Environmental drainage system with low impact development planning in office area

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Abstract. The development of residential and office the North Bandung area led to the expansion of impermeable areas. This condition causes water shortage and increase surface runoff. The high demand for water in office areas increases the excessive exploitation of groundwater in cities by rainwater harvesting. The method applied is Low Impact Development (LID). This concept combines rainwater harvesting and artificial recharge to fulfill of water needed and to increase groundwater savings. One of the pilot locations is the LIPI Bandung office area. The purpose of this study was to determine the volume of runoff rainfall that occurred in this area. The analysis used is descriptive analysis with a quantitative approach. Rainwater harvesting volume is 1.2263.7 m³ / year which can reduce groundwater use by 1.02%. The media used to store rainwater is a reservoir that is installed in each building. The construction of artificial recharge from reservoir delegation serves to reduce surface runoff and increase groundwater storage. This method is expected to be a solution to reduce excessive use of ground water and reduce surface runoff to support urban groundwater conservation.

1. Introduction
The development in the North Bandung region has changed its hydrogeological conditions, reducing groundwater storage and increasing surface runoff [1]. Floods and lack of clean water supply are routine problems faced by many major cities in Indonesia, including Bandung. During the rainy season there are floods, while in the dry season people have difficulty getting water to meet their water needs. To meet various community needs around 317 million m³ / year shallow ground water is taken from the Bandung groundwater basin [2]. The impact of changing land functions from non-built into a maintained area that can increase rainwater runoff:In the 10% rural area to runoff, rural suburban with 10-50 watersheds, 20-30% runoff values, while in urban areas with 75% -100% watertight will increase rainfall runoff by 55% [3].

Currently direct runoff is channelled into conventional drainage and drain excess water into the river which has an impact on flooding that occurs in the rainy season. Conventional drainage errors are to throw water as quickly as possible into the river, so that the river load will increase and reduce the chance of water infiltration into the groundwater, consequently the ground water reserves will decrease so that drought will occur during the dry season [4]. One way to control rainwater runoff so that it can be used as a water source can be minimized by the development approach based on the concept of Low Impact Development (LID). This concept applies surface runoff treatments that protect aspects of conservation [5]. One effort to implement LID is the overall management of rainwater starting from the process of shelter, benefits, recharge and drainage of the remaining rainwater so as to achieve zero run off [6]. Zero run off is the amount of runoff water coming out of
the system reaching zero or near zero percent or the detained runoff of rainwater can be reached 100%. The standard guidelines and standards are rainwater artificial recharge [7]. Artificial recharge that are integrated between rain water harvesting and artificial recharge can be applied to office areas to reduce rainwater runoff originating from the roofs of office buildings. This study aims to determine the volume of rainwater as a source of rainwater harvesting which can be used as water reserves to reduce groundwater use and surface runoff. In particular, the activity of rainwater harvesting utilizes a rainwater roof to overcome the problem of land deficit and flooding in the Bandung Basin. To realize the above objectives, an environmentally friendly office drainage system is planned.

Changes in built land in the North Bandung area are increasing. Populated residential areas and offices meet in this region. This condition will affect the use of groundwater and increase surface runoff. The LIPI office area is a research institution located in North Bandung with. The choice of location is expected to represent other regions or to identify the volume of surface runoff that can be reused as a water resource. To ensure the availability of sustainable water, efforts must be made to increase the availability of ground water. One effort that can be done is to harvest rainwater to increase the availability of ground water. Based on a review of the Regulation of the Minister of Environment No. 12 - 2009 [8], rainwater is a source of water that can be used as a groundwater recharge and used directly to overcome water shortages during the dry season and flooding in the rainy season. With increasing development activities resulting in reduced water catchment areas that can cause environmental damage. Utilization of rainwater attacks activities to collect, use and or absorb rainwater into the soil. The basic principle of water conservation is to prevent or minimize water that is lost as surface runoff and store it as close as possible, this concept can be tried for office buildings.

