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Model of Ciliwung River Flood Diversion Tunnel Using HEC-RAS Software

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Abstract. As a coastal city which lies in lowland area, Jakarta is prone to flooding. One major river which flow through Jakarta is Ciliwung River. There are alternatives to reduce flood risk, such as: river capacity improvement, existing natural reservoir and polder system improvement, upstream reservoir construction, city drainage improvement, flood channel construction and flood diversion. This paper presents capacity analysis of a proposed flood diversion of Ciliwung River to Cipinang River. Cipinang River has its downstream end at Eastern Flood Canal (Kanal Banjir Timur, KBT). This diversion is based on the available capacity of KBT. A 1-D numerical hydraulic model using HEC-RAS based on a proposed design is used to assess the performance of the diversion system in any combination of upstream and downstream boundary condition. Simulations were done for steady condition. The results show that capacity of the system can be achieved for certain condition at upstream and downstream boundary. The effects at the downstream reach of Ciliwung and Cipinang River due to the diversion are also obtained.

1 Introduction

Jakarta is a coastal city with 13 rivers pass through its area. Flood is one of main problem at Jakarta. Ciliwung River is one of the rivers which has a significant contribution on flooding of Jakarta region. Ciliwung River has a length of 117 km. The catchment area of Ciliwung River is 382.6 km^2.

Cipinang River has 48 km^2 catchment areas, approximately. This river has its downstream end at Kanal Banjir Timur (KBT, Eastern Flood Canal). KBT receives flow from Cipinang, Sunter, Buaran, Cakung and Jati Kramat rivers. Total catchment of KBT is 207 km^2, approximately.

Based on previous feasibility study, Kanal Banjir Timur has an extra capacity which could be provided for diverted partial discharge from Ciliwung River at any possible condition. It is expected to utilize this capacity to reduce flood risk at the downstream reach of Ciliwung River.

The purpose of research is to study the capacity of flood diversion tunnel by using HEC-RAS software and explore its application in this case.

2 Literature Review

Flood is frequently occurred in Jakarta, due to drainage problem and river flood. In the last twenty years there are at least five major floods event occurred, i.e. in 1996, 2002, 2007, 2013 and 2014. This flood caused severe inundation, public utilities and service disruptions and fatalities. For example, flood event in 2013 resulted in about 40 death tolls, 45,000 people evacuated, and severe economic lost [1]. The estimated economic loss due to flood in early 2007 was 566 million dollar, approximately [2].

HEC-RAS (Hydrologic Engineering Software-River Analysis System) was developed by Corps' Civil Works Hydrologic Engineering Research and Development Program. HEC-RAS is a one dimensional flow model which capable to perform calculation of steady flow, unsteady flow, movable boundary sediment and water quality analysis for a network of natural or constructed channel. HEC-RAS was developed based one dimensional energy, momentum and continuity equations. The equations are solved numerically by finite difference approach [3]. HEC-RAS is equipped with graphical user interface to facilitate data input and result visualization in tables and graphic [3]. HEC RAS has been applied in design of flood control [4], flood waves analysis [5] and river system modelling [6].

3 Ciliwung River – Kanal Banjir Timur (Eastern Flood Channel) Diversion System

The diversion system consists of inlet at Ciliwung River, transition, tunnel and outlet at Cipinang River. The connection between Ciliwung River, diversion tunnel and Cipinang River is presented in Figure 1. Inlet invert level elevation is at +9.150. Outlet invert elevation is at +7.00. The length of inlet transition is 53 meters. The horizontal length of diversion tunnel is 1,200 m, with

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longitudinal slope of 0.586% for the first 670 meter of tunnel and 0.711% for the rest. The tunnel consists of two circular barrels with inside diameter of 3.5 meter.

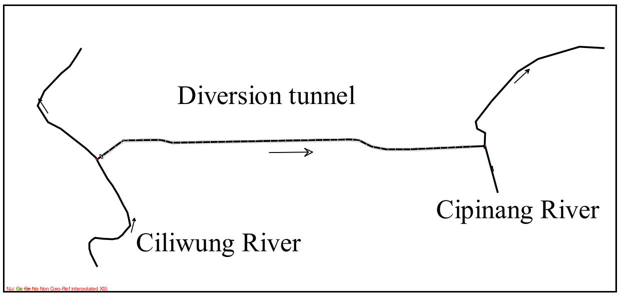

Figure 1. Layout of diversion system in HEC-RAS.

4 Methodology

In this study, hydrological data is obtained from previous study. River cross sections are available for Ciliwung and Cipinang river reach. In this study, normalized cross section is used in the modelling. Steady discharges applied for the model are presented in Table 1.

Table 1. Flood discharges and water level of Ciliwung and Cipinang River after normalization.

Return Period	Ciliwung		Cipinang	
(years)	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)
Normal flow	n/a	n/a	7	6.481
2	301	11.086	84	7.951
5	400	11.929	106	8.233
10	452	12.342	114	8.330
25	509	12.773	122	8.425
50	547	13.048	127	8.483
100	570	13.227	130	8.517

The model consists of three main reach, i.e. Ciliwung river reach, diversion tunnel reach, and Cipinang river reach. The downstream of Cipinang river reach is connected with Kanal Banjir Timur (KBT, Eastern Flood Channel). Steady flow condition is assumed to obtained diversion capacity of the tunnel.

