REGION 13

Agusan River Basin:

DREAM Flood Forecasting and Flood Hazard Mapping

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

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For questions/queries regarding this report, contact:

Alfredo Mahar Francisco A. Lagmay, PhD.
Project Leader, Flood Modeling Component, DREAM Program
University of the Philippines Diliman
Quezon City, Philippines 1101
Email: amfal2@yahoo.com

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

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List of Abbreviations

ACDP	Acoustic Doppler Current Profiler
AOI	Area of Interest
ARG	Automated Rain Gauge
AWLS	Automated Water Level Sensor
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DOST	Department of Science and Technology
DPC	Data Processing Component
DREAM	Disaster Risk Exposure and Assessment for Mitigation
DTM	Digital Terrain Model
DVC	Data Validation Component
FMC	Flood Modelling Component
GDS	Grid Developer System
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
LiDAR	Light Detecting and Ranging
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
RIDF	Rainfall Intensity Duration Frequency
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
UP-TCAGP	UP Training Center for Applied Geodesy and Photogrammetry

Introduction

Introduction

1.1 About the DREAM Program

The UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) conducts a research program entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program" funded by the Department of Science and Technology (DOST) Grants-in-Aid Program. The DREAM Program aims to produce detailed, up-to-date, national elevation dataset for 3D flood and hazard mapping to address disaster risk reduction and mitigation in the country.

The DREAM Program consists of four components that operationalize the various stages of implementation. The Data Acquisition Component (DAC) conducts aerial surveys to collect Light Detecting and Ranging (LiDAR) data and aerial images in major river basins and priority areas. The Data Validation Component (DVC) implements ground surveys to validate acquired LiDAR data, along with bathymetric measurements to gather river discharge data. The Data Processing Component (DPC) processes and compiles all data generated by the DAC and DVC. Finally, the Flood Modeling Component (FMC) utilizes compiled data for flood modeling and simulation.

Overall, the target output is a national elevation dataset suitable for 1:5000 scale mapping, with 50 centimeter horizontal and vertical accuracies. These accuracies are achieved through the use of state-of-the-art airborne Light Detection and Ranging (LiDAR) technology and appended with Synthetic-aperture radar (SAR) in some areas. It collects point cloud data at a rate of 100,000 to 500,000 points per second, and is capable of collecting elevation data at a rate of 300 to 400 square kilometers per day, per sensor

1.2 Objectives and Target Outputs

The program aims to achieve the following objectives:

a) To acquire a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management,
b) 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,
c) To develop the capacity to process, produce and analyze various proven and potential thematic map layers from the 3D data useful for government agencies,
d) To transfer product development technologies to government agencies with geospatial information requirements, and,

e) To generate the following outputs
1) flood hazard map
2) digital surface model
3) digital terrain model and
4) orthophotograph.

1.3 General Methodological Framework

The methodology to accomplish the program's expected outputs are subdivided into four (4) major components, as shown in Figure 1. Each component is described in detail in the following section.

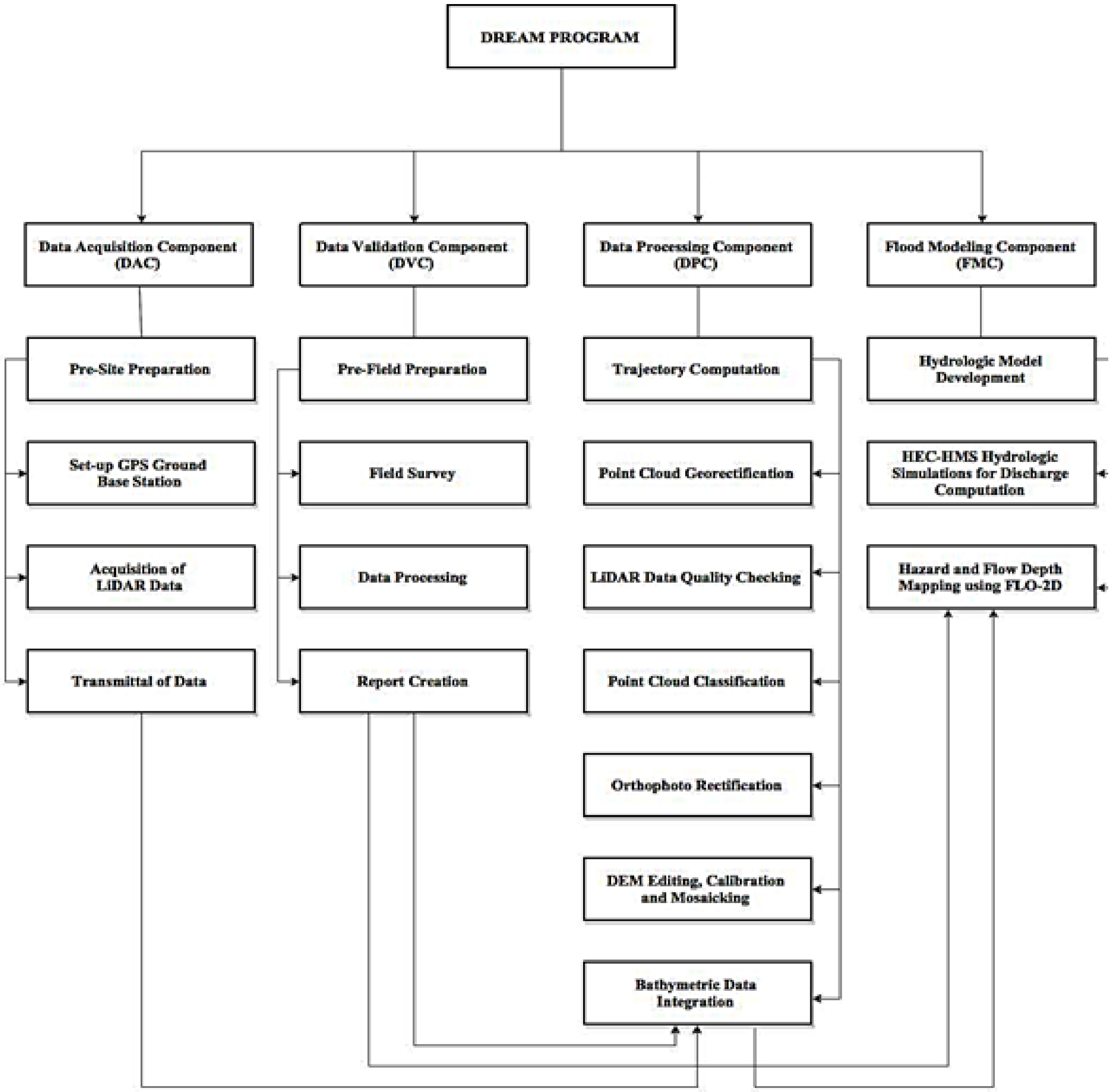


Figure 1. The general methodological framework of the program

1.4 Scope of Work of the Flood Modeling Component

The scope of work of the Flood Modeling Component is listed as the following:

a) To develop the watershed hydrologic model of the Agusan River Basin;
b) To compute the discharge values quantifying the amount of water entering the floodplain using HEC-HMS;
c) To create flood simulations using hydrologic models of the Agusan floodplain using FLO-2D GDS Pro; and
d) To prepare the static flood hazard and flow depth maps for the Agusan river basin.

1.5 Limitations

This research is limited to the usage of the available data, such as the following:

1. Digital Elevation Models (DEM) surveyed by the Data Acquisition Component (DAC) and processed by the Data Processing Component (DPC)
2. Outflow data surveyed by the Data Validation and Bathymetric Component (DVC)
3. Observed Rainfall from ASTI sensors

While the findings of this research could be further used in related-studies, the accuracy of such is dependent on the accuracy of the available data. Also, this research adapts the limitations of the software used: ArcGIS 10.2, HEC-GeoHMS 10.2 extension, WMS 9.1, HEC-HMS 3.5 and FLO-2D GDS Pro.

1.6 Operational Framework

The flow for the operational framework of the Flood Modeling Component is shown in Figure 2.

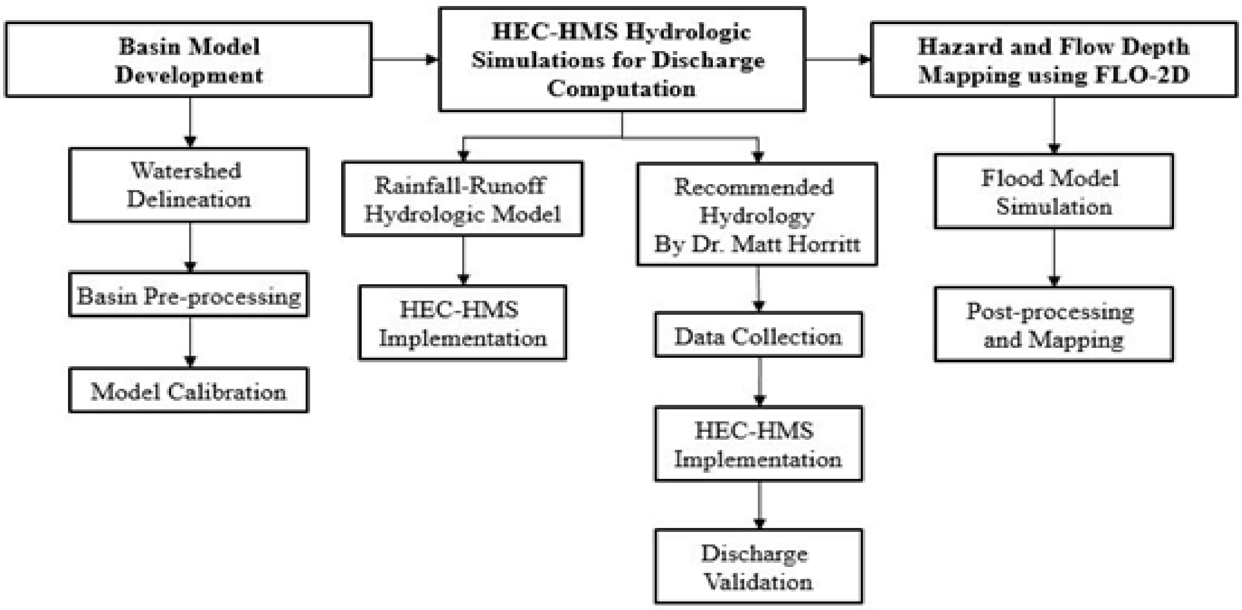


Figure 2. The operational framework and specific work flow of the Flood Modeling Component

The Agusan River Basin

The Agusan River Basin

The Agusan River Basin is located in the eastern part of Mindanao and covers the provinces of Agusan Oriental, Compostela Valley, Agusan del Sur, Agusan del Norte and Surigao del Norte. It is the third largest river system in the Philippines in terms of basin size, with an estimated basin area of 10,921 square kilometers. The location of Agusan River Basin is as shown in Figure 3.

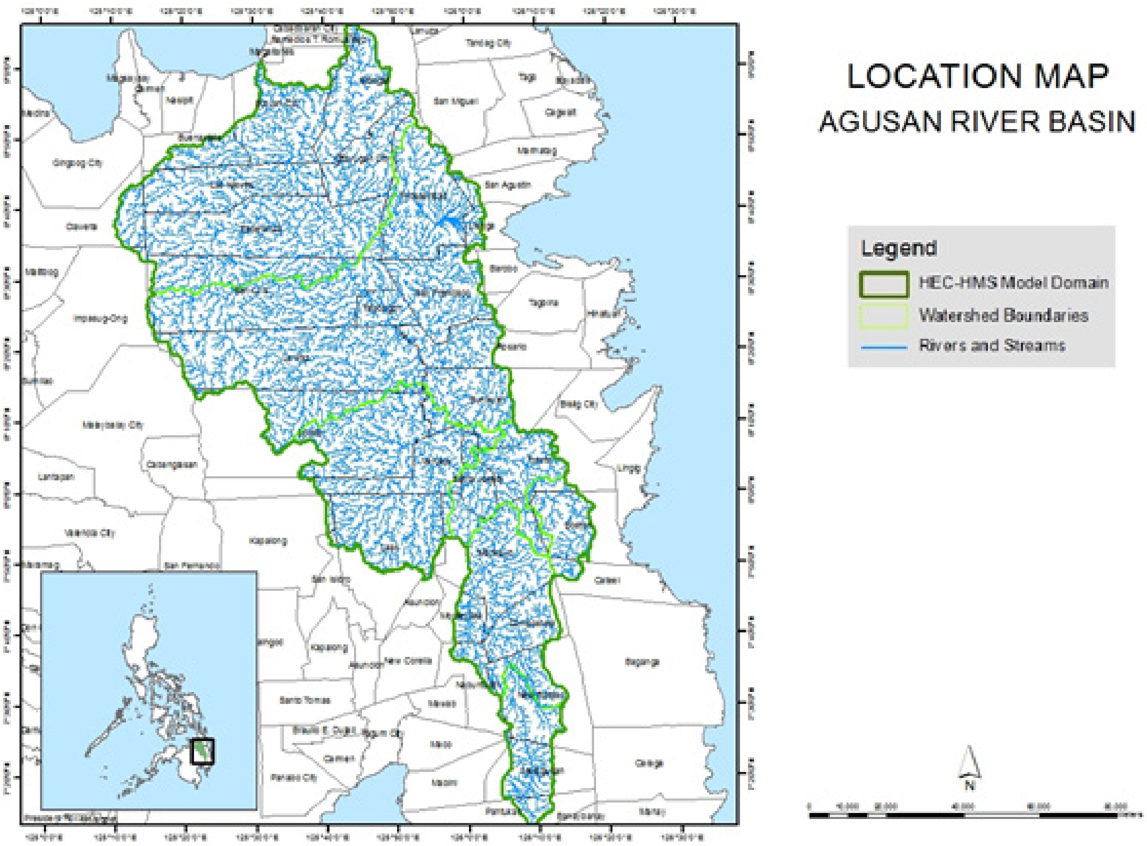


Figure 3. Agusan River Basin Location Map

The headwaters of the river come from the mountains of Compostela Valley, draining the northern portion of the island and traverses through Butuan City and the town of Magallanes in Agusan del Norte. One prominent feature of the Agusan River Basin is the presence of the Agusan Marsh, as it serves as a flood retention basin for the Agusan River, alleviating the flash floods occurring in the lower reaches of the river.

The Agusan River Basin is divided into three sub-basins based on the topographic features of each. First is the upper Agusan River basin, traversing from its headwaters in the Compostela Valley province to Santa Josefa, Agusan del Sur and finally to Veruela, Agusan del Sur. Second is the middle Agusan River basin, comprised of the section of the river from Santa Josefa to Amparo, Agusan del Sur. The last would be the lower Agusan River basin, starting from Amparo all the way to its mouth at Butuan City, Agusan del Norte. Shown in Figure 2 is the location map of Agusan River Basin.

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e.

rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

The shape files of the soil and land cover were taken from the Bureau of Soils, which is under the Department of Environment and Natural Resources Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Agusan River Basin are shown in Figures 4 and 5, respectively.

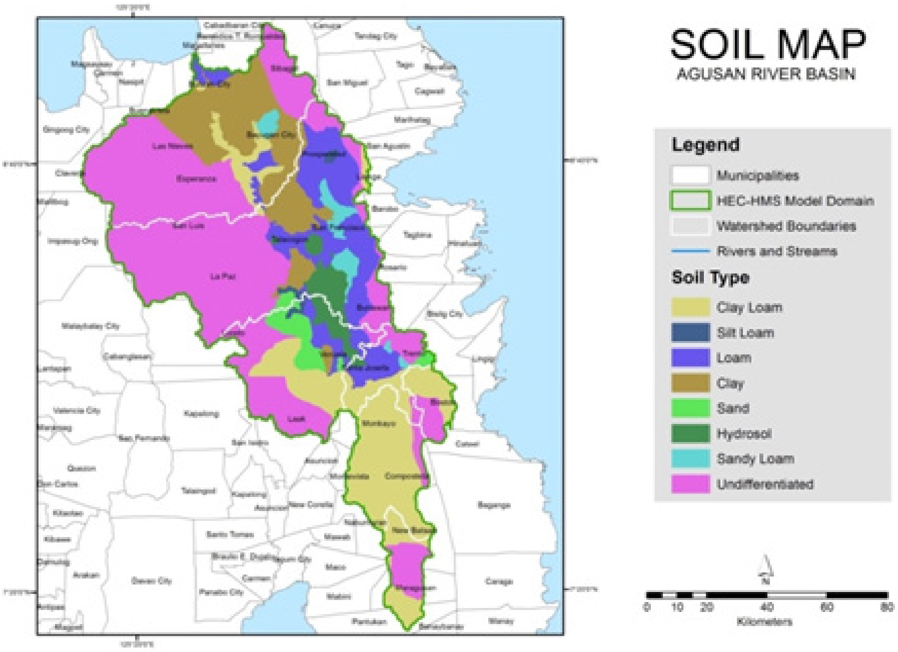


Figure 4. Agusan River Basin Soil Map

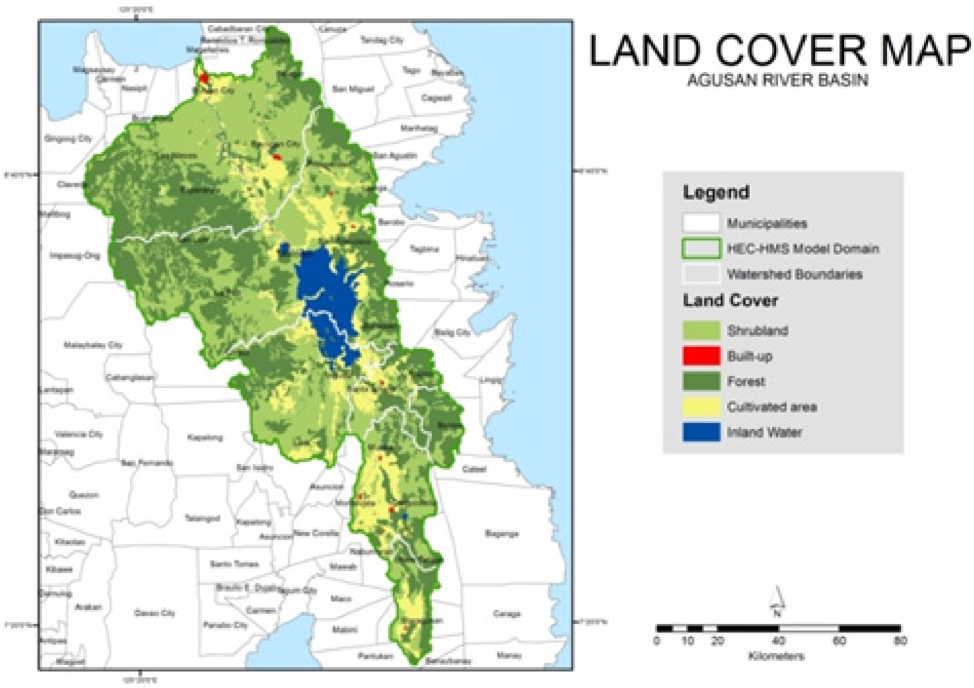


Figure 5. Agusan River Basin Land Cover Map

Methodology

3.1 Pre-processing and Data Used

Flood modeling involved several data and parameters to achieve realistic simulations and outputs. Figure 6 shows a summary of the data needed to for the research.

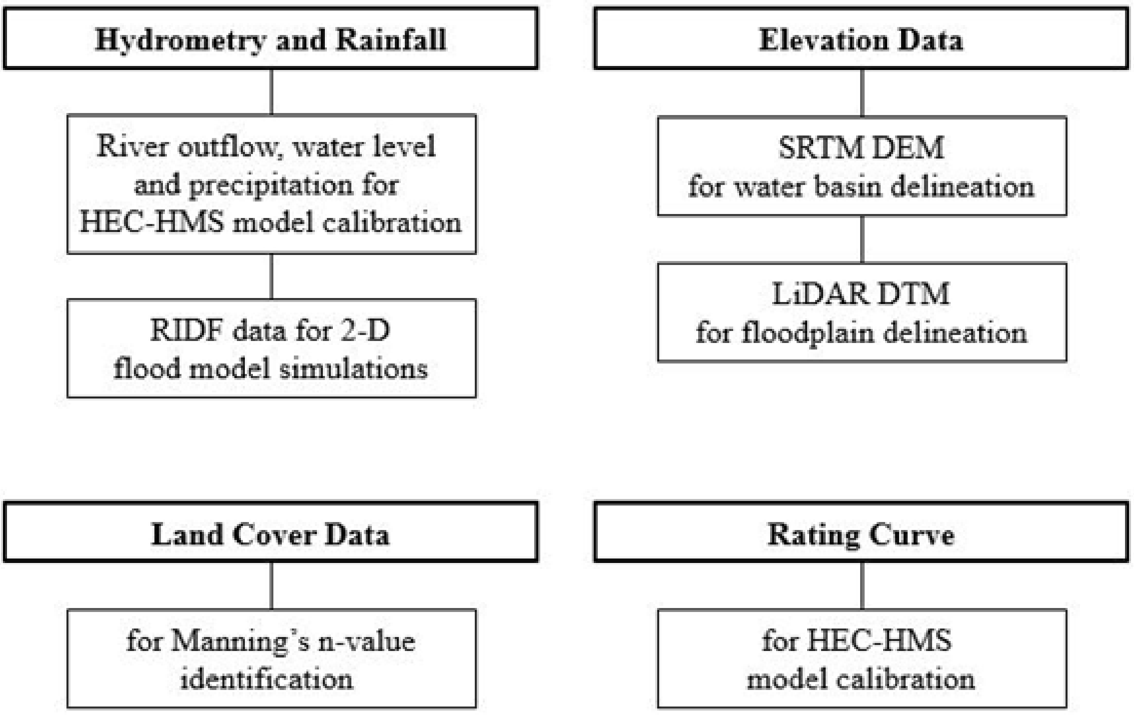


Figure 6. Summary of data needed for the purpose of flood modeling

3.1.1 Elevation Data

3.1.1.1 Hydro Corrected SRTM DEM

With the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) data as an input in determining the extent of the delineated water basin, the model was set-up. The Digital Elevation Model (DEM) is a set of elevation values for a range of points within a designated area. SRTM DEM has a 90 meter spatial mosaic of the entire country. Survey data of cross sections and profile points were integrated to the SRTM DEM for the hydro-correction.

3.1.1.2 LiDAR DEM

LiDAR was used to generate the Digital Elevation Model (DEM) of the different floodplains. DEMs used for flood modeling were already converted to digital terrain models (DTMs) which only show topography, and are thus cleared of land features such as trees and buildings. These terrain features would allow water to flow realistically in the models.

Figure 7 shows an image of the DEM generated through LiDAR.

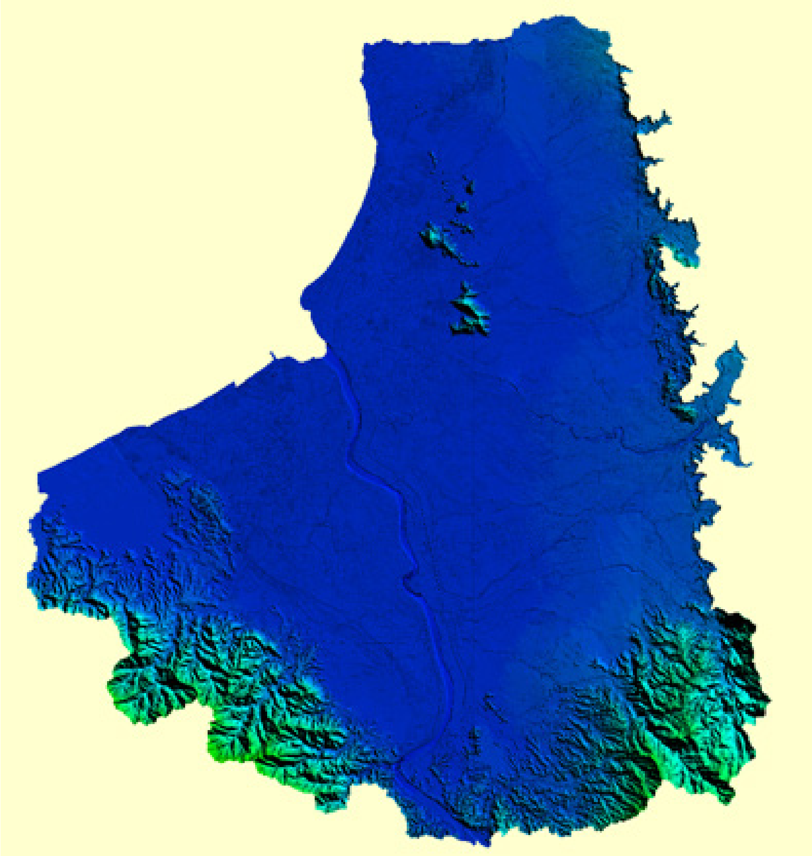


Figure 7. Digital Elevation Model (DEM) of the AgusanRiver Basin using Light Detection and Ranging (LiDAR) technology

Elevation points were created from LiDAR DTMs. Since DTMs were provided as 1-meter spatial resolution rasters (while flood models for Agusan were created using a 10-meter grid), the DTM raster had to be resampled to a raster grid with a 10-meter cell size using ArcGIS.

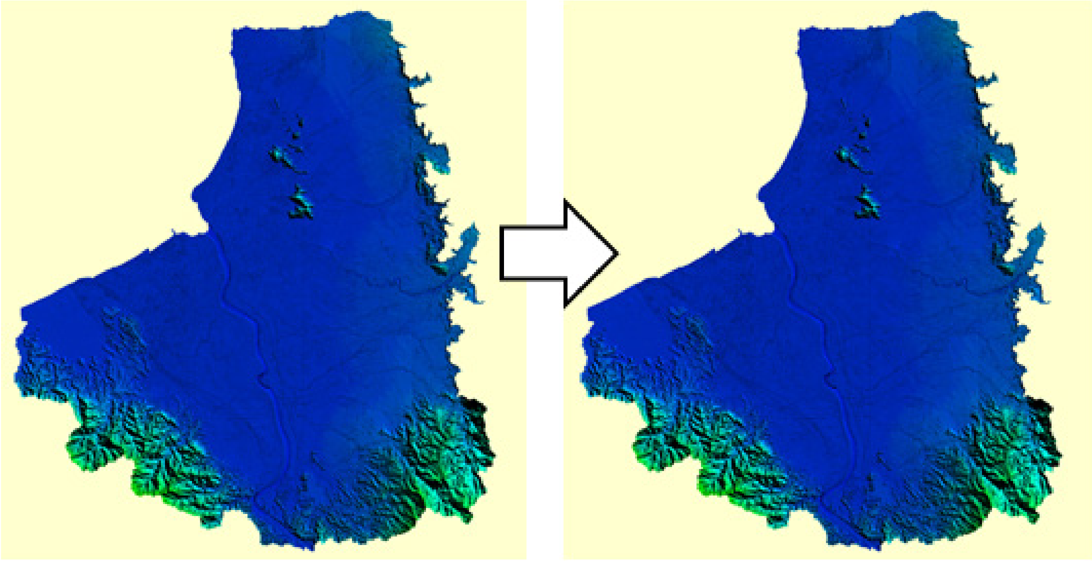


Figure 8. The 1-meter resolution LiDAR data resampled to a 10-meter raster grid in GIS software to ensure that values are properly adjusted.

3.1.2 Land Cover and Soil Type

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

A general approach was done for the Agusan floodplain. Streams were identified against built-up areas and rice fields. Identification was done visually using stitched Quickbird images from Google Earth. Areas with different land covers are shown on Figure 9. Different Manning n-values are assigned to each grid element coinciding with these main classifications during the modeling phase.

Figure 9. Stitched Quickbird images for the Agusan floodplain.

3.1.3 Hydrometry and Rainfall Data

3.1.3.1 Hydrometry for different discharge points

3.1.3.1.1 Las Nieves, Agusan del Norte

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from Las Nieves located in the municipality of Las Nieves, Agusan del Norte (11°23'31.95"N, 122°41'13.65"E). This was recorded during the typhoon Yolanda event on November 9, 2013. Peak discharge is 745.1 at 7:00 AM.

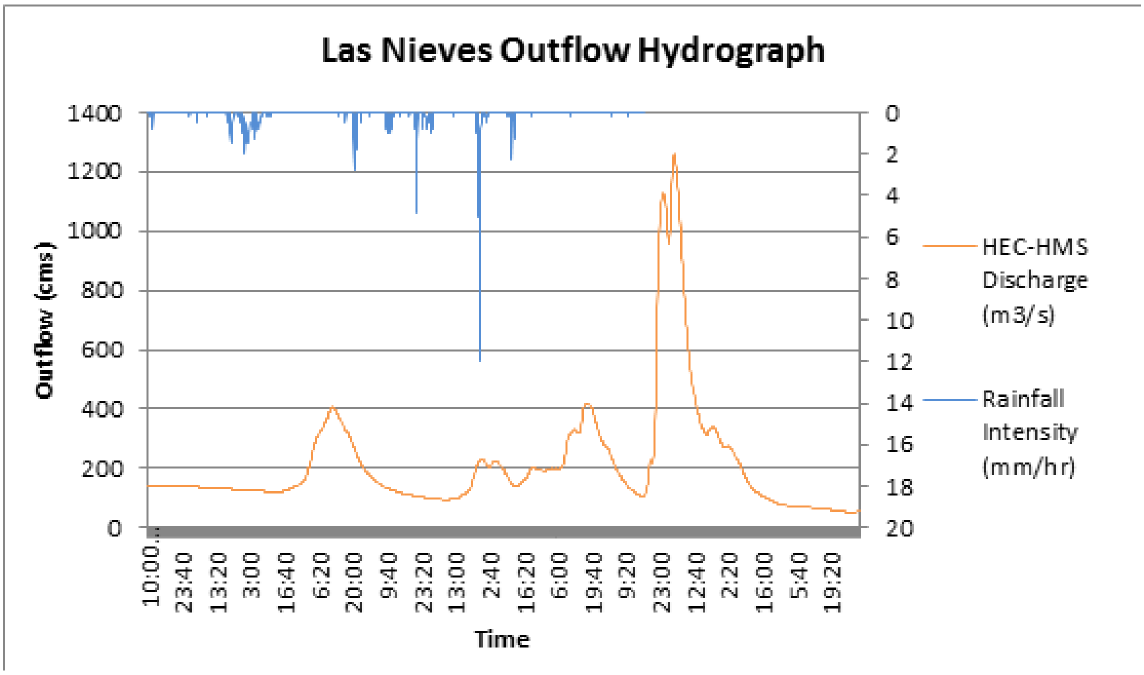


Figure 10. Las Nieves Rainfall and outflow data used for modeling.

3.1.3.1.2 Andanan Bridge –Bayugan City, Agusan del Sur

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from Andanan Bridge, Agusan (8°43'51.75"N, 125°43'45.12"E). The peak discharge is 28.90 m3/s. This historical event was recorded at 2:10 P.M., January 20, 2014.

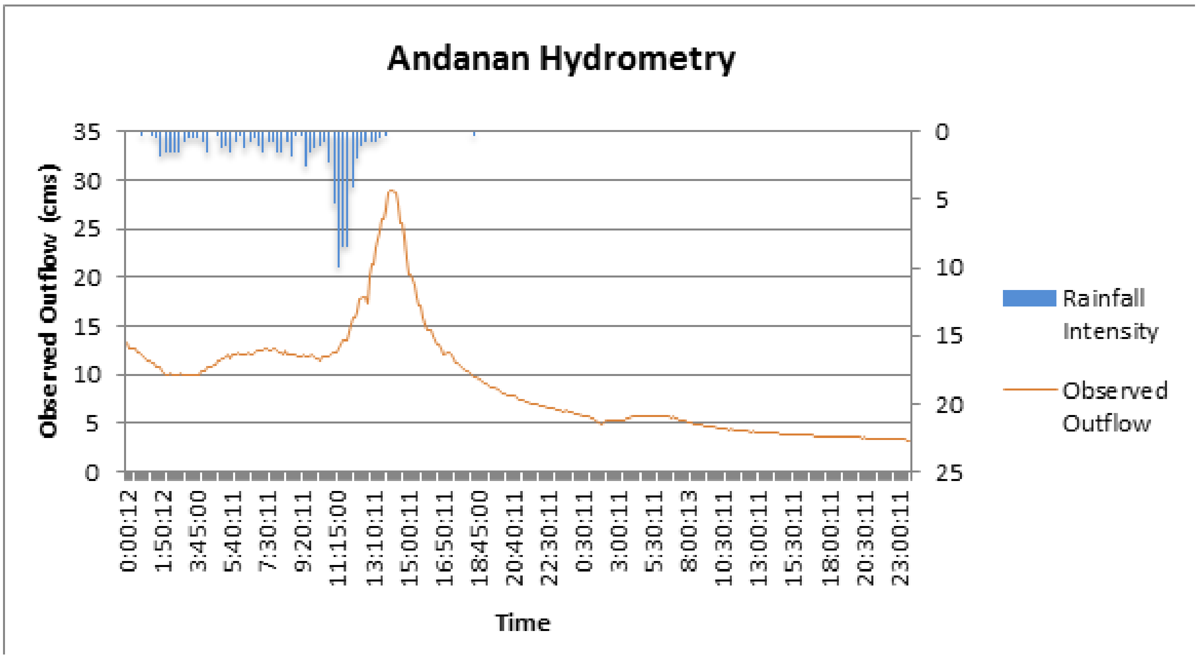


Figure 11. Andanan Rainfall and outflow data used for modeling.

3.1.3.1.3 DRRM River Base Leon Kilat – Butuan City, Agusan del Norte

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from DRRM River Base, Butuan City, Agusan del Norte (8°57'4.34211"N, 125°32'37.52101"E). The recorded peak discharge is 1068.00 cms at 22:30, November 12, 2014.

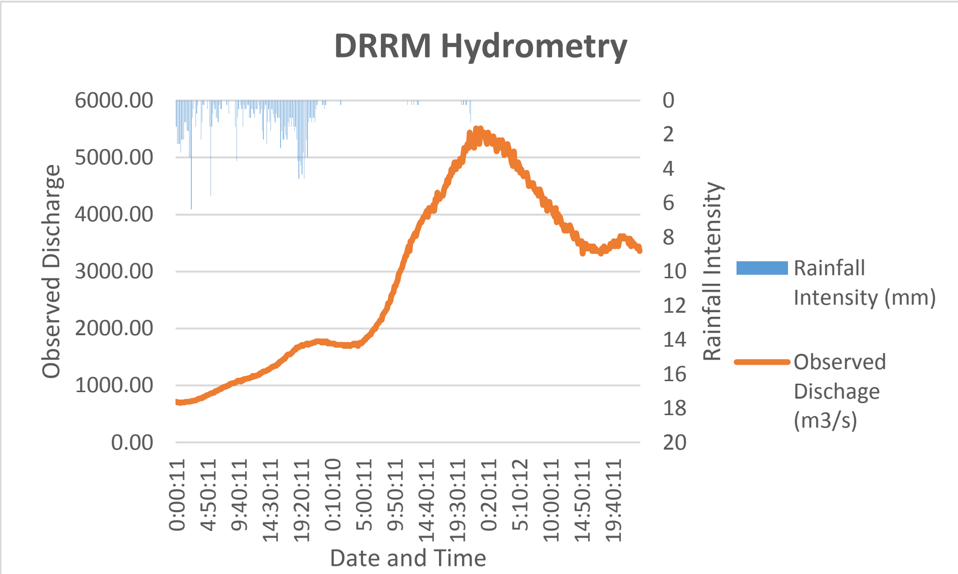


Figure 12. DRRM Rainfall and outflow data used for modeling.

3.1.3.1.4 Brgy .Poblacion, Compostella, Compostella Valley

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from Brgy. Poblacion, Compostela, Compostela Valley (7°40'33.64"N, 126° 5'22.50"E). The recorded peak discharge is 78.8 cms at 2:40 PM, January 19, 2014.

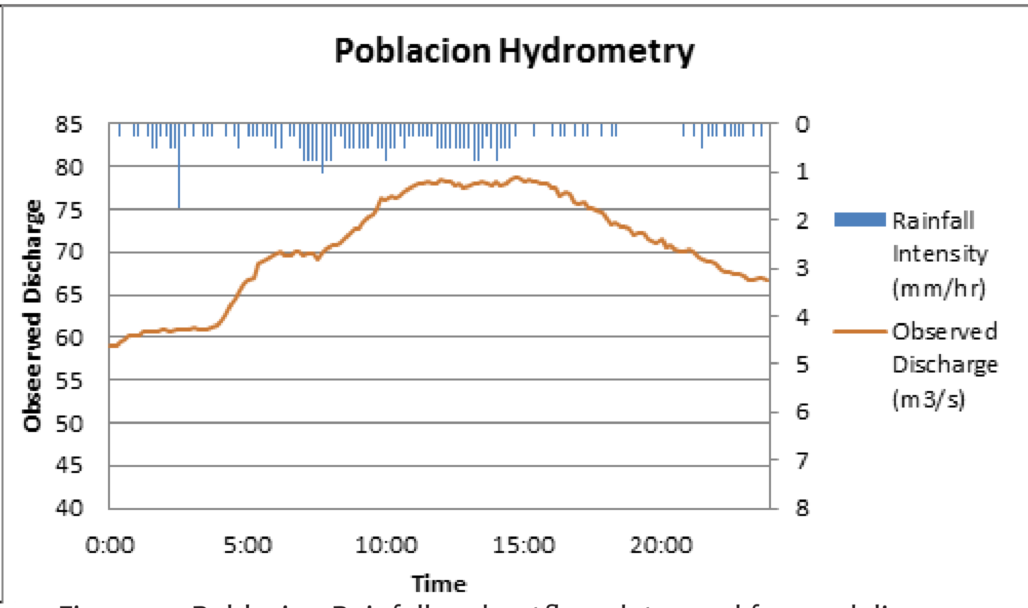


Figure 13. Poblacion Rainfall and outflow data used for modeling.

