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

LiDAR Surveys and Flood Mapping of Lipadas River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAM-RIA	National Mapping and Resource Information Authority
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
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 THE LIPADAS RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (UPM). UPM is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 22 river basins in the Southern Mindanao Region. The university is located in Tugbok, Davao City in Davao del Sur.

1.2 Overview of the Lipadas River Basin

Lipadas River is a stream in Davao City in the province of Davao del Sur, on the southeastern side of Mindanao. It cuts across the slopes of Mt. Apo and drains towards Lizada in Toril District and into the Davao Gulf (Mines and Geosciences Bureau, 2014). It is one of three rivers located inside the boundaries of Davao City. It has 57 subbasins, 28 junctions, and 28 reaches.

Davao City can be found north of Digos City, east of Cotabato province, south of Davao del Norte, and east of Davao Gulf. The name "Davao" was derived from three Bagobo subgroups' name for the Davao River: "Davah", meaning "a place beyond the high grounds" by the Obos, "Dawaw" by the Diangan-Clata or K'lata, and "Dabo" by the Tagabawa (Official Website of the City Government of Davao, 2017).

Although these subgroups belong to one socio-linguistic group known as Bagobo, they each have their own dialects, dance, and costume among others. The boundary between Tagabawa and Diangan-Clata was fixed at Lipadas River (Mangune, 2015; Diaz, 2017; GreedyPeg, 2017).

The river also serves as one of the major drainage systems of Mt. Talomo in the eastern part of Mt. Apo along with Talomo and Sibulan Rivers (GreedyPeg, 2016). The coastal aquifer of Lipadas watershed, along with Talomo watershed, provide Davao City's water supply. The river and its tributaries are used for domestic, agricultural, and industrial uses (Gamboa, 2015). At its headwaters in Mt. Apo Natural Park, the surface water is rated fit for drinking. The river is also used for recreational activities, fishery, and sand and gravel extraction (UPMin Phil-LiDAR 1 DVC; IDIS, 2016).

Before the Second World War, the Lipadas River was mainly utilized for irrigation to large Japanese-owned abaca, ramie, and coconut plantations. It was also said to be a favorite sanctuary of local water buffaloes or carabaos where they would wallow in the cold water to escape the scorching sun (IDIS, 2016). Now, it has been replaced by banana plantations and contamination due to pesticides and has been a serious issue especially near the downstream area (IDIS, 2016).

Pollution is the primary problem identified in the Talomo-Lipadas Watersheds (Mallare, 2016). Shortage is also seen as a threat to the watershed mainly due to rapid population and industrial growth (Petalurca, 2016). Other issues include deforestation, land use conflict, and improper cultivation of hilly lands (PCEEM, 2017). Population increase near Lipadas River also increases the demand for water, food, and shelter resulting to depletion of groundwater resources, to increase in volume of wastewater, and increase in risk of agricultural runoff (Sherbinin, 1998; Abayon et.al., 2013).

According to locals, the river is susceptible to flooding. From the year 2000 to 2017, local rainfall, upstream rainfall, and buhawi are the usual causes of flooding near the river. Based from the UP Mindanao Phil-LiDAR 1 reconnaissance survey, all nearby residences along the Lipadas river in the downstream area experienced flooding.

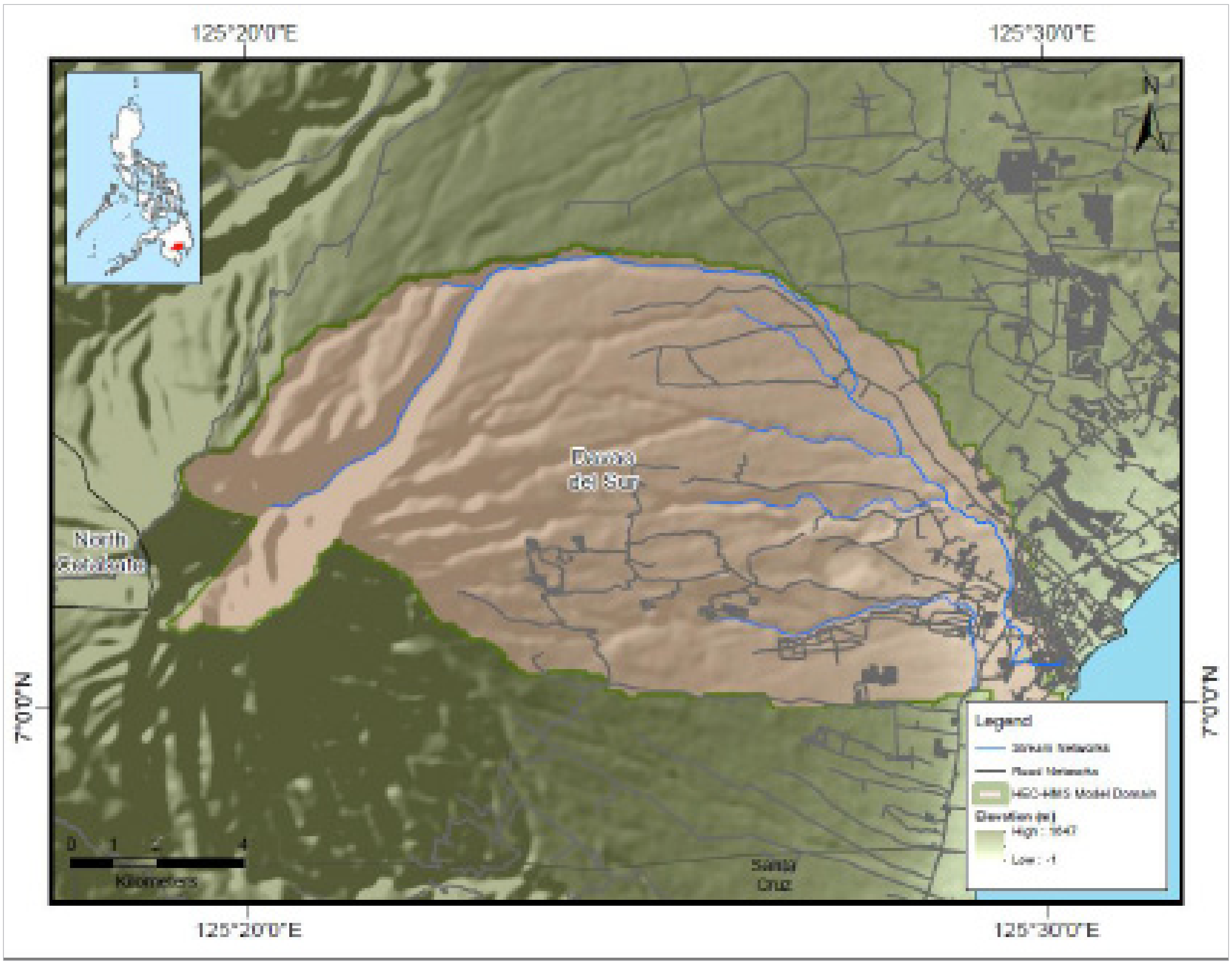

Figure 1. Map of the Lipadas River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LIPADAS 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 Lipadas floodplain in Davao del Sur. These missions were planned for 14 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 2 shows the flight plans and base stations for Lipadas floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK82A	1000	30	40	100	50	130	5
BLK82B	1000	30	40	100	50	130	5
BLK82C	850/800	30	50	125	40	130	5
BLK82D	1000	30	40	100	50	130	5
BLK82E	1000/850	30	40/50	100/125	50/40	130	5
BLK82F	1000	30	40	100	50	130	5
BLK82_voids	1000	35	40	100	40	130	5

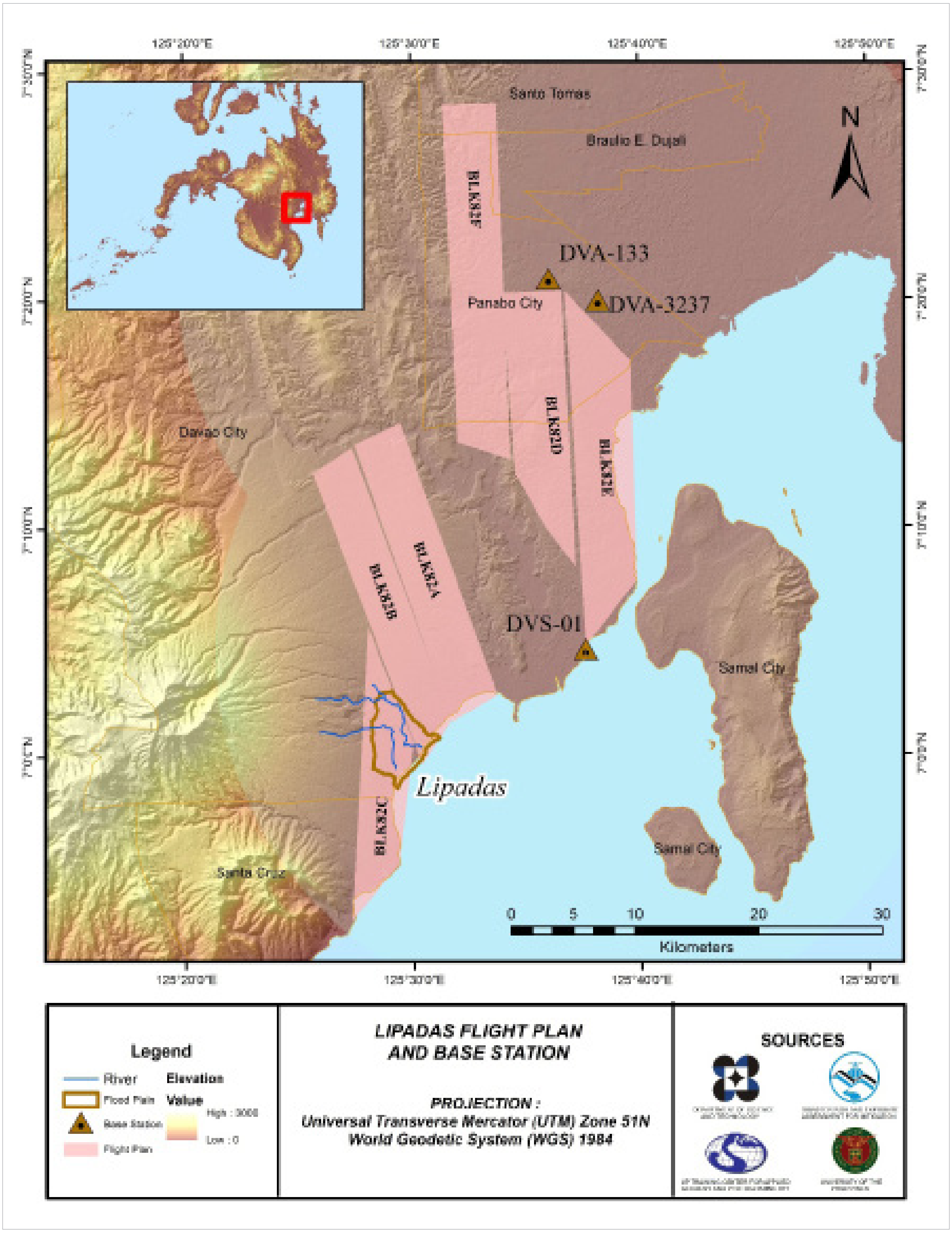
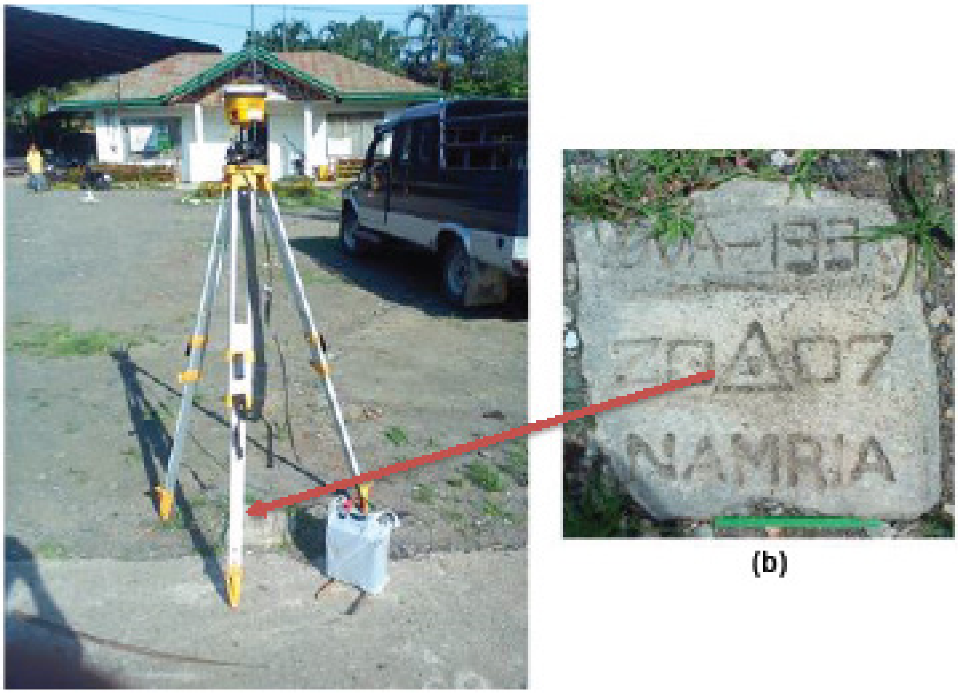


Figure 2. Flight plans and base stations used for Lipadas floodplain.

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA ground control points: DVS-01 and DVA-133 which are of second (2nd) order accuracy, DVA-3237 which are of fourth (4th) order accuracy. The team also established one (1) ground control point: DVS-01A. Established and 4th order ground control points where then re-processed to obtain coordinates of 2nd order accuracy. The certifications for the NAMRIA reference points are found in ANNEX B. Baseline processing reports for the re-processed control points are found in ANNEX C. These were used as base stations during flight operations for the entire duration of the survey (July 18 – August 11, 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 Lipadas floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 show the details about the following NAMRIA control stations and established points, while Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(b)

(a)

Figure 3. GPS set-up over DVA-133 as located in front of the barangay hall of Manay (a) and NAMRIA reference point DVA-133 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point DVA-133 used as base station for the LiDAR acquisition.

Station Name	**DVA-133**	
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°20'57.02014" North 125°35'57.50044" East 23.957 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	566168.597 meters 812626.211 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°20'53.82313" North 125°36'2.99870" East 96.163 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	786976.44 meters 813130.63 meters

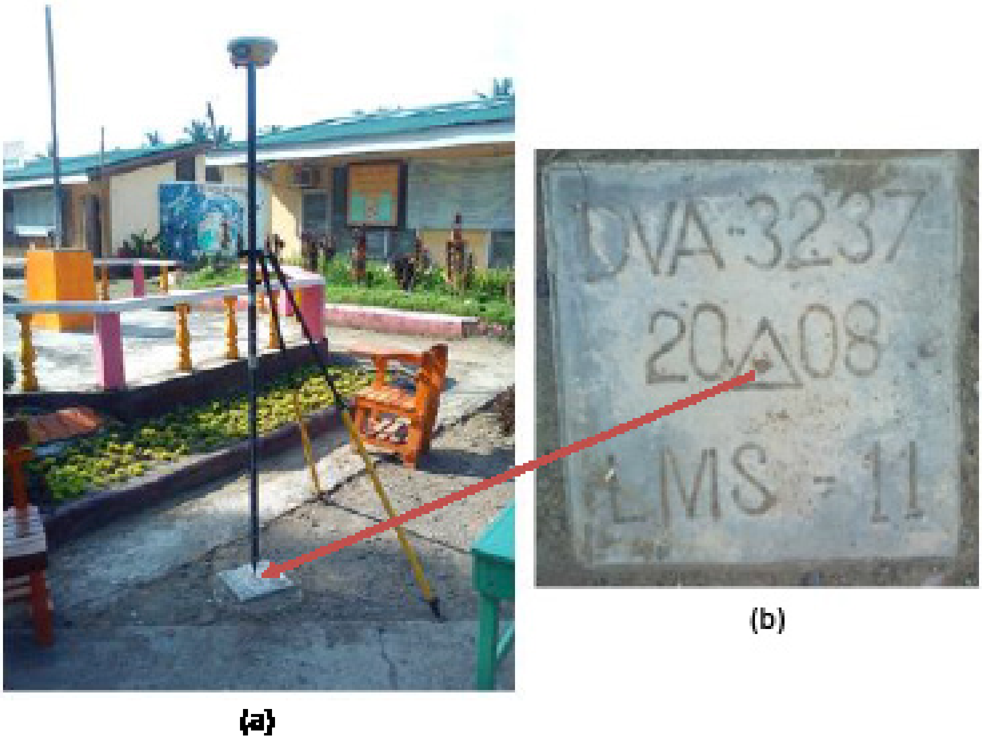


Figure 4. GPS set-up over DVA-3237 located beside the flagpole inside the compound of Nanyo Elementary School (a) and NAMRIA reference point DVA-3237 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point DVA-3237 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	**DVA-3237**	
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°19'59.95215" North 125°38'7.26797" East 17.228 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°19'56.76267" North 125°38'12.76731" East 89.553 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	790969.206 meters 811399.786 meters

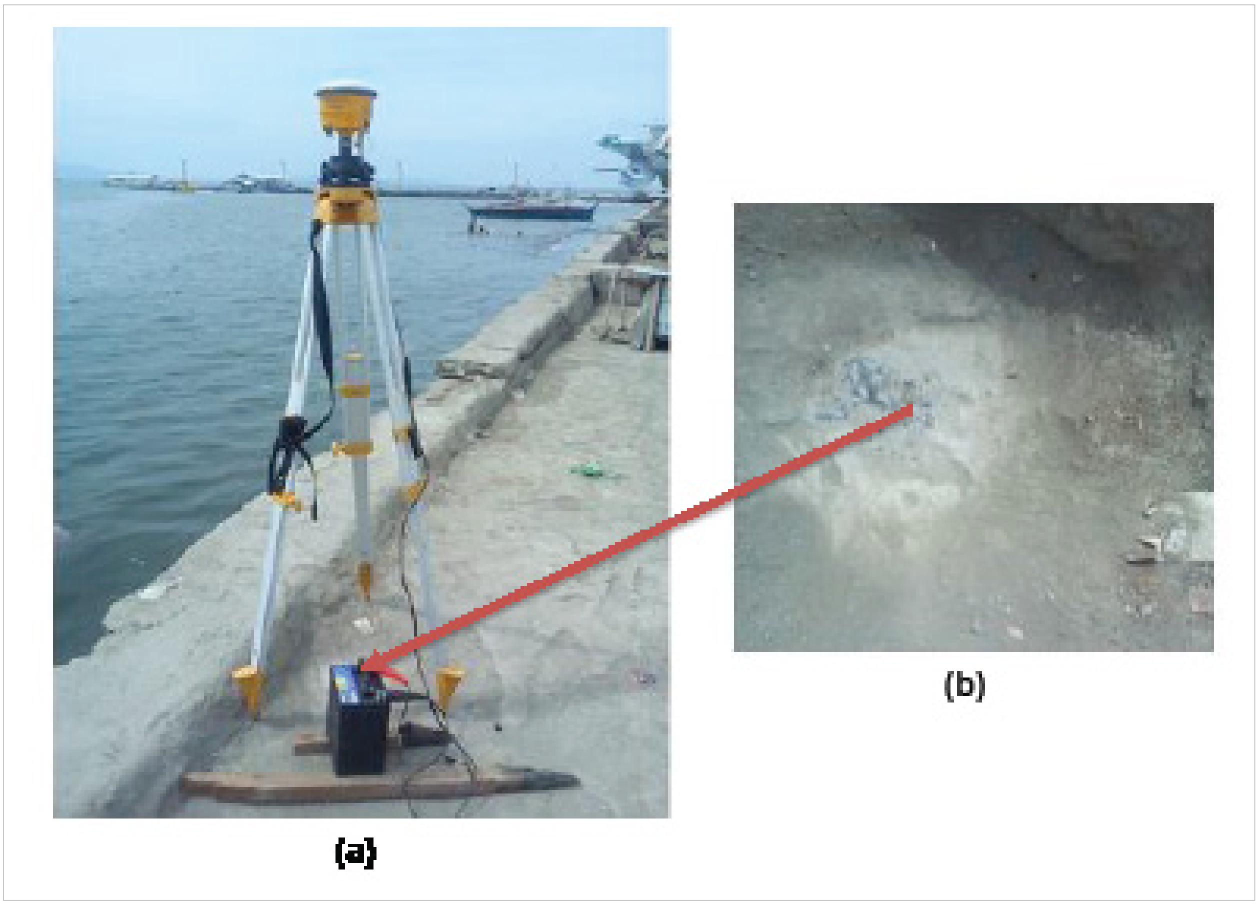


Figure 5. GPS set-up over DVS-01 located at the east side of the pier in Davao City (a) and NAMRIA reference point DVS-01 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point DVS-01 used as base station for the LiDAR acquisition.

Station Name	DVS-01	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°4’41.48387” North 125°37’31.24815” East -4.507 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	569084.935 meters 782663.345 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°4’38.36201” North 125°37’36.77094” East 68.275 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	790026.110 meters 783162.170 meters

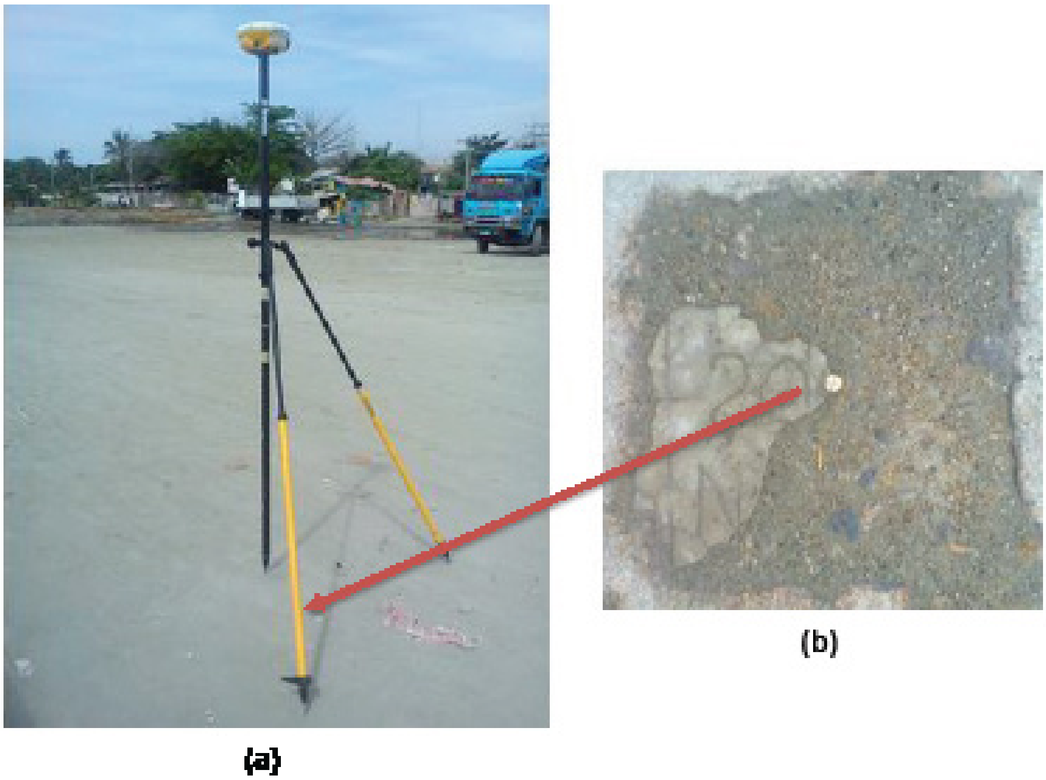


Figure 6. GPS set-up over DVS-01A located at the east side of the pier in Davao City, near DVS-01 (a) and NAMRIA reference point DVS-01A (b) as recovered by the field team.

Table 5. Details of the established horizontal control point DVS-01A used as base station for the LiDAR acquisition.

Station Name	DVA-3237	
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°4’41.46785” North 125°37’31.08587” East -4.269 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°4’38.34598” North 125°37’36.60866” East 68.513 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	790021.135 meters 783161.647 meters

Table 6. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 18, 2014	7378GC	2BLK82A199A	DVS-01 & DVS-01A
July 22, 2014	7386GC	2BLK82CSD203A	DVS-01 & DVS-01A
July 23, 2014	7388GC	2BLK82AB204A	DVS-01 & DVS-01A
July 29, 2014	7401GC	2BLK82EFGHS210B	DVS-01 & DVS-01A
August 11, 2014	7426GC	2BLK82V223A	DVA-3237 & DVA-133
August 11, 2014	7427GC	2BLK82V223B	DVA-3237 & DVA-133

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR data acquisition in Lipadas floodplain, for a total of nineteen hours and forty-eight minutes (19+48) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Lipadas floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
July 18, 2014	7378GC	65.694	175.283	14.250	160.750	NA	4	5
July 22, 2014	7386GC	65.694	249.113	8.957	240.156	NA	4	29
July 23, 2014	7388GC	197.577	205.138	1.353	203.785	NA	4	5
July 29, 2014	7401GC	110.175	83.269	0	83.269	NA	1	59
August 11, 2014	7426GC	818.466	95.826	0	95.826	NA	2	41
August 11, 2014	7427GC	818.466	47.889	8.143	39.746	NA	2	29
TOTAL		**2076.07**	**790.829**	**32.703**	**823.532**	**NA**	**19**	**48**

Table 8. 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)
7378GC	850	30	50	125	40	130	5
7386GC	800	35	50	125	40	130	5
7388GC	1000	30	40	100	50	130	5
7401GC	1000, 850	30	40, 50	100, 125	50, 40	130	5
7426GC	1000	35	40	100	40	130	5
7427GC	1000	35	40	100	40	130	5

2.4 Survey Coverage

Lipadas floodplain is located in the province of Davao Del Sur, specifically within the city of Davao. The city surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Lipadas floodplain is presented in Figure 7.

Table 9. City surveyed during Lipadas floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Davao del Sur	Davao	2224.82	427.58	19%

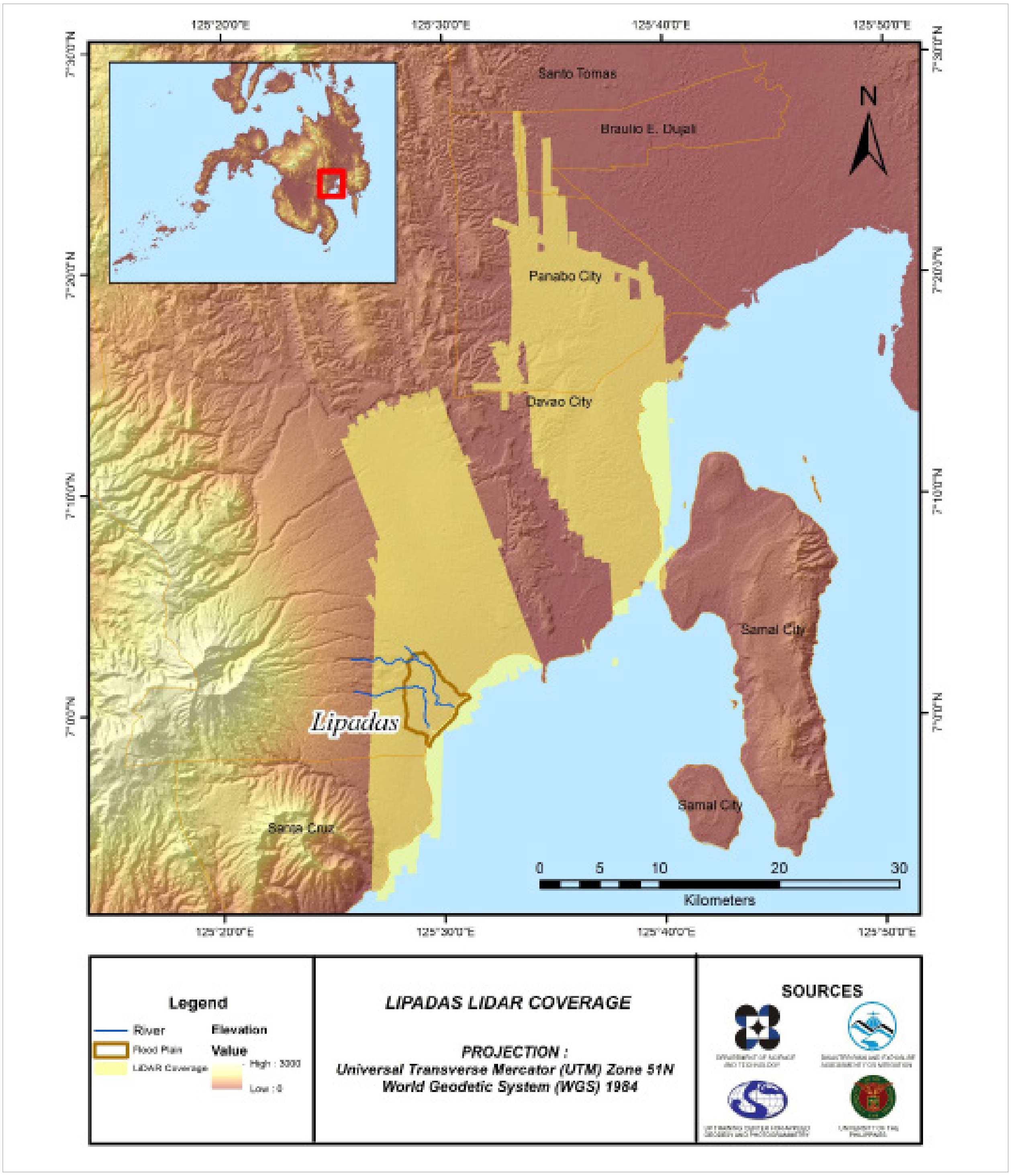


Figure 7. Actual LiDAR survey coverage for Lipadas floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LIPADAS FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

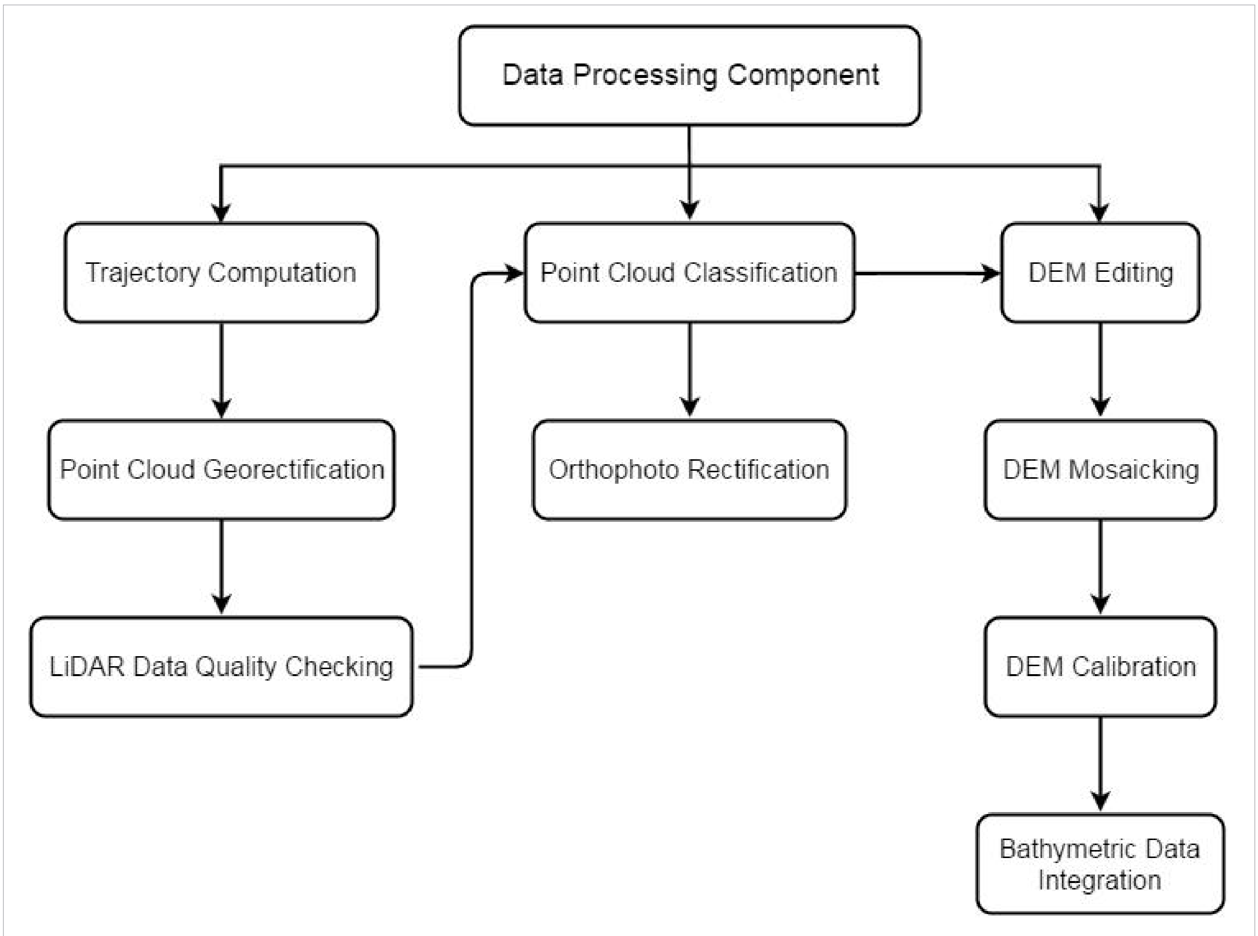


Figure 8. Schematic Diagram for Data Pre-Processing Component.

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 8.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Lipadas floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on July 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Davao and Davao Oriental. The Data Acquisition Component (DAC) transferred a total of 98.21 Gigabytes of Range data, 1.109 Gigabytes of POS data, and 48.85 Megabytes of GPS base station data to the data server on August 11, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Lipadas was fully transferred on August 29, 2014, as indicated on the Data Transfer Sheets for Lipadas floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 7401GC, one of the Lipadas flights, which is the North, East, and Down position RMSE values are shown in Figure 9. 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 29, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

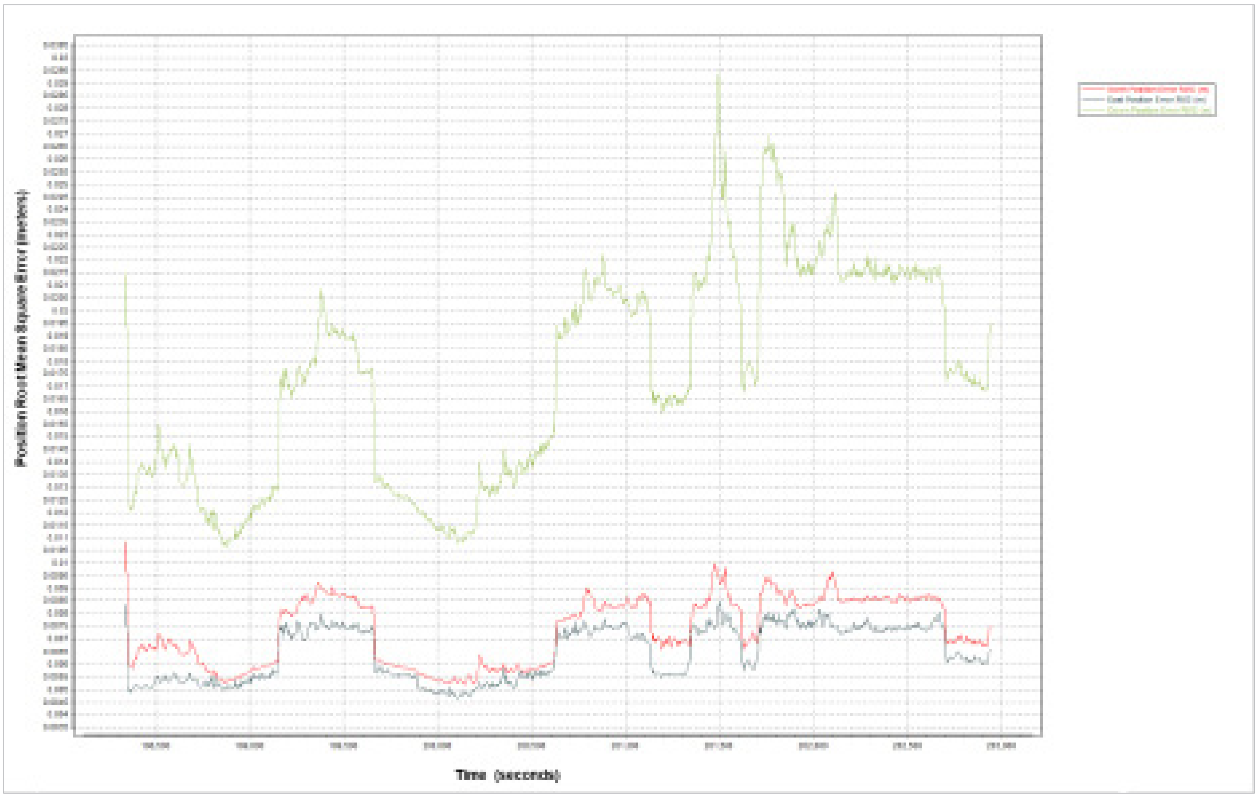


Figure 9. Smoothed Performance Metric Parameters of a Lipadas Flight 7401GC.

The time of flight was from 198300 seconds to 202900 seconds, which corresponds to afternoon of July 29, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 0.85 centimeters, and the Down position RMSE peaks at 2.95 centimeters, which are within the prescribed accuracies described in the methodology.

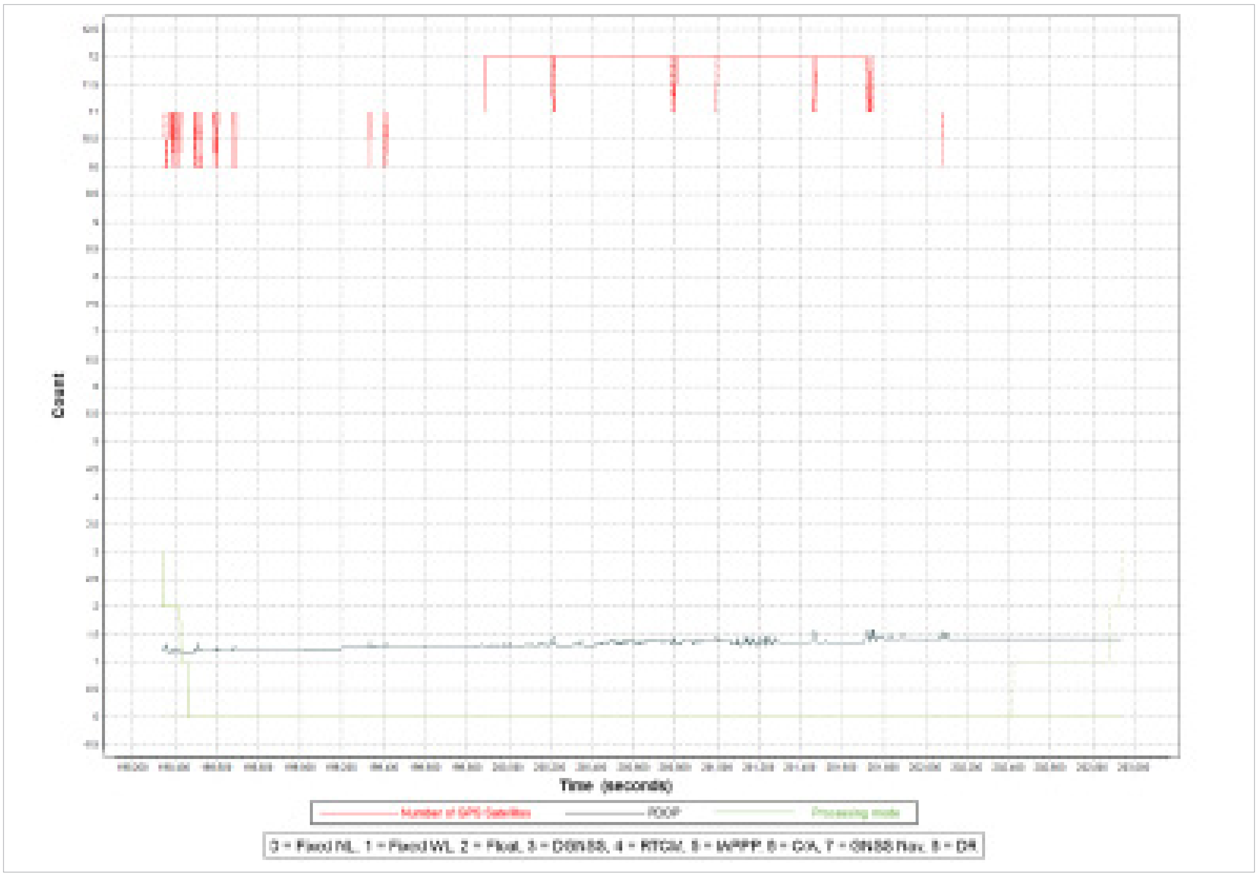


Figure 10. Solution Status Parameters of Lipadas Flight 7401GC.

The Solution Status parameters of flight 7401GC, one of the Lipadas flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. 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 10 and 12. 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 3 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 Lipadas flights is shown in Figure 11.

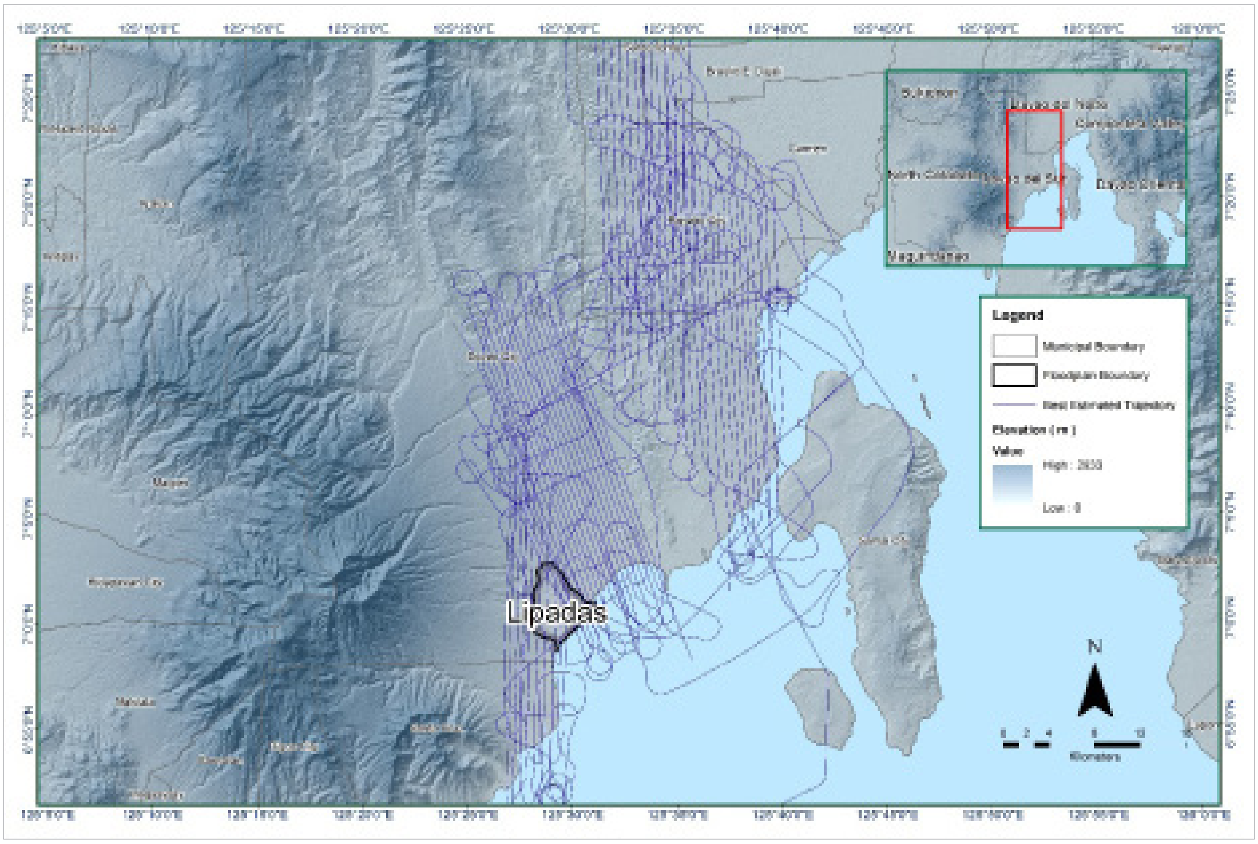


Figure 11. Best Estimated Trajectory for Lipadas floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 60 flight lines, with each flight line containing one channel, since the 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 Lipadas floodplain are given in Table10.

Table 10. Self-Calibration Results values for Lipadas flights.

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000183
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000717
GPS Position Z-correction stdev (<0.01meters)	0.0028

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Lipadas Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

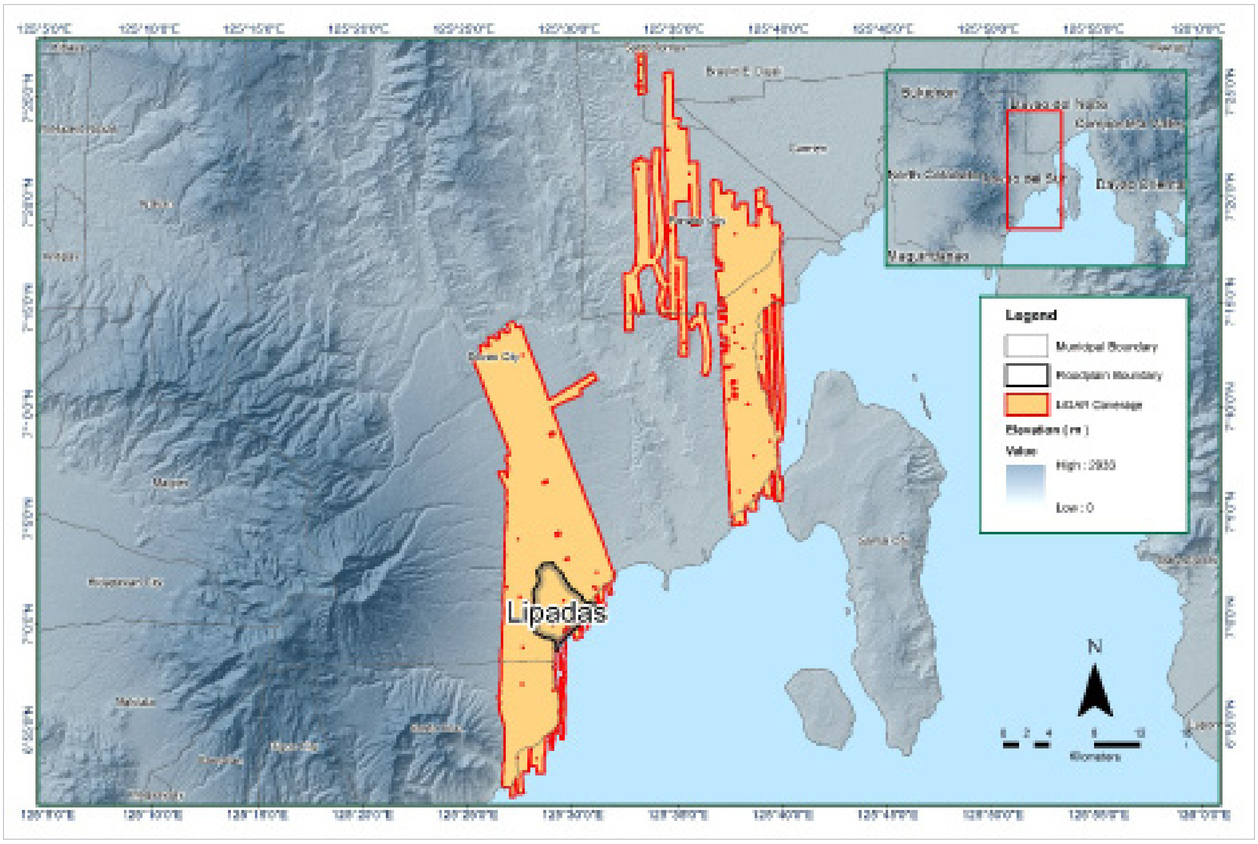


Figure 12. Boundary of the processed LiDAR data over Lipadas Floodplain

The total area covered by the Lipadas missions is 590.34 sq.km that is comprised of six (6) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Lipadas floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
DavaoDelSur_Blk82B	7378GC	120.50
	7388GC	
DavaoDelSur_Blk82C	7378GC	124.17
	7386GC	
DavaoDelSur_Blk82_voids	7427GC	116.99
	7426GC	
DavaoDelSur_Blk82E	7388GC	228.68
	7401GC	
	TOTAL	**590.34 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

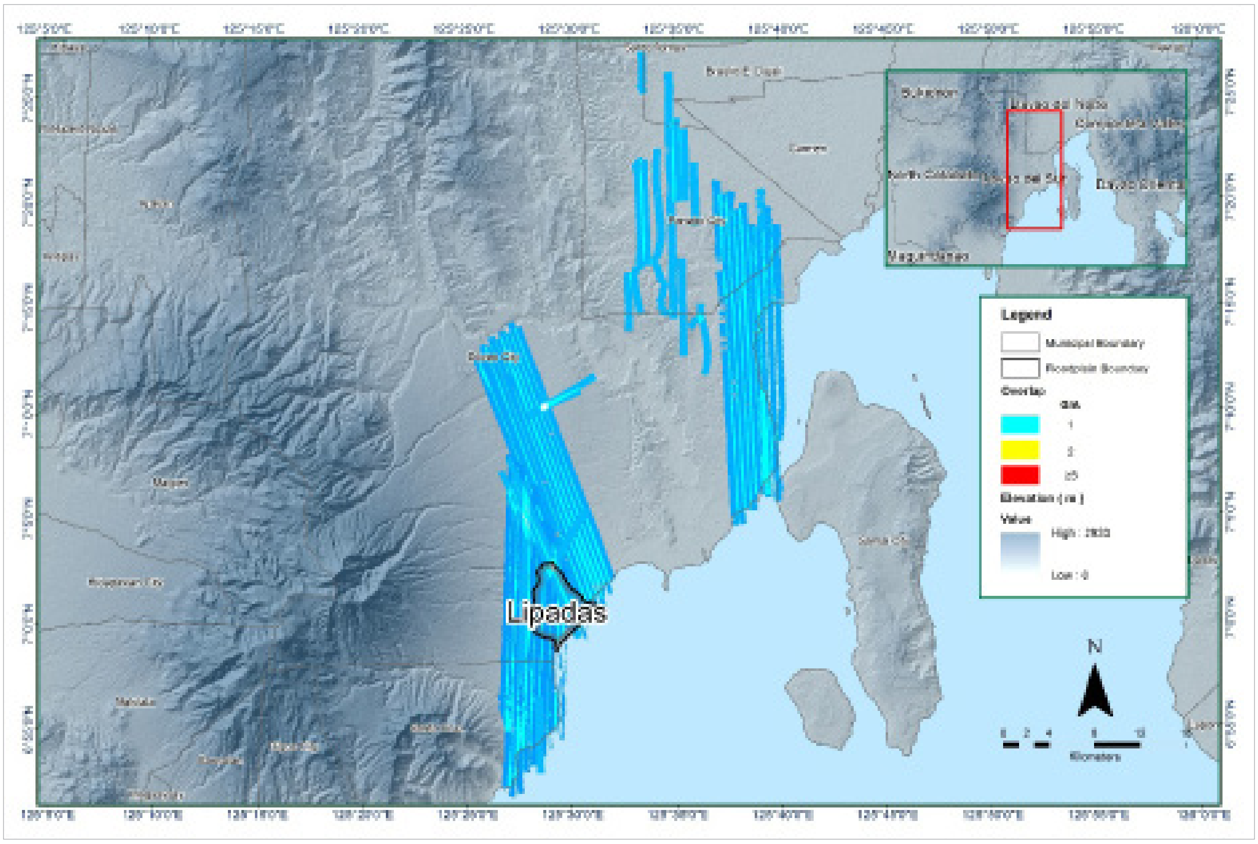


Figure 13. Image of data overlap for Lipadas floodplain.

The overlap statistics per block for the Lipadas floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, percent overlap is 29.34%, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Lipadas floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.19 points per square meter.

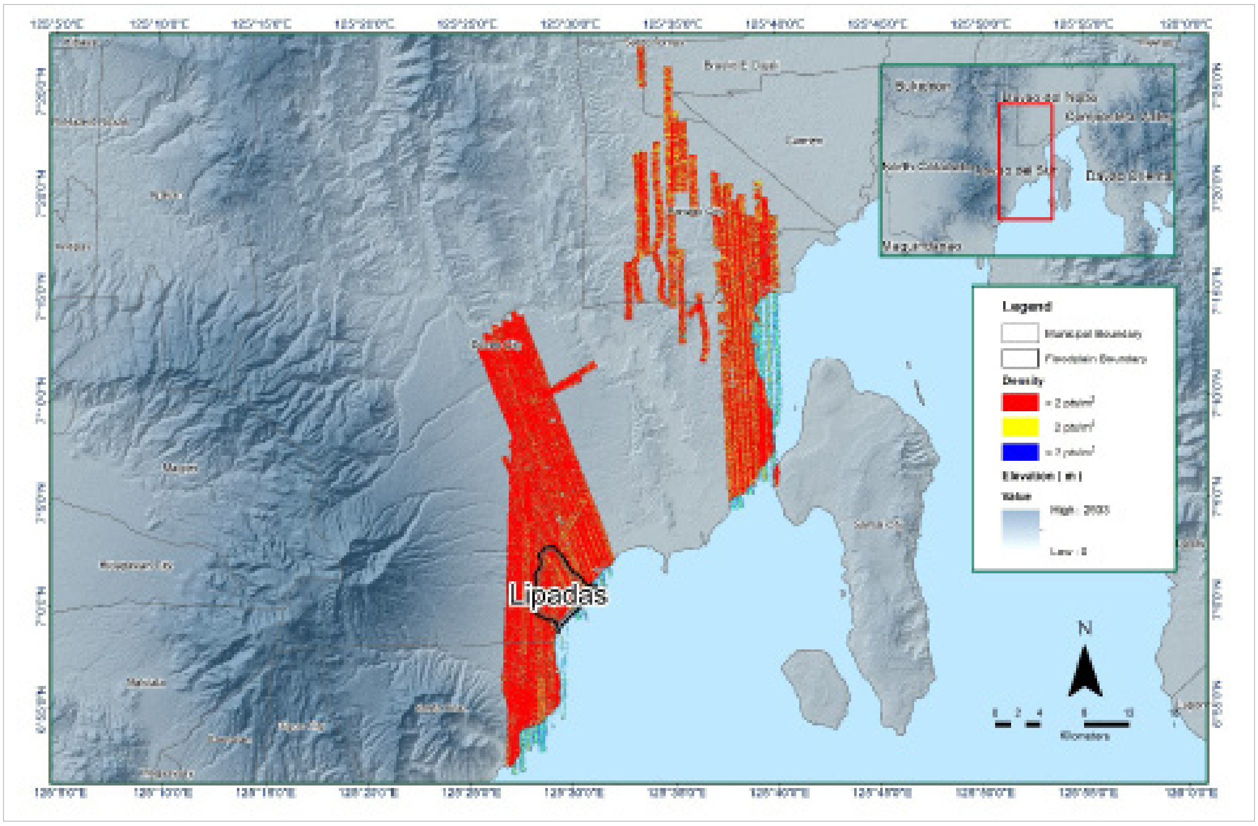


Figure 14. Pulse density map of merged LiDAR data for Lipadas floodplain.

