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

LiDAR Surveys and Flood Mapping of Sapangdaku River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
University of San Carlos

APRIL 2017

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

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

E. C. Paringit and R. S. Otadoy (eds.) (2017), LiDAR Surveys and Flood Mapping of Sapangdaku River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-154pp.

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National Library of the Philippines
ISBN: 978-621-430-187-4

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CHAPTER 1: OVERVIEW OF THE PROGRAM AND SAPANGDAKU RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland Otadoy, and Engr. Aure Flo Oraya

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos (USC). USC 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 17 river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Sapangdaku River Basin

Sapangdaku River Basin covers two (2) municipalities and three (3) cities in the central part of the Province of Cebu. A huge portion of the catchment of Sapangdaku River drains to the City of Toledo, while small portions cover Balamban, Cebu City, Talisay City, Minglanilla and Naga City. According to the DENR River Basin Control Office Sapangdaku River Basin has a drainage area of 147 km^2 and an estimated 88 million cubic meter (MCM) annual run-off (RCBO, 2015). The catchment is classified under Type III weather in the Corona climate classification and experiences dry season from November to April and wet season for the other months of the year.

Its main stem, Sapangdaku River, also known as Hinulawan river, is one of the river systems in Visayas Region. Its main river stream network passes along ten (10) barangays in Toledo City. According to the Philippine Statistics Authority Census, an estimated 41,137 people are residing within the immediate vicinity of the river which is distributed among the 10 barangays in 2010.

Meanwhile, Toledo City, which is mostly affected by the flooding of Sapangdaku river, is a 3rd income class component city and was previously known as Pueblo Hinulawan. It has a population of 170,335. Mining industry is prominent in the area and it is where we can find Carmen Copper Corporation. Malubog Lake and Biga Pit are part of the Sapangdaku catchment.

In addition, most of the livelihood of the population in Western Cebu including the areas surrounding the river are the extraction, consumption, and management of coastal and marine resources found in their province. Threats of typhoons and potential flooding are a challenge to the residents' source of income, wherein the most recent flooding event in the area was brought by Typhoon Seniang on December 2014.

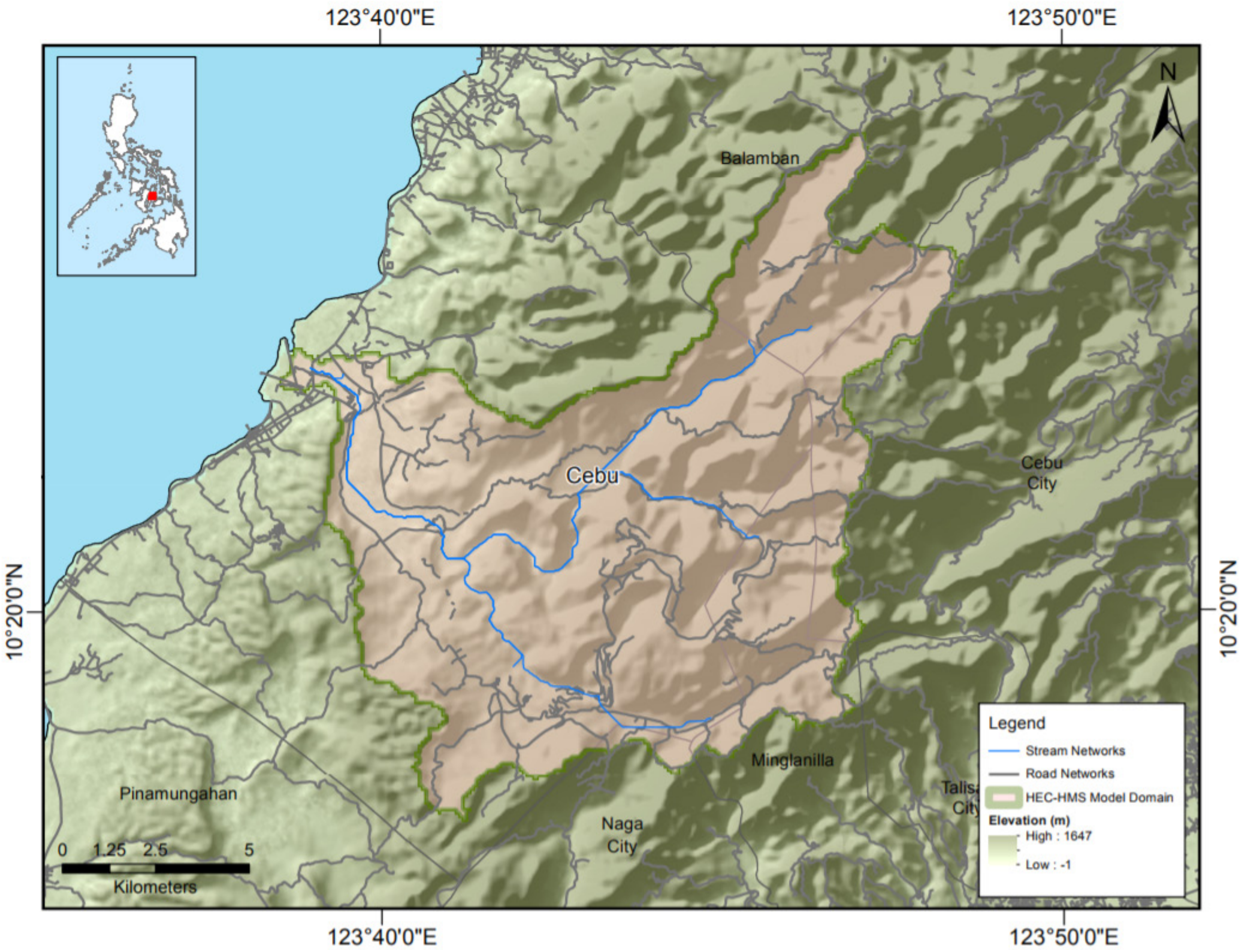

Figure 1. Map of Sapangdaku River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SAPANGDAKU FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Sapangdaku floodplain in Cebu. These missions were planned for 16 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Sapangdaku floodplain.

Table 1. Flight planning parameters for Pegasus 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)
BLK36E	1000, 1200	30	50	200	30	130	5
BLK36F	1000, 1200	30	50	200	30	130	5
BLK36G	1000, 1200	30	50	200	30	130	5
BLK36H	1000, 1200	30	50	200	30	130	5

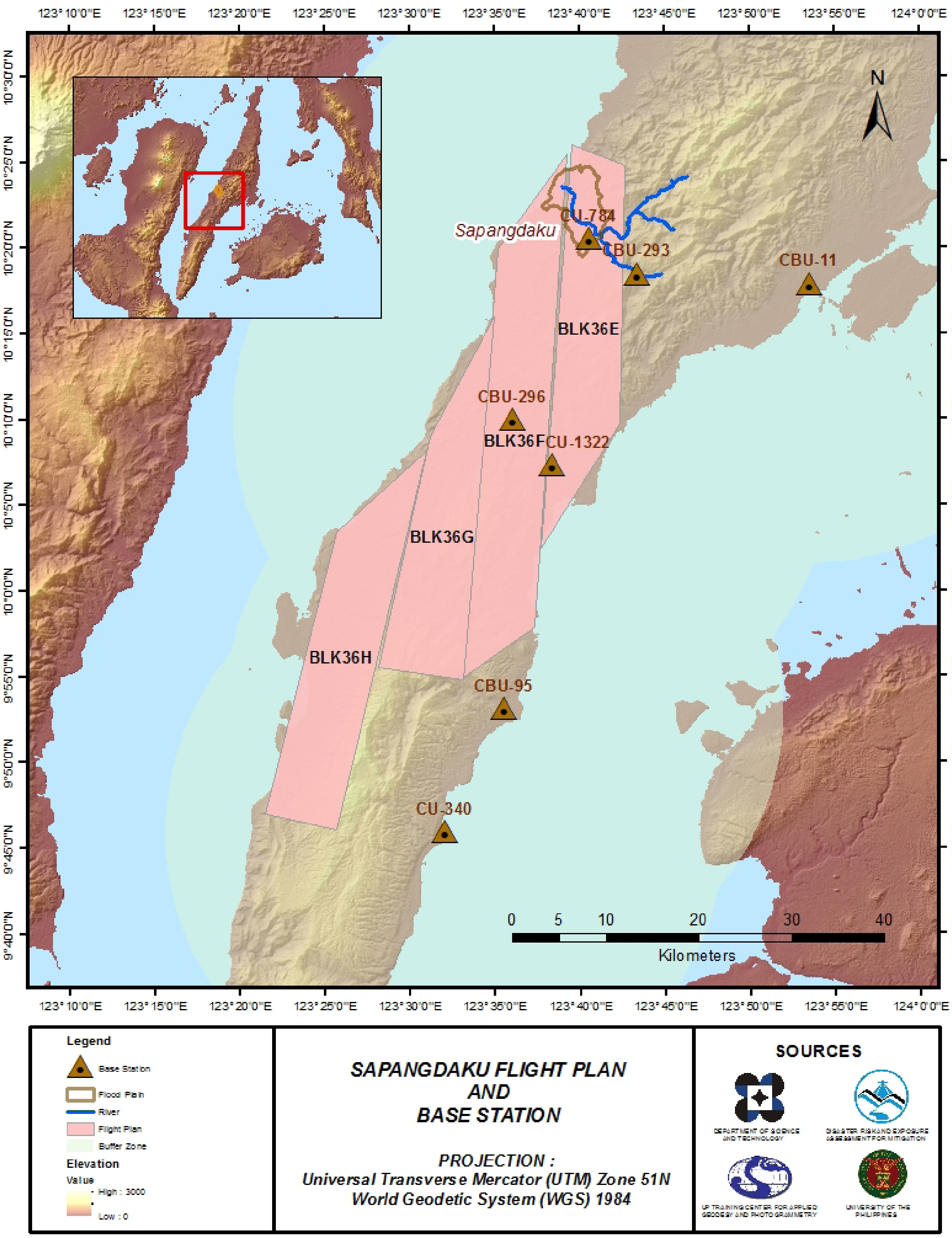


Figure 2. Flight plans and base stations used for Sapangdaku Floodplain

2.2 Ground Base Station

The project team was able to recover four (4) NAMRIA ground control points: CBU-95 which is of first (1st) order accuracy, and CBU-11, CBU-293 and CBU-296 which are of second (2nd) order accuracy. Three (3) NAMRIA benchmark were also recovered: CU-340, CU-784 and CU-1322 which are of first (1st) order accuracy. This benchmark was used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (July 22 and 30, August 1, 2 and 13, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Sapangdaku floodplain are shown in Figure 2.

Figure 3 to Figure 9 show the recovered NAMRIA control station within the area, in addition Table 2 to Table 8 show the details about the following NAMRIA control stations and established points, Table 9 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

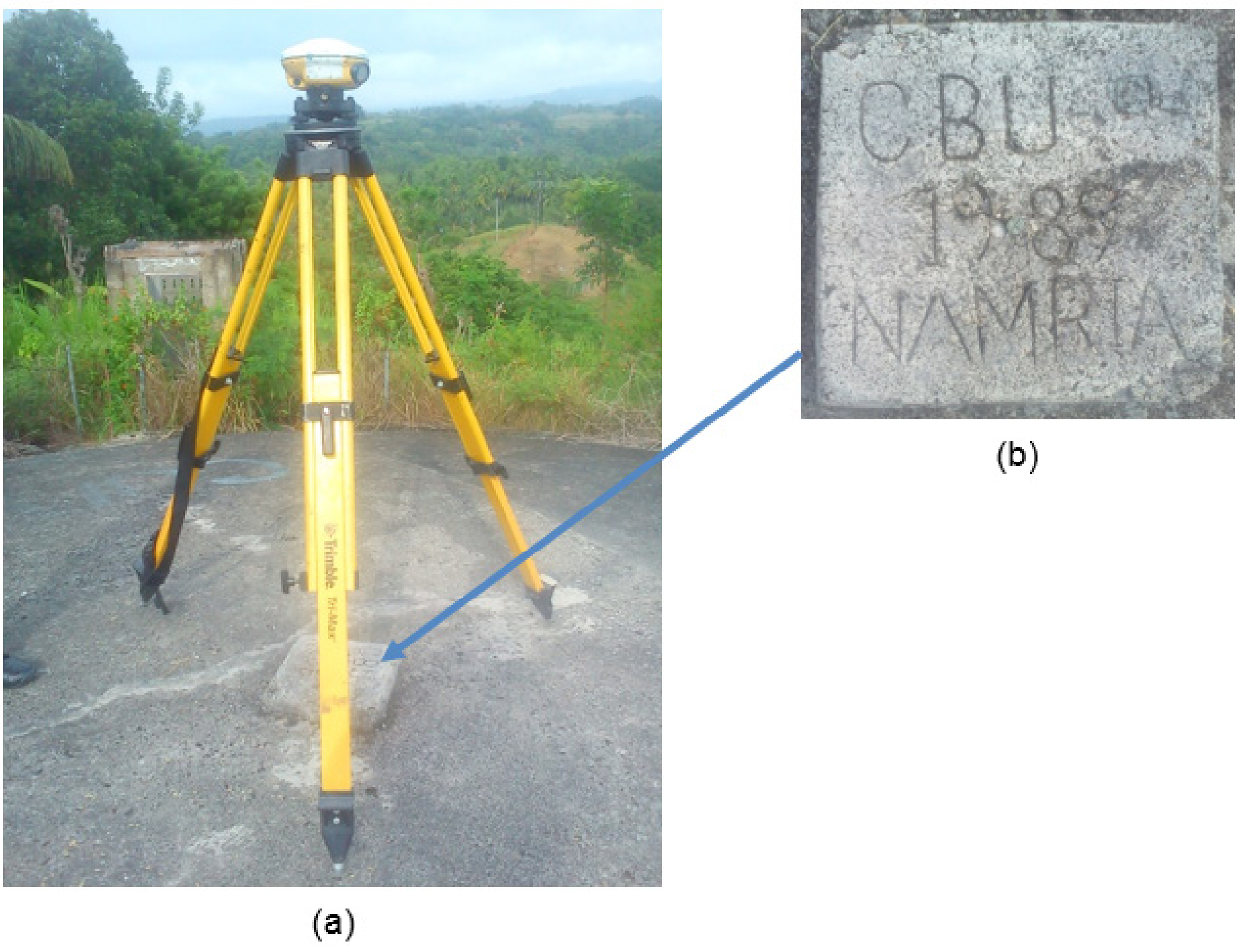
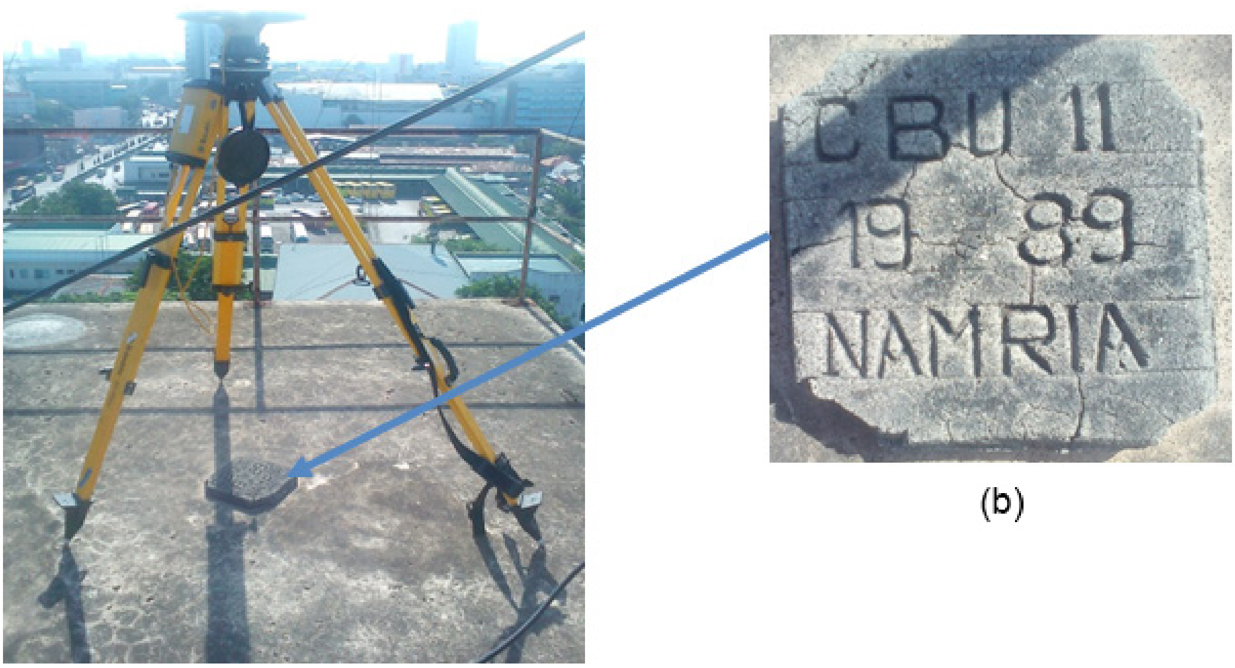


Figure 3. GPS set-up over CBU-95 on the center top of convex concrete shell of water tank in Barangay Canbanua, Argao, Cebu (a) and NAMRIA reference point CBU-95 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point CBU-95 used as base station for the LiDAR Acquisition

Station Name	CBU-95	
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	9° 53’ 12.12011” 123° 35’ 25.30633” 53.60100 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	564,747.93 m 1,093,256.973 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 53’ 8.07702” North 123° 36’ 30.59401” East 115.55540 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	564,725.27 m 1,092,874.31 m



(b)

(a)

Figure 4. GPS set-up over CBU-11 on the roof top of the 75 feet concrete tower of Metro Cebu Fire Station, Cebu City Proper (a) and NAMRIA reference point CBU-11 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point CBU-11 used as base station for the LiDAR Acquisition

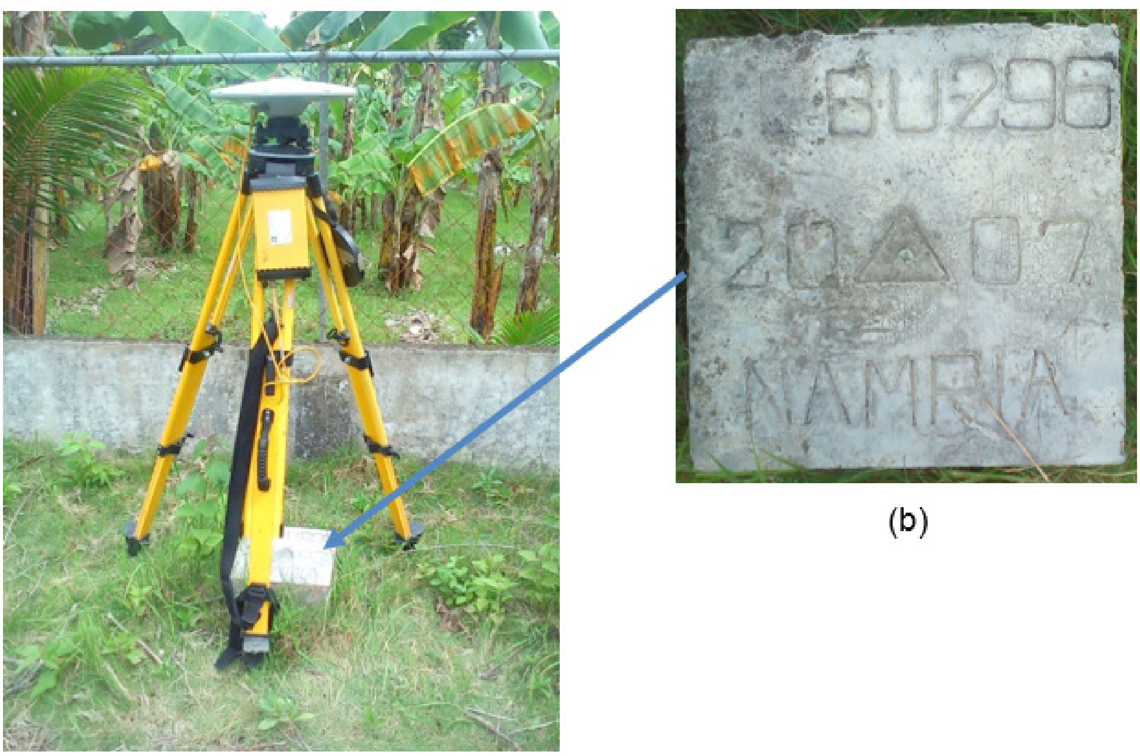
Station Name	CBU-11	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 17’ 56.00367” 123° 53’ 26.63633” 44.27700 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	597,568.76 m 1,138,921.917 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 17’ 51.88109” North 125° 53’ 31.88503” East 106.03300 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	597,534.61 m 1,138,523.27 m

(a) (b)

Figure 5. GPS set-up over CBU-293 inside the premises of Cantabaco National High School in Barangay Cantabaco, Toledo City, Cebu (a) and NAMRIA reference point CBU-293 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point CBU-293 used as base station for the LiDAR Acquisition

Station Name	CBU-293	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 18’ 32.84815” 123° 43’ 15.51183” 289.625 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	578,970.41 m 1,140,007.158 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 18’ 28.70835” North 123° 43’ 20.76082” East 350.938 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	578,942.77 m 1,139,608.14 m



(a) (b)

Figure 6. GPS set-up over CBU-296 near a basketball court and a concrete fence in Barangay Zaragosa, Aloguinsan, Cebu (a) and NAMRIA reference point CBU-296 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point CBU-296 used as base station for the LiDAR Acquisition

Station Name	CBU-296	
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	10° 10' 2.93937" 123° 35' 54.77903" 144.990 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	565,589.364 m 1,124,313.588 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 9' 58.82504" North 123° 36' 0.04167" East 206.327 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	565,692.642 m 1,123,854.689 m

(a) (b)

Figure 7. GPS set-up over CU-340 in aconcrete sidewalk at the end of Dalaguete bridge in Barangay Balud, Dalaguete, Cebu (a) and NAMRIA reference point CU-340 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point CU-340 used as base station for the LiDAR Acquisition

Station Name	CU-340	
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	9° 45' 58.58693" 123° 31' 54.56064" 10.395 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	558,384.358 m 1,079,936.601 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 45' 54.56965" North 123° 31' 59.85960" East 72.475 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	558,328.0075 m 1,079,549.213 m


(a)

(b)

Figure 8. GPS set-up over CU-784 at the end of Balud bridge in Barangay Balud, Toledo City, Cebu (a) and NAMRIA reference point CU-784 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point CU-784 used as base station for the LiDAR Acquisition

Station Name	CU-784	
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	10° 20’ 31.55040” 123° 40’ 25.52663” 60.2685 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	573,882.788 m 1,143,653.145 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 20’ 27.39793” North 125° 40’ 30.77278” East 121.3885 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	573,764.72 m 1,143,242.558 m

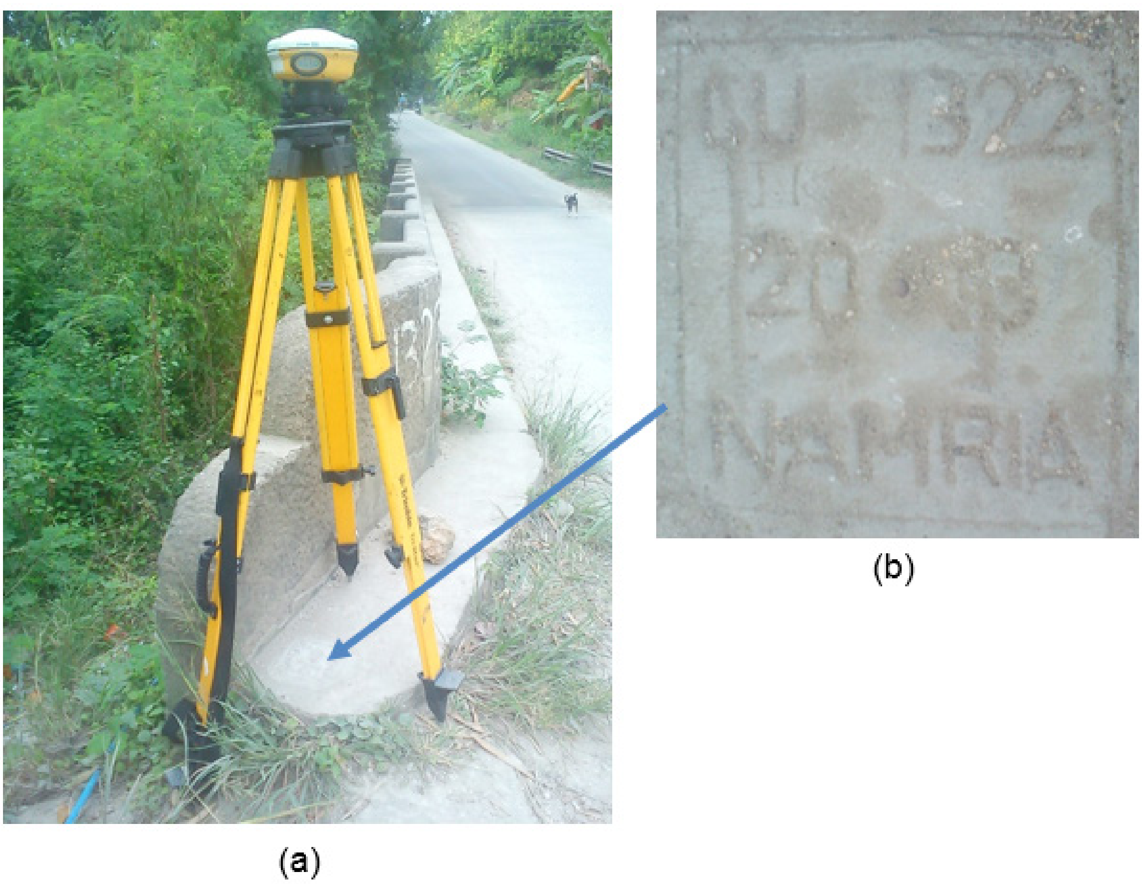


Figure 9. GPS set-up over CU-1322 on a bridge near Gaisano Mall Carcar in Barangay Liburon, Carcar City, Cebu (a) and NAMRIA reference point CU-1322 (b) as recovered by the field team

Table 8. Details of the recovered NAMRIA horizontal control point CU-1322 used as base station for the LiDAR Acquisition

Station Name	CU-1322	
Order of Accuracy		
Relative Error (horizontal positioning)		
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 07' 23.08378" 123° 38' 15.19077" 49.078 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	569,906.791 m 1,119,420.541 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 07' 18.98416" North 123° 38' 20.45712" East 110.613 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	569,848.6915 m 1,119,018.663 m

Table 9. Ground control used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 22, 2014	1741P	1BLK36H203A	CBU-95 and CU-340
July 22, 2014	1743P	1BLK36H203B	CBU-95 and CU-340
July 30, 2014	1777P	1BLK36E212A	CBU-293 and CU-784
July 30, 2014	1779P	1BLK36E212B	CBU-293 and CU-784
August 1, 2014	1781P	1BLK36F213A	CBU-296 and CU-1322
August 2, 2014	1785P	1BLK36GF214A	CBU-296 and CU-1322
August 2, 2014	1787P	1BLK36G214B	CBU-296 and CU-1322
August 13, 2014	1829P	1BLK36H47A225A	CBU-11

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR data acquisition in Sapangdaku floodplain, for a total of twenty-eight hours and fifty-three minutes (28+53) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 shows the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Sapangdaku 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
July 22, 2014	1741P	278.12	186.66	NA	186.66	NA	4	12
July 22, 2014	1743P	278.12	182.89	NA	182.89	NA	2	52
July 30, 2014	1777P	240.48	261.24	31.20	230.04	NA	4	12
July 30, 2014	1779P	240.48	229.13	0.06	229.07	NA	3	47
August 1, 2014	1781P	1084.32	232.23	0.06	232.17	NA	3	36
August 2, 2014	1785P	1084.32	363.48	15.69	347.79	NA	4	5
August 2, 2014	1787P	228.59	263.07	NA	263.07	NA	3	54
August 13, 2014	1829P	267.94	59.44	NA	59.44	NA	2	15
TOTAL		3702.37	1778.14	47.01	1731.13	NA	28	53

Table 11. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHZ)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1741P	1000	30	50	200	30	130	5
1743P	1200	30	50	200	30	130	5
1777P	1000	30	50	200	30	130	5
1779P	1000	30	50	200	30	130	5
1781P	1000	30	50	200	30	130	5
1785P	1200	30	50	200	30	130	5
1787P	1000	30	50	200	30	130	5
1829P	1200	30	50	200	30	130	5

2.4. Survey Coverage

Sapangdaku floodplain is located in the province of Cebu with majority of the floodplain situated within the city of Toledo. The list of cities and municipalities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Sapangdaku floodplain is presented in Figure 10.

Table 12. List of municipalities and cities surveyed during the Ocoy Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City	Total Area Surveyed (km²)	Percentage of Area Surveyed
Cebu	Alcantara	31.56	31.54	99.92%
	Alegria	100.37	28.31	28.20%
	Aloguinsan	65.65	30.46	46.40%
	Argao	199.38	147.24	73.85%
	Asturias	252.52	17.77	7.04%
	Badian	105.71	76.89	72.74%
	Balamban	236.29	55.93	23.67%
	Barili	116.51	97.26	83.48%
	Carcar City	85.08	72.54	85.26%
	Cebu City	290.59	17.29	5.95%
	Dalaguete	116.17	7.97	6.86%
	Dumanjug	81.01	80.99	99.98%
	Mandaue City	31	1.57	5.08%
	Moalboal	81.08	72.72	89.70%
	Naga City	98.77	50.84	51.48%
	Pinamungahan	108.99	47.17	43.28%
	Ronda	42.48	42.42	99.87%
	San Fernando	76.46	75.9	99.27%
	Sibonga	120.92	115.94	95.88%
	Talisay City	48.91	1.1	2.25%
	Toledo City	214.07	164.54	76.86%
Total		2503.52	1236.39	49.39%

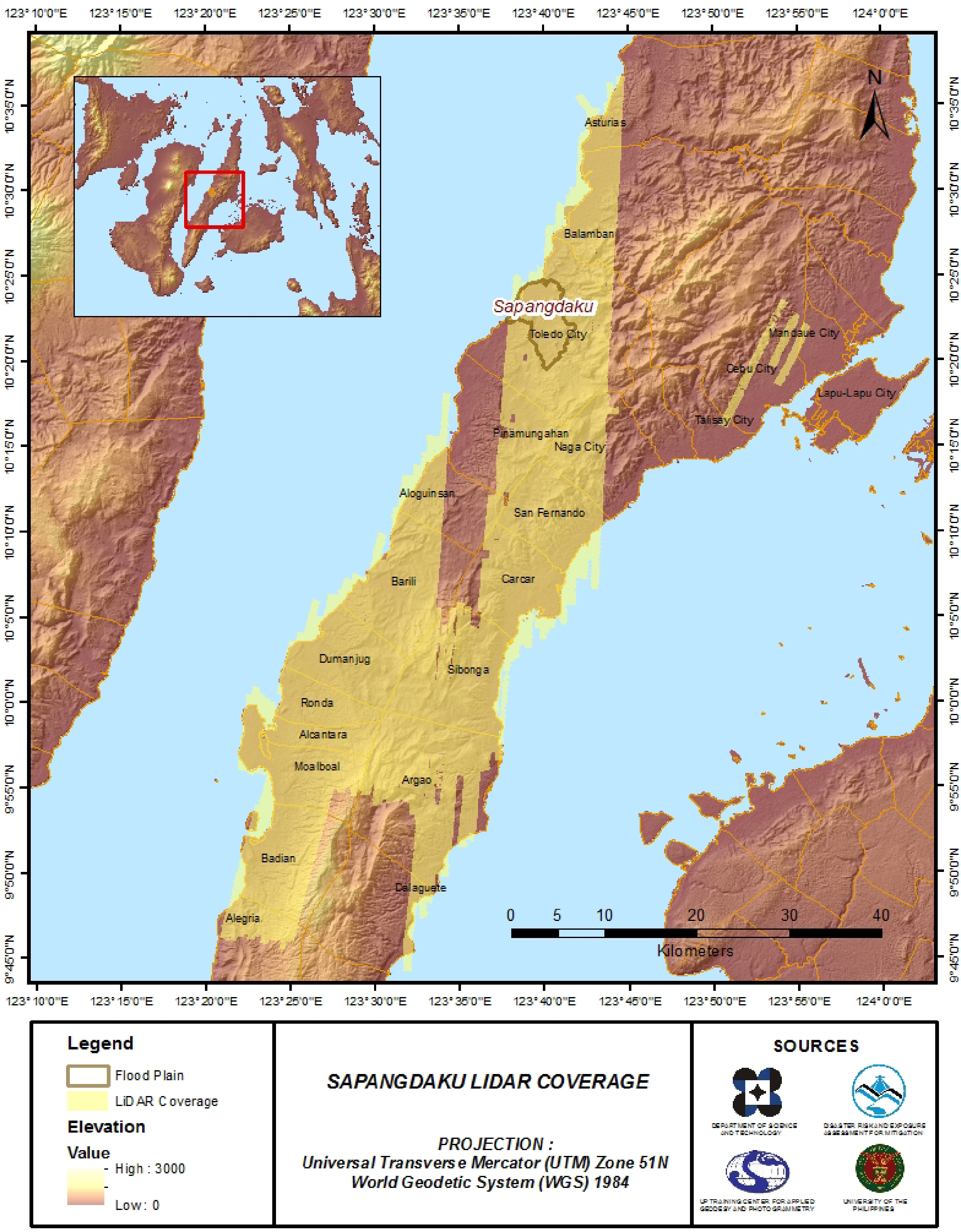


Figure 10. Actual LiDAR survey coverage for Sabangdaku Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SAPANGDAKU FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 11.

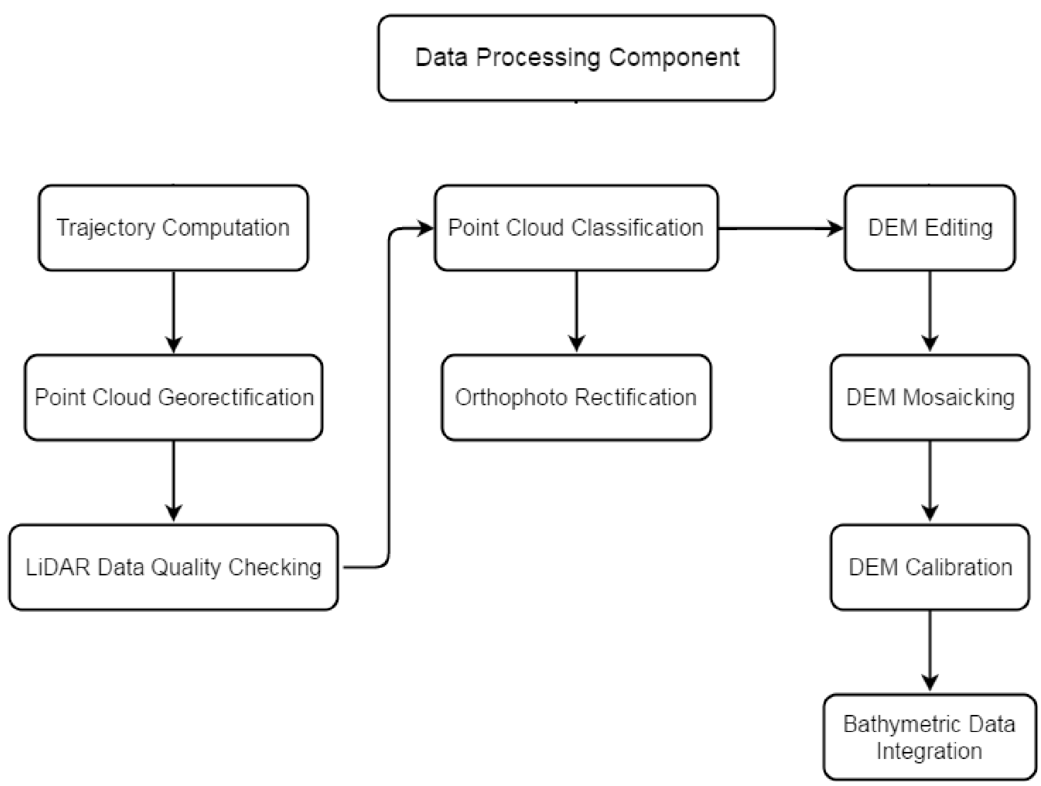

Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Sapangdaku floodplain can be found in Annex 5. Missions flown during the first survey conducted on July 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on April were flown using the Aquarius system over Cebu and Bacolod.

The Data Acquisition Component (DAC) transferred a total of 213.24 Gigabytes of Range data, 2.17 Gigabytes of POS data, 343.54 Megabytes of GPS base station data, and 374.24 Gigabytes of raw image data to the data server on July 22, 2014 for the first survey and April 26, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sapangdaku was fully transferred on May 20, 2016, as indicated on the Data Transfer Sheets for Sapangdaku floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 1785P, one of the Sapangdaku flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 20, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

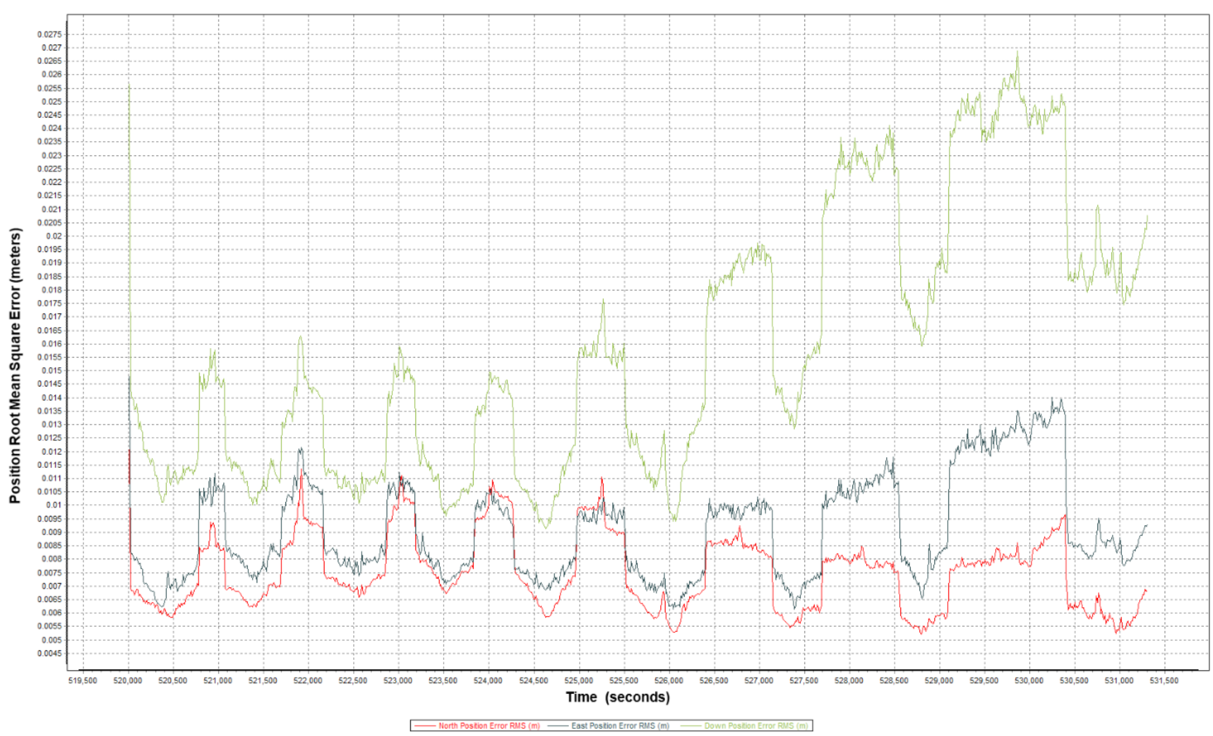

Figure 12. Smoothed Performance Metrics of Sapangdaku Flight 1785P.

The time of flight was from 519500 seconds to 531500 seconds, which corresponds to morning of August 2, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turnaround period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaks at 1.15 centimeters, the East position RMSE peaks at 1.40 centimeters, and the Down position RMSE peaks at 2.70 centimeters, which are within the prescribed accuracies described in the methodology.

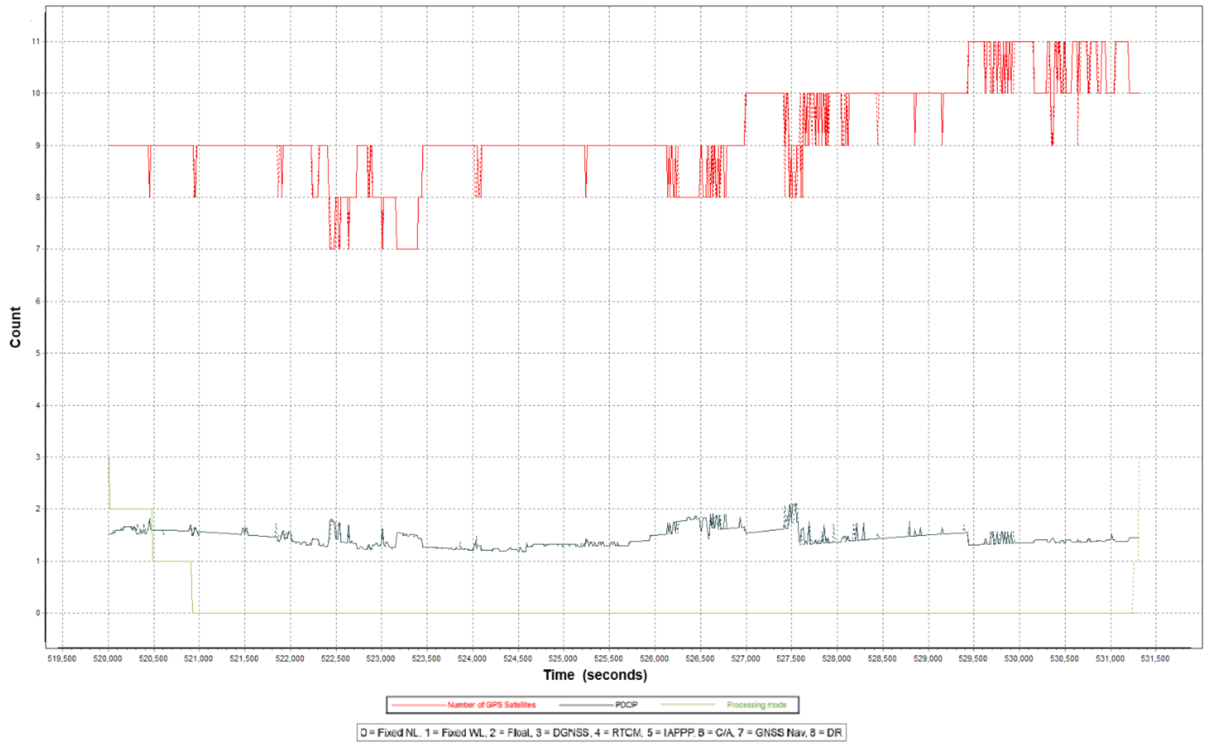

Figure 13. Solution Status Parameters of Sapangdaku Flight 1785P.

The *Solution Status* parameters of flight 1785P, one of the Sapangdaku flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 11. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sapangdaku flights is shown in Figure 14.

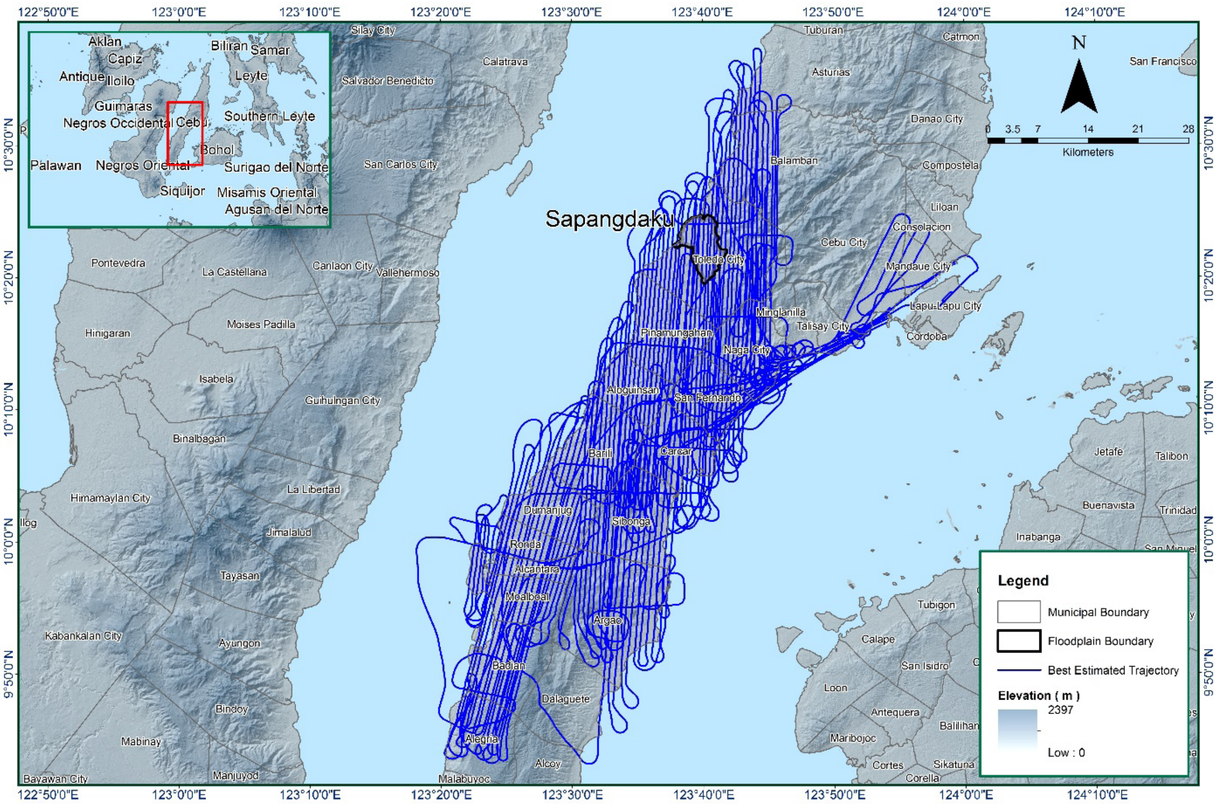

Figure 14. Best Estimated Trajectory for Sapangdaku Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 130 flight lines, with each flight line containing two channel, since the Pegasus systems contain two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Sapangdaku floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Sapangdaku flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000199
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.001228
GPS Position Z-correction stdev (<0.01meters)	0.0027

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Sapangdaku Floodplain is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

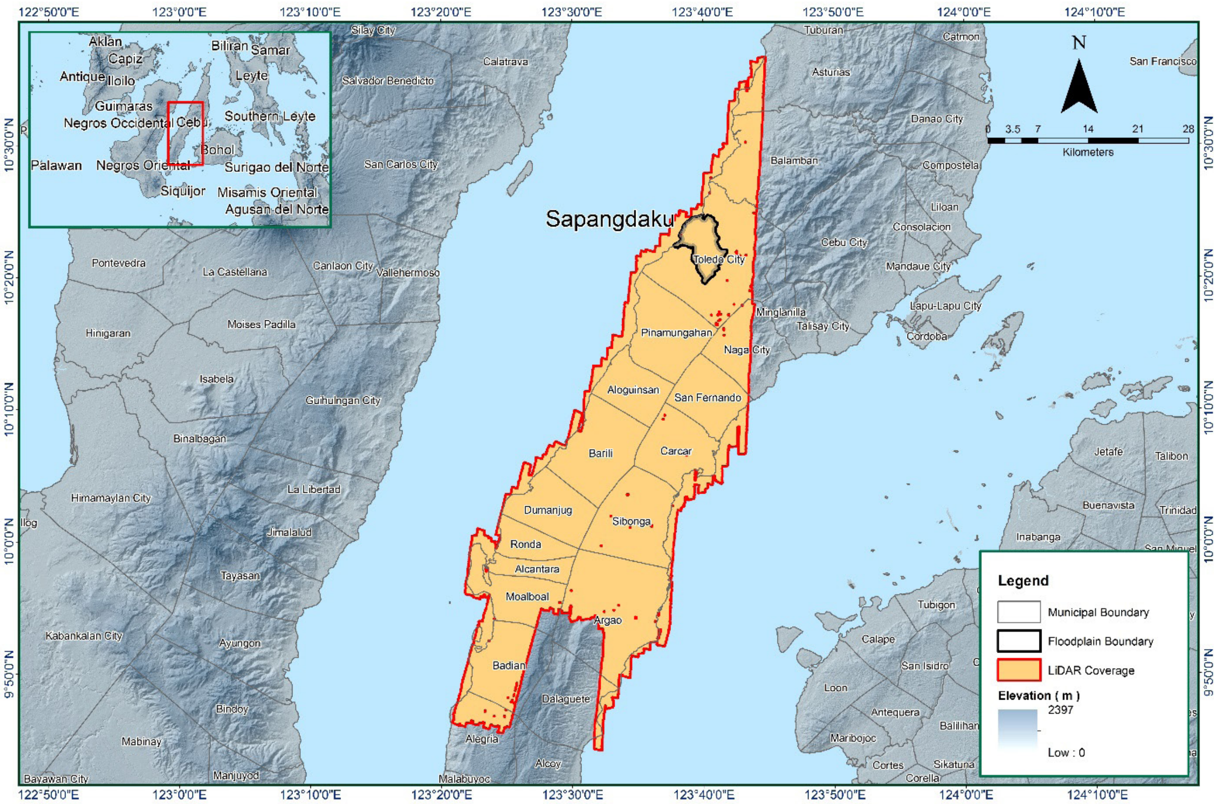

Figure 15. Boundary of the processed LiDAR data over Sapangdaku Floodplain

The total area covered by the Sapangdaku missions is 1,685.43sq.km that is comprised of nine (9) flight acquisitions grouped and merged into five (5) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Sapangdaku Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cebu_Blk36E	1777P	461.81
	1779P	
Cebu_Blk36F	1781P	568.66
	1785P	
	1793P	
Cebu_Blk36H	1741P	355.71
	1743P	
Cebu_Blk36G	1787P	264.15
Cebu_Blk36H_supplement	1829P	35.10
	TOTAL	**1,685.43 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 16. Since the Since the Pegasus system employ two channels, we would expect 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.

