Rainwater Harvesting for Water Security in Campus (case study Engineering Faculty in University of Pancasila)

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Abstract. Global climate change is a worldwide issue affecting rain and groundwater supplies. To realize the SDGs’ 6th goal regarding clean water and proper sanitation, Rainwater Harvesting (RWH) is one solution for pure water requirements and useless groundwater. RWH, which is equipped with infiltration wells, can overcome water scarcity during the dry season and reduce flooding in the rainy season. This research was conducted to harvest rainwater that falls on the roof into the reservoir to the ground, so it is necessary to calculate the rainwater availability and water demand to design RWH building plan. This research was conducted at the Faculty of Engineering, Pancasila University, which uses groundwater for essential water requirements. Two RWH reservoirs are planned in different locations, with the dimensions of the RWH reservoir are 4 m (length) x 3.5 m (width) x 3 m (height). Based on the flood discharge from the roof of 84 m³, the amount of water needed is 19.4 m³. For that, it is necessary to be equipped with 4 infiltration wells with a diameter of about 1.5 m and a height of 3 m to store groundwater around 6.402 m³. RWH application can also be applied to campus that use groundwater to reduce groundwater use.

1. Introduction
Rainwater Harvesting (RWH) collects water from the roof, filtering and storing it for further use [1]. The RWH system provides a cheap and high-quality water source reducing dependence on wells and other sources, and is cost-effective in many contexts. RWH systems are economically less expensive in construction than other sources, namely wells, canals, dams, and diversions [2]. Rainwater harvesting systems are widely adopted in other countries, for example, in central Mexico proposing estimates where users can select rainwater harvesting systems for non-potable water consumption. For Pachuca and Mineral de la Reforma, Hidalgo State, Central Mexico, the historical rainfall records analyzed cover 33 years (1980-2013) [3].

The RWH system’s sustainability was also assessed from several water quality parameters from the collected rainwater concerning allowable limits. Several parameters were included in the analysis: pH, fecal coliform, total coliform, total dissolved solids, turbidity, NH3-N, lead, BOD5, etc., [4–7]. In an RWH system, the water availability comes from the roof (rooftop), and it is necessary to estimate the potential rooftop rainwater harvesting from a building, the conveyance system, and the groundwater filling system [8–10].

Several studies have stated that RWH is highly recommended for campuses because it is known to be cost-effective and very useful for replenishing groundwater in several parts of the
country [9–13]. RWH planning is based on existing guidelines and is adjusted to the site. Season conditions in the study area [1]. However, it is necessary to evaluate the existing RWH. System performance can be improved by monitoring water levels and complying with demand guidelines. This is a useful strategy for practitioners in water supply [14–16]. It is necessary to check methodologies for evaluating RWH, such as the evaluation method carried out in Iraq’s semi-arid areas. More than 95% of the assessed sites received a low or moderate suitability score based on the selected criteria, with only two sites receiving a high suitability score. This integrated methodology, which is highly flexible, saves time and cost, is easy to adapt to different areas, and can support designers and decision-makers to improve existing and new RWH sites [17]. RWH’s research was conducted at Pancasila University, in the engineering faculty. The research problem is the impact of using groundwater as the primary means of water needs. Even though there are regulations that regulate water extraction to fulfill life utilities, namely Law Number 43 of 2008, exploration of groundwater extraction is still massive. The result that occurs is a decrease in groundwater level in Jakarta [18–21]. The incident was exacerbated by the extraction of shallow groundwater in various places in the Jakarta area. This groundwater extraction activity must be reduced by using surface water or rainwater in the raw water supply. Here educational institutions can be an example in reducing groundwater use by collecting rainwater. A case study is taken at the engineering faculty as a pilot project to use RWH, and it can be seen how many cubic meters of groundwater can be saved.

2. Methode and Material

2.1. Location

The research location is Pancasila University which is on the edge of Jalan Lenteng Agung, a land area of about 12 hectares. Sampling was focused on the Faculty of Engineering, Pancasila University, FTUP, an educational facility building with four floors bordering Jagakarsa in Lenteng Agung villages Srenseng Sawah and Ciganjur. Location map (figures 2 and 3).

2.2. Amount of Rainwater Harvested

To calculate the amount of rainfall that can be harvested, you can use the formula as:

$$Q = A \times C \times P$$

(1)

where $Q$ is the total quantity of rainwater harvested (liters/m$^3$), $A$ is the catchment area (m$^2$), $C$ is the runoff coefficient (based on the coefficient runoff is 0.9), and $P$ is the average annual rainfall.
### Table 1. Data used for research

| Data Information | Map | Rainfall | Humidity, temperature, solar radiation, and wind speed data |
|------------------|-----|----------|------------------------------------------------------------|
| The Study Location Map data is taken from google earth | Rainfall data from Indonesian university stations for the past 15 years until 2019 | Climatological data were obtained from BMKG, as well as from other reference journals |

To calculate the concentration-time, it is necessary first to know the length of the rainwater flow path on the roof and the slope of the rain gutters, using the following formula

\[
t_c = \left( \frac{0.87 \times L^2}{1000 \times S} \right)^{0.385} \times \left( \frac{0.87 \times L^2}{1000 \times S} \right)^{0.385}
\]  

(2)

design Rainfall Intensity, calculated with mononobe formula \( I \).

\[
I = \frac{R_{24}}{24} \left( \frac{24}{t_c} \right)^{2/3} \times \frac{R_{24}}{24} \left( \frac{24}{t_c} \right)^{2/3}
\]

(3)

with \( L \) is the length of the gutter, \( S \) is the slope of the roof, \( I \) is the rain intensity for the hour of rain (mm/hour), \( R_{24} \) is the effective rainfall in 1 day or 24 hours (mm), and \( t_c \) is the concentration-time (hour).

