Evaluation of Urban Flood Control Project
–Case Study at Bendung Watershed in Palembang City, Indonesia–

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INFO ARTIKEL

Abstrak: Konfigurasi topografi dan curah hujan musiman yang tinggi, sebagian Kota Palembang sangat rentan terhadap genangan dan bencana banjir. DAS Bendung merupakan salah satu dari sembilan belas DAS yang ada di Kota Palembang yang sering mengalami bencana banjangan akibat banjir.

Pemerintah Daerah Kota Palembang telah menerapkan beberapa proyek pengendalian banjir seperti proyek normalisasi sungai. Proyek ini cukup sukses mencegah air sungai Bendung meluap melewati tanggul sungai tersebut, tetapi beberapa lokasi yang jauh dari sungai Bendung masih mengalami genangan karena topografinya. Berdasarkan kondisi ini, studi ini mengevaluasi efisiensi proyek normalisasi di DAS ini untuk mencari solusi yang dapat mengurangi banjir di wilayah tersebut. Penelitian ini menggunakan bantuan program Hec-Ras, perhitungan analisa metode sumur resapan dan analisa cost and benefit. Studi ini membuktikan bahwa proyek normalisasi mampu mencegah banjir di sepanjang sungai Bendung. Selanjutnya, sistem sumur resapan mampu mengurangi genangan yang ada hingga 80% dan manfaat yang didapat dari metode sumur resapan ini melampui biaya konstruksinya setelah 4 tahun berjalan.

Abstract: Palembang City locates on a lowland where the altitude is between 12 and 30m above sea level. There are many small rivers that flow into a main river, Musi river. Due to the topographical configuration and a seasonal heavy rainfall, those rivers had been overflowed and the city had an inundation disaster. Bendung watershed is one of the nineteen watersheds in Palembang City, and the watershed also experiences the inundation disaster frequently due to the flood caused by a poor river maintenance and drainage system. The local government of Palembang City has applied some flood control projects such as a normalization project to reduce the flood damages. These measures checked the river flow over the dike, but some areas still suffered from the flood damages due to their topography. Based on the current situation, this study evaluates the efficiency of the existing normalization project in this watershed to find a solution that reduces the flood in those areas. This study confirmed that the normalization project is preventing the flood along Bendung River, furthermore the infiltration-well system can reduces 80% of inundation area and the benefit of this infiltration-well method exceeds the cost after four years from the beginning of the system installation.

A. BAGROUND

Palembang City is one of cities in Indonesia, and it is now under the rapid economic growth. Its population is about 1.5 million. The rapid economic growth is encouraging an urbanization and land use changes, those sometimes increase damages by river floods.

Palembang City locates on a flat area where the altitude is between 12 and 30m above sea level. There are many small rivers that flow into a main river, Musi River. Due to the topographical configuration and a seasonal heavy rainfall, those rivers had been overflowed and the city had an inundation disaster. Bendung watershed is one of the nineteen watersheds in Palembang City. It also experiences the inundation disaster frequently due to the flood caused by a poor river maintenance and drainage system.

Bendung River is one of the channels that plays an important role in the drainage system of Palembang City. The river empties into the Musi River, and it is a kind of a natural drainage system.

A rapid urban growth brings the change of land use. The land use change sometimes increases a flood disaster if an appropriate measure is not taken on that area. The local government of Palembang City has applied some flood control projects such as a
normalization project to reduce the flood damages. These countermeasures have been used to monitor the river flow over the dike, but some areas still suffered from the flood damages due to their topography.

Based on the current situation, this study evaluates the efficiency of the existing normalization project in this watershed to find a solution that reduces the flood in those areas. Furthermore, this study investigates the feasibility of infiltration-well system to overcome the flood. The feasibility study includes the cost and benefit analysis to realize the infiltration-well system for easing the inundation problem.

B. RESEARCH METHOD

1. Research Area and Data Collection

Fig. 1 shows the location of Bendung watershed in Palembang City. Bendung watershed is one of the eighteen watersheds in Palembang City, and the area of the watershed is about 14.5 km².

![Fig. 1 Location of Bendung watershed in Palembang City](image)

In order to check the flood of Bendung river, a normalization project was applied along the river since 2014. This project excavated the river bottom and raised the crown height of the dike on both sides to increase the flow capacity.

The data needed in this research were primary data and secondary data. Primary data were obtained by direct observation in the field, such as the location of flood. The secondary data were obtained from official government, such as rainfall data and documents.

