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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND ORAS RIVER

Dr. Chelo Pascua and Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LiDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Baguio (UPB). UPB 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 12 river basins in the Ilocos Region and the Cordillera Administrative Region. The university is located in Baguio City in the province of Benguet.

1.2 Overview of the Oras River Basin

The Oras River Basin covers three (3) municipalities in Eastern Samar; namely, the municipalities of Arteche, Jipadpad, and Oras. It also covers some portions of the municipalities of Maslog and San Policarpo in Eastern Samar; some portions of the municipalities of Catubig, Gamay, Lapinig, and Las Navas in Northern Samar; and a portion of the Municipality of Matuguinao in Samar. The DENR River Basin Control Office (RBCO) states that the Oras Basin has a drainage are of 491 km² and an estimated 933 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Oras River, is among the twenty-eight (28) river systems in Eastern Visayas Region. According to the 2015 national census of PSA, a total of 13,207 persons are residing within the immediate vicinity of the river, which is distributed among barangays Cadian, Cagdine, Balingasag, Alang-Alang, Minap-Os, Iwayan, Agsam, Nadacpan, Binalayan, Paypayon, Riverside, Tiguib, Tawagan, and Balocawe in the Municipality of Oras. The economy of the Municipality of Oras is primarily agriculture-based with coconut, rice, abaca, and fish as the major crops (Commission on Audit, 2015). On December 2016, the municipalities of Maslog, Oras, Jipadpdad, Can-avid, Dolores, Taft, and Sulat were badly affected by floods due to torrential rains in Eastern Visayas as per an Inquirer news report (Gabieta, 2016).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE ORAS FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data nearest the delineated priority area for Oras floodplain in Eastern Samar. These missions were planned for 17 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Error: Reference source not found. Error: Reference source not found shows the flight plan for the LiDar survey nearest Oras floodplain.

Table 1. Flight planning parameters for the Aquarius LiDAR System

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

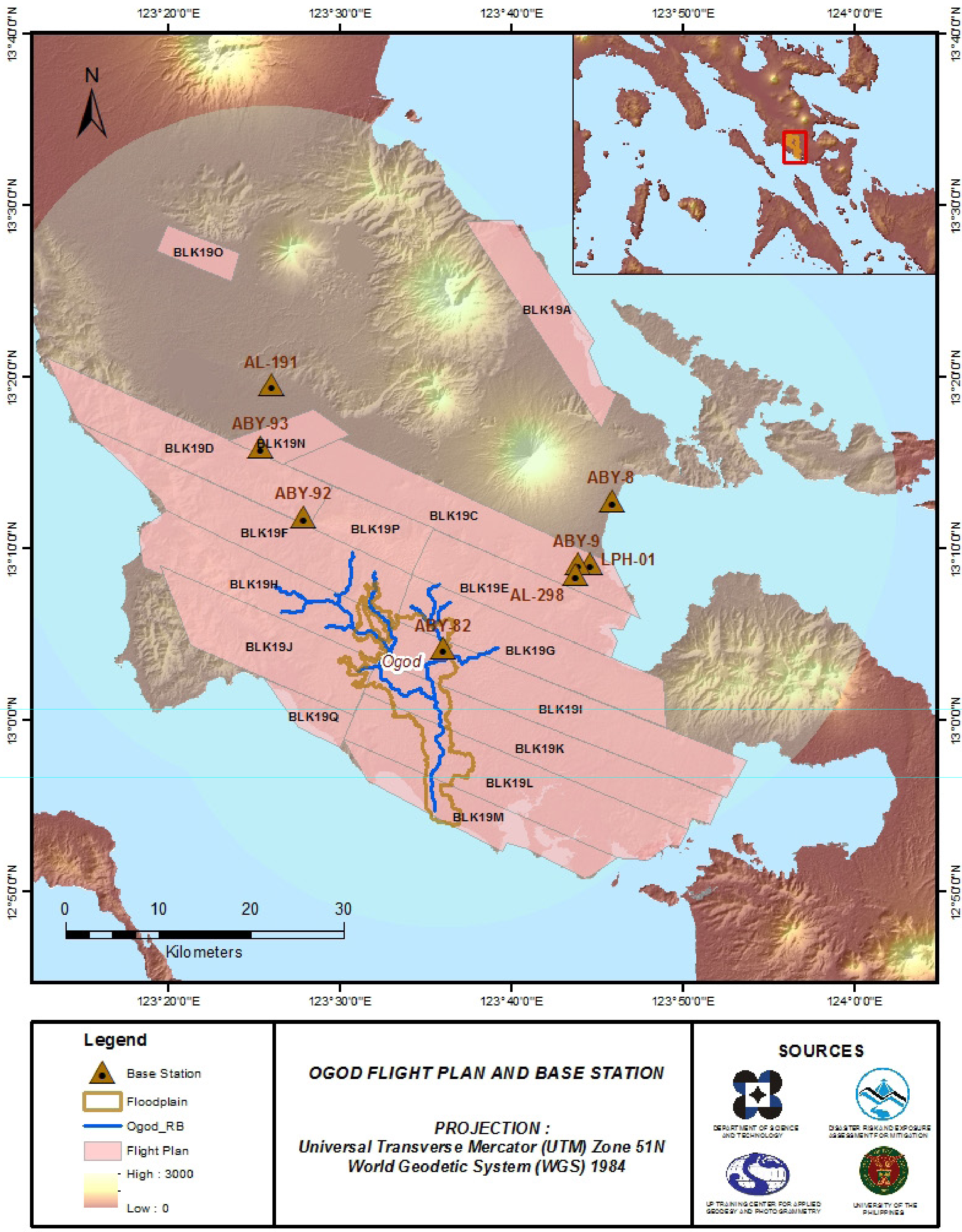


Figure 1. Flight plan and base stations used nearest Oras floodplain.

2.2 Ground Base Stations

The project team were able to recover one (1) NAMRIA horizontal ground control point, SME-3139 which is of fourth (4th) order accuracy. One (1) NAMRIA benchmark was recovered, SE-16. This 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 A-2 while the baseline processing report for the established control point is found in ANNEX A-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 nearest Oras floodplain are shown in Figure 1.

Figure 2 shows the recovered NAMRIA reference points within the area. Table 2 to Table 3 shows the details about the following NAMRIA control stations and established point, while Table 4 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

Figure 2. GPS set-up over SME-3139 located along the highway in Brgy. Sto. Nino, Oras, 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	11° 30’ 17.85657” North 125° 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	11° 30’ 13.52495” North 125° 1’ 34.96980” East 87.78700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	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	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	11° 50’ 03.05106” North 125° 26’ 03.03429” East 0.472 meters
Grid Coordinates, Universal Transverse System 1984 Datum (WGS84)	Latitude Longitude Ellipsoidal Height	11° 49’ 58.67117” North 125° 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 Oras 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 systems. 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 Oras floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
9 JUN 14	1558A	225.57	117.98	NA	117.98	98	4	41
9 JUN 14	1560A	225.57	127.54	NA	127.54	1294	3	53
TOTAL		**451.14**	**245.52**	**NA**	**245.52**	**1392**	**8**	**34**

Table 6. Actual parameters used during the LiDAR data acquisition

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)
1558A	500	30	44	50	45	120	5
1560A	500	20	44	50	45	120	5

2.4 Survey Coverage

Oras floodplain is located in the province of Eastern Samar. 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 nearest Oras floodplain is presented in Figure 3.

Table 7. List of municipalities and cities surveyed during LiDAR survey nearest Oras floodplain.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Eastern Samar	Sulat	150.05	39.95	26.63%
	San Julian	127.43	22.72	17.83%
	Borongan City	596.08	69.2	11.61%
	Taft	230.27	1.95	0.85%
Total		**1,103.83**	**133.82**	**12.12%**

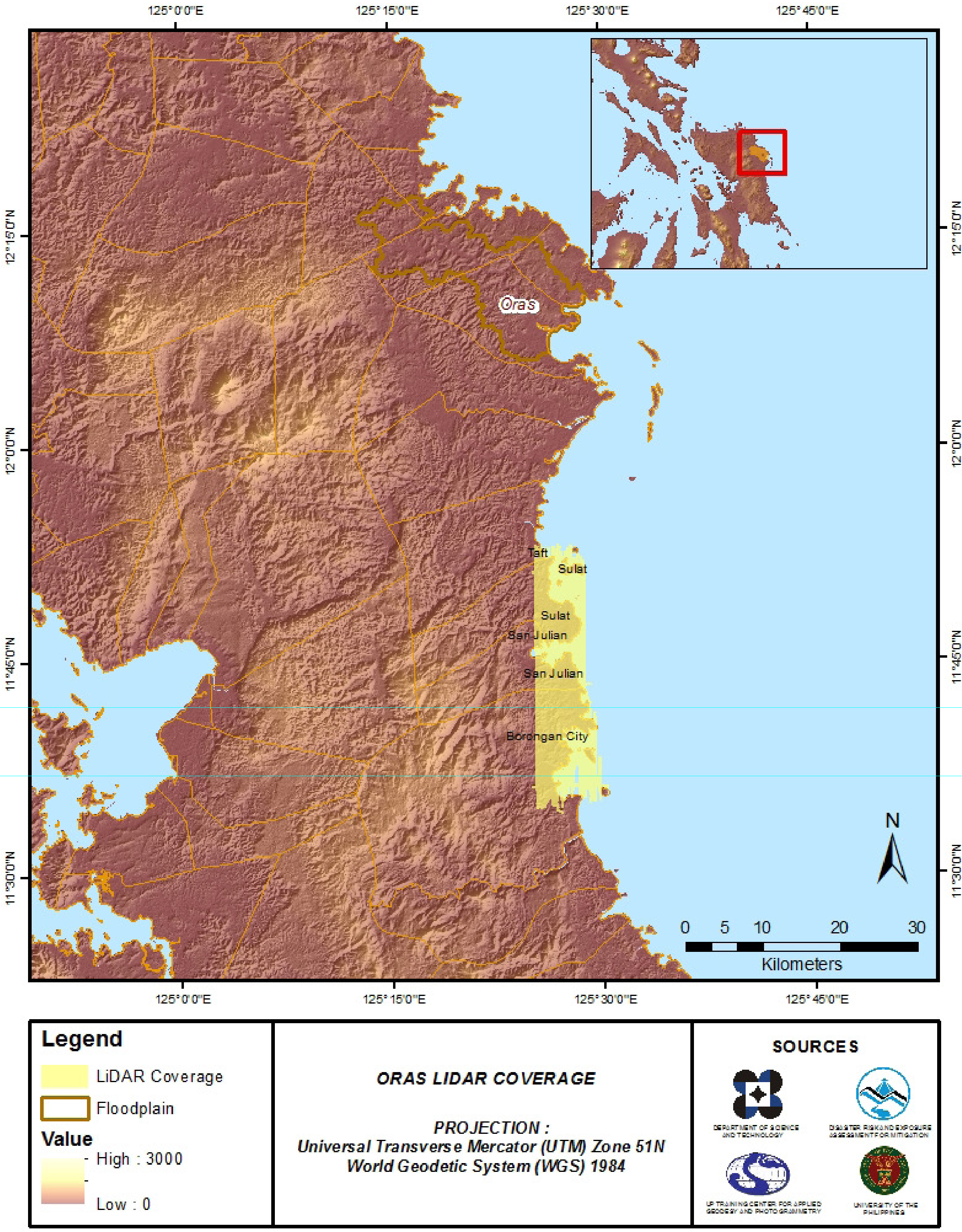


Figure 3. Actual LiDAR survey coverage nearest Oras floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE ORAS FLOODPLAIN

Engr. Ma. Ailyn L. Olanda, Engr. Chelou P. Prado, Jovy Anne S. Narisma, and Engr. Vincent Louise DL. Azucena

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

3.1 Overview of the LIDAR Data Pre-Processing

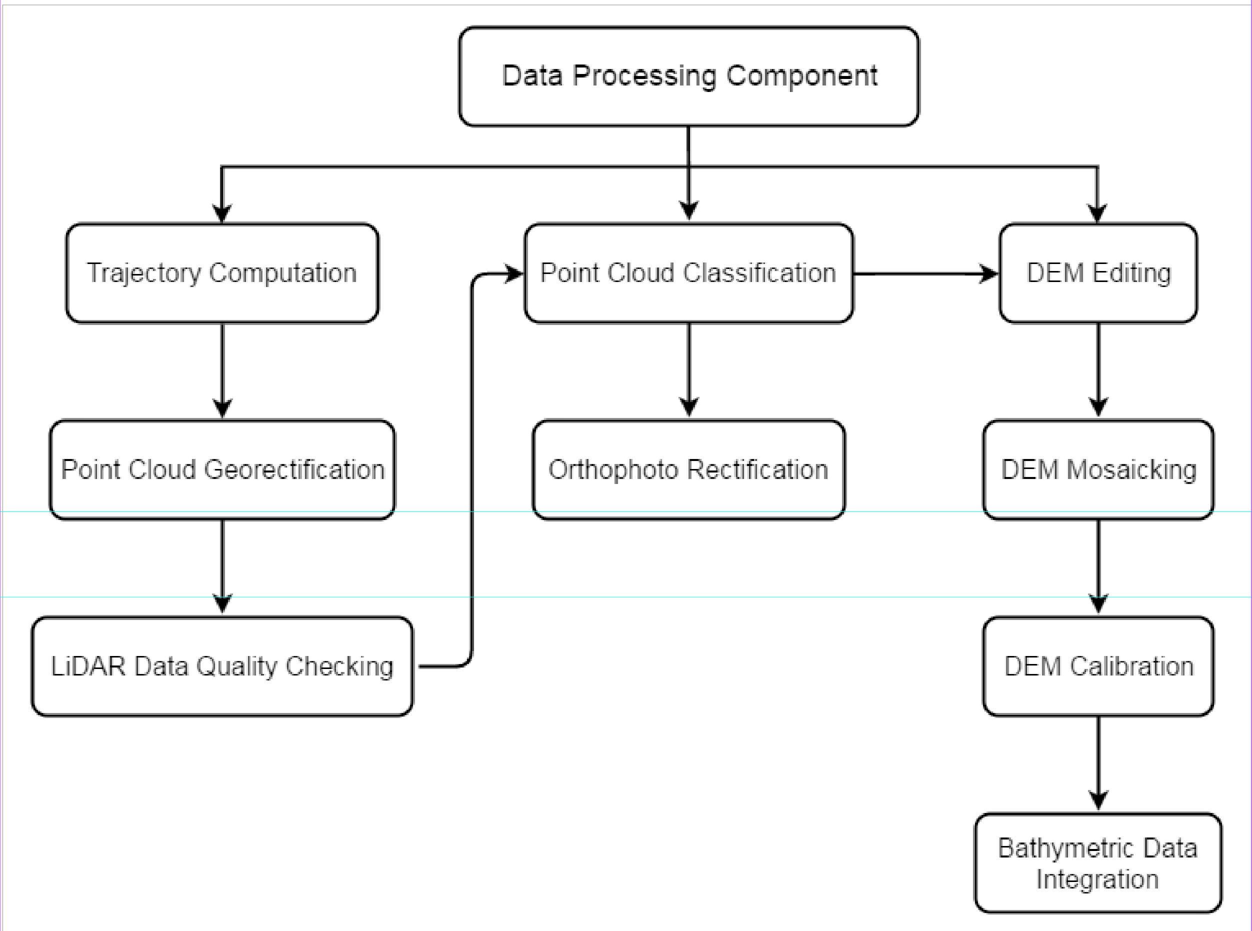


Figure 4. Schematic diagram for the Data Pre-Processing Component

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

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

These processes are summarized in the flowchart shown in Figure 4.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Oras floodplain can be found in ANNEX A-5, Data Transfer Sheets. Missions flown during the survey conducted on June 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system over Municipality of Oras, Eastern Samar. The Data Acquisition Component (DAC) transferred a total of 26.30 Gigabytes of Range data, 500 Megabytes of POS data, 32.20 Megabytes of GPS base station data, and 167.90 Gigabytes of raw image data to the data server on June 19, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Oras was fully transferred on June 19, 2014 as indicated on the Data Transfer Sheets for Oras floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1560A, one of the Oras flights, which is the North, East, and Down position RMSE values are shown in Figure 5. 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 08, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

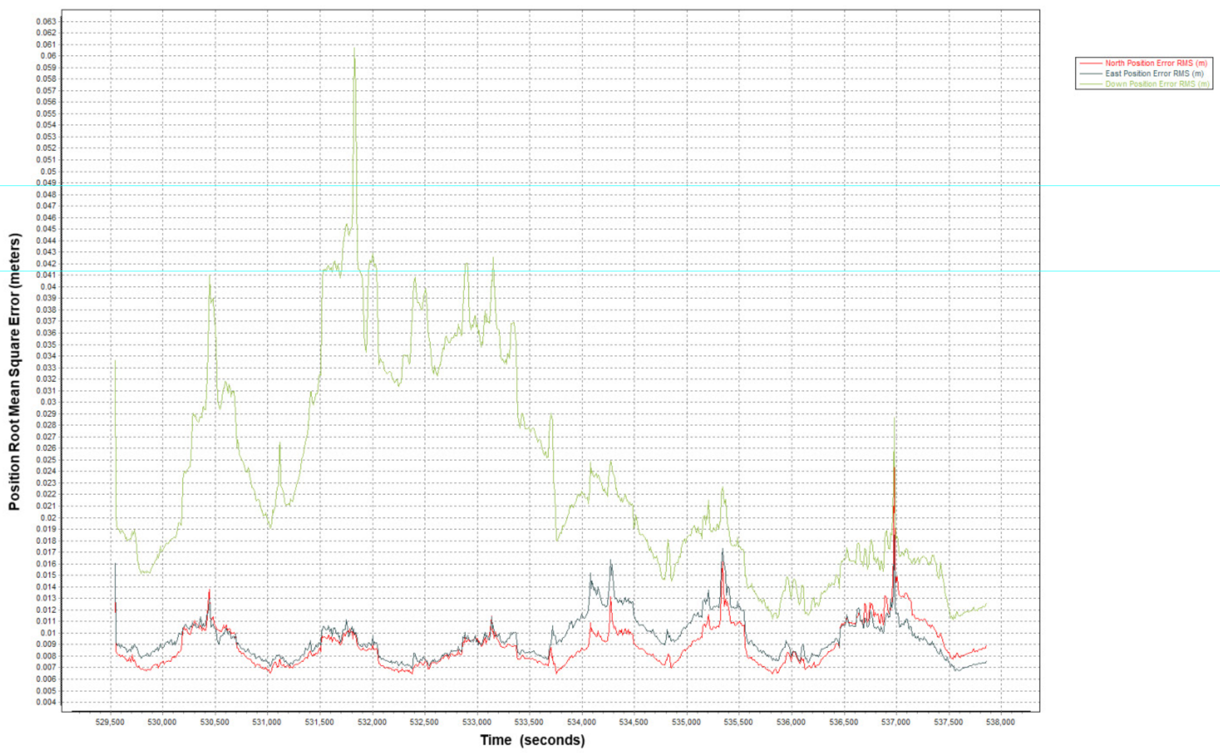


Figure 5. Smoothed Performance Metric Parameters of a Oras Flight 1560A.

The time of flight was from 529,500 seconds to 538,000 seconds, which corresponds to afternoon of June 09, 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 minimize 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 5 shows that the North position RMSE peaks at 2.44 centimeters, the East position RMSE peaks at 1.85 centimeters, and the Down position RMSE peaks at 6.08 centimeters, which are within the prescribed accuracies described in the methodology.

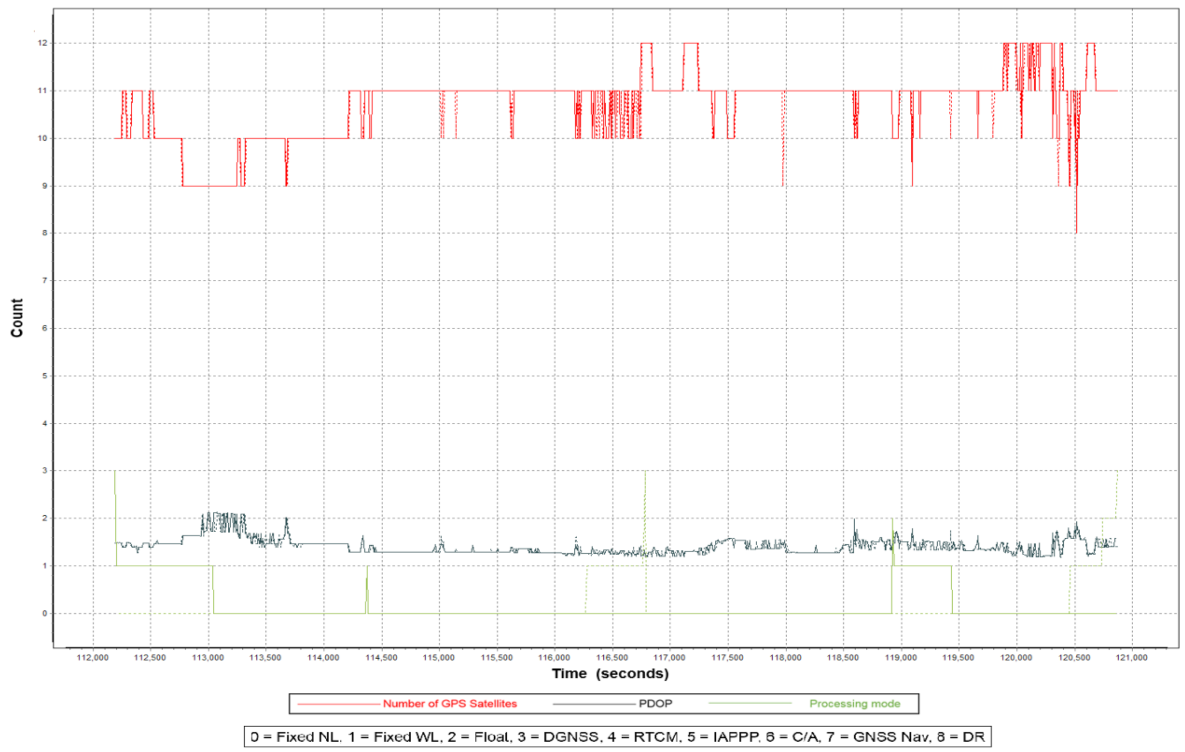


Figure 6. Solution Status Parameters of Oras Flight 1560A.

The Solution Status parameters of flight 1560A, one of the Oras flights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used, are shown in Figure 6. The graphs indicate that the number of satellites during the acquisition did not go down below 8. Majority of the time, the number of satellites tracked was between 10 and 11. The PDOP value also did not go above the value of 3, which still indicates optimal GPS geometry. The processing mode stayed at the value of 0 for almost the entire survey time with some sudden peaks go beyond 1 attributed to the turn 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 Oras flights is shown in Figure 7.

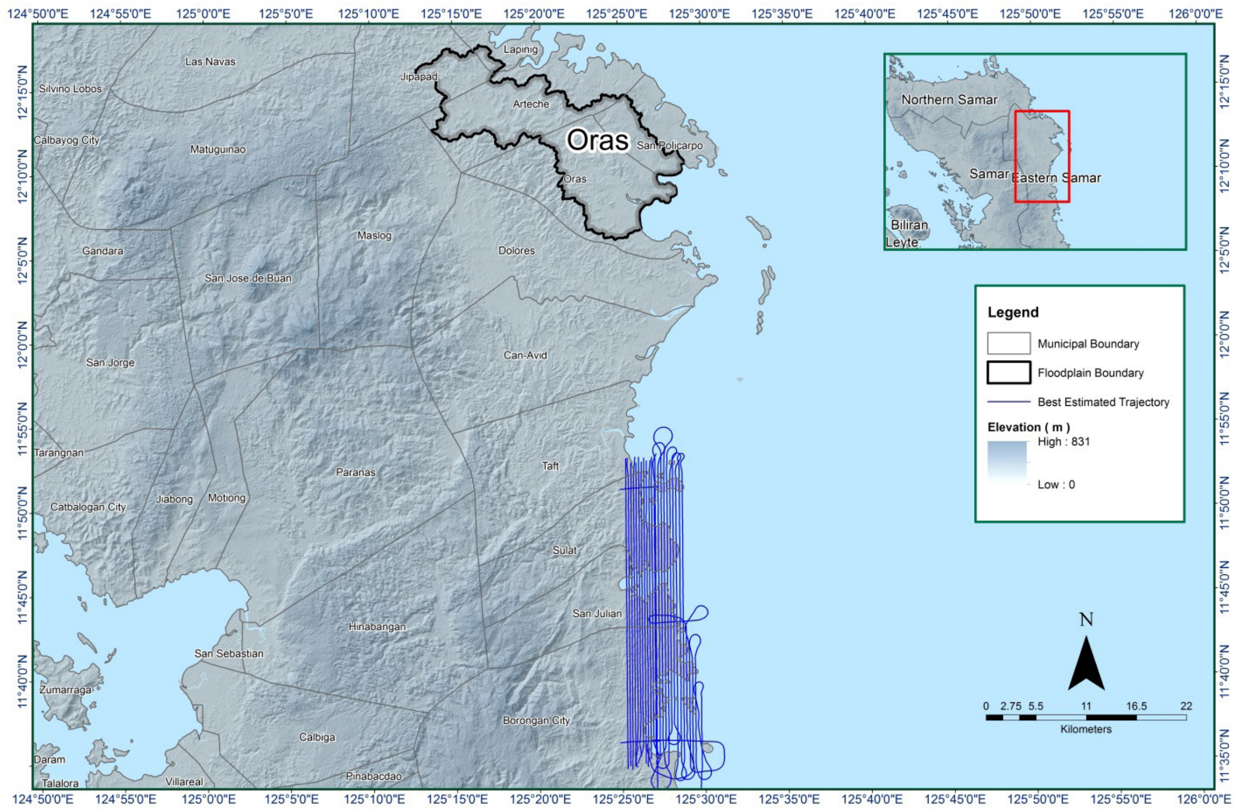


Figure 7. Best Estimated Trajectory for Oras floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 28 flight lines, with each flight line containing one (2) channel, since the Aquarius system contains one channel. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Oras floodplain are given in Table 8.

Table 8. Self-calibration results for the Oras flights

Parameter		Acceptable 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 Oras flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the ANNEX B-1. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Oras Floodplain is shown in Figure 8. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

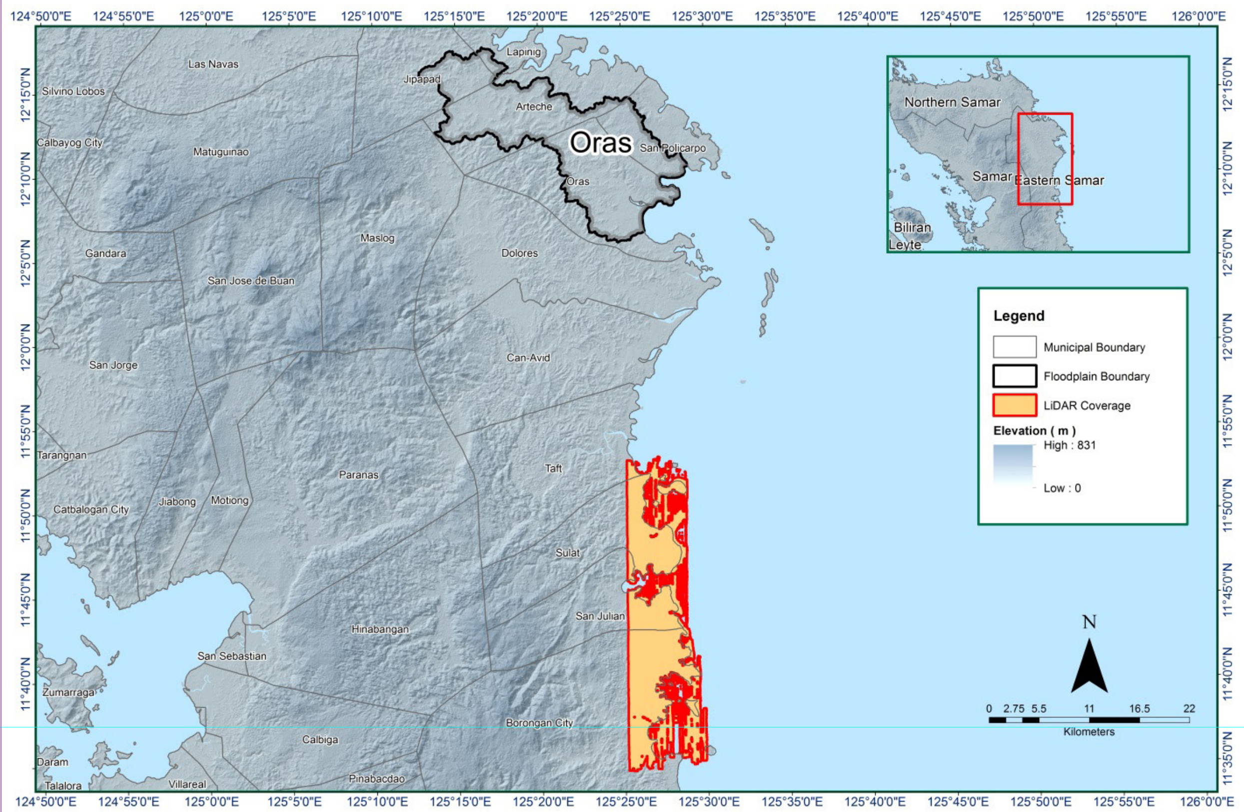


Figure 8. Boundary of the processed LiDAR data over Oras Floodplain

The total area covered by the Oras missions is 174.99 sq.km that is 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 the Oras floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk33J	1558A	174.99
	1560A	
TOTAL		**174.99**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 9. 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.

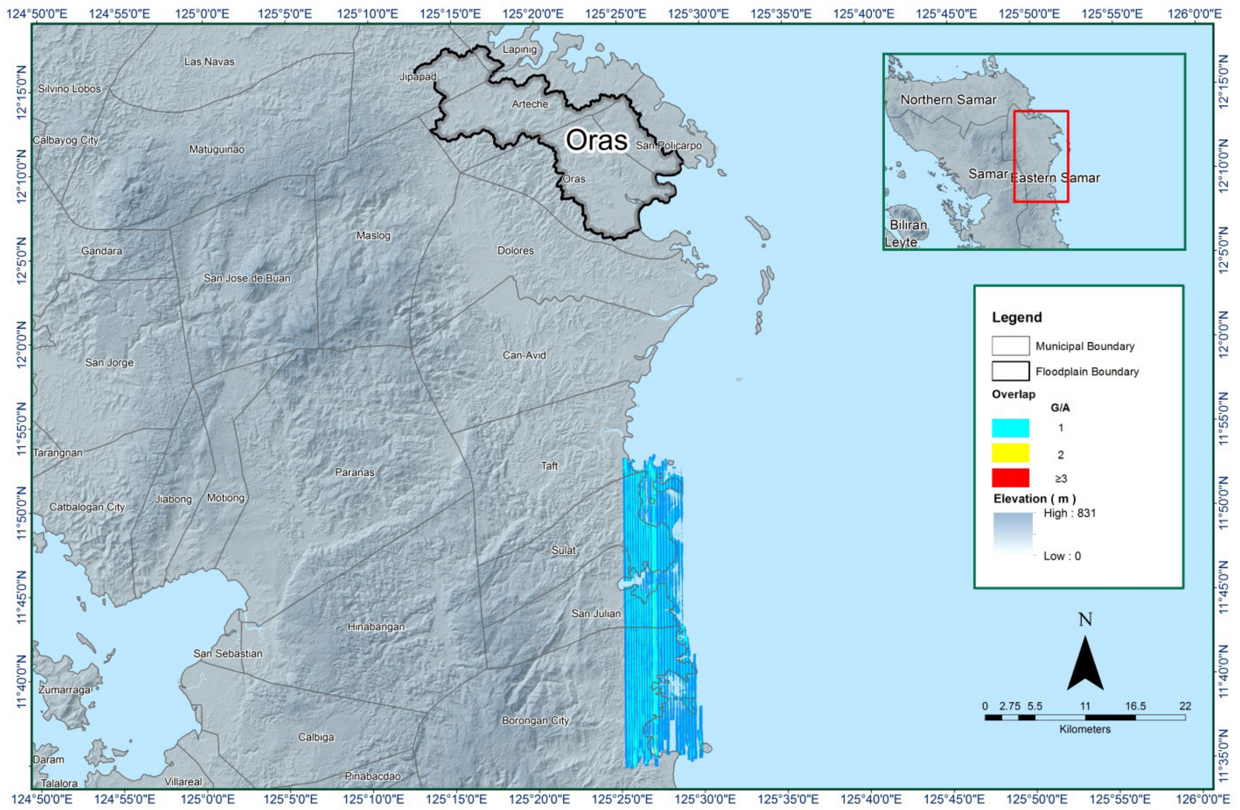


Figure 9. Image of data overlap for Oras floodplain.

The overlap statistics per block for the Oras floodplain can be found in ANNEX B-1. Mission Summary Reports. It should be noted that 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 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 10. It was determined that all LiDAR data for Oras floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.71 points per square meter.

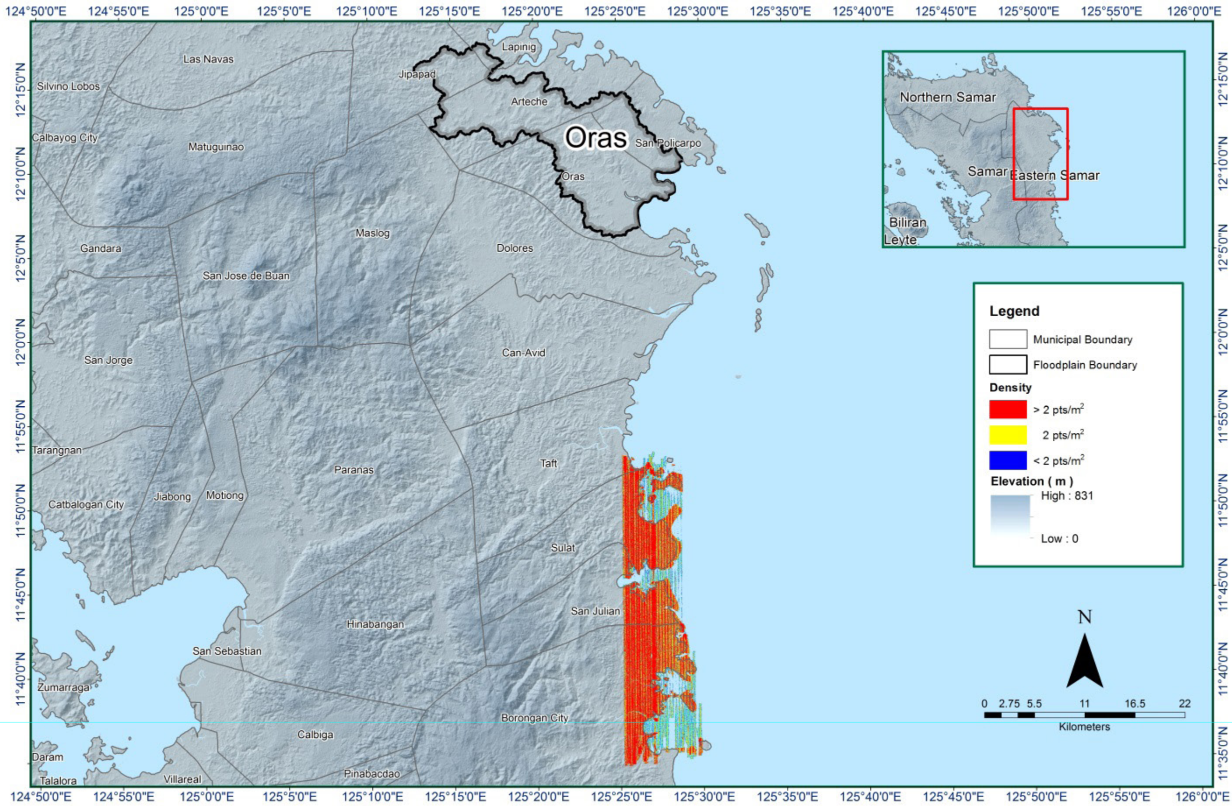


Figure 10. Density map of merged LiDAR data for Oras floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 11. 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.

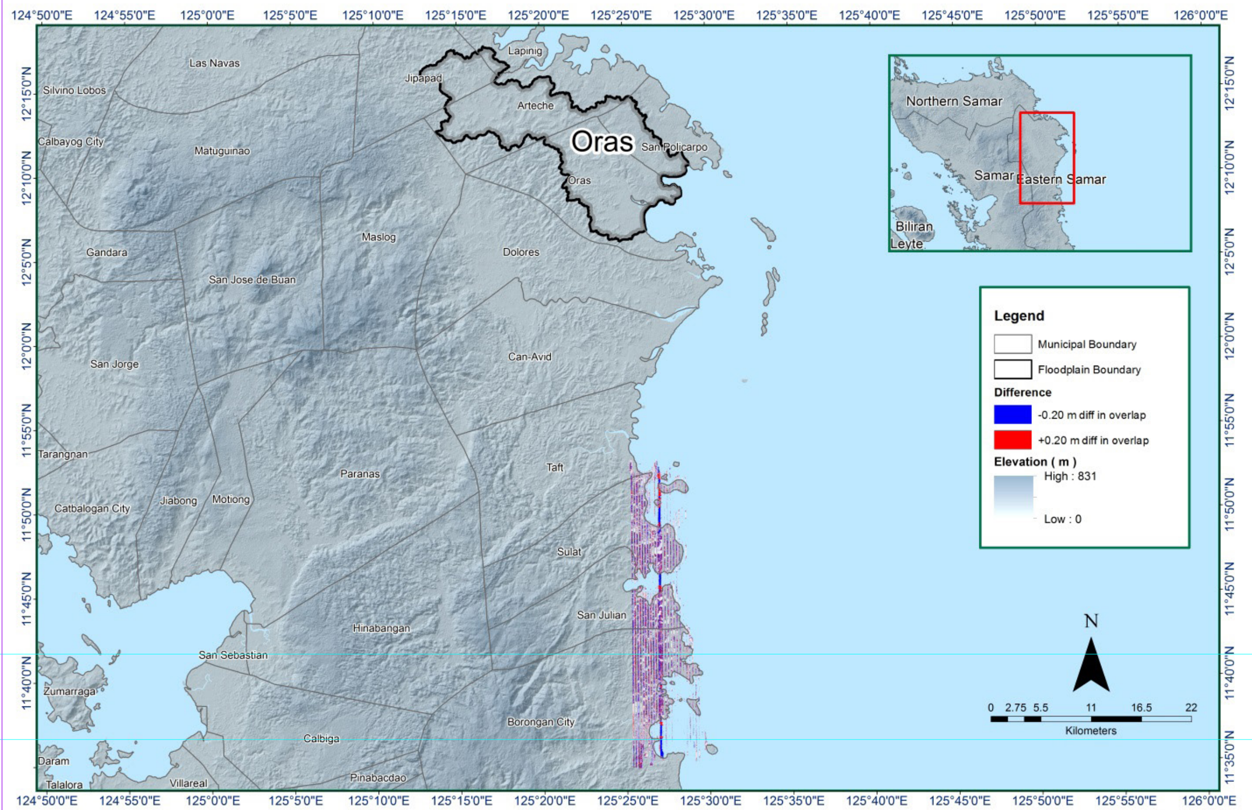


Figure 11. Elevation difference map between flight lines for Oras floodplain.

A screen capture of the processed LAS data from a Oras flight 1560A loaded in QT Modeler is shown in Figure 12. 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.

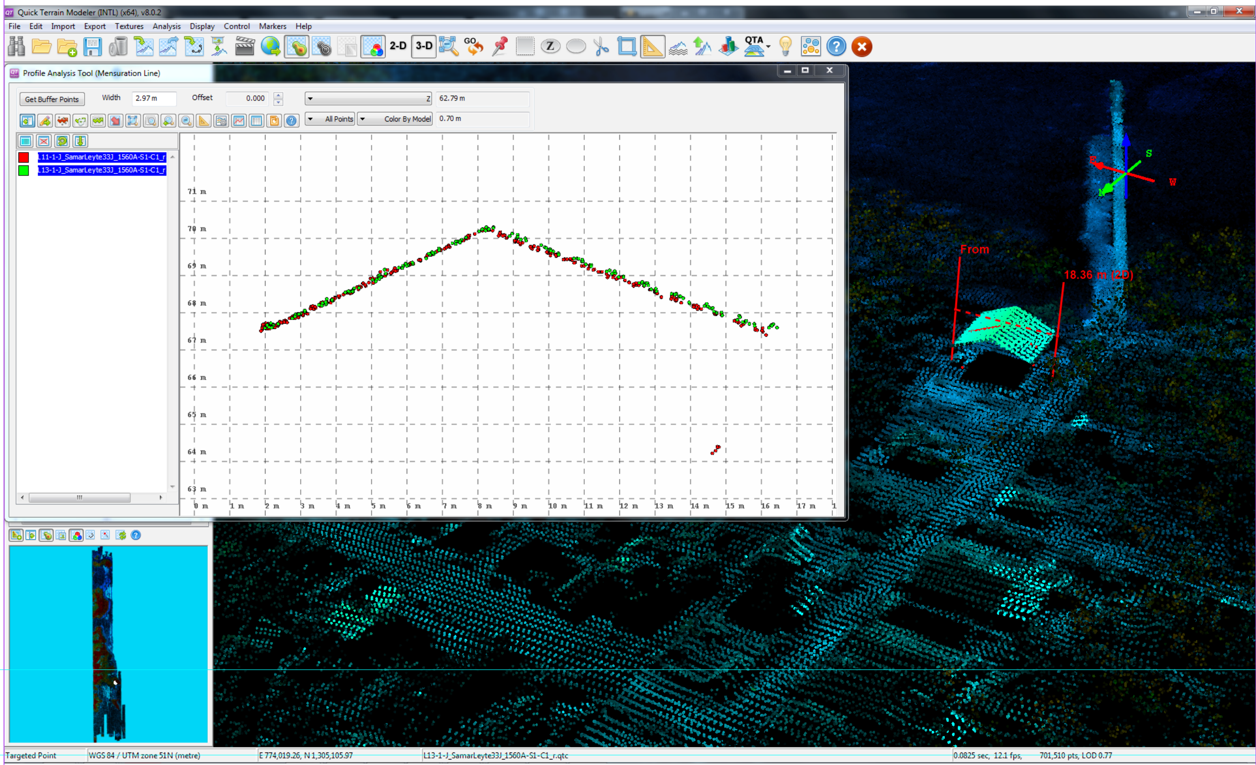


Figure 12. Quality checking for a Oras flight 1560A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Oras 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 Oras floodplain is shown in Figure 13. 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.

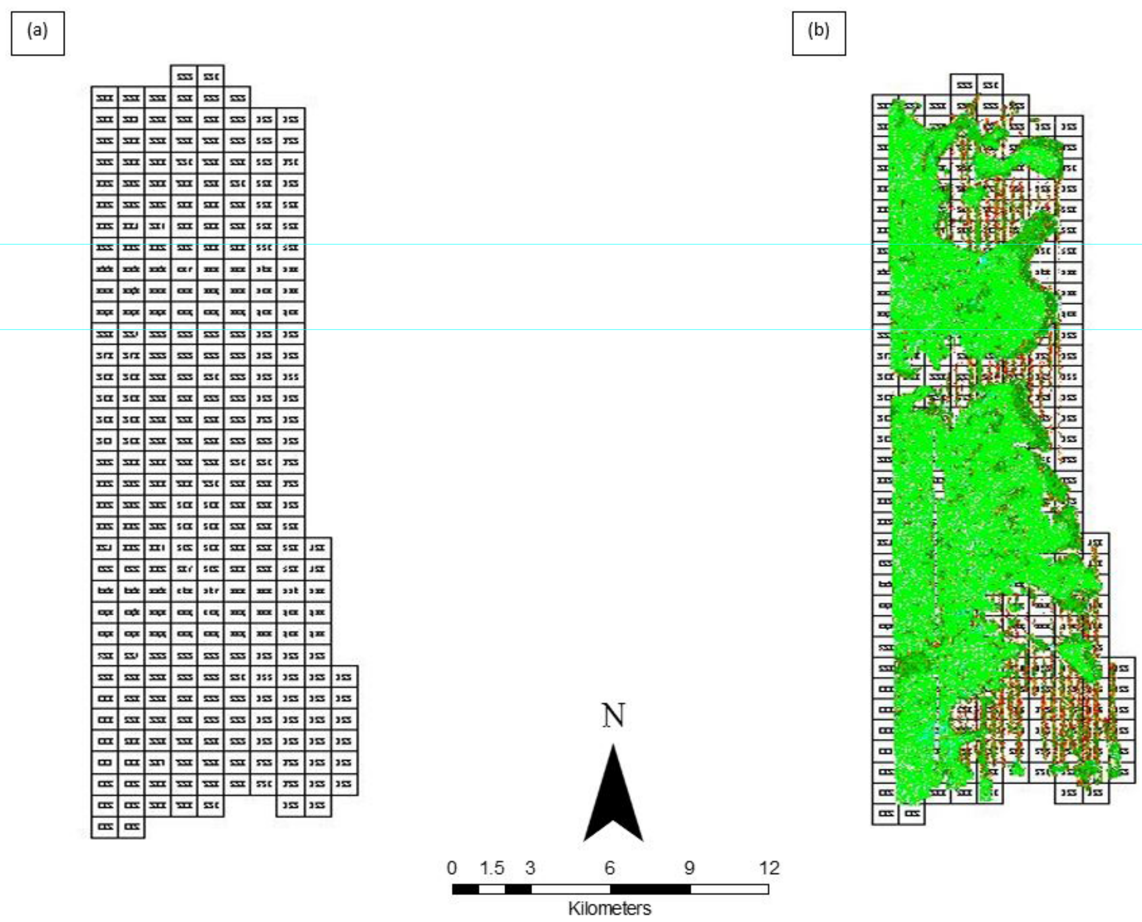


Figure 13. Tiles for Oras floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is evident that residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

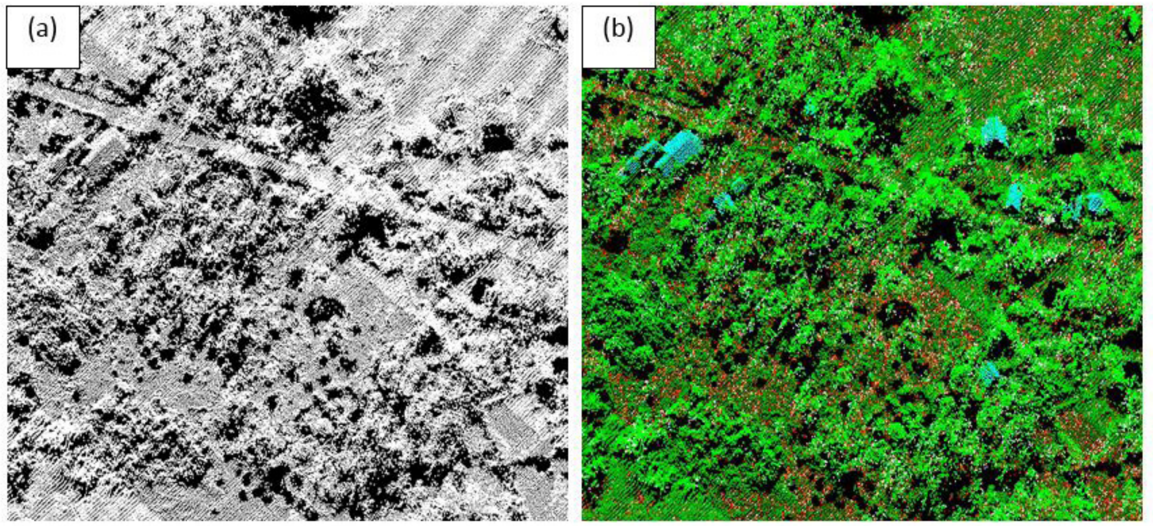


Figure 14. Point cloud before (a) and after (b) classification.

