Analysis of drainage dimension at the density of housing environment (case study: urban drainage at Gampong Keuramat, Kuta Alam, Banda Aceh, Indonesia)

Akmal
Civil Engineering Department, Faculty of Engineering, Universitas Muhammadiyah Aceh, 23245 Banda Aceh, Indonesia
Email: akmal@unmuha.ac.id

Abstract. In the relatively flat area such as Banda Aceh, the effort to prevent flooding could be made by monitoring the drainage system. This study was conducted at Gampong Keuramat, Kuta Alam subdistrict, Banda Aceh, in which the area has been densely populated yet having uneven population distribution and experience the continuous increasing of less-planned residential area coverage as the rise in the number of immigration to the region. If not anticipated further, the condition could lead to flooding since the amount of water discharge to the drainage could be larger than the capacity of existing drainage. Thus, this study was conducted to analyze the capacity of existing drainage and to identify the cause of drainage inundation in the area. The study was focus on the part of the drainage that was not functioned normally, while Rational Method was used to analyze the channel discharge data. The result shows that the E-F channel and F-G channel are not in the safe condition since the channel design is broader (0.06 m³/sec and 0.08 m³/sec, respectively) than the actual channel discharge (0.05 m³/sec and 0.07 m³/sec, respectively). Furthermore, those channels can be improved by increasing the slope and enlarging the channel's dimension.

Keywords: flooding, drainage dimension, Banda Aceh

1. Introduction
The city of Banda Aceh has relatively flat topography, so it needs to pay attention to the drainage network system in preventing flooding, drainage system is one of the government's efforts to overcome the flood disaster that often struck the city of Banda Aceh. One of the areas that often occur flood the area Gampong Keuramat, Kuta Alam subdistrict. The drainage problem in this village is caused by uneven distribution of population, and the volume of the immigrant population is quite large; this resulted in the development of less planned settlements, resulting in drainage disposal system is not well coordinated. Based on the above problems, an analysis of the capacity of drainage channel dimensions can be known, so that the capacity of the drainage services is adequate or not, without causing puddles or floods.

The purpose of this paper is to analyze the capacity of channel dimension and to identify the cause of the inundation that occurred in the densely populated residential area of Gampong Keuramat, to give an illustration of the drainage condition. The method used in analyzing the discharge is the rational method.
2. Urban Drainage
The infrastructure of an area consists of several groups, namely: water infrastructure group, road groups, transportation equipment groups, waste management groups, urban building groups, energy groups, and telecommunications groups [1]. The drainage system is part of the water infrastructure group.

In order to support urban development, the need to improve and to have additional drainage facilities, especially rainfall discharge systems, are required. This is because rainfall discharge systems are set to prevent harmfully or disturbing effects on the environment resulted from rain streams by discharging them as quickly as possible to the receiving water bodies [2]. Thus, the condition of rainfall drainage system facilities should be the main concern in the flooding prevention, especially for areas that always experience flood every rainy season. Furthermore, the safety and reliability of the drainage system, as well as the problems related to that, should be taken into account and must be handled seriously.

3. Rainfall Design
The calculation of rainfall design can be done by statistical analysis, that is by calculating statistical parameters of data analyzed. The statistical parameters are an average value (\( \bar{y} \)), standard deviation (SD), asymmetric coefficient (Cs), and coefficient of variation (Cv) [3]. The value of asymmetric coefficient (Cs) determines the type of data distribution. If the coefficient asymmetric (Cs) = 0, the distribution is normal, if (Cs) = 3 \( C_v + C_s^3 \), the distribution is log-normal, if the (Cs) = 1.14 the distribution is Gumbel. If rainfall data do not follow either normal distribution, normal log or Gumbel, the data is suspected not to follow distribution [1].

4. Channel Dimension
The channel dimension must be capable of flowing the discharge plan rate(Qs), which has to be equal to or greater than the discharge design (Qr) [4]. This relation is shown as follows:

\[
Q_s \geq Q_r
\]

where \( Q_s \) is measured discharge (m³/sec.), and \( Q_r \) for discharge design(m³/sec.).

The measured discharge (Qs) can be obtained using the following formula:

\[
Q_s = A_s \cdot V
\]

where \( A_s \) for area section(m²), and \( V \) is velocity (m/sec.).

