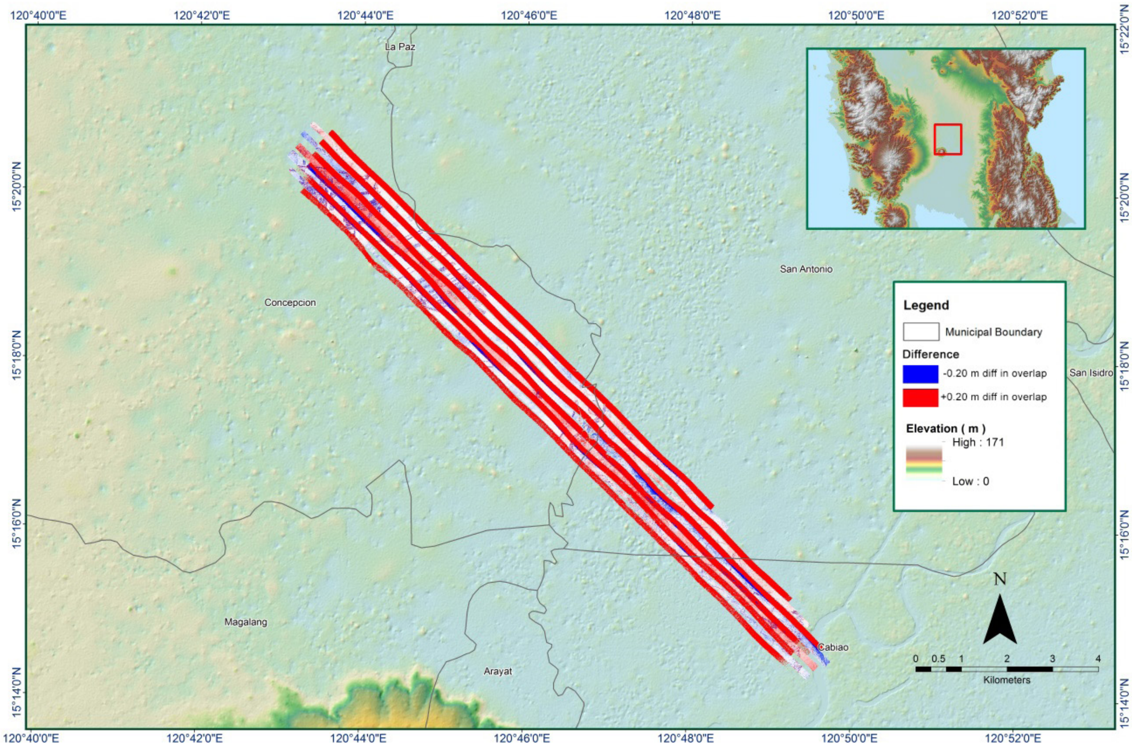


Figure A-8.56. Elevation Difference Between flight lines

Table A-8.9. Mission Summary Report for Mission Pam3B_additional

Flight Area	**Clark Reflights**
Mission Name	**Pam3B_additional**
Inclusive Flights	2304A
Range data size	4.2 GB
POS data size	173 MB
Base data size	31.1 MB
Image	n/a
Transfer date	December 12, 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)	1.64
RMSE for East Position (<4.0 cm)	1.77
RMSE for Down Position (<8.0 cm)	3.51
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	40.76
Ave point cloud density per sq.m. (>2.0)	2.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	30
Maximum Height	180.45 m
Minimum Height	67.4 m
Classification (# of points)	
Ground	7,789,358
Low vegetation	4,799,315
Medium vegetation	8,409,557
High vegetation	1,836,058
Building	99,159
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Sueden Lyle Magtalas

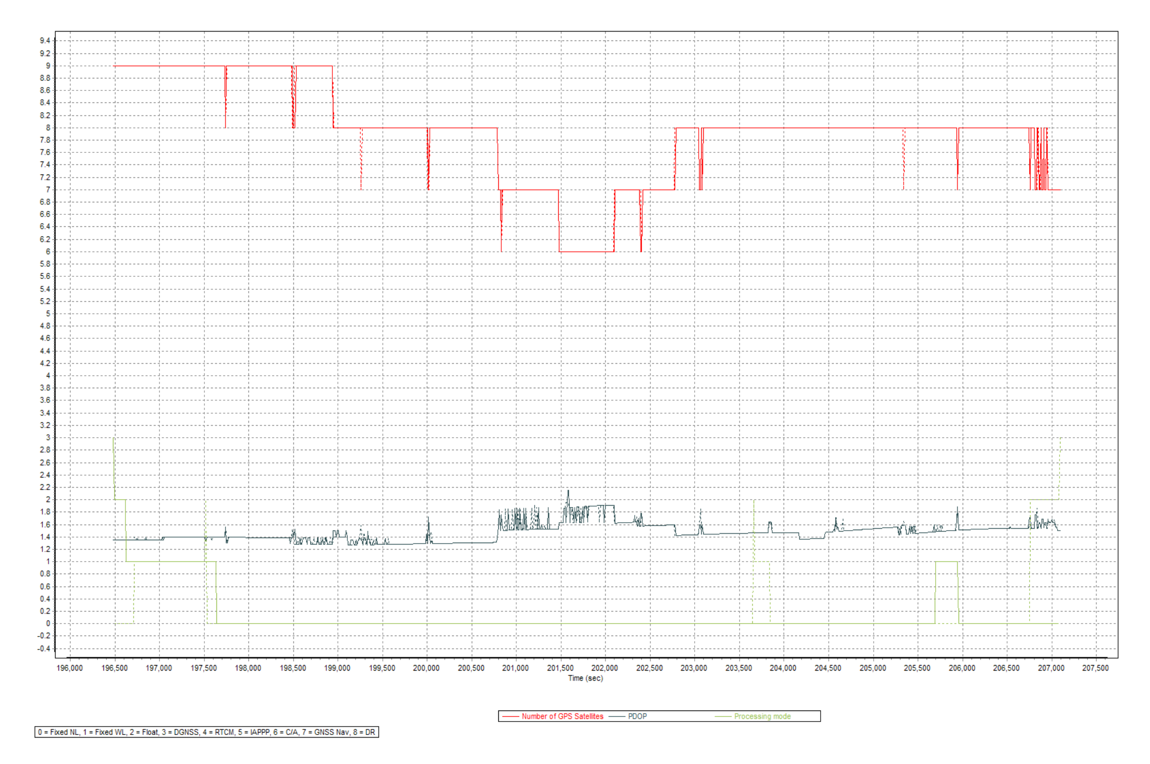


Figure A-8.57. Solution Status

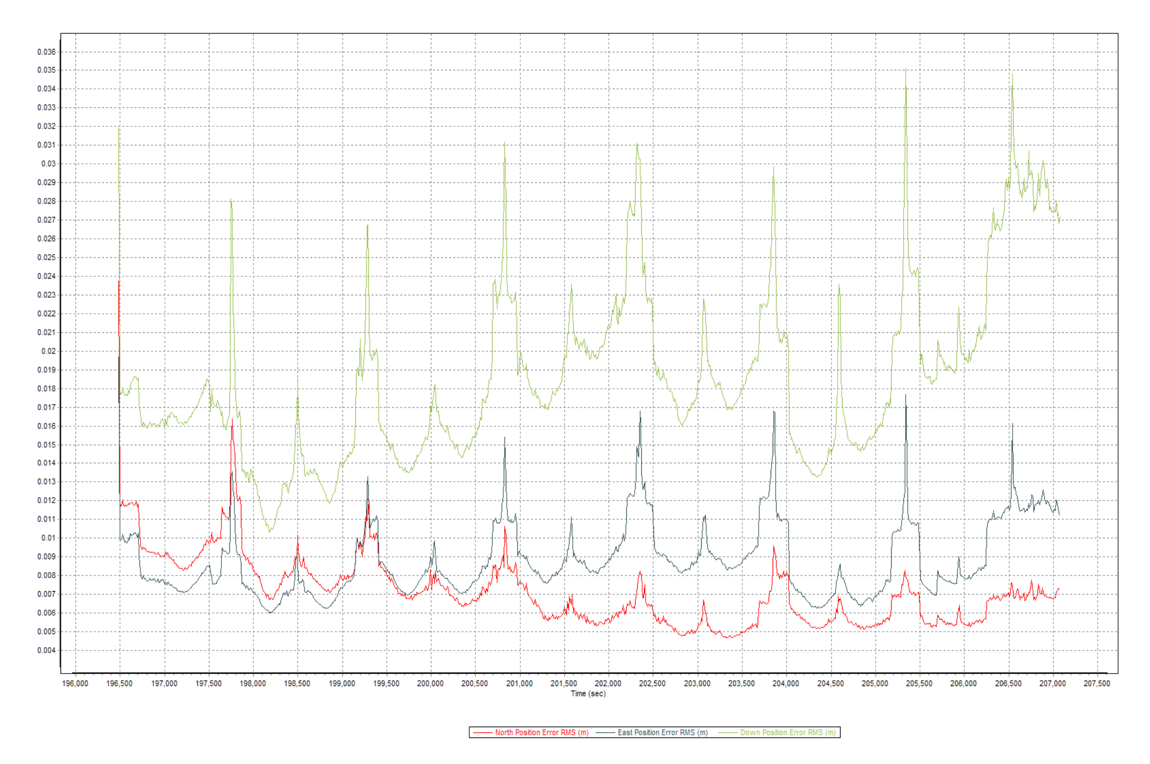


Figure A-8.58. Smoothed Performance Metric Parameters

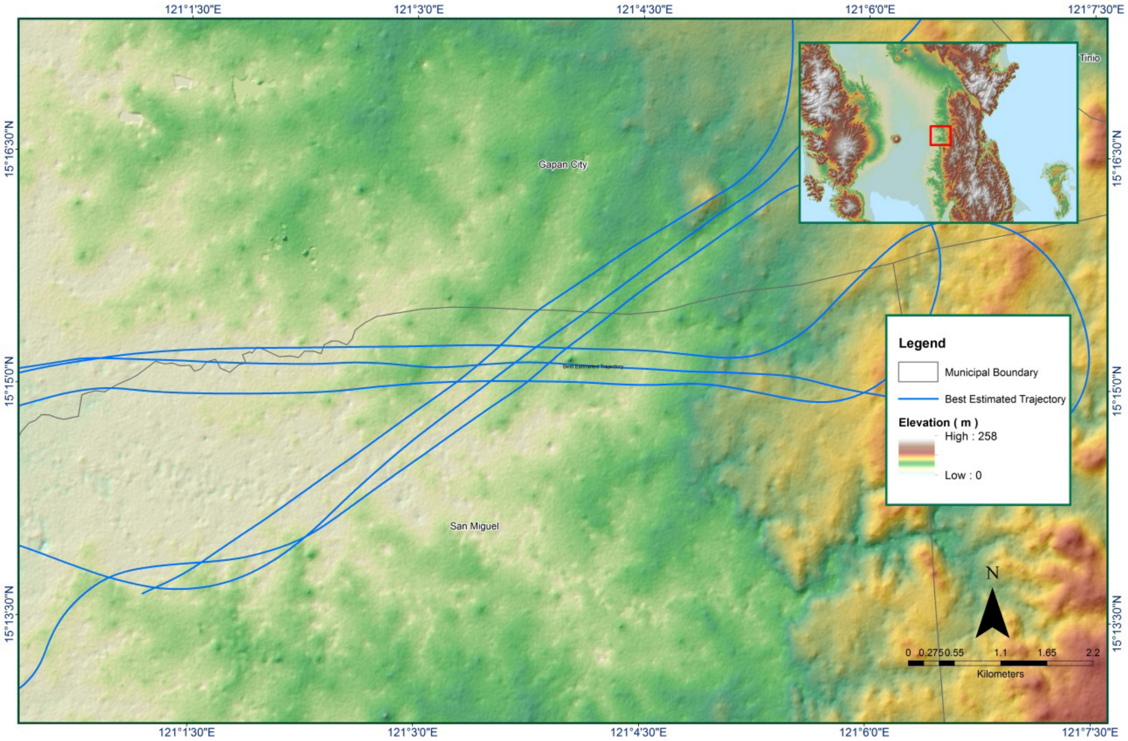


Figure A-8.59. Best Estimate Trajectory

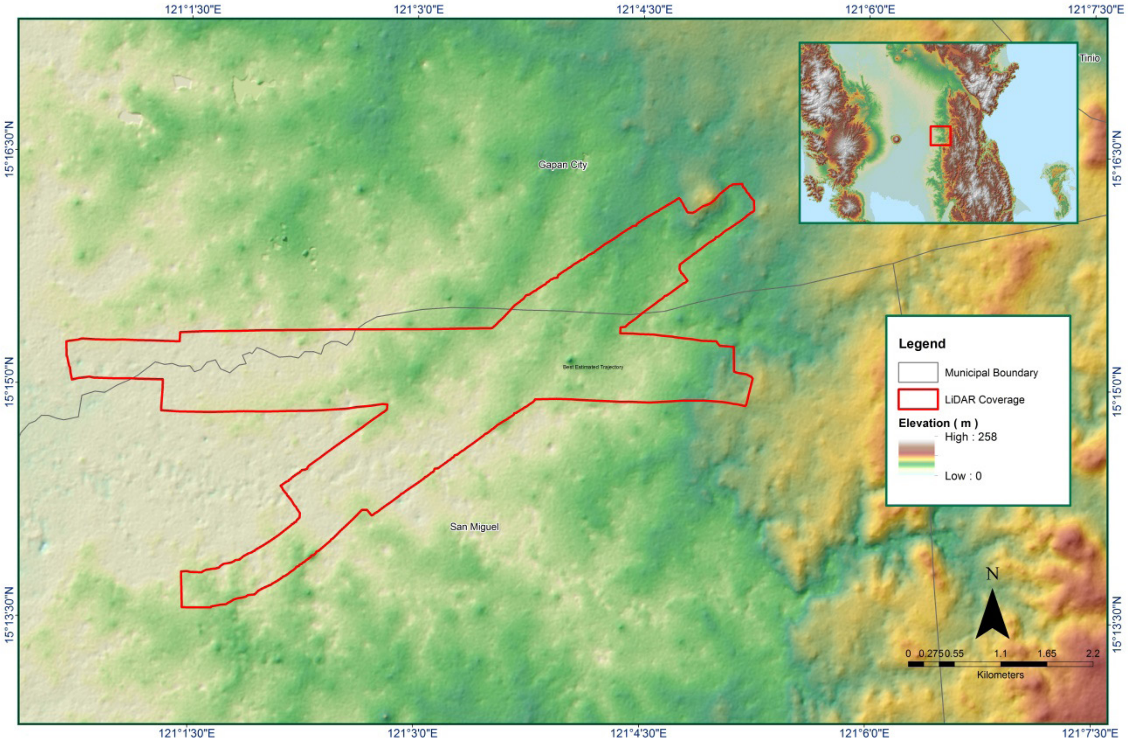


Figure A-8.60. Coverage of LiDAR data

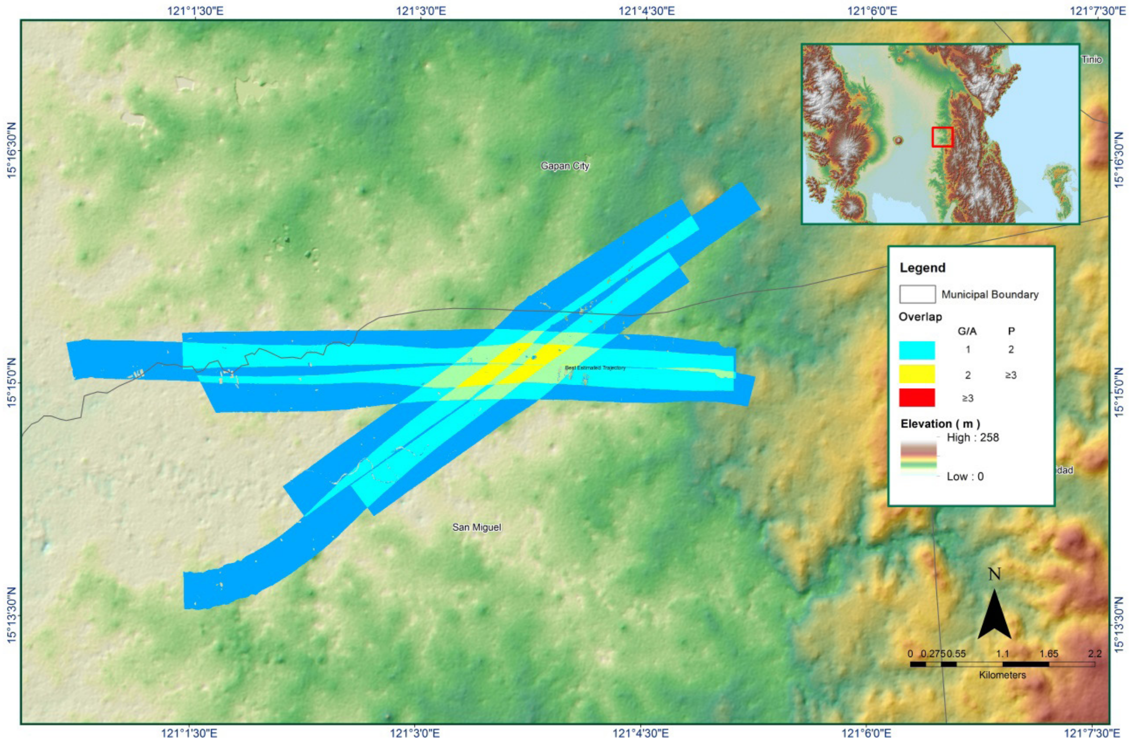


Figure A-8.61. Image of data overlap

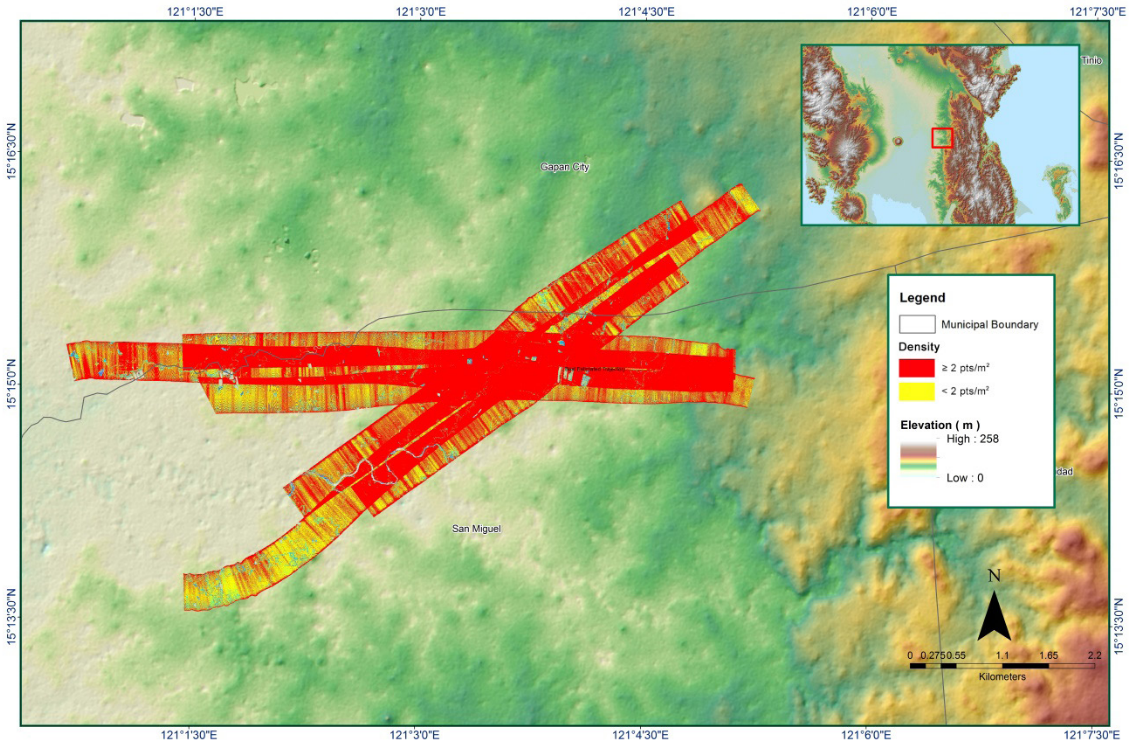


Figure A-8.62. Density Map of merged LiDAR data

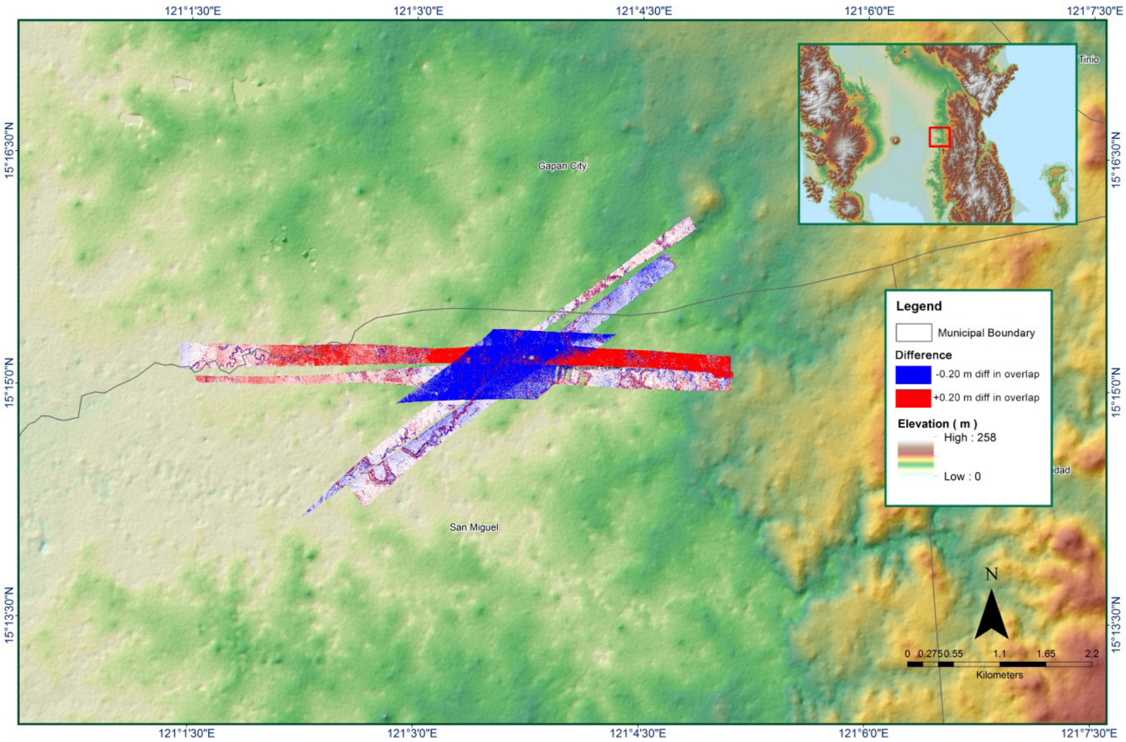


Figure A-8.63. Elevation Difference Between flight lines

Table A-8.10. Mission Summary Report for Mission Blk Umy_AB

Flight Area	**Clark Reflights**
Mission Name	**Blk Umy_AB**
Inclusive Flights	2666G, 2670G
Range data size	28.9 GB
POS data size	486 MB
Base data size	188.5 MB
Image	46.7 GB
Transfer date	August 30, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.65
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.001440
IMU attitude correction stdev (<0.001deg)	0.451855
GPS position stdev (<0.01m)	0.0314
Minimum % overlap (>25)	41.09%
Ave point cloud density per sq.m. (>2.0)	4.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	185
Maximum Height	765.53 m
Minimum Height	42.58 m
Classification (# of points)	
Ground	14,811,215
Low vegetation	8,077,599
Medium vegetation	70,781,631
High vegetation	532,874,222
Building	4,660,395
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Jovelle Anjeanette Canlas, Jovy Narisma

