Effectiveness Of Boezem As A Zero Runoff In Blimbing Subdistrict, Malang

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Abstract. During the rainy season, inundation often occurs in Blimbing Hamlet, Malang, which is caused by inadequate existing drains and lack of utilization in water catchment buildings. Therefore, it is necessary to accommodate this condition using zero runoff concept, by utilizing boezem, which is expected there is no inundation at all by flowing flow immediately either seeping into the ground or into an artificial landfill. In Blimbing Hamlet, there is a boezem for serving and accommodating rainwater. For overcoming inundation in this area, maximalizing the boezem is significantly essential. This research is aimed to know the effectiveness of boezem for zero runoff. This assessment was done by hydrology analysis to obtain Q2, and Q5, for boezem planning, inlet and outlets gate, and new drainage channels. The evaluation for existing drainage system showed there was inundation in some drainage channels. A boezem area of 836.9 m² with 1.1 m depth can reduce inundation to 10%. Alternative inundation countermeasures are carried out with the added depth of 3 m, floodgates on inlets and outlets with of 0.5 m width steel gate, and drainage channel inlets and outlets. With the rehabilitation of boezem and other complementary buildings, it can reduce inundation by 30%.

keywords: boezem, steel gate, zero runoff

1. Introduction
Urban inundations often times staggers the livelihood in an urban area, which most likely happens in the lowland urban area. Therefore, the existing urban drainage system should be improved in order to tackle the upcoming urban inundation events, which are more than likely to be more devastating than those in the previous years [1].

Inundation is a problem that always occurs in urban areas, one of which is Blimbing Hamlet in the City of Malang, especially during the rainy season. Here, inundations occur with a height of 0.1 to 0.3 meters. In addition, inundations occur due to urbanization or population displacement that is not balanced by the provision of adequate facilities and infrastructure. Inundations are caused by inadequate existing drains and lack of utilization in water catchment buildings.[2] In urban areas, efforts are needed to avoid inundation with the principle of zero runoff. Zero Runoff System (ZROS) is one of the water conservation ways which can infiltrate runoff to the ground using permeation structures.[3]
The concept of zero runoff is a concept that seeks in an area where there is no inundation at all by flowing flow immediately, either seeping into the ground or into an artificial landfill. Therefore, it takes zero runoff efforts in the area, with one of them utilizing boezem. In Blimbing Hamlet, there is a boezem infiltration pond, and the function is only to serve and accommodate rainwater. Therefore, planning is needed in the repair of boezem in order to be maximal in overcoming inundation in Blimbing hamlet. Based on the Methodology of Composing Master Plans for Urban Drainage Systems by the Ministry of Public Works,[4] an inundation height of 0.1 to 0.3 meters is classified for priority management, as it has a priority value of 50%. However, the area possesses an inadequate drainage channel. According to the Ministry of Public Works, drainage channels that are considered proper must have capacities that exceed the planned flood discharge. The water infiltration structure (boozem) is also not as effective in its usage. As such, the water infiltration structure is to be utilized in order to serve more houses or the wider region [5].

There needs to be further research on the solution and management of inundation in the area of Blimbing Hamlet in the City of Malang by applying zero runoff. The solution is in the form of evaluating the existing drainage channel and the effectiveness of the water infiltration structure (a retarding basin or reservoir, also called boozem) as well as planning for the repair of the water infiltration structure. The purpose of this study is to establish the effectiveness of the drainage channel and the water infiltration structure (boozem) on inundation in the area to achieve zero runoff. The expected benefit is to find out the effectiveness of drainage and the water infiltration structure in reducing inundation occurring in the area during the rainy season.

2. Materials and Methods

Study Location
The location of the study is the retarding basin located on the coordinates 112°38'26.728" East Longitude and 7°56'21.141" South Latitude. Its map location is Jalan A. Yani Gang III, RW 09 in Blimbing Hamlet in Blimbing Sub-District, City of Malang.

![Figure 1: Map of the Study Location](Source: Malang Spatial Planning Information System)
This study requires data to support its execution, and the following are the required data:

- **Rainfall Data**
The rainfall data comprises a period of 11 years, from 2009-2019. Rainfall data covers data from Blimbing Station, the Hydrology Laboratory Station of Water Resources Engineering of UB, and the Malang Climatology Station.

