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

LiDAR Surveys and Flood Mapping of Taft River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Visayas State University
Department of Science and Technology

APRIL 2017

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

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

E.C. Paringit, and F.F Morales, (Eds.). (2017), LiDAR Surveys and Flood Mapping of Taft River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry. 130 pp.

For questions/queries regarding this report, contact:

Engr. Florentino Morales, Jr.
Project Leader, PHIL-LiDAR 1 Program
Visayas State University
Baybay, Leyte, Philippines 6521
ffmorales_jr@yahoo.com

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

National Library of the Philippines
ISBN: 978-621-430-218-5

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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]
WGS	World Geodetic System

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

CHAPTER 1: INTRODUCTION

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU 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 ________ river basins in the ___________________ (LiDAR covered area). The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Taft River Basin

Taft River Basin covers the Municipality of Taft, and a small portion in the Municipalities of Can-Avid, Sulat, San Julian, and Borongan City in the province of Eastern Samar; in the Municipality of Hinabangan; and a small portion in the Municipalities of Calbiga and Paranas in the province of Samar. According to the DENR River Basin Control Office (2015) identified the basin to have a drainage area of 375km2and an estimated 713 million cubic meter (MCM) annual run-off.

Its main stem, Taft River, is part of the 19 river systems in Eastern Visayas Region. According to the 2015 national census of NSO, a total of 6,633 persons distributed among eight (8) Barangays in the Municipality of Taft (NSO, 2015). are residing within the immediate vicinity of the river .

Since the province of Eastern Samar is mostly coastal, its primary economic activity is fishing. Agricultural products such as coconut, copra, etc. also play important roles in their economy for domestic and international export. Furthermore, tourism is a blooming economic activity that has yet to be developed (Source: http://www.nscb.gov.ph/ru8/profiles/provincial_profiles/esamar.htm). Last December 2014, Typhoon Ruby, internationally known as Hagupit, made landfall in Eastern Samar and brought with it strong winds and storm surges. In the Municipality of Taft, 5,362 families were affected during the typhoon (Source: http://ndrrmc.gov.ph/attachments/article/1356/FINAL_REPORT_re_Effects_of_Typhoon_RUBY_(HAGUPIT)_04_-_10DEC2014.pdf).

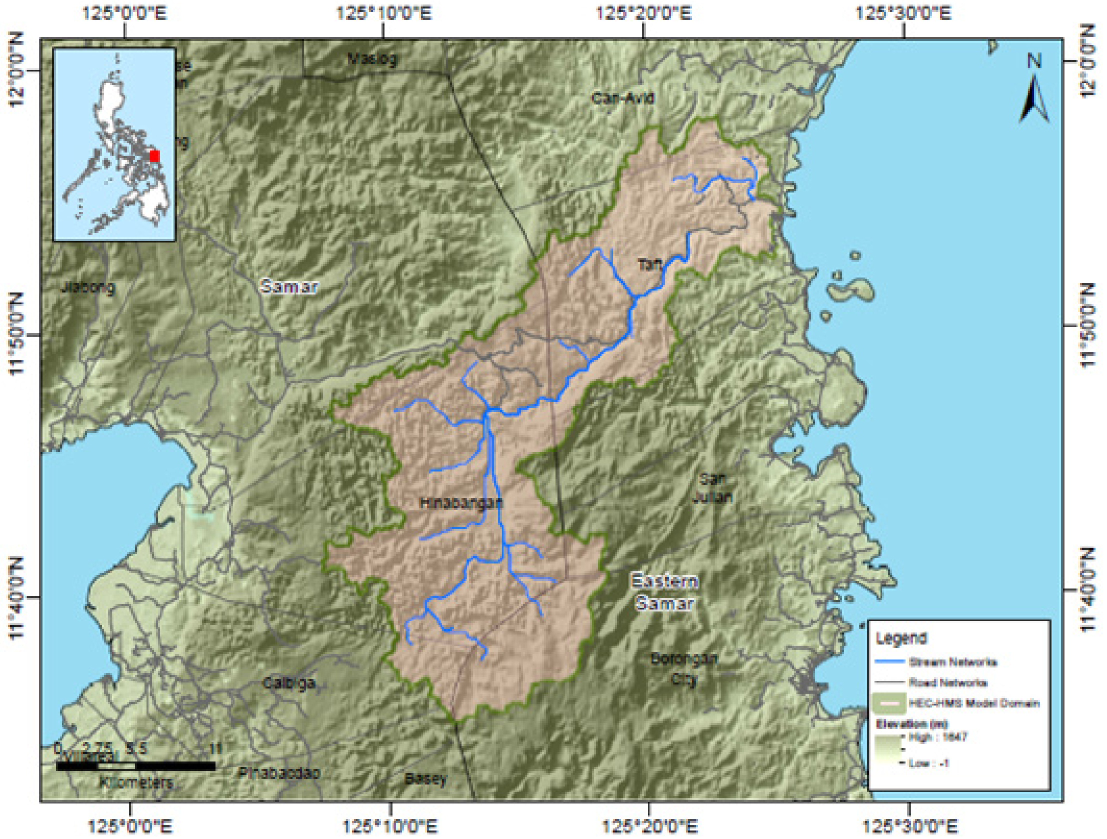


Figure 1. Map of Taft River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN TAFT FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, Ms. Mary Catherine Elizabeth M. Baliguas

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).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Taft Floodplain in Eastern Samar. These missions were planned for 17 lines that ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for Aquarius LiDAR system are found in Table 1. Figure 2 shows the flight plan for Taft floodplain survey.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK33J	500	20	44	50	45	120	5

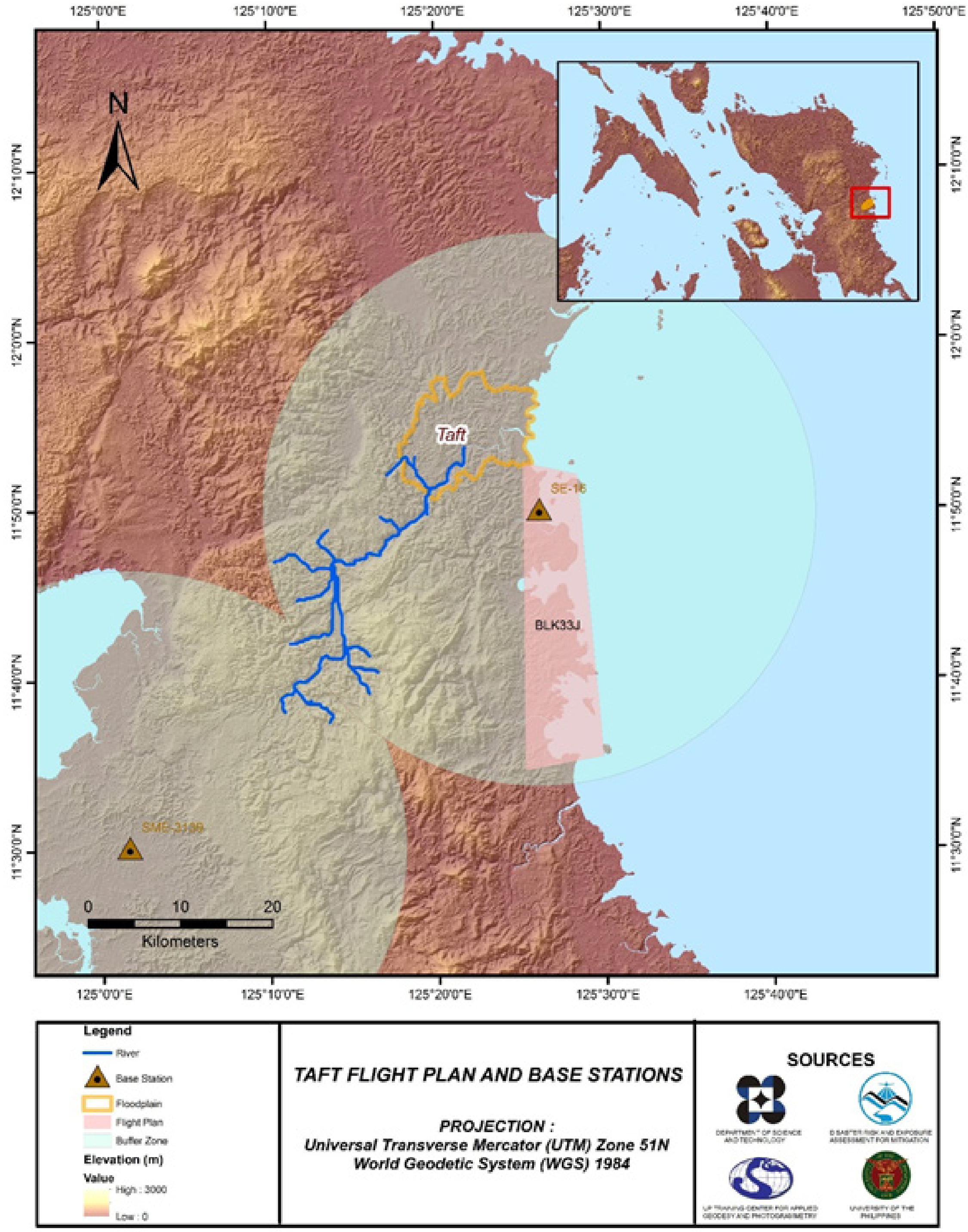


Figure 2. Flight plan and base stations used for Taft Floodplain.

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA horizontal ground control points, SME-3139 which is of fourth (4th) order accuracy and a Benchmark (SE-16) which is of first order accuracy. These benchmark was used as vertical reference point and was also established as ground control point. The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing report for the established control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 9, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Taft Floodplain are shown in Figure 2.

Figure 3 shows the recovered NAMRIA reference point within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations and established points while Table 4 lists all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

Figure 3. GPS set-up over SME-3139 located along the highway in Brgy. Sto. Nino, Taft, Eastern Samar (a) and NAMRIA reference point SME-3139 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point SME-3139 used as base station for the LiDAR acquisition.

Station Name	SME-3139	
Order of Accuracy	4th Order	
Relative Error (horizontal positioning)	1:10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 30’ 17.85657” North 125o 1’ 29.837339” East 26.13400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	502722.403 meters 1272180.079 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 30’ 13.52495” North 125o 1’ 34.96980” East 87.78700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North	Easting Northing	720874.14 meters 1272513.40 meters

Table 3. Details of the recovered NAMRIA horizontal control point SE-16 used as base station for the LiDAR acquisition.

Station Name	SE-16	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1:10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 50’ 03.05106” North 125o 26’ 03.03429” East 0.472 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 49’ 58.67117” North 125o 26’ 08.13400” East 62.301 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	765219.942 meters 1309292.154 meters

Table 4. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
9 JUN 14	1558A	3BLK33J160A	SE-16,SME-3139
9 JUN 14	1560A	3BLK33JS160B	SE-16,SME-3139

2.3 Flight Missions

Two (2) missions were conducted to complete LiDAR data acquisition nearest Taft Floodplain, for a total of eight hours and thirty four minutes (8+34) of flying time for RP-9122. The missions were acquired using Aquarius LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition nearest Taft floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
9 JUN 14	1558A	225.57	117.98	0.54	117.44	98	4	41
9 JUN 14	1560A	225.57	127.54	-	127.54	1294	3	53
TOTAL		451.14	245.52	0.54	244.98	1392	8	34

Table 6. 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)
1558A	500	30	44	50	45	120	5
1560A	500	20	44	50	45	120	5

2.4 Survey Coverage

Taft floodplain is located in the province of Eastern Samar with majority of the floodplain situated within the municipality of Taft. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Taft Floodplain is presented in Figure 4.

Table 7. List of municipalities and cities surveyed during LiDAR survey nearest Taft Floodplain.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Eastern Samar	Sulat	150.05	39.95	27%
	San Julian	127.43	22.72	18%
	Borongan City	596.08	69.2	12%
	Taft	**230.27**	**1.95**	**1%**
Total		1,103.83	133.82	12.12%

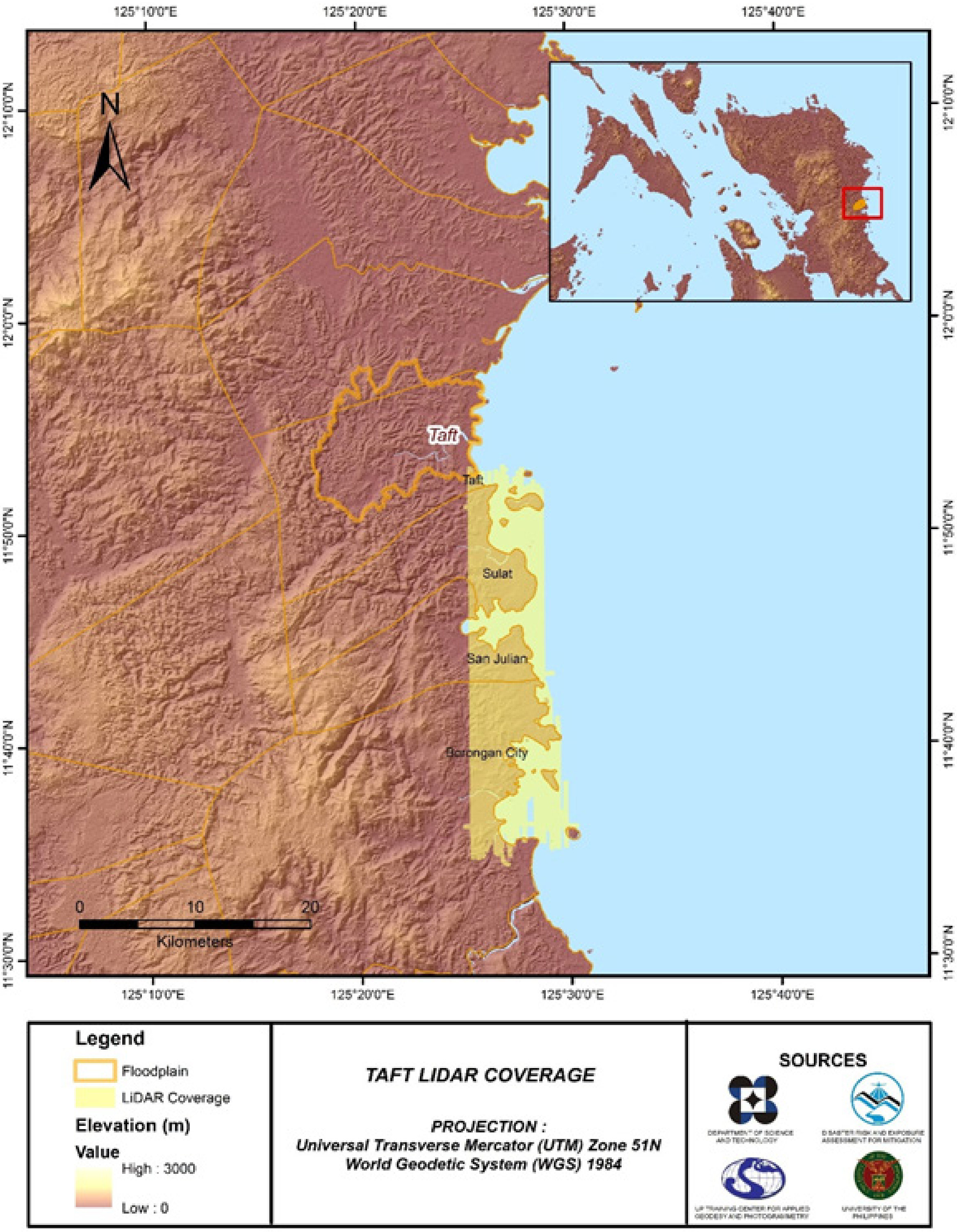


Figure 4. Actual LiDAR survey coverage nearest Taft Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR TAFT FLOODPLAIN

Engr. Ma. Ailyn L. Olanda, Engr. Velina Angela S. Bemida, Jovy Anne S. Narisma,
Engr. Karl Adrian P. Vergara

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory wasdone to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were 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 were 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 were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was 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 5.

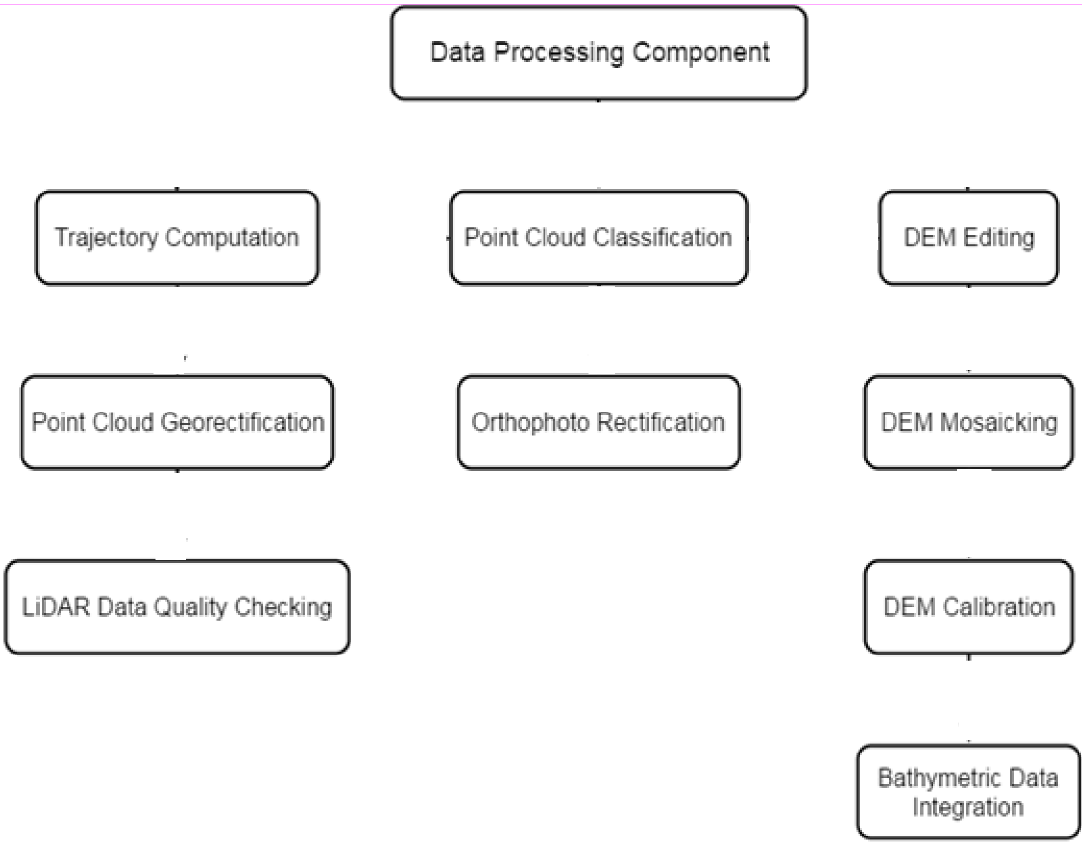


Figure 5. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Taft Floodplain can be found in Annex A-5. Missions flown during the survey conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Taft, Eastern Samar. The Data Acquisition Component (DAC) transferred a total of 26.3 Gigabytes of Range data, 500 Megabytes of POS data, 32.2 Megabytes of GPS base station data, and 167.9 Gigabytes of raw image data to the data server on June 9, 2014 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Taft was fully transferred on June 19, 2014, as indicated on the Data Transfer Sheets for Taft floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metricparameters of the computed trajectory for flight 1560A, one of the Taft flights, which is the North, East, and Down position RMSE values are shown in Figure 6. 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 June 9, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

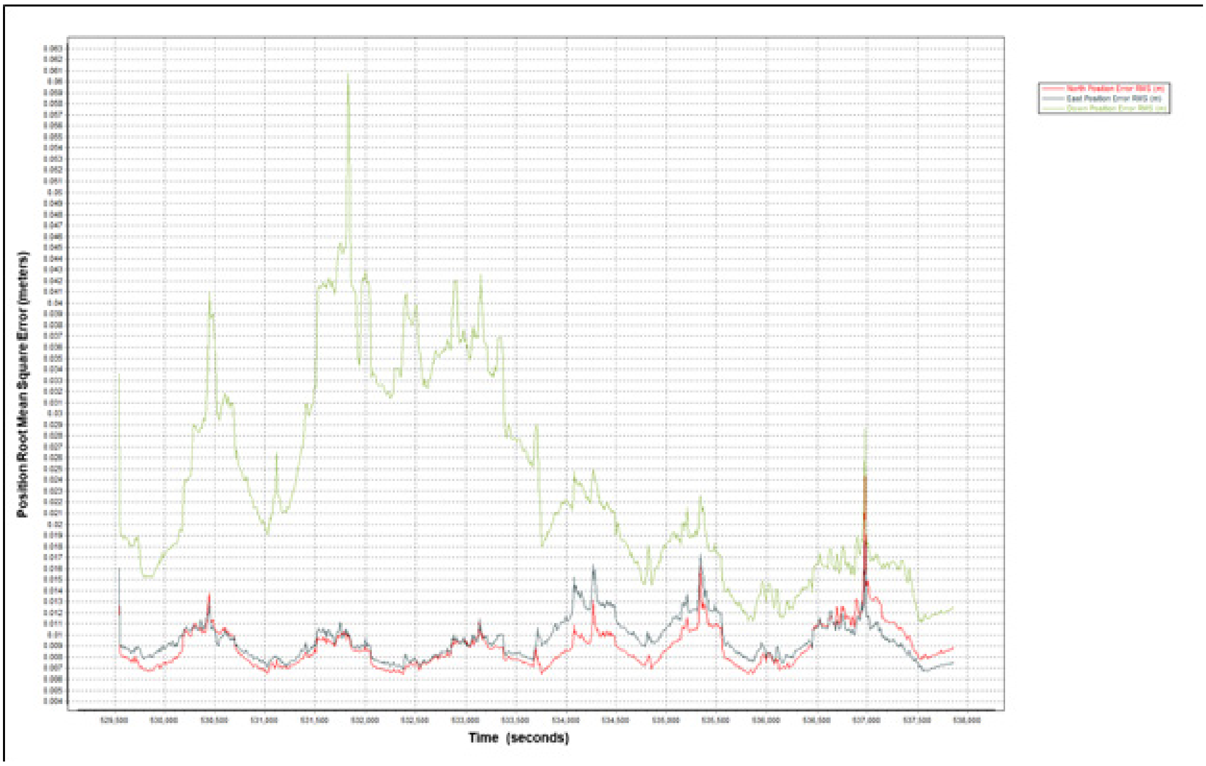


Figure 6. Smoothed Performance Metric Parameters of a Taft Flight 1560A.

The time of flight was from 529500 seconds to 538000 seconds, which corresponds to afternoon of June 9, 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 6 shows that the North position RMSE peaks at 1.62 centimeters, the East position RMSE peaks at 1.74 centimeters, and the Down position RMSE peaks at 4.26 centimeters, which are within the prescribed accuracies described in the methodology.

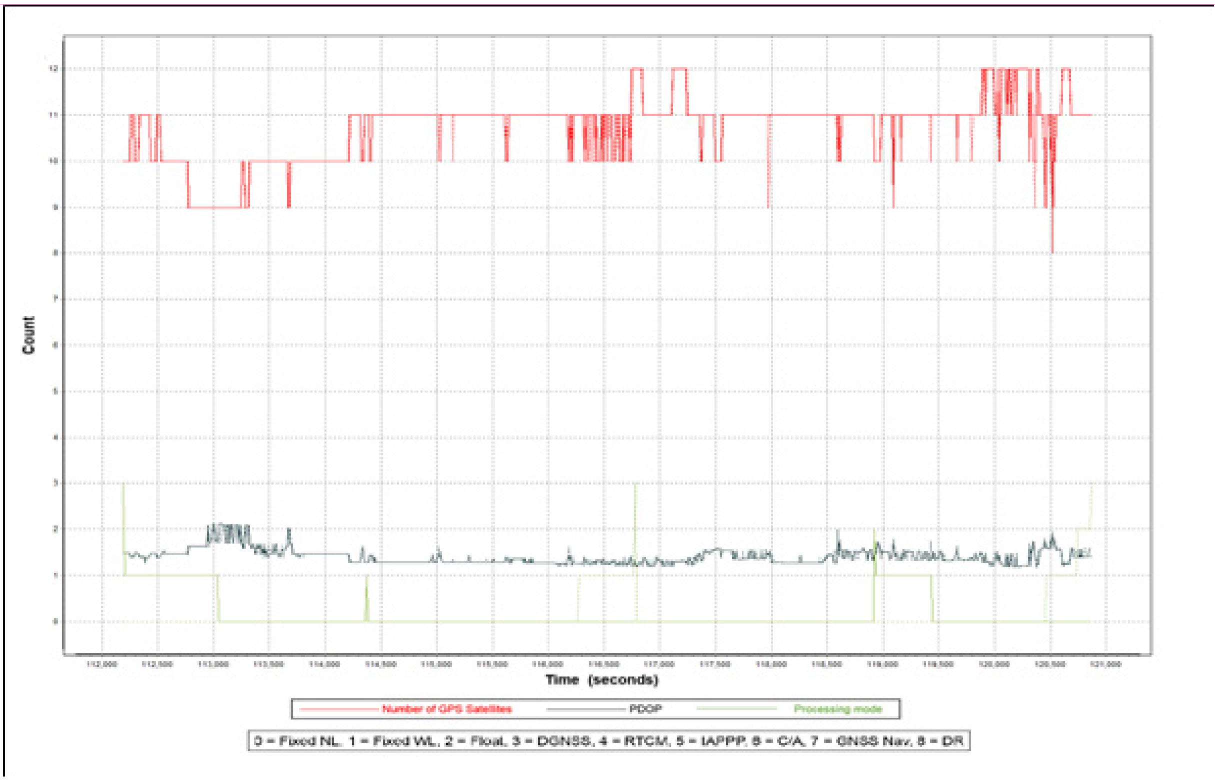


Figure 7. Solution Status Parameters of Taft Flight 1560A.

The Solution Statusparameters of flight 1560A, one of the Taftflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 7. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Taft flights is shown in Figure 8.

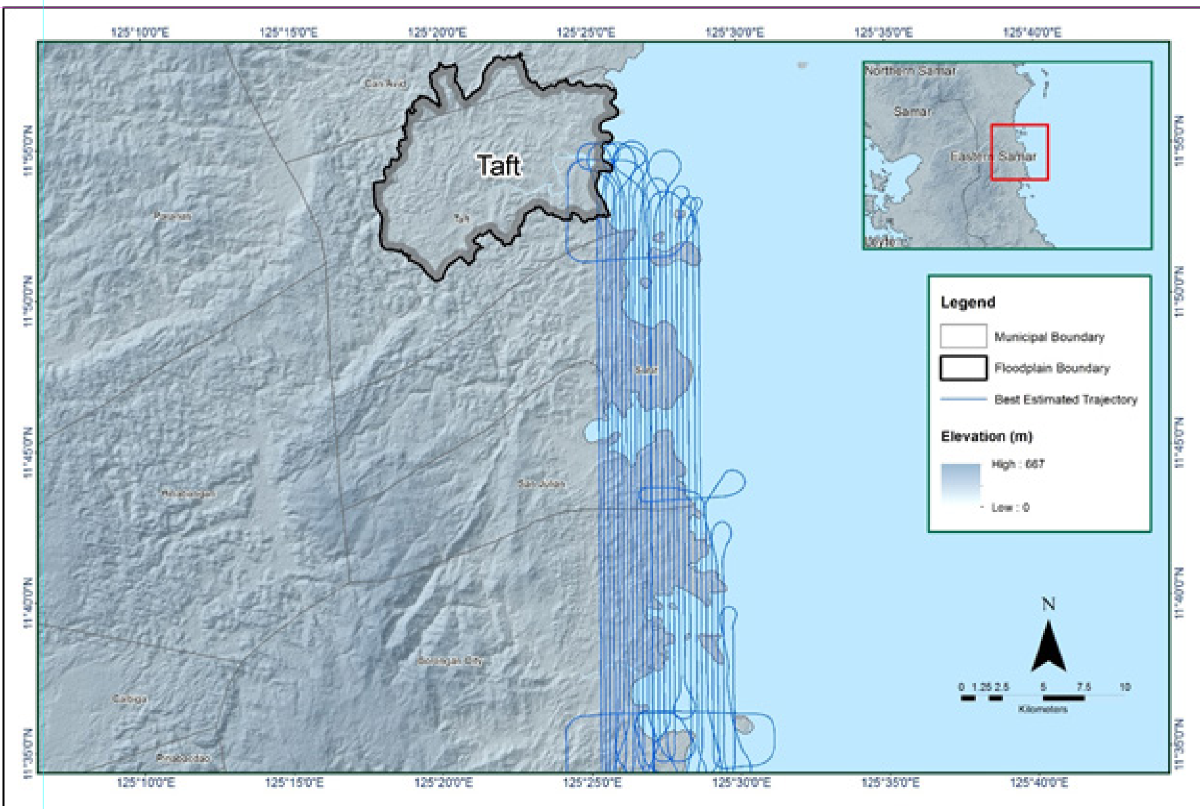


Figure8.Best Estimated Trajectory for Taft FloodplainFloodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 28 flight lines, with each flight line containing one channel, since the Aquarius 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 Taft Floodplain are inidicated in Table 8.

Table 8. Self-Calibration Results values for Taft flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000327
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000898
GPS Position Z-correction stdev (<0.01meters)	0.0098

The optimum accuracy is obtained for all Taft 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.

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Taft Floodplain is shown in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

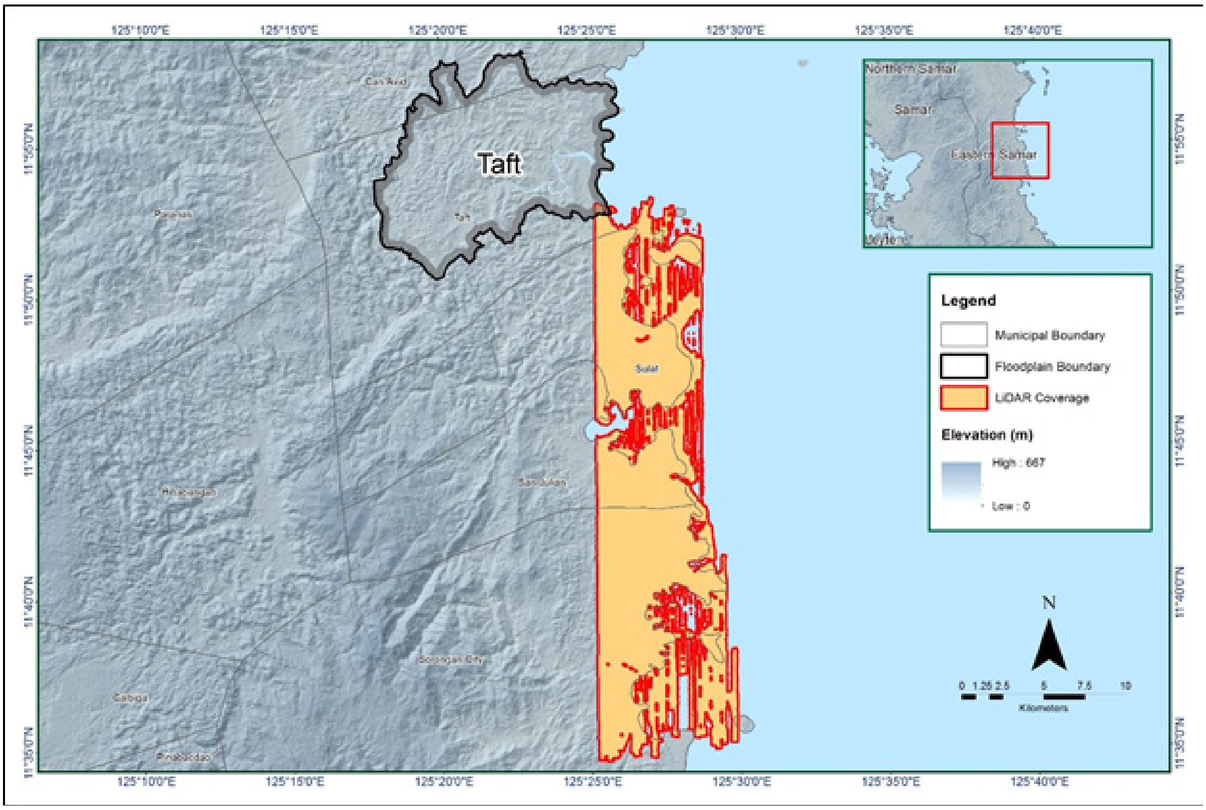


Figure 9. Boundary of the processed LiDAR data over Taft Floodplain

The total area covered by the Taft missions is 174.99 sq.km comprised of two (2) flight acquisitions grouped and merged into one (1) block as shown in Table 9.

Table 9. List of LiDAR blocks for Taft Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Samar_Leyte Blk33J	1558A	174.99
	1560A	
TOTAL		**174.99 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 10. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

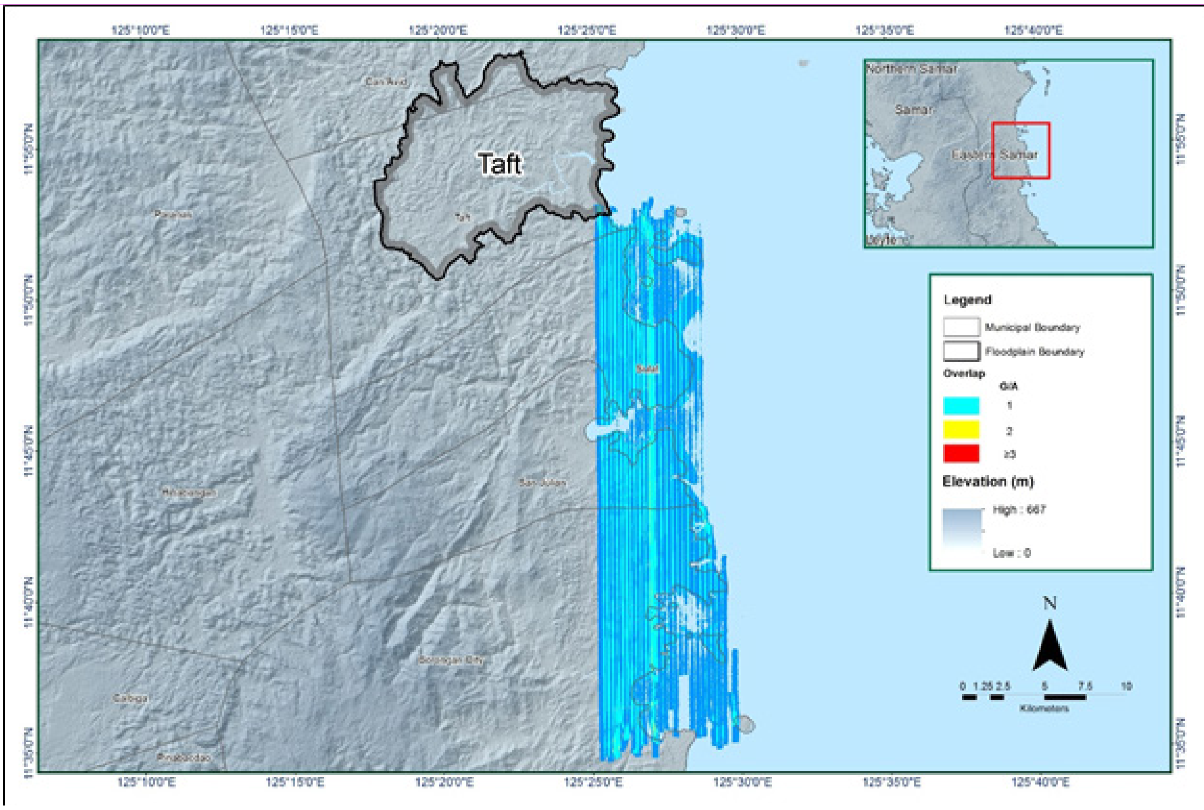


Figure 10. Image of data overlap for Taft floodplain.

The overlap statistics per block for the Taft floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap is 36.01%, 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 11. It was determined that all LiDAR data for Taft floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.71 points per square meter.

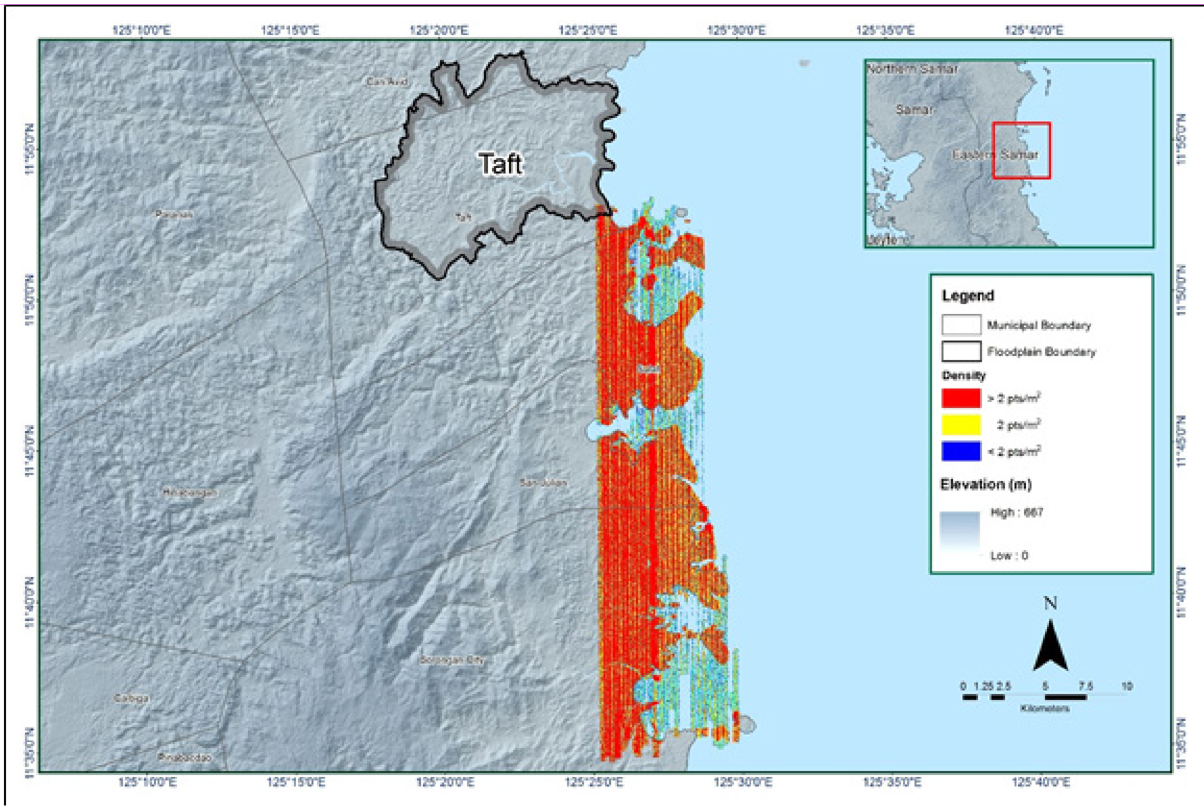


Figure 11. Pulse density map of merged LiDAR data for Taft Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 12. 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.