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

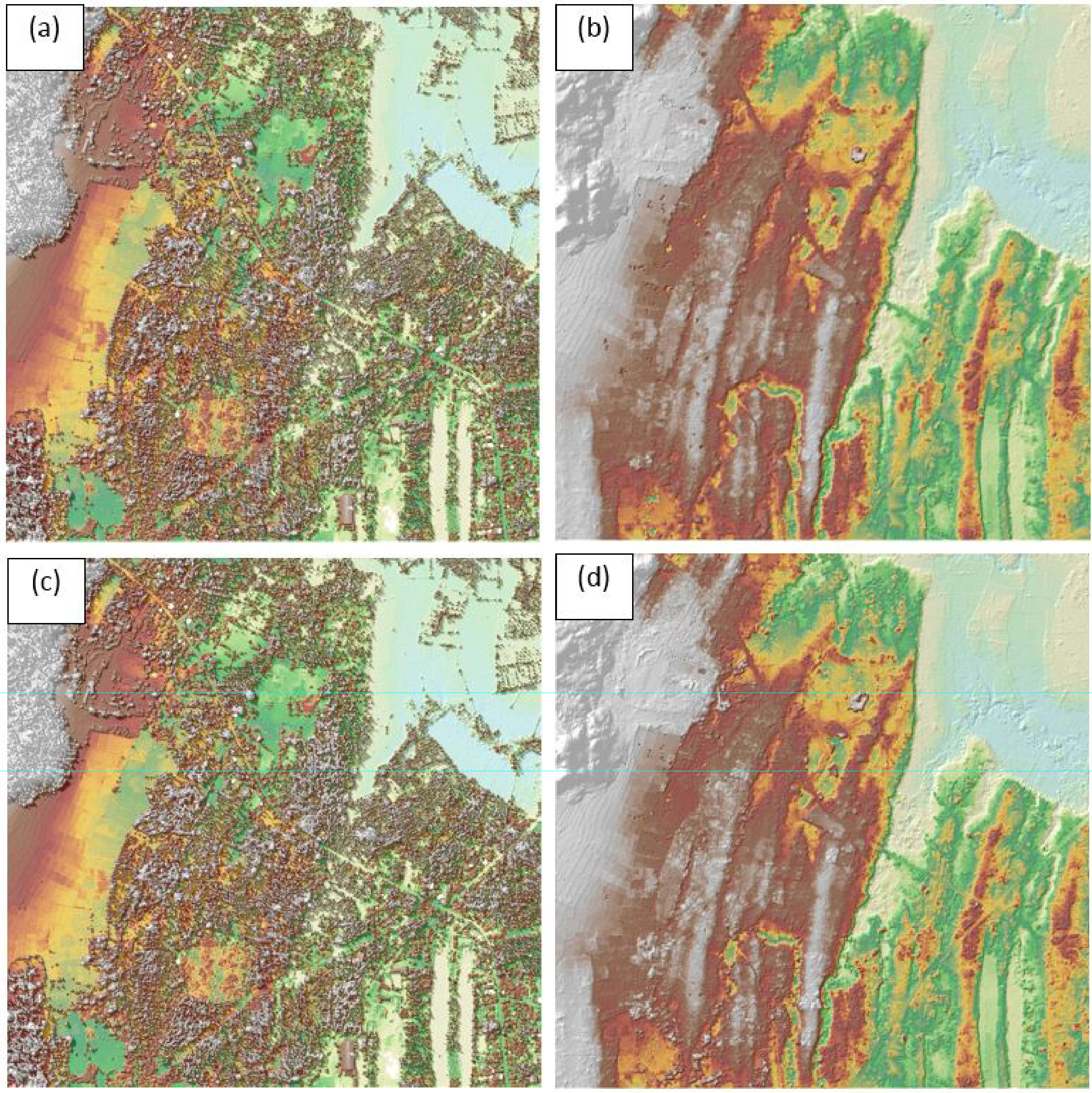


Figure 15. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion near Oras floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 273 1km by 1km tiles of the block covering the Oras floodplain is shown in Figure 16. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The block covering the Oras floodplain has a total of 219.66 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 Oras floodplain. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 17.

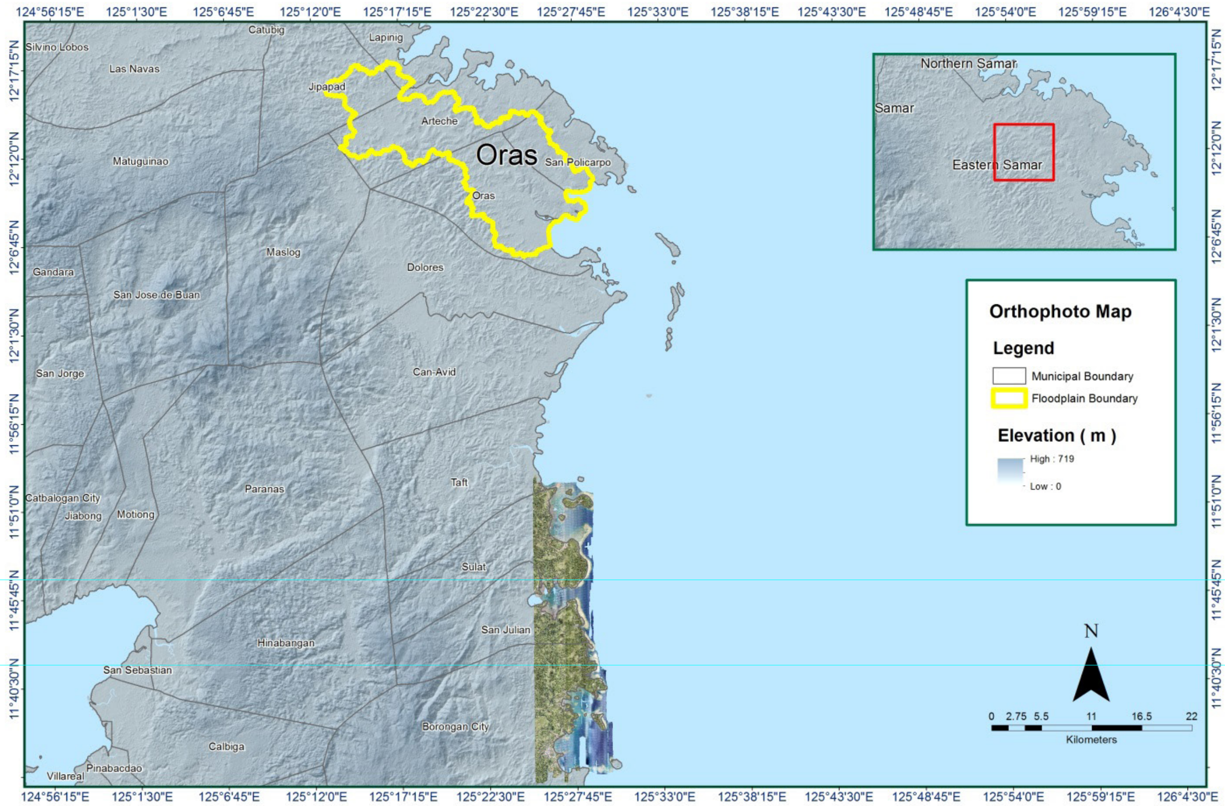


Figure 16. Available orthophotographs near Oras floodplain.

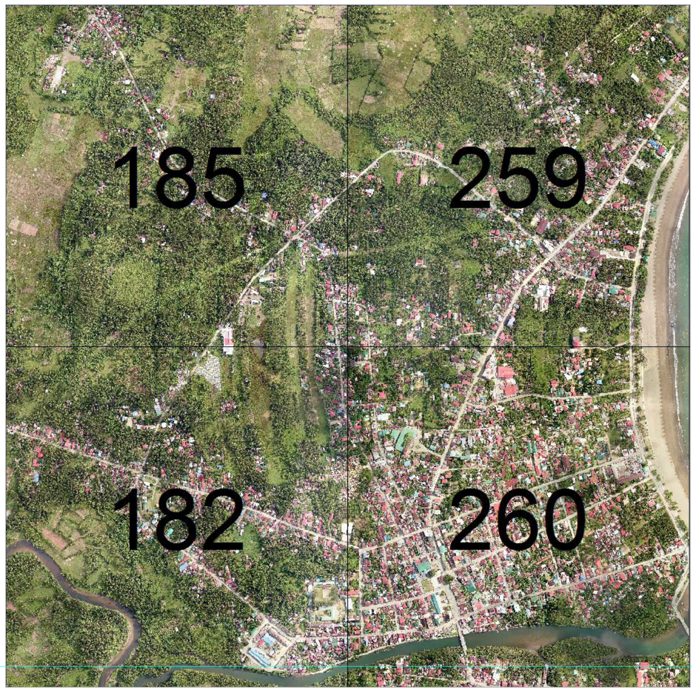


Figure 17. Sample orthophotograph tiles near Oras floodplain.

3.8 DEM Editing and Hydro-Correction

SamarLeyte_Blk33J is the nearby block to the Oras floodplain. It was processed in order to produce DEMs covering municipalities neighboring the Oras floodplain. It has an area of 174.99 square kilometers. Table 11 shows the LiDAR block/s and their corresponding area 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 18. The bridge (Figure 18a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 18b) in order to hydrologically correct the river. The paddy field (Figure 18c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 18d) to allow the correct flow of water.

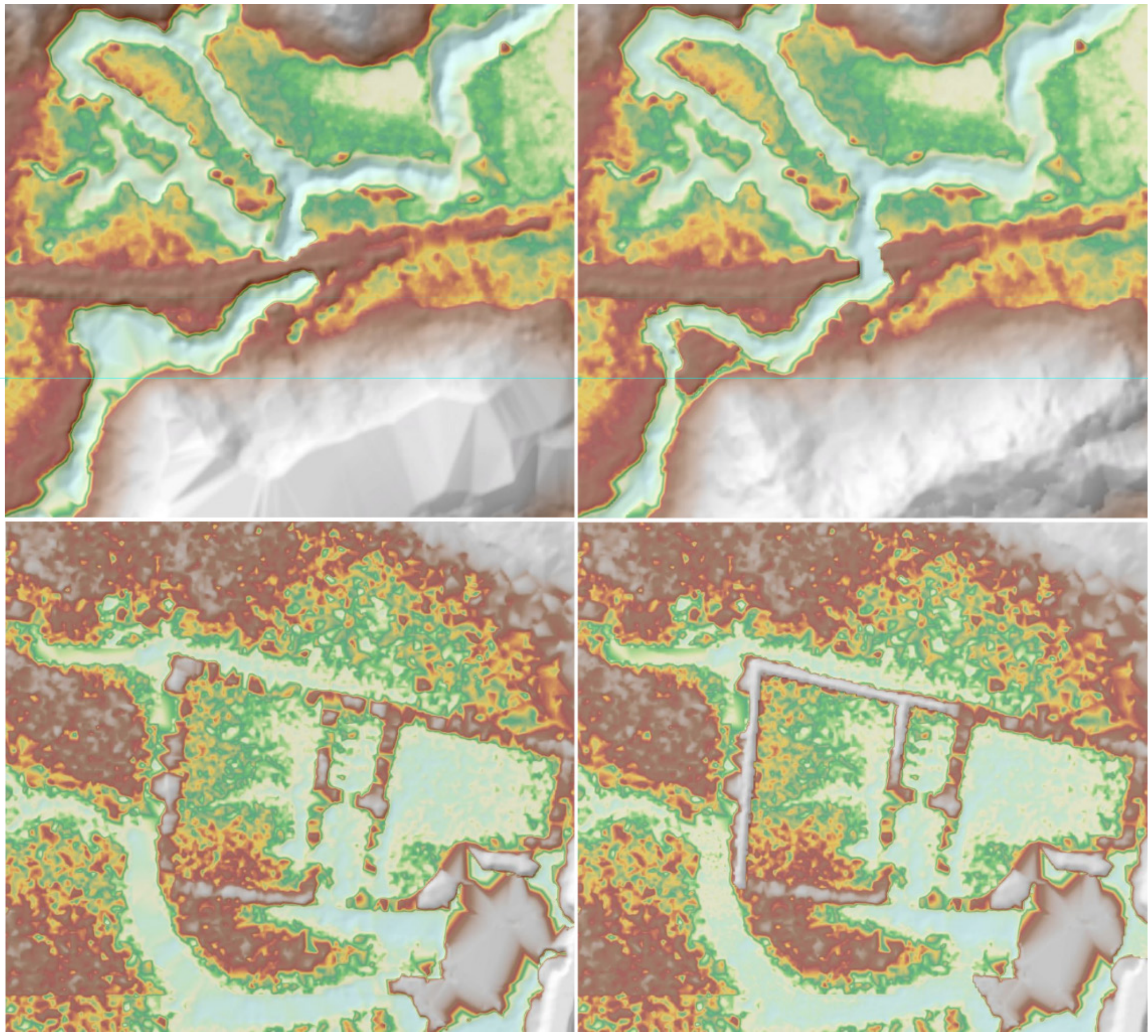


Figure 18. Portions in the DTM of Oras floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (a) and after (b) manual editing.

3.9 Mosaicking of Blocks

The IFSAR data covering all flood plains located in Eastern Samar such as Ulot, Oras and Oras and the processed LiDAR data Samar Leyte Blk 33J were mosaicked to the calibrated Tacloban LiDAR data. Table 12 shows the shift values applied to the LiDAR/IFSAR during mosaicking.

IFSAR data for Oras flood plain is shown in Figure 19.

Table 12. Shift Values of each IFSAR Block of Oras floodplain and the nearby LiDAR Block.

Mission Blocks	Shift Values (meters)		
	x	y	z
4025-III-5,10,15,20	0.09	-1.37	-1.00
4025-I-16-18, 21-25	0.56	1.72	-1.00
4025-II-1-5,6-10,11-15,16-20	0.09	-2.12	-1.00
4025-IV-20,25	0.56	-1.21	-1.00
SamarLeyte_Blk33J	-1.00	2.00	-1.00

Figure 19. Map of IFSAR Data for Oras Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Oras to collect points with which the LiDAR dataset is validated is shown in Figure 20. A total of 11,683 survey points were gathered for the Oras flood plain. However, the point dataset was not used for the calibration of the LiDAR data for Oras because during the mosaicking process, the IFSAR data covering Eastern Samar was referred to the calibrated Tacloban DEM. Therefore, the IFSAR DEM of Oras 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 21. 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 B-6 shows the statistical values of the compared elevation values between Tacloban LiDAR data and calibration data. These values were also applicable to the Oras DEM.

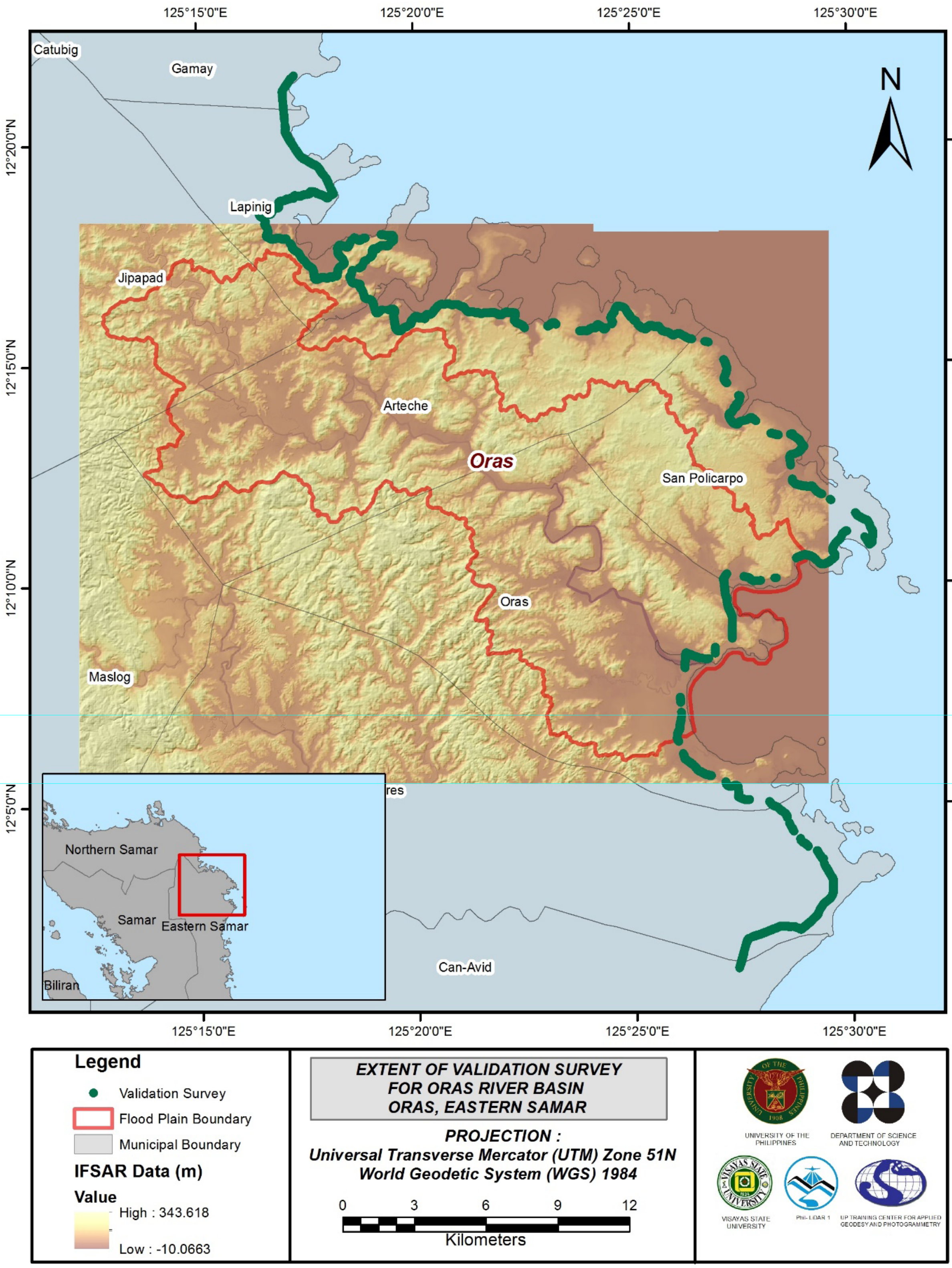


Figure 20. Map of Oras Flood Plain with validation survey points in green.

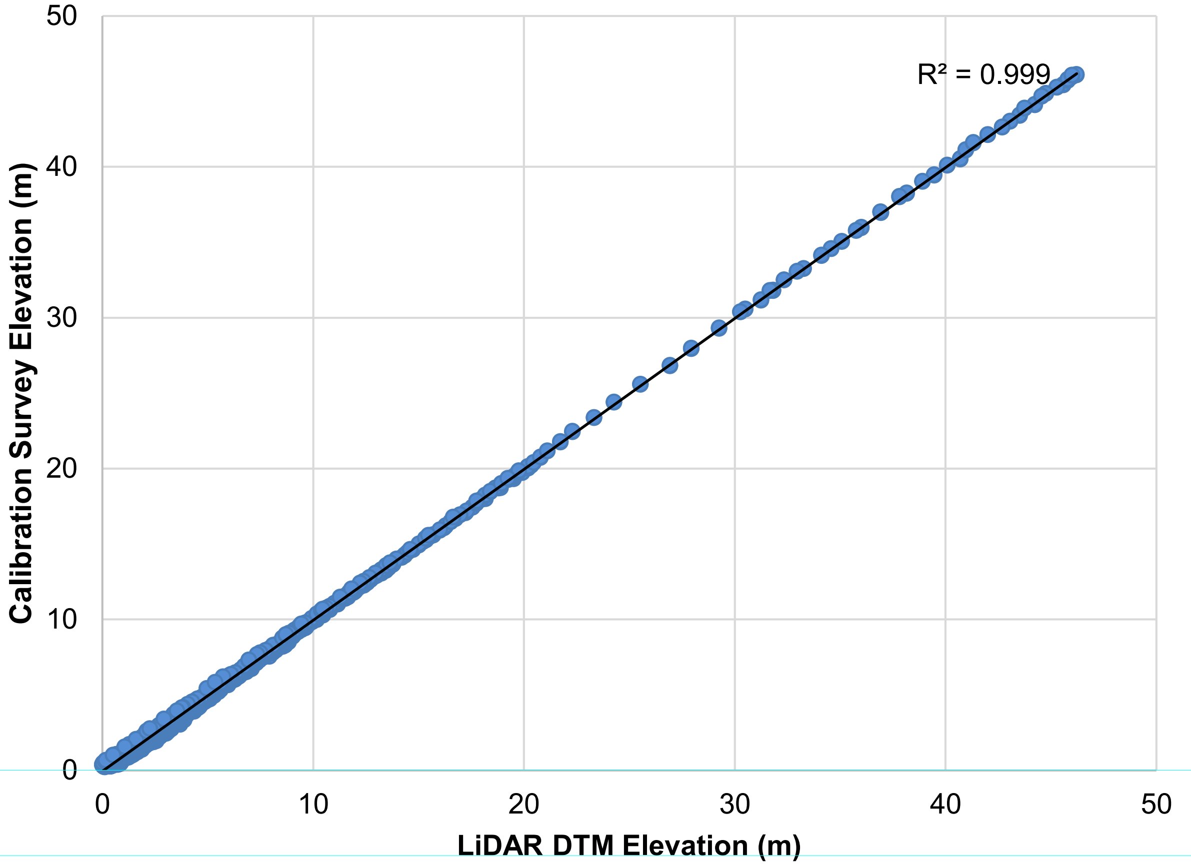


Figure 21. Correlation plot between calibration survey points and LiDAR data.

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 285 survey points were used for the validation of the calibrated Oras DTM. A good correlation between the calibrated mosaicked IFSAR elevation values and the ground survey elevation, which reflects the quality of the IFSAR DTM is shown in Figure 22. The computed RMSE between the calibrated IFSAR DTM and validation elevation values is 1.08 meters with a standard deviation of 0.85 meters, as shown in Table 14.

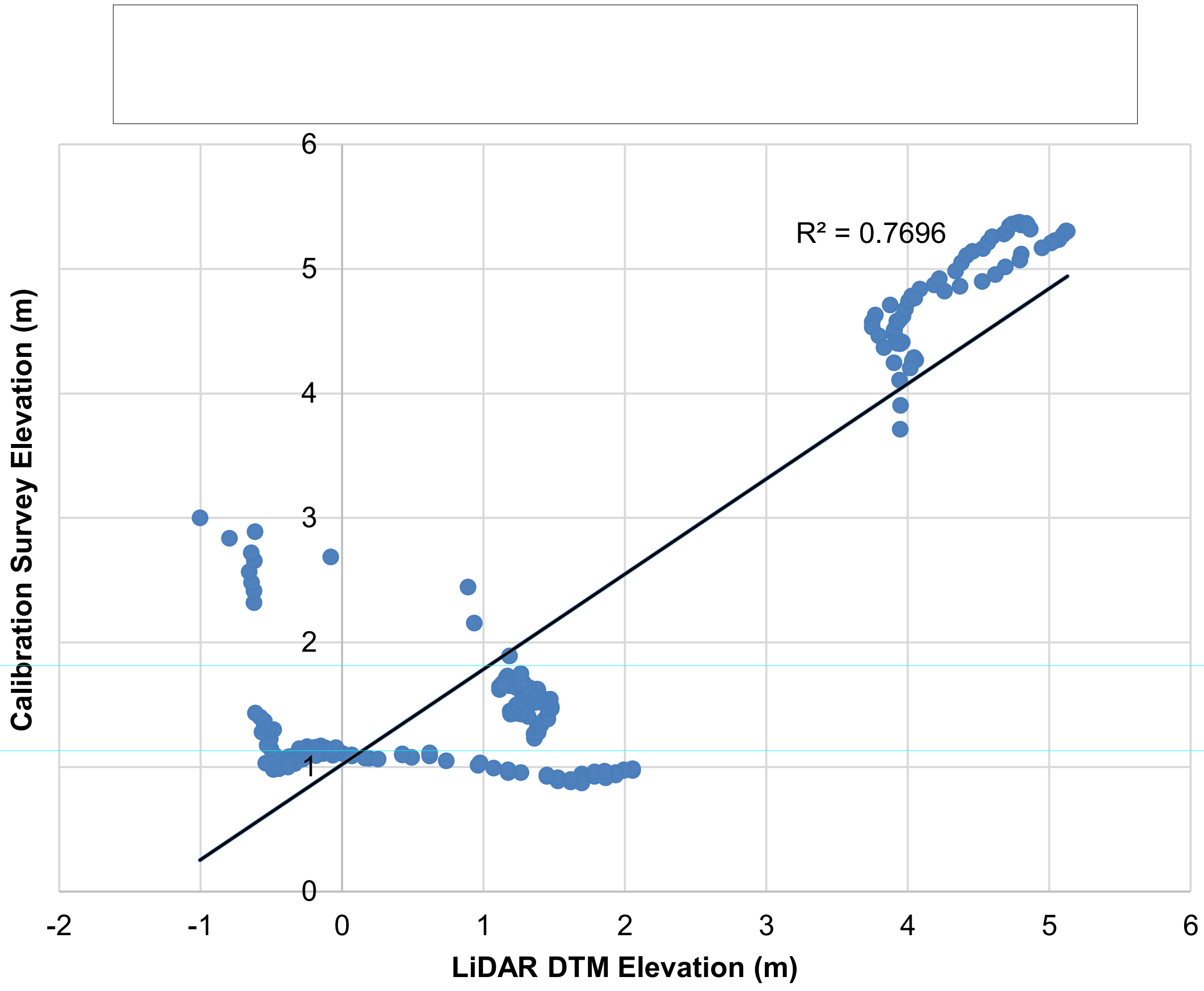


Figure 22. Correlation plot between validation survey points and IFSAR data.

Table 14. Validation statistical measures

Calibration Statistical Measures	Value (meters)
RMSE	1.08
Standard Deviation	0.85
Average	0.66
Minimum	-1.08
Maximum	4.00

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 are the available data for Oras with 9,003 bathymetric survey points. The resulting raster surface was obtained using the 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 0.50 meters. The extent of the bathymetric data surveyed by the Data Validation and Bathymetry Component (DVBC) in Oras integrated with the processed IFSAR DEM is shown in Figure 23.

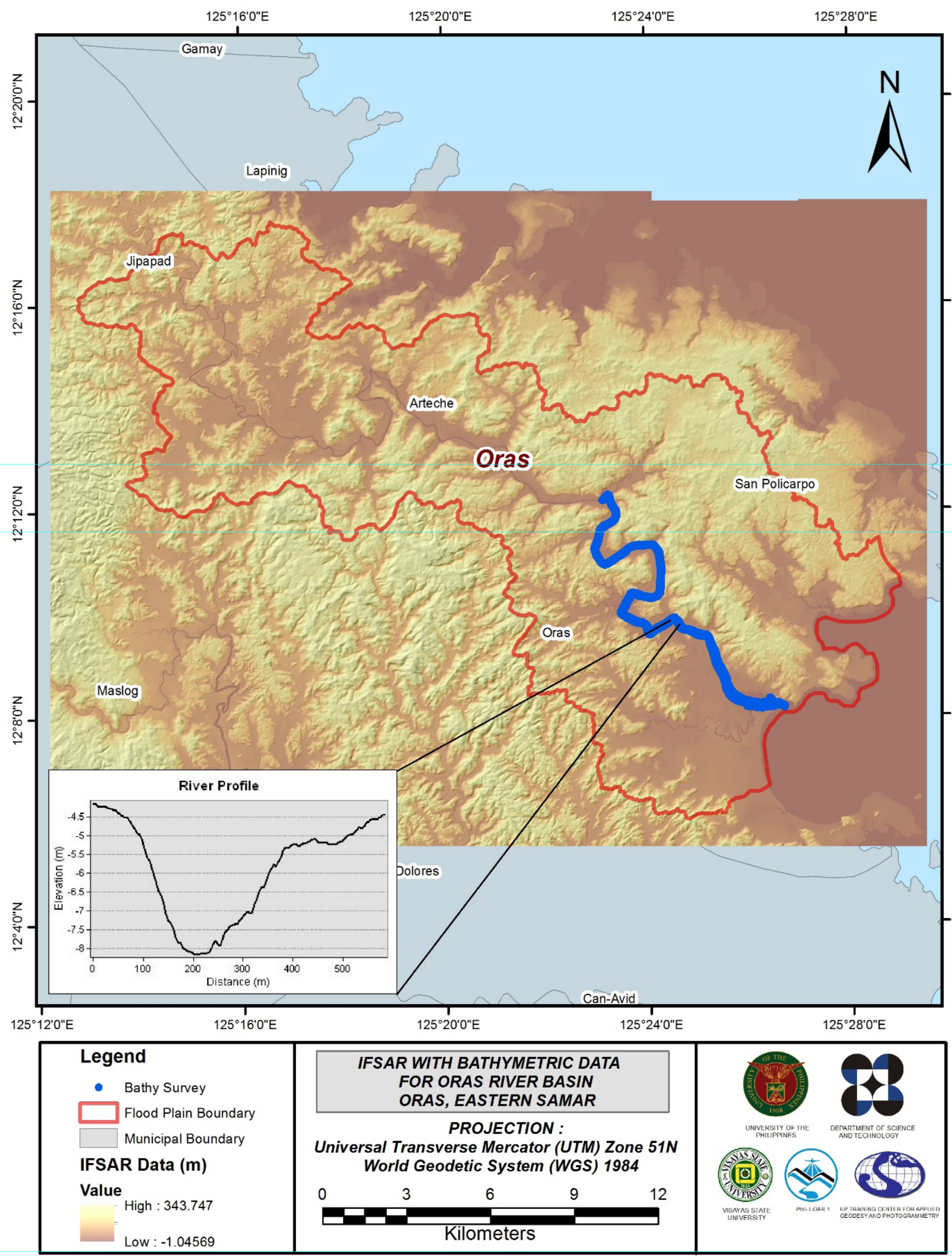


Figure 23. Map of Oras Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Due to unavailability of LiDAR data in Oras floodplain, Google Earth images taken on March 22 and May 19, 2015 were used as bases for the extraction of exposed features.

Oras floodplain, including its 200 m buffer, has a total area of 276.03 sq km. Figure 24 shows the extent of the floodplain with buffer (in white) and the extracted building features (in red).

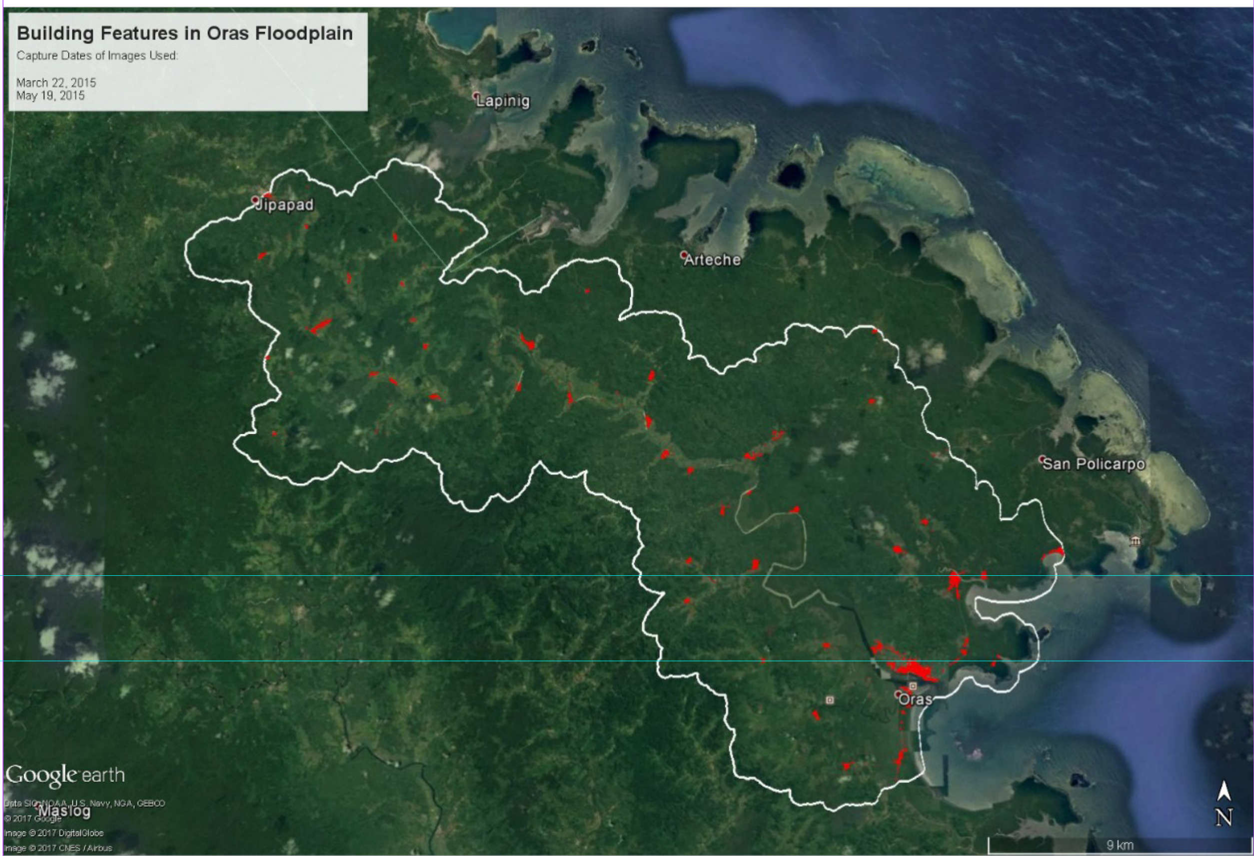


Figure 24. Oras building features extracted from Google Earth images.

3.12.1 Feature Attribution

For feature attribution, the digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. Error: Reference source not found summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Error: Reference source not found shows the number of water features extracted per type.

Table 15. Building Features Extracted for Oras Floodplain.

Facility Type	No. of Features
Residential	13,177
School	261
Market	18
Agricultural/Agro-Industrial Facilities	7
Medical Institutions	22
Barangay Hall	25
Military Institution	0
Sports Center/Gymnasium/Covered Court	7
Telecommunication Facilities	0
Transport Terminal	2
Warehouse	21
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	2
Religious Institutions	27
Bank	0
Factory	0
Gas Station	4
Fire Station	1
Other Government Offices	15
Other Commercial Establishments	63
Total	**13,655**

Table 16. Total Length of Extracted Roads for Oras Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Oras	75.53	5.16	0.00	13.42	0.00	**94.11**

Table 17. Number of Extracted Water Bodies for Oras Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Oras	104	0	0	0	0	**104**

A total of 12 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.2 Final Quality Checking of Extracted Features

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

Error: Reference source not found5 shows the Interferometric Synthetic Aperture Radar Digital Elevation Model (IFSAR DEM) of Oras floodplain overlaid with its ground features.

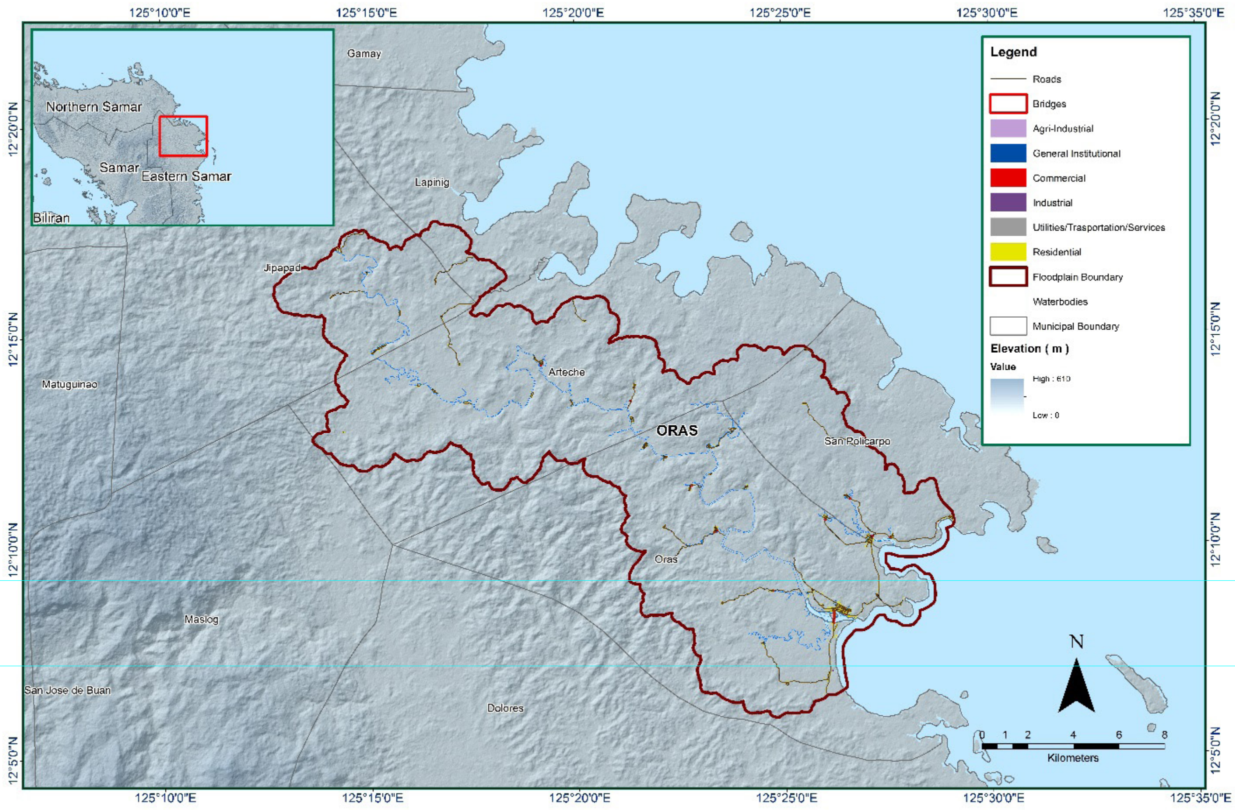


Figure 25. Extracted features for Oras floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, Engr. Bernard Paul D. Maramot, Engr. Precious Annie C. Lopez, Mr. Jann Russell J. Manzano

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

4.1 Summary of Activities

The H.O. Noveloso Surveying (HONS) conducted a field survey in Oras River on Dec. 10 and 12, 2016, Feb. 3, 7, and 9, 2017 with the following scope: reconnaissance; control survey; cross-section and as-built survey at Oras Bridge in Brgy. Balocawe, Oras, Eastern Samar; and bathymetric survey of the river from the upstream in Brgy. Cadian, Oras to the mouth of the river in Brgy. Balocawe, Oras, Eastern Samar with an approximate length of 16.5 km. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on January 27 – February 9, 2017 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 985 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Oras River Basin area. The entire survey extent is illustrated in Figure 26.

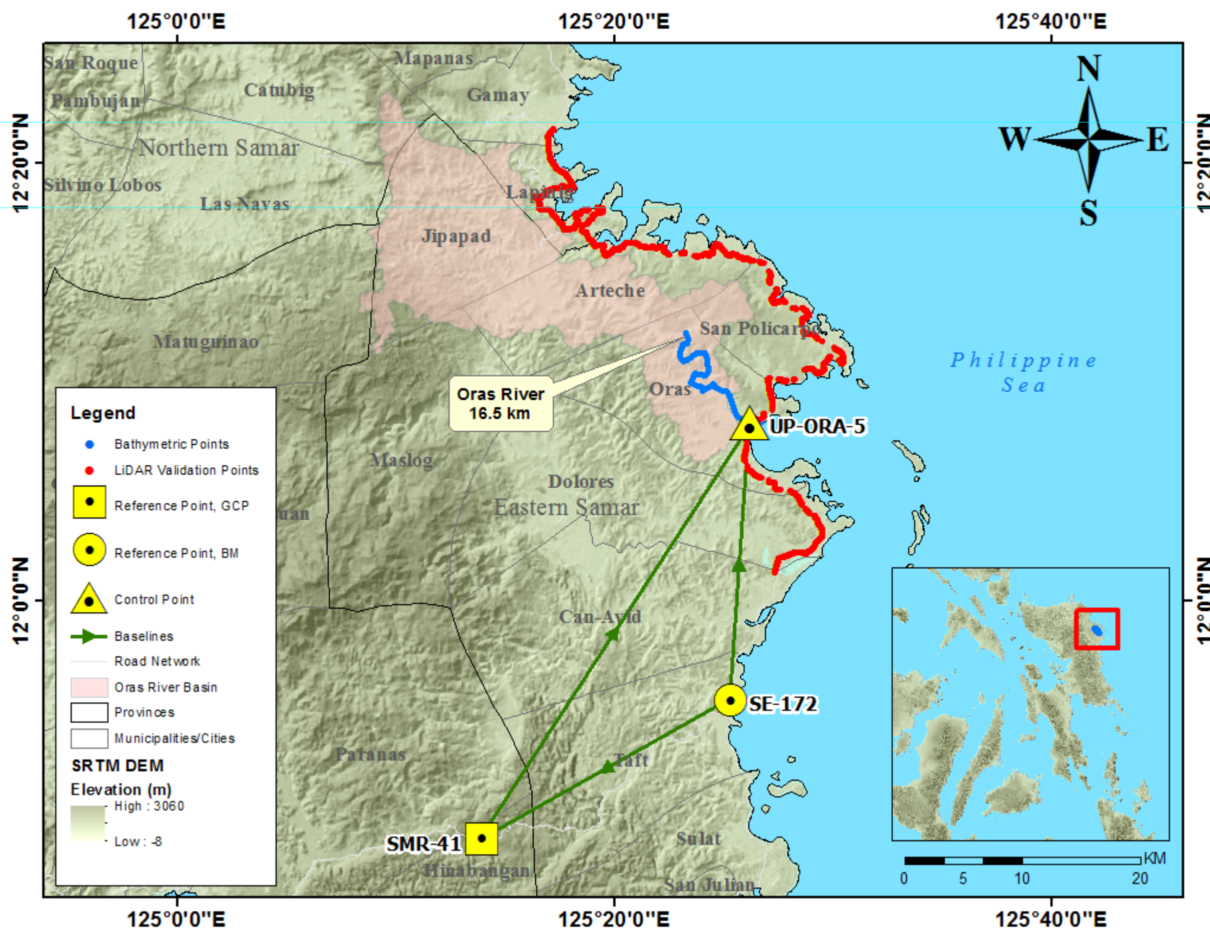


Figure 26. Oras River Survey Extent

4.2 Control Survey

The GNSS network used for Oras River is composed of one (1) loop established on February 3, 2017 occupying the following reference points: SMR-41, a second-order GCP, in Brgy. Bagacay, Hinabangan, Eastern Samar and SE-172, a first-order BM in Brgy. Nato, Taft, Eastern Samar.

One (1) control point established in the area by HONS was also occupied: UP-ORA-5, located at the top of the abutment of the bridge in Brgy. Tawagan, Oras, Eastern Samar.

The summary of reference and control points and its location is summarized in Error: Reference source not found8 while GNSS network established is illustrated in Error: Reference source not found7.

Table 18. List of reference and control points used during the survey in Oras River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
SMR-41	2nd Order, GCP	11°49'03.09527"	125°13'56.04673"	-	171.203	2007
SE-172	1st Order, BM	11°55'25.95793"	125°25'18.96212"	-	3.155	2007
UP-ORA-5	Established	-	-	-	-	10-12-16

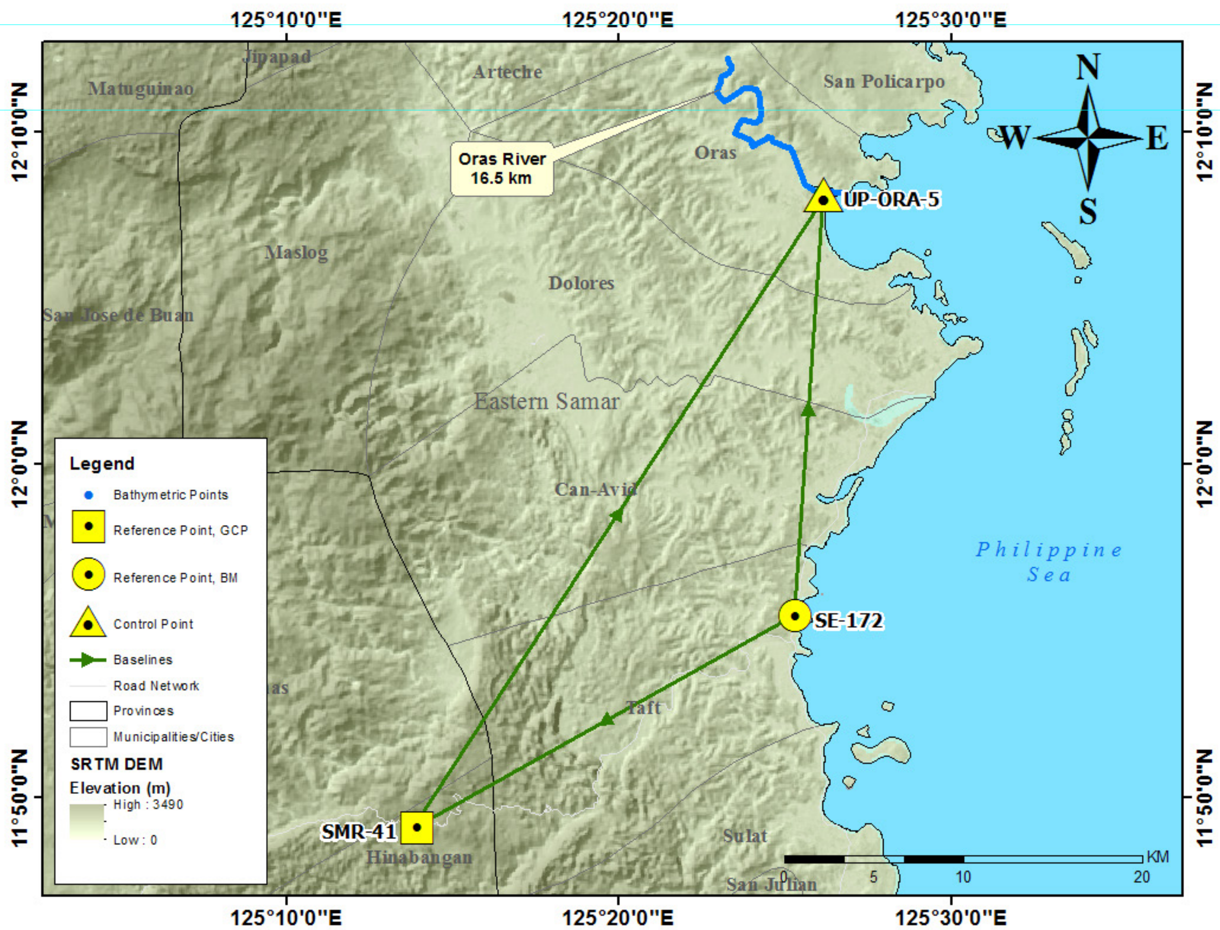


Figure 27. Oras River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Oras River are shown from Error: Reference source not found to Error: Reference source not found.