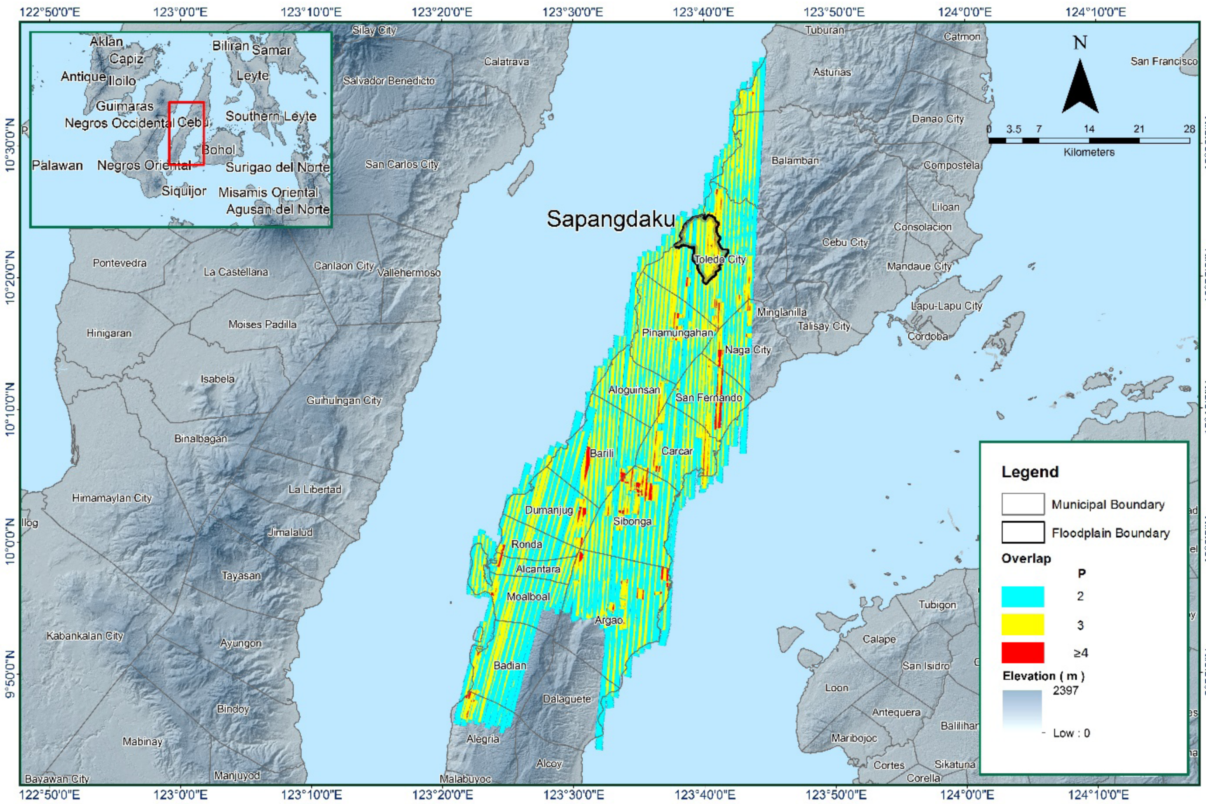

Figure 16. Image of data overlap for Sapangdaku Floodplain.

The overlap statistics per block for the Sapangdaku floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 37.88% and 51.18% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 17. It was determined that all LiDAR data for Sapangdaku floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.49 points per square meter.

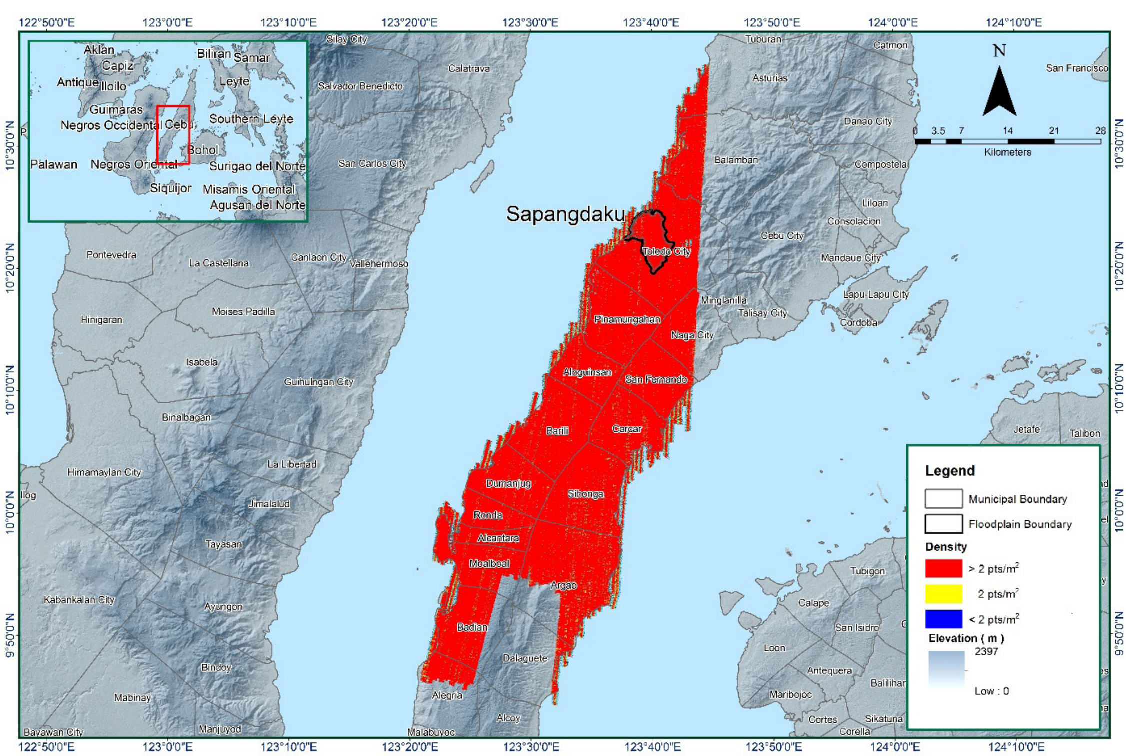

Figure 17. Pulse density map of merged LiDAR data for Sapangdaku Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

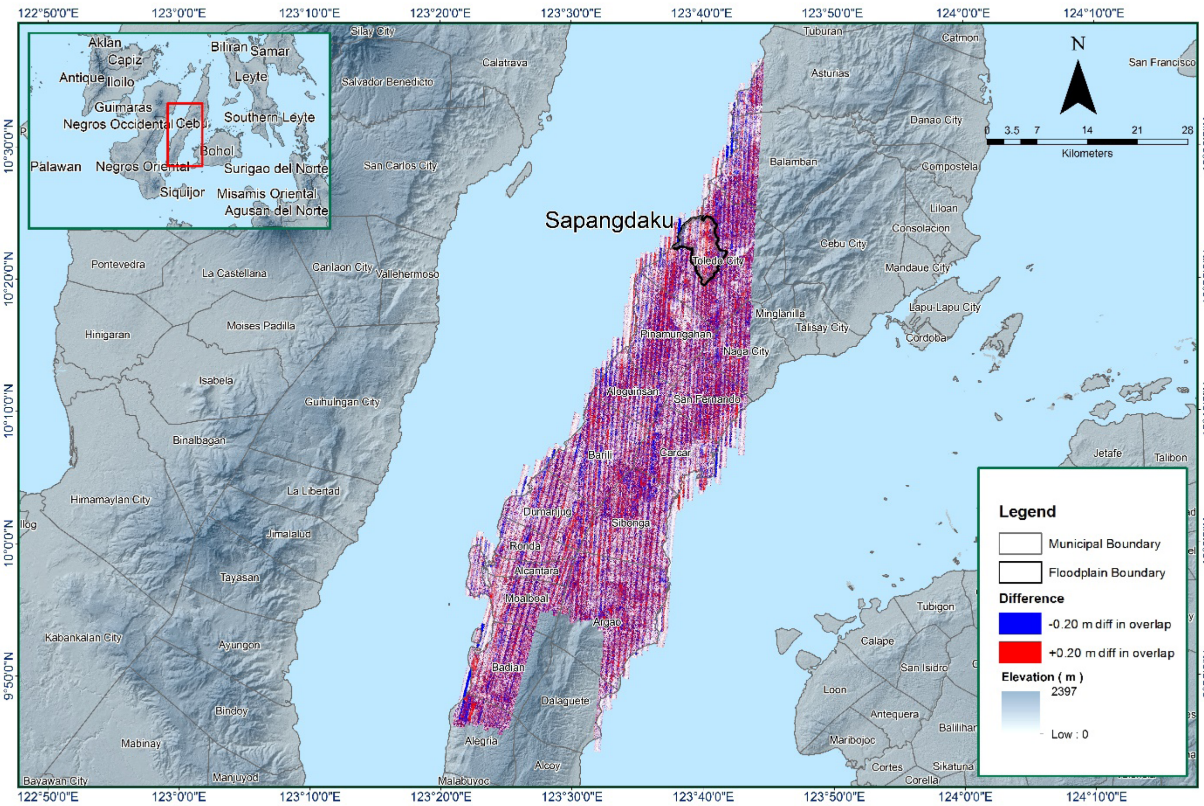

Figure 18. Elevation difference map between flight lines for Sapangdaku Floodplain.

A screen capture of the processed LAS data from a Sapangdaku flight 1785P loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

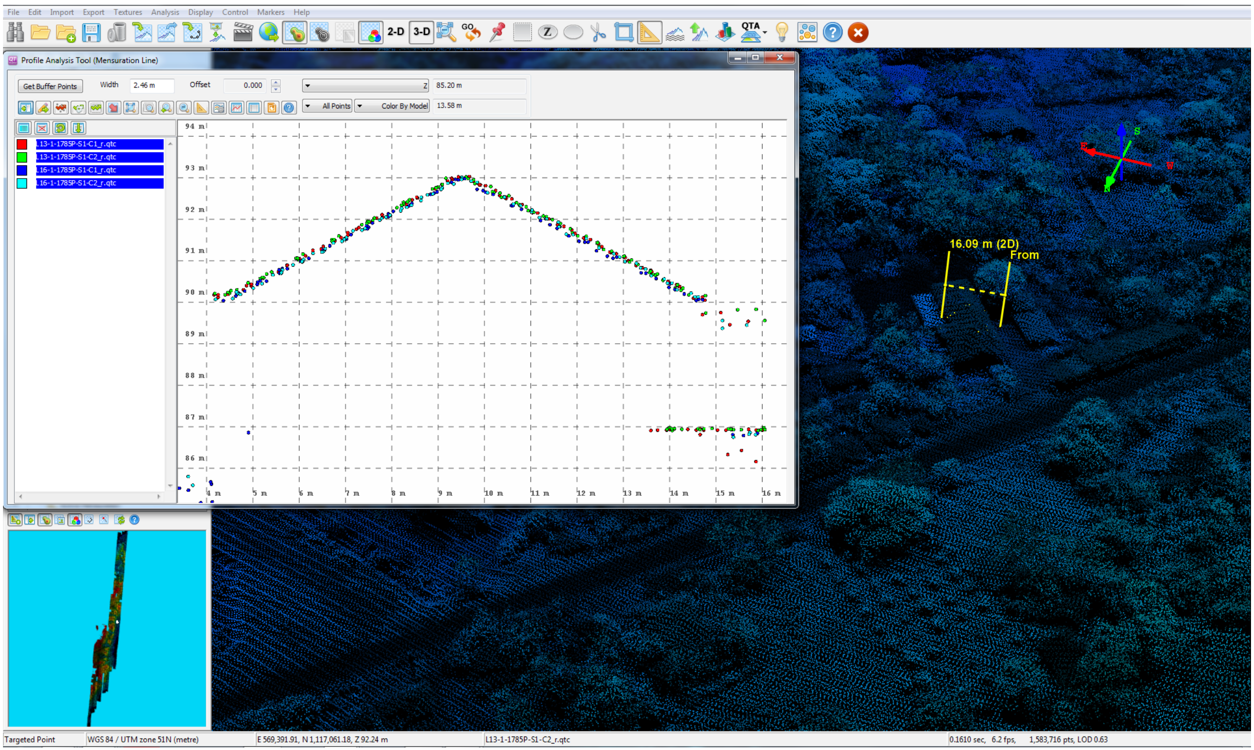

Figure 19. Quality checking for Sapangdaku Flight 1785P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Sapangdaku classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,690,985,864
Low Vegetation	1,372,990,484
Medium Vegetation	2,997,808,159
High Vegetation	2,100,036,019
Building	89,247,490

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sapangdaku floodplain is shown in Figure 20. A total of 2055 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 998.24 meters and 46.63 meters respectively.

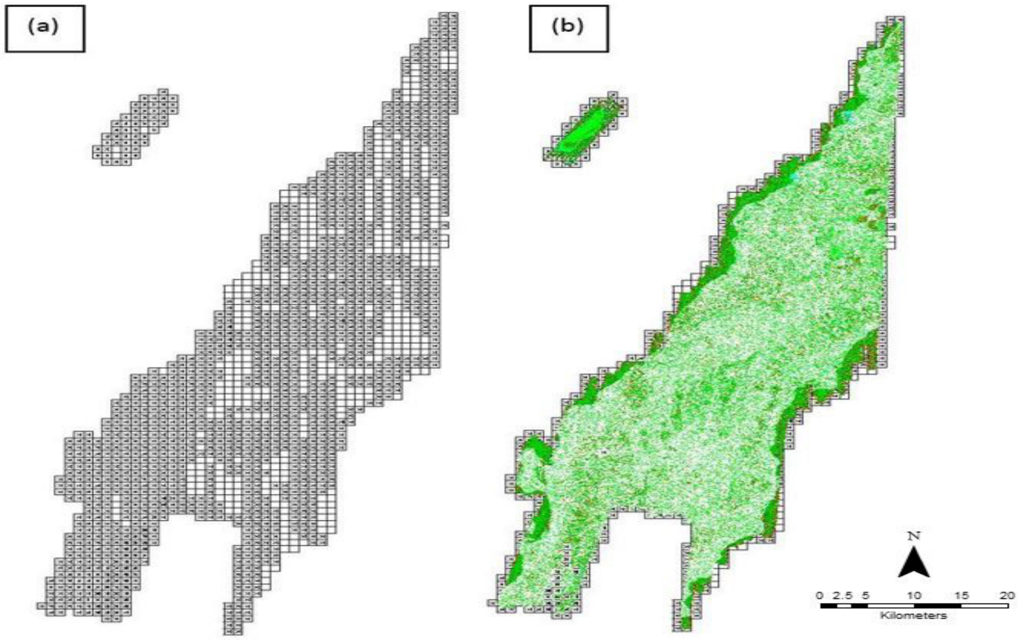

Figure 20. Tiles for Sapangdaku Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

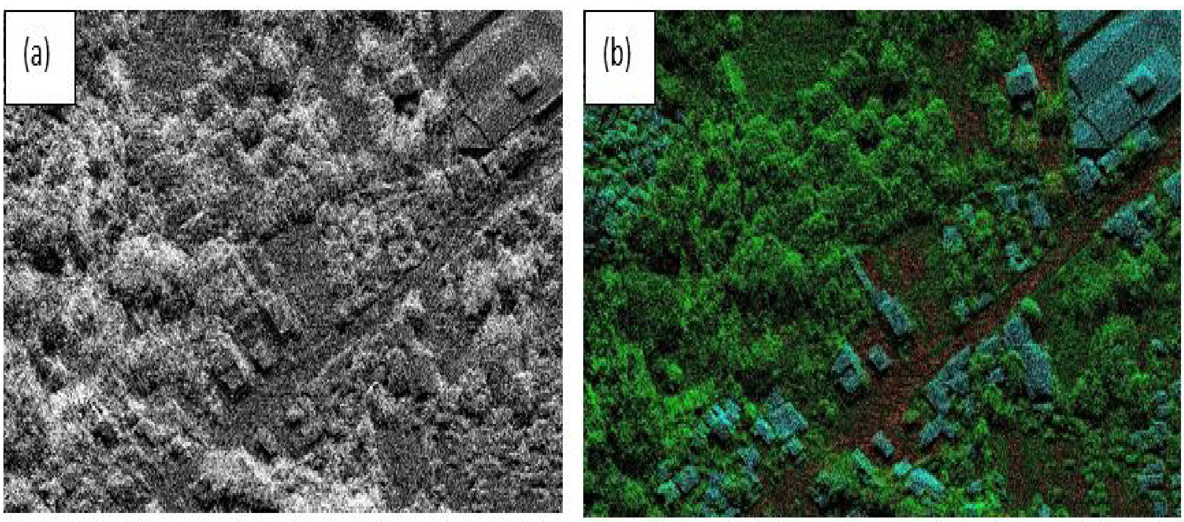

Figure 21. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 22. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

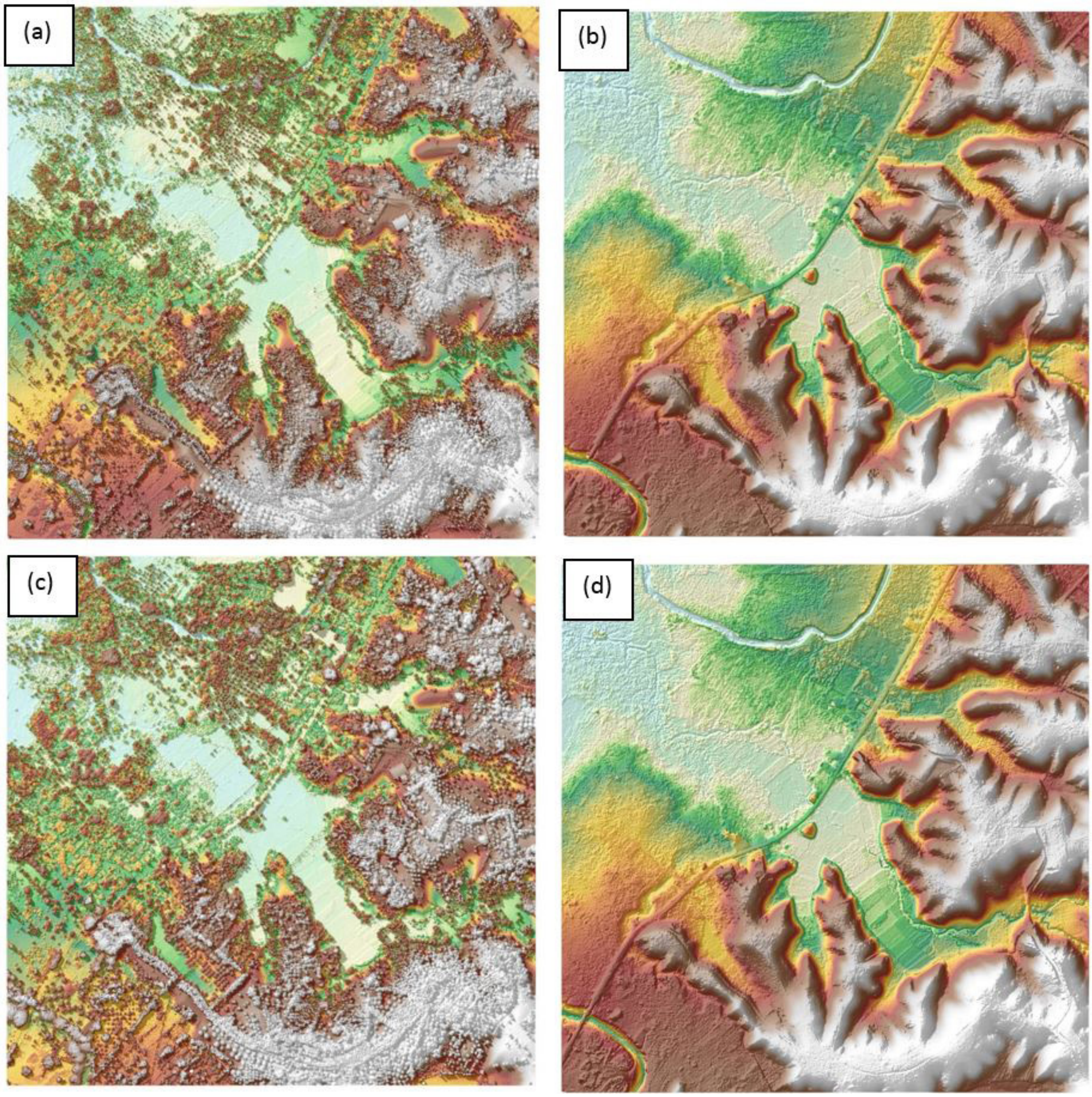

Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sapangdaku Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,985 1km by 1km tiles area covered by Sapangdaku floodplain is shown in Figure 23. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sapangdaku floodplain has a total of 1,544.39 sq.km orthophotogaph coverage comprised of 4881 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

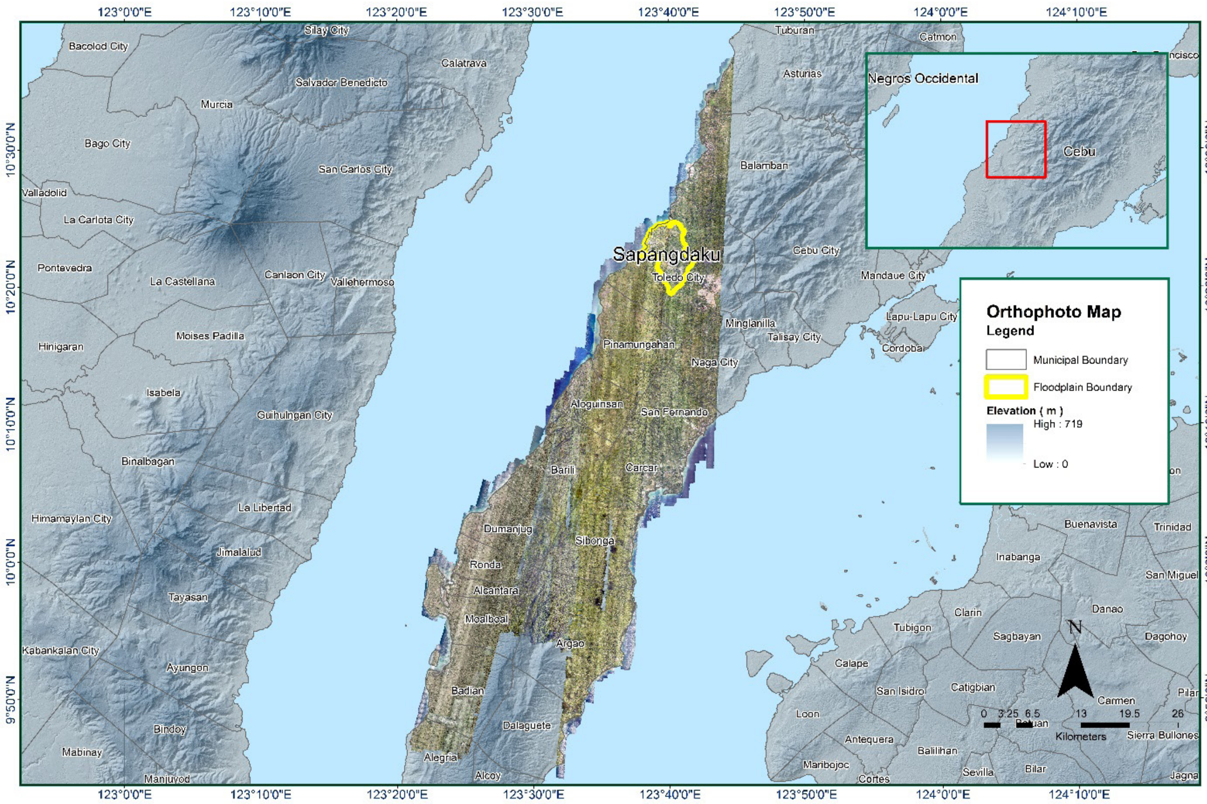

Figure 23. Sapangdaku Floodplain with available orthophotographs

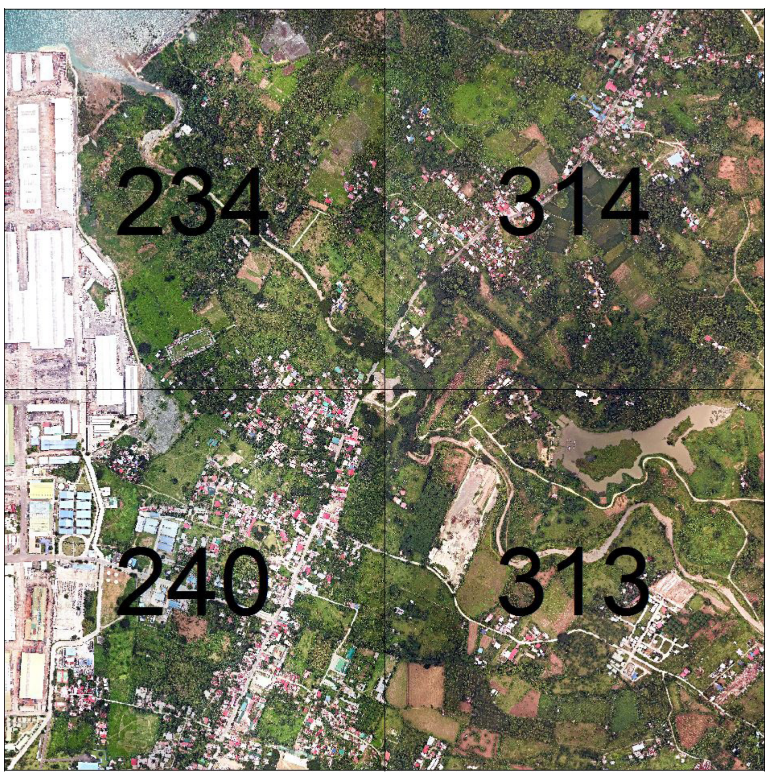

Figure 24. Sample orthophotograph tiles for Sapangdaku floodplain

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Sapangdaku flood plain. These blocks are composed of Cebu blocks with a total area of 1,685.43 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

LiDAR Blocks	Area (sq.km)
Cebu_Blk36E	461.81
Cebu_Blk36F	568.66
Cebu_Blk36H	355.71
Cebu_Blk36G	264.15
Cebu_Blk36H_supplement	35.10
TOTAL	**1,685.43 sq.km.**

Portions of DTM before and after manual editing are shown in Figure 25. The bridge (Figure 25a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 25b) in order to hydrologically correct the river. The paddy field (Figure 25c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 25d) to allow the correct flow of water.

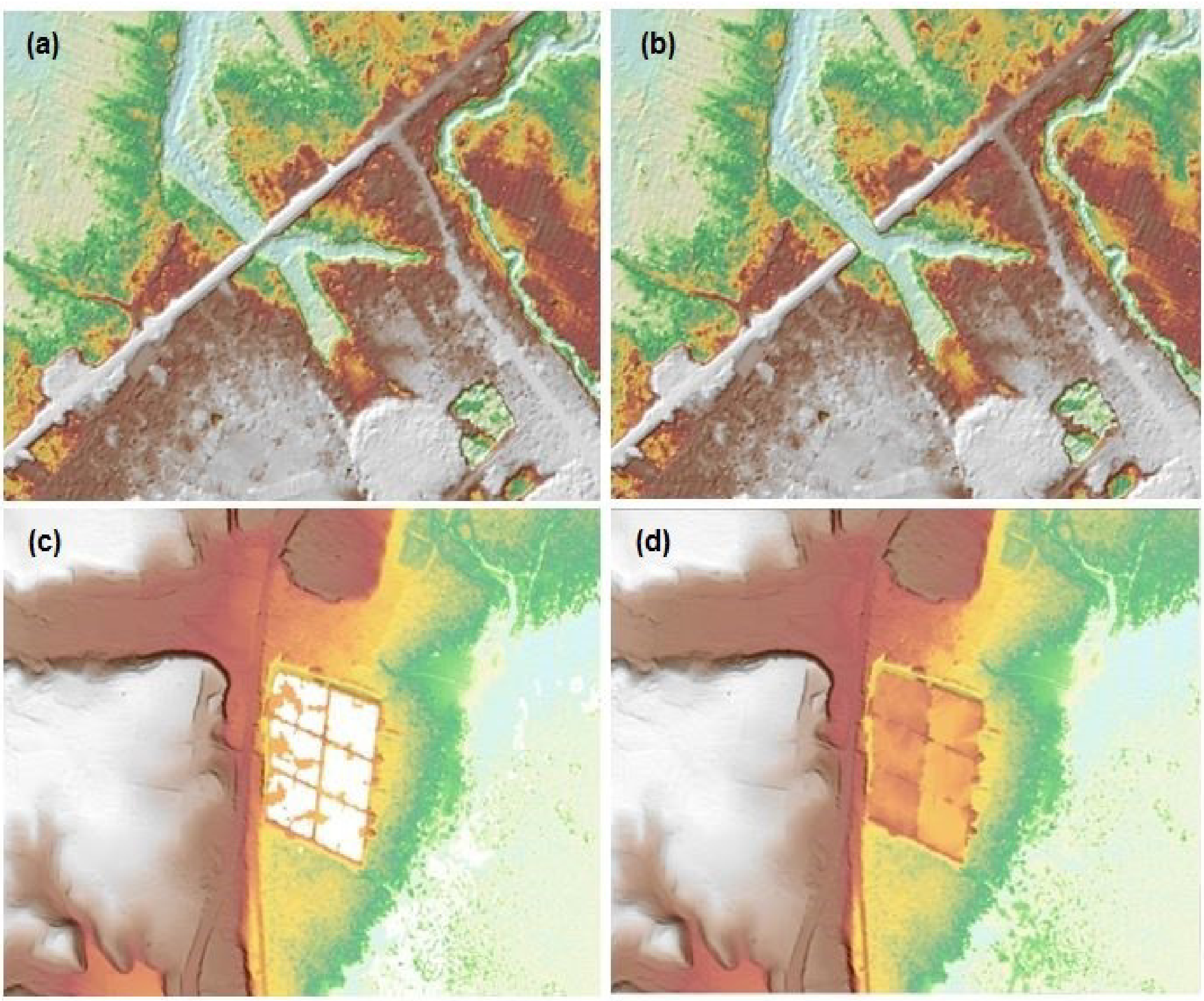

Figure 25. Portions in the DTM of Sapangdaku floodplain – a bridge before (a) and after (b) manual editing; and a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Cebu_Blk36G was used as the reference block at the start of mosaicking because of the presence of more fixed built-up structures. Table 17 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sapangdaku floodplain is shown in Figure 26. It can be seen that the entire Sapangdaku floodplain is 100% covered by LiDAR data.

Table 17. Shift Values of each LiDAR Block of Sapangdaku Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Cebu_Blk36E	0.00	0.00	-0.24
Cebu_Blk36F	0.00	0.00	0.00
Cebu_Blk36G	0.00	0.00	0.00
Cebu_Blk36H	0.00	0.00	-0.03
Cebu_Blk36H_supplement	0.00	0.00	-3.70

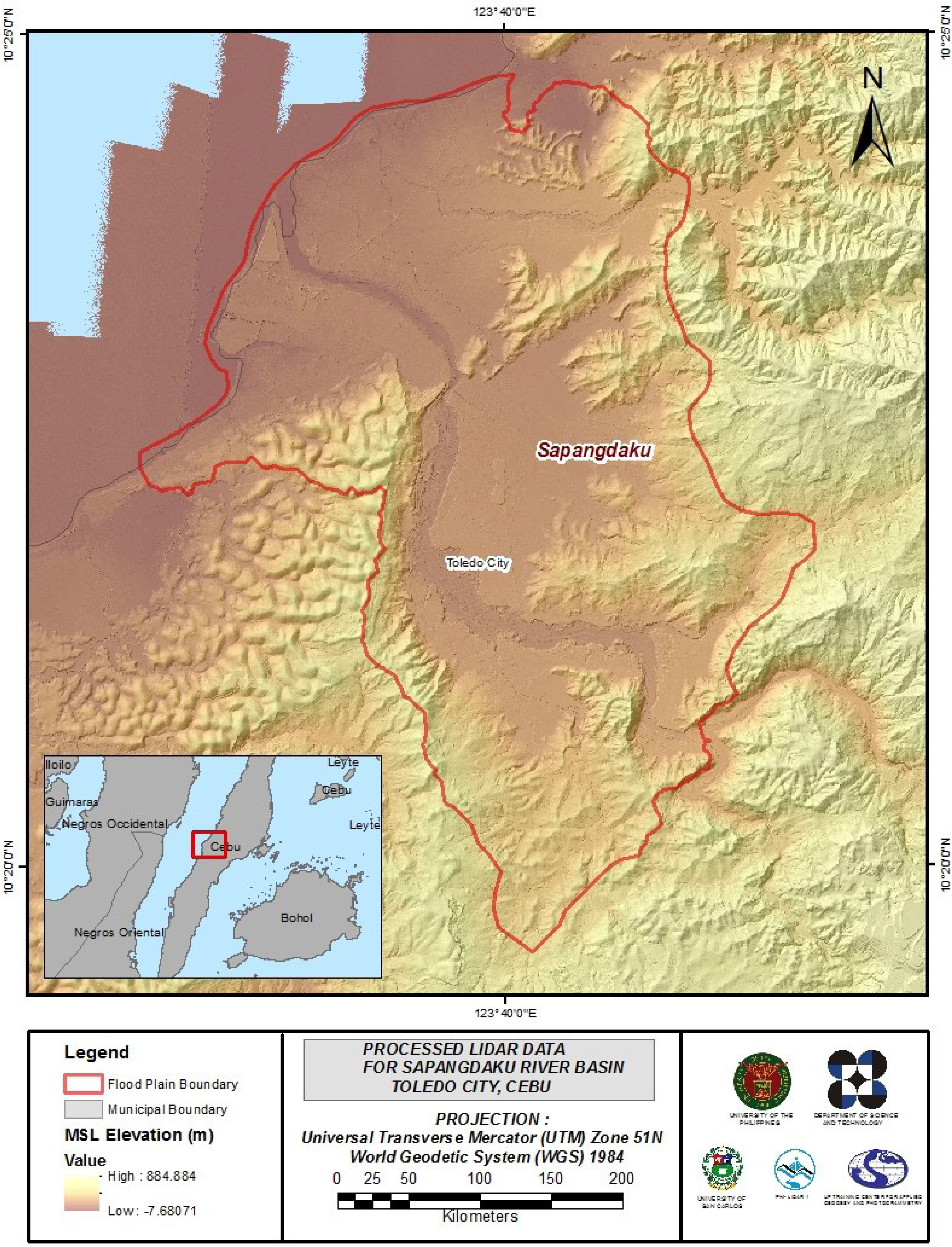

Figure 26. Map of Processed LiDAR Data for Sapangdaku Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Sapangdaku to collect points with which the LiDAR dataset is validated is shown in Figure 27. A total of 22,471 survey points were gathered for all the flood plains within the province of Cebu wherein the Sapangdaku floodplain is located. Random selection of 80% of the survey points, resulting to 17,977 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 28. 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 points is 0.55 meters with a standard deviation of 0.20 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 0.55 meters, to the mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

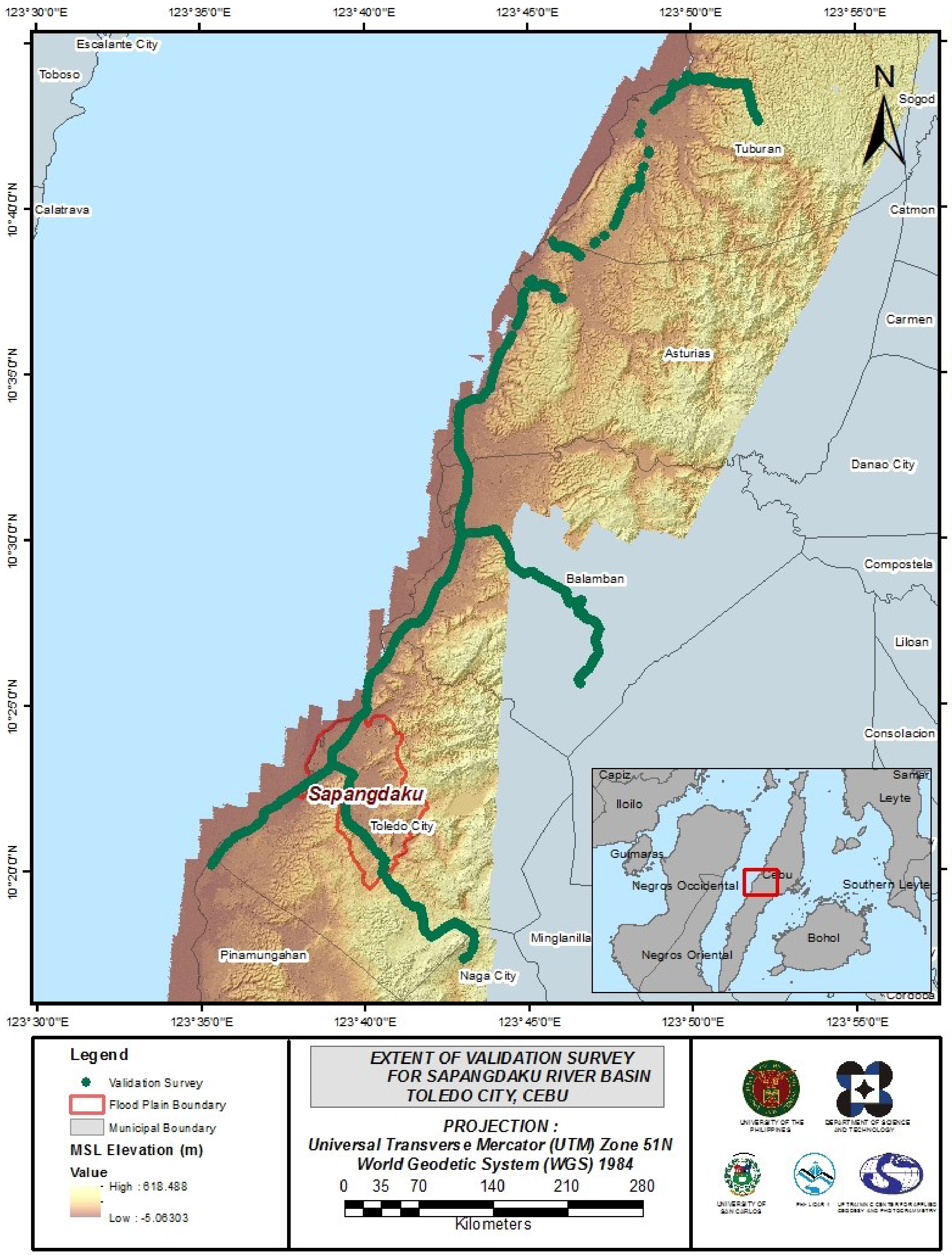

Figure 27. Map of Sapangdaku Floodplain with validation survey points in green.

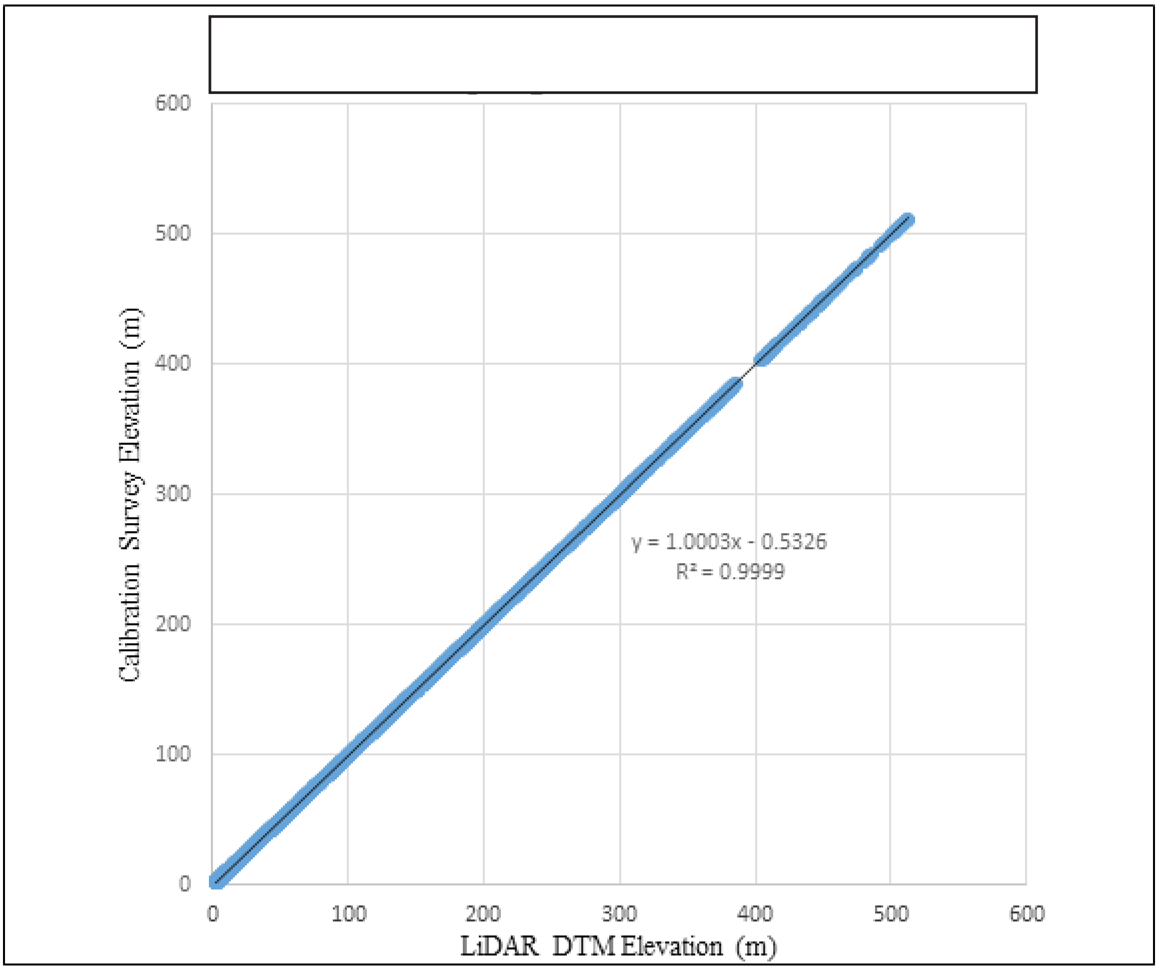

Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.55
Standard Deviation	0.20
Average	-0.51
Minimum	-1.01
Maximum	-0.00005

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 302 points, were used for the validation of calibrated Sapangdaku DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 29. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.13 meters with a standard deviation of 0.13 meters, as shown in Table 19.

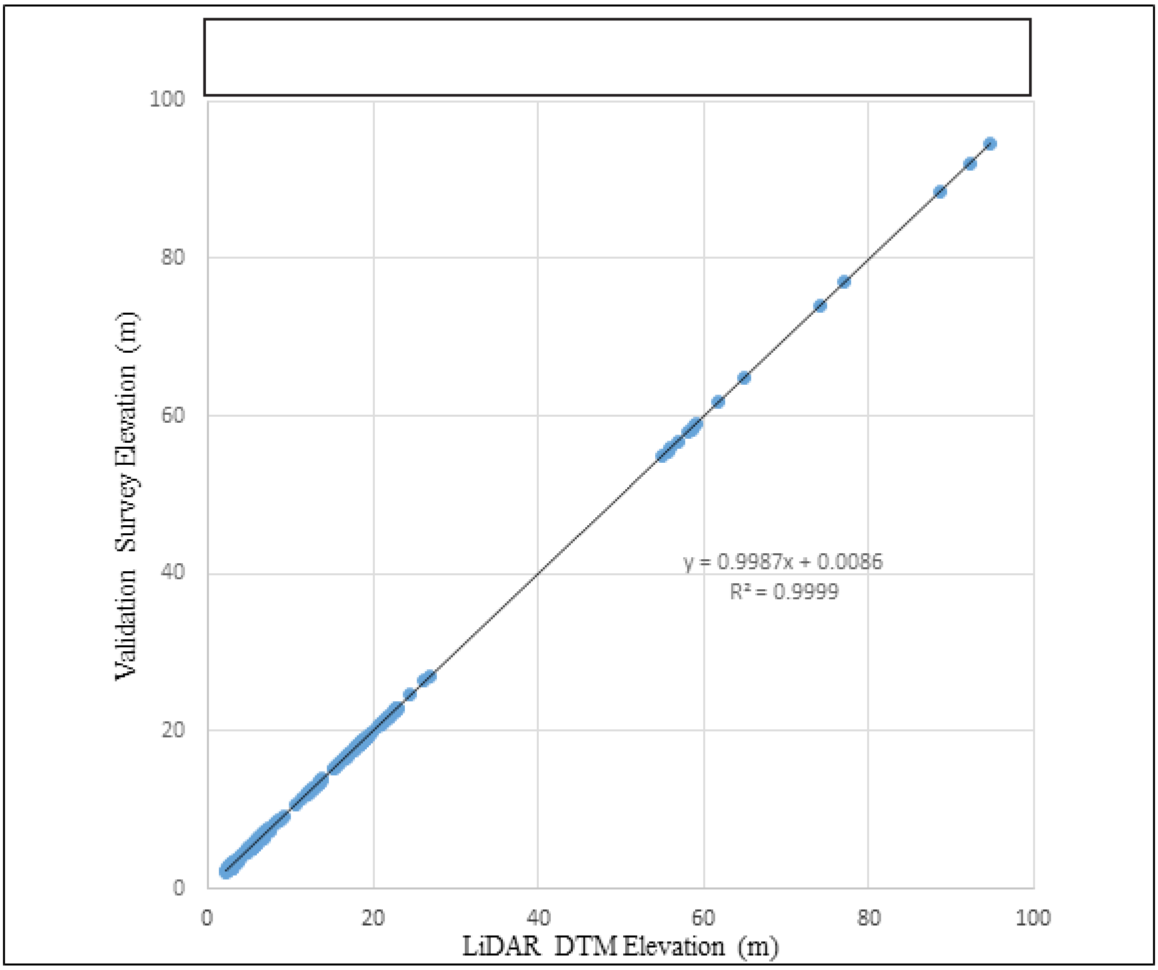

Figure 29. Correlation plot between validation survey points and LiDAR data.

Table 19. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.13
Average	-0.01
Minimum	-0.24
Maximum	0.34

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, both centerline and zigzag data was available for Sapangdaku with 21,870 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.03 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sapangdaku integrated with the processed LiDAR DEM is shown in Figure 30.

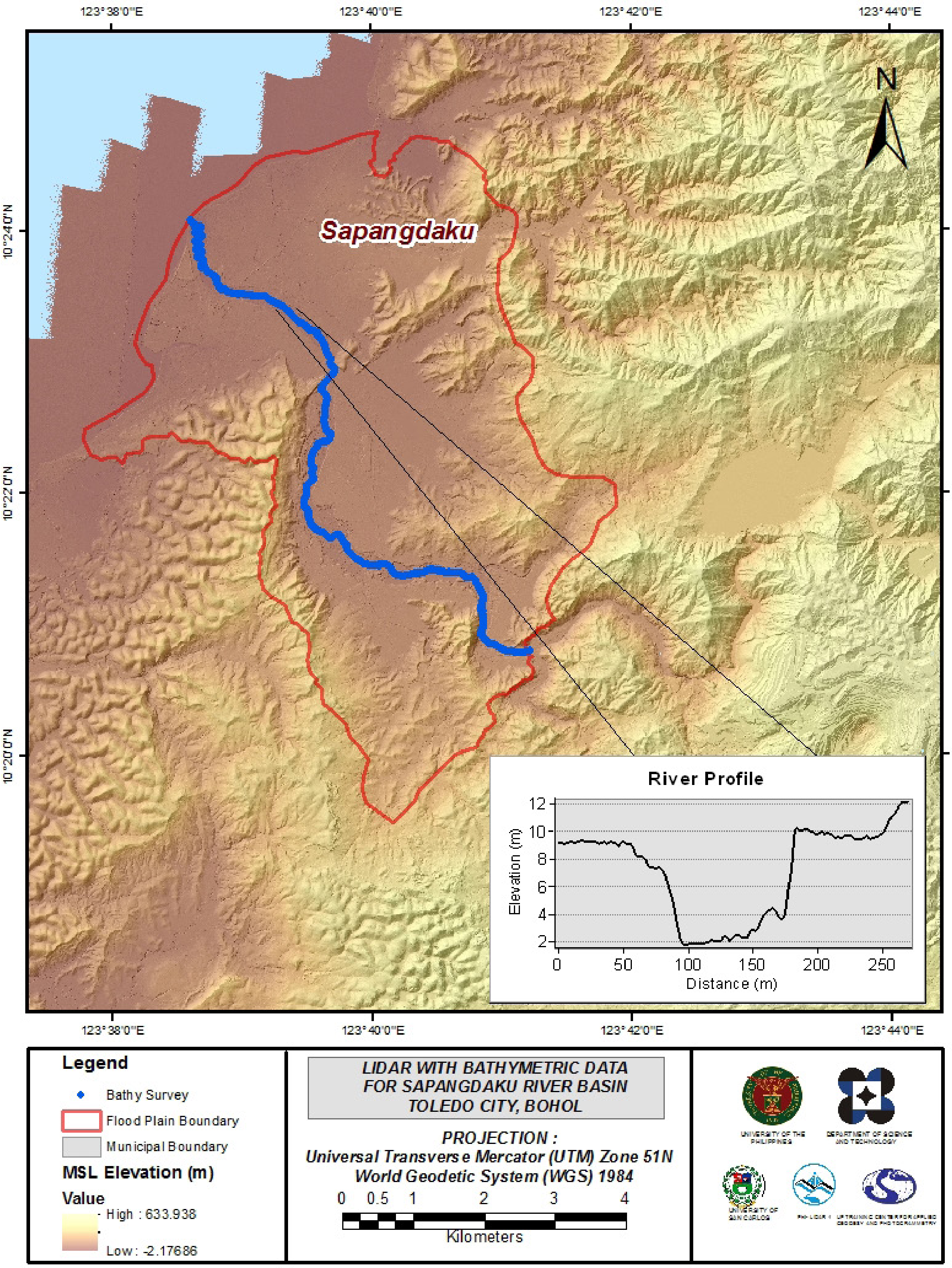

Figure 30. Map of Supangdaku Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Sapangdaku floodplain, including its 200 m buffer, has a total area of 42.73 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,634 building features, are considered for QC. Figure 31 shows the QC blocks for Sapangdaku floodplain.