- **Land Use Map**
The map was utilized to determine the flow (runoff) coefficient in the catchment area.

- **Topography Map**
The map was utilized in depicting the flow direction in the drainage channel.

- **Population Data**
The data was utilized as a reference for the population in the catchment area. The utilized data was the population in 2018.

- **Technical Data on the Retarding Basin and the Existing Drainage Channel**
The data was utilized to evaluate the solution for flood management in the study location.

In this study, hydrological data such as rainfall data are needed. The hydrological analysis was performed as the feasibility testing of the data that comprises consistency testing, outlier testing, and stationary testing to find out whether the data are feasible or not if the rainfall data are feasible. In this study, consistency testing of rainfall data utilized the double mass curve. This test involved comparing the cumulative figures of the stations against the cumulative average of rainfall stations in the area to find out whether the data were consistent or not [5]. The other test is Outlier testing utilized the method by Grubbs and Beck. The purpose of this test is to find out whether the data is feasible or not by establishing two thresholds, the lower limit (XL) and the upper limit (XH) [6].

\[
X_H = \exp(x + K_n \cdot S) \quad (1)
\]
\[
X_L = \exp(x - K_n \cdot S) \quad (2)
\]
\[
K_n = -3.62201 + 6.28446 \cdot n^{0.25} - 2.49835 \cdot n^{0.5} + 0.491436 \cdot n^{0.75} - 0.037811 \cdot n \quad (3)
\]

The analysis of average regional rainfall was conducted with the method of Thiessen polygons. This method has the objective to accommodate non-uniform distances by showing the proportions of the extents of areas of influence of rain stations [5].

\[
R = \frac{A_1 R_1 + A_2 R_2 + \ldots + A_n R_n}{A_1 + A_2 + \ldots + A_n} \quad (5)
\]

The design flood discharge is the sum of the magnitude of the rainwater discharge and the sewage discharge at specific return periods [6]. This calculation was utilized to determine the capacity of the drainage channel.

\[
Q_r = Q_{ah} + Q_{ak} \quad (6)
\]
\[
Q_{ah} = 0.278 \cdot C \cdot I \cdot A \quad (7)
\]
\[
Q_{ak} = \frac{P_n - q}{A} \quad (8)
\]
Where:
\[ Q_r = \text{design flood discharge (m}^3/\text{s}) \]
\[ Q_{ah} = \text{design flood discharge (m}^3/\text{s}) \]
\[ C = \text{runoff coefficient} \]
\[ I = \text{rainfall intensity (mm/h)} \]
\[ A = \text{area of drainage (km}^2) \]
\[ Q_{ak} = \text{sewage discharge (l/s/km}^2) \]
\[ P_n = \text{population (people)} \]
\[ q = \text{amount of wastewater (liters/person/day)} \]
\[ A = \text{area (km}^2) \]

This evaluation was utilized to determine the current condition of a channel to find out the magnitude of discharge that can be accommodated by the channel. The drainage channel can be said to be feasible if the capacity of the channel is larger than the planned discharge and is not feasible otherwise.

\[
Q = A_{sal} V_{sal} \quad (9)
\]

\[
V_{sal} = \frac{1}{n} R^{2/3} S^{1/2} \quad (10)
\]

Where:
\[ Q = \text{total discharge (m}^3/\text{s}) \]
\[ A_{sal} = \text{channel area (m}^2) \]
\[ V_{sal} = \text{flow velocity (m/s)} \]
\[ n = \text{Manning’s coefficient} \]
\[ R = \text{hydraulic radius (m)} \]
\[ S = \text{slope of channel} \]

3. Results and Discussion

3.1. Hydrological Analysis

A hydrological analysis is the preliminary stage of analysis in obtaining hydrological data such as average rainfall, frequency distribution, rainfall intensity, and planned flood discharge. The data were then utilized to determine the hydrological conditions of the study location.