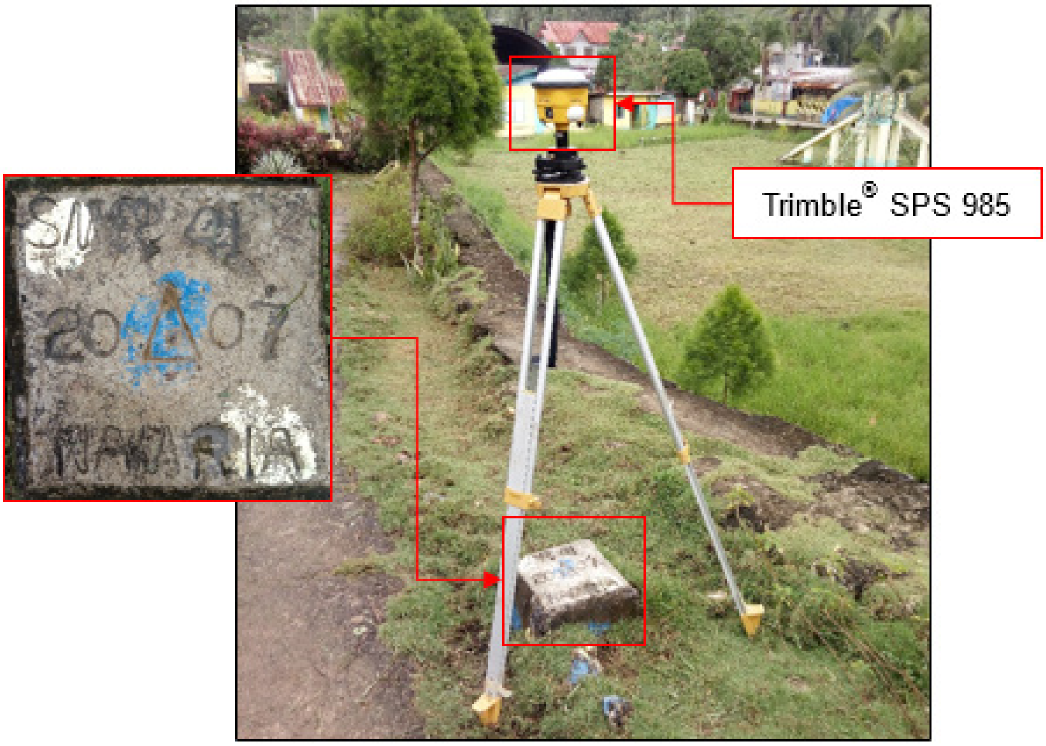


Figure 28. GNSS base set up, Trimble® SPS 985, at SMR-41, located 20 m SW from the flagpole in Bagacay Elementary School playground in Brgy. Bagacay, Hinabangan, Eastern Samar

Figure 29. GNSS receiver set up, Trimble® SPS 885, at SE-172, located beside the walkway leading to the office of Nato Elementary School in Brgy. Nato, Taft, Eastern Samar

Figure 30. GNSS receiver set up, Trimble® SPS 885, at UP-ORA-5, located at the top of bridge abutment in Brgy. Tawagan, Oras, 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 is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Oras River Basin is summarized in Error: Reference source not found generated by TBC software.

Table 19. Baseline Processing Report for Oras River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
SE-172 --- SMR-41	2-3-2017	Fixed	0.003	0.017	240°22'16"	23782.987	170.787
SE-172--- UP-ORA-5	2-3-2017	Fixed	0.003	0.016	3°45'40"	23422.305	-1.820
UP-ORA-5--- SMR-41	2-3-2017	Fixed	0.003	0.017	32°15'45"	41561.555	-172.585

As shown Error: Reference source not found a total of three (3) baselines were processed with coordinate and elevation values of 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 is performed using TBC. Looking at the Adjusted Grid Coordinates table of the TBC generated Network Adjustment Report, it is observed that the square root of the squares of x and y must be less than 20 cm and z less than 10 cm in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown from Error: Reference source not found to Error: Reference source not found for the complete details. Refer to Appendix C for the computation for the accuracy of HONS.

The three (3) control points, SMR-41, SE-172, and UP-DOL-3 were occupied and observed simultaneously to form a GNSS loop. The coordinate and elevation values of SMR-41 and SE-172 were held fixed during the processing of the control points as presented in Error: Reference source not found. Through this reference point, the coordinates and elevations of the unknown control points will be computed.

Table 20. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
SE-172	Grid	Fixed	Fixed		Fixed
SMR-41	Global	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

Table 21. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SE-172	763795.614	?	1319288.604	?	3.155	?	ENe
SMR-41	743218.063	?	1307346.858	?	171.203	?	ENe
UP-ORA-5	765126.316	0.008	1342683.225	0.008	3.685	0.035	

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

a. SE-172

horizontal accuracy = Fixed
vertical accuracy = Fixed

b. SMR-41

horizontal accuracy = Fixed
vertical accuracy = Fixed

c. UP-ORA-5

horizontal accuracy $= \sqrt{((0.8)^2 + (0.8)^2}$
$= \sqrt{(0.64 + 0.64)}$
$= 1.13 < 20$ cm
vertical accuracy $= 3.5 < 10$ cm

Following the given formula, the horizontal and vertical accuracy result of the occupied control point is within the required precision.

Table 22. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
SE-172	N11°55'25.95793"	E125°25'18.96212"	61.761	?	ENe
SMR-41	N11°49'03.09527"	E125°13'56.04673"	232.562	?	ENe
UP-ORA-5	N12°08'06.52488"	E125°26'09.76837"	59.960	0.035	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Error: Reference source not found. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Error: Reference source not found.

Table 23. 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	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SMR-41	2nd Order, GCP	11°49'03.09527"	125°13'56.04673"	232.562	1307346.858	743218.063	171.203
SE-172	1st Order, GCP	11°55'25.95793"	125°25'18.96212"	61.761	1319288.604	763795.614	3.155
UP-ORA-5	Established	12°08'06.52488"	125°26'09.76837"	59.960	1342683.225	765126.316	3.685

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

The cross-sectional line of Oras Bridge is about 232 m with seven hundred thirty-one (731) cross-sectional points using the control points UP_ORA-5 and UP_ORA-6 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown from Error: Reference source not found4 to Error: Reference source not found.

Gathering of random points for the checking of HONS's bridge cross-section and bridge points data was performed by DVBC on February 6, 2017 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Error: Reference source not found.

Figure 31. Oras Bridge facing upstream

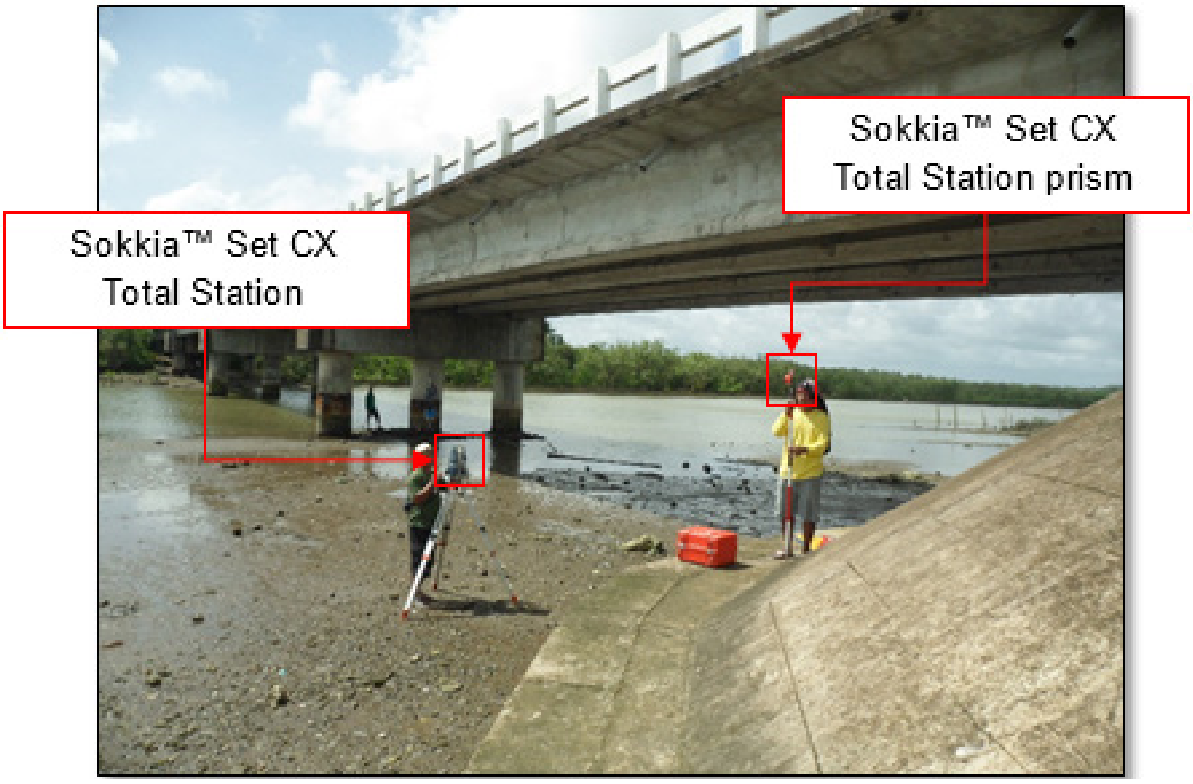


Figure 32. As-built survey of Oras Bridge

The cross-sectional line of Oras Bridge is about 232 m with seven hundred thirty-one (731) cross-sectional points using the control points UP_ORA-5 and UP_ORA-6 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown from Error: Reference source not found4 to Error: Reference source not found.

Gathering of random points for the checking of HONS's bridge cross-section and bridge points data was performed by DVBC on February 6, 2017 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Error: Reference source not found.

Figure 33. Gathering of random cross-section points along Oras Bridge

Linear square correlation (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R^2 value must be within 0.85 to 1. An R^2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R^2 value of 0.987 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.367 was acquired. The computed R^2 and RMSE values are within the accuracy requirement of the program.

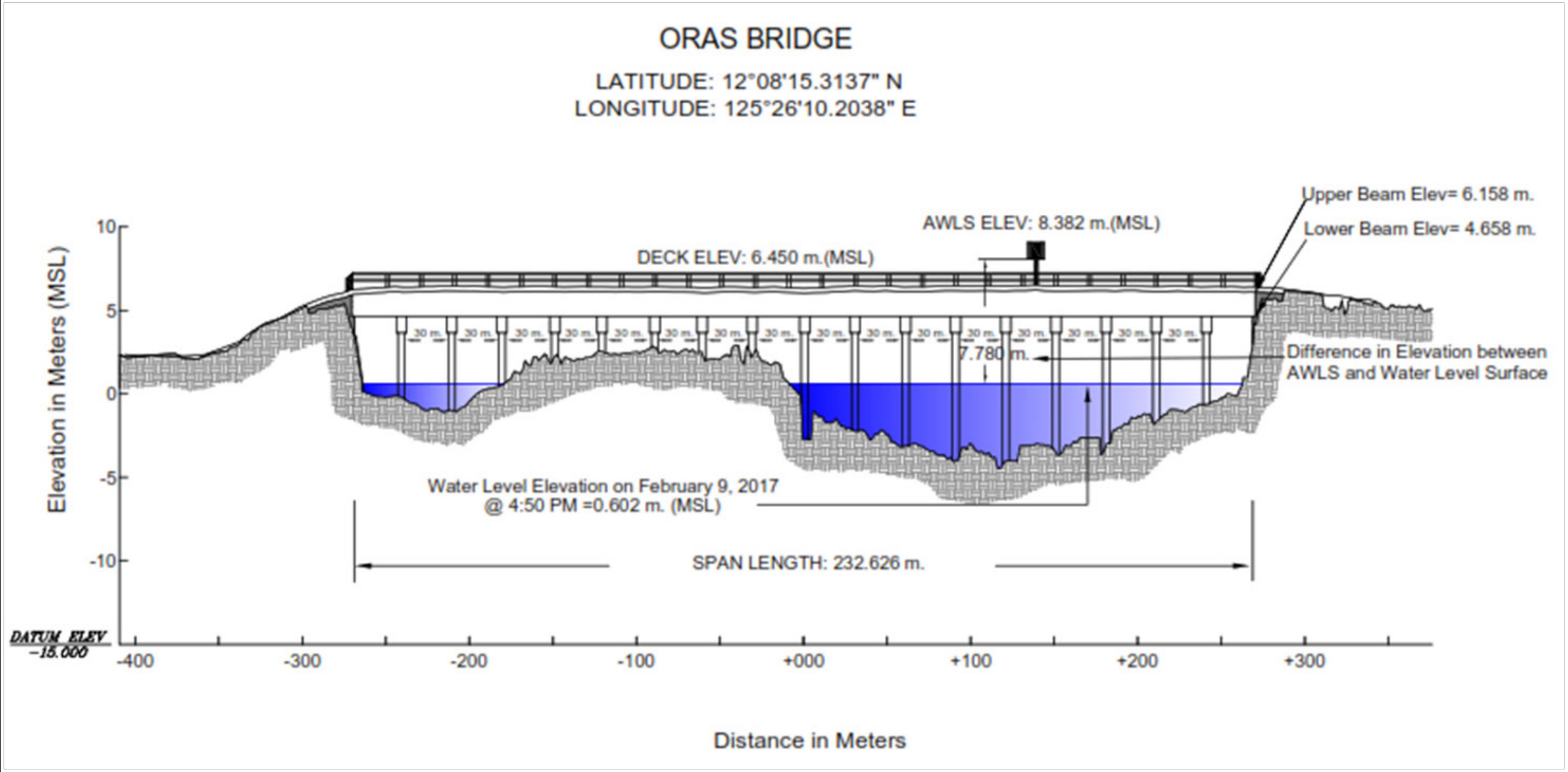


Figure 34. Oras Bridge Cross-section Diagram

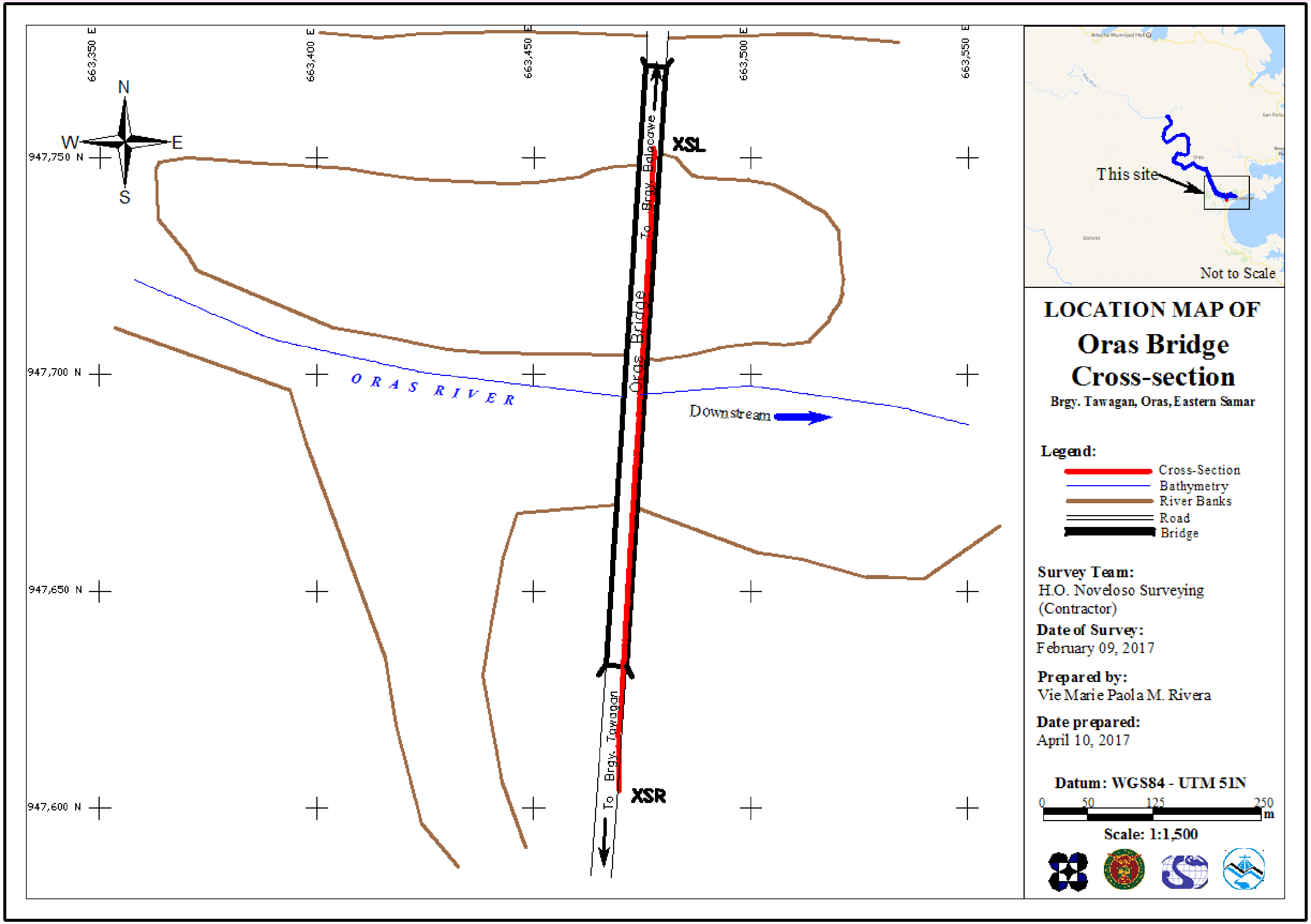


Figure 35. Oras Bridge Cross-section Diagram

BRIDGE DATA FORM

Bridge Name: Oras Bridge

River Name: Oras River

Location (Brgy., City, Region): Brgy. Balocawe, Oras, Eastern Samar

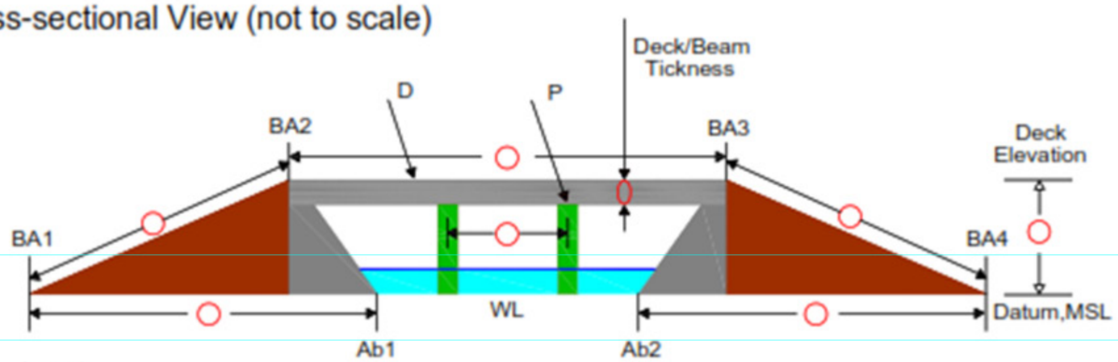
Survey Team: Julieto Cabilin, Urbano Castillo, Jodel dela Cruz, Oscar Agustin, Rhey Joseph Domingo, and Eduardo Cuizon

Date and Time: February 9, 2017 @ 8:00 am - 5:00 pm

Flow Condition: Low Normal High

Weather Condition: Fair Rainy

Cross-sectional View (not to scale)



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

Line Segment	Measurement, m	Remarks	Line Segment	Measurement, m	Remarks
1. BA1-BA2	5.991 m.	Concrete	14. P7-P8	30.000 m.	Concrete
2. BA2-BA3	232.626 m.	Concrete	15. P8-P9	30.000 m.	Concrete
3. BA3-BA4	5.176 m.	Concrete	16. P9-P10	30.000 m.	Concrete
4. BA1-Ab1	12.476 m.	Concrete	17. P10-P11	30.000 m.	Concrete
5. Ab2-BA4	11.319 m.	Concrete	18. P11-P12	30.000 m.	Concrete
6. Beam thickness	1.500 m.	Concrete	19. P12-P13	30.000 m.	Concrete
7. Deck Elevation	6.450 m. MSL	Concrete	20. P13-P14	30.000 m.	Concrete
8. P1-P2	30.000 m.	Concrete	21. P14-P15	30.000 m.	Concrete
9. P2-P3	30.000 m.	Concrete	22. P15-P16	30.000 m.	Concrete
10. P3-P4	30.000 m.	Concrete			
11. P4-P5	30.000 m.	Concrete			
12. P5-P6	30.000 m.	Concrete			
13. P6-P7	30.000 m.	Concrete			

Note: Observer should be facing downstream

Figure 36. Oras Bridge Data Sheet

Water surface elevation of Oras River was determined by a Sokkia™ Set CX Total Station on February 9, 2017 at the railings of Oras Bridge in Brgy. Balocawe, Oras, Eastern Samar with a value of 6.631 m in MSL. This was translated into marking on the bridge's sidewalk 7.795 m away from the AWLS as shown in Error: Reference source not found.

Figure 37. Water surface elevation marking on Oras Bridge sidewalk

Water surface elevation of Oras River was also determined by a Sokkia™ Set CX Total Station on February 9, 2017 at 4:50 PM at Oras Bridge area with a value of 0.602 m in MSL as shown in Error: Reference source not found. This was translated into marking on the bridge's pier as shown in Error: Reference source not found8. The markings will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Oras River, the Visayas State University.

Figure 38. Water level markings on the pier of Oras Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on February 6, 2017 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the front of the vehicle as shown in Error: Reference source not found. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.188 m and measured from the ground up to the bottom of the antenna mount of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-ORA-5 occupied as the GNSS base station in the conduct of the survey.

Figure 39. Validation points acquisition survey set-up for Oras River.

The survey started from Brgy. Cagamutan del Norte, Gamay, Northern Samar going southeast along the national highway, covering 1 (1) barangay in Gamay, Northern Samar, eleven (11) barangays in Lapinig, nine (9) barangays in Arteche, Eastern Samar, twelve (12) barangays in San Policarpio, Eastern Samar, twelve (12) barangays in Oras, Eastern Samar, twelve (12) barangays in Dolores, Eastern Samar, and ended in Brgy. Carolina, Can-Avid, Eastern Samar. The survey gathered a total of 11,695 points with approximate length of 54.53 km using UP-ORA-5 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 40.

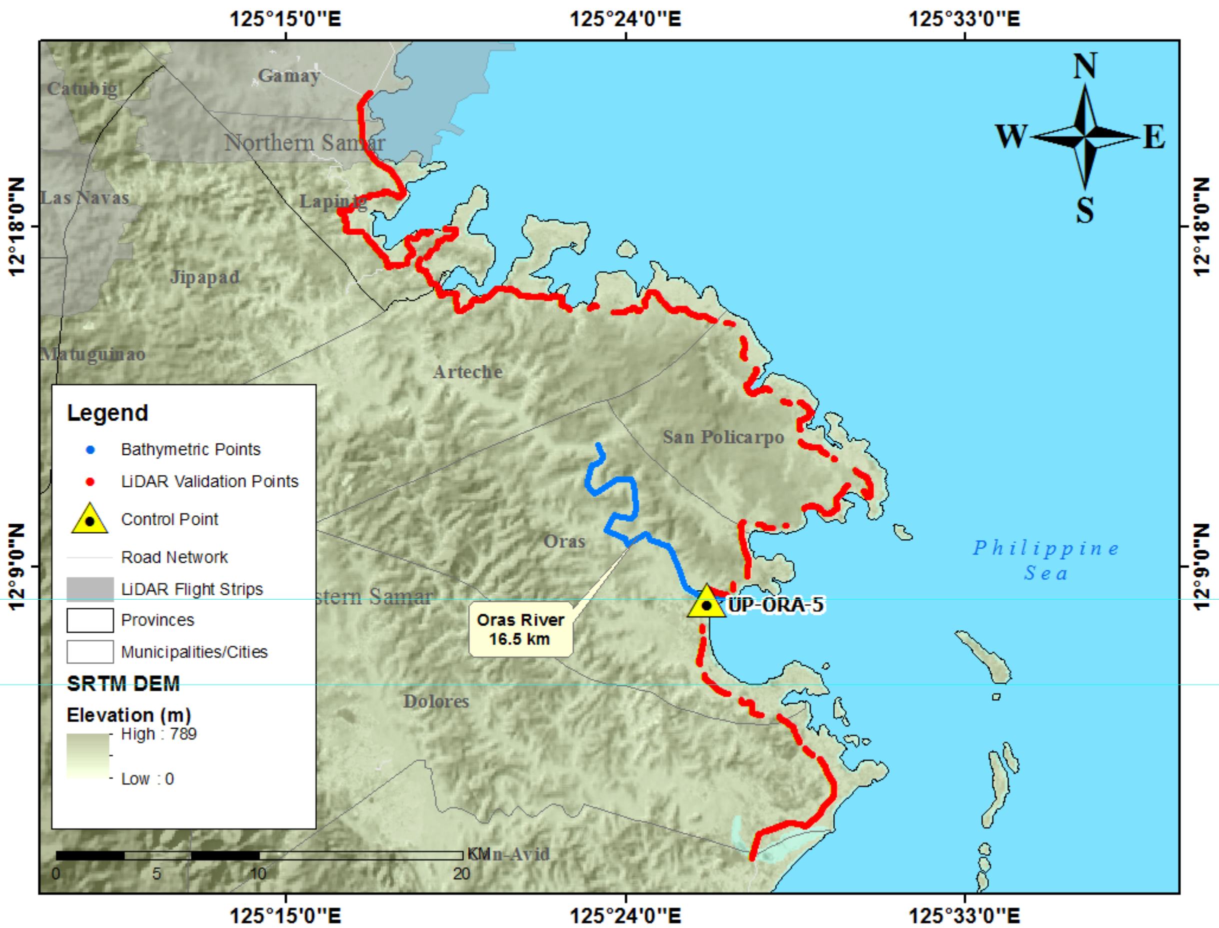


Figure 40. Validation points acquisition covering the Oras Basin Area

4.7 Bathymetric Survey

Bathymetric survey was executed on February 3 and 7, 2016 using a dual frequency Hi-Target™ V30 GNSS and a Hi-Target™ Single Beam Echo Sounder mounted in a motor boat as illustrated in Error: Reference source not found. The survey started in Brgy. Cadian, Oras, Eastern Samar with coordinates 12°12'10.9133"N, 125°23'06.7570"E and ended at the mouth of the river in Brgy. Balocawe, also in the Municipality of Oras with coordinates 12°08' 12.0647"N, 125°26' 37.1508"E. The control points UP-ORA-1 and UP-ORA-6 were used as the GNSS base station throughout the survey.

Figure 41. Bathymetric survey of HONS along Oras River

Gathering of random points for the checking of HONS's bathymetric data was performed by DVBC on February 6, 2017 using a survey grade GNSS Rover receiver attached to a boat as seen in Error: Reference source not found. A map showing the DVBC bathymetric checking points is shown in Error: Reference source not found.

Figure 42. Gathering of random bathymetric points along Oras River

Linear square correlation (R^2) and RMSE analysis were also performed on the two (2) datasets and a computed R^2 value of 0.940 for the bathymetric data is within the required range for R^2, which is 0.85 to 1. Additionally, an RMSE value of 0.361 for the bathymetric data was obtained. Both the computed R^2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Oras River gathered a total of 9,126 points covering 16.5 km of the river traversing barangays Cadian, Cagdine, Balingasag, Alang-Alang, Minap-Os, Iwayan, Agsam, Nadacpan, Binalayan, Paypayon, Riverside, Tiguib, Tawagan, and Balocawe in the Municipality of Oras. A CAD drawing was also produced to illustrate the riverbed profile of Oras River. As shown in Error: Reference source not found, the highest and lowest elevation has a 9.60-m difference. The highest elevation observed was -1.906 m below MSL located in Brgy. Balocawe, Oras, Eastern Samar while the lowest was -11.509 m below MSL located in Binalayan, Oras, Eastern Samar.

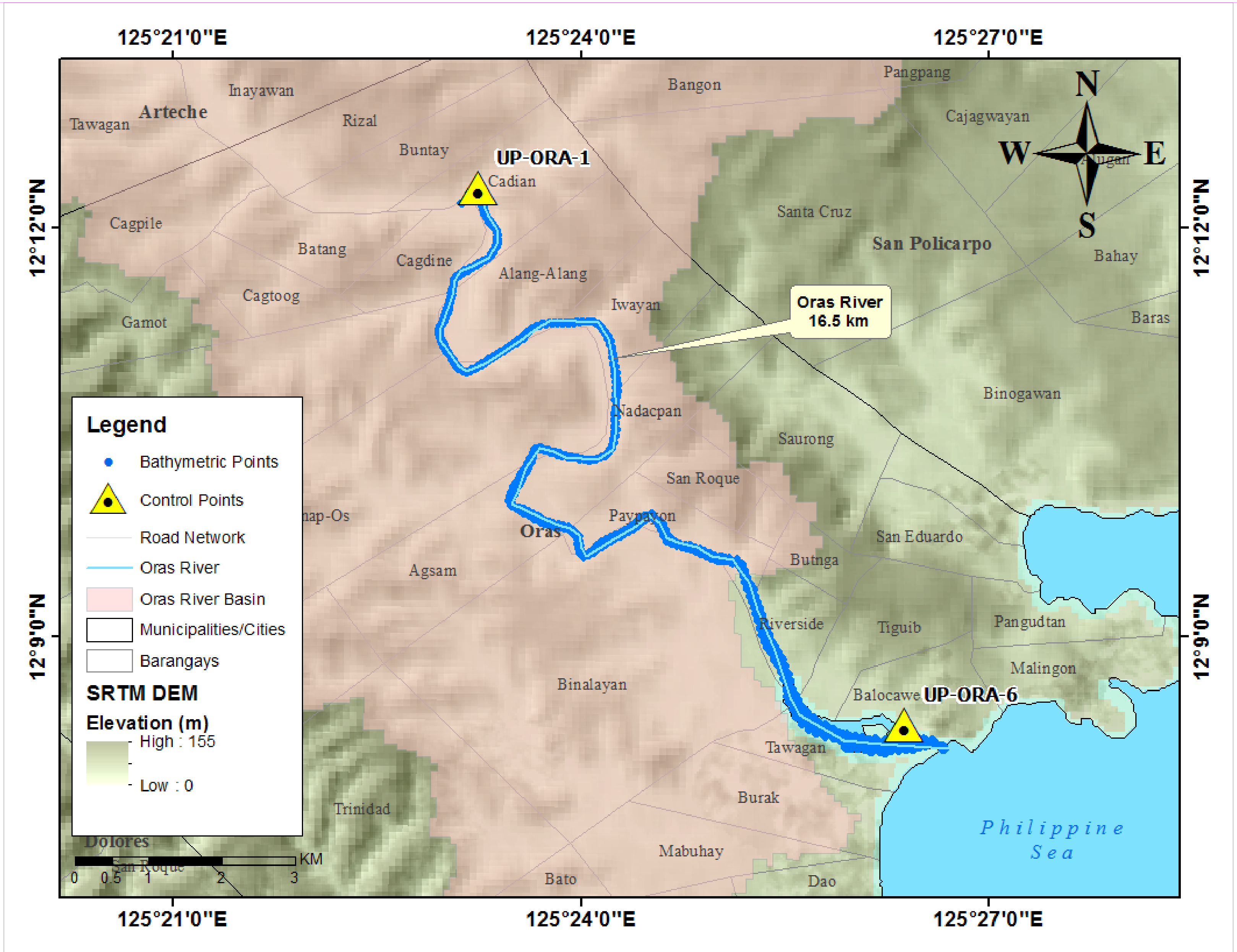


Figure 43. Bathymetric survey of Oras River

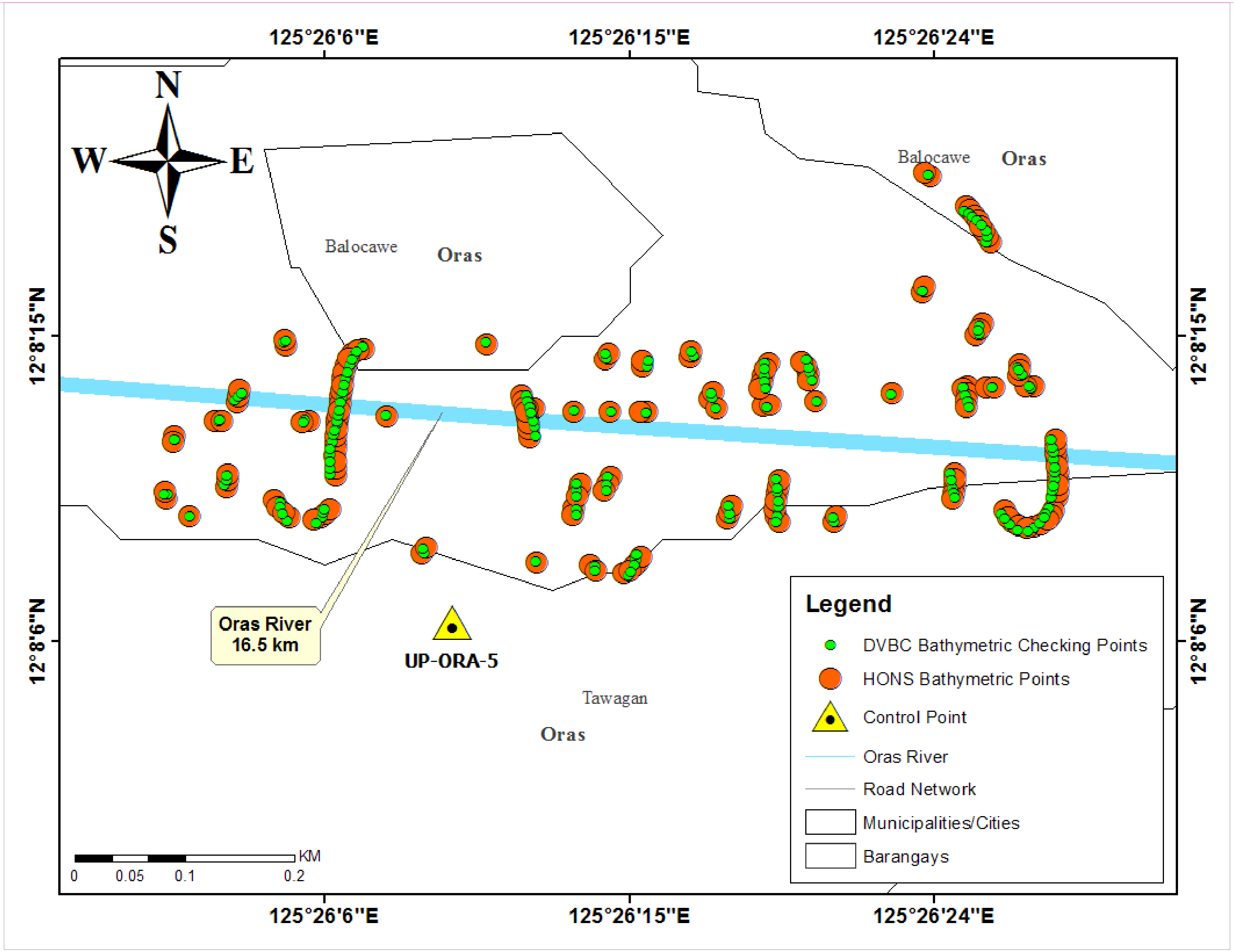


Figure 44. Oras Bridge Cross-section Diagram

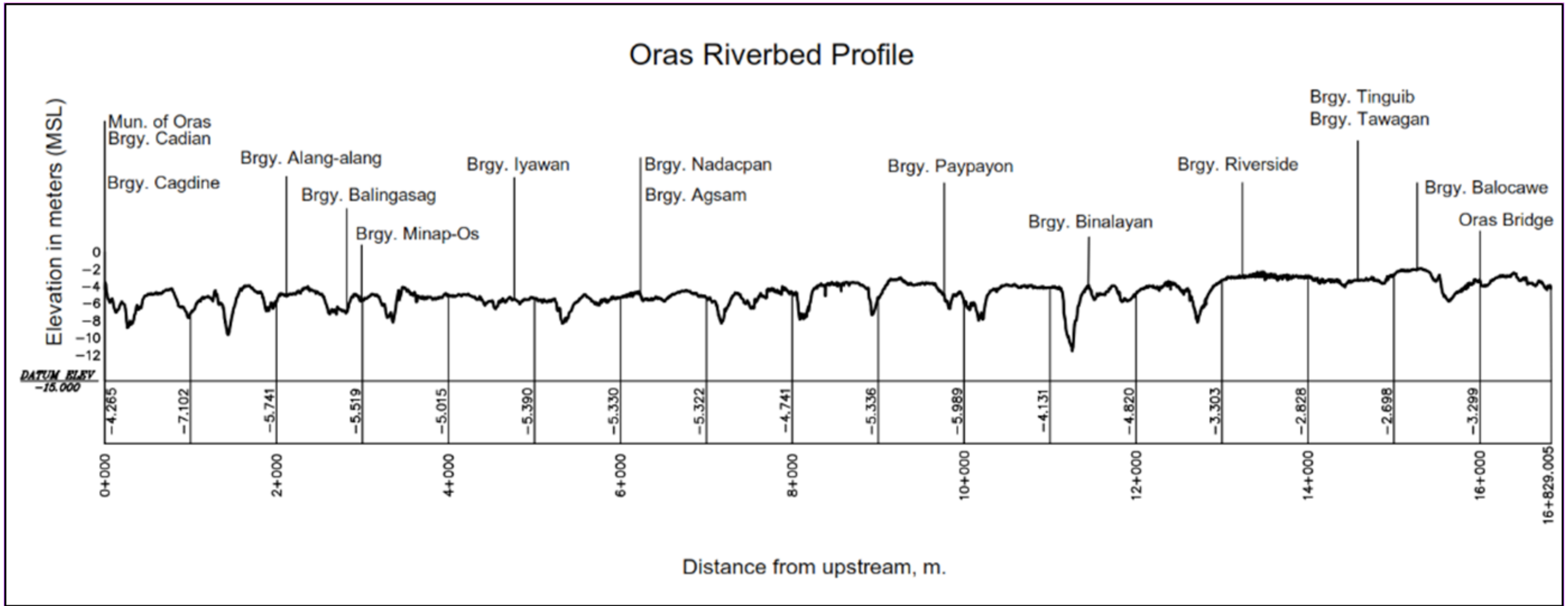


Figure 45. Oras Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, and Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the automatic rain gauge (ARG) installed by the Flood modeling Component at Brgy. Malinao, Oras, Eastern Samar. The location of the rain gauge is shown in Figure 46 below.

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. A summary of the data is seen in Table 1.1. The lag time between the peak rainfall and discharge is five hours and fifty minutes, as seen in Figure 49.

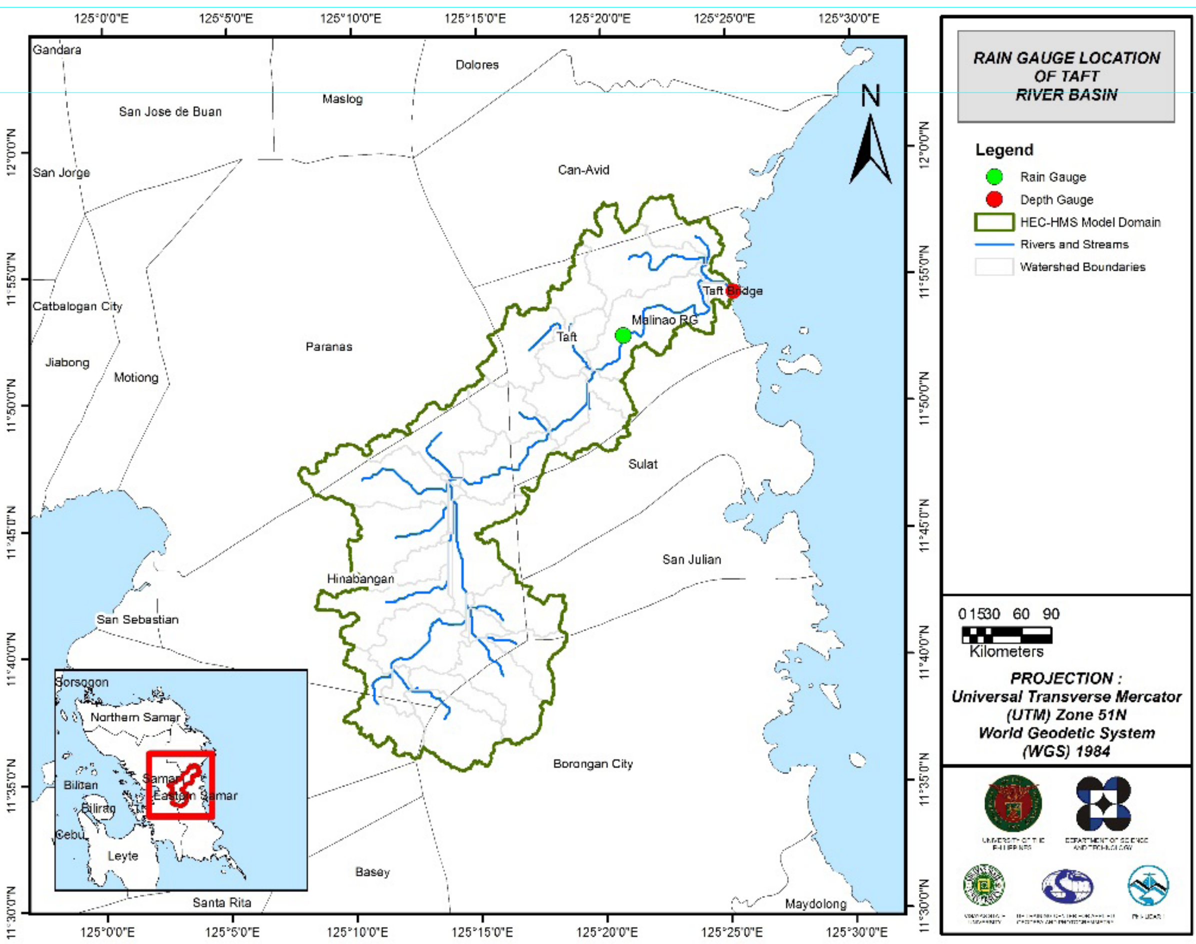


Figure 46. The location map of Oras HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Oras Bridge, Brgy. Poblacion, Oras, Eastern Samar. It gives the relationship between the observed water levels from the depth gauge deployed at Orasbridge and outflow of the watershed at this location. It is expressed in the form of the following equation:

$$Q=anh$$

where,

Q: Discharge (m³/s),
h: Gauge height (reading from Oras Bridge depth gauge), and
a and n: Constants.

For Oras Bridge, the rating curve is expressed as $Q = 199.66e^{0.8747h}$ as shown in Figure 6.

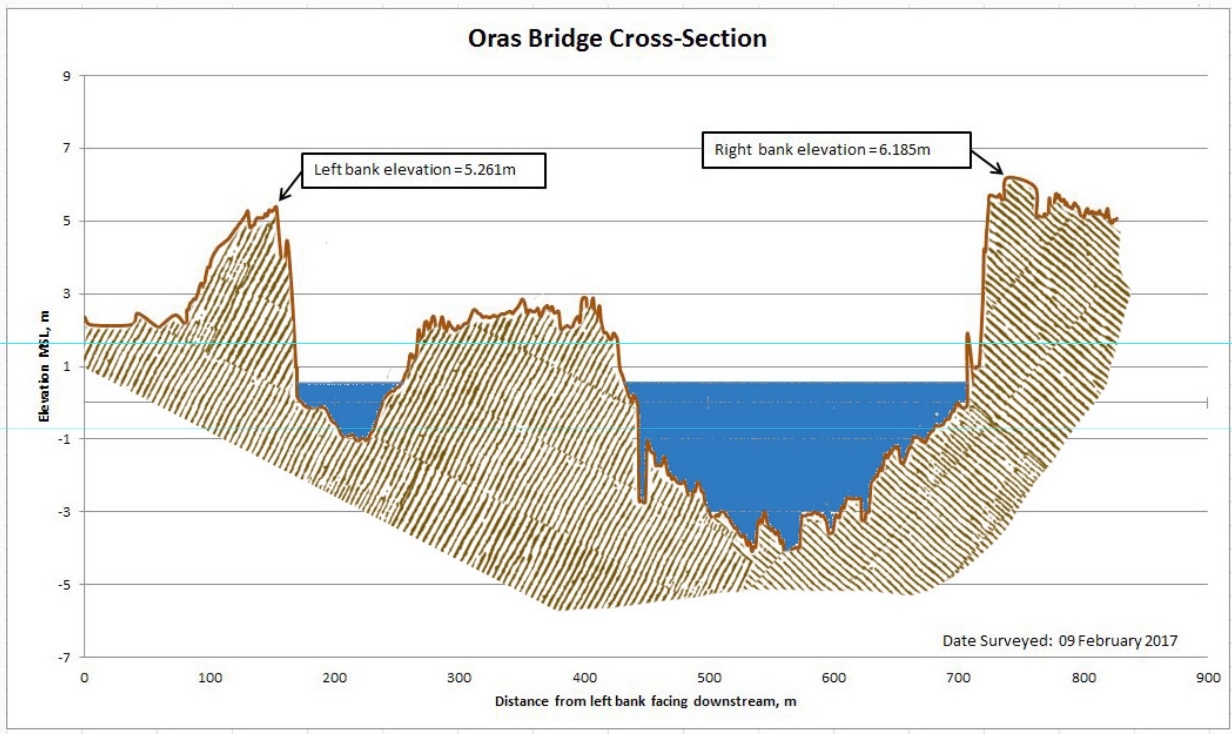


Figure 47. Cross-Section Plot of Liloan Bridge

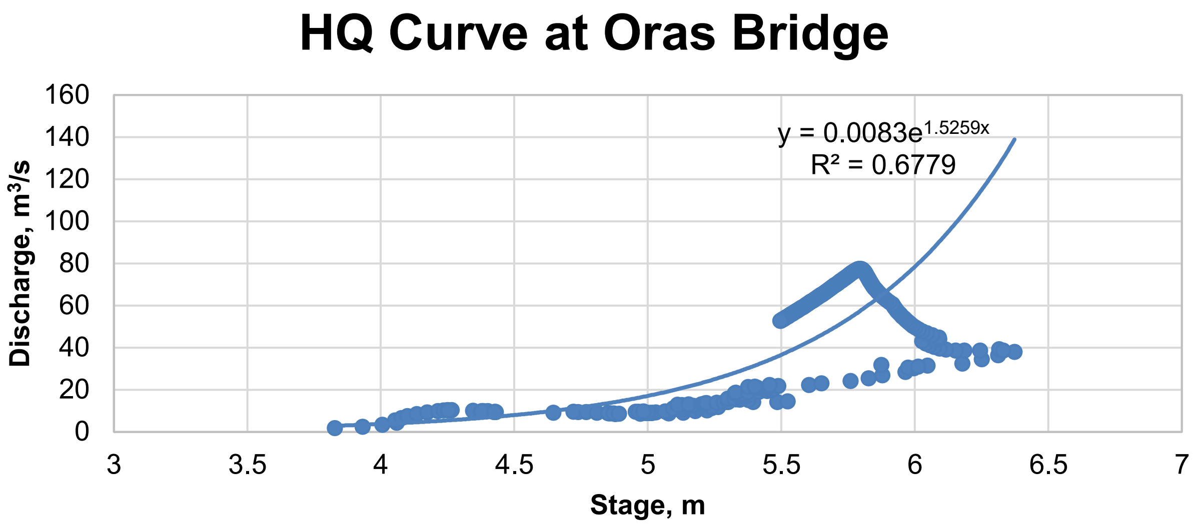


Figure 48. Rating Curve at Palico Bridge

The resulting rating curve equation was used to compute the river outflow at Oras Bridge for the calibration of the HEC-HMS model shown in Figure 46. 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. A summary of the data is seen in Table 1.1. The lag time between the peak rainfall and discharge is five hours and fifty minutes.Peak discharge is 165 cu.m/s at 7:20 PM, December 30, 2014.

