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DISTRIBUTION OF INFILTRATION WELLS FOR SURFACE RUNOFF CONTROL IN BANDUNG DISTRICT

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ABSTRACT

The purpose of this study was to analyze the volume of surface runoff in the watersheds, the smallest land unit, and the distribution of infiltration wells to accommodate the volume of rainfall in Bandung Regency. The experimental research method is related to the volume of rainfall that must be controlled in each watershed. Landcover area is known by utilizing Landsat 8 OLI imagery in 2020. The calculation of rainfall intensity is needed to get the volume of rain. Samples were analyzed based on built-up land in each watershed. The built area of the Ci Widey watershed is 23.36 km2 and the volume of rainfall and runoff is 680,243 m^3, built area of the Ci Sangkuy watershed is 20.05 km^2, and the volume is 583,860 m^3, the built area of the Ci Rasea watershed is 11.74 km^2 and the volume is 1.258,275 m^3, and a built area of the Ci Tarik watershed is 68.59 km^2 and the volume is 1.997,340 m3. On a land unit of 100 m^2, the volume of rainfall is 2,912 m^3 and the lowest is 0.284 m^3. Based on the land area of 100 m2, the distribution of the number of infiltration wells is Ci Widey 340, Ci Sangkuy 292, Ci Rasea 629, and Ci Tarik 999. Control of surface flow according to the volume of rainfall is inserted into infiltration wells that can accommodate a surface runoff volume of 2 m^3. With the availability of infiltration wells, the surface flow can be controlled.
***Keywords:** Landcover, built-up land, surface runoff, infiltration wells*

INTRODUCTION

Bandung Regency is located in the southern part of the Bandung Basin. The Bandung Basin consists of the City of Bandung, Cimahi, Bandung Regency, and West Bandung. Bandung Regency is fed by several rivers, namely; Ci Widey, Ci Sangkuy, Ci Rasea, and Ci Tarik. These 4 rivers empty into Citarum. To the north of the Bandung Basin flows Ci Kapundung, Ci Beureum, Ci Waruga, Cicadas, and Ci Pamokolan, all these rivers along with rivers from the southern part of the Bandung Basin empty into Ci Tarum. The impact of several rivers flowing into the upstream Ci Tarum caused the overflow of Ci Tarum and inundated areas in Bandung Regency, such as; Dayeuhkolot area, Baleendah, and Bojongsoang which is part of Bandung Regency. The development aims to improve the welfare and prosperity of the community because it will facilitate mobility. Infrastructure simultaneously affects economic growth significantly and has a positive effect (Gusnita W, 2019; Winey A.R and Siregar S, 2019). This development has an impact on the development of various fields, resulting in changes in land cover (Hanafi, 2018). The development is not only agricultural development, but the land is built. Development of built-up land such as;

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settlements, industry, social, and public facilities provide a sense of comfort and security for the community, but the negative impact of these developments causes the ground surface to become impermeable to water. The expansion of built-up land causes a decrease in the groundwater level (Noeraga M.A.A et al, 2020). The wider the use of built-up land, the greater the runoff volume (Jibran I et al, 2021). Rainfall in the built-up area becomes surface run-off streaming on the surface of the land and ending in the river because the soil is covered by impermeable layers or lacks dense vegetation and residential developments affect lawn infiltration rates and stormwater runoff (Iskandar D and Sugandi D, 2015; Sugandi D and Pascawijaya R, 2020; Woltemade C.J; 2010). The impermeable layer results in rainfall not absorbing into the soil, but flowing as surface runoff. To overcome the increase in surface runoff by including rainfall in infiltration wells, especially on built-up land. The results of the research through analysis of Landsat 8 imagery in 2020 regarding the area of built-up land are shown in Table 1.

Table 1. Area of Built-up Land in 4 Watersheds in Bandung Regency.

Land Use	Ci Widey		Ci Sangkuy		Ci Rasea		Ci Tarik		DAS	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Building	12.70	0.09	51.70	0.20	44.30	0.10	250.50	0.60	109.00	0.10
Residential Area	2306.10	8.50	1950.90	6.40	4245.70	11.60	6192.00	14.00	8529.20	9.0
Built-up Land	2318.80	8.59	2002.60	6.57	4290.00	11.70	6442.50	14.60	8638.20	10.78
Watershed Area	27006.37		30461.70		36666.66		44127.80		80160.80	

Source: Sugandi D, et. al, 2021.

