Drainage System Evaluation as An Effort to Reduce Flood Inundation in Gedebage Area, Bandung - West Java

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Abstract. Flooding in Gedebage area of Bandung is a recurring chronic problem. Various factors are alleged to be the cause of floods other than natural factors, such as several river courses across the region, and topography. The increase of runoff due to rainfall is not proportional to the drainage capacity. There are only two outlets which are Cinambo outlet and Cisalatri outlet. Various efforts have been made, such as dredging channels, rivers and elevating roads. However, those efforts have not solved the problem yet. Integrated efforts from upstream to downstream to address flooding in this region are needed. This study presents the results of an alternative evaluation of flood mitigation with several scenarios such as improving drainage channel capacity, channel addition, and combination of improving flow capacity and retention basins. The hydraulic analysis was performed using EPA-SWMM model. The analysis result shows almost some segments are overtopping. Increasing carrying capacity only reduces a few segments from overtopping. It needs a combination of increased channel capacity by widening and deepening, adding channels, creating a retention basin to overcome Gedebage flooding problems.

Keywords: drainage, flooding, retention pond

1. Introduction
1.1 General
As a tropical country with heavy rainfall, regional development systems that do not consider environmental impacts result in various of environmental problems. One is the potential for flooding, especially in urban areas where land use changes occur very quickly and are not matched by a good rainwater management system. The sustainable drainage system becomes an absolute necessity of a region in rainwater management.

The geographical location of Gedebage is adjacent to Bandung Regency. There are Primary Arterial road network and Primary Collector road, including Buahbatu Canal, Kiaraccondong Canal, Cipagalo, Marga cinta, and Gedebage Canal Road. Gedebage area is a strategic location that can be accessed easily from many areas both in Bandung District and in Bandung Regency. Thus, the flood case occurred in Gedebage area is such important issue because of the strategic location and the function of the region as a residential centre, as a centre of commercial activity, office area, industry center, trade and other uses [1].

When heavy rainfall comes, people who live in the area of Gedebage or who will cross the road Sukarno-Hatta and surrounding areas are always worried because the flood is almost certain to happen. It sometimes comes with a height of 30 cm or more than 1.0 m along the Sukarno-Hatta road and the area around Gedebage. Various factors are alleged to be the cause of floods other than natural factors of heavy rainfall, such as several river courses that across the region, and topography. The increase of runoff generated from rainfall is not proportional to the capacity drainage channel which
also affects discharge of river flows into this area. There are only two outlets which are Cinambo outlet and Cisalatri outlet.

Various efforts have been made, such as dredging channels, rivers and elevating roads. But this effort has not solved the problem. Integrated efforts from upstream to downstream to address flooding in this region are needed. This study presents the results of an alternative evaluation of flood mitigation of Gedebage area by conducting several scenarios, such as improving drainage channel capacity, channel addition, and combination of improving flow capacity, the addition of channel and retention basins.

1.2 Drainage System on Gedebage Area

The existence of several numbers of rivers in the upper reaches of Gedebage area, the decreasing of the downstream river area due to narrowing, silting and other utilities have decreased the capacity of the river flow so that potentially flooding occurs. The rivers that pass through Gedebage are three main rivers namely Cinambo, Cilameta, and Cisalatri. These three rivers outlets meet at downstream of the Gedebage region before entering the Citarum river. Cinambo River has tributaries namely Cijalupang River, Cijambe River, Jangjawa River, Ciseupan River, Ciwaru River, Cinambo River and Cipamulihan River. While the river Cilameta and Cisalatri River is separated. The existing system in the Gedebage region is shown in Figure 1.

![River system on gedebage area](image)

**Figure 1. River system on gedebage area**

2. Methodology

The first step in this research data collection, i.e. primary data and secondary data. Primary data includes channel measurement data. The secondary data includes data of drainage system, inundation data, map of rain stations, site map, rainfall data and land use.
The obtained data were analyzed in order to know the causes of the flood and what the impact of the occurrence of the flood. The analysis will yield recommendations based on theories and literature studies.