3.1.3.1.5 Wawa Bridge – Bayugan City, Agusan del Sur

The river outflow was computed using the derived rating curve equation. This discharge was used to calibrate the HEC-HMS model. It was taken from Wawa Bridge, Agusan (8°48'14.75762"N, 125°42'30.09845"E). The recorded peak discharge is 306.18 cms at 3:20 PM, January 19, 2014.

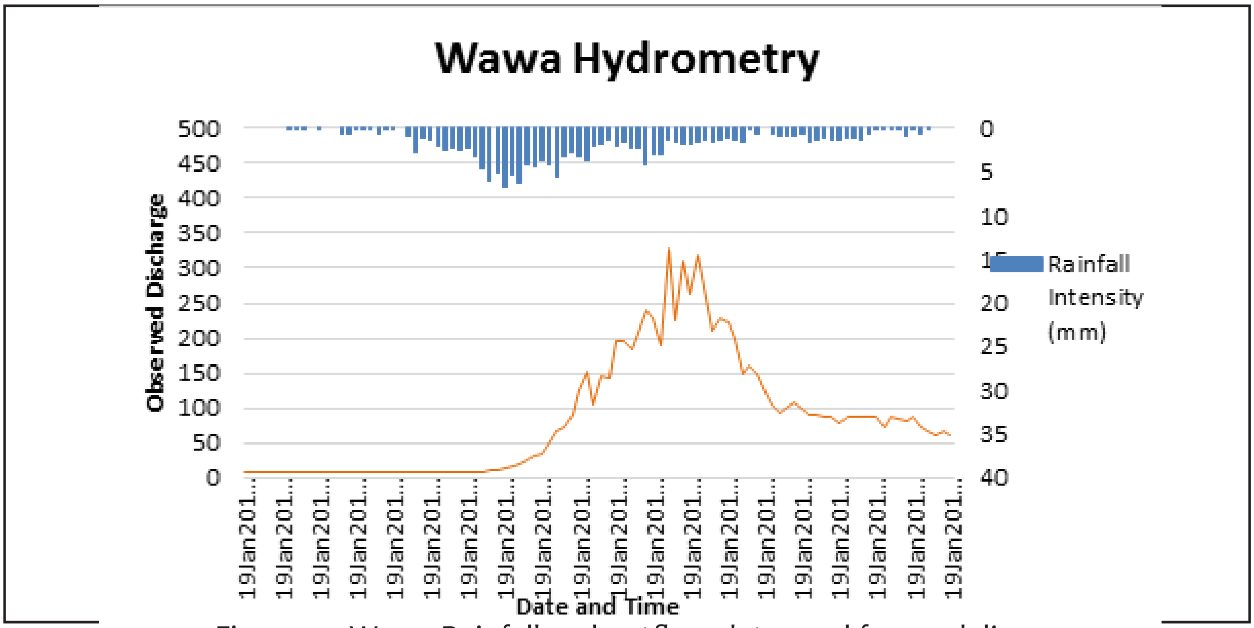


Figure 14. Wawa Rainfall and outflow data used for modeling.

3.1.3.2 Rainfall Intensity Duration Frequency (RIDF)

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

Five return periods were used, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs. All return periods are 24 hours long and peaks after 12 hours.

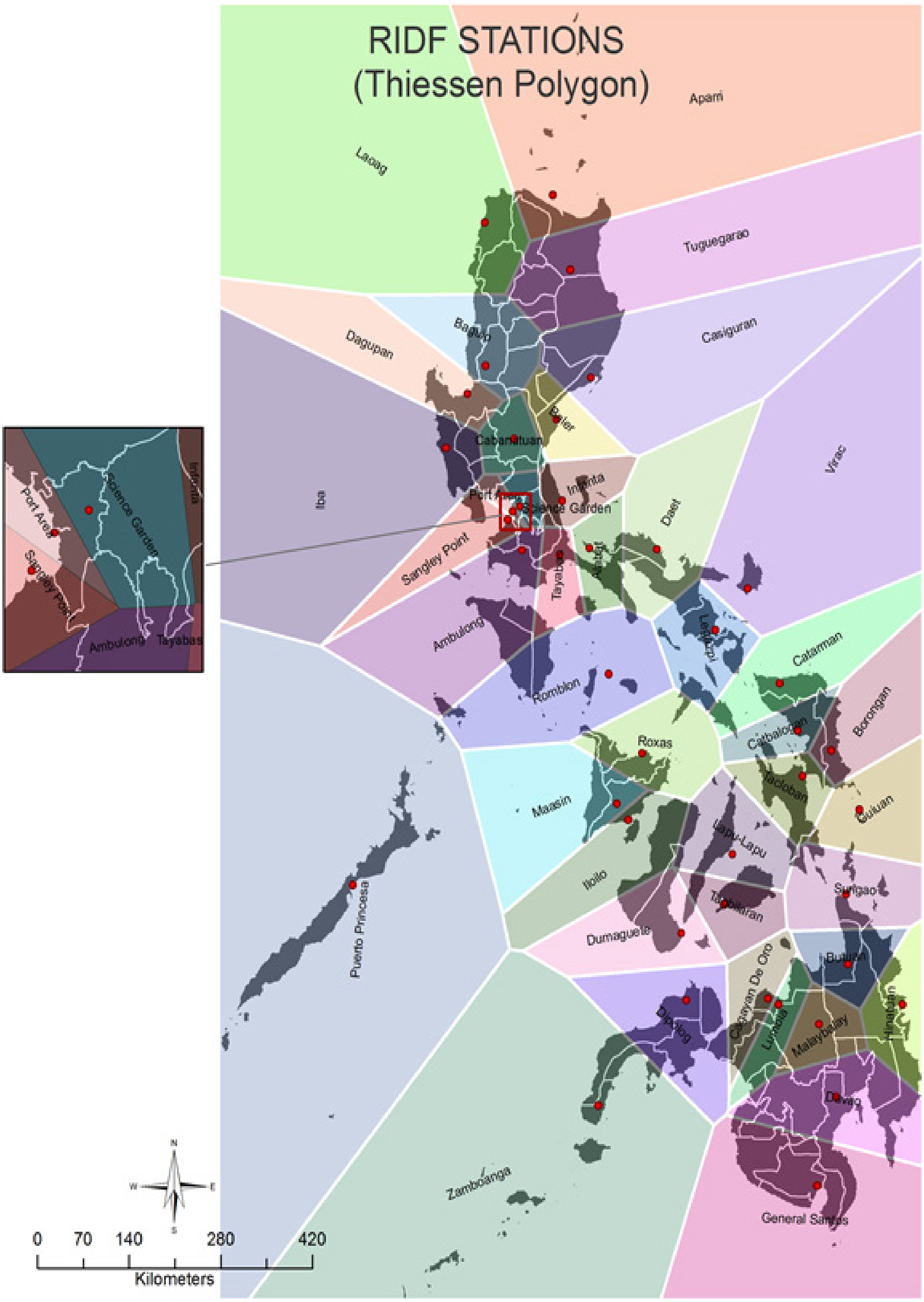


Figure 15. Thiessen Polygon of Rain Intensity Duration Frequency (RIDF) Stations for the whole Philippines.

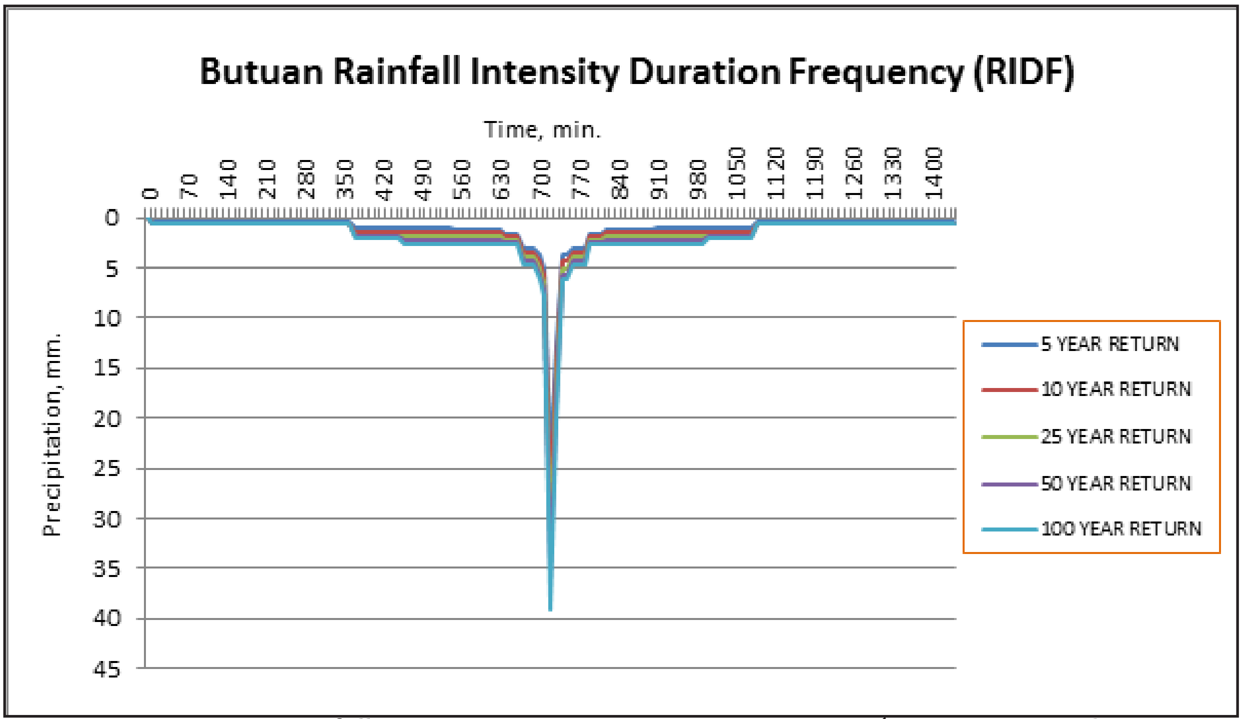


Figure 16. Butuan Rainfall Intensity Duration Frequency Curves (Las Nieves, Andanan, DRRM, Wawa)

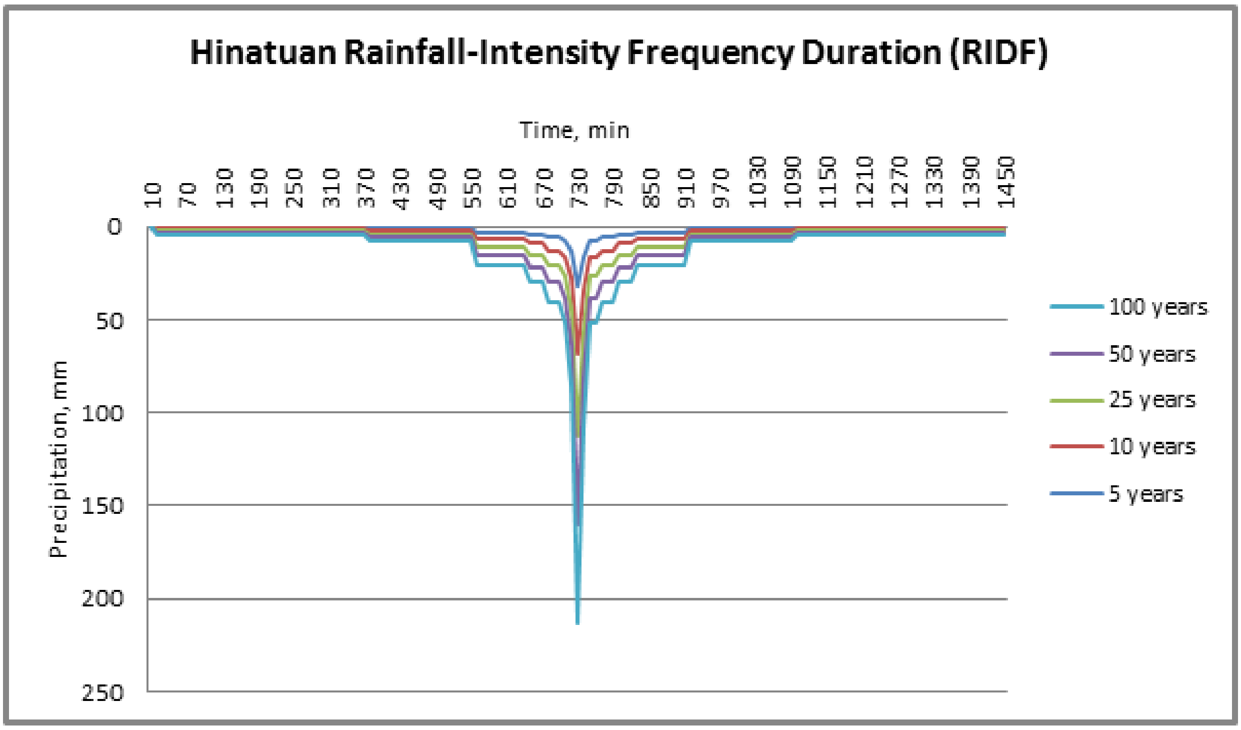


Figure 17. Hinatuan Rainfall Intensity Duration Frequency Curves (Panag and Poblacion)

The Agusan outflow was computed for the five return periods, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs.

3.1.4 Rating Curves

Rating curves were provided by DVC. This curve gives the relationship between the observed water levels from the AWLS used and outflow watershed at the said locations.

Rating curves are expressed in the form of Equation 1 with the discharge (Q) as a function of the gauge height (h) readings from AWLS and constants (a and n).

$$Q = a^{nh}$$

Equation 1. Rating Curve

3.1.4.1 Las Nieves, Agusan del Norte Rating Curve

For Las Nieves, Agusan del Sur, the rating curve is expressed as $Q= 0.8853e^{0.0005x}$ as shown in Figure 19.

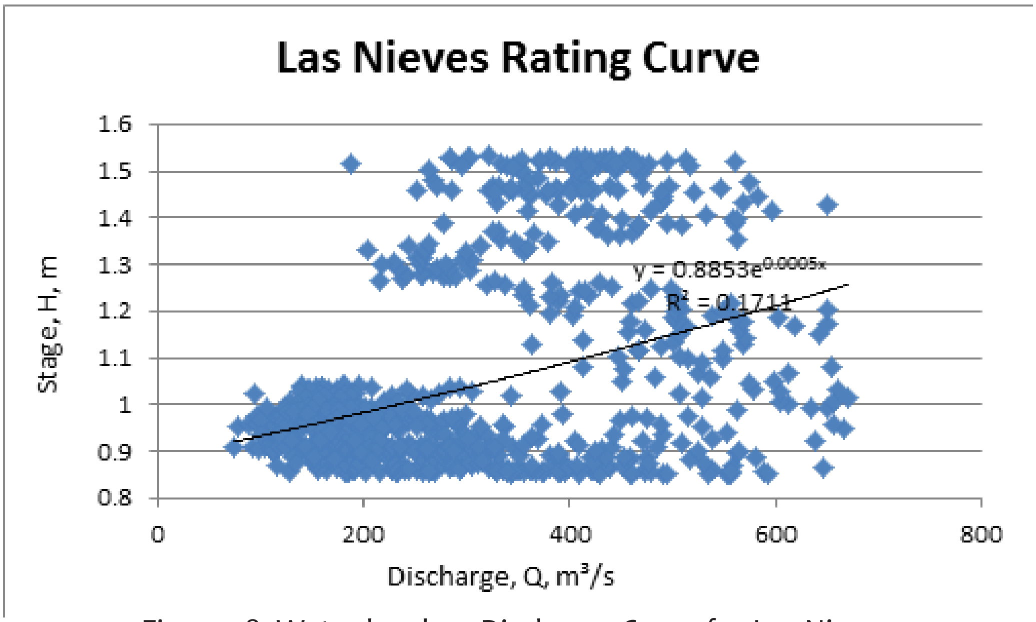


Figure 18. Water level vs. Discharge Curve for Las Nieves

3.1.4.2 Andanan Bridge –Bayugan City, Agusan del Sur Rating Curve

For Andanan Bridge, Agusan, the rating curve is expressed as $Q = 3E^{-06e0.7368h}$ as shown in Figure 20.

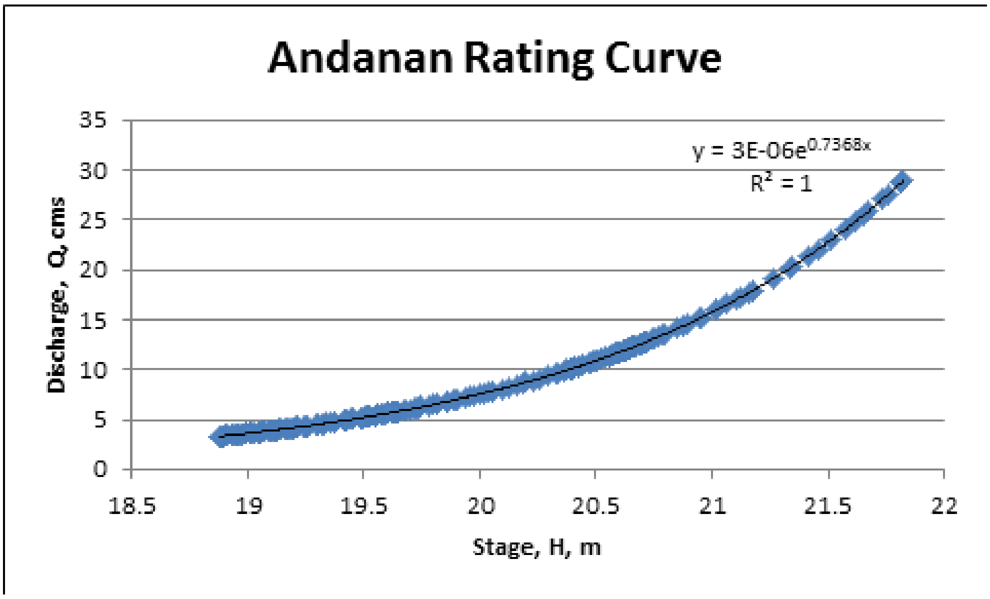


Figure 19. Water level vs. Discharge Curve for Andanan Bridge

3.1.4.3 DRRM River Base Leon Kilat – Butuan City, Agusan del Norte Rating Curve

For DRRM River Base, Butuan City, Agusan del Norte, the rating curve is expressed as $Q = 32.67e^{1.1285h}$ as shown in Figure 20.

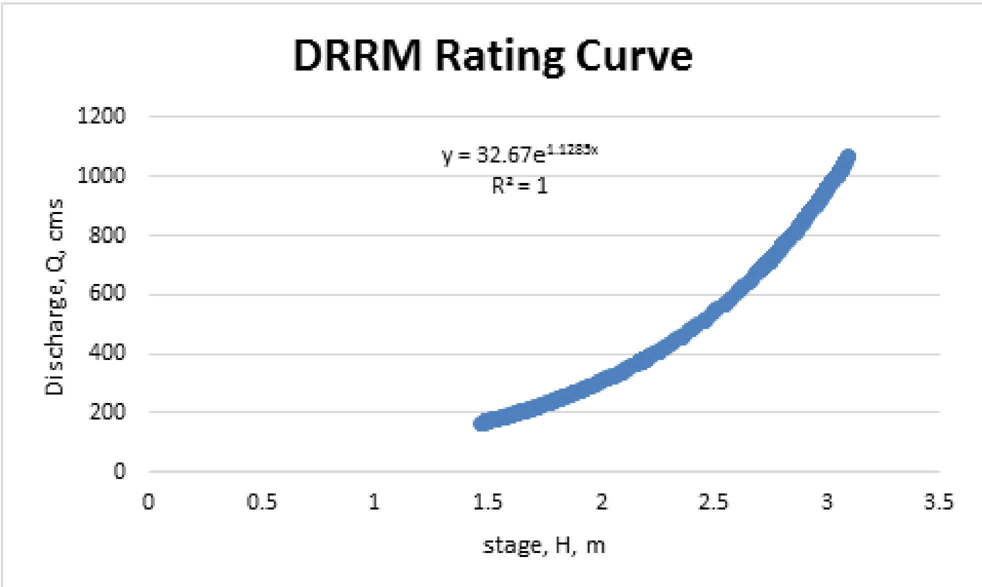


Figure 20. Water level vs. Discharge Curve for DRRM

3.1.4.4 Brgy. Poblacion, Compostela, Compostela Valley

For Brgy. Poblacion, Compostela Valley, the rating curve is expressed as $Q = 58.866e^{0.3168h}$ as shown in Figure 21.

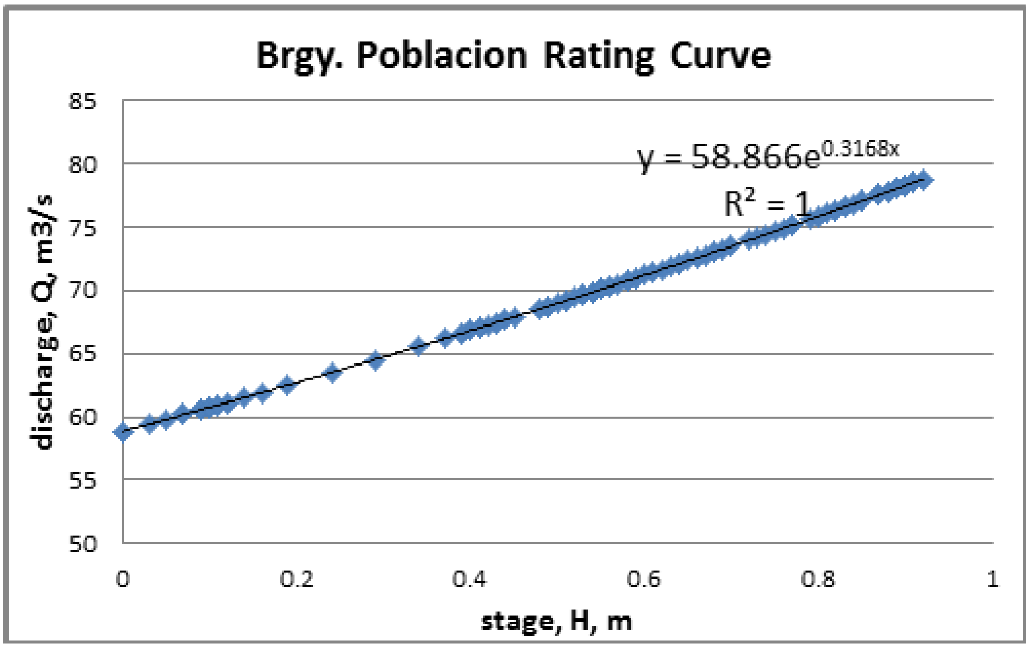


Figure 21. Water level vs. Discharge Curve for Brgy. Poblacion Bridge

3.1.4.5 Wawa Bridge – Bayugan City, Agusan del Sur

For Wawa Bridge, Agusan, the rating curve is expressed as $Q = 6E\text{-}23e^{1.3765x}$ as shown in Figure 22.

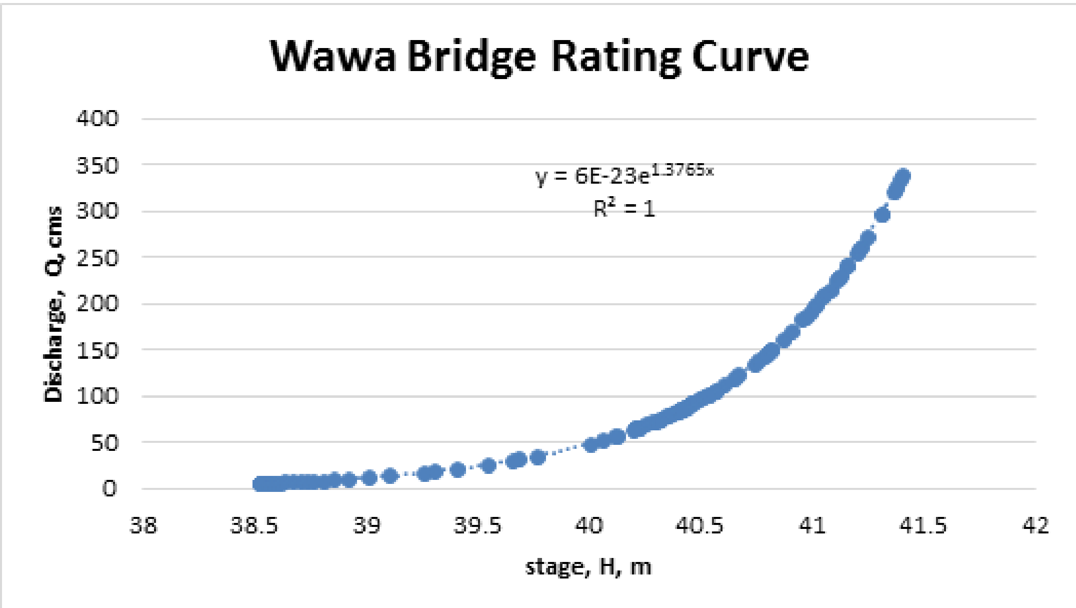


Figure 22. Water level vs. Discharge Curve for Wawa Bridge

3.2 Rainfall-Runoff Hydrologic Model Development

3.2.1 Watershed Delineation and Basin Model Pre-processing

The hydrologic model of Agusan River Basin was developed using Watershed Modeling System (WMS) version 9.1. The software was developed by Aquaveo, a water resources engineering consulting firm in United States. WMS is a program capable of various watershed computations and hydrologic simulations. The hydrologic model development follows the scheme shown in Figure 23.

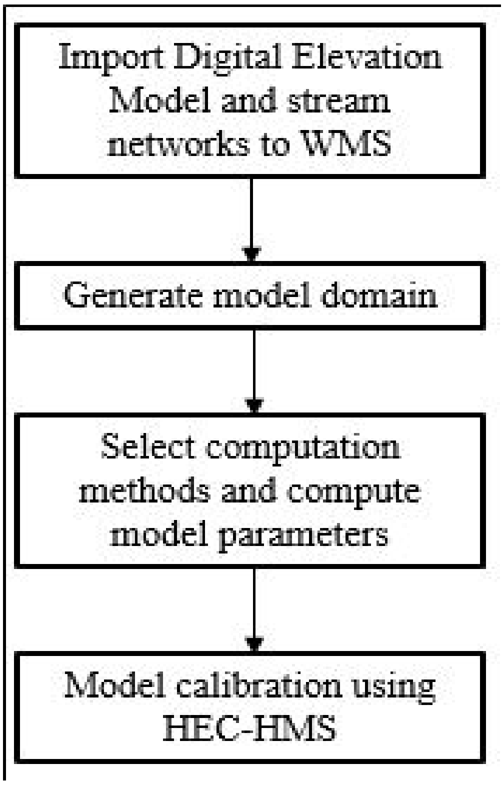


Figure 23. The Rainfall-Runoff Basin Model Development Scheme

Hydro-corrected SRTM DEM was used as the terrain for the basin model. The watershed delineation and its hydrologic elements, namely the subbasins, junctions and reaches, were generated using WMS after importing the elevation data and stream networks.

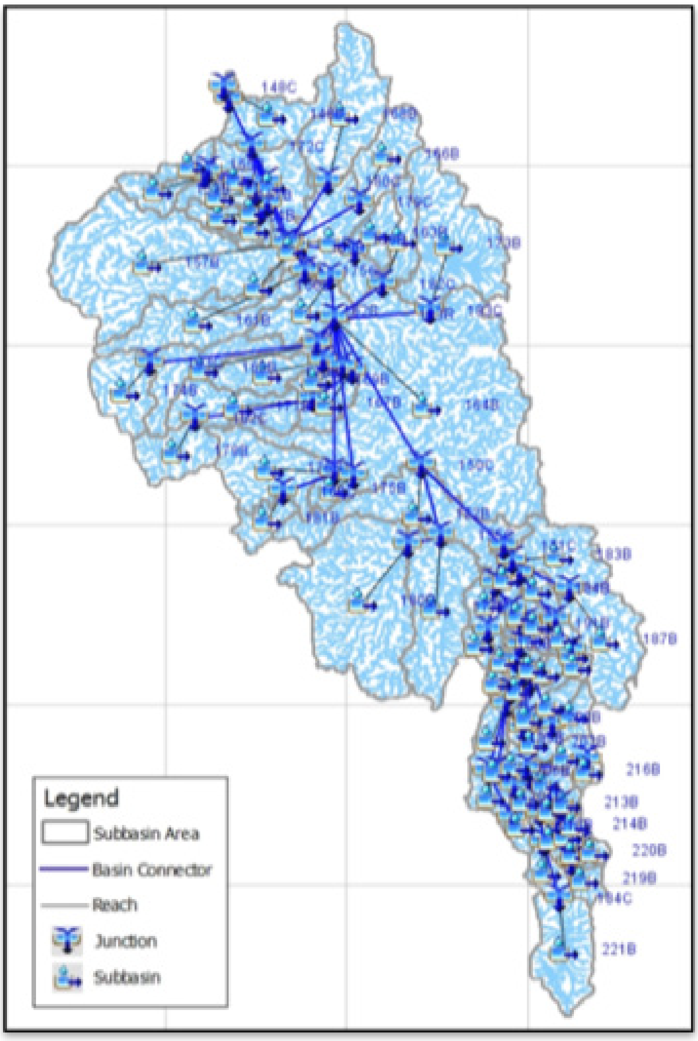


Figure 24. Agusan HEC-HMS Model domain generated by WMS

The parameters for the subbasins and reaches were computed after the model domain was created. There are several methods available for different calculation types for each subbasin and reach hydrologic elements. The methods used for this study is shown in Table 1. The necessary parameter values are determined by the selected methods. The initial abstraction, curve number, percentage impervious and manning's coefficient of roughness, n, for each subbasin were computed based on the soil type, land cover and land use data. The subbasin time of concentration and storage coefficient were computed based on the analysis of the topography of the basin.

Table 1. Methods used for the different Calculation types for the hydrologic elements

Hydrologic Element	Calculation Type	Method
Subbasin	Loss Rate	SCS Curve Number
	Transform	Clark's unit hydrograph
	Baseflow	Bounded recession
Reach	Routing	Muskingum-Cunge

3.2.2 Basin Model Calibration

The basin model made using WMS was exported to Hydrologic Modeling System (HEC-HMS) version 3.5, a software made by the Hydrologic Engineering Center of the US Army Corps of Engineers, to create the final rainfall-runoff model. The developers described HEC-HMS as a program designed to simulate the hydrologic processes of a dendritic watershed systems. In this study, the rainfall-runoff model was developed to calculate inflow from the watershed to the floodplain.

Precipitation data was taken from one automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This is the ARG located in Talacogon, Agusan del Sur. The location of the rain gauge is seen in Figure 25.

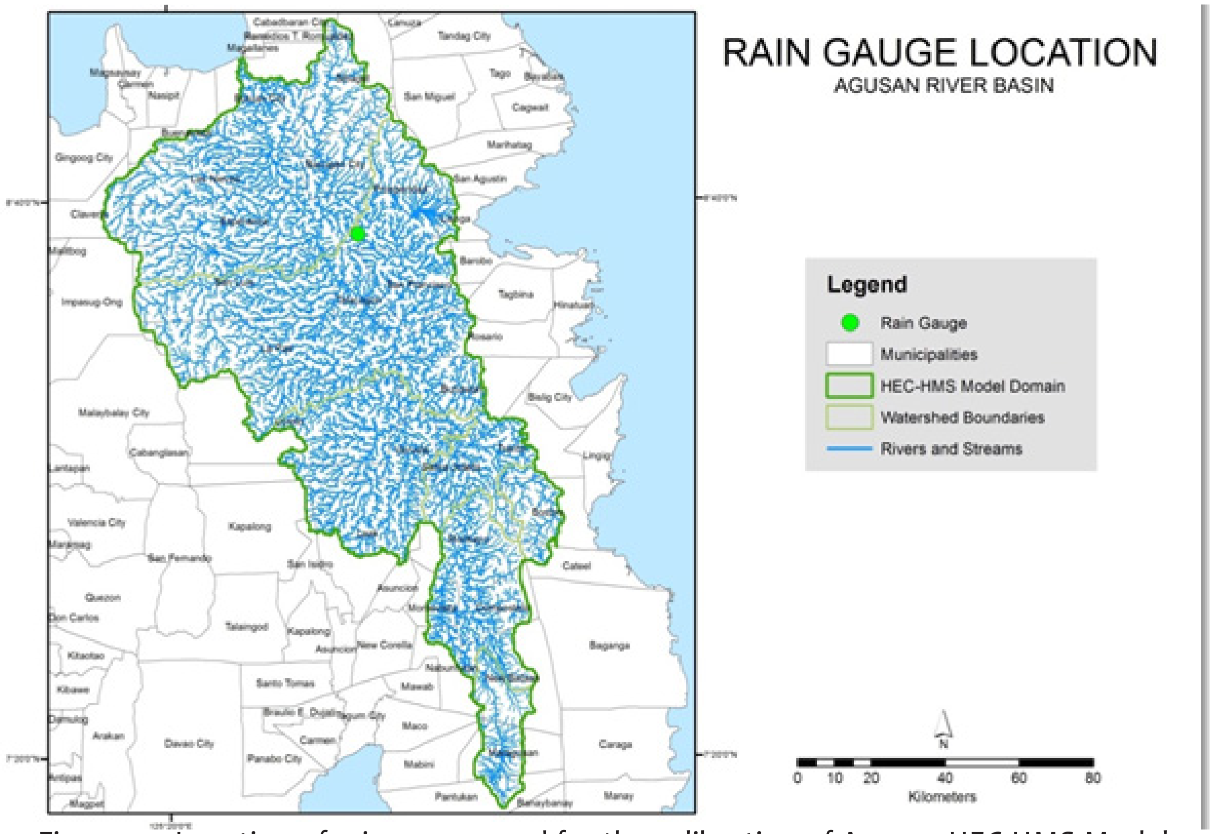


Figure 25. Location of rain gauge used for the calibration of Agusan HEC-HMS Model.

The outflow hydrograph for the downstream-most discharge point with field data was also encoded to the model as a basis for the calibration. Using the said data, HEC-HMS could perform rainfall-runoff simulation and the resulting outflow hydrograph was compared with the observed hydrograph. The values of the parameters were adjusted and optimized in order for the calculated outflow hydrograph to appear like the observed hydrograph. Acceptable values of the subbasin and reach parameters from the manual and past literatures were considered in the calibration.

After the calibration of the downstream-most discharge point, model calibration of the discharge points along the major tributaries of the main river/s were also performed.

3.3 HEC-HMS Hydrologic Simulations for Discharge Computations using PAGASA RIDF Curves

3.3.1 Discharge Computation using Rainfall-Runoff Hydrologic Model

The calibrated rainfall-Runoff Hydrologic Model for the Agusan River Basin using WMS and HEC-HMS was used to simulate the flow for the five return periods, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs. Time-series data of the precipitation data using the Butuan RIDF curves were encoded to HEC-HMS for the aforementioned return periods, wherein each return period corresponds to a scenario. This process was performed for all discharge points. The output for each simulation was an outflow hydrograph from that result, the total inflow to the floodplain and time difference between the peak outflow and peak precipitation could be determined.

3.3.2 Discharge Computation using Dr. Horritt's Recommended Hydrological Method

The required data to be accumulated for the implementation of Dr. Horrit's method is shown on Figure 26.

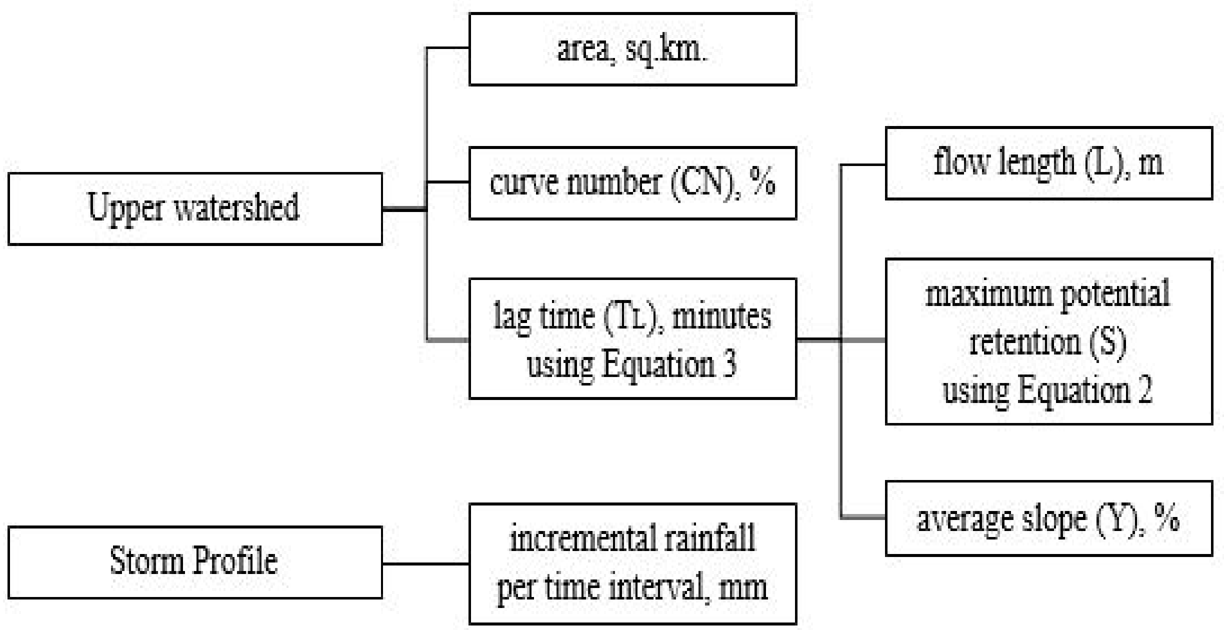


Figure 26. Different data needed as input for HEC-HMS discharge simulation using Dr. Horritt's recommended hydrology method.

