REGION 4B

Mag-asawang Tubig River Basin:

DREAM Flood Forecasting and Flood Hazard Mapping

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

2015

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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.

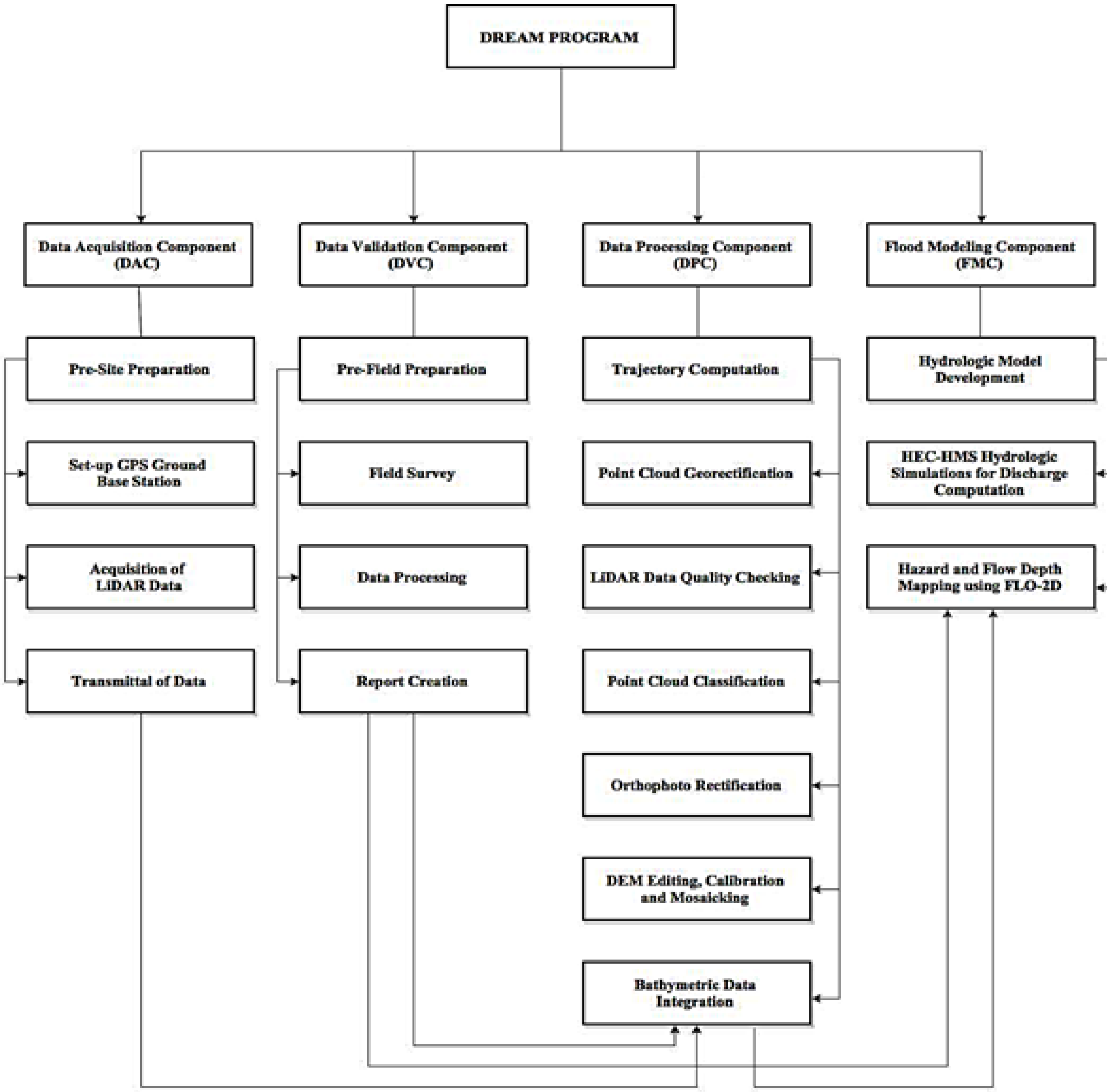


Figure 1. The general methodological framework of the program

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 Mag-asawang Tubig 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 Mag-asawang Tubig floodplain using FLO-2D GDS Pro; and
d) To prepare the static flood hazard and flow depth maps for the Mag-asawang Tubig 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.

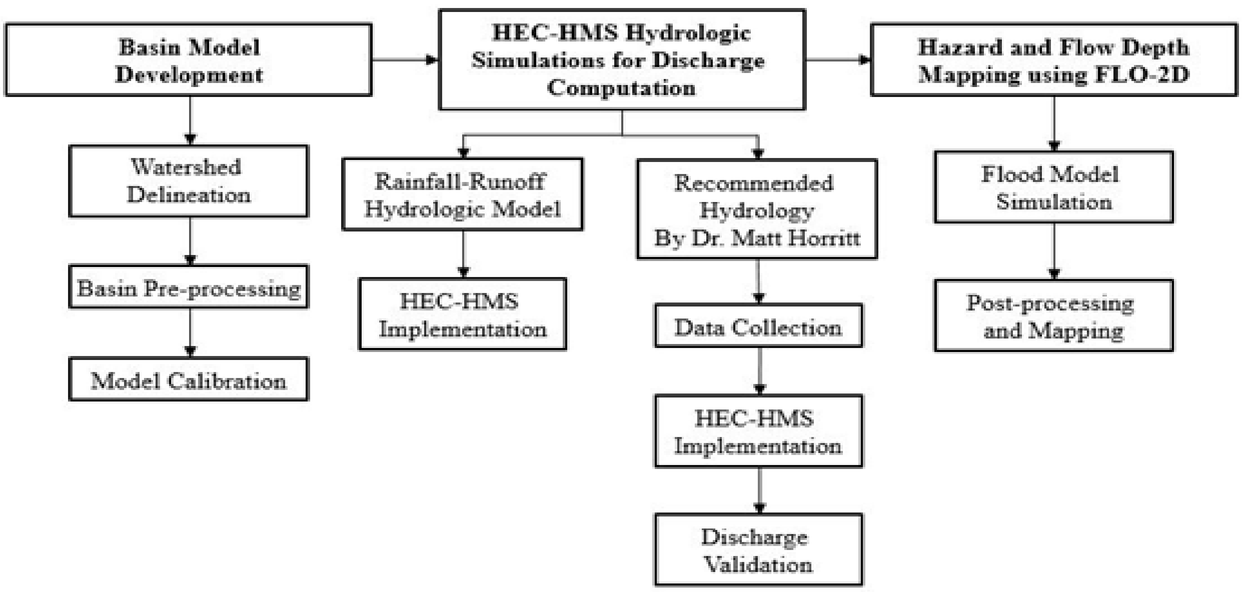


Figure 2. The operational framework and specific work flow of the Flood Modeling Component

The Mag-asawang Tubig River Basin

The Mag-asawang Tubig River Basin

The Mag-asawang Tubig River Basin is located in the island of Mindoro, northeast of Palawan. It traverses through Calapan City in Oriental Mindoro and the municipalities of San Teodoro, Baco, Naujan, Victoria and Sablayan. It covers an estimate area of 491 square kilometres.The location of the Mag-asawang Tubig River Basin is as shown in Figure 3.

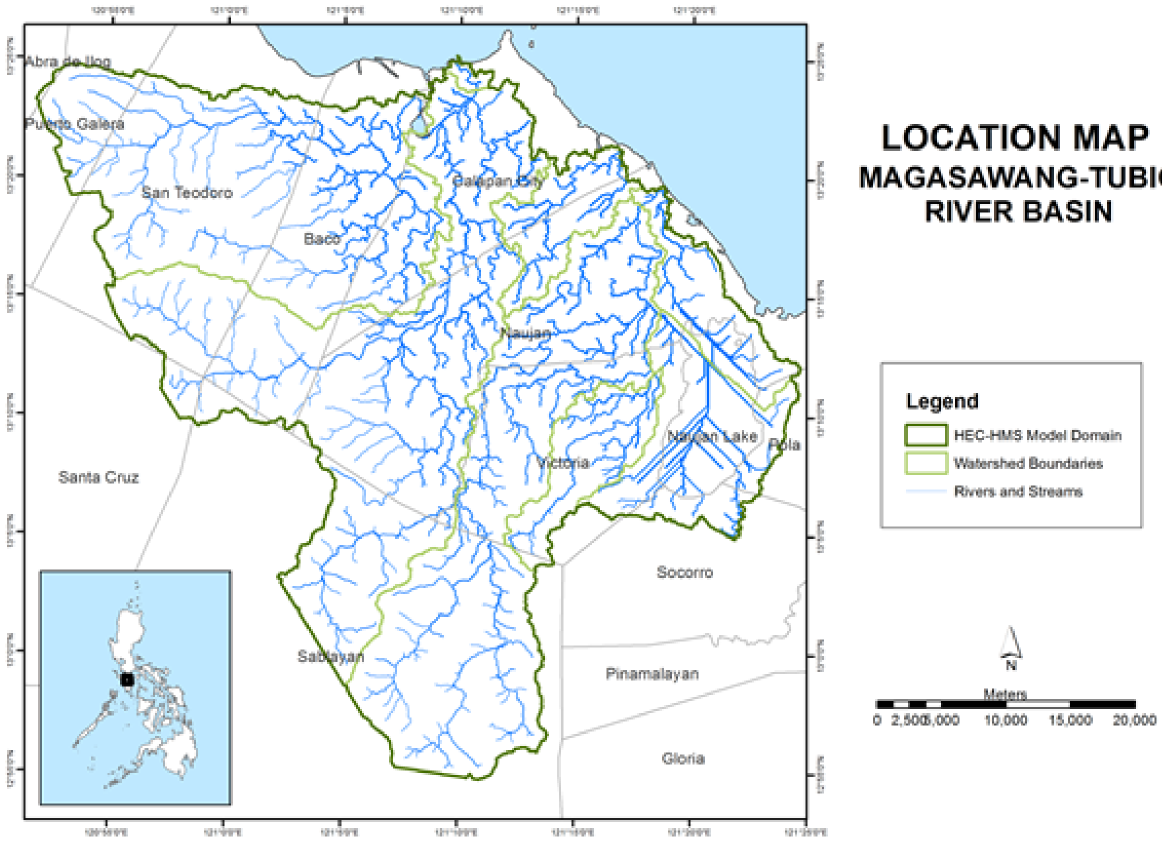


Figure 3. Mag-asawang Tubig River Basin Location Map

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 Mag-Asawang Tubig River Basin are shown in Figures 4 and 5, respectively.

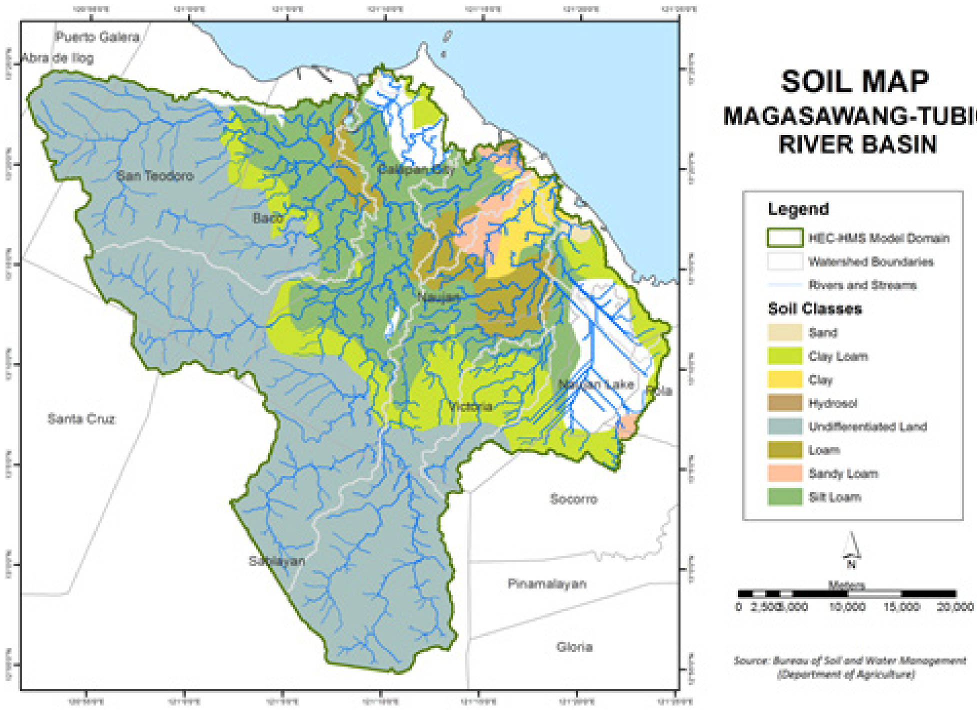


Figure 4. Mag-asawang Tubig River Basin Soil Map

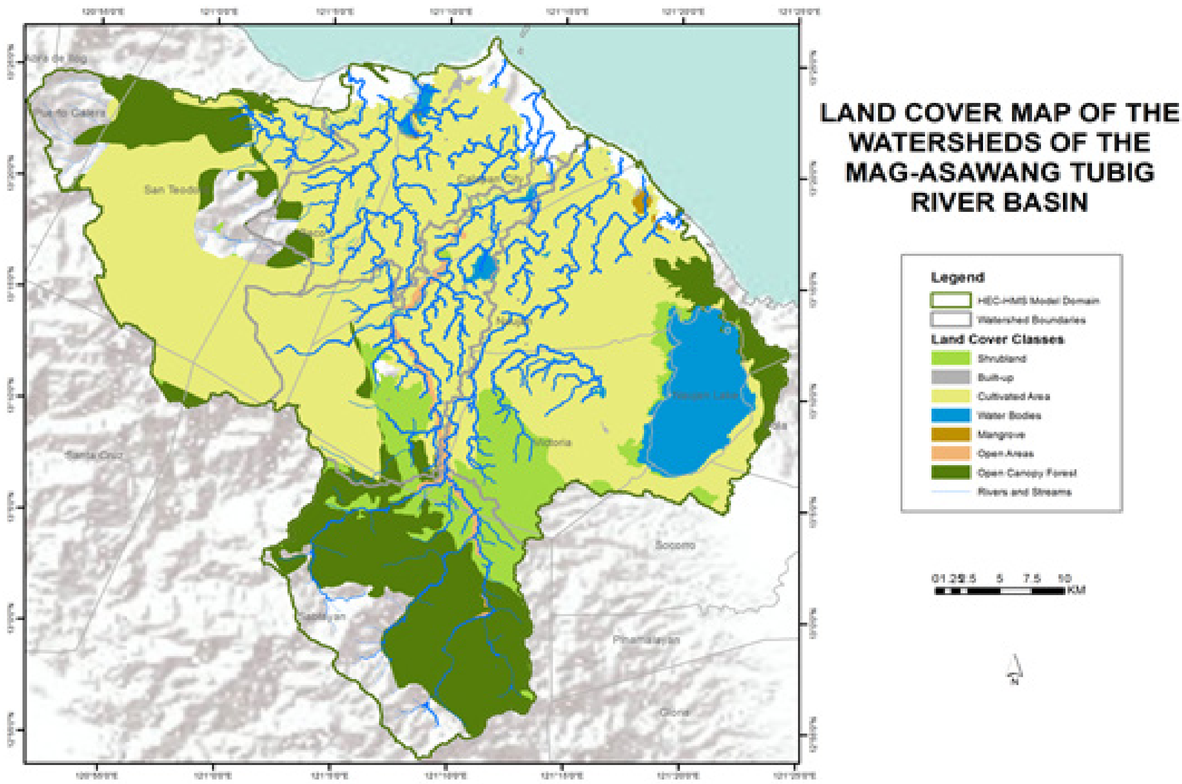


Figure 5. Mag-asawang Tubig River Bain Land Cover Map

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.

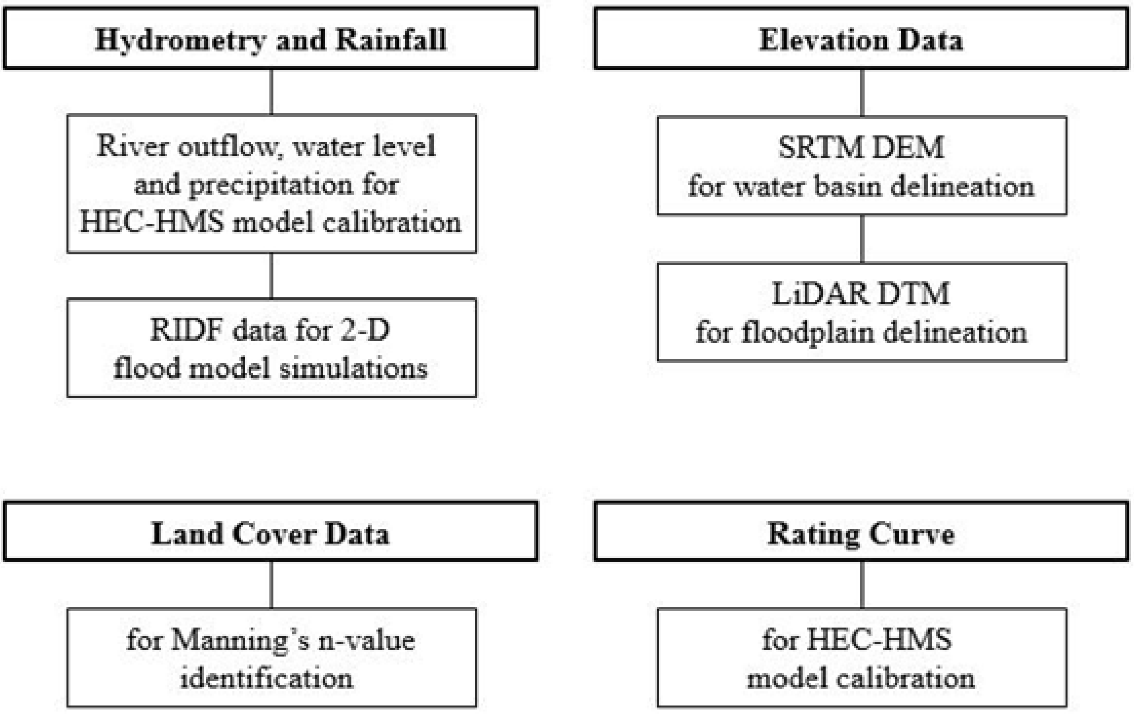


Figure 6. Summary of data needed for the purpose of flood modeling

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.

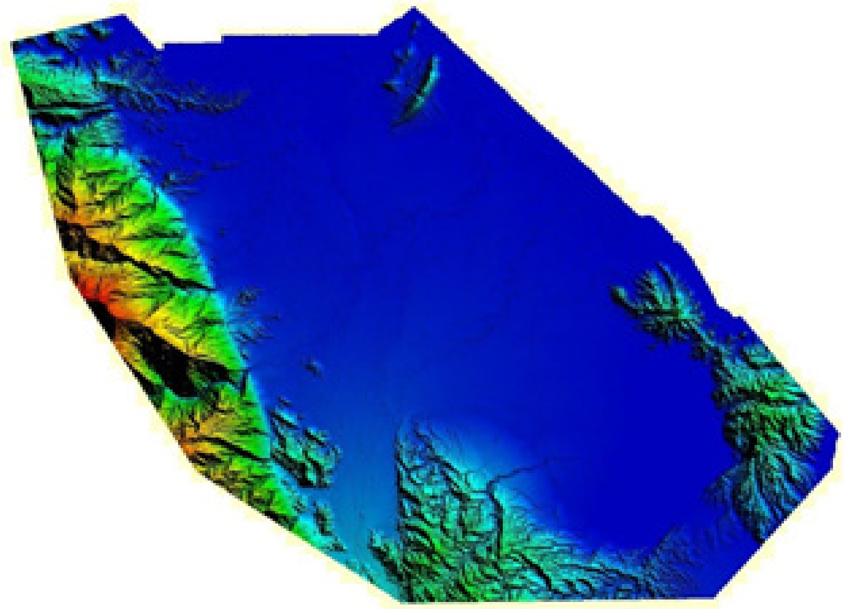


Figure 7. Digital Elevation Model (DEM) of the Mag-asawang Tubig River Basin using Light Detection and Ranging (LiDAR) technology

Elevation points were created from LiDAR DTMs. Since DTMs were provided as 1-meter spatial resolution rasters (while flood models for Mag-asawang Tubig 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.

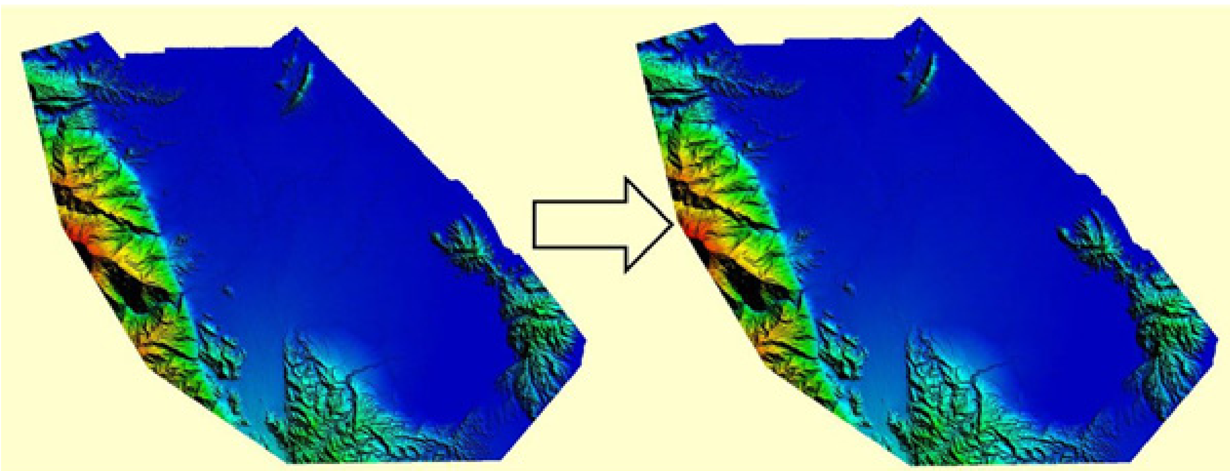


Figure 8. The 1-meter resolution LiDAR data resampled to a 10-meter raster grid in GIS software to ensure that values are properly adjusted.

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 Mag-asawang Tubig 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.

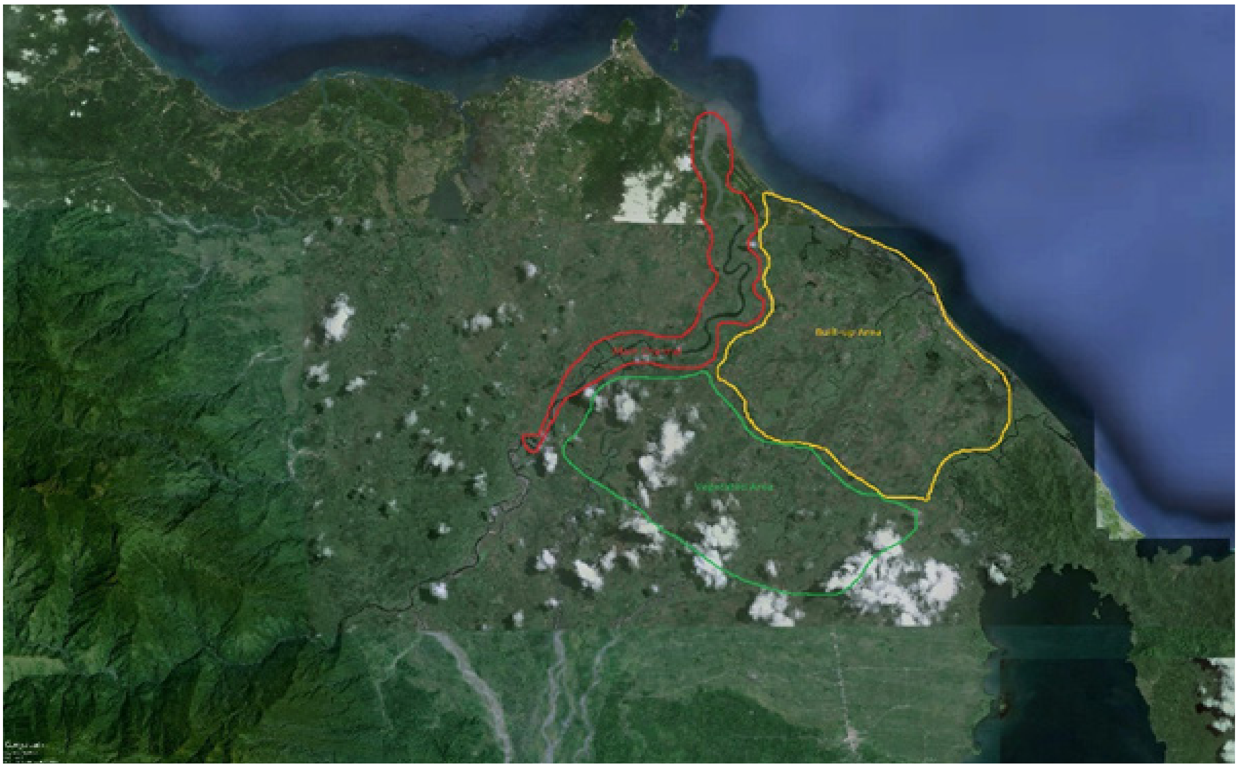


Figure 9. Stitched Quickbird images for the Mag-asawang Tubig floodplain.

3.1.3 Hydrometry and Rainfall Data

3.1.3.1 Hydrometry for different discharge points

3.1.3.1.1 Mag-asawang Tubig Bridge

Stage values downloadable from the REPO website was used to calibrate the HEC-HMS model. This was taken from the Mag-asawang Tubig Bridge (pos x: 13.2741167 pos y: 121.2601833). This was recorded during typhoon Santi event on October 2013. Peak discharge was at 51.5cms on 18 Oct 2013.

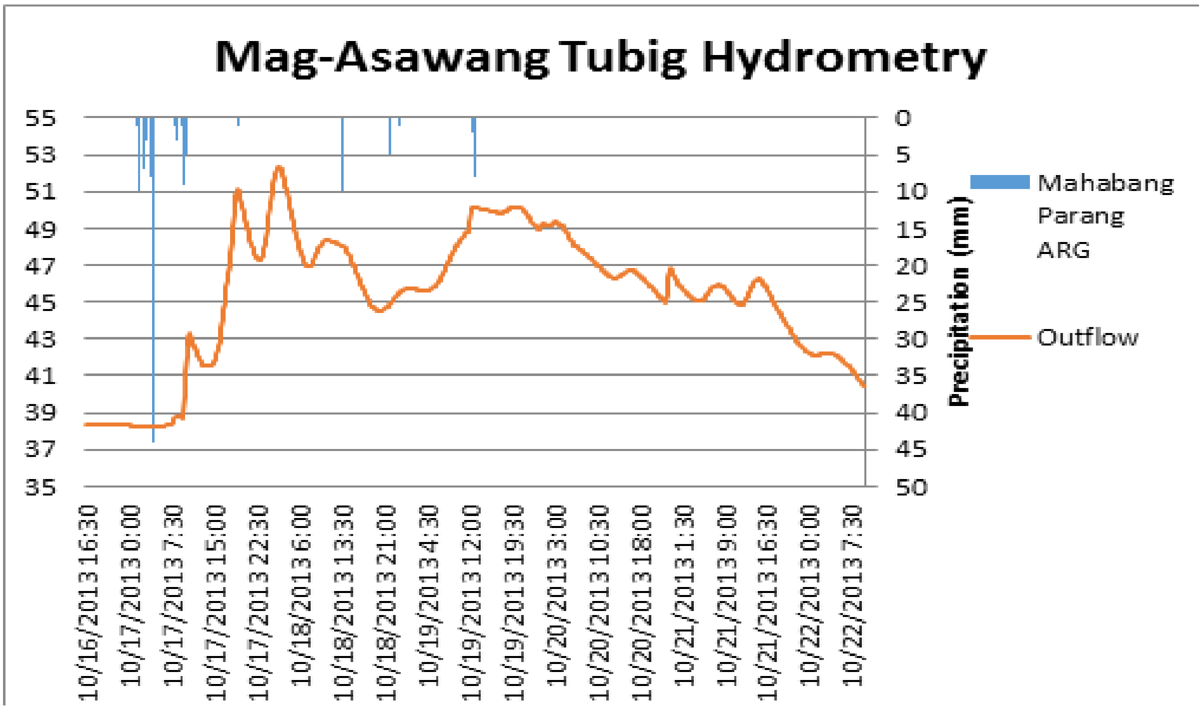


Figure 10. Mag-asawang Tubig rainfall and outflow data used for modeling.