2.1 Hydrological Analysis

2.1.1 Design rainfall calculation

Calculation of average rainfall was done by processing rain data that was obtained from each rain gauge station. Maximum daily rainfall plan from the maximum rainfall data were determined from several rain gauge stations. The used methods were the distribution of Gumble and Log Pearson Type III [2].

2.1.2 Test the suitability of Distribution

This test aims to find out the data of the selected distribution type can be representative of the statistical distribution of the data samples. Testing goodness of fit data used the Smirnov Kolmogorov Test [3]. This test was performed by describing the probabilities for each theoretical and empirical distribution data.

2.1.3 Rainfall Intensity Analysis

The drainage system planning requires rain intensity with short duration which is described in the form of IDF curve (intensity-duration-frequency). Because there is no observation data, rain intensity was analyzed by Talbot, Ishiguro and Sherman methods [4,5]. From those three methods, one method that was the closest to the empirical data of rain was selected.

2.1.4 Calculation of Design discharge

This calculation was used as a reference for planning the level of flood hazard in an area with the application of the number of possible floods. With relatively small catchment area, flood discharge analysis used Rational method [6].

2.2 Hydraulics Analysis

Hydraulics analysis consisted two calculations, i.e. calculating channel capacity in order to know whether the existing channel was able to accommodate the existing discharge safely or overflow, and comparison of existing Q with Q design to find out whether the existing channel capacity is capable of drain flood discharge design.

2.3 Evaluation of Drainage System

Hydrological and hydraulic analyzes were conducted simultaneously using the SWMM model (Storm Water Management Modeling 5.1 [7,8]. Evaluation of Drainage system is a step to know extension drainage capacity to design flood. Channel normalization is a re-planning of the existing drainage channel so that it can drain the design flood discharge. Channel normalization is accomplished by improving channel both by widening and/or by lining up depending on topographic conditions and availability of land. Retention ponds are an alternative that can be used if field coding is not possible with normalization solutions. The alternative uses sustainable drainage system concept.

3. Result and Discussion

3.1 Rainfall Analysis

Rainfall data used for analysis is rainfall data from influential rainfall observation station that is from Cipadung Station, Dago, Cibiru, Ciparay, Ujung Berung, Tanjungsari and data period of last 10 years. Analysis of the areal rainfall used algebraic methods. The frequency distribution analysis used Gumbel distribution and Log Pearson Type III distribution. Based on the test of the suitability of the distribution using the Smirnov Kolmogorov method it is concluded that the appropriate distribution is the result of the Gumble distribution method. The results design rainfall are presented in Table 1.
Table 1. Result of design rainfall (mm)

| Return period (year) | Distribution | Probability |
|----------------------|--------------|-------------|
|                      | Gumbel       | Log Pearson III |
| 2                    | 84.27        | 85.56       |
| 5                    | 102.09       | 98.75       |
| 10                   | 113.89       | 106.13      |
| 25                   | 128.8        | 114.36      |
| 50                   | 139.86       | 119.88      |
| 100                  | 150.84       | 124.98      |

Max. Def.       12.62  14.98

Critical Delta (Sig. Level 0.1)  33

Based on the design rainfall, magnitude of rain intensity was calculated using Gumbel method. The intensity of rain in drainage planning is used in short duration, the Talbot, Sherman and Ishiguro methods are used. The most suitable method for rainfall in the Cinambo sub watershed is the Talbot method, with IDF curves as shown in Figure 2.

![Figure 2. IDF curve at Cinambo basin](image)

3.2 Discharge Analysis

The next step counts the discharge of each sub watershed entering the Cinambo river system. In this study, the evaluation of the drainage system used SWMM model which performs hydrological and hydraulic calculations in one program.

The method used to calculate the flood discharge plan is the EPA SWMM (Storm Water Management Model) Version 5.0 Program. EPA SWMM is a periodic rainfall runoff simulation model used to simulate a single occurrence or a continuous occurrence with the quantity and runoff quality of the area under review. The SWMM runoff component is operated by summing the area of the catchment (subcatchment) that receives the total rain and generates it in runoff and pollution load. The runoff flow in SWMM can be traced through piped systems, open drains, catch ponds and pumps. SWMM is the quantity and quality of runoff generated in each catchment area, and the average flow, flow depth and quality of water in each pipeline and open channel during the simulation period are included in additional time.