The elevatiovn difference between overlaps of adjacent flight lines is shown in Figure 15. 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.

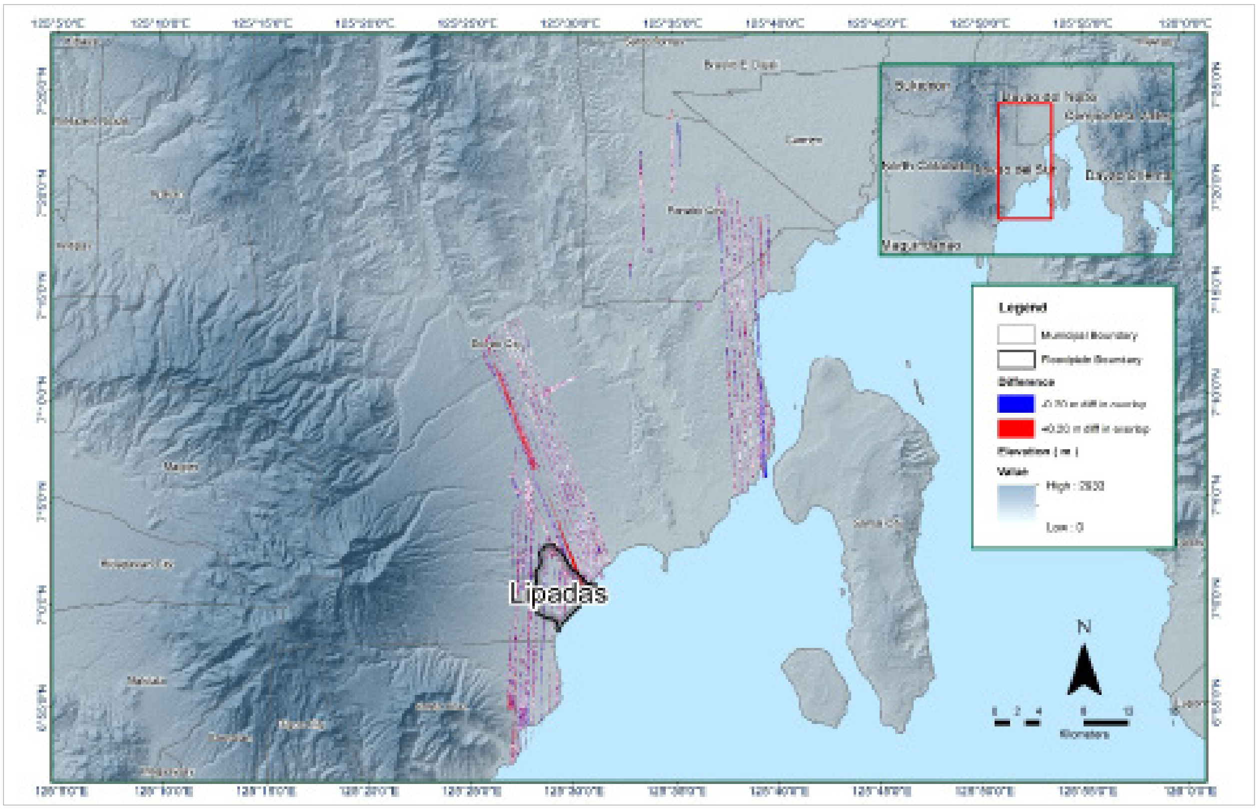


Figure 15. Elevation difference map between flight lines for Lipadas floodplain.

A screen capture of the processed LAS data from a Lipadas flight 7401GC loaded in QT Modeler is shown in Figure 16. 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.

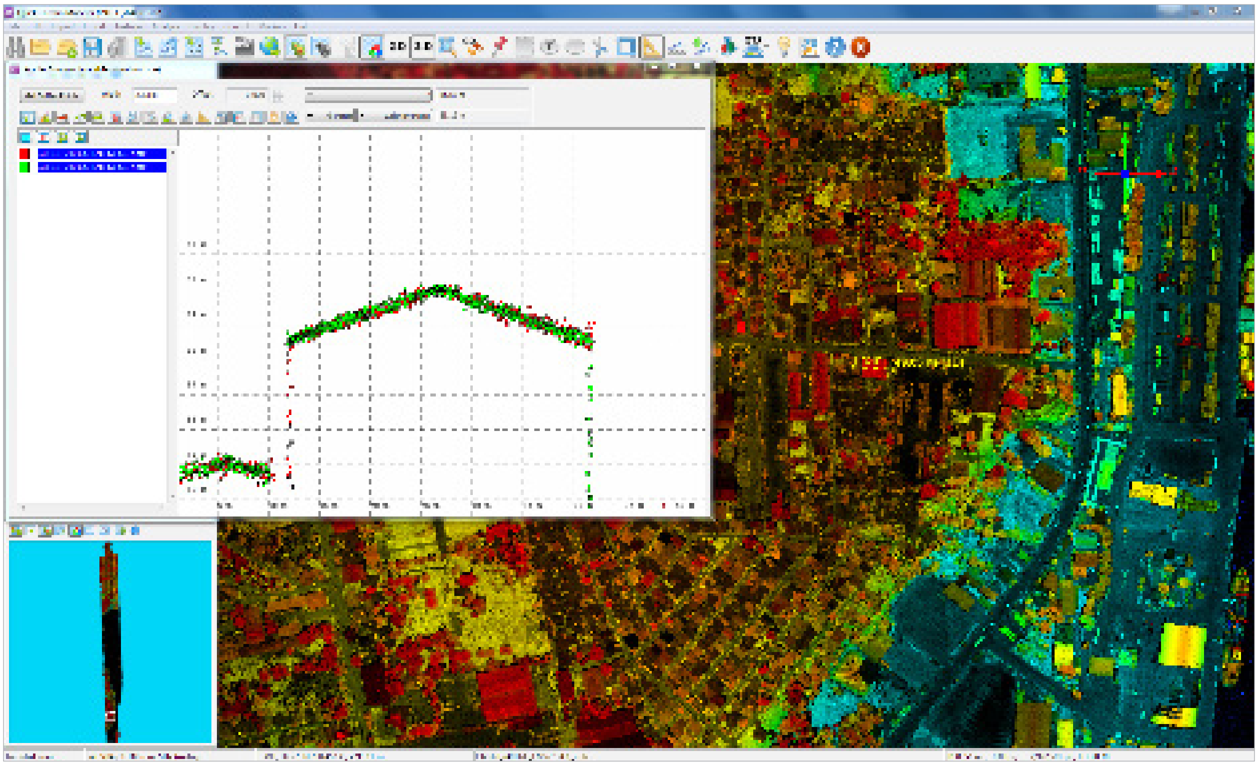


Figure 16. Quality checking for a Lipadas flight 7401GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Lipadas classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	191,360,353
Low Vegetation	195,090,349
Medium Vegetation	424,852,765
High Vegetation	860,727,657
Building	41,975,669

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Lipadas floodplain is shown in Figure 17. A total of 919 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 460.63 meters and 59.35 meters respectively.

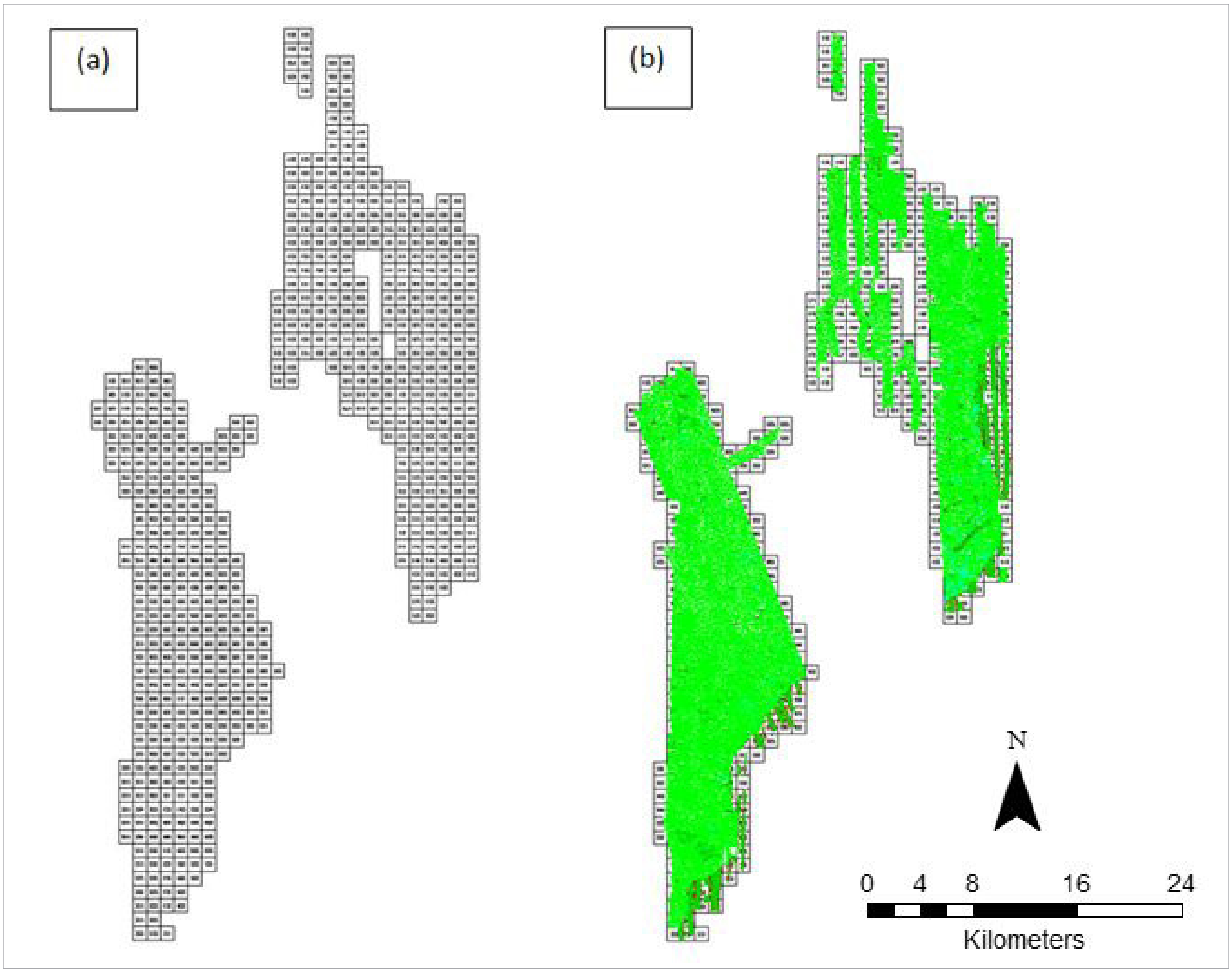


Figure 17. Tiles for Lipadas floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

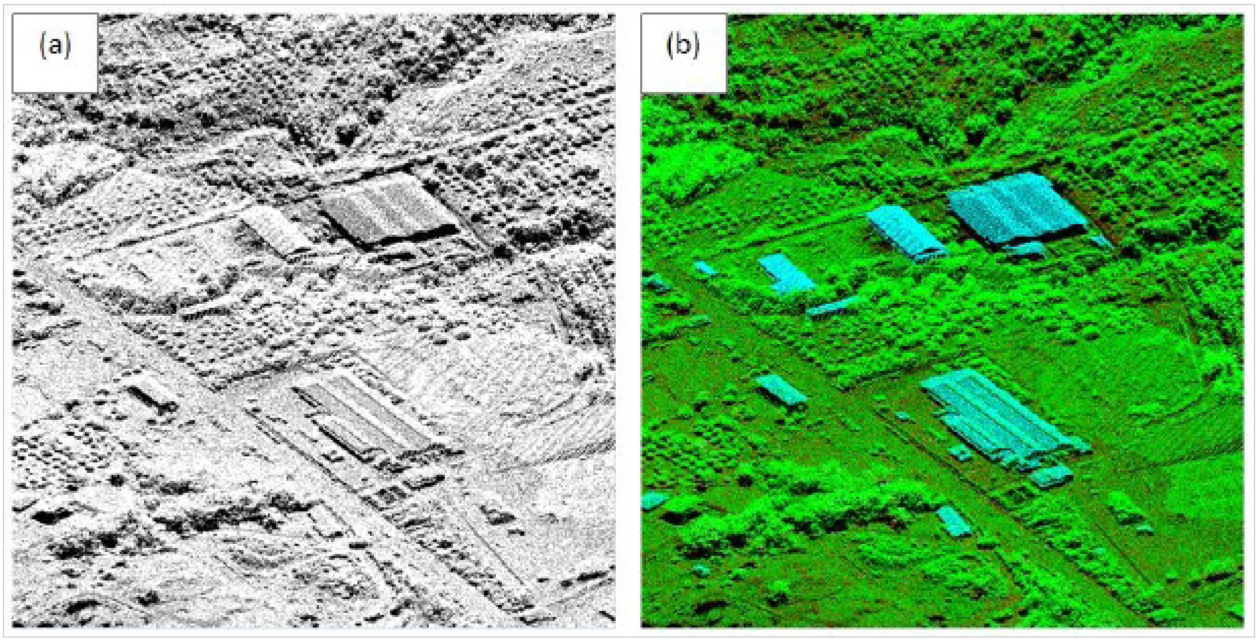


Figure 18. Point cloud before (a) and after (b) classification.

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

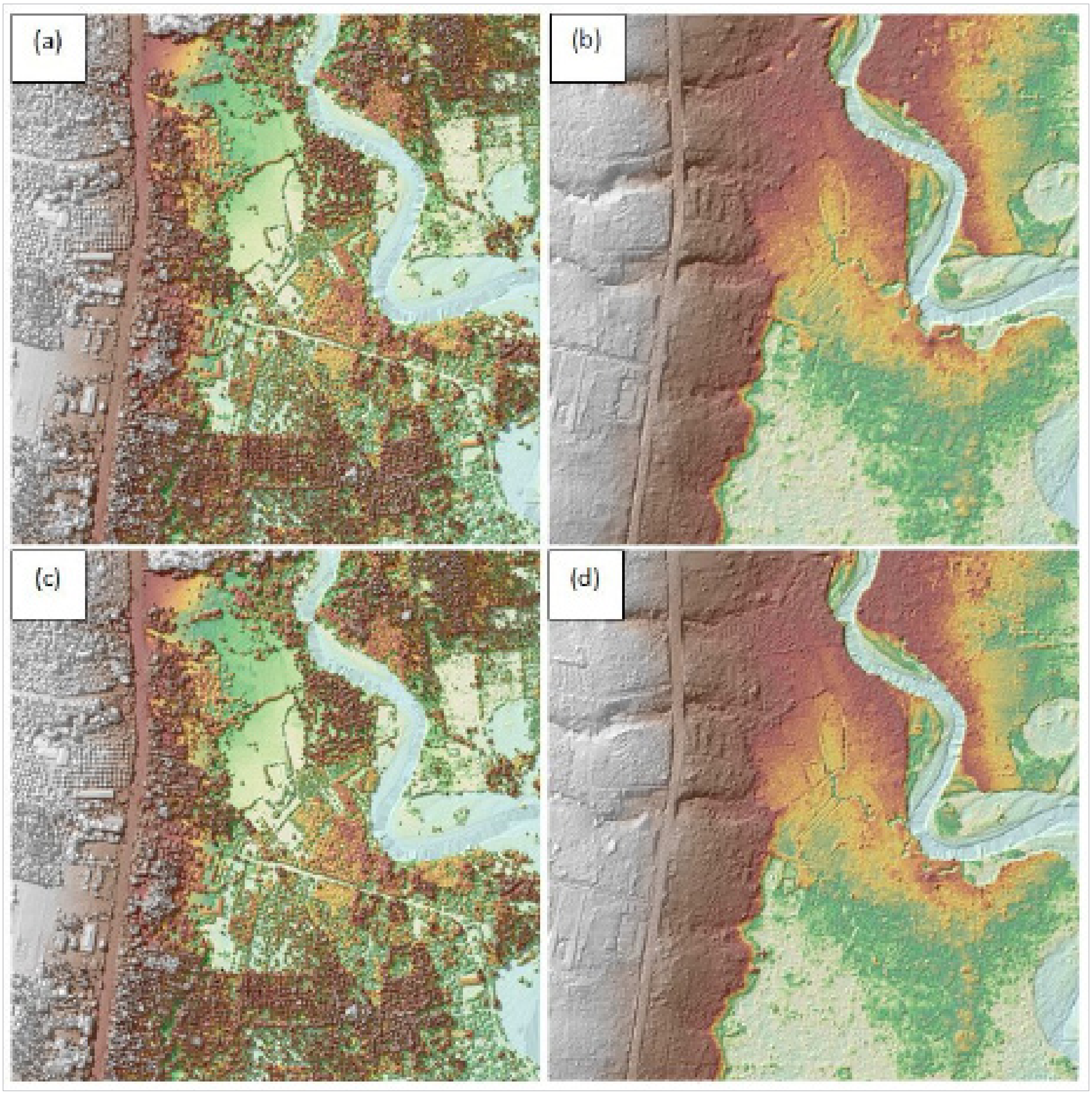


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Lipadas floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Lipadas floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Lipadas flood plain. These blocks are composed of DavaoDelSur blocks with a total area of 590.34 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
DavaoDelSur_Blk82B	120.50
DavaoDelSur_Blk82C	124.17
DavaoDelSur_Blk82_voids	116.99
DavaoDelSur_Blk82E	228.68
TOTAL	**590.34 sq.km**

Portions of DTM before and after manual editing are shown in Figure 20. The bridge (Figure 20a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 20b) in order to hydrologically correct the river. The embankment (Figure 20c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 20d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 20e) and has to be removed through manual editing (Figure 20f).

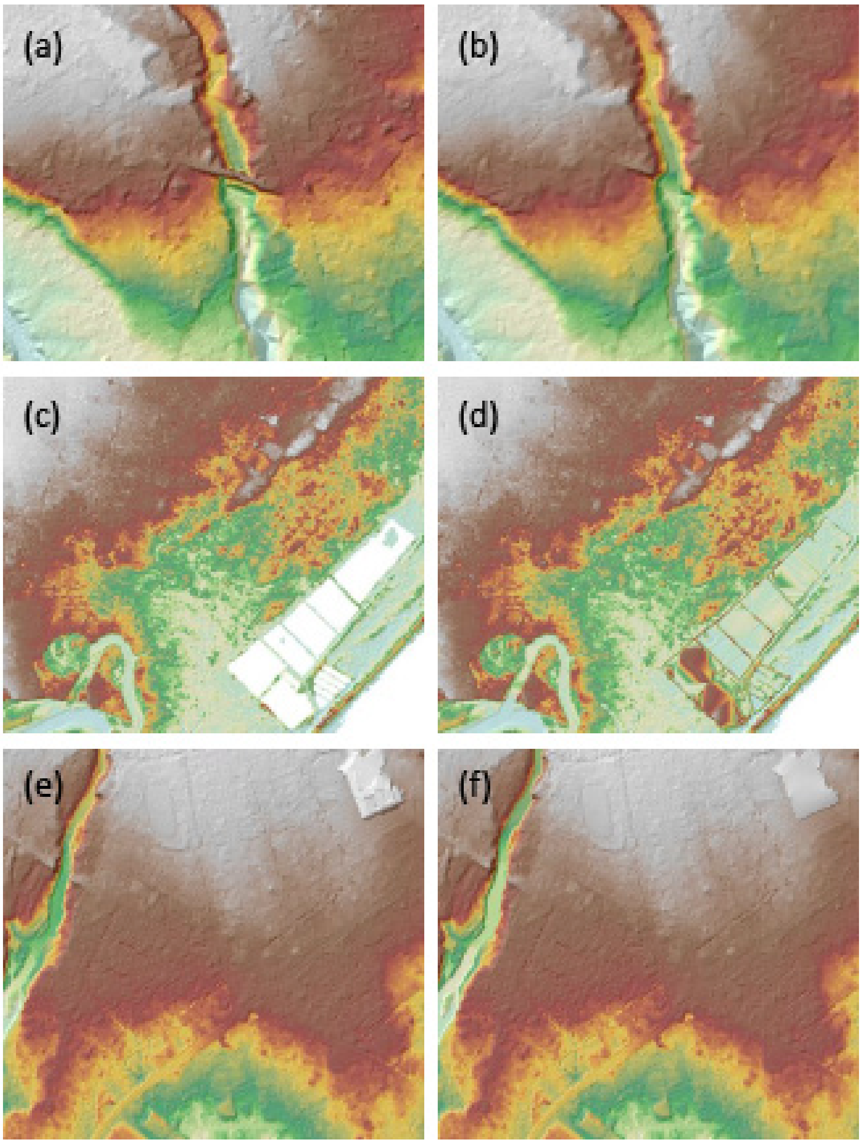


Figure 20. Portions in the DTM of Lipadas floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

DavaoDelSur_Blk82A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy.

Mosaicked LiDAR DTM for Lipadas floodplain is shown in Figure 21. It can be seen that the entire Lipadas floodplain is 96% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Lipadas floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
DavaoDelSur_Blk82B	0.00	0.00	-0.63
DavaoDelSur_Blk82C	0.00	0.00	0.00
DavaoDelSur_Blk82_voids	0.50	0.50	0.00
DavaoDelSur_Blk82E	0.00	0.00	0.00

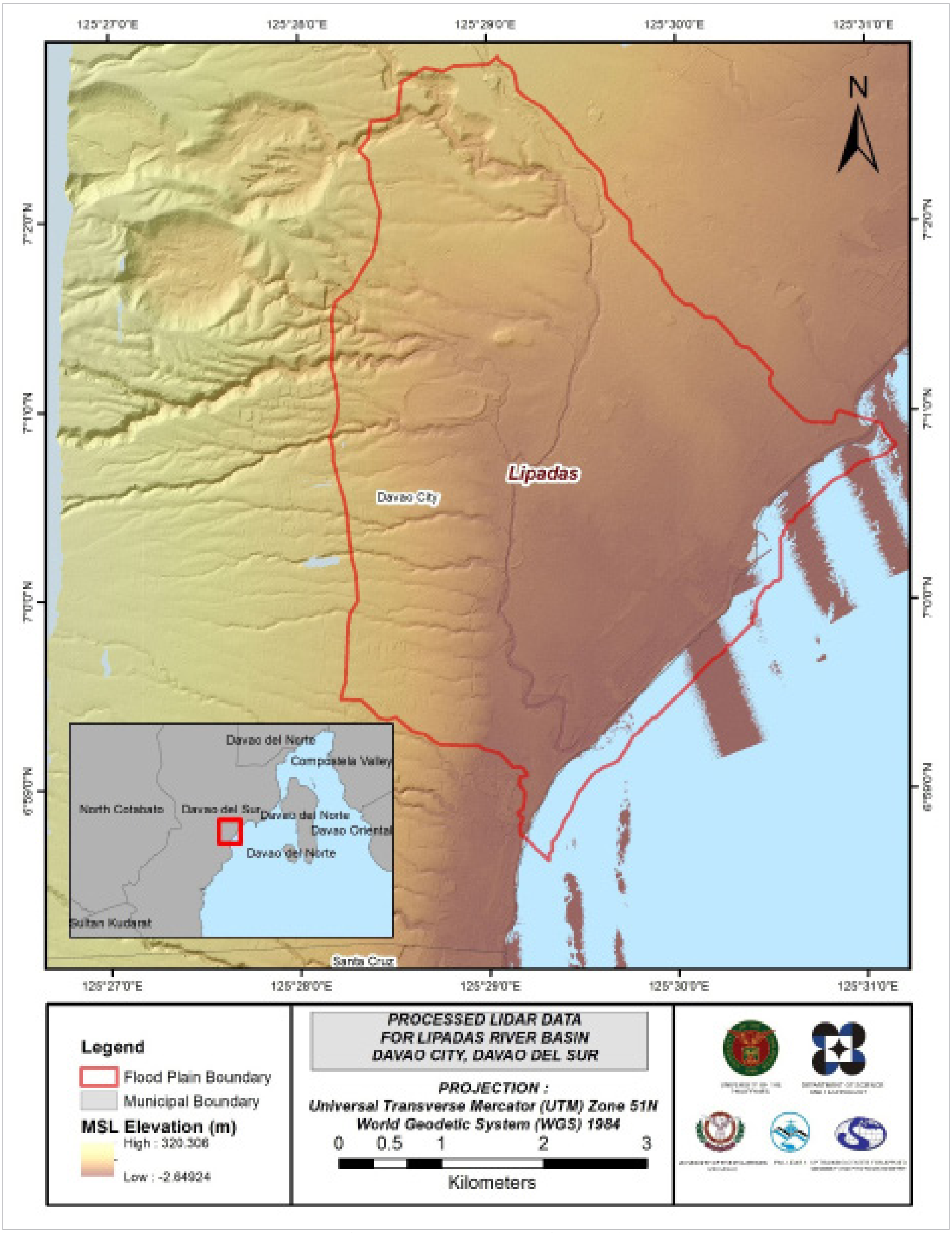


Figure 21. Map of Processed LiDAR Data for Lipadas Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Lipadas to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 21,221 survey points were used for calibration and validation of Lipadas LiDAR data. Random selection of 80% of the survey points, resulting to 16,977 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in

Figure 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.58 meters with a standard deviation of 0.12 meters. Calibration of Lipadas LiDAR data was done by adding the height difference value, 0.58 meters, to Lipadas mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

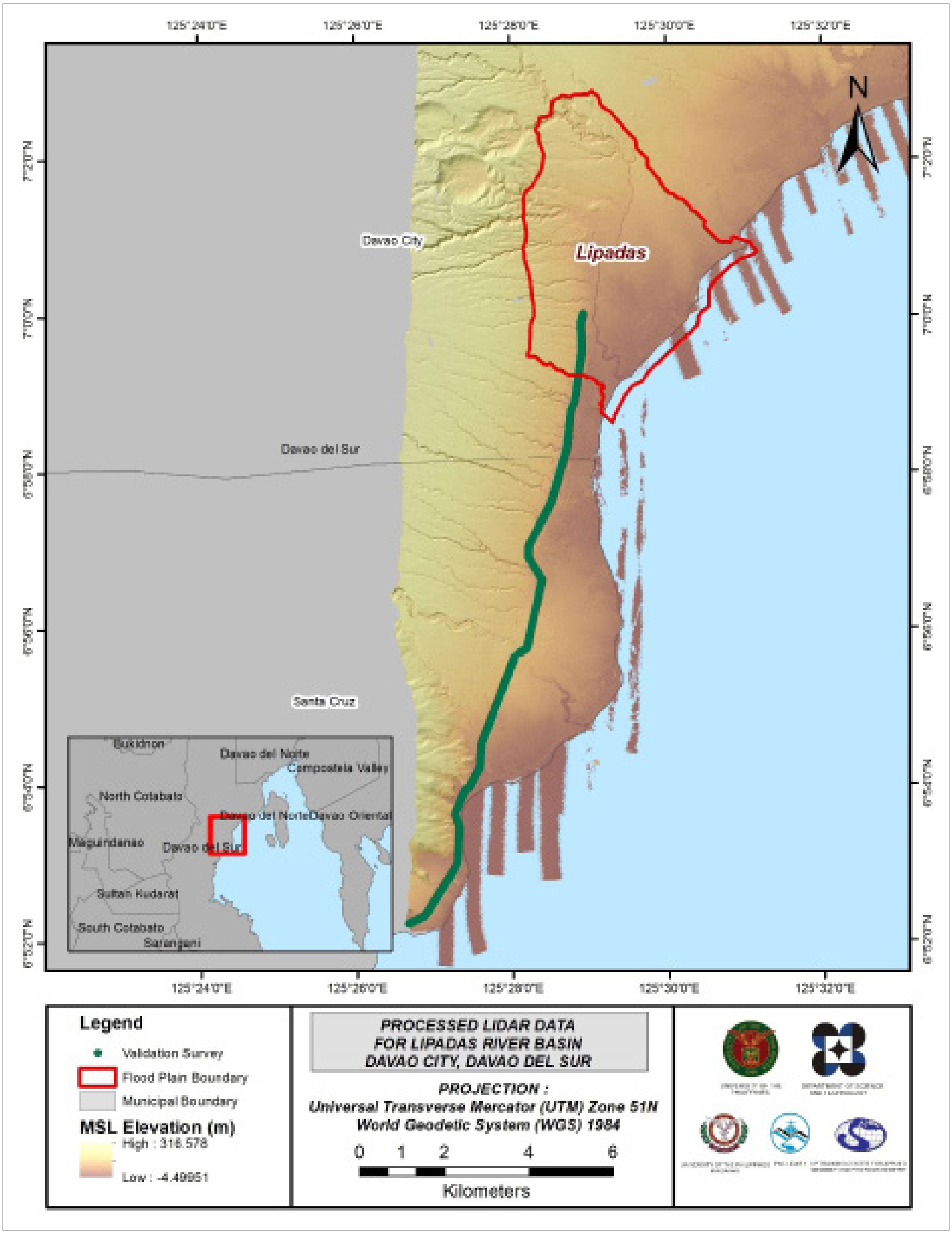


Figure 22. Map of Lipadas Flood Plain with validation survey points in green.

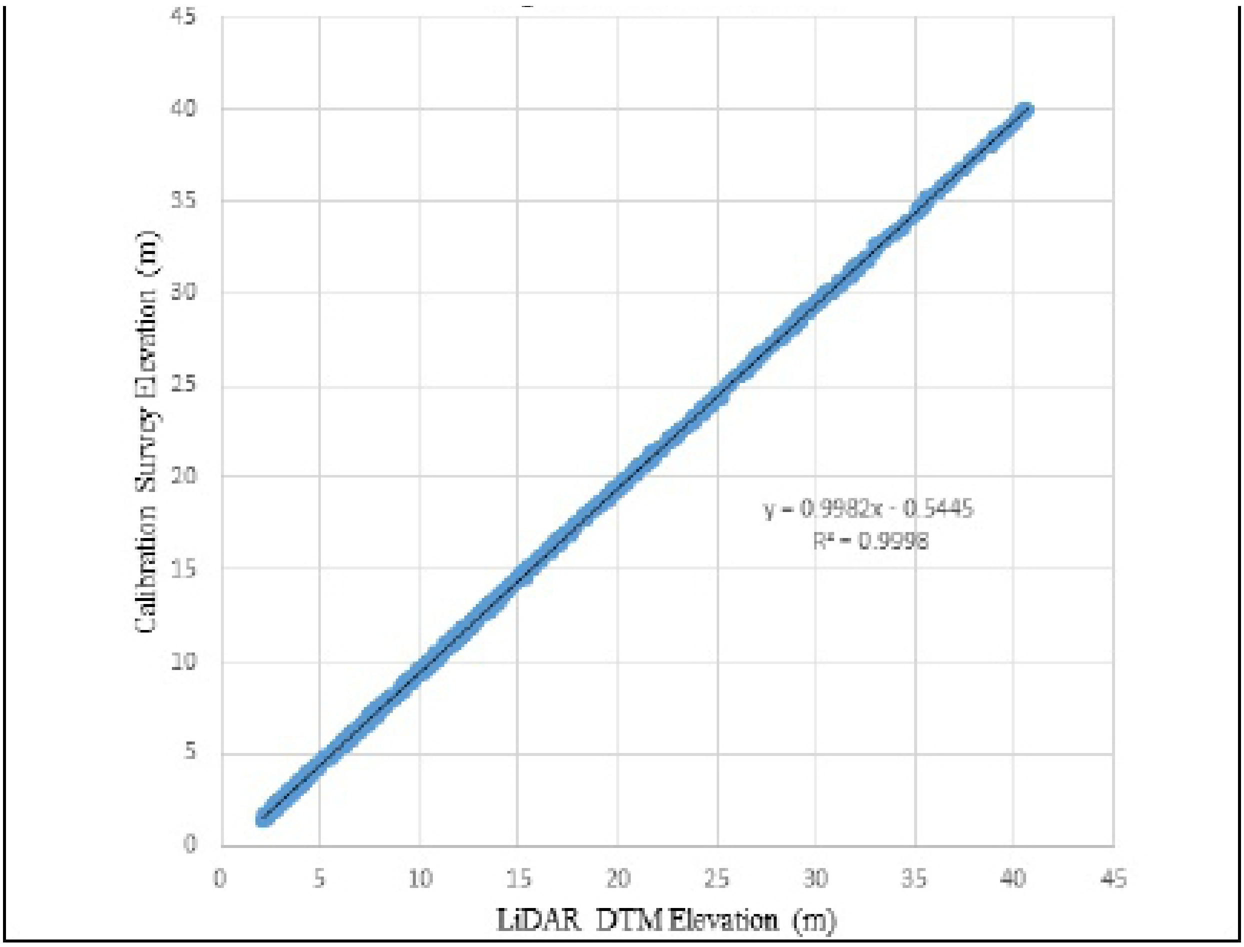


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.58
Standard Deviation	0.12
Average	0.57
Minimum	0.32
Maximum	0.82

The remaining 20% of the total survey points, resulting to 4,244 points, were used for the validation of calibrated Lipadas 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 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.18 meters with a standard deviation of 0.18 meters, as shown in Table 16.

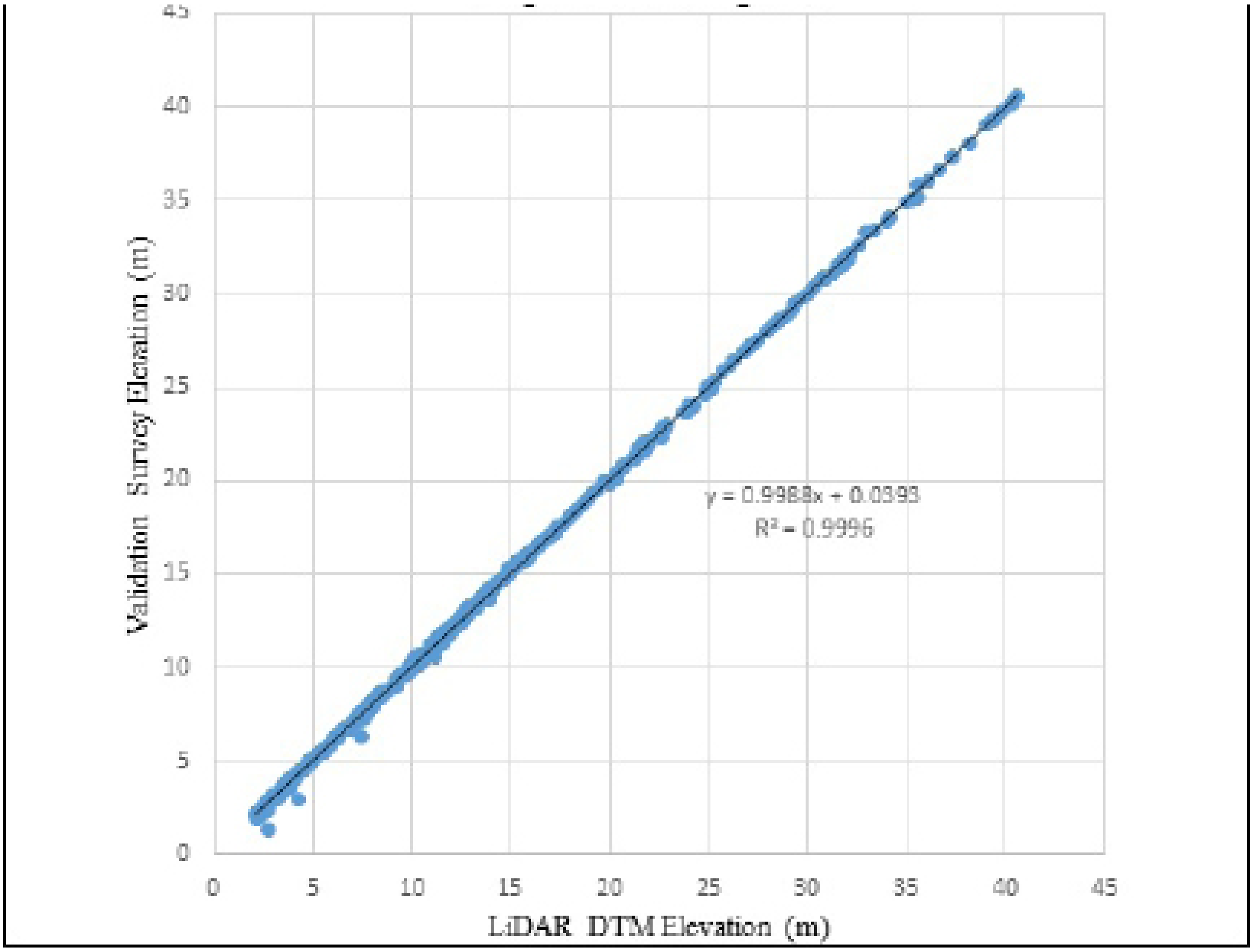


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Calibration Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.18
Average	-0.02
Minimum	-0.39
Maximum	0.34

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross section data were available for Lipadas with 2,056 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 0.46 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Lipadas integrated with the processed LiDAR DEM is shown in Figure 25.

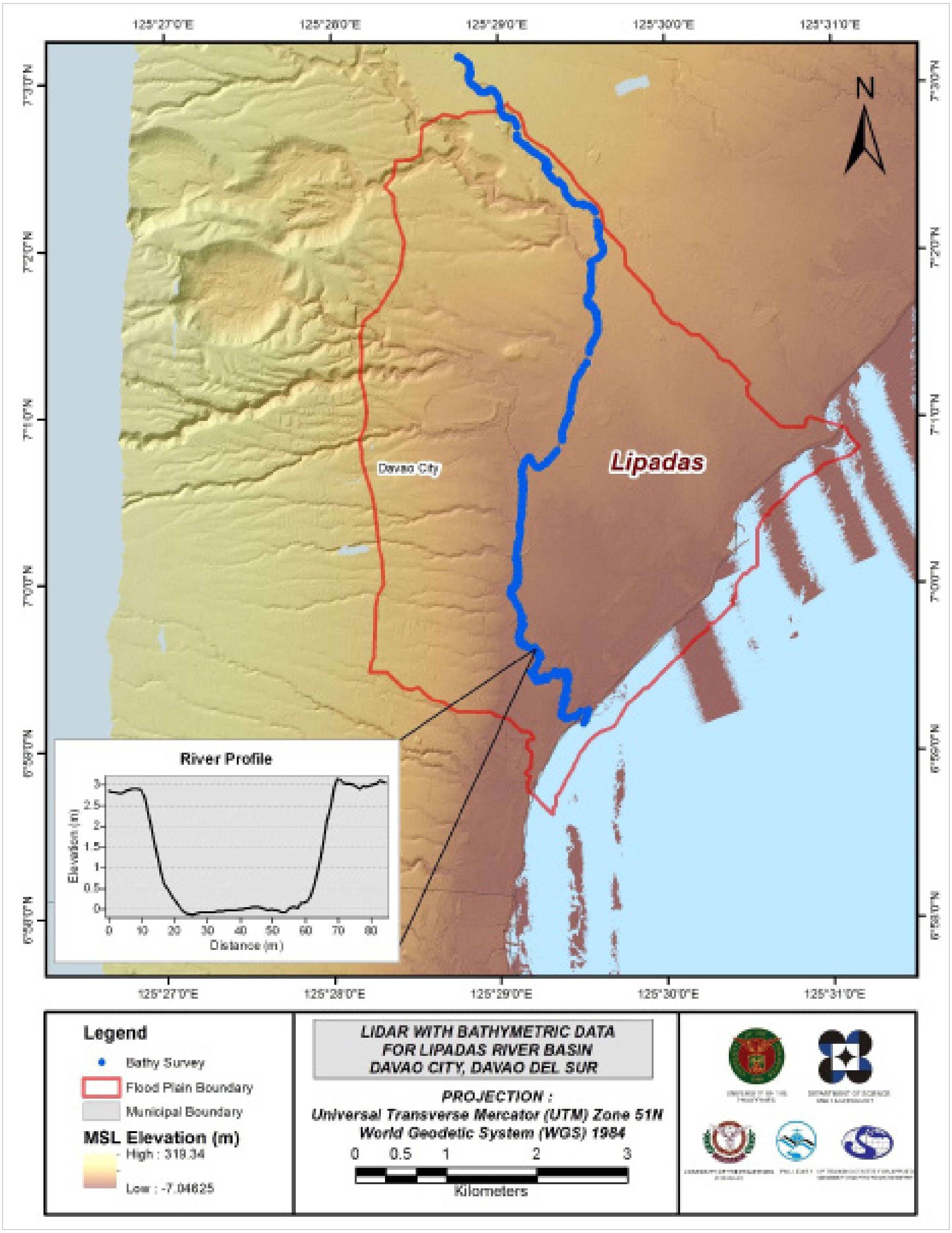


Figure 25. Map of Lipadas Flood Plain with bathymetric survey points shown in blue.

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

Lipadas floodplain, including its 200 m buffer, has a total area of 27.64 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 4,323 building features, are considered for QC. Figure 26 shows the QC blocks for Lipadas floodplain.

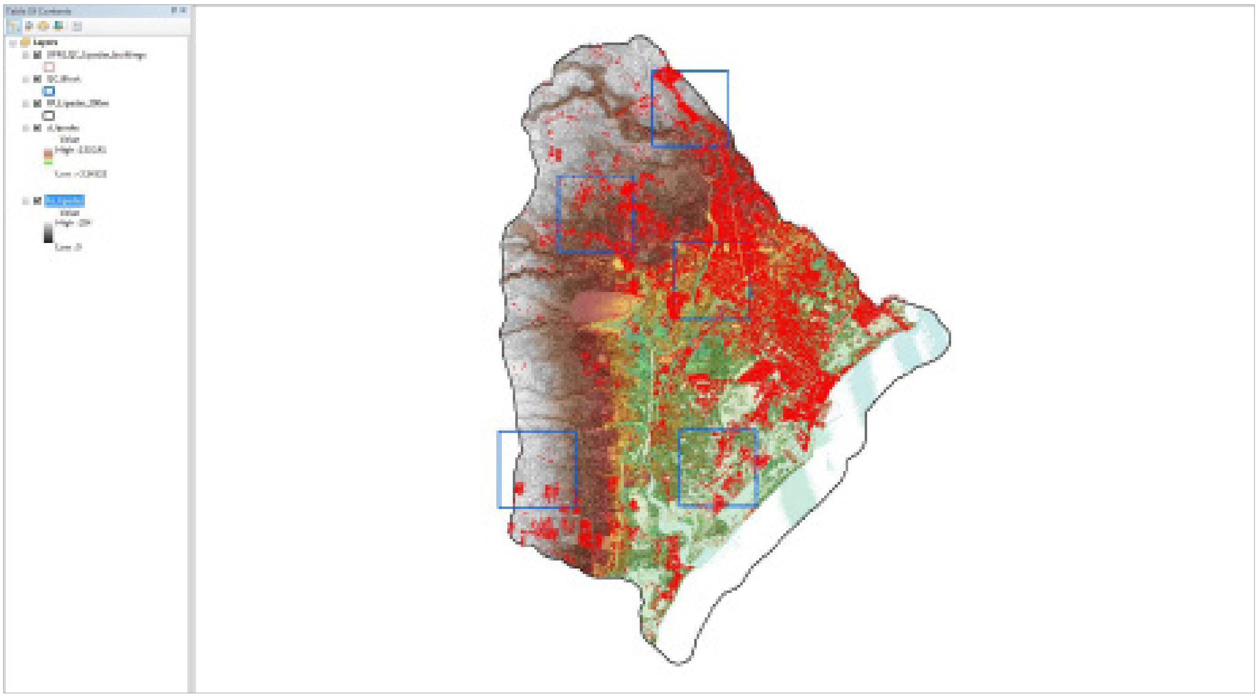


Figure 26. QC blocks for Lipadas building features.

Quality checking of Lipadas building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Lipadas Building Features

Floodplain	Completeness	Correctness	Quality	Remarks
Lipadas	97.38	99.84	95.33	PASSED

3.12.2 Height Extraction

Height extraction was done for 19,195 building features in Lipadas floodplain. Of these building features, 3,173 filtered out after height extraction, resulting to 16,022 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

Field validation for Lipadas floodplain has already been completed last October, 2015. However, in November of the same year, there were changes in the Feature Extraction Manual given by UP Diliman Data Pre-Processing Component, which then prompted for the conduct of the another field work on August 8-11, 2016 for the digitized features in the additional area scope. A spot checking to randomly selected buildings in the floodplain was also conducted on November 15, 2016.

Before the actual field validation, courtesy calls were conducted to seek permission and assistance from the Local Government Units 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.

Barangay Health Workers (BHWs) were requested and hired to guide the University of the Philippines Mindanao Phil-LiDAR1 field enumerators during validation. 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 eleven (11) barangays covered by the floodplain namely Barangays Lubogan, Marapangi, Toril, Bato, Crossing Bayabas, Sirawan, Lizada, Daliao, Binugao, Baliok and Bangkas, Davao City.

There were areas in Brgy. Lizada with no data in the Digital Surface Model. The buildings were not digitized. Hence, the addition of building shapefiles using google earth after the spot checking activity.

Table 18 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Lipadas Floodplain.

Facility Type	No. of Features
Residential	14,498
School	275
Market	30
Agricultural/Agro-Industrial Facilities	170
Medical Institutions	44
Barangay Hall	11
Military Institution	10
Sports Center/Gymnasium/Covered Court	24
Telecommunication Facilities	5
Transport Terminal	5
Warehouse	151
Power Plant/Substation	1
NGO/CSO Offices	14
Police Station	7
Water Supply/Sewerage	1
Religious Institutions	153
Bank	10
Factory	45
Gas Station	23
Fire Station	1
Other Government Offices	18
Other Commercial Establishments	526
Total	**16,022**

Table 19. Total Length of Extracted Roads for Lipadas Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Lipadas	118.68	27.82	0.00	5.63	0.00	**152.13**

Table 20. Number of Extracted Water Bodies for Lipadas Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Lipadas	1	0	0	0	22	**23**

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

3.12.4 Final Quality Checking of Extracted Features

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

Figure 27 shows the Digital Surface Model (DSM) of Lipadas floodplain overlaid with its ground features.

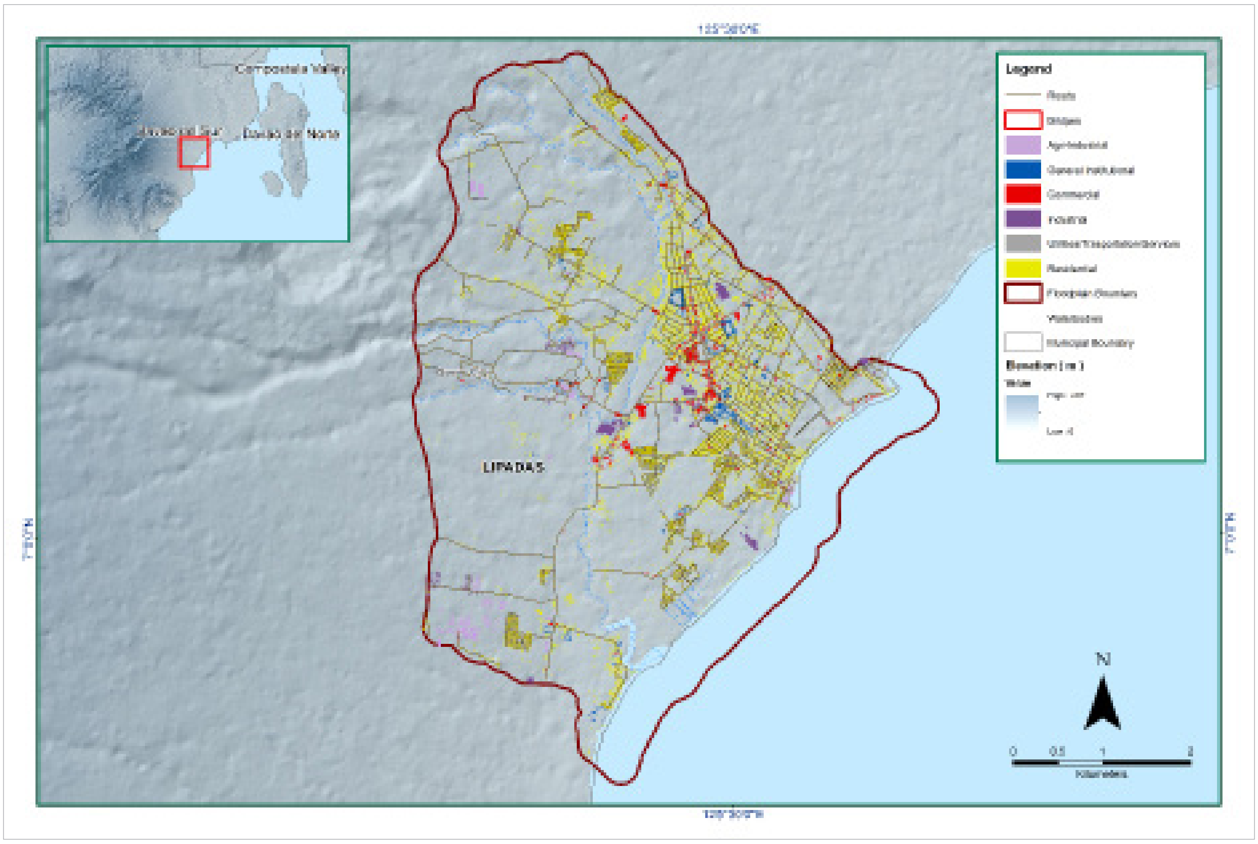


Figure 27. Extracted features for Lipadas floodplain.

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

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Harmond F. Santos, Engr. John Dill P. Macapagal, Engr. Ma. Ailyn L. Olanda, Engr. Antonio B. Chua Jr., Engr. Krisha Marie Bautista, Engr. Ben Joseph J. Harder, and Engr. Karl Adrian P. Vergara

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

Lipadas River Basin is located in Davao City in the Province of Davao del Sur. It occ-upies a total area of 16, 796 ha and encompasses a total of 19 barangays (People Collaborating for Environmental and Economic Management in Davao Foundation, Inc.).The basin has a catchment area of 133 km2 with an estimated annual run-off of 266 million cubic meters (MCM) according to DENR-RCBO. It is one of the eight (8) watersheds located in Davao City, Davao del Sur (People Collaborating for Environmental and Economic Management in Davao Foundation, Inc.).

Its main stem, Lipadas River, is one of the main sources of Davao City's drinking water together with the Talomo River. Along the length of the river are forests, grasslands, population centers, agricultural lands, and other human constructs such as poultries, plantations, resorts, and residential areas (People Collaborating for Environmental and Economic Management in Davao Foundation, Inc.) A recent flooding event on January 22, 2013 occurred in Davao City when Lipadas River, together with Davao, Lasang, and Talomo Rivers, overflowed due to continuous rains brought about by the inter-tropical convergence zone (ITCZ) (Bagaforo, 2013).The University of the Philippines Mindanao is the partner HEI that is responsible for monitoring Lipadas River.

In line with this, a field survey in Lipadas River from June 28 to July 12, 2015 was conducted with the following scope of work: reconnaissance survey to assess the actual condition of the river and recovery of existing control points; courtesy call with UP Mindanao and LGUs of Davao City; control survey for the establishment of a control point at the approach of Lipadas Bridge II; cross-section, bridge-as-built and water level marking on Lipadas Bridge II; validation points acquisition along concrete roads with estimated distance of 28.7 km; and bathymetric survey of Lipadas River with an approximate length of 9.5 km as shown in Figure 28.

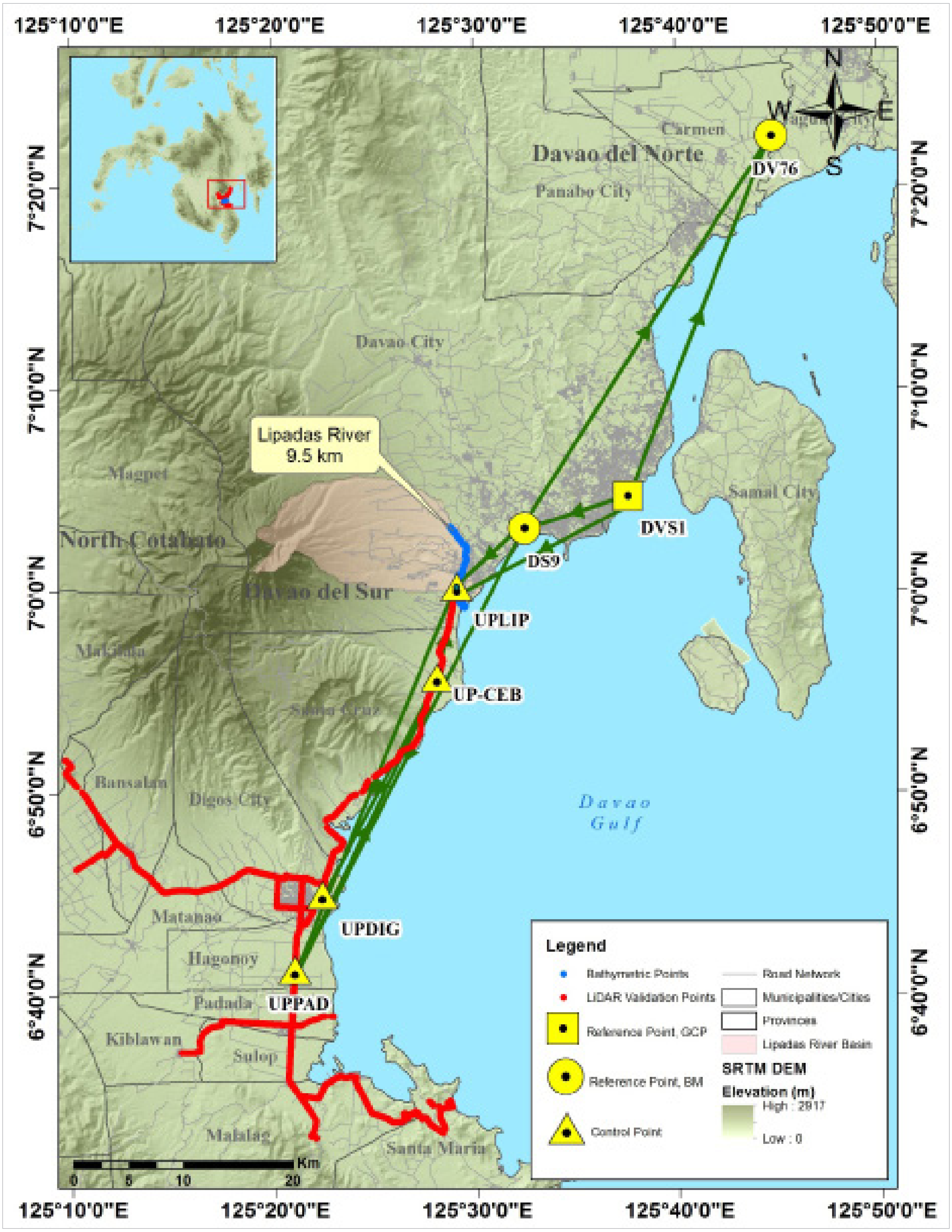


Figure 28. Lipadas River survey extent

4.2 Control Survey

The GNSS network used in Lipadas River survey was composed of six (6) loops established on July 4 and 5, 2015 with the following reference points: DVS-1, a first order GCP in Brgy. Leon Garcia Sr, Davao City, Davao Del Sur; and DV-76, a first order benchmark located Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte.