Flows from streams were computed using the hydrology method developed by the flood modeling component with Dr. Matt Horritt, a British hydrologist that specializes in flood research. The methodology was based on an approach developed by CH2M Hill and Horritt Consulting for Taiwan which has been successfully validated in a region with meteorology and hydrology similar to the Philippines. It utilizes the SCS curve number and unit hydrograph method to have an accurate approximation of river discharge data from measurable catchment parameters.

3.3.2.1 Determination of Catchment Properties

RADARSAT DTM data for the different areas of the Philippines were compiled with the aid of ArcMap. RADARSAT satellites provide advance geospatial information and these were processed in the forms of shapefiles and layers that are readable and can be analyzed by ArcMap. These shapefiles are digital vectors that store geometric locations.

The watershed flow length is defined as the longest drainage path within the catchment, measured from the top of the watershed to the point of the outlet. With the tools provided by the ArcMap program and the data from RADARSAT DTM, the longest stream was selected and its geometric property, flow length, was then calculated in the program.

The area of the watershed is determined with the longest stream as the guide. The compiled RADARSAT data has a shapefile with defined small catchments based on mean elevation. These parameters were used in determining which catchments, along with the area, belong in the upper watershed.

Figure 27. Delineation upper watershed for Agusan floodplain discharge computation

The value of the curve number was obtained using the RADARSAT data that contains information of the Philippine national curve number map. An ArcMap tool was used to determine the average curve number of the area bounded by the upper watershed shapefile. The same method was implemented in determining the average slope using RADARSAT with slope data for the whole country.

After determining the curve number (CN), the maximum potential retention (S) was determined by Equation 2.

$$S = \frac{1000}{CN} - 10$$

Equation 2. Determination of maximum potential retention using the average curve number of the catchment

The watershed length (L), average slope (Y) and maximum potential retention (S) are used to estimate the lag time of the upper watershed as illustrated in Equation 3.

$$T_L = \frac{L^{0.8}(S+1)^{0.7}}{560Y^{0.5}}$$

Equation 3. Lag Time Equation Calibrated for Philippine Setting

Finally, the final parameter that will be derived is the storm profile. The synoptic station which covers the majority of the upper watershed was identified. Using the RIDF data, the incremental values of rainfall in millimeter per 0.1 hour was used as the storm profile.

3.3.2.2 HEC-HMS Implementation

With all the parameters available, HEC-HMS was then utilized. Obtained values from the previous section were used as input and a brief simulation would result in the tabulation of discharge results per time interval. The maximum discharge and time-to-peak for the whole simulation as well as the river discharge hydrograph were used for the flood simulation process. The time series results (discharge per time interval) were stored as HYD files for input in FLO-2D GDS Pro.

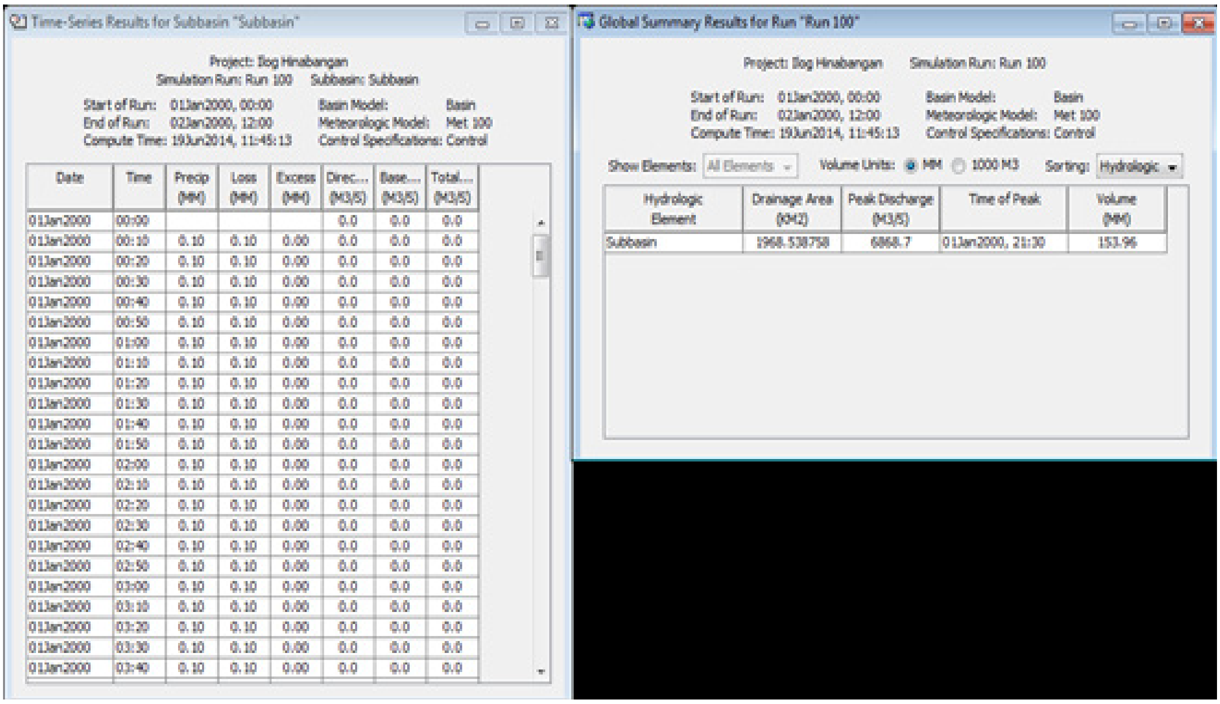


Figure 28. HEC-HMS simulation discharge results using Dr. Horritt's Method

3.3.2.3 Discharge validation against other estimates

As a general rule, the river discharge of a 2-year rain return, QMED, should approximately be equal to the bankful discharge, Qbankful, of the river. This assumes that the river is in equilibrium, with its deposition being balanced by erosion. Since the simulations of the river discharge are done for 5-, 25-, and 100-year rainfall return scenarios, a simple ratio for the 2-year and 5-year return was computed with samples from actual discharge data of different rivers. It was found out to have a constant of 0.88. This constant, however, should still be continuously checked and calibrated when necessary.

$$Q_{MED} = 0.88 Q_{5yr}$$

Equation 4. Ratio of river discharge of a 5-year rain return to a 2-year rain return scenario from measured discharge data

For the discharge calculation to pass the validation using the bankful method, Equation 5 must be satisfied.

$$50\% \, Q_{bankful} \leq Q_{MED} \leq 150\% \, Q_{bankful}$$

Equation 5. Discharge validation equation using bankful method

The bankful discharge was estimated using channel width (w), channel depth (h), bed slope (S) and Manning's constant (n). Derived from the Manning's Equation, the equation for the bankful discharge is by Equation 6.

$$Q_{bankful} = \frac{(wh)^{\frac{5}{3}} S^{\frac{1}{2}}}{n(w + 2h)^{\frac{2}{3}}}$$

Equation 6. Bankful discharge equation using measurable channel parameters

3.4 Hazard and Flow Depth Mapping using FLO-2D

3.4.1 Floodplain Delineation

The boundaries of subbasins within the floodplain were delineated based on elevation values given by the DEM. Each subbasin is marked by ridges dividing catchment areas. These catchments were delineated using a set of ArcMap tools compiled by Al Duncan, a UK Geomatics Specialist, into a single processing model. The tool allows ArcMap to compute for the flow direction and acceleration based on the elevations provided by the DEM.

Running the tool creates features representing large, medium-sized, and small streams, as well as large, medium-sized, and small catchments. For the purpose of this particular model, the large, medium-sized, and small streams were set to have an area threshold of 100,000sqm, 50,000sqm, and 10,000sqm respectively. These thresholds define the values where the algorithm refers to in delineating a trough in the DEM as a stream feature, i.e. a large stream feature should drain a catchment area totalling 100,000 sqm to be considered as such. These values differ from the standard values used (10,000sqm, 1,000 sqm and 100sqm) to limit the detail of the project, as well as the file sizes, allowing the software to process the data faster.

The tool also shows the direction in which the water is going to flow across the catchment area. This information was used as the basis for delineating the floodplain. The entire area of the floodplain was subdivided into several zones in such a way that it can be processed properly. This was done by grouping the catchments together, taking special account of the inflows and outflows of water across the entire area. To be able to simulate actual conditions, all the catchments comprising a particular computational domain were set to have outflows that merged towards a single point. The area of each subdivision was limited to 250,000 grids or less to allow for an optimal simulation in FLO-2D GDS Pro. Larger models tend to run longer, while smaller models may not be as accurate as a large one.

3.4.2 Flood Model Generation

The software used to run the simulation is FLO-2D GDS Pro. It is a GIS integrated software tool that creates an integrated river and floodplain model by simulating the flow of the water over a system of square grid elements.

After loading the shapefile of the subcatchment onto FLO-2D, 10 meter by 10 meter grids that encompassed the entire area of interest were created.

The boundary for the area was set by defining the boundary grid elements. This can either be done by defining each element individually, or by drawing a line that traces the boundaries of the subcatchment. The grid elements inside of the defined boundary were considered as the computational area in which the simulation will be run.

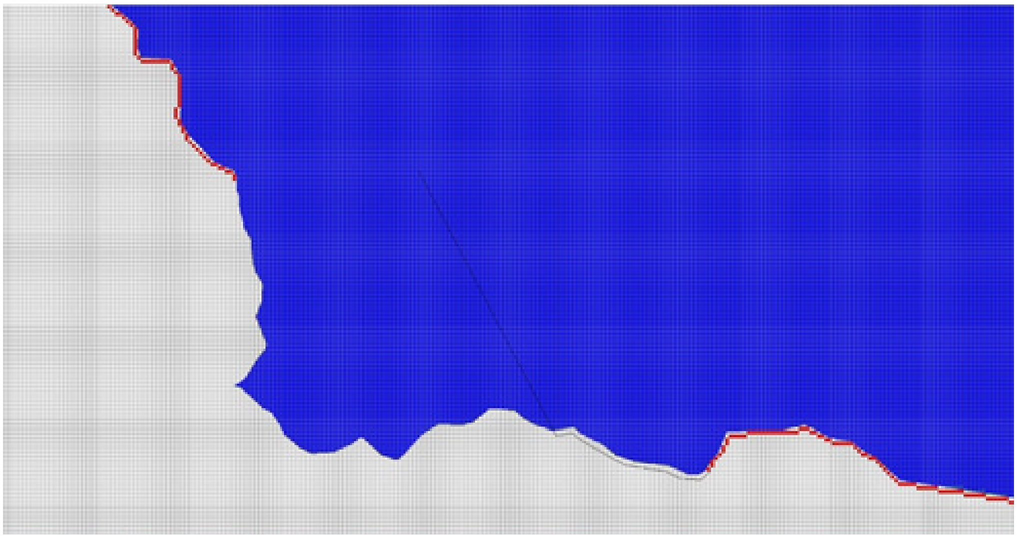


Figure 29. Screenshot showing how boundary grid elements are defined by line

Elevation data was imported in the form of the DEM gathered through LiDAR. These elevation points in PTS format were extrapolated into the model, providing an elevation value for each grid element.

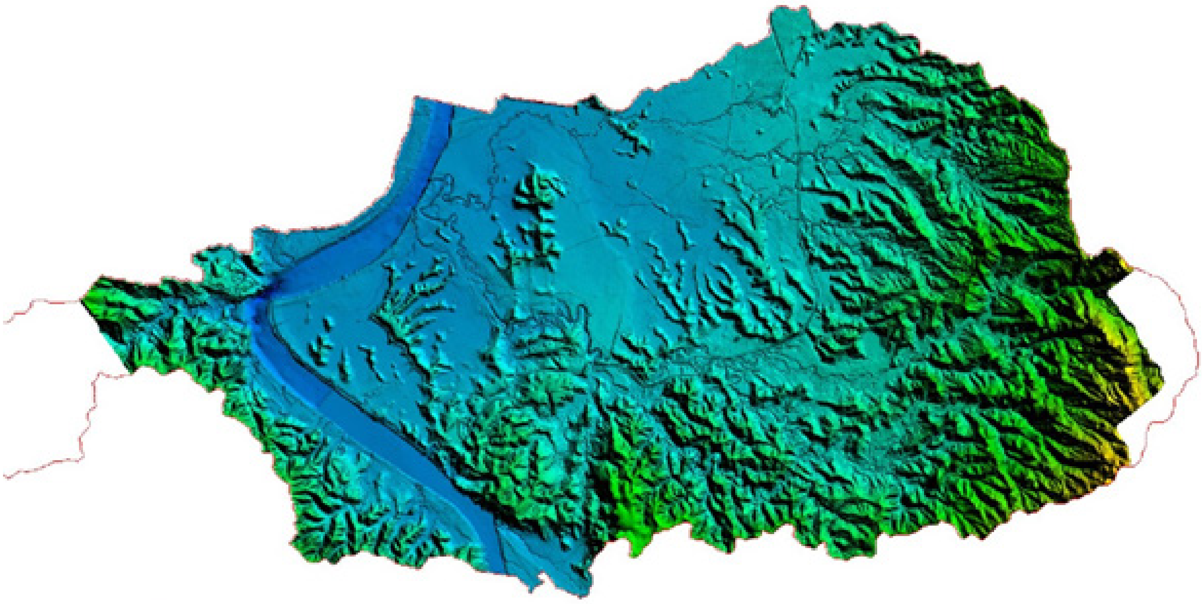


Figure 30. Screenshots of PTS files when loaded into the FLO-2D program

The floodplain is predominantly composed of rice fields, which have a Manning coefficient of 0.15. All the inner grid elements were selected and the Manning coefficient of 0.15 was assigned. To differentiate the streams from the rest of the floodplain, a shapefile containing all the streams and rivers in the area were imported into the software. The shapefile was generated using Al Duncan's catchment tool for ArcMap. The streams were then traced onto their corresponding grid elements.

These grid elements were all selected and assigned a Manning coefficient of 0.03. The DEM and aerial imagery were also used as bases for tracing the streams and rivers.

Figure 31. Aerial Image of Agusan floodplain

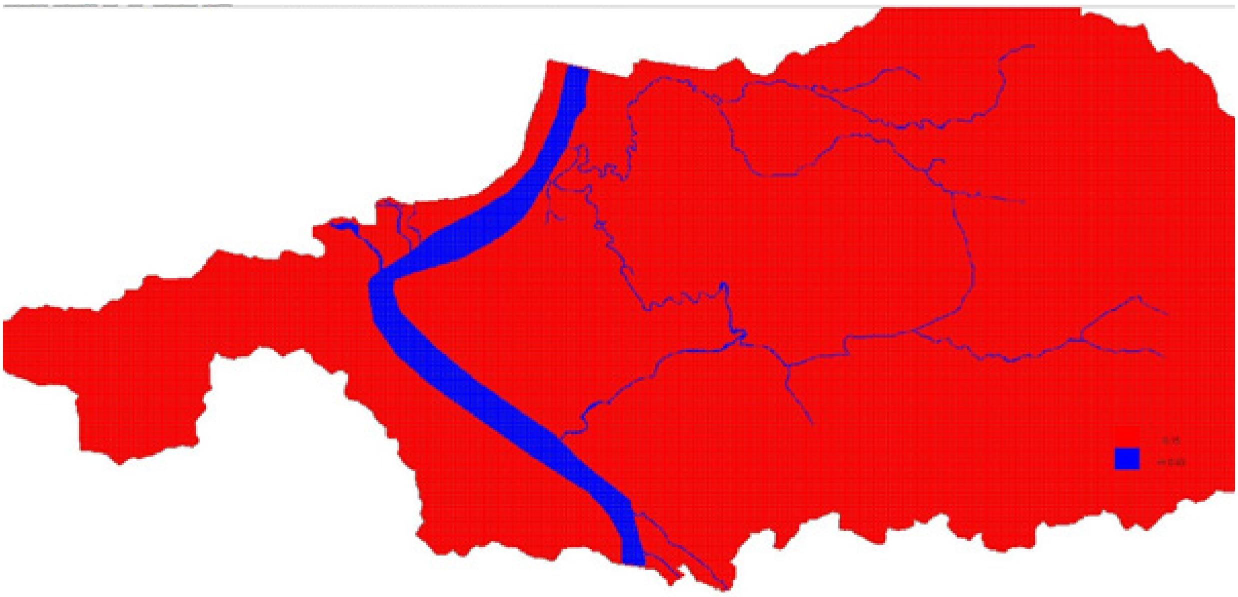


Figure 32. Screenshot of Manning's n-value rendering

After assigning Manning coefficients for each grid, the infiltration parameters were identified. Green-Ampt infiltration method by W. Heber Green and G.S Ampt were used for all the models. The initial saturations applied to the model were 0.99, 0.8, and 0.7 for 100-year, 25-year, and 5-year rain return periods respectively. These initial saturations were used in the computation of the infiltration value.

The Green-Ampt infiltration method by W. Heber Green and G.S Ampt method is based on a simple physical model in which the equation parameter can be related to physical properties of the soil. Physically, Green and Ampt assumed that the soil was saturated behind the wetting front and that one could define some "effective" matric potential at the wetting front (Kirkham, 2005). Basically, the system is assumed to consist of a uniformly wetted near-saturated transmission zone above a sharply defined wetting front of constant pressure head (Diamond & Shanley, 2003).

The next step was to allocate inflow nodes based on the locations of the outlets of the streams from the upper watershed. The inflow values came from the computed discharges that were input as hyd files.

Outflow nodes were allocated for the model. These outflow nodes show the locations where the water received by the watershed is discharged. The water that will remain in the watershed will result to flooding on low lying areas.

For the models to be able to simulate actual conditions, the inflow and outflow of each computational domain should be indicated properly. In situations wherein water flows from one subcatchment to the other, the corresponding models are processed one after the other. The outflow generated by the source subcatchment was used as inflow for the subcatchment area that it flows into.

The standard simulation time used to run each model is the time-to-peak (TP) plus an additional 12 hours. This gives enough time for the water to flow into and out of the model area, illustrating the complete process from entry to exit as shown in the hydrograph. The additional 12 hours allows enough time for the water to drain fully into the next subcatchment. After all the parameters were set, the model was run through FLO-2D GDS Pro.

3.4.3 Flow Depth and Hazard Map Simulation

After running the flood map simulation in FLO-2D GDS Pro, FLO-2D Mapper Pro was used to read the resulting hazard and flow depth maps. The standard input values for reading the simulation results are shown on Figure 24.

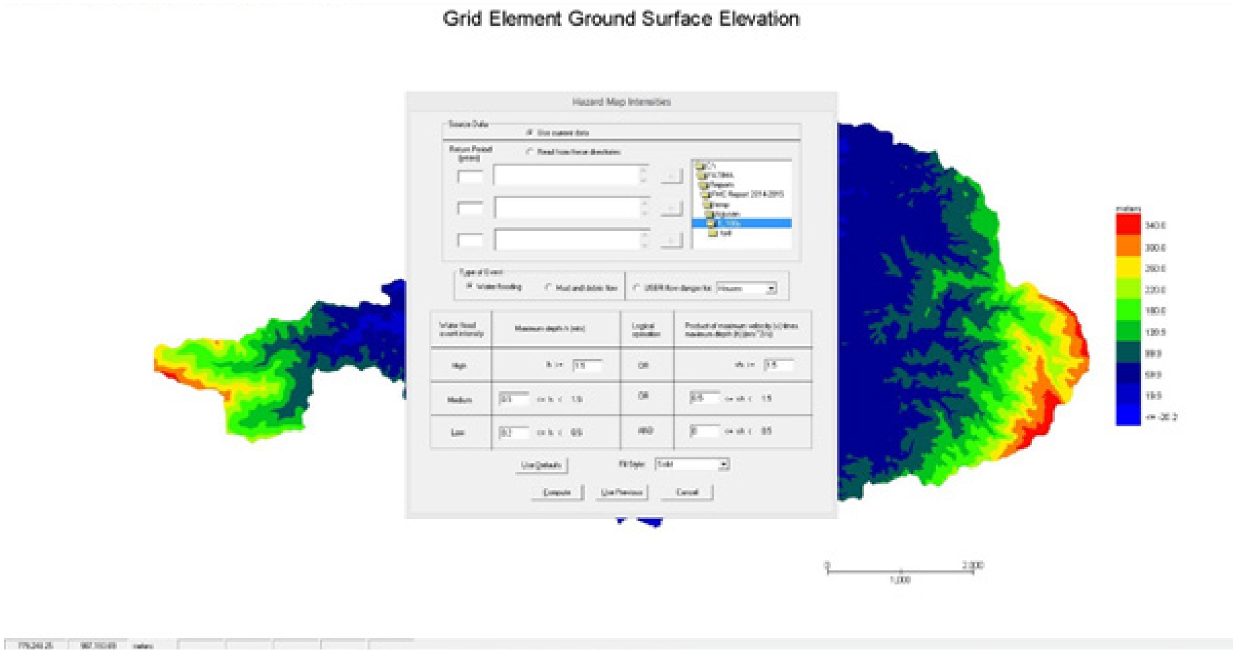


Figure 33. Flo-2D Mapper Pro General Procedure

In order to produce the hazard maps, set input for low maximum depth as 0.2 m, and vh, product of maximum velocity and maximum depth (m^2/s), as greater than or equal to zero. The program will then compute for the flood inundation and will generate shapefiles for the hazard and flow depth scenario.

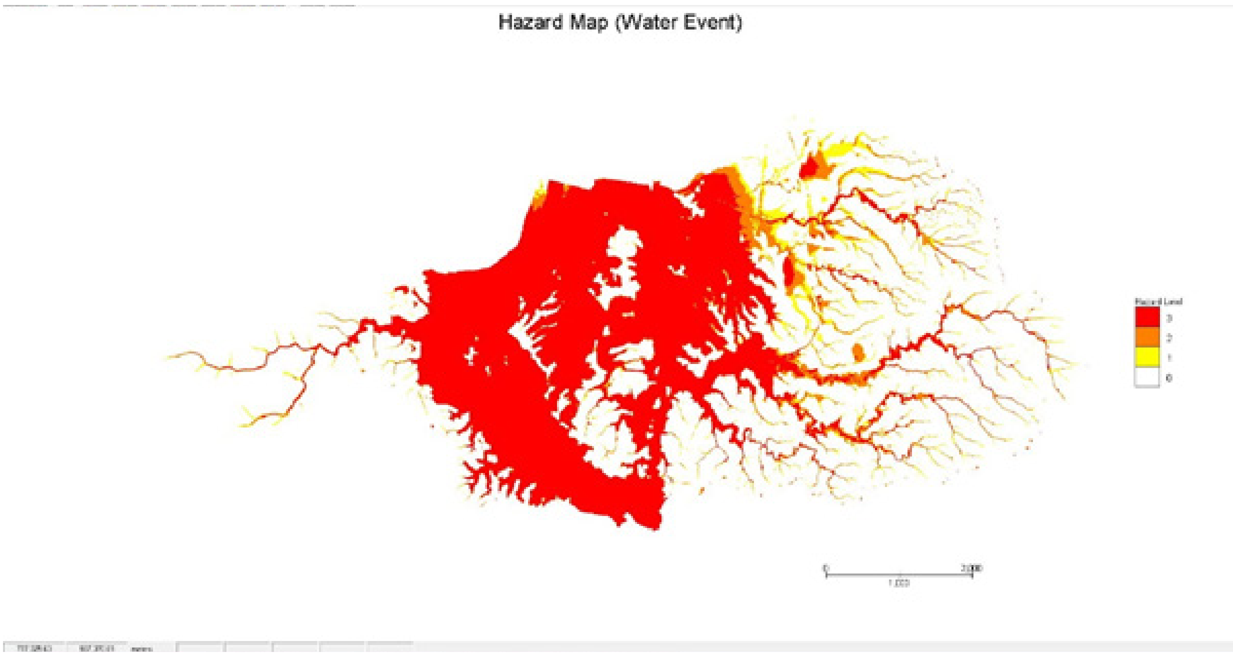


Figure 34. Agusan Floodplain Generated Hazard Maps using Flo-2D Mapper

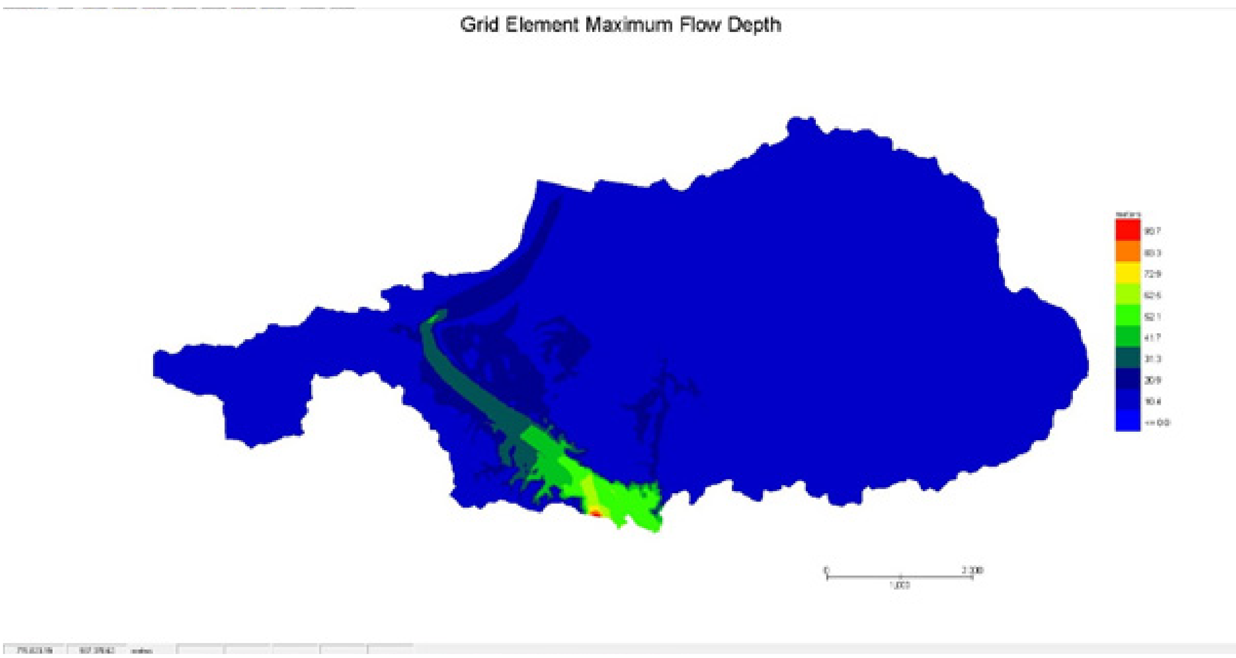
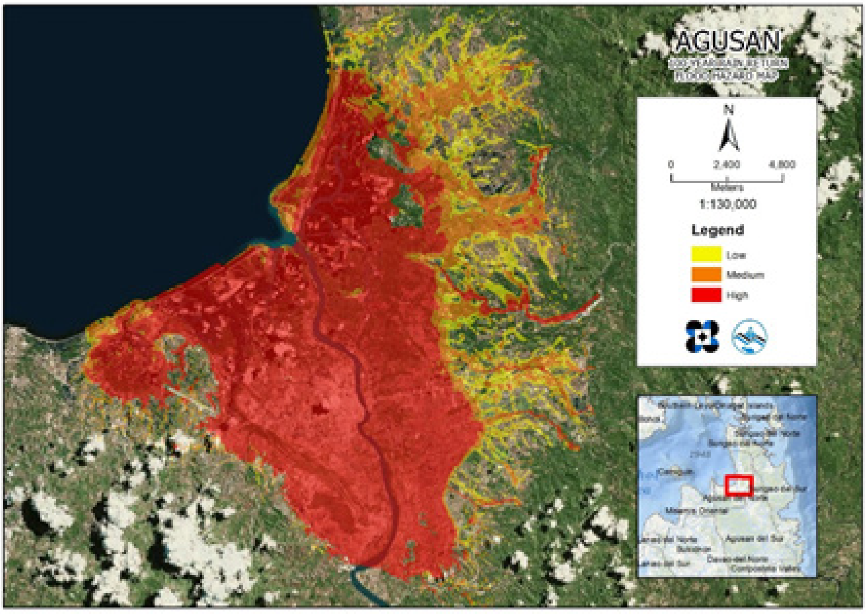


Figure 35. Agusan floodplain generated flow depth map using Flo-2D Mapper

3.4.4 Hazard Map and Flow Depth Map Creation

The final procedure in creating the maps is to prepare them with the aid of ArcMap. The generated shapefiles from FLO-2D Mapper Pro were opened in ArcMap. The basic layout of a hazard map is shown in Figure 27. The same map elements are also found in a flow depth map.



ELEMENTS:
1. River Basin Name
2. Hazard/Flow Depth Shapefile
3. Provincial Inset
4. Philippine Inset
5. Hi-Res image of the area
6. North Arrow
7. Scale Text and Bar

Figure 36. Basic Layout and Elements of the Hazard Maps

Results and Discussion

4.1 Efficiency of HEC-HMS Rainfall-Runoff Models calibrated based on field survey and gauges data

4.1.1 Las Nieves, Agusan del Norte HMS Calibration Results

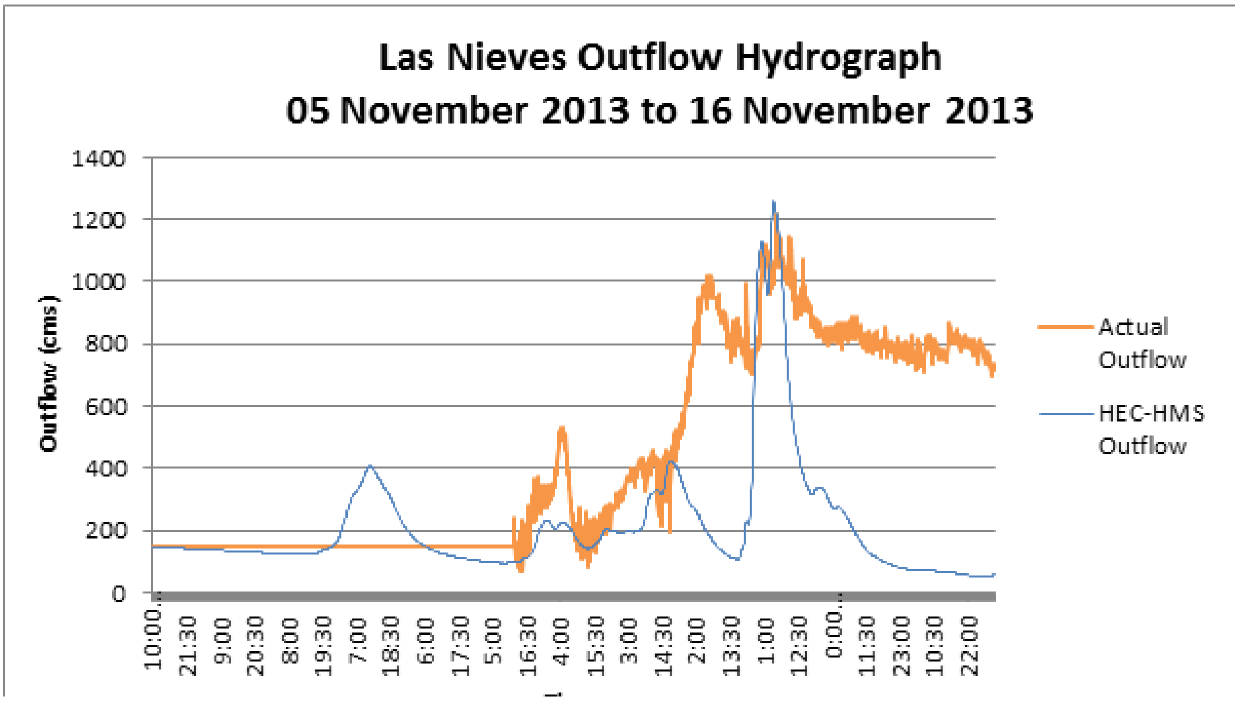


Figure 37. Las Nieves Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow

After calibrating the Agusan (Las Nieves) HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 37 shows the comparison between the two discharge data.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 334.32.

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 -0.99.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.027.

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 1.41.

4.1.2 Andanan Bridge –Bayugan City, Agusan del Sur HMS Calibration Results

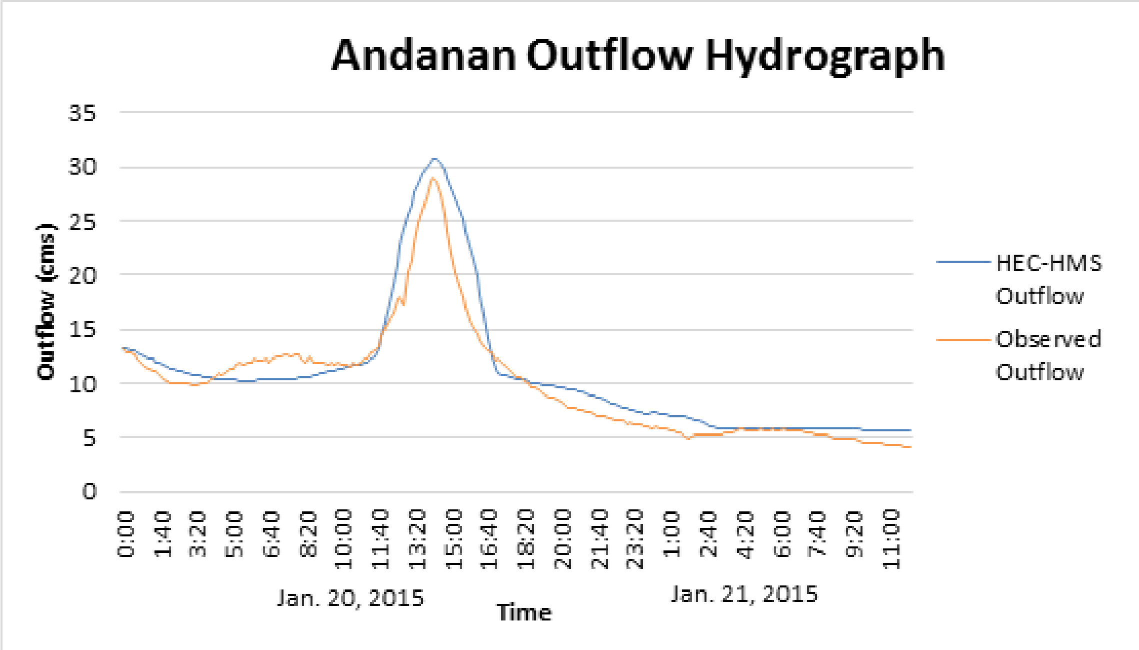


Figure 38. Andanan Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Andanan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 38 shows the comparison between the two discharge data.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 1.9.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9615.

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 0.87.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -11.29.

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 0.36.

4.1.3 DRRM River Base Leon Kilat – Butuan City, Agusan del Norte HMS model Calibration Results

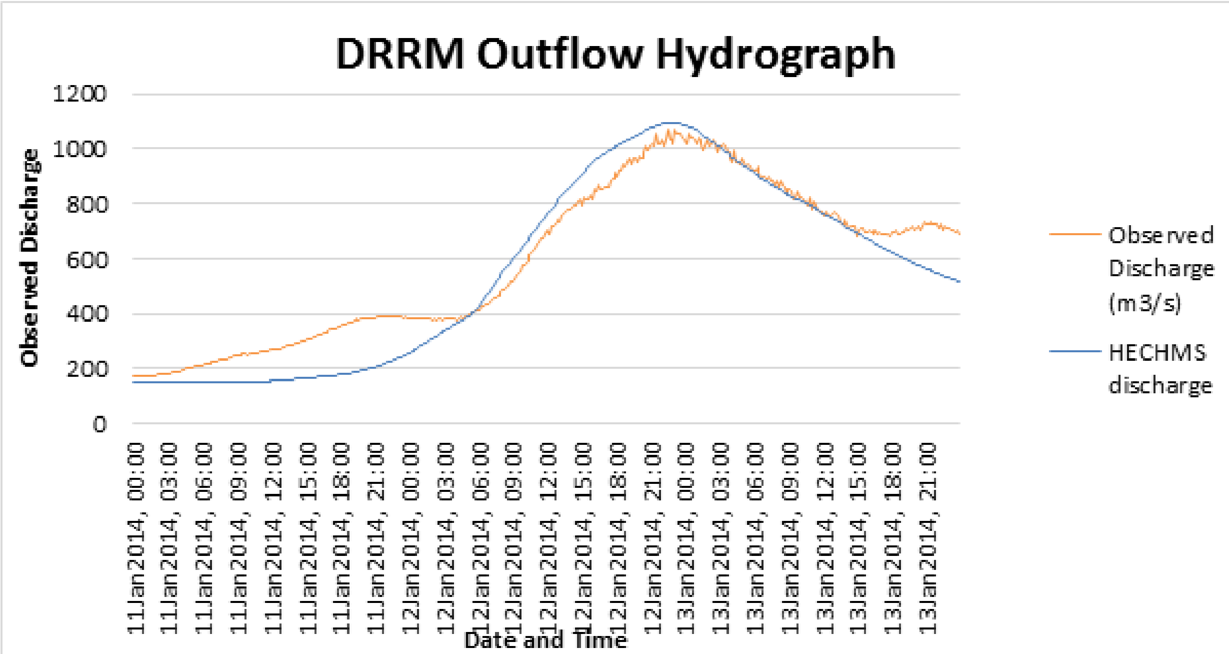


Figure 39. DRRM Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the DRRM HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 39 shows the comparison between the two discharge data.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 94.7.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9763.

