Contribution of Manggarai gate improvement to flood in Manggarai Village based on recorded flood event

T N A Kesuma1,*, D Saputra2, M Farid3,4, M S B Kusuma3 and A A Kuntoro3

1 Civil Engineering Doctoral Program, Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Bandung, Jawa Barat, Indonesia
2 Civil Engineering Master Program, Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Bandung, Jawa Barat, Indonesia
3 Water Resources Engineering Research Group, Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Bandung, Jawa Barat, Indonesia
4 Center for Coastal and Marine Development, Institut Teknologi Bandung, Bandung, Jawa Barat, Indonesia

*tri.adikesuma@gmail.com

Abstract. Manggarai Gate is one of the most important flood control structures of the Jakarta Flood Control System. Its performance capacity is a compulsory parameter for flood risk reduction of the Jakarta Flood Prone Area. This paper aims to evaluate the contribution of the capacity improvement of Manggarai Gate to reduce the flood hazard at Manggarai flood-prone areas located in the upper part of this gate. An additional gate section was conducted in 2015 as the structural flood hazard reduction effort to increase the capacity of this gate from 330 m$^3$/s to 507 m$^3$/s. Recorded floods characteristic event before and after this improvement was compared to determine the flood hazard changes during the flood observation period. Based on this determination results it is found that the contribution of the increment capacity of Manggarai gates in reducing the flood hazard depends on the sustainability of the river capacity, river water quality, and flood control operation. It could also be concluded the sustainability of the river capacity and river water quality is very sensitive to the social behavior of the community and the river stakeholder along the river catchment area in addressing the environmental condition of the river catchment area.

1. Introduction
Jakarta is one of the most well-known flood-prone areas in Indonesia. Most of the flood-prone area in Jakarta is a natural floodplain as it is concluded in several previous studies [1-3]. Kusuma et al. [2], Farid et al. [3], and Tambunan [4] also discussed several well-known large floods of Jakarta in 1619, 1872, 1996, 2002, 2007, and 2013. Most of those floodplain areas located in the flat riverine area of central Jakarta and the coastal area of the northern part of Jakarta. The recorded flood in 1619 was used by the Dutch colonial government to develop a flood canals system of Batavia (Jakarta) area. Heavy precipitation of 286 mm generates a big flood in 1872 where the flood gate located in Pasar Baru Area was failed. However, the recorded flood of 2007 is a well-known devastating flood that frequently used as a flood reference for Jakarta Flood Study.

The existing flood control system is developed based on its masterplan in 1996 with several updates in the last decade regarding the influence of land subsidence, sea-level rise, and land-use
change. There have been many studies on supporting the development of the Jakarta floods system, but there is not yet a proper alternative solution to solve the Jakarta flood problems generated by sedimentation, solid waste, land subsidence, land-use change, and social problem. There are several structural flood mitigation efforts proposed in that masterplan such as river normalization, flood dyke, flood gate, and polder system had been done, but this development is far from its proposed ultimate flood control system due to the lack of funding and or policy support. Juliana et al. discussed the effectiveness of rain harvesting in decreasing the peak discharge \[5\]. Furthermore, all that structural effort could not significantly decrease its flood risk. Furthermore, Sarminingsih et al. discussed the important relationship of the increasing flood hazard to the increasing flood damage factor of the flooded area \[6\]. However, Kusuma et al. concluded that an improvement of flood early warning systems could significantly contribute to the flood disaster risk reduction effort whenever the flood hazard models could predict a reliable flood propagation \[2\].

One of the most difficult efforts of flood propagation model prediction improvement is to determine the reliable flood hydrograph \[7,8\]. Meanwhile, Kusuma et al. concluded that urbanization significantly increased the influence of sedimentation, solid waste, and land-use change in increasing the flood hazard in most of the developed areas in Indonesia \[7\]. Nowadays, the flood hydrograph is influenced not only by land-use change but also by climate change where the flash flood is more frequently recorded than the previous time \[3,7-9,12\] suggested encountering the correlation of the trend of extreme rainfall and run-off discharge in addressing the influence of land-use change and climate change. Jongman et al. discussed the adaptation strategy to decrease the flood vulnerability \[13\]. Based on all the above previous study it is shown that most structural flood mitigation efforts, that caused high cost construction and social problem, may need assessment improvement regarding the influence of land-use change and climate change to the flood parameter as discussed above. This paper discusses the contribution of the Manggarai gate capacity improvement to reduce the risk of Manggarai and Kebon Manggis flood areas along the Ciliwung flood area.