| Rainfall Station       | Feasibility Testing |   |   |
|------------------------|---------------------|--|--|
|                        | Double Mass         | Outlier Testing | Stationary Testing |
| Blimming               | Accepted            | Accepted       | Homogeneous        |
| Malang Climatology     | Accepted            | Accepted       | Homogeneous        |
| Hydrology Lab, WRE UB  | Accepted            | Accepted       | Homogeneous        |

Based on the results of the analysis for design rainfall with the Log Pearson III method, the following was obtained for the design rainfall data.
Table 2. Summary of Planned Rainfall

| Tr (years) | Pr (%) | K   | Sd Log X | X_mean | Log X planned (mm) | X planned (mm) |
|------------|--------|-----|----------|--------|--------------------|----------------|
| 2          | 50     | 0.028 | 0.079    | 1.921  | 1.924              | 83.890         |
| 5          | 20     | 0.849 | 0.079    | 1.921  | 1.988              | 97.324         |

The table above shows that the obtained planned rainfall for a return period of 2 years was 83.890 mm and for a return period of 5 years was 97.324 mm. Next, distribution suitability testing was performed with the chi-squared test and Kolmogorov-Smirnov test, with the following results:

Table 3. Distribution Suitability Testing

| Distribution Method | Probability | Kolmogorov-Smirnov Test | Chi-Squared Test | Remarks |
|---------------------|-------------|-------------------------|------------------|---------|
| Log Pearson III     | 5%          | ∆max 0.193, ∆cr 0.391   | Xh2 0.27, Xcr2 3.841 | Accepted |

After calculations were performed for distribution suitability testing with the chi-squared test and the Kolmogorov-Smirnov test with a probability of 5%, it was found that the Log Pearson distribution was acceptable. This is because ∆max < ∆cr and Xh² < Xcr². Therefore, data from the Log Pearson III test could be utilized.

Table 4. Summary of the Flood Discharge Design

| Qr total (m³/s) |
|-----------------|
| Q_2            |
| Q_5            |
| 3.970          |
| 4.606          |

From the table, the resulting magnitude of the planned flood discharge of the study location was 3.970 m³/s and 4.606 m³/s, and the calculated volume of the planned flood was 8816.75 m³ and 10244.40 m³, with return periods of 2 and 5 years.
3.2. Evaluation of the Existing Structure

Table 5. Summary of Evaluation for the Capacity of the Existing Drainage

| Channel | Description | Channel | Description |
|---------|-------------|---------|-------------|
| A1      | accepted    | A25     | accepted    |
| A2      | Not accepted| A26     | Not accepted|
| A3      | accepted    | A27     | accepted    |
| A4      | accepted    | A28     | Not accepted|
| A5      | accepted    | A29     | Not accepted|
| A6      | accepted    | A30     | accepted    |
| A7      | accepted    | A30a    | accepted    |
| A8      | accepted    | A30b    | accepted    |
| A9      | accepted    | A31     | accepted    |
| A10     | accepted    | A32     | Not accepted|
| A11     | accepted    | A33     | Not accepted|
| A12     | Not accepted| A34     | accepted    |
| A13     | accepted    | A35     | accepted    |
| A14     | accepted    | A36     | accepted    |
| A15     | accepted    | A37     | accepted    |
| A16     | accepted    | A38     | Not accepted|
| A17     | accepted    | A39     | Not accepted|
| A18     | accepted    | A40     | Not accepted|
| A19     | accepted    | A41     | accepted    |
| A20     | accepted    | A42     | Not accepted|
| A21     | Not accepted| A43     | Not accepted|
| A22     | Not accepted| A44     | Not accepted|
| A23     | Not accepted| A45     | Not accepted|
| A24     | accepted    |         |             |

Table 5 shows that some parts of the existing drainage channel could not meet the planned discharge. It can therefore be said that in the area upstream of the retarding basin, runoff of water has occurred at some points of the existing drainage channel.

From the results of calculations for evaluating the boezem, with a structural area of 836.9 m², an effective depth of 1.1 m, and a containment volume of 920.6 m³, it was found that the retarding basin could only reduce floods by 10%. It means that inundation still occurs 90%, zero runoff has not been reached.

