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Drainage Network System of Sekaran Village, Gunungpati District, Semarang City

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Abstract. Drainage functions to drain, deplete, remove or transport water. Generally, drainage is defined as a series of water facility used to reduce and/or remove excess water from an area or land, so that the land can be functioned optimally. Drainage is also realized as an effort to control the quality of groundwater in relation to salinity. The case study was carried on in Sekaran Village, Gunungpati District, Semarang City. The area size of Sekaran Village is 6,21 km^2. According to the writing method, the author used tools and materials required in this research. The tools used were a roll meter and Arcmap software as a medium for data-processing, and the materials taken was data regarding information about the condition of Sekaran Village in the extent of topographic maps, rainfall data. The method of data calculation used manual calculations in accordance with the rational method to figure out the rain discharge, and the manning formula for channel flowrate. The numbers of design rainfall for 5 years and 10 years was 169,365 mm and 171,502 mm; while the design discharge with return period of 5 and 10 years, for example, in channel 1 was branch 1 was of 0,6772 m^3/s and the main channel was 5,7910 m^3/s; The economic channel dimensions for the main channels 1 and 4 were the base width B = 1,596 m ≈ 1.6 m and the water height h = 0,796 m ≈ 8 0,8 m, the cross section was square.

Keywords : drainage system, rainfall, discharge, Sekaran, gunungpati.

INTRODUCTION

Drainage has several functions such as to drain, deplete, remove or divert water [1]. In general, drainage can be defined as one of engineering measures to diminish the excess water from rain, runoffs, or exceeding irrigation water of an area or land [1]. Drainage is required in urban or developed areas because stormwater must drain properly to keep out flooding and infrastructure damage [2].

The changes of land use in the Gunungpati area were caused by an increase in the number of residence due to the relocation of the Universitas Negeri Semarang campus to Sekaran sub-district. These changes resulted in an increase in surface runoff in the Gunungpati area, especially in the Sekaran sub-district. The change of land use in Gunungpati in 1994 until 2008 has been studied and the residence area increased approximately 21.84% [3]. The effect of land use change can increase flood discharge. Therefore, the dimension of drainage must be changed. This study is aimed to review the dimension of drainage caused by the new condition of land use in Sekaran in 2018. The return period used in this study is 10 years.

STUDY AREA

The study area was conducted in the area of Sub District of Sekaran, Gunungpati District, Semarang (see figure 1). The location has an area approximately 6.21 km^2.

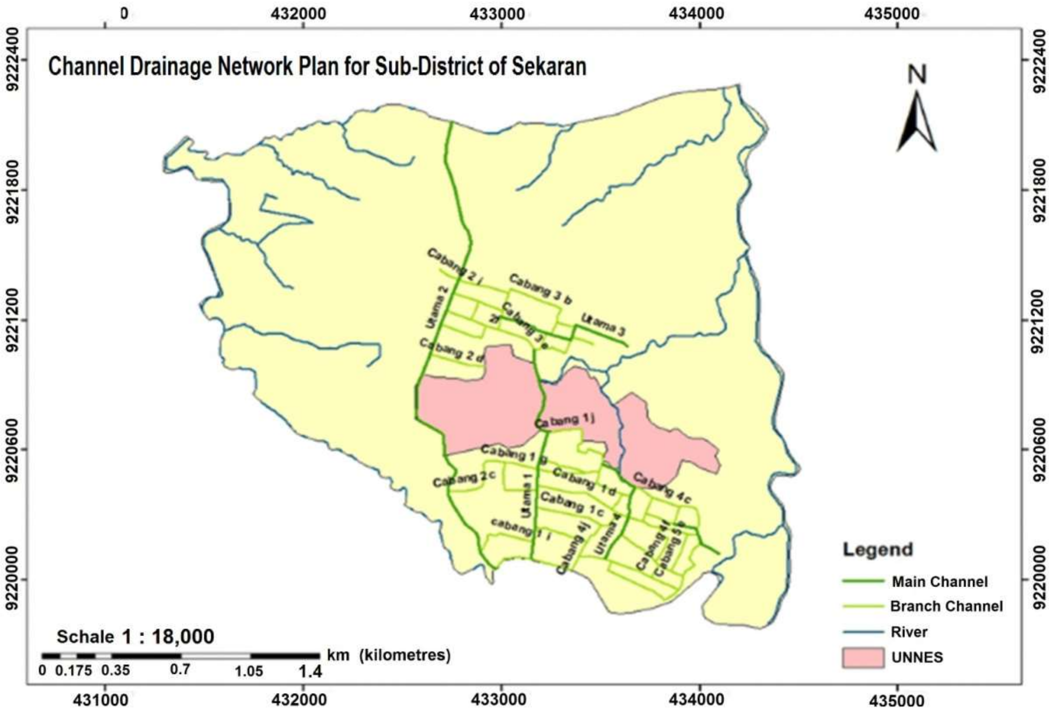

FIGURE 1. Site location and drainage system in study area

RAINFALL ANALYSIS

The rainfall data used in this study was rainfall data for 10 years long, ranging from 2008 to 2017. The rainfall data was the daily maximum annual rainfall. Rainfall data was obtained from Mijen, Ngaliyan, and Gunungpati Rainfall Stations located around the Kaligarang River watershed. Data can be seen below in Table 1:

TABLE 1. Daily maximum rainfall

	Maximum Rainfall		
Year	**Gunungpati**	**Mijen**	**Ngaliyan**
	CH Max	**CH Max**	**CH Max**
2008	102	118	84
2009	156	162	165
2010	155	172	205
2011	158	172	107
2012	184	247	133
2013	171	214	175
2014	155	210	131
2015	161	180	1.9
2016	171	186	139
2017	154	193	120

The average of rainfall over a catchment was obtained by the thiessen polygon method [1], [4]–[6]. Table 1 shows the data on point rainfall recorded in all three rain stations during 2008 to 2017. The boundaries and the affected area based on thre rainfall stations (Gunungpati, Mijen and Ngaliyan). All of the rainfall stations are located outside of the catchment area. Analysis of thiessen polygon is performed by using ArcMap to figure out the area from the polygon station area. Just two rainfall stations were affected in the thiessen polygon (Gunungpati and Ngaliyan) see figure 2. Thiessen coefficient and affected area can be seen in table 2.

Table 2. Rain station affected area

Rain Station	Affected area (km²)	Thiessen Coefficient
Gunungpati	4.669	75
Ngaliyan	1.549	25
Jumlah	6.218	100

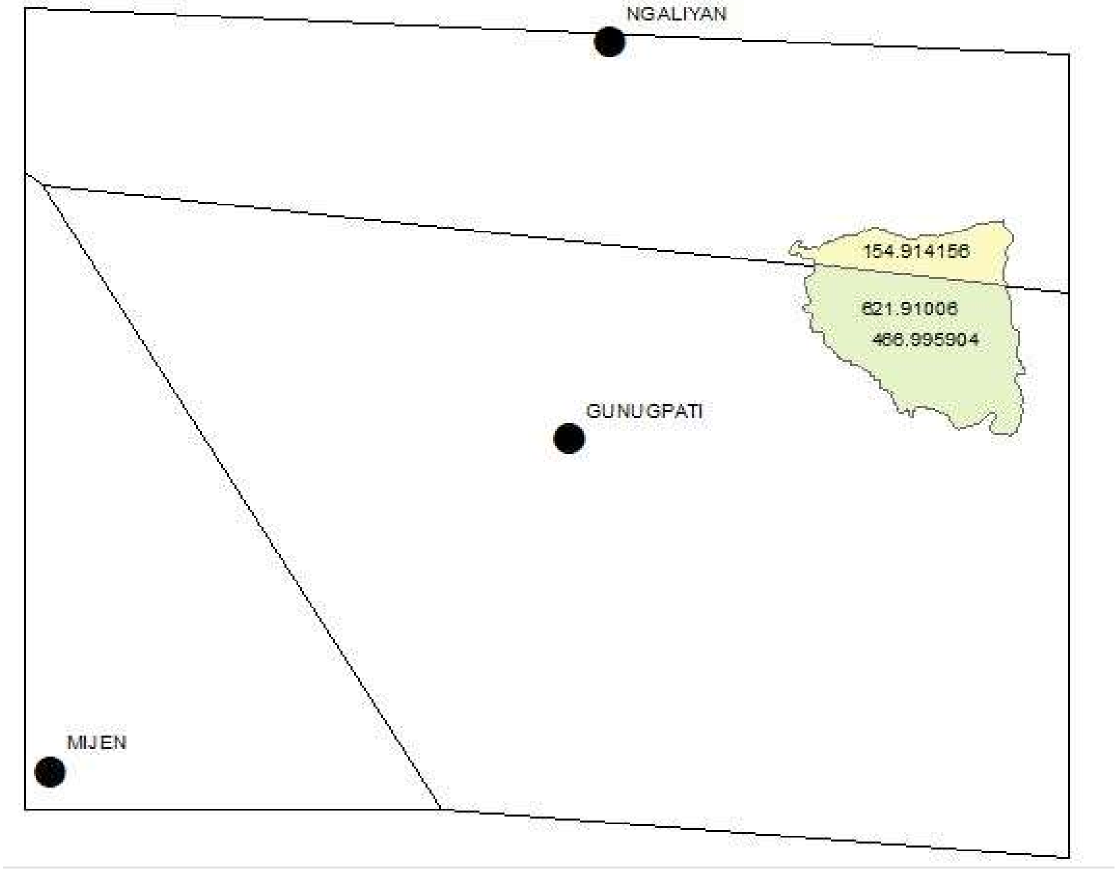

FIGURE 2. Polygon Thiessen affected area

Based on the Thiessen's Polygon, example of calculations of the area rainfall in 2008 can be seen as follows:

$$P = \frac{P_1A_1+P_2A_2+P_3A_3+\ \dots\ +P_nA_n}{n} = \sum_{i=1}^{i=n} P_iA_i$$

$$P = \frac{(102\ .4.669)+(84\ .1.549)}{6.218}$$

$P = 97.515$ mm

The complete result of mean rainfall in each year between 2008 - 2017 can be seen in table 3.

TABLE 3. Mean rainfall based on Thiessen polygon

Year	Gunungpati St.	Ngaliyan St.	P (mm)
2008	102	84	97.5159
2009	156	165	158.2420
2010	155	205	167.4558
2011	158	107	145.2951
2012	184	133	171.2951
2013	171	175	171.9965
2014	155	131	149.0212
2015	161	109	148.0460
2016	171	139	163.0283
2017	154	120	145.5301

FREQUENCY ANALYSIS

Based on distribution test, the proper distribution to use in the frequency analysis are Log Pearson III. The goodness of fit test used in selection of probability distribution [7]. Statistical analysis was used to find the average, standard deviation and skewness coefficient. The results can be seen in Table 4.

TABLE 4. Statistical Analysis

Maximum Rainfall in **Logarithmic**					
No	**R (mm)**	**Y = Log X**	**(Log Xi -Log X)**	**(Log Xi -Log x)^2**	**(Log Xi -Log X)^3**
1	97.52	1.99	-0.1872	0.0350	-0.0066
2	158.24	2.20	0.0231	0.0005	0.0000
3	167.46	2.22	0.0476	0.0023	0.0001
4	145.30	2.16	-0.0140	0.0002	0.0000
5	171.30	2.23	0.0575	0.0033	0.0002
6	172.00	2.24	0.0593	0.0035	0.0002
7	149.02	2.17	-0.0030	0.0000	0.0000
8	148.05	2.17	-0.0059	0.0000	0.0000
9	163.03	2.21	0.0360	0.0013	0.0000
10	145.53	2.16	-0.0133	0.0002	0.0000
Total	1517.4260	21.76	0.0000	0.0464	-0.0060

$Y = \overline{Y} + Kt\ x\ S$ then equation becomes log X = $\overline{\log(X)} + K(\overline{Sxlog(X)})$

$\overline{Y}$ = average count value Y or $\overline{\log(X)}$ = $\sqrt{\frac{\sum \log(X)}{n}}$ = 2.17

Standard Deviation (S)

$$S = \sqrt{\frac{\sum(\log(X) - \overline{\log(X)})^2}{n-1}}$$

$$= 0.0718$$

Skewness Coefficient (Cs)

$$Cs = \frac{\sum(\log(X) - \overline{\log(X)})^3}{(n-1)(n-2)(\overline{Sxlog(X)})^3}$$

= -2.2534 figured out the value of *K* from (Table *K*) through interpolation.

TIME OF CONCENTRATION

Time of concentration of Sekaran catchment area can be calculated by applying equation formulated by Kirpich[1], where in the case, rain duration was assumed to be equal to the time of concentration. As an instance for calculation in Branch Channel 1 in Main Channel 1 (Cabang 1 Channel in Utama 1) Channel shows in Figure 1):

L = 1397 meter

$So = \frac{H}{L} = 0.01789$

$$tc = \left(\frac{0.87 \, . \, L^2}{1000 \, . \, So}\right)^{0.385}$$

$$tc = \left(\frac{0.87 \, . \, L^2}{1000 \, . \, 0.01789}\right)^{0.385}$$

$tc = 0.4$ hour

RAINFALL INTENSITY

After obtaining *tc* (time of concentration) or rain duration in each channel segment then the calculation of rain intensity was carried out accordingly. Analysis of rainfall intensity was conducted based on Mononobe equation [5]. Rainfall intensity for 10 years period can be calculated as follows:

$$I_{10} = \frac{R^{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}}$$

$$I_{10} = \frac{171.502}{24}\left(\frac{24}{0.453}\right)^{\frac{2}{3}}$$

$I_{10} = 100.6590$ mm/hour

PEAK DISCHARGE ANALYSIS

Runoff Coefficient

The land use situation in Sub District of Sekaran includes roofs, asphalt roads and open space with runoff coefficient shows in the Table 5. The catchment area was heavily influenced by the conditions of existing land or ground.