2. Literature Review

Rainwater harvesting can be divided into two parts, the first is to collect rainwater on the roof of the building and the second is to collect soil infiltration water [9]. Rainwater harvesting is a method or technology used to collect rainwater originating from from building roofs, ground level, rocky roads or hills and used as a source of clean water supply [10]. Rainwater harvesting can be used for various purposes. Rainwater is usually collected or harvested from roofs, concrete floors in the yard, roads and other waterproof surfaces. Rainwater then flows into the collection tank or pool. The rain harvest helps reduce surface runoff from rain [11]. Water use can be grouped into four groups based on their intended use, water for public purposes is distinguished from domestic consumption water and water for social and commercial consumption [12]. According to WHO calculations in developed countries, everyone needs water between 60 - 120 liters per day. Whereas in developing countries, including Indonesia, everyone needs water between 30-60 liters per day. Among these uses of water, the most important is the need for drinking [13]. Environmental friendly local rainwater management is known as the "Low Impact Development" (LID) technique. LID is the design of an area with the aim of maintaining hydrological functions before development by creating functions similar to the hydrological landscape. LID Principles which are based on micro-control of rainwater spread throughout the region [3]. The concept of rainwater treatment with this technique is micro-scale rainwater treatment carried out at the location or around the catchment area. LIDs are developed to maintain environmental conditions from the negative impacts caused by economic development and the limitations of conventional rainwater management practices [14].

The LID principles are: utilizing shelter in buildings in an effort to hold down the flow of rainwater downstream, reducing land conversion into water resistant land; multiply cover crops such as land and plants covered with grass; extend the concentration time by extending the flow path; conservation of natural drainage systems to reduce flooding; Permanent or temporary watermarks are needed to control the volume and peak of floods, as well as runoff water quality [14]. Rainwater harvesting is one example of a LID by storing rainwater runoff to reduce surface runoff. The aim of adapting this LID to the office area is to improve water conservation activities and reduce rainwater runoff. When rainwater harvesting is used to meet daily needs, evapotranspiration by vegetation or absorb rainwater into the soil, thus helping maintain water balance [3]. Some of the infrastructure used to rainwater
harvesting includes storage tanks. There are three things that need to be considered in rainwater harvesting: groundwater needs, the existence of adequate rainwater sources and the existence of policy support [15]. Therefore the analysis of rainwater harvesting to increase groundwater availability in the Bandung area was analyzed based on location requirements and suitability.

3. Method

3.1 Time and Location of Research
This research was conducted during 2017. The research locations were in the LIPI office. This area is located in a densely populated settlement in the Coblong District of Bandung. This location is expected to represent other regions or to identify surface runoff volumes that can be reused as water resources (Figure 1). This area is almost an impermeable area, during the rainy season there is a high surface runoff which causes flooding or "Cileuncang" in the city of Bandung.

![Rainwater Harvesting Map at the Bandung LIPI office area](image)

Figure 1. Rainwater Harvesting Map at the Bandung LIPI office area

3.2 Research methods
This research is a descriptive study with a quantitative approach. Quantitative research methods can be interpreted as a research method based on the philosophy of positivism, which is used to examine certain populations or samples [16]. At the beginning of the study carried out a description of the roof area to be used as experimental land, the location of artificial recharge, followed by the calculation of rainwater and office water requirements.

3.3 Research focus
This study only focuses on the quantity of water. The type of data is divided into two, namely primary and secondary data. Primary data collection is obtained by observation and interview. While secondary data, obtained from local governments that have rainfall and each observation post and evaporation value in the area. Primary data is obtained from managers of office such as data on the number of employees and the size of office buildings. Observations were made to find out the types of buildings that fall into rainwater. Interviews were conducted to determine the conditions or conditions of rainwater management in the study area and the water sources used for water supply and water storage capacity in the LIPI office area.

