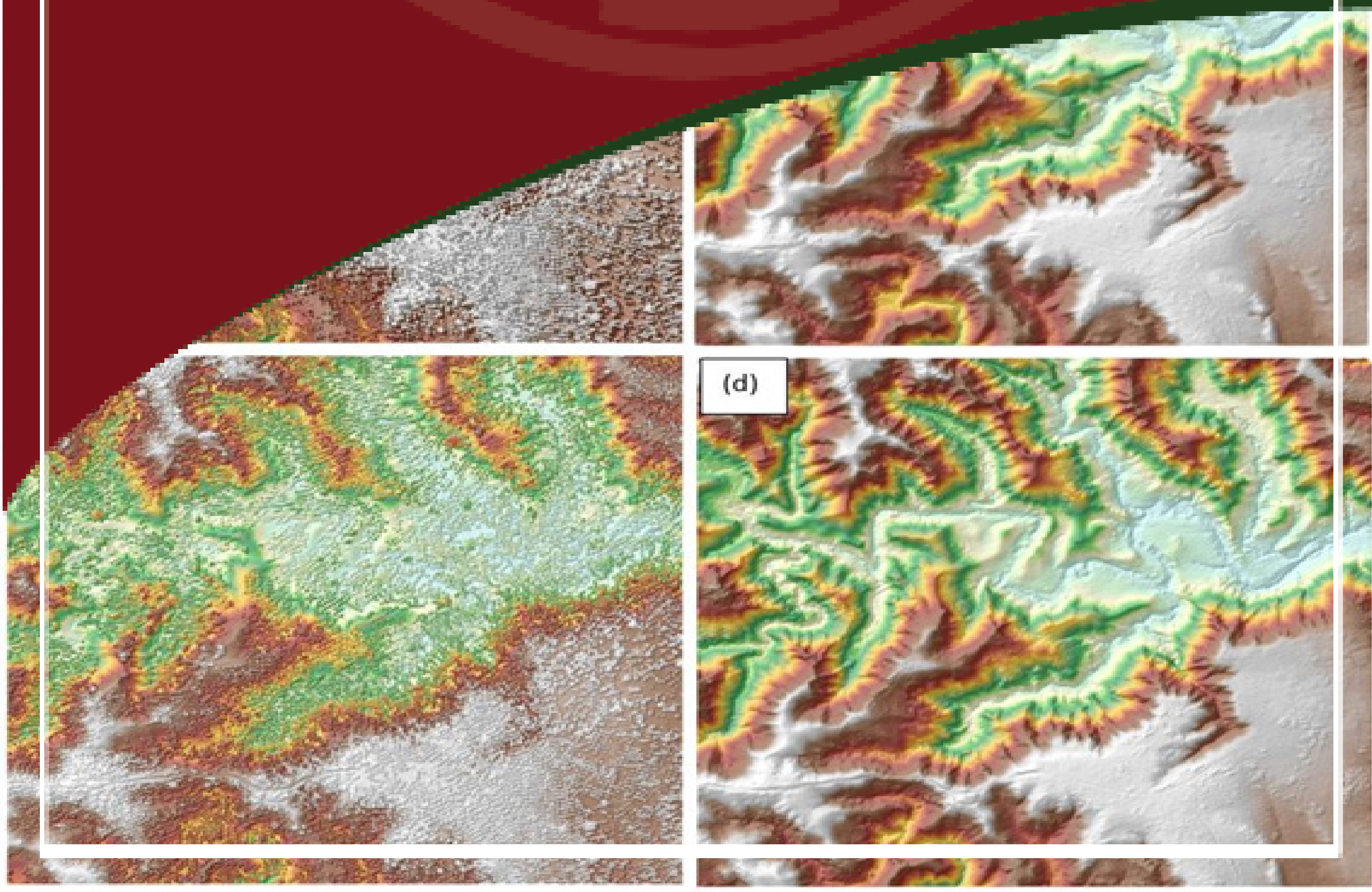
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Caraga River



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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UPM	University of the Philippines Mindanao
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CARAGA RIVER

Dr. Joseph E. Acosta and Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (UPMin). UPMin 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 13 river basins in the Davao Region. The university is located in Municipality of Tugbok in the province of Davao del Sur.

1.2 Overview of the Tanao River Basin

Caraga watershed is located in the Caraga Municipality with its mouth in Caraga Bay facing the Pacific Ocean. The watershed area is 524.26 sq.km. and its river length is 63.33 km with 59 subbasins, 29 junctions, and 29 reaches. The municipality of Caraga is bounded on the north by the municipality of Baganga, south by Manay, portions of Maragusan and Compostela Valley on the west, and the Pacific Ocean on the east (Bugayong et.al, 2016).

The name of the municipality was derived from the word Cagang, which is the name of a local fresh water crab found in the area (UP Manila, 2000). Another etymology for the word Caraga is the native word Kalag meaning spirit of the soul. In 1622, the Provincia de Caraga was called "Region de Gente Animosa" or "Region of Spirited Men" pertaining to the locals being grounded on its cultural, religious, and political background (Combes, 1667; Caraga Tourism, 2017).

The municipality was originally part of the Caraga Region that extensively covered the province of eastern Davao and the Surigao and Agusan provinces. Caraga was officially founded in 1861 along with Mati. However, it was on July 15, 1903 when it was incorporated and is the official date of the municipality's anniversary. It was only in 1967, by virtue of Republic Act No. 4867, when the province of Davao Oriental was created (Alo, 2013; Official Website of the Province of Davao Oriental, 2014).

Caraga, being the oldest town of the province of Davao Oriental, is endowed with rich historico-religio-cultural heritage. Its history under the Spanish colonialism started as far back as 1521. It is said to be where Christianization started in this part of the Philippines (Caraga Tourism, 2017; Sillada, 2017). During the period when the bagani leadership was the prevailing political system, the Mandaya resided near the Caraga and Manurigao Rivers.

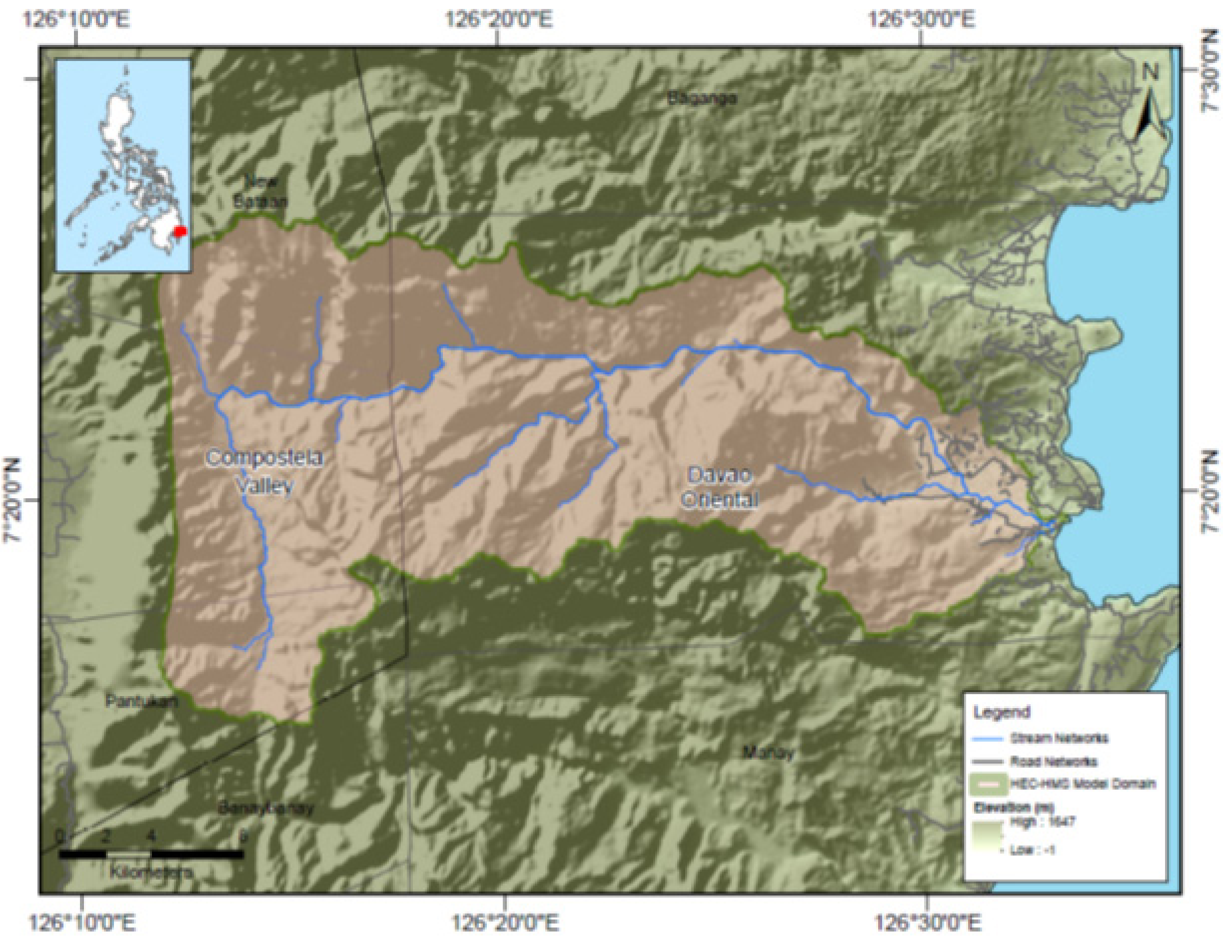

Figure 1. Map of the Caraga River Basin (in brown)

Caraga Watershed is one of the priority watersheds in the Province of Davao Oriental that is used for domestic purposes and for irrigation (Official Website of the Province of Davao Oriental, 2017).

The Caraga watershed is also home to numerous waterfalls including Ugwad Falls in Brgy. Lamiawan, Magpangaw Falls and Cave in Brgy. Mercedes, Pinutoan Falls and Pygasabangan Falls in Pichon, Sungkuan Falls at Brgy. Sobrecarey, and Kapuka Falls at Brgy. Lamiawan (Caraga Tourism, 2017).

Caraga bridge, which connects the Manay and Caraga towns, collapsed after being hit by Typhoon Pablo in 2013. Its destruction has rendered Caraga isolated from its neighboring towns (Alconaba and Zonio, 2013). Typhoon Bopha, known in the Philippines as Typhoon Pablo, is one of the strongest and deadliest tropical cyclone to hit Mindanao (Legazpi, 2012; Masters, 2012).

The Caraga Church or the church of San Salvador del Mundo, located in the town proper of Caraga, is considered as one of the oldest churches in Mindanao. It houses the 1802 Church Bell brought by friars from Spain (Dacumos, 2012). When Typhoon Pablo devastated Davao Oriental, surrounding buildings crumbled and tens of thousands were left homeless. The church, on the other hand, only underwent minor damage (Lacorte, 2013).

Sitio Sangab in Caraga is one of the upland barangays in Davao Oriental that has been declared as an ancestral domain where Mandaya tribe reside. According to the leaders of Sitio Sangab, there are three major subtribes of the Mandaya: the Mangallagan-Mandaya (living near the Caraga River), the Manlawud (living near coastal rivers or sea openings), and the Munuligaw (living near the Suligaw or Surigao River) (UP Manila, 2000).

According to locals, from the year 1970 to 2017, local rainfall and upstream rainfall are the usual cause of flooding near the river. However, PAGASA only noted typhoon events such as Titang in 1970; Ondoy in 2009; Pablo in 2012; Crising, Yolanda, and Zoraida in 2013; and Agaton in 2014. The town has no dry season but with pronounced rainfall from November to January (Bugayong et.al., 2016).

CHAPTER 2: LIDAR DATA AACQUISITION OF THE CARAGA 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 Caraga floodplain in Davao Oriental. These missions were planned for 17 lines and ran 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 1 shows the flight plans and base stations for Caraga floodplain.

Table 1. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK79A	1000	45	40	100	50	130	5
BLK79B	1000	45	40	100	50	130	5
	1000	35	40	100	50	130	5
BLK79C	1000	45	40	100	50	130	5
BLK79D	1200	40	24	70	60	130	5
BLK79E	1200	40	24	70	60	130	5
BLK80A	1000	30	40	100	50	130	5
BLK80B	1200	40	24	70	60	130	5
		30	40	100	50	130	5

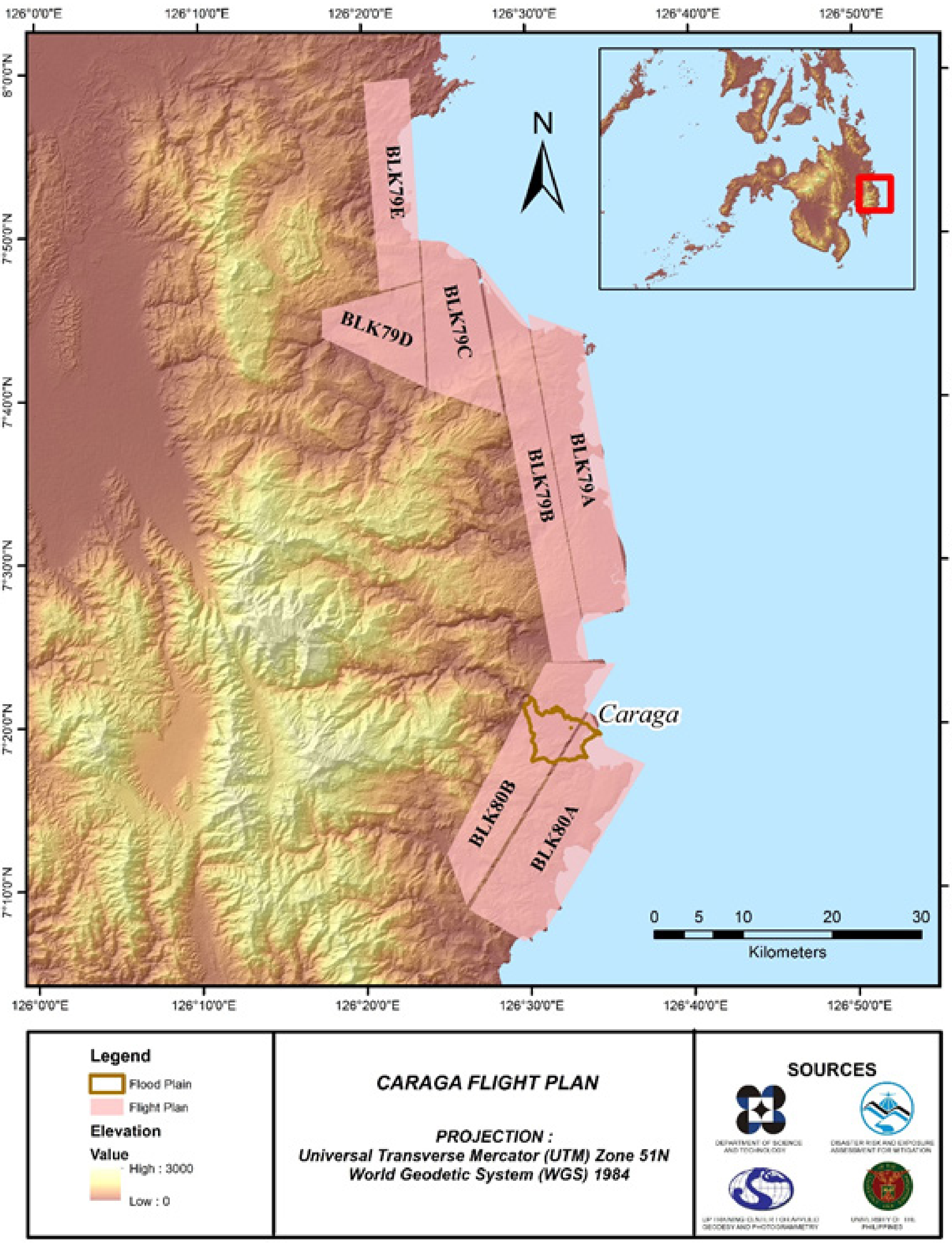

Figure 1. Flight plans and base stations used for Caraga floodplain.

2.2 Ground Base Stations

The project team was able to recover seven (7) NAMRIA ground control points: DVE-19 and DVE-20 (3rd order accuracy); DVE-3126, DVE-3131, DVE-3153, BMDE-55 and CATEEL BLLM-03 (4th order accuracy). The third (3rd) and fourth (4th) order ground control points where then re-processed to obtain coordinates of second (2nd) order accuracy. The baseline processing reports for the re-processed control points are found in Annex B. These were used as base stations during flight operations for the entire duration of the survey (June 22 – July 16, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Caraga floodplain are shown in Figure 1.

Figure 2 to Figure 8 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 8 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

Figure 2. GPS set-up over DVE-3126 located inside the compound of Kinablangan Barangay Hall (a) and NAMRIA reference point DVE-3126 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point DVE-3126 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	**DVE-3126**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°41'33.20427" North 126°32'59.94854" East -5.941 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°41'30.00136" North 126°33'5.40517" East 67.952 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	891740.922 meters 851882.057 meters

Figure 3. GPS set-up over DVE-19 located in front of the flagpole of Gregorio Moralizon Elementary School II (a) and NAMRIA reference point DVE-19 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point DVE-19 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	**DVE-19**	
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	7°12'55.40701" North 126°32'20.36757" East -5.263 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°12'52.33155" North 126°32'25.86780" East 69.522 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	228220.964 meters 798242.634 meters

Figure 4. GPS set-up over DVE-3131 located inside the premises of DENR CENRO Office (a) and NAMRIA reference point DVE-3131 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point DVE-3131 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	**DVE-3131**	
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	7°36'29.46050" North 126°33'39.32918"East -5.921 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°36'26.28124" North 126°33'44.79335" East 68.184 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	230883.431 meters 841687.881 meters

Figure 5. GPS set-up over DVE-20 located inside the premises of Gregorio Moralizon Elementary School I, at the corner side of the basketball court 3 meters from the gate of the school (a) and NAMRIA reference point DVE-20 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point DVE-20 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	**DVE-20**	
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	7°12'51.11197" North 126°32'20.35543" East -6.215 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°12'48.03684" North 126°32'25.85577" East 68.572 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	228219.879 meters 798110.635 meters

Figure 6. GPS set-up over DVE-3153 located inside the compound of San Rafael Elementary School (a) and NAMRIA reference point DVE-3153 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point DVE-3153 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	**DVE-3153**	
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	7°46'1.89052" North 126°27'0.70790" East -3.275 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°45'58.65857" North 126°27'6.15889" East 70.225 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	218763.330 meters 859352.572 meters

Figure 7. GPS set-up over BMDE-55 located at Dapnan Bridge (a) and NAMRIA reference point BMDE-55 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point BMDE-55 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	BMDE-55	
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	7°38'34.72769" North 126°32'15.14877" East -2.412 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°38'31.53697" North 126°32'20.61004" East 71.547 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	228323.840 meters 845552.457 meters

Figure 8. GPS set-up over CATEEL BLLM-03 located inside the compound of San Rafael Elementary School (a) and NAMRIA reference point CATEEL BLLM-03 (b) as recovered by the field team.

Table 9. Details of the recovered horizontal control point CATEEL BLLM-03 used as base station for the LiDAR acquisition with established coordinates.

Station Name	CATEEL BLLM-03	
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	7°46'1.73124" North 126°27'0.03988" East -3.164 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°45'58.49928" North 126°27'5.49087" East 70.335 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	218742.821 meters 859347.799 meters

Table 10. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
June 22, 2014	7326GC	2BLK83B173A	DVE-19 & DVE-20
June 23, 2014	7328GC	2BLK80ABS174A	DVE-19 & DVE-20
June 28, 2014	7339GC	2BLK79C179A	BMDE-55 & DVE-3131
June 29, 2014	7340GC	2BLK79B180A	DVE-3126 & DVE-3131
July 2, 2014	7346GC	2BLK79BSA183A	DVE-3126 & DVE-3131
July 3, 2014	7348GC	2BLK79D184A	DVE-3126 & DVE-3131
July 7, 2014	7356GC	2BLK80AS188A	DVE-19 & DVE-20
July 7, 2014	7357GC	2BLK80AS188B	DVE-19 & DVE-20
July 12, 2014	7366GC	2BLK79D80V193A	DVE-3126 & DVE-3131
July 15, 2014	7372GC	2BLK79ES196A	CATEEL BLLM-03 & DVE-3153
July 16, 2014	7374GC	2BLK79E197A	CATEEL BLLM-03 & DVE-3153

2.3 Flight Missions

Eleven (11) missions were conducted to complete the LiDAR data acquisition in Caraga Floodplain, for a total of forty two hours and thirty minutes (42+30) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR system. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in Caraga 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
June 22, 2014	7326GC	164.06	175.21	23.31	151.90	NA	4	23
June 23, 2014	7328GC	369.20	244.67	11.36	233.32	NA	4	23
June 28, 2014	7339GC	122.65	131.42	0.00	131.42	NA	4	23
June 29, 2014	7340GC	173.96	217.22	0.00	217.22	NA	4	22
July 2, 2014	7346GC	360.01	284.06	0.00	284.06	NA	4	35
July 3, 2014	7348GC	173.96	42.89	0.00	361.45	NA	3	47
July 7, 2014	7356GC	369.20	235.92	15.74	220.18	NA	4	29
July 7, 2014	7357GC	205.14	44.12	15.74	262.68	NA	1	47
July 12, 2014	7366GC	86.17	102.18	0.00	102.18	NA	4	17
July 15, 2014	7372GC	115.36	23.88	0.00	23.88	NA	2	53
July 16, 2014	7374GC	115.36	69.78	0.00	69.78	NA	3	11
TOTAL		**2255.06**	**1889.92**	**66.15**	**2058.07**	**2058.07**	**42**	**30**

Table 12. 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)
7326GC	1200	40	26	70	60	130	5
7328GC	1100	30	40	100	50	130	5
7339GC	1100	45	40	100	50	130	5
7340GC	1100	45	40	100	50	130	5
7346GC	1100	45	40	100	50	130	5
7348GC	1100	35	40	100	50	130	5
7356GC	1100	30	40	100	50	130	5
7357GC	1100	30	40	100	50	130	5
7366GC	1400	40	24	70	60	130	5
7372GC	1200	40	38	100	52	130	5
7374GC	1200	40	26	70	60	130	5

2.4 Survey Coverage

Caraga floodplain is located in the province of Davao Oriental, specifically within the municipality of Caraga. The list of municipalities/cities surveyed, with at least one (1) square kilometer coverage is shown in Table 12. The actual coverage of the LiDAR acquisition for Caraga floodplain is presented in Figure 9.

Table 13. List of municipalities and cities surveyed during Caraga floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Davao Oriental	Manay	430.89	233.26	54.13%
	Cateel	263.64	126.84	48.11%
	Baganga	1153.13	443.19	38.43%
	Caraga	569.48	158.43	27.82%
	Lingig	227.04	13.09	5.77%
	Boston	392.62	22.17	5.65%
	Tarragona	277.90	12.26	4.41%
	Bislig City	269.88	3.18	1.18%

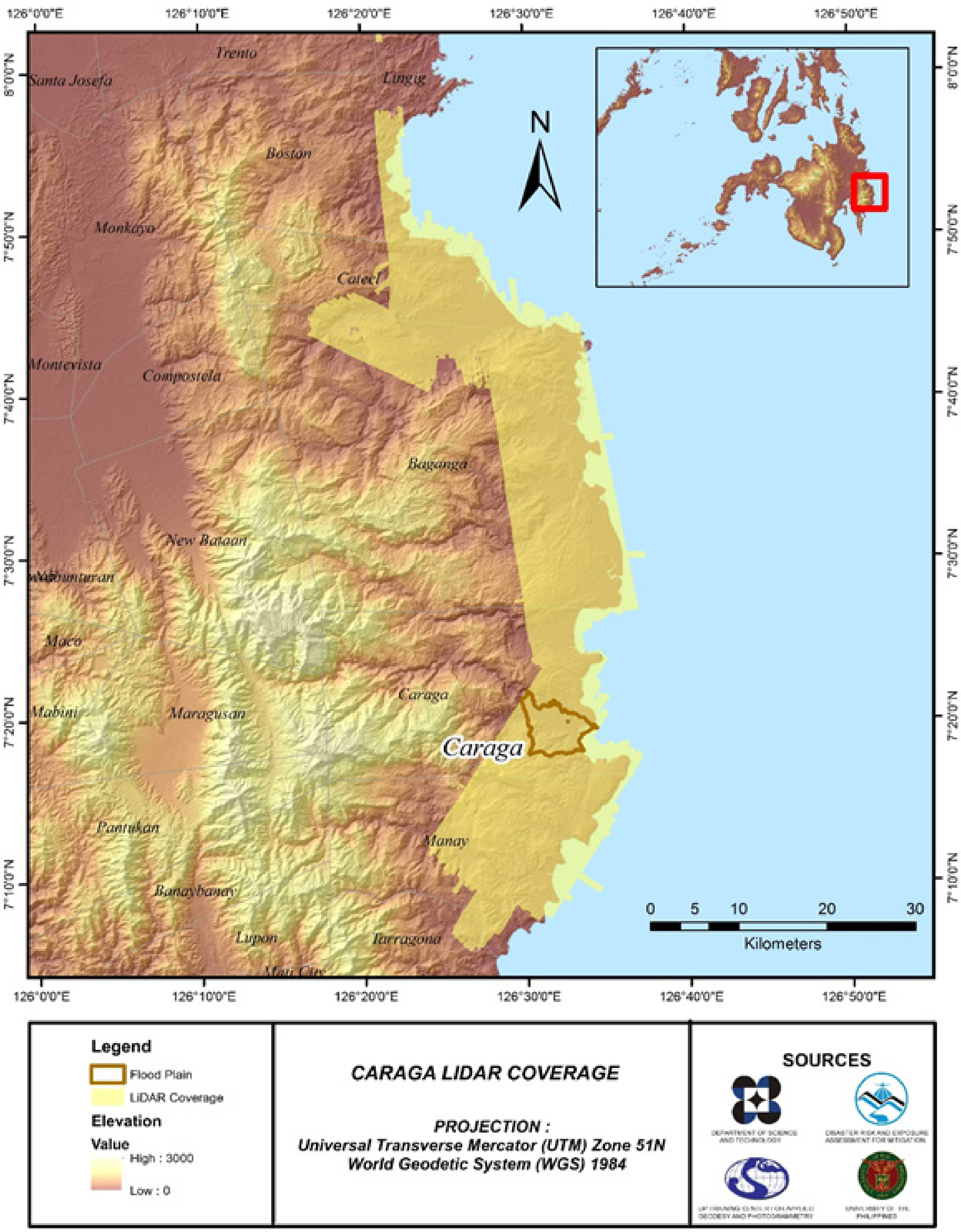

Figure 9. Actual LiDAR survey coverage for Caraga floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE CARAGAFLOODPLAIN

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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 10.

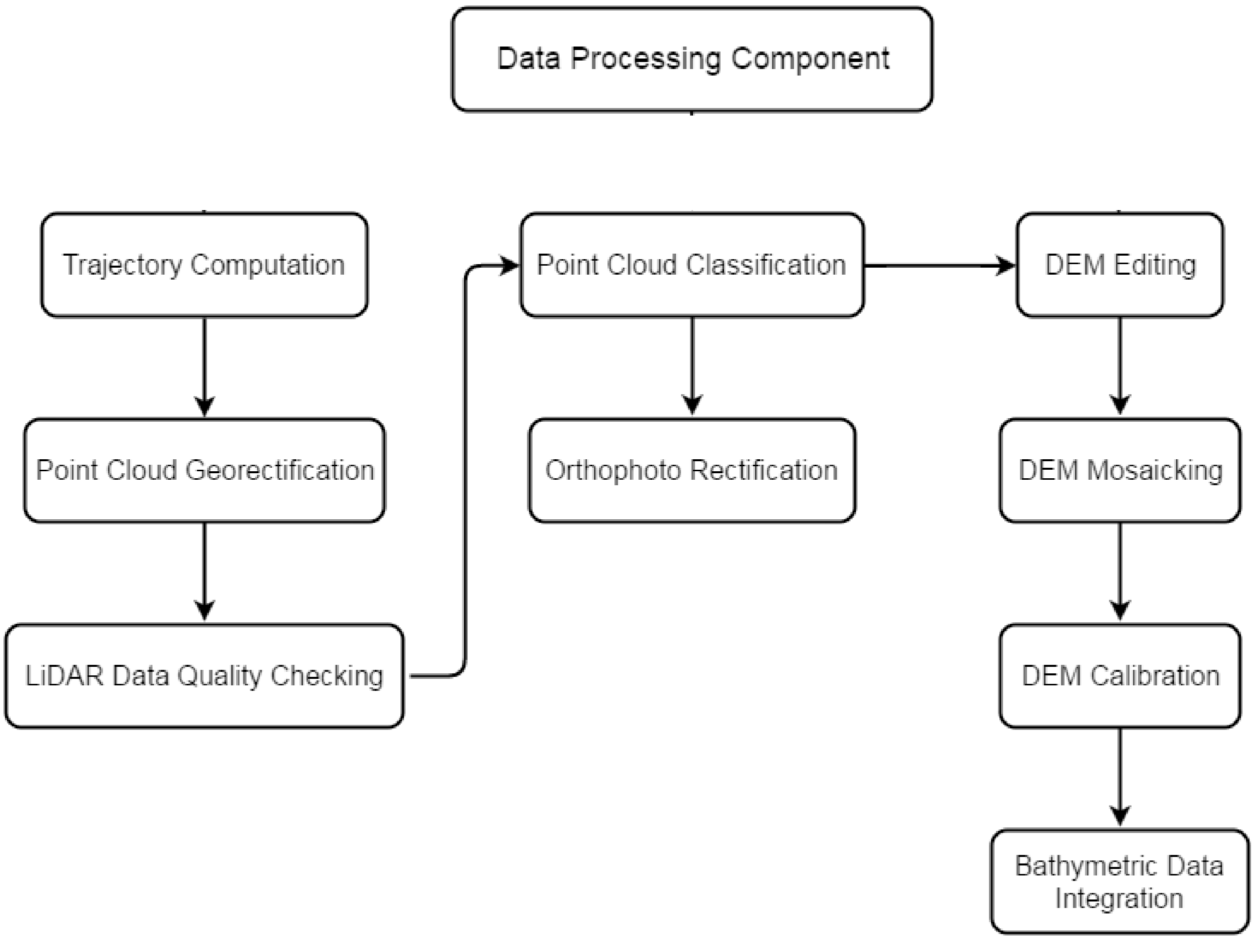

Figure 10. Schematic diagram for Data Pre-processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Caraga floodplain can be found in Annex A-5. Missions flown during the first survey conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Caraga, Davao Oriental.

The Data Acquisition Component (DAC) transferred a total of 174.03 Gigabytes of Range data, 1.92 Gigabytes of POS data, 56.33 Megabytes of GPS base station data, and 91.3 Gigabytes of raw image data to the data server on July 2, 2014 for the first survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Caraga was fully transferred on July 28, 2014 as indicated on the Data Transfer Sheets for Caraga floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 7346GC, one of the Caraga flights, which is the North, East, and Down position RMSE values are shown in Figure B-2. 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 July 08, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

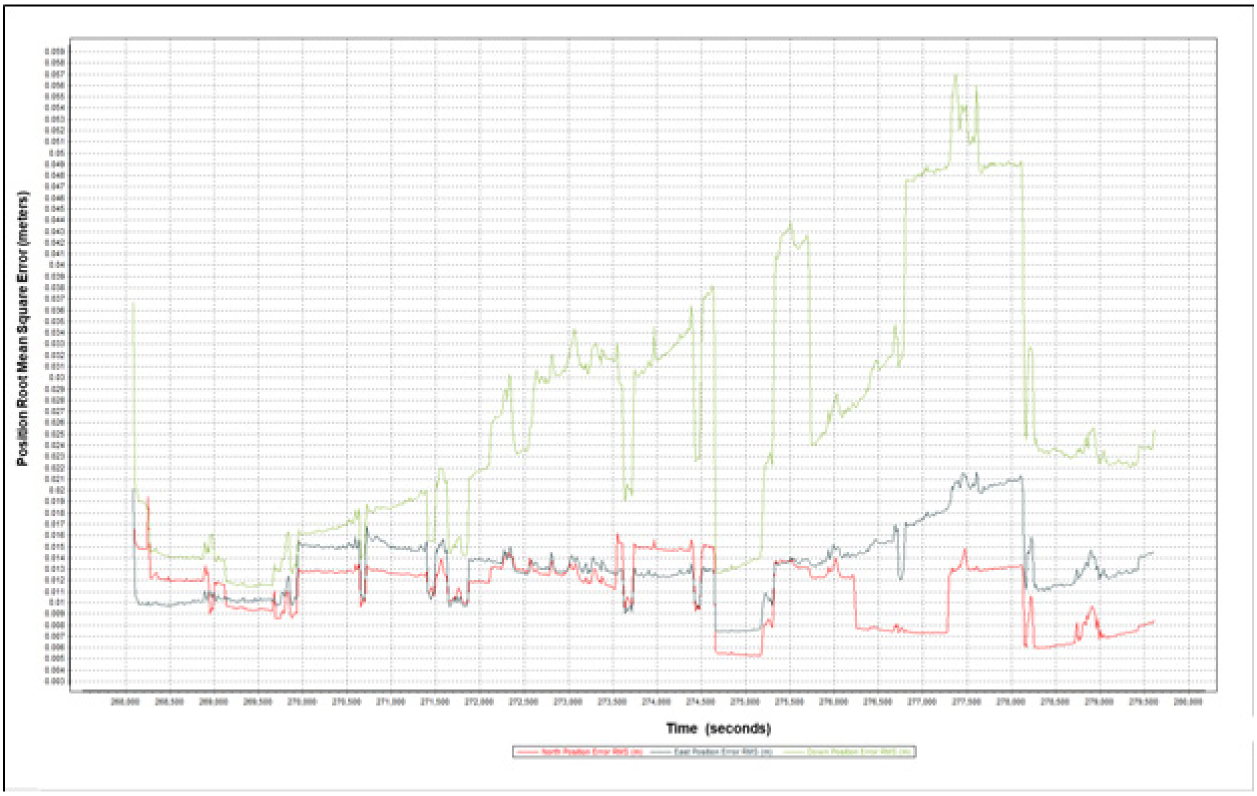

Figure 11 Smoothed Performance Metric of a Caraga Flight 7346GC.

The time of flight was from 266,100 seconds to 279,600 seconds, which corresponds to morning of May 11, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure B-2 shows that the North position RMSE peaks at 1.60 centimeters, the East position RMSE peaks at 2.20 centimeters, and the Down position RMSE peaks at 5.70 centimeters, which are within the prescribed accuracies described in the methodology.

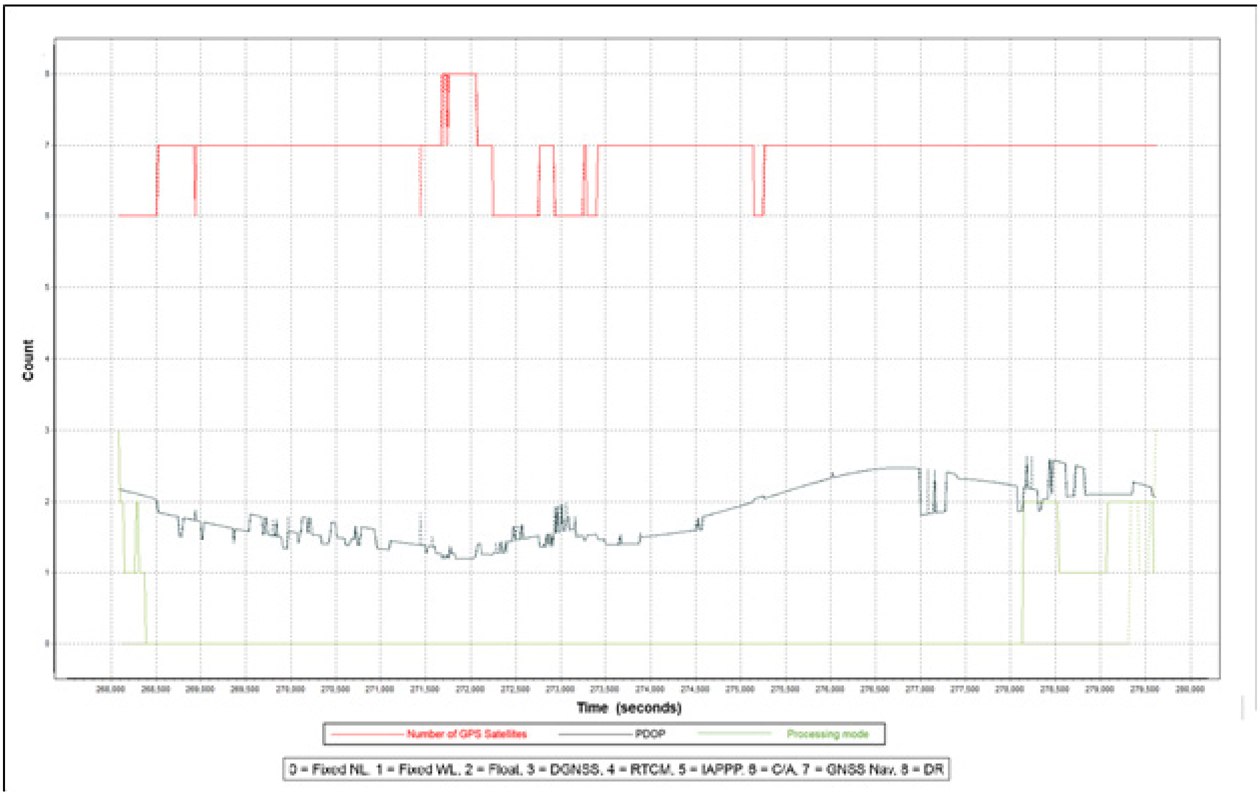

Figure 12. Solution Status Parameters of Caraga Flight 7346GC

The Solution Status parameters of flight 7346GC, one of the Caraga flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure B-3. 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 6 and 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Caraga flights is shown in Figure B-4.

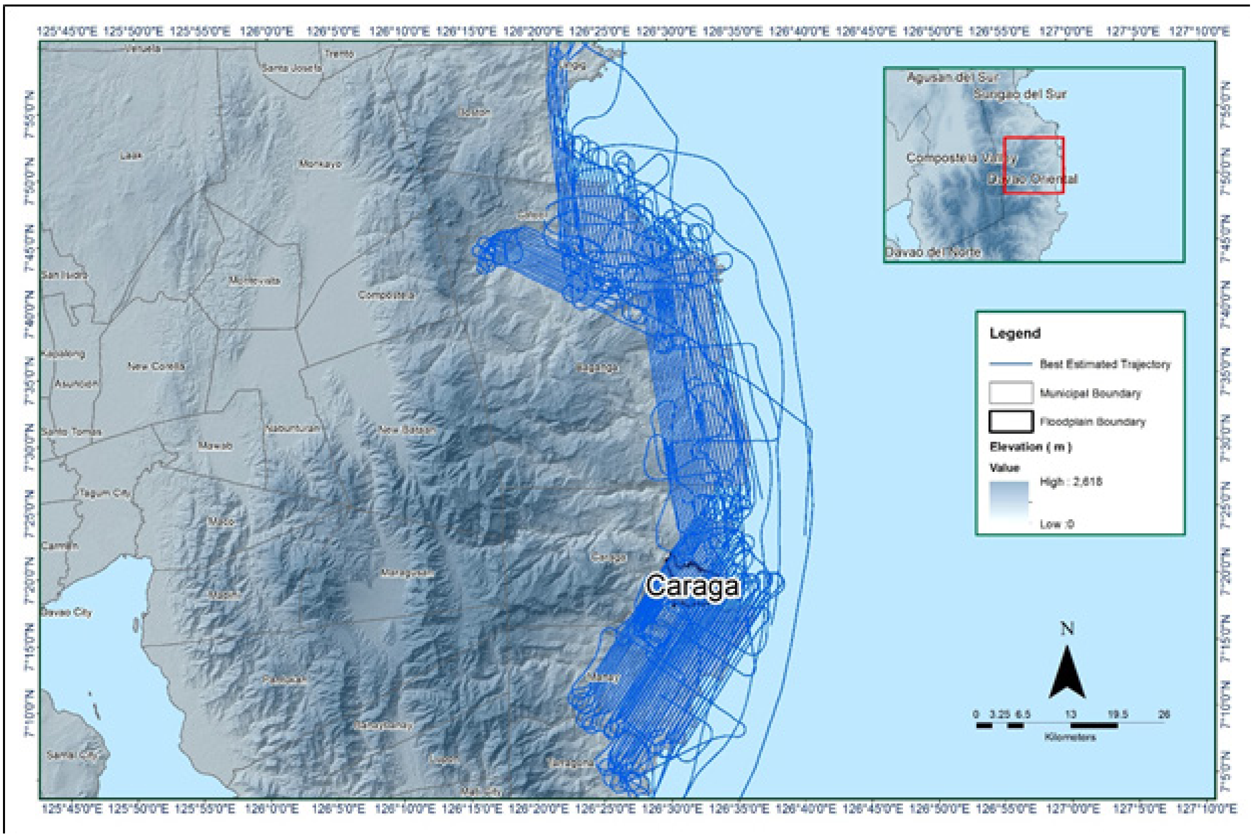

Figure 13. Best Estimated Trajectory for Caraga floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 128 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Caraga floodplain are given in Table B-1.

Table 14. Self-Calibration Results values for Caraga flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000381
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000979
GPS Position Z-correction stdev)	<0.01meters	0.0079

The optimum accuracy is obtained for all Caraga flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex B-1. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Caraga Floodplain is shown in Figure B-5. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

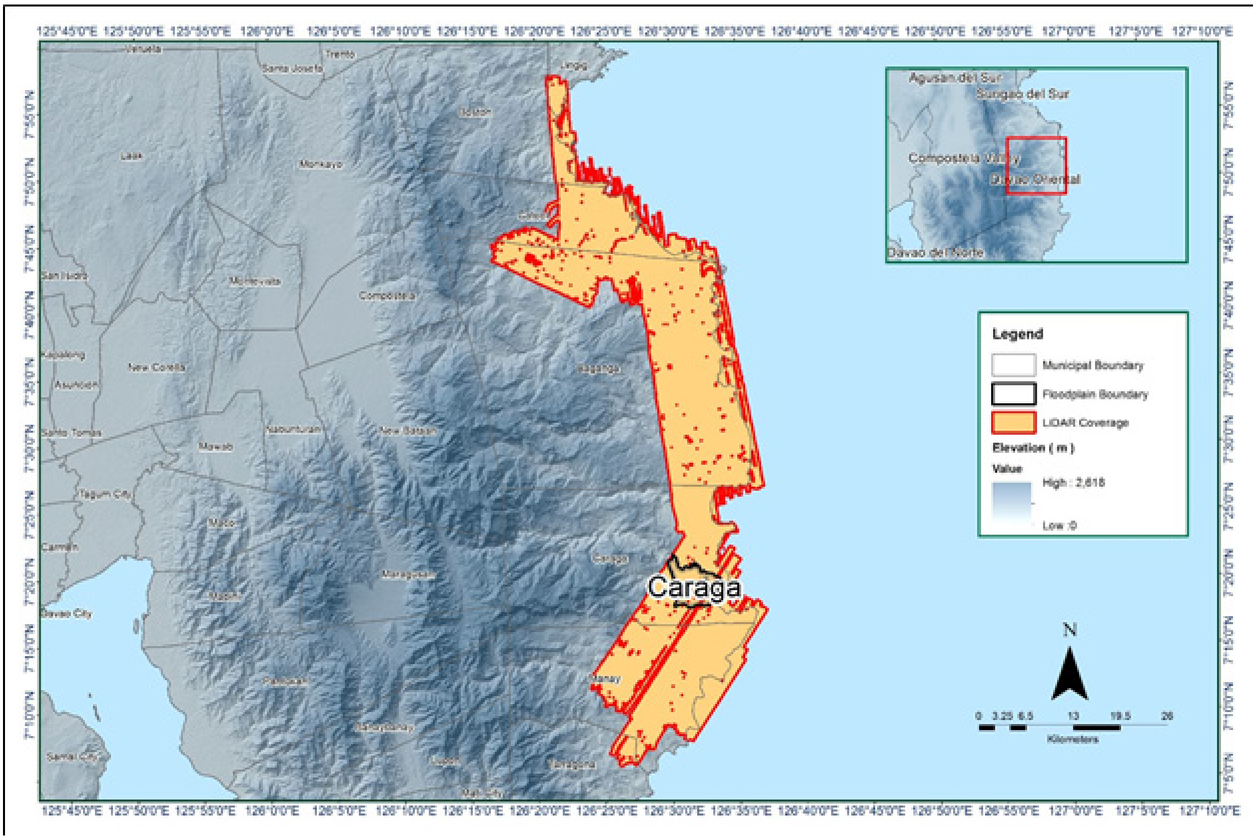

Figure 114 Boundary of the processed LiDAR data over Caraga Floodplain

The total area covered by the Caraga missions is 1,128.36 sq.km that is comprised of eleven (11) flight acquisitions grouped and merged into eight (8) blocks as shown in Table B-2.

Table 15. List of LiDAR blocks for Caraga floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Davao_Oriental_Blk80A	7356GC	217.04
	7357GC	
	7328GC	
Davao_Oriental_Blk80A_additional	7356GC	17.50
Davao_Oriental_Blk80B	7328GC	167.48
	7326GC	
Davao_Oriental_Blk80B_supplement	7366GC	9.71
Davao_Oriental_Blk79AB	7340GC	448.77
	7346GC	
	7348GC	
Davao_Oriental_Blk79C	7339GC	110.00
Davao_Oriental_Blk79D	7366GC	87.53
Davao_Oriental_Blk79E	7372GC	70.33
	7374GC	
TOTAL		**1,128.36 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure B-6. Since the Gemini system both employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

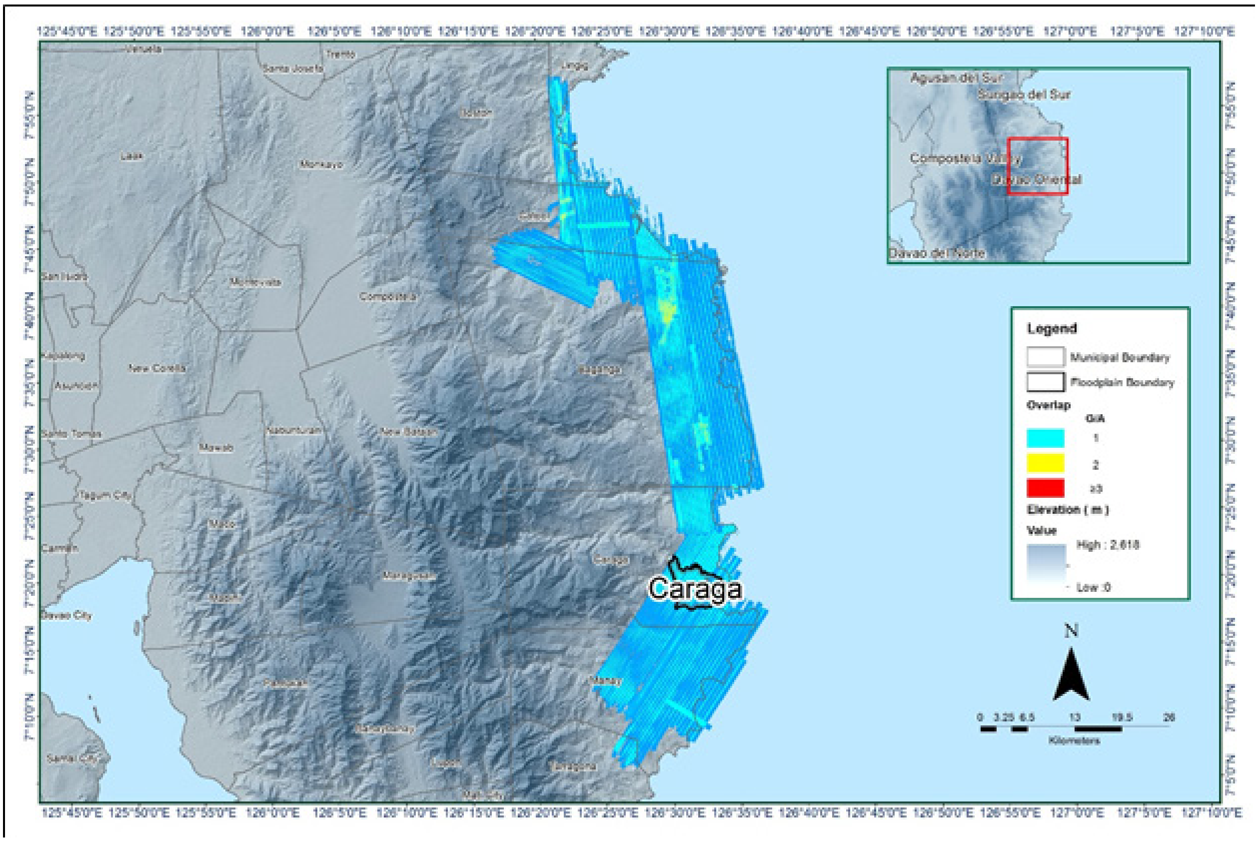

Figure 15. Image of data overlap for Caraga floodplain.

The overlap statistics per block for the Caraga floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.79% and 43.49% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure B-7. It was determined that all LiDAR data for Caraga floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.69 points per square meter.

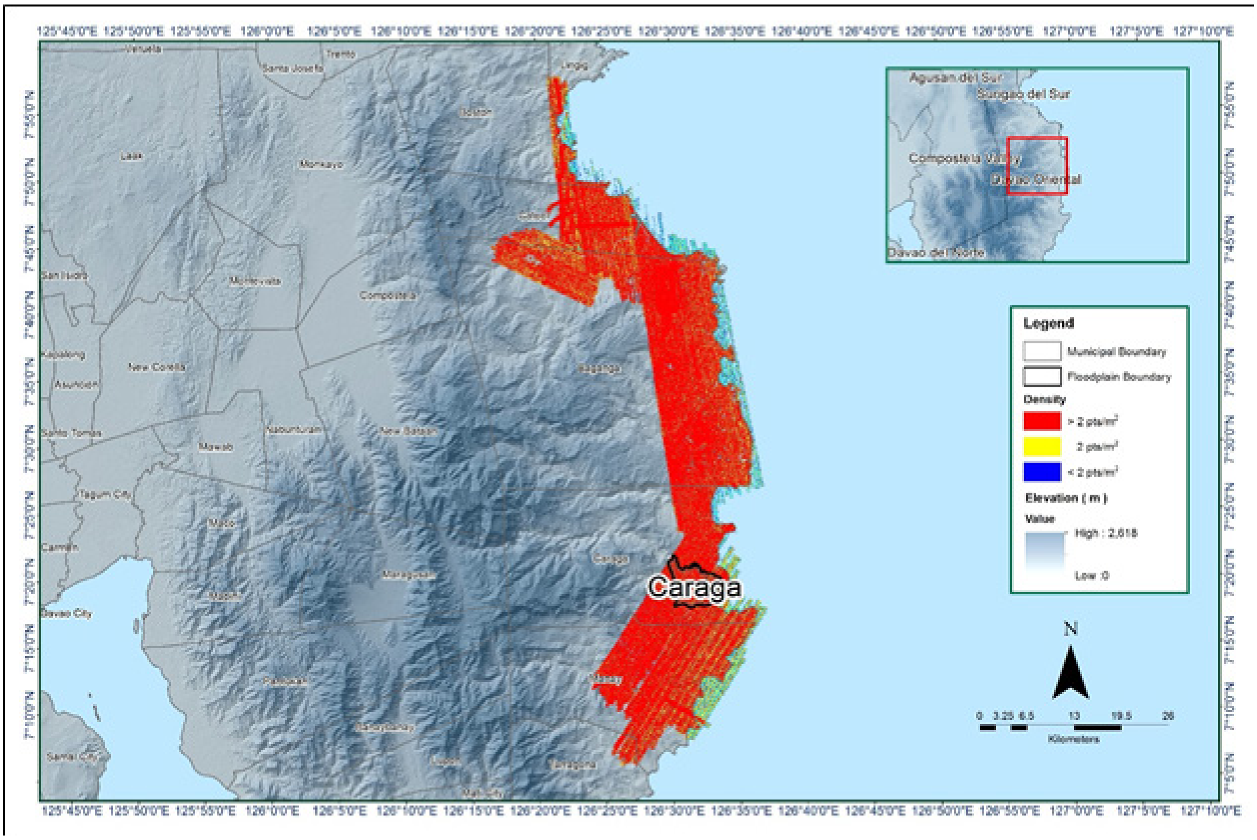

Figure 16. Density map of merged LiDAR data for Caraga floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure B-8. 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.

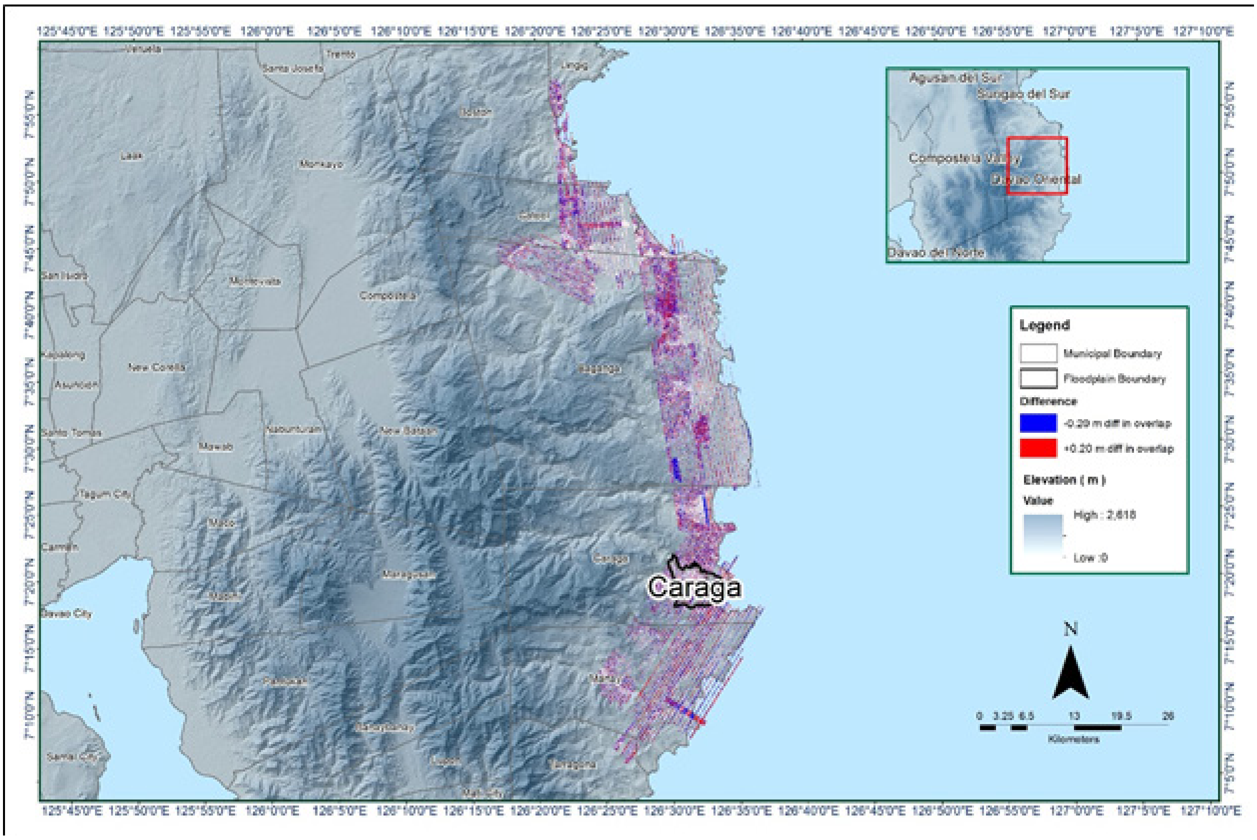

Figure 17. Elevation difference map between flight lines for Caraga floodplain.

A screen capture of the processed LAS data from a Caraga flight 7346GC loaded in QT Modeler is shown in Figure B-9. 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.

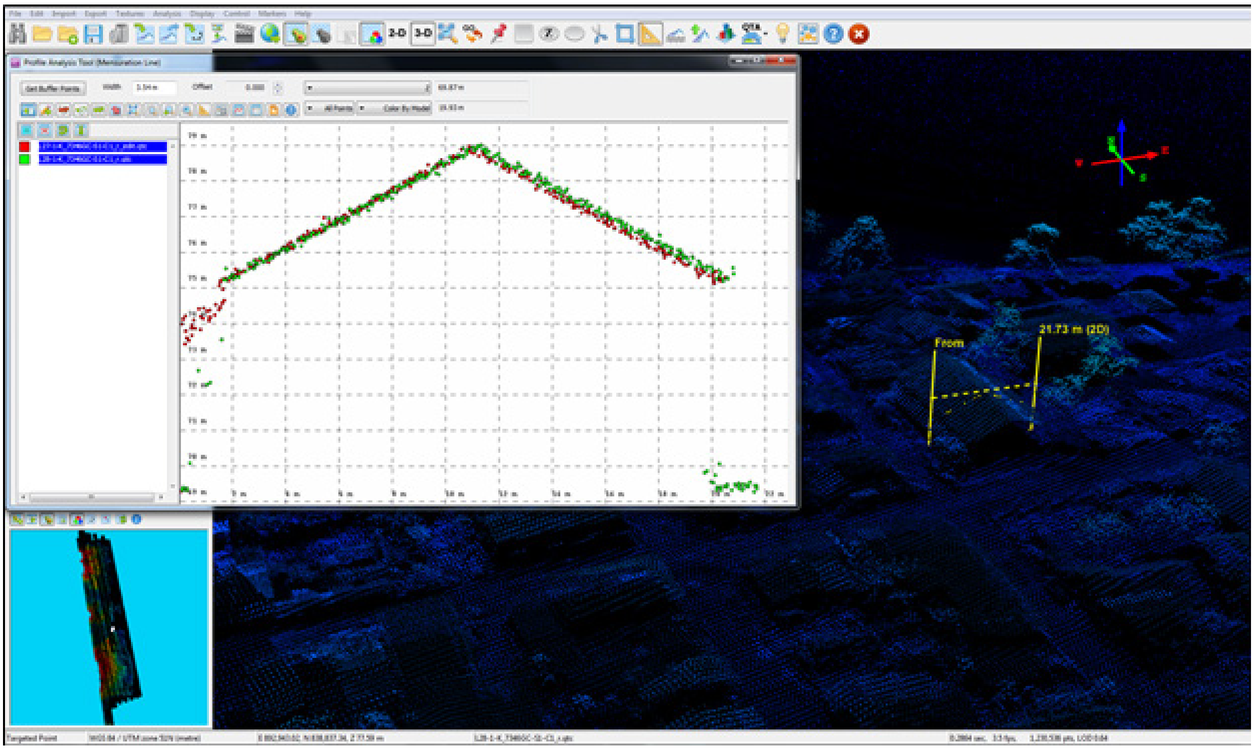

Figure 18. Quality checking for a Caraga flight 7346GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Caraga classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	383,683,916
Low Vegetation	316,730,190
Medium Vegetation	1,258,102,773
High Vegetation	1,519,223,820
Building	19,666,265

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Caraga floodplain is shown in Figure B-10. A total of 1,560 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table B-3. The point cloud has a maximum and minimum height of 911.28 meters and 50.32 meters respectively.

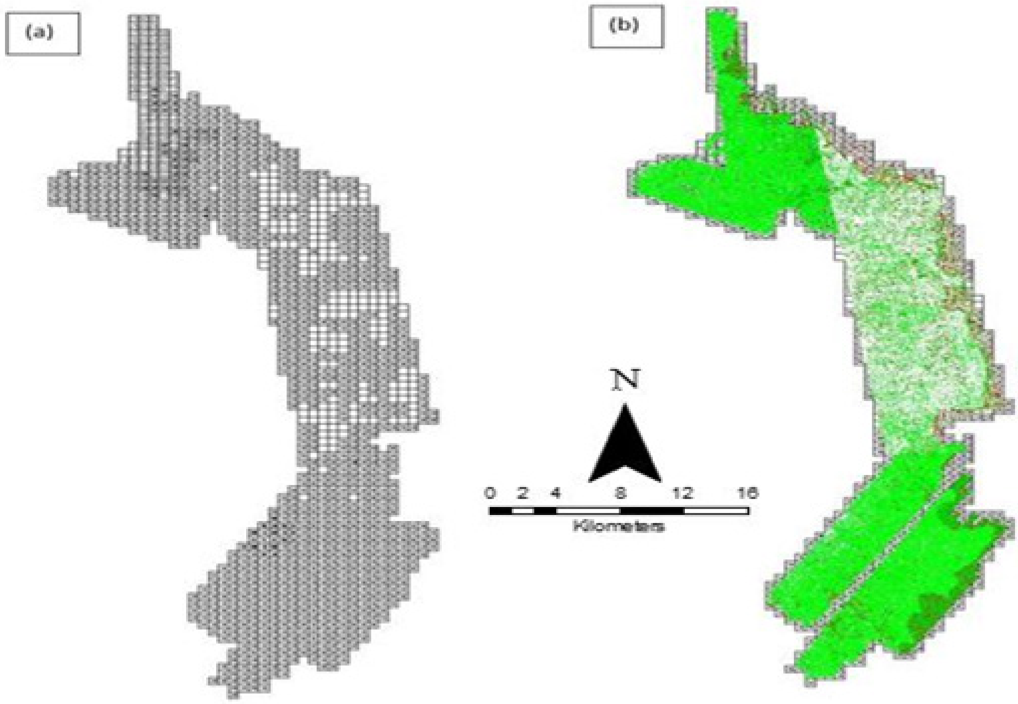

Figure 19. Tiles for Caraga floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure B-11. 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.

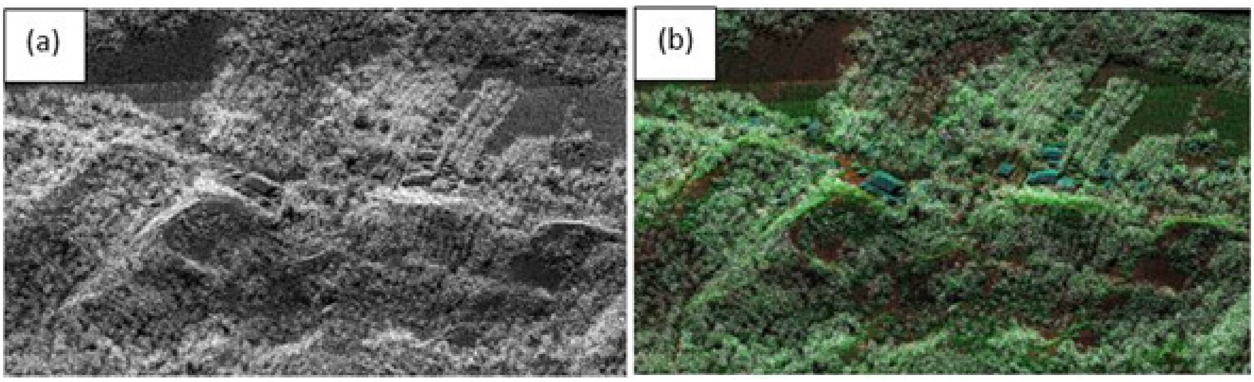

Figure 20. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure B-12. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

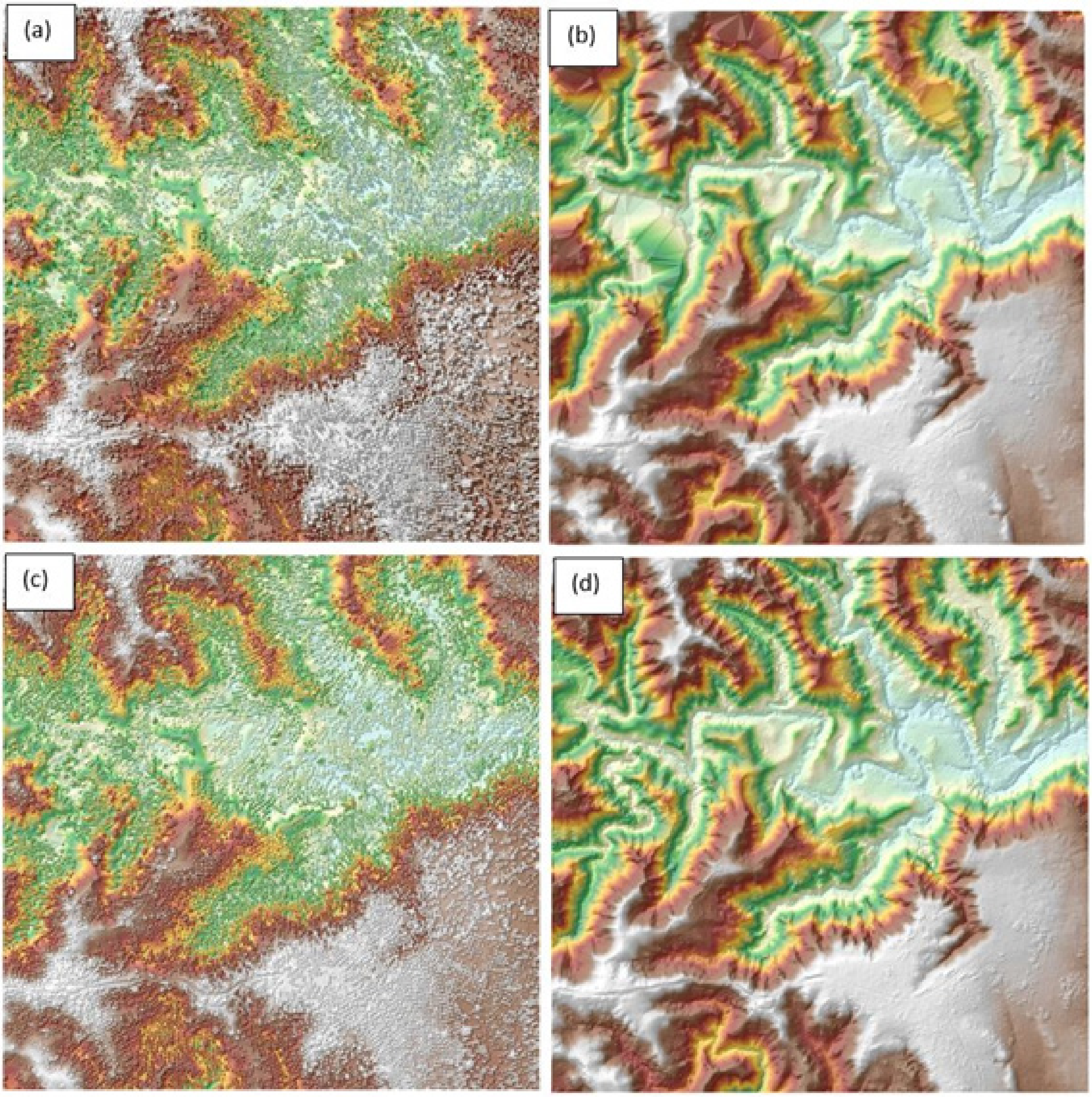

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Caraga floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Caraga floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks was processed for Caraga flood plain. These blocks are composed of DavaoOriental block with a total area of 1,128.36 square kilometers. Table B-4 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Davao_Oriental_Blk80A	217.04
Davao_Oriental_Blk80A_additional	17.50
Davao_Oriental_Blk80B	167.48
Davao_Oriental_Blk80B_supplement	9.71
Davao_Oriental_Blk79AB	448.77
Davao_Oriental_Blk79C	110
Davao_Oriental_Blk79D	87.53
Davao_Oriental_Blk79E	70.33
TOTAL	1,128.36 sq.km

Portions of DTM before and after manual editing are shown in Figure B-13. The bridge (Figure B-13a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure B-13) in order to hydrologically correct the river.

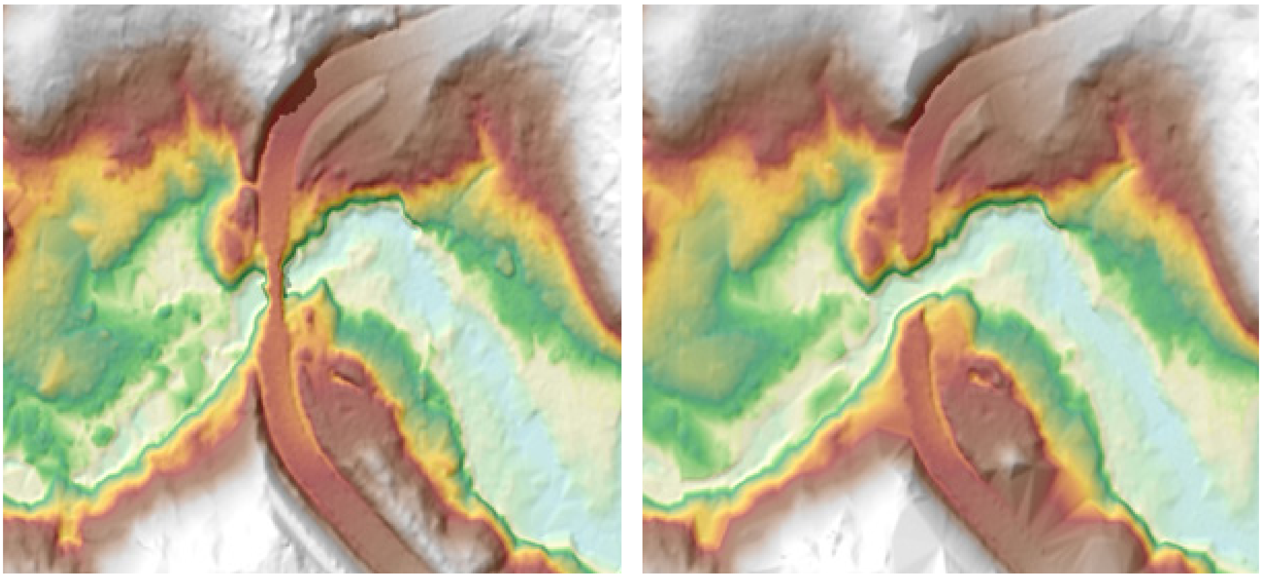

Figure 22. Portions in the DTM of Caraga Floodplain – a bridge before (a) and after (b) manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Sumlog DEM overlapping with the blocks to be mosaicked. Table B-5 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Caraga floodplain is shown in Figure B-14. It can be seen that the entire Caraga floodplain is 100% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Caraga floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Davao_Oriental_Blk80A	9.40	3.70	-2.86
Davao_Oriental_Blk80A_additional	9.00	-2.70	0.36
Davao_Oriental_Blk80B	9.40	6.70	-2.86
Davao_Oriental_Blk80B_supplement	14.20	6.00	-1.70
Davao_Oriental_Blk79AB	1.70	5.50	-3.35
Davao_Oriental_Blk79C	2.00	5.50	-1.49
Davao_Oriental_Blk79D	10.00	5.50	-1.49
Davao_Oriental_Blk79E	-1.70	5.00	-1.64

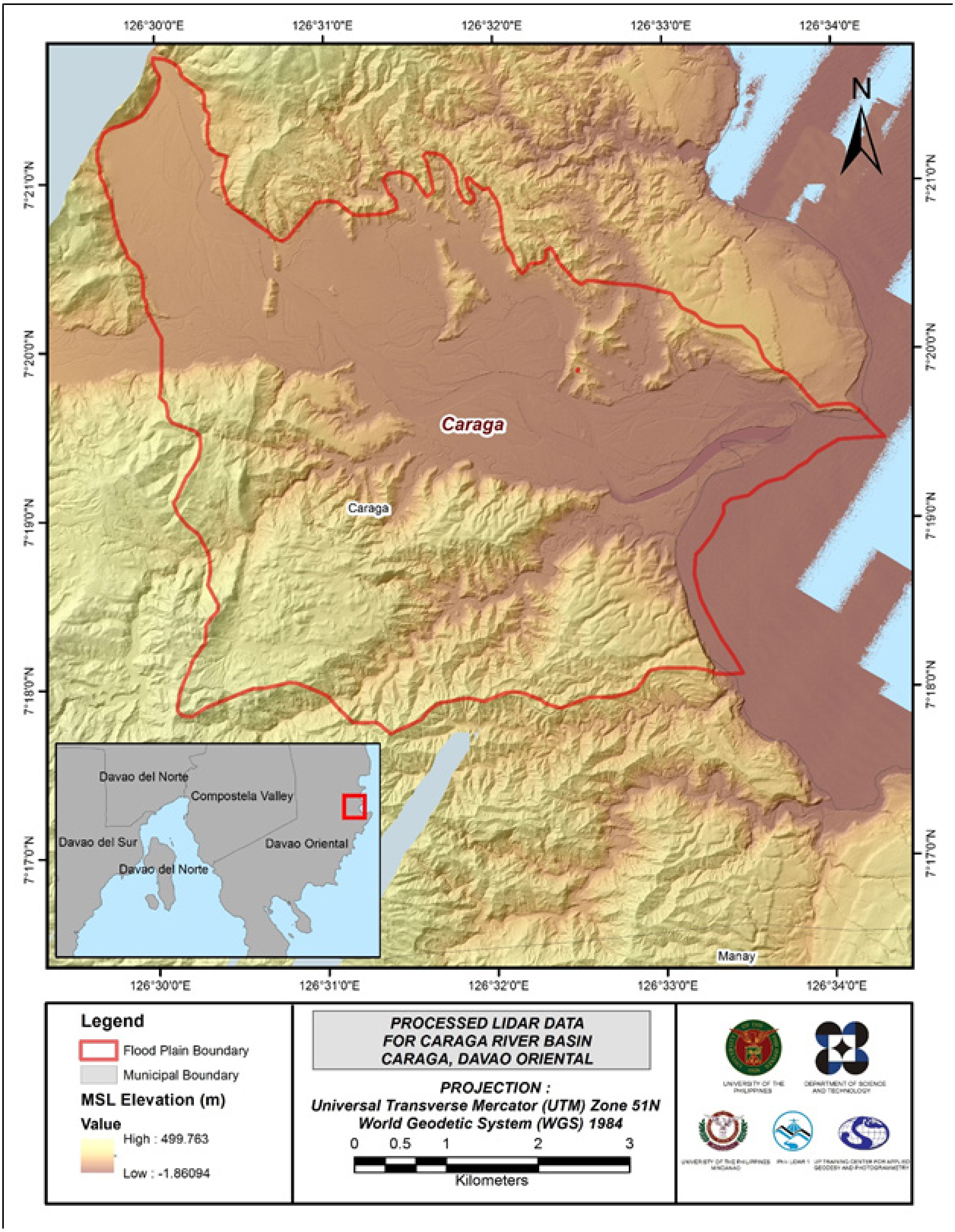

Figure 23. Map of Processed LiDAR Data for Caraga Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Caraga to collect points with which the LiDAR dataset is validated is shown in Figure B-15. A total of 7,104 survey points were used for calibration and validation of Caraga LiDAR data. Random selection of 80% of the survey points, resulting to 5,683 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure B-16. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 1.81 meters with a standard deviation of 0.20 meters. Calibration of Caraga LiDAR data was done by adding the height difference value, 1.81 meters, to Caraga mosaicked LiDAR data. Table B-6 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

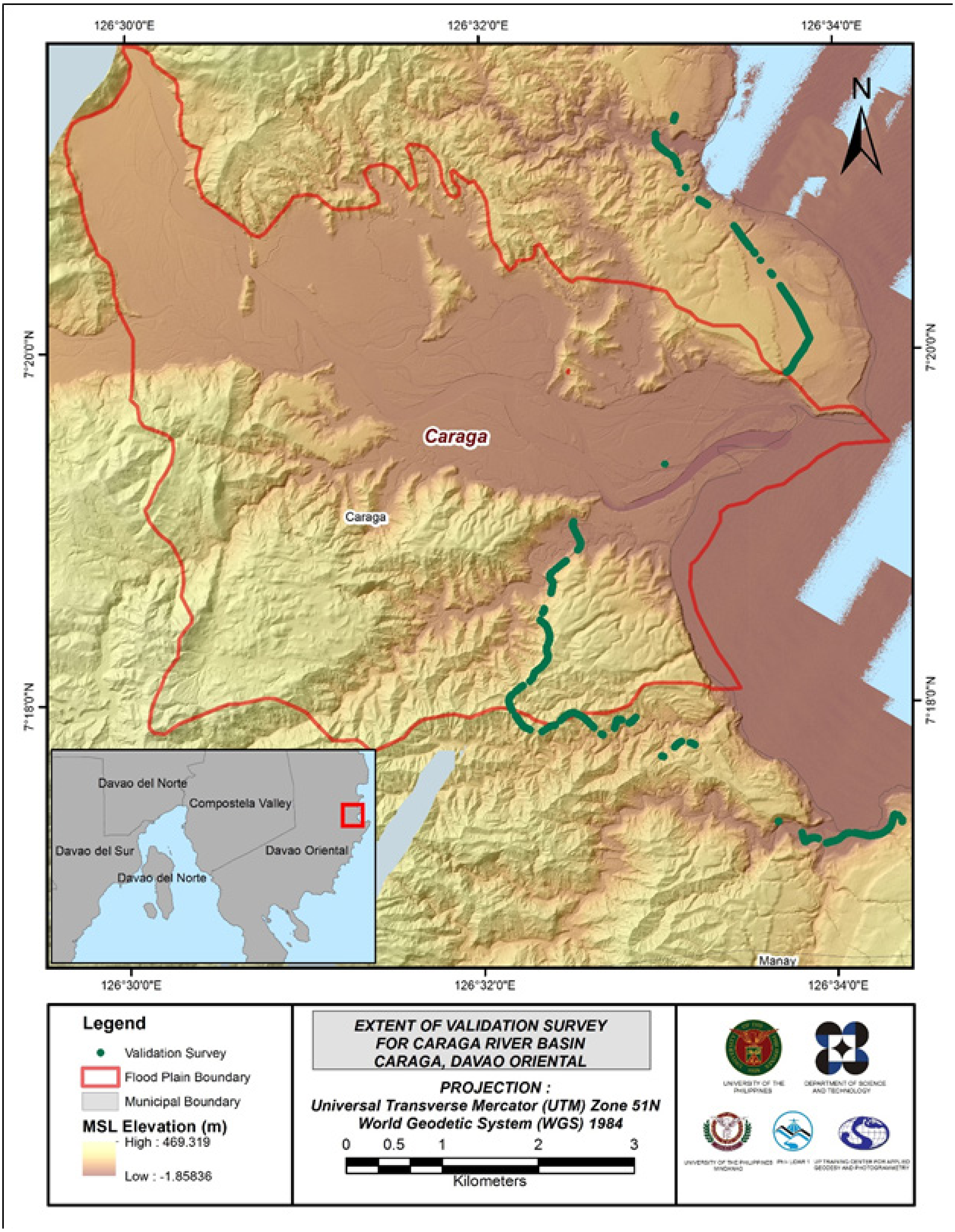

Figure 2. Map of Caraga Flood Plain with validation survey points in green.

