Development of Flood Inundation Map for Bago River Basin

Thet Hnin Aye - Student, Department of Civil Engineering, Yangon Technological University,
Dr Win Win Zin - Supervisor, Department of Civil Engineering, Yangon Technological University,
U Tin Maung - Visiting Professor, Department of Civil Engineering, Yangon Technological University**,** Yangon, Republic of the Union of Myanmar
Email - poohtha@gmail.com

Abstract: *Flooding is the major natural hazard affecting the entire bago basin, it causes significant interruption to economic progress and inflicts recognizable social and psychological scars mostly on the economically disadvantaged peoples of the region. Flood inundation maps are useful in rescue and relief operations related with flood. Bago river basin is located in the lower part of Myanmar and floods often occur seriously in monsoon season. In order to perform river flood hazard mapping, HEC-HMS and HEC-RAS were utilized as hydrological and hydraulic models, respectively. Three flood events were applied to calibrate and validate the results. The highest depth of inundation can seriously affect the upper part of bago city areas and downstream rural areas including the paddy fields.*

Key Words: *Flood Inundation map, HEC-HMS, HEC-RAS.*

1. INTRODUCTION :

Although floods happen most years in monsoon-affected countries, many countries still lack flood hazard maps to prevent or mitigate the damage. This is particularly true of flood prone countries such as Myanmar. Hydrological modeling which is a simplified representation of the real situation, is a challenging task particularly for regions with limited data and hydrologic models should be well calibrated.

Flooding has received much recent attention in Myanmar from the perspective of improving water resource management. Flooding is one of the major natural disasters that affect many parts of the world including developed nations. One of the keys in preventing and reducing losses is to provide reliable information to the public about the flood-risk through flood inundation maps.

Besides identifying future floodprone areas, flood inundation maps are also useful in rescue and relief operations related to flooding. As floods are becoming increasing menace throughout the world, it has become clear that the problem has to be assessed at a river basin scale. This requires the evaluation of various hydrological, hydraulic, topographic and social parameters. Geographic Information System (GIS) linked the hydraulic numerical models can provide the functionality capable of assessing and analyzing these parameters and visualization of the results.

It is widely accepted that flood would affect the distribution of precipitation as well as the intensities and frequencies of extreme hydrological events. Hydrological model of HEC-HMS has designed base on simulation of rainfall-runoff in watersheds that can solve different problems using graphical interface. Hydrographs produced by programs use directly or in conjunction with other software for studies of water availability, urban drainage, future urbanization impact, reservoir spillway design, flood damage reduction, flood plain regulation, and systems operation transfers operated under a single organization.

The estimation of flood extents is not straightforward because the extent of the inundation is dependent on the topography and it changes with time. When bank full flow depth is reached in a flood event, water ceases to be contained solely in the main river channel and water spills onto adjacent flood plains. These make flood prediction a very complex and time consuming process.

In order to address this issue, we developed hydrologic and hydrodynamic models and generated flood inundation maps using the Bago River Basin as a study area. Although the design of our study was not new, our study is one of very few to have analyzed the flood inundation area in Myanmar. Furthermore, our study is significant because a local climate and hydrological dataset as well as a topographic dataset was used to assess the possible flood

inundation in the data-scarce country of Myanmar. In this study, the HEC-RAS model was used for flood hazard map development.

2. LOCATION OF STUDY AREA:

Bago river basin is a flood prone area in Myanmar. During 2011, two severe floods occurred in the Bago river basin in July and Augest. Nearly all of the rivers and creeks were flooded and adjacent paddy fields areas of 498 km^2 were inundated. Thousands of households and properties were also affected and the duration of inundation was above five days. Bago River originates from the middle mountainous region named Bago Yoma and the large portion of the river itself is within the bago township of bago region. A small portion of the river (the outlet) is in yangon region where bago river joins the yangon river and, from there, enters the Gulf of Mottama.

The basin has a catchment area of 5,348 km2, and the main river is about 331 km long, lying between longitudes 95 53'30"E and 96'43'30"E and between latitudes 16'43'15" N and 18'26'17" N in lower Myanmar.Annual total rainfall at Bago station is about 3,300 mm. Only two rain-gauge and water level stations, Bago and Zaung Tu, are located in the Bago River Basin.