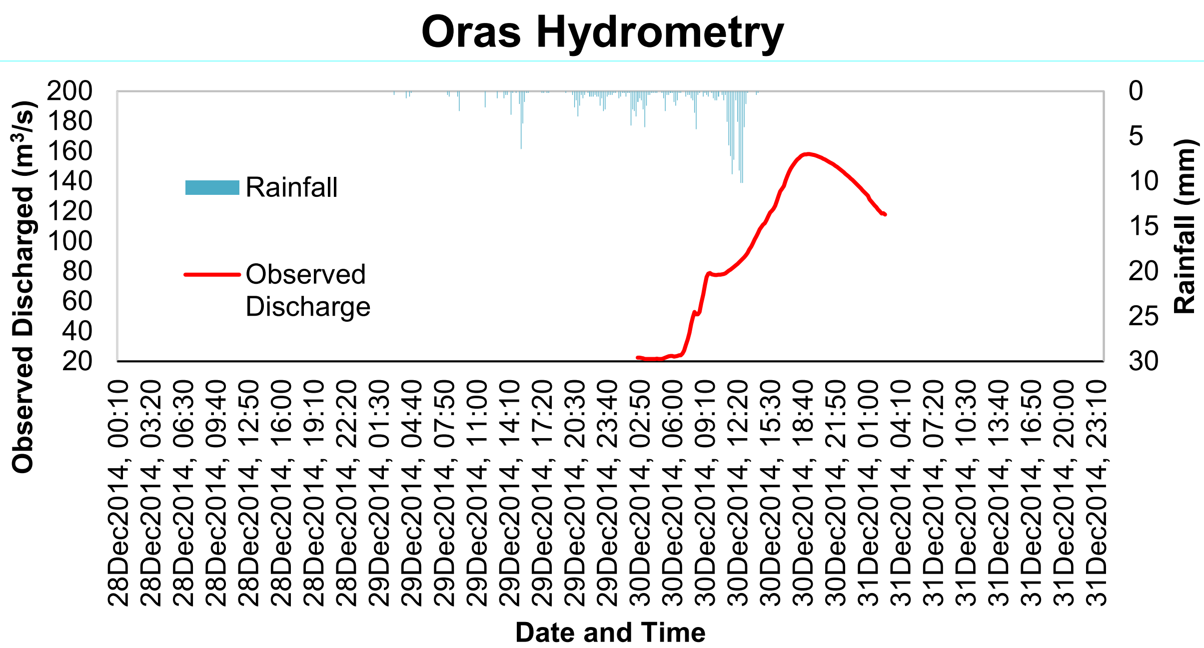


Figure 49. Rainfall and outflow data at Oras used for modelling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Catbalogan Rain Gauge. This station chosen based on its proximity to the Oras watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 24. RIDF values for Catbalogan 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	18.5	28.1	35.6	48.1	68	82.1	104.6	124.9	145
5	25.9	38.3	63.8	63.8	90.4	108.8	137.5	165.2	190.8
10	30.8	45	74.2	74.2	105.3	126.5	159.3	191.9	221.2
15	33.5	48.8	80.1	80.1	113.7	136.5	171.5	206.9	238.4
20	35.5	51.5	84.2	84.2	119.6	143.5	180.1	217.5	250.4
25	37	53.6	87.3	87.3	124.1	148.9	186.7	225.6	259.6
50	41.5	59.9	97.1	97.1	138.1	165.5	207.1	250.6	288.1
100	46.1	66.2	106.8	106.8	151.9	181.9	227.4	275.4	316.3

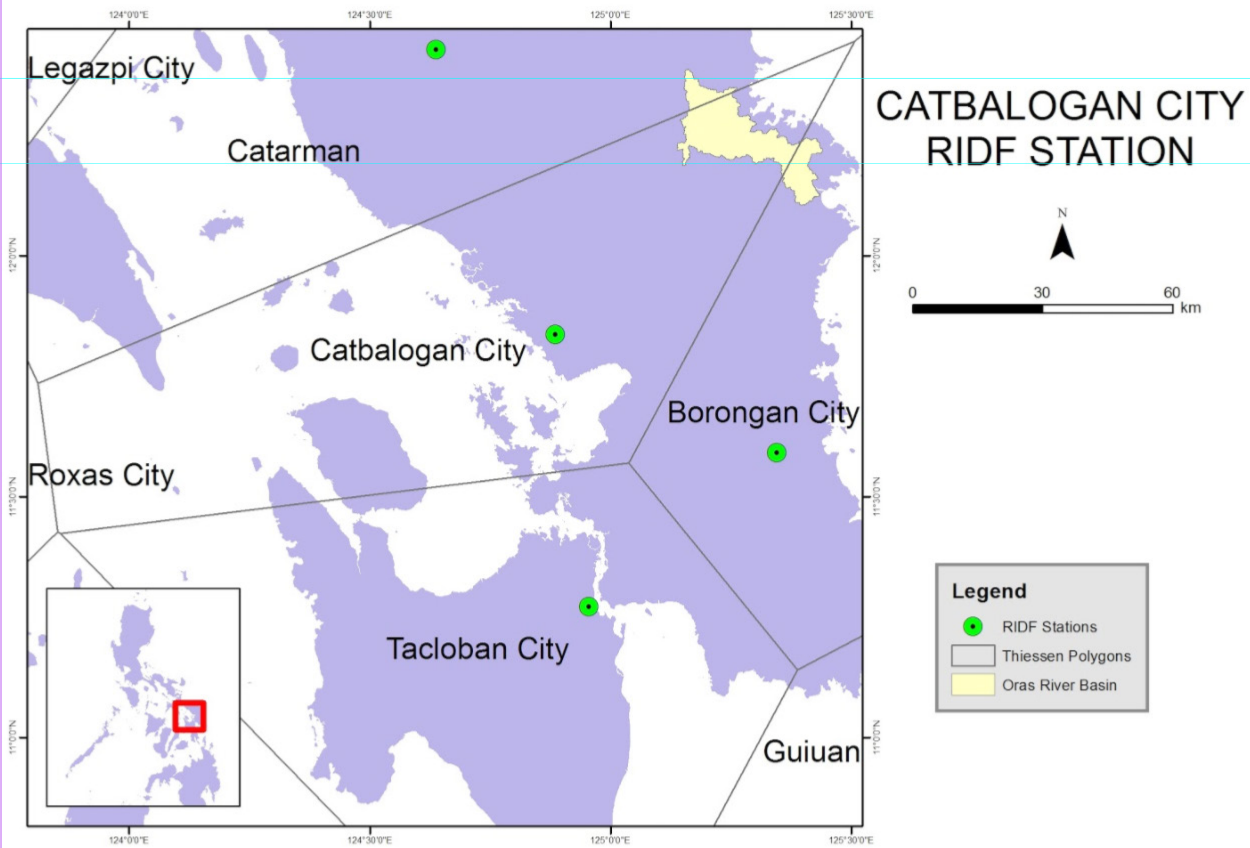


Figure 50. Location of Dipolog RIDF station relative to Oras River Basin

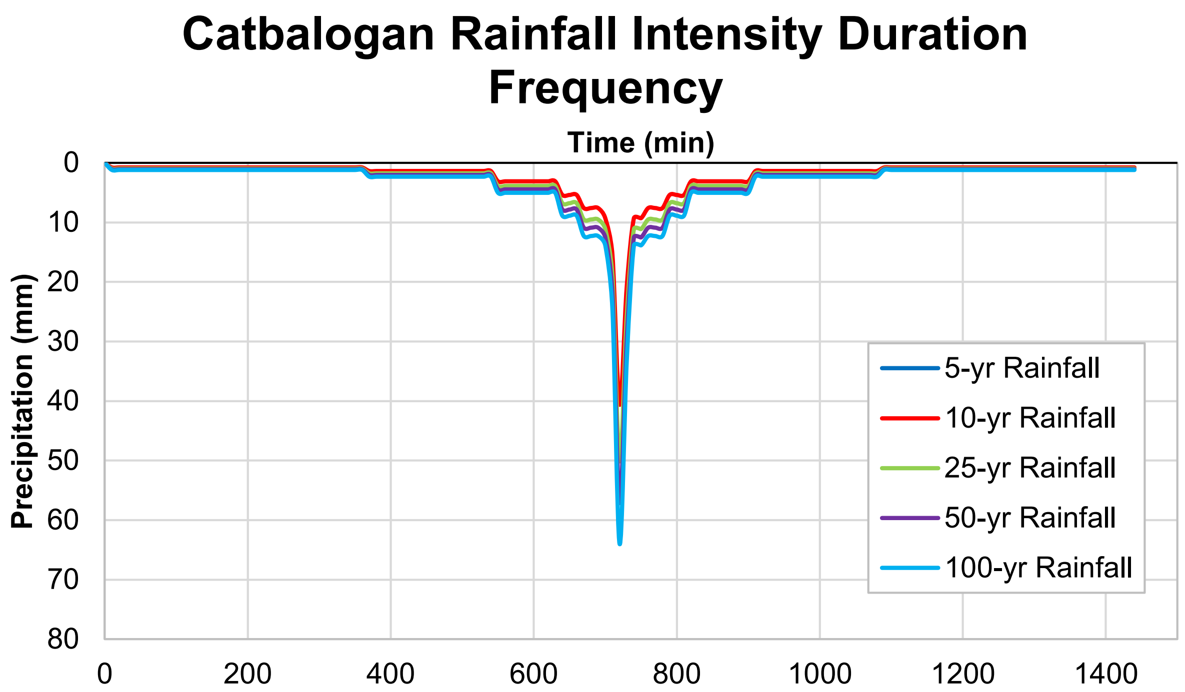


Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shape file was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA).

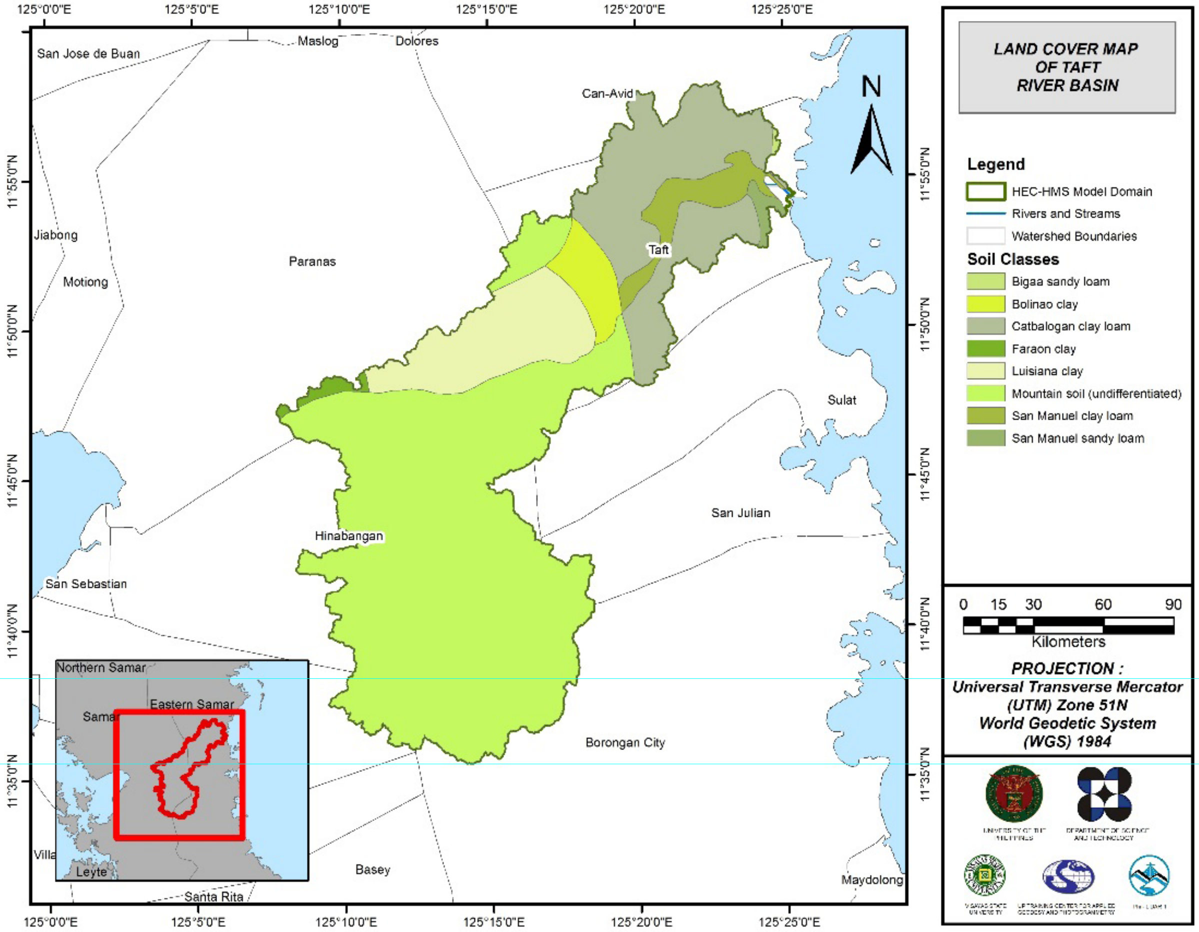


Figure 52. Soil Map of Oras River Basin

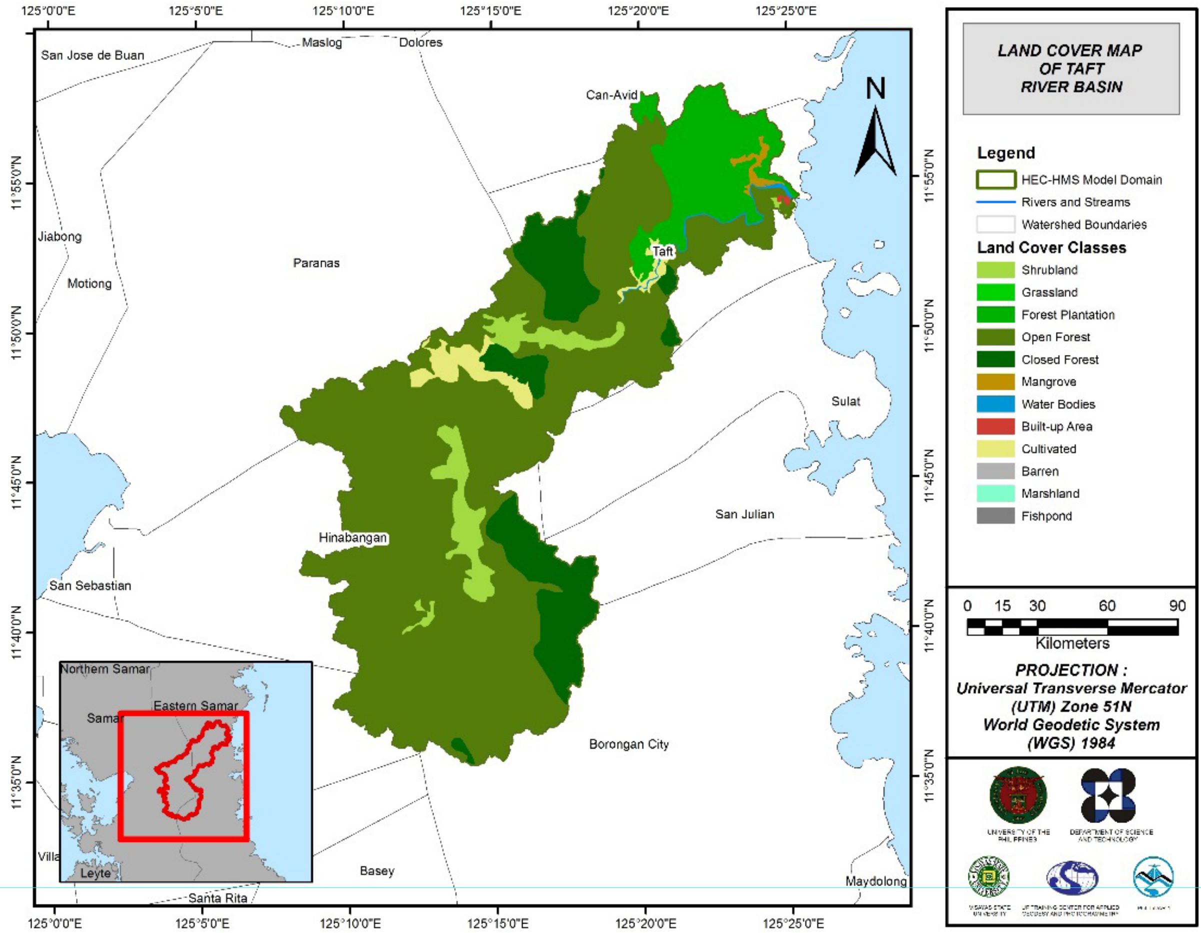


Figure 53. Land cover map of the Oras River Basin (Source: NAMRIA)

For Oras, the soil class identified were Bolinao clay, Catbalogan clay loam, Faraon clay, Luisiana clay, undifferentiated and San Manuel clay loam. The land cover types identified were shrubland, forest plantation, open forest, closed forest, and cultivated.

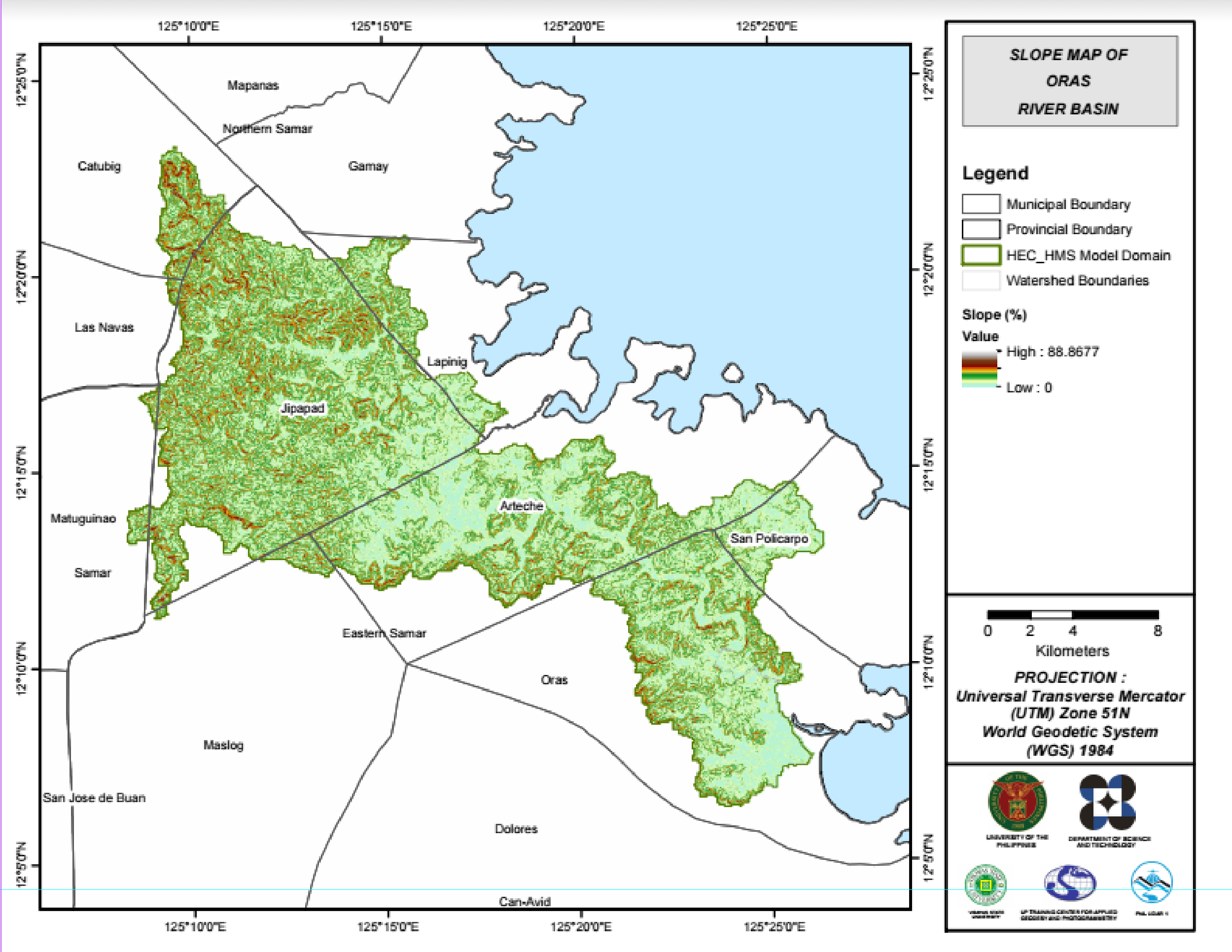


Figure 54. Slope Map of the Oras River Basin

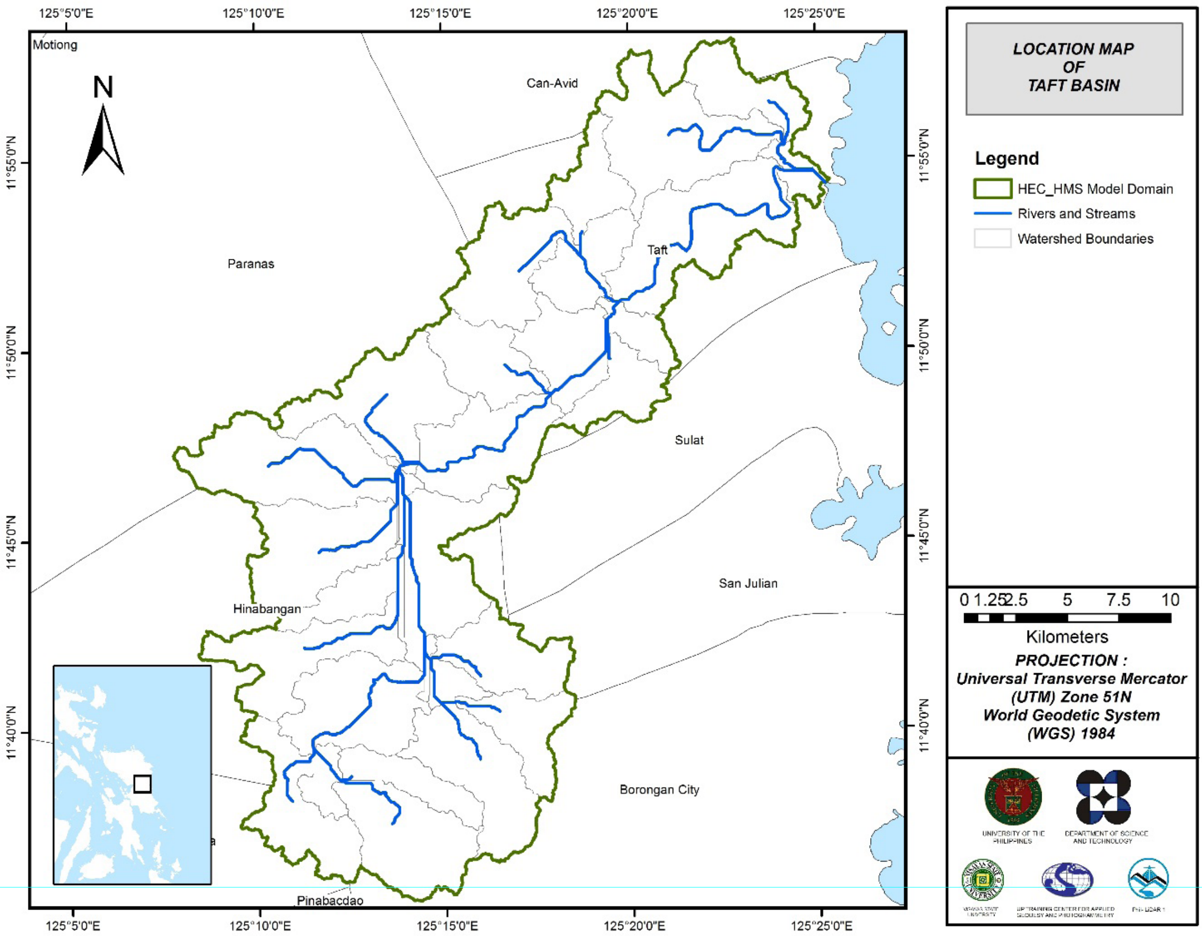


Figure 55. Stream delineation map of Oras river basin

The Oras basin model consists of 13 sub basins, 6 reaches, and 6 junctions. This basin model is illustrated in Figure 52. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 28-31 December (Typhoon Seniang) was taken from the rain gauge installed by the Flood Modelling Component. Finally, it was calibrated using the water level data from the Oras depth gauge.

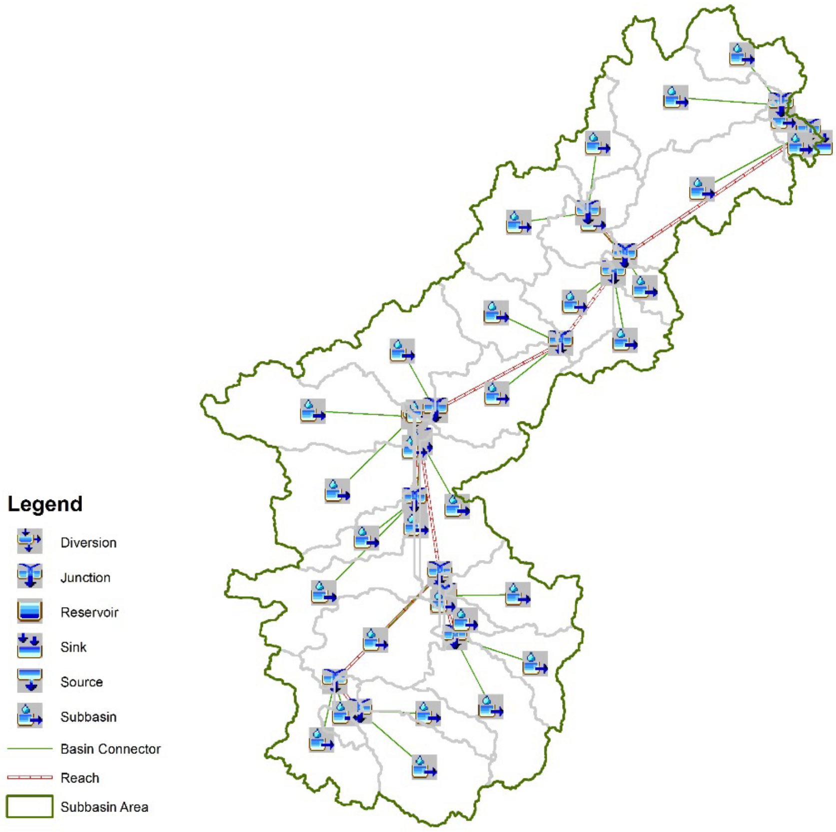


Figure 56. The Oras Hydrologic Model generated in HEC-GeoHMS

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.

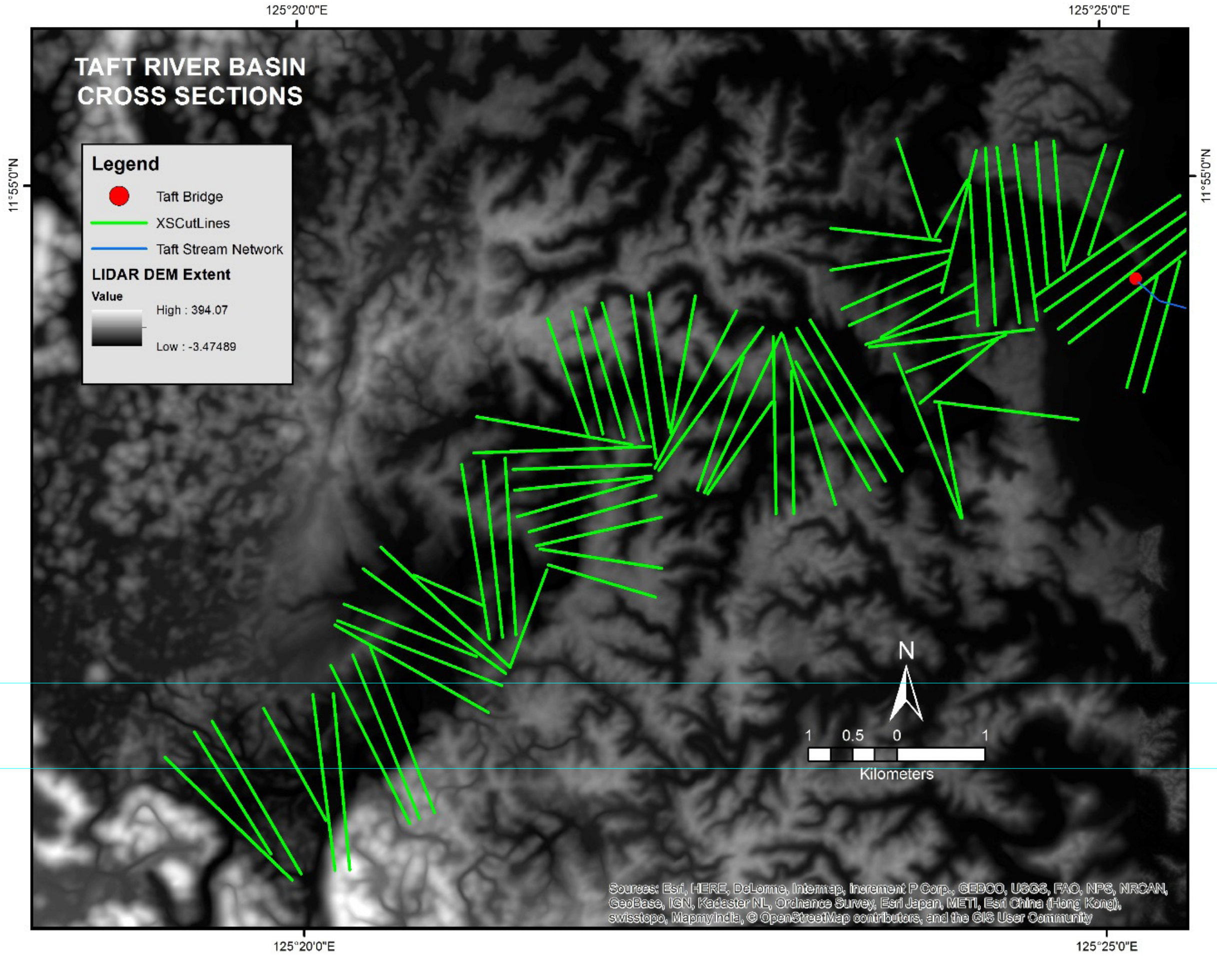


Figure 57. River cross-section of Oras River generated through Arcmap HEC GeoRAS

5.5 Flo 2D Model

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

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

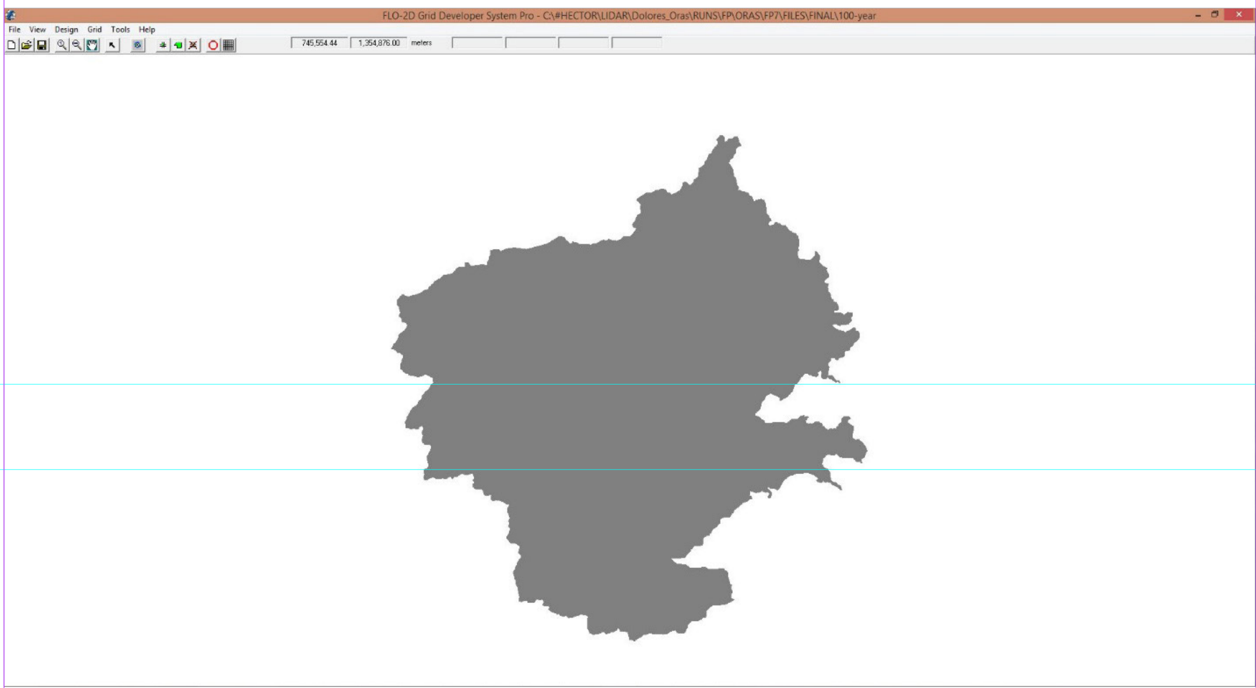


Figure 58. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 145.81274 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 **m²**/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 100 006 272.00 **m²**.

There is a total of 67 662 967.63 m³ of water entering the model. Of this amount, 52 477 076.61 m³ is due to rainfall while 15 185 891.02 m³ is inflow from other areas outside the model. 12 941 394.00 m³ of this water is lost to infiltration and interception, while 33 391 089.87 m³ is stored by the flood plain. The rest, amounting up to 21 330 334.51 m³, is outflow.

5.6 Results of HMS Calibration

After calibrating the Oras HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

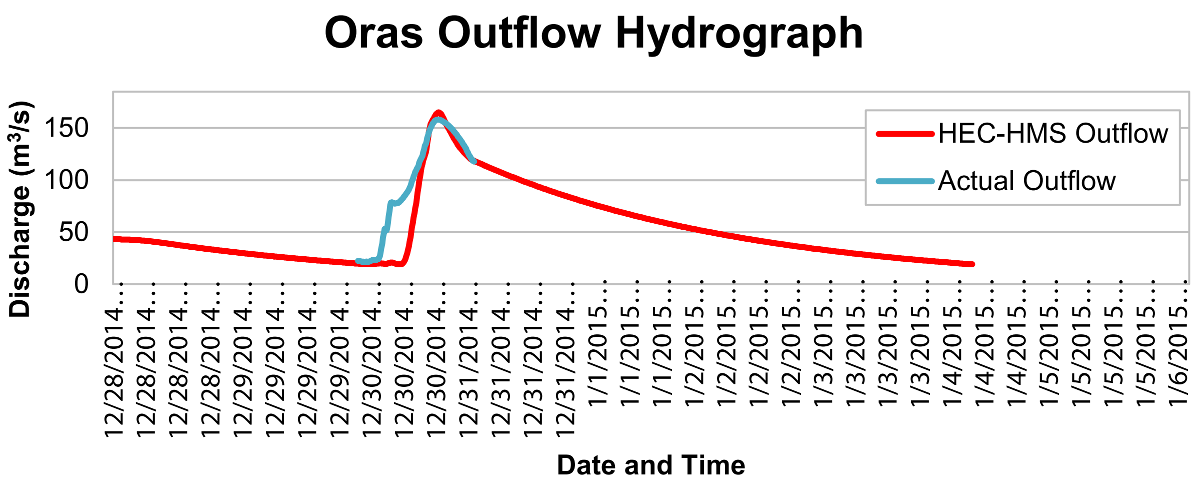


Figure 59. Outflow Hydrograph of Oras Bridge generated in HEC-HMS model compared with observed outflow

Enumerated in Table 25 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 25. Range of Calibrated Values for Oras

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)	0.6 - 6
	Baseflow	Recession	Recession Constant	0.65
			Ratio to Peak	0.55
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.01 - 1

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

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 relatively low compared to the advisable values for Philippine watersheds depending on the soil and land cover of the area.

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 0.6 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 a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.01 to 1 means that there is a diverse roughness for each reach within the watershed.

Table 26. Summary of the Efficiency Test of Oras HMS Model

Accuracy measure	Value
RMSE	9.4
r^2	0.86
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 identified at 9.4.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8582.

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 0.653.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. 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 0.588.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graphs show the Oras outflow using the Catbalogan Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (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.

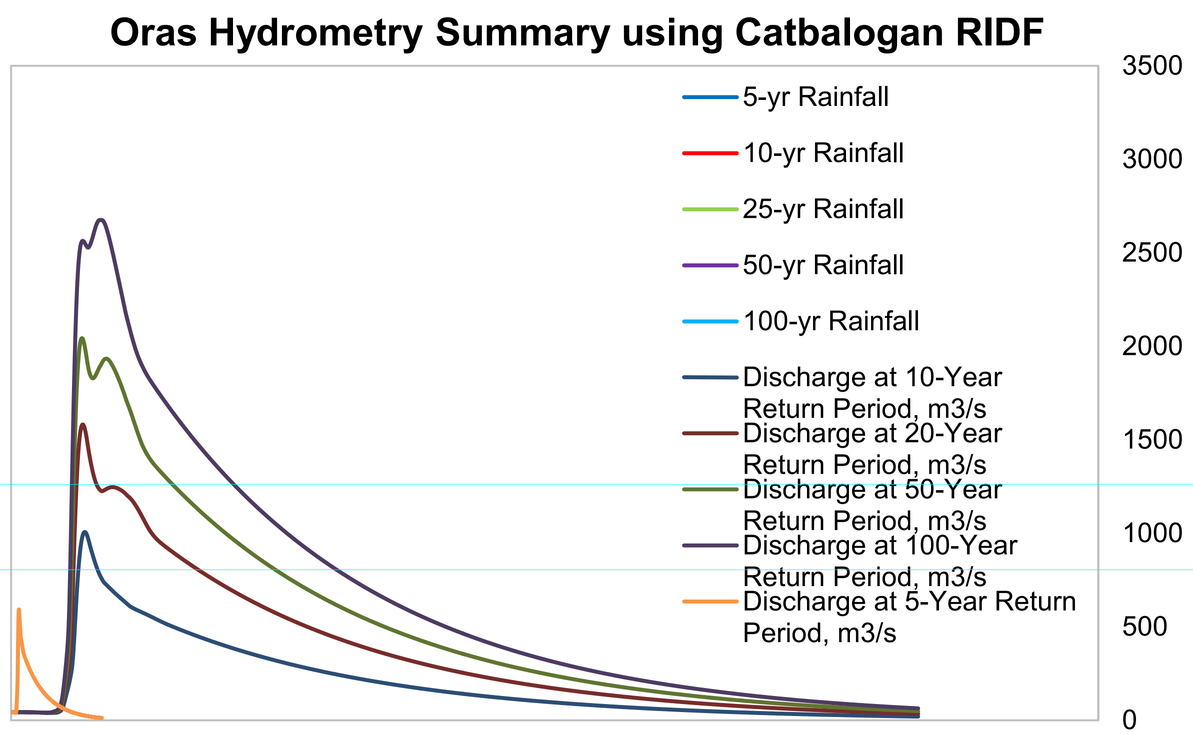


Figure 60. Outflow hydrograph at Oras Station generated using Catbalogan RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Oras discharge using the Catbalogan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 27.

Table 27. Peak values of the Oras HECHMS Model outflow using Catbalogan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	278.6	32.2	591.02	15 hours 40 mins
10-Year	344.7	40.6	1,003.36	15 hours 30 mins
25-Year	428.2	50.1	1578.95	15 hours 30 mins
50-Year	490.2	57.10	2,038.44	15 hours 30 mins
100-Year	551.7	64	2675.7	15 hours 30 mins

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, 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 Oras River using the calibrated HEC-HMS model for Typhoon Seniang is shown in Figure 61.

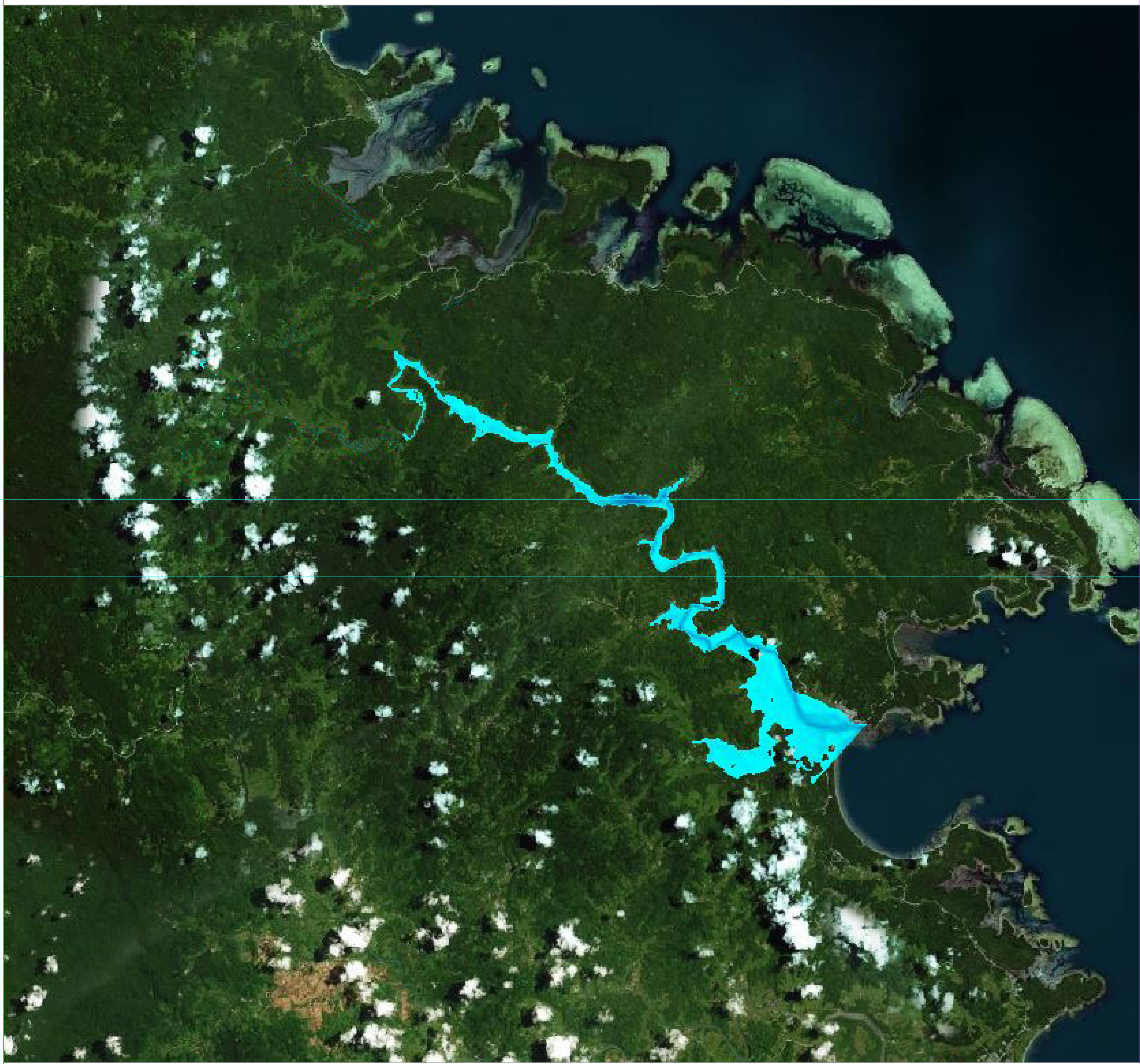


Figure 61. Sample output of Oras RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 62 to Error: Reference source not found67 shows the 5-, 25-, and 100-year rain return scenarios of the Oras floodplain. The floodplain, with an area of 372.44 sq. km., six municipalities namely Arteche, Jipapad, Maslog, Oras, San Policarpo and Lapinig. Table shows the percentage of area affected by flooding per municipality.