The concept of SWMM is the modeling of the hydrological cycle that exists on earth, this model contains about:

- Rainfall modeling. Rain is the most important factor in hydrology. The degree of rainfall is usually expressed by the amount of rainfall in a given time unit and is called the bulk intensity. In SWMM rainfall is described as Rain Gage symbol to represent rain to be simulated.
• Soil surface modeling which is represented in this case by a subcatchment symbol. The soil surface receives rainfall from the atmosphere then some water will seep into the soil as infiltration and some will become surface runoff.

• Groundwater modeling, through the infiltration process receives water from the surface. In the SWMM symbolized by the Aquifer symbol.

• Modeling of water transport network. Water is channeled through canals, canals, pipes, then can also be simulated about the use of pumps, storage ponds and waste treatment. In SWMM this section is symbolized as Node and Link.

   Modeling as mentioned above is assembled into a single unit that describes a drainage system. Pictures and sequences can be seen in Figure 3.

   ![Figure 3. Modelling the drainage system on SWMM](image)

In the Cinambo sub watershed, there are several natural river flowing into the Cinambo drainage system as seen in the sub catchment of Cinambo watersheds namely Cijalupang, Cipanjalu, Cipamulihan, Ciwaru, Cinambo and Irrigation sub-districts, Cilameta and Cisalatri. In the EPA SWMM Model, it can be described schematically of the Cinambo Sub-Basin Drainage system as well as the existing Sub-Basin input as described in Figure 4. Table 2 shows the results of the discharge calculation of each Sub Catchment on the main channel.

### 3.3 Evaluation of Drainage System Capacity

#### 3.3.1 Existing Conditions

The results of hydraulic analysis based on design rainfall of 5 year return period show that some areas in the sub-watershed of Cinambo are flooded. Location of flooded as shown in Figure 5. Flooding occurred at the confluence of the river Cinambo and Janjawariver, Ciwaru channel, Cipamulihan river, also the Cisalatri river on the left side of Cinambo sub watershed. The depth of flooding ranges from 0.30 m to 1.80 m with the duration of inundation ranging from 0.5 hours to more than 11 hours.
Figure 4. Modelling the drainage system on Gedebage

Table 2. Characteristic of catchment area and flood discharge

| No | Element ID         | Area (ha) | Curve Number CN | Average Slope (%) | Imperious Area (%) | Q2 (cms) | Q5 (cms) | Q10 (cms) | Q25 (cms) | Q50 (cms) | Q100 (cms) |
|----|--------------------|-----------|-----------------|-------------------|--------------------|----------|----------|-----------|-----------|-----------|------------|
| 1  | Cijalupang_ Hulu   | 429.00    | 63.00           | 19.1000           | 40.00              | 11.98    | 15.06    | 20.14     | 24.74     |
| 2  | Cijambe            | 185.00    | 63.00           | 16.3500           | 40.00              | 5.74     | 7.21     | 8.24      | 9.62      | 10.68     | 11.79      |
| 3  | Cilameta           | 185.00    | 63.00           | 10.0000           | 50.00              | 4.60     | 5.81     | 6.73      | 7.83      | 8.73      | 9.66       |
| 4  | Cinambo            | 59.00     | 63.00           | 7.4200            | 40.00              | 3.11     | 3.84     | 4.36      | 5.04      | 5.56      | 6.10       |
| 5  | Cipamulihan        | 427.00    | 63.00           | 3.5040            | 40.00              | 5.29     | 6.71     | 7.73      | 9.11      | 10.18     | 11.30      |
| 6  | Cipanjalu          | 1613.00   | 63.00           | 30.7500           | 40.00              | 18.52    | 23.53    | 27.11     | 31.74     | 35.72     | 39.65      |
| 7  | Cisalatri_hulu     | 196.00    | 63.00           | 5.0000            | 40.00              | 3.91     | 4.93     | 5.67      | 6.65      | 7.42      | 8.21       |
| 8  | Ciwaru             | 403.00    | 63.00           | 2.8010            | 40.00              | 5.73     | 7.27     | 8.36      | 9.84      | 11.00     | 12.19      |
| 9  | Irigasi_Jangjawa   | 98.40     | 63.00           | 2.0600            | 40.00              | 3.87     | 4.83     | 5.50      | 6.40      | 7.09      | 7.80       |
| 10 | Sukamulya2         | 33.34     | 77.00           | 1.9200            | 50.00              | 2.05     | 2.55     | 2.90      | 3.36      | 3.72      | 4.08       |
3.4 Alternative Drainage System