### 2.3. Water Storage volume and Infiltration wells

Storage volume is based on the rainfall and standing water from the roof that can be accommodated. After knowing the storage volume requirements, the next step is to simulate the water needs obtained from rainfall and the reservoir volume reduced by water demand. Thus, this study’s main purpose is to determine the balance value between the amount of water storage, rainfall, and the level of demand.

\[
ξ = V_s + V_{Rsp}
\]

(6)

### 2.4. Infiltration wells

For the number of infiltration wells referring to SNI 03-2453-2002, the procedure for engineering rainwater infiltration wells for yards. The infiltration well is planned with a circular cross-section, using the formula below

\[
V_s = \frac{1}{4} \pi D^2 H \times \frac{1}{4} \pi D^2 H
\]

(4)

\[
V_{Rsp} = \frac{t}{24} \sum AK \times \frac{t}{24} \sum AK
\]

(5)

with \( ξ \) is infiltration well capacity, \( D \) is the diameter of the well (m), \( H \) is the depth of the well (m), \( t \) is the rainy time (hours), \( A \) is the cross-sectional area (m²), \( K \) is the soil permeability coefficient, \( V_s \) is the volume of the well, and \( V_{Rsp} \) is the volume of a well infiltration.
3. Result and Discussion

The research data was taken from Pancasila University for 17 years from 2003 to 2019 with a graphic display shown in Figure 2. Figure 3 shows that the most significant rainfall occurred from 2003 to 2019 in February 2007 at 830.6 mm. With a large amount of rain each year, it is possible to plan rainwater harvesting structures. Before calculating the RWH building, we must determine the rooftop area. For the roof area in the Pancasila University engineering faculty building, data is taken from the top view map on the google map, ignoring the slope of the roof, and is considered flat so that a roof area of 3,238 m\(^2\) is obtained.

From the results of the maximum rainfall, it can be seen that the highest maximum rainfall occurred in 2013 at 249 mm. From the maximum rainfall data, the amount of design rainfall that occurred was calculated. The result of design rainfall was used to calculate the value of the intensity of rain that occurred. The concentration-time is needed to see how long it takes the rainwater to pass through the gutter and the reservoir. From the calculation results, it is found that the concentration-time is 0.17 hours. Based on the long concentration-time, the rain fills the reservoir with a maximum path length of 70 meters and the return period of the 2-year plan shows a concentration-time of 0.17 hours or 10 minutes. The rain intensity is 96.62 mm or 0.09 m, then the runoff height can be calculated, and the planned water tank dimensions are as follows.

The maximum volume of average daily rainfall data from 2003 to 2019 is 84.41 m\(^3\). The daily average volume from 2003 to 2019 is 21.8 m\(^3\). This average daily volume is the reference for calculating the number of infiltration wells planned in the Pancasila University Engineering Faculty Building. Based on Table 2, the total runoff that can be accommodated by the water tank is 78 m\(^3\). for planning, it uses a reservoir volume of 84m3. Based on the total runoff, two

| Information          | C   | A (m\(^2\)) | Rainfall Intensity (m/hour) |
|----------------------|-----|------------|-----------------------------|
|                      |     |            | 2 years | 5 years | 10 years | 25years | 50 years |
| FTUP Building rooftop| 0.9 | 3,238,00   | 0.097   | 0.155   | 0.170    | 0.187    | 0.318    |
| Run off (m\(^3\))   |     |            | 78,2798 | 125,964 | 137,612  | 151,835  | 257,369  |
| Run off (Liter)      |     |            | 78279,801 | 125964,15 | 137611  | 151835,99 | 257368,69 |

Table 2. Runoff Calculation Results
reservoir dimensions were designed for a water tank with $4m \times 3.5m \times 3m$. Water Requirement planning regulations on a per person and per day basis for the water needs of educational institutions (schools and universities) 10 liters/person/day (see table 3), so it can be calculated the amount of use of one building per day (1400 people/day).

Total water needs in 1 day = $(1400 \text{ people } \times 10 \text{ L / person}) + (3 \text{ Lab } \times 1800 \text{ L / Lab}) = 14000 \text{ L} + 5400 \text{ L} = 19.4 \text{ m}^3$. From this calculation can be found daily water requirement are 19.4 m³. Total water demand to know final reservoir is calculate by simulation water balance with participation and reservoir storage volume so that the total final reservoir is obtain, the maximum volume of the water reservoir in the water tank is 84 m³. Therefore the water tank planning based on the maximum storage is 84 m³.