The bago river is one of the most important and useful river basins in lower Myanmar for hydropower generation, irrigation use, fisheries and navigation use. In the bago river basin, a hydropower dam for electricity and diversion weir for irrigation use were constructed near Zaung Tu village in 1996 and 1998, respectively. For the purpose of flood control during the rainy season and the irrigation water use for summer paddy cultivation, three earthen dams namely kodukwe, Salu and Shwe laung dam were constructed in 2011 and opened in May, 2012.

The location of the Bago River Basin is shown in Figure 1.

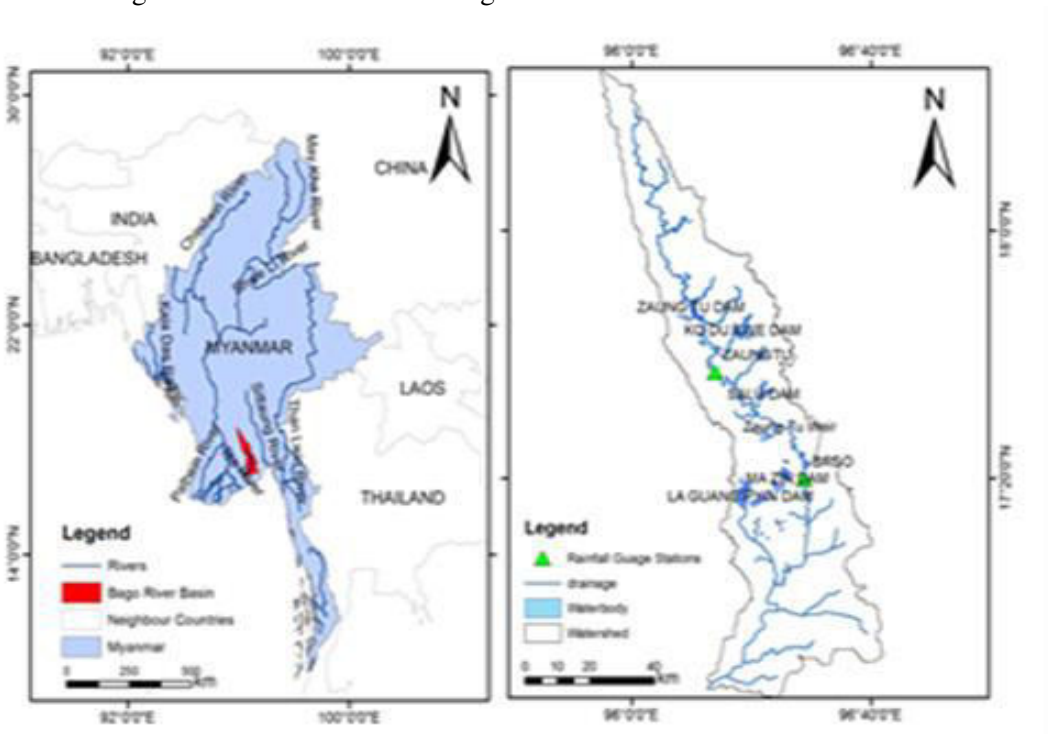

Figure. 1 Location of Bago River basin

Data Collection: Data were collected from various sources (Table 1).

Table. 1 Data Collection

Sr.No	Sources	Collected Data	Remarks
1	Department of Meteorology and Hydrology	Precipitation, water level and discharge data	Daily 1987-2015

2	Department of Hydropower	Zaung Tu Reservoir outflow and water level data	Daily 2011-2015
3	Irrigation Department	Reservoir outflow and water level data Dam Rainfall data (Gamone, Kawliya, Warkatoke, Minhla, Bawbin-1, Bawbin-2 , Ye Nwe) Rating Curve (Bago and ZaungTu station) 68 River cross-section	2004-2015 (daily) 2012-2015 (daily) 2014
4	Khaing (2014)	10 m Digital Elevation model	2014

3. METHODOLOGY:

In this study, HEC-HMS and HEC-RAS were utilized as the hydrologic and hydrodynamic models using HEC-Geo HMS and HEC-Geo RAS for linking to a GIS environment. The procedure for developing the flood inundation maps consisted of four steps: (i) extraction of geospatial data, (ii) development of design flood hydrographs, (iii) computation of water surface profiles and (iv) flood Inundation mapping.