3.4.1 Mitigation Alternative with Dredging

Flooding in the drainage system of the Cinambo Sub-watershed is largely due to the presence of a wavy channel slope due to sedimentation. Sedimentation is caused by erosion in the upstream of the river and household waste disposed into the river, so the first alternative to problem solving is dredging the channel.

In the scenario of channel dredging without widening at the site, the analysis shows that there is a reduction in the area, depth and length of the puddle, but there are still many locations that occur overflow and cause flooding. The impact of dredging conducted on rivers and canals with flood problems to the depth and length of inundation as shown in Table 3.

| No | Node | Location                      | Time of inundation (hr) | Discharge (m³/S) | Volume (x 10⁶ Lt) | Depth (m) |
|----|------|-------------------------------|-------------------------|------------------|-------------------|-----------|
| 1  | C65  | Upstream of Janjawa channel   | 2.2                     | 16.638           | 24.307            | 1.18      |
| 2  | C75  | Ciwaru Channel               | 0.96                    | 11.693           | 19.465            | 1.59      |
| 3  | F33  | Cipamulihan channel          | 11.2                    | 24.885           | 218.215           | 4         |
| 4  | F36  | Cipamulihan2 channel         | 8.71                    | 0.245            | 2.474             | 0.51      |
| 5  | F37  | Cipamulihan River            | 3.9                     | 1.577            | 8.947             | 1.21      |
3.4.2 Alternative Handling with Dredging, Widening channels and Cross cut

Alternative Problem handling with dredging has not fully solved the flood existing problem in Cinambo Sub-watershed, so additional alternatives are needed by widening of channels and spacing areas that are not allowed. Additional alternatives are as follows:

1. Making Channels in the right and left of Jl. Rumahsakit with the width of 1.6 m to reduce discharge from Jangjawa and Cinambo River channel
2. Widening Channels on the left and right of Gedebage with 1.6 m wide to drain discharge towards New Cinambo.
3. Distributing channels beside Depo Pertamina 2.5 m wide in the upstream and 3 meters downstream
4. Normalization of river channels on the side of the railroad
5. Preparation of cross cut from Cipamulihan Channel to Cilameta River
6. Normalization of outlet Cinambo River

Optimum result reduction of flooding in the southern side of Gedebage area (around the Gedebage market) by dredging efforts, cross cut, and widening of channels with locations as shown in Figure 6.

3.4.3 Handling Flood.

Cisalatri River outlet meets the Cinambo River in the downstream of the Purbaleunyi Toll Road. As discussed in the study of existing conditions on the Cisalatri River there are also flood puddles. A major problem in the normalization of the Cisalatri River is the social problem in the downstream area that crosses the dense residential area. Cisalatri River is located in the northern part of Jalan Sukarno-Hatta in which there is still open land in the form of paddy fields. Thus, in order to avoid the widening of the proposed river, a retention pond needs to build. In addition, the normalization of the river is still required but in the form of dredging.

Figure 6. Optimum flood-handling scheme in Gedebage
4. Conclusions
The flooding in the Gedebage area is due to the capacity of the channel which is unable to drain the 5 year discharge of return periods. The required handling effort is by enlarging the channel capacity, dredging the sediment as well as the garbage as well as widening and deepening the channel as well as the need for a short cut to shorten the flow. Cisalatri River requires to normalize channel and alternative making of retention pond.

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