![Figure 1](image-url) (a) Embankment condition of Manggarai and Kebon Manggis (b) Manggarai flood gate.

### 2. Method of the study and case study location

The flood comparison before and after the Manggarai Gate improvement is conducted based on its flood occurrence characteristic where not only its flood hazard but also its discharge and or rainfall intensity that generated the flood were used \[14\]. The contribution of the Manggarai Gate is improved whenever the higher flood discharge (rainfall intensity) could generate lower flood hazard.

Recorded discharge at Manggarai gate and regional rainfall intensity recorded in Ciliwung River are used for the analysis. Flood event recorded between 2014 to 2018 are used as data base of comparison study. An analysis of the relationship between rain, discharge, and the occurrence of floods was carried out. Case studies were conducted by comparing the inundation distribution of flood events of the Manggarai region to the occurrence of discharge and flood management programs.

Daily rainfall data and maximum daily discharge data are compared to compare the relationship between rainfall and the generated discharge. The rainfall compared is the regional average of rainfall in a day. The results of this comparison are used to determine the rain and discharge limits that cause
flooding. This boundary is then compared with data on the appearance of historical flood inundation to see the effect of rain and discharge on the occurrence of a flood. In this paper, historical data on the extent of floods that appear are taken as the extent of RWs affected by flooding.

Manggarai is an area directly adjacent to the Manggarai Flood Gate and is a flood-prone area. Manggarai is located on the west side of the Ciliwung River as seen in Figure 2.b. The condition of the riverbanks on this area is filled with semi-permanent buildings with high density. Buildings that occupy the riverbank are on average built with wood or wood and concrete composite materials with the position of the back of the building directly on the river body. Some buildings in this area are even built protruding into the river, to utilize the river body as a washing and bathing place.

3. Results and discussions

According to the plan, normalization project to increase the capacity of the Ciliwung River from 200 m$^3$/s to 570 m$^3$/s should occur from 2013 to 2016. However, this activity was stopped prematurely before reaching Manggarai floodgate in 2015 due to social conflicts (Figure 1 (a), 2 (a), (b)). Even so, the capacity increase of the Manggarai Floodgate was carried out in 2014-2015 with the addition of one flood gate. The addition of the floodgates increased the capacity of the Manggarai floodgate from 330 m$^3$/s to 507 m$^3$/s. [15] stated that increasing the capacity of the Manggarai gate by 150 m$^3$/s could reduce the water elevation in the upper reaches of the Manggarai Flood Gate to 1 m so that after the addition of the flood gate capacity, the area of flood inundation at the upstream should be reduced.

From January 2014 - December 2018, several major flood events in the Manggarai area occurred in January - February 2014, March 2016, and February 2018. However, there were other flood events in the Manggarai area that occurred in November 2014, 2015, 2016, and February 2015. In general, these flood events occur because of high rainfall causing the Ciliwung River to overflow. From the average regional rainfall that emerged in the 2014 - 2015 period, flooding occurred when the discharge of 300 m$^3$/s was exceeded. This discharge condition is equivalent to the magnitude of regional rainfall that appears, with a limit on the average amount of regional rainfall that produces floods is 40 mm. However, this condition can only occur if the rain that occurs in areas after Depok also has high magnitude. This is due to efforts to reduce peak discharge in the Depok Reservoir, so that the outflow from the Depok area is smaller than the natural discharge.

![Figure 2](image-url)

Figure 2. (a) Ciliwung River flood control system (b) Map of finished embankment improvement project.
The basic difference in flood sampling in the observation data for the period January 2014 - December 2018, with the results of the 2007 flood modeling by [1] caused a difference in the appearance of inundation areas in the study area. However, the occurrence of floods in 2014, prior to the normalization activity, showed the area affected by flooding which was more or less similar to the flood in 2007 flood modeling (Figure 4).

**Figure 3.** Manggarai flood parameter.

**Figure 4.** Flood area in (a) January 2007 [5] (b) January 2014 (c) February 2015 (d) February 2018.
4. Conclusion
The contribution of Manggarai Gate capacity improvement to reduce the flood risk in the Manggarai and Kebon Manggis flood area is done based on a comparison study of flood hazards in both areas before and after the improvement. It is found that the improvement of other structural flood mitigation is required to enable the Manggarai Gate capacity improvement to contribute to the risk reduction of the Manggarai flood area. The study is done based only on secondary data and site visits that focused on the Manggarai flood area. A more integrated study involving primary data and larger flood areas is needed to achieve better results and conclusions.