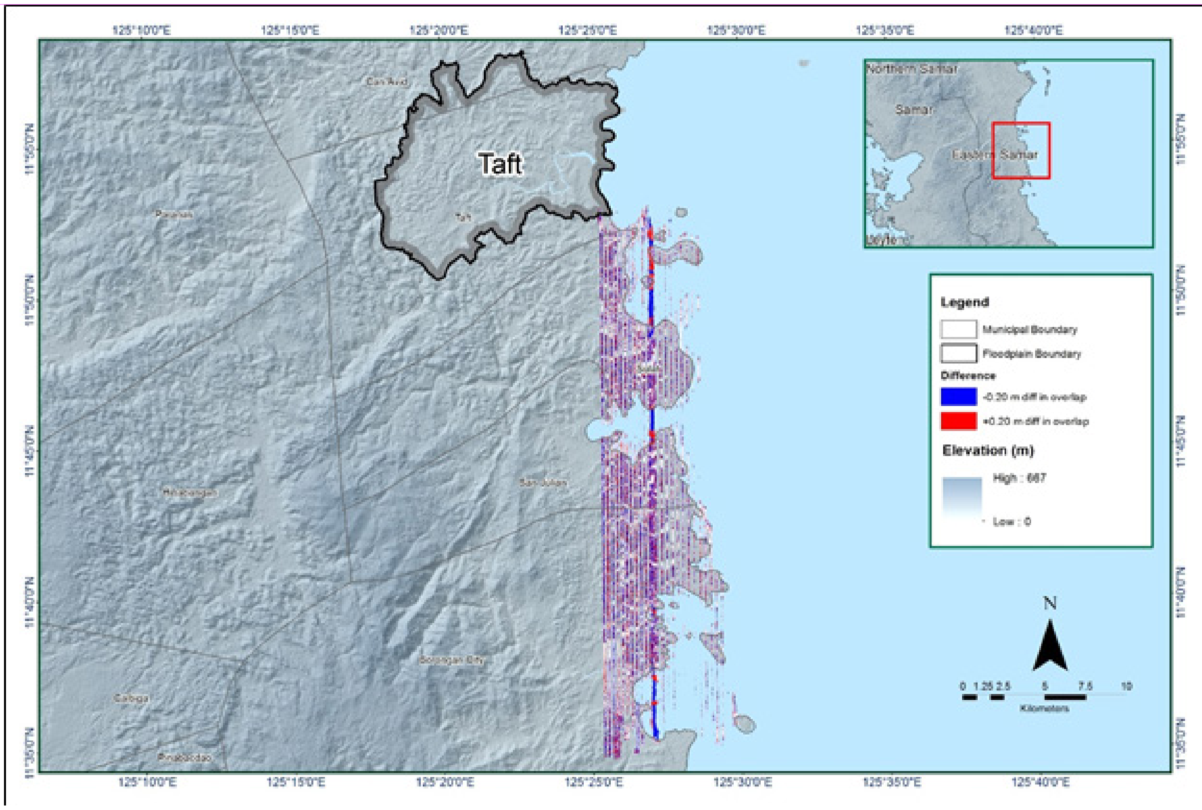


Figure 12. Elevation difference map between flight lines for Taft Floodplain.

A screen capture of the processed LAS data from a Taft flight 1560A loaded in QT Modeler is shown in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

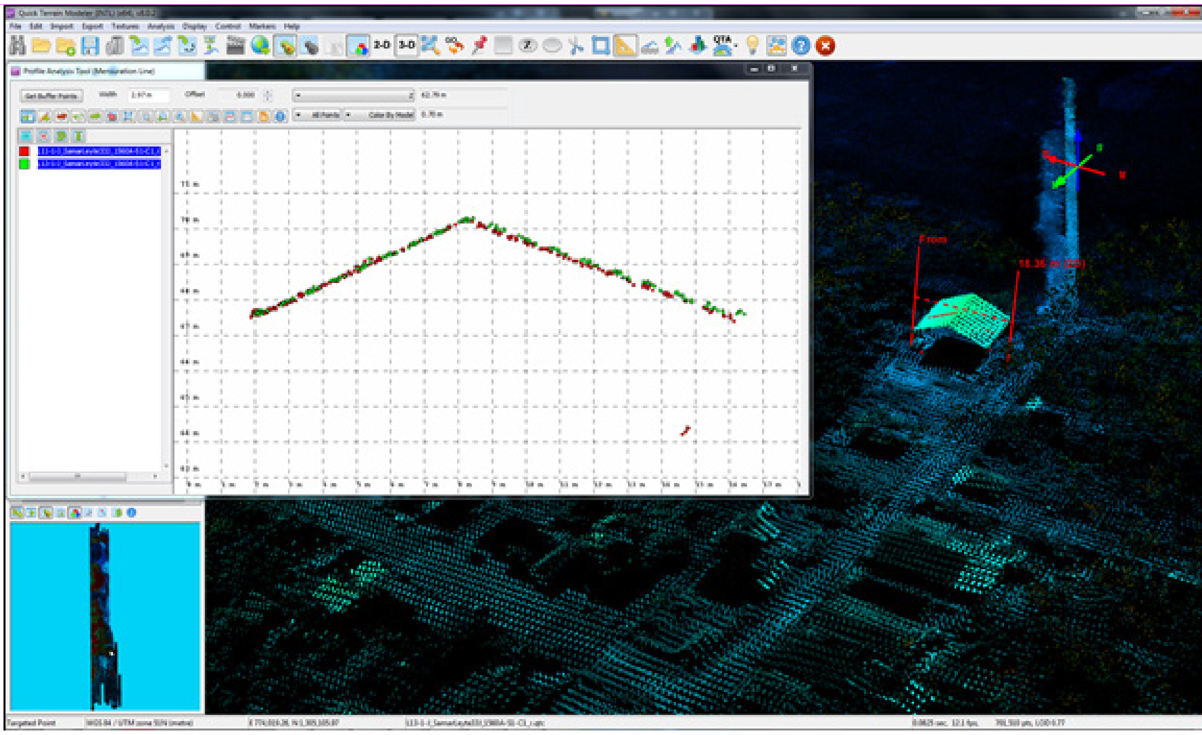


Figure 13. Quality checking for a Taft flight 1560A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Taft classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	110,486,647
Low Vegetation	51,277,620
Medium Vegetation	61,095,498
High Vegetation	151,119,077
Building	2,518,830

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block near Taft Floodplain is shown in Figure 14. A total of 291 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 248.48 meters and 49.30 meters, respectively.

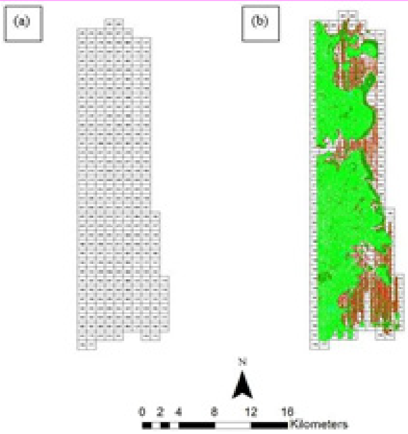


Figure 14. Tiles for Taft floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 15. 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.

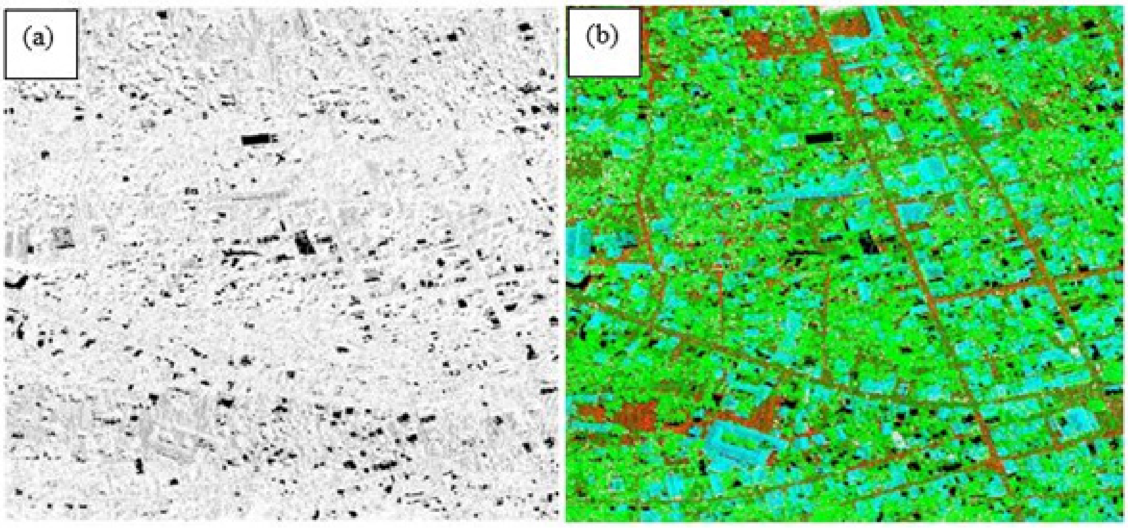


Figure 15. Point cloud before (a) and after (b) classification.

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

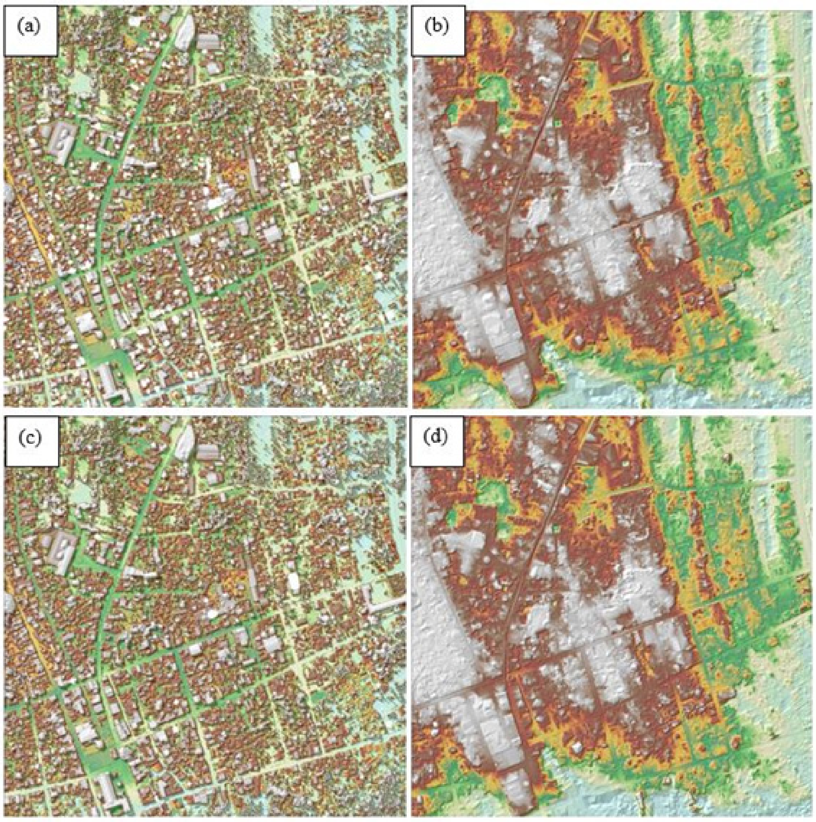


Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Taft Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 292 1km by 1km tiles area covered by Taft Floodplain is shown in Figure 17. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Taft Floodplain has a total of 219.659 sq.km orthophotogaph coverage comprised of 2,657 images. However, the block does not have a complete set of orthophotographs and no orthophotographs cover the area of the Taft Floodplain. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 18.

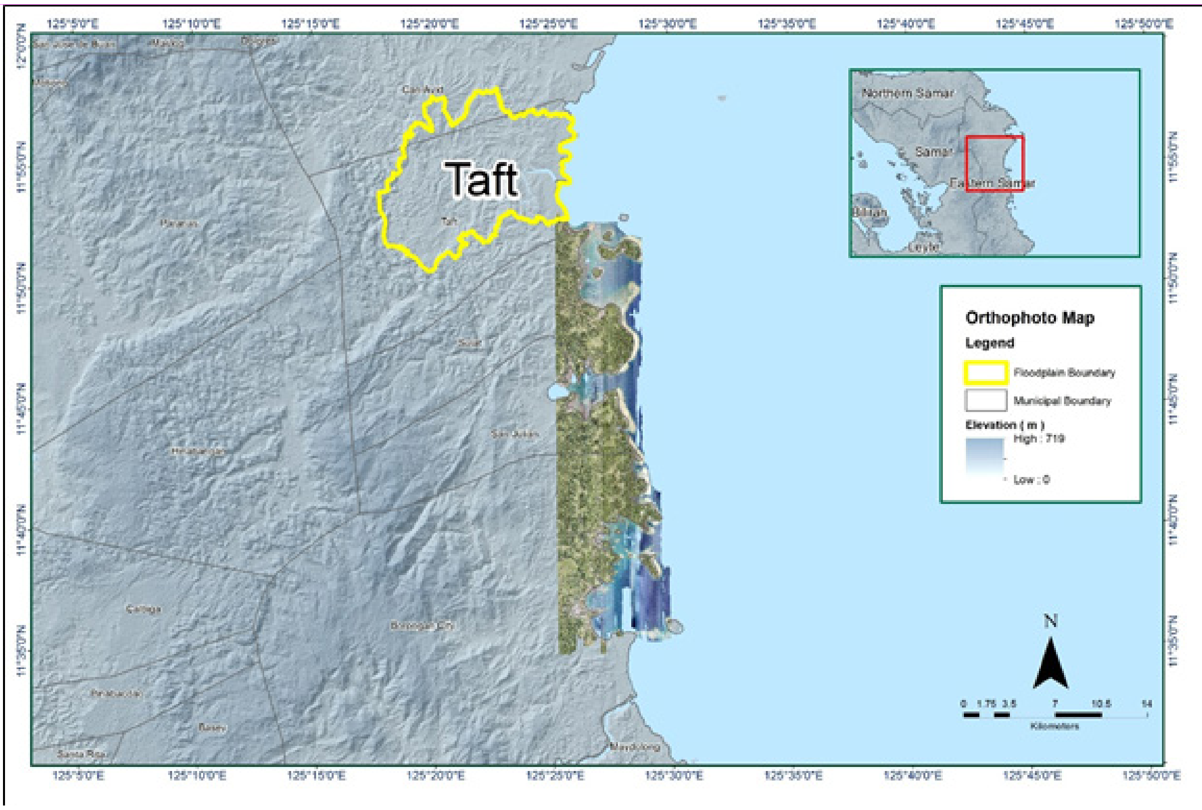


Figure 17. Available orthophotographs near Taft Floodplain.

Figure 18. Sample orthophotograph tiles near Taft Floodplain.

3.8 DEM Editing and Hydro-Correction

One (1) mission block was processed for Taft Floodplain. This block is aSamarLeyte block with an area of 174.99 square kilometers. Table 11 shows the name and corresponding area of the block in square kilometers.

Table 11. LiDAR block/s with its corresponding area.

LiDAR Blocks	Area (sq. km.)
SamarLeyte_Blk33J	174.99

Portions of DTM before and after manual editing are shown in Figure 19. The bridge (Figure 19a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 19b) in order to hydrologically correct the river. The paddy field (Figure 19c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19d) to allow the correct flow of water.

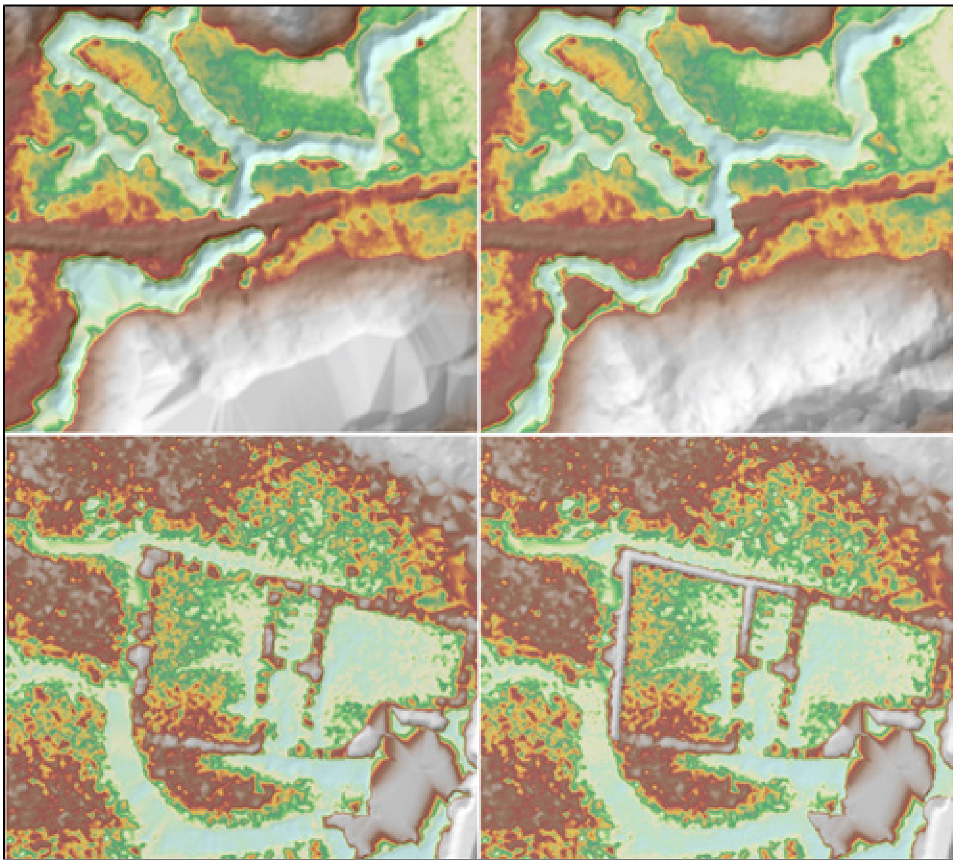


Figure 19. Portions in the DTM of Taft Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (a) and after (b) manual editing.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Tacloban DEM overlapping with the blocks to be mosaicked. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Taft Floodplain is shown in Figure 20. It can be seen that the entire Taft floodplain is 0.34% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 12. Shift Values of each LiDAR Block of Taft Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Samar_Leyte_Blk33J	-1.00	2.00	-1.00

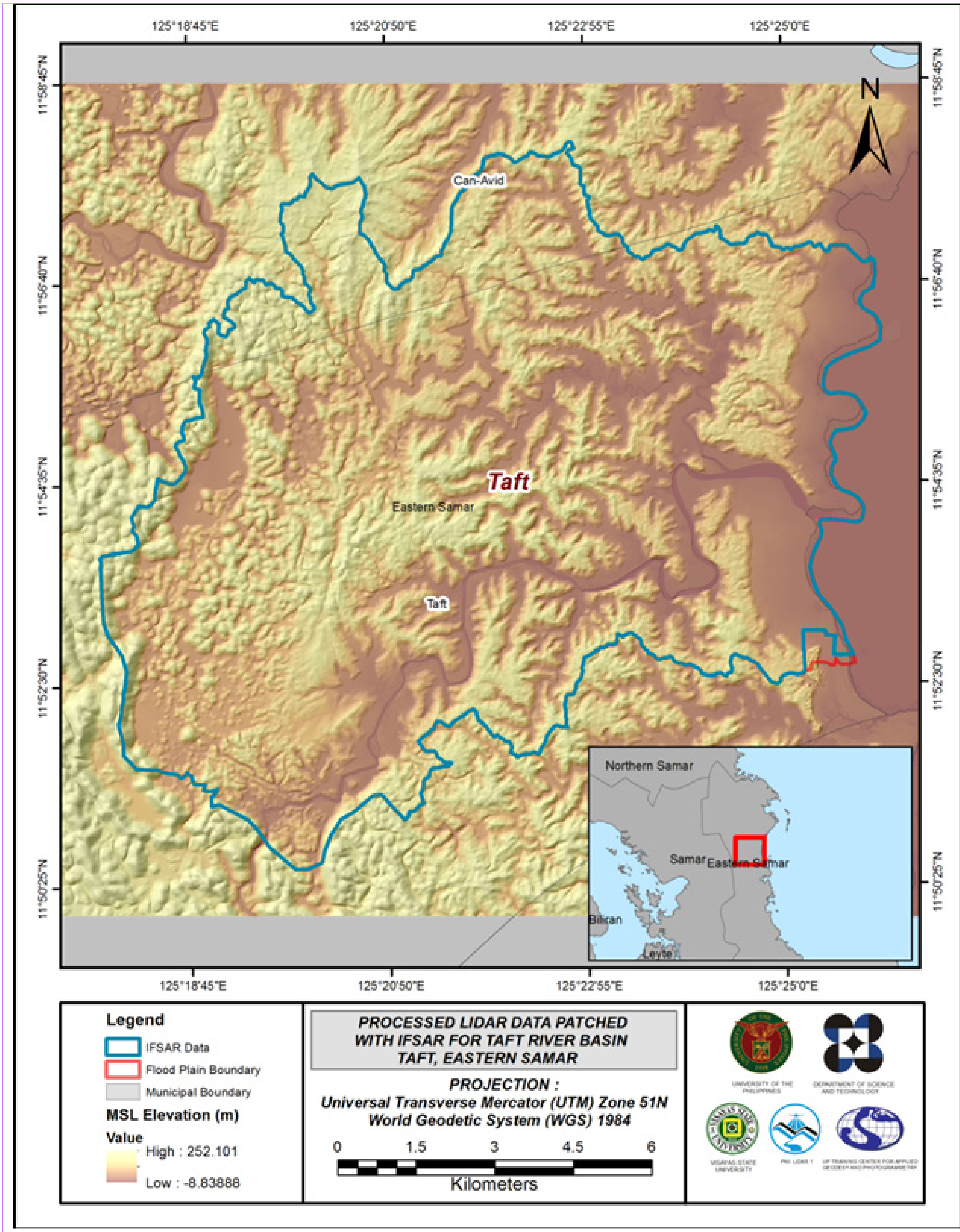


Figure 20. Map of Processed LiDAR Data for Taft Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Taft to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 3,494 survey points were gathered for the Taft flood plain. However, the point dataset was not used for the calibration of the LiDAR data for Taft because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Taft can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and ground survey elevation values is shown in Figure 22. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.14 meters with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, to Tacloban mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Taft DEM.

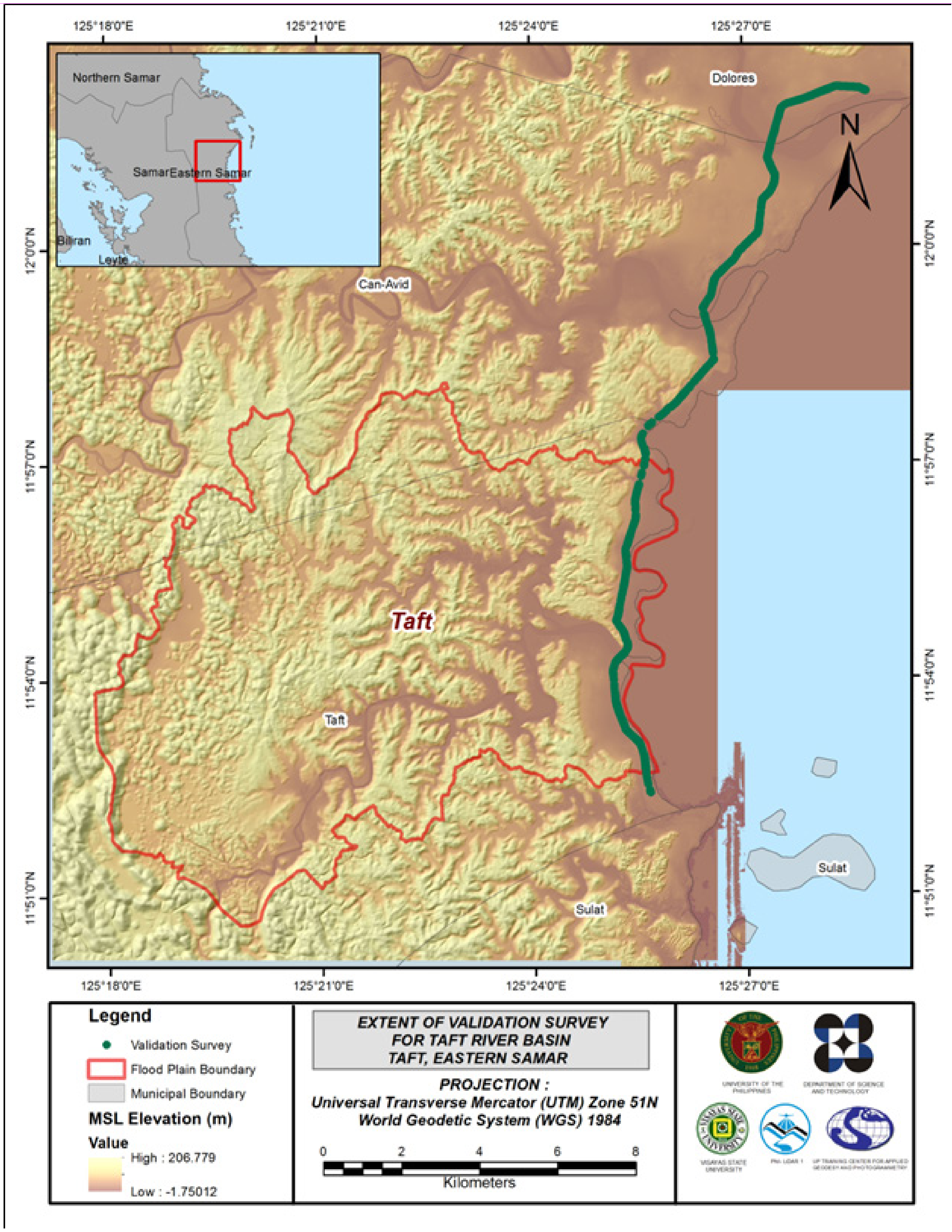


Figure 21. Map of Taft Floodplain with validation survey points in green.

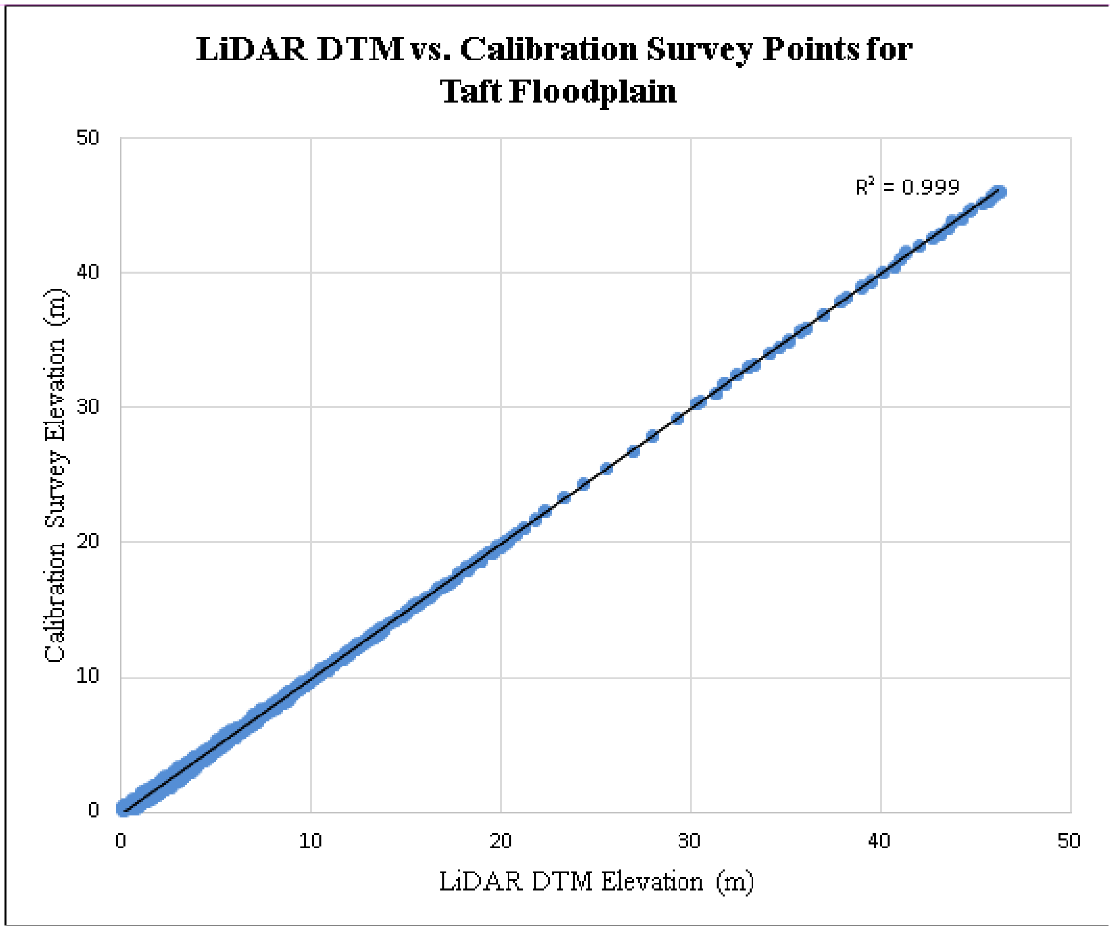


Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.32
Maximum	0.22

A total of 477 survey points were used for the validation of the calibrated Taft 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.90meters with a standard deviation of 0.49meters, as shown in Table 14.

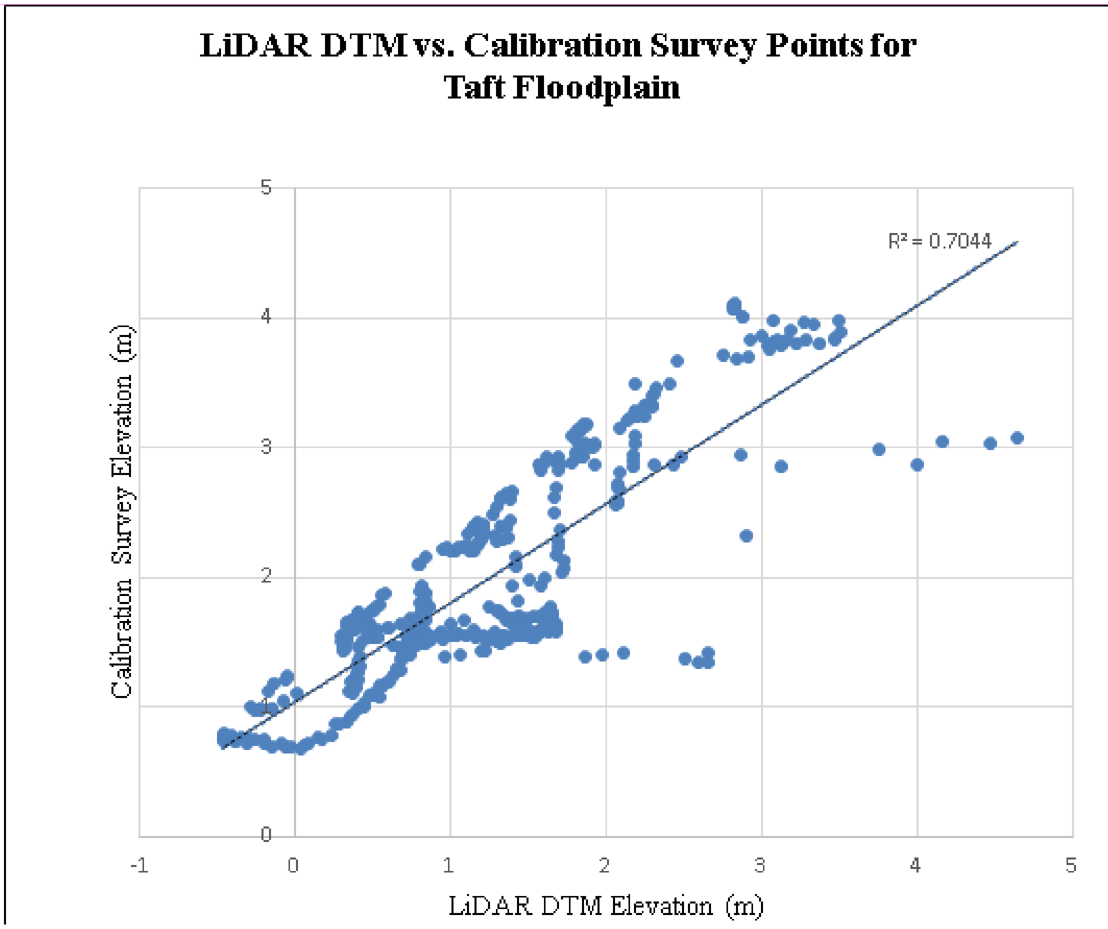


Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.90
Standard Deviation	0.49
Average	0.76
Minimum	-1.56
Maximum	1.32

Note: Validation points lie within the IFSAR data, thus, the RMSE and Standard Deviation values are obtained are still acceptable.

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data was available for Taft with 7,822 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.6 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Taft integrated with the processed LiDAR DEM is shown in Figure 24.

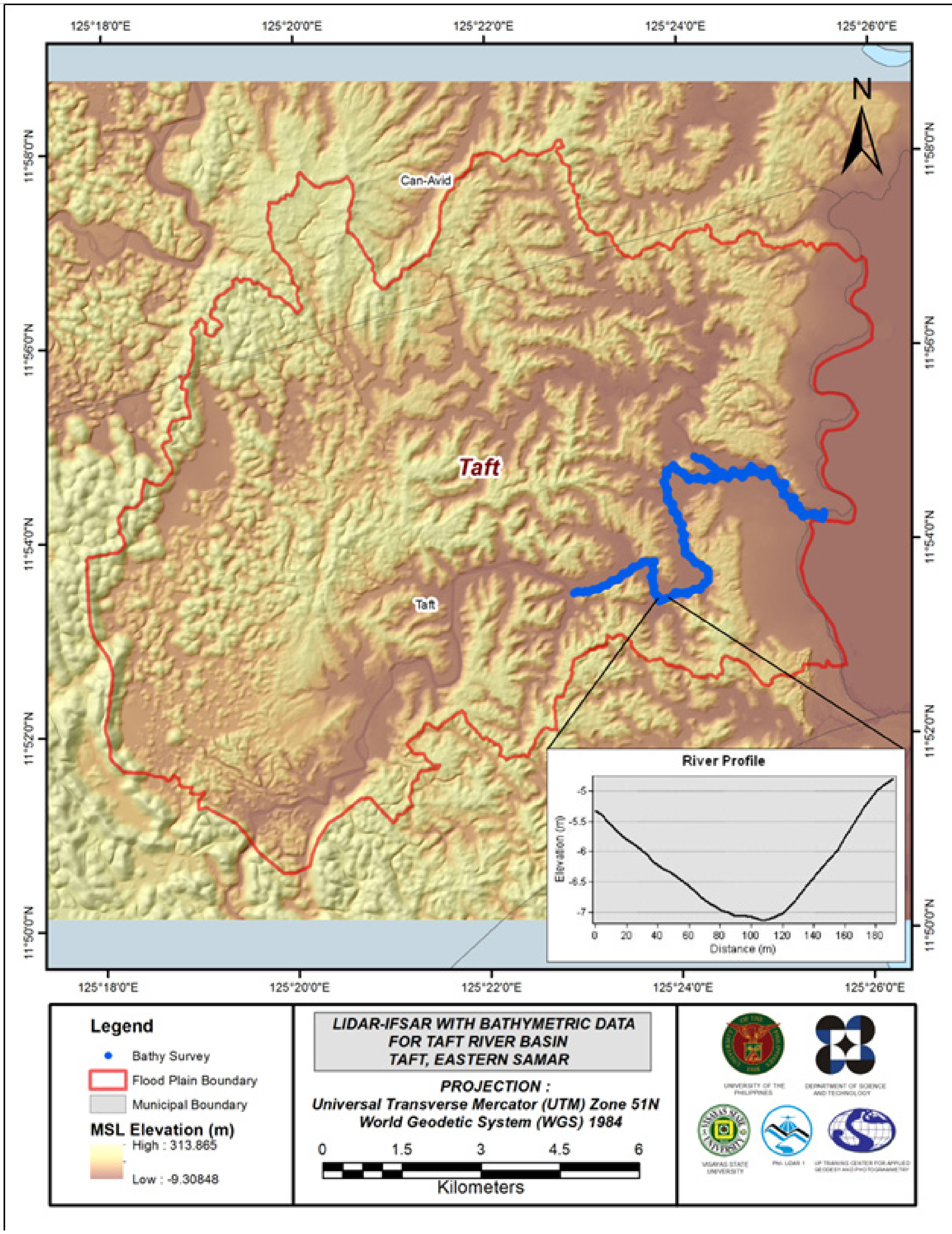


Figure 24. Map of Taft Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

3.12.3 Feature Attribution

3.12.4 Final Quality Checking of Extracted Features

CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE LIBERTAD RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo Engr. Mark Lester D. Rojas, Geol. Anthony Felix J. Abogado, Engr. Caren Joy S. Ordoña

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).