Surface runoff increases due to built-up land, so the river's capacity is unable to accommodate and circulate air. Residential development affects surface runoff (Xu C et al, 2020). Although surface runoff does not only come from rivers flowing in Bandung Regency, the comes from Bandung City, Cimahi, and West Bandung. Therefore, in overcoming runoff, it is necessary to do areas located in the Bandung basin. Both rivers in the Bandung Basin flow in West Bandung Regency, Cimahi City, Bandung empties into Ci Tarum which is located in Bandung Regency. The expansion of the airtight layer leads to an increase in surface runoff.

The expansion of the airtight surface leads to reduced infiltration, decreased water supply, and surface runoff (Bela K.R, et al, 2019). The volume and runoff flow rate rapidly into areas with low morphology and cause flooding. Because of that. To overcome flooding by reducing runoff. Land use changes with land development followed by vegetation increases runoff. To reduce it by applying water conservation technology (Biopore and Infiltration Wells) (Rahardian A, and Buchori I, 2016). Reduction of runoff and runoff volume will reduce flood disasters. To overcome surface runoff, it is carried out on built-up land units with an area of every 100 m2. When it rains, the volume of rainfall is absorbed into infiltration wells. Rainfall that is accommodated in the infiltration well will percolate so that the water in the infiltration well will run out.

In making infiltration wells, it is necessary to consider a slope because a steep slope with a large volume of water will affect the occurrence of landslides. Slope affects accelerating surface flow so it will increase (Mujiyo, et al, 2021). This means that infiltration wells are only made on flat to gentle slopes. Meanwhile, land with steep to very steep slopes needs to be reforested with perennials and annuals. By absorbing rainfall in infiltration wells and reforestation in watersheds in Bandung Regency, it can reduce flood disasters and increase groundwater

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resources. Groundwater recharge is affected by forestry, largely due to the greater uptake of soil water by trees and to the increased water-holding capacity of forest soils, arising from higher organic contents (Scullion J.J et al). Conservation by increasing infiltration will raise the groundwater level. The decrease in volume and flow rate will automatically reduce floods, landslides, erosion, and drought, especially during the dry season.

Surface flow control is an effort to conserve groundwater to control flooding and increase water absorption (Jia et al., 2013). Because flooding is caused by an increase in surface runoff, the volume of runoff is not by the capacity of the river body. By controlling runoff in infiltration wells, surface runoff decreases and rainfall can be absorbed. Control of surface flow as needed, such as; Bioretention, Infiltration Wells, Vegetation Filter Land, Buffer Vegetation, Grass Canals, and Infiltration Channels (Budinetro et al, 2012). This infiltration is an effort to conserve groundwater. Therefore, to increase the supply of groundwater, it is necessary to absorb rainfall into the soil as groundwater storage during the rainy season. Infiltration is the process of permeating rainfall that functions in providing water for evaporation and transpiration, as well as the availability of opportunities to increase groundwater reserves (Sudarmanto A et al, 2013). The increase in surface runoff is caused by the construction of built-up land, so to overcome it, the rainfall needs to be absorbed on the built-up land by accommodating rainfall by channeling rainfall to the smallest land unit in infiltration wells.

Built-up land in the watershed in Bandung Regency continues to develop along with development so that surface flow control is based on the watershed and built-up area. Surface flow control can be controlled through infiltration wells. Thus, it is necessary to pay attention to surface flow control.

Based on groundwater conservation by controlling surface runoff, this study aims to (1) calculate the volume of runoff in the watershed in Bandung Regency; (2) calculate the volume of rainfall on the smallest land unit in the watershed in Bandung Regency; and (3) analyze the distribution of infiltration wells to accommodate the volume of rainfall in the watershed in Bandung Regency.

RESEARCH METHOD

The method used in this research is an experimental approach with spatial analysis because it relates to the volume of rainfall that must be controlled in each watershed, namely; Ci Widey, Ci Sangkur, Ci Tarik, and Ci Rasea which flow in Bandung Regency. The distribution of infiltration wells is based on the volume of rainfall in each watershed and built-up land. Analysis of built-up land is done by analyzing Landsat 8 OLI imagery in 2021.