3.1.3.1.2 Bucayao Bridge

Stage values downloadable from the REPO website was used to calibrate the HEC-HMS model. This was taken from the Bucayao Bridge (pos x: 13.3094444 pos y: 121.1913889). This was recorded during typhoon Santi event on October 2013. Peak discharge was at 6.94cms on 12 Oct 2013.

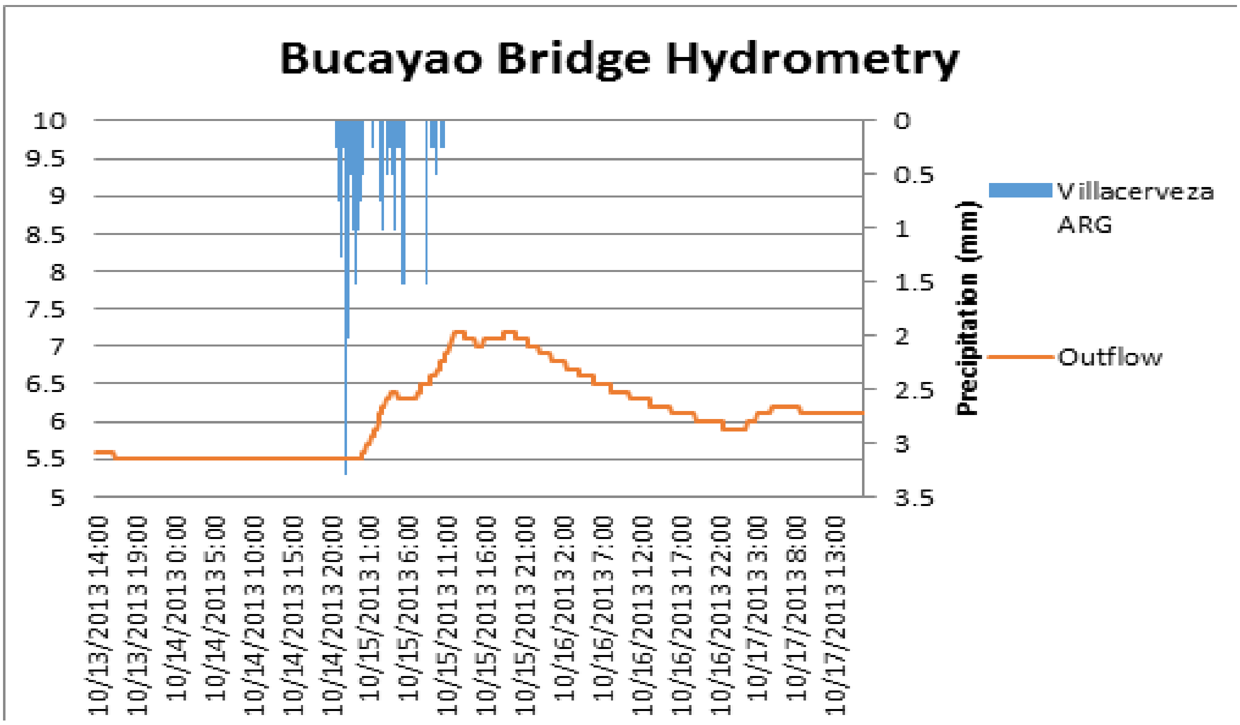


Figure 11. Bucayao Bridge Rainfall and outflow data used for modeling.

3.1.3.1.3 Alag Bridge

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 Alag Bridge, Oriental Mindoro (13°22'5.82"N, 121° 4'46.74"E). The recorded peak discharge is 7.0 cms at 07:20 AM, December 22, 2013.

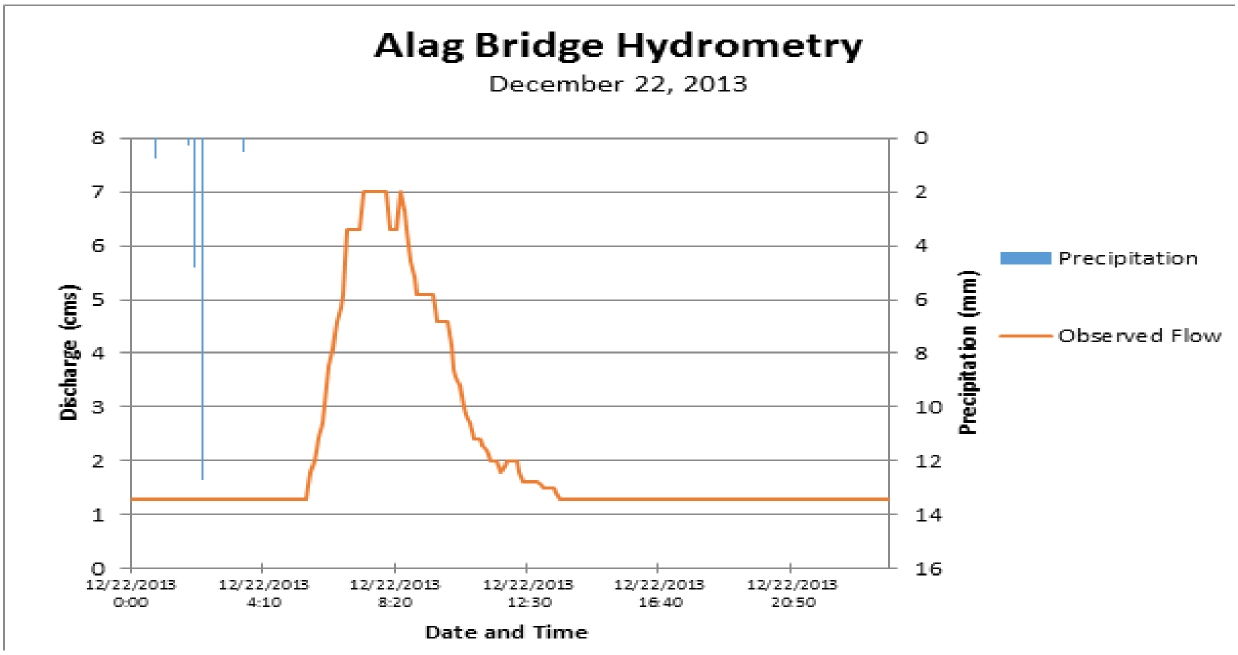


Figure 12. Alag Bridge Rainfall and outflow data used for modeling.

3.1.3.2 Rainfall Intensity Duration Frequency

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Ambulong Rain Gauge. This station was chosen based on its proximity to the Mag-asawang Tubig watershed. The extreme values for this watershed were computed based on a 57-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 13. Thiessen Polygon of Rain Intensity Duration Frequency (RIDF) Stations for the whole Philippines.

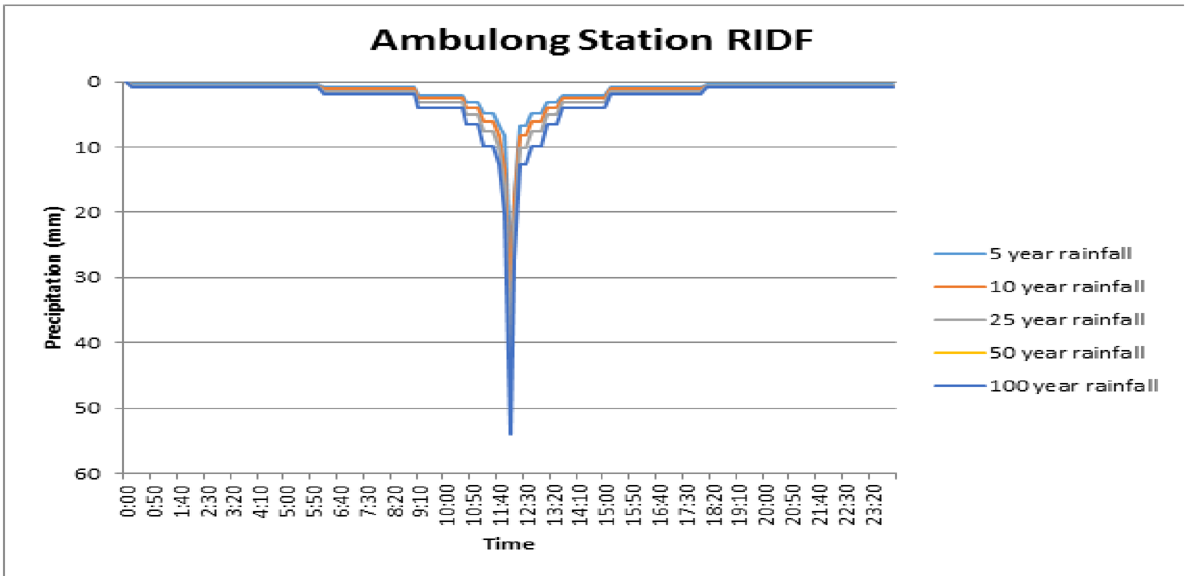


Figure 14. Ambulong Rainfall-Intensity Duration Frequency (RIDF) curves.

The outflow values at the discharge points in the Mag-Asawang Tubig river basin were 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 the AWLS and constants (a and n).

$$Q = a^{nh}$$

Equation 1. Rating Curve

3.1.4.1 Mag-asawang Tubig Rating Curve

For Mag-Asawang Tubig Bridge, the rating curve is expressed as $Q = 7.0975e^{0.0009x}$ as shown in Figure 15.

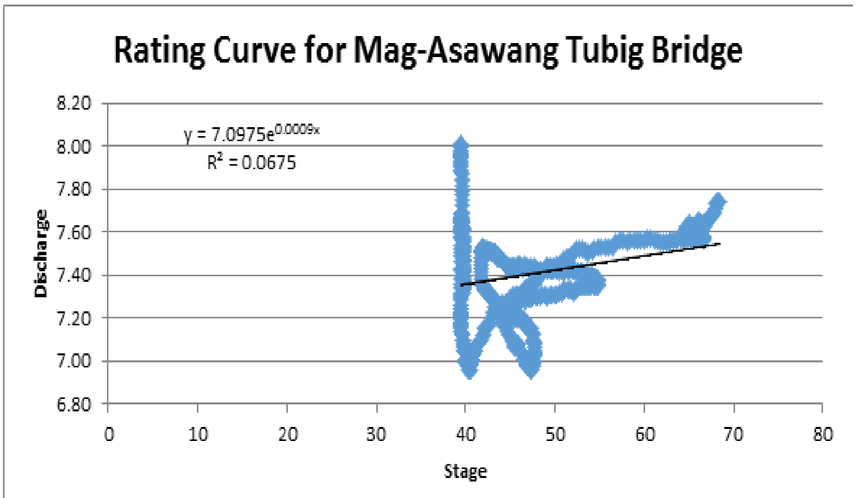


Figure 15. Water level vs. Discharge Curve for Mag-Asawang Tubig

3.1.4.2 Bucayao Bridge Rating Curve

For Bucayao Bridge, the rating curve is expressed as Q = 5. $5.1252e^{0.0013x}$ as shown in Figure 16.

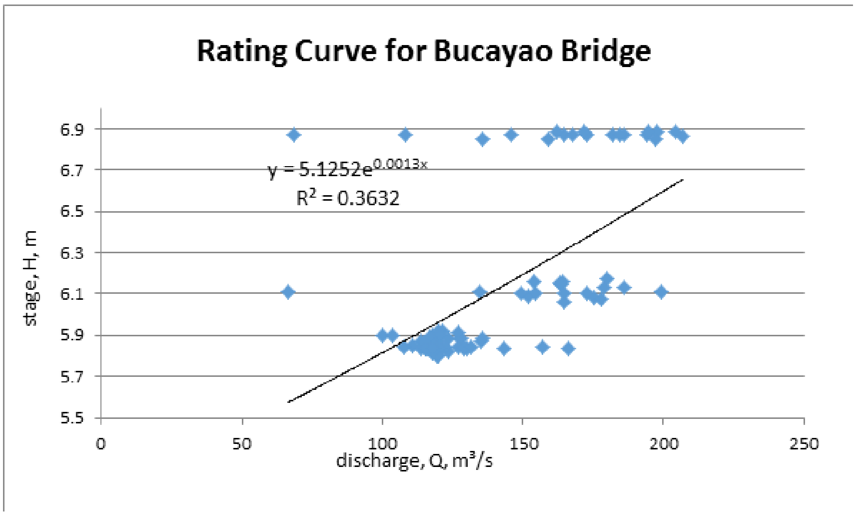


Figure 16. Water level vs. Discharge Curve for Bucayao Bridge

3.1.4.3 Alag Bridge Rating Curve

For Alag Bridge, the rating curve is expressed as Q= $1E\text{-}13e^{10.45h}$ as shown in Figure 17.

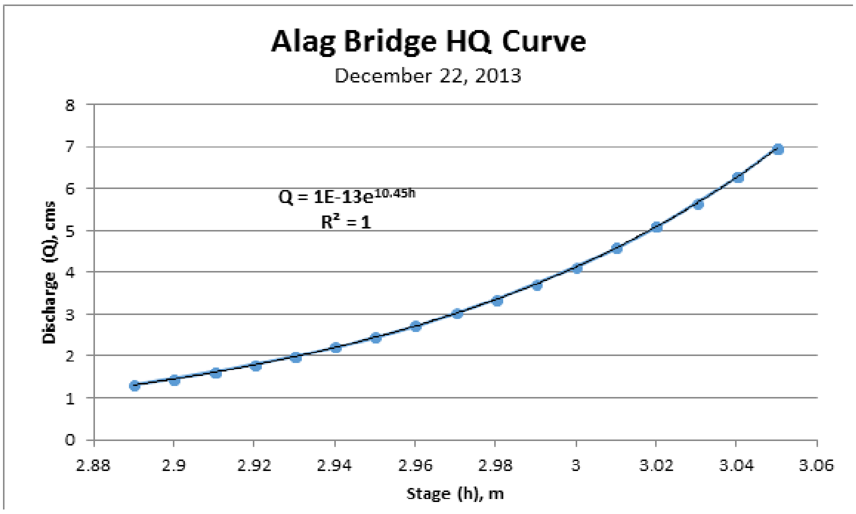


Figure 17. Water level vs. Discharge Curve for Alag Bridge

3.2 Rainfall-Runoff Hydrologic Model Development

3.2.1 Watershed Delineation and Basin Model Pre-processing

The hydrologic model of Mag-asawang Tubig 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 the Figure 18.

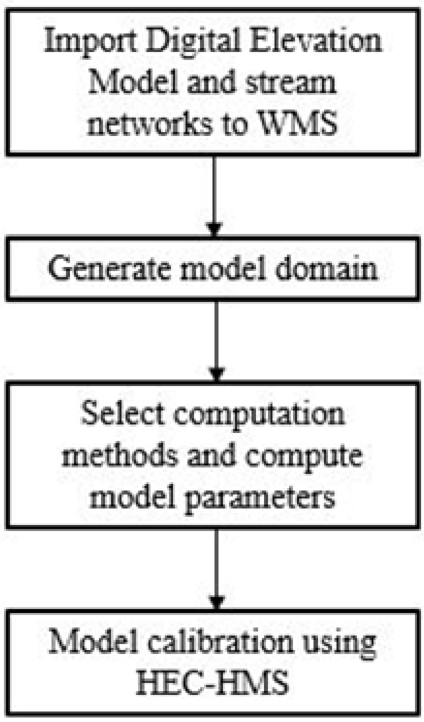


Figure 18. The Rainfall-Runoff Basin Model Development Scheme

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.

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.

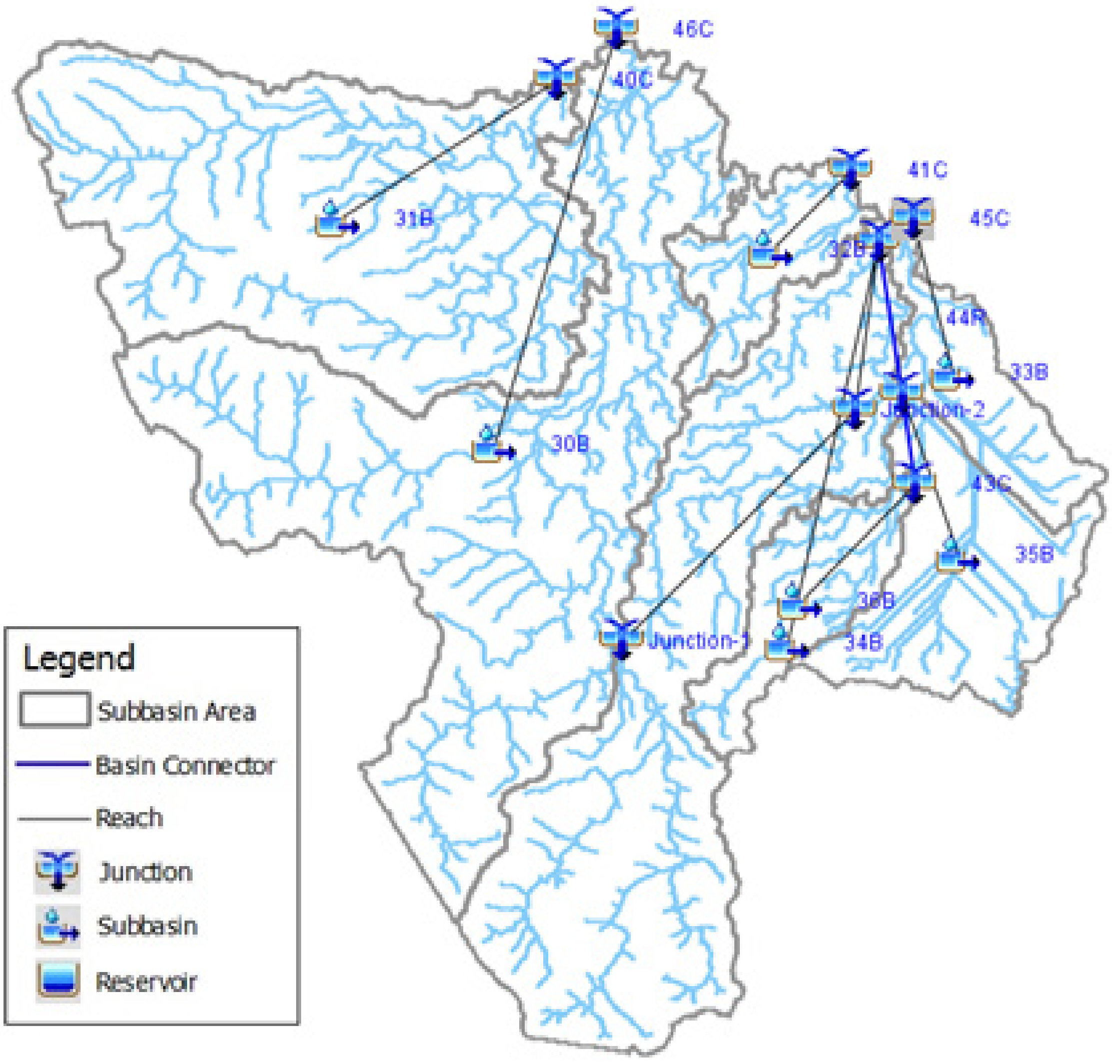


Figure 19. Mag-asawang Tubig HEC-HMS Model domain generated by WMS

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 an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This is located at Bayanan Elementary School, Oriental Mindoro and is shown in Figure 20.

Total rain from the rain gauge is 19.05 mm. It peaked to 12.7mm on 22 December 2013, 02:15. The lag time between the peak rainfall and discharge is 5 hours and 5 minutes.

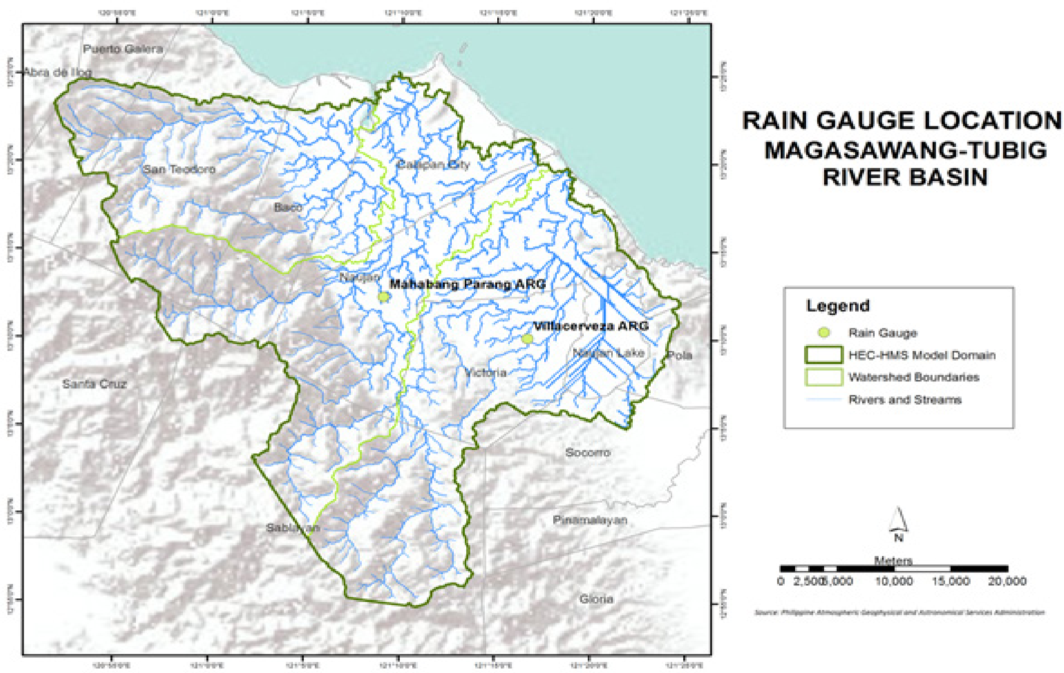


Figure 20. Location of rain gauge used for the calibration of Mag-asawang Tubig HEC-HMS Model.

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.

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 Mag-Asawang Tubig River Basin using WMS and HEC-HMS was used to simulate the flow for for the five return periods, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs. Time-series data of the precipitation data using the Ambulong 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 – Mag-Asawang Tubig, Bucayao, and Alag. 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 21.

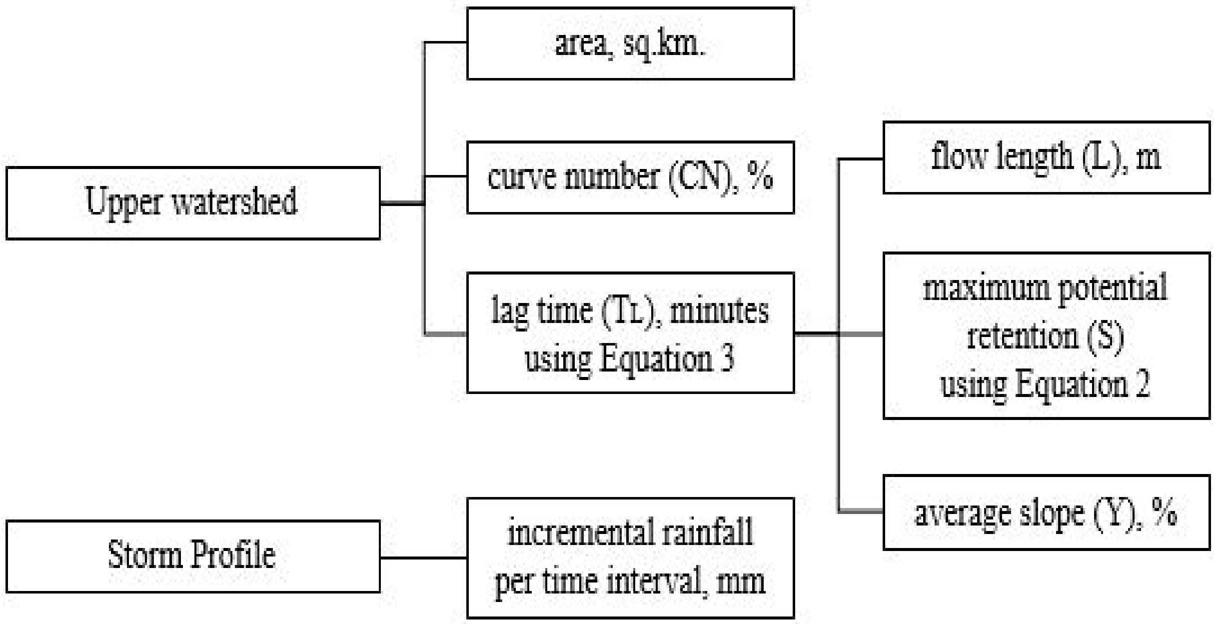


Figure 21. Different data needed as input for HEC-HMS discharge simulation using Dr. Horritt's recommended hydrology method.

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. The method 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.

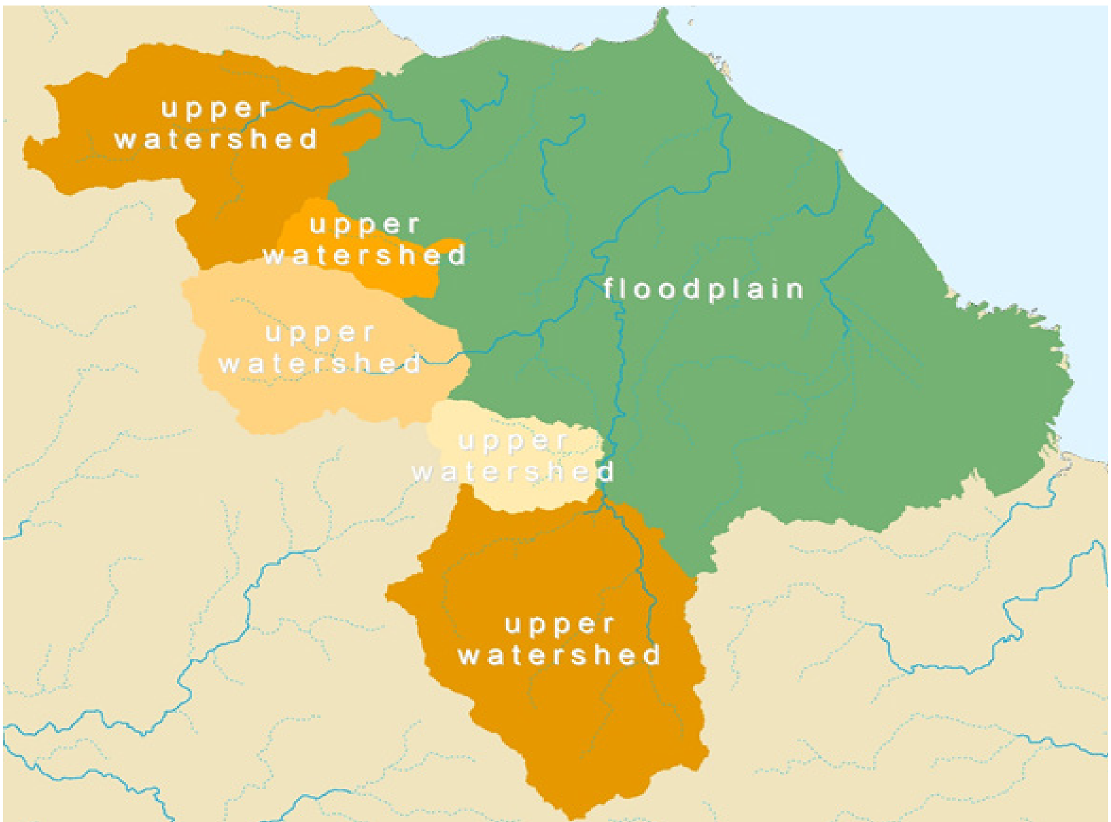


Figure 22. Delineation of upper watershed for Mag-asawang Tubig floodplain discharge computation

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.