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 0.89.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 6.54.

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 0.34.

4.1.4 Brgy. Poblacion, Compostela, Compostela Valley HMS Calibration Results

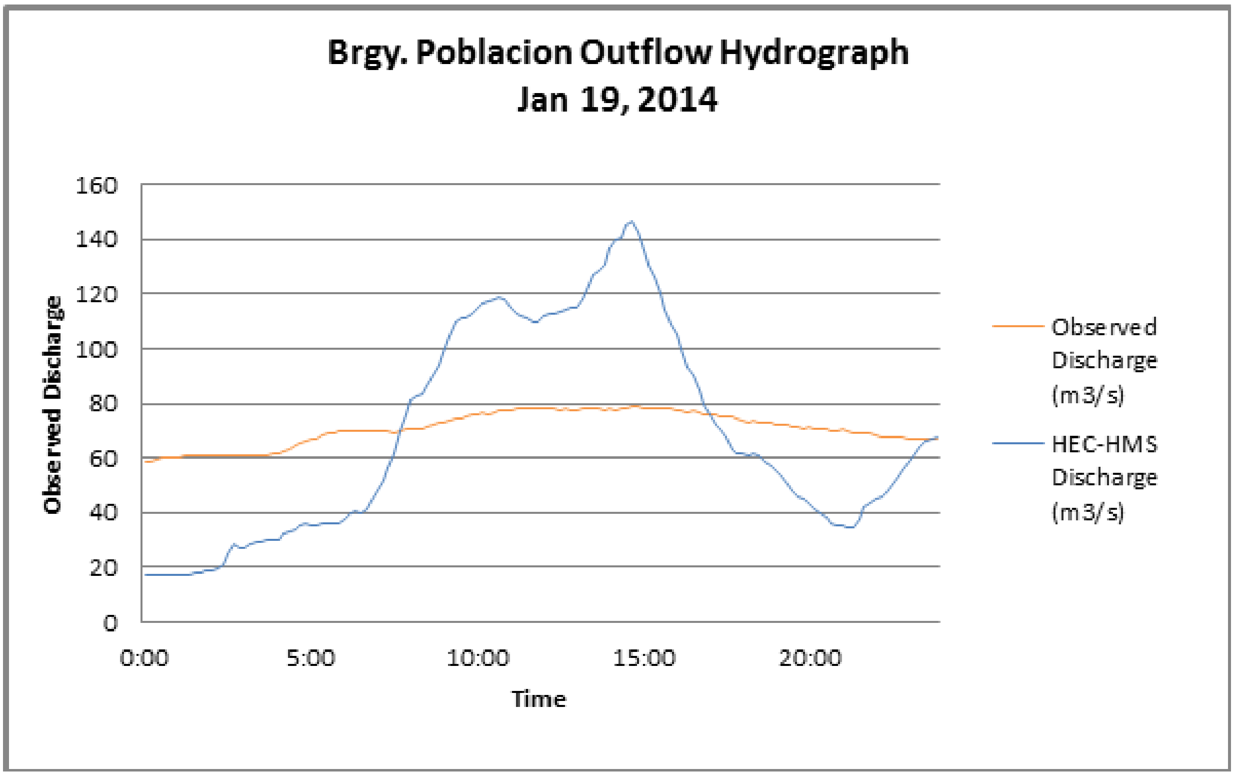


Figure 40. Poblacion Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Brgy. Poblacion HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 40 shows the comparison between the two discharge data.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 33.01.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 6.16452E-14.

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 0.25.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -3.19.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.86.

4.1.5 Wawa Bridge – Bayugan City, Agusan del Sur HMS model Calibration Results

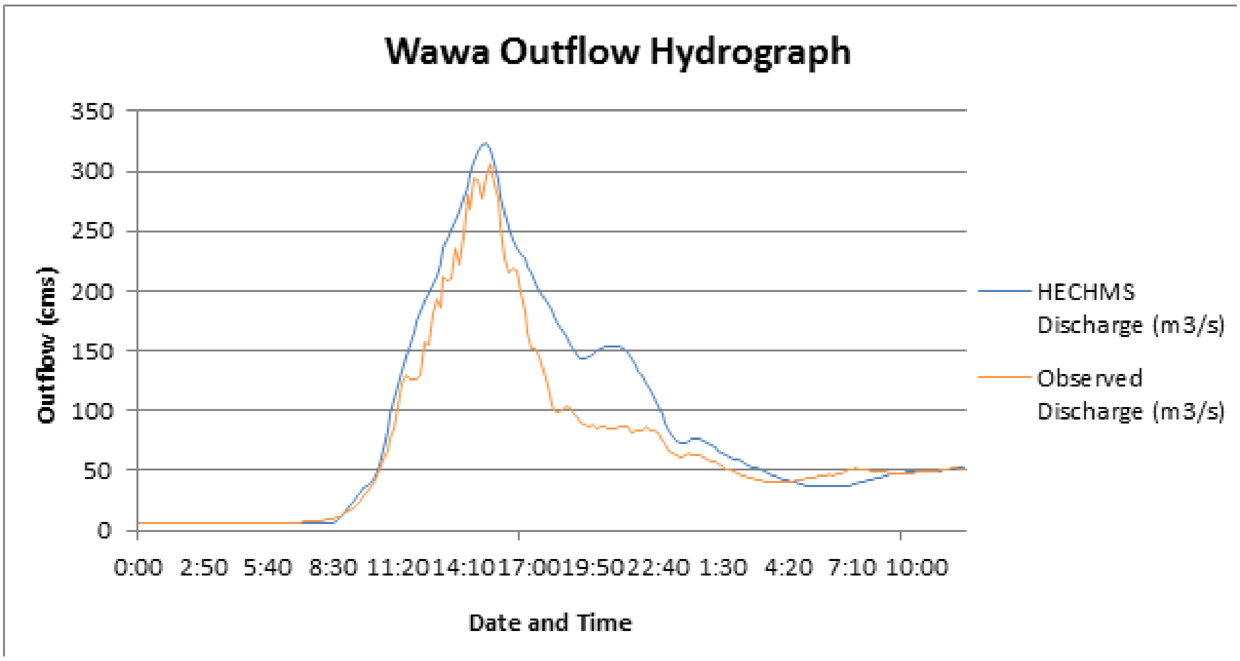


Figure 41. Wawa Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Wawa HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 41 shows the comparison between the two discharge data.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 27.4.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9732.

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 0.85.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -17.18.

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 0.38.

The calibrated models of the other discharge points are used in flood forecasting. DREAM project offers the LGUs and other disaster mitigation agencies a water level forecast tool, which can be found on the DREAM website.

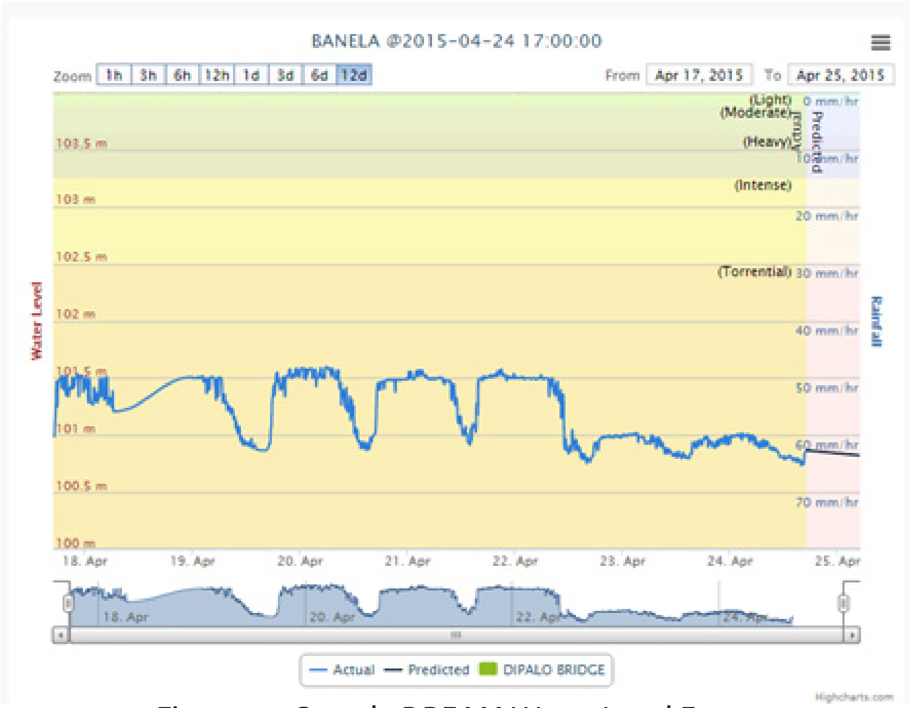


Figure 42. Sample DREAM Water Level Forecast

Given the predicted and real-time actual water level on specific AWLS, possible river flooding can be monitored and information can be disseminated to LGUs. This will help in the early evacuation of the probable affected communities. The calibrated models can also be used for flood inundation mapping.

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

4.2.1 Hydrograph using the Rainfall-Runoff Model

4.2.1.1 Las Nieves, Agusan del Norte

The outflow of Las Nieves using the Butuan 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 PAG-ASA data are shown in Figures 43-47. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 5784.4 cms. This occurs after 9 hours after the peak precipitation of 24.48 mm, as shown in Figure 43.

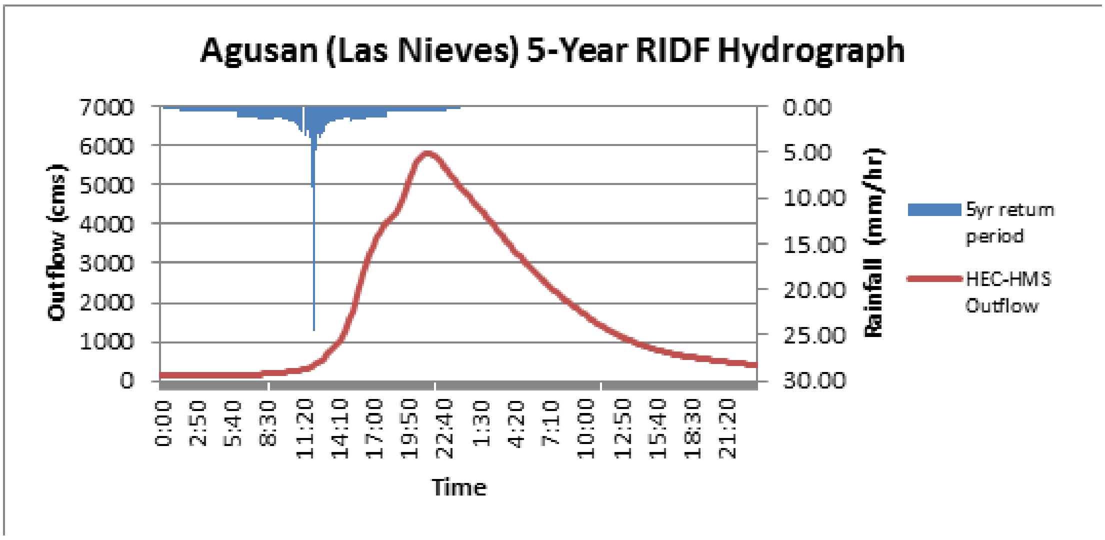


Figure 43. Las Nieves outflow hydrograph generated using the Butuan 5-Year RIDF inputted in HEC-HMS.

In the 10-year return period graph, the peak outflow is 8707 cms. This occurs after 8 hours and 40 minutes after the peak precipitation of 28.93 mm, as shown in Figure 44.

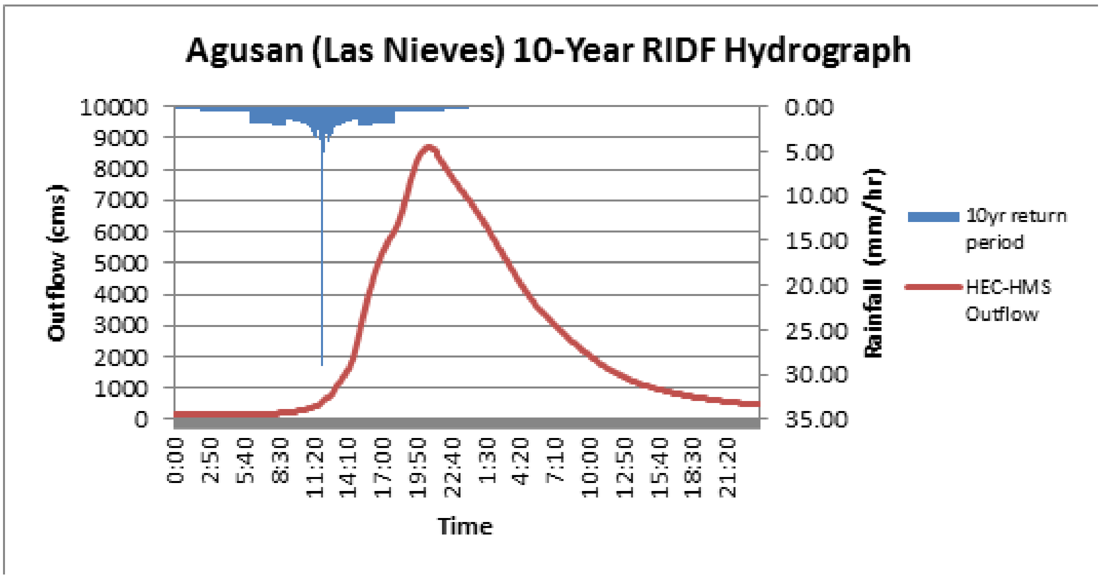


Figure 44. Las Nieves outflow hydrograph generated using the Butuan 10-Year RIDF inputted in HEC-HMS.

In the 25-year return period graph, the peak outflow is 12764.5 cms. This occurs after 8 hours and after the peak precipitation of 34.45 mm as shown in Figure 45.

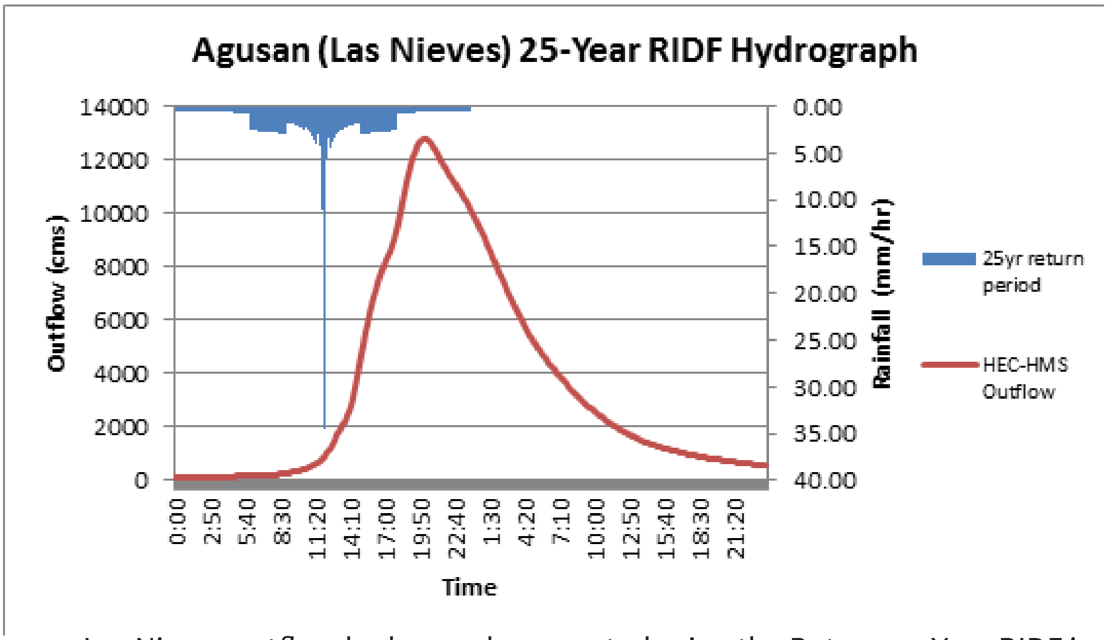


Figure 45. Las Nieves outflow hydrograph generated using the Butuan 25-Year RIDF inputted in HEC-HMS.

In the 50-year return period graph, the peak outflow is 16137.7 cms. This occurs after 7 hours and 50 minutes after the peak precipitation of 38.56 mm as shown in Figure 46.

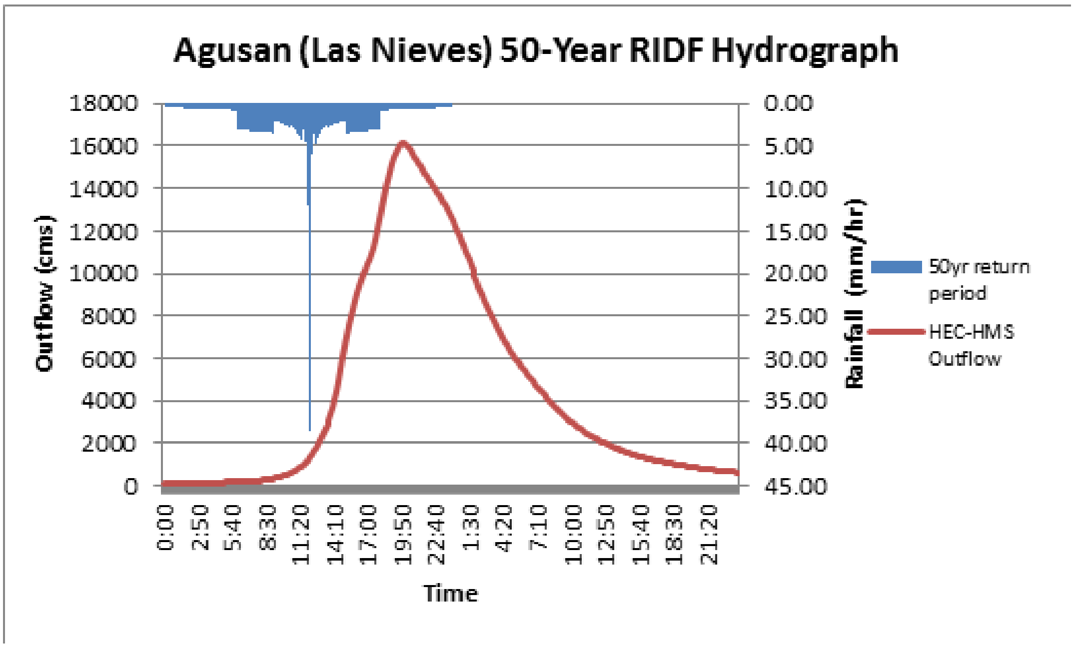


Figure 46. Las Nieves outflow hydrograph generated using the Butuan 50-Year RIDF inputted in HEC-HMS.

In the 100-year return period graph, the peak outflow is 19714.1 cms. This occurs after 7 hours and 40 minutes after the peak precipitation of 42.67mm, as shown in Figure 47.

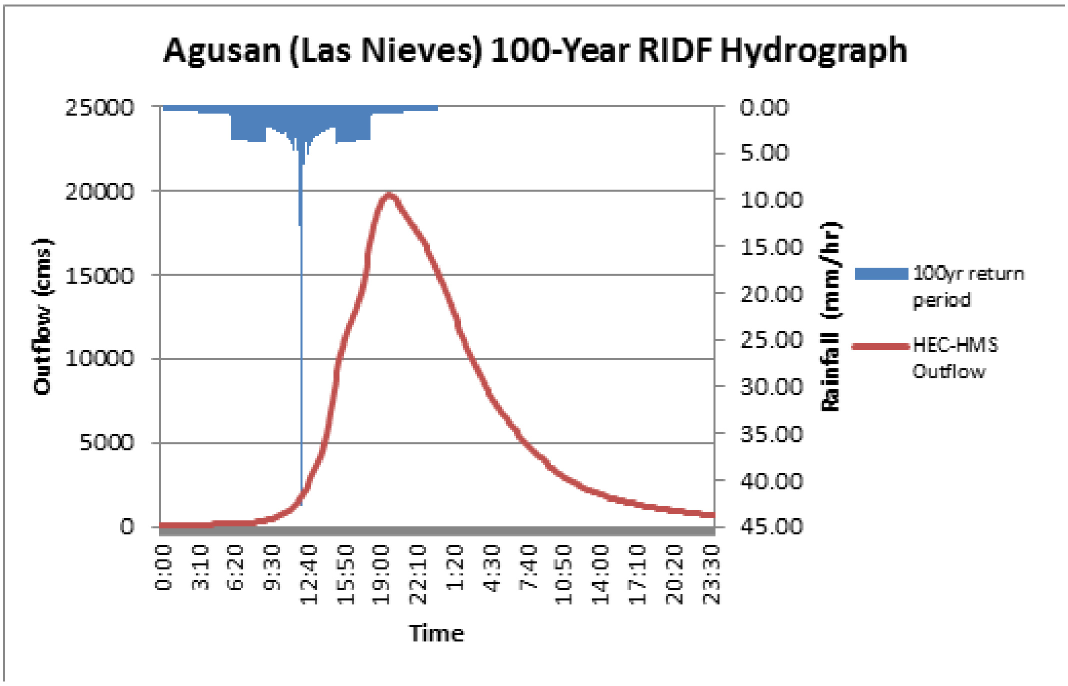


Figure 47. Las Nieves outflow hydrograph generated using the Butuan 100-Year RIDF inputted in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Las Nieves discharge using the Butuan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 2.

Table 2. Summary of Las Nieves discharge using Butuan Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	185.06	24.48	5784.4	9 hours
10-Year	225.22	28.93	8707	8 hours and 40 minutes
25-Year	275.97	34.45	12764.5	8 hours
50-Year	313.55	38.56	16137.7	7 hours and 50 minutes
100-Year	350.94	42.67	19714.1	7 hours and 40 minutes

4.2.1.2 Andanan Bridge –Bayugan City, Agusan del Sur

The outflow of Andanan using the Butuan Rainfai 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 PAG-ASA data are shown in Figures 48-52. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 64.9 cms. This occurs after 3 hours and 10 minutes after the peak precipitation of 23.9 mm, as shown in Figure 48.

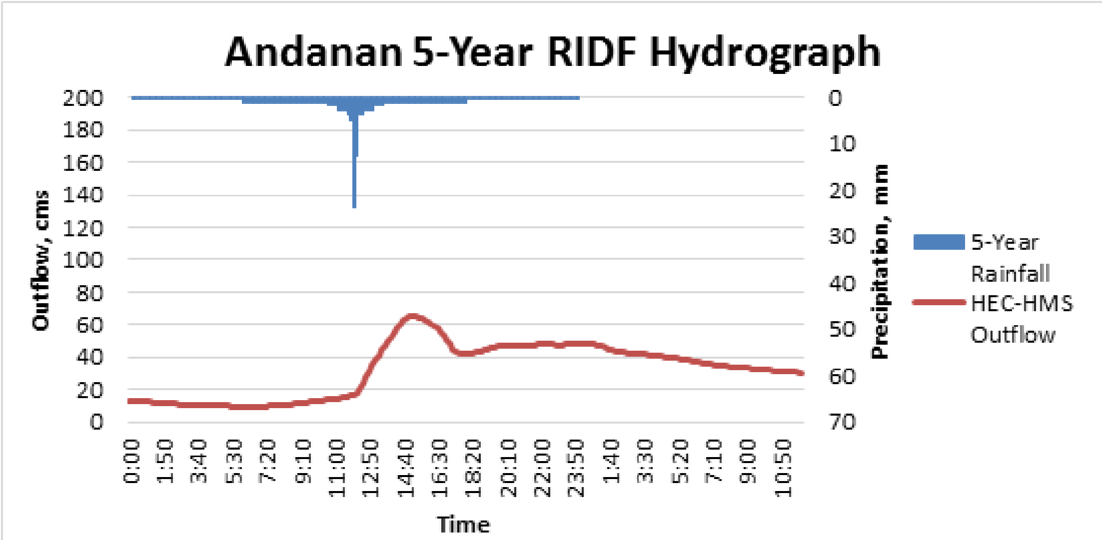


Figure 48. Andanan outflow hydrograph generated using the Butuan 5-Year RIDF inputted in HEC-HMS.

In the 10-year return period graph, the peak outflow is 81 cms. This occurs after 3 hours and 10 minutes after the peak precipitation of 27.6 mm, as shown in Figure 49.

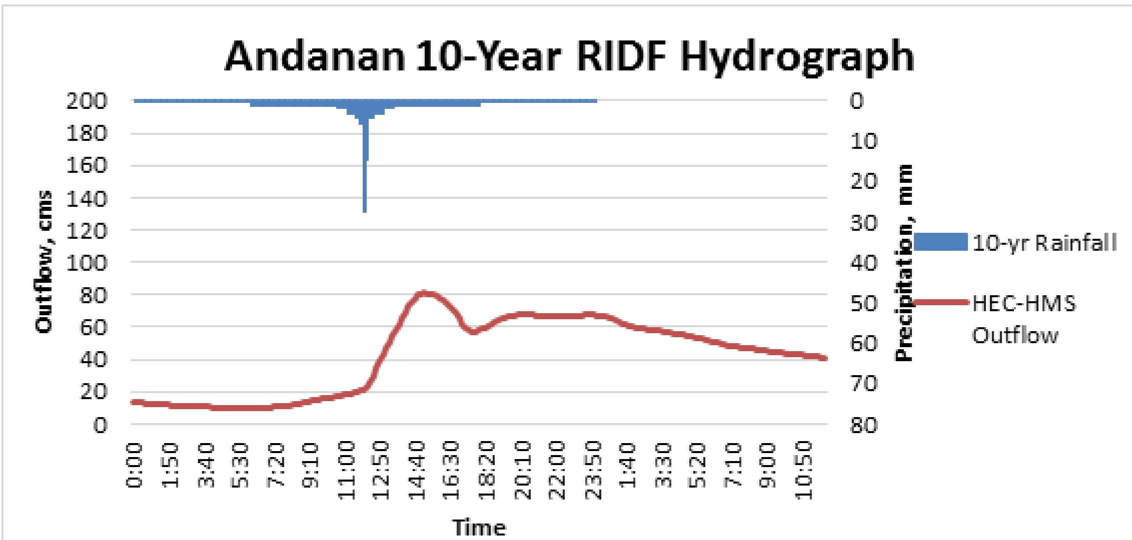


Figure 49. Andanan outflow hydrograph generated using the Butuan 10-Year RIDF inputted in HEC-HMS.

In the 25-year return period graph, the peak outflow is 103.2 cms. This occurs after 3 hours and 20 minutes after the peak precipitation of 32.3 mm, as shown in Figure 50.

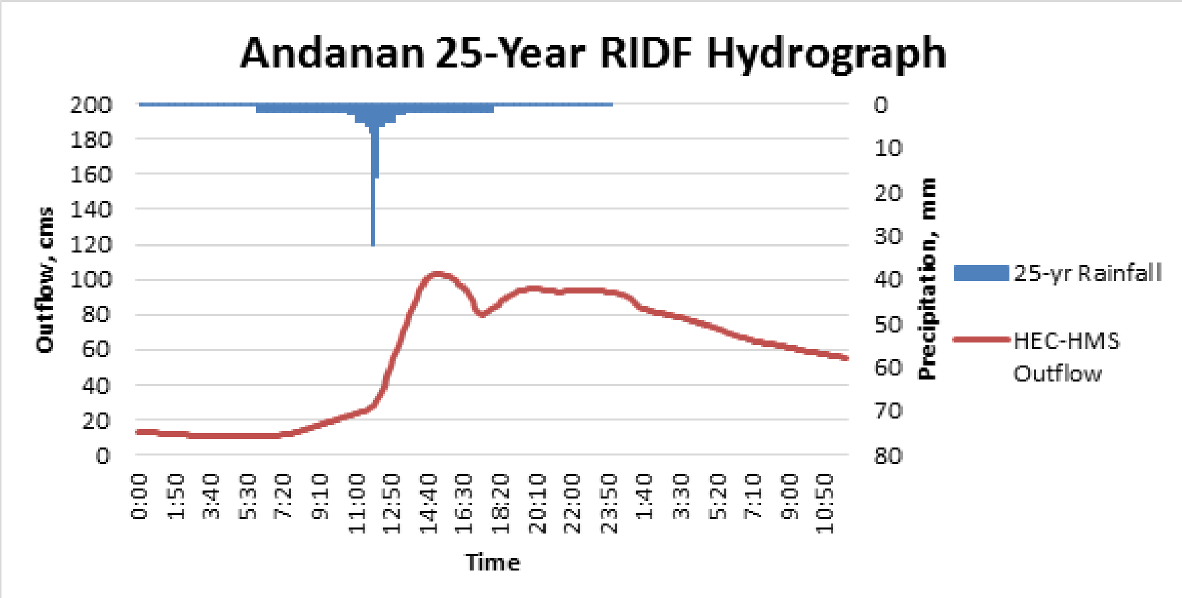


Figure 50. Andanan outflow hydrograph generated using the Butuan 25-Year RIDF inputted in HEC-HMS.

In the 50-year return period graph, the peak outflow is 120.8 cms. This occurs after 3 hours and 20 minutes after the peak precipitation of 35.8 mm, as shown in Figure 51.

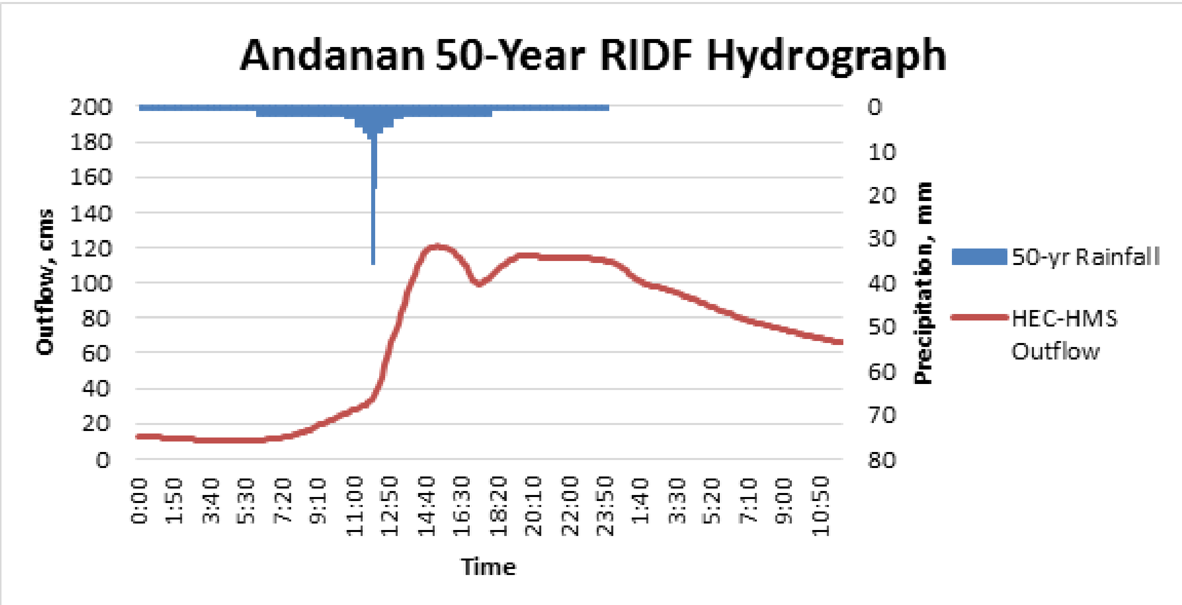


Figure 51. Andanan outflow hydrograph generated using the Butuan 50-Year RIDF inputted in HEC-HMS.

In the 100-year return period graph . Outflow hydrograph generated using the Butuan100-Year RIDF inputted in HEC-HMS.the peak outflow is 138.9 cms. This occurs after 3 hours and 20 minutes after the peak precipitation of 39.2 mm, as shown in Figure 52.

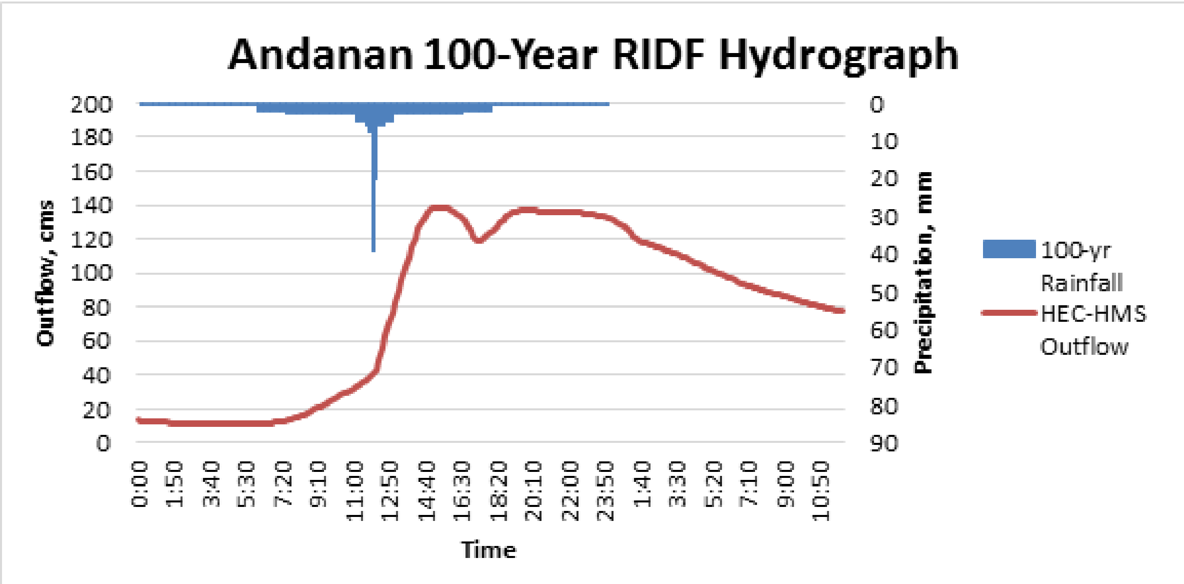


Figure 52. Andanan outflow hydrograph generated using the Butuan 100-Year RIDF inputted in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Andanan discharge using the Butuan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 3.

Table 3. Summary of Andanan discharge using Butuan Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	175.2	23.9	64.9	3 hours and 10 minutes
10-Year	207.5	27.6	81	3 hours and 10 minutes
25-Year	248.3	32.3	103.2	3 hours and 20 minutes
50-Year	278.6	35.8	120.8	3 hours and 20 minutes
100-Year	308.6	39.2	138.9	3 hours and 20 minutes

4.2.1.3 DRRM River Base Leon Kilat – Butuan City, Agusan del Norte

The outflow of DRRM using the Butuan 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 PAG-ASA dataare shown in Figures 53-57. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 4499.3 cms. This occurs after 23 hours and 30 minutes after the peak precipitation of 23.9 mm, as shown in Figure 53.

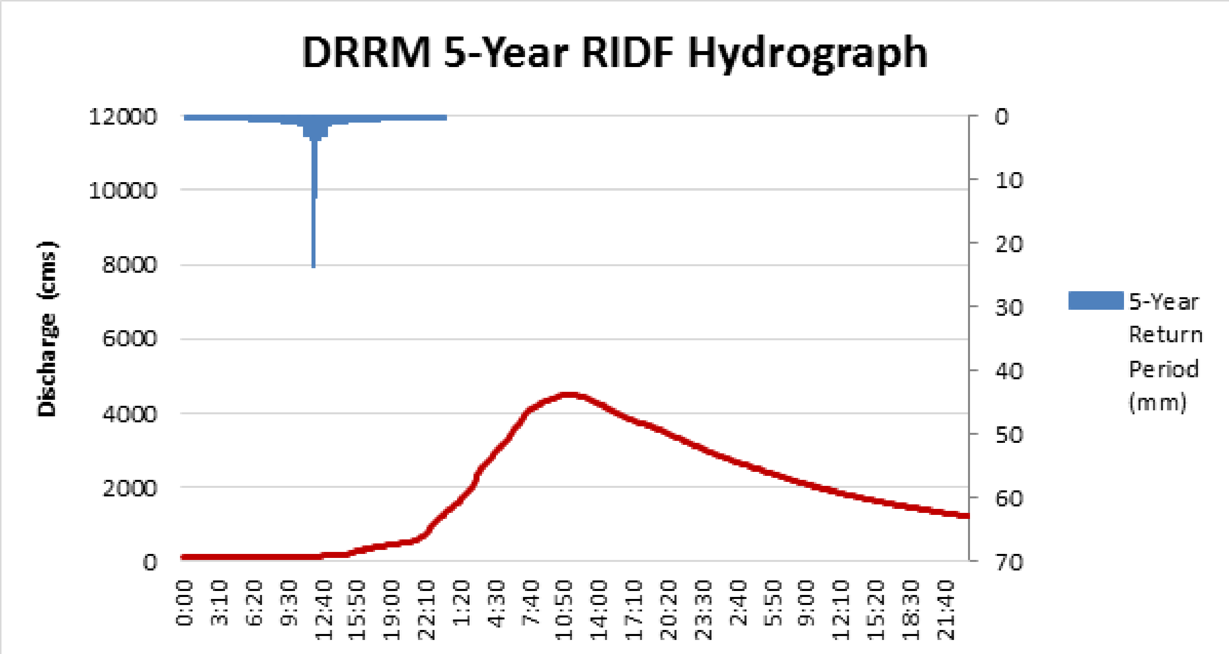


Figure 53. DRRM Outflow hydrograph generated using the Butuan 5-Year RIDF inputted in HEC-HMS.

