

Infiltration wells utilizing watershed conservation for flood prevention

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Infiltration wells utilizing watershed conservation for flood prevention

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Abstract. Rainfall is a determining factor in analyzing planned floods. This research was conducted by collecting secondary data and the field data concerning the soil's ability to infiltrate the volume of rainfall. Data processing is carried out by statistical analysis to estimate the average rainfall, intensity value, estimated discharge plan, volume of runoff and estimated infiltration rate. These parameters are important related to the infiltration well dimensions planning and the conserving water area. From the research results, it is shown that infiltration rate and optimal dimensions of infiltration wells very dependent on rainfall discharge and runoff volume in each region. Artificial infiltration is an alternative solution for maintaining groundwater balance and overcoming water problems. With groundwater infiltration, groundwater infiltration can maintain a relatively stable groundwater depth. Infiltration rate in RT 06 Cawang are 54,03 cm/hour lower than in Kelurahan 11 Cawang East Jakarta are 54,12 cm/hour, with perimeter area of wells DSP = 1,5 m², Depth of well (HSP) = -1,89 m² and coverage area of well (ASP) = 1,77 m².

1. Introduction

Rain in the hydrological cycle can be categorized in 3 (three) forms, namely run-off, base flow, and the lose water. Rainwater flow collected in the catchment area consisting of surface runoff and infiltration water into ground called groundwater. Surface run off is the part of water flow that flows on the ground surface and channels. Nowadays development in urban areas changing land use caused catchment area reducing. Previous zone that can be infiltrate rainwater have turned into area of settlement covered with impermeable materials such as housing, roads, shops and others. This condition influenced the volume of rainwater infiltrating the soil decreases when it rains. Thus, various environmental problems such as drought in the dry season and floods in the rainy season arised. The management system by conserving rainwater in ground surface that can be easily infiltrate into soils is an alternative solution to prevent floods. To determine the capacity of infiltration wells and reservoirs in conserving rainwater, tests were carried out by conducting field research [1-3].

The hydrological cycle starts when water moves from the sea to the air, then falls back to the earth's surface as rain or other forms of precipitation and finally flows back into the sea. This includes various forms of water which changes forms between liquid, solid, and gas state in the atmosphere. Initial study for hydrological aspect are needed to provide a valid data for research improvement [4-6]. Rain is the most observed climate element because it is closely related to the climate of an area and an important factor used in obtaining planned flood figures. The purpose of this research is to find alternative systems



for controlling and managing rainwater in order to conserve rainwater into the ground for flood prevention [7].

2. Methods

This research was conducted by collecting secondary data and the field data concerning the soil's capacity to infiltrate the volume of rainfall. The workflow for collecting field data consist of several sequence as follows:

- Making infiltration modeling using an infiltrometer to get infiltration power optimally, such as single ring infiltrometer
- Determining area designated as experimental location with certain type and surface characteristics, including the amount of rainfall (R_t), value of rain intensity (I), covered area (A), duration of rain (t), amount of infiltration power (f); and amount surface run off (Op) in Cawang, East Jakarta
- Collecting secondary data from Badan Pusat Statistik (BPS), East Jakarta

Processing data is base on data collected from field experiments as primary data and from other sources as secondary data. All data are processed into tabulations and grouped to see the relationship between one variable and another, such as the relationship between the amount of infiltration and surface characteristics of soil and infiltration time. The variables correlation is examined to observe rainfall variables such as rainfall intensity, soil surface characteristics, infiltration power and run-off capacity.

3. Results and discussions

The purpose of this study was to measure the capacity of infiltration wells to conserve some rainwater into the ground, in order to cut off the peak of rainwater runoff in heavy rainy season.

3.1. Research result

The results of research and analysis of data obtained from the field and data from other sources. This analysis will involve the variables that will be needed in the research discussion, such as: main data as secondary data obtained from existing sources, such as rainfall and catchment area. Besides the secondary data, primary data is obtained from the results of field experiments, such as infiltration power and water presentation that can be conserved into the soil. Then, the main and secondary data analyzed to get results in accordance with the objectives of the study and problem solving, and their direct contribution to researchers and the community. The results of this study were tested in tables and graphs and explanations in the form of research summaries.

