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ANALYSIS OF INFILTRATION WELLS AS PRO-CONSERVATION DRAINAGE

(Case Study of Kalongan, Maguwoharjo, Depok, Sleman, Yogyakarta)

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ABSTRACT

Indonesia has two seasons, namely the dry season and the rainy season where the rainfall in the two seasons has a very large difference. Rainfall in the rainy season will be a source of groundwater reserves, because in the dry season there tends to be no rain. Efforts to increase groundwater reserves are carried out, among others, to use environmentally friendly drainage, namely by using infiltration wells and water will be infiltrated so as to reduce runoff. This research will begin by mapping the land covered by buildings in Kalongan and then calculating the area of land covered by the buildings. Rainfall data used is data at the Maguwoharjo rain station which is close to Kalongan with a span of 10 years. The number of infiltration wells currently available is 8 and by analyzing the needs of infiltration wells it will be known how many infiltration wells are needed so that as much water can be infiltrated to reduce runoff and increase groundwater reserves.

The results of the frequency analysis for rainfall with a maximum return period of 5 years as a basis for planning infiltration wells. This large runoff during the rainy season can be reduced by having sufficient infiltration wells, so that rainwater entering the infiltration well will become a source of groundwater reserves. The total requirement for infiltration wells is 464 pieces with a diameter of 80 cm and a depth of 3 m. There are 8 infiltration wells so it is necessary to make 456 infiltration wells to reduce runoff.

Keyword: *groundwater, infiltration, runoff*

I. INTRODUCTION

Water is a very important need for every living thing, without water living things can die. Humans generally use groundwater to obtain clean water and are used for various purposes of life. Rapid human growth will require large amounts of water, especially groundwater so that it can cause serious problems. Groundwater problems have occurred in Indonesia, especially during the dry season. Indonesia which has 2 seasons and between the dry season and the rainy season has a very large difference in rainfall so that it will affect ground water reserves. Most regions in Indonesia experience this, as well as in the Special Region of Yogyakarta.

Kalongan, Maguwoharjo Depok Sleman is an area located in the southern area of Mount Merapi, Yogyakarta. This area is located north of Adisutjipto Airport and south of Jl. Yogyakarta - Solo. The condition of ground water in Kalongan has decreased compared to the condition 15 years ago. This condition can be seen from the water level in the well which has decreased and the condition that is clearly experiencing a difference is the condition of the springs in the west of Kalongan which has experienced a very large decrease in discharge. The spring which 15 years ago was still used by residents for bathing needs (there are more than 5 bathrooms) and for washing now only drops of water entering the fish pond.

The decrease in the water flow from the springs and the lowering of the water level in the wells in Kalongan are signs that ground water reserves have decreased a lot. The rapid population development in Kalongan and also economic growth (hotels) can affect groundwater conditions. The large land that can absorb water is now covered by buildings, so the water that used to seep into the ground now mostly flows as surface runoff to the river next to the Kalongan.

Surface runoff in the rainy season is large due to land covered by this building, it is necessary to develop a method so that water can seep back, namely the pro-conservation drainage concept by using rainwater infiltration wells. The concept of pro-conservation drainage is very good because besides being able to reduce the dimensions of the channel, even if it is possible to eliminate drainage channels in the Kalongan, it is much more important as a function of groundwater conservation.

This research is to determine the number of rainwater infiltration wells needed due to land covered by buildings to reduce surface runoff

during the rainy season. The rain data used is rain data from the rain station closest to Kalongan.

II. LITERATURE REVIEW

Every inhabited area will need clean water for daily needs. Water is a vital need and the amount of water needed will be directly proportional to the number of people in a place. The increasing need for water will cause the amount of water in the soil to decrease and this has been felt by many regions in Indonesia. If the rainy season is big, if it is not managed to increase groundwater reserves, it will cause groundwater to decrease. According to Siswanto (2001) that quantitatively surface water is increasingly limited in availability and qualitatively it is decreasing. This will worsen the condition of the water especially the amount of water pollution. Groundwater conservation according to Danaryanto, et al in Riasika (2011) is an effort to protect and maintain the existence, condition, and environment of groundwater.

The significant hydrological impacts of urban development often occur in small watersheds. Prior to increased development, much of the rainfall falling in the valley would be subsurface runoff, aquifer filling or utilization into downstream flow networks. Urban development can literally change landscapes in small watersheds, unlike in larger watersheds where natural vegetation and soil are preserved (Christopher Konrad, 2003). This land conversion causes water that used to seep into surface runoff and if this gets bigger it can cause flooding in the downstream area.

