Evaluation of micro-scale drainage systems in Kelapa Gading, North Jakarta

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Abstract. Kelapa Gading is one of the sub-districts located in North Jakarta which consists of low-level plains prone to flooding. One of the areas in Kelapa Gading that is most severely affect by the floods is in front of the Mall of Indonesia (MOI). Based on earlier research, it has been reported that one of the causes of flooding in Kelapa Gading is its drainage system's inability to pass the flood discharge. Therefore, this study discusses the micro-scale drainage system in the MOI catchment area. The purpose of this study is to evaluate the performance of the micro-scale drainage system in the Mall of Indonesia (MOI) area by comparing the results of the calculation of the flood discharge of the planned catchment area with the capacity of the drainage channels using the help of WinTR-20 and HEC-RAS applications. From the simulation results using the two applications, it can be seen that all micro drainage channels in the MOI catchment area are able to pass flood discharge up to period of 25 years, except in reach 6. Based on this, an open drainage system analysis is carried out into a polder system by placing two pumps with a capacity of 0.25 m³/s. With this proposed polder system design, the flooding in the MOI catchment area can contain the discharge up to a 25-year return period floodings.

1. Introduction
North Jakarta is a low-lying area that is prone to flooding. With a coastline of 35 km and a total area of about 139.5 km² as can be seen in Figure 1., North Jakarta has an altitude of 0-20 m above sea level, although certain areas have an altitude of 1 - 1.5 m below sea level [1]. Coastal areas such as the northern part of Jakarta are transitional areas where land is directly adjacent to the sea. This phenomenon can cause coastal hazards such as an increased water level due to the contour conditions in the area [3]. One area in North Jakarta that often experiences floodings is Kelapa Gading. This area was developed by the Summarecon Agung property company in 1975. during which the Kelapa Gading District was still comprised of swamps and rice fields. Along with the development of the Capital City of Jakarta, the Kelapa Gading Sub-district developed into an area with a high population density. Currently, almost 80% of Kelapa Gading are residential areas, shopping centers, and shops. Due to these significant land use changes, runoff water cannot be absorbed into the ground nor flowed directly into the sea, resulting in increased floodings[2]. Therefore, the Kelapa Gading region is included in one of the areas in DKI Jakarta that are prone to floodings, based on the map issued by The Ciliwung-Cisadane River Basin Center as shown in Figure 2 below.
One of the locations which has the most frequent flooding occurrences in the district of Kelapa Gading is on Highway Boulevard North, specifically located exactly in front of the Mall of Indonesia (MOI). Based on the latest news released by Seputar Indonesia on February 15, 2018, there was a pool of 50 cm in height at the aforementioned location. Based on previous research, it is reported that the causes of flooding in Kelapa Gading are due to the micro-scale drainage system which still cannot meet the flood discharge, meaning that these channels are not effective in accommodating the actual flood discharge [5]. Therefore, this research will discuss how to improve the performance of the micro-scale drainage system by increasing its storage capacity into a polder system in the MOI catchment area located in Kelapa Gading, North Jakarta.
2. Research Objectives
The purpose of this study is to evaluate the performance of the micro-scale drainage system in Kelapa Gading, North Jakarta by comparing the results of the calculation of the flood discharge of the catchment area with the capacity of the drainage channel and by increasing the effectiveness of the reservoir on the MOI catchment area by converting drainage system into a polder system.

3. Research Methodology
This research is a continuation of a previous research conducted by Kusumawardhani (2018), in which it was found that the existing drainage capacity had not been able to accommodate the existing flow capacity, thus resulting in flooding. In this study, calculations were conducted to increase storage of the drainage system by changing it into a polder system, thus reducing the water level due to flooding.

Based on Figure 3., in the area of the reviewed location, which is in front of Mall of Indonesia (MOI), there is a river running through the area, namely the Sunter River. Next to the river, there is an elongated channel-shaped reservoir, but it is utilized only as a standard reservoir and has not been maximized as part of a polder system. Applications used in this study include ArcGIS, WinTR20, and HEC-RAS. The MOI catchment area is affected by the Kemayoran rain station with rainfall data records from 2005-2018. Data from the rain station is then calculated using the Gumbel and Log Pearson Type III methods and the distribution of data is then tested by the Chi Square and Smirnov-Kolmogorov methods.

Checking of the micro-scale drainage system on the MOI catchment area is conducted to find out whether the drainage capacity of the MOI catchment area, especially the main channel, can accommodate the drainage load due to the 2-year, 5-year, 10-year and 25-year return period floods. Since the channels contained in the MOI catchment area are mostly closed, it is assumed that the channel dimensions contained at that location are uniform with the channel dimensions measured at the outlet. Based on these observations, it is known that the channels in Reach 1, Reach 3, and Reach 5...
have a width of 1.5 meters with a depth of 1.2 meters, while the channels in Reach 2, Reach 4, and Reach 6 have a width of 1.2 meters with a depth of 1 meter.

4. Results and Discussion
MOI's catchment area is defined by the area that is often flooded and is then divided based on their drainage system placement patterns. This is done with aims to simplify the calculation of drainage channel capacity in the catchment area. The division of the sub-catchment areas can be seen in Figure 4.