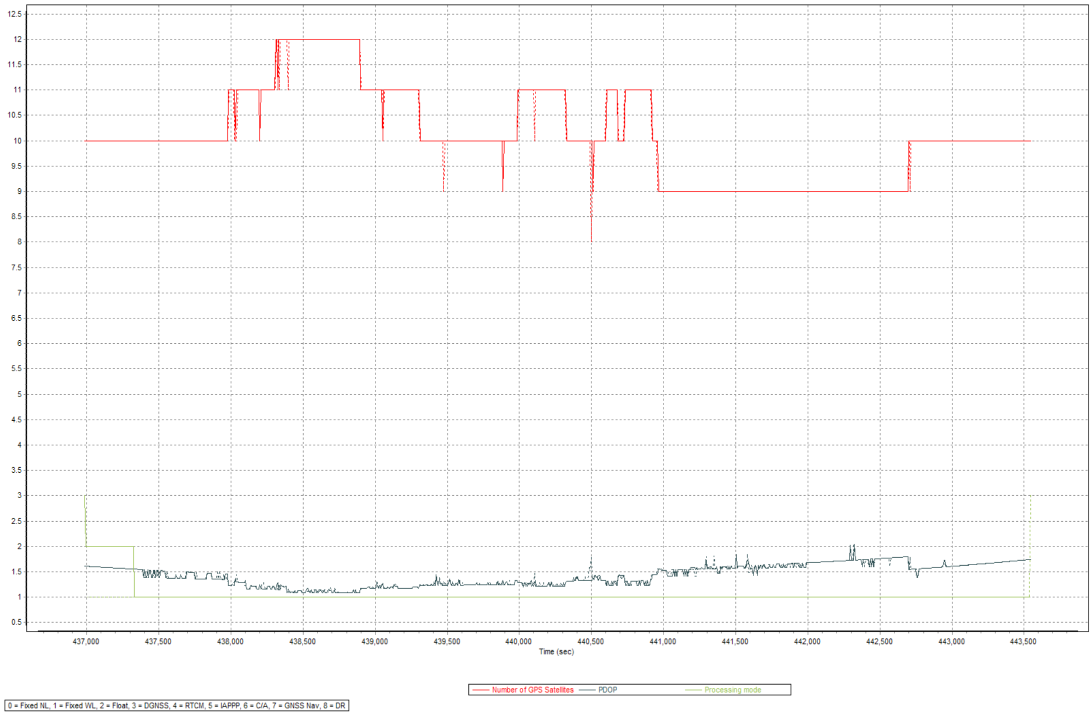


Figure A-8.64. Solution Status

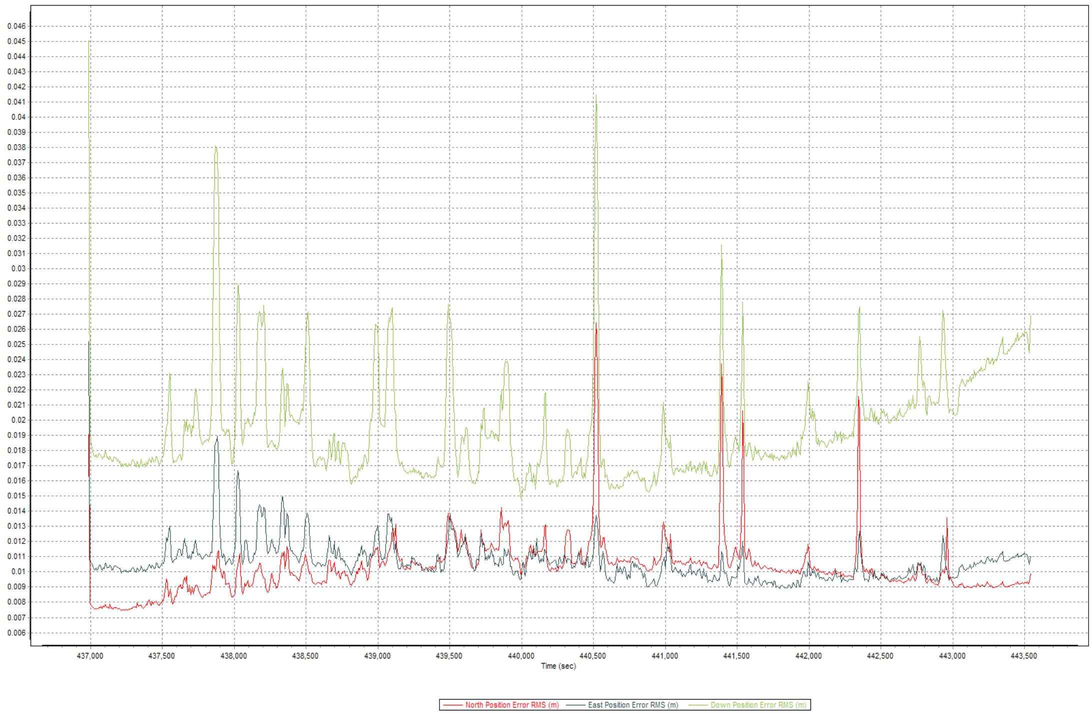


Figure A-8.65. Smoothed Performance Metric Parameters

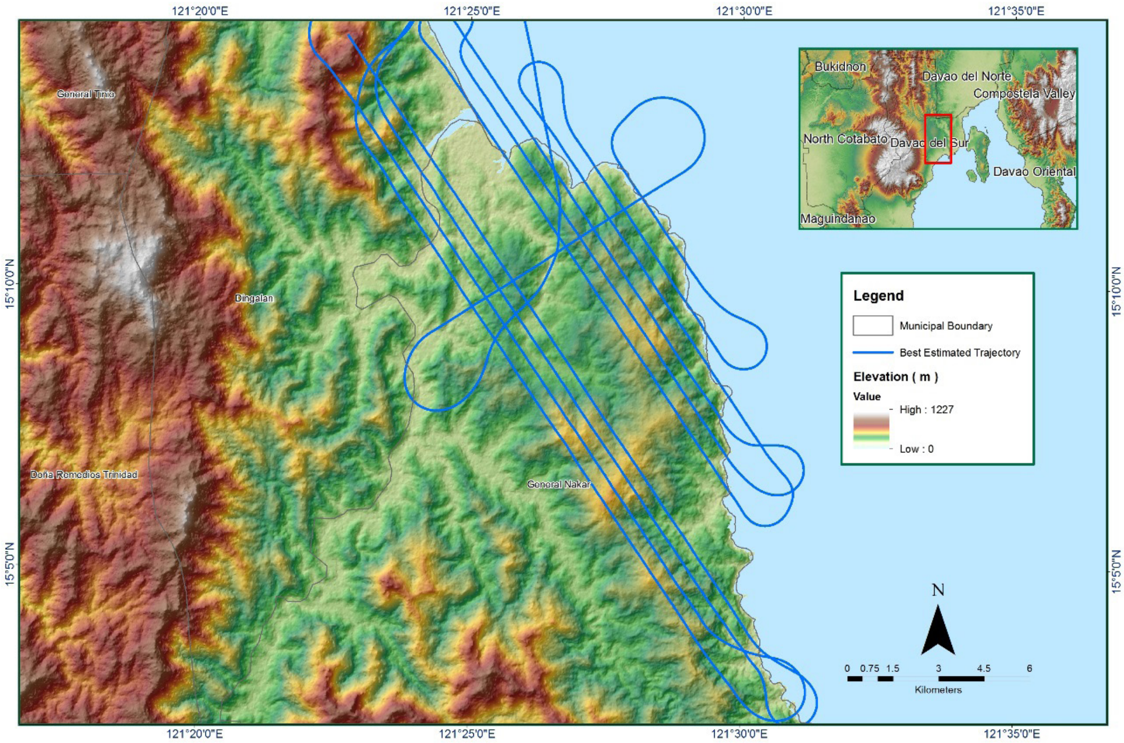


Figure A-8.66. Best Estimated Trajectory

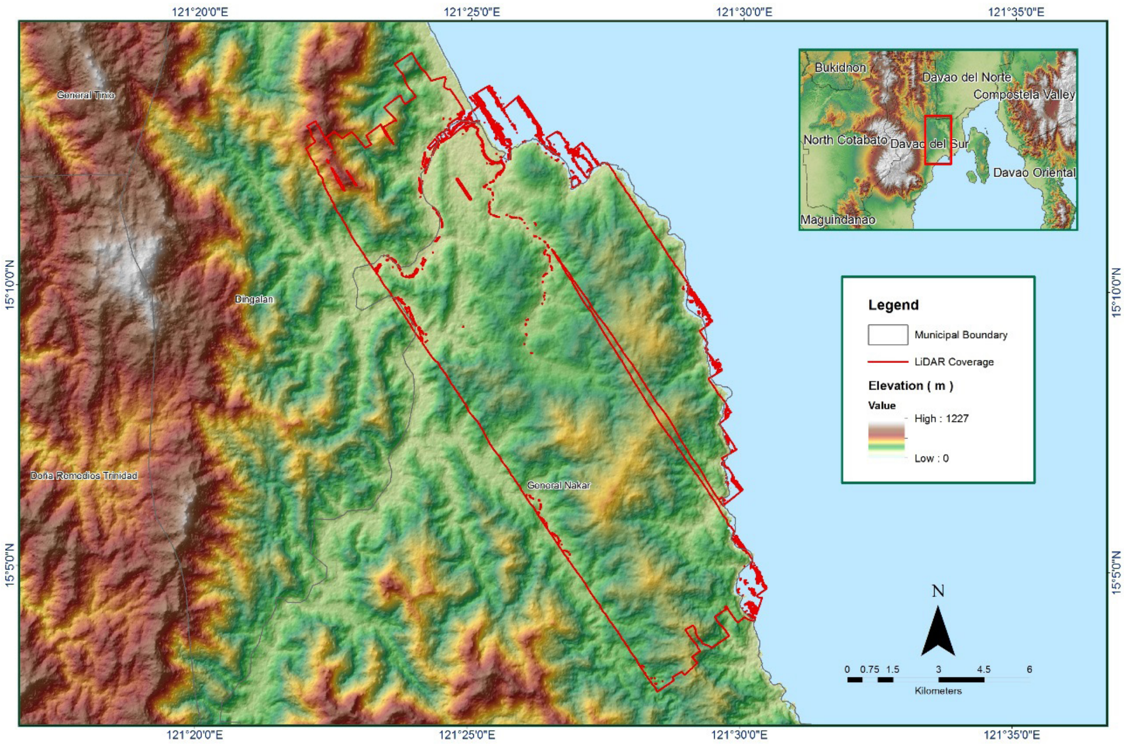


Figure A-8.67. Coverage of LiDAR data

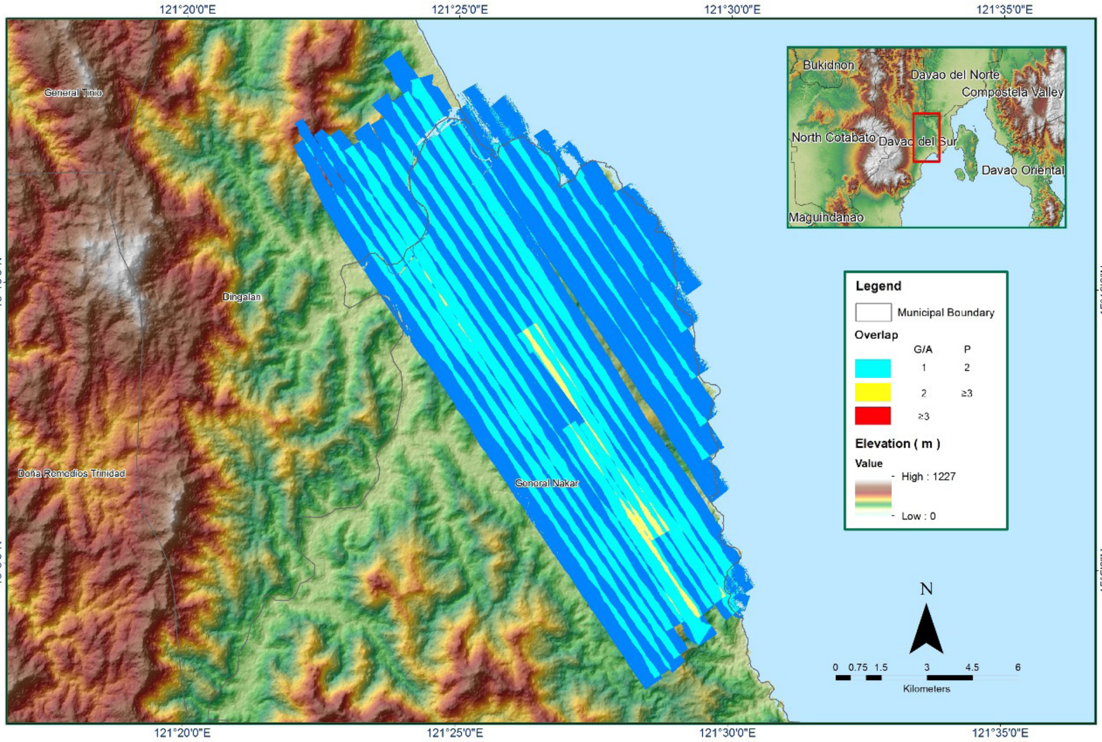


Figure A-8.68. Image of data overlap

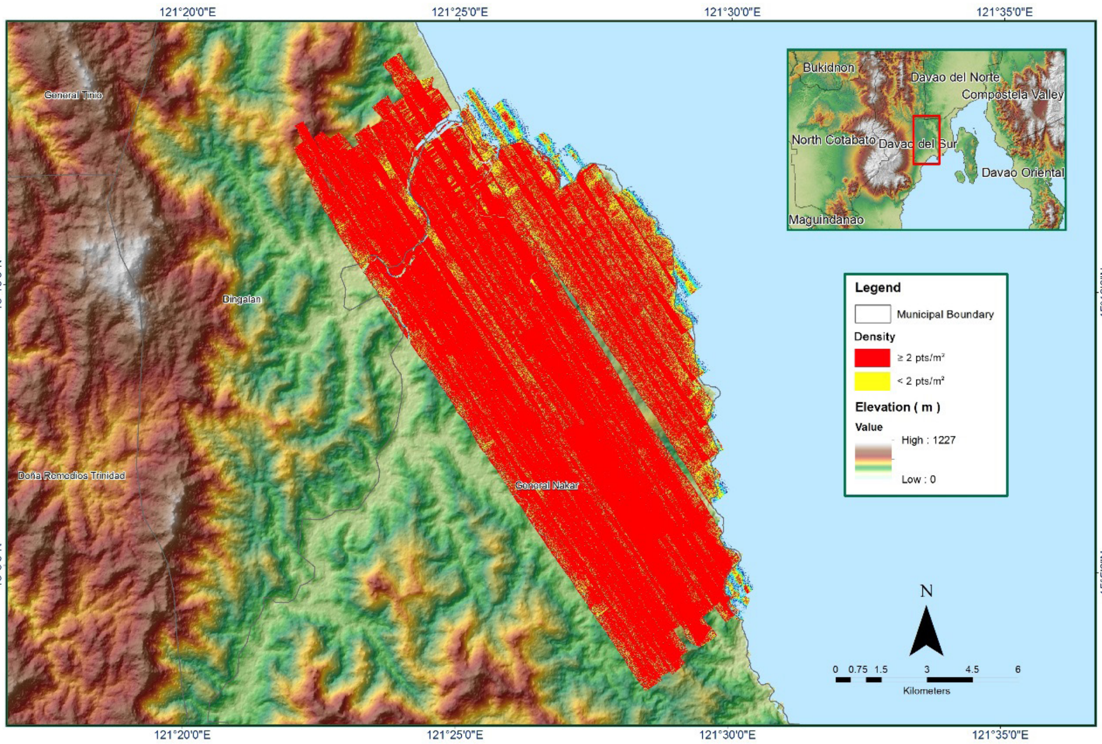


Figure A-8.69. Density map of merged LiDAR data

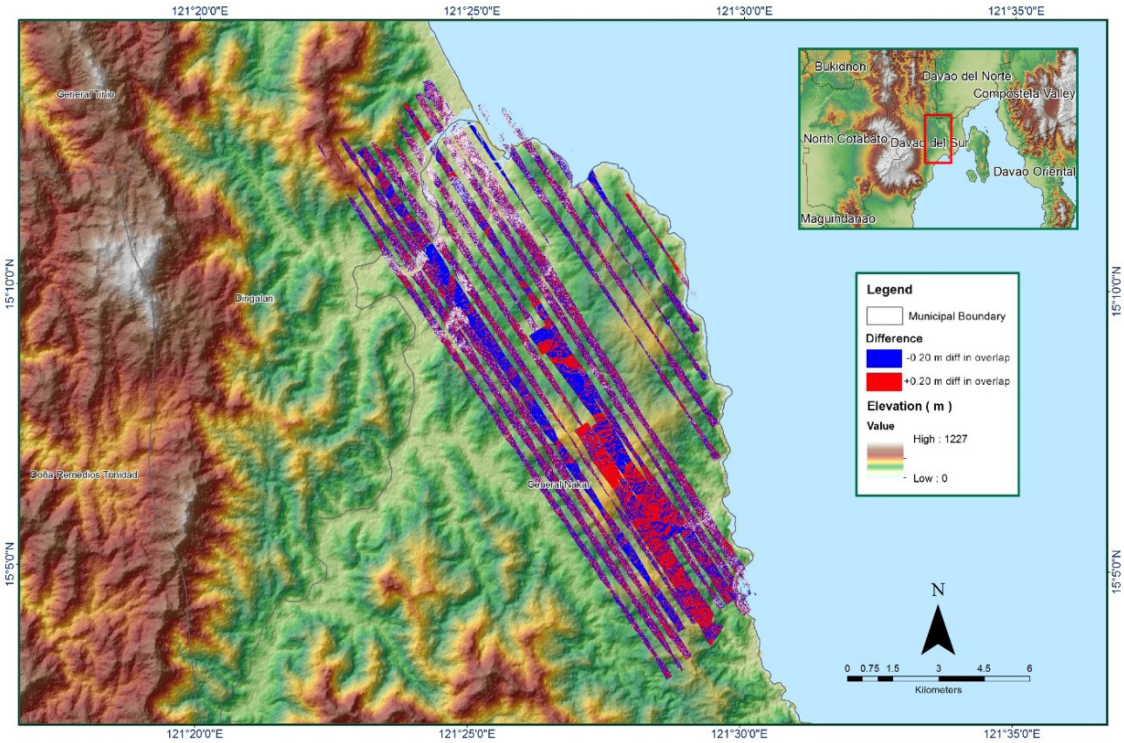


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk Umy_A

Flight Area	**Clark Reflights**
Mission Name	Blk Umy_A
Inclusive Flights	2662G
Range data size	8.59 GB
POS data size	232 MB
Base data size	137 MB
Image	25.1 GB
Transfer date	August 28, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.65
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000820
IMU attitude correction stdev (<0.001deg)	0.000985
GPS position stdev (<0.01m)	0.0109
Minimum % overlap (>25)	42.08%
Ave point cloud density per sq.m. (>2.0)	4.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	91
Maximum Height	1576.52 m
Minimum Height	44.51 m
Classification (# of points)	
Ground	24,929,023
Low vegetation	15,188,669
Medium vegetation	44,953,188
High vegetation	154,505,119
Building	11,499,844
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Jovelle Anjeanette Canlas, Engr. Melissa Fernandez

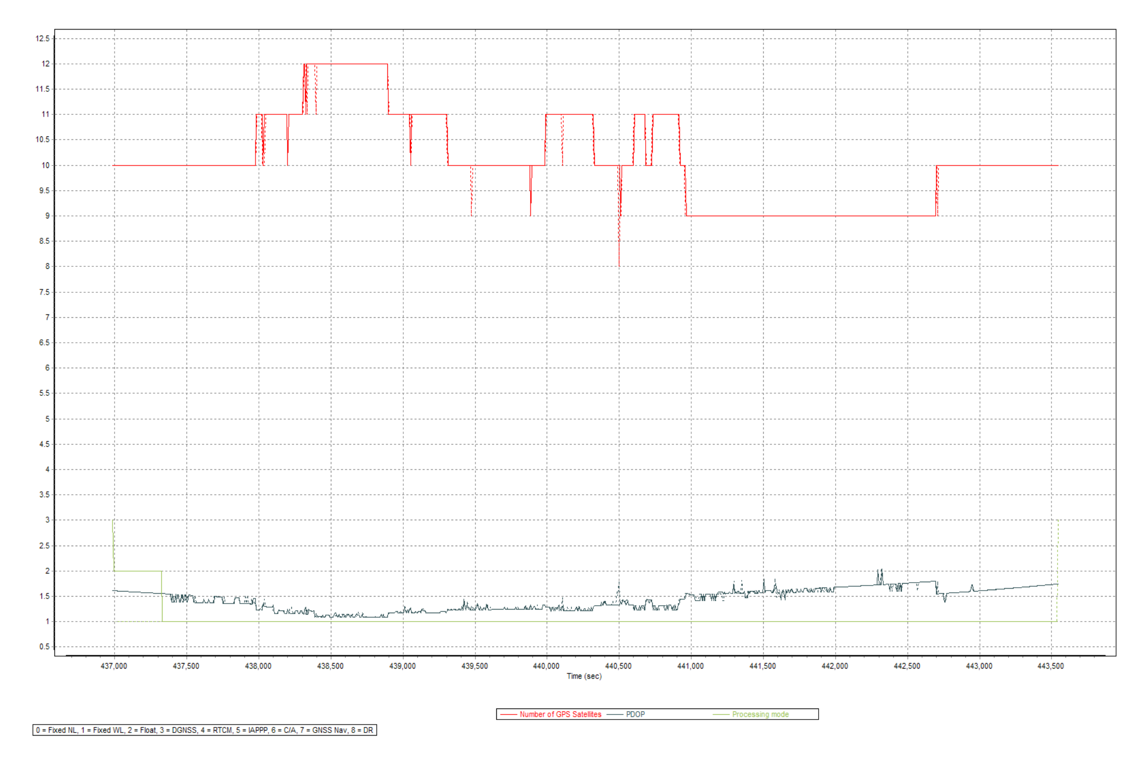


Figure A-8.71. Solution Status

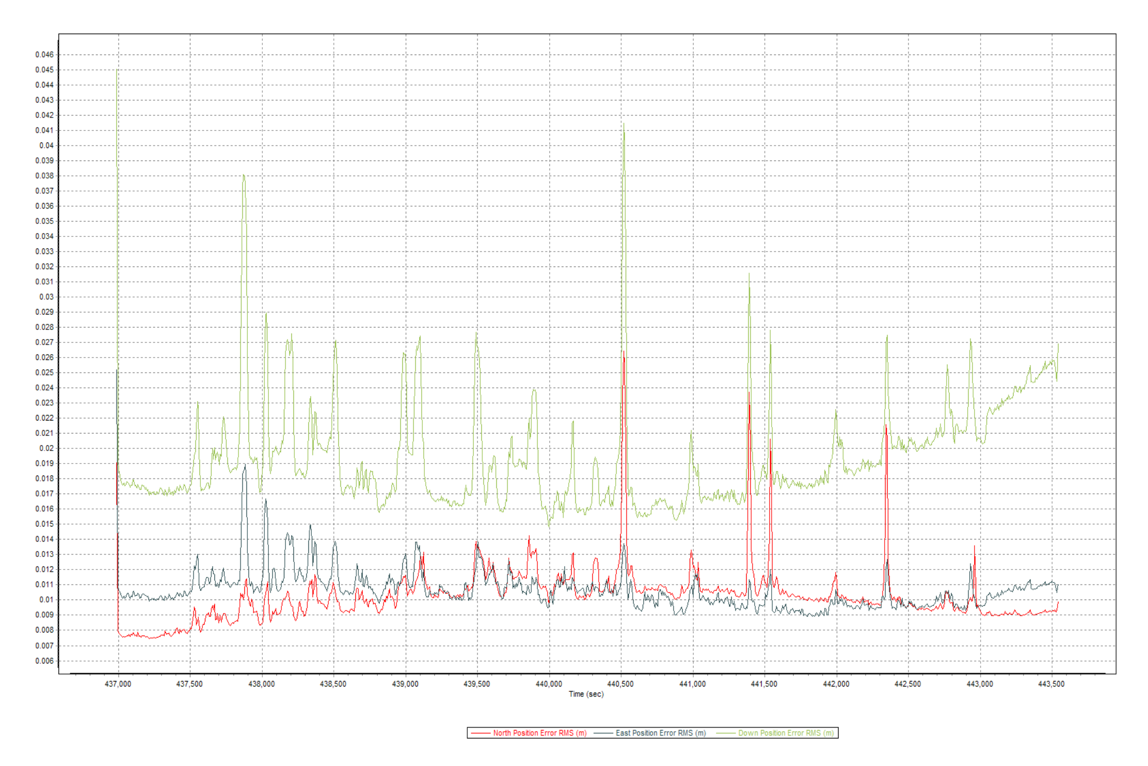


Figure A-8.72. Smoothed Performance Metric Parameters

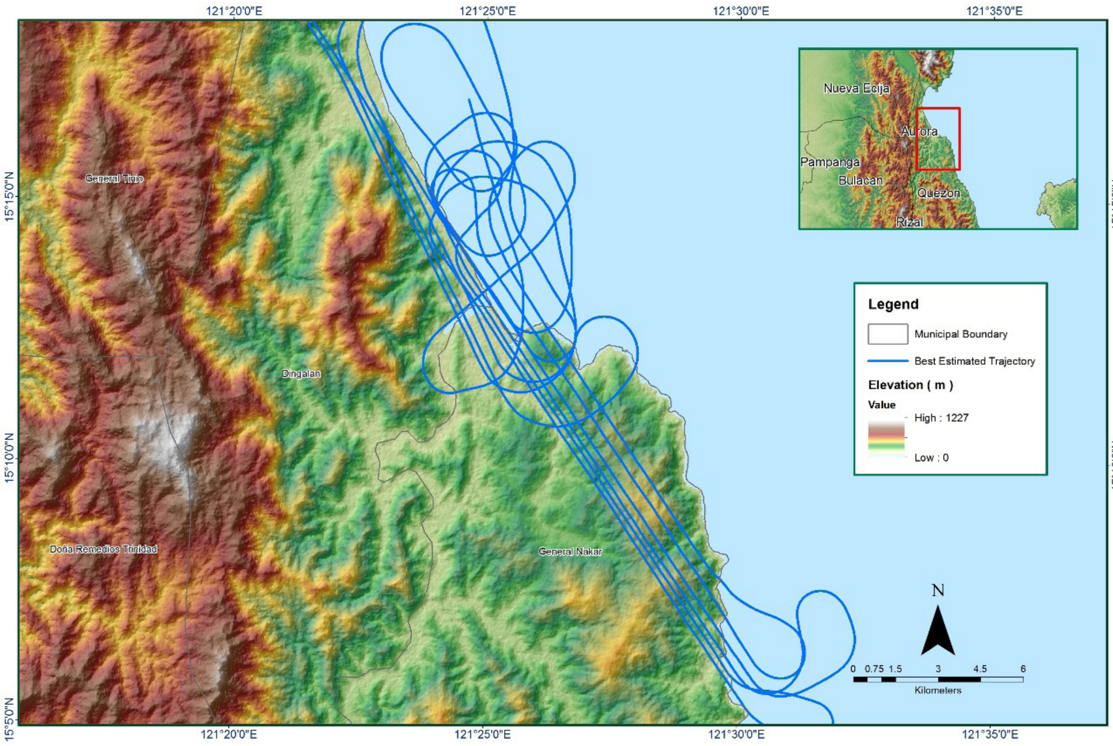


Figure A-8.73. Best Estimated Trajectory

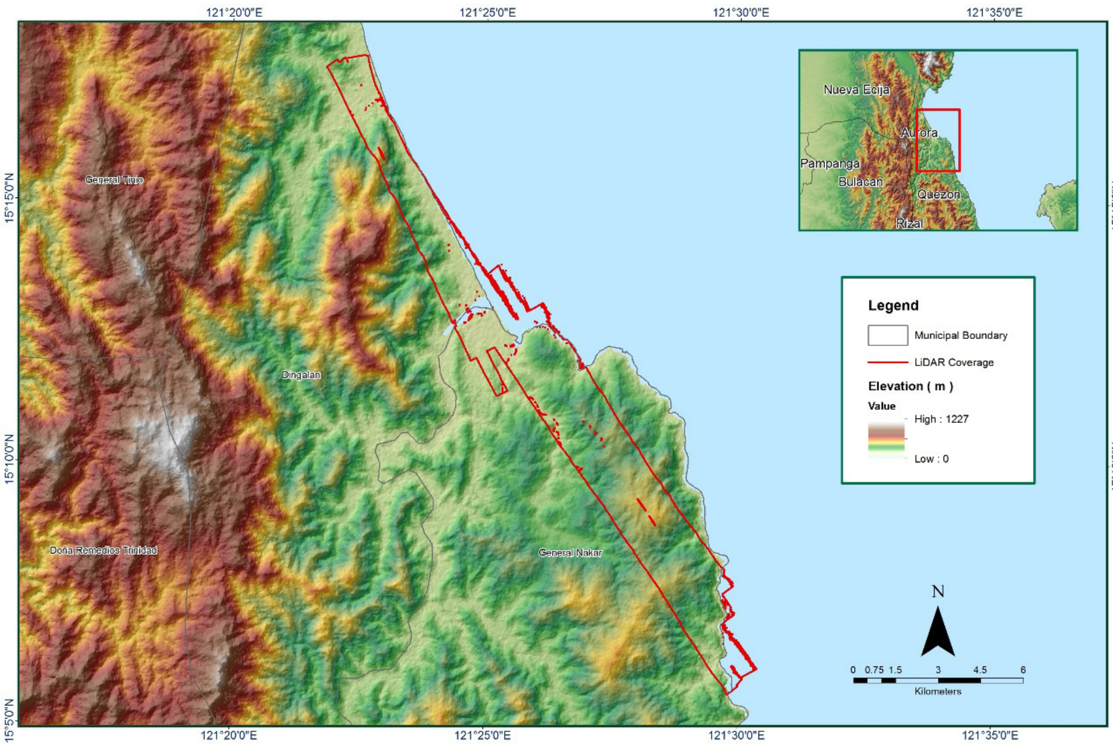


Figure A-8.74. Coverage of LiDAR data

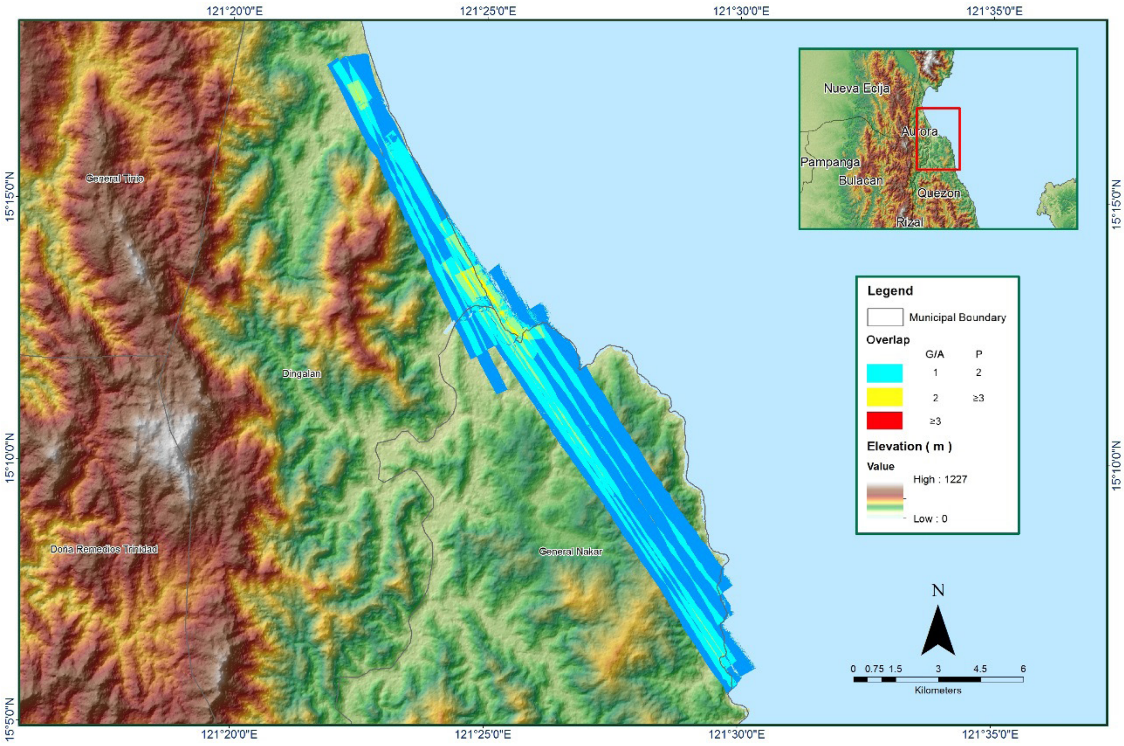


Figure A-8.75. Image of data overlap

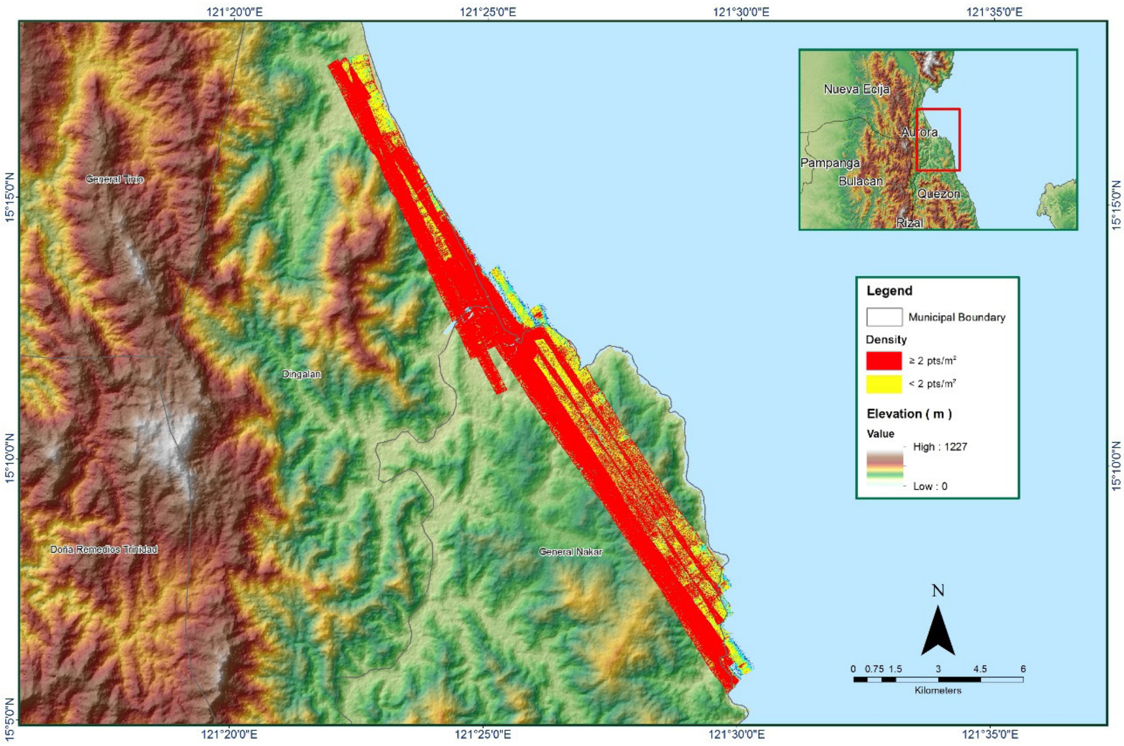


Figure A-8.76, Density map of merged LiDAR data

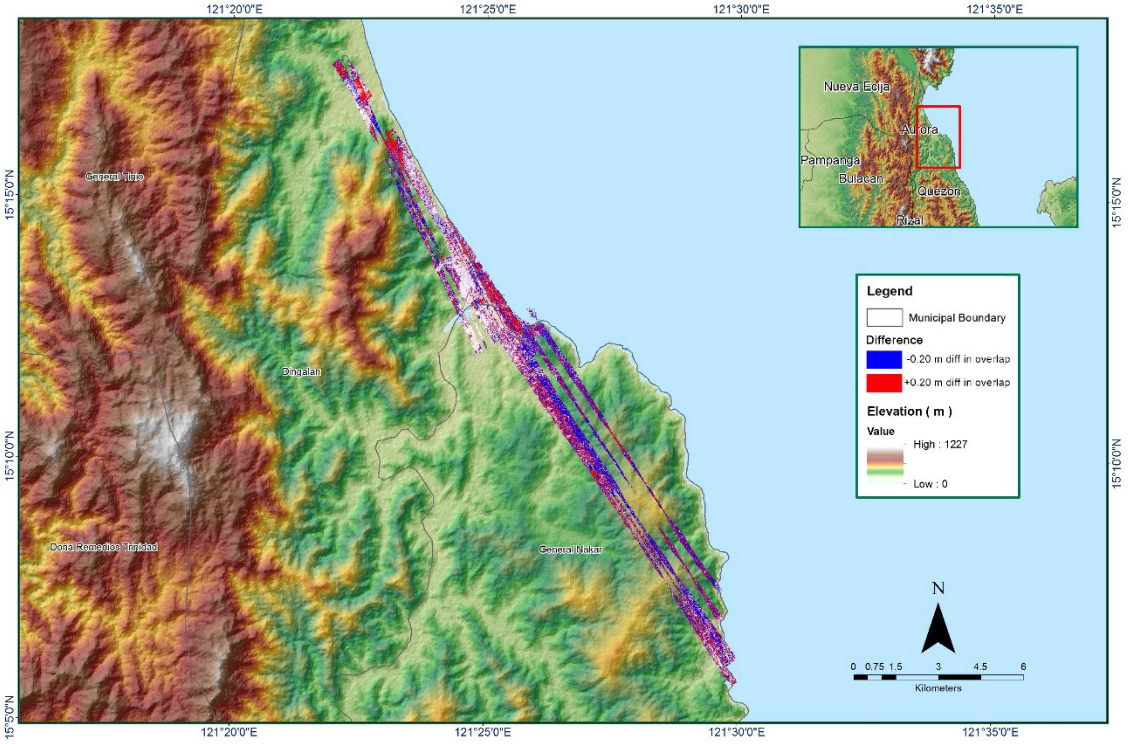


Figure A-8.77. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission Pam8D_additional