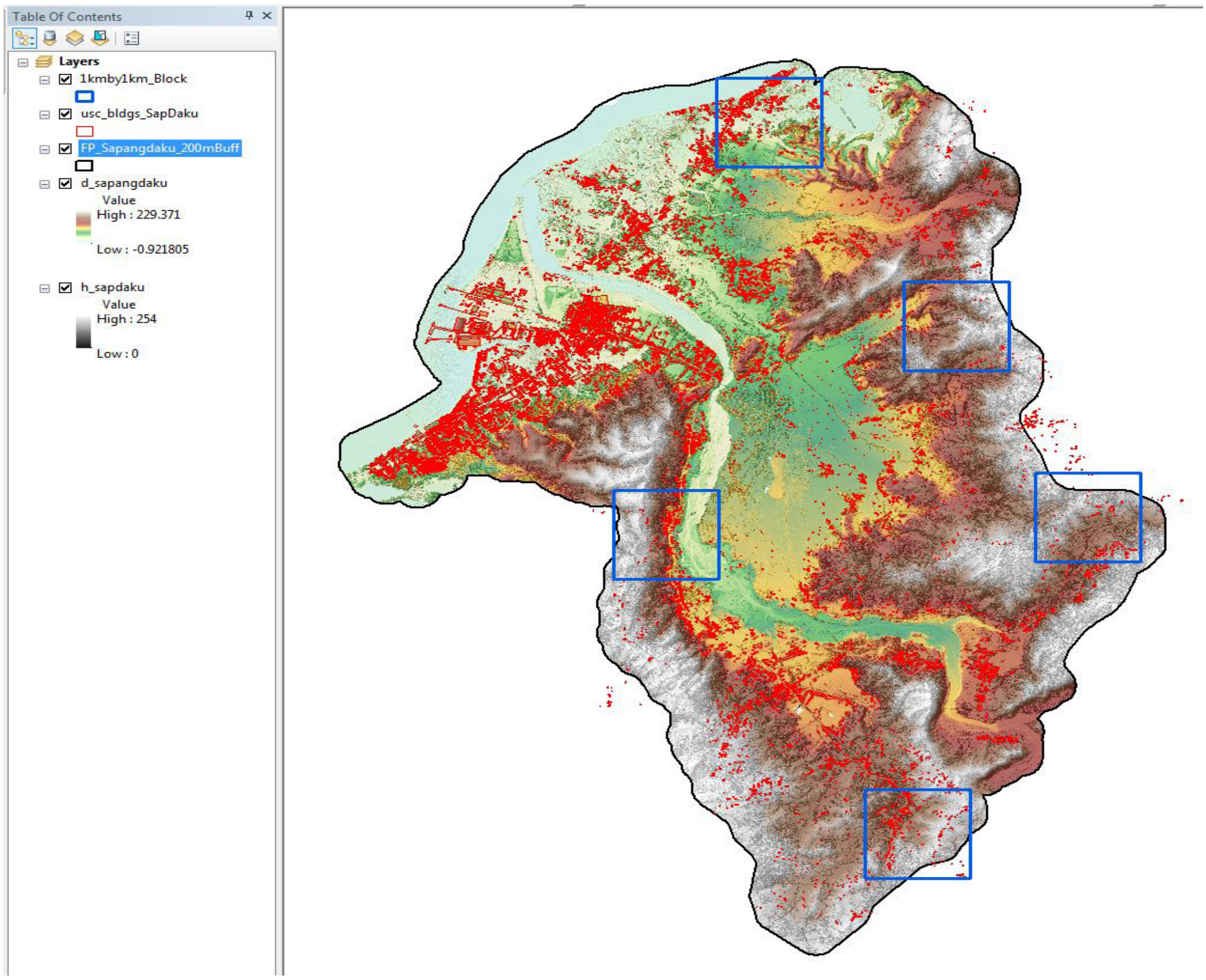

Figure 31. QC blocks for Sapangdaku building features.

Quality checking of Sapangdaku building features resulted in the ratings shown in Table 20.

Table 20. Quality Checking Ratings for Sapangdaku Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Sapangdaku	100.00	100.00	93.45	PASSED

3.12.2 Height Extraction

Height extraction was done for 16,725 building features in Sapangdaku floodplain. Of these building features, 4,438 were filtered out after height extraction, resulting to 12,287 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.57 m.

3.12.3 Feature Attribution

In attribution, combination of participatory mapping and actual field validation was done. Representatives from LGU were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

Table 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building Features Extracted for Sapangdaku Floodplain.

Facility Type	No. of Features
Residential	11,656
School	148
Market	9
Agricultural/Agro-Industrial Facilities	23
Medical Institutions	2
Barangay Hall	6
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	2
Power Plant/Substation	148
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	13
Bank	0
Factory	0
Gas Station	3
Fire Station	1
Other Government Offices	9
Other Commercial Establishments	261

Table 22. Total Length of Extracted Roads for Sapangdaku Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Sapangdaku	34.70	36.20	0	14.60	0	85.48

Table 23. Number of Extracted Water Bodies for Sapangdaku Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Sapangdaku	4	2	0	0	0	**6**

A total of 15 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 32 shows the Digital Surface Model (DSM) of Sapangdaku floodplain overlaid with its ground features.

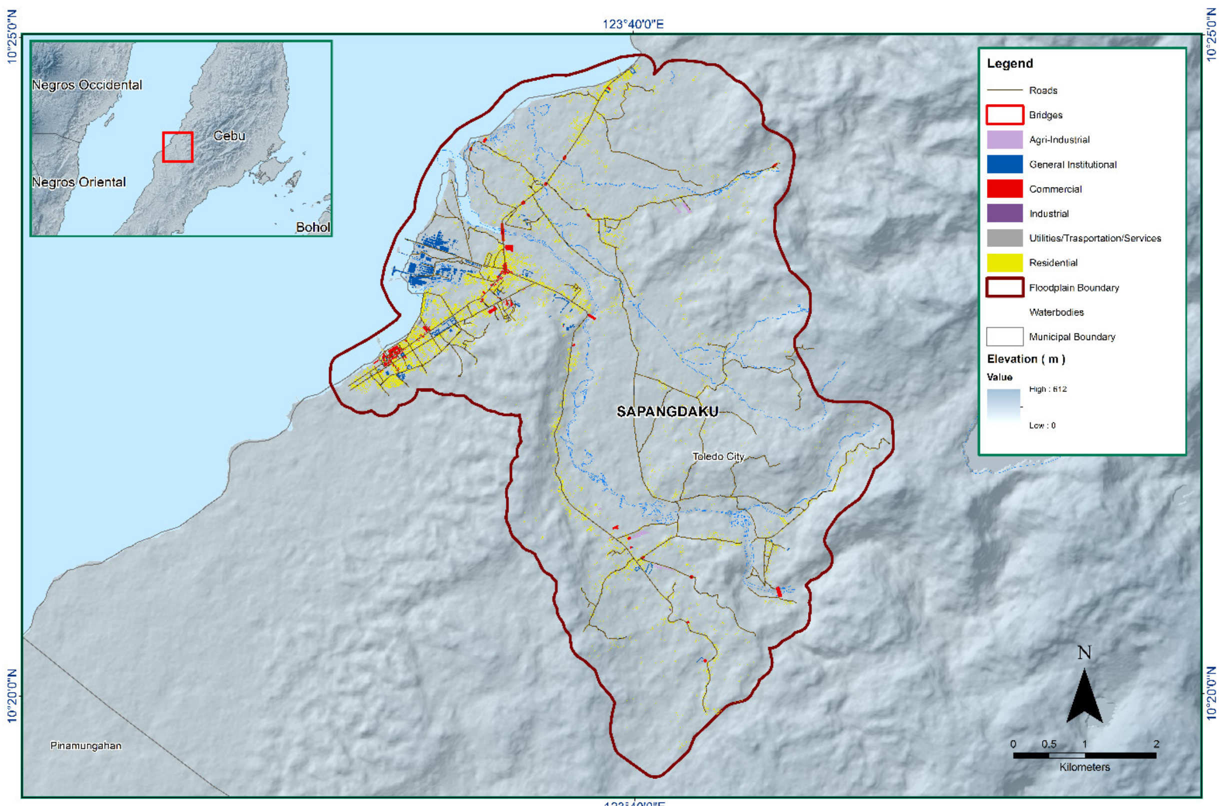

Figure 32. Extracted features for Sapangdaku Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF SAPANGDAKU RIVER BASIN

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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 survey in Sapangdaku River on December 5-17, 2015 with the following scope of work: reconnaissance; control survey; cross-section survey, bridge as-built survey and water level marking in MSL of Ilihan Foot Bridge in Brgy. Ilihan, Toledo City; validation point acquisition survey of about 27 km covering Sapang-Dako river basin; and bathymetric survey from Brgy. Don Andres Soriano down to the mouth of the river in Brgy. Daang-Lungsod with an approximate length of 10.337 km using Hi-Target™ echosounder and Trimble® SPS 882 GNSS PPK survey technique. The entire survey extent is shown in Figure 33.

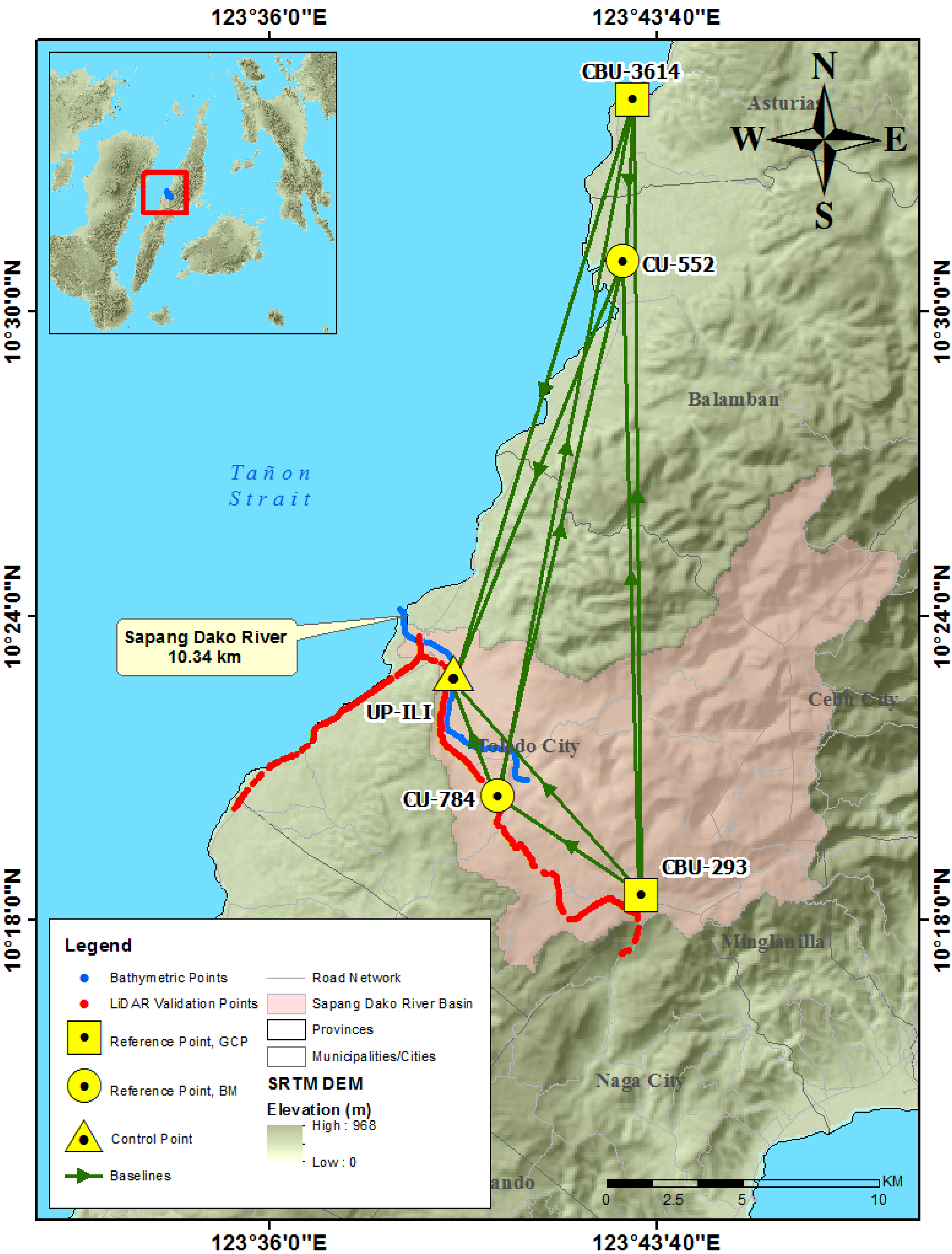


Figure 33. Sapangdaku River Survey Extent

4.2 Control Survey

The GNSS network for this survey is composed of five (5) loops established on December 7, 2015 occupying the following reference points: CBU-293, a second order GCP located inside Cantabaco National High School in Brgy. Cantabaco, Toledo City; and, CU-784, a first order BM in Brgy. Balud, Toledo City.

One (1) control point was established along the approach of a bridge namely UP-ILI at Ilihan Bridge in Brgy. Ilihan, Toledo City. The control points CBU-3614, in Brgy. Poblacion, Municipality of Asturias; and, CU-552 in Brgy. Cantuod, Municipality of Balamban both established by NAMRIA, were also occupied to use as markers for the network.

The summary of reference and control points and its location is summarized in Table 24 while the GNSS network established is illustrated in Figure 34.

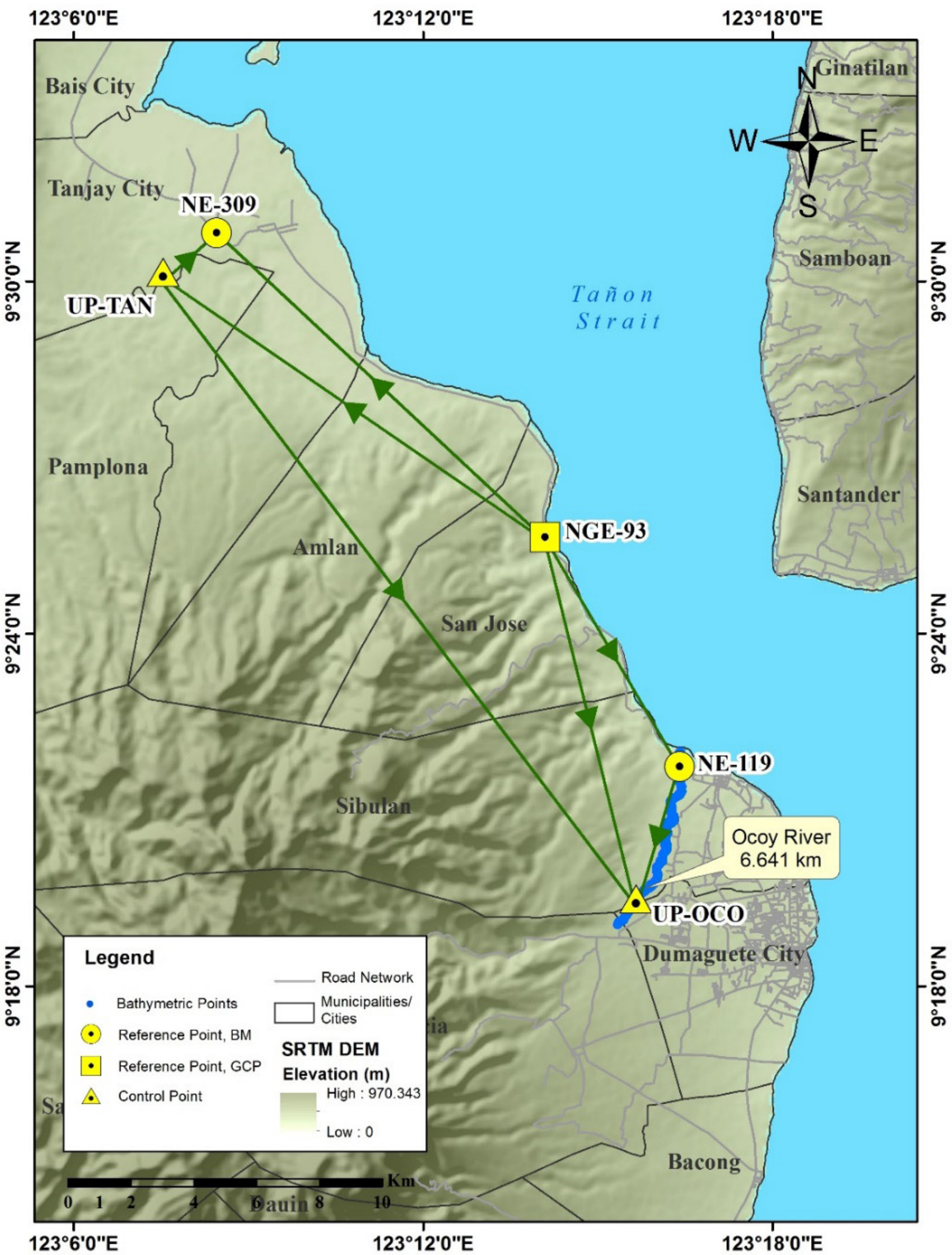


Figure 34. GNSS Network covering Sapangdaku River

Table 24. List of reference and control points used in Sapangdaku River Basin survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	BM Ortho (m)	Date Established
CBU-293	2nd order, GCP	10°18'28.70835"	123°43'20.76082"	350.838	-	2007
CU-784	1st order, BM	-	-	121.354	58.767	2014
CBU-3614	Used as marker	-	-	-	-	2007
CU-552	used as marker	-	-	-	-	2003
UP-ILI	UP Established	-	-	-	-	12-7-2015

The GNSS set-ups on recovered reference points and established control points in Balamban River are shown in Figure 35 to Figure 39.

Figure 35. GNSS receiver set-up, Trimble® SPS 852, at CBU-293 in front of Cantabaco National High School in Brgy. Cantabaco, Toledo City, Cebu

Figure 36. GNSS receiver setup, Trimble® Zephyr ™ Model 2, at CU-784 Balud Bridge approach in Brgy. Balud, Toledo City, Cebu

Figure 37. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at CBU-3614, Lapu-lapu Bridge approach in Brgy. Poblacion, Municipality of Asturias, Cebu

Figure 38. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at CU-552 along the national highway in Brgy. Cantuod, Balamban, Cebu

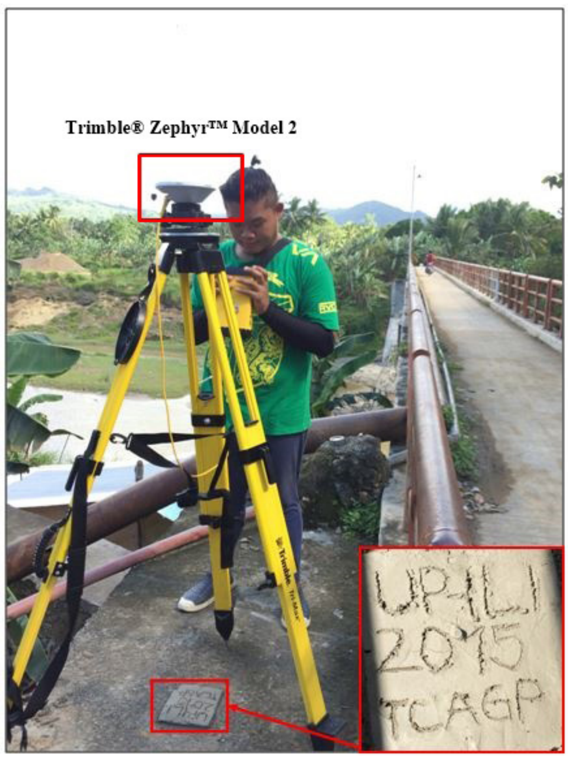


Figure 39. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at control point UP-ILI in the approach of Ilihan Foot Bridge in Brgy. Ilihan, Toledo City, Cebu

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Sapang-Dako River Basin is summarized in Table 25 generated by TBC software.

Table 25. Baseline Processing Report for Ocoy River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CU-784 --- UP-ILI (B1)	12-7-2015	Fixed	0.006	0.034	340°45’16”	4741.533	-45.998
CU-552 --- UP-ILI (B9)	12-7-2015	Fixed	0.004	0.022	202°05’36”	16152.939	9.102
CBU-293 --- CU-784 (B3)	12-7-2015	Fixed	0.006	0.028	305°11’33”	6328.249	-229.449
CU-784 --- CBU--3614 (B6)	12-7-2015	Fixed	0.006	0.042	10°56’41”	25772.836	-56.329
CU784 --- CU-552 (B10)	12-7-2015	Fixed	0.004	0.021	13°03’37”	19960.518	-55.135
CBU-3614 --- CU-552 (B7)	12-7-2015	Fixed	0.005	0.026	183°44’41”	5872.324	1.233
CBU-293 --- CBU-3614 (B4)	12-7-2015	Fixed	0.008	0.035	359°27’24”	28951.752	-285.917
CBU-293 --- CU-552 (B8)	12-7-2015	Fixed	0.006	0.022	358°22’03”	23100.039	-284.613
CBU-293 --- UP-ILI (B2)	12-7-2015	Fixed	0.004	0.019	320°20’42”	10551.869	-275.506
CBU-3614 --- UP-ILI (B5)	12-7-2015	Fixed	0.004	0.027	197°13’50”	21805.194	10.384

As shown in Table 25, a total of ten (10) baselines were processed with reference point CBU-293 and CU-784 held fixed for coordinate and elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates (Table 27) 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:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 26 to Table 28 for the complete details.

The five (5) control points, CBU-293, CU-784, CBU-3614, CU-552 and UP-ILI were occupied and observed simultaneously to form a GNSS loop. Coordinates of CBU-293 and elevation value of CU-784 were held fixed during the processing of the control points as presented in Table 26. Through these reference points, the coordinates of the unknown control points will be computed.

Table 26. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CBU-293	Global	Fixed	Fixed		
CU-784	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 27. The fixed control point CBU-293 has no values for standard errors.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CBU-293	579101.757	?	1139552.798	?	287.891	0.028	LL
CBU-3614	578761.189	0.004	1168493.192	0.004	3.267	0.033	
CU-552	578391.244	0.004	1162634.434	0.003	4.293	0.026	
CU-784	573923.645	0.004	1143187.034	0.004	58.767	?	e
UP-ILI	572351.798	0.004	1147658.769	0.003	13.024	0.029	

The network is fixed at reference point CBU-293 with known coordinates, and CU-784 with known elevation. With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)} < 20cm\sqrt{((x_e)^2+(y_e)^2)} < 20cm$ for horizontal and $z_e < 10\ cm z_e < 10\ cm$ for the vertical; the computation for the accuracy are as follows:

a. **CBU-293** = fixed
= 2.8 < 10 cm

b. **CU-784**
horizontal accuracy = $\sqrt{(0.4)^2 + (0.3)^2}$
= $\sqrt{0.16 + 0.9}$
= 1.03 cm < 20 cm
vertical accuracy = fixed

c. **CBU-3614**
horizontal accuracy = $\sqrt{(0.4)^2 + (0.4)^2}$
= $\sqrt{0.16 + 0.16}$
= 0.57 cm < 20 cm
vertical accuracy = 3.3 < 10 cm

d. **CU-552**
horizontal accuracy = $\sqrt{(0.4)^2 + (0.3)^2}$
= $\sqrt{0.16 +0.9}$
= 1.03 cm < 20 cm
vertical accuracy = 2.6 < 10 cm

e. **UP-ILI**
horizontal accuracy = $\sqrt{(0.4)^2 + (0.3)^2}$
= $\sqrt{0.16 + 0.9}$
= 1.03 cm < 20 cm
vertical accuracy = 2.9 < 10 cm

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

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
CBU-293	N10°18'28.70835"	E123°43'20.76082"	350.838	0.028	LL
CBU-3614	N10°34'10.94597"	E123°43'11.73023"	64.969	0.033	
CU-552	N10°31'00.23116"	E123°42'59.11634"	66.222	0.026	
CU-784	N10°20'27.39811"	E123°40'30.77220"	121.354	?	e
UP-ILI	N10°22'53.09406"	E123°39'39.39389"	75.336	0.029	

The adjusted geodetic coordinates is presented in Table 28. The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 29.

Table 29. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N			
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	EGM Ortho (m)	BM Ortho (m)
CBU-293	2nd order GCP	10°18'28.70835"	123°43'20.76082"	350.838	1139553	579101.8	287.992	287.844
CU-784	1st order BM	10°20'27.39811"	123°40'30.77220"	121.354	1143187	573923.6	58.915	58.767
CBU-3614	Used as Marker	10°34'10.94597"	123°43'11.73023"	64.969	1168493	578761.2	3.465	3.317
CU-552	Used as Marker	10°31'00.23116"	123°42'59.11634"	66.222	1162634	578391.2	4.480	4.332
UP-ILI	UP Established	10°22'53.09406"	123°39'39.39389"	75.336	1147659	572351.8	13.149	13.001

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

Bridge as-built and cross-section survey was conducted on December 12, 2015 at the downstream side of Ilihan Foot Bridge in Brgy. Ilihan, Toledo City using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 40.

Figure 40. Bridge as-built and cross-section survey at the downstream side of Ilihan Foot Bridge in Brgy. Ilihan, Toledo City, Cebu

The cross-sectional line length in Ilihan Foot Bridge is about 50.613 m with 57 cross-sectional points acquired using UP-ILI as the GNSS base station. The location map, cross section diagram, and the bridge data form are shown in Figure 41 to Figure 43, respectively.

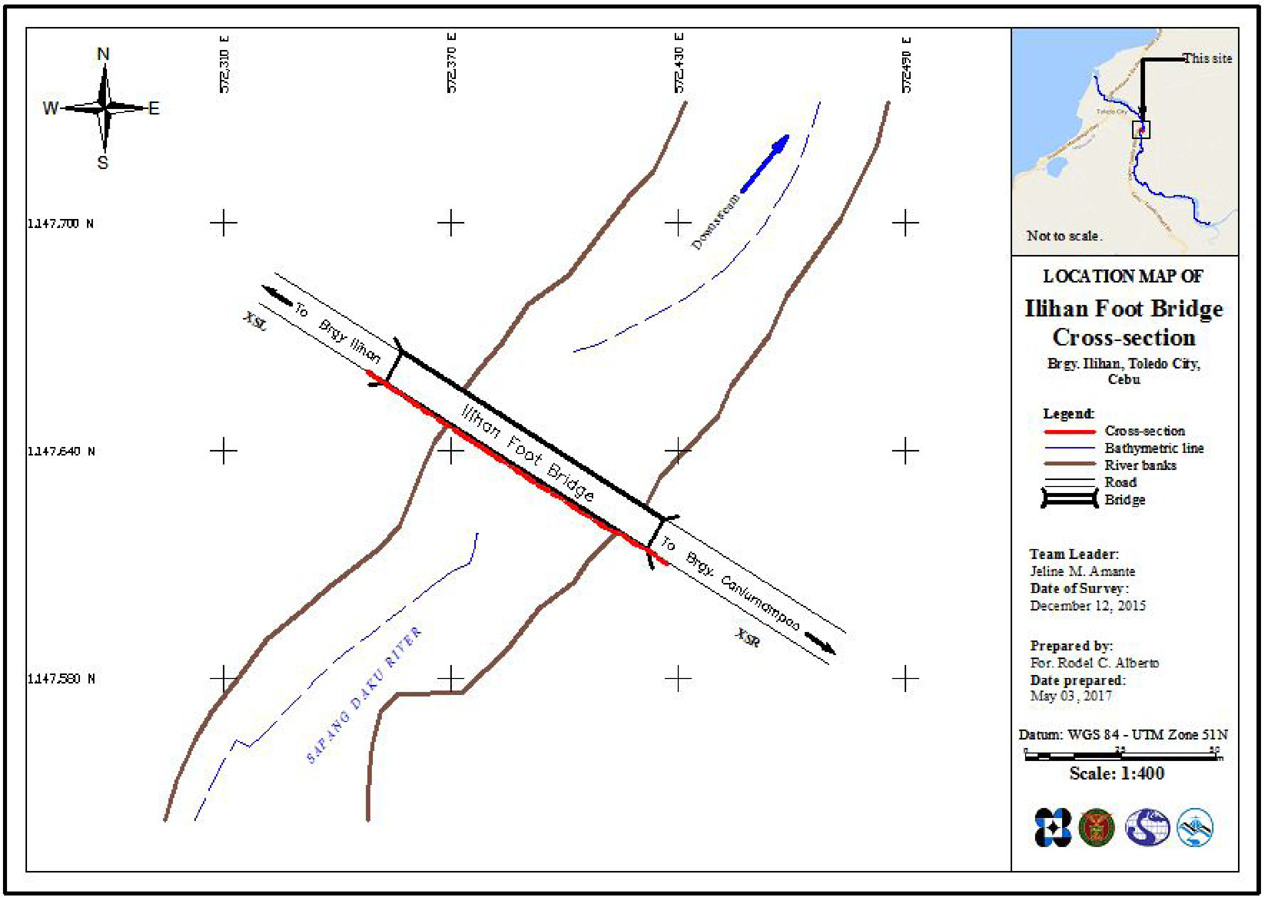


Figure 41. Location map of Sapangdaku Bridge cross-section survey

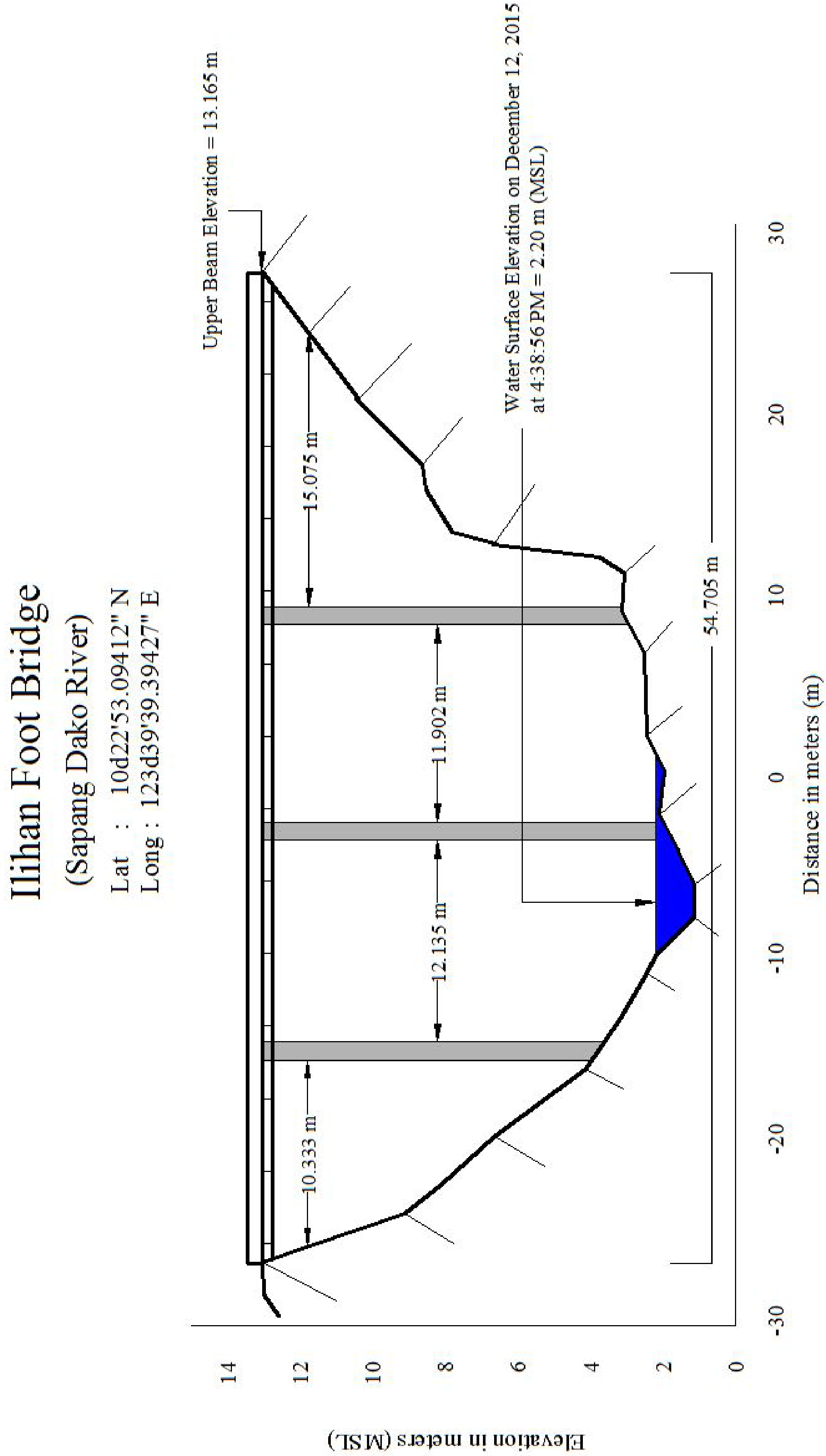


Figure 42. Sapangdaku Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Ilihan Foot Bridge **Date:** December 12, 2015

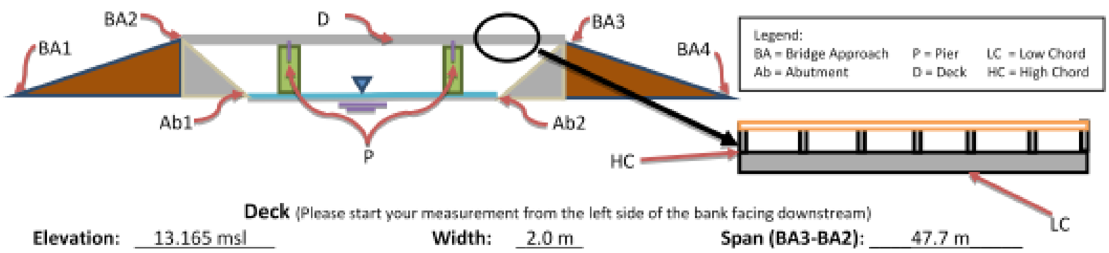
River Name: Sapang-Dako River **Time:** 04:30 PM

Location (Brgy, City, Region): Brgy. Ilihan, Toledo City, Cebu

Survey Team: Team Jeline

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

Latitude: 10d22'53.09412" N **Longitude:** 123d39'39.39427" E



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

Elevation: 13.165 msl **Width:** 2.0 m **Span (BA3-BA2):** 47.7 m

	Station	High Chord Elevation	Low Chord Elevation
1	-	-	-
2	-	-	-

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	-		BA3	-	
BA2	-		BA4	-	

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

	Station (Distance from BA1)	Elevation
Ab1	NA	-
Ab2	NA	-

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

Shape: ________ **Number of Piers:** 3 **Height of column footing:** ________

	Station (Distance from Bridge Approach)	Elevation	Pier Width
Pier 1	14.601	13.165	-
Pier 2	26.736	13.139	-
Pier 3	38.638	13.12	-

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

Figure 43. Sapangdaku Bridge Data Form

Water surface elevation in MSL of Sapangdaku River was determined using Trimble® SPS 882 in PPK mode technique on December 12, 2015 at 04:38 PM with a value of 2.20 m in MSL. This was translated onto marking on the bridge's pier using a digital level with the value of 4.0 m MSL which will be used by USC PHIL-LiDAR 1 (Figure 44). The marked pier will serve as their reference for flow data gathering and depth gauge deployment for Sapangdaku River.

Figure 44. Water level marking using a Digital Level at Ilihan Foot Bridge, Brgy. Ilihan Toledo City

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 12, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the side of vehicle as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.170 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-ILI occupied as the GNSS base stations in the conduct of the survey.

Figure 45. Validation points acquisition survey set-up

The survey was along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate length of 27 km with 3,441 validation points gathered. The gaps in the validation line as shown in Figure 46 were due to road constructions and difficulties in receiving satellite signals brought by dense canopy cover of trees along the roads.

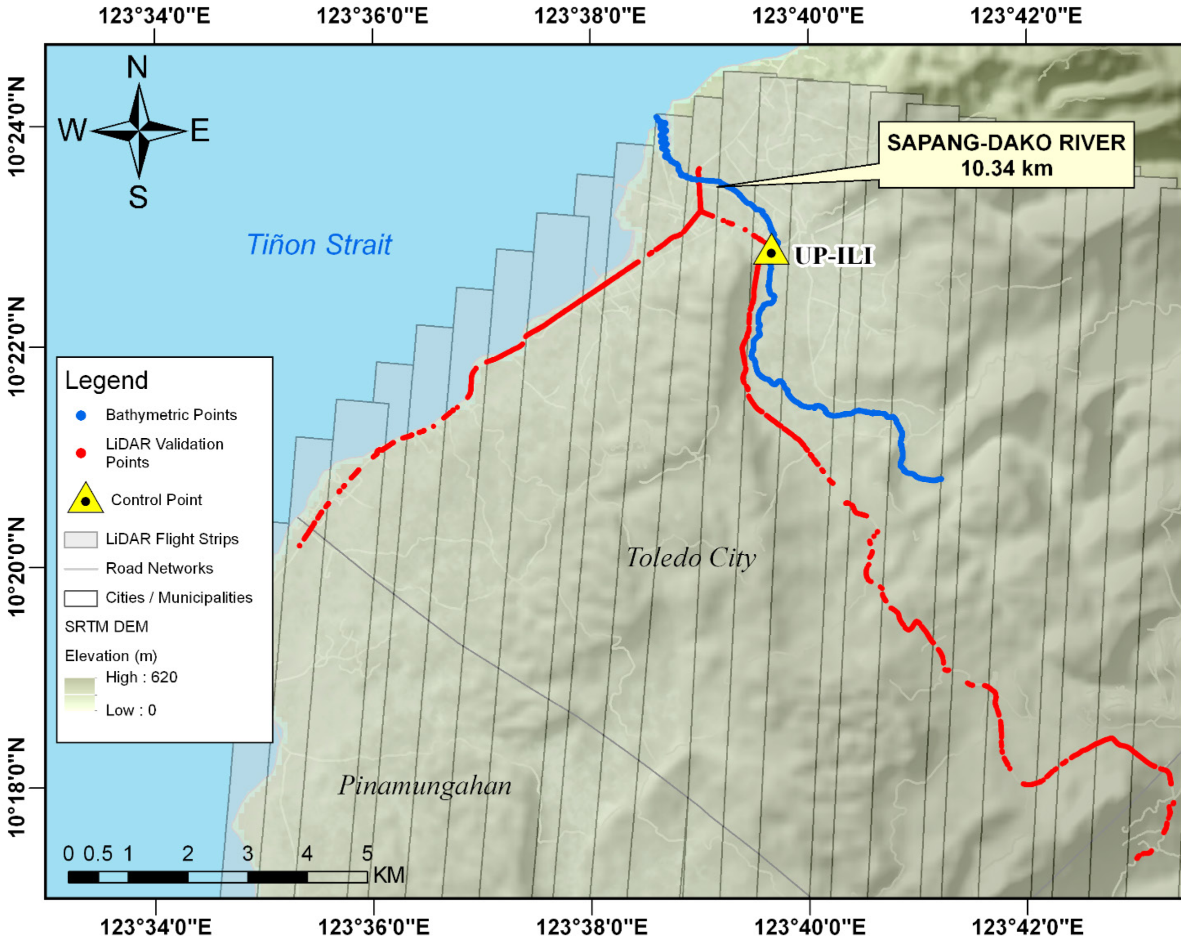


Figure 46. LiDAR Validation points acquisition survey for Sapangdaku River Basin

4.7 Bathymetric Survey

Manual bathymetric survey was executed on December 10, 2015 using Trimble® SPS 882 GNSS PPK technique as shown in Figure 47. The survey began from the upstream of the river in Brgy. Don Andres, Municipality of Soriano, with coordinates 10°20'47.4847"N 123°41'13.0232"E and traversed by foot down to Brgy. Ilihan in Toledo City with coordinates 10°23'29.8709"N 123°39'7.9822"E.

Figure 47. Manual bathymetry along Sapangdaku River

Bathymetric survey using Hi-Target™ echo sounder and a Trimble® SPS 882 attached to a pole secured on the side of a boat was executed on December 13, 2015 as shown in Figure 48. The survey started from Brgy. Ilihan where manual bathymetry survey ended down to the mouth of the river in Brgy. Daang-Lungsod in Toledo City with coordinates 10°24'4.9041"N 123°38'36.3445"E

Figure 48. Bathymetric survey using Ohmex™ Echo Sounder along Sapangdaku River

The entire bathymetric data coverage for Sapangdaku River is illustrated in the map in Figure 49. The gaps in the bathymetric survey was due to the difficulties in acquiring satellite caused by obstructions such as dense canopy of trees and presence of rapids along the river.

A CAD drawing was also produced to illustrate the Sapangdaku riverbed profile as illustrated in Figure 50. An elevation drop of 29.95 meters in MSL was observed within the distance of approximately 10.34 km from the upstream in Brgy. Don Andres Soriano down to Brgy. Daang-Lungsod with a total of 21,959 bathymetric points.

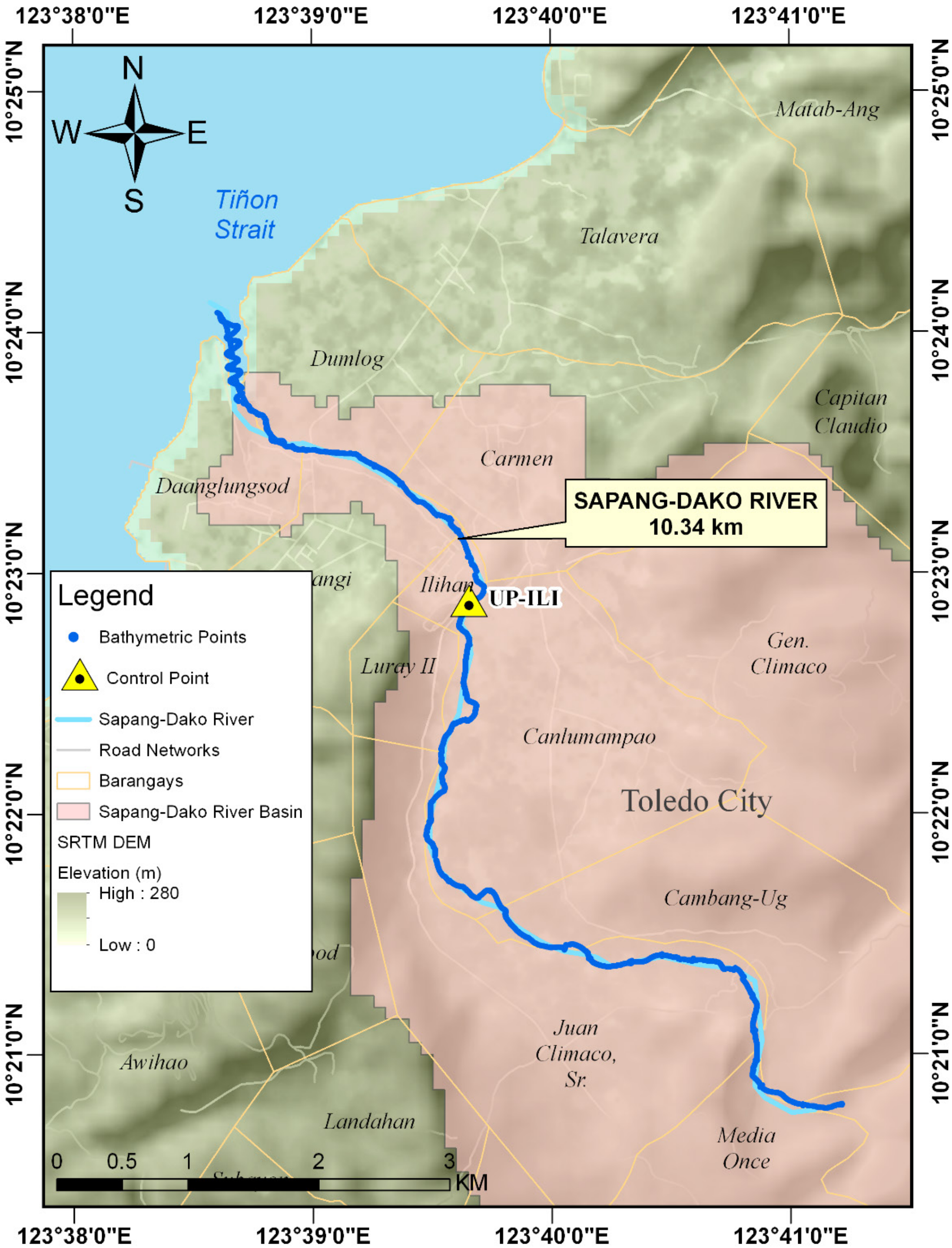


Figure 49. Bathymetric survey of Sapangdaku River

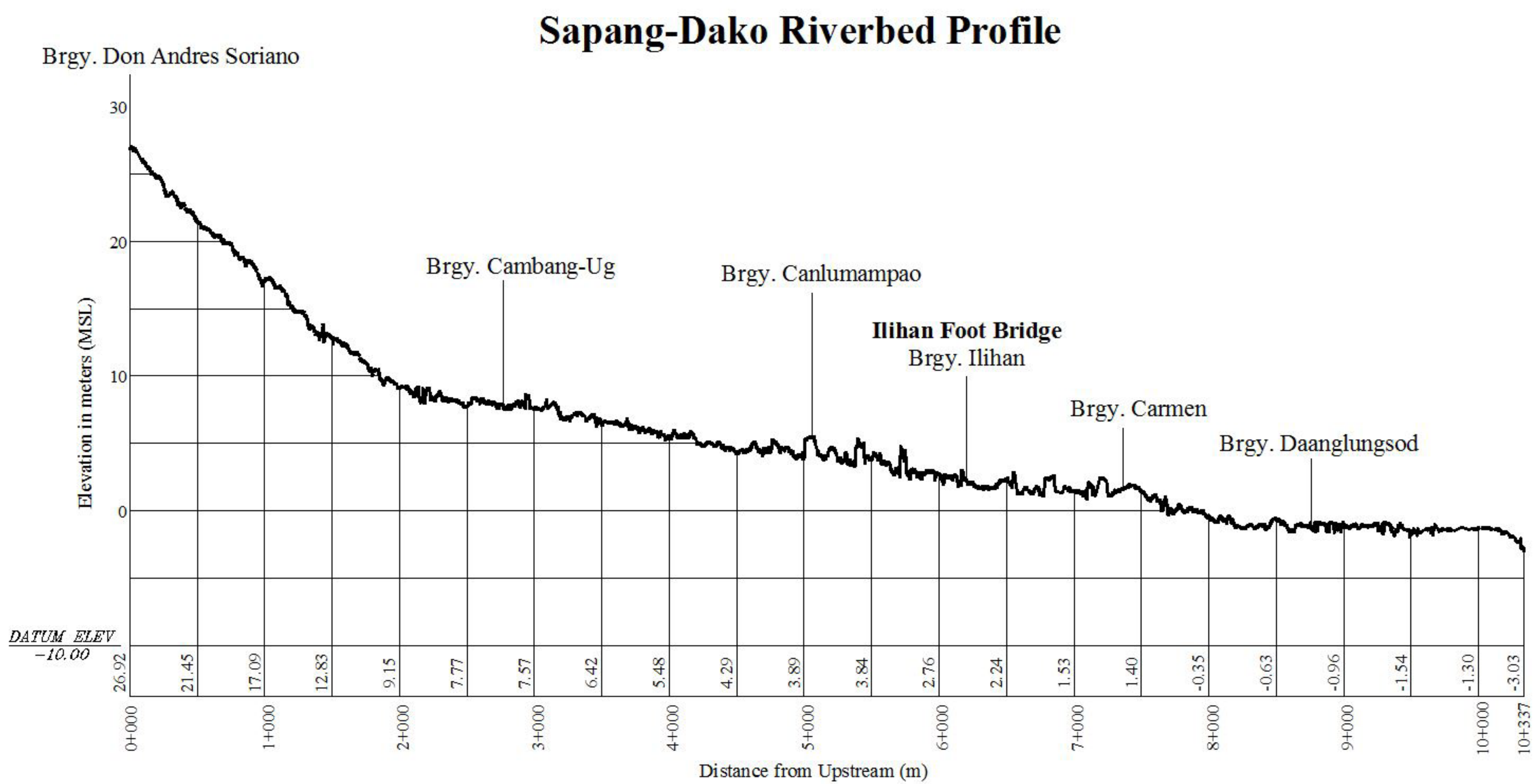


Figure 50. Sapangdaku Riverbed Profile

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, and Pauline Racoma

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

5.1 Data used in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an installed data logging rain gauge installed by the USC Phil LIDAR 1. The gauge station is located in Brgy. Don Andres Soriano, Toledo City with geographic coordinates of 10°22’52.32”N and 123°39’39.60”E. The location of the installed station in the watershed is presented in Figure 51. The total rainfall data used for calibration is mm and was acquired last May 30, 2016.