In the 10-year return period graph, the peak outflow is 6361.6 cms. This occurs after 21 hours and 10 minutes after the peak precipitation of 27.6 mm, as shown in Figure 54.

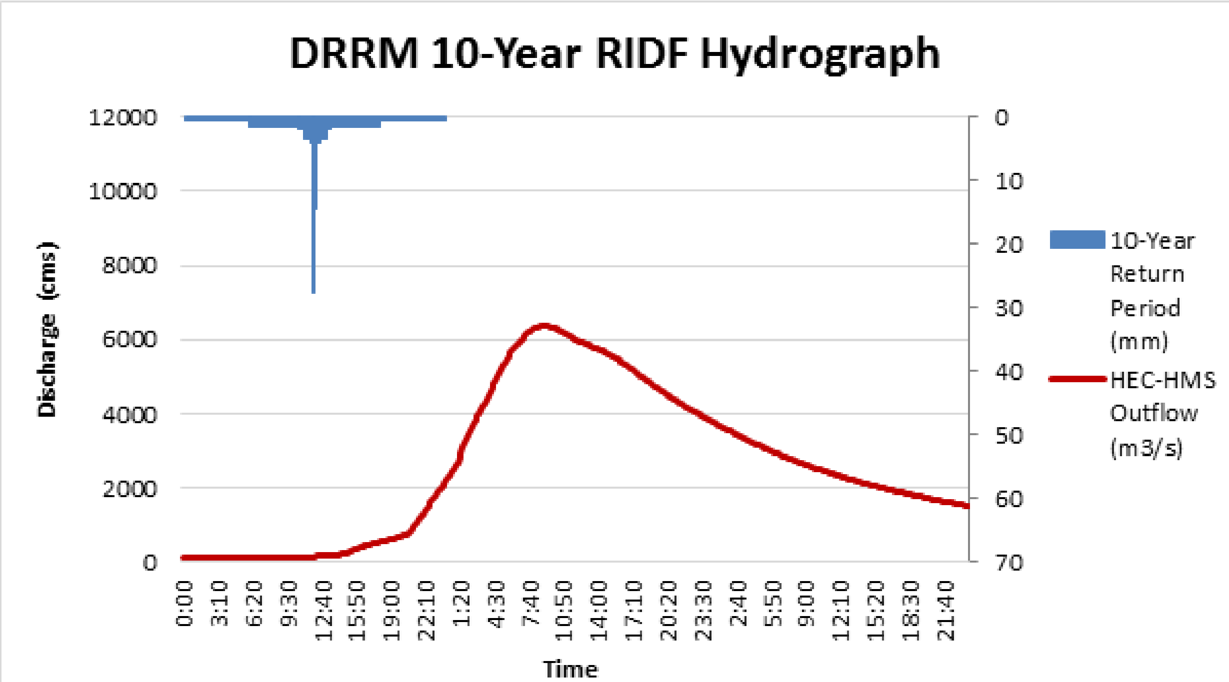


Figure 54. DRRM Outflow hydrograph generated using the Butuan 10-Year RIDF inputted in HEC-HMS.

In the 25-year return period graph, the peak outflow is 8936.0 cms. This occurs after 19 hours and 10 minutes after the peak precipitation of 32.3 mm, as shown in Figure 55.

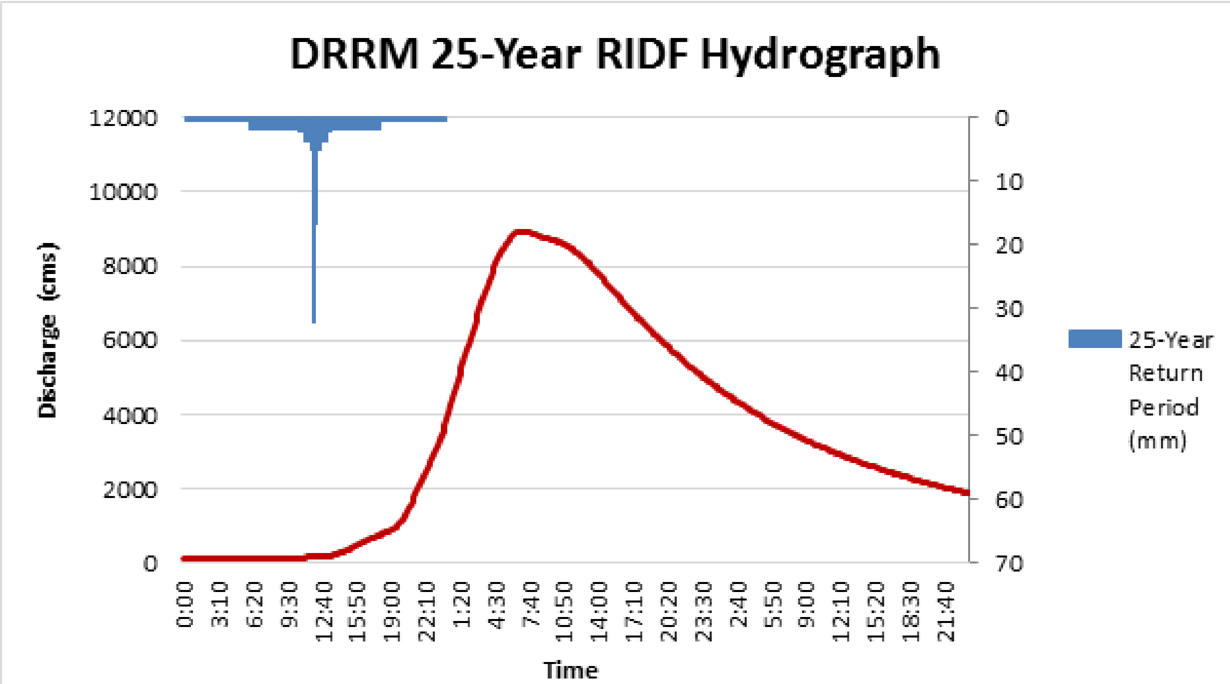


Figure 55. DRRM Outflow hydrograph generated using the Butuan 25-Year RIDF inputted in HEC-HMS.

In the 50-year return period graph, the peak outflow is 10989.5 cms. This occurs after 18 hours and 20 minutes after the peak precipitation of 35.8 mm, as shown in Figure 56.

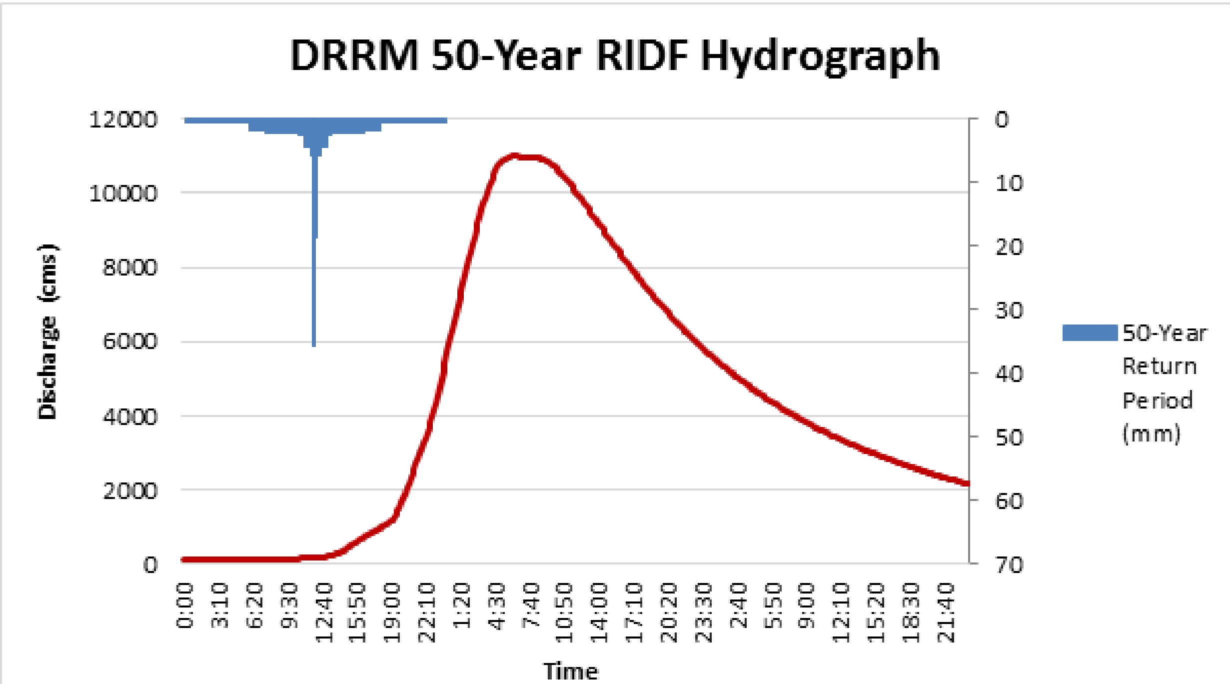


Figure 56. DRRM Outflow hydrograph generated using the Butuan 50-Year RIDF inputted in HEC-HMS.

In the 100-year return period graph, the peak outflow is 13381.3 cms. This occurs after 19 hours and 10 minutes after the peak precipitation of 39.2 mm, as shown in Figure 57.

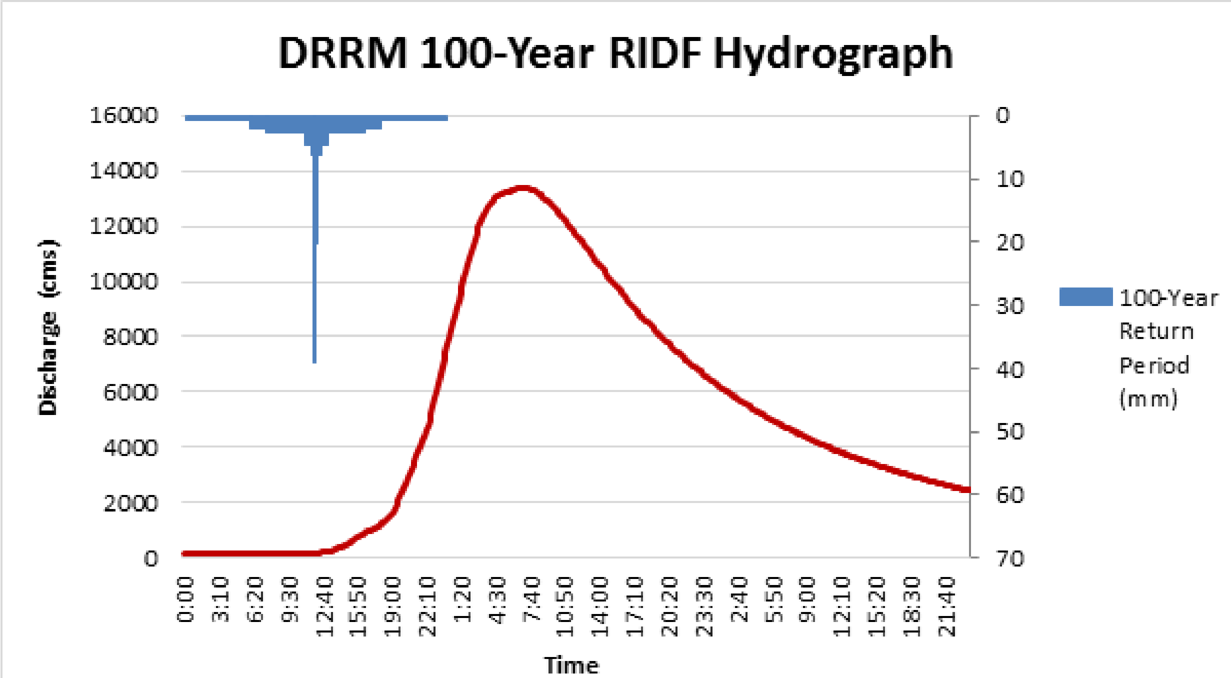


Figure 57. DRRM Outflow hydrograph generated using the Butuan 100-Year RIDF inputted in HEC-HMS.

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

Table 4. Summary of Las Nieves discharge using Butuan Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	175.2	23.9	4499.3	23hours, 30 minutes
10-Year	207.5	27.6	6361.6	21 hours, 10 minutes
25-Year	248.3	32.3	8936.0	19 hours, 10 minutes
50-Year	278.6	35.8	10989.5	18 hours, 20 minutes
100-Year	308.6	39.2	13381.3	19 hours, 10 minutes

4.2.1.4 Brgy Poblacion, Compostela, Compostela Valley

The outflow of Brgy. Poblacion using the Hinatuan 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 PAG-ASA data are shown in Figures 58-62. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 3368.1 cms. This occurs after 50 minutes after the peak precipitation of 31.9 mm, as shown in Figure 58.

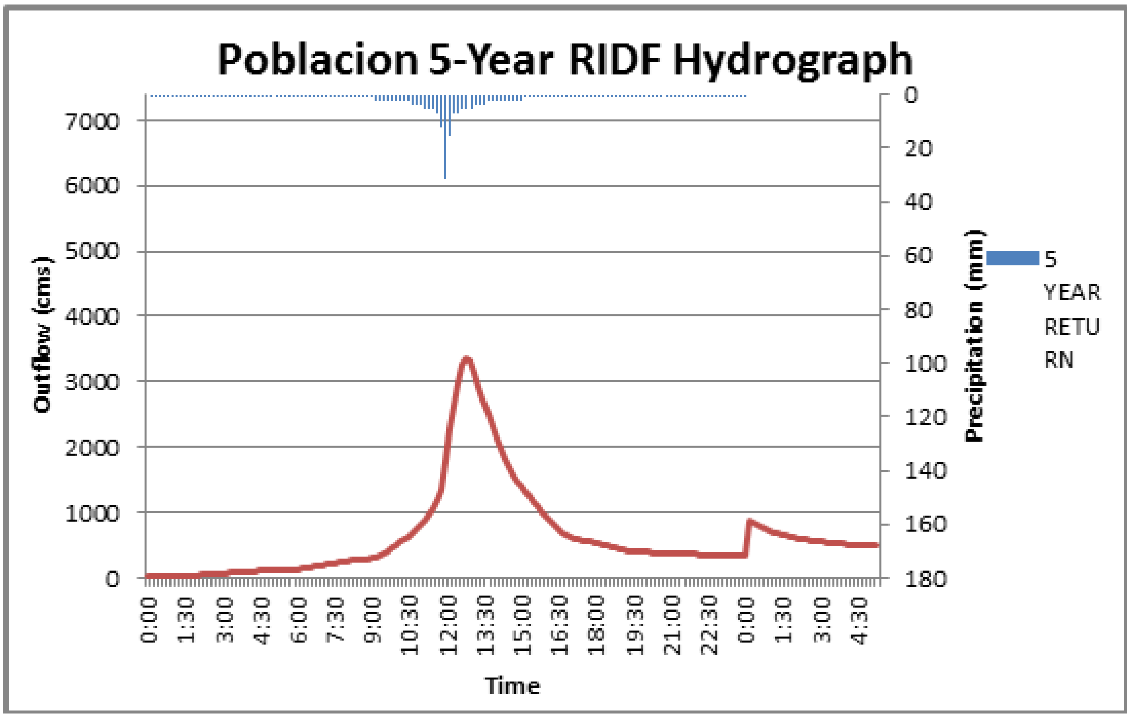


Figure 58. Brgy. Poblacion outflow hydrograph generated using the Hinatuan 5-Year RIDF inputted in HEC-HMS.

In the 10-year return period graph, the peak outflow is 4056.4 cms. This occurs after 50 minutes after the peak precipitation of 36.9 mm, as shown in Figure 59.

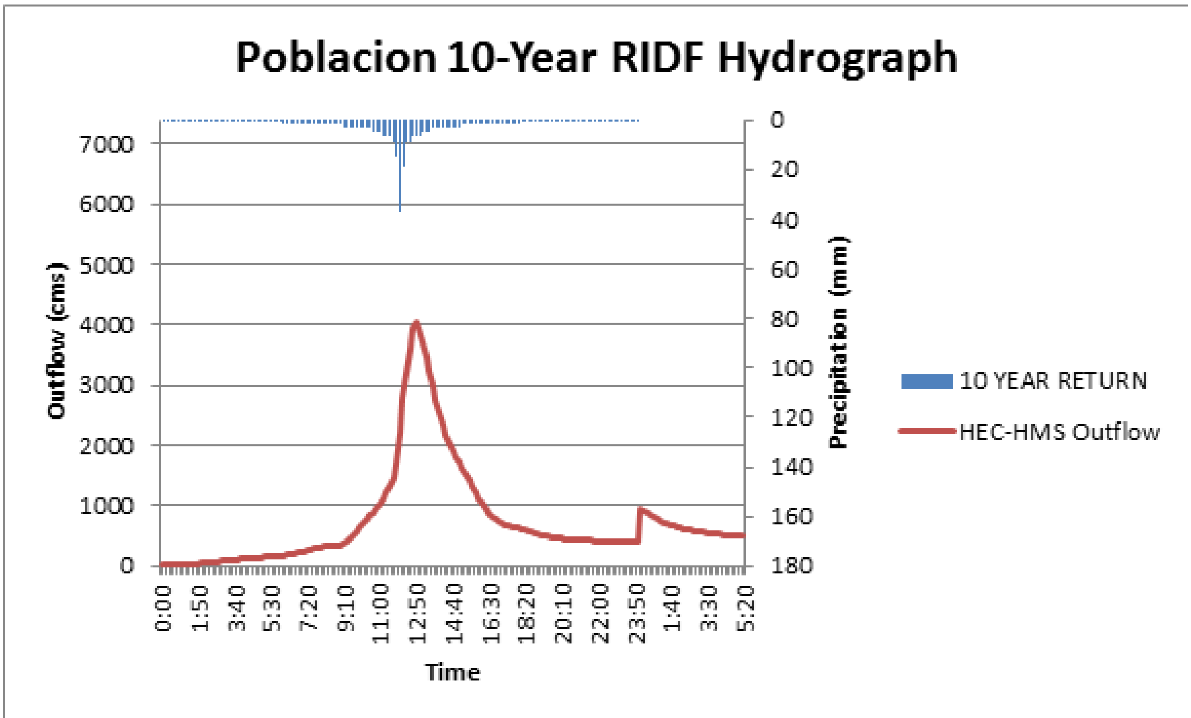


Figure 59. Brgy. Poblacion outflow hydrograph generated using the Hinatuan 10-Year RIDF inputted in HEC-HMS.

In the 25-year return period graph, the peak outflow is 4900.6 cms. This occurs after 50 minutes after the peak precipitation of 43.3 mm, as shown in Figure 60.

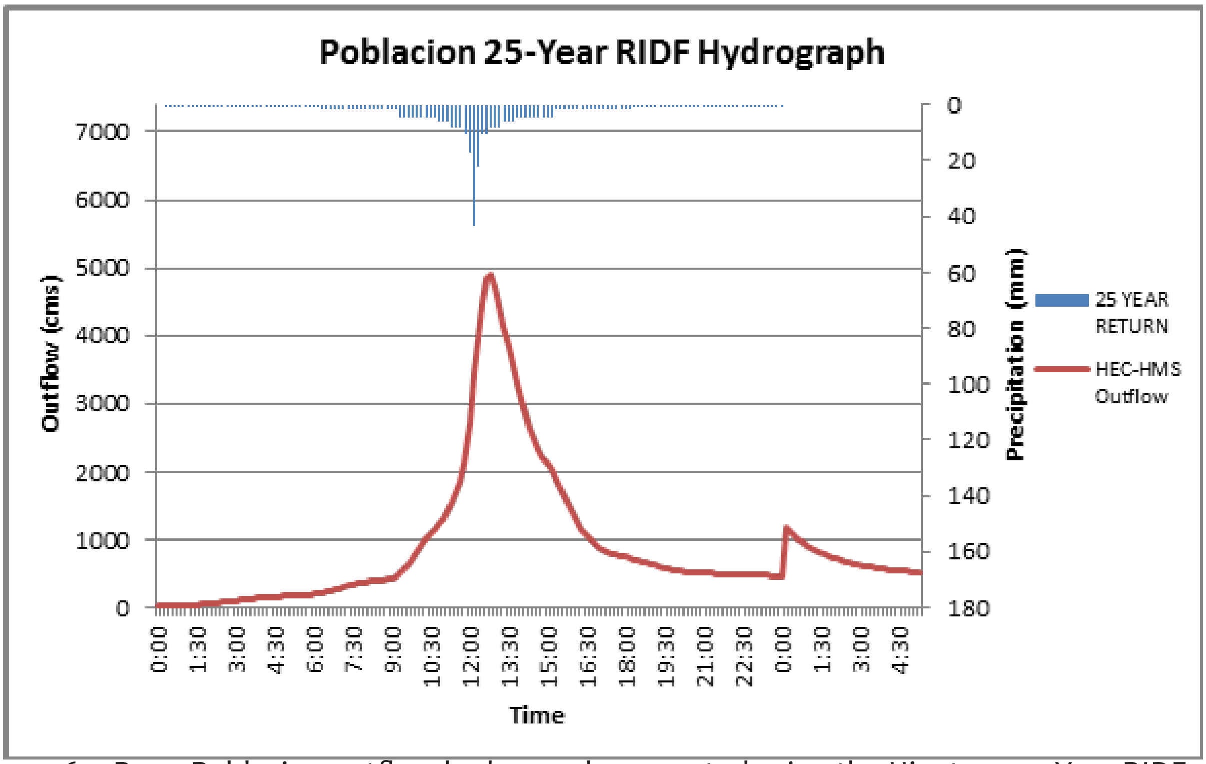


Figure 60. Brgy. Poblacion outflow hydrograph generated using the Hinatuan 25-Year RIDF inputted in HEC-HMS.

In the 50-year return period graph, the peak outflow is 5530.4 cms. This occurs after50 minutes after the peak precipitation of 48.1 mm, as shown in Figure 61.

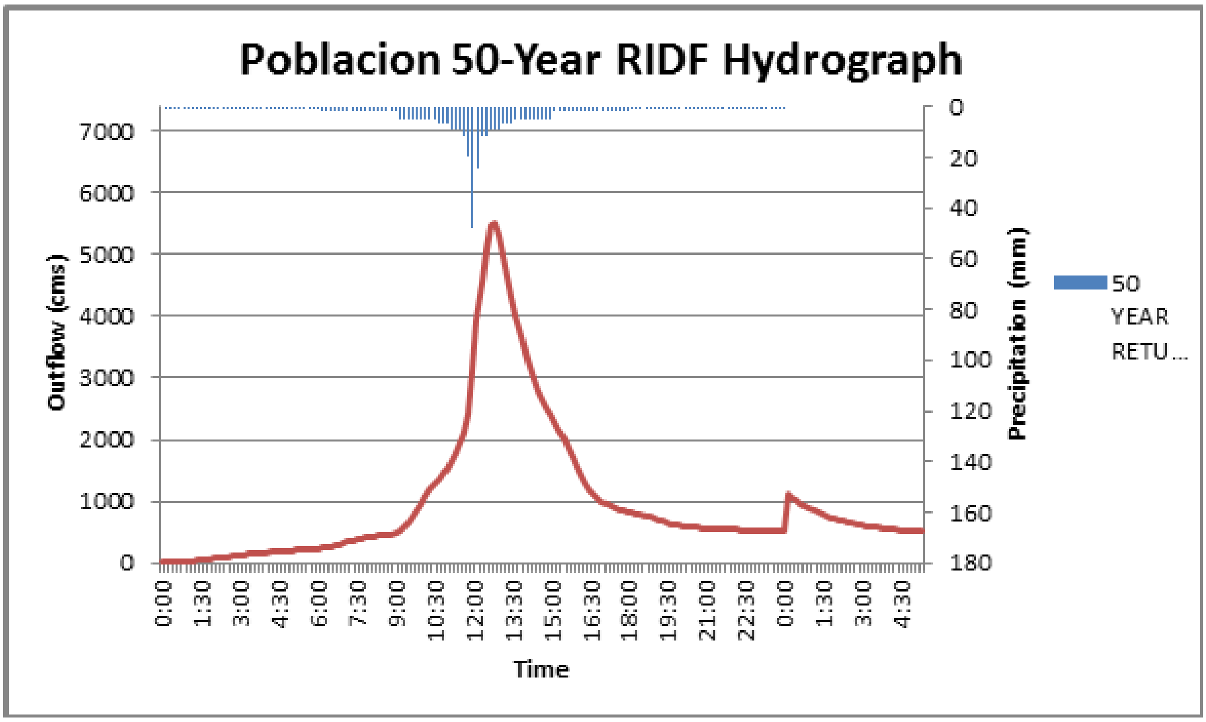


Figure 61. Brgy. Poblacion outflow hydrograph generated using the Hinatuan 50-Year RIDF inputted in HEC-HMS.

In the 100-year return period graph, the peak outflow is 6150.6 cms. This occurs after 50 minutes after the peak precipitation of 52.8 mm, as shown in Figure 62.

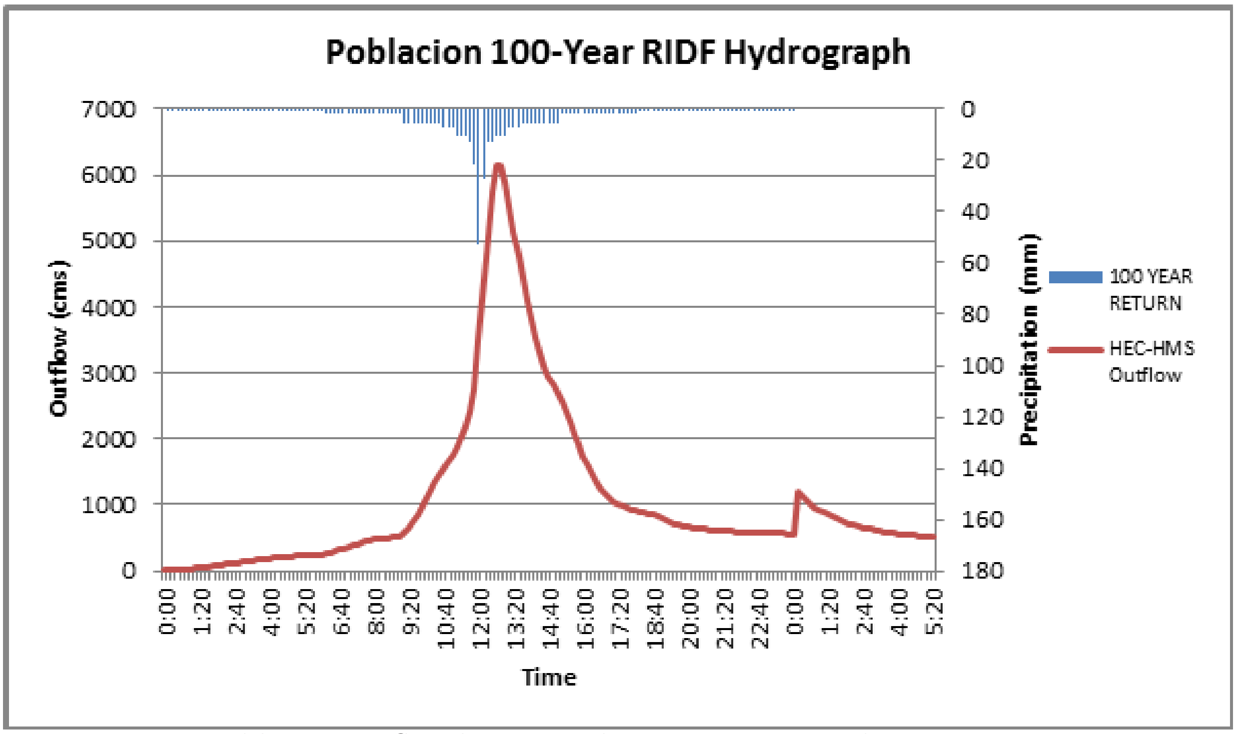


Figure 62. Brgy. Poblacion outflow hydrograph generated using the Hinatuan 100-Year RIDF inputted in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Poblacion discharge using the Hinatuan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 5.

Table 5. Summary of Poblacion discharge using Hinatuan Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	276.5	31.9	3368.1	50 minutes
10-Year	326.5	36.9	4056.4	50 minutes
25-Year	389.7	43.3	4900.6	50 minutes
50-Year	436.6	48.1	5530.4	50 minutes
100-Year	483.1	52.8	6150.6	50 minutes

4.2.1.5 Wawa Bridge – Bayugan City, Agusan del Sur

The outflow of Wawa using the Butuan 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 PAGASA data are shown in Figures 63-67. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

In the 5-year return period graph, the peak outflow is 540.6 cms. This occurs after 1 hour and 40 minutes after the peak precipitation of 23.9 mm, as shown in Figure 63.

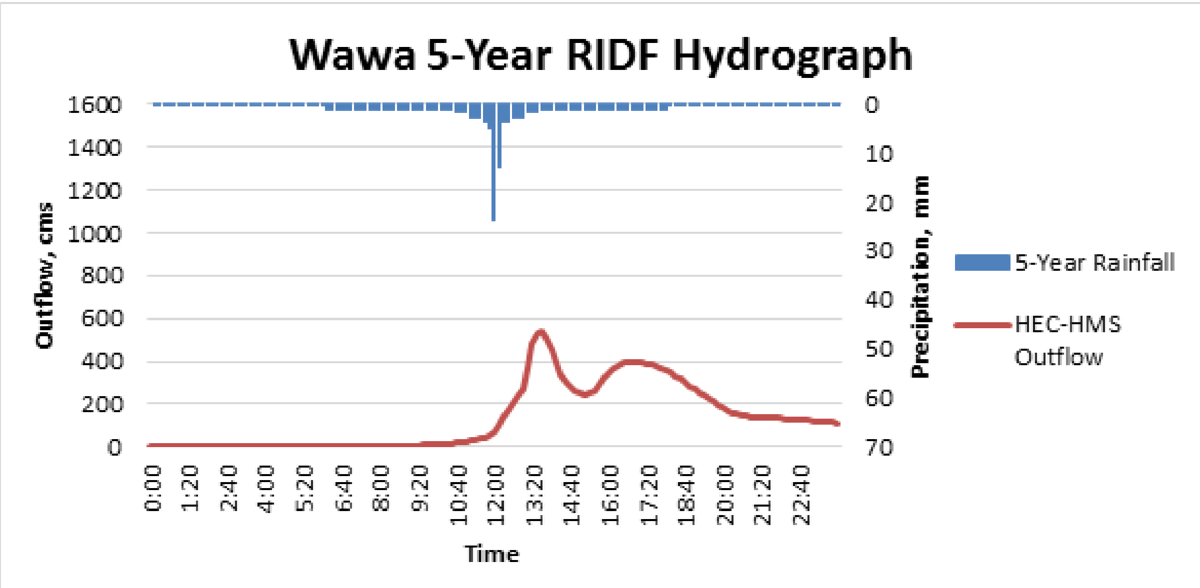


Figure 63. Wawa Bridge outflow hydrograph generated using the Butuan 5-Year RIDF inputted in HEC-HMS.

In the 10-year return period graph, the peak outflow is 748.3 cms. This occurs after 1 hour and 30 minutes after the peak precipitation of 27.6mm, as shown in Figure 64.

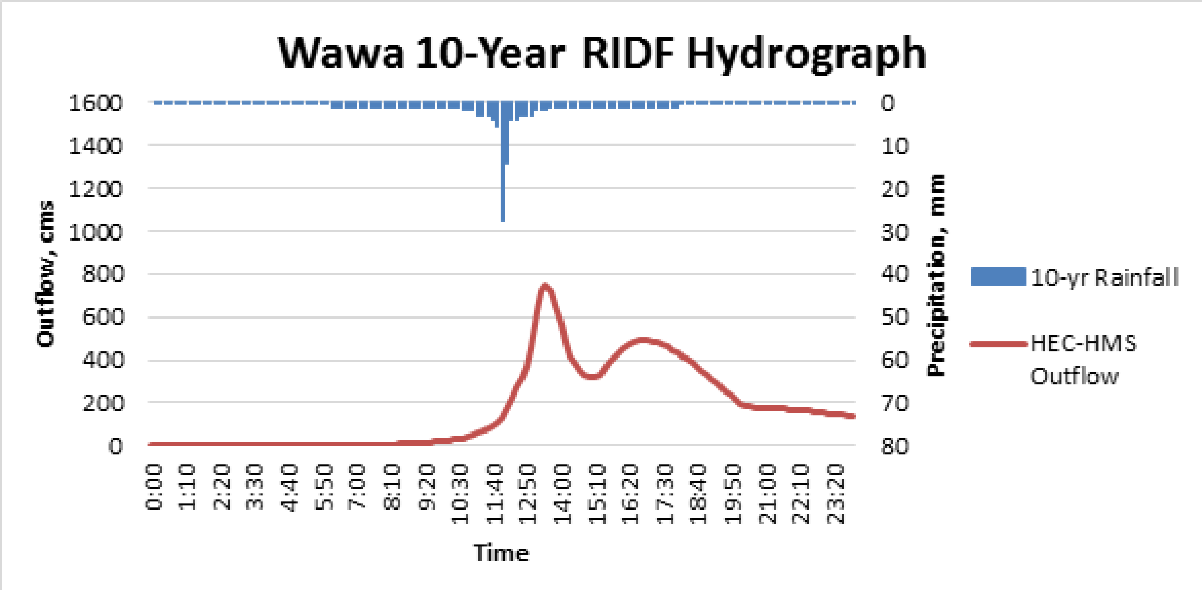


Figure 64. Wawa Bridge outflow hydrograph generated using the Butuan 10-Year RIDF inputted in HEC-HMS.

In the 25-year return period graph, the peak outflow is 1002.6 cms. This occurs after 1 hour and 30 minutes after the peak precipitation of 32.3 mm, as shown in Figure 65.

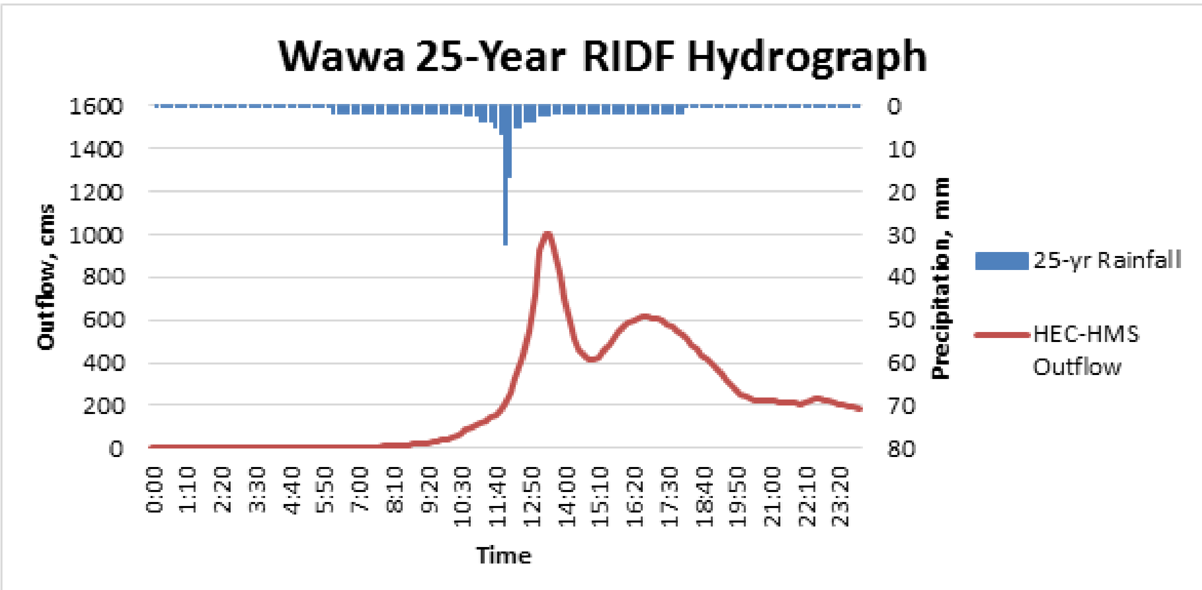


Figure 65. Wawa Bridge outflow hydrograph generated using the Butuan 25-Year RIDF inputted in HEC-HMS.

In the 50-year return period graph, the peak outflow is 1204.7 cms. This occurs after 1 hour and 20 minutes after the peak precipitation of 35.8 mm, as shown in Figure 66.

