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Analysis of Rainwater Harvesting as An Alternative to Non-Domestic Water Supply at PLN Institute of Technology

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ABSTRACT

Clean water is one of the targets in the Sustainable Development Goals (SDG's), specifically ensuring the availability and sustainability of water management. Continued use of groundwater results in land subsidence. The high level of rainfall in Jakarta requires rainwater to be utilized to reduce surface water runoff, especially by rainwater harvesting. PLN Institute of Technology has a total of more than 3.000 employees and students. Based on the use of non-domestic water needs in universities per day for universities of 10 liters/student/day. The volume of rainwater generated by the roof area of PLN Institute of Technology with an area of 1.024 m^2 and the mainstay rainfall from 2012 to 2022 was obtained a total of 2.159,18 m^3 per year. The storage tanks are made the size of each storage tank that can accommodate a volume of water of 300 m^3 with a length of 15 meters, a width of 10 meters and a depth of 2 meters. By using the rainwater harvesting system at PLN Institute of Technology based on the calculation of the potential for meeting water needs, there is an excess of harvested rainwater of 1,202.78 m^3 when the number of users is 10% and as much as 248.78 m^3 when the number of users is 20% that can be accommodated for use.

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1. INTRODUCTION

The Sustainable Development Goals (SDGs) is a global agenda that includes various aspects of human life with a focus on sustainable development for the next few years. the next few years. One of the crucial goals in the SDGs is Sustainable Development Goal 6 (SDGs 6), which targets Clean Water and Sanitation (SDG 6), which targets Clean Water and Sanitation [1], [2]. Increasing population growth requires more clean water. The rapid development has resulted in less land for water absorption so that the volume of stored groundwater is decreasing. Meanwhile, currently the fulfilment of clean water needs is partly from groundwater. The increasing need for clean water that is not balanced with the availability of clean water causes a clean water crisis that must be resolved.

Infiltration in each land use can be different if the physical properties of the soil are different. Different land uses show differences in vegetation cover, and each type of vegetation has a different root system and produces different and produce different sources of soil organic matter in different amounts. This can cause differences in the characteristics of physical properties of soil in different land uses [3]. Rainwater that falls undergoes an infiltration process by plants or is absorbed back into groundwater. On office and residential land that has no more infiltration land will flow into the drainage channel. The rainwater should be used to fulfil some of the clean water needs.

Rainwater can be an alternative source of available every rainy season and has the potential to reduce pressure on fresh water sources. on the use of fresh water sources. Rainwater harvesting from rooftops is from the roof of the house is usually an alternative source of clean water and only requires simple treatment before the water is used, requires only simple treatment before the water is used, such as the construction of a pipe filters consisting of palm fibre adsorbents, sand, gravel, charcoal, and sponge can be utilized to reduce rainwater pollution can be utilized to reduce rainwater pollution for daily needs [4]. Based on the hydrological cycle, the amount of water volume in the world is fixed. With the hydrological cycle, rainwater can be utilized to reduce surface water runoff that occurs, so a good water treatment method is needed to create a balance in water utilization. Methods to anticipate raw water needs in the dry season is by using rainwater harvesting or rainwater harvesting, rainwater harvesting techniques rainwater harvesting technique is by utilizing the roof building as a medium for collecting rainwater or rainwater harvesting means when it rains the water that falls on the roof side of the building is collected and stored in a catch basin or infiltrated into the ground or infiltrated into the ground through pipes or gutters through pipes or gutters [5]. Rainwater harvesting can control erosion and flooding and reduce water pollution [6]. Alternative solution to the problem through water conservation efforts with rainwater harvesting techniques. This solution is an important agenda agenda in saving and managing water resources internationally [7]. Rainwater harvesting is performed in many regions of the world to capture and store rainwater to meet domestic water needs, i.e. water for drinking and cooking, irrigation, stormwater control, supplementing municipal water supply in urban areas, and assisting in rural and urban water control and management [8]. Rainwater harvesting in urban areas is a strategy that brings many benefits and can serve to address current water shortages, urban stream degradation and flooding [9], [10], [11].

The regulation of the minister of public works of the Republic of Indonesia number 11/PRT/M/2014 describes efforts to conserve the natural water cycle using collection, rainwater capture, and storage to reduce flooding. DKI Jakarta Province, explains that every building and parcel must deal with rainwater so that it needs to be handled in rainwater management [12].

In line with the vision of PLN Institute of Technology to become an international-class, modern, independent, and superior university in the field of energy and technology that is environmentally sound that supports the Sustainable Development Goals program, it should develop the potential for utilizing rainwater harvesting from buildings to realize the SDGs 6 program. This research will examine the study of rainwater harvesting to fulfil non-domestic water usage at the PLN Institute of Technology by implementing rainwater harvesting through the roof of the building which can be used as washing water, toilet flushes, and plant watering. So, with the rainwater harvesting system with good management in the PLN Institute of Technology environment can meet the needs of non-domestic water at the PLN Institute of Technology optimally.