5. Rainfall and Runoff
There are many empiric-rational formulas that can explain the relation between rainfall and its runoff. Urban drainage design often uses the following rational modification formula [5]:

\[
Q_r = 0.278 \cdot C \cdot C_s \cdot I \cdot A
\]

where \( Q_r \) discharge design(m³/sec.), \( C \) as a runoff coefficient, \( C_s \) for the storage coefficient, \( I \) is rainfall intensity during the time on concentration (mm/hour), and \( A \) for area (km²).

6. Research Method
The data used in this research are primary data and secondary data. The primary data are photo of water puddles and channel dimension measurement data. The secondary data consists of rainfall data [3], population data [2] and topographic maps. Equipment used to analyze the dimensions of drainage channels is tape measure, wood measuring, stationery, and spray paint.

The stages of analysis conducted based on the data obtained are as follows; calculate the rainfall plan, calculate the flow coefficient, calculate the channel sectional discharge, calculate the concentration-time, calculate the coefficient of the shelter, calculate the rain intensity, calculate the rain and runoff. The research flows diagram is shown in Figure 1.
7. Results and Discussion
The discharge flow in the channel is influenced by the cross-sectional area, and the measured discharge in the channel, which is by using Formula 2. The calculation result can be seen in Table 1. Discharge design is calculated for each channel using Formula 3 which is influenced by flow coefficient, rain during concentration time. The results of the calculation of flood discharge can be seen in Table 2.

Table 1. Measured Discharge

| Channel ID | \( A_s \) (m\(^3\)) | \( V \) (m/sec.) | \( Q_s \) (m\(^3\)/sec.) |
|------------|-------------------|-----------------|-----------------|
| A-B        | 0.16              | 0.80            | 0.13            |
| B-C        | 0.19              | 0.19            | 0.03            |
| C-D        | 0.14              | 0.19            | 0.03            |
| D-E        | 0.14              | 0.51            | 0.07            |
| E-F        | 0.18              | 0.25            | 0.05            |
| F-G        | 0.23              | 0.32            | 0.07            |
| G-H        | 0.51              | 0.20            | 0.10            |
| A-I        | 0.10              | 1.20            | 0.12            |
| I-J        | 0.17              | 0.24            | 0.04            |
| J-K        | 0.15              | 0.44            | 0.07            |
| K-L        | 0.19              | 0.74            | 0.14            |
| L-M        | 0.42              | 0.60            | 0.25            |
| N-O        | 0.30              | 0.12            | 0.04            |
| O-P        | 0.30              | 1.17            | 0.35            |
| P-Q        | 0.59              | 1.35            | 0.79            |
| Q-R        | 0.22              | 1.34            | 0.30            |
### Table 2. Discharge Design