Table 28. Municipalities affected in Oras floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Arteche	162.30	131.70	81.15%
Jipapad	173.29	58.93	34.01%
Maslog	284.92	2.93	1.03%
Oras	173.99	95.09	54.65%
San Policarpo	77.28	66.39	85.91%
Lapinig	57.03	16.60	29.10%

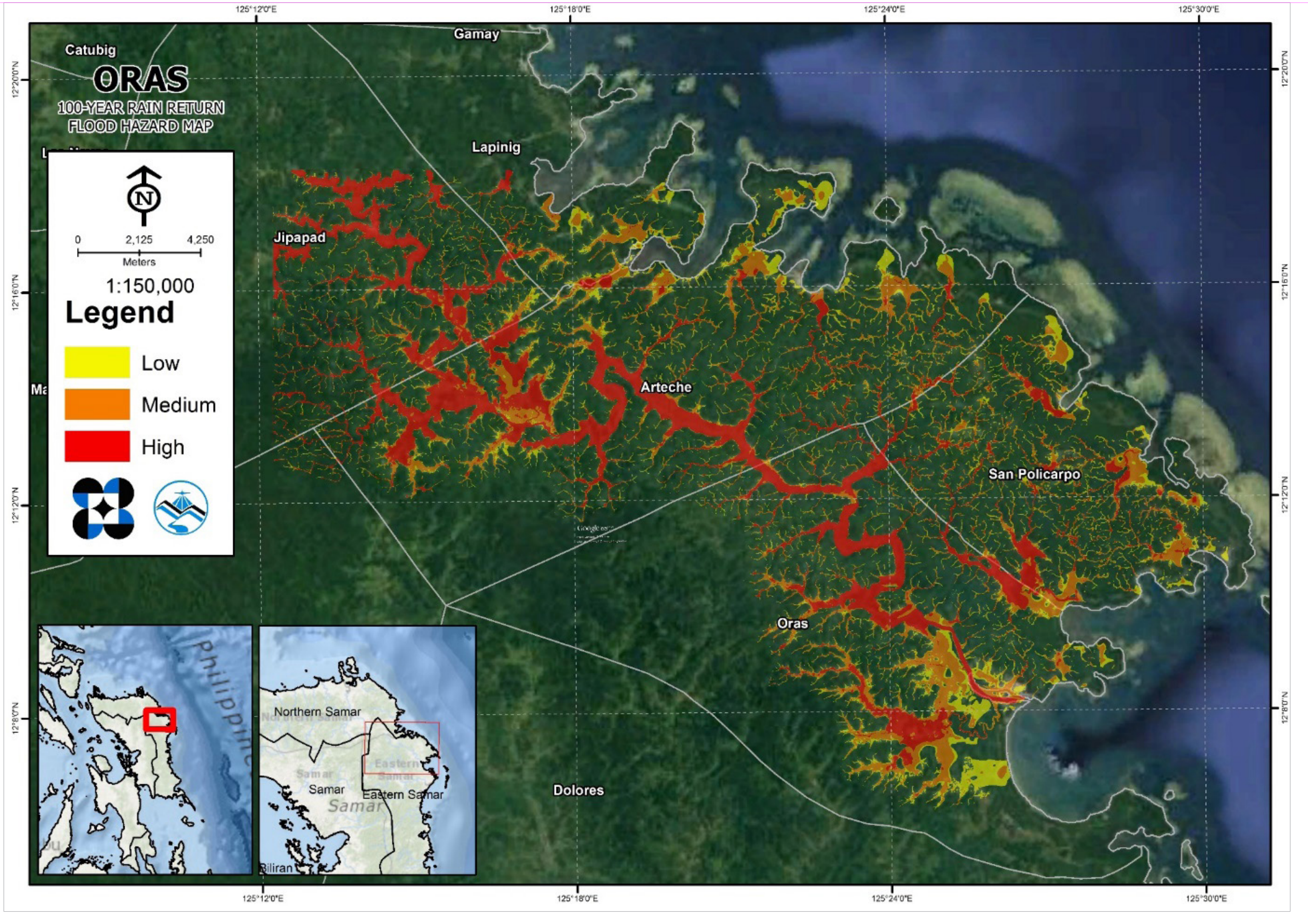


Figure 62. 100-year Hazard Map for Oras Floodplain

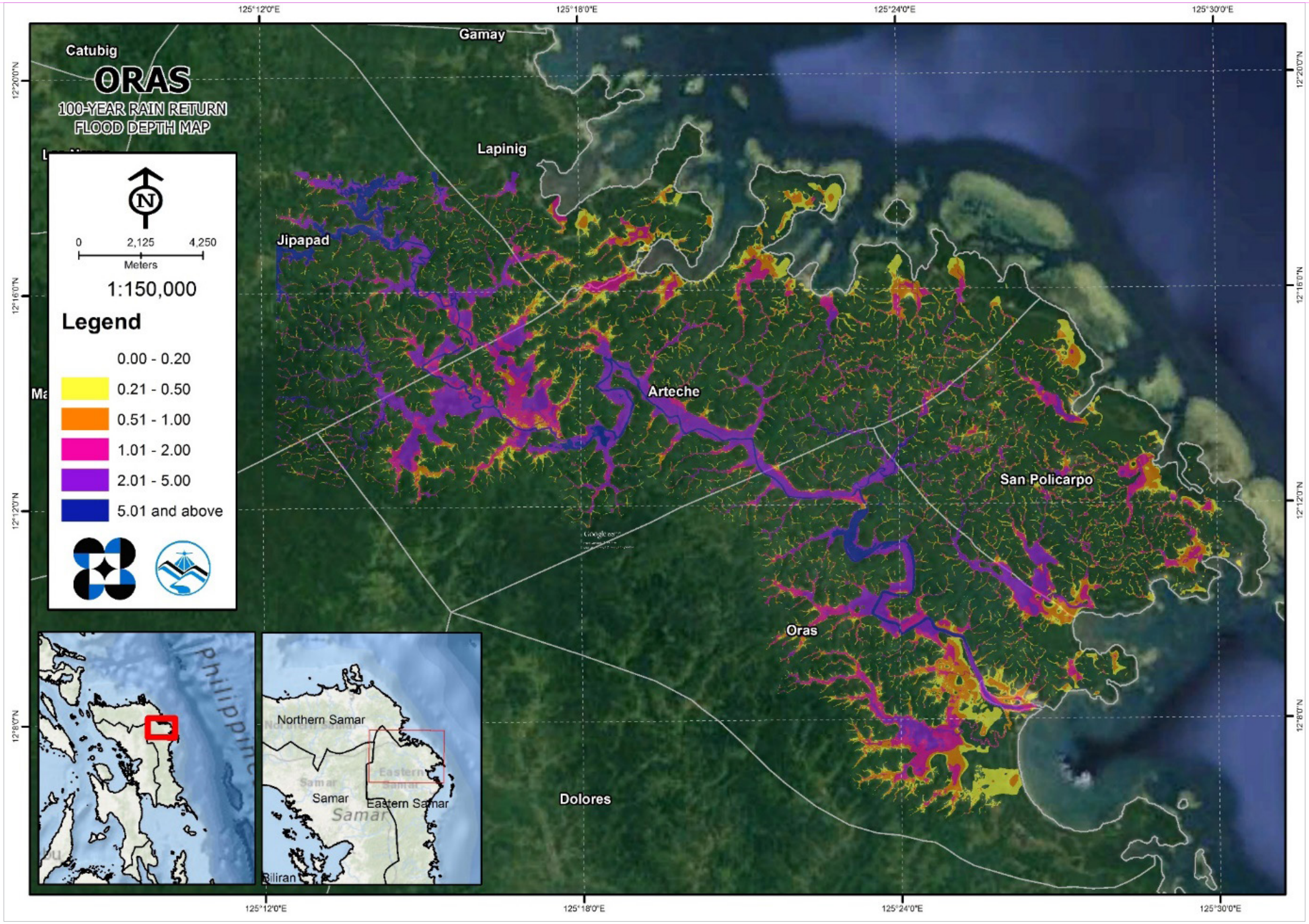


Figure 63. 100-year Flood Depth Map for Oras Floodplain

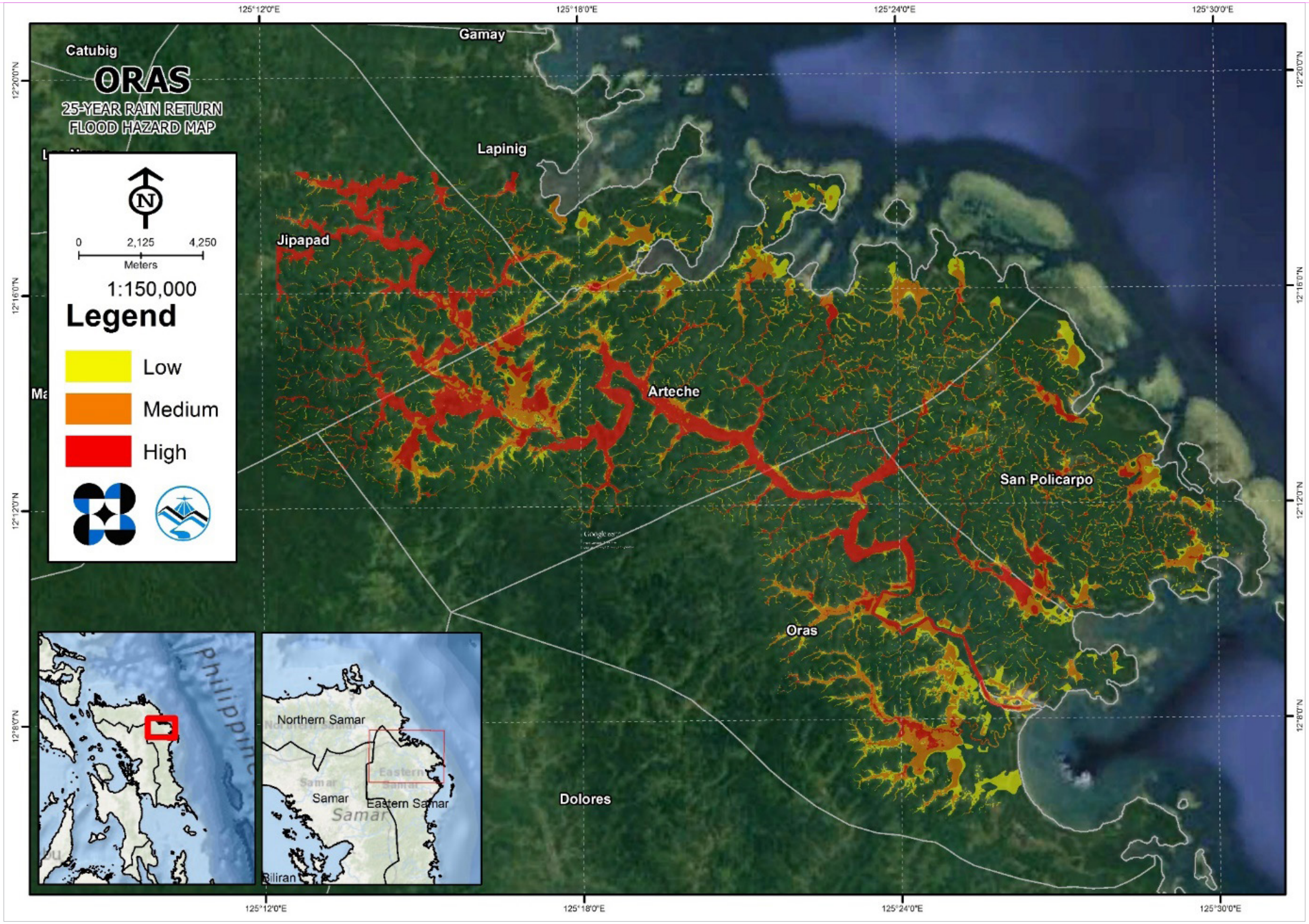


Figure 64. 25-year Hazard Map for Oras Floodplain

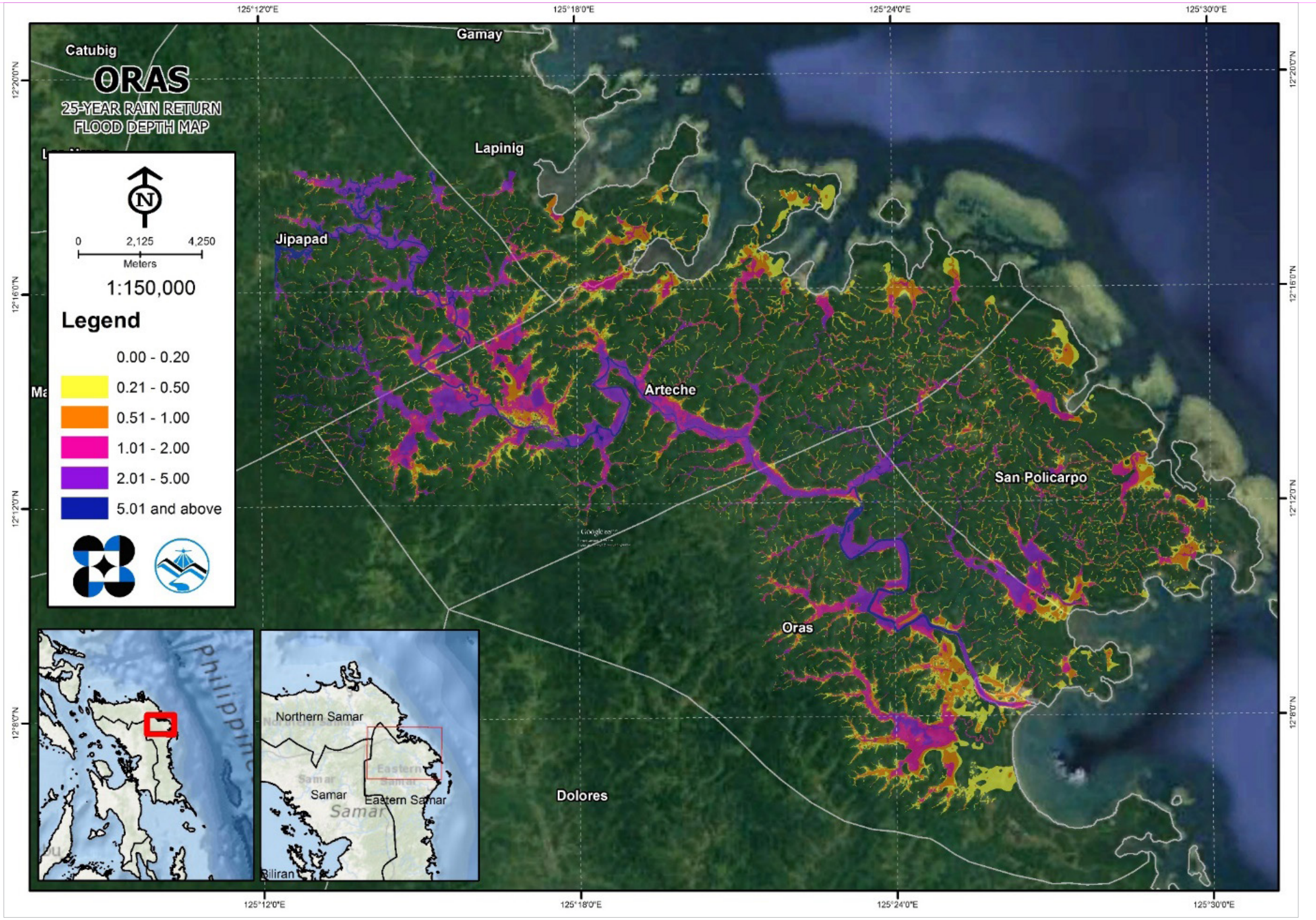


Figure 65. 25-year Flood Depth Map for Oras Floodplain

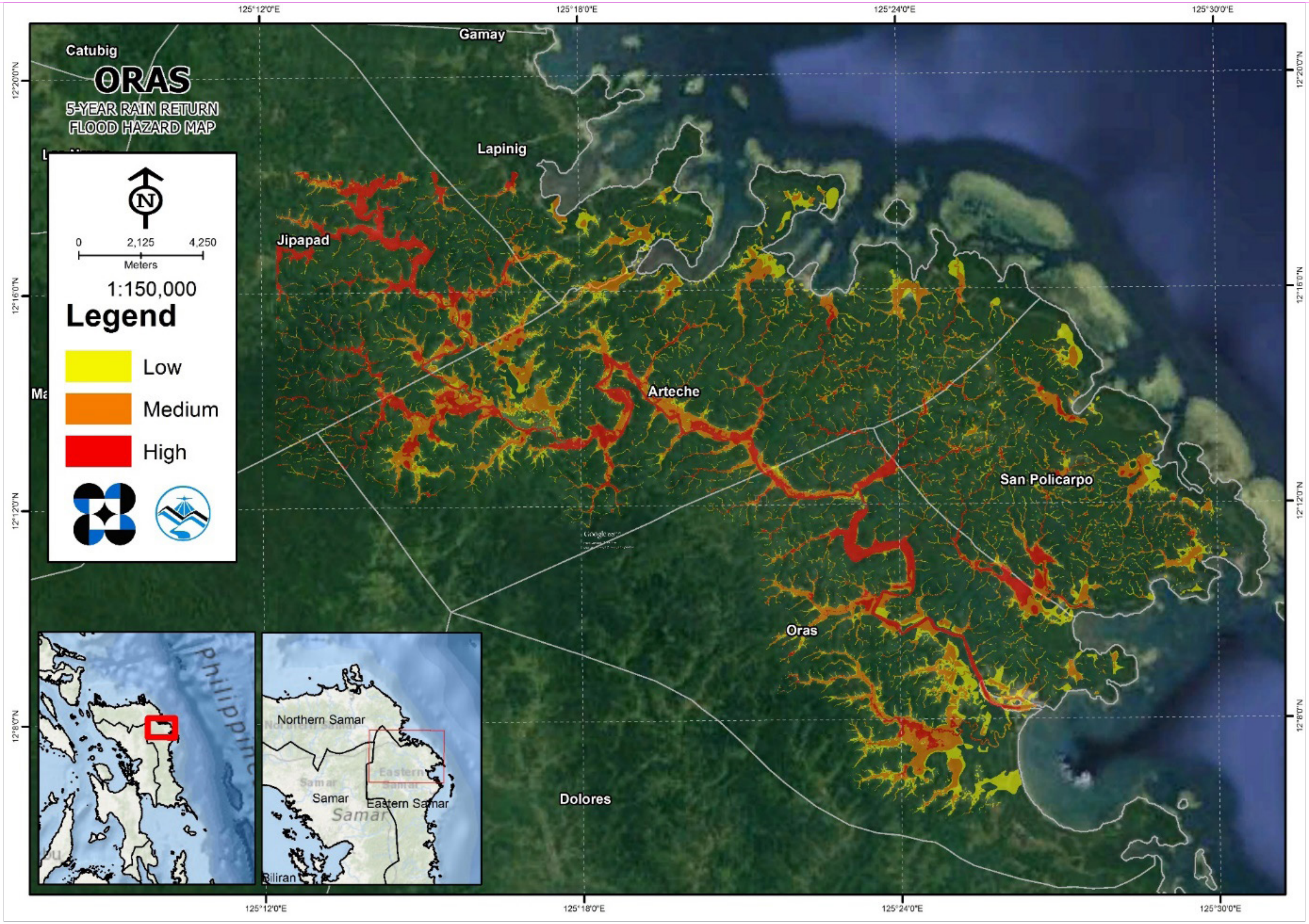


Figure 66. 5-year Hazard Map for Oras Floodplain

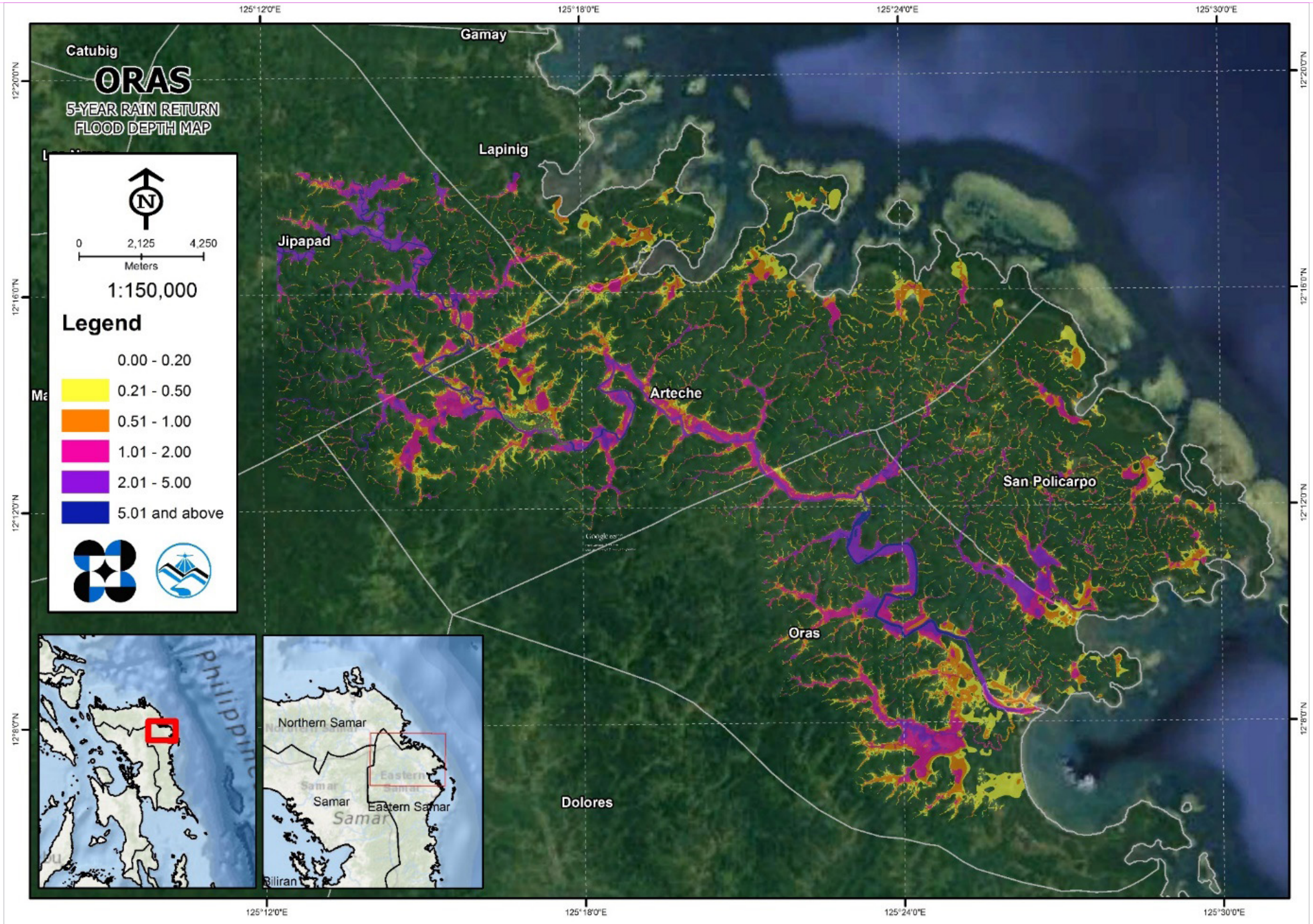


Figure 67. 5-year Flood Depth Map for Oras Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Oras River Basin, grouped accordingly by municipality. For the said basin, six (6) municipalities consisting of 92 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 62.18% of the municipality of Arteche with an area of 162.3 sq. km. will experience flood levels of less 0.20 meters, while 5.59% of the area will experience flood levels of 0.21 to 0.50 meters; 5.51%, 5.48%, 2.09%, and 0.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 29 depicts the areas affected in Arteche in square kilometers by flood depth per barangay.

Table 29. Affected areas in Arteche, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)									
	Aguinaldo	Balud	Bato	Beri	Bigo	Buenavista	Cagsalay	Campacion	Carapdapan	Casidman
0.03-0.20	1.5	4.41	7.55	2.84	12.01	1.02	5.84	4.71	4.89	3.05
0.21-0.50	0.17	0.22	0.41	0.67	0.96	0.13	0.35	0.54	0.6	0.36
0.51-1.00	0.16	0.17	0.34	0.15	1.21	0.052	0.39	0.44	0.58	0.37
1.01-2.00	0.077	0.14	0.2	0.006	2.25	0.015	0.78	0.33	0.24	0.24
2.01-5.00	0.0052	0.043	0.041	0	0.86	0	0.8	0.036	0.035	0.1
> 5.00	0	0	0.0002	0	0.2	0	0.16	0	0	0

Table 30. Affected areas in Arteche, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)									
	Catumsan	Central	Concepcion	Garden	Inayawan	Macarthur	Rawis	Tangbo	Tawagan	Tebalawon
0.03-0.20	1.5	2.74	6.43	5.17	14.97	0.12	1.73	7.22	9.77	3.45
0.21-0.50	0.25	0.22	1.2	0.53	0.82	0.0014	0.12	0.84	0.4	0.28
0.51-1.00	0.23	0.091	1.57	0.55	1	0	0.16	0.75	0.47	0.26
1.01-2.00	0.076	0.012	1.05	0.21	1.62	0	0.29	0.3	0.64	0.41
2.01-5.00	0.0013	0	0.07	0.024	0.7	0	0.069	0.037	0.27	0.3
> 5.00	0	0	0.013	0	0.022	0	0.0002	0	0.0071	0.046

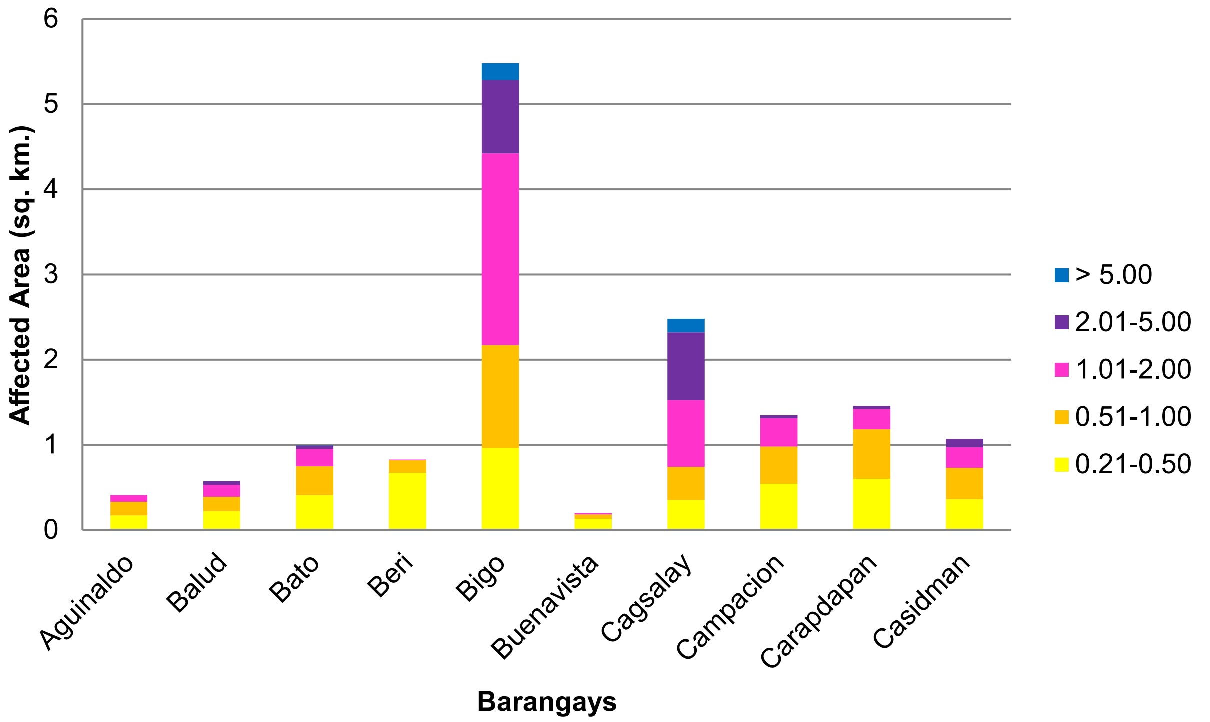


Figure 68. Affected areas in Arteche, Eastern Samar during a 5-Year rainfall Return period.

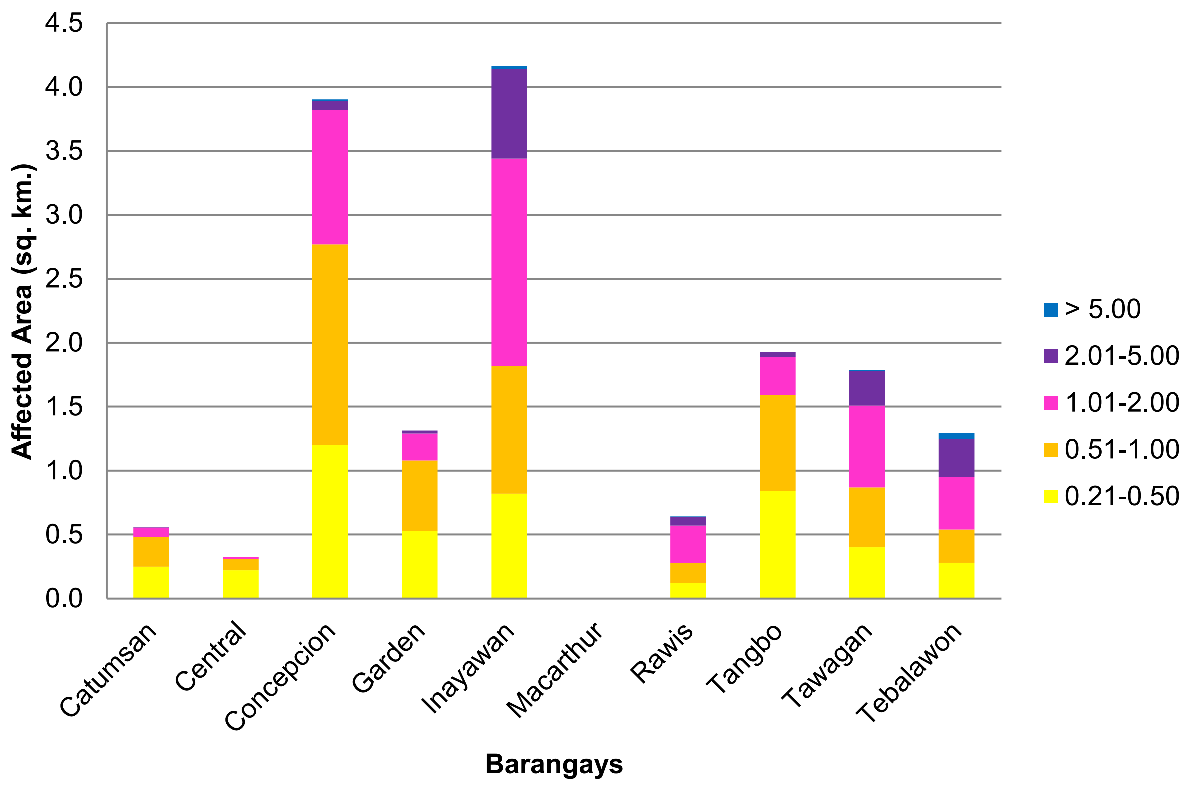


Figure 69. Affected areas in Arteche, Eastern Samar during a 5-Year rainfall Return period.

For the municipality of Jipapad, with an area of 173.29 sq. km., 26.84% will experience flood levels of less 0.20 meters. 1.18% of the area will experience flood levels of 0.21 to 0.50 meters while 1.28%, 1.85%, 2.35%, and 0.51% 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. Error: Reference source not found1 depicts the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Jipapad, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jipapad (in sq. km.)								
	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Dorillo	Jewaran	Recare	Roxas	San Roque
0.03-0.20	4.19	1.21	0.99	2.52	3.15	4.4	1.12	28.9	0.037
0.21-0.50	0.13	0.042	0.033	0.067	0.083	0.15	0.035	1.5	0.002
0.51-1.00	0.21	0.043	0.043	0.066	0.061	0.17	0.03	1.6	0.0021
1.01-2.00	0.41	0.063	0.053	0.087	0.067	0.32	0.06	2.14	0.0094
2.01-5.00	1.42	0.14	0.042	0.36	0.067	0.38	0.024	1.62	0.02
> 5.00	0.31	0.015	0.011	0.077	0.035	0.013	0.0039	0.42	0

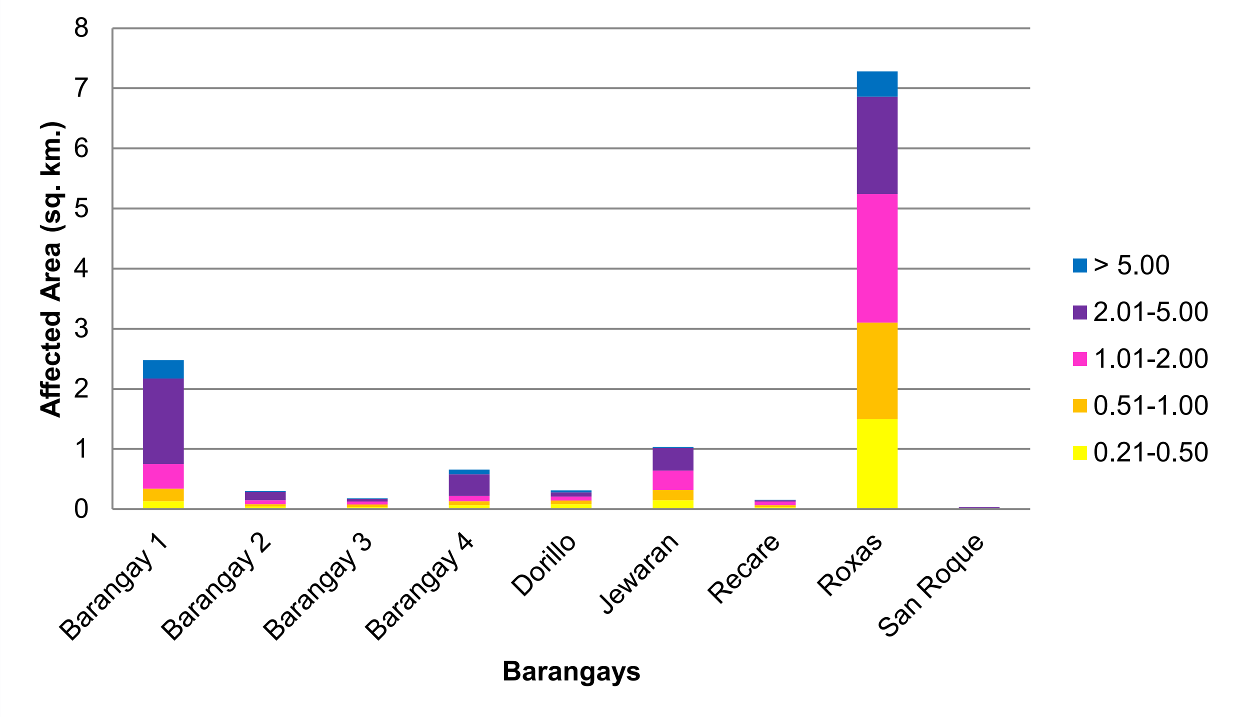


Figure 70. Affected areas in Jipapad, Eastern Samar during a 5-Year rainfall Return period.

For the municipality of Maslog, with an area of 284.92 sq. km., 0.94% will experience flood levels of less 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.02%, 0.01%, and 0.001% 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 32 depicts the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected areas in Maslog, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maslog (in sq. km.)
	San Roque
0.03-0.20	2.67898
0.21-0.50	0.093656
0.51-1.00	0.068938
1.01-2.00	0.052745
2.01-5.00	0.0304
> 5.00	0.0024

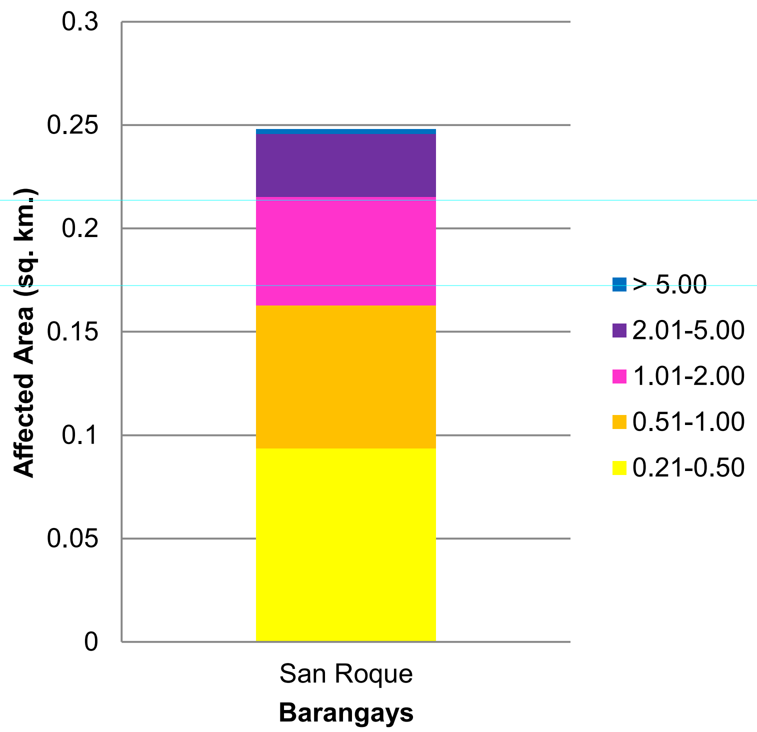


Figure 71. Affected areas in Maslog, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Oras, with an area of 173.99 sq. km., 37.34% will experience flood levels of less 0.20 meters. 4.73% of the area will experience flood levels of 0.21 to 0.50 meters while 4.14%, 4.21%, 2.9%, and 0.63% 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 depicts the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Agsam	Alang-Alang	Balingasag	Balocawe	Bantayan	Batang	Bato	Binalayan	Buntay
0.03-0.20	2.6	2.56	3.64	1.48	0.64	1.84	1.56	7.73	1.92
0.21-0.50	0.16	0.085	0.17	0.28	0.2	0.06	0.26	1.41	0.085
0.51-1.00	0.2	0.048	0.2	0.16	0.33	0.053	0.33	2.09	0.094
1.01-2.00	0.19	0.055	0.25	0.038	0.14	0.052	0.14	1.37	0.23
2.01-5.00	0.19	0.52	0.17	0.0058	0.00052	0.012	0.022	0.54	0.11
> 5.00	0.035	0.17	0.0065	0	0	0	0	0.14	0

Table 34. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Burak	Butnga	Cadian	Cagdine	Cagpile	Cagtoog	Camanga	Dao	Gamot
0.03-0.20	1.11	0.78	1.59	1.19	2.03	1.46	0.28	1.26	0.47
0.21-0.50	0.39	0.031	0.095	0.085	0.081	0.06	0.012	1.28	0.011
0.51-1.00	0.31	0.016	0.12	0.039	0.086	0.045	0.015	0.061	0.0031
1.01-2.00	0.52	0.006	0.33	0.033	0.11	0.05	0.023	0.00023	0.0057
2.01-5.00	0.12	0	0.41	0.15	0.027	0.017	0.0023	0	0
> 5.00	0	0	0.19	0.02	0.0003	0	0	0	0

Table 35. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Iwayan	Japay	Kalaw	Mabuhay	Malingon	Minap-Os	Nadacpan	Naga	Pangudtan
0.03-0.20	1.66	0.68	1.47	0.72	1.28	6.58	2.65	1.48	0.93
0.21-0.50	0.071	0.088	0.21	0.31	0.21	0.38	0.11	0.061	0.19
0.51-1.00	0.059	0.027	0.15	0.32	0.14	0.53	0.12	0.065	0.11
1.01-2.00	0.051	0.003	0.047	0.96	0.076	0.92	0.33	0.093	0.032
2.01-5.00	0.18	0.0002	0	0.2	0.0015	0.78	0.28	0.025	0
> 5.00	0.1	0	0	0	0	0.096	0.21	0	0

Table 36. Affected areas in Oras, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)									
	Paypayon	Riverside	Rizal	Sabang	San Eduardo	San Roque	Saurong	Tawagan	Tiguib	Trinidad
0.03-0.20	0.67	0.95	2.25	0.15	0.94	0.037	3.05	0.77	1.91	2.65
0.21-0.50	0.12	0.12	0.14	0.2	0.14	0.002	0.17	0.32	0.29	0.34
0.51-1.00	0.26	0.067	0.11	0.23	0.13	0.0021	0.14	0.06	0.18	0.31
1.01-2.00	0.28	0.028	0.22	0.19	0.17	0.0094	0.22	0.024	0.031	0.1
2.01-5.00	0.12	0.18	0.13	0.19	0.068	0.02	0.54	0.019	0.0017	0.0069
> 5.00	0.12	0.0011	0	0	0	0.0024	0	0.0071	0	0

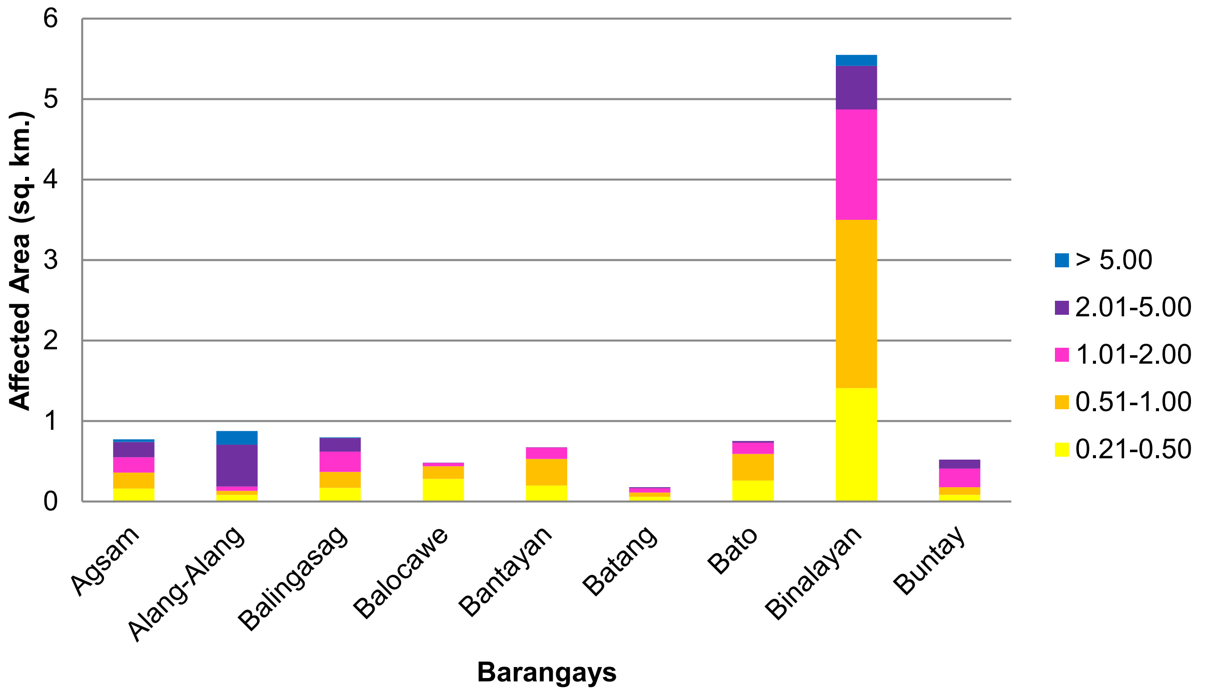


Figure 72. Affected areas in Oras, eastern Samar during a 5-Year Rainfall Return Period.

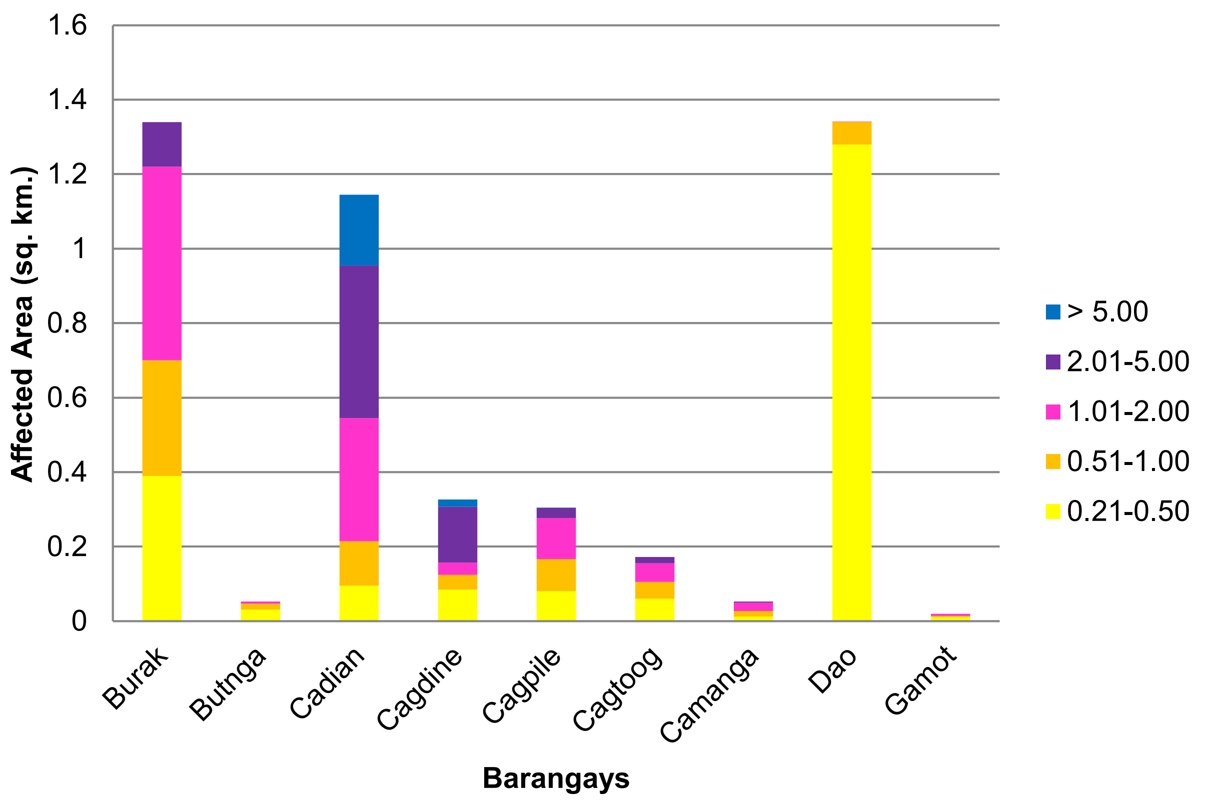


Figure 73. Affected areas in Oras, eastern Samar during a 5-Year Rainfall Return Period.