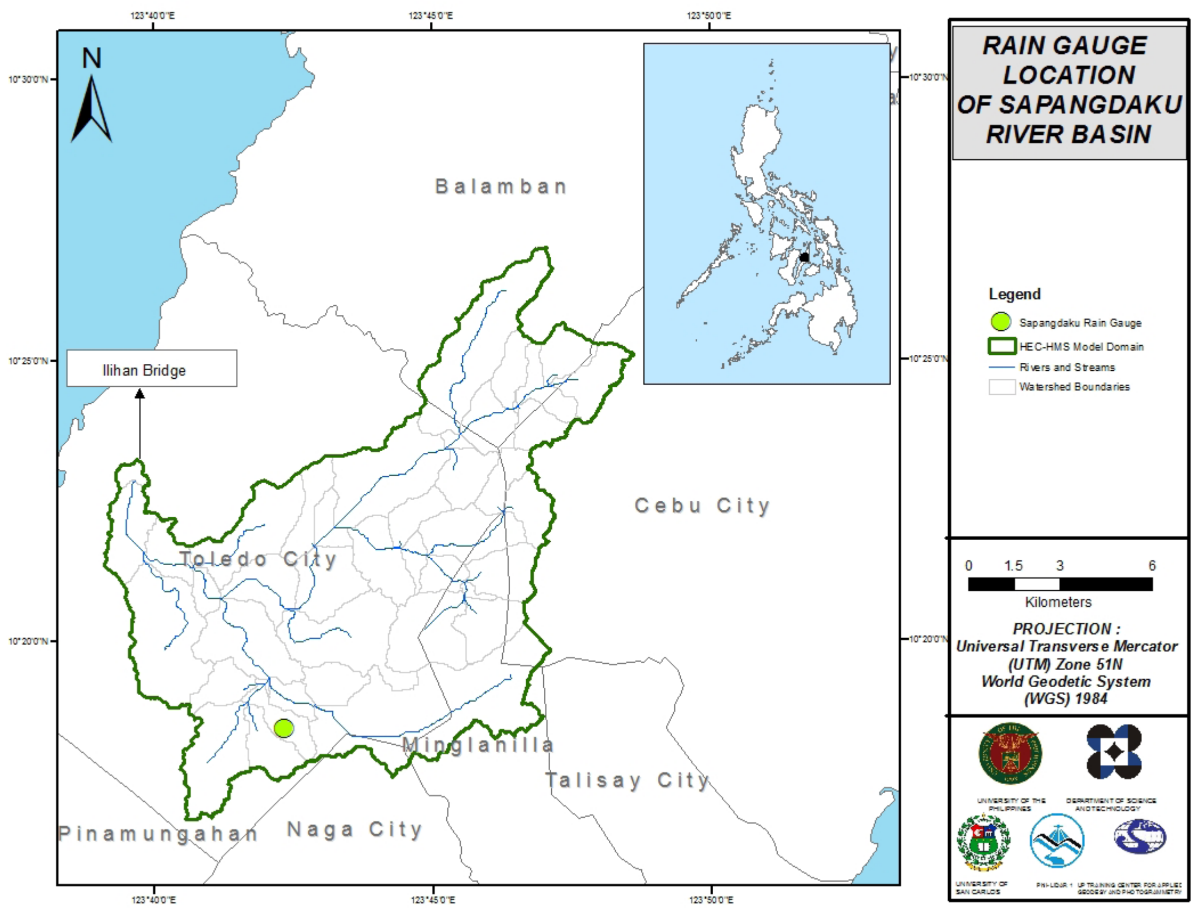


Figure 51. Location map of Sapangdaku HEC-HMS model used for calibration.

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Ilihan Bridge (10°22'52.32"N and 123°39'39.60"E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

For Ilihan Bridge, the rating curve is expressed $y = 0.0053e^{2.567x} y = 0.0053e^{2.567x}$ as shown in Figure 52.

This image is not available for this river basin.

Figure 52. Cross-Section Plot of Sapangdaku Bridge

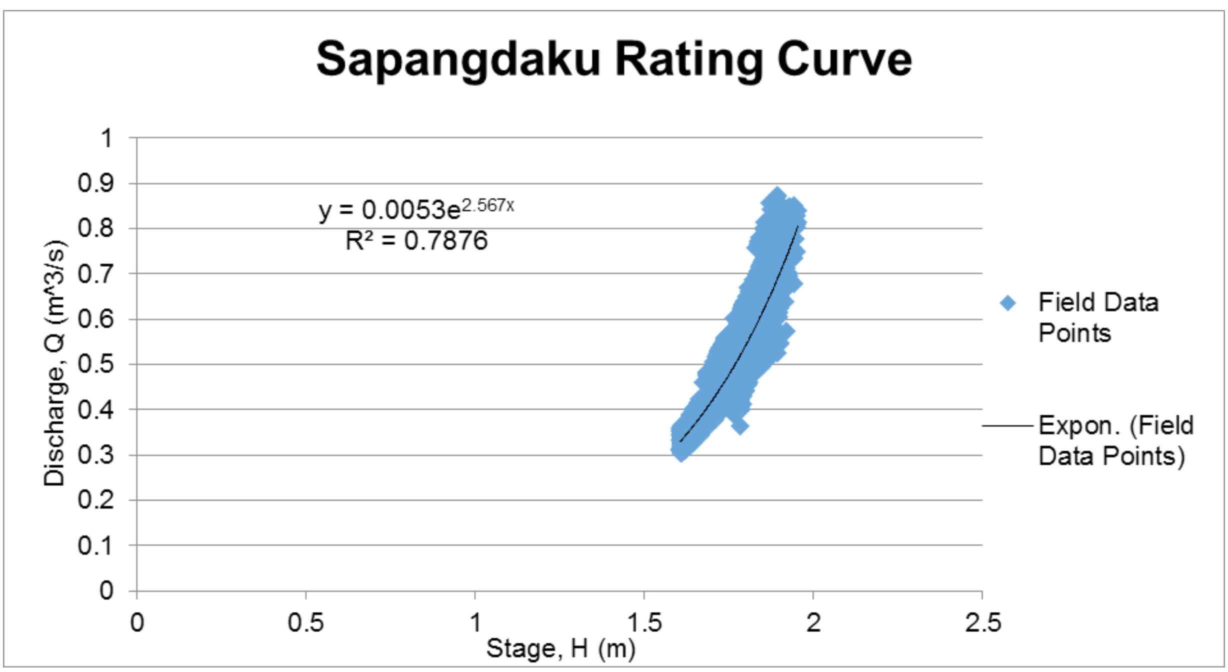


Figure 53. Rating curve at Ilihan Bridge in Ocoy River

This rating curve equation was used to compute the river outflow at Ilihan Bridge for the calibration of the HEC-HMS model shown in Figure 54. Peak discharge is 0.8738 m^3/s at 17:51, May 30, 2016.

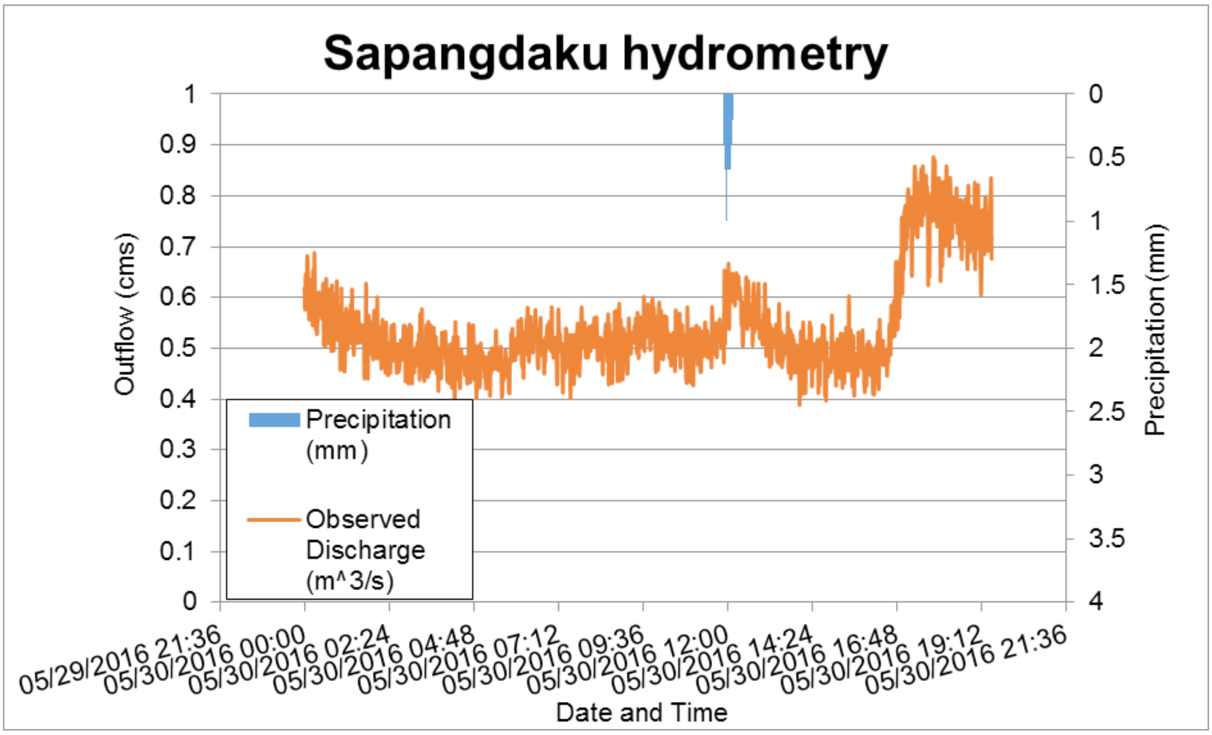


Figure 54. Rainfall and outflow data at Ilihan Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Mactan Point Gauge. This station chosen based on its proximity to the Sapangdaku watershed. The extreme values for this watershed were computed based on a 37-year record, as shown in Table 30.

Table 30. RIDF values for Mactan Point Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	15.9	24.7	31.4	41.4	53.7	60.5	73.1	83.4	92.8
5	21.9	34	43.2	58.4	74.9	84	105.2	122.6	139.1
10	25.8	40.2	51.1	69.7	88.9	99.6	126.3	148.6	169.7
15	28.1	43.6	55.5	76	96.8	108.4	138.3	163.3	187
20	29.6	46.1	58.6	80.5	102.3	114.5	146.7	173.5	199.1
25	30.9	48	61	83.9	106.6	119.3	153.1	181.4	208.5
50	34.6	53.8	68.3	94.4	119.7	133.9	173	205.8	237.2
100	38.3	59.5	75.6	104.9	132.7	148.4	192.7	230	265.7

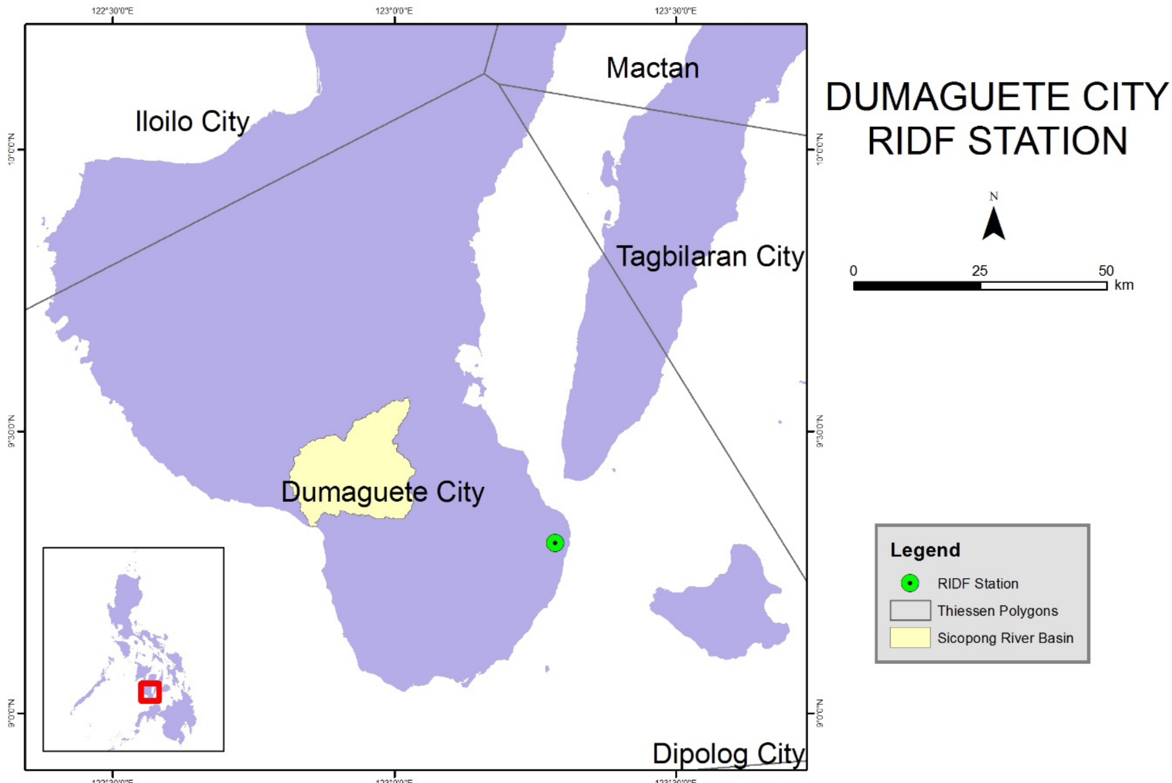


Figure 55.Location of Mactan Point RIDF Station relative to Sapangdaku River Basin

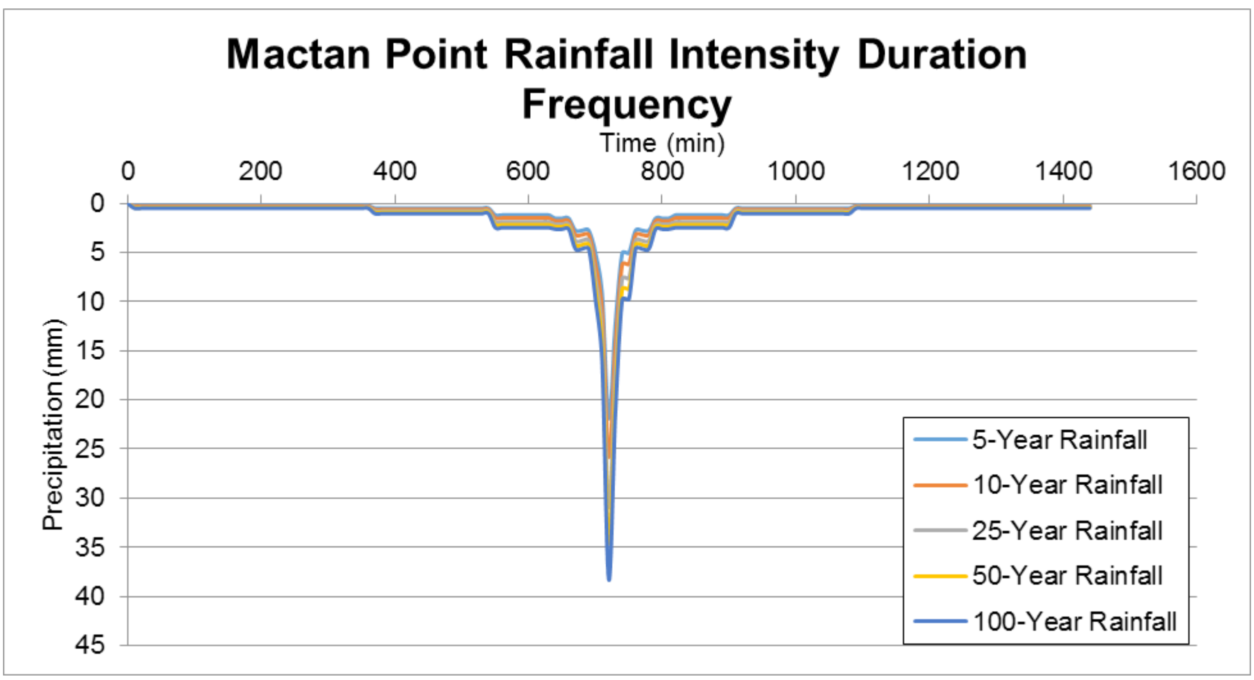


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Sapangdaku River Basin are shown in Figure 57 and Figure 58, respectively.

This image is not available for this river basin.

Figure 57. Soil map of the Sapangdaku River Basin used for the estimation of the CN parameter. (Source: DA)

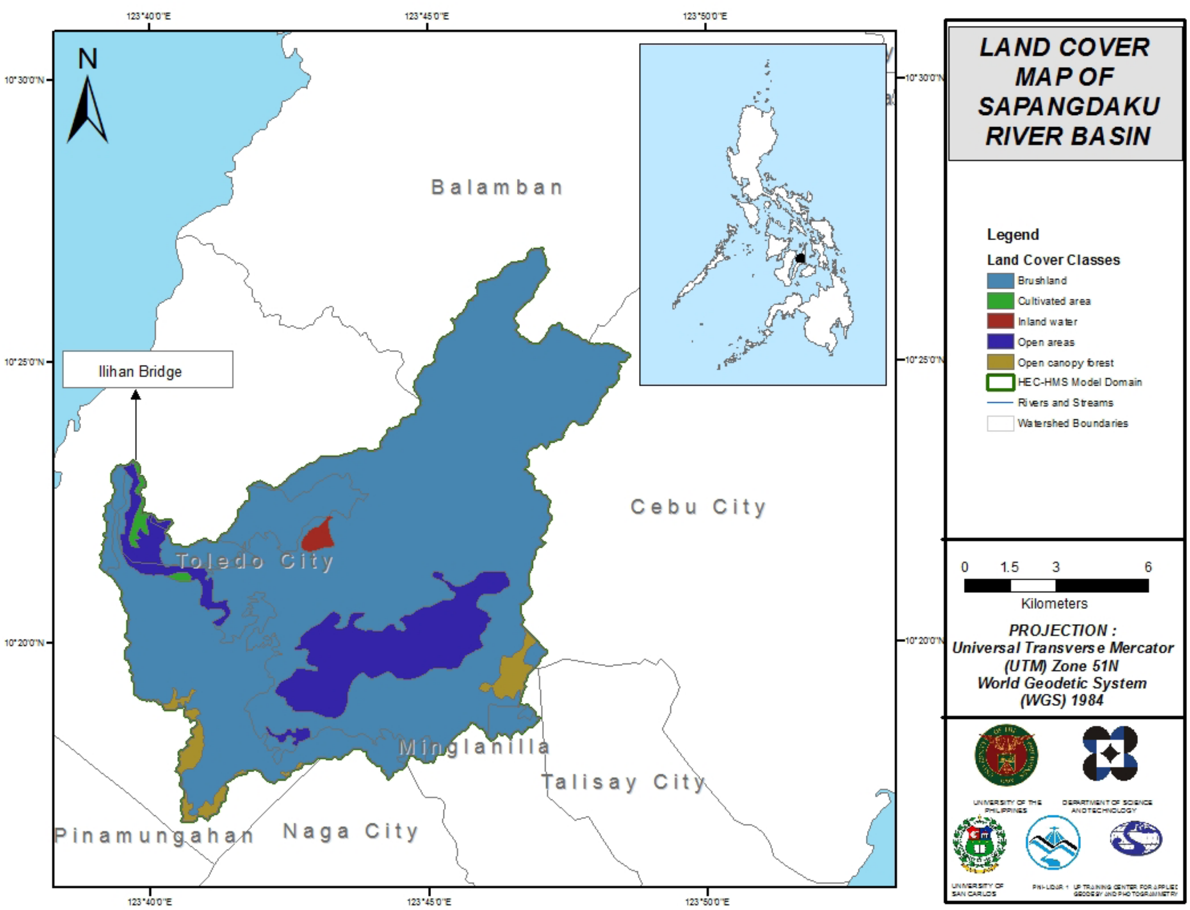


Figure 58. Land cover map of Sapangdaku River Basin used for the estimation of the Curve Number (CN) and the watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For the Sapangdaku river basin, two (2) soil classes were identified, largely Baguio clay loam with a small portion of Faraon clay (steep phase). Moreover, five (5) land cover classes were identified. Most of the Sapangdaku river basin is brushland, with some open areas, open canopy forest, cultivated area, and inland water.

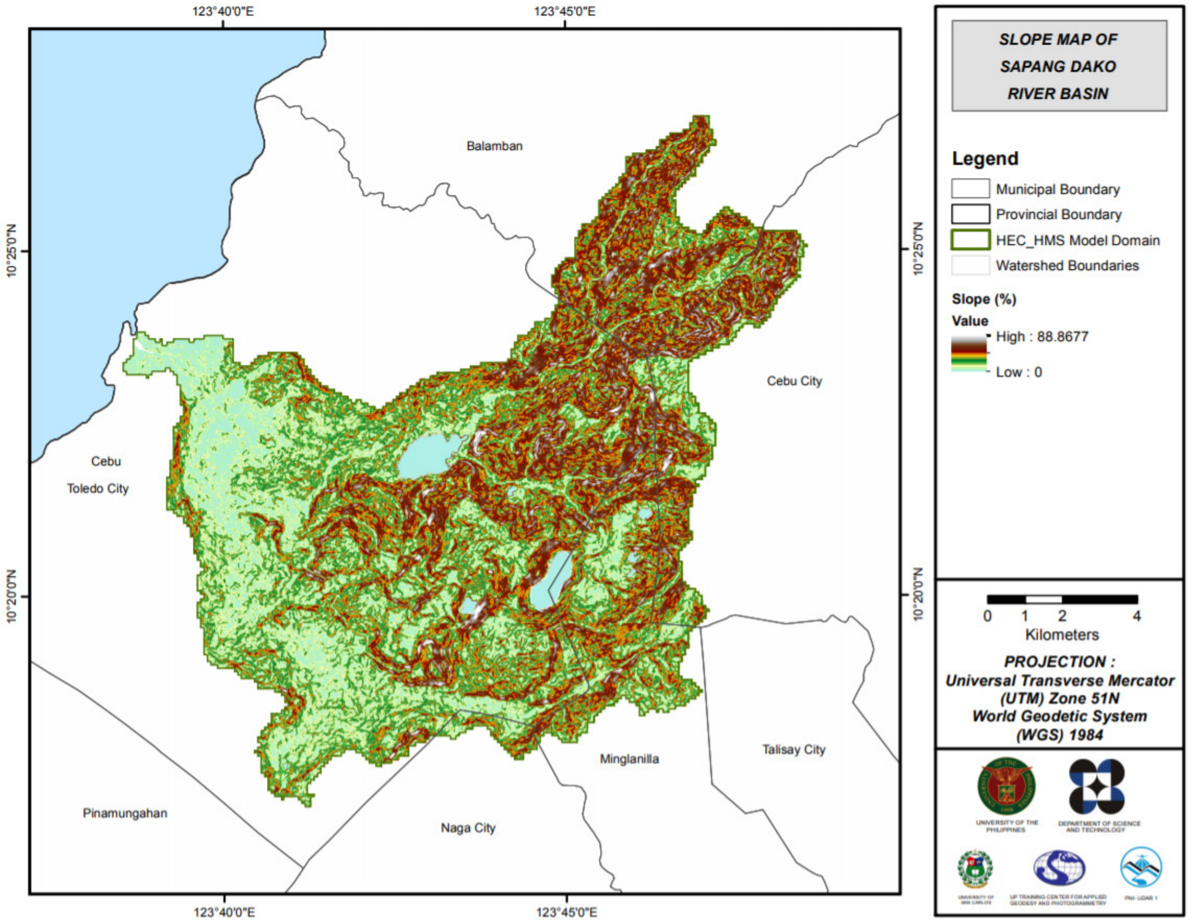


Figure 59. Slope map of Sapangdaku River Basin

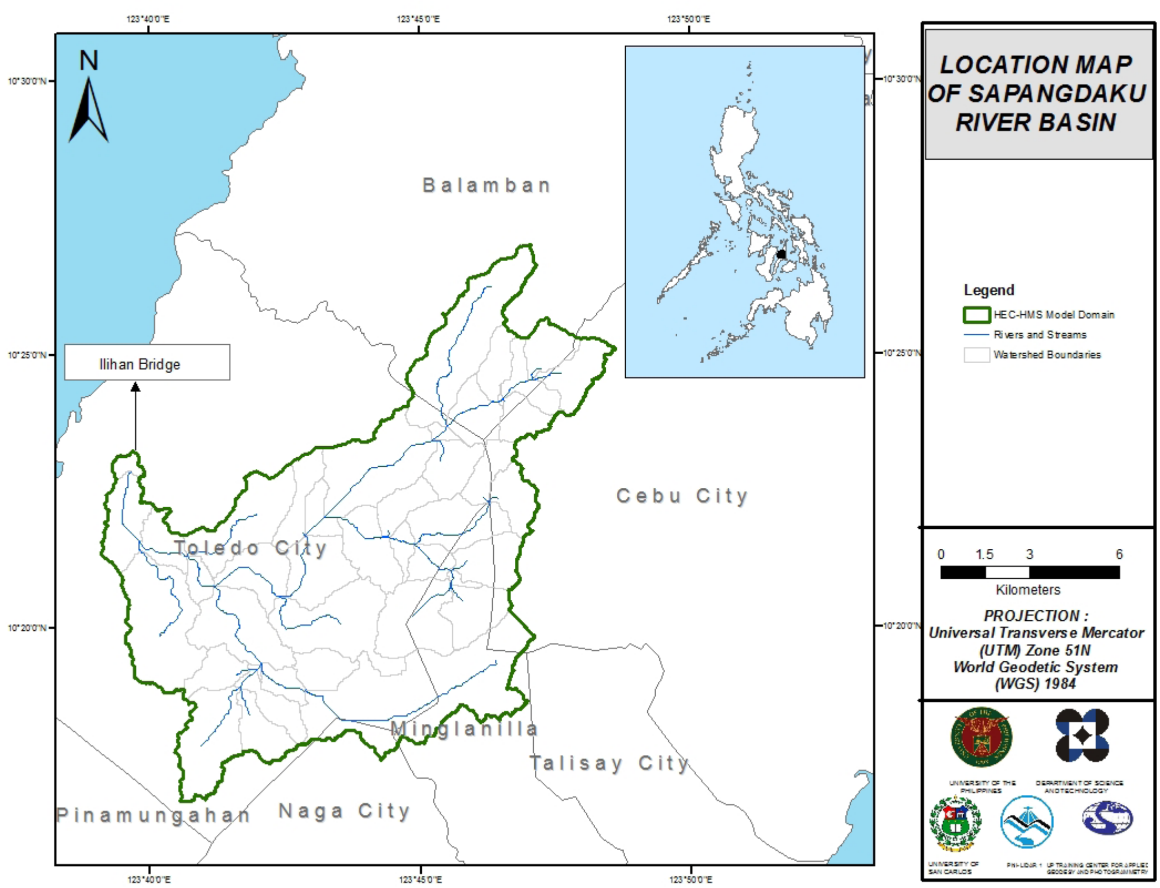


Figure 60. Stream delineation map of Sapangdaku River Basin

The Sapangdaku basin model comprises 42 sub basins, 21 reaches, and 21 junctions. The main outlet is outlet 1. This basin model is illustrated in Figure 61. The basins were identified based on soil and land cover characteristic of the area. Precipitation was taken from an installed Rain Gauge near and inside the river basin. Finally, it was calibrated using the data from actual discharge flow gathered in the Ilihan Bridge.

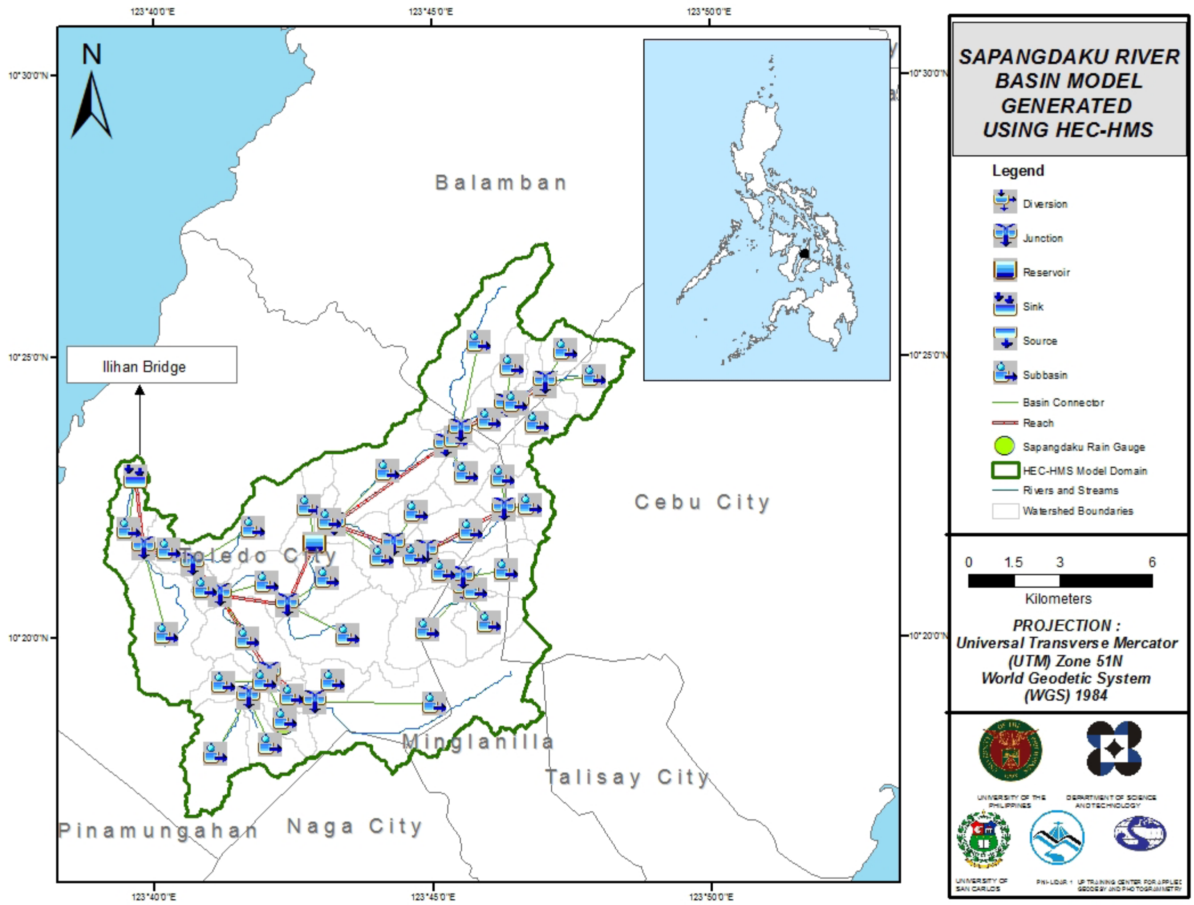


Figure 61. HEC-HMS generated Sapangdaku River Basin Model.

5.4 Cross-section Data

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

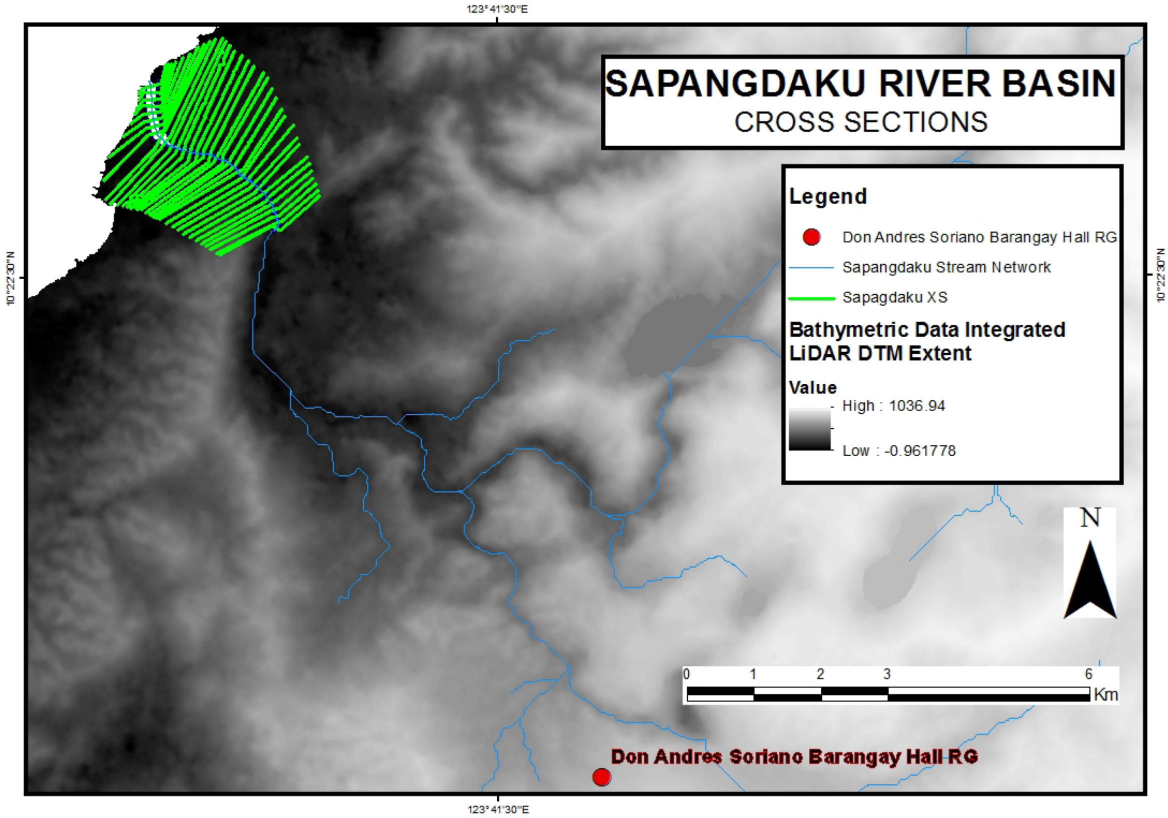


Figure 62. River cross-section of Sapangdaku River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

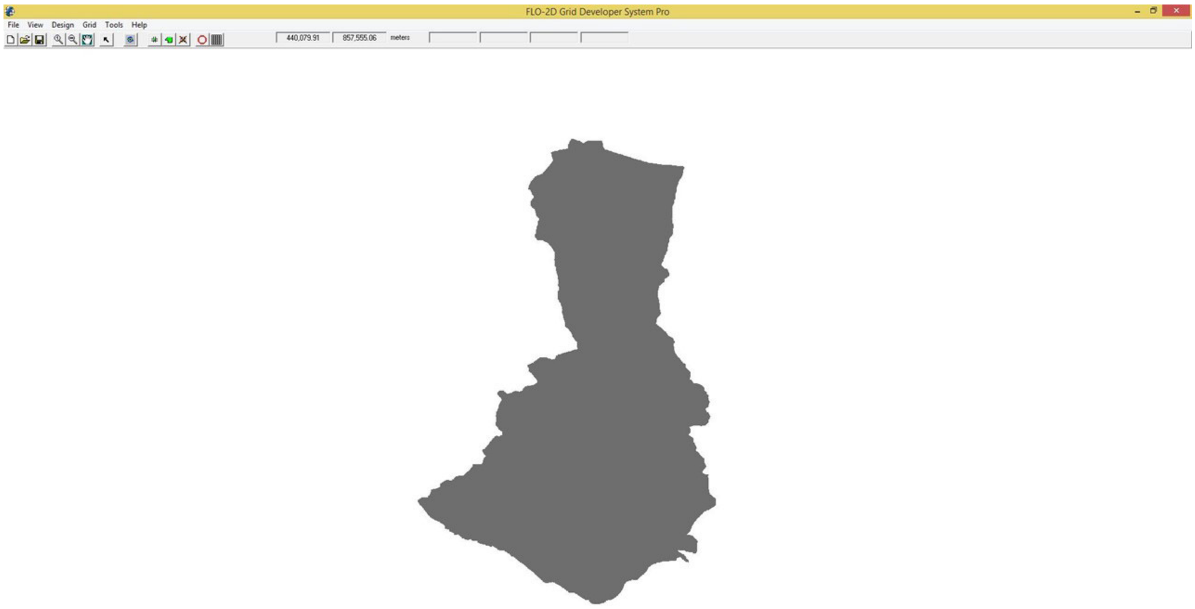


Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 23.91504 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 38,515,400.00m^2.

There is a total of 36,519,889.86m^3 of water entering the model. Of this amount, 7,884,112.82 m^3 is due to rainfall while 28,635,777.03 m^3 is inflow from other areas outside the model. 3,314,226.25 m^3 of this water is lost to infiltration and interception, while 1,945,968.08 m^3 is stored by the flood plain. The rest, amounting up to 31,259,694.77 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Sapangdaku HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 64 shows the comparison between the two discharge data.

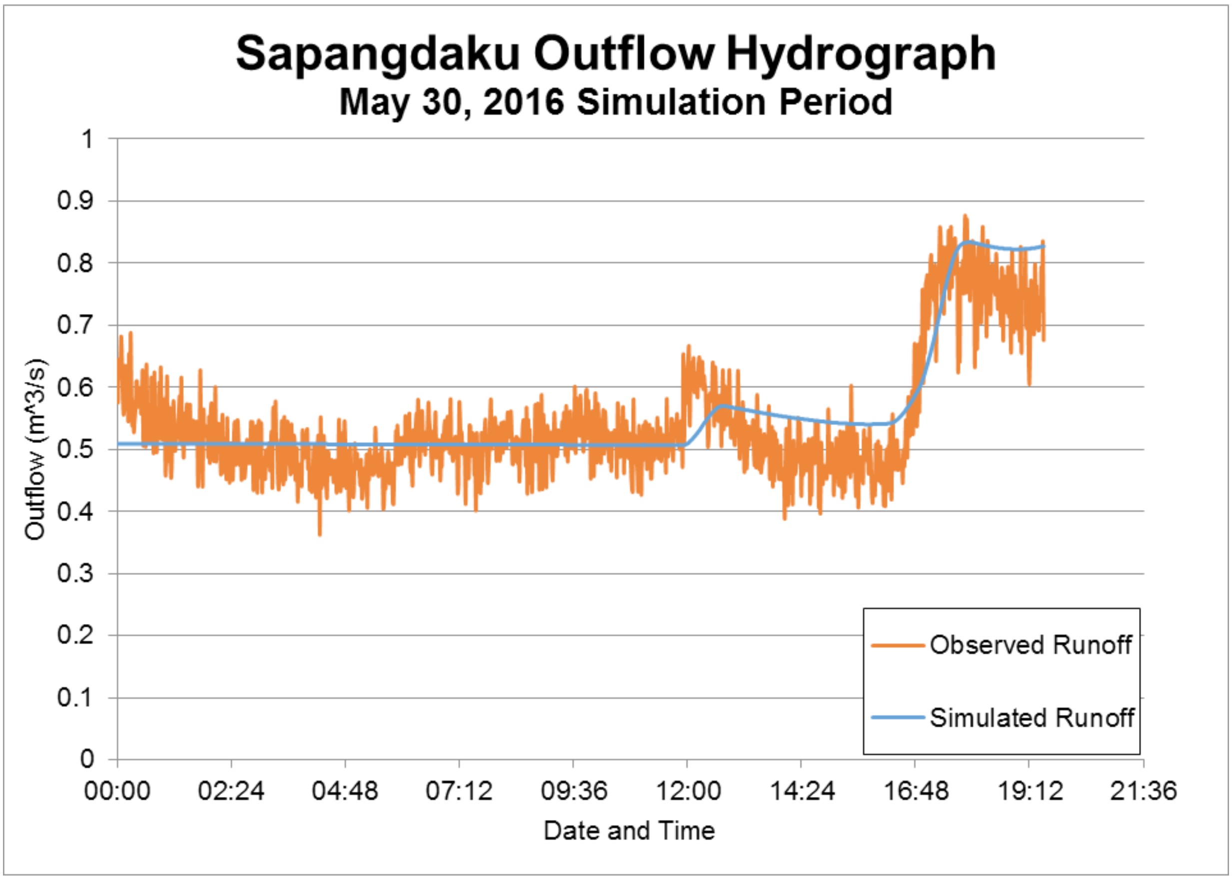


Figure 64. Outflow Hydrograph of Sapangdaku produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of calibrated values for Sapangdaku Watershed

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	1.24-8.03
			Curve Number	53.28-79.20
			Impervious (%)	0
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-1.38
			Storage Coefficient (hr)	0.17-10.36
	Baseflow	Recession	Recession Constant	0.53-1
			Ratio to Peak	0.10
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.40

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 1.24 to 8.03 mm signifies that there is minimal to average 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 curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Sapangdaku, the basin mostly consists of brushlands and the soil consists of clay, clay loam, and mountain soil, the curve number is 53.28 to 79.20.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 to 1.38 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.53 to 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.10 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.4 corresponds to the common roughness in Sapangdaku watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 32. Summary of the Efficiency Test of Sapangdaku HMS Model

Accuracy measure	Value
RMSE	0.0035
r^2	0.6780
NSE	0.6292
PBIAS	-2.4907
RSR	0.0363

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.0035.

The Pearson correlation coefficient $(r^2)r^2)$ assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.6780.

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 0.6292.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -2.4907.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.0363.

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 show the Sapangdaku outflow using the Mactan Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-, 10-, 25-, 50-, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a uniform duration of 24 hours and varying return periods.

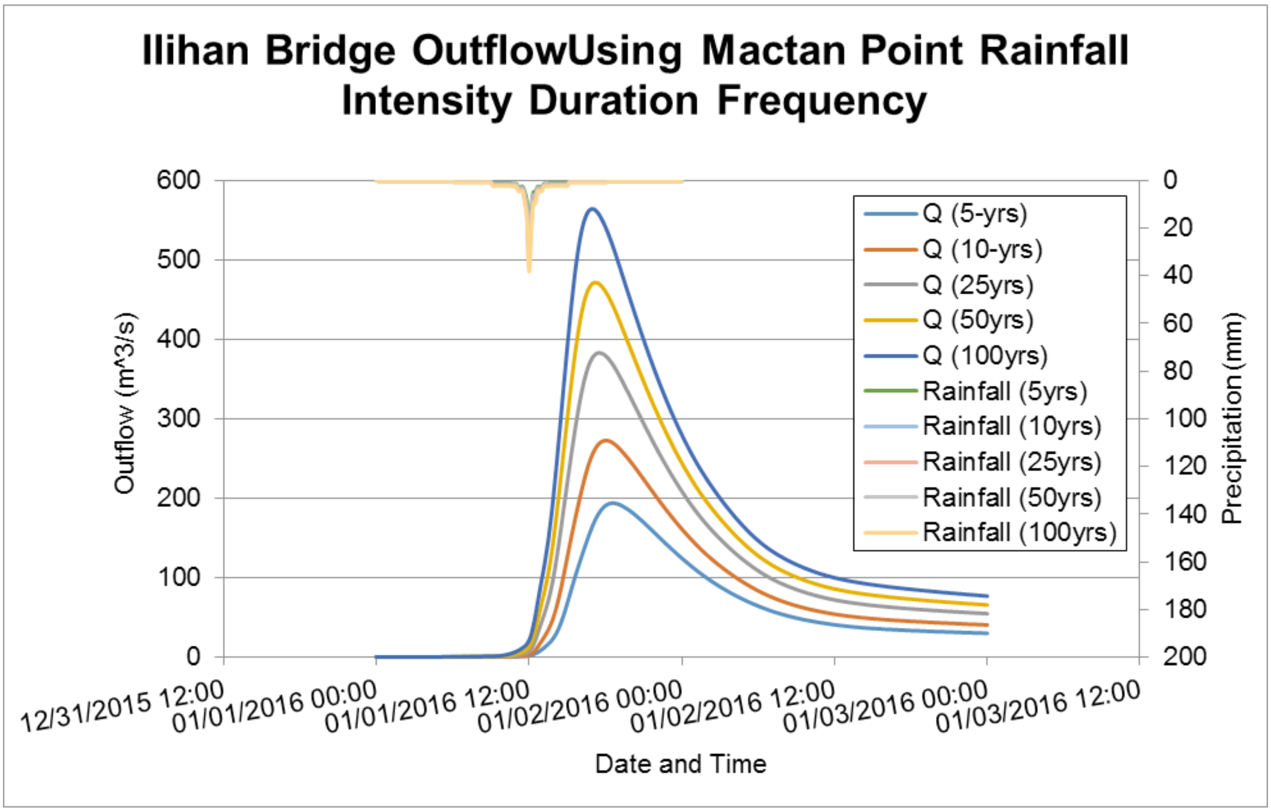


Figure 65. Outflow hydrograph at Ilihan Bridge, Toledo City generated using Mactan PointRIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Sapangdaku River discharge using the Mactan Point Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. Peak values of the Sapangdaku HECHMS Model outflow using the Dumaguete RIDF

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow $\left(\frac{m^3}{s}\right)$	Time to Peak
5-year RIDF	139.1	21.900	193.807	6:30
10-year RIDF	169.7	25.800	272.642	6:00
25-year RIDF	208.5	30.900	382.849	5:30
50-year RIDF	237.2	34.600	471.331	5:10
100-year RIDF	265.7	38.300	563.924	5:00

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Sapangdaku River using the calibrated event flow is shown in Figure 66.

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Figure 66. Sample output of Sapangdaku RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 67 to Figure 72 shows the 5-, 25-, and 100-year rain return scenarios of the Sapangdaku floodplain. The floodplain covers one city namely Toledo City. Table 34 shows the percentage of area affected by flooding per per city.

Table 34. Municipalities affected in Sapangdaku Floodplain

Municipality/ City	Total Area (sq.km.)	Area Flooded (sq. km.)	% Flooded
Toledo City			

This image is not available for this river basin.