Human activities are increasing due to the increasing flow of urbanization. The general effect of urbanization on the characteristics of a watershed is reduced infiltration into the soil and increased flow velocity. The effect of urbanization on the overall watershed response tends to increase the frequency of floods. Urbanization also affects water balance due to changes in drainage patterns (Wohl, 2000 in Mansell, 2003).

One of the environmentally sound drainage systems for controlling water, both for dealing with floods and droughts, is through infiltration wells. Infiltration wells are a force that increases the infiltration of rainwater into the ground and reduces surface runoff as a cause of flooding (Yasir Arafat, 2008). Infiltration wells are wells or holes on the ground surface that are used to collect rainwater so that it can seep into the ground. This infiltration well is the opposite of drinking water wells. Infiltration wells are used to enter water into

the ground, while drinking water wells raise groundwater to the surface (Kusnaedi, 2011).

Infiltration wells are made in the yard of each house with the number and dimensions according to the calculation. Water can be entered directly from gutters or water can fall in the yard and then flowed into infiltration wells. The infiltration well for the inlet road can be directly from the well cover or with construction from the side. All infiltration wells must be equipped with an 'air outlet' or water outlet with the aim of eliminating barriers to water entry due to pressure from the air flowing out (Sunjoto, 2016).

Parameter calculation is based on maximum daily rainfall data, at least the last 10 years data (Muttuqin, 2006). Frequency analysis or frequency distribution is used to obtain the probability of the planned rainfall in various return periods. The basis for calculating the frequency distribution is a parameter related to data analysis which includes the average, standard deviation, coefficient of variation and coefficient of skewness. Rain measurements are carried out for 24 hours, both manually and automatically, in this way it means that the rain that is known is the total rain that occurs for one day. Based on statistics, there are several types of frequency distributions that are widely used in the field of hydrology, namely Normal distribution, Log Normal distribution, Log Person III distribution and Gumbel distribution (Pongtuluran, 2017).

Calculating the incoming runoff discharge as a function of land area characteristics can use the rational method. The use of the rational method is very simple and is often used in urban drainage planning.

The runoff coefficient is determined based on the land use in the area concerned. The runoff coefficient value is determined subjectively and qualitatively. This depends on the observations of researchers. The determination of the value considers the density level for land use in the form of settlements and buildings. Open land and agricultural land consider the presence of vegetation, topography, and soil texture.

The basic concept of infiltration wells is essentially a drainage system where rainwater that falls on the roof is accommodated in a water absorption system. In contrast to the conventional method where rainwater is discharged / channeled into rivers and continues to the sea, this method drains rainwater from the roof through gutters and then

into infiltration wells made in the yard (Suripin, 2002).

This infiltration well is an empty well with the intention of having a large enough storage capacity before water seeps into the ground. With the reservoir, the rainwater has enough time to seep into the soil, so that the soil filling becomes optimal (Suripin, 2004).

Theoretically, the volume and efficiency of infiltration wells with circular views can be calculated based on the balance of water entering the well and water that seeps into the ground (Sunjoto, 2016).

III. METHODOLOGY

Location The research was conducted at Kalongan, Maguwoharjo, Depok, Sleman, Yogyakarta. The area of Dusun Kalongan is limited by:

1. North side : Jl. Admiral Adisutjipto
2. West : River
3. South side: Railroad (TNI AU Adisutjipto Base)
4. East : Jl Marsma Dewanto

The image of the research location can be seen in Figure 4.1.



Figure 1. Research Locations in Kalongan Maguwoharjo

The stages of the research are divided into several stages, namely as follows:

1. Data Collection

a. Rainfall data

This rainfall data is needed in determining the local rainfall intensity for the calculation of the planned discharge (Tamimi, 2015). Rainfall data used is rainfall data for 10 years. Rain station data was taken from the Maguwoharjo rain station/rain post which is located in the Kembang, Maguwoharjo, Depok, Sleman, Yogyakarta. The location and pictures of the Maguwoharjo rain station can be seen in Figure 2.



Figure 2. Location of the Maguwoharjo Rain Post in Kembang

b. Kalongan Situation Map

Map of the situation in the Kalongan using Google Earth Pro and AutoCad applications. This situation map is to determine the area of land covered by buildings and the location of existing infiltration wells. The results of this map are to determine the area of land covered by buildings, the area of the road with pavement and the number of infiltration wells. The situation map of Kalongan can be seen in Figure 3.