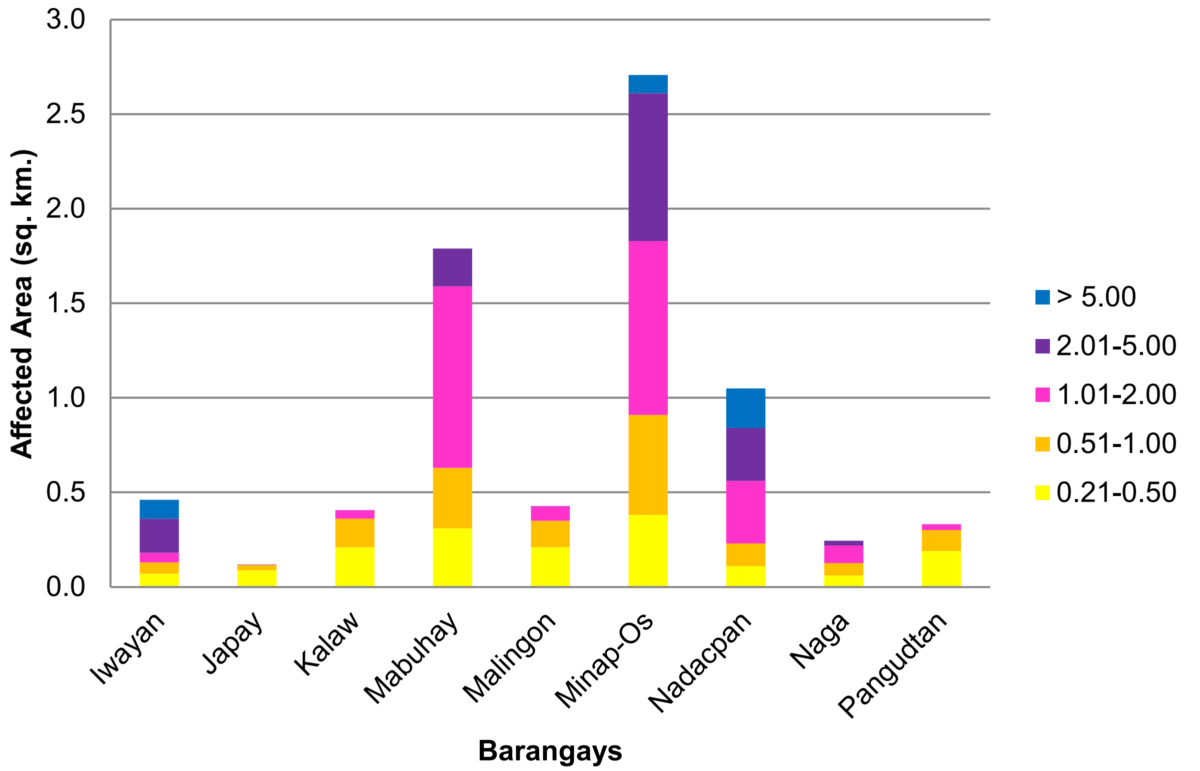


Figure 74. Affected areas in Oras, eastern Samar during a 5-Year Rainfall Return Period.

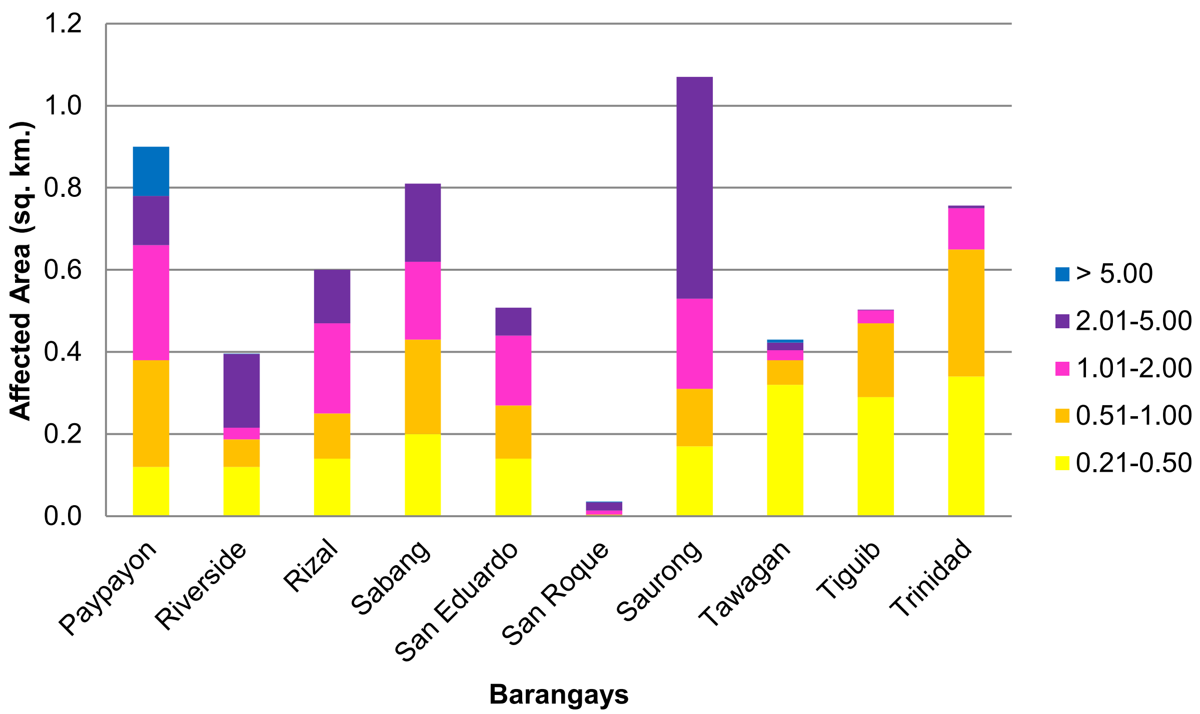


Figure 75. Affected areas in Oras, eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of San Policarpo, with an area of 77.28 sq. km., 68.63% will experience flood levels of less 0.20 meters. 6.76% of the area will experience flood levels of 0.21 to 0.50 meters while 4.93%, 3.89%, 1.69%, and 0.02%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 37 depicts the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in San Policarpo, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Policarpo (in sq. km.)							
	Alugan	Bahay	Bangon	Barangay No. 1	Barangay No. 2	Barangay No. 3	Barangay No. 4	Barangay No. 5
0.03-0.20	3.57	4.17	5.37	0.56	0.14	0.41	0.72	1.39
0.21-0.50	0.37	0.66	0.35	0.0014	0.0073	0.065	0.094	0.12
0.51-1.00	0.35	0.41	0.26	0	0.0013	0.012	0.066	0.077
1.01-2.00	0.27	0.28	0.24	0	0	0.02	0.061	0.047
2.01-5.00	0.0043	0.011	0.16	0	0	0	0.0048	0
> 5.00	0	0	0.0044	0	0	0	0	0

Table 38. Affected areas in San Policarpo, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Policarpo (in sq. km.)								
	Baras	Binogawan	Cajagwayan	Japunan	Natividad	Pangpang	Santa Cruz	Tabo	Tan-Awan
0.03-0.20	1.97	9.42	3.73	2.27	1.87	1.78	10.9	1.76	3.01
0.21-0.50	0.21	1.15	0.37	0.25	0.55	0.081	0.69	0.075	0.18
0.51-1.00	0.14	1.01	0.25	0.32	0.19	0.071	0.49	0.039	0.12
1.01-2.00	0.054	0.86	0.2	0.21	0.051	0.14	0.45	0.029	0.097
2.01-5.00	0.002	0.77	0.043	0.033	0.0022	0.005	0.25	0.0053	0.018
> 5.00	0	0	0	0	0	0	0.014	0	0

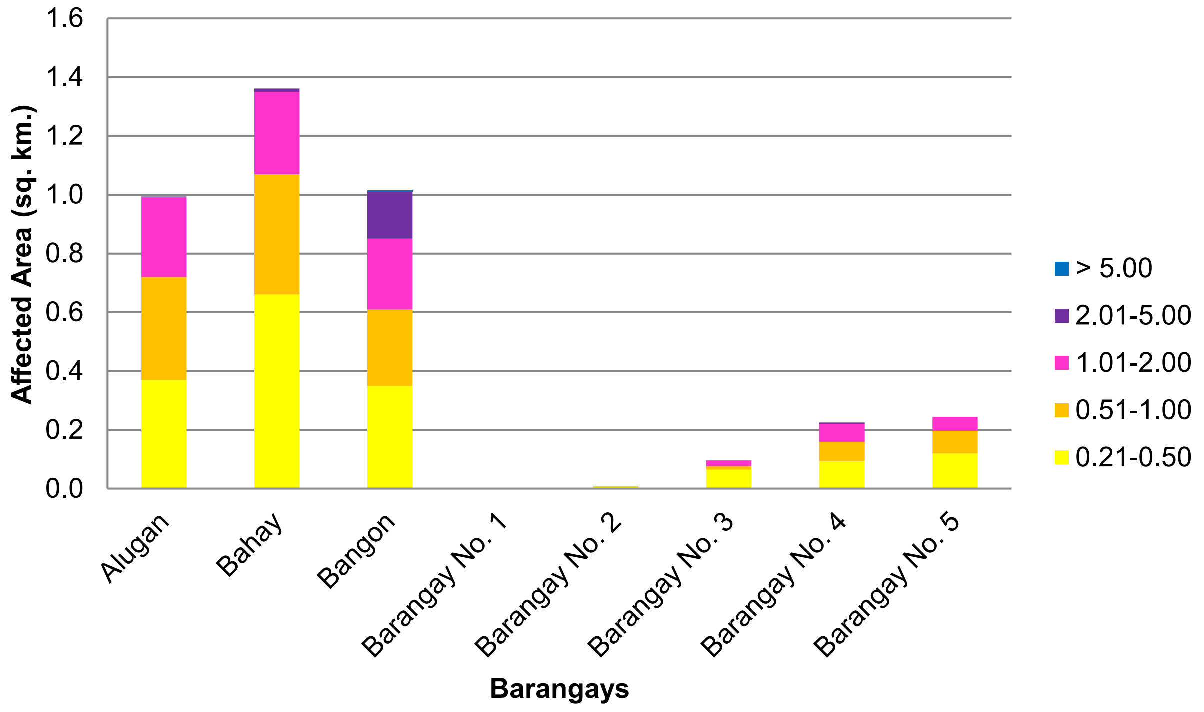


Figure 76. Affected areas in San Policarpo, Eastern Samar during a 5-Year Rainfall Return Period.

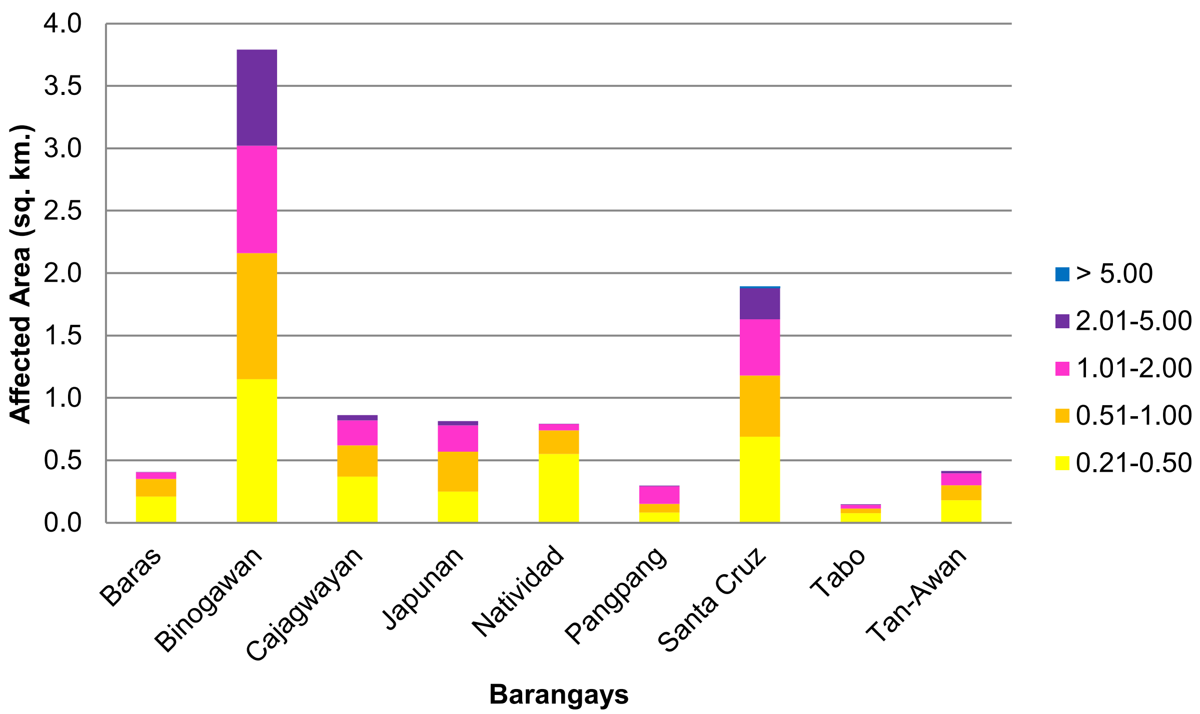


Figure 77. Affected areas in San Policarpo, Eastern Samar during a 5-Year Rainfall Return Period.

For the municipality of Lapinig, with an area of 57.03 sq. km., 23.02% will experience flood levels of less 0.20 meters. 2.78% of the area will experience flood levels of 0.21 to 0.50 meters while 2.22%, 0.89%, and 0.18%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 39 depicts the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Lapinig, Northern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lapinig (in sq. km.)							
	Bagacay	Cahagwayan	Can Omanio	Imelda	Lo-Ok	Mabini	May-Igot	Palanas
0.03-0.20	1.99	1.66	0.22	0.1	1.78	0.72	4.05	2.61
0.21-0.50	0.23	0.063	0.0071	0.004	0.14	0.034	0.67	0.44
0.51-1.00	0.16	0.064	0.0034	0.011	0.22	0.0086	0.59	0.21
1.01-2.00	0.099	0.065	0.0008	0.071	0.13	0.0047	0.08	0.058
2.01-5.00	0.0027	0.018	0	0.056	0.025	0	0	0
> 5.00	0	0	0	0	0	0	0	0

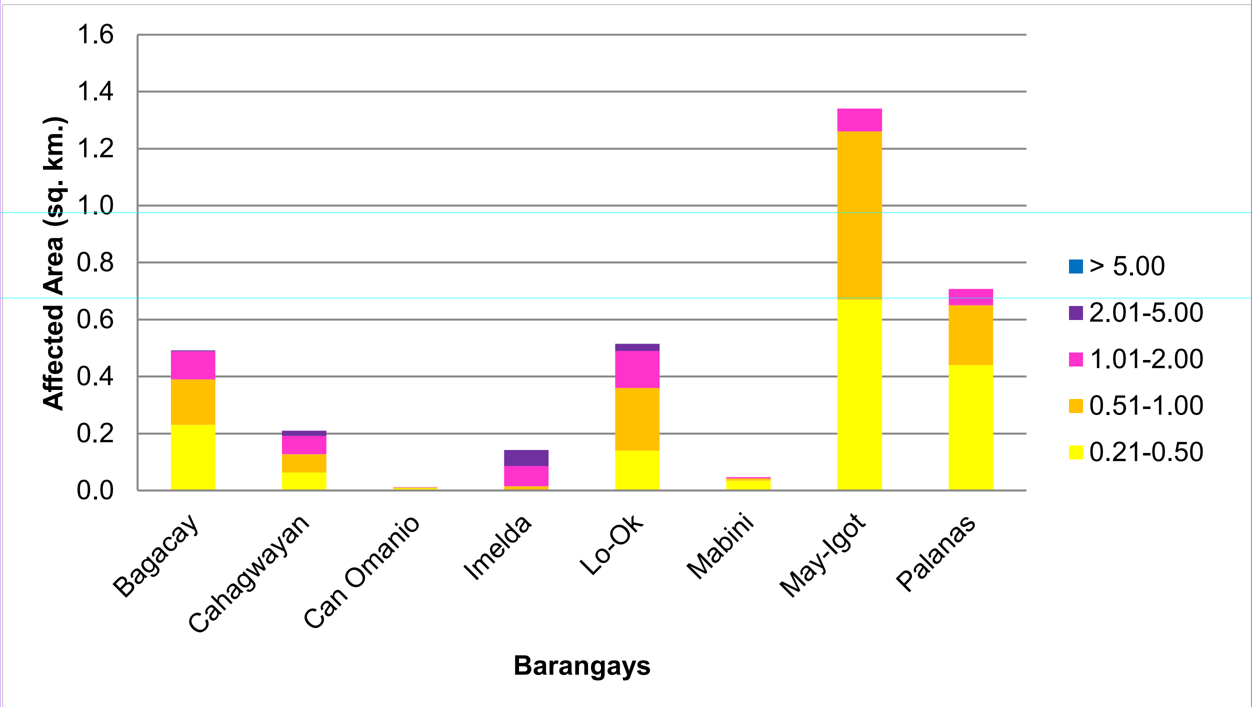


Figure 78. Affected areas in Lapinig, Northern Samar during a 5-Year Rainfall Return Period.

For the 25-year return period, 59.24% of the municipality of Arteche with an area of 162.3 sq. km. will experience flood levels of less 0.20 meters, while 5.13% of the area will experience flood levels of 0.21 to 0.50 meters; 4.96%, 6.27%, 4.99%, and 0.57% 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 40 depicts the areas affected in Arteche in square kilometers by flood depth per barangay.

Table 40. Affected areas in Arteche, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)									
	Aguinaldo	Balud	Bato	Beri	Bigo	Buenavista	Cagsalay	Campacion	Carapdapan	Casidman
0.03-0.20	1.44	4.33	7.39	2.59	11.5	0.99	5.59	4.53	4.71	2.85
0.21-0.50	0.18	0.24	0.45	0.81	0.69	0.14	0.3	0.52	0.6	0.33
0.51-1.00	0.19	0.18	0.35	0.26	0.89	0.067	0.22	0.45	0.63	0.36
1.01-2.00	0.11	0.16	0.28	0.0097	1.76	0.023	0.43	0.45	0.36	0.36
2.01-5.00	0.0072	0.078	0.07	0	2.42	0.0007	1.36	0.1	0.053	0.2
> 5.00	0	0	0.0019	0	0.25	0	0.41	0.0035	0.0033	0.022

Table 41. Affected areas in Arteche, Eastern Samar during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)									
	Catumsan	Central	Concepcion	Garden	Inayawan	Macarthur	Rawis	Tangbo	Tawagan	Tebalawon
0.03-0.20	1.38	2.66	5.17	4.95	14.54	0.12	1.67	6.93	9.57	3.24
0.21-0.50	0.27	0.27	0.68	0.51	0.71	0.0022	0.12	0.88	0.38	0.24
0.51-1.00	0.25	0.12	1.36	0.65	0.63	0	0.13	0.74	0.35	0.22
1.01-2.00	0.16	0.025	2.47	0.33	1.43	0	0.3	0.54	0.72	0.26
2.01-5.00	0.0032	0	0.66	0.051	1.69	0	0.14	0.055	0.5	0.71
> 5.00	0	0	0.014	0	0.12	0	0.0037	0	0.026	0.077

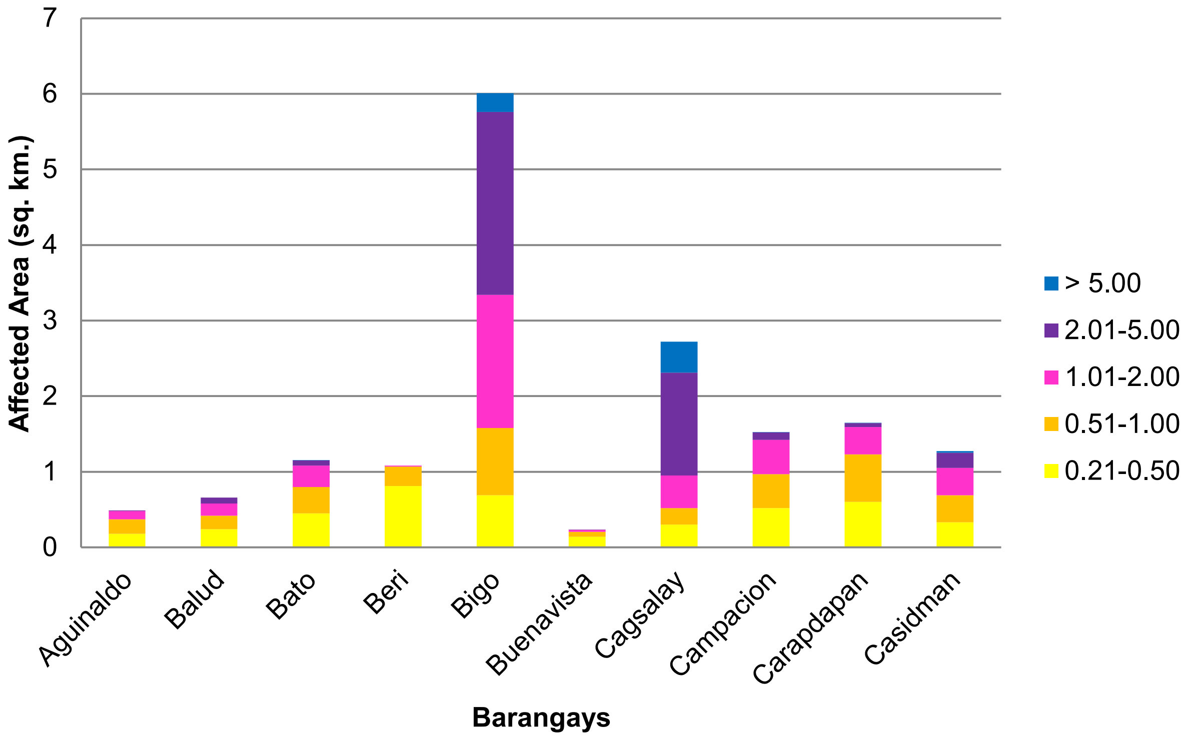


Figure 79. Affected areas in Arteche, Eastern Samar during a 25-Year rainfall Return period.

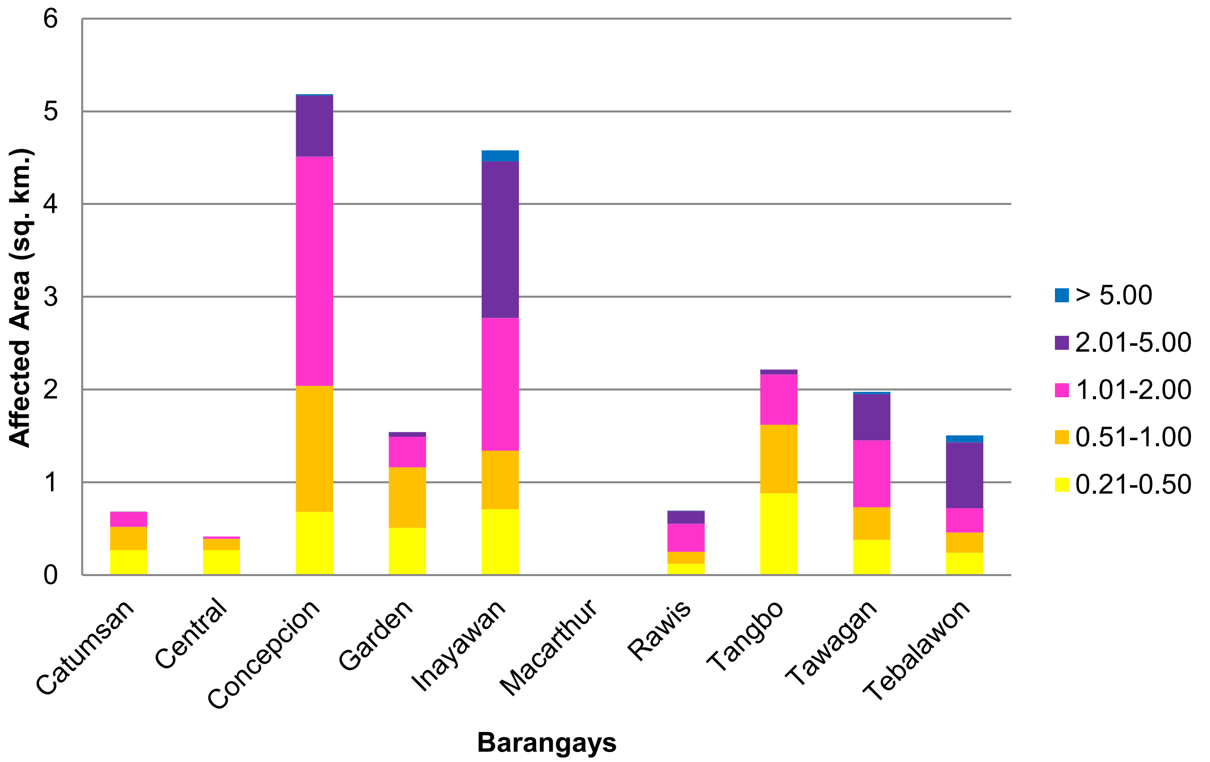


Figure 80. Affected areas in Arteche, Eastern Samar during a 25-Year rainfall Return period.

For the municipality of Jipapad, with an area of 173.29 sq. km., 26.02% will experience flood levels of less 0.20 meters. 1.06% of the area will experience flood levels of 0.21 to 0.50 meters while 1.002%, 1.73%, 3.15%, and 1.05% 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 42 depicts the affected areas in square kilometers by flood depth per barangay.

For the municipality of Guinobatan with an area of 174.07 sq. km., 0.23% will experience flood levels of less than 0.20 meters. 0.009% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.006%, 0.007%, 0.01%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 42 depicts the areas affected in Guinobatan in square kilometers by flood depth per barangay.

Table 42. Affected areas in Jipapad, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jipapad (in sq. km.)								
	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Dorillo	Jewaran	Recare	Roxas	San Roque
0.03-0.20	4	1.17	0.96	2.44	3.1	4.26	1.09	28.04	0.033
0.21-0.50	0.11	0.045	0.03	0.066	0.087	0.13	0.036	1.34	0.00075
0.51-1.00	0.12	0.027	0.029	0.064	0.069	0.13	0.026	1.27	0.00092
1.01-2.00	0.22	0.043	0.028	0.089	0.068	0.18	0.037	2.33	0.003
2.01-5.00	1.59	0.17	0.098	0.14	0.078	0.66	0.077	2.63	0.017
> 5.00	0.64	0.054	0.028	0.38	0.058	0.063	0.011	0.56	0.017

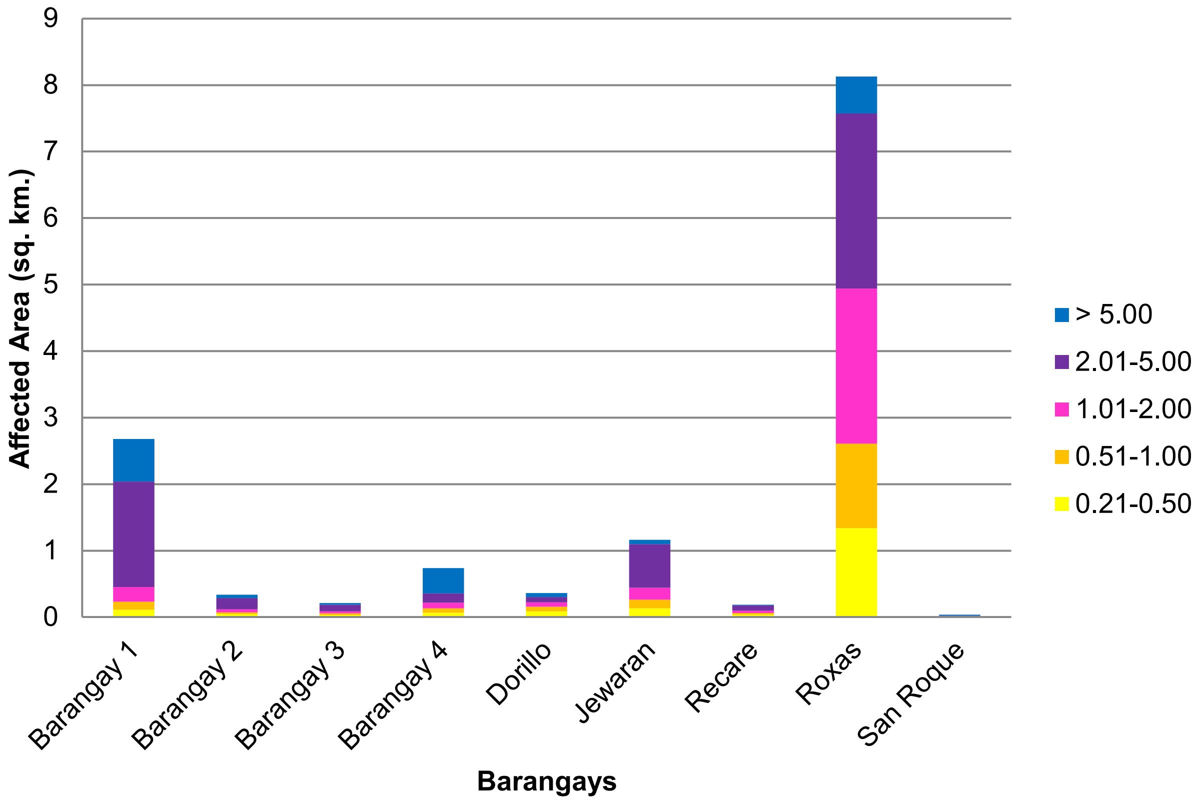


Figure 81. Affected areas in Jipapad, Eastern Samar during a 25-Year rainfall Return period.

For the municipality of Maslog, with an area of 284.92 sq. km., 0.93% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.02%, and 0.002% 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 43 depicts the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Maslog, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maslog (in sq. km.)
	San Roque
0.03-0.20	2.64
0.21-0.50	0.1
0.51-1.00	0.074
1.01-2.00	0.063
2.01-5.00	0.043
> 5.00	0.0064

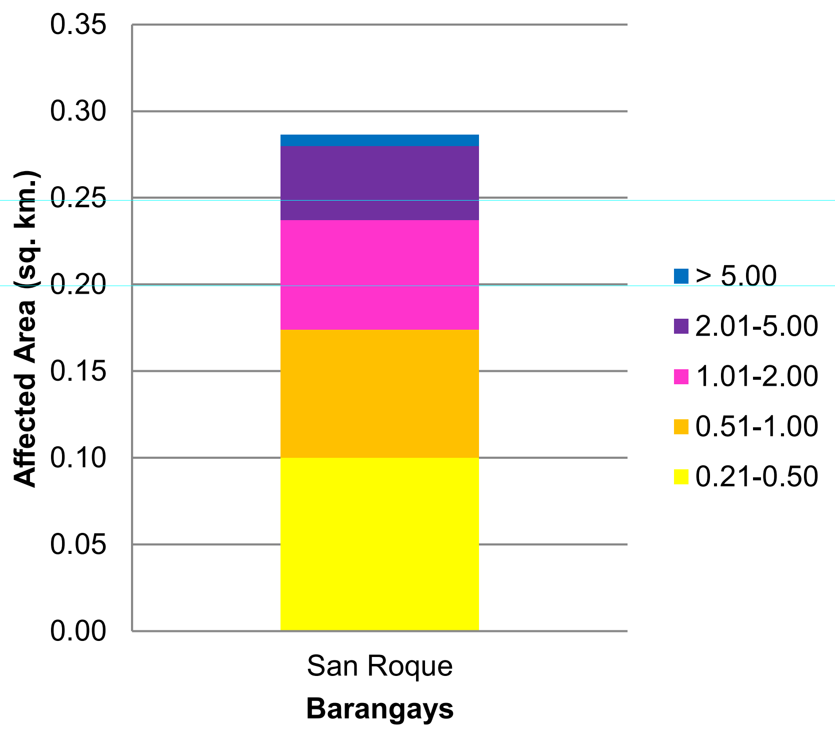


Figure 82. Affected areas in Maslog, Eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of Oras, with an area of 173.99 sq. km., 37.79% will experience flood levels of less 0.20 meters. 4.72% of the area will experience flood levels of 0.21 to 0.50 meters while 4.1%, 4.08%, 3.27%, and 0.67% 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 44 depicts the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in Oras, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Agsam	Alang-Alang	Balingasag	Balocawe	Bantayan	Batang	Bato	Binalayan	Buntay
0.03-0.20	2.6	2.55	3.64	1.48	0.64	1.81	1.56	7.73	1.86
0.21-0.50	0.16	0.09	0.17	0.28	0.2	0.064	0.26	1.41	0.088
0.51-1.00	0.2	0.049	0.2	0.16	0.33	0.044	0.33	2.09	0.062
1.01-2.00	0.19	0.057	0.25	0.038	0.14	0.072	0.14	1.37	0.14
2.01-5.00	0.19	0.52	0.17	0.0058	0.00052	0.027	0.022	0.54	0.3
> 5.00	0.035	0.17	0.0065	0	0	0	0	0.14	0

Table 45. Affected areas in Oras, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Burak	Butnga	Cadian	Cagdine	Cagpile	Cagtoog	Camanga	Dao	Gamot
0.03-0.20	1.11	0.78	1.5	1.13	1.99	1.44	0.28	1.26	0.47
0.21-0.50	0.39	0.031	0.082	0.062	0.085	0.063	0.012	1.28	0.013
0.51-1.00	0.31	0.016	0.058	0.075	0.072	0.048	0.015	0.061	0.0037
1.01-2.00	0.52	0.006	0.19	0.079	0.14	0.044	0.023	0.00023	0.0052
2.01-5.00	0.12	0	0.64	0.16	0.051	0.036	0.0023	0	0.0012
> 5.00	0	0	0.25	0.021	0.001	0	0	0	0

Table 46. Affected areas in Oras, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Iwayan	Japay	Kalaw	Mabuhay	Malingon	Minap-Os	Nadacpan	Naga	Pangudtan
0.03-0.20	1.66	0.68	1.47	0.72	1.28	6.58	2.65	1.48	0.93
0.21-0.50	0.071	0.088	0.21	0.31	0.21	0.38	0.11	0.061	0.19
0.51-1.00	0.059	0.027	0.15	0.32	0.14	0.53	0.12	0.065	0.11
1.01-2.00	0.051	0.003	0.047	0.96	0.076	0.92	0.33	0.093	0.032
2.01-5.00	0.18	0.0002	0	0.2	0.0015	0.78	0.28	0.025	0
> 5.00	0.1	0	0	0	0	0.096	0.21	0	0

Table 47. Affected areas in Oras, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)									
	Paypayon	Riverside	Rizal	Sabang	San Eduardo	San Roque	Saurong	Tawagan	Tiguib	Trinidad
0.03-0.20	0.67	0.95	2.19	0.15	0.94	1.19	3.05	0.77	1.91	2.65
0.21-0.50	0.12	0.12	0.11	0.2	0.14	0.04	0.17	0.32	0.29	0.34
0.51-1.00	0.26	0.067	0.1	0.23	0.13	0.018	0.14	0.06	0.18	0.31
1.01-2.00	0.28	0.028	0.13	0.19	0.17	0.018	0.22	0.024	0.031	0.1
2.01-5.00	0.12	0.18	0.31	0.19	0.068	0.0065	0.54	0.019	0.0017	0.0069
> 5.00	0.12	0.0011	0.0068	0	0	0	0	0.0071	0	0

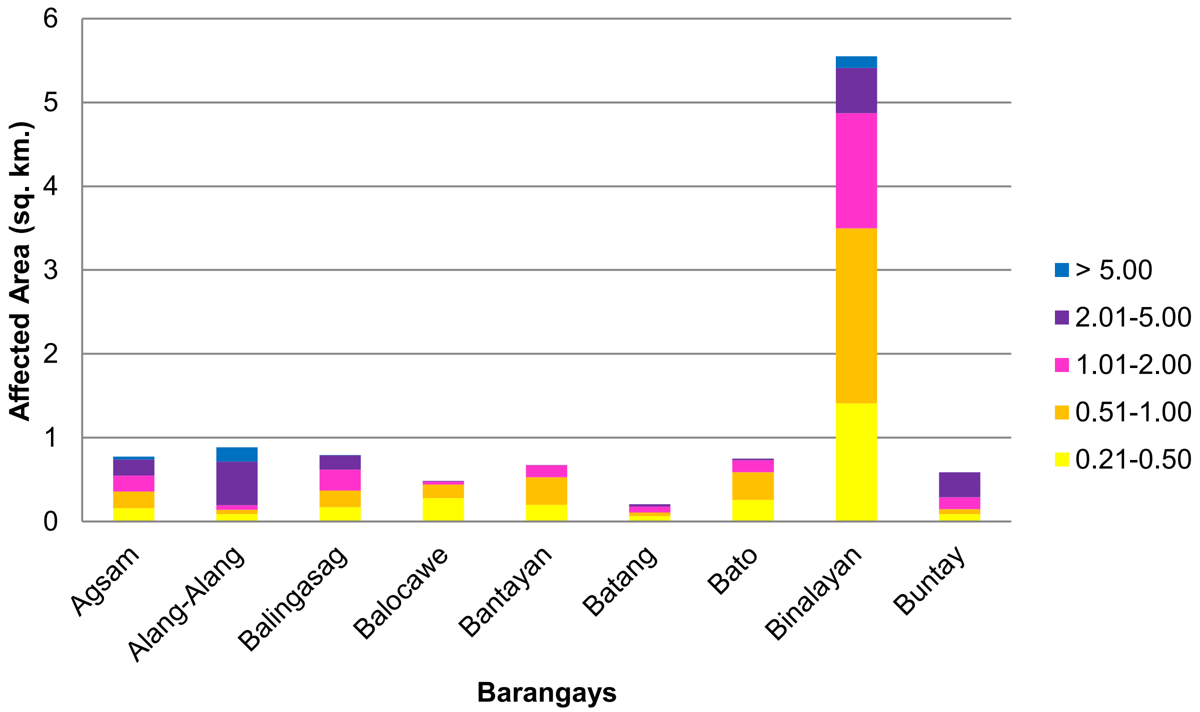


Figure 83. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

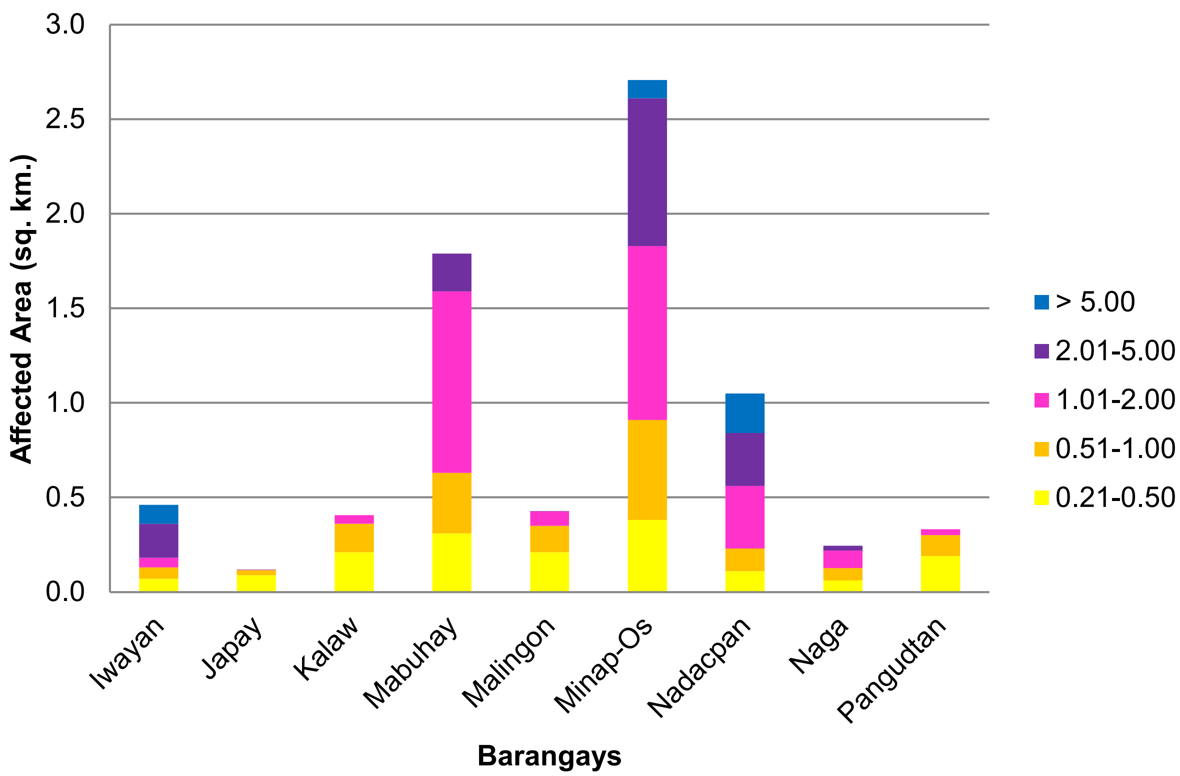


Figure 84. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

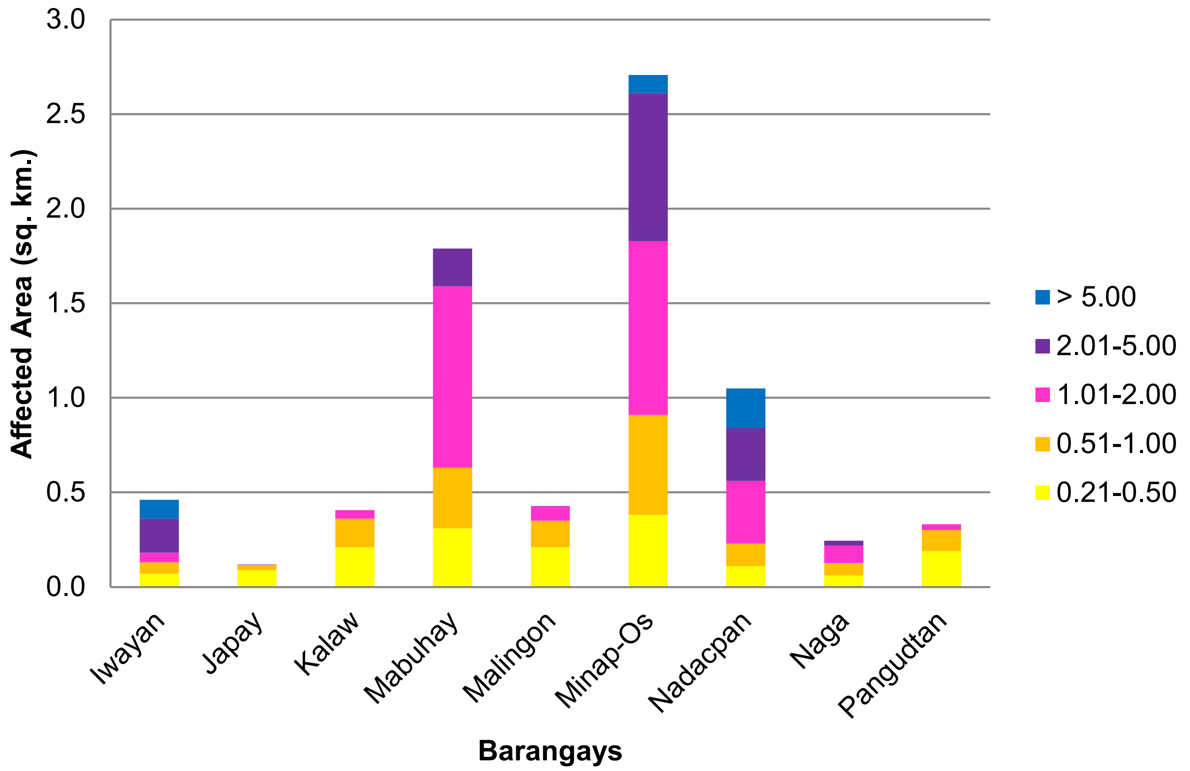


Figure 85. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

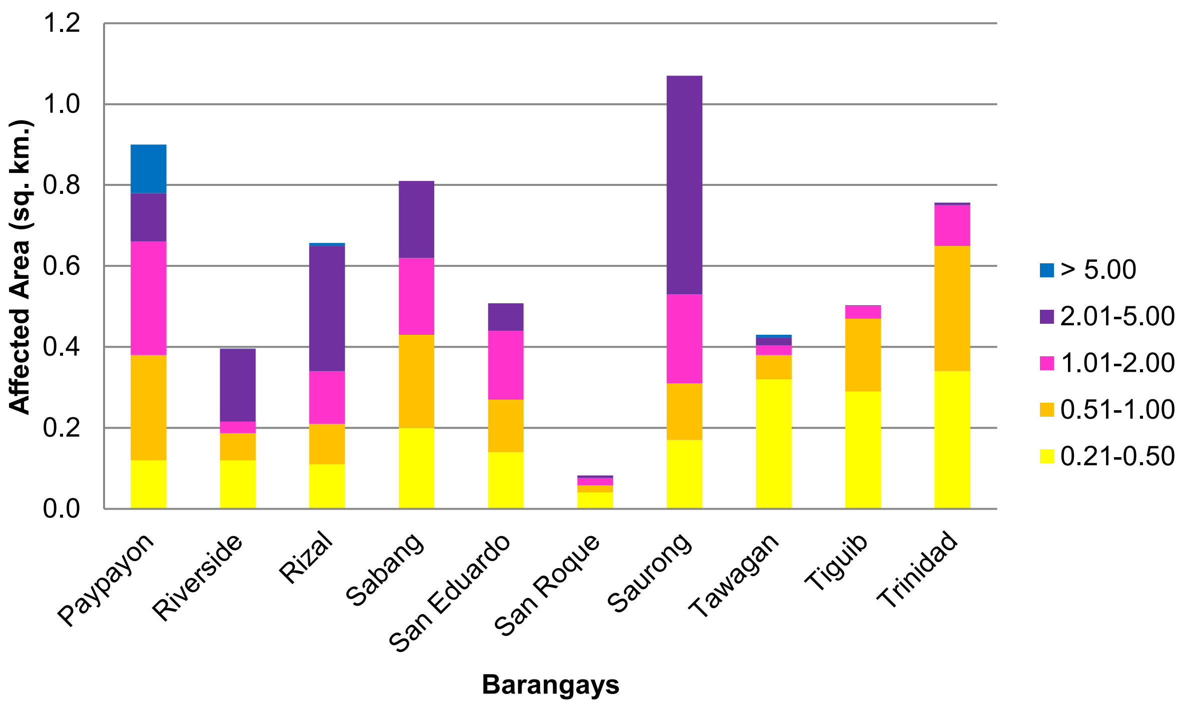


Figure 86. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of San Policarpo, with an area of 77.28 sq. km., 66.53% will experience flood levels of less 0.20 meters. 6.94% of the area will experience flood levels of 0.21 to 0.50 meters while 5.53%, 4.76%, 2.07%, and 0.07%, 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 48 depicts the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected areas in San Policarpio, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Policarpo (in sq. km.)							
	Alugan	Bahay	Bangon	Barangay No. 1	Barangay No. 2	Barangay No. 3	Barangay No. 4	Barangay No. 5
0.03-0.20	3.39	3.94	5.18	0.56	0.13	0.37	0.67	1.3
0.21-0.50	0.42	0.58	0.37	0.0032	0.018	0.1	0.1	0.15
0.51-1.00	0.35	0.54	0.29	0	0.0015	0.018	0.089	0.095
1.01-2.00	0.38	0.44	0.29	0	0.000045	0.024	0.074	0.08
2.01-5.00	0.018	0.038	0.21	0	0	0	0.013	0
> 5.00	0	0	0.036	0	0	0	0	0

Table 49. Affected areas in San Policarpio, Eastern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Policarpo (in sq. km.)								
	Baras	Binogawan	Cajagwayan	Japunan	Natividad	Pangpang	Santa Cruz	Tabo	Tan-Awan
0.03-0.20	1.9	9.24	3.59	2.17	1.73	1.74	10.86	1.72	2.92
0.21-0.50	0.18	1.14	0.37	0.26	0.58	0.098	0.69	0.093	0.21
0.51-1.00	0.21	1.1	0.3	0.27	0.27	0.071	0.49	0.047	0.13
1.01-2.00	0.083	0.94	0.27	0.32	0.071	0.11	0.45	0.03	0.12
2.01-5.00	0.0054	0.78	0.08	0.056	0.011	0.054	0.28	0.016	0.036
> 5.00	0	0	0	0	0	0	0.018	0	0

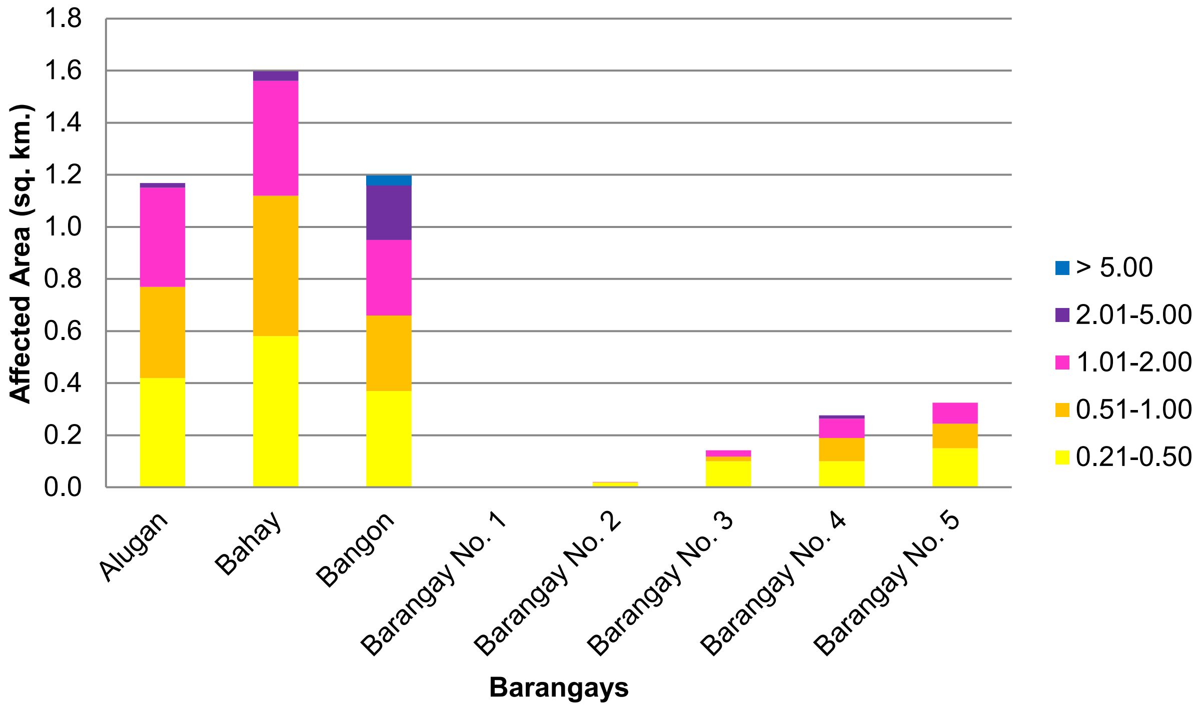


Figure 87. Affected areas in San Policarpo, Eastern Samar during a 25-Year Rainfall Return Period.