2. Analysis of Normalization Project

This study used the Hec-Ras model to evaluate the effectiveness of normalization project applied on Bendung watershed in Palembang City. This model at first determines the rainfall distribution with Smirnov-Kolmogorov method, and calculates the rainfall intensity. After that, the model calculates the design river discharge.

This study employed ten years rainfall data, measured by Palembang Meteorological and Geophysical Agency at Kenten Branch Station from 2009 to 2018. Table 1 shows the rainfall intensity obtained by Pearson Log Distribution III. Regarding the balance of flood control design in Palembang City, the normalization project chosen the return period as five years.

| Return Period (Year) | Rainfall Intensity (mm/hour) |
|----------------------|------------------------------|
| 2                    | 74.759                       |
| 5                    | 88.973                       |
| 10                   | 96.431                       |
| 20                   | 105.634                      |
| 50                   | 110.587                      |
| 100                  | 115.376                      |

A runoff coefficient is an important value in calculating the river discharge, and it has a different value depending on the land use condition. The current land use pattern in Palembang City. Based on the land use condition, this study calculated the representative runoff coefficient in Bendung watershed.

![Fig. 2 Current land use of Palembang City](image)

Table 2 shows the coverage area of each land use, A, the runoff coefficient, C, and the product of them. The runoff coefficient takes different values depending on the land use condition. This study calculated the representative runoff coefficient with Eq. (1), and the results was 0.46.

\[
C_w = \frac{\sum A \cdot C}{\sum A}
\]

3. Analysis of Infiltration Well

An infiltration–well system, which penetrates rainwater to underground, is one of the countermeasures to mitigate the inland flood disaster. Indonesian national standard states the general requirements for the infiltration well system.

| Land use     | A(m²)   | C  | A * C  |
|--------------|---------|----|--------|
| Open space   | 6,045,122.5 | 0.40 | 2,418,049.0 |
| Tree         | 420,178.4    | 0.25 | 105,044.6 |
| Reed         | 100,573.2    | 0.21 | 21,120.4 |
| Reed         | 93,710.1     | 0.30 | 28,113.0 |
| Pond         | 62,056.1     | 0.35 | 21,719.6 |
| Garden       | 117,452.4    | 0.20 | 23,490.5 |
| Grave        | 101,105.7    | 0.15 | 15,165.9 |
| Vacant land  | 11,525.3     | 0.80 | 9,220.2  |
| River        | 95,349.1     | 0.30 | 28,604.7 |
| Street       | 1,104,618.4  | 0.70 | 773,232.9 |
| Building     | 6,294,732.7  | 0.50 | 3,147,366.4 |
| Total        | 14,446,423.9 |     | 6,591,127.2 |

Table 2. Calculation of representative runoff coefficient
C. RESULT AND DISCUSSIONS

1. Evaluation of The Normalization Project

A design flood discharge was determined by Synthetic Unit Hydrograph (Nakayasu) method. This method needs data of the river length and its area of Bendung watershed.

The water level of two cases, before and after the normalization project, were compared to evaluate the performance of normalization project. Fig. 3 and Fig. 4 show the water level and dike height along Bendung river in the case of the design discharge.

Fig. 3 shows the result before the normalization project. The water level exceeds the height of the dike on both sides of upstream from about 1300m section. The river bottom becomes shallow at 1000m section and it reduces the river capacity.

Fig. 4 shows the result of water level after the project. The capacity of the river flow becomes large by the normalization project and the water level is lower than the dike height on both sides along the river. The local government conducted field observation and hearing survey along the river, and any floods over the dike were never seen after the project. This means that the project shows good performance in checking the flood along Bendung river.

2. Evaluation of The Infiltration Well

Some areas in Bendung watershed are still suffering from the flood by inland water even after the
normalization project due to the poor drainage. From the field survey, the local government recognized four areas as shown in Fig.5. Each area is 1,150m$^3$, 1,215m$^3$, 1,175m$^3$, and 1,110m$^3$.

![Fig.6 Location of areas that are suffering from flooding](Source : Public Work Agency, Palembang City (2019))

Regarding the topography of those areas, this study proposed the application of infiltration-well system to overcome the flood by inland water. The value of a soil permeability is the important factor in the application of the infiltration well.$^1$.