4. HYDROLOGICAL MODELING:

HEC-HMS is an abbreviation for Hydrologic Engineering Center's-Hydrologic Modeling System. HEC-HMS version 3.5 was used in this study. HEC-HMS is hydrologic model simulation software for modeling precipitation-runoff processes for a dendritic watershed. The basic components of the HEC-HMS are the basin model, meteotologic model, control specifications, time-series data and pair data.
The basin model was used for physical representation of the watershed. Available elements in the basin model were: sub basin, reach, junction, reservoir, diversion, source and sink. Computation proceeded from the upstream elements in a downstream direction. The meteotologic model us has four basic components: Loss model, Direct runoff model Base flow model and Routing model.

Loss model calculates actual infiltration, which is interacted by infiltration, surface runoff and sub-surface processes together at the sub basin. The initial and constant rate method was used in this study.
The direct runoff method of the HEC-HMS model represents the actual surface runoff, which is performed by a transform method contained within the sub-catchment. A total of six different base-flow methods are provided. The SCS Unit Hydrograph Method was used in this method.

A baseflow model represents the subsurface model which is interacted with infiltration and surface runoff process. The actual subsurface runoff is calculated by baseflow method contained within sub catchment. A total of six different base-flow methods are provided. In this study, recession method was adopted.
A reach element conceptually represents a segment of stream or river. The actual calculations are performed by routing method contained within the reach. Each of the methods implements a hydrological routing methodology as compared to a hydraulic approach that implements the full unsteady floe equations. The lag method was adopted in this study.

HEC-HMS 3.5 was used as hydrological model in this study which was linked to GIS environment using HEC-GeoHMS extension. In this operation, the outlet of the Bago River was allocated at the Tarwa station. Figure.2 shows catchment rainfall by using Thiessen-polygon method in bago river basin.

Two flood events of 2014 and 2015 were selected for the calibration process. In the calibration procedure, six parameters which include initial abstraction, curve number, base-flow initial flow rate, recession constant, base-flow threshold ratio and SCS lag, were adjusted. The calibration result of the 2014 flood event is shown in Figure.3.

2013 flood event was used for validation. The coefficient of determination (R^2), and efficiency index (EI) values are obtained as 0.89 and 0.84, respectively for 2013 flood event. That indicated a close and good correlation between the observed and simulated flow. The validation result of 2013 flood event is as shown in Figure.4.

For model performance, Efficiency Index (EI) and Root Mean Squared Error (RMSE) are determined.

$$EI = \frac{\sum_{i=1}^{n}(Xi-\bar{X})^2 - \sum_{i=1}^{n}(Xi-Yi)^2}{\sum_{i=1}^{n}(Xi-\bar{X})^2}$$