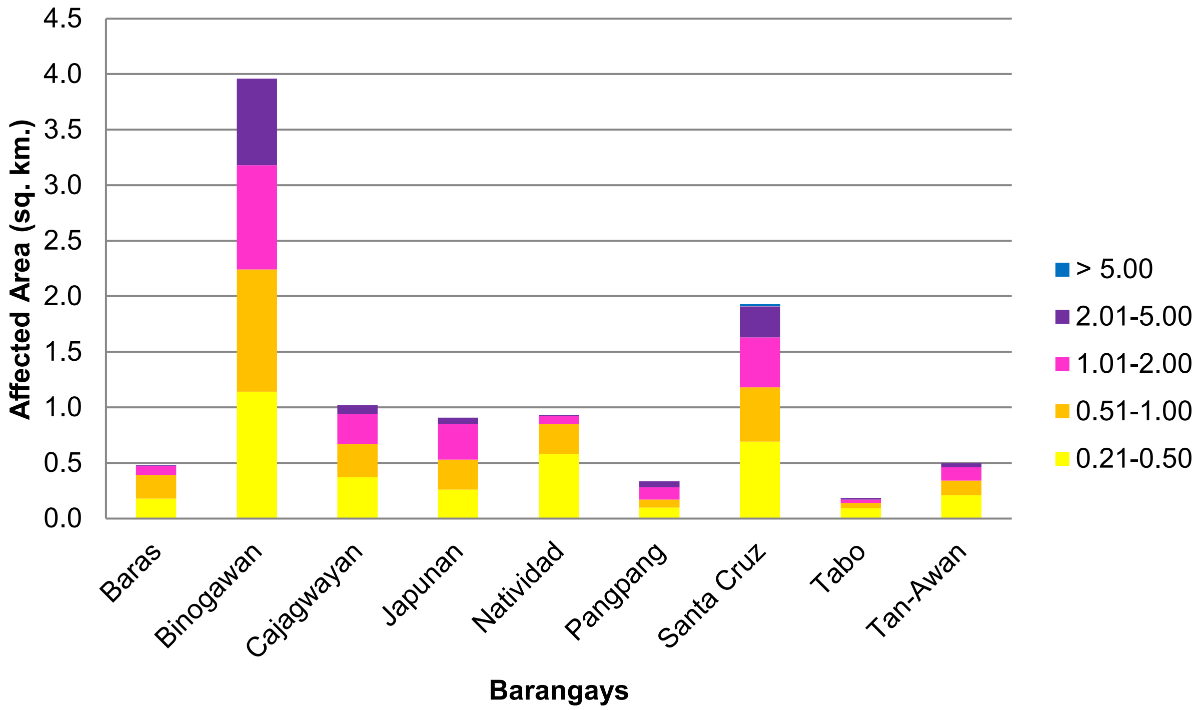


Figure 88. Affected areas in San Policarpo, Eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of Lapinig, with an area of 57.03 sq. km., 22.14% will experience flood levels of less 0.20 meters. 2.69% of the area will experience flood levels of 0.21 to 0.50 meters while 2.56%, 1.34%, and 0.39%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 50 depicts the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected areas in Lapinig, Northern Samar during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lapinig (in sq. km.)							
	Bagacay	Cahagwayan	Can Omanio	Imelda	Lo-Ok	Mabini	May-Igot	Palanas
0.03-0.20	1.93	1.64	0.21	0.097	1.73	0.71	3.83	2.48
0.21-0.50	0.21	0.061	0.0083	0.0028	0.11	0.041	0.64	0.46
0.51-1.00	0.2	0.057	0.0037	0.0046	0.22	0.0074	0.72	0.25
1.01-2.00	0.14	0.067	0.0013	0.018	0.19	0.0087	0.21	0.13
2.01-5.00	0.011	0.05	0	0.12	0.041	0	0	0.0002
> 5.00	0	0	0	0	0	0	0	0

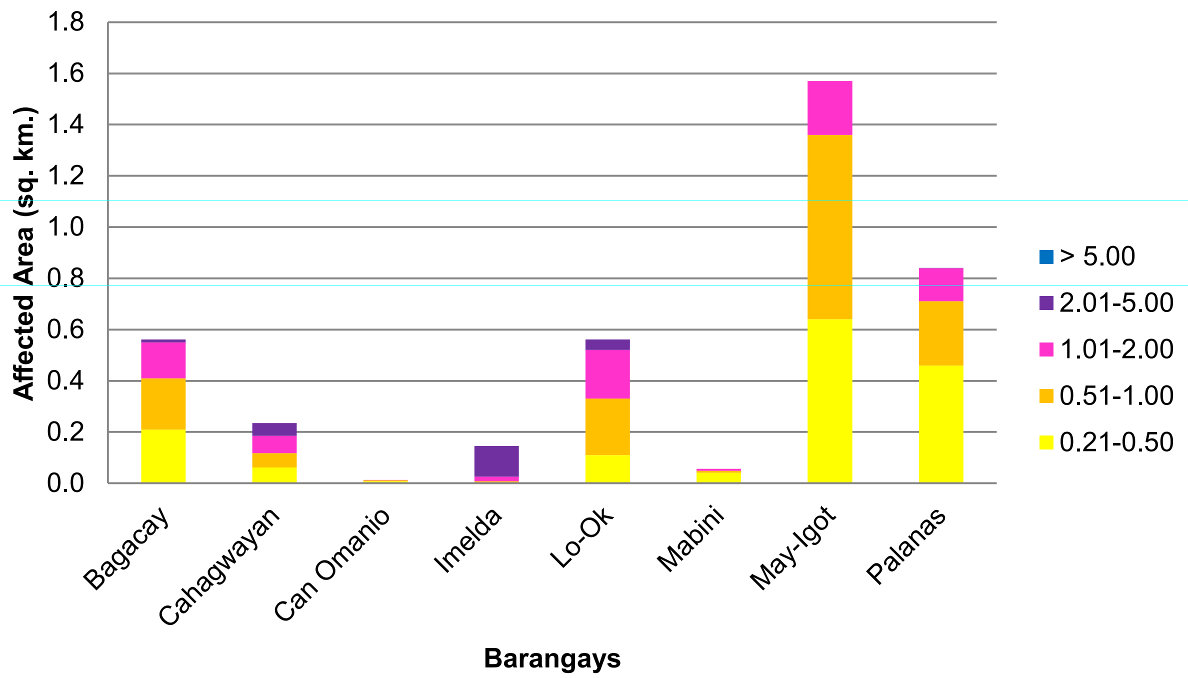


Figure 89. Affected areas in Lapinig, Northern Samar during a 25-Year Rainfall Return Period.

For the 100-year return period, 57.57% of the municipality of Arteche with an area of 162.3 sq. km. will experience flood levels of less 0.20 meters, while 5.005% of the area will experience flood levels of 0.21 to 0.50 meters; 4.5%, 5.89%, 7.14%, and 1.05% 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 51 depicts the areas affected in Arteche in square kilometers by flood depth per barangay.

Table 51. Affected areas in Arteche, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)									
	Aguinaldo	Balud	Bato	Beri	Bigo	Buenavista	Cagsalay	Campacion	Carapdapan	Casidman
0.03-0.20	1.39	4.26	7.27	2.39	11.23	0.97	5.42	4.42	4.58	2.72
0.21-0.50	0.19	0.25	0.49	0.89	0.62	0.14	0.28	0.48	0.57	0.29
0.51-1.00	0.19	0.19	0.35	0.37	0.77	0.083	0.21	0.44	0.63	0.32
1.01-2.00	0.13	0.18	0.33	0.017	1.33	0.029	0.24	0.51	0.46	0.45
2.01-5.00	0.0097	0.11	0.1	0	3.23	0.0015	1.37	0.17	0.086	0.3
> 5.00	0	0	0.0027	0	0.33	0	0.8	0.02	0.012	0.049

Table 52. Affected areas in Arteche, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Arteche (in sq. km.)									
	Catumsan	Central	Concepcion	Garden	Inayawan	Macarthur	Rawis	Tangbo	Tawagan	Tebalawon
0.03-0.20	1.32	2.59	4.84	4.69	14.28	0.12	1.63	6.76	9.44	3.11
0.21-0.50	0.25	0.31	0.43	0.64	0.71	0.0025	0.12	0.86	0.39	0.21
0.51-1.00	0.27	0.13	0.76	0.65	0.56	0.0001	0.12	0.74	0.32	0.2
1.01-2.00	0.21	0.038	2.53	0.43	0.88	0	0.27	0.7	0.58	0.24
2.01-5.00	0.0054	0	1.77	0.073	2.46	0	0.22	0.091	0.75	0.84
> 5.00	0	0	0.017	0	0.25	0	0.0086	0	0.066	0.15

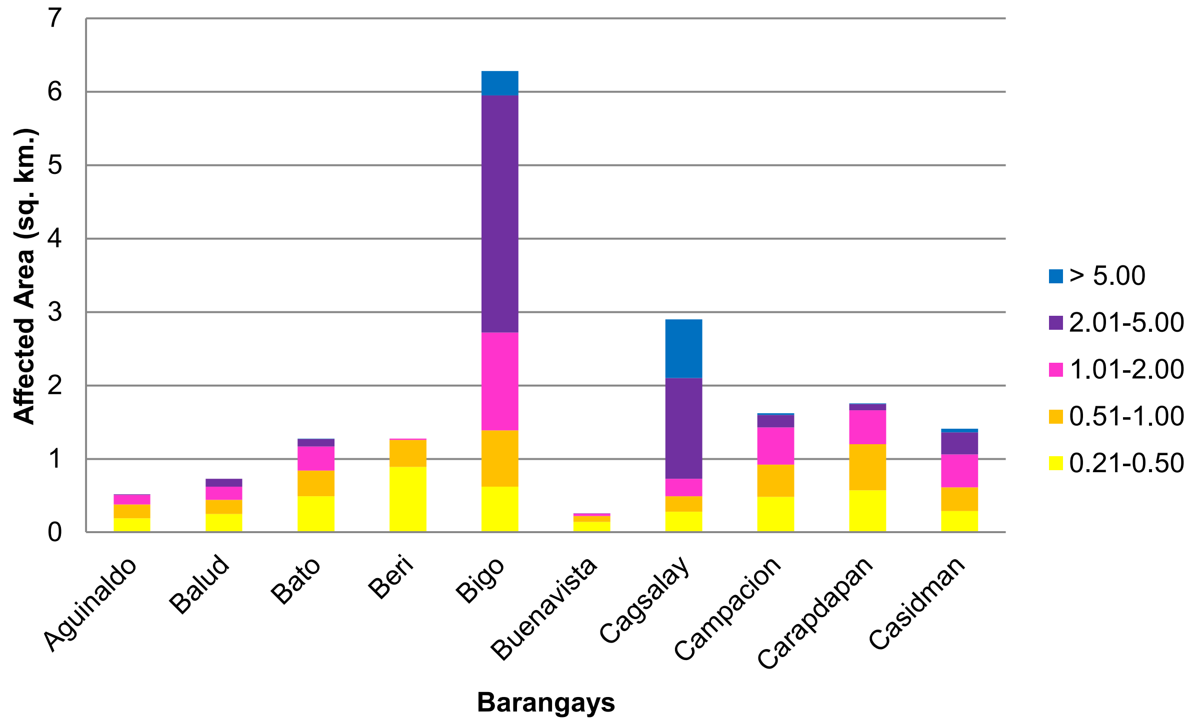


Figure 90. Affected areas in Arteche, Eastern Samar during a 100-Year rainfall Return period.

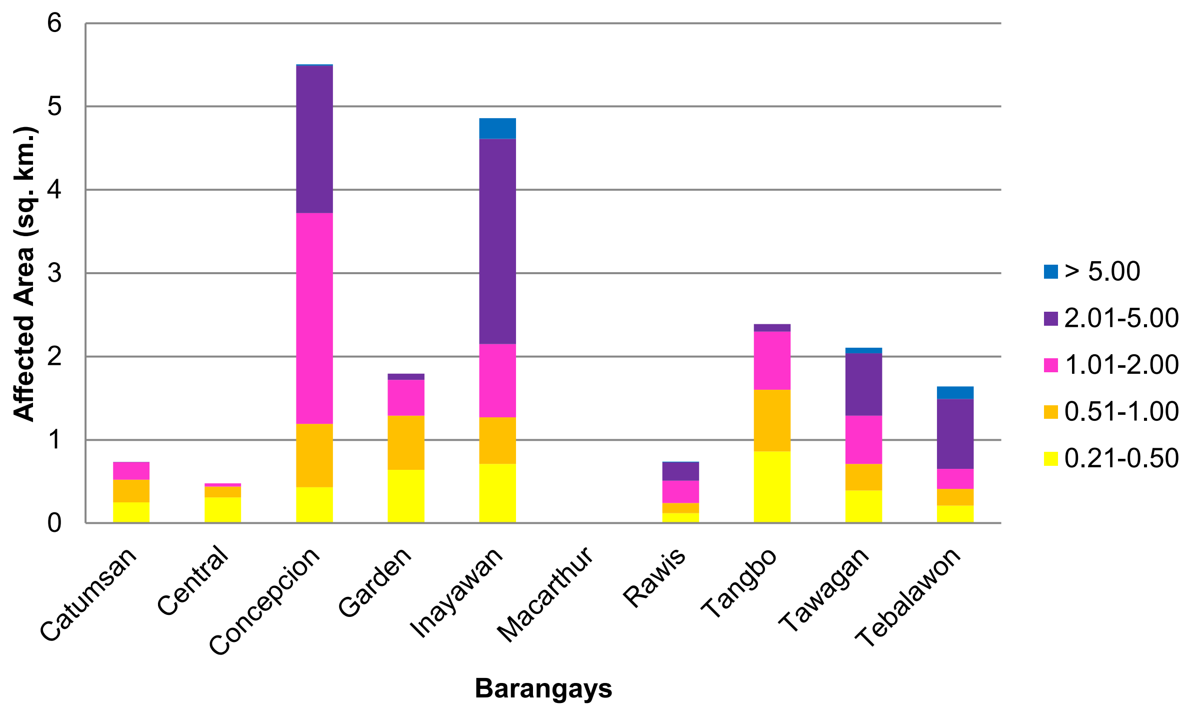


Figure 91. Affected areas in Arteche, Eastern Samar during a 100-Year rainfall Return period.

For the municipality of Jipapad, with an area of 173.29 sq. km., 25.49% will experience flood levels of less 0.20 meters. 1.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.87%, 1.5%, 3.13%, and 1.96% 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. Error: Reference source not found depicts the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected areas in Jipapad, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jipapad (in sq. km.)								
	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Dorillo	Jewaran	Recare	Roxas	San Roque
0.03-0.20	3.86	1.14	0.94	2.35	3.07	4.17	1.05	27.56	0.028
0.21-0.50	0.11	0.046	0.026	0.068	0.09	0.14	0.039	1.33	0.00036
0.51-1.00	0.097	0.027	0.023	0.057	0.071	0.11	0.026	1.09	0.0007
1.01-2.00	0.15	0.033	0.033	0.077	0.072	0.15	0.033	2.05	0.0021
2.01-5.00	0.92	0.13	0.095	0.14	0.09	0.55	0.058	3.44	0.0066
> 5.00	1.53	0.12	0.061	0.49	0.073	0.31	0.073	0.7	0.033

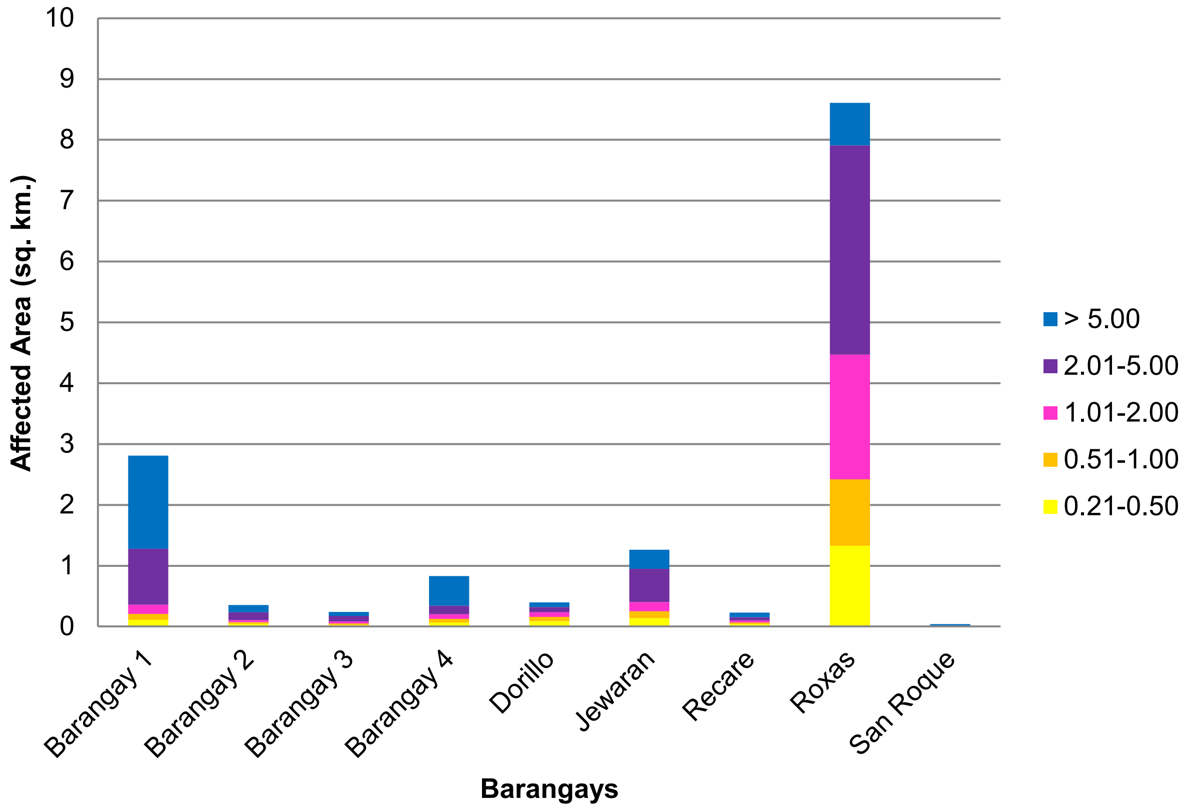


Figure 92. Affected areas in Jipapad, Eastern Samar during a 100-Year rainfall Return period.

For the municipality of Maslog, with an area of 284.92 sq. km., 0.92% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.02%, and 0.003% 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 54 depicts the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected areas in Maslog, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maslog (in sq. km.)
	San Roque
0.03-0.20	2.62
0.21-0.50	0.1
0.51-1.00	0.075
1.01-2.00	0.071
2.01-5.00	0.053
> 5.00	0.009

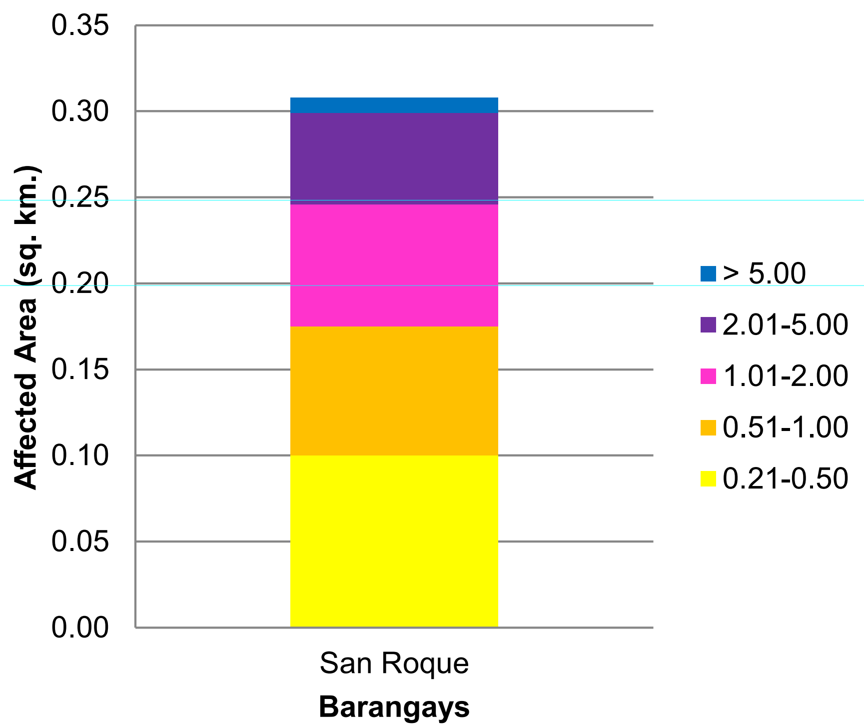


Figure 93. Affected areas in Maslog, Eastern Samar during a 100-Year Rainfall Return Period.

For the municipality of Oras, with an area of 173.99 sq. km., 35.72% will experience flood levels of less 0.20 meters. 4.54% of the area will experience flood levels of 0.21 to 0.50 meters while 4.27%, 4.25%, 4.02%, and 1.18% 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 55 depicts the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Agsam	Alang-Alang	Balingasag	Balocawe	Bantayan	Batang	Bato	Binalayan	Buntay
0.03-0.20	2.55	2.51	3.58	1.42	0.59	1.79	1.51	7.28	1.82
0.21-0.50	0.15	0.095	0.17	0.27	0.19	0.071	0.22	1.19	0.093
0.51-1.00	0.18	0.051	0.18	0.2	0.32	0.045	0.36	2.15	0.063
1.01-2.00	0.23	0.05	0.27	0.045	0.22	0.063	0.2	1.6	0.084
2.01-5.00	0.24	0.18	0.18	0.012	0.0078	0.05	0.033	0.91	0.34
> 5.00	0.038	0.55	0.067	0	0	0.0048	0	0.15	0.042

Table 56. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Burak	Butnga	Cadian	Cagdine	Cagpile	Cagtoog	Camanga	Dao	Gamot
0.03-0.20	1	0.78	1.44	1.09	1.96	1.43	0.28	1.02	0.47
0.21-0.50	0.38	0.035	0.074	0.049	0.085	0.061	0.012	1.42	0.014
0.51-1.00	0.32	0.017	0.069	0.053	0.067	0.052	0.014	0.15	0.0048
1.01-2.00	0.54	0.0096	0.11	0.11	0.12	0.044	0.026	0.00043	0.0041
2.01-5.00	0.2	0	0.7	0.13	0.1	0.05	0.0055	0	0.0028
> 5.00	0	0	0.33	0.083	0.0018	0	0	0	0

Table 57. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)								
	Iwayan	Japay	Kalaw	Mabuhay	Malingon	Minap-Os	Nadacpan	Naga	Pangudtan
0.03-0.20	1.64	0.66	1.42	0.58	1.23	6.44	2.59	1.46	0.9
0.21-0.50	0.075	0.091	0.21	0.27	0.22	0.34	0.11	0.062	0.18
0.51-1.00	0.061	0.038	0.17	0.38	0.14	0.42	0.11	0.058	0.13
1.01-2.00	0.056	0.0048	0.077	0.87	0.12	0.89	0.17	0.11	0.047
2.01-5.00	0.17	0.0002	0.0005	0.41	0.0015	1.01	0.51	0.036	0.0002
> 5.00	0.13	0	0	0	0	0.18	0.23	0	0

Table 58. Affected areas in Oras, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oras (in sq. km.)									
	Paypayon	Riverside	Rizal	Sabang	San Eduardo	San Roque	Saurong	Tawagan	Tiguib	Trinidad
0.03-0.20	0.61	0.89	2.16	0.081	0.91	0.028	2.99	0.59	1.86	2.59
0.21-0.50	0.09	0.14	0.1	0.14	0.12	0.00036	0.18	0.43	0.28	0.29
0.51-1.00	0.16	0.083	0.091	0.31	0.14	0.0007	0.14	0.12	0.22	0.37
1.01-2.00	0.41	0.033	0.13	0.18	0.16	0.0021	0.18	0.036	0.044	0.15
2.01-5.00	0.17	0.18	0.32	0.25	0.12	0.0066	0.64	0.021	0.004	0.0098
> 5.00	0.14	0.0088	0.056	0	0	0.033	0	0.0094	0	0

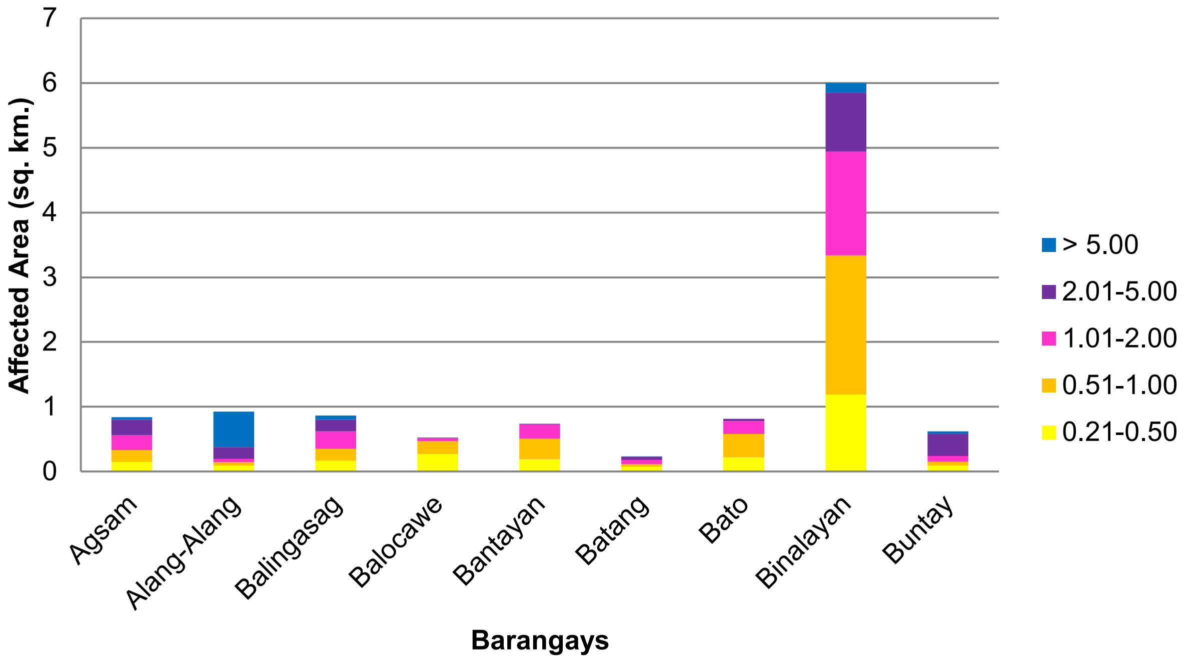


Figure 94. Affected areas in Oras, eastern Samar during a 100-Year Rainfall Return Period.

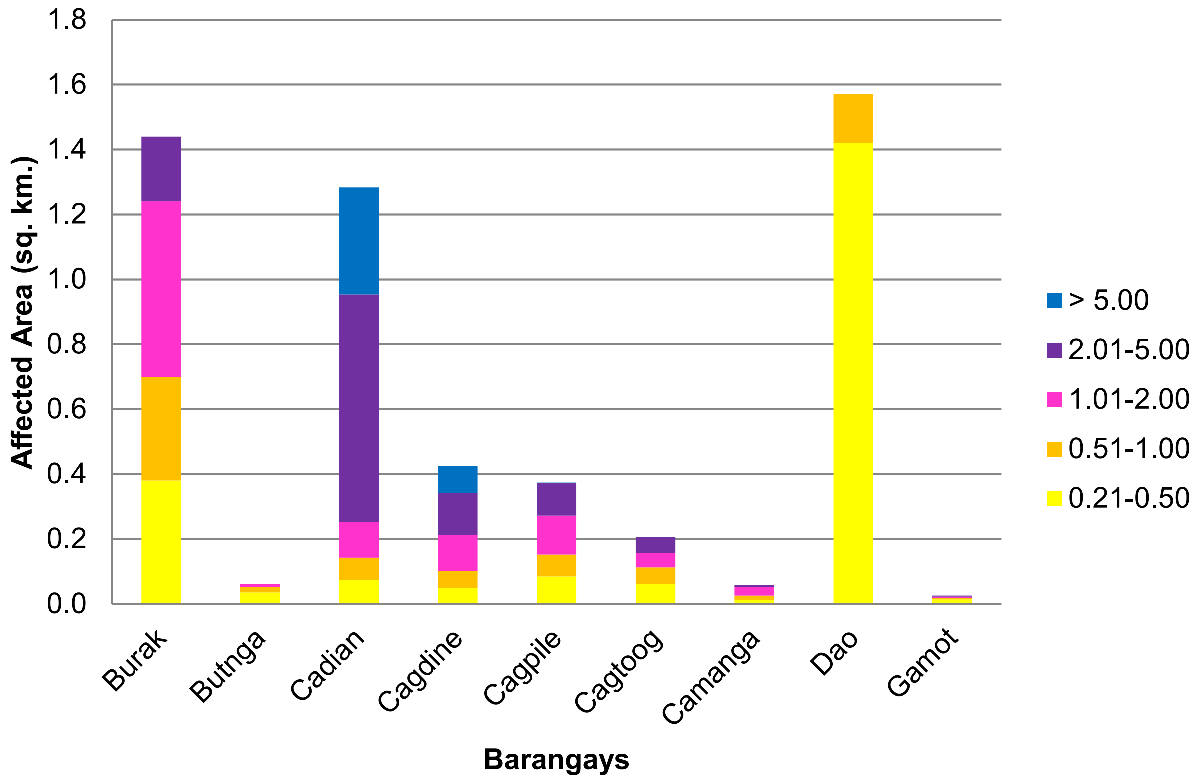


Figure 95. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

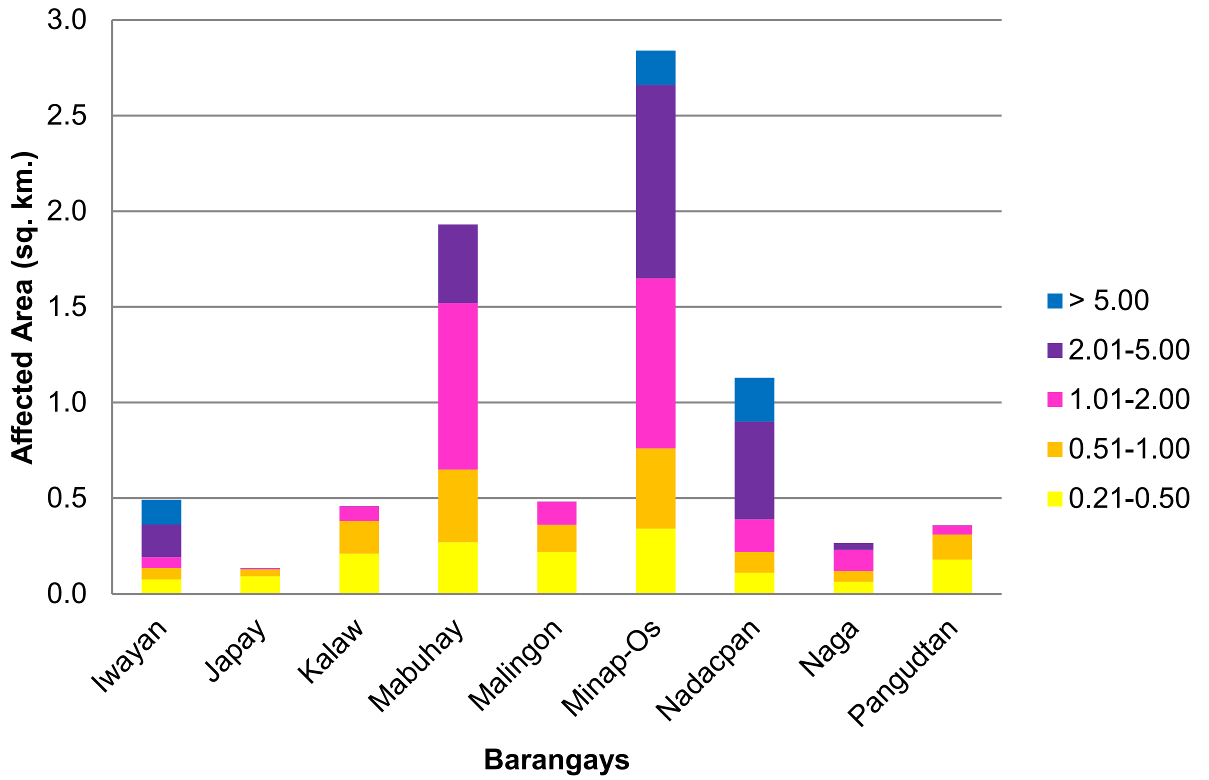


Figure 96. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

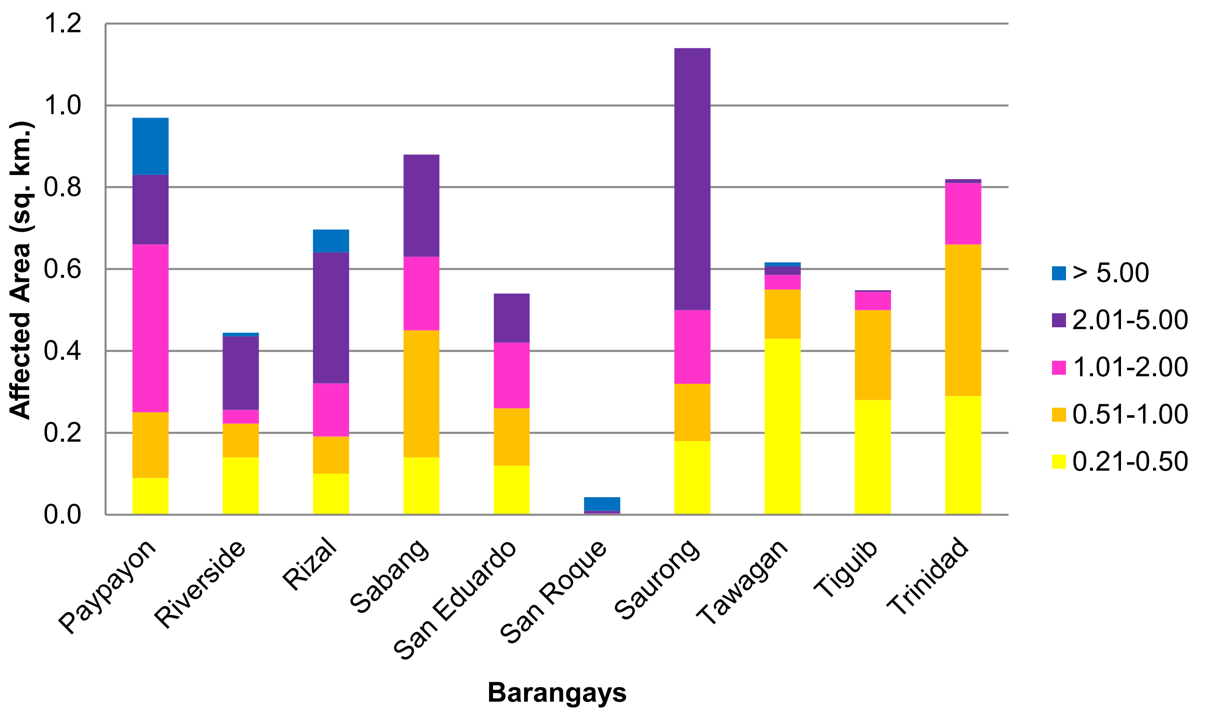


Figure 97. Affected areas in Oras, eastern Samar during a 25-Year Rainfall Return Period.

For the municipality of San Policarpo, with an area of 77.28 sq. km., 64.58% will experience flood levels of less 0.20 meters. 7.04% of the area will experience flood levels of 0.21 to 0.50 meters while 5.94%, 5.4%, 2.81%, and 0.13%, 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 59 depicts the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected areas in San Policarpio, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Policarpo (in sq. km.)							
	Alugan	Bahay	Bangon	Barangay No. 1	Barangay No. 2	Barangay No. 3	Barangay No. 4	Barangay No. 5
0.03-0.20	3.28	3.81	5.05	0.52	0.12	0.34	0.64	1.24
0.21-0.50	0.47	0.5	0.38	0.039	0.026	0.11	0.087	0.18
0.51-1.00	0.32	0.63	0.3	0	0.0013	0.032	0.11	0.11
1.01-2.00	0.44	0.52	0.33	0	0.00032	0.026	0.084	0.099
2.01-5.00	0.061	0.062	0.25	0	0	0.0006	0.02	0
> 5.00	0	0	0.069	0	0	0	0	0

Table 60. Affected areas in San Policarpio, Eastern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Policarpo (in sq. km.)								
	Baras	Binogawan	Cajagwayan	Japunan	Natividad	Pangpang	Santa Cruz	Tabo	Tan-Awan
0.03-0.20	1.87	8.91	3.48	2.1	1.65	1.7	10.64	1.69	2.87
0.21-0.50	0.17	1.07	0.38	0.27	0.56	0.12	0.74	0.11	0.23
0.51-1.00	0.19	1.17	0.32	0.28	0.35	0.073	0.51	0.053	0.14
1.01-2.00	0.14	1.04	0.28	0.33	0.088	0.099	0.52	0.033	0.14
2.01-5.00	0.0083	1	0.14	0.099	0.017	0.09	0.35	0.022	0.05
> 5.00	0	0	0	0	0	0	0.035	0	0

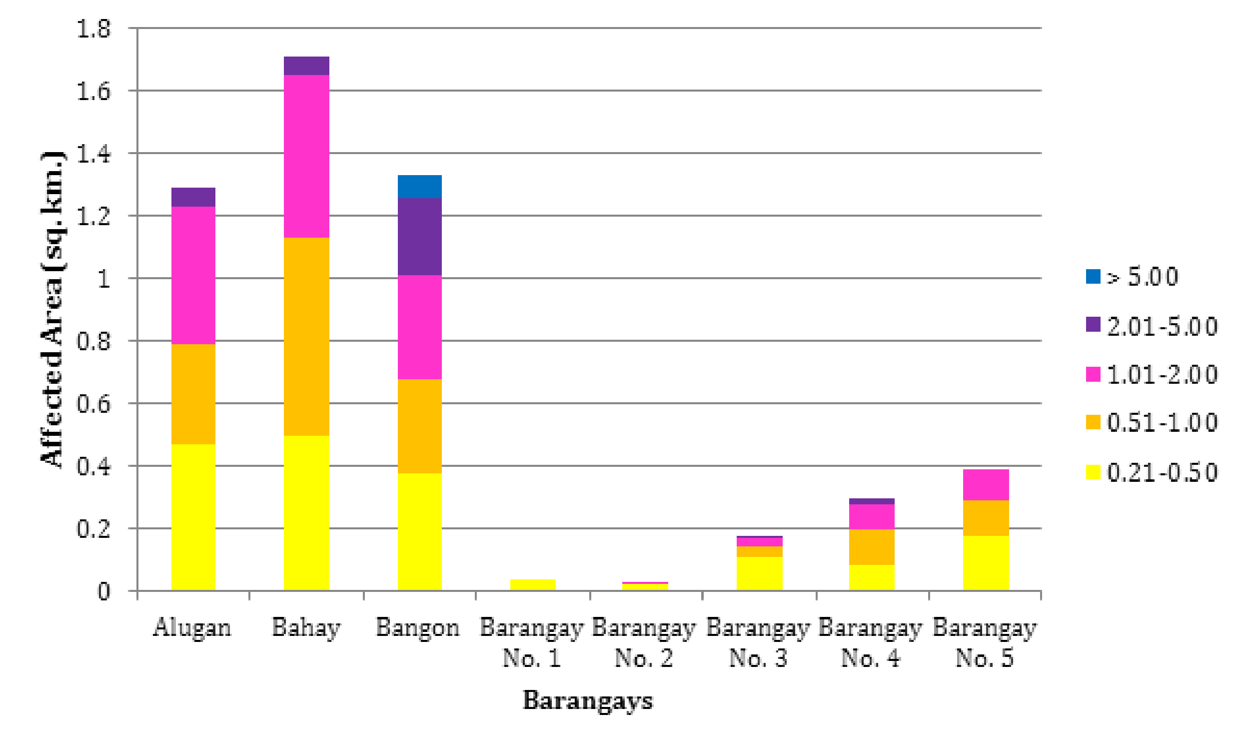


Figure 98. Affected areas in San Policarpo, Eastern Samar during a 100-Year Rainfall Return Period.

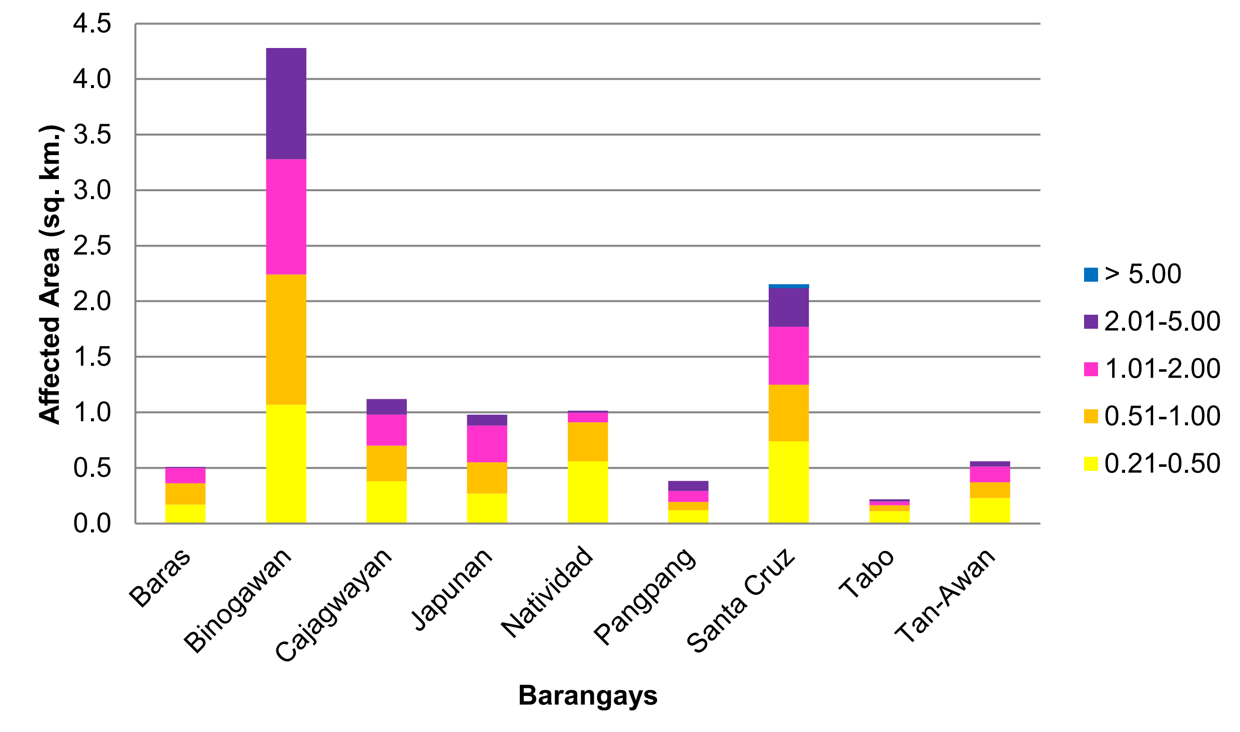


Figure 99. Affected areas in San Policarpo, Eastern Samar during a 100-Year Rainfall Return Period.