Table 3 shows the permeability of each area that was obtained by the field survey. Table 4 shows the volume of water that was calculated by Eq. (2). This calculation set the design rainfall as 88.97mm/day and the runoff coefficient as 0.95, respectively.

| Location | Permeability value, $K,$ (cm/hour) |
|----------|----------------------------------|
| No.1     | 2.24                             |
| No.2     | 2.32                             |
| No.3     | 2.22                             |
| No.4     | 2.34                             |
| Average  | 2.28                             |

In order to calculate the volume of water, $V_2$, from Eq. (3), both $t_0$ and $A_i$ should be set in advance. The duration time, $t_0$, is calculated as 0.93 hour from the design rainfall intensity, $R$. From the previous cases that are installed other site, this study calculated the total surface area of well, $A_i$, as 10.21m$^2$. On the other hand, the average of permeability is $K=2.28$cm/hour. Finally, $V_2$ is calculated as 0.283m$^3$.

From the balance of inflow and outflow of infiltration well, the volume of water stored in the well, $V_3$, is calculated in Table 5. Furthermore, Table 6 shows the number of wells required in each location. This study set the cross section of the infiltration well, $A_b$, is 0.786m$^2$, and the depth of each well, $H_d$, is 3m. Based on analysis, this infiltration-well system reduces 80% of inundation area by inland water.

| Location | $V_1$(m$^3$) | $V_2$(m$^3$) | $V_3$(m$^3$) |
|----------|--------------|--------------|--------------|
| No.1     | 918.86       | 0.283        | 918.58       |
| No.2     | 1,062.67     | 0.283        | 1,062.39     |
| No.3     | 1,095.19     | 0.283        | 1,094.91     |
| No.4     | 903.68       | 0.283        | 903.40       |

### 3 Cost and Benefit Analysis

a. Cost and Benefit Analysis for Normalization Project

In the calculation of costs and benefits for the normalization project, this study estimates the total benefits for 5 years. The total costs by the construction cost and its maintenance were also calculated for five years. The normalization project eliminates some renovation costs for the repairing of resident’s houses, buildings, public facilities and infrastructures. Those costs are included as the benefit of the project in addition to the benefit for easing the damages on economic activities.$^3$

Table 7 shows the list of the annual benefit obtained by the normalization project. The project brings the benefit of 1848 million Rupiah every year, and five times of this benefit becomes the total benefit by the normalization project for 5 years.

The initial construction cost for the normalization project was 5,900 million Rupiah. In addition to this, the maintenance costs, such as an excavation of the river, are needed every year. Table 8 shows the list of annual maintenance costs, and their total is about 608 million Rupiah.

| Components | Saved Cost ($10^6$Rp.) |
|------------|------------------------|
| HOUSING    |                        |
| Houses     | 250.00                 |
| Building (school, office, etc.) | 200.00                 |
| INFRASTRUCTURE |                    |
| Road       | 750.00                 |
| Water and Sanitation | 24.00                 |
| Water Resources | 24.00                 |
| ECONOMY    |                        |
| Traditional Market | 600.00                |
| Total      | 1,848.00               |

### Table 8. Annual costs for the maintenance of the normalization projects

| Components | Price |
|------------|-------|
| MAN POWER  |        |
| Worker     | 4,687.50 |
| Foreman    | 770.00  |
| TOOLS      |        |
| Excavator  | 12,750.00 |
Fig. 6 shows the cost and benefit ratio calculated from Eq. (4). The ratio is 0.31 in the first year and it gradually increases more than 1.0 after 5 years. This means that the project shows its effectiveness against the cost after 5 years.

**Fig. 7 Cost and benefit ratio of the normalization project**

### 4 CONCLUSIONS

This study evaluated the efficiency of the existing normalization project in Bendung watershed. Based on Hec-Ras model and field observation, this study confirmed that the normalization project is preventing the flood along Bendung River. Based on the cost and benefit analysis of the project, this study confirmed that the benefit sufficiently exceeds the cost after five years from the beginning of the project.

On the other hand, some inundation areas remain due to the poor drainage condition. In order to clear this problem, this study investigated the feasibility of the infiltration-well system. Through the hydrological...
analysis, it was cleared that the infiltration-well system reduces 80% of inundation area by inland water.

Furthermore, the installation of the infiltration-well system seemed feasible in the discussion of the cost and benefit analysis. Based on the analysis of the system installation, this study confirmed that the benefit exceeds the cost after four years from the beginning of the system installation.

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