Injection well as an eco-drainage solution to reduce surface run-off at the State University of Malang

Gilang Idfi^{1,*}, *Anie Yulistyorini*¹ and *Tika Apriliani*¹

¹Civil Engineering Department, Faculty of Engineering, State University of Malang, 65145 Malang, Indonesia

Abstract. This study aims to investigate the plan design and reduction of the runoff discharge using the eco-drainage system in the form of injection well. This research was conducted through an analysis of the injection well plan design at Graha Rektorat of the State University of Malang (SUM) and testing of soil permeability coefficient in the laboratory using Falling Head Permeability method. The result showed that design of injection wells using 1.5 m diameter and 3 m of depth for ten injection wells reduced drainage load by 44%, 34.35%, and 28.9% at return period of 2, 5, and 10 years respectively and the value of soil permeability coefficient was 2.01 cm/hour.

1 Introduction

The drainage system is an infrastructure engineering use to cope with flooding problem (1). Inappropriate drainage systems at the surrounding of the building will lead to generating water inundation or even flooding. In general, flood water that produced in the upper catchment flows into the ephemeral river, channel, crosses the downstream plain. (11). The conventional concept of drainage is to eliminate water as quickly as possible into water bodies, and it is considering ineffective because it reduces the opportunity of rainwater to seep into the soil (2). Meanwhile, the application of the eco-drainage system is used to control the excess of rainwater on the surface and to conserve the water by maximising the absorption of water into the soil. Thus, an eco-drainage system can improve water infiltration and minimise the catastrophe due to floods and droughts, but also serve as a water conservation method (1). An injection well becomes a sustainable solution to be implemented.

The implementation of the injection well not only be applied in residential areas but also in the campus. Furthermore, the use of the injection well in the campus area is expected to be an added value for a green campus by applying the eco-drainage system (3). The injection well is water construction with a certain depth to collect and to infiltrate the rainwater into the soil. According to PERMENLH No. 12/2009 about rainwater utilisation, an injection well can be made in circle or rectangle shape using brick, red brick or concrete. The well with the circular shape shown to be stronger to withstand the forces compares to the square one (4). By implementating of this system, the water runoff can infiltrate into the

* Corresponding author : gilang.idfi@gmail.com

soil, and the flooding can reduce, and therefore the injection well can stimulate groundwater recharging. Also, as groundwater is a valuable water resource that requires a modelling techniques to determine both natural and artificial boundary conditions (18). The natural recharge occurs through an infiltration process where the water percolates from the surface into the bed of the aquifer where rainwater recharge is a fundamental component of the groundwater system (10, 13). Most of the water filled up unsaturated zone before reaching the groundwater (12). The rainwater well will help the water to have longer residence time at ground level and increase the groundwater table. Different methods have proposed to estimate groundwater recharge adequately. Examples include water table fluctuation methods (14), Darcy law (14), tracer techniques (15), mathematical models (16) and the combination of several ways (17).

2 Methodology

The study was conducted at Graha Rektorat of the SUM which covers an area of 17261,215 m². Graha Rektorat of the SUM is located in District Lowokwaru of Malang City at an altitude of 451 above sea level (5). A quantitative descriptive method was used to analyse the data. This research method includes data collection, data analysis and an interpretation of the results of the study to obtain information to design an injection well in the campus. Soil permeability test was conducted to determine the velocity of the infiltration of the rainwater into the soil using triplicate Falling Head Permeability method.

The drainage channel of S1 and S2 were located at the surrounding of the building while S3 was drained water from S1 and S2 to the river. S1 and S2 are square with 0.6 m wide and 0.6 m high. S3 has a length of 1.0 m and 1.0 m high (Figure 1).

Fig. 1. Site plan of drainage channel and injection wells.

