The comparative study of flood modelling with the unsteady and the steady flow on Ngotok river

G Idfi 1, I D Wahyono1, A Yulistyorini1, and N L Khomsiati 1
1 Departement of Civil Engineering, State University of Malang, Indonesia

gilang.idfi.ft@um.ac.id

Abstract. The Flood modeling in a river is usually modeled with the one-dimensional flow. The Flood is one form of unsteady flow that can be simulated with the HEC-RAS program. The unsteady flow modeling results often occur error due to unstable program analysis. The stability of the model is influenced by the river channel, the slope of the river bed and the cross-sectional of the river. In flood forecasting required by maximum discharge data and maximum flood elevation, then the steady flow model is often used as an alternative to the calculation of flood forecasting. This study aims to compare the advantages and disadvantages of flood modeling with a steady flow and unsteady flow. The location of study in Ngotok River, Mojokerto Regency, Indonesia. Hydrological modeling uses HEC-HMS and hydraulic modeling uses HEC-RAS. The resulting modeling shows that the water elevation profile of the steady flow model has a higher than the unsteady flow model. The time required for the simulation of the unsteady flow model is longer than the steady flow model. The average water level elevation produced by the unsteady flow model is +27.17 m while the steady flow model is +29.62 m.

1. Introduction
The full bank capacity of a river is expected to accommodate the flood discharge. To find the optimal of flood modeling, the method must be approaching the existing condition. The simulation model with the software is often used in flood modeling planning on the steady or the unsteady flow. HEC-RAS is one of the software to analyze the flood problem. The unsteady flow model creates by the component flow according to the function of distance and time. While the steady flow is the modeling with the same component flow in every place and time [1]. In the unsteady modeling is often found the stable results. The input data on the unsteady model is more complicated like a cross-section of the river, the initial condition of the river, the upstream and downstream boundary condition. When the unsteady modeling on HEC-RAS occurs constraints, the engineers can replace it with the steady flow model. Flood routing methods on the rivers need to simulate with the unstable component flow [2]. If the flood modeling generated by the unsteady flow is unstable, then the simulation can be diverted to steady flow [3]. In the unsteady flow must be changed the discrete finite difference approximation to solve it, so there are some forms of error.

2. Location of Study
Area of this study on Ngotok River in Mojokerto, Indonesia. The length of this river is ± 26 km and the width is 60 m. The Ngotok river has the downstream area in Brantas River [5]. This river has the mild slope from the upstream area until the downstream area. The upstream boundary condition is the hydrograph entered on cross-section number 267. The downstream boundary condition is water surface, rating curve and stage hydrograph entered on a first cross-section. Location of study can be shown in figure 1.
3. Methodology

A drainage basin with rain gauge data is not uniformly distributed [6]. To determine the maximum precipitation is used The Thiessen Polygon Method [7]. This method using the rainfall data from Balai Besar Wilayah Sungai (BBWS) Brantas for 20 years (1995-2004). To create the Thiessen Polygon, draw lines connecting the stations and drag a straight line from the middle position from the line connection [8]. The hydrology analysis using the Soil Conservation Service (SCS) with HEC-HMS 4.1 [9]. The SCS methods determine the runoff discharge based on the cumulative of rainfall, land covers, soil characteristic and humidity [10]. The model equations can be shown below:

\[ P_e = \frac{(P-Ia)^m}{P-Ia+S} \]  

(1)

Where Pe: The Cumulative Precipitation, P: Time Concentrate (hours), Ia: Initial loss, S: Storage capacity

\[ S = \frac{1000-10CN}{CN} \text{ (English Unit)} \]  

(2)

The storage capacity depends on by Curve Number (CN) [11]. It can be shown below

\[ S = \frac{25400-254CN}{CN} \text{ (Metric Unit)} \]  

(3)

The hydraulics model using the one dimension steady and unsteady flow with HEC-RAS 4.1. To calculate the water surface elevation, this software using the cross section and long section data from the rivers. The unsteady model can be done by the St. Venant equation [4]. This equation develops from the continuity equation and the momentum equations. The flow chart of this study can be shown in figure 2 below.