Acknowledgements
The authors would like to acknowledge the support given by Ministry of Research and Technology of the Republic of Indonesia through 2020 Applied Research and the support given by join cooperation between Bandung Institute of Technology and Huddersfield University through the UK’s Natural Environment Research Council (NERC) and Economic and Social Research Council (ESRC).

References
[1] Formánek A, Silasari R, Kusuma M S B and Kardhana H 2014 Two-dimensional model of Ciliwung river flood in DKI Jakarta for development of the regional flood index Map Journal of Engineering and Technological Sciences 45 3 307-325
[2] Kusuma M S B, Rahayu H P, Farid M, Adityawan M B, Setiawati T and Silasari R 2010 Studi Pengembangan peta indeks resiko banjir pada kelurahan Bukit Duri Jakarta Jurnal Teknik Sipil 17 2 123-134
[3] Farid M, Pusparani H H, Kusuma M S B and Natasaputra S 2017 Study on effectiveness of flood control based on risk level: case study of Kampung Melayu Village and Bukit Duri village MATEC Web Conf. 101 05003
[4] Tambunan M P 2016 The pattern of spatial flood disaster region in DKI Jakarta IOP Conf. Series: Earth and Environmental Science 56 DOI: 10.1088/1755-1315/56/1/012014
[5] Juliana I C, Kusuma M S B, Cahyono M, Kardhana H, Martokusumo W 2017 Performance of rainwater harvesting system based on roof catchment area and storage tank capacity MATEC Web of Conferences 101 05014
[6] Sarminingsih A, Soekarno I, Hadihardaja I K and Kusuma M S B 2014 Flood vulnerability assessment of upper Citarum river basin, West Java, Indonesia International Journal of Applied Engineering Research 9 23 22921-22940
[7] Kusuma M S B, Kuntoyo A A and Silasari R 2011 Preparedness effort toward climate change adaptation in upper Citarum River Basin, West Java Indonesia Society for Social Management Systems Internet Journal 7 8
[8] Farid M, Marlina A and Kusuma M S B 2017 Flood hazard mapping of Palembang City by using 2D model AIP Conference Proceeding 1903 100009
[9] Ruin I, Lutolf C, Boudevillain B, Creutin J-D, Anquetin S, Rojo M B, Boissier L, Bonnifait L, Borga M, Colbeau-Justin L, Creton-Cazanave L, Delrieu G, Douvinet J, Gaume E, Gruntfist E, Naulin J-P, Payrastre O and Vannier O 2014 Social and Hydrological Responses to Extreme Precipitations: An Interdisciplinary Strategy For Postflood Investigation Weather Clim. Soc. 6 135-153, DOI: https://doi.org/10.1175/WCASD-13-00009.1, 2014
[10] Kuntoyo A A, Putro A W, Kusuma M S B, Natasaputra S 2017 The effect of land use change to maximum and minimum discharge in Cikapundung river basin The 3rd International Conference on Construction and Building Engineering (ICONBUILD) 1903 p 100011-1,100011-7, DOI: https://doi.org/10.1063/1.5011621
[11] Papagiannaki K, Lagouvardos K, Kotroni V and Bezes A 2015 Flash flood occurrence and relation to the rainfall hazard in a highly urbanized area Nat. Hazards Earth Syst. Sci. 15 1859–1871, www.nat-hazards-earth-syst-sci.net/15/1859/2015/, DOI: 10.5194/nhess-15-1859-2015
[12] Papagiannaki K, Kotroni V, Lagouvardos K, Ruin I and Bezes A 2017 Urban area response to flash flood–triggering rainfall, featuring human behavioral factors: the case of 22 October 2015 in Attica, Greece Weather Clim. Soc. 9 621-638, DOI: https://doi.org/10.1175/wcas-d-16-0068.1

[13] Jongman B, Winsemsius H C, Aerts J, de Perez E C, van Aalst M K, Kron W and Ward P J 2015 Declining vulnerability to river floods and the global benefits of adaptation Proceedings of the National Academy of Sciences of the United States of America 112 E2271–E2280

[14] Diakakis M 2012 Rainfall thresholds for flood triggering. the case of marathons in Greece Nat. Hazards 60 789–800, DOI:10.1007/s11069-011-9904-7

[15] Zulfan J 2015 Hydraulic effectiveness of adding gate using 3D physical model test and 1D numerical modelling (case study: Manggarai sluice gate) Jurnal Teknik Hidraulik 6 1 27-38