



Journal of Global Environmental Dynamics (JGED)

Contents list available at JGED website: <https://jurnal.uns.ac.id/jged/index>
ISSN: 2774-7727

Ex-Poste Study of Jakarta Flood Disasters from 2000 until 2019

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ABSTRACT. The need for land use in Jakarta can be a contributing factor to the reduced function of infiltration and water flow, resulting in changes and problems in the drainage system. It is suspected that downstream areas such as Jakarta are unable to accommodate excess water, because there may be problems with the drains or drainage systems. This study aims to determine the impact of drainage problems and to find out how to solve drainage problems in Jakarta. The method used in this research is a qualitative method with a descriptive approach carried out by studying the literature and distributing questionnaires. The research sample is residents of the Greater Jakarta area, especially Jakarta. The results showed that the problems that occurred in the operational drainage system were influenced by factors of rain intensity, catchment area, population growth, and environmental factors. A problematic drainage system causes flooding. To solve problems in the drainage system, namely by optimizing the drainage function, mapping the drainage area, making storage tanks and filters, implementing environmentally friendly drainage or Eco drainage, and normalizing and cleaning the drainage system.

Keywords: Floods, Urban Problems, Drainage Systems, Water Discharge.

Article History: Received: 15 October 2020; Revised: 26 March 2021; Accepted: 26 March 2021; Available online: 15 April 2021

How to Cite This Article: Erwandha, R., Nurhidayah, I., Azzahra, S. I. N., Pramadaningtyas, P. S., and Nurshillah, C. (2021) Ex-Poste Study of Jakarta Flood Disasters from 2000 until 2019. *Journal of Global Environmental Dynamics*, 2(1), 13-18.

1. Introduction

Jakarta is the capital city of Indonesia. Jakarta has a large population, Jakarta is known as the city with the largest population in Indonesia. The large population has certainly triggered various problems in Jakarta, for example flood. Flood is a phenomenon where the land sunk by water, both river water and sea water. Although Jakarta holds the status as the capital of a country, flood often happens in this city. Flood in Jakarta not only happens once or twice in a year, currently flood can occur more than twice a year. Large flood often occurs in the city of Jakarta. Usually, big floods in Jakarta occurs every five years, but currently big floods can come at any time without being predictable. An ex-poste study is needed to dissect the flood phenomenon that occurred in the last 20 years. An ex-poste study is an environmental or disaster impact study that is made after an event occurs. The purpose of this research is to examine the various factors that cause flood in Jakarta, the impacts are caused by flood in Jakarta, and the flood management effort are implemented by Jakarta City Government. Researchers hopes the ex-poste study in this article will be able to become evaluation and consideration material for take an action about mitigation of flood disasters that will occur in the future.

Overall, the factors that cause flood in Jakarta are divided into two factors, there are natural factors and anthropogenic factors. Natural factors include high rain fall and location. Whereas, anthropogenic factors include land surface subsidence, limited green open space, decrease quality of watersheds, and inhabitant bad habit about throw away the rubbish in rivers. Flood also can occur due to an increase in

the volume of river water and drainage channels (Rosyidie, 2013). The anthropogenic factors that have been mentioned are closely related to urban and population problems. The land surface in Jakarta is estimated to have decreased by 7cm/year. Land subsidence is caused by excessive buildings loads and massive use of groundwater (Ramadhanis et al., 2017).

Flood impacts in Jakarta has been felt by the people that living in this city. Loss of property, death tolls, crop failure, disruption of daily activities, and reduced biodiversity in flooded areas is the impact are caused by flood. Various efforts have been implemented by the Jakarta City Government, both structurally and non-structural. However, the efforts that have been implemented are not optimal, so the flood has still continued to occur in Jakarta in the last 20 years. Even, flood in Jakarta is unpredictable.

2. Materials and Methods

The research method that used by researchers is a quantitative method with a descriptive approach. Researchers used quantitative methods because in this research involve numbers and calculations. Researchers used a descriptive approach to describe the data in more detail. With a descriptive approach, data can be analyzed deeply and accurately. Researchers used secondary data from literature studies. Researchers collected information about the city of Jakarta from various literatures. From the literature study,

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researchers obtained complete data and information about flood in Jakarta.