To calculate the volume, the rainfall intensity is calculated by the formula:

$$I = h \; x \; w \quad (1)$$

I = Rain intensity
h = Precipitation rate (mm)
w = Time (hour)

The volume of rainfall is calculated by the formula:

$$V = t \; x \; k \quad (2)$$

V = Volume (m^3)
t = Precipitation rate (m)
k = Built-up Land Area (m^2)

RESULTS AND DISCUSSION

Results

1. Surface Flow Volume

The impact of the large runoff is the overflow of the river flow. The large surface runoff is caused by rainfall that does not absorb into the ground. Less pervasive rainfall due to changes in soil function. Changes in the function of the land due to the land surface being watertight because it was built for the benefit of roads, settlements, industry, and public facilities. Residential area development must be stopped, it is necessary to consider efforts to control the impact of non-pervasive rainfall. The volume of runoff is calculated from the thickness of the rainfall times the area so that the volume of runoff is known. Rainfall on non-built land will partially absorb into the soil, while on built-up land it has the potential to become surface runoff. The monthly rainfall volume in Bandung Regency is shown below in Table 2.

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Table 2. Monthly Rainfall Volume in Bandung Regency

Years	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Ags	Sep	Oct	Nov	Dec
2010	264.7	223.6	403.7	172.9	219.4	41	59.1	54.3	163.4	147.4	374.6	244.7
2011	27.7	70.7	123.5	197.5	158.8	43.7	24.4	0	1.4	10.3	0	0
2012	159.9	207.1	143.3	140.9	64.5	67.9	0	1	21.4	60.2	302	591.3
2013	261.3	204.3	325.3	302.5	178.7	139.1	107.9	4.6	5.7	27.6	167.7	425.2
2014	226.5	138.2	415.9	308.3	35.3	128	62.8	13.4	2.5	21.6	197.3	477.2
2015	240.5	368.9	282.4	218.1	61.9	26.4	0	0	2	9.6	210.2	334.6
2016	191.4	441.5	446.5	175.1	119.8	152.7	141.9	57.6	230.3	521	400.4	192.7
2017	118.8	170.6	435.3	205.5	42.6	38.7	38.1	6.1	59	231	538.2	242.1
2018	142.6	287.3	380.5	167.8	59.6	10.4	2	4.9	2.5	56.4	332.6	310.4
2019	116.1	378.1	293.1	347.1	67	0	4	0	0	28.1	98	205.4
Mean (mm)	175	249	324.9	223.6	100.8	64.8	44	14.2	48.8	111.3	262.1	302.4
Day rainfall	17	18	18	16	14	9	7	5	5	6	9	13
Depth rain (mm)	10.29	13.83	18.05	13.98	7.2	7.2	6.29	2.84	9.76	18.55	29.12	23.26
Depth rain (m)	0.01029	0.01383	0.01805	0.01398	0.0072	0.0072	0.00629	0.00284	0.00976	0.01855	0.02912	0.02326
Area (Km^2)							10,589					
Rain intensity mm/hour	0.43	0.58	0.75	0.58	0.3	0.3	0.26	0.12	0.41	0.77	1.21	0.97
Volume rainfall (m^3)	108,960.81	146,445.87	191,131.45	148,034.22	76,240.80	76,240.80	66,604.81	30,072.76	103,348.64	196,425.95	308,351.68	246,300.14

Source: BBWS Ci Tarum, 2021

The rainfall that occurs is the potential for surface runoff. A naturally formed river will form a river body with a flow capacity. With the expansion of built-up land, it will increase the volume of flow, so that the discharge and volume of runoff exceed the capacity of the river and will cause the river to overflow. The expansion of built-up land without considering the impact on rainfall infiltration affects the infiltration process by increasing surface runoff. To control runoff, it is necessary to analyze the surface flow of the watersheds that flow in Bandung Regency, because the watershed is a drainage system, where the flow will flow in other river networks, except where it empties into the main river. The watersheds in Bandung Regency flow and empty into Ci Tarum, so Ci Tarum overflows every rainy season.

The results of the research in 2021 about the land cover of 4 watersheds in Bandung Regency are shown in Table 3.

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Table 3. Area of Landuse in Bandung Regency

Landuse	Ci Widey		Ci Sangkuy		Ci Rasea		Ci Tarik		Total	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Pond	0.56	0.27	2.21	0.73	0.72	0.20	0.02	0.01	3.51	0.25
Shrub	1.88	9.51	5.27	5.27	3.26	0.89	20.40	4.69	30.81	2.23
Building	2.29	0.82	2.05	2.05	3.34	0.91	9.30	21.61	16.98	1.23
Forest	99.57	35.91	90.12	29.65	80.37	21.96	79.93	18.38	349.99	25.32
Plantation	3.02	1.09	7.68	2.51	17.31	4.73	15.08	3.47	43.09	3.12
Residential Area	41.77	15.06	51.09	16.81	58.92	16.10	94.00	21.61	245.78	17.78
Barren	4.28	1.54	9.87	3.25	10.96	2.99	12.13	2.79	37.24	2.69
Irrigated Rice Field	46.91	16.91	63.17	20.79	83.37	22.78	120.94	27.81	314.39	22.75
Moorland	77.03	27.78	72.52	23.86	107.72	29.43	83.14	19.12	340.41	24.63
Total	277.30	100	303.92	100	365.98	100	434.93	100	1382.13	100