Five (5) control points were established along approach of bridges namely: UP-CEB at Cebulan Bridge in Brgy. Darong, Municipality of Sta. Cruz Davao Del Sur; UP-DIG in Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur; UP-LIP2 at Lipadas Bridge approach in Brgy. Lizada, Davao City, Daao Del Sur; and UP-PAD at Padada Bridge, in Brgy. Guihing, Muncipality of Hagonoy, Davao Del Sur. A NAMRIA established control point namely DS-9, located in Brgy. Talomo, Davao City, was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 21, and the GNSS network established is illustrated in Figure 29.

Figure 29. GNSS network covering the Lipadas River.

Table 21. List of Reference and Control Points used in Lipadas River Survey
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
DVS-1	1st order GCP	7°04'38.36201"	125°37'36.77094"	68.5	-	2013
DV-76	1st order BM	-	-	76.155	8.359	2007
DS-9	Used as Marker	-	-	-	-	2007
UP-CEB	UP Established	-	-	-	-	7-5-2015
UP-DIG	UP Established	-	-	-	-	7-5-2015
UP-LIP2	UP Established	-	-	-	-	7-4-2015
UP-PAD	UP Established	-	-	-	-	7-5-2015

The GNSS set up for control points used are shown in Figure 30 to Figure 36 respectively.

Figure 30. GNSS base receiver setup, Trimble® SPS 852 at DVS-1 at the east side of Pier, in Brgy. Leon Garcia Sr., Davao City, Davao Del Sur

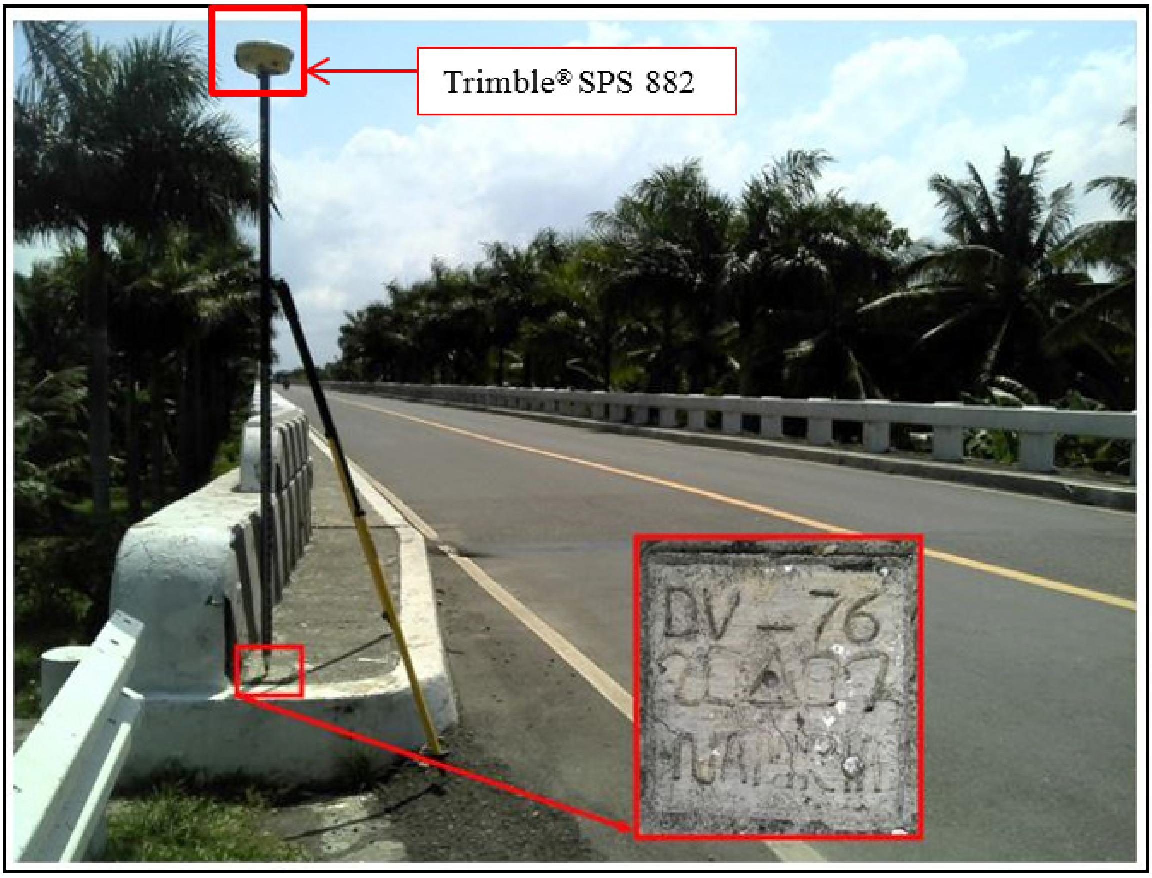


Figure 31. GNSS base receiver setup, Trimble® SPS 882 at DV-76 at the Gov. Miranda Bridge Approach, Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte

Figure 32. GNSS base receiver setup, Trimble® SPS 882 at DS-09 located at stair of Nograles Park along Mac Arthur Highway, in Brgy. Talomo, Davao City, Davao Del Sur

Figure 33. GNSS base receiver setup, Trimble® SPS 852 at UP-CEB on the right approach of Cebulan Bridge in Brgy Darong, Municipality of Santa Cruz, Davao Del Sur

Figure 34. GNSS base receiver setup, Trimble® SPS 882 at UP-DIG, right approach of Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur

Figure 35. GNSS base receiver setup, Trimble® SPS 852 at UP-LIP2, on the right approach of Lipadas Bridge along National Highway in Brgy. Lizada, Toril District, Davao Del Sur

Figure 36. GNSS base receiver setup, Trimble® SPS 882 at UP-PAD, Padada Bridge, Brgy. Guihing, Municipality of Hagonoy, Davao del Sur

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing 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 Lipadas River Basin is summarized in Table 22, generated by TBC software.

Table 22. Baseline Processing Report for Lipadas River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
UPPAD --- UPCEB	7-4-2015	Fixed	0.005	0.024	26°11'09"	29668.539	20.427
DVS1 --- DS9	6-30-2015	Fixed	0.004	0.013	252°53'03"	9875.482	3.720
DVS1 --- UPLIP2	7-4-2015	Fixed	0.003	0.016	242°19'23"	17735.680	10.641
UPLIP2 --- UPPAD	7-4-2015	Fixed	0.004	0.017	203°09'13"	37929.527	4.455
UPLIP2 --- UPCEB	7-4-2015	Fixed	0.004	0.024	192°23'44"	8451.500	24.864
UPPAD --- UPTOL	7-4-2015	Fixed	0.003	0.014	240°13'14"	2487.973	1.230
DVS1 --- DS9	6-30-2015	Fixed	0.006	0.033	252°53'03"	9875.477	3.723
DS9 --- UPLIP2	6-30-2015	Fixed	0.006	0.042	229°36'22"	8229.009	6.907
UPLIP2 --- DS9	6-30-2015	Fixed	0.006	0.035	229°36'23"	8228.967	6.965
DS9 --- UPPAD	6-30-2015	Fixed	0.011	0.036	207°47'10"	45445.416	11.450
DS9 --- UPCEB	7-5-2015	Fixed	0.011	0.046	210°44'50"	15809.215	31.878
DS9 --- DV76	6-30-2015	Fixed	0.005	0.049	32°23'13"	42306.620	3.850
DVS1 --- DV76	7-5-2015	Fixed	0.003	0.015	21°57'24"	35381.584	7.644
UPLIP2 --- DV76	7-5-2015	Fixed	0.006	0.021	35°09'36"	50225.907	-2.996
DS9 --- UPDIG	6-30-2015	Fixed	0.006	0.039	209°08'05"	38212.638	8.511
UPLIP2 --- UPDI	7-5-2015	Fixed	0.003	0.017	203°44'17"	30638.805	1.495
UPDIG --- UPPAD	7-5-2015	Fixed	0.004	0.017	200°41'13"	7298.998	2.930
UPDIG --- UPCEB	7-5-2015	Fixed	0.004	0.025	27°58'39"	22414.077	23.379

As shown in Table 22 a total of 18 baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table 24 of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for the complete details.

The seven (7) control points, DVS-1, DV-76, DS-9, UP-CEB, UP-DIG, UP-LIP2 and UP-PAD were occupied and observed simultaneously to form GNSS LOOP. Coordinates of DVS-1 and elevation value of DV-76 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
DVS-1	Global	Fixed	Fixed	Fixed	
Global	Fixed	Fixed			
DV-76	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control point DV-76 and DVS-1, has no values for standard elevation and coordinates error, respectively.

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
DS9	780765.613	0.009	780155.271	0.007	3.801	0.079	
DV76	803241.598	0.008	816030.498	0.008	8.359	?	e
DVS1	790192.921	?	783116.705	?	0.771	0.064	LL
UPCEB	772752.259	0.012	766517.370	0.011	34.883	0.097	
UPDIG	762330.012	0.011	746661.467	0.009	10.556	0.090	
UPLIP2	774523.929	0.008	774785.649	0.007	10.067	0.072	
UPPAD	759783.560	0.011	739817.613	0.010	13.208	0.089	

The networks are fixed at reference points DVS-1 and DV-76. With the mentioned equation, $\sqrt{(x_e)^2 + (y_e)^2} < 20\ cm$ and $z_e < 10\ cm$ for the vertical, the computations for the horizontal and vertical accuracy are as follows:

a. DVS-1

horizontal accuracy = Fixed
vertical accuracy = 6.4cm < 10 cm

b. DV-76

horizontal accuracy = √((0.8)² + (0.8)²
= √(0.64 + 0.64)
= 1.13 cm < 20 cm
vertical accuracy = Fixed

c. DS-09

horizontal accuracy = √((0.9)² + (0.7)²
= √(0.81 + 0.49)
= 1.14 cm < 20 cm
vertical accuracy = 7.9 cm < 10 cm

d. UP-CEB

horizontal accuracy = √((1.2)² + (1.1)²
= √(1.44 + 1.21)
= 2.69 cm < 20 cm
vertical accuracy = 1.63 cm < 10 cm

e. UP-DIG

horizontal accuracy = √((1.1)² + (0.9)²
= √(1.21 + 0.81)
= 1.42 cm < 20 cm
vertical accuracy = 9.0 cm < 10 cm

f. UP-LIP2

horizontal accuracy = √((0.8)² + (0.7)²
= √(0.64+ 0.49
= 1.06 cm < 20 cm
vertical accuracy = 7.2 cm< 10 cm

g. UP-PAD

horizontal accuracy = √((1.1)² + (1.0)²
= √(1.21 + 1.0)
= 1.49 cm < 20 cm
vertical accuracy = 8.9 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the seven (7) occupied control points are within the required accuracy of the program.

Table 25.Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
DS9	N7°03'03.72282"	E125°32'29.23786"	72.195	0.079	
DV76	N7°22'26.51286"	E125°44'48.14120"	76.155	?	e
DVS1	N7°04'38.36201"	E125°37'36.77094"	68.500	0.064	LL
UPCEB	N6°55'41.41306"	E125°28'05.94638"	104.051	0.097	
UPDIG	N6°44'57.07991"	E125°22'23.41362"	80.677	0.090	
UPLIP	N7°00'10.77316"	E125°29'05.16478"	78.215	0.089	
UPLIP2	N7°00'10.11838"	E125°29'05.04512"	79.165	0.072	
UPPAD	N6°41'14.79422"	E125°20'59.46050"	83.620	0.089	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
DVS-1	1st Order GCP	7°04'38.36201"	125°37'36.77094"	68.5	783116.705	790192.921	0.771
DV-76	1st Order M	7°22'26.51286"	125°44'48.14120"	76.155	816030.498	803241.598	8.359
DS-9	Used as Marker	7°03'03.72282"	125°32'29.23786"	72.195	780155.271	780765.613	3.801
UP-CEB	UP Established	6°55'41.41306"	125°28'05.94638"	104.051	766517.37	772752.259	34.883
UP-DIG	UP Established	6°44'57.07991"	125°22'23.41362"	80.677	746661.467	762330.012	10.556
UP-LIP2	UP Established	7°00'10.11838"	125°29'05.04512"	79.165	774785.649	774523.929	10.067
UP-PAD	UP Established	6°41'14.79422"	125°20'59.46050"	83.62	739817.613	759783.56	13.208

4.5 Cross-section, bridge as-built and water level marking

Cross-section and as-built survey were conducted on June 30, 2015 at the downstream side of Lipadas Bridge I and Lipadas Bridge II using GNSS receiver, Trimble® SPS 882 in PPK survey technique as shown in Figure 37.

Figure 37 Cross-section and bridge as-built survey at the downstream side of Lipadas Bridge, Brgy. Lizada, Toril District, Davao del Sur

Cross-section survey of Lipadas Bridge I gathered seventy (70) points with an estimated length of 95.79 m while the Lipadas Bridge II cross-section gathered forty-nine (49) points with an estimated length of 83.15 m. The established point in the bridge, UP-LIP 2, served as the GNSS base station.

The summary of gathered cross-section for Lipadas Bridge 1 and Lipadas Bridge II is displayed in Figure 38 and Figure 39, respectively. While the location map is in Figure 40. The as-built data of Lipadas Bridge I and Lipadas Bridge II is shown in Figure 41 and Figure 42, respectively

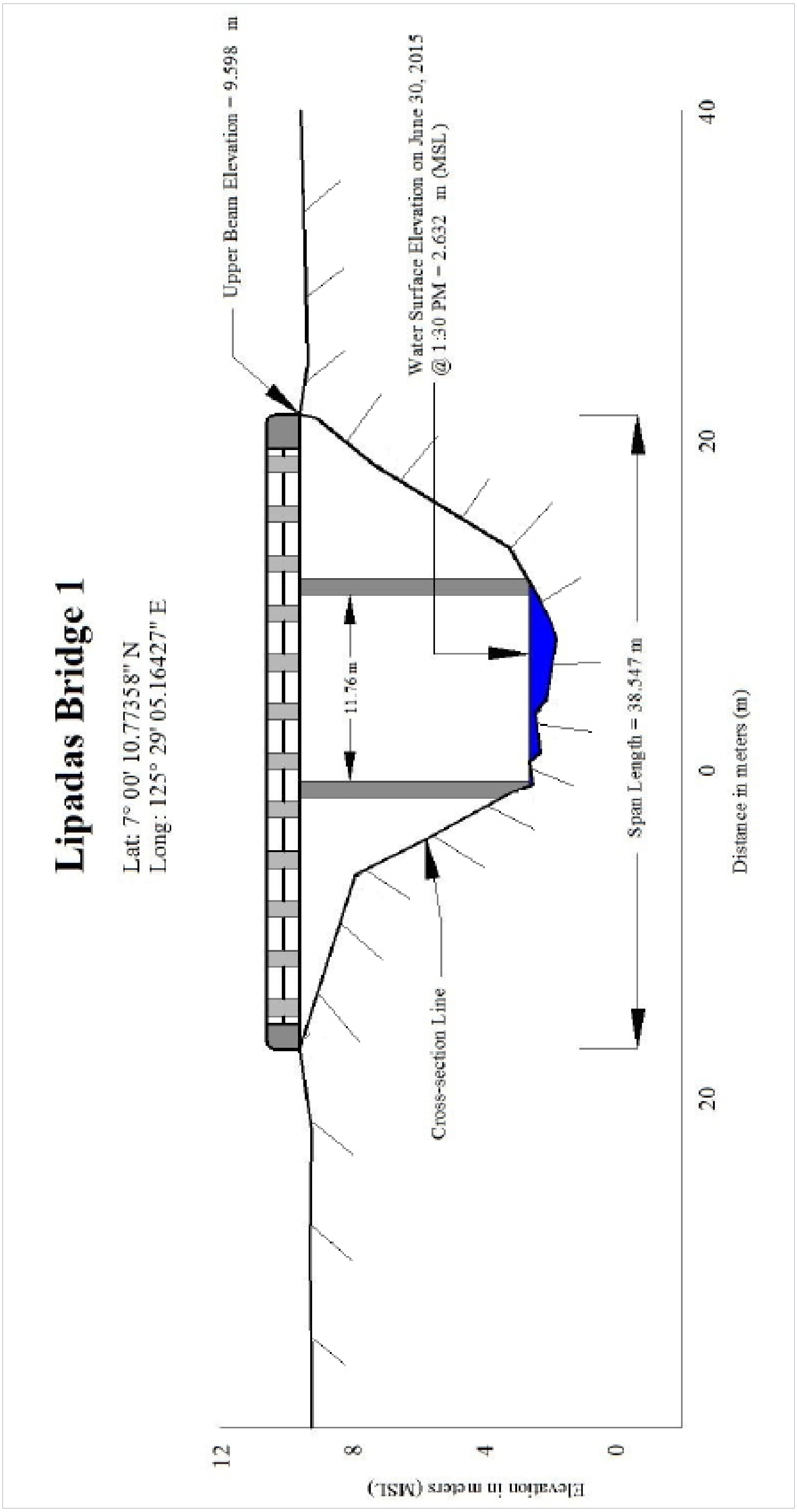


Figure 38 Lipadas Bridge I cross-sectional diagram

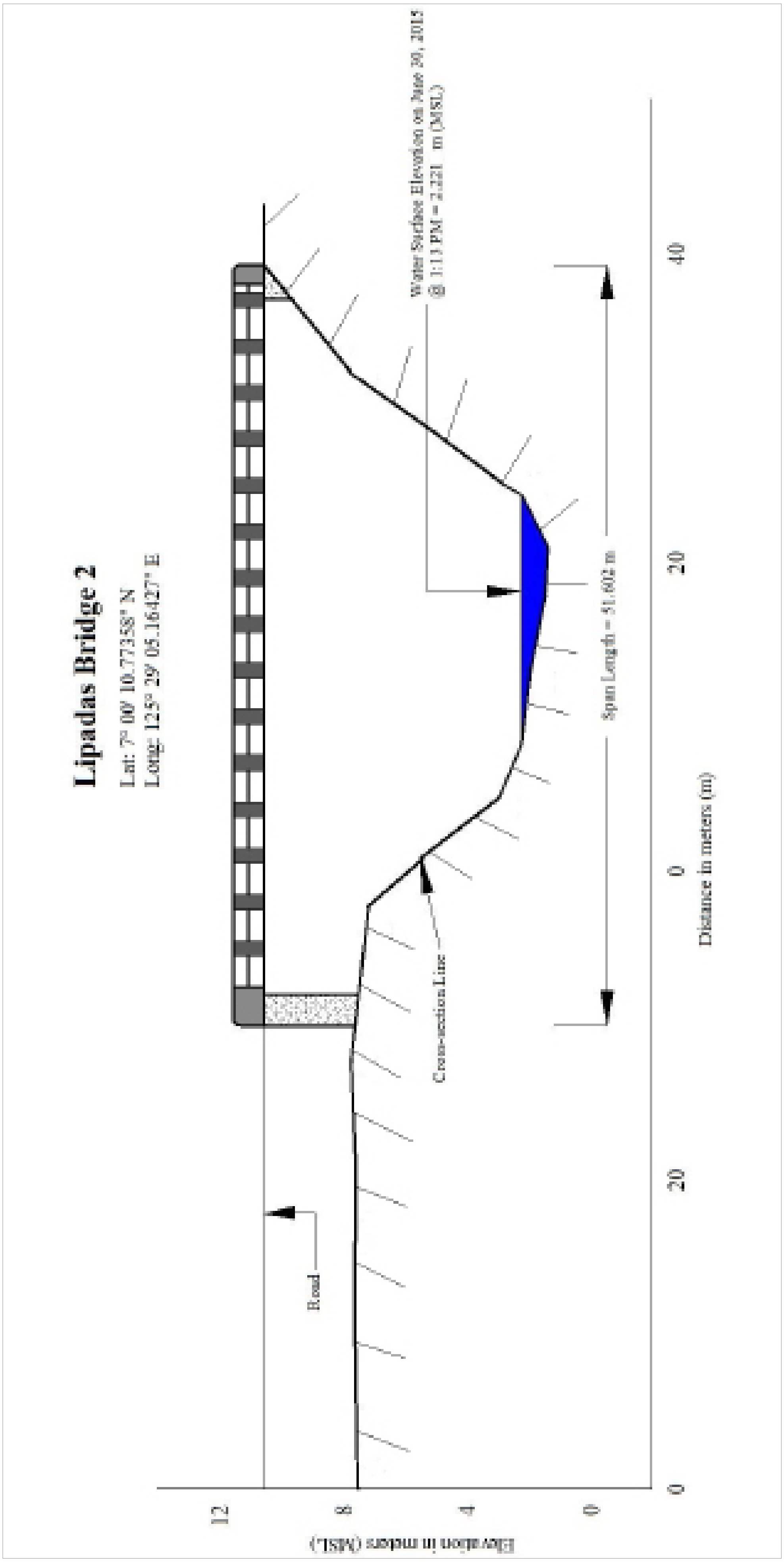


Figure 39. Lipadas Bridge II cross-sectional diagram

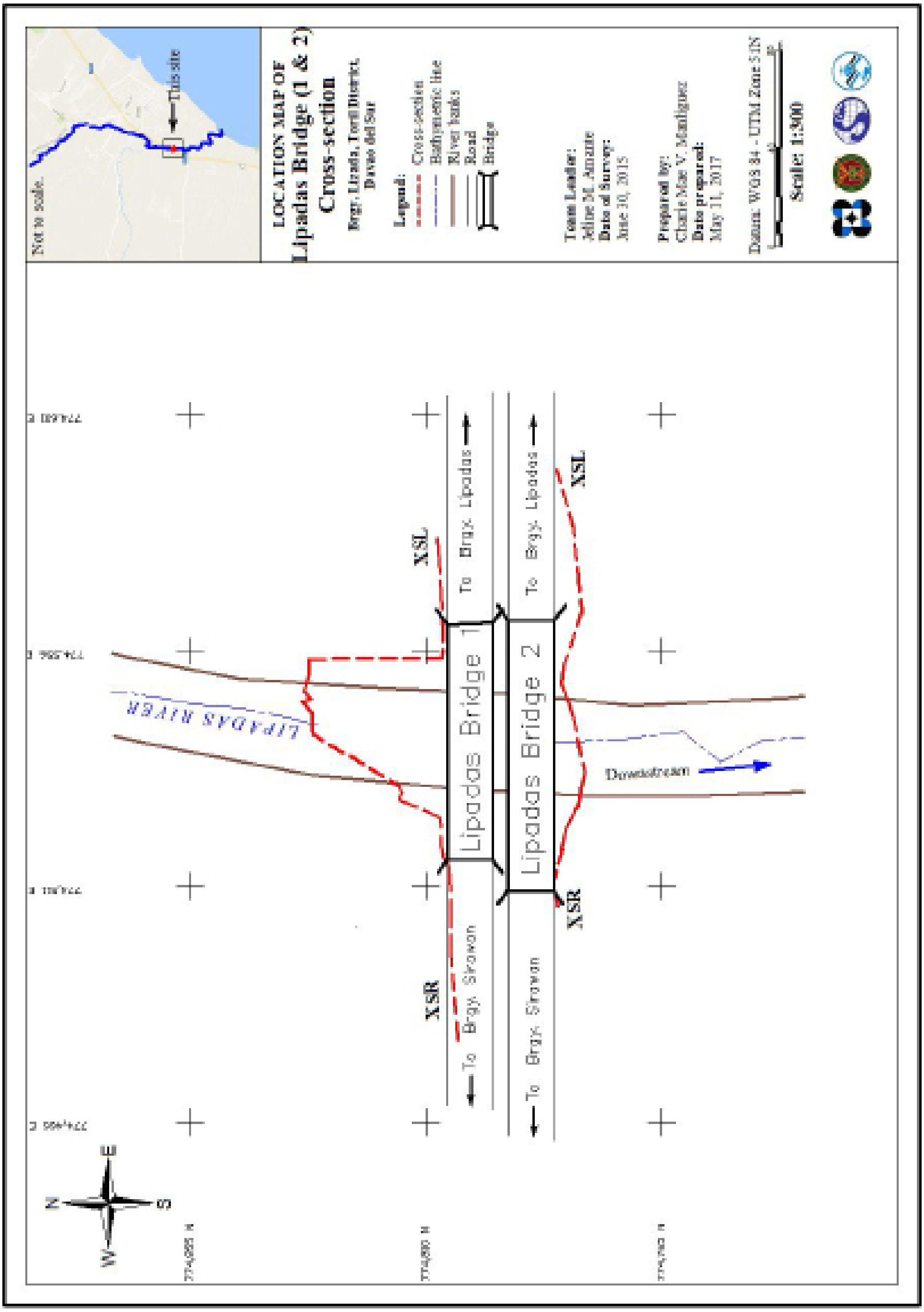


Figure 40. Lipadas 1 and 2 bridge cross-section location map

Bridge Data Form

Bridge Name: LIPADAS BRIDGE 1 **Date:** June 30, 2015

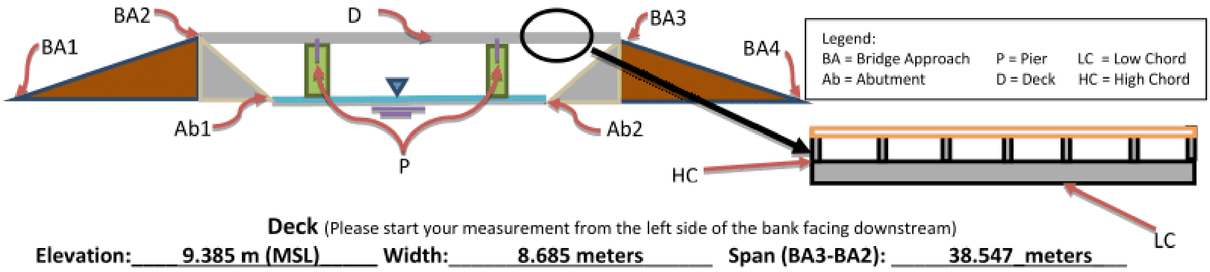
River Name: LIPADAS RIVER **Time:** 1:18 pm

Location (Brgy, City, Region): Brgy. Lizada, Toril District, Davao del Sur

Survey Team: DVBC/DVC Davao del Sur Survey Team

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

Latitude: 7°00'10.77358"N **Longitude:** 125°29'05.16427" E



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

Elevation: 9.385 m (MSL) **Width:** 8.685 meters **Span (BA3-BA2):** 38.547 meters

	Station	High Chord Elevation	Low Chord Elevation
1	-	9.598	-
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	9.2172	**BA3**	61.560	9.588
BA2	23.013	9.5852	**BA4**	95.793	9.719

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

	Station (Distance from BA1)	Elevation
Ab1	38.626	3.153
Ab2	53.494	3.218

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

Shape: ___ **Number of Piers:** 2 **Height of column footing:** ___

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	34.292	9.613	-
Pier 2	50.049	9.646	-
Pier 3			
Pier 4			

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

Figure 41. Lipadas Bridge I Data Form

Bridge Data Form

Bridge Name: LIPADAS BRIDGE 2 **Date:** June 30, 2015

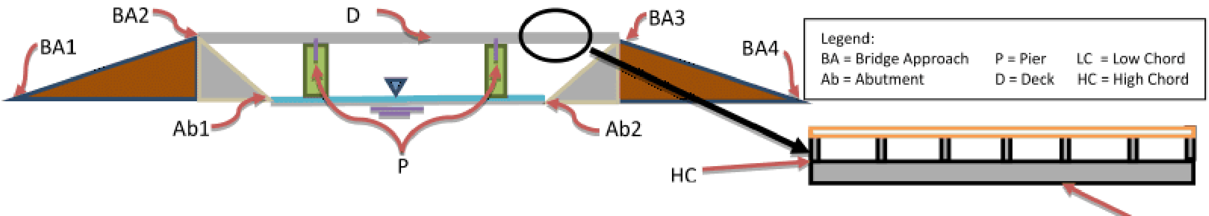
River Name: LIPADAS RIVER **Time:** 1:00 pm

Location (Brgy, City, Region): Brgy. Lizada, Toril District, Davao del Sur

Survey Team: DVBC/DVC Davao del Sur Survey Team

Flow condition: low <u>normal</u> high **Weather Condition:** <u>fair</u> rainy

Latitude: 7°00'10.77358"N **Longitude:** 125°29'05.16427" E



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

Elevation: 10.718 m (MSL) **Width:** ____ **Span (BA3-BA2):** 51.602 meters

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	7.524	**BA3**	79.252	10.564
BA2	27.649	7.715	**BA4**	83.149	10.563

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

	Station (Distance from BA1)	Elevation
Ab1	37.617	7.182
Ab2	72.283	7.816

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

Shape: ____ **Number of Piers:** 0 **Height of column footing:** ____

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	-	-	-
Pier 2	-	-	-
Pier 3			
Pier 4			

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

Figure 42. Lipadas Bridge II Data Form

Figure 43. Water level markings on the post of Lipadas Bridge II

Water surface elevation in MSL of Lipadas Bridge II was determined using Trimble® SPS 882 in PPK mode survey on June 30, 2015 at 1:30 P.M. This was translated onto marking the bridge's pier using a measuring tape. The marked pier, see Figure 43, shall serve as reference for flow data gathering and depth gauge deployment by the accompanying SUC, UP Mindanao, who is responsible for Lipadas River. Water surface elevation in MSL and water level marking on Lipadas Bridge I was no longer performed because Lipadas Bridges II does not have piers and because the two (2) bridges traverse the same river.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted from July 8 to 11, 2015 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the left side of the vehicle as shown in Figure 44. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.463 m from the ground up to the bottom of notch of the GNSS Rover receiver.

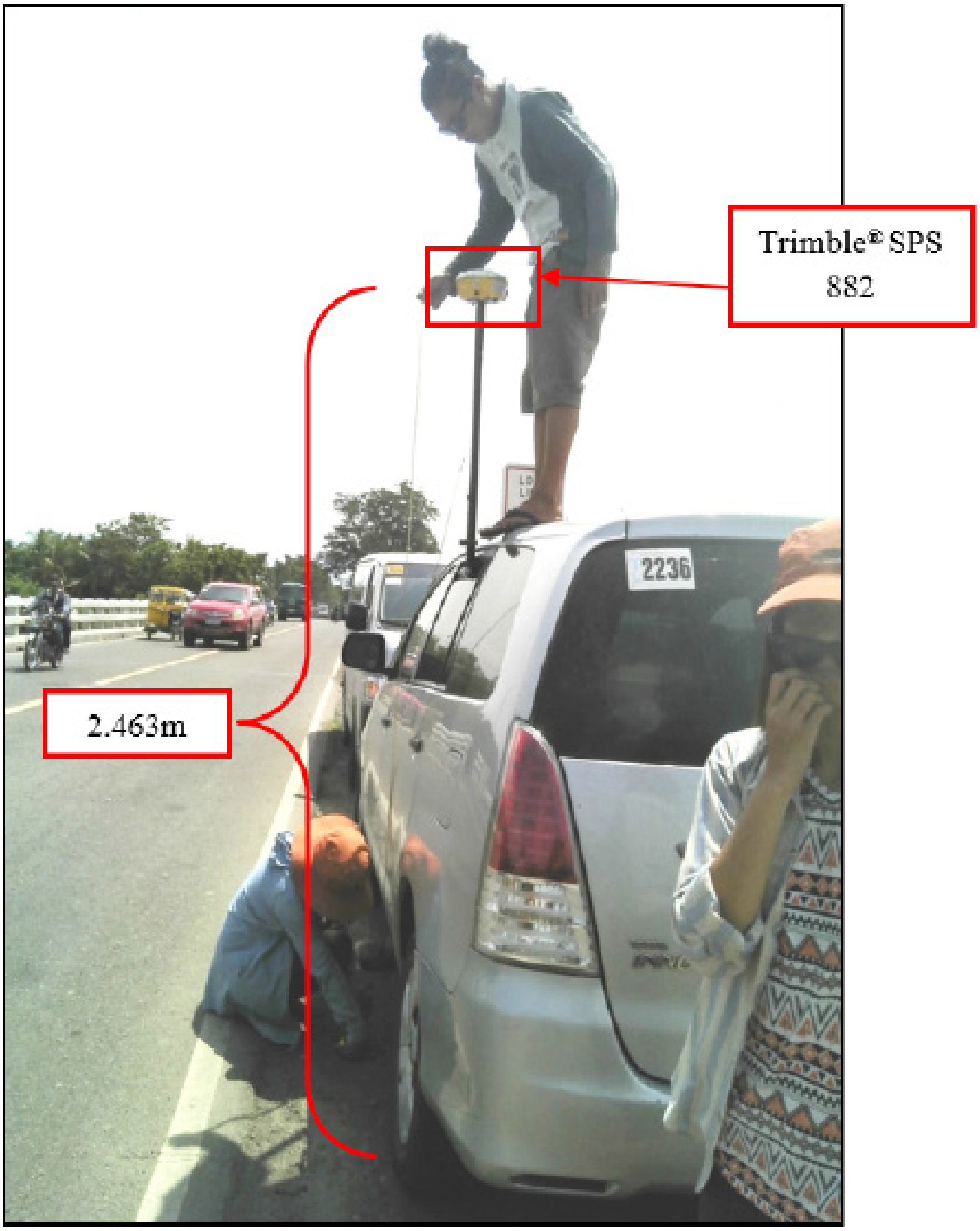


Figure 44 Validation points acquisition survey vehicle set up

The survey was conducted using PPK technique on a continuous topography mode, which covered the major roads of the Municipality of Santa Cruz and Davao City, as illustrated in Figure 45. The survey gathered a total of 2,927 validation points covering an approximate distance of 19.9 km using the control point UP-LIP 2 as the GNSS base station

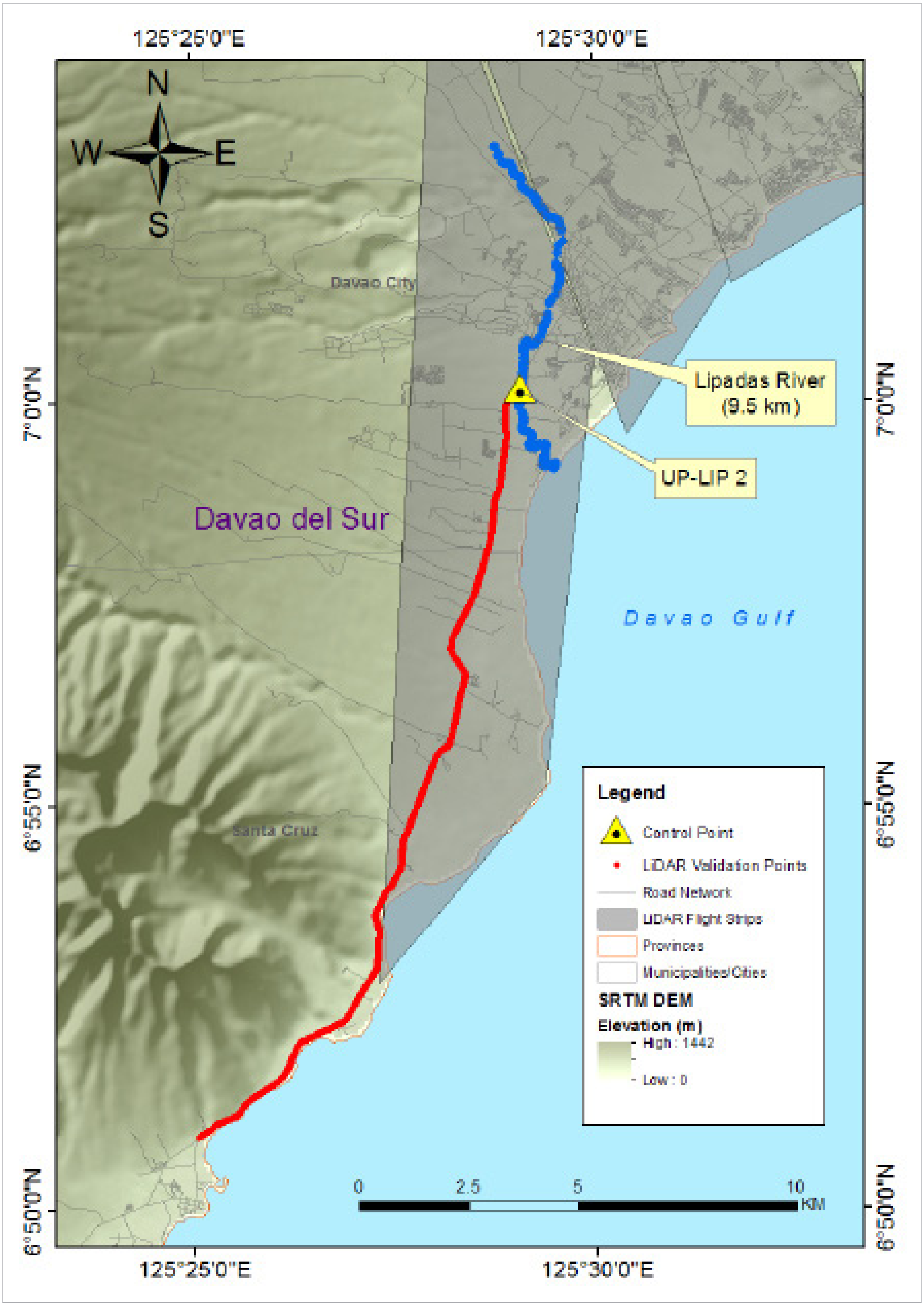


Figure 45 Validation points acquisition survey coverage for Lipadas River

4.7 River Bathymetric Survey

Manual bathymetric survey was conducted from July 1 to 2, 2015 using a survey grade GNSS Rover receiver Trimble® SPS 882 at Lipadas River shown in Figure 46. The survey started at the upstream part of the river in Brgy. Alambre, Davao City with coordinates 7°03'09.37675" 125°28'46.15610", traversed down the river by foot and ended at the mouth of the river in Brgy. Sirawan, Davao City with coordinates 6°59'10.24252" 125°29'30.07420". The control point UP-LIP 2 was occupied as GNSS base station for the survey.

Figure 46. Bathymetric survey in Lipadas River.

The survey gathered about 9.5 km of bathymetry line with a total of 1,953 bathymetric points gathered as shown in Figure 47 while a CAD drawing illustrating the riverbed profile is shown in Figure 48. An abrupt elevation drop of 93.9 m was observed within the distance of approximately 3.5 km from downstream in Brgy. Alambre to just after Piedad Bridge in Brgy. Toril. The bathymetric survey passed the barangay boundaries of Alambre, Lubogan, Toril, Lizada and Sirawan. The highest elevation observed was 114.263 m in MSL in Brgy. Alambre, while the lowest elevation observed was -2.673 m below MSL in Brgy. Sirawan.

Figure 47. Bathymetric survey of Lipadas River

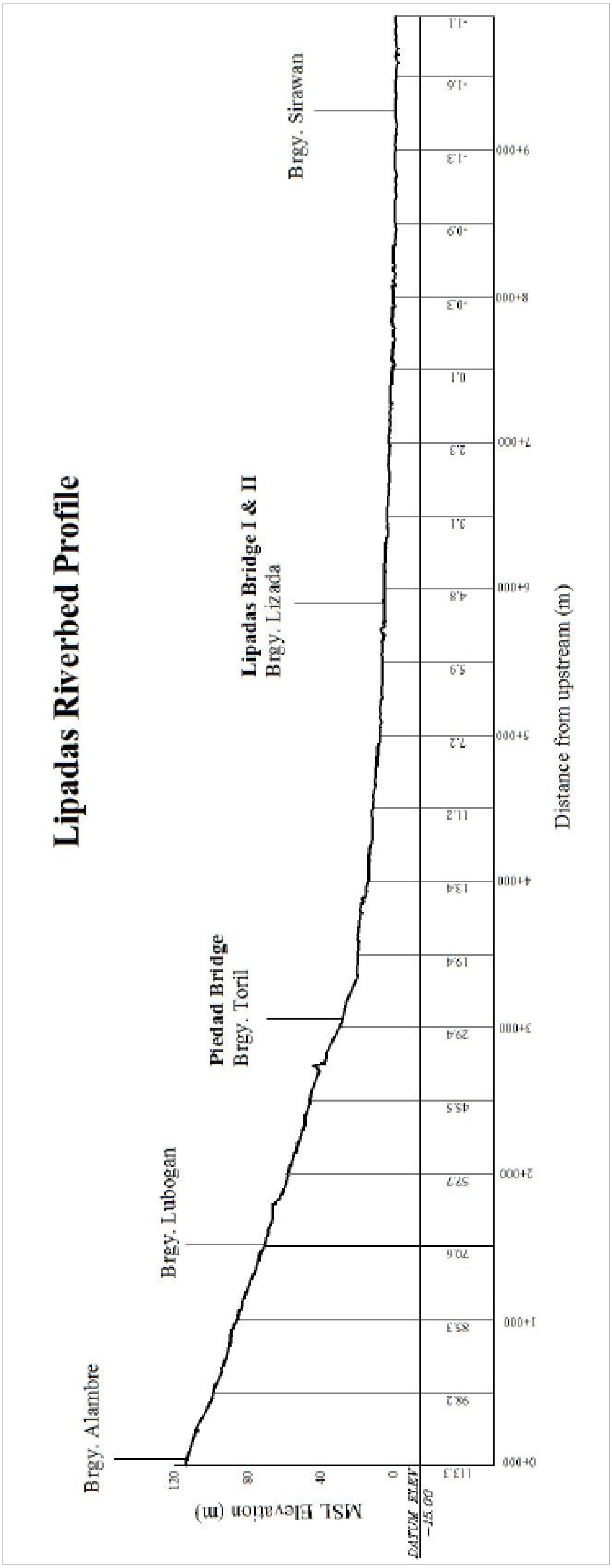


Figure 48. Lipadas Riverbed Profile

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, and 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 Tungkalan, Davao, Davao del Sur with the following coordinates: 7° 2' 4.27" N, 125° 30' 8.89" E (Figure 49). The precipitation data collection started from August 17, 2015 at 6:00 PM to 10:00 PM on the same day with a 10-minute recording interval.

The total precipitation for this event in the installed rain gauge was 5 mm. It has a peak rainfall of 1.6 mm. on August 17, 2015 at 7:10 PM. The lag time between the peak rainfall and discharge is 30 minutes.

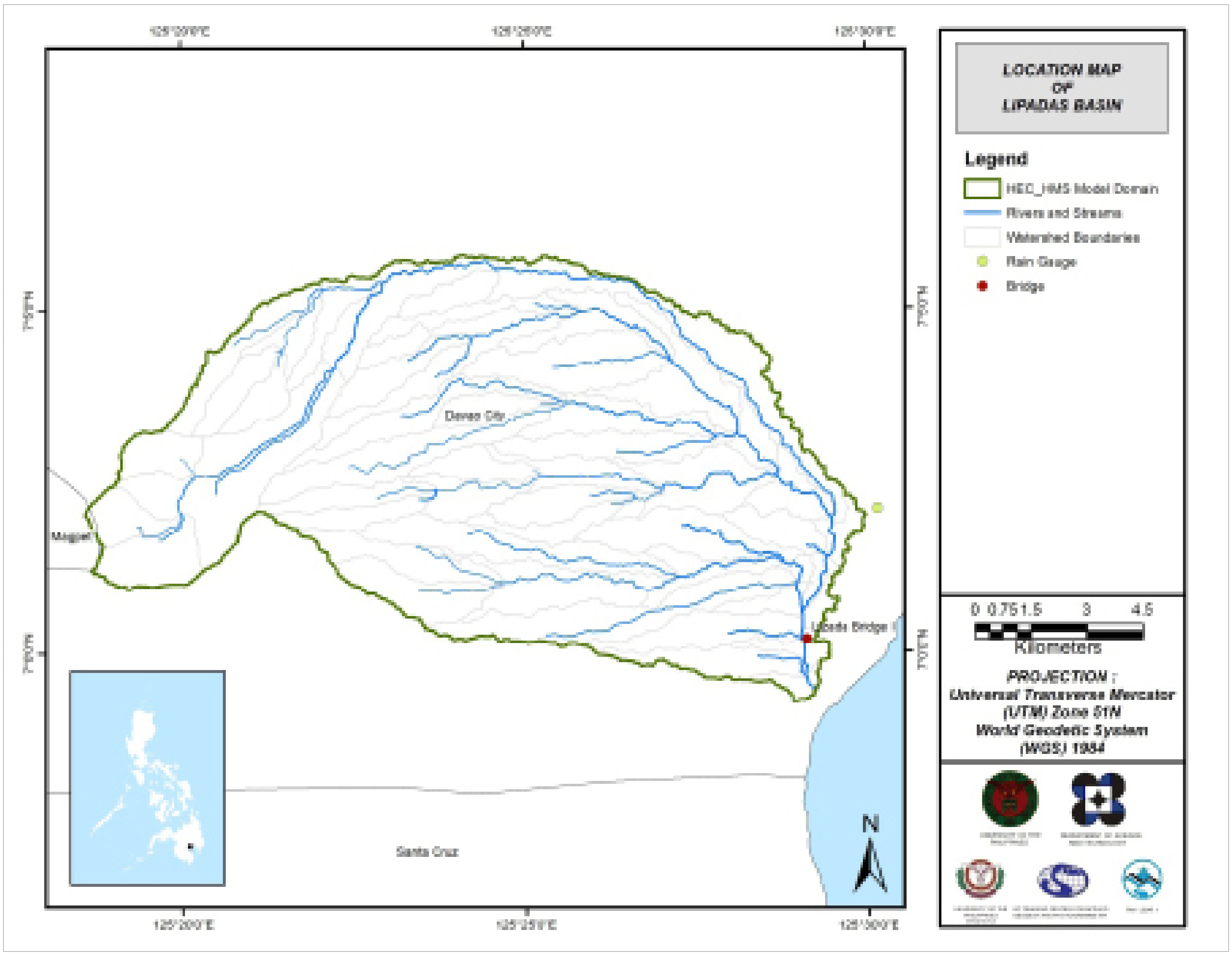


Figure 49. The location map of Lipadas HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Lipadas Bridge, Barangay Lizada, Davao, Davao del Sur (7° 0' 10.22" N, 125° 29' 6.83" E). It gives the relationship between the observed water level at the Lipadas Bridge and outflow of the watershed at this location.

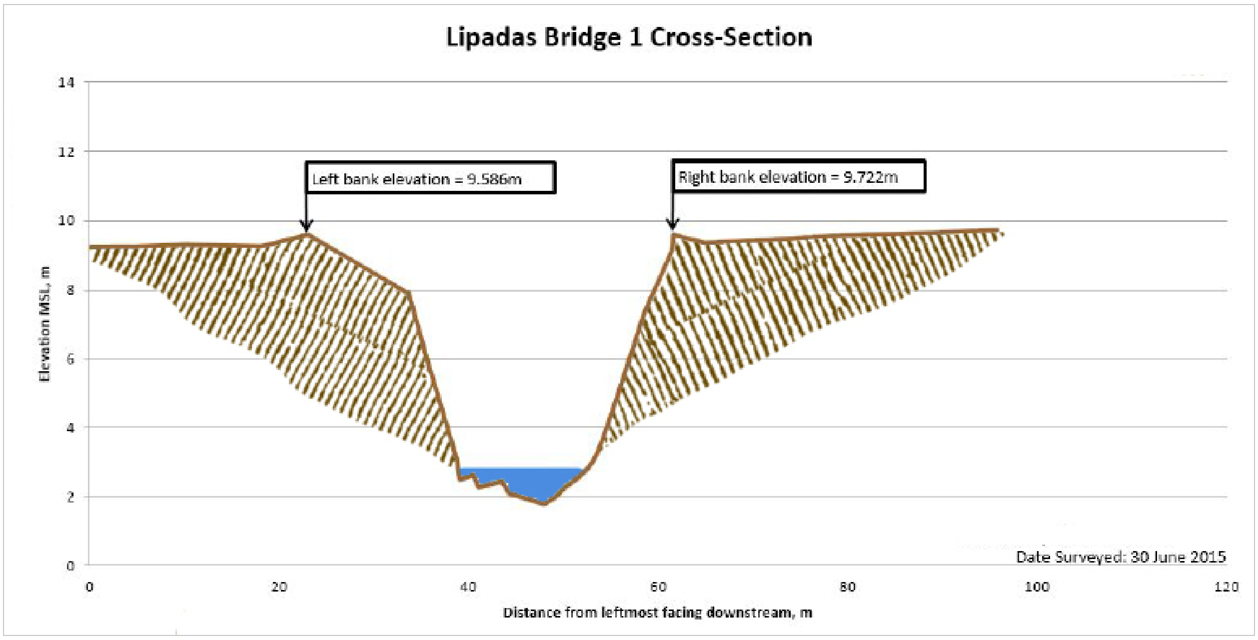


Figure 50. Cross-Section Plot of Lipadas Bridge

For Lipadas Bridge, the rating curve is expressed as Q = y = 0.0003e3.1551x as shown in Figure 51.

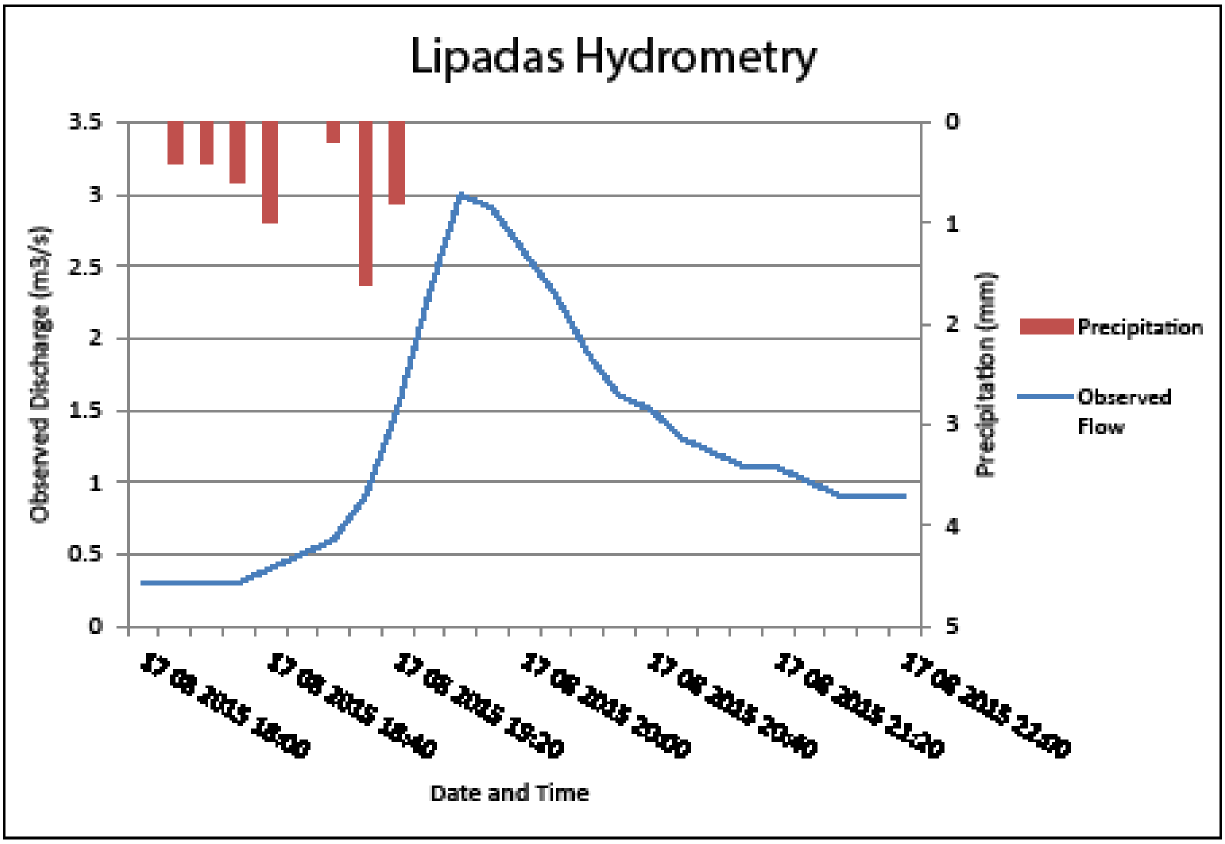


Figure 51. Rating Curve at Lipadas Bridge, Davao, Davao del Sur

The rating curve equation was used to compute for the river outflow at Lipadas Bridge for the calibration of the HEC-HMS model for Lipadas, as shown in Figure 52. The total rainfall for this event is 5 mm and the peak discharge is 3 m3/s at 7:40 PM of August 17, 2015.