2.1 Study Area

The Research took a place in Jakarta. Jakarta has five administrative city, there are West Jakarta, East Jakarta, South Jakarta, North Jakarta, and Central Jakarta. Overall, the research also took a place in Jakarta five administrative city. The research for calculate the sediment took a place in Ciliwung Watershed.

2.2 Data Analysis

Data that obtained from a research must be processed and analyzed first. In this research, the data was analyzed using a calculation formula. To calculate sediment transport in the Ciliwung watershed, researchers used the Acker Whites equation. The formula for sediment transport is:

$$Q_s = Q \cdot X$$

$$X = \frac{S \cdot D}{H} \left(\frac{V}{U^*}\right)^n G_{gr}$$

$$G_{gr} = C \left(\frac{F_{gr}}{A} - 1\right)$$

$$D_{gr} = D \left[\frac{g(S-1)}{v^2}\right]^{1/2}$$

$$F_{gr} = \left[\frac{V_0}{gD(s-1)\sqrt{32 \log \frac{\alpha H}{D}}}\right] \left[\frac{U^*}{V} \sqrt{32 \log \frac{\alpha H}{D}}\right]^n$$

Where is :

- D = Sediment diameter
- v = Viscosity
- A,C,n,m= A constant that depends on D_{gr} value
- D_{gr} = A dimensionless number of grain diameter
- H = Water depth
- S = Relative density of sediment
- α = 12,3
- F_{gr} = Mobility function
- V = Average water velocity
- U^* = Sliding speed
- Q_s = Sediment transport

3. Result and Discussion

3.1 The Characteristics of Jakarta City

Jakarta is the capital city of Indonesia. Jakarta is the second city in the world that has the largest population (Prakoso and Herdiansyah, 2019).). Jakarta is the city with the largest population in Indonesia (Eni, 2007). Surely, the large population causes complex urban problems. Even though the population is large, total wide area of Jakarta only 661.52 [km]^2. Based on geomorphology characteristic, Jakarta include as sorrowful city of flood disaster, because Jakarta is located in the lowlands, Jakarta also formed from alluvial process (Dahlia et al., 2018). Jakarta is the city that has tropical climate. The population of Jakarta continues to increase every year. Based on table 1, the total population Jakarta City in 2000 was 7,798,679 inhabitants, in 2010 total population in Jakarta 9,567,127 inhabitants, in 2014 total population in Jakarta 10.075.320 inhabitants, in 2015 total

population in Jakarta 10,177,924 and in 2020 total population in Jakarta 11.284. 161 inhabitants.



Fig.1 Jakarta Area Map

Table 1. Total Population in DKI Jakarta

Year	Total Population
2000	7.798.679
2010	9.567.127
2014	10.075.320
2015	10.177.924
2020	11.284.161

Source: BPS and UKI Lecturer Scientific Work Collection

The large population which continues to increase every year certainly creates a complex urban problem. The problem that most often affects Jakarta is flood. Flood is an event when the land are sunk by water and has an adverse impact. The city of Jakarta is traversed by a large river which is connected to the Bogor area, the river is the Ciliwung River. The Ciliwung River is often unable to accommodate excessive water discharge, so that it overflows and causes flood in Jakarta.



Fig.2 Flood in Ciliwung River

Flood can be caused by natural or anthropogenic factors, natural factors that cause flood are high rainfall. Meanwhile,

anthropogenic factors that cause flood include deforestation in the upstream, land conversion, reduction in green open spaces, and the habit of throwing garbage in rivers. In history, there have been 6 major and severe flood in Jakarta, major and severe flood in Jakarta is occurred in 1918, 1979, 1996, 2002, 2007, and 2013. Floods in an area can be classified as mild flood if the area of inundation is 0.2 m - 0.5 in depth reaches 1-5 hectares, it is classified as moderate if the inundation is 0.5 m - 1 m depth, reaches 5-10 hectares, and severe, if the inundation area with a depth of more than 1 m reaches more than 10 hectares (Kusuma et al., 2007). Based on the data in table 2, during 2009-2018 there were 228 flood incidents in Jakarta.

