Study on the Effectiveness of Infiltration Wells to Reduce Excess Surface Run Off In ITB

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Abstract. Institut Teknologi Bandung (ITB), Ganesha Campus, Indonesia, has an area of 28.86 hectares. The campus is located in Bandung. Starting from 2012, new buildings were constructed within the area, reducing the area of permeable surface significantly. In the past few years, there were several excess run off incidents in the campus. The insufficient area of permeable surface as well as the inadequate capacity of the drainage system contributes to the excess surface run off. The drainage system has only two outlets. Moreover, in some areas, the drainage systems are disconnected. Thus, most the surface run off are stored within the drainage system. The purpose of this study is to evaluate the effectiveness of infiltration wells for reducing the local excess run off in ITB. Precipitation data and drained service area are used to estimate the design discharge from each building in ITB. In order to avoid the excess surface run off of certain locations in ITB, then the infiltration wells are proposed to balance the area of impermeable surface. The effectiveness of the infiltration wells are evaluated by assessing their number to their contribution in reducing the excess surface runs off.

1 Introduction

Precipitation in Bandung area has increased in the past few years. The rainfall intensity in the last 25 years ascends by 10-20 mm every year [1].Based on Regional Regulation No. 26 of 2007 on Green Area (Ruang Terbuka Hijau/RTH), − from 661.4 thousands hectare area of Citarum River Basin, 198 thousands is supposed to be reserved area. In accordance with Regional Regulation No. 2 of 2016 on controlling the utilization of North Bandung Area (Kawasan Bandung Utara/KBU), the local government – tries to protect KBU by limiting physical development to only 20% of land area. Area of KBU Bandung is 38 thousands, but 80% have been intervened by constructions. The increase in industrial activities eventually increases the degree of groundwater withdrawal from the aquifers in Bandung [2]. Thus, most the surface run off are stored within the drainage system. Furthermore, land use and land cover change affect hydrological components such as interception, infiltration and evaporation. They influence the soil moisture content, runoff generation (both process and volume) and stream flow regimes [3]. Previous surfaces decrease the amount of runoff as precipitation infiltrates [4]. These also affect the groundwater table [5].

As well as the city of Bandung, new buildings have been constructed within the area of ITB. These building significantly reduce the permeable area. Soil type in the area is mostly clay up to 6 meters depth, which has a slow infiltration rate. The construction was not followed by increasing the capacity of the drainage system. Thus, excess runoff occurs quite frequently during the last few years in a few internodes such as Labtek V,VI,VII,VIII, Aula Timur and Lapangan Seni Rupa.

One of the solutions to reduce excess surface run off is infiltration wells. Infiltration wells are structures that highly allow surface runoff to drain through underground [6]. Infiltration well was initiated in Indonesia by Sunjoto [7] and developed by some other researchers [6,8-10]. The benefits of infiltration wells are a quantity of unconfined groundwater can be conserved, the surface level of unconfined ground water stays stable, the area of ponding water is minimized, and the dimension of drainage networks is minimized. In addition, the groundwater quality is improved, land subsidence is prevented, and salt water intrusion in coastal area is avoided [11]. The disadvantage of infiltration wells is the infiltration takes time depending on the permeability. The purpose of this study is to evaluate the affectivity of infiltration wells in order to reduce the excess surface run off in ITB.

2 Methodology

The results in this paper are based on two well-established and complementary hydrology analysis and infiltration wells standard design. They are SNI T-02-02-2006 for Local Drainage Design and SNI 03-2453-2002 for Infiltration Wells Design. The design is based on the available topography, hydrology, and soil data. The hydrology data are as follows:

1. Precipitation of Metropolitan Bandung Raya Data (2017-2015)

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2. Precipitation of ITB station (AWS November 2011-December 2016)

3. Drainage system map

2.1. Hydrology

Hydrology analysis was conducted based on the daily maximum precipitation. The maximum precipitation in a return period can be estimated through 4 distribution methods such as normal, log normal, log pearson III and gumbel [12]. The methods concepts are fitted to probability concepts. SNI T-02-02-2006 states that the local drainage system design is based on a 5 years return period.