Source: Sugandi et al (2021)

Table 3 shows land cover from the classification of Landsat 8 OLI imagery. The forest area is still dominant, but population development will increase the area of built-up land. Built-up land has a great potential for surface runoff because the land surface becomes impermeable to water. The area of built-up land is shown in the following table 4.

Table 4. Built-up Land Area in Bandung Regency

Land	Ci Widey		Ci Sangkuy		Ci Rasea		Ci Tarik	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Landcover	277.3	100	303.92	100	365.98	100	434.93	100
Built up area	23.36	8.57	20.05	6.58	43.21	11.78	68.59	15.53
Non-Built-up area	253.94	91.43	283.87	93.42	322.77	88.22	366.34	84.47

Source: Sugandi et al (2021)

Rainfall that occurs on built-up land will flow on the surface and become surface runoff so that the wider the built-up land will flow on the river body. To control surface runoff, it is necessary to carry out each built-up area, so that the volume of rainfall on the built-up land does not have the potential to become runoff (Jaya et al., 2022).

For control on the smallest land unit considering a land area of 100 m^2, even though in reality the built-up area is different. Therefore, it is necessary to take into account the volume of the built-up area. The volume of rainfall that must be controlled on the built-up land is shown in Table 5.

2. Volume of flow in the small land unit

Table 5. Rainfall Volume in Built-up Lands in Bandung Regency

Land Characteristic	Ci Widey		Ci Sangkuy		Ci Rasea		Ci Tarik	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest

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Rainfall Depth (mm)	29.12	2.84	29.12	2.84	29.12	2.84	29.12	2.84
Rainfall Depth (m)	0.02912	0.00284	0.02912	0.00284	0.02912	0.00284	0.02912	0.00284
Built-up area (Km^2)	23.36	8.57	20.05	6.58	43.21	11.78	68.59	15.53
Volume (m^3)	680.243	24.339	583.860	18.687	1258.275	33.455	1997.340	44.105
Land unit (m^2)	100							
Volume (m^3)	2.912	0.284	2.912	0.284	2.912	0.284	2.912	0.284

Source: Sugandi et al (2021)

The thickness of rainfall in these watersheds can be used as a basis for calculating the volume of rainfall in 100 m^2 land units. This area is used as a measure in making infiltration wells. Meanwhile, for surface flow control, it is necessary to take into account the depth of the well that can accommodate the volume of water in the smallest land unit of about 100 m^2.

3. Distribution of Infiltration Wells

To control the flow in each watershed, each 100 m^2 land unit needs to control 2 m^3 of rainfall volume. The shape of the infiltration well that accommodates the volume of rainfall, if the diameter of the infiltration well is 1 m with a radius of 0.5 m, then:

$$Ks = \pi r^2 \quad (3)$$

$$Ks = \frac{22}{7}\ x\ 0.5\ x\ 0.5 = 2.6\ m$$

Ks = Depthness of the well (m)

With an infiltration well depth of 2.6 m, the well will be able to accommodate a rainfall volume of 2 m^3. The ability of the infiltration wells and the number of infiltration wells in each watershed made on built-up land with a land unit of 100 m^2 will be able to control the surface flow of watersheds in Bandung Regency. The number of infiltration wells in each watershed is shown in Table 6.

Table 6. Several infiltration wells in the watersheds in Bandung Regency.

Land Characteristic	Ci Widey		Ci Sangkuy		Ci Rasea		Ci Tarik	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
Volume (m^3)	680.243	24.339	583.86	18.687	1258.275	33.455	1997.340	44.105
Capacity (m^3)	2							
Number of wells	340.12	12.17	291.93	9.34	629.14	16.73	998.67	22.05

Source: Sugandi et al (2021)

Table 6 illustrates that infiltration wells are spread out in each different watershed. This difference is due to the different volumes of rainfall. With the distribution of infiltration wells, the surface flow can be controlled. The distribution of the wells is based on the built-up land in each of the smallest land areas of 100 m^2.