Figure 67. 100-year Flood Hazard Map for Sapangdaku Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 68. 100-year Flow Depth Map for Sapangdaku Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 69. 25-year Flood Hazard Map for Sapangdaku Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 70. 25-year Flow Depth Map for Sapangdaku Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 71. 5-year Flood Hazard Map for Sapangdaku Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 72. 5-year Flood Depth Map for Sapangdaku Floodplain overlaid on Google Earth imagery

5.10 Areas Exposed to Flooding

Affected barangays in the Sapangdaku river basin, grouped by municipality, are listed below. For the said basin, one (1) city consisting of 22 barangays is expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 23.85% of Toledo City with an area of 232.21 sq. km. will experience flood levels of less 0.20 meters. 2.02% of the area will experience flood levels of 0.21 to 0.50 meters while 1.37%, 1%, 0.69%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 35 and Table 36, and shown in Figure 73 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Toledo City, Cebu during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Toledo City (in sq. km.)										
	Bunga	Calongcalong	Cambang-Ug	Canlumampao	Capitan Claudio	Carmen	Daanglungsod	Don Andres Soriano	Dumlog	Gen. Climaco	Ilihan
0.03-0.20	0.15	0.23	3.23	2.33	5.55	2.73	1.08	4.91	1.1	9.62	0.22
0.21-0.50	0.0048	0.013	0.21	0.78	0.13	0.36	0.16	0.11	0.47	0.56	0.028
0.51-1.00	0.0043	0.004	0.14	0.47	0.13	0.25	0.036	0.073	0.37	0.29	0.0045
1.01-2.00	0.004	0.00082	0.16	0.13	0.17	0.11	0.062	0.13	0.2	0.21	0.012
2.01-5.00	0.0038	0	0.13	0.44	0.1	0.04	0.0048	0.14	0.037	0.027	0.022
> 5.00	0	0	0.0037	0.011	0.0019	0	0	0.0059	0	0	0

Table 36. Affected Areas in Toledo City, Cebu during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Toledo City (in sq. km.)										
	Juan Climaco, Sr.	Landahan	Luray II	Matab-Ang	Media Once	Poblacion	Poog	Sam-Ang	Sangi	Talavera	Tubod
0.03-0.20	3.46	0.24	0.66	3.07	3.86	0.66	2.76	3.91	1.58	3.79	0.22
0.21-0.50	0.37	0.0018	0.031	0.092	0.13	0.079	0.12	0.16	0.25	0.61	0.00076
0.51-1.00	0.31	0.001	0.011	0.088	0.12	0.061	0.087	0.1	0.1	0.51	0.0005
1.01-2.00	0.29	0.0001	0.0066	0.064	0.14	0.029	0.065	0.041	0.081	0.41	0.0002
2.01-5.00	0.29	0.0002	0.0077	0.019	0.087	0.0025	0.08	0.0072	0.071	0.078	0.0001
> 5.00	0.059	0	0	0.0001	0.00044	0	0.0096	0.0006	0	0.0025	0

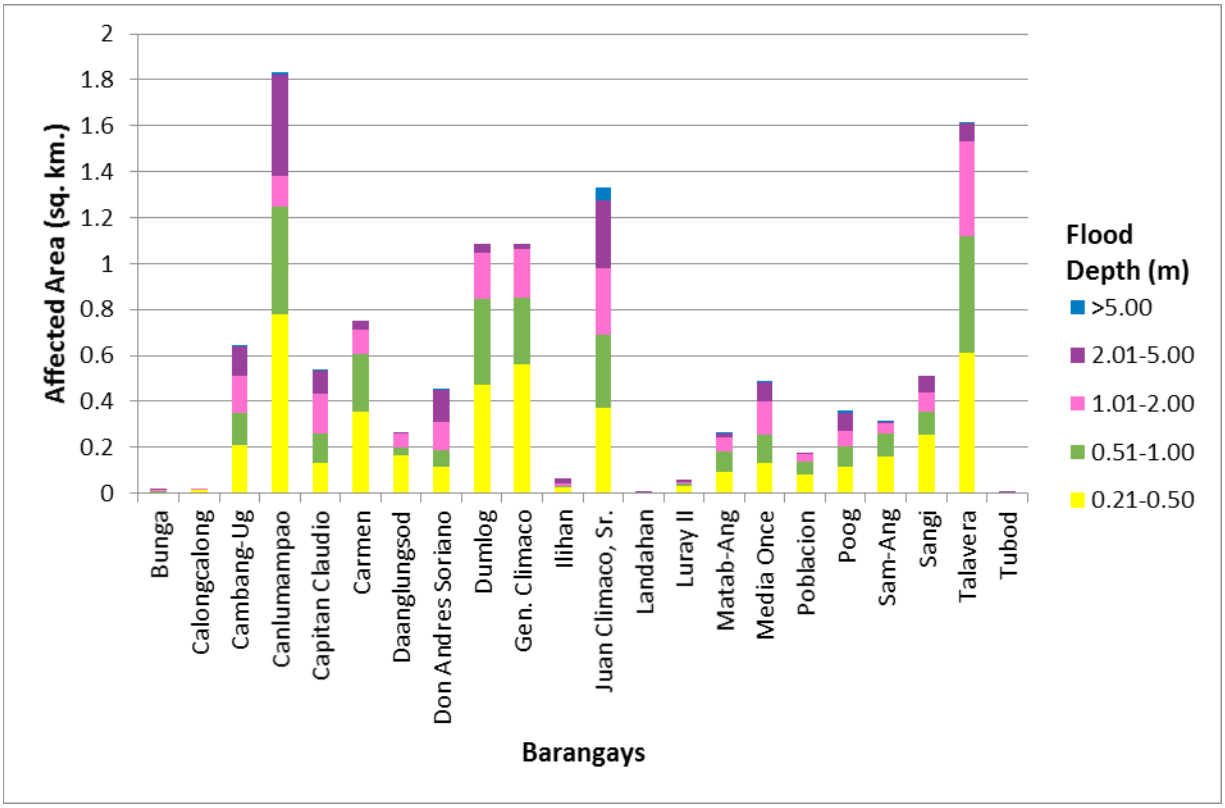

Figure 73. Affected Areas in Toledo City, Cebu during 5-Year Rainfall Return Period

For the 25-year return period, 22.81% of the municipality of Toledo City with an area of 232.21 sq. km. will experience flood levels of less 0.20 meters. 2.14% of the area will experience flood levels of 0.21 to 0.50 meters while 1.63%, 1.23%, 0.9%, and 0.24% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 37 and Table 38, and shown in Figure 74 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Toledo City, Cebu during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Toledo City (in sq. km.)										
	Bunga	Calongcalong	Cambang-Ug	Canlumampao	Capitan Claudio	Carmen	Daanglungsod	Don Andres Soriano	Dumlog	Gen. Climaco	Ilihan
0.03-0.20	0.14	0.23	3.13	2.02	5.48	2.49	0.96	4.81	0.8	9.44	0.2
0.21-0.50	0.0053	0.014	0.22	0.83	0.14	0.38	0.23	0.13	0.44	0.59	0.037
0.51-1.00	0.0041	0.0085	0.15	0.55	0.11	0.35	0.069	0.064	0.55	0.34	0.0056
1.01-2.00	0.0055	0.0017	0.16	0.2	0.2	0.14	0.037	0.11	0.31	0.25	0.0087
2.01-5.00	0.0056	0	0.17	0.37	0.16	0.1	0.05	0.22	0.08	0.085	0.032
> 5.00	0.0002	0	0.044	0.19	0.0064	0.012	0	0.023	0.0004	0	0.0018

Table 38. Affected Areas in Toledo City, Cebu during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Toledo City (in sq. km.)										
	Juan Climaco, Sr.	Landahan	Luray II	Matab-Ang	Media Once	Poblacion	Poog	Sam-Ang	Sangi	Talavera	Tubod
0.03-0.20	3.26	0.24	0.64	3.02	3.78	0.63	2.69	3.85	1.46	3.47	0.22
0.21-0.50	0.41	0.0027	0.031	0.099	0.14	0.087	0.12	0.18	0.31	0.55	0.0013
0.51-1.00	0.3	0.0008	0.018	0.083	0.11	0.08	0.099	0.11	0.14	0.65	0.0004
1.01-2.00	0.35	0.0003	0.012	0.095	0.15	0.038	0.08	0.066	0.06	0.59	0.0004
2.01-5.00	0.27	0.0003	0.011	0.029	0.16	0.0032	0.1	0.0099	0.12	0.1	0.0001
> 5.00	0.21	0.0002	0.0021	0.0001	0.0088	0	0.023	0.0026	0.0004	0.026	0

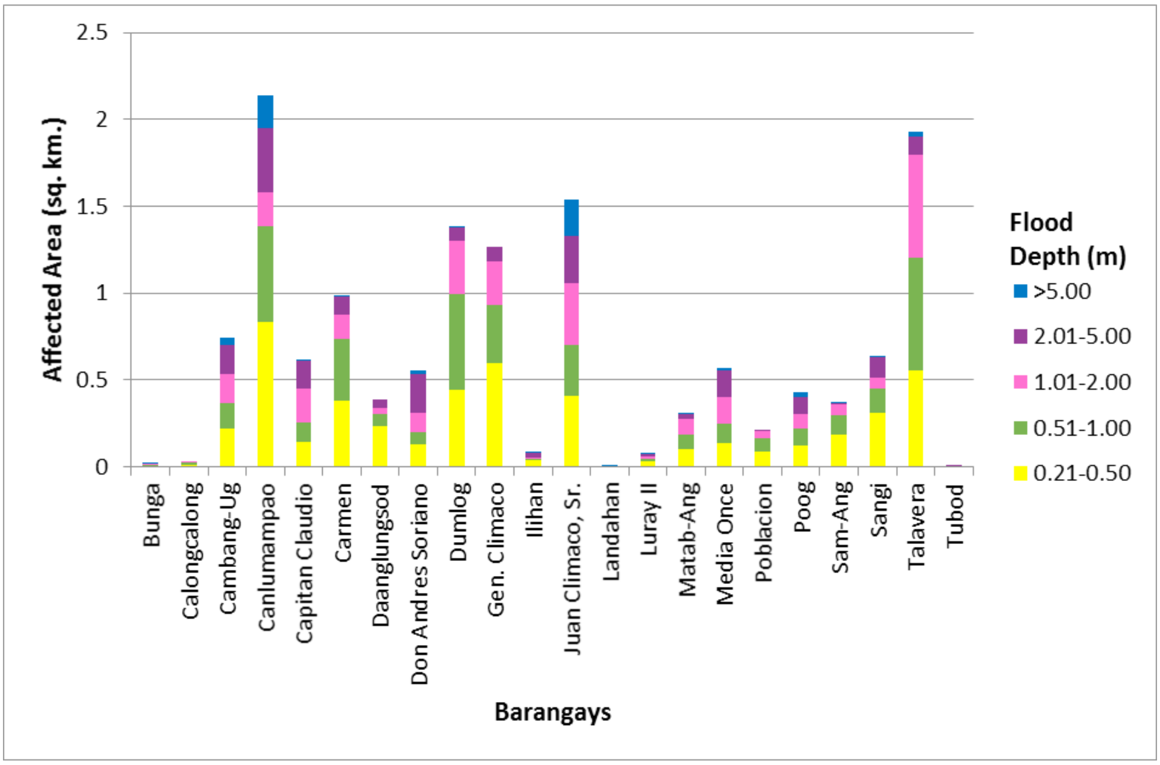

Figure 74. Affected Areas in Toledo City, Cebu during 5-Year Rainfall Return Period

For the 100-year return period, 22.2% of the municipality of Toledo City with an area of 232.21 sq. km. will experience flood levels of less 0.20 meters. 2.23% of the area will experience flood levels of 0.21 to 0.50 meters while 1.72%, 1.45%, 0.91%, and 0.46% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 39 and Table 40, and shown in Figure 75 and Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Toledo City, Cebu during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Toledo City (in sq. km.)										
	Bunga	Calongcalong	Cambang-Ug	Canlumampao	Capitan Claudio	Carmen	Daanglungsod	Don Andres Soriano	Dumlog	Gen. Climaco	Ilihan
0.03-0.20	0.14	0.22	3.05	1.81	5.43	2.42	0.87	4.76	0.64	9.32	0.19
0.21-0.50	0.0049	0.015	0.23	0.88	0.15	0.39	0.27	0.15	0.43	0.62	0.042
0.51-1.00	0.0046	0.01	0.17	0.54	0.1	0.37	0.11	0.071	0.59	0.38	0.0059
1.01-2.00	0.0059	0.0031	0.18	0.32	0.2	0.17	0.041	0.096	0.41	0.24	0.0056
2.01-5.00	0.0073	0	0.12	0.17	0.2	0.13	0.062	0.27	0.1	0.16	0.036
> 5.00	0.00057	0	0.13	0.43	0.014	0.012	0	0.029	0.0048	0.0004	0.0046

Table 40. Affected Areas in Toledo City, Cebu during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Toledo City (in sq. km.)										
	Juan Climaco, Sr.	Landahan	Luray II	Matab-Ang	Media Once	Poblacion	Poog	Sam-Ang	Sangi	Talavera	Tubod
0.03-0.20	3.14	0.24	0.63	2.99	3.73	0.61	2.65	3.81	1.37	3.31	0.22
0.21-0.50	0.4	0.0035	0.032	0.11	0.14	0.086	0.12	0.2	0.34	0.55	0.002
0.51-1.00	0.31	0.0008	0.018	0.087	0.12	0.09	0.11	0.11	0.18	0.61	0.0006
1.01-2.00	0.38	0.0006	0.014	0.1	0.16	0.044	0.089	0.079	0.065	0.77	0.0005
2.01-5.00	0.24	0.0003	0.017	0.04	0.17	0.0046	0.11	0.016	0.13	0.13	0.0001
> 5.00	0.32	0.0002	0.004	0.0001	0.037	0	0.036	0.0033	0.01	0.026	0

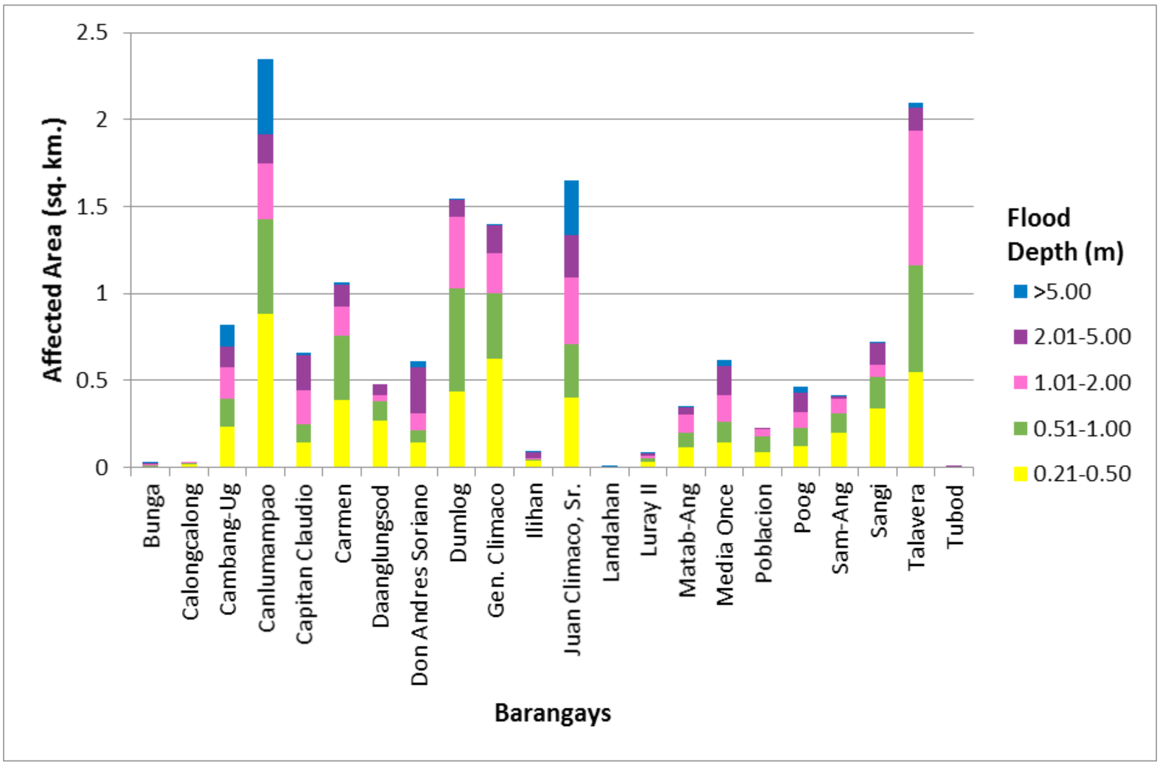

Figure 75. Affected Areas in Toledo City, Cebu during 100-Year Rainfall Return Period

Among the barangays in the city of Toledo, Gen. Climac is projected to have the highest percentage of area that will experience flood levels at 4.61%. Meanwhile, Capitan Claudio posted the second highest percentage of area that may be affected by flood depths at 2.62%.

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

Table 41. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	4.76	5.05	5.24
Medium	4.69	5.61	6.15
High	2.73	3.96	4.66
TOTAL	**12.18**	**14.62**	**16.05**

Of the 20 identified Education Institutions in the Sapangdaku Flood plain, 7 schools were assessed to be exposed to Low level flooding during a 5 year scenario, while 3 schools were assessed to be exposed to medium level flooding in the same scenario. In the 25 year scenario, 5 schools were assessed to be exposed to low level flooding, while 7 schools were assessed to be exposed to medium level flooding in the same scenario. In the 100 year scenario, 4 schools were assessed to be exposed to low level flooding, while 9 schools were assessed to be exposed to medium level flooding in the same scenario. The educational institutions exposed to flooding are shown in Annex 12.

1 Medical Institution was identified in the Sapangdaku Flood Plain, and upon assessment, it was not exposed to any of the flooding levels in any scenario. The medical institutions exposed to flooding are shown in Annex 13.

5.11 Flood Validation

Survey was done along the floodplain of Sapangdaku River to validate the generated flood maps. The team gathered secondary data regarding flood occurrence in the area. Ground validation points were acquired as well as the other necessary details like date of occurrence, name of typhoon and actual flood depth.

During validation, the team was assisted by the local Disaster Risk Reduction and Management representative from the City of Toledo. Residents along the floodplain were interviewed of the historical flood events they experiences.

Flood validation points were obtained on January 13-15, 2016. Actual flood depth acquired from the ground validation were then computed and compared to the flood depth simulated by the model. An RMSE value of 1.11 was obtained.

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Figure 76. Sapangdaku River Basin Flood Validation Points

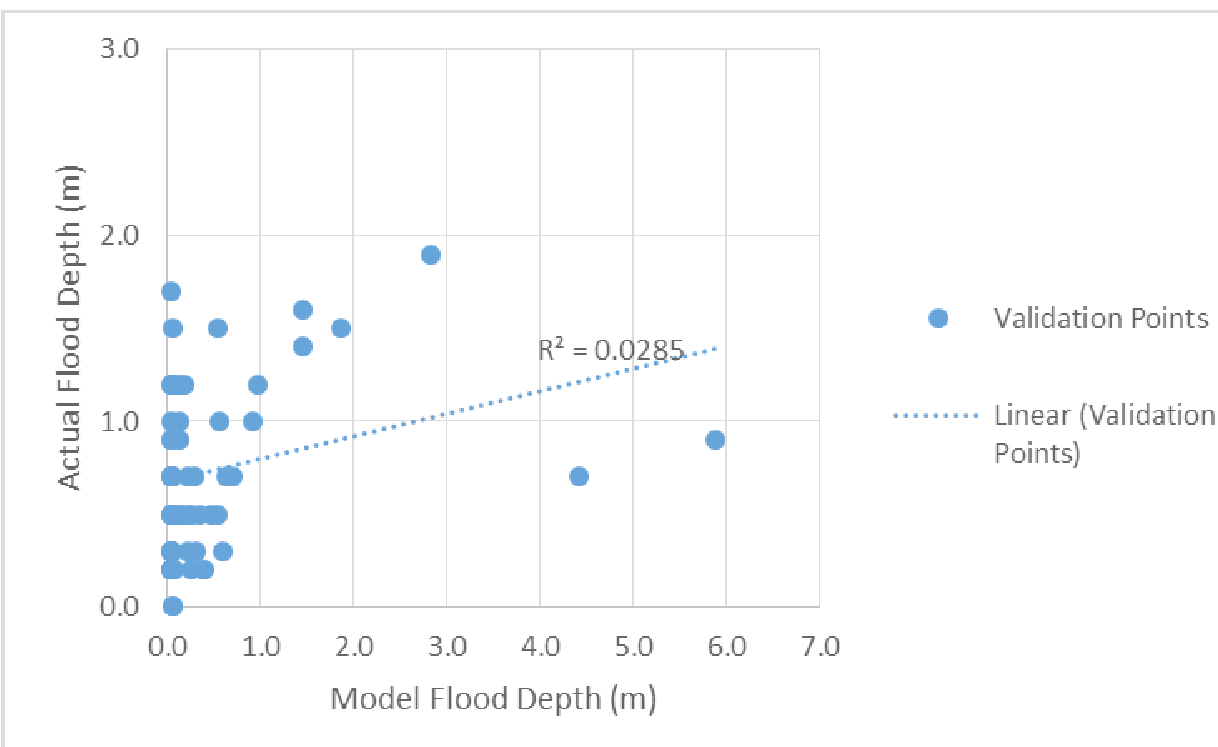

Figure 77. Flood map depth vs. actual flood depth

Table 42. Actual flood vs simulated flood depth of Sapangdaku River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	12	3	0	0	0	0	15
0.21-0.50	13	6	2	0	0	0	21
0.51-1.00	11	2	4	0	1	1	19
1.01-2.00	8	0	2	3	1	0	14
2.01-5.00	1	0	0	0	0	0	1
> 5.00	0	0	0	0	0	0	0
Total	45	11	8	3	2	1	70

The overall accuracy generated by the flood model is estimated at 35.71% with 25 points correctly matching the actual flood depths. In addition, there were 21 points estimated one level above and below the correct flood depths while there were 12 points and 10 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 37 points were underestimated in the modelled flood depths of Sapangdaku. The summary of the accuracy assessment is presented in Table 43.

Table 43. Summary of the Accuracy Assessment in the Sapangdaku River Basin Survey

	No. of Points	%
Correct	25	**35.71**
Overestimated	8	**11.43**
Underestimated	37	**52.86**
Total	70	**100.00**

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor

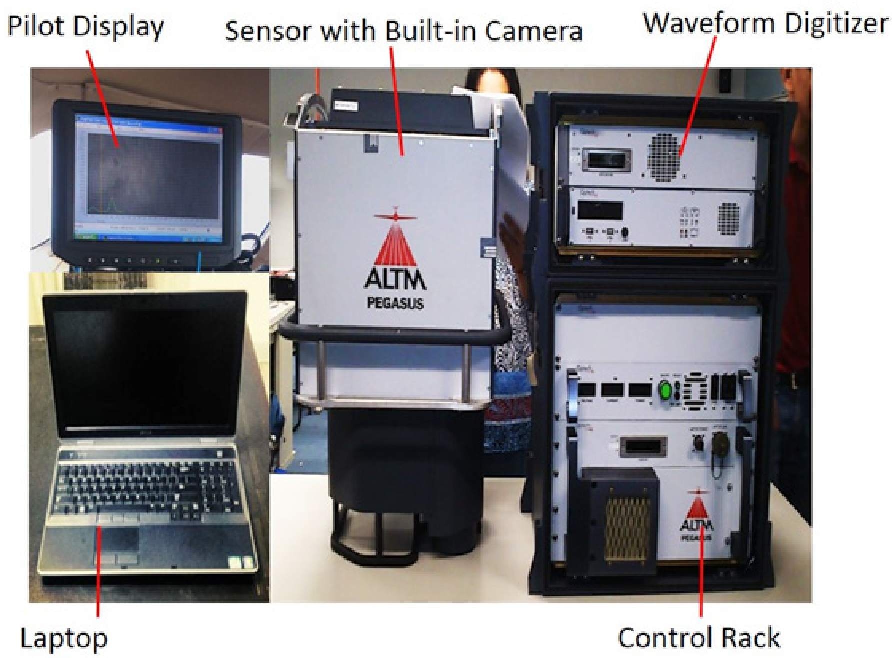

Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and 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

1 Target reflectivity ≥20%

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

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certificates of Reference Points Used

1. CBU-95

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

July 25, 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: **CEBU**
Station Name: **CBU-95**
Order: **1st**

Island: **VISAYAS**		Barangay: **CANBANUA**
Municipality: **ARGAO**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **9° 53' 12.12011"**	Longitude: **123° 35' 25.30633"**	Ellipsoidal Hgt: **53.60100 m.**
	WGS84 Coordinates	
Latitude: **9° 53' 8.07702"**	Longitude: **123° 35' 30.59401"**	Ellipsoidal Hgt: **115.55540 m.**
	PTM / PRS92 Coordinates	
Northing: **1093256.973 m.**	Easting: **564747.93 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,092,874.31**	Easting: **564,725.27**	Zone: **51**

Location Description

CBU-95

From the capitol building of Cebu CIty travel south on the national highway, along the east coast of Cebu island for 65 kilometers up to Argao bridge, passing through the towns of Miglanilla, Naga, San Fernando, Carcar and Sibonga. After crossing Argao bridge, travel for 850 meters, then turn right and travel west for 1.3 kilometers through Aragao town proper; and then turn right, and travel 300 meters up to the "T" road junction,which is the end of the concrete road. From this "T" junction, turn left and wlak for 150 meters NW, uphill to Aragao water tank. The station is located on the top and center of convex concrete shell of water tank, on top of the hill. Station mark; 0.15 m x 0.01 m in diameter brass rod, embedded in a drill hole at the top and center of convex shell of Argao water tank. All reference marks are 0.15 m x 0.01 m in diameter brass rods, embedded in the concrete in the edge of the water tank.

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1730**

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

9 9 0 7 2 5 2 0 1 4 1 3 1 8 1 8

CIP/4701/12/09/814

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

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Figure A-2.1 CBU-95

2. CBU-11

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

July 25, 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: **CEBU**
Station Name: **CBU-11**
Order: **2nd**

Island: **VISAYAS**		Barangay: **TOWN PROPER**
Municipality: **CEBU CITY (CAPITAL)**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **10° 17' 56.00367"**	Longitude: **123° 53' 26.63633"**	Ellipsoidal Hgt: **44.27700 m.**
	WGS84 Coordinates	
Latitude: **10° 17' 51.88109"**	Longitude: **123° 53' 31.88503"**	Ellipsoidal Hgt: **106.03300 m.**
	PTM / PRS92 Coordinates	
Northing: **1138921.917 m.**	Easting: **597568.76 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,138,523.27**	Easting: **597,534.61**	Zone: **51**

Location Description

CBU-11 , "FIRE TOWER""

From the intersection of Jonas Avenue and Cebu South Expressway drive 600 meters going West to Metro Cebu Fire Department station. The staion is located on the roof top of 75 feet concrete tower of Metro Cebu Fire Department at the left side of the road.

Staion mark is a cross cut on top of 0.15 m x 0.01 min diameter brass rod, set in drill hole; centered in 0.25 m c 0.25 m cement patty; 0.03 m protruding above roof top of the 75 feet concrete tower of Metro Cebu Fire department station. Inacribed with station name.

recomputed 3/19/2014

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1728**

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

9 9 0 7 2 5 2 0 1 4 1 3 1 7 4 1

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 CBU-11

3. CBU-293

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

July 25, 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: **CEBU**
Station Name: **CBU-293**
Order: **2nd**

Island: **VISAYAS**
Municipality: **TOLEDO CITY**
Barangay: **CANTABACO**
MSL Elevation:

PRS92 Coordinates

Latitude: **10° 18' 32.84815"**	Longitude: **123° 43' 15.51183"**	Ellipsoidal Hgt: **289.62500 m.**

WGS84 Coordinates

Latitude: **10° 18' 28.70835"**	Longitude: **123° 43' 20.76082"**	Ellipsoidal Hgt: **350.93800 m.**

PTM / PRS92 Coordinates

Northing: **1140007.158 m.**	Easting: **578970.41 m.**	Zone: **4**

UTM / PRS92 Coordinates

Northing: **1,139,608.14**	Easting: **578,942.77**	Zone: **51**

Location Description

CBU-293

From Naga City Hall, travel about 400 m going S along Nat'l Highway to reach the junction road going to Toledo City. From the Toledo-Naga Road travel about 17 Km. to reach the junction road at Brgy. Lutopan, turn right until you will reach the next junction, turn right following the road going to Brgy. Cantabaco until you reach Cantabaco Nat'l High School. The station is located at the S center edge of a basketball court inside the school compus about 150 m E of the maingate.

The station is concrete putty cement with 30 cm x 30 cm in dimension, leveled on the concrete pavement of the basketball court centered with a 3 in. copper nail with inscriptions, "CBU-293, 2007, NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1729**

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

9 9 0 7 2 5 2 0 1 4 1 3 1 8 0 4

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3 CBU-293

4. CBU-296

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

August 08, 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: **CEBU**
Station Name: **CBU-296**
Order: **2nd**

Island: **VISAYAS**
Municipality: **ALOGUINSAN**

Barangay: **ZARAGOSA**
MSL Elevation:

PRS92 Coordinates

Latitude: **10° 10' 2.93937"**	Longitude: **123° 35' 54.77903"**	Ellipsoidal Hgt: **144.99000 m.**

WGS84 Coordinates

Latitude: **10° 9' 58.82504"**	Longitude: **123° 36' 0.04167"**	Ellipsoidal Hgt: **206.32700 m.**

PTM / PRS92 Coordinates

Northing: **1124313.588 m.**	Easting: **565589.364 m.**	Zone: **4**

UTM / PRS92 Coordinates

Northing:	Easting:	Zone:

Location Description

CBU-296

To reach the station, from Cebu City you have to travel 1 hr. along S along Nat'l Highway to reach Mun. of Carcar. Before reaching Carcar Town Proper, take a right turn at the road right before Gaisano Mall following a Brgy. Road going to Brgy. Zaragoza, travel along this road about 8.1 Km. to reach station. The station is located at the basketball court near the concrete fence.

The station is 30 cm x 30 cm x 120 cm monument with 20 cm procuring into the ground, centered with a 3 in. copper nail with inscriptions, "CBU-296, 2007, NAMRIA".

Requesting Party:	**ENGR. CHRISTOPHER CRUZ**
Pupose:	**Reference**
OR Number:	**8799670 A**
T.N.:	**2014-1777**

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

9 9 0 8 0 8 2 0 1 4 1 4 0 2 1 0

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

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

Figure A-2.4 CBU-296

5. CU-340

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

August 08, 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: **CEBU**
Station Name: **CU-340**

Island: **CEBU**	Municipality: **DALAGUETE**	Barangay: **BALUD**
Elevation: **9.4185 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM CU-340 is located at Barangay Poblacion, Dalaguete, Cebu beside km post 84. Monument is situated at a concrete sidewalk at an end of Dumaguete bridge and at the right side of the road going SW. Mark is the head of a 3" copper nail set on a drilled hole and cemented on a 6" x 6" x 1/2" cement putty flushed on a concrete sidewalk of a bridge with inscription "CU-340; 2007; NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Pupose: **Reference**
OR Number: **8799670 A**
T.N.: **2014-1778**

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

99080820141140423

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.5 CU-340

6. CU-784

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

August 08, 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: **CEBU**
Station Name: **CU-784**

Island: **CEBU**	Municipality: **TOLEDO CITY**	Barangay: **BALUD**
Elevation: **58.7670 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM CU-784 is located along the national highway of Brgy. Balud, Toledo, 10 m SE of a Sari-Sari store, 20 m NW of Bega's store, 35 m NW of Balud bridge and Sw of km post 47. Mark is set on a drilled hole centered with 3" copper nail on top of a concrete foundation of km post 47 embedded with concrete cement putty, 0.20 m x 0.20 m x 0.30 m with inscription CU-784 2008 NAMRIA.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Pupose: **Reference**
OR Number: **8799670 A**
T.N.: **2014-1779**

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

99080820141405 05

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

NAMRIA OFFICES:
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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-2.6 CU-784

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

1. CU-340

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CBU-95 --- CU-340 (B1)	CBU-95	CU-340	Fixed	0.004	0.016	205°44'46"	14786.402	-43.202
CBU-95 --- CU-340 (B2)	CBU-95	CU-340	Fixed	0.007	0.015	205°44'46"	14786.398	-43.210

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	CBU-95				
Grid		Local		Global	
Easting	564725.267 m	Latitude	N9°53'12.12011"	Latitude	N9°53'08.07702"
Northing	1092874.314 m	Longitude	E123°35'25.30633"	Longitude	E123°35'30.59407"
Elevation	52.386 m	Height	53.601 m	Height	115.555 m

To:	CU-340				
Grid		Local		Global	
Easting	558328.012 m	Latitude	N9°45'58.58681"	Latitude	N9°45'54.56953"
Northing	1079549.209 m	Longitude	E123°31'54.56077"	Longitude	E123°31'59.85973"
Elevation	9.223 m	Height	10.399 m	Height	72.479 m

Vector					
ΔEasting	-6397.255 m	NS Fwd Azimuth	205°44'46"	ΔX	4117.818 m
ΔNorthing	-13325.105 m	Ellipsoid Dist.	14786.402 m	ΔY	5408.684 m
ΔElevation	-43.163 m	ΔHeight	-43.202 m	ΔZ	-13131.295 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Figure A-3.1 CU-340

2. CU-784

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CBU-293 --- CU-784 (B1)	CBU-293	CU-784	Fixed	0.008	0.025	305°11'38"	6328.292	-229.377
CBU-293 --- CU-784 (B2)	CBU-293	CU-784	Fixed	0.016	0.056	305°11'38"	6328.321	-229.336

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	CBU-293				
Grid		Local		Global	
Easting	578942.769 m	Latitude	N10°18'32.84815"	Latitude	N10°18'28.70836"
Northing	1139608.136 m	Longitude	E123°43'15.51183"	Longitude	E123°43'20.76082"
Elevation	287.991 m	Height	289.625 m	Height	350.938 m

To:	CU-784				
Grid		Local		Global	
Easting	573764.736 m	Latitude	N10°20'31.55031"	Latitude	N10°20'27.39783"
Northing	1143242.555 m	Longitude	E123°40'25.52669"	Longitude	E123°40'30.77330"
Elevation	58.781 m	Height	60.248 m	Height	121.368 m

Vector					
ΔEasting	-5178.033 m	NS Fwd Azimuth	305°11'38"	ΔX	4790.876 m
ΔNorthing	3634.419 m	Ellipsoid Dist.	6328.292 m	ΔY	2137.897 m
ΔElevation	-229.211 m	ΔHeight	-229.377 m	ΔZ	3546.676 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.007 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.011 m
σ ΔElevation	0.013 m	σ ΔHeight	0.013 m	σ ΔZ	0.004 m

Figure A-3.2 CU-784

3. CU-1322

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CBU-296 --- CU-1322 (B1)	CBU-296	CU-1322	Fixed	0.007	0.017	138°57'44"	6510.812	-95.924
CBU-296 --- CU-1322 (B2)	CBU-296	CU-1322	Fixed	0.005	0.014	138°57'44"	6510.823	-95.900

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	CBU-296				
Grid		Local		Global	
Easting	565566.407 m	Latitude	N10°10'02.93937"	Latitude	N10°09'58.82505"
Northing	1123920.059 m	Longitude	E123°35'54.77903"	Longitude	E123°36'00.04167"
Elevation	143.486 m	Height	144.990 m	Height	206.327 m

To:	CU-1322				
Grid		Local		Global	
Easting	569848.689 m	Latitude	N10°07'23.08395"	Latitude	N10°07'18.98433"
Northing	1119018.668 m	Longitude	E123°38'15.19068"	Longitude	E123°38'20.45703"
Elevation	47.518 m	Height	49.066 m	Height	110.601 m

Vector					
ΔEasting	4282.282 m	NS Fwd Azimuth	138°57'44"	ΔX	-3986.354 m
ΔNorthing	-4901.391 m	Ellipsoid Dist.	6510.812 m	ΔY	-1724.916 m
ΔElevation	-95.967 m	ΔHeight	-95.924 m	ΔZ	-4851.259 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Figure A-3.3 CU-1322

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
		KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FERDINAND DE OCAMPO	AAC

Annex 5. Data Transfer Sheets

DATA TRANSFER SHEET
08/01/2014(CEBU ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
7/18/2014	1725P	1BLK47B199A	Pegasus	2.62	1.67	13.8	232	45.1	315	26	117	5.03	1KB	1KB	51	NA	Z:\Airborne_Raw
7/22/2014	1741P	1BLK36H203A	Pegasus	2.24	1.5	12.1	250	40.4	288	23.3	69.3	10.4	1KB	1KB	55/53	NA	Z:\Airborne_Raw
7/22/2014	1743P	1BLK36H203B	Pegasus	1.93	1.15	7.95	170	29.6	243	18.5	124	10.4	1KB	1KB	55	NA	Z:\Airborne_Raw
7/23/2014	1747P	1BLK36A204B	Pegasus	NA	1.82	12.8	227	48.4	385	27.5	NA	9.78	1KB	1KB	38/30	NA	Z:\Airborne_Raw
7/24/2014	1749P	1BLK36AS205A	Pegasus	NA	708	7.24	192	13.8	114	10.9	NA	3.45	1KB	1KB	37	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 8/4/2014

Figure A-5.1 Data Transfer Sheet for Sapangdaku Floodplain - A

DATA TRANSFER SHEET
08/15/2014(CEBU ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
7/29/2014	1769P	1BLK47A210A	Pegasus	931	0.99	3.45	95.7	10.5	85	9.18	NA	6.47	1KB	1KB	495	NA	Z:\DAC\RAWDATA
730/2014	1773P	1BLK47A211A	Pegasus	2.31	2.06	8.4	238	38.5	318	22.9	NA	8.16	1KB	1KB	97.7	NA	Z:\DAC\RAWDATA
7/30/2014	1775P	1BLK47A211B	Pegasus	1.61	1.67	7.96	141	22.5	200	15.1	NA	8.16	1KB	1KB	1	NA	Z:\DAC\RAWDATA
7/31/2014	1777P	1BLK36E212A	Pegasus	3.37	3.82	9.71	262	59.6	442	32.4	NA	9.13	1KB	1KB	45	NA	Z:\DAC\RAWDATA
7/31/2014	1779P	1BLK36EF212B	Pegasus	2.64	3.04	8.87	239	41.3	359	25.8	NA	9.13	1KB	1KB	96.4	NA	Z:\DAC\RAWDATA
8/01/2014	1781P	1BLK36F213A	Pegasus	2.57	2.94	9.09	215	41.7	340	25.5	NA	6.61	1KB	1KB	33	NA	Z:\DAC\RAWDATA
8/02/2014	1785P	1BLK36GF214A	Pegasus	3.36	3.78	9.87	250	46.2	335	32.7	NA	10.9	1KB	1KB	163	NA	Z:\DAC\RAWDATA
8/02/2014	1787P	1BLK36G214B	Pegasus	3.07	3.41	9.24	250	48.3	45/57/270	29.5	NA	10.9	1KB	1KB	40	NA	Z:\DAC\RAWDATA
8/03/2014	1789P	1MCTN215A	Pegasus	732	1.02	7.16	250	13.4	105	9.33	NA	8.84	1KB	1KB	612	NA	Z:\DAC\RAWDATA
8/03/2014	1791P	1MCTN215B	Pegasus	517	736	5.44	167	7.61	69	6.52	NA	8.84	1KB	1KB	624	NA	Z:\DAC\RAWDATA
8/04/2014	1793P	1BLK36EFGS216A	Pegasus	NA	746	5.12	144	11	77	6.7	NA	2.11	1KB	1KB	189	NA	Z:\DAC\RAWDATA
8/06/2014	1801P	1BLK36D218A	Pegasus	NA	3.6	9.62	258	54	384	32.1	NA	8.9	1KB	1KB	59.3	NA	Z:\DAC\RAWDATA
8/06/2014	1803P	1BLK36C218B	Pegasus	3.58	3.83	12.1	224	22.7/37.1	153/1/275	33	NA	8.9	1KB	1KB	93.8	NA	Z:\DAC\RAWDATA
8/07/2014	1805P	1BLK36B219A	Pegasus	3.41	3.91	10,945	280	60.4	441	34.5	NA	7.01	1KB	1KB	121	NA	Z:\DAC\RAWDATA

Received from
Name TIN ANDAYA
Position RA
Signature

Received by
Name JOIDA PRIETO
Position SSRS
Signature 8/20/14

Figure A-5.2 Data Transfer Sheet for Sapangdaku Floodplain - B

DATA TRANSFER SHEET
09/05/2014(CEBU ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
8/9/2014	1813P	1MCTN221A	Pegasus	1.28	1.52	6.95	204	13.7	98	13.3	NA	5.23	1KB	1KB	222	NA	Z:\DAC\RAW DATA
8/11/2014	1821P	1BLK36AS223A	Pegasus	1.99	1.99	2.38	225	30.2	234	20.2	NA	4.45	1KB	1KB	314	NA	Z:\DAC\RAW DATA
8/12/2014	1825P	1BLK36ABC224A	Pegasus	1.31	1.36	5.78	164	20.8	159	12.5	NA	6.47	1KB	1KB	209	NA	Z:\DAC\RAW DATA
8/12/2014	1827P	1BLK36ES224B	Pegasus	1.88	2.02	6.41	187	27	245	18.2	NA	6.47	1KB	1KB	56.9	NA	Z:\DAC\RAW DATA
8/13/2014	1829P	1BLK36H47A225A	Pegasus	602	661	4.46	131	8.96	67	6.25	NA	8.78	1KB	1KB	265	NA	Z:\DAC\RAW DATA
8/13/2014	1831P	1OLNG225B	Pegasus	556	1.12	4.25	143	13.7	113	9.04	NA	8.78	1KB	1KB	29.8	NA	Z:\DAC\RAW DATA

Received from

Name TIN ANDAYA
Position RA
Signature

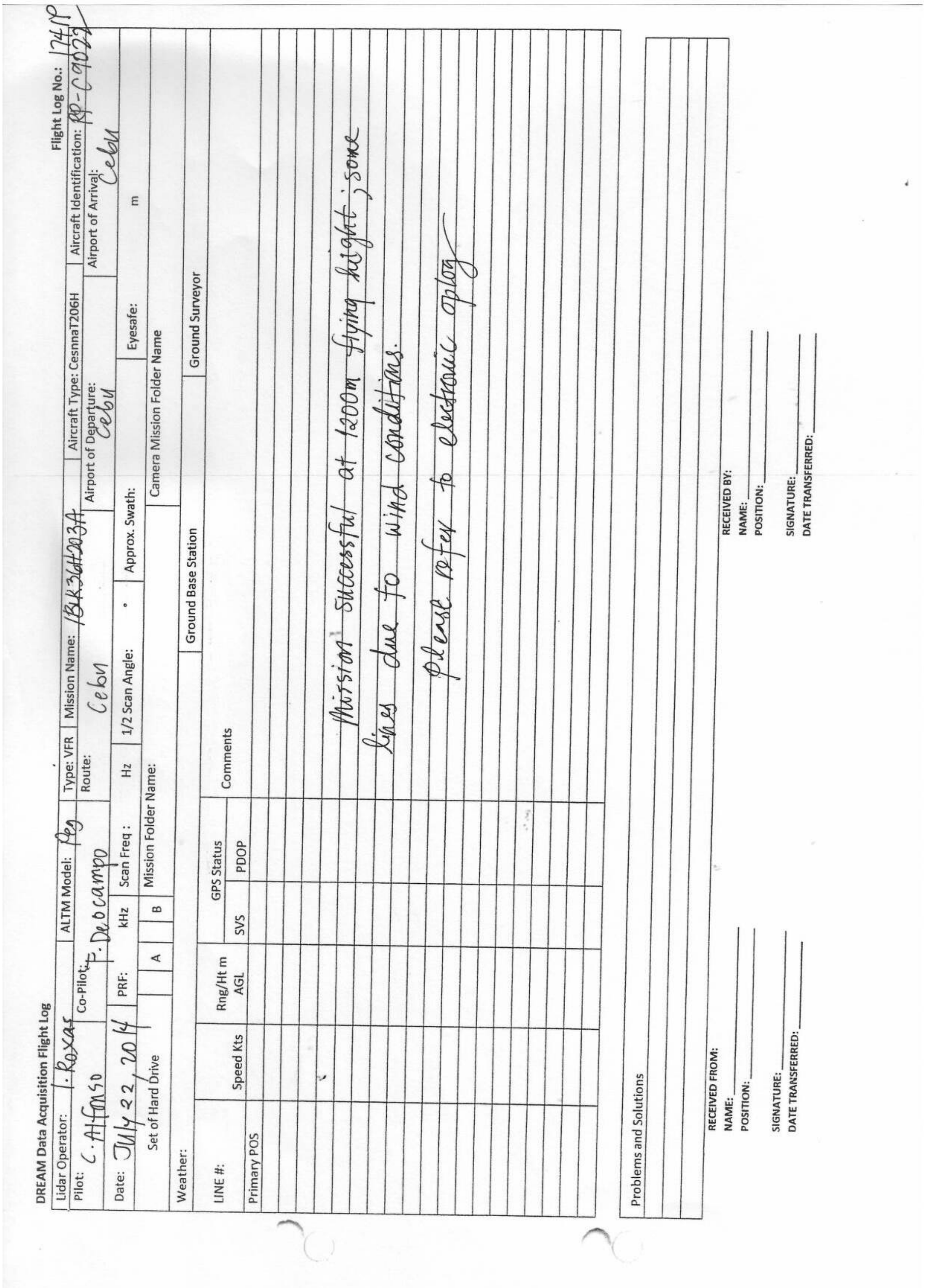
Received by

Name JOIDA F. PRIETO
Position SSRS 9/16/14
Signature

Figure A-5.3 Data Transfer Sheet for Sapangdaku Floodplain - C

Annex 6. Flight Logs

1. Flight Log for 1741P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1741P

Lidar Operator: I. Roxas | ALTM Model: Peg | Type: VFR | Mission Name: 1BLK36H203A | Aircraft Type: CesnnaT206H | Aircraft Identification: RP-C9022

Pilot: C. Alfonso | Co-Pilot: F. De Ocampo | Route: Cebu | Airport of Departure: Cebu | Airport of Arrival: Cebu

Date: July 22, 2014 | PRF: kHz | Scan Freq: Hz | 1/2 Scan Angle: ° | Approx. Swath: | Eyesafe: m

Set of Hard Drive: A B | Mission Folder Name: | Camera Mission Folder Name

Weather: | Ground Base Station | Ground Surveyor

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					Mission successful at 1200m flying height; some lines due to wind conditions. Please refer to electronic oplog

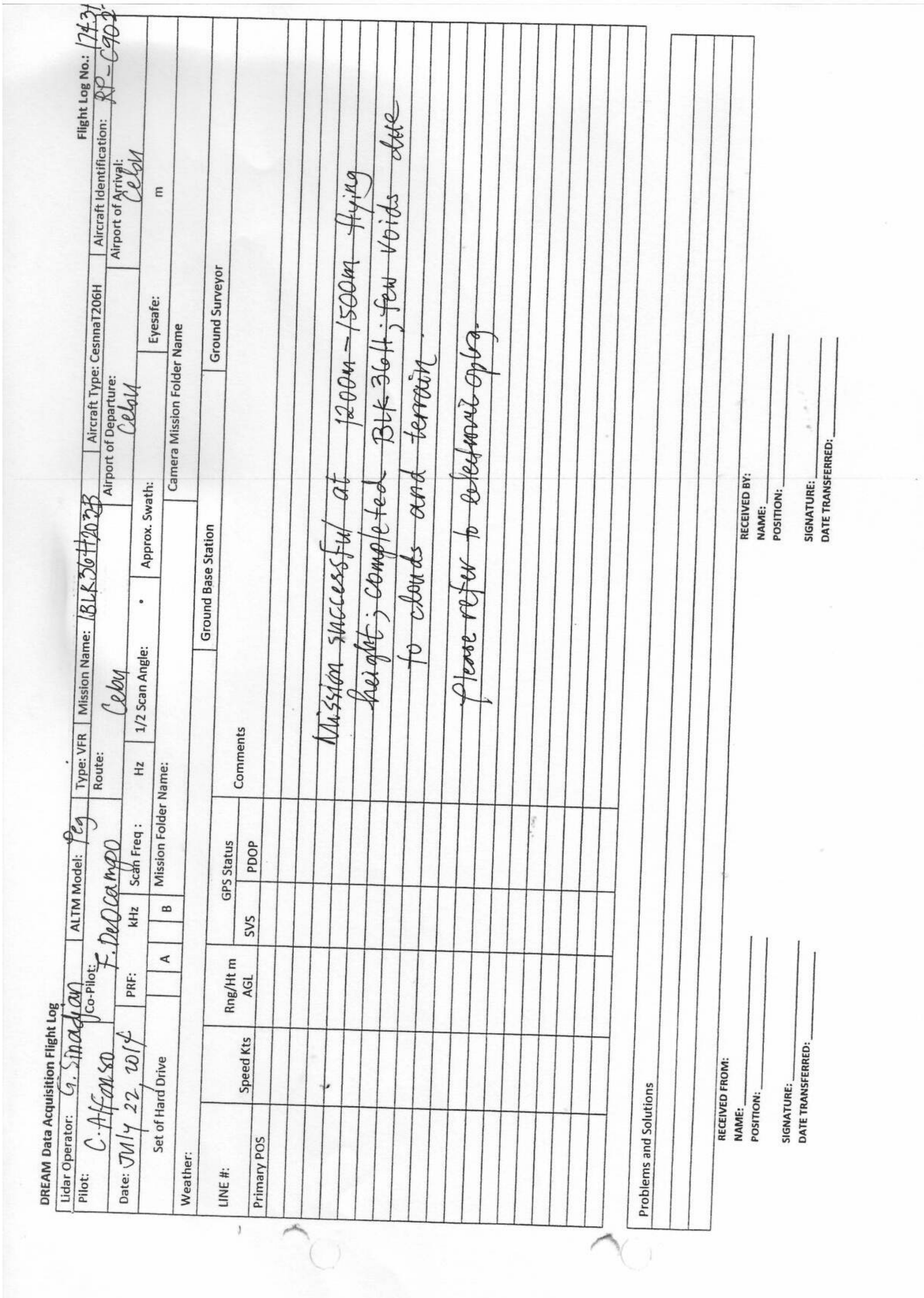
Problems and Solutions

RECEIVED FROM:
NAME:
POSITION:
SIGNATURE:
DATE TRANSFERRED:

RECEIVED BY:
NAME:
POSITION:
SIGNATURE:
DATE TRANSFERRED:

Figure A-6.1 Flight Log for 1741P Mission

2. Flight Log for 1743P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1743P

Lidar Operator: G. Sinadjan	ALTM Model: Peg	Type: VFR	Mission Name: 3BLK36H203B	Aircraft Type: CesnnaT206H	Aircraft Identification: RP-C9022
Pilot: C. Alfonso	Co-Pilot: F. DelOcampo	Route: Cebu			
Date: July 22, 2014	PRF: kHz	Scan Freq: Hz	1/2 Scan Angle: °	Approx. Swath:	Airport of Departure: Cebu / Airport of Arrival: Cebu
Set of Hard Drive: A / B	Mission Folder Name:			Camera Mission Folder Name	Eyesafe: m
Weather:					

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments	Ground Base Station	Ground Surveyor
Primary POS					Mission successful at 1200m-1500m flying height; completed BLK36H; few voids due to clouds and terrain. Please refer to [illegible]		

Problems and Solutions

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POSITION:
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DATE TRANSFERRED:

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Figure A-6.2 Flight Log for 1743P Mission