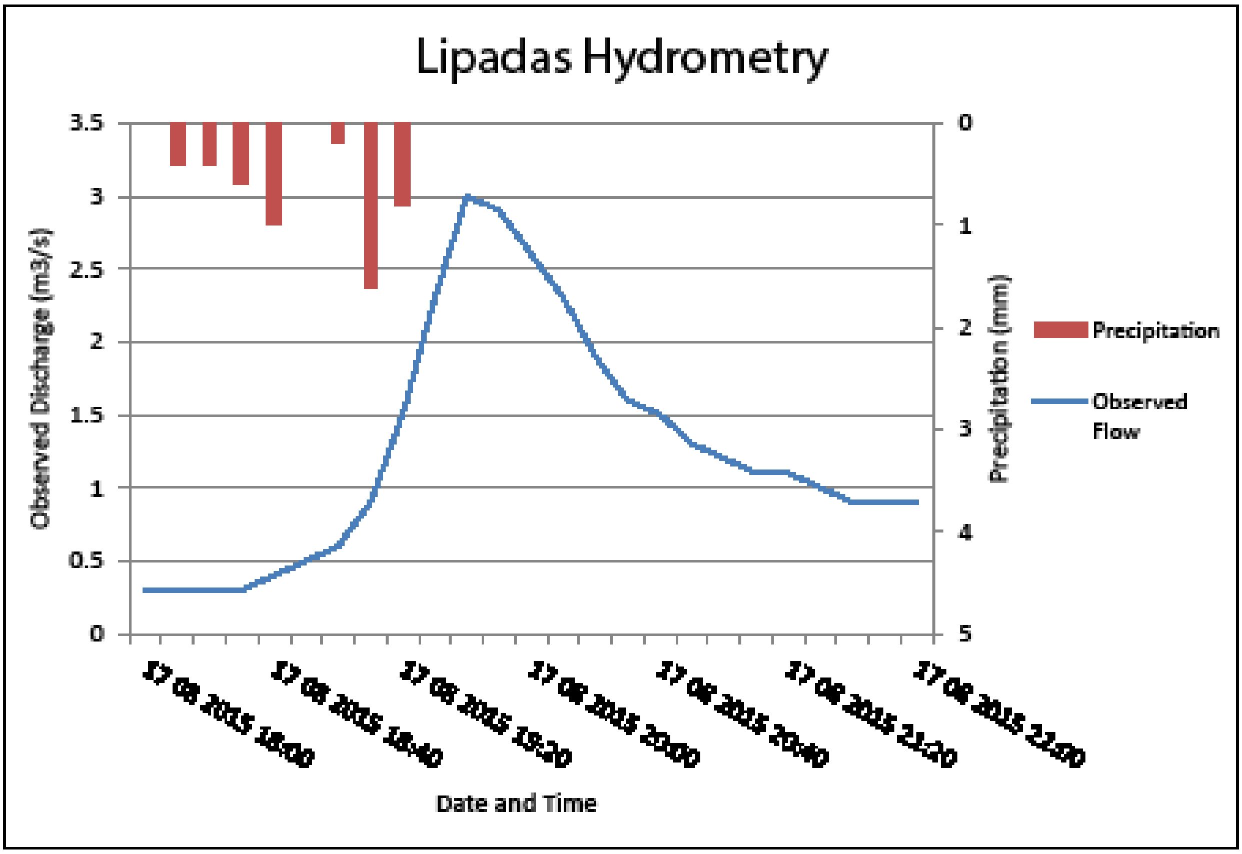


Figure 52. Rainfall and outflow data at Lipadas Bridge used for modeling

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 Lipadas watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 27. 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

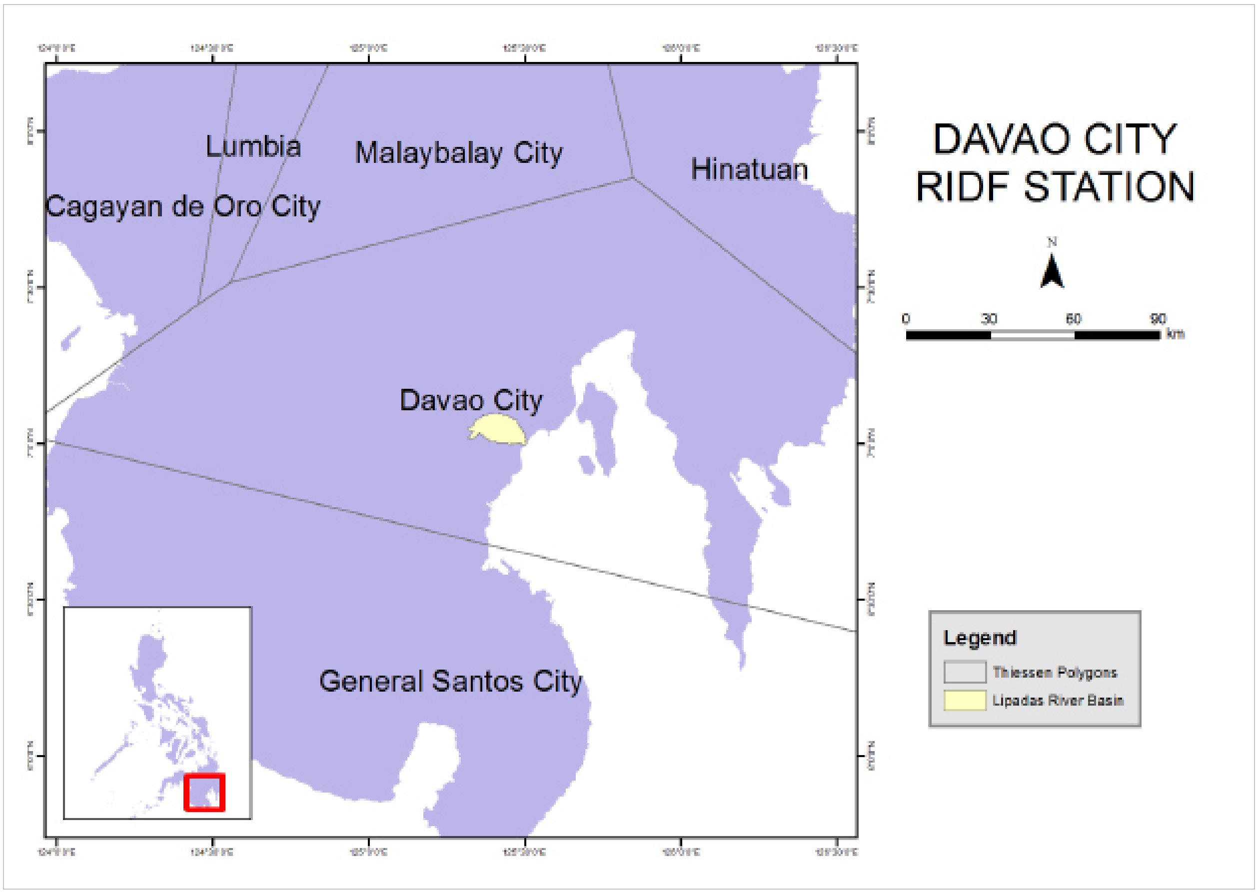


Figure 53. Location of Davao RIDF Station relative to Lipadas River Basin

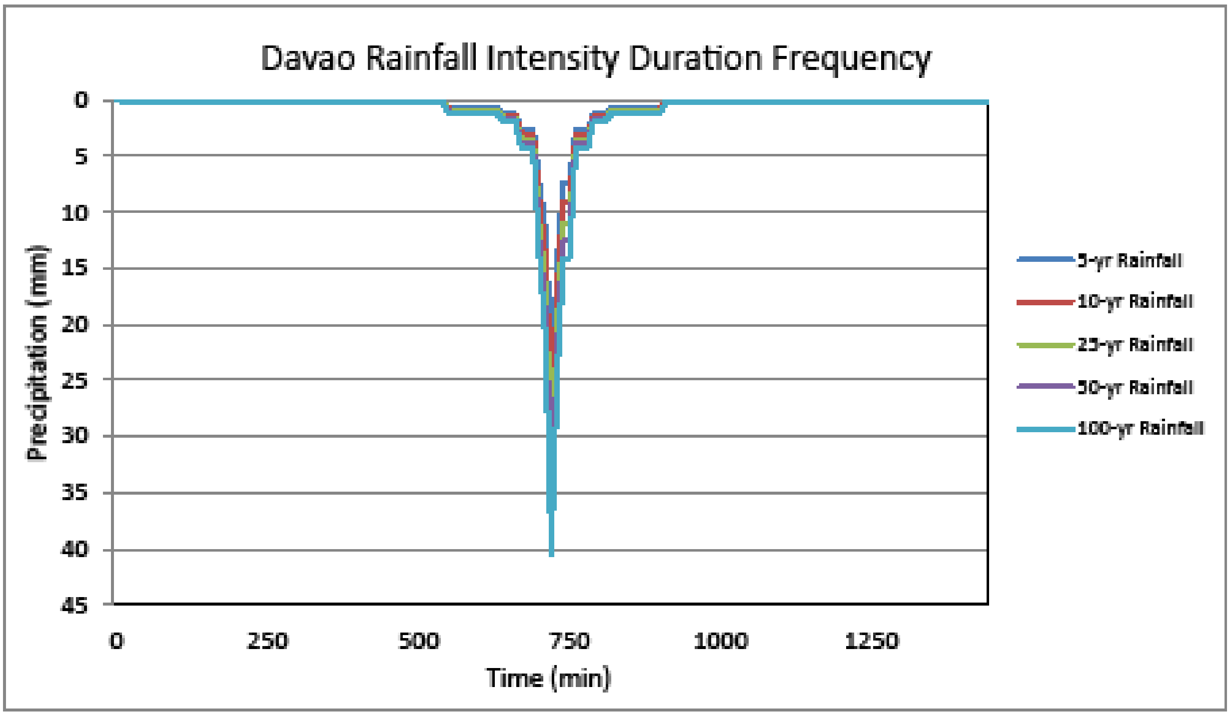


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

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 Lipadas River Basin are shown in Figures 55 and 56 respectively.

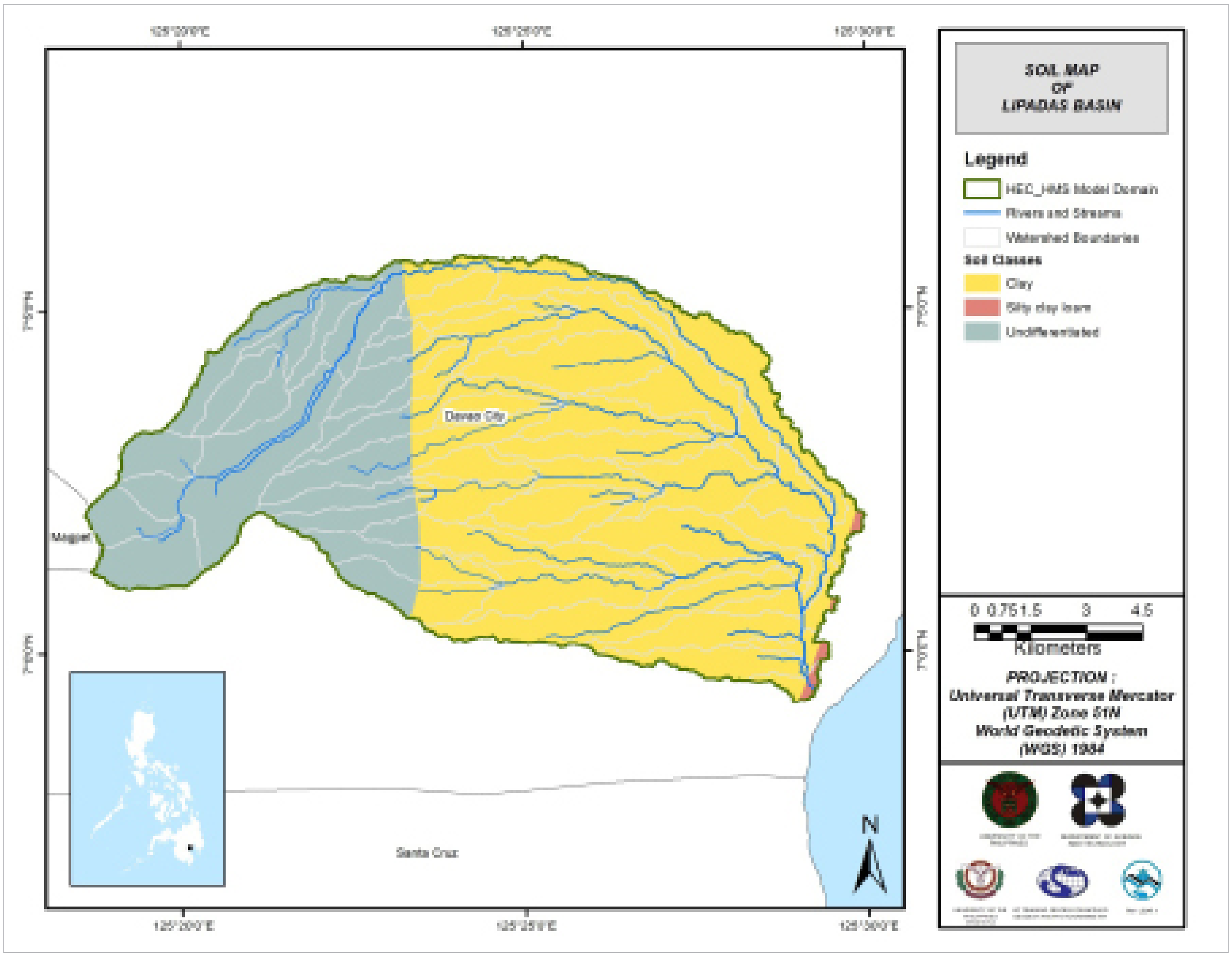


Figure 55. Soil Map of Lipadas River Basin

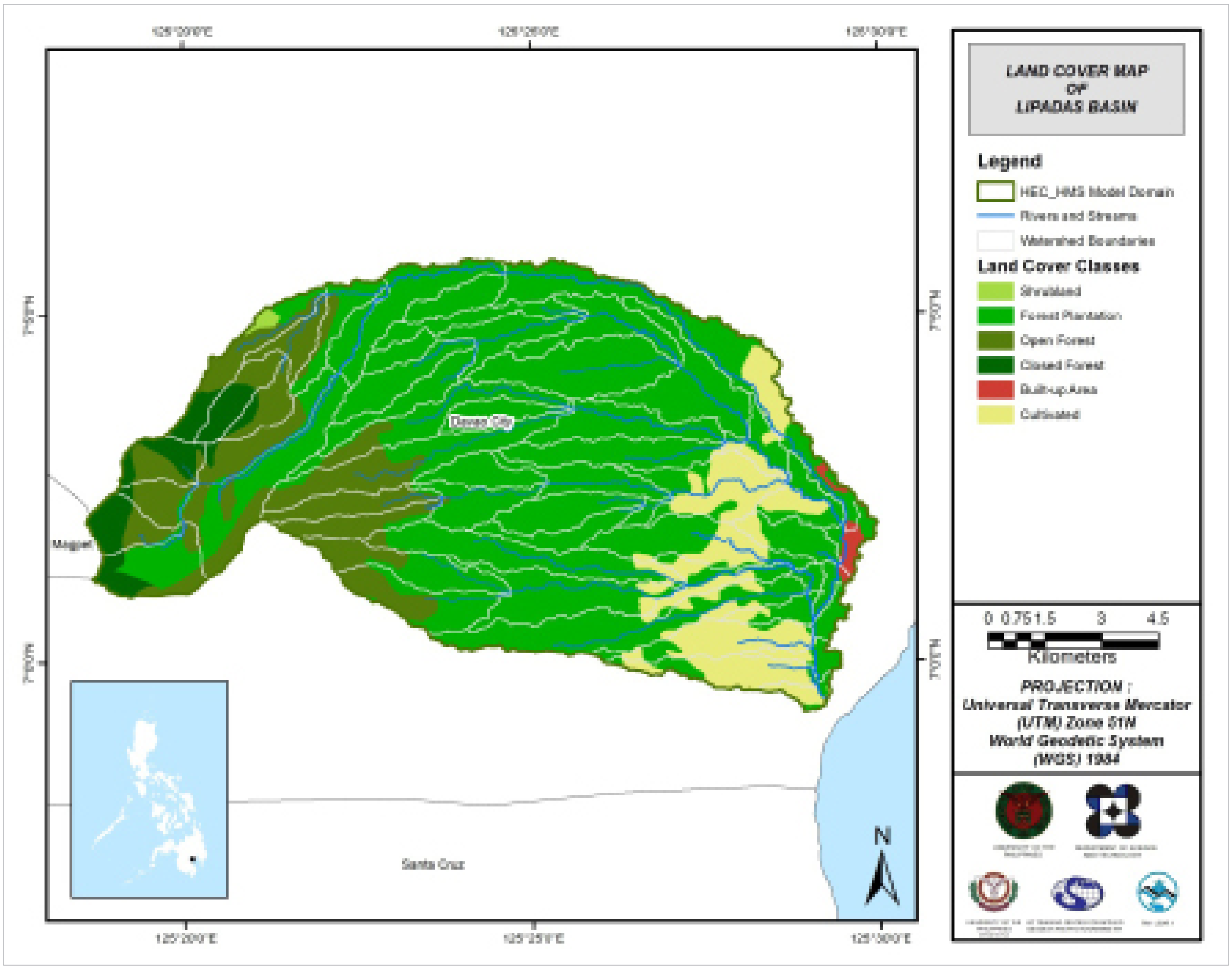


Figure 56. Land Cover Map of Lipadas River Basin

For Lipadas, three soil classes were identified. These are clay, silty clay loam and undifferentiated land. Moreover, six land cover classes were identified. These are shrublands, forest plantations, open forests, closed forests, built-up areas, and cultivated areas.

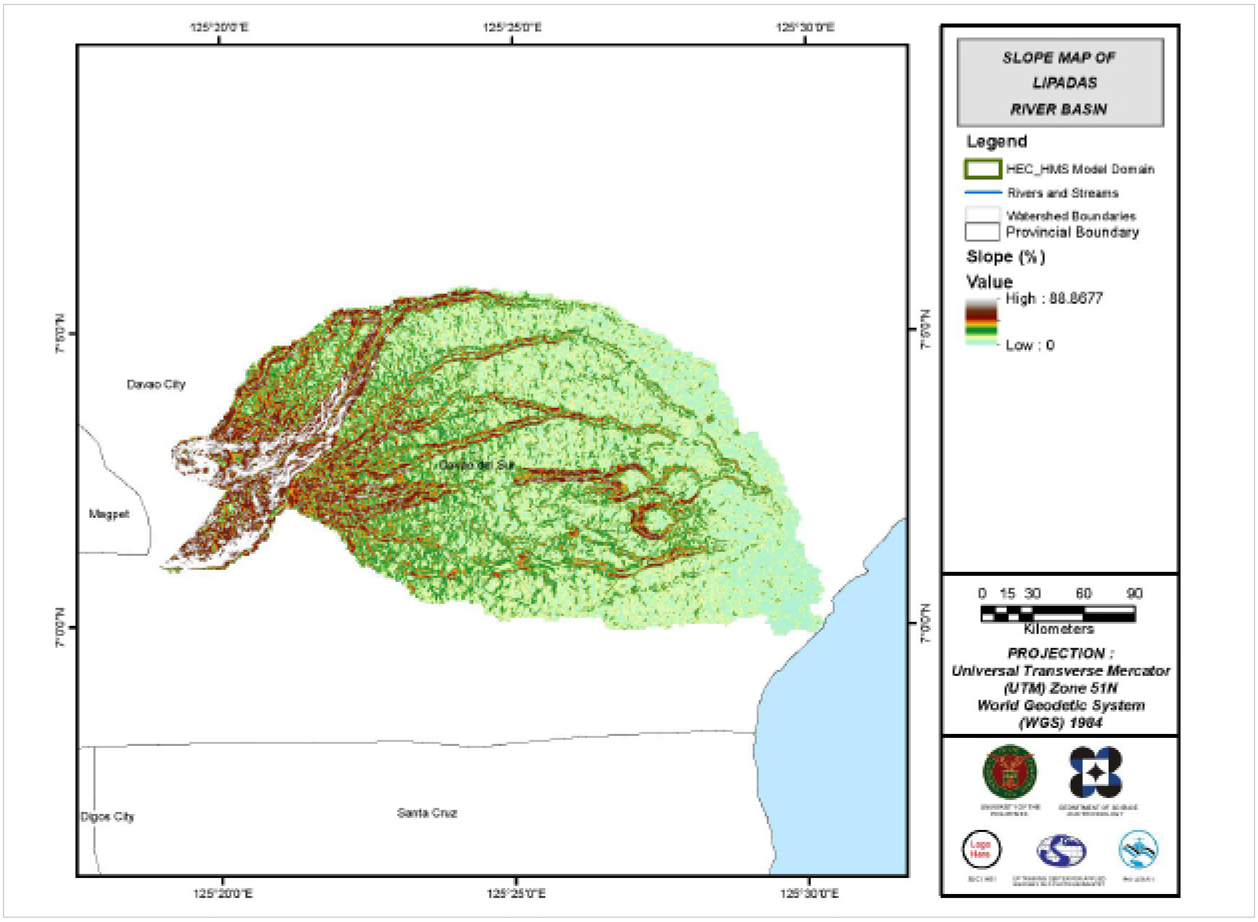


Figure 57. Slope Map of Lipadas River Basin

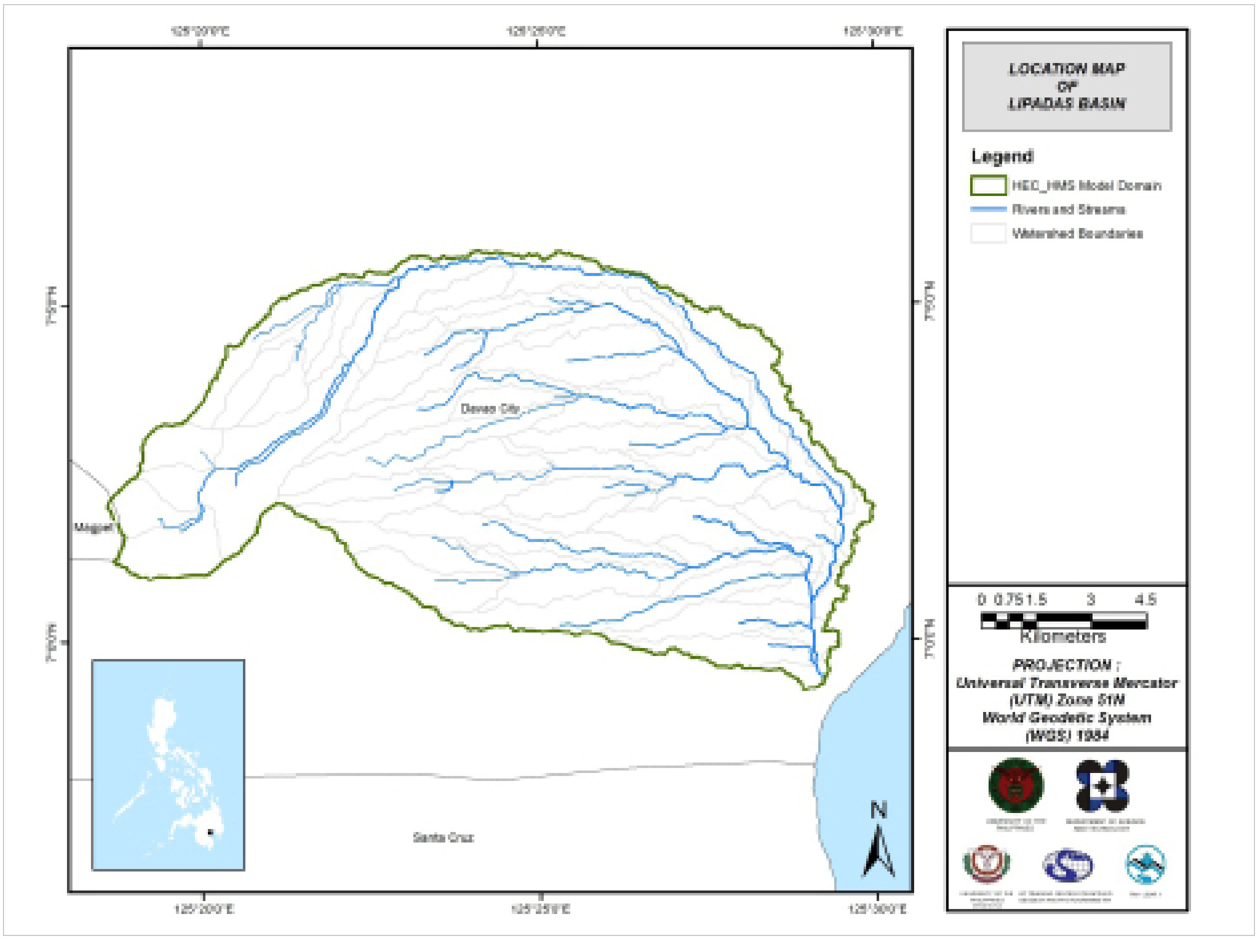


Figure 58. Stream Delineation Map of Lipadas River Basin

Using the SAR-based DEM, the Lipadas basin was delineated and further subdivided into subbasins. The model consists of 57 sub basins, 28 reaches, and 28 junctions, as shown in Figure 59. The main outlet is at Lipadas Bridge.

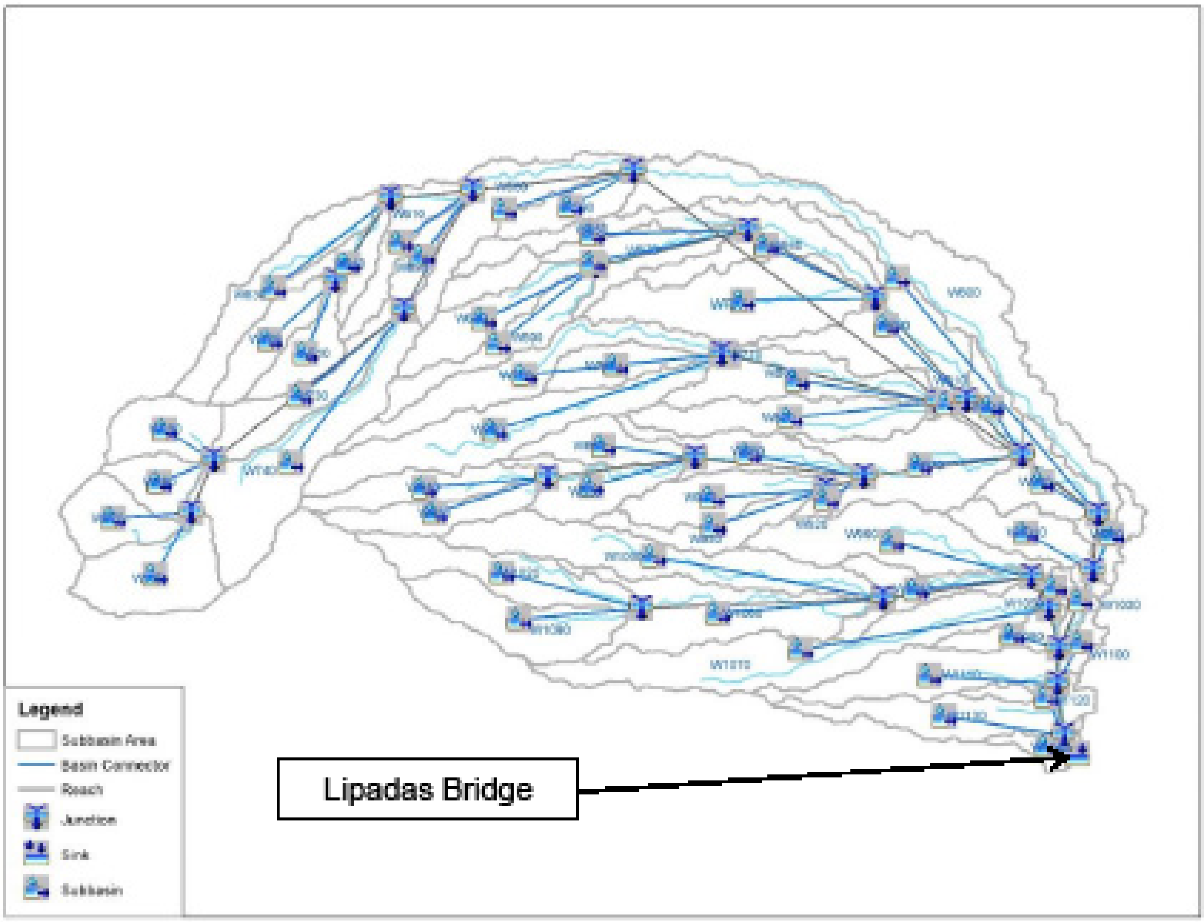


Figure 59. The Lipadas river basin model generated using HEC-HMS.

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.

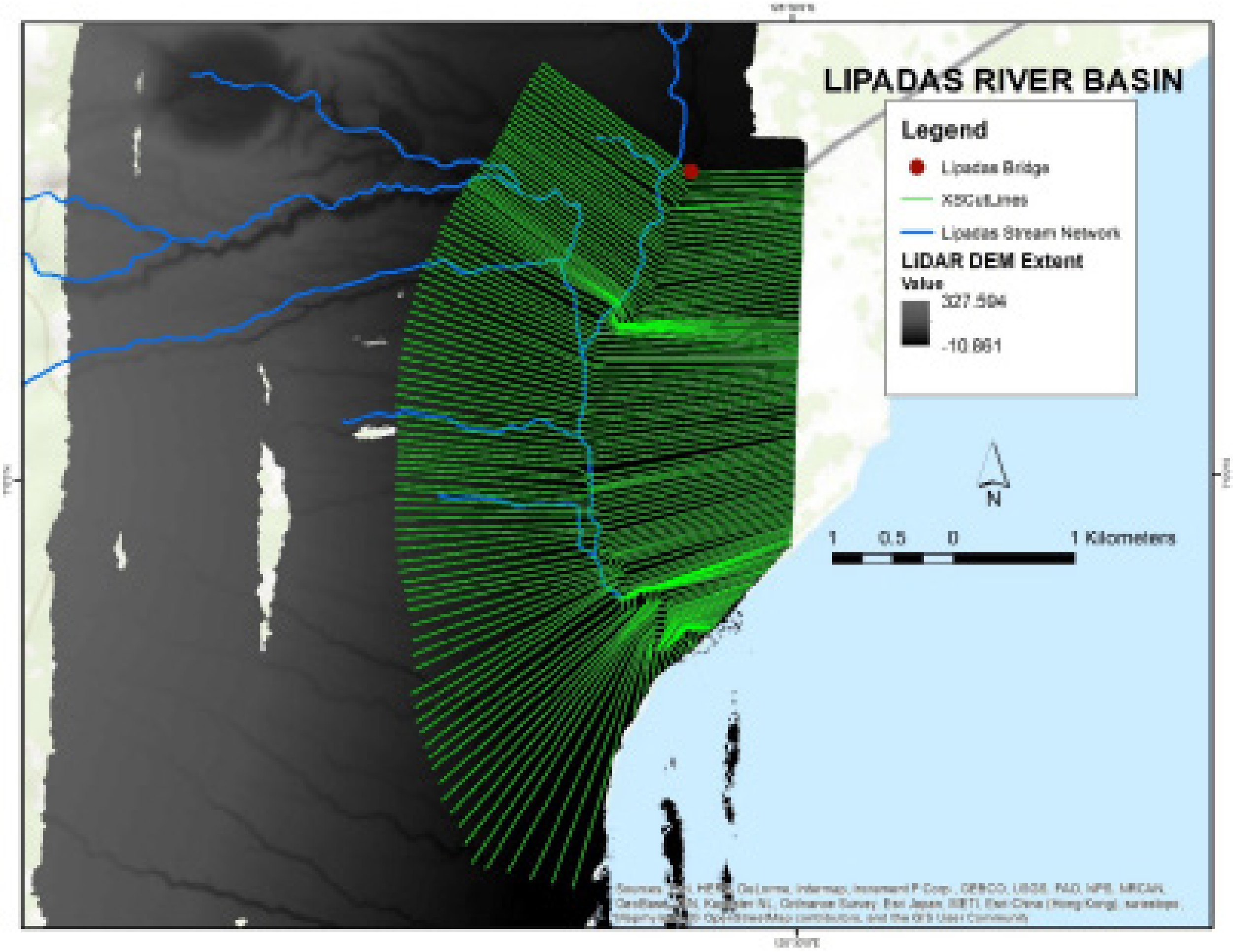


Figure 60. River cross-section of Lipadas River generated through Arcmap HEC GeoRAS tool

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

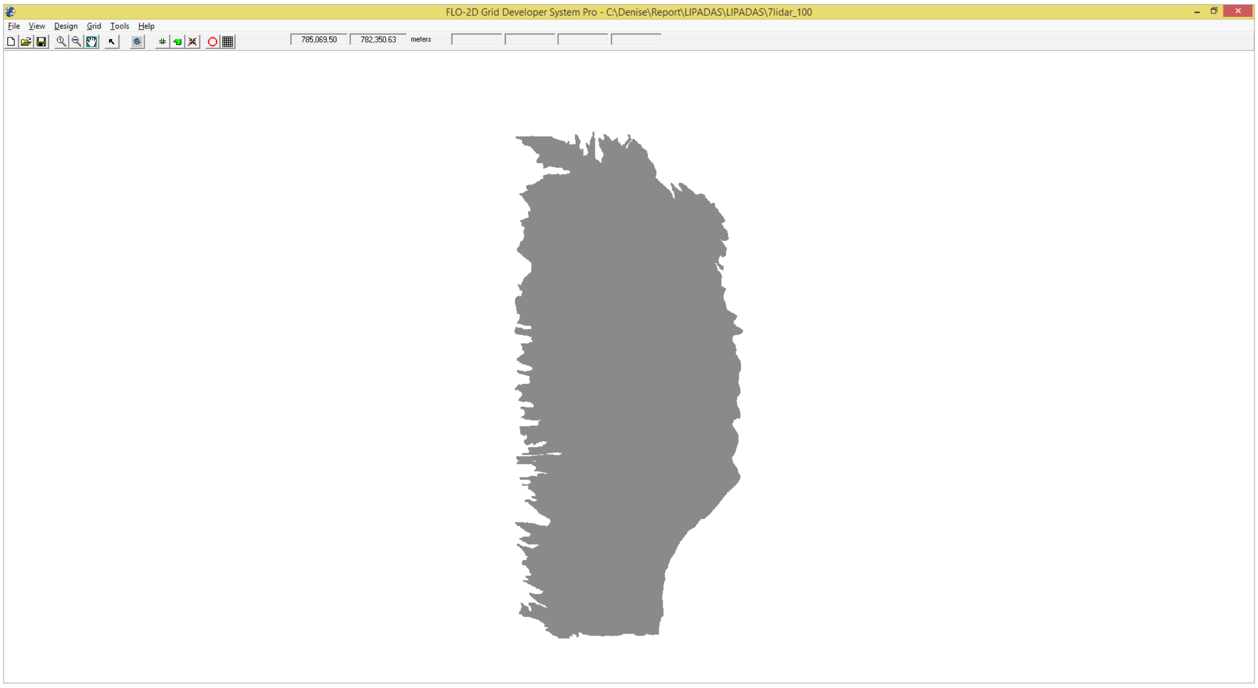


Figure 61. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 58.36890 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 Lipadas are in Figures 65, 67, and 69.

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 43894900.00 m2. The generated flood depth maps for Lipadas are in Figures 66, 68, and 70.

There is a total of 34088534.89 m3 of water entering the model. Of this amount, 15257043.87 m3 is due to rainfall while 18831491.02 m3 is inflow from other areas outside the model. 6156764.50 m3 of this water is lost to infiltration and interception, while 19224428.46 m3 is stored by the flood plain. The rest, amounting up to 8707324.78 m3, is outflow.

5.6 Results of HMS Calibration

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

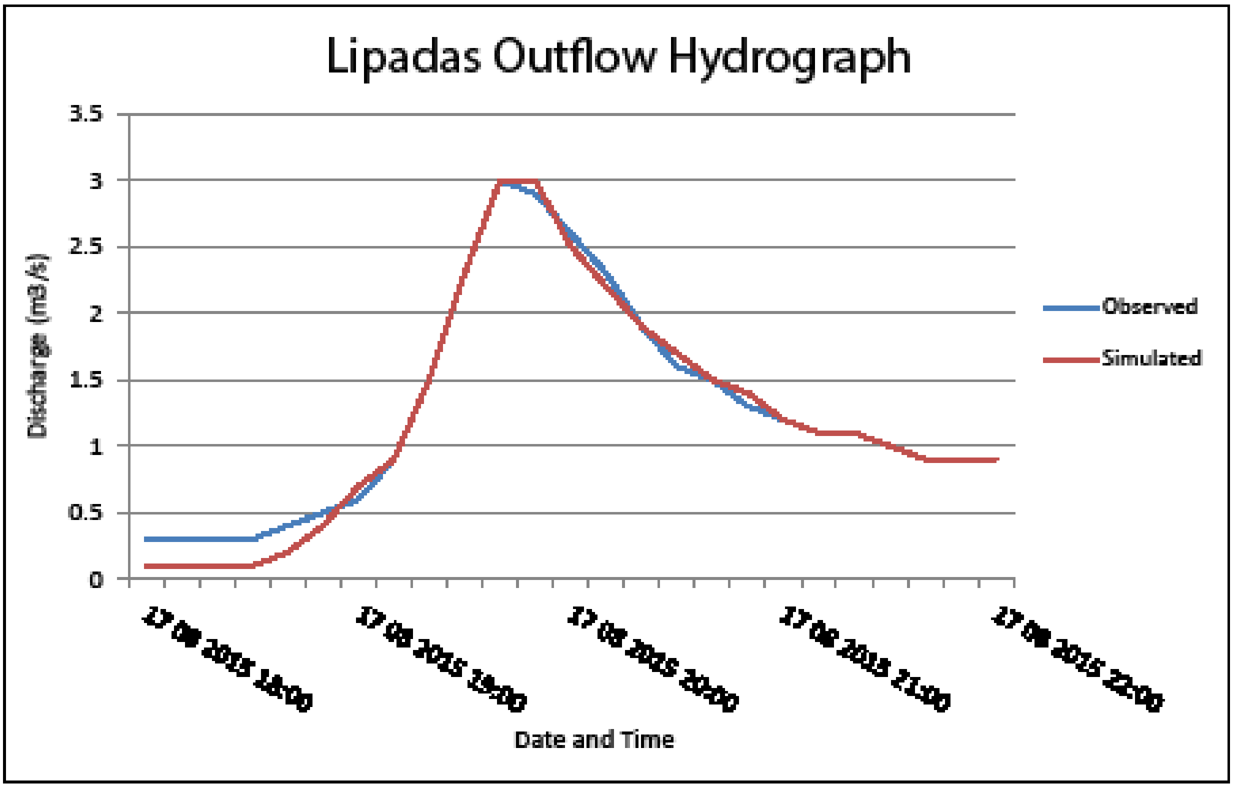


Figure 62. Outflow Hydrograph of Lipadas produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of Calibrated Values for Lipadas

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	0.77 – 9.88
			Curve Number	56.24 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.0167 – 2.48
			Storage Coefficient (hr)	0.0167 – 10.08
	Baseflow	Recession	Recession Constant	0.0087 – 0.5
			Ratio to Peak	0.076 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.045 – 0.07

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 0.77 mm to 9.88 mm means that there is a small initial fraction of the storm depth after which runoff begins, increasing 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 Lipadas, the basin consists mainly of forest plantations and the soil consists of mostly undifferentiated land and clay.

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 0.0167 hours to 10.08 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 0.0087 to 0.5 indicate that the basin is likely to quickly go back to its original discharge. Values of ratio to peak within the range of 0.076 to 0.5 indicate a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Lipadas river basin reaches' Manning's coefficients range from 0.045 to 0.07, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Lipadas HMS Model

RMSE	0.104
r^2	0.99
NSE	0.98
PBIAS	2.93
RSR	0.13

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.104 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 0.99.

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 0.98.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 2.93.

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 0.13.

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 63) shows the Lipadas 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.

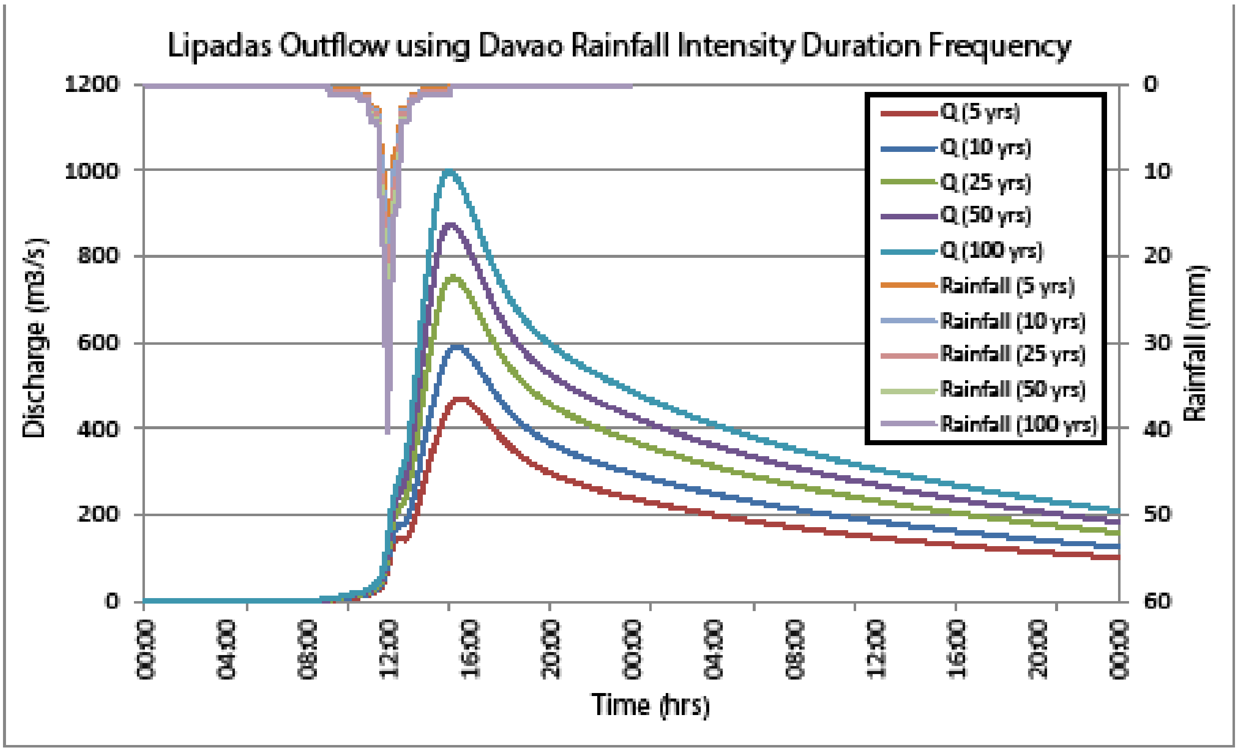


Figure 63. Outflow hydrograph at Lipadas Station generated using the Davao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Lipadas discharge using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Lipadas HEC-HMS Model outflow using the Davao RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3/s)	Time to Peak
5-Year	121.1	25.1	470.9	3 hours, 30 minutes
10-Year	140.7	28.8	591.9	3 hours, 20 minutes
25-Year	165.5	33.5	751.5	3 hours, 10 minutes
50-Year	183.9	37	873.6	3 hours, 10 minutes
100-Year	202.1	40.5	998.1	3 hours

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Lipadas River using the calibrated HMS base flow is shown in Figure 64.

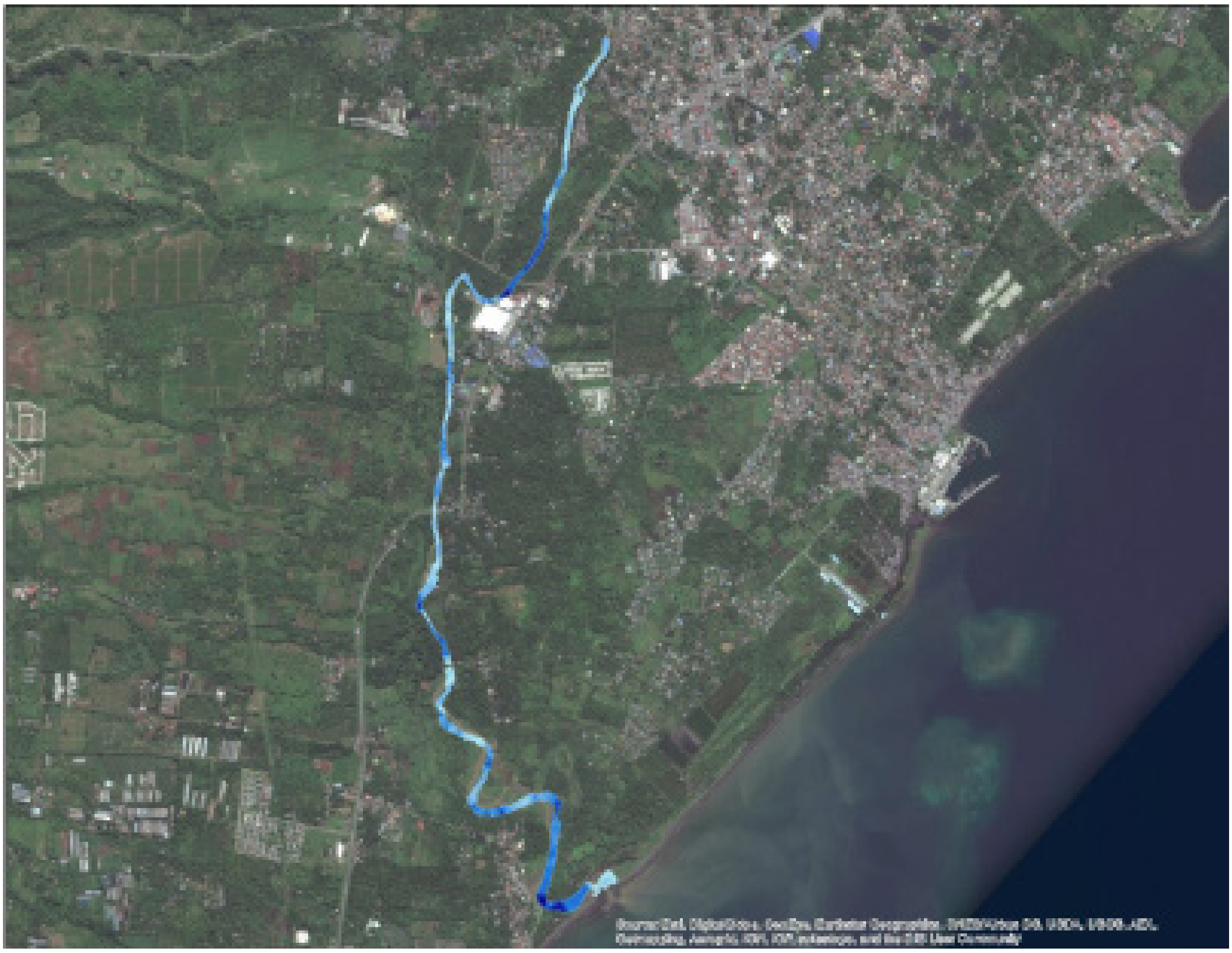


Figure 64. Sample output of Lipadas RAS Model

5.9 Flow Depth and Flvood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Lipadas floodplain are shown in Figures 65 to 70. The floodplain, with an area of 33.62 sq. km., covers two municipalities. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Lipadas floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Davao del Sur	Davao City	2224.82	33.2687	1.50%
Davao del Sur	Santa Cruz	267.54	0.35547	0.13%

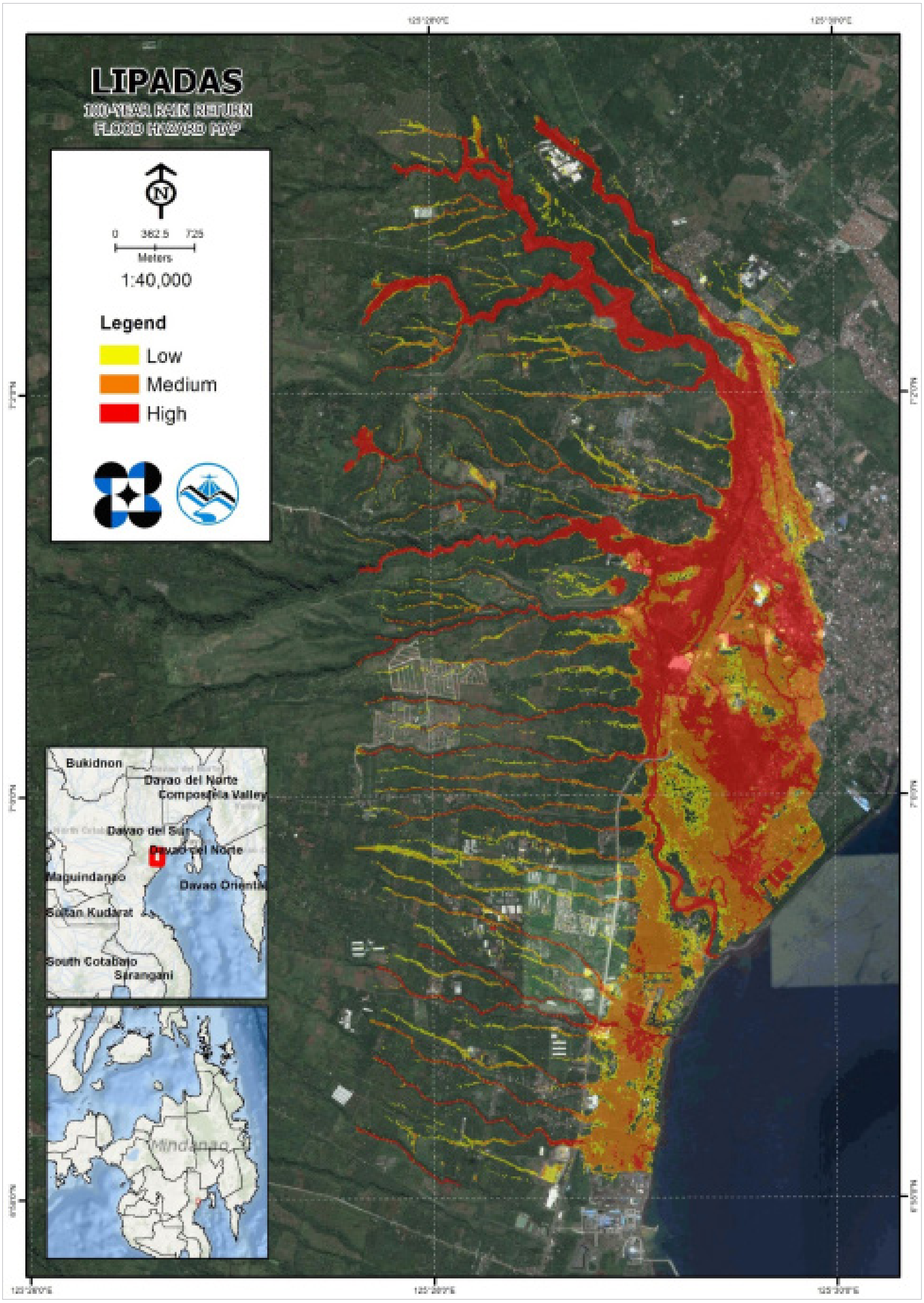


Figure 65. 100-year Flood Hazard Map for Lipadas Floodplain overlaid on Google Earth imagery

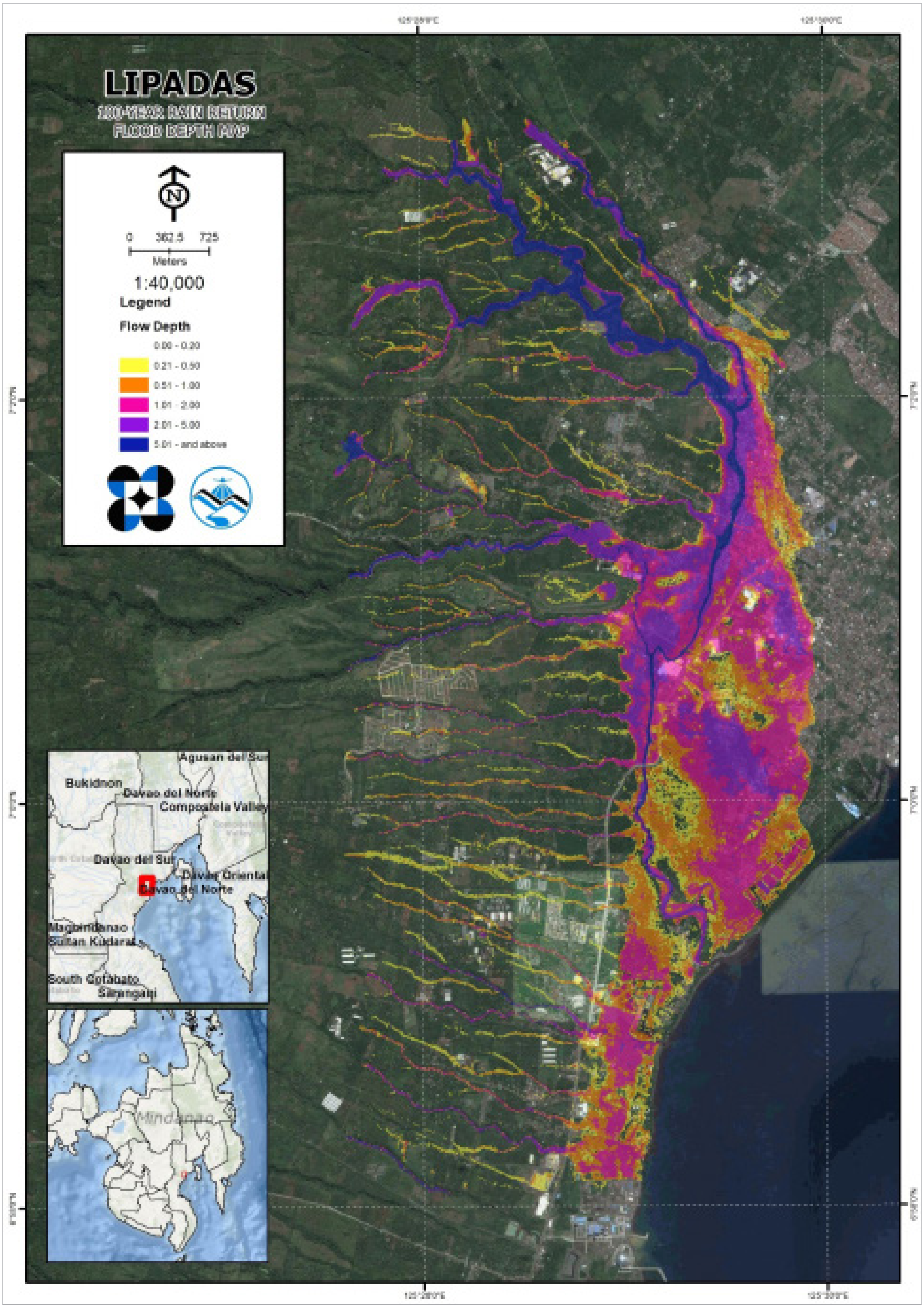


Figure 66. 100-year Flow Depth Map for Lipadas Floodplain overlaid on Google Earth imagery

