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Alubijid River Basin Hydrologic Modeling in Misamis Oriental for Flood Risk Management

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ABSTRACT

Flood modeling studies for the purpose of forecasting, early warning, and disaster management of the local government and other disaster agencies have been done in many countries nowadays. With a similar rationale, this study aims to assess the precipitation-runoff capacity of the Alubijid River Basin which can put a significant number of 41,936 populations at risk to flooding. Using the 10-meter resolution SAR-DEM, the drainage system of the river basin was delineated in ArcMap 10.1 with the aid of HEC-GeoHMS. Data were collected last November 26-27, 2014 during the "Typhoon Queenie" which contributes to water level rise of 1.04 meter MSL of 86.7 mm accumulated rainfall with a peak discharge of 18.7 m3/s. The hydrologic data and generated basin model were inputted in HEC-HMS for calibration. After series of manual adjusting the river basin's parameters, the hydrologic modeling revealed that the river basin was accepted based on the conducted model validation and performance rating. The overall statistical measures conducted obtained very good and satisfactory ratings. As a result, the basin model is accepted for water level monitoring and forecasting as it gives lead time for the preparation of evacuation of the vulnerable community to the safe sites identified by the local government unit.

Keywords: *hydrologic modeling, Alubijid river basin, basin model calibration, SAR-DEM, water level monitoring and forecasting.*

INTRODUCTION

Like many countries nowadays, the Philippines has an increase in frequency and intensity in flooding, causing severe social, economic, and environmental impact. To mitigate the costly impacts of flooding to properties and human lives, it needs to be addressed in a more scientific approach. Flood studies are the important step towards understanding and managing flood behavior of a river. Flood modeling, one of the flood studies conducted by many researchers, is found to be very helpful in analyzing flood events for flood protection measures and mitigation strategies of any local government and other disaster agencies.

In the Philippines, as one of the world's disaster-prone countries, several flood modeling studies had been conducted for the purpose of flood risk management. It essentially predicts stream flow using the precipitation data and other relevant hydro-meteorological parameters using rainfall-runoff models (Santillan, 2013). Alubijid River Basin in Misamis Oriental, Mindanao is one of the identified critical rivers prone to flooding. The flood model of Alubijid River Basin consists of two components—the hydrologic and the hydraulic. However, this study focused on the first component, the hydrologic modeling.

This study aims to aid flood disaster risk management of the river basin with the integration of Geographic Information System (GIS), Hydrologic Engineering Center's Geospatial Hydrologic Modeling System (HEC-GeoHMS), and Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). However, the limitation of this study is the climatological condition of the river basin. The generated resource information of this study will be useful in providing the information requirements of various sectors of the local government unit and non-government offices.

METHODOLOGY

Alubijid River is one of the 13 river basins pre-assigned to Central Mindanao University in its collaboration with the University of the Philippines Diliman, the lead program implementer of Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program involving 18 major river basins in the Philippines. The program has resulted in an expansion that crafted the "Hazard Mapping of the Philippines Using Light Detection and Ranging (Phil-LiDAR)" program. It is funded by the Department of Science and Technology (DOST) starting February 2014 for a three-year duration.

Alubijid River Basin is located in the western part of Misamis Oriental. Most of the river channels traverse the municipality of Alubijid. The river basin is bounded on the north by Macajalar Bay; on the east by El Salvador City; on the south by the

Municipality of Manticao; and on the west by the Municipalities of Laguindingan, Gitagum, Libertad, Initao and Naawan (Alubijid LGU, 2014). Alubijid River Basin has a total land area of 12,206 hectares nested within the 29 barangay jurisdiction distributed in one (1) city and six (6) municipalities of Misamis Oriental—fifteen (15) in the Municipality of Alubijid; six (6) in El Salvador City; three (3) barangays in the Municipality of Libertad; two (2) in the Municipality of Laguindingan; and one (1) each in the municipalities of Initao, Gitagum and Naawan (Figure 1). Alubijid River is classified as one of eleven (11) big water resources in the province of Misamis Oriental.