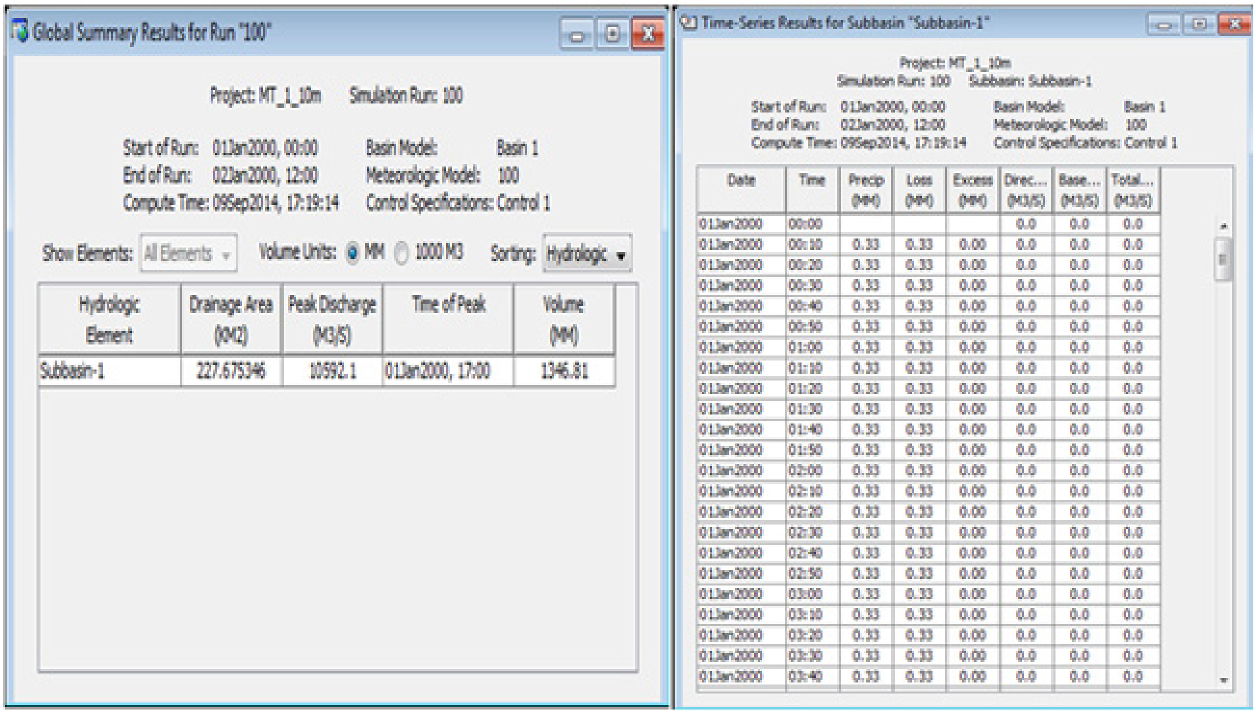


Figure 23. HEC-HMS simulation discharge results using Dr. Horritt's Method

3.3.2.3 Discharge validation against other estimates

As a general rule, the river discharge of a 2-year rain return, Q_{MED}, should approximately be equal to the bankful discharge, $Q_{bankful}$, 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.

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

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.

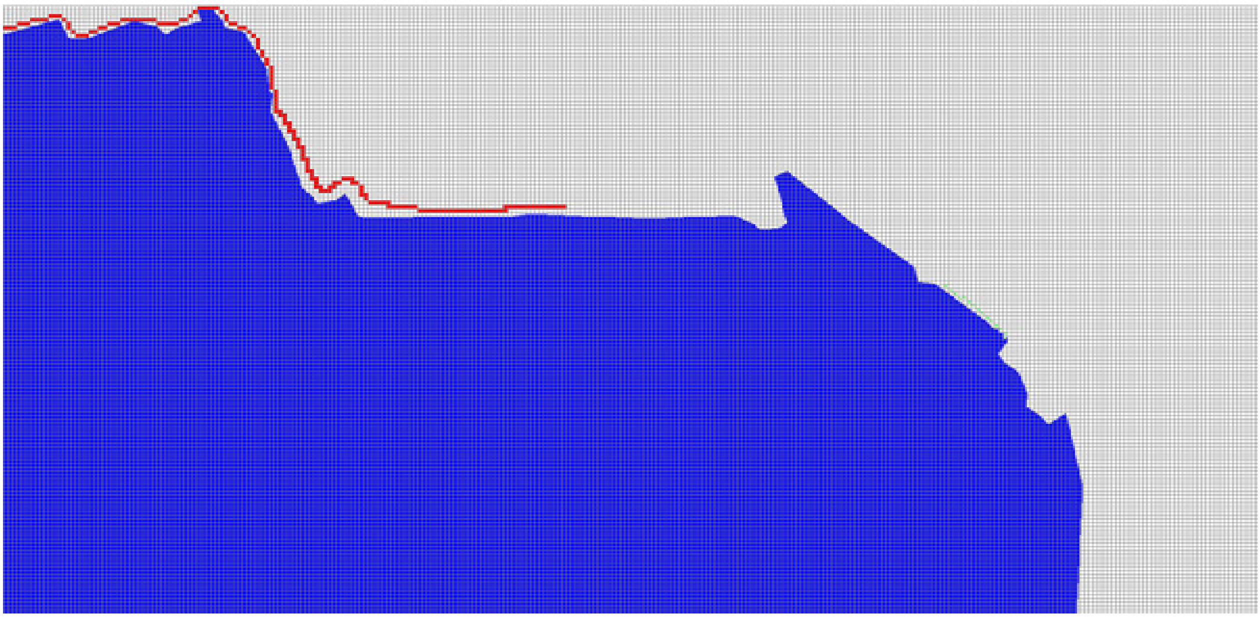


Figure 24. Screenshot showing how boundary grid elements are defined by line

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.

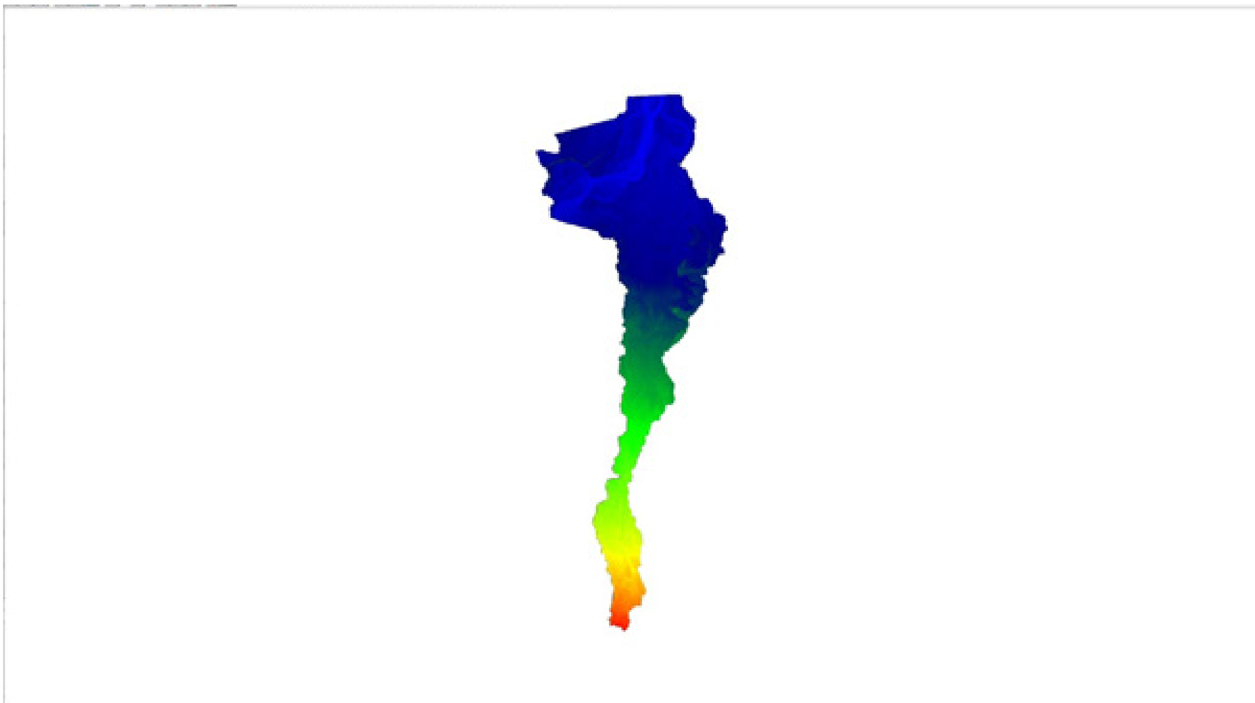


Figure 25. Screenshots of PTS files when loaded into the FLO-2D program

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 26. Areal image of Mag-asawang Tubig floodplain

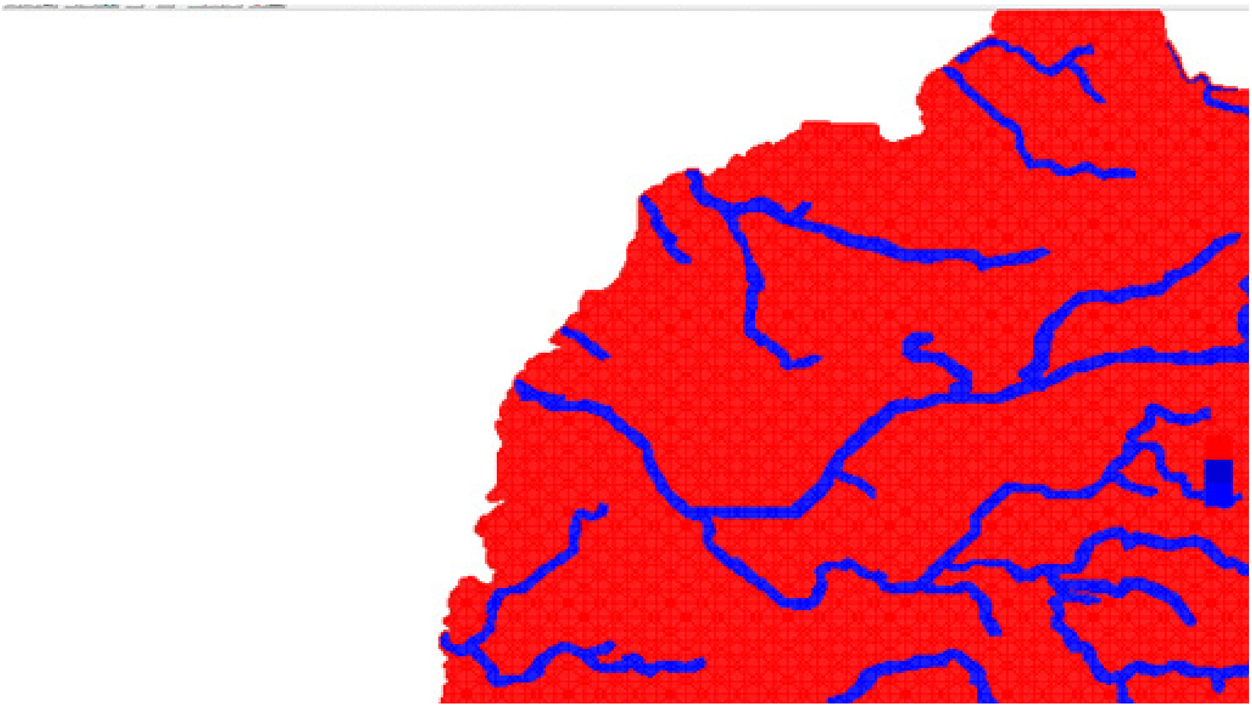


Figure 27. Screenshot of Manning's n-value rendering

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 28.

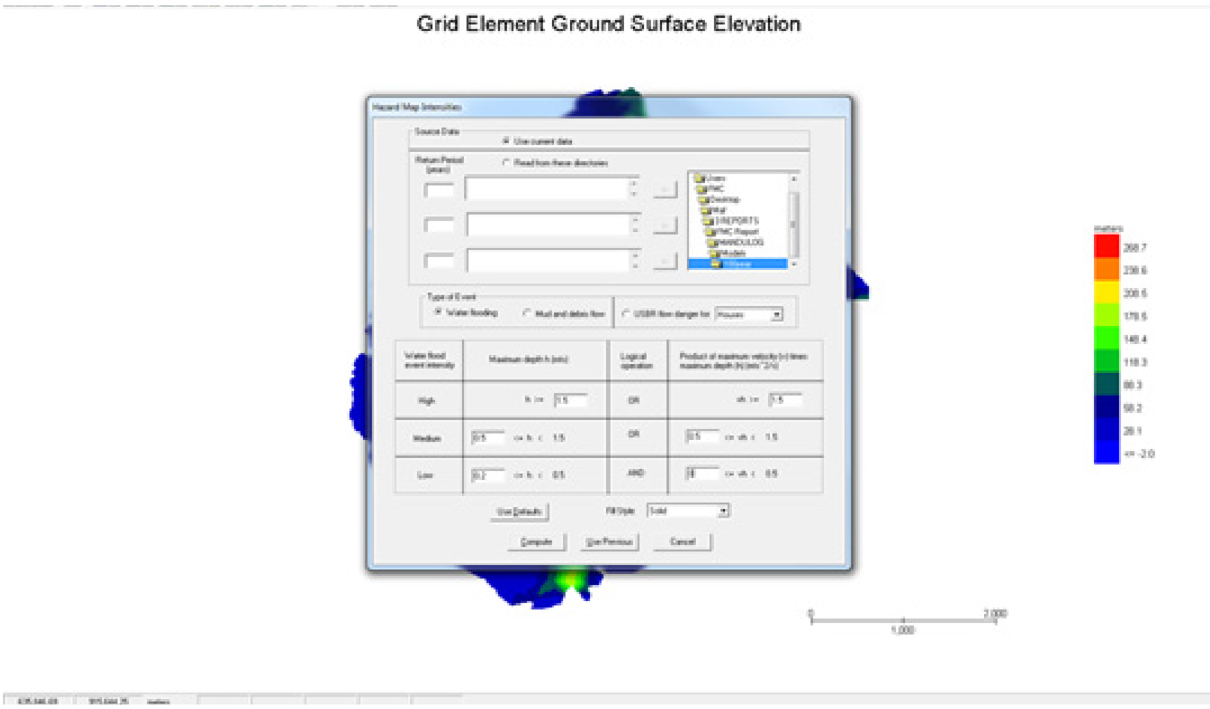


Figure 28. Flo-2D Mapper Pro General Procedure

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.

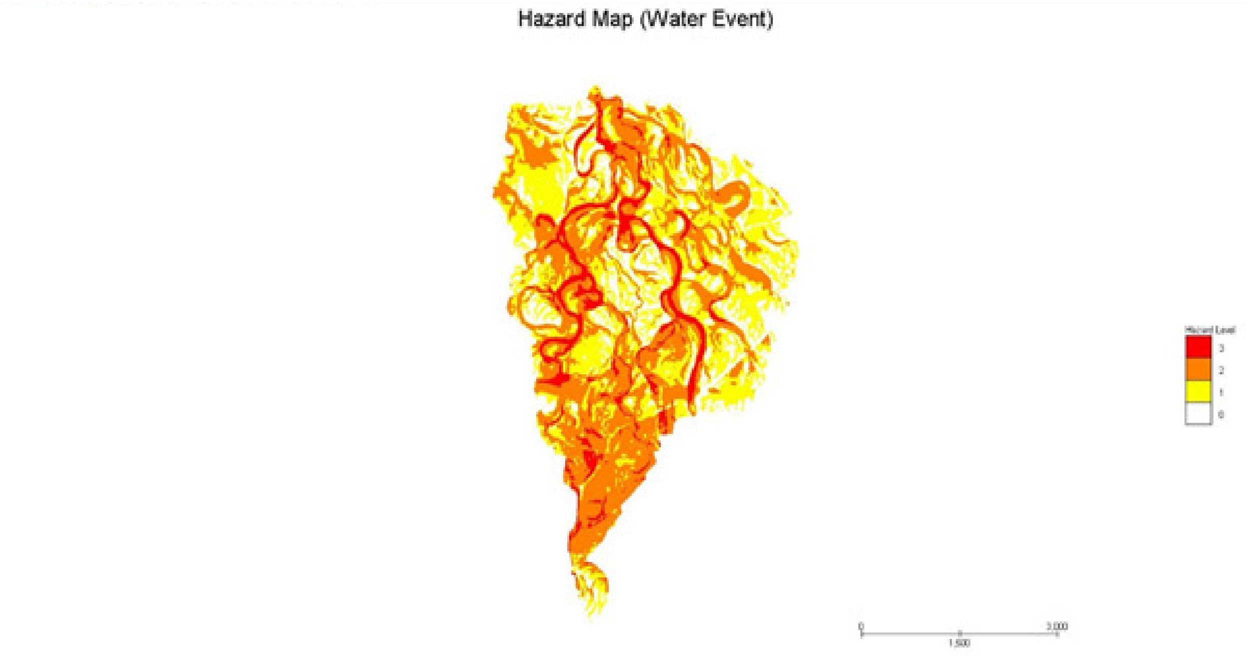


Figure 29. Mag-asawang Tubig Floodplain Generated Hazard Maps using FLO-2D Mapper

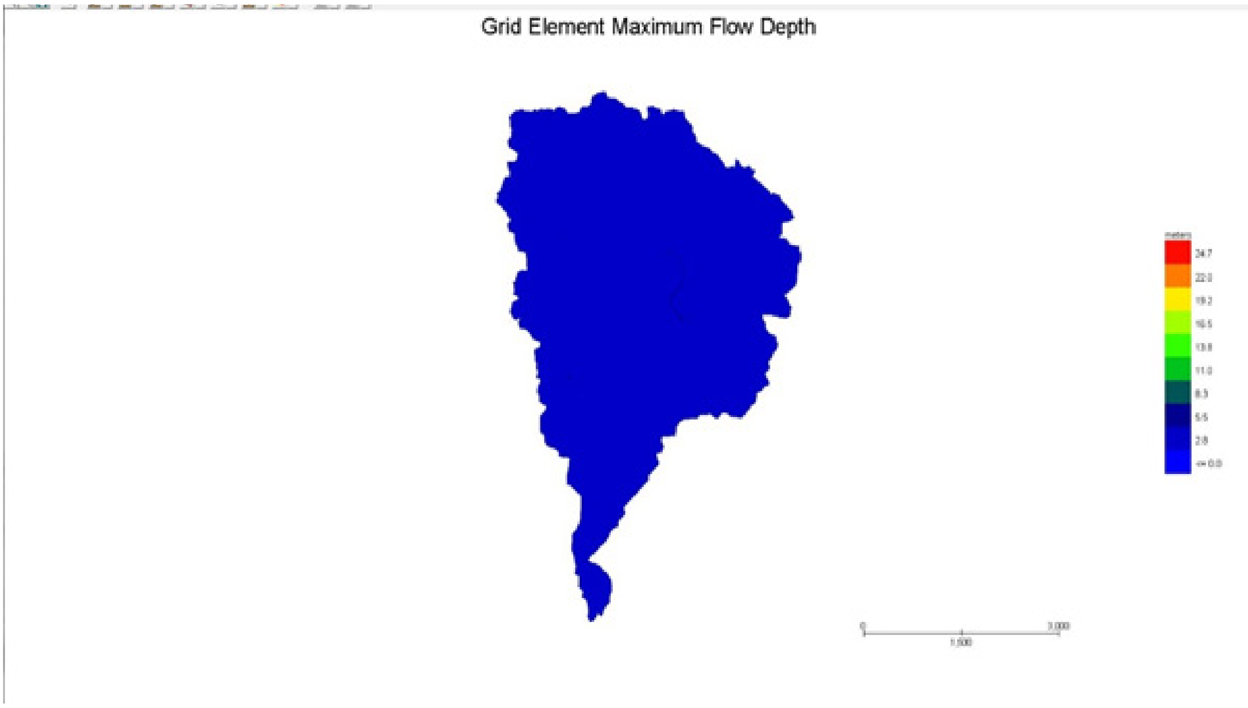
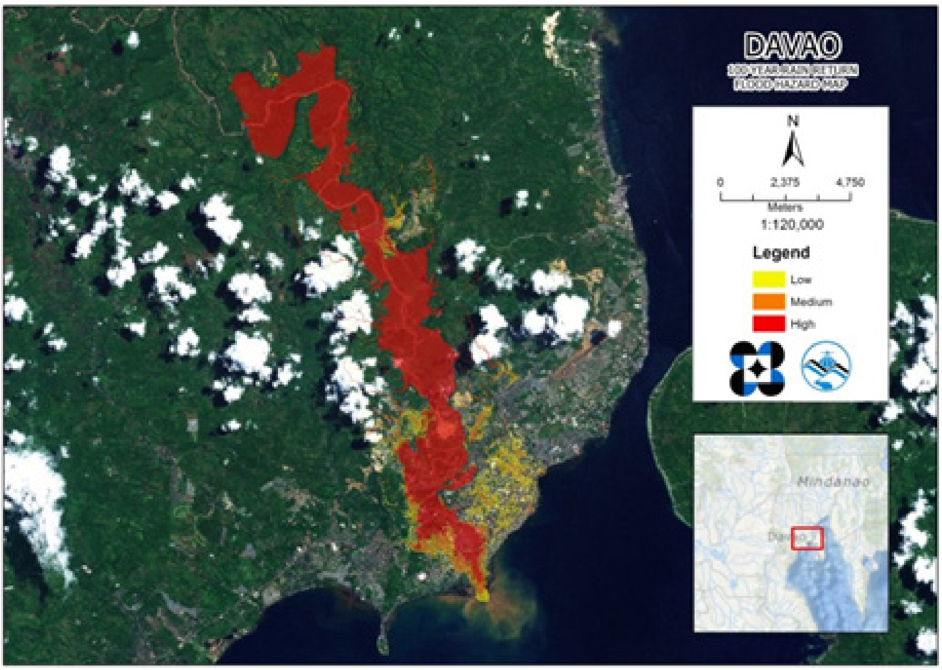


Figure 30. Mag-asawang Tubig floodplain generated flow depth map using FLO-2D Mapper

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 31. 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 31. 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 Mag-asawang Tubig HMS Model Calibration Result

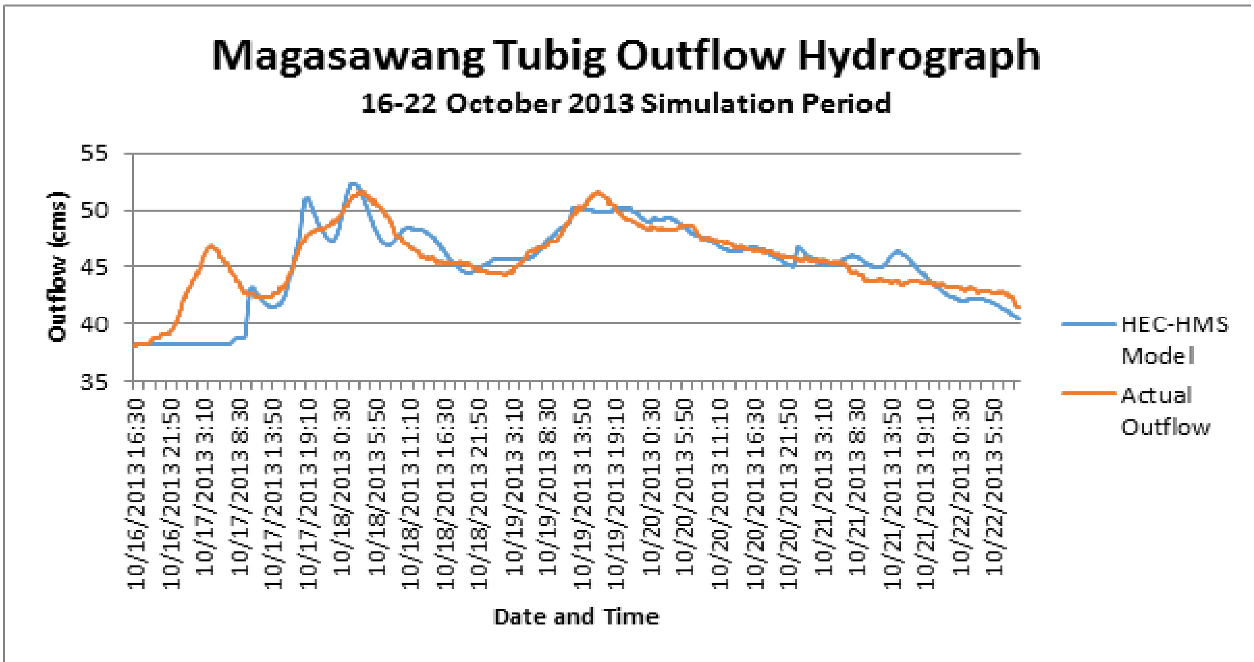


Figure 32. Mag-asawang Tubig Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Mag-asawang Tubig HEC-HMS river basin model, its accuracy was measured against the observed values. The comparison between the two discharge data are shown in Figure 32.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 2.1.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.832951809.

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 0.506480479.

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 -0.84.

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 0.56.

4.1.2 Bucayao Bridge HMS Model Calibration Result

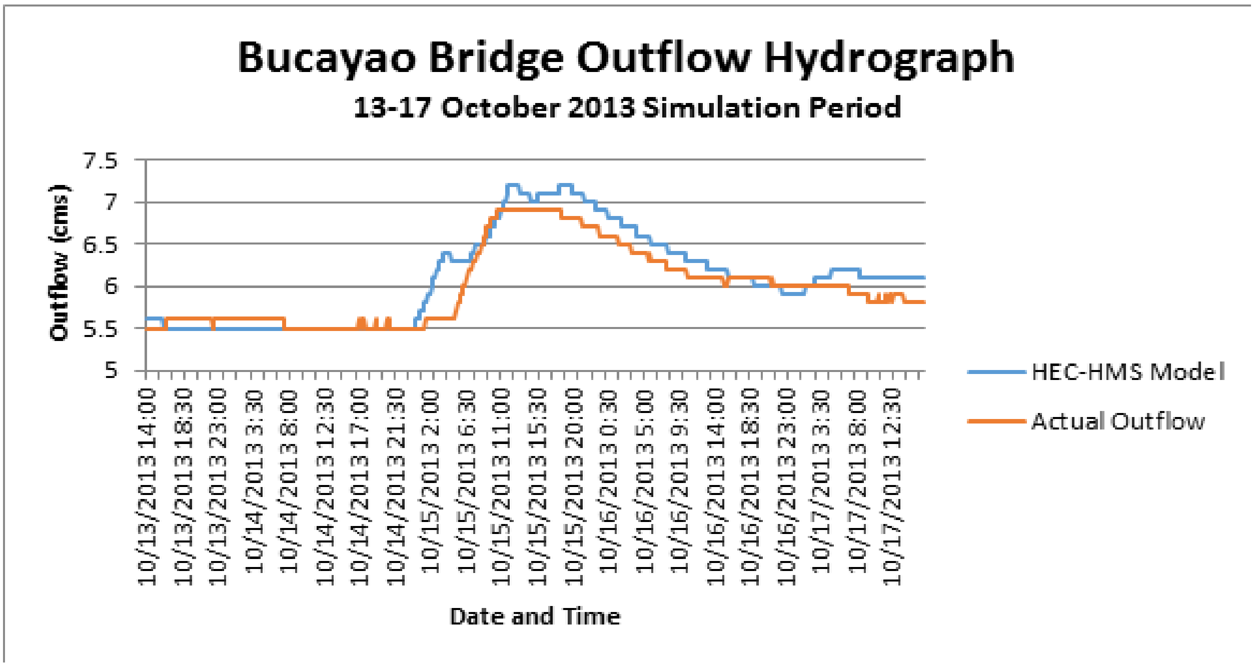


Figure 33. Bucayao Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Mag-asawang Tubig HEC-HMS river basin model, its accuracy was measured against the observed values. The comparison between the two discharge data are shown in Figure 33.

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 23.1 m3/s.

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 -28.34.

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 -80.18

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 5.42

4.1.3 Alag Bridge HMS model Calibration Results

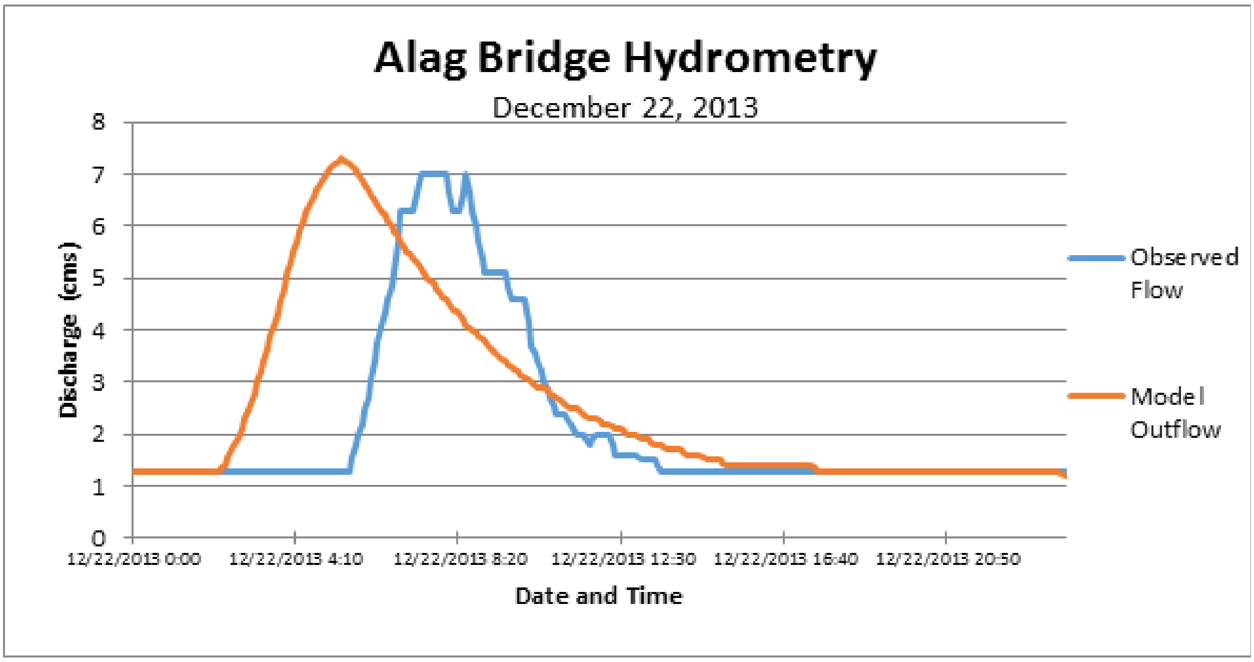


Figure 34. Alag Bridge Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow.