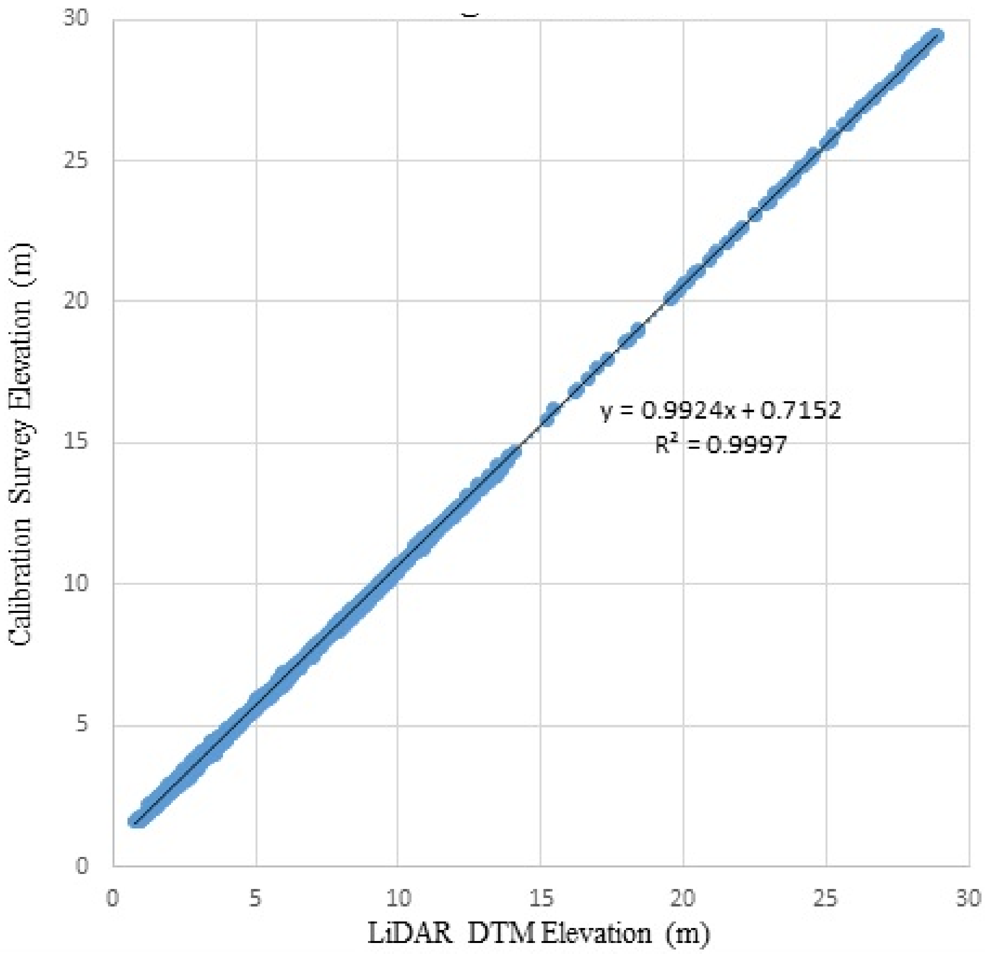

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	1.81
Standard Deviation	0.19
Average	1.80
Minimum	1.41
Maximum	2.20

The remaining 20% of the total survey points, resulting to 1,421 points, were used for the validation of calibrated Caraga DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure B-17. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.20 meters, as shown in Table B-7.

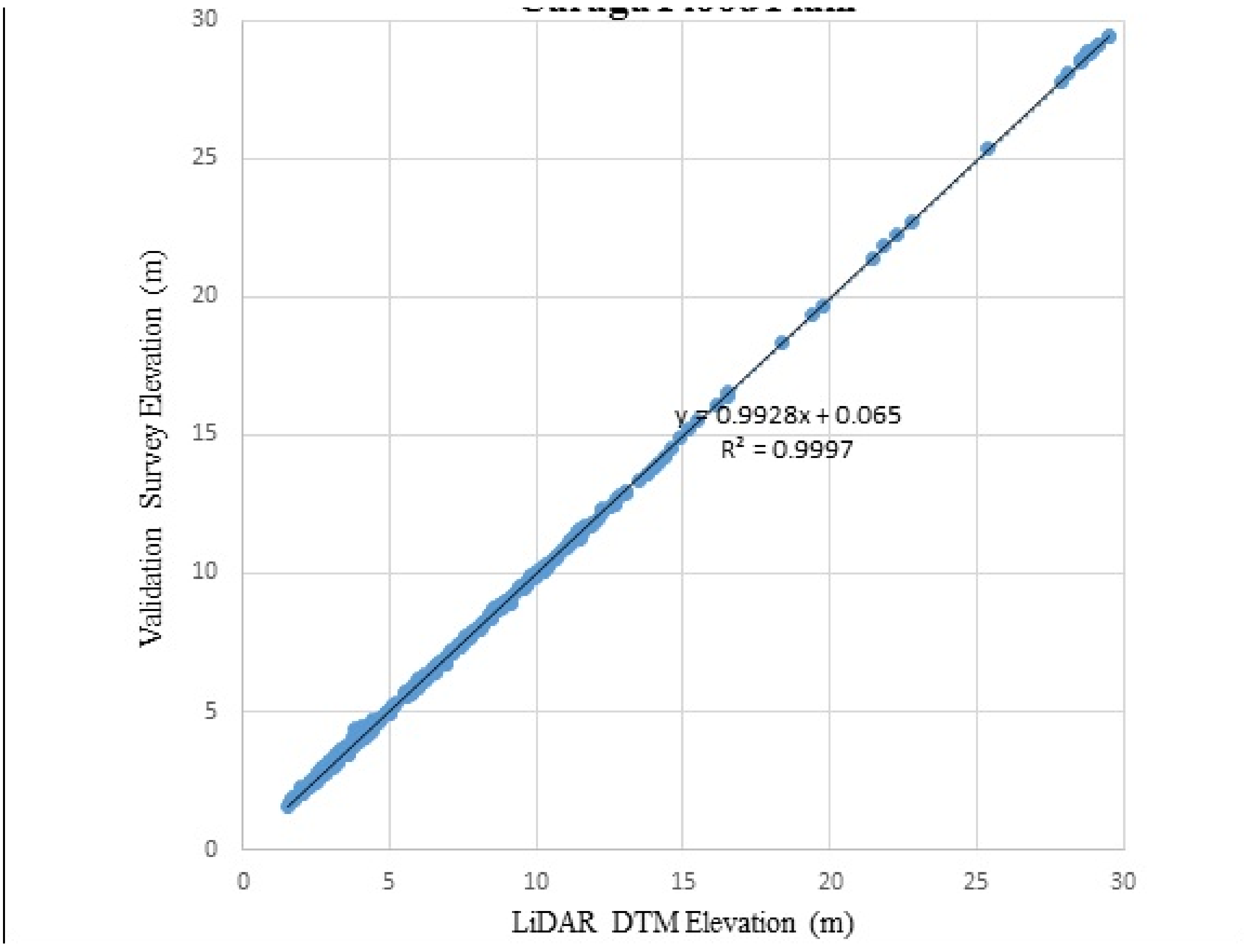

Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.07
Average	0.01
Minimum	-0.16
Maximum	0.19

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only zigzag and centerline data was available for Caraga with 6,769 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 0.23 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Caraga integrated with the processed LiDAR DEM is shown in Figure B-18.

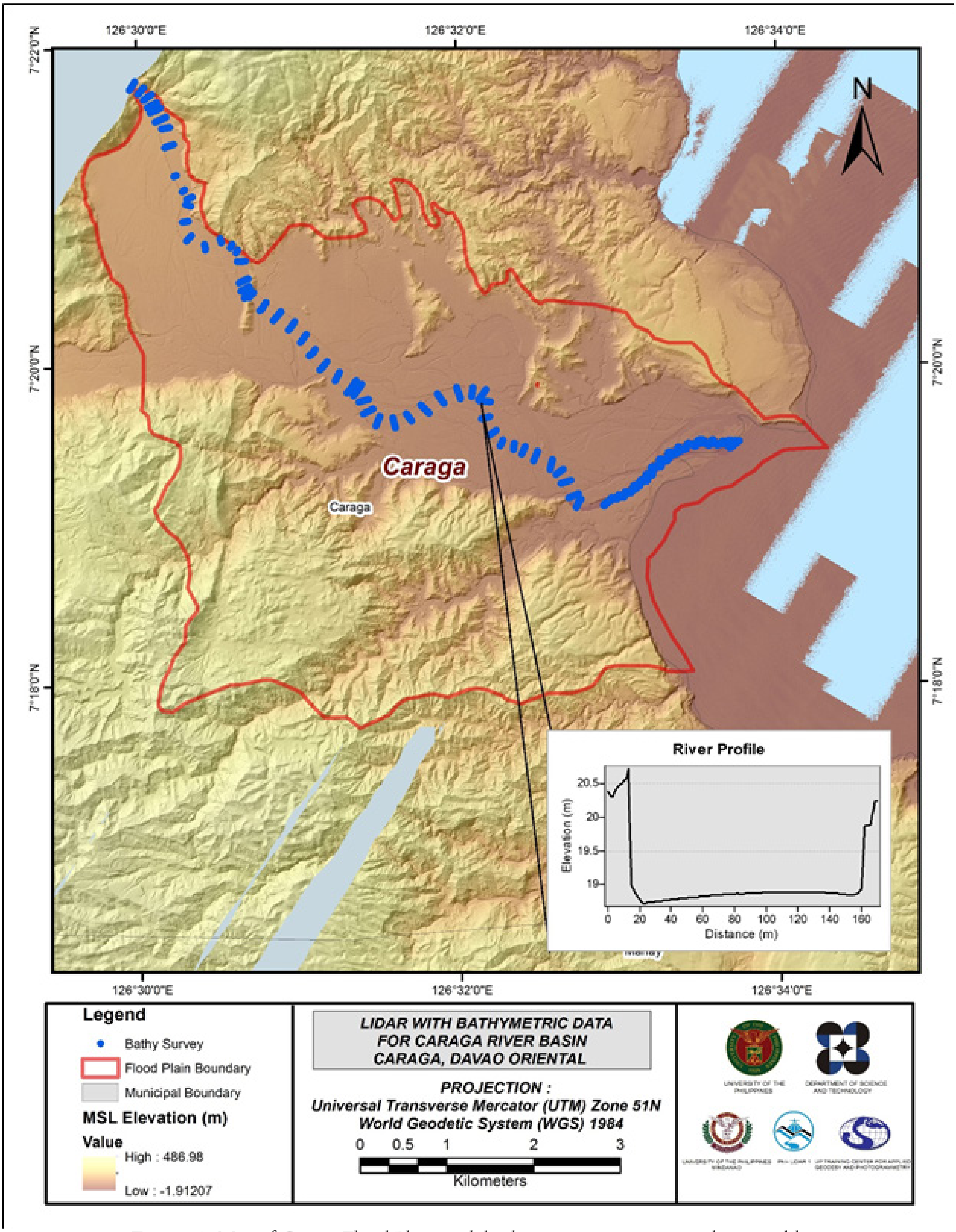

Figure 25. Map of Caraga Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Caraga floodplain, including its 200 m buffer, has a total area of 39.50 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 316 building features, are considered for QC. Figure B-19 shows the QC blocks for Caraga floodplain.

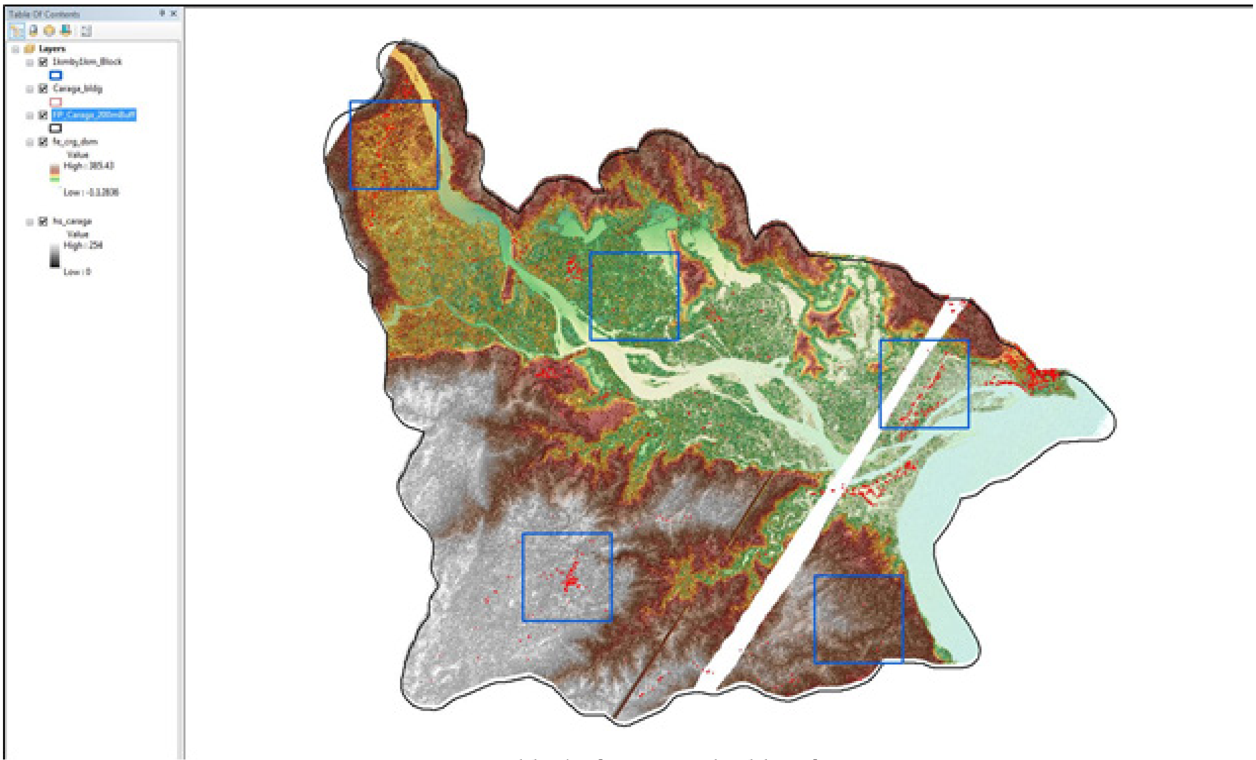

Figure 26. QC blocks for Caraga building features.

Quality checking of Caraga building features resulted in the ratings shown in Table B-8.

Table 21. Details of the quality checking ratings for the building features extracted for the Tanao River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Caraga	99.65	95.25	89.49	PASSED

3.12.2 Height Extraction

Height extraction was done for 1,205 building features in Caraga floodplain. Of these building features, four (4) were filtered out after height extraction, resulting to 1,201 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 11.96m. There were 27 buildings that were not included in the height extraction since the features were only noted to be existing during field validation.

3.12.3 Feature Attribution

Before the actual field validation, courtesy calls were conducted to seek permission and assistance from the Local Government Units (LGUs) of each barangay. This was done to ensure the safety and security in the area for the field validation process to go smoothly. Verification of barangay boundaries was also done to finalize the distribution of features for each barangay.

The courtesy calls and project presentations were done on June 24, 2016. Barangay Health Workers (BHWs) were requested and hired to guide the University of the Philippines Mindanao Phil-LiDAR1 field enumerators during validation. The field work activity was conducted from July 4-14, 2016. The local hires deployed by the barangay captains were given a brief orientation by the field enumerators before the actual field work. The team surveyed the seven (7) barangays covered by the floodplain namely Poblacion, San Pedro, Don Leon Balante, Sobrecarey, Mercedes, San Jose and San Miguel, Caraga Municipality.

According to the Municipal Planning and Development Office (MPDO) during the courtesy call, barangays San Luis, San Antonio, Manurigao, and Lamiawan should also be checked since these areas are traversed by Manurigao River on the northern part of the municipality.

During the field work, there had been issues regarding the political boundaries between Brgy. Poblacion and Brgy. San Jose. Despite this, the field validation continued. Some of the areas in Brgy. San Pedro were across the river and the nearby bridge was still under repair during fieldwork. This then resulted to the assigned local guides, together with the enumerators and SRAs, to go across the Caraga River on a boat maneuvered by a local citizen. Also, some of the areas in barangays San Miguel and Mercedes can’t be reached through van ride due to steep roads—which led to the hiring of motorcycle services. The locals of the said barangays also raised concerns on earthquake risks in their area. In Brgy. Sobrecarey, the SRAs were informed by the local guides that an unknown number of Communist Party of the Philippines–New People's Army (CPP-NPA) rebels went down from their camps to the municipal proper. The captain of the said barangay, however, managed to assure the safety of the validation team.

Table B-9 summarizes the number of building features per type. The 27 building features that were only noted during field validation but are not present on the LiDAR data are also included in this summary since building types for the features are available.On the other hand, Table B-10 shows the total length of each road type, while Table B-11 shows the number of water features extracted per type.

Table B- 9. Building Features Extracted for Caraga Floodplain.

Facility Type	No. of Features
Residential	1,062
School	37
Market	0
Agricultural/Agro-Industrial Facilities	35
Medical Institutions	4
Barangay Hall	4
Military Institution	0
Sports Center/Gymnasium/Covered Court	7
Telecommunication Facilities	1
Transport Terminal	1
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	23
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	3
Other Commercial Establishments	20
Total	1,201
Total	12444

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Caraga	31.05	0.00	4.33	9.17	0.00	44.55

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

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Caraga	2	0	0	0	0	2

A total of 2 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 27 shows the Digital Surface Model (DSM) of Caraga floodplain overlaid with its ground features.

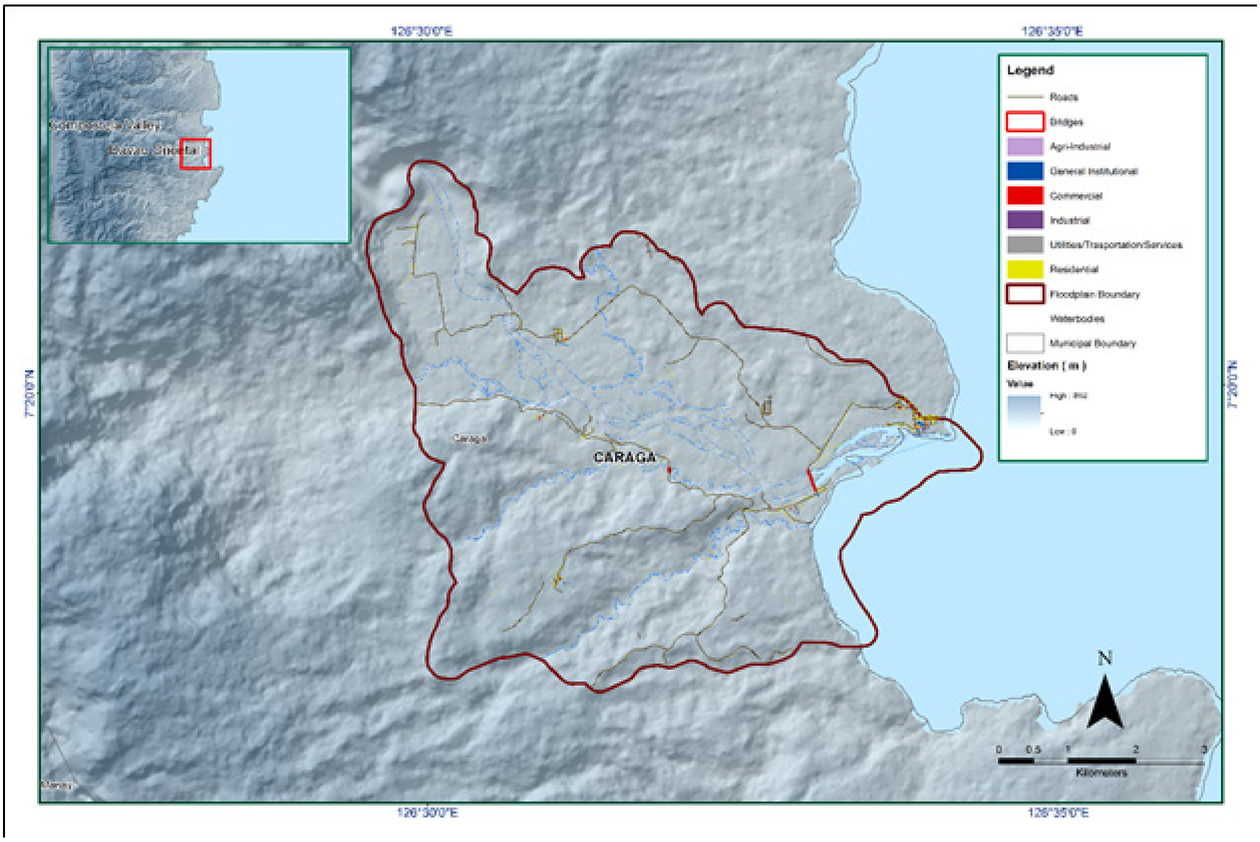

Figure 27. Extracted features for Caraga floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE CARAGA 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 Caraga River Basin covers the Municipality of Caraga in Davao Oriental and three (3) municipalities in Compostela Valley; namely, the municipalities of Pantukan, Maragusan, and New Bataan. The DENR River Basin Control Office (RBCO) states that the Caraga River Basin has a drainage are of 498 km² and an estimated 996 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Caraga River, is part of the fourteen (14) river systems under the PHIL-LIDAR 1 Program partner HEI, UP Mindanao. According to the 2015 national census of PSA, a total of 18,734 persons are residing within the immediate vicinity of the river, which is distributed among barangays Poblacion, San Jose, Don Leon Balante, San Pedro, Pichon, and Santa Fe in the Municipality of Caraga. The leading industries in the Province of Davao Oriental are agriculture, fisheries, and forestry or wood. Coconut, rice, corn, mango, abaca, banana, cassava, and rubber are the major products of the province (Province of Davao Oriental). On January 13, 2014, some municipalities and cities in Regions X, XI, and XIII (CARAGA) were declared under State of Calamity due to Tropical Depression “Agaton”. In the Municipality of Caraga, a total of 53,520 persons were affected by the flashfloods as per NDRRMC report (National Distater Risk Reduction and Management Council, 2014).

In line with this, AB Surveying and Development (ABSD) conducted a field survey in Caraga River on February 28, 2016, March 1, 2016, March 7-10, 2016, and March 20, 2016 with the following scope: reconnaissance; control survey; cross-section and as-built survey at Caraga Bridge in Brgy. San Jose, Caraga, Davao Oriental; and bathymetric survey from its upstream in Brgy. Santa Fe to the mouth of the river located in Brgy. Poblacion, Caraga, with an approximate length of 10.7 km using a Hi-target™ Echo Sounder and Horizon® Total Station. Random checking points for the contractor’s cross-section and bathymetry data were gathered by DVBC on May 10-24, 2016 using a survey grade GNSS receiver Trimble® SPS 985 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Caraga River Basin area. The entire survey extent is illustrated in Figure C- 1.

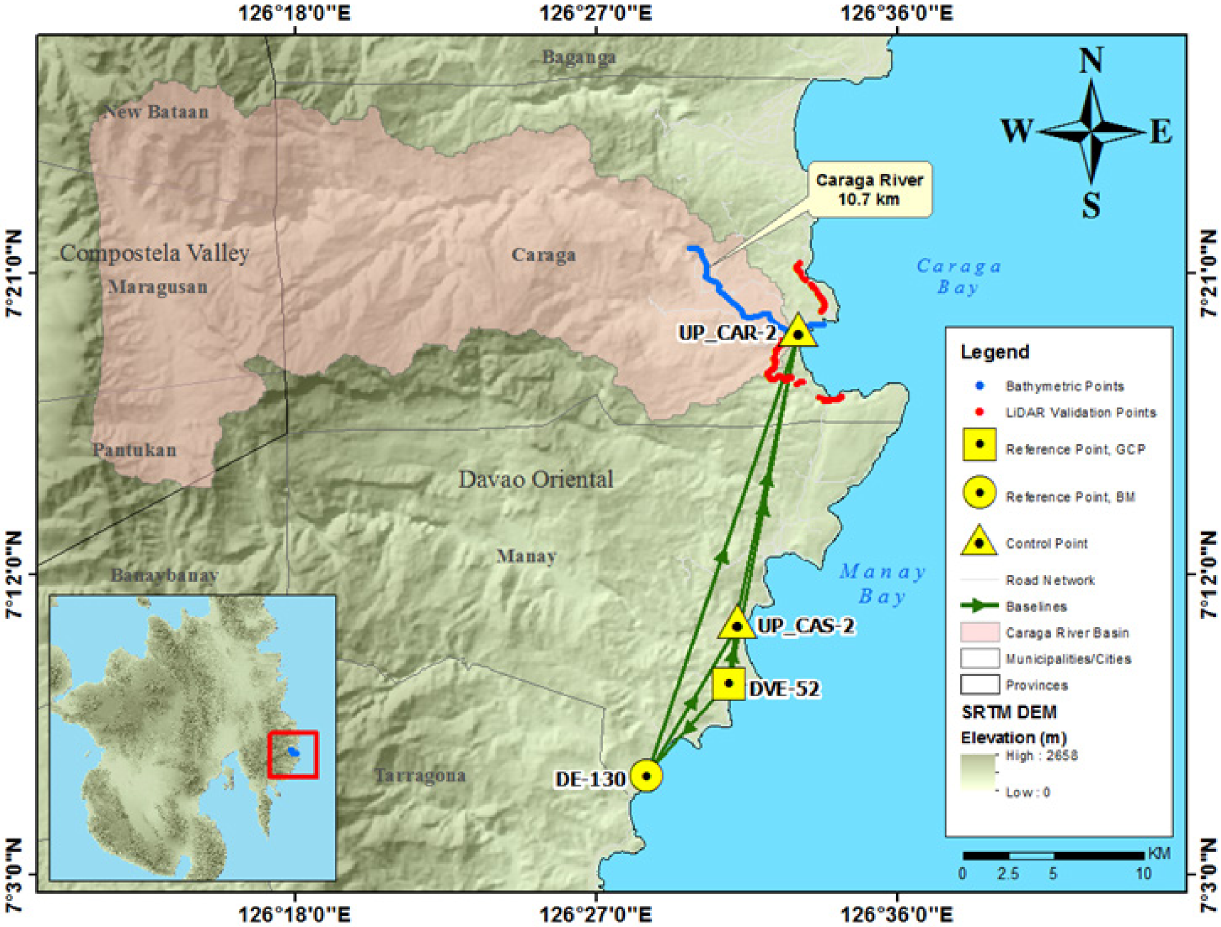


Figure 28. Caraga River Survey Extent

4.2 Control Survey

The GNSS network used for Caraga River is composed of four (4) loops established on May 21, 2016 occupying the following reference points: DVE-52 a second-order GCP, in Brgy. Holy Cross, Manay, Davao Oriental and DE-130, a first-order BM, in Brgy. San Ignacio, Manay, Davao Oriental.

Two (2) control points established in the area by ABSD were also occupied: UP_CAR-2 beside the railings near Caraga Bridge in Brgy. Poblacion, Caraga, Province of Davao Oriental and UP_CAS-2 located beside the railings near Casaunan Bridge in Brgy. Zaragosa, Manay, Davao Oriental.

The summary of reference and control points and its location is summarized in Table C- 1 while GNSS network established is illustrated in Figure C- 2.

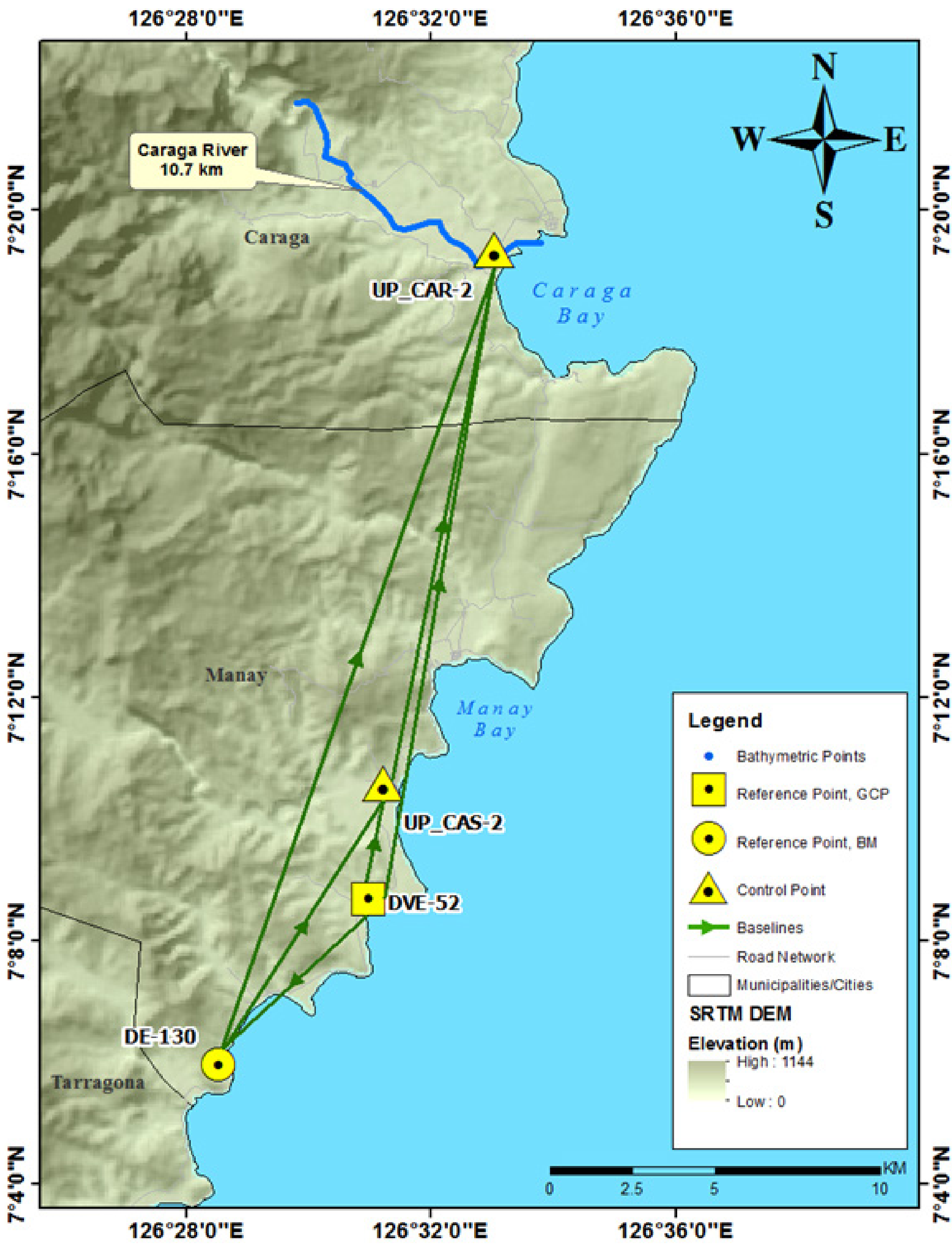


Figure 29. Caraga River Basin Control Survey Extent

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
DVE-52	2nd order, GCP	7°08'41.11589"N	126°30'57.88590"E	83.666	19.242	2007
DE-130	1st order, BM	7°05'57.25021"N	126°28'30.44531"E	101.499	36.988	2009
UP_CAR-2	Established	7°19'20.88068"N	126°33'02.08750"E	72.980	7.391	3-11-16
UP_CAS-2	Established	7°10'34.98817"N	126°31'12.23401"E	74.558	9.812	3-11-16

The GNSS set-ups on recovered reference points and established control points in Caraga River are shown from Figure C- 3 to Figure C- 6.

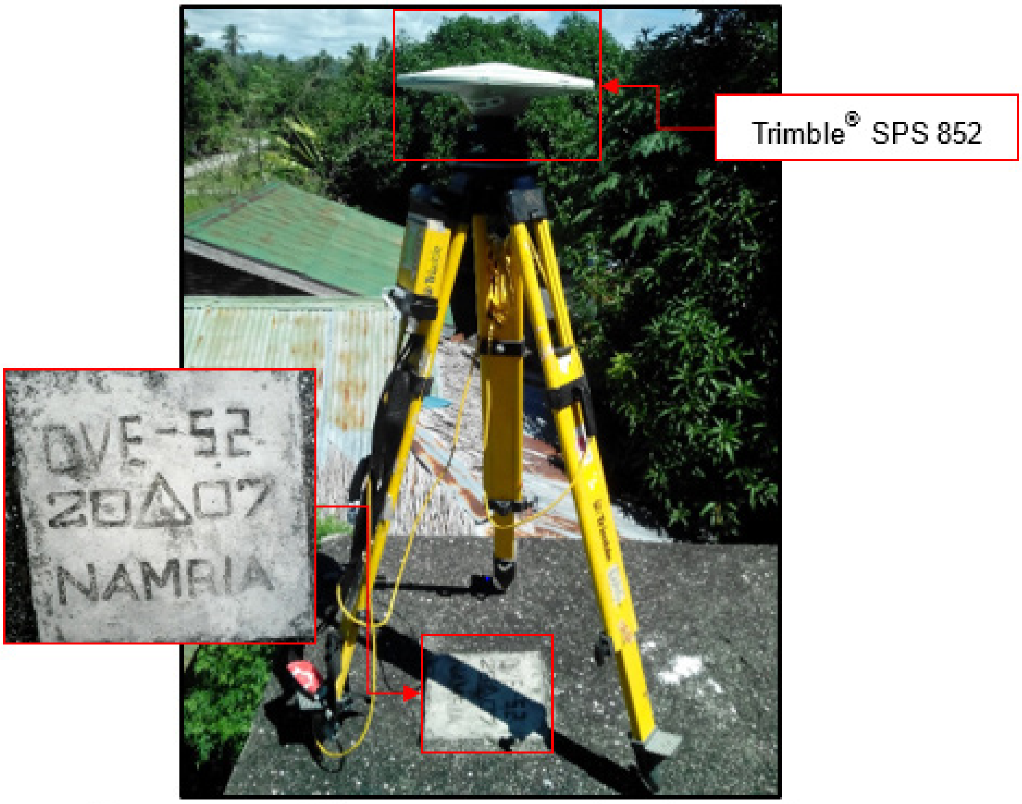


Figure 30 GNSS base set up, Trimble® SPS 852, at DVE-52, located on top of a water reservoir inside the grounds of the barangay of Brgy. Holy Cross in Manay, Davao Oriental

Figure 31 GNSS receiver set up, Trimble® SPS 985, at DE-130, located on top of a culvert at the side of the road in Brgy. San Ignacio, Municipality of Manay, Province of Davao Oriental

Figure 32 GNSS receiver set up, Trimble® SPS 852, at UP_CAR-2, located at the side of the railing near Caraga Bridge in Brgy. Poblacion, Caraga, Davao Oriental

Figure 33 GNSS receiver set up, Trimble® SPS 985, at UP_CAS-2, located beside the railings near Casaunan Bridge in Brgy. Zaragosa, Manay, Davao Oriental

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 Caraga River Basin is summarized in Table C- 2 generated by TBC software.

Table 25. Baseline Processing Report for Caraga River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
DVE-52 --- UP_CAR-2	5-21-2016	Fixed	0.007	0.017	10°58'11"	20019.494	-10.696
DE-130 – UP_CAR-2	5-21-2016	Fixed	0.020	0.037	18°38'54"	26056.144	-28.533
DE-130 ---	5-21-2016	Fixed	0.019	0.048	30°11'24"	9871.200	-26.967
UP_CAS-2	5-21-2016	Fixed	0.008	0.032	11°46'50"	16503.147	-1.535
UP_CAS-2 ---	5-21-2016	Fixed	0.011	0.031	221°57'01"	6768.248	17.831
UP_CAR-2	5-21-2016	Fixed	0.004	0.014	7°10'21"	3525.735	-9.099
DVE-52 --- DE-130	5-21-2016	Fixed	0.011	0.031	221°57'01"	6768.248	17.831
DVE-52 --- UP_CAS-2	5-21-2016	Fixed	0.004	0.014	7°10'21"	3525.735	-9.099

As shown Table C- 2 a total of six (6) baselines were processed with coordinates of DVE-52 and elevation of DE-130 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown from Table C- 3 to Table C- 5 for the complete details. Refer to Appendix C for the computation for the accuracy of ABSD.

The four (4) control points, DVE-52, DE-130, UP-CAR-2, and UP_CAR-2 were occupied and observed simultaneously to form a GNSS loop. The coordinate values of DVE-52 and elevation of DE-130 were held fixed during the processing of the control points as presented in Table C- 3. Through these reference points, the coordinates and elevation 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)
DE-130	Global	Fixed	Fixed	Fixed	
DVE-52	Global	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table C- 4. All fixed control points have no values for grid errors and elevation error.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
DE-130	785478.959	0.007	221096.035	0.015	36.988	?	e
DVE-52	790491.017	?	225649.982	?	19.242	0.046	LL
UP_CAR-2	810133.793	0.004	229568.764	0.009	7.391	0.048	
UP_CAS-2	793988.582	0.004	226109.356	0.006	9.812	0.049	

The results of the computation for accuracy are as follows:

a. DE-130

horizontal accuracy = $\sqrt{(0.7)^2 + (1.5)^2}$

= $\sqrt{(0.49 + 2.25)}$

= 2.74 < 20 cm

vertical accuracy = Fixed

b. DVE-52

horizontal accuracy = Fixed

vertical accuracy = 4.6 < 10 cm

c. UP_CAR-2

horizontal accuracy = $\sqrt{(0.4)^2 + (0.9)^2}$

= $\sqrt{(0.16 + 0.81)}$

= 0.97 < 20 cm

vertical accuracy = 4.8 < 10 cm

d. UP_CAS-2

horizontal accuracy = $\sqrt{(0.4)^2 + (0.6)^2}$

= $\sqrt{(0.16 + 0.36)}$

= 0.52 < 20 cm

vertical accuracy = 4.9 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
DE-130	N7°05'57.25021"	E126°28'30.44531"	101.499	?	e
DVE-52	N7°08'41.11589"	E126°30'57.88590"	83.666	0.046	LL
UP_CAR-2	N7°19'20.88068"	E126°33'02.08750"	72.980	0.048	
UP_CAS-2	N7°10'34.98817"	E126°31'12.23401"	74.558	0.049	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table C- 5. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met. The summary of reference control points used is indicated in Table C- 6.

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude		Northing (m)	Easting (m)	BM Ortho (m)
DVE-52	2nd order, GCP	7°08'41.11589"N	126°30'57.88590"E	83.666	790491.017	225649.982	19.242
DE-130	1st order, BM	7°05'57.25021"N	126°28'30.44531"E	101.499	785478.959	221096.035	36.988
UP_CAR-2	Established	7°19'20.88068"N	126°33'02.08750"E	72.980	810133.793	229568.764	7.391
UP_CAS-2	Established	7°10'34.98817"N	126°31'12.23401"E	74.558	793988.582	226109.356	9.812

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

Cross-section and as-built surveys were conducted on March 20, 2016 at the downstream side of Caraga Bridge in Brgy. San Jose, Caraga as shown in Figure C- 7. A Horizon® Total Station was utilized for this survey as shown in Figure C- 8.

Figure 34. Caraga Bridge facing upstream

Figure 35. As-built survey of Caraga Bridge

The cross-sectional line of Caraga Bridge is about 306 m with one hundred eighty-four (184) cross-sectional points using the control points UP_CAR-2 and UP_CAR-3 as the GNSS base stations. The cross-section diagram and the bridge data form are shown in Figure C- 10 and Figure C- 11. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on May 14, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole, as seen in Figure C- 9.

Figure 36. Gathering of random cross-section points along Caraga Bridge

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.01 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets. The obtained value is not within the required range of R2 because the cross-section points gathered by ABSD add DVBC were on paved or concrete roads because Caraga Bridge was under construction.

In addition to linear square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.056 was acquired. The computed RMSE value is within the accuracy requirement of the program.

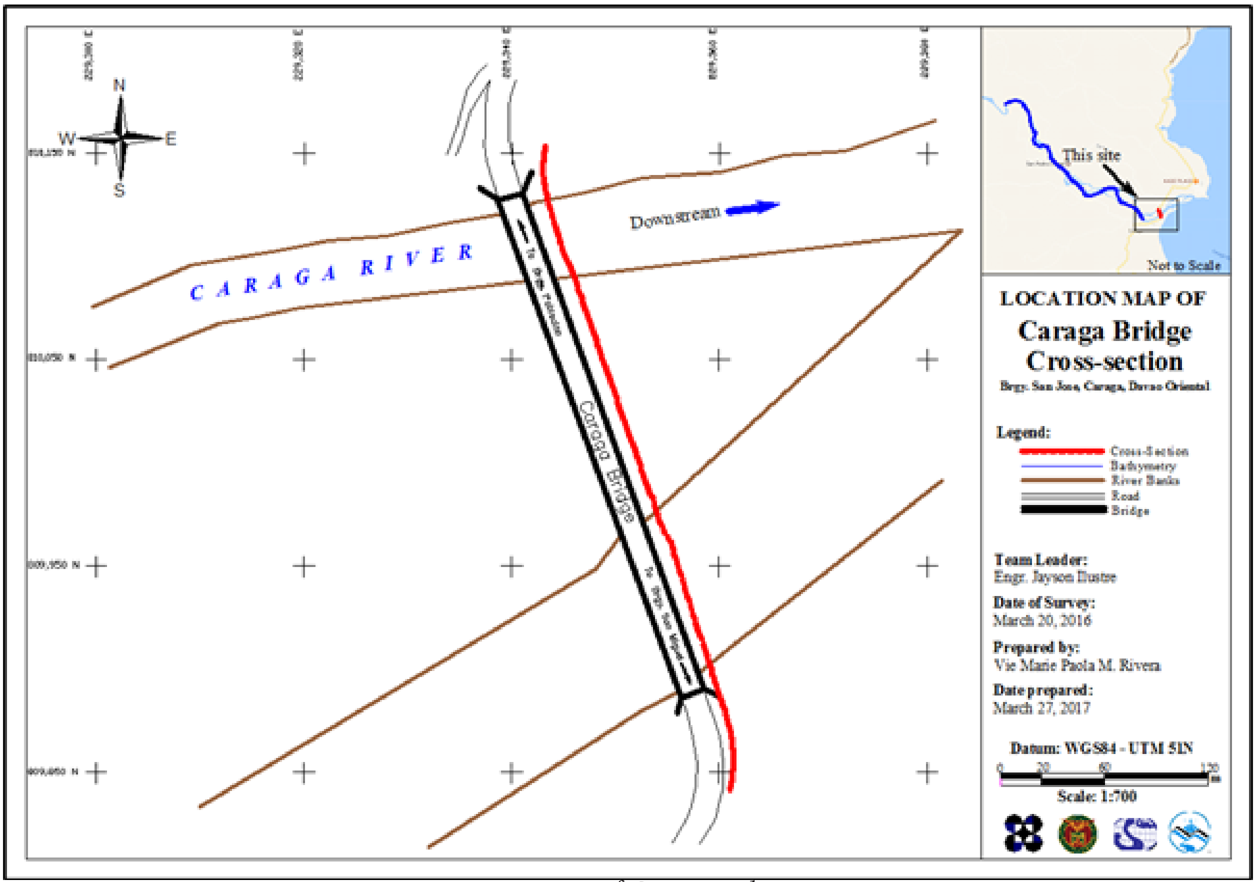


Figure 37 . Location map of Caraga Bridge cross section

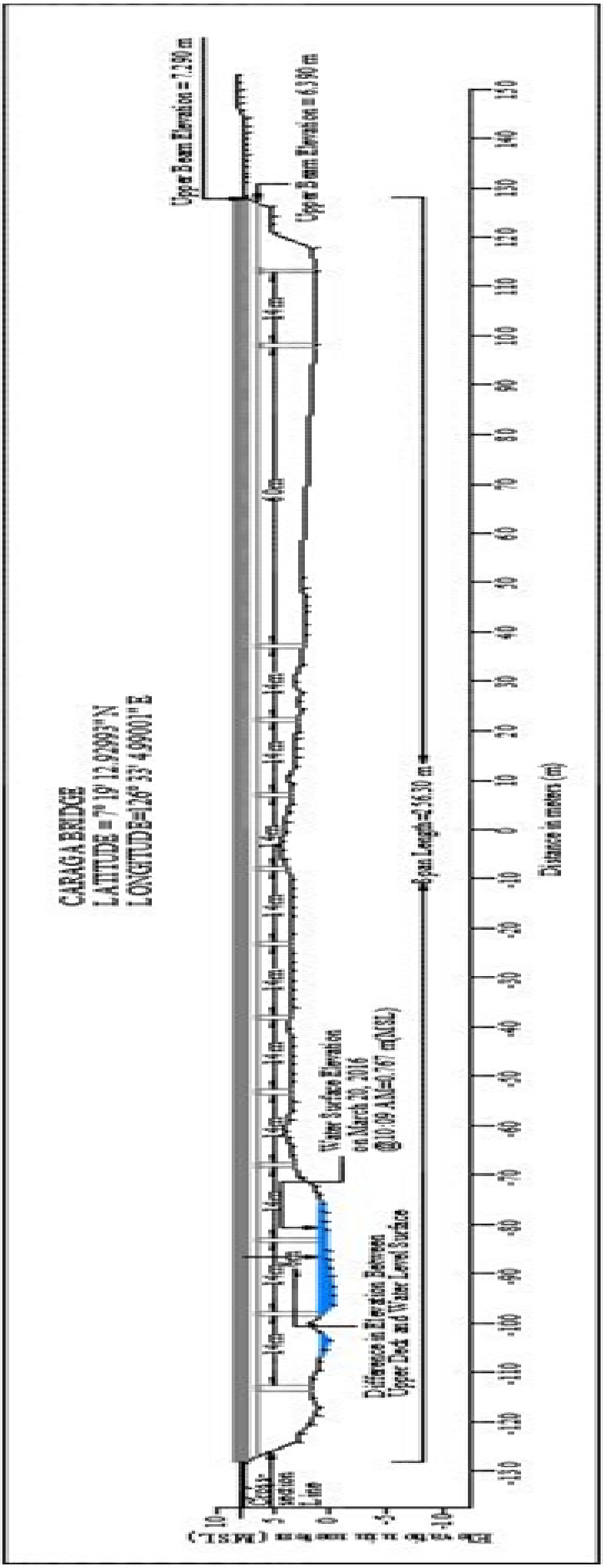


Figure 38. Caraga Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: CARAGA BRIDGE

River Name: CARAGA RIVER

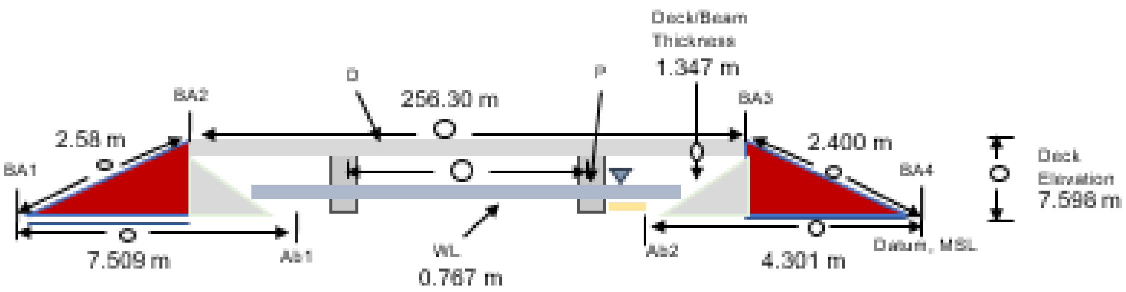
Location (Brgy, City, Region): Brgy. San Jose, Caraga, Davao Oriental

Survey Team: Jayson Illustre, Ryan Antonio

Date and Time: March 20, 2016, 10:09 AM

Flow Condition: low ✔ normal high

Cross-sectional View (not to scale)



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

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	2.58 m	Under Construction
2. BA2-BA3	256.30 m	
3. BA3-BA4	2.400 m	
4. BA1-Ab1	7.509 m	
5. Ab2-BA4	4.301 m	
6. Deck/beam thickness	1.347 m	
7. Deck elevation	7.598 m	

Note: Observer should be facing downstream

Figure 39.Caraga Bridge Data Sheet

Water surface elevation of Caraga River was determined by a Horizon® Total Station on March 20, 2016 at 10:09 AM at Caraga Bridge area with a value of 0.767 m in MSL as shown in Figure C- 10. This was translated into marking on the bridge's pier as shown in Figure C- 12. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Caraga River, UP Mindanao.

Figure 40. Water-level markings on Caraga Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on May 13, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the front of the vehicle as shown in Figure C- 13. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.476 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP_CAR-2 occupied as the GNSS base station in the conduct of the survey.

Figure 41. Validation points acquisition survey set-up for Caraga River

The survey started from Brgy. Santiago, Caraga, Davao Oriental going north along national high way, traversing three (3) barangays in the Municipality of Caraga, and ended in Brgy. Palma Gil, Caraga, Davao Oriental. The survey gathered a total of 815 points with approximate length of 15.28 km using UP_CAR-2 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure C- 14. A gap in the dataset is due to the unpaved roads leading to Caraga Bridge; thus, no validation points were acquired.

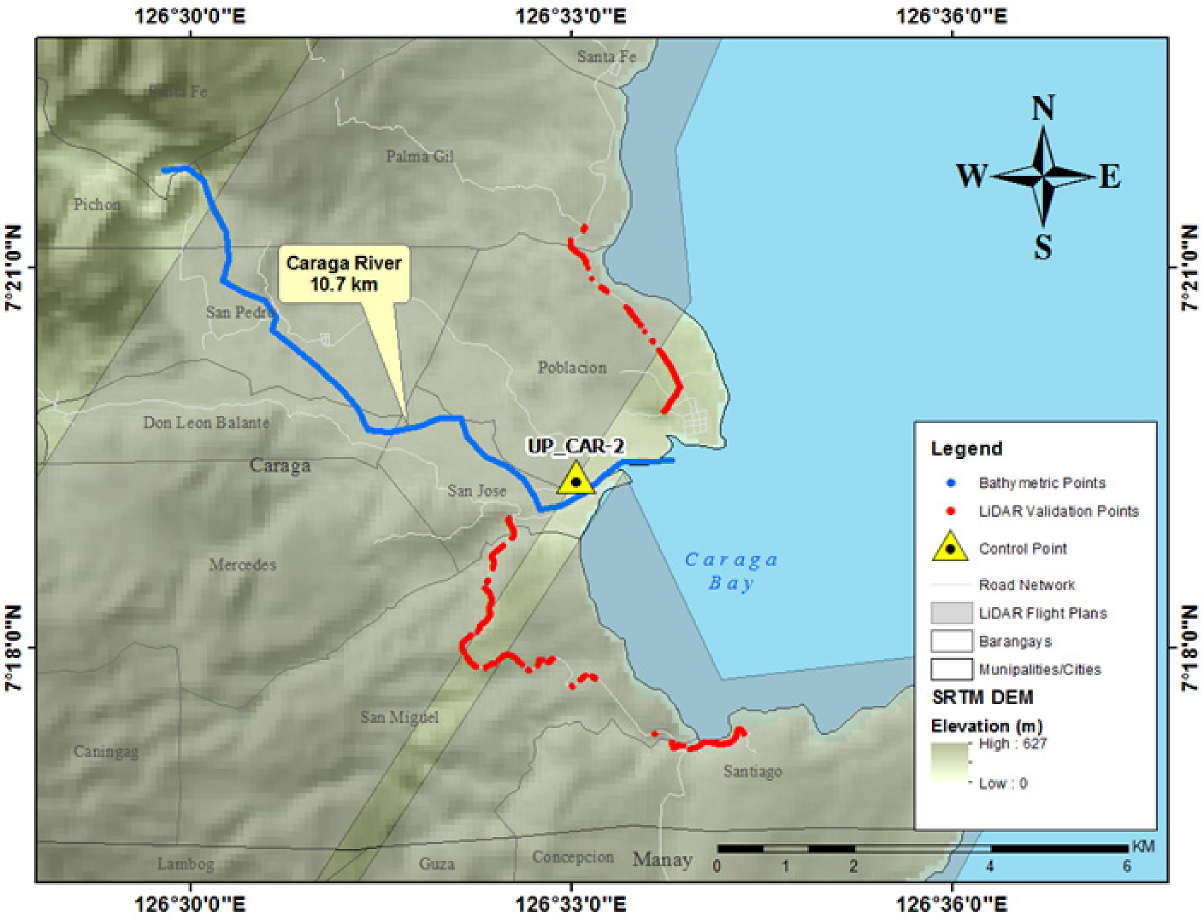


Figure 42. Validation points acquisition covering the Caraga River Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed on February 28, 2016 using a Hi-Target™ Echo Sounder as seen in Figure C- 15. The survey started in Brgy. San Jose, Caraga, Davao Oriental with coordinates 7° 19' 6.85200"N, 120° 32' 54.16800"E and ended at the mouth of the river in Brgy. Poblacion, Caraga, Davao Oriental with coordinates 7° 19' 30.97200"N, 120° 33' 45.25200"E.

Figure 43 Bathymetric survey of ABSD at Caraga River using Hi-Target™ Echo Sounder

Manual bathymetric survey, on the other hand, was executed on March 7-10, 2016 using a Horizon® Total Station as seen in Figure C- 16. The survey started in Brgy. Santa Fe, Caraga, Davao Oriental with coordinates 7° 21' 42.33066"N, 126° 29' 39.36225"E and ended at the starting point of the bathymetric survey using a boat in Brgy. San Jose, Caraga, Davao Oriental. The control points UP_CAR-2 and UP_CAR-3 served as the GNSS base stations all throughout the survey.

Figure 44 Manual bathymetric survey of ABSD at Caraga River using Horizon® Total Station

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on May 13, 2016 using a GNSS Rover receiver, Trimble® SPS 985 attached to a 2-m pole, see Figure C- 17. A map showing the DVBC bathymetric checking points is shown in Figure C- 19.

Figure 45. Gathering of random bathymetric points along Caraga River

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 value of 0.99 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.245 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Caraga River gathered a total of 5,576 points covering 10.7 km of the river traversing barangays Poblacion, San Jose, Don Leon Balonte, San Pedro, and Pichon in the Municipality of Caraga. A CAD drawing was also produced to illustrate the riverbed profile of Caraga River. As shown in Figure C- 20, the highest and lowest elevation has a 66-m difference. The highest elevation observed was 64.406 m above MSL located in Brgy. Del Pilar, Manay while the lowest was -1.446 m below MSL located in Brgy. Holy Cross, Manay.

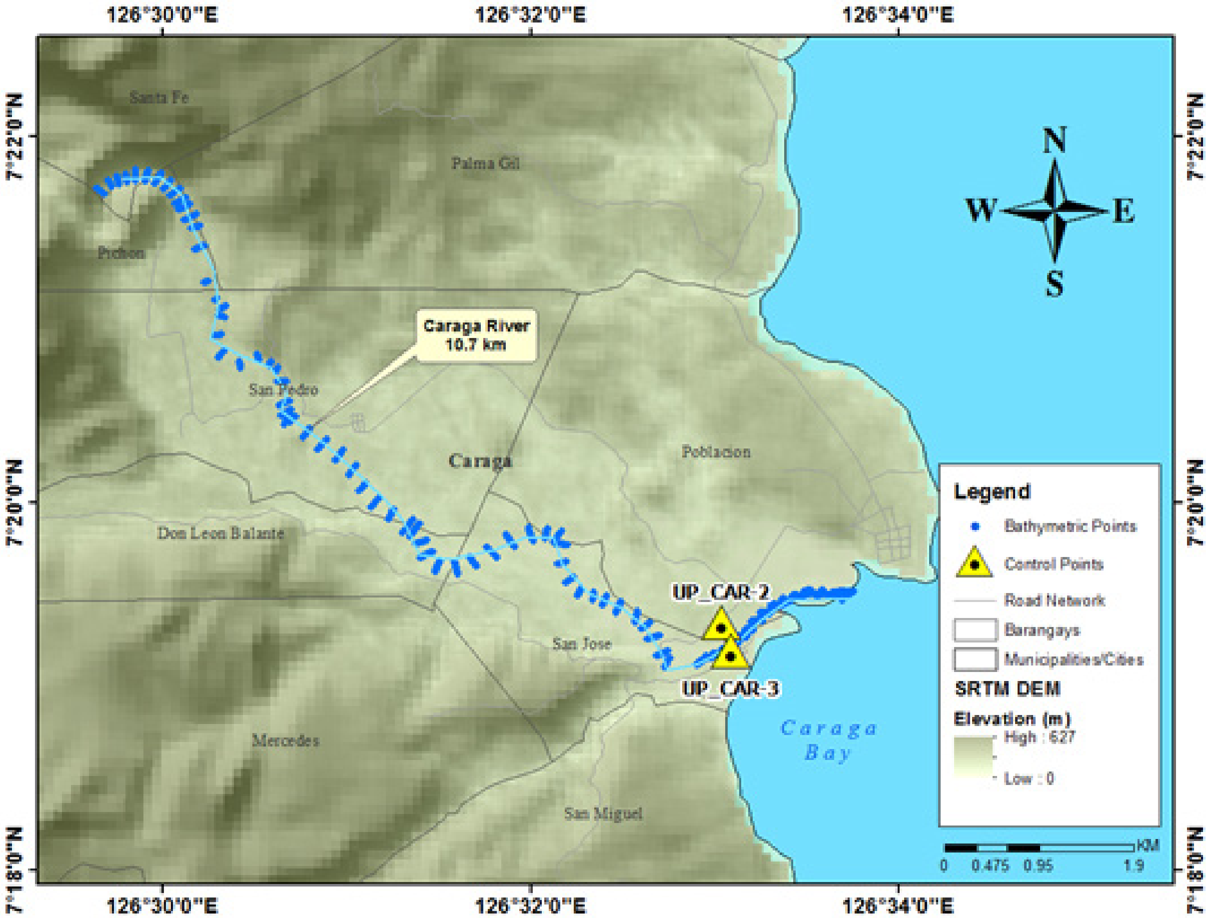


Figure 46. Bathymetric survey of Caraga River

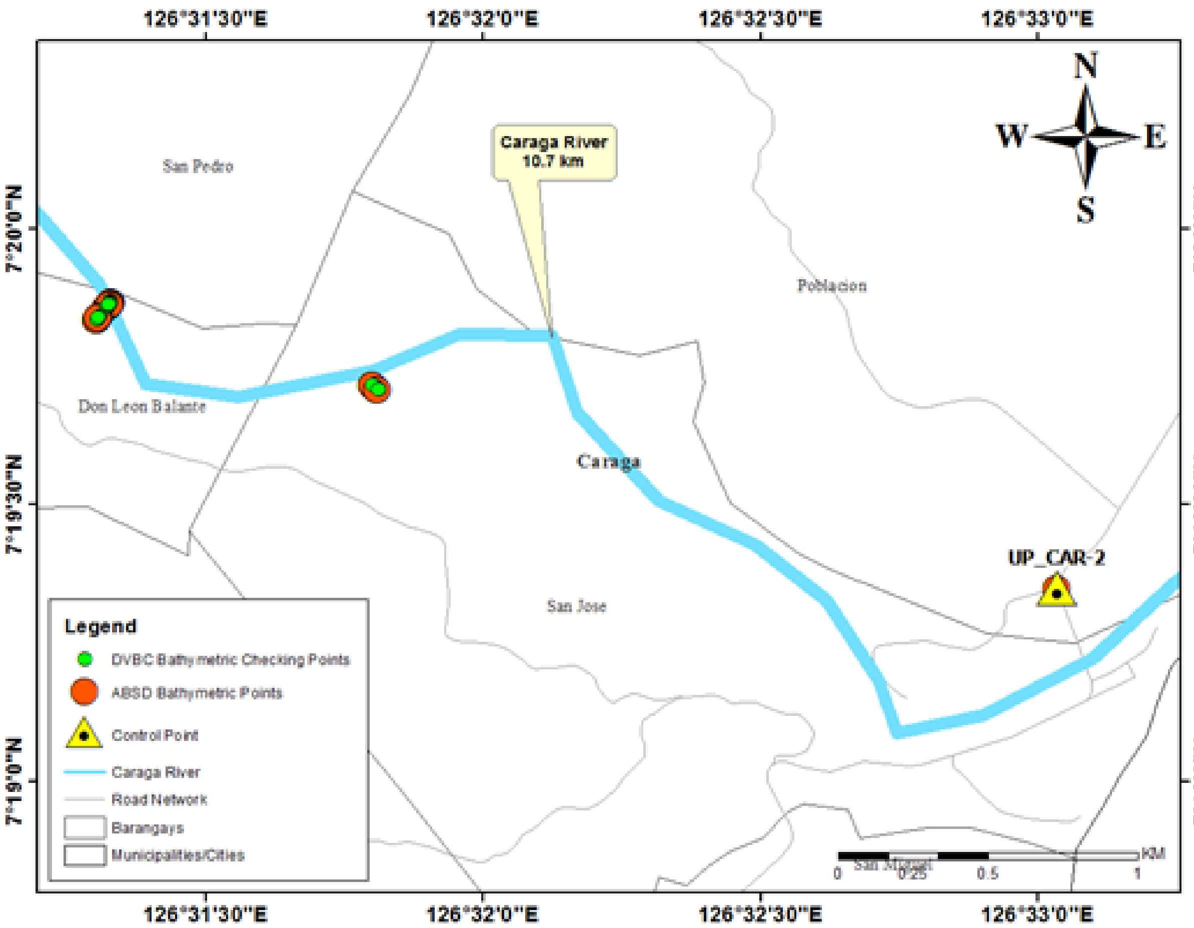


Figure 47. Quality checking points gathered along Caraga River by DVBC

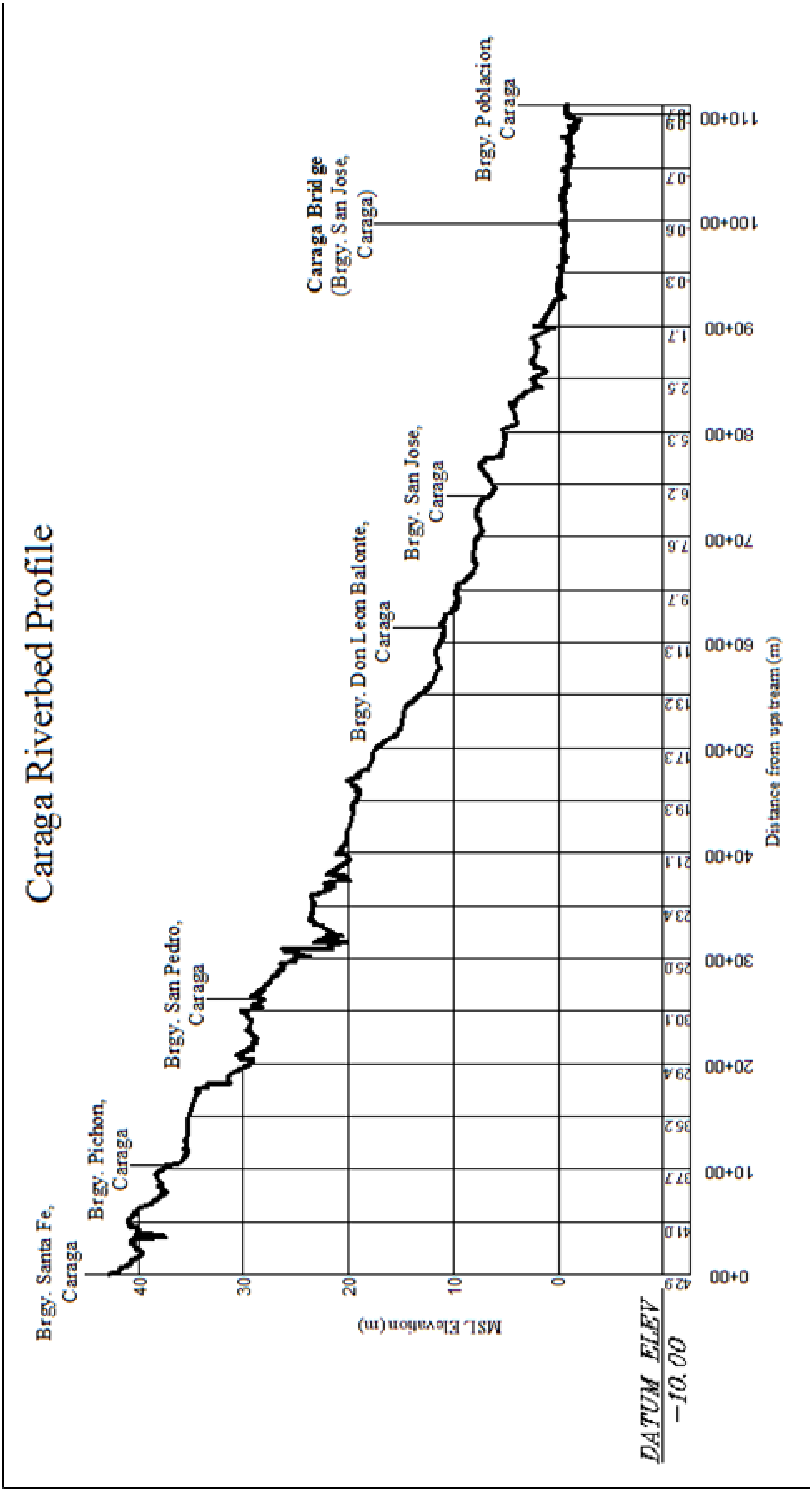


Figure 48. Caraga Riverbed Profile

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, Narvin Clyd Tan, Hannah Aventurado

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin were monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed by the University of the Philippines Mindanao Phil. LiDAR 1. This rain gauge is located in Barangay Sobrecarey, Caraga, Davao Oriental with the following coordinates: 7° 19' 58.22" N, 126° 28' 47.24" E (Figure 1). The precipitation data collection started from March 10, 2016 at 6:00 AM to March 16, 2016 at 12:00 NN with a 10-minute recording interval.

The total precipitation for this event in the installed rain gauge was 82 mm. It has a peak rainfall of 4.6 mm. on March 11, 2016 at 10:50 PM. The lag time between the peak rainfall and discharge is 11 hours and 50 minutes.

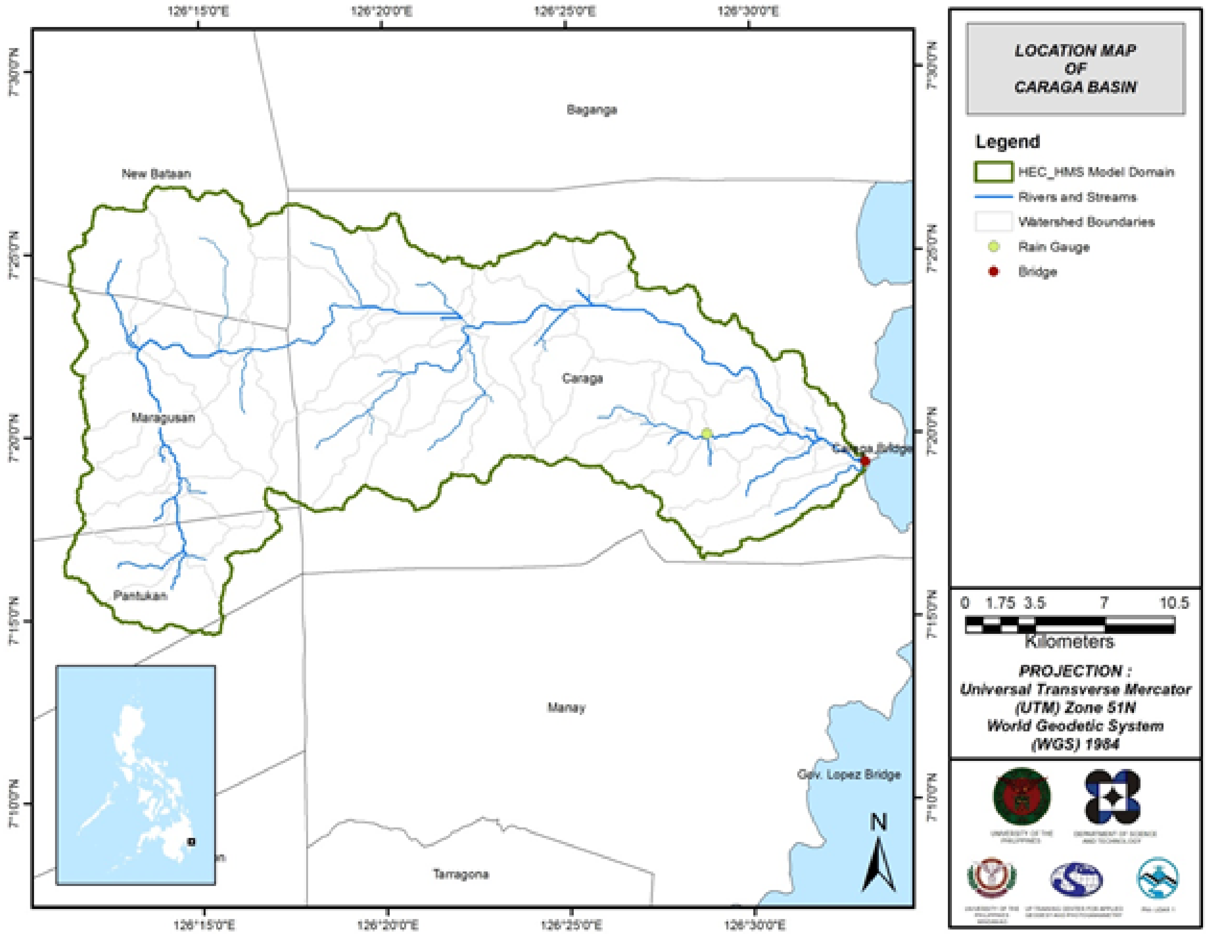


Figure 49. The location map of Caraga HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Caraga Bridge, Barangay San Jose, Caraga, Davao Oriental (7° 24' 51.8" N, 126° 31' 10.7" E). It gives the relationship between the observed water level at the Caraga Bridge and outflow of the watershed at this location.