THE DIVISION OF THE SUB-CATCHEMENT BASED ON DRAINAGE PATTERNS

![Figure 4. Division of Sub-Catchment Area Based on Drainage Patterns](image)

After knowing the distribution of sub-catchment areas in the reviewed area, the schematic and other hydrological properties contained in the MOI catchment area can then be observed. The schematic made is based on the main drainage channel which holds the flow load from the collection channel. The reaches that connect each sub-catchment area's POI along with the schematic of the MOI catchment area are determined and illustrated in Figure 5.

![Figure 5. Schematic of MOI Catchment Area](image)
Then, a map of land cover in the MOI catchment area is also reviewed to obtain the weighted Curve Number (CN) value of the catchment area, shown in the MOI catchment area land cover map Figure 6. From that map the weighted CN value of 92 is obtained.

**LAND COVERAGE MAP OF MOI SUB-CATCHMENT AREAS**

![Land Coverage Map of MOI Sub-Catchment Areas](image)

**Figure 6. Land Coverage Map of MOI Sub-Catchment Areas**

By using the Log Pearson Type III method, the planned rainfall data on the MOI catchment area based on the return period can be determined. The results can be seen in Table 1.

**Table 1. Aquired Return Period Values in Catchment Area Based on Log-Pearson Type III**

| Return Period | \( X_T \) (mm) |
|---------------|----------------|
| 2             | 83.7           |
| 5             | 123.0          |
| 10            | 161.9          |
| 25            | 231.0          |

After the design rainfall that affects the MOI catchment area is determined, the peak discharge of the flood plan in each sub-catchment area and reach can be seen. The output of the application is the flood hydrograph as shown in Figure 7.
Figure 7. Hydrograph of the 2, 5, 10 and 25-year Flooding in the Outlet of MOI Catchment Area

Afterwards, checks and evaluations are made on the existing drainage channels in the MOI catchment area. Checking of the drainage is carried out with the help of the HEC-RAS application with the output being the water level at each reach in each return period as shown in Table 2.

| Reach | Channel Depth (m) | Water level from the bottom of channel (m) |
|-------|------------------|-----------------------------------------|
|       |                  | 2-Year | 5-Year | 10-Year | 25-Year |
| 1     | 1.2              | 0.08   | 0.1    | 0.1     | 0.2     |
| 2     | 1                | 0.09   | 0.14   | 0.14    | 0.19    |
| 3     | 1.2              | 0.28   | 0.36   | 0.44    | 0.56    |
| 4     | 1                | 0.33   | 0.47   | 0.59    | 0.78    |
| 5     | 1.2              | 0.35   | 0.44   | 0.56    | 0.76    |
| 6     | 1                | 0.45   | 0.63   | 0.79    | 1.08    |

Based on these results it can be concluded that in the MOI catchment area, only Reach 6 is unable to accommodate the drainage load due to rainfall in the area.

After evaluating the performance of the existing drainage, evaluation is also done on the capacity of the reservoir, which is an outlet for the reach with an area of 4000 m² and a depth of 2 m, located in the land area owned by the developer of Mall of Indonesia. Based on the results of the routing done, it can be seen that the capacity of the reservoir is only able to accommodate floods due to 2-year and 5-year return period rains. As for the 10-year and 25-year return period rains, the reservoir is unable to accommodate the incoming water debit, causing flooding in the MOI region. Based on this, it is recommended to improve the drainage system in the reservoir by changing it into a polder system, doable by replacing the damaged pump in the reservoir with two new pumps with a capacity of 0.25 m³/second. The pump is planned to flow water from the reservoir to Sunter River which is located right next to it. Based on the results of the calculation, it can be seen that the effectiveness of the pump is 34.53% in the 10-year floods by only activating 1 pump, where the hydrograph of the reservoir due to the pump can be seen in Figure 8, while the effectiveness of the pump in the polder due to 25 annual
flooding of 6.52% by activating the two pumps, where the hydrograph of the reservoir due to the pump can be seen as shown in Figure 8.

**Figure 8.** Graph of the Proposed Polder System with 10-year Return Period

With this polder system, it can also be seen that the water level measured from the bottom of the channel in Reach 5 and Reach 6 has decreased as shown in Figure 10 and Figure 11.

**Figure 9.** Graph of the Proposed Polder System with 25-year Return Period
With the decrease of water level due to the pump on the polder, the dimensions of Reach 6 do not need to be enlarged. This allows funds that was needed to enlarge the drainage capacity to be diverted into funds for the maintenance of the polder and pump so that they are well maintained and not quickly damaged.

The common thread from the results above is that the proposed polder system, with the use of pumps, is able to reduce water levels on the reservoir, preventing flooding from happening in the MOI catchment area.

5. Conclusion

Based on the discussion above, it can be concluded that the capacity of the reservoir located in the MOI catchment area is able to accommodate the 2-year and 5-year return period design flood discharges, but is unable to withstand 10-year and 25-year return period flood discharges. Improvement of the drainage system with a polder system is done by adding two pumps, each with a capacity of 0.25 m³/sec. Therefore, the flooding that occurred in the MOI catchment area was not due to lack of capacity of the main drainage channel, but because the reservoir contained in the MOI
catchment area was not able to accommodate the design flood discharge of 10 and 25-year return periods.

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Acknowledgments
The authors express their appreciation as the study was conducted using the research funding for indexed international publication “Hibah Penugasan Publikasi Internasional Terindeks 9 (PIT 9)” fiscal year 2019 granted by Universitas Indonesia number NKB-0053/UN2.R3.1/HKP.05.00/2019.