3. Flight Log for 1777P Mission

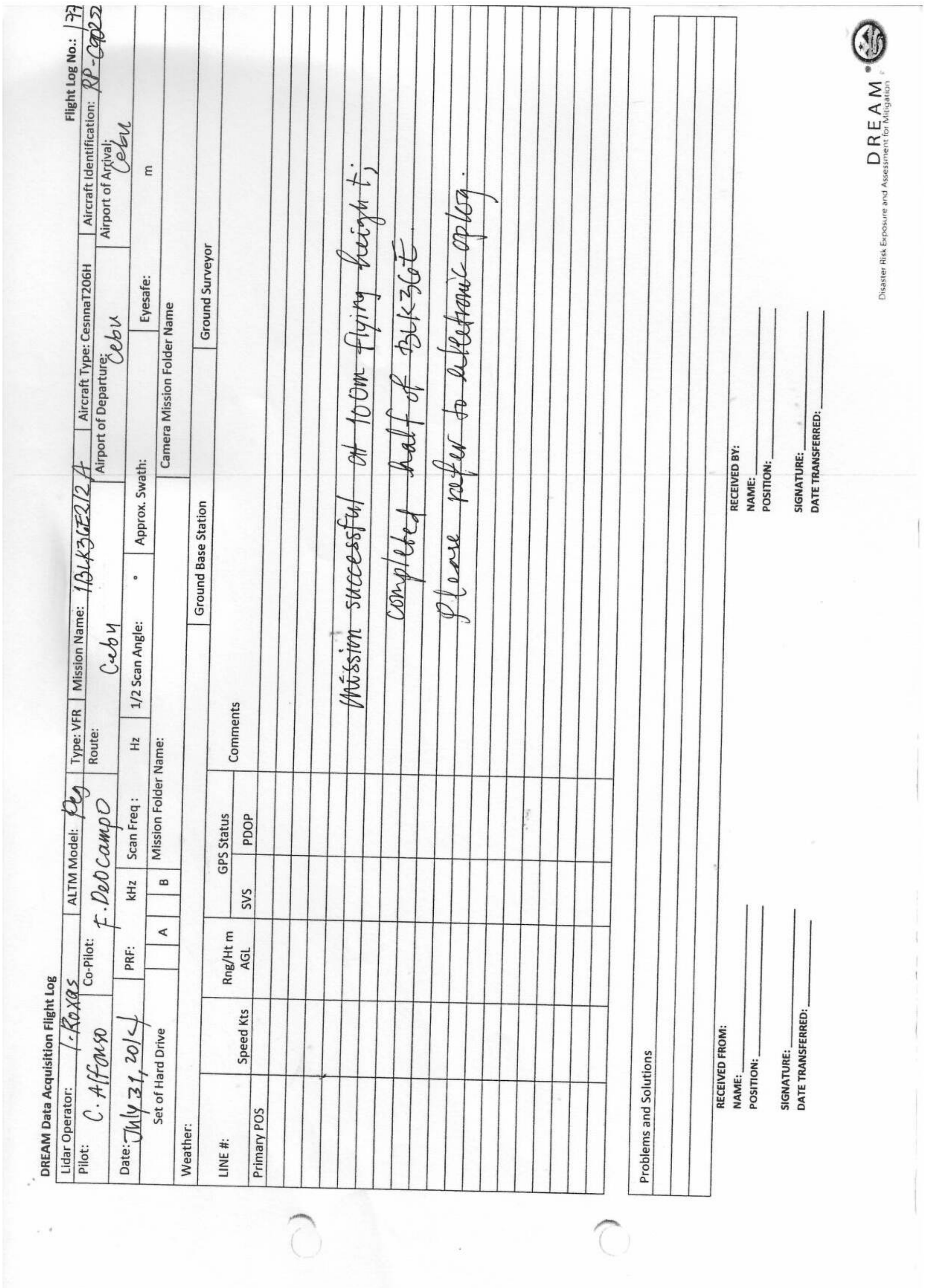
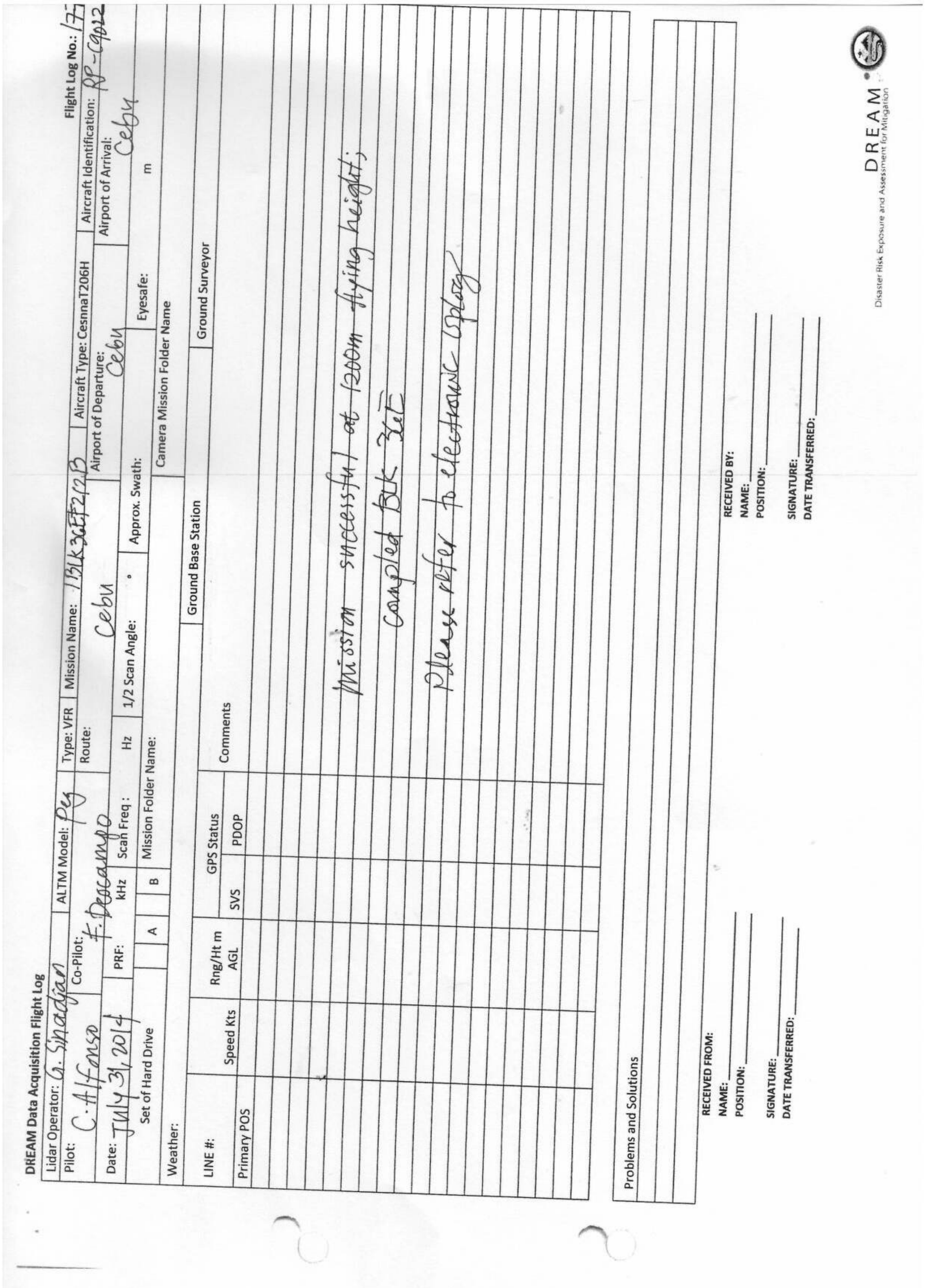


Figure A-6.3 Flight Log for 1777P Mission

4. Flight Log for 1779P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 17[illegible]

Lidar Operator: G. Sinadjan | ALTM Model: Peg | Type: VFR | Mission Name: 1BLK36EF212B | Aircraft Type: CesnnaT206H | Aircraft Identification: RP-C9022

Pilot: C. Alfonso | Co-Pilot: F. Descampo | Route: Cebu | Airport of Departure: Cebu | Airport of Arrival: Cebu

Date: July 31, 2014 | PRF: kHz | Scan Freq: Hz | 1/2 Scan Angle: ° | Approx. Swath: m | Eyesafe:

Set of Hard Drive: A B | Mission Folder Name: | Camera Mission Folder Name

Weather: | Ground Base Station | Ground Surveyor

LINE #	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					
					Mission successful at 1200m flying height;
					Completed BLK 36E
					Please refer to electronic Logbook

Problems and Solutions

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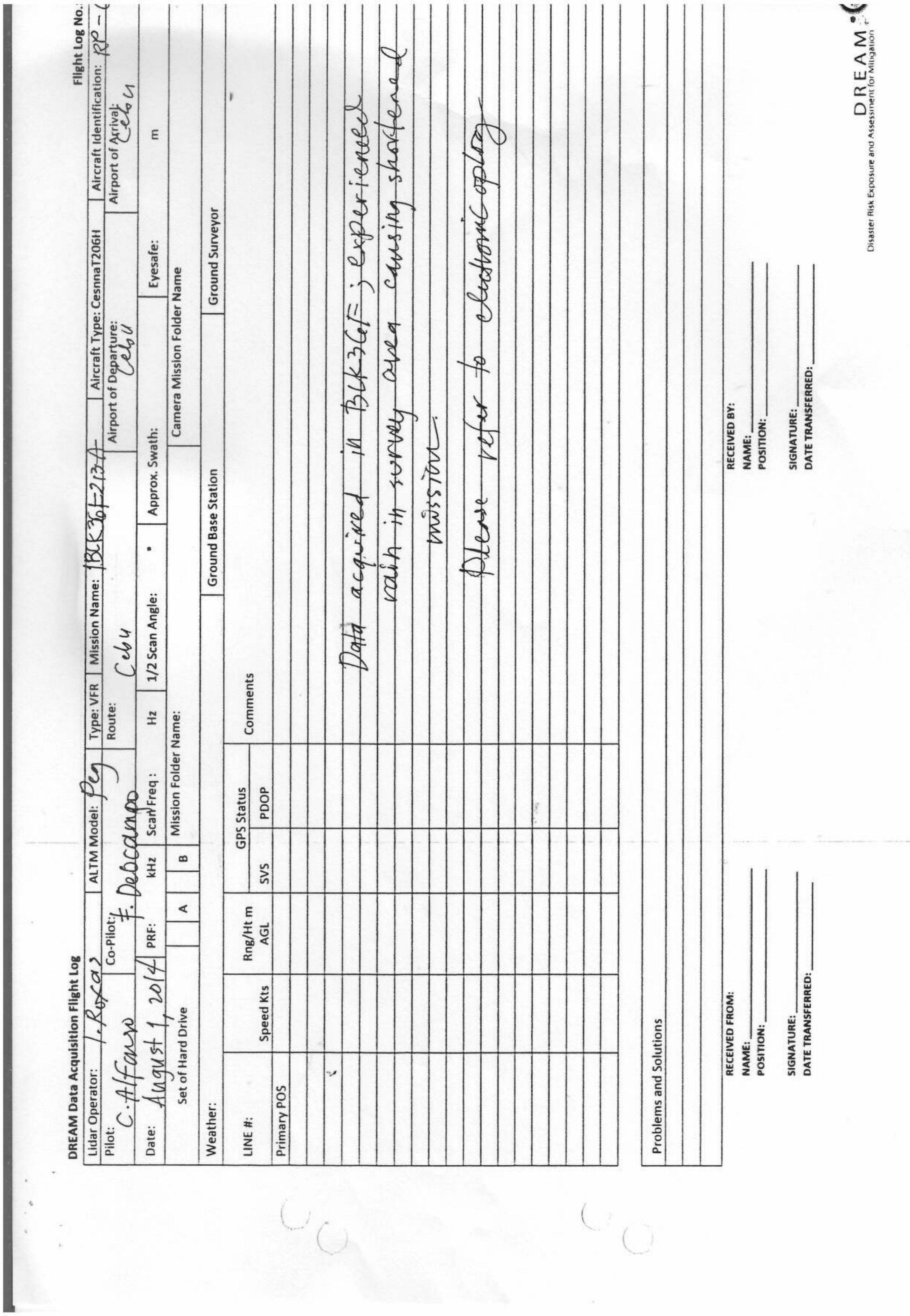
Figure A-6.4 Flight Log for 1779P Mission

5. Flight Log for 1781P Mission



DREAM Data Acquisition Flight Log — Flight Log No.:

Lidar Operator: I. Roxas	ALTM Model: Peg	Type: VFR	Mission Name: 1BLK36F213A	Aircraft Type: CesnnaT206H	Aircraft Identification: RP-C
Pilot: C. Alfonso	Co-Pilot: F. Delcampo	Route: Cebu		Airport of Departure: Cebu	Airport of Arrival: Cebu
Date: August 1, 2014	PRF: kHz	Scan Freq: Hz	1/2 Scan Angle:	Approx. Swath:	Eyesafe: m
Set of Hard Drive: A B	Mission Folder Name:			Camera Mission Folder Name	
Weather:			Ground Base Station		Ground Surveyor

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					Data acquired in BLK36F; experienced rain in survey area causing shortened mission. Please refer to electronic oplog.

Problems and Solutions

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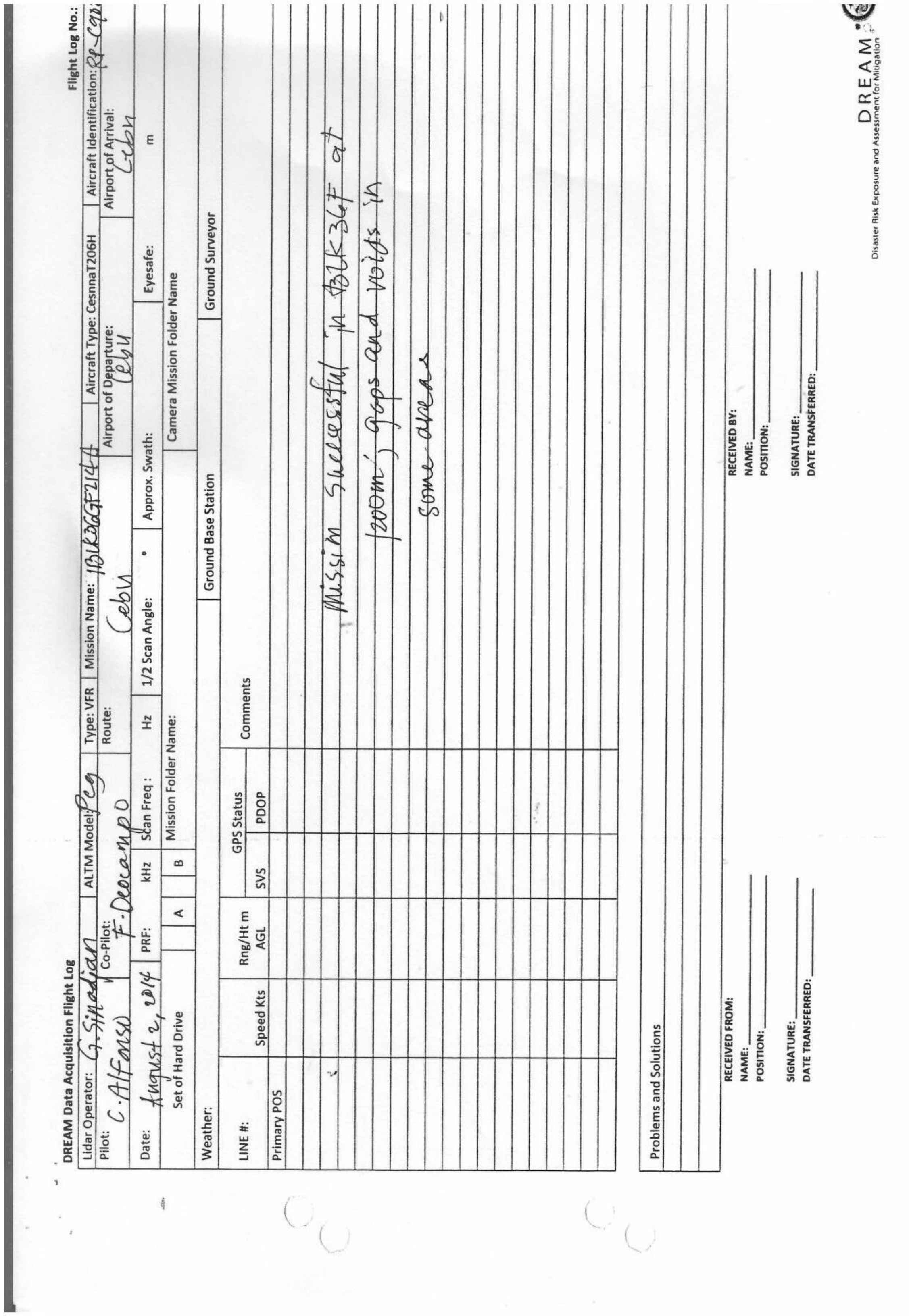
DATE TRANSFERRED:

DREAM
Disaster Risk Exposure and Assessment for Mitigation

Figure A-6.5 Flight Log for 1781P Mission

6. Flight Log for 1785P Mission


DREAM Data Acquisition Flight Log

Flight Log No.:

Lidar Operator: G. Sinadjan	ALTM Model: Peg	Type: VFR	Mission Name: 1BLK36GF214A	Aircraft Type: CesnnaT206H	Aircraft Identification: RP-C9022
Pilot: C. Alfonso	Co-Pilot: F. Deocampo	Route: Cebu		Airport of Departure: Cebu	Airport of Arrival: Cebu
Date: August 2, 2014	PRF: kHz	Scan Freq: Hz	1/2 Scan Angle: °	Approx. Swath:	Eyesafe: m
Set of Hard Drive	A	B	Mission Folder Name:	Camera Mission Folder Name	
Weather:			Ground Base Station		Ground Surveyor

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					
					Mission successful in BLK36F at 1200m; gaps and voids in some areas

Problems and Solutions

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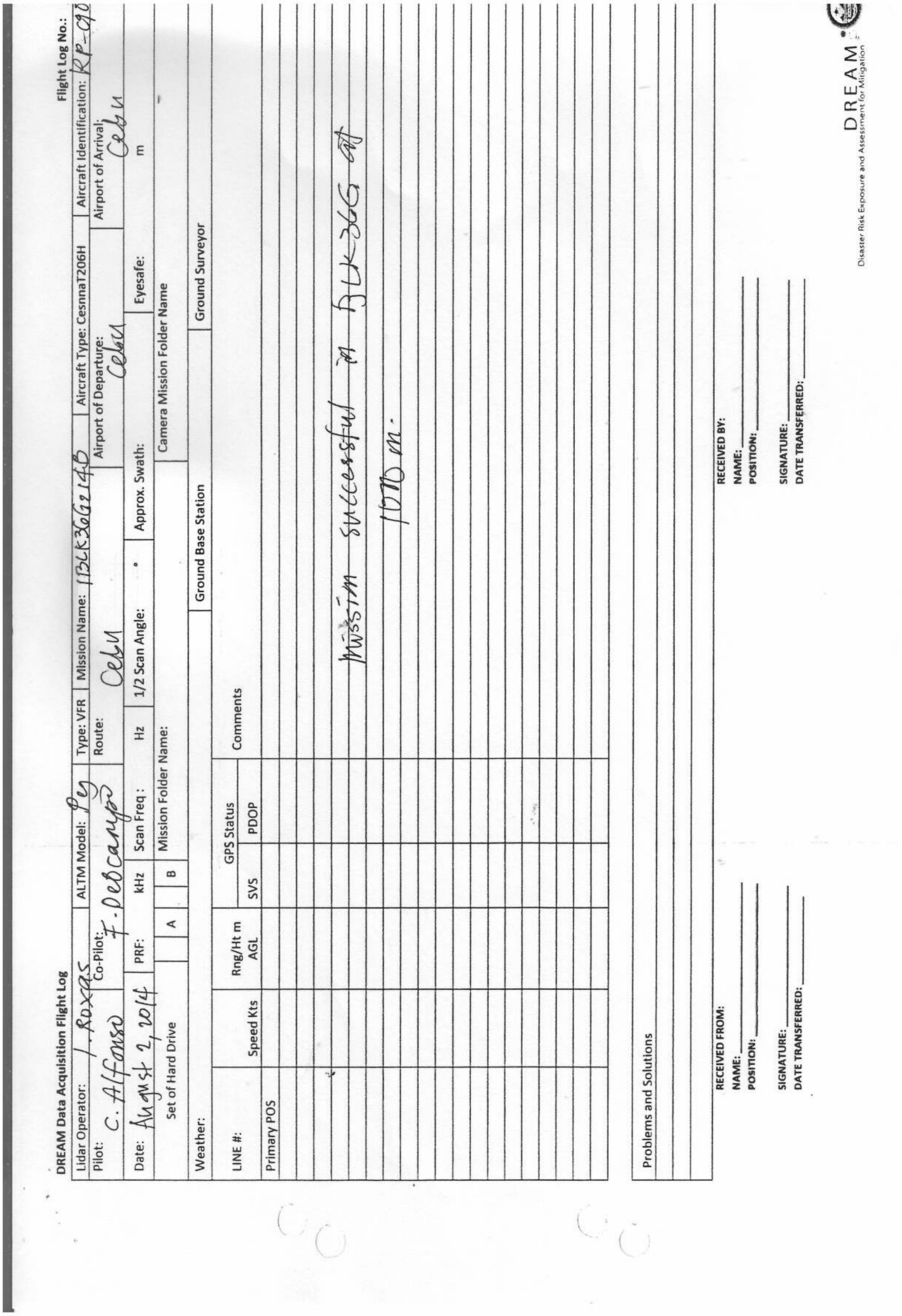
DREAM Disaster Risk Exposure and Assessment for Mitigation

Figure A-6.6 Flight Log for 1785P Mission

7. Flight Log for 1787P Mission



DREAM Data Acquisition Flight Log

Flight Log No.:

Lidar Operator: I. Roxas | ALTM Model: Peg | Mission Name: 1BLK36G214B | Aircraft Type: CesnnaT206H | Aircraft Identification: RP-C90

Pilot: C. Alfonso | Co-Pilot: F. Delcampo | Route: Cebu | Airport of Departure: Cebu | Airport of Arrival: Cebu

Date: August 2, 2014 | PRF: kHz | Scan Freq: Hz | 1/2 Scan Angle: ° | Approx. Swath: | Eyesafe: m

Set of Hard Drive: A B | Mission Folder Name: | Camera Mission Folder Name

Weather: | Ground Base Station | Ground Surveyor

LINE #:	Speed Kts	Rng/Ht m AGL	GPS Status SVS	GPS Status PDOP	Comments
Primary POS					
					Mission successful at BLK36G at 1070 m.

Problems and Solutions

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POSITION:
SIGNATURE:
DATE TRANSFERRED:

DREAM Disaster Risk Exposure and Assessment for Mitigation

Figure A-6.7 Flight Log for 1787P Mission

8. Flight Log for 1829P Mission

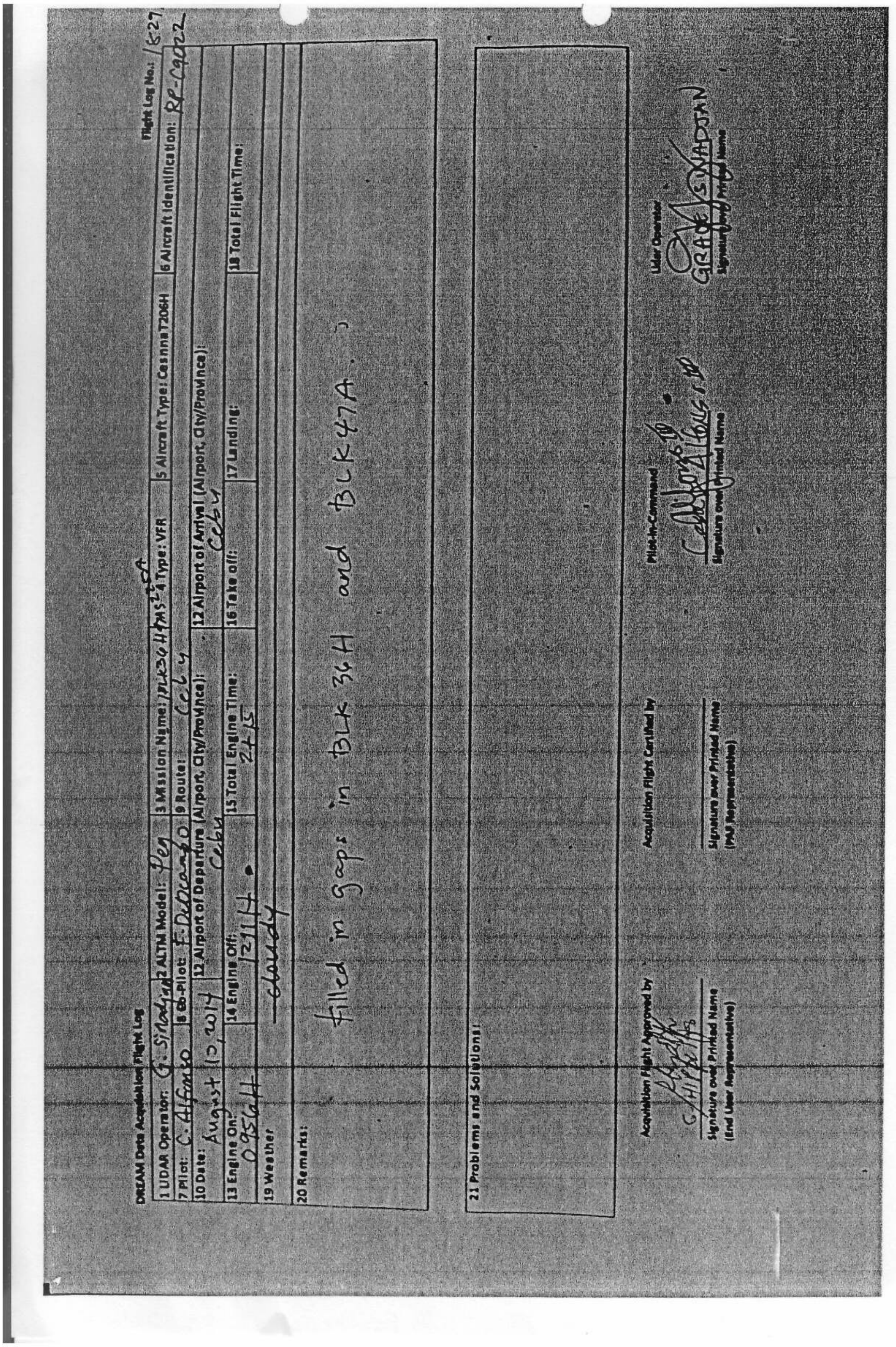

Figure A-6.8 Flight Log for 1829P Mission

Annex 7. Flight Status Report

CEBU (July 22 and 30, August 1-2 and 13, 2014)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1741P	BLK36H	1BLK36H203A	I. Roxas	July 22	Mission successful at 1200m flying height; some lines due to wind conditions.
1743P	BLK36H	1BLK36H203B	G. Sinadjan	July 22	Mission successful at 1200-1500m flying height; completed BLK 36H; few voids due to clouds and terrain.
1777P	BLK36E	1BLK36E212A	I. Roxas	July 30	Mission successful at 1000m flying height; completed half of BLK 36E.
1779P	BLK36D, BLK36E	1BLK36E212B	G. Sinadjan	July 30	Mission successful at 1200m flying height; completed BLK 36E.
1781P	BLK36E, BLK36F, BLK36G	1BLK36F213A	I. Roxas	August 1	Data acquired IN BLK 36F; experienced rain in survey area causing shortened mission.
1785P	BLK36E, BLK36F, BLK36G	1BLK36GF214A	G. Sinadjan	August 2	Mission successful in BLK 36F at 1200m; gaps and voids in some areas; extended survey area to include coastline.
1787P	BLK36G	1BLK36G214B	I. Roxas	August 2	Mission successful in BLK 36G at 1000m.
1829P	BLK36H, BLK47A		G. Sinadjan	August 13	Filled in gaps in BLK36H and BLK47A.

LAS BOUNDARIES PER FLIGHT

Flight No. : 1741P
Area: BLK36H
Mission Name: 1BLK36H203A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS

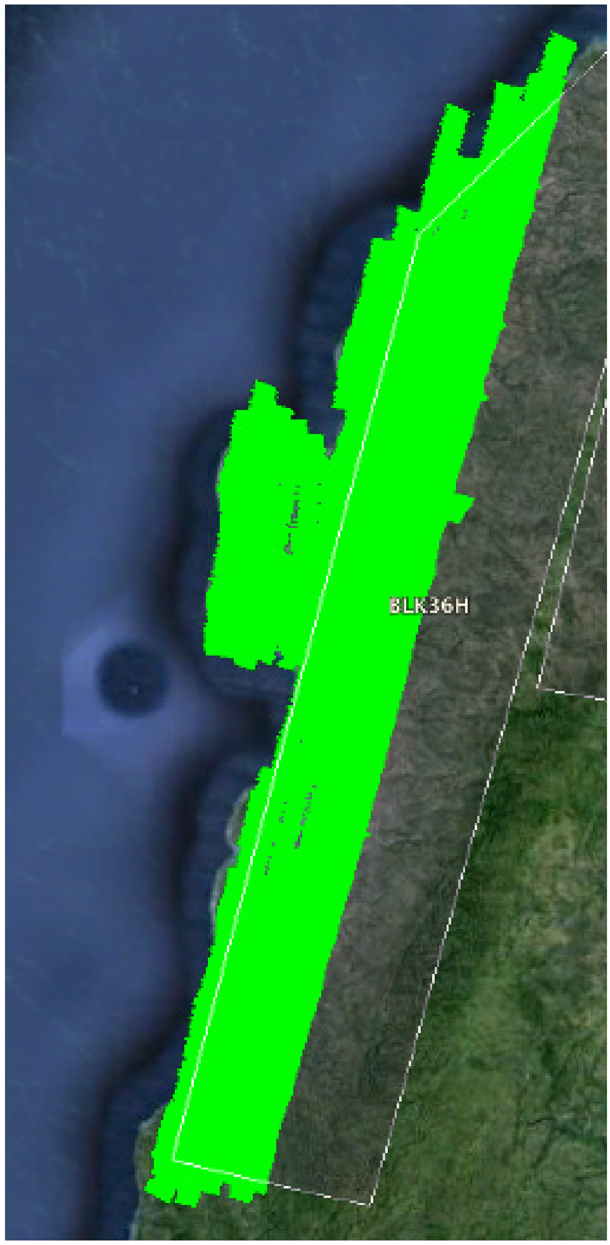

Figure A-7.1 Swath for Flight No. 1741P

Flight No. : 1743P
Area: BLK36H
Mission Name: 1BLK36H203B
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS

Figure A-7.2 Swath for Flight No. 1743P

Flight No. :	1779P			
Area:	BLK36D, BLK36E			
Mission Name: 1BLK36E212B				
Parameters:	Altitude:	1000m; Scan Frequency:		30Hz;
	Scan Angle:	25deg;	Overlap:	30%

LAS

Figure A-7.3 Swath for Flight No. 1779P

Flight No. : 1781P
Area: BLK36E, BLK36F, BLK36G
Mission Name: 1BLK36F213A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS

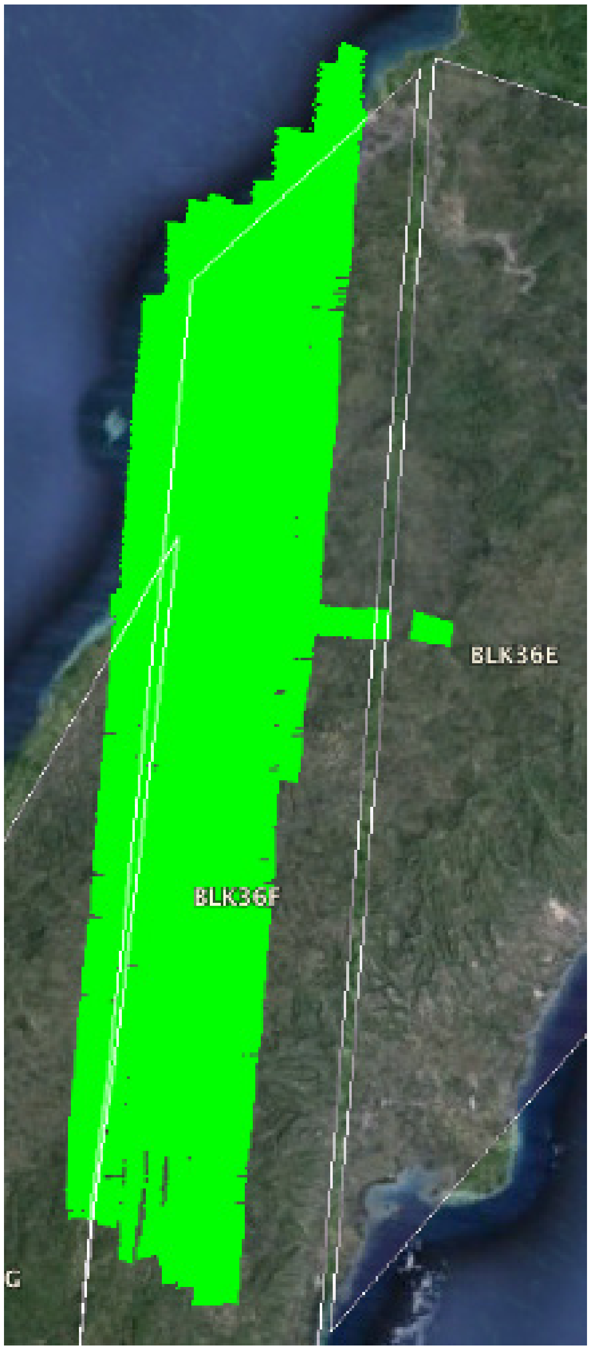

Figure A-7.4 Swath for Flight No. 1781P

Flight No. : 1785P
Area: BLK36E, BLK36F, BLK36G
Mission Name: 1BLK36GF214A
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS

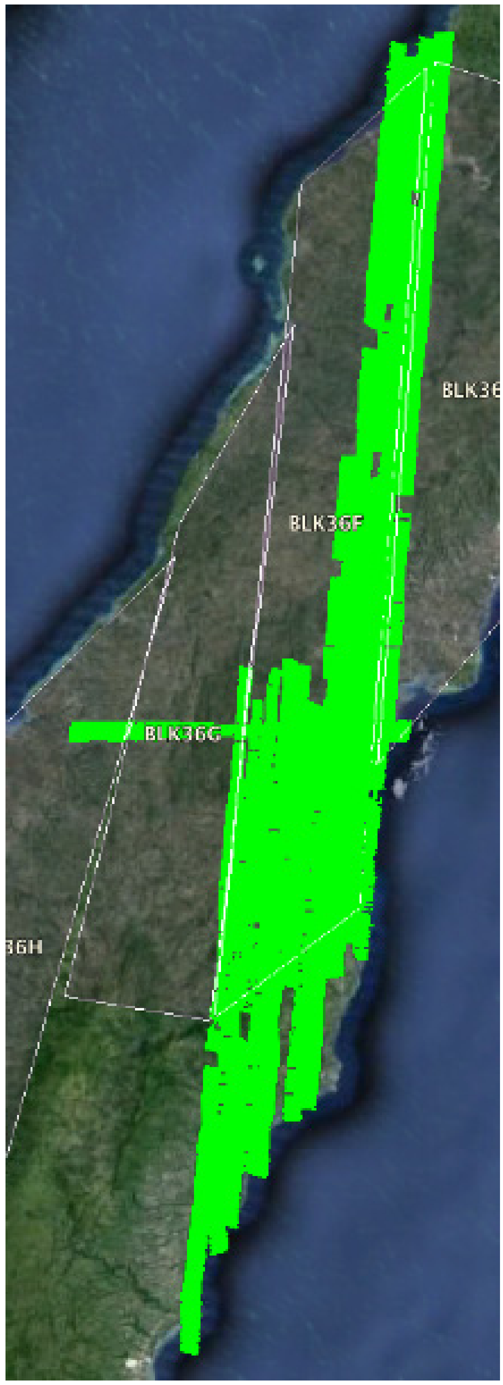

Figure A-7.5 Swath for Flight No. 1785P

Flight No. : 1787P
Area: BLK36G
Mission Name: 1BLK36G214B
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS

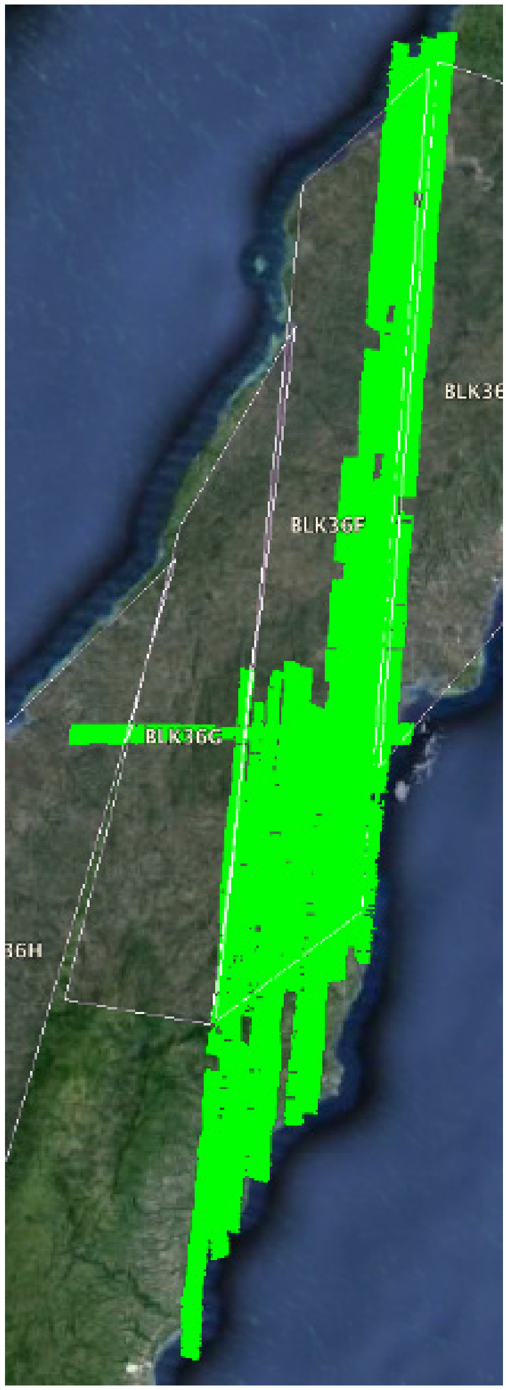

Figure A-7.6 Swath for Flight No. 1787P

Flight No. : 1829P
Area: BLK36H, BLK47A
Mission Name: 1BLK36H47A225A
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS

Figure A-7.7 Swath for Flight No. 1829P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk36E

Flight Area	**Cebu**
Mission Name	**Blk36E**
Inclusive Flights	1777P, 1779P
Range data size	58.2 GB
POS data size	501 MB
Base data size	18.26 MB
Image	100.9 GB
Transfer date	August 20, 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)	1.5
RMSE for East Position (<4.0 cm)	2.4
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000297
IMU attitude correction stdev (<0.001deg)	0.002948
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	51.18%
Ave point cloud density per sq.m. (>2.0)	7.19
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	547
Maximum Height	707.71 m
Minimum Height	53.14 m
Classification (# of points)	
Ground	450,661,930
Low vegetation	381,095,661
Medium vegetation	830,378,069
High vegetation	60,5642,860
Building	36,666,032
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Harmond Santos, Engr. Melissa Fernandez

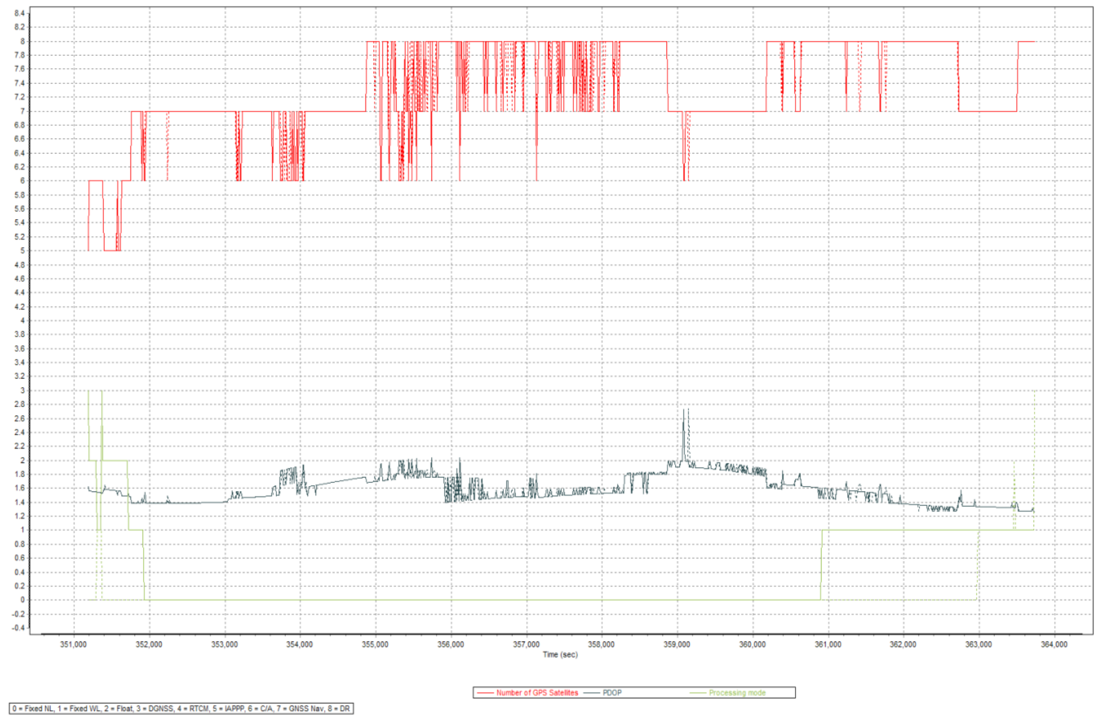

Figure A-8.1 Solution Status

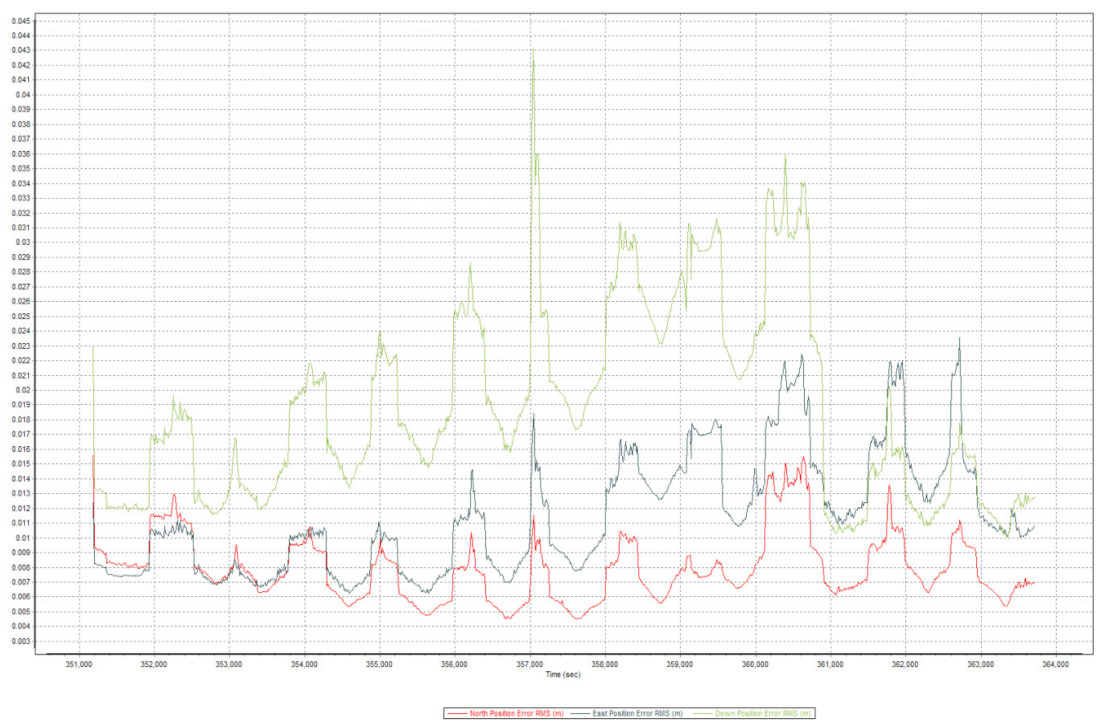

Figure A-8.2 Smoothed Performance Metrics Parameters

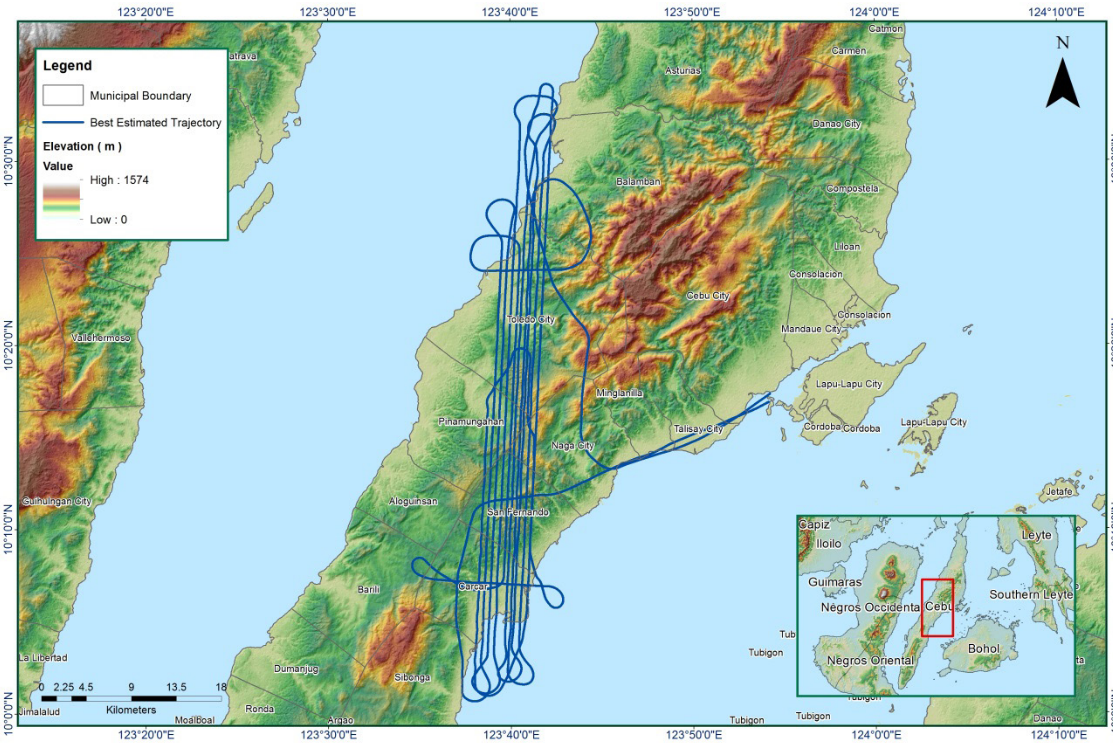

Figure A-8.3 Best Estimated Trajectory

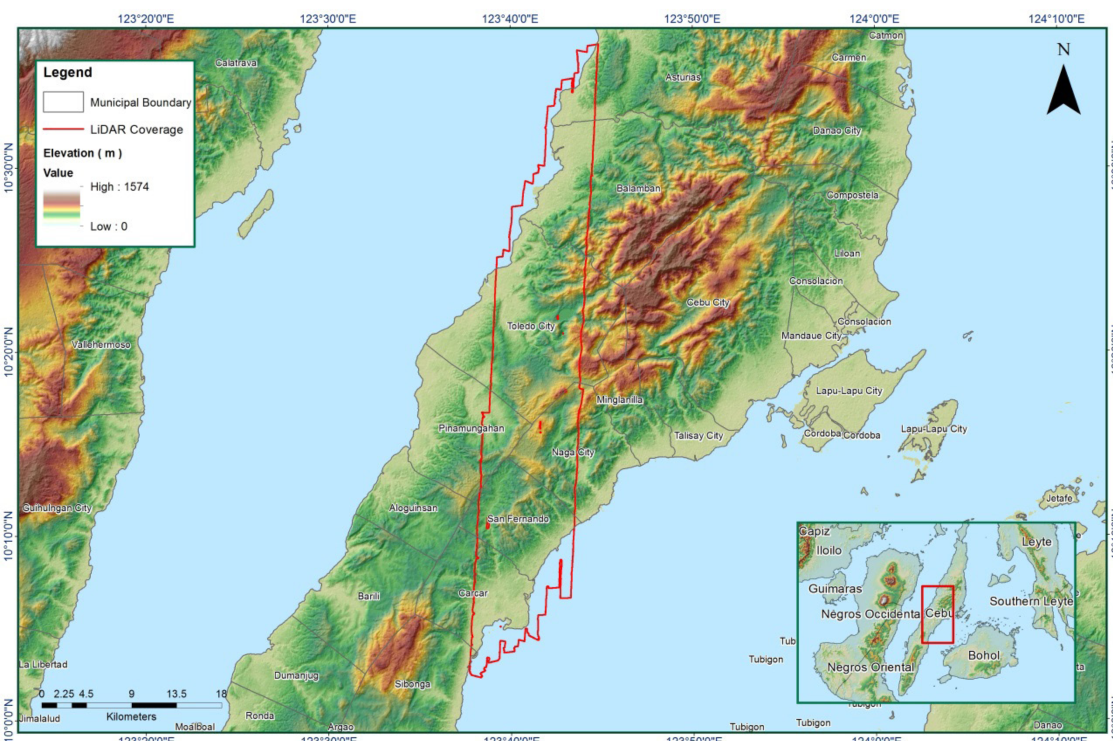

Figure A-8.4. Coverage of LiDAR data

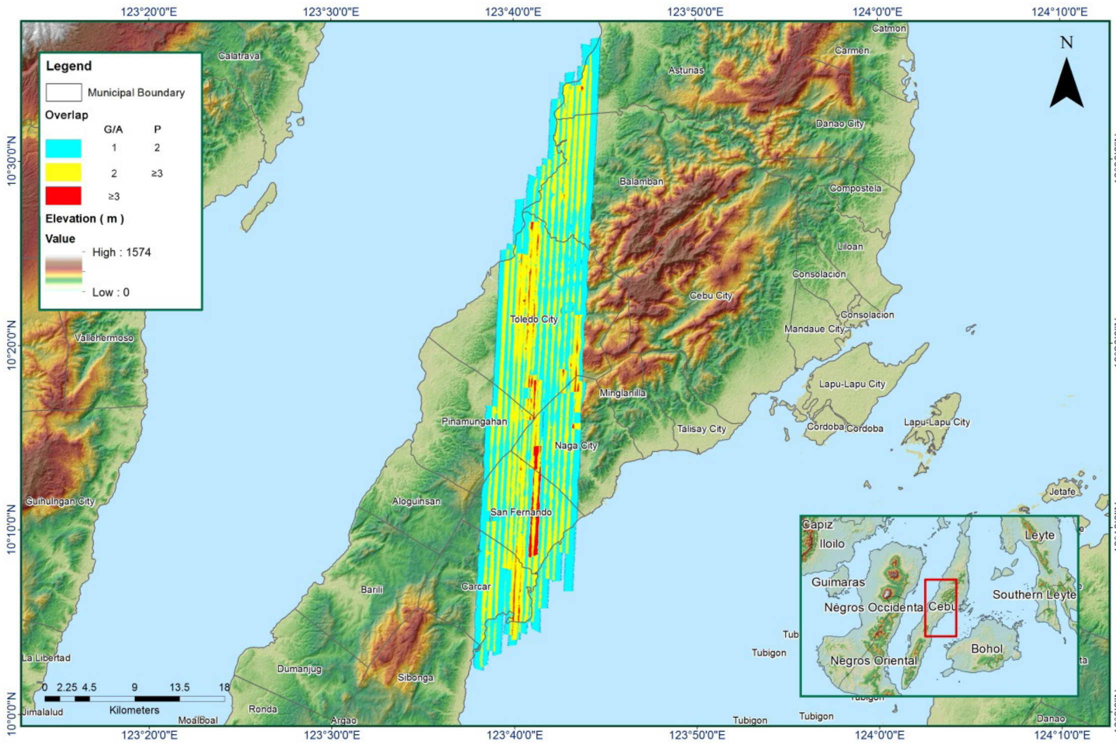

Figure A-8.5. Image of data overlap

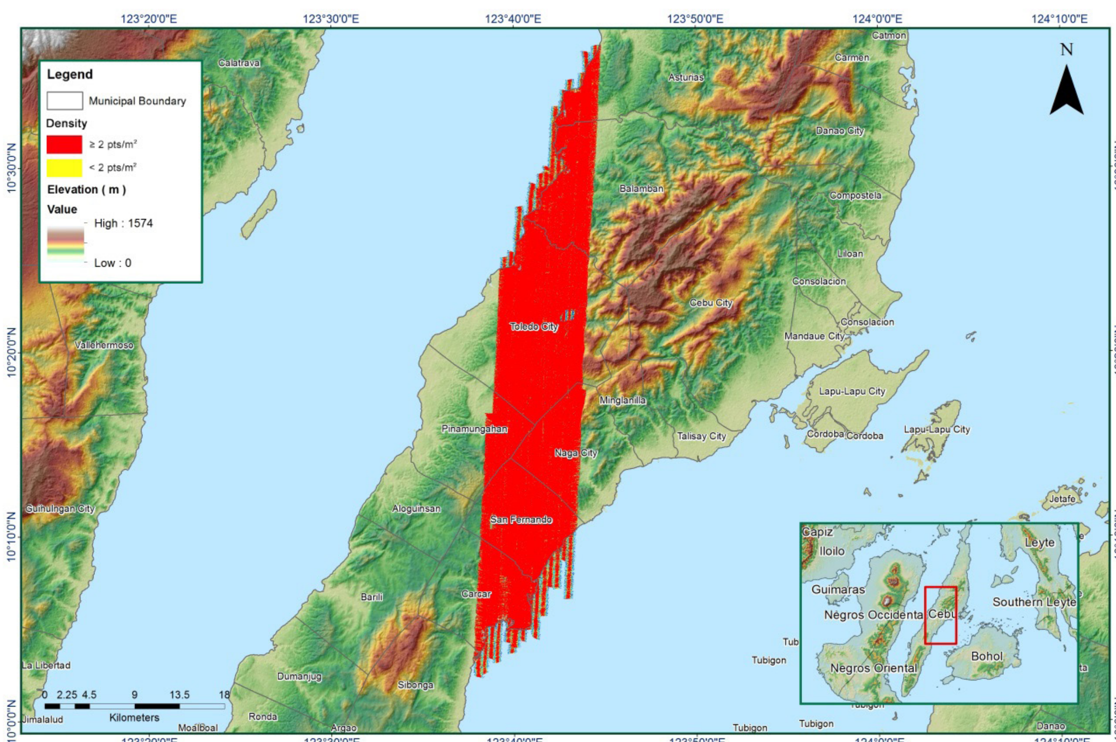

Figure A-8.6 Density of merged LiDAR data

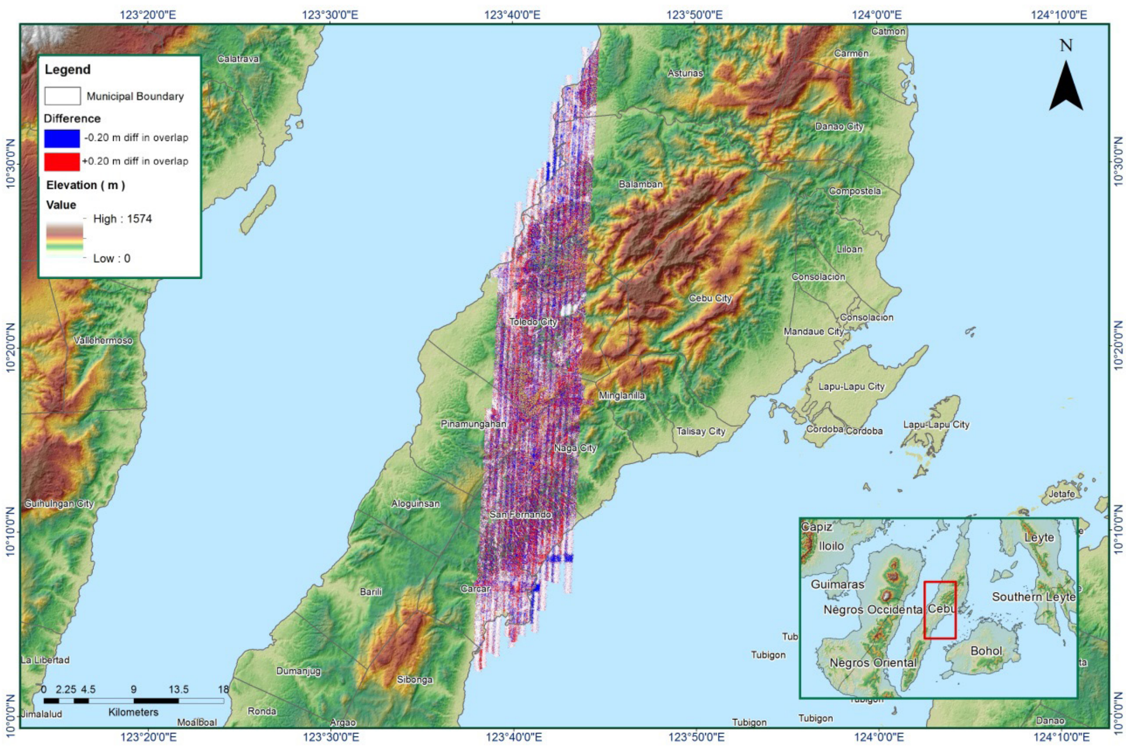

Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk36F

Flight Area	**Cebu**
Mission Name	**Blk36F**
Inclusive Flights	1781P, 1785P, 1793P
Range data size	64.9 GB
POS data size	609 MB
Base data size	19.62 MB
Image	98.9 GB
Transfer date	August 20, 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)	1.15
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000199
IMU attitude correction stdev (<0.001deg)	0.001406
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	44.99%
Ave point cloud density per sq.m. (>2.0)	6.84
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	673
Maximum Height	754.61 m
Minimum Height	63.83 m
Classification (# of points)	
Ground	630,207,533
Low vegetation	490,773,780
Medium vegetation	1,009,481,285
High vegetation	741,855,943
Building	31,121,044
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Aljon Rie Araneta, Engr. Roa Shalemar Redo