Figure 1. Location of Alubijid River Basin relative to the Philippines

Necessary data of field observations such as hydrographic surveys and hydrologic data were gathered with the aim of hydrologic modeling. The hydrographic survey includes the water surface elevation and the geometric verification of the river profile for the river discharge computation. On the other hand, hydrologic data incorporate the river velocity, water level, and rainfall collected from data logging sensors (mechanical velocity meter, depth gauge, and rain gauges) in a specific period.

Misamis Oriental, including the Alubijid River basin, was under Signal No. 1 during the landfall of Tropical Depression Queenie last November 27, 2014. The hydrologic data collection covered the period starting 10:20 a.m. on November 26, 2014, until 4:10 p.m. on November 27, 2014. Precipitation data were taken from three automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These were the Pigsag-an, Pugaan, and San Simon ARGs. The location of the rain gauges is seen in Figure 2. Rainfall data were downloaded from the web portal of Philippine E-Science Grid-ASTI (http://repo.pscigrid.gov.ph).

Tropical Depression Queenie that occurred on November 26-27, 2014 contributed to a 1.04-meter water level rise with a peak discharge of 18.668 m3/s recorded at 2:20 p.m. on November 27, 2014, with accumulated 86.7 mm-rainfall. These hydrologic data are the actual event of Alubijid River and inputted to hydrologic modeling. Hydrologic measurements were taken from Alubijid Bridge, Poblacion Alubijid, Misamis Oriental.

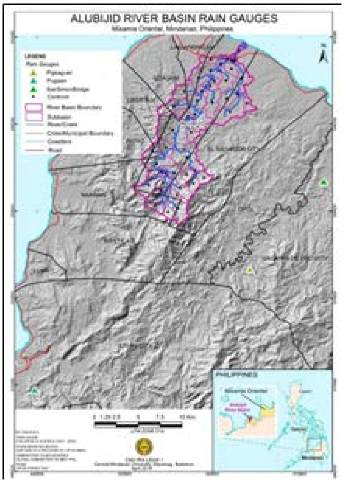

Figure 2. The monitoring stations used for the rainfall interpolation of the Alubijid River Basin.

Through the application of Geographic Information System (GIS), these datasets have been integrated, processed, and analyzed to create a database of spatial and hydrological data for the hydrologic modeling. This database is then utilized in the development, calibration, and validation of the basin model. The hydrologic modeling process involves the application of Geographic Information System, ArcMap 10.1 to be specific, Hydrologic Engineering Center's Geospatial Hydrologic Modeling (HEC-GeoHMS) 10.1extension, and Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) 3.5. HEC-HMS is designed to simulate the complete hydrologic processes of dendritic watershed systems and to model the volume of water in a river in relation to precipitation (USACE, 2010).

A drainage system includes the basin boundary, sub-basin, and the stream networks of the basin. Using ArcMap 10.1 with HEC-GeoHMS version 10.1 extension, the Alubijid River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the Alubijid River basin. The river centerline was digitized starting from upstream towards downstream in Google Earth (2014). Default threshold area used is 140 hectares. Using the rainfall and discharge of Tropical Depression Queenie, the basin model was then validated and assessed for accuracy and the performance rating.

RESULTS AND DISCUSSION

Using the 10m SAR-DEM with default threshold area of 140 hectares of the basin, the delineated drainage system of Alubijid River Basin generated 48 sub-basins, 25 reaches, and 26 junctions (Figure 3). Alubijid River Basin has a total length of 82 kilometers. It has a perimeter of 101,620 square meters with an average width of 32,856 meters and an axial length of 23,867 meters. The value of elongation ratio of the Alubijid River Basin is 0.52 indicating low relief of the terrain and elongated in shape. Narrow and elongated shape results to the irregular hydrologic process of the basin.