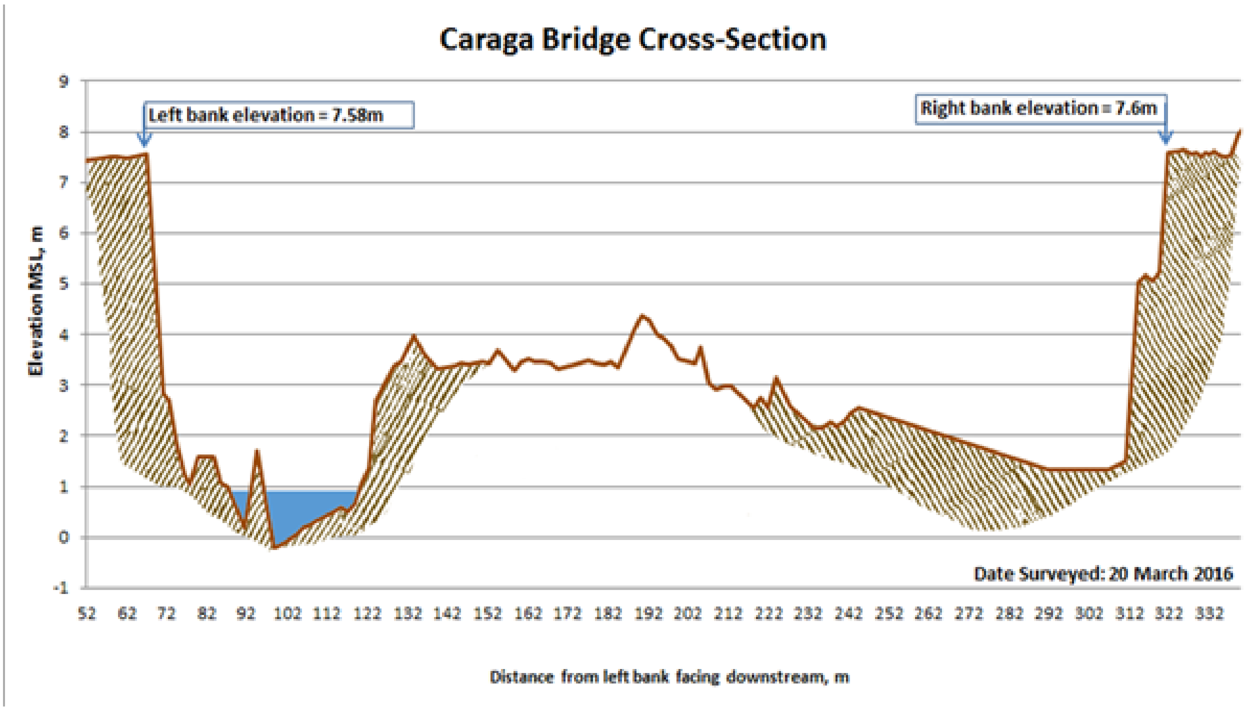


Figure 50. Cross-Section Plot of Caraga Bridge

For Caraga Bridge, the rating curve is expressed as Q = 3.0425e1.8408x as shown in Figure 3.

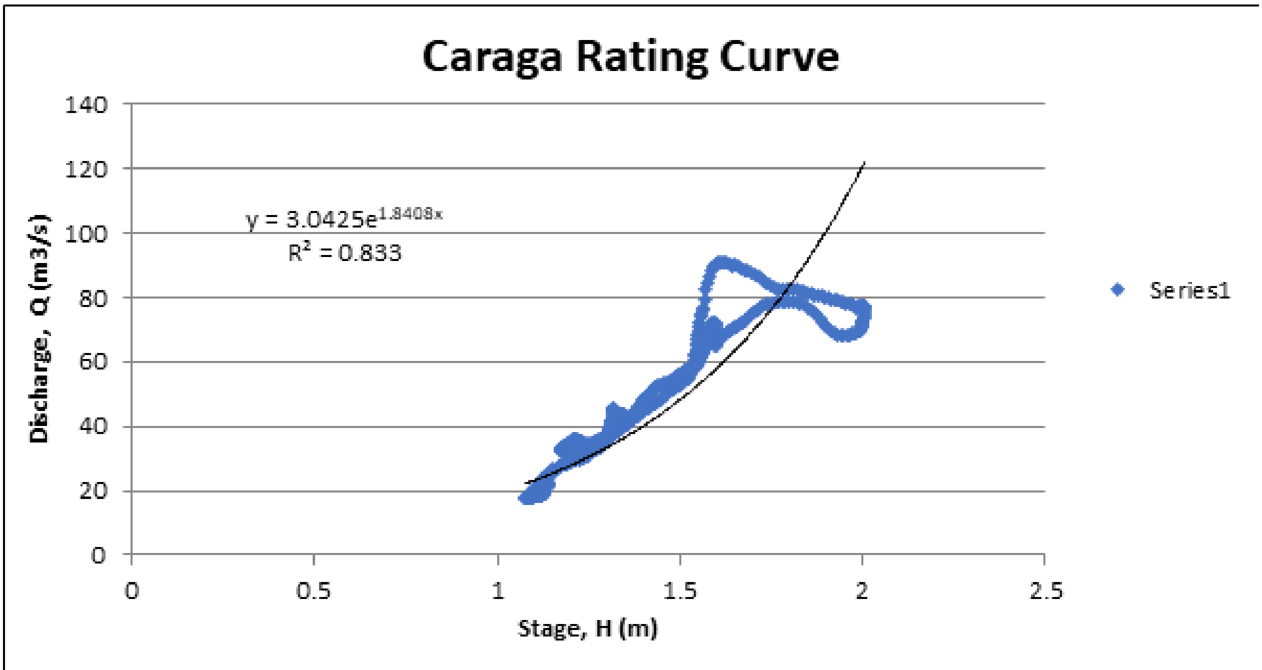


Figure 51. Rating Curve at Caraga Bridge, Caraga, Davao Oriental

The rating curve equation was used to compute for the river outflow at Caraga Bridge for the calibration of the HEC-HMS model for Caraga, as shown in Figure 4. The total rainfall for this event is 82 mm and the peak discharge is 91.1 m3/s at 10:40 AM of March 12, 2016.

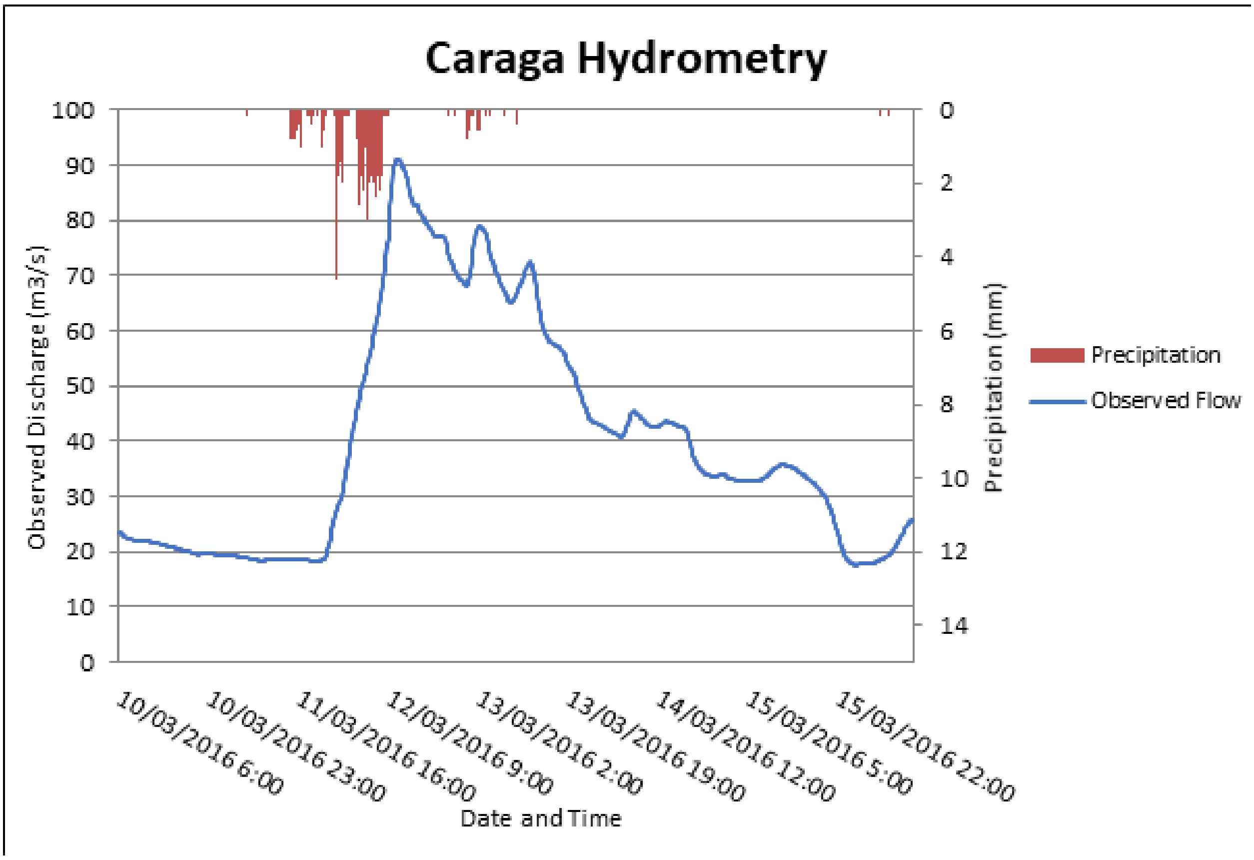


Figure 52. Rainfall and outflow data at Caraga Bridge used for modeling

5.2 RIDF Station

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

Table 30. RIDF values for Davao Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	19.5	30	38.2	53.2	65.2	71.6	80.3	85.8	91.4
5	25.1	39.3	51	73.2	88.8	96.4	108.7	114.9	121.1
10	28.8	45.4	59.4	86.5	104.5	112.8	127.5	134.1	140.7
15	30.9	48.9	64.2	94	113.3	122.1	138.1	145	151.8
20	32.4	51.3	67.6	99.3	119.5	128.6	145.5	152.6	159.5
25	33.5	53.2	70.1	103.3	124.2	133.6	151.2	158.5	165.5
50	37	59	78.1	115.8	138.9	149	168.8	176.5	183.9
100	40.5	64.7	85.9	128.1	153.5	164.2	186.3	194.4	202.1

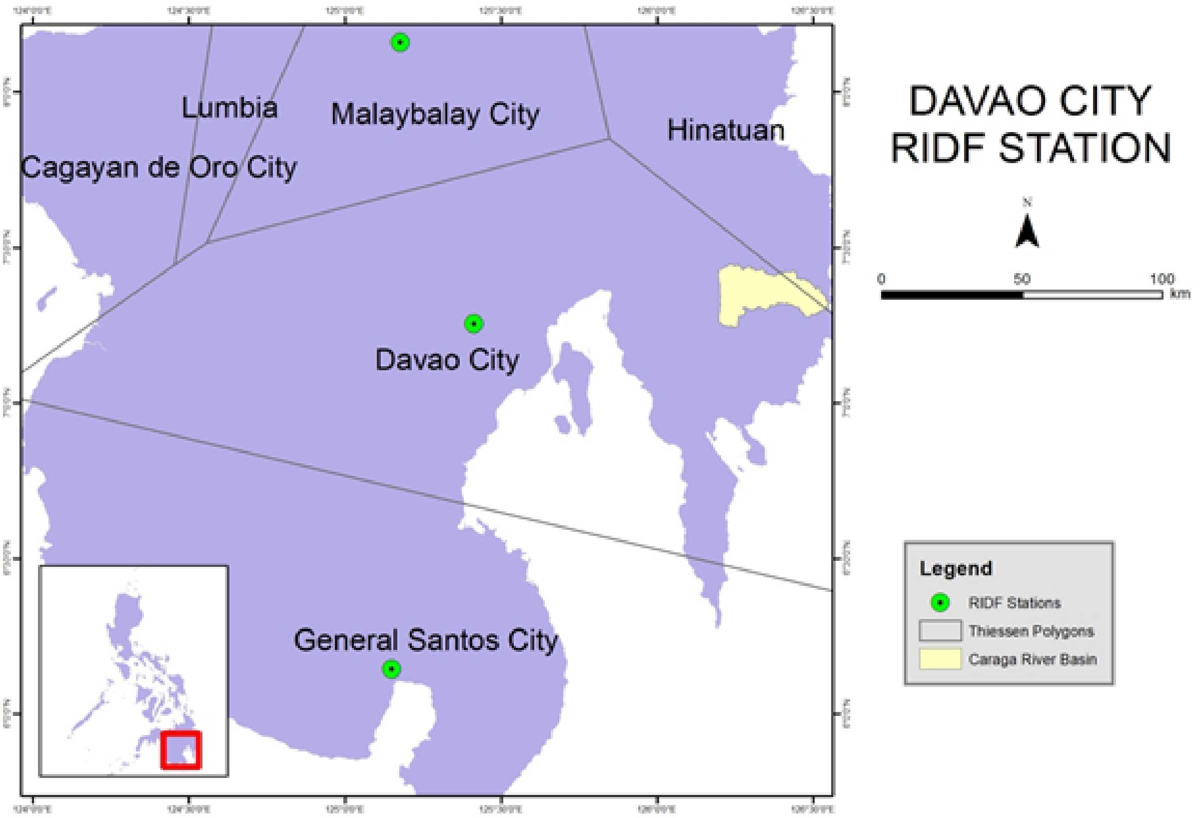


Figure 53. Location of Davao RIDF Station relative to Caraga River Basin

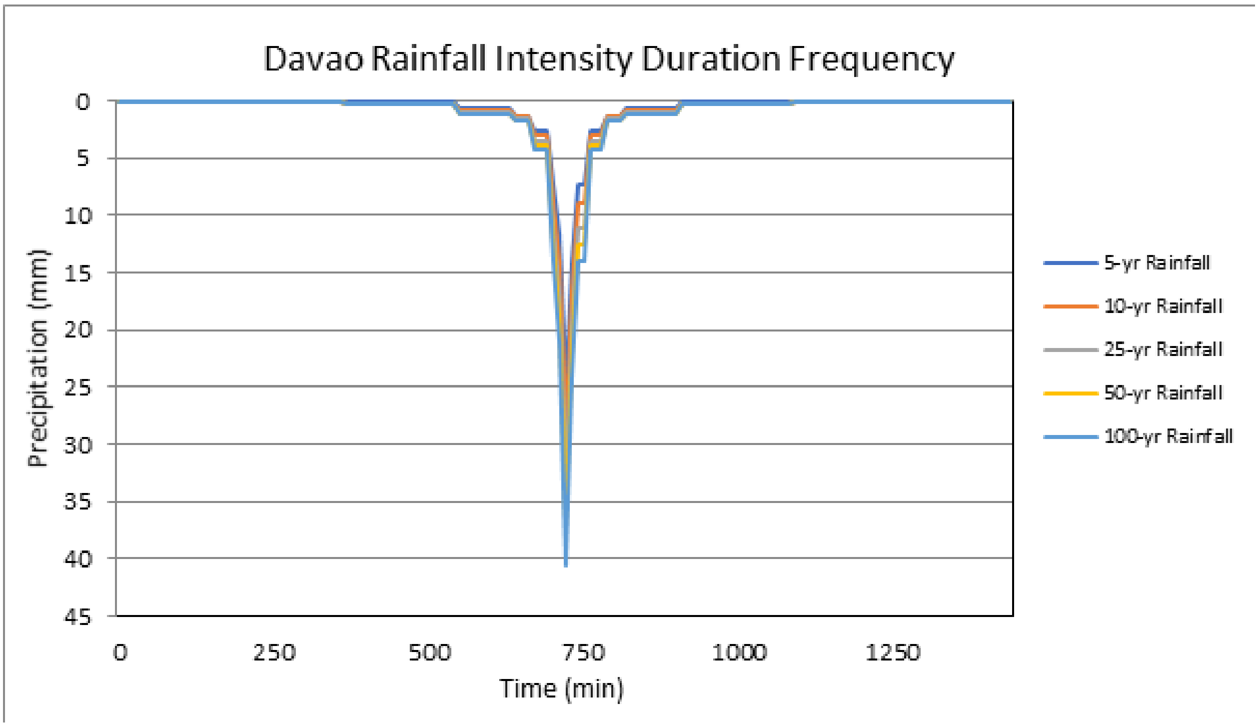


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Caraga River Basin are shown in Figures __ and __, respectively.

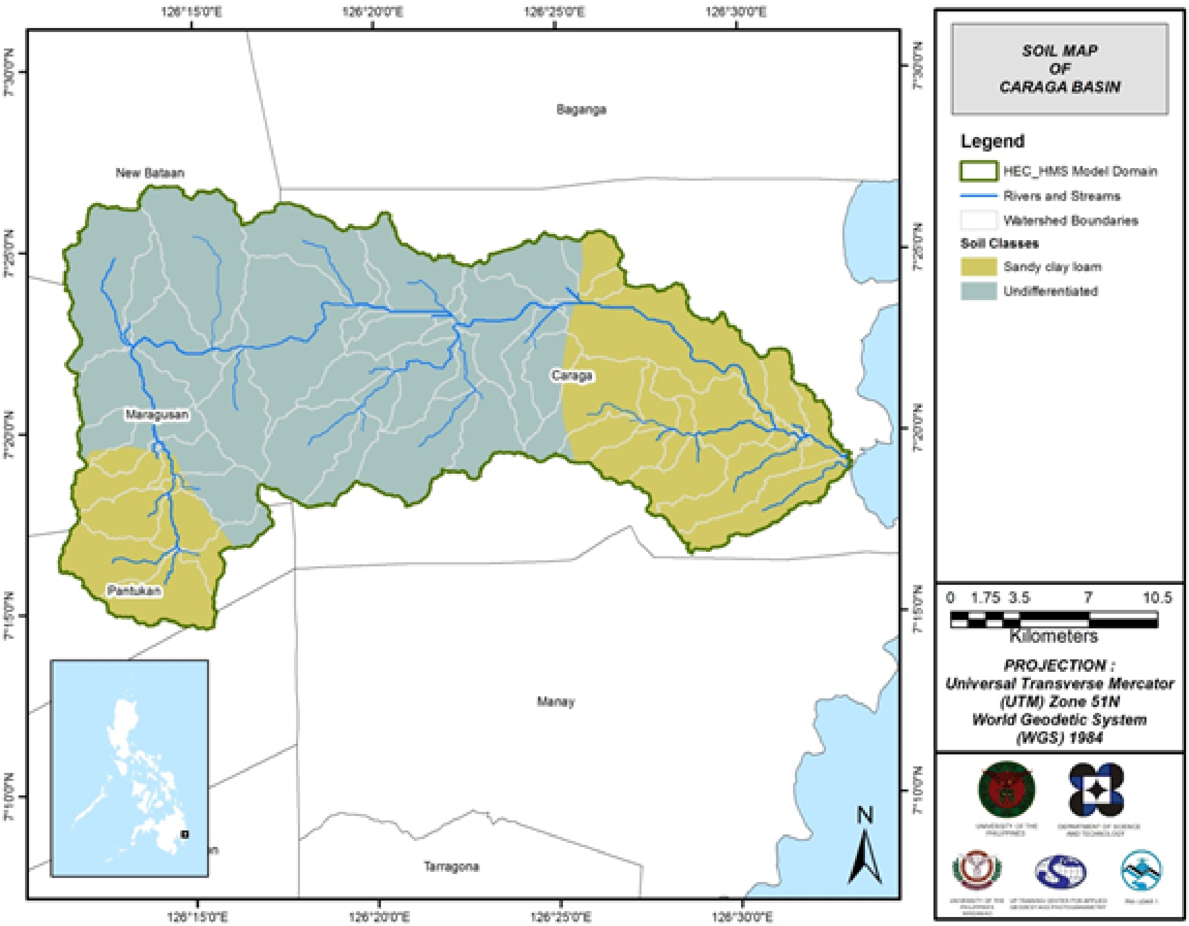


Figure 55. Soil Map of Caraga River Basin

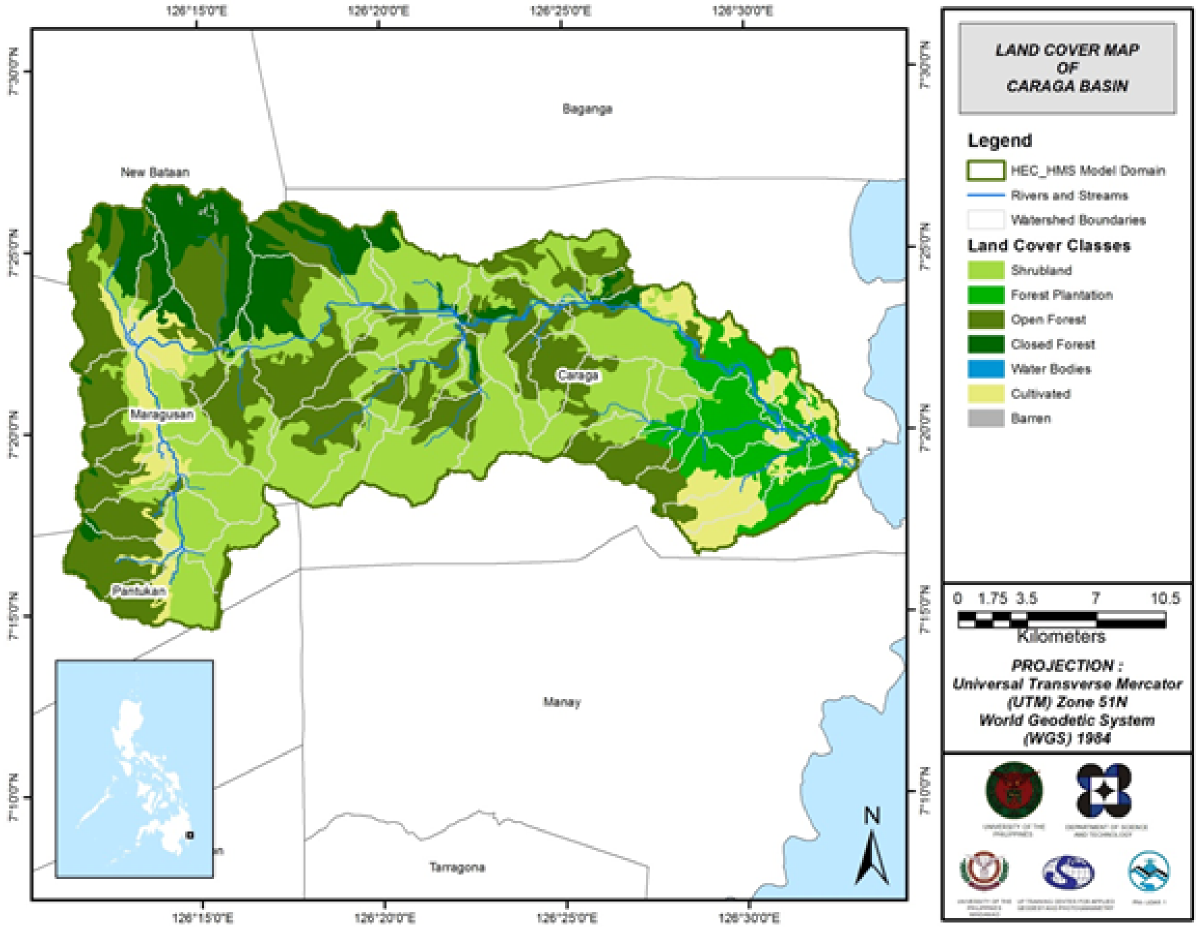


Figure 56. Land Cover Map of Caraga River Basin

For Caraga, two soil classes were identified. These are sandy clay loam, and undifferentiated land. Moreover, seven land cover classes were identified. These are shrublands, forest plantations, open forest, closed forests, water bodies, barren areas, and cultivated areas.

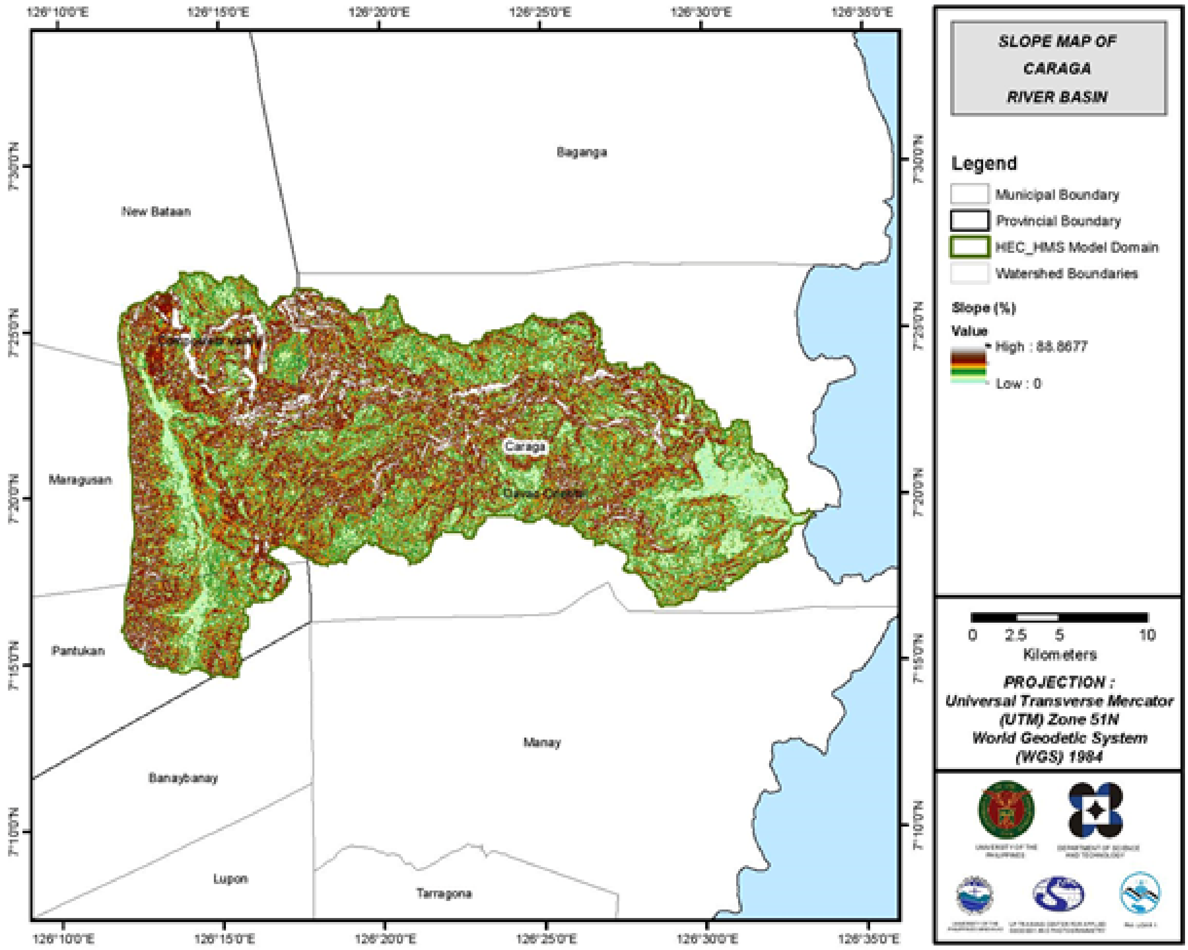


Figure 57. Slope Map of Caraga River Basin

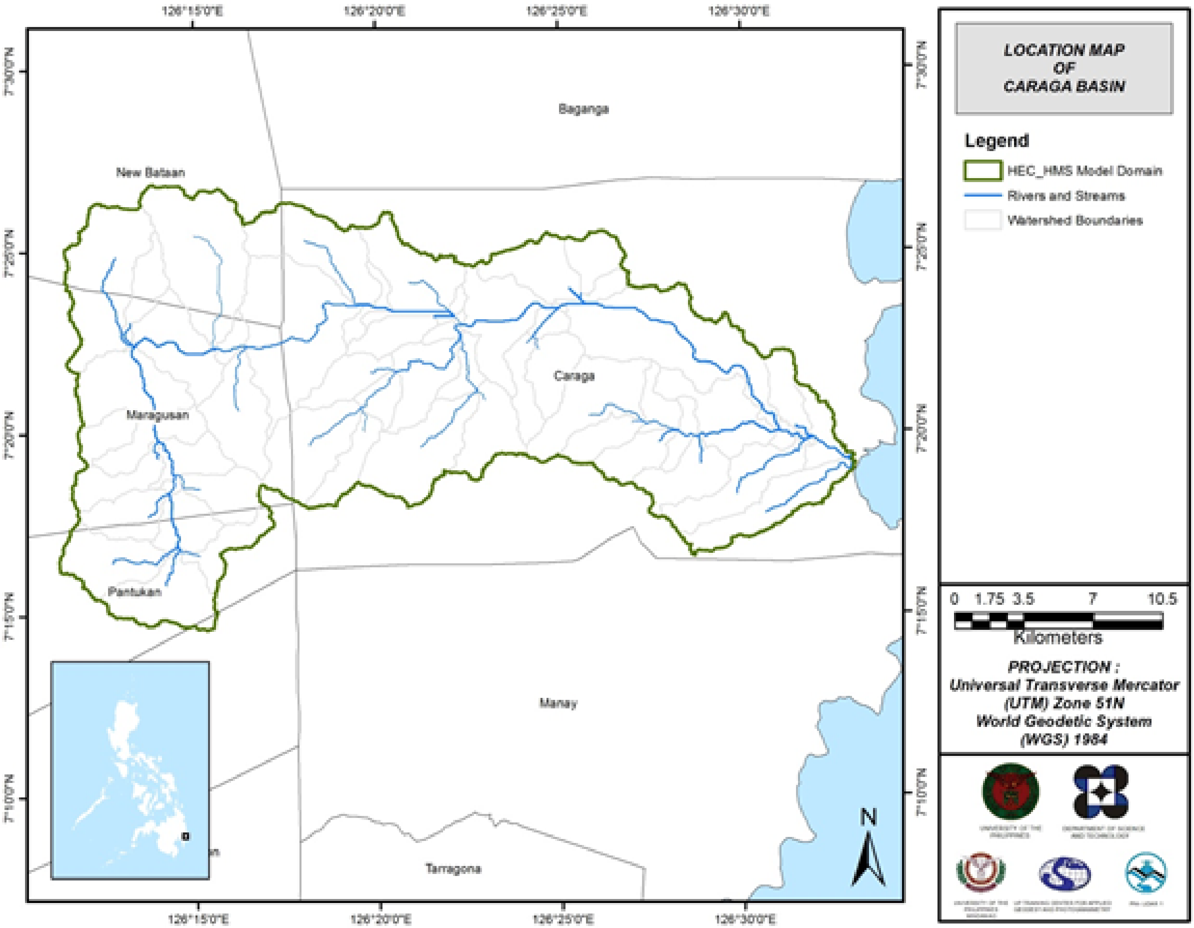


Figure 58. Stream Delineation Map of Caraga River Basin

Using the SAR-based DEM, the Caraga basin was delineated and further subdivided into subbasins. The model consists of 59 sub basins, 29 reaches, and 29 junctions, as shown in Figure 7. The main outlet is at Caraga Bridge.

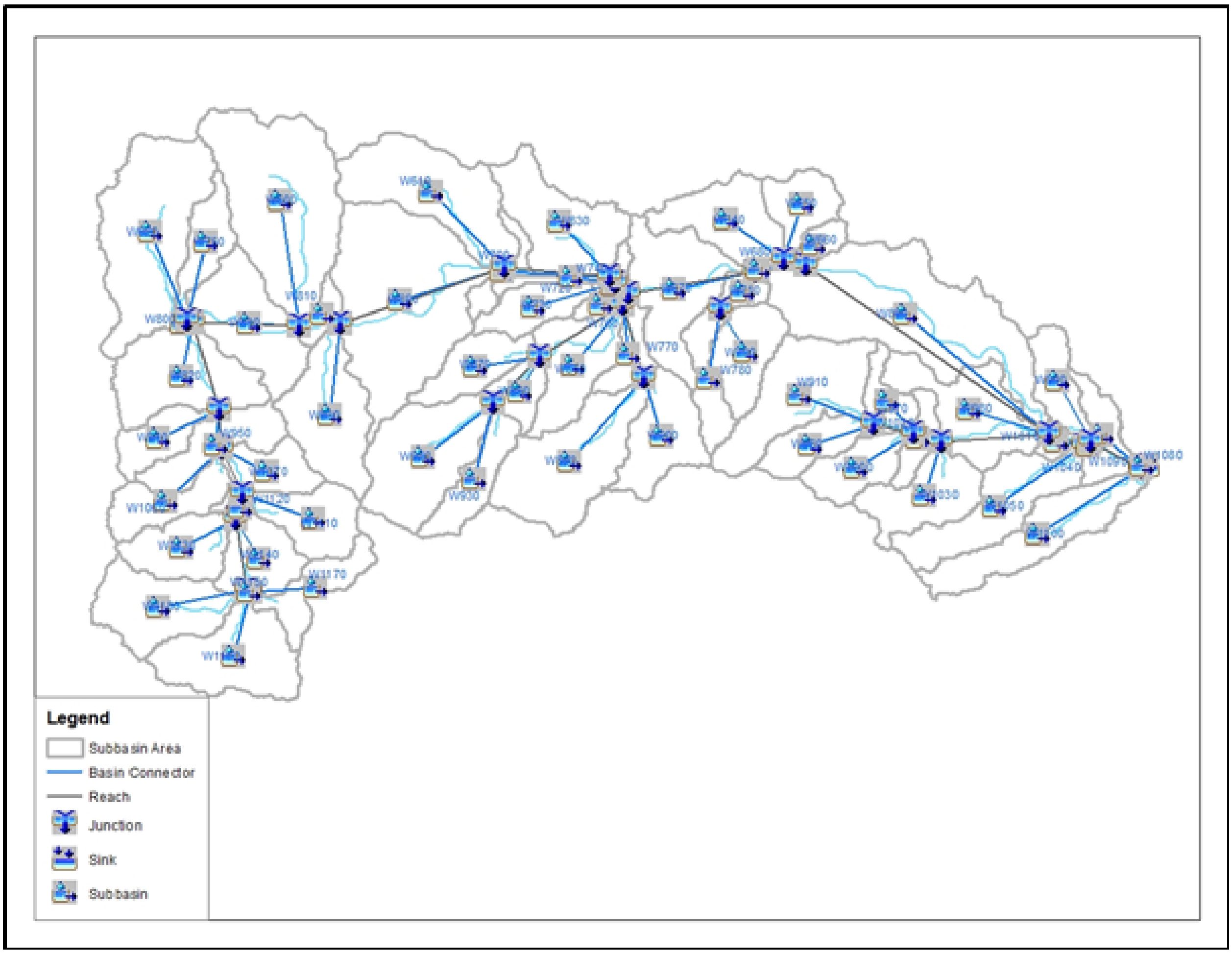


Figure 59. The Caraga river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

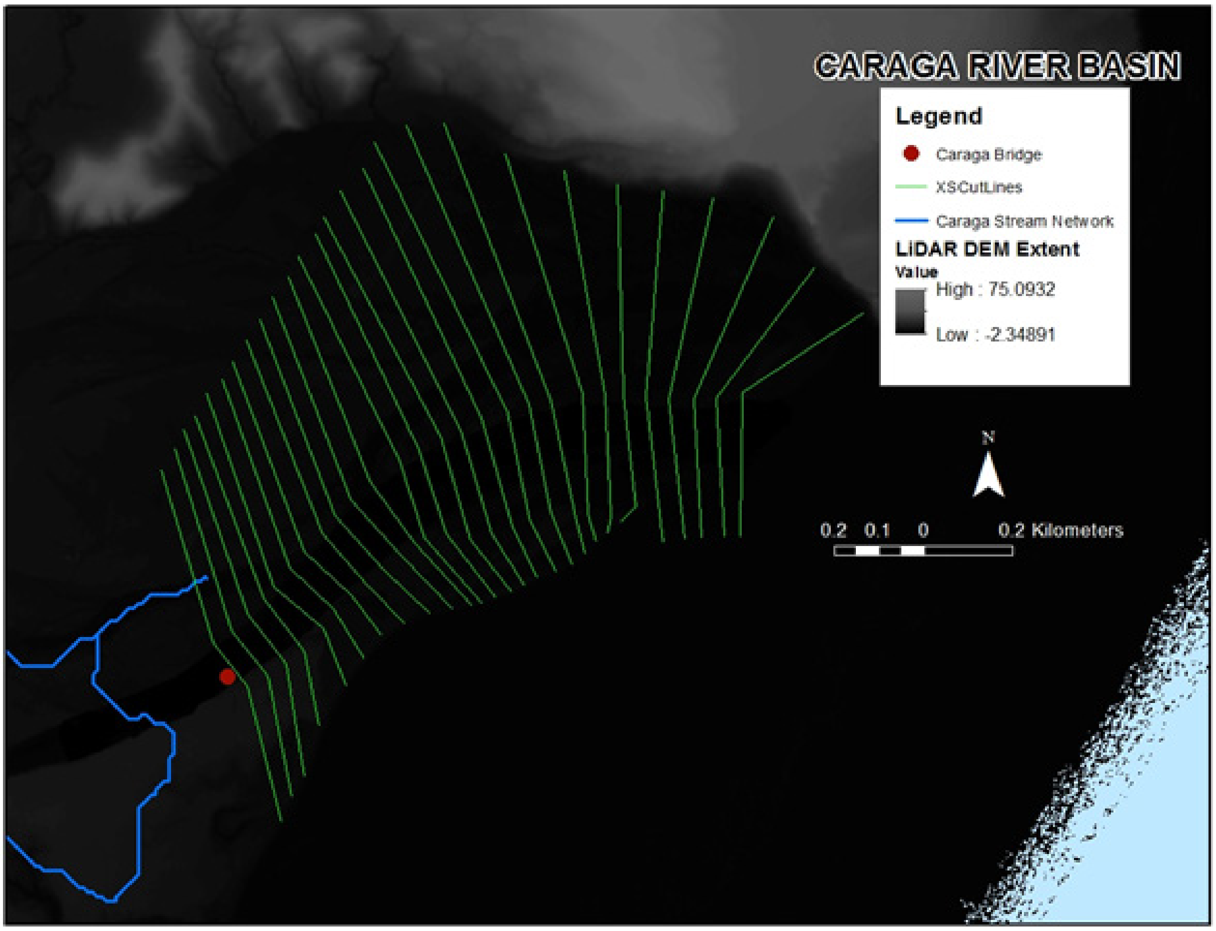


Figure 60. River cross-section of Caraga River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 61. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 27.20636 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Caraga are in Figures __, __, and __.

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 39 161 000.00 m2. The generated flood depth maps for Caraga are in Figures __, __, and __.

There is a total of 182 815 955.37 m3 of water entering the model. Of this amount, 17 232 790.67 m3 is due to rainfall while 165 583 164.70 m3 is inflow from other areas outside the model. 5 654 793.50 m3 of this water is lost to infiltration and interception, while 4 918 111.53 m3 is stored by the flood plain. The rest, amounting up to 172 243 025.70 m3, is outflow.

5.6 Results of HMS Calibration

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

Enumerated in Table 2 are the adjusted ranges of values of the parameters used in calibrating the model.

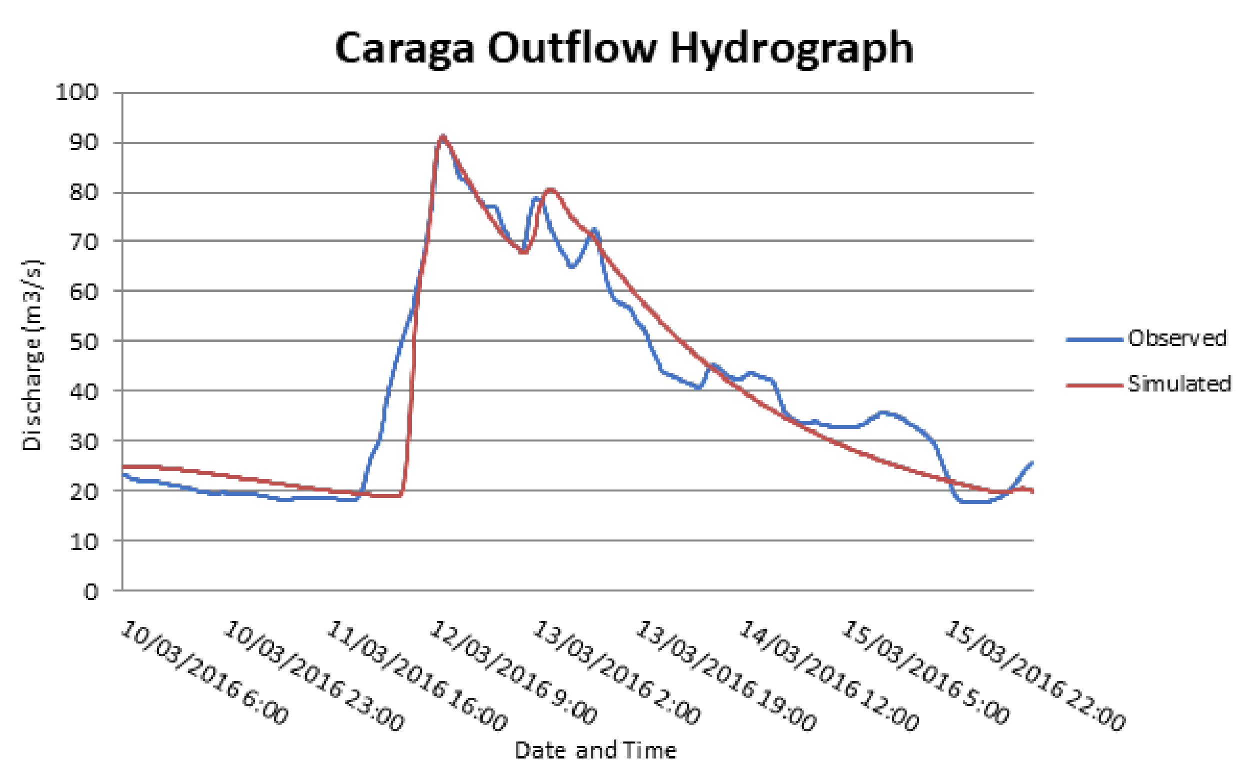


Figure 62. Outflow Hydrograph of Caraga produced by the HEC-HMS model compared with observed outflow

Table 31. Range of Calibrated Values for Caraga

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	26.4 – 484.25
			Curve Number	98.26 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.09 – 25.73
			Storage Coefficient (hr)	0.02 – 0.44
	Baseflow	Recession	Recession Constant	0.013 - 1
			Ratio to Peak	1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.087 – 0.197

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 26.4 mm to 484.25 mm means that there is a large initial fraction of the storm depth after which runoff begins, decreasing the river outflow.

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 Caraga, the basin consists mainly of shrublands and the soil consists of mostly undifferentiated land and clay loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 25.73 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant values within the range of 0.013 to 1 indicate that the discharge leaving every subbasin within Caraga recede differ significantly. Ratio to peak which is 1 indicates a less steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Caraga river basin reaches' Manning's coefficients range from 0.087 to 0.197, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

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

Accuracy measure	Value
RMSE	6.4
r2	0.914
NSE	0.91
PBIAS	1.19
RSR	0.31

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 6.4 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.914.

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 0.91.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.19.

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 0.31.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 13) shows the Caraga outflow using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

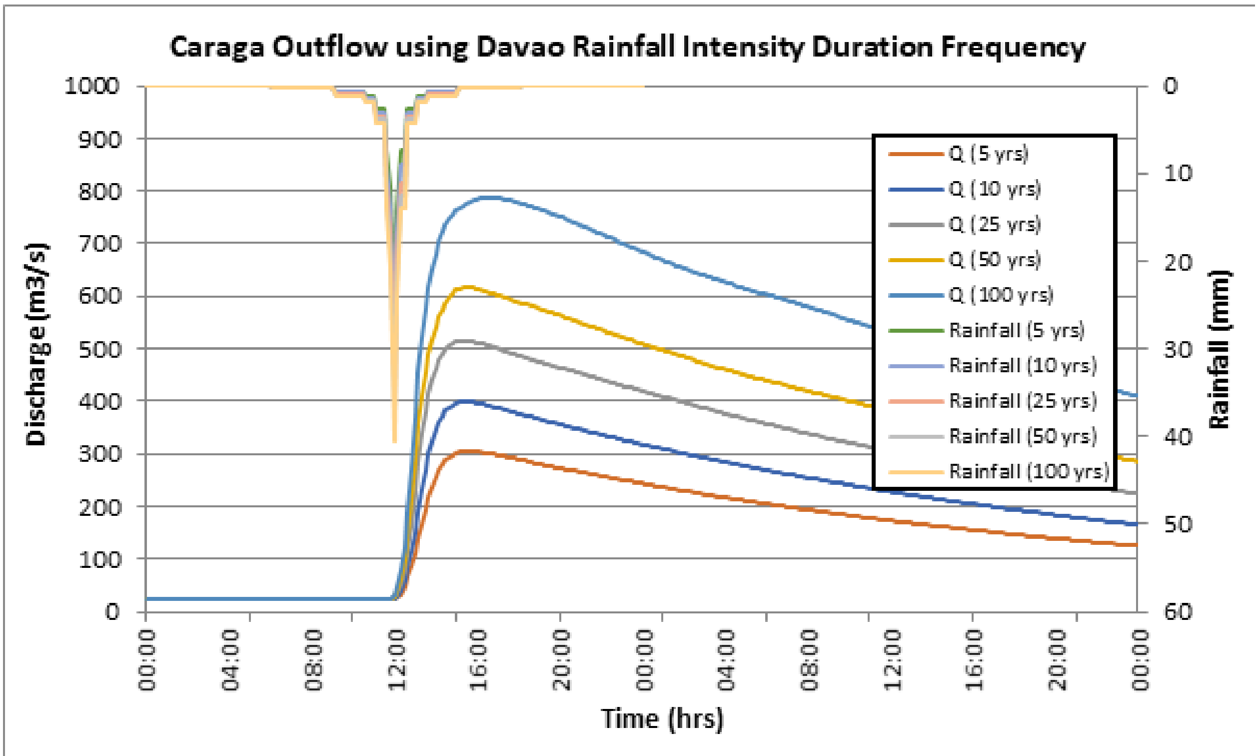


Figure 63. Outflow hydrograph at Caraga Station generated using the Davao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Caraga discharge using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 4.

Table 33. Peak values of the Caraga HEC-HMS Model outflow using the Davao RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	121.1	25.1	305.6	3 hours, 40 minutes
10-Year	140.7	28.8	399.2	3 hours, 30 minutes
25-Year	165.5	33.5	515.5	3 hours, 20 minutes
50-Year	183.9	37	616.4	3 hours, 30 minutes
100-Year	202.1	40.5	787.9	4 hours, 30 minutes

5.7.2 Discharge Values using Dr. Horritt's Recommended Hydrological Method

The river discharge values for the three rivers entering the floodplain are shown in __ to Figure __ and the peak values are summarized in Table __ to Table __.

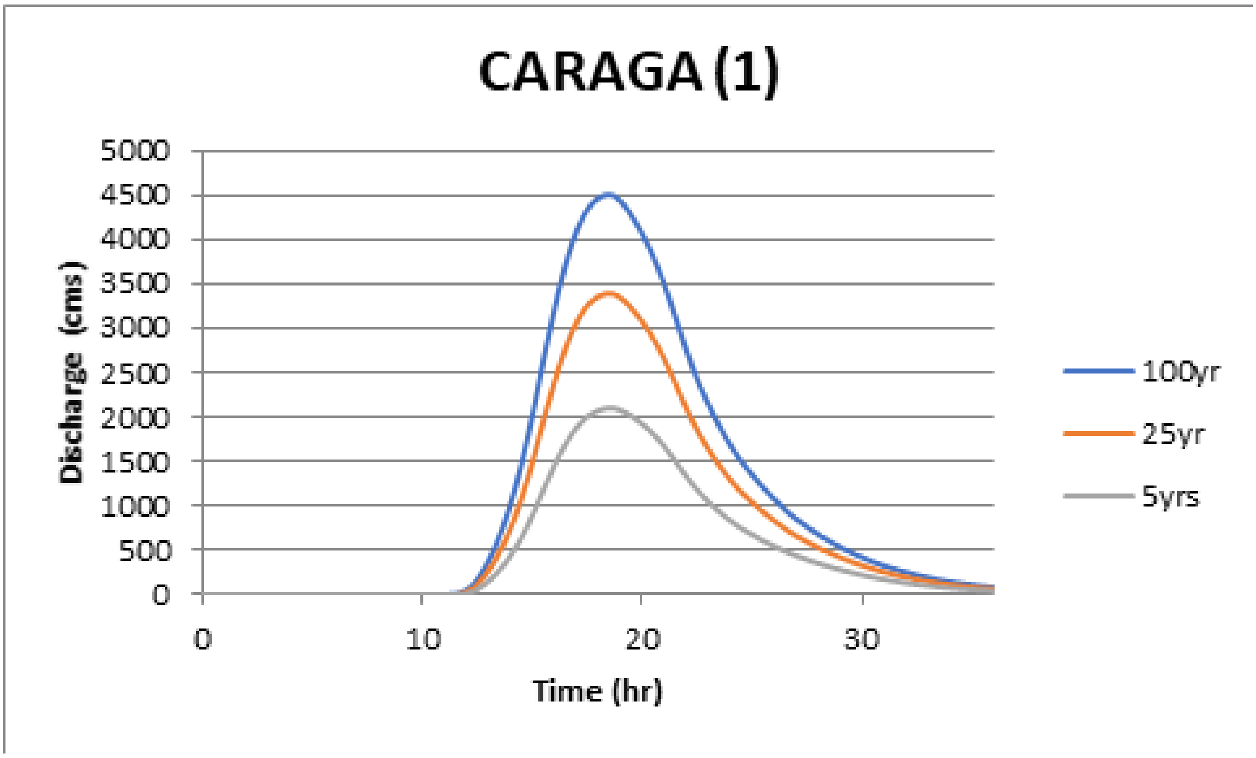


Figure 64. Caraga river (1) generated discharge using 5-, 25-, and 100-year Davao rainfall intensity-duration-frequency (RIDF) in HEC-HMS

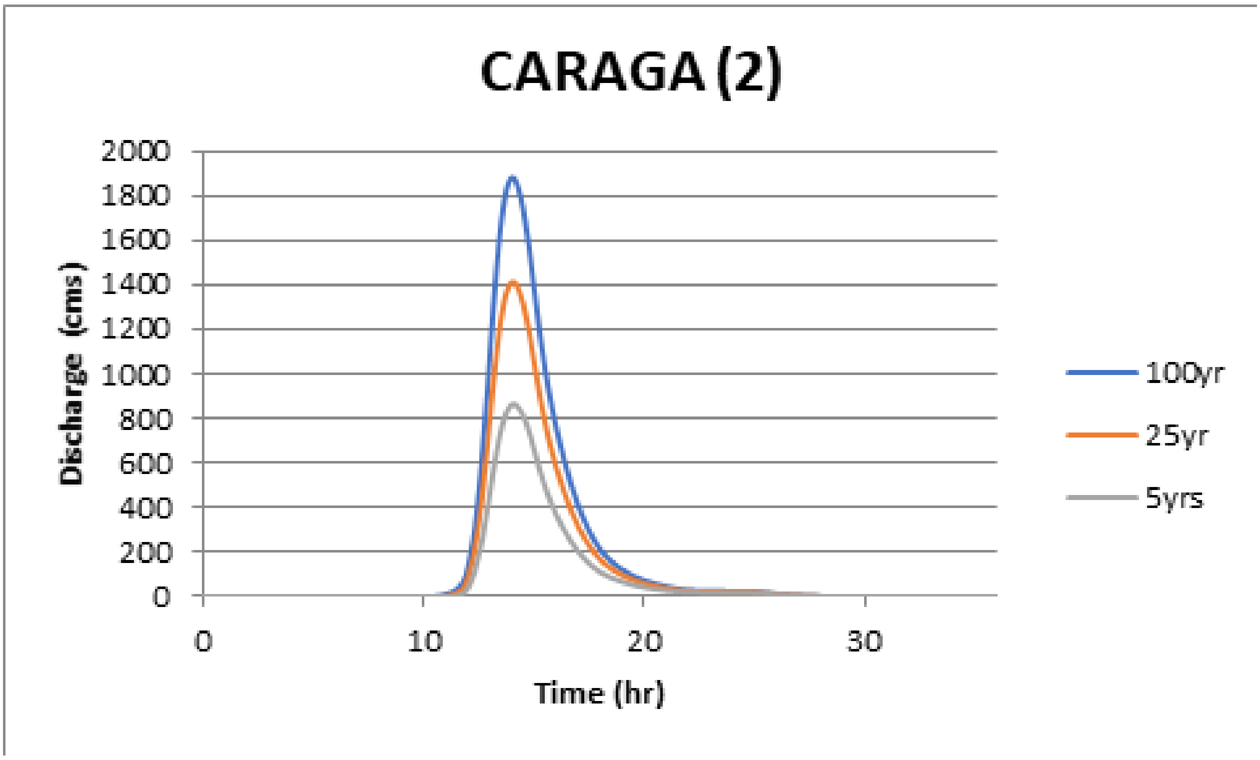


Figure 65. Caraga river (2) generated discharge using 5-, 25-, and 100-year Davao rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 34. Summary of Caraga river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak (minutes)
100-Year	4497.3	18 hours, 30 minutes
25-Year	3396.6	18 hours, 30 minutes
5-Year	2107.1	18 hours, 40 minutes

Table 35. Summary of Caraga river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak (minutes)
100-Year	1882.8	14 hours
25-Year	1410.6	14 hours
5-Year	858.7	14 hours, 10 minutes

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

Table 36 Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Caraga (1)	1854.248	1395.890	740.529	Pass	Fail
Caraga (2)	755.656	1153.833	251.921	Pass	Fail

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

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Caraga River using the calibrated HMS base flow is shown in Figure 14.

Figure 66. Sample output of Caraga RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Caraga floodplain are shown in Figures 15 to 20. The floodplain, with an area of 38.97 sq. km., covers only one municipality. Table __ shows the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in Silaga floodplain

Municipality	Total Area	Area Flooded	% Flooded
Caraga, Davao Oriental	569.48	38.91	6.83%

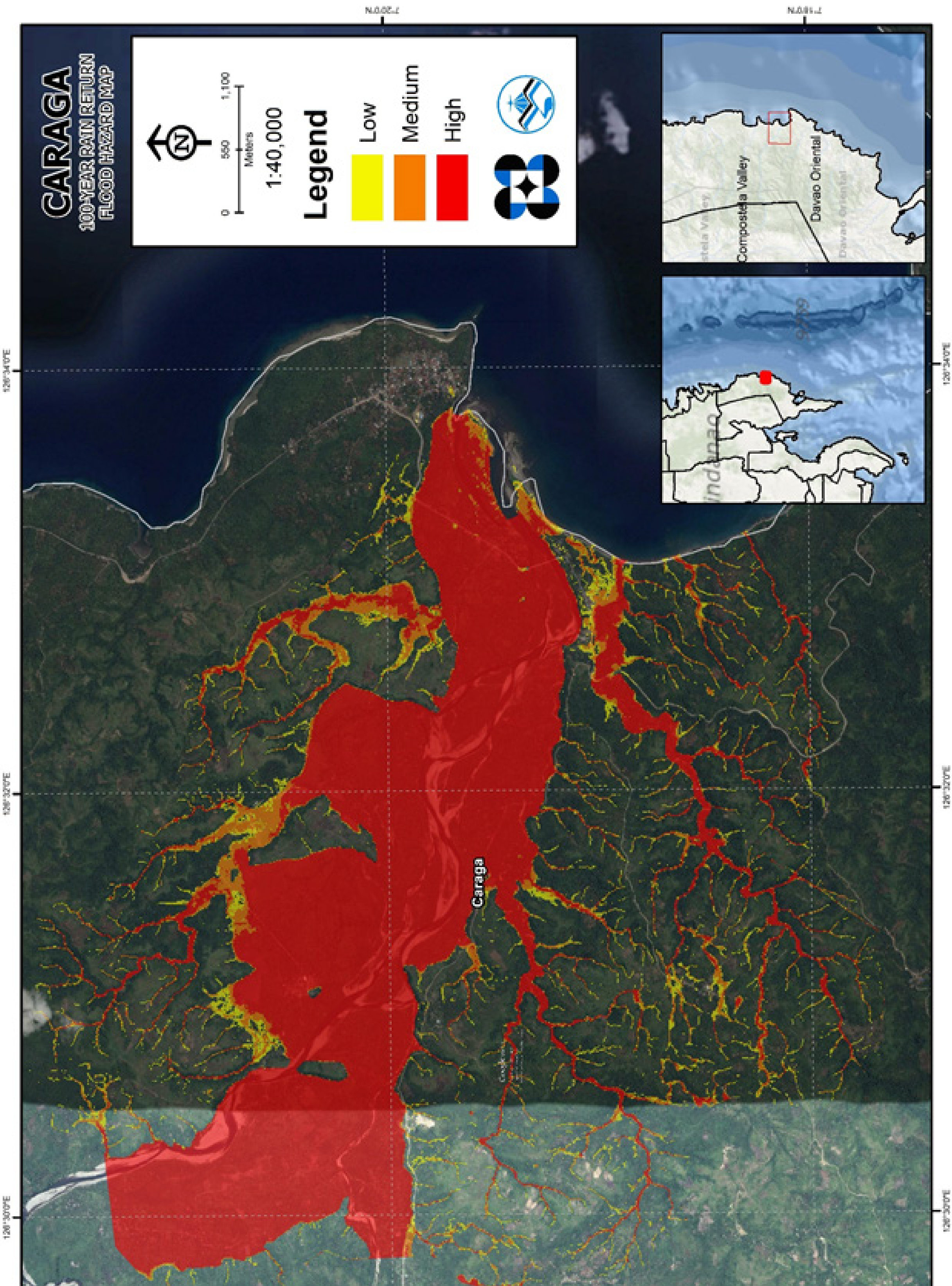


Figure 67. 100-year Flood Hazard Map for Caraga Floodplain overlaid on Google Earth imagery

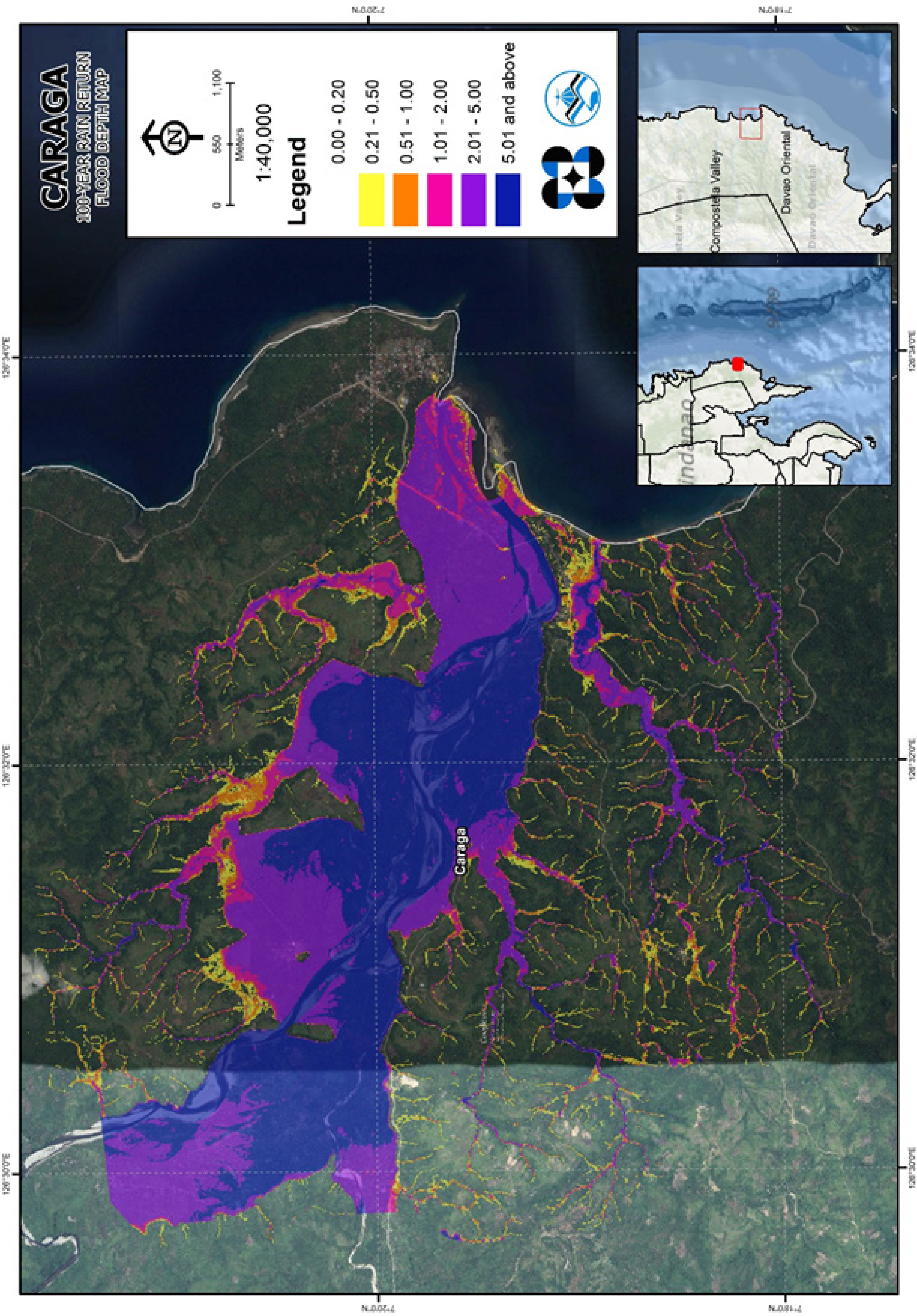


Figure 68. 100-year Flow Depth Map for Caraga Floodplain overlaid on Google Earth imagery

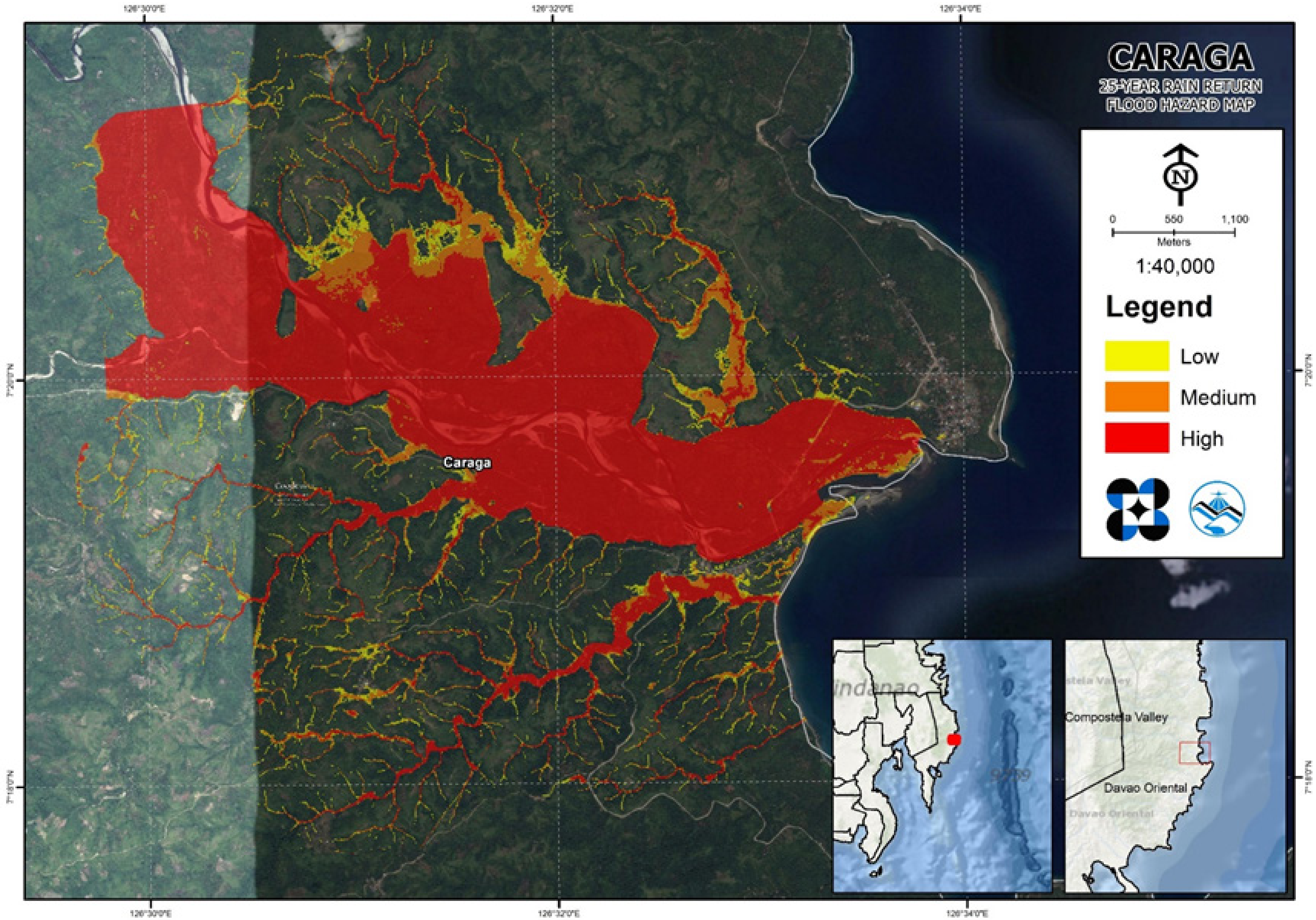


Figure 69. 25-year Flood Hazard Map for Caraga Floodplain overlaid on Google Earth imagery

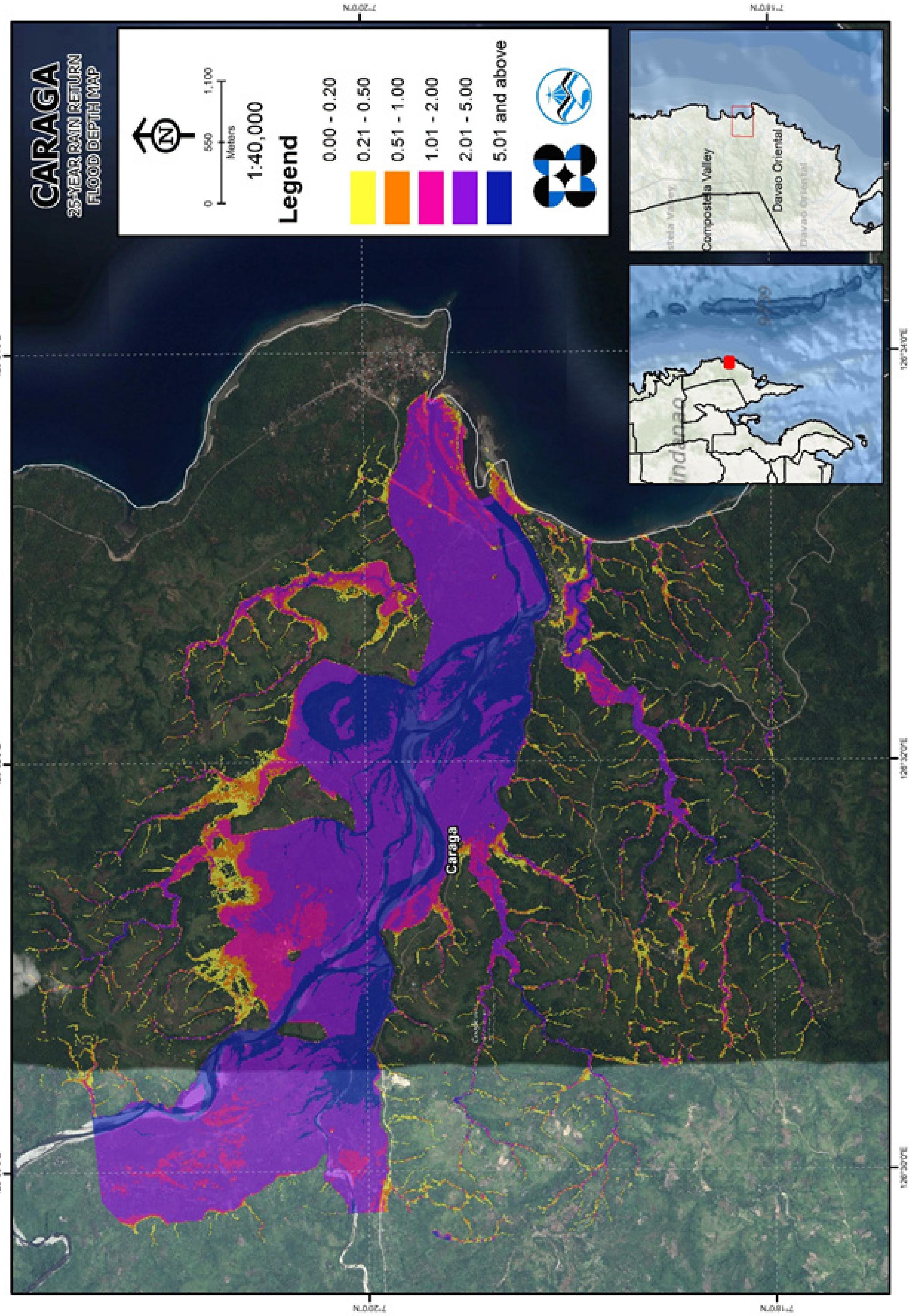


Figure 70. 25-year Flow Depth Map for Caraga Floodplain overlaid on Google Earth imagery

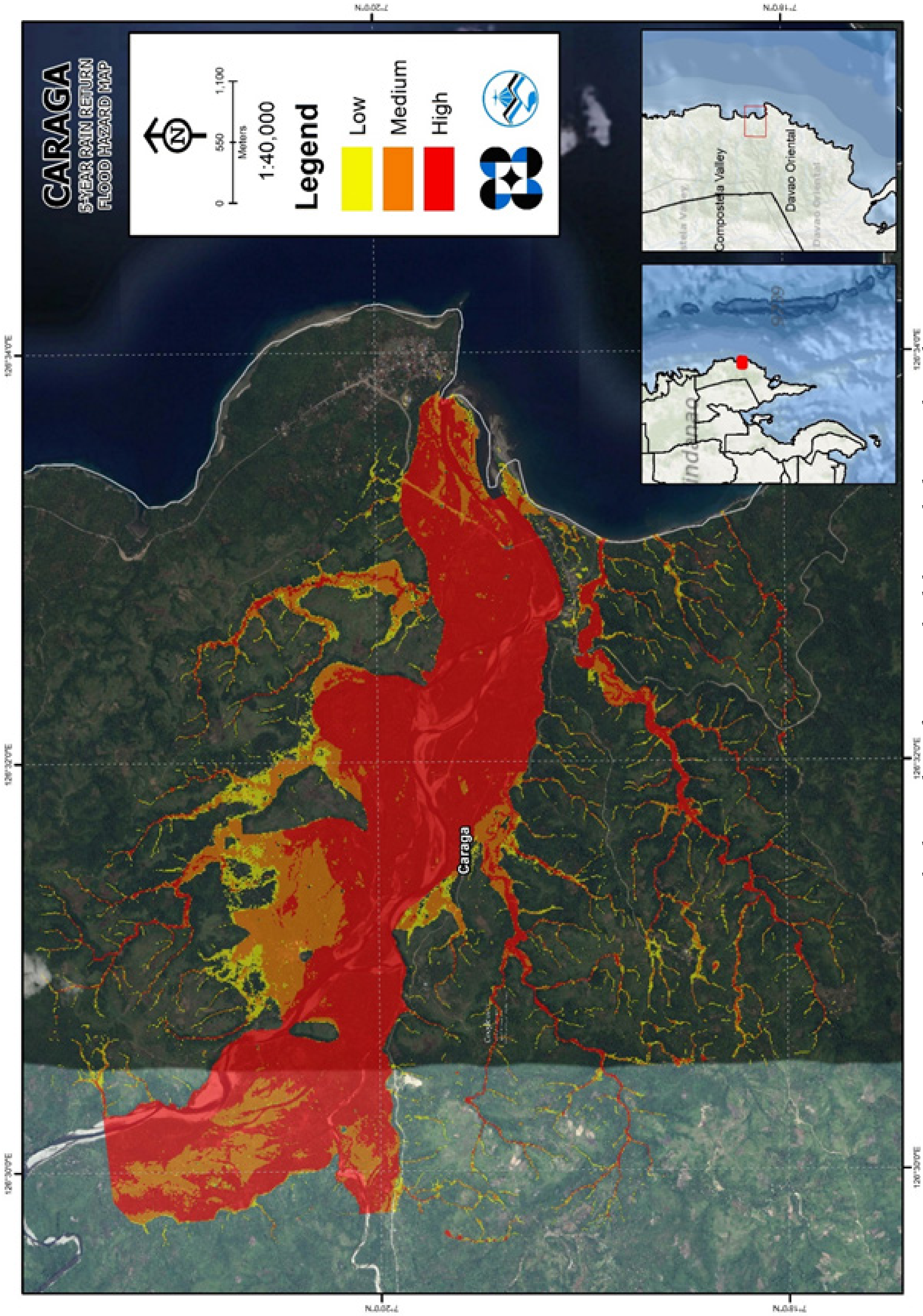


Figure 71. 5-year Flood Hazard Map for Caraga Floodplain overlaid on Google Earth imagery