After calibrating the Alag HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 34 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 1.8.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.5.

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 -0.16.

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 -17.44.

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 1.08.

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

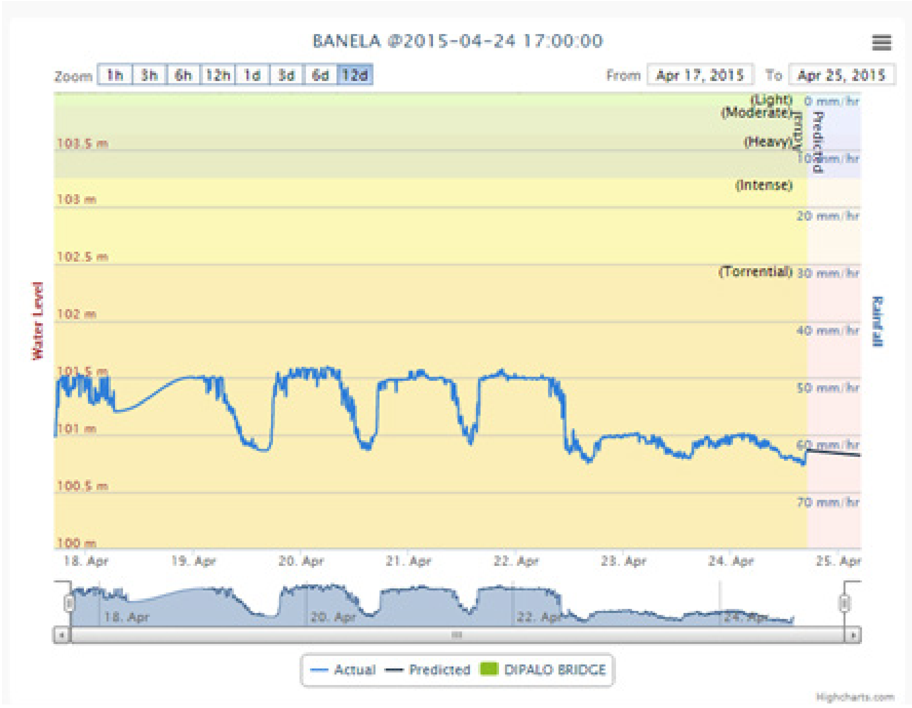


Figure 35. Sample DREAM Water Level Forecast

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 Mag-Asawang Tubig Bridge

The outflow of Mag-Asawang Tubig using the Ambulong station 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 PAGASA data are shown in Figures 36-40. 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 311.8 cms. This occurs after 32 hours and 10 minutes after the peak precipitation of 27.9 mm, as shown on Figure 36.

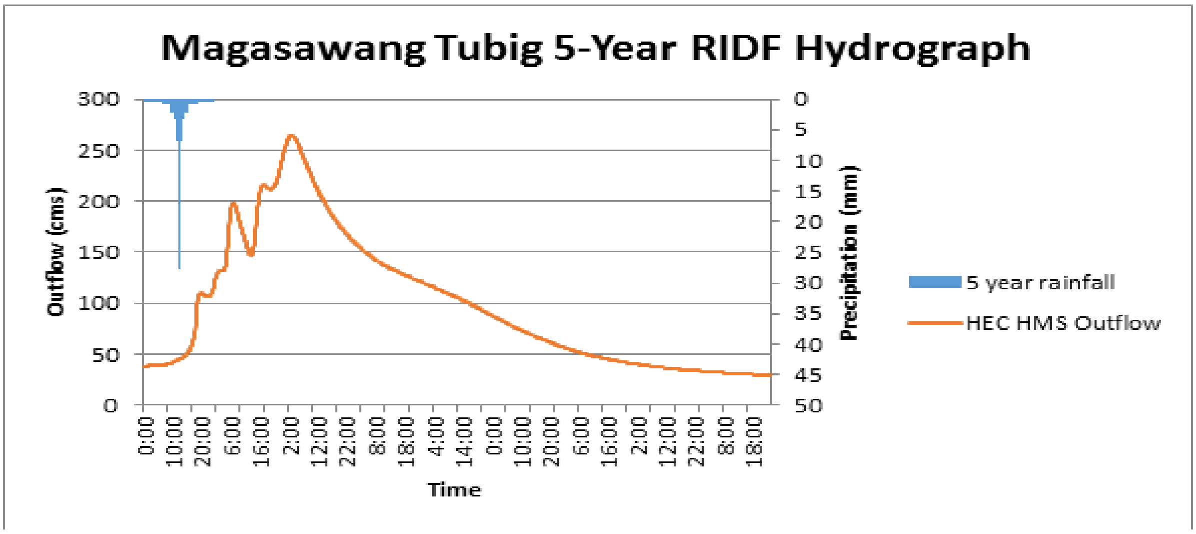


Figure 36. Mag-asawang Tubig Bridge outflow hydrograph generated using the Ambulong 5-Year RIDF in HEC-HMS

In the 10-year return period graph, the peak outflow is 405.4 cms. This occurs after 30 hours and 10 minutes after the peak precipitation of 34.2 mm, as shown on Figure 37.

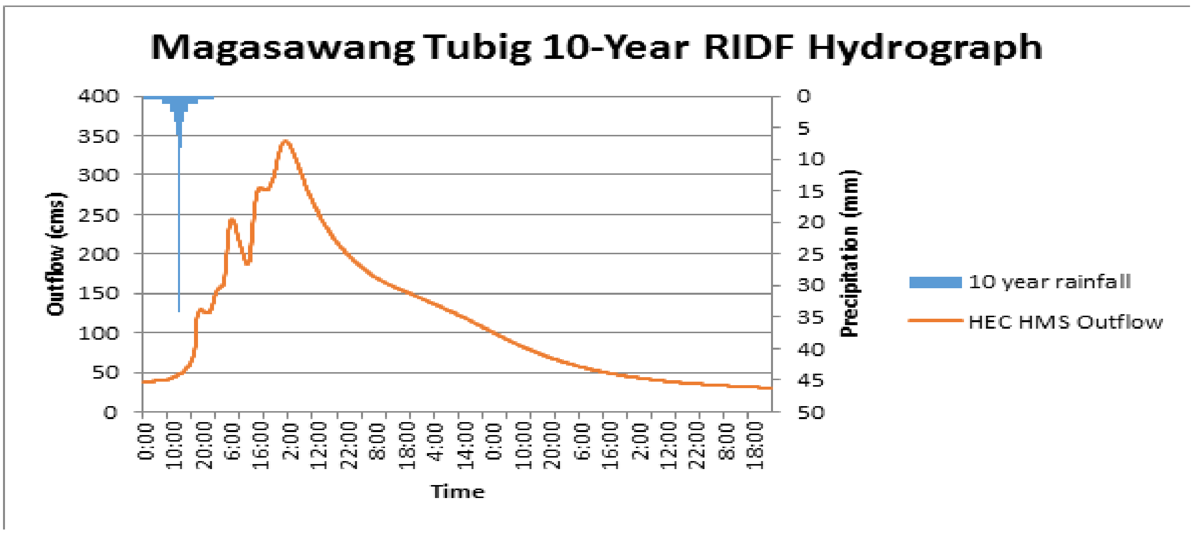


Figure 37. Mag-asawang Tubig Bridge Outflow hydrograph generated using the Ambulong 10-Year RIDF in HEC-HMS

In the 25-year return period graph, the peak outflow is 532.6 cms. This occurs 28 hours and 20 minutes after the peak precipitation of 42.2 mm, as shown on Figure 38.

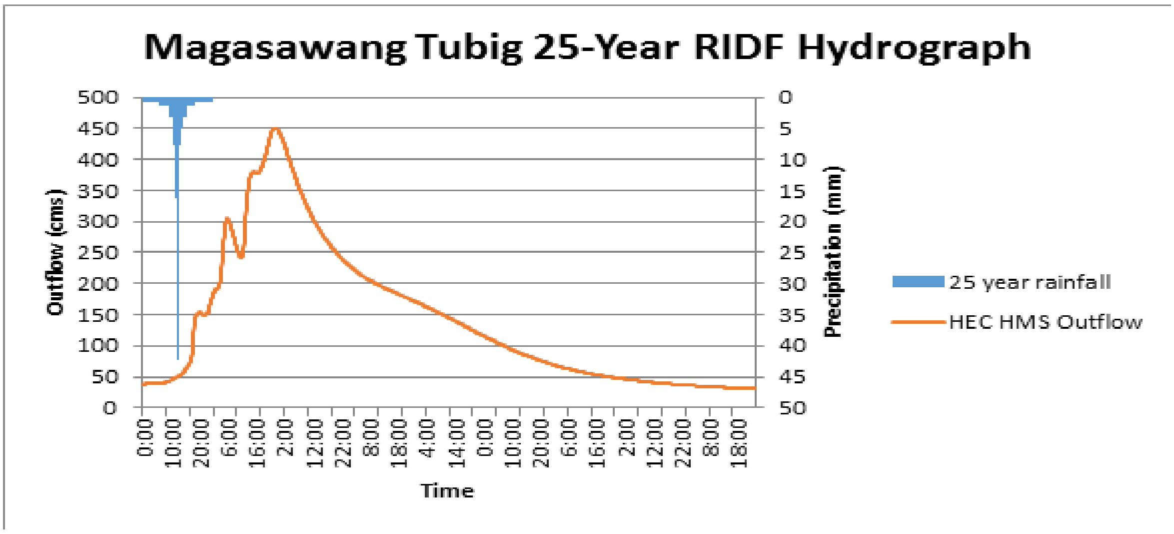


Figure 38. Mag-asawang Tubig Bridge Outflow hydrograph generated using the Ambulong 25-Year RIDF in HEC-HMS

In the 50-year return period graph, the peak outflow is 632.9 cms. This occurs after 27 hours and 10 minutes after the peak precipitation of 48.1 mm, as shown on Figure 39.

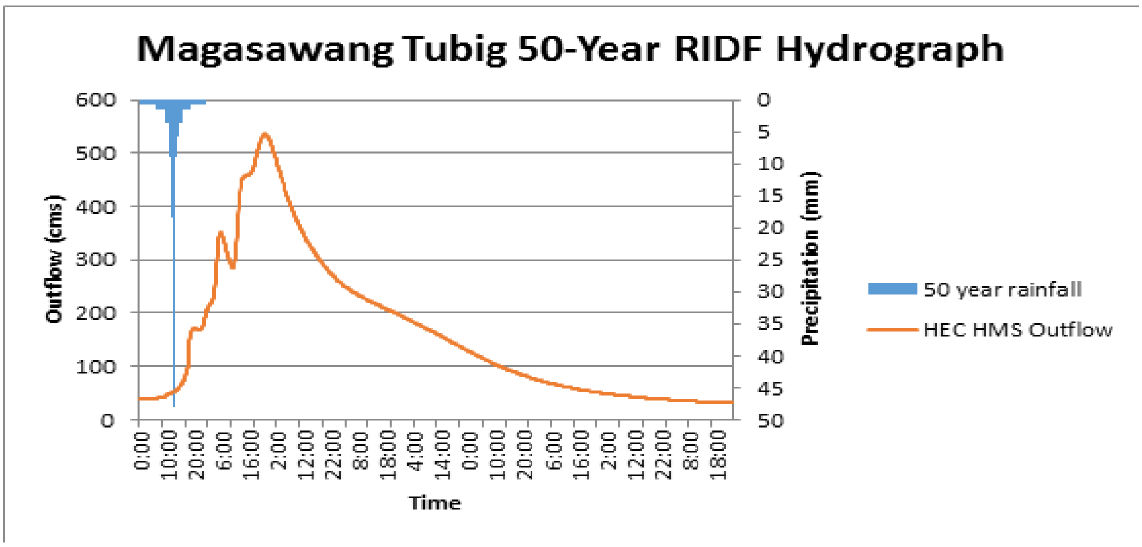


Figure 39. Mag-asawang Tubig Bridge Outflow hydrograph generated using the Ambulong 50-Year RIDF in HEC-HMS

In the 100-year return period graph, the peak outflow is 733.9 cms. This occurs after 26 hours and 10 minutes after the peak precipitation of 54 mm, as shown on Figure 40.

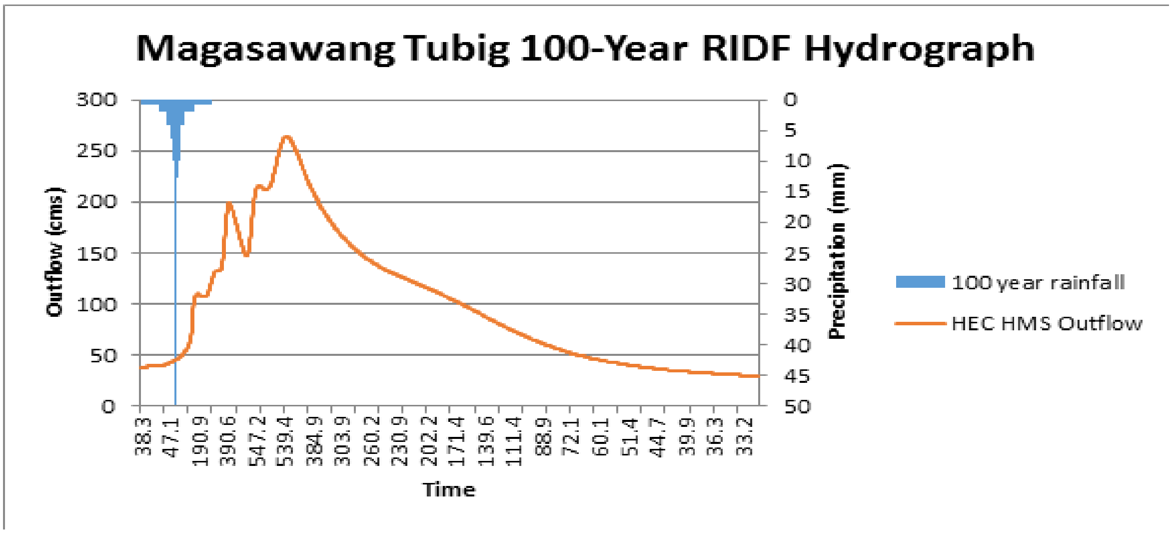


Figure 40. Mag-asawang Tubig Bridge outflow hydrograph generated using the Ambulong 100-Year RIDF in HEC-HMS

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

Table 2. Summary of Mag-asawang Tubig discharge using the Ambulong Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	226.7	27.9	311.8	32 hours 10 minutes
10-Year	276.9	34.2	405.4	30 hours 10 minutes
25-Year	340.4	42.2	532.6	28 hours 20 minutes
50-Year	387.5	48.1	632.9	27 hours 10 minutes
100-Year	434.3	54	733.9	26 hours 10 minutes

4.2.1.2 Bucayao Bridge

The outflow of Bucayao using the Ambulong 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 PAGASA data are shown in Figures 41-45. 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 128.7 cms. This occurs after 96 hours and 20 minutes after the peak precipitation of 27.9 mm, as shown on Figure 41.

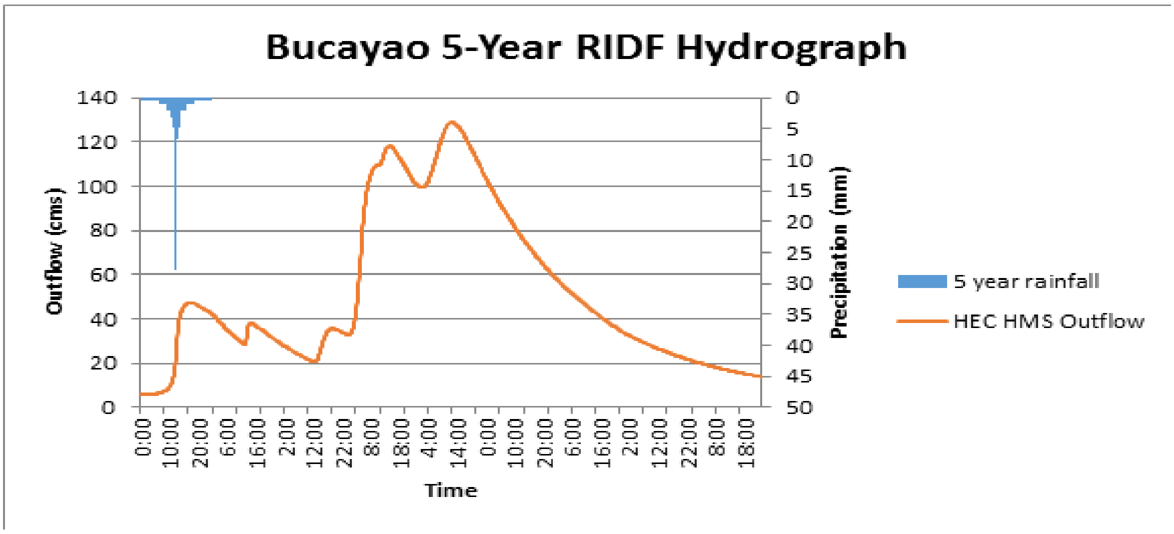


Figure 41. Bucayao Bridge Outflow hydrograph generated using the Ambulong 5-Year RIDF in HEC-HMS

In the 10-year return period graph, the peak outflow is 170.5 cms. This occurs after 90 hours and 20 minutes after the peak precipitation of 34.2 mm, as shown on Figure 42.

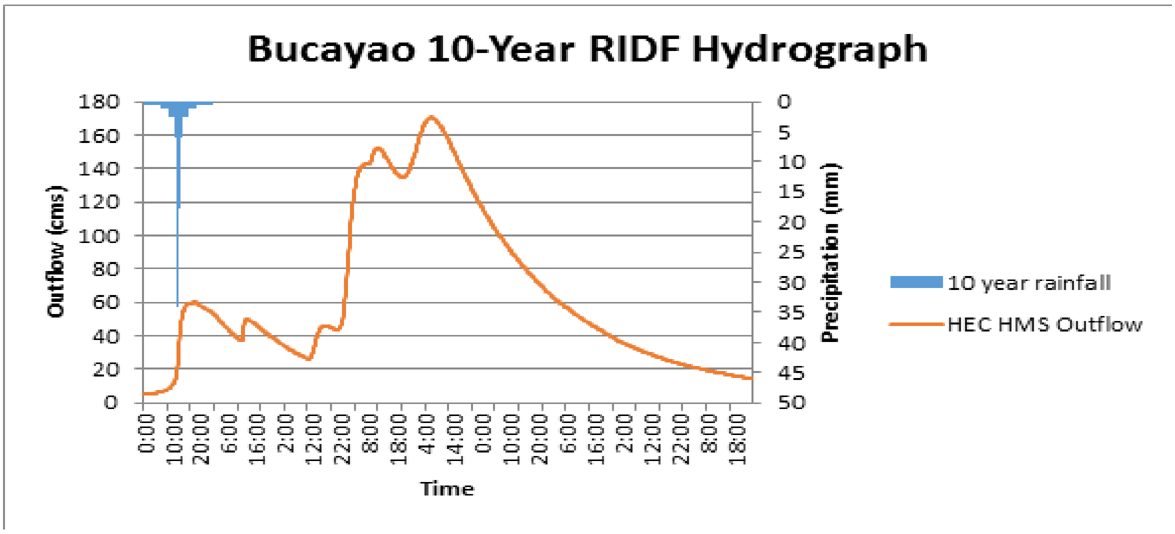


Figure 42. Bucayao Bridge Outflow hydrograph generated using the Ambulong 10-Year RIDF in HEC-HMS

In the 25-year return period graph, the peak outflow is 227.1 cms. This occurs 84 hours and 30 minutes after the peak precipitation of 42.2 mm, as shown on Figure 43.

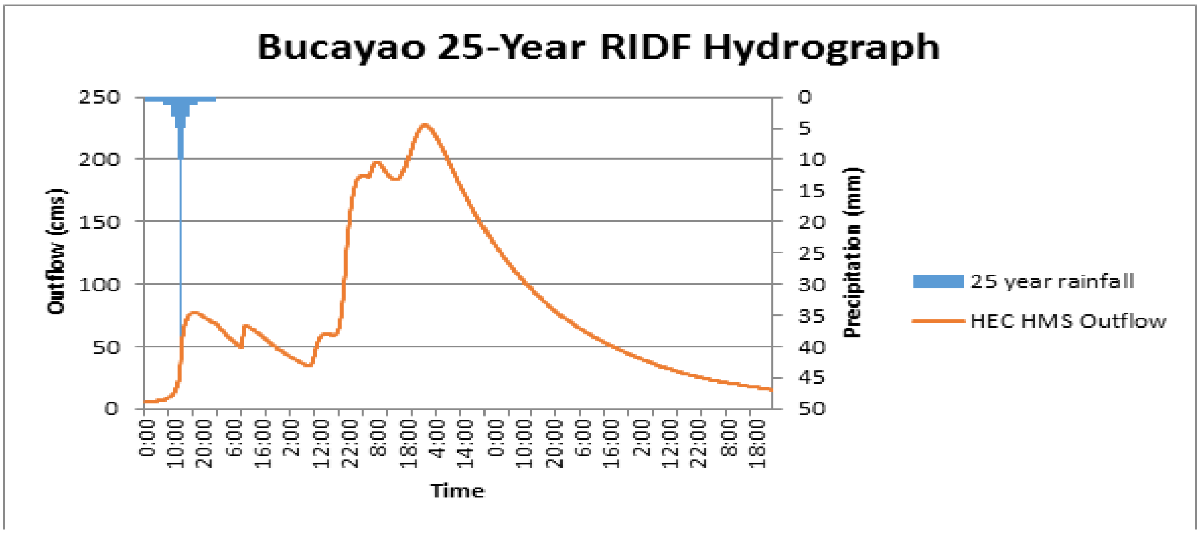


Figure 43. Bucayao Bridge outflow hydrograph generated using the Ambulong 25-Year RIDF in HEC-HMS

In the 50-year return period graph, the peak outflow is 271.6 cms. This occurs after 81 hours after the peak precipitation of 48.1 mm, as shown on Figure 44.

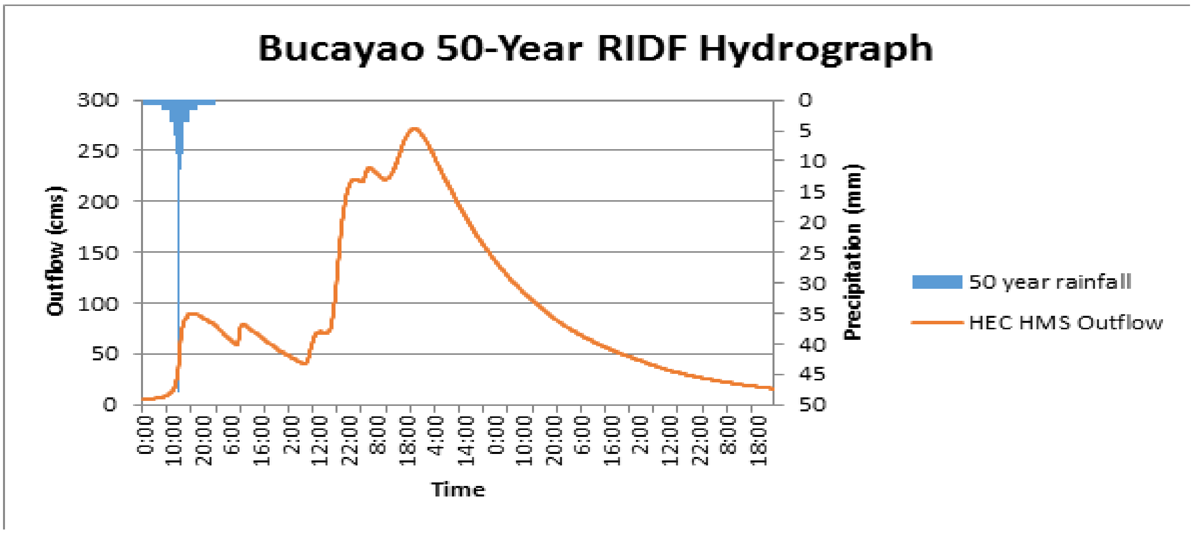


Figure 44. Bucayao Bridge outflow hydrograph generated using the Ambulong 50-Year RIDF in HEC-HMS

In the 100-year return period graph, the peak outflow is 434.3 cms. This occurs after 78 hours and 10 minutes after the peak precipitation of 54 mm, as shown on Figure 45.

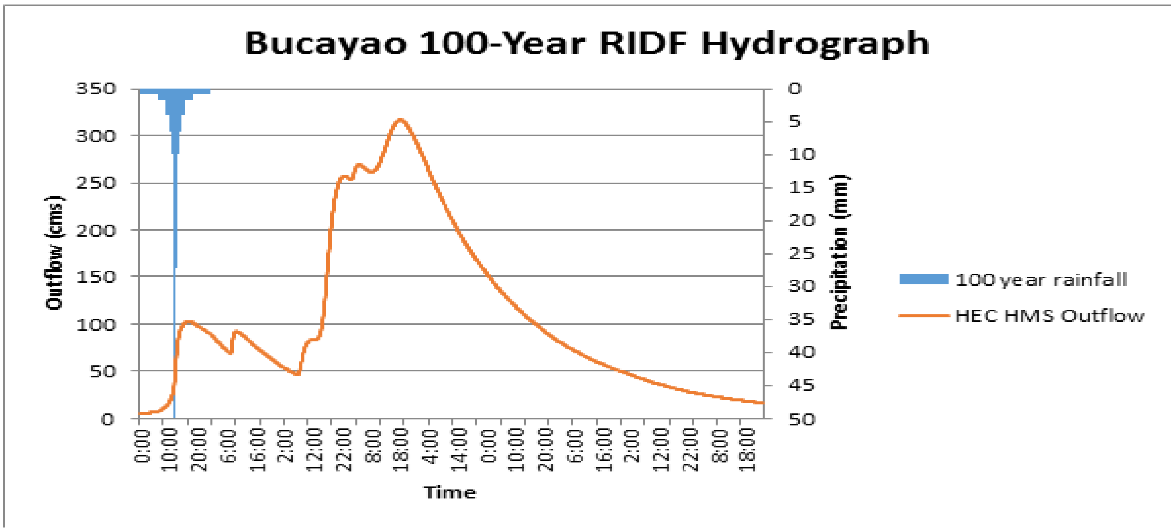


Figure 45. Bucayao Bridge outflow hydrograph generated using the Ambulong 100-Year RIDF in HEC-HMS

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

Table 3. Summary of Bucayao Bridge discharge using Ambulong Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	226.7	27.9	128.7	96 hours 20 minutes
10-Year	276.9	34.2	170.5	90 hours 20 minutes
25-Year	340.4	42.2	227.1	84 hours 30 minutes
50-Year	387.5	48.1	271.6	81 hours
100-Year	434.3	54	316.7	78 hours 10 minutes

4.2.1.3 Alag Bridge

The outflow of Alag Bridge using the Ambulong 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 PAGASA data are shown in Figures 46-50. 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 209.7 cms. This occurs 3 hours and 30 minutes after the peak precipitation of 27.9 mm, as shown on Figure 46.

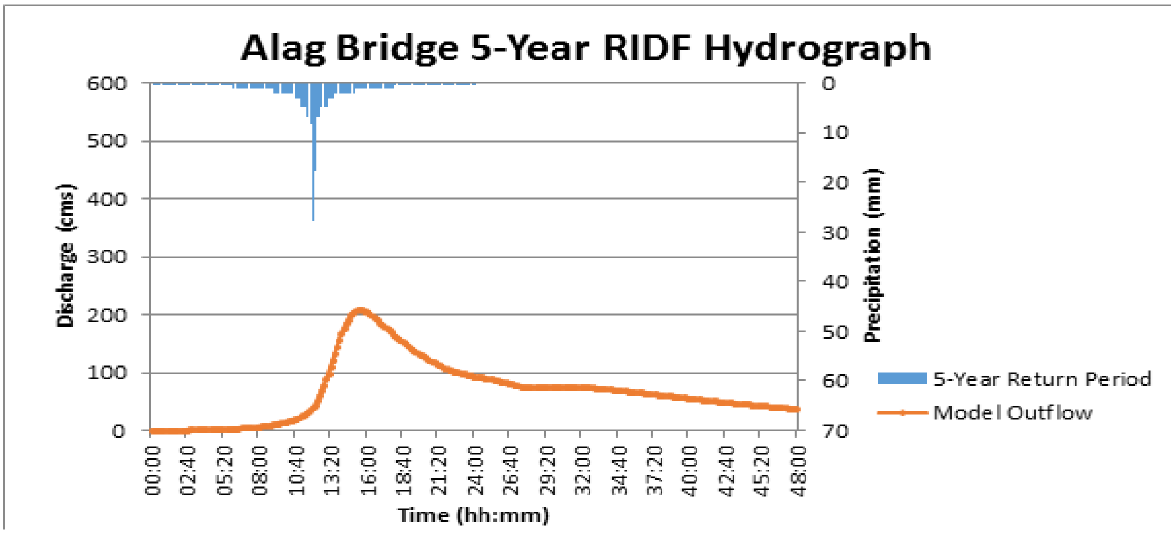


Figure46.AlagBridgeoutflowhydrographgeneratedusingtheAmbulong5-YearRIDFinHEC-HMS

In the 10-year return period graph, the peak outflow is 271.2 cms. This occurs 3 hours and 30 minutes after the peak precipitation of 34.2 mm, as shown on Figure 47.