Typical normalized Ciliwung and Cipinang River are presented in Figure 2. Ciliwung and Cipinang River were modelled as open channel, and the diversion tunnel was modelled as open channel with lid. Example of a cross section with lid is presented in Figure 3.

The flow in the diversion tunnel may be in the state of flow with free surface, as flow in a closed conduit or flow with free surface at upstream part and closed conduit at the downstream. This will depend on the upstream and downstream flow boundary conditions. An example of flow condition in the diversion tunnel is presented in Figure 4.

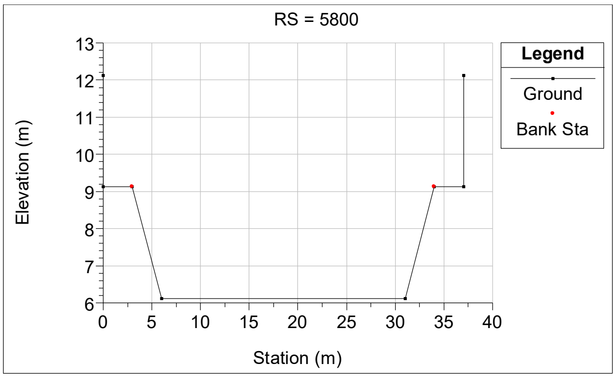

Figure 2. Typical cross section of Ciliwung River at upstream of the diversion inlet.

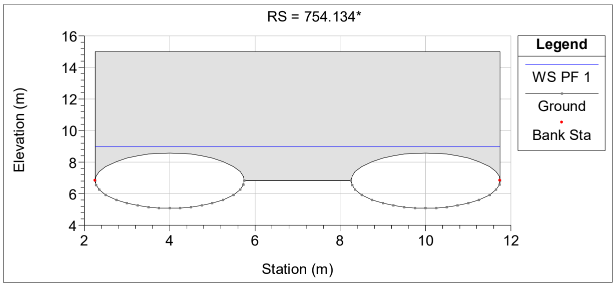

Figure 3. Cross sections of Ciliwung river diversion tunnel.

Boundary conditions of steady discharges were applied for upstream boundary of Ciliwung and Cipinang River. Boundary condition of normal depths was applied for downstream end of Ciliwung and Cipinang River.

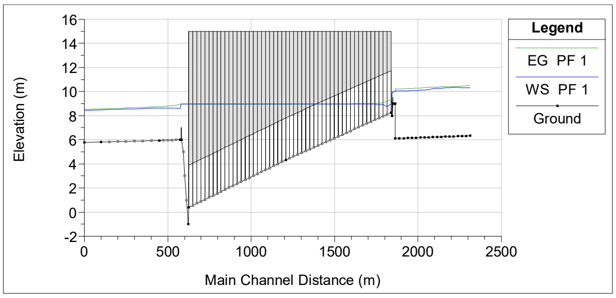

Figure 4. Long section of Ciliwung River (upstream)-diversion tunnel-Cipinang River (downstream).

For every scenario of discharge condition at Ciliwung and Cipinang River, the discharge of diverted flow was assumed first. After a calculation of a scenario in HEC RAS is completed, the energy gradient before and after every junction were checked. If energy level upstream and downstream of a junction is equal, the assumed diversion discharge is acceptable. Otherwise, another assumption of diverted discharge must be taken until equality of energy level at the junction is satisfied. The results of all scenarios are presented in Table 2.

5 Results and Discussion

Simulations were conducted for different combinations of Ciliwung and Cipinang river discharge. The discharge which flow through the diversion tunnel for these combinations are presented in Table 2.

Simulation showed that the discharges through diversion tunnel ranges from 10 to 75 m^3/s, or 5% to 13% of the respective discharges at Ciliwung River. Based on rating curve of Ciliwung River, the maximum reduction of flow depth is 0.52 m. This reduction will reduce risk of river bank overtopping, and also add more time for evacuation of people and their valuable properties.

Table 2. Flow discharge (m^3/s) through diversion tunnel.

				Cipinang								
	Return Period (year)			**Normal**	**2**	**5**	**10**	**20**	**25**	**50**	**100**	**100***
		Discharge (m^3/s)		7	84	106	114	122	127	130	135	152
			Elevation (+m)	6.481	7.951	8.233	8.330	8.425	8.483	8.517	8.574	8.740
Ciliwung	**1.01**	200	10.006	10	10	10	10	10	10	10	10	10
	2	301	11.086	38	39	38	38	38	38	38	38	35
	5	400	11.929	59	59	58	58	57	56	56	55	56
	10	452	12.342	66	66	64	63	62	62	61	61	58
	25	509	12.773	70	70	69	68	67	66	66	66	63
	50	547	13.048	73	73	71	71	70	69	69	69	66
	100	572	13.227	75	74	73	72	72	71	71	70	66

*) : After Cipinang river improvement.

6 Conclusion

System of diversion from Ciliwung River to eastern flood canal was successfully modeled and simulated in HEC-RAS. According to the simulation result, the diversion capacity ranges from 10 to 75 m^3/s. Reduction of flow at the downstream of diversion point will result in reduction of flood water level and reduce inundation area. Hence the diversion tunnel will reduce impact of flood along the downstream reach of Ciliwung River and can be proposed as alternative in flood disaster mitigation.

However, the presented results are limited to 1 D assumption. Three dimensional flow eventually will affect flow condition at inlet and outlet where change of flow direction occurred. Further study is required to accommodate these considerations.

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