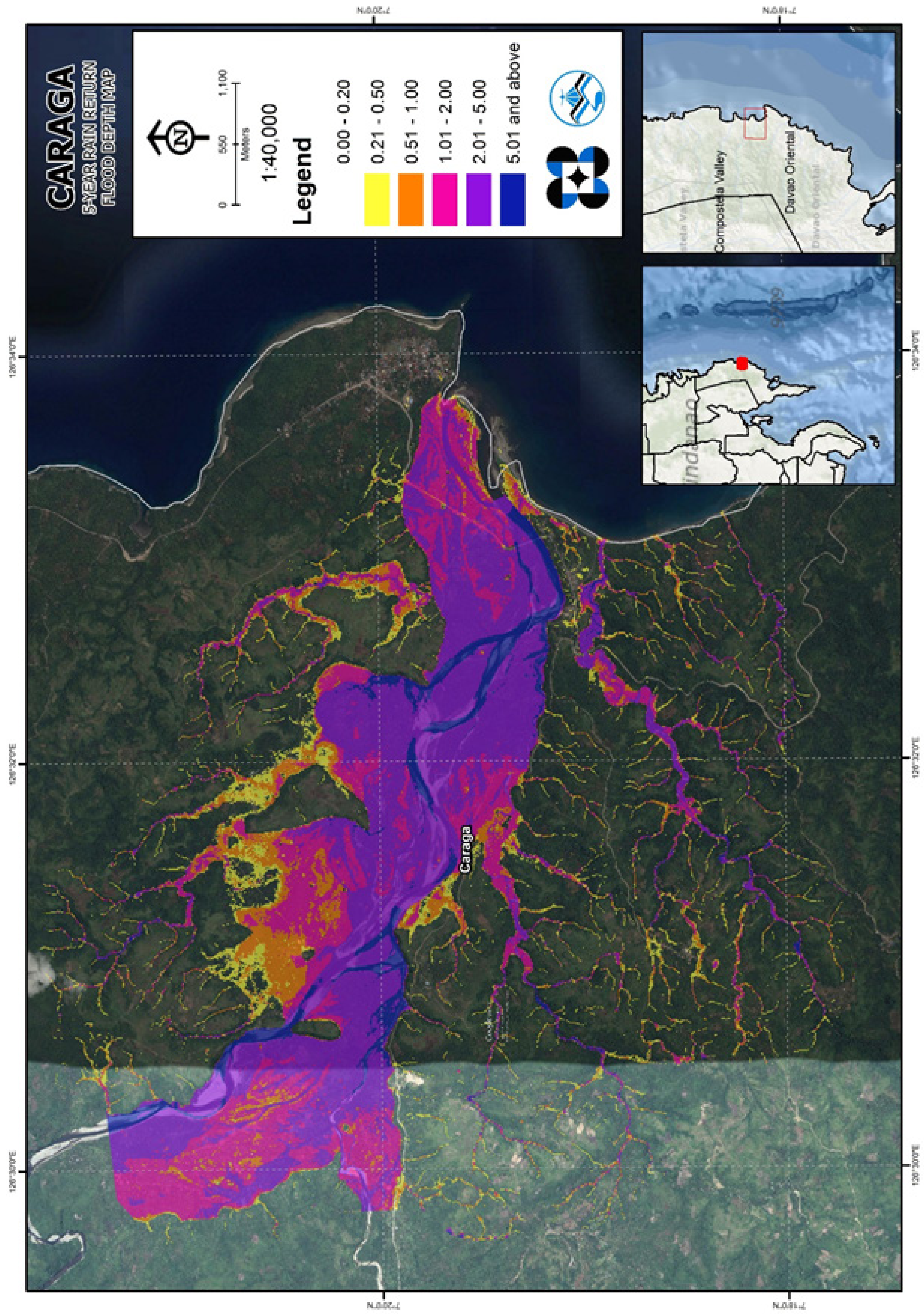


Figure 72. 5-year Flow Depth Map for Caraga Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Caraga river basin, grouped by municipality, are listed below. For the said basin, only one municipality consisting of eight barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 4.30% of the municipality of Caraga with an area of 569.48 sq. km. will experience flood levels of less than 0.20 meters. 0.27% of the area will experience flood levels of 0.21 to 0.50 meters while 0.30%, 0.67%, 1.13%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Caraga, Davao Oriental during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Caraga (in sq. km)							
		Don Leon Balante	Mercedes	Palma Gil	Pichon	Poblacion	San Jose	San Miguel	San Pedro
0.03-0.20	2.3	7.78	1.99	0.0083	3.16	1.43	4.36	3.48	
	0.21-0.50	0.14	0.33	0.078	0.0015	0.28	0.11	0.15	0.43
	0.51-1.00	0.13	0.2	0.039	0.0043	0.32	0.14	0.1	0.77
	1.01-2.00	0.37	0.21	0.023	0.12	0.89	0.4	0.12	1.69
	2.01-5.00	0.53	0.17	0.022	0.12	1.68	1.59	0.12	2.18
	> 5.00	0.13	0.021	0.0068	0.045	0.14	0.36	0.013	0.22

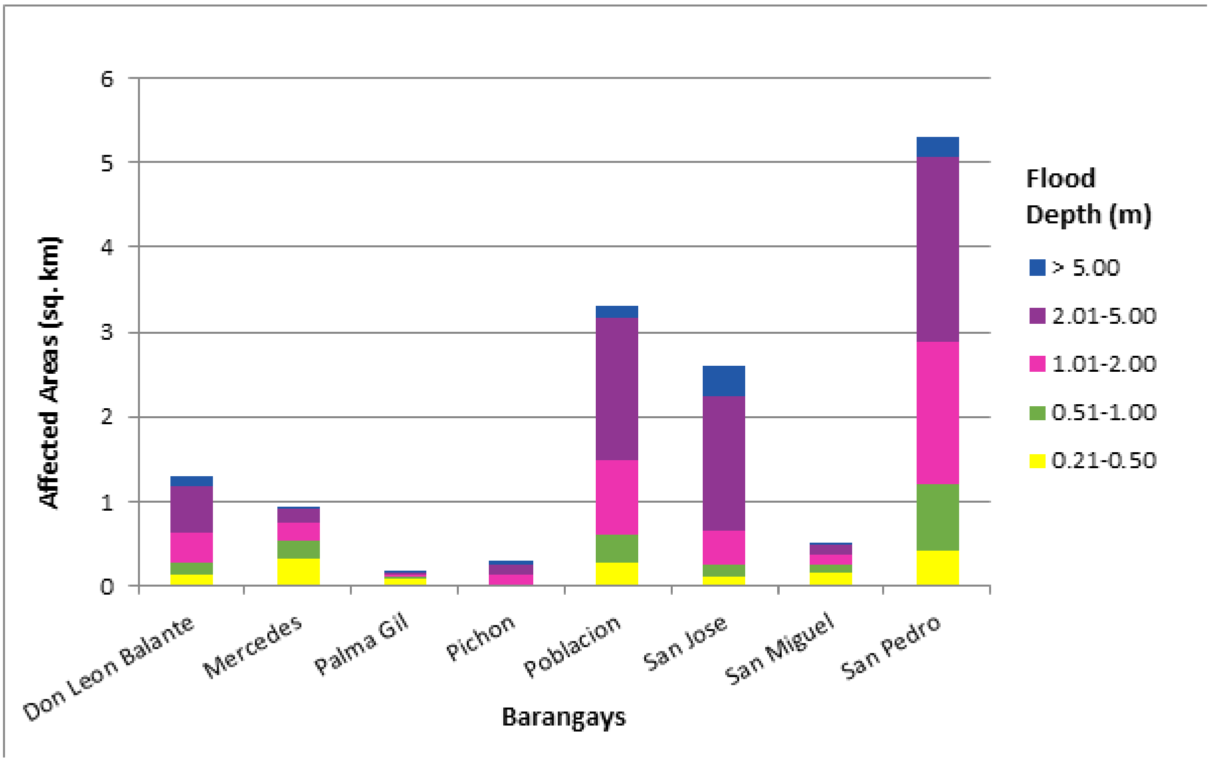


Figure 71 Affected Areas in Carga, Davao Oriental during 5-Year Rainfall Return Period

For the 25-year return period, 4.15% of the municipality of Caraga with an area of 569.48 sq. km. will experience flood levels of less than 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.37%, 1.34%, and 0.53% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Caraga, Davao Oriental during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Caraga (in sq. km)							
		Don Leon Balante	Mercedes	Palma Gil	Pichon	Poblacion	San Jose	San Miguel	San Pedro
0.03-0.20	2.3	2.22	7.63	1.96	0.0066	2.97	1.32	4.28	3.25
	0.21-0.50	0.11	0.39	0.089	0.0005	0.22	0.11	0.17	0.34
	0.51-1.00	0.076	0.22	0.047	0.0016	0.22	0.1	0.11	0.31
	1.01-2.00	0.18	0.2	0.026	0.019	0.53	0.16	0.12	0.86
	2.01-5.00	0.61	0.25	0.027	0.23	1.9	1.15	0.16	3.3
	> 5.00	0.39	0.037	0.01	0.048	0.63	1.19	0.029	0.7

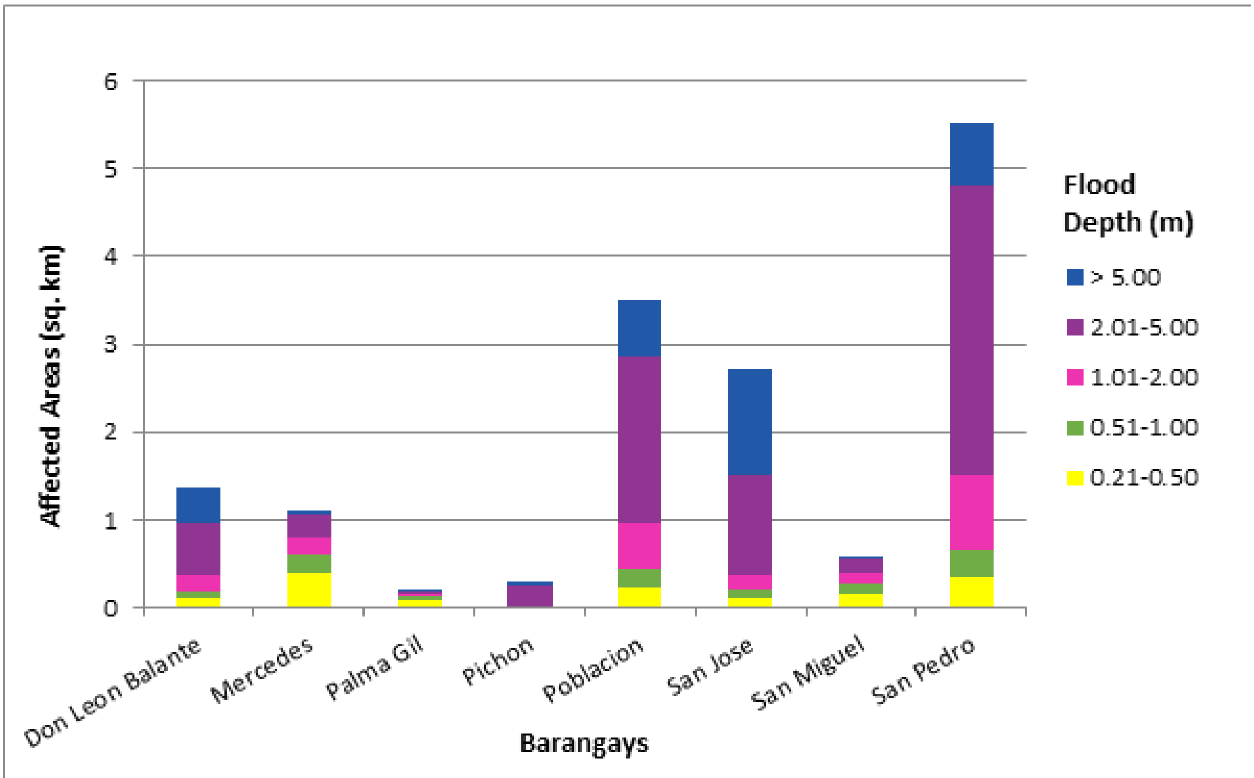


Figure 73 Affected Areas in Carga, Davao Oriental during 25-Year Rainfall Return Period

For the 100-year return period, 4.05% of the municipality of Caraga with an area of 569.48 sq. km. will experience flood levels of less than 0.20 meters. 0.24% of the area will experience flood levels of 0.21 to 0.50 meters while 0.18%, 0.23%, 0.96%, and 1.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Caraga, Davao Oriental during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		**Area of affected barangays in Caraga (in sq. km)**							
		Don Leon Balante	Mercedes	Palma Gil	Pichon	Poblacion	San Jose	San Miguel	San Pedro
0.03-0.20	**2.3**	2.18	7.52	1.93	0.0041	2.89	1.23	4.22	3.08
	0.21-0.50	0.12	0.42	0.097	0.0005	0.21	0.13	0.17	0.24
	0.51-1.00	0.066	0.24	0.055	0.00083	0.19	0.1	0.12	0.23
	1.01-2.00	0.07	0.19	0.029	0.0024	0.47	0.15	0.11	0.3
	2.01-5.00	0.46	0.29	0.027	0.21	1.82	0.48	0.19	1.99
	> 5.00	0.71	0.057	0.015	0.082	0.89	1.94	0.047	2.92

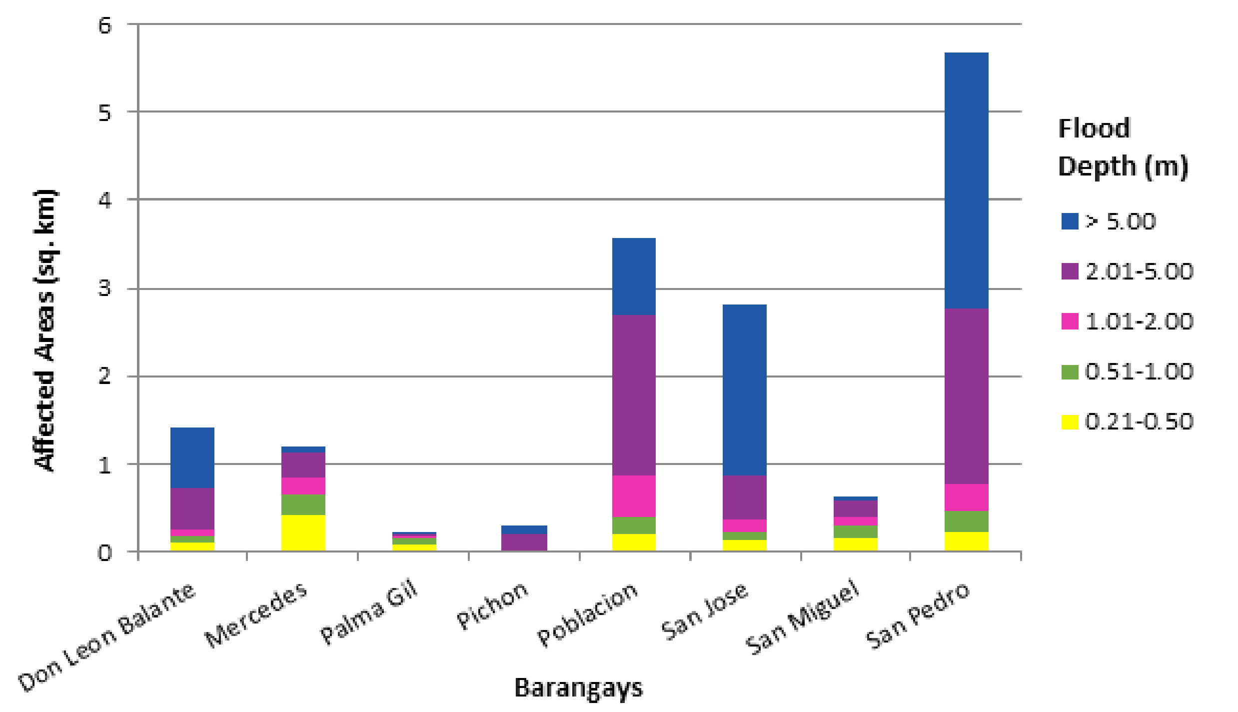


Figure 74. Affected Areas in Carga, Davao Oriental during 25-Year Rainfall Return Period

Among the barangays in the municipality of Caraga in Davao Oriental, San Pedro is projected to have the highest percentage of area that will experience flood levels at 1.54%. Meanwhile, Mercedes posted the second highest percentage of area that may be affected by flood depths at 1.53%.

Moreover, the generated flood hazard maps for the Caraga Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA 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	1.46	1.34	1.30
Medium	3.46	1.91	1.59
High	9.49	12.03	12.97
TOTAL	14.41	15.28	15.86

Of the 16 identified educational institutions in the Caraga floodplain, three schools were assessed to be highly prone to flooding as they are exposed to the High level flooding for all three rainfall scenarios. These are the Papag Day Care and Papag Primary School in Brgy. Poblacion and Potenciano A. Mabanding Elementary School in Brgy. San Pedro. Five other institutions were found to be also susceptible to flooding, experiencing Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios. See Appendix D for a detailed enumeration of schools in the Caraga floodplain.

Two medical institutions were identified in the Caraga floodplain. The Health Center in Brgy. San Jose was found to be relatively prone to flooding, having Medium level flooding in the 25- and 100-year rainfall scenarios. See Appendix E for a detailed enumeration of hospitals and clinics in the Caraga floodplain.

5.11 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.
The flood validation survey was conducted on January 24-27, 2017. The flood validation consists of 180 points randomly selected all over the Caraga flood plain. It has an RMSE value of 0.38.

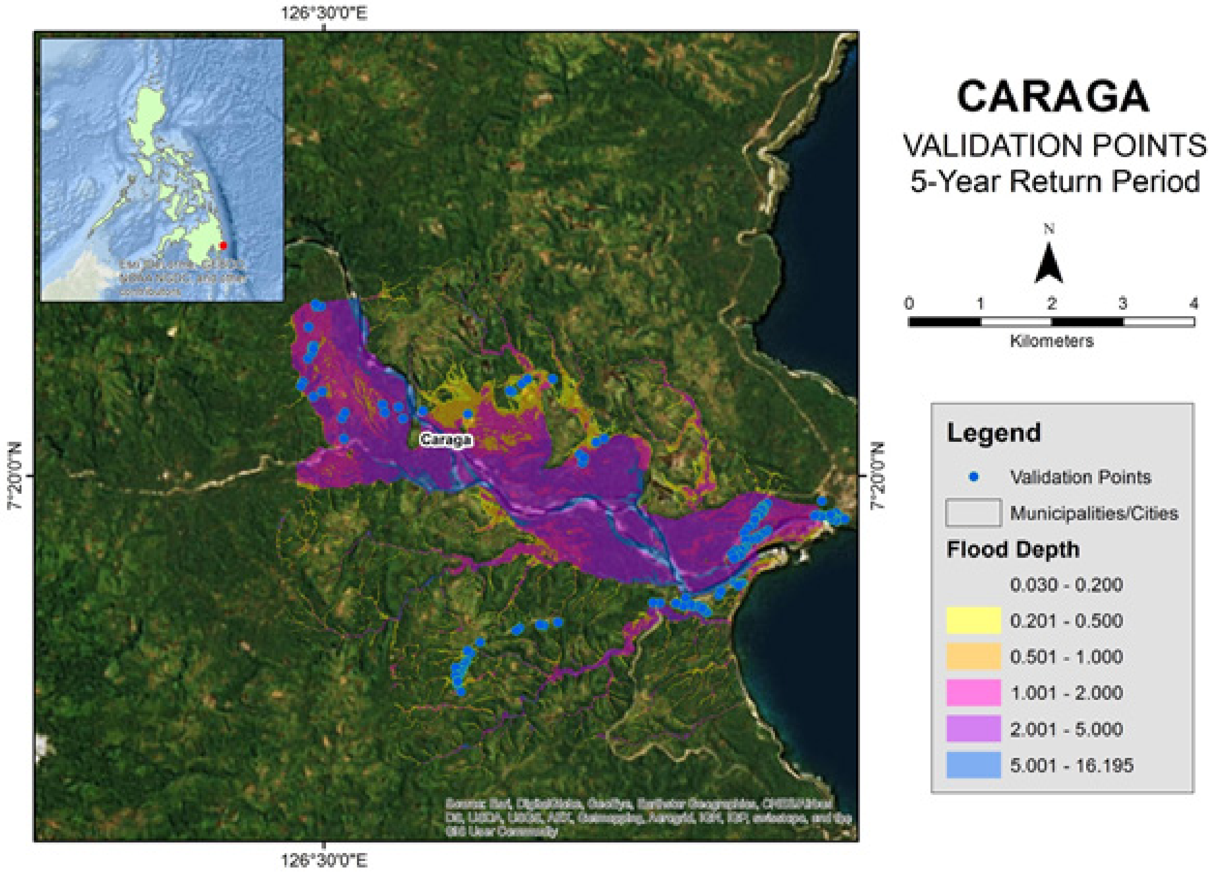


Figure 75. Flood Validation Points of Caraga River Basin

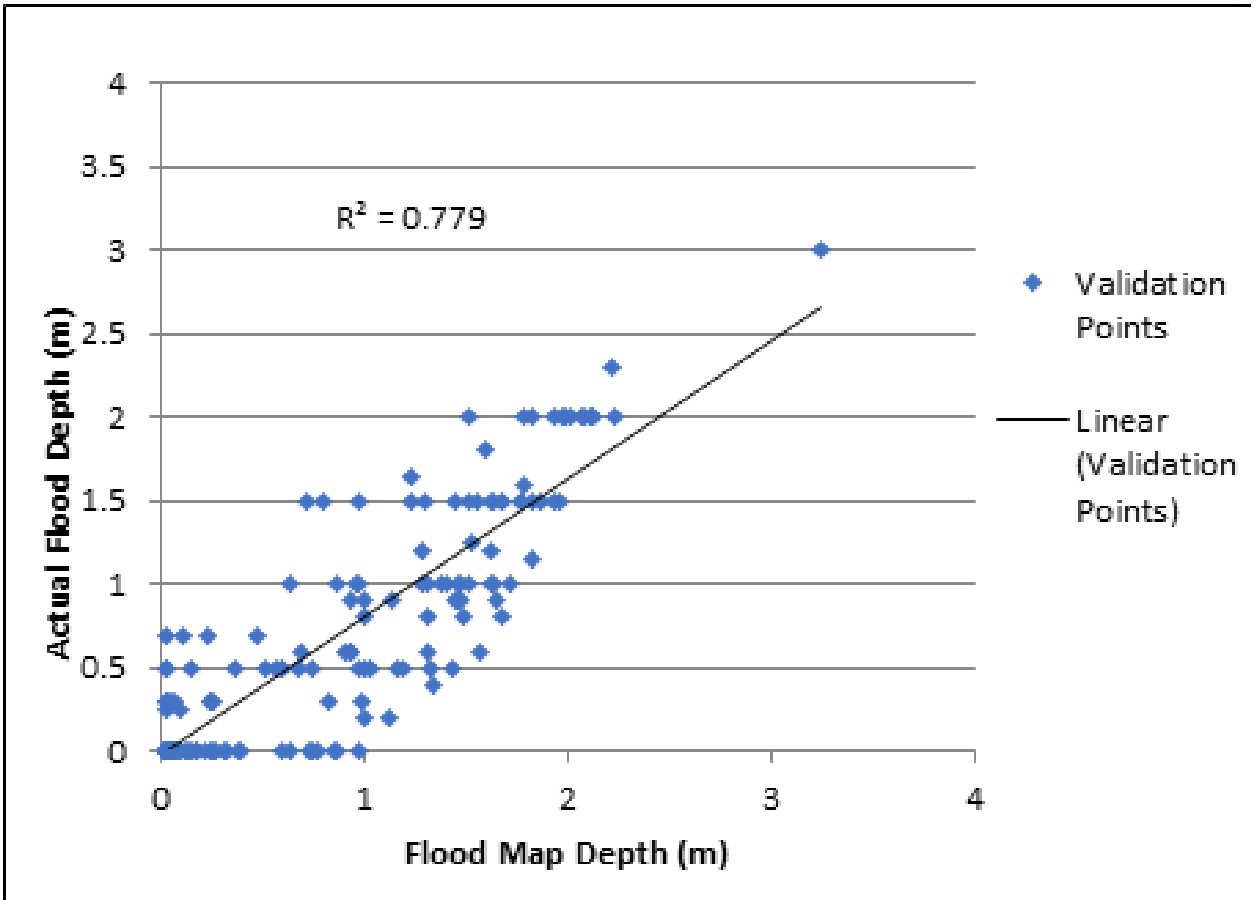


Figure 76. Flood Map Depth vs Actual Flood Depth for Caraga

Table 42. Actual Flood Depth vs Simulated Flood Depth in Caraga

HIMOGAANTANAO BASIN		**Modeled Flood Depth (m)**						
		0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
Actual Flood Depth (m)	**0-0.20**	55	8	8	2	0	0	73
	0.21-0.50	11	4	9	8	0	0	32
	0.51-1.00	2	2	9	22	0	0	35
	1.01-2.00	0	0	3	28	7	0	38
	2.01-5.00	0	0	0	0	2	0	2
	> 5.00		0	0	0	0	0	0
Total		68	14	29	60	9	0	180

The overall accuracy generated by the flood model is estimated at 54.44%, with 98 points correctly matching the actual flood depths. In addition, there were 62 points estimated one level above and below the correct flood depths while there were 18 points and 2 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 64 points were overestimated while a total of 18 points were underestimated in the modelled flood depths of Carga.

Table 43. Summary of Accuracy Assessment in Caraga

	No. of Points	**%**
Correct	98	54.44
Overestimated	64	35.56
Underestimated	18	10.00
Total	180	100

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UP TCAGP 2016. Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM)

ANNEXES

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

Parameter	Specifications
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy A(2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg
Operating temperature	Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Relative humidity	-10˚C to +35˚C (with insulating jacket)

ANNEX 2. Baseline Processing Reports of Control Points used in the LIDAR Survey

1. DVE-3126

Vector Components (Mark to Mark)

From:	SRS-51				
Grid		Local		Global	
Easting	846621.372 m	Latitude	N8°59'14.14996"	Latitude	N8°59'10.56678"
Northing	994872.010 m	Longitude	E126°09'06.83415"	Longitude	E126°09'12.17832"
Elevation	5.763 m	Height	3.970 m	Height	74.223 m

To:	DVE-3126				
Grid		Local		Global	
Easting	891740.922 m	Latitude	N7°41'33.20427"	Latitude	N7°41'30.00136"
Northing	851882.057 m	Longitude	E126°32'59.94854"	Longitude	E126°33'05.40517"
Elevation	0.998 m	Height	-5.941 m	Height	67.952 m

Vector					
ΔEasting	45119.550 m	NS Fwd Azimuth	162°56'36"	ΔX	-47621.341 m
ΔNorthing	-142989.954 m	Ellipsoid Dist.	149746.573 m	ΔY	-9273.608 m
ΔElevation	-4.766 m	ΔHeight	-9.911 m	ΔZ	-141665.618 m

Standard Errors

Vector errors:					
σ ΔEasting	0.020 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.021 m
σ ΔNorthing	0.007 m	σ Ellipsoid Dist.	0.009 m	σ ΔY	0.024 m
σ ΔElevation	0.026 m	σ ΔHeight	0.026 m	σ ΔZ	0.007 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0004612106		
Y	-0.0001109864	0.0005957667	
Z	-0.0000176080	0.0000629753	0.0000484189

Occupations

	From	To
Point ID:	SRS-51	DVE-3126
Data file:	C:\Users\Francis\Documents\Business Center - HCE\Unnamed\SRS51 (Modular) 7-12-14 [1.745m].T02	C:\Users\Francis\Documents\Business Center - HCE\Unnamed\DVE-3126 07-12-2014.T02
Receiver type:	SPS852	SPS985
Receiver serial number:	5203K81512	5245F15419
Antenna type:	Zephyr Geodetic 2	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.745 m	1.318 m
Antenna method:	Bottom of notch	Bottom of antenna mount

2. DVE-3131

Vector Components (Mark to Mark)

From:	SRS-51				
Grid		Local		Global	
Easting	186815.622 m	Latitude	N8°59'14.14996"	Latitude	N8°59'10.56678"
Northing	994598.260 m	Longitude	E126°09'06.83416"	Longitude	E126°09'12.17833"
Elevation	5.763 m	Height	3.970 m	Height	74.223 m

To:	DVE-3131				
Grid		Local		Global	
Easting	230883.431 m	Latitude	N7°36'29.46050"	Latitude	N7°36'26.28124"
Northing	841687.881 m	Longitude	E126°33'39.32918"	Longitude	E126°33'44.79335"
Elevation	1.547 m	Height	-5.921 m	Height	68.164 m

Vector					
ΔEasting	44067.809 m	NS Fwd Azimuth	163°30'38"	ΔX	-49330.944 m
ΔNorthing	-152910.379 m	Ellipsoid Dist.	159030.189 m	ΔY	-8994.816 m
ΔElevation	-4.216 m	ΔHeight	-9.891 m	ΔZ	-150913.103 m

Standard Errors

Vector errors:					
σ ΔEasting	0.034 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.039 m
σ ΔNorthing	0.013 m	σ Ellipsoid Dist.	0.017 m	σ ΔY	0.038 m
σ ΔElevation	0.043 m	σ ΔHeight	0.043 m	σ ΔZ	0.012 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0015296729		
Y	-0.0003741356	0.0014376767	
Z	0.0000465303	0.0001216775	0.0001381710

Occupations

	From	To
Point ID:	SRS-51	DVE-3131
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\SRS51 (Modular) 7-12-14 [1.745m].T02	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\DVE-3131 07-12-2014.T02
Receiver type:	SPS852	SPS882
Receiver serial number:	5203K81512	5152479948
Antenna type:	Zephyr Geodetic 2	R8 GNSS/SPS88x Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.745 m	2.000 m
Antenna method:	Bottom of notch	Bottom of antenna mount

3. DVE-3153

Vector Components (Mark to Mark)

From:	SRS-53				
Grid		Local		Global	
Easting	194250.425 m	Latitude	N8°44'37.87785"	Latitude	N8°44'34.36515"
Northing	967600.492 m	Longitude	E126°13'16.64511"	Longitude	E126°13'22.01039"
Elevation	1.580 m	Height	-1.349 m	Height	69.593 m

To:	DVE-3153				
Grid		Local		Global	
Easting	218763.330 m	Latitude	N7°46'01.89052"	Latitude	N7°45'58.65857"
Northing	859352.572 m	Longitude	E126°27'00.70790"	Longitude	E126°27'06.15889"
Elevation	1.857 m	Height	-3.275 m	Height	70.225 m

Vector					
ΔEasting	24512.905 m	NS Fwd Azimuth	166°50'26"	ΔX	-29505.700 m
ΔNorthing	-108247.921 m	Ellipsoid Dist.	110914.749 m	ΔY	-2452.737 m
ΔElevation	0.277 m	ΔHeight	-1.926 m	ΔZ	-106888.401 m

Standard Errors

Vector errors:					
σ ΔEasting	0.005 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.021 m
σ ΔNorthing	0.007 m	σ Ellipsoid Dist.	0.007 m	σ ΔY	0.025 m
σ ΔElevation	0.032 m	σ ΔHeight	0.032 m	σ ΔZ	0.005 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0004293989		
Y	-0.0004977399	0.0006189728	
Z	-0.0000093219	0.0000181871	0.0000254883

Occupations

	From	To
Point ID:	SRS-53	DVE-3153
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\SRS53 (Modular) 7-15-14 [1.485m].T02	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\DVE-3153 07-15-2014.T02
Receiver type:	SPS852	SPS985
Receiver serial number:	5203K81512	5245F15419
Antenna type:	Zephyr Geodetic 2	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.485 m	1.398 m
Antenna method:	Bottom of notch	Bottom of antenna mount

4. BMDE-55

Vector Components (Mark to Mark)

From:	DVE-3131				
Grid		Local		Global	
Easting	230883.431 m	Latitude	N7°36'29.46049"	Latitude	N7°36'26.28124"
Northing	841687.880 m	Longitude	E126°33'39.32918"	Longitude	E126°33'44.79335"
Elevation	1.548 m	Height	-5.921 m	Height	68.164 m

To:	BMDE-55				
Grid		Local		Global	
Easting	228323.839 m	Latitude	N7°38'34.72735"	Latitude	N7°38'31.53663"
Northing	845552.447 m	Longitude	E126°32'15.14874"	Longitude	E126°32'20.61002"
Elevation	4.466 m	Height	-2.399 m	Height	71.560 m

Vector					
ΔEasting	-2559.591 m	NS Fwd Azimuth	326°09'31"	ΔX	2374.874 m
ΔNorthing	3864.566 m	Ellipsoid Dist.	4633.000 m	ΔY	1129.207 m
ΔElevation	2.918 m	ΔHeight	3.522 m	ΔZ	3814.380 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000119555		
Y	-0.0000124714	0.0000165411	
Z	-0.0000018989	0.0000030005	0.0000014243

Occupations

	From	To
Point ID:	DVE-3131	BMDE-55
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\DVE-3131 06-29-2014.T02	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\BMDE-55 06-29-2014.T02
Receiver type:	SPS882	SPS985
Receiver serial number:	5152479948	5245F15419
Antenna type:	R8 GNSS/SPS88x Internal	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	2.000 m	1.573 m
Antenna method:	Bottom of antenna mount	Bottom of antenna mount

5. CATEEL BLLM-03

Vector Components (Mark to Mark)

From:	DVE-3153				
Grid		Local		Global	
Easting	218763.545 m	Latitude	N7°46'01.89052"	Latitude	N7°45'58.65857"
Northing	859352.570 m	Longitude	E126°27'00.71491"	Longitude	E126°27'06.16589"
Elevation	1.857 m	Height	-3.275 m	Height	70.225 m

To:	BLLM-03				
Grid		Local		Global	
Easting	218742.813 m	Latitude	N7°46'01.73121"	Latitude	N7°45'58.49925"
Northing	859347.798 m	Longitude	E126°27'00.03964"	Longitude	E126°27'05.49063"
Elevation	1.971 m	Height	-3.158 m	Height	70.341 m

Vector					
ΔEasting	-20.732 m	NS Fwd Azimuth	256°41'32"	ΔX	16.181 m
ΔNorthing	-4.772 m	Ellipsoid Dist.	21.262 m	ΔY	12.917 m
ΔElevation	0.114 m	ΔHeight	0.116 m	ΔZ	-4.834 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'05"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000005860		
Y	-0.0000007795	0.0000016813	
Z	0.0000000073	0.0000000468	0.0000001947

Occupations

	From	To
Point ID:	DVE-3153	BLLM-03
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\DVE-3153 07-16-2014.T02	C:\Users\Windows User\Documents \Business Center - HCE\BMDE-55 BLLM-03\CATEEL BLLM-03 7-16-14.T02
Receiver type:	SPS985	SPS882
Receiver serial number:	5245F15419	5152479948
Antenna type:	SPS985 Internal	R8 GNSS/SPS88x Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.449 m	2.000 m
Antenna method:	Bottom of antenna mount	Bottom of antenna mount

6. DVE-19

Vector Components (Mark to Mark)

From:	SRS-51				
Grid		Local		Global	
Easting	186815.622 m	Latitude	N8°59'14.14995"	Latitude	N8°59'10.56678"
Northing	994598.260 m	Longitude	E126°09'06.83416"	Longitude	E126°09'12.17833"
Elevation	5.763 m	Height	3.970 m	Height	74.223 m

To:	DVE-19				
Grid		Local		Global	
Easting	228220.944 m	Latitude	N7°12'55.40692"	Latitude	N7°12'52.33147"
Northing	798242.632 m	Longitude	E126°32'20.36690"	Longitude	E126°32'25.86714"
Elevation	4.520 m	Height	-5.421 m	Height	69.364 m

Vector					
ΔEasting	41405.322 m	NS Fwd Azimuth	167°41'20"	ΔX	-50724.032 m
ΔNorthing	-196355.628 m	Ellipsoid Dist.	200641.192 m	ΔY	-3061.651 m
ΔElevation	-1.243 m	ΔHeight	-9.391 m	ΔZ	-193987.320 m

Standard Errors

Vector errors:					
σ ΔEasting	0.015 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.018 m
σ ΔNorthing	0.007 m	σ Ellipsoid Dist.	0.009 m	σ ΔY	0.024 m
σ ΔElevation	0.027 m	σ ΔHeight	0.027 m	σ ΔZ	0.008 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0003330378		
Y	-0.0002190878	0.0005839047	
Z	-0.0000099289	0.0000986309	0.0000610561

Occupations

	From	To
Point ID:	SRS-51	DVE-19
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\DVE-19 DVE-201\SRS51 (Modular) 7-8-14 [1.629m].T02	C:\Users\Windows User\Documents \Business Center - HCE\DVE-19 DVE-201\DVE-19 07-08-2014.T02
Receiver type:	SPS852	SPS985
Receiver serial number:	5203K81512	5245F15419
Antenna type:	Zephyr Geodetic 2	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	1.629 m	1.481 m
Antenna method:	Bottom of notch	Bottom of antenna mount

7. DVE-20

Vector Components (Mark to Mark)

From:	DVE-20				
Grid		Local		Global	
Easting	228219.879 m	Latitude	N7°12'51.11197"	Latitude	N7°12'48.03684"
Northing	798110.635 m	Longitude	E126°32'20.35643"	Longitude	E126°32'25.85577"
Elevation	3.741 m	Height	-6.215 m	Height	68.572 m

To:	DVE-19				
Grid		Local		Global	
Easting	228220.734 m	Latitude	N7°12'55.40683"	Latitude	N7°12'52.33137"
Northing	798242.630 m	Longitude	E126°32'20.36008"	Longitude	E126°32'25.86031"
Elevation	4.340 m	Height	-5.601 m	Height	69.184 m

Vector					
ΔEasting	0.855 m	NS Fwd Azimuth	0°03'43"	ΔX	9.390 m
ΔNorthing	131.995 m	Ellipsoid Dist.	131.930 m	ΔY	-12.906 m
ΔElevation	0.599 m	ΔHeight	0.614 m	ΔZ	130.962 m

Standard Errors

Vector errors:					
σ ΔEasting	0.008 m	σ NS fwd Azimuth	0°00'12"	σ ΔX	0.011 m
σ ΔNorthing	0.006 m	σ Ellipsoid Dist.	0.006 m	σ ΔY	0.012 m
σ ΔElevation	0.015 m	σ ΔHeight	0.015 m	σ ΔZ	0.006 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0001243942		
Y	-0.0000742449	0.0001516896	
Z	-0.0000004838	0.0000124527	0.0000328557

Occupations

	From	To
Point ID:	DVE-20	DVE-19
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\DVE-19 DVE-201\DVE-20 07-08-2014.T02	C:\Users\Windows User\Documents \Business Center - HCE\DVE-19 DVE-201\DVE-19 07-08-2014.T02
Receiver type:	SPS882	SPS985
Receiver serial number:	5152479948	5245F15419
Antenna type:	R8 GNSS/SPS88x Internal	SPS985 Internal
Antenna serial number:	--------	--------
Antenna height (measured):	2.000 m	1.481 m
Antenna method:	Bottom of antenna mount	Bottom of antenna mount

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
		LOVELY GRACIA ACUÑA	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
		FOR. MA. VERLINA TONGA	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download & Transfer	Research Associate (RA)	ENGR. KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN JOHN DONGUINES	AAC

Annex 5. Data Transfer Sheet for Caraga Floodplain

DATA TRANSFER SHEET

[illegible] DAVAO ORIENTAL - [illegible]

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	
6/18/2014	7318GC*	2BLK84A169A	GEMINI	NA	217	6.21	217	17.3	106KB	17.8	NA	4.66	1KB	2KB	3	9	Z:\Airborne_Raw\7318GC
6/19/2014	7320G	2BLK85A84B170A	GEMINI	NA	116/58	330	224	na	na	13.3	NA	3.62	1KB	1KB	4	NA	Z:\Airborne_Raw\7320GC
6/20/2014	7322G	2BLK84AS6B171A	GEMINI	NA	405	524	242	na	na	22	NA	4.66	1KB	1KB	6	9	Z:\Airborne_Raw\7322GC
6/20/2014	7323G	2BLK86CS3A171B	GEMINI	NA	393/191	509	244	na	na	20.4	NA	5.26	1KB	1KB	4	na	Z:\Airborne_Raw\7323GC
6/22/2014	7326G	2BLK80B173A	GEMINI	NA	335	533	252	na	na	23.4	NA	7	1KB	1KB	4	9	Z:\Airborne_Raw\7326G
6/23/2014	7328GC*	2BLK80A8174A	GEMINI	NA	na	582	239	91.3	177kb	20.9	NA	5.81	1KB	1KB	8	na	Z:\Airborne_Raw\7328GC

Received from

Name C. Joaquin

Position

Signature

Received by

Name LIDA F. PRIETO

Position

Signature 07/02/2014

*PRIORITY FLIGHTS WITH CASI DATA

DATA TRANSFER SHEET
07/08/2014(Davao Oriental - 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	
6/27/2014	7337GC	2BLK86A178A	Gemini	NA	209/70	366	163	NA	NA	16.9	NA	7.59	1KB	1KB	4/4/5/5/5/4	24	Z:\Airborne_Raw\7337GC
6/28/2014	7339GC	2BLK79C179A	Gemini	NA	179/11	367	74.8	NA	NA	14.3	NA	5.08	1KB	1KB	5	179/11	Z:\Airborne_Raw\7339GC
6/29/2014	7340GC	2BLK79B180A	Gemini	NA	119	580	265	NA	NA	28.2	NA	4.68	1KB	1KB	5	119	Z:\Airborne_Raw\7339
7/1/2014	7344GC	2BLK84B182A	Gemini	NA	158/22	188	174	NA	NA	2.90/6.69	NA	6.95	1KB	1KB	9	158/22	Z:\Airborne_Raw\1634A
7/2/2014	7346GC	2BLK79BSA183A	Gemini	NA	376	612	279	NA	NA	29.7	NA	5.32	1KB	1KB	9	376	Z:\Airborne_Raw\1636A
7/3/2014	7348GC	2BLK79V184A	Gemini	NA	597	200	212	NA	NA	6.58	NA	6.49	1KB	1KB	14	597	Z:\Airborne_Raw\1636A
7/4/2014	7350GC	2BLK85B185A	Gemini	NA	300	499	258	NA	NA	23.8	NA	7.05	1KB	1KB	8	300	Z:\Airborne_Raw\1636A

Received from

Name Kristine Andaya
Position R.A.
Signature

Received by

Name JCIDA F. PRIETO
Position SSRS
Signature 7/14/14

DATA TRANSFER SHEET
07/08/2014(Davao Oriental - 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	
7/7/2014	7356GC	2BLK80AS188A	Gemini	NA	347/11	589	265	NA	NA	27.7	NA	9.58	1KB	1KB	4	374/11	Z:\Airborne_Raw
7/7/2014	7357GC	2BLK80BS188B	Gemini	NA	406	111	79.8	NA	NA	5.05	NA	7.68	1KB	1KB	4	406	Z:\Airborne_Raw
7/8/2014	7358GC	2BLK80BS189A	Gemini	NA	165/7/14	318	196	NA	NA	20.1		4.83	1KB	1KB	7/3	165/7/14	Z:\Airborne_Raw
7/10/2014	7362GC	2BLK85CS191A	Gemini	NA	138	244	188	NA	NA	7.95	NA	4.7	1KB	1KB	8/5/4	138	Z:\Airborne_Raw
7/11/2014	7364GC	2BLK85V192A	Gemini	NA	234/9/12	488	207	NA	NA	27.3	NA	5.8	1KB	1KB	4/9	234/9/12	Z:\Airborne_Raw
7/12/2014	7366GC	2BLK79D80BV193A	Gemini	NA	60	409	241	NA	NA	12.2	NA	4.89	1KB	1KB	5/7	14/17	Z:\Airborne_Raw
7/15/2014	7372GC	2BLK79E196A	Gemini	NA	30/6	68.7	158	NA	NA	3.47	NA	4.56	1KB	1KB	3	30/6	Z:\Airborne_Raw
7/16/2014	7374GC	2BLK79ES197A	Gemini	NA	139	239	156	NA	NA	9.01	NA	3.42	1KB	1KB	3/4	139	Z:\Airborne_Raw

Received from

Name TIN ANTOMIA
Position
Signature KA

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 7/28/14

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 7326GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7326

1 LIDAR Operator: MV Tonga	2 ALTM Model: Gemini/CASI	3 Mission Name: 2BLK80A173A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: B. Dongumes	9 Route:			
10 Date: 6-22-14	12 Airport of Departure (Airport, City/Province): RPMQ		12 Airport of Arrival (Airport, City/Province): RPMQ		
13 Engine On: 9:10	14 Engine Off: 13:33	15 Total Engine Time: 4:23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

completed 15 lines in BLK 80A (without CASI)

21 Problems and Solutions:

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

2. Flight Log for 7328GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7328

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini/CASI	3 Mission Name: 2BLKABS174A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: B. Dirogunes	9 Route:			
10 Date: 6-23-14	12 Airport of Departure (Airport, City/Province): RPMQ		12 Airport of Arrival (Airport, City/Province): RPMQ		
13 Engine On: 8+7	14 Engine Off: 12+30	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed Block 80A and Block 80B (with CASI)					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
P. Maro		R. SAMAR II	LK Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 7339GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7339

1 LiDAR Operator: MVE TONGA	2 ALTM Model: Gemini CASI	3 Mission Name: 2BLK79CI79A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: B. Dongallnes	9 Route: MATI			
10 Date: June 23, 2014	12 Airport of Departure (Airport, City/Province): MATI		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 11:01	14 Engine Off: 15:24	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 12 lines of BLK 79 A (without CASI)

21 Problems and Solutions:

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

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

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

Lidar Operator — MVE TONGA — Signature over Printed Name

4. Flight Log for 7340GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7390

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gem 1 CASI	3 Mission Name: 2BLK79B180A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: C2 Samar	8 Co-Pilot: B. Donguines	9 Route:			
10 Date: June 29, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:57	14 Engine Off: 13:19	15 Total Engine Time: 4 22	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks: Surveyed 13 lines of BLK79 (without CASI)					

21 Problems and Solutions:

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

5. Flight Log for 7346GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7346

1 LiDAR Operator: LK Paragas	2 ALTM Model: GEMINI	3 Mission Name: 2BLK79A183A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAK	8 Co-Pilot: B. DONGUINES	9 Route: MATI			
10 Date: July 2, 2014	12 Airport of Departure (Airport, City/Province): MATI		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 9:47	14 Engine Off: 14:22	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Mission completd (without GASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
P. [signature]	[signature]	R. SAMAK	LK Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

7. Flight Log for 7356GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7356

1 LiDAR Operator: MVE TONGA	2 ALTM Model: GEMI OASI	3 Mission Name: 2BLK80AS188A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: K. SAMAR	8 Co-Pilot: B-Dongcuines	9 Route: MATI			
10 Date: July 7, 2014	12 Airport of Departure (Airport, City/Province): MATI		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 9:58	14 Engine Off: 14:27	15 Total Engine Time: 9:29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: Surveyed 20 lines of BLK 8DA (without OASI)					

21 Problems and Solutions:

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

8. Flight Log for 7357GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7357

1 LiDAR Operator: LK Paragas	2 ALTM Model: GEM+CASI	3 Mission Name: 2BLK80S188B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAK	8 Co-Pilot: B. Donguines	9 Route: MATI			
10 Date: July 7, 2014	12 Airport of Departure (Airport, City/Province): MATI		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 16:19	14 Engine Off: 18:06	15 Total Engine Time: 1	16 Take off: 47	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Completed the rest of BLK 80A (without CASI)

21 Problems and Solutions:

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

9. Flight Log for 7366GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7366

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini	3 Mission Name: 2BLK79D193A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9372
7 Pilot: R. Samar	8 Co-Pilot: B. Dongiuinas	9 Route: MATI			
10 Date: July 12, 2014	12 Airport of Departure (Airport, City/Province): MATI		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:50	14 Engine Off: 12:07	15 Total Engine Time: 4:17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 26 lines of BLK 79D and voids of BLK80 (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	R. SAMAR II Signature over Printed Name	LK Paragas Signature over Printed Name

10. Flight Log for 7372GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7372

1 LIDAR Operator: MV Tanya	2 ALTM Model: GC	3 Mission Name: 2BLK79ES19GA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9322
7 Pilot: Samar-II	8 Co-Pilot: Dongungues	9 Route: Mati			
10 Date: 7-15-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8+58	14 Engine Off: 11+51	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Flight Aborted due to strong wind in the area

21 Problems and Solutions:

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

11. Flight Log for 7374GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7374

1 LiDAR Operator: LK Paragas	2 ALTM Model: GC	3 Mission Name: 2BLK79ES	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9322
7 Pilot: Lamar	8 Co-Pilot: Dongunes	9 Route: Mati	197A		
10 Date: 7-16-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6+31	14 Engine Off: 9+42	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Fair				

20 Remarks:

Surveyed 8 lines over Boston - Blk 79E (without CASI)

21 Problems and Solutions:

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

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

Pilot-in-Command
FOR
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

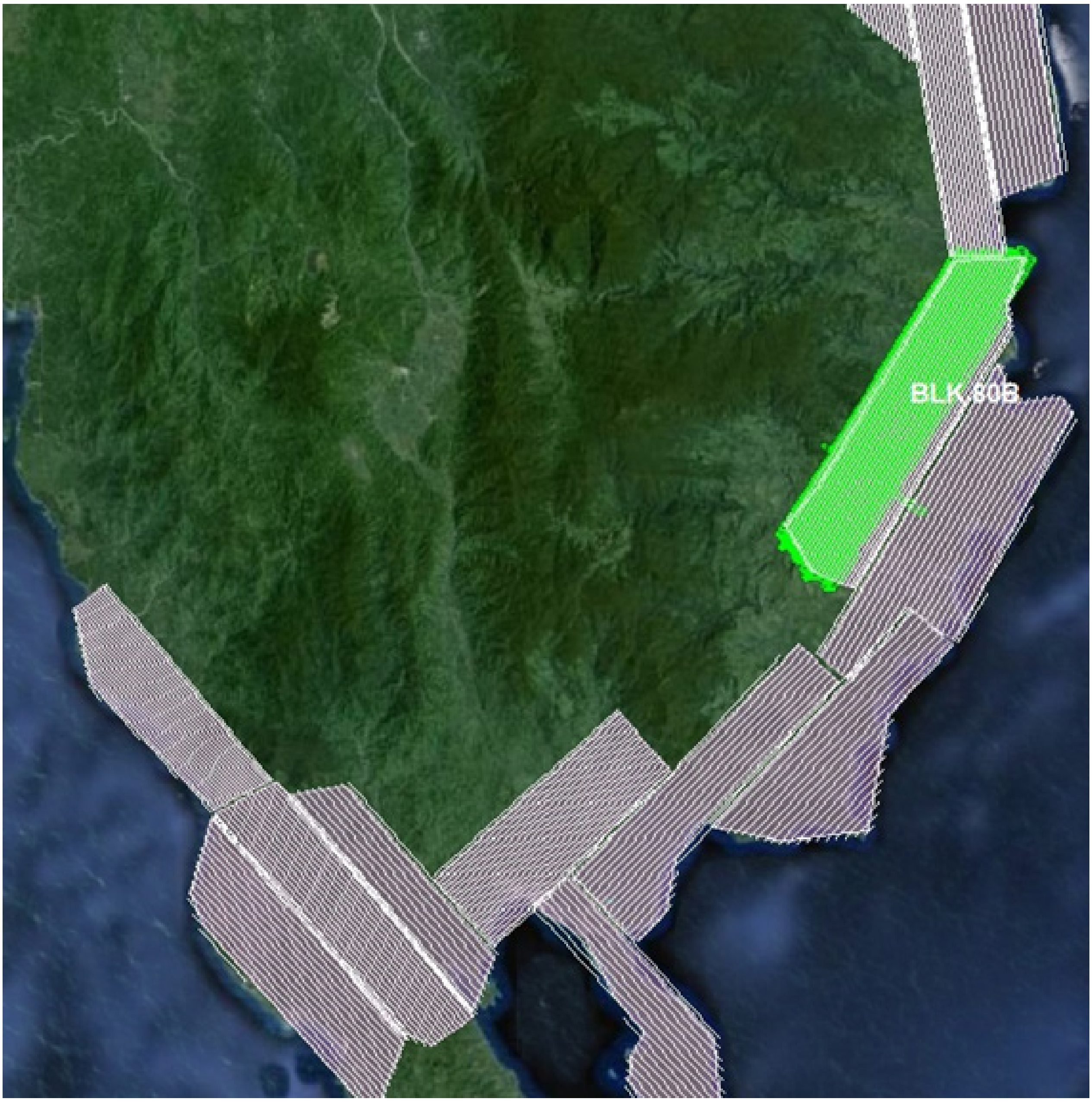
ANNEX 7. Flight status reports

DAVAO ORIENTAL
(June 16 - July 16, 2014)

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7326GC	BLK80B	2BLK80B173A	MV TONGA	June 22, 2014	9 lines at 1200m. 7 lines at 1000m.
7328GC	BLK80A, BLK80B	2BLK80AB174A	LK PARAGAS	June 23, 2014	With CASI (19 lines)
7339GC	BLK79C	2BLK79C179A	MV TONGA	June 28, 2014	Rebooted system due to 100%DO. Completed 14 lines
7340GC	BLK79B	2BLK79B180A	LK PARAGAS	June 29, 2014	12 lines at 1000m
7346GC	BLK79B, BLK 79A	2BLK79BSA183A	LK PARAGAS	July 02, 2014	Completed 4 lines of BLK79B and 15 lines of BLK79A
7348GC	BLK79B	2BLK79V184A	MV TONGA	July 03, 2014	Voids on BLK79B
7356GC	BLK80AB	2BLK80AS188A	MV TONGA	July 07, 2014	*reflight (flown without CASI)
7357GC	BLK 89A	2BLK80BS188B	LK PARAGAS	July 07, 2014	*reflight (flown without CASI)
7366GC	BLK79D	2BLK79D80BV193A	LK PARAGAS	July 12, 2014	Covered BLK 79D. with voids area in BLK 80B.
7372GC	BLK 79E	2BLK79E196A	MV TONGA	July 15, 2014	Strong head and tail wind at 1200m. 3 lines.
7374GC	BLK 79E	2BLK79ES197A	LK PARAGAS	July 16, 2014	Strong head and tail wind at 1200m.

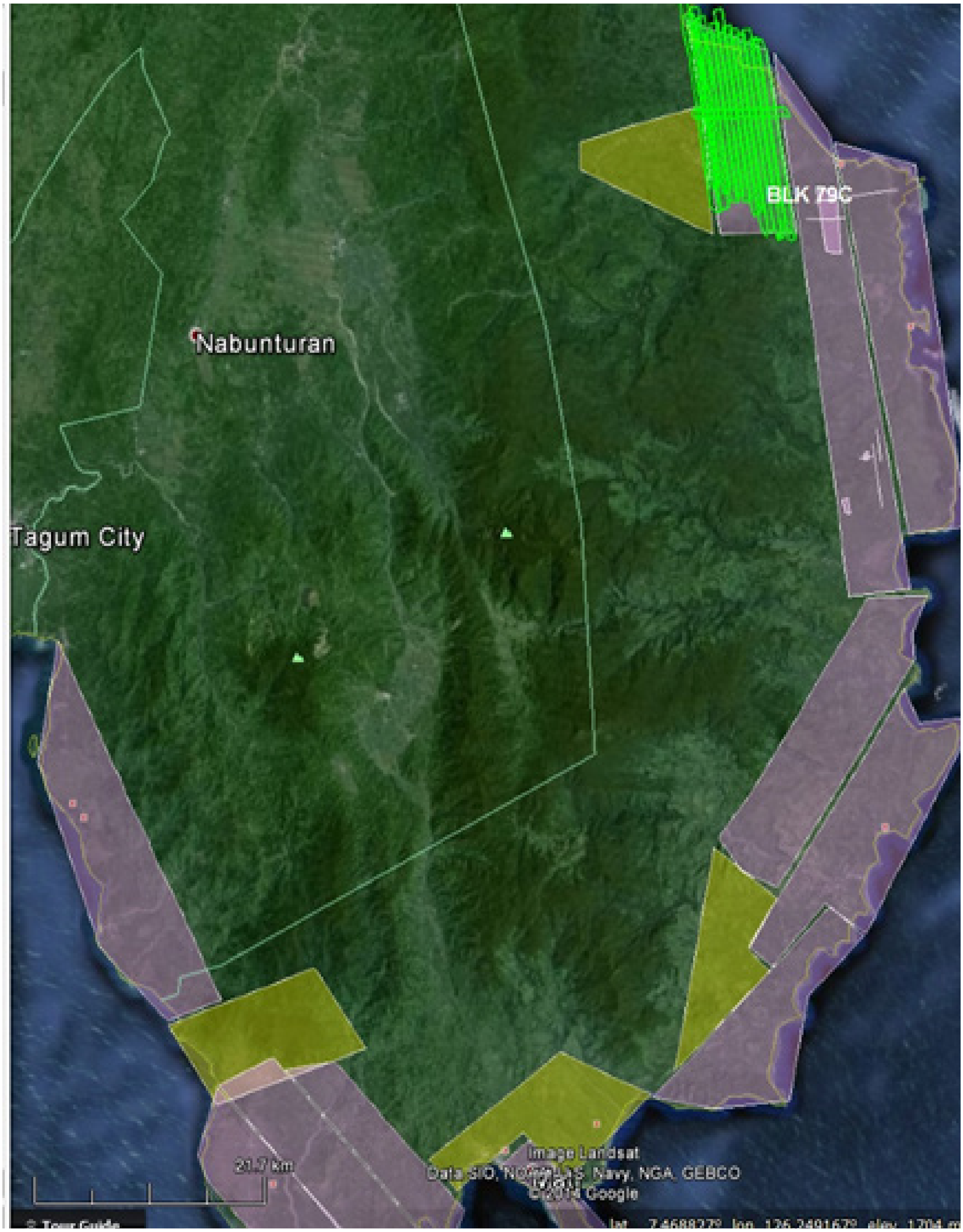
LAS BOUNDARIES PER FLIGHT

Flight No. : 7326GC
Area: BLK80B
Mission name: 2BLK83B173A
Parameters: Altitude: 1200 m; Scan Frequency: 60 Hz;
Scan Angle: 13 deg; Overlap: 40 %
Area covered: 175.22 km2

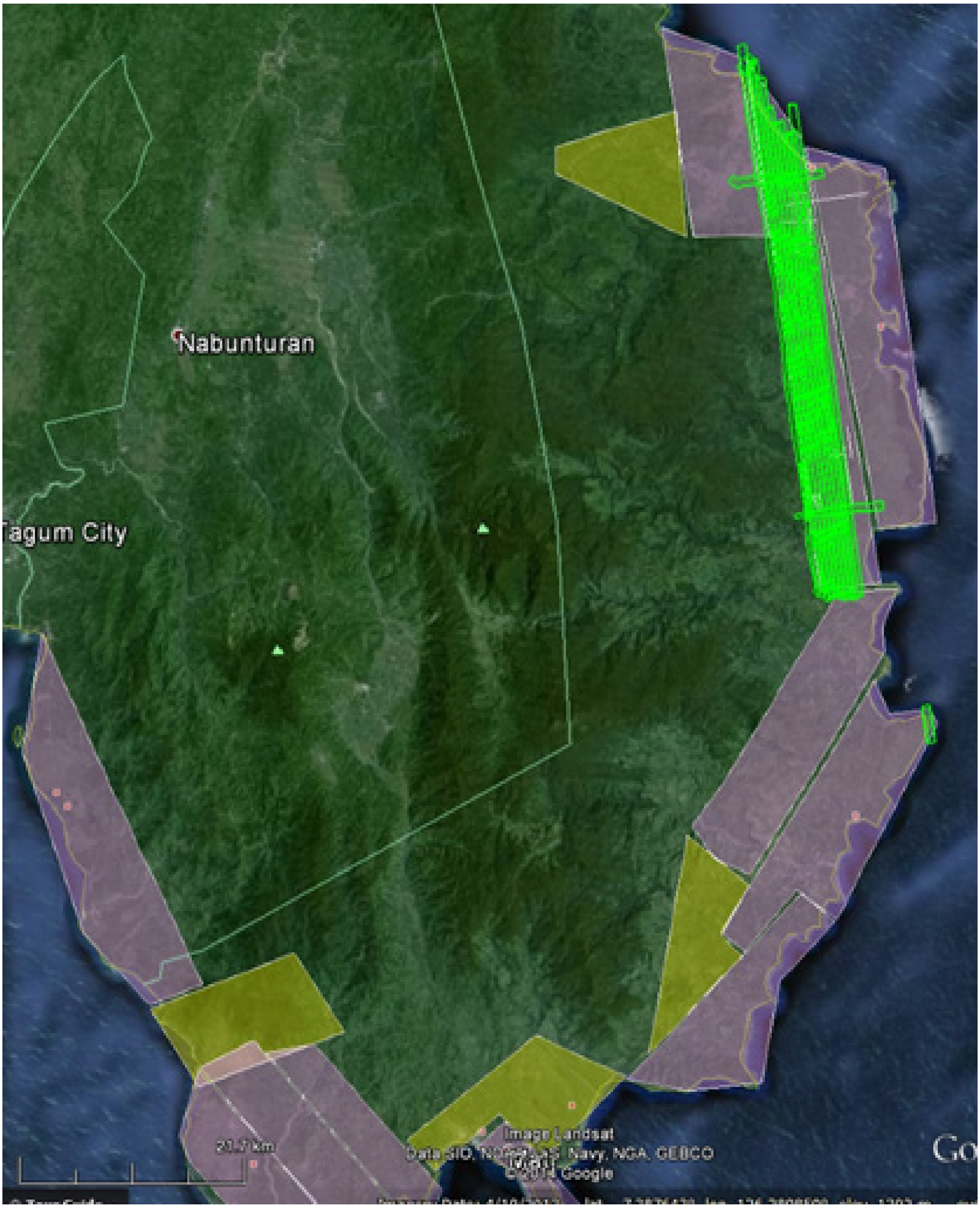


Flight No. :	7328GC	
Area:	BLK80A, BLK80B	
Mission name:	2BLK80ABS174A	
Parameters:	Altitude: 1100 m;	Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 30 %	
Area covered:	244.67 km2	

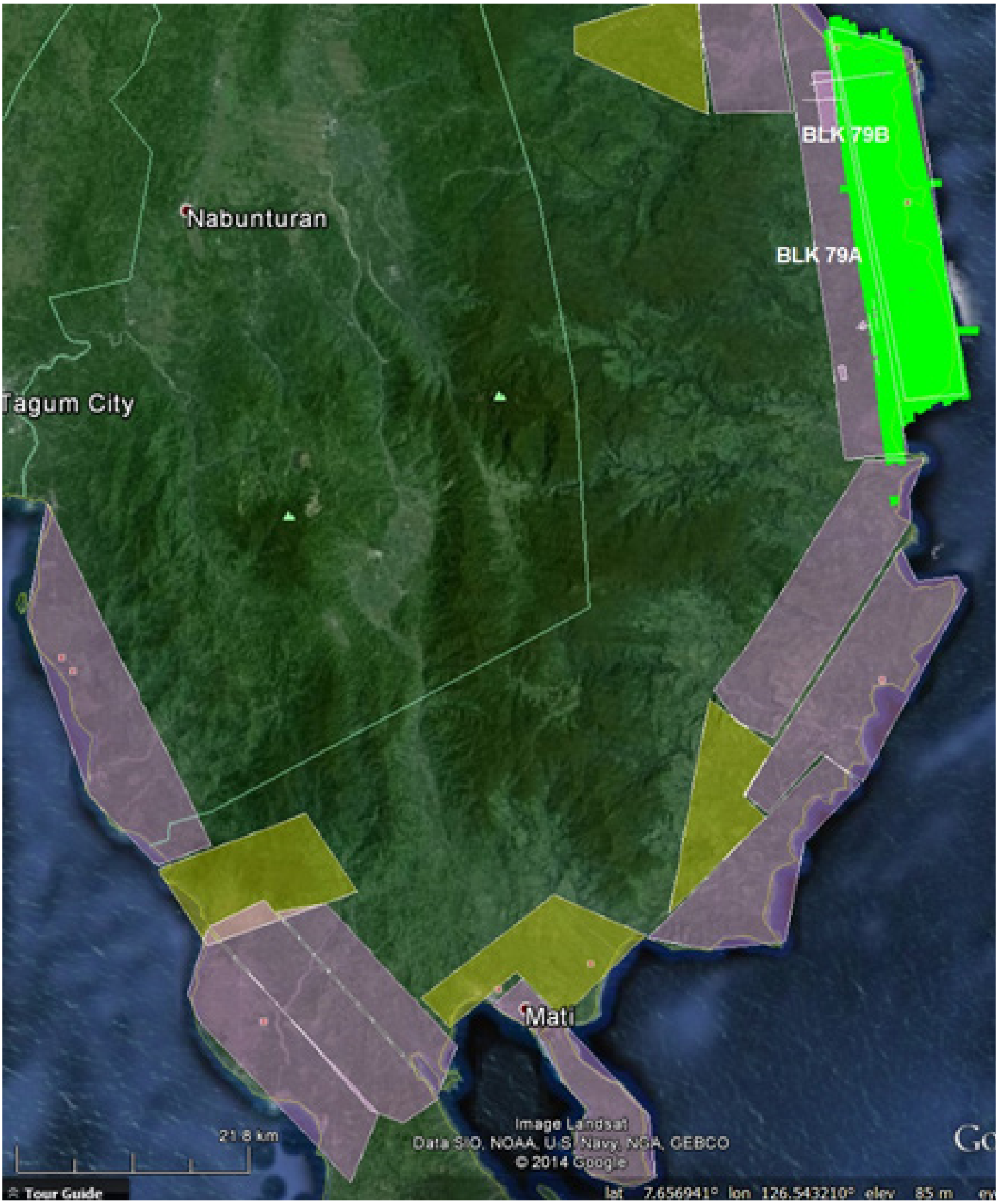
Flight No. :	7339GC	
Area:	BLK79C	
Mission name:	2BLK79C179A	
Parameters:	Altitude: 1100 m;	Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 45 %	
Area covered:	131.42 km2	



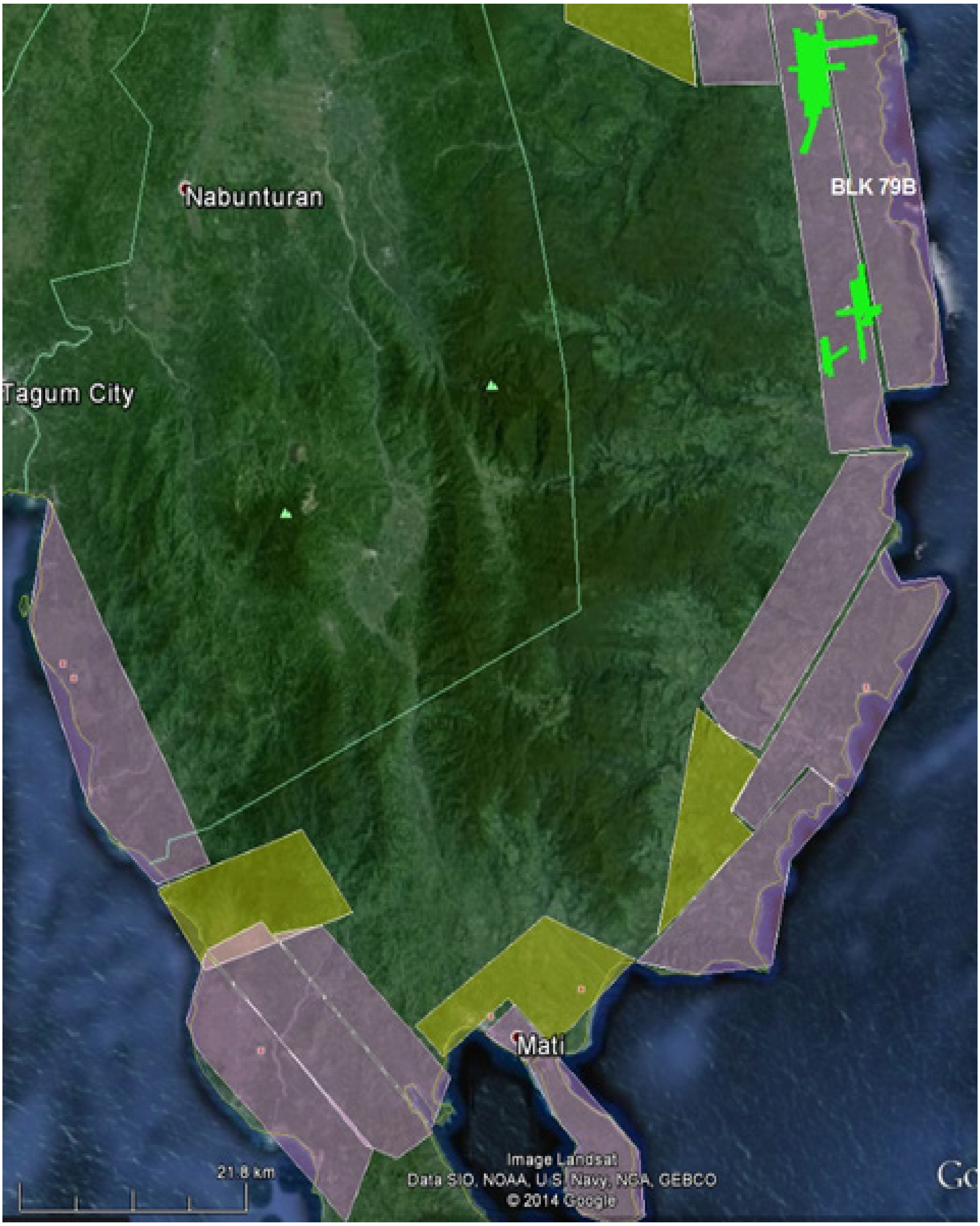
Flight No. :	7340GC
Area:	BLK79B
Mission name:	2BLK79B180A
Parameters:	Altitude: 1100 m; Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 45 %
Area covered:	217.22 km2



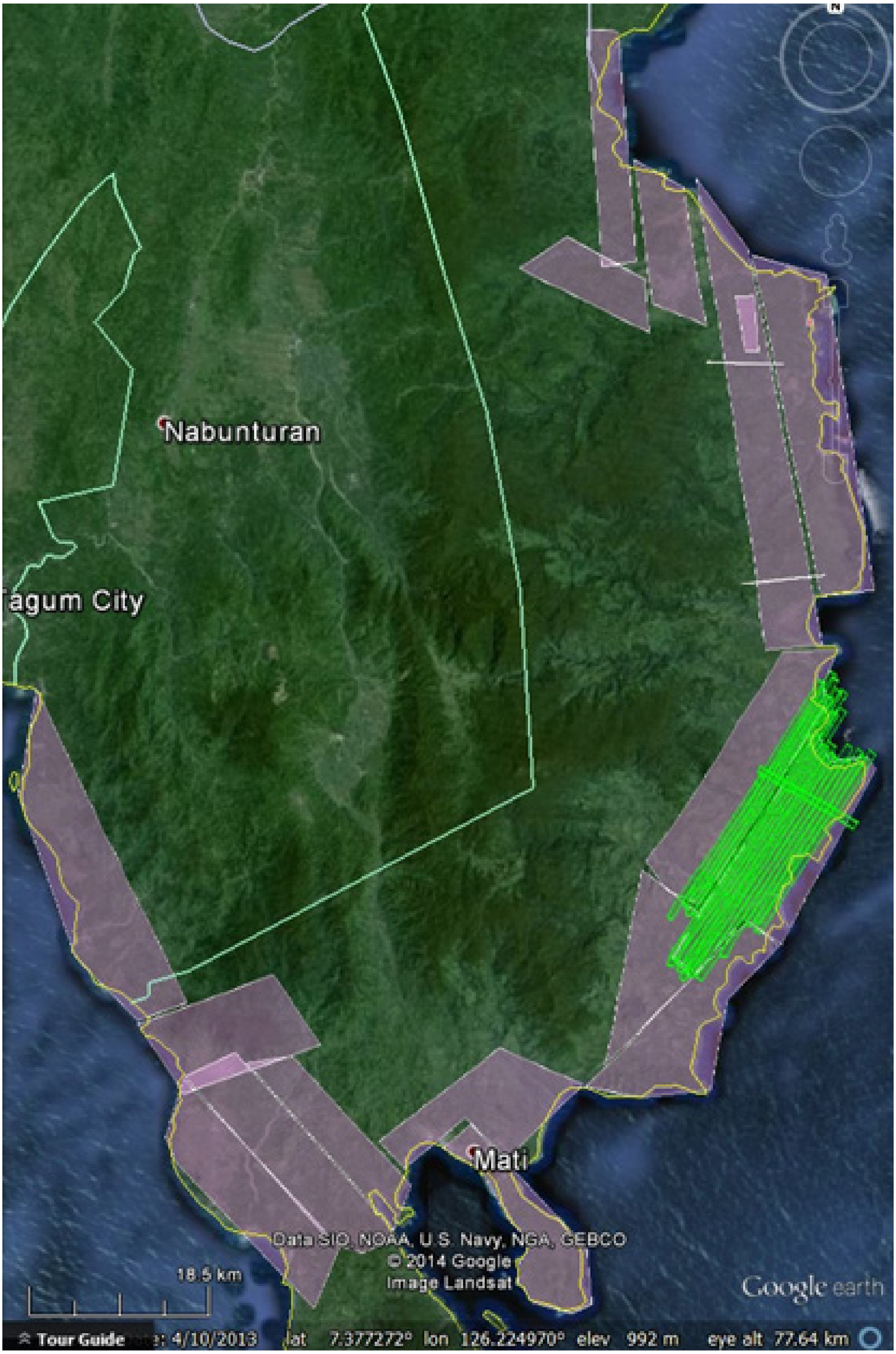
Flight No. :	7346GC	
Area:	BLK79B, BLK79A	
Mission name:	2BLK79BSA183A	
Parameters:	Altitude: 1100 m;	Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 45 %	
Area covered:	284.06 km2	