Table 2. Number of Flood Incidents in Jakarta

Year	Number of Flood Incidents
2009	8
2010	12
2011	8
2012	50
2013	26
2014	55
2015	5
2016	36
2017	14
2018	14
Total	228

Source: BNPB 2019

Flood in Jakarta often occurs. The factors that causes flood in Jakarta is natural factors and anthropogenic factors. Natural factors that cause flood in the Jakarta area are high rainfall and location. Based on data from BNPB, the rainfall in the last few days has tended to be high. For example, in 2020 the rainfall reached 377 mm / day, in 2015 the rainfall was 277 mm / day, in 2013 the rainfall was 100 mm / day, and in 2007 the rainfall was 340 mm / day. Apart from the influence of rainfall, the location of the area is also one of the causing factors of flood in Jakarta. Geologically, Jakarta is located in a flood basin which was formed due to tectonic processes so that the northern area of Jakarta was lifted (Harsoyo, 2013). Therefore, the water from the 13 flowing rivers cannot reach the sea and it is trapped in the large Jakarta basin. Geomorphologically, Jakarta is located in an area formed by flood sedimentation, known as a flood plain (Harsoyo, 2013).

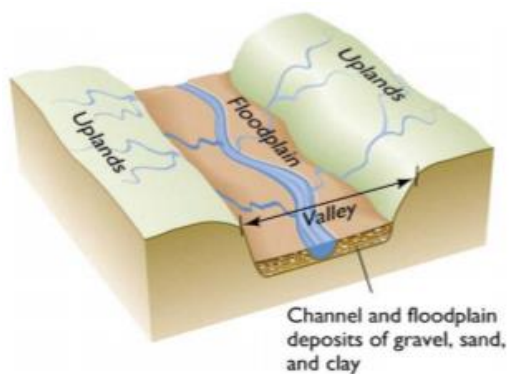


Fig.3 Foodplain

In addition to natural factors, anthropogenic factors also can cause flood in Jakarta. The first anthropogenic factor is the decrease in the quality of watershed, including land changes in river basins, erosion, sedimentation, and deforestation upstream. The watershed connects the upstream and downstream areas, changes in the upstream area will affect the downstream area (Satriawan, 2010). Ability of watershed to hold water upstream otherwise known as the retention of watershed affected by physical changes in the watershed (Slamet, 2012). Deforestation upstream can cause flood in downstream area such as Jakarta. The forest has been balded cannot restrain rainwater, so the rainwater is not absorbed all into the soil properly. The existence of forests can actually increase the rate of water infiltration. The ability of the soil to absorb water is called infiltration capacity, infiltration capacity can be reflected in plant species found at ground level (Setyowati, 2007). In addition, the absence of vegetation also can increase the rate of erosion and sedimentation in the watershed. Jakarta is traversed by 13 rivers, Ciliwung River is the longest river between 13 other rivers. Based on table 3, the area of Ciliwung River is 347 km² and its length is 117 km.

Table 3. Wide and Long River in Jakarta

Watershed	Wide (km ²)	Length (km)
Cakung	55	33
Buaran	30	23
Sunter	73	40
Cipinang	48	30
Ciliwung	347	117
Krukut	98	37
Grogol	33	27
Pesanggrahan	110	83
Angke	263	100

Source: NEDECO, 1973

The decrease in watershed function also can be caused by erosion and sedimentation. Erosion is the event that the soil is eroded by the flow of river water. Erosion also can be caused by wind, rain, and transport of ice. Sedimentation is the river relief process caused by erosion. Continuous erosion in the rainy season can cause an erosion of the land and be carried down by river streams downriver, so that sedimentation or siltification is provided (Mawardi, 2010). Based on table 4, throughout 2006 to 2015, the biggest erosion rate occurred in 2010.

Table 4. Accumulation of Erosion, Sediment, and Run off in Ciliwung Watershed

Year	Erosion (Ton/Ha)	Sediment (Ton/Ha)	Run Off Coefficient (mm)
2006	56.340	39.694	113.088
2007	89.780	72.139	149.955
2008	67.468	52.602	139.734
2009	74.225	61.200	143.193
2010	91.177	86.271	171.218
2011	37.973	25.569	92.390

2012	49.897	40.013	109.731
2013	62.960	52.219	132.154
2014	75.319	65.683	144.671
2015	66.278	57.025	140.862