Where, EI = efficiency index

X = observed value

Y = simulated value

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Xi - Yi)^2}$$

Where, RMSE = root mean squared error

X = observed value

Y = simulated value

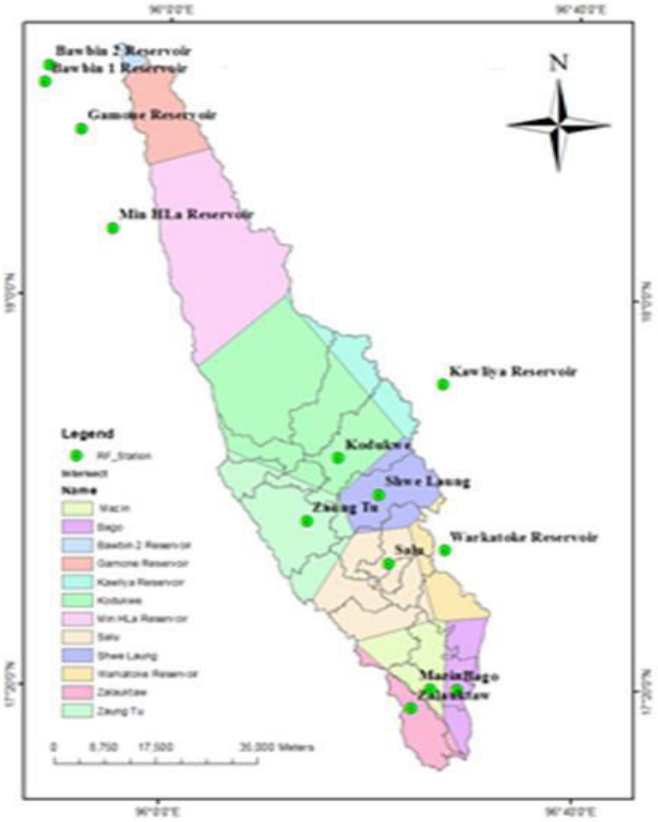

Figure. 2 Catchment Rainfall by using Thiessen - polygon method

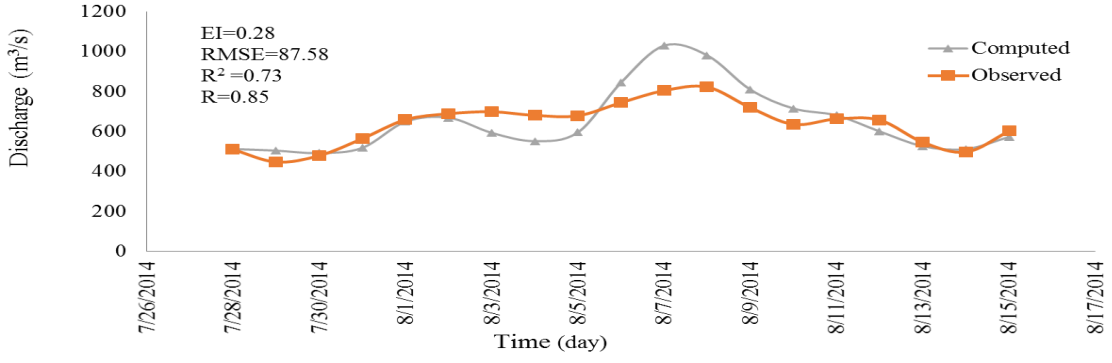

Figure. 3 Calibration result for2014 flood event at Bago station

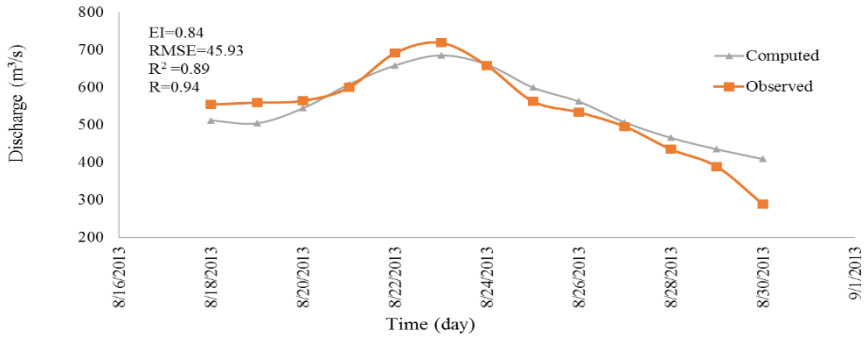

Figure. 4 Validation result for 2013flood event at Bago station

5. HYDRAULIC MODELING:

Hydrologic Engineering Center's River Analysis System (HEC-RAS) is a one dimensional model, intended for hydraulic analysis of river channels. The model is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphic and reporting facilities.

HEC-RAS system includes steady flow water surface profile computations, unsteady flow simulation, sediment transport computations and water quality analysis. HEC-RAS application includes flood plain management studies, bridge and culvert analysis and design, and channel modification studies.

HEC-RAS was used for hydraulic modeling using a river cross-sections dataset, Manning's n values, and flow data including flow rates, flow change locations, and boundary conditions. The 1D HEC-RAS model can be adequately calibrated using hydrometric data, and can then be used to make adequate predictions of flood extent when water free surfaces are extrapolated onto a high resolution DEM.

The important input data for hydraulic modeling is geometry data which were prepared using HEC-GeoRAS extension. The data needed to perform these computations are separated into geometric data (elevation, river center-line, hydraulic structures etc) and steady flow data (flow values of various recurrence intervals).

Hydraulic modeling in this study was conducted for 50 km reach of the Bago River and it started from Zaung Tu Weir to Tarwa outlet. The 68 cross sections nearly 500m to1500m interval was given as input data. The simulated flow data with time series flood event were used for calibrating the model. As a boundary condition, normal depth was taken. The calibration process was undertaken for 3 different flood events between 2013 and 2015. Figure 5 illustrates the generated river flood extend and water depth distribution map for 2014 flood event.