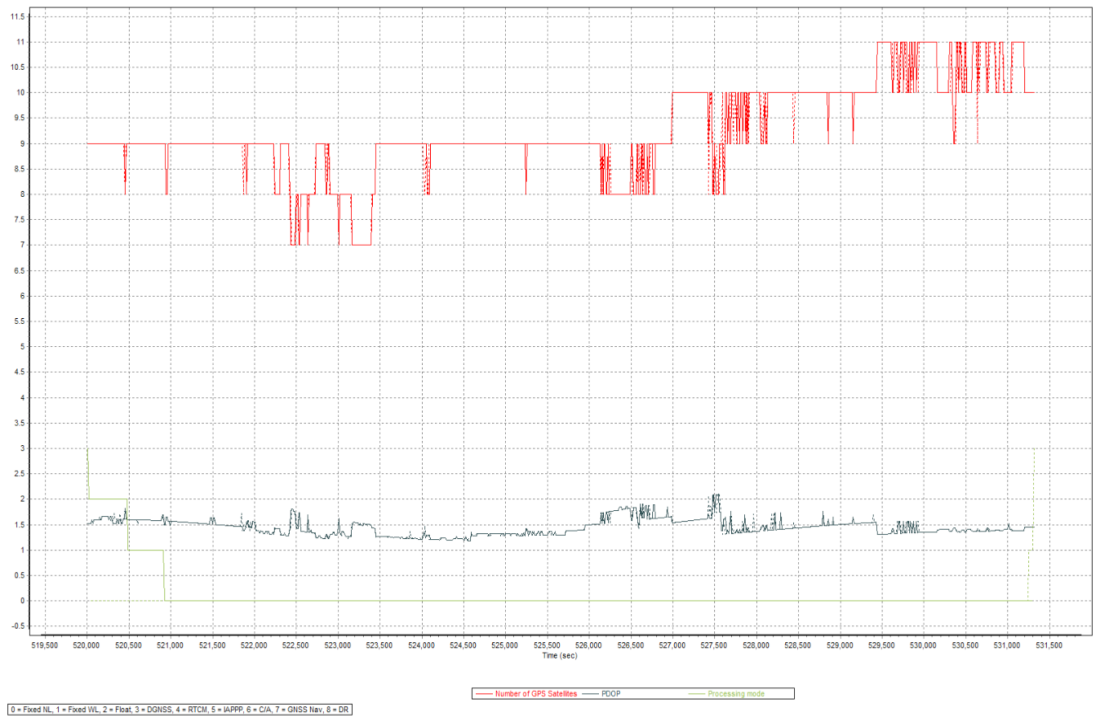

Figure A-8.8. Solution Status

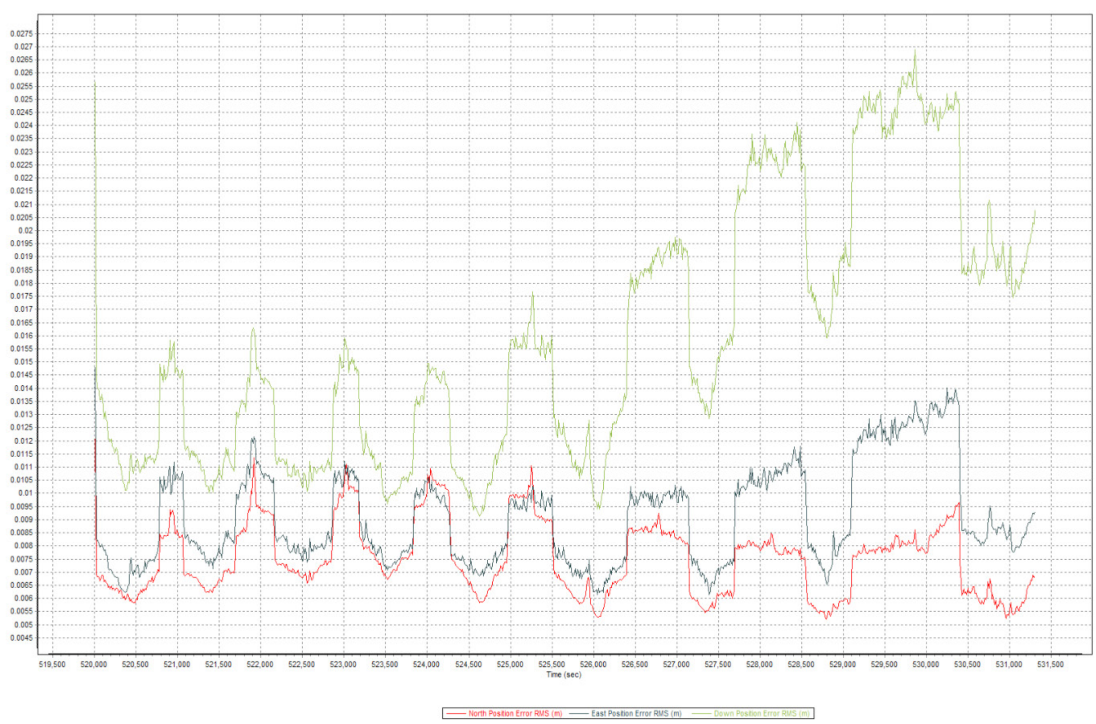

Figure A-8.9. Smoothed Performance Metrics Parameters

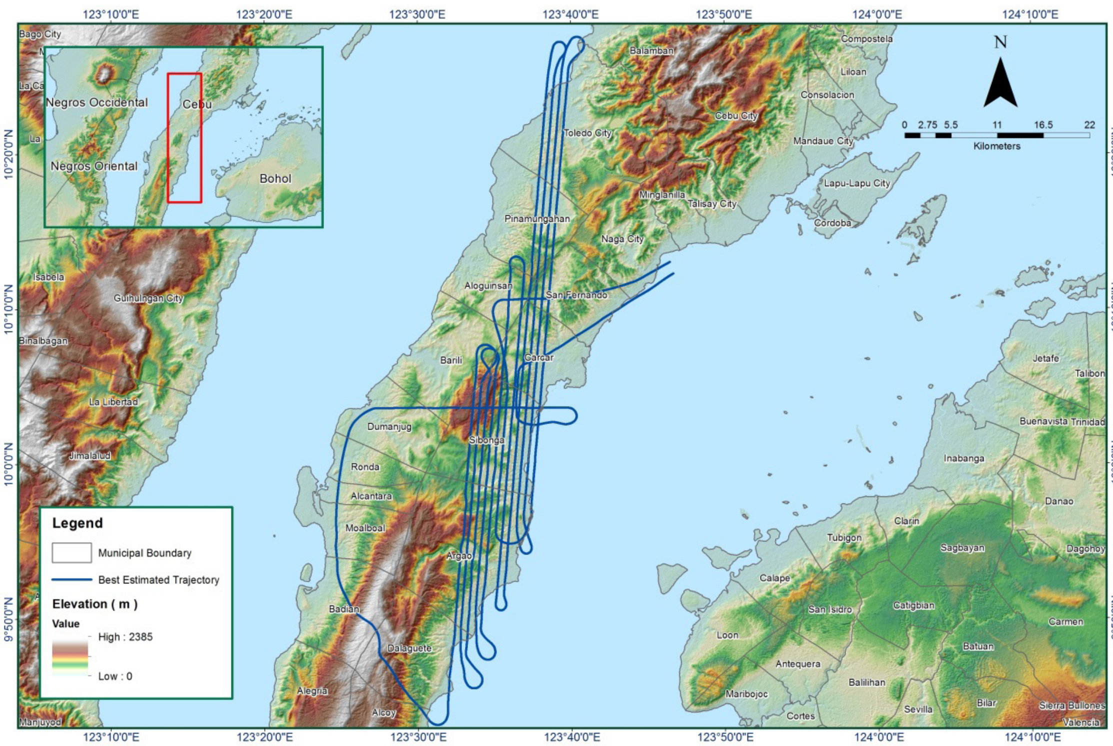

Figure A-8.10. Best Estimated Trajectory

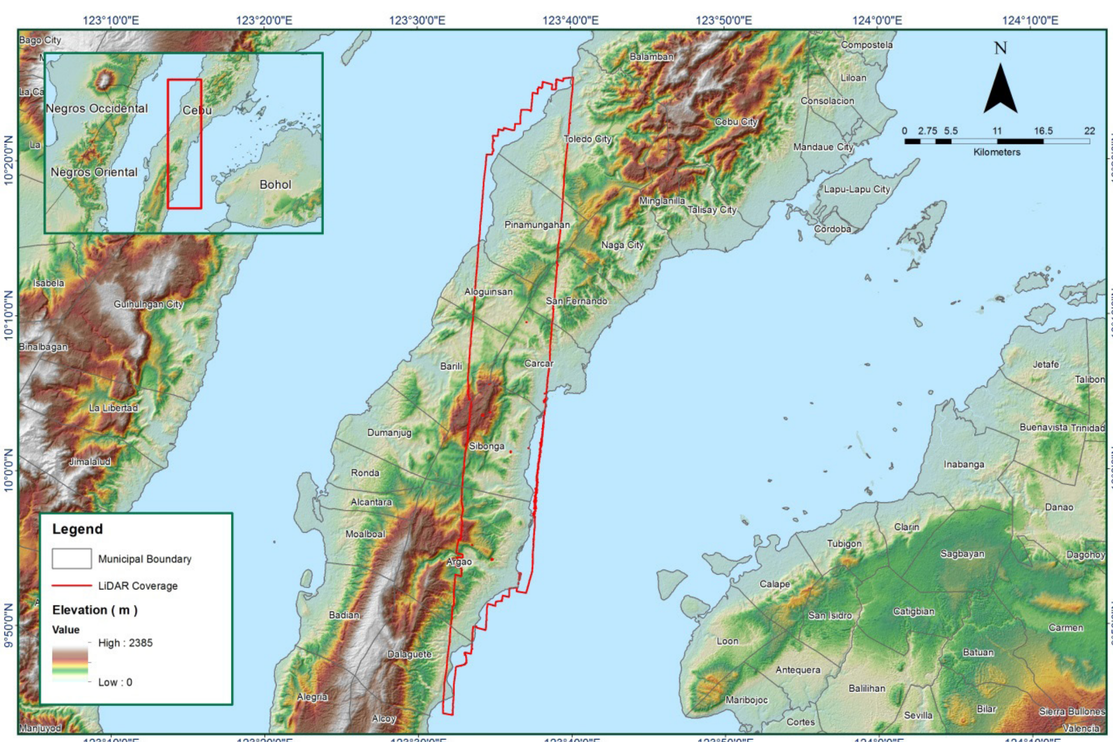

Figure A-8.11. Coverage of LiDAR data

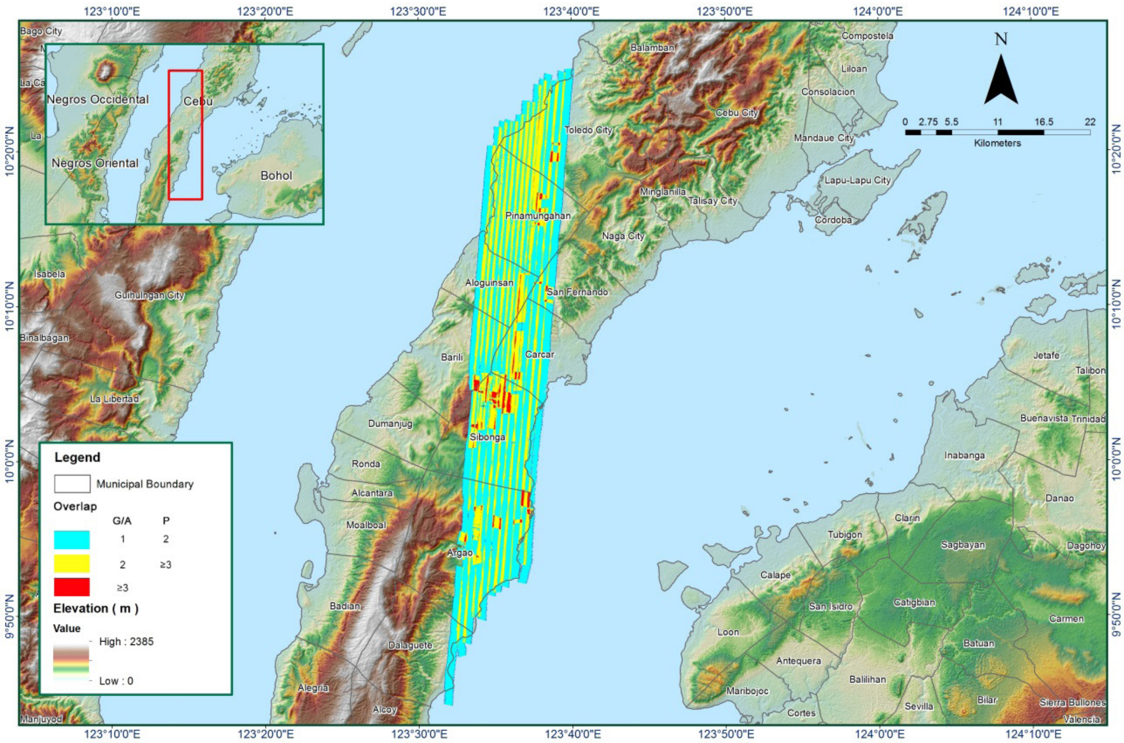

Figure A-8.12. Image of data overlap

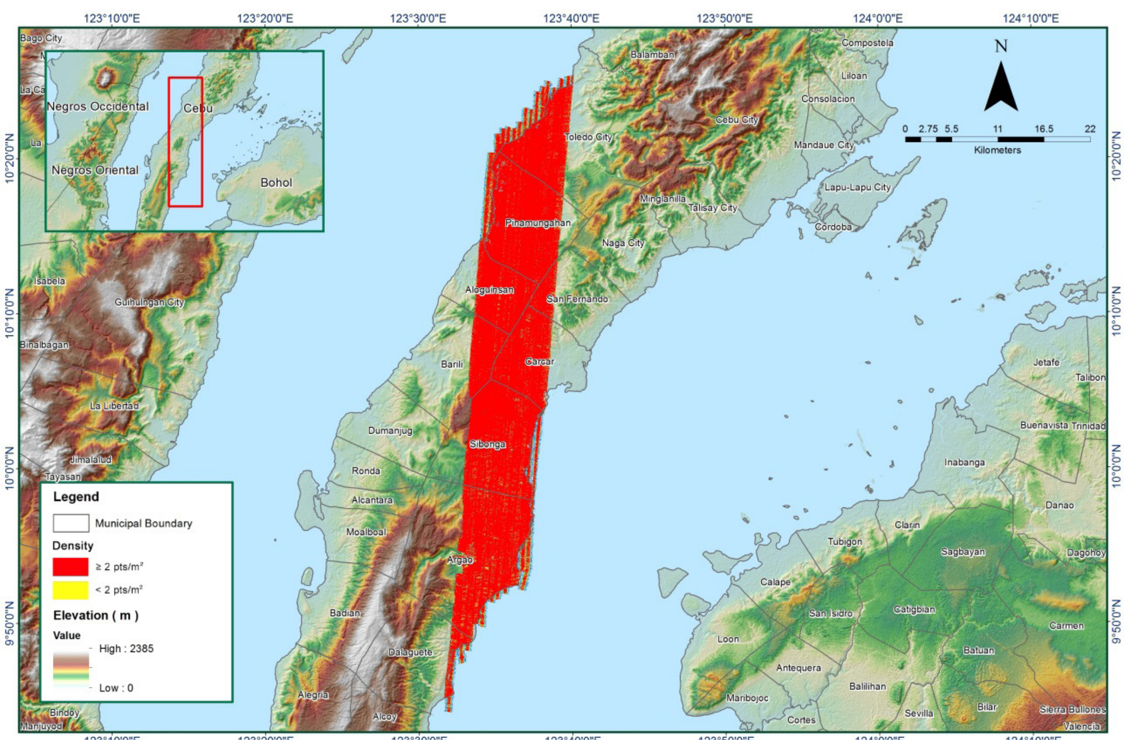

Figure A-8.13. Density of merged LiDAR data

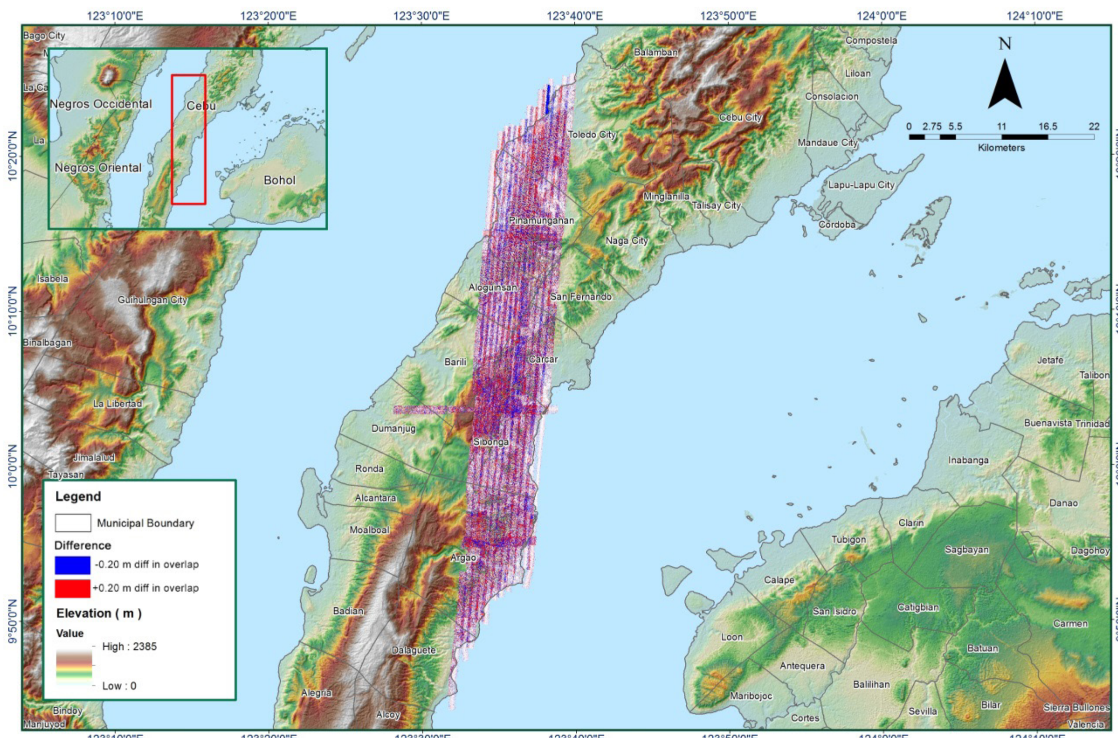

Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk36H

Flight Area	**Cebu**
Mission Name	**Blk36H**
Inclusive Flights	1741P, 1743P
Range data size	41.8 GB
POS data size	420 MB
Base data size	20.8 MB
Image	70 GB
Transfer date	August 4, 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)	1.6
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000165
IMU attitude correction stdev (<0.001deg)	0.000824
GPS position stdev (<0.01m)	0.0066
Minimum % overlap (>25)	37.88%
Ave point cloud density per sq.m. (>2.0)	6.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	442
Maximum Height	998.24m
Minimum Height	61.32m
Classification (# of points)	
Ground	336510447
Low vegetation	288340067
Medium vegetation	615334756
High vegetation	354939457
Building	14040070
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Chelou Prado, Engr. Roa Shalemar Redo

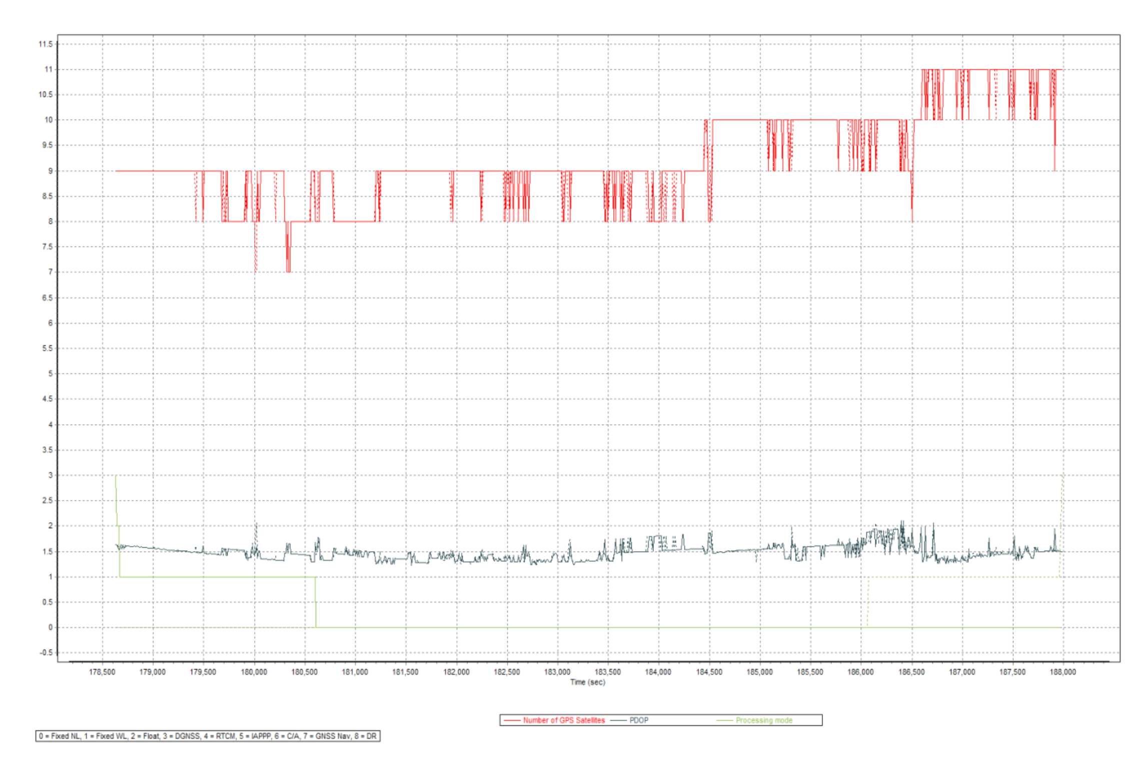

Figure A-8.15. Solution Status

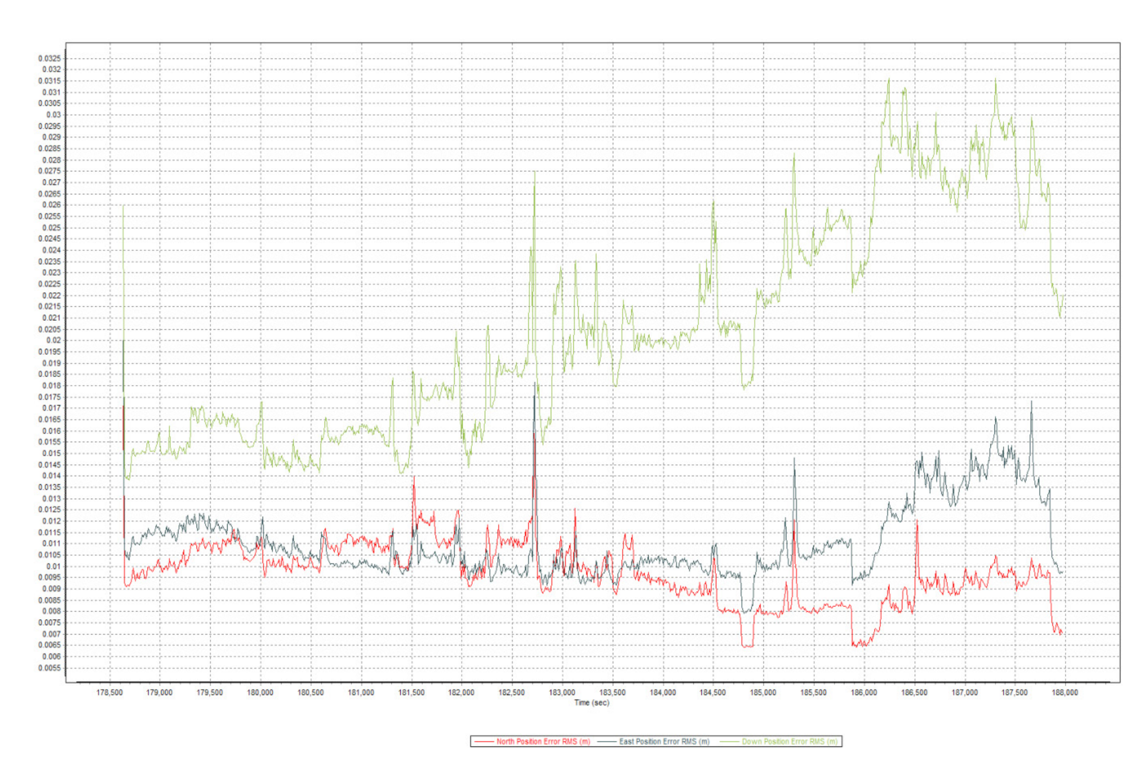

Figure A-8.16. Smoothed Performance Metrics Parameters

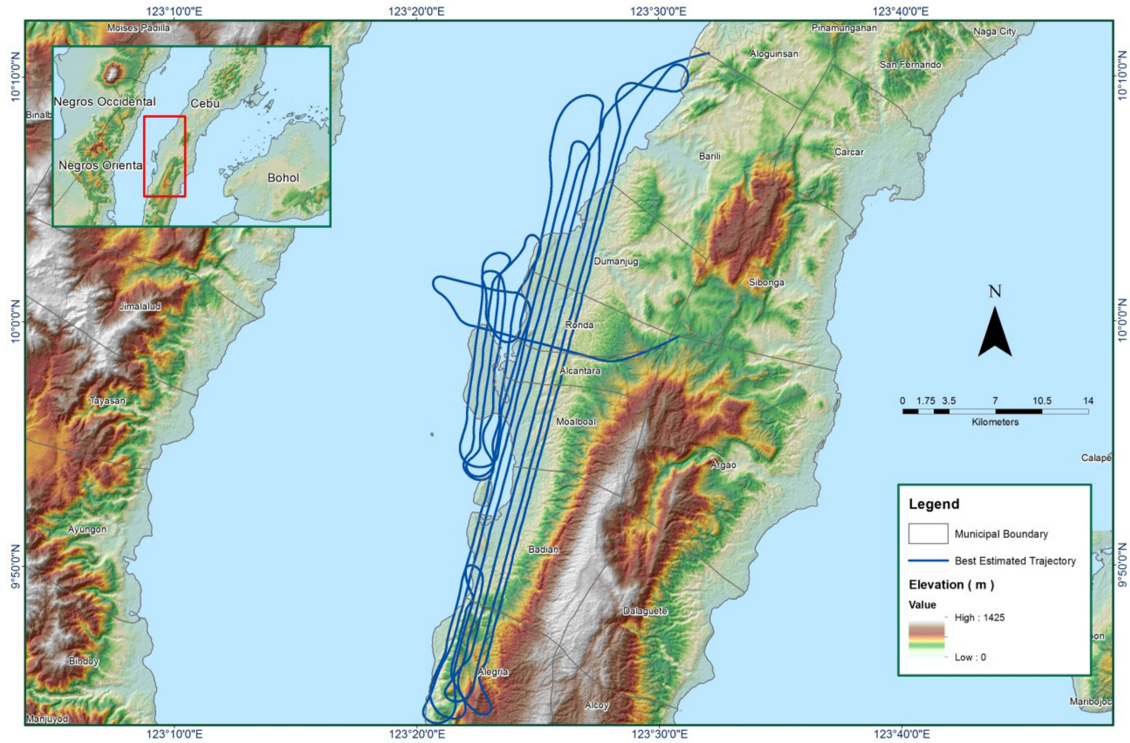

Figure A-8.17. Best Estimated Trajectory

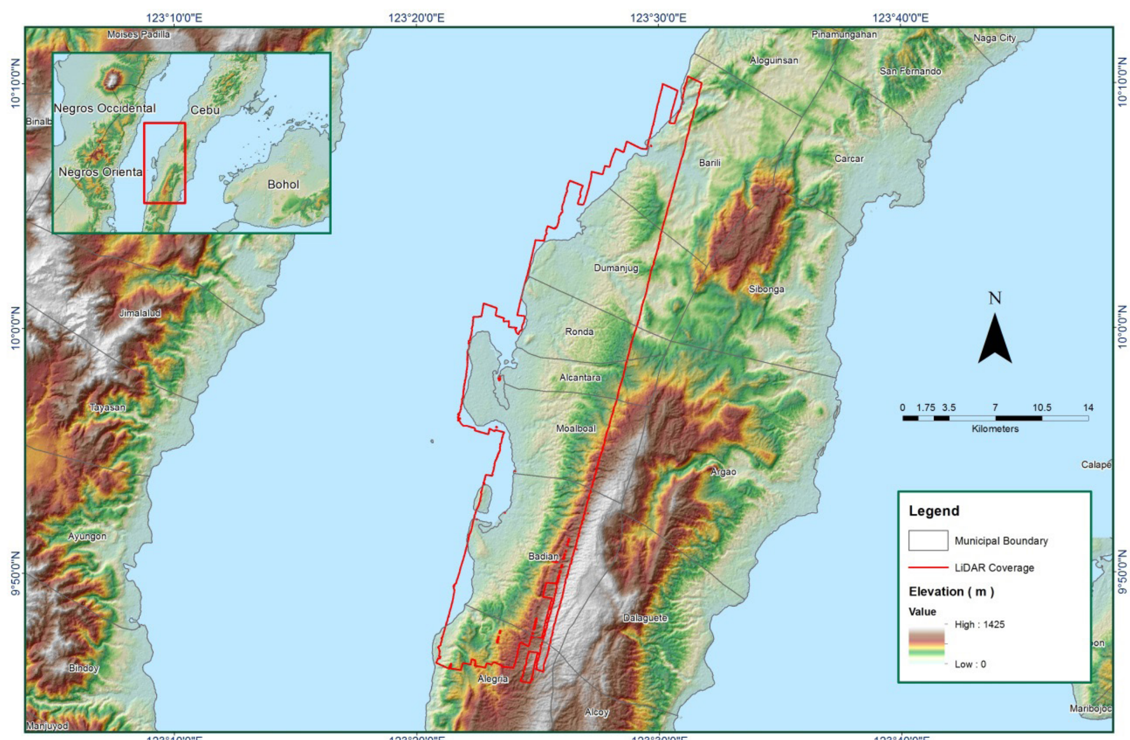

Figure A-8.18. Coverage of LiDAR data

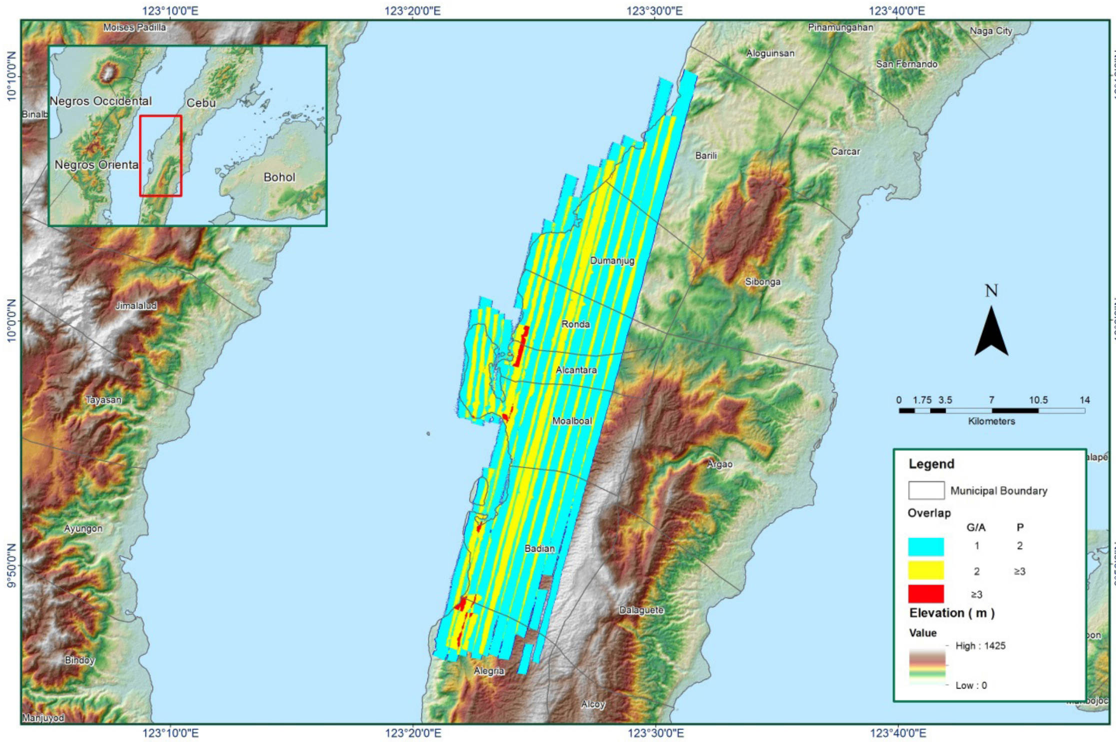

Figure A-8.19. Image of data overlap

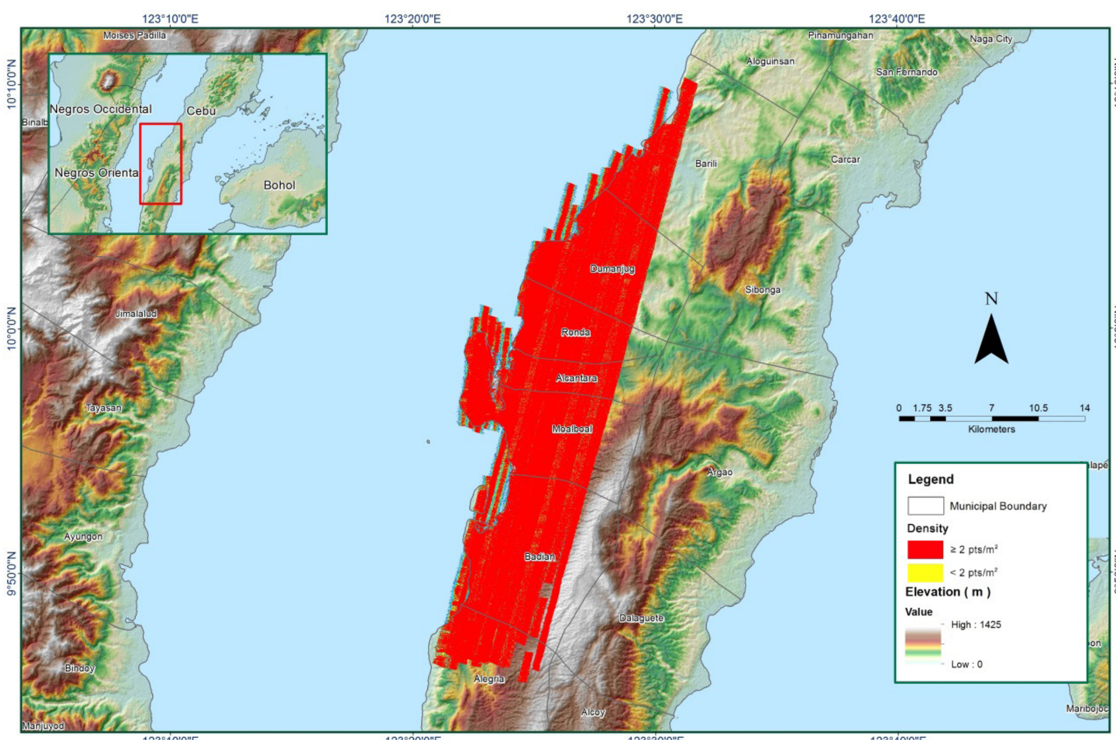

Figure A-8.20. Density of merged LiDAR data

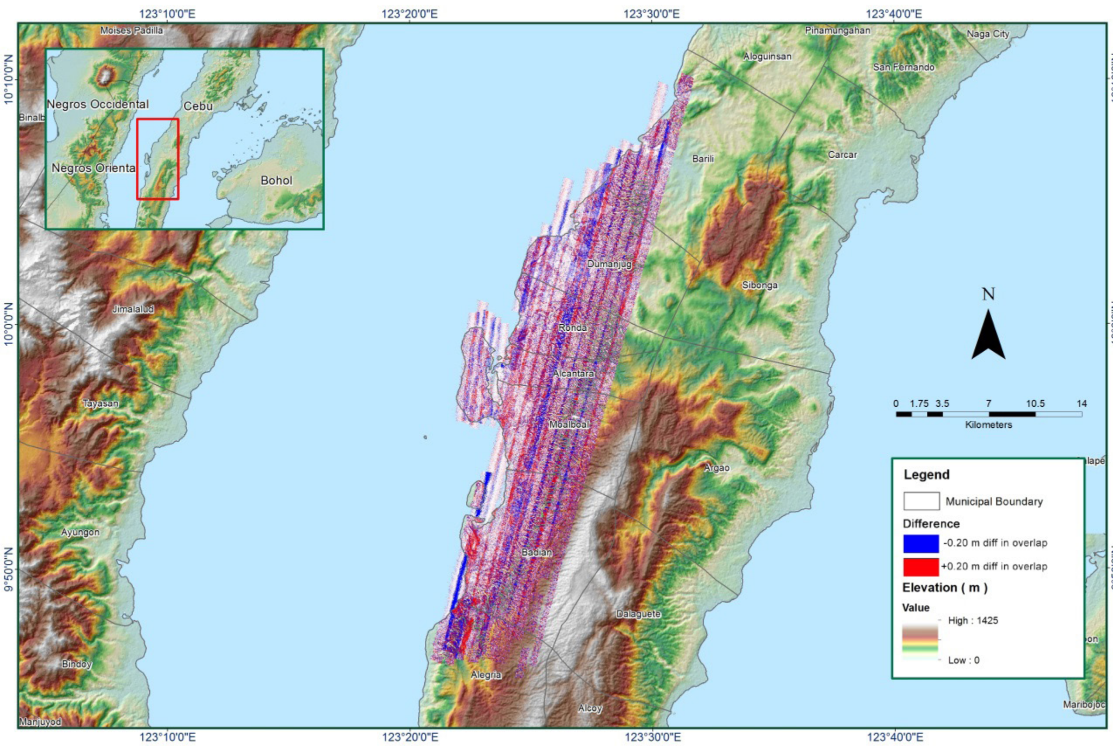

Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk36G

Flight Area	**Cebu**
Mission Name	**Blk36G**
Inclusive Flights	1787P
Range data size	29.5 GB
POS data size	250 MB
Base data size	10.9 MB
Image	48.3 GB
Transfer date	August 20, 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)	1.6
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000152
IMU attitude correction stdev (<0.001deg)	0.000469
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	47.95%
Ave point cloud density per sq.m. (>2.0)	6.92
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	328
Maximum Height	897.59 m
Minimum Height	62.19 m
Classification (# of points)	
Ground	239,514,559
Low vegetation	191,635,235
Medium vegetation	449,076,316
High vegetation	318,903,601
Building	6,322,067
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Harmond Santos, Engr. Jeffrey Delica