Source: BNPB

Sedimentation downstream also can be caused by the application of a false hydraulic concept. In the current era, the concept of pure hydraulics is widely applied to rivers in some major cities. The pure hydraulic concept is a hydraulic engineering concept with hardening on the walls and riverbed, so that the water flow can quickly flow from upstream to downstream. This concept is actually not quite appropriate to apply because the water has not been absorbed into the ground, this is often causes drought problems in the upstream and flood in the downstream. Additionally, the application of the pure hydraulic concept also can increase sedimentation in the downstream area because hardening will increase the water flow velocity, the sediment will be carried away and accumulate in downstream. Based on table 5, data on sediment transport in the Ciliwung watershed were obtained. The data is obtained from the calculation using the Ackers White equation. Table 4 shows that sediment transport in the upstream of the river before the application of the pure hydraulic concept was 59.25 tons per month and after the application of the pure hydraulic concept was 214.40 tons per month. Sediment transport in the central area of the Ciliwung watershed before the implementation of the pure hydraulic concept was 12.18 tons per month and afterwards was 101.82 tons per month. Sediment transport in the downstream area of the Ciliwung watershed before the implementation of the pure hydraulic concept was 0.74 tons per month and afterwards was 0.46 tons per month.

Table 5. Sediment Transport in Ciliwung Watershed before and After Application of Pure Hydraulic Concept

Location	Sediment Transport (ton/month)	
	Before	After
Upstream	59,25	214,40
Middle	12,18	101,82
Downstream	0,74	0,46

Source: Analysis Result

The next anthropogenic factors can be caused flood in Jakarta is land subsidence. Land subsidence is caused by excessive building load and excessive use of groundwater.. Logically soil has a special cavity that is filled by groundwater, but along with the large utilization of groundwater which is not accompanied by replacement, the cavity will be empty and soil structure will decline. Based on the data from table 6, groundwater volume was extracted by Jakarta inhabitant from 2013 until 2015 experiencing an increasing trend

Table 6. Groundwater Volume were Extracted by Jakarta Citizen

Regional	Groundwater volume were extracted (m ³)		
	2013	2014	2015
Central Jakarta	817.255	902.159	1.069.829
West jakarta	1.088.695	1.113.293	1.217.673

South Jakarta	3.833.332	4.886.166	5.182.929
East Jakarta	1.500.107	1.385.193	1.247.004
North Jakarta	518.727	562.977	426.049

Source: Ministry of PUPR

Rapid population growth in Jakarta will be directly proportional to the level of water demand and utilization. The used of water from year to year is increasing. Land subsidence in Jakarta becoming increasingly unavoidable. Based on table 7, the average of land subsidence in Central Jakarta is 6.9 cm / year, 8.2 cm / year in North Jakarta, 7.3 cm / year in South Jakarta, 5.7 cm / year in West Jakarta, and 7.4 cm / year in East Jakarta (Cyntia and Pudja, 2018). The average of land subsidence in Jakarta City is obtained from the analysis in 2016 and 2017.

Table 7. Jakarta Land Subsidence in 2016-2017

Zone	2016 (cm/year)	2017 (cm/year)	Average (cm/year)
West Jakarta	-11,7	0,3	-5,7
Central Jakarta	-13,1	-0,7	-6,9
North Jakarta	-13	-3,5	-8,2
East Jakarta	-12,1	-2,6	-7,4
South Jakarta	-13,2	-1,4	-7,3

Source: Jurnal Ilmu dan Inovasi Fisika

Another anthropogenic factor that may cause flood in Jakarta is land-use change and decrease in green open space. Some of the rainwater will seep into the ground, some will evaporate, and some will flow as surface water. Covering the land by waterproof buildings or settlements will increase the runoff coefficient. Run-off is rain water that flows over the land surface because it is no longer able to be absorbed into the soil. Then, the rainwater flows into the river so that it is overflow (Jufianto et al., 2013). Green open space is a supplier of oxygen for living things. Of course, its existence in the middle of city that is densely developed is very much needed. In addition, this green open space has a function in terms of ecological balance. The dense development in big cities, especially Jakarta, makes the percentage of green open space very small (Lestari et al., 2019). Figure 4 shows that the area of land developed in Jakarta is increasing, while the area of land covered by vegetation is decreasing.