The distribution of infiltration wells is shown in Figure 1. The infiltration wells that are spread over each watershed. The largest watershed is the Ci Tarik watershed with 999 infiltration wells and the least is the Ci Widey watershed with 292 infiltration wells. Many and few infiltration wells are due to the large area of land building. The number of infiltration wells is analyzed based on the area of built-up land in each watershed so that in controlling runoff it is necessary to observe the built-up land.

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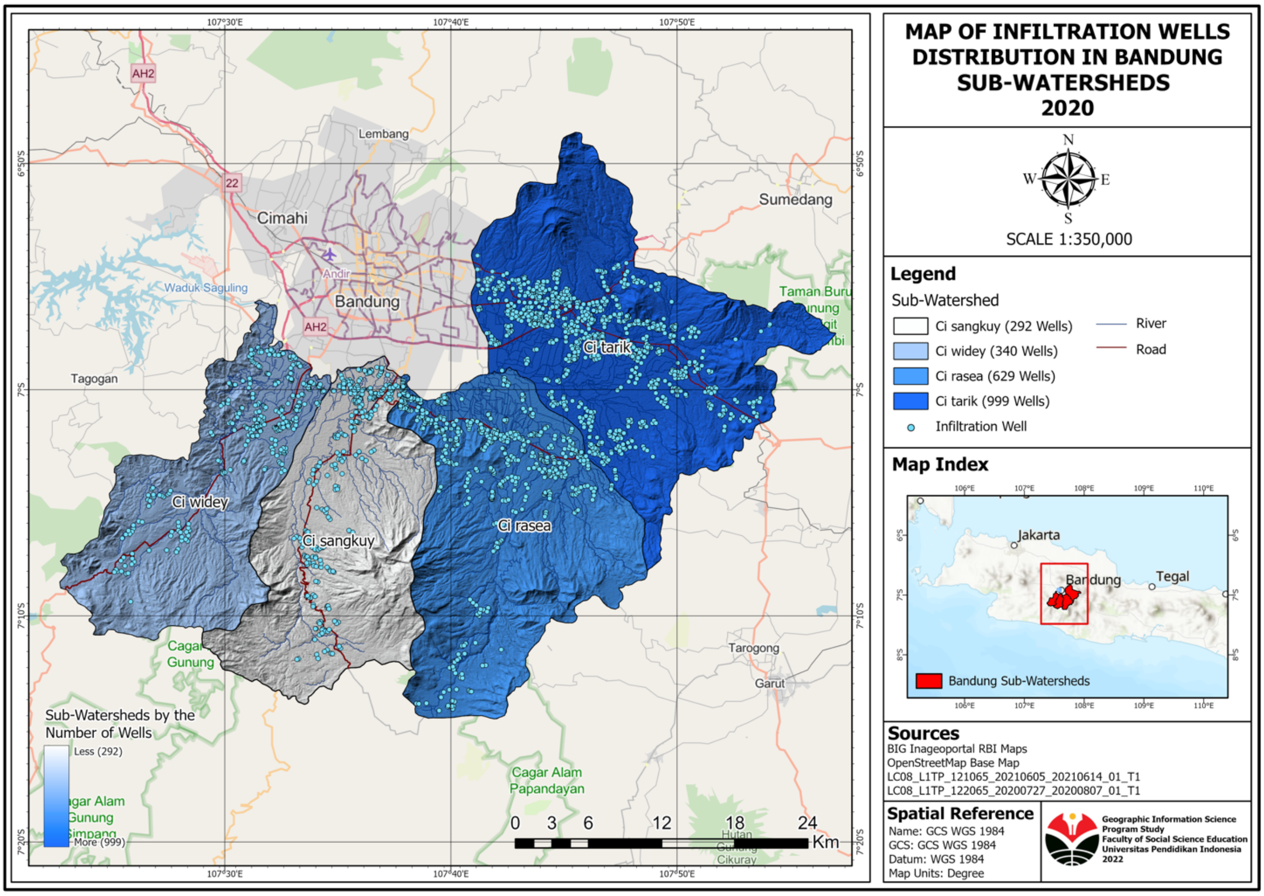