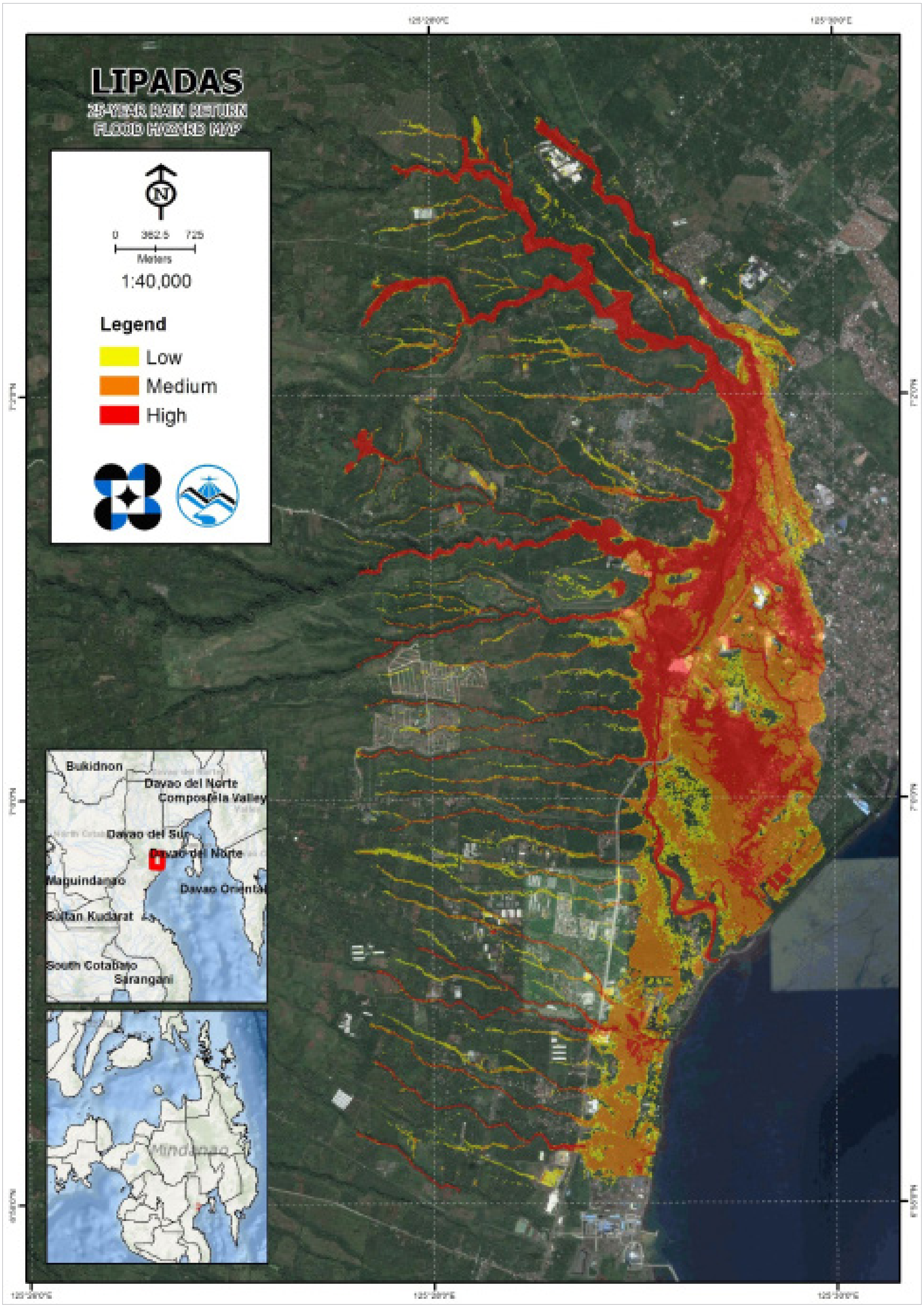


Figure 67. 25-year Flood Hazard Map for Lipadas Floodplain overlaid on Google Earth imagery

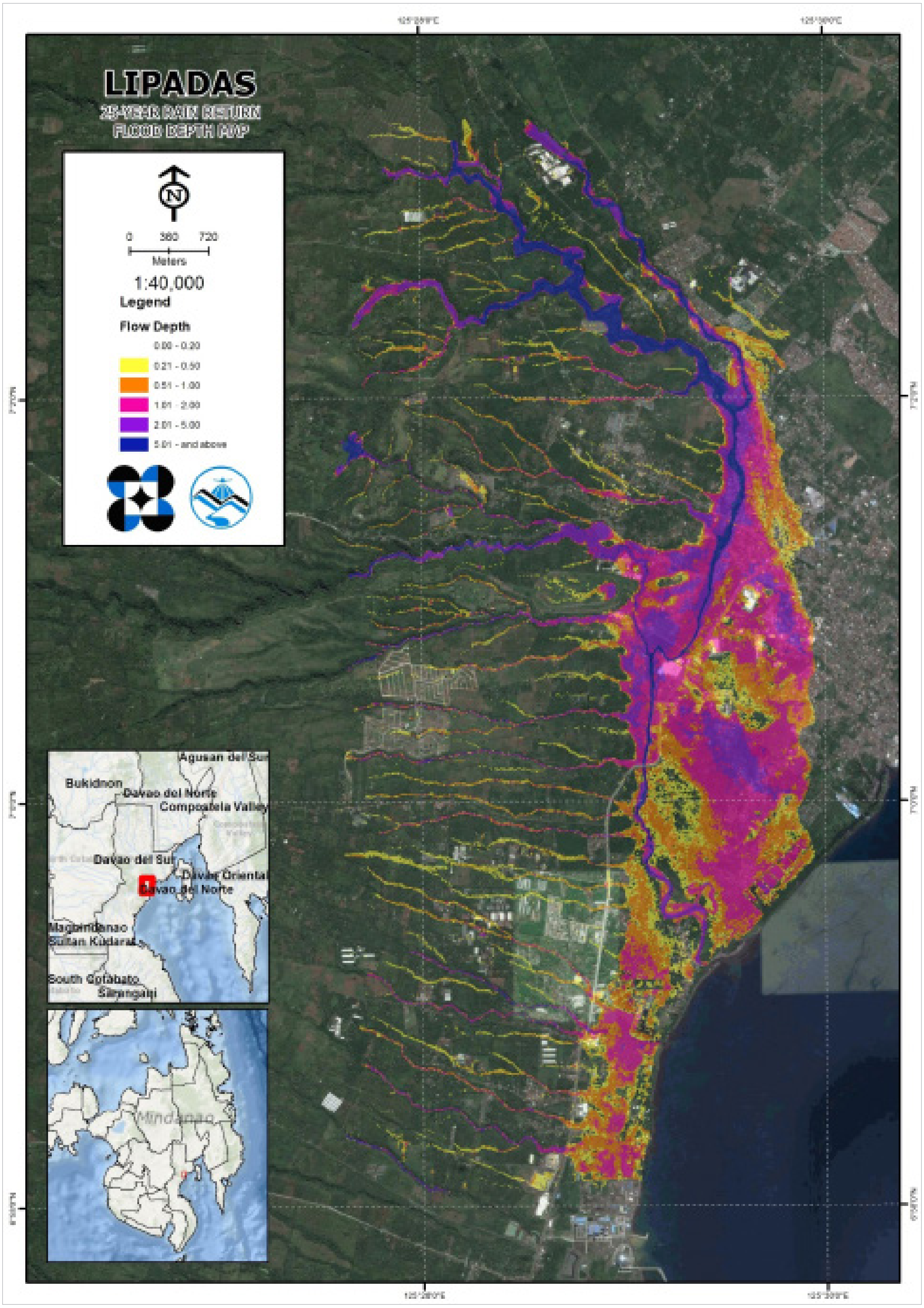


Figure 68. 25-year Flow Depth Map for Lipadas Floodplain overlaid on Google Earth imagery

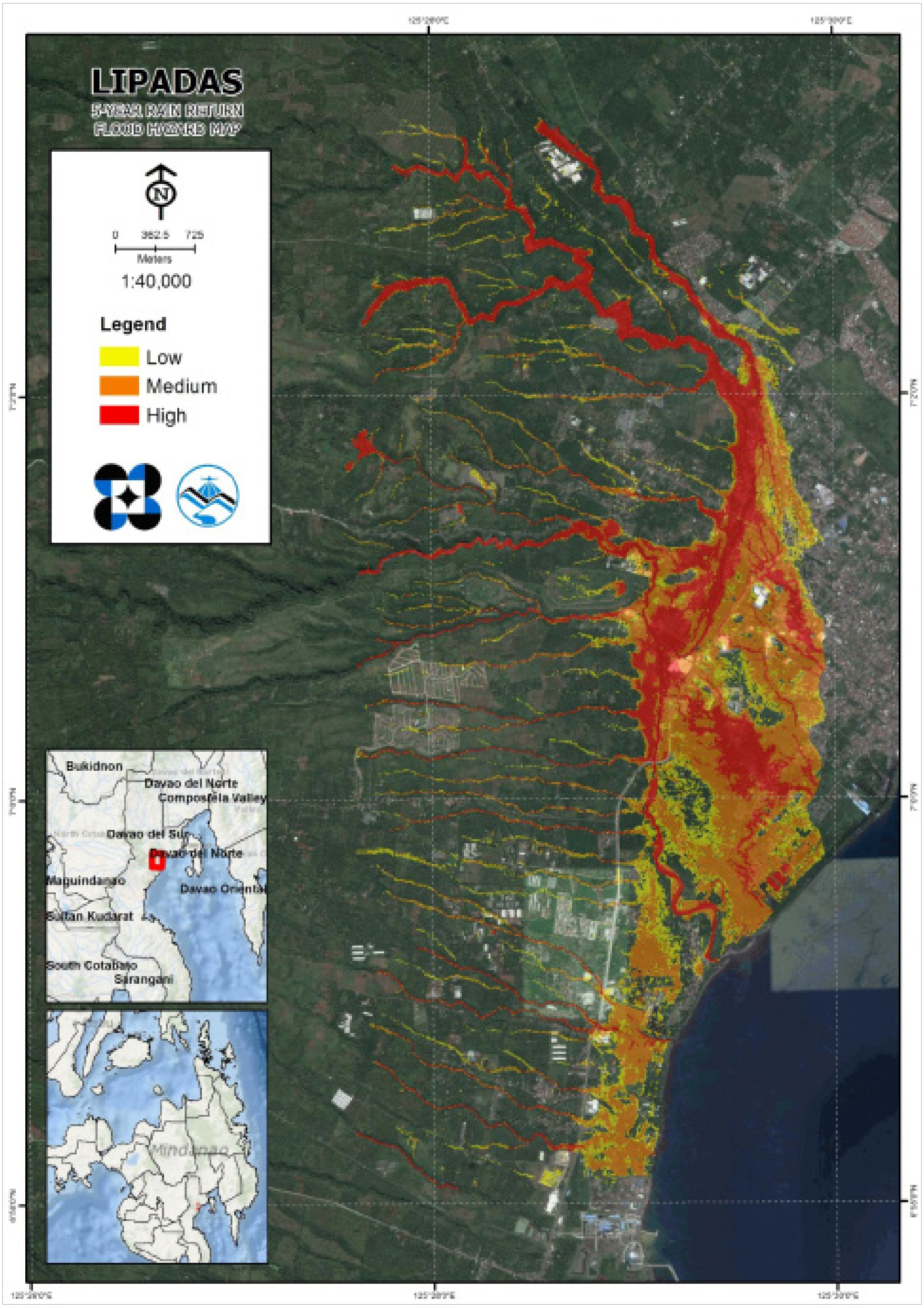


Figure 69. 5-year Flood Hazard Map for Lipadas Floodplain overlaid on Google Earth imagery

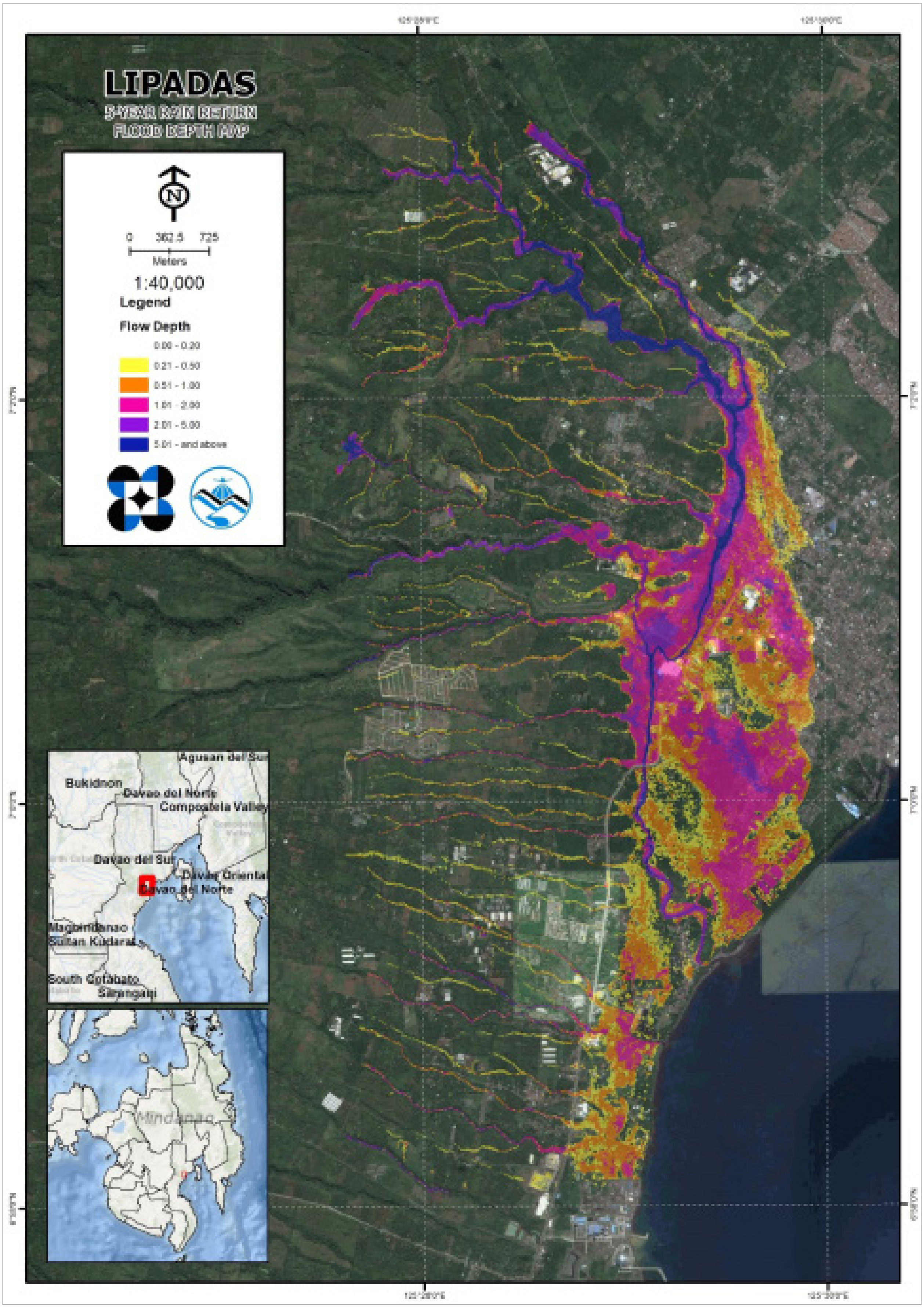


Figure 70. 5-year Flow Depth Map for Lipadas Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Lipadas river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 14 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 1.07% of the municipality of Davao City with an area of 2224.82 sq. km. will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.13%, 0.05%, and 0.02% 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 32.bAffected Areas in Davao City, Davao del Sur during 5-Year Rainfall Return Period

<insert table>

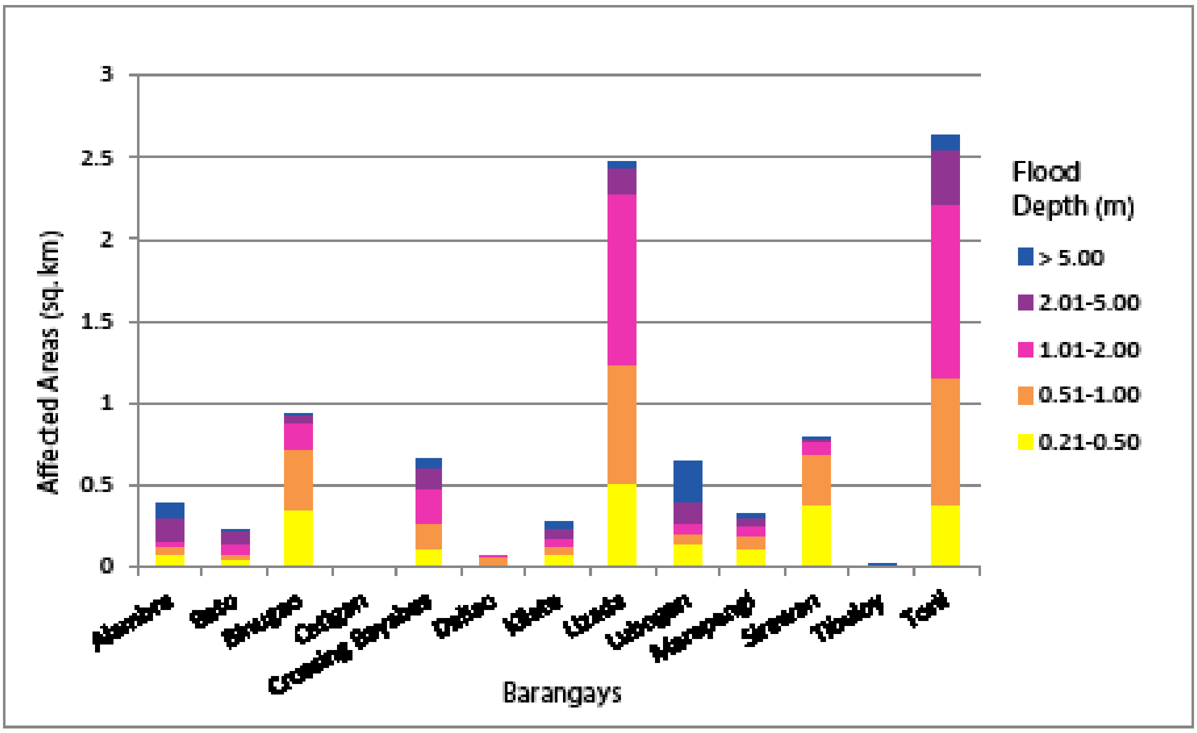


Figure 71. Affected Areas in Davao City, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 0.12% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Santa Cruz, Davao del Sur during 5-Year Rainfall Return Period

<insert table>

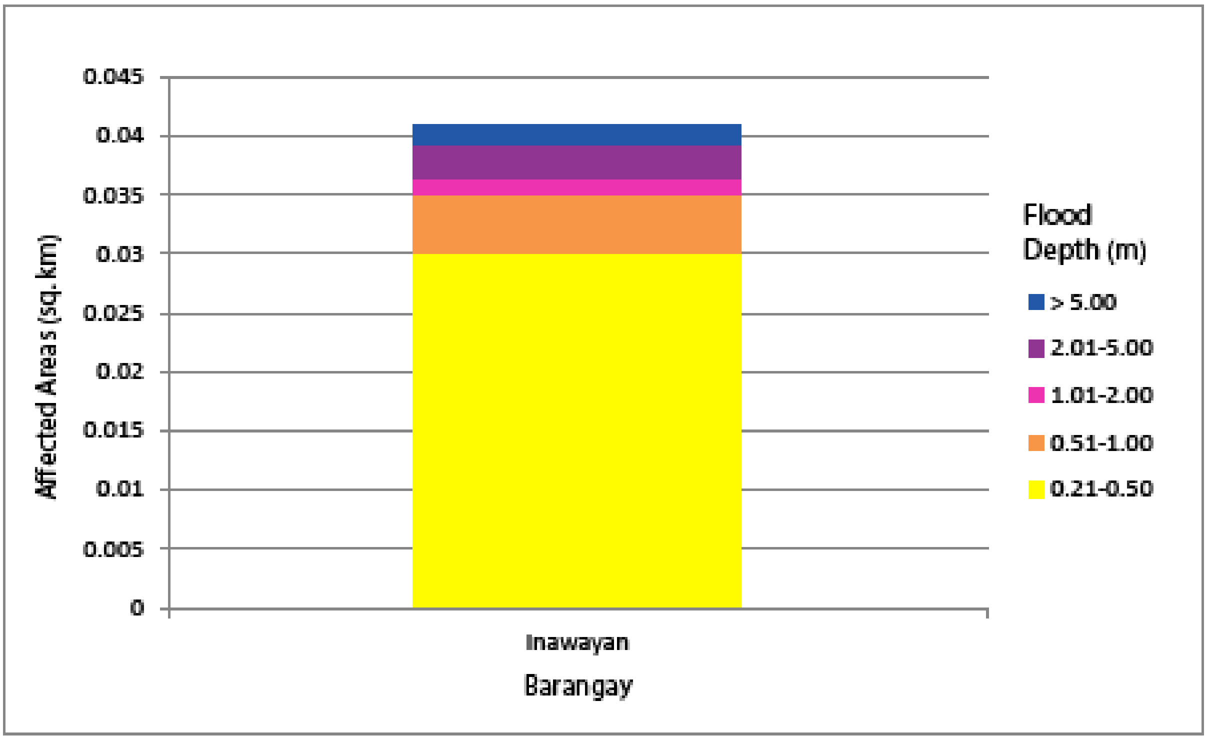


Figure 72. Affected Areas in Santa Cruz, Davao del Sur during 5-Year Rainfall Return Period

For the 25-year return period, 1.01% of the municipality of Davao City with an area of 2224.82 sq. km. will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.15%, 0.08%, and 0.03% 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 34. Affected Areas in Davao City, Davao del Sur during 25-Year Rainfall Return Period

<insert table>

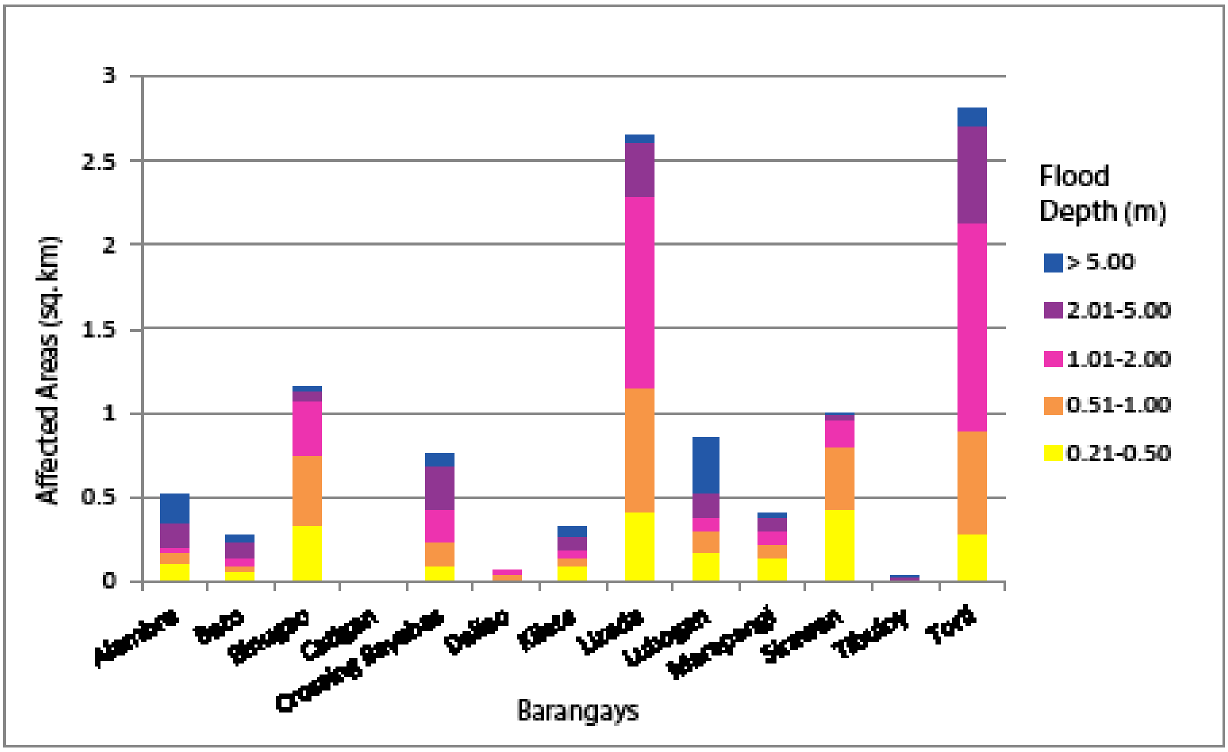


Figure 73. Affected Areas in Davao City, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 0.11% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period

<insert table>

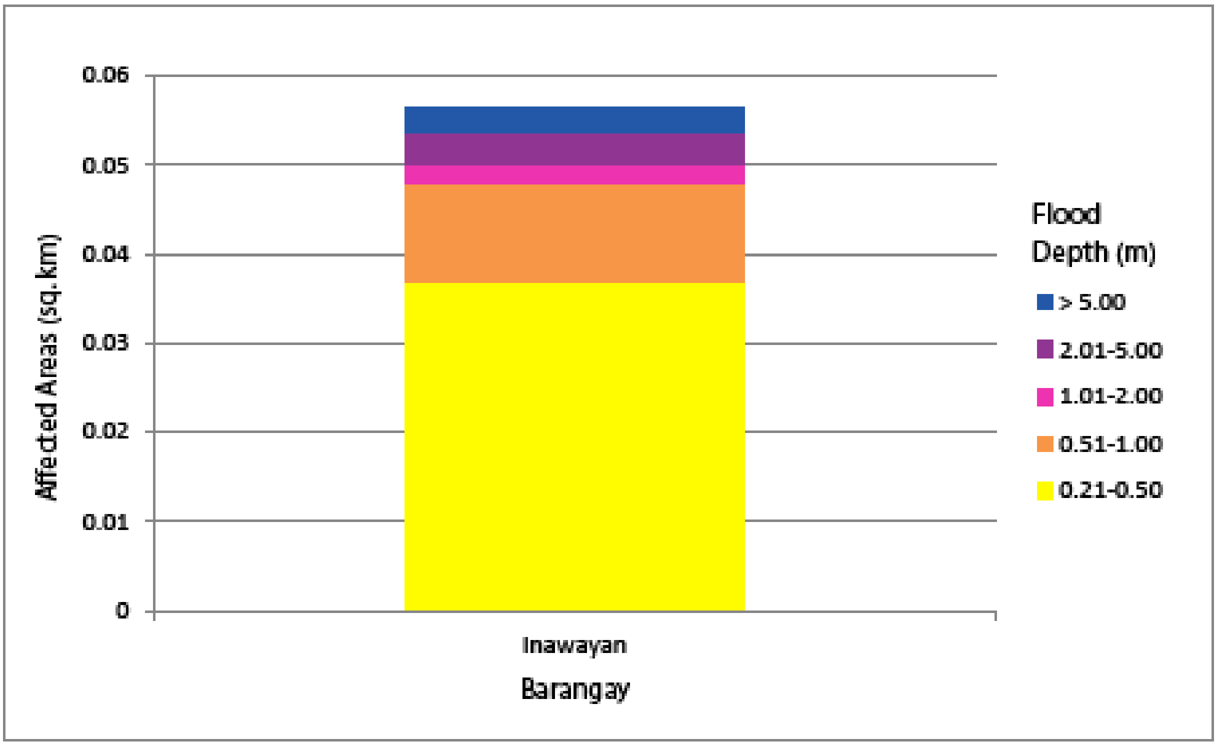


Figure 74. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period

For the 100-year return period, 0.97% of the municipality of Davao City with an area of 2224.82 sq. km. will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.16%, 0.10%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Davao City, Davao del Sur during 100-Year Rainfall Return Period

<insert table>

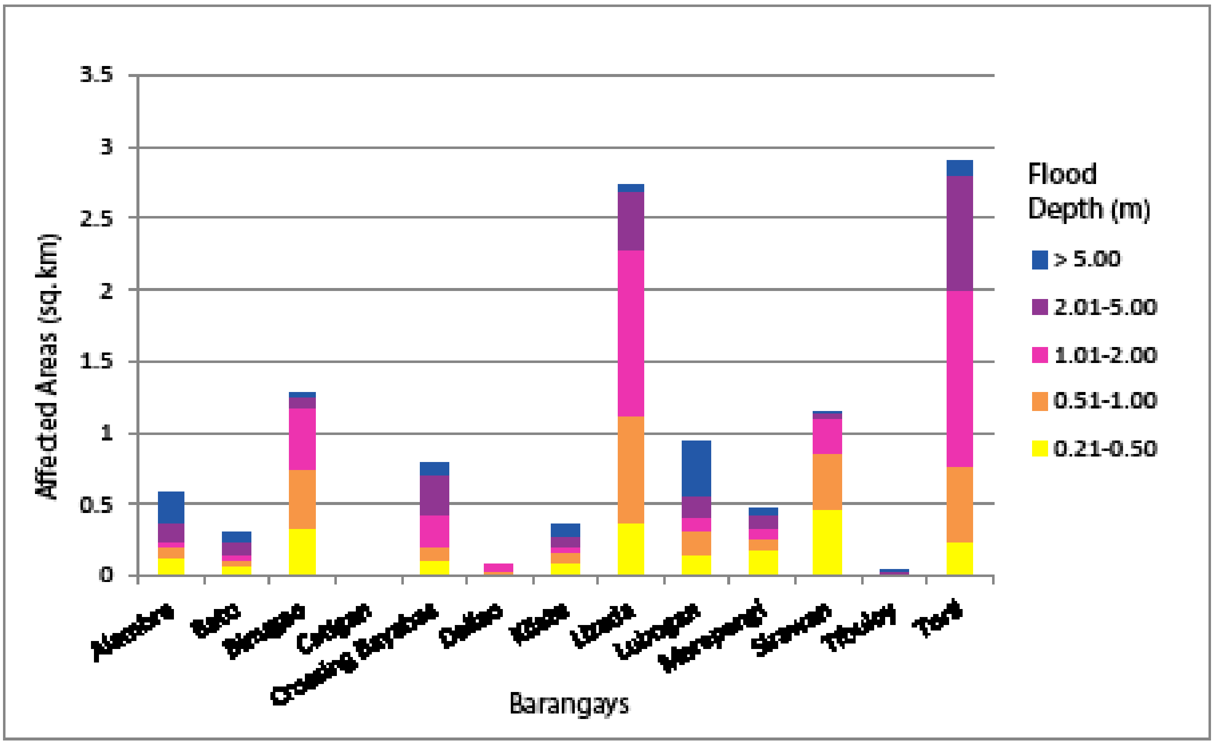


Figure 75. Affected Areas in Davao City, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 0.11% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period

<insert table>

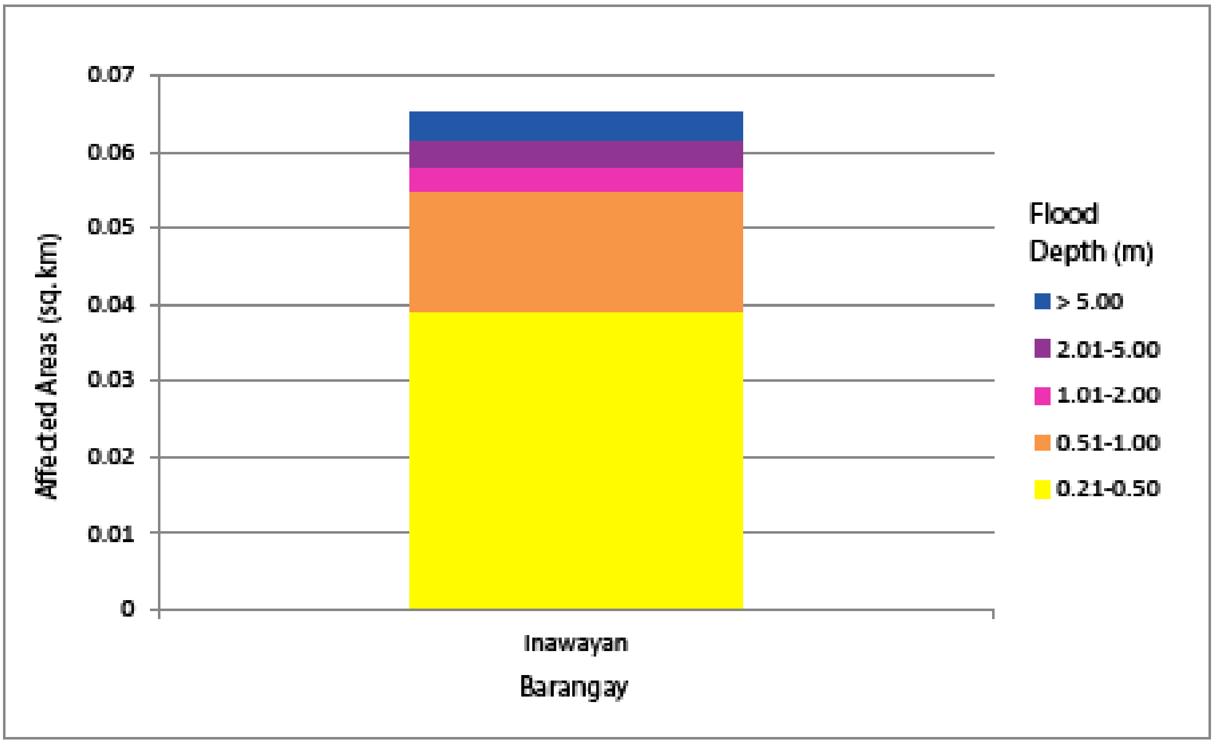


Figure 76. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Davao City in Davao del Sur, Sirawan is projected to have the highest percentage of area that will experience flood levels at 0.22%. Meanwhile, Binugao posted the second highest percentage of area that may be affected by flood depths at 0.20%.

Brgy. Inawayan is the only barangay affected in the municipality of Santa Cruz in Davao del Sur. The barangay is projected to experience flood in 0.13% of the municipality.

Moreover, the generated flood hazard maps for the Lipadas 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 38. 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	2.14	2.15	2.14
Medium	4.13	4.36	4.38
High	3.30	4.45	5.22

Of the 77 identified educational institutions in the Lipadas floodplain, 31 schools were assessed to be prone to flooding as they are exposed to the High level flooding for all three rainfall scenarios. Six 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 ANNEX 12.

22 medical institutions were identified in the Lipadas floodplain. Proposed Health Center in Brgy. Lizada and Sta. Ana Drug Store in Brgy. Toril were found to be prone to flooding, having High level flooding in all three rainfall scenarios. See ANNEX 13.

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 March 7-11 and May 5-6, 2016. The flood validation consists of 180 points randomly selected all over the Lipadas flood plain. It has an RMSE value of 1.92.

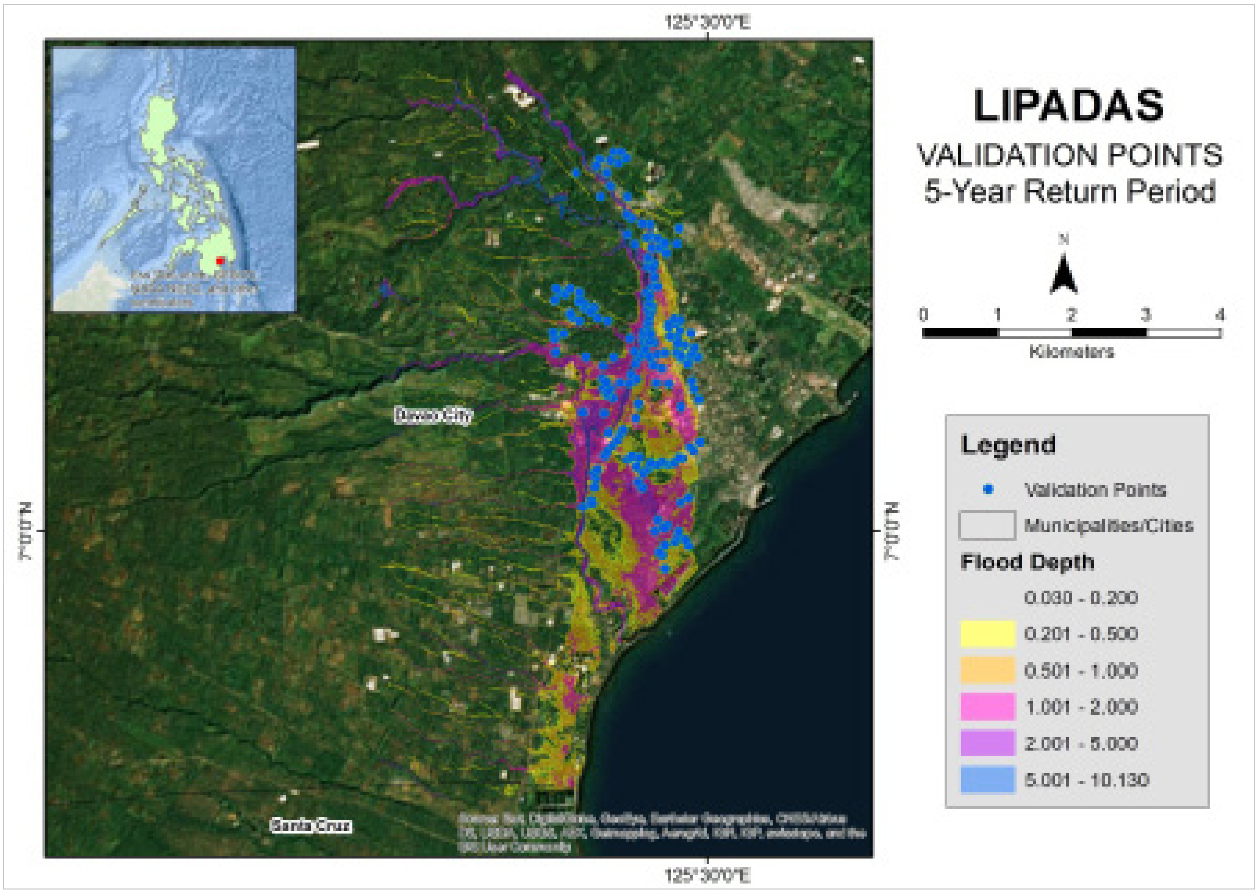


Figure 77. Flood Validation Points of Lipadas River Basin

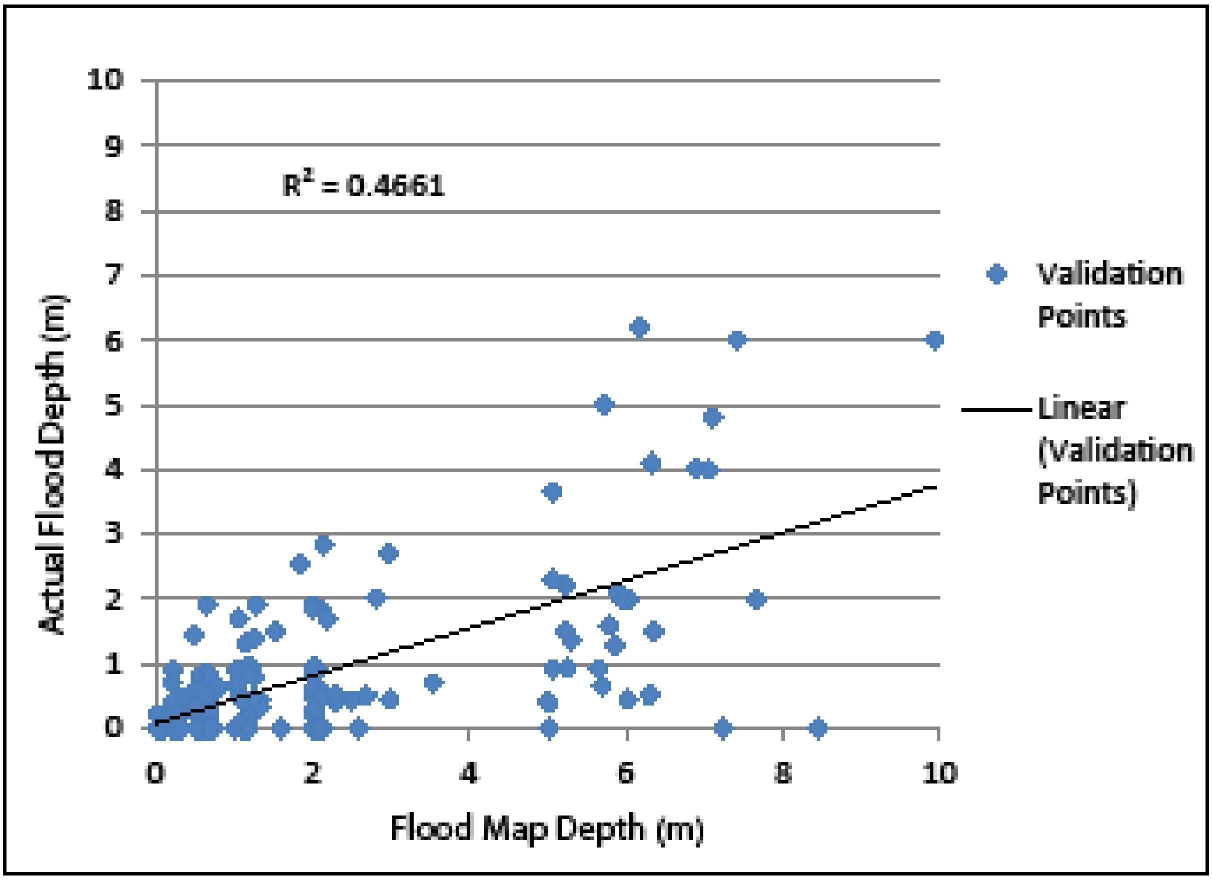


Figure 78. Flood Map Depth vs Actual Flood Depth for Lipadas

Table 39. Actual Flood Depth vs Simulated Flood Depth in Lipadas

KINGKING 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	30	20	15	9	6	3	**83**
	0.21-0.50	0	8	8	6	9	3	**34**
	0.51-1.00	0	2	5	9	8	4	**28**
	1.01-2.00	0	0	2	5	5	8	**20**
	2.01-5.00	0	0	0	1	2	9	**12**
	> 5.00	0	0	0	0	0	3	**3**
	Total	**30**	**30**	**30**	**30**	**30**	**30**	**180**

The overall accuracy generated by the flood model is estimated at 29.44%, with 53 points correctly matching the actual flood depths. In addition, there were 56 points estimated one level above and below the correct flood depths while there were 37 points and 34 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 122 points were overestimated while a total of 5 points were underestimated in the modelled flood depths of Lipadas.

Table 40. Summary of Accuracy Assessment in Lipadas

	No. of Points	%
Correct	53	29.44
Overestimated	122	67.78
Underestimated	5	2.78
Total	**180**	**100**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

ANNEX 1. Optech Technical Specifications of the LiDAR Sensor

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

ANNEX 2. NAMRIA Certificates of Reference Points Used

1. DVS-01

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

April 26, 2013

CERTIFICATION

To whom it may concern:

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

	Province: **DAVAO DEL SUR**	
	Station Name: **DVS-1**	
	Order: **1st**	Barangay: **TOWN PROPER**
Island: **MINDANAO**		
Municipality: **DAVAO CITY**	*PRS92 Coordinates*	
Latitude: **7° 4' 41.48387"**	Longitude: **125° 37' 31.24815"**	Ellipsoidal Hgt: **-4.50700 m.**
	WGS84 Coordinates	
Latitude: **7° 4' 38.36201"**	Longitude: **125° 37' 36.77094"**	Ellipsoidal Hgt: **68.27510 m.**
	PTM Coordinates	
Northing: **782663.345 m.**	Easting: **569084.935 m.**	Zone: **5**
	UTM Coordinates	
Northing: **783,162.17**	Easting: **790,026.11**	Zone: **51**

Location Description

DVS-1
From Davao City hall travel southeast along San Pedro street for 400 meters. Upon reaching the "T" intersection of San Pedro street and Quezon boulevard travel for 2.1 kms. up to the cross intersection of roads at Monteverde street, Leon Garcia street and Quezon boulevard. From this intersection turn right to Sta. Ana pier. The station is located on the east side of the new pier, 94 meters Northeast of coast guard house and north of the old pier. Station mark is 0.15 m x 0.01 m in diameter brass rod with cross cut on top, set in a drill hole, centered in a 30 cm x 30 cm cement patty on top of concrete pavement of wharf. Inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rods with cross cut on top, set in drill holes, centered in cement patty on concrete pavement of wharf. Inscribed on top with the reference mark numbers and arrow pointing to the station.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943584 B**
T.N.: **2013-0366**

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

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

2. DVA-3237

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

July 25, 2014

CERTIFICATION

To whom it may concern:

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

Province: **DAVAO DEL NORTE**
Station Name: **DVA-3237**
Order: **4th**

Island: **MINDANAO**		Barangay: **NANYO**
Municipality: **CITY OF PANABO**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **7° 19' 59.93670"**	Longitude: **125° 38' 7.27962"**	Ellipsoidal Hgt: **16.91200 m.**
	WGS84 Coordinates	
Latitude: **7° 19' 56.74722"**	Longitude: **125° 38' 12.77896"**	Ellipsoidal Hgt: **89.23800 m.**
	PTM / PRS92 Coordinates	
Northing: **810878.179 m.**	Easting: **570181.447 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **811,399.31**	Easting: **790,969.56**	Zone: **51**

Location Description

DVA-3237

The station is located beside the flagpole inside the compound of Nanyo Elementary School.

Marked is the head of a 4" copper nail embedded and centered on a 0.25cm. x 0.25cm. x 1.00m. concrete monument with inscriptions "DVA-3237; 2008; LMS XI."

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799682 A**
T.N.: **2014-1737**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. DVA-133

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

July 25, 2014

CERTIFICATION

To whom it may concern:

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

Province: **DAVAO DEL NORTE**
Station Name: **DVA-133**
Order: **2nd**

Island: **MINDANAO**		Barangay: **MANAY**
Municipality: **CITY OF PANABO**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **7° 20' 57.02014"**	Longitude: **125° 35' 57.50044"**	Ellipsoidal Hgt: **23.95700 m.**
	WGS84 Coordinates	
Latitude: **7° 20' 53.82313"**	Longitude: **125° 36' 2.99870"**	Ellipsoidal Hgt: **96.16300 m.**
	PTM / PRS92 Coordinates	
Northing: **812626.211 m.**	Easting: **566188.597 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **813,130.63**	Easting: **786,976.44**	Zone: **51**

Location Description

DVA-133
"DVA-133" is in Barangay Manay, Municipality of Panabo. To reach the station travel for about 9 kms. from the intersection of National Highway and barangay road turn right going to Barangay Manay. Station is located infront of the Barangay Hall 15 m. from the flagpole and "NW" of volleyball court. Mark is the head of 4" copper nail embedded in a 30 x 30 cm. concrete monument with the inscription "DVA-133 2007 NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1736**

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

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ANNEX 3. Baseline Processing Reports of Reference Points Used

1. DVS-01A

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
DVS-01 --- DVS-01A (B1)	DVS-01	DVS-01A	Fixed	0.001	0.001	264°18'19"	5.002	-0.009
DVS-01 --- DVS-01A (B2)	DVS-01	DVS-01A	Fixed	0.001	0.001	264°19'14"	4.993	-0.006
DVS-01 --- DVS-01A (B3)	DVS-01	DVS-01A	Fixed	0.001	0.001	264°19'50"	4.999	0.844

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

Vector Components (Mark to Mark)

From:	DVS-01				
Grid		Local		Global	
Easting	790026.116 m	Latitude	N7°04'41.48388"	Latitude	N7°04'38.36201"
Northing	783162.167 m	Longitude	E125°37'31.24815"	Longitude	E125°37'36.77094"
Elevation	0.546 m	Height	-4.507 m	Height	68.275 m

To:	DVS-01A				
Grid		Local		Global	
Easting	790021.138 m	Latitude	N7°04'41.46772"	Latitude	N7°04'38.34585"
Northing	783161.643 m	Longitude	E125°37'31.08595"	Longitude	E125°37'36.60874"
Elevation	0.537 m	Height	-4.516 m	Height	68.266 m

Vector					
ΔEasting	-4.978 m	NS Fwd Azimuth	264°18'19"	ΔX	4.016 m
ΔNorthing	-0.525 m	Ellipsoid Dist.	5.002 m	ΔY	2.942 m
ΔElevation	-0.009 m	ΔHeight	-0.009 m	ΔZ	-0.494 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000001709		
Y	-0.0000000623	0.0000001761	
Z	-0.0000000132	0.0000000282	0.0000000414

2. DVA-3237

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
DVA-133 --- DVA-3237 (B1)	DVA-133	DVA-3237	Fixed	0.004	0.014	113°46'08"	4349.013	-6.729

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	DVA-133				
Grid		Local		Global	
Easting	786976.453 m	Latitude	N7°20'57.02014"	Latitude	N7°20'53.82313"
Northing	813130.631 m	Longitude	E125°35'57.50044"	Longitude	E125°36'02.95670"
Elevation	27.682 m	Height	23.957 m	Height	96.163 m

To:	DVA-3237				
Grid		Local		Global	
Easting	790969.206 m	Latitude	N7°19'59.95215"	Latitude	N7°19'56.76267"
Northing	811399.786 m	Longitude	E125°38'07.26797"	Longitude	E125°38'12.76731"
Elevation	21.363 m	Height	17.228 m	Height	89.553 m

Vector					
ΔEasting	3992.752 m	NS Fwd Azimuth	113°46'08"	ΔX	-3362.078 m
ΔNorthing	-1730.846 m	Ellipsoid Dist.	4349.013 m	ΔY	-2141.246 m
ΔElevation	-6.319 m	ΔHeight	-6.729 m	ΔZ	-1739.408 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

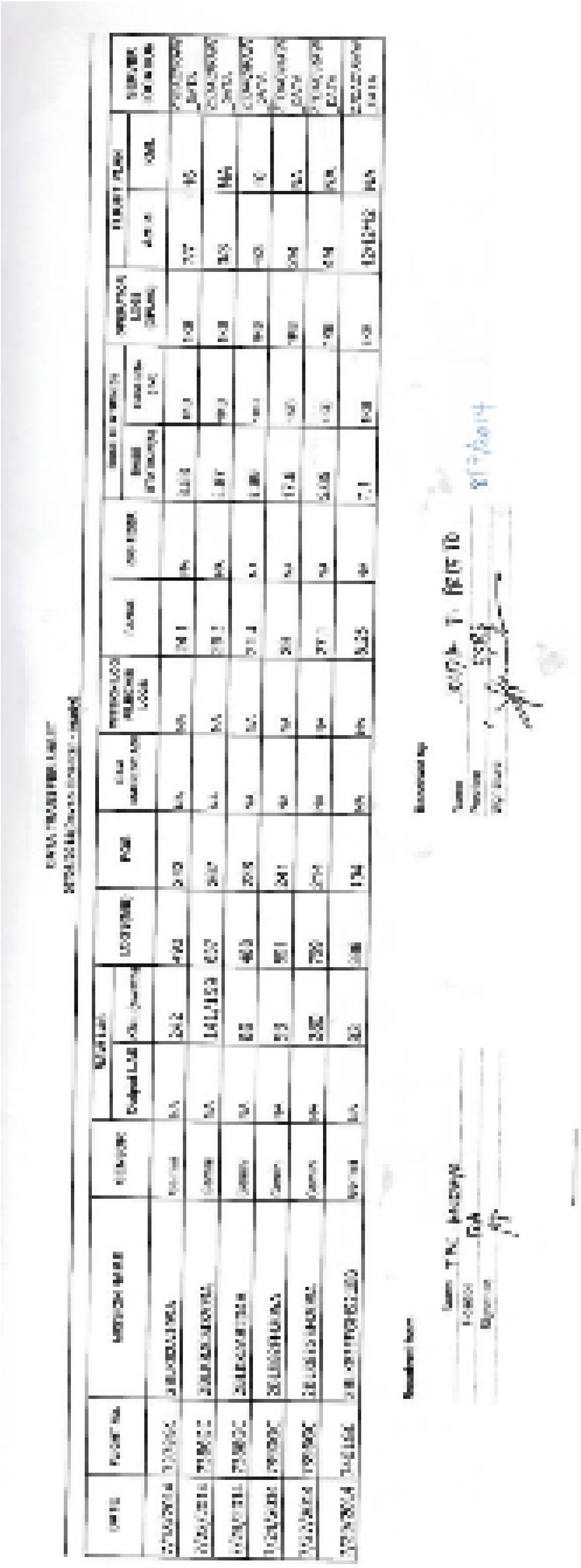
Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000160458		
Y	-0.0000220689	0.0000368585	
Z	-0.0000043801	0.0000072587	0.0000024695

ANNEX 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Research Associate (RA)	FOR. MA. VERLINA TONGA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey	RA	JERIEL PAUL ALAMBAN, GEOL	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	Philippine Air Force (PAF)
	Pilot	CAPT. JOHN BRYAN DONGUINES	Asian Aerospace Corporation (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