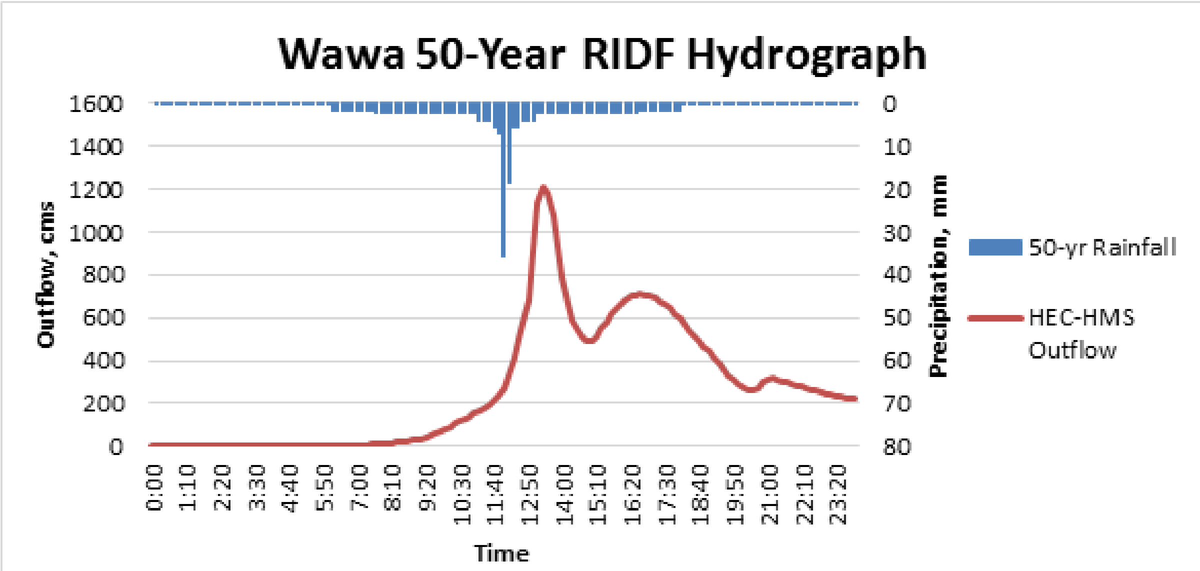


Figure 66. Wawa Bridge outflow hydrograph generated using the Butuan 50-Year RIDF inputted in HEC-HMS.

In the 100-year return period graph, the peak outflow is 1411 cms. This occurs after 1 hours and 20 minutes after the peak precipitation of 39.2 mm, as shown in Figure 67.

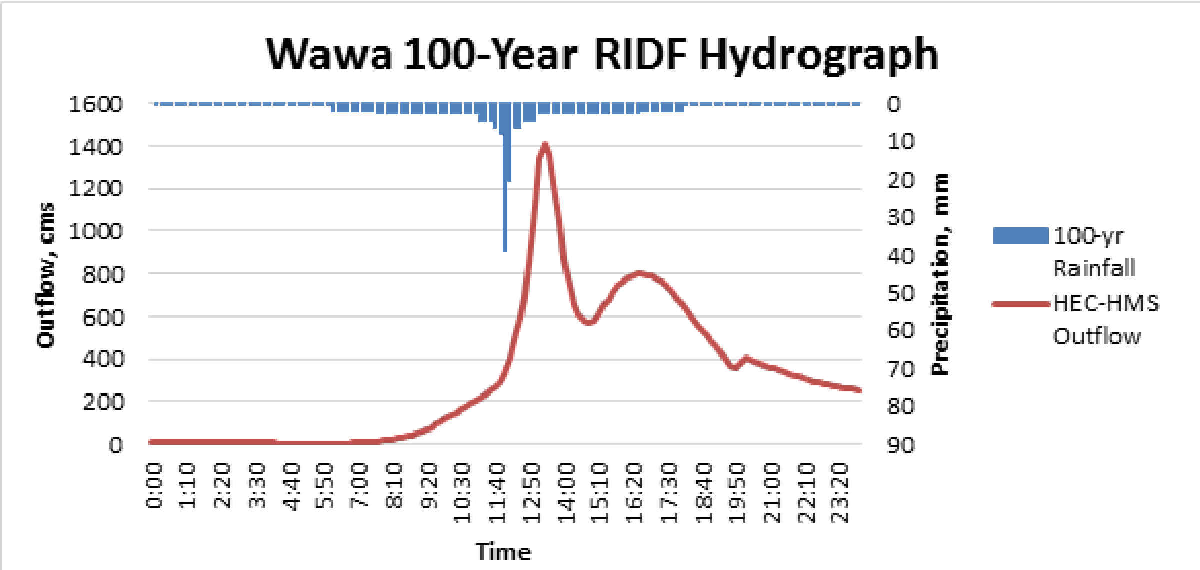


Figure 67. Wawa Bridge outflow hydrograph generated using the Butuan 100-Year RIDF inputted in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of Wawa discharge using the Butuan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 6.

Table 6. Summary of Wawa Bridge discharge using Butuan Station Rainfaill Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	175.2	23.9	540.6	1 hour, 40 minutes
10-Year	207.5	27.6	748.3	1 hour, 30 minutes
25-Year	248.3	32.3	1002.6	1 hour, 30 minutes
50-Year	278.6	35.8	1204.7	1 hour, 20 minutes
100-Year	308.6	39.2	1411	1 hour, 20 minutes

Results and Discussion

4.2.2 Discharge Data using Dr. Horritt's Recommended Hydrological Method

The river discharge values using Dr. Horritt's recommended hydrological method are shown in Figure 35 and the peak discharge values are summarized in Table 3.

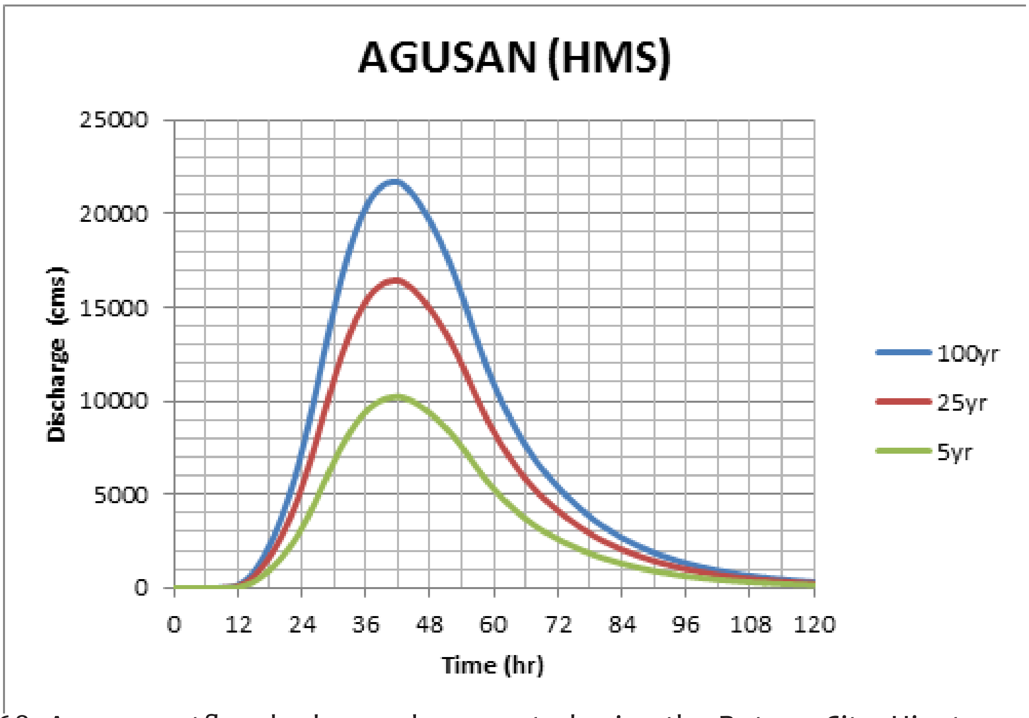


Figure 68. Agusan outflow hydrograph generated using the Butuan City, Hinatuan, Malaybalay City, and Agusan City rain stations' 5-, 25-, 100-Year RIDF in HEC-HMS

Table 3. Summary of Agusan river discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	9,364.6	35 hours, 50 minutes
25-Year	15,226.8	35 hours, 50 minutes
100-Year	20,214.5	35 hours, 50 minutes

The comparison of discharge values obtained from HEC-HMS, QMED, and from the bankful discharge method, Qbankful, are shown in Table 4. Using values from the DTM of Agusan, the bankful discharge for the river was computed.

Table 8. Validation of river discharge estimate using the bankful method

Discharge Point	Qbankful, cms	QMED, cms	Validation
Agusan	6,268.15	9,364.6	Pass

The discharge value from the HEC-HMS discharge estimate were able to satisfy the condition for validating the computed discharge using the bankful method. Since the computed value are based on theory, the actual discharge value was still used for flood modeling but will need further investigation for the purpose of validation. It is recommended, therefore, to use the actual value of the river discharge for higher-accuracy modeling.

4.3 Flood Hazard and Flow Depth Maps

The following images are the hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Agusan river basin.

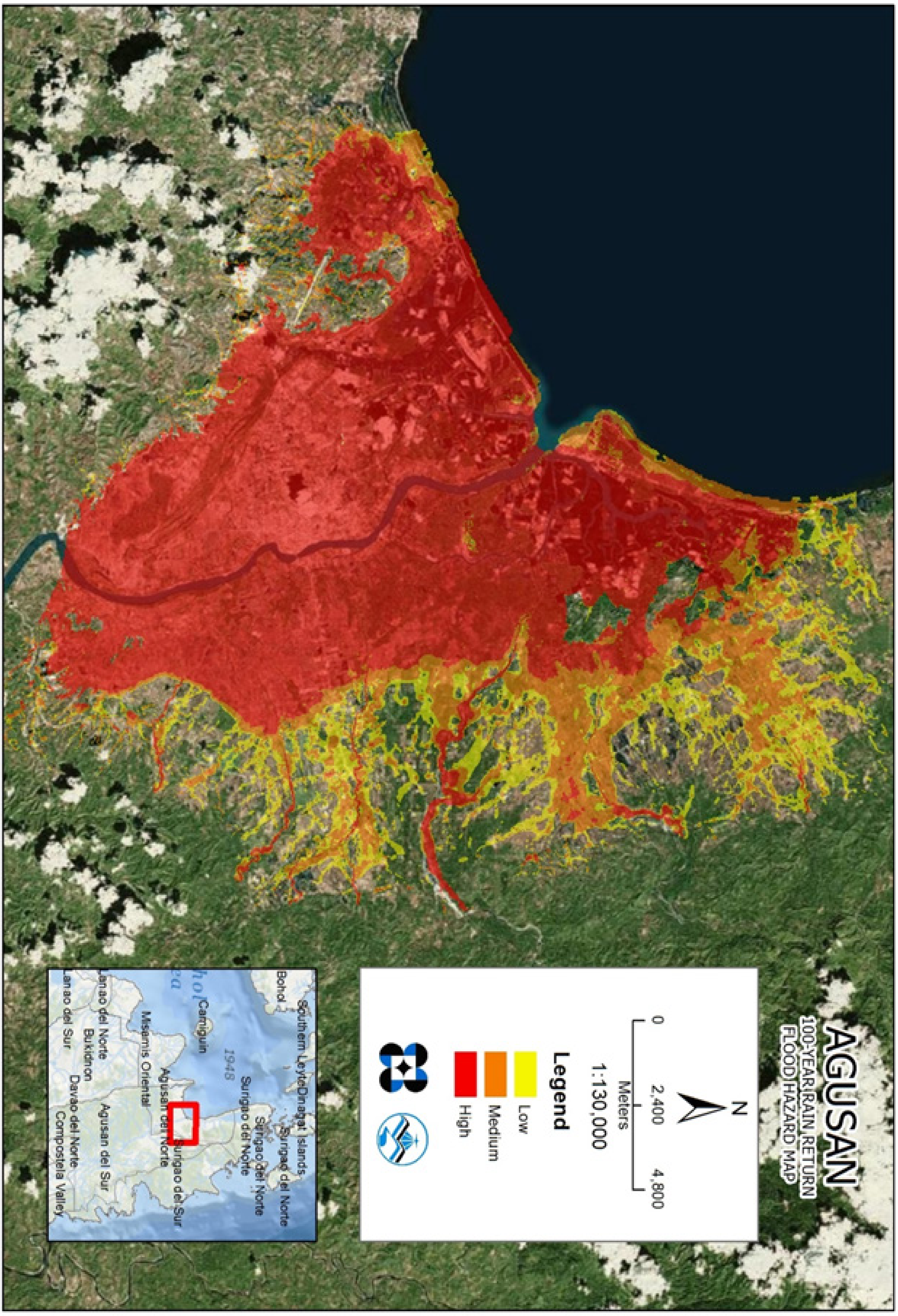


Figure 69. 100-year Flood Hazard Map for Agusan River Basin

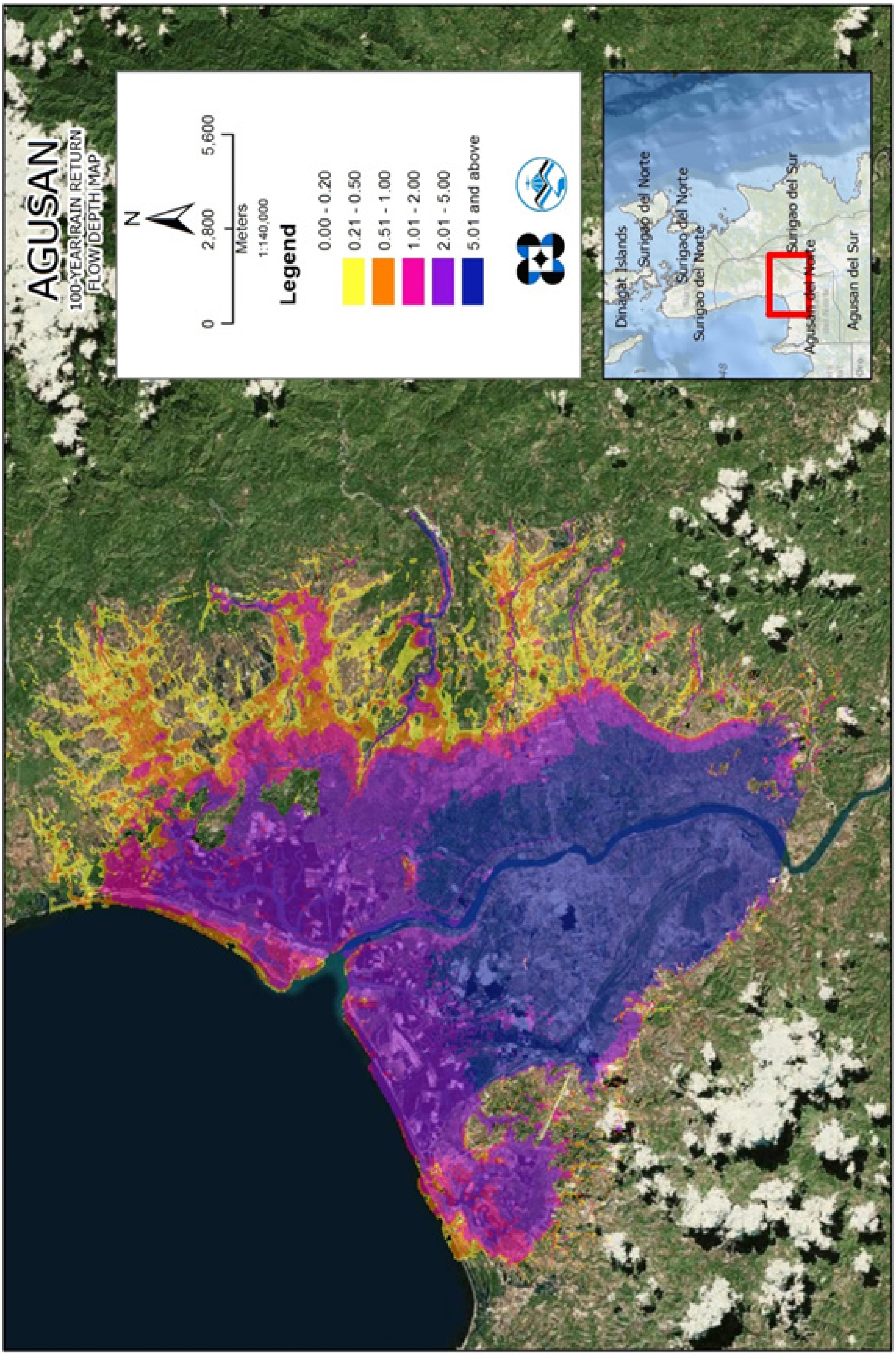


Figure 70. 100-year Flow Depth Map for Agusan River Basin

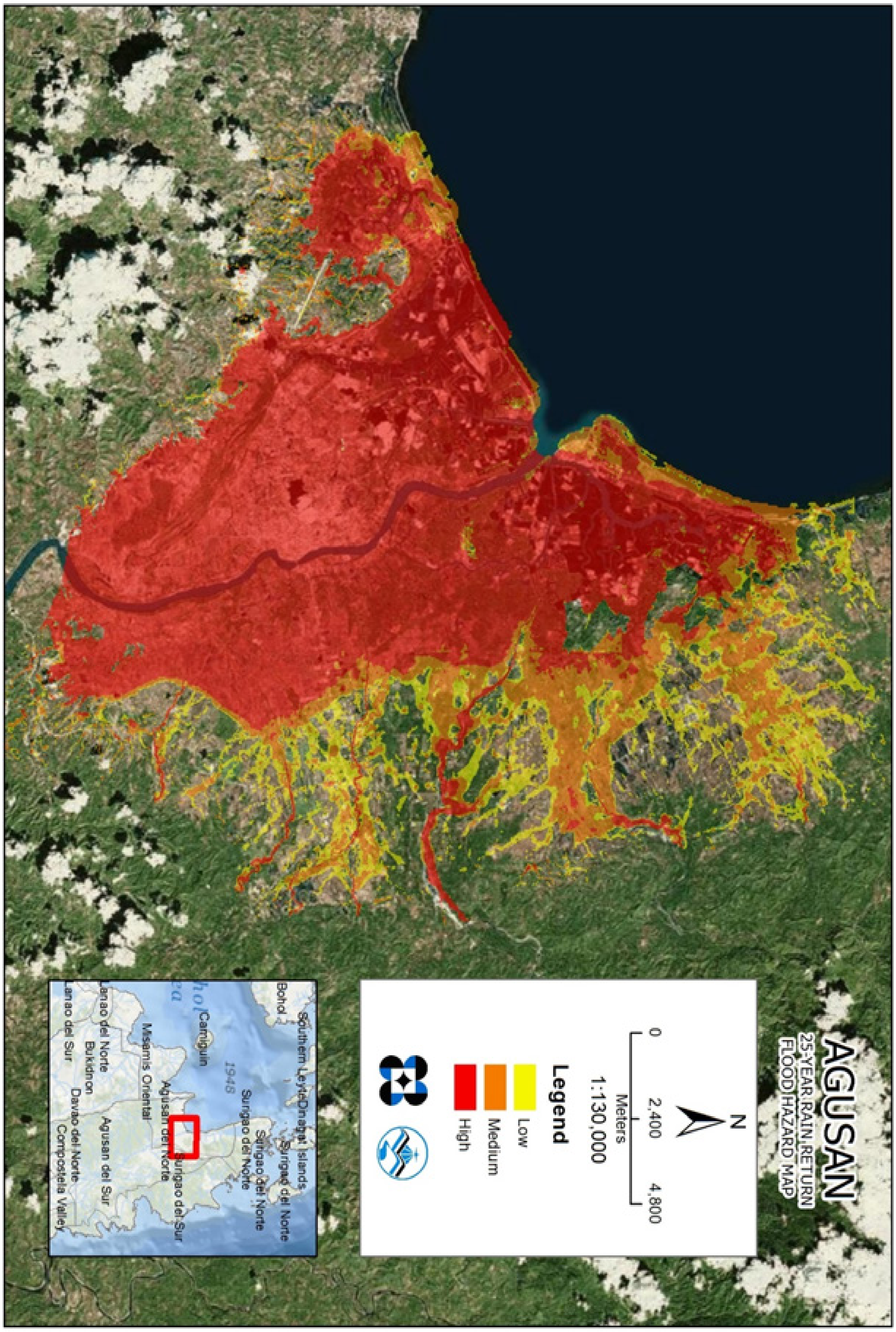


Figure 71. 25-year Flood Hazard Map for Agusan River Basin

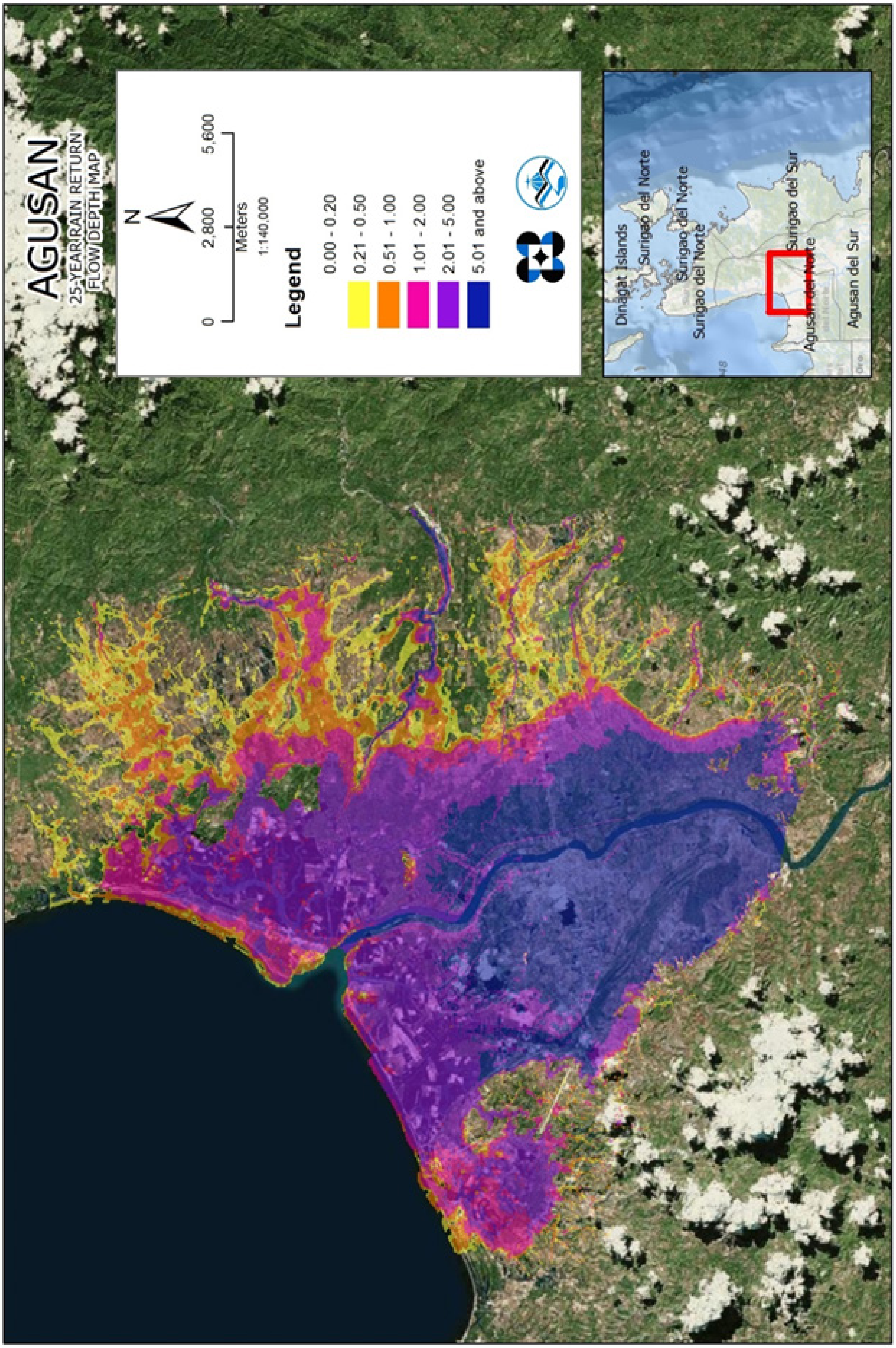


Figure 72. 25-year Flow Depth Map for Agusan River Basin

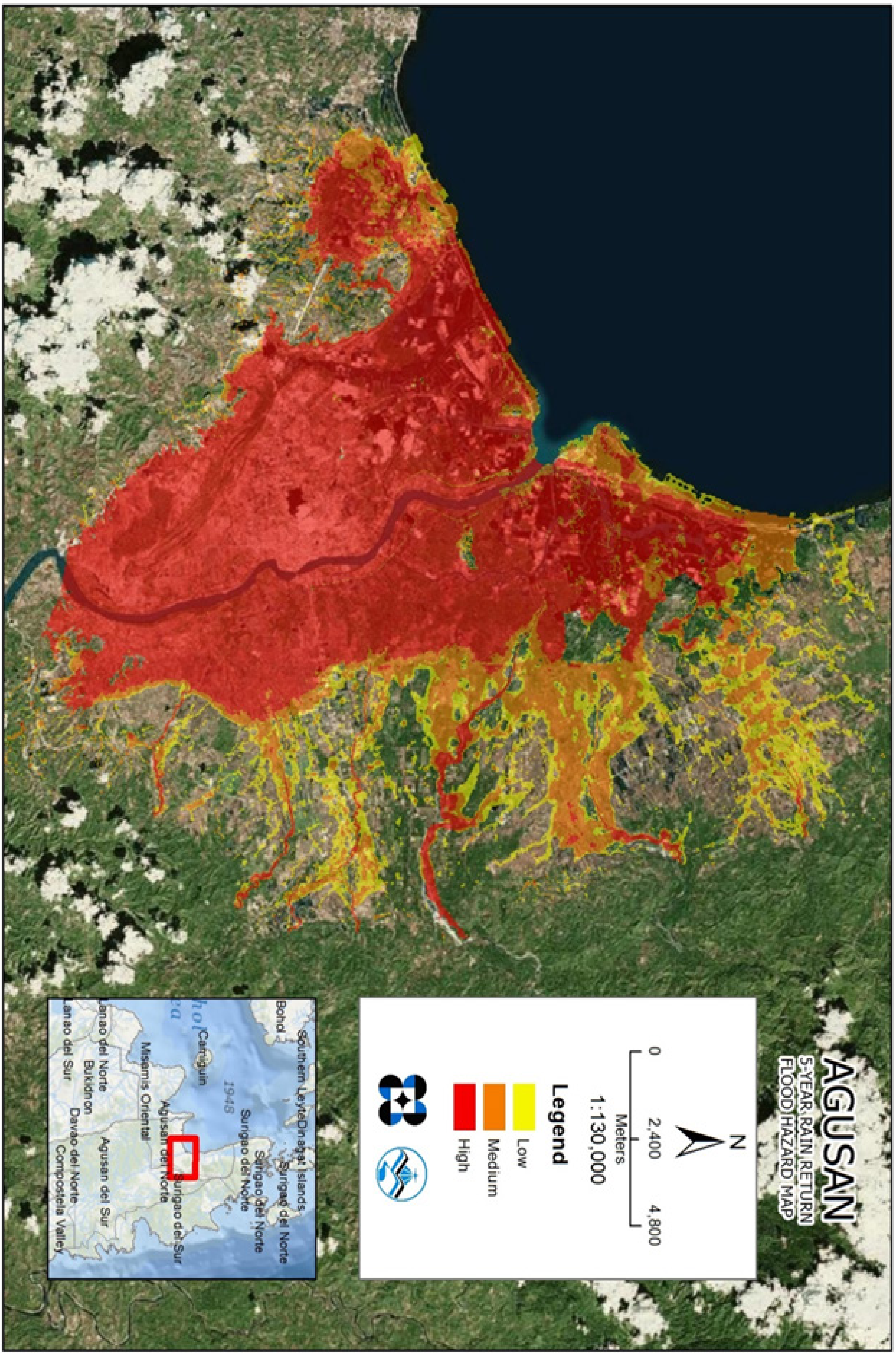


Figure 73. 5-year Flood Hazard Map for Agusan River Basin

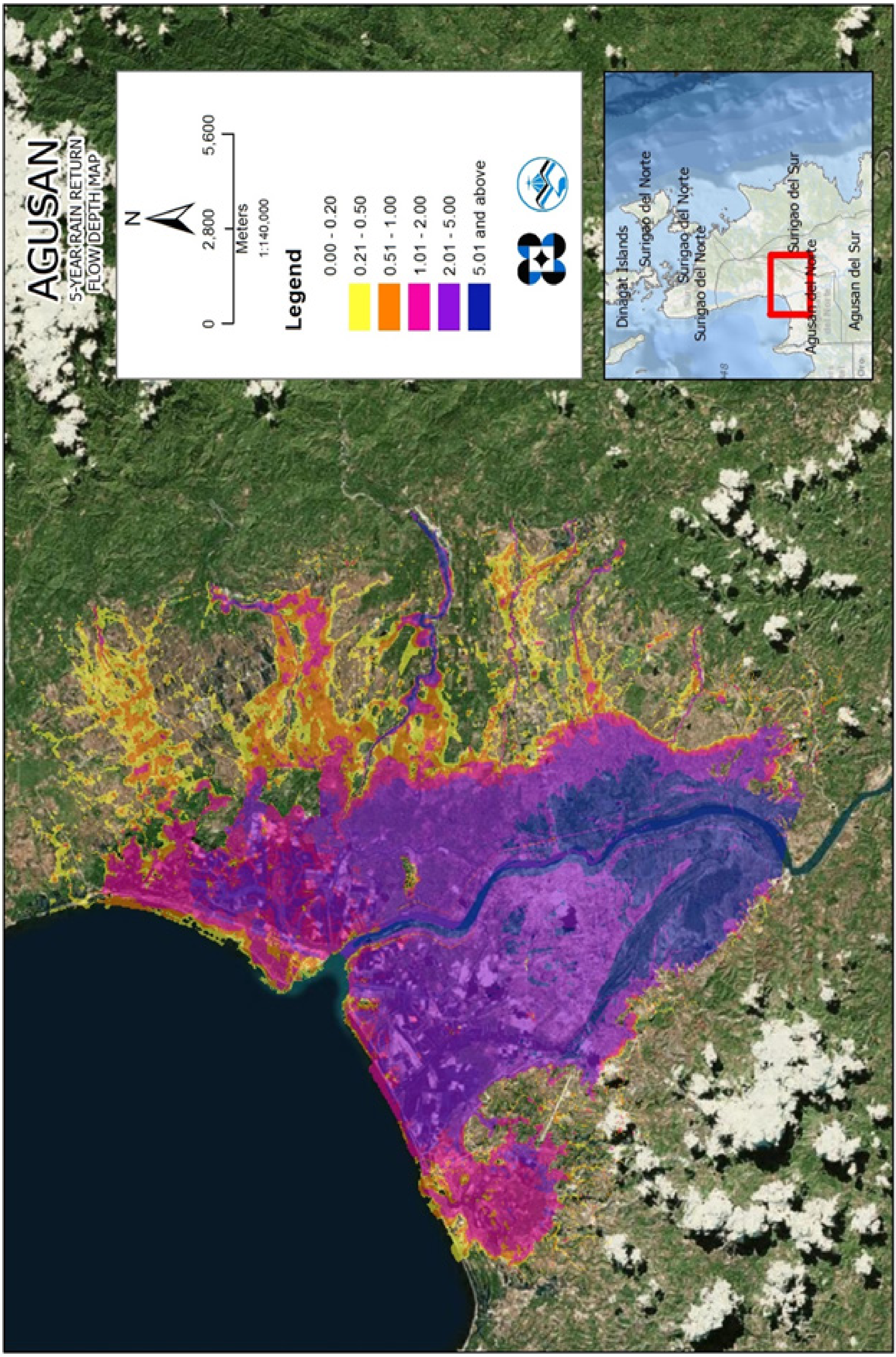


Figure 74. 5-year Flood Hazard Map for Agusan River Basin

Bibliography

- Aquaveo. (2012). Watershed Modeling - HEC HMS Interface. Aquaveo.

- Asian Development Bank. (2004). Technical assistance to the Republic of the Philippines for a master plan for the Agusan River Basin. Retrieved August 12, 2015, from http://www.worldcat.org/title/technical-assistance-to-the-republic-of-the-philippines-for-a-master-plan-for-the-agusan-river-basin/oclc/58999955

- Feldman, A. D. (2000). Hydrologic Modeling System HEC-HMS Technical Reference Manual. Davis, CA: US Army Corps of Engineers - Hydrologic Engineering Center.

- FLO-2D Software, I. Flo-2D Reference Manual. FLO-2D Software, Inc.

- Kundell, J. (Ed.). (2008, April 3). Water profile of Philippines. Retrieved August 12, 2015, from http://www.eoearth.org/view/article/156982/#River_Basins_and_Water_Resources

- Merwade, V. (2012). Terrain Processing and HMS- Model Development using GeoHMS. Lafayette, Indiana.

- Santillan, J. (2011). Profile and Cross Section Surveys, Inflow measurement and flood modeling of Surigao River, Surigao City for Flood Hazard Assessment Purposes. Quezon City: Training Center for Applied Geodesy and Photogrammetry (TCAGP).

- Scharffenberg, W. A., & Fleming, M. J. (2010). Hydrologic Modeling System HEC-HMS User's Manual. Davis, California: U.S Army Corps of Engineers - Hydrologic Engineering Center.