Flight No. :	7348GC	
Area:	VOIDS ON BLK79B	
Mission name:	2BLK79D184A	
Parameters:	Altitude: 1100 m;	Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 35 %	
Area covered:	42.89 km2	

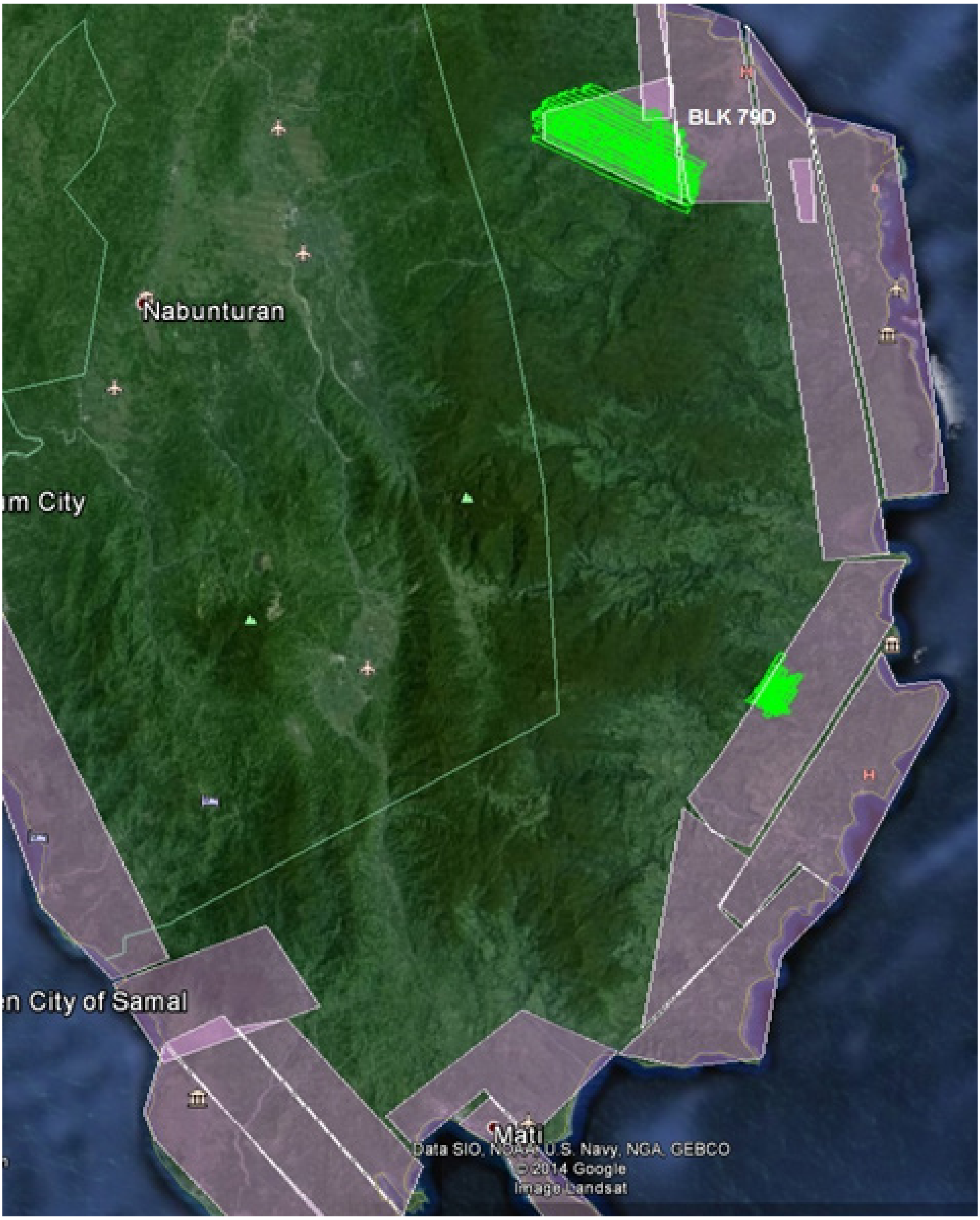


Flight No. :	7356GC	
Area:	BLK80AB	
Mission name:	2BLK80AS188A	
Parameters:	Altitude: 1100 m;	Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 30 %	
Area covered:	235.92 km2	



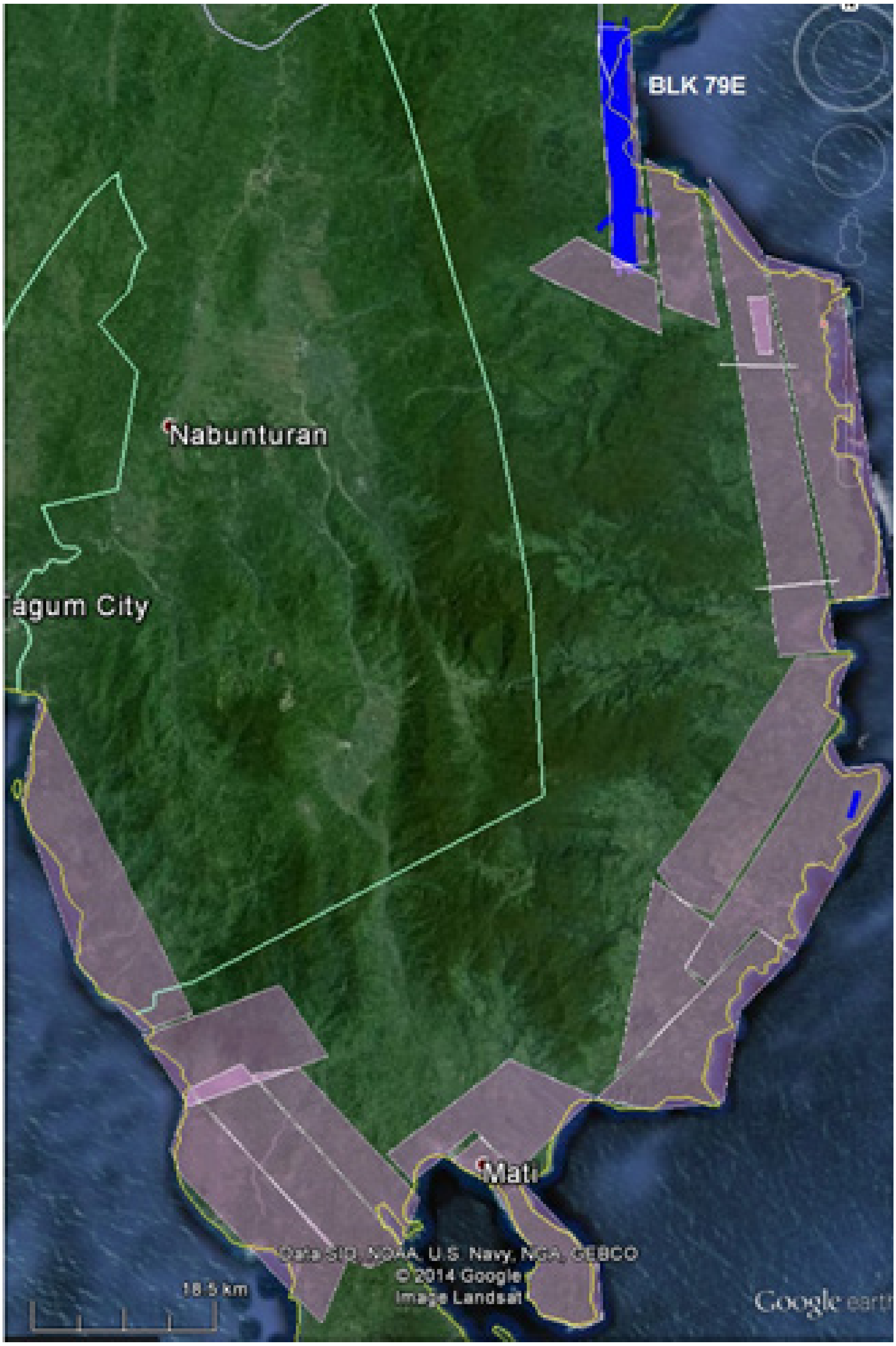
Flight No. :	7357GC	
Area:	BLK80B	
Mission name:	2BLK80AS188B	
Parameters:	Altitude: 1100 m;	Scan Frequency: 50 Hz;
Scan Angle: 20 deg;	Overlap: 30 %	
Area covered:	44.12 km2	

Flight No. :	7366GC	
Area:	BLK79D	
Mission name:	2BLK79D80V193A	
Parameters:	Altitude: 1400 m;	Scan Frequency: 70 Hz;
Scan Angle: 12 deg;	Overlap: 40 %	
Area covered:	102.18 km2	



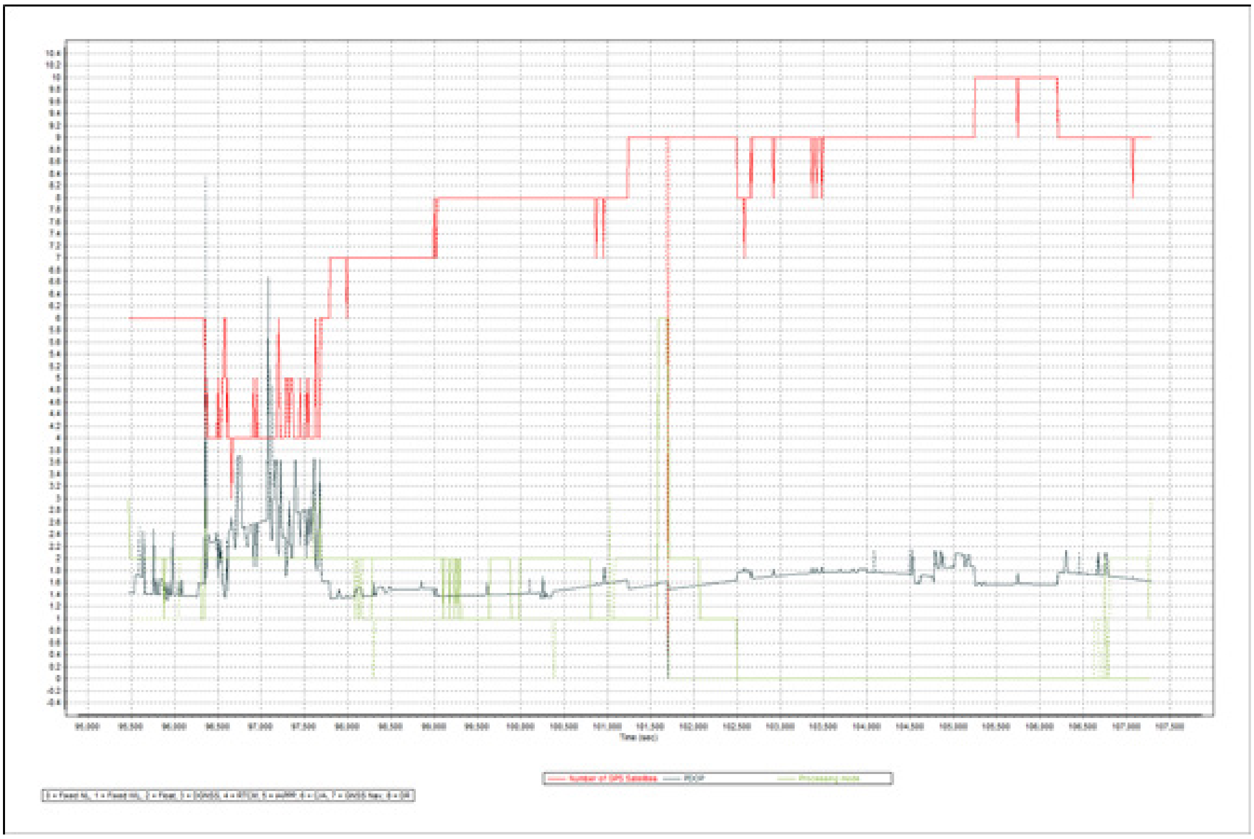
Flight No. :	7372GC	
Area:	BLK79E	
Mission name:	2BLK79ES196A	
Parameters:	Altitude: 1200 m;	Scan Frequency: 52 Hz;
Scan Angle: 19 deg;	Overlap: 40 %	
Area covered:	23.88 km2	

Flight No. :	7374GC	
Area:	BLK79E	
Mission name:	2BLK79E197A	
Parameters:	Altitude: 1200 m;	Scan Frequency: 60 Hz;
Scan Angle: 13 deg;	Overlap: 40 %	
Area covered:	69.78 km2	

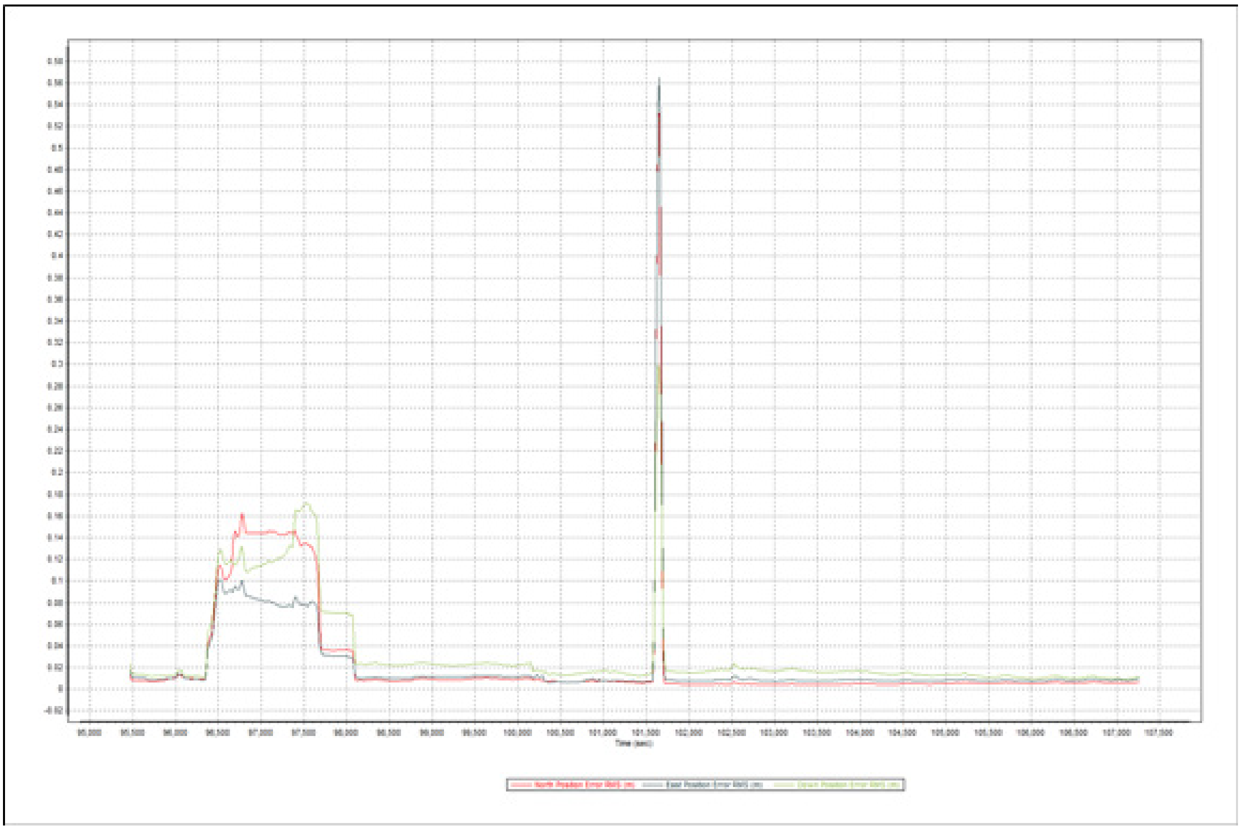


ANNEX 8. Mission Summary Reports

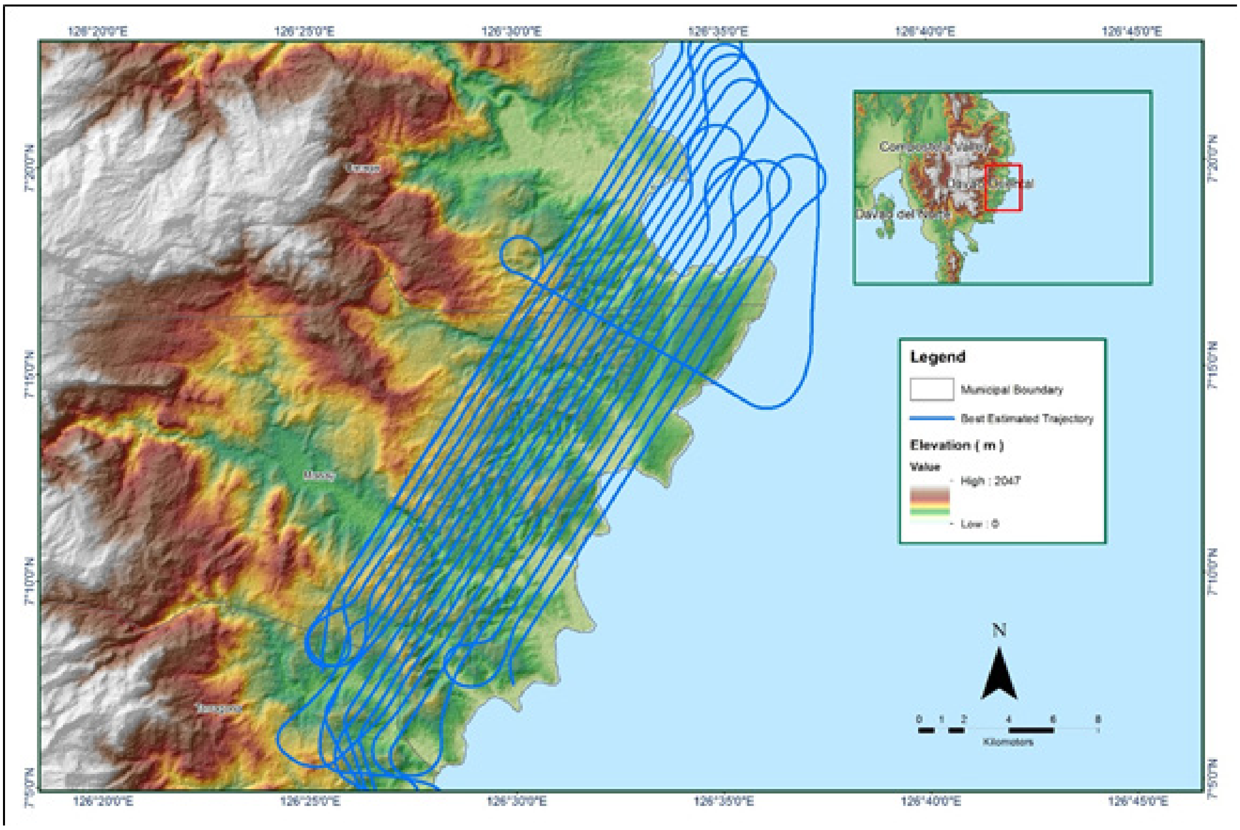
Flight Area	Davao Oriental
Mission Name	Blk80A
Inclusive Flights	7356G,7357G,7328G
Range data size	59.65 GB
Base data size	22.87 MB
POS	583.8 MB
Image	na
Transfer date	July 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.2
RMSE for East Position (<4.0 cm)	5.6
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000359
IMU attitude correction stdev (<0.001deg)	0.091610
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	27.79%
Ave point cloud density per sq.m. (>2.0)	3.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	283
Maximum Height	486.68 m
Minimum Height	61.17 m
Classification (# of points)	
Ground	76,073,098
Low vegetation	52,339,767
Medium vegetation	142,481,912
High vegetation	301,965,591
Building	1,771,922
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Angelo Carlo Bongat, Aljon Rie Araneta, Ailyn Biñas



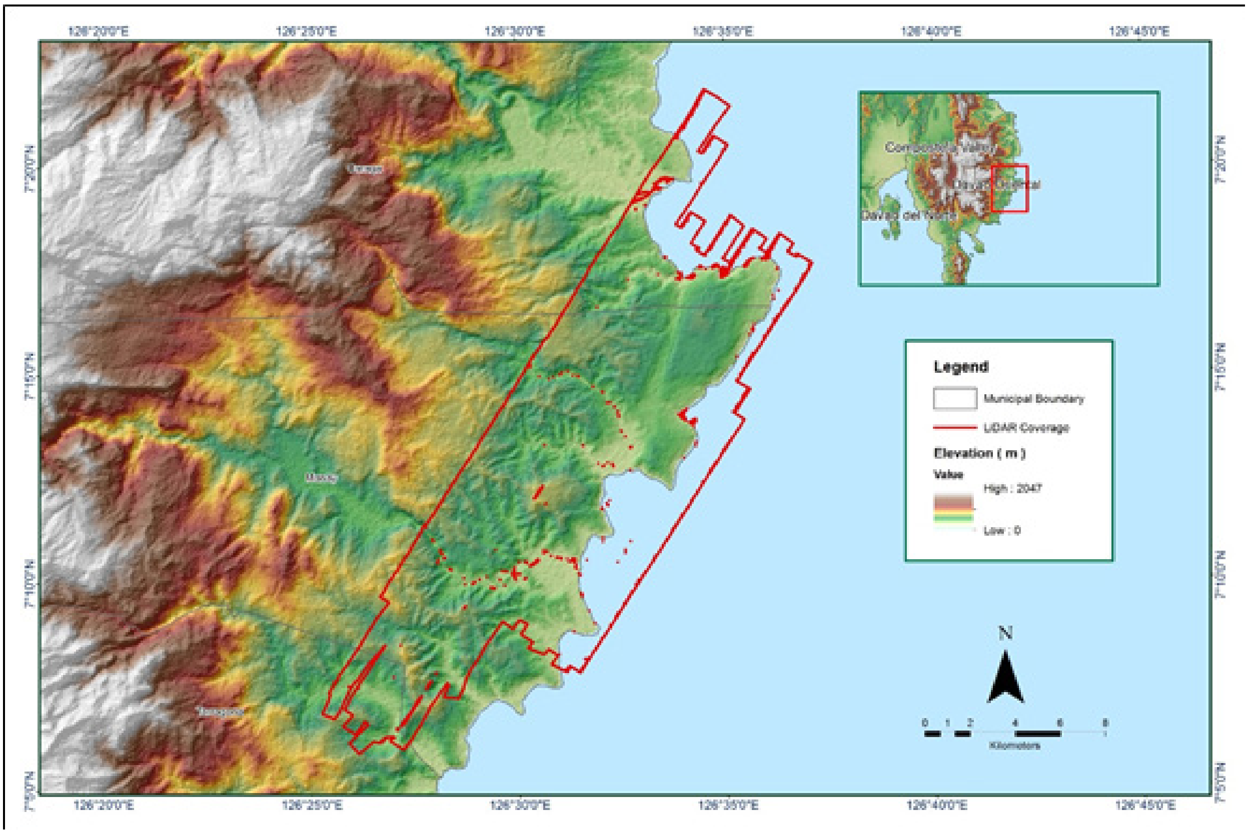
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

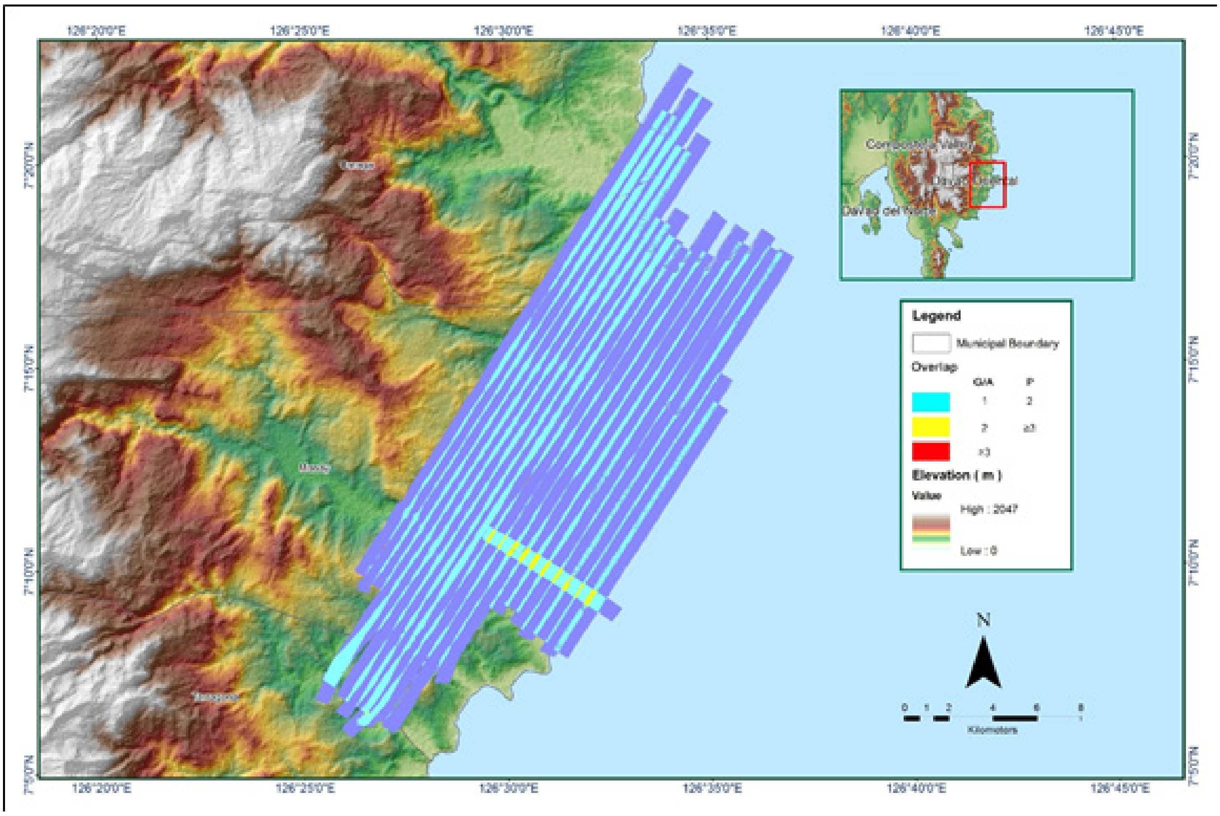
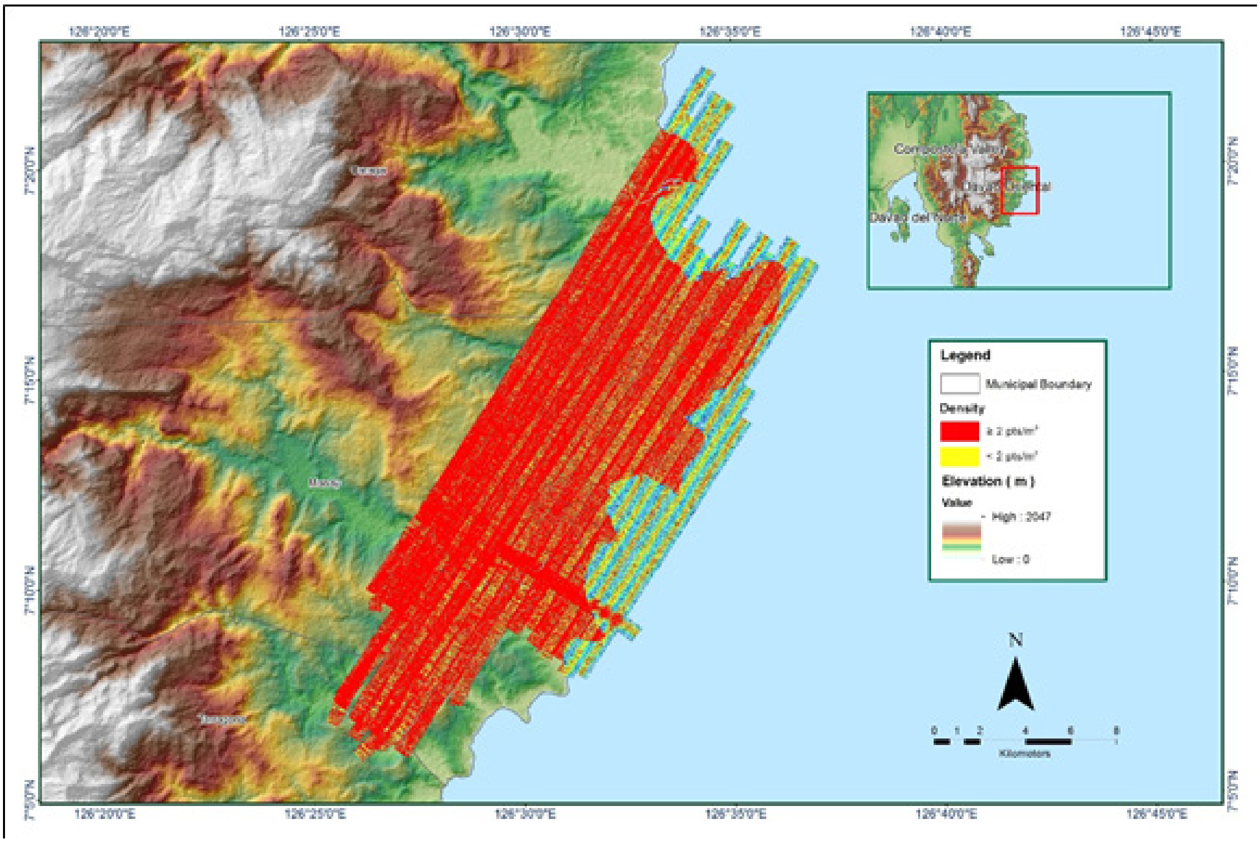
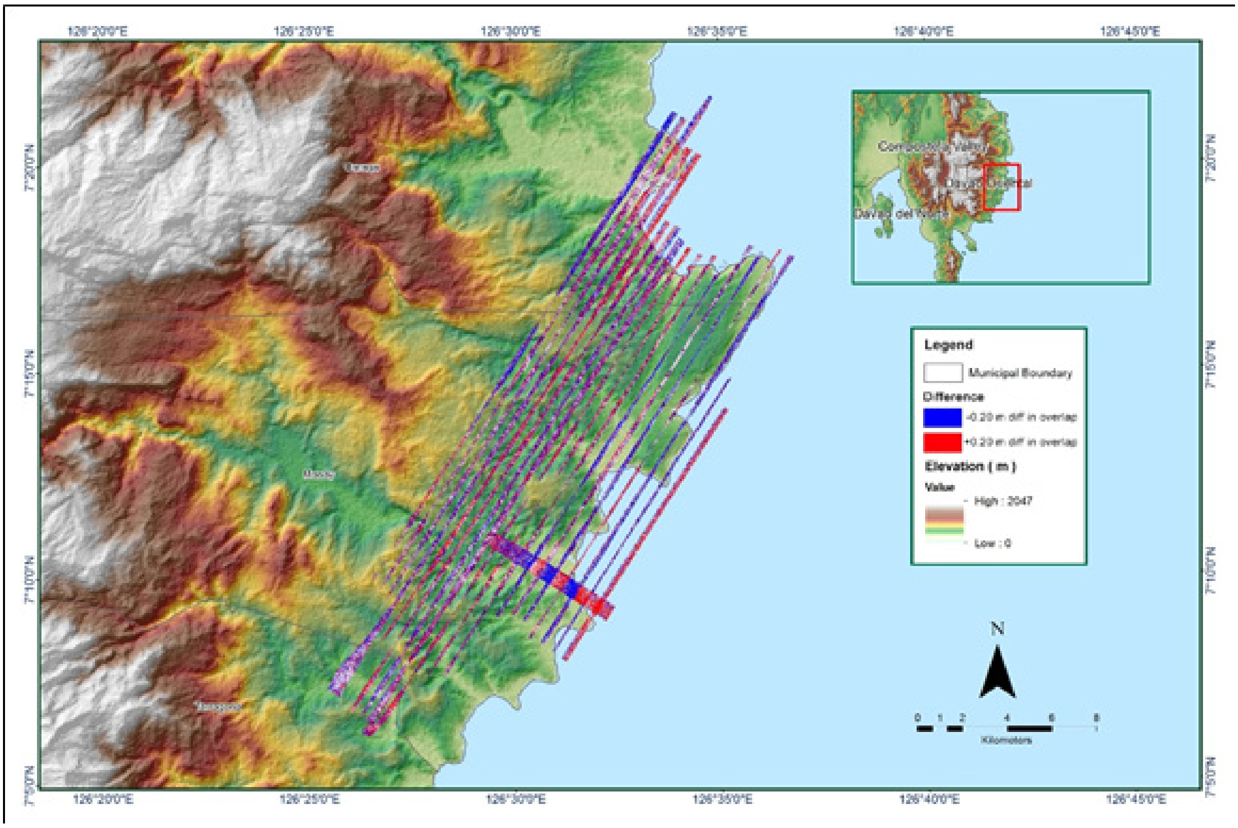


Image of Data Overlap

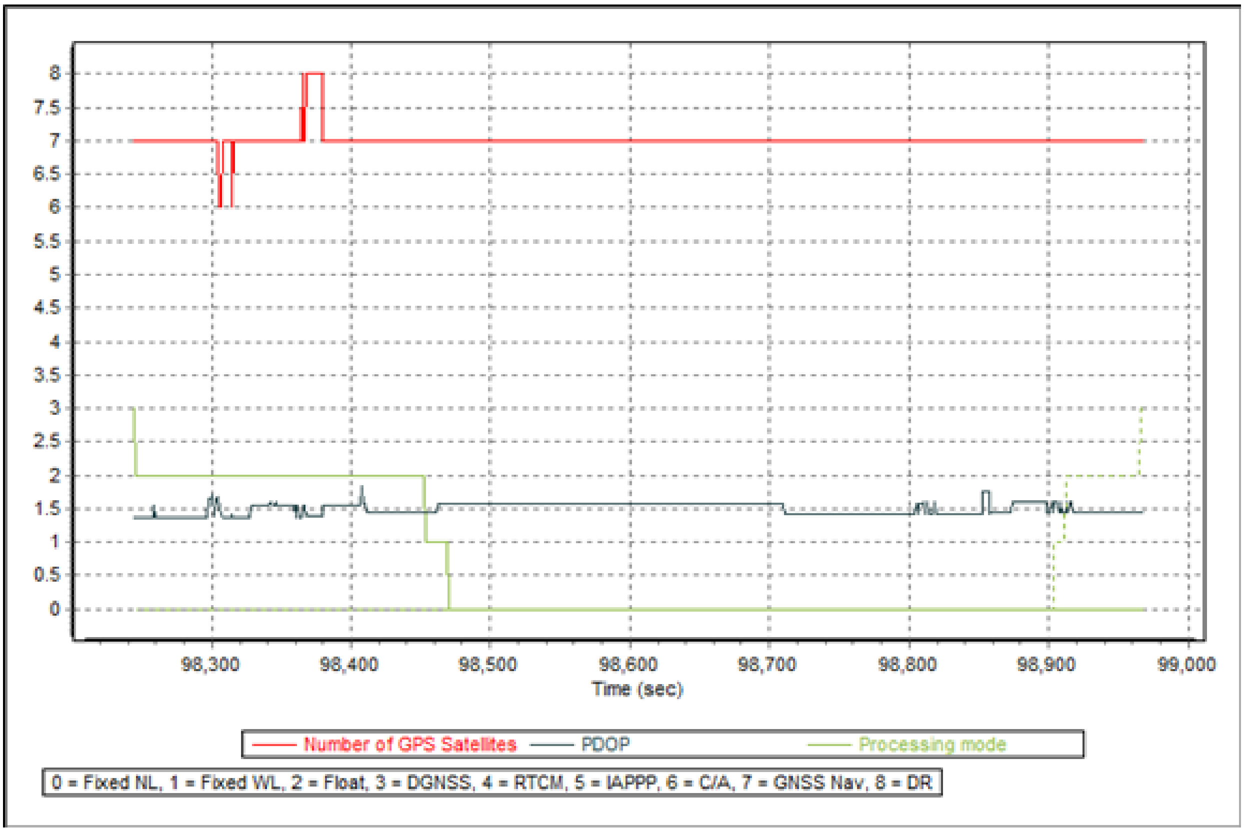


Density map of merged LiDAR data

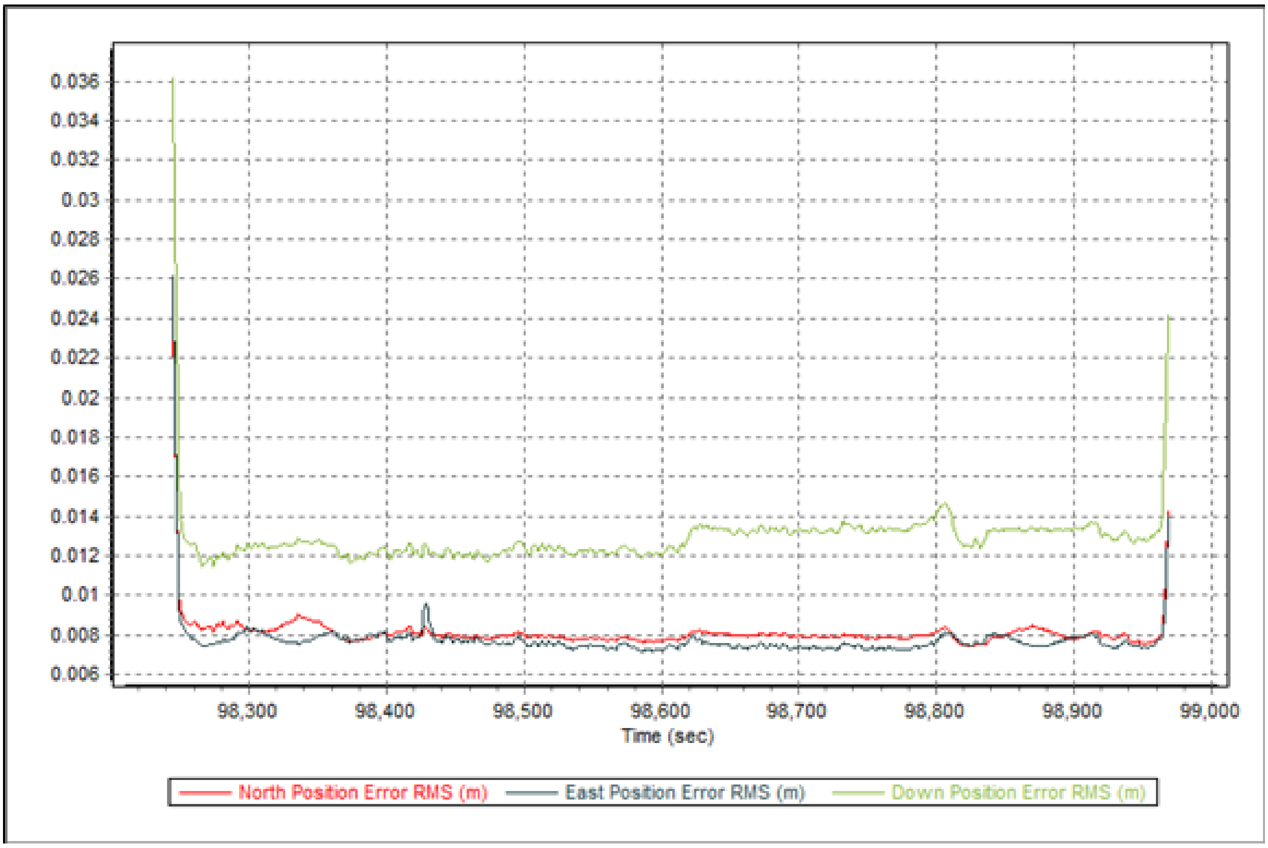


Elevation difference between flight lines

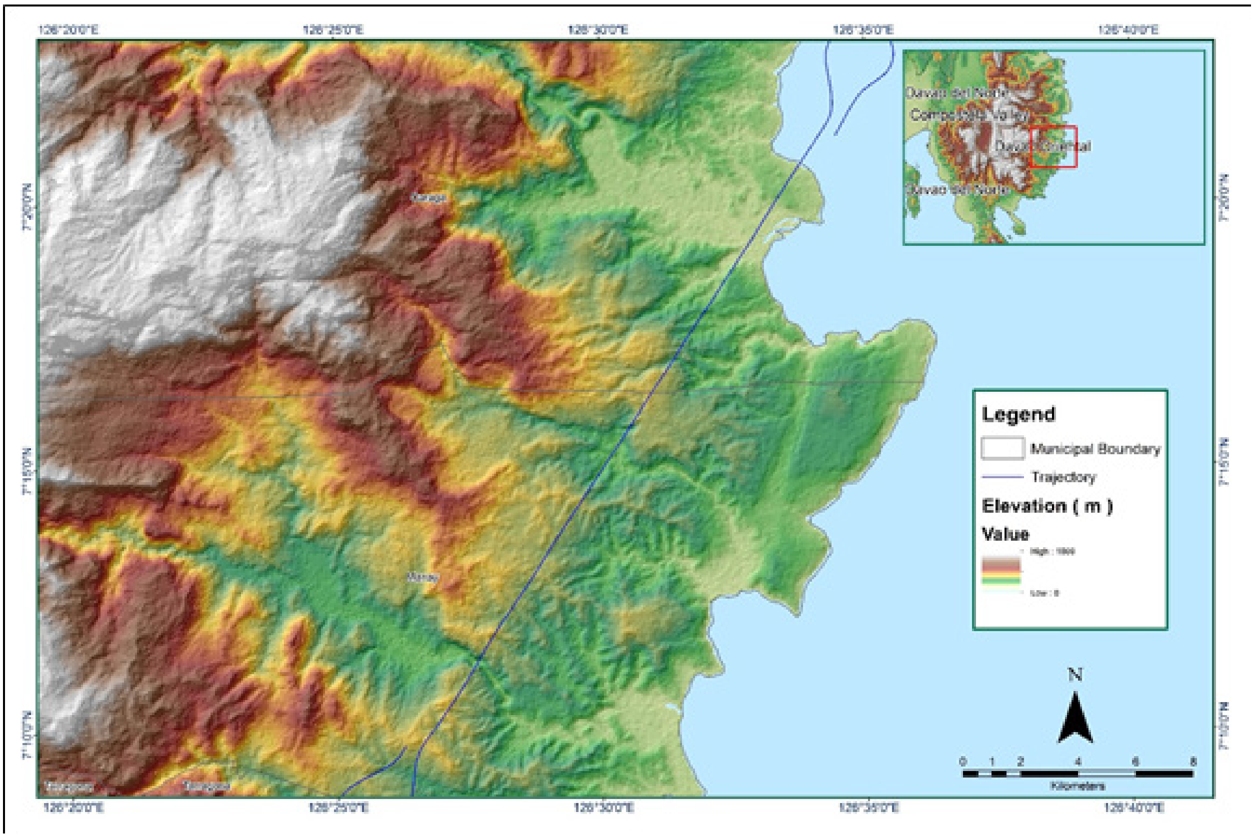
Flight Area	Davao Oriental
Mission Name	Blk80A_additional
Inclusive Flights	7356G
Range data size	27.7 GB
POS	265 MB
Image	NA
Transfer date	July 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.90
RMSE for East Position (<4.0 cm)	1.00
RMSE for Down Position (<8.0 cm)	1.47
Boresight correction stdev (<0.001deg)	0.000359
IMU attitude correction stdev (<0.001deg)	0.091610
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	13.51%
Ave point cloud density per sq.m. (>2.0)	3.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	499.73 m
Minimum Height	63.16 m
Classification (# of points)	
Ground	8,068,004
Low vegetation	5,235,396
Medium vegetation	10,957,440
High vegetation	22,559,130
Building	70,113
Orthophoto	No



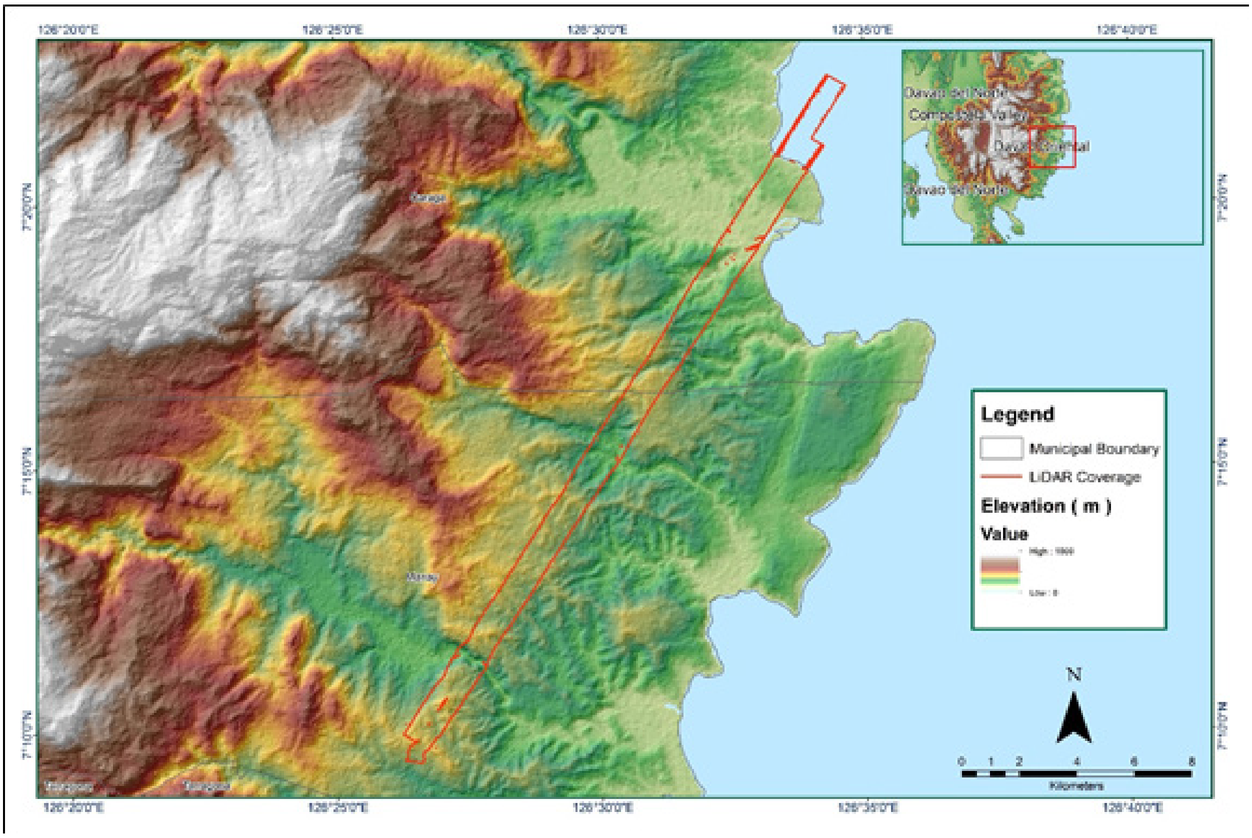
Solution Status Parameters



Smoothed Performance Metrics Parameters



Best Estimated Trajectory



Coverage of LiDAR data

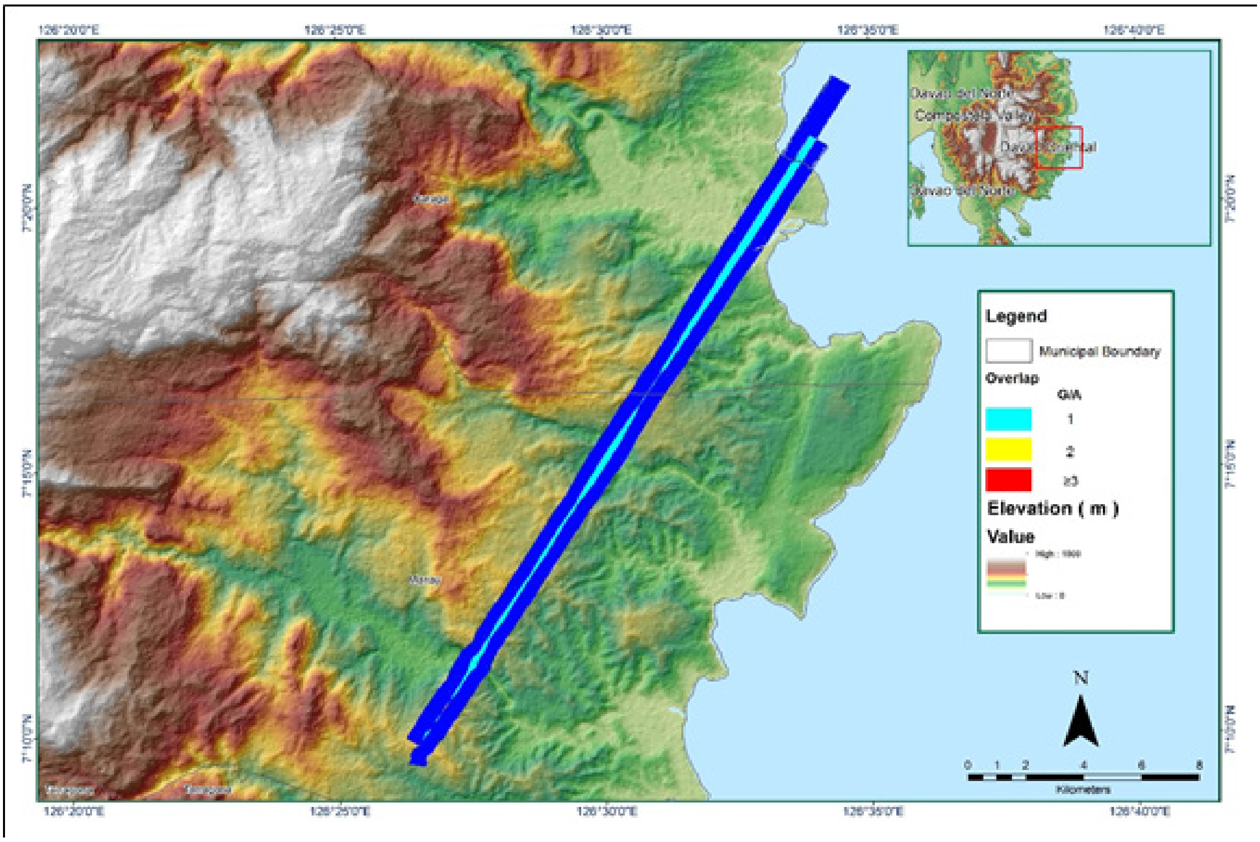
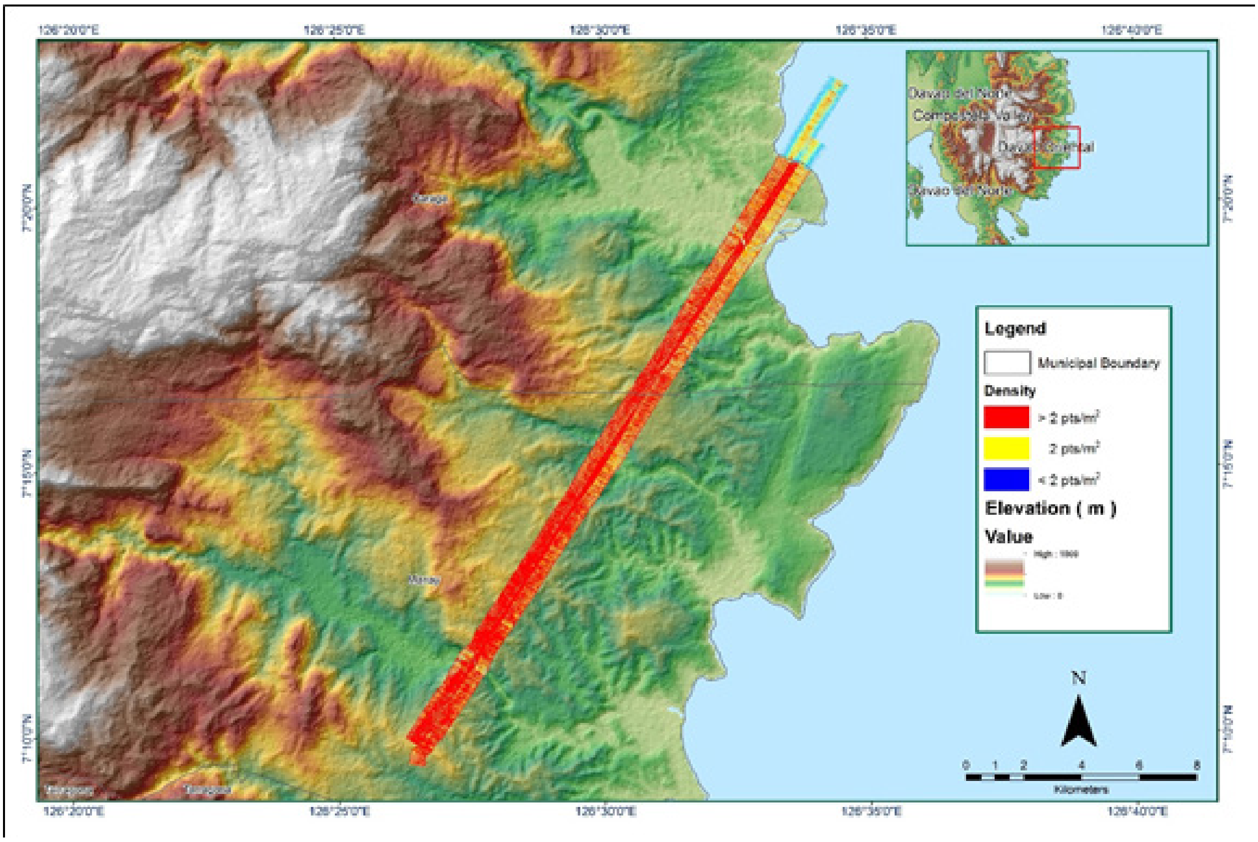
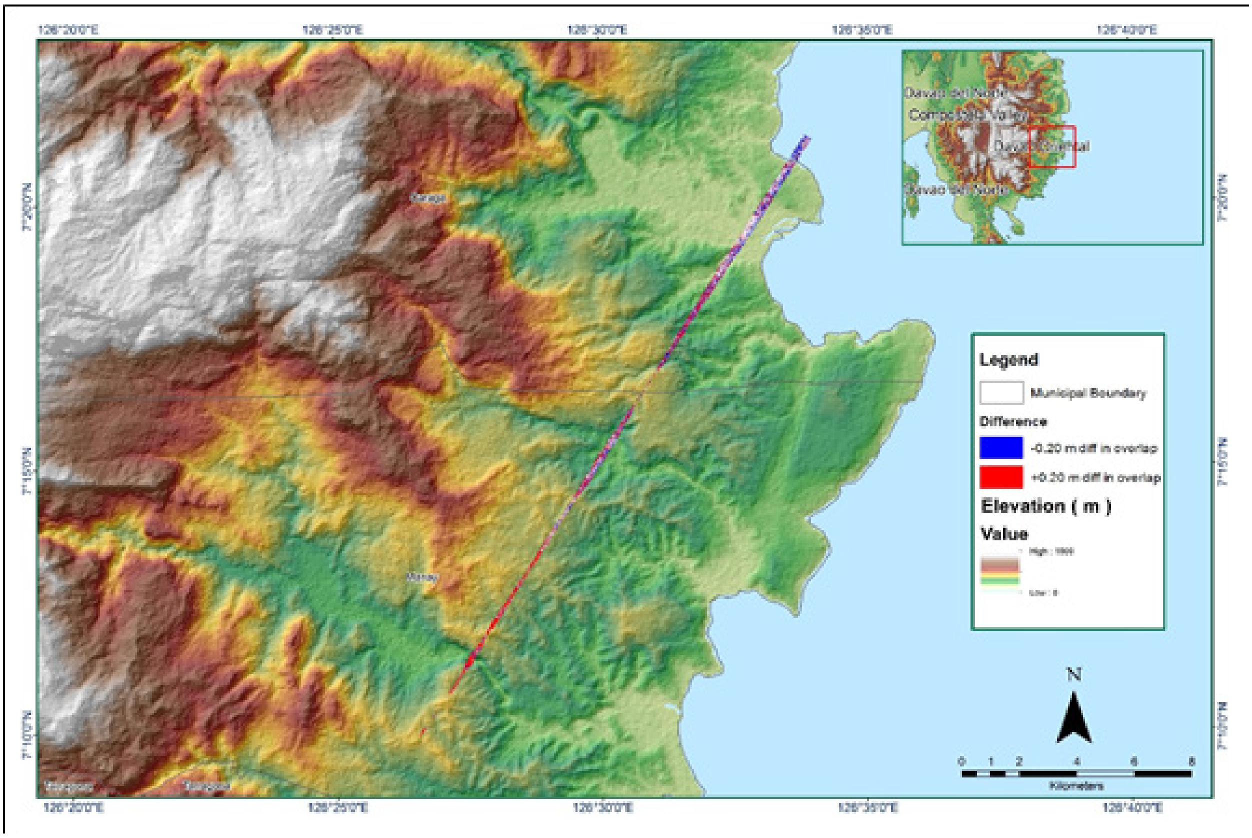


Image of Data Overlap

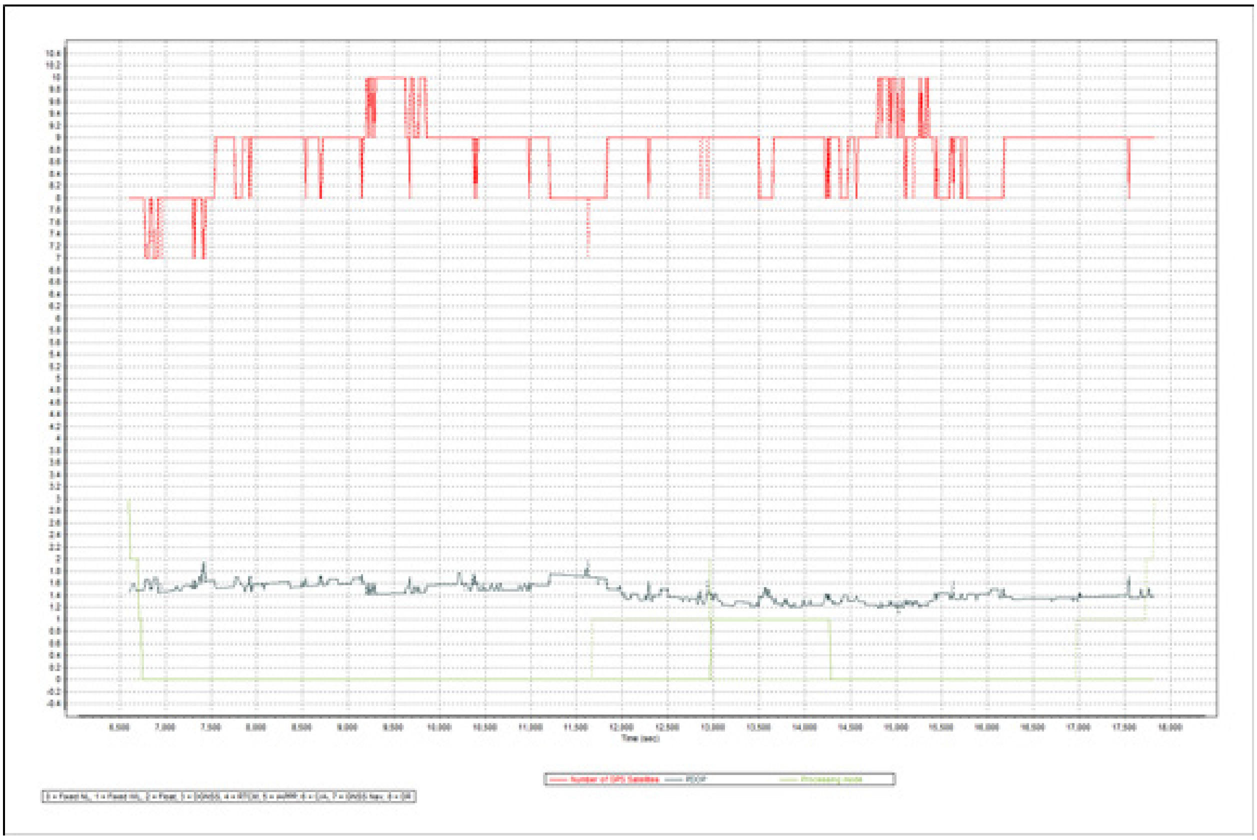


Density map of merged LiDAR data

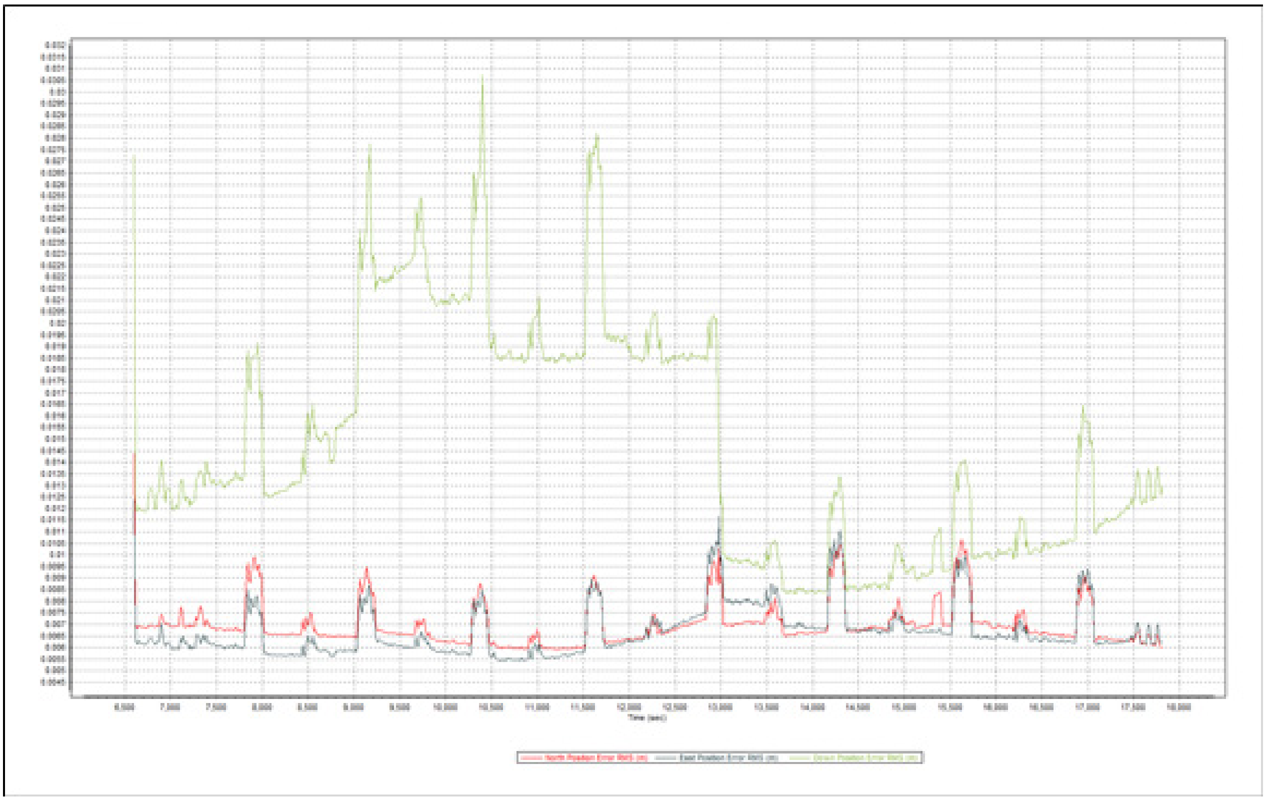


Elevation difference between flight lines

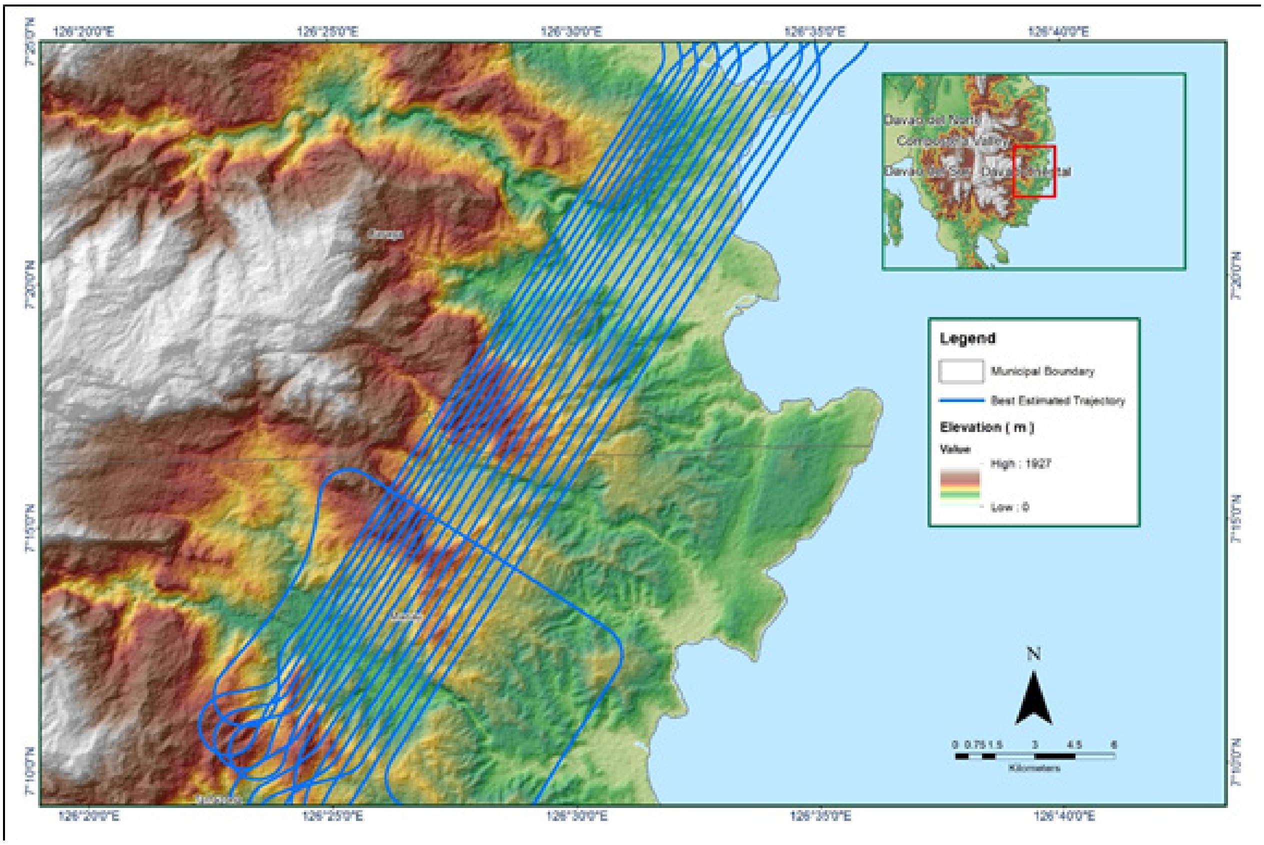
Flight Area	**Davao Oriental**
Mission Name	Blk80B
Inclusive Flights	7326G
Range data size	23.4 GB
Base data size	7 MB
POS	262 MB
Image	na
Transfer date	July 2, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.06
RMSE for East Position (<4.0 cm)	3.05
RMSE for Down Position (<8.0 cm)	3.05
Boresight correction stdev (<0.001deg)	0.000158
IMU attitude correction stdev (<0.001deg)	0.000344
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	3.96
Ave point cloud density per sq.m. (>2.0)	38.07%
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	223
Maximum Height	911.28 m
Minimum Height	63.70 m
Classification (# of points)	
Ground	71,756,747
Low vegetation	58,222,632
Medium vegetation	139,463,364
High vegetation	324,083,199
Building	5,354,520
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Aljon Rie Araneta, Engr. Gladys Mae Apat



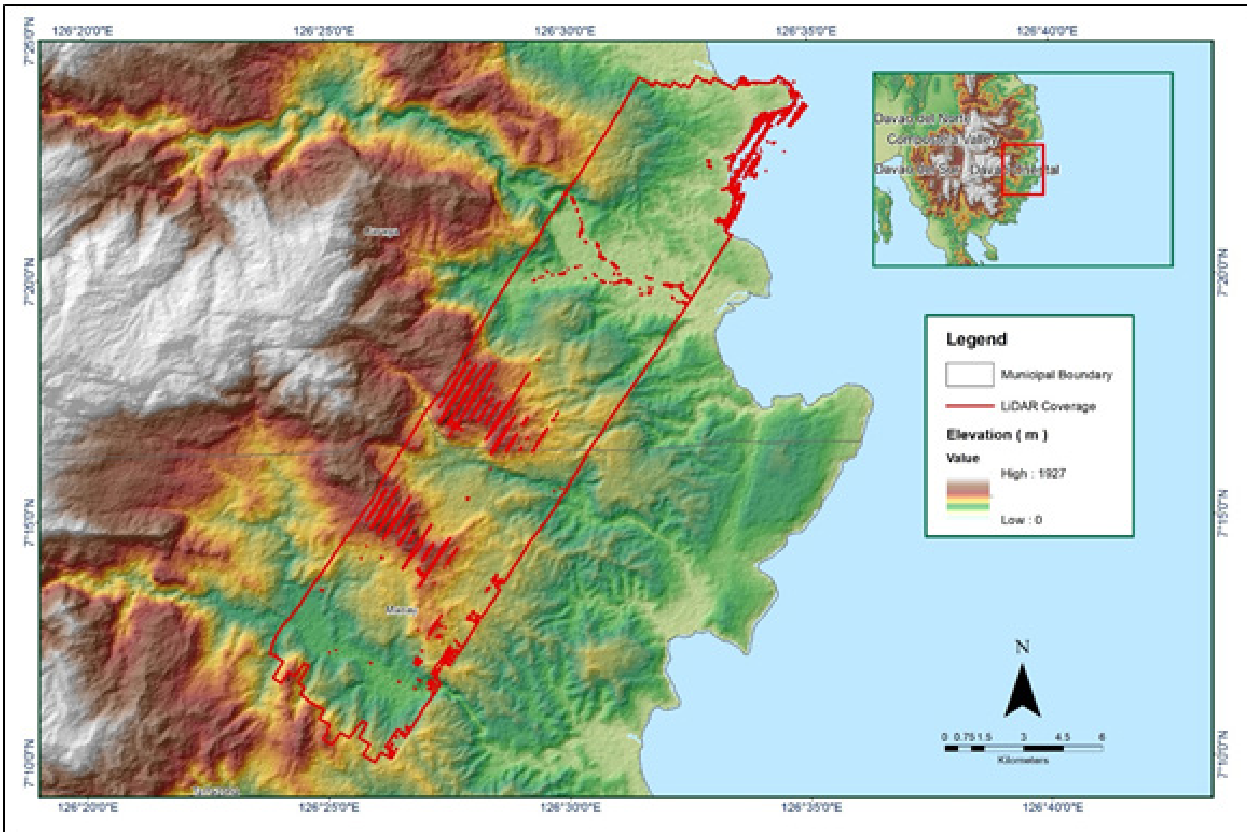
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