3.4 Data analysis method
The amount of rainfall intensity is different because of the duration of rainfall or frequency of events. And if no data is found for the duration of the rain, an empirical approach is needed with reference to the duration of 60 minutes and the maximum daily rainfall that occurs every year [17]:
\[ I = (90\% \times R24) / 4 \]  
(1)

With \( I \) is rain intensity, \( R24 \) is Maximum daily rainfall (mm / 24 hours). Calculation of average rainfall uses 10 years of data, namely rainfall in Dago Station which covers the study area. Analysis of rainwater harvesting potential (RWH) per building is used to determine the rainfall capacity generated based on the amount of rainfall and captured by the roof of the building per month. The following formula [18]:

\[ VR = R \times Hra \times Rc / 1000 \]  
(2)

With \( VR \) is rainwater potential harvesting (mm3), \( R \) is monthly rainfall (mm), and \( Hra \) is roof area (m2), \( Rc = \) runoff coefficient. Runoff coefficient (Rc) for the calculation of impermeable buildings using a value of 0.9. The results of this study [18], which assume that 0.1 rainwater evaporates or is lost in the gutter when rainfall is attached to the reservoir. As for the calculation of rainwater harvesting in open space, use the same formula but the value of R is replaced by the calculation of Rain Intensity.

**Table 1. Land Cover Runoff Coefficient**

| No | Land Cover          | Coefficient of Run Off |
|----|---------------------|------------------------|
| 1  | Grasses             | 0.02                   |
| 2  | Park (50 % grasst: 50% tree) | 0.04                  |
| 3  | Road                | 0.09                   |
| 4  | Paving Block        | 0.07                   |
| 5  | Swimming            | 0.02                   |
| 6  | Grass Block         | 0.06                   |

Source: [18]

Residence Capacity Analysis Rainfall per building is used to determine the capacity of shelters that need to be available to collect rainwater taken by the roof per building [19]. The following formula is in [20]. Analysis of office area water requirements using SNI 03-7065-2005 standard [21], standard water requirements for offices are 80 l / employee / day. with the results of the total analysis of rainwater harvesting in the office and education area, then for pond locations or artificial lakes analyzed using spatial analysis using contour data, flow direction, drainage network and land use.

**Figure 2. The concept of environmental drainage**

Low impact development drainage design concept and environmentally sound with the initial steps as shown in Figure 2. The average rainfall falls on the roof of the building, flowing into the drainage of the building and then accommodating it in a rainwater reservoir to be used as raw water. Average rainfall and runoff volume that falls on the roof assuming: (1) rainwater from office roofs, which are relatively large in size and accommodated in large volumes of reservoirs can be used for rain water harvesting facilities, (2) rainwater consumption is obtained by specifying a number of marches and
calculating water requirements, (3) rainfall that is not accommodated in the reservoir will flow to artificial recharge (4) rainwater reservoirs can be used to fulfill raw water, reduce surface runoff and increase groundwater reserves so that the system is realized insightful drainage in the LIPI office area.

4. Results and analysis

4.1 Rainfall analysis

Calculation of average rainfall using 12 years of data from Dago Station closest to the research location. Rainfall Harvesting Potential (RWH) uses baseline rainfall data in 2017 with reference to 12-year rainfall data at the nearest station (Figure 3). Observation of the rain time series is done to observe the fluctuations and anomalies of rainfall that occur in this region. The value of rainfall at Dago Station tends to be stable, but in 2010 there was extreme rainfall in 12 years which was influenced by global climate.

![Figure 3. Analysis of annual rainfall during 2004 - 2017 at Dago station](image)

The data used for the analysis of rainwater harvests and the determined rainfall intensity are 2017 data (Figure 4). Rainfall is highest in November, whereas in April and June rainfall is lowest, it is assumed that the dry season begins in April - June and the rainy season starts in September - December 2017. The potential for high rainfall can be used as a reserve for use return groundwater consumption and surface runoff.

![Figure 4. Analysis of 2017 rainfall at Dago Station](image)

The amount of rainfall intensity is different because of the duration of rainfall or frequency of events. Rainfall intensity based on maximum rainfall. The highest rainfall intensity was in November, due to the highest rainfall this month among other months (Table 2).

| 2017  | Rainfall (mm) | Max Rainfall (mm/24 hours) | I (mm/hours) |
|-------|---------------|-----------------------------|--------------|
| January | 185           | 47                          | 10,6         |
| February | 384           | 56                          | 12,6         |
| March | 389           | 43                          | 9,7          |
| April | 0             | 0                           | 0,0          |
| May | 40            | 22                          | 5,0          |
| June | 0             | 0                           | 0,0          |
4.2 Water requirements and availability

Water requirements in the LIPI office are stable every month. The highest water requirements are in January, December, May, July, August and November. This is because the number of days in a month is 31 days. The number of employees working is around 500 people with water needs of 40000 l/person/day or 1200000 l/person/month. Coefficient of runoff (Rc) for of watertight buildings uses 0.90, which assumes that 0.1 rainwater is evaporated or lost (Table 3).

