MODEL OF PEAK DISCHARGE REDUCTION USING SIDE CHANNEL

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ABSTRACT

Special Region of Jakarta Capital as downstream area of Ciliwung river encounter overflow of the river anually. The watershed area start from upstream to downstream of the Ciliwung river had encounter degradation, from landuse to the riverbank of Ciliwung river had more then 20% degradatation. Ciliwung river devided into 2 area, upstream Ciliwung, middle Ciliwung area and downstream Ciliwung. This research was done in the middle section of the Ciliwung river, starting from Katulampa Weir until the bridge of Ciliwung Kepala Dua. This research purpose are to reduce the peak of the hydrograph discharge graphic in the middle area by installing Side channel with the capacity of 96, 956 m$^3$ with the flood discharge of 538.64 m$^3$/sec. the analysis of the research using Nakayassu hydrograph and simulated using iRIC software. Instalation of side channel are based on the elevation of the area and the potency of a green area in the middle area therefore the Kalo Baru 2, Sugutamu, Cikumpa and Ciparigi area are choosen. Declining of the Nakayussu hydrograph graphic are 12 - 15% with the callibration using iRIC Software simulation shows 14.76% and deceleration of the flow time until 15,200 second. The acquired mathematic equation are $Y = 4.723X_1+0.00005X_2+62.925$ with $Y$ as the declining of the flood discharge, $X_1$ as the number of side channel and $X_2$ as the volume of the reservoirs.

Key words: side channel, peak discharge, flow discharge, capacity.
1. INTRODUCTION

1.1. Background
Flood in Jakarta region had a high flood cycle of every 5 years. In the mid 2013, high flood occur in jakarta. This flood causing large portion of Jakarta city flooded even the Presidential Palace been flood. Economy activities, transportations access, and electricity was paralyzed. Flood mitigation should be handled by related parties to plan the flood mitigation including landscape, environment, landuse and safety [5]. Periodic flood in jakarta had been increasing in frequency and one of the factor that causing the increasing of the frequency awas because the flood discharge of Ciliwung river watershed. In general, it was known that water flow in the recharge area is the transformation of the rainfall occurrence. The flow is divided into two major factor that are the rainfall itself and the characteristic of the recharge area (watershed) [4]. Land use transformation give a significant impact to the overflow coefficient. Land use had space dimension that connected to the land use pattern and the time dimension is connected to the changing of the land use pattern. According to Muh. Saleh Pallu [6], the region characteristic like rainfall, type of soil/ground and topography of the region determine the result of the hydrograph model. One of the parameter that used was land covers and type of soil, where the physical condition of the watershed will become the potential discharge index [7]. The impact of the land use transformation that had been happening in the last two decades, the flood discharge had increased to 68% in the upstream Ciliwung river and 24% in the middle Ciliwung river and the flood volume had been increase to 59% in the upstream Ciliwung and 15% in middle Ciliwung river. To reduce the flood discharge of Ciliwung river that occur in Jakarta, there are work that can be done by reducing and controlling the flood discharge and flood volume in the middle Ciliwung watershed by temporarily hold some of the discharge as maximum as possible into the side channel along the middle Ciliwung watershed before flowing into downstream Ciliwung watershed.

The alteration of land use in Ciliwung watershed in some years back had increasing the frequency and intensity of the flood in jakarta that got through by Ciliwung river. The upstream Ciliwung watershed area covers 15,252 Ha with fan-like shape and wavy topography, steep slope and turbulence water flow. Middle Ciliwung watershed covers the area of 16,706 Ha with wavy topography with rolling hills that varies between 100 m to 300 m asl [2].

1.2. Formulation of Problems
This research had the formulation of problems to gain the model of reduction of peak discharge after the installation of side channel in the middle Ciliwung watershed, there are:

- How was the condition of the sub-watershed that covers the upstream and middle Ciliwung watershed in Bogor?
- How was the percentage of the land use transformation now, in some Bogor city area, some of Bogor Regency area, and Depok city as the middle Ciliwung river watershed that goes to Manggarai water gate?
- Are the rainfall data in the observation post in the middle ciliwung watershed area can represent the rainfall in the whole area?
Model of Peak Discharge Reduction Using Side Channel

- How much percentage decreasing of the flood discharge after the side channel installed in the middle Ciliwung river watershed?
- How was the model of peak discharge reduction in the middle Ciliwung watershed until Manggarai watergate?
- How was the hydrograph model for the flow discharge in the middle Ciliwung watershed after the installation of side channel?