4.1 Summary of Activities

The DVBC conducted a field survey in Taft River on December 5 – 16, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built surveys at Taft Bridge in Brgy. Poblacion Barangay 1, Municipality of Taft and at Danao Bridge in Brgy. Bongdo, Municipality of Taft; validation points acquisition of about 22 km starting in Barangay 12 in the Municipality of Dolores going southwards to the Municipality of Can-Avid and ending in Brgy. Mantang, Municipality of Taft; and bathymetric survey from itsupstream in Brgy. Gayam, in the Municipality of Taft,to the mouth of the river in Brgy. Nato, in the same Municipality, with an approximate length of 9.108 km using Trimble® SPS 985 GNSS PPK survey technique.

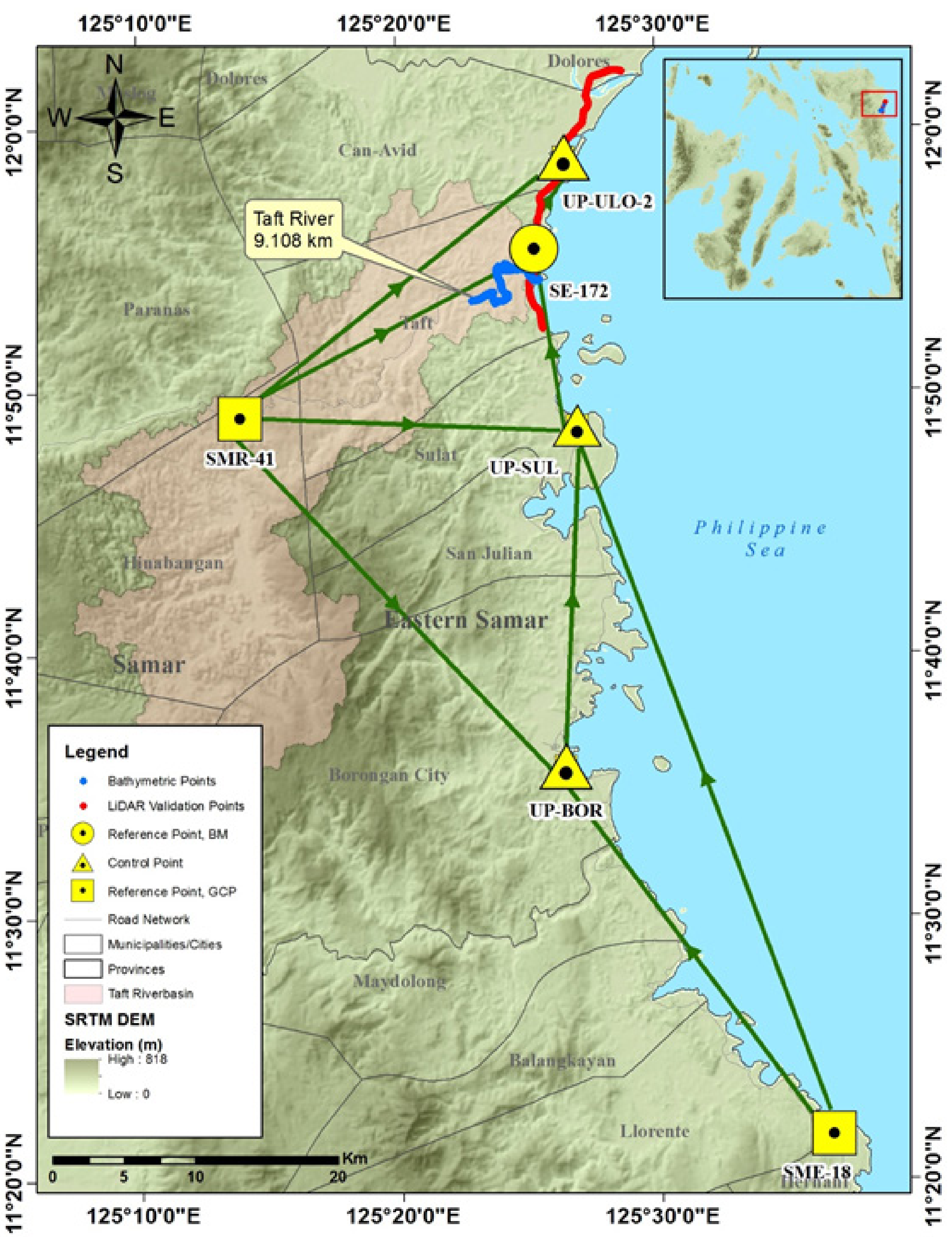


Figure 25. Taft River Basin Survey Extent

4.2 Control Survey

The GNSS network used for Taft River Basin is composed of four (4) loopsestablished on December 10, 2016, occupying the reference points: SME-18, a 2nd order NAMRIA GCP in Brgy. Canciledes, Municipality of Hernani, Eastern Samar; SMR-41, a 2nd order NAMRIA GCP in Brgy. Fatima, Municipality of Hinabangan, Samar; and,SE-172, a 1st order BM in Brgy. Nato, Municipality of Taft, Eastern Samar.

Control points were established namely UP-BOR located at the approach of Can-Obing Bridge in Brgy. Can-Abong, Borongan City, Eastern Samar; UP-SUL located at the approach of Sulat Bridge in Brgy. Maramara, Municipality of Sulat, Eastern Samar; and, UP-ULO-2 located at the approach of Can-Avid Bridge in Brgy. Canteros, Municipality of Can-Avid, Eastern Samar. These established points were also occupied to use as markers for the survey.

The summary of reference and control points and its location is summarized in Table 15 while the GNSS network established is illustrated in Figure 26.

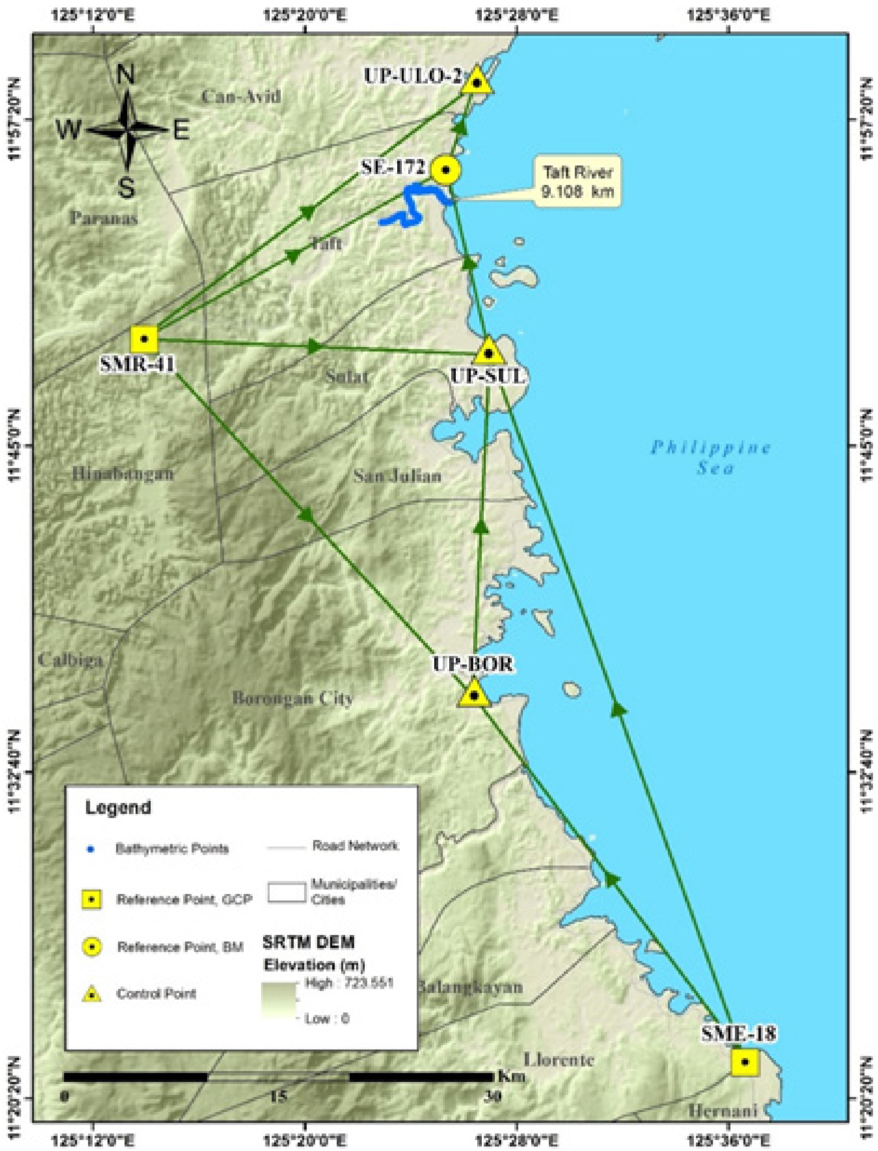


Figure 26. Taft River Basin Control Survey Extent

Table 15. List of Reference and Control Points occupied for Taft River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
Control Survey on December 10, 2016						
SME-18	2nd Order, GCP	11°21'43.08128"	125°36'37.41861"	78.216	17.659	12-10-16
SMR-41	2nd Order, GCP	11°49'03.09527"	125°13'56.04672"	232.562	-	12-10-16
SE-172	1st Order, BM	-	-	61.761	3.155	12-6-16
UP-BOR	UP established	-	-	67.048	-	12-6-16
UP-SUL	UP established	-	-	64.565	-	12-6-16
UP-ULO-2	UP established	-	-	63.77	-	12-9-16

The GNSS set-ups on recovered reference points and established control points in Taft River are shown in Figure 27 to Figure 32.

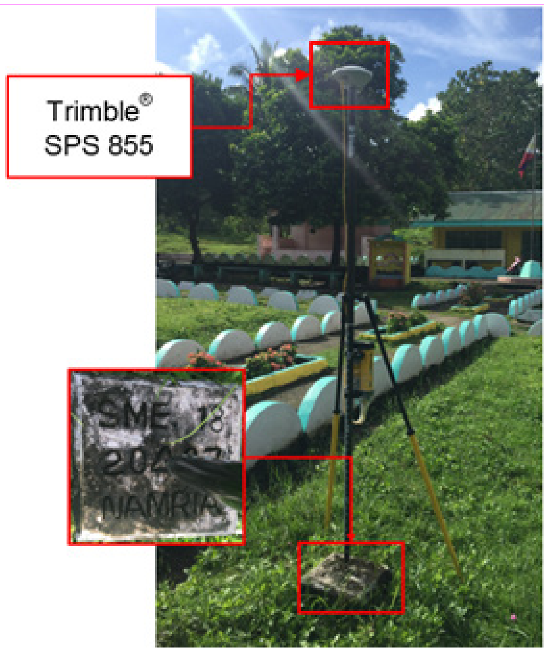


Figure 27. GNSS receiver setup, Trimble® SPS 855, at SME-18, located within the grounds of San Jose Elementary School in Brgy. Canciledes, Municipality of Hernani, Eastern Samar

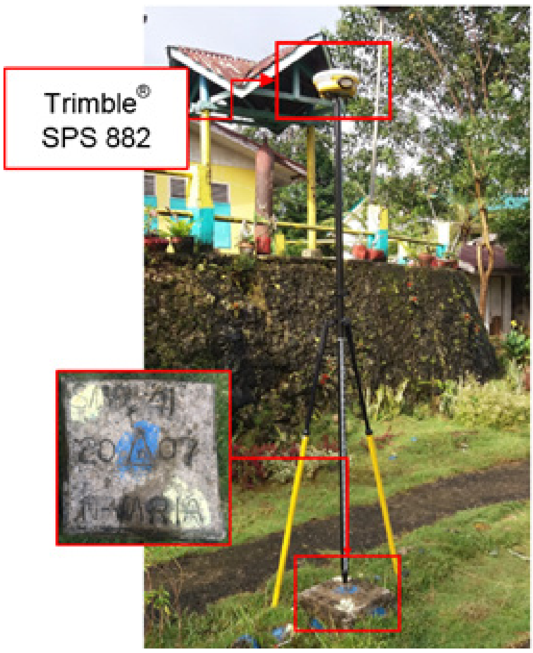


Figure 28. GNSS base set up, Trimble® SPS 882, at SMR-41, located within the grounds of Hinabangan Elementary School in Brgy. Fatima, Municipality of Hinabangan, Samar

Figure 29. GNSS receiver setup, Trimble® SPS 855 at SE-172, located within the grounds of Nato Elementary School in Brgy. Nato, Municipality of Taft, Eastern Samar

Figure 30. GNSS receiver setup, Trimble® SPS 855, at UP-BOR, located at the approach of Can-Obing Bridge in Brgy. Can-Abong, Borongan City, Eastern Samar

Figure 31. GNSS receiver setup, Trimble® SPS 985, at UP-SUL, located at the approach of Sulat Bridge in Brgy. Maramara, Municipality of Sulat, Eastern Samar

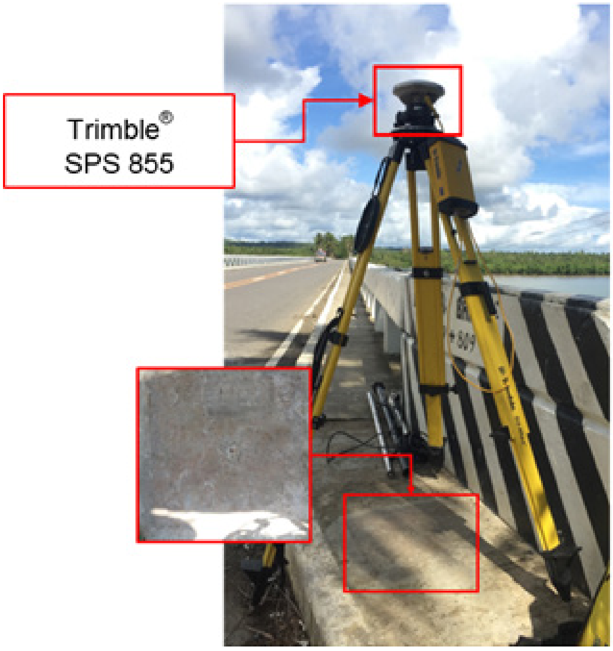


Figure 32. GNSS receiver setup, Trimble® SPS 855, at UP-ULO-2, located at the approach of Can-Avid Bridge in Brgy. Canteros, Municipality of Can-Avid, Eastern Samar

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Taft River Basin is summarized in Table 16 generated by TBC software.

Table 16. Baseline Processing Summary Report for Taft River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-41--- SE-172 (B1)	12-10-16	Fixed	0.003	0.019	60°19'56"	23782.994	-170.787
SMR-41 --- UP-ULO-2 (B2)	12-10-16	Fixed	0.004	0.027	51°26'56"	29152.677	-168.797
SE-172 --- UP-ULO-2 (B3)	12-10-16	Fixed	0.003	0.014	18°29'10"	6742.890	2.008
SMR-41 --- SE-172 (B6)	12-10-16	Fixed	0.003	0.017	60°19'55"	23782.982	-170.797
SMR-41 --- UP-SUL (B7)	12-10-16	Fixed	0.003	0.025	91°37'24"	23648.007	-168.014
SME-18 --- UP-SUL (B8)	12-10-16	Fixed	0.005	0.019	340°32'04"	52735.660	-13.625
UP-SUL --- SE-172 (B9)	12-10-16	Fixed	0.003	0.018	346°36'16"	12792.116	-2.807
UP-BOR --- UP-SUL (B10)	12-10-16	Fixed	0.003	0.014	2°25'05"	23870.045 "	-2.491
SMR-41 --- UP-BOR (B11)	12-10-16	Fixed	0.003	0.018	137°16'15"	33379.379	-165.537
SME-18 --- UP-BOR (B12)	12-10-16	Fixed	0.003	0.012	324°17'43"	31862.093	-11.163

As shown in Table 16 a total of ten (10) baselines were processed withcoordinate and elevation values of SME-18, SMR-41, and SE-172 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown in Table C-3 to Table C-6 for complete details.

The three (3) control points, UP-BOR, UP-SUL, and UP-ULO-2 were occupied and observed simultaneously to form a GNSS loop. Coordinates of SME-18 and SMR-41; elevation value of SME-18 and SE-172; and fixed values of SME-18, SMR-41, and SE-172 were held fixed during the processing of the control points as presented in Table 17. Through these reference points, the coordinates and elevation of the unknown control

Table 17. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SME-18	Grid	Fixed	Fixed		Fixed
SMR-41	Global	Fixed	Fixed		
SE-172	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 18. All fixed control points have no values for grid and elevation errors.

Table 18. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SME-18	528987.231	?	1115622.481	?	7.275	0.040	LL
784907.431	?	1257282.043	?	17.659	?	ENe	e
SMR-41	523151.163	0.007	1112861.259	0.005	26.540	0.051	
743218.063	?	1307346.858	?	171.203	0.041	LL	
SE-172							
763795.614	0.007	1319288.604	0.006	3.155	?	e	
UP-BOR	766068.889	0.006	1282998.400	0.005	5.989	0.039	
UP-SUL	766869.986	0.007	1306865.645	0.006	5.374	0.042	
UP-ULO-2	765878.376	0.010	1325704.856	0.009	5.912	0.05	

With the mentioned equation, 〖〖√((x〗_e)〗^2+〖〖(y〗_e)〗^2)<20cm for horizontal and z_e<10 cm for the vertical; the computation for the accuracy are as follows:

a. NGE-67

SME-18

horizontal accuracy = Fixed

vertical accuracy = Fixed

SMR-41

horizontal accuracy = Fixed

vertical accuracy = 4.1 < 10 cm

SE-172

horizontal accuracy = $\sqrt{(0.7)^2 + (0.6)^2}$

= √ (0.49 + 0.36)

= 1.77< 20 cm

vertical accuracy = Fixed

UP-BOR

horizontal accuracy = $\sqrt{(0.6)^2 + (0.5)^2}$

= √ (0.36 + 0.25)

= 0.78< 20 cm

vertical accuracy = 3.9 < 10 cm

UP-SUL

horizontal accuracy = $\sqrt{(0.7)^2 + (0.6)^2}$

= √ (0.49 + 0.36)

= 0.92< 20 cm

vertical accuracy = 4.2 < 10 cm

UP-ULO-2

horizontal accuracy = $\sqrt{(1)^2 + (0.9)^2}$

= √ (1.81 + 1.44)

= 1.35< 20 cm

vertical accuracy = 5.3 < 10 cm

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

Table 19. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
SME-18	N11°21'43.08128"	E125°36'37.41861"	78.216	?	ENe
SMR-41	N11°49'03.09527"	E125°13'56.04672"	232.562	0.041	LL
SE-172	N11°55'25.95794"	E125°25'18.96211"	61.761	?	e
UP-BOR	N11°35'44.89710"	E125°26'23.64085"	67.048	0.039	
UP-SUL	N11°48'41.00280"	E125°26'56.90219"	64.565	0.042	
UP-ULO-2	N11°58'54.06226"	E125°26'29.62952"	63.770	0.053	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 19. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 20.

Table 20. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SME-18	2nd Order, GCP	11°21'43.08128"	125°36'37.41861"	78.216	1257282.043	784907.431	17.659
SMR-41	2nd Order, GCP	11°49'03.09527"	125°13'56.04672"	232.562	1307346.858	743218.063	171.203
SE-172	1st Order, BM	11°55'25.95794"	125°25'18.96211"	61.761	1319288.604	763795.614	3.155
UP-BOR	UP established	11°35'44.89710"	125°26'23.64085"	67.048	1282998.400	766068.889	5.989
UP-SUL	UP established	11°48'41.00280"	125°26'56.90219"	64.565	1306865.645	766869.986	5.374
UP-ULO-2	UP established	11°58'54.06226"	125°26'29.62952"	63.77	1325704.856	765878.376	5.912

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

Cross-section and as-built surveys were conducted on December 8, 2016 at the downstream side of Taft bridge in Brgy. Poblacion Barangay 1, Municipality of Taft, Eastern Samar; and, on the same day, at the downstream side of Danao Bridge in Brgy. Bongdo, Municipality of Taft, Eastern Samar as shown in Figure 33 and Figure 34. A survey grade GNSS receiver Trimble® SPS 985 in PPK survey technique was utilized for this survey as shown in Figure 35 and Figure 36

Figure 33. Taft Bridge facing upstream

Figure 34. Danao Bridge facing upstream

Figure 35. As-built survey of Taft Bridge

Figure 36. As-built survey of Danao Bridge

The cross-sectional line of Taft Bridge is about 187.91 m with eighty-seven (87) cross-sectional points, using the control point SE-172; while, the cross-sectional line of Danao Bridge is about 118.42 m with fifty five (55) cross-sectional points, using the control point SE-172 as GNSS base stations. The cross-section diagrams, location maps, and the bridge data forms are shown in to Figure 37 to Figure 42, respectively.

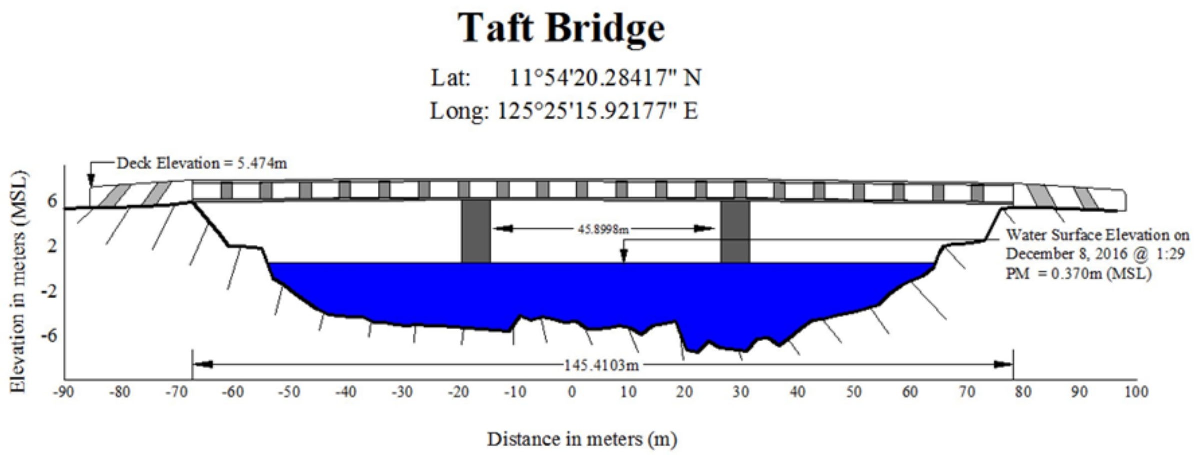


Figure 37. Taft Bridge cross-section diagram

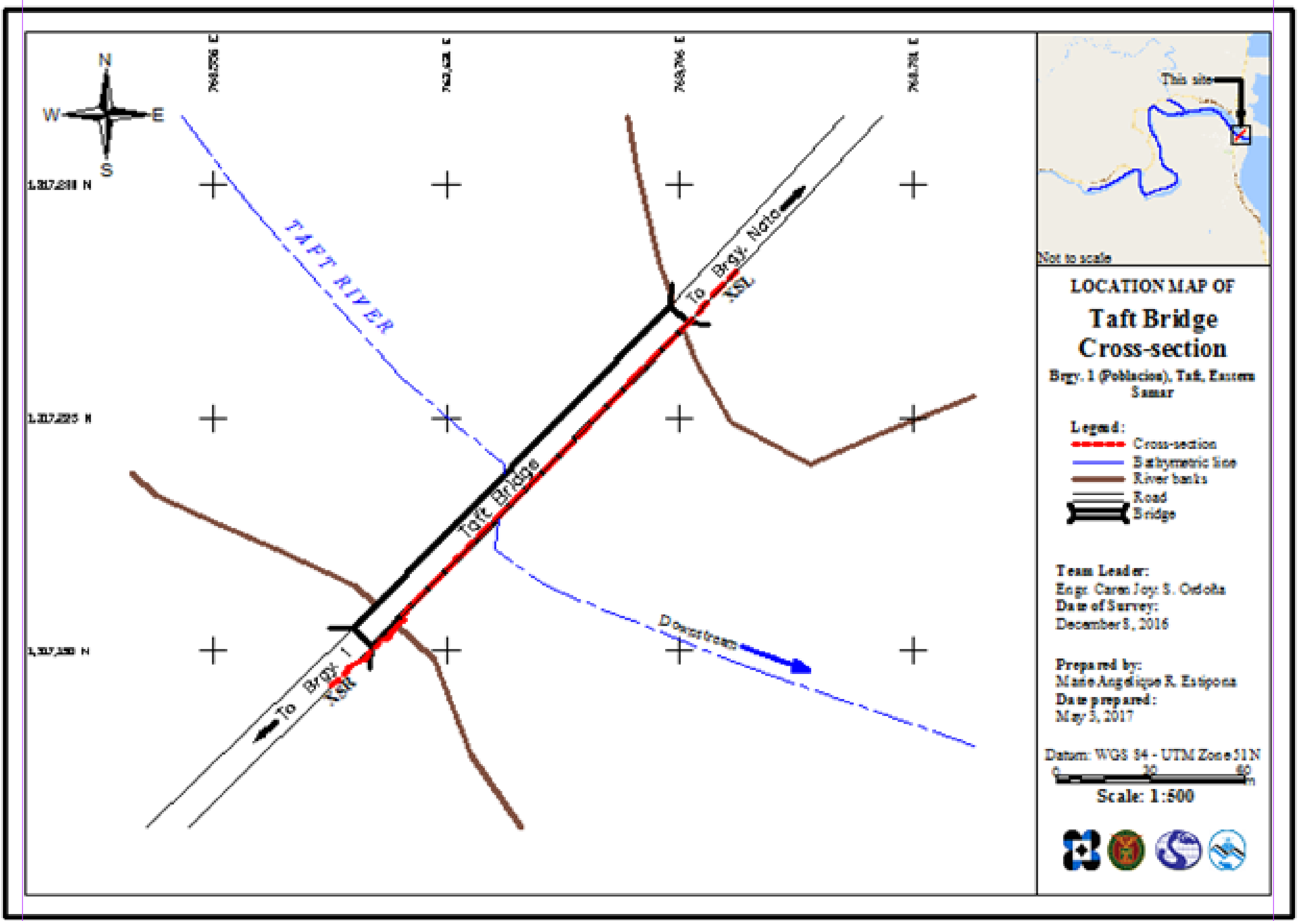


Figure 36. Deployment site, Cangabo Spillway, cross-section diagram

The water surface elevation of Libertad River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on January 29, 2016 at 2:46 PM with a value of 28.153 m in MSL. This was translated into marking on the bridge's pier as shown in Figure 37. It now serves as the reference for flow data gathering and depth gauge deployment of the University of San Carlos, the partner HEI responsible for the monitoring of the Libertad River.

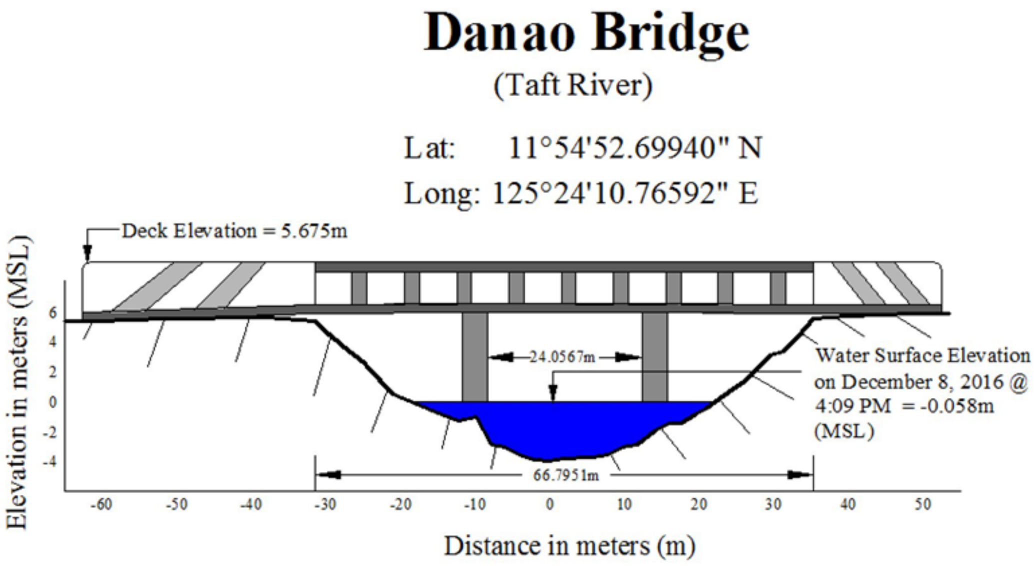


Figure 39. Danao Bridge cross-section diagram

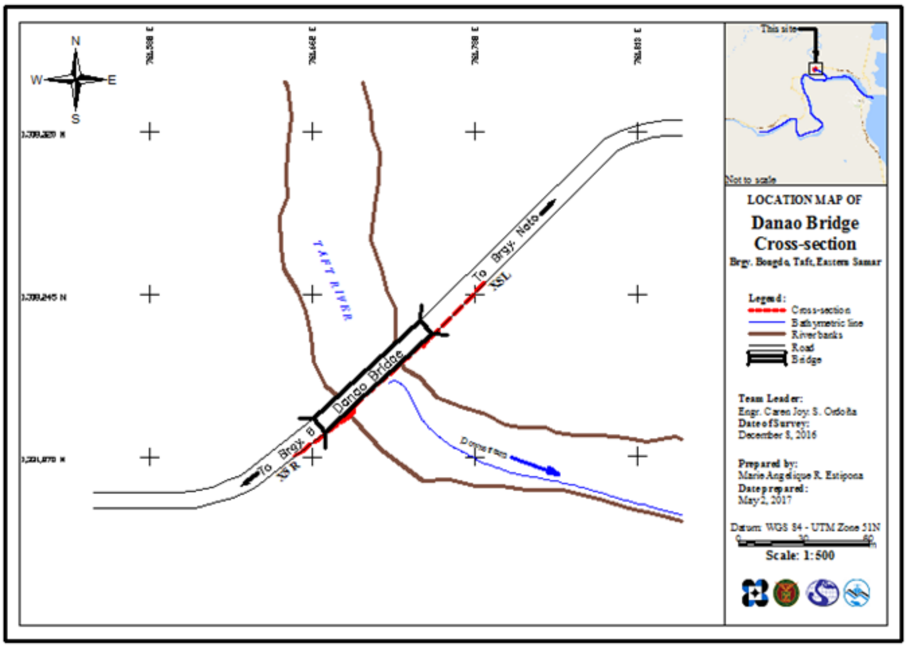


Figure 40. Danao bridge cross-section location map

Bridge Data Form

Bridge Name: Taft Bridge　　Date: December 8, 2016

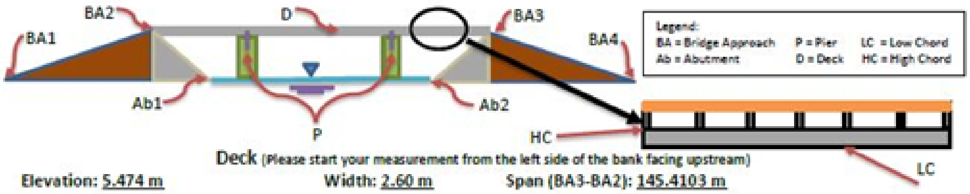
River Name: Taft River　　Time: 1:29 PM

Location (Brgy, City,Region): Brgy. Poblacion Barangay I, Municipality of Taft, Eastern Samar

Survey Team: Caren Ordoña, Marion Dimain, John Christopher Santos

Flow condition: normal　　Weather Condition: fair

Latitude: 11°54'20.28417" N　　Longitude: 125°25'15.92177" E



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

Elevation: 5.474 m　　Width: 2.60 m　　Span (BA3-BA2): 145.4103 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.205 m	BA3	168.150 m	5.514 m
BA2	22.740 m	5.748 m	BA4	187.930 m	4.926 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: rectangular　　Number of Piers: 2　　Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	72.609 m	5.934 m	1.20 m
Pier 2	118.508 m	5.87 m	1.20 m

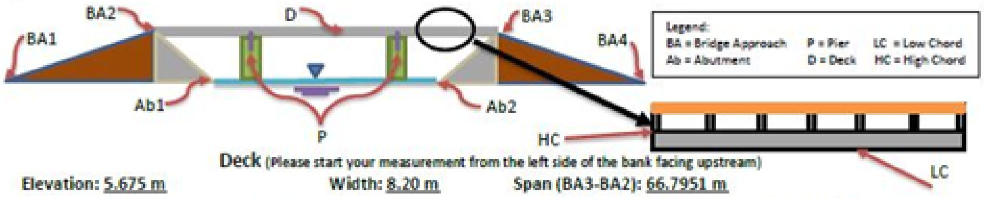
NOTE: Use the center of the pier as reference to its station

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 41. Bridge as-built form of Taft Bridge

Bridge Data Form

Bridge Name: Danao Bridge	Date: December 8, 2016
River Name: Taft River	Time: 4:09 PM
Location (Brgy, City,Region): Brgy. Bongdo, Municipality of Taft, Eastern Samar	
Survey Team: Caren Ordoña, Marion Dimain, John Christopher Santos	
Flow condition: normal	Weather Condition: fair
Latitude: 11°54'52.69940" N	Longitude: 125°24'10.76592" E



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

Elevation: 5.675 m Width: 8.20 m Span (BA3-BA2): 66.7951 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.337 m	BA3	100.237 m	5.822 m
BA2	33.442 m	5.832 m	BA4	117.347 m	5.859 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: circular Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	54.734 m	5.959 m	0.80 m
Pier 2	78.791 m	5.915 m	0.80 m

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 42. Bridge as-built form of Danao Bridge

Water surface elevation of Taft River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on December 8, 2016 at 1:29 PM at Taft Bridge with a value of 0.370 m in MSL as shown in Figure 37. This was translated into marking on the bridge's deck as shown in Figure 43. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Taft River, the Visayas State University.

Figure 43. Water-level markings onTaft Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 10, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted in frontof a vehicle as shown in Figure 44. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.305m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-ULO-2 occupied as the GNSS base station in the conduct of the survey.

Figure 44. Validation points acquisition survey set up along Taft River Basin

The survey started in Barangay 12, Municipality of Dolores going south along national highway covering twenty (20) barangays in the Municipalities of Can-Avid and Taft which ended in Brgy. Mantang, Municipality of Taft, Eastern Samar. A total of 3,597 points with approximate length of 22 km using UP-ULO-2 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 45.

Figure 45. Validation point acquisition survey of Taft River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on December 10, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 46. It started in Brgy. Gayam, Municipality of Taft with coordinates 11°53'27.55028"N, 125°22'53.47263"E, traversed down the river by boat and ended at the mouth of the river in Brgy. Nato, Municipality of Taft, Eastern Samar with coordinates 11°54'11.56061"N, 125°25'29.59274"E. The control pointsUP-ULO-2was used as GNSS base stations all throughout the entire survey.

Figure 46. Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in Taft River

The bathymetric survey for Taft River gathered a total of 8,850 points covering 9.108 km of the river traversing Brgy. Gayam, Municipality of Taft, Eastern Samar.A CAD drawing was also produced to illustrate the riverbed profile of Taft River. As shown in Figure 48, the highest and lowest elevation has a 9.617-m difference. The highest elevation observed was –0.823 m below MSL located at the downstream part of the river; while the lowest was –10.44 m below MSL located in the upstream portion of the river.