2.2 Standard Design for Infiltration Wells

SNI 03-2453-2002 states the general requirements of infiltration wells are as follows:

1. Infiltration wells are placed relatively in flat contour;
2. The water entering the catchment is unpolluted rainwater;
3. Decision of infiltration wells shall take into safety building;
4. It must pay attention to local regulations;
5. Things that do not meet these requirements shall be approved by authorized agencies.

Technical requirements that must be included are in the following:

1. To ground water minimum 1.5 meter in the rainy season;
2. The usable soil structure should have soil permeability ≥ 2.0 cm / hour.

The shape and type of the infiltration well can be either an infiltration wells made in quadrilateral or cylindrical with a certain depth and the bottom of the well is located above the groundwater level. Based on the Regional Disaster Management Agency of Jakarta, types of infiltration wells construction are:

1. Wells without couple walls, bottom without filled stone or fibers (empty).
2. Wells without couple walls, bottom filled with stones and fibers
3. Wells with brick, stone or stone compartments on the wells wall, bottom filled with stones and fibers or empty
4. Wells use blawong (rock formed specifically for wells wall).

3 Results and Discussions

3.1 Topography and Impermeable Surface

Topography map data with a 50 cm contour interval is provided to continue the study. ITB has a relatively mild slope, almost flat, with the north is higher than the south.

The map of constructed area in ITB is also given to by Infrastructure Facilities Division of ITB. Most of areas in ITB are impermeable surface, such as building, pavement area (parking, plaza, and corridor) and roadway thus ITB has more impermeable surface. The total building area in ITB is 99,733 m^2. Open space are garden, median, and island. ITB has less of infiltration

area and the excess surface run off would drastically increase at the time of heavy precipitation.

3.2 Drainage Systems

The existing drainage systems were analyzed based on the drainage network data as shown in figure 1. In addition, field survey was conducted to assess the flow direction. In general, the condition of existing drainage in ITB: (1) The drainage systems are disconnected in some places, (2) The drainage system has 2 outlet points but the remaining functional outlet is Dago. Furthermore, the drainages in several points were clogged as shown in figure 1. In some places, the channels dimensions were relatively small and might be in insufficient during a heavy rain. Additionally, the flow directions in some sections were not heading to any outlet causing excess surface run off within the area.

Fig. 1. Existing Drainage of ITB

Depth	
	0.00-1.5 m **Silty Clay,** dark brown, medium stiff, high plasticity
1.50-2.00	
2.00-2.45	
3.00-3.50	2.45-3.00 m **Silty Clay with some gravel,** brown, medium stiff, high plasticity
	3.50-4.00 m **D.O**
4.00-4.45	
	4.45-5.00 m **D.O**
	5.00-6.00 m **Clayey Silt with some gravel,** brown, spoted yellow, low plasticity
6.00-6.45	
	6.45-8.00 m **Sandy Gravel with some clay,** brown, well graded, fine grained
8.00-8.45	
	8.45-10.00 m **Gravelly Sand,** grey brown, well graded, coarse grained
10.00-10.45	

3.3 Soil Characteristics

Fig. 2. Soil Characteristics in ITB

The characteristic of soil in ITB depend on the depth of the soil (Soil investigation FTTM Building, 2012). Between 0-1.5 meter depth is silty clay with dark brownish, medium stiff and high plasticity. This kind of soil takes time to infiltrate water [12]. The ground water table reached >20 m. The coefficients permeability of silty clay is 0.48 (m^3/m^2/day) or 1.3 x 10-4 m/sec.

3.4 Hydrology Analysis

The data are ITB station and Dago Pakar Station in 06° 52' 51'' South Latitude and 107° 36' 52'' East Longitude. Maximum daily precipitation design for the area is calculated using arithmetic mean method. The average maximum daily precipitation data of both stations are shown in the table 1.

Table 1. Maximum Daily Precipitation Design

Year	Maximum Precipitation (mm)
2007	113
2008	80
2009	73
2010	104
2011	45
2012	61.6
2013	70.75
2014	95.65
2015	65.3
2016	71.4

The design precipitation was statistically analyzed using the Normal, Log Normal, Log Pearson III, and Gumbel methods. The area design is the area of ITB which is 28.865 ha. According to SNI T-02-2006, the design precipitation return periods are 5, 10, 15, 20 year. In this paper, the return period used is 5 years because the scope of the area is university. Based on the results, the smallest error is Log Normal Method with a 5 years return period daily precipitation of 98.15 mm.