Based on the flood discharge and the volume of rainwater storage at Pancasila University, the reservoir and absorption dimensions can be designed. The Pancasila University rainwater storage building design can be seen in Figures 3 (building details) below.

### Table 3. Runoff Calculation Results. Sources: Kriteria Perencanaan Ditjen Cipta Karya Dinas PU, 1996

| Sector                | Value   | Unit                  |
|-----------------------|---------|-----------------------|
| School                | 10      | Liter/student/day     |
| Hospital              | 200     | Liter/bed/day         |
| Public health center  | 2000    | Liter/unit/day        |
| Mosque                | 3000    | Liter/unit/day        |
| Office                | 10      | Liter/employees/day   |
| Market                | 12000   | Liter/hectare/day     |
| Hotel                 | 150     | Liter/bed/day         |
| Restaurant            | 100     | Liter/seat /day       |
| Military Complex      | 60      | Liter/person/day      |
| Industrial area       | 0.2-0.8 | Liter/second/hectares |
| Tourism Area          | 0.1-0.3 | Liter/second/hectares |

Water sources for domestic water Faculty of Engineering, Pancasila University, takes from groundwater, taken from deep wells using pumps, and does not use water sources from PDAM. Regulation of groundwater use is regulated by the Government Regulation of the Republic of Indonesia Number 43 of 2008 concerning groundwater, and its use is limited. Further analysis is needed to see the groundwater basin map at Pancasila University, whether it is still allowed to take ground water and the limit of groundwater discharge that is allowed to be taken. To
know groundwater used at Pancasila University, the research was conducted to see how much rainwater can be harvested for domestic water needs at the Faculty of Engineering, Pancasila University. Based on existing research, Rain Water Harvesting (RWH) reduces groundwater use and can be used as a recharge for groundwater conservation in the campus environment. RWH uses simple techniques, comfortable construction and installation, and low investment costs and techniques in its implementation. This can also be applied on campus to meet drinking water needs and other water needs. Simple techniques that tend to increase greenery on and around campus increase the aesthetic factor for liveable housing institutions [9].

The analysis found that the discharge of rainwater that can be accommodated based on rainfall data from the Pancasila university station showed a rainfall intensity of 96.62 mm, from the FTUP roof area of 3.238 m$^2$. The water flow rate from the roof is found to be 78 m$^3$/hour. Based on this flood discharge, the water storage volume design is used for rain duration for one hour, assuming it is the most extended rain. Based on the volume of the tank, a reservoir with a size of $4 \times 3.5 \times 3$ m is planned, which is placed in the catchment area of the Pancasila University engineering faculty building with a rectangular cross-section shape. The infiltration wells calculation is based on the daily average volume of runoff from the daily rainfall data for 2003 to 2019. The average runoff volume is 21.49 m$^3$, based on the average runoff volume. RWH Potential. Savings in maximum water use when using RWH based on an analysis from 2003 to 2019 is 6,402 m$^3$. The average savings is 3,903 m$^3$. With the remaining volume of final storage in the reservoir a maximum of 84m$^3$ from 2003 to 2019. Based on a study conducted at Amity University Mumbai for the RWH design on campus, it can overcome water scarcity during several seasons by storing a total of 6109.42 m of water a year. This initiative could increase the water supply for construction work and gardening and help replenish groundwater artificially, thereby enriching surface and groundwater sources [22]. RWH application has also been developed in dry areas with high rainfall intensity [23].

4. Conclusion
Rainwater harvesting is an alternative source of water to meet water needs on campus. The research location was taken at the Pancasila University Engineering Faculty Building because it only uses groundwater to meet domestic water needs. RWH can be used in areas with high rain intensity. In China itself, useful regional research has been carried out for making RWH in dry areas, and the result is that 24.9% of the site can be built RWH [23]. Besides, rainwater can also be used to meet drinking water needs. According to standards drinking water from rain has an average PH of 8 to be consumed immediately [24] [25]. The benefits of using rainwater for consumption also have an impact on reducing the use of bottled water. Based on the research results, the amount of clean water demand in the Pancasila University engineering faculty building is 19.4 m$^3$, the calculation of water needs is based on the number of residents of 1400 people with water needs of 10 liters/person, according to SNI. The amount of water used in civil, electrical, and mechanical laboratories, the amount of water availability design in the RWH building is 84 m$^3$, with the dimensions of the RWH building, is 4 m (length) x 3.5m (width) x 3m (height). RWH can save an average of 3,903 m$^3$ of groundwater, with maximum savings from 2003 to 2019 of 6,402 m$^3$. The RWH building is equipped with 4 infiltration wells where each well has a capacity of 5.5 m$^3$ with a diameter of 1.5 m and a height of 3 m. RWH building design can be applied to campuses that only use groundwater to meet domestic water needs and drinking water to reduce groundwater and infiltration wells as recharge for replenishing groundwater.

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