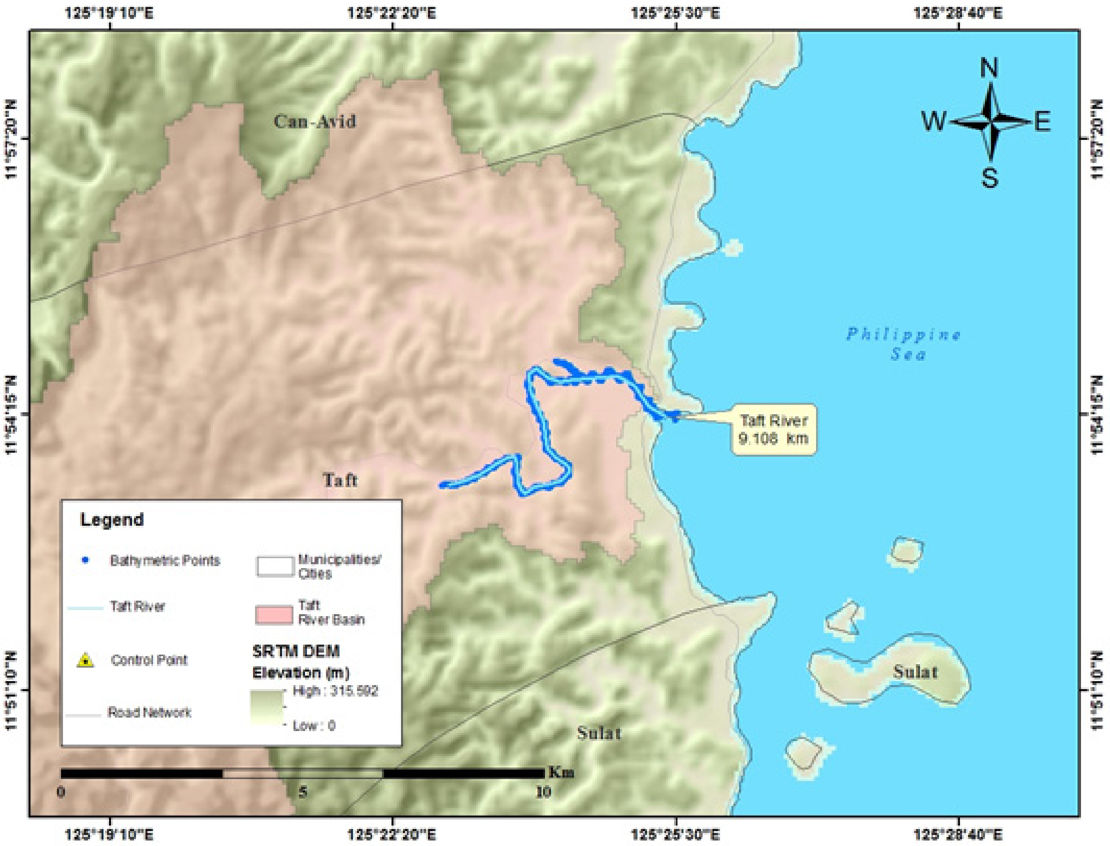


Figure 47. Bathymetric survey of Taft River

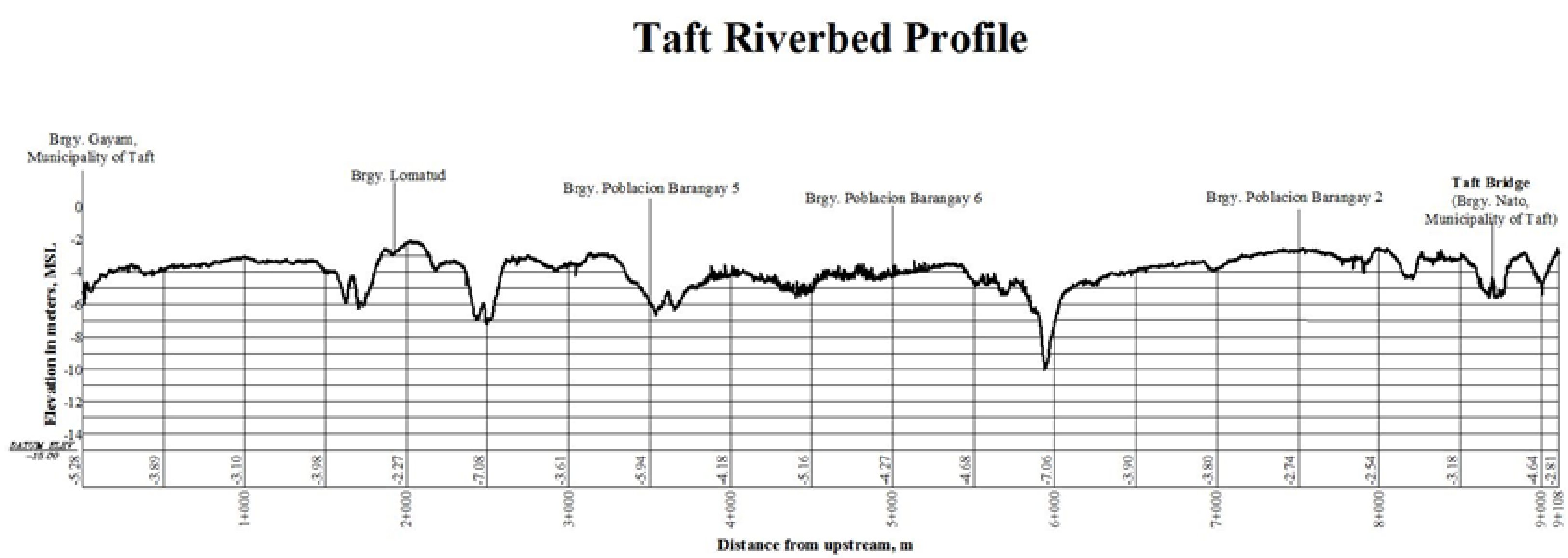


Figure 43. The Libertad Riverbed Profile.

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the automatic rain gauge (ARG) installed by the Flood modeling Component at Brgy. Malinao, Taft, Eastern Samar. The location of the rain gauges is seen in Figure 49.

Total rain from Malinao rain gauge is 173.8 mm. It peaked to 10.2 mm on 30 July 2016, 7:00 to 7:15 PM. The lag time between the peak rainfall and discharge is five hours and fifty minutes.

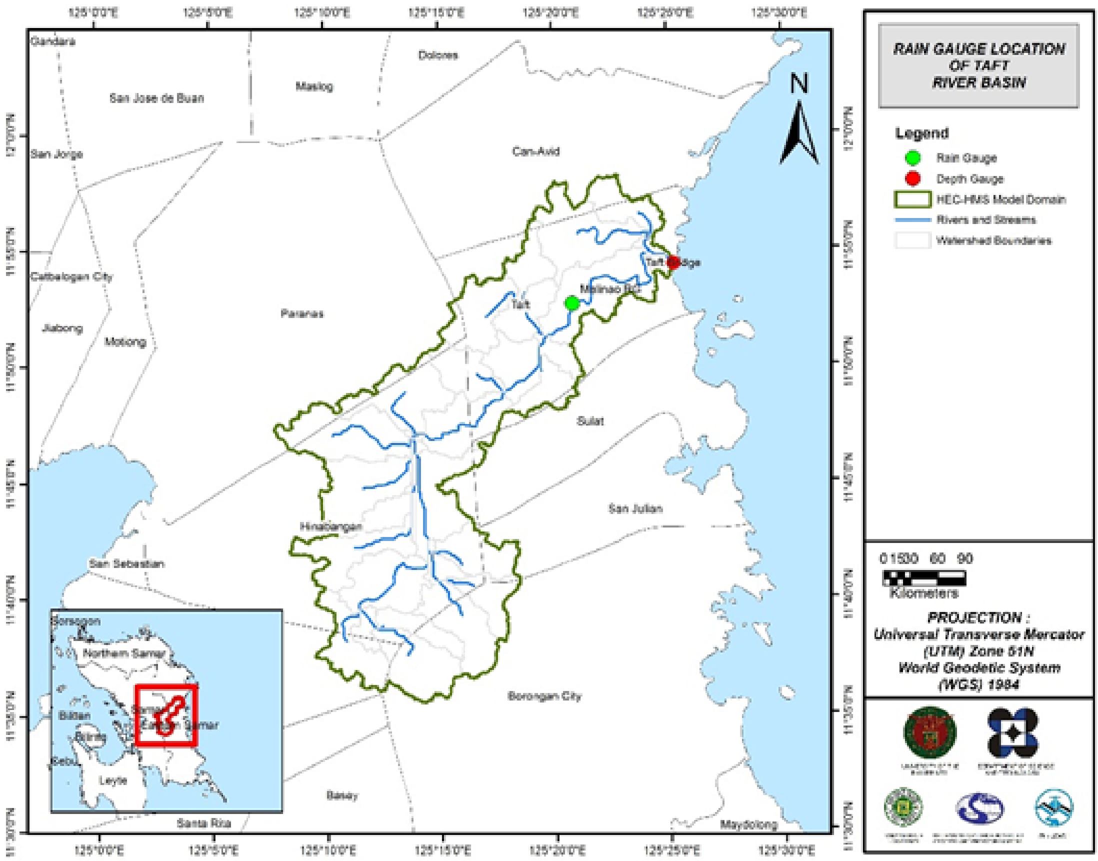


Figure 49. The location map of Taft HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Taft Bridge, Brgy. Poblacion, Taft, Eastern Samar. It gives the relationship between the observed water levels at Taft Bridge and outflow of the watershed at this location.
For Taft Bridge, the rating curve is expressed as Q = 199.66e0.8747h as shown in Figure 51.

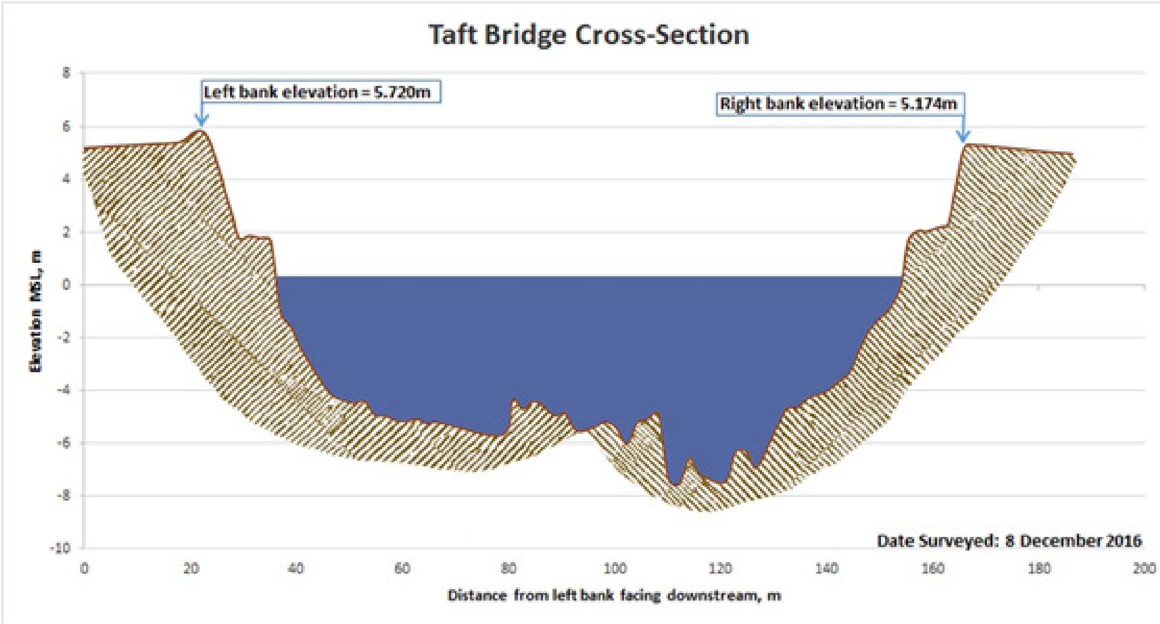


Figure 50. Cross-Section Plot of Taft Bridge

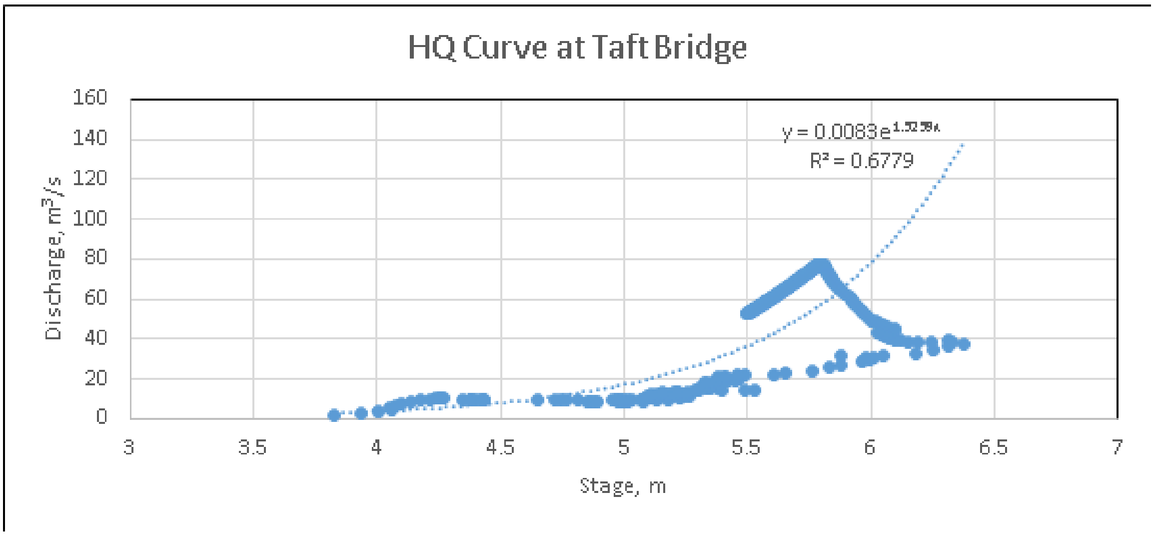


Figure 51. Rating Curve at Taft Bridge

This rating curve equation was used to compute the river outflow at Taft Bridge for the calibration of the HEC-HMS model. Total rain from Malinao rain gauge is 173.8 mm. It peaked to 10.2 mm on 30 July 2016, 7:00 to 7:15 PM. The lag time between the peak rainfall and discharge is five hours and fifty minutes.

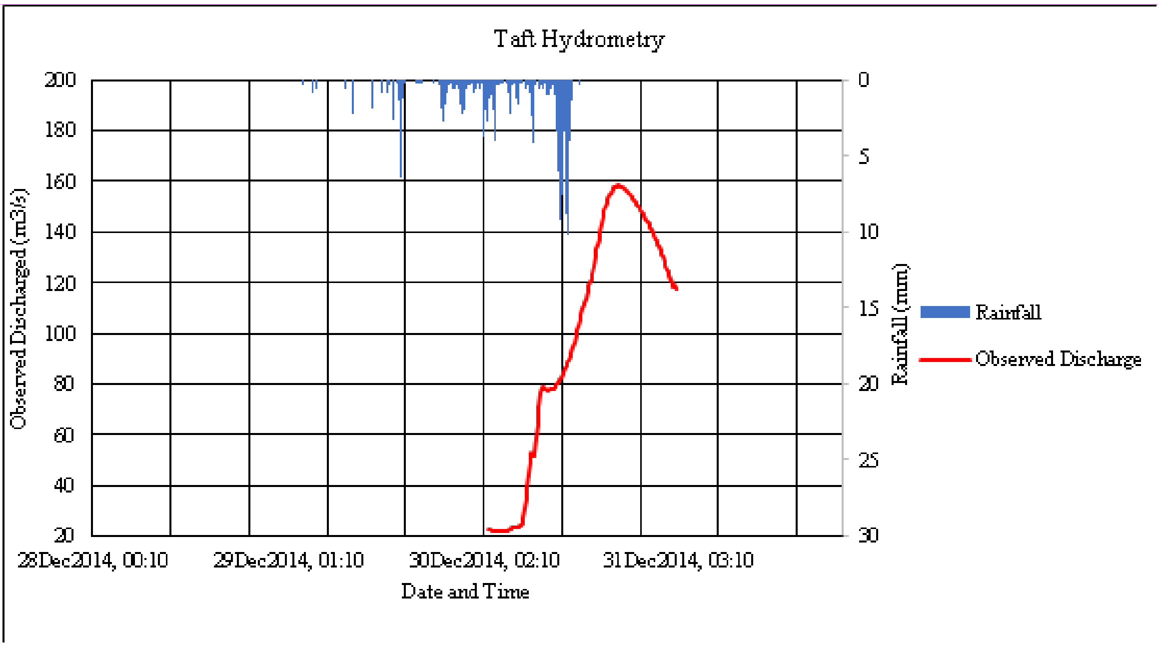


Figure 52. Rainfall and outflow data at Taft used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Borongan Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Taft watershed. The extreme values for this watershed were computed based on a 36-year record.

Table 21. RIDF values for Borongan 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	22.5	35.3	44.5	60.6	83.7	100.8	133.7	170.7	201.4
5	31.5	49.1	61	82.3	116.1	140.8	186.5	241	283.8
10	37.4	58.2	71.9	96.6	137.6	167.2	221.4	287.6	338.4
15	40.7	63.3	104.7	104.7	149.8	182.1	241.2	313.9	369.2
20	43	66.9	110.4	110.4	158.3	192.6	255	332.3	390.8
25	44.8	69.7	114.8	114.8	164.8	200.6	265.6	346.4	407.4
50	50.4	78.2	128.3	128.3	185	225.4	298.4	390.1	458.6
100	55.9	86.7	141.6	141.6	205	205	330.9	433.4	509.4

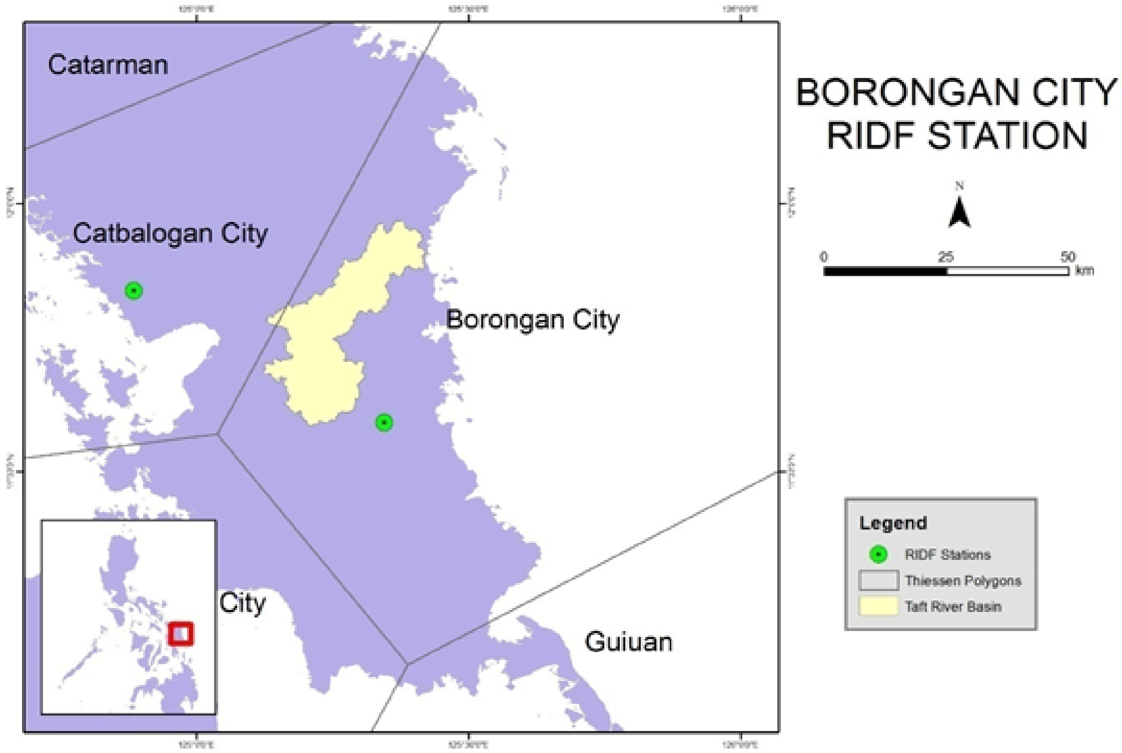


Figure 53. Location of Borongan RIDF Station relative to Taft River Basin

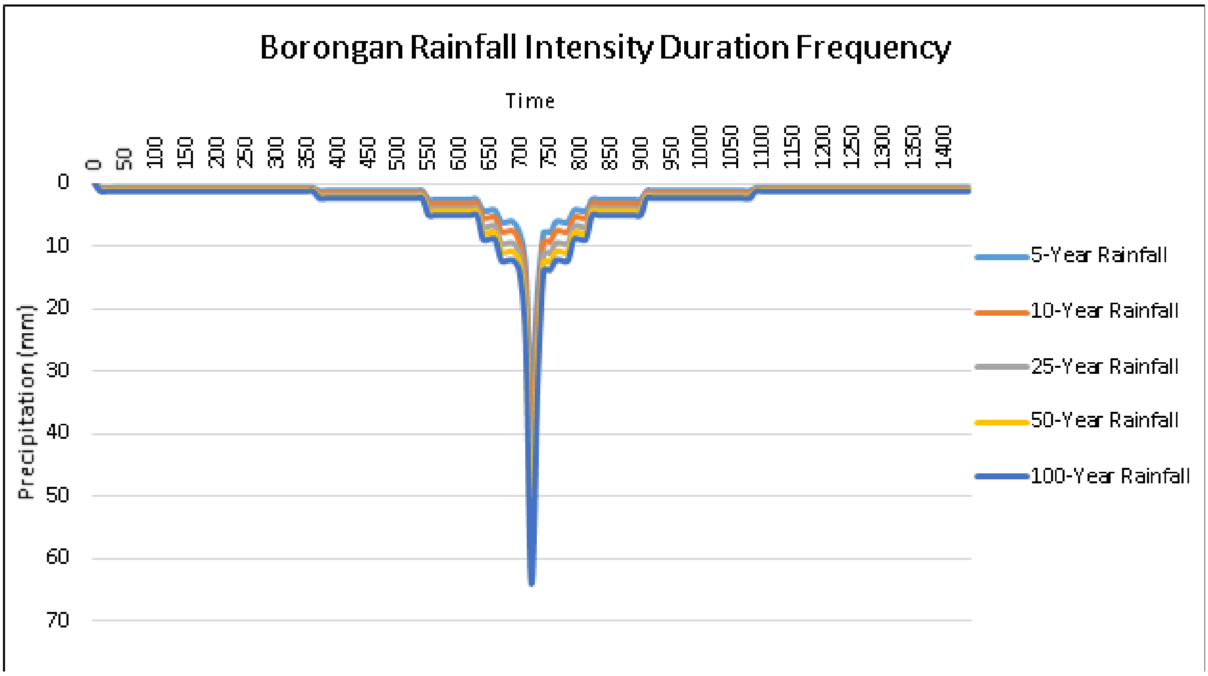


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Taft River Basin are shown in Figures 55 and 56, respectively.

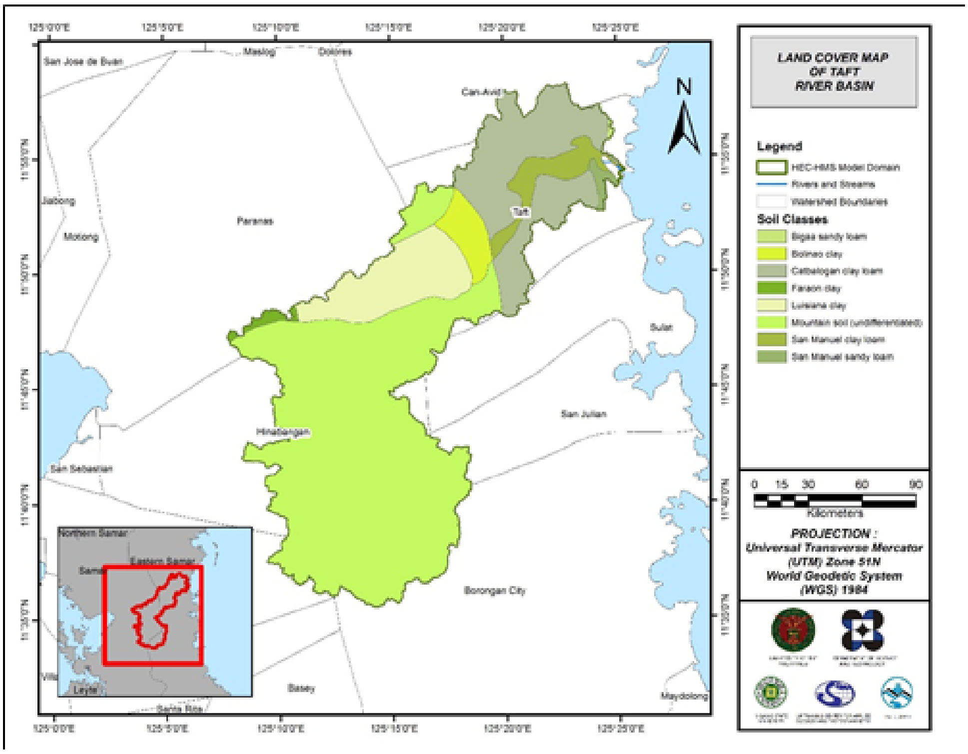


Figure 55. Soil Map of Taft River Basin

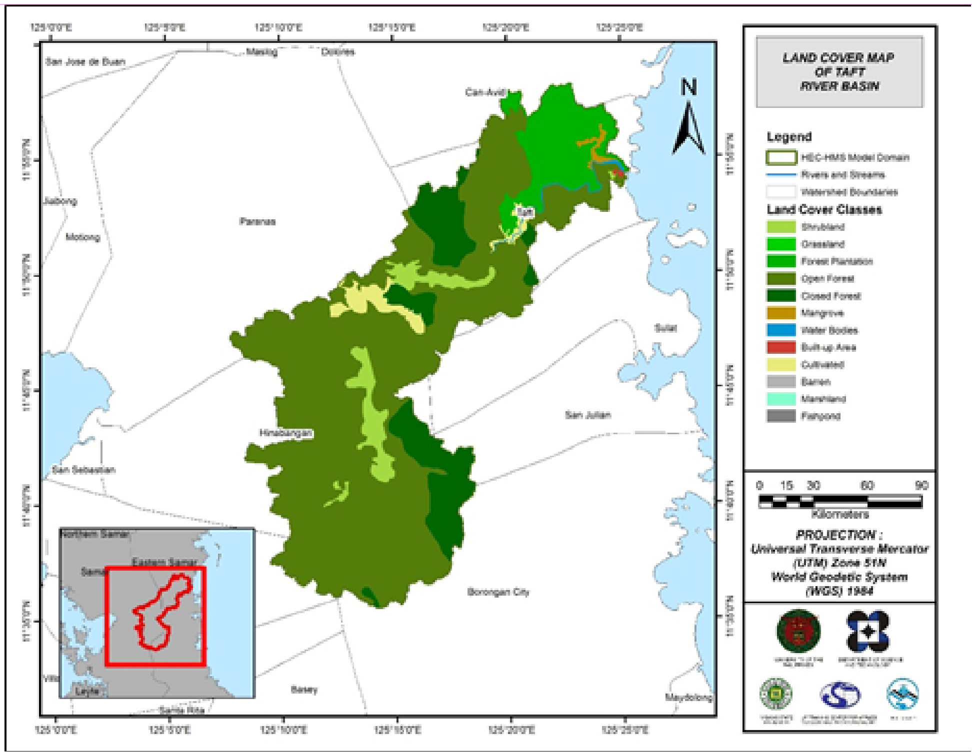


Figure 56. Land Cover Map of Taft River Basin

For Taft, the soil classes identified were clay, clay loam, sandy loam, and mountain soil. The land cover types identified were shrubland, grassland, forest plantation, open forest, closed forest, and cultivated area.

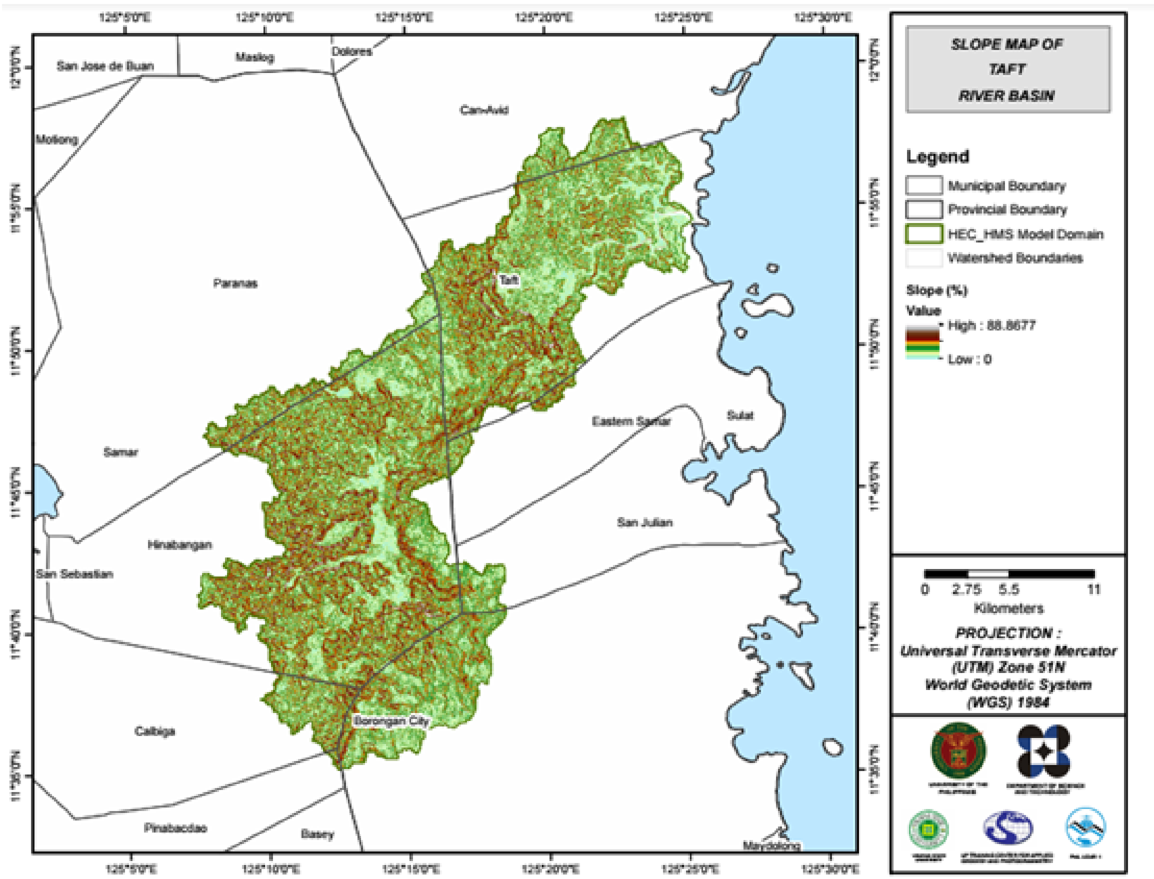


Figure 57. Slope Map of the Taft River Basin

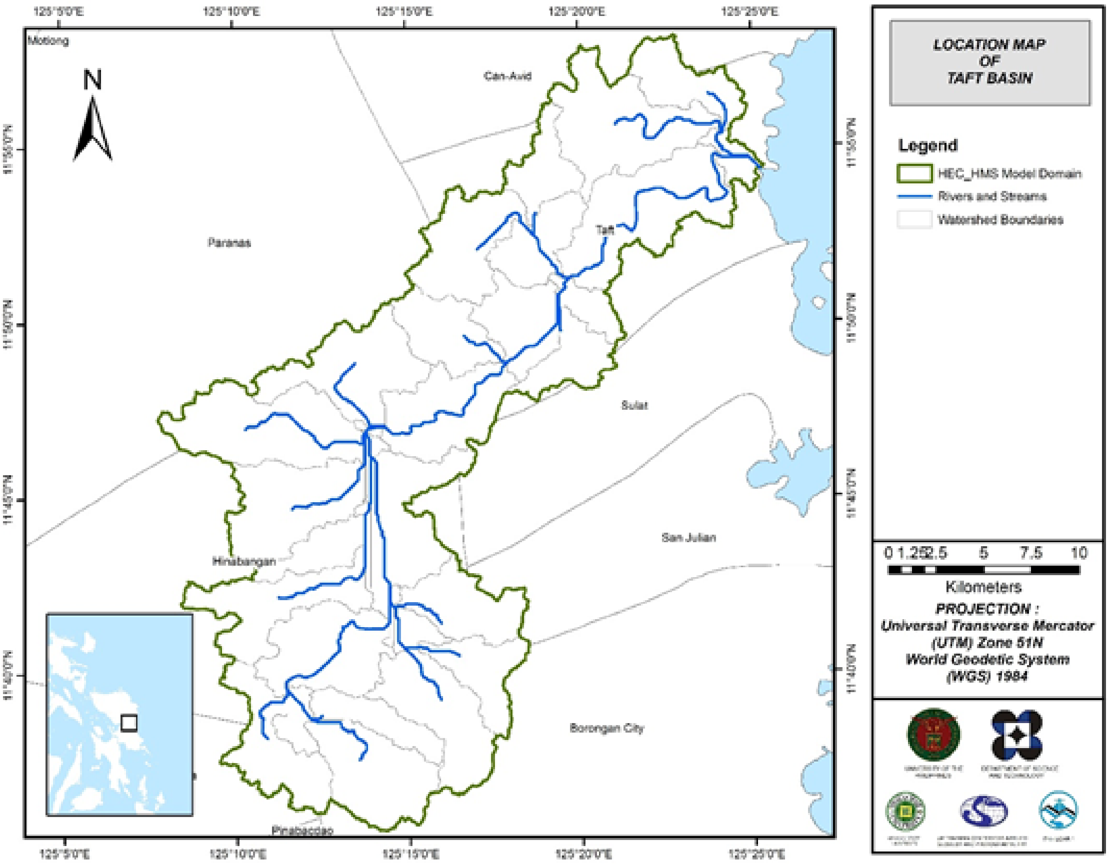


Figure 58. Stream Delineation Map of the Taft River Basin

Using the SAR-based DEM, the Taft basin was delineated and further subdivided into subbasins. The model consists of 13 sub basins, 6 reaches, and 6 junctions. The main outlet is Taft Bridge. This basin model is illustrated in Figure 59.

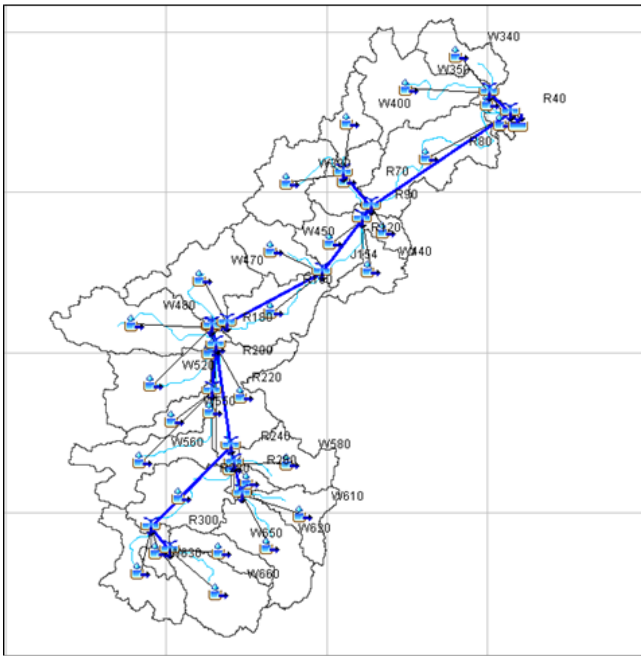


Figure 59. The Taft river basin model generated using HEC-HMS

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.

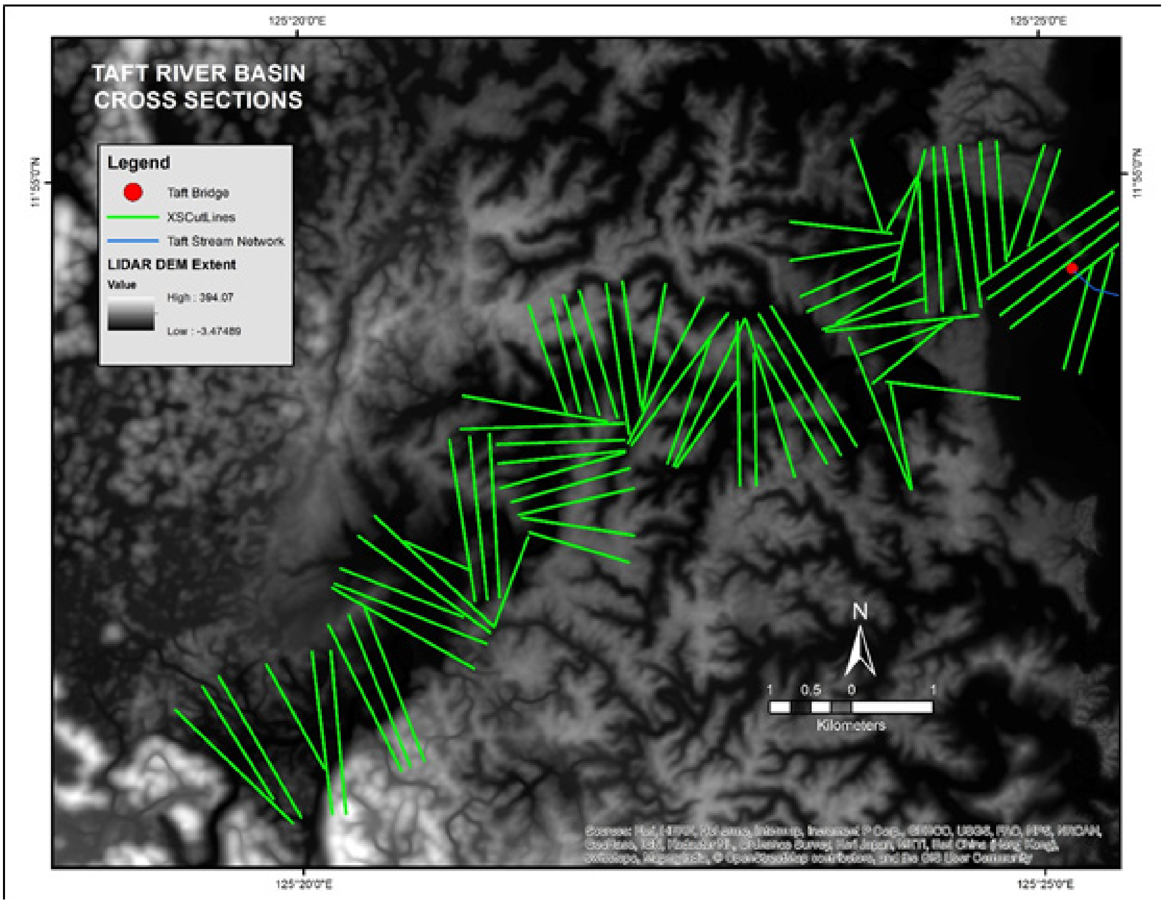


Figure 60. River cross-section of Taft River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modelling process allowed 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 was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served 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 were 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 were assigned as inflow and outflow elements respectively.