Utilizing the nearest available rain gauges adjacent to the river basin for the meteorological model, namely the Pigsag-an, Pugaan, and San Simon ARGs, a total precipitation of 86.7 mm was accumulated during the Tropical Depression Queenie. The said tropical depression hit the study area on November 26, 2014, to November 27, 2014. Table 1 summarized each rain gauge rainfall peak and the corresponding date and time when it peaked.

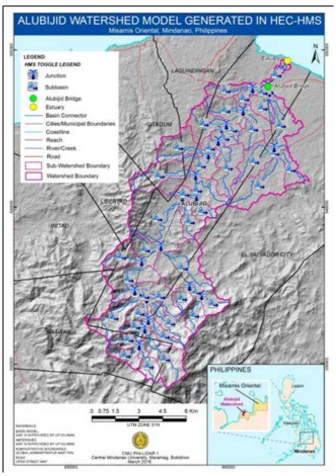

Figure 3. The Alubijid Basin model generated using HEC-GeoHMS.

Table 1
The Precipitation Summary of the Alternative Rain Gauges in Pigsag-an, Pugaan, and San Simon

Rain Gauge Name	Total Precipitation (mm)	Peak (mm)	Date and Time
Pigsag-an	6.2	5.6	26-Nov-2014 22:30
Pugaan	58.7	8.9	26-Nov-2014 23:30
San Simon	21.8	2.2	26-Nov-2014 22:15
Total	86.7		

Through the IDW method of rainfall interpolation, precipitation of the three rain gauges was evenly distributed to every sub-basin. However, distances from the observation points were also considered as the distance of the alternative rain gauge used for interpolation is critical (Mair and Fares, 2011). For strong interpolation result, the statistical distance was used in interpolating the available course network. Basin W920 (downstream) for example, has the least rainfall with the value of compare to W890 (upstream) for the limitation of interpolating rainfall decreases the weighted mean as the distance increases.

Tropical Depression Queenie last November 26-27, 2014 contributed to the water level rise of 1.04 meter mean sea level (MSL). The regression analysis resulted with the value of 0.8 (Figure 4). The regression analysis performed supports on the decision-making on the qualification of the data to proceed for the calibration of the basin model. Thus, the regression value reveals that discharge and water level have a very strong relationship with 0.93.

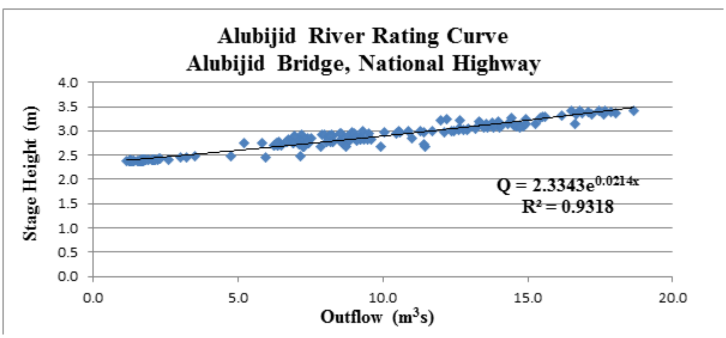

Figure 4. Rating curve of HEC-HMS Model.

Among the three alternative rain gauges used, Pugaan rain gauge in Lanao del Norte has registered the highest rainfall peak of 8.9 mm. Figure 5 plotted the rainfalls and actual outflow with a lag time of 2 hours and 50 minutes.