Equation 1 and 2 were used to calculate the discharge that can be accommodated by the drainage channel (9).

$$Q = A \times V$$

(1)

Where:

Q = channel discharge (m³/sec)

A = broad channel (m²)

V = channel volume (m/sec)

$$Q = \frac{HFK}{(1 - \exp(\frac{-FKT}{\pi R^2}))}$$

(2)

Where:

F = geometric factor (depending on the method used in dimming absorption wells)

H = height of well (m),

T = streaming time (seconds),

K = soil permeability coefficient (m/sec),

R = the radius of the well (m)

3 Research Results

3.1 Drainage Channel Capacity

Graha Rektorat is located on a flat surface which suitable to build an injection well in the campus. The nine floors building must be equipped with drainage channels to drain the rainwater coming from the rooftop or the surrounding of the building. The existing drainage channel in Graha Rektorat of the SUM itself is a closed system that drains the water directly into the river. The drainage channel must have a higher capacity than the runoff discharges. The size of the existing drainage channels in Graha Rektorat is listed in Table 1.

Table 1. Drainage channel capacity.

Channel	A(m ²)	V (m/s)	Q (m ³ /s)
S1	0.36	3.151	1.134
S2	0.36	3.151	1.134
S3	1.00	4.429	4.429

To determine whether the dimension of the drainage channel has met the design standard where it can retain rainwater debit, the capacity of the channel must be bigger than the runoff discharge capacity. It compares to the runoff discharge based on the hydrological analysis. Furthermore, the runoff debit occurred in the Graha Rectorate of the SUM is presented in Figure 2.

Fig. 2. Runoff discharge at the Graha Rektorat of the SUM.

From these data, the drainage channel S1 and S2 can hold the runoff discharge up to 10-year return period. Meanwhile, the drainage channel of S3 able to retain runoff discharge up to 50 years. Runoff discharge about 0.62 m³/s of the return period two years was used as basic calculation for designing the injection well because this value is more realistic to be implemented at the Graha Rektorat area (Figure 2).

3.2 Design of the injection well system

The injection well was designed for a circle shape with a diameter of 1.5 m and depth of 3 m. The coefficient of soil permeability of 0.0056 ± 0.0006 cm/s was used to measure the velocity of rainwater infiltration into the soil. The injection well was planned to construct next to the five drainage channel where the rainwater was directed by the additional shortcut channel (3 m from the building). The well made from the concrete-bus with a height of 1 m and the remaining depth is soil. The concave well-cover made from the concrete plate with the thickness of 10 cm (SNI 03-2459-1991) which equipped with several holes to allow the rainwater flow into the well. The arrangement of the rainwater filter were sand, gravel, and stones for about 25% (44 cm) of the injection well dimension.

According to the soil permeability measurement, the flow of the rainwater into one injection well was $0.0302 \text{ m}^3/\text{sec}$. There were 10 of the injection well which designed to retain the rainwater at the surrounding building with a total water debit of $0.302 \text{ m}^3/\text{sec}$. Figure 3 shows the design of the injection well suitable for Graha Rektorat at SUM.

Fig. 3. Design of injection well

The rainwater debit calculation generated 0.0263 m³/sec for one of the injection well, however, the design of one injection well that suitable with the area of the Graha Rektorat was 0.0302 m³/sec. By constructing of 10 of the injection well at the surrounding of the Graha Rektorat, the rainwater runoff can be reduced up to 44%. It means that 0.302 m³/sec of rainwater will infiltrate into the soil. The reduction of rainwater runoff is presented in Figure 4.

Fig. 4. Runoff discharge reduction using an injection well.

4 Conclusion

- Based on the analysis of the existing drainage channel, the runoff discharge at the Graha Rektorat of SUM can be accommodated the rainfall for a return period of 10 years.
- The drainage load can be reduced by 44.07%, 34.35% and 28.87% for a return period of 2, 5, and ten years respectively.
- The use of the injection well at Graha Rektorat of the SUM can reduce the drainage load for the return period of 2 years.

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