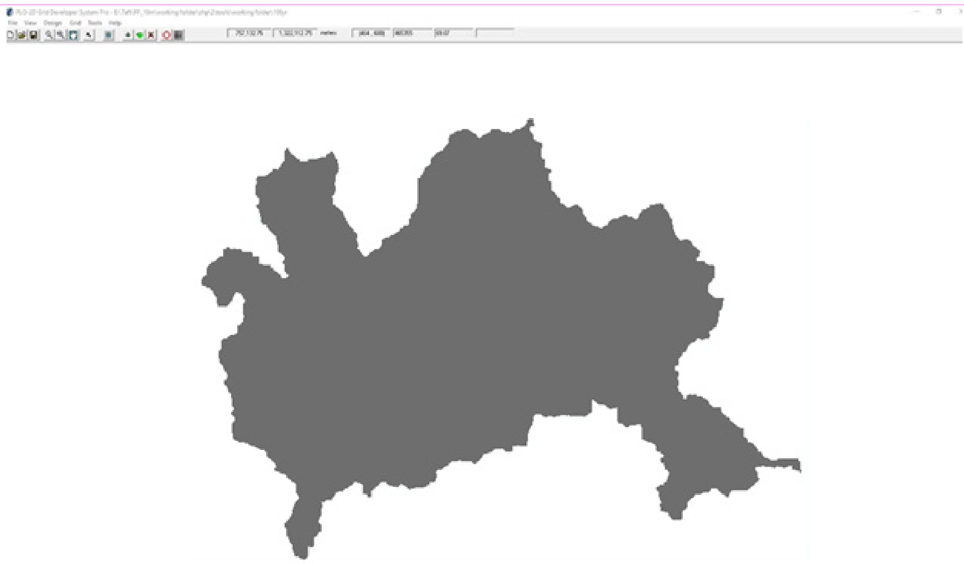


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 97.82812 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element.The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 53860900.00 m2.

There is a total of 44075463.84 m3 of water entering the model. Of this amount, 27135232.81 m3 is due to rainfall while 16940231.02 m3 is inflow from other areas outside the model. 5738050.00 m3 of this water is lost to infiltration and interception, while 12268493.43 m3 is stored by the flood plain. The rest, amounting up to 9165987.51 m3,is outflow.

5.6 Results of HMS Calibration

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

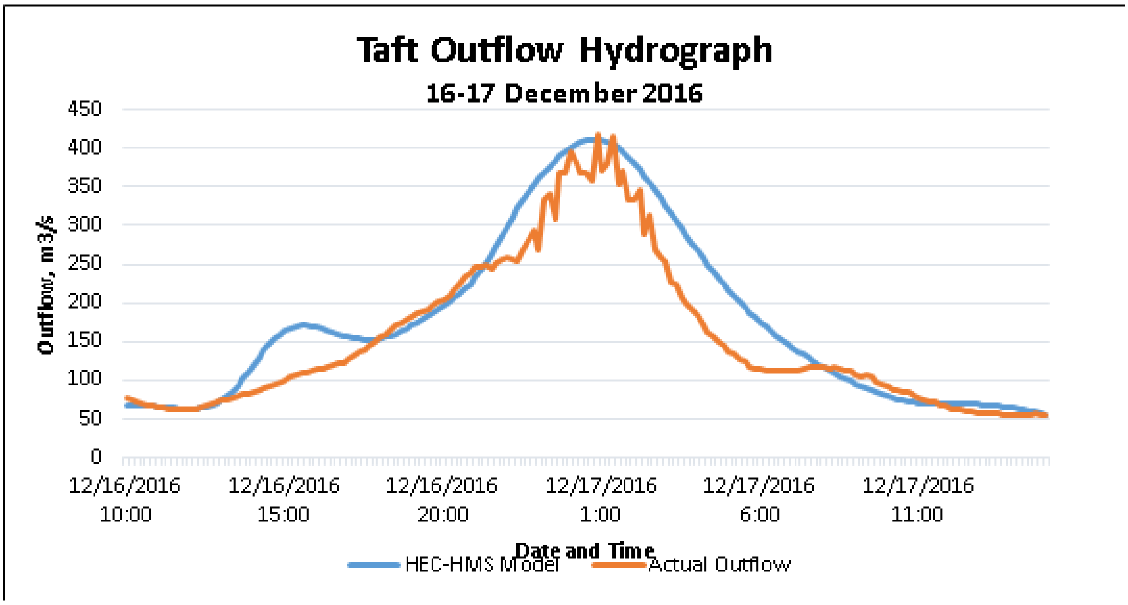


Figure 62. Outflow Hydrograph of Taft produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 22 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 22. Range of Calibrated Values for Taft

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	70 - 500
			Curve Number	60 - 98
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 10
			Storage Coefficient (hr)	0.5 - 6
	Baseflow	Recession	Recession Constant	0.65
			Ratio to Peak	0.55
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

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 70mm to 500mm means that there is a high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 60 to 98 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 0.5 hours to 10 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.65 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.55 indicates an average slope of the receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness Taft watershed, which is determined to be cultivated with mature field crops (Brunner, 2010

Table 23. Summary of the Efficiency Test of Taft HMS Model

RMSE	9.4
r2	0.8582
NSE	0.65
PBIAS	17.63
RSR	0.59

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 9.4 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8582.

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 0.65.

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 17.63.

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 0.59.

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 Taft outflow using the Borongan RIDF in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

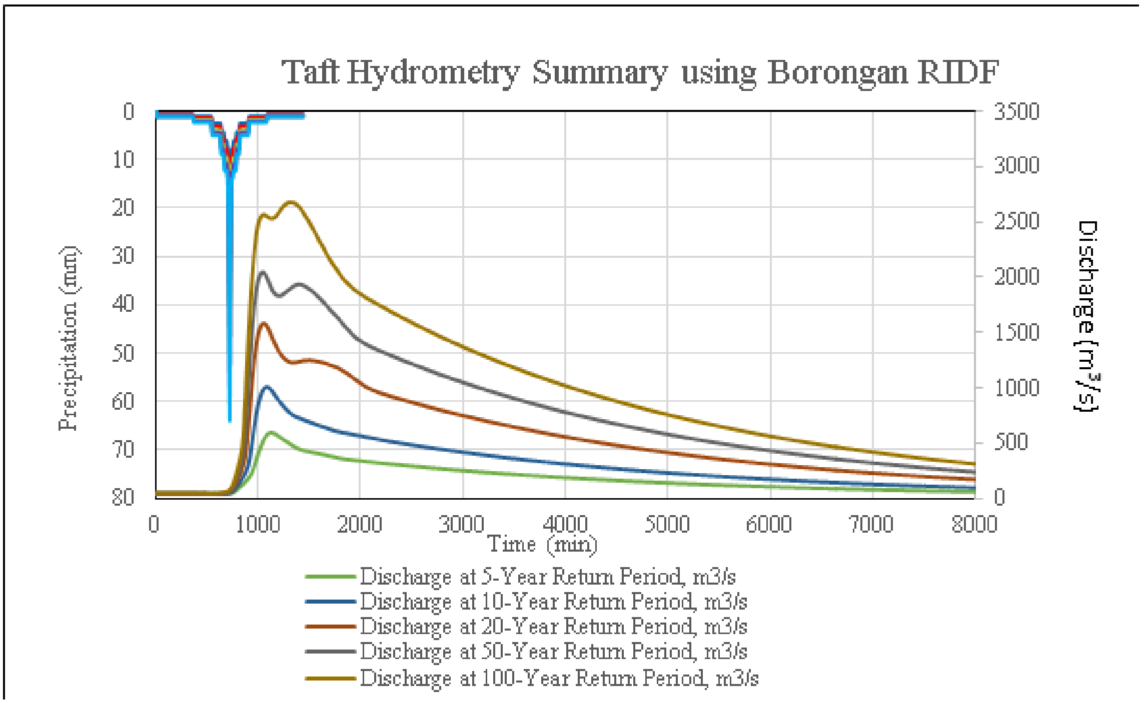


Figure 63. Outflow hydrograph at Taft Station generated using Borongan RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Taft discharge using the Borongan RIDF curves in five different return periods is shown in Table 24.

Table 24. Peak values of the Taft HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	278.6	33.2	591.02	6 hours, 20 minutes
10-Year	344.7	40.6	1,003.36	5 hours, 41 minutes
25-Year	428.2	50.1	1578.95	5 hours, 14 minutes
50-Year	490.2	57.1	2,038.44	5 hours, 1 minute
100-Year	551.7	64	2675.7	10 hours, 53 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model was 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, a sample output for the river flow during Typhoon Seniang was to be shown, since the model was calibrated from this event. The sample generated map of Taft River using the calibrated HEC-HMS model for Typhoon Seniang is shown in Figure 64.

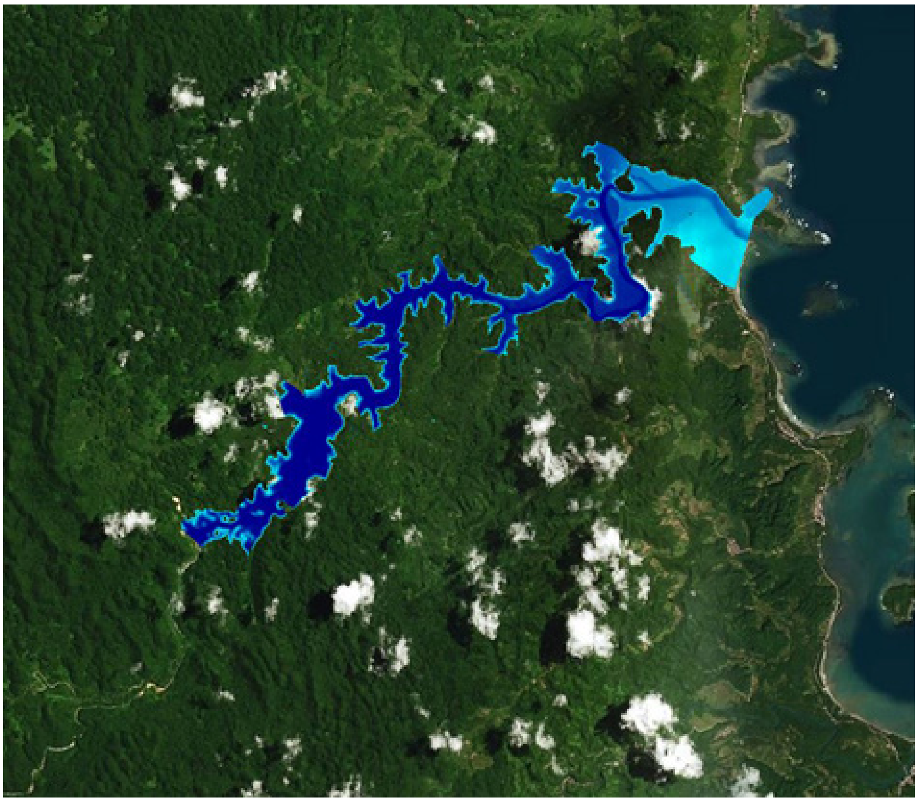


Figure 64. Sample output of Taft RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 shows the 100-, 25-, and 5-year rain return scenarios of the Taft floodplain.
The floodplain, with an area of 196.55 sq. km., covers three municipalities namely Can-Avid, Sulat, and Taft. Table 25 shows the percentage of area affected by flooding per municipality

Table 25. Municipalities affected in Taft Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Can-Avid	285.22	35.56	12.47%
Sulat	230.27	11.7993	5.12%
Taft	150.05	149.017	99.31%

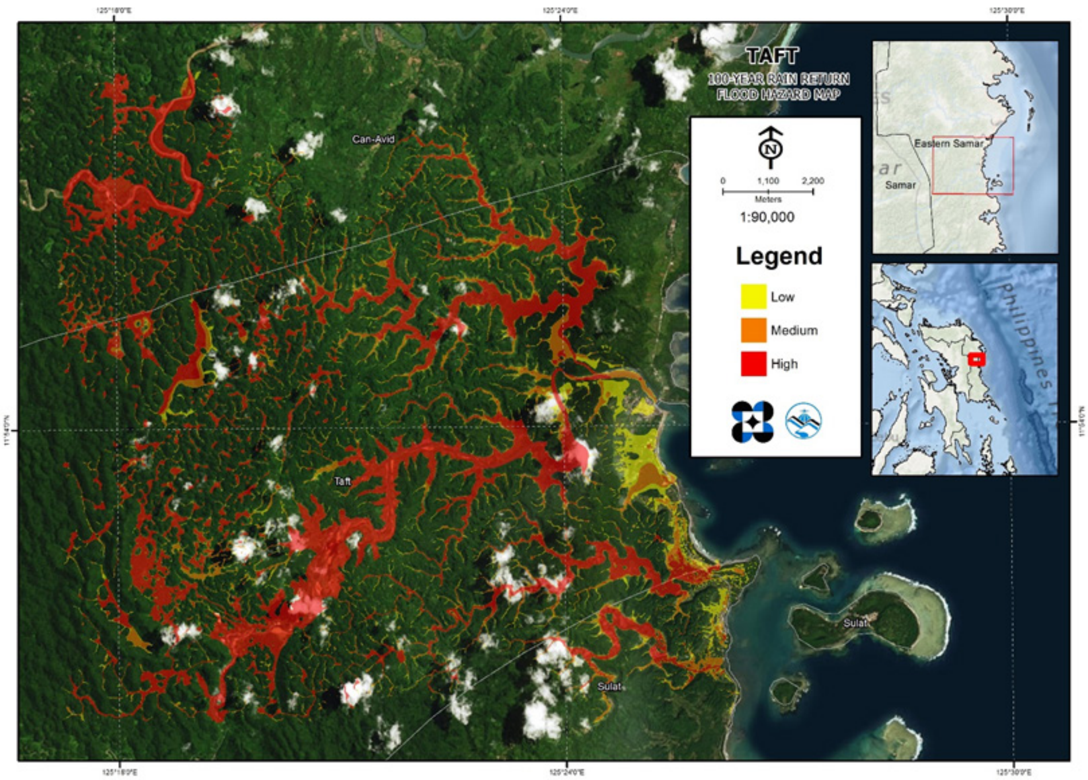


Figure 59. A 100-year Flood Hazard Map for Libertad Floodplain overlaid on Google Earth imagery.

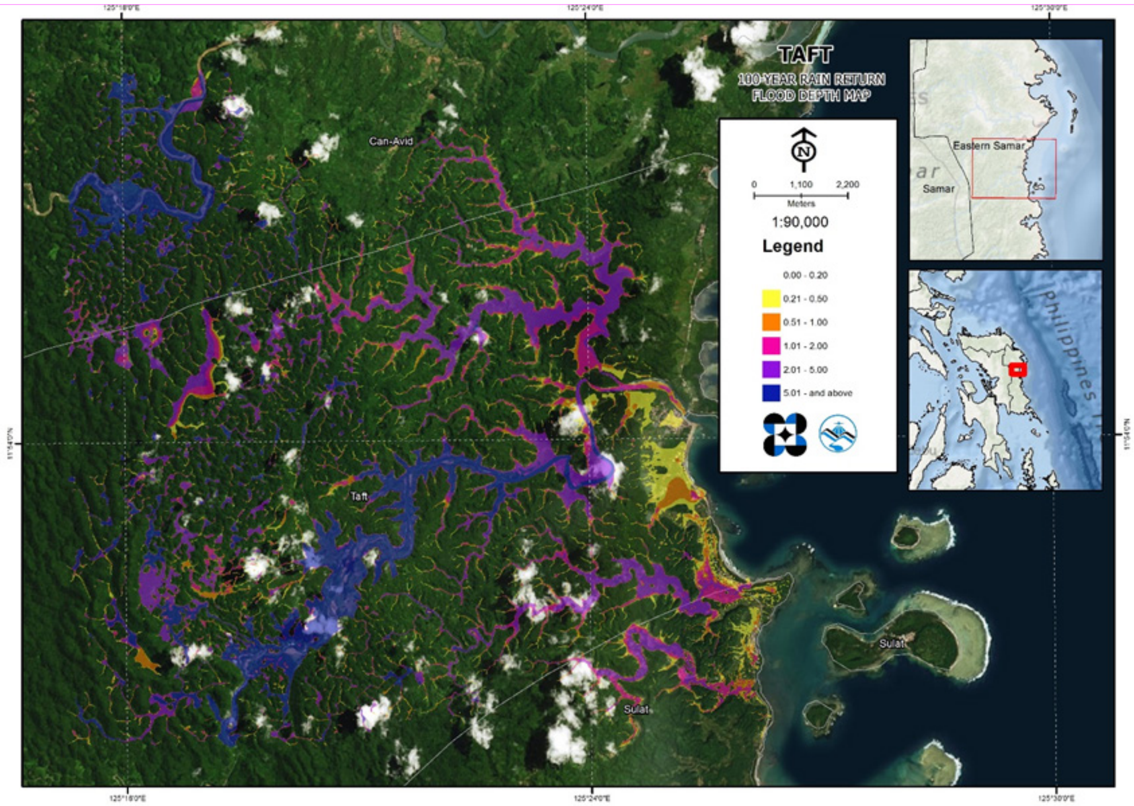


Figure 66. 100-year Flood Depth Map for Taft Floodplain

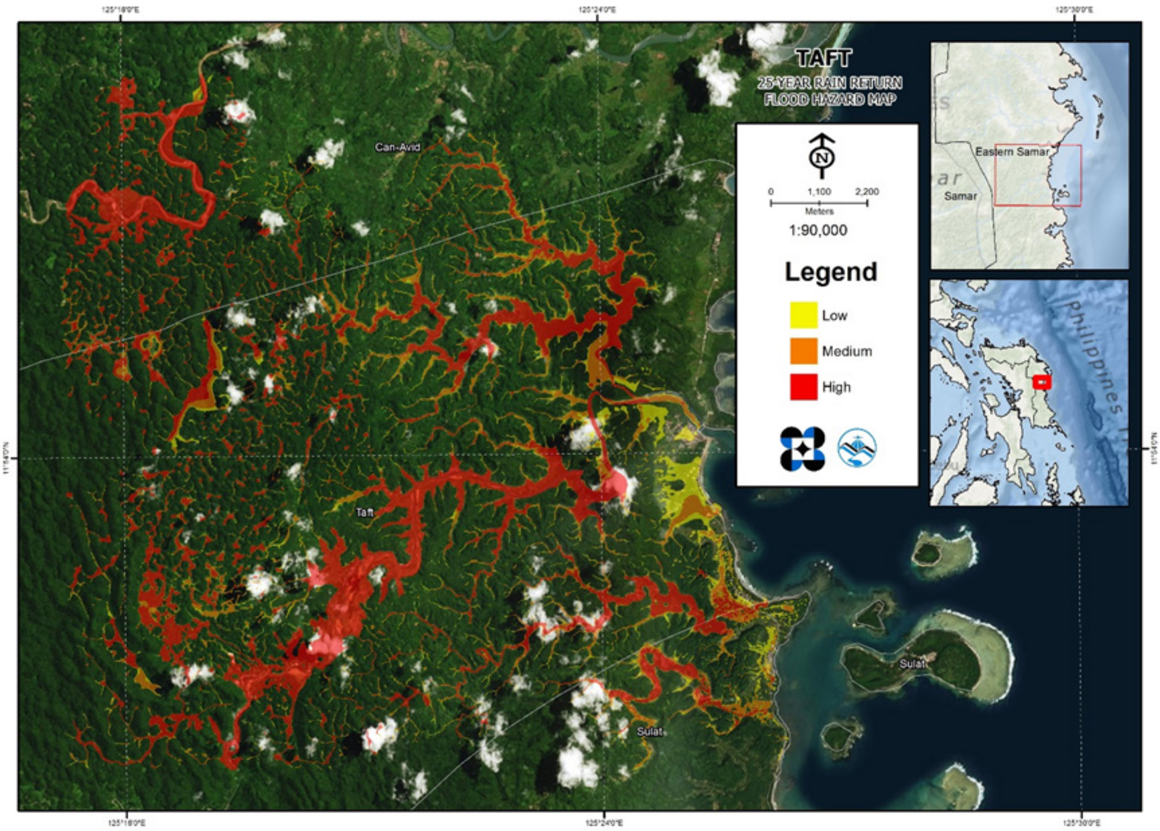


Figure 67. 25-year Flood Hazard Map for Taft Floodplain

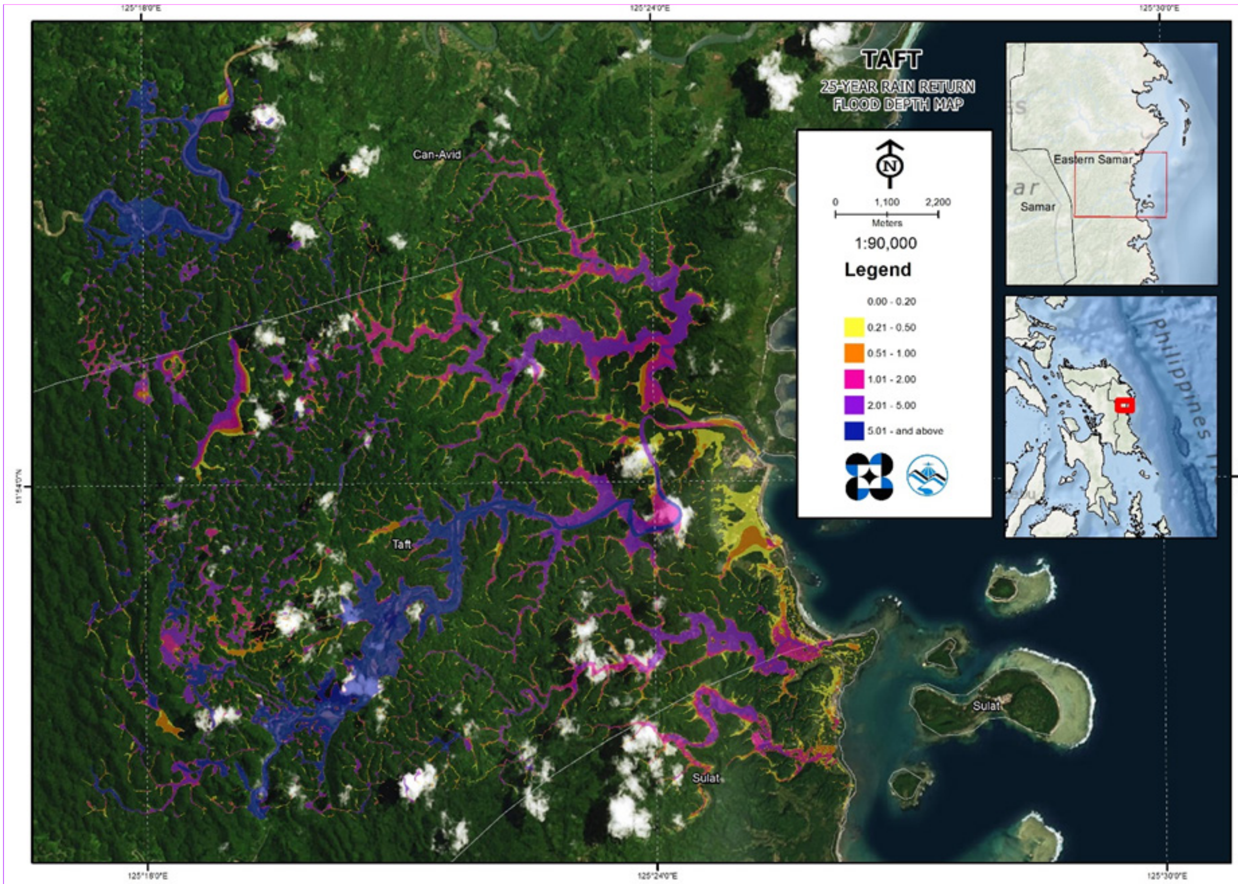


Figure 68. 25-year Flood Depth Map for Taft Floodplain

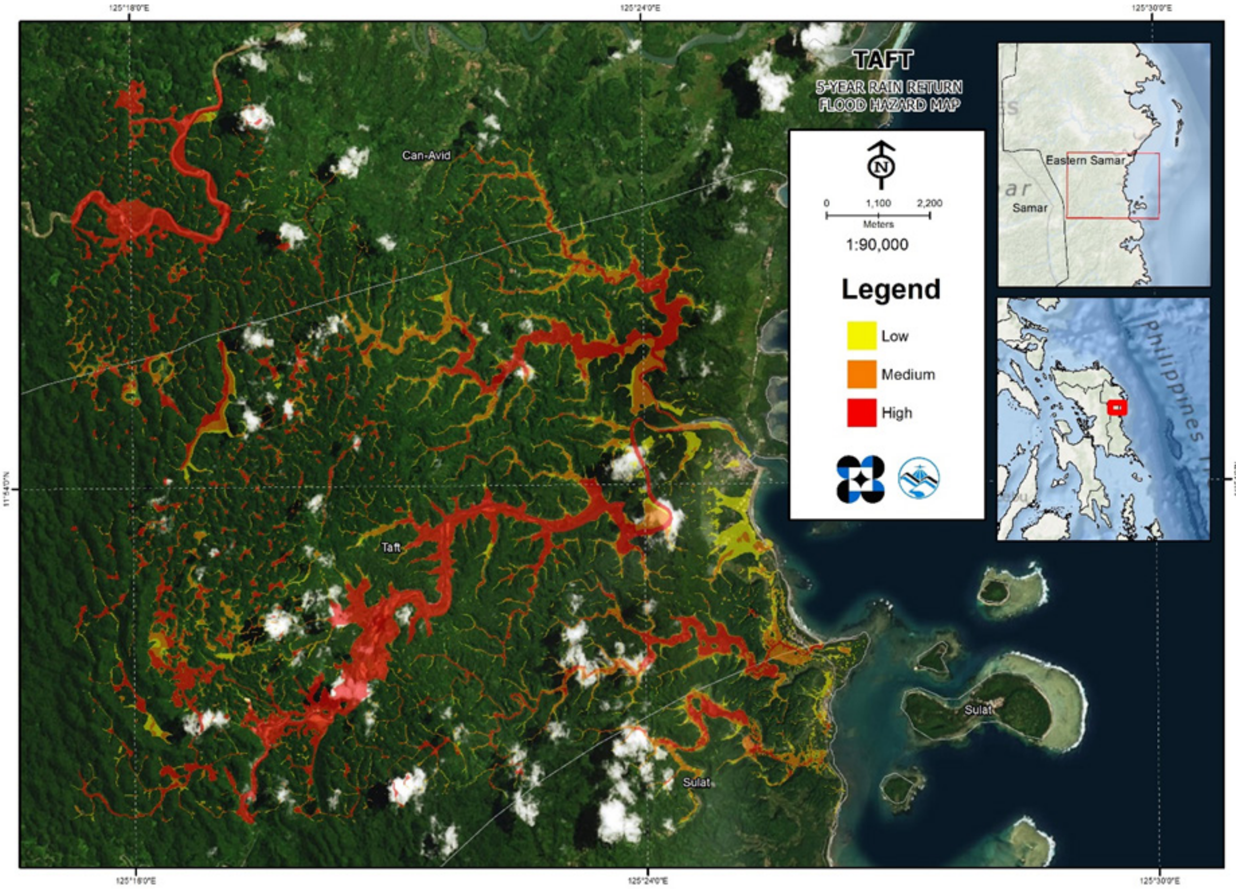


Figure 69. 5-year Flood Hazard Map for Taft Floodplain

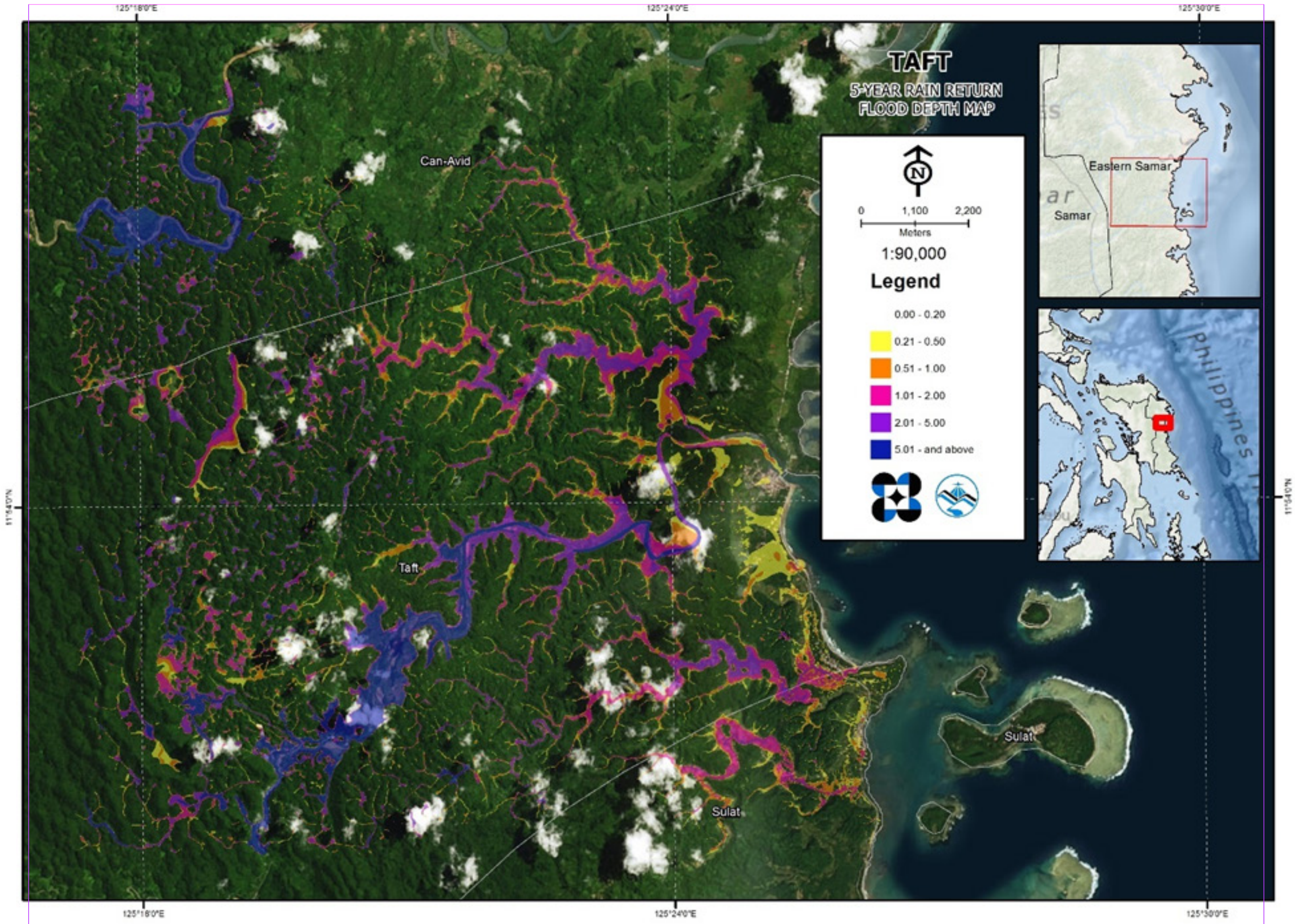


Figure 70. 5-year Flood Depth Map for Taft Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Taft river basin, grouped by municipality, are listed below. For the said basin, 3 municipalities consisting of 34 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 10.42% of the municipality of Can-avid with an area of 285.22 sq. km. will experience flood levels of less 0.20 meters; 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.22%, 0.29%, 0.38% and 0.91% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 26 are the affected areas in square kilometres by flood depth per barangay.

Table 26. Affected Areas in Can-avid, Eastern Samar during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Can-avid					
		Baruk	Camantang	Can-Ilay	Guibuangan	Jepaco	Salvacion
Affected Area (sq. km.)	0.03-0.20	5.750846761	9.138196666	6.589841248	1.880975419	4.023187915	2.351117986
	0.21-0.50	0.147884452	0.221562939	0.108758735	0.062506205	0.105571639	0.064972461
	0.51-1.00	0.088485141	0.149622715	0.094539212	0.10760313	0.080831751	0.102550191
	1.01-2.00	0.074576338	0.152769766	0.171569082	0.126934695	0.139364045	0.147897373
	2.01-5.00	0.10969214	0.267214059	0.497029102	0.036491385	0.055000229	0.110611834
	> 5.00	0.0479	1.024748041	1.429125447	0	0	0.105873621

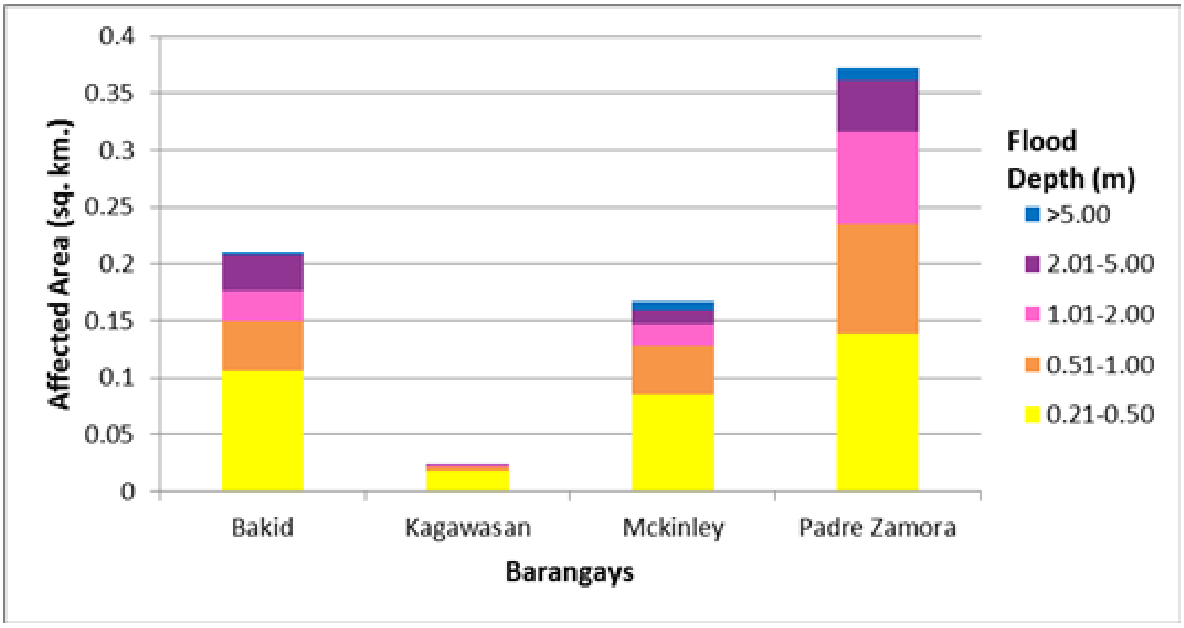


Figure 71. Affected Areas in Can-avid, Eastern Samar during 5-Year Rainfall Return Period

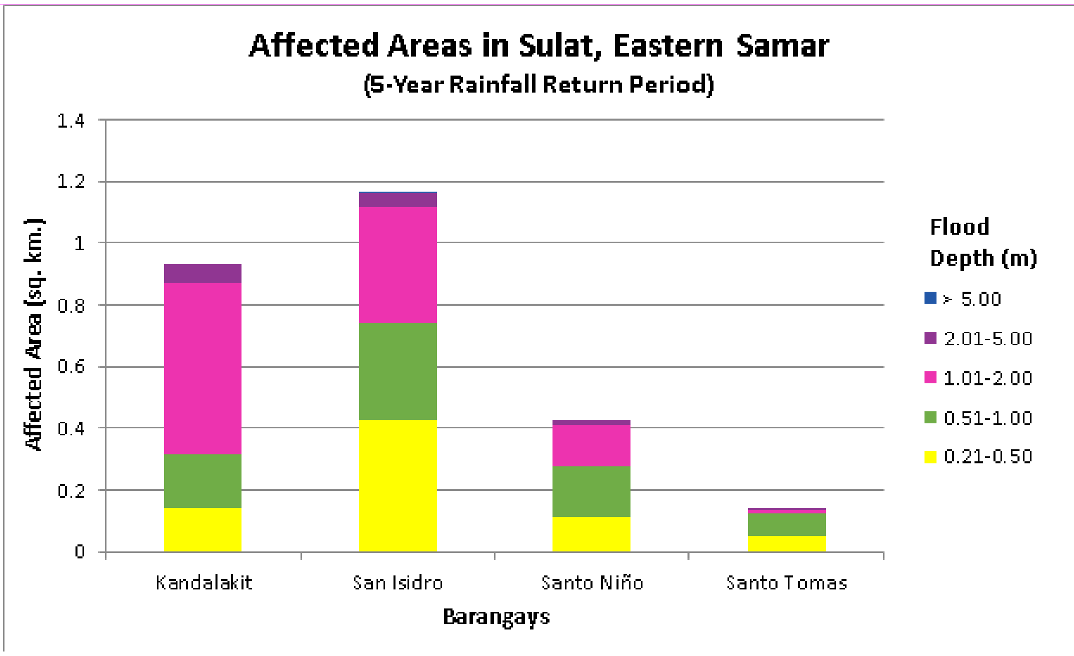


Figure 72. Affected Areas in Sulat, Eastern Samarduring 5-Year Rainfall Return Period

For the municipality of Sulat, with an area of 230.27 sq. km., 3.96% will experience flood levels of less 0.20 meters. 0.32% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.47%, 0.06% and 0.0000869% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively.

Table 27. Affected Areas in Sulat, Eastern Samar during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Sulat			
		Kandalakit	San Isidro	Santo Niño	Santo Tomas
Affected Area (sq. km.)	0.03-0.20	3.064123049	3.796841066	1.068991315	1.207754
	0.21-0.50	0.13915007	0.42912304	0.111361917	0.05065
	0.51-1.00	0.175644168	0.31201115	0.163413035	0.072704
	1.01-2.00	0.554305306	0.374440921	0.136727575	0.013744
	2.01-5.00	0.061720438	0.049114285	0.017166662	0.0001
	> 5.00	0	0.0002	0	0

For the municipality of Taft, with an area of 150.05 sq. km., 79.896% will experience flood levels of less 0.20 meters. 3.57% of the area will experience flood levels of 0.21 to 0.50 meters while 3.44%, 4.5%, 4.56%, and 3.36% 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.