3.2. Rain intensity

The occurrence of flooding is determined by the intensity of rain in the water catchment area and the capacity of the soil to conserve rainwater into it [8,9]. To determine the amount of rain intensity this formula is used and the rainfall intensity for flood return period of 2 years, 5 years, 10 years, 25 years, 50 years and 100 years shows in Figure 1:

$$I = \left(\frac{R_t}{24} \right) \times \left[\frac{24}{t} \right]^{2/3} \quad (1)$$

where: I = rain intensity (mm/hour)
 R_t = thickness of maximum daily rain (mm)
 t = length of rain (hours)

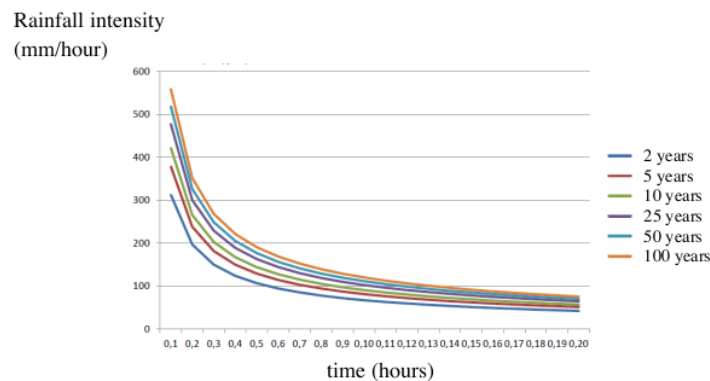


Figure 1. Rainfall intensity.

3.3. Infiltration power

The amount of infiltration power for each experimental location, can be seen from table Infiltration Rate data of Mayjen Sutoyo street, RT 06 and Kelurahan 11 Cawang, East Jakarta as follow:

Table 1. Rainfall water level difference.

Time (min)	Time (hours)	Water Level Difference (cm)	
		RT 06	Kelurahan 11 Cawang - East Jakarta
0	0,000	0,0	0,0
2	0,033	3,9	2,5
4	0,066	3,5	2,4
6	0,100	2,3	1,5
8	0,130	2,0	1,5
10	0,160	1,8	1,5

The formula used to calculate the infiltration capacity power in this test is Horton method [10] which states that the infiltration formula as follows:

$$f = f_c + (f_0 - f_c) \cdot e^{-kt} \quad (2)$$

Where: f = real infiltration rate (cm/min)
 f_0 = initial infiltration rate (cm/min)
 f_c = fixed infiltration rate (cm/min)
 k = geophysical constant
 e = natural number (2,718)

How to obtain the constant K value to complete the infiltration capacity curve equation, then the Horton equation is processed as follows:

$$f - f_c = (f_0 - f_c) \cdot e^{-kt}$$

$$\log(f - f_c) = \log(f_0 - f_c) - kt \log e$$

$$\log(f - f_c) - \log(f_0 - f_c) = -kt \log e$$

Hence,
$$t = \frac{1}{K \log e} \log(f - f_c) + \frac{1}{K \log e} \log(f_0 - f_c) \quad (3)$$

Using $y = m_x + c$; $y = t$; $m = -\frac{1}{K \log e}$; thus $K = \frac{-1}{m \log 2,718} = \frac{-1}{0,434 m}$ where m is gradient.

The result of infiltration power on field data shows in Table 2 and Table 3 as follow:

Table 2. Field data of infiltration power in RT 06 Cawang.

Time (hours)	Infiltration rate (cm/hr)	fc	f-fc (cm/hr)	Log f-fc
0,000	121,5	54	67,5	1,829
0,033	115,0	54	61,0	1,785
0,066	105,0	54	51,0	1,707
0,100	69,0	54	15,0	1,176
0,160	60,0	54	6,0	0,778
0,200	54,0	54	0,0	0,000

Table 3. Field data of infiltration power in Kelurahan 11 Cawang.