Figure 1. Location of the Ngotok river
Figure 2. Flow chart
4. Analysis and discussion

4.1. Hydrology model
The result of the modeling must be calibrated to know whether the modeling results in accordance with the existing. Due to the existing discharge data not recorded by the Automatic Water Level Recorder (AWLR), so the calibration method using the survey by the residents around the Ngotok River to determine the behavior of this river. The flow characteristic like a flood surface elevation and the inundation area. The survey was conducted on 29 October 2016. From this survey can be known when the Ngotok overtopping, flood inundates the resident and the rice field. The depth of inundation is 20-30 cm. The survey method can be shown at the figure 3.

![Survey method](image)

**Figure 3.** The survey method

In this study, the return period of discharge using 25 years. The input data of the hydrology model is catchment area, the land cover, curve number, lag time and the effective precipitation. The all of them is inputted by HEC-HMS model. The result of the hydrology model is the flood hydrograph. It can be shown at figure 4.

![Hydrograph modelling](image)

**Figure 4.** Hydrograph modelling

From the hydrograph on figure 4, the maximum discharge model on The Ngotok River is 566.72 m$^3$/s. the result of the hydrology model used the upstream boundary condition for the hydraulics model.
4.2. Hydraulic model

The input data on this model is maximum flood discharge for the steady flow model and the hydrograph data for the unsteady flow [12]. The result of the modeling must be calibrated to know whether the modeling results in accordance with the existing. Due to the existing discharge data not recorded by the Automatic Water Level Recorder (AWLR) [13], so the calibration method using the survey by the residents around the Ngotok River to determine the behavior of this river. Flood is modeled by the steady flow and the unsteady flow. The water surface of the steady flow and the unsteady flow can be shown in figure. 5 and 6.

![Figure 5. Steady flow model result](image1.png)

![Figure 6. Unsteady flow model result](image2.png)

From both of the figures, the upstream section of the Ngotok River is overtopping condition on the steady flow and the unsteady flow modeling. This condition can be explained that the water surface elevation (blue line) higher than the right and left levee of river elevation (green and red line). This result also conforms with the survey data that the inundation area at the upstream section of Ngotok River. The steady flow model result (black line) has a higher water surface elevation than the
unsteady flow model (blue line). The overlay long section of the Ngotok river with the both of modeling can be shown at figure.7

![Figure 7. The comparation result](image)

5. Results and conclusion
The comparison of the steady flow and the unsteady flow one-dimensional flow models using HEC-RAS (Table 1)

| Method | The Unsteady Flow Model | The Steady Flow Model |
|--------|-------------------------|-----------------------|
|        | The Gradually Varied Flow, except at culvert, siphon, pier of bridge and weir. The equation used is momentum equation and energy conservation | The uniform flow that not depend by the time and distance |
| Hydraulic Input Data | The geometric and the cross section of river with a much the cross section to eliminate the errors | The geometric and the cross section of river |
| Hydrology Input Data | Upstream Boundary: Flood Hydrograph | Upstream Boundary: Maximum Discharge Downstream Boundary: tide of water, rating curve |
| Model Stability | Discharge, River Geometric sungai | None |
| Water | Average = +27.17 m | Average = +29.62 m |

References
[1] Istiarto 2014 The Flow Simulation of 1-D using HEC-RAS (istiarto.staff.ugm.ac.id)
[2] Istiarto 2014 HEC-RAS Steady or Unsteady Flow Analysis (istiarto.staff.ugm.ac.id)
[3] Anggrahini 1997 Hidrolika Saluran Terbuka (CV. Citra Media, Surabaya)
[4] V. T. Chow 1992 Open Channel Flow, (Erlangga, Jakarta)
[5] Sri Harto Br 1993 Analysis of Hydrology. (PT Gramedia Utama, Jakarta)
[6] Lensley, Ray K, Franzini, Joseph B. 1991 Teknik Sumber Daya Air Jilid II, (CV. Citra Media, Surabaya)
[7] C.D. Soemarto 1987 Hydrology Engineering, (Erlangga, Jakarta.)
[8] E. Suhartanto 2008 The Manual Book of HEC-HMS and Application at Water Resource
Management, (CV Citra, Malang)

[9] B. Triatmojo 2008 Hidrologi Terapan (Beta Offset, Yogyakarta)

[10] USACE 2000 Hydrologic Modelling System HEC-HMS Technical Reference Manual (http://www.hec.usace.army.mil. Maret)

[11] US Army Corp of Engineering 2008 HEC-RAS User Manual (Davis, California)

[12] Van Rijn, C. Leo 1990 Principles of Fluid Flow and Surface Waves in Rivers, Estuaries, Seas and Ocean (Delft Hydraulic)