Table 28. Affected Areas in Taft, Eastern Samarduring 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Sulat							
		Batiawan	Beto	Binaloan	Bongdo	Dacul	Danao	Del Remedios	Gayam
Affected Area (sq. km.)	0.03-0.20	0.405437492	3.80950805	21.31312987	2.300063921	9.964465947	2.606037774	5.963578799	6.187389934
	0.21-0.50	0.0191	0.160665118	0.707051533	0.210117463	0.413421111	0.096037506	0.232415223	0.193805534
	0.51-1.00	0.01749441	0.257975001	0.740567615	0.420272718	0.338565462	0.167581973	0.378312488	0.260062042
	1.01-2.00	0.017088821	0.295439951	1.180814948	0.54294623	0.474810829	0.342680826	0.464361544	0.397644597
	2.01-5.00	0.0012	0.092105803	1.14636066	0.301575975	0.407992894	0.442152668	0.125014491	0.824517351
	> 5.00	0	0	0.898155937	0.001	0.0002	0	0	0.24882891

Table 29. Affected Areas in Taft, Eastern Samar during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Sulat							
		Lomatud	Mabuhay	Malinao	Mantang	Nato	Pangabutan	Pob. Brgy 1	Pob. Brgy 2
Affected Area (sq. km.)	0.03-0.20	6.097900504	6.701916161	18.17188701	8.942434915	0.973360699	3.280288384	0.663014654	0.605933468
	0.21-0.50	0.289528019	0.131739552	0.554176691	0.385046822	0.079775455	0.161690836	0.060528475	0.084339239
	0.51-1.00	0.394347427	0.130611595	0.512124714	0.397491172	0.046962405	0.19144176	0.002260797	0.031804654
	1.01-2.00	0.323399124	0.15568049	0.689118025	0.632660792	0.008649894	0.332484192	0	0.000277951
	2.01-5.00	0.356042948	0.59725528	0.736467914	0.397278419	0.000978811	0.251678556	0	0
	> 5.00	0.099710905	1.078959459	1.883642108	0.05	0	0	0	0

Table 30. Affected Areas in Taft, Eastern Samar during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Sulat							
		Pob. Brgy 3	Pob. Brgy 4	Pob. Brgy 5	Pob. Brgy 6	Polangi	San Luis	San Pablo	San Rafael
Affected Area (sq. km.)	0.03-0.20	0.209668089	0.158307052	0.307797171	1.803738514	1.759732115	1.077203919	11.96445814	4.616604748
	0.21-0.50	0.046234744	0.184709564	0.015559243	0.280796623	0.576838152	0.054741993	0.324979553	0.087290768
	0.51-1.00	0	0	0.028950184	0.131849665	0.130394615	0.062976046	0.460559353	0.05636009
	1.01-2.00	0	0	0.003441074	0.110483244	0.015062777	0.1761035	0.536507197	0.053514768
	2.01-5.00	0	0	0.005405869	0.11989355	0.008354915	0.327506945	0.599768939	0.094907877
	> 5.00	0	0	0.016071544	0.000584039	0.014662234	0	0.670410271	0.081927484

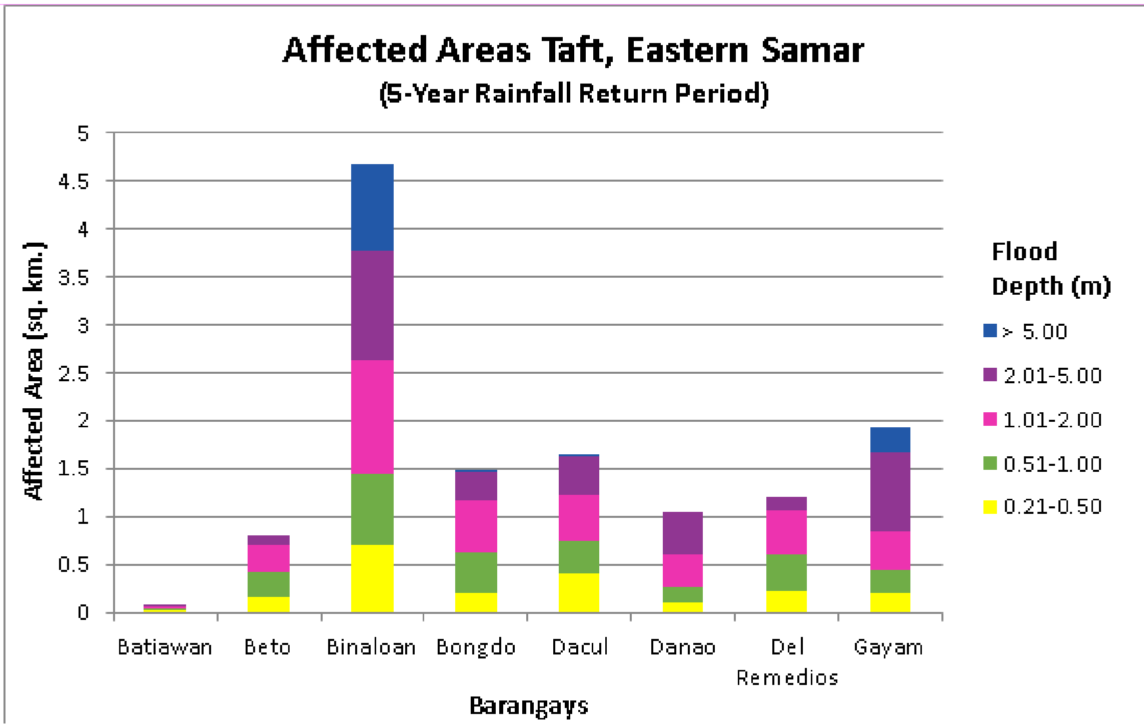


Figure 73. Affected Areas in Taft, Eastern Samar during 5-Year Rainfall Return Period

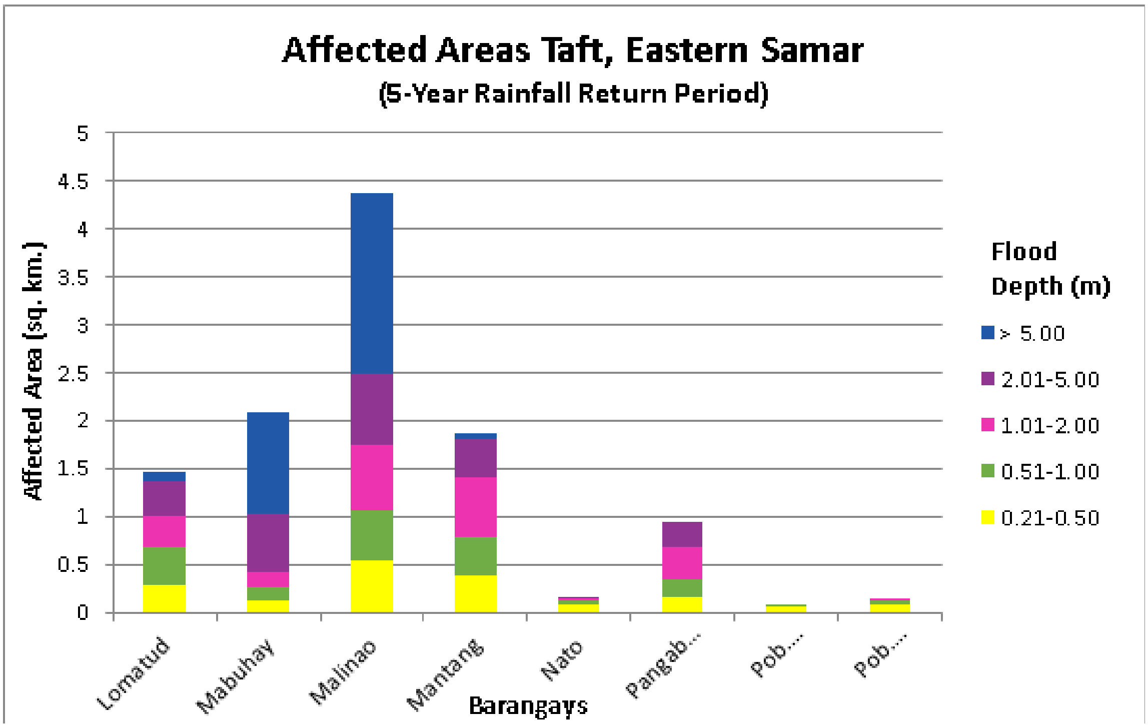


Figure 74. Affected Areas in Taft, Eastern Samar during 5-Year Rainfall Return Period

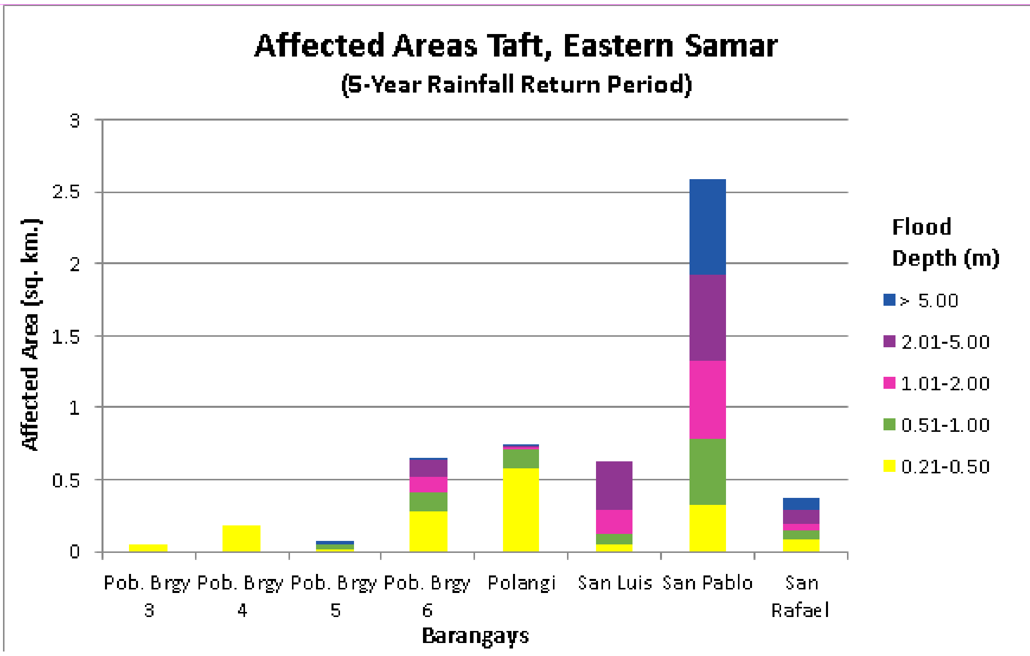


Figure 75. Affected Areas in Taft, Eastern Samar during 5-Year Rainfall Return Period

For the 25-year return period, 10.12% of the municipality of Can-avid with an area of 285.22 sq. km. will experience flood levels of less 0.20 meters. 0.26% of the area will experience flood levels of 0.21 to 0.50 meters while 0.2%, 0.3%, 0.42% and 1.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 31are the affected areas in square kilometres by flood depth per barangay.

Table 31. Affected Areas in Can-avid, Eastern Samar during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Can-avid					
		Baruk	Camantang	Can-llay	Guibuangan	Jepaco	Salvacion
Affected Area (sq. km.)	0.03-0.20	5.659214055	8.849784457	6.295946038	1.843103282	3.974149407	2.239172751
	0.21-0.50	0.176578655	0.238073339	0.107233878	0.054375833	0.119417623	0.05719272
	0.51-1.00	0.102750044	0.1561536	0.086450837	0.073955026	0.079409027	0.074477183
	1.01-2.00	0.07651526	0.163632179	0.135013832	0.173143654	0.127421734	0.181714062
	2.01-5.00	0.129726818	0.325344203	0.391578643	0.069933039	0.103557788	0.172938539
	> 5.00	0.0747	1.221426407	1.874639598	0	0	0.157528211

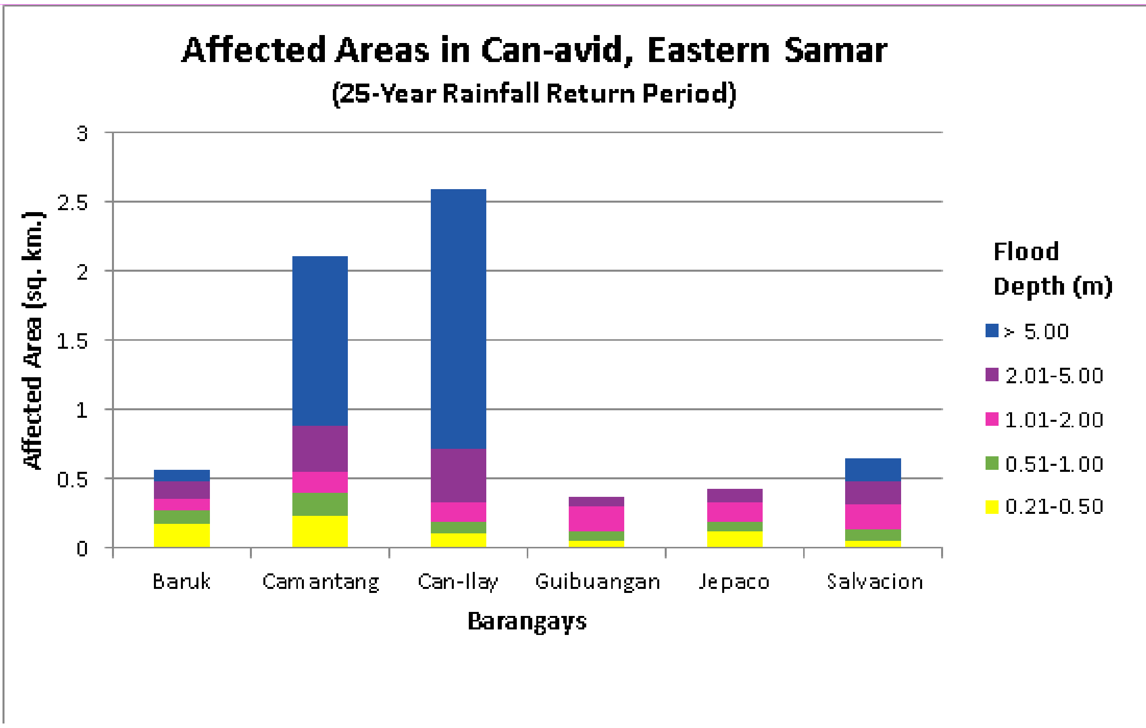


Figure 76. Affected Areas in Can-avid, Eastern Samar during 25-Year Rainfall Return Period

For the municipality of Sulat, with an area of 230.27 sq. km., 3.8% will experience flood levels of less 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.27%, 0.43%, 0.29% and 0.00013% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 32 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Sulat, Eastern Samar during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Sulat			
		Baruk	Camantang	Can-Ilay	Guibuangan
Affected Area (sq. km.)	0.03-0.20	2.989252252	3.568456733	1.009559378	1.187657
	0.21-0.50	0.125726635	0.498114189	0.104541844	0.042505
	0.51-1.00	0.129780751	0.295542672	0.126564406	0.074564
	1.01-2.00	0.340778713	0.394401058	0.205950525	0.040126
	2.01-5.00	0.40940468	0.204915811	0.05104435	0.0001
	> 5.00	0	0.0003	0	0

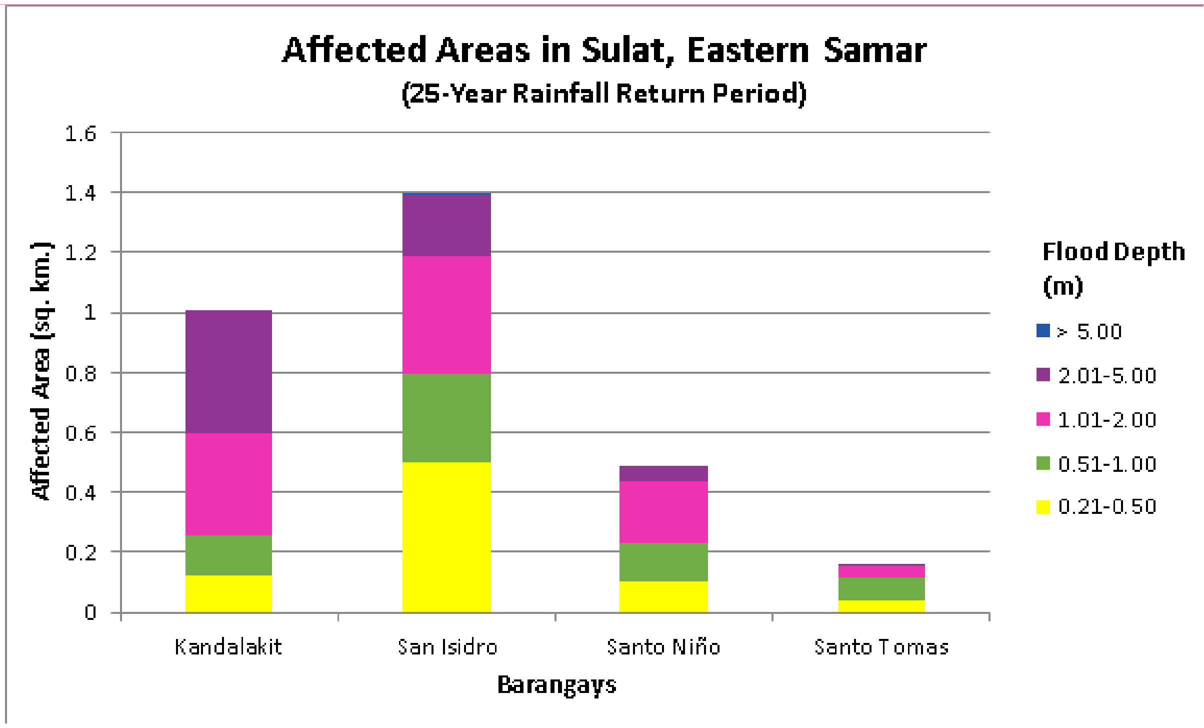


Figure 77. Affected Areas in Sulat, Eastern Samar during 25-Year Rainfall Return Period

For the municipality of Taft, with an area of 150.05 sq. km., 76.92% will experience flood levels of less 0.20 meters. 3.53% of the area will experience flood levels of 0.21 to 0.50 meters while 3.04%, 4.56%, 6.39%, and 4.88% 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.

Table 33. Table 9 Affected Areas in Taft, Eastern Samar during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Taft							
		Batiawan	Beto	Binaloan	Bongdo	Dacul	Danao	Del Remedios	Gayam
Affected Area (sq. km.)	0.03-0.20	0.399143082	3.710009139	20.45708096	2.191217503	9.723308914	2.524547573	5.834588524	6.023927951
	0.21-0.50	0.019571507	0.137774648	0.534496716	0.160290501	0.457907711	0.077527775	0.194215431	0.174829837
	0.51-1.00	0.017122903	0.1975381	0.707918895	0.232437487	0.333486062	0.108987405	0.259593966	0.173941309
	1.01-2.00	0.019190229	0.377880711	1.061892324	0.626188958	0.446551471	0.233109656	0.521665221	0.333793496
	2.01-5.00	0.005293002	0.192491324	1.875280568	0.563741859	0.629668404	0.710318336	0.353583242	0.855330123
	> 5.00	0	0	1.349411104	0.0021	0.008933681	0	3.61632E-05	0.550525652

Table 34. Affected Areas in Taft, Eastern Samar during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Taft							
		Lomatud	Mabuhay	Malinao	Mantang	Nato	Pangabutan	Pob. Brgy 1	Pob. Brgy 2
Affected Area (sq. km.)	0.03-0.20	5.903461464	6.455736633	17.44046539	8.622202625	0.940128308	3.179790113	0.596238071	0.463938271
	0.21-0.50	0.241471208	0.135286019	0.565871827	0.40542532	0.089273926	0.146283189	0.118700381	0.184441435
	0.51-1.00	0.278923391	0.119951271	0.535985731	0.368086766	0.054486727	0.149077392	0.010763308	0.063005749
	1.01-2.00	0.472983901	0.134319051	0.670339711	0.62154487	0.024209597	0.274933227	0.000102166	0.010969856
	2.01-5.00	0.42799302	0.336036117	1.017196838	0.709295201	0.001628705	0.467499807	0	0
	> 5.00	0.236095943	1.615333445	2.317856967	0.078357337	0	0	0	0

Table 35. Affected Areas in Taft, Eastern Samar during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Taft							
		Pob. Brgy 3	Pob. Brgy 4	Pob. Brgy 5	Pob. Brgy 6	Polangi	San Luis	San Pablo	San Rafael
Affected Area (sq. km.)	0.03-0.20	0.178848777	0.080099203	0.303579599	1.678763591	1.578114973	1.037138036	11.5548955	4.547506514
	0.21-0.50	0.076554056	0.262917414	0.011301508	0.313680304	0.53551573	0.048900051	0.311063857	0.097365465
	0.51-1.00	0.0005	0	0.0032808	0.163145489	0.310349264	0.051664502	0.355472521	0.061315671
	1.01-2.00	0	0	0.033777382	0.129783144	0.055204079	0.112735138	0.625168416	0.061160513
	2.01-5.00	0	0	0.006392365	0.136233911	0.007149368	0.448094678	0.736548366	0.102780895
	> 5.00	0	0	0.018893433	0.026239196	0.018711393	0	0.973534793	0.120476675

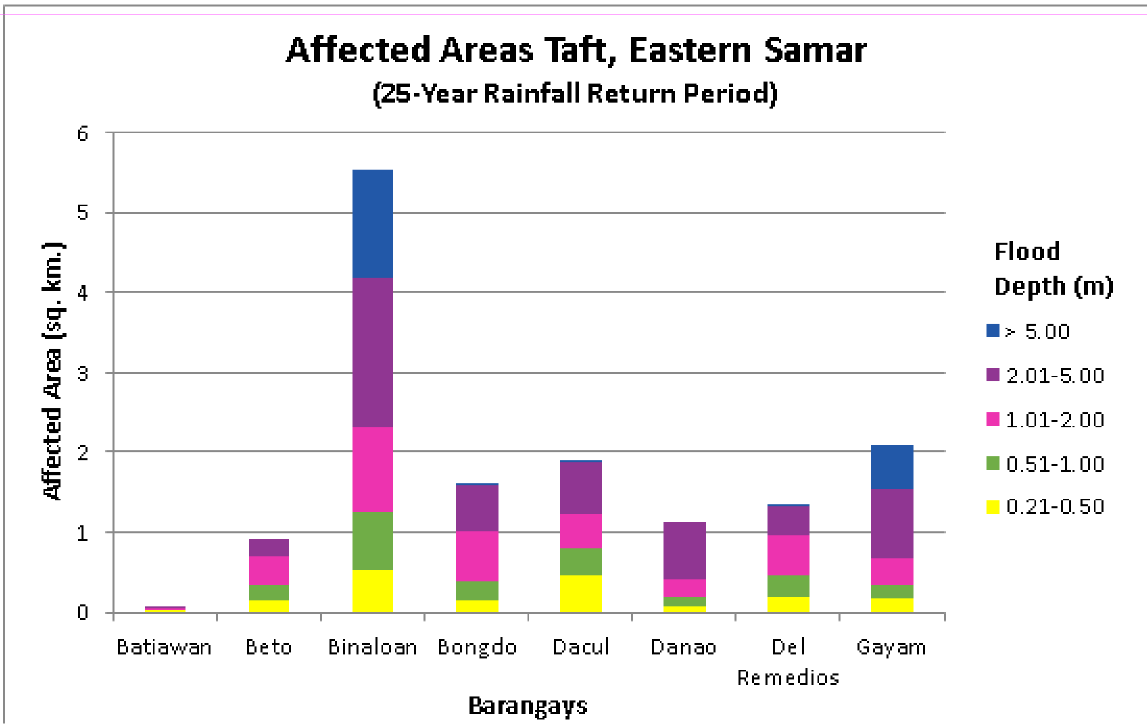


Figure 78. Affected Areas in Taft, Eastern Samar during 25-Year Rainfall Return Period

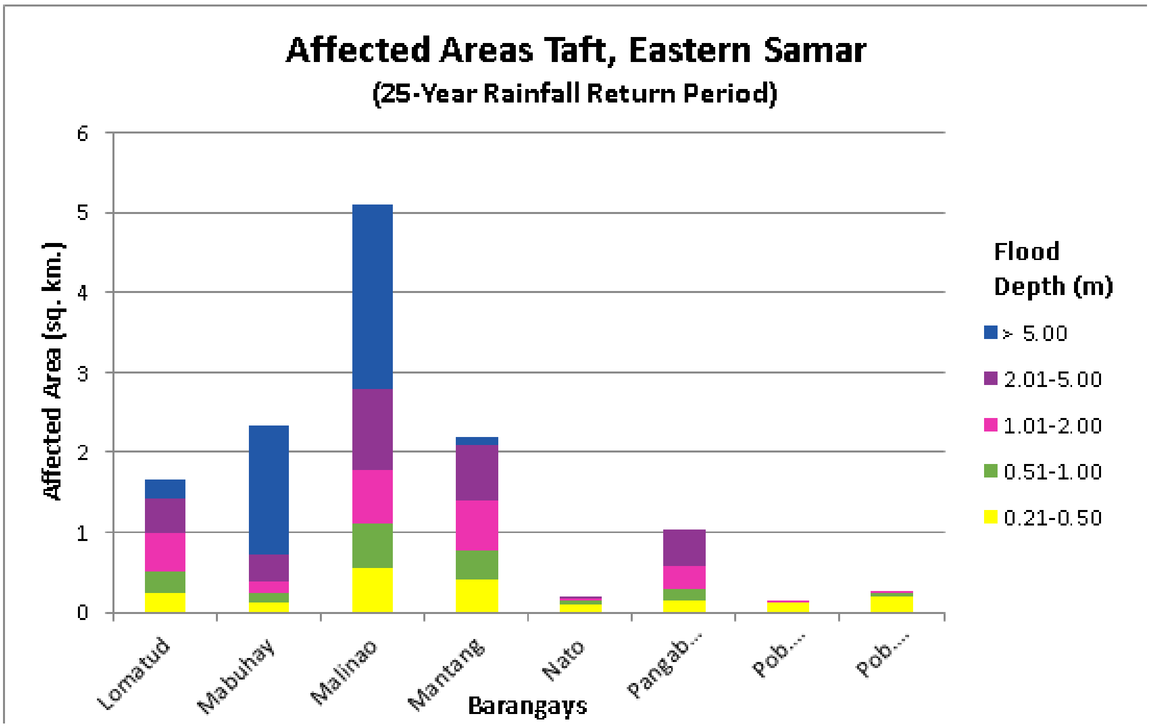


Figure 79. Affected Areas in Taft, Eastern Samar during 25-Year Rainfall Return Period

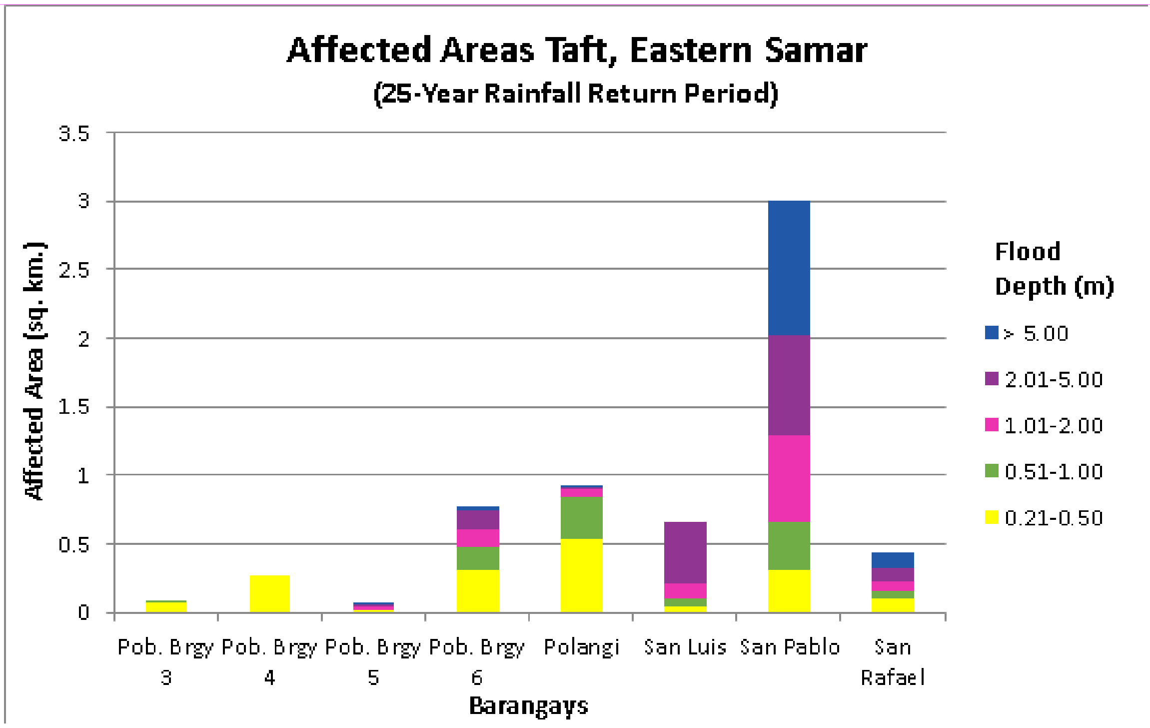


Figure 80. Affected Areas in Taft, Eastern Samar during 25-Year Rainfall Return Period

For the 100-year return period, 9.9% of the municipality of Can-avid with an area of 285.22 sq. km. will experience flood levels of less 0.20 meters. 0.27% of the area will experience flood levels of 0.21 to 0.50 meters while 0.2%, 0.29%, 0.48% and 1.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Can-avid, Eastern Samar during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Can-avid					
		Baruk	Camantang	Can-Ilay	Guibuangan	Jepaco	Salvacion
Affected Area (sq. km.)	0.03-0.20	5.599159495	8.64284424	6.087015878	1.819386362	3.93697106	2.158950761
	0.21-0.50	0.193337346	0.236597905	0.107479136	0.055346153	0.128474208	0.049612714
	0.51-1.00	0.112216895	0.152509302	0.085917484	0.065218036	0.084067631	0.067384069
	1.01-2.00	0.080000146	0.213045942	0.120728383	0.162712176	0.119108551	0.140357462
	2.01-5.00	0.125970949	0.359114645	0.356789089	0.111848107	0.135334129	0.265995043
	> 5.00	0.1089	1.350402152	2.132932855	0	0	0.200723416

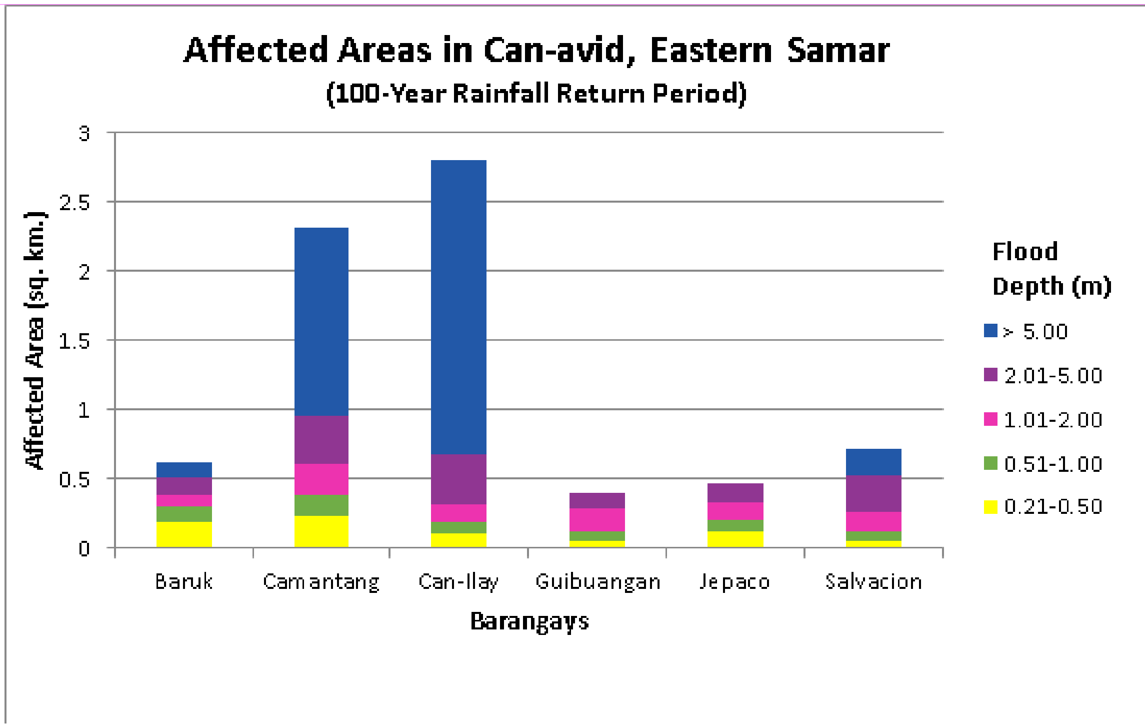


Figure 81. Affected Areas in Can-avid, Eastern Samar during 100-Year Rainfall Return Period

For the municipality of Sulat, with an area of 230.27 sq. km., 3.69% will experience flood levels of less 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters while 0.26%, 0.42%, 0.39% and 0.00013% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Sulat, Eastern Samar during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Affected Barangays in Sulat			
		Kandalakit	San Isidro	Santo Niño	Santo Tomas
Affected Area (sq. km.)	0.03-0.20	2.939111126	3.413194856	0.97728331	1.172184
	0.21-0.50	0.121565386	0.567619516	0.101787428	0.04077
	0.51-1.00	0.109503145	0.302279035	0.119935774	0.064332
	1.01-2.00	0.284539501	0.391271604	0.222090602	0.067466
	2.01-5.00	0.540223872	0.28706545	0.076563391	0.0002
	> 5.00	0	0.0003	0	0

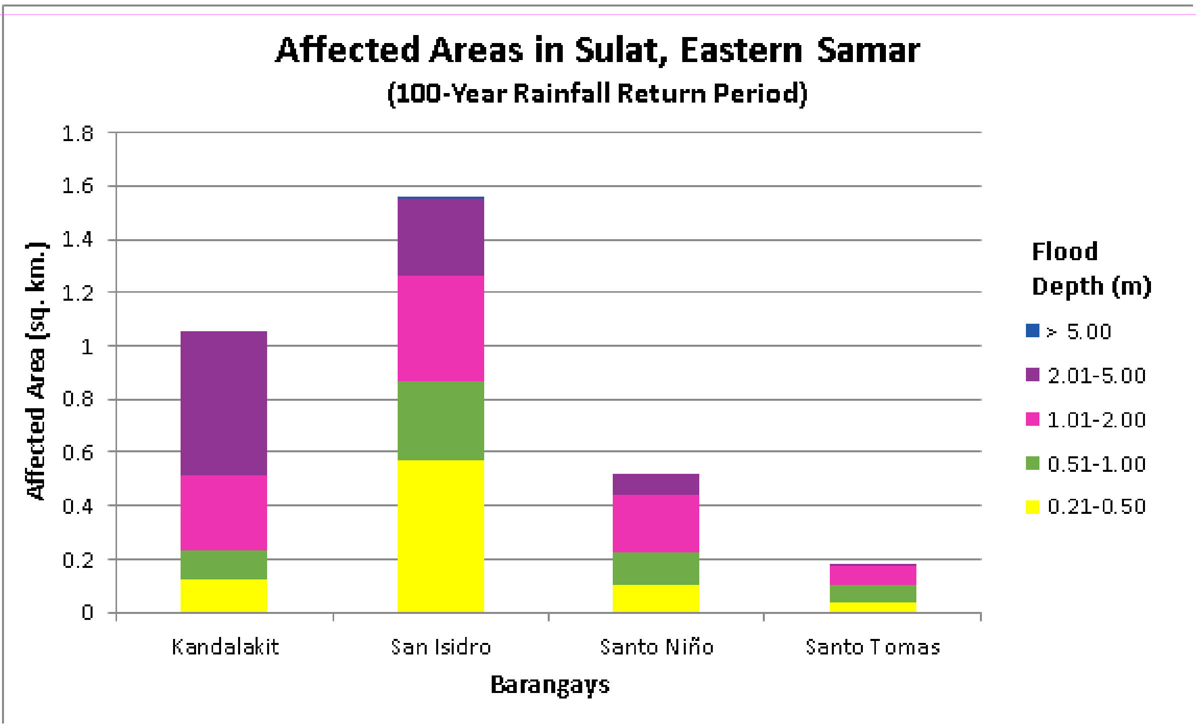


Figure 82. Affected Areas in Sulat, Eastern Samar during 100-Year Rainfall Return Period

For the municipality of Taft, with an area of 150.05 sq. km., 74.95% will experience flood levels of less 0.20 meters. 3.63% of the area will experience flood levels of 0.21 to 0.50 meters while 2.9%, 4.05%, 7.87%, and 5.92% 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.