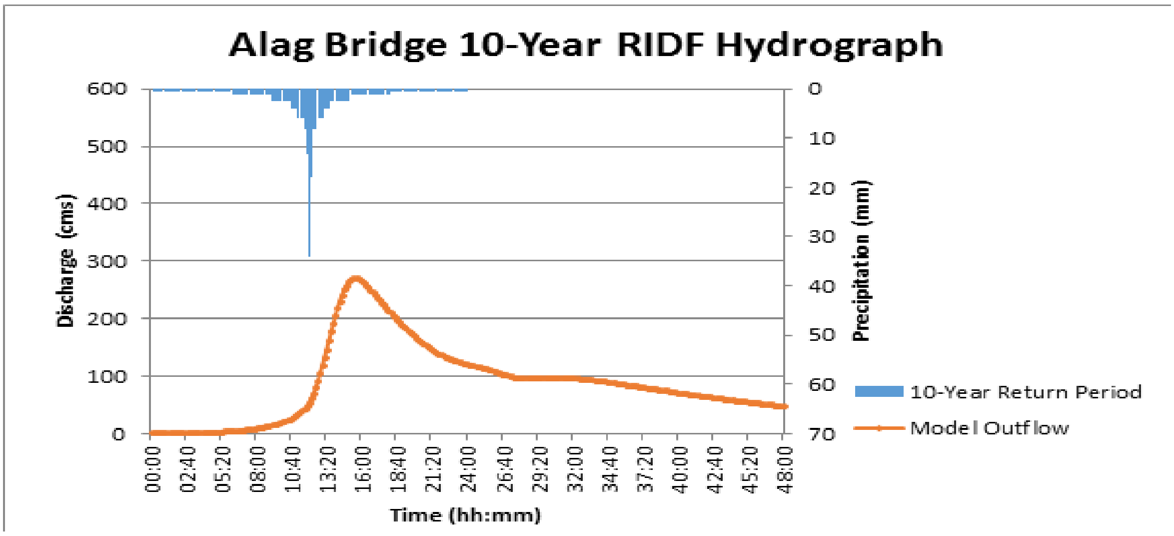


Figure 47. Alag Bridge outflow hydrograph generated using the Ambulong 10-Year RIDF in HEC-HMS

In the 25-year return period graph, the peak outflow is 350.9 cms. This occurs 3 hours and 30 minutes after the peak precipitation of 42.2 mm, as shown on Figure 48.

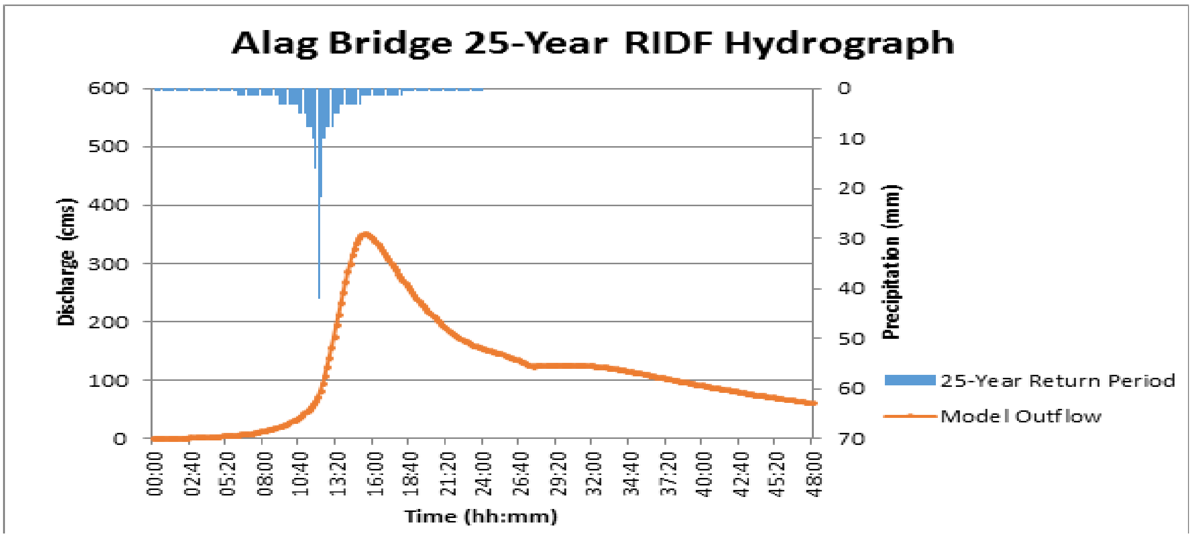


Figure 48. Alag Bridge outflow hydrograph generated using the Ambulong 25-Year RIDF in HEC-HMS

In the 50-year return period graph, the peak outflow is 410.9 cms. This occurs 3 hours and 20 minutes after the peak precipitation of 48.1 mm, as shown on Figure 49.

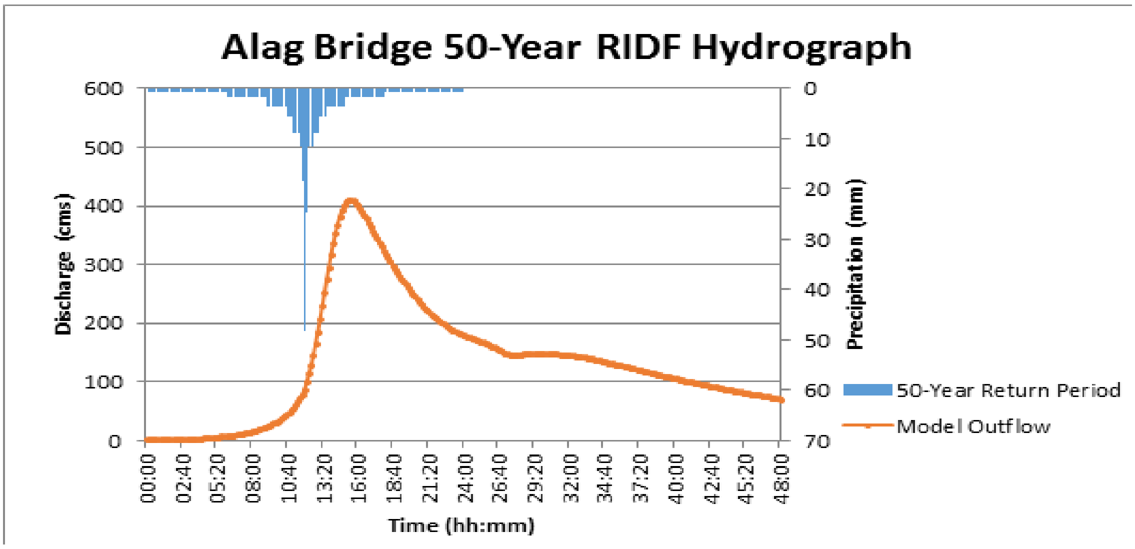


Figure 49. Alag Bridge outflow hydrograph generated using the Ambulong 50-Year RIDF in HEC-HMS

In the 100-year return period graph, the peak outflow is 470.4 cms. This occurs 3 hours and 20 minutes after the peak precipitation of 54 mm, as shown on Figure 50.

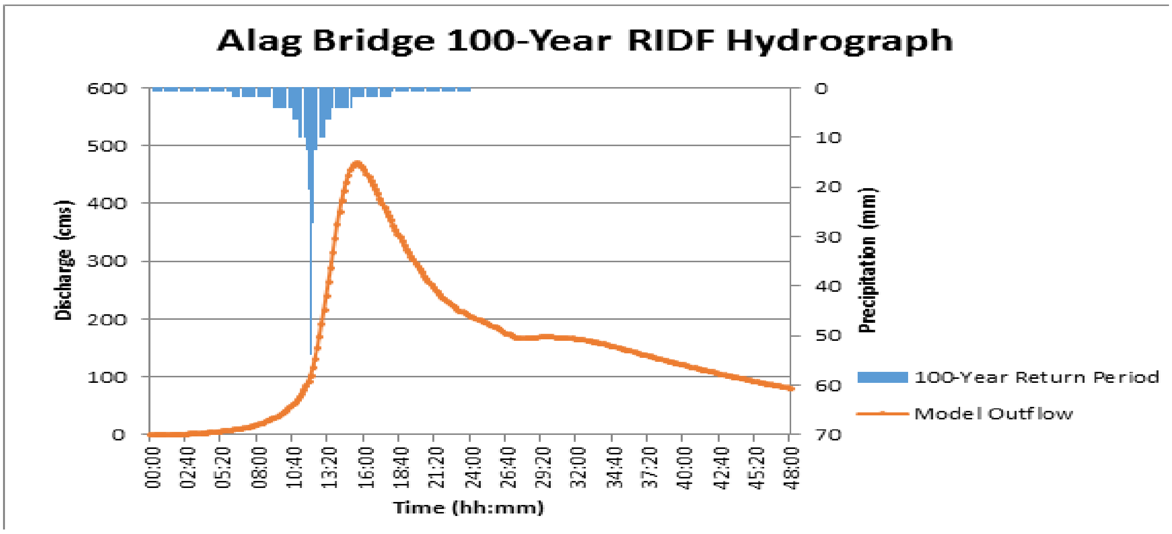


Figure 50. Alag Bridge outflow hydrograph generated using the Ambulong 100-Year RIDF in HEC-HMS

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

Table 4. Summary of Alag Bridge discharge using Ambulong Station Rainfall Intensity Duration Frequency (RIDF)

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	563.6	49.3	1866.1	13 Hours, 50 mins
10-Year	701.7	63.8	2362.9	13 Hours, 50 mins
25-Year	876.1	82.1	2987.8	13 Hours, 50 mins
50-Year	1005.5	95.8	3449.5	13 Hours, 50 mins
100-Year	1134	109.3	3904.4	13 Hours, 50 mins

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 Figures 51-55 and the peak discharge values are summarized in Table 5-9.

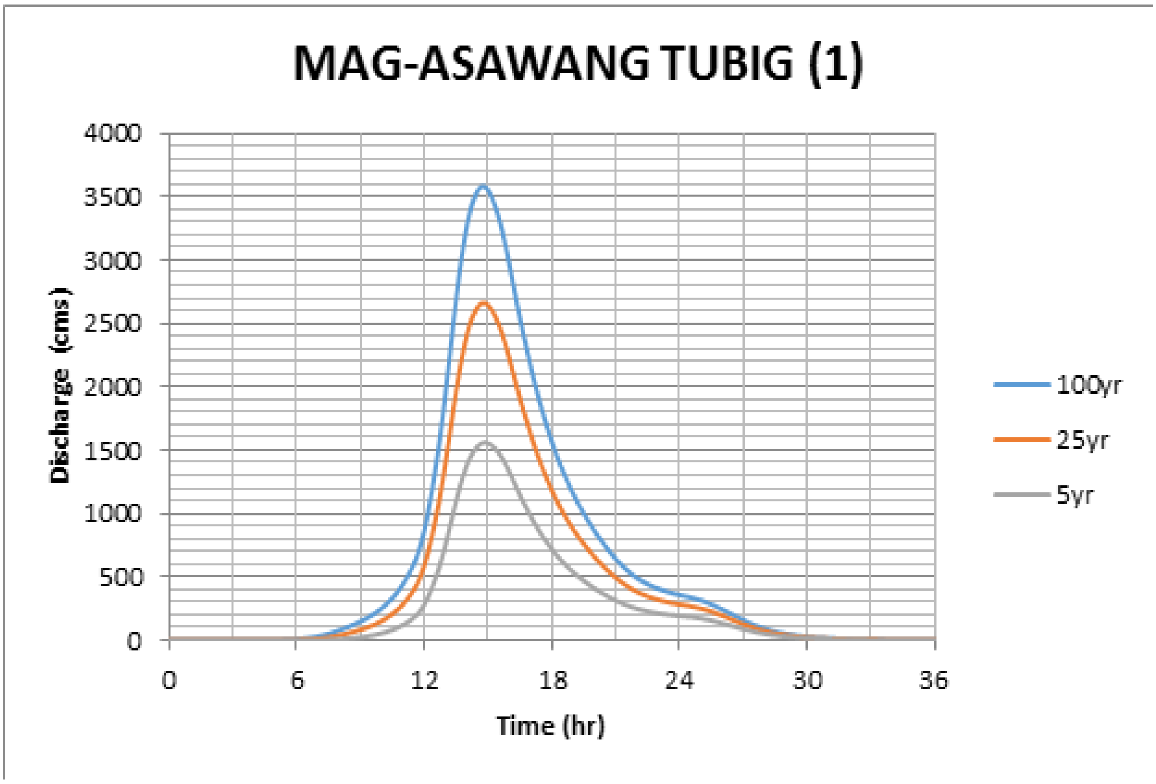


Figure 51. Outflow hydrograph generated using the Mag-Asawang Tubig (1) 5-,25-, 100-Year RIDF in HEC-HMS.

Table 5. Summary of Mag-Asawang Tubig river (1) discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	1559.8	14 hours, 50 minutes
25-Year	2661.2	14 hours, 50 minutes
100-Year	3578.7	14 hours, 40 minutes

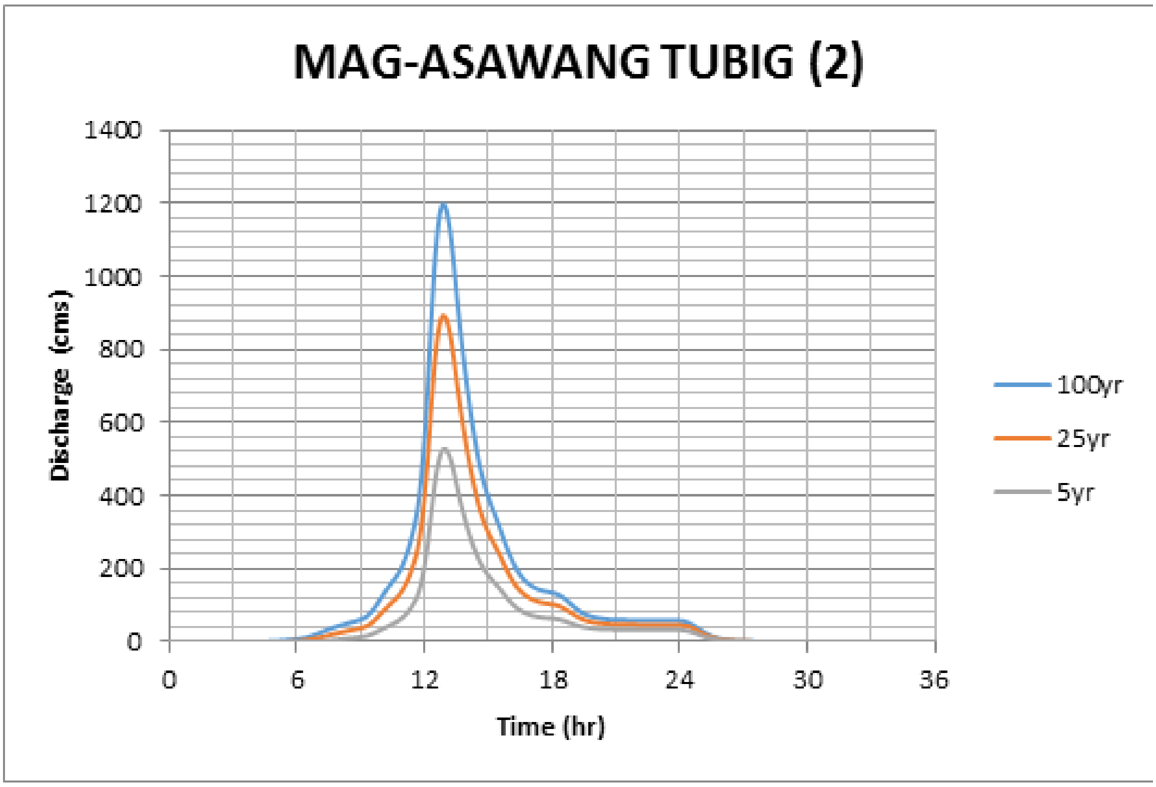


Figure 52. Outflow hydrograph generated using the Mag-Asawang Tubig (2) 5-,25-, 100-Year RIDF in HEC-HMS.

Table 6. Summary of Mag-Asawang Tubig (2) discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	526.0	13 hours
25-Year	891.4	12 hours, 50 minutes
100-Year	1196.3	12 hours, 50 minutes

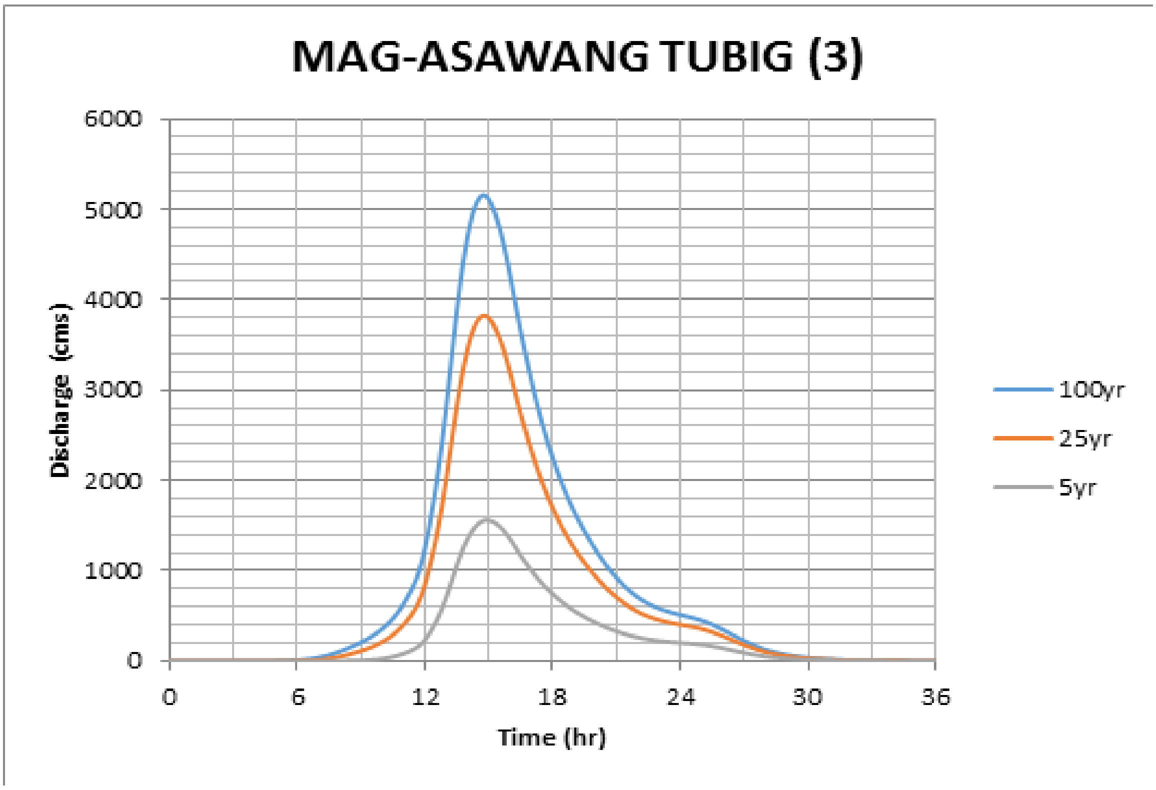


Figure 53. Outflow hydrograph generated using the Mag-Asawang Tubig (3) 5-,25-, 100-Year RIDF in HEC-HMS

Table 7. Summary of Mag-Asawang Tubig (3) discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	1560.9	14 hours, 50 minutes
25-Year	3825.0	14 hours, 50 minutes
100-Year	5153.4	14 hours, 50 minutes

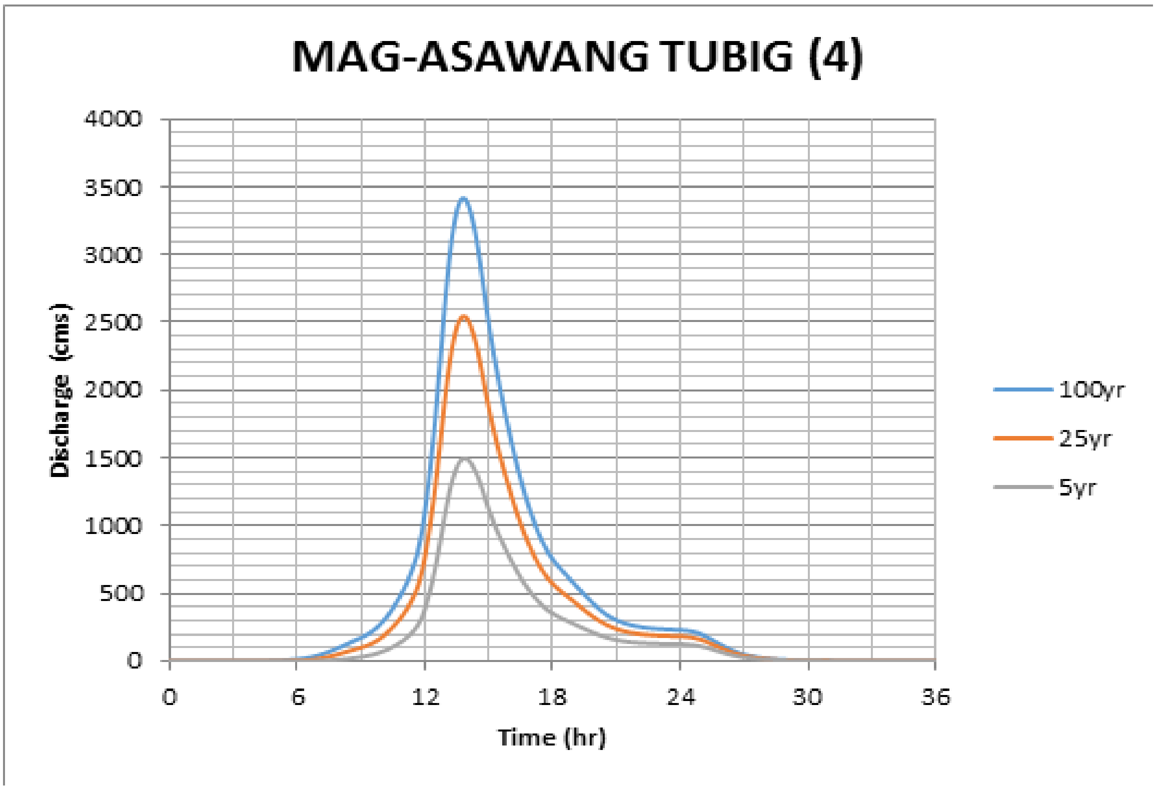


Figure 54. Outflow hydrograph generated using the Mag-Asawang Tubig (4) 5-,25-, 100-Year RIDF in HEC-HMS

Table 8. Summary of Mag-Asawang Tubig (4) discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	1496.1	13 hours, 50 minutes
25-Year	2544.8	13 hours, 50 minutes
100-Year	3417.1	13 hours, 50 minutes

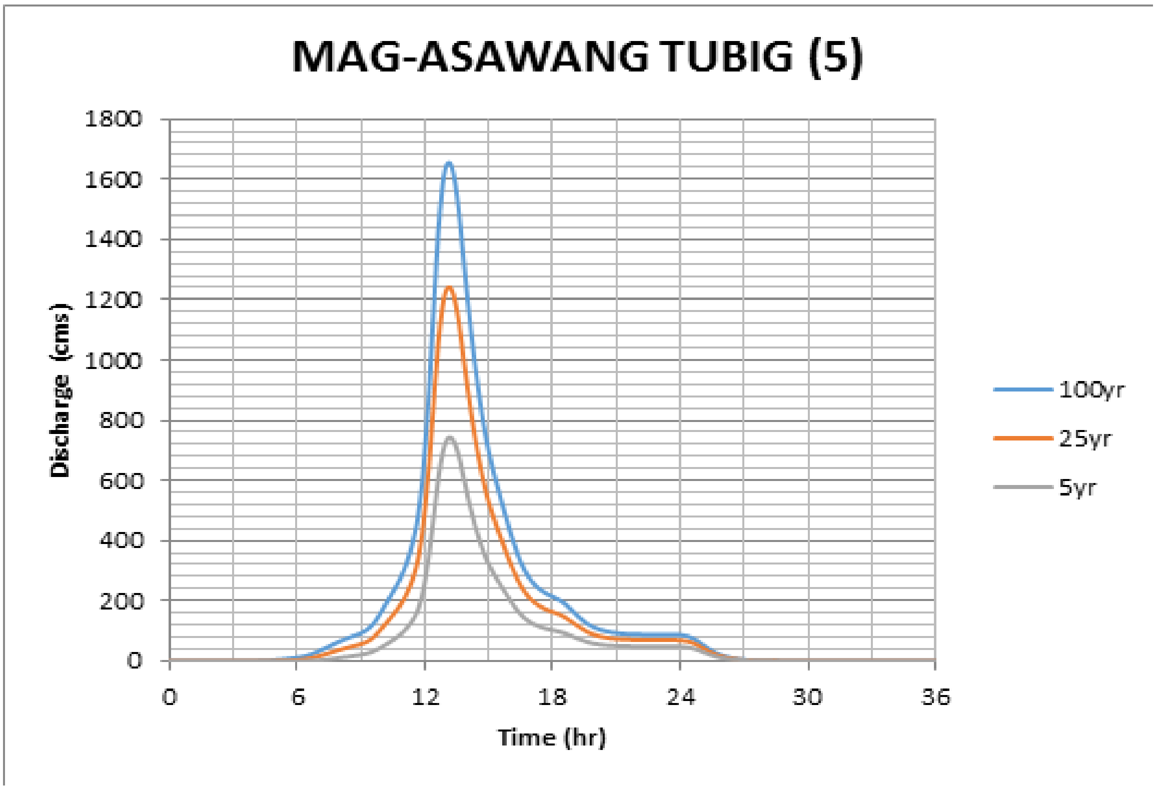


Figure 55. Outflow hydrograph generated using the Mag-Asawang Tubig (5) 5-,25-, 100-Year RIDF in HEC-HMS

Table 9. Summary of Mag-Asawang Tubig (5) discharge using the recommended hydrological method by Dr. Horritt

RIDF Period	Peak discharge (cms)	Time-to-peak
5-Year	743.3	13 hours, 10 minutes
25-Year	1241.7	13 hours, 10 minutes
100-Year	1665.1	13 hours, 10 minutes

The comparison of discharge values obtained from HEC-HMS, Q_{5yr}, and from the bankful discharge method, $Q_{bankful}$, are shown in Table 10. Using values from the DTM of Mag-Asawang Tubig, the bankful discharge for the river was computed.

Table 10. Validation of river discharge estimate using the bankful method

Floodplain	Qbankful, cms	Q5yr, cms	Validation
Mag-asawang Tubig (1)	1289.82	1372.62	Pass
Mag-asawang Tubig (2)	387.04	462.88	Pass
Mag-asawang Tubig (3)	1453.19	1373.59	Pass
Mag-asawang Tubig (4)	1112.39	1316.57	Pass
Mag-asawang Tubig (5)	1224.11	654.1	Pass

The value from the HEC-HMS discharge estimate was able to satisfy the conditions for validating the computed discharge using the bankful method. Since the computed values are based on theory, the actual discharge values were 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 Mag-asawang Tubig river basin.