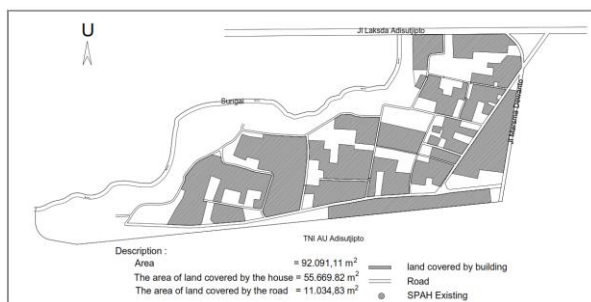


Figure 3. Map situation in Kalongan

Based on Figure 3 the total area of land covered by buildings is 66,704.65 m² and the number of infiltration wells is 8 pieces.

c. Permeability Value Data

Soil conditions in the Sleman area are almost the same, namely the type of regosol soil. Regosol soil is a coarse-grained soil and comes from volcanic material. The soil in the research location is also regosol soil type (sand texture). Map of soil types in Yogyakarta City, Sleman Regency and Bantul Regency can be seen in Figure 4.

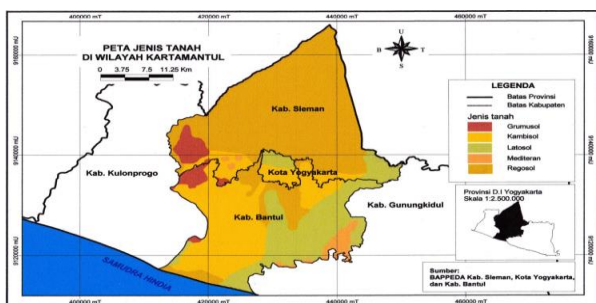


Figure 4. Map of Soil Types in Kartamantul . Region

Soil permeability values for soil types can be seen in Figure 5 below.

Table 1. Soil Permeability Coefficient Value

Type of soil	Texture	Permeability Coefficient (cm/s)	Classification
Grumusol	clay	10 ⁻⁶ – 10 ⁻⁹	very slow
Kambisol	clay/dusty	5x10 ⁻⁴ – 10 ⁻⁵	slow – medium
Latosol	clay	10 ⁻⁶ – 10 ⁻⁹	very slow
Mediteran	loamy	5x10 ⁻⁴ – 10 ⁻⁵	slow – medium
Regosol	sand	1 – 10 ⁻²	fast

Based on the results of the data analysis presented in Table 1, the permeability value of the regosol soil at the research site is 1-10⁻² cm/s (Sustanugraha, 2012).

2. Data Analysis

a. Hydrological Analysis

Hydrological analysis is carried out to obtain the intensity of rainfall, as the basis for calculating the planned discharge in an area to determine the planning of infiltration wells. The following steps are carried out in a hydrological analysis:

1) Frequency Analysis

Rainfall data is processed through frequency analysis with the best method, namely the Normal, Log-Normal, Gumbel and Log-Pearson III distribution methods. Then the suitability was tested using the Smirnov-Kolmogorov Test and the Chi-Square Test.

2) Analysis of planned rainfall

Calculation of planned rainfall using the best distribution method that has been determined in the frequency analysis.

3) Rain intensity analysis

The results of the analysis of rainfall intensity are used as the main data in the infiltration well analysis. This data is in the form of hourly rainfall data. If the daily rainfall data, then to calculate the intensity of rainfall is calculated by the Mononobe formula (Suripin, 2004).

b. Permeability Coefficient Calculation

This calculation is carried out to obtain the value of soil permeability which will later function as a parameter for calculating the volume of infiltration.

c. Infiltration Well Hydraulic Analysis

After getting the data from the hydrological analysis and the calculation of the permeability coefficient, the next step is to plan the dimensions of the infiltration well.

IV. RESULT AND DISCUSSION

Image analysis and interpretation using Google Earth created in the AutoCad program obtained the area of land covered by land as shown in Figure 3. Areas in the form of roads, houses and yards covered with concrete/paving are assumed to be land covered by buildings which are included in the classification of concrete/asphalt roads. Land in the form of land such as gardens, yards of soil and also dirt roads is assumed to be land that is able to absorb water with a sandy soil classification of land with a slope of > 7%. Based on Figure 3 the total area of land covered by buildings (classification of concrete/asphalt roads) is 66,704.65 m² and land classified as sandy soil with a slope of > 7% is 25,386.46 m². There are 8 infiltration wells that have been built in Kalongan with a diameter of 80 cm and a depth of 3 m.

Frequency analysis is an analysis of the repetition of an event data to determine the return period and its probability. To determine the suitability of the frequency distribution of the sample data to the probability distribution function which is expected to describe or represent the frequency distribution, it is necessary to test several methods as parameters. Frequency analysis is used to determine the amount of design rain (Pongtulan, 2017).