3.3. Budget Plan Costs

The budget plan is necessary to determine the costs that will be spent for the planning of supplementary structures for the retarding basin. The calculation of the budget plan was based on analysis according to the work unit price of the City of Malang.
Table 6. Summary of Budget Plan

| No. | Activity Description        | Volume   | Unit | Unit Price (Rp) | Total Price (Rp) |
|-----|-----------------------------|----------|------|-----------------|------------------|
| A   | Retarding Basin             |          |      |                 |                  |
| 1   | Excavation                  | 2510.82  | m³   | 53,755          | 134,969,129      |
|     | Total                       |          |      |                 | 134,969,129      |
| B   | Sluice                      |          |      |                 |                  |
|     | Installation                | 3        | pieces | 13,567,422    | 40,702,267       |
|     | Lubrication                 | 3        | pieces | 278,027        | 834,082          |
|     | Total                       |          |      |                 | 41,536,350       |
| C   | Inlet Drainage Channel      |          |      |                 |                  |
| 1   | Excavation                  | 2.76     | m³   | 53,755          | 148,364          |
| 2   | Sand Filling                | 0.345    | m³   | 226,165         | 78,027           |
| 3   | Formwork, 2 Sides           | 2.3      | m²   | 2,201.736       | 5,063,993        |
| 4   | Concrete                    | 0.621    | m³   | 1,124,193       | 698,124          |
|     | Total                       |          |      |                 | 5,988,507        |
| D   | Outlet Drainage Channel     |          |      |                 |                  |
| 1   | Excavation                  | 1.288    | m³   | 53,755          | 69,236           |
| 2   | Sand Filling                | 0.161    | m³   | 226,165         | 36,413           |
| 3   | Formwork, 2 Sides           | 2.3      | m²   | 2,201.736       | 5,063,993        |
| 4   | Concrete                    | 0.437    | m³   | 1,124,193       | 491,272          |
|     | Total                       |          |      |                 | 5,660,914        |
|     | Grand Total                 |          |      | 146,618,550     |                  |
|     | Rounding                    |          |      | 146,620,000     |                  |

Based on the above table, the total cost of the planned budget for the planning of supplementary structures was found to be Rp. 146,620,000. The grand total for the budget was obtained from the planning for the drainage channel, increased basin containment, and sluices.

3.4. Flood Control Alternative

1. The retarding basin/boezem is to have its depth of 3 meters increased to an effective depth of 3.5 meters, with a structural area of 836.9 m² and a containment volume of 2929 m³.
2. The inlet and outlet are planned to have sluices in the form of steel sliding gates with a width of 0.5 meters; the inlet will have two sluices, and the outlet will have one sluice for a total of 3 sluices. The discharge at the inlet is 0.628 m³/s with an opening of 0.3 meters for each sluice. The discharge at the outlet sluice is 0.349 m³/s with an opening of 0.2 meters for the sluice.
3. Drainage channels are planned with the function to connect the previous drainage channel with the retarding basin/boezem. The plan involves two channels at the inlet and outlet. The inlet channel will have a width of 1.3 meters and a depth of 0.5 meters, and the outlet channel will have a width of 0.5 meters and a depth of 0.5 meters.

Therefore, based on the results for the flood control alternative, it was found that the retarding basin/boezem can reduce floods by 30%. Boozem can reduce flooding by 30%, and repair of drains will reduce flooding by 70% so that zero runoff has been achieved.
4. Conclusion
The planned discharge that flows into the retarding basin is 3.970 m³/s for a 2-year return period and 4.606 m³/s for a 5-year return period.

The results of the evaluation show that there has been runoff in some parts of the existing drainage channel and that a retarding basin with an area of 836.9 m² and an effective depth of 1.1 m can reduce floods by 10%.

The flood control alternative involves increasing the depth of the retarding basin by 3 m with a structural area of 836.9 m² and the planning of supplementary structures in the form of inlet and outlet sluices with a gate width of 0.5 m as well as drainage channels at the inlet and outlet. The retarding basin will thus be able to reduce floods by 30%.

The total for the budget plan, in accordance with analysis by the work activity unit price of the City of Malang, amounts to Rp. 146,620,000.

So that zero runoff can be achieved, what must be done is to repair the drainage channel with optimal operation of the bozem.

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