Flood Hazard Maps and Flow Depth Maps

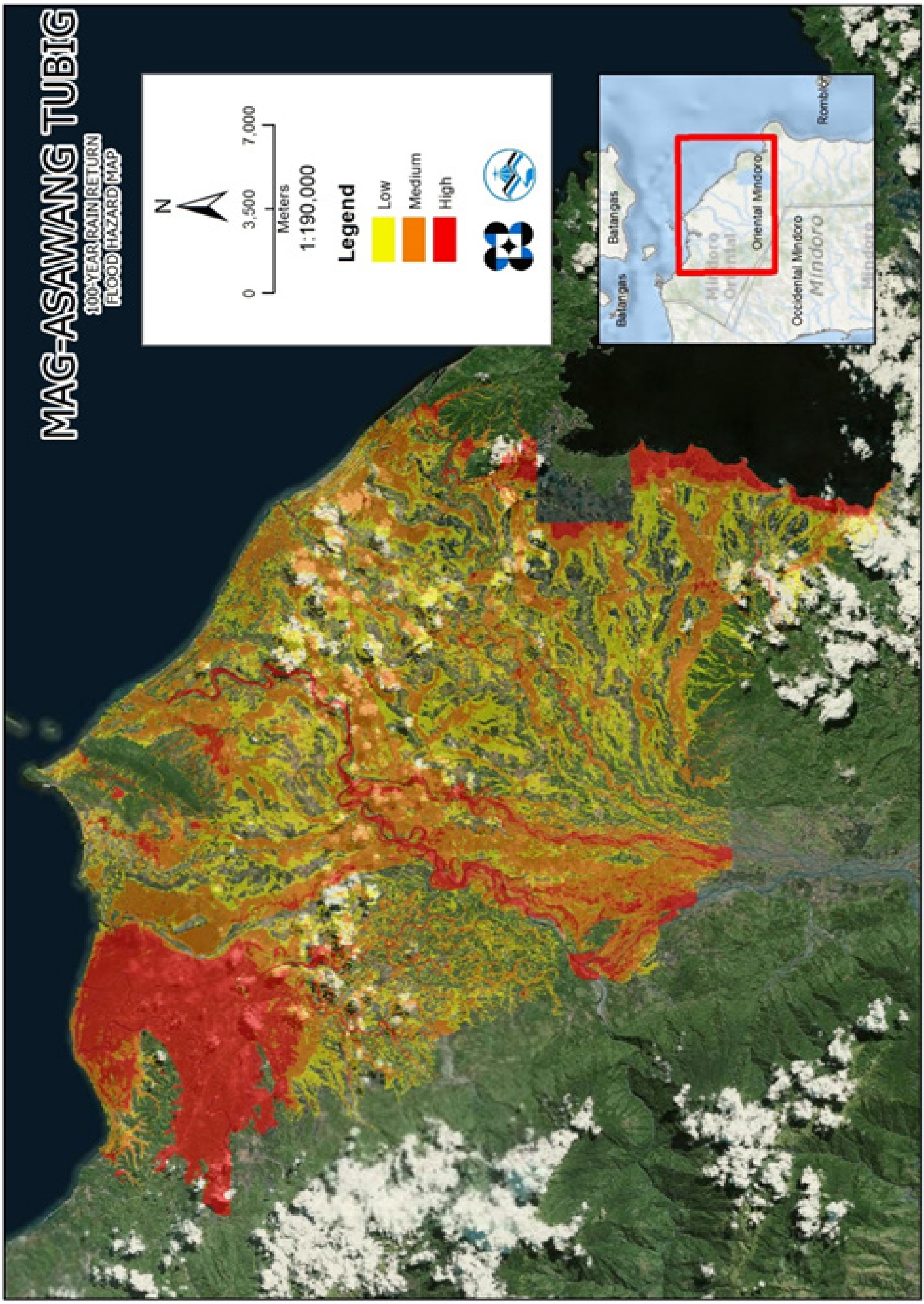


Figure 56. 100-year Flood Hazard Map for Mag-Asawang Tubig River Basin

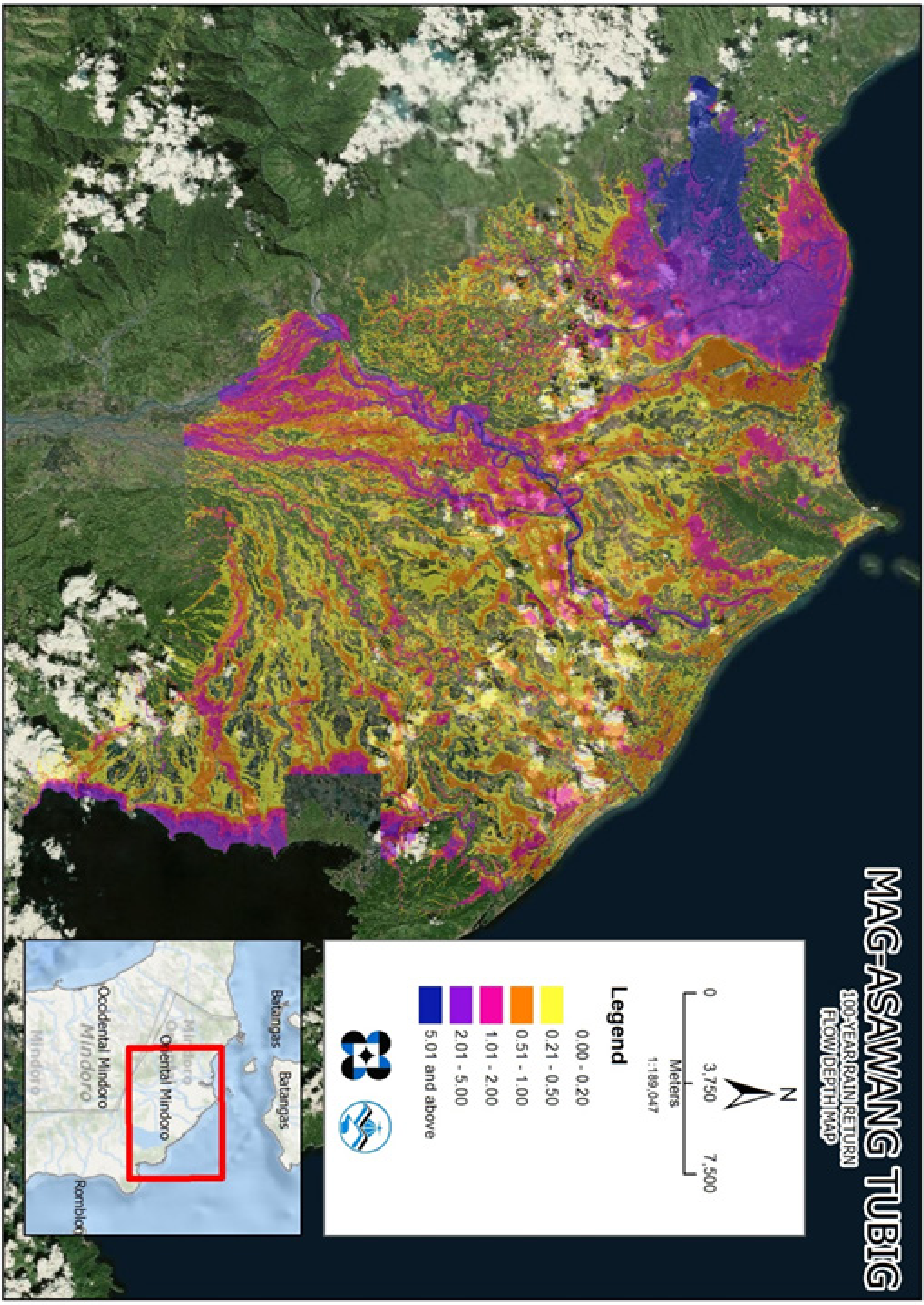


Figure 57. 100-year Flow Depth Map for Mag-Asawang Tubig River Basin

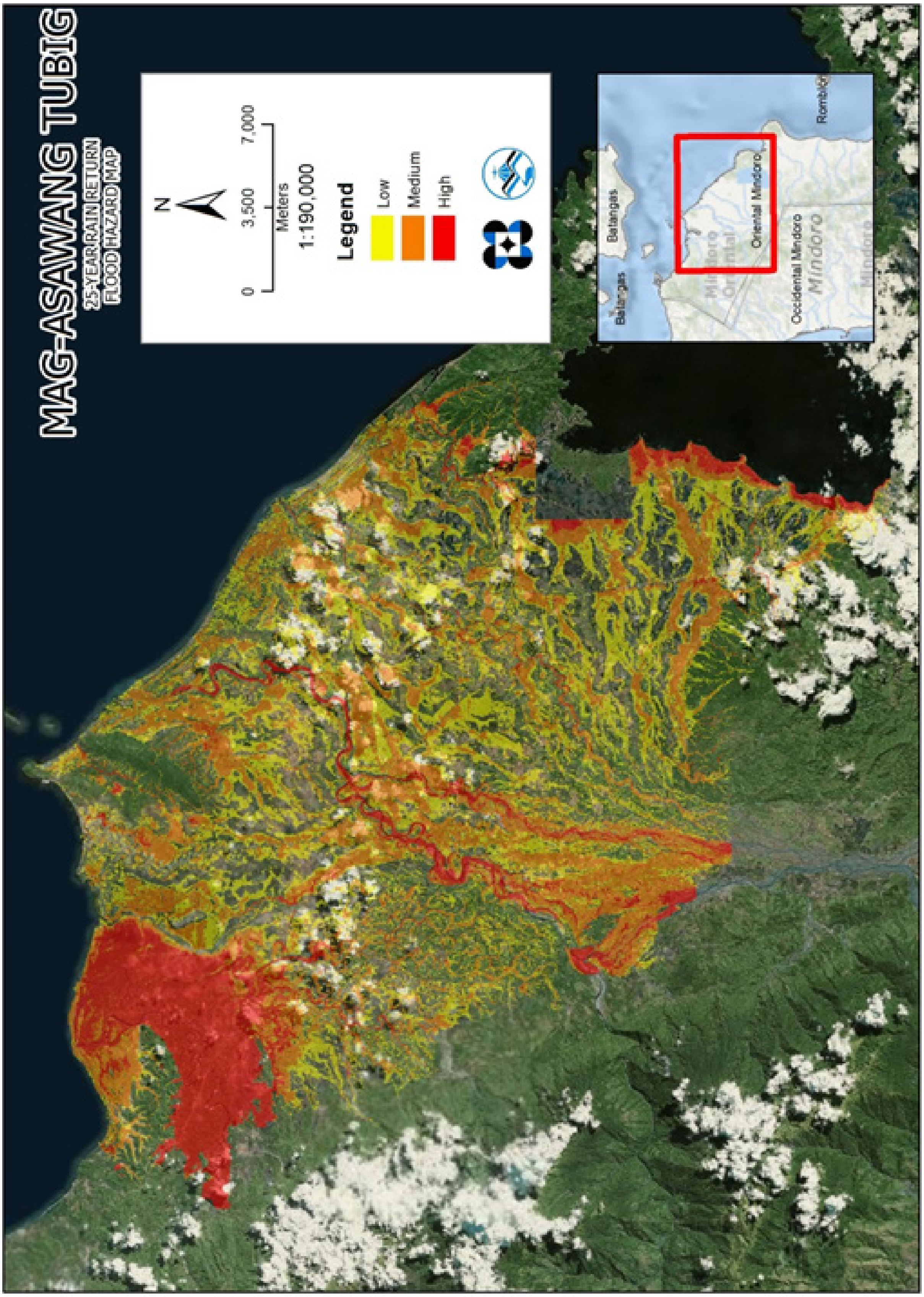


Figure 58. 25-year Flood Hazard Map for Mag-Asawang Tubig River Basin

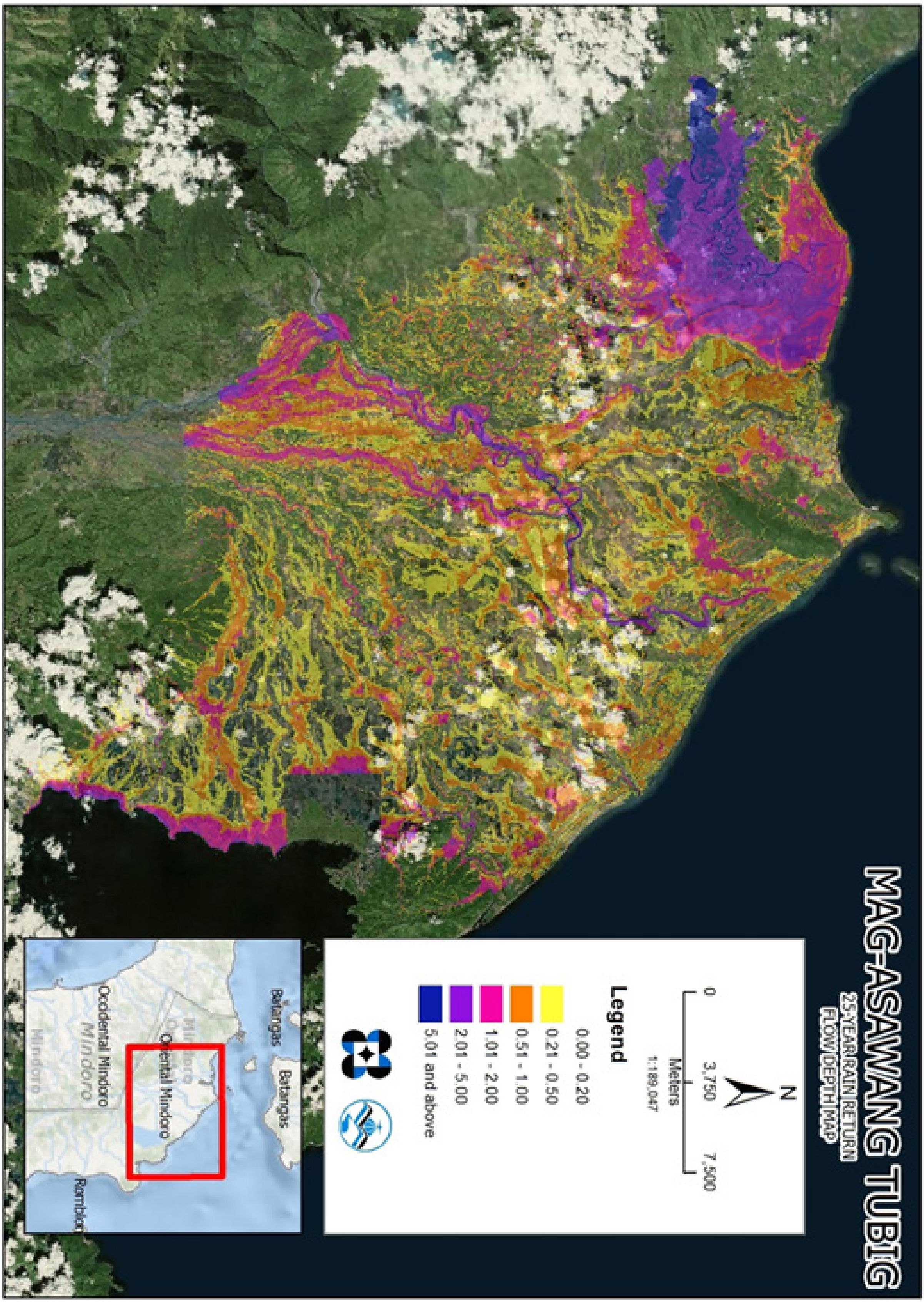


Figure 59. 25-year Flow Depth Map for Mag-Asawang Tubig River Basin

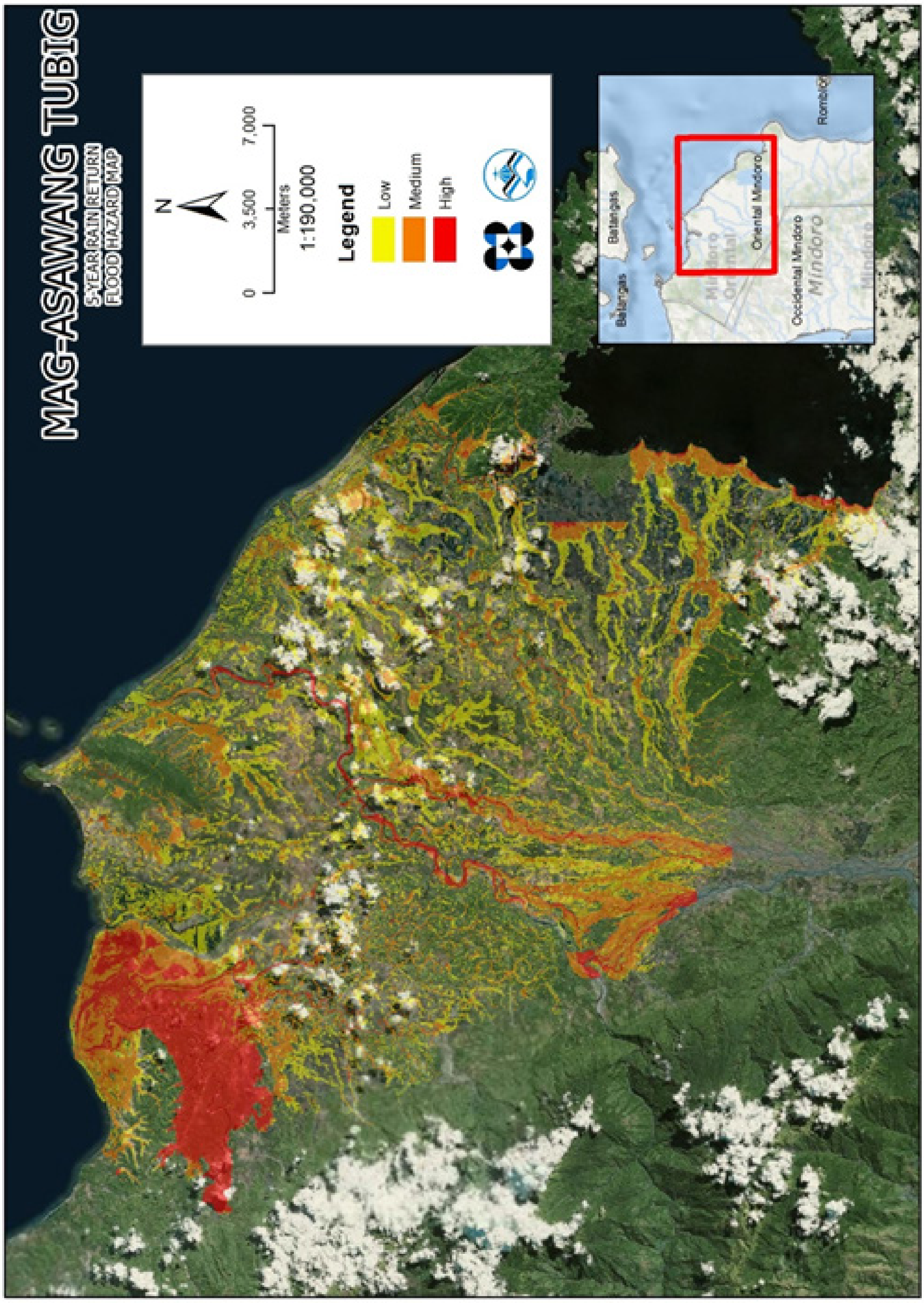


Figure 60. 5-year Flood Hazard Map for Mag-Asawang Tubig River Basin

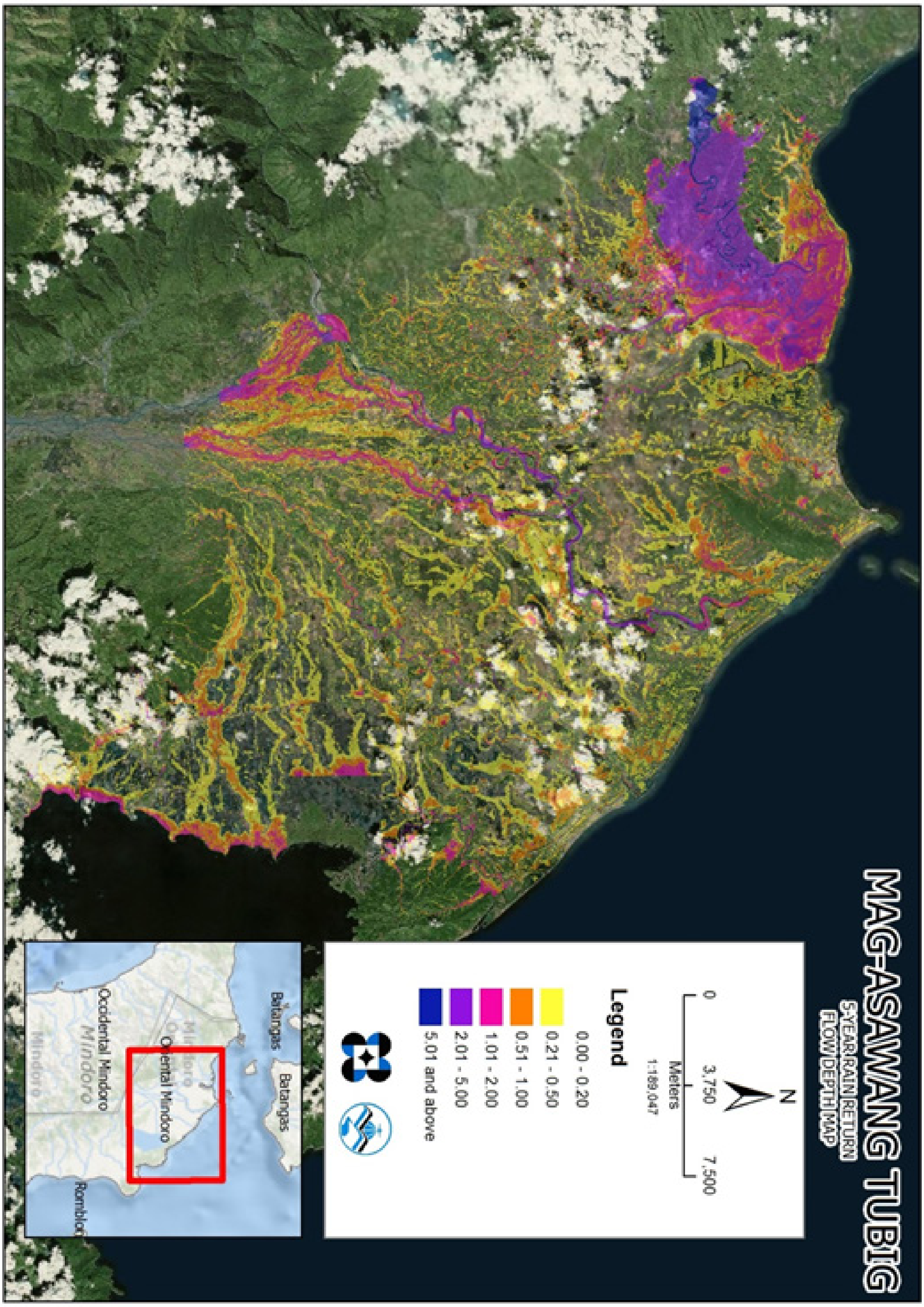


Figure 61. 5-year Flood Hazard Map for Mag-Asawang Tubig River Basin

Bibliography

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

- 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.

- 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. Mag-Asawang Tubig 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
183B	0.105	79	0	1.468206	1.3416192	Discharge	0.10134	0.95	Ratio to Peak	0
184B	0.105	75.24	0	5.521932	5.0590656	Discharge	0.21038	0.95	Ratio to Peak	0
185B	0.105	79.18	0	2.363904	2.1674304	Discharge	0.77412	0.95	Ratio to Peak	0
186B	0.105	78.18	0	1.320462	1.2120192	Discharge	0.55785	0.95	Ratio to Peak	0
187B	0.105	72.78	0	13.444704	12.3125184	Discharge	0.47649	0.95	Ratio to Peak	0
188B	0.105	75.53	0	3.6936	3.3846336	Discharge	0.29486	0.95	Ratio to Peak	0
189B	0.105	78.13	0	12.770622	11.6940672	Discharge	0.45455	0.95	Ratio to Peak	0
190B	0.105	80.17	0	2.040714	1.8729792	Discharge	0.73949	0.95	Ratio to Peak	0
191B	0.105	79.88	0	3.167262	2.9035584	Discharge	0.69421	0.95	Ratio to Peak	0
192B	0.105	82.86	0	5.143338	4.7091456	Discharge	0.098377	0.95	Ratio to Peak	0
193B	0.105	79.86	0	3.628962	3.3239808	Discharge	0.28007	0.95	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
194B	0.105	79	0	2.040714	1.8652032	Discharge	0.50227	0.95	Ratio to Peak	0
195B	0.105	78.76	0	1.412802	1.2923712	Discharge	0.526543	0.95	Ratio to Peak	0
196B	0.105	64.97	0	3.989088	3.657312	Discharge	0.10256	0.95	Ratio to Peak	0
197B	0.105	80.43	0	8.255196	7.5629376	Discharge	0.34398	0.95	Ratio to Peak	0
198B	0.105	73.92	0	8.338302	7.6417344	Discharge	0.25502	0.95	Ratio to Peak	0
199B	0.105	82.77	0	8.21826	7.524576	Discharge	0.45325	0.95	Ratio to Peak	0
200B	0.105	82.32	0	3.721302	3.405888	Discharge	0.14686	0.95	Ratio to Peak	0
201B	0.105	82.59	0	11.607138	10.6303104	Discharge	0.43248	0.95	Ratio to Peak	0
202B	0.105	79.46	0	4.4248	11.073024	Discharge	0.60781	0.95	Ratio to Peak	0
203B	0.105	59.27	0	5.6313	6.1388928	Discharge	0.2225	0.95	Ratio to Peak	0
204B	0.105	83.89	0	20	3.3846336	Discharge	0.12161	0.95	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
205B	0.105	76.98	0	6.7482	4.413139	Discharge	0.20655	0.95	Ratio to Peak	0
206B	0.105	83.65	0	8.1392	6.657293	Discharge	0.25491	0.95	Ratio to Peak	0
207B	0.105	82.19	0	7.1231	4.661971	Discharge	0.21557	0.95	Ratio to Peak	0
208B	0.105	79	0	6.7741	2.218752	Discharge	1.1503	0.95	Ratio to Peak	0
209B	0.105	79.17	0	6.3294	1.293926	Discharge	0.35123	0.95	Ratio to Peak	0
210B	0.105	78.42	0	6.3087	1.032134	Discharge	0.086925	0.95	Ratio to Peak	0
211B	0.105	79.45	0	7.7359	1.579046	Discharge	0.09478	0.95	Ratio to Peak	0
212B	0.105	78.65	0	6.6603	1.361318	Discharge	0.25061	0.95	Ratio to Peak	0
213B	0.105	77.79	0	9.1424	1.871424	Discharge	0.33993	0.95	Ratio to Peak	0
214B	0.105	78.4	0	6.4276	0.955411	Discharge	0.28417	0.95	Ratio to Peak	0
215B	0.105	79	0	6.6603	0.948672	Discharge	0.29734	0.95	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
216B	0.105	79.44	0	5.531166	5.069434	Discharge	0.19646	0.95	Ratio to Peak	0
217B	0.105	74.28	0	6.057504	5.54999	Discharge	0.18743	0.95	Ratio to Peak	0
218B	0.105	80.91	0	6.657714	6.098976	Discharge	0.30868	0.95	Ratio to Peak	0
219B	0.009218	81.952	0	0.45864	5.1321	Discharge	1.393026	0.95533	Ratio to Peak	0
220B	0.33354	99	0	3.6448	8.8881	Discharge	1.6659	0.93387	Ratio to Peak	0
221B	0.03158	78.876	0	1.4499	6.3426	Discharge	2.9908	0.94255	Ratio to Peak	0
222B	0.12631	99	0	0.026878	0.026428	Discharge	0.19279	1	Ratio to Peak	0
223B	0.40126	72.429	0	0.024902	5.1901	Discharge	1.7684	0.95501	Ratio to Peak	0
224B	0.37205	99	0	74.364	15.404	Discharge	2.1149	0.9558	Ratio to Peak	0
225B	0.003566	99	0	27.045	32.987	Discharge	1.4885	0.95811	Ratio to Peak	0
226B	0.001204	55.267	0	0.10527	65.34	Discharge	3.8941	0.95135	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
227B	0.10725	99	0	90.428	18	Discharge	0.9871	0.96105	Ratio to Peak	0
228B	0.035843	66.2	0	0.023183	28.15	Discharge	2.0255	0.95473	Ratio to Peak	0
229B	0.004002	75.024	0	4.3621	21.652	Discharge	1.2478	0.95728	Ratio to Peak	0
230B	0.006179	35.821	0	0.026829	3.1212	Discharge	2.4089	0.95097	Ratio to Peak	0
231B	0.004103	67.452	0	2.8212	12.502	Discharge	2.6943	0.95182	Ratio to Peak	0
232B	0.048131	74.769	0	5.0816	26.706	Discharge	2.1362	0.95527	Ratio to Peak	0
233B	0.003901	37.831	0	1.0856	28.647	Discharge	1.8902	0.95174	Ratio to Peak	0
234B	0.077386	94.366	0	75.375	15.928	Discharge	1.28	0.95722	Ratio to Peak	0
235B	0.11102	56.671	0	0.02898	30.997	Discharge	2.4304	0.95093	Ratio to Peak	0
236B	0.00494	69.722	0	4.6269	36.402	Discharge	2.694	0.95485	Ratio to Peak	0
237B	0.00922	46.306	0	42.91	19.87	Discharge	1.0092	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
238B	0.003881	59.038	0	0.12722	6.3704	Discharge	1.9683	0.95503	Ratio to Peak	0
239B	0.006697	64.48	0	7.211754	6.6096	Discharge	0.13455	0.95	Ratio to Peak	0
240B	0.009367	70.02	0	8.938512	8.189683	Discharge	0.41969	0.95	Ratio to Peak	0
241B	0.004349	63.48	0	5.826654	5.335373	Discharge	0.20786	0.95	Ratio to Peak	0
242B	0.105	78.58	0	4.580064	4.195411	Discharge	0.609	0.95	Ratio to Peak	0
243B	0.105	78.73	0	4.838616	4.428691	Discharge	0.60955	0.95	Ratio to Peak	0