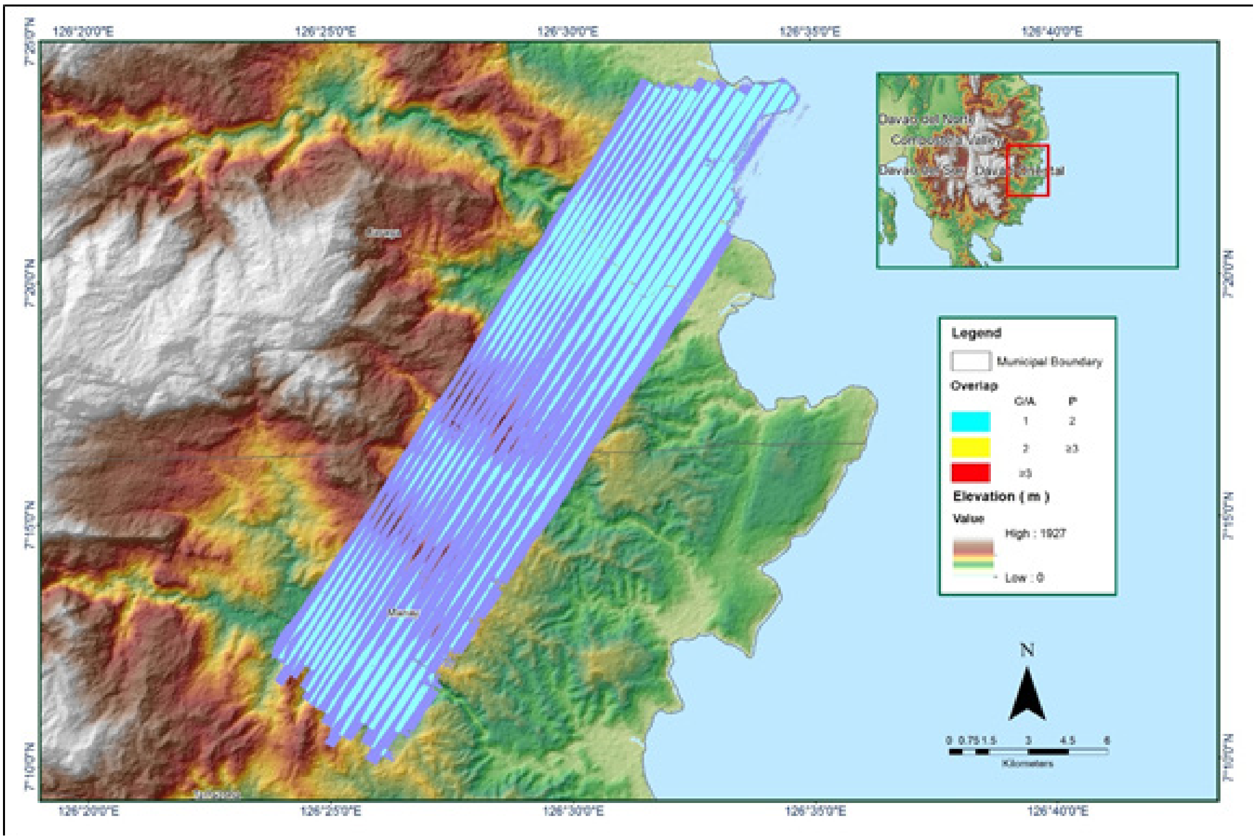
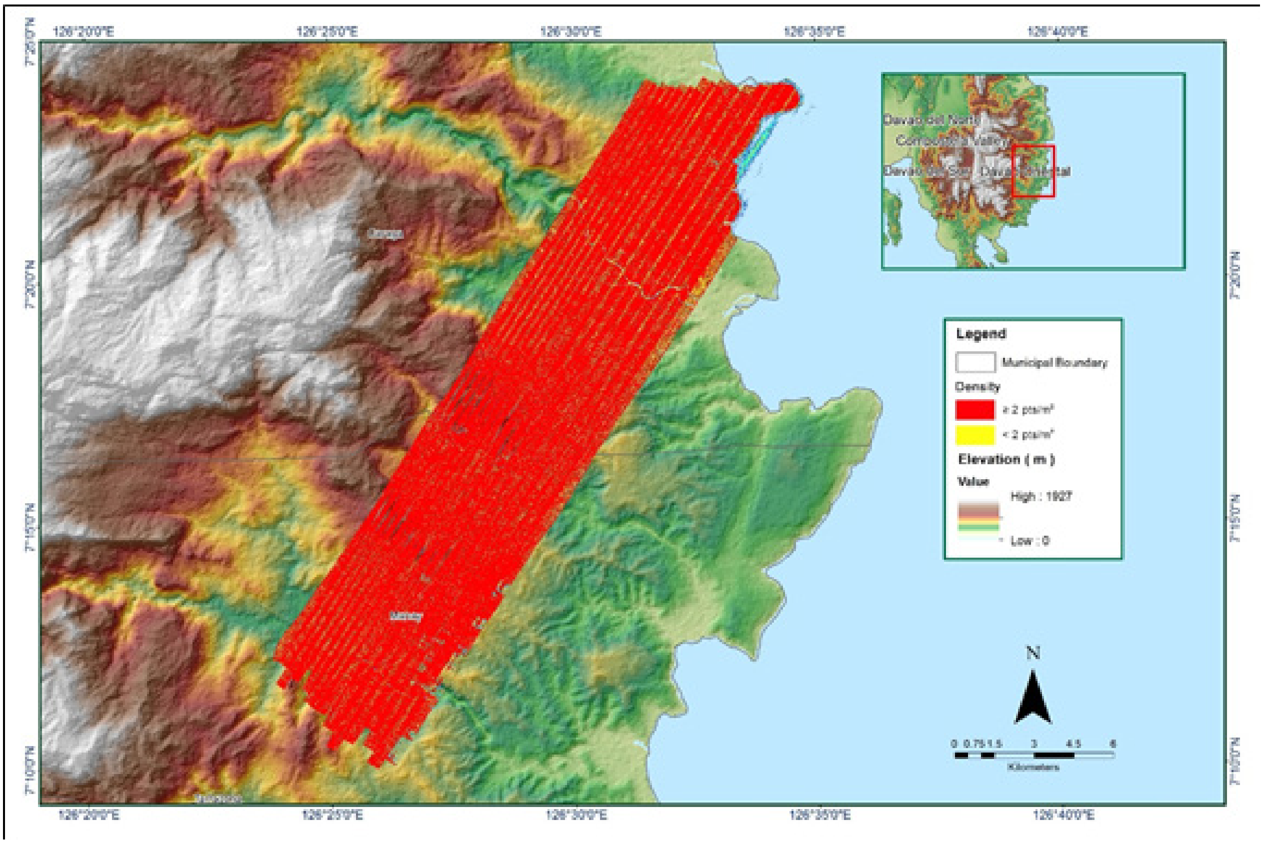
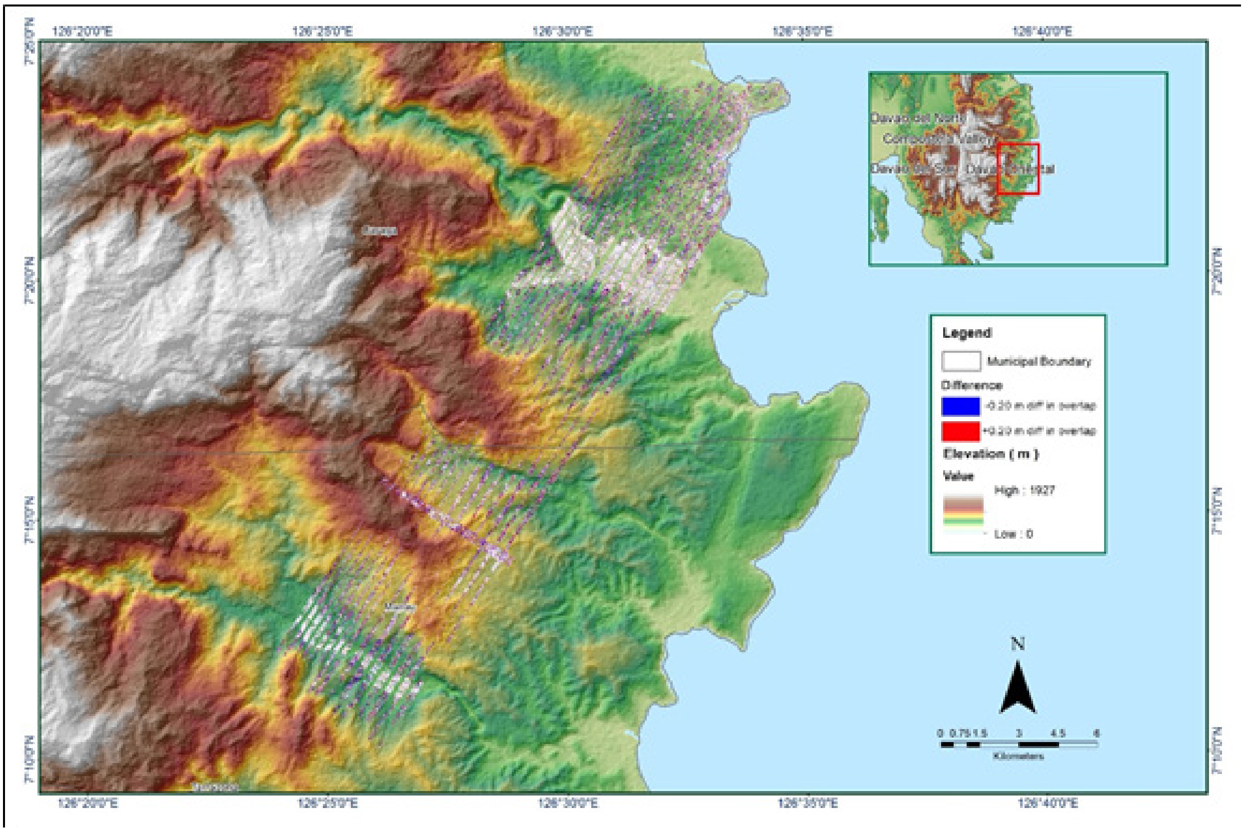


Image of Data Overlap

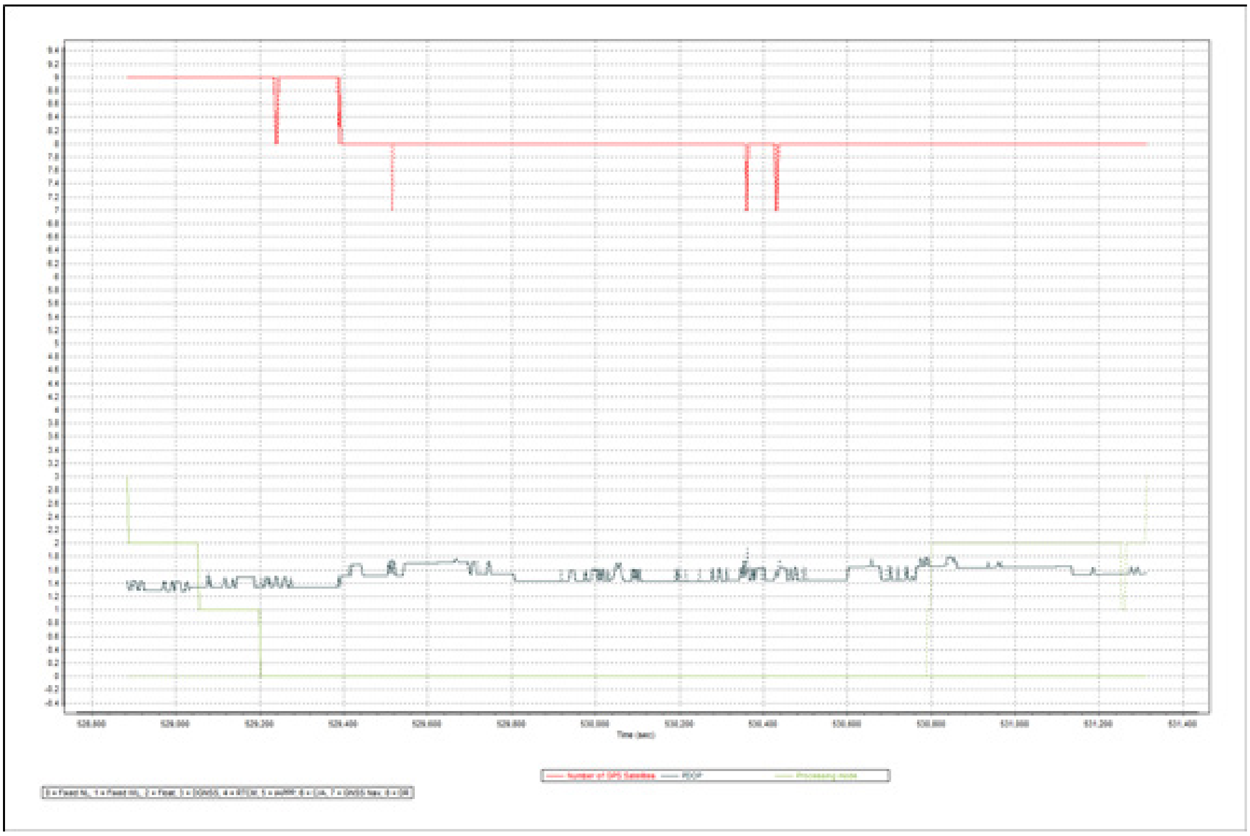


Density map of merged LiDAR data

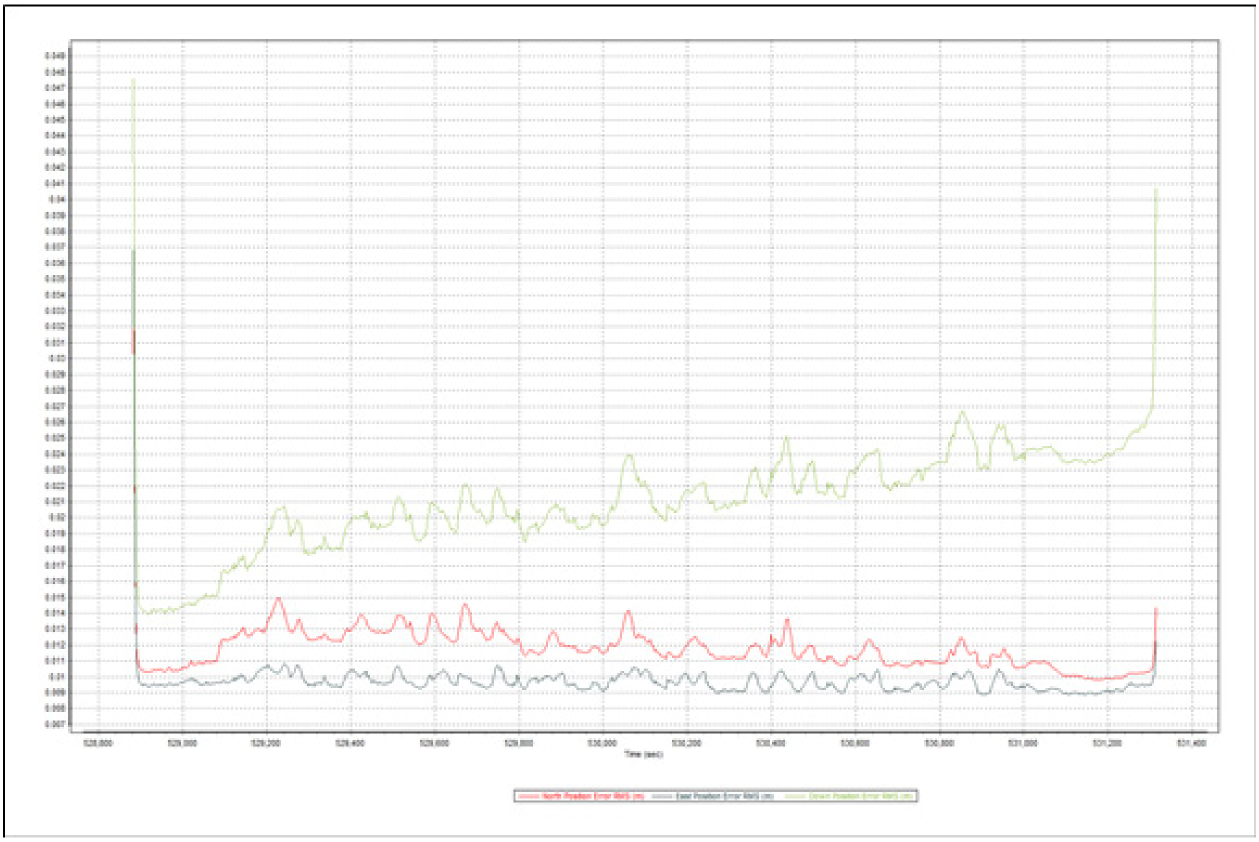


Elevation difference between flight lines

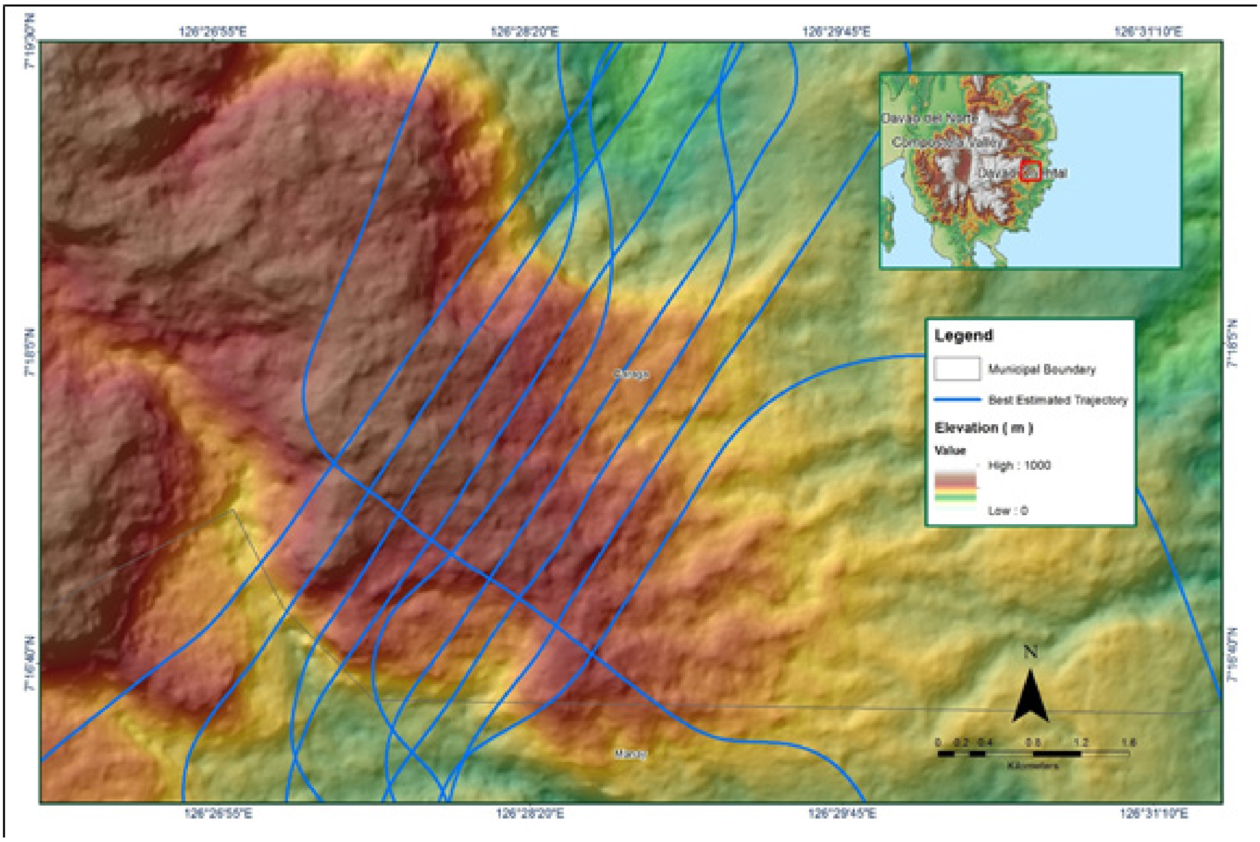
Flight Area	Davao Oriental
Mission Name	Blk80B_supplement
Inclusive Flights	7366G
Range data size	12.2 GB
Base data size	4.89 MB
POS	241 MB
Image	na
Transfer date	July 12, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.45
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.009500
IMU attitude correction stdev (<0.001deg)	0.010244
GPS position stdev (<0.01m)	0.0241
Minimum % overlap (>25)	9.76%
Ave point cloud density per sq.m. (>2.0)	6.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	24
Maximum Height	910.06 m
Minimum Height	179.02 m
Classification (# of points)	
Ground	3,036,472
Low vegetation	1,689,828
Medium vegetation	6,771,340
High vegetation	19,041,789
Building	331,090
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez,Engr. Harmond Santos,Engr. Jeffrey Delica



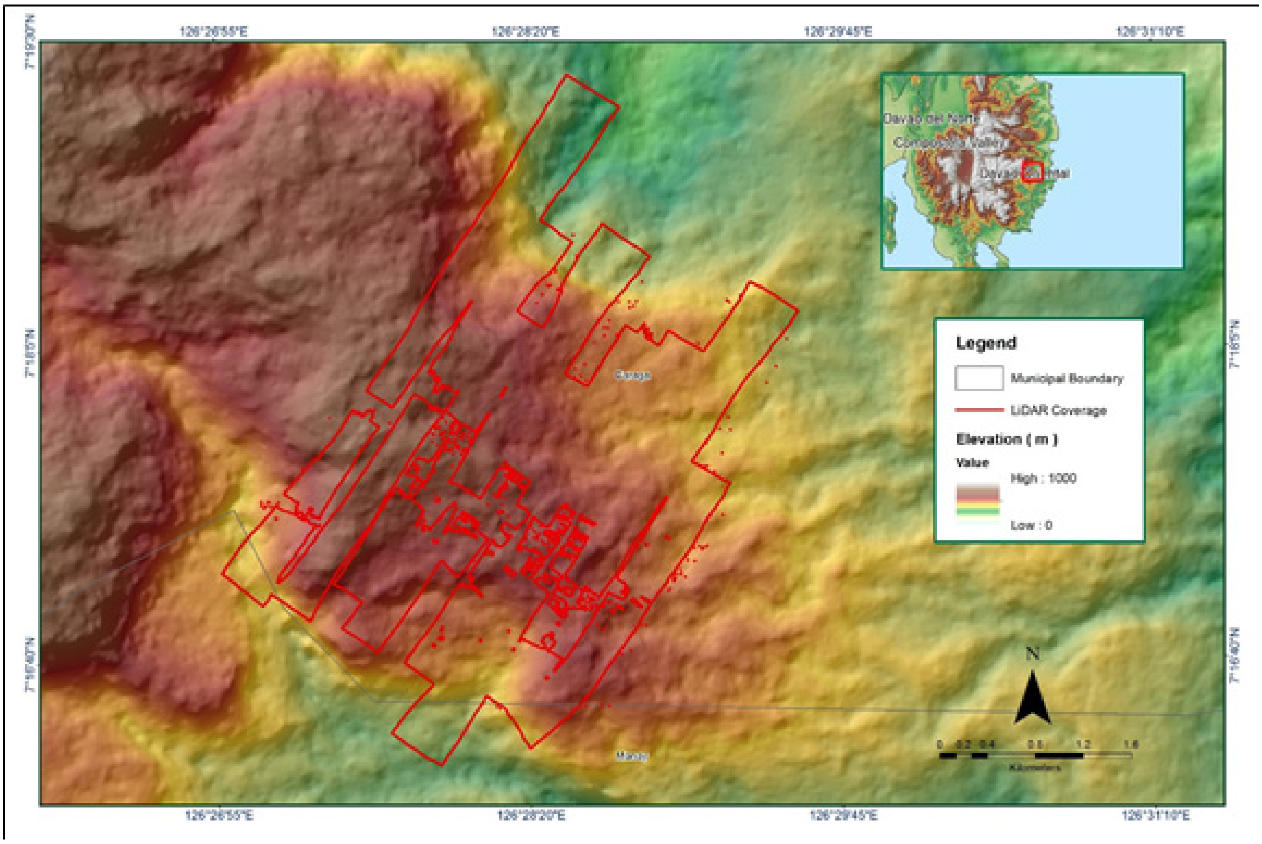
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

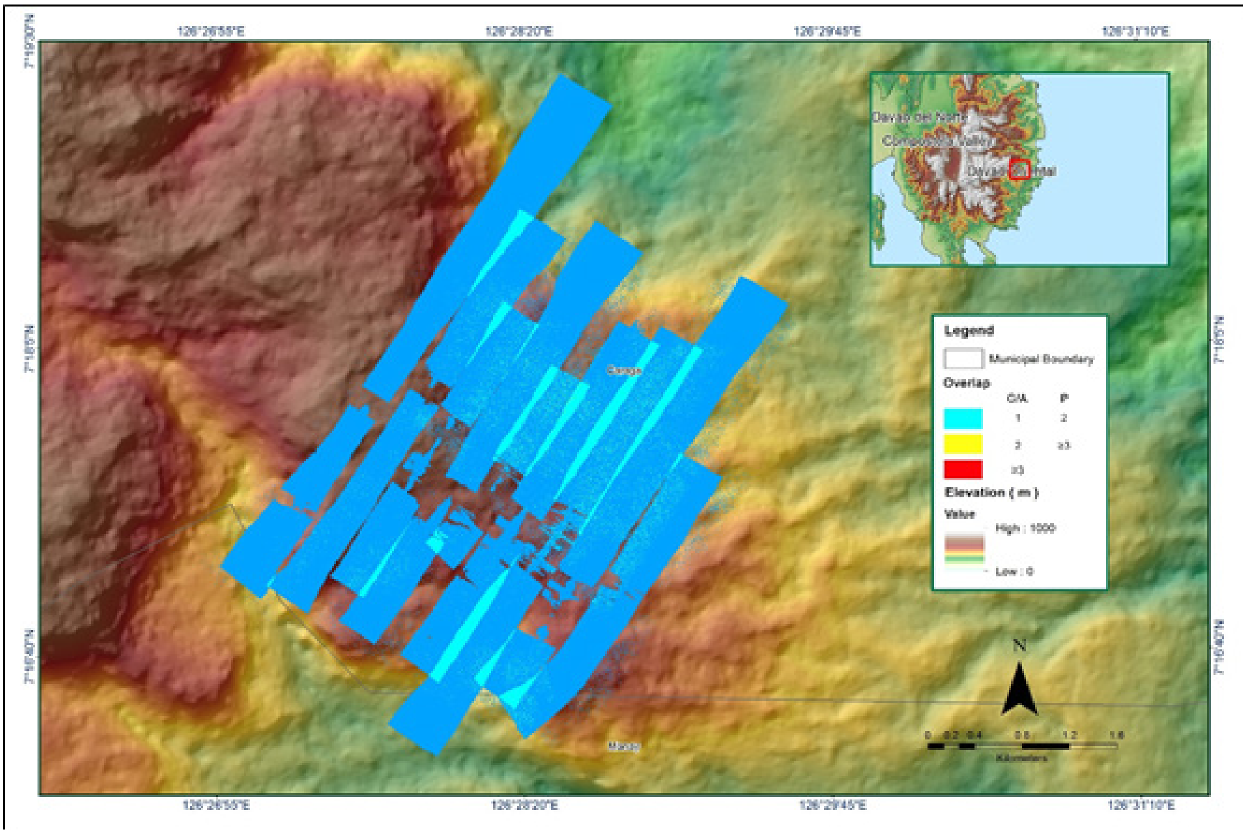
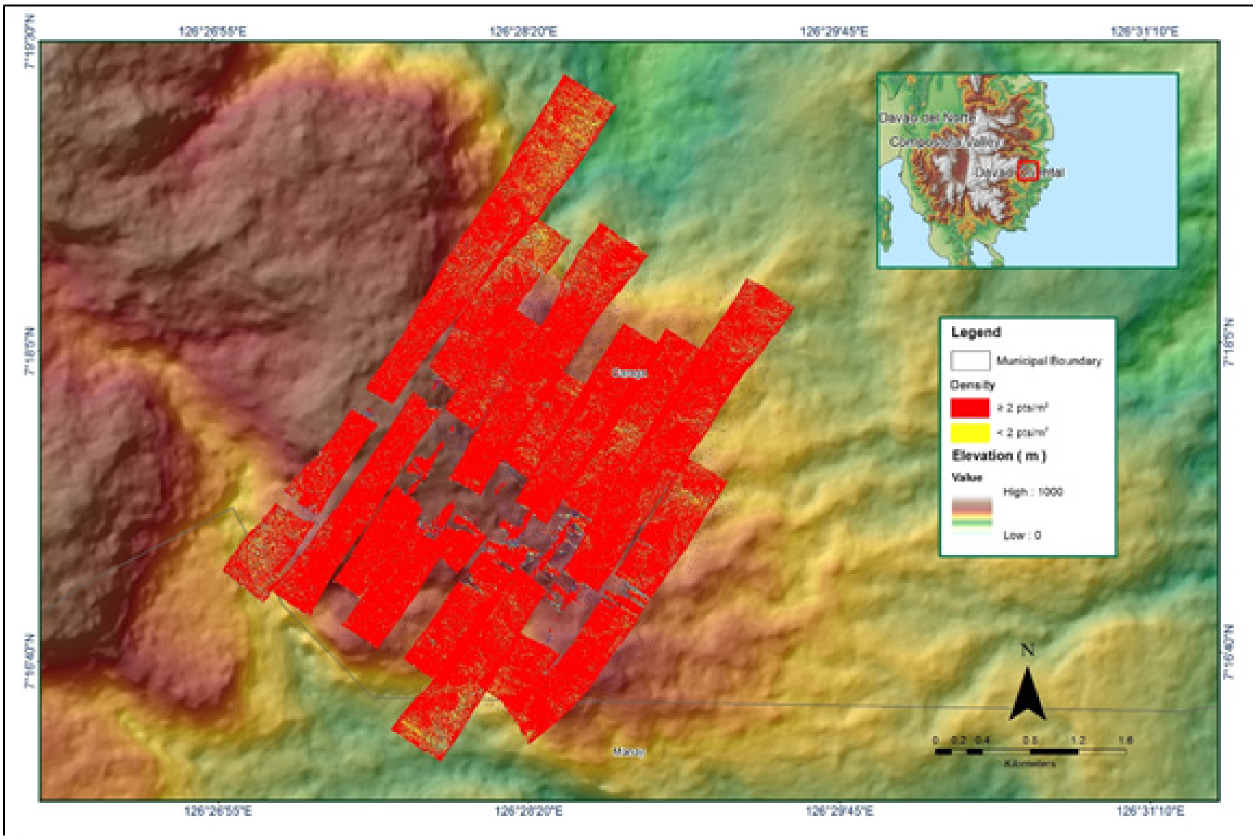
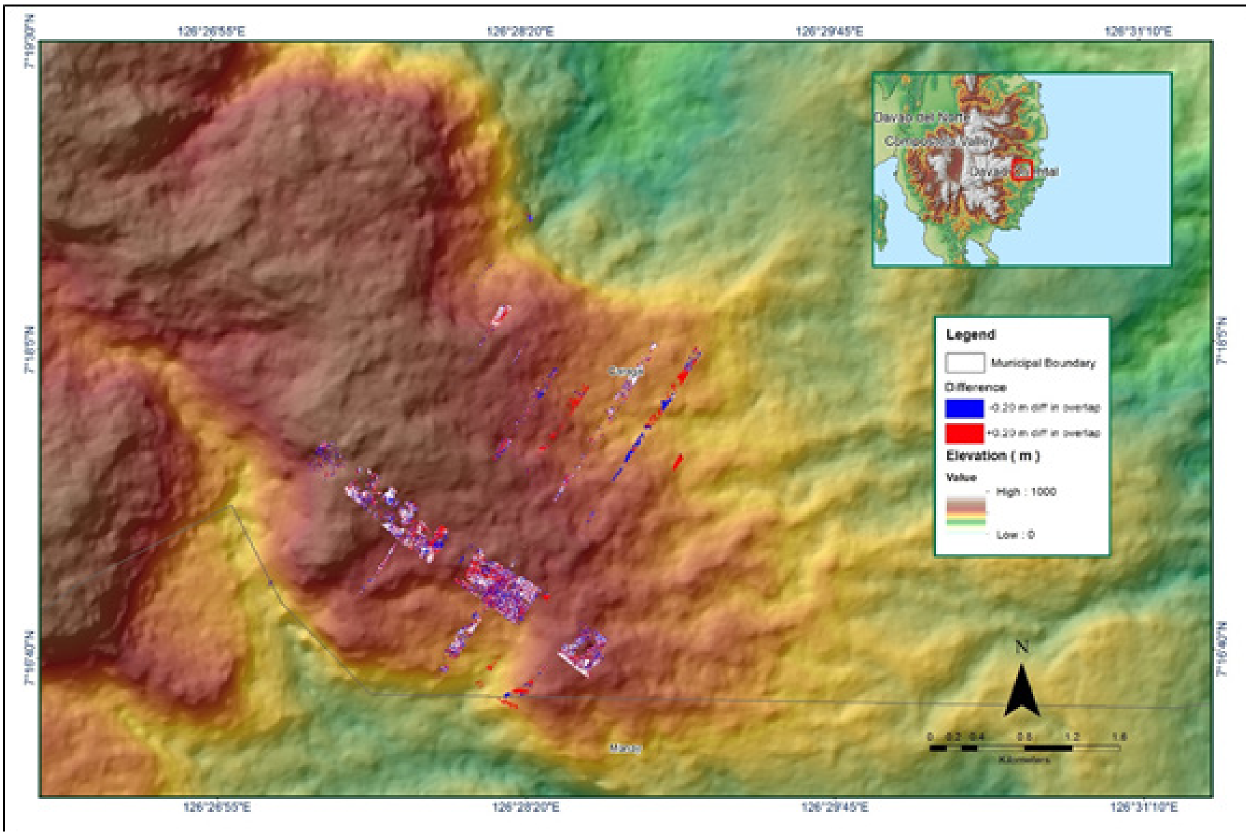


Image of Data Overlap

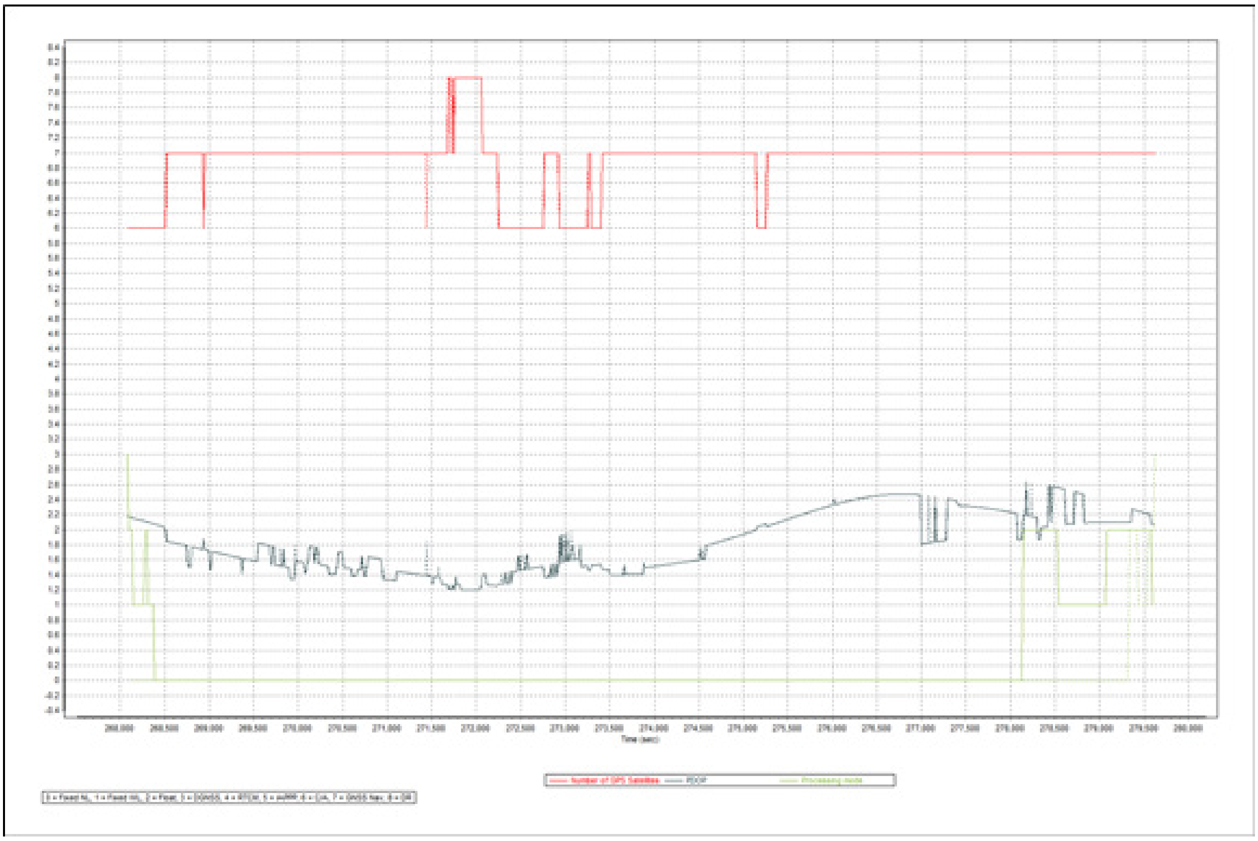


Density map of merged LiDAR data

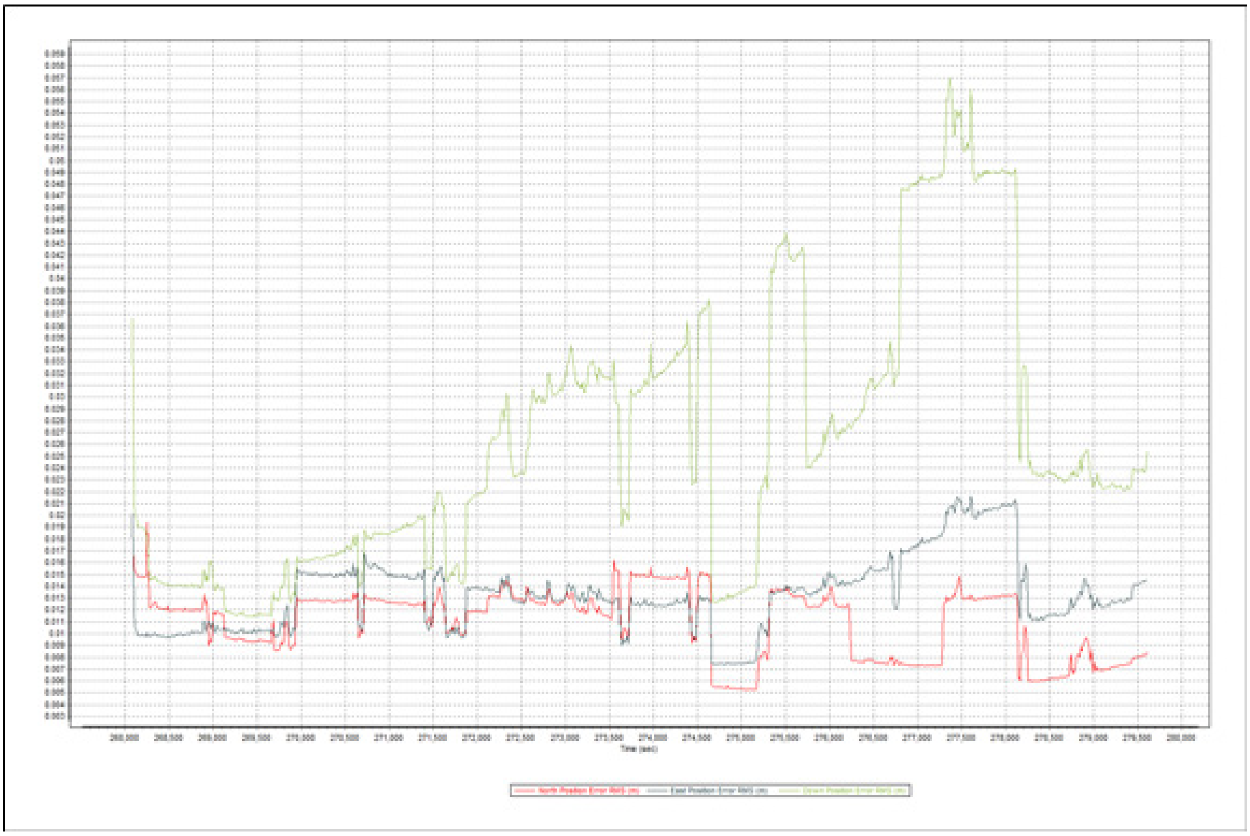


Elevation difference between flight lines

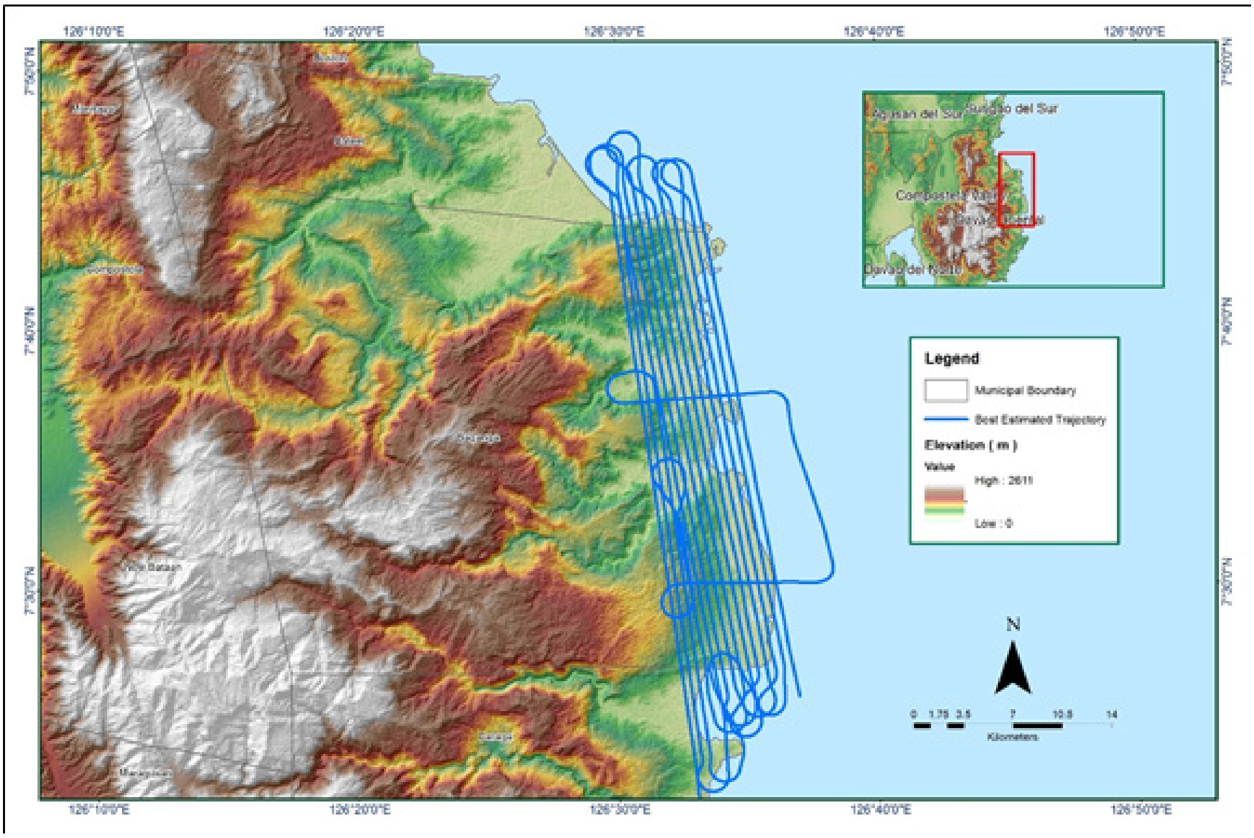
Flight Area	Davao Oriental
Mission Name	Blk79AB
Inclusive Flights	7340G,7346G,7348G
Range data size	64.48 GB
Base data size	16.49 MB
POS	756 MB
Image	na
Transfer date	July 14, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.9
RMSE for East Position (<4.0 cm)	2.15
RMSE for Down Position (<8.0 cm)	5.7
Boresight correction stdev (<0.001deg)	0.000381
IMU attitude correction stdev (<0.001deg)	0.008796
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	35.86%
Ave point cloud density per sq.m. (>2.0)	3.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	556
Maximum Height	688.01 m
Minimum Height	61.98 m
Classification (# of points)	
Ground	138,300,189
Low vegetation	119,214,466
Medium vegetation	650,437,257
High vegetation	524,436,568
Building	6,018,526
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Angelo Carlo Bongat, Engr. Irish Cortez, Engr. Gladys Mae Apat



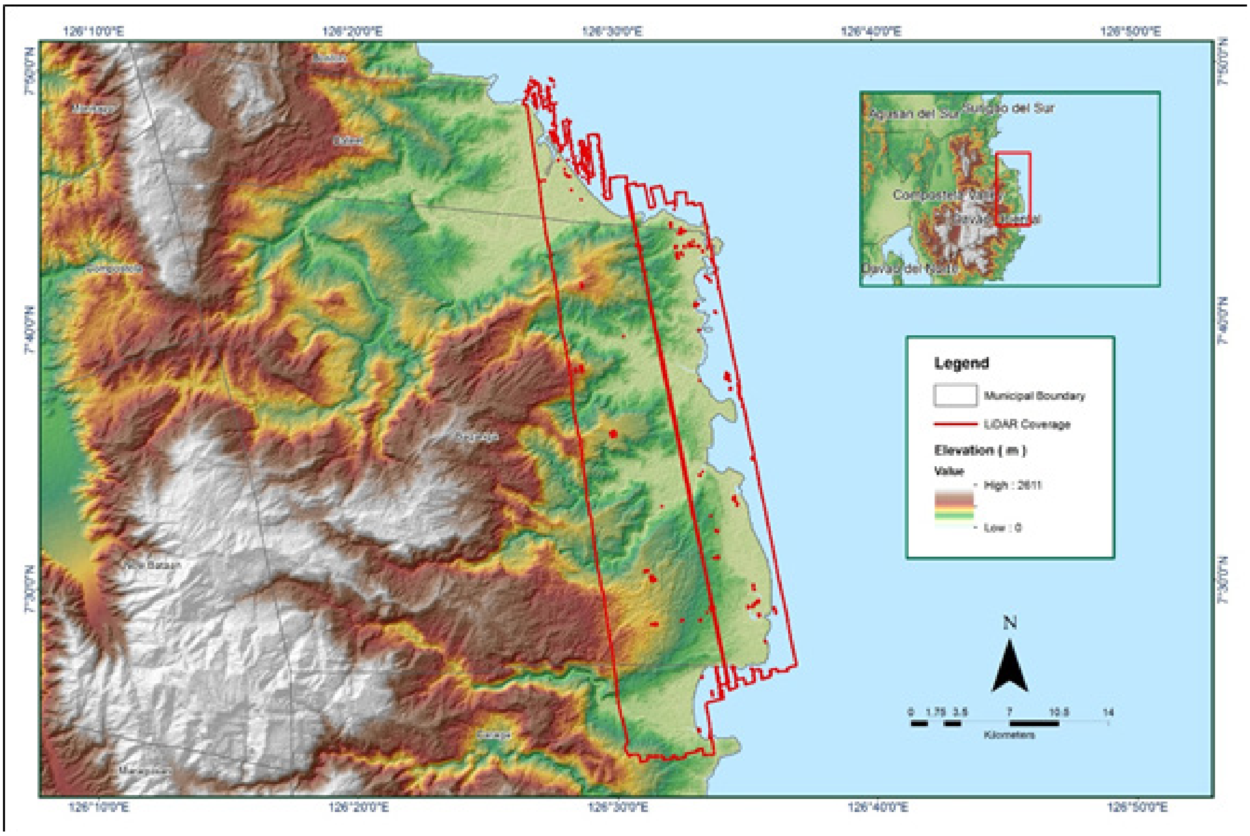
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

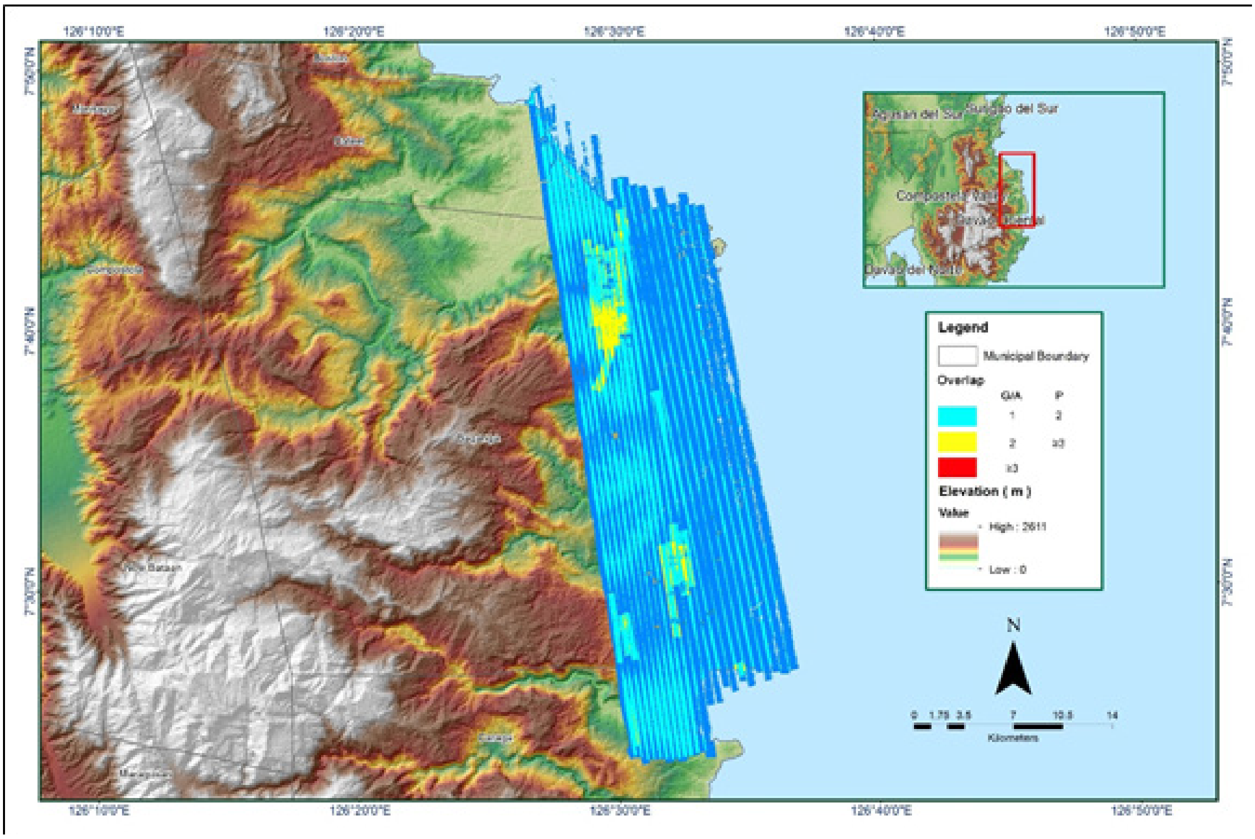
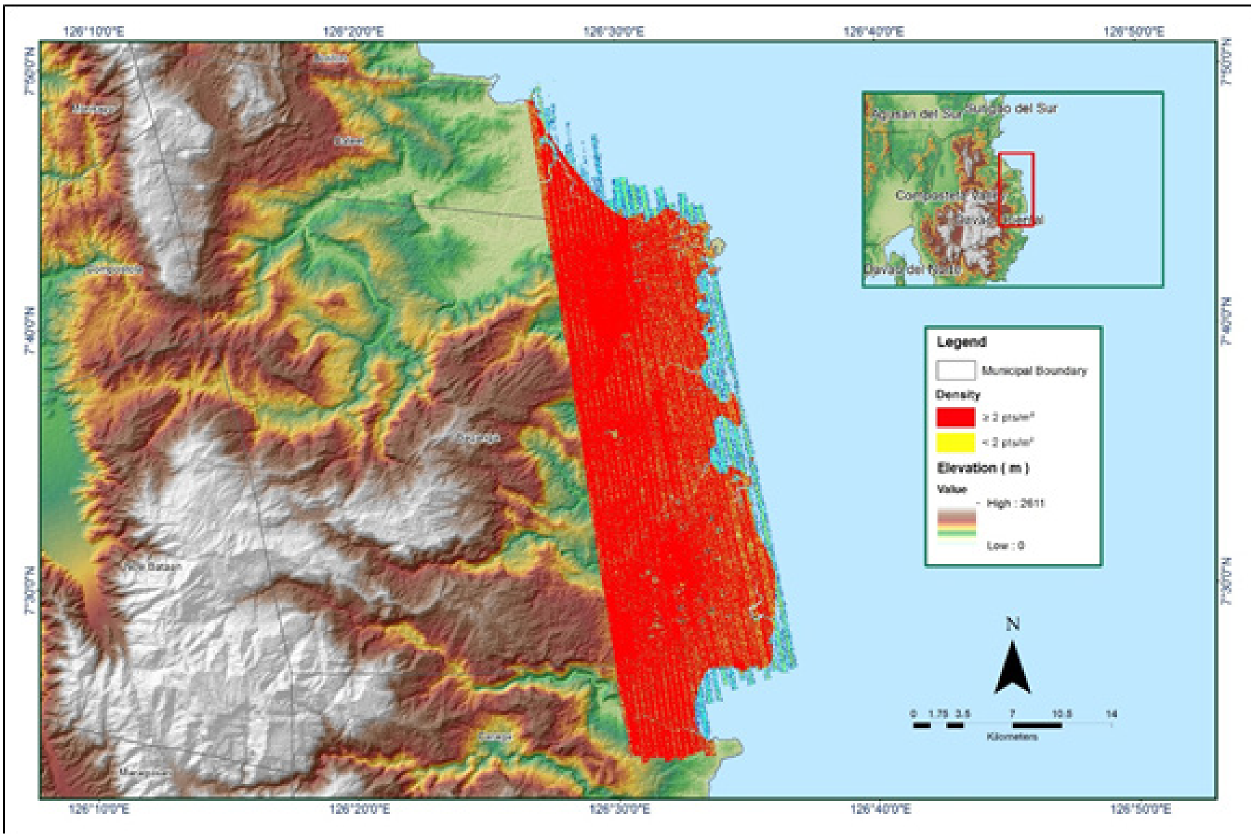
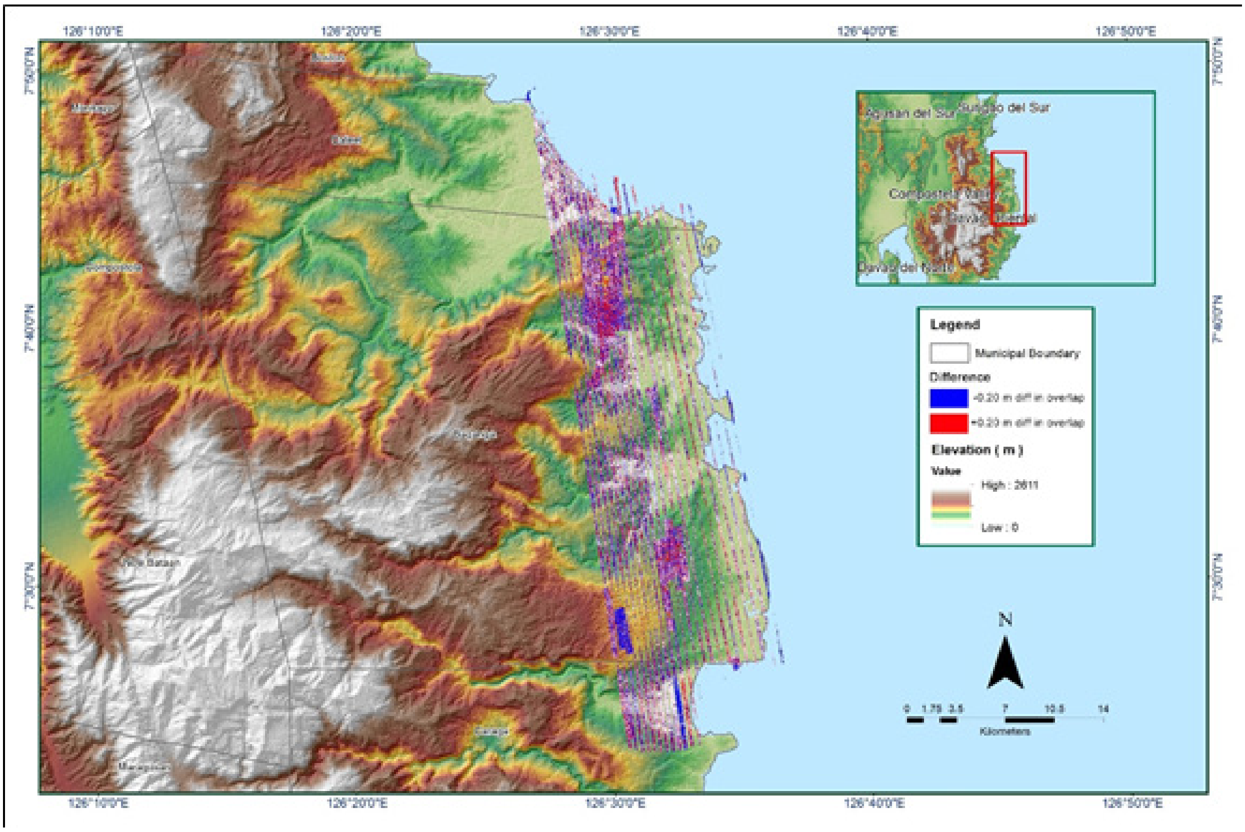


Image of Data Overlap

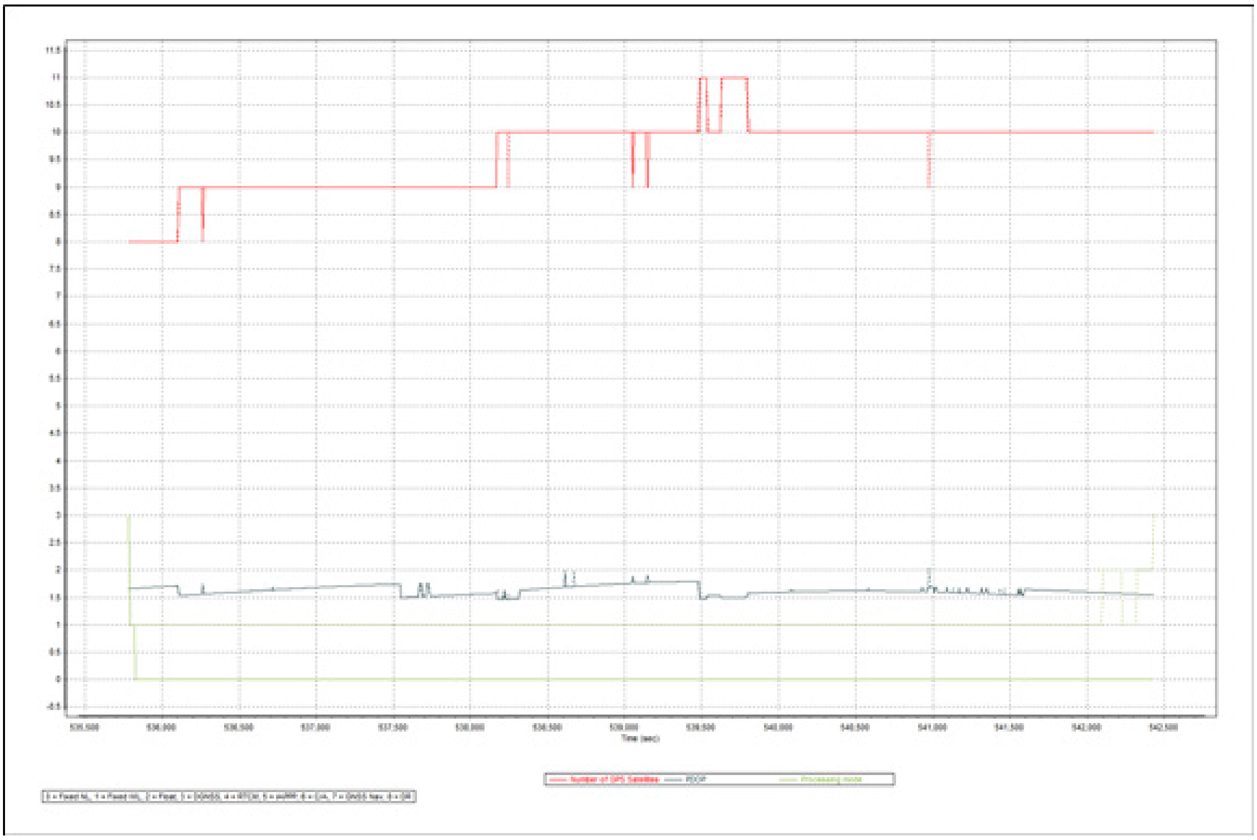


Density map of merged LiDAR data

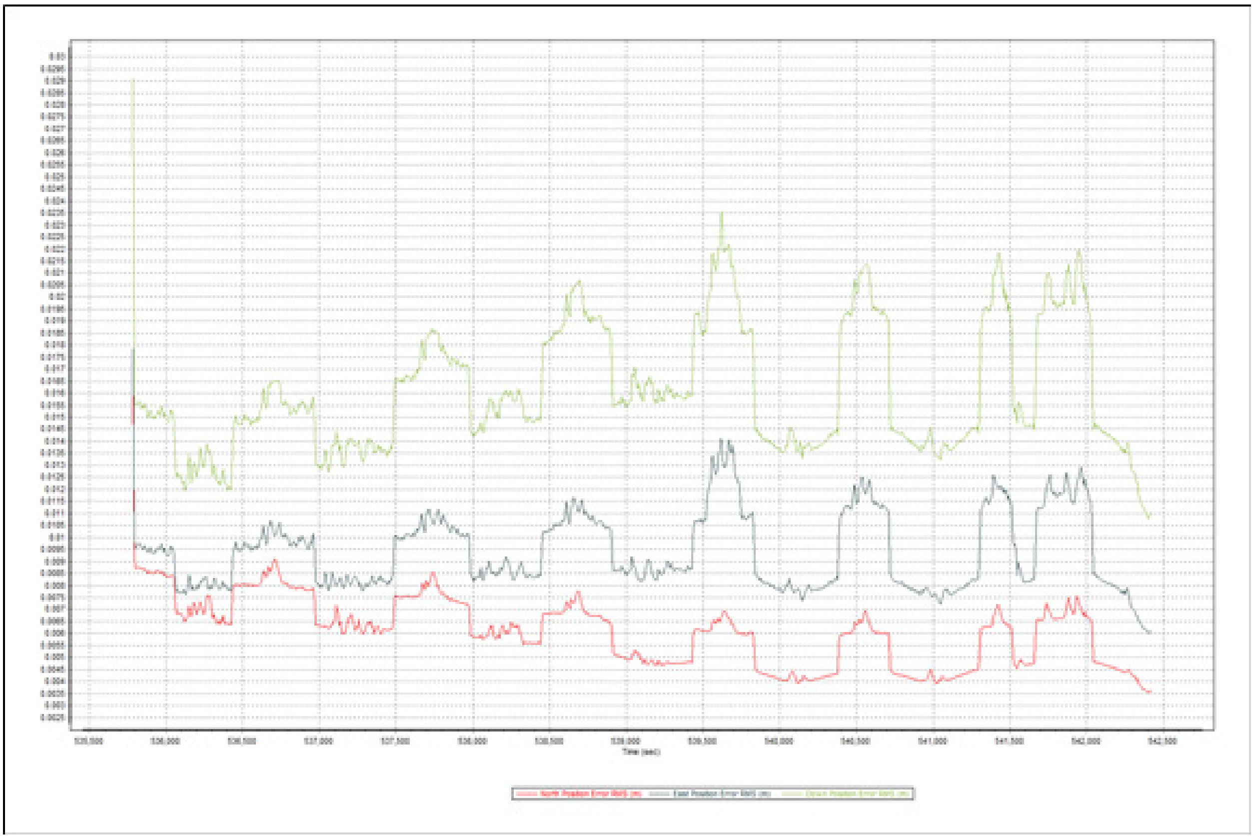


Elevation difference between flight lines

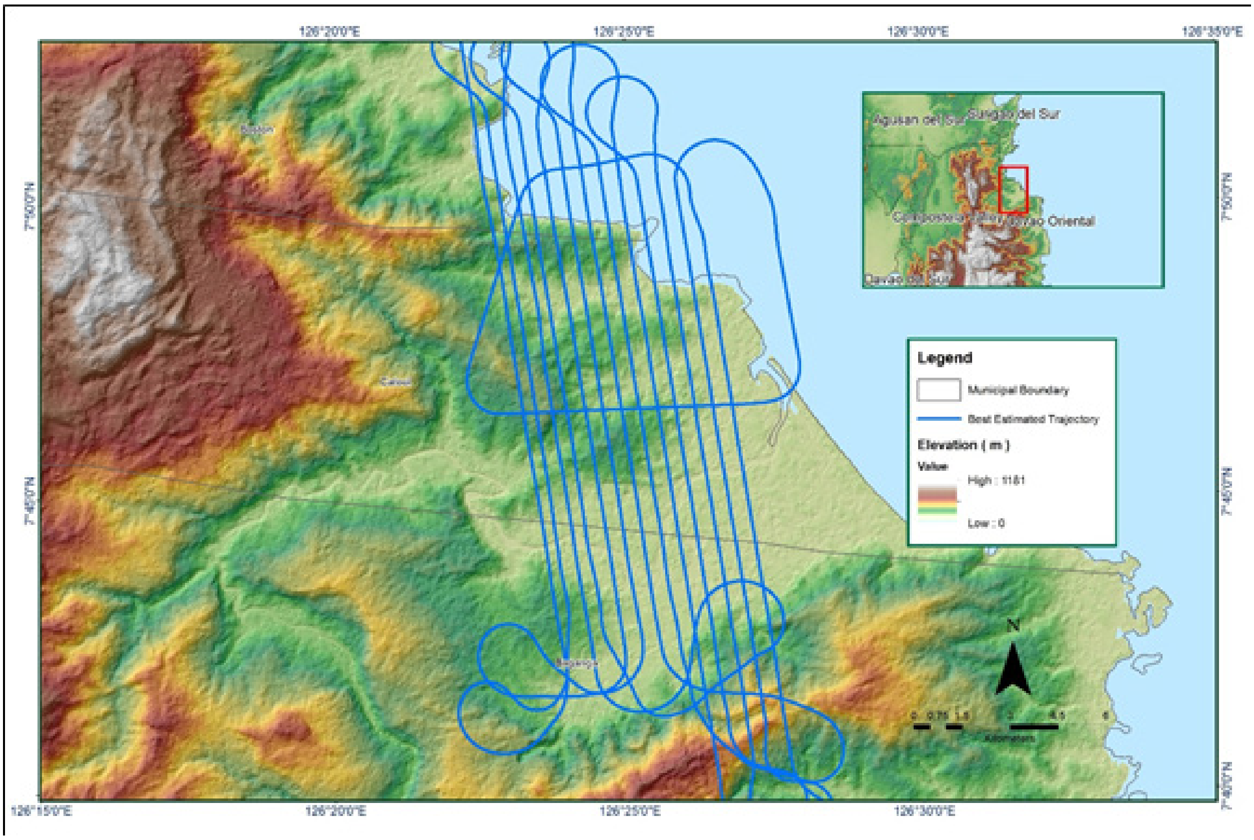
Flight Area	Davao Oriental
Mission Name	Blk79C
Inclusive Flights	7339G
Range data size	30.3 GB
Base data size	5.08 MB
POS	318 MB
Image	na
Transfer date	July 14, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.09
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.35
Boresight correction stdev (<0.001deg)	0.000551
IMU attitude correction stdev (<0.001deg)	0.000981
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	30.52%
Ave point cloud density per sq.m. (>2.0)	3.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	166
Maximum Height	657.39 m
Minimum Height	66.35 m
Classification (# of points)	
Ground	42,376,559
Low vegetation	46,914,428
Medium vegetation	129,819,767
High vegetation	101,299,262
Building	1,183,752
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Gladys Mae Apat



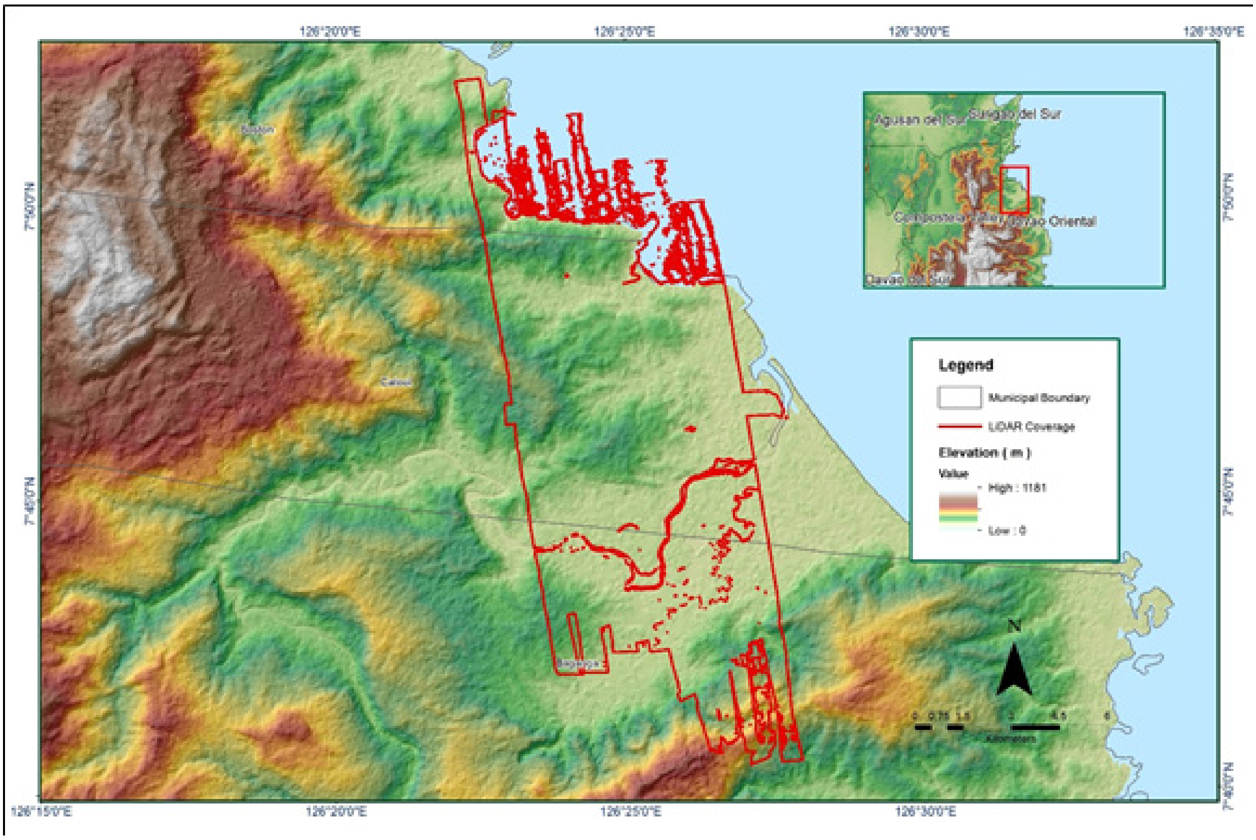
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

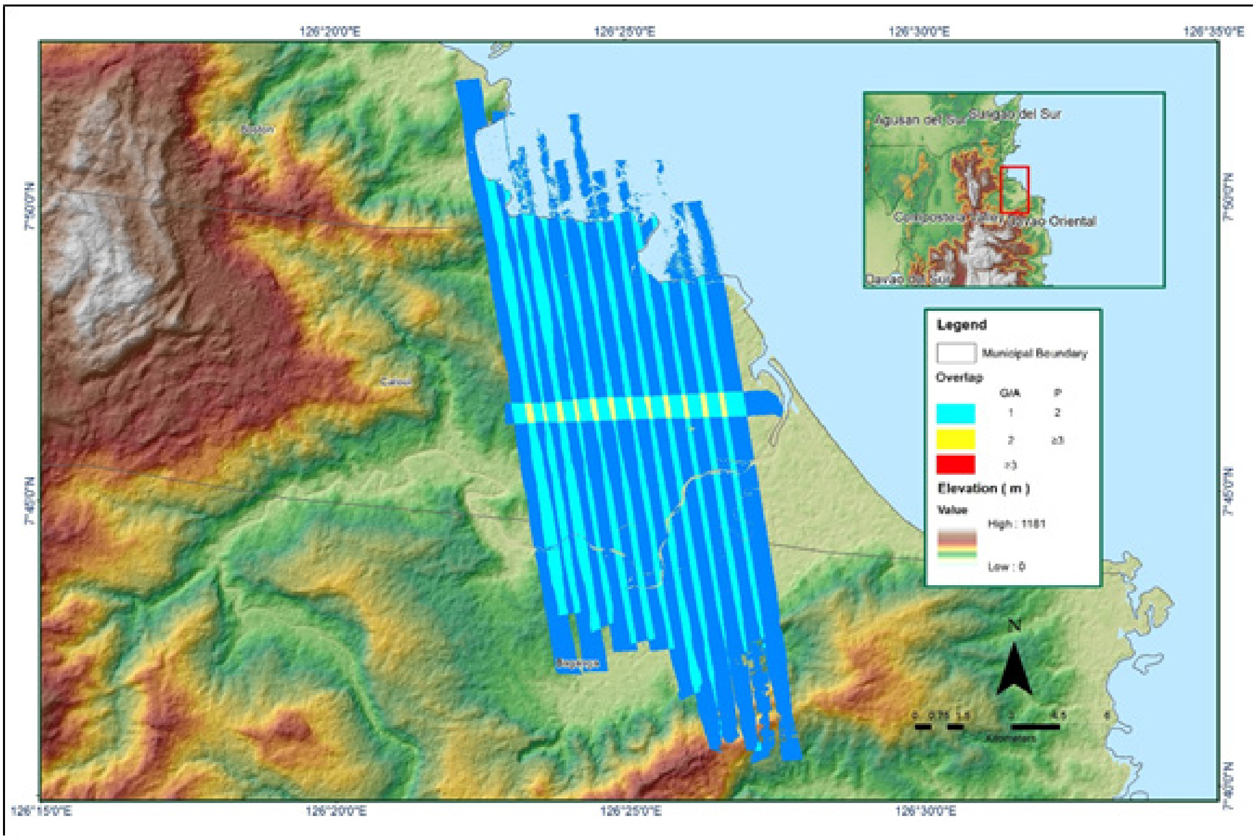
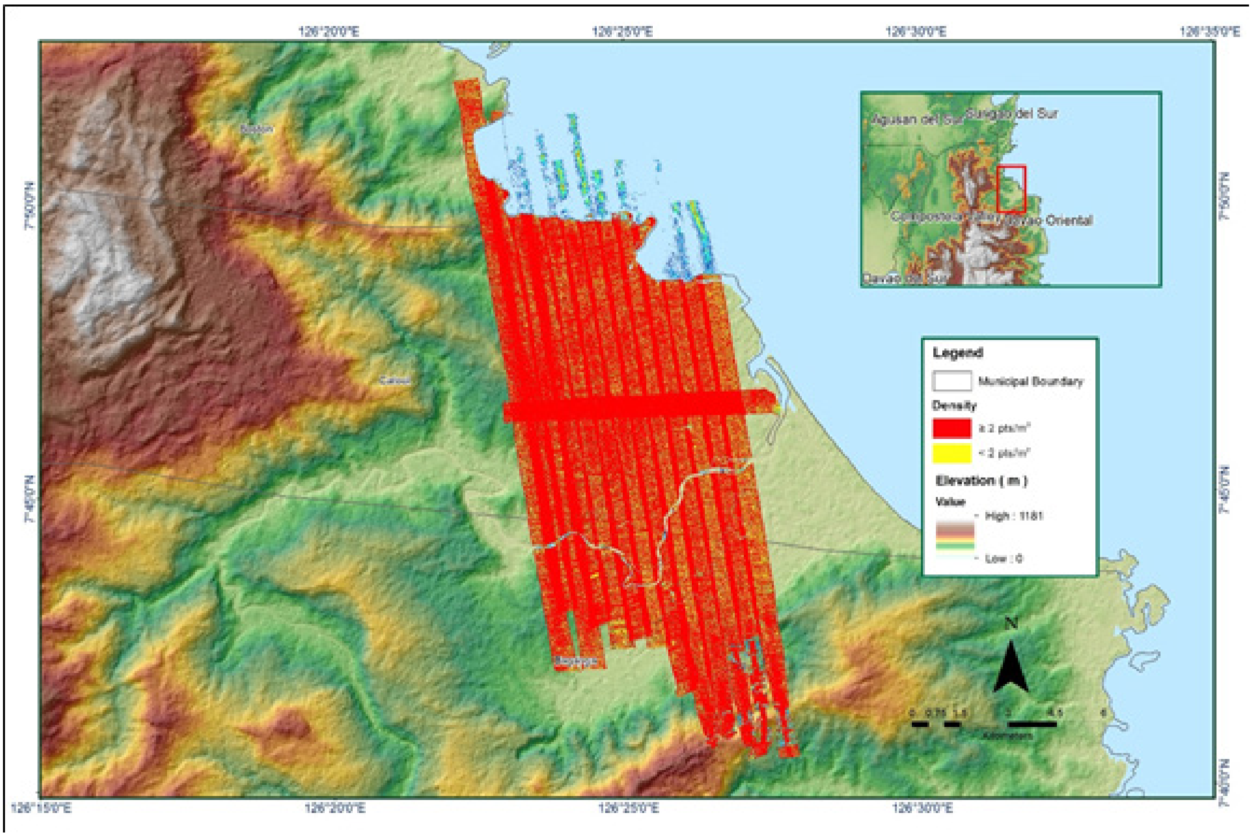
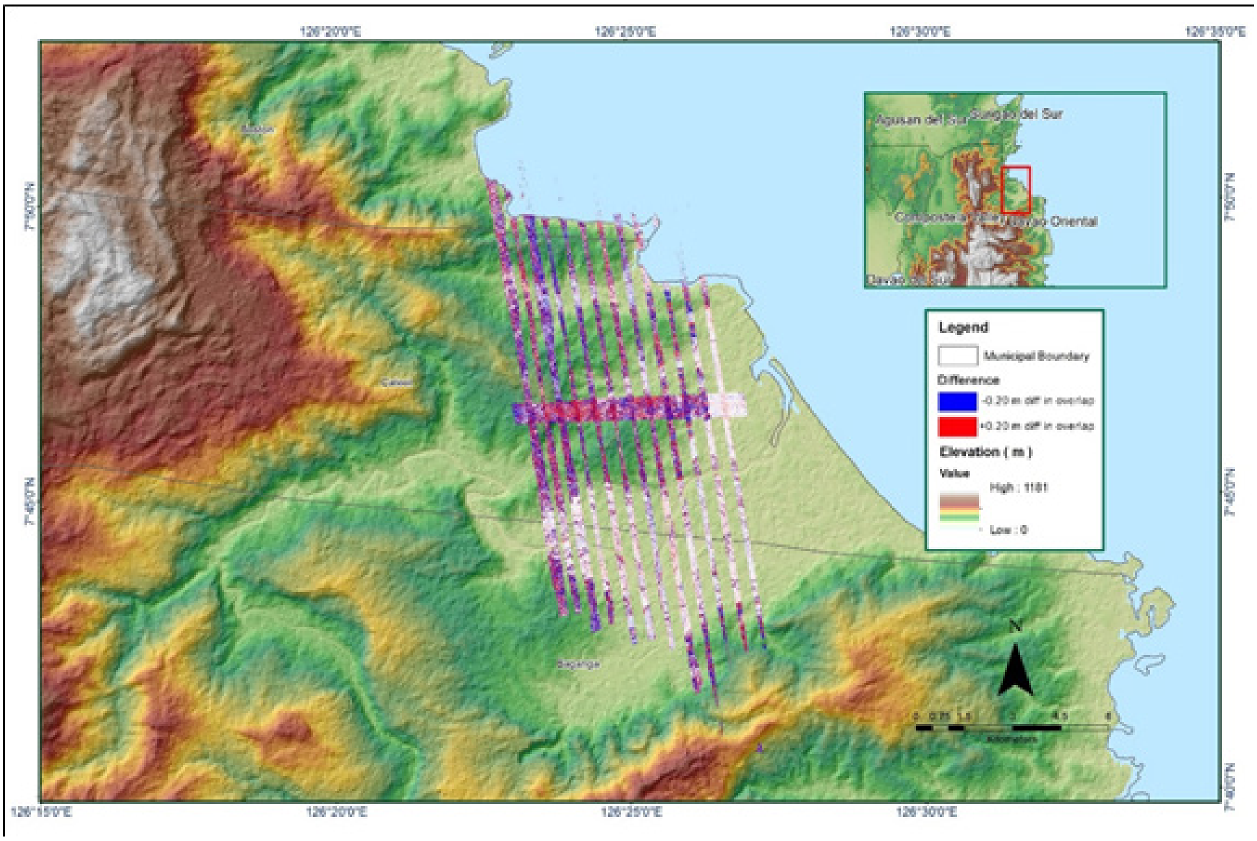