The rainfall used in this research is from the Post of the Kembang Maguwoharjo Rain Station. The data used in this study uses secondary data from the P3BA Sleman Service with 10 years of data, from 2002 to 2011. The distance from the research location to the Kembang Rain Station is about 200 m so that the rain data is quite representative at the research location.

The maximum annual rainfall at the Kembang Maguwoharjo Rain Station Post can be seen in Table 2 below.

Table 2. Annual Maximum Rainfall Post Rain Flower Station

No.	Year	Maximum Daily Rain (mm)
1	2002	80
2	2003	196
3	2004	116
4	2005	145
5	2006	95
6	2007	157
7	2008	68

8	2009	98
9	2010	105
10	2011	128

In addition to data loss or damage, there are still errors in the form of data inconsistency. The nature of this data needs attention to obtain good analysis results. Inconsistent rain data can occur for several reasons (Harto, 1993). The RAPS (Rescaled Adjusted Partial Sums) method is used to test the discrepancy between data within the station itself by detecting a shift in the mean value. The consistency of the rain data is indicated by the cumulative value of its deviation from the average value. The results of the compatibility test can be seen in Table 3 below.

Table 3. Data Consistency Test Results

No	Year	Rainfall	Sk*	Cumulative	Dy	Sk**	Sk**
1	2002	80	-38.80	-38.80	38.692	-1.00	1.00
2	2003	196	77.20	38.40	38.692	0.99	-0.99
3	2004	116	-2.80	35.60	38.692	0.92	-0.92
4	2005	145	26.20	61.80	38.692	1.60	-1.60
5	2006	95	-23.80	38.00	38.692	0.98	-0.98
6	2007	157	38.20	76.20	38.692	1.97	-1.97
7	2008	68	-50.80	25.40	38.692	0.66	-0.66
8	2009	98	-20.80	4.60	38.692	0.12	-0.12
9	2010	105	-13.80	-9.20	38.692	-0.24	0.24
10	2011	128	9.20	0.00	38.692	0.00	0.00
Total		1188			386.919		
Xr (Average)		118.80			38.692		
Discription				OK			

$$\begin{aligned}
 Sk^{**} \text{ maks} &= 1.97 \\
 Sk^{**} \text{ min} &= -1.00 \\
 Q &= |Sk^{**}| \text{ maks} \\
 &= 1.00 \\
 R &= Sk^{**} \text{ maks} - Sk^{**} \\
 &= 1.97 - (-1.00) \\
 &= 2.97 \\
 Q/\sqrt{n} &= 1 / \sqrt{10} \\
 &= 0.32 < 1,42 \quad \text{OK} \\
 R/\sqrt{n} &= 2.97 / \sqrt{10} \\
 &= 0.94 < 1,60 \quad \text{OK}
 \end{aligned}$$

Based on Table 3, the data at the Kembang Maguwoharjo Rain Station Post is consistent so that it can be used in this study.

Design rainfall analysis can be done by several methods. The rainfall frequency distribution method according to the probability used is normal, Log Normal, Gumbel and Log Person III. The results of the design rain calculations can be seen in Table 4.

Table 4. Results of Frequency Analysis

P(x >= X _m) T	Repeat	Rainfall Characteristics According to Probability							
		NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
		X _T	K _T	X _T	K _T	X _T	K _T	X _T	K _T
0.9	1.1	69.214	-1.282	75.246	-1.126	76.226	-1.100	75.583	-1.268
0.5	2.	118.800	0.000	113.421	-0.139	112.444	-0.164	112.679	-0.020
0.2	5.	151.364	0.842	148.500	0.768	146.637	0.719	148.187	0.835
0.1	10.	168.386	1.282	170.963	1.348	169.276	1.305	171.642	1.294
0.04	25.	186.537	1.751	198.673	2.064	197.881	2.044	201.336	1.792
0.02	50.	198.264	2.054	218.918	2.588	219.101	2.592	223.551	2.119
0.01	100.	208.811	2.326	238.885	3.104	240.165	3.137	245.884	2.417
0.001	1,000.	238.367	3.090	305.079	4.814	309.766	4.936	322.835	3.267

Discription : 1. $X_T = m + K_T * s$

2. According to the Chi-Square Test, it is best to use the LOG-NORMAL distribution

3. Meanwhile, according to the Smirnov-Kolmogorov test, it is best to use the LOG-NORMAL distribution

4. The calculations were carried out using the formulas in the book 'Applied Hydrology', 1988, Ven Te Chow, et. al.

Source: Soft file calculation from Djoko Luknanto

According to the Chi Square and Smirnov-Kolmogorov data consistency tests, the best method of rainfall frequency distribution is using the Log-Normal distribution.