Appendix B. Mag-asawang Tubig Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
241R	Automatic Fixed Interval	15146.89	0.00011	0.24	Trapezoid	30	45
242R	Automatic Fixed Interval	11593.24	0.00012	0.24	Trapezoid	30	45
243R	Automatic Fixed Interval	15375.31	0.00161	0.24	Trapezoid	30	45
244R	Automatic Fixed Interval	15336.52	0.00011	0.24	Trapezoid	30	45
245R	Automatic Fixed Interval	21650.16	0.0017	0.24	Trapezoid	30	45
246R	Automatic Fixed Interval	29822.83	0.00029	0.24	Trapezoid	30	45
247R	Automatic Fixed Interval	17083.13	0.00236	0.95761	Trapezoid	30	45
248R	Automatic Fixed Interval	29824.83	0.0004	0.24	Trapezoid	30	45
249R	Automatic Fixed Interval	38546.06	0.00162	0.96694	Trapezoid	30	45
250R	Automatic Fixed Interval	5849.083	0.00011	0.96682	Trapezoid	30	45
251R	Automatic Fixed Interval	50436.06	0.00149	0.95274	Trapezoid	30	45
252R	Automatic Fixed Interval	27171.77	0.00134	0.96694	Trapezoid	30	45
253R	Automatic Fixed Interval	7917.984	0.00138	0.96694	Trapezoid	30	45
254R	Automatic Fixed Interval	9034.446	0.00399	0.96346	Trapezoid	30	45
255R	Automatic Fixed Interval	43715.12	0.00407	0.96642	Trapezoid	30	45
256R	Automatic Fixed Interval	13967.88	0.00544	0.98074	Trapezoid	30	45
257R	Automatic Fixed Interval	14219.43	0.00523	0.97757	Trapezoid	30	45
258R	Automatic Fixed Interval	10494.12	0.04729	0.96869	Trapezoid	30	45
259R	Automatic Fixed Interval	19148	0.00086	0.24	Trapezoid	30	45
260R	Automatic Fixed Interval	23610.66	0.0012	0.24	Trapezoid	30	45
261R	Automatic Fixed Interval	24807.58	0.001	0.023082	Trapezoid	30	45
262R	Automatic Fixed Interval	35012.83	0.001	0.023387	Trapezoid	30	45
263R	Automatic Fixed Interval	31879.26	0.001	0.049399	Trapezoid	30	45
264R	Automatic Fixed Interval	3994.952	0.001	0.000535	Trapezoid	30	45
265R	Automatic Fixed Interval	7033.505	0.001	0.11164	Trapezoid	30	45
266R	Automatic Fixed Interval	13655.19	0.001	0.011329	Trapezoid	30	45
267R	Automatic Fixed Interval	23295.49	0.001	0.000839	Trapezoid	30	45
268R	Automatic Fixed Interval	14792.81	0.001	0.01017	Trapezoid	30	45
269R	Automatic Fixed Interval	16730.51	0.001	0.000294	Trapezoid	30	45
270R	Automatic Fixed Interval	9025.577	0.001	0.023224	Trapezoid	30	45
271R	Automatic Fixed Interval	24276.66	0.001	0.002929	Trapezoid	30	45
272R	Automatic Fixed Interval	16778.31	0.001	0.000875	Trapezoid	30	45
273R	Automatic Fixed Interval	9764.694	0.001	0.008196	Trapezoid	30	45
274R	Automatic Fixed Interval	14793.57	0.001	0.001543	Trapezoid	30	45
275R	Automatic Fixed Interval	13433.65	0.001	0.006926	Trapezoid	30	45

Appendix

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
276R	Automatic Fixed Interval	18834.86	0.001	0.000646	Trapezoid	30	45
277R	Automatic Fixed Interval	18027.83	0.001	0.01039	Trapezoid	30	45
278R	Automatic Fixed Interval	13010.35	0.001	0.1545	Trapezoid	30	45
279R	Automatic Fixed Interval	20076.61	0.001	0.001686	Trapezoid	30	45
280R	Automatic Fixed Interval	28403.18	0.00168	0.009957	Trapezoid	30	45
283R	Automatic Fixed Interval	17172.49	0.00078	0.003704	Trapezoid	30	45
290R	Automatic Fixed Interval	11868.11	0.00138	0.001579	Trapezoid	30	45
291R	Automatic Fixed Interval	16863.99	0.00126	0.00615	Trapezoid	30	45
292R	Automatic Fixed Interval	48022.59	0.0004	0.001	Trapezoid	30	45
293R	Automatic Fixed Interval	24292.68	0.00085	0.011223	Trapezoid	30	45
294R	Automatic Fixed Interval	17428.61	0.00218	0.018518	Trapezoid	30	45
295R	Automatic Fixed Interval	48968.14	0.0093	0.007897	Trapezoid	30	45
296R	Automatic Fixed Interval	29801.28	0.00051	0.24	Trapezoid	30	45
298R	Automatic Fixed Interval	34404.59	0.00075	0.24	Trapezoid	30	45
299R	Automatic Fixed Interval	25210.12	0.00085	0.24	Trapezoid	30	45

Appendix C. Bucayao 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
183B	0.105	79	0	1.468206	1.341619	Discharge	0.10134	0.95	Ratio To Peak	0
184B	0.105	75.24	0	5.521932	5.059066	Discharge	0.21038	0.95	Ratio To Peak	0
185B	0.105	79.18	0	2.363904	2.16743	Discharge	0.77412	0.95	Ratio To Peak	0
186B	0.105	78.18	0	1.320462	1.212019	Discharge	0.55785	0.95	Ratio To Peak	0
187B	0.105	72.78	0	13.4447	12.31252	Discharge	0.47649	0.95	Ratio To Peak	0
188B	0.105	75.53	0	3.6936	3.384634	Discharge	0.29486	0.95	Ratio To Peak	0
189B	0.105	78.13	0	12.77062	11.69407	Discharge	0.45455	0.95	Ratio To Peak	0
190B	0.105	80.17	0	2.040714	1.872979	Discharge	0.73949	0.95	Ratio To Peak	0
191B	0.105	79.88	0	3.167262	2.903558	Discharge	0.69421	0.95	Ratio To Peak	0
192B	0.105	82.86	0	5.143338	4.709146	Discharge	0.098377	0.95	Ratio To Peak	0
193B	0.105	79.86	0	3.628962	3.323981	Discharge	0.28007	0.95	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
194B	0.105	79	0	2.040714	1.865203	Discharge	0.50227	0.95	Ratio To Peak	0
195B	0.105	78.76	0	1.412802	1.292371	Discharge	0.526543	0.95	Ratio To Peak	0
196B	0.105	64.97	0	3.989088	3.657312	Discharge	0.10256	0.95	Ratio To Peak	0
197B	0.105	80.43	0	8.255196	7.562938	Discharge	0.34398	0.95	Ratio To Peak	0
198B	0.105	73.92	0	8.338302	7.641734	Discharge	0.25502	0.95	Ratio To Peak	0
199B	0.105	82.77	0	8.21826	7.524576	Discharge	0.45325	0.95	Ratio To Peak	0
200B	0.105	82.32	0	3.721302	3.405888	Discharge	0.14686	0.95	Ratio To Peak	0
201B	0.105	82.59	0	11.60714	10.63031	Discharge	0.43248	0.95	Ratio To Peak	0
202B	0.1071	68.71608	0	1.197288	23.8119	Discharge	0.77376	0.95	Ratio To Peak	0
203B	0.096849	60.21324	0	1.654128	25.41529	Discharge	0.28326	0.95	Ratio To Peak	0
204B	0.105	83	0	1	1	Discharge	0.15482	0.95	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
205B	0.096849	76.68432	0	4.415328	18.27034	Discharge	0.26295	0.95	Ratio To Peak	0
206B	0.020741	56.68596	0	3.568392	27.56119	Discharge	0.32451	0.95	Ratio To Peak	0
207B	0.044819	81.87372	0	2.092032	19.30016	Discharge	0.27443	0.95	Ratio To Peak	0
208B	0.1071	80.30232	0	1.950912	27.55688	Discharge	1.4644	0.95	Ratio To Peak	0
209B	0.10711	53.65008	0	1.822896	16.07096	Discharge	0.44713	0.95	Ratio To Peak	0
210B	0.10711	89.1	0	1.81692	17.09216	Discharge	0.11066	0.95	Ratio To Peak	0
211B	0.10711	68.9688	0	2.227968	19.61153	Discharge	0.12066	0.95	Ratio To Peak	0
212B	0.15987	53.298	0	1.918152	16.90759	Discharge	0.31903	0.95	Ratio To Peak	0
213B	0.10711	71.20764	0	2.63304	23.24351	Discharge	0.43274	0.95	Ratio To Peak	0
214B	0.10568	89.1	0	1.85112	15.8217	Discharge	0.36176	0.95	Ratio To Peak	0
215B	0.10552	89.1	0	1.918152	15.71044	Discharge	0.37852	0.95	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
216B	0.105	79.44	0	5.531166	5.069434	Discharge	0.19646	0.95	Ratio To Peak	0
217B	0.105	74.28	0	6.057504	5.54999	Discharge	0.18743	0.95	Ratio To Peak	0
218B	0.105	80.91	0	6.657714	6.098976	Discharge	0.30868	0.95	Ratio To Peak	0
219B	0.009218	81.952	0	0.45864	5.1321	Discharge	1.393026	0.95533	Ratio To Peak	0
220B	0.33354	99	0	3.6448	8.8881	Discharge	1.6659	0.93387	Ratio To Peak	0
221B	0.03158	78.876	0	1.4499	6.3426	Discharge	2.9908	0.94255	Ratio To Peak	0
222B	0.12631	99	0	0.026878	0.026428	Discharge	0.19279	1	Ratio To Peak	0
223B	0.40126	72.429	0	0.024902	5.1901	Discharge	1.7684	0.95501	Ratio To Peak	0
224B	0.37205	99	0	74.364	15.404	Discharge	2.1149	0.9558	Ratio To Peak	0
225B	0.003566	99	0	27.045	32.987	Discharge	1.4885	0.95811	Ratio To Peak	0
226B	0.001204	55.267	0	0.10527	65.34	Discharge	3.8941	0.95135	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
227B	0.10725	99	0	90.428	18	Discharge	0.9871	0.96105	Ratio To Peak	0
228B	0.035843	66.2	0	0.023183	28.15	Discharge	2.0255	0.95473	Ratio To Peak	0
229B	0.004002	75.024	0	4.3621	21.652	Discharge	1.2478	0.95728	Ratio To Peak	0
230B	0.006179	35.821	0	0.026829	3.1212	Discharge	2.4089	0.95097	Ratio To Peak	0
231B	0.004103	67.452	0	2.8212	12.502	Discharge	2.6943	0.95182	Ratio To Peak	0
232B	0.048131	74.769	0	5.0816	26.706	Discharge	2.1362	0.95527	Ratio To Peak	0
233B	0.003901	37.831	0	1.0856	28.647	Discharge	1.8902	0.95174	Ratio To Peak	0
234B	0.077386	94.366	0	75.375	15.928	Discharge	1.28	0.95722	Ratio To Peak	0
235B	0.11102	56.671	0	0.02898	30.997	Discharge	2.4304	0.95093	Ratio To Peak	0
236B	0.00494	69.722	0	4.6269	36.402	Discharge	2.694	0.95485	Ratio To Peak	0
237B	0.00922	46.306	0	42.91	19.87	Discharge	1.0092	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
238B	0.003881	59.038	0	0.12722	6.3704	Discharge	1.9683	0.95503	Ratio To Peak	0
239B	0.006697	64.48	0	7.211754	6.6096	Discharge	0.13455	0.95	Ratio To Peak	0
240B	0.009367	70.02	0	8.938512	8.189683	Discharge	0.41969	0.95	Ratio To Peak	0
241B	0.004349	63.48	0	5.826654	5.335373	Discharge	0.20786	0.95	Ratio To Peak	0
242B	0.105	78.58	0	4.580064	4.195411	Discharge	0.609	0.95	Ratio To Peak	0
243B	0.105	78.73	0	4.838616	4.428691	Discharge	0.60955	0.95	Ratio To Peak	0

Appendix D. Bucayao Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
241R	Automatic Fixed Interval	15146.89	0.00011	0.24	Trapezoid	30	45
242R	Automatic Fixed Interval	11593.24	0.00012	0.24	Trapezoid	30	45
243R	Automatic Fixed Interval	15375.31	0.00161	0.24	Trapezoid	30	45
244R	Automatic Fixed Interval	15336.52	0.00011	0.24	Trapezoid	30	45
245R	Automatic Fixed Interval	21650.16	0.0017	0.24	Trapezoid	30	45
246R	Automatic Fixed Interval	29822.83	0.00029	0.24	Trapezoid	30	45
247R	Automatic Fixed Interval	17083.13	0.00236	0.183862	Trapezoid	30	45
248R	Automatic Fixed Interval	29824.83	0.0004	1	Trapezoid	30	45
249R	Automatic Fixed Interval	38546.06	0.00162	0.186977	Trapezoid	30	45
250R	Automatic Fixed Interval	5849.083	0.00011	0.18563	Trapezoid	30	45
251R	Automatic Fixed Interval	50436.06	0.00149	0.179009	Trapezoid	30	45
252R	Automatic Fixed Interval	27171.77	0.00134	0.185652	Trapezoid	30	45
253R	Automatic Fixed Interval	7917.984	0.00138	0.185652	Trapezoid	30	45
254R	Automatic Fixed Interval	9034.446	0.00399	0.184985	Trapezoid	30	45
255R	Automatic Fixed Interval	43715.12	0.00407	0.185554	Trapezoid	30	45
256R	Automatic Fixed Interval	13967.88	0.00544	0.188302	Trapezoid	30	45
257R	Automatic Fixed Interval	14219.43	0.00523	0.187694	Trapezoid	30	45
258R	Automatic Fixed Interval	10494.12	0.04729	0.185988	Trapezoid	30	45
259R	Automatic Fixed Interval	19148	0.00086	0.24	Trapezoid	30	45
260R	Automatic Fixed Interval	23610.66	0.0012	0.24	Trapezoid	30	45
261R	Automatic Fixed Interval	24807.58	0.001	0.023082	Trapezoid	30	45
262R	Automatic Fixed Interval	35012.83	0.001	0.023387	Trapezoid	30	45
263R	Automatic Fixed Interval	31879.26	0.001	0.049399	Trapezoid	30	45
264R	Automatic Fixed Interval	3994.952	0.001	0.000535	Trapezoid	30	45
265R	Automatic Fixed Interval	7033.505	0.001	0.11164	Trapezoid	30	45
266R	Automatic Fixed Interval	13655.19	0.001	0.011329	Trapezoid	30	45
267R	Automatic Fixed Interval	23295.49	0.001	0.000839	Trapezoid	30	45
268R	Automatic Fixed Interval	14792.81	0.001	0.01017	Trapezoid	30	45
269R	Automatic Fixed Interval	16730.51	0.001	0.000294	Trapezoid	30	45
270R	Automatic Fixed Interval	9025.577	0.001	0.023224	Trapezoid	30	45
271R	Automatic Fixed Interval	24276.66	0.001	0.002929	Trapezoid	30	45
272R	Automatic Fixed Interval	16778.31	0.001	0.000875	Trapezoid	30	45
273R	Automatic Fixed Interval	9764.694	0.001	0.008196	Trapezoid	30	45
274R	Automatic Fixed Interval	14793.57	0.001	0.001543	Trapezoid	30	45
275R	Automatic Fixed Interval	13433.65	0.001	0.006926	Trapezoid	30	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
276R	Automatic Fixed Interval	18834.86	0.001	0.000646	Trapezoid	30	45
277R	Automatic Fixed Interval	18027.83	0.001	0.01039	Trapezoid	30	45
278R	Automatic Fixed Interval	13010.35	0.001	0.1545	Trapezoid	30	45
279R	Automatic Fixed Interval	20076.61	0.001	0.001686	Trapezoid	30	45
280R	Automatic Fixed Interval	28403.18	0.00168	0.009957	Trapezoid	30	45
283R	Automatic Fixed Interval	17172.49	0.00078	0.003704	Trapezoid	30	45
290R	Automatic Fixed Interval	11868.11	0.00138	0.001579	Trapezoid	30	45
291R	Automatic Fixed Interval	16863.99	0.00126	0.00615	Trapezoid	30	45
292R	Automatic Fixed Interval	48022.59	0.0004	0.001	Trapezoid	30	45
293R	Automatic Fixed Interval	24292.68	0.00085	0.011223	Trapezoid	30	45
294R	Automatic Fixed Interval	17428.61	0.00218	0.018518	Trapezoid	30	45
295R	Automatic Fixed Interval	48968.14	0.0093	0.007897	Trapezoid	30	45
296R	Automatic Fixed Interval	29801.28	0.00051	0.24	Trapezoid	30	45
298R	Automatic Fixed Interval	34404.59	0.00075	0.24	Trapezoid	30	45
299R	Automatic Fixed Interval	25210.12	0.00085	0.24	Trapezoid	30	45

Appendix E. Alag 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
185B	1.2458	75.44682	0	3.46926	4.06359	0.75554	0.449075	0.15	185B	1.2458
186B	8.8245	76.93947	0	20.394	15.322	0.54446	0.1375024	0.15	186B	8.8245

Appendix F. Alag Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
298R	Automatic Fixed Interval	34404.587	0.00075	0.001	Trapezoid	60	1
299R	Automatic Fixed Interval	25210.117	0.00085	0.0037794	Trapezoid	60	1

Appendix G. Mag-asawang Tubig (1) 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	5.833333	7.3	1.3	0
0.166667	0	0	0	6	9.1	1.9	0
0.333333	0	0	0	6.166667	11.2	2.6	0
0.5	0	0	0	6.333333	13.8	3.6	0.1
0.666667	0	0	0	6.5	16.8	4.9	0.2
0.833333	0	0	0	6.666667	20.4	6.4	0.3
1	0	0	0	6.833333	24.5	8.4	0.5
1.166667	0	0	0	7	29.3	10.8	0.8
1.333333	0	0	0	7.166667	34.9	13.7	1.3
1.5	0	0	0	7.333333	41.3	17.1	1.9
1.666667	0	0	0	7.5	48.6	21.1	2.8
1.833333	0	0	0	7.666667	56.8	25.7	3.8
2	0	0	0	7.833333	65.8	30.8	5.1
2.166667	0	0	0	8	75.6	36.6	6.6
2.333333	0	0	0	8.166667	86.2	42.9	8.5
2.5	0	0	0	8.333333	97.4	49.6	10.6
2.666667	0	0	0	8.5	109.1	56.8	13
2.833333	0	0	0	8.666667	121.3	64.5	15.7
3	0	0	0	8.833333	133.8	72.4	18.6
3.166667	0	0	0	9	147.1	80.9	21.9
3.333333	0	0	0	9.166667	161.1	90	25.6
3.5	0	0	0	9.333333	176.3	100	29.8
3.666667	0	0	0	9.5	192.8	111	34.5
3.833333	0	0	0	9.666667	210.7	123	39.9
4	0.1	0	0	9.833333	230.3	136.3	46
4.166667	0.2	0	0	10	251.9	151	53
4.333333	0.3	0	0	10.16667	275.7	167.4	60.8
4.5	0.5	0	0	10.33333	302.2	185.6	69.7
4.666667	0.8	0	0	10.5	332.1	206.4	79.9
4.833333	1.2	0.1	0	10.66667	365.4	229.6	91.4
5	1.8	0.1	0	10.83333	402.5	255.5	104.4
5.166667	2.5	0.2	0	11	444	284.7	119.2
5.333333	3.3	0.4	0	11.16667	490.2	317.3	135.8
5.5	4.4	0.6	0	11.33333	542.1	354.1	154.9
5.666667	5.7	0.9	0	11.5	600.6	395.8	176.7

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
11.66667	668.7	444.8	202.3	18	1561.4	1178.4	715.1
11.83333	758.4	509.8	237	18.16667	1482.1	1119.2	680.3
12	868.8	590.8	281.6	18.33333	1406.6	1062.8	646.9
12.16667	1002.6	689.5	336.9	18.5	1336.8	1010.6	616
12.33333	1156.8	804	402.6	18.66667	1271.8	962.1	587.3
12.5	1328.1	931.6	476.4	18.83333	1210	916	560.1
12.66667	1521.9	1076.6	560.9	19	1151.7	872.4	534.4
12.83333	1734.7	1236.6	655.2	19.16667	1097.2	831.8	510.4
13	1966.8	1411.8	759.4	19.33333	1045.3	793.1	487.7
13.16667	2213.4	1598.6	871.9	19.5	995.5	756	465.9
13.33333	2464.9	1789.9	989	19.66667	948.6	721.1	445.4
13.5	2702.3	1971.4	1101.9	19.83333	903.3	687.4	425.8
13.66667	2920.8	2139.1	1207.3	20	859.6	654.9	406.8
13.83333	3110.3	2285.4	1300.6	20.16667	818.2	624.1	388.8
14	3268.8	2408.4	1379.9	20.33333	778.8	594.9	371.7
14.16667	3396.4	2508.4	1445.8	20.5	741.2	567	355.5
14.33333	3486.1	2579.9	1494.6	20.66667	705.3	540.3	340
14.5	3546.4	2629.2	1529.3	20.83333	671.6	515.3	325.4
14.66667	3578.7	2657.4	1551.8	21	639.6	491.6	311.7
14.83333	3578.6	2661.2	1559.8	21.16667	609.6	469.3	298.7
15	3547.5	2641.6	1553.4	21.33333	581.8	448.7	286.8
15.16667	3493.1	2604.2	1535.7	21.5	556	429.6	275.7
15.33333	3420	2552.6	1509.3	21.66667	531.9	411.7	265.3
15.5	3329.8	2487.9	1474.9	21.83333	509.7	395.3	255.8
15.66667	3222.9	2410.5	1432.7	22	489.4	380.2	247.1
15.83333	3099.8	2320.5	1382.7	22.16667	471	366.6	239.2
16	2961.5	2218.8	1325.1	22.33333	454.5	354.3	232.1
16.16667	2815.3	2110.8	1262.6	22.5	439.8	343.4	225.8
16.33333	2671.6	2004.2	1200.1	22.66667	426.5	333.6	220.1
16.5	2532.5	1901	1139.5	22.83333	414.5	324.7	215
16.66667	2401	1803.3	1082	23	403.7	316.7	210.3
16.83333	2275	1709.7	1027.2	23.16667	394	309.5	206.2
17	2152.9	1619	974.1	23.33333	385.2	303	202.5
17.16667	2038	1533.5	923.8	23.5	377	297	199
17.33333	1930.1	1453.2	876.7	23.66667	369.5	291.4	195.8
17.5	1830	1378.6	832.8	23.83333	362.5	286.3	192.9
17.66667	1735.3	1308.1	791.5	24	355.9	281.3	190
17.83333	1645.3	1241	752	24.16667	349.3	276.5	187.2

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
24.33333	342.7	271.5	184.2	30.5	19.8	15.9	11
24.5	335.9	266.4	181.1	30.66667	17.9	14.3	9.9
24.66667	328.8	261	177.7	30.83333	16.2	13	9
24.83333	321.1	255	174	31	14.6	11.7	8.1
25	312.6	248.5	169.8	31.16667	13.2	10.6	7.3
25.16667	303.2	241.2	165.1	31.33333	11.9	9.5	6.6
25.33333	292.7	233	159.7	31.5	10.8	8.6	6
25.5	281	223.7	153.5	31.66667	9.7	7.8	5.4
25.66667	268.3	213.8	146.8	31.83333	8.8	7.1	4.9
25.83333	255.1	203.3	139.7	32	8	6.4	4.4
26	241.4	192.4	132.3	32.16667	7.2	5.8	4
26.16667	227.2	181.2	124.7	32.33333	6.5	5.2	3.6
26.33333	212.8	169.8	116.9	32.5	5.9	4.7	3.3
26.5	198.4	158.3	109	32.66667	5.3	4.3	3
26.66667	184.2	147	101.3	32.83333	4.8	3.8	2.7
26.83333	170.1	135.8	93.6	33	4.3	3.5	2.4
27	156.4	124.9	86.1	33.16667	3.9	3.1	2.2
27.16667	143.4	114.4	78.9	33.33333	3.5	2.8	1.9
27.33333	130.9	104.5	72.1	33.5	3.1	2.5	1.7
27.5	119.1	95.1	65.6	33.66667	2.8	2.3	1.6
27.66667	107.9	86.2	59.4	33.83333	2.5	2	1.4
27.83333	97.5	77.9	53.7	34	2.3	1.8	1.3
28	88	70.3	48.5	34.16667	2	1.6	1.1
28.16667	79.4	63.4	43.8	34.33333	1.8	1.4	1
28.33333	71.8	57.3	39.6	34.5	1.6	1.3	0.9
28.5	65	51.9	35.8	34.66667	1.4	1.1	0.8
28.66667	58.9	47.1	32.5	34.83333	1.3	1	0.7
28.83333	53.5	42.7	29.5	35	1.1	0.9	0.6
29	48.5	38.7	26.8	35.16667	1	0.8	0.5
29.16667	44	35.2	24.3	35.33333	0.9	0.7	0.5
29.33333	39.9	31.9	22	35.5	0.7	0.6	0.4
29.5	36.2	28.9	20	35.66667	0.6	0.5	0.3
29.66667	32.8	26.2	18.1	35.83333	0.5	0.4	0.3
29.83333	29.7	23.7	16.4	36	0.4	0.5	0.2
30	26.8	21.4	14.8				
30.16667	24.2	19.4	13.4				
30.33333	21.9	17.5	12.1				
30.5	19.8	15.9	11				

Appendix H. Mag-asawang Tubig (2) 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	5.833333	5.8	1.3	0
0.166667	0	0	0	6	6.8	1.8	0
0.333333	0	0	0	6.166667	8	2.5	0
0.5	0	0	0	6.333333	9.7	3.5	0
0.666667	0	0	0	6.5	12.1	4.7	0.1
0.833333	0	0	0	6.666667	15.1	6.4	0.3
1	0	0	0	6.833333	18.5	8.3	0.6
1.166667	0	0	0	7	22.2	10.4	1
1.333333	0	0	0	7.166667	26.1	12.7	1.6
1.5	0	0	0	7.333333	29.9	15.1	2.4
1.666667	0	0	0	7.5	33.7	17.4	3.2
1.833333	0	0	0	7.666667	37.2	19.8	4.1
2	0	0	0	7.833333	40.5	22	5.1
2.166667	0	0	0	8	43.7	24.2	6.2
2.333333	0	0	0	8.166667	46.7	26.3	7.2
2.5	0	0	0	8.333333	49.6	28.4	8.3
2.666667	0	0	0	8.5	52.3	30.4	9.4
2.833333	0	0	0	8.666667	55	32.4	10.5
3	0	0	0	8.833333	57.5	34.3	11.5
3.166667	0	0	0	9	60.6	36.6	12.8
3.333333	0	0	0	9.166667	65.1	39.8	14.4
3.5	0	0	0	9.333333	71.9	44.5	16.7
3.666667	0	0	0	9.5	82	51.3	19.9
3.833333	0	0	0	9.666667	94.7	60	24
4	0	0	0	9.833333	109.1	69.8	28.7
4.166667	0.1	0	0	10	124	80	33.8
4.333333	0.3	0	0	10.16667	138.5	90.2	38.8
4.5	0.5	0	0	10.33333	152	99.8	43.8
4.666667	0.9	0	0	10.5	165.2	109.2	48.8
4.833333	1.4	0	0	10.66667	178.5	118.9	54.1
5	2	0.1	0	10.83333	193.7	130	60.1
5.166667	2.7	0.2	0	11	213.8	144.6	68
5.333333	3.4	0.4	0	11.16667	239.9	163.4	77.9
5.5	4.2	0.6	0	11.33333	272.3	186.8	90.4
5.666667	5	0.9	0	11.5	312.8	216.1	106.2