Flight Area	**Clark Reflights**
Mission Name	**Pam8D_additional**
Inclusive Flights	2302A
Range data size	5.17 GB
POS data size	169 MB
Base data size	31.1 MB
Image	N/A
Transfer date	December 12, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.14
RMSE for East Position (<4.0 cm)	2.44
RMSE for Down Position (<8.0 cm)	5.4
Boresight correction stdev (<0.001deg)	0.000496
IMU attitude correction stdev (<0.001deg)	0.002611
GPS position stdev (<0.01m)	0.001
Minimum % overlap (>25)	48.99
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	55
Maximum Height	222.86 m
Minimum Height	76.06 m
Classification (# of points)	
Ground	20,763,862
Low vegetation	23,427,564
Medium vegetation	28,782,097
High vegetation	26,945,708
Building	1,326,832
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Krisha Marie Bautista

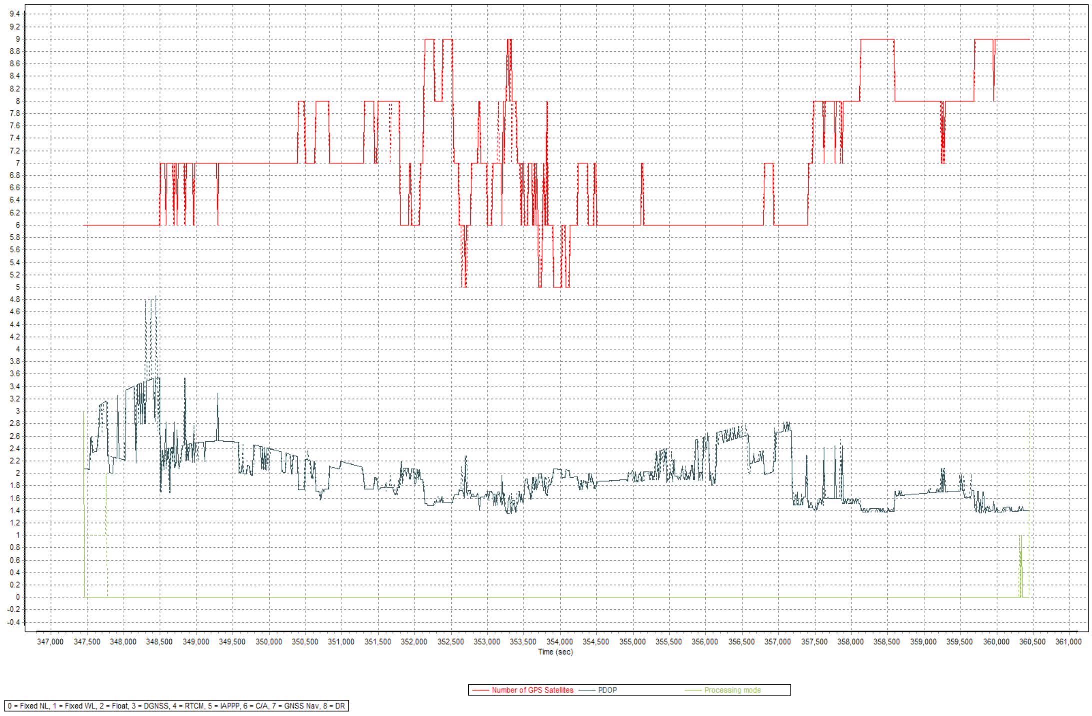


Figure A-8.78. Solution Status

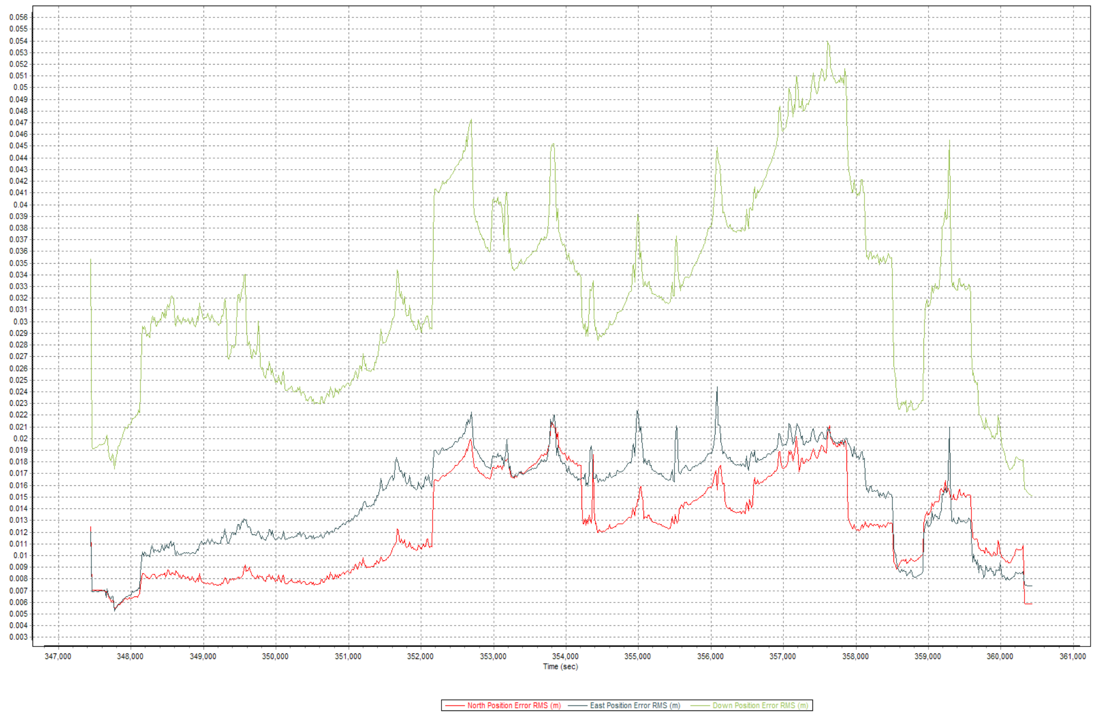


Figure A-8.79. Smoothed Performance Metric Parameters

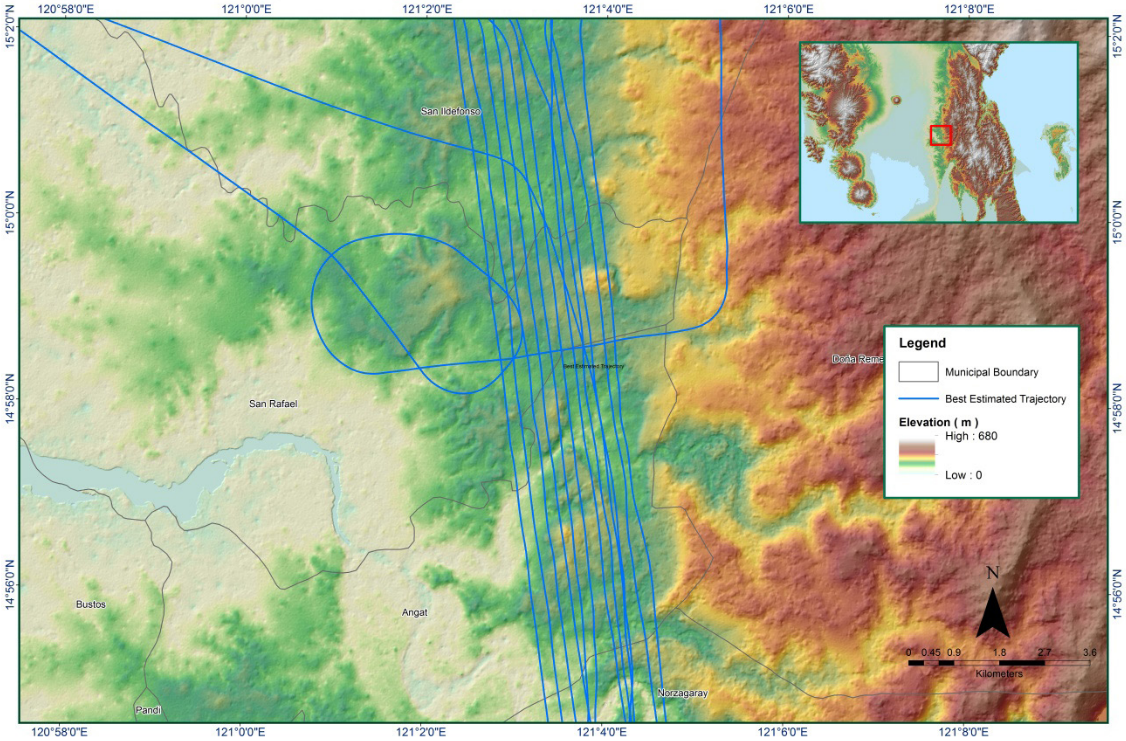


Figure A-8.80. Best Estimate Trajectory

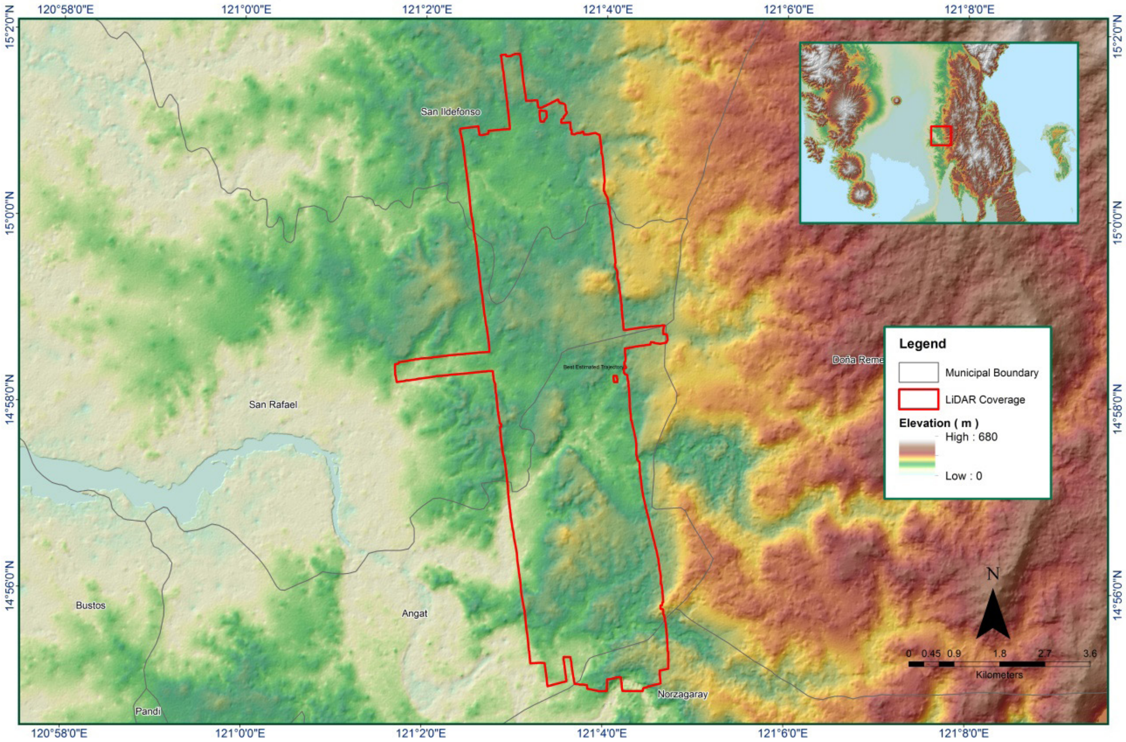


Figure A-8.81. Coverage of LiDAR data

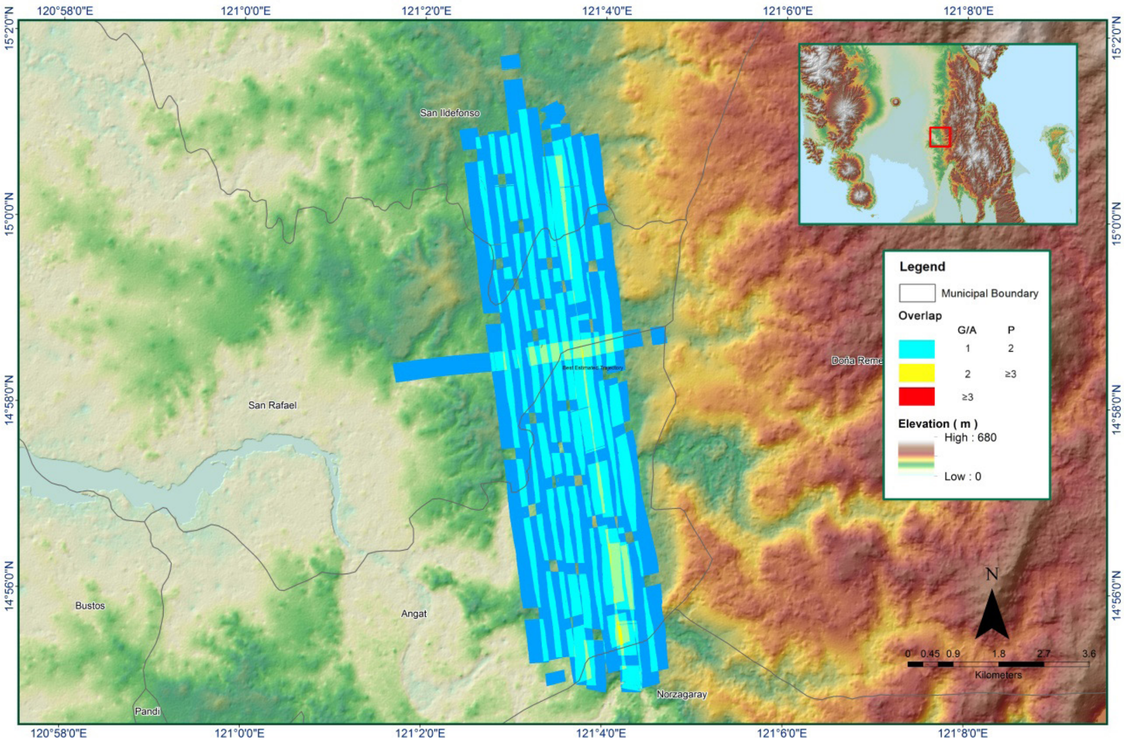


Figure A-8.82. Image of data overlap

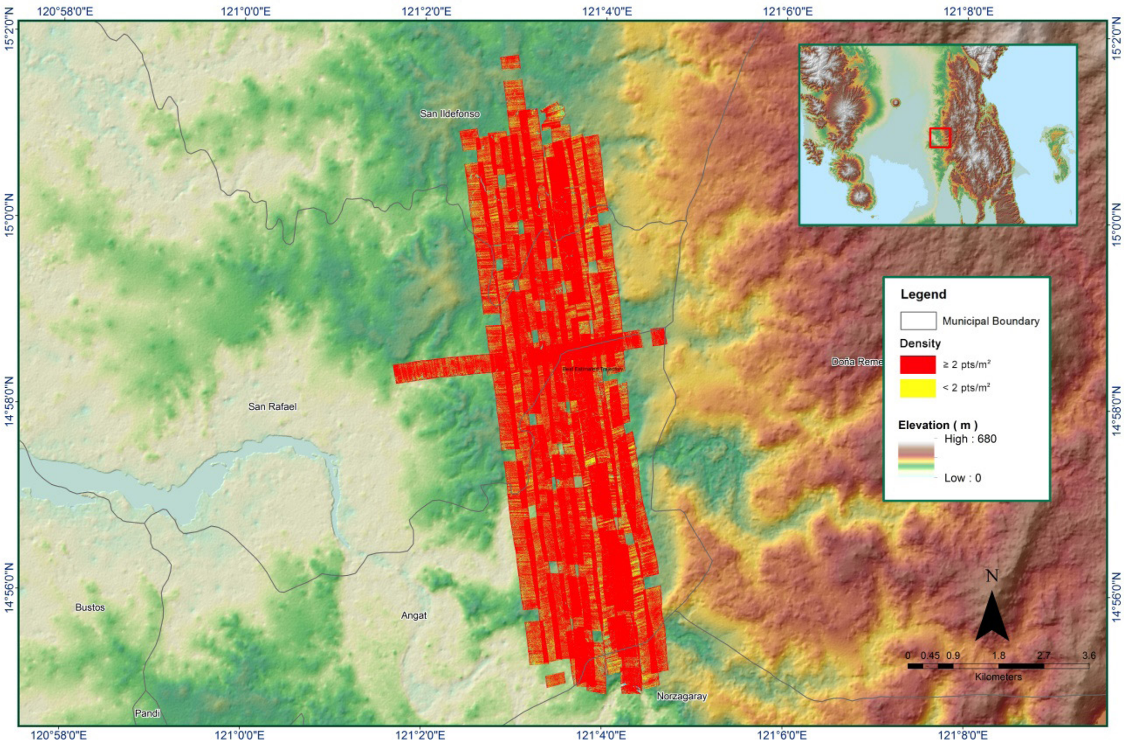


Figure A-8.83. Density Map of merged LiDAR data

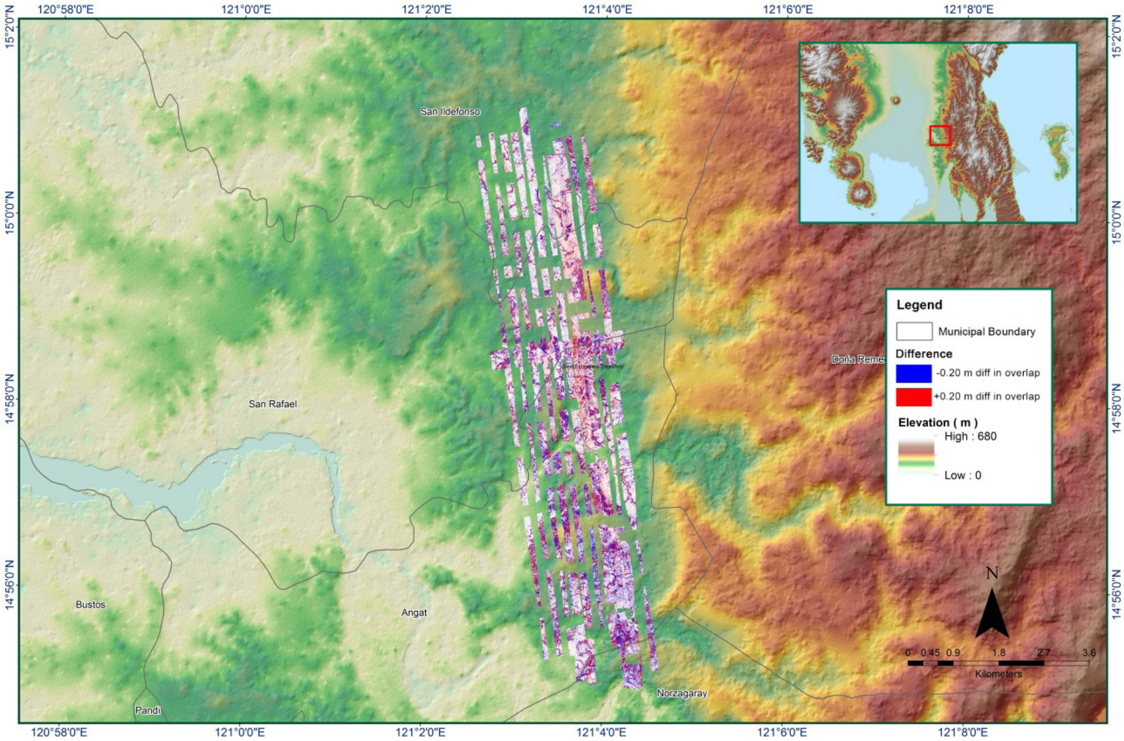


Figure A-8.84. Elevation Difference Between flight lines

Table A-8.13. Mission Summary Report for Mission Pam8B_additional

Flight Area	**Clark Reflights**
Mission Name	**Pam8B_additional**
Inclusive Flights	2304A
Range data size	4.2 GB
POS data size	173MB
Base data size	31.1MB
Image	N/A
Transfer date	December 12, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.721
RMSE for East Position (<4.0 cm)	1.568
RMSE for Down Position (<8.0 cm)	2.560
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	31.90
Ave point cloud density per sq.m. (>2.0)	2.88
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	29
Maximum Height	250.35 m
Minimum Height	77.52 m
Classification (# of points)	
Ground	4,573,992
Low vegetation	4,563,281
Medium vegetation	6,027,974
High vegetation	6,091,204
Building	181,511
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda

Figure A-8.85. Solution Status

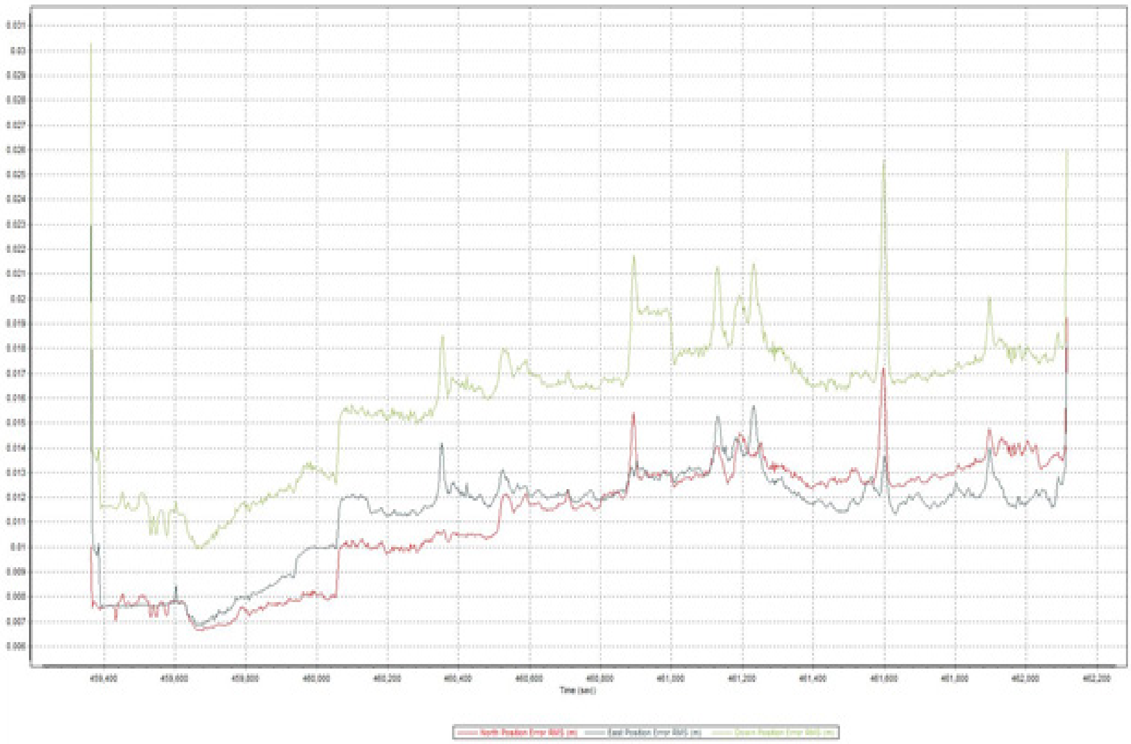


Figure A-8.86. Smoothed Performance Metric Parameters

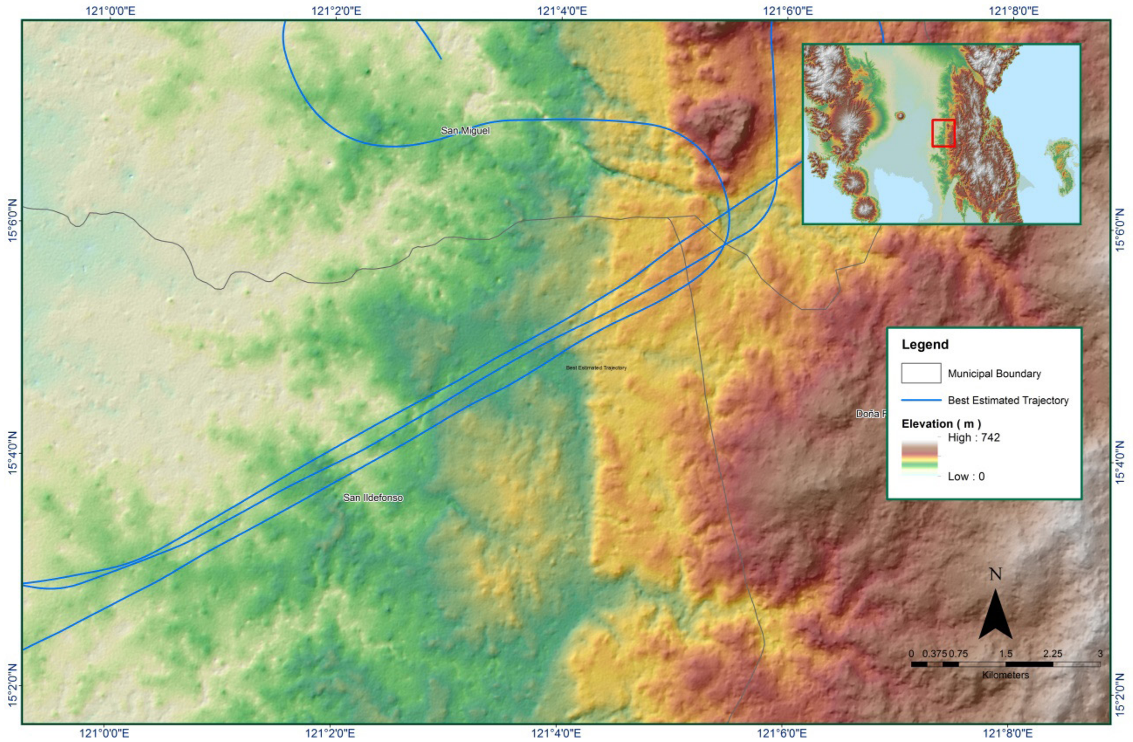


Figure A-8.87. Best Estimate Trajectory

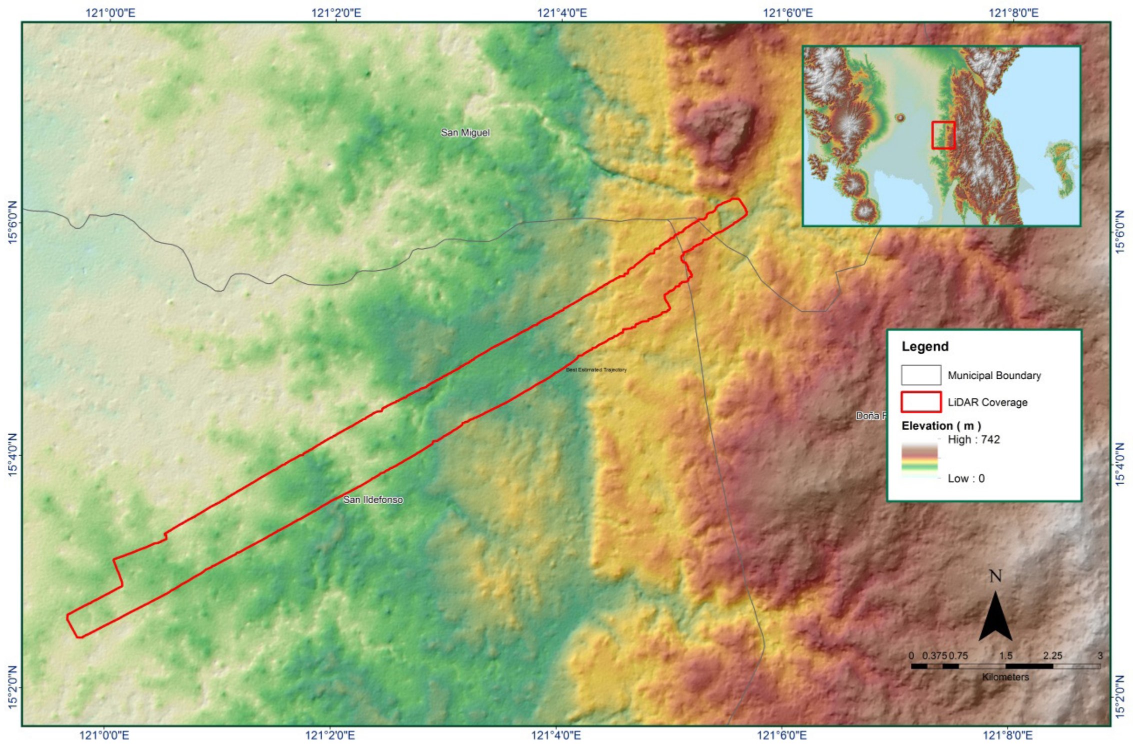


Figure A-8.88. Coverage of LiDAR data

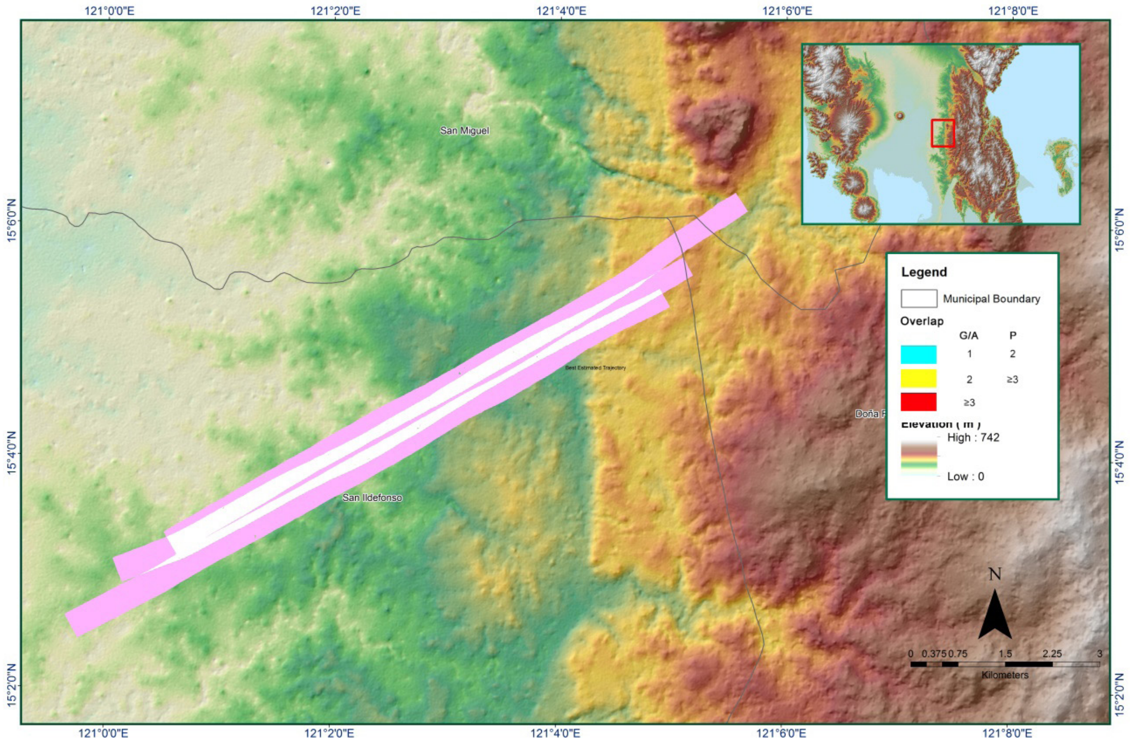


Figure A-8.89. Image of data overlap

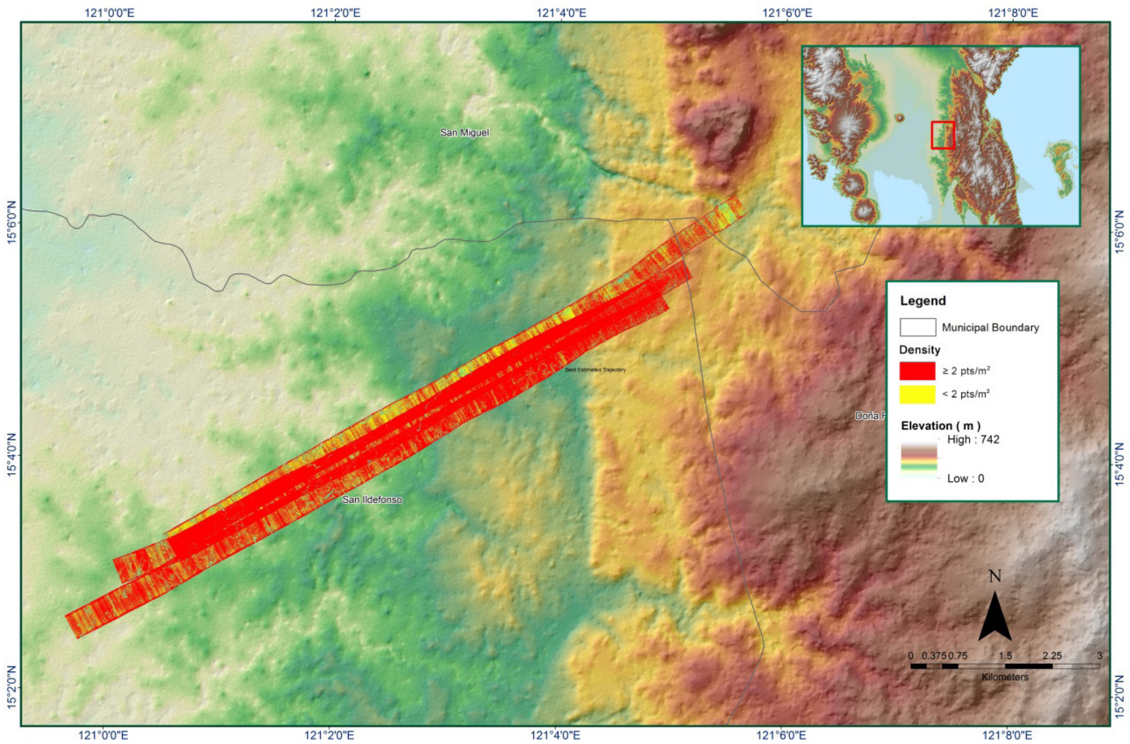


Figure A-8.90. Density Map of merged LiDAR data

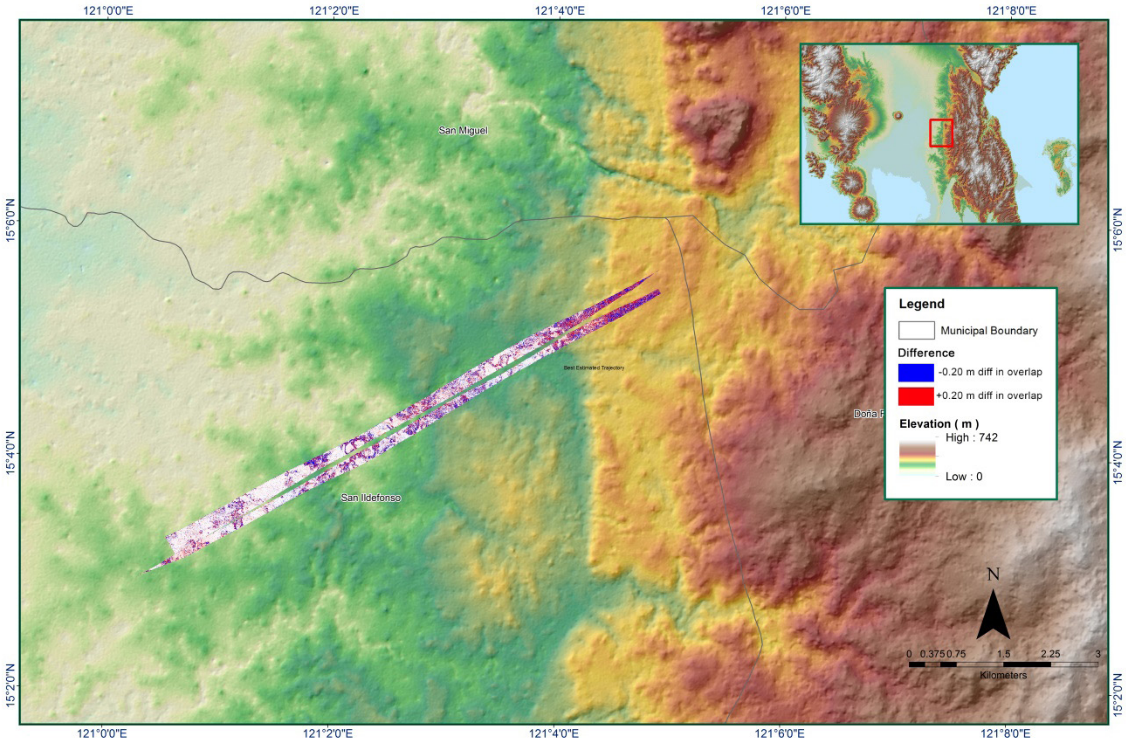


Figure A-8.91. Elevation Difference Between flight lines

Table A-8.14. Mission Summary Report for Mission Pam_Blk8_reflight_additional

Flight Area	**Pam_Agno Reflights**
Mission Name	**Pam_Blk8_reflight_additional**
Inclusive Flights	7271GC
Range data size	15.5 GB
POS data size	233 MB
Base data size	17 MB
Image	n/a
Transfer date	May 25, 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)	
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)	35.10
Ave point cloud density per sq.m. (>2.0)	3.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	29
Maximum Height	250.35 m
Minimum Height	77.52 m
Classification (# of points)	
Ground	4,573,992
Low vegetation	4,563,281
Medium vegetation	6,027,974
High vegetation	6,091,204
Building	181,511
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Chelou Prado, Engr. Gladys Mae Apat

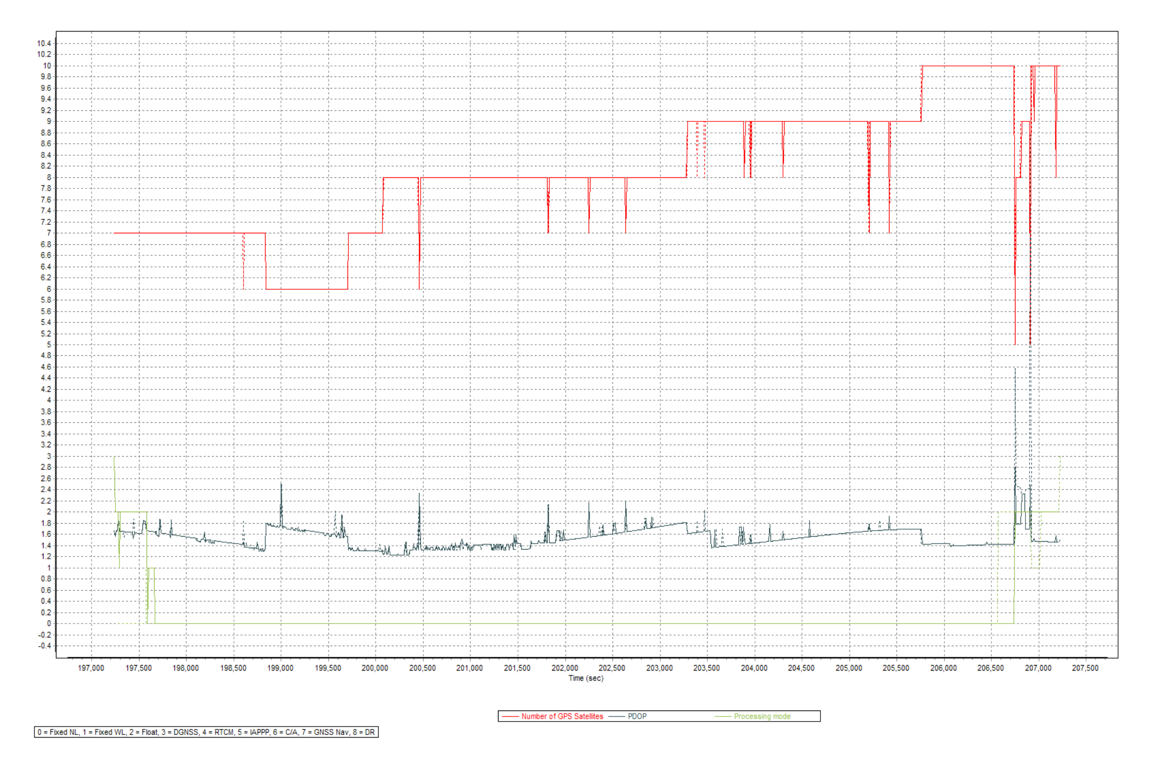


Figure A-8.92. Solution Status

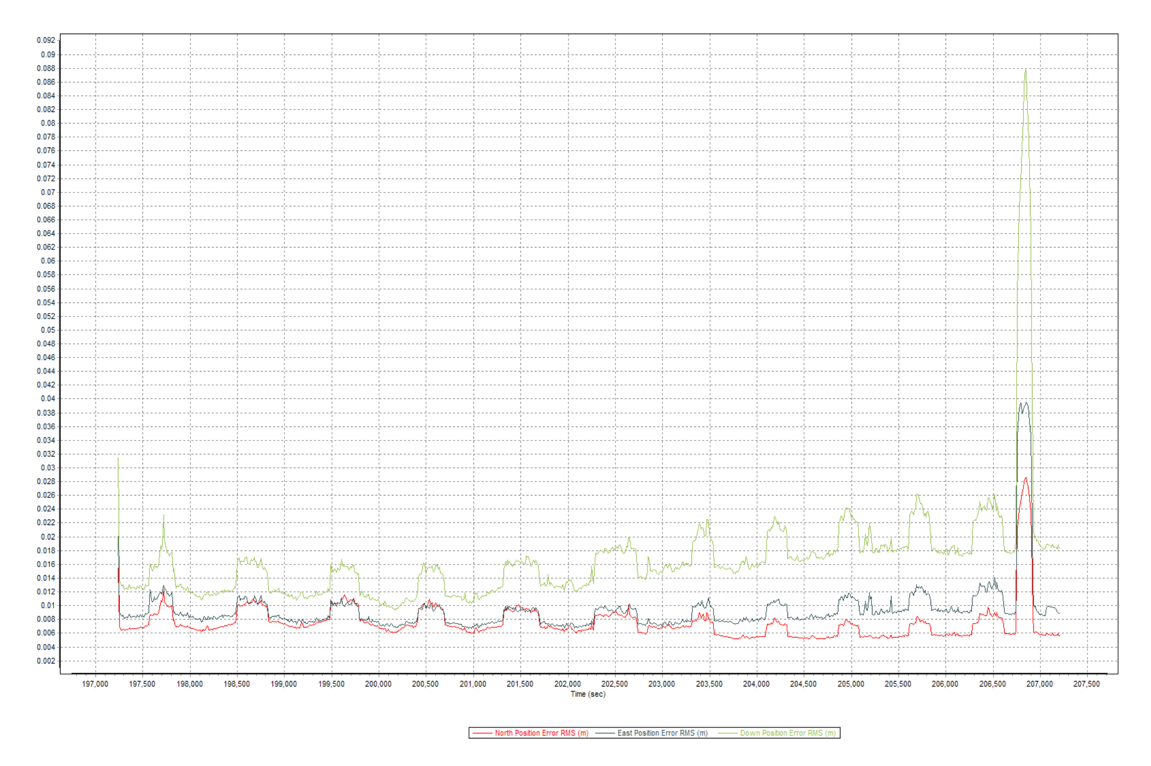


Figure A-8.93. Smoothed Performance Metric Parameters

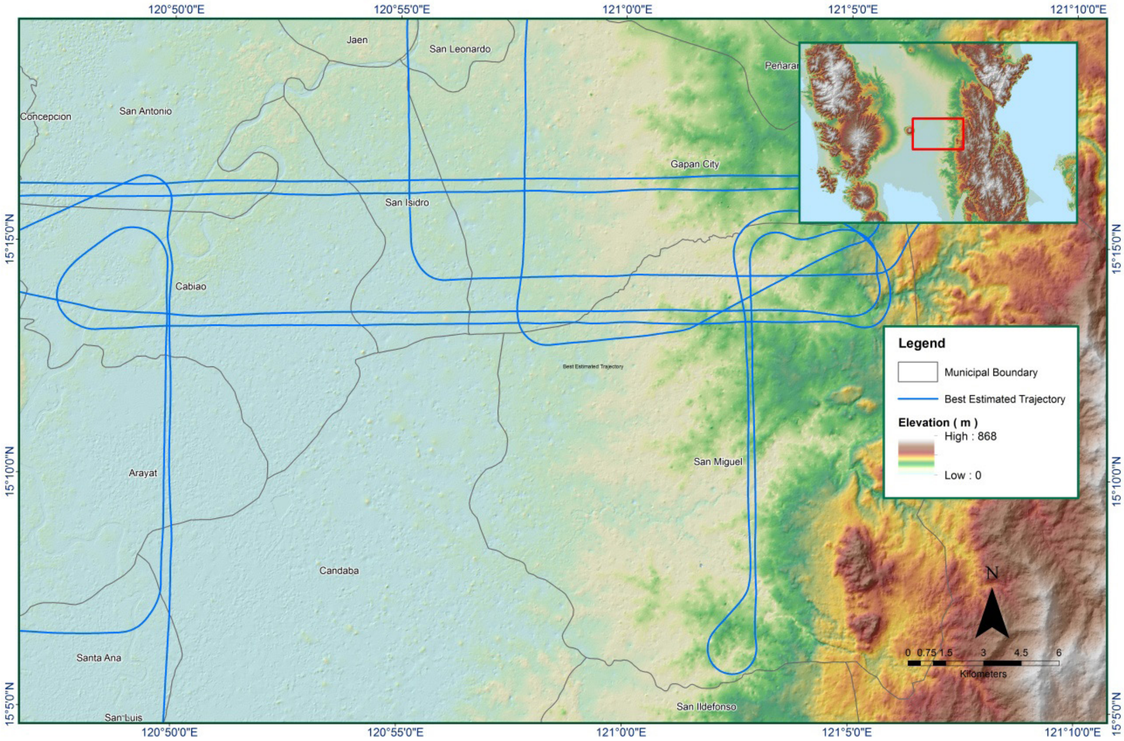


Figure A-8.94. Best Estimate Trajectory

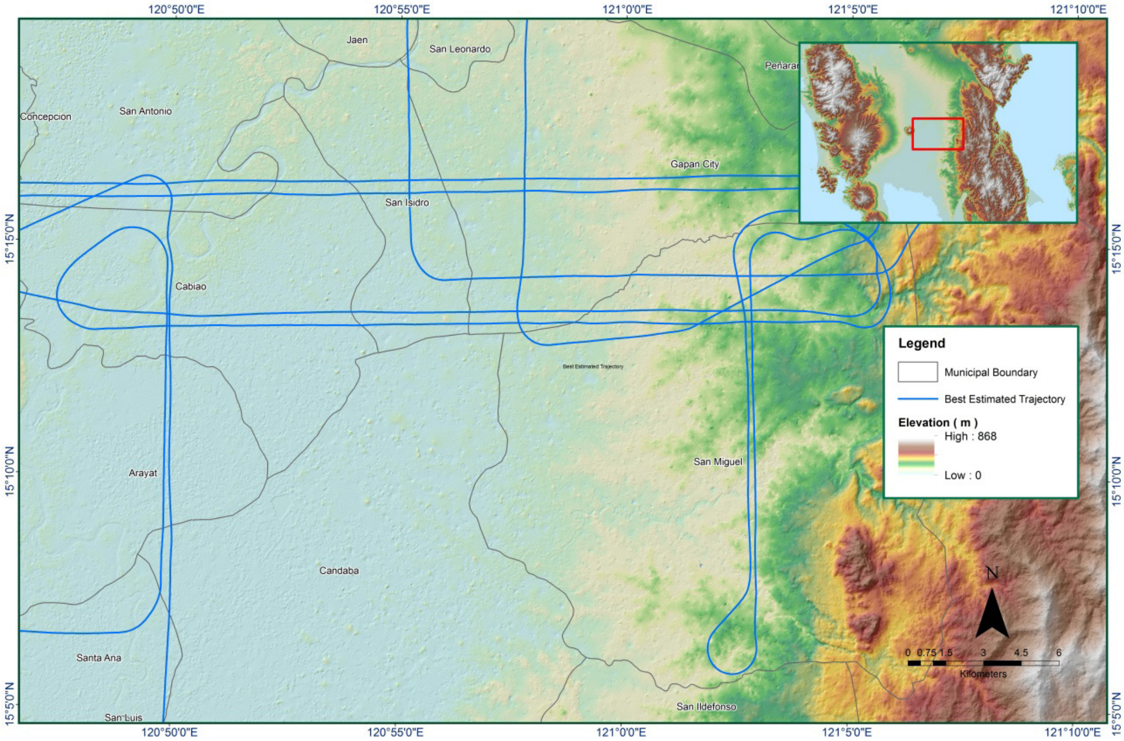


Figure A-8.95. Coverage of LiDAR data

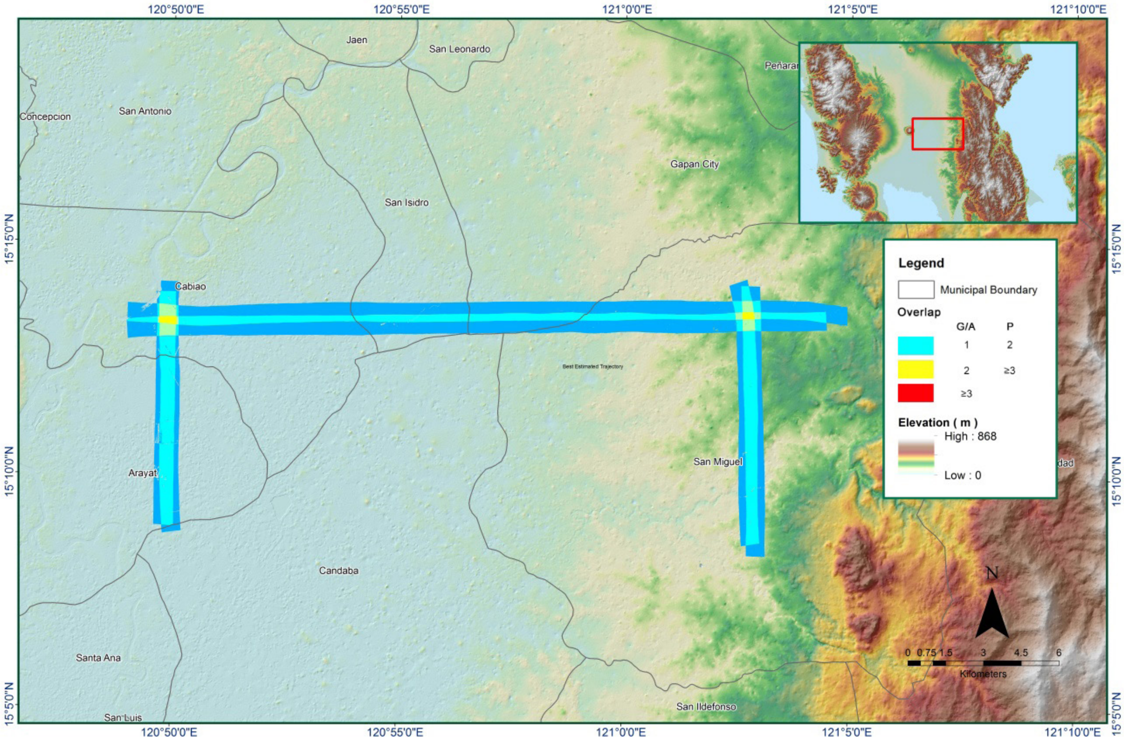


Figure A-8.96. Image of data overlap

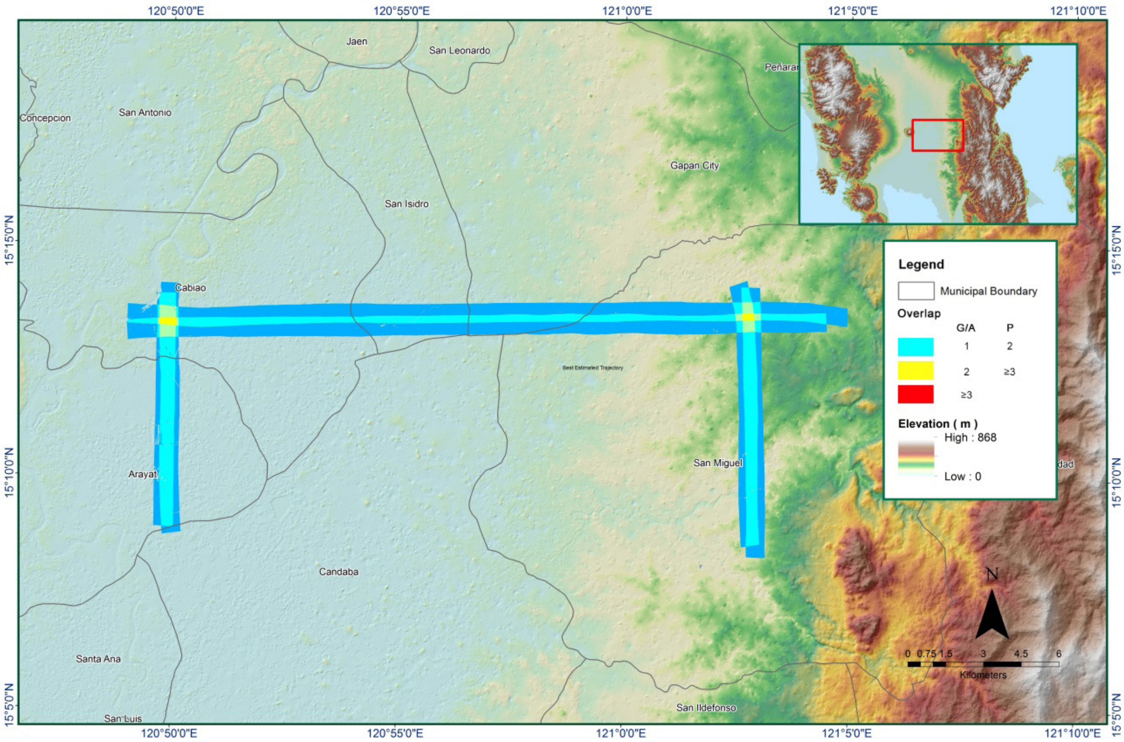


Figure A-8.97. Density Map of merged LiDAR data

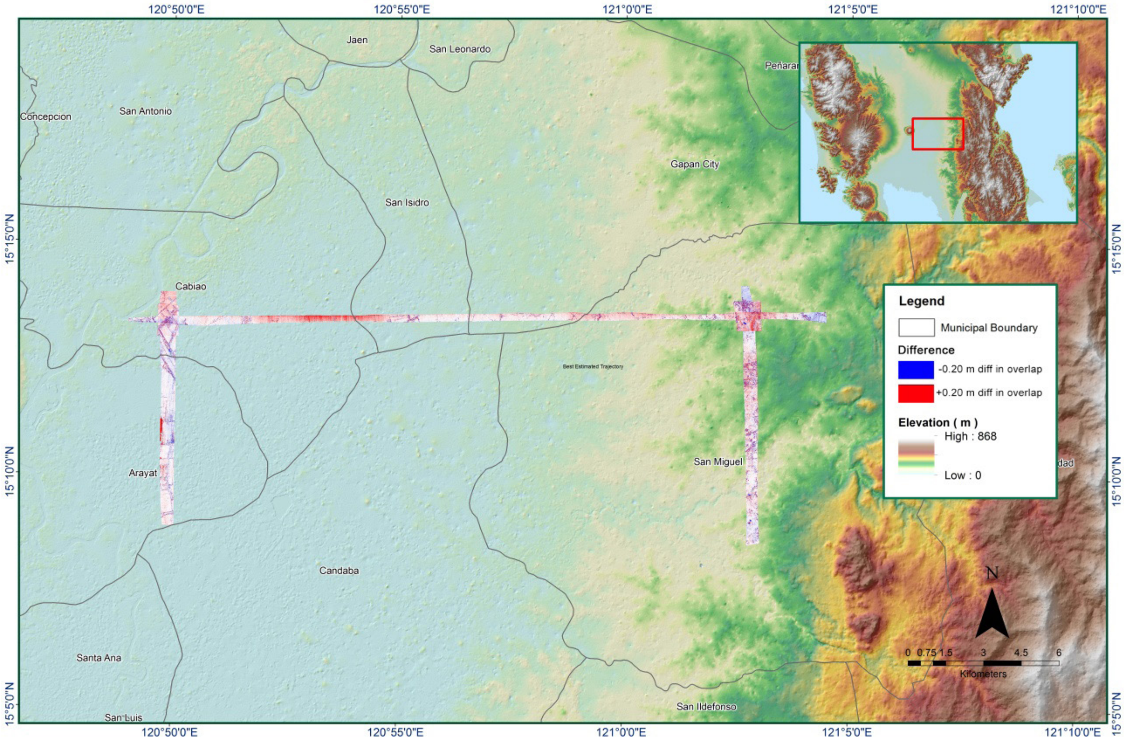


Figure A-8.98. Elevation Difference Between flight lines

Table A-8.15. Mission Summary Report for Mission Pam_Blk3D_reflight

Flight Area	**Pam_Agno_Reflights**
Mission Name	**Pam_Blk3D_reflight**
Inclusive Flights	7268GC
Range data size	14.7 GB
POS data size	223 MB
Base data size	11.3 MB
Image	n/a
Transfer date	May 24, 2014
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)	2.197
RMSE for East Position (<4.0 cm)	1.996
RMSE for Down Position (<8.0 cm)	8.218
Boresight correction stdev (<0.001deg)	0.001711
IMU attitude correction stdev (<0.001deg)	0.002627
GPS position stdev (<0.01m)	0.001800
Minimum % overlap (>25)	n/a
Ave point cloud density per sq.m. (>2.0)	2.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	29
Maximum Height	250.35 m
Minimum Height	77.52 m
Classification (# of points)	
Ground	4,573,992
Low vegetation	4,563,281
Medium vegetation	6,027,974
High vegetation	6,091,204
Building	181,511
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Jeffrey Delica