Table 5. Runoff Coefficient [1]

Compositions	C
Roofs	0.95
Asphalt Roads	0.7
Open space	0.25

Below are the figure of runoff areas and runoff coefficient in the study area. The catchment area in this study was divided in to several zones. Each zone was defined according to runoff area size determined based on land use of the study area and adjacent areas. Where each channel segment is figured out, finding out the overland runoff area burdening the width of the channel using ArcMap software. Finding out the value of *C* combination (C_{comb}) for every zone from each channel segment in catchment area. For *n* channel segments, calculation can be expressed in to an equation as shown in Main Channel 1 (see figure 1) as follows:

$$C_{\text{comb}} = \frac{\Sigma_{i=1}^{n}{}_{\text{i}}C_i A_{\text{i}_i}}{\Sigma_{i=1}^{n} A_{\text{i}_i}}$$

$$C_{\text{comb}} = \frac{(200730.6\ .\ 0.25)+(161691.8\ .\ 0.95)+(4720\ .\ 0.70)}{367142{,}4}$$

$$C_{\text{comb}} = 0.5641$$

Discharge of Rational Method

To calculate the hydrology discharge for each channel segment, 10-year return period was used for the main channel with the example of the main channel 1 using the following equation:

$Q = 0{,}002778\ C\ .I.A$

$Q = 0{,}002778\ .0.564\ .100.6590\ .36.714$

$Q = 5.7910$ m³/second

DRAINAGE DIMENSION

The Most Economical Square-shaped Cross-section

By identifying runoff discharge in each channel, it came up with an economical square-shaped channel dimension according an equation as shown below:

$$\left.\begin{array}{r} A = B.h \\ P = B + 2h \end{array}\right\} R = \frac{h}{2}$$

A square-shape channel dimension also shows an economical advantage related to very steepness existing topographical condition and land acquisition cost. Calculation of drainage capacity in main channel 1 is shown below

Q = 5.7910 (in main drainage 1 with the most interference)

Q = 2.8995 (for left and right channel)

n = 0.015 (concrete)

S plan (Is) = 4/1000 = 0.004

$Q = A\ V$

$$Q = B\ .h\ .\tfrac{1}{n}\ .\left(\tfrac{h}{2}\right)^{\frac{2}{3}}.S^{\frac{1}{2}}$$

$$2.8995\ = 2h\ .h\ .\frac{1}{0.015}\ .\left(\frac{h}{2}\right)^{\frac{2}{3}}\ .0.004^{\frac{1}{2}}$$

$$2.8995\ = 2h\ .h\ .66.667\ .\left(\frac{h}{2}\right)^{\frac{2}{3}}\ .0.0632$$

$$2.8995\ = 2h^2\ .\left(\frac{h}{2}\right)^{\frac{2}{3}}\ .\ 4.213$$

$$\frac{2.8995}{4.213} = 2h^2\ .\ \frac{h^{2/3}}{1.587}$$

$$0.6872 = 1.260\ .\ h^{\frac{8}{3}}$$

$$\frac{0.6872}{1.260} = h^{\frac{8}{3}}$$

$$h^{\frac{8}{3}} = 0.545$$

$$h^{\frac{8}{3}} = \sqrt[8/3]{0.545}$$

$h = 0.796 \approx 0.8$

Find out the base width of channel (B)

$B = 2h$

$B = 2 \,.\, 0.796$

$B = 1.592 \approx 1.6$

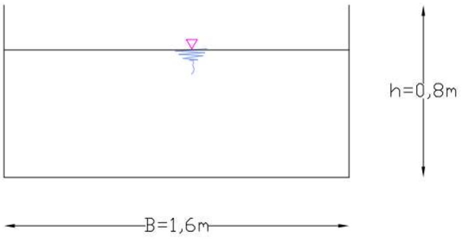

FIGURE 3. Dimensions of Main Channel 1

Therefore, the economical, square-shaped channel dimensions for the Main Channels 1 and 4 were designed with the base width B = 1.6 m length and the water height h = 0.8 m height.

CONCLUSIONS

The size of design rainfall for return period of 10 years is 171.502 mm. Design of discharge for return period of 10 years, as an instance in Main Channel 1, was 5.7910 m³/s, while the existing channel discharge in channel 1 (= Main Channel 1) was 4.964 m³/s. The economical channel dimension for Main Channel 1 was base width B = 1.596 m ≈ 1.6 m and water height h = 0.796 m ≈ 0.8 m.

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