1.3. Scope of Problems
The scope of problems in this research are the observation areas to collecting data and modelling of peak discharge reduction after the side channel are:
- Middle Ciliwung watershed flow from Katulampa weir to manggarai watergate
- Daily rainfall in the observation post of Cibinong, UI Station, and Cawang
- Nakayasu hydrograph modelling before and after the side channel installation.
- Mathematical equation for the side channel number and volume of reservoirs
- iRIC software simulation after and before the side channel installation.

1.4. Research Purpose
This research has purposes as follows:
- Determine the side channel area that will be used to reduce the peak of the flood hydrograph in the middle Ciliwung watershed
- To simulate overflow reduction model to decrease or stabilize the peak flood hydrograph in the middle Ciliwung watershed
- To analyze percentage number of decreasing overflow reduction in order to reduce the discharge flow into Manggarai watergate.

The result of the data processing and simulation of iRIC software can obtain a model of peak discharge model as a mathematic equation that has variables of number and volume of reservoirs in the side channel installation area. The decreasing of peak discharge will be displayed in graphic of hydrograph before and after the installation of side channel. Rainfall data in 10 years will be used in data processing on HSS Nakayasu. The result of the peak discharge calculation will become the input for the iRIC software simulation. The systematic of the research writing will be started the introduction that explain the background of the research by showing the problems that become the benchmark of the research. The next step is to do desk study that consist of theoretical study and also mathematic equation that used in order to get the calculation data of flood peak discharge and also percentage of flood peak discharge reduction. Method and the result of analysis is the most important phase in this research to obtain mathematic equation and hydrograph reduction graphic before and after installation of side channel.

2. THEORETICAL BASIS
2.1. Synthetic Hysdrograph Unit (HSS) Nakayasu
Calculation method that used in order to get the value of the peak discharge with HSS Nakayasu equation [8] as follow,

\[ Q_p = \frac{C A R_0}{3.6 (0.3 T_p + T_{0.3})} \]  (1)
Where, $Q_p$ : flood peak discharge ($m^3/sec$); $C$ : flow coefficient; $A$ : area of recharge to outlet ($km^2$); $R_0$ : rainfall unit (mm); $T_p$ : time duration from the start of rain until flood peak (hour); $T_{0.3}$ : times required to reduce the discharge from the peak until 30% of the peak.

To determine $T_p$ and $T_{0.3}$ are required approach with equation as follows,

\[ T_p = tg + 0.8 t_r \]  
\[ T_{0.3} = \alpha tg \]  
\[ t_r = 0.5 tg \text{ until } tg \]

$tg$ is the time lag that are times between rain to flood discharge peak (hour), $tg$ is calculated following this dihitung dengan ketentuan sebagai berikut,

\[ tg = 0.4 + 0.058 L \text{ condition } L > 15 \text{ km} \]  
\[ tg = 0.21 L^{0.7} \text{ condition } L < 15 \text{ km} \]

Where, $t_r$ : rainfall duration unit (hour); $\alpha$ : hydrograph parameter for: $\alpha > 2$ in regular flow area; $\alpha > 1.5$ in the increasing part, the hydrograph slowing and then rapidly dropping; $\alpha = 3$ in the increasing part, the hydrograph raising and slowly dropping.

2.2. iRIC Software

Simulation of peak discharge reduction in the middle Ciliwung watershed also will be using iRIC (International River Interface Cooperative) software that will analyze river flow and the variation of the riverbed by input the topography data, elevation of the river and also inflow discharge data. Analysis using iRIC software are divided into three important parts that are preprocessor (establish the river flow based on the elevation data), postprocessor (analysis results of the program in JPG or graphic) and solver calculation (determining method that will be used to analyze the existing data) [8]. This research is using solver calculation Nays 2D Flood which is analysis breaker of the flood flow that depend on the simulation of 2 dimension plane flow that unstable using coordinate that installed as the general curve coordinate, to adjust inflow condition from a random river inflow from the top of upstream to the riverbank. This method had been applied in small to medium scale of river flood flow. Because the breaker doesn’t require river channel data, it will be used to analyze flood process of the river in the developed country.

3. ANALYSIS AND SYSTEM PLANNING

3.1. Research Location

This research conducted in the middle Ciliwung watershed in the coordinate 6°39'54" LS and 106°51'49" BT to 6°12'28" LS and 106°50'54" BT and it was part of the third to fifth segment of the Ciliwung watershed segmentation [1] as shown in the Figure 1. The area that included in the Middle Ciliwung watershed are Bogor regency (Sukaraja district, Cibinong, Bojonggede and Cimanggis), Bogor City (city district of Bogor Timur, Bogor Tengah, Bogor Utara and Tanah Sereal) and administrative city of Depok (Pancoranmas district, Sukmajaya and Beji) [2].
Katulampa weir is one of the input point of the inflow until Manggarai watergate as the output point. Sub-watershed of Ciliwung that will be chosen as reservoir installation location based on the percentage of public green area and the elevation of the area that will be called side channel.