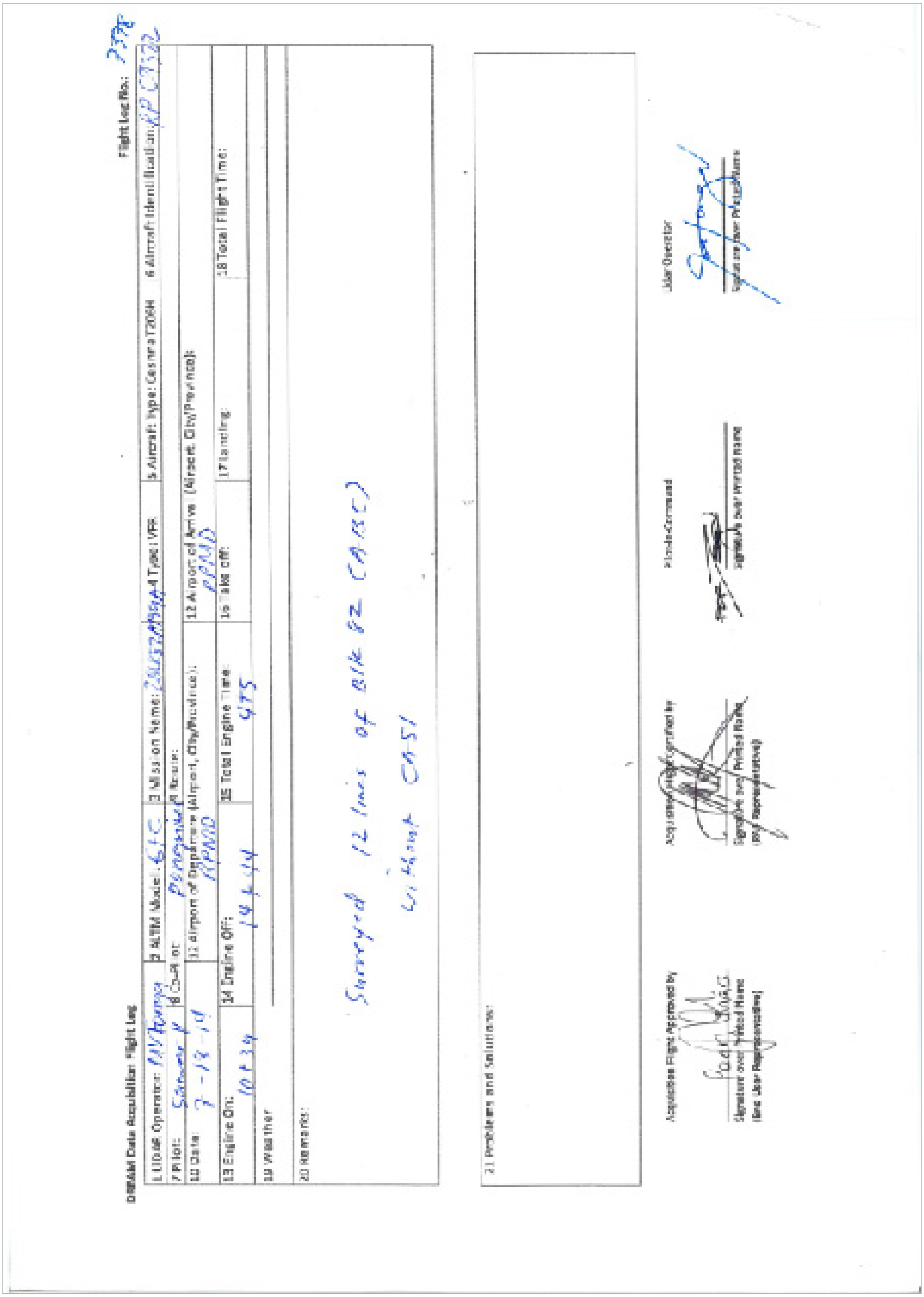
ANNEX 5. Data Transfer Sheet for Lipadas Floodplain



[illegible]

ANNEX 6. Flight Logs

1. Flight Log for 7378GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7378

1 LIDAR Operator: MV Tornga	2 ALTM Model: GFC	3 Mission Name: 2BLK82A199A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP C9322
7 Pilot: Sanchez K	8 Co-Pilot: Peñaruben	9 Route:			
10 Date: 7-18-19	11 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 10:34	14 Engine Off: 14:44	15 Total Engine Time: 4:15	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 12 lines of BLK 82 (A,B,C) without CASI					

21 Problems and Solutions:

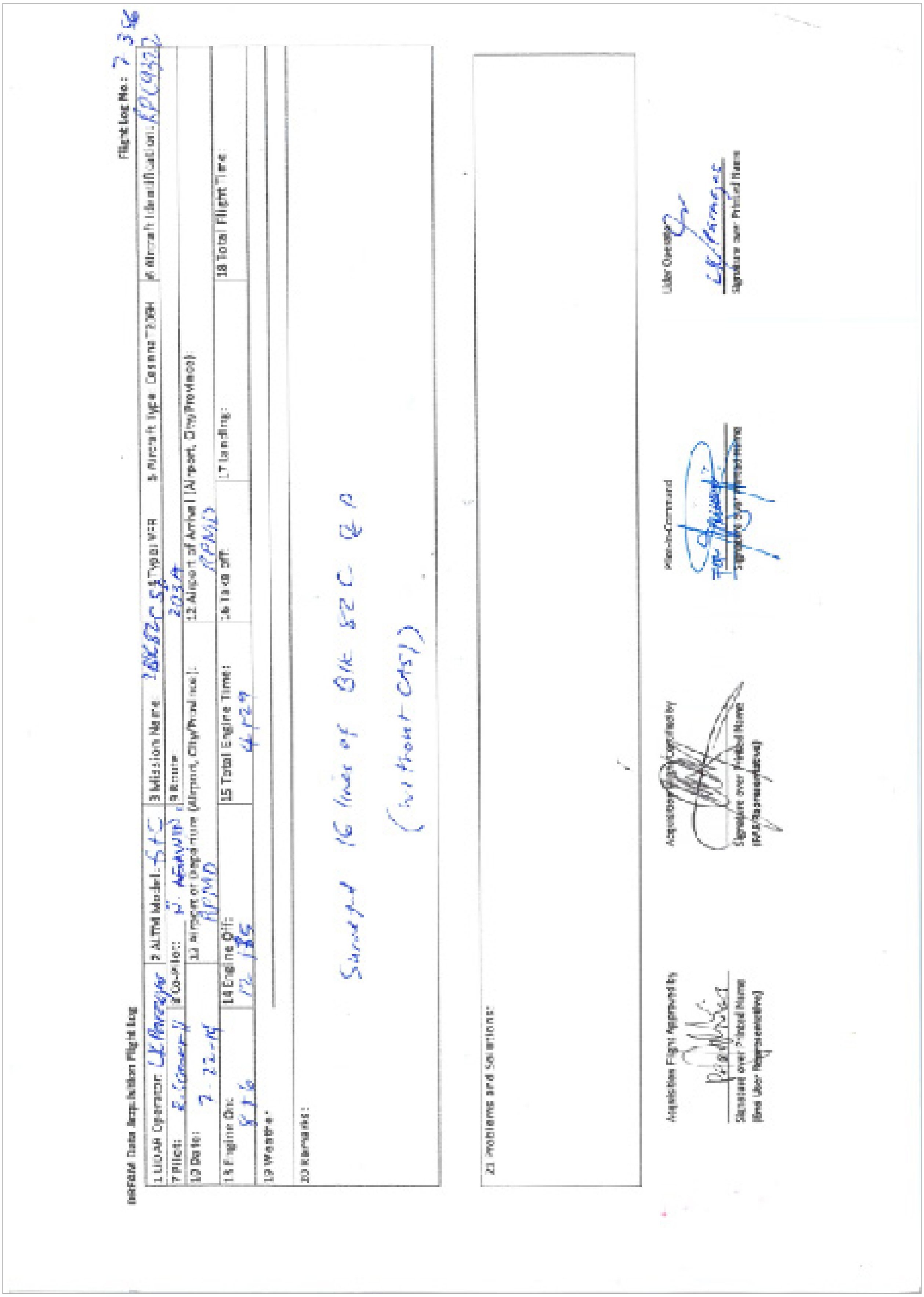
Acquisition Flight Approved by: Signature over Printed Name (End User Representative)

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

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

2. Flight Log for 7386GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7356

1 LIDAR Operator: LK Paragas	2 ALTM Model: GMC	3 Mission Name: 3BLK82C S	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: E. Gonzales II	8 Co-Pilot: N. Aguanta	9 Route: 203A			
10 Date: 7-22-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 8+6	14 Engine Off: 12+35	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather:					

20 Remarks:

Surveyed 16 lines of Blk 82C & A (without CAS)

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

Signature over Printed Name (PAF Representative)

Pilot-in-Command

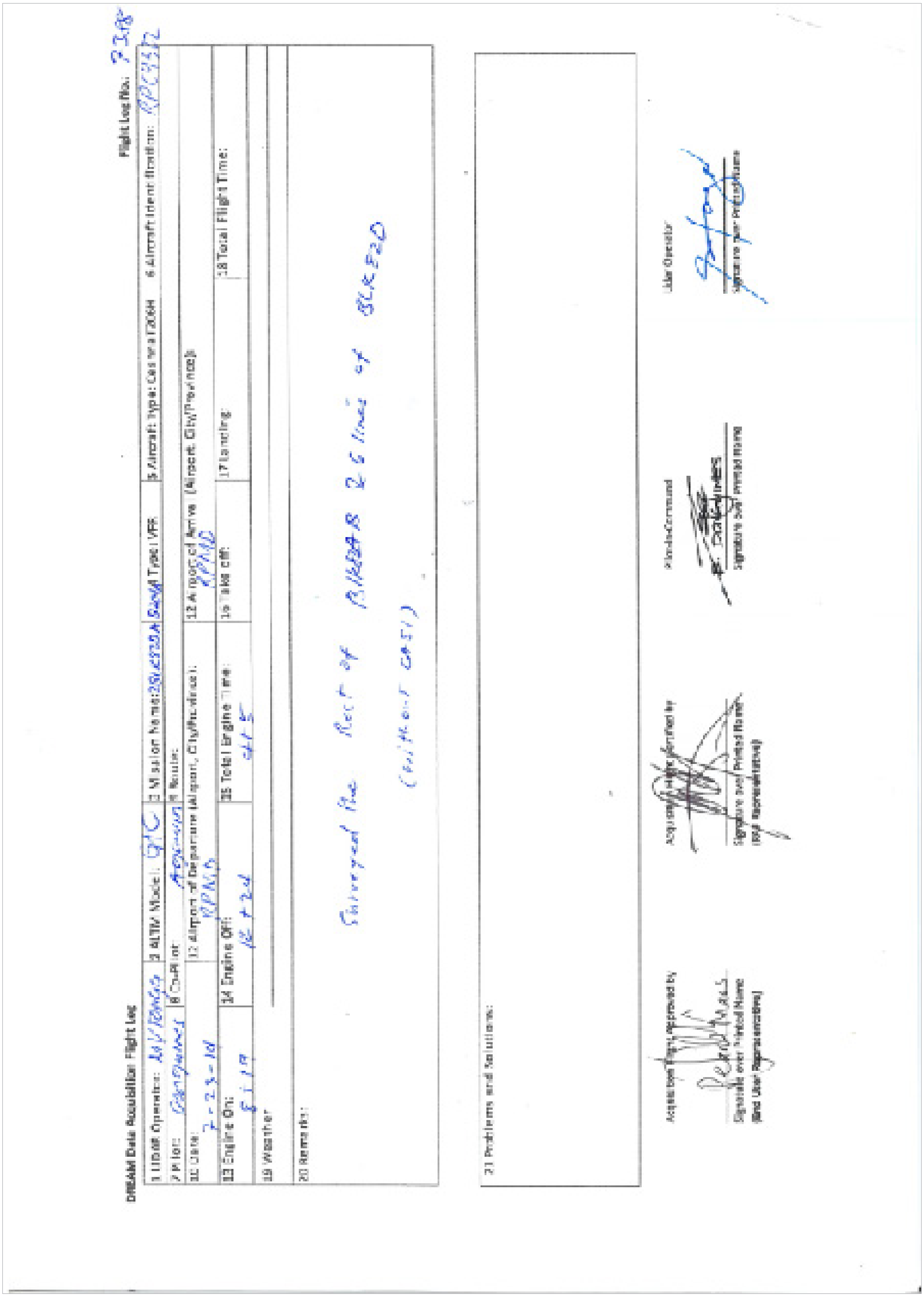
Signature over Printed Name

Lidar Operator

LK Paragas

Signature over Printed Name

3. Flight Log for 7388GC Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 7388

1 LIDAR Operator: ML VILLANUEVA	2 ALTM Model: GC	3 Mission Name: 2BLK52DA 204A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC9322
7 Pilot: G. Sagarino	8 Co-Pilot: A. Jimenez	9 Route:			
10 Date: 7-23-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 8:19	14 Engine Off: 12:24	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed the rest of BLK52A,B & 6 lines of BLK52D (without GASI)					

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: G. Sagarino — Signature over Printed Name

Lidar Operator: Signature over Printed Name

4. Flight Log for 7401GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7401

1 LIDAR Operator: LK Paragas	2 ALTM Model: GTC	3 Mission Name: 2BLK82	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RPC9122
7 Pilot: G. Donguines	8 Co-Pilot: N. Angeles	9 Route: RPCM5 2208			
10 Date: 7-29-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 14+41	14 Engine Off: 16+40	15 Total Engine Time: 1+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

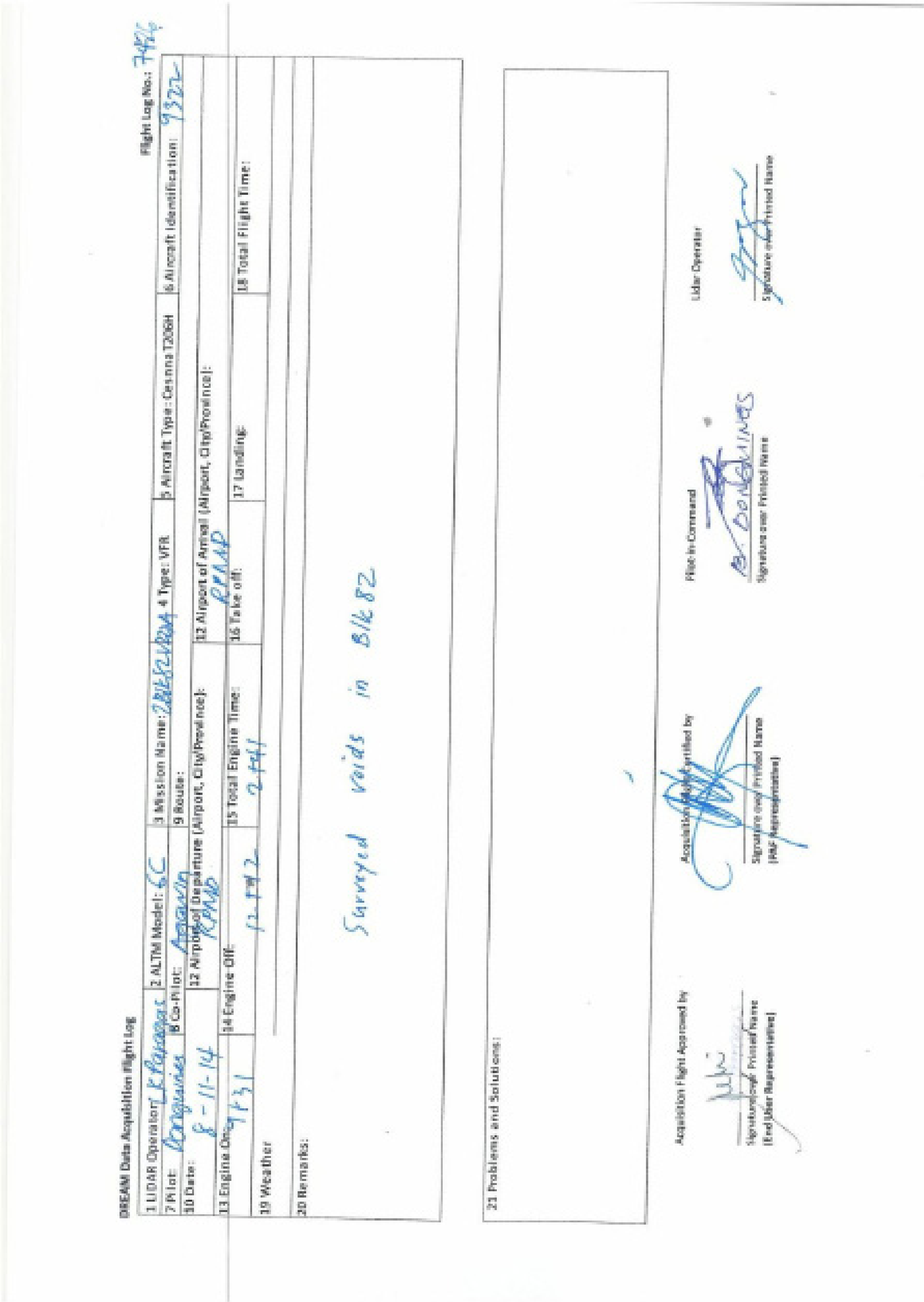
20 Remarks:

completed Blk 82G and voids of Blocks 82E, F, H

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
		G. DONGUINES	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 7426GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7426

1 LiDAR Operator: LK Paragas	2 ALTM Model: GC	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Dongalines	8 Co-Pilot: Agacaoili	9 Route:			
10 Date: 8-11-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 7+31	14 Engine Off: 12+12	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed voids in Blk 82					
21 Problems and Solutions:					

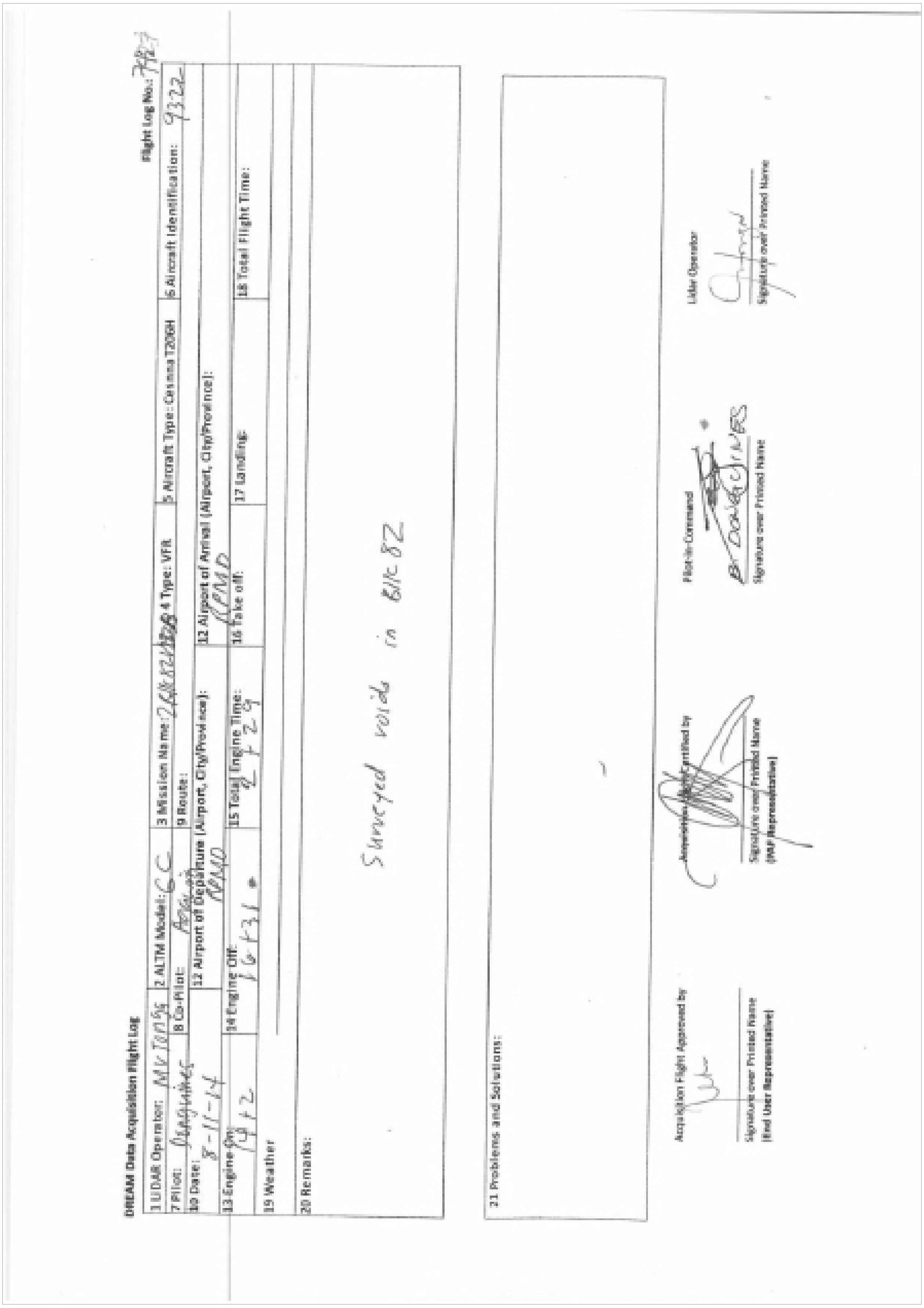
Acquisition Flight Approved by: Signature over Printed Name (End User Representative)

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

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

Lidar Operator: Signature over Printed Name

6. Flight Log for 7427GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7427

1 LIDAR Operator: MV Tongs	2 ALTM Model: GC	3 Mission Name: 2BLK82V	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Dangui-nes	8 Co-Pilot: Agno	9 Route:			
10 Date: 8-11-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 1412	14 Engine Off: 1641	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed voids in Blk 82					
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

B. DONGUINES

Signature over Printed Name

Lidar Operator

Signature over Printed Name

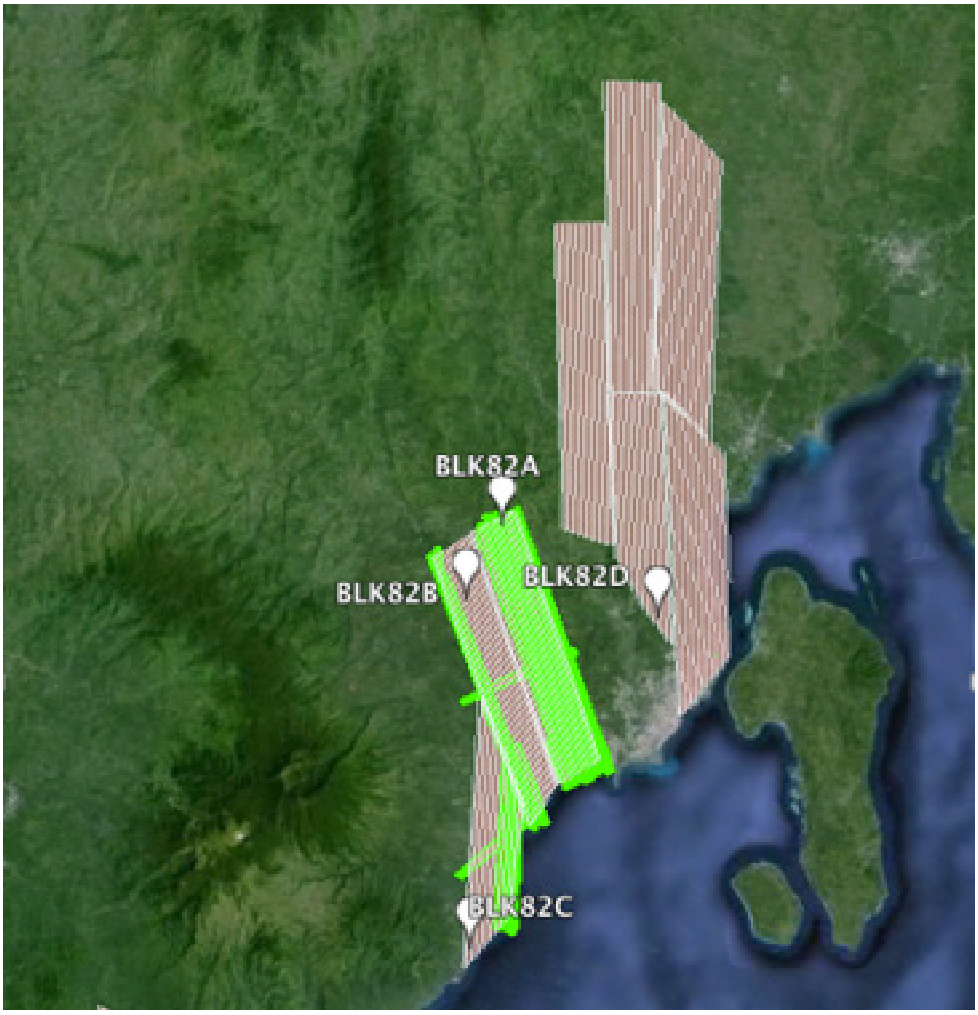
ANNEX 7. Flight Status Reports

DAVAO ORIENTAL
(July 16 – August 13, 2014)

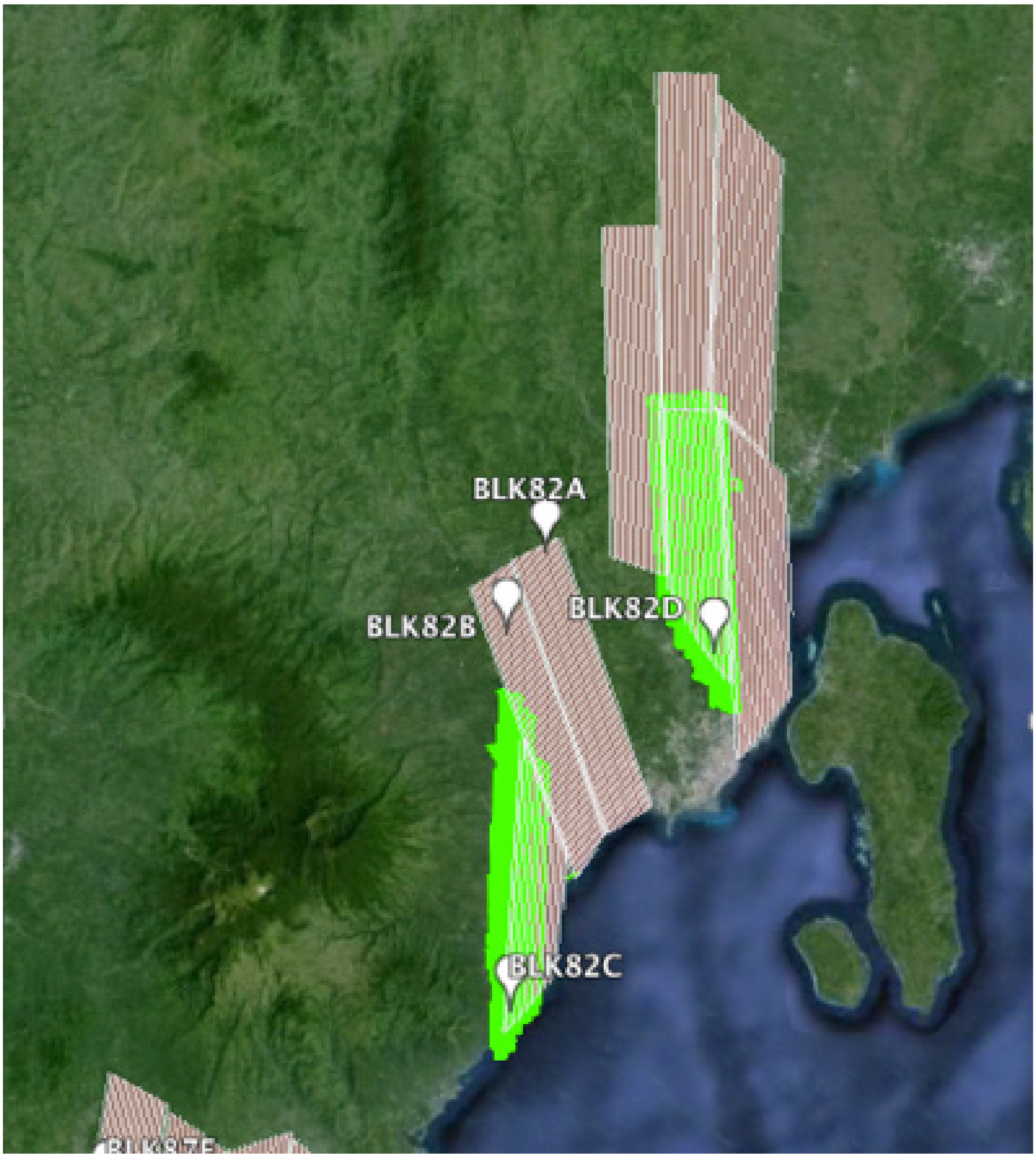
Flight No	Area	Mission	Operator	Date Flown	Remarks
7378GC	BLK82C	2BLK82A199A	MVE TONGA	July 18, 2014	Flown BLK82ABC and surveyed 12 lines without CASI @ 850 AGL
7386GC	BLK82C	2BLK82CSD203A	LK PARAGAS	July 22, 2014	Completed BLK82C (9 lines) and surveyed BLK82C (7 lines) without CASI @ 800 AGL
7388GC	BLK82BE	2BLK82DAB204A	MVE TONGA	July 23, 2014	Completed the remaining lines of BLK82AB (8 lines) and proceed to BLK82D (6 lines) without CASI @ 1000 AGL
7401GC	BLK82E	2BLK87EFGHS210B	LK PARAGAS	July 29, 2014	Surveyed BLK87EFGH (7 lines) without CASI @ 850 AGL
7426GC	BLK82	2BLK82V223A	LK PARAGAS	Aug 11, 2014	14 lines that filled up BLK 82 voids
7427GC	BLK82	2BLK82V223B	MVE TONGA	Aug 11, 2014	Filled up voids in BLK 82@1000m

LAS BOUNDARIES PER FLIGHT

Flight No. :	7378GC
Area:	BLK82C
Mission name:	2BLK82A199A
Parameters:	Altitude: 850 m; Scan Frequency: 40 Hz; Scan Angle: 25 deg; Overlap: 30%
Scan Angle:	Overlap: 40%
Area covered:	175.283 km^2



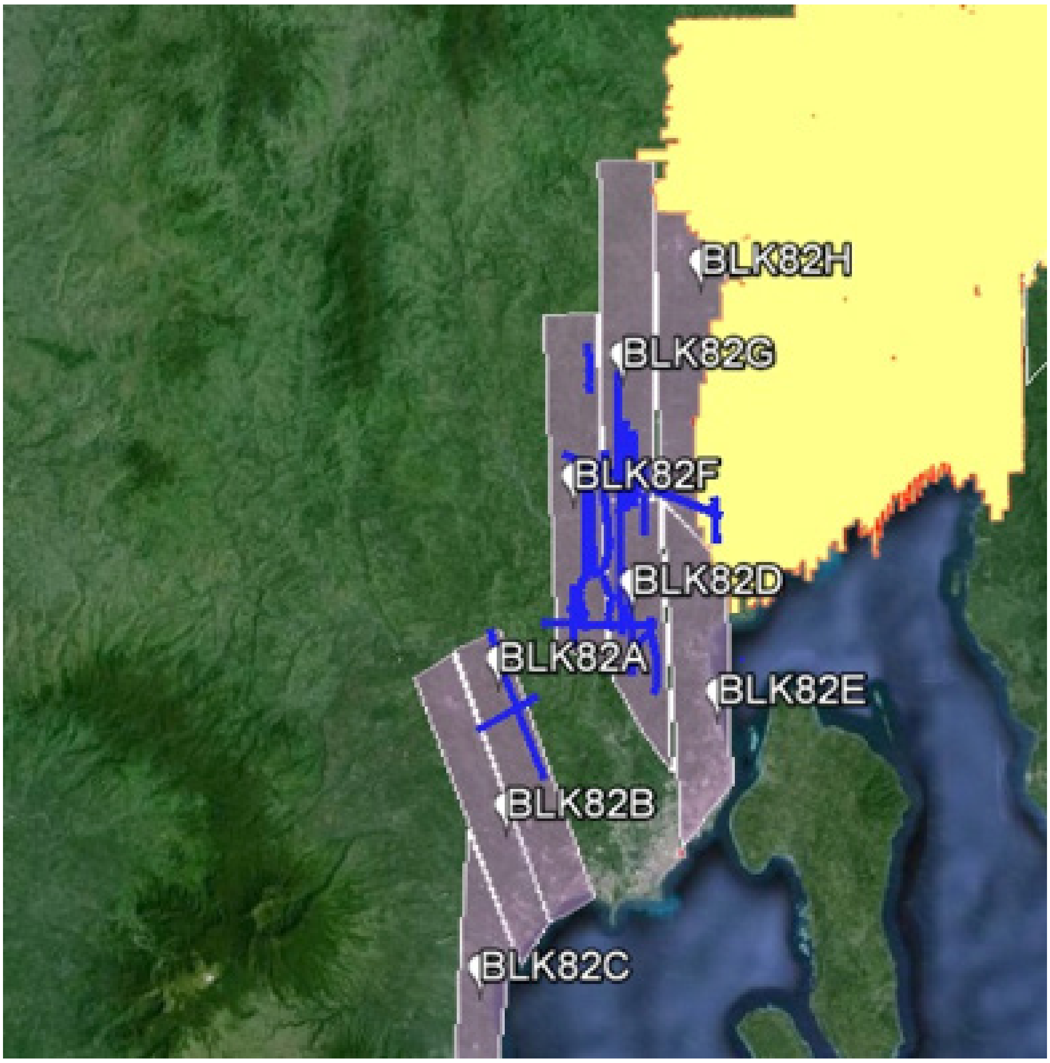
Flight No. :	7386GC
Area:	BLK82C
Mission name:	2BLK82CSD203A
Parameters:	Altitude: 800 m; Scan Frequency: 40 Hz; Scan Angle: 25 deg; Overlap: 35%
Area covered:	249.133 km^2



Flight No. :	7388GC
Area:	BLK82BE
Mission name:	2BLK82DAB204A
Parameters:	Altitude: 1000 m; Scan Frequency: 50 Hz; Scan Angle: 20 deg; Overlap: 30 %
Area covered:	205.138 km^2

Flight No. :	7401GC
Area:	BLK82E
Mission name:	2BLK82EFGHS210B
Parameters:	Altitude: 850 m; Scan Frequency: 40 Hz; Scan Angle: 25 deg; Overlap: 30 %
Area covered:	83.269 km^2

Flight No. :	7426GC
Area:	BLK82_voids
Mission name:	2BLK82V223A
Parameters:	Altitude: 1000 m; Scan Frequency: 50 Hz; Scan Angle: 20 deg; Overlap: 35 %
Area covered:	95.826 km^2



Flight No. :	7427GC
Area:	BLK82B_voids
Mission name:	2BLK82V223B
Parameters:	Altitude: 1000 m; Scan Frequency: 50 Hz; Scan Angle: 20 deg; Overlap: 35 %
Area covered:	42.889 km^2

ANNEX 8. Mission Summary Report

Flight Area	Davao Oriental
Mission Name	Blk82B
Inclusive Flights	7378G,7388G
Range data size	69.7 GB
POS	471 MB
Image	na
Transfer date	August 7, 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)	1.25
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000555
IMU attitude correction stdev (<0.001deg)	0.002846
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	10.46%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	164
Maximum Height	460.63 m
Minimum Height	66.77 m
Classification (# of points)	
Ground	42,418,988
Low vegetation	48,280,364
Medium vegetation	94,050,611
High vegetation	197,058,041
Building	10,388,900
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Antonio Chua Jr., Engr. Jeffrey Delica

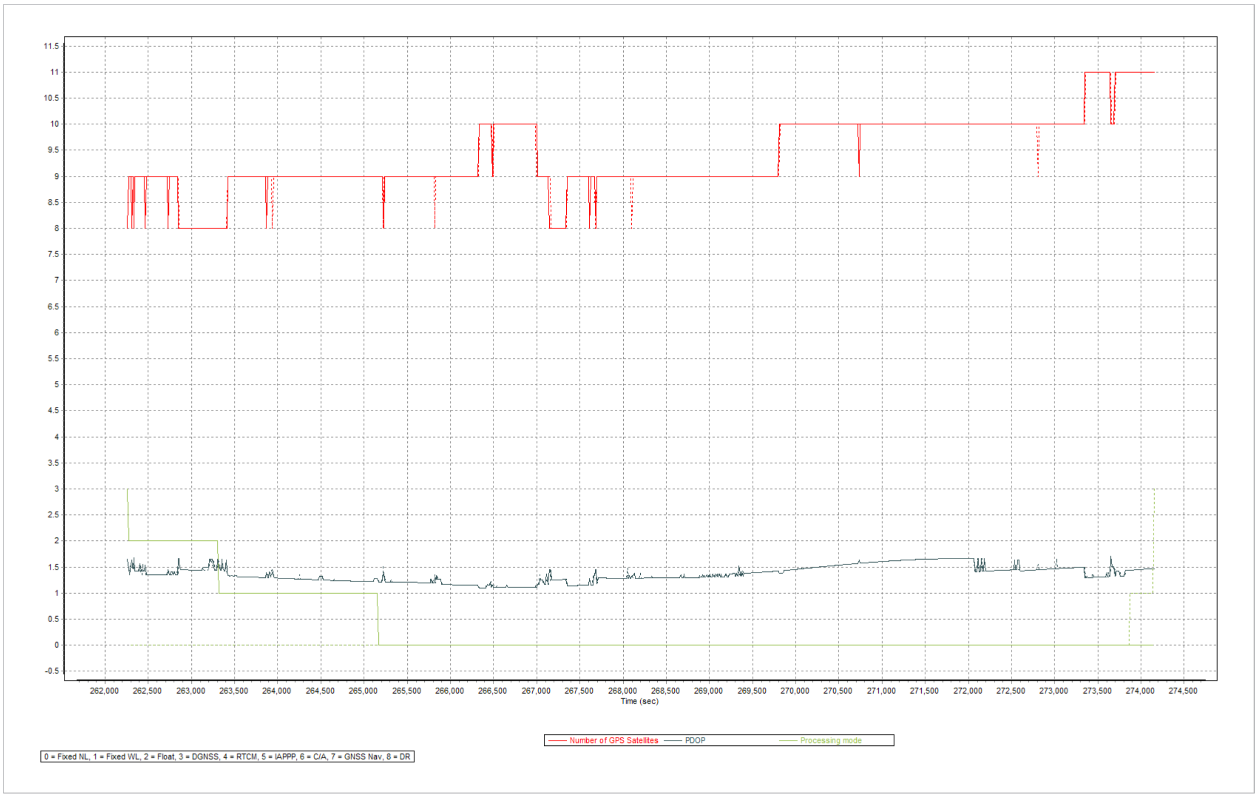


Figure 1.1.1 Solution Status

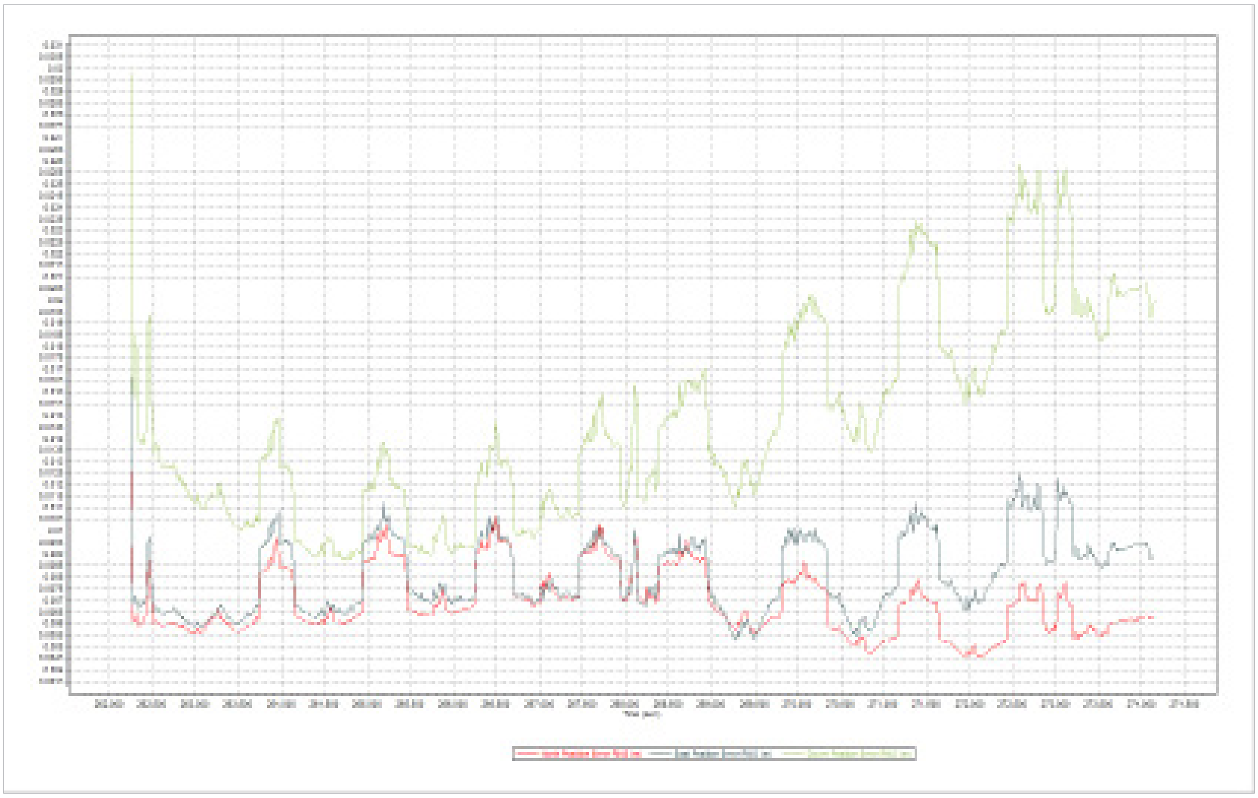


Figure 1.1.2 Smoothed Performance Metric Parameters

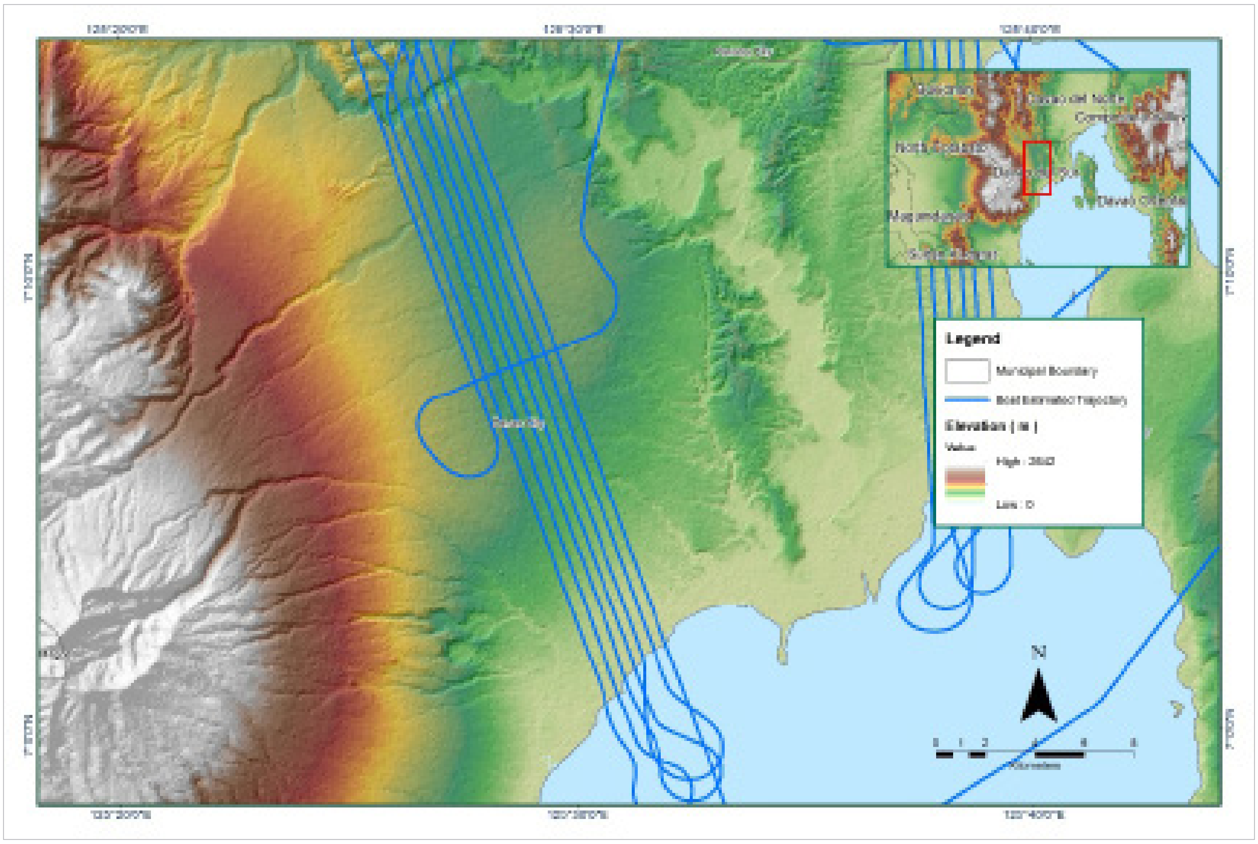


Figure 1.1.3 Best Estimated Trajectory

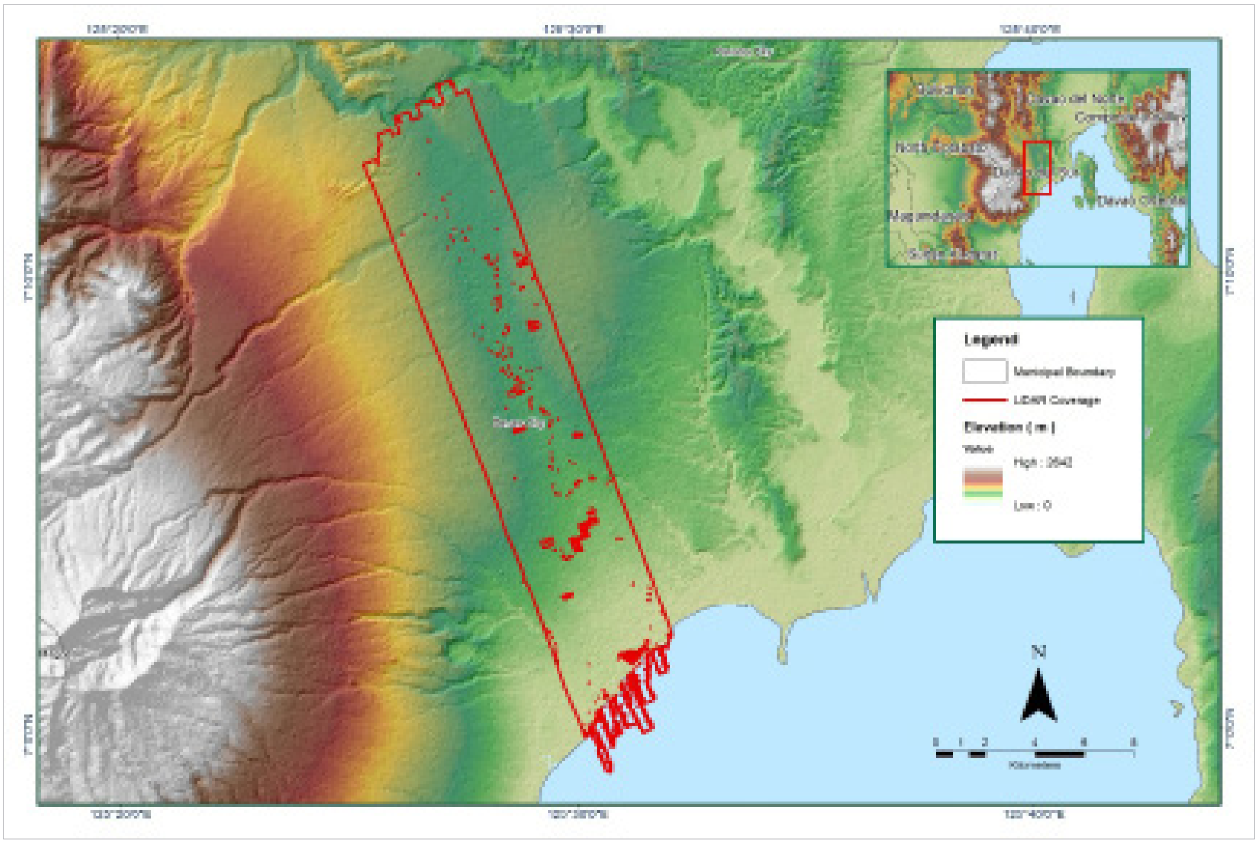


Figure 1.1.4 Coverage of LiDAR data

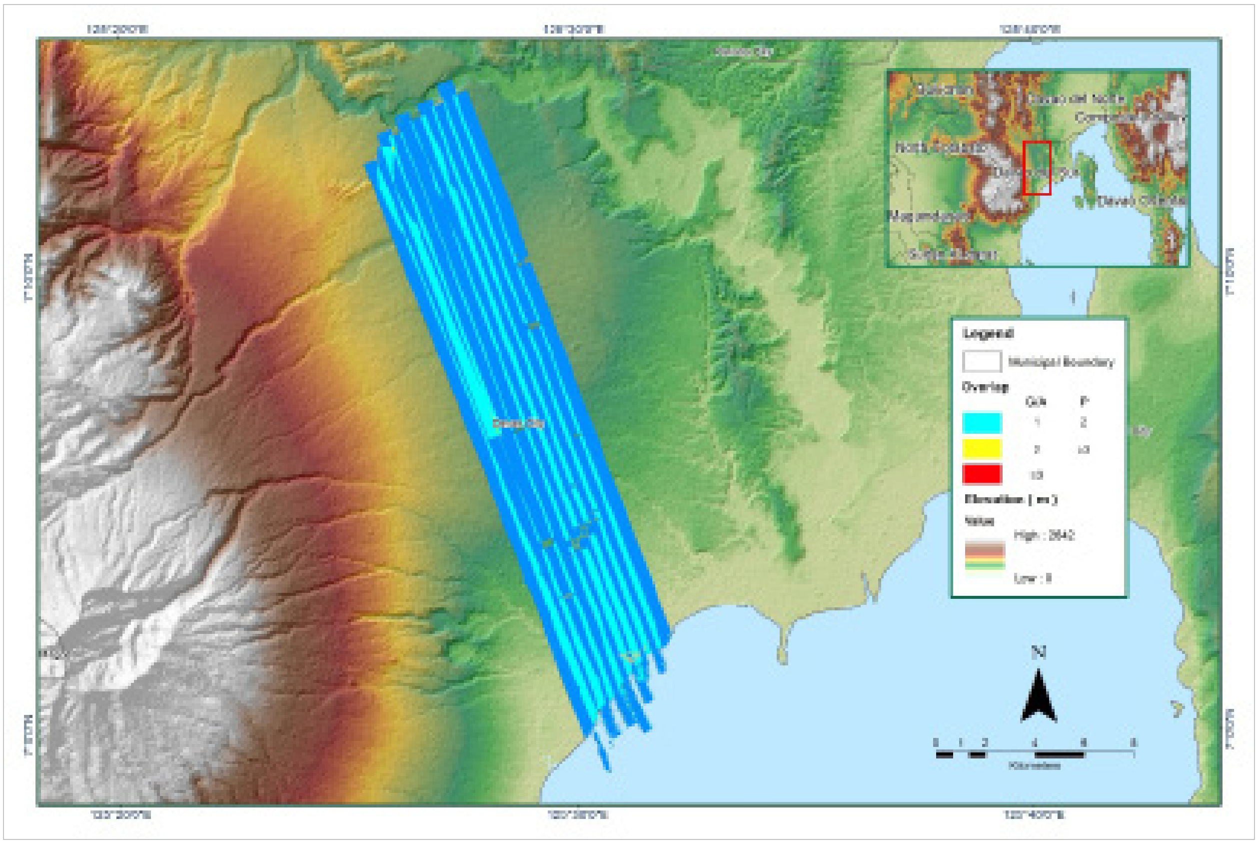


Figure 1.1.5 Image of data overlap

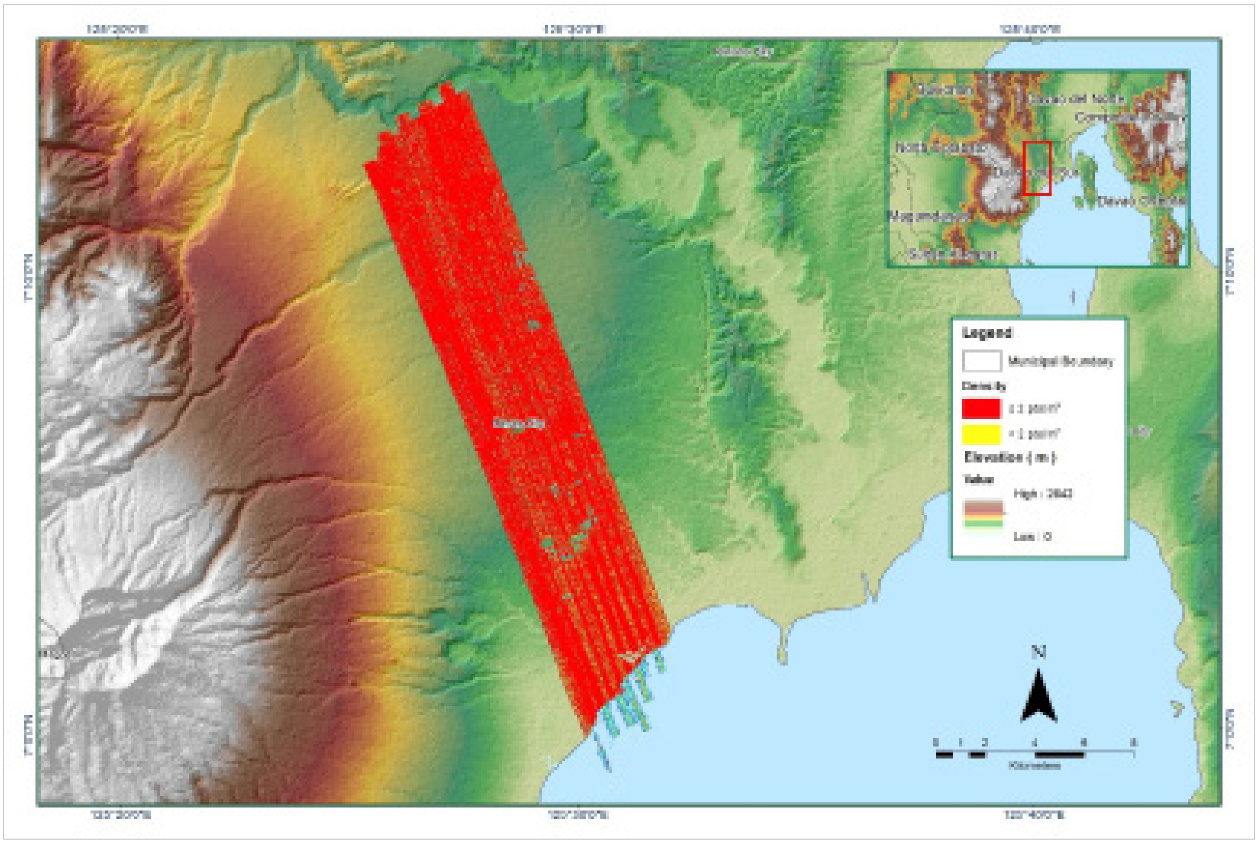


Figure 1.1.6 Density map of merged LiDAR data

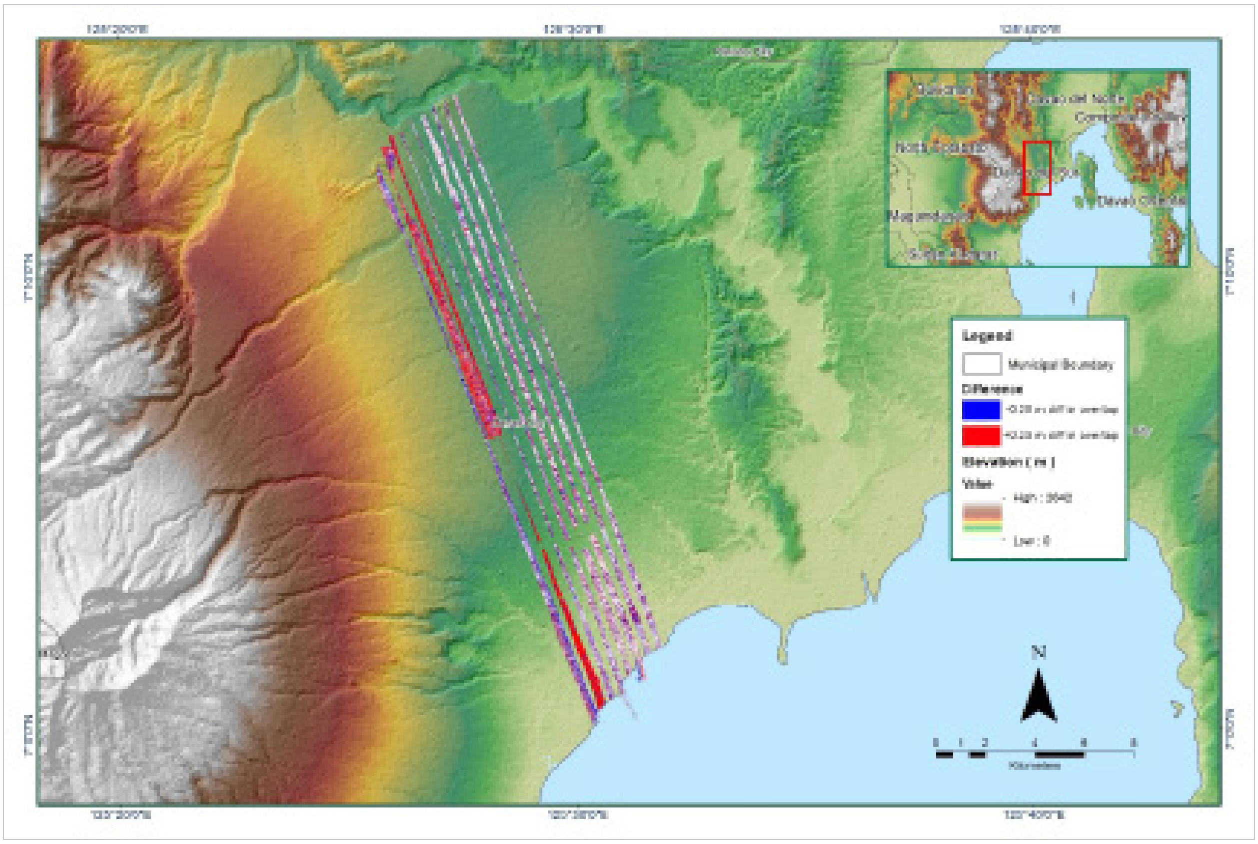


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82C
Inclusive Flights	7378G,7386G
Range data size	77.5 GB
POS	510 MB
Image	na
Transfer date	August 7, 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)	1.12
RMSE for East Position (<4.0 cm)	1.26
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000930
IMU attitude correction stdev (<0.001deg)	0.061913
GPS position stdev (<0.01m)	0.0120
Minimum % overlap (>25)	21.43%
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	165
Maximum Height	415.85 m
Minimum Height	59.35 m
Classification (# of points)	
Ground	32,667,342
Low vegetation	33,428,343
Medium vegetation	125,375,546
High vegetation	215,082,432
Building	2,016,848
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Engr. Jeffrey Delica