Table 38. Affected Areas in Taft, Eastern Samar during 100-Year Rainfall Return Period

TAFT BASIN		Affected Barangays in Taft							
		Batiawan	Beto	Binaloan	Bongdo	Dacul	Danao	Del Remedios	Gayam
Affected Area (sq. km.)	0.03-0.20	0.395178917	3.646282885	19.91259377	2.135247673	9.554534007	2.473126474	5.737414112	5.88605481
	0.21-0.50	0.018064165	0.137464153	0.503945591	0.143031277	0.495192295	0.069446563	0.182512141	0.168407146
	0.51-1.00	0.01649441	0.160033848	0.655545545	0.17860293	0.34691105	0.087484023	0.216588575	0.147727056
	1.01-2.00	0.02069441	0.371342732	0.864527035	0.590472053	0.386748201	0.193869062	0.379807309	0.221268978
	2.01-5.00	0.009888821	0.300570306	2.378835917	0.726222373	0.793122899	0.814364624	0.642051919	0.811556461
	> 5.00	0	0	1.670832701	0.0024	0.023647791	0.0162	0.00530849	0.877333917

Table 39. Affected Areas in Taft, Eastern Samar during 100-Year Rainfall Return Period

TAFT BASIN		Affected Barangays in Taft							
		Lomatud	Mabuhay	Malinao	Mantang	Nato	Pangabutan	Pob. Brgy 1	Pob. Brgy 2
Affected Area (sq. km.)	0.03-0.20	5.769057621	6.270902736	16.93101875	8.402429261	0.920881158	3.123415999	0.535523723	0.388959574
	0.21-0.50	0.218385436	0.147587355	0.572069769	0.441081412	0.094645161	0.136343831	0.172863093	0.245653361
	0.51-1.00	0.238196416	0.108793119	0.536541901	0.367983794	0.058530399	0.143225767	0.016447146	0.060455075
	1.01-2.00	0.380830307	0.135125294	0.694992025	0.570935953	0.033241841	0.223016508	0.000969964	0.027287301
	2.01-5.00	0.654242206	0.298998561	1.170694945	0.919264262	0.002428705	0.591581623	0	0
	> 5.00	0.300216941	1.835255471	2.64249907	0.103217438	0	0	0	0

Table 40. Affected Areas in Taft, Eastern Samar during 100-Year Rainfall Return Period

TAFT BASIN		Affected Barangays in Taft							
		Pob. Brgy 3	Pob. Brgy 4	Pob. Brgy 5	Pob. Brgy 6	Polangi	San Luis	San Pablo	San Rafael
Affected Area (sq. km.)	0.03-0.20	0.155893691	0.037650612	0.299998065	1.582958491	1.478543696	1.015601633	11.30815811	4.502501446
	0.21-0.50	0.097809142	0.294366004	0.013806996	0.308737574	0.546611629	0.042458295	0.28983425	0.106721447
	0.51-1.00	0.0022	0.011	0.003734245	0.186556048	0.379567346	0.049716192	0.315998122	0.062881248
	1.01-2.00	0	0	0.0016226	0.175996277	0.047955886	0.091795129	0.603339144	0.064541785
	2.01-5.00	0	0	0.037533958	0.139307422	0.03154498	0.498961155	0.881681811	0.104142377
	> 5.00	0	0	0.020529222	0.054789823	0.020921271	0	1.157672011	0.149817431

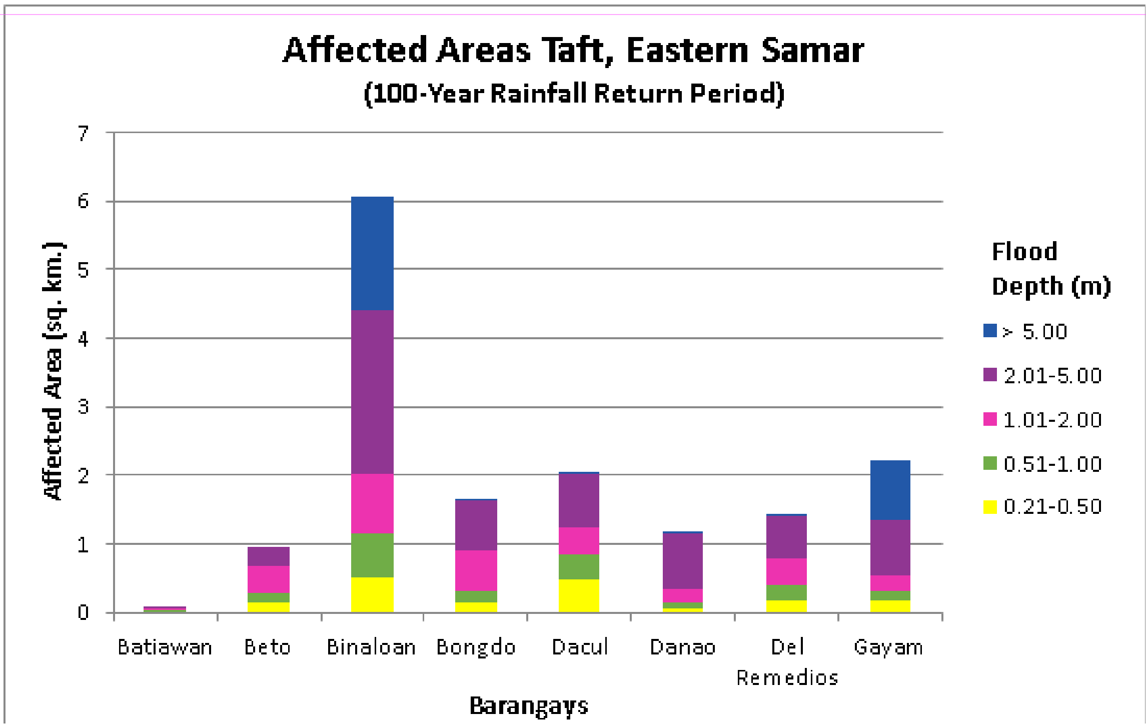


Figure 83. Affected Areas in Taft, Eastern Samar during 100-Year Rainfall Return Period

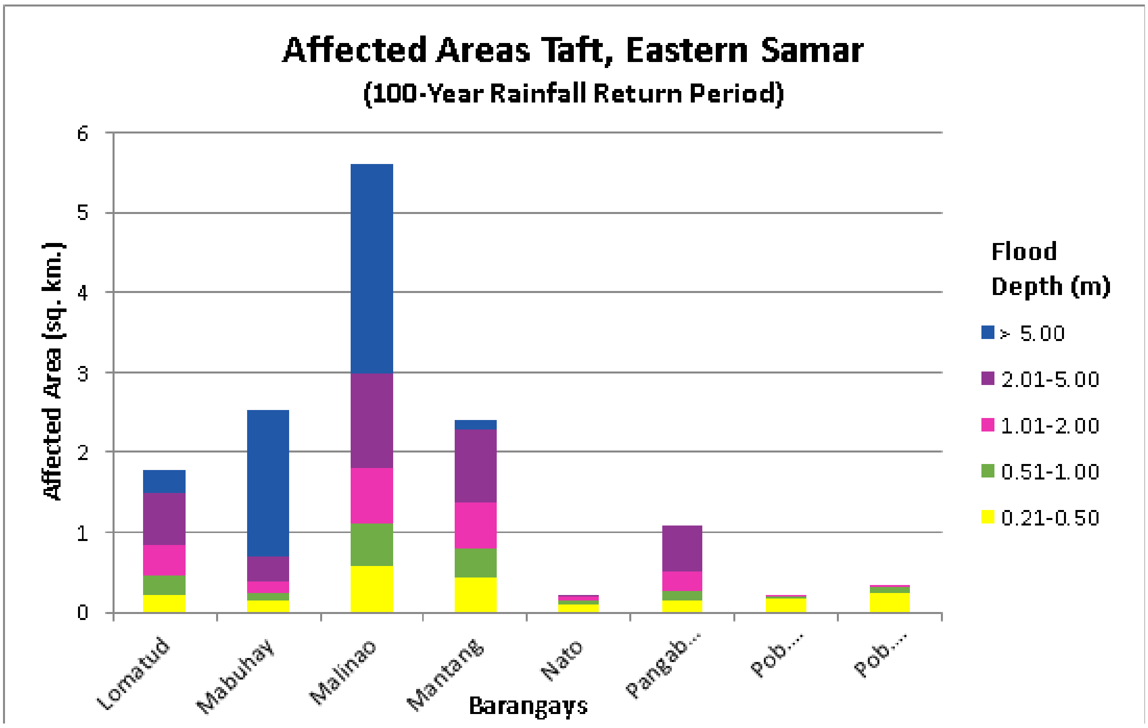


Figure 84. Affected Areas in Taft, Eastern Samar during 100-Year Rainfall Return Period

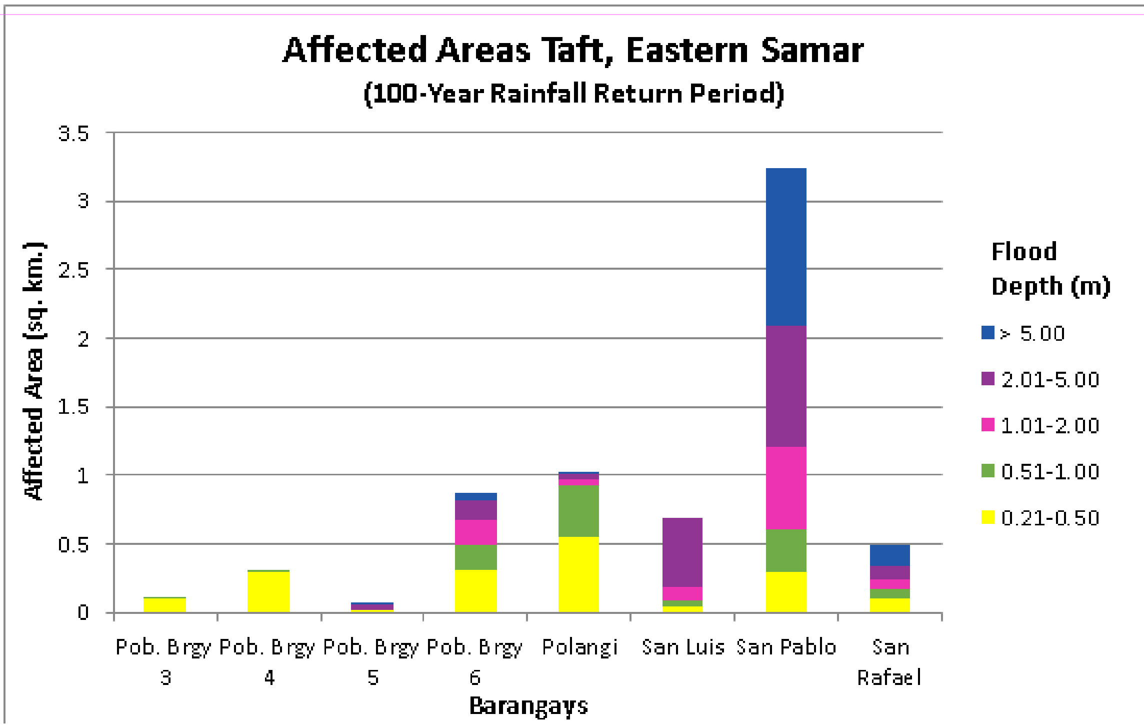


Figure 85. Affected Areas in Taft, Eastern Samar during 100-Year Rainfall Return Period

Among the barangays in the municipality of Can-avid, Camantang is projected to have the highest percentage of area that will experience flood levels at 3.84%. Meanwhile, Can-Ilay posted the second highest percentage of area that may be affected by flood depths at 3.12%.
Among the barangays in the municipality of Sulat, San Isidro is projected to have the highest percentage of area that will experience flood levels at 2.15%. Meanwhile, Kandalakit posted the second highest percentage of area that may be affected by flood depths at 1.73%.
Among the barangays in the city of Taft, Binaloan is projected to have the highest percentage of area that will experience flood levels of at 17.32%. Meanwhile, Malinao posted the second highest percentage of area that may be affected by flood depths of at 15.03%.
Moreover, the generated flood hazard maps for the Taft Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

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

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	6.92	6.99	7.21
Medium	11.27	10.24	9.56
High	19.82	26.53	30.84

For Taft, only one educational institution, which is the Brgy. Dacul Day Care Center, was identified and is not assessed to be exposed to any level of flooding.

5.11 Flood Validation

IIn 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 consists of 170 points randomly selected all over the Taft Floodplain. It has an RMSE value of 0.98.

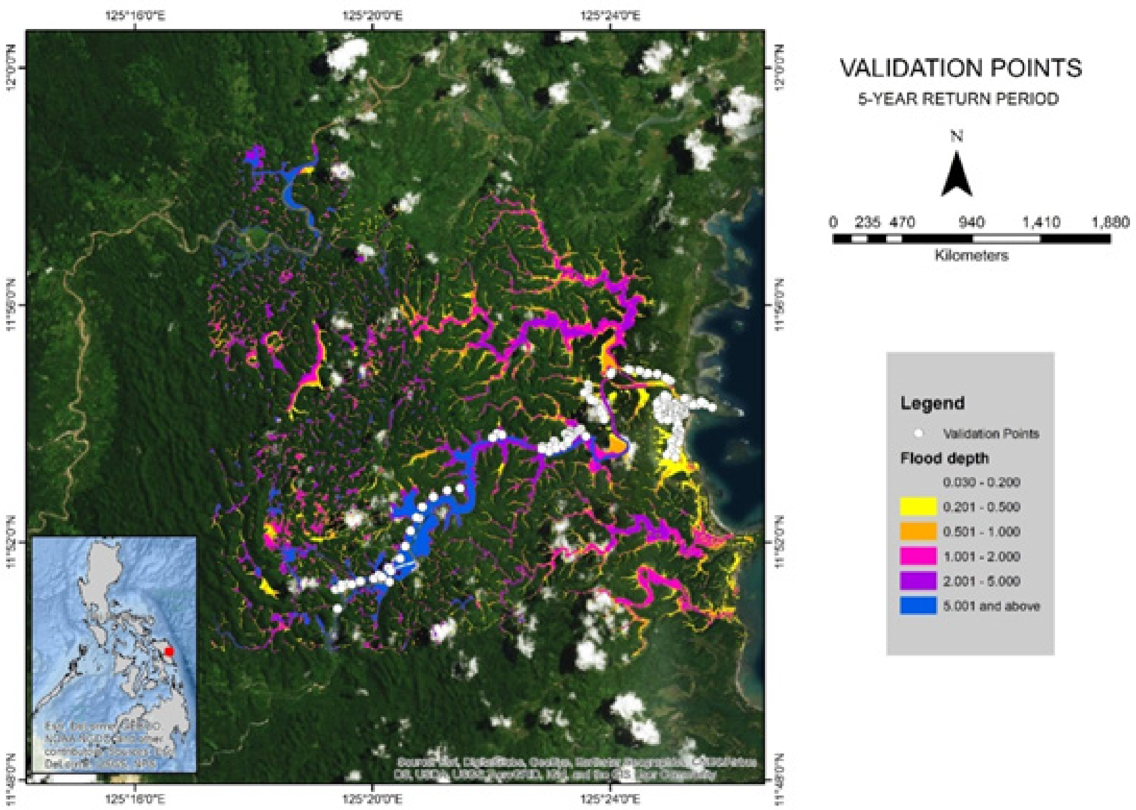


Figure 86. Validation points for 5-year Flood Depth Map of Taft Floodplain

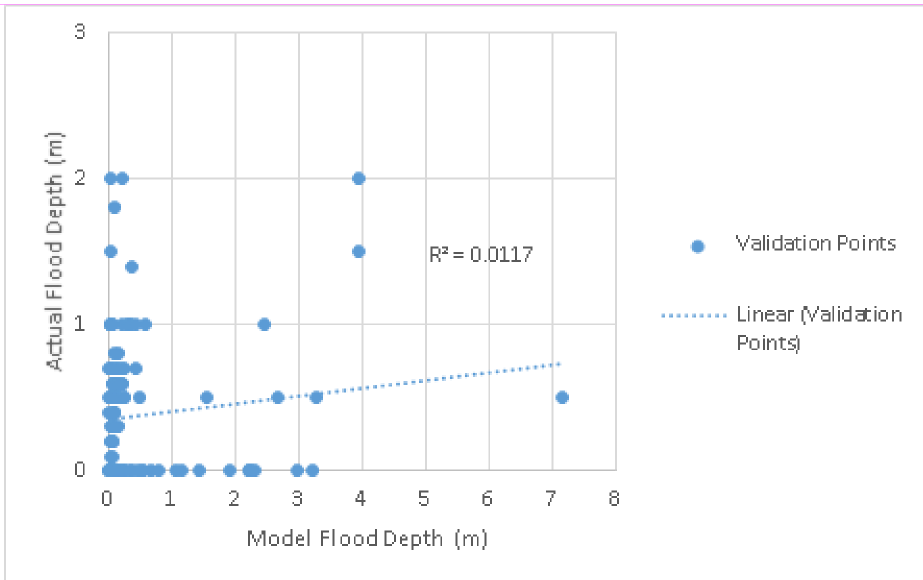


Figure 87. .Flood map depth vs actual flood depth

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

LIBERTAD 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	60	9	4	4	6	0	83
	0.21-0.50	36	3	0	1	2	1	43
	0.51-1.00	24	11	1	0	1	0	37
	1.01-2.00	3	2	0	0	2	0	7
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	123	25	5	5	11	1	170

The overall accuracy generated by the flood model is estimated at 37.65% with 64 points correctly matching the actual flood depths. In addition, there were 47 points estimated one level above and below the correct flood depths while there were 32 points and 16 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 76 points were underestimated in the modelled flood depths of Taft.

Table 43. Summary of Accuracy Assessment in Taft

	No. of Points	%
Correct	64	37.65
Overestimated	30	17.65
Underestimated	76	44.71
Total	170	100.00

REFERENCES

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

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

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.

LDRRM Office of Siay
Philippine Information Agency- IX
Mines and Geosciences Bureau- IX

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Taft Flood-plain Survey

1. PEGASUS SENSOR

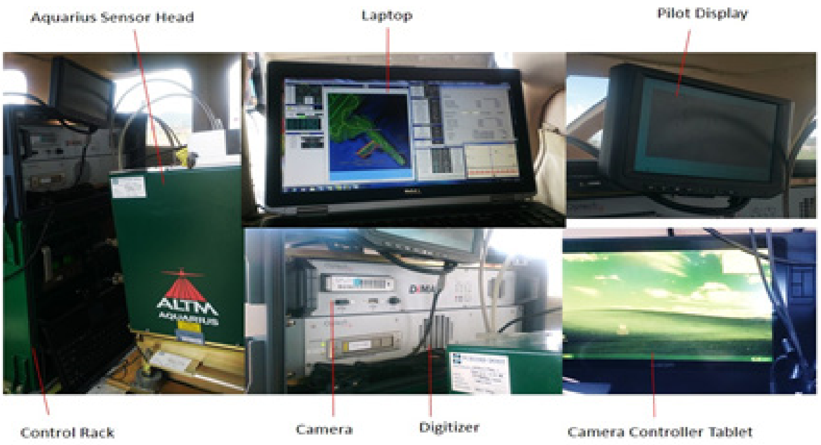


Table A-1.1 Parameters and Specifications

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

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

SME-3139

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

May 09, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS OCCIDENTAL**
Station Name: **NGW-87**
Order: **2nd**

Island: **VISAYAS**		Barangay: **BALUCANAG**
Municipality: **LA CASTELLANA**		
	PRS92 Coordinates	
Latitude: **10° 20' 32.34942"**	Longitude: **123° 8' 53.05808"**	Ellipsoidal Hgt: **333.32600 m.**
	WGS84 Coordinates	
Latitude: **10° 20' 28.15138"**	Longitude: **123° 8' 58.30851"**	Ellipsoidal Hgt: **393.14800 m.**
	PTM Coordinates	
Northing: **1143593.27 m.**	Easting: **516216.608 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,143,192.99**	Easting: **516,210.93**	Zone: **51**

Location Description

NGW-87
The station is at the SE side of Moises Padilla-Canlaon road. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the headwall with inscriptions "NGW-87; 2007; NAMRIA". The station is on the SE side of the road, NE of the wooden electric post.

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1071**

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

9 9 0 5 0 9 2 0 1 4 1 0 2 4 5 1

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 SME-3139

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

SE-16

SME-3139 - SE-16 (6:11:03 AM-11:04:02 AM) (S2)

Baseline observation:	SME-3139 --- SE-16 (B2)
Processed:	6/30/2014 5:42:19 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	3.434
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	6/9/2014 6:11:10 AM (Local: UTC+8hr)
Processing stop time:	6/9/2014 11:04:02 AM (Local: UTC+8hr)
Processing duration:	04:52:52
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SME-3139				
Grid		Local		Global	
Easting	765219.591 m	Latitude	N11°50'02.95701"	Latitude	N11°49'58.57713"
Northing	1309289.260 m	Longitude	E125°26'03.02189"	Longitude	E125°26'08.12160"
Elevation	2.987 m	Height	0.356 m	Height	62.185 m

To:	SE-16				
Grid		Local		Global	
Easting	765219.942 m	Latitude	N11°50'03.05106"	Latitude	N11°49'58.67117"
Northing	1309292.154 m	Longitude	E125°26'03.03429"	Longitude	E125°26'08.13400"
Elevation	3.103 m	Height	0.472 m	Height	62.301 m

Vector					
ΔEasting	0.350 m	NS Fwd Azimuth	7°23'58"	ΔX	-0.028 m
ΔNorthing	2.894 m	Ellipsoid Dist.	2.914 m	ΔY	-0.608 m
ΔElevation	0.116 m	ΔHeight	0.116 m	ΔZ	2.852 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'35"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Figure A-3.1 SE-16

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. 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
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	PAULINE JOANNE ARCEO	UP-TCAGP
	RA	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. NEIL ACHILLES AGAWIN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC

Annex 5. Data Transfer Sheet for Taft Floodplain

DATA TRANSFER SHEET
6/19/2014 (Samar - Leyte)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)		MB	GB		GB		BASE STATION(S)	Base Info (.txt)		Actual	KML	
30-May-14	1520A	3BLK33VSS150A	Aquarius	NA	424/602	1.48	289	88.5	748	14	164	10.5	1KB	1KB	4	NA	X:\Airborne_Raw\1520A
31-May-14	1522A	3BLK33SS151A	Aquarius	NA	288	469KB	112	9.78/21	164/59	4.87	59.1	4.53	1KB	1KB	5	NA	X:\Airborne_Raw\1522A
1-Jun-14	1526A	3BLK33SSR152A	Aquarius	NA	456/784	1.68	277	119	403	15.5	204	8.36	1KB	1KB	6	NA	X:\Airborne_Raw\1526A
2-Jun-14	1530A	3BLK33RSQ153A	Aquarius	NA	353/605	1.48	254	30.9/80.2	555/246	15.6	165	7.88	1KB	1KB	3	NA	X:\Airborne_Raw\1530A
3-Jun-14	1534A	3BLK33QS154A	Aquarius	NA	1175	1.49	250	56.9/35.1	399/154	14.5	114/95.5	6.6	1KB	1KB	7	NA	X:\Airborne_Raw\1534A
7-Jun-14	1550A	3BLK33P158A	Aquarius	NA	657	1.03	199	52.9	na	10.8	149	7	1KB	1KB	3	NA	X:\Airborne_Raw\1550A
8-Jun-14	1554A	3BLK33PSM159A	Aquarius	NA	533/1012	1.78	257	99.8	695	14.5	27.2/59/32.2	16.4	1KB	1KB	3	NA	X:\Airborne_Raw\1554A
8-Jun-14	1556A	3BLK33MS159B	Aquarius	NA	982	1.52	291	97.2	477	15.9	216	16.4	1KB	1KB	5	NA	X:\Airborne_Raw\1556A
9-Jun-14	1558A	3BLK33J160A	Aquarius	NA	833	1.27	277	95.7	452	14.2	95.6/80.5	16.1	1KB	1KB	4	NA	X:\Airborne_Raw\1558A
9-Jun-14	1560A	3BLK33J	Aquarius	NA	1583	1.67	223	72.2	357	12.1	123	16.1	1KB	1KB	5	NA	X:\Airborne_Raw\1560A

Received from
Name O. Joaquin
Position DA
Signature

Received by
Name JOIDA PRIETO
Position SERS
Signature
6/17/14

Figure A-5.1. Transfer Sheet for Taft Floodplain

Annex 6. Flight logs for the flight missions

Flight Log for 3BLK33J160A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 1558

1 LiDAR Operator: P. ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK33P158A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALAWIN	9 Route:			
10 Date: 09 JUN 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1030	14 Engine Off: 1353	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					

21 Problems and Solutions:

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

Acquisition Flight Certified by
A1C RAYMUND D CEDANA
Signature over Printed Name
(PAF Representative)

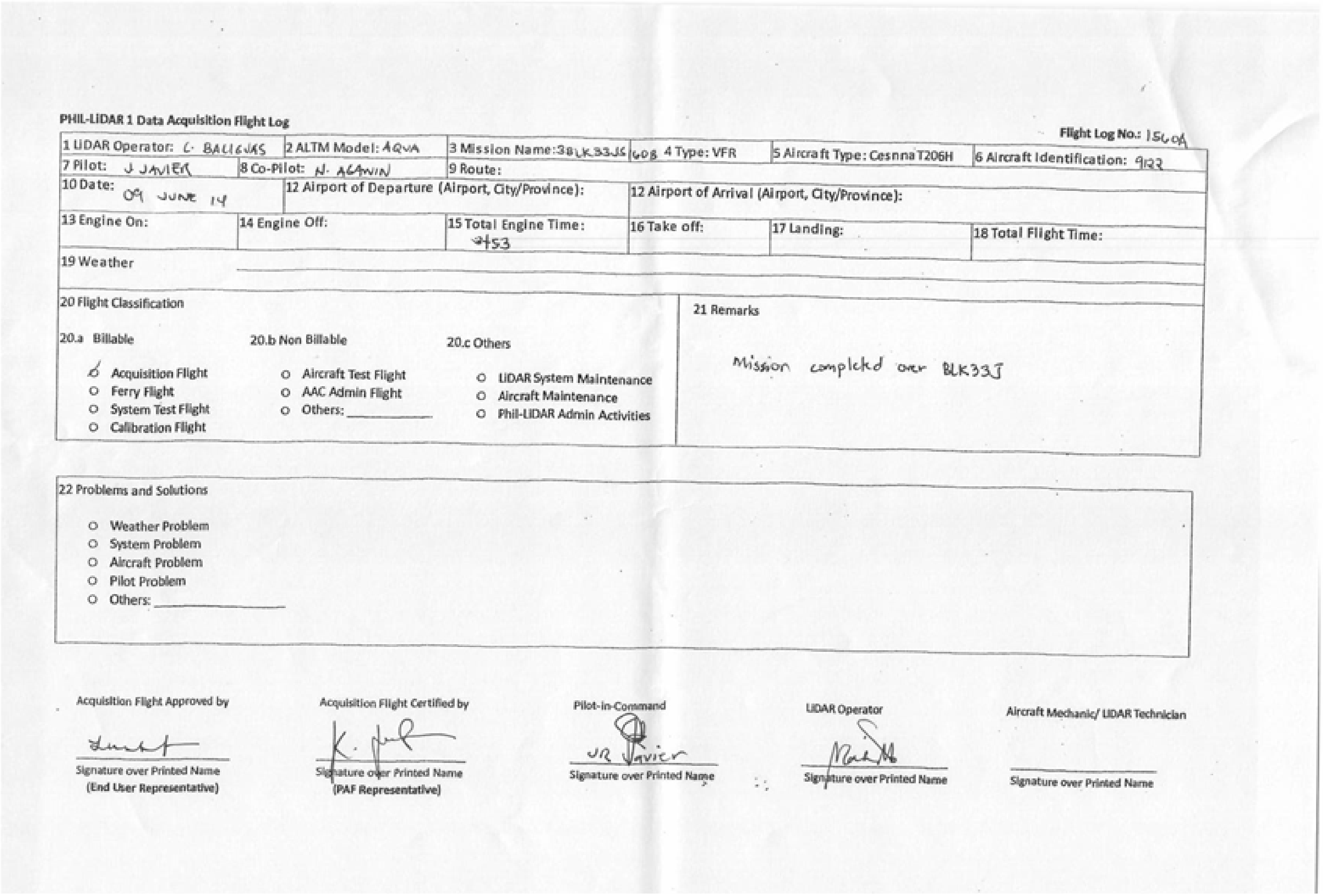
Pilot-in-Command
JR S JAVIER
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1 Flight Log for 3BLK33J160A Mission.

Flight Log for 3BLK33J160A Mission.



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 1560A

1 LiDAR Operator: C. BALICUAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK33J160B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: 09 JUNE 14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Mission completed over BLK33J

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

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

Figure A-6.2 Flight Log for 3BLK33J160A Mission.

Annex 7. Flight status reports

FLIGHT STATUS REPORT
TACLOBAN

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1558A	BLK33J	3BLK33J160A	PJ ARCEO	9 JUN 14	Completed 12 lines over BLK33J
1560A	BLK33J	3BLK33JS160B	MCE BALIGUAS	9 JUN 14	Mission completed over BLK33J

Flight No. :	1558A		
Area:	BLOCK 33J		
Total Area:	115.55 sq. km.		
Mission Name:	3BLK33J60A		
Altitude:	500m		
PRF:	50 kHz	SCF:	45 Hz
Lidar FOV:	22 deg	Sidelap:	30%

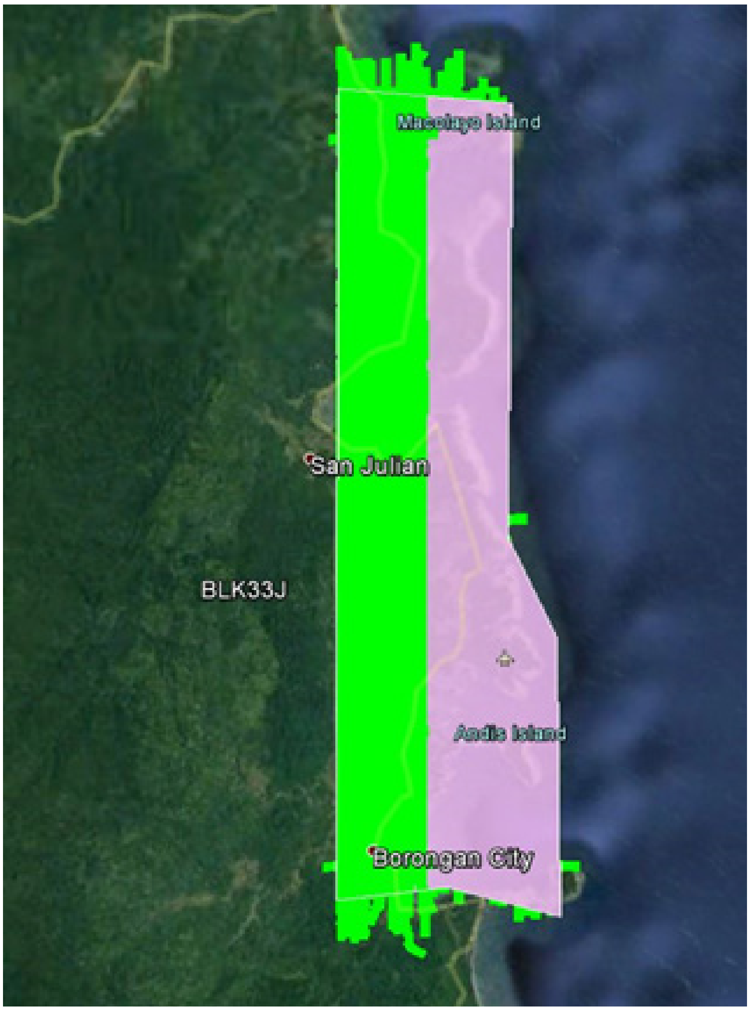


Figure A-7.1. Swath Coverage of Mission 3BLK33J60A

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk33J

Flight Area	Samar-Leyte
Mission Name	Blk33J
Inclusive Flights	1560A, 1558A
Range data size	26.3 GB
POS	500 MB
Image	167.9 GB
Transfer date	June 19, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000327
IMU attitude correction stdev (<0.001deg)	0.000898
GPS position stdev (<0.01m)	0.0098
Minimum % overlap (>25)	36.01%
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	291
Maximum Height	248.48 m
Minimum Height	49.30 m
Classification (# of points)	
Ground	110,486,647
Low vegetation	51,277,620
Medium vegetation	61,095,498
High vegetation	151,119,077
Building	2,518,830
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga Jr., Engr. Gladys Mae Apat