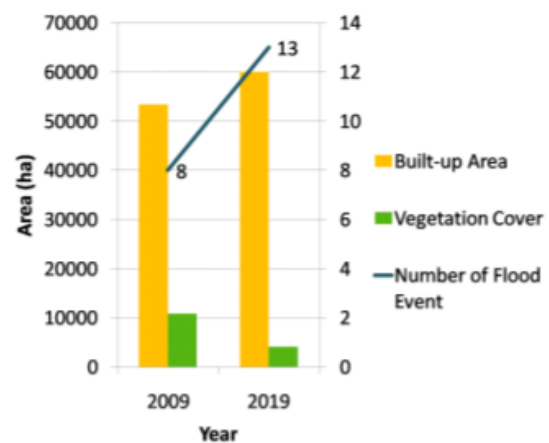


Fig.4 Land Cover Change Graphic in Jakarta

The city of Jakarta really needs to increase the green open space as a water catchment area. The number of green openings which owned by Jakarta has decreased from year to year, and has not even fulfilled the requirement of 30% from the total area. According to Law number 26 of 2007, a city should own green open space at least 30% of the total area which emphasized in Government Regulation 2008 (Aprilia et al., 2020). Based on table 8, the area of green open space in Jakarta is decreasing every year.

Table 8. Green Open Space Percentage in Jakarta

Category	Percentage Area (%)			
	1995	2002	2009	2014
Industry	4,25	8,57	4,12	4,96
Trade Services	1,29	11,01	8,86	11,44
Settlement	61,62	57,45	66,36	67,17
wet soil	8,96	3,93	3,31	3,13
Green Open Space	23,88	19,04	17,36	13,30

Source: BPPT and BIG

Socio Culture, can be one of causes flood in Jakarta. Inhabitant in riverbanks careless with their environment. The habit of throwing garbage in the river had been becoming custom for Jakarta inhabitant. Unavailability of adequate waste places also be the reason why the people choose to throw the rubbish in river. This is shows that low level of public awareness is due to the lack of facilities. (Isthofiyani et al., 2016). Such patterns of community behaviour indicate that environmental education has not succeeded in society. Because people who understand and are sensitive to the environment will be willing to participate, and protect the environment. If the community understands the benefits of managing waste into useful materials, the impact of flood due to dumping garbage into the river can be minimized (Silalahi, 2017).

3.3 Adverse Impact from Flood in Jakarta

The flood in Jakarta certainly has significant impact, including economic losses, activity disruptions, crop failures, clean water crises, health problems, and fatalities. Based on data from fire Department and BNPB, flood in 2012 has claimed four lives. Economic losses are felt by the community because various goods owned are damaged by flood water. In addition, flood also can have an impact on ecological aspects, flood can degrade biodiversity because various small plants die submerged by water and cannot take photosynthesis. Flood water also have the potential to be a medium introduction of invasive species into other ecosystems, it can certainly disrupt the balance of the ecosystem.

3.4 Flood Management Effort in Jakarta

Flood control efforts in Jakarta are divided into structural efforts, non-structural efforts and efforts to increase community participation (Muslimah et al., 2014). An example of the structural efforts made by the Jakarta City Government is the construction of an embankment retaining wall along the river and dredging to deepen the riverbed. Non-structural efforts that can be made for mitigation measures are to improve flood disaster early warning facilities and technology. Efforts that can be made to improve the role of the community

is to provide an understanding of water culture and socio hydraulic. In addition, flood control efforts can also be done with the application of eco-hydraulic concepts, by planting trees in upstream of the Ciliwung River, and conduct regular garbage filtration in the rundown river.

4. Conclusion

In summary, we have demonstrated that Flood is caused by natural and anthropogenic factors, natural factors are high rainfall and location. Meanwhile, anthropogenic factors cause of the flood include deforestation in the upstream, land conversion, reduction of green open space, and dumping garbage in rivers. Based on study, flood in Jakarta has a significant impact, include economic losses, disruption of activities, crop failure, clean water crisis, disruption of ecosystem because invasive species can move in the other place through floodwater, health problems, and casualties. From the research, we conclude that flood management effort in Jakarta divided into structural effort, non-structural effort, and socio culture effort. Structural effort to manage flood in Jakarta can be in the form of making embankment, doing sediment dredging, and hardening river wall or implementing pure hydraulic concept. Non-structural effort to manage flood can be in the form of increasing facilities, infrastructures, and doing surveillance with flood mitigation technology. Socio culture effort to manage flood in Jakarta can be in the form of increasing the environmental awareness and planting water culture to inhabitant in Jakarta. All flood management effort that was implemented by Jakarta Government still not optimal. Jakarta City Government can applicate ecohydraulic concept along Ciliwung Riverside, this effort can inrease water infiltration rate and prevent flooding in the downstream.

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