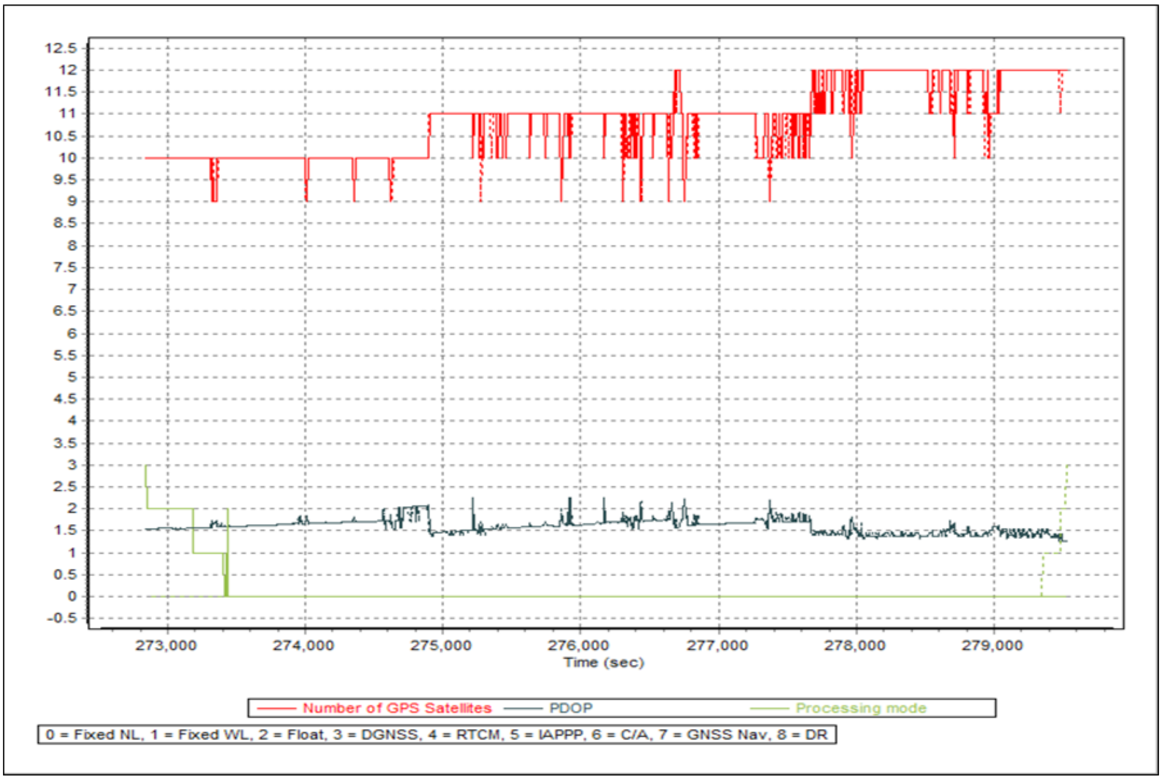


Figure A-8.99. Solution Status

Figure A-8.100. Smoothed Performance Metric Parameters

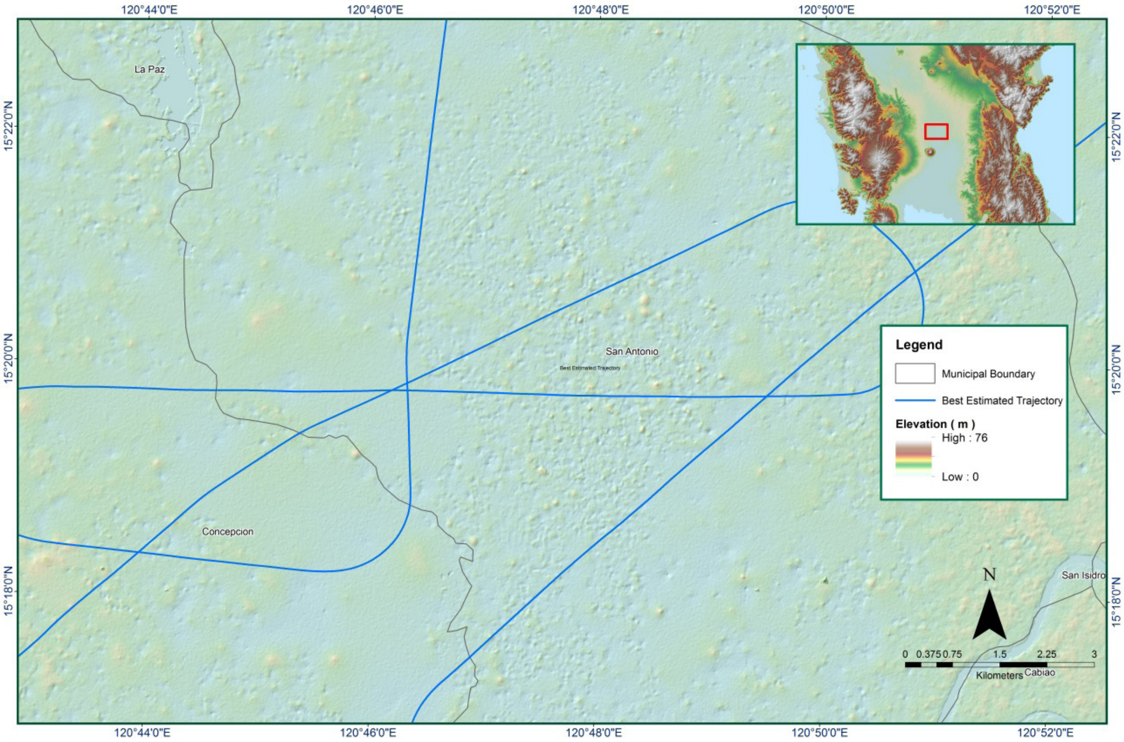


Figure A-8.101. Best Estimate Trajectory

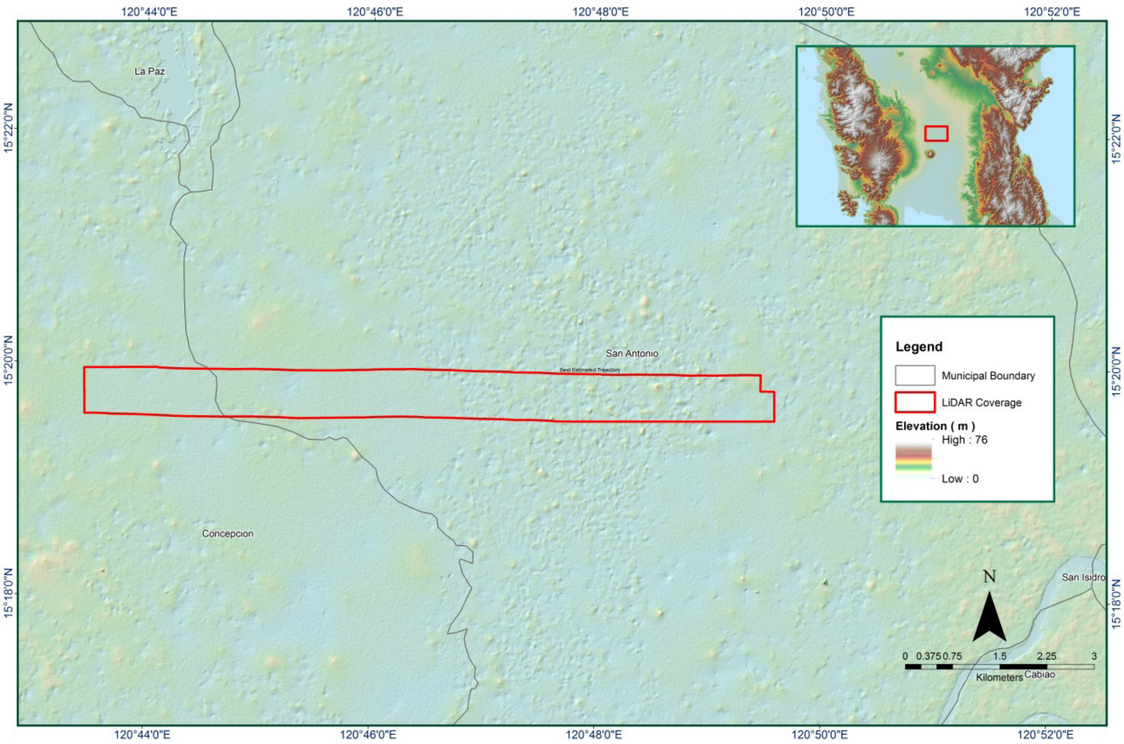


Figure A-8.102. Coverage of LiDAR data

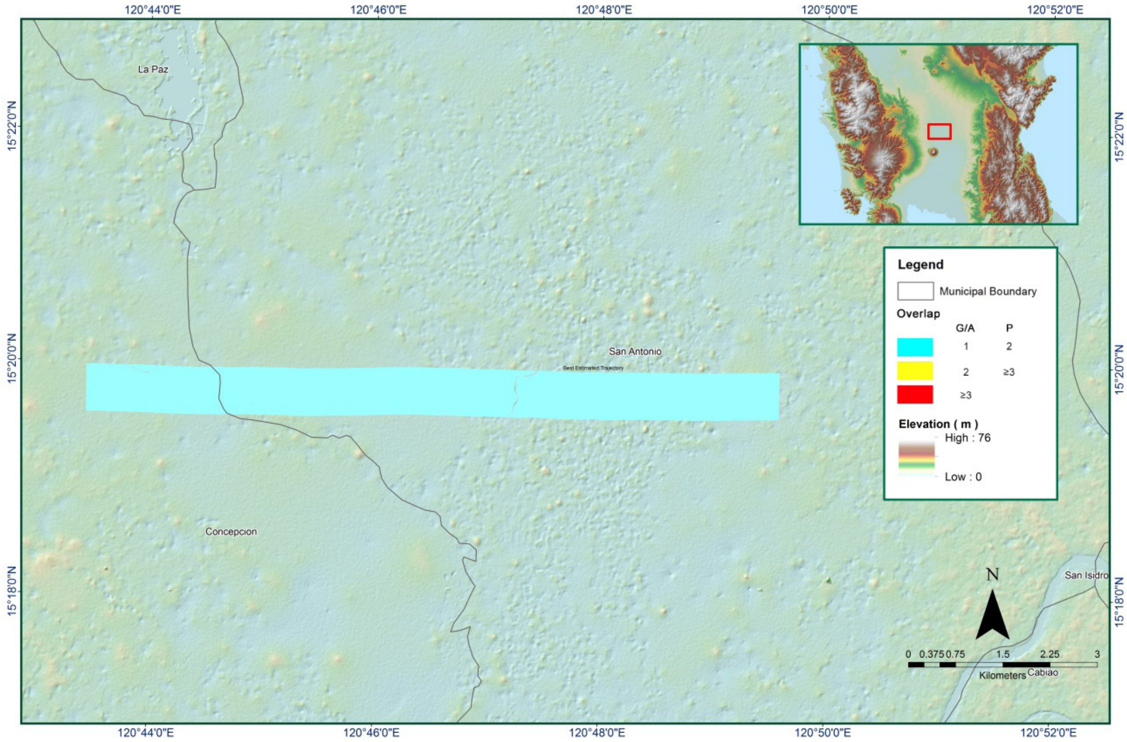


Figure A-8.103. Image of data overlap

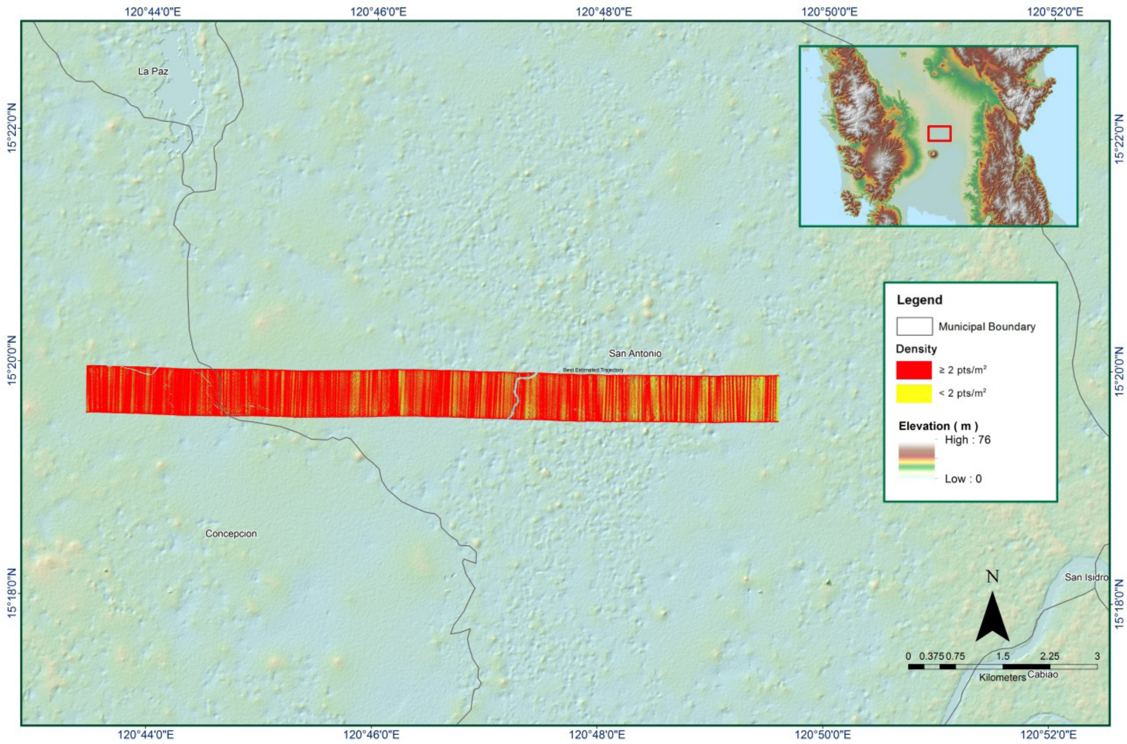


Figure A-8.104. Density Map of merged LiDAR data

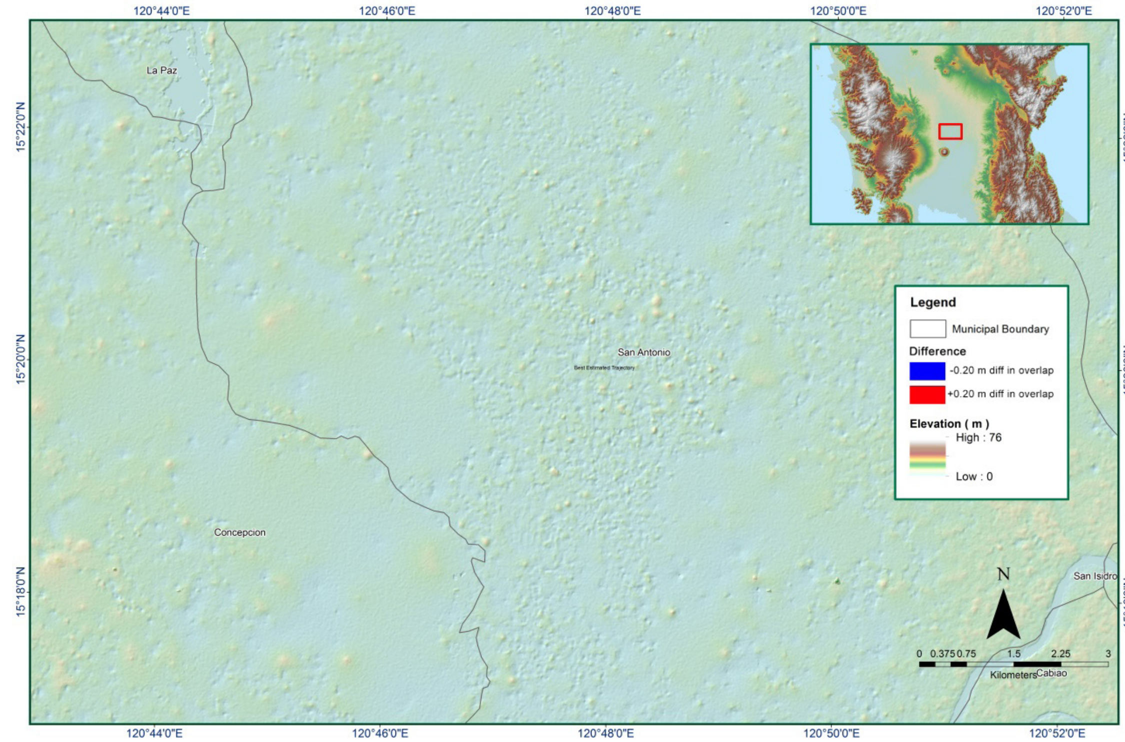


Figure A-8.105. Elevation Difference Between flight lines

Table A-8.16. Mission Summary Report for Mission Pam3C_reflight

Flight Area	**Pam_Agno_Reflights**
Mission Name	**Pam3C_reflight**
Inclusive Flights	7268GC
Range data size	14.7 GB
POS data size	223 MB
Base data size	11.3 MB
Image	n/a
Transfer date	May 24, 2014
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)	2.197
RMSE for East Position (<4.0 cm)	1.996
RMSE for Down Position (<8.0 cm)	8.218
Boresight correction stdev (<0.001deg)	0.001711
IMU attitude correction stdev (<0.001deg)	0.002627
GPS position stdev (<0.01m)	0.001800
Minimum % overlap (>25)	19.10
Ave point cloud density per sq.m. (>2.0)	2.72
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	29
Maximum Height	250.35 m
Minimum Height	77.52 m
Classification (# of points)	
Ground	4,573,992
Low vegetation	4,563,281
Medium vegetation	6,027,974
High vegetation	6,091,204
Building	181,511
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga, Jr., Engr. Melissa Fernandez

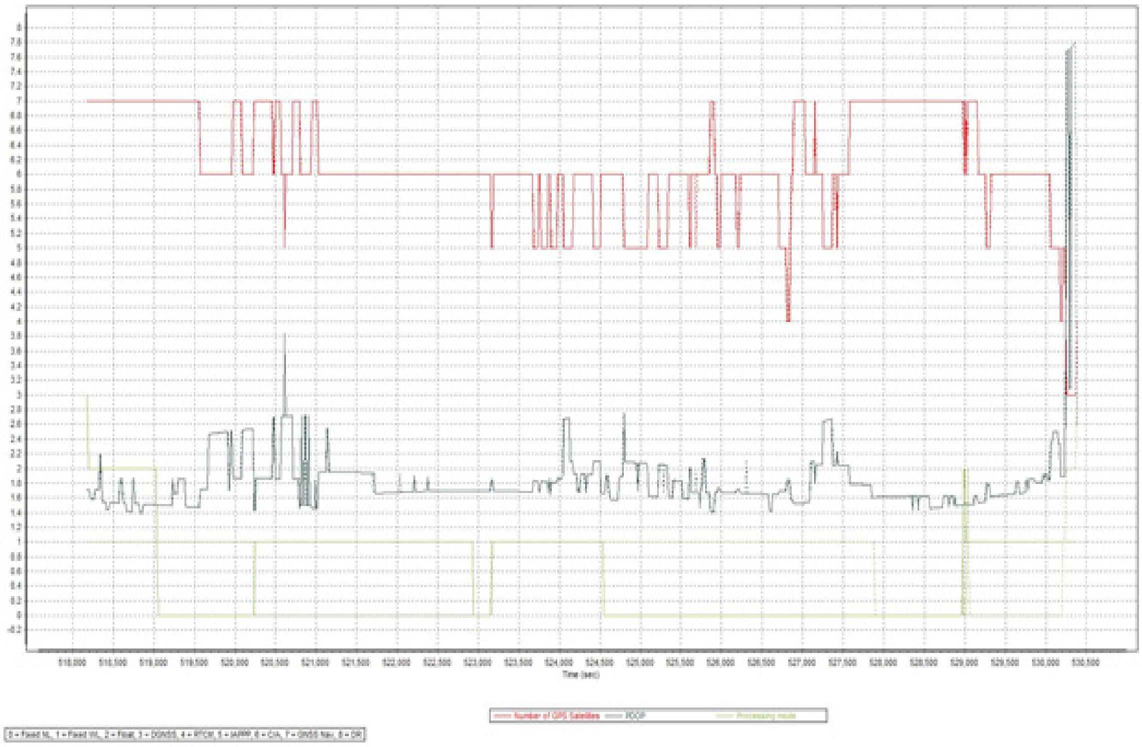


Figure A-8.106. Solution Status

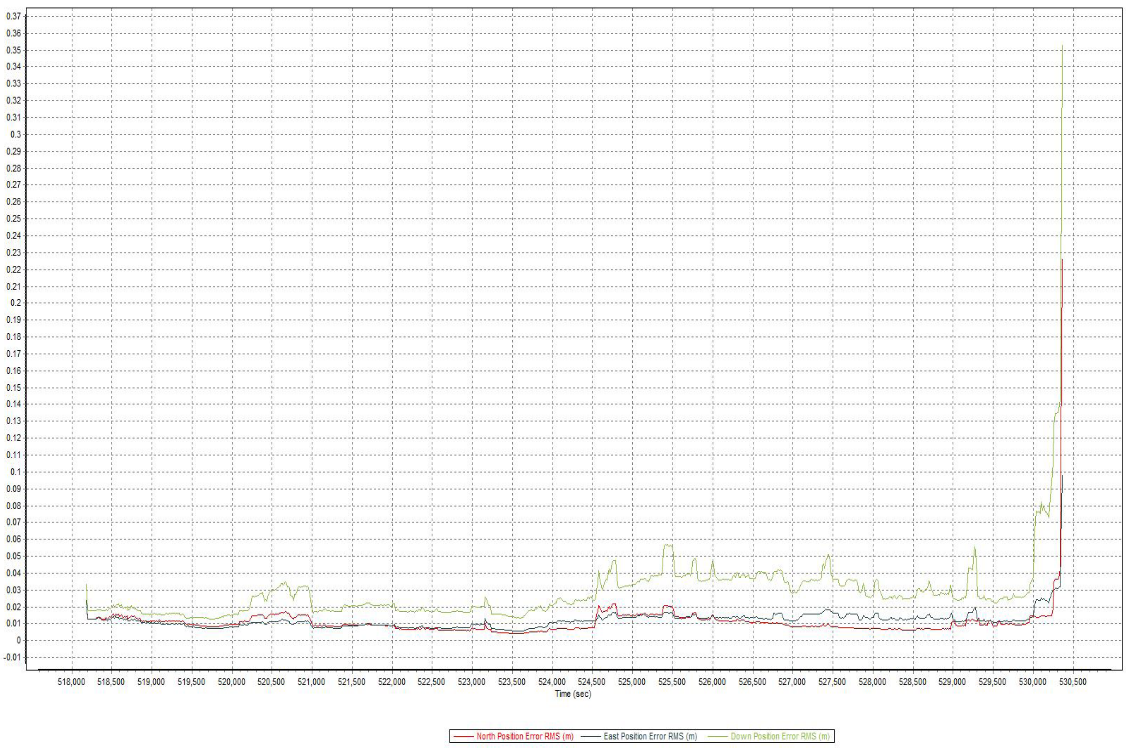


Figure A-8.107. Smoothed Performance Metric Parameters

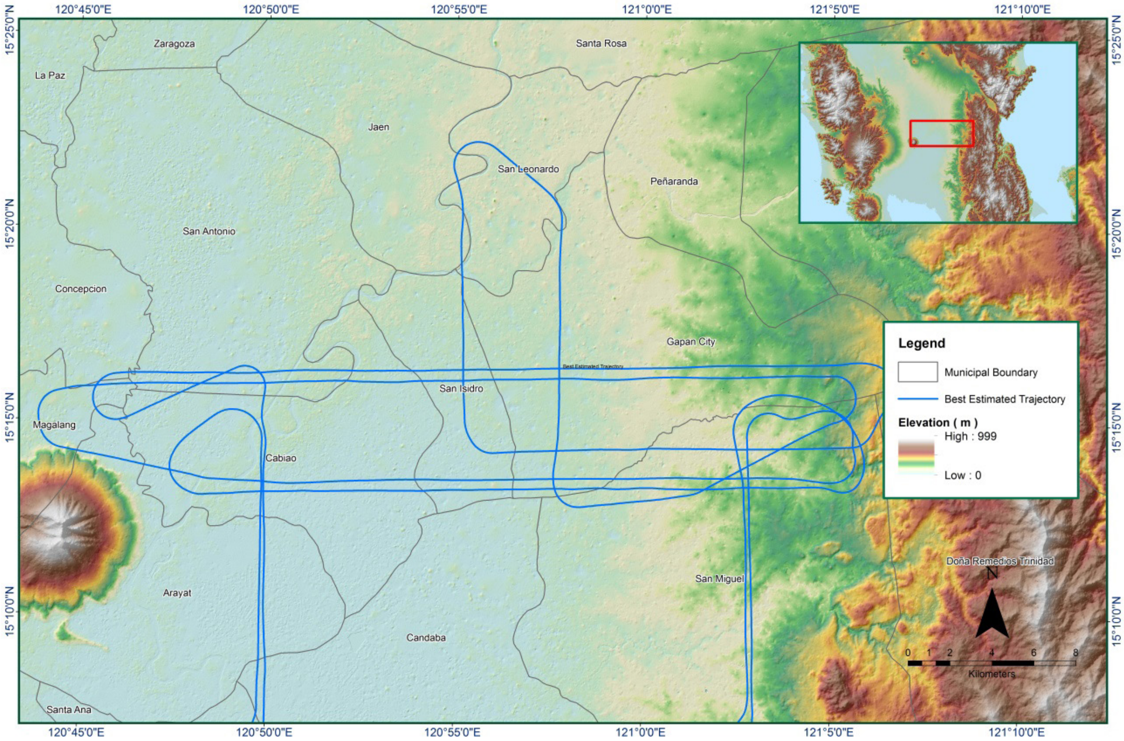


Figure A-8.108. Best Estimate Trajectory

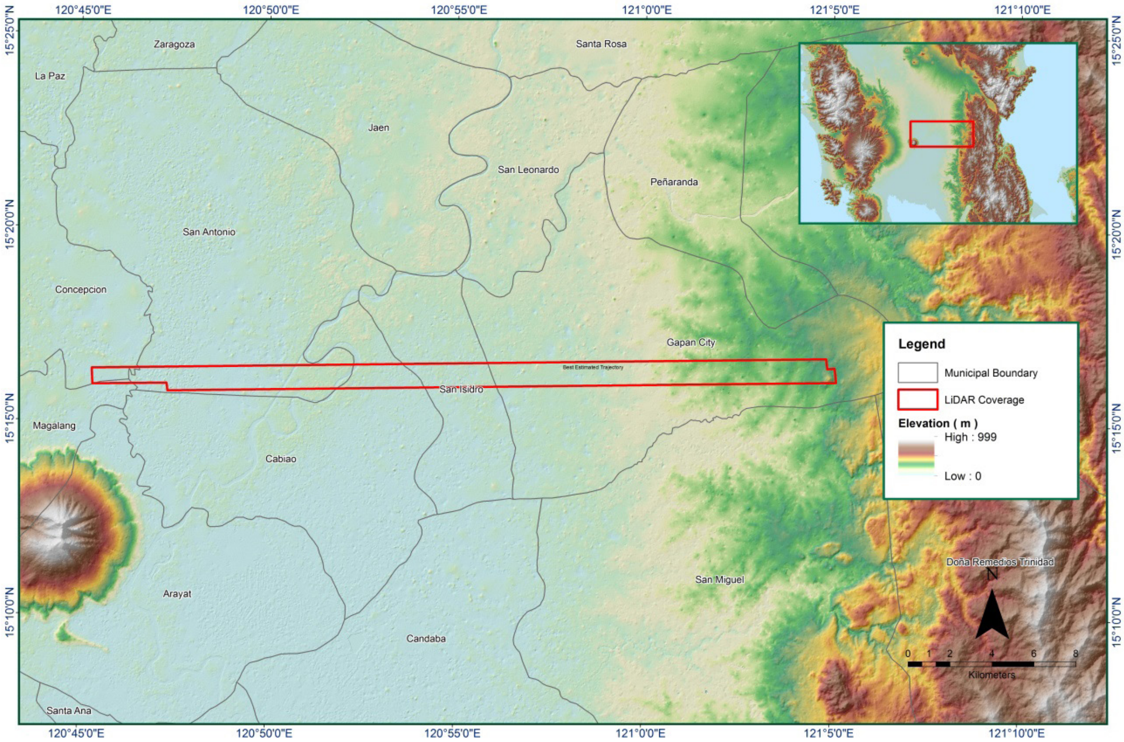


Figure A-8.109. Coverage of LiDAR data

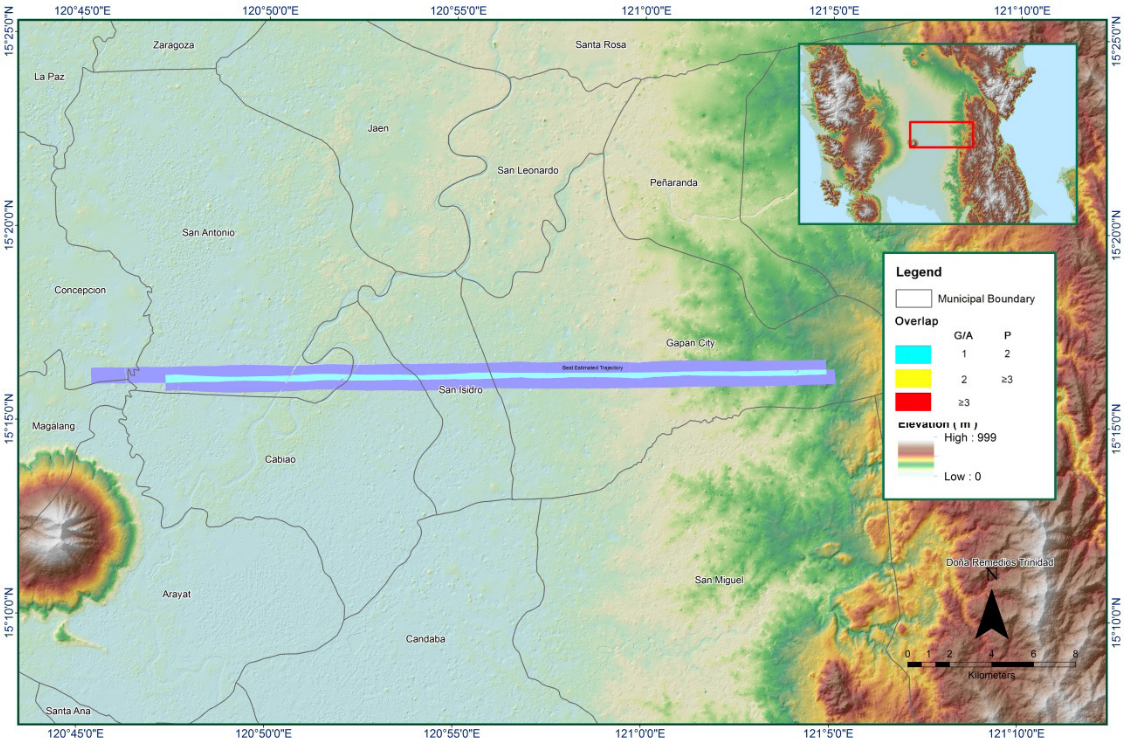


Figure A-8.110. Image of data overlap

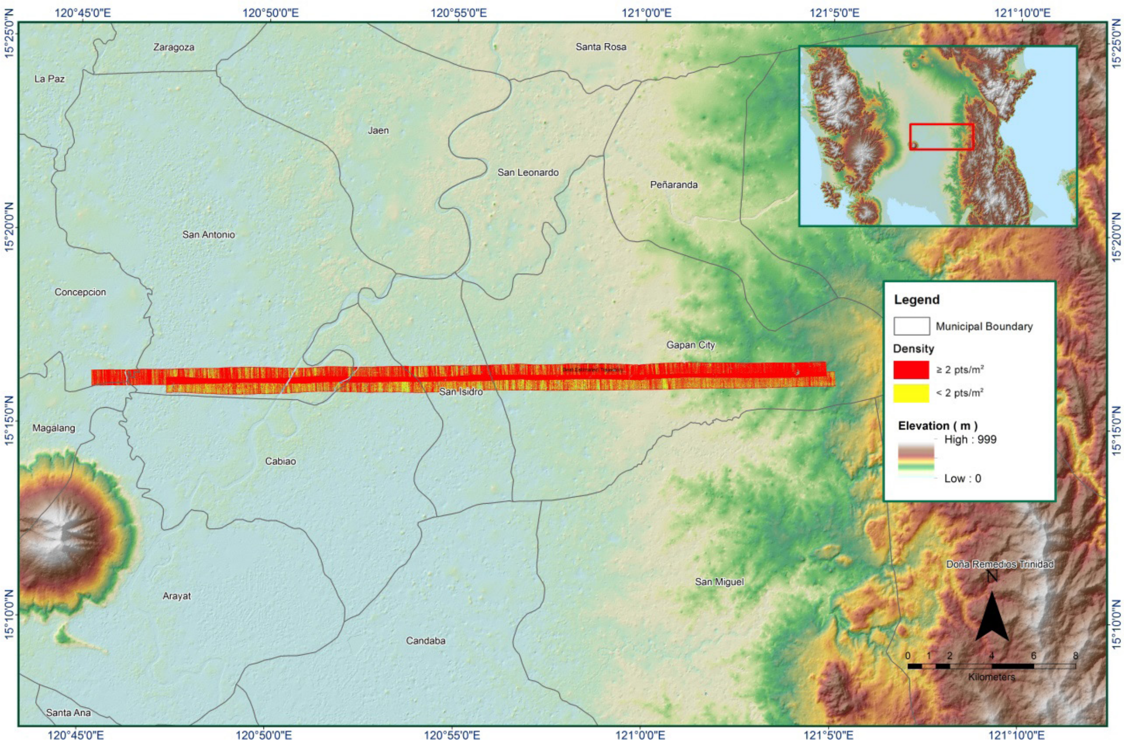


Figure A-8.111. Density Map of merged LiDAR data

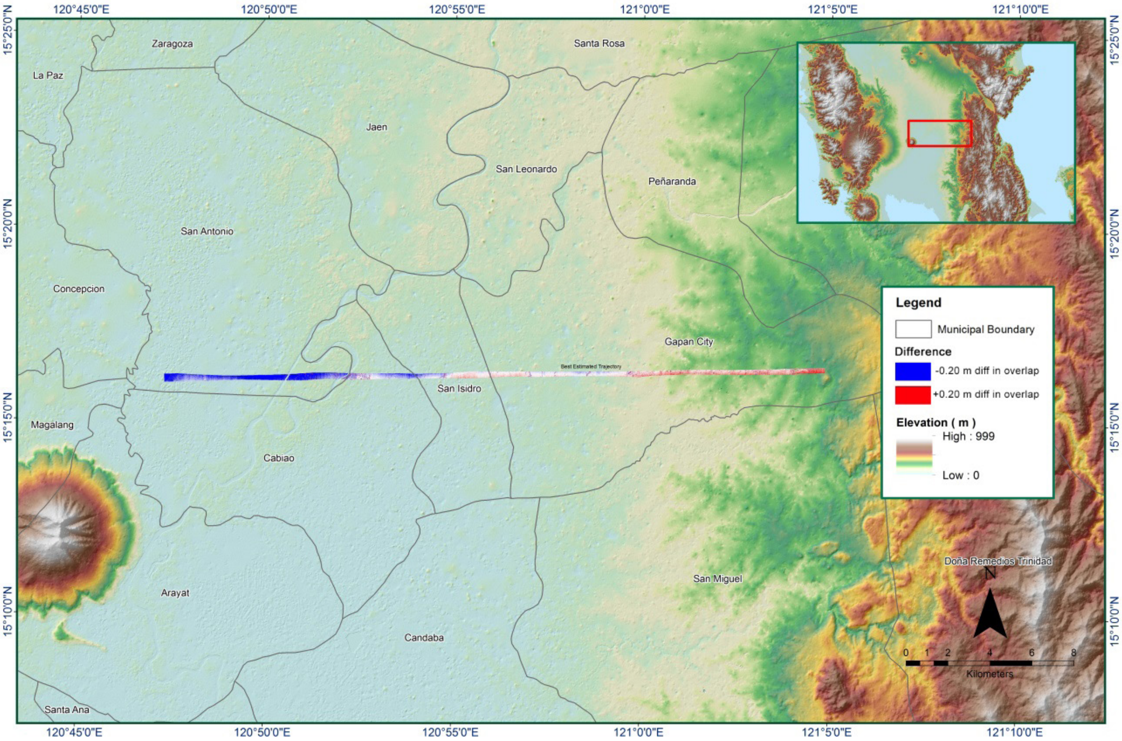


Figure A-8.112. Elevation Difference Between flight lines

Table A-8.17. Mission Summary Report for Mission Pam3A_reflight

Flight Area	**Pam_Agno_Reflights**
Mission Name	**Pam3A_reflight**
Inclusive Flights	7253G
Range data size	10.8 GB
POS data size	228 MB
Base data size	11.7 MB
Image	n/a
Transfer date	May 16, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1374
RMSE for East Position (<4.0 cm)	1.3443
RMSE for Down Position (<8.0 cm)	2.1918
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	40.19
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	29
Maximum Height	250.35 m
Minimum Height	77.52 m
Classification (# of points)	
Ground	4,573,992
Low vegetation	4,563,281
Medium vegetation	6,027,974
High vegetation	6,091,204
Building	181,511
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Engr. Elainne Lopez