| Channel ID | $Q_s$ (m$^3$) | $A$ (m$^2$) | $C$ | $I$ (mm/hr) | $Q_r$ (m$^3$/sec.) |
|------------|--------------|-------------|-----|-------------|---------------------|
| A-B        | 907          | 0.00091     | 0.34| 63.86       | 0.01                |
| B-C        | 9671         | 0.00967     | 0.31| 45.30       | 0.03                |
| C-D        | 5254         | 0.00525     | 0.36| 51.74       | 0.03                |
| D-E        | 6017         | 0.00602     | 0.37| 63.99       | 0.04                |
| E-F        | 9555         | 0.00956     | 0.35| 68.17       | 0.06                |
| F-G        | 11667        | 0.01167     | 0.33| 92.46       | 0.08                |
| G-H        | 6695         | 0.00670     | 0.44| 87.46       | 0.06                |
| A-I        | 5369         | 0.00537     | 0.41| 58.85       | 0.04                |
| I-J        | 2740         | 0.00274     | 0.37| 64.18       | 0.02                |
| J-K        | 4178         | 0.00418     | 0.34| 68.11       | 0.03                |
| K-L        | 4127         | 0.00413     | 0.34| 74.58       | 0.03                |
| L-M        | 6196         | 0.00620     | 0.43| 54.29       | 0.04                |
| N-O        | 5443         | 0.00544     | 0.37| 65.65       | 0.03                |
| O-P        | 4209         | 0.00421     | 0.36| 210.47      | 0.08                |
| P-Q        | 7210         | 0.00721     | 0.40| 77.61       | 0.06                |
| Q-R        | 2873         | 0.00287     | 0.36| 63.64       | 0.02                |
| R-S        | 3215         | 0.00322     | 0.36| 163.64      | 0.05                |
| S-T        | 4045         | 0.00405     | 0.35| 256.32      | 0.09                |
| T-U        | 5469         | 0.00547     | 0.36| 89.60       | 0.04                |
| U-V        | 5469         | 0.00547     | 0.36| 76.04       | 0.03                |
| V-W        | 2854         | 0.00285     | 0.36| 189.27      | 0.05                |
| W-H        | 4035         | 0.00404     | 0.35| 119.93      | 0.04                |
| X-J        | 6038         | 0.00604     | 0.37| 66.83       | 0.04                |
| D-X        | 4915         | 0.00492     | 0.36| 148.99      | 0.07                |
| Y-K        | 6081         | 0.00608     | 0.37| 59.29       | 0.04                |
| E-Y        | 6819         | 0.00682     | 0.37| 63.81       | 0.04                |
| Z-M        | 7477         | 0.00748     | 0.38| 54.25       | 0.04                |
| F-Z        | 5357         | 0.00536     | 0.35| 137.03      | 0.07                |
| I-N        | 5952         | 0.00595     | 0.38| 90.17       | 0.05                |
| G-I        | 6607         | 0.00661     | 0.37| 145.41      | 0.09                |
| 2-O        | 6640         | 0.00664     | 0.37| 100.36      | 0.06                |
| H-Q        | 7117         | 0.00712     | 0.46| 126.06      | 0.11                |
| W-R        | 4907         | 0.00491     | 0.36| 128.24      | 0.06                |
| V-S        | 5343         | 0.00534     | 0.35| 84.53       | 0.04                |
Conditions of channel discharge value must be greater than or equal to the design discharge ($Q_S \geq Q_T$), meaning the channel can accommodate the existing capacity. The results of the calculation of channel discharge for all channels have different values. The summary result of flood discharge control can be seen in Table 3.

**Table 3. Discharge Control**

| Channel ID | $Q_S$ (m$^3$/sec.) | $Q_T$ (m$^3$/sec.) | Note |
|------------|---------------------|---------------------|------|
| A-B        | 0.13                | 0.01                | safe |
| B-C        | 0.03                | 0.03                | safe |
| C-D        | 0.03                | 0.03                | safe |
| D-E        | 0.07                | 0.04                | safe |
| E-F        | 0.05                | 0.06                | unsafe |
| F-G        | 0.07                | 0.08                | unsafe |
| G-H        | 0.10                | 0.06                | safe |
| A-I        | 0.12                | 0.04                | safe |
| I-J        | 0.04                | 0.02                | safe |
| J-K        | 0.07                | 0.03                | safe |
| K-L        | 0.14                | 0.03                | safe |
| L-M        | 0.25                | 0.04                | safe |
| N-O        | 0.04                | 0.03                | safe |
| O-P        | 0.35                | 0.08                | safe |
| P-Q        | 0.79                | 0.06                | safe |
| Q-R        | 0.30                | 0.02                | safe |
| R-S        | 0.17                | 0.05                | safe |

Based on results in Table 3, two channels are not secure, namely, channel E-F and F-G.

**8. Conclusion**

Based on the result, the physical condition of the drain in Gampong Keuramat is good, only E-F channel and F-G channel is not secure (where $Q_S < Q_T$) from thirty-four measurements. In this channel it requires slope repair and expansion of the channel dimension so that it can accelerate flow and not create puddles.

**References**

[1] Suripin, 2004. *Sistem Drainase Perkotaan yang Berkelanjutan*, Penerbit Andi, Yogyakarta
[2] Hendrasarie, N. 2005. *Evaluasi banjir pada area drainase Kali Kepiting dan Kali Kenjeran Surabaya Timur*. J. Rekayasa Perencanaan 2(1):1-17
[3] Triatmojo, 1998. *Hidrologi Terapan*, Yogyakarta
[4] Chow, V. T, 1989. *Hidrolika Saluran Terbuka*. Terjemah Suyetman, dkk, Penerbit Erlangga, Jakarta.
[5] Wesli. 2008. *DrainasePerkotaan*, GrahaIlmu, Yogyakarta
[6] Data Curah Hujan Banda Aceh, 2015
[7] Data Penduduk Banda Aceh, 2012.

**Acknowledgments**

This research was supported by Universitas Muhammadiyah Aceh. We appreciate and thank to all colleagues and all those who have contributed from research conducted until this paper was published.