Appendix

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
11.66667	364.1	253.6	126.1	18	133.9	102.2	63.7
11.83333	445.7	314.2	158.9	18.16667	131.2	100.2	62.6
12	563.2	402.6	209.3	18.33333	127.1	97.2	60.9
12.16667	717	519.3	277.7	18.5	120.9	92.6	58.3
12.33333	896.8	656.5	361.8	18.66667	113.2	86.9	55
12.5	1053.9	777.6	440.9	18.83333	104.7	80.7	51.4
12.66667	1155	857.1	496.5	19	96.3	74.5	47.9
12.83333	1196.3	891.4	524.4	19.16667	88.5	68.8	44.7
13	1184.5	885.1	526	19.33333	81.7	63.8	41.8
13.16667	1134.8	849.5	508.2	19.5	76.2	59.7	39.5
13.33333	1054.6	790.4	475.2	19.66667	72.1	56.7	37.8
13.5	953.9	715.4	430.7	19.83333	68.9	54.3	36.5
13.66667	860	645.2	387.5	20	66.5	52.6	35.4
13.83333	775.4	582	349.1	20.16667	64.6	51.1	34.6
14	698.1	524.2	314.3	20.33333	63.1	50	34
14.16667	626.5	470.8	282.8	20.5	61.9	49.2	33.5
14.33333	561.2	422.2	254.1	20.66667	61	48.5	33.2
14.5	505.8	381	229.7	20.83333	60.3	48	32.9
14.66667	460.8	347.5	210.1	21	59.8	47.6	32.7
14.83333	423.9	320	194	21.16667	59.4	47.3	32.5
15	393.3	297.3	180.7	21.33333	59	47.1	32.4
15.16667	367.2	277.9	169.3	21.5	58.8	46.9	32.3
15.33333	342.6	259.5	158.4	21.66667	58.6	46.8	32.2
15.5	316.7	240	146.8	21.83333	58.4	46.6	32.1
15.66667	289.5	219.6	134.6	22	58.3	46.6	32.1
15.83333	262.7	199.4	122.4	22.16667	58.2	46.5	32.1
16	237.8	180.6	111	22.33333	58.1	46.4	32
16.16667	215.8	164	101	22.5	58.1	46.4	32
16.33333	196.9	149.8	92.4	22.66667	58	46.4	32
16.5	181.6	138.1	85.4	22.83333	58	46.4	32
16.66667	169.8	129.3	80	23	58	46.3	32
16.83333	160.7	122.4	75.8	23.16667	58	46.3	32
17	153.4	116.9	72.5	23.33333	58	46.4	32
17.16667	147.6	112.5	69.9	23.5	58	46.4	32
17.33333	143.3	109.3	67.9	23.66667	58	46.4	32
17.5	140.2	106.9	66.5	23.83333	58	46.4	32.1
17.66667	137.7	105.1	65.4	24	57.6	46	31.8
17.83333	135.9	103.7	64.6	24.16667	56.3	45	31.1

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
24.33333	53.7	42.9	29.7	30.66667	0	0	0
24.5	49.2	39.3	27.2	30.83333	0	0	0
24.66667	43.4	34.7	24	31	0	0	0
24.83333	36.8	29.4	20.4	31.16667	0	0	0
25	30.2	24.2	16.7	31.33333	0	0	0
25.16667	24.2	19.3	13.4	31.5	0	0	0
25.33333	18.9	15.1	10.4	31.66667	0	0	0
25.5	14.5	11.6	8	31.83333	0	0	0
25.66667	11.3	9.1	6.3	32	0	0	0
25.83333	8.8	7.1	4.9	32.16667	0	0	0
26	6.9	5.5	3.8	32.33333	0	0	0
26.16667	5.4	4.3	3	32.5	0	0	0
26.33333	4.2	3.3	2.3	32.66667	0	0	0
26.5	3.2	2.6	1.8	32.83333	0	0	0
26.66667	2.5	2	1.4	33	0	0	0
26.83333	1.9	1.6	1.1	33.16667	0	0	0
27	1.5	1.2	0.8	33.33333	0	0	0
27.16667	1.2	0.9	0.6	33.5	0	0	0
27.33333	0.9	0.7	0.5	33.66667	0	0	0
27.5	0.7	0.5	0.4	33.83333	0	0	0
27.66667	0.5	0.4	0.3	34	0	0	0
27.83333	0.4	0.3	0.2	34.16667	0	0	0
28	0.3	0.2	0.2	34.33333	0	0	0
28.16667	0.2	0.2	0.1	34.5	0	0	0
28.33333	0.1	0.1	0.1	34.66667	0	0	0
28.5	0.1	0.1	0.1	34.83333	0	0	0
28.66667	0.1	0	0	35	0	0	0
28.83333	0	0	0	35.16667	0	0	0
29	0	0	0	35.33333	0	0	0
29.16667	0	0	0	35.5	0	0	0
29.33333	0	0	0	35.66667	0	0	0
29.5	0	0	0	35.83333	0	0	0
29.66667	0	0	0	36	0	0	0
29.83333	0	0	0				
30	0	0	0				
30.16667	0	0	0				
30.33333	0	0	0				
30.5	0	0	0				

Appendix I. Mag-asawang Tubig (3) 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	5.833333	9.8	1.6	0
0.166667	0	0	0	6	12.3	2.3	0
0.333333	0	0	0	6.166667	15.2	3.3	0
0.5	0	0	0	6.333333	18.8	4.6	0
0.666667	0	0	0	6.5	23.1	6.3	0
0.833333	0	0	0	6.666667	28.1	8.5	0
1	0	0	0	6.833333	33.9	11.2	0
1.166667	0	0	0	7	40.7	14.5	0
1.333333	0	0	0	7.166667	48.6	18.4	0
1.5	0	0	0	7.333333	57.6	23.2	0.1
1.666667	0	0	0	7.5	68	28.7	0.2
1.833333	0	0	0	7.666667	79.7	35.2	0.4
2	0	0	0	7.833333	92.6	42.4	0.6
2.166667	0	0	0	8	106.6	50.5	1
2.333333	0	0	0	8.166667	121.7	59.3	1.5
2.5	0	0	0	8.333333	137.7	68.9	2.2
2.666667	0	0	0	8.5	154.4	79	3
2.833333	0	0	0	8.666667	171.8	89.8	4.1
3	0	0	0	8.833333	189.8	101.1	5.4
3.166667	0	0	0	9	208.8	113.1	7
3.333333	0	0	0	9.166667	228.9	126.1	9.1
3.5	0	0	0	9.333333	250.7	140.3	11.6
3.666667	0	0	0	9.5	274.4	155.9	14.6
3.833333	0	0	0	9.666667	300	173	18.3
4	0.1	0	0	9.833333	328.2	192	22.7
4.166667	0.2	0	0	10	359.2	213	27.8
4.333333	0.4	0	0	10.16667	393.5	236.4	33.8
4.5	0.6	0	0	10.33333	431.5	262.6	40.9
4.666667	1	0	0	10.5	474.5	292.3	49.2
4.833333	1.6	0.1	0	10.66667	522.3	325.5	58.7
5	2.3	0.1	0	10.83333	575.6	362.6	69.8
5.166667	3.2	0.3	0	11	635.3	404.4	82.6
5.333333	4.4	0.5	0	11.16667	701.6	451.2	97.3
5.5	5.9	0.7	0	11.33333	776.3	504	114.4
5.666667	7.7	1.1	0	11.5	860.4	563.9	134.4

DIRECT FLOW (cms)							
Time (hr)	**100-yr**	**25-yr**	**5-year**	**Time (hr)**	**100-yr**	**25-yr**	**5-year**
11.66667	958.4	634.2	158	18	2250.6	1695.4	743.1
11.83333	1087.3	727.7	191	18.16667	2136.5	1610.3	708
12	1246.3	844	234	18.33333	2027.7	1529.1	674.2
12.16667	1438.9	985.8	288	18.5	1927.2	1454	642.8
12.33333	1661	1150.4	352.8	18.66667	1833.6	1384.2	613.7
12.5	1907.8	1334	426.1	18.83333	1744.6	1317.7	586
12.66667	2186.8	1542.4	510.7	19	1660.6	1255.1	559.9
12.83333	2493.5	1772.5	605.7	19.16667	1582.1	1196.6	535.4
13	2827.9	2024.5	711.2	19.33333	1507.4	1141	512.2
13.16667	3183.3	2293.3	826	19.5	1435.7	1087.6	489.9
13.33333	3545.8	2568.6	946.1	19.66667	1368	1037.3	468.8
13.5	3888.1	2829.9	1062.8	19.83333	1302.8	988.9	448.5
13.66667	4203.1	3071.4	1172.6	20	1239.8	942.1	428.9
13.83333	4476.5	3282.1	1270.8	20.16667	1180	897.8	410.3
14	4705.2	3459.4	1355.2	20.33333	1123.2	855.6	392.6
14.16667	4889.4	3603.5	1426.4	20.5	1069	815.5	375.7
14.33333	5019	3706.8	1480.5	20.66667	1017.3	777.2	359.6
14.5	5106.3	3778.1	1520.5	20.83333	968.5	741.1	344.3
14.66667	5153.2	3819.1	1548.1	21	922.5	707	330
14.83333	5153.4	3825	1560.9	21.16667	879.2	674.9	316.5
15	5109	3797.2	1559.1	21.33333	839.1	645.3	304
15.16667	5030.9	3744	1545.6	21.5	801.9	617.7	292.4
15.33333	4925.9	3670.1	1523	21.66667	767.1	592	281.6
15.5	4796.2	3577.5	1492.1	21.83333	735.1	568.3	271.6
15.66667	4642.5	3466.4	1452.9	22	705.8	546.7	262.4
15.83333	4465.3	3337.3	1405.5	22.16667	679.2	527	254.2
16	4266.4	3191.3	1350	22.33333	655.3	509.4	246.7
16.16667	4056	3036.1	1289.1	22.5	634.1	493.7	240.1
16.33333	3849	2883	1227.8	22.66667	615	479.6	234.2
16.5	3648.9	2734.7	1167.9	22.83333	597.7	466.8	228.9
16.66667	3459.5	2594.3	1111	23	582.1	455.3	224
16.83333	3278.1	2459.6	1056.4	23.16667	568.1	445	219.7
17	3102.3	2329.2	1003.4	23.33333	555.4	435.5	215.8
17.16667	2936.8	2206.2	953.1	23.5	543.6	426.9	212.2
17.33333	2781.6	2090.8	905.7	23.66667	532.8	418.9	208.9
17.5	2637.3	1983.5	861.7	23.83333	522.7	411.5	205.9
17.66667	2501	1882	820.2	24	513.1	404.4	202.9
17.83333	2371.4	1785.4	780.4	24.16667	503.7	397.4	199.9

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
24.33333	494.1	390.2	196.8	30.66667	25.8	20.6	10.6
24.5	484.3	382.8	193.6	30.83333	23.3	18.6	9.6
24.66667	474.1	375	190.1	31	21.1	16.8	8.7
24.83333	462.9	366.5	186.1	31.16667	19	15.2	7.9
25	450.7	357.1	181.7	31.33333	17.2	13.7	7.1
25.16667	437.2	346.6	176.7	31.5	15.5	12.4	6.4
25.33333	422	334.8	170.9	31.66667	14	11.2	5.8
25.5	405.1	321.5	164.4	31.83333	12.7	10.1	5.2
25.66667	386.8	307.2	157.3	32	11.5	9.2	4.7
25.83333	367.8	292.1	149.7	32.16667	10.4	8.3	4.3
26	348	276.5	141.8	32.33333	9.4	7.5	3.9
26.16667	327.6	260.4	133.6	32.5	8.5	6.8	3.5
26.33333	306.8	243.9	125.2	32.66667	7.7	6.1	3.2
26.5	286.1	227.5	116.8	32.83333	6.9	5.5	2.9
26.66667	265.5	211.2	108.5	33	6.2	5	2.6
26.83333	245.3	195.1	100.3	33.16667	5.6	4.5	2.3
27	225.6	179.4	92.3	33.33333	5	4	2.1
27.16667	206.7	164.4	84.6	33.5	4.5	3.6	1.9
27.33333	188.7	150.2	77.2	33.66667	4.1	3.2	1.7
27.5	171.7	136.6	70.3	33.83333	3.6	2.9	1.5
27.66667	155.6	123.8	63.7	34	3.3	2.6	1.4
27.83333	140.6	111.9	57.6	34.16667	2.9	2.3	1.2
28	126.8	101	52	34.33333	2.6	2.1	1.1
28.16667	114.5	91.1	46.9	34.5	2.3	1.9	1
28.33333	103.5	82.4	42.4	34.66667	2.1	1.6	0.9
28.5	93.7	74.6	38.4	34.83333	1.8	1.5	0.8
28.66667	85	67.6	34.8	35	1.6	1.3	0.7
28.83333	77.1	61.4	31.6	35.16667	1.4	1.1	0.6
29	69.9	55.7	28.7	35.33333	1.2	1	0.5
29.16667	63.4	50.5	26	35.5	1.1	0.8	0.4
29.33333	57.6	45.8	23.6	35.66667	0.9	0.7	0.4
29.5	52.2	41.6	21.4	35.83333	0.8	0.6	0.3
29.66667	47.3	37.6	19.4	36	0.7	0.5	0.3
29.83333	42.8	34.1	17.6				
30	38.7	30.8	15.9				
30.16667	35	27.9	14.4				
30.33333	31.6	25.2	13				
30.5	28.6	22.8	11.8				

Appendix J. Mag-asawang Tubig (4) 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	5.833333	11.7	2.3	0
0.166667	0	0	0	6	14.2	3.2	0
0.333333	0	0	0	6.166667	17.2	4.4	0
0.5	0	0	0	6.333333	20.6	6	0.1
0.666667	0	0	0	6.5	24.7	8.1	0.2
0.833333	0	0	0	6.666667	29.6	10.6	0.5
1	0	0	0	6.833333	35.5	13.8	0.9
1.166667	0	0	0	7	42.5	17.7	1.5
1.333333	0	0	0	7.166667	50.6	22.3	2.4
1.5	0	0	0	7.333333	59.8	27.6	3.5
1.666667	0	0	0	7.5	69.7	33.4	5
1.833333	0	0	0	7.666667	80.4	39.8	6.8
2	0	0	0	7.833333	91.6	46.6	8.9
2.166667	0	0	0	8	103.2	53.9	11.4
2.333333	0	0	0	8.166667	115	61.3	14.1
2.5	0	0	0	8.333333	126.9	69	17
2.666667	0	0	0	8.5	138.8	76.7	20.2
2.833333	0	0	0	8.666667	150.6	84.5	23.6
3	0	0	0	8.833333	162	92.3	27.1
3.166667	0	0	0	9	173.7	100.4	30.9
3.333333	0	0	0	9.166667	186.5	109.2	35.2
3.5	0	0	0	9.333333	200.9	119.2	40.1
3.666667	0	0	0	9.5	217.5	130.8	45.8
3.833333	0	0	0	9.666667	237	144.4	52.5
4	0.1	0	0	9.833333	260.3	160.6	60.5
4.166667	0.2	0	0	10	288.1	179.8	70
4.333333	0.5	0	0	10.16667	319.8	201.9	80.9
4.5	0.9	0	0	10.33333	354.8	226.2	93
4.666667	1.4	0	0	10.5	392.9	252.9	106.5
4.833333	2.2	0.1	0	10.66667	434.2	282.1	121.3
5	3.1	0.2	0	10.83333	478.8	313.6	137.6
5.166667	4.4	0.4	0	11	528.1	348.7	155.9
5.333333	5.9	0.6	0	11.16667	583.8	388.6	176.8
5.5	7.6	1	0	11.33333	647.6	434.3	201
5.666667	9.6	1.6	0	11.5	722.2	488.1	229.8

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
11.66667	812.5	553.7	264.7	18	752.2	571.6	352.6
11.83333	937.9	645.8	314.3	18.16667	718.2	546.1	337.4
12	1106.9	771.1	384.5	18.33333	687.2	522.9	323.6
12.16667	1311.4	923.9	472.7	18.5	658.3	501.3	310.8
12.33333	1549.5	1102.9	577.5	18.66667	630.4	480.5	298.5
12.5	1823.2	1309.9	700.2	18.83333	602.6	459.8	286.4
12.66667	2129.4	1542.3	839.9	19	574.2	438.6	274
12.83333	2453	1789.1	991.7	19.16667	545.6	417.3	261.5
13	2753.8	2019.9	1137.7	19.33333	517.1	396.2	249.2
13.16667	3003.5	2213	1262.7	19.5	489.2	375.5	237.3
13.33333	3195	2362.5	1361.8	19.66667	462.2	355.5	225.7
13.5	3325.1	2465.8	1432.7	19.83333	436.2	336.2	214.6
13.66667	3398.4	2525.9	1476.8	20	411.4	317.9	204
13.83333	3417.1	2544.8	1496.1	20.16667	388.3	300.8	194.1
14	3377.2	2519.3	1488	20.33333	366.9	285	185
14.16667	3295.7	2462	1459.1	20.5	347.5	270.6	176.7
14.33333	3180.8	2379.1	1414.6	20.66667	330.1	257.7	169.3
14.5	3031.1	2269.5	1353.9	20.83333	314.9	246.5	162.8
14.66667	2853.2	2138.3	1279.1	21	301.8	236.7	157.2
14.83333	2666	1999.6	1197.9	21.16667	290.4	228.3	152.3
15	2487.4	1866.9	1119.2	21.33333	280.7	221.1	148.1
15.16667	2325	1746.2	1047.8	21.5	272.7	215.2	144.7
15.33333	2173.7	1633.8	981.8	21.66667	266	210.2	141.8
15.5	2032.6	1529.1	920.1	21.83333	260.1	205.9	139.3
15.66667	1903.3	1433	863.8	22	255	202.1	137.2
15.83333	1779.9	1341.3	810.2	22.16667	250.7	198.9	135.3
16	1660.9	1252.6	758.1	22.33333	247	196.2	133.8
16.16667	1546.8	1167.4	708	22.5	243.8	193.9	132.5
16.33333	1438.4	1086.4	659.9	22.66667	241.1	191.8	131.3
16.5	1339.3	1012.2	615.7	22.83333	238.7	190.1	130.4
16.66667	1246.8	943	574.5	23	236.7	188.6	129.5
16.83333	1161.4	878.9	536.3	23.16667	235	187.3	128.8
17	1082.2	819.5	500.9	23.33333	233.4	186.2	128.2
17.16667	1010.1	765.3	468.5	23.5	232.1	185.3	127.6
17.33333	944.9	716.4	439.2	23.66667	231	184.5	127.2
17.5	886.3	672.4	412.8	23.83333	230.1	183.8	126.8
17.66667	835	633.8	389.7	24	228.9	182.9	126.3
17.83333	790.4	600.3	369.7	24.16667	227	181.4	125.4

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
24.33333	224.2	179.2	123.9	30.66667	2	1.6	1.1
24.5	220.2	176.1	121.8	30.83333	1.7	1.3	0.9
24.66667	214.5	171.6	118.7	31	1.4	1.1	0.8
24.83333	206.9	165.4	114.5	31.16667	1.2	1	0.7
25	196.8	157.4	109	31.33333	1	0.8	0.6
25.16667	184.9	147.9	102.4	31.5	0.8	0.7	0.5
25.33333	171.5	137.2	95	31.66667	0.7	0.6	0.4
25.5	157.2	125.7	87.1	31.83333	0.6	0.5	0.3
25.66667	142.5	114	79	32	0.4	0.4	0.2
25.83333	127.9	102.3	70.9	32.16667	0.3	0.3	0.2
26	113.5	90.8	63	32.33333	0.3	0.2	0.1
26.16667	100	80	55.5	32.5	0.2	0.1	0.1
26.33333	87.3	69.9	48.4	32.66667	0.1	0.1	0.1
26.5	75.7	60.6	42	32.83333	0.1	0.1	0
26.66667	65.3	52.3	36.2	33	0	0	0
26.83333	56.3	45.1	31.3	33.16667	0	0	0
27	48.7	39	27.1	33.33333	0	0	0
27.16667	42.3	33.9	23.5	33.5	0	0	0
27.33333	36.8	29.4	20.4	33.66667	0	0	0
27.5	32	25.6	17.8	33.83333	0	0	0
27.66667	27.8	22.3	15.4	34	0	0	0
27.83333	24.1	19.3	13.4	34.16667	0	0	0
28	20.9	16.7	11.6	34.33333	0	0	0
28.16667	18.1	14.5	10.1	34.5	0	0	0
28.33333	15.7	12.6	8.7	34.66667	0	0	0
28.5	13.6	10.9	7.6	34.83333	0	0	0
28.66667	11.8	9.4	6.5	35	0	0	0
28.83333	10.2	8.2	5.7	35.16667	0	0	0
29	8.8	7.1	4.9	35.33333	0	0	0
29.16667	7.6	6.1	4.2	35.5	0	0	0
29.33333	6.6	5.3	3.7	35.66667	0	0	0
29.5	5.7	4.6	3.2	35.83333	0	0	0
29.66667	4.9	3.9	2.7	36	0	0	0
29.83333	4.2	3.4	2.4				
30	3.7	2.9	2				
30.16667	3.1	2.5	1.7				
30.33333	2.7	2.2	1.5				
30.5	2.3	1.8	1.3				

Appendix K. Mag-asawang Tubig (5) 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	5.833333	10.6	3.3	0
0.166667	0	0	0	6	12.1	4.2	0
0.333333	0	0	0	6.166667	13.8	5.3	0.1
0.5	0	0	0	6.333333	16.1	6.6	0.3
0.666667	0	0	0	6.5	19	8.4	0.6
0.833333	0	0	0	6.666667	22.9	10.6	1.1
1	0	0	0	6.833333	27.5	13.3	1.7
1.166667	0	0	0	7	32.7	16.4	2.6
1.333333	0	0	0	7.166667	38.2	19.8	3.7
1.5	0	0	0	7.333333	44	23.4	4.9
1.666667	0	0	0	7.5	49.8	27	6.3
1.833333	0	0	0	7.666667	55.5	30.7	7.9
2	0	0	0	7.833333	61	34.4	9.4
2.166667	0	0	0	8	66.2	37.9	11.1
2.333333	0	0	0	8.166667	71.1	41.3	12.8
2.5	0	0	0	8.333333	75.8	44.6	14.4
2.666667	0	0	0	8.5	80.2	47.8	16.1
2.833333	0	0	0	8.666667	84.4	50.9	17.8
3	0	0	0	8.833333	88.5	53.8	19.5
3.166667	0	0	0	9	93	57.2	21.3
3.333333	0	0	0	9.166667	99	61.5	23.6
3.5	0	0	0	9.333333	106.9	67.1	26.5
3.666667	0.1	0	0	9.5	118	74.9	30.4
3.833333	0.2	0	0	9.666667	132.7	85.1	35.5
4	0.3	0	0	9.833333	150.4	97.4	41.6
4.166667	0.6	0	0	10	170	111.1	48.5
4.333333	1.1	0	0	10.16667	190.2	125.3	55.8
4.5	1.7	0.1	0	10.33333	210.4	139.6	63.2
4.666667	2.5	0.2	0	10.5	230.7	154.2	70.9
4.833333	3.4	0.3	0	10.66667	251.7	169.4	79.1
5	4.4	0.6	0	10.83333	273.8	185.4	87.9
5.166667	5.5	0.9	0	11	299.3	204.1	98.1
5.333333	6.7	1.4	0	11.16667	331.3	227.4	110.8
5.5	8	2	0	11.33333	370.3	255.8	126.3
5.666667	9.3	2.6	0	11.5	418.2	290.8	145.6

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
11.66667	479.8	336.2	170.1	18	213.9	163.6	102.7
11.83333	573.5	406	208.4	18.16667	208	159.2	100
12	705	505	265.5	18.33333	201.7	154.5	97.2
12.16667	869.6	629.9	339.4	18.5	194.2	149	94
12.33333	1068.3	781.7	431.1	18.66667	184.9	142	89.9
12.5	1280.8	944.9	533.8	18.83333	174.1	134	85.4
12.66667	1461.3	1084.9	626	19	162.7	125.6	80.5
12.83333	1585.6	1182.6	693.8	19.16667	151.4	117.2	75.7
13	1646.8	1232.5	731.7	19.33333	140.7	109.3	71.1
13.16667	1655.1	1241.7	743.3	19.5	131	102.2	67
13.33333	1618.2	1216.1	732.2	19.66667	122.5	95.9	63.4
13.5	1546.7	1163.8	703.6	19.83333	115.5	90.7	60.4
13.66667	1441.4	1085.5	658.7	20	110	86.7	58.1
13.83333	1316.9	992.3	602.7	20.16667	105.7	83.5	56.3
14	1198.5	903.4	548	20.33333	102.1	80.8	54.8
14.16667	1090.6	822.3	498.5	20.5	99.2	78.7	53.5
14.33333	992.3	748.6	453.9	20.66667	96.8	76.9	52.5
14.5	904.1	682.5	414.4	20.83333	94.9	75.5	51.7
14.66667	824.4	623	379	21	93.4	74.4	51.1
14.83333	754.3	570.6	347.8	21.16667	92.1	73.5	50.5
15	695.6	526.7	321.6	21.33333	91.1	72.7	50.1
15.16667	644	488.1	298.8	21.5	90.4	72.2	49.8
15.33333	597.4	453.2	277.9	21.66667	89.7	71.7	49.6
15.5	554.3	420.9	258.6	21.83333	89.2	71.3	49.4
15.66667	511.8	388.9	239.3	22	88.8	71	49.2
15.83333	470.1	357.4	220.3	22.16667	88.4	70.8	49.1
16	430.4	327.4	202.1	22.33333	88.2	70.6	48.9
16.16667	393.2	299.3	185.1	22.5	87.9	70.4	48.9
16.33333	359.5	273.8	169.5	22.66667	87.8	70.3	48.8
16.5	329.9	251.4	155.9	22.83333	87.6	70.2	48.7
16.66667	304.2	231.9	144.1	23	87.5	70.1	48.7
16.83333	283.1	216	134.3	23.16667	87.4	70	48.7
17	266.7	203.5	126.8	23.33333	87.3	70	48.7
17.16667	253.4	193.5	120.7	23.5	87.3	69.9	48.6
17.33333	242.5	185.3	115.7	23.66667	87.2	69.9	48.6
17.5	233.5	178.4	111.6	23.83333	87.2	69.9	48.6
17.66667	225.9	172.7	108.1	24	86.7	69.5	48.4
17.83333	219.6	167.9	105.2	24.16667	85.5	68.5	47.7

DIRECT FLOW (cms)							
Time (hr)	100-yr	25-yr	5-year	Time (hr)	100-yr	25-yr	5-year
24.33333	83.1	66.6	46.4	30.66667	0	0	0
24.5	79	63.4	44.1	30.83333	0	0	0
24.66667	73	58.6	40.8	31	0	0	0
24.83333	65.6	52.6	36.6	31.16667	0	0	0
25	57.4	46	32.1	31.33333	0	0	0
25.16667	49.1	39.4	27.4	31.5	0	0	0
25.33333	41.1	33	23	31.66667	0	0	0
25.5	33.8	27.1	18.9	31.83333	0	0	0
25.66667	27.3	21.9	15.3	32	0	0	0
25.83333	22	17.6	12.3	32.16667	0	0	0
26	17.8	14.3	9.9	32.33333	0	0	0
26.16667	14.5	11.6	8.1	32.5	0	0	0
26.33333	11.8	9.4	6.6	32.66667	0	0	0
26.5	9.6	7.7	5.3	32.83333	0	0	0
26.66667	7.7	6.2	4.3	33	0	0	0
26.83333	6.3	5	3.5	33.16667	0	0	0
27	5.1	4.1	2.8	33.33333	0	0	0
27.16667	4.1	3.3	2.3	33.5	0	0	0
27.33333	3.3	2.7	1.8	33.66667	0	0	0
27.5	2.7	2.1	1.5	33.83333	0	0	0
27.66667	2.2	1.7	1.2	34	0	0	0
27.83333	1.7	1.4	1	34.16667	0	0	0
28	1.4	1.1	0.8	34.33333	0	0	0
28.16667	1.1	0.9	0.6	34.5	0	0	0
28.33333	0.9	0.7	0.5	34.66667	0	0	0
28.5	0.7	0.6	0.4	34.83333	0	0	0
28.66667	0.6	0.4	0.3	35	0	0	0
28.83333	0.4	0.3	0.2	35.16667	0	0	0
29	0.3	0.3	0.2	35.33333	0	0	0
29.16667	0.2	0.2	0.1	35.5	0	0	0
29.33333	0.2	0.1	0.1	35.66667	0	0	0
29.5	0.1	0.1	0.1	35.83333	0	0	0
29.66667	0.1	0.1	0	36	0	0	0
29.83333	0	0	0				
30	0	0	0				
30.16667	0	0	0				
30.33333	0	0	0				
30.5	0	0	0				

DREAM

Disaster RIsk and Exposure Assessment for Mitigation