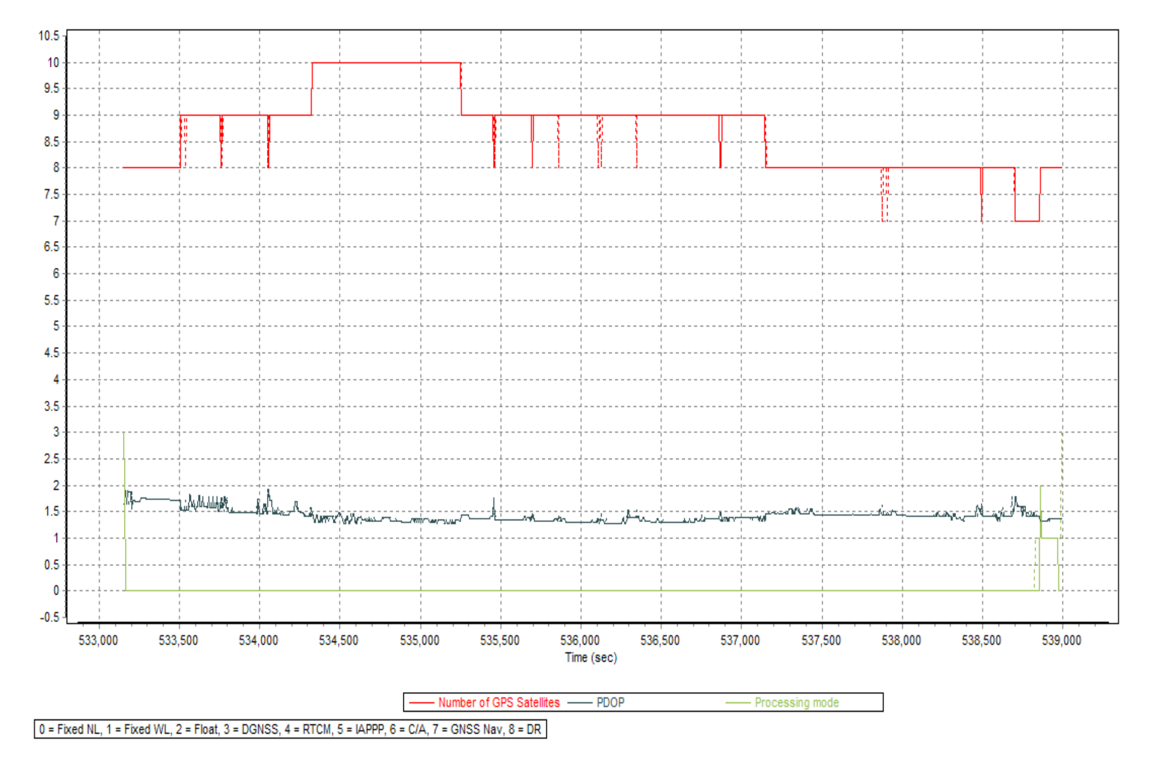


Figure A-8.113. Solution Status

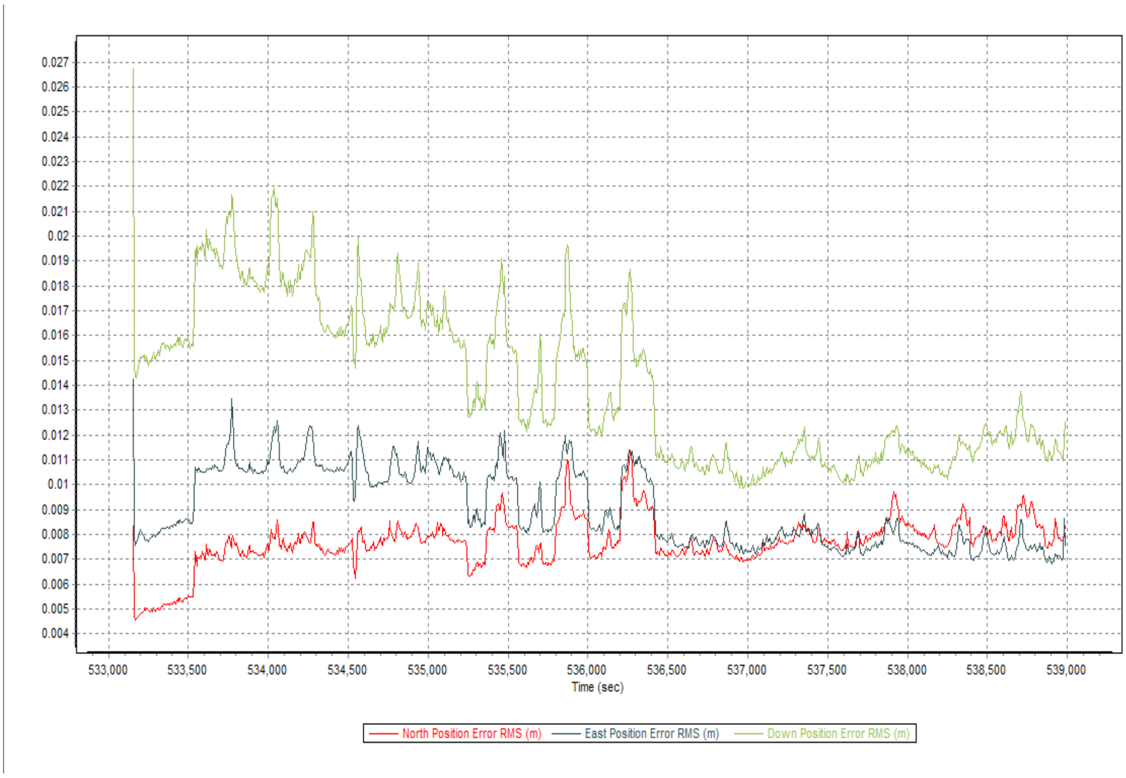


Figure A-8.114. Smoothed Performance Metric Parameters

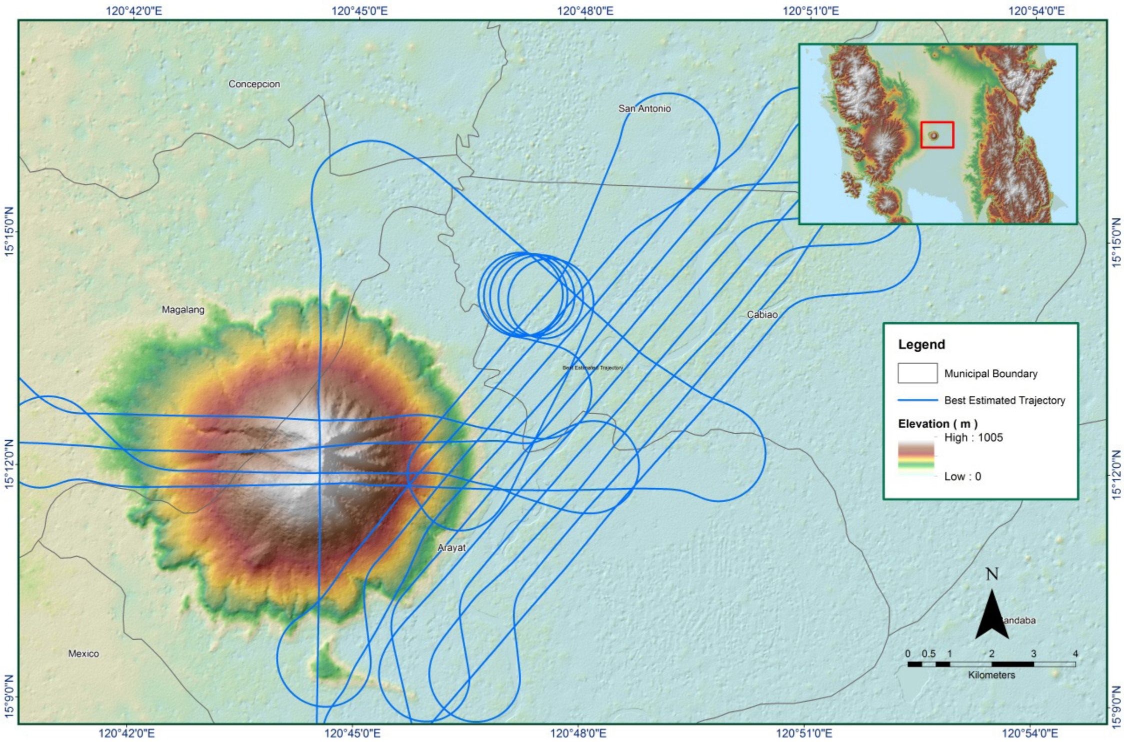


Figure A-8.115. Best Estimate Trajectory

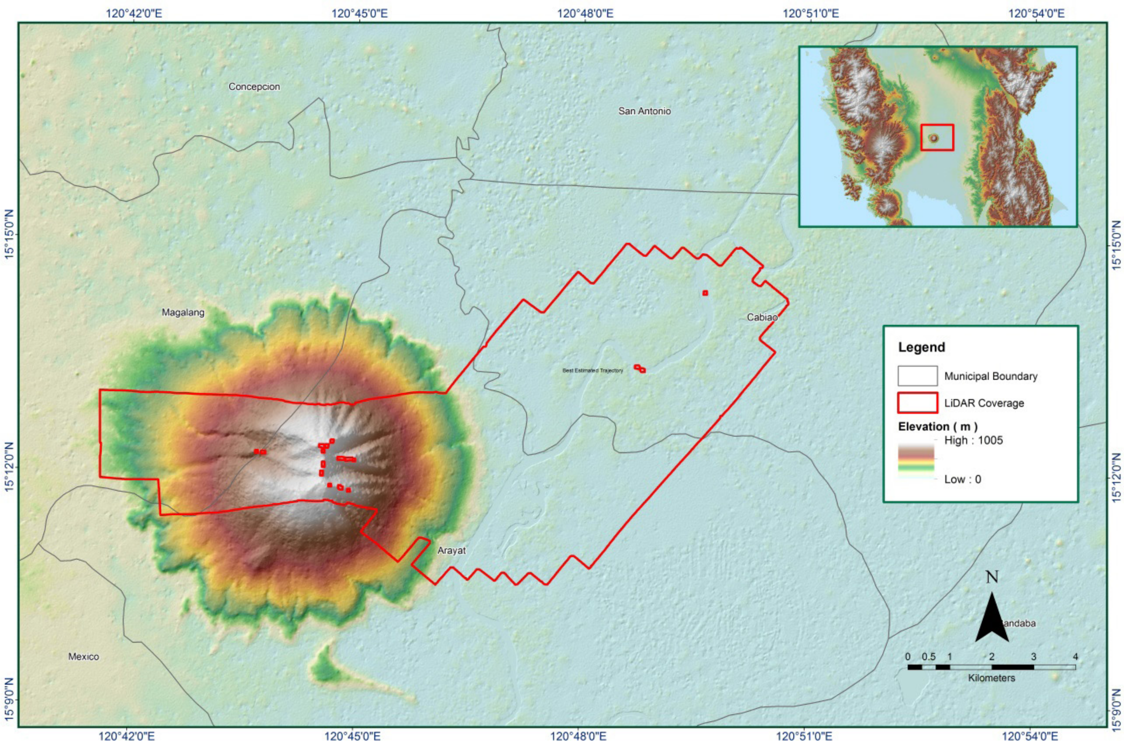


Figure A-8.116. Coverage of LiDAR data

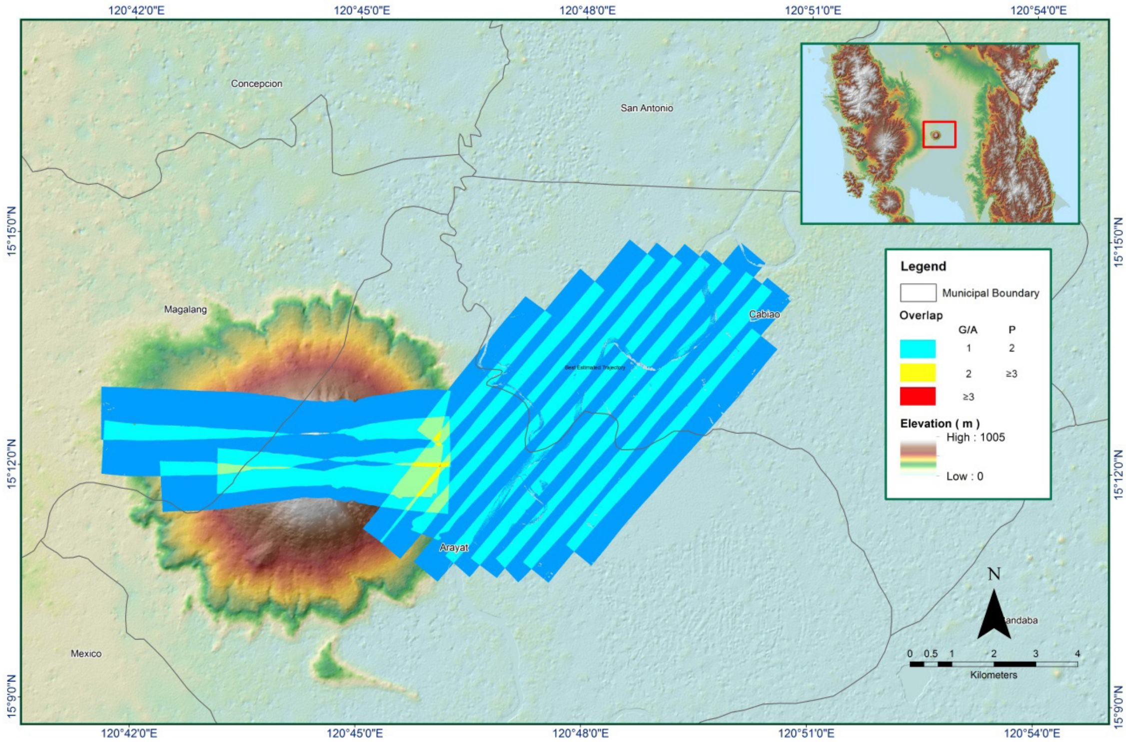


Figure A-8.117. Image of data overlap

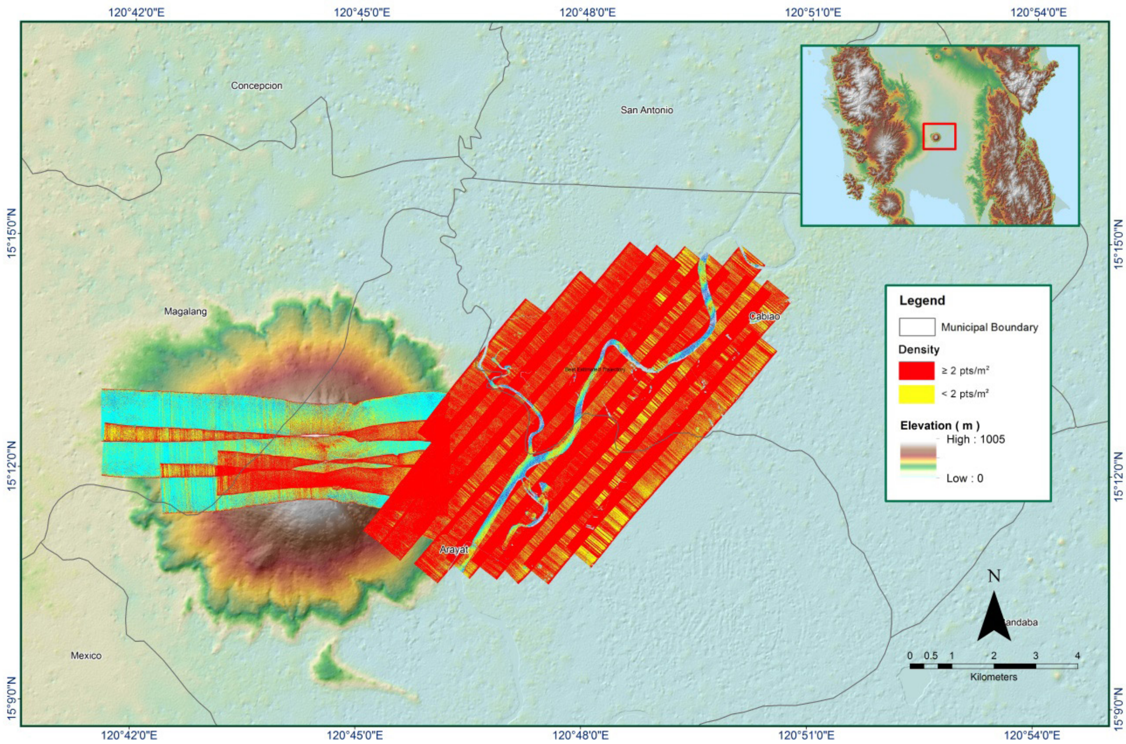


Figure A-8.118. Density Map of merged LiDAR data

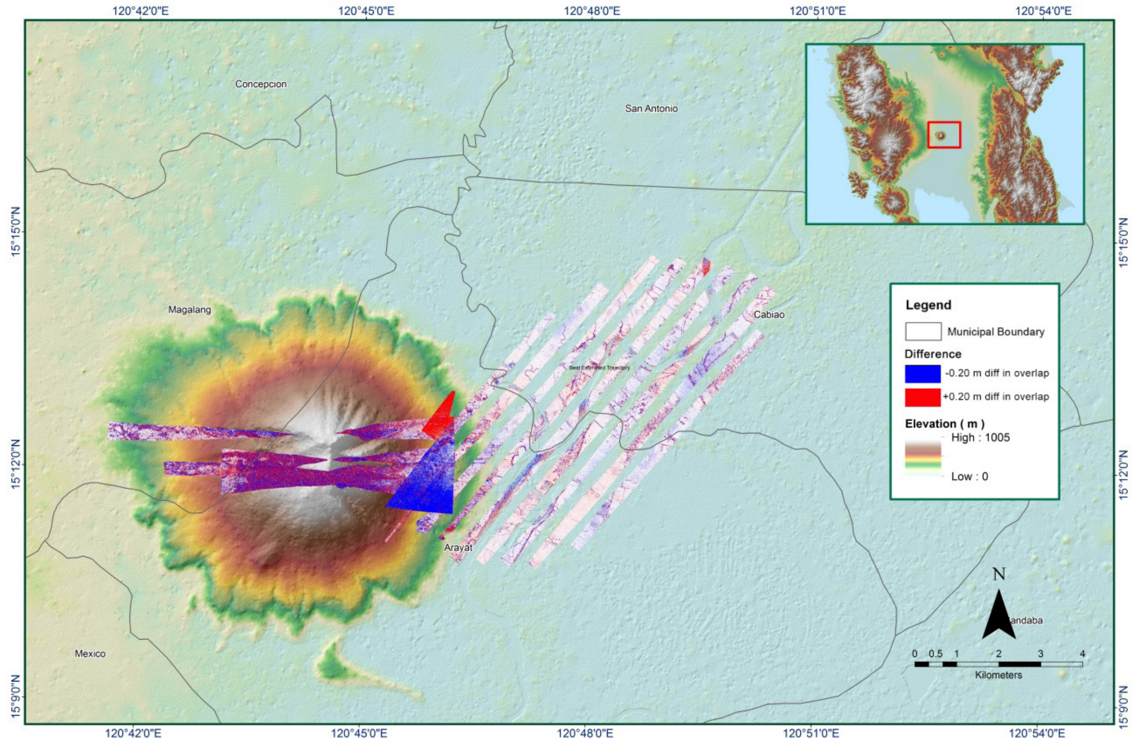


Figure A-8.119. Elevation Difference Between flight lines

Table A-8.18. Mission Summary Report for Mission Blk_7038GC

Flight Area	**Clark Reflights**
Mission Name	**Blk_7038GC**
Inclusive Flights	7038GC
Range data size	8.65 GB
POS data size	n/a
Base data size	3.77 MB
Image	n/a
Transfer date	January 29, 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)	0.750
RMSE for East Position (<4.0 cm)	1.010
RMSE for Down Position (<8.0 cm)	2.700
Boresight correction stdev (<0.001deg)	0.001711
IMU attitude correction stdev (<0.001deg)	0.002627
GPS position stdev (<0.01m)	0.001800
Minimum % overlap (>25)	28.71
Ave point cloud density per sq.m. (>2.0)	3.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	29
Maximum Height	250.35 m
Minimum Height	77.52 m
Classification (# of points)	
Ground	4,573,992
Low vegetation	4,563,281
Medium vegetation	6,027,974
High vegetation	6,091,204
Building	181,511
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