Image of Data Overlap

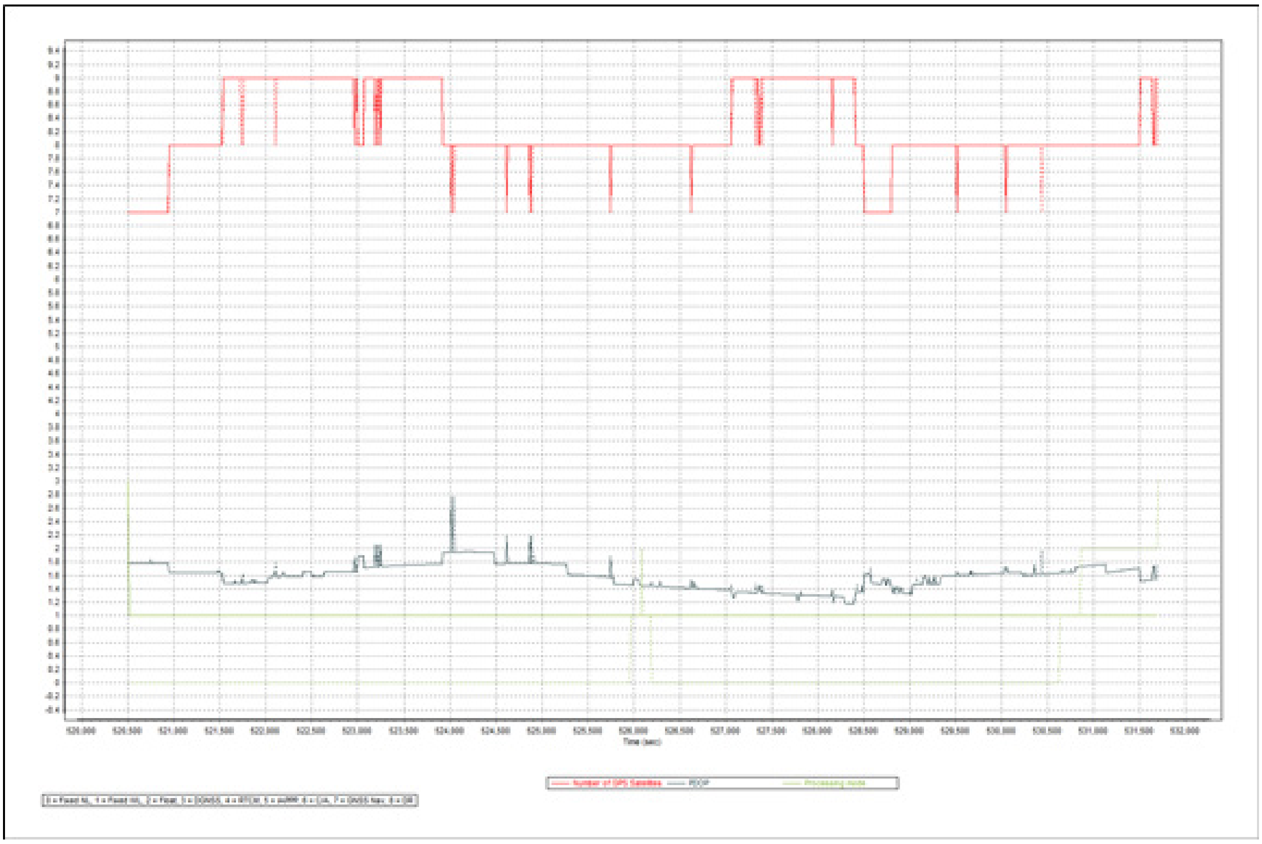


Density map of merged LiDAR data

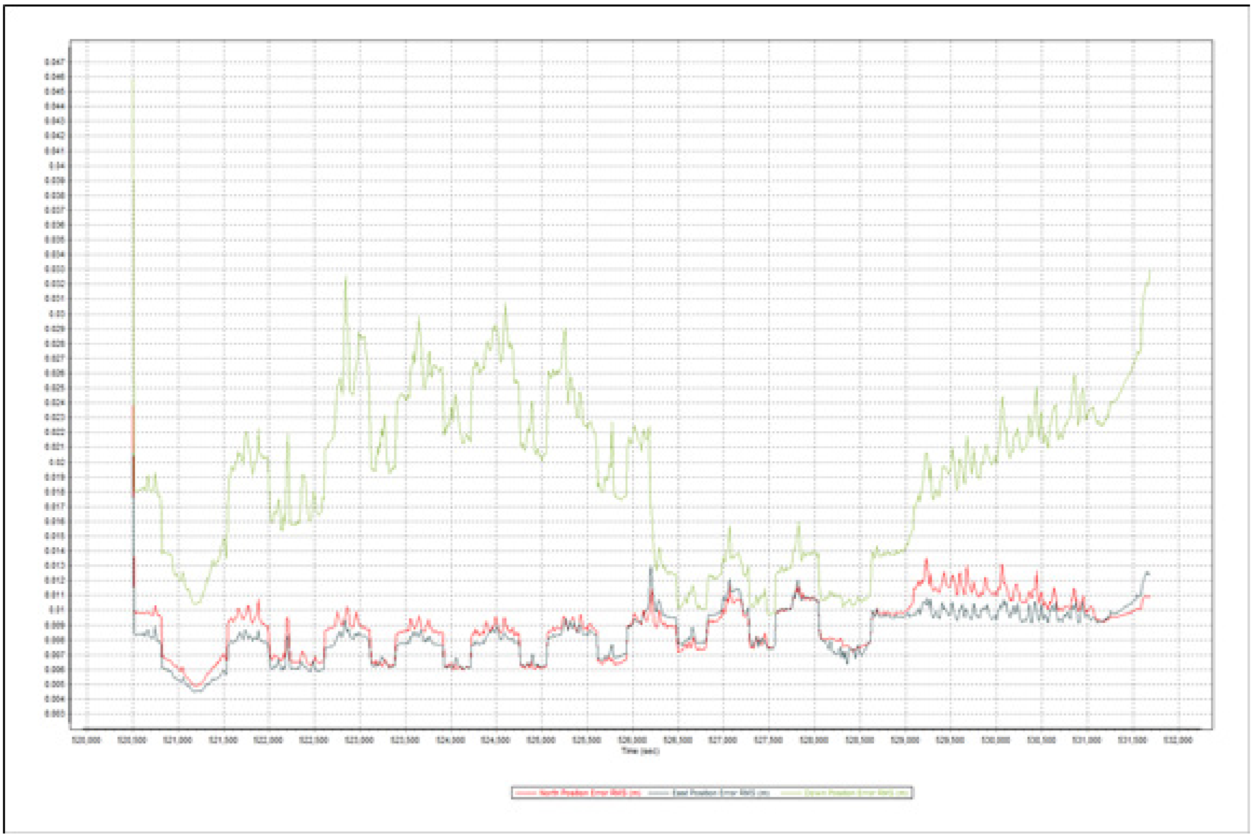


Elevation difference between flight lines

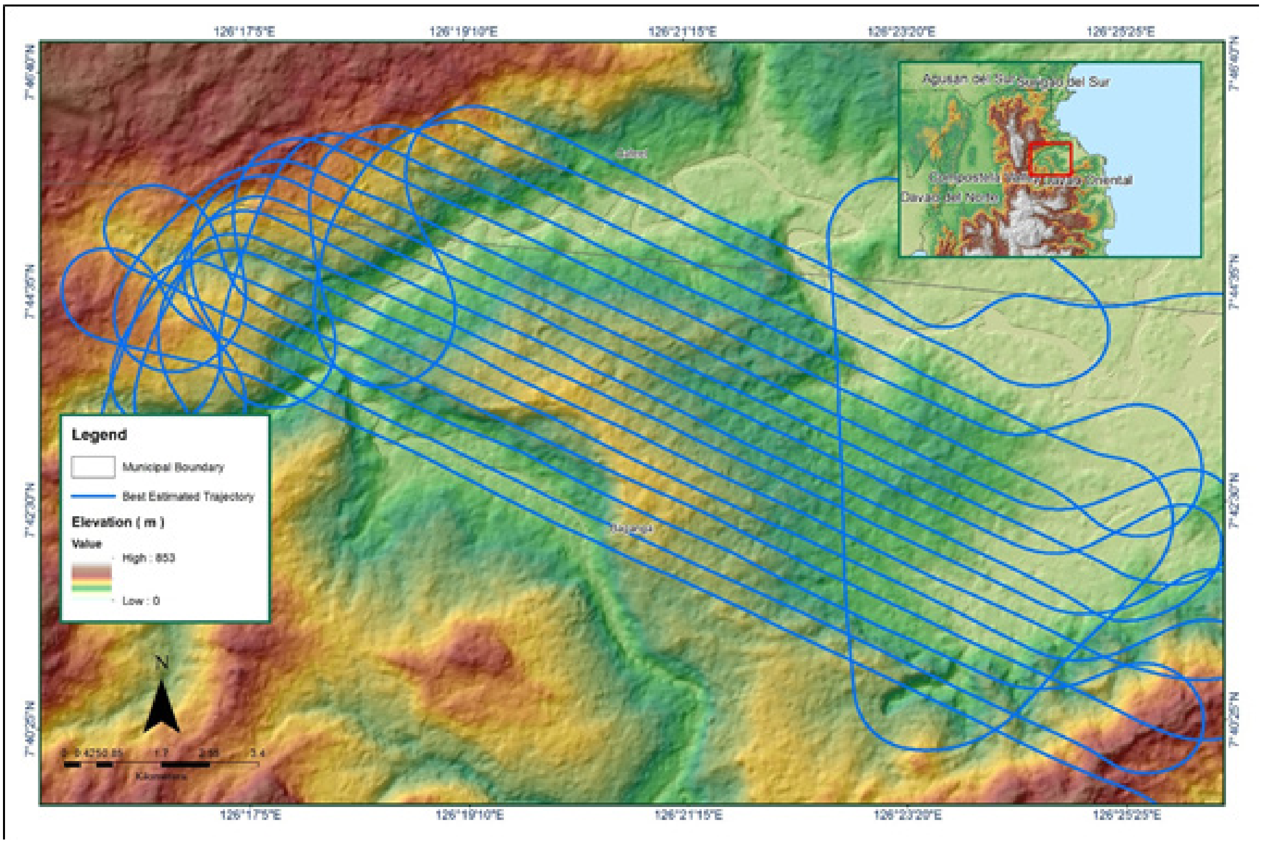
Flight Area	Davao Oriental
Mission Name	Blk79D
Inclusive Flights	7366G
Range data size	12.2 GB
Base data size	4.89 MB
POS	241 MB
Image	na
Transfer date	July 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.35
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000590
IMU attitude correction stdev (<0.001deg)	0.002686
GPS position stdev (<0.01m)	0.0125
Minimum % overlap (>25)	28.69%
Ave point cloud density per sq.m. (>2.0)	3.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	122
Maximum Height	655.61 m
Minimum Height	50.32 m
Classification (# of points)	
Ground	19,098,352
Low vegetation	12,418,990
Medium vegetation	82,752,828
High vegetation	127,634,219
Building	2,941,075
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Edgardo Gubatanga, Jr., Engr. Jeffrey Delica



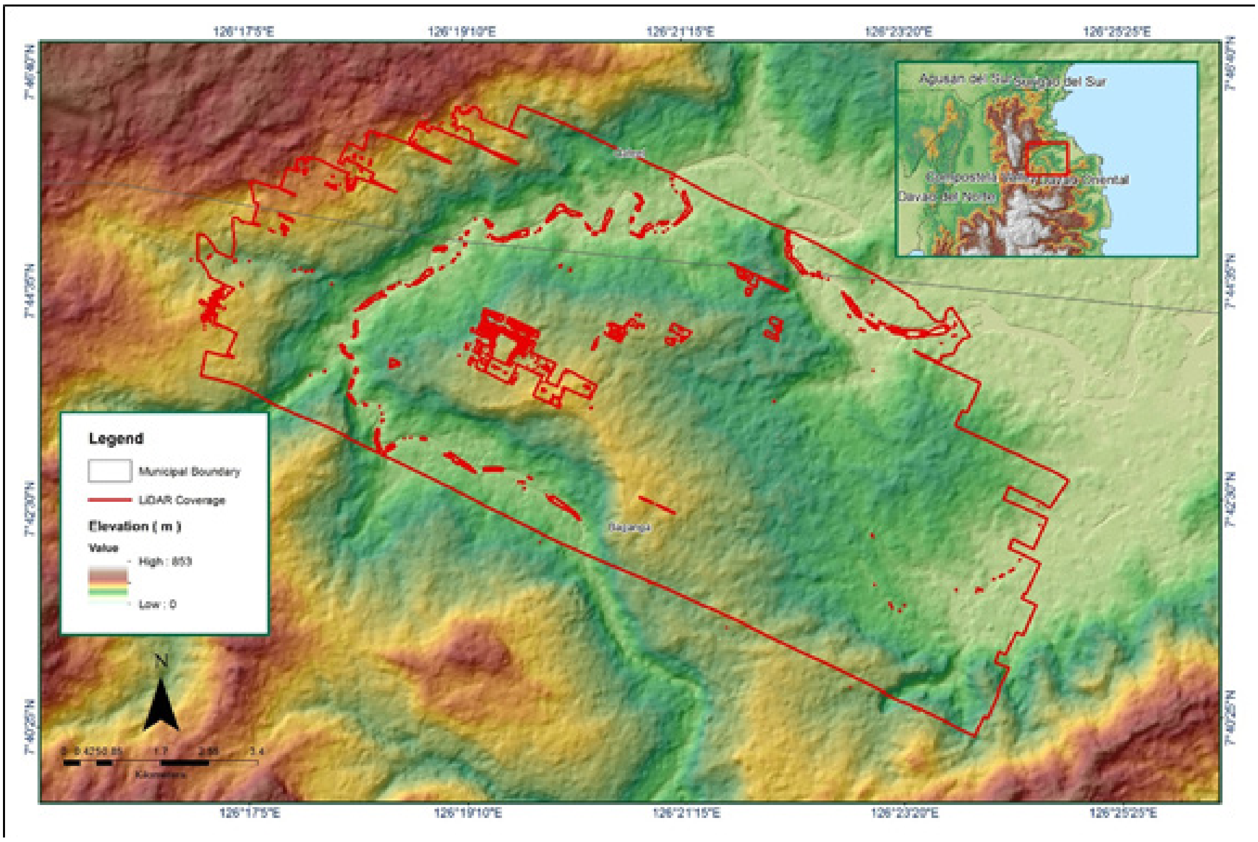
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

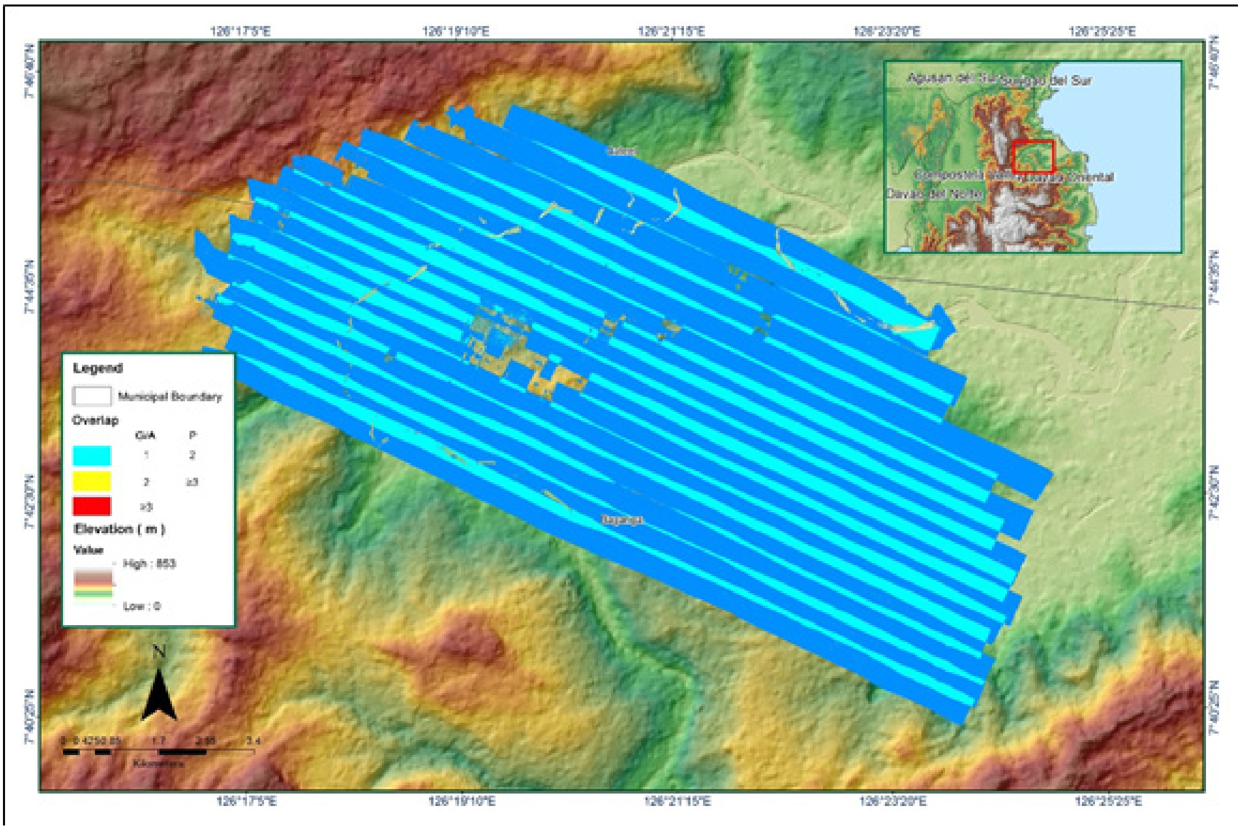
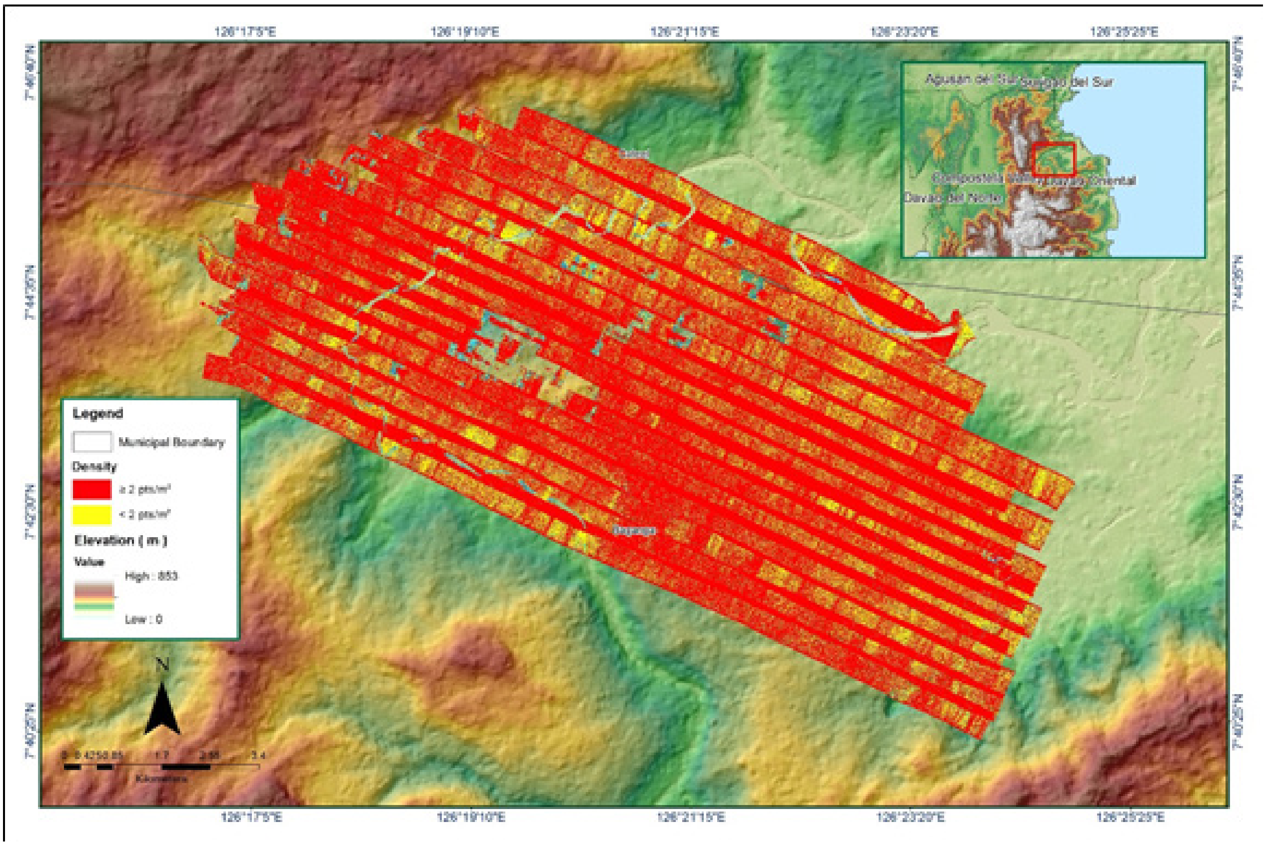
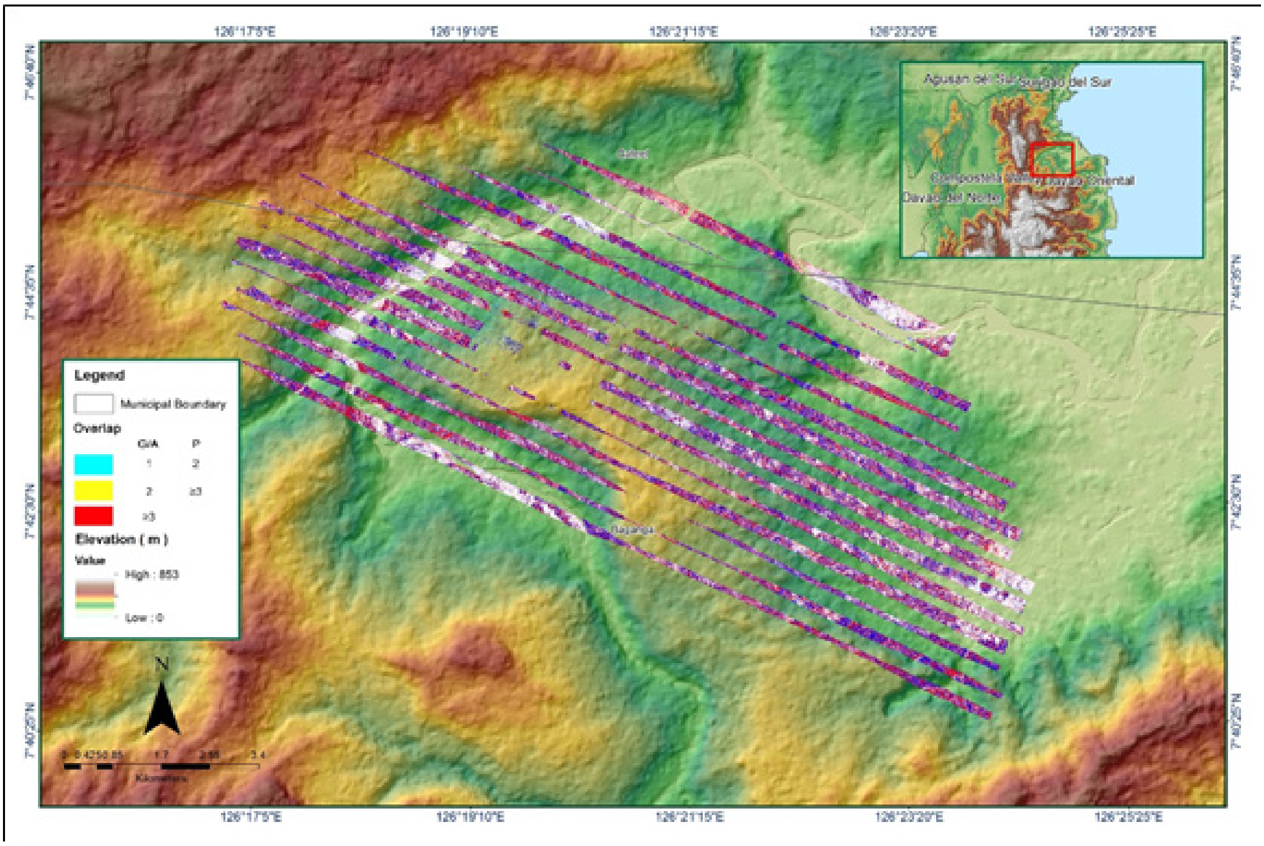


Image of Data Overlap

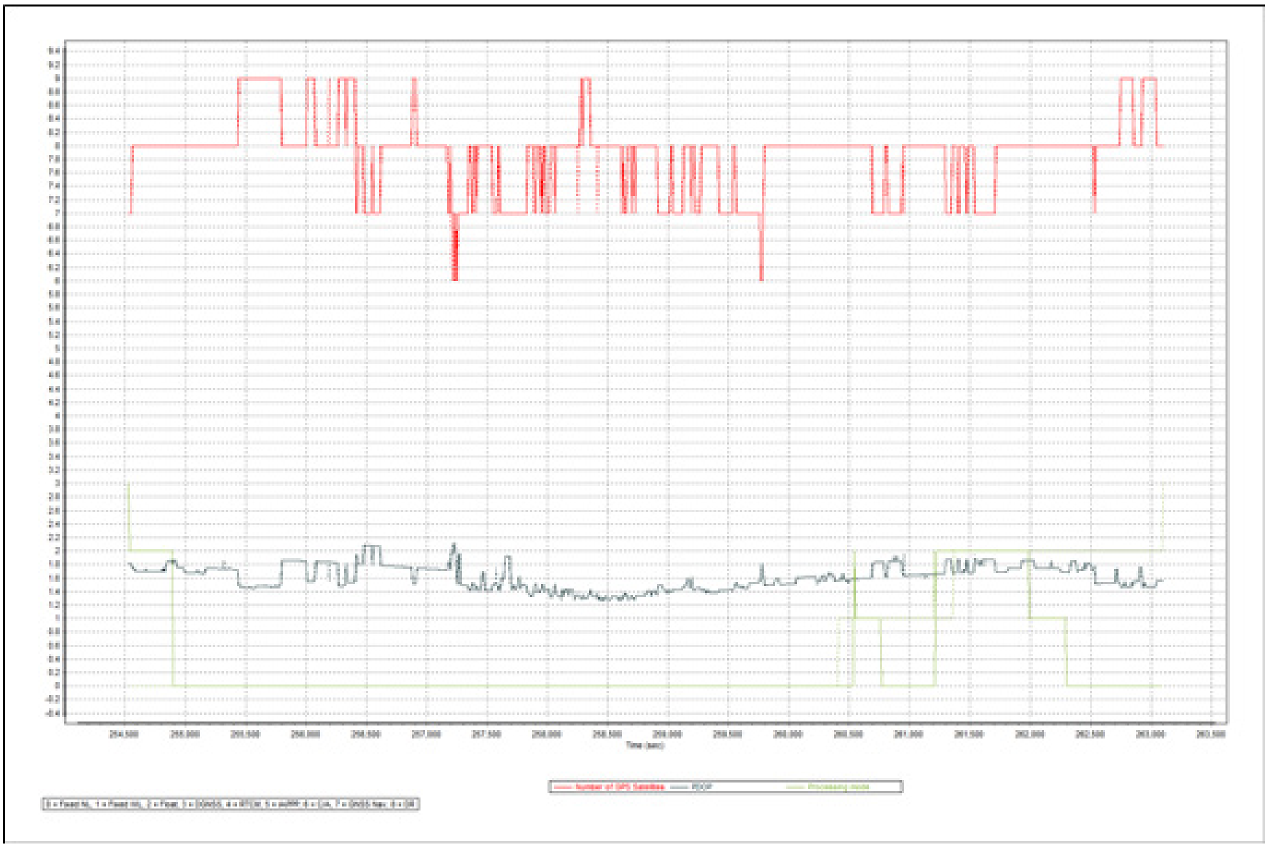


Density map of merged LiDAR data

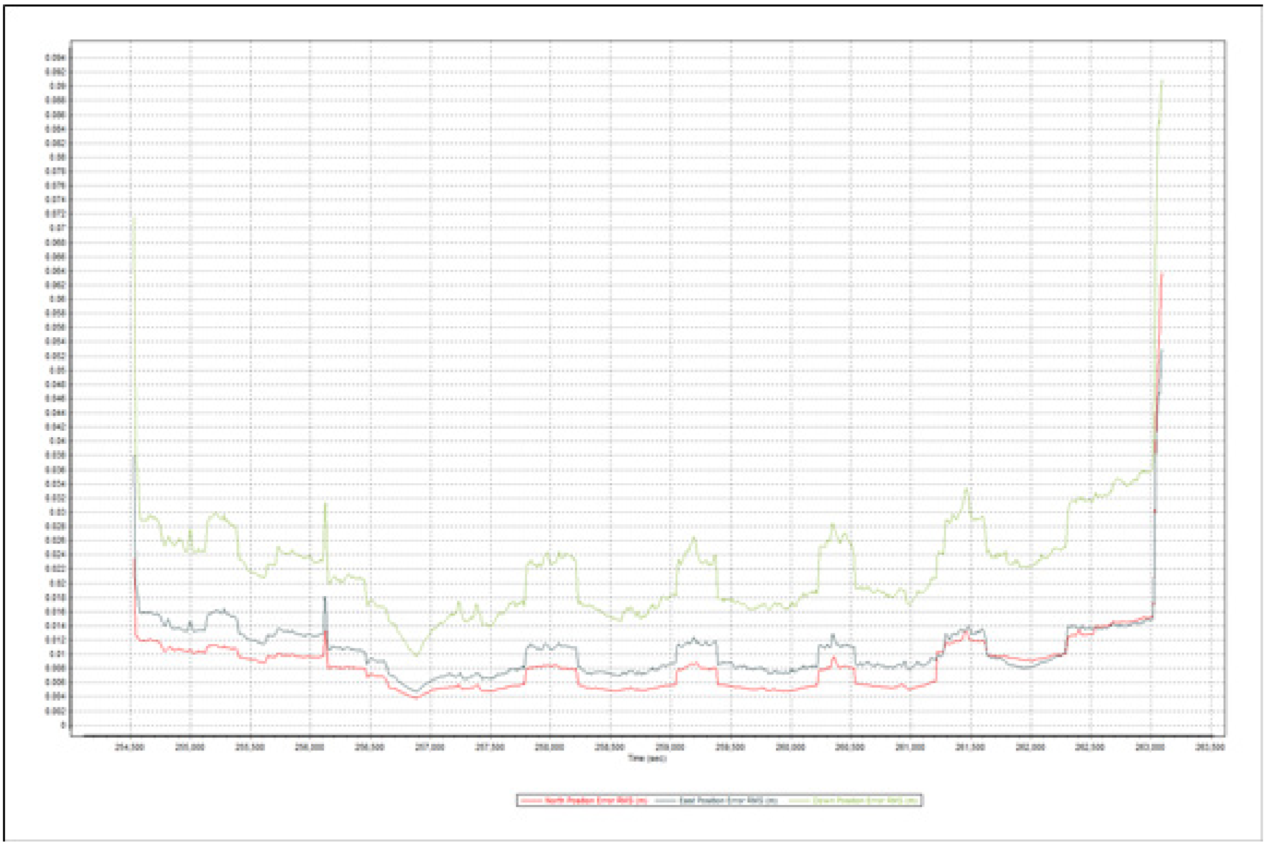


Elevation difference between flight lines

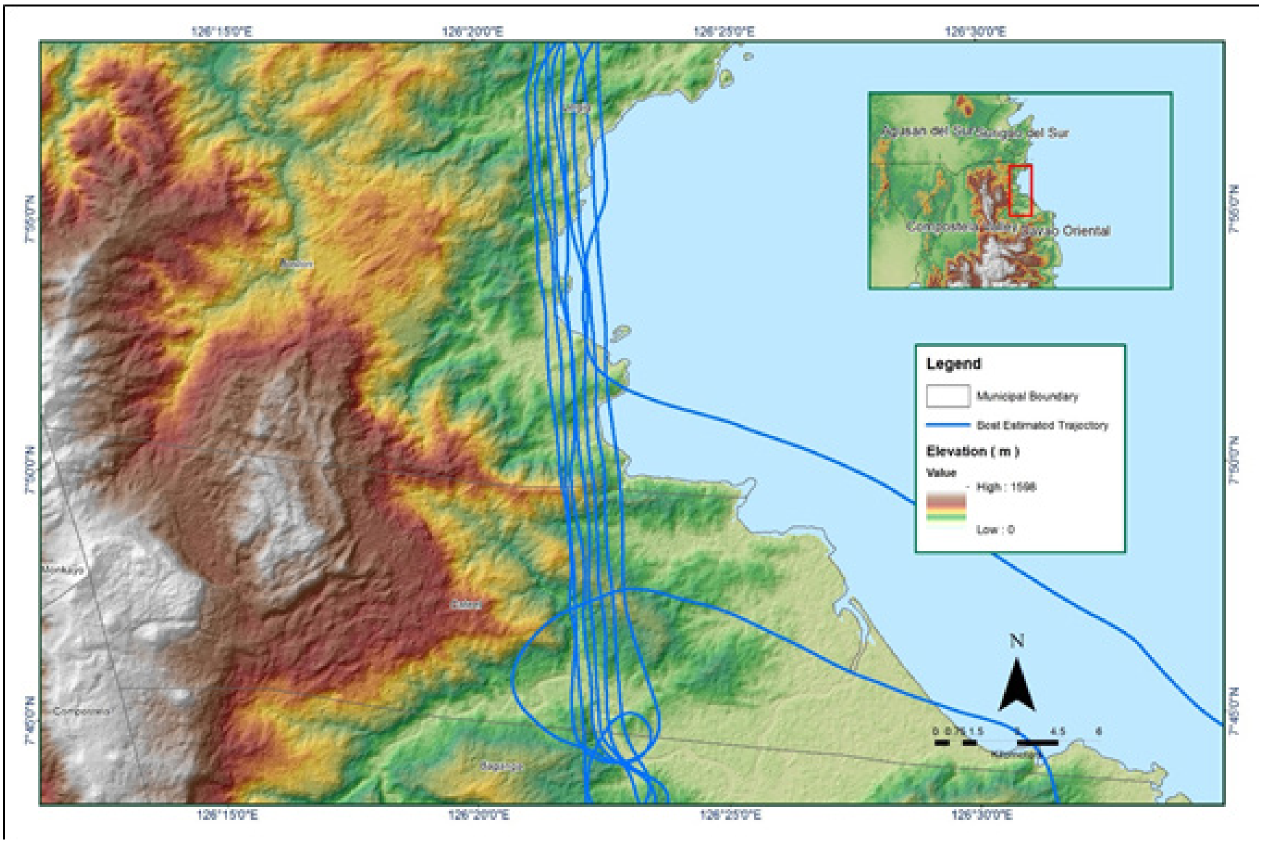
Flight Area	Davao Oriental
Mission Name	Blk79E
Inclusive Flights	7372G,7374G
Range data size	12.48 GB
Base data size	7.98 MB
POS	314 MB
Image	na
Transfer date	July 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000266
IMU attitude correction stdev (<0.001deg)	0.000557
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	43.49%
Ave point cloud density per sq.m. (>2.0)	3.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	129
Maximum Height	564.32 m
Minimum Height	68.17 m
Classification (# of points)	
Ground	24,974,495
Low vegetation	20,694,683
Medium vegetation	95,418,865
High vegetation	98,204,062
Building	1,995,267
Orthophoto	No
Processed by	Engr. Irish Cortez,Aljon Rie Araneta,
Engr. Melissa Fernandez	



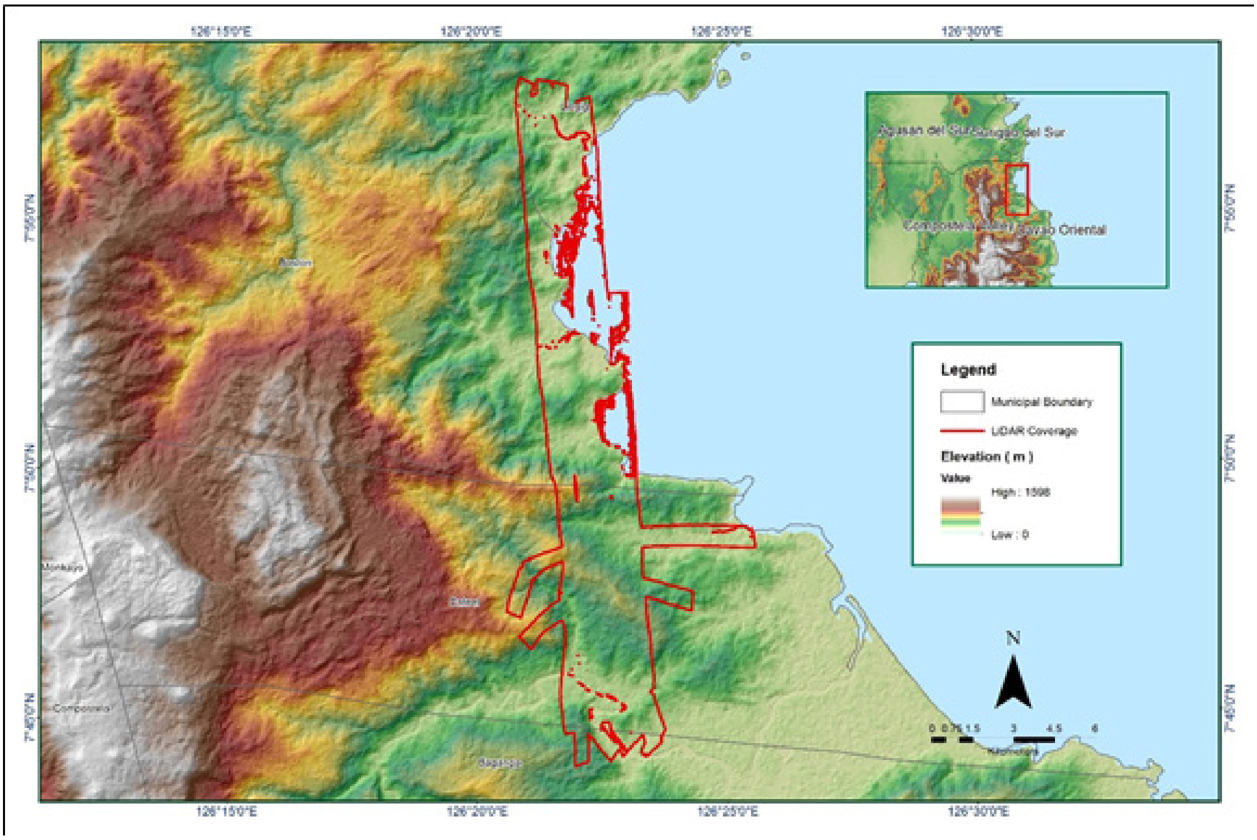
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

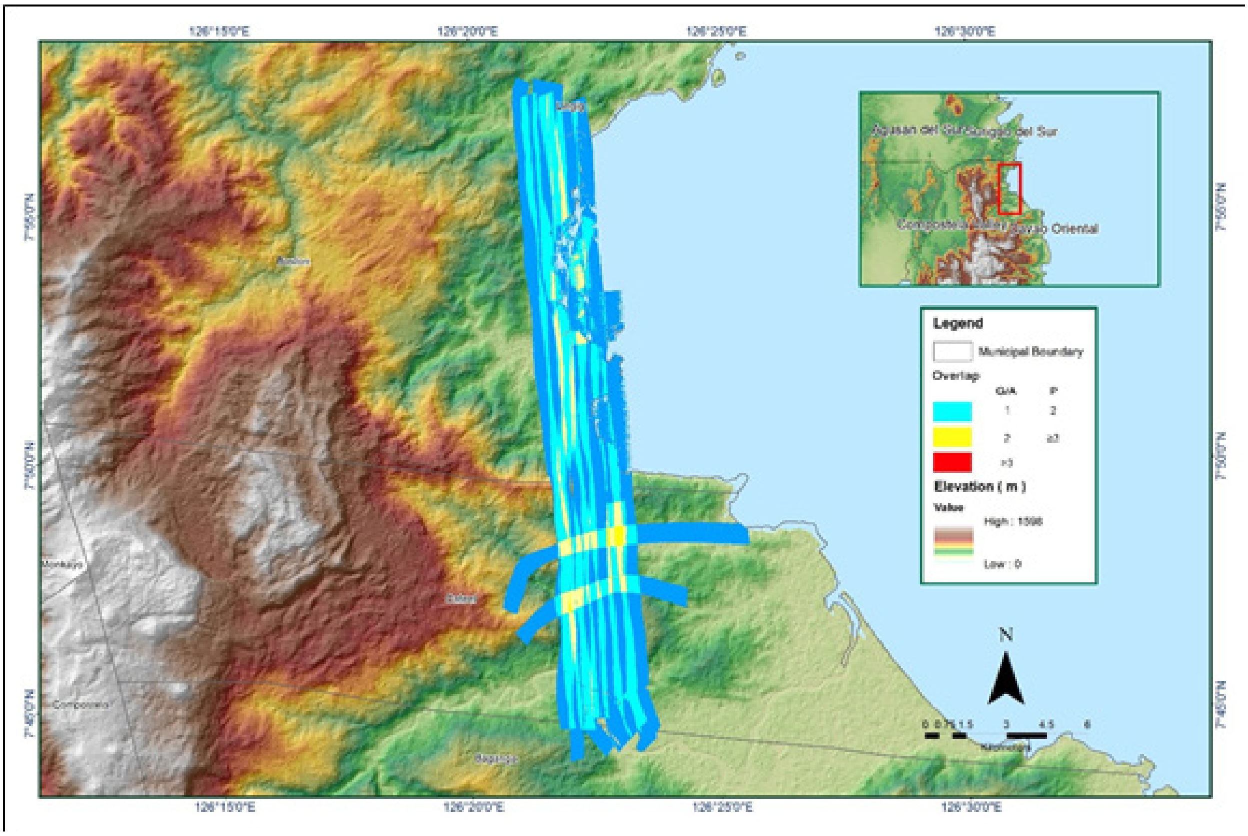
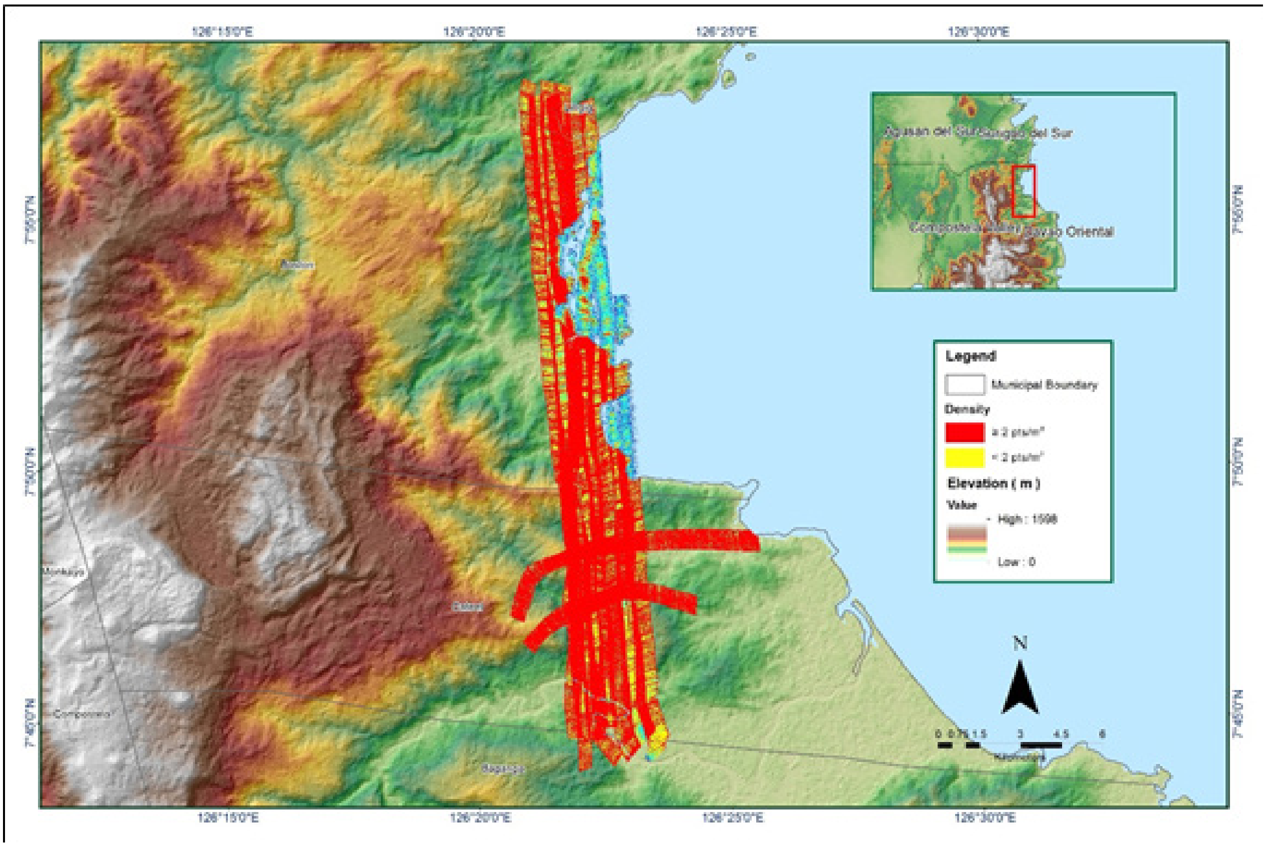
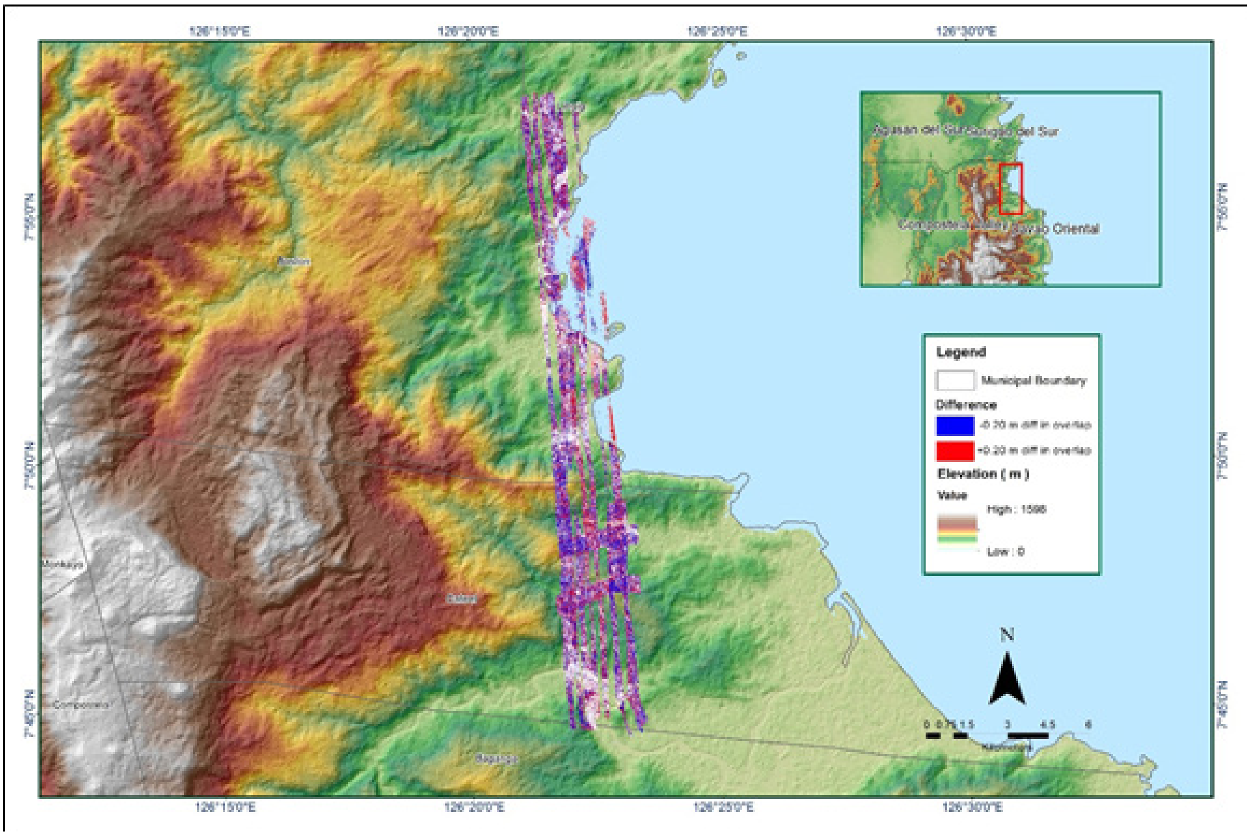


Image of Data Overlap

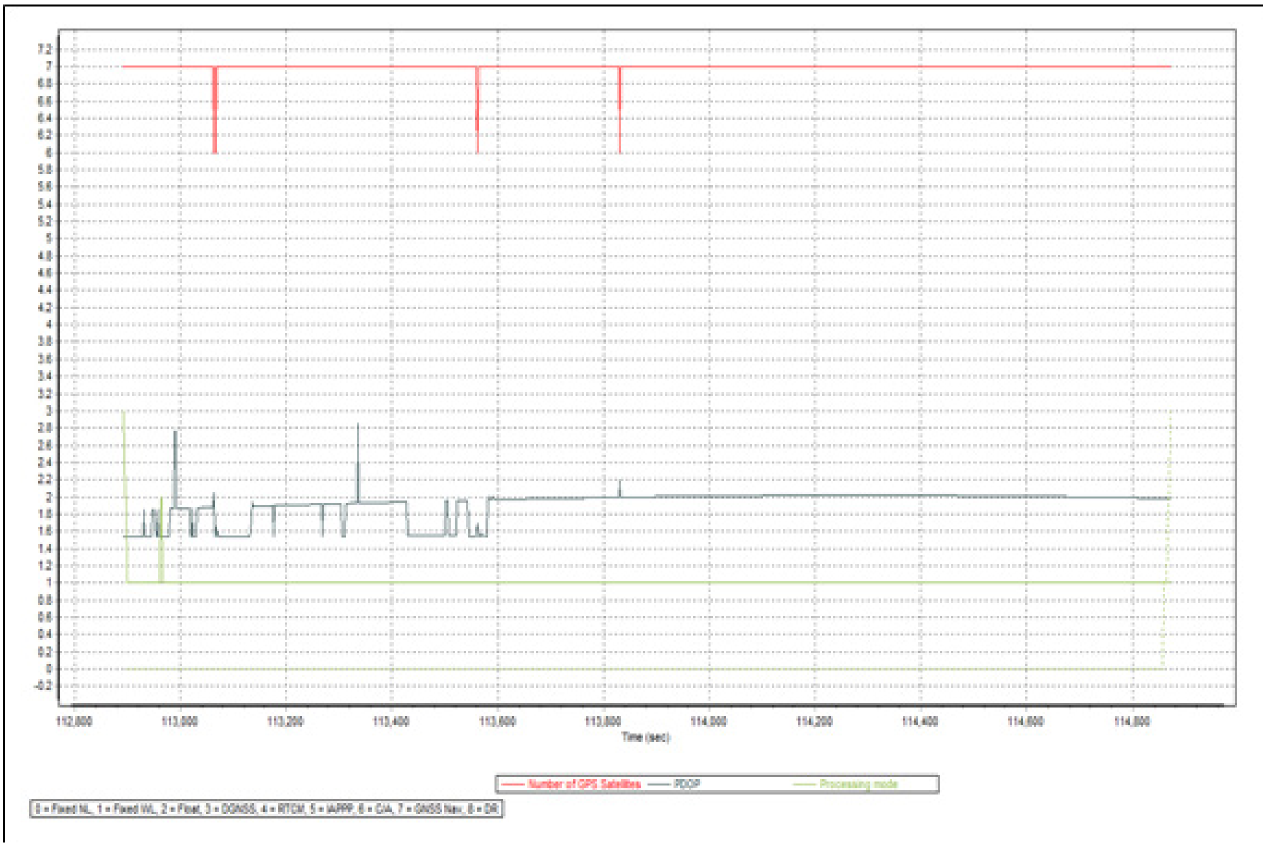


Density map of merged LiDAR data

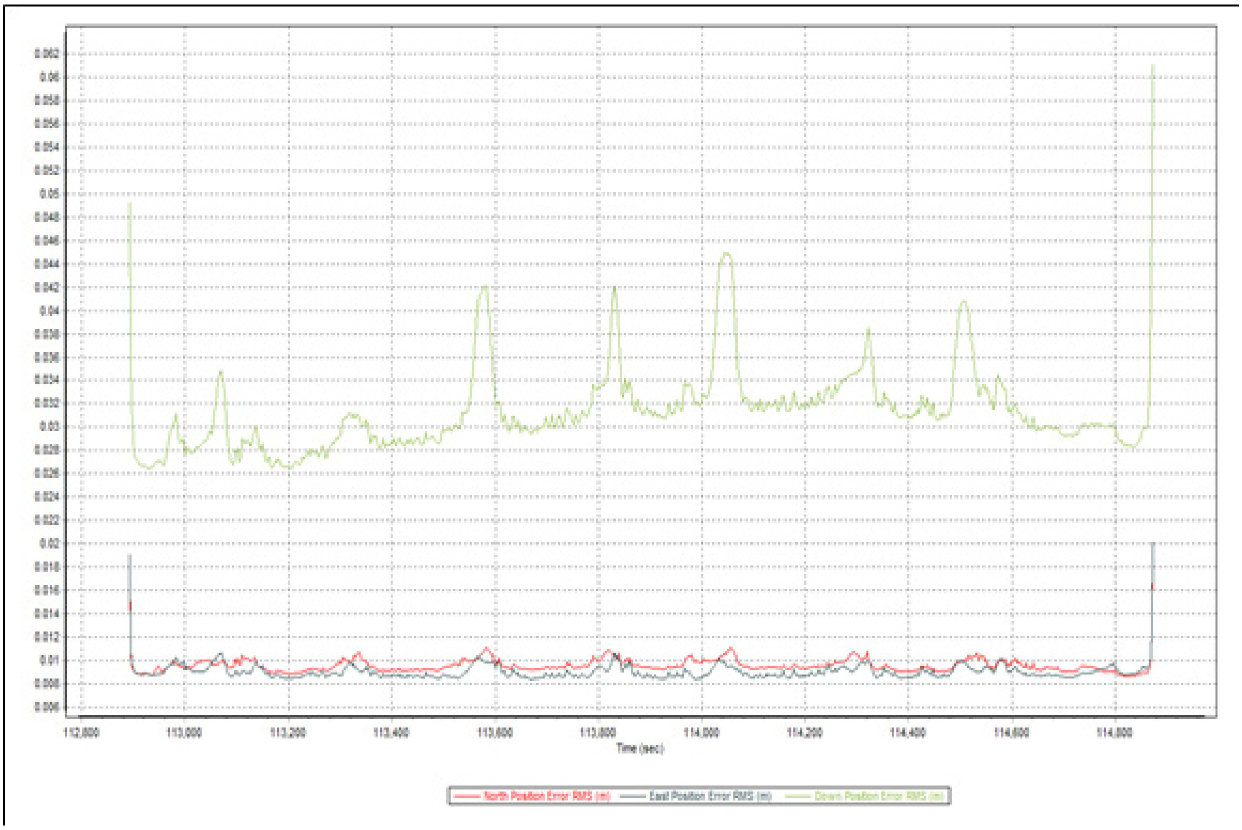


Elevation difference between flight lines

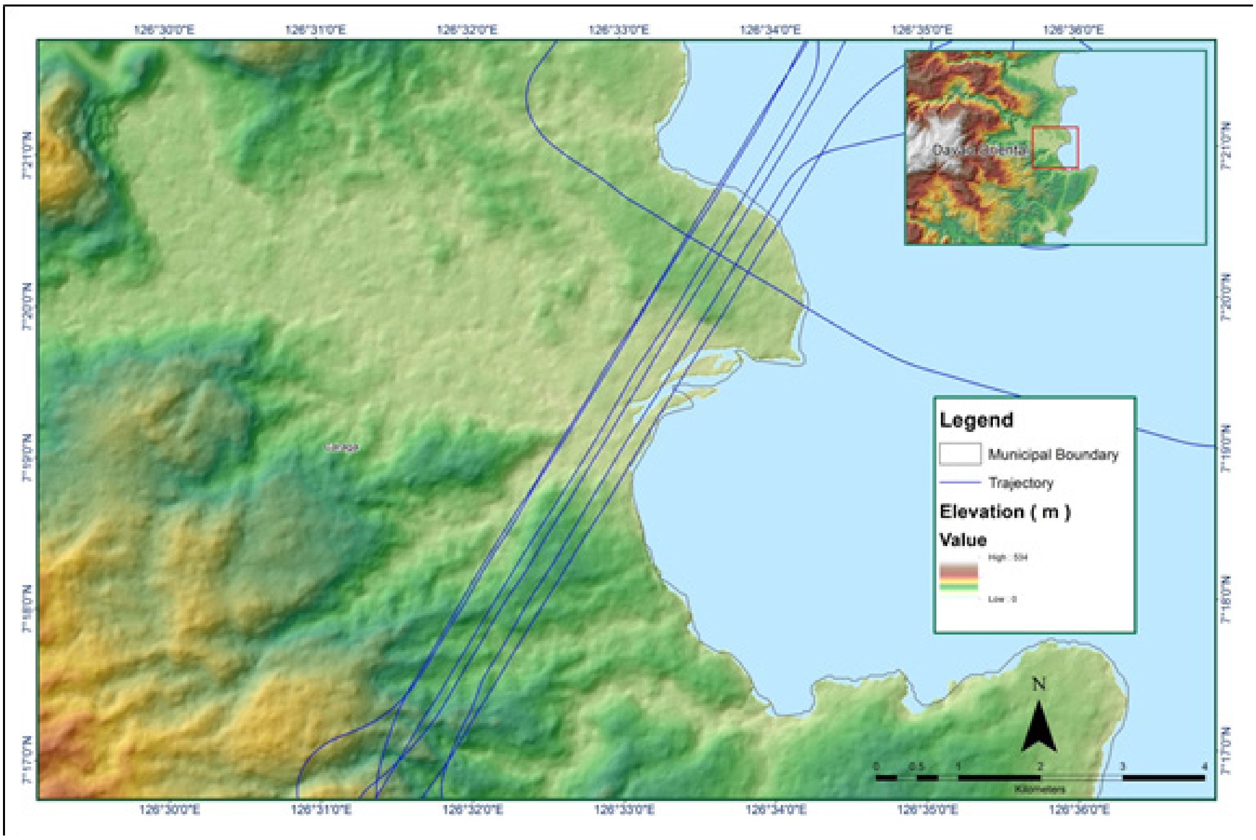
Flight Area	Tandag
Mission Name	Blk80A
Inclusive Flights	23630P
Range data size	4.98 GB
Base data size	377 MB
POS	107 MB
Image	NA
Transfer date	December 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	Yes
RMSE for East Position (<4.0 cm)	Yes
RMSE for Down Position (<8.0 cm)	Yes
Boresight correction stdev (<0.001deg)	0.000329
IMU attitude correction stdev (<0.001deg)	0.000364
GPS position stdev (<0.01m)	0.0083
Minimum % overlap (>25)	51.33
Ave point cloud density per sq.m. (>2.0)	8.23
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	27
Maximum Height	299.46 m
Minimum Height	63.84 m
Classification (# of points)	
Ground	15,680,751
Low vegetation	14,860,238
Medium vegetation	34,308,139
High vegetation	104,829,198
Building	946,856
Ortophoto	No
Processed by	



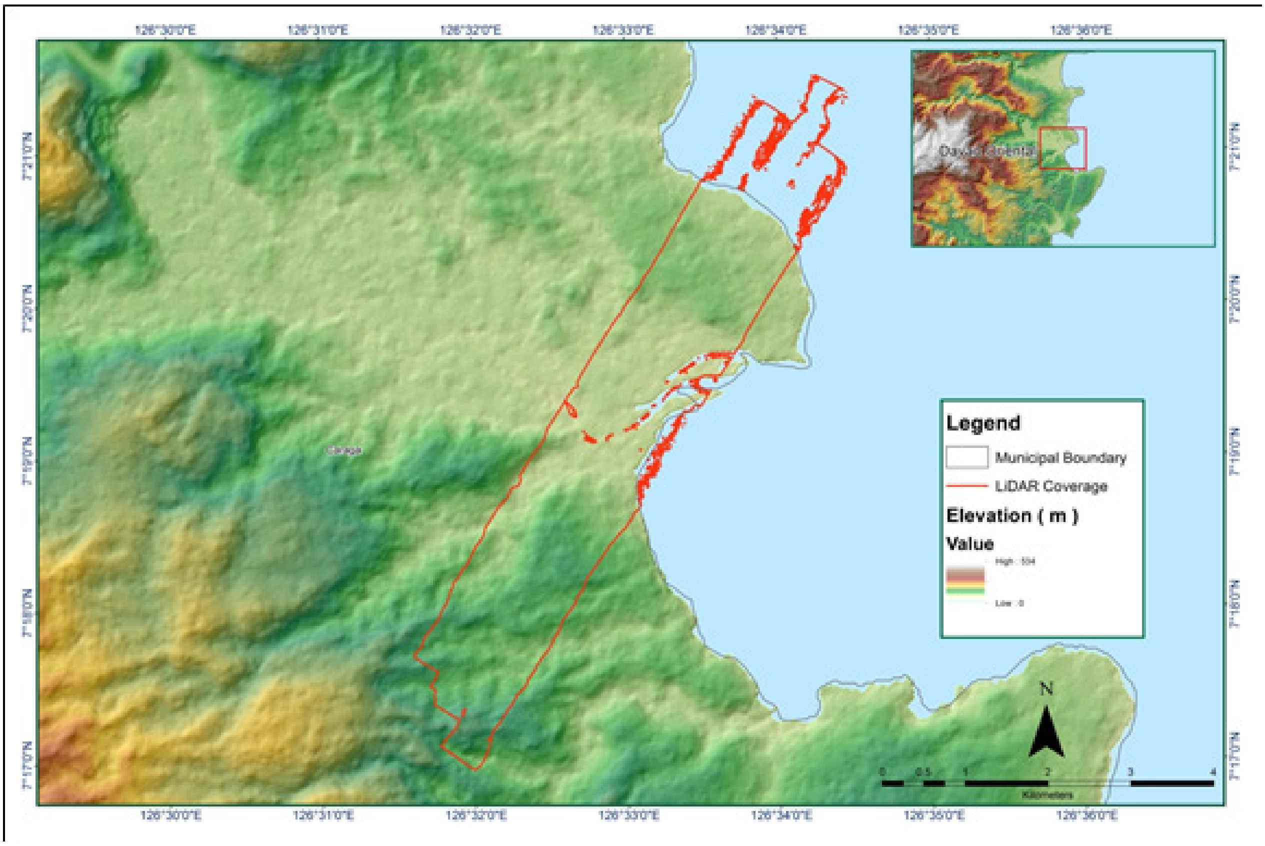
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

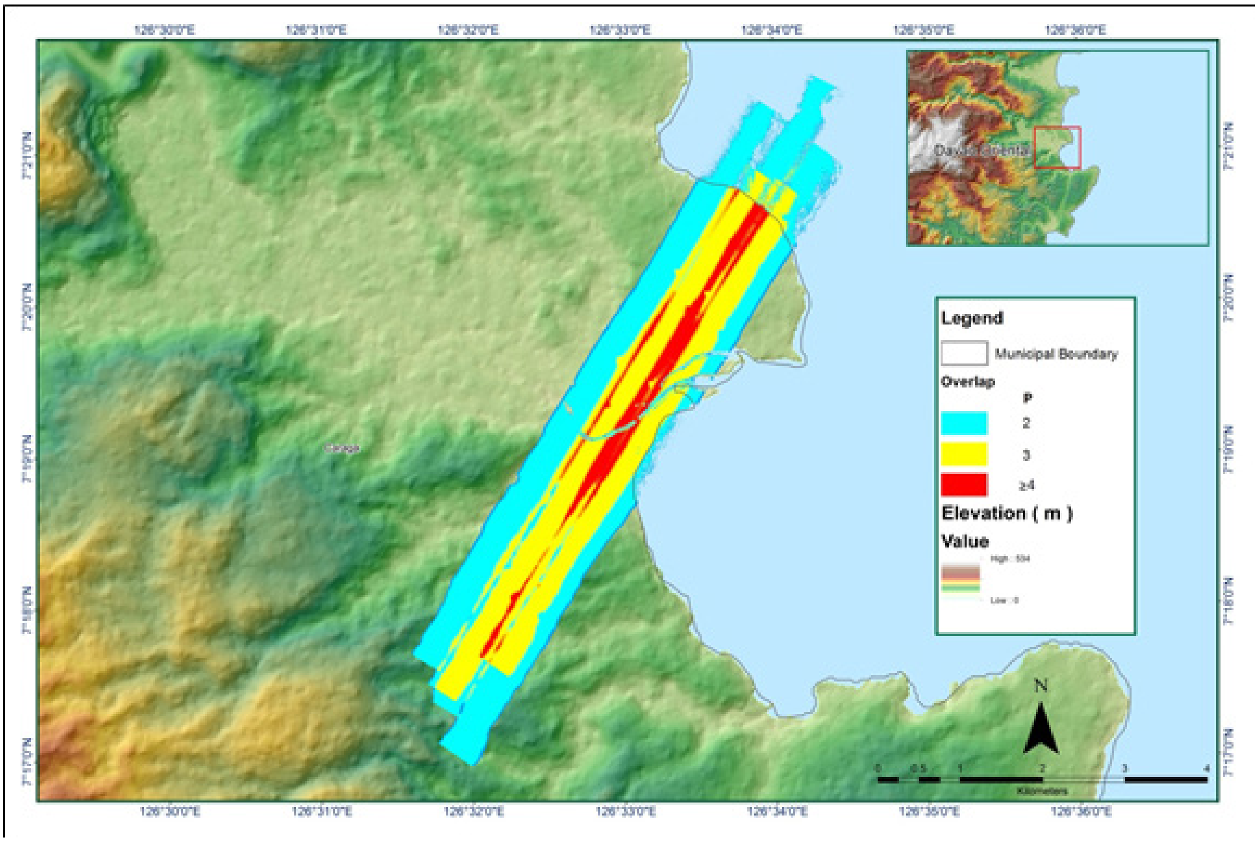
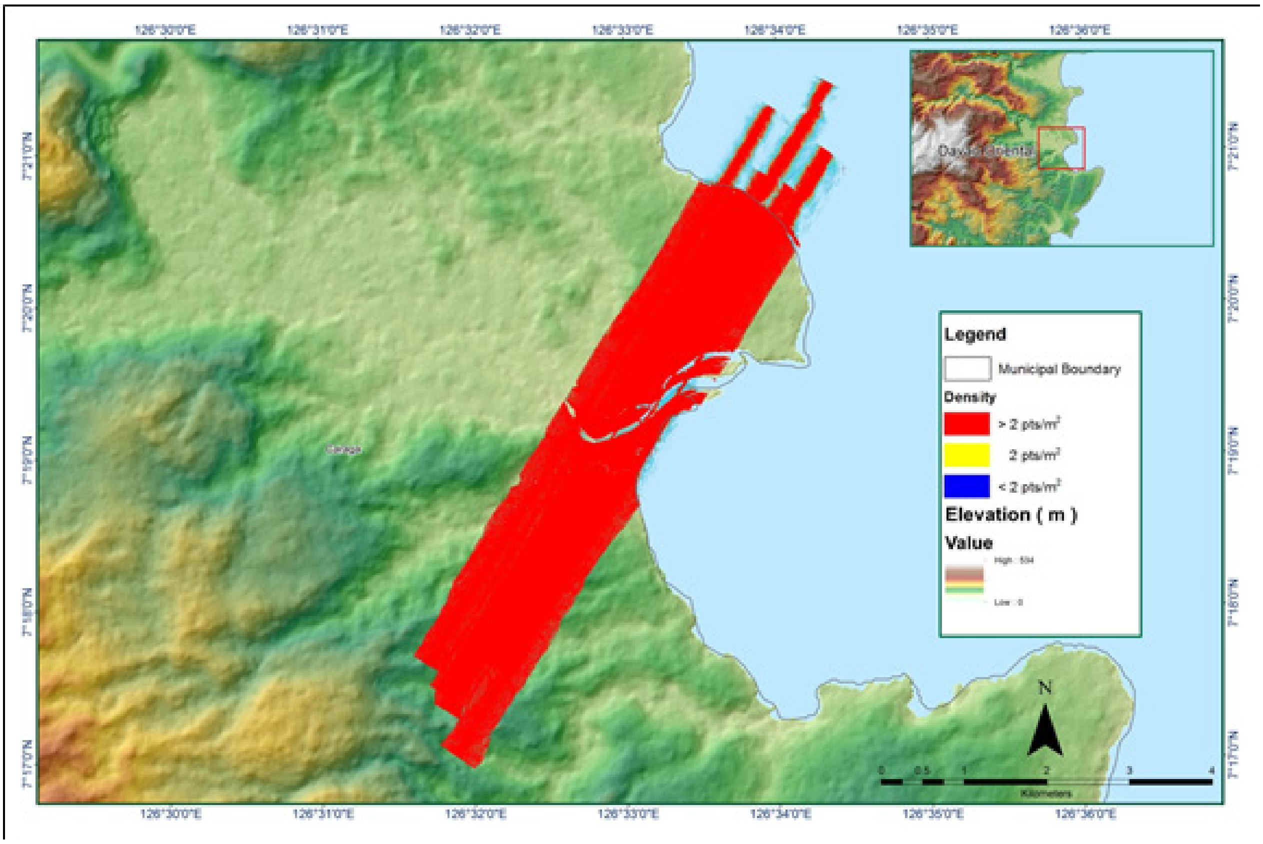
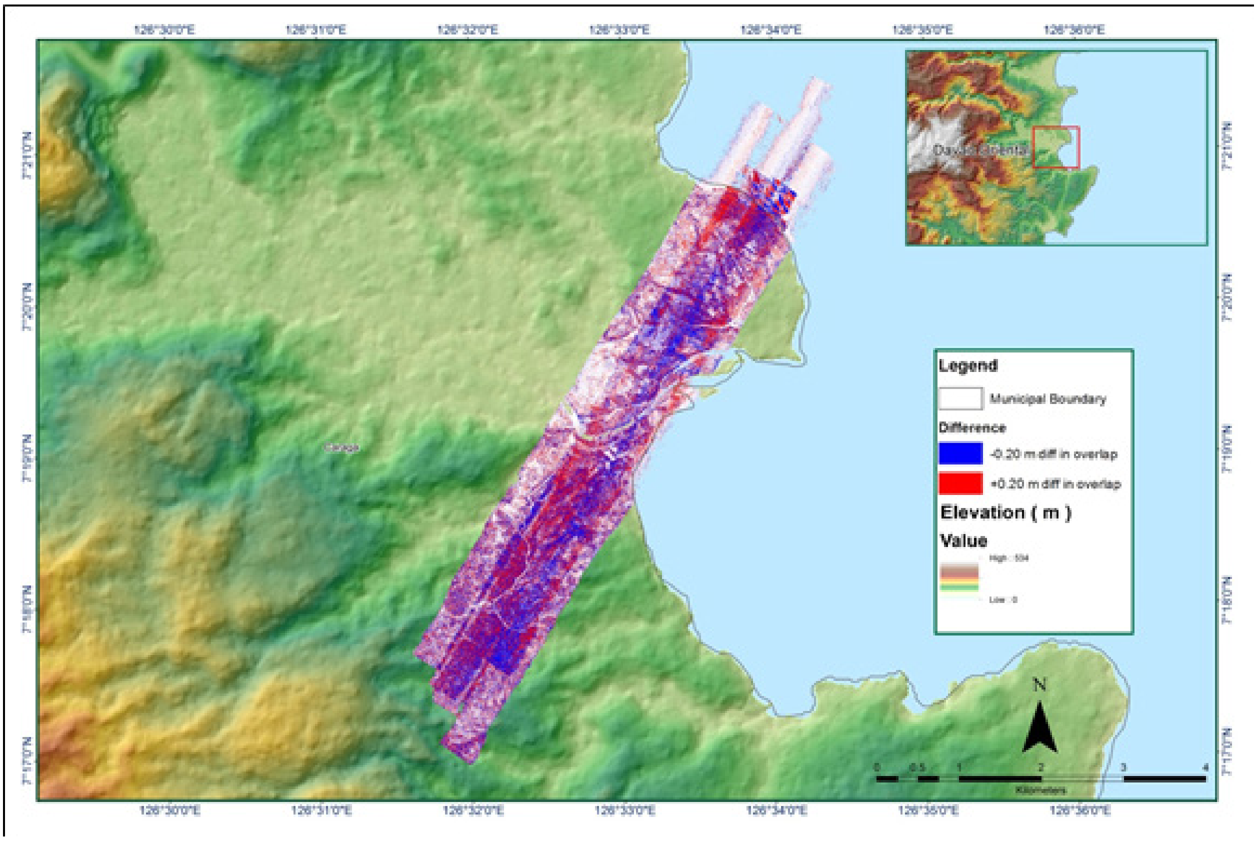