Design rainfall is the largest annual rainfall with a certain probability or rain with a certain probability period. The amount of rain intensity varies depending on the duration of the rain and the frequency of its occurrence. The rainfall intensity of the study area design was obtained by calculation using the Mononobe formula with a return period of 2 years, 5 years, 10 years and 25 years. The return period used in this study was 5 years which was taken from the results of frequency analysis.

Rain intensity was calculated using the Hasper equation (1951) with the duration of the dominant rain in the Sleman area being 1.5 hours and R^{24j} being 148.5 mm/day.

$$\frac{R^{24j}}{T} = 0,06 \times \left\{ T + 60 - 0,0008 \times \frac{(120 - T)^2}{60} \times (260 - R^{24j}) \right\} \quad (1)$$

where :

R^{24j} = the biggest rainfall in 24 hours (mm/day)

I = Rain intensity ($m^3/s/km^2$)

T = duration of rain (minutes)

The results of calculations using the Hasper equation (1951) obtained the value of rainfall intensity of $16.65 m^3/s/km^2$.

Rain intensity is then converted to m/hours with the following equation.

$$I(m^3/s/km^2) = \frac{10.000}{36} \times I(m/j) \quad (2)$$

The results of the conversion obtained an intensity of 0.059 m/hours.

The average runoff coefficient is usually used because the catchment area consists of a single land use with varying extents. The rational method assumes that all land uses that include a catchment area are uniformly distributed throughout the area. The more pavement buildings in the area, the higher the coefficient value of the area.

Conditions at the research site are divided into 2 classifications, namely:

1. Classification of concrete/asphalt roads (runoff coefficient 0.95, area of 66,704.65 m^2) includes roads, houses and yards covered with concrete/paving.

2. Classification of sandy soil with a slope of > 7% (runoff coefficient 0.20, area of 25,386.46 m^2) which includes land in the form of soil such as gardens, soil courtyards and also dirt roads.

The combined coefficient can be calculated by the following equation.

$$C_{combined} = \frac{A1 * C1 + A2 * C2 + \dots + An * Cn}{A1 + A2 + \dots + An} \quad (3)$$

Based on the above equation, the combined coefficient at the research site is 0.74.

The dimensions of the infiltration well with a circular cross-section on the soil are all porous with impermeable walls and the bottom of the infiltration well is flat. The equation used to calculate the height of the infiltration well is the Sunyoto equation below.

$$H = \frac{Q}{FK} \left\{ 1 - \exp\left(\frac{-FKTd}{\pi R^2}\right) \right\} \quad (4)$$

$$Q = CIA \quad (5)$$

$$F = 2 \pi R \quad (6)$$

where:

H = water level in the well (m),

F = geometric factor of circular section (m),
Q = inlet water discharge (m³/hours),
T_d = dominant duration of rain(hours),
K = soil permeability coefficient (m/hours),
R = radius of the well (m).
C = Runoff coefficient
I = Rain intensity (m/hours)
A = area (m²)

The flow rate due to runoff and which will be infiltrated in the infiltration well is calculated by the equation.

$$Q = CIA$$

Based on the above equation, the discharge flowing into the infiltration well is 3912.03 m³/h.

The value of soil permeability at the research site is regosol soil (sand). The permeability value of regosol soil is 1-10⁻² cm/second (Sustanugraha, 2012). In this study, the value of permeability (K) = 0.8 cm/second (0.48 m/hour).

The height of the infiltration well required to absorb water as much as 3912.03 m³/hours is calculated by the equation.

$$H = \frac{Q}{FK} \left\{ 1 - \exp\left(\frac{-FKTd}{\pi R^2}\right) \right\}$$

Based on the above equation, the required infiltration well height is 1391.7 m.

The number of infiltration wells with a depth of 3 m needed for the entire area of Kalongan is :

$$1391.7 : 3 = 463.9 \text{ (464 infiltration wells)}$$

There are currently 8 infiltration wells in the Kalongan with a depth of 3 m. Based on the results of the need for infiltration wells, Kalongan still lacks 456 infiltration wells with a diameter of 80 cm and a depth of 3 m.

V. CONCLUSION

Based on the results of the study, it can be concluded that:

1. The need for infiltration wells with a diameter of 80 cm and a depth of 3 m is 464 pieces
2. Infiltration wells that need to be added are 456 pieces.

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