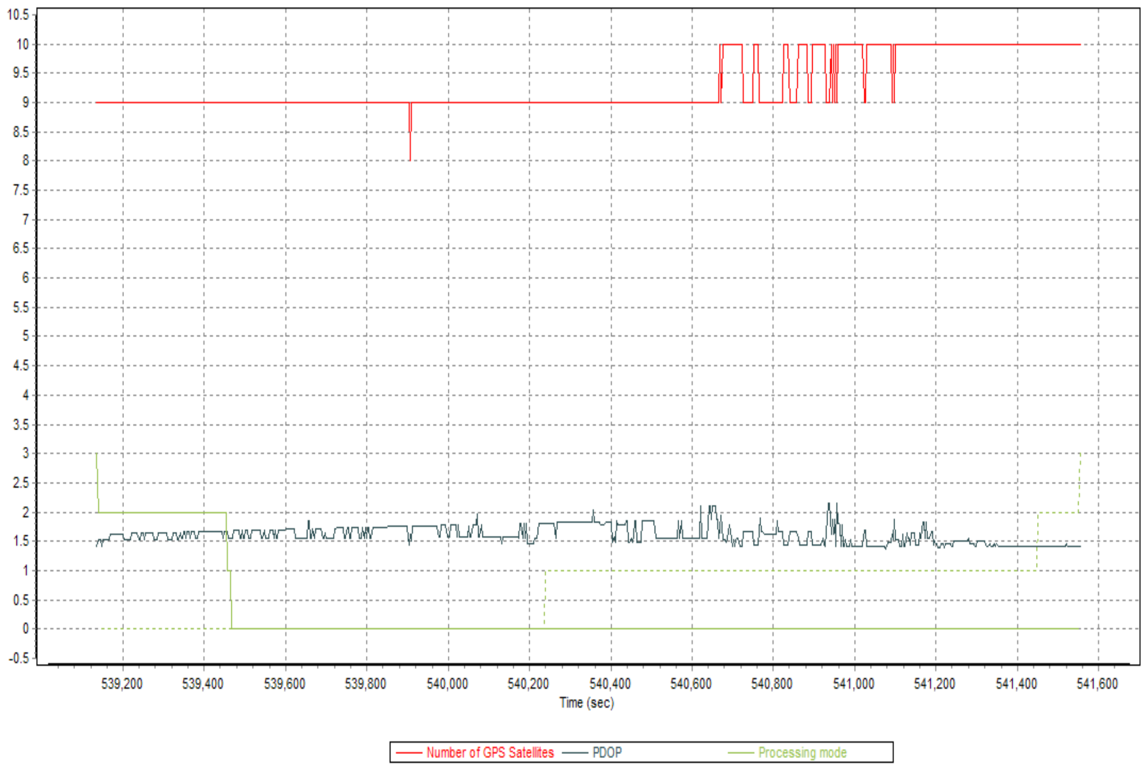


Figure A-8.120. Solution Status

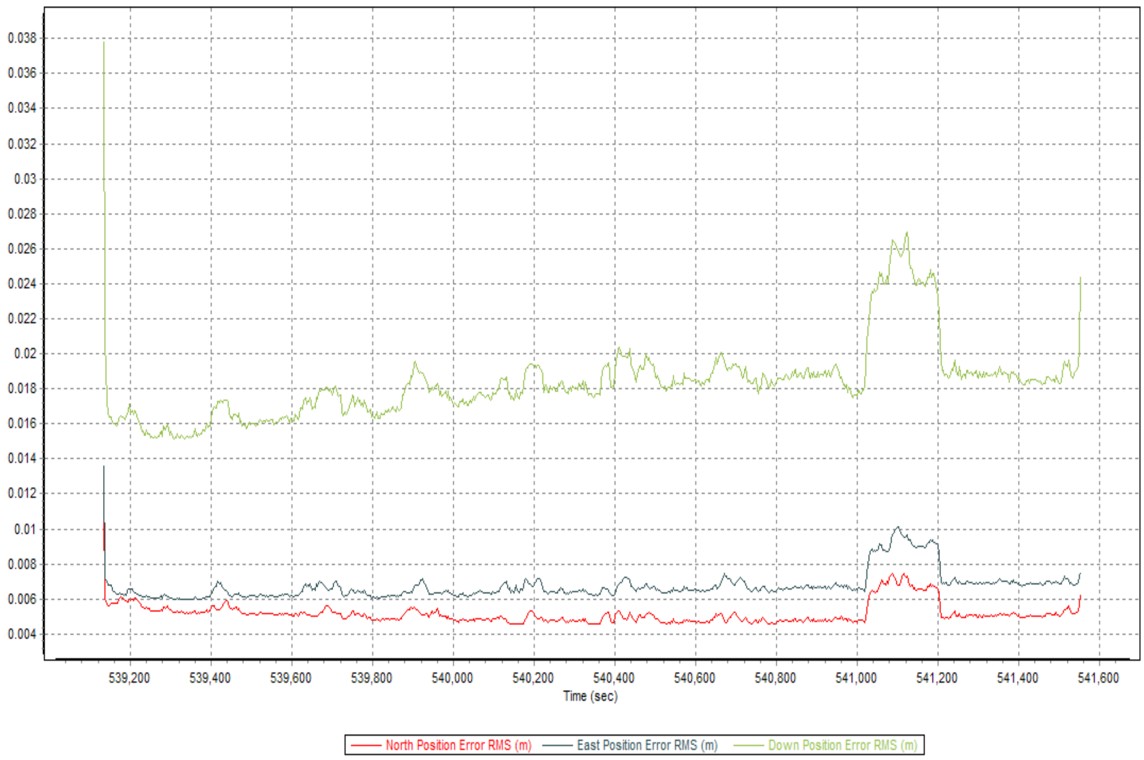


Figure A-8.121. Smoothed Performance Metric Parameters

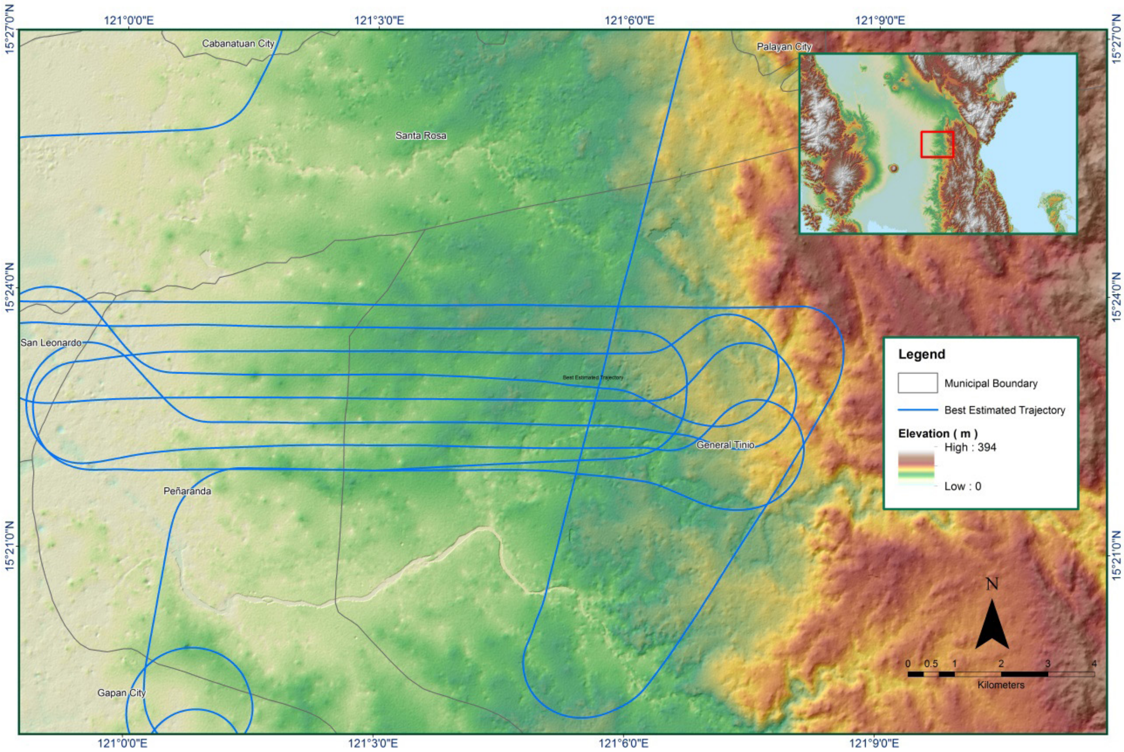


Figure A-8.122. Best Estimate Trajectory

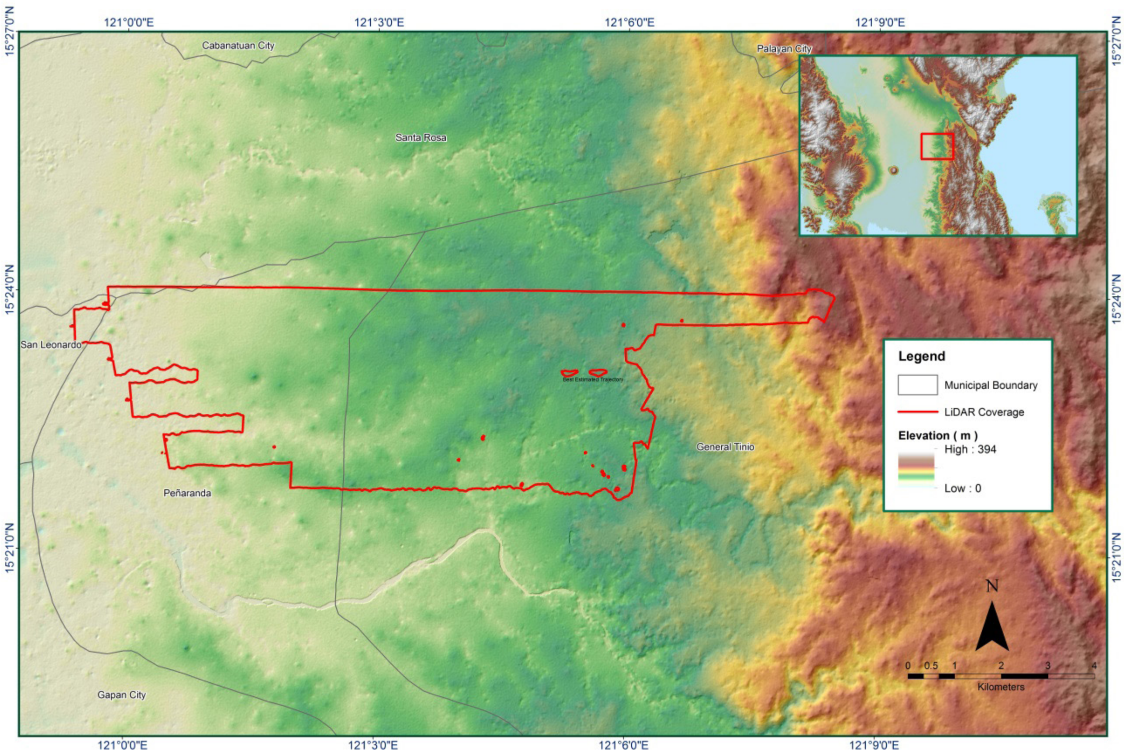


Figure A-8.123. Coverage of LiDAR data

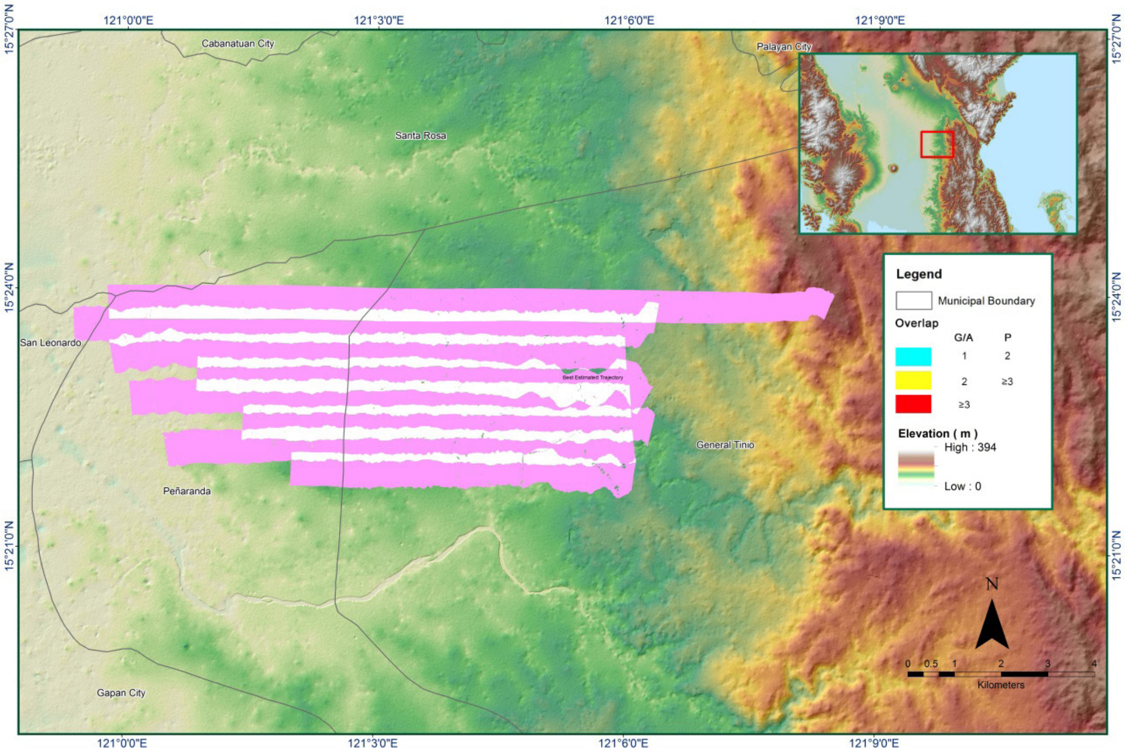


Figure A-8.124. Image of data overlap

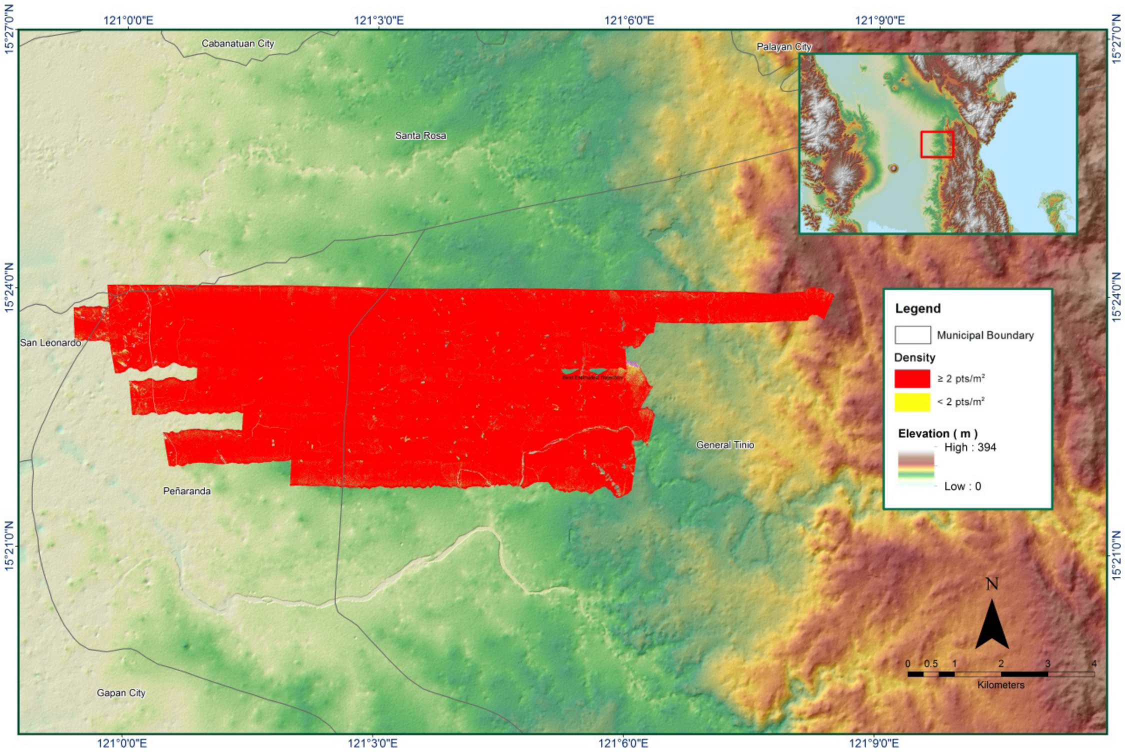


Figure A-8.125. Density Map of merged LiDAR data

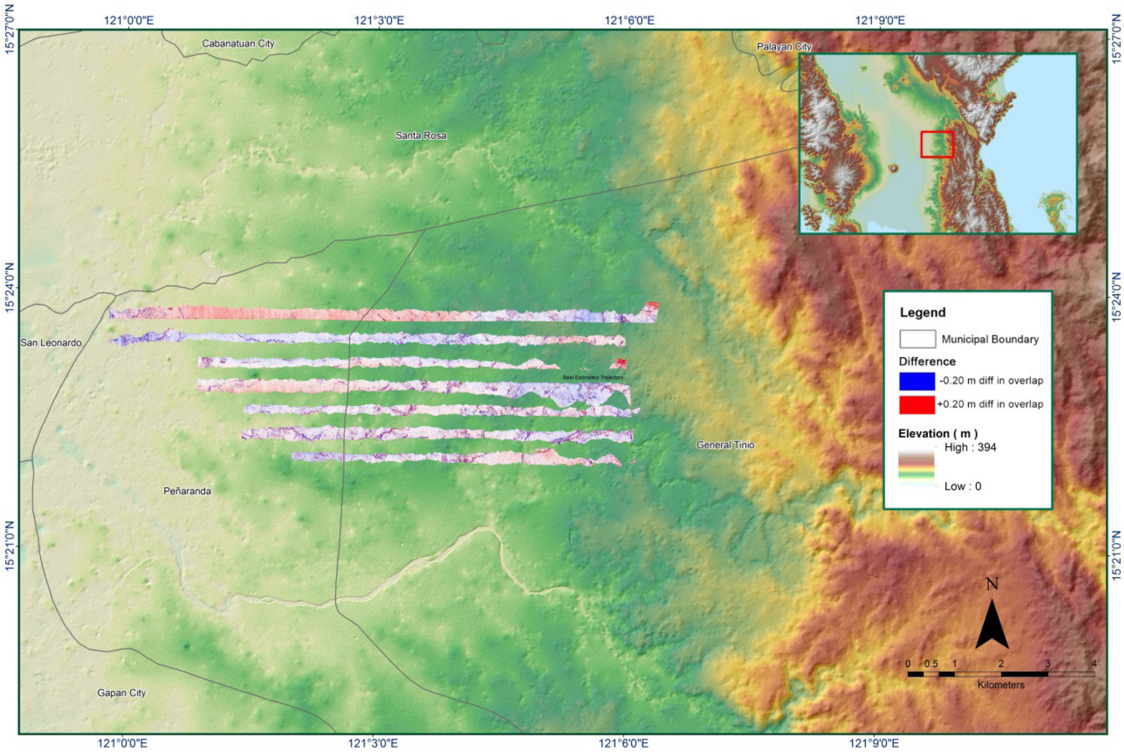


Figure A-8.126. Elevation Difference Between flight lines

Table A-8.19. Mission Summary Report for Mission UMYAB_additional

Flight Area	Clark Reflights
Mission Name	**UMYAB_additional**
Inclusive Flights	2666G
Range data size	12.5 GB
POS	238 MB
Base data size	104 MB
Image	17.6 MB
Transfer date	October 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.6 cm
RMSE for East Position (<4.0 cm)	2.3 cm
RMSE for Down Position (<8.0 cm)	6 cm
Boresight correction stdev (<0.001deg)	0.004246
IMU attitude correction stdev (<0.001deg)	0.111194
GPS position stdev (<0.01m)	0.0308
Minimum % overlap (>25)	16.67%
Ave point cloud density per sq.m. (>2.0)	3.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	62
Maximum Height	458.99
Minimum Height	48.36
Classification (# of points)	
Ground	1246149
Low vegetation	177585
Medium vegetation	4867487
High vegetation	24160057
Building	137136
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

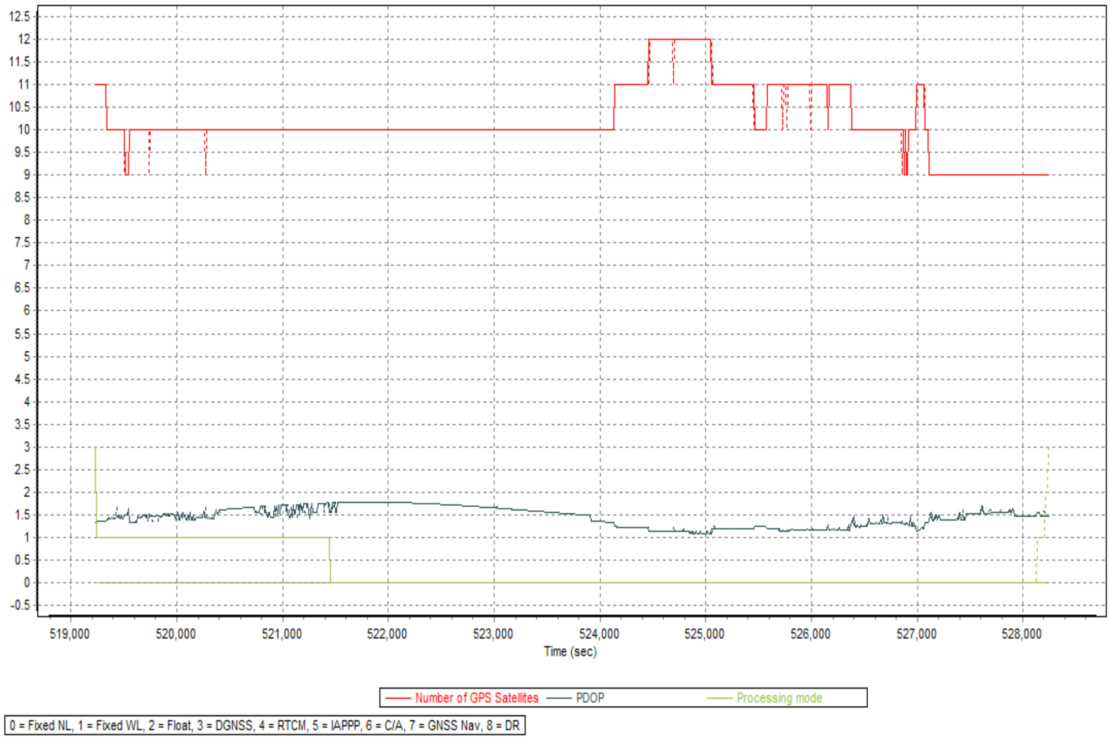


Figure A-8.127. Solution Status

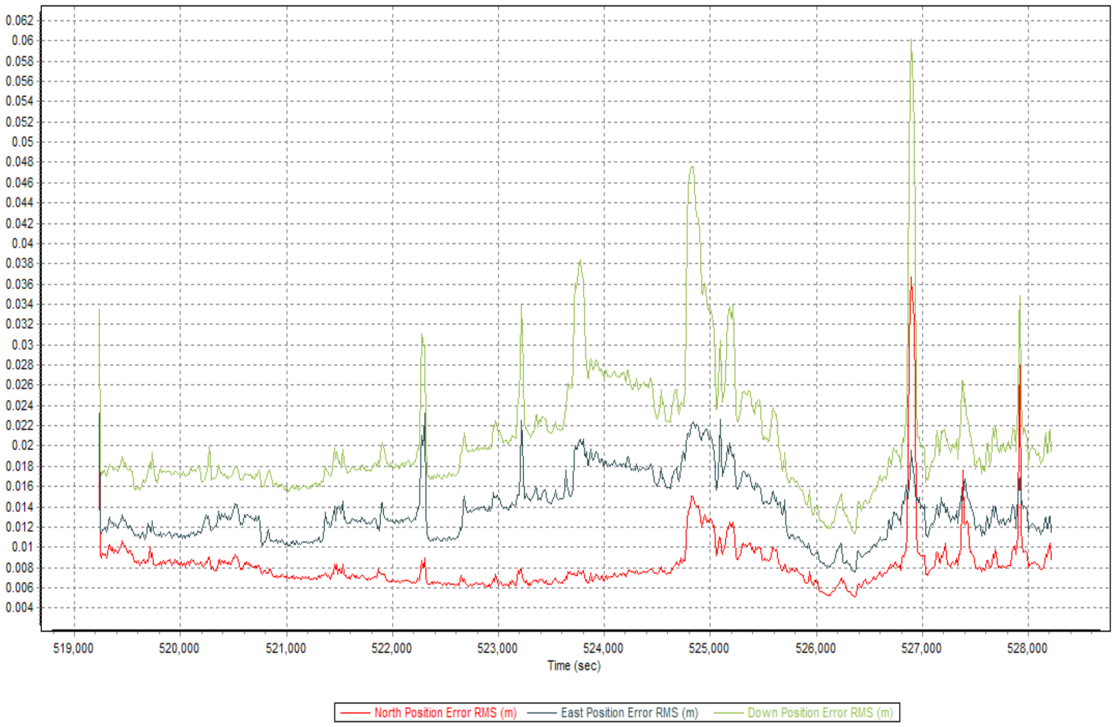


Figure A-8.128. Smoothed Performance Metric Parameters

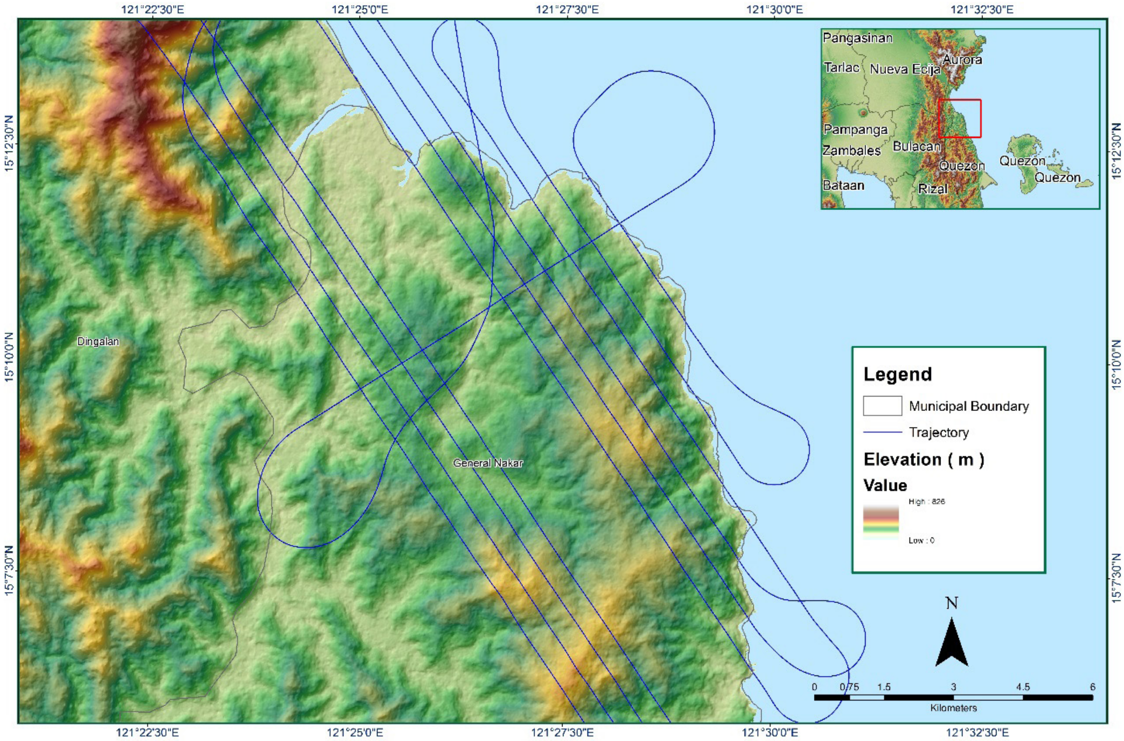


Figure A-8.129. Best Estimated Trajectory

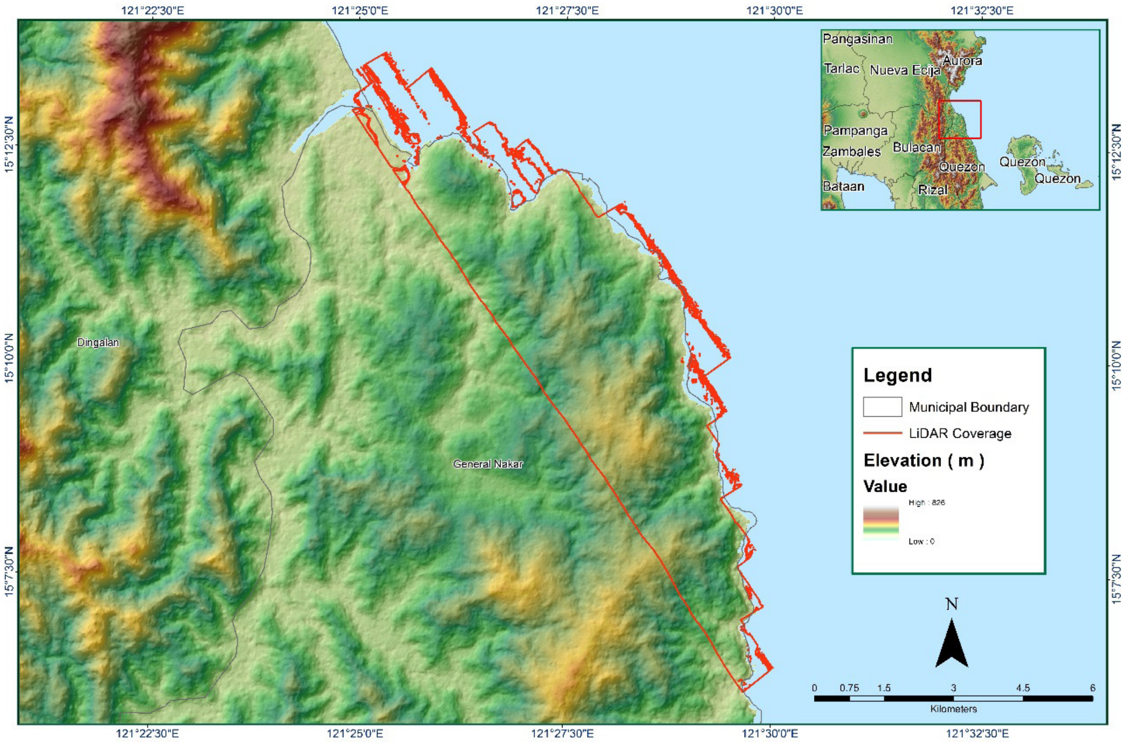


Figure A-8.130. Coverage of LIDAR data

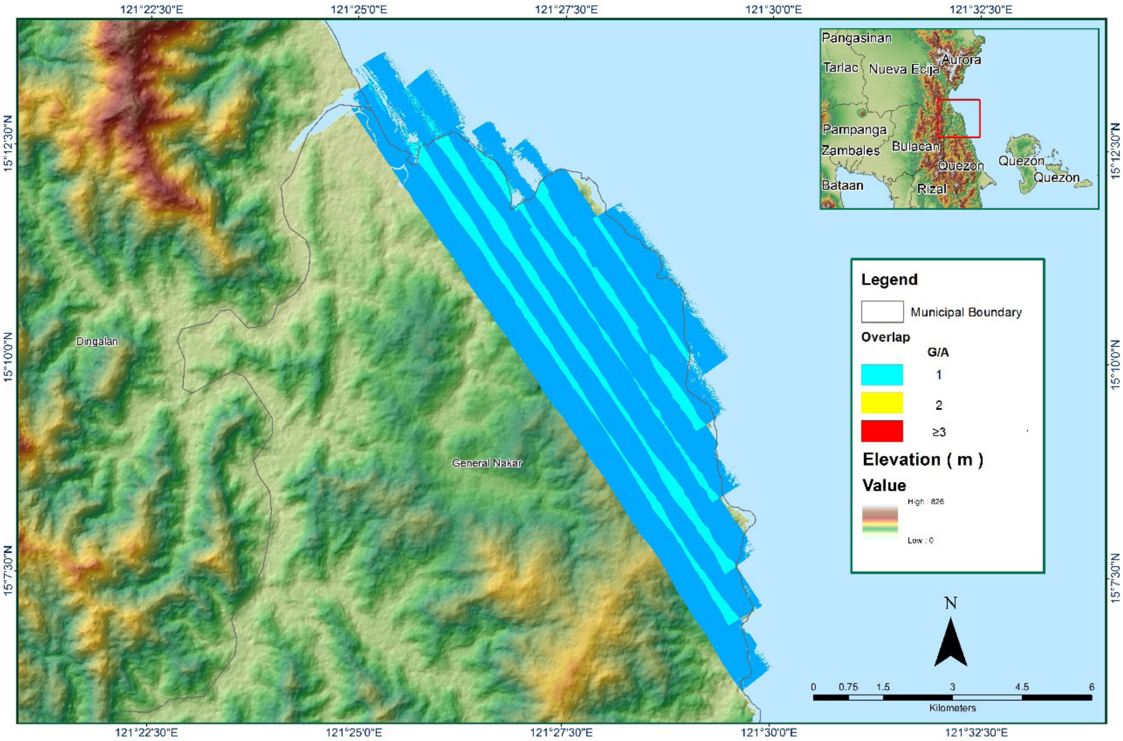


Figure A-8.131. Image of data overlap

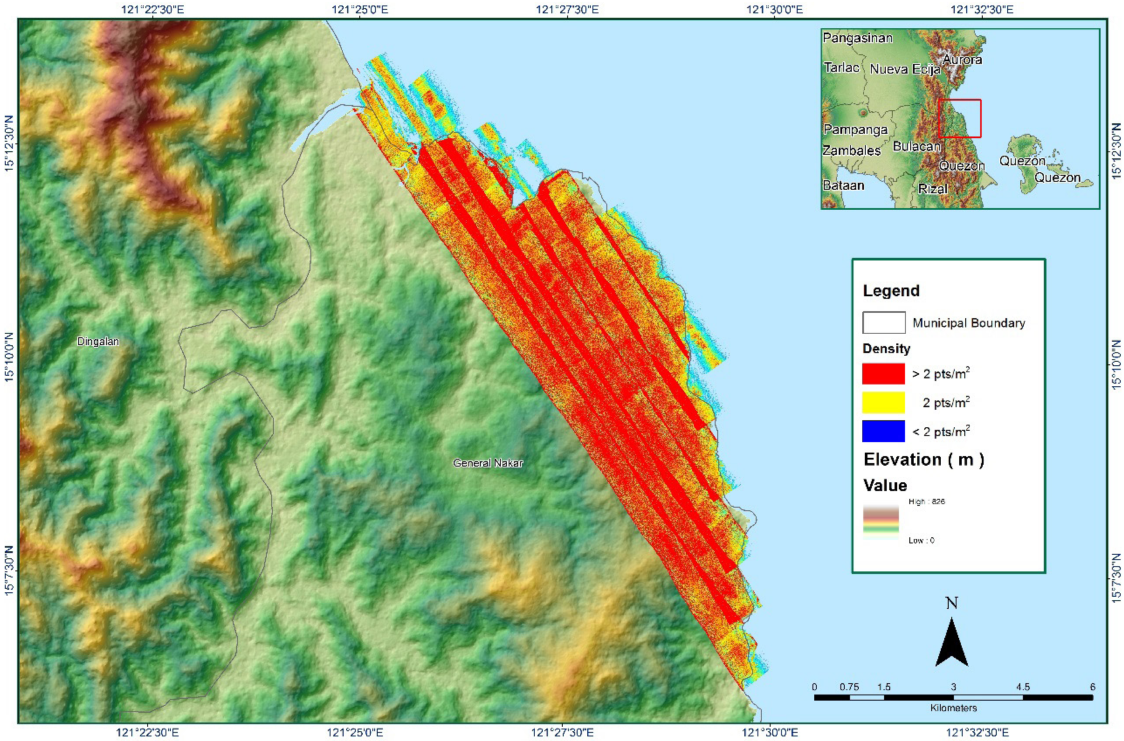


Figure A-8.132. Density map of merged LIDAR data

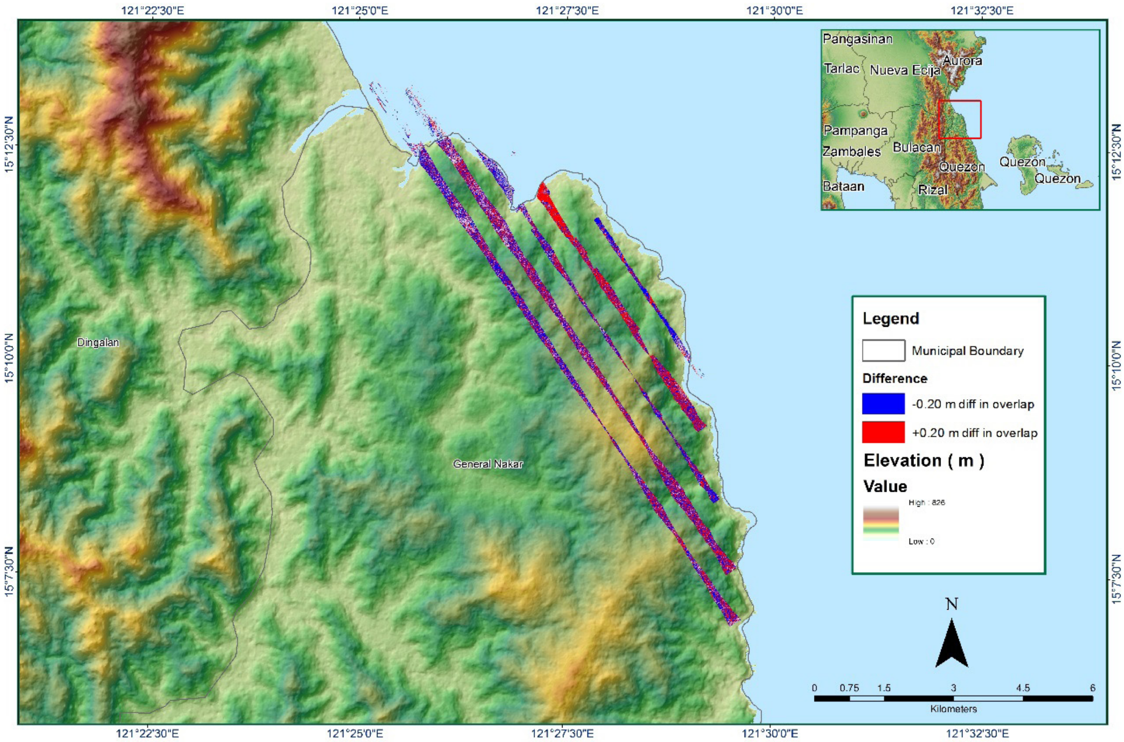


Figure A-8.133. Elevation difference between flight lines

Annex 9. Umiray Model Basin Parameters

Table A-9.1. Umiray 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
W1000	20.782	66.000	0	2.8116	4.9435	Discharge	1.2595	0.5	Ratio to Peak	0.1500
W1010	18.775	68.999	0	3.4938	4.2221	Discharge	1.3400	0.5	Ratio to Peak	0.1500
W1020	20.782	66.000	0	5.0651	0.9018	Discharge	3.0256	0.5	Ratio to Peak	0.1500
W1030	16.743	72.325	0	3.1411	2.6159	Discharge	3.5873	0.5	Ratio to Peak	0.1470
W1040	17.027	71.842	0	1.4975	3.0857	Discharge	0.5587	0.5	Ratio to Peak	0.1500
W1050	18.953	68.722	0	3.7064	7.2310	Discharge	2.8498	0.5	Ratio to Peak	0.1500
W1060	20.477	66.438	0	4.8559	1.2230	Discharge	3.1463	0.5	Ratio to Peak	0.1500
W1070	20.782	66.000	0	1.9846	5.7499	Discharge	0.9932	0.5	Ratio to Peak	0.1470
W1080	18.568	69.323	0	2.121	1.5296	Discharge	0.6283	0.5	Ratio to Peak	0.1500
W1090	15.445	74.624	0	0.58268	2.9770	Discharge	0.0158	0.5	Ratio to Peak	0.1470
W1100	20.438	66.496	0	2.851	5.0567	Discharge	1.3955	0.5	Ratio to Peak	0.1470
W1110	17.533	70.994	0	1.5505	3.6352	Discharge	1.1453	0.5	Ratio to Peak	0.1500
W1120	19.310	68.172	0	2.4244	2.4349	Discharge	1.1513	0.5	Ratio to Peak	0.1500
W1130	20.782	66.000	0	4.6082	3.3894	Discharge	4.3678	0.5	Ratio to Peak	0.1500
W1140	17.645	70.810	0	1.9424	6.2727	Discharge	1.3059	0.5	Ratio to Peak	0.1000
W1150	18.305	69.740	0	2.2627	1.0161	Discharge	0.9606	0.5	Ratio to Peak	0.1500
W1160	20.733	66.070	0	2.7367	6.0763	Discharge	1.9619	0.5	Ratio to Peak	0.1500
W1170	20.782	66.000	0	3.0539	4.7662	Discharge	2.3402	0.5	Ratio to Peak	0.1470
W1180	18.002	70.228	0	1.6091	2.0332	Discharge	0.5602	0.5	Ratio to Peak	0.1470
W1190	18.683	69.143	0	5.4325	0.8995	Discharge	6.2358	0.5	Ratio to Peak	0.1500
W1200	19.658	67.646	0	2.2878	4.3570	Discharge	0.5152	0.5	Ratio to Peak	0.1500
W1210	20.360	66.608	0	2.2872	2.7547	Discharge	1.0265	0.5	Ratio to Peak	0.1500
W1220	20.456	66.469	0	1.9969	3.2709	Discharge	0.4521	0.5	Ratio to Peak	0.1470