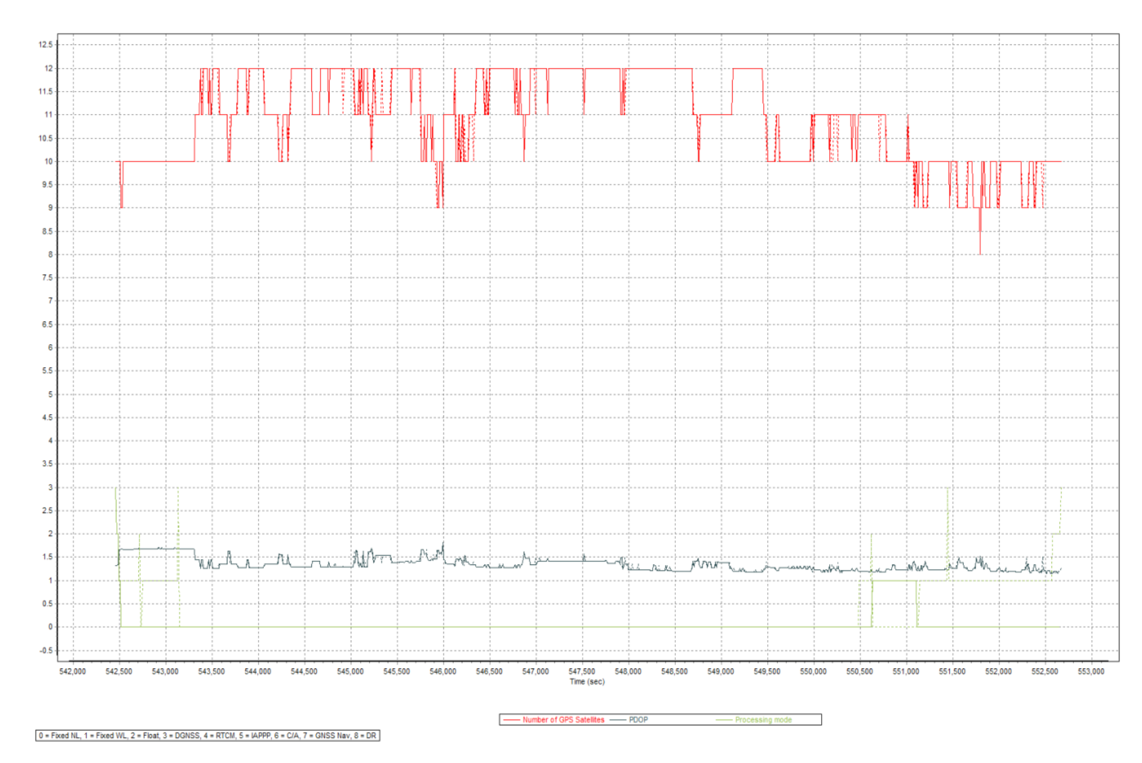

Figure A-8.22. Solution Status

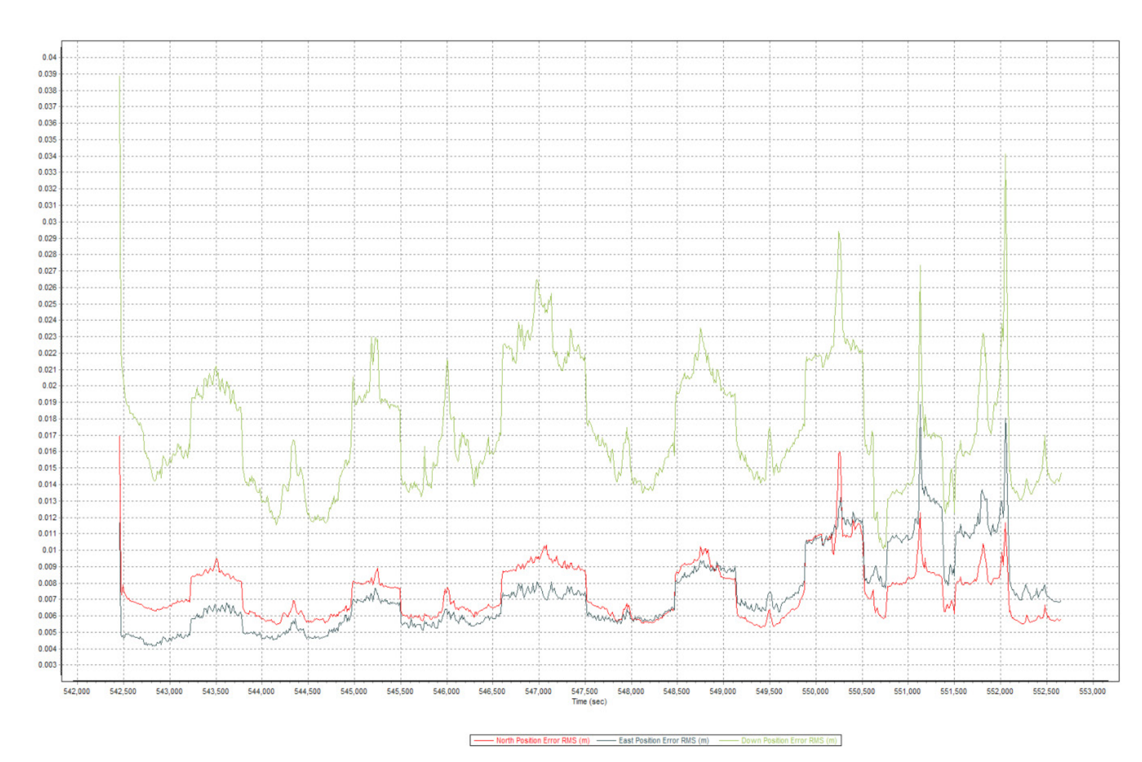

Figure A-8.23. Smoothed Performance Metrics Parameters

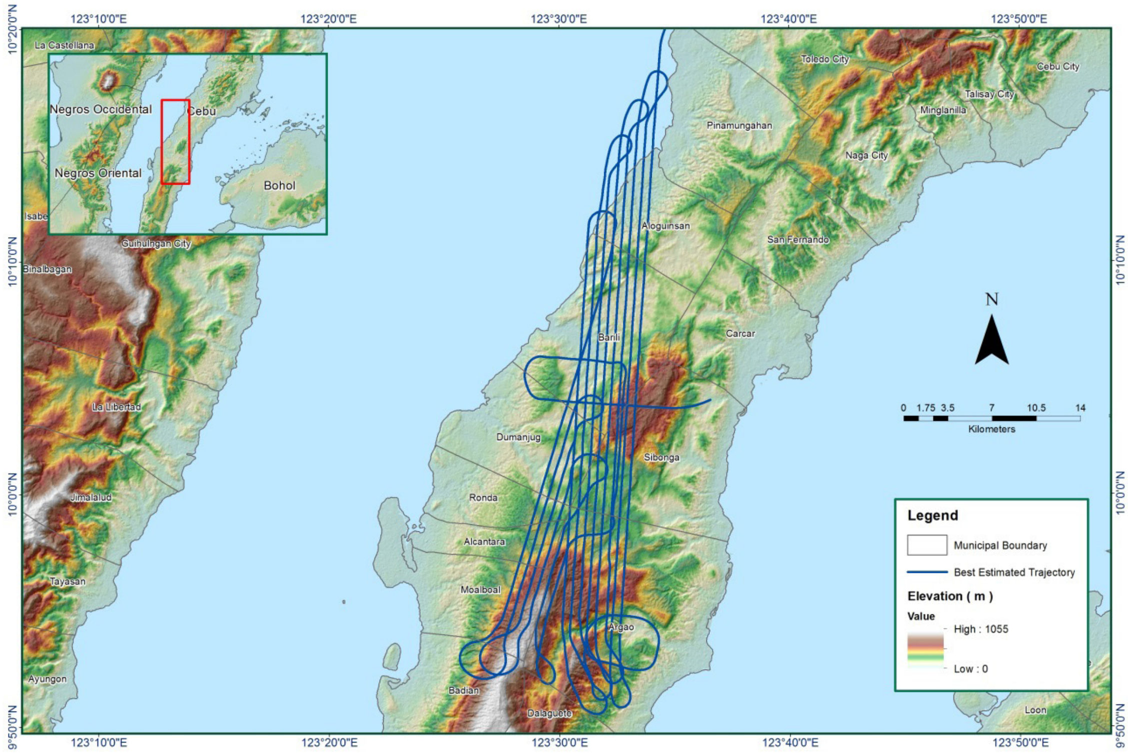

Figure A-8.24. Best Estimated Trajectory

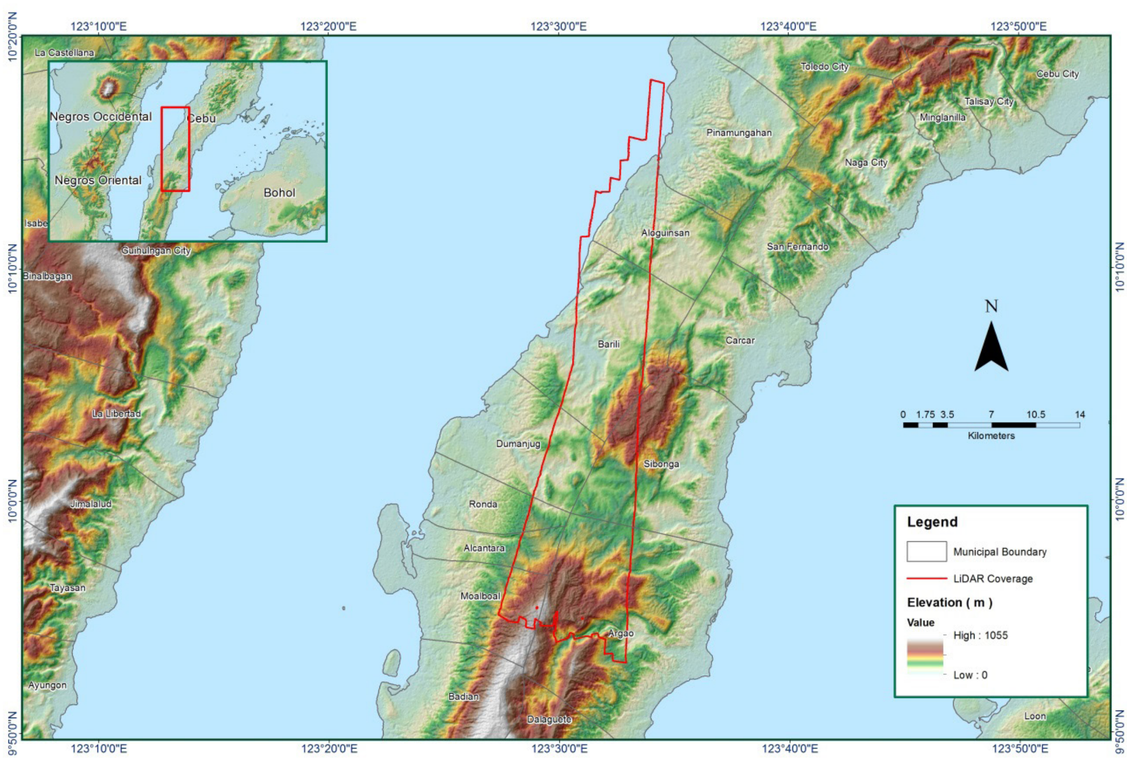

Figure A-8.25. Coverage of LiDAR data

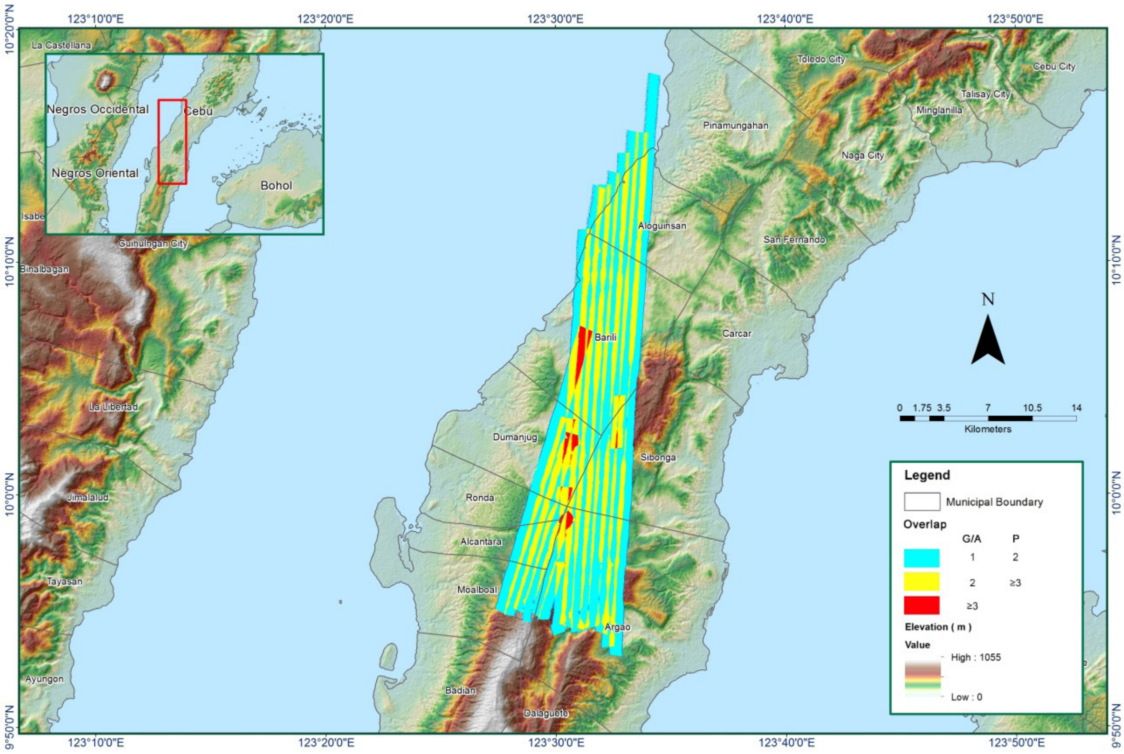

Figure A-8.26. Image of data overlap

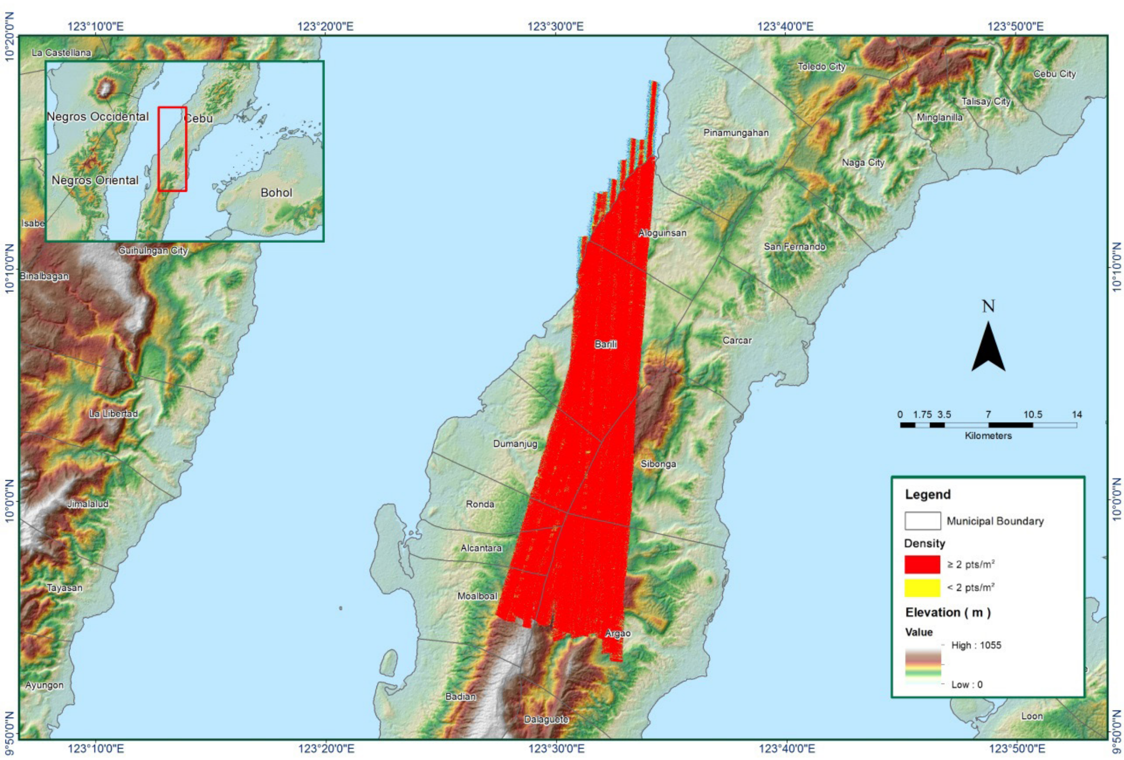

Figure A-8.27. Density of merged LiDAR data

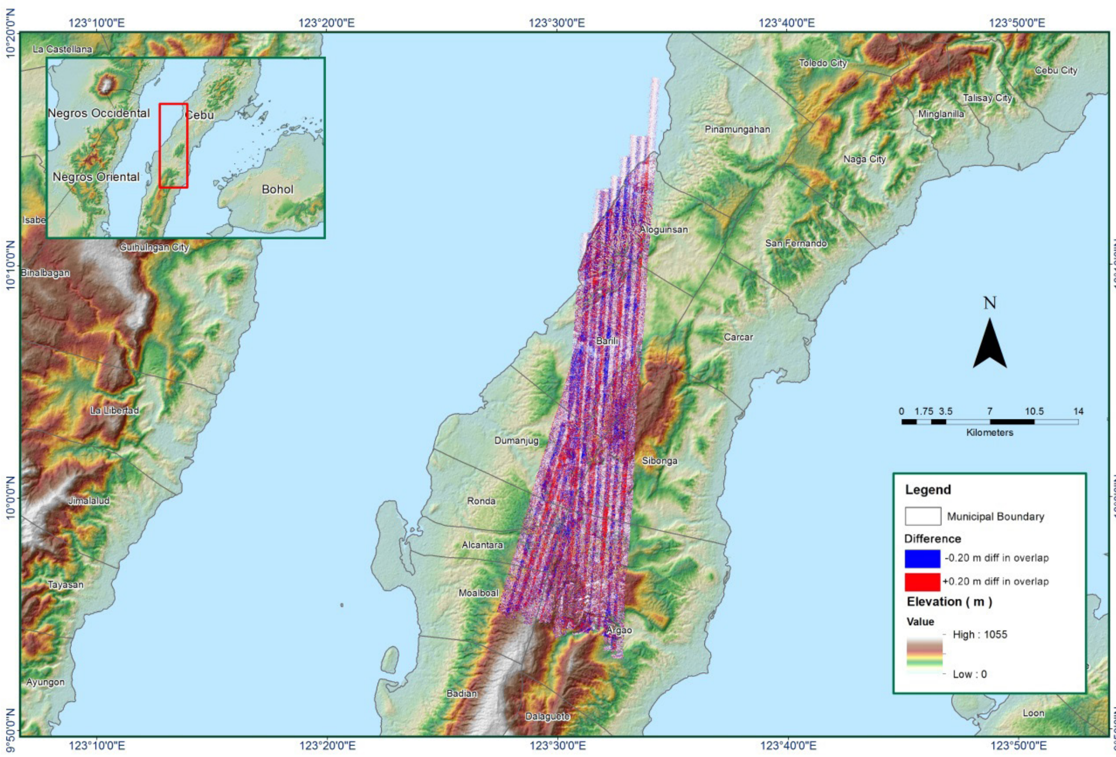

Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk36H_supplement

Flight Area	**Cebu**
Mission Name	**Blk36H_supplement**
Inclusive Flights	1829P
Range data size	6.25 GB
POS data size	131 MB
Base data size	8.78 MB
Image	8.96 GB
Transfer date	August 4, 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)	0.95
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.00165
IMU attitude correction stdev (<0.001deg)	0.000824
GPS position stdev (<0.01m)	0.0066
Minimum % overlap (>25)	13.87%
Ave point cloud density per sq.m. (>2.0)	7.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	65
Maximum Height	909.07 m
Minimum Height	67.88 m
Classification (# of points)	
Ground	34,091,395
Low vegetation	21,145,741
Medium vegetation	93,537,733
High vegetation	78,694,158
Building	1,098,277
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Jovy Narisma

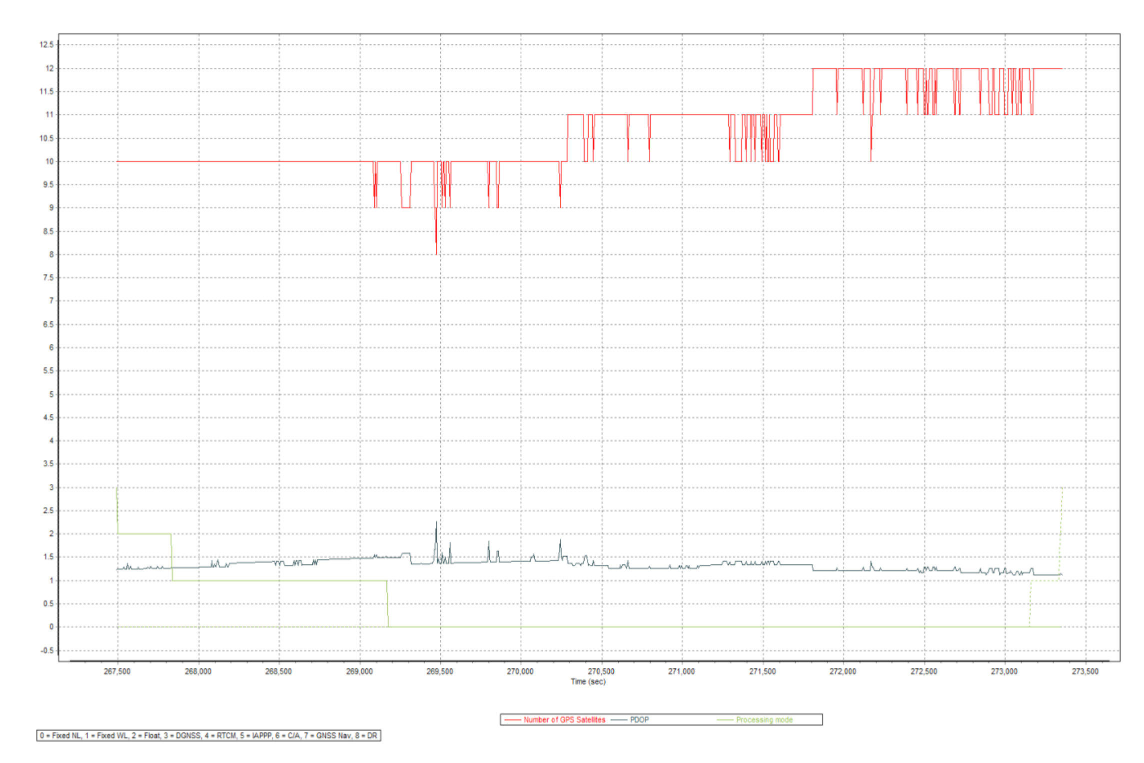

Figure A-8.29. Solution Status

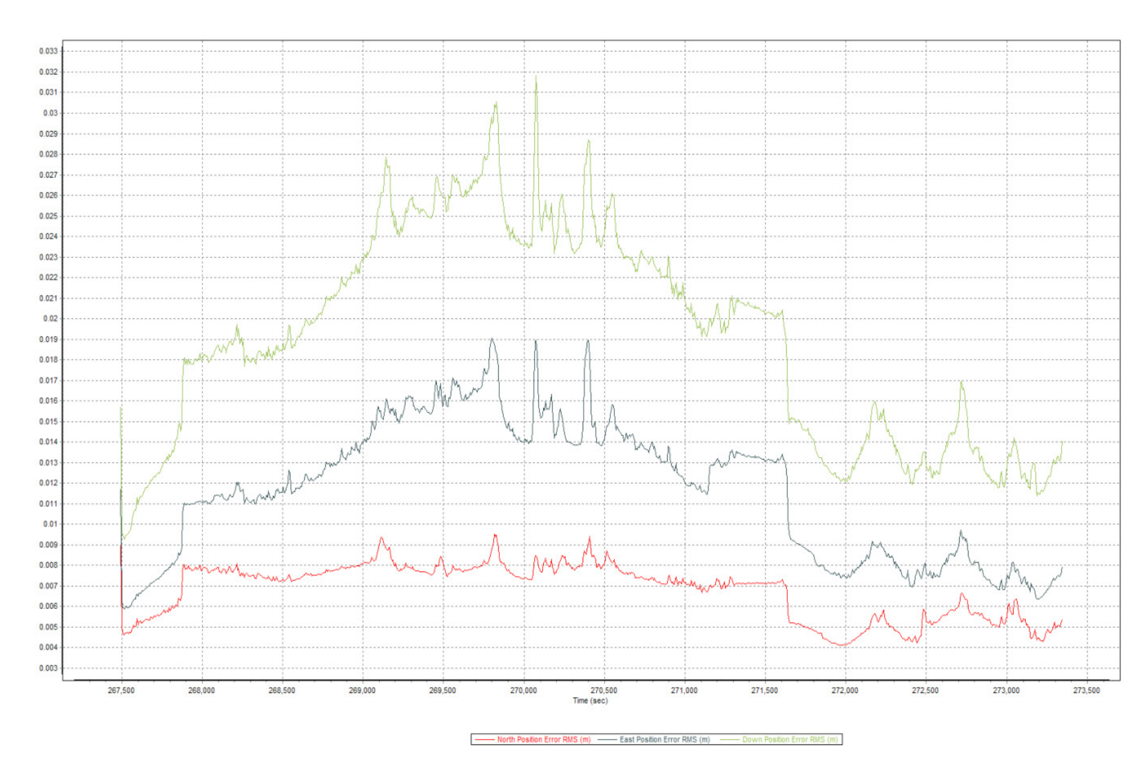

Figure A-8.30. Smoothed Performance Metrics Parameters

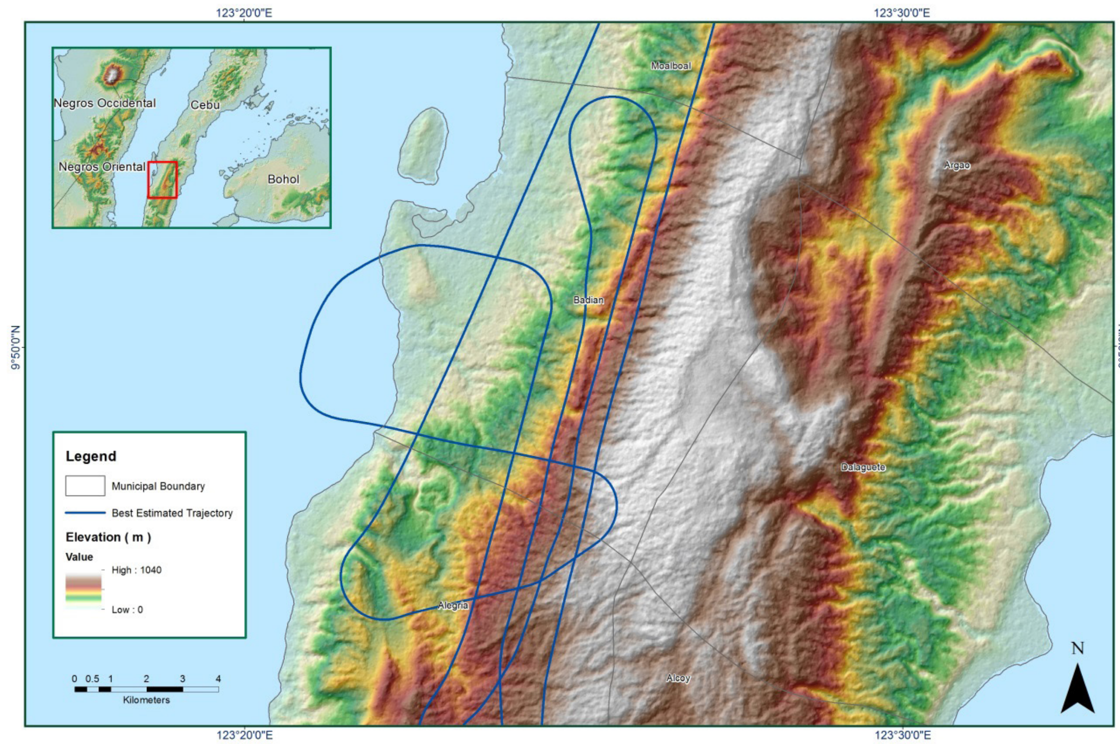

Figure A-8.31. Best Estimated Trajectory

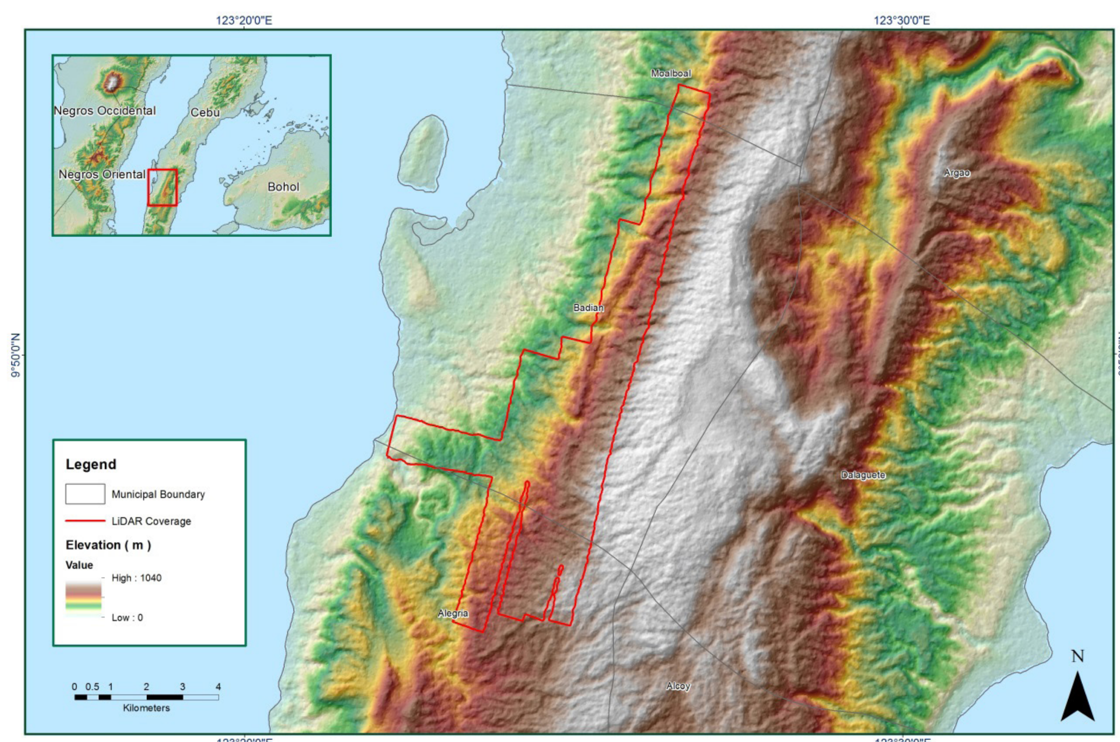

Figure A-8.32. Coverage of LiDAR data

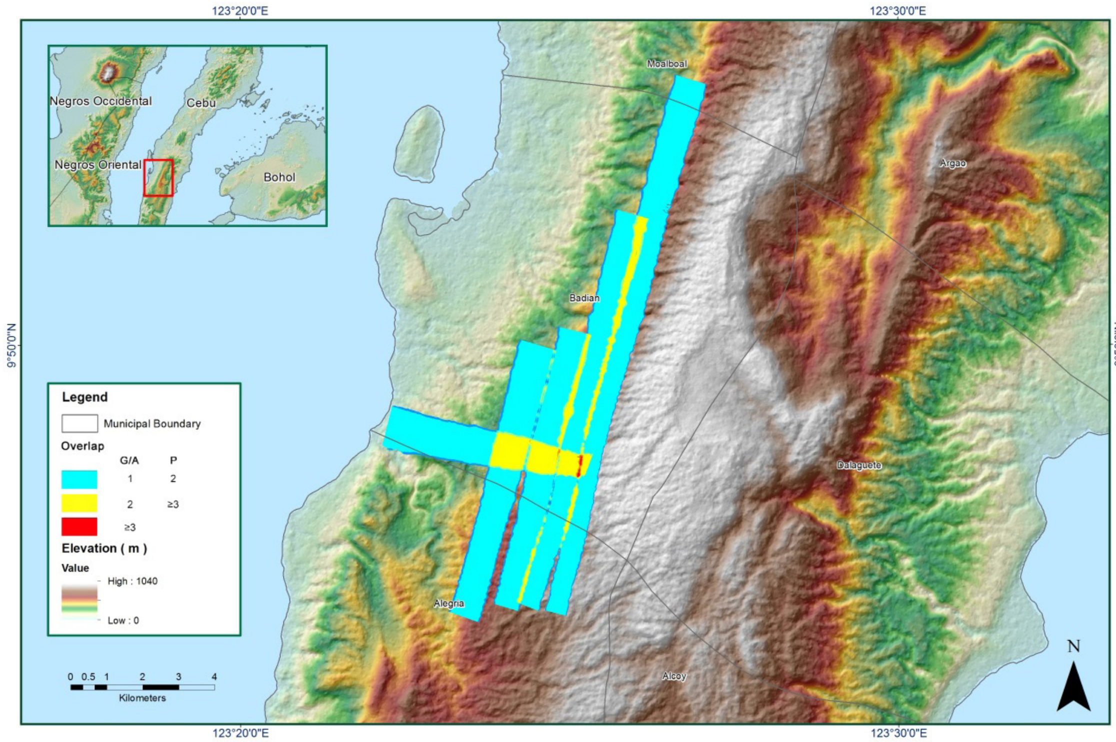

Figure A-8.33. Image of data overlap

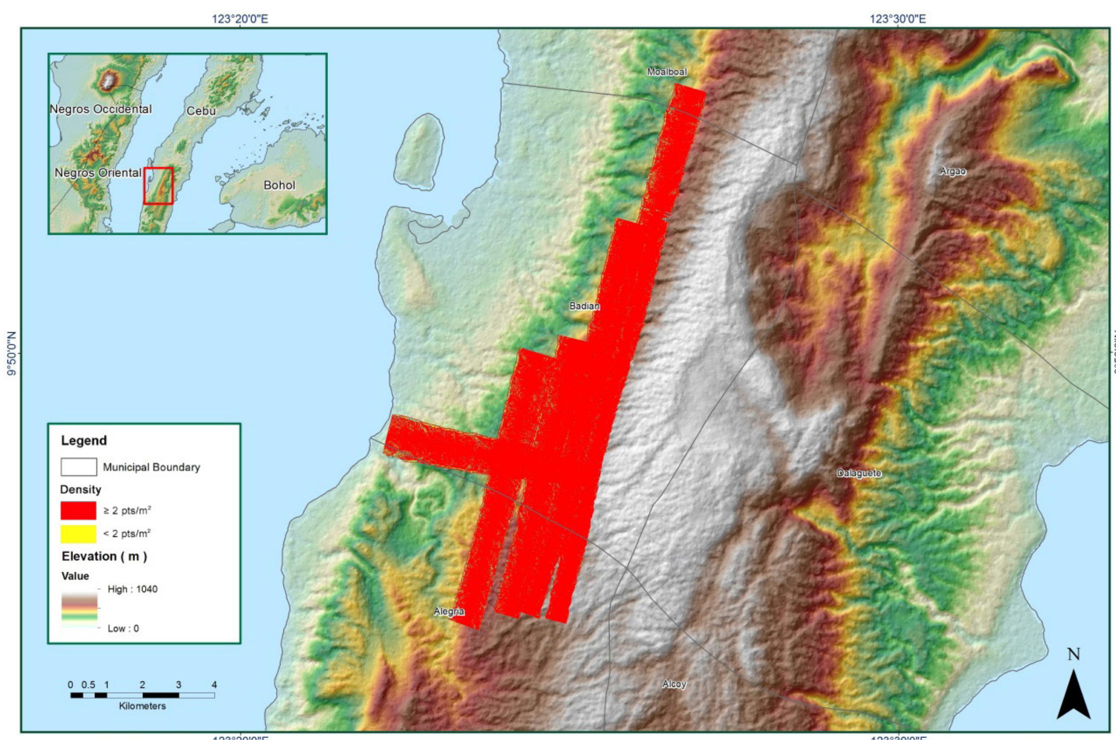

Figure A-8.34. Density of merged LiDAR data

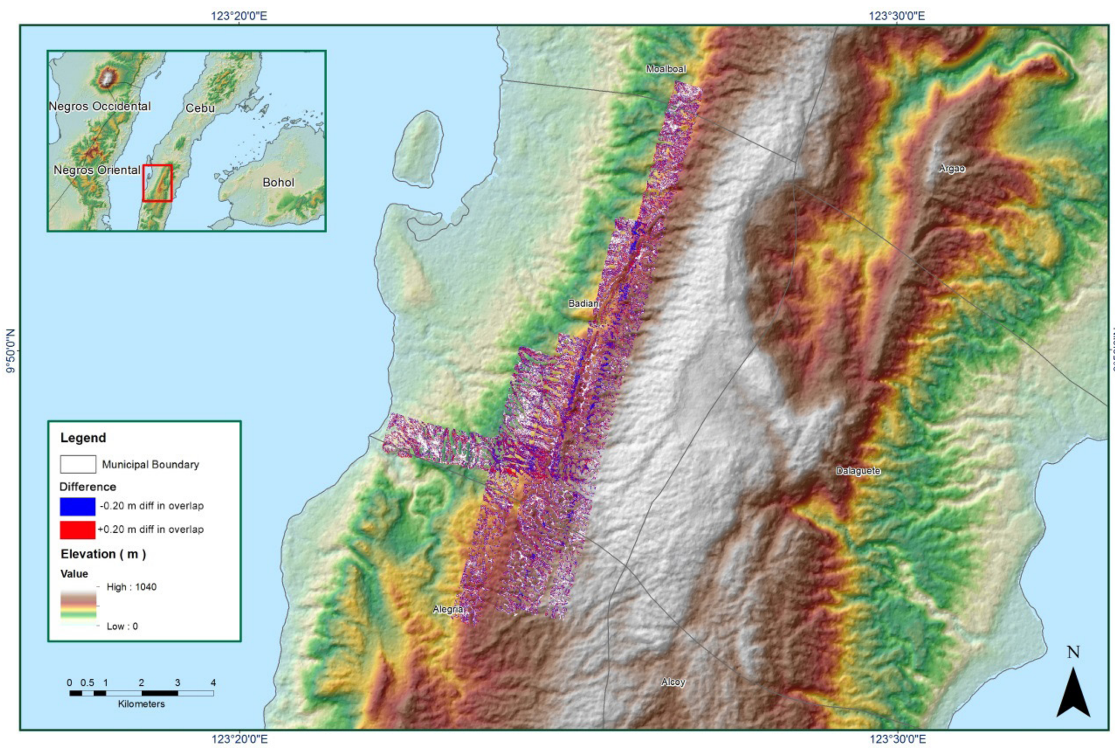

Figure A-8.35. Elevation difference between flight lines

Annex 9. Sapangdaku Model Basin Parameters

Basin Number	SCS Curve Number Loss Model			Clark Transform Model		Recession Constant Baseflow Model				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W420	6.2101	58.4	0	0.96044	4.8475	Discharge	0.035903	0.78008	Ratio to Peak	0.1
W430	6.2101	58.4	0	0.353784	1.7754	Discharge	0.00803	0.8	Ratio to Peak	0.1
W440	6.2101	58.4	0	0.4022	2.0256	Discharge	0.010638	0.8	Ratio to Peak	0.1
W450	6.2101	58.4	0	0.332936	2.5072	Discharge	0.007222	0.8	Ratio to Peak	0.1
W460	6.2101	58.4	0	0.110036	0.55554	Discharge	0.000243	0.8	Ratio to Peak	0.1
W470	6.2101	58.4	0	0.220276	1.6599	Discharge	0.006807	0.8	Ratio to Peak	0.1
W480	6.2101	58.4	0	0.312312	1.5772	Discharge	0.006701	0.8	Ratio to Peak	0.1
W490	6.2101	58.4	0	0.316556	1.5957	Discharge	0.009746	0.784	Ratio to Peak	0.1
W500	6.2101	58.4	0	0.16492	0.82852	Discharge	0.001482	0.79257	Ratio to Peak	0.1
W510	6.2013	58.4272	0	0.75892	3.8131	Discharge	0.028166	0.53333	Ratio to Peak	0.1
W520	6.2101	58.4	0	0.341856	1.7172	Discharge	0.009298	0.796	Ratio to Peak	0.1
W530	6.8142	56.592	0	0.83708	4.2014	Discharge	0.012272	0.53333	Ratio to Peak	0.1
W540	6.2101	58.4	0	0.386748	2.9006	Discharge	0.006995	0.796	Ratio to Peak	0.1
W550	6.2101	58.4	0	0.330788	1.662	Discharge	0.008601	0.86	Ratio to Peak	0.1
W560	6.2101	58.4	0	0.49072	3.6804	Discharge	0.015533	0.784	Ratio to Peak	0.1
W570	8.0266	53.2816	0	0.9114	4.5753	Discharge	0.021284	0.53333	Ratio to Peak	0.1
W580	4.0531	65.9192	0	0.321748	1.6164	Discharge	0.004894	0.784	Ratio to Peak	0.1
W590	6.2101	58.4	0	0.41592	2.0892	Discharge	0.00691	0.72	Ratio to Peak	0.1
W600	5.8057	59.676	0	0.43608	3.2706	Discharge	0.008638	0.53333	Ratio to Peak	0.1
W620	6.2101	58.4	0	0.56684	2.848	Discharge	0.01303	0.53333	Ratio to Peak	0.1
W630	6.2101	58.4	0	0.23288	1.1701	Discharge	0.00327	0.53333	Ratio to Peak	0.1
W640	6.4307	57.7264	0	0.48728	2.4479	Discharge	0.007361	0.53333	Ratio to Peak	0.1
W650	5.2758	61.4352	0	0.322676	1.6176	Discharge	0.011211	1	Ratio to Peak	0.1
W660	6.3502	57.9704	0	0.56292	10.364	Discharge	0.012011	0.784	Ratio to Peak	0.1
W670	5.8144	59.648	0	0.261256	2.8276	Discharge	0.005453	0.53333	Ratio to Peak	0.1
W680	3.7598	67.0936	0	0.166376	1.3124	Discharge	0.001074	0.53333	Ratio to Peak	0.1
W690	6.0963	58.7536	0	1.07752	1.2478	Discharge	0.031402	0.7864	Ratio to Peak	0.1
W700	3.4519	68.3728	0	0.45964	5.2798	Discharge	0.019362	0.53333	Ratio to Peak	0.1

Basin Number	SCS Curve Number Loss Model			Clark Transform Model		Recession Constant Baseflow Model				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W710	4.4395	64.4328	0	0.29188	2.3054	Discharge	0.003742	0.788	Ratio to Peak	0.1
W720	5.9492	59.2168	0	0.65696	1.4664	Discharge	0.020546	0.53333	Ratio to Peak	0.1
W730	4.628	63.732	0	0.276844	3.3009	Discharge	0.011404	0.53333	Ratio to Peak	0.1
W740	4.3763	64.6712	0	0.67896	1.389	Discharge	0.026135	0.8	Ratio to Peak	0.1
W750	5.9354	59.2608	0	1.38188	3.4105	Discharge	0.061941	0.53333	Ratio to Peak	0.1
W760	6.2101	58.4	0	0.165372	0.83077	Discharge	0.000379	0.53333	Ratio to Peak	0.1
W770	6.146	58.5984	0	0.52776	2.6513	Discharge	0.007205	0.53333	Ratio to Peak	0.1
W780	5.5885	60.3848	0	0.396508	2.9738	Discharge	0.007252	0.53333	Ratio to Peak	0.1
W790	5.8159	59.6432	0	0.83944	6.2958	Discharge	0.020744	0.784	Ratio to Peak	0.1
W800	6.1656	58.5376	0	0.4304	3.228	Discharge	0.008978	0.53333	Ratio to Peak	0.1
W810	3.245	69.26	0	0.234416	1.7581	Discharge	0.007773	0.53333	Ratio to Peak	0.1
W820	4.5013	64.2016	0	0.31062	1.557	Discharge	0.004708	0.53333	Ratio to Peak	0.1
W850	6.1327	58.64	0	0.59384	2.9829	Discharge	0.014646	0.53333	Ratio to Peak	0.1
W860	1.2438	79.2	0	0.0224272	0.1682	Discharge	0.00001	0.53333	Ratio to Peak	0.1

Annex 10. Sapangdaku Model Reach Parameters

Reach No.	Muskingum Cunge Routing Model						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R130	Automatic Fixed Interval	4911.7	0.0098739	0.4	Trapezoid	20	1
R150	Automatic Fixed Interval	868.53	0.00001	0.4	Trapezoid	20	1
R170	Automatic Fixed Interval	2335.8	0.0149843	0.4	Trapezoid	20	1
R180	Automatic Fixed Interval	2708.8	0.0012136	0.4	Trapezoid	20	1
R190	Automatic Fixed Interval	1234.3	0.0263232	0.4	Trapezoid	20	1
R200	Automatic Fixed Interval	3561.9	0.0488293	0.4	Trapezoid	20	1
R220	Automatic Fixed Interval	1924.4	0.004826	0.4	Trapezoid	20	1
R230	Automatic Fixed Interval	1658.9	0.0599383	0.4	Trapezoid	20	1
R250	Automatic Fixed Interval	488.7	0.1017	0.4	Trapezoid	20	1
R260	Automatic Fixed Interval	1757.8	0.0053843	0.4	Trapezoid	20	1
R270	Automatic Fixed Interval	3007.5	0.0222059	0.4	Trapezoid	20	1
R280	Automatic Fixed Interval	2754.5	0.0205979	0.4	Trapezoid	20	1
R30	Automatic Fixed Interval	1232	0.11127	0.4	Trapezoid	20	1
R330	Automatic Fixed Interval	3776.9	0.0361161	0.4	Trapezoid	20	1
R340	Automatic Fixed Interval	283.85	0.00001	0.4	Trapezoid	20	1
R360	Automatic Fixed Interval	857.11	0.0146647	0.4	Trapezoid	20	1
R380	Automatic Fixed Interval	2069.2	0.0170225	0.4	Trapezoid	20	1
R60	Automatic Fixed Interval	398.99	0.0459955	0.4	Trapezoid	20	1
R80	Automatic Fixed Interval	1843.1	0.0210815	0.4	Trapezoid	20	1
R870	Automatic Fixed Interval	70.711	0.23494	0.4	Trapezoid	20	1
R90	Automatic Fixed Interval	751.54	0.0191891	0.4	Trapezoid	20	1

Annex 11. Sapangdaku Flood Validation Data

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
1	123.647667	10.399333	0.04	0.7	0.4356	Yolanda	100-Year
2	123.659944	10.37525	2.83	1.9	0.8649	Basyang	100-Year
3	123.661056	10.381583	0.03	0.9	0.7569	Wilfreng	100-Year
4	123.659972	10.384833	0.03	0.7	0.4489	Yolanda	100-Year
5	123.656028	10.388417	0.08	0.5	0.1764	Yolanda	100-Year
6	123.651861	10.390444	0.19	1.2	1.0201	Basyang	100-Year
7	123.654472	10.39175	0.54	0.5	0.0016	Basyang	100-Year
8	123.650194	10.393	0.03	0.9	0.7569	Basyang	100-Year
9	123.648694	10.393222	0.03	1.7	2.7889	Yolanda	100-Year
10	123.661194	10.38125	5.88	0.9	24.8004	Wilfreng	100-Year
11	123.659944	10.375611	0.03	0.3	0.0729	Wilfreng	100-Year
12	123.659528	10.375722	0.22	0.3	0.0064	Wilfreng	100-Year
13	123.660055	10.3755	4.41	0.7	13.7641	Yolanda	100-Year
14	123.6585	10.376111	0.06	0	0.0036	Basyang	100-Year
15	123.6625	10.381778	0.06	0	0.0036	Wilfreng	100-Year
16	123.662139	10.381861	1.86	1.5	0.1296	Yolanda	100-Year
17	123.660055	10.384833	0.03	0.5	0.2209	Basyang	100-Year
18	123.660611	10.382	0.06	0.2	0.0196	Wilfreng	100-Year
19	123.656305	10.388111	0.03	1.2	1.3689	Yolanda	100-Year
20	123.65	10.393806	0.14	0.5	0.1296	Yolanda	100-Year
21	123.648583	10.393472	0.03	0.2	0.0289	Ruby	100-Year
22	123.651806	10.395139	0.03	0.2	0.0289	Basyang	100-Year
23	123.647472	10.399583	0.03	0.2	0.0289	Wilfreng	100-Year
24	123.647861	10.397167	0.03	0.5	0.2209	Yolanda	100-Year
25	123.647833	10.397194	0.03	0.3	0.0729	Wilfreng	100-Year
26	123.647833	10.397194	0.03	0.3	0.0729	Ruby	100-Year
27	123.647833	10.397167	0.03	5	24.7009	Wilfreng	100-Year
28	123.648722	10.396417	0.13	0.9	0.5929	Ruby	100-Year
29	123.650889	10.395167	0.03	0.7	0.4489	Lando	100-Year
30	123.650889	10.395167	0.03	0.2	0.0289	Ruby	100-Year
31	123.650333	10.392805	0.08	0.2	0.0144	Ruby	100-Year
32	123.650778	10.393639	0.63	0.7	0.0049	Yolanda	100-Year
33	123.653722	10.392055	0.03	0.5	0.2209	Wilfreng	100-Year
34	123.6841753	10.35156733	0.39	0.2	0.0361	Wilfreng	100-Year
35	123.6841266	10.35184309	0.59	0.3	0.0841	Wilfreng	100-Year
36	123.6846736	10.35266889	1.45	1.6	0.0225	Ruping	100-Year
37	123.6847108	10.3524592	1.45	1.4	0.0025	Ruping	100-Year
38	123.6842518	10.35343071	0.7	0.7	0	Ruby	100-Year
39	123.6847947	10.35370234	0.3	0.3	0	Wilfreng	100-Year
40	123.6839364	10.35374723	0.91	1	0.0081	Wilfreng	100-Year
41	123.6830888	10.35337575	0.47	0.5	0.0009	Ruby	100-Year
42	123.683451	10.35321992	0.54	1.5	0.9216	Yolanda	100-Year
43	123.6762291	10.35300929	0.26	0.2	0.0036	Yolanda	100-Year
44	123.6768784	10.3528701	0.03	0.2	0.0289	Basyang	100-Year
45	123.6666921	10.35070089	0.03	1	0.9409	Wilfreng	100-Year
46	123.6665902	10.35047426	0.03	0.2	0.0289	Ruby	100-Year
47	123.6669893	10.34999965	0.03	1.2	1.3689	Ruby	100-Year
48	123.6671664	10.35005671	0.07	0.5	0.1849	Yolanda	100-Year
49	123.6673429	10.34986971	0.28	0.7	0.1764	Basyang	100-Year
50	123.6672608	10.34951234	0.55	1	0.2025	Yolanda	100-Year
51	123.6653258	10.35188387	0.12	1.2	1.1664	Basyang	100-Year
52	123.6590539	10.35735054	0.35	0.5	0.0225	Yolanda	100-Year
53	123.6582247	10.35841275	0.09	1.2	1.2321	Wilfreng	100-Year
54	123.6564698	10.36671779	0.05	0.7	0.4225	Basyang	100-Year
55	123.6565366	10.36678944	0.05	0.7	0.4225	Basyang	100-Year
56	123.6569824	10.36696287	0.37	0.2	0.0289	Yolanda	100-Year
57	123.6567593	10.3665162	0.12	1	0.7744	Basyang	100-Year

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period
	Longitude	Latitude					
58	123.6568057	10.36650462	0.12	0.5	0.1444		100-Year
59	123.642965	10.38247693	0.05	1.2	1.3225		100-Year
60	123.643015	10.38238112	0.05	0.3	0.0625		100-Year
61	123.64271	10.38261527	0.03	0.3	0.0729		100-Year
62	123.649421	10.39042159	0.26	0.5	0.0576		100-Year
63	123.6498989	10.39008802	0.03	0.2	0.0289		100-Year
64	123.6499443	10.38986779	0.04	0.7	0.4356		100-Year
65	123.6496489	10.38957885	0.06	1.5	2.0736	Wilfreng	100-Year
66	123.6500642	10.38940572	0.03	0.3	0.0729		100-Year
67	123.6502922	10.39092711	0.22	0.5	0.0784	Basyang	100-Year
68	123.6503261	10.39098686	0.22	0.7	0.2304	Yolanda	100-Year
69	123.6505101	10.39065628	0.03	0.2	0.0289	Basyang	100-Year
70	123.6529161	10.40155396	0.97	1.2	0.0529	Basyang	100-Year

Annex 12. Educational Institutions Affected in Sapangdaku Floodplain

Cebu				
Toledo City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Cambang-og Elementary School	Cambang-Ug			
Carmen Elementary School	Carmen			
Dumlog Elementary School	Dumlog			Low
Toledo City Science High School	Ilihan			
Toledo National Vocational School	Ilihan		Low	Low
Magdugo Elementary School	Juan Climaco, Sr.	Low	Low	Medium
Magdugo High School	Juan Climaco, Sr.	Low	Medium	Medium
Toledo City Science High School	Luray II			
Media Onse National High School	Media Once		Low	Medium
North City Central School	Poblacion	Medium	Medium	Medium
South City Central School	Poblacion	Low	Medium	Medium
University of the Visayas	Poblacion			
Leaton School	Sangi	Low	Low	Low
North City Central School	Sangi	Medium	Medium	Medium
Sangi Elementary School	Sangi			
St. Bernard School	Sangi	Low	Low	Low
TESDA	Sangi	Low	Medium	Medium
Toledo National Vocational School	Sangi			
West Bay Learning Center	Sangi	Medium	Medium	Medium
Talavera Elementary School	Talavera	Low	Medium	Medium

Annex 13. Health Institutions Affected in Sapangdaku Floodplain

Cebu				
Toledo City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Medical Clinic	Poblacion			