3.5 Infiltration Wells Design

3.5.1 Infiltration Wells Capacity

The design of infiltration wells has 1 meter diameter with the depth of 10 meter and infiltration efficiency is 100%. Soil clay has coefficient permeability 0.48 m3/m2/day and course sand has 0.864 $m^3/m^2/day$.

1. Surface run off volume (V_{AB})

For every 500 m^2 of service area, the surface run off volume is given as.

$$V_{AB} = 0.855 \times 0.75 \times 500 \times 98.15 \times 10^{-3} = 31.47 \ m^3 \quad (1)$$

2. Storage volume after precipitation (V_{STO})

The infiltration wells have 1 meter diameter and 10 meter depth along the vertical permeability (Kv) is calculated as below:

$$K_V = (0.48 \times 1.5 + 0.864 \times 4.95 + 8.64 \times 3.55)/10 \quad (2)$$

$$Kv = 3.57 \ m^3/m^2 hr \quad (3)$$

The infiltration wells is not impermeable, thus the water could flow as an infiltration or percolation (flowing through 2 axes). The horizontal permeability (Kh) is twice the vertical permeability, so the value is 7.13 $m^3/m^2/day$.

The precipitation duration (Tc) is the time for the precipitation to prolong.

$$Tc = 0.9 \times R^{0.92} \quad (4)$$

$$Tc = 0.9 \times 98.15^{0.92} = 1.02 \ hours \quad (5)$$

The total permeability (Kaverage) of the infiltration wells for permeable walls is

$$K_{average} = (Kv \times Ah + Kh \times Av)/(Ah+Av) \quad (6)$$

Where Ah is area of base wells, Av is area of wall wells. For the 10 meter depth of wells,

$$Ah = \Pi D^2/4 = \Pi 1^2/4 = 0.785 \ m^2 \quad (7)$$

$$Av = \Pi DH = \Pi \times 1 \times 10 = 31.4 \ m^2 \quad (8)$$

D is diameter of wells and H is height of wells

$$K_{average} = (3.57 \times 0.785 + 7.13 \times 31.4)/(0.785+31.4) \quad (9)$$

$$K_{average} = 7.0468 \ m^3/m^2/day \quad (10)$$

Volume of infiltration water during the precipitation with Tc=1.02 hours is

$$V_{rsp} = Tc/24 \ A_{total} \times K_{average} \times efficiency \quad (11)$$

$$V_{rsp} = 1.02/24 \times (0.785+31.4) \times 7.0468 \times 100\% \quad (12)$$

$$V_{rsp} = 9.64 \ m^3 \quad (13)$$

$$V_{STO} = V_{AB} - V_{rsp} = 31.47 - 9.64 = 21.82 \ m^3 \quad (14)$$

3. Infiltration Wells Total

The total of infiltration wells is depends on storage volume.

$$H = V_{STO}/Ah = 21.82/0.7854 = 27.79 \ m \quad (15)$$

For 10 meter depth of infiltration wells, with a service area of 500 m2, the number of infiltration wells needed is:

$$Total \ wells = H/Hdesign = 27.79/10 \approx 3 \ wells \quad (16)$$

3.5.2 Infiltration Wells Application for ITB

If the totals of infiltration wells are designed according to roof area per building, with the total roof area 99,733 m^2, ITB is supposed to have 770 wells with the total area of wells is 604.757 m^2. The number of infiltration wells per building is given in table 2.