Table 3. Data on Volume Harvesting in 2017 (Source: 2018 analysis)

| 2017 Yr | Rainfall(m) | Hra(m^3) | Rc | VR(m^3/month) |
|---------|-------------|----------|----|---------------|
| jan     | 185         | 6265     | 0.9| 1043.1        |
| feb     | 384         | 6265     | 0.9| 2165.2        |
| mar     | 389         | 6265     | 0.9| 2193.4        |
| apr     | 0           | 6265     | 0.9| 0.0           |
| mei     | 40          | 6265     | 0.9| 225.5         |
| jun     | 0           | 6265     | 0.9| 0.0           |
| jul     | 107         | 6265     | 0.9| 603.3         |
| agust   | 62          | 6265     | 0.9| 349.6         |
| sep     | 100         | 6265     | 0.9| 563.9         |
| okt     | 304         | 6265     | 0.9| 1714.1        |
| nor     | 476         | 6265     | 0.9| 2683.9        |
| des     | 128         | 6265     | 0.9| 721.7         |

The highest rainwater harvesting potential is in November with value of 2683.9 m^3/month and the lowest in April and June in the dry season (Figure 5).

![Figure 5. Rainwater harvesting at LIPI office area](image)

Comparison of rainwater harvesting results with water requirements in the LIPI office area is presented in percentage, that is how much rain water can reduce water consumption in LIPI office which source of water comes from groundwater. Total volume of rainwater harvesting is 12263.7 m^3/year which can reduce ground water usage by 1.02%.

4.3 Rainwater harvesting and artificial recharge

Water requirements in the LIPI region can be reduced by the presence of rainwater harvesting. In January, the percentage of rainwater harvest that can be used for water needs is 0.07% of water use this month (more than 3). The average rainwater harvesting that can be used to reduce water use from
groundwater sources is 0.06% (Figure 6). The existing water source used in the area is now a well then with a pump house, water from the well is pumped into the main reservoir and pumped again to be accommodated in the roof reservoir, by using the gravitational force for all activities in this area.

![Figure 6. Percentage of rain harvest in the LIPI area](image)

Analysis of the potential of rainwater harvesting per building is used to determine the rainfall capacity generated based on the amount of rainfall and captured by the roof of the building per month (Figure 7). Large buildings can accommodate more rainfall reserves. This value is used as a guide for building water reservoirs that can be distributed to other building units.

![Figure 7. Rainwater harvesting map based on buildings in the LIPI office area](image)

The construction of artificial recharge that are integrated with rainwater harvesting is a concept that strongly supports groundwater conservation for areas with limited land (Figure 8). The water source that is included is rainwater from the roof. This artificial recharge can be used in areas that have a depth of groundwater > 5 meters. Construction of artificial recharge to a depth of 35 meters to facilitate the process of storing groundwater into aquifers and avoiding the overflow of water put into the well.
5. Conclusion
The low impact development concept applied in this office area combines rainwater harvesting and artificial recharge. Rainwater harvesting carried out in this study is used as raw water supplies for water needs by using reservoirs which also function as conservation of rainwater and anticipation of flooding in the rainy season. The volume of rainwater harvesting in the LIPI office area is 1.226.7 m$^3$/year which can reduce groundwater use by 1.02%. The media used to store rainwater is a reservoir that is installed in each building. The construction of artificial recharge from reservoir delegation serves to reduce surface runoff and increase groundwater storage. This method is expected to be a solution to reduce excessive use of ground water in office areas and reduce surface runoff to support urban groundwater conservation.

6. Suggestions
Further research needs to be carried out on water quality studies from rainwater harvesting practices and detailed planning of rainwater harvesting practices, especially distribution network locations, to pipe diameters and details of the components of screening tools to be used and future trends in water use. In addition to further research, there is a need for detailed calculations such as the speed of water flow from open space to the channel, the speed of water flow in drainage to the lake, calculation of the volume of water left in drainage.

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