Time (hours)	Infiltration rate (cm/hr)	fc	f-fc (cm/hr)	Log f-fc
0,000	80	45	35	1,544
0,033	75	45	30	1,477
0,066	60	45	15	1,176
0,100	45	45	0	0
0,160	45	45	0	0
0,200	45	45	0	0

3.4. Watershed conservation area

Supply of groundwater sources in Cawang area are partly derived from shallow groundwater which source from rainwater infiltration and seepage such as rivers and reservoirs. Growth of developments in the DKI Jakarta tend to change land use and shifting area function to become impermeable zone. This results in the less rain water will seep into the ground. In the heavy rainy season, flooding disaster often occurs because of rainwater reaches the peak point of the channel without prior obstruction [11]. To solve this problem, it is necessary to study important data for planning. The data required are as follows (1) Discharge and rain volume in the catchment area (Q_p); (2) Infiltration power at each watershed location (f); (3) Capacity of all ground infiltration in the unit area of residential and settlement (A); (4) Volume of rainwater runoff related to determining dimensions of the rainwater collection container (V_p).

3.5. Rain discharge

Rain discharge of the flood return period based on Haspers the formula is used as follow:

$$r = \frac{t \times R_t}{t + 1 - 0,008(260 - R_t)(2 - t)^2} \quad (4)$$

$$q = \frac{r}{3,6 t} \quad (5)$$

$$Q = \alpha. \beta. q. F \quad (6)$$

Where: R_t = rainfall discharge (mm)
 q = periodic discharge
 Q = flood return period (mm^3/sec)

The result of rain discharge on field data shows in Table 4 as follow:

Table 4. Flood discharge return period based on haspers formulae.

Return period (year)	Rt (mm)	r	q	Q (m ³)
2	190,58	113,96	23,06	189,24
5	227,87	136,24	27,56	226,27
10	250,21	149,62	30,27	248,45
25	276,43	165,30	33,44	274,49
50	294,78	176,27	35,66	292,71
100	312,32	186,76	37,79	310,13

3.6. Surface Water Runoff

Field data shows that volume of Surface Water Run Off in Kelurahan 11 Cawang are higher than in RT 06, can be seen in Figure 2 as follow:

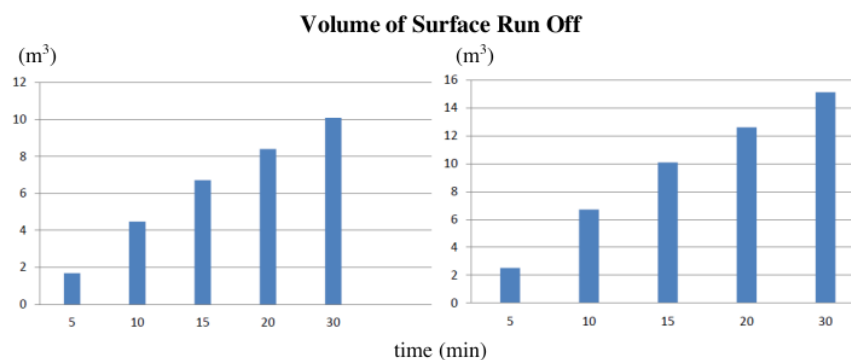


Figure 2. Surface water run off in RT 06 and Kelurahan 11 Cawang.

Maximum run off volume as basis planning for flood return period 2 years in RT 06 are 604,8 m²/min lower than 900,72 m²/min in Kelurahan 11 Cawang.

3.7. Discharge and infiltration power

Soil infiltration power is the capacity of a soil to pass water from the surface into the soil vertically. In order to determine the dimensions of the infiltration wells accurately, the results of the field data are important. To determine the appropriate dimensions of wells, field the data is collected from two location. In general, most of the water seep into the ground and some are expected to flow into wells. As a comparison, the catchment area is covered with impermeable material and the infiltration rate measured. Infiltration rate of wells is strongly influenced by the characteristics of the media [12]. Infiltration rate in RT 06 Cawang are 54,03 cm/hour lower than in Kelurahan 11 Cawang are 54,12 cm/hour, with perimeter area of wells $D_{SP} = 1,5 \text{ m}^2$, Depth of well (H_{SP}) = -1,89 m² and coverage area of well (A_{SP}) = 1,77 m².

4. Conclusion

Artificial infiltration is an alternative solution for maintaining groundwater balance and overcoming water problems. With groundwater infiltration, groundwater infiltration can maintain a relatively stable groundwater depth, at least it can reduce the criticality level of groundwater reserves while reducing the risk of flooding.

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