Table 2. Number of infiltration wells per building

No	Building	Area (m^2)	n_1	n_2
1	Kriya	153	0.4	1
2	STJR	190	0.4	1
3	FSRD	294	1.2	2
4	FTSL	341	1.6	2
5	PPFK	409	2.4	3
6	LAB RADAR	452	2.8	3
7	KANTIN BENGKOK	460	2.8	3
8	PSDA II	583	3.6	4
9	PSDA I	611	4.0	4
10	KIMIA BARU	741	4.8	5
11	DOPPING	794	5.2	6
12	BANKER	807	5.6	6
13	BSC B	847	5.6	6
14	OKTAGON	1036	7.2	8
15	TVST	1036	7.2	8
16	BSCA A	1066	7.6	8
17	LAB PLN	1098	7.6	8
18	GKU TIMUR	1116	8.0	8
19	CC TIMUR	1177	8.4	9
20	COMLAB TPB	1157	8.4	9
21	KONVERSI	1291	9.2	10
22	PPTI	1394	10.0	10
23	CADL	1634	12.0	12
24	KIMIA LAMA	1647	12.0	12
25	GKU BARAT	1675	12.4	13
26	CC BARAT	1776	13.2	14
27	AULA BARAT	1879	14.0	14
28	RME	1888	14.0	14
29	LAB HIDRAULIKA	1993	14.8	15
30	CRCS	2028	15.2	16
31	LABTEK CIII	2134	16.0	17
32	CAS	2172	16.4	17
33	SBM	2312	17.6	18
34	PERPUS PUSAT	2428	18.4	19
35	T.LING	2496	18.8	19
36	LABTEK VI	2732	20.8	21
37	PAU	2736	20.8	21
38	LABTEK II	2930	22.4	23
39	LABTEK VIII	2982	22.8	23
40	LABTEK I	2995	22.8	23
41	LABTEK VII	3088	23.6	24
42	LABTEK V	3158	24.4	25
43	LABTEK III	3259	25.2	26
44	LABTEK VI	3281	25.2	26
45	TEKNIK SIPIL	3354	26.0	27
46	LAB MESIN	3423	26.4	27
47	AULA TIMUR	3572	27.6	28
48	CADL LAMA	4076	31.6	32
49	LABTEK IX	4147	32.0	33
50	FISIKA	5265	41.2	42
51	LABTEK X&XI	5620	44.0	45
	TOTAL	99733	745.5	770
	TOTAL AREA OF WELLS (m^2)		585.5	604.8

Nb. n_1 is number of wells and n_2 is number of wells round up.

Infiltration wells are expected to reduce the amount of water that flow from the outlets to the roadside public drainage. This means that ITB run off contribution to the city drainage system will be reduced significantly.

Infiltration wells are prioritized in the area with known history of excess surface run off such as Aula Timur, Lapangan Seni Rupa and Aula Barat. The wells can either be an infiltration well, connected to the drainage system (drainage well), or not (RTH well). The locations are shown in figure 3.
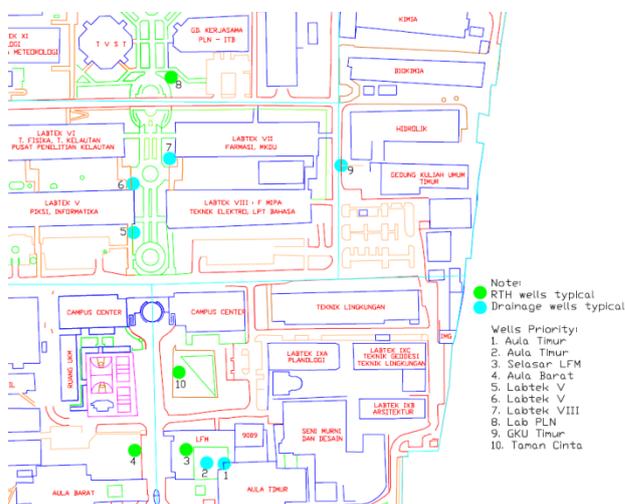

Fig. 3. Priority Wells of ITB

4 Conclusions

In this study, the effectiveness of infiltration wells to reduce the excess local run off in ITB has been assessed. The ground water table is located 20 meter depth and in general, the soil type is clay thus the infiltration wells may not be the best answer to the excess run off problem for ITB.

Dimension of the infiltration well is 1 meter diameter and 10 meter depth. It was found that for a service area of 500 m^2, 3 wells are needed. Therefore, to retain 100%

precipitation from the buildings into wells, ITB needs approximately 770 wells.

Due to the large number of wells needed, it is recommended to construct these wells only in several locations, at internodes that have high excess run off. In addition, it is recommended to develop a new master plaster plan for the ITB drainage system.

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