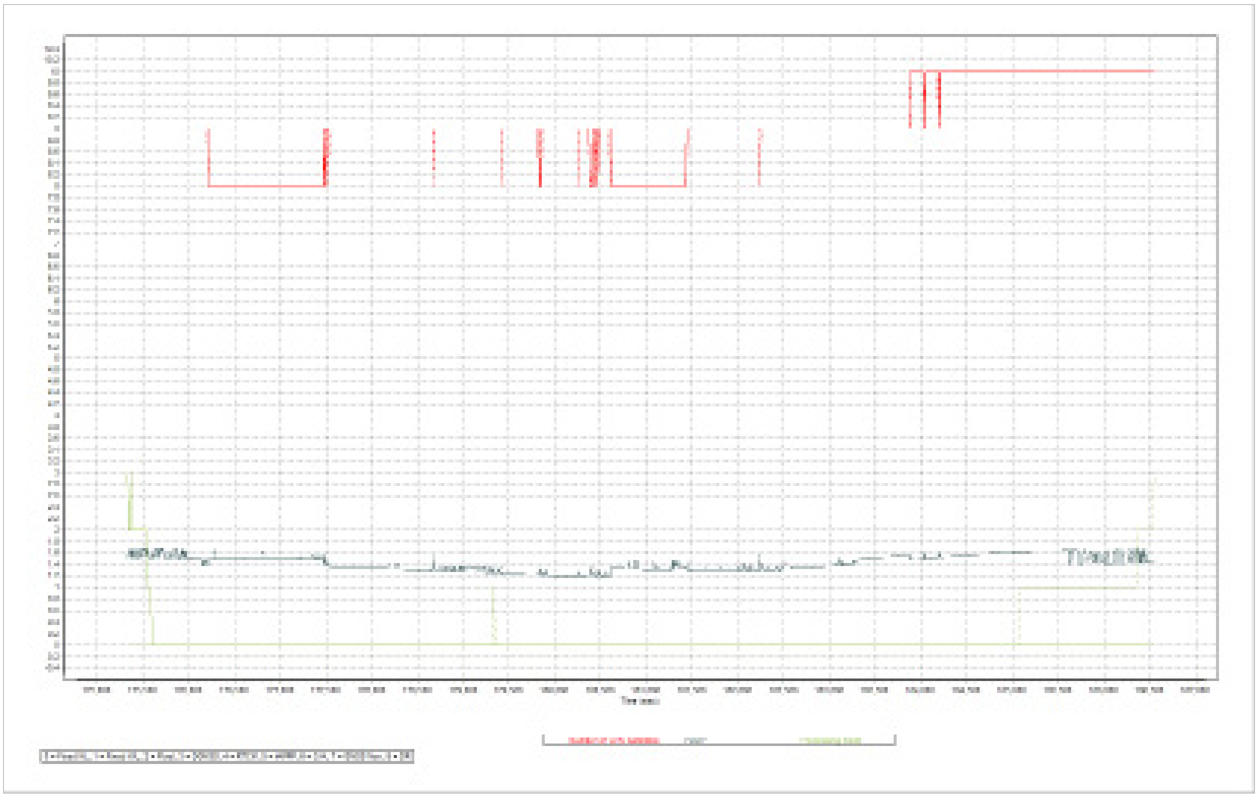


Figure 1.2.1 Solution Status

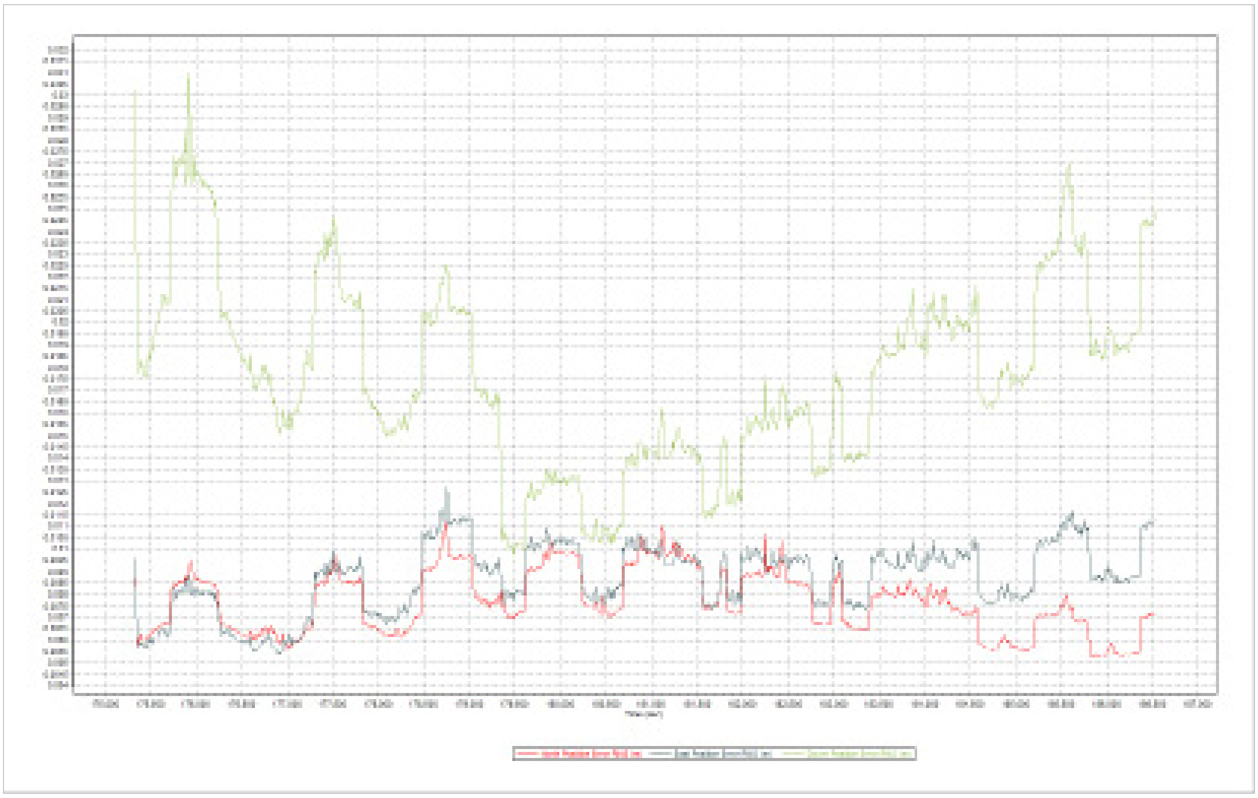


Figure 1.2.2 Smoothed Performance Metric Parameters

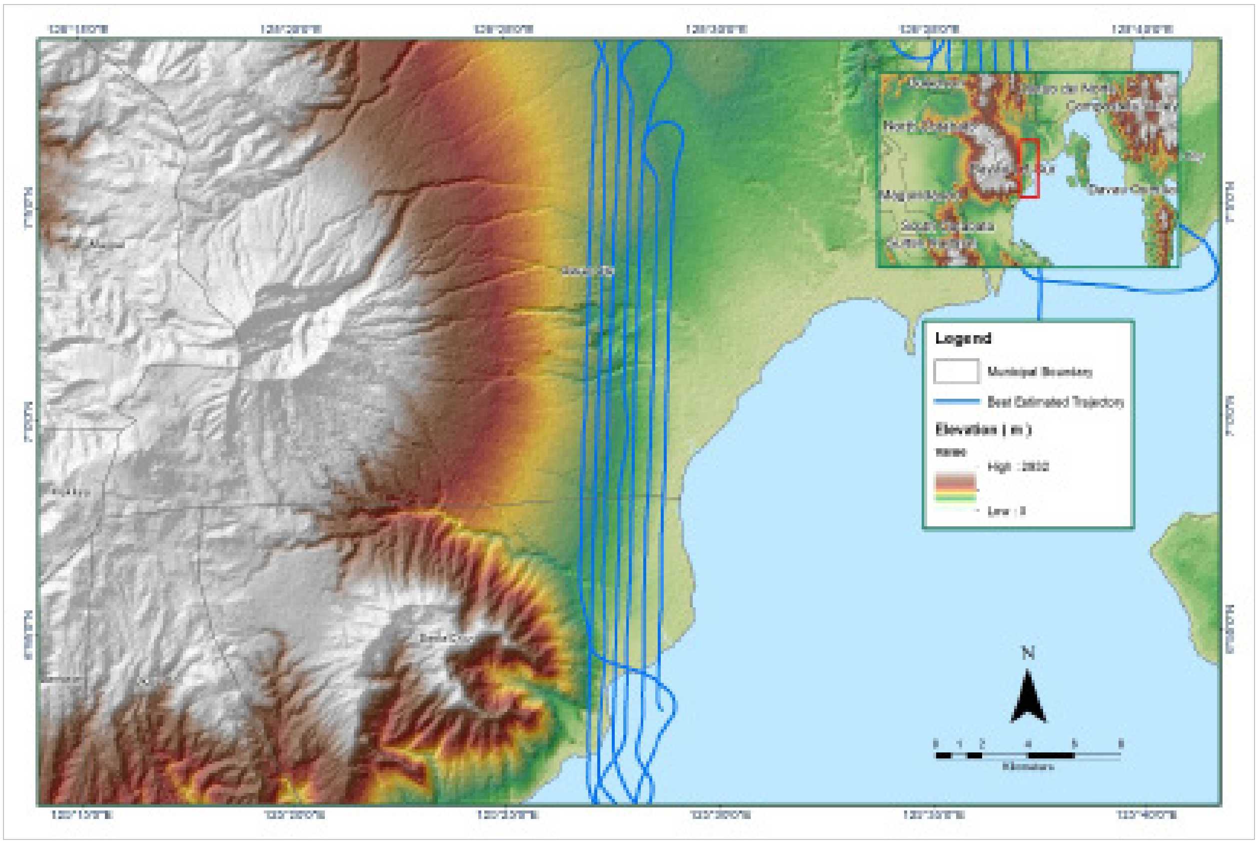


Figure 1.2.3 Best Estimated Trajectory

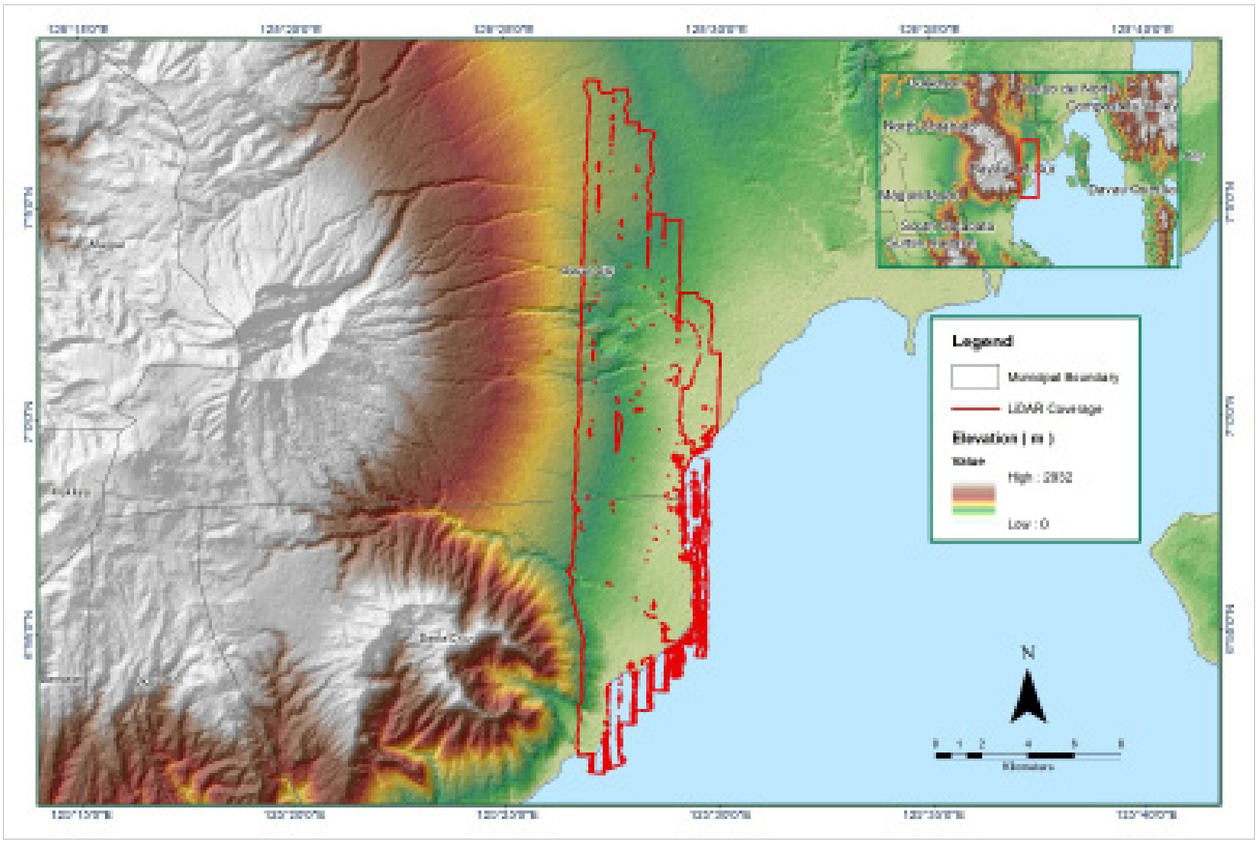


Figure 1.2.4 Coverage of LiDAR data

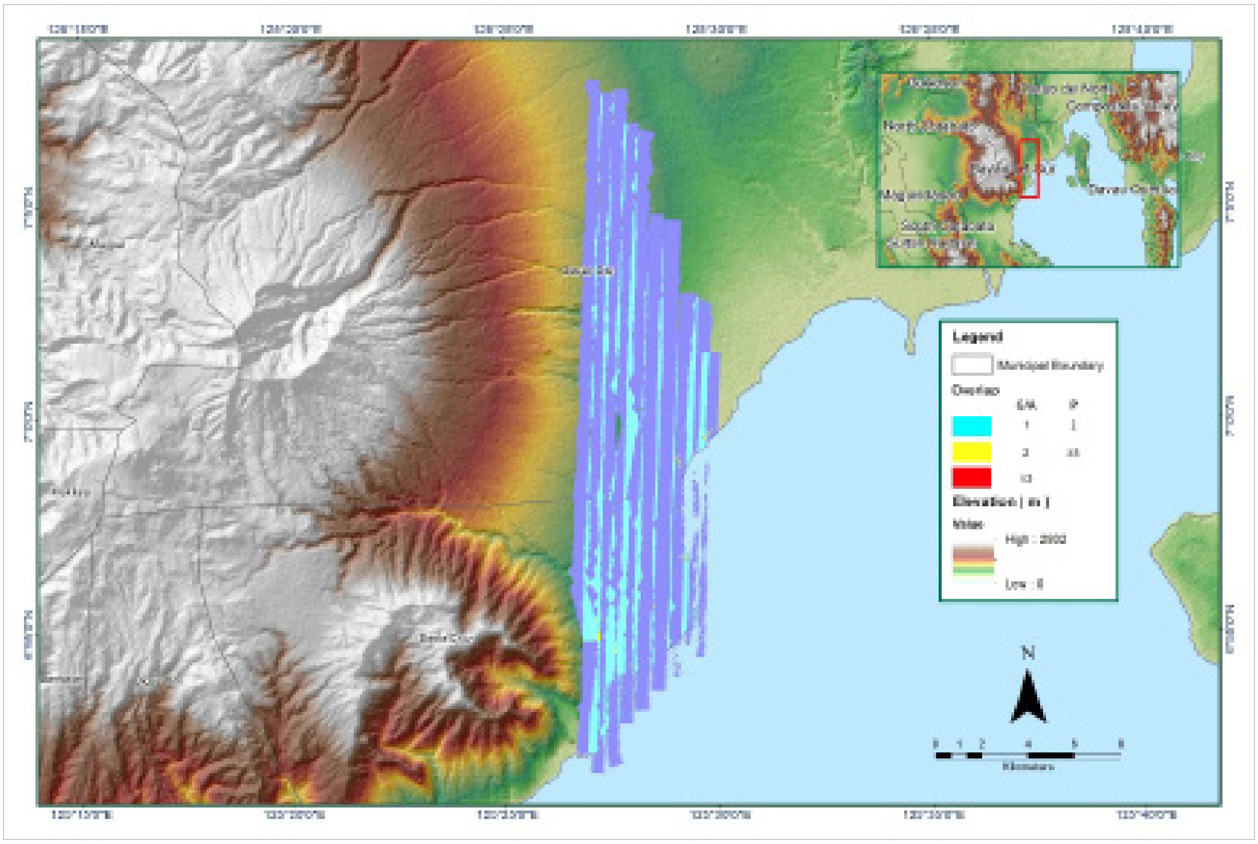


Figure 1.2.5 Image of data overlap

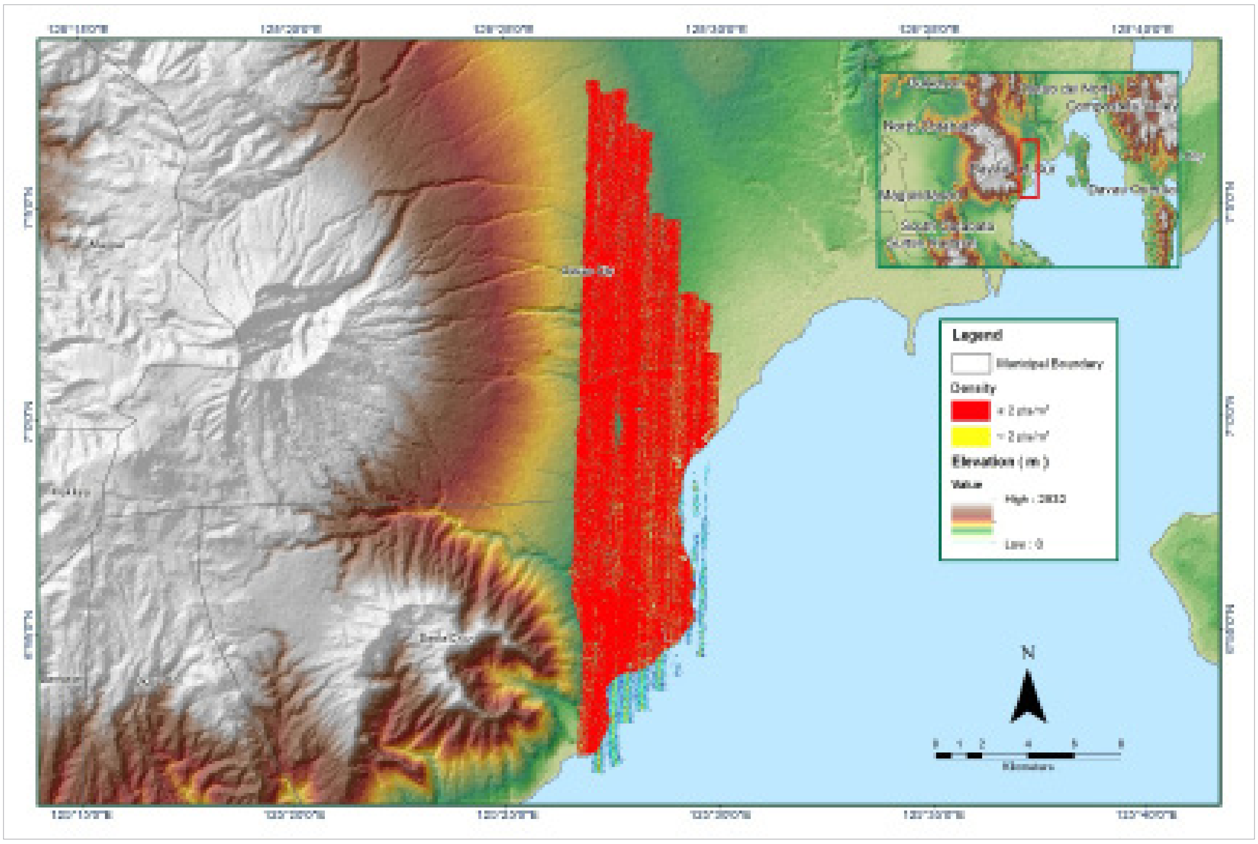


Figure 1.2.6 Density map of merged LiDAR data

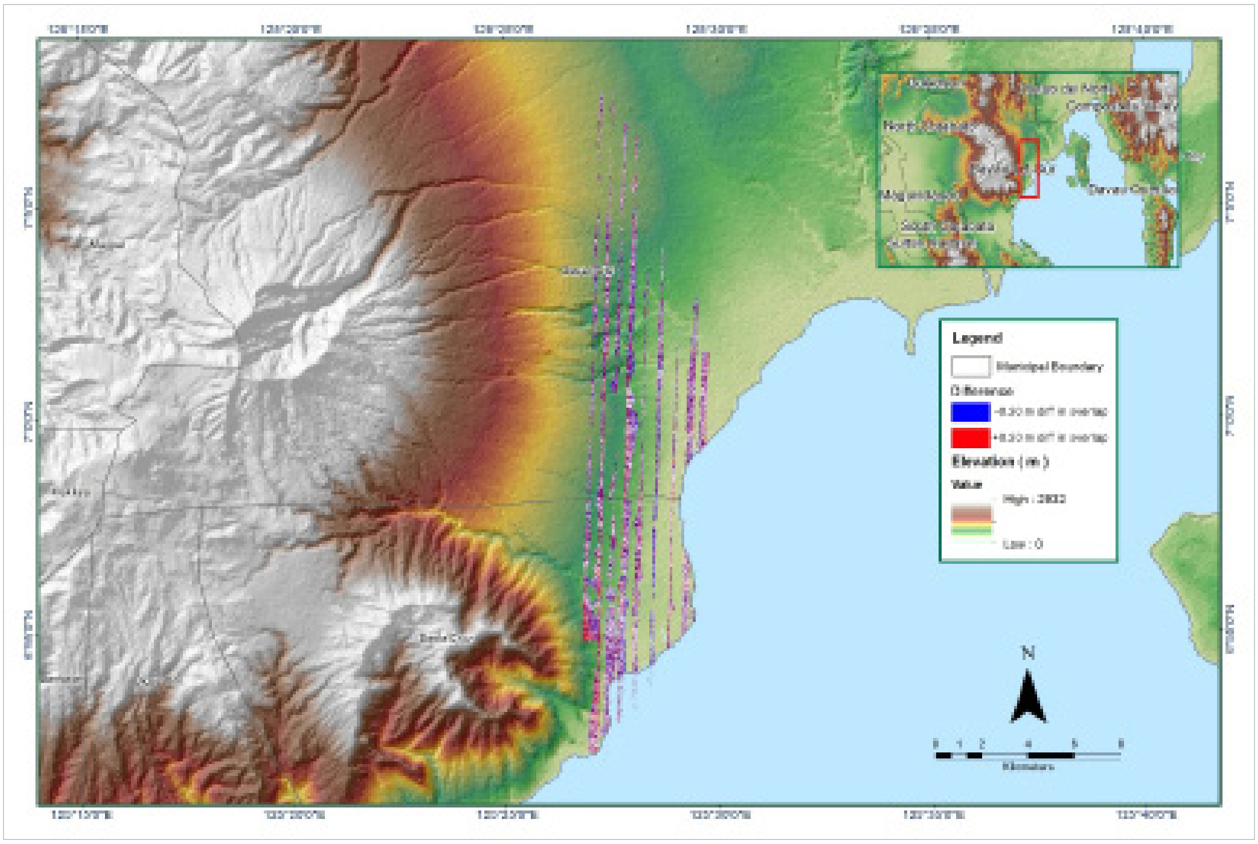


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82E
Inclusive Flights	7388G,7401G
Range data size	29.65 GB
POS	332 MB
Image	na
Transfer date	August 7, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.05
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.000183
IMU attitude correction stdev (<0.001deg)	0.633546
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	24.76%
Ave point cloud density per sq.m. (>2.0)	2.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	318
Maximum Height	403.82 m
Minimum Height	62.44 m
Classification (# of points)	
Ground	75,679,213
Low vegetation	78,983,338
Medium vegetation	146,928,343
High vegetation	282,014,947
Building	24,716,788
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Ailyn Biñas

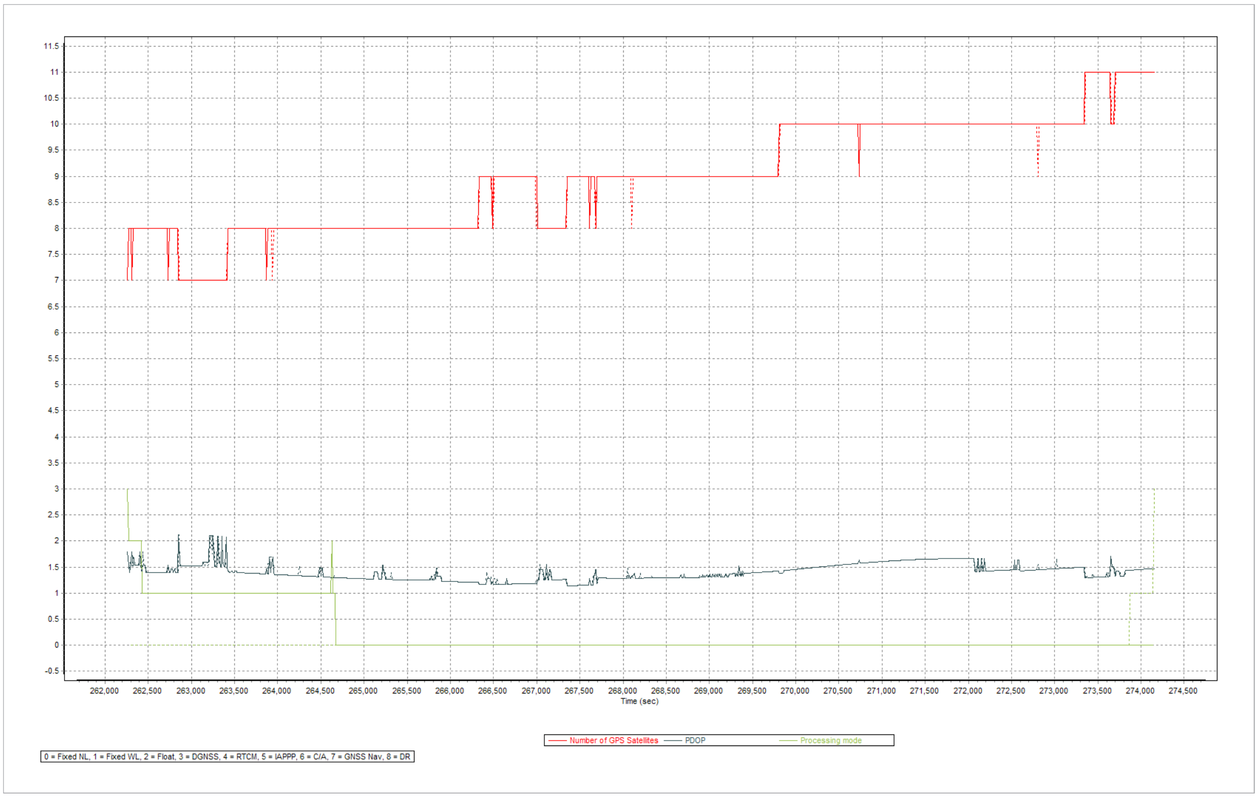


Figure 1.3.1 Solution Status

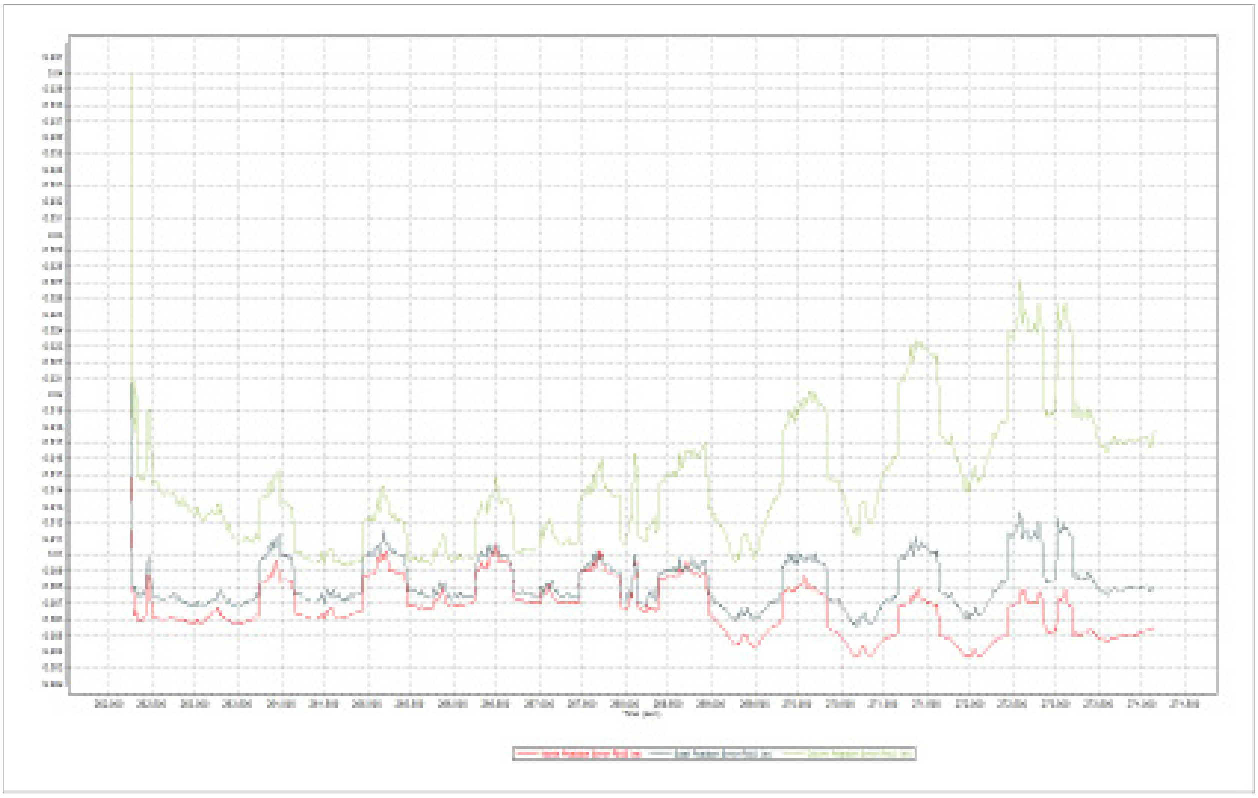


Figure 1.3.2 Smoothed Performance Metric Parameters

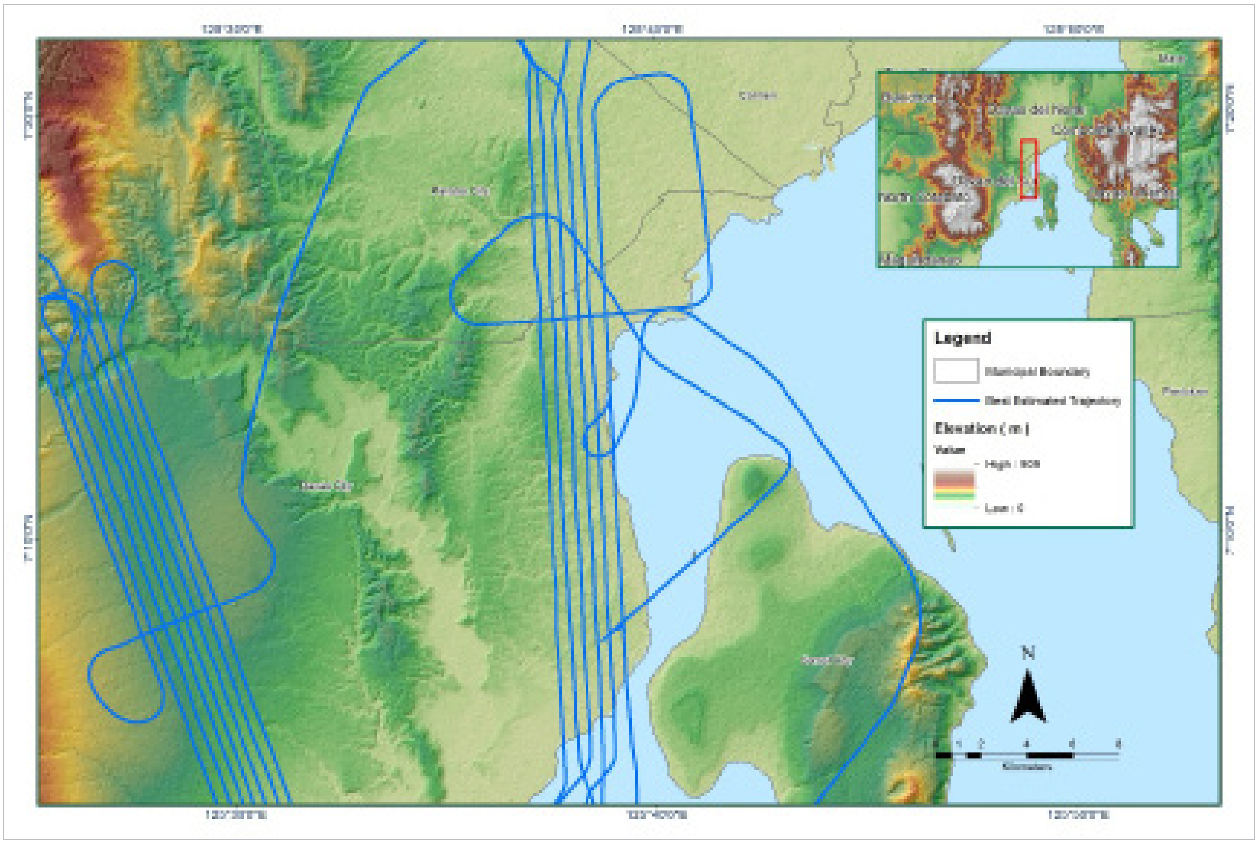


Figure 1.3.3 Best Estimated Trajectory

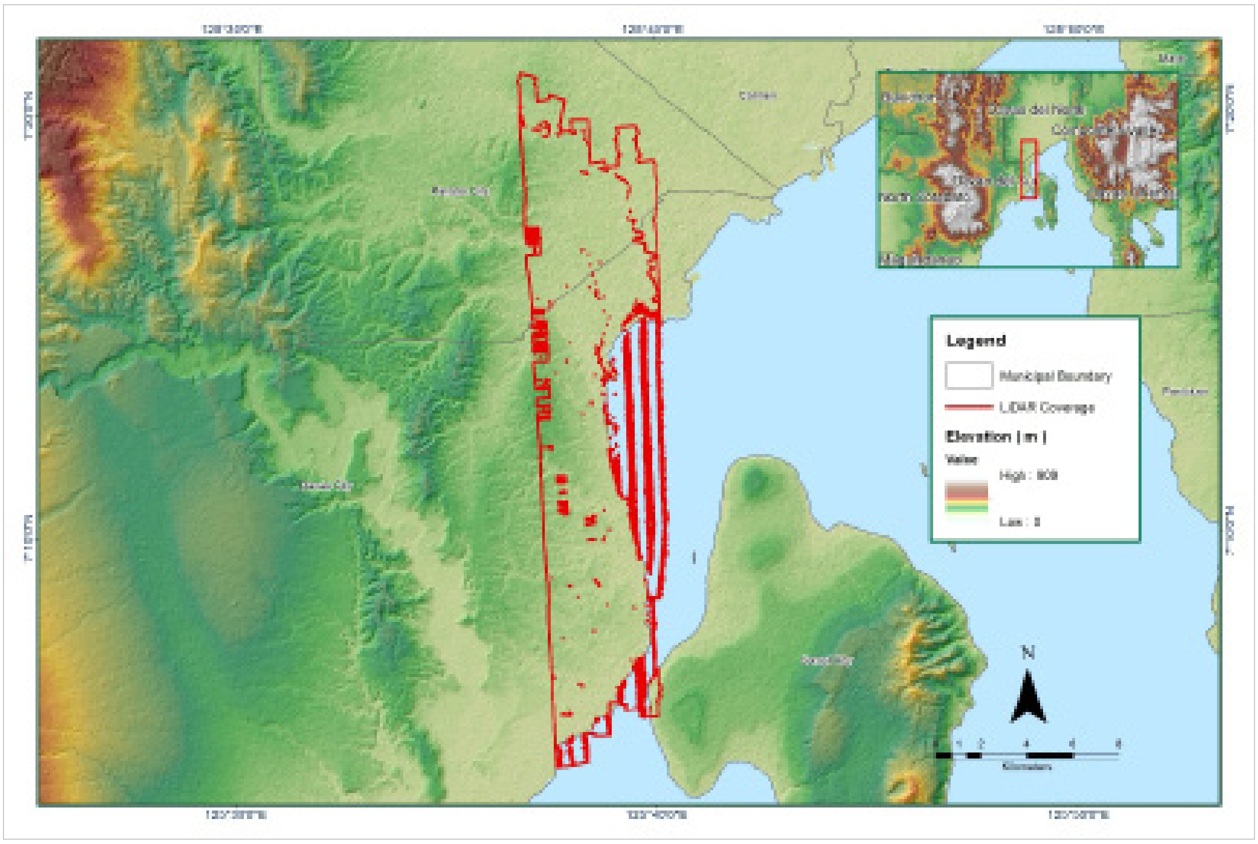


Figure 1.3.4 Coverage of LiDAR data

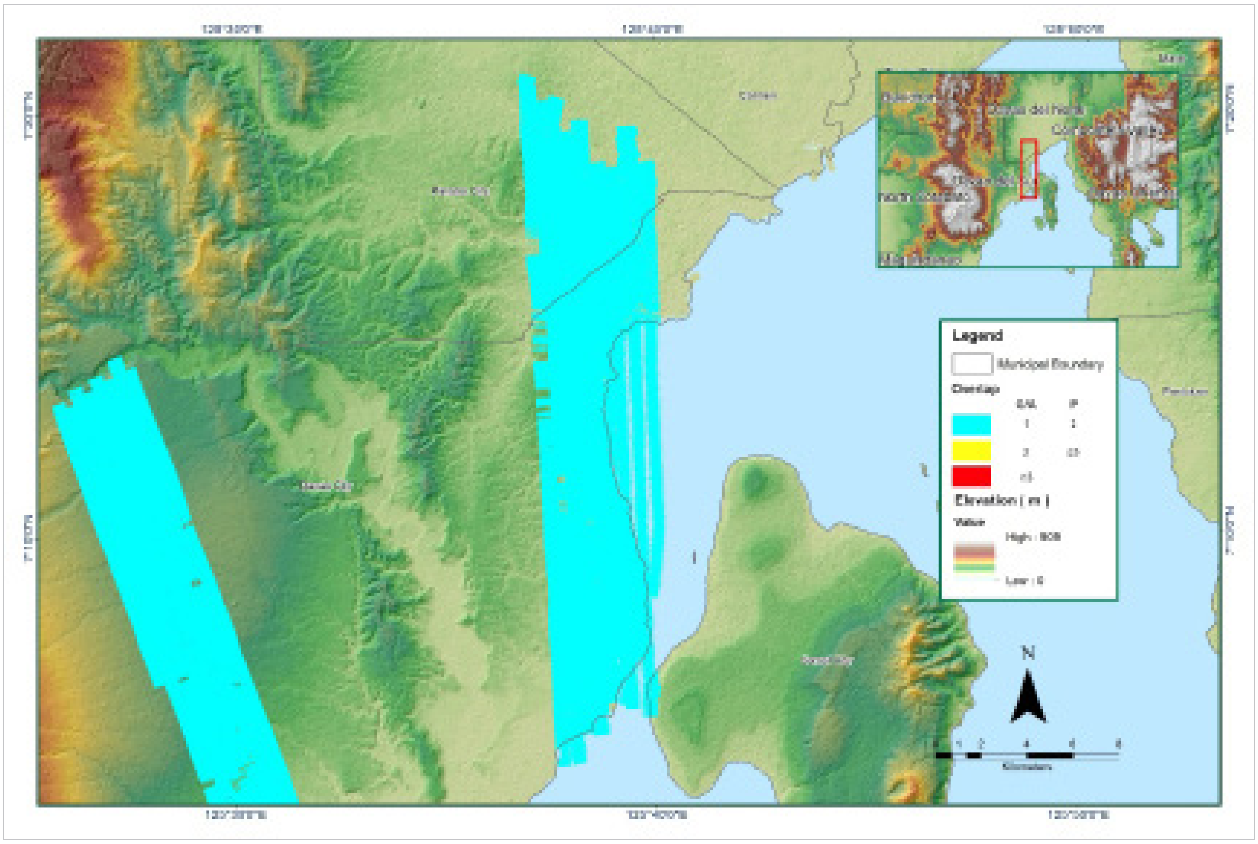


Figure 1.3.5 Image of data overlap

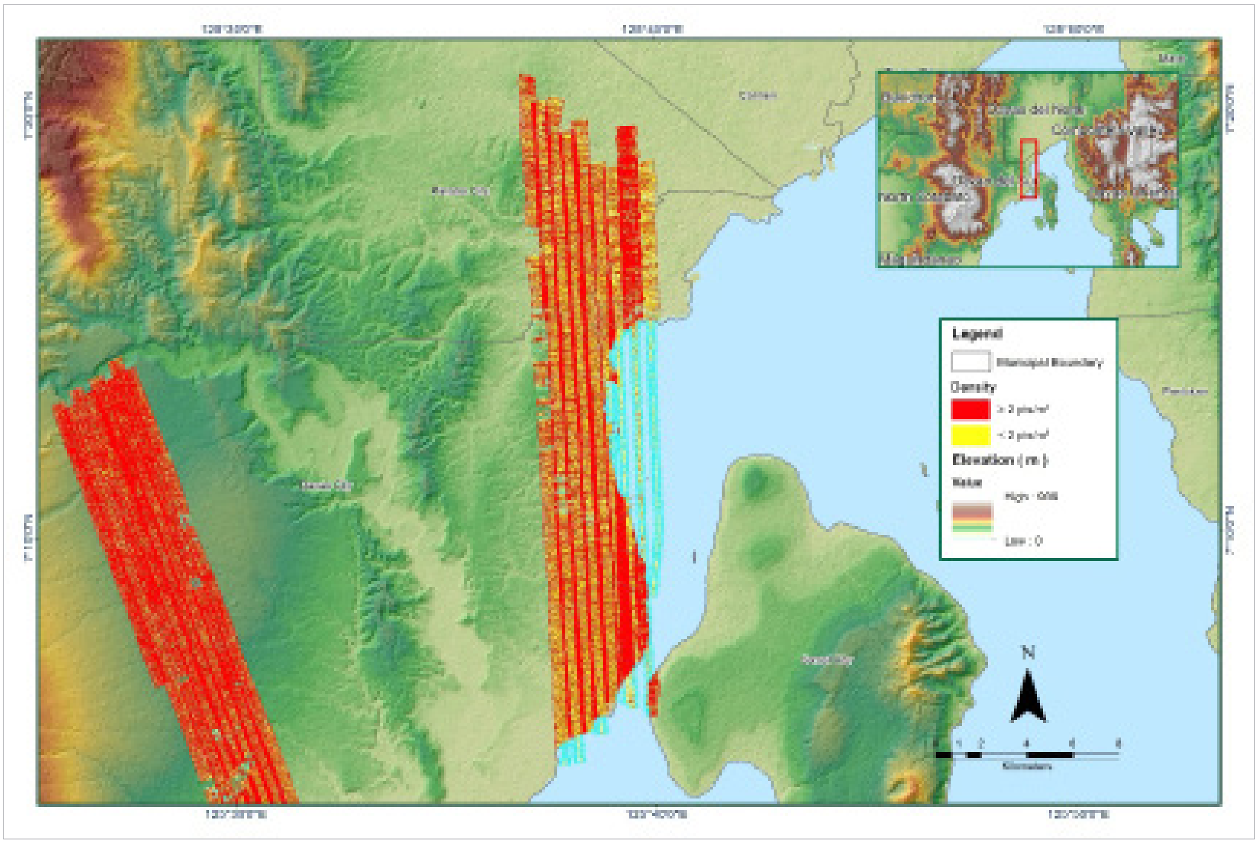


Figure 1.3.6 Density map of merged LiDAR data

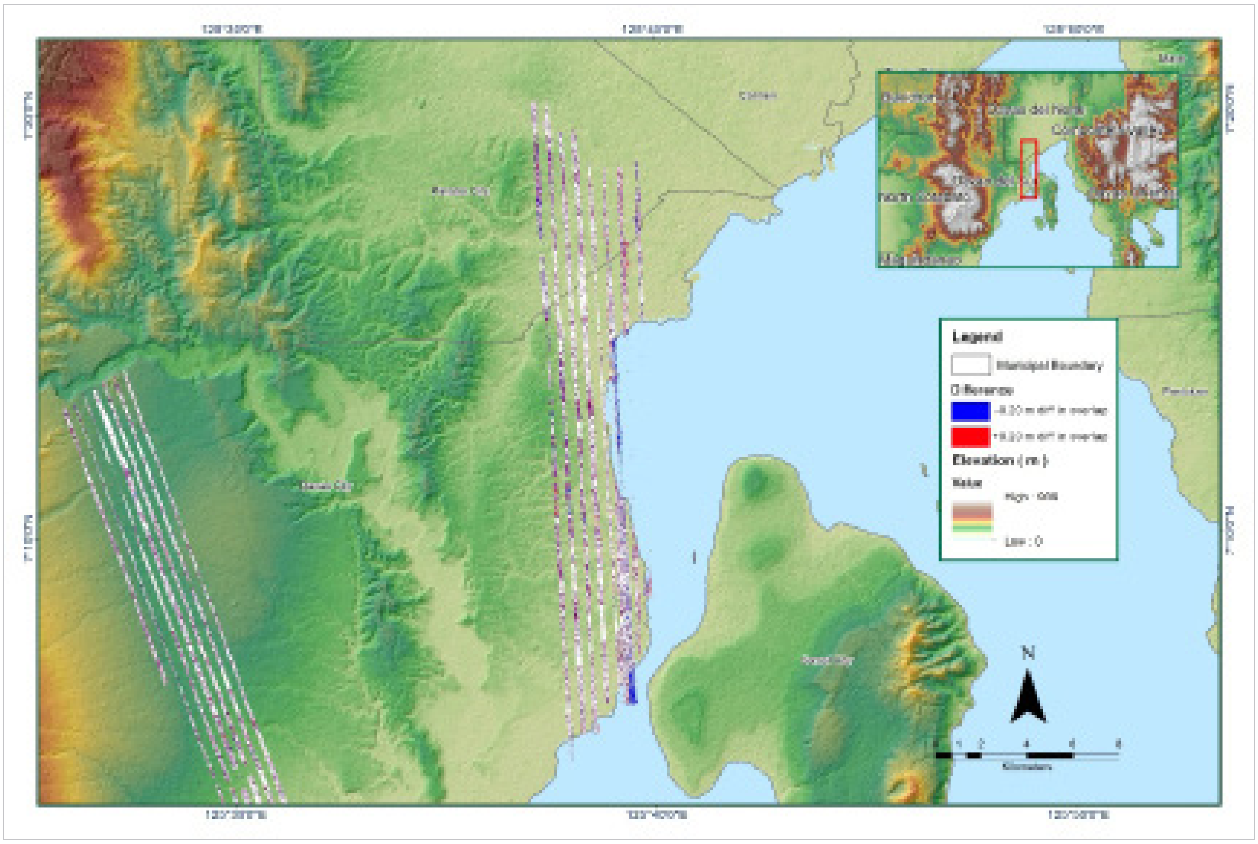


Figure 1.3.7 Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82 Voids
Inclusive Flights	7427G,7426G
Range data size	15.26 GB
POS	267 MB
Image	na
Transfer date	August 29, 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)	2.5
RMSE for East Position (<4.0 cm)	3.1
RMSE for Down Position (<8.0 cm)	7.4
Boresight correction stdev (<0.001deg)	0.001127
IMU attitude correction stdev (<0.001deg)	0.016683
GPS position stdev (<0.01m)	0.0248
Minimum % overlap (>25)	10.46%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	272
Maximum Height	421.89 m
Minimum Height	67.51 m
Classification (# of points)	
Ground	40,594,810
Low vegetation	34,398,304
Medium vegetation	58,498,265
High vegetation	166,572,237
Building	4,853,133
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Ailyn Biñas