Figure 1. The distribution of infiltration wells

Discussion

The impact of the incompatibility of the surface runoff volume with the capacity of the river causes the overflow of the river flow, thus causing flooding (Mishra & Shah, 2018). Therefore, to overcome flooding by controlling surface runoff. The cause of large surface runoff is that rainfall is less absorbed into the ground. Lack of groundwater absorption, because the land surface is impermeable due to construction by walls, asphalt, and soil compaction. The impermeable surface changes the function of the soil that should absorb it because it is impermeable to rainfall flowing on the land surface. The lowest volume of rainfall occurred in August at 30,072 m^3, while the highest was in November at 308,351 m^3. This rainfall has the potential to become surface runoff, but rainfall on forest land, agriculture, shrubs, ponds, and vacant land will absorb. However, rainfall on built-up land has the potential to become surface runoff, because built-up land such as settlements, roads, industry (buildings), and compaction of land with stones makes the land surface impermeable to water. Built-up land, namely; The Ci Widey watershed is 253.94 Km^2, Ci Sangkuy is 283, 87 Km^2, Ci Rasea is 322.77 Km^2 and Ci Tarik is 366.34 Km^2. The surface runoff volume in the Ci Widey watershed is 680,243 m^3, Ci Sangkuy is 583,860 m^3, and Ci Rasea is 1,258. 275 m^3 and Ci Pull of 1,997,340 m^3.

The volume of rainfall that does not absorb especially on built-up land will flow together in a large river flow and form a large force so that it overflows. Therefore, overcoming this runoff needs to be done on each built-up area in units of every 100 m^2. To calculate the volume of rainfall based on the thickness of the highest rainfall 29.12 mm (0.02912 m) and the lowest 2.84 mm (0.00284 m). From the thickness of rainfall that occurs on the built-up land, the smallest land unit is 100 m^2, the highest volume is 2,912 m^3 and the lowest is 0.284 m^3. The fact is that not all built-up land is the same, therefore it is

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necessary to take into account the area of built-up land with the thickness of the rainfall. With the volume of rainfall accommodated in infiltration wells, rainfall does not have the potential to become surface runoff. In addition to controlling surface flow, infiltration wells can function as suppliers of groundwater reserves, because the stored water will absorb into the ground.

Infiltration wells function as a reservoir for rainfall, then all directions of water flow are directed at infiltration wells. To accommodate the volume of rainfall on a land unit per 100 m^2 with a diameter of 1 m and a depth of 2.6 m, the rainfall volume of 2,912 m^3 can be accommodated. With this infiltration well, rainfall does not have the potential to become surface runoff. Making infiltration wells can be done on every built-up land with a flat to gentle slope, which is around 0-8%. The construction of wells with the capacity according to the highest rainfall volume is spread according to the built-up watershed with a slope of 0 - 8%, so the number of infiltration wells is different for each watershed. The number of infiltration wells in the Ci Widey watershed is 340, Ci Sangkuy is 291, Ci Rasea is 629 and Ci Tarik is 998. In making this infiltration well, it is necessary to make it flexible so that it is easy to open and close to facilitate controlling the condition of the well, and spread according to the direction of water flow on the surface. Infiltration wells will function if the flow in the smallest unit on the built-up land can accommodate the volume of rainfall, therefore the rainfall that becomes flowed into infiltration wells.

CONCLUSIONS

The surface runoff will continue to increase due to the expansion of development, especially on built-up land. From the watershed flowing in Bandung Regency, the surface runoff volume in the Ci Widey watershed is 680,243 m^3, Ci Sangkuy is 583,860 m^3, and Ci Rasea is 1,258. 275 m^3 and Ci Pull of 1,997,340 m^3. Ci Tarik watershed is a watershed with the largest built-up area, so the volume of surface runoff is large.

For the smallest unit 100 m^2. The thickness of rainfall on the smallest land unit is 2.84 mm (0.00284 m) with the largest volume of 2,912 m^3. Rainfall in the land unit can be absorbed in infiltration wells. By being accommodated and impregnated in infiltration wells, rainfall does not have the potential to become surface runoff.

Therefore, the size of the infiltration well must be able to accommodate the volume of rainfall on a land unit of 100 m^2. To accommodate and absorb the rainfall volume of 2 m^3, the size of the infiltration well is made up of a diameter of 1 m and a depth of 2.6 m. Infiltration wells are spread across each watershed with 340 Ci Widey, 291 Ci Sangkuy, 629 Ci Rasea, and 999 Ci Tarik watersheds are placed with a slope of 0 - 8%.

RECOMMENDATIONS

Currently, we can still see flooding happen, especially in some parts of Bandung Regency. Thus, surface flow control needs to be carried out on built-up land with the smallest area according to the thickness of rainfall and the area of built-up land.

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