For the municipality of Lapinig, with an area of 57.03 sq. km., 21.52% will experience flood levels of less 0.20 meters. 2.71% of the area will experience flood levels of 0.21 to 0.50 meters while 2.38%, 1.94%, and 0.55%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 61 depicts the affected areas in square kilometers by flood depth per barangay.

Table 61. Affected areas in Lapinig, Northern Samar during a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lapinig (in sq. km.)							
	Bagacay	Cahagwayan	Can Omanio	Imelda	Lo-Ok	Mabini	May-Igot	Palanas
0.03-0.20	1.89	1.62	0.21	0.094	1.69	0.7	3.68	2.39
0.21-0.50	0.19	0.061	0.0092	0.0006	0.1	0.046	0.67	0.47
0.51-1.00	0.21	0.052	0.0037	0.0039	0.13	0.01	0.67	0.28
1.01-2.00	0.18	0.064	0.0024	0.0088	0.29	0.0095	0.37	0.18
2.01-5.00	0.023	0.074	0	0.14	0.078	0	0	0.0012
> 5.00	0	0	0	0	0	0	0	0

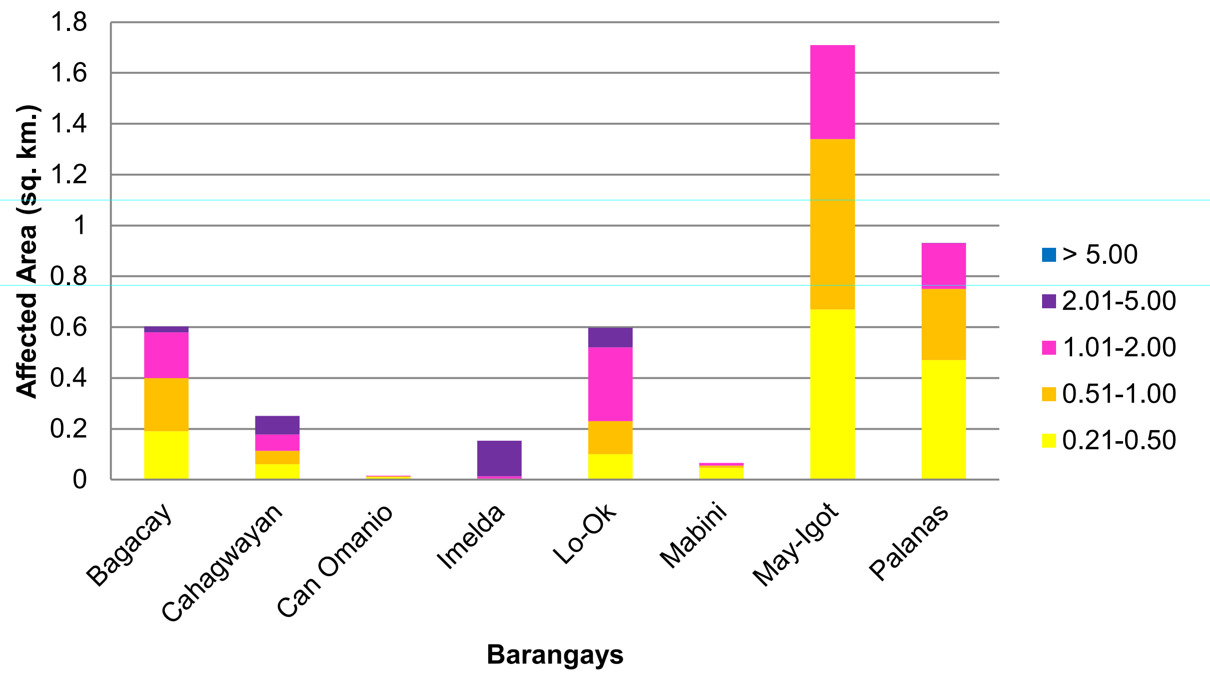


Figure 100. Affected areas in Lapinig, Northern Samar during a 25-Year Rainfall Return Period.

Among the barangays in the municipality of Arteche, Inayawan is projected to have the highest percentage of area that will experience flood levels of at 11.79%. On the other hand, Bigo posted the percentage of area that may be affected by flood depths of at 10.78%.

Among the barangays in the municipality of Jipapad, Roxas is projected to have the highest percentage of area that will experience flood levels of at 20.88%. On the other hand, Barangay 1 posted the percentage of area that may be affected by flood depths of at 3.85%.

Among the barangays in the municipality of Maslog, San Roque is projected to have the highest percentage of area that will experience flood levels of at 1.03%.

Among the barangays in the municipality of Oras, Binalayan is projected to have the highest percentage of area that will experience flood levels of at 7.63%. On the other hand, Minap-Os posted the percentage of area that may be affected by flood depths of at 5.34%.

Among the barangays in the municipality of San Policarpo, Binogawan is projected to have the highest percentage of area that will experience flood levels of at 17.09%. On the other hand, Santa Cruz posted the percentage of area that may be affected by flood depths of at 16.56%.

Among the barangays in the municipality of Lapinig, May-Igot is projected to have the highest percentage of area that will experience flood levels of at 9.45%. On the other hand, Palanas posted the percentage of area that may be affected by flood depths of at 5.82%.

Moreover, the generated flood hazard maps for the Oras Floodplain were used to assess the vulnerability of the area 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 62. 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	27.08	26.22	25.59
Medium	37.10	36.12	36.53
High	22.28	32.85	45.69
Total	**86.46**	**95.19**	**107.81**

5.11 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure.

The flood validation consists of 146 points randomly selected all over the Oras flood plain. It has an RMSE value of 0.11.

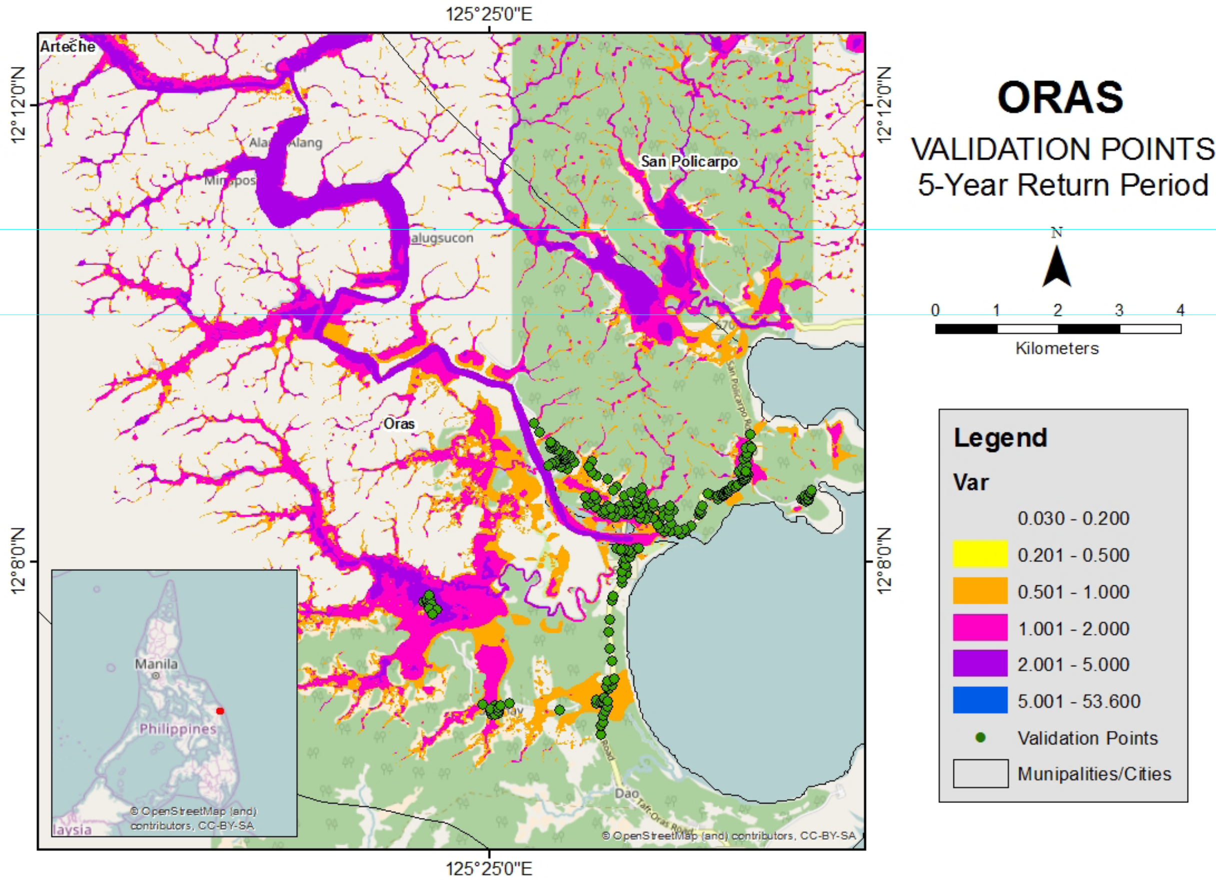


Figure 101. Validation points for 5-year Flood Depth Map of Oras Floodplain

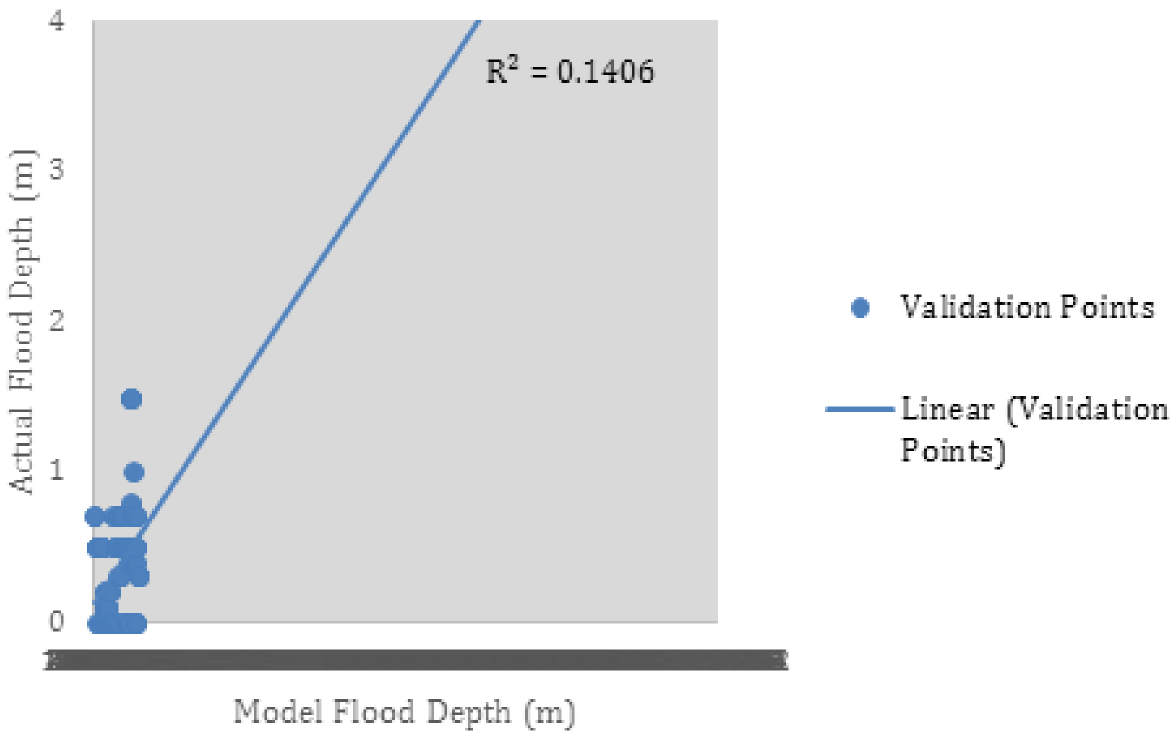


Figure 102. Flood map depth vs actual flood depth

Table 63. Actual Flood Depth vs Simulated Flood Depth in Oras

ORAS 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	40	0	15	6	2	0	**63**
	0.21-0.50	29	0	15	16	0	0	**60**
	0.51-1.00	5	0	7	5	1	0	**18**
	1.01-2.00	0	0	5	0	0	0	**5**
	2.01-5.00	0	0	0	0	0	0	**0**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**74**	**0**	**42**	**27**	**3**	**0**	**146**

The overall accuracy generated by the flood model is estimated at 32.19% with 47 points correctly matching the actual flood depths. In addition, there were 54 points estimated one level above and below the correct flood depths while there were 37 points and 8 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 39 points were underestimated in the modelled flood depths of Oras.

Table 64. Summary of Accuracy Assessment in the Oras River Basin Survey for the 5-year return scenario

	No. of Points	%
Correct	47	32.19
Overestimated	60	41.10
Underestimated	39	26.71
Total	**146**	**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.

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

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

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

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

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

ANNEX

ANNEX 1. Technical Specifications of the LiDAR Sensors

1. AQUARIUS SENSOR

Table A.1.1 Technical specifications of the Aquarius sensor

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

ANNEX 2. Namria Certificates of Reference Points Used

1. SME-3139

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

June 24, 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: **EASTERN SAMAR**
Station Name: **SME-3139**
Order: **4th**

Island: **VISAYAS**
Municipality: **SULAT**
Barangay: **SANTO NIÑO**

	PRS92 Coordinates	
Latitude: **11° 50' 2.95701"**	Longitude: **125° 26' 3.02189"**	Ellipsoidal Hgt: **0.35600 m.**
	WGS84 Coordinates	
Latitude: **11° 49' 58.57713"**	Longitude: **125° 26' 8.12160"**	Ellipsoidal Hgt: **62.18500 m.**
	PTM Coordinates	
Northing: **1308628.152 m.**	Easting: **547309.911 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,309,289.26**	Easting: **765,219.59**	Zone: **51**

Location Description

SME-3139

From Tacloban City, travel about 70 Km. NE towards the junction of Buena Vista, Quinapondan. Then travel about 170 Km. NW pass Gen. Mc Arthur, Hernani, Llorente, Balangkayan, Maydolong, Borongan and San Julian pass Sulat proper towards Brgy. Sto. Niño until reaching a bridge near the Km. post 900 S-4. Station is located at the right side of the road about 1 m S of the bridge, about 100 m S of Km. post 900 S-4, about 500 m S of the brgy. basketball court. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument with inscriptions, "SME-3139, 2008, NAMRIA".

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1442**

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

9 9 0 6 2 4 2 0 1 4 1 1 1 7 1 8

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

CIP/4701/12/09/814

Figure A-2.1 SME-3139

ANNEX 3. Baseline Processing Report

1. 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 Survey Team

Table A.4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	PAULINE JOANNE ARCEO	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. NEIL ACHILLES AGAWIN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	

ANNEX 5. Data Transfer Sheet For The Survey Nearest Oras 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	164/69	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:

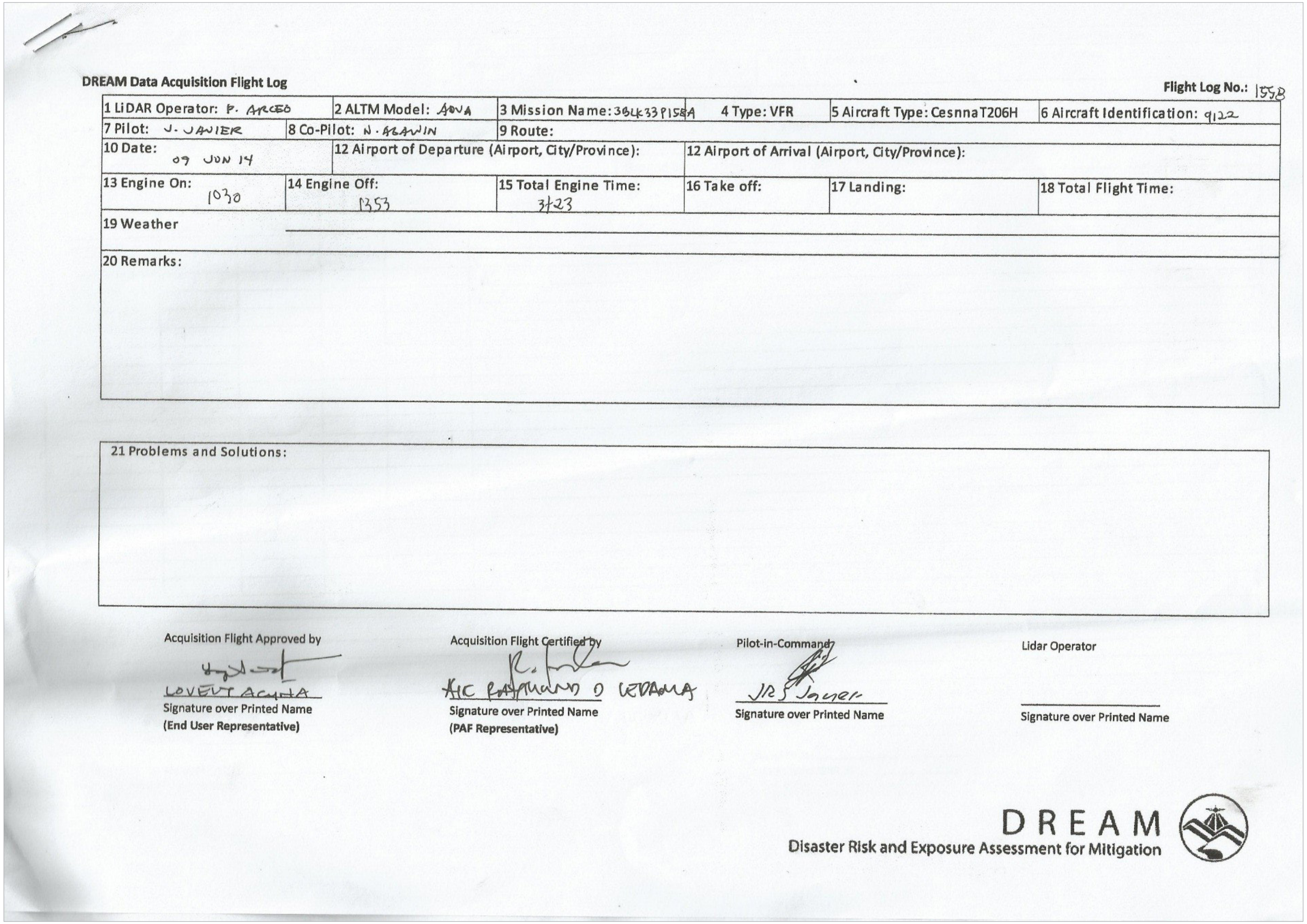
Received by
Name: JOIDA PRIETO
Position: SSRS
Signature:
6/19/14

14-43

Figure A-5.1 Data Transfer Sheet for Oras Floodplain

ANNEX 6. Flight Logs

1. 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: Cesnna T206H	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 — Signature over Printed Name (End User Representative)

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

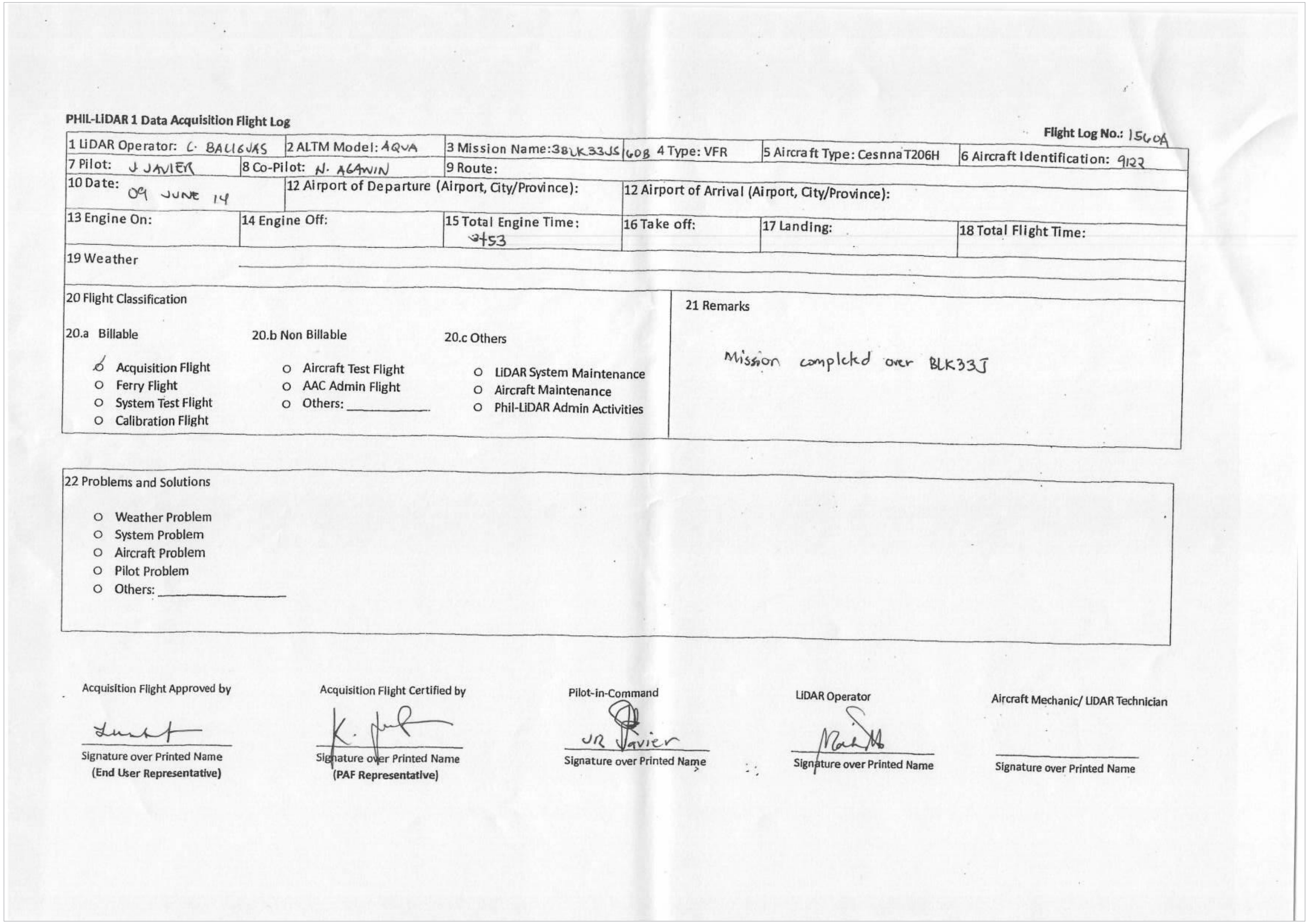
Pilot-in-Command — JR S Javier — Signature over Printed Name

Lidar Operator — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-5.2 Flight Log for 3BLK33J160A Mission.

2. Flight Log for 3BLK33J160A Mission.



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 1560A

1 LiDAR Operator: C. BALIGUAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK33JS160B	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 — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — JR Javier — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.1 Flight Log for 3BLK33J160A Mission.

ANNEX 7. Flight Status Reports

Oras FLOODPLAIN
(January 28, May 15-26, 2014; January 21-February 17, 2015; March 9-19, April 16, 2016)

Table A.7.1 Flight Status Report

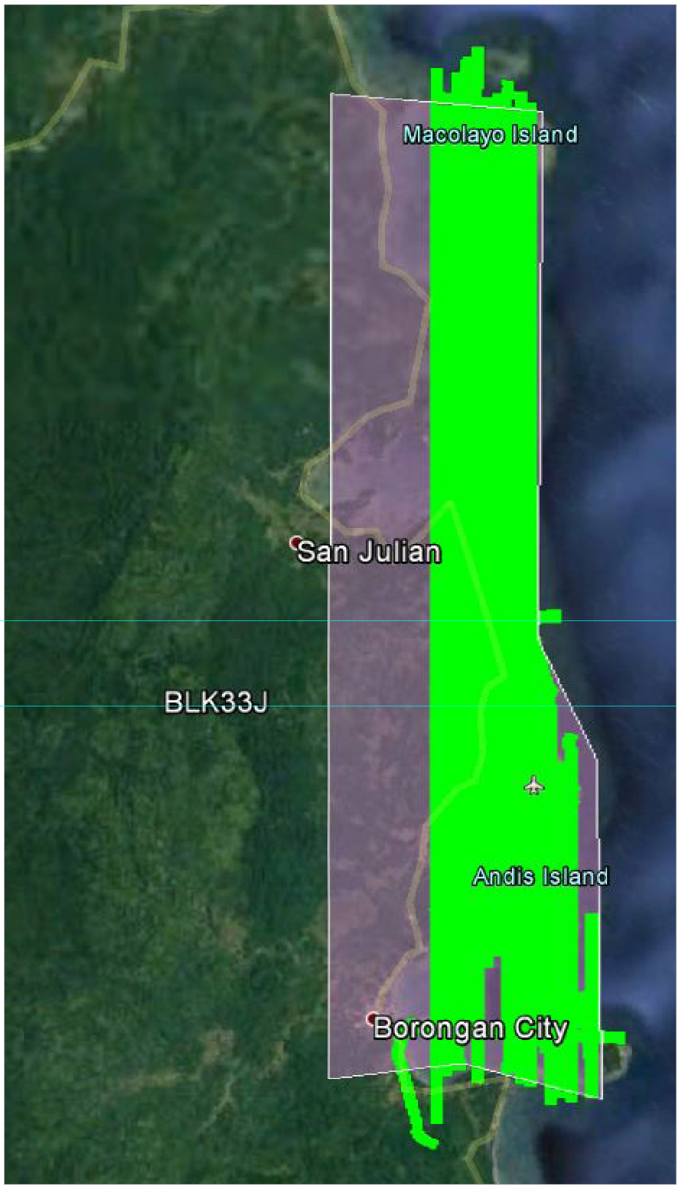
Flight No	Area	Mission	Operator	Date Flown	Remarks
1558A	BLK33J	3BLK33J160A	PJ ARCEO	9 JUN 14	Completed 12 lines over BLK33J
1560A	BLK33J	3BLK33JS160B	MCE BALIGUAS	9 JUN 14	Mission completed over BLK33J

SWATH PER FLIGHT MISSION

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 for Flight No.1558A

Flight No. :	**1560A**		
Area:	BLOCK 33J		
Total Area:	105.37 sq. km.		
Mission Name:	3BLK33JS60A		
Altitude:	500m		
PRF:	50 kHz	SCF:	45 Hz
Lidar FOV:	22 deg	Sidelap:	25%



ANNEX 8. Mission Summary Reports

Table A.8.1 Mission Summary Report for Mission [ ]

Flight Area	

ANNEX 9. Oras Model Basin Parameters

Table A-9.1. Oras Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
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

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
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

ANNEX 10. Oras Model Reach Parameters

Table A-10.1. Oras Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	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. Oras Field Validation Points

Table A-11.1. Oras Field Validation Points for the 5-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
470	12.14998	125.4541	2	0.7	1.3	January heavy rain	1/17/2017	5-Year
770	12.14865	125.4541	2	0.7	1.3	January heavy rain	1/17/2017	5-Year
870	12.14825	125.4537	2	0.5	1.5	January heavy rain	1/17/2017	5-Year
1280	12.15182	125.4548	2	0.5	1.5	January heavy rain	1/17/2017	5-Year
1290	12.14728	125.4542	2	0.5	1.5	January heavy rain	1/17/2017	5-Year
1370	12.14704	125.4535	2	0.5	1.5	January heavy rain	1/17/2017	5-Year
1580	12.14643	125.453	0	0.5	-0.5	January heavy rain	1/17/2017	5-Year
1870	12.14611	125.4538	1	0.5	0.5	January heavy rain	1/17/2017	5-Year
2190	12.15019	125.4545	0	0.5	-0.5	January heavy rain	1/17/2017	5-Year
3017	12.14225	125.4632	0	0	0	Ruby	12/7/2014	5-Year
3119	12.14285	125.4627	0	0	0	Ruby	12/7/2014	5-Year
3513	12.14234	125.4623	0	0	0	Ruby	12/7/2014	5-Year
3613	12.14513	125.4537	0	0	0	Ruby	12/7/2014	5-Year
3713	12.145	125.4536	0	0	0	Ruby	12/7/2014	5-Year
3813	12.14446	125.4529	0	0	0	Ruby	12/7/2014	5-Year
3913	12.14426	125.4526	1	0	1	Ruby	12/7/2014	5-Year
4013	12.14442	125.452	0	0	0	Ruby	12/7/2014	5-Year
4513	12.14365	125.4517	1	0	1	Ruby	12/7/2014	5-Year
4913	12.14359	125.4512	0	0	0	Ruby	12/7/2014	5-Year
5103	12.14942	125.4545	2	0.5	1.5	January heavy rain	1/17/2017	5-Year
5222	12.14304	125.4507	2	0	2	Ruby	12/7/2014	5-Year
5522	12.14293	125.45	0	0	0	Ruby	12/7/2014	5-Year
5618	12.14242	125.45	0	0	0	Ruby	12/7/2014	5-Year
5813	12.14312	125.4488	2	0.5	1.5	Ruby	12/7/2014	5-Year
5913	12.1415	125.4478	0	0.5	-0.5	Ruby	12/7/2014	5-Year
6117	12.14053	125.4476	0	0.5	-0.5	Ruby	12/7/2014	5-Year
6215	12.14047	125.4473	0	0.5	-0.5	Ruby	12/7/2014	5-Year
6313	12.14017	125.4472	0	0.5	-0.5	Ruby	12/7/2014	5-Year
6413	12.1535	125.4231	1	0.1	0.9	Ruby	12/7/2014	5-Year
6514	12.15215	125.4239	0	0.1	-0.1	Ruby	12/7/2014	5-Year
6913	12.15023	125.4261	0	0.1	-0.1	Ruby	12/7/2014	5-Year
7215	12.14959	125.4267	0	0	0	Ruby	12/7/2014	5-Year
7313	12.14974	125.4261	0	0	0	Ruby	12/7/2014	5-Year
7413	12.14948	125.4273	0	0.2	-0.2	Ruby	12/7/2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
7713	12.14883	125.4282	0	0	0	Ruby	12/7/2014	5-Year
7813	12.14841	125.4285	0	0.2	-0.2	Ruby	12/7/2014	5-Year
8013	12.14866	125.4276	0	0.1	-0.1	Ruby	12/7/2014	5-Year
8413	12.14779	125.429	0	0.2	-0.2	Ruby	12/7/2014	5-Year
8513	12.14735	125.4252	3	0.2	2.8	Ruby	12/7/2014	5-Year
8713	12.14774	125.4262	0	0.2	-0.2	Ruby	12/7/2014	5-Year
8813	12.14754	125.426	0	0.2	-0.2	Ruby	12/7/2014	5-Year
8913	12.14815	125.4266	0	0.2	-0.2	Ruby	12/7/2014	5-Year
9117	12.14845	125.4271	0	0.1	-0.1	Ruby	12/7/2014	5-Year
9414	12.14676	125.428	1	0.1	0.9	Ruby	12/7/2014	5-Year
9513	12.14704	125.4276	1	0.1	0.9	Ruby	12/7/2014	5-Year
10015	12.14723	125.4311	1	0	1	Ruby	12/7/2014	5-Year
10118	12.14798	125.4316	1	0.2	0.8	Ruby	12/7/2014	5-Year
10216	12.1464	125.4315	1	0.2	0.8	Ruby	12/7/2014	5-Year
10315	12.14586	125.4321	0	0	0	Ruby	12/7/2014	5-Year
10414	12.14531	125.4338	0	0	0	Ruby	12/7/2014	5-Year
10415	12.14112	125.4342	1	0	1	Ruby	12/7/2014	5-Year
10614	12.1428	125.4306	0	0	0	Ruby	12/7/2014	5-Year
10714	12.1429	125.4318	2	0	2	Ruby	12/7/2014	5-Year
10814	12.14244	125.4322	1	0	1	Ruby	12/7/2014	5-Year
10914	12.14254	125.4314	0	0	0	Ruby	12/7/2014	5-Year
11019	12.14188	125.4314	1	0	1	Ruby	12/7/2014	5-Year
11101	12.14608	125.4543	1	0.7	0.3	January heavy rain	1/17/2017	5-Year
11118	12.14122	125.4321	0	0	0	Ruby	12/7/2014	5-Year
11215	12.14157	125.4309	0	0	0	Ruby	12/7/2014	5-Year
11315	12.14078	125.4329	1	0	1	Ruby	12/7/2014	5-Year
11414	12.14137	125.4338	1	0	1	Ruby	12/7/2014	5-Year
11714	12.14026	125.4333	2	0	2	Ruby	12/7/2014	5-Year
11814	12.14014	125.4343	2	0	2	Ruby	12/7/2014	5-Year
11914	12.14096	125.4349	1	0	1	Ruby	12/7/2014	5-Year
12014	12.13987	125.435	2	0.5	1.5	Ruby	12/7/2014	5-Year
12118	12.1407	125.4358	1	0.5	0.5	Ruby	12/7/2014	5-Year
12215	12.14068	125.4363	2	0.5	1.5	Ruby	12/7/2014	5-Year
12414	12.14028	125.4363	2	0.5	1.5	Ruby	12/7/2014	5-Year
12514	12.14018	125.437	2	0.5	1.5	Ruby	12/7/2014	5-Year
12614	12.14378	125.4346	0	0	0	Ruby	12/7/2014	5-Year
12714	12.14429	125.4351	0	0	0	Ruby	12/7/2014	5-Year
12814	12.14341	125.4373	0	0	0	Ruby	12/7/2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
12914	12.14285	125.4362	1	0	1	Ruby	12/7/2014	5-Year
13014	12.14143	125.4356	0	0.5	-0.5	Ruby	12/7/2014	5-Year
13118	12.14179	125.4366	1	0.5	0.5	Ruby	12/7/2014	5-Year
13215	12.14413	125.4389	0	0.7	-0.7	Ruby	12/7/2014	5-Year
13313	12.14342	125.4381	0	0.7	-0.7	Ruby	12/7/2014	5-Year
13414	12.14312	125.4387	1	0.7	0.3	Ruby	12/7/2014	5-Year
13614	12.14247	125.439	2	0.7	1.3	Ruby	12/7/2014	5-Year
13914	12.14145	125.4429	0	0.3	-0.3	Ruby	12/7/2014	5-Year
14014	12.14078	125.4428	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14118	12.14078	125.4434	0	0.3	-0.3	Ruby	12/7/2014	5-Year
14215	12.13982	125.4428	0	0.3	-0.3	Ruby	12/7/2014	5-Year
14314	12.13886	125.4432	1	0.3	0.7	Ruby	12/7/2014	5-Year
14414	12.13995	125.442	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14514	12.14128	125.4406	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14614	12.14083	125.442	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14714	12.14178	125.4381	2	0.7	1.3	Ruby	12/7/2014	5-Year
14814	12.14107	125.4384	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14914	12.14068	125.4375	1	0.5	0.5	Ruby	12/7/2014	5-Year
15118	12.1405	125.4382	1	0.5	0.5	Ruby	12/7/2014	5-Year
15215	12.1413	125.4392	0	0.7	-0.7	Ruby	12/7/2014	5-Year
15314	12.14103	125.4399	0	0.5	-0.5	Ruby	12/7/2014	5-Year
15414	12.13963	125.4385	0	0.5	-0.5	Ruby	12/7/2014	5-Year
15514	12.13941	125.4394	1	0.5	0.5	Ruby	12/7/2014	5-Year
15614	12.1402	125.4397	0	0.5	-0.5	Ruby	12/7/2014	5-Year
15814	12.13964	125.4405	1	0.5	0.5	Ruby	12/7/2014	5-Year
16014	12.13954	125.4415	0	0.5	-0.5	Ruby	12/7/2014	5-Year
16119	12.13819	125.4415	0	0.5	-0.5	Ruby	12/7/2014	5-Year
16215	12.13816	125.4425	0	0.5	-0.5	Ruby	12/7/2014	5-Year
16314	12.13768	125.4421	2	0.5	1.5	Ruby	12/7/2014	5-Year
16714	12.13804	125.4451	1	0.5	0.5	Ruby	12/7/2014	5-Year
17118	12.13852	125.4461	0	0.5	-0.5	Ruby	12/7/2014	5-Year
17414	12.13512	125.4363	0	0	0	Ruby	12/7/2014	5-Year
17514	12.13488	125.4369	0	0	0	Ruby	12/7/2014	5-Year
17613	12.13532	125.4383	0	0	0	Ruby	12/7/2014	5-Year
17713	12.13457	125.4373	0	0	0	Ruby	12/7/2014	5-Year
17814	12.13474	125.436	0	0	0	Ruby	12/7/2014	5-Year
17914	12.13392	125.4371	0	0	0	Ruby	12/7/2014	5-Year
18014	12.13377	125.4365	0	0.5	-0.5	Ruby	12/7/2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
18313	12.13186	125.436	0	0.5	-0.5	Yolanda	11/8/2013	5-Year
19513	12.13496	125.4375	0	0	0	Ruby	12/7/2014	5-Year
19613	12.13521	125.4352	0	0	0	Ruby	12/7/2014	5-Year
19713	12.13248	125.4366	0	0.5	-0.5	Yolanda	11/8/2013	5-Year
20215	12.11623	125.4348	0	0.5	-0.5	January heavy rain	1/17/2017	5-Year
20313	12.11582	125.4339	1	0.4	0.6	January heavy rain	1/17/2017	5-Year
20413	12.11581	125.4344	1	0.4	0.6	January heavy rain	1/17/2017	5-Year
20513	12.1151	125.4345	1	0.8	0.2	January heavy rain	1/17/2017	5-Year
21014	12.11287	125.4338	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21100	12.14566	125.4541	0	0.7	-0.7	January heavy rain	1/17/2017	5-Year
21215	12.11468	125.4339	1	0.4	0.6	January heavy rain	1/17/2017	5-Year
21414	12.11316	125.4333	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21713	12.1127	125.4328	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21813	12.1131	125.4322	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21913	12.11264	125.4322	1	1.5	-0.5	Ruby	12/7/2014	5-Year
22013	12.11155	125.4268	0	0.5	-0.5	Ruby	12/7/2014	5-Year
22117	12.11263	125.4195	0	1	-1	Ruby	12/7/2014	5-Year
22413	12.11149	125.4178	1	0.7	0.3	Ruby	12/7/2014	5-Year
22513	12.11183	125.4166	2	0.4	1.6	Ruby	12/7/2014	5-Year
22813	12.11108	125.4179	1	0.7	0.3	Ruby	12/7/2014	5-Year
22913	12.11141	125.4167	1	0.4	0.6	Ruby	12/7/2014	5-Year
23013	12.11154	125.4172	1	0.7	0.3	Ruby	12/7/2014	5-Year
23117	12.11092	125.4169	1	0.7	0.3	Ruby	12/7/2014	5-Year
23214	12.11234	125.4155	2	0.4	1.6	Ruby	12/7/2014	5-Year
23313	12.12565	125.4082	2	0.7	1.3	Ruby	12/7/2014	5-Year
23413	12.12624	125.4088	3	0.7	2.3	Ruby	12/7/2014	5-Year
23513	12.12645	125.4078	2	0.5	1.5	Ruby	12/7/2014	5-Year
23713	12.12697	125.4077	2	0.5	1.5	Ruby	12/7/2014	5-Year
23913	12.12767	125.4079	3	0	3	Ruby	12/7/2014	5-Year
24013	12.12779	125.4074	2	0	2	Ruby	12/7/2014	5-Year
24215	12.12621	125.4083	2	0.5	1.5	Ruby	12/7/2014	5-Year
24412	12.12736	125.4069	2	0	2	Ruby	12/7/2014	5-Year
24612	12.11145	125.4334	1	0.3	0.7	Ruby	12/7/2014	5-Year
24712	12.11085	125.4333	1	0.3	0.7	Ruby	12/7/2014	5-Year
24812	12.10978	125.4332	0	0.3	-0.3	Ruby	12/7/2014	5-Year
24912	12.10931	125.4328	0	0.3	-0.3	Ruby	12/7/2014	5-Year
13118	12.14179	125.4366	1	0.5	0.5	Ruby	12/7/2014	5-Year
13215	12.14413	125.4389	0	0.7	-0.7	Ruby	12/7/2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
13313	12.14342	125.4381	0	0.7	-0.7	Ruby	12/7/2014	5-Year
13414	12.14312	125.4387	1	0.7	0.3	Ruby	12/7/2014	5-Year
13614	12.14247	125.439	2	0.7	1.3	Ruby	12/7/2014	5-Year
13914	12.14145	125.4429	0	0.3	-0.3	Ruby	12/7/2014	5-Year
14014	12.14078	125.4428	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14118	12.14078	125.4434	0	0.3	-0.3	Ruby	12/7/2014	5-Year
14215	12.13982	125.4428	0	0.3	-0.3	Ruby	12/7/2014	5-Year
14314	12.13886	125.4432	1	0.3	0.7	Ruby	12/7/2014	5-Year
14414	12.13995	125.442	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14514	12.14128	125.4406	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14614	12.14083	125.442	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14714	12.14178	125.4381	2	0.7	1.3	Ruby	12/7/2014	5-Year
14814	12.14107	125.4384	0	0.5	-0.5	Ruby	12/7/2014	5-Year
14914	12.14068	125.4375	1	0.5	0.5	Ruby	12/7/2014	5-Year
15118	12.1405	125.4382	1	0.5	0.5	Ruby	12/7/2014	5-Year
15215	12.1413	125.4392	0	0.7	-0.7	Ruby	12/7/2014	5-Year
15314	12.14103	125.4399	0	0.5	-0.5	Ruby	12/7/2014	5-Year
15414	12.13963	125.4385	0	0.5	-0.5	Ruby	12/7/2014	5-Year
15514	12.13941	125.4394	1	0.5	0.5	Ruby	12/7/2014	5-Year
15614	12.1402	125.4397	0	0.5	-0.5	Ruby	12/7/2014	5-Year
15814	12.13964	125.4405	1	0.5	0.5	Ruby	12/7/2014	5-Year
16014	12.13954	125.4415	0	0.5	-0.5	Ruby	12/7/2014	5-Year
16119	12.13819	125.4415	0	0.5	-0.5	Ruby	12/7/2014	5-Year
16215	12.13816	125.4425	0	0.5	-0.5	Ruby	12/7/2014	5-Year
16314	12.13768	125.4421	2	0.5	1.5	Ruby	12/7/2014	5-Year
16714	12.13804	125.4451	1	0.5	0.5	Ruby	12/7/2014	5-Year
17118	12.13852	125.4461	0	0.5	-0.5	Ruby	12/7/2014	5-Year
17414	12.13512	125.4363	0	0	0	Ruby	12/7/2014	5-Year
17514	12.13488	125.4369	0	0	0	Ruby	12/7/2014	5-Year
17613	12.13532	125.4383	0	0	0	Ruby	12/7/2014	5-Year
17713	12.13457	125.4373	0	0	0	Ruby	12/7/2014	5-Year
17814	12.13474	125.436	0	0	0	Ruby	12/7/2014	5-Year
17914	12.13392	125.4371	0	0	0	Ruby	12/7/2014	5-Year
18014	12.13377	125.4365	0	0.5	-0.5	Ruby	12/7/2014	5-Year
18313	12.13186	125.436	0	0.5	-0.5	Yolanda	11/8/2013	5-Year
19513	12.13496	125.4375	0	0	0	Ruby	12/7/2014	5-Year
19613	12.13521	125.4352	0	0	0	Ruby	12/7/2014	5-Year
19713	12.13248	125.4366	0	0.5	-0.5	Yolanda	11/8/2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
20215	12.11623	125.4348	0	0.5	-0.5	January heavy rain	1/17/2017	5-Year
20313	12.11582	125.4339	1	0.4	0.6	January heavy rain	1/17/2017	5-Year
20413	12.11581	125.4344	1	0.4	0.6	January heavy rain	1/17/2017	5-Year
20513	12.1151	125.4345	1	0.8	0.2	January heavy rain	1/17/2017	5-Year
21014	12.11287	125.4338	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21100	12.14566	125.4541	0	0.7	-0.7	January heavy rain	1/17/2017	5-Year
21215	12.11468	125.4339	1	0.4	0.6	January heavy rain	1/17/2017	5-Year
21414	12.11316	125.4333	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21713	12.1127	125.4328	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21813	12.1131	125.4322	1	1.5	-0.5	Ruby	12/7/2014	5-Year
21913	12.11264	125.4322	1	1.5	-0.5	Ruby	12/7/2014	5-Year
22013	12.11155	125.4268	0	0.5	-0.5	Ruby	12/7/2014	5-Year
22117	12.11263	125.4195	0	1	-1	Ruby	12/7/2014	5-Year
22413	12.11149	125.4178	1	0.7	0.3	Ruby	12/7/2014	5-Year
22513	12.11183	125.4166	2	0.4	1.6	Ruby	12/7/2014	5-Year
22813	12.11108	125.4179	1	0.7	0.3	Ruby	12/7/2014	5-Year
22913	12.11141	125.4167	1	0.4	0.6	Ruby	12/7/2014	5-Year
23013	12.11154	125.4172	1	0.7	0.3	Ruby	12/7/2014	5-Year
23117	12.11092	125.4169	1	0.7	0.3	Ruby	12/7/2014	5-Year
23214	12.11234	125.4155	2	0.4	1.6	Ruby	12/7/2014	5-Year
23313	12.12565	125.4082	2	0.7	1.3	Ruby	12/7/2014	5-Year
23413	12.12624	125.4088	3	0.7	2.3	Ruby	12/7/2014	5-Year
23513	12.12645	125.4078	2	0.5	1.5	Ruby	12/7/2014	5-Year
23713	12.12697	125.4077	2	0.5	1.5	Ruby	12/7/2014	5-Year
23913	12.12767	125.4079	3	0	3	Ruby	12/7/2014	5-Year
24013	12.12779	125.4074	2	0	2	Ruby	12/7/2014	5-Year
24215	12.12621	125.4083	2	0.5	1.5	Ruby	12/7/2014	5-Year
24412	12.12736	125.4069	2	0	2	Ruby	12/7/2014	5-Year
24612	12.11145	125.4334	1	0.3	0.7	Ruby	12/7/2014	5-Year
24712	12.11085	125.4333	1	0.3	0.7	Ruby	12/7/2014	5-Year
24812	12.10978	125.4332	0	0.3	-0.3	Ruby	12/7/2014	5-Year
24912	12.10931	125.4328	0	0.3	-0.3	Ruby	12/7/2014	5-Year