Appendix

Appendix A. Las Nieves Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
148B	0.5	18.335	0	6.76	0.10603	Discharge	2.9111	0.9	Ratio to Peak	0
149B	0.5	16.6327	0	14.1301	0.22222	Discharge	3.2512	1	Ratio to Peak	0
150B	0.5	16.496	0	4.8672	0.11615	Discharge	0.59291	1	Ratio to Peak	0
151B	0.5	16.4094	0	5.33874	0.08407	Discharge	0.97788	1	Ratio to Peak	0
152B	0.5	17.2606	0	4.9712	0.11859	Discharge	0.6218	1	Ratio to Peak	0
153B	0.5	15.628	0	1.09547	0.0172	Discharge	0.03942	1	Ratio to Peak	0
154B	0.5	17.238	0	4.68686	0.11035	Discharge	0.84978	1	Ratio to Peak	0
155B	0.5	16.4652	0	2.19794	0.11581	Discharge	0.72403	1	Ratio to Peak	0
156B	0.5	19.454	0	13.1248	0.0598	Discharge	3.9908	1	Ratio to Peak	0
157B	0.5	21.36	0	12.3205	0.12763	Discharge	11.686	1	Ratio to Peak	0
158B	0.5	20.729	0	3.5776	0.0555	Discharge	1.2191	1	Ratio to Peak	0

Appendix

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
159B	0.5	23.442	0	1.248	0.0237	Discharge	0.01019	1	Ratio to Peak	0
160B	0.5	20.417	0	9.11726	0.21759	Discharge	1.0675	1	Ratio to Peak	0
161B	0.5	21.511	0	10.0603	0.15789	Discharge	3.6871	1	Ratio to Peak	0
162B	0.5	20.729	0	8.83314	0.08871	Discharge	2.5197	1	Ratio to Peak	0
163B	0.5	16.549	0	3.8688	0.13723	Discharge	1.3763	1	Ratio to Peak	0
164B	0.5	20.601	0	27.456	0.27633	Discharge	23.023	1	Ratio to Peak	0
165B	0.5	21.4885	0	9.95634	0.14996	Discharge	3.0134	1	Ratio to Peak	0
166B	0.5	19.976	0	4.8672	0.11529	Discharge	2.4498	1	Ratio to Peak	0
167B	0.5	21.589	0	6.48274	0.10185	Discharge	1.2362	1	Ratio to Peak	0
168B	0.5	19.289	0	6.26766	0.04198	Discharge	4.7986	1	Ratio to Peak	0
169B	0.5	21.511	0	4.9088	0.17217	Discharge	0.53871	1	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
170B	0.5	21.4885	0	7.28	0.1313	Discharge	2.032	1	Ratio to Peak	0
171B	0.5	21.4885	0	7.62674	0.16127	Discharge	3.001	1	Ratio to Peak	0
172B	0.5	21.692	0	33.981	2.6989	Discharge	5.6045	1	Ratio to Peak	0
173B	0.5	21.7258	0	7.60594	0.03464	Discharge	6.432	1	Ratio to Peak	0
174B	0.5	21.634	0	3.432	0.27243	Discharge	2.5075	1	Ratio to Peak	0
175B	0.5	21.4885	0	4.13234	0.11087	Discharge	0.74956	1	Ratio to Peak	0
176B	0.5	21.4885	0	7.05806	0.11077	Discharge	3.9022	1	Ratio to Peak	0
177B	0.5	21.458	0	11.2597	0.05129	Discharge	5.4908	1	Ratio to Peak	0
178B	0.5	19.697	0	5.70606	0.08955	Discharge	1.4909	1	Ratio to Peak	0
179B	0.5	21.5	0	3.90354	0.13805	Discharge	2.2237	1	Ratio to Peak	0
180B	0.5	21.762	0	12.2235	0.18103	Discharge	9.8379	1	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
181B	0.5	21.4885	0	4.4928	0.0705	Discharge	1.1793	1	Ratio to Peak	0
182B	0.5	22.343	0	7.61966	0.03471	Discharge	0.71115	1	Ratio to Peak	0
183B	0.5	21.868	0	8.95794	0.06017	Discharge	2.8522	1	Ratio to Peak	0
184B	0.5	22.164	0	4.0352	0.0407	Discharge	0.74452	1	Ratio to Peak	0
185B	0.5	22.4513	0	4.68	0.07347	Discharge	1.3078	1	Ratio to Peak	0
186B	0.5	20.727	0	2.8288	0.01974	Discharge	0.51598	0.90464	Ratio to Peak	0
187B	0.5	21.575	0	8.008	0.05361	Discharge	4.0235	1	Ratio to Peak	0
188B	0.5	21.4885	0	1.87893	0.01969	Discharge	0.52964	1	Ratio to Peak	0
189B	0.5	21.5444	0	2.1632	0.02216	Discharge	0.44689	1	Ratio to Peak	0
190B	0.5	21.536	0	1.69173	0.02651	Discharge	0.51531	1	Ratio to Peak	0
191B	0.5	21.734	0	1.35893	0.02137	Discharge	0.19349	1	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
192B	0.5	22.114	0	6.8848	0.13643	Discharge	1.8084	1	Ratio to Peak	0
193B	0.5	21.536	0	1.28267	0.02013	Discharge	0.34208	1	Ratio to Peak	0
194B	0.5	21.4885	0	1.248	0.02013	Discharge	0.03594	1	Ratio to Peak	0
195B	0.5	21.4885	0	1.8512	0.02841	Discharge	0.24186	1	Ratio to Peak	0
196B	0.5	21.4885	0	1.33813	0.02104	Discharge	0.14142	1	Ratio to Peak	0
197B	0.5	21.65	0	1.96213	0.02839	Discharge	0.44197	1	Ratio to Peak	0
198B	0.5	21.65	0	1.90667	0.01997	Discharge	0.27792	1	Ratio to Peak	0
199B	0.5	22.421	0	4.68	0.04702	Discharge	1.268	0.9	Ratio to Peak	0
200B	0.5	23.442	0	1.248	0.02173	Discharge	0.00784	0.9	Ratio to Peak	0
201B	0.5	22.161	0	2.3296	0.02439	Discharge	0.71608	0.9	Ratio to Peak	0
202B	0.5	22.499	0	2.96754	0.02068	Discharge	0.61318	0.9	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
203B	0.5	21.603	0	2.08686	0.03336	Discharge	0.83119	0.9	Ratio to Peak	0
204B	0.5	22.781	0	7.0096	0.24987	Discharge	0.99893	0.9	Ratio to Peak	0
205B	0.5	23.163	0	4.1392	0.11977	Discharge	0.70746	0.9	Ratio to Peak	0
206B	0.5	23.163	0	0.94466	0.3554	Discharge	0.00795	0.9	Ratio to Peak	0
207B	0.5	22.016	0	2.704	0.02771	Discharge	0.9341	0.9	Ratio to Peak	0
208B	0.5	22.728	0	3.02286	0.0211	Discharge	0.44421	0.9	Ratio to Peak	0
209B	0.5	21.106	0	2.32274	0.02426	Discharge	0.59067	0.9	Ratio to Peak	0
210B	0.5	22.722	0	1.9968	0.02087	Discharge	0.54442	0.9	Ratio to Peak	0
211B	0.5	22.195	0	3.02286	0.04743	Discharge	0.29998	0.9	Ratio to Peak	0
212B	0.5	21.963	0	2.27406	0.02376	Discharge	0.59884	0.9	Ratio to Peak	0
213B	0.5	21.717	0	1.1856	0.01862	Discharge	0.30155	0.9	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
214B	0.5	21.589	0	1.13013	0.01772	Discharge	0.23526	0.9	Ratio to Peak	0
215B	0.5	21.86	0	1.40053	0.022	Discharge	0.24623	0.9	Ratio to Peak	0
216B	0.5	21.4885	0	1.51147	0.02368	Discharge	0.40614	0.9	Ratio to Peak	0
217B	0.5	21.79	0	2.13554	0.05094	Discharge	0.96926	0.9	Ratio to Peak	0
218B	0.5	21.8234	0	1.11627	0.01755	Discharge	0.23224	0.9	Ratio to Peak	0
219B	0.5	21.776	0	1.2064	0.01891	Discharge	0.71239	0.9	Ratio to Peak	0
220B	0.5	21.729	0	1.066	0.401	Discharge	0.32058	0.9	Ratio to Peak	0
221B	0.5	22.3676	0	5.65074	0.08876	Discharge	3.4824	0.9	Ratio to Peak	0

Appendix B. Las Nieves Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
149R	Automatic Fixed Interval	39795.6	0.00016	0.00121	Trapezoid	30	45
150R	Automatic Fixed Interval	161327	0.00034	0.0007	Trapezoid	30	45
151R	Automatic Fixed Interval	142557	0.00043	0.0012	Trapezoid	30	45
152R	Automatic Fixed Interval	62250.8	0.00037	0.00175	Trapezoid	30	45
153R	Automatic Fixed Interval	16966.8	0.00069	0.00119	Trapezoid	30	45
154R	Automatic Fixed Interval	33384.7	0.00258	0.0001	Trapezoid	30	45
155R	Automatic Fixed Interval	69295.1	0.0001	0.0012	Trapezoid	30	45
156R	Automatic Fixed Interval	38155.7	0.00022	0.00179	Trapezoid	30	45
157R	Automatic Fixed Interval	33075.1	0.00119	0.0018	Trapezoid	30	45
158R	Automatic Fixed Interval	58815.9	0.00103	0.0012	Trapezoid	30	45
159R	Automatic Fixed Interval	51259.7	0.00109	0.00117	Trapezoid	30	45
160R	Automatic Fixed Interval	46673.6	0.00016	0.001	Trapezoid	30	45
161R	Automatic Fixed Interval	42059.9	0.00489	0.00074	Trapezoid	30	45
162R	Automatic Fixed Interval	142719	0.00538	0.00035	Trapezoid	30	45
163R	Automatic Fixed Interval	150098	0.00471	0.00074	Trapezoid	30	45
164R	Automatic Fixed Interval	21950.8	0.00053	0.0018	Trapezoid	30	45
165R	Automatic Fixed Interval	20135.6	0.00039	0.0018	Trapezoid	30	45
166R	Automatic Fixed Interval	64025.5	0.00114	0.00052	Trapezoid	30	45
167R	Automatic Fixed Interval	85625.4	0.00019	0.00179	Trapezoid	30	45
168R	Automatic Fixed Interval	43824.6	0.00068	0.00074	Trapezoid	30	45
169R	Automatic Fixed Interval	30872.8	0.00018	0.0005	Trapezoid	30	45
170R	Automatic Fixed Interval	46839.1	0.00147	0.0005	Trapezoid	30	45
171R	Automatic Fixed Interval	50056.6	0.00246	0.0005	Trapezoid	30	45
172R	Automatic Fixed Interval	59678.1	0.001	0.00118	Trapezoid	30	45
173R	Automatic Fixed Interval	8117.21	0.0008	0.00401	Trapezoid	30	45
174R	Automatic Fixed Interval	5211.94	0.00082	0.00268	Trapezoid	30	45
175R	Automatic Fixed Interval	23979.7	0.00024	0.0018	Trapezoid	30	45
176R	Automatic Fixed Interval	42677.5	0.00061	0.0012	Trapezoid	30	45
177R	Automatic Fixed Interval	47129.3	0.00015	0.0012	Trapezoid	30	45
178R	Automatic Fixed Interval	83367.5	0.0001	0.0012	Trapezoid	30	45
179R	Automatic Fixed Interval	122373	0.00208	0.0012	Trapezoid	30	45
180R	Automatic Fixed Interval	133097	0.00022	0.0012	Trapezoid	30	45
181R	Automatic Fixed Interval	74386.8	0.00099	0.0012	Trapezoid	30	45
182R	Automatic Fixed Interval	23317.9	0.00091	0.0018	Trapezoid	30	45
183R	Automatic Fixed Interval	184249	0.00045	0.00178	Trapezoid	30	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
184R	Automatic Fixed Interval	47589.6	0.0269	0.0019	Trapezoid	30	45
185R	Automatic Fixed Interval	47995	0.02534	0.00177	Trapezoid	30	45
186R	Automatic Fixed Interval	23938.6	0.01462	0.00118	Trapezoid	30	45
187R	Automatic Fixed Interval	10570.1	0.05204	0.00118	Trapezoid	30	45
188R	Automatic Fixed Interval	19441.1	0.02234	0.00118	Trapezoid	30	45
189R	Automatic Fixed Interval	21088.2	0.00893	0.00118	Trapezoid	30	45
190R	Automatic Fixed Interval	18954.8	0.00852	0.00118	Trapezoid	30	45
191R	Automatic Fixed Interval	13018.5	0.00718	0.00118	Trapezoid	30	45
192R	Automatic Fixed Interval	21783.3	0.00197	0.00115	Trapezoid	30	45
193R	Automatic Fixed Interval	56874.9	0.02075	0.00136	Trapezoid	30	45
194R	Automatic Fixed Interval	12718.6	0.00102	0.00136	Trapezoid	30	45
195R	Automatic Fixed Interval	22934.3	0.00119	0.00117	Trapezoid	30	45
196R	Automatic Fixed Interval	59203.3	0.00001	0.00178	Trapezoid	30	45
197R	Automatic Fixed Interval	25298.6	0.00095	0.00118	Trapezoid	30	45
198R	Automatic Fixed Interval	45880.8	0.00109	0.00118	Trapezoid	30	45
199R	Automatic Fixed Interval	55727	0.00017	0.00118	Trapezoid	30	45
200R	Automatic Fixed Interval	74055.7	0.00078	0.00117	Trapezoid	30	45
201R	Automatic Fixed Interval	95713.4	0.00405	0.00118	Trapezoid	30	45
202R	Automatic Fixed Interval	70011.4	0.00064	0.00118	Trapezoid	30	45
203R	Automatic Fixed Interval	51828.4	0.00081	0.00117	Trapezoid	30	45
204R	Automatic Fixed Interval	42492	0.00043	0.00118	Trapezoid	30	45
205R	Automatic Fixed Interval	33510.2	0.00155	0.00118	Trapezoid	30	45
206R	Automatic Fixed Interval	27387.5	0.00115	0.00113	Trapezoid	30	45
207R	Automatic Fixed Interval	13930.8	0.00224	0.00118	Trapezoid	30	45
208R	Automatic Fixed Interval	23289.8	0.00168	0.00118	Trapezoid	30	45
209R	Automatic Fixed Interval	5150.21	0.00491	0.00118	Trapezoid	30	45
210R	Automatic Fixed Interval	30386.4	0.02309	0.00118	Trapezoid	30	45
211R	Automatic Fixed Interval	57588.4	0.00729	0.00177	Trapezoid	30	45
212R	Automatic Fixed Interval	46376	0.00097	0.00118	Trapezoid	30	45
213R	Automatic Fixed Interval	32851.3	0.00091	0.00117	Trapezoid	30	45
214R	Automatic Fixed Interval	12500.2	0.00014	0.00266	Trapezoid	30	45
215R	Automatic Fixed Interval	27264.3	0.00063	0.00113	Trapezoid	30	45
216R	Automatic Fixed Interval	32250.5	0.00094	0.00266	Trapezoid	30	45

Appendix C. Andanan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
111B	52.755	73.1409	0.0	12.079912	0.11811	0.91421	0.0135006	0.2	Ratio to Peak	0
112B	1.2959	78.95685	0.0	4.8981634	0.12415	0.70445	0.0217097	0.2	Ratio to Peak	0
117B	58.653	40.8765	0.0	18.39916	0.29472	0.75914	0.0208594	0.2	Ratio to Peak	0
118B	43.005	59.77335	0.0	22.21011	0.34945	0.78699	0.0018286	0.2	Ratio to Peak	0
123B	28.392	61.64865	0.0	68.78898	1.0480	0.86946	0.00085705	0.2	Ratio to Peak	0
124B	11.953	39.00015	0.0	142.62014	1.3699	4.7293	0.06582	0.2	Ratio to Peak	0
128B	11.972	46.47825	0.0	69.875234	1.0054	0.85299	0.0212935	0.2	Ratio to Peak	0
129B	25.294	47.46945	0.0	96.278988	0.41652	2.5051	0.0039025	0.2	Ratio to Peak	0
132B	17.87	48.5394	0.0	141.57546	0.92482	1.0783	0.0306374	0.2	Ratio to Peak	0

Appendix D. Andanan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
122R	Automatic Fixed Interval	14994.944	0.035440	0.0243872	Trapezoid	30	45
123R	Automatic Fixed Interval	14998.363	0.035640	0.0001	Trapezoid	30	45
124R	Automatic Fixed Interval	50243.335	0.015520	0.0001	Trapezoid	30	45
125R	Automatic Fixed Interval	50265.873	0.015510	0.013601	Trapezoid	30	45
130R	Automatic Fixed Interval	23299.420	0.005760	0.023733	Trapezoid	30	45
131R	Automatic Fixed Interval	23299.680	0.005530	0.0001	Trapezoid	30	45
135R	Automatic Fixed Interval	37347.689	0.004130	0.0001	Trapezoid	30	45
136R	Automatic Fixed Interval	37336.095	0.004220	0.0214934	Trapezoid	30	45

Appendix E. DRRM Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
148B	32.031	44.2075185	0	6.643	15.26784	2.9111	0.9	0.001	Ratio to Peak	0
149B	37.2585	40.1032905	0	13.8855052	31.99968	3.2512	0.9	0.001	Ratio to Peak	0
150B	37.7260773	39.7735056	0	4.78296	16.72608	0.59291	0.9	0.001	Ratio to Peak	0
151B	38.026	39.5648115	0	5.2463348	12.1056	0.97788	0.9	0.001	Ratio to Peak	0
152B	35.211	41.6169255	0	4.88516	17.07648	0.6218	0.9	0.001	Ratio to Peak	0
153B	40.8795	37.6808	0	1.0765	2.4768	0.039417	0.9	0.001	Ratio to Peak	0
154B	35.2815	41.5625418	0	4.6057452	15.88992	0.84978	0.9	0.001	Ratio to Peak	0
155B	37.8315	39.69955	0	2.1598948	16.67712	0.72403	0.9	0.001	Ratio to Peak	0
156B	29.0925	46.9055394	0	12.89764	8.6107584	3.9908	0.9	0.001	Ratio to Peak	0
157B	24.798	51.501096	0	12.1072252	18.3792	11.686	0.9	0.001	Ratio to Peak	0
158B	26.1315	49.9796919	0	3.51568	7.9914048	1.2191	0.9	0.001	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
159B	20.9025	56.5212	0	1.2264	3.4133376	0.01019	0.9	0.001	Ratio to Peak	0
160B	26.823	49.2274287	0	8.9594652	31.33344	1.0675	0.9	0.001	Ratio to Peak	0
161B	24.489	51.8651721	0	9.8862148	22.73664	3.6871	0.9	0.001	Ratio to Peak	0
162B	26.1315	49.9796919	0	8.6802548	12.77472	2.5197	0.9	0.001	Ratio to Peak	0
163B	37.545	39.901026	0	3.80184	19.7616	1.3763	0.9	0.001	Ratio to Peak	0
164B	26.4135	49.6710711	0	26.9808	39.792	23.023	0.9	0.001	Ratio to Peak	0
165B	24.5355	51.8111	0	9.7840148	21.59424	3.0134	0.9	0.001	Ratio to Peak	0
166B	27.8355	48.1641336	0	4.78296	16.60224	2.4498	0.9	0.001	Ratio to Peak	0
167B	24.3321933	52.0532379	0	6.3705348	14.66688	1.2362	0.9	0.001	Ratio to Peak	0
168B	29.505	46.5077079	0	6.1591852	6.0457536	4.7986	0.9	0.001	Ratio to Peak	0
169B	24.489	51.8651721	0	4.82384	24.792	0.53871	0.9	0.001	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
170B	24.5355	51.8111	0	7.154	18.9072	2.032	0.9	0.001	Ratio to Peak	0
171B	24.5355	51.8111	0	7.4947348	23.22336	3.001	0.9	0.001	Ratio to Peak	0
172B	24.126	52.3015812	0	33.392828	18	5.6045	0.9	0.001	Ratio to Peak	0
173B	24.06	52.382487	0	7.4742948	4.9886112	6.432	0.9	0.001	Ratio to Peak	0
174B	24.2415	52.1617374	0	3.3726	39.2304	2.5075	0.9	0.001	Ratio to Peak	0
175B	24.5355	51.8111	0	4.0608148	15.9648	0.74956	0.9	0.001	Ratio to Peak	0
176B	24.5355	51.8111	0	6.9359052	15.95136	3.9022	0.9	0.001	Ratio to Peak	0
177B	24.597	51.7373838	0	11.0647852	7.3861824	5.4908	0.9	0.001	Ratio to Peak	0
178B	28.499	47.4914367	0	5.6073052	12.89472	1.4909	0.9	0.001	Ratio to Peak	0
179B	24.5117754	51.83865	0	3.8359748	19.87872	2.2237	0.9	0.001	Ratio to Peak	0
180B	23.988	52.4703582	0	12.0119748	26.06784	9.8379	0.9	0.001	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
181B	24.5355	51.8111	0	4.41504	10.152	1.1793	0.9	0.001	Ratio to Peak	0
182B	22.8675	53.8712073	0	7.4877852	4.9980864	0.71115	0.9	0.001	Ratio to Peak	0
183B	23.778	52.7259348	0	8.8028948	8.6651904	2.8522	0.9	0.001	Ratio to Peak	0
184B	23.2065	53.4396204	0	3.96536	5.8601088	0.74452	0.9	0.001	Ratio to Peak	0
185B	22.6665	54.131874	0	4.599	10.58016	1.3078	0.9	0.001	Ratio to Peak	0
186B	26.136	49.9748697	0	2.77984	2.8424544	0.51598	0.9	0.001	Ratio to Peak	0
187B	24.36	52.0194825	0	7.8694	7.7204928	4.0235	0.9	0.001	Ratio to Peak	0
188B	24.5355	51.8111	0	1.8464	2.8351968	0.52964	0.9	0.001	Ratio to Peak	0
189B	24.4215	51.94581	0	2.12576	3.1905696	0.44689	0.9	0.001	Ratio to Peak	0
190B	24.4395	51.9254496	0	1.6625	3.81696	0.51531	0.9	0.001	Ratio to Peak	0
191B	24.0435	52.4028474	0	1.3354	3.0768	0.19349	0.9	0.001	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
192B	23.3025	53.3190654	0	6.76564	19.6464	1.8084	0.9	0.001	Ratio to Peak	0
193B	24.4395	51.9254496	0	1.2605	2.89824	0.34208	0.9	0.001	Ratio to Peak	0
194B	24.5355	51.8111	0	1.2264	2.89824	0.035944	0.9	0.001	Ratio to Peak	0
195B	24.5355	51.8111	0	1.81916	4.0915392	0.24186	0.9	0.001	Ratio to Peak	0
196B	24.5355	51.8111	0	1.3150	3.02976	0.14142	0.9	0.001	Ratio to Peak	0
197B	24.21	52.200315	0	1.9282	4.0882272	0.44197	0.9	0.001	Ratio to Peak	0
198B	24.21	52.200315	0	1.8737	2.87616	0.27792	0.9	0.001	Ratio to Peak	0
199B	22.7223639	54.0592731	0	4.599	6.7710528	1.268	0.9	0.001	Ratio to Peak	0
200B	20.9025	56.5212	0	1.2264	3.1288896	0.007837	0.9	0.001	Ratio to Peak	0
201B	23.2125	53.4323871	0	2.28928	3.5123232	0.71608	0.9	0.001	Ratio to Peak	0
202B	22.578	54.2473389	0	2.9161748	2.9785632	0.61318	0.9	0.001	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
203B	24.3045	52.0869933	0	2.0507452	4.8031392	0.83119	0.9	0.001	Ratio to Peak	0
204B	22.062	54.9272691	0	6.88828	35.98176	0.99893	0.9	0.001	Ratio to Peak	0
205B	21.384	55.8486	0	4.06756	17.24736	0.70746	0.9	0.001	Ratio to Peak	0
206B	21.384	55.8486	0	0.92831	1.70592	0.007949	0.9	0.001	Ratio to Peak	0
207B	23.4915	53.0827776	0	2.6572	3.9908736	0.9341	0.9	0.001	Ratio to Peak	0
208B	22.158	54.7994808	0	2.9705452	3.0382944	0.44421	0.9	0.001	Ratio to Peak	0
209B	25.3245	50.8886766	0	2.2825348	3.4937568	0.59067	0.9	0.001	Ratio to Peak	0
210B	22.1685	54.7850142	0	1.96224	3.0054432	0.54442	0.9	0.001	Ratio to Peak	0
211B	23.1477099	53.5143645	0	2.9705452	6.82944	0.29998	0.9	0.001	Ratio to Peak	0
212B	23.594	52.9544535	0	2.2347052	3.42144	0.59884	0.9	0.001	Ratio to Peak	0
213B	24.076	52.3618587	0	1.16508	2.68128	0.30155	0.9	0.001	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
214B	24.3321933	52.0532379	0	1.1106	2.55168	0.23526	0.9	0.001	Ratio to Peak	0
215B	23.7945	52.706646	0	1.3763	3.168	0.24623	0.9	0.001	Ratio to Peak	0
216B	24.5355	51.8111	0	1.4853	3.40992	0.40614	0.9	0.001	Ratio to Peak	0
217B	23.9325	52.537869	0	2.0985748	7.3348704	0.96926	0.9	0.001	Ratio to Peak	0
218B	23.8665	52.618239	0	1.0969	2.52672	0.23224	0.9	0.001	Ratio to Peak	0
219B	23.9596515	52.5041136	0	1.18552	2.72256	0.71239	0.9	0.001	Ratio to Peak	0
220B	24.0525	52.3907919	0	1.04755	1.9248	0.32058	0.9	0.001	Ratio to Peak	0
221B	22.8225	53.930949	0	5.5529348	12.78144	3.4824	0.9	0.001	Ratio to Peak	0

Appendix F. DRRM Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
149R	Automatic Fixed Interval	39795.62	0.00016	0.0041963	Trapezoid	150	1
150R	Automatic Fixed Interval	161327.1	0.00034	0.0019906	Trapezoid	150	1
151R	Automatic Fixed Interval	142557.3	0.00043	0.0028481	Trapezoid	150	1
152R	Automatic Fixed Interval	62250.76	0.00037	0.0008151	Trapezoid	150	1
153R	Automatic Fixed Interval	16966.75	0.00069	0.0334535	Trapezoid	150	1
154R	Automatic Fixed Interval	33384.68	0.00258	0.0012715	Trapezoid	150	1
155R	Automatic Fixed Interval	69295.07	0.0001	0.0044224	Trapezoid	150	1
156R	Automatic Fixed Interval	38155.7	0.00022	0.0102747	Trapezoid	150	1
157R	Automatic Fixed Interval	33075.1	0.00119	0.0102391	Trapezoid	150	1
158R	Automatic Fixed Interval	58815.88	0.00103	0.0066349	Trapezoid	150	1
159R	Automatic Fixed Interval	51259.71	0.00109	0.0074677	Trapezoid	150	1
160R	Automatic Fixed Interval	46673.55	0.00016	0.0097260	Trapezoid	150	1
161R	Automatic Fixed Interval	42059.94	0.00489	0.0027104	Trapezoid	150	1
162R	Automatic Fixed Interval	142719.3	0.00538	.00026056	Trapezoid	150	1
163R	Automatic Fixed Interval	150097.6	0.00471	0.0042137	Trapezoid	150	1
164R	Automatic Fixed Interval	21950.79	0.00053	0.0019003	Trapezoid	150	1
165R	Automatic Fixed Interval	20135.57	0.00039	0.0012031	Trapezoid	150	1
166R	Automatic Fixed Interval	64025.55	0.00114	0.00078	Trapezoid	150	1
167R	Automatic Fixed Interval	85625.37	0.00019	0.0066190	Trapezoid	150	1
168R	Automatic Fixed Interval	43824.61	0.00068	0.000496	Trapezoid	150	1
169R	Automatic Fixed Interval	30872.84	0.00018	.0003376	Trapezoid	150	1
170R	Automatic Fixed Interval	46839.07	0.00147	0.000156	Trapezoid	150	1
171R	Automatic Fixed Interval	50056.65	0.00246	0.000338	Trapezoid	150	1
172R	Automatic Fixed Interval	59678.09	0.001	0.00085	Trapezoid	150	1
173R	Automatic Fixed Interval	8117.206	0.0008	0.0040303	Trapezoid	150	1
174R	Automatic Fixed Interval	5211.943	0.00082	0.0065708	Trapezoid	150	1
175R	Automatic Fixed Interval	23979.68	0.00024	0.0177783	Trapezoid	150	1
176R	Automatic Fixed Interval	42677.48	0.00061	0.0045477	Trapezoid	150	1
177R	Automatic Fixed Interval	47129.33	0.00015	.00025381	Trapezoid	150	1
178R	Automatic Fixed Interval	83367.47	0.0001	0.0026313	Trapezoid	150	1
179R	Automatic Fixed Interval	122373.2	0.00208	0.0005488	Trapezoid	150	1
180R	Automatic Fixed Interval	133096.7	0.00022	0.0008380	Trapezoid	150	1
181R	Automatic Fixed Interval	74386.77	0.00099	0.0093947	Trapezoid	150	1
182R	Automatic Fixed Interval	23317.93	0.00091	0.0027062	Trapezoid	150	1
183R	Automatic Fixed Interval	184249.1	0.00045	0.0017844	Trapezoid	150	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
184R	Automatic Fixed Interval	47589.57	0.0269	0.0242919	Trapezoid	150	1
185R	Automatic Fixed Interval	47995.05	0.02534	0.0095502	Trapezoid	150	1
186R	Automatic Fixed Interval	23938.62	0.01462	0.0152122	Trapezoid	150	1
187R	Automatic Fixed Interval	10570.09	0.05204	0.0027762	Trapezoid	150	1
188R	Automatic Fixed Interval	19441.08	0.02234	0.0063464	Trapezoid	150	1
189R	Automatic Fixed Interval	21088.18	0.00893	0.0065114	Trapezoid	150	1
190R	Automatic Fixed Interval	18954.75	0.00852	0.0028672	Trapezoid	150	1
191R	Automatic Fixed Interval	13018.49	0.00718	0.0017413	Trapezoid	150	1
192R	Automatic Fixed Interval	21783.27	0.00197	0.0028421	Trapezoid	150	1
193R	Automatic Fixed Interval	56874.88	0.02075	0.0114844	Trapezoid	150	1
194R	Automatic Fixed Interval	12718.59	0.00102	.00056098	Trapezoid	150	1
195R	Automatic Fixed Interval	22934.26	0.00119	0.0064978	Trapezoid	150	1
196R	Automatic Fixed Interval	59203.3	0.00001	0.0066594	Trapezoid	150	1
197R	Automatic Fixed Interval	25298.55	0.00095	0.0151356	Trapezoid	150	1
198R	Automatic Fixed Interval	45880.8	0.00109	0.0140707	Trapezoid	150	1
199R	Automatic Fixed Interval	55726.97	0.00017	0.0028717	Trapezoid	150	1
200R	Automatic Fixed Interval	74055.69	0.00078	0.000363	Trapezoid	150	1
201R	Automatic Fixed Interval	95713.41	0.00405	0.0011626	Trapezoid	150	1
202R	Automatic Fixed Interval	70011.36	0.00064	0.0005380	Trapezoid	150	1
203R	Automatic Fixed Interval	51828.37	0.00081	0.0223951	Trapezoid	150	1
204R	Automatic Fixed Interval	42492.01	0.00043	0.0003608	Trapezoid	150	1
205R	Automatic Fixed Interval	33510.18	0.00155	0.0003660	Trapezoid	150	1
206R	Automatic Fixed Interval	27387.52	0.00115	0.0007748	Trapezoid	150	1
207R	Automatic Fixed Interval	13930.83	0.00224	0.0012669	Trapezoid	150	1
208R	Automatic Fixed Interval	23289.76	0.00168	0.0091331	Trapezoid	150	1
209R	Automatic Fixed Interval	5150.214	0.00491	0.0073668	Trapezoid	150	1
210R	Automatic Fixed Interval	30386.39	0.02309	0.0005679	Trapezoid	150	1
211R	Automatic Fixed Interval	57588.37	0.00729	0.0028362	Trapezoid	150	1
212R	Automatic Fixed Interval	46375.97	0.00097	0.0012594	Trapezoid	150	1
213R	Automatic Fixed Interval	32851.29	0.00091	0.0148293	Trapezoid	150	1
214R	Automatic Fixed Interval	12500.24	0.00014	0.0005725	Trapezoid	150	1
215R	Automatic Fixed Interval	27264.28	0.00063	0.0016412	Trapezoid	150	1
216R	Automatic Fixed Interval	32250.5	0.00094	0.0252714	Trapezoid	150	1

Appendix G. Brgy. Panag Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
221B	0.5	65.8889	0	0.108668	2.6628	277.0038	0.99	0	Ratio to Peak	0
217B	0.5	65.37	0	0.041068	1.528098	77.098	0.99	0	Ratio to Peak	0
219B	0.5	65.328	0	0.0232	0.5672	56.66554	0.99	0	Ratio to Peak	0
212B	0.5	67.10286	0	0.043732	0.7128	47.634	0.99	0	Ratio to Peak	0

Appendix H. Brgy. Panag Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
184R	Automatic Fixed Interval	47589.57	0.0269	0.000237	Trapezoid	30	45
186R	Automatic Fixed Interval	23938.62	0.01462	0.000148	Trapezoid	30	45
185R	Automatic Fixed Interval	47995.05	0.02534	0.000221	Trapezoid	30	45

Appendix I. Brgy. Poblacion Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
204B	0.5	91.124	0	0.1348	7.4962	4.887	0.99	0	Ratio to Peak	0
205B	0.5	92.6519	0	0.0796	3.5932	3.461	0.99	0	Ratio to Peak	0
206B	0.5	92.6519	0	0.018167	0.3554	0.038887	0.99	0	Ratio to Peak	0
207B	0.5	88.064	0	0.052	0.831432	4.5698	0.99	0	Ratio to Peak	0
208B	0.5	90.912	0	0.058132	0.632978	2.1731	0.99	0	Ratio to Peak	0
209B	0.5	84.424	0	0.044668	0.727866	2.8897	0.99	0	Ratio to Peak	0
210B	0.5	90.888	0	0.0384	0.626134	2.6634	0.99	0	Ratio to Peak	0
211B	0.5	88.78	0	0.058132	1.4228	1.4676	0.99	0	Ratio to Peak	0
212B	0.5	87.85187	0	0.043732	0.7128	2.9297	0.99	0	Ratio to Peak	0
213B	0.5	86.868	0	0.0228	0.5586	1.4752	0.99	0	Ratio to Peak	0
214B	0.5	86.356	0	0.021733	0.5316	1.1509	0.99	0	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
215B	107.9	99	0	0.026933	18.394	1.2046	0.99	0	Ratio to Peak	0
216B	0.5	85.95418	0	0.029067	0.7104	1.9869	0.99	0	Ratio to Peak	0
217B	0.5	87.16	0	0.041068	1.528098	4.7418	0.99	0	Ratio to Peak	0
218B	5.5217	99	0	0.021467	2.4883	1.1361	0.99	0	Ratio to Peak	0
219B	0.5	87.104	0	0.0232	0.5672	3.4851	0.99	0	Ratio to Peak	0
220B	12.362	99	0	0.0205	16.247	1.5684	0.99	0	Ratio to Peak	0
221B	0.5	89.47048	0	0.108668	2.6628	17.037	0.99	0	Ratio to Peak	0

Appendix J. Brgy. Poblacion Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
154R	Automatic Fixed Interval	33384.68	0.00258	0.0002	Trapezoid	30	45
184R	Automatic Fixed Interval	47589.57	0.0269	0.003791	Trapezoid	30	45
185R	Automatic Fixed Interval	47995.05	0.02534	0.003544	Trapezoid	30	45
186R	Automatic Fixed Interval	23938.62	0.01462	0.002362	Trapezoid	30	45
187R	Automatic Fixed Interval	10570.09	0.05204	0.5488	Trapezoid	30	45
188R	Automatic Fixed Interval	19441.08	0.02234	0.004837	Trapezoid	30	45
189R	Automatic Fixed Interval	21088.18	0.00893	0.002362	Trapezoid	30	45
190R	Automatic Fixed Interval	18954.75	0.00852	0.002351	Trapezoid	30	45
191R	Automatic Fixed Interval	13018.49	0.00718	0.002362	Trapezoid	30	45
192R	Automatic Fixed Interval	21783.27	0.00197	0.002292	Trapezoid	30	45
193R	Automatic Fixed Interval	56874.88	0.02075	0.002717	Trapezoid	30	45
194R	Automatic Fixed Interval	12718.59	0.00102	0.002717	Trapezoid	30	45
195R	Automatic Fixed Interval	22934.26	0.00119	0.002339	Trapezoid	30	45
197R	Automatic Fixed Interval	25298.55	0.00095	0.002362	Trapezoid	30	45
198R	Automatic Fixed Interval	45880.8	0.00109	0.002362	Trapezoid	30	45

Appendix K. Wawa Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
105B	6.8465	39.4636	0	7.9067	27.6975	0.37648	0.28456	0	Ratio to Peak	0
106B	48.842	68.75	0	9.1206	16.005	0.40039	1	0	Ratio to Peak	0
107B	29.875	77.2024	0	58.36	4.8783	0.89743	1	0	Ratio to Peak	0
108B	23.614	40.8232	0	14.916	5.3355	0.0986430	0.19753	0	Ratio to Peak	0
109B	109.87	42.108	0	0.70544	0.0715905	0.44398	0.0260123	0	Ratio to Peak	0
110B	8.8609	88.4631	0	3.7798	0.611805	0.78372	0.0382381	0	Ratio to Peak	0
113B	34.38	45.6632	0	14.241	26.4645	0.54648	0.29037	0	Ratio to Peak	0
114B	44.402	62.5889	0	0.85339	0.0730638	0.61757	0.011561	0	Ratio to Peak	0
115B	45.707	89.0483	0	0.28315	0.098448	0.11372	0.29037	0	Ratio to Peak	0
116B	43.691	75.3489	0	1.4123	0.16575	0.32554	0.0877915	0	Ratio to Peak	0
119B	48.341	49.0248	0	30.419	10.85805	0.59900	0.19753	0	Ratio to Peak	0

Appendix

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
120B	16.192	73.0609	0	18.709	5.32635	0.21261	0.19753	0	Ratio to Peak	0
121B	34.381	40.2589	0	50.086	26.223	0.17800	0.29037	0	Ratio to Peak	0
122B	23.033	59.1162	0	31.543	16.2945	0.69369	0.29037	0	Ratio to Peak	0
125B	29.889	73.348	0	0.75658	0.82545	0.34875	1	0	Ratio to Peak	0
105B	6.8465	39.4636	0	7.9067	27.6975	0.37648	0.28456	0	Ratio to Peak	0
106B	48.842	68.75	0	9.1206	16.005	0.40039	1	0	Ratio to Peak	0
107B	29.875	77.2024	0	58.36	4.8783	0.89743	1	0	Ratio to Peak	0
108B	23.614	40.8232	0	14.916	5.3355	0.0986430	0.19753	0	Ratio to Peak	0
109B	109.87	42.108	0	0.70544	0.0715905	0.44398	0.0260123	0	Ratio to Peak	0
110B	8.8609	88.4631	0	3.7798	0.611805	0.78372	0.0382381	0	Ratio to Peak	0
113B	34.38	45.6632	0	14.241	26.4645	0.54648	0.29037	0	Ratio to Peak	0

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
114B	44.402	62.5889	0	0.85339	0.0730638	0.61757	0.011561	0	Ratio to Peak	0
115B	45.707	89.0483	0	0.28315	0.098448	0.11372	0.29037	0	Ratio to Peak	0
116B	43.691	75.3489	0	1.4123	0.16575	0.32554	0.0877915	0	Ratio to Peak	0
119B	48.341	49.0248	0	30.419	10.85805	0.59900	0.19753	0	Ratio to Peak	0
120B	16.192	73.0609	0	18.709	5.32635	0.21261	0.19753	0	Ratio to Peak	0
121B	34.381	40.2589	0	50.086	26.223	0.17800	0.29037	0	Ratio to Peak	0
122B	23.033	59.1162	0	31.543	16.2945	0.69369	0.29037	0	Ratio to Peak	0
125B	29.889	73.348	0	0.75658	0.82545	0.34875	1	0	Ratio to Peak	0