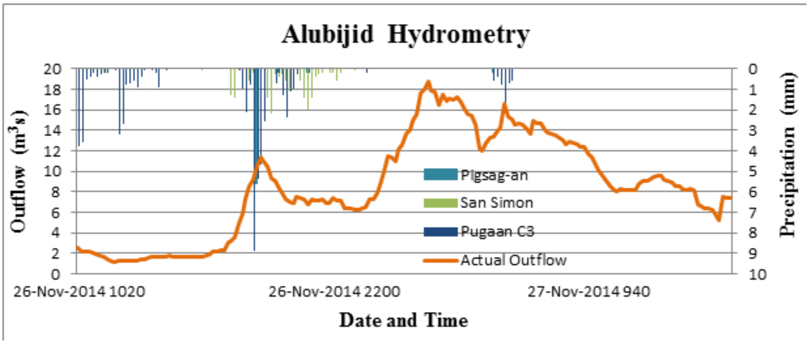

Figure 5. Rainfall and outflow data used for modeling.

The calibration of the basin model of the Alubijid River Basin was done through the manual and automatic adjustments of model parameters using the trial-and-error method until the appropriate fit between observed and simulated hydrographs attained (Figure 7). Three statistical measures of model efficiency evaluated the accuracy of the basin model calibration. According to the performance rating of the Alubijid basin model presented in Table 2, NSE is found to be very good with the value of 0.75 while the RSR is similarly very good with the value of 0.50 that implies better model simulation performance. Furthermore, the PBIAS is satisfactory with the value of 24.74. This means that the basin model is accepted according to the accuracy test of the three statistical measures.

Table 2
Alubijid Basin Model Performance Rating

Statistical Measures	MODEL PERFORMANCE	
	Values	Rating
NSE	0.75	Very Good
RSR	0.50	Very Good
PBIAS	24.74	Satisfactory

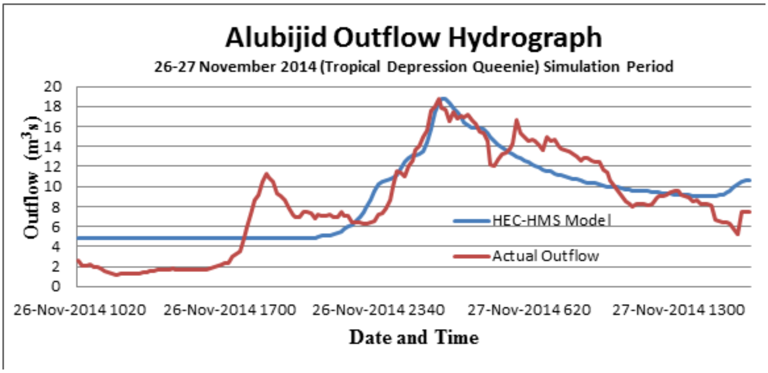

Figure 6. Outflow hydrograph produced by the HEC-HMS model compared with actual outflow.

As a result, the model of Alubijid River Basin is accepted for water level monitoring and forecasting based on the conducted model validation and performance rating. There are several benefits flood forecasting, and warning system can bring. It can give forewarning of the upcoming flooding and allows early evacuation and management of the affected infrastructure. The calibrated basin model is then efficient for the continuous hydrologic model and even for the hypothetical rainfall events and scenarios of the river basin.

CONCLUSION

Hydrologic modeling is essential for the use of disaster preparedness of the local government for the affected and flood-prone areas along the river. It can be used for water level monitoring and forecasting. It gives lead time for the preparation of evacuation of the vulnerable community to the safe places identified by the local government unit. However, basin model calibration is also dependent on the quality of hydrologic data especially the rainfall from upstream. It is very important for the critical rivers to have monitoring stations for very accurate flood forecasting. Moreover, the simulations provide hydrologic details about quantity, variability, and source of run-off in the river basin.

RECOMMENDATION

The model output suggests that the fine-scale time event hydrologic modeling, supported by intensive field data, is useful for improving the coarse-scale (hourly time step) continuous modeling by providing more accurate and wellcalibrated parameters. Thus, every river basins in the Philippines, especially those river basins that pose a greater risk to the vulnerable community downstream must have at least an automated rain gauge and a water level sensor for forewarning of the upcoming flooding, early evacuation, relocation of valuables, and management of the affected infrastructures.

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