Image of Data Overlap

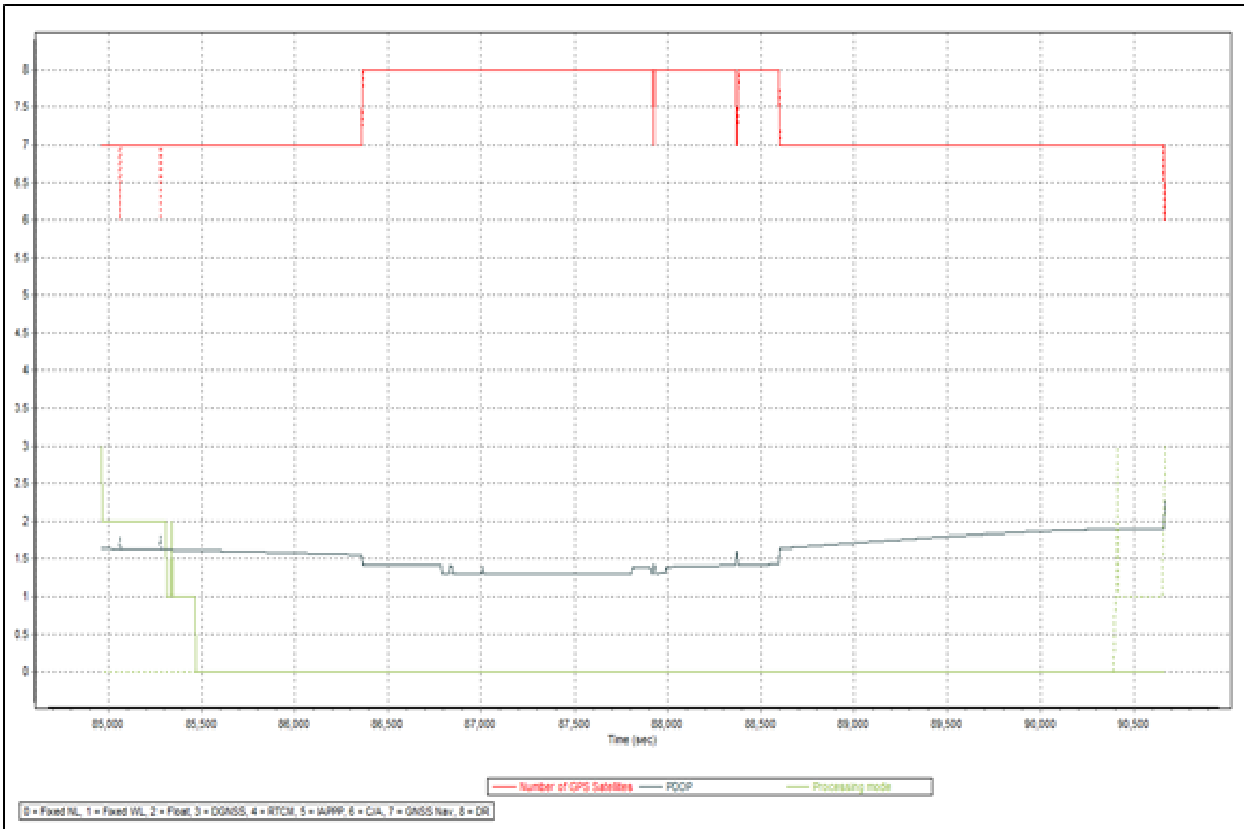


Density map of merged LiDAR data

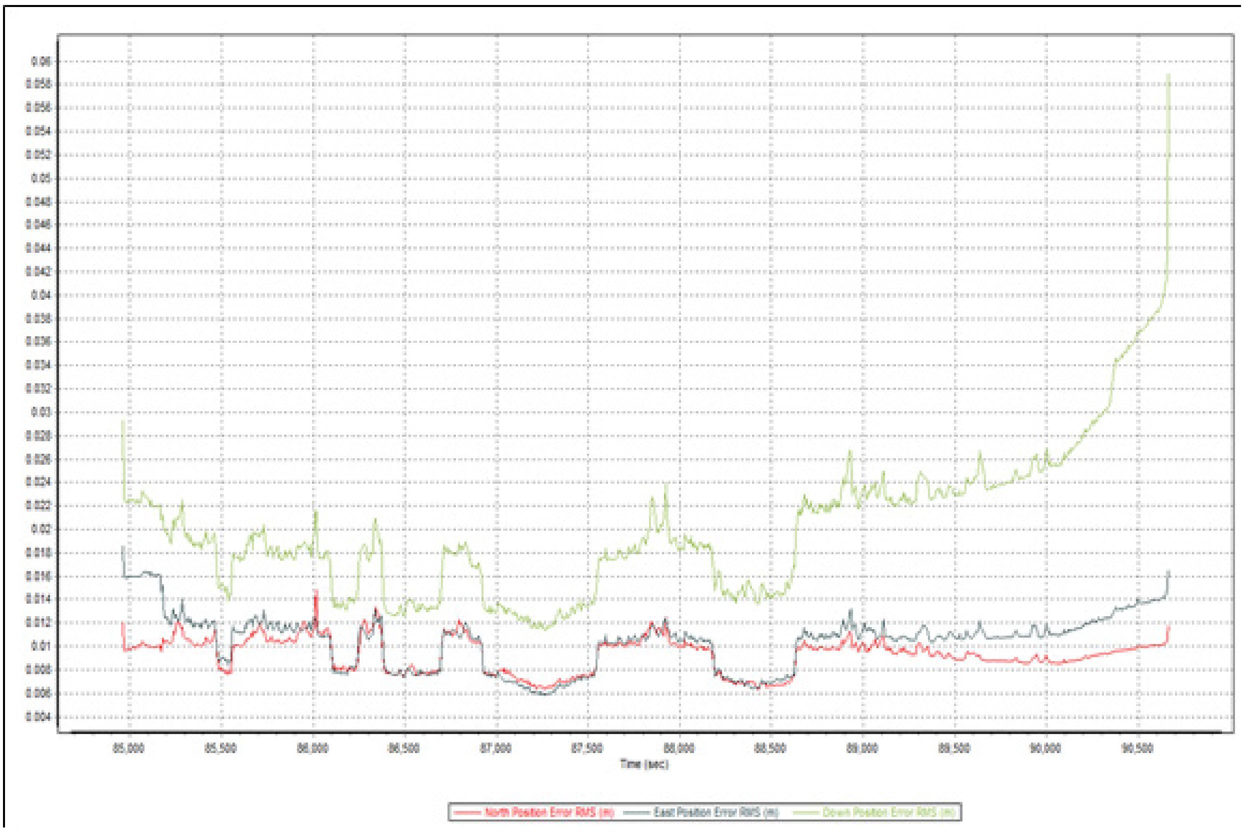


Elevation difference between flight lines

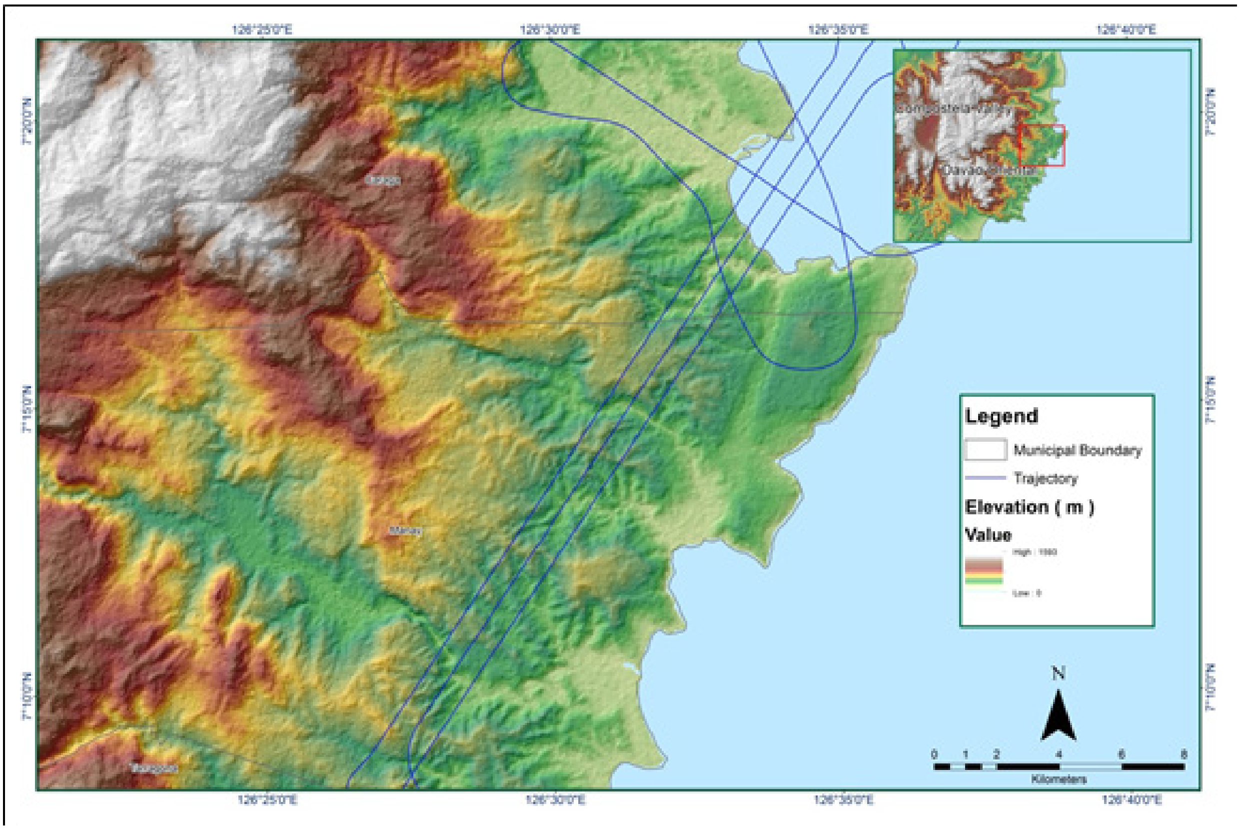
Flight Area	Tandag
Mission Name	Blk80A_additional
Inclusive Flights	23628P
Range data size	9.82 GB
Base data size	377 MB
POS	246 MB
Image	NA
Transfer date	December 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	Yes
RMSE for East Position (<4.0 cm)	Yes
RMSE for Down Position (<8.0 cm)	Yes
Boresight correction stdev (<0.001deg)	0.002162
IMU attitude correction stdev (<0.001deg)	0.005690
GPS position stdev (<0.01m)	0.0233
Minimum % overlap (>25)	14.97
Ave point cloud density per sq.m. (>2.0)	3.04
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	99
Maximum Height	462.33 m
Minimum Height	62.86 m
Classification (# of points)	
Ground	41,423,932
Low vegetation	20,204,675
Medium vegetation	40,870,636
High vegetation	130,335,782
Building	960,994
Ortophoto	No
Processed by	



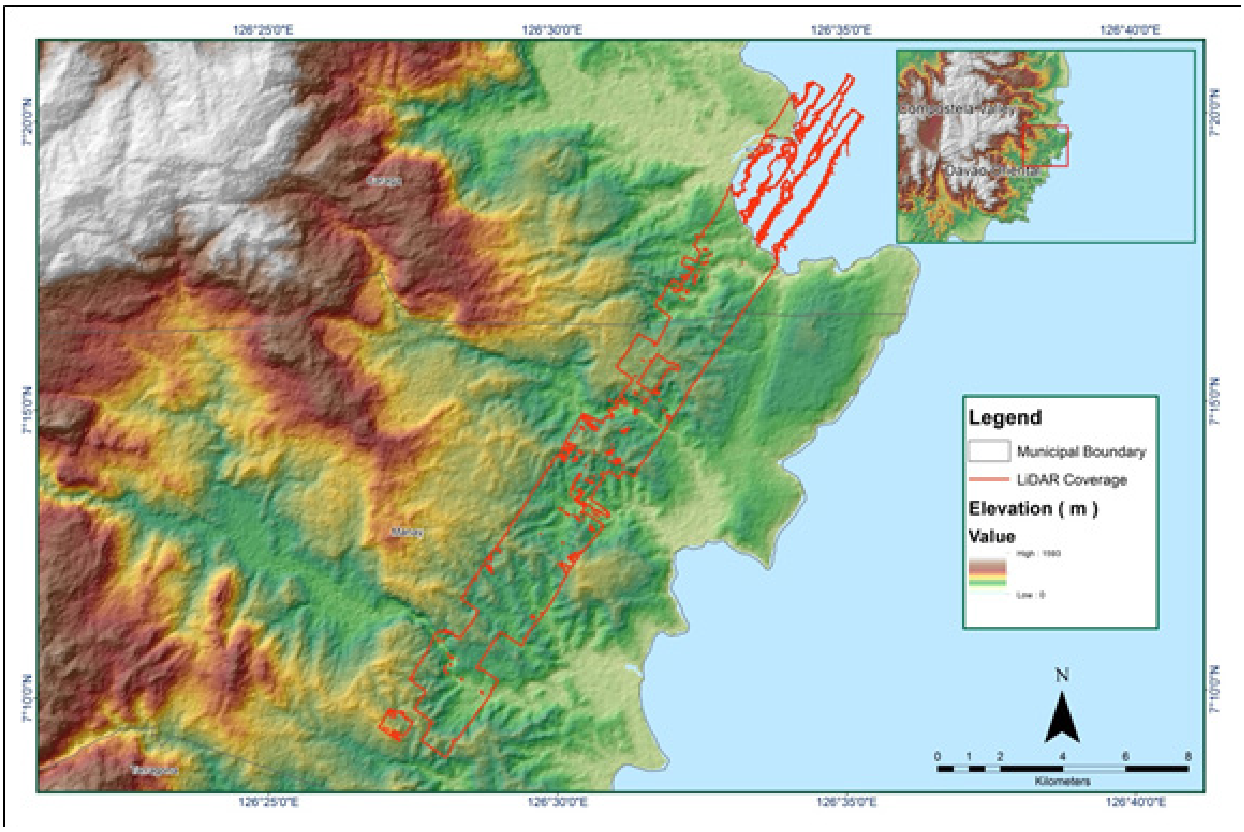
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

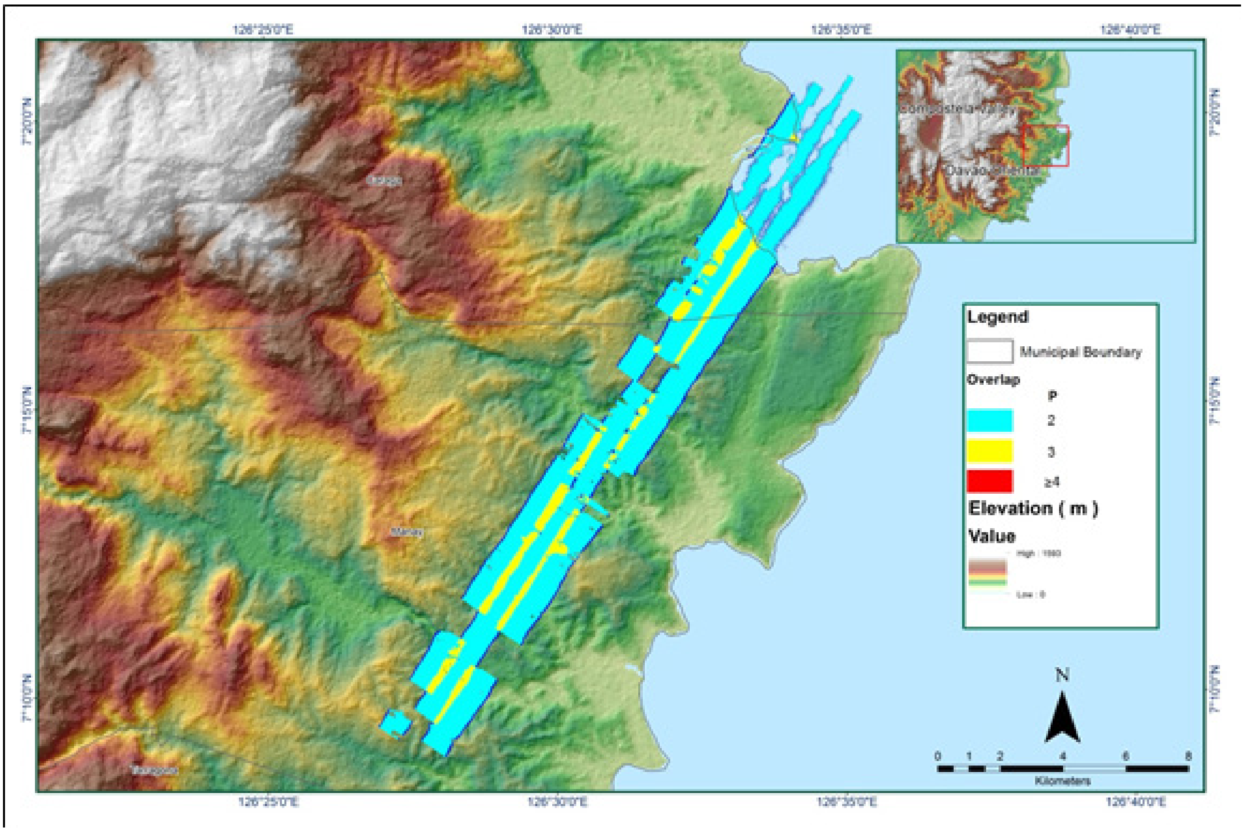
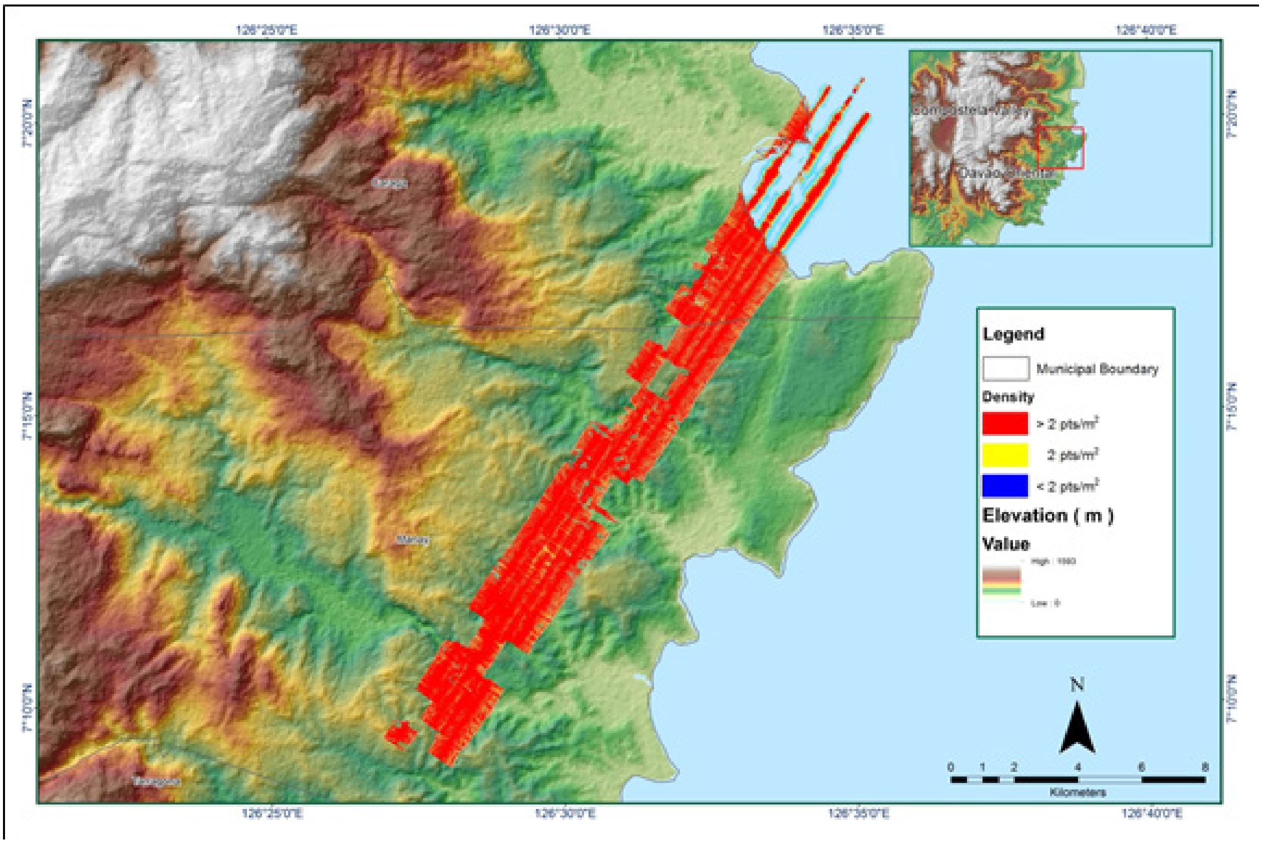
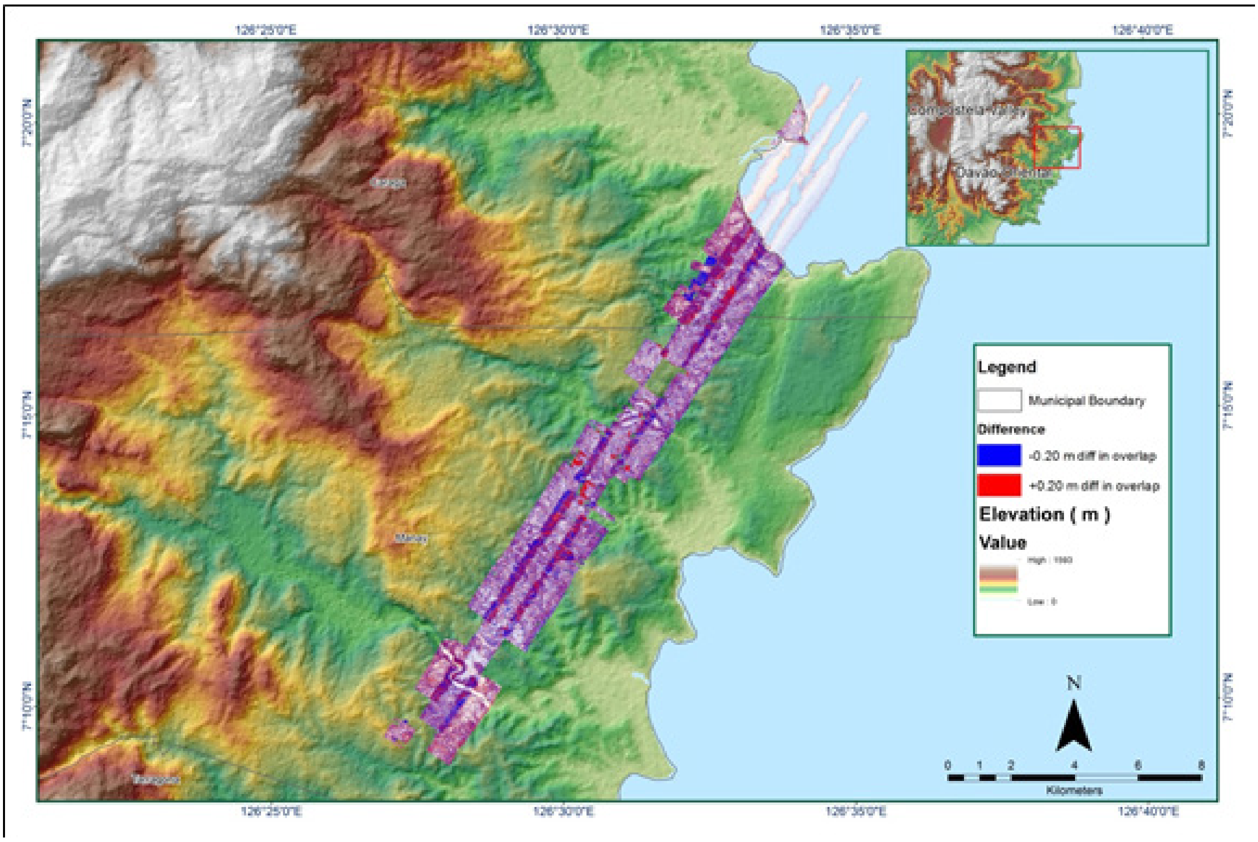


Image of Data Overlap

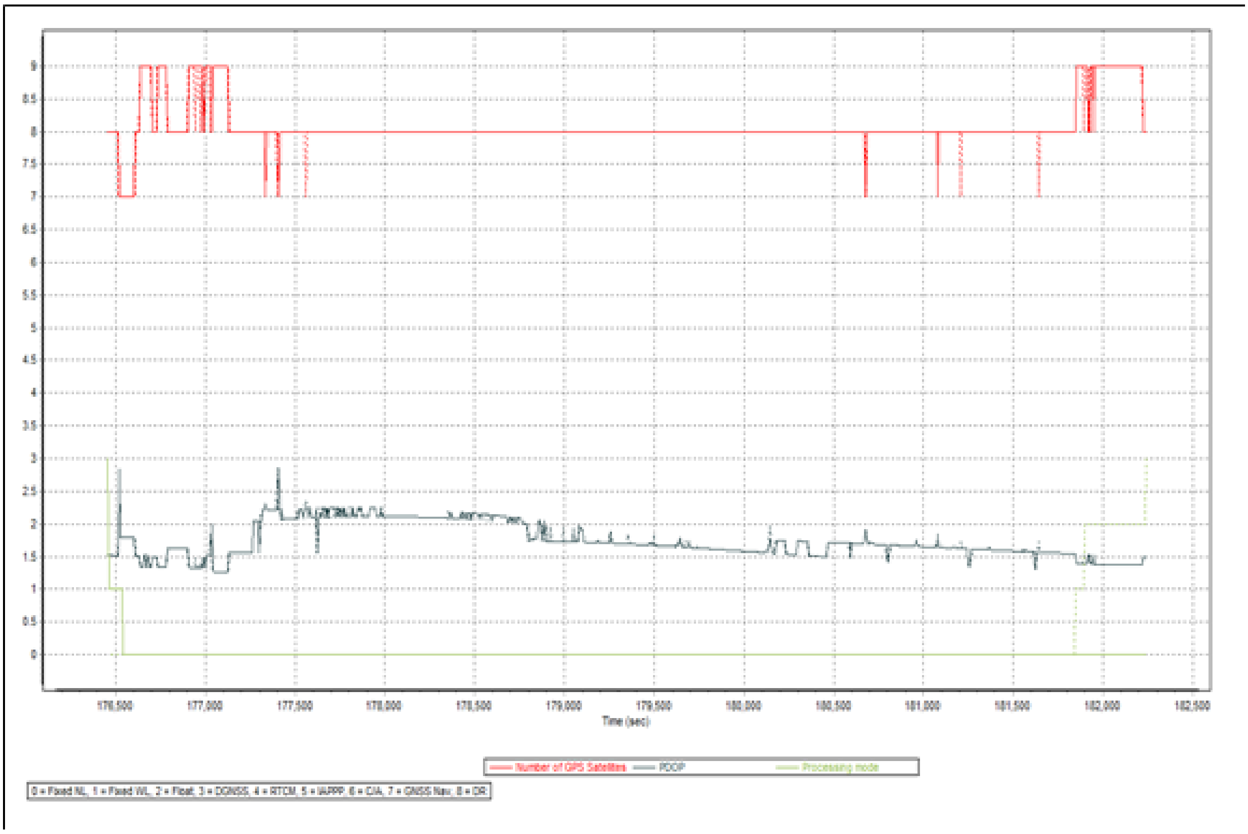


Density map of merged LiDAR data



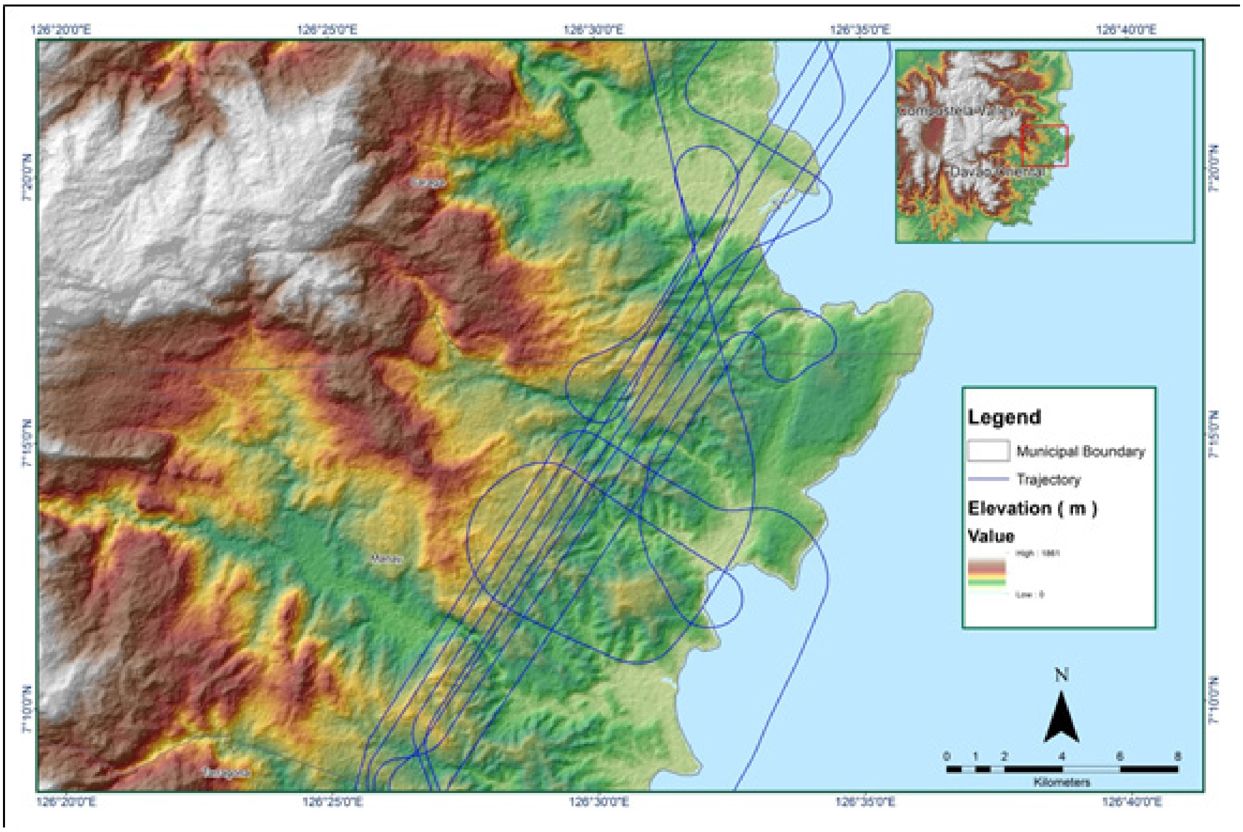
Elevation difference between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	Blk80B
Inclusive Flights	23632P
Range data size	12.6 GB
Base data size	327 MB
POS	253 MB
Image	NA
Transfer date	December 13, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	Yes
RMSE for East Position (<4.0 cm)	Yes
RMSE for Down Position (<8.0 cm)	Yes
Boresight correction stdev (<0.001deg)	0.000160
IMU attitude correction stdev (<0.001deg)	0.000269
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	20.27
Ave point cloud density per sq.m. (>2.0)	4.62
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	134
Maximum Height	500.48 m
Minimum Height	62.61 m
Classification (# of points)	
Ground	123,224,544
Low vegetation	62,182,856
Medium vegetation	142,397,710
High vegetation	399,919,738
Building	5,597,972
Ortophoto	No
Processed by	

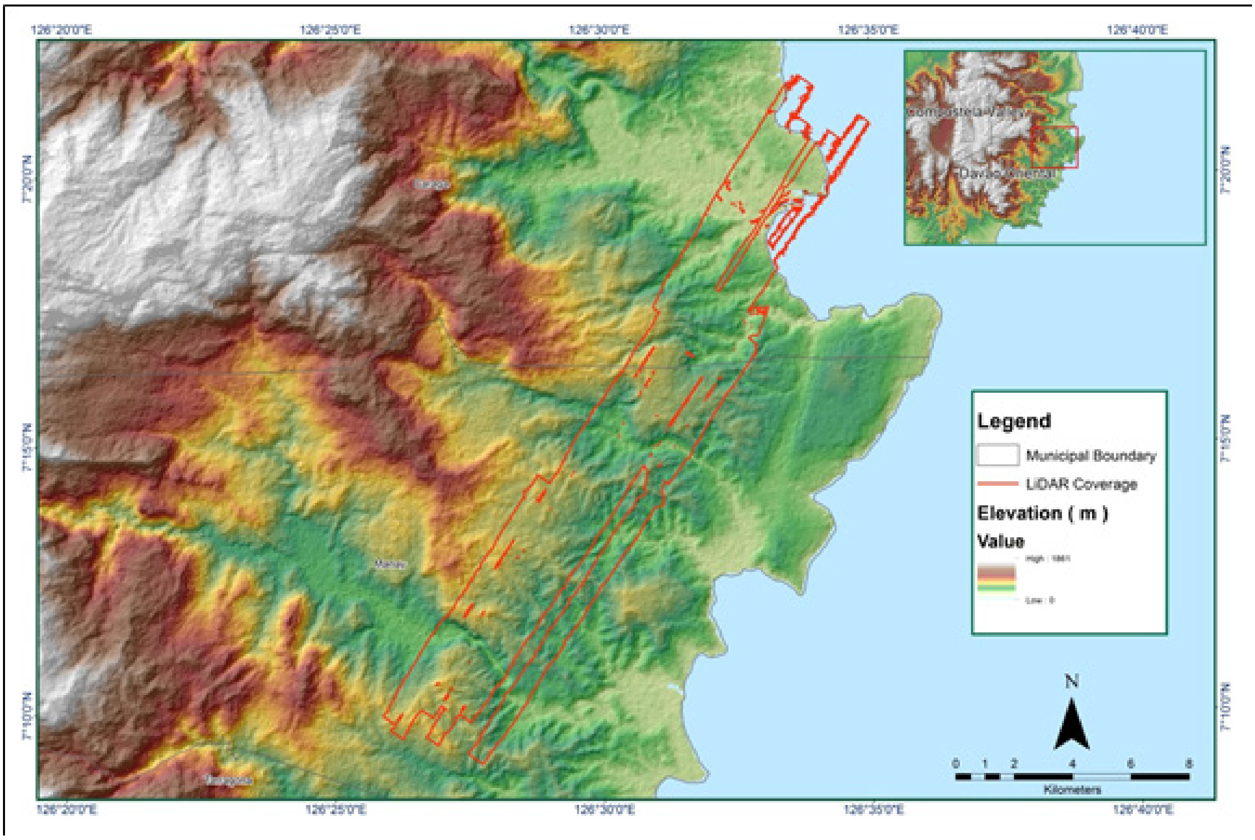


Solution Status

Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

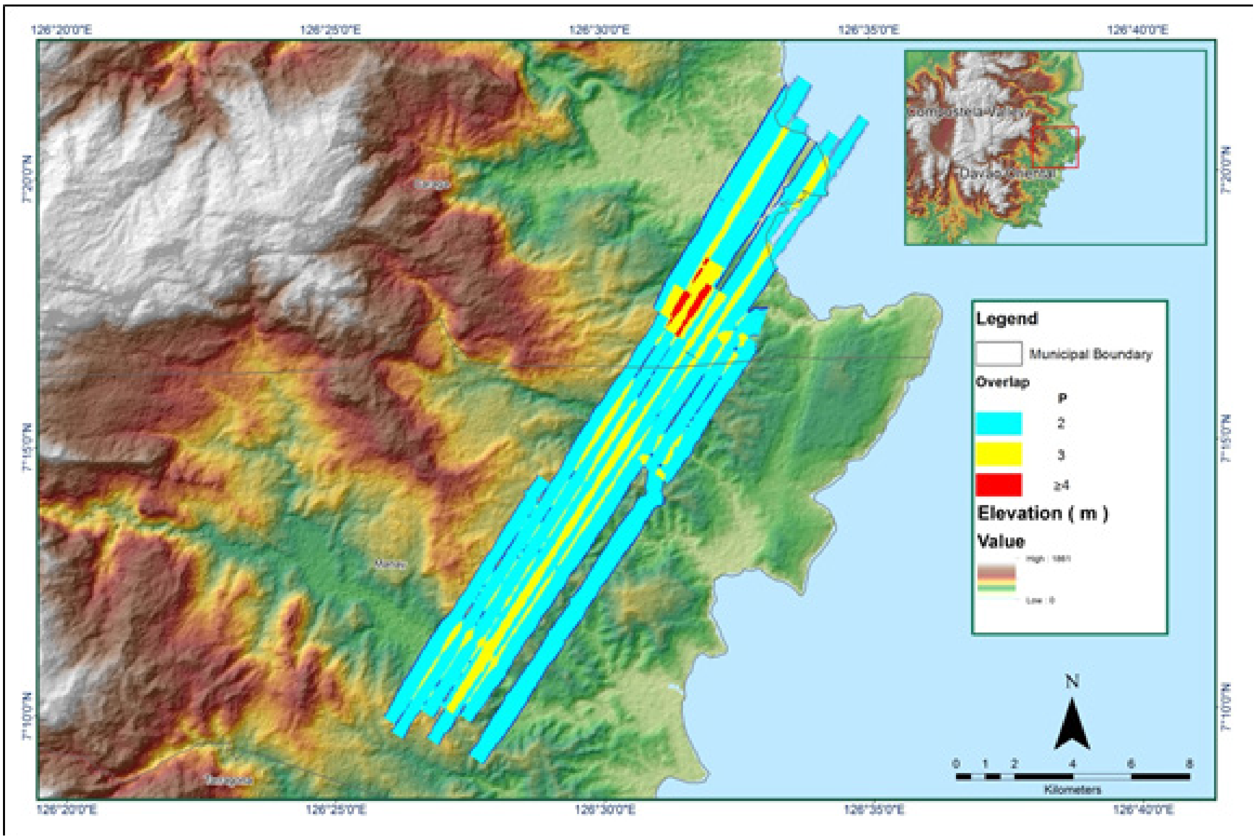
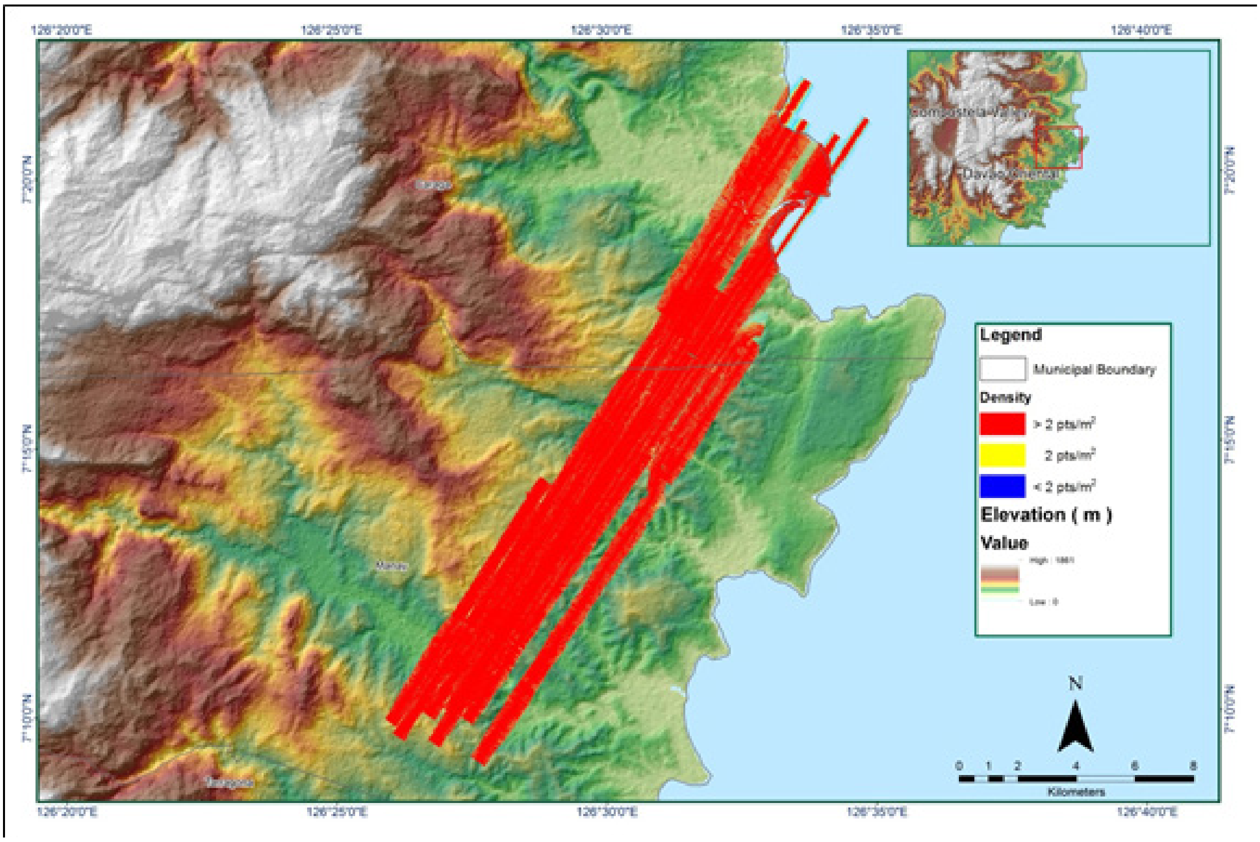
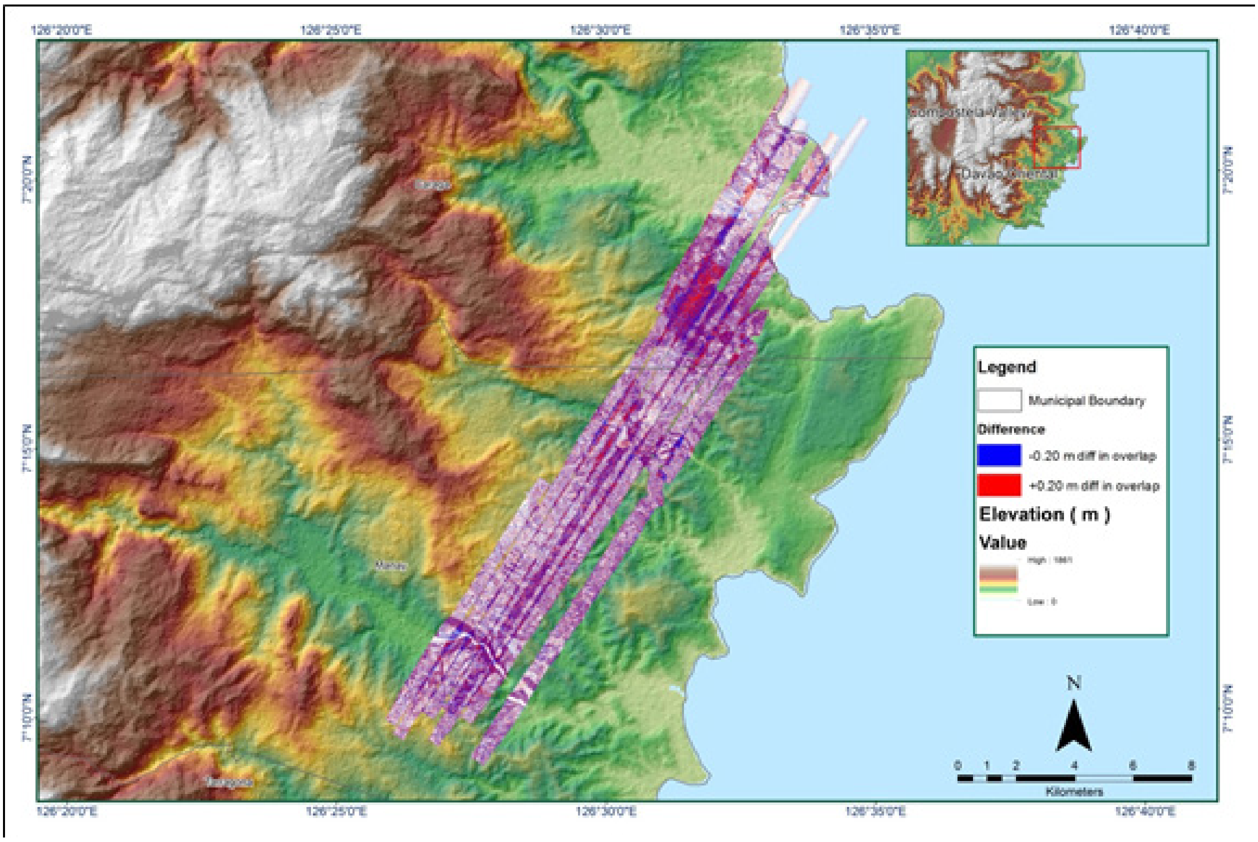


Image of Data Overlap



Density map of merged LiDAR data



Elevation difference between flight lines

Annex 9. Caraga Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1000	56.265	98.26	0	0.1203	0.020426	Discharge	0.31106	0.51794	Ratio to Peak	1
W1010	154.07	99	0	0.11408	0.04261	Discharge	0.06779	0.074906	Ratio to Peak	1
W1020	180.73	99	0	0.13288	0.057922	Discharge	0.15437	0.38379	Ratio to Peak	1
W1030	183.48	99	0	0.26237	0.44385	Discharge	0.46845	1	Ratio to Peak	1
W1040	119.79	99	0	0.13206	0.08048	Discharge	0.006995	0.013	Ratio to Peak	1
W1050	243.63	99	0	0.11919	0.29773	Discharge	0.63226	1	Ratio to Peak	1
W1060	371.63	99	0	38.895	0.1419	Discharge	0.33522	0.8334	Ratio to Peak	1
W1070	179.38	99	0	9.6168	0.29748	Discharge	0.3007	0.7476	Ratio to Peak	1
W1080	151.71	99	0	0.1015	0.06736	Discharge	0.004644	0.013	Ratio to Peak	1
W1090	172.26	99	0	0.1343	0.08842	Discharge	0.25514	0.63432	Ratio to Peak	1
W1100	236.25	99	0	0.21307	0.1137	Discharge	0.6286	1	Ratio to Peak	1
W1110	208.22	99	0	11.562	0.13943	Discharge	0.38963	0.96868	Ratio to Peak	1
W1120	334.76	99	0	0.13069	0.022931	Discharge	0.032268	0.053749	Ratio to Peak	1
W1130	216.82	99	0	15.61	0.95118	Discharge	0.3917	0.97384	Ratio to Peak	1
W1140	332	99	0	0.44604	0.036696	Discharge	0.35708	0.88776	Ratio to Peak	1
W1150	199.11	99	0	0.090848	0.035877	Discharge	0.000988	0.019597	Ratio to Peak	1
W1160	456.99	99	0	1.0426	0.094461	Discharge	0.65824	1	Ratio to Peak	1
W1170	315.44	99	0	15.566	0.1462	Discharge	0.30016	0.74624	Ratio to Peak	1
W1180	437.4	99	0	2.683	0.21176	Discharge	0.58571	1	Ratio to Peak	1
W600	207.72	99	0	13.959	0.075104	Discharge	1.3416	1	Ratio to Peak	1
W610	366.12	99	0	8.4264	0.061806	Discharge	0.8534	1	Ratio to Peak	1
W620	417.8	99	0	2.491	0.14621	Discharge	1.1411	0.8571	Ratio to Peak	1
W630	312.89	99	0	20.897	0.048772	Discharge	0.66931	1	Ratio to Peak	1

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W640	130.26	99	0	21.127	0.16584	Discharge	0.49291	0.81846	Ratio to Peak	1
W650	184.28	99	0	0.2635	0.13226	Discharge	0.28374	0.46088	Ratio to Peak	1
W660	158.34	99	0	0.129	0.062871	Discharge	0.12449	0.13755	Ratio to Peak	1
W670	230.91	99	0	25.727	0.18876	Discharge	0.70322	0.85648	Ratio to Peak	1
W680	201.25	99	0	0.6054	0.088547	Discharge	0.012613	0.013937	Ratio to Peak	1
W690	131.44	99	0	41.874	0.38679	Discharge	1.5676	0.85691	Ratio to Peak	1
W700	402.38	99	0	0.44434	0.042682	Discharge	0.1383	0.23032	Ratio to Peak	1
W710	388.09	99	0	0.11306	0.075458	Discharge	0.10981	0.12134	Ratio to Peak	1
W720	240.64	99	0	16.67	0.096223	Discharge	0.10383	0.25815	Ratio to Peak	1
W730	440.96	99	0	3.7678	0.044423	Discharge	0.27847	0.45231	Ratio to Peak	1
W740	222.49	99	0	0.2225	0.12583	Discharge	0.029286	0.03236	Ratio to Peak	1
W750	343.19	99	0	16.322	0.020326	Discharge	0.27745	0.45066	Ratio to Peak	1
W760	140.42	99	0	0.91536	0.09375	Discharge	0.067543	0.074633	Ratio to Peak	1
W770	186.85	99	0	0.13233	0.044662	Discharge	0.18699	0.30373	Ratio to Peak	1
W780	409.96	99	0	4.8641	0.030087	Discharge	0.26704	0.43376	Ratio to Peak	1
W790	331.65	99	0	0.9288	0.044132	Discharge	0.38235	0.9506	Ratio to Peak	1
W800	147.23	99	0	0.1084	0.029009	Discharge	0.00425	0.013	Ratio to Peak	1
W810	345.41	99	0	0.55584	0.021597	Discharge	0.11234	0.18708	Ratio to Peak	1
W820	157.58	99	0	16.584	0.31838	Discharge	0.70996	1	Ratio to Peak	1
W830	301.01	99	0	11.755	0.059685	Discharge	0.65762	0.83606	Ratio to Peak	1
W840	312.28	99	0	13.145	0.060736	Discharge	0.65634	0.56875	Ratio to Peak	1
W850	246.24	99	0	13.359	0.30411	Discharge	0.50226	0.83268	Ratio to Peak	1
W860	245.46	99	0	0.53007	0.85834	Discharge	1.5936	0.89719	Ratio to Peak	1
W870	330.12	99	0	16.376	0.056455	Discharge	0.3366	0.54674	Ratio to Peak	1
W880	332.98	99	0	2.757	0.043114	Discharge	0.19149	0.31104	Ratio to Peak	1

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W890	248.12	99	0	15.704	0.030968	Discharge	0.85952	0.83606	Ratio to Peak	1
W900	310.11	99	0	16.378	0.077265	Discharge	0.48379	0.53457	Ratio to Peak	1
W910	182.29	99	0	2.0226	0.35863	Discharge	0.76881	0.85379	Ratio to Peak	1
W920	252.49	99	0	7.9597	0.058528	Discharge	0.78747	1	Ratio to Peak	1
W930	351.64	99	0	5.6864	0.025163	Discharge	0.30941	0.50257	Ratio to Peak	1
W940	484.25	99	0	0.78833	0.15641	Discharge	0.26238	0.42617	Ratio to Peak	1
W950	306.72	99	0	12.059	0.031226	Discharge	0.38069	0.61836	Ratio to Peak	1
W960	245.32	99	0	0.61257	0.61941	Discharge	0.26916	0.43719	Ratio to Peak	1
W970	253.72	99	0	0.12521	0.11425	Discharge	0.19919	0.32353	Ratio to Peak	1
W980	162.22	99	0	0.8464	0.17559	Discharge	0.6277	0.83606	Ratio to Peak	1
W990	26.399	99	0	0.2029	0.033035	Discharge	0.2754	0.44733	Ratio to Peak	1

Annex 10. Caraga Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	700.78	0.001	0.0874	Trapezoid	60	1
R110	Automatic Fixed Interval	5555.3	0.001905	0.12848	Trapezoid	80	1
R120	Automatic Fixed Interval	910.05	0.015986	0.12848	Trapezoid	80	1
R130	Automatic Fixed Interval	2039.3	0.001	0.0874	Trapezoid	80	1
R170	Automatic Fixed Interval	244.83	0.24741	0.13163	Trapezoid	80	1
R200	Automatic Fixed Interval	8524.4	0.007459	0.19665	Trapezoid	80	1
R210	Automatic Fixed Interval	1722.1	0.042061	0.13114	Trapezoid	80	1
R220	Automatic Fixed Interval	5049.6	0.046276	0.19665	Trapezoid	60	1
R230	Automatic Fixed Interval	5408.6	0.011215	0.0874	Trapezoid	60	1
R250	Automatic Fixed Interval	3380.2	0.036133	0.1313	Trapezoid	60	1
R270	Automatic Fixed Interval	2843.4	0.042993	0.12848	Trapezoid	60	1
R290	Automatic Fixed Interval	4076.9	0.014408	0.19665	Trapezoid	60	1
R30	Automatic Fixed Interval	951.05	0.078634	0.0874	Trapezoid	60	1
R330	Automatic Fixed Interval	1756	0.10355	0.0874	Trapezoid	60	1
R340	Automatic Fixed Interval	13791	0.088766	0.0874	Trapezoid	60	1
R360	Automatic Fixed Interval	1330.4	0.008227	0.13099	Trapezoid	50	1
R370	Automatic Fixed Interval	4872.4	0.082412	0.19665	Trapezoid	15	1
R390	Automatic Fixed Interval	1703.5	0.017194	0.1311	Trapezoid	80	1
R400	Automatic Fixed Interval	343.82	0.036511	0.13167	Trapezoid	20	1
R410	Automatic Fixed Interval	1766.7	0.007075	0.13116	Trapezoid	20	1
R450	Automatic Fixed Interval	300.9	0.003734	0.0874	Trapezoid	160	1
R460	Automatic Fixed Interval	2376.2	0.001	0.12848	Trapezoid	150	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R490	Automatic Fixed Interval	2304.6	0.020704	0.13141	Trapezoid	50	1
R50	Automatic Fixed Interval	2041	0.047786	0.0874	Trapezoid	110	1
R520	Automatic Fixed Interval	1248	0.004003	0.13175	Trapezoid	80	1
R550	Automatic Fixed Interval	3112.8	0.023025	0.15076	Trapezoid	50	1
R560	Automatic Fixed Interval	127.27	0.029185	0.13166	Trapezoid	50	1
R60	Automatic Fixed Interval	4146.4	0.021037	0.1317	Trapezoid	50	1
R80	Automatic Fixed Interval	339.38	0.001	0.1311	Trapezoid	20	1

ANNEX 11. Tanao Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	7.341613	126.5125	0.103	0.25	0.021609		5-Year
2	7.34061	126.51	0.031	0.25	0.047961	Agaton/ January 2014	5-Year
3	7.342083	126.5094	0.989	0.3	0.474721	Agaton/ January 2014	5-Year
4	7.340667	126.5023	0.641	0	0.410881	Agaton/ January 2014	5-Year
5	7.341367	126.5027	1.125	0.2	0.855625	Agaton/ January 2014	5-Year
6	7.344047	126.4998	1.009	0.5	0.259081	Crising/ February 2013	5-Year
7	7.343375	126.4987	0.089	0	0.007921	Agaton/ January 2014	5-Year
8	7.345261	126.4974	0.251	0.3	0.002401	Agaton/ January 2014	5-Year
9	7.344731	126.4971	0.054	0.3	0.060516	Agaton/ January 2014	5-Year
10	7.34823	126.498	0.034	0.3	0.070756	Agaton/ January 2014	5-Year
11	7.348961	126.4985	0.031	0	0.000961	Agaton/ January 2014	5-Year
12	7.349522	126.4985	0.03	0	0.0009	Agaton/ January 2014	5-Year
13	7.349802	126.4986	0.03	0	0.0009	Agaton/ January 2014	5-Year
14	7.349837	126.4988	0.032	0	0.001024	Agaton/ January 2014	5-Year
15	7.349425	126.4987	2.122	2	0.014884	Agaton/ January 2014	5-Year
16	7.352213	126.4981	1.823	2	0.031329	Agaton/ January 2014	5-Year
17	7.354756	126.4991	1.866	1.5	0.133956	Agaton/ January 2014	5-Year
18	7.354794	126.4996	2.023	2	0.000529	Agaton/ January 2014	5-Year
19	7.355169	126.499	1.52	2	0.2304	Agaton/ January 2014	5-Year
20	7.338056	126.5025	0.643	1	0.127449	Agaton/ January 2014	5-Year
21	7.342394	126.5074	0.805	1.5	0.483025	Agaton/ January 2014	5-Year
22	7.341394	126.5077	0.72	1.5	0.6084	Agaton/ January 2014	5-Year
23	7.341175	126.5182	0.982	1.5	0.268324	Agaton/ January 2014	5-Year
24	7.344006	126.5238	0.594	0.5	0.008836		5-Year
25	7.34414	126.5235	0.603	0.5	0.010609		5-Year
26	7.34506	126.525	0.743	0	0.552049	Agaton/ January 2014	5-Year
27	7.345651	126.5257	1.161	0.5	0.436921		5-Year
28	7.345651	126.5289	1.328	0.5	0.685584	Agaton/ January 2014	5-Year
29	7.334999	126.5326	0.973	0	0.946729	Agaton/ January 2014	5-Year
30	7.336072	126.5322	0.867	0	0.751689	Agaton/ January 2014	5-Year
31	7.337605	126.5343	0.728	0	0.529984		5-Year
32	7.338121	126.5354	0.597	0	0.356409	Agaton	5-Year
33	7.335643	126.5328	0.779	0	0.606841		5-Year
34	7.314791	126.5295	0.749	0.5	0.062001		5-Year
35	7.314408	126.5278	0.849	0	0.720801		5-Year
36	7.314531	126.5273	1.626	1.5	0.015876		5-Year
37	7.314093	126.5247	0.04	0	0.0016		5-Year
38	7.313785	126.5243	0.03	0	0.0009		5-Year
39	7.312283	126.5197	0.368	0.5	0.017424		5-Year
40	7.310916	126.5185	0.056	0	0.003136		5-Year
41	7.31123	126.5181	3.242	3	0.058564		5-Year
42	7.309921	126.5181	1.997	2	9E-06		5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
43	7.309767	126.5179	1.556	1.5	0.003136		5-Year
44	7.309522	126.5178	1.674	1.5	0.030276		5-Year
45	7.309134	126.5176	1.191	0.5	0.477481		5-Year
46	7.309254	126.5175	2.218	2.3	0.006724	Agaton/ January 2014	5-Year
47	7.30881	126.5175	2.234	2	0.054756	Agaton/ January 2014	5-Year
48	7.308725	126.5173	1.96	1.5	0.2116	Agaton/ January 2014	5-Year
49	7.308535	126.5172	1.002	0.8	0.040804	Agaton/ January 2014	5-Year
50	7.309075	126.5166	1.312	0.8	0.262144		5-Year
51	7.308212	126.5172	1.308	1	0.094864	Agaton/ January 2014	5-Year
52	7.307992	126.517	1.46	1	0.2116	Agaton/ January 2014	5-Year
53	7.308072	126.5169	1.378	1	0.142884	Agaton/ January 2014	5-Year
54	7.308057	126.5167	1.289	1	0.083521		5-Year
55	7.307469	126.5169	1.599	1.8	0.040401		5-Year
56	7.306968	126.5169	1.48	1	0.2304	Agaton/ January 2014	5-Year
57	7.3072	126.5169	1.623	1	0.388129	Agaton/ January 2014	5-Year
58	7.307333	126.5169	1.513	1	0.263169	Agaton/ January 2014	5-Year
59	7.306016	126.5173	1.934	1.5	0.188356	Agaton/ January 2014	5-Year
60	7.329866	126.5559	1.286	1.2	0.007396	Agaton	5-Year
61	7.329482	126.5553	1.98	2	0.0004	Agaton	5-Year
62	7.32938	126.5553	0.824	0.3	0.274576	Agaton	5-Year
63	7.329229	126.5552	0.312	0	0.097344	Agaton	5-Year
64	7.329039	126.5554	0.515	0.5	0.000225	Agaton/ January 2014	5-Year
65	7.328824	126.5554	0.03	0.5	0.2209	Agaton/ January 2014	5-Year
66	7.328846	126.5552	0.378	0	0.142884	Agaton/ January 2014	5-Year
67	7.328997	126.5552	0.241	0.3	0.003481	Agaton/ January 2014	5-Year
68	7.328657	126.5548	1.65	0.9	0.5625	Agaton/ January 2014	5-Year
69	7.328398	126.5549	1.345	0.4	0.893025	Agaton/ January 2014	5-Year
70	7.328627	126.5545	0.396	0	0.156816	Agaton/ January 2014	5-Year
71	7.328083	126.5545	1.009	0.2	0.654481	Agaton/ January 2014	5-Year
72	7.327923	126.5544	1.435	0.5	0.874225	Agaton/ January 2014	5-Year
73	7.327207	126.5542	0.03	0	0.0009	Agaton/ January 2014	5-Year
74	7.326825	126.5535	0.031	0	0.000961	Agaton/ January 2014	5-Year
75	7.326158	126.553	0.032	0	0.001024	Agaton/ January 2014	5-Year
76	7.326516	126.556	0.03	0	0.0009	Agaton/ January 2014	5-Year
77	7.326197	126.5557	0.03	0	0.0009	Agaton/ January 2014	5-Year
78	7.326044	126.5553	0.03	0	0.0009	Agaton/ January 2014	5-Year
79	7.32566	126.5549	0.138	0	0.019044	Agaton/ January 2014	5-Year
80	7.325658	126.5546	0.267	0	0.071289	Agaton/ January 2014	5-Year
81	7.325437	126.5547	0.031	0	0.000961	Agaton/ January 2014	5-Year
82	7.325344	126.5541	0.03	0	0.0009	Agaton/ January 2014	5-Year
83	7.325304	126.5538	0.031	0	0.000961	Agaton/ January 2014	5-Year
84	7.325184	126.5532	0.06	0	0.0036	Agaton/ January 2014	5-Year
85	7.324376	126.5533	0.256	0.3	0.001936	Agaton/ January 2014	5-Year
86	7.324269	126.5532	0.03	0.3	0.0729	Agaton/ January 2014	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
87	7.324178	126.5529	0.041	0.3	0.067081	Agaton/ January 2014	5-Year
88	7.323937	126.5529	0.03	0.3	0.0729	Agaton/ January 2014	5-Year
89	7.324032	126.5526	0.031	0	0.000961	Agaton/ January 2014	5-Year
90	7.323966	126.5519	0.066	0.3	0.054756	Agaton/ January 2014	5-Year
91	7.323308	126.5526	0.031	0.5	0.219961	Agaton/ January 2014	5-Year
92	7.323542	126.5521	0.146	0.5	0.125316	Agaton/ January 2014	5-Year
93	7.32321	126.5523	0.171	0	0.029241	Agaton/ January 2014	5-Year
94	7.323143	126.5518	0.031	0	0.000961	Agaton/ January 2014	5-Year
95	7.323459	126.5514	0.233	0.7	0.218089	Agaton/ January 2014	5-Year
96	7.322902	126.5517	0.482	0.7	0.047524	Agaton/ January 2014	5-Year
97	7.31977	126.5519	0.105	0.7	0.354025		5-Year
98	7.3196	126.5521	0.03	0.7	0.4489		5-Year
99	7.318252	126.5499	1.726	1	0.527076		5-Year
100	7.318728	126.5501	1.024	0.5	0.274576		5-Year
101	7.316041	126.5484	0.981	0.5	0.231361		5-Year
102	7.316235	126.5482	1.031	0.5	0.281961		5-Year
103	7.316648	126.5478	1.634	1	0.401956		5-Year
104	7.316893	126.5472	1.53	1.25	0.0784		5-Year
105	7.316549	126.5477	1.487	0.8	0.471969		5-Year
106	7.316821	126.5467	1.679	0.8	0.772641		5-Year
107	7.316846	126.5464	0.929	0.6	0.108241		5-Year
108	7.317083	126.5463	1.312	0.6	0.506944		5-Year
109	7.316876	126.5454	1.573	0.6	0.946729		5-Year
110	7.317228	126.5444	0.937	0.6	0.113569		5-Year
111	7.317899	126.5456	0.912	0.6	0.097344		5-Year
112	7.317265	126.5424	1.783	1.6	0.033489		5-Year
113	7.317298	126.5415	1.227	1.65	0.178929		5-Year
114	7.319637	126.5525	1.408	1	0.166464		5-Year
115	7.319838	126.5529	1.142	0.9	0.058564		5-Year
116	7.31971	126.5527	0.934	0.9	0.001156		5-Year
117	7.319637	126.5526	1.008	0.9	0.011664		5-Year
118	7.319464	126.5523	1.465	0.9	0.319225		5-Year
119	7.327864	126.5543	1.451	0.9	0.303601	Agaton/ January 2014	5-Year
120	7.328334	126.565	1.475	0.9	0.330625		5-Year
121	7.328085	126.5648	1.831	1.15	0.463761		5-Year
122	7.327903	126.5652	1.625	1.2	0.180625		5-Year
123	7.328339	126.5647	2.112	2	0.012544		5-Year
124	7.328675	126.5646	1.455	1.5	0.002025		5-Year
125	7.328314	126.5642	1.513	1.5	0.000169		5-Year
126	7.328175	126.5643	1.792	2	0.043264		5-Year
127	7.327819	126.5647	1.935	2	0.004225		5-Year
128	7.327729	126.5647	2.08	2	0.0064		5-Year
129	7.327689	126.5645	1.635	1.5	0.018225		5-Year
130	7.327891	126.5658	1.305	1.5	0.038025		5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return
	Lat	Long					
131	7.327837	126.5641	1.828	1.5	0.107584		5-Year
132	7.328006	126.5639	1.779	1.5	0.077841		5-Year
133	7.328273	126.5634	2.071	2	0.005041	Agaton/ January 2014	5-Year
134	7.328305	126.5632	1.779	1.5	0.077841	Agaton/ January 2014	5-Year
135	7.328387	126.5628	2.132	2	0.017424	Agaton/ January 2014	5-Year
136	7.328426	126.5627	0.071	0	0.005041	Agaton/ January 2014	5-Year
137	7.328214	126.5627	0.03	0	0.0009	Agaton/ January 2014	5-Year
138	7.328467	126.5639	0.03	0	0.0009		5-Year
139	7.330164	126.5628	0.03	0	0.0009		5-Year
140	7.328486	126.5621	0.03	0	0.0009	Agaton/ January 2014	5-Year
141	7.328281	126.5619	0.03	0	0.0009	Agaton/ January 2014	5-Year
142	7.179357	126.5193	0.044	0	0.001936		5-Year
143	7.17381	126.5244	0.03	0	0.0009		5-Year
144	7.178802	126.5211	0.327	0	0.106929		5-Year
145	7.175646	126.5206	0.222	0	0.049284		5-Year
146	7.176344	126.5237	0.156	0	0.024336		5-Year
147	7.181162	126.5195	0.03	0	0.0009		5-Year
148	7.17336	126.5242	0.03	0	0.0009		5-Year
149	7.177733	126.5192	0.253	0	0.064009		5-Year
150	7.177831	126.5182	0.06	0	0.0036		5-Year
151	7.176073	126.5237	0.068	0	0.004624		5-Year
152	7.176547	126.5207	0.032	0	0.001024		5-Year
153	7.176458	126.5206	0.067	0	0.004489		5-Year
154	7.180614	126.5202	0.03	0	0.0009		5-Year
155	7.180251	126.5206	0.05	0	0.0025		5-Year
156	7.176366	126.5208	0.091	0	0.008281		5-Year
157	7.178525	126.5219	0.03	0	0.0009		5-Year
158	7.175826	126.5206	0.696	0.6	0.009216		5-Year
159	7.176097	126.5206	0.176	0	0.030976	Yolanda/ November 2013	5-Year
160	7.175283	126.5208	0.249	0	0.062001		5-Year
161	7.175918	126.5204	0.03	0	0.0009		5-Year
162	7.176933	126.5176	0.069	0	0.004761		5-Year
163	7.17546	126.5213	0.03	0	0.0009		5-Year
164	7.175285	126.5205	0.039	0	0.001521		5-Year
165	7.175453	126.5222	0.128	0	0.016384		5-Year
166	7.177113	126.5176	0.03	0	0.0009		5-Year
167	7.17519	126.5212	0.03	0	0.0009		5-Year
168	7.176376	126.5196	0.031	0	0.000961		5-Year
169	7.175551	126.5211	0.031	0	0.000961		5-Year
170	7.176839	126.518	0.035	0	0.001225		5-Year
171	7.177193	126.5189	0.032	0	0.001024		5-Year
172	7.176744	126.5187	0.861	1	0.019321		5-Year
173	7.177376	126.5187	0.959	1	0.001681		5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
174	7.177379	126.5183	1.228	1.5	0.073984		5-Year
175	7.175367	126.5216	1.673	1.5	0.029929		5-Year
176	7.175914	126.5209	0.568	0.5	0.004624		5-Year
177	7.17582	126.5215	0.031	0	0.000961		5-Year
178	7.17674	126.5191	0.03	0	0.0009		5-Year
179	7.176646	126.5197	0.977	1	0.000529		5-Year
180	7.175183	126.522	0.684	0.5	0.033856	Upstream rainfall	5-Year

Annex 12. Educational Institutions affected by flooding in Caraga Floodplain

Davao Oriental				
Caraga				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DAY CARE CENTER	Don Leon Balante			
TIGBAWAN ELEMENTARY SCHOOL	Don Leon Balante			
TIGBAWAN ELEMENTARY SCHOOL	Don Leon Balante			
MERCEDES ELEMENTARY SCHOOL	Mercedes	Low	Low	Medium
DAY CARE CENTER	Poblacion	Medium	High	High
MAILUM PRIMARY SCHOOL	Poblacion	Medium	High	High
PAPAG DAY CARE	Poblacion	High	High	High
PAPAG PRIMARY SCHOOL	Poblacion	High	High	High
ST. MARY'S ACADEMY OF CARAGA	Poblacion			
SAN JOSE ELEMENTARY SCHOOL	San Jose		Low	Medium
SAN JOSE ELEMENTARY SCHOOL - PRINCIPAL'S OFFICE	San Jose			Low

Annex 13. Health Institutions affected by flooding in Caraga Floodplain

Davao Oriental				
Caraga				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
HEALTH CENTER	Don Leon Balante			