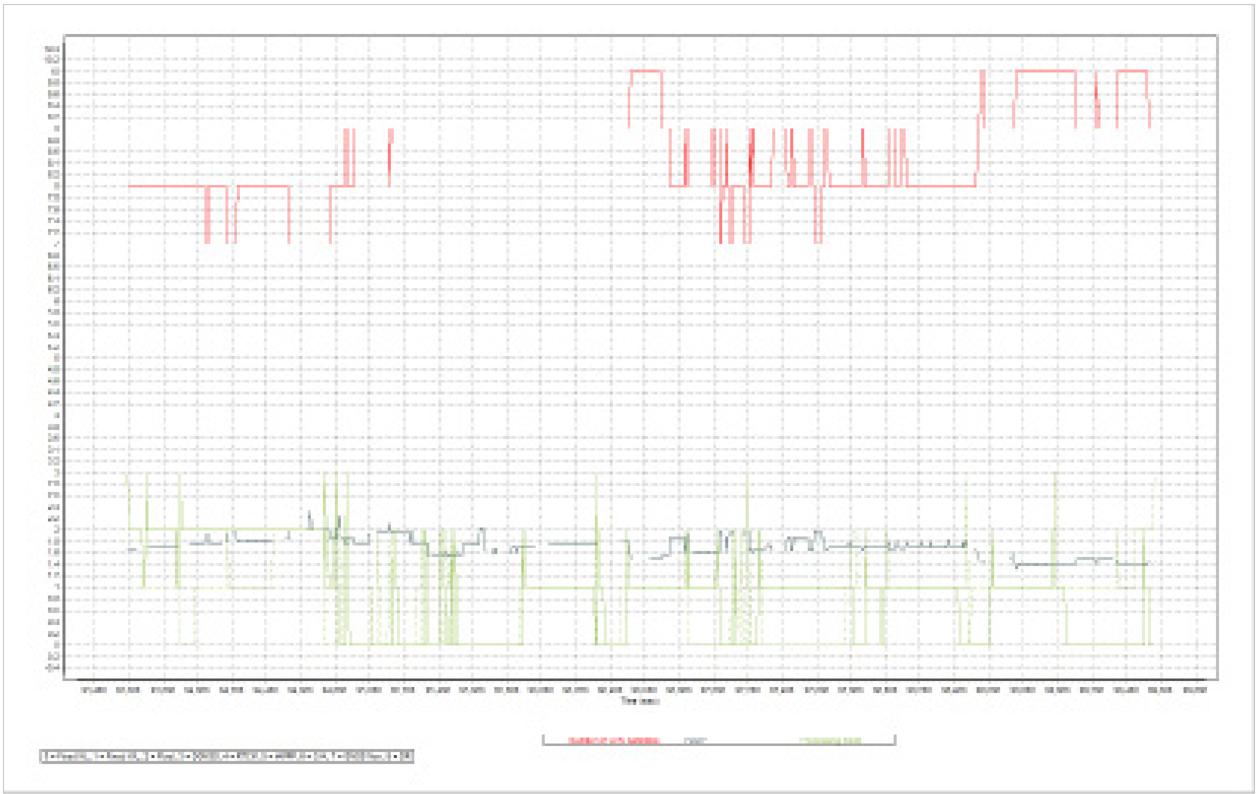


Figure 1.4.1 Solution Status

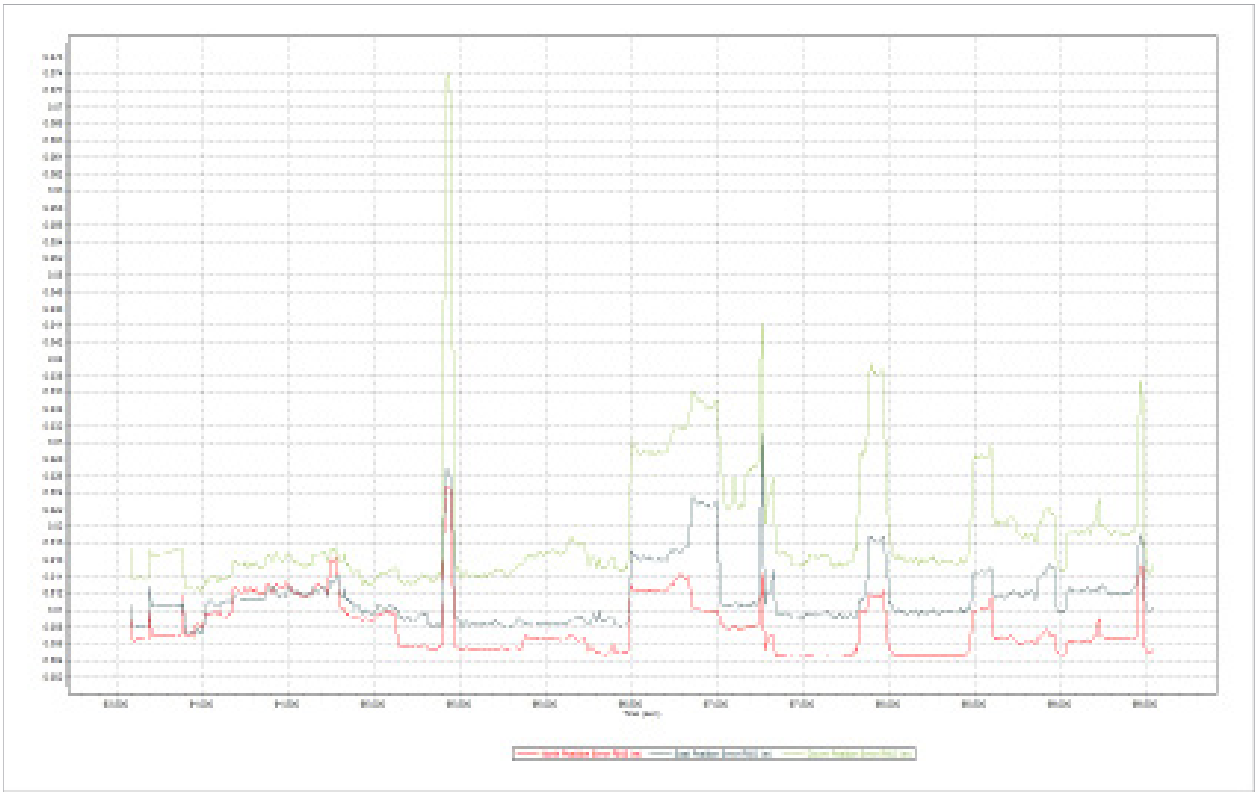


Figure 1.4.2 Smoothed Performance Metric Parameters

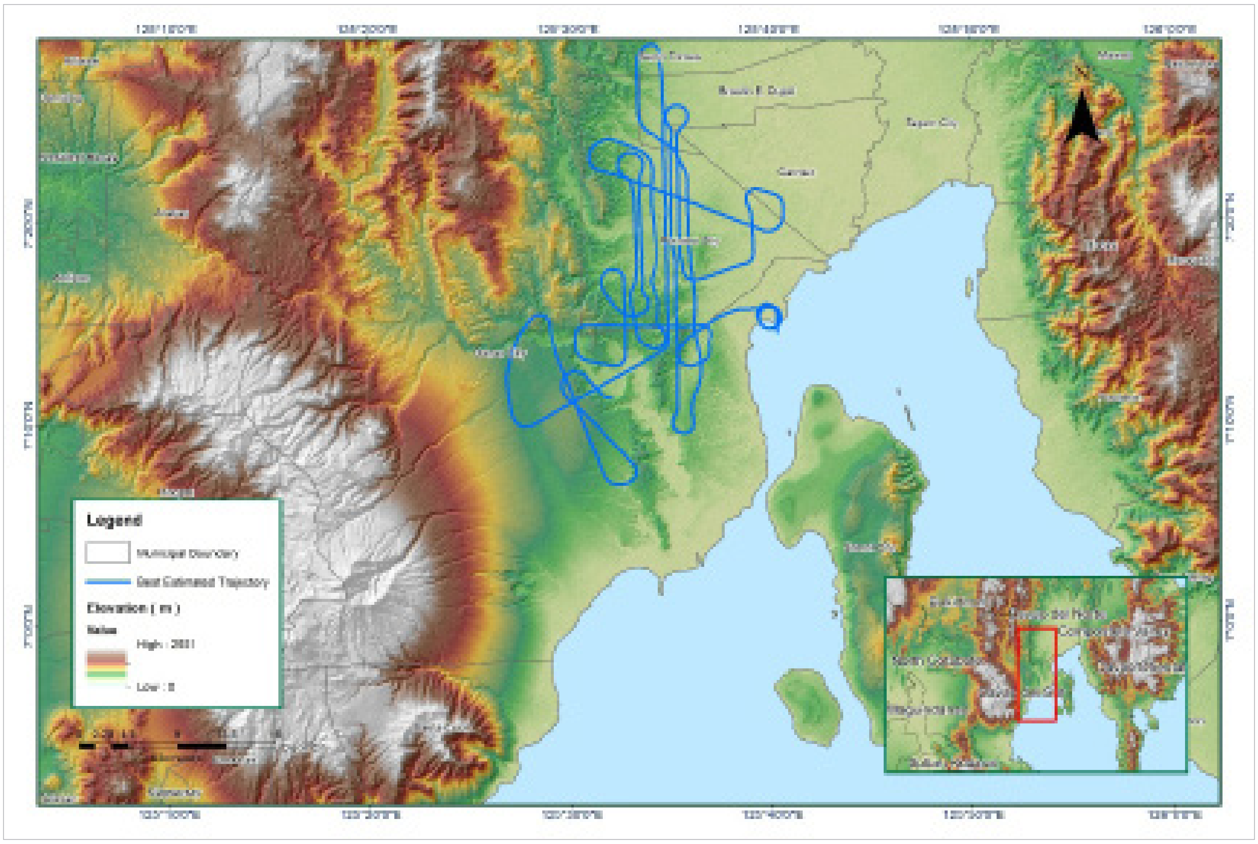


Figure 1.4.3 Best Estimated Trajectory

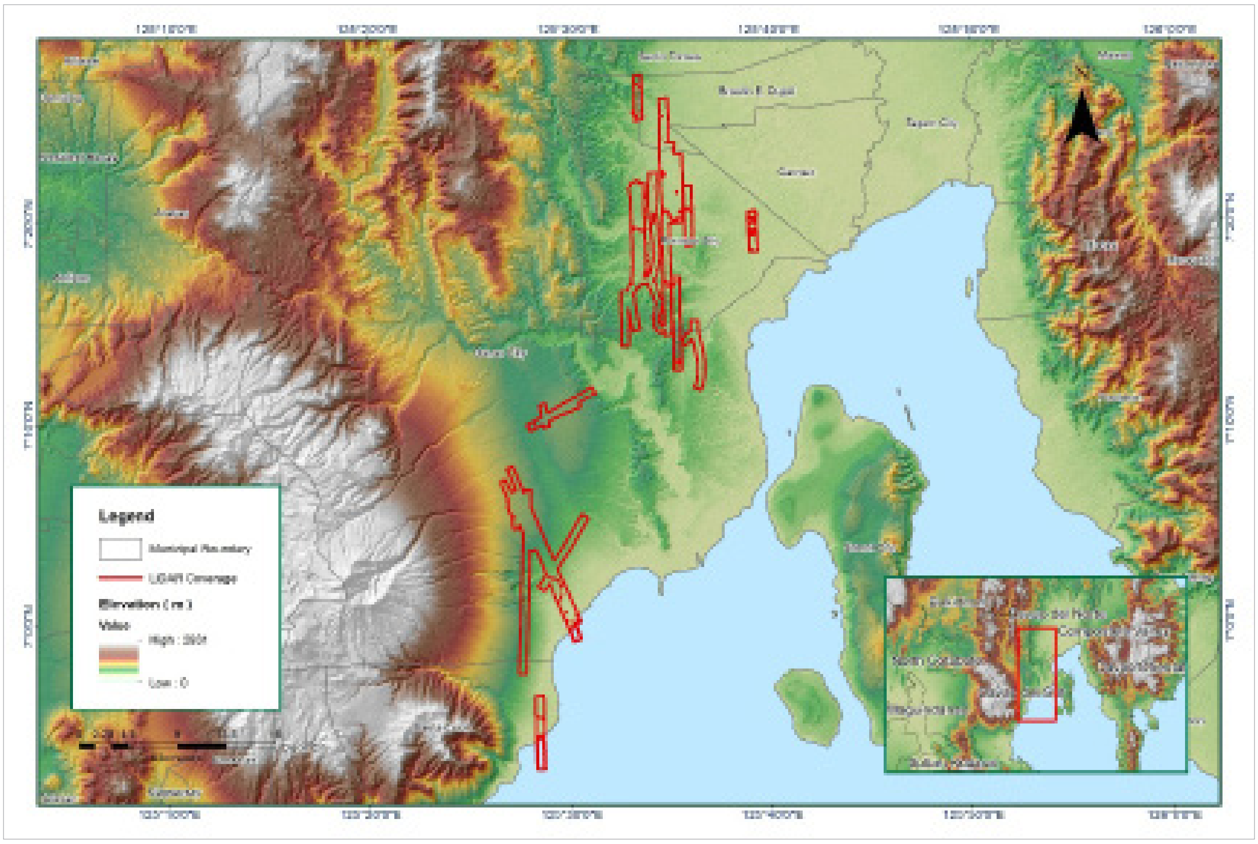


Figure 1.4.4 Coverage of LiDAR data

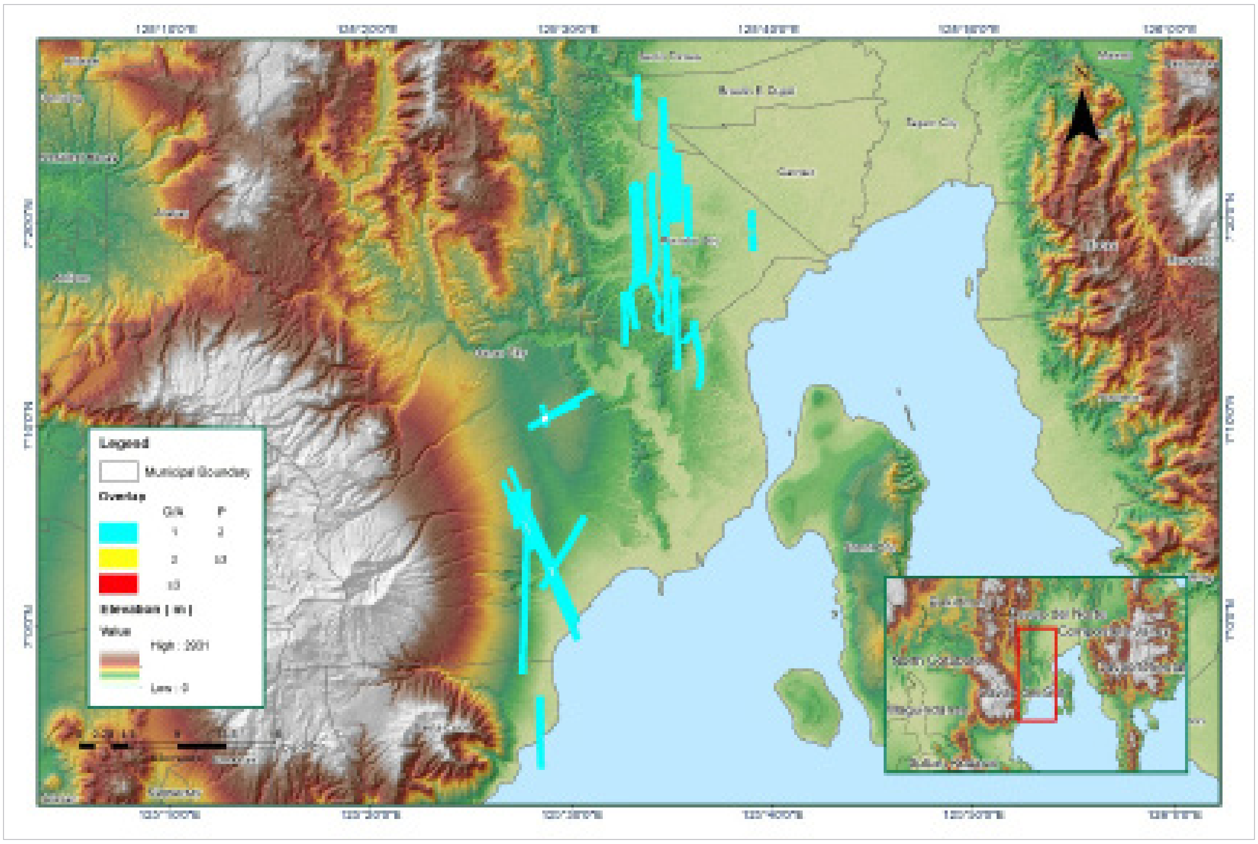


Figure 1.4.5 Image of data overlap

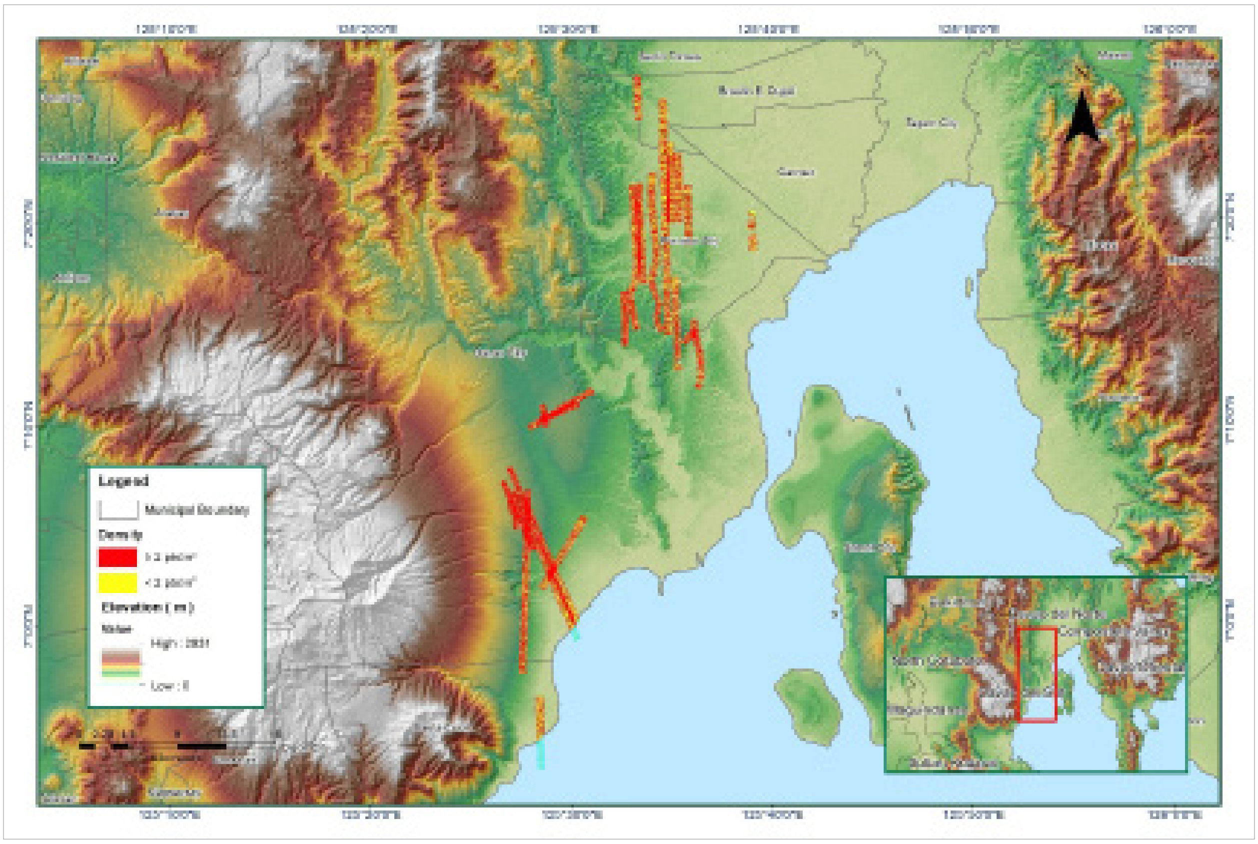


Figure 1.4.6 Density map of merged LiDAR data

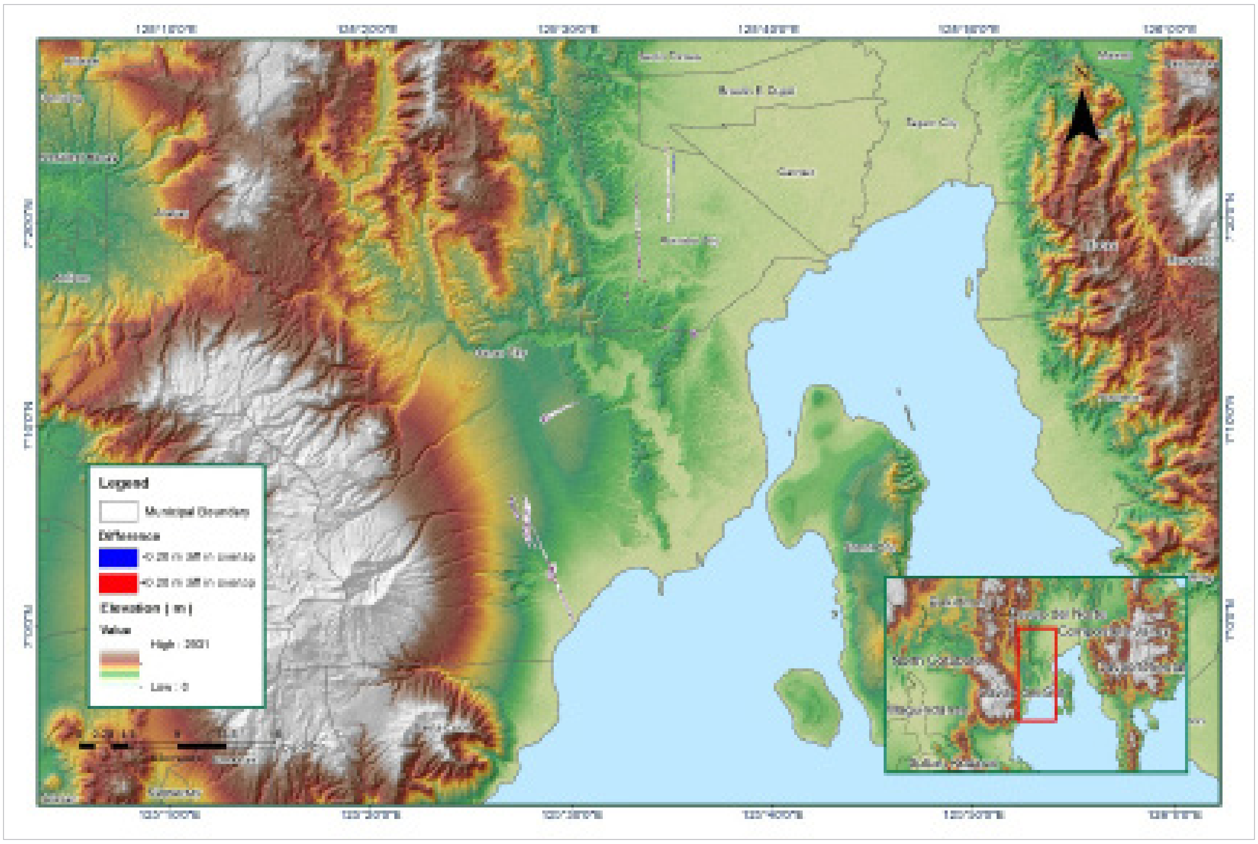


Figure 1.4.7 Elevation difference between flight lines

ANNEX 9. Lipadas 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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1000	2.1221	79.959	0	1.8636	3.0413	Discharge	0.003518	0.49	Ratio to Peak	0.49
W1010	2.2911	92.361	0	1.8009	3.02	Discharge	0.001305	0.008671	Ratio to Peak	0.4802
W1020	5.4131	70.115	0	1.65	2.6927	Discharge	0.002198	0.4802	Ratio to Peak	0.49
W1030	2.4366	99	0	2.4265	5.8301	Discharge	0.000409	0.008714	Ratio to Peak	0.48635
W1040	1.8565	96.854	0	0.016667	3.7668	Discharge	0.001313	0.037336	Ratio to Peak	0.33333
W1050	1.6896	99	0	1.7643	8.5308	Discharge	0.00028	0.012778	Ratio to Peak	0.49
W1060	2.569	83.175	0	1.6429	2.6812	Discharge	0.003183	0.49	Ratio to Peak	0.49
W1070	2.443	88.49	0	4.1698	6.7818	Discharge	0.004579	0.028679	Ratio to Peak	0.49
W1080	2.3548	99	0	0.55665	10.083	Discharge	0.000725	0.008714	Ratio to Peak	0.5
W1090	4.9661	71.889	0	1.343	2.1917	Discharge	0.00237	0.49	Ratio to Peak	0.5
W1100	2.1878	99	0	0.15944	0.49268	Discharge	0.000422	0.019986	Ratio to Peak	0.075624
W1110	2.9527	99	0	0.22107	1.0667	Discharge	0.002339	0.019494	Ratio to Peak	0.37421
W1120	0.76777	99	0	0.56785	0.21706	Discharge	0.000675	0.008714	Ratio to Peak	0.36552
W1130	1.0239	99	0	0.28348	1.4113	Discharge	0.001904	0.008714	Ratio to Peak	0.24127
W1140	1.571	99	0	0.44925	0.78851	Discharge	0.000493	0.008714	Ratio to Peak	0.24865
W580	4.5874	73.464	0	2.0387	3.3271	Discharge	0.002207	0.45	Ratio to Peak	0.48746
W590	2.8048	81.91	0	0.94087	1.5355	Discharge	0.001092	0.5	Ratio to Peak	0.5
W600	2.4135	67.394	0	2.4811	0.016667	Discharge	0.005382	0.043896	Ratio to Peak	0.49
W610	7.6487	62.412	0	1.6876	2.7541	Discharge	0.001302	0.4975	Ratio to Peak	0.49749
W620	6.8391	64.998	0	1.446	2.3599	Discharge	0.00069	0.5	Ratio to Peak	0.5

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W630	9.4416	57.358	0	2.1973	3.586	Discharge	0.002145	0.49	Ratio to Peak	0.5
W640	8.2	60.752	0	1.2535	2.0472	Discharge	0.000972	0.5	Ratio to Peak	0.5
W650	3.42	78.806	0	1.6414	2.6787	Discharge	0.001286	0.49	Ratio to Peak	0.5
W660	2.6	83	0	1.4582	2.3799	Discharge	0.001981	0.5	Ratio to Peak	0.49
W670	3.39	78.921	0	1.6565	2.7034	Discharge	0.002167	0.485	Ratio to Peak	0.4802
W680	5.29	70.601	0	1.6731	2.7305	Discharge	0.001613	0.49	Ratio to Peak	0.5
W690	4.4	74.251	0	1.6745	2.7328	Discharge	0.00149	0.49	Ratio to Peak	0.5
W700	9.31	57.694	0	1.2163	1.9849	Discharge	0.001275	0.498	Ratio to Peak	0.49
W710	9.3314	57.645	0	1.2153	1.9833	Discharge	0.001097	0.4975	Ratio to Peak	0.49
W720	2.6	83	0	1.4893	2.4305	Discharge	0.003668	0.49	Ratio to Peak	0.49
W730	8.61	59.589	0	2.0606	3.3629	Discharge	0.0018	0.5	Ratio to Peak	0.5
W740	7.33	63.409	0	1.9995	3.2632	Discharge	0.003881	0.5	Ratio to Peak	0.5
W750	4.3474	74.498	0	2.1128	3.4481	Discharge	0.00254	0.49	Ratio to Peak	0.49
W760	2.6012	83	0	0.90371	1.4749	Discharge	0.001114	0.48754	Ratio to Peak	0.4925
W770	2.6012	83	0	0.10949	0.17869	Discharge	2.15E-05	0.49	Ratio to Peak	0.49
W780	5.2912	70.59	0	2.3167	3.7809	Discharge	3.70E-03	0.49	Ratio to Peak	0.4802
W790	2.6012	83	0	1.9431	3.1712	Discharge	0.003072	0.49	Ratio to Peak	0.49
W800	2.6012	83	0	1.5247	2.5122	Discharge	0.00228	0.5	Ratio to Peak	0.49
W810	2.6012	83	0	0.34666	0.56575	Discharge	0.000124	0.5	Ratio to Peak	0.49
W820	2.6012	9.7038	0	1.6001	2.6114	Discharge	0.002336	0.49	Ratio to Peak	0.49
W830	9.8625	56.288	0	0.7807	1.2741	Discharge	0.001459	0.5	Ratio to Peak	0.5

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W840	2.3458	84.409	0	1.1985	1.956	Discharge	0.000904	0.5	Ratio to Peak	0.49
W850	2.6734	82.61	0	0.90055	1.4697	Discharge	0.001207	0.49	Ratio to Peak	0.4802
W860	2.6012	83	0	1.2717	2.0754	Discharge	0.001522	0.49	Ratio to Peak	0.49
W870	2.0397	86.162	0	0.016667	2.4996	Discharge	0.002792	0.5	Ratio to Peak	0.49
W880	2.7797	82.043	0	0.96594	1.5764	Discharge	0.001516	0.50435	Ratio to Peak	0.4802
W890	8.855	58.919	0	0.68792	1.1227	Discharge	0.001	0.5	Ratio to Peak	0.5
W900	2.9766	99	0	1.4523	0.016667	Discharge	0.001439	0.043896	Ratio to Peak	0.20915
W910	7.944	61.519	0	1.5905	2.5957	Discharge	0.001427	0.4802	Ratio to Peak	0.5
W920	2.6012	83	0	0.49635	0.81004	Discharge	0.000266	0.5	Ratio to Peak	0.49
W930	7.9062	61.632	0	1.6665	2.7197	Discharge	0.001315	0.48647	Ratio to Peak	0.5
W940	2.6012	83	0	1.1263	1.8381	Discharge	0.001657	0.49	Ratio to Peak	0.49
W950	2.6012	83	0	1.2367	2.0183	Discharge	0.001138	0.49	Ratio to Peak	0.49
W960	7.9618	61.466	0	0.91406	1.4917	Discharge	0.002302	0.5	Ratio to Peak	0.49
W970	9.8802	56.244	0	0.98893	1.6139	Discharge	0.001388	0.5	Ratio to Peak	0.49
W980	2.2246	99	0	1.7165	5.3847	Discharge	0.000702	0.01307	Ratio to Peak	0.49
W990	2.2946	86.617	0	1.6524	4.0651	Discharge	0.003012	0.064205	Ratio to Peak	0.49

ANNEX 10. Lipadas 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	3399.9	0.058345	0.07245	Trapezoid	31.09	1
R130	Automatic Fixed Interval	3556.3	0.048088	0.07245	Trapezoid	31.09	1
R150	Automatic Fixed Interval	148.28	0.028946	0.07245	Trapezoid	31.09	1
R180	Automatic Fixed Interval	3063.3	0.033432	0.07245	Trapezoid	31.09	1
R190	Automatic Fixed Interval	4786.2	0.081222	0.07245	Trapezoid	31.09	1
R20	Automatic Fixed Interval	4131.1	0.051917	0.07245	Trapezoid	31.09	1
R200	Automatic Fixed Interval	622.13	0.030522	0.07245	Trapezoid	31.09	1
R230	Automatic Fixed Interval	1915.5	0.080885	0.07245	Trapezoid	31.09	1
R260	Automatic Fixed Interval	5466.7	0.1005	0.07245	Trapezoid	31.09	1
R270	Automatic Fixed Interval	3903.3	0.079579	0.07245	Trapezoid	31.09	1
R280	Automatic Fixed Interval	3602.4	0.11464	0.07245	Trapezoid	31.09	1
R290	Automatic Fixed Interval	3385.6	0.09242	0.07245	Trapezoid	31.09	1
R30	Automatic Fixed Interval	1942.1	0.047673	0.07245	Trapezoid	31.09	1
R340	Automatic Fixed Interval	918.41	0.011709	0.07245	Trapezoid	31.09	1
R360	Automatic Fixed Interval	1277.8	0.036713	0.07245	Trapezoid	31.09	1
R370	Automatic Fixed Interval	2308.7	0.008627	0.07245	Trapezoid	31.09	1
R380	Automatic Fixed Interval	13609	0.043666	0.07245	Trapezoid	31.09	1
R420	Automatic Fixed Interval	1305.7	0.005039	1	Trapezoid	31.09	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R450	Automatic Fixed Interval	3402.9	0.076168	0.07245	Trapezoid	31.09	1
R470	Automatic Fixed Interval	1213	0.063992	0.063014	Trapezoid	31.09	1
R480	Automatic Fixed Interval	5544.9	0.002834	0.07245	Trapezoid	31.09	1
R50	Automatic Fixed Interval	3555	0.16243	0.07245	Trapezoid	31.09	1
R500	Automatic Fixed Interval	848.7	0.001469	0.062001	Trapezoid	31.09	1
R510	Automatic Fixed Interval	1872.4	0.012549	0.055462	Trapezoid	31.09	1
R540	Automatic Fixed Interval	708.99	0.004514	0.24141	Trapezoid	31.09	1
R560	Automatic Fixed Interval	1095.3	0.004514	0.016533	Trapezoid	31.09	1
R570	Automatic Fixed Interval	487.84	0.10986	0.045299	Trapezoid	31.09	1
R70	Automatic Fixed Interval	2264.5	0.034167	0.07245	Trapezoid	31.09	1

ANNEX 11. Lipadas Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	7.002939	125.484971	7.43	6.00	2.0449	Typhoon/ June 22, 2005	5-Year
2	7.000716	125.495090	2.03	0.87	1.3456	Intense local rainfall/ June 2009	5-Year
3	7.001355	125.493918	2.1	1.85	0.0625	Upstream rainfall/ 2001	5-Year
4	7.005341	125.492130	2.05	0.90	1.3225	Intense local rainfall/ August 1, 2008	5-Year
5	7.005977	125.491591	2.01	1.90	0.0121	Intense local rainfall/ October 21, 2001	5-Year
6	7.000001	125.493639	1.53	1.52	0.0001	Upstream rainfall/ June 2003	5-Year
7	7.000392	125.494696	1.19	0.89	0.09	Intense local rainfall/ 2009	5-Year
8	7.003286	125.485790	1.84	2.55	0.5041	Buhawi/ 1998	5-Year
9	7.003509	125.496733	1.07	0.50	0.3249	Intense local rainfall/ 2015	5-Year
10	7.003871	125.485999	1.33	0.42	0.8281	Upstream rainfall/ 2012	5-Year
11	7.006465	125.486447	1.13	0.40	0.5329	Buhawi/ 2001	5-Year
12	7.007058	125.492230	1.29	1.90	0.3721	Intense local rainfall/ October 21, 2001	5-Year
13	7.007107	125.486287	1.07	1.70	0.3969	Buhawi/ 2001	5-Year
14	7.007480	125.486699	1.05	0.66	0.1521	Buhawi/ April 1996	5-Year
15	7.008127	125.495220	1.25	0.80	0.2025	Intense local rainfall/ November 1999	5-Year
16	7.008695	125.490248	1.12	0.80	0.1024	Intense local rainfall/ November 2000	5-Year
17	7.009156	125.487543	1.21	0.95	0.0676	Upstream rainfall/ October 2002	5-Year
18	7.010191	125.497945	1.2	0.15	1.1025	Intense local rainfall/ 2014	5-Year
19	6.997163	125.494525	0.63	0.83	0.04	Buhawi/ November 2002	5-Year
20	6.997495	125.494147	0.57	0.80	0.0529	Buhawi/ 2006	5-Year
21	6.998382	125.494835	0.7	0.42	0.0784	Opening of Dam/ 2012	5-Year
22	7.003385	125.486059	0.66	1.90	1.5376	Intense local rainfall/ 1990s	5-Year
23	7.004131	125.497750	0.67	0.44	0.0529	Buhawi/ January 2000	5-Year
24	7.005372	125.486341	0.81	0.60	0.0441	Pablo/ August 2012	5-Year
25	7.007587	125.492872	0.59	0.50	0.0081	Intense local rainfall/ 1999	5-Year
26	7.008202	125.494698	0.61	0.00	0.3721		5-Year
27	7.008296	125.495928	0.57	0.43	0.0196	Buhawi	5-Year
28	7.008402	125.494555	0.52	0.60	0.0064	Intense local rainfall	5-Year
29	7.008846	125.490645	0.64	0.50	0.0196	Intense local rainfall/ 2009-2010	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
30	7.008817	125.497031	0.54	0.20	0.1156	Intense local rainfall	5-Year
31	7.008883	125.496506	0.53	0.20	0.1089	Upstream rainfall	5-Year
32	7.009079	125.490823	0.52	0.00	0.2704		5-Year
33	7.009698	125.498328	0.69	0.22	0.2209	Intense local rainfall	5-Year
34	7.010843	125.499115	0.7	0.25	0.2025	Intense local rainfall/ May 2014	5-Year
35	6.995436	125.494832	0.21	0.40	0.0361	Buhawi/ 2002	5-Year
36	6.998317	125.497737	0.28	0.20	0.0064	Intense local rainfall/ 2008	5-Year
37	6.998760	125.496040	0.21	0.00	0.0441		5-Year
38	6.999004	125.497328	0.21	0.70	0.2401	Buhawi/ 2000	5-Year
39	6.999444	125.496414	0.22	0.00	0.0484		5-Year
40	6.999967	125.496474	0.21	0.00	0.0441		5-Year
41	7.007983	125.493322	0.22	0.30	0.0064	Intense local rainfall/ October 2001	5-Year
42	7.008068	125.493935	0.23	0.00	0.0529	Intense local rainfall/ October 2001, 2009	5-Year
43	7.008315	125.493114	0.27	0.30	0.0009	Intense local rainfall/ January 29, 1997	5-Year
44	7.008902	125.491765	0.22	0.90	0.4624	Intense local rainfall/ June 2010	5-Year
45	7.007840	125.491412	0.03	0.00	0.0009		5-Year
46	7.011961	125.488004	7.06	4.00	9.3636	Heavy rainfall/ 2006	5-Year
47	7.017912	125.490569	5.65	0.92	22.3729	Upstream rainfall/ June 28, 2009	5-Year
48	7.018995	125.490755	5.08	0.92	17.3056	Buhawi/ November 2005	5-Year
49	7.020348	125.491305	6.9	4.00	8.41	Heavy rainfall/ 2006	5-Year
50	7.014313	125.487474	2.1	0.61	2.2201	Intense local rainfall/ January 2012	5-Year
51	7.014417	125.484942	2.02	1.85	0.0289	Heavy rainfall/ 2013	5-Year
52	7.016115	125.488479	2.04	0.85	1.4161	Upstream rainfall/ June 2007	5-Year
53	7.017297	125.487309	2.01	0.00	4.0401		5-Year
54	7.017291	125.488304	2.29	0.40	3.5721	Intense local rainfall	5-Year
55	7.018009	125.489393	2.02	0.50	2.3104	Intense local rainfall/ 2006	5-Year
56	7.018449	125.491476	2.3	0.50	3.24	Buhawi/ 2007	5-Year
57	7.020098	125.487324	2.01	0.61	1.96	Buhawi/ 2014	5-Year
58	7.021665	125.481633	2.21	1.69	0.2704	Buhawi/ March 2012	5-Year
59	7.009674	125.487890	1.17	0.94	0.0529	Buhawi/ November 2001	5-Year
60	7.010422	125.488448	1.05	0.70	0.1225	Upstream rainfall/ May 2008	5-Year
61	7.011142	125.489085	1.15	1.33	0.0324	Intense local rainfall (La Niña)/ 2011	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
62	7.016460	125.487843	1.2	0.83	0.1369	Intense local rainfall/ August 2002	5-Year
63	7.016683	125.487739	1.12	0.12	1	Intense local rainfall (Buhawi)/ June 2005	5-Year
64	7.017013	125.488038	1.62	0.00	2.6244		5-Year
65	7.018562	125.487225	1.22	0.26	0.9216	Intense local rainfall/ March 2001	5-Year
66	7.021086	125.488595	1.03	0.00	1.0609		5-Year
67	7.011863	125.489451	0.7	0.83	0.0169	Intense local rainfall/ 2001	5-Year
68	7.012368	125.489743	0.51	1.45	0.8836	Buhawi/ November 2007	5-Year
69	7.021149	125.485326	0.22	0.00	0.0484		5-Year
70	7.023928	125.482547	0.21	0.20	1E-04	Intense local rainfall	5-Year
71	7.025535	125.484581	0.32	0.47	0.0225	Upstream rainfall/ 2014	5-Year
72	7.025990	125.483576	0.28	0.30	0.0004	Intense local rainfall/ 2015	5-Year
73	7.026419	125.483350	0.3	0.00	0.09		5-Year
74	7.027069	125.485106	0.26	0.00	0.0676		5-Year
75	7.027153	125.486259	0.34	0.00	0.1156		5-Year
76	7.027581	125.485165	0.24	0.00	0.0576		5-Year
77	7.027838	125.484337	0.21	0.00	0.0441		5-Year
78	7.028925	125.482191	0.24	0.00	0.0576		5-Year
79	7.018138	125.487684	0.03	0.00	0.0009		5-Year
80	7.023320	125.481439	0.03	0.00	0.0009		5-Year
81	7.024126	125.481281	0.03	0.00	0.0009		5-Year
82	7.025518	125.487895	0.04	0.00	0.0016		5-Year
83	7.025864	125.486743	0.03	0.00	0.0009		5-Year
84	7.026613	125.485911	0.03	0.00	0.0009		5-Year
85	7.027992	125.481486	0.06	0.00	0.0036		5-Year
86	7.027975	125.484652	0.04	0.00	0.0016		5-Year
87	7.028708	125.482756	0.07	0.20	0.0169	Intense local rainfall/ 2016	5-Year
88	7.028970	125.484567	0.07	0.20	0.0169	Intense local rainfall/ 2016	5-Year
89	7.029437	125.481674	0.07	0.00	0.0049		5-Year
90	7.029428	125.483303	0.03	0.00	0.0009		5-Year
91	7.021069	125.491761	5.3	1.35	15.6025	Buhawi/ 2013	5-Year
92	7.021795	125.491132	5.89	2.12	14.2129	Buhawi/ 2012	5-Year
93	7.022964	125.492314	9.94	6.00	15.5236	Heavy rainfall/ 2014	5-Year
94	7.023506	125.492227	5.73	5.00	0.5329	Heavy rainfall/ 2014	5-Year
95	7.023594	125.492679	6.32	4.10	4.9284	Heavy rainfall/ January 2014	5-Year
96	7.024139	125.492320	5.23	2.20	9.1809	Upstream rainfall/ 2009	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
97	7.024316	125.492955	7.11	4.80	5.3361	Heavy rainfall/ January 2014	5-Year
98	7.024859	125.492777	5.25	0.94	18.5761	Buhawi/ August 2009	5-Year
99	7.025401	125.492870	5.06	2.30	7.6176	Buhawi/ 2001	5-Year
100	7.026123	125.492964	6.03	0.45	31.1364	Upstream rainfall/ 2006	5-Year
101	7.026845	125.493239	6.34	1.50	23.4256	Buhawi/ 2006	5-Year
102	7.026938	125.492788	5.07	3.65	2.0164	Buhawi/ 2000	5-Year
103	7.015077	125.496795	2.16	0.00	4.6656		5-Year
104	7.017887	125.495272	3	0.45	6.5025	Intense local rainfall/ 2012	5-Year
105	7.017985	125.493825	2.07	0.90	1.3689	Intense local rainfall/ 2004	5-Year
106	7.021428	125.492216	3.55	0.70	8.1225	Intense local rainfall/ 2010	5-Year
107	7.021969	125.492490	2.15	2.84	0.4761	Intense local rainfall/ July 2014	5-Year
108	7.022867	125.493580	2.04	0.20	3.3856		5-Year
109	7.022960	125.493038	2.12	0.45	2.7889	Heavy rainfall/ 2014	5-Year
110	7.023334	125.490597	2.52	0.43	4.3681	Intense local rainfall/ 2009	5-Year
111	7.023863	125.493133	2.82	2.00	0.6724	Buhawi/ 2014	5-Year
112	7.027296	125.493332	2.7	0.50	4.84	Buhawi/ 1987	5-Year
113	7.013750	125.491361	1.03	0.90	0.0169	Intense local rainfall/ Buhawi/ 2000	5-Year
114	7.015285	125.491640	1.02	0.00	1.0404		5-Year
115	7.019789	125.494468	1.33	0.30	1.0609	Intense local rainfall/ 2015	5-Year
116	7.020156	125.493475	1.13	0.00	1.2769		5-Year
117	7.021152	125.493028	1.26	1.40	0.0196	Intense local rainfall/ 1962	5-Year
118	7.021419	125.493934	1.12	0.00	1.2544		5-Year
119	7.021595	125.494840	1.27	0.45	0.6724	Typhoon/ 1990s	5-Year
120	7.015466	125.491641	0.6	0.00	0.36		5-Year
121	7.021126	125.498003	0.67	0.00	0.4489		5-Year
122	7.022537	125.497277	0.75	0.00	0.5625		5-Year
123	7.023575	125.496298	0.52	0.30	0.0484		5-Year
124	7.023594	125.495440	0.71	0.00	0.5041		5-Year
125	7.020992	125.496777	0.23	0.30	0.0049		5-Year
126	7.021080	125.498866	0.27	0.00	0.0729		5-Year
127	7.021564	125.498155	0.24	0.00	0.0576		5-Year
128	7.021587	125.496209	0.22	0.40	0.0324	Buhawi	5-Year
129	7.022784	125.496354	0.23	0.40	0.0289	Intense local rainfall/ 1980s	5-Year
130	7.015969	125.498971	0.03	0.00	0.0009		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
131	7.017147	125.498434	0.03	0.00	0.0009		5-Year
132	7.018237	125.498156	0.03	0.00	0.0009		5-Year
133	7.020314	125.497637	0.03	0.00	0.0009		5-Year
134	7.021343	125.496842	0.03	0.20	0.0289		5-Year
135	7.022208	125.498461	0.03	0.00	0.0009		5-Year
136	7.027479	125.493062	6.31	0.50	33.7561	Buhawi/ 1981	5-Year
137	7.027751	125.492882	5.02	0.40	21.3444	Buhawi/ 2008	5-Year
138	7.028927	125.492617	6.17	6.20	0.0009	Heavy rainfall/ January 2014	5-Year
139	7.031999	125.492724	6.05	2.00	16.4025	Heavy rainfall/ 2016	5-Year
140	7.032446	125.493631	5.69	0.65	25.4016	Intense local rainfall/ 2000	5-Year
141	7.034346	125.493280	8.45	0.00	71.4025		5-Year
142	7.034809	125.491201	5.02	0.00	25.2004		5-Year
143	7.035702	125.493196	5.79	1.60	17.5561	Heavy rainfall/ March 2016	5-Year
144	7.035989	125.490303	7.25	0.00	52.5625		5-Year
145	7.037149	125.493023	5.22	1.50	13.8384	Heavy rainfall/ March 2016	5-Year
146	7.037884	125.490765	7.66	2.00	32.0356	Upstream rainfall/ 2014	5-Year
147	7.038339	125.490225	5.94	2.00	15.5236	Intense local rainfall/ 2013	5-Year
148	7.041874	125.488254	5.87	1.30	20.8849	Heavy rainfall/ 2014	5-Year
149	7.028473	125.492977	2.04	0.00	4.1616		5-Year
150	7.029646	125.493435	2.03	0.32	2.9241	Upstream rainfall/ 2015	5-Year
151	7.029643	125.493978	2.04	0.29	3.0625	Intense local rainfall	5-Year
152	7.030819	125.493623	2.01	0.96	1.1025	Upstream rainfall/ 2012	5-Year
153	7.031905	125.493357	2.09	0.00	4.3681		5-Year
154	7.033173	125.492821	2.6	0.00	6.76		5-Year
155	7.037244	125.492119	2.96	2.70	0.0676	Buhawi/ 2004	5-Year
156	7.035517	125.494009	1.12	0.00	1.2544		5-Year
157	7.035615	125.492653	1.18	0.00	1.3924		5-Year
158	7.024328	125.496693	0.58	0.00	0.3364		5-Year
159	7.024743	125.495282	0.56	0.00	0.3136		5-Year
160	7.025192	125.496021	0.66	0.00	0.4356		5-Year
161	7.025244	125.495298	0.66	0.00	0.4356		5-Year
162	7.025836	125.495948	0.56	0.00	0.3136		5-Year
163	7.034328	125.494210	0.52	0.00	0.2704		5-Year
164	7.034941	125.494854	0.71	0.00	0.5041		5-Year
165	7.024002	125.498022	0.28	0.00	0.0784		5-Year
166	7.025608	125.496725	0.24	0.00	0.0576		5-Year
167	7.033726	125.495020	0.3	0.00	0.09		5-Year
168	7.040615	125.487071	0.24	0.00	0.0576		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
169	7.045044	125.486914	0.32	0.00	0.1024		5-Year
170	7.034872	125.496268	0.03	0.00	0.0009		5-Year
171	7.036679	125.496543	0.03	0.00	0.0009		5-Year
172	7.040598	125.490328	0.03	0.00	0.0009		5-Year
173	7.043432	125.484101	0.09	0.00	0.0081		5-Year
174	7.043413	125.487810	0.03	0.00	0.0009		5-Year
175	7.044233	125.486548	0.07	0.00	0.0049		5-Year
176	7.044580	125.489173	0.06	0.00	0.0036		5-Year
177	7.044947	125.488180	0.03	0.00	0.0009		5-Year
178	7.045208	125.490171	0.03	0.00	0.0009		5-Year
179	7.046029	125.488638	0.03	0.00	0.0009		5-Year
180	7.046024	125.489542	0.04	0.00	0.0016		5-Year
				RMSE	**1.921041**		

ANNEX 12. Educational Institutions Affected in Lipadas Floodplain

DAVAO DEL SUR
Davao City

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
GASCO ELEMENTARY SCHOOL	Bato			
SIRAWAN BEACH ELEMENRTARY SCHOOL	Binugao			
SIRAWAN BEACH ELEMENTARY SCHOOL	Binugao			Low
SIRAWAN NATIONAL HIGHSCHOOL	Binugao		Low	Low
SIRAWAN NATIONAL HIGSCHOOL	Binugao		Low	Low
DAYCARE CENTER	Crossing Bayabas			
SAINT PETER PROJECT HOPE	Crossing Bayabas	Medium	Medium	High
SOUTHERN MINDANAO INSTITUTE OF TECHNOLOGY	Crossing Bayabas			
SOUTHERN MINDANAO INSTITUTE OF TECHNOLOGY (COLLEG*	Crossing Bayabas	Low	Low	Low
PROJECT HOPE. DAY CARE	Daliao	Medium	Medium	Medium
TOLIDA HOME BASED DAYCARE CENTER	Kilate			
AL-MADRASATOL IBTIDA-IYAAL ISLAMIYA	Lizada	Medium	Medium	Medium
BABISA DAY CARE CENTER	Lizada	High	High	High
CULUSA OLD DAY CARE CENTER/ABANDONED	Lizada	High	High	High
JV FERRIORS ELEMENTARY SCHOOL	Lizada	High	High	High
JV FERRIORS ELEMENTARY SCHOOL - GRADE2	Lizada	High	High	High
JV FERRIORS ELEMENTARY SCHOOL - GRADE2 & GRADE1	Lizada	High	High	High
JV FERRIORS ELEMENTARY SCHOOL - GRADE3	Lizada	Medium	High	High
JV FERRIORS ELEMENTARY SCHOOL - GRADE3 & GRADE4	Lizada	High	High	High
JV FERRIORS ELEMENTARY SCHOOL - GRADE6	Lizada	High	High	High
JV FERRIORS ELEMENTARY SCHOOL SECURITY BANK FOUND*	Lizada	High	High	High
JV FERRIORS HIGH SCHOO	Lizada	High	High	High
JV FERRIORS HIGH SCHOOL	Lizada	High	High	High
JV FERRIORS HIGH SCHOOL - STAGE SOLAR DRYER	Lizada	High	High	High
JV FERRIORS HIGH SCHOOL - COMPUTER LABORATORY & P*	Lizada	High	High	High
JV FERRIORS HIGH SCHOOL - GRADE 8 & SSO/ CLINIC	Lizada	High	High	High

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
JV FERRIORS HIGH SCHOOL - GRADE 8 RESPECT & GRADE*	Lizada	High	High	High
JV FERRIORS HIGH SCHOOL - LIBRARY & FACULTY & GRA*	Lizada	High	High	High
JV FERRIORS HIGH SCHOOL - UNDER CONSTRACTION	Lizada	High	High	High
LIZADA PROPER DAY CARE CENTER	Lizada	High	High	High
MALATABIS DAY CARE CENTER	Lizada	Medium	High	High
DAY CARE CENTER	Lubogan			
MARHABA LEARNING CENTER	Lubogan			
PROJECT HOPE DAY CARE CENTER	Lubogan	Low	Low	Low
SAN MIGUEL ELEMENTARY SCHOOL (CLASSROOMS)	Lubogan		Low	Low
SAN MIGUEL ELEMENTARY SCHOOL GYM	Lubogan	Low	Medium	Medium
ST. JOSEPH SCHOOL OF TORIL	Lubogan			
DAVAO LEAGUE ISLAMIC INSTITUTE	Sirawan			
DAYCARE CENTER	Sirawan			
EASTERN MINDANAO ISLAMIC ACADEMY	Sirawan			
EASTERN MINDANAO ISLAMIC ACADEMY LIBRARY	Sirawan			
MADRASA	Sirawan	Low	Low	Low
SIRAWAN ELEMENTARY SCHOOL	Sirawan			
A. LOYOLA ELEMENTARY SCHOOL	Toril	Low	Medium	Medium
BIBLE BAPTIST CHURCH, ELEMENTARY DEPARTMENT	Toril	High	High	High
BIBLE BAPTIST CHURCH, KINDER GARTEN DEPARTMENT	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - FUNCTION HALL AND S*	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - GRADE 1	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - GRADE 2	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - GRADE 3	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - GRADE 4 AND GRADE 5	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - GRADE 4, 5 & 6	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - KINDER	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - OFFICE OF THE PRINI*	Toril	High	High	High
C. BANGOY ELEMENTARY SCHOOL - SINING PANTAHANAN	Toril	High	High	High

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
C. BANGOY ELEMENTARY SCHOOL - STOCK ROOM	Toril	High	High	High
CROSSING BAYABAS NATIONAL HIGH SCHOOL	Toril	Low	Medium	Medium
DAVAO CENTRAL COLLEGE	Toril		Low	Medium
DAY CARE	Toril	Medium	Medium	Medium
DON JUAN DELA CRUZ ELEMENTARY SCHOOL	Toril	Medium	High	High
DO NA CARMEN DENIA HIGH SCHOOL	Toril	High	High	High
DO NA CARMEN DENIA NATIONAL HIGH SCHOOL	Toril	High	High	High
LITTLE SUNBEAM PRESCHOOL OF TORIL	Toril	Medium	High	High
MARAPANGI DAY CARE CENTER	Toril	Medium	High	High
PEARL ACE INTERNATIONAL TRAINING AND ASSESSMENT C*	Toril	Medium	High	High
PHILIPPINE NIKKEI-JIN KAI TORIL CHAPTER	Toril		Low	Low
PIEDAD CENTRAL ELEMENTARY SCHOOL	Toril	Medium	Medium	Medium
PIEDAD ELEMENTARY SCHOOL	Toril	Low	Low	Medium
SECOND BUILDING/YAGI METHOD ACADEMY	Toril			
ST. PETER'S COLLEGE CAFETERIA	Toril			
ST. PETER'S COLLEGE CANTEEN AREA	Toril			
ST. PETER'S COLLEGE GB BUILDING	Toril			
ST. PETER'S COLLEGE GUIDANCE OFFICE	Toril			Low
ST. PETER'S COLLEGE PARENT'S WAITING SHED	Toril			
ST. PETER'S COLLEGE STOCK ROOM	Toril			
VITALEARN DE TORIL	Toril	Medium	Medium	High
YAGI METHOD CHILDREN'S ACADEMY LEARNING SCHOOL	Toril	Low	Low	Low

ANNEX 13. Medical Institutions Affected in Lipadas Floodplain

DAVAO DEL SUR
Davao City

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
TORIL MATERNITY AND MEDICAL CLINIC	Crossing Bayabas	Low	Medium	Medium
PROPOSED HEALTH CENTER	Lizada	High	High	High
LUBOGAN HEALTH CENTER	Lubogan			
HEALTH CENTER	Sirawan			
ABA ANIMAL CLINIC	Toril	Medium	Medium	High
BARANGAY HEALTH CENTER	Toril	Medium	Medium	Medium
BRGY. HEALTH CENTER	Toril	Low	Low	Medium
DAVAO MEDIQUEST HOSPITAL	Toril	Low	Medium	Medium
DENTAL CLINIC	Toril	Medium	Medium	Medium
DOLOR MEDICAL CLINIC	Toril	Medium	Medium	Medium
GENERIKA DRUGSTORE	Toril	Low	Medium	Medium
HEALTH CENTER	Toril	Low	Low	Low
MATERNITY CLINIC	Toril	Low	Medium	Medium
MERCURY DRUG	Toril	Low	Medium	Medium
NEW BOTICA PHARMACY	Toril	Medium	High	High
PAANAKAN	Toril	Medium	Medium	Medium
ROSE PHARMACY	Toril	Medium	Medium	Medium
STA. ANA DRUG	Toril	High	High	High
T AND R LYING IN CLINIC PAANAKAN	Toril	Medium	High	High
TESCO DRUG	Toril		Low	Medium
TORIL DIAGNOSTIC	Toril			Low
TORIL WISEBUY PHARMACY	Toril	Medium	Medium	High