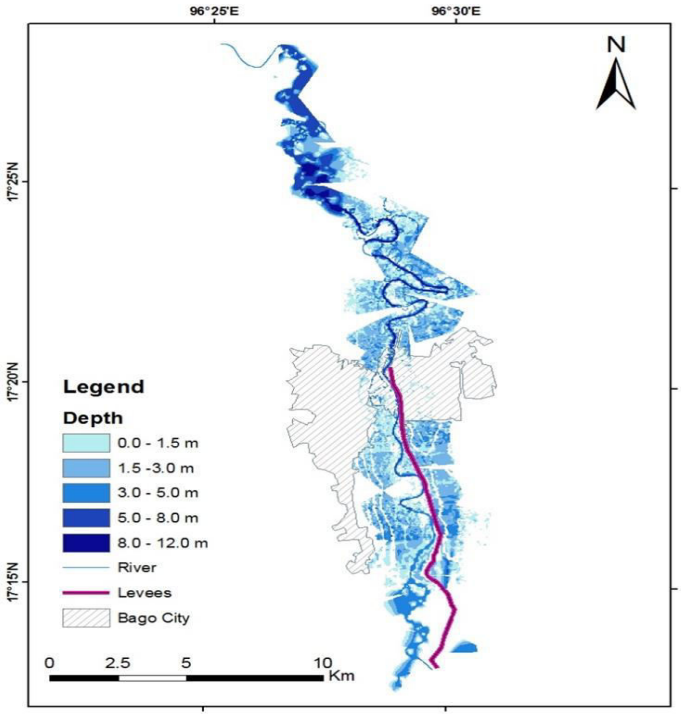

Figure. 5 Flood inundation map for 2014 flood event

6. CONCLUSION:

The highest depth of inundation can seriously affect the Bago City urban areas and around Bago Bridge. The largest flood extent can occur in the rural areas located near the upper areas of Bago City. The flood can also affect the downstream rural areas including the paddy fields. In this study, the analysis undertaken demonstrated that the model is currently at the limit of predictive ability for flood inundation, but the results of calibration and validation indicated acceptable results in simulating the flood events. The results of the hydrologic model could be further improved by installing a dense network of gauged stations. For a given topography and flow condition, all elements of geometric description including number of cross-sections, spacing, location and structural details (bridge/culverts) play a key role in describing the inundation extent. From a disaster reduction viewpoint, we believe the information derived from this study can contribute to assessing the possibility of flood damage for the local population and for those locations where data is limited, such as in Myanmar. Such an analysis would also be helpful in formulating and directing post-even relief efforts.

REFERENCES:

1. Alexandros Gkiokas., (2009): Elaboration of an integrated methodology for the production of flood hazard maps in the upper basin of Alfeios river, master paper of Water resources science and technology, N.T.U.A,
2. Clark, M.J., (1998): Putting water in its place: a perspective in GIS in hydrology and water management, Hydrological Process Vol.12, John Wiley & Sons, Ltd.,
3. Hausmann, P., M. Weber, (1988): Possible contributions of hydro informatics to risk analysis in insurance, in proceedings of the Second International Conference on Hydro informatics, Zurich, Switzerland,
4. Hlaing KY, Haruyama S, Aye MM. (2008): Using GIS-based Distributed Soil Loss Modeling and Morphometric Analysis to Prioritize Watershed for Soil Conservation in Bago River Basin of Lower Myanmar, Front. Earth Sci. China, 2(4): 465–478.
5. Khaing AM. (2014): Mapping Flood Inundation in the Bago River Basin, Myanmar. Master Thesis, Asian Institute of Technology (AIT), Thailand.
6. Rajesh Raj Shrestha., (2000): Application of geographic information system and numerical modeling tools for floodplain analysis and flood risk assessment of Babai River in Nepal, Resources Engineering Programme, University of Karlsruhe, Germany,
7. Sravani Duvvuri et al., (2013): Flood inundation mapping of Thamiraparani river basin using HEC-GeoRAS and SWAT, International Journal of Engineering Research and Technology, Vol.2 (7), 2013.
8. S. Alaghmand, et al., (2010): GIS-based river flood hazard mapping in urban area (A case study in Kayu Ara river basin, Malaysia), International Journal of Engineering Research and Technology, Vol.2(6), pp. 488-500, 2010.