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
W1230	20.783	65.998	0	4.5108	1.2187	Discharge	2.5800	0.5	Ratio to Peak	0.1500
W1240	21.638	64.799	0	2.9068	4.3165	Discharge	0.6850	0.5	Ratio to Peak	0.1500
W1250	20.721	66.086	0	4.0202	3.5848	Discharge	1.6534	0.5	Ratio to Peak	0.1500
W1260	20.924	65.797	0	3.7459	5.6976	Discharge	1.7864	0.5	Ratio to Peak	0.1500
W1270	26.424	58.814	0	2.6376	5.8981	Discharge	1.5871	0.5	Ratio to Peak	0.1000
W1280	20.782	66.000	0	0.19861	0.9562	Discharge	0.0019	0.5	Ratio to Peak	0.1500
W1290	19.695	67.591	0	2.2656	12.0640	Discharge	1.5144	0.5	Ratio to Peak	0.1500
W1300	21.117	65.525	0	4.1058	4.2061	Discharge	1.4937	0.5	Ratio to Peak	0.1500
W1310	20.614	66.240	0	2.2907	5.2267	Discharge	1.1673	0.5	Ratio to Peak	0.1500
W1320	26.027	59.268	0	0.95252	7.5773	Discharge	0.0672	0.5	Ratio to Peak	0.1500
W1330	17.258	71.453	0	1.5954	4.6990	Discharge	1.0074	0.5	Ratio to Peak	0.1500
W1340	19.695	67.591	0	4.7258	2.2402	Discharge	4.7469	0.5	Ratio to Peak	0.1500
W1350	18.183	69.936	0	1.3987	5.5448	Discharge	0.5933	0.5	Ratio to Peak	0.1500
W1360	20.739	66.061	0	2.2274	7.2645	Discharge	1.1930	0.5	Ratio to Peak	0.1500
W1370	17.256	71.455	0	2.4556	2.9689	Discharge	1.9078	0.5	Ratio to Peak	0.1500
W1380	19.622	67.700	0	3.6424	3.1731	Discharge	2.0805	0.5	Ratio to Peak	0.1003
W700	11.075	83.564	0	3.3044	0.8717	Discharge	4.4841	0.5	Ratio to Peak	0.1500
W710	19.744	67.518	0	2.8223	4.2650	Discharge	2.0603	0.5	Ratio to Peak	0.1005
W720	8.928	88.790	0	0.6028	2.3195	Discharge	0.1209	0.5	Ratio to Peak	0.1000
W730	7.258	93.331	0	1.7485	3.6268	Discharge	1.7453	0.5	Ratio to Peak	0.1500
W740	16.934	71.999	0	2.0627	6.8940	Discharge	1.1868	0.5	Ratio to Peak	0.1500
W750	10.512	84.874	0	4.8336	2.9060	Discharge	3.4902	0.5	Ratio to Peak	0.1470
W760	15.041	75.368	0	0.81748	3.3850	Discharge	0.1440	0.5	Ratio to Peak	0.1500
W770	17.391	71.230	0	3.8435	4.0942	Discharge	2.7740	0.5	Ratio to Peak	0.1500
W780	16.230	73.217	0	1.0224	4.5686	Discharge	0.0569	0.5	Ratio to Peak	0.1000
W790	8.263	90.544	0	1.99	2.4071	Discharge	0.6804	0.5	Ratio to Peak	0.1500

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
W800	17.689	70.738	0	3.3802	8.1271	Discharge	1.3398	0.5	Ratio to Peak	0.1470
W810	6.968	94.166	0	2.43	3.4225	Discharge	1.5963	0.5	Ratio to Peak	0.1000
W820	8.088	91.018	0	1.6277	3.4217	Discharge	1.2025	0.5	Ratio to Peak	0.1000
W830	6.488	95.585	0	2.2656	2.9875	Discharge	2.7265	0.5	Ratio to Peak	0.1500
W840	14.026	77.310	0	4.1929	6.7481	Discharge	3.8643	0.5	Ratio to Peak	0.1470
W850	4.823	99.000	0	0.67919	4.3485	Discharge	0.1654	0.5	Ratio to Peak	0.1500
W860	11.120	83.461	0	4.0618	6.0143	Discharge	3.0122	0.5	Ratio to Peak	0.1500
W870	17.137	71.656	0	3.1859	5.6039	Discharge	1.9627	0.5	Ratio to Peak	0.1000
W880	6.698	94.958	0	1.3591	3.9459	Discharge	1.0154	0.5	Ratio to Peak	0.0980
W890	5.184	99.000	0	0.60126	0.2971	Discharge	0.1906	0.5	Ratio to Peak	0.1500
W900	12.283	80.885	0	2.9125	3.3894	Discharge	1.4736	0.5	Ratio to Peak	0.1500
W910	17.041	71.818	0	1.8414	6.1422	Discharge	1.1708	0.5	Ratio to Peak	0.1500
W920	16.933	72.000	0	2.1864	3.4269	Discharge	0.4397	0.5	Ratio to Peak	0.1005
W930	12.148	81.176	0	0.81462	1.4250	Discharge	0.0455	0.5	Ratio to Peak	0.1470
W940	16.902	72.053	0	2.8853	2.3867	Discharge	1.4252	0.5	Ratio to Peak	0.1500
W950	17.099	71.719	0	2.3963	7.0698	Discharge	1.5841	0.5	Ratio to Peak	0.1500
W960	18.515	69.407	0	3.8086	2.0924	Discharge	2.9113	0.5	Ratio to Peak	0.1500
W970	7.959	91.369	0	3.9426	3.3323	Discharge	3.9794	0.5	Ratio to Peak	0.1500
W980	19.664	67.637	0	0.63919	3.6735	Discharge	0.0164	0.5	Ratio to Peak	0.1500
W990	19.723	67.548	0	8.0639	5.4490	Discharge	5.2472	0.5	Ratio to Peak	0.1500

Annex 10. Umiray Model Reach Parameters

Table A-10.1. Umiray Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R130	Automatic Fixed Interval	4309.2	0.00214	0.022050	Trapezoid	136.63	1
R140	Automatic Fixed Interval	846.69	0.00983	0.015000	Trapezoid	101.79	1
R150	Automatic Fixed Interval	4426.5	0.00252	0.015000	Trapezoid	72.19	1
R170	Automatic Fixed Interval	1257.1	0.00947	0.010032	Trapezoid	69.43	1
R20	Automatic Fixed Interval	928.82	0.00401	0.014406	Trapezoid	42.23	1
R210	Automatic Fixed Interval	2794.5	0.01522	0.015071	Trapezoid	30.91	1
R220	Automatic Fixed Interval	6952.1	0.00296	0.010023	Trapezoid	142.92	1
R230	Automatic Fixed Interval	401.84	0.00674	0.015000	Trapezoid	188.81	1
R260	Automatic Fixed Interval	3279.5	0.00227	0.022540	Trapezoid	112.38	1
R280	Automatic Fixed Interval	7097.4	0.00642	0.022500	Trapezoid	61.28	1
R290	Automatic Fixed Interval	418.99	0.00783	0.022050	Trapezoid	28.41	1
R320	Automatic Fixed Interval	4313.9	0.00465	0.015000	Trapezoid	167.25	1
R350	Automatic Fixed Interval	1936.4	0.00275	0.010019	Trapezoid	133.43	1
R360	Automatic Fixed Interval	98.995	0.00401	0.014773	Trapezoid	113.16	1
R380	Automatic Fixed Interval	6841.1	0.02975	0.014702	Trapezoid	37.41	1
R410	Automatic Fixed Interval	2597.9	0.01247	0.015014	Trapezoid	78.13	1
R430	Automatic Fixed Interval	3234.5	0.01837	0.015038	Trapezoid	58.97	1
R470	Automatic Fixed Interval	2630.8	0.00565	0.022553	Trapezoid	51.26	1
R480	Automatic Fixed Interval	3546.6	0.00899	0.015047	Trapezoid	42.83	1
R490	Automatic Fixed Interval	1711	0.06720	0.022500	Trapezoid	47.69	1
R50	Automatic Fixed Interval	2178.1	0.01349	0.014605	Trapezoid	66.95	1
R500	Automatic Fixed Interval	2308.7	0.00401	0.022500	Trapezoid	40.73	1
R520	Automatic Fixed Interval	1032.4	0.03145	0.022500	Trapezoid	63.11	1
R540	Automatic Fixed Interval	2617.9	0.00571	0.022500	Trapezoid	50.61	1
R570	Automatic Fixed Interval	4646.9	0.00315	0.022575	Trapezoid	55.82	1
R580	Automatic Fixed Interval	28.284	0.02937	0.015074	Trapezoid	54.17	1
R60	Automatic Fixed Interval	7810.4	0.00401	0.014753	Trapezoid	194.45	1
R610	Automatic Fixed Interval	2562.8	0.03249	0.022546	Trapezoid	50.61	1
R630	Automatic Fixed Interval	1016	0.00385	0.015075	Trapezoid	23.00	1
R640	Automatic Fixed Interval	4213.7	0.03524	0.022500	Trapezoid	23.40	1
R660	Automatic Fixed Interval	1755.8	0.05168	0.022343	Trapezoid	23.57	1
R70	Automatic Fixed Interval	964.68	0.00401	0.014773	Trapezoid	171.63	1
R80	Automatic Fixed Interval	848.7	0.00401	0.015103	Trapezoid	133.47	1
R90	Automatic Fixed Interval	3234	0.00100	0.015068	Trapezoid	117.26	1

Annex 11. Umiray Field Validation Points

Table A-11.1. Umiray Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	121.41051	15.19586	0.09	0	-0.09	Winnie, 2004	5 -Year
2	121.41012	15.19796	0.12	0	-0.12	Winnie, 2004	5 -Year
3	121.41063	15.19836	0.11	0	-0.11	Winnie, 2004	5 -Year
4	121.40984	15.20303	0.03	0	-0.03	Winnie, 2004	5 -Year
5	121.4093	15.20771	0.03	0	-0.03	Winnie, 2004	5 -Year
6	121.40903	15.20846	0.06	0	-0.06	Winnie, 2004	5 -Year
7	121.40911	15.20917	0.03	0.5	0.47	Winnie, 2004	5 -Year
8	121.40839	15.20986	0.03	0.5	0.47	Winnie, 2004	5 -Year
9	121.40969	15.20984	0.03	0.91	0.88	Winnie, 2004	5 -Year
10	121.40877	15.2103	0.5	2.13	1.63	Winnie, 2004	5 -Year
11	121.40908	15.21059	1.21	1.59	0.38	Winnie, 2004	5 -Year
12	121.40944	15.21015	0.03	0.5	0.47	Winnie, 2004	5 -Year
13	121.40899	15.21002	0.03	0.5	0.47	Winnie, 2004	5 -Year
14	121.40749	15.20946	0.03	0.5	0.47	Winnie, 2004	5 -Year
15	121.41175	15.21088	0.03	0.5	0.47	Winnie, 2004	5 -Year
16	121.41332	15.21059	0.03	0.5	0.47	Winnie, 2004	5 -Year
17	121.41514	15.21033	0.03	0.61	0.58	Winnie, 2004	5 -Year
18	121.41548	15.21133	0.03	0.91	0.88	Winnie, 2004	5 -Year
19	121.41728	15.20822	0.4	0.3	-0.1	Winnie, 2004	5 -Year
20	121.41658	15.20917	0.03	0.3	0.27	Winnie, 2004	5 -Year
21	121.40899	15.21499	0.13	0.5	0.37	Winnie, 2004	5 -Year
22	121.40906	15.2168	0.13	0	-0.13	Winnie, 2004	5 -Year
23	121.41056	15.21938	0.05	0.75	0.7	Winnie, 2004	5 -Year
24	121.41182	15.22093	0.03	0.5	0.47	Winnie, 2004	5 -Year
25	121.40902	15.21825	0.58	0.76	0.18	Winnie, 2004	5 -Year
26	121.40859	15.21838	0.43	0.46	0.03	Winnie, 2004	5 -Year
27	121.41011	15.21791	0.25	0.5	0.25	Winnie, 2004	5 -Year
28	121.41056	15.21872	0.13	0.75	0.62	Winnie, 2004	5 -Year
29	121.41218	15.22476	1.28	1.59	0.31	Winnie, 2004	5 -Year
30	121.41267	15.22501	0.08	0.5	0.42	Winnie, 2004	5 -Year
31	121.41267	15.22545	0.04	0.05	0.01	Winnie, 2004	5 -Year
32	121.41135	15.22607	0.62	0.91	0.29	Winnie, 2004	5 -Year
33	121.41149	15.22665	0.03	0.03	0	Winnie, 2004	5 -Year
34	121.41156	15.22777	0.14	0.5	0.36	Winnie, 2004	5 -Year
35	121.41132	15.22814	0.03	0.5	0.47	Winnie, 2004	5 -Year
36	121.41116	15.22849	0.03	0.76	0.73	Winnie, 2004	5 -Year
37	121.41096	15.22868	0.03	0.05	0.02	Winnie, 2004	5 -Year
38	121.40778	15.23326	0.03	0	-0.03	Winnie, 2004	5 -Year
39	121.40707	15.23273	0.04	0	-0.04	Winnie, 2004	5 -Year
40	121.40659	15.23361	0.03	0	-0.03	Winnie, 2004	5 -Year
41	121.4059	15.23257	0.15	0	-0.15	Winnie, 2004	5 -Year
42	121.40955	15.23064	0.36	0	-0.36	Winnie, 2004	5 -Year
43	121.40897	15.22855	0.09	0.91	0.82	Winnie, 2004	5 -Year
44	121.41185	15.22586	0.04	0.91	0.87	Winnie, 2004	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
45	121.41311	15.22405	0.04	0.75	0.71	Winnie, 2004	5 -Year
46	121.41445	15.22207	0.03	0.91	0.88	Winnie, 2004	5 -Year
47	121.41516	15.2207	0.03	0.5	0.47	Winnie, 2004	5 -Year
48	121.40925	15.21623	0.09	0.3	0.21	Winnie, 2004	5 -Year
49	121.40918	15.21559	0.08	0.76	0.68	Winnie, 2004	5 -Year
50	121.42145	15.20339	1.28	1.22	-0.06	Winnie, 2004	5 -Year
51	121.42233	15.20061	1.43	0.3	-1.13	Winnie, 2004	5 -Year
52	121.41964	15.20448	2.16	0.61	-1.55	Winnie, 2004	5 -Year
53	121.42083	15.20369	1.31	0.76	-0.55	Winnie, 2004	5 -Year
54	121.42211	15.20147	1.15	0.3	-0.85	Winnie, 2004	5 -Year
55	121.41162	15.19232	0.08	0	-0.08	Winnie, 2004	5 -Year
56	121.41148	15.19204	0.07	0	-0.07	Winnie, 2004	5 -Year
57	121.41251	15.18873	0.03	0	-0.03	Winnie, 2004	5 -Year
58	121.41139	15.22029	0.14	0.5	0.36	Winnie, 2004	5 -Year
59	121.41081	15.21987	0.24	0.75	0.51	Winnie, 2004	5 -Year
60	121.4084	15.21941	0.04	0.61	0.57	Winnie, 2004	5 -Year
61	121.40951	15.21562	1.42	1.22	-0.2	Winnie, 2004	5 -Year
62	121.40854	15.21424	0.03	0.5	0.47	Winnie, 2004	5 -Year
63	121.40834	15.21447	0.03	0.5	0.47	Winnie, 2004	5 -Year
64	121.40944	15.21736	0.69	0.3	-0.39	Winnie, 2004	5 -Year
65	121.41133	15.21956	0.1	0.75	0.65	Winnie, 2004	5 -Year
66	121.41175	15.22013	0.17	1.37	1.2	Winnie, 2004	5 -Year
67	121.41047	15.22902	0.29	0.61	0.32	Winnie, 2004	5 -Year
68	121.41016	15.22955	0.4	0.39	-0.01	Winnie, 2004	5 -Year
69	121.40898	15.22832	0.06	0.3	0.24	Winnie, 2004	5 -Year
70	121.40677	15.23321	0.06	0	-0.06	Winnie, 2004	5 -Year
71	121.40657	15.23427	0.03	0	-0.03	Winnie, 2004	5 -Year
72	121.40753	15.23271	0.25	0	-0.25	Winnie, 2004	5 -Year
73	121.40735	15.23204	0.47	0	-0.47	Winnie, 2004	5 -Year
74	121.40563	15.23858	0.03	0	-0.03	Winnie, 2004	5 -Year
75	121.40482	15.24005	0.03	0	-0.03	Winnie, 2004	5 -Year
76	121.40473	15.24067	0.03	0	-0.03	Winnie, 2004	5 -Year
77	121.40424	15.24105	0.03	0.3	0.27	Winnie, 2004	5 -Year
78	121.4041	15.24087	0.04	0	-0.04	Winnie, 2004	5 -Year
79	121.416	15.21051	0.28	0.91	0.63	Winnie, 2004	5 -Year
80	121.41692	15.2112	0.05	1.22	1.17	Winnie, 2004	5 -Year
81	121.41569	15.21	0.03	0.61	0.58	Winnie, 2004	5 -Year
82	121.41451	15.21009	0.03	0.5	0.47	Winnie, 2004	5 -Year
83	121.4109	15.21081	0.03	0.5	0.47	Winnie, 2004	5 -Year
84	121.41043	15.21042	0.03	0.61	0.58	Winnie, 2004	5 -Year
85	121.40889	15.20803	0.06	0	-0.06	Winnie, 2004	5 -Year
86	121.40948	15.20683	0.06	0	-0.06	Winnie, 2004	5 -Year
87	121.40978	15.20263	0.03	0	-0.03	Winnie, 2004	5 -Year
88	121.41697	15.20868	0.56	0.3	-0.26	Winnie, 2004	5 -Year
89	121.41606	15.20929	0.03	0.46	0.43	Winnie, 2004	5 -Year
90	121.41616	15.20988	0.03	0.61	0.58	Winnie, 2004	5 -Year
91	121.41706	15.21031	0.03	0.61	0.58	Winnie, 2004	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
92	121.41307	15.2254	0.04	0.5	0.46	Winnie, 2004	5 -Year
93	121.4132	15.22499	0.04	0.5	0.46	Winnie, 2004	5 -Year
94	121.41316	15.22465	0.03	0.75	0.72	Winnie, 2004	5 -Year
95	121.41335	15.22432	0.03	0.75	0.72	Winnie, 2004	5 -Year
96	121.40679	15.23216	0.08	0.3	0.22	Winnie, 2004	5 -Year
97	121.41175	15.22633	0.03	1.68	1.65	Winnie, 2004	5 -Year
98	121.41195	15.22517	1.23	2.29	1.06	Winnie, 2004	5 -Year
99	121.41072	15.22914	0.03	0.91	0.88	Winnie, 2004	5 -Year
100	121.4114	15.22742	0.03	0.91	0.88	Winnie, 2004	5 -Year
101	121.41187	15.22178	0.14	0.5	0.36	Winnie, 2004	5 -Year
102	121.41172	15.22124	0.15	0.75	0.6	Winnie, 2004	5 -Year
103	121.41134	15.22059	0.28	0.75	0.47	Winnie, 2004	5 -Year
104	121.41116	15.22002	0.06	0.75	0.69	Winnie, 2004	5 -Year
105	121.41025	15.21815	0.08	0.5	0.42	Winnie, 2004	5 -Year
106	121.40967	15.21724	0.46	0.3	-0.16	Winnie, 2004	5 -Year
107	121.40934	15.2169	0.09	0.3	0.21	Winnie, 2004	5 -Year
108	121.40875	15.21457	0.03	0.5	0.47	Winnie, 2004	5 -Year
109	121.4089	15.20962	0.03	0.5	0.47	Winnie, 2004	5 -Year
110	121.41193	15.21051	0.16	0.5	0.34	Winnie, 2004	5 -Year
111	121.4092	15.20792	0.13	0	-0.13	Winnie, 2004	5 -Year
112	121.4101	15.21009	0.04	0.76	0.72	Winnie, 2004	5 -Year
113	121.41282	15.21063	0.16	1.07	0.91	Winnie, 2004	5 -Year
114	121.41562	15.21035	0.07	0.61	0.54	Winnie, 2004	5 -Year
115	121.40855	15.21469	0.07	1.52	1.45	Winnie, 2004	5 -Year
116	121.40936	15.21596	0.07	0.91	0.84	Winnie, 2004	5 -Year
117	121.40939	15.21792	0.98	0.91	-0.07	Winnie, 2004	5 -Year
118	121.41088	15.21936	0.16	0.5	0.34	Winnie, 2004	5 -Year
119	121.412	15.22127	0.15	0.5	0.35	Winnie, 2004	5 -Year
120	121.41098	15.22826	0.03	0.91	0.88	Winnie, 2004	5 -Year
121	121.40875	15.21527	0.11	0.3	0.19	Winnie, 2004	5 -Year
122	121.40807	15.20965	0.03	1.22	1.19	Winnie, 2004	5 -Year
123	121.41081	15.19385	0.03	0	-0.03	Winnie, 2004	5 -Year
124	121.4099	15.1971	0.03	0	-0.03	Winnie, 2004	5 -Year
125	121.41104	15.19741	0.03	0	-0.03	Winnie, 2004	5 -Year
126	121.41188	15.22556	0.58	0.75	0.17	Winnie, 2004	5 -Year
127	121.41191	15.22606	0.03	0.05	0.02	Winnie, 2004	5 -Year
128	121.41123	15.22637	0.3	0.76	0.46	Winnie, 2004	5 -Year
129	121.41085	15.22025	0.03	0.75	0.72	Winnie, 2004	5 -Year
130	121.40842	15.21867	0.1	0.61	0.51	Winnie, 2004	5 -Year
131	121.40945	15.21659	0.1	0.3	0.2	Winnie, 2004	5 -Year
132	121.40897	15.21613	0.2	0.3	0.1	Winnie, 2004	5 -Year
133	121.40991	15.20947	0.26	0.75	0.49	Winnie, 2004	5 -Year
134	121.40908	15.2076	0.03	0	-0.03	Winnie, 2004	5 -Year
135	121.40923	15.20286	0.03	0	-0.03	Winnie, 2004	5 -Year
136	121.41014	15.20209	0.03	0	-0.03	Winnie, 2004	5 -Year
137	121.41106	15.19847	0.03	0	-0.03	Winnie, 2004	5 -Year
138	121.41005	15.1986	0.04	0	-0.04	Winnie, 2004	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
139	121.40995	15.19906	0.14	0	-0.14	Winnie, 2004	5 -Year
140	121.41104	15.19519	0.03	0	-0.03	Winnie, 2004	5 -Year
141	121.41045	15.1949	0.09	0	-0.09	Winnie, 2004	5 -Year
142	121.41039	15.19551	0.31	0	-0.31	Winnie, 2004	5 -Year
143	121.41262	15.18844	0.03	0	-0.03	Winnie, 2004	5 -Year
144	121.41509	15.211	0.27	1.07	0.8	Winnie, 2004	5 -Year
145	121.41489	15.21127	0.04	0.5	0.46	Winnie, 2004	5 -Year
146	121.41525	15.21009	0.03	0.03	0	Winnie, 2004	5 -Year
147	121.41231	15.21071	0.07	0.05	-0.02	Winnie, 2004	5 -Year
148	121.41119	15.2106	0.03	0.3	0.27	Winnie, 2004	5 -Year
149	121.41138	15.21068	0.26	0.5	0.24	Winnie, 2004	5 -Year
150	121.40973	15.21005	0.04	0.05	0.01	Winnie, 2004	5 -Year
151	121.40965	15.21026	0.03	2.44	2.41	Winnie, 2004	5 -Year
152	121.40936	15.21024	0.06	0.5	0.44	Winnie, 2004	5 -Year
153	121.40842	15.2101	0.91	0.5	-0.41	Winnie, 2004	5 -Year
154	121.40819	15.21002	1.1	1.52	0.42	Winnie, 2004	5 -Year
155	121.4089	15.20914	0.04	0.75	0.71	Winnie, 2004	5 -Year
156	121.40945	15.20945	0.09	1.52	1.43	Winnie, 2004	5 -Year
157	121.40957	15.21692	0.2	0.3	0.1	Winnie, 2004	5 -Year
158	121.41203	15.22056	0.2	0.75	0.55	Winnie, 2004	5 -Year
159	121.41143	15.22075	0.3	1.22	0.92	Winnie, 2004	5 -Year
160	121.41248	15.22498	0.18	0.5	0.32	Winnie, 2004	5 -Year
161	121.41149	15.22647	0.05	1.52	1.47	Winnie, 2004	5 -Year
162	121.41067	15.22879	0.09	0.76	0.67	Winnie, 2004	5 -Year
163	121.41037	15.22931	0.06	0.91	0.85	Winnie, 2004	5 -Year
164	121.40935	15.23043	0.51	0	-0.51	Winnie, 2004	5 -Year
165	121.40662	15.23345	0.09	0	-0.09	Winnie, 2004	5 -Year
166	121.40693	15.23225	0.06	0	-0.06	Winnie, 2004	5 -Year
167	121.41276	15.22516	0.03	0.05	0.02	Winnie, 2004	5 -Year
168	121.41321	15.22387	0.03	3.05	3.02	Winnie, 2004	5 -Year
169	121.41419	15.22244	0.03	0.3	0.27	Winnie, 2004	5 -Year
170	121.41486	15.22131	0.03	0.05	0.02	Winnie, 2004	5 -Year
171	121.41539	15.22012	0.03	0.05	0.02	Winnie, 2004	5 -Year
172	121.40876	15.21478	0.05	0.03	-0.02	Winnie, 2004	5 -Year
173	121.40915	15.21494	1.52	1.52	0	Winnie, 2004	5 -Year
174	121.40933	15.21541	1.3	0.91	-0.39	Winnie, 2004	5 -Year
175	121.40903	15.2152	0.14	0.5	0.36	Winnie, 2004	5 -Year
176	121.40893	15.21481	0.08	0.05	-0.03	Winnie, 2004	5 -Year
177	121.40629	15.21303	0.03	0.05	0.02	Winnie, 2004	5 -Year
178	121.40949	15.20797	0.07	0	-0.07	Winnie, 2004	5 -Year
179	121.40919	15.20817	0.11	0	-0.11	Winnie, 2004	5 -Year
180	121.40908	15.20867	0.04	0	-0.04	Winnie, 2004	5 -Year

Annex 12. Educational Institutions Affected by Flooding in Umiray Floodplain

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

Quezon				
General Nakar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DAY CARE CENTER	Umiray			
UMIRAY ELEMENTARY SCHOOL 1	Umiray			Low
UMIRAY ELEMENTARY SCHOOL 10	Umiray			
UMIRAY ELEMENTARY SCHOOL 11	Umiray			
UMIRAY ELEMENTARY SCHOOL 12	Umiray		Low	Low
UMIRAY ELEMENTARY SCHOOL 13	Umiray			
UMIRAY ELEMENTARY SCHOOL 14	Umiray			
UMIRAY ELEMENTARY SCHOOL 15	Umiray			
UMIRAY ELEMENTARY SCHOOL 2	Umiray		Low	Low
UMIRAY ELEMENTARY SCHOOL 3	Umiray		Low	Low
UMIRAY ELEMENTARY SCHOOL 4	Umiray			
UMIRAY ELEMENTARY SCHOOL 5	Umiray			
UMIRAY ELEMENTARY SCHOOL 6	Umiray			
UMIRAY ELEMENTARY SCHOOL 7	Umiray			
UMIRAY ELEMENTARY SCHOOL 8	Umiray			
UMIRAY ELEMENTARY SCHOOL 9	Umiray			
UMIRAY NATIONAL HIGH SCHOOL 1	Umiray			
UMIRAY NATIONAL HIGH SCHOOL 2	Umiray			
UMIRAY NATIONAL HIGH SCHOOL 3	Umiray			
UMIRAY NATIONAL HIGH SCHOOL 4	Umiray			
UMIRAY NATIONAL HIGH SCHOOL 5	Umiray			

Annex 13. Health Institutions Affected by Flooding in Umiray Floodplain

Table A-13.1. Health Institutions Affected by Flooding in the Umiray Floodplain

Quezon				
General Nakar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
HEALTH CENTER	Umiray	Low	Low	Low