Appendix L. Wawa Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
126R	Automatic Fixed Interval	14186.035	0.0091734	0.10539	Trapezoid	0.3	0.45
127R	Automatic Fixed Interval	14168.473	0.0011525	0.0527890	Trapezoid	0.3	0.45
128R	Automatic Fixed Interval	12272.531	0.0040612	0.0362275	Trapezoid	0.3	0.45
129R	Automatic Fixed Interval	12303.208	0.0025234	0.0046000	Trapezoid	0.3	0.45
141R	Automatic Fixed Interval	22504.715	0.0061133	0.0126439	Trapezoid	0.3	0.45
142R	Automatic Fixed Interval	22490.397	0.0060722	0.0499903	Trapezoid	0.3	0.45
143R	Automatic Fixed Interval	37241.442	0.0091438	0.0581014	Trapezoid	0.3	0.45
144R	Automatic Fixed Interval	37229.408	0.0091532	0.0091404	Trapezoid	0.3	0.45
145R	Automatic Fixed Interval	11499.660	0.0011525	0.0011852	Trapezoid	0.3	0.45
146R	Automatic Fixed Interval	11442.582	0.0061232	0.0062258	Trapezoid	0.3	0.45
147R	Automatic Fixed Interval	40865.279	0.0024904	.000393651	Trapezoid	0.3	0.45
148R	Automatic Fixed Interval	40851.625	0.0060537	0.0031234	Trapezoid	0.3	0.45
149R	Automatic Fixed Interval	14512.255	0.0091519	0.10919	Trapezoid	0.3	0.45
150R	Automatic Fixed Interval	14498.902	0.0061294	0.376932	Trapezoid	0.3	0.45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
80R	Automatic Fixed Interval	5436.7	0.01	0.0022	Trapezoid	15	45
81R	Automatic Fixed Interval	32244.0	0.00	0.0017	Trapezoid	15	45
82R	Automatic Fixed Interval	20500.0	0.00	0.0003	Trapezoid	15	45
83R	Automatic Fixed Interval	32337.5	0.00	0.0012	Trapezoid	15	45
84R	Automatic Fixed Interval	43199.3	0.01	0.0033	Trapezoid	15	45
85R	Automatic Fixed Interval	15752.4	0.03	0.0012	Trapezoid	15	45
86R	Automatic Fixed Interval	19948.5	0.00	0.0013	Trapezoid	15	45
87R	Automatic Fixed Interval	40384.2	0.01	0.0003	Trapezoid	15	45
88R	Automatic Fixed Interval	34330.5	0.00	0.0011	Trapezoid	15	45
89R	Automatic Fixed Interval	45395.1	0.02	0.0009	Trapezoid	15	45
90R	Automatic Fixed Interval	10816.0	0.01	0.0004	Trapezoid	15	45
91R	Automatic Fixed Interval	33575.5	0.01	0.0032	Trapezoid	15	45
92R	Automatic Fixed Interval	28124.9	0.01	0.0021	Trapezoid	15	45
93R	Automatic Fixed Interval	17568.4	0.02	0.0006	Trapezoid	15	45
94R	Automatic Fixed Interval	7638.7	0.00	0.0006	Trapezoid	15	45
95R	Automatic Fixed Interval	17770.6	0.01	0.0004	Trapezoid	15	45
96R	Automatic Fixed Interval	13235.9	0.01	0.0004	Trapezoid	15	45
97R	Automatic Fixed Interval	25949.2	0.02	0.0008	Trapezoid	15	45
98R	Automatic Fixed Interval	3893.6	0.01	0.0002	Trapezoid	15	45
99R	Automatic Fixed Interval	17543.9	0.03	0.0003	Trapezoid	15	45

Appendix M. Agusan River Discharge from HEC-HMS Simulation

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
0	0	0	0	5.833333333	0.4	0.1	0
0.166666667	0	0	0	6	0.5	0.1	0
0.333333333	0	0	0	6.166666667	0.7	0.2	0
0.5	0	0	0	6.333333333	0.9	0.2	0
0.666666667	0	0	0	6.5	1.1	0.3	0
0.833333333	0	0	0	6.666666667	1.4	0.5	0
1	0	0	0	6.833333333	1.7	0.6	0
1.166666667	0	0	0	7	2.1	0.8	0.1
1.333333333	0	0	0	7.166666667	2.6	1	0.1
1.5	0	0	0	7.333333333	3.1	1.3	0.2
1.666666667	0	0	0	7.5	3.7	1.6	0.3
1.833333333	0	0	0	7.666666667	4.4	1.9	0.3
2	0	0	0	7.833333333	5.1	2.3	0.5
2.166666667	0	0	0	8	6	2.8	0.6
2.333333333	0	0	0	8.166666667	6.9	3.3	0.7
2.5	0	0	0	8.333333333	7.9	3.8	0.9
2.666666667	0	0	0	8.5	9	4.4	1.1
2.833333333	0	0	0	8.666666667	10.3	5.1	1.4
3	0	0	0	8.833333333	11.6	5.9	1.6
3.166666667	0	0	0	9	13.3	6.9	2
3.333333333	0	0	0	9.166666667	15.4	8.1	2.4
3.5	0	0	0	9.333333333	17.9	9.5	2.9
3.666666667	0	0	0	9.5	20.7	11.2	3.6
3.833333333	0	0	0	9.666666667	24	13.2	4.3
4	0	0	0	9.833333333	27.8	15.5	5.2
4.166666667	0	0	0	10	32.1	18.1	6.3
4.333333333	0	0	0	10.16666667	36.8	21.1	7.4
4.5	0	0	0	10.33333333	42.1	24.3	8.8
4.666666667	0	0	0	10.5	48	28	10.3
4.833333333	0	0	0	10.66666667	54.5	32.2	12.1
5	0.1	0	0	10.83333333	61.8	36.9	14.2
5.166666667	0.1	0	0	11	70.1	42.3	16.7
5.333333333	0.1	0	0	11.16666667	79.3	48.4	19.5
5.5	0.2	0	0	11.33333333	89.5	55.2	22.8
5.666666667	0.3	0	0	11.5	101	63	26.6
5.83333333	0	0	0	11.66666667	114.7	72.3	31.4
				11.83333333	133.7	85.8	38.8
				12	155.9	101.7	47.7
				12.16666667	179.8	118.8	57.3

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
11.66666667	114.7	72.3	31.4	17.16666667	1842.2	1337.4	769.6
11.83333333	133.7	85.8	38.8	17.33333333	1930.8	1402.9	808.5
12	155.9	101.7	47.7	17.5	2023.4	1471.5	849.4
12.16666667	179.8	118.8	57.3	17.66666667	2118.7	1542.1	891.4
12.33333333	205.5	137.3	67.8	17.83333333	2215.6	1613.9	934.2
6.666666667	1.4	0.5	0	18	2314.1	1686.9	977.7
6.833333333	1.7	0.6	0	18.16666667	2414.1	1761	1021.9
7	2.1	0.8	0.1	18.33333333	2515.6	1836.2	1066.8
7.166666667	2.6	1	0.1	18.5	2618.5	1912.5	1112.3
7.333333333	3.1	1.3	0.2	18.66666667	2722.8	1989.8	1158.5
7.5	3.7	1.6	0.3	18.83333333	2828.5	2068.2	1205.3
12.66666667	261.7	177.8	90.7	19	2935.8	2147.7	1252.7
12.83333333	292.2	199.7	103.2	19.16666667	3044.4	2228.2	1300.9
13	324	222.7	116.2	19.33333333	3154.6	2310	1349.7
13.16666667	357.3	246.7	129.9	19.5	3266.6	2393	1399.2
13.33333333	392.1	271.8	144.2	19.66666667	3380.3	2477.3	1449.6
13.5	428.3	298	159.1	19.83333333	3495.9	2563	1500.8
13.66666667	466	325.2	174.6	20	3614	2650.7	1553.2
13.83333333	505.5	353.8	190.8	20.16666667	3737.2	2742.1	1608
14	546.8	383.6	207.8	20.33333333	3865	2837.2	1665.1
14.16666667	590.1	414.9	225.6	20.5	3995.8	2934.5	1723.6
14.33333333	635.7	448	244.5	20.66666667	4128.7	3033.4	1783.1
14.5	685.6	484.3	265.3	20.83333333	4263.7	3133.9	1843.5
14.66666667	742.3	525.8	289.5	21	4400.7	3235.8	1904.8
14.83333333	802.9	570.3	315.6	21.16666667	4539.7	3339.2	1967.1
15	865.8	616.5	342.8	21.33333333	4680.4	3444	2030.1
15.16666667	930.7	664.4	370.9	21.5	4822.9	3550.1	2094
15.33333333	997.5	713.6	400	21.66666667	4967.3	3657.6	2158.7
15.5	1066.2	764.3	429.9	21.83333333	5113.5	3766.5	2224.3
15.66666667	1136.8	816.3	460.7	22	5261.5	3876.7	2290.6
15.83333333	1208.8	869.5	492.1	22.16666667	5411.6	3988.5	2357.9
16	1282.4	923.9	524.4	22.33333333	5563.9	4101.9	2426.2
16.16666667	1357.7	979.4	557.4	22.5	5718.3	4217	2495.5
16.33333333	1434.3	1036.1	591	22.66666667	5875.3	4333.9	2565.9
16.5	1512.5	1093.8	625.2	22.83333333	6035.7	4453.5	2637.9
16.66666667	1592.3	1152.8	660.2	23	6203.4	4578.7	2713.6
16.83333333	1673.7	1212.9	695.8	23.16666667	6376.3	4707.9	2791.8
17	1756.9	1274.4	732.3	23.33333333	6552.1	4839.4	2871.5
17.16666667	1842.2	1337.4	769.6				
17.33333333	1930.8	1402.9	808.5				
17.5	2023.4	1471.5	849.4				
17.66666667	2118.7	1542.1	891.4				
17.83333333	2215.6	1613.9	934.2				

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
23.5	6730.5	4972.9	2952.5	29.83333333	14640.7	10940.1	6627.3
23.66666667	6911.1	5108.1	3034.6	30	14845.1	11095.8	6724.7
23.83333333	7094	5244.9	3117.8	30.16666667	15048.2	11250.5	6821.7
24	7278.9	5383.4	3202	30.33333333	15250.1	11404.3	6918.2
24.16666667	7465.6	5523.3	3287.1	30.5	15450.4	11557.1	7014.2
24.33333333	7654.1	5664.5	3373.1	30.66666667	15649	11708.7	7109.6
24.5	7844.5	5807.2	3459.9	30.83333333	15845.8	11859	7204.4
24.66666667	8036.5	5951.1	3547.6	31	16040.5	12007.9	7298.3
24.83333333	8230.2	6096.4	3636.1	31.16666667	16232.4	12154.6	7391
25	8425.8	6243.1	3725.5	31.33333333	16417.9	12296.5	7480.8
25.16666667	8623.4	6391.3	3815.7	31.5	16596.2	12433	7567.1
25.33333333	8822.9	6540.9	3906.9	31.66666667	16770.6	12566.5	7651.7
25.5	9024.7	6692.3	3999.2	31.83333333	16942.4	12698.1	7735.1
25.66666667	9229.6	6846.2	4093	32	17111.8	12828	7817.5
25.83333333	9440.2	7004.4	4189.8	32.16666667	17278.9	12956.1	7898.9
26	9654.1	7165.3	4288.3	32.33333333	17443.5	13082.5	7979.3
26.16666667	9869.6	7327.6	4387.8	32.5	17606	13207.3	8058.8
26.33333333	10086.5	7491	4488.2	32.66666667	17766.5	13330.6	8137.4
26.5	10304.5	7655.4	4589.3	32.83333333	17924.8	13452.3	8215.1
26.66666667	10523.6	7820.6	4691.1	33	18080.9	13572.5	8291.9
26.83333333	10743.6	7986.7	4793.4	33.16666667	18235.1	13691.2	8367.8
27	10964.3	8153.4	4896.3	33.33333333	18386.9	13808.2	8442.9
27.16666667	11185.6	8320.6	4999.6	33.5	18536.2	13923.4	8516.9
27.33333333	11407.3	8488.3	5103.3	33.66666667	18683	14036.8	8589.9
27.5	11629.3	8656.2	5207.2	33.83333333	18826.9	14148	8661.6
27.66666667	11851.5	8824.3	5311.3	34	18966.9	14256.3	8731.6
27.83333333	12073.6	8992.5	5415.5	34.16666667	19098.6	14358.4	8797.7
28	12295.8	9160.7	5519.8	34.33333333	19223.3	14455	8860.4
28.16666667	12517.8	9328.9	5624.2	34.5	19344	14548.7	8921.2
28.33333333	12739.3	9496.7	5728.3	34.66666667	19461.8	14640.1	8980.7
28.5	12958.6	9663	5831.6	34.83333333	19576.9	14729.6	9039
28.66666667	13174	9826.2	5933	35	19689.4	14817.1	9096.1
28.83333333	13387.5	9988.1	6033.5	35.16666667	19799.3	14902.7	9152
29	13599.6	10149	6133.6	35.33333333	19906.6	14986.4	9206.8
29.16666667	13810.4	10309	6233.2	35.5	20011.7	15068.4	9260.5
29.33333333	14019.9	10468.1	6332.4	35.66666667	20114.3	15148.4	9313.1
29.5	14228.1	10626.3	6431.1	35.83333333	20214.5	15226.8	9364.6
29.66666667	14434.9	10783.6	6529.4	36	20312.3	15303.4	9415.1
29.83333333	14640.7	10940.1	6627.3				

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
36.16666667	20407.5	15378	9464.5	42.5	21636.1	16399.5	10207.5
36.33333333	20499.8	15450.5	9512.6	42.66666667	21608.8	16381	10198.5
36.5	20589.3	15521	9559.5	42.83333333	21576.8	16358.7	10187.1
36.66666667	20675.5	15589	9605	43	21541.7	16334.1	10174.1
36.83333333	20757.2	15653.5	9648.3	43.16666667	21503.8	16307.3	10159.7
37	20829.4	15710.8	9687	43.33333333	21463.4	16278.5	10144
37.16666667	20895.4	15763.3	9722.6	43.5	21420.6	16247.9	10127.1
37.33333333	20957.9	15813.1	9756.5	43.66666667	21375.6	16215.5	10109
37.5	21017.4	15860.6	9789	43.83333333	21328.8	16181.7	10090
37.66666667	21074.4	15906.2	9820.2	44	21280	16146.4	10070
37.83333333	21128.7	15949.8	9850.2	44.16666667	21229.3	16109.7	10049.1
38	21180.4	15991.4	9878.8	44.33333333	21177.1	16071.7	10027.4
38.16666667	21229.9	16031.2	9906.4	44.5	21123.1	16032.4	10004.9
38.33333333	21277.2	16069.3	9932.9	44.66666667	21067.3	15991.7	9981.6
38.5	21322.1	16105.6	9958.2	44.83333333	21009.8	15949.8	9957.4
38.66666667	21364.9	16140.4	9982.5	45	20950.4	15906.4	9932.4
38.83333333	21405.6	16173.6	10005.9	45.16666667	20889.1	15861.5	9906.4
39	21444.1	16205	10028.2	45.33333333	20824.9	15814.5	9879.1
39.16666667	21480.4	16234.8	10049.5	45.5	20758	15765.4	9850.5
39.33333333	21514.3	16262.8	10069.7	45.66666667	20689.1	15714.7	9820.8
39.5	21545.7	16288.9	10088.7	45.83333333	20618.8	15662.9	9790.5
39.66666667	21573.6	16312.5	10106.2	46	20547.3	15610.2	9759.5
39.83333333	21596.4	16332	10121.1	46.16666667	20474.6	15556.5	9727.8
40	21615.5	16348.8	10134.3	46.33333333	20400.7	15502	9695.6
40.16666667	21632.1	16363.7	10146.3	46.5	20325.9	15446.7	9662.9
40.33333333	21646.6	16376.9	10157.3	46.66666667	20250.1	15390.6	9629.6
40.5	21658.9	16388.6	10167.3	46.83333333	20173.2	15333.7	9595.9
40.66666667	21669.2	16398.7	10176.3	47	20095.3	15276.1	9561.6
40.83333333	21677.5	16407.3	10184.4	47.16666667	20016.5	15217.6	9526.8
41	21683.9	16414.5	10191.7	47.33333333	19936.6	15158.4	9491.5
41.16666667	21688.3	16420.3	10198	47.5	19855.6	15098.3	9455.6
41.33333333	21690.7	16424.4	10203.4	47.66666667	19773.5	15037.4	9419.2
41.5	21691	16427	10207.8	47.83333333	19690.3	14975.6	9382.2
41.66666667	21689.2	16427.9	10211.1	48	19605.6	14912.6	9344.6
41.83333333	21684.8	16427	10213.4	48.16666667	19518.5	14847.9	9305.7
42	21677.9	16424.2	10214.5	48.33333333	19429.4	14781.6	9265.8
42.16666667	21668.3	16419.3	10214.3	48.5	19338.9	14714.1	9225.2
42.33333333	21655.3	16411.8	10212.4	48.66666667	19247.1	14645.7	9184
25.16666667	8623.4	6391.3	3815.7				

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
48.83333333	19154.2	14576.5	9142.2	55.16666667	14654.8	11199.7	7081
49	19060.2	14506.4	9099.9	55.33333333	14513.3	11092.6	7014.6
49.16666667	18965.2	14435.5	9057.2	55.5	14371.7	10985.4	6948.1
49.33333333	18869.3	14364.1	9014	55.66666667	14230.1	10878.1	6881.5
49.5	18772.6	14291.9	8970.5	55.83333333	14088.5	10770.8	6814.9
49.66666667	18674.9	14219	8926.4	56	13947.1	10663.6	6748.2
49.83333333	18576.3	14145.4	8882	56.16666667	13805.8	10556.5	6681.6
50	18476.7	14071.1	8837.1	56.33333333	13665	10449.7	6615.2
50.16666667	18376	13996	8791.6	56.5	13526	10344.3	6549.7
50.33333333	18274.2	13920	8745.7	56.66666667	13389.4	10240.7	6485.3
50.5	18171.3	13843.1	8699.3	56.83333333	13254	10138.1	6421.4
50.66666667	18067.1	13765.3	8652.2	57	13119.5	10036	6357.9
50.83333333	17961	13686	8604.2	57.16666667	12985.9	9934.6	6294.7
51	17851	13603.7	8554.2	57.33333333	12853.2	9833.8	6231.8
51.16666667	17738.5	13519.5	8503	57.5	12721.3	9733.6	6169.3
51.33333333	17624.5	13434.1	8451.1	57.66666667	12590.2	9634	6107.1
51.5	17509.2	13347.6	8398.4	57.83333333	12459.9	9534.9	6045.1
51.66666667	17392.5	13260.2	8345.2	58	12330.3	9436.3	5983.4
51.83333333	17274.7	13171.9	8291.3	58.16666667	12201.6	9338.4	5922.1
52	17155.7	13082.6	8236.9	58.33333333	12073.7	9241	5861
52.16666667	17035.6	12992.6	8181.9	58.5	11946.7	9144.2	5800.2
52.33333333	16914.6	12901.8	8126.5	58.66666667	11820.8	9048.2	5739.9
52.5	16792.4	12810.1	8070.5	58.83333333	11695.9	8953	5680
52.66666667	16669.3	12717.7	8014.1	59	11572.3	8858.7	5620.6
52.83333333	16545.2	12624.4	7957.1	59.16666667	11450.6	8765.7	5561.9
53	16419.9	12530.4	7899.7	59.33333333	11333	8675.9	5505.3
53.16666667	16293.4	12435.4	7841.6	59.5	11219.2	8589.1	5450.6
53.33333333	16165.7	12339.4	7783	59.66666667	11107.3	8503.7	5396.7
53.5	16036.5	12242.4	7723.7	59.83333333	10996.8	8419.4	5343.5
53.66666667	15905.2	12143.7	7663.3	60	10887.5	8335.9	5290.9
53.83333333	15770.3	12042.2	7601	60.16666667	10779.4	8253.4	5238.8
54	15633.6	11939.1	7537.7	60.33333333	10672.4	8171.7	5187.3
54.16666667	15495.8	11835.2	7473.8	60.5	10566.4	8090.7	5136.2
54.33333333	15357.1	11730.6	7409.3	60.66666667	10461.3	8010.5	5085.5
54.5	15217.7	11625.3	7344.4	60.83333333	10357.2	7930.9	5035.3
54.66666667	15077.6	11519.5	7279	61	10253.8	7852	4985.4
54.83333333	14937	11413.2	7213.3	61.16666667	10151.3	7773.6	4935.9
55	14796.1	11306.6	7147.3	61.33333333	10049.7	7695.9	4886.7
55.16666667	14654.8	11199.7	7081	61.5	9948.9	7618.9	4837.9
55.33333333	14513.3	11092.6	7014.6	61.66666667	9849.1	7542.5	4789.5

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
55.5	14371.7	10985.4	6948.1	61.83333333	9750.2	7466.8	4741.4
				62	9652.5	7392	4694
				62.16666667	9557.1	7318.9	4647.5
				62.33333333	9463.3	7247	4601.9
				62.5	9370.5	7175.9	4556.6
61.5	9948.9	7618.9	4837.9	67.83333333	6812.4	5212.5	3304.5
61.66666667	9849.1	7542.5	4789.5	68	6749.2	5164	3273.6
61.83333333	9750.2	7466.8	4741.4	68.16666667	6686.9	5116.1	3243
62	9652.5	7392	4694	68.33333333	6625.4	5069	3213
62.16666667	9557.1	7318.9	4647.5	68.5	6564.7	5022.4	3183.3
62.33333333	9463.3	7247	4601.9	68.66666667	6504.7	4976.4	3154
62.5	9370.5	7175.9	4556.6	68.83333333	6445.3	4930.9	3125
62.66666667	9278.4	7105.3	4511.7	69	6386.5	4885.8	3096.3
62.83333333	9186.9	7035.2	4467.1	69.16666667	6328.3	4841.2	3068
63	9096	6965.5	4422.8	69.33333333	6270.5	4797	3039.9
63.16666667	9005.8	6896.4	4378.8	69.5	6213.3	4753.1	3012
63.33333333	8916.2	6827.7	4335.1	69.66666667	6156.5	4709.6	2984.4
63.5	8827.2	6759.4	4291.6	69.83333333	6100.2	4666.5	2957
63.66666667	8738.9	6691.7	4248.5	70	6044.3	4623.8	2929.9
63.83333333	8651.2	6624.4	4205.7	70.16666667	5989	4581.4	2902.9
64	8564.1	6557.6	4163.1	70.33333333	5934.1	4539.4	2876.3
64.16666667	8477.7	6491.3	4120.9	70.5	5879.8	4497.8	2849.8
64.33333333	8391.9	6425.5	4079	70.66666667	5825.9	4456.6	2823.7
64.5	8306.9	6360.3	4037.4	70.83333333	5772.6	4415.7	2797.7
64.66666667	8222.8	6295.7	3996.2	71	5719.6	4375.2	2772
64.83333333	8139.7	6232	3955.5	71.16666667	5667	4334.9	2746.4
65	8058.8	6169.9	3915.9	71.33333333	5614.6	4294.9	2721
65.16666667	7979.3	6108.8	3877	71.5	5562.6	4255	2695.8
65.33333333	7900.6	6048.4	3838.4	71.66666667	5510.8	4215.4	2670.6
65.5	7822.7	5988.6	3800.3	71.83333333	5459.2	4175.9	2645.6
65.66666667	7745.5	5929.3	3762.4	72	5407.9	4136.7	2620.7
65.83333333	7668.9	5870.5	3724.9	72.16666667	5356.9	4097.6	2595.9
66	7593.1	5812.3	3687.8	72.33333333	5306.2	4058.8	2571.3
66.16666667	7518	5754.6	3650.9	72.5	5255.7	4020.2	2546.9
66.33333333	7443.6	5697.5	3614.4	72.66666667	5205.7	3981.9	2522.6
66.5	7369.9	5640.9	3578.3	72.83333333	5155.9	3943.9	2498.4
66.66666667	7296.9	5584.8	3542.5	73	5106.6	3906.1	2474.5
66.83333333	7224.7	5529.3	3507.1	73.16666667	5057.8	3868.7	2450.8
67	7153.2	5474.4	3472	73.33333333	5010	3832.2	2427.7

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
67.16666667	7082.6	5420.1	3437.3	73.5	4963.1	3796.4	2405
67.33333333	7012.8	5366.5	3403	73.66666667	4916.8	3761	2382.6
67.5	6944.1	5313.7	3369.2	73.83333333	4870.9	3725.9	2360.4
67.66666667	6877	5262.1	3336.3	74	4825.3	3691.1	2338.4
68	6749.2	5164	3273.6	74.16666667	4780.2	3656.6	2316.7
55.33333333	14513.3	11092.6	7014.6	74.33333333	4735.3	3622.3	2295
55.5	14371.7	10985.4	6948.1	74.5	4690.8	3588.3	2273.5
				62	9652.5	7392	4694
				62.16666667	9557.1	7318.9	4647.5
				62.33333333	9463.3	7247	4601.9
				62.5	9370.5	7175.9	4556.6
74.16666667	4780.2	3656.6	2316.7	80.5	3296.1	2522.2	1599.2
74.33333333	4735.3	3622.3	2295	80.66666667	3265.2	2498.6	1584.3
74.5	4690.8	3588.3	2273.5	80.83333333	3234.6	2475.2	1569.5
74.66666667	4646.5	3554.5	2252.2	81	3204.2	2452	1554.8
74.83333333	4602.4	3520.9	2231	81.16666667	3174.1	2428.9	1540.2
75	4558.7	3487.4	2209.9	81.33333333	3144.1	2406.1	1525.7
75.16666667	4515.1	3454.2	2188.9	81.5	3114.4	2383.4	1511.3
75.33333333	4471.8	3421.1	2168	81.66666667	3085	2360.8	1497.1
75.5	4428.7	3388.2	2147.3	81.83333333	3055.8	2338.5	1482.9
75.66666667	4385.8	3355.5	2126.6	82	3026.9	2316.4	1468.8
75.83333333	4343.2	3323	2106.1	82.16666667	2998.1	2294.3	1454.8
76	4300.8	3290.6	2085.7	82.33333333	2969.4	2272.4	1440.9
76.16666667	4258.7	3258.5	2065.4	82.5	2940.9	2250.6	1427.1
76.33333333	4217	3226.6	2045.2	82.66666667	2912.6	2228.9	1413.3
76.5	4175.5	3194.9	2025.2	82.83333333	2884.4	2207.3	1399.6
76.66666667	4134.2	3163.4	2005.3	83	2856.4	2185.8	1385.9
76.83333333	4093.2	3132	1985.4	83.16666667	2828.5	2164.5	1372.3
77	4052.4	3100.8	1965.7	83.33333333	2800.8	2143.2	1358.9
77.16666667	4011.9	3069.8	1946.1	83.5	2773.3	2122.2	1345.5
77.33333333	3971.6	3039	1926.6	83.66666667	2746	2101.2	1332.2
77.5	3931.5	3008.3	1907.1	83.83333333	2718.9	2080.5	1319
77.66666667	3891.6	2977.8	1887.8	84	2692	2059.9	1305.9
77.83333333	3852.1	2947.6	1868.6	84.16666667	2665.4	2039.5	1292.9
78	3812.8	2917.5	1849.6	84.33333333	2639.2	2019.4	1280.2
78.16666667	3774	2887.8	1830.7	84.5	2613.6	1999.8	1267.7
78.33333333	3735.5	2858.3	1812	84.66666667	2588.8	1980.8	1255.7
78.5	3697.4	2829.1	1793.4	84.83333333	2564.4	1962.1	1243.8
78.66666667	3659.8	2800.3	1775.1	85	2540.2	1943.6	1232.1

Appendix

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
78.83333333	3623	2772.1	1757.3	85.16666667	2516.3	1925.4	1220.5
79	3588	2745.3	1740.3	85.33333333	2492.7	1907.3	1209.1
79.16666667	3553.8	2719.2	1723.7	85.5	2469.3	1889.4	1197.7
79.33333333	3520.2	2693.4	1707.4	85.66666667	2446	1871.6	1186.5
79.5	3487.1	2668.1	1691.4	85.83333333	2423	1854	1175.3
79.66666667	3454.4	2643.1	1675.6	86	2400.1	1836.5	1164.3
79.83333333	3422.1	2618.4	1660	86.16666667	2377.3	1819.1	1153.3
80	3390.2	2594.1	1644.6	86.33333333	2354.7	1801.8	1142.3
80.16666667	3358.5	2569.9	1629.3	86.5	2332.3	1784.7	1131.5
80.33333333	3327.2	2545.9	1614.2	86.66666667	2309.9	1767.6	1120.7
55.16666667	14654.8	11199.7	7081	61.5	9948.9	7618.9	4837.9
55.33333333	14513.3	11092.6	7014.6	61.66666667	9849.1	7542.5	4789.5
55.5	14371.7	10985.4	6948.1	61.83333333	9750.2	7466.8	4741.4
				62	9652.5	7392	4694
				62.16666667	9557.1	7318.9	4647.5
				62.33333333	9463.3	7247	4601.9
				62.5	9370.5	7175.9	4556.6
86.83333333	2287.8	1750.6	1109.9	93.16666667	1574.9	1205.4	764.5
87	2265.7	1733.8	1099.3	93.33333333	1559.4	1193.5	757
87.16666667	2243.8	1717.1	1088.7	93.5	1543.9	1181.7	749.5
87.33333333	2222.1	1700.4	1078.2	93.66666667	1528.5	1169.9	742
87.5	2200.6	1684	1067.7	93.83333333	1513.2	1158.2	734.6
87.66666667	2179.1	1667.6	1057.3	94	1498	1146.5	727.2
87.83333333	2157.9	1651.3	1047	94.16666667	1482.9	1135	719.8
88	2136.7	1635.1	1036.7	94.33333333	1467.9	1123.5	712.5
88.16666667	2115.6	1619	1026.5	94.5	1453	1112.1	705.3
88.33333333	2094.7	1602.9	1016.3	94.66666667	1438.2	1100.7	698.1
88.5	2073.8	1587	1006.2	94.83333333	1423.6	1089.5	690.9
88.66666667	2053.1	1571.1	996.1	95	1409	1078.3	683.8
88.83333333	2032.5	1555.4	986.1	95.16666667	1394.7	1067.3	676.8
89	2012.1	1539.7	976.2	95.33333333	1380.4	1056.4	669.9
89.16666667	1991.8	1524.2	966.3	95.5	1366.4	1045.7	663.1
89.33333333	1971.7	1508.8	956.6	95.66666667	1352.8	1035.2	656.4
89.5	1951.8	1493.5	946.9	95.83333333	1339.7	1025.2	650.1
89.66666667	1932.1	1478.4	937.3	96	1327	1015.4	643.8
89.83333333	1912.6	1463.5	927.8	96.16666667	1314.4	1005.8	637.7
90	1893.4	1448.8	918.5	96.33333333	1301.9	996.3	631.7
90.16666667	1874.9	1434.6	909.5	96.5	1289.7	986.9	625.8
90.33333333	1856.9	1420.9	900.8	96.66666667	1277.6	977.6	619.9

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
90.5	1839.1	1407.2	892.1	96.83333333	1265.6	968.5	614.1
90.66666667	1821.5	1393.8	883.7	97	1253.7	959.4	608.3
90.83333333	1804.2	1380.6	875.3	97.16666667	1241.9	950.4	602.6
91	1787	1367.4	867	97.33333333	1230.2	941.4	597
91.16666667	1770	1354.5	858.8	97.5	1218.6	932.6	591.3
91.33333333	1753.1	1341.6	850.6	97.66666667	1207.1	923.8	585.8
91.5	1736.4	1328.8	842.6	97.83333333	1195.7	915	580.2
91.66666667	1719.7	1316.1	834.5	98	1184.3	906.3	574.7
91.83333333	1703.2	1303.5	826.6	98.16666667	1173.1	897.7	569.3
92	1686.8	1290.9	818.6	98.33333333	1161.9	889.2	563.9
92.16666667	1670.5	1278.4	810.8	98.5	1150.9	880.7	558.5
92.33333333	1654.3	1266.1	802.9	98.66666667	1139.9	872.3	553.2
92.5	1638.2	1253.8	795.1	98.83333333	1129	864	547.9
92.66666667	1622.2	1241.5	787.4	99	1118.2	855.7	542.6
92.83333333	1606.3	1229.4	779.7	99.16666667	1107.5	847.5	537.4
93	1590.5	1217.3	772.1	99.33333333	1096.8	839.3	532.2
68	6749.2	5164	3273.6	74.16666667	4780.2	3656.6	2316.7
55.33333333	14513.3	11092.6	7014.6	74.33333333	4735.3	3622.3	2295
55.5	14371.7	10985.4	6948.1	74.5	4690.8	3588.3	2273.5
				62	9652.5	7392	4694
				62.16666667	9557.1	7318.9	4647.5
				62.33333333	9463.3	7247	4601.9
				62.5	9370.5	7175.9	4556.6
99.5	1086.1	831.2	527	106	745.9	570.7	361.7
99.66666667	1075.6	823.1	521.8	106.1666667	738.5	565	358.1
99.83333333	1065.1	815	516.7	106.3333333	731.2	559.4	354.5
100	1054.6	807	511.6	106.5	724	553.9	351
100.1666667	1044.3	799.1	506.6	106.6666667	716.9	548.4	347.6
100.3333333	1034	791.2	501.6	106.8333333	709.9	543.1	344.2
100.5	1023.8	783.3	496.6	107	703.2	537.9	340.9
100.6666667	1013.7	775.6	491.7	107.1666667	696.6	532.9	337.7
100.8333333	1003.7	767.9	486.8	107.3333333	690.1	527.9	334.6
101	993.8	760.3	481.9	107.5	683.7	523	331.5
101.1666667	984	752.9	477.2	107.6666667	677.3	518.2	328.4
101.3333333	974.6	745.6	472.6	107.8333333	671.1	513.4	325.4
101.5	965.4	738.6	468.1	108	664.8	508.6	322.4
101.6666667	956.4	731.7	463.8	108.1666667	658.7	503.9	319.4
101.8333333	947.5	724.9	459.4	108.3333333	652.6	499.3	316.4
102	938.7	718.2	455.2	108.5	646.5	494.6	313.5

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
102.1666667	930	711.5	450.9	108.6666667	640.4	490	310.6
102.3333333	921.3	704.9	446.8	108.8333333	634.4	485.4	307.7
102.5	912.8	698.3	442.6	109	628.5	480.9	304.8
102.6666667	904.3	691.9	438.5	109.1666667	622.5	476.3	301.9
102.8333333	895.8	685.4	434.4	109.3333333	616.7	471.8	299.1
103	887.5	679	430.4	109.5	610.8	467.4	296.3
103.1666667	879.2	672.6	426.4	109.6666667	605	462.9	293.5
103.3333333	870.9	666.3	422.4	109.8333333	599.3	458.5	290.7
103.5	862.7	660.1	418.4	110	593.5	454.2	287.9
103.6666667	854.5	653.8	414.4	110.1666667	587.9	449.8	285.1
103.8333333	846.4	647.6	410.5	110.3333333	582.2	445.5	282.4
104	838.4	641.5	406.6	110.5	576.6	441.2	279.7
104.1666667	830.4	635.4	402.8	110.6666667	571	436.9	277
104.3333333	822.5	629.3	398.9	110.8333333	565.4	432.6	274.2
104.5	814.6	623.3	395.1	111	559.9	428.4	271.6
104.6666667	806.8	617.3	391.3	111.1666667	554.3	424.2	268.9
104.8333333	799	611.4	387.5	111.3333333	548.9	420	266.2
105	791.3	605.4	383.8	111.5	543.4	415.8	263.6
105.1666667	783.6	599.6	380	111.6666667	538	411.7	261
105.3333333	776	593.7	376.3	111.8333333	532.7	407.6	258.4
105.5	768.4	587.9	372.6	112	527.4	403.5	255.8
105.6666667	760.8	582.1	368.9	112.1666667	522.1	399.5	253.2
105.8333333	753.3	576.4	365.3	61.5	9948.9	7618.9	4837.9
55.33333333	14513.3	11092.6	7014.6	61.66666667	9849.1	7542.5	4789.5
55.5	14371.7	10985.4	6948.1	61.83333333	9750.2	7466.8	4741.4
				62	9652.5	7392	4694
				62.16666667	9557.1	7318.9	4647.5
				62.33333333	9463.3	7247	4601.9
				62.5	9370.5	7175.9	4556.6
112.3333333	517	395.5	250.7	118.6666667	356.2	272.5	172.7
112.5	511.9	391.7	248.3	118.8333333	352.9	270	171.1
112.6666667	507	388	245.9	119	349.6	267.5	169.6
112.8333333	502.2	384.3	243.6	119.1666667	346.4	265	168
113	497.5	380.6	241.3	119.3333333	343.2	262.6	166.4
113.1666667	492.7	377	239	119.5	340	260.1	164.9
113.3333333	488.1	373.5	236.7	119.6666667	336.9	257.7	163.4
113.5	483.5	369.9	234.5	119.8333333	333.7	255.4	161.9
113.6666667	478.9	366.4	232.3	120	330.7	253	160.4
113.8333333	474.3	363	230.1				

114	469.8	359.5	227.9				
114.1666667	465.3	356.1	225.8				
114.3333333	460.8	352.7	223.6				
114.5	456.4	349.3	221.5				
114.6666667	452	345.9	219.3				
114.8333333	447.6	342.6	217.2				
115	443.3	339.2	215.1				
115.1666667	438.9	335.9	213				
115.3333333	434.6	332.6	210.9				
115.5	430.4	329.4	208.9				
115.6666667	426.2	326.1	206.8				
115.8333333	422	322.9	204.8				
116	417.8	319.7	202.8				
116.1666667	413.6	316.5	200.7				
116.3333333	409.5	313.4	198.7				
116.5	405.4	310.2	196.7				
116.6666667	401.3	307.1	194.7				
116.8333333	397.2	304	192.8				
117	393.2	300.9	190.8				
117.1666667	389.2	297.8	188.9				
117.3333333	385.3	294.8	186.9				
117.5	381.3	291.8	185				
117.6666667	377.5	288.8	183.1				
117.8333333	373.7	285.9	181.3				
118	369.9	283.1	179.4				
118.1666667	366.4	280.3	177.7				
118.3333333	362.9	277.7	176				
118.5	359.5	275.1	174.4				
68	6749.2	5164	3273.6	74.16666667	4780.2	3656.6	2316.7
55.33333333	14513.3	11092.6	7014.6	74.33333333	4735.3	3622.3	2295
55.5	14371.7	10985.4	6948.1	74.5	4690.8	3588.3	2273.5
				62	9652.5	7392	4694
				62.16666667	9557.1	7318.9	4647.5
				62.33333333	9463.3	7247	4601.9
				62.5	9370.5	7175.9	4556.6

DREAM

Disaster RIsk and Exposure Assessment for Mitigation