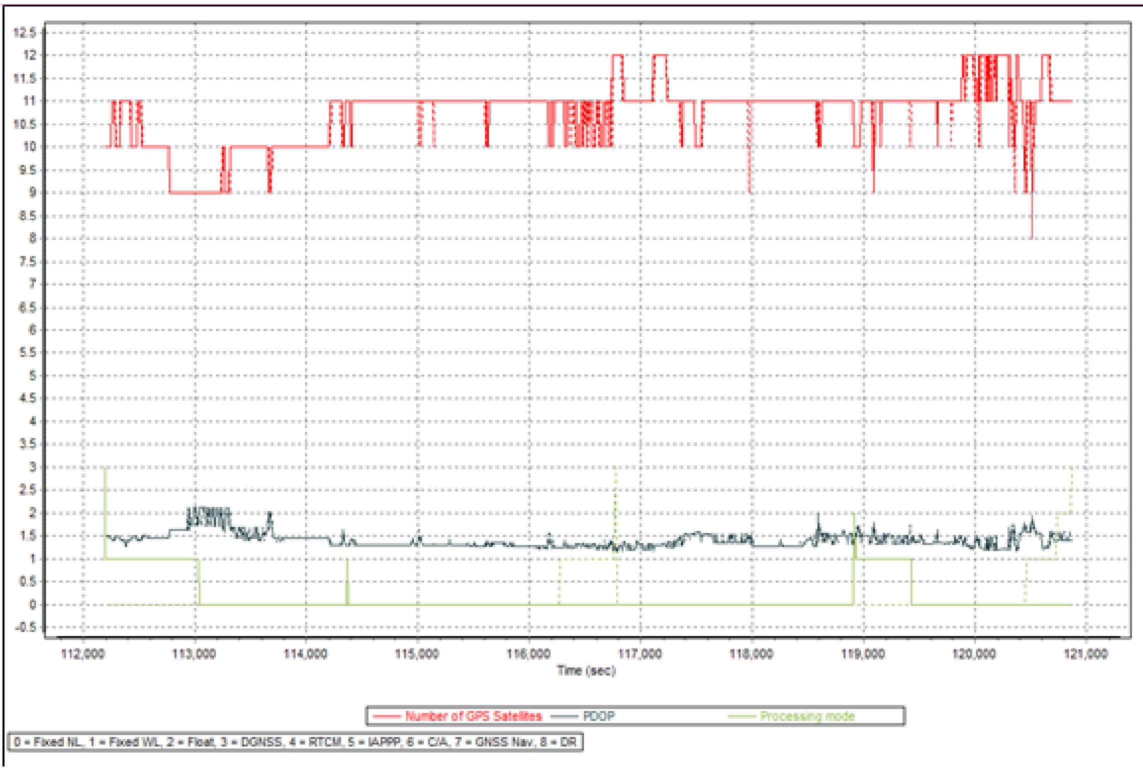


Figure A-8.1 Solution Status

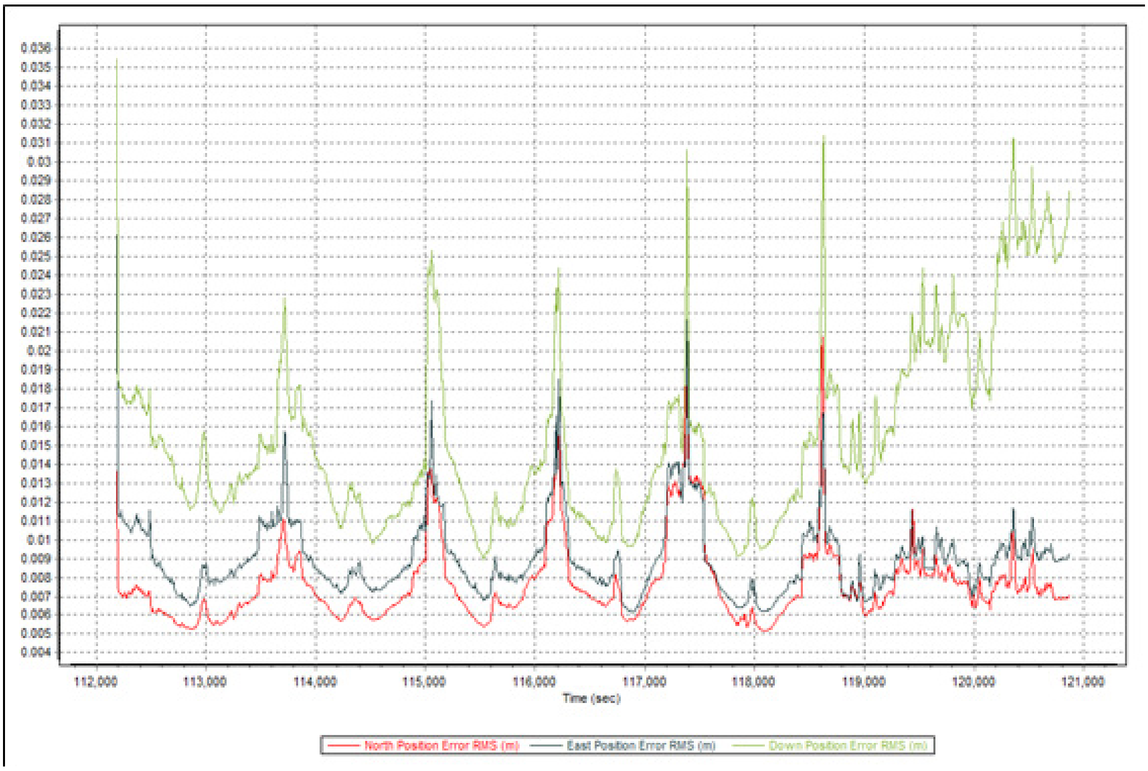


Figure A-8.2. Smoothed Performance Metric Parameters

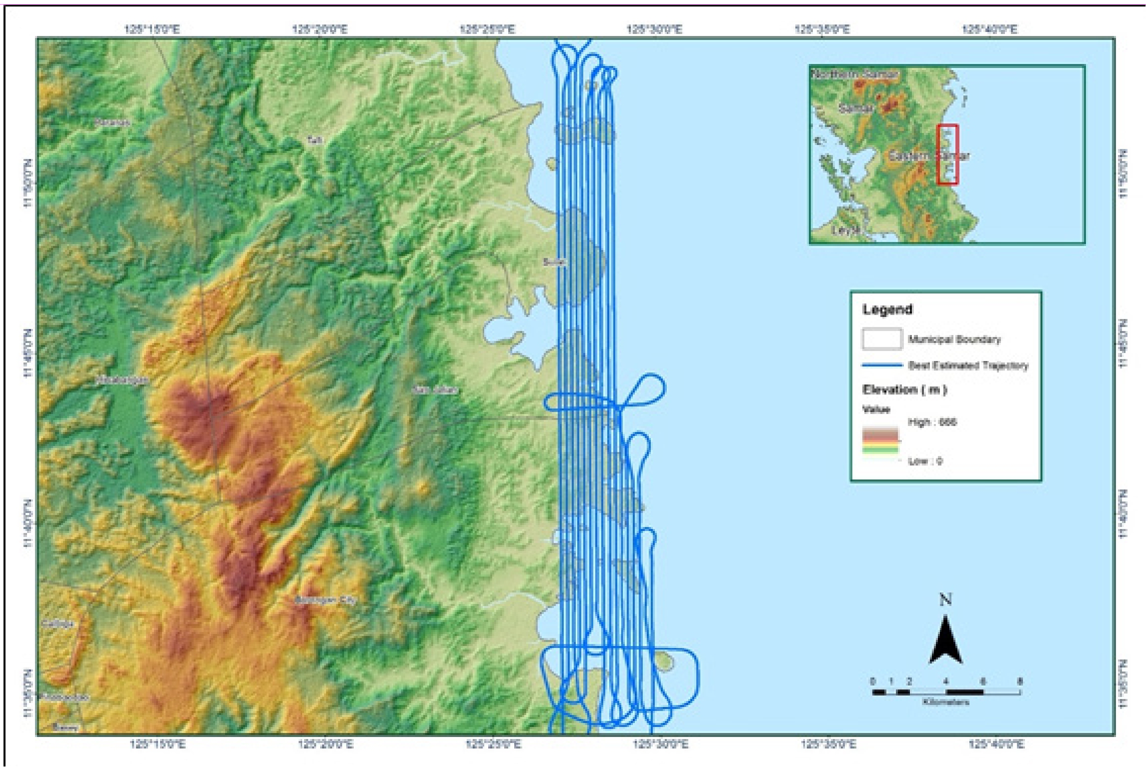


Figure A-8.3. Best Estimated Trajectory

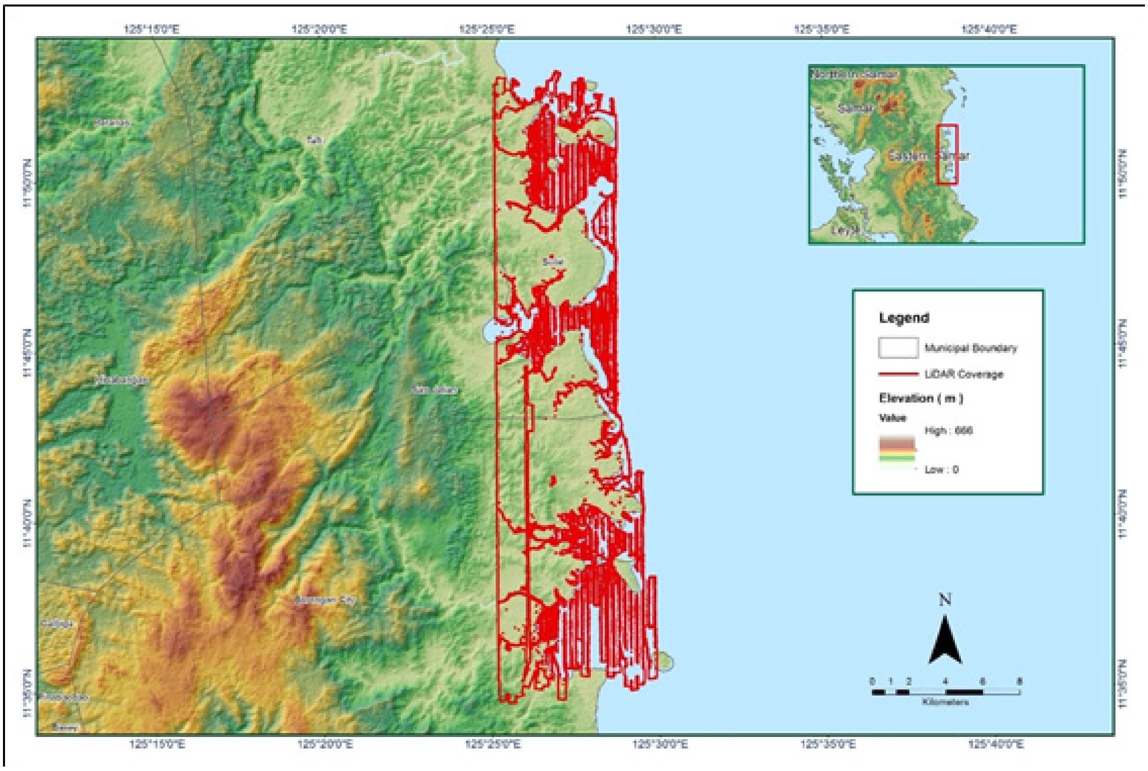


Figure A-8.4. Coverage of LiDAR data

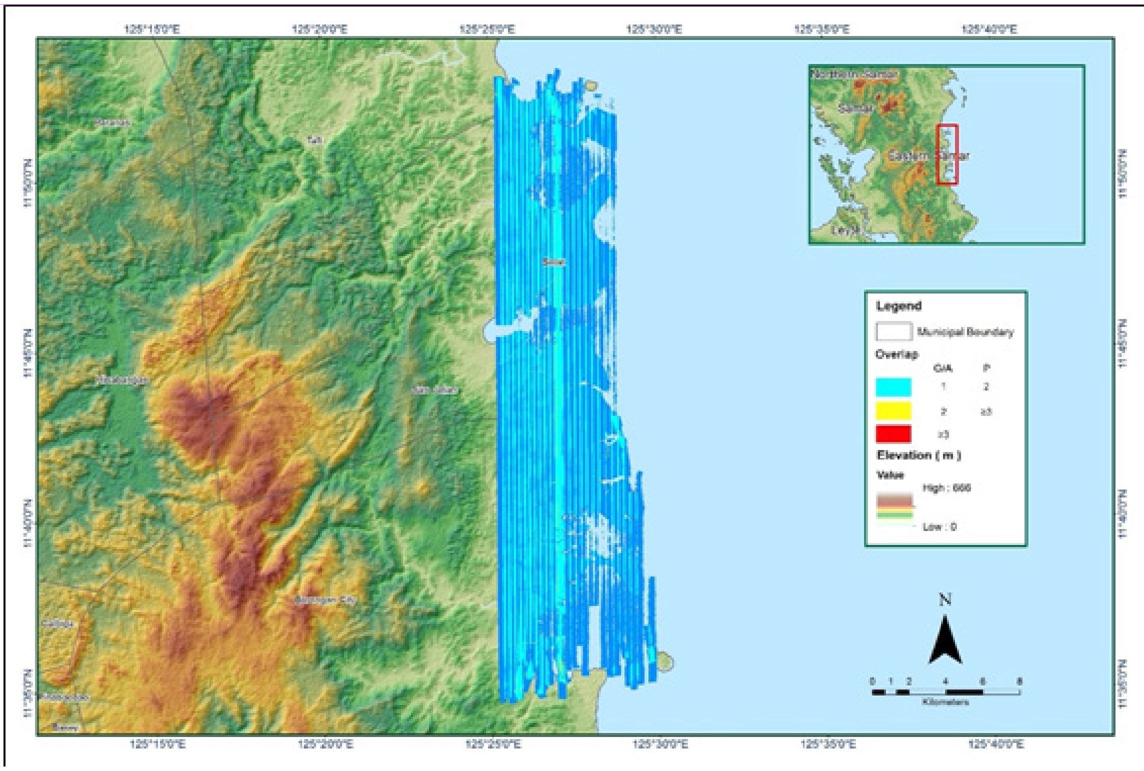


Figure A-8.5. Image of data overlap

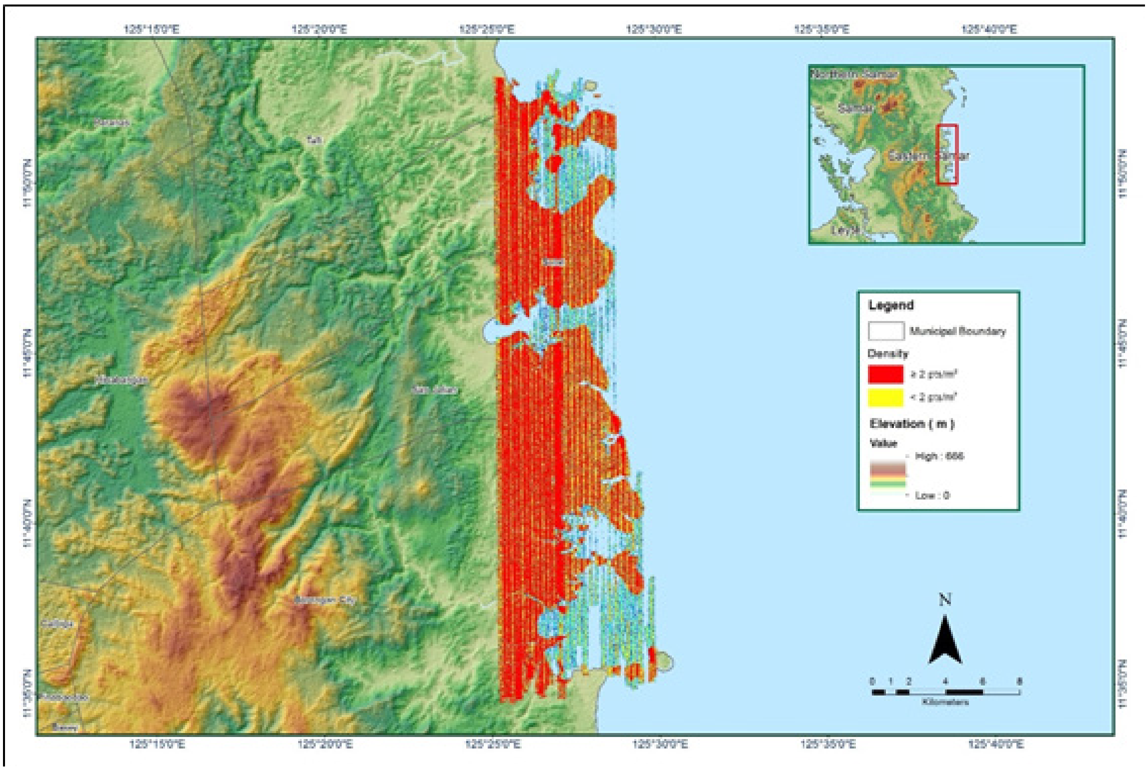


Figure A-8.6. Density map of merged LiDAR data

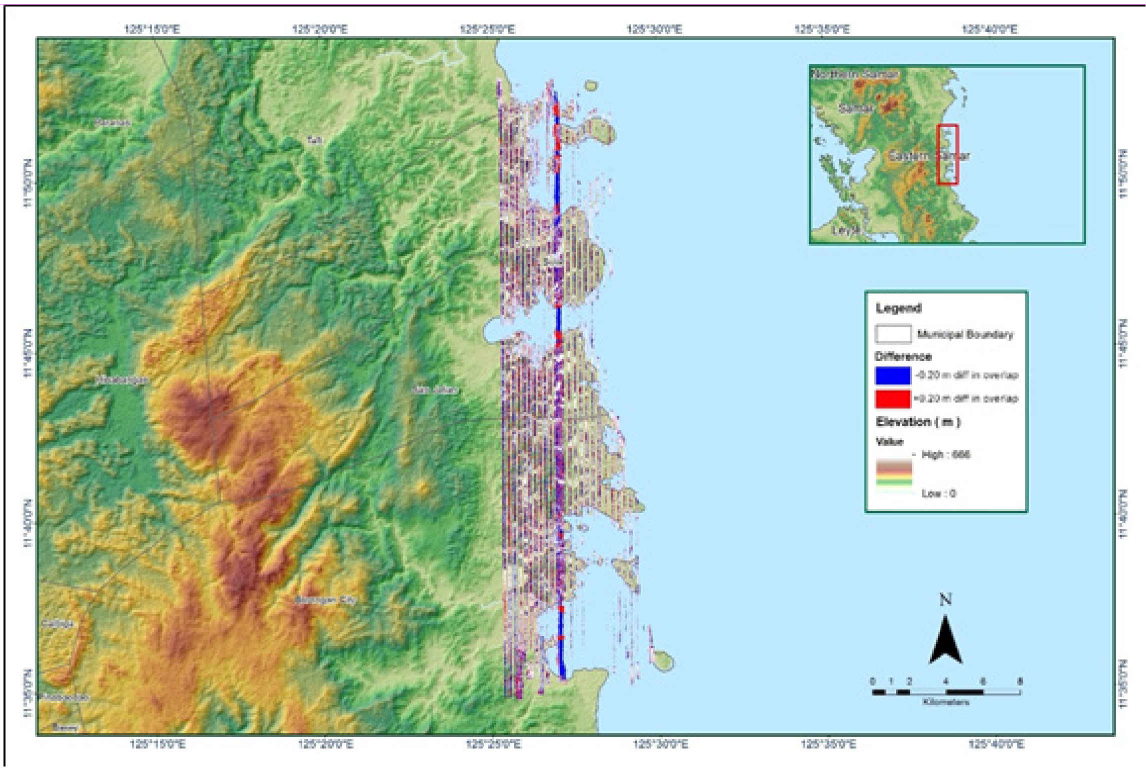


Figure A-8.7. Elevation difference between flight lines

Annex 9. Taft Model Basin Parameters

Table A-9.1. Taft Model Basin Parameters

Basin Number	SCS Curve Number Loss Model			Clark Transform Model		Recession Constant Baseflow Model				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge	Recession Constant	Threshold Type	Ratio to Peak
W340	109.9177215	91.679	0.0	4.1089	2.23524	Discharge	1.2401	0.65	Ratio to Peak	0.55
W350	116.4759494	90.732	0.0	6.1497	3.3453	Discharge	2.7955	0.65	Ratio to Peak	0.55
W360	70.094	97.881	0.0	1.6441	0.89439	Discharge	0.17846	0.65	Ratio to Peak	0.55
W370	445.7347503	59.752	0.0	3.537	1.92414	Discharge	0.23532	0.65	Ratio to Peak	0.55
W380	126.443038	89.33	0.0	10.352	5.6316	Discharge	3.0362	0.65	Ratio to Peak	0.55
W390	251.1458172	74.858	0.0	5.5148	3	Discharge	1.9203	0.65	Ratio to Peak	0.55
W400	141.2168232	87.33	0.0	3.3562	1.8258	Discharge	0.98251	0.65	Ratio to Peak	0.55
W410	141.7966516	87.253	0.0	3.1187	1.69656	Discharge	1.1748	0.65	Ratio to Peak	0.55
W420	133.950592	88.302	0.0	2.0686	1.12533	Discharge	0.54151	0.65	Ratio to Peak	0.55
W430	192.768477	81.001	0.0	3.1741	1.72674	Discharge	1.3475	0.65	Ratio to Peak	0.55
W440	229.2348661	77.051	0.0	3.4721	1.88883	Discharge	0.98734	0.65	Ratio to Peak	0.55
W450	172.564312	83.369	0.0	3.3029	1.79676	Discharge	1.3574	0.65	Ratio to Peak	0.55
W460	326.5077032	68.182	0.0	8.4191	4.5801	Discharge	2.0363	0.65	Ratio to Peak	0.55
W470	138.6810943	90	0.0	3.8343	2.0859	Discharge	2.3170	0.65	Ratio to Peak	0.55
W480	320.4641423	85.842	0.0	8.828	4.8024	Discharge	2.8285	0.65	Ratio to Peak	0.55
W490	345.7193411	83.333	0.0	1.0547	0.57378	Discharge	0.0529461	0.65	Ratio to Peak	0.55
W500	499.8401003	70.722	0.0	2.924	1.59063	Discharge	0.0237982	0.65	Ratio to Peak	0.55
W510	454.4742622	74.019	0.0	3.08	1.6755	Discharge	0.13634	0.65	Ratio to Peak	0.55
W520	353.6420156	82.576	0.0	9.8632	5.3658	Discharge	2.3308	0.65	Ratio to Peak	0.55
W530	459.189361	73.6625	0.0	6.5063	3.5394	Discharge	0.14252	0.65	Ratio to Peak	0.55
W540	404.0445259	78.065	0.0	4.7614	2.5902	Discharge	2.1809	0.65	Ratio to Peak	0.55
W550	345.8778251	83.318	0.0	4.2248	2.2983	Discharge	0.83802	0.65	Ratio to Peak	0.55

W560	347.914458	83.122	0.0	8.0021	4.353	Discharge	1.9912	0.65	Ratio to Peak	0.55
W570	494.3893278	71.103	0.0	2.3219	1.26312	Discharge	0.0995593	0.65	Ratio to Peak	0.55
W580	403.5687438	78.106	0.0	5.2285	2.84433	Discharge	1.4671	0.65	Ratio to Peak	0.55
W590	417.7715143	76.921	0.0	2.6025	1.41576	Discharge	0.35322	0.65	Ratio to Peak	0.55
W600	357.5618452	82.207	0.0	8.9453	4.8663	Discharge	2.2058	0.65	Ratio to Peak	0.55
W610	404.487937	78.028	0.0	5.2166	2.83782	Discharge	1.1441	0.65	Ratio to Peak	0.55
W620	353.6126759	82.579	0.0	5.8014	3.156	Discharge	2.0824	0.65	Ratio to Peak	0.55
W630	345.7193411	83.333	0.0	6.6025	3.5916	Discharge	1.7270	0.65	Ratio to Peak	0.55
W640	345.7193411	83.333	0.0	2.8135	1.53054	Discharge	0.42717	0.65	Ratio to Peak	0.55
W650	345.7193411	83.333	0.0	5.0835	2.76543	Discharge	0.91100	0.65	Ratio to Peak	0.55
W660	348.1461716	83.1	0.0	6.2659	3.4086	Discharge	2.1073	0.65	Ratio to Peak	0.55
W780	11.24	35.271	0	5.6952	1.4536	Discharge	0.46564	0.2	Ratio to Peak	0.001

Annex 10. Taft Model Reach Parameters

Reach Number	Muskingum Cunge Routing Model						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R120	Automatic Fixed Interval	5065.7	0.00125	0.5175	Trapezoid	30	1
R140	Automatic Fixed Interval	1173.8	0.01213	0.1459	Trapezoid	30	1
R150	Automatic Fixed Interval	113.14	0.00125	0.3649	Trapezoid	30	1
R160	Automatic Fixed Interval	9527.2	0.00807	0.0129	Trapezoid	30	1
R180	Automatic Fixed Interval	1403.6	0.00125	0.0583	Trapezoid	30	1
R200	Automatic Fixed Interval	3184.3	0.00125	0.0257	Trapezoid	30	1
R220	Automatic Fixed Interval	7230.1	0.00125	0.1611	Trapezoid	30	1
R240	Automatic Fixed Interval	1209.4	0.00125	0.0964	Trapezoid	30	1
R260	Automatic Fixed Interval	2349.5	0.01865	0.0325	Trapezoid	30	1
R280	Automatic Fixed Interval	10352	0.00623	0.1623	Trapezoid	30	1
R30	Automatic Fixed Interval	3022.8	0.00414	0.0129	Trapezoid	30	1
R300	Automatic Fixed Interval	2071.9	0.00920	0.1621	Trapezoid	30	1
R40	Automatic Fixed Interval	827.31	0.00125	0.0622	Trapezoid	30	1
R70	Automatic Fixed Interval	3348.2	0.01068	0.4026	Trapezoid	30	1
R80	Automatic Fixed Interval	17777	0.00125	1	Trapezoid	30	1
R90	Automatic Fixed Interval	1236.1	0.04759	0.0331	Trapezoid	30	1

Annex 11. Taft Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	11.9154451	125.404965	0.59	1	-0.410	Typhoon Ruby/ December 07, 2014	5 -Year
2	11.9151591	125.405401	0.03	1	-0.970	Typhoon Ruby/ December 07, 2014	5 -Year
3	11.9145189	125.400393	0.05	1	-0.950	Typhoon Ruby/ December 07, 2014	5 -Year
4	11.9139467	125.40002	0.03	1	-0.970	Typhoon Ruby/ December 07, 2014	5 -Year
5	11.9123774	125.416275	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
6	11.9119981	125.416509	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
26	11.9073316	125.422249	0.00	0	0.000	Typhoon Ruby/ December 07, 2014	5 -Year
28	11.9069925	125.422415	0.00	0	0.000	Typhoon Ruby/ December 07, 2014	5 -Year
29	11.9063808	125.421924	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
30	11.9059095	125.421492	0.06	0.3	-0.240	Typhoon Ruby/ December 07, 2014	5 -Year
30	11.9059095	125.421492	0.06	0.2	-0.140	Heavy Rain/December 17, 2016	5 -Year
31	11.9062626	125.421186	0.04	0.2	-0.160	Typhoon Ruby/ December 07, 2014	5 -Year
31	11.9062626	125.421186	0.04	0.1	-0.060	Heavy Rain/ December 17, 2016	5 -Year
32	11.9056867	125.423446	0.06	0.2	-0.140	Typhoon Ruby/ December 07, 2014	5 -Year
32	11.9056867	125.423446	0.06	0.1	-0.040	Heavy Rain/ December 17, 2016	5 -Year
33	11.9055197	125.426535	0.04	0.5	-0.460	Heavy Rain/ December 17, 2016	5 -Year
34	11.9054049	125.424522	0.04	0.5	-0.460	Heavy Rain/ December 17, 2016	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
35	11.9046299	125.428528	0.00	0	0.000	Typhoon Ruby/ December 07, 2014	5 -Year
36	11.9074706	125.415482	0.06	0.3	-0.240	Typhoon Yolanda/ November 08, 2013	5 -Year
36	11.9074706	125.415482	0.06	0.6	-0.540	Typhoon Ruby/ December 07, 2014	5 -Year
37	11.9059318	125.418172	0.06	0.2	-0.140	Typhoon Yolanda/ November 08, 2013	5 -Year
37	11.9059318	125.418172	0.06	0.4	-0.340	Typhoon Ruby/ December 07, 2014	5 -Year
38	11.9052177	125.418907	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
39	11.9046882	125.419513	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
43	11.902181	125.421937	0.00	0.5	-0.500	Typhoon Ruby/ December 07, 2014	5 -Year
43	11.902181	125.421937	0.00	0.7	-0.700	Typhoon Yolanda/ November 08, 2013	5 -Year
44	11.9027248	125.420926	0.07	0.5	-0.430	Heavy Rain/De-cember 17, 2016	5 -Year
45	11.9037405	125.419191	0.13	0.5	-0.370	Heavy Rain/De-cember 17, 2016	5 -Year
46	11.90255	125.420212	0.09	0.4	-0.310	Typhoon Ruby/ December 07, 2014	5 -Year
46	11.90255	125.420212	0.09	0.5	-0.410	Typhoon Yolanda/ November 08, 2013	5 -Year
47	11.9027339	125.419621	0.13	0	0.130	Typhoon Ruby/ December 07, 2014	5 -Year
48	11.9029523	125.418899	0.17	0.7	-0.530	Typhoon Ruby/ December 07, 2014	5 -Year
49	11.9019971	125.4193	0.06	1	-0.940	Typhoon Ruby/ December 07, 2014	5 -Year
50	11.9022449	125.418623	0.13	0.5	-0.370	Heavy Rain/ December 17, 2016	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
51	11.9035639	125.418675	0.17	0.5	-0.330	Heavy Rain/ December 17, 2016	5 -Year
52	11.9025265	125.418177	0.15	0.8	-0.650	Typhoon Ruby/ December 07, 2014	5 -Year
52	11.9025265	125.418177	0.15	0.5	-0.350	Typhoon Yolanda/ November 08, 2013	5 -Year
53	11.9020668	125.417988	0.11	0.8	-0.690	Heavy Rain/De-cember 17, 2016	5 -Year
54	11.9016394	125.41841	0.07	0	0.070	Typhoon Ruby/ December 07, 2014	5 -Year
55	11.9010166	125.418389	0.04	0	0.040	Typhoon Ruby/ December 07, 2014	5 -Year
56	11.9025153	125.416996	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
57	11.9033901	125.41757	0.22	0	0.220	Typhoon Ruby/ December 07, 2014	5 -Year
58	11.9043228	125.417949	0.21	2	-1.790	Typhoon Yolanda/ November 08, 2013	5 -Year
59	11.9047765	125.416754	0.10	1.8	-1.700	Typhoon Yolanda/ November 08, 2013	5 -Year
60	11.9043565	125.416655	0.13	0.5	-0.370	Heavy Rain/De-cember 17, 2016	5 -Year
61	11.9037835	125.416528	0.22	0	0.220	Typhoon Ruby/ December 07, 2014	5 -Year
62	11.9030972	125.416233	0.22	0	0.220	Typhoon Ruby/ December 07, 2014	5 -Year
63	11.9026796	125.416093	0.13	0	0.130	Typhoon Ruby/ December 07, 2014	5 -Year
64	11.9055607	125.415959	0.08	0.6	-0.520	Heavy Rain/De-cember 17, 2016	5 -Year
65	11.9048913	125.415299	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
66	11.9042706	125.41505	0.07	0	0.070	Typhoon Ruby/ December 07, 2014	5 -Year
67	11.9036495	125.414763	0.10	0.4	-0.300	Heavy Rain/ December 17, 2016	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
68	11.9032807	125.414763	0.10	0.5	-0.400	Typhoon Ruby/ December 07, 2014	5 -Year
69	11.9025048	125.414373	0.06	0.6	-0.540	Typhoon Ruby/ December 07, 2014	5 -Year
70	11.9020173	125.414835	0.10	0	0.100	Typhoon Ruby/ December 07, 2014	5 -Year
71	11.9013349	125.414358	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
72	11.9033211	125.413377	0.09	0	0.090	Typhoon Ruby/ December 07, 2014	5 -Year
73	11.9023889	125.413384	0.03	0.5	-0.470	Heavy Rain/De-cember 17, 2016	5 -Year
74	11.9063577	125.41351	0.15	0.3	-0.150	Heavy Rain/De-cember 17, 2016	5 -Year
75	11.9055972	125.414105	0.06	0.3	-0.240	Heavy Rain/De-cember 17, 2016	5 -Year
76	11.904934	125.413528	0.04	0	0.040	Typhoon Ruby/ December 07, 2014	5 -Year
77	11.9047141	125.414529	0.05	0	0.050	Typhoon Ruby/ December 07, 2014	5 -Year
78	11.9042293	125.413211	0.05	0	0.050	Typhoon Ruby/ December 07, 2014	5 -Year
79	11.9056651	125.413024	0.13	0.6	-0.470	Typhoon Ruby/ December 07, 2014	5 -Year
80	11.913989	125.409968	0.04	0.5	-0.460	Typhoon Ruby/ December 07, 2014	5 -Year
81	11.914212	125.410517	0.04	0.5	-0.460	Typhoon Ruby/ December 07, 2014	5 -Year
82	11.9109894	125.393743	0.81	0	0.810	Typhoon Ruby/ December 07, 2014	5 -Year
83	11.9097782	125.393868	0.07	0	0.070	Typhoon Ruby/ December 07, 2014	5 -Year
84	11.9091981	125.393717	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
85	11.9086162	125.393585	0.68	0	0.680	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
86	11.9081878	125.393546	1.07	0	1.070	Typhoon Ruby/ December 07, 2014	5 -Year
87	11.9087506	125.393356	0.03	0.7	-0.670	Heavy Rain/De-cember 17, 2016	5 -Year
88	11.9086741	125.392601	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
89	11.9072256	125.394226	0.50	0.5	0.000	Heavy Rain/De-cember 17, 2016	5 -Year
90	11.9064671	125.395523	0.03	0.7	-0.670	Heavy Rain/De-cember 17, 2016	5 -Year
91	11.9040906	125.397094	0.06	0.5	-0.440	Heavy Rain/De-cember 17, 2016	5 -Year
92	11.9035208	125.397274	0.03	0.5	-0.470	Heavy Rain/De-cember 17, 2016	5 -Year
93	11.9067258	125.394647	0.15	0.5	-0.350	Heavy Rain/De-cember 17, 2016	5 -Year
94	11.902677	125.397894	0.26	0	0.260	Typhoon Ruby/ December 07, 2014	5 -Year
95	11.9012501	125.398231	0.18	0	0.180	Typhoon Ruby/ December 07, 2014	5 -Year
96	11.8986444	125.391635	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
97	11.8980548	125.39113	2.32	0	2.320	Typhoon Ruby/ December 07, 2014	5 -Year
98	11.8978993	125.39042	2.21	0	2.210	Typhoon Ruby/ December 07, 2014	5 -Year
99	11.897331	125.389342	1.15	0	1.150	Typhoon Ruby/ December 07, 2014	5 -Year
100	11.898088	125.388589	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
101	11.8972108	125.389906	1.93	0	1.930	Typhoon Ruby/ December 07, 2014	5 -Year
102	11.8965517	125.393095	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
103	11.8974797	125.388694	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
104	11.8972295	125.38746	0.47	0	0.470	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
105	11.8969647	125.388949	0.57	0	0.570	Typhoon Ruby/ December 07, 2014	5 -Year
106	11.8965823	125.38936	1.42	0	1.420	Typhoon Ruby/ December 07, 2014	5 -Year
107	11.8970201	125.388345	0.23	0	0.230	Typhoon Ruby/ December 07, 2014	5 -Year
108	11.8966356	125.388741	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
109	11.8960476	125.388592	0.03	0.5	-0.470	Heavy Rain/De-cember 17, 2016	5 -Year
110	11.8998419	125.418887	0.09	0	0.090	Typhoon Ruby/ December 07, 2014	5 -Year
111	11.898292	125.418484	0.09	0	0.090	Typhoon Ruby/ December 07, 2014	5 -Year
112	11.8980094	125.419699	0.20	0	0.200	Typhoon Ruby/ December 07, 2014	5 -Year
113	11.8970074	125.418688	0.23	1	-0.770	Typhoon Ruby/ December 07, 2014	5 -Year
113	11.8970074	125.418688	0.23	0.6	-0.370	Heavy Rain/De-cember 17, 2016	5 -Year
114	11.8965335	125.419034	0.30	1	-0.700	Typhoon Ruby/ December 07, 2014	5 -Year
114	11.8965335	125.419034	0.30	1	-0.700	Heavy Rain/De-cember 17, 2016	5 -Year
115	11.8962157	125.419469	0.34	1	-0.660	Typhoon Ruby/ December 07, 2014	5 -Year
115	11.8962157	125.419469	0.34	1	-0.660	Heavy Rain/De-cember 17, 2016	5 -Year
116	11.895987	125.418489	0.35	0	0.350	Typhoon Ruby/ December 07, 2014	5 -Year
117	11.8954805	125.419209	0.38	0	0.380	Typhoon Ruby/ December 07, 2014	5 -Year
118	11.8947351	125.418948	0.37	1.4	-1.030	Typhoon Ruby/ December 07, 2014	5 -Year
119	11.8956061	125.417467	0.25	0	0.250	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
120	11.8949163	125.417021	0.18	0	0.180	Typhoon Ruby/ December 07, 2014	5 -Year
121	11.8952306	125.384215	0.54	0	0.540	Typhoon Ruby/ December 07, 2014	5 -Year
122	11.8942225	125.384824	1.55	0.5	1.050	Heavy Rain/December 17, 2016	5 -Year
123	11.8936175	125.383059	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
124	11.8930644	125.384649	2.24	0	2.240	Typhoon Ruby/ December 07, 2014	5 -Year
125	11.8921994	125.382752	3.23	0	3.230	Typhoon Ruby/ December 07, 2014	5 -Year
126	11.8935536	125.38089	0.03	1	-0.970	Typhoon Ruby/ December 07, 2014	5 -Year
126	11.8935536	125.38089	0.03	1	-0.970	Heavy Rain/December 17, 2016	5 -Year
127	11.8929391	125.380846	2.68	0.5	2.180	Heavy Rain/December 17, 2016	5 -Year
128	11.8937877	125.386776	2.47	1	1.470	Heavy Rain/December 17, 2016	5 -Year
129	11.8973113	125.368181	0.42	1	-0.580	Heavy Rain/December 17, 2016	5 -Year
130	11.8946215	125.387908	2.22	0	2.220	Typhoon Ruby/ December 07, 2014	5 -Year
131	11.8961174	125.366975	2.98	0	2.980	Typhoon Ruby/ December 07, 2014	5 -Year
132	11.8954541	125.388143	0.03	2	-1.970	Typhoon Ruby/ December 07, 2014	5 -Year
132	11.8954541	125.388143	0.03	1.5	-1.470	Heavy Rain/December 17, 2016	5 -Year
133	11.8969232	125.369638	3.96	2	1.960	Typhoon Ruby/ December 07, 2014	5 -Year
133	11.8969232	125.369638	3.96	1.5	2.460	Heavy Rain/December 17, 2016	5 -Year
136	11.8766725	125.347205	3.27	0.5	2.770	Heavy Rain/December 17, 2016	5 -Year
137	11.879505	125.350368	7.15	0.5	6.650	Heavy Rain/December 17, 2016	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
138	11.8813008	125.354199	0.05	0	0.050	Typhoon Ruby/ December 07, 2014	5 -Year
139	11.8819211	125.357814	0.03	0.5	-0.470	Heavy Rain/De-cember 17, 2016	5 -Year
140	11.8480655	125.323457	0.03	0.5	-0.470	Heavy Rain/De-cember 17, 2016	5 -Year
156	11.8941581	125.417263	0.14	0.5	-0.360	Typhoon Ruby/ December 07, 2014	5 -Year
156	11.8941581	125.417263	0.14	0.7	-0.560	Heavy Rain/De-cember 17, 2016	5 -Year
157	11.8924273	125.419554	0.21	0.7	-0.490	Typhoon Ruby/ December 07, 2014	5 -Year
157	11.8924273	125.419554	0.21	0.6	-0.390	Heavy Rain/De-cember 17, 2016	5 -Year
158	11.8922731	125.418451	0.24	0.7	-0.460	Typhoon Ruby/ December 07, 2014	5 -Year
158	11.8922731	125.418451	0.24	0.5	-0.260	Heavy Rain/De-cember 17, 2016	5 -Year
159	11.8932269	125.417075	0.11	0.7	-0.590	Typhoon Ruby/ December 07, 2014	5 -Year
159	11.8932269	125.417075	0.11	0.6	-0.490	Heavy Rain/De-cember 17, 2016	5 -Year
160	11.8921725	125.41666	0.15	0.6	-0.450	Typhoon Ruby/ December 07, 2014	5 -Year
160	11.8921725	125.41666	0.15	0.6	-0.450	Heavy Rain/De-cember 17, 2016	5 -Year
161	11.8905074	125.418192	0.44	0.7	-0.260	Heavy Rain/De-cember 17, 2016	5 -Year
162	11.8912466	125.415766	0.18	0	0.180	Typhoon Ruby/ December 07, 2014	5 -Year
169	11.9015337	125.419813	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
170	11.9013016	125.419678	0.00	0	0.000	Typhoon Ruby/ December 07, 2014	5 -Year
171	11.9021843	125.420042	0.07	0	0.070	Typhoon Ruby/ December 07, 2014	5 -Year
172	11.9035344	125.419987	0.15	0	0.150	Typhoon Ruby/ December 07, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
173	11.9045974	125.419083	0.10	0	0.100	Typhoon Ruby/ December 07, 2014	5 -Year
174	11.9053761	125.418027	0.13	0.5	-0.370	Heavy Rain/December 17, 2016	5 -Year
175	11.9049994	125.418373	0.09	0.5	-0.410	Heavy Rain/December 17, 2016	5 -Year
176	11.903872	125.417742	0.25	0.5	-0.250	Heavy Rain/December 17, 2016	5 -Year
177	11.9018276	125.416513	0.04	0.5	-0.460	Heavy Rain/December 17, 2016	5 -Year
178	11.9009725	125.417943	0.04	0.5	-0.460	Heavy Rain/December 17, 2016	5 -Year
179	11.9015342	125.419082	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
180	11.9045901	125.420143	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
181	11.9054466	125.421008	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
182	11.9051928	125.421589	0.03	0.7	-0.670	Typhoon Yolanda/ November 08, 2013	5 -Year
183	11.9053879	125.422668	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
184	11.9052691	125.423185	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
186	11.9139899	125.413149	0.03	1	-0.970	Typhoon Yolanda/ November 08, 2013	5 -Year
187	11.9070658	125.420693	0.03	1	-0.970	Typhoon Yolanda/ November 08, 2013	5 -Year
188	11.9064927	125.415863	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
189	11.9070181	125.41526	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
190	11.9075449	125.415999	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
191	11.9010993	125.416062	0.03	0.3	-0.270	Typhoon Ruby/ December 07, 2014	5 -Year
191	11.9010993	125.416062	0.03	0.2	-0.170	Heavy Rain/December 17, 2016	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
192	11.90091	125.42026	0.00	0.4	-0.400	Typhoon Ruby/ December 07, 2014	5 -Year
216	11.9128013	125.415524	0.03	0	0.030	Typhoon Ruby/ December 07, 2014	5 -Year
217	11.9149526	125.408157	0.06	0	0.060	Typhoon Ruby/ December 07, 2014	5 -Year
218	11.9080634	125.415188	0.10	0.4	-0.300	Typhoon Ruby/ December 07, 2014	5 -Year
218	11.9080634	125.415188	0.10	0.3	-0.200	Typhoon Yolanda/ November 08, 2013	5 -Year
221	11.9062143	125.425513	0.04	0	0.040	Typhoon Ruby/ December 07, 2014	5 -Year

Annex 12. Educational Institutions affected by flooding in Taft Floodplain

Table A-12.1. Educational Institutions affected by flooding in Taft Floodplain

EASTERN VISAYAS				
TAFT				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Dacul Day Care Center	Dacul			

Annex 13. Health Institutions affected by flooding in Taft Floodplain