3.2. Research Method

The method that will be used in this research are as follows:

- rainfall data from 2007-2016 on 3 rain station that are Cibinong, Fakultas Teknik UI and Cawang
- selecting and scoring middle Ciliwung watershed area that still has public green area available and adjusted to the elevation of the area to install side channel
- calculate value of peak discharge with HSS Nakayasu before and after installation of side channel
- conducting iRIC software simulation before and after installation of side channel
- obtaining mathematic equation with the variable of number and volume of reservoir of side channel
- calibrating reduction of peak discharge as the result of HSS Nakayasu with iRIC software simulation
4. RESULT AND DISCUSSION

4.1. Calculation of flood peak discharge

The result of HSS Nakayasu calculation are showing the number of peak discharge before and after installation of side channel for 24 hours as shown in the Table 1.

<table>
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<th>T (hour)</th>
<th>Before side channel</th>
<th>4 side channel</th>
<th>3 side channel</th>
<th>2 side channel</th>
<th>1 side channel</th>
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<tr>
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<td>142.55</td>
<td>142.96</td>
<td>142.2</td>
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</table>

Flood peak discharge before installation side channel shown in the middle Ciliwung watershed during 0.6 hour with the discharge of 538 m³/sec, there are large reduction of discharge about 12.19% - 14.96% by installing side channel with reservoir capacity of 96,956 m². Declining of the hydrograph graphic in the side channel installation are shown in Figure 2.
Figure 2 Declining of hydrograph graphic before and after installation of side channel

According to the Figure 2, the declining of hydrograph graphic are seen to be constant in each side channel installation at the hour of 18\textsuperscript{th} that shown significantly in the flow discharge. Before side channel installation, it was seen that flow discharge had declining at the hour of 15\textsuperscript{th} – 24\textsuperscript{th} with flow discharge of 220 m\textsuperscript{3}/sec to 26.25 m\textsuperscript{3}/sec, therefore this indicates that elevation of Ciliwung river are causing the peak discharge are rapidly dropping. Fourth Side channel installation in the area can be used as water resource conservation to reserve flow discharge temporarily before flowing to the downstream area.

Mathematic equation that acquired by this number and volume of side channel in four area of Middle Ciliwung watershed are \( Y = 4.723X_1 + 0.00005X_2 + 62.925 \) where \( Y \) is the reduction of flood discharge, \( X_1 \) as number of side channel and \( X_2 \) as reservoir volume on side channel. This mathematic equation can only be used with minimum of 1 side channel installation while if there was no side channel installed therefore this equation can not be used. The relationship of the flood discharge declining that caused by the number and the volume of the reservoirs are showns in the Figure 3.
The chosen area for side channel installation are Kali Baru 2, Kali Sugutamu, Cikumpa and Ciparigi, those location are acquired according to elevation and the availability of public green area.

4.2. iRIC Software Analysis
iRIC Software analysis are done by calibrate the mathematic equation or flood discharge reduction in that occur at the middle Ciliwung watershed. The first step was drawing process of the location and input of data before running software is undergo [3]. After the research location had been drawn, the flood discharge will become the input data at the inflow area. Determining the fourth area of the side channel was done by input the elevation data in the area and the value of the flow discharge that will be diverted and temporarily stored in the reservoir. Running iRIC software also done before the side channel installation also as shown in Figure 4 as a comparison against data after side channel installed.

Figure 4 The result of iRIC Software simulation before side channel installation

After that, running program with the input of additional four side channel in the middle Ciliwung watershed as shown in Figure 5.
Based on the analysis, the result of the flood discharge on the iRIC software simulation had reduction percentage of 14.76% from before to after side channel installation. Reduction percentage was about 12-15% in accordance to teh number and reservoir volume of side channel.

5. CONCLUSION

According to HSS Nakayasu and iRIC software analysis for the flood discharge in the middle Ciliwung watershed can be concluded as follows:
1. Installation of four side channel with reservoir volume of 96,956 m$^3$ causing deceleration of the flow for 15,400 second
2. Mathematic equation the obtain for the flood discharge after the side channel installation are $Y = 4.723X_1 + 0.00005X_2 + 62.925$
3. the percentage of flood discharge are 12 - 15% with the callibration on the iRIC Software are 14.76%

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