2. RESEARCH METHOD

Data collection is conducted both directly and indirectly as a result. Direct review, collection and/or measurement of data in the field is referred to as direct data collection. Indirect data collection refers to the collection of information from organizations or officials involved in data provision to supplement and enhance the data.

2.1. Research Location

Rainwater harvesting research using gadung roof as rainwater catchment area. The research was conducted at the main building of PLN Institute of Technology located at Jalan Lingkar Luar Barat, Duri kosambi, Cengkareng, West Jakarta, DKI Jakarta 11750 as on figure 1.

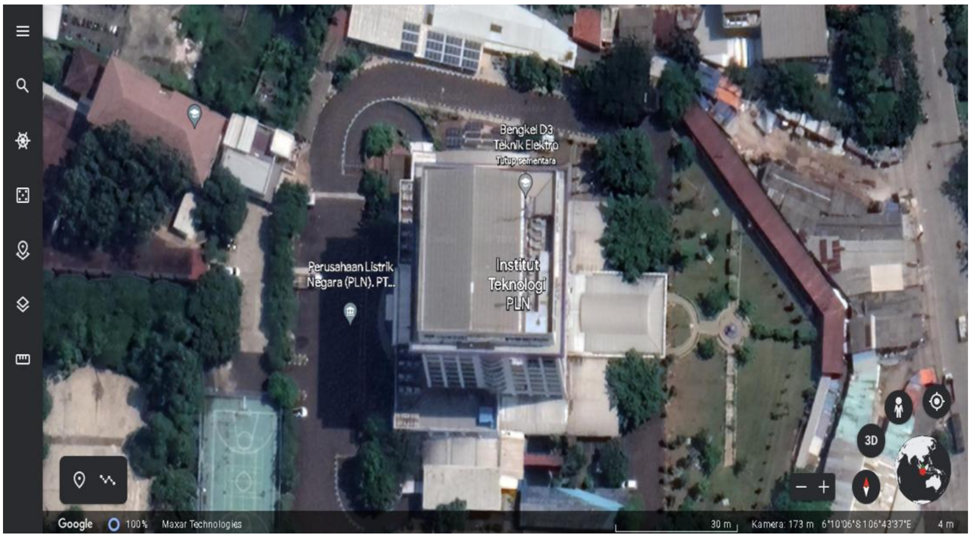

Figure 1. Research location

2.2. Data analysis

The data analysis method is a series of techniques and procedures used to process and interpret data so that useful and useful information can be produced for decision makers. This stage is carried out to obtain the required research results. The stages of data analysis in this study are as follows:

1. Water Calculation
   Based on the percentage of the number of employees and students and individual water needs per day according to Non-Domestic Water Needs for Categories I, II, III, IV, V. The water needs met in this planning are limited only to the needs of toilet flushes, plant watering and washing.
2. Calculation of Rainfall
   Using data that has been obtained from the Kemayoran Rain Station and Soekarno-Hatta Class I Meteorological Station by taking a span of 11 years from 2012 to 2022, the volume that can be captured by the roof area will be obtained. Results will be obtained from multiplying the average rainfall by the area of the rain catchment area and the runoff coefficient. By using reliable rainfall data that will be calculated through the plan discharge that has been calculated based on the maximum daily rainfall with the plan rainfall calculation method [13], [14], [15].

- Calculation of the mainstay rainfall is done by processing annual rainfall data that has been sorted and then calculated the chances of each can be calculated by the equation (1).

$$P = \frac{m}{n+1} \times 100\ \% \quad (1)$$

Where :
P : probability (%)
m : Sorted data sequence number
n : Number of data

- The amount of rainfall intensity is needed to calculate the discharge plan. Rainfall intensity is the amount of rainfall in a unit of time, such as mm/hour for short-term rainfall, and the amount of rainfall intensity depends on the length of the rainfall, using quotation (2) and (3)

$$I = \frac{R_{24}}{24} \times \left(\frac{24}{tc}\right)^{m} \quad (2)$$

$$Tc = 0{,}0195 \times \left(\frac{L}{\sqrt{S}}\right)^{0{,}77} \quad (3)$$

- Using the rational method, after the rainfall intensity has been calculated based on a small research area with the rainfall intensity used, namely the highest rainfall intensity, the water discharge can be calculated using the equation (4).

$$Q = 0{,}00278.C.I.A \quad (4)$$

Where :
Q : average rainwater discharge (m^3/s)
C : runoff coefficient
I : rainfall intensity (mm/hour)
A : roof area as a water catchment area (Ha)

- The amount of rainwater that can be collected is calculated using the formula below to determine the amount of rainwater available using the quotation (5).

$$S = A \times M \times F \quad (5)$$

Where :
S : Rainwater supply that can be accommodated (m3)
A : Rainwater catchment area (m2)
M : Average rainfall (mm/month)
F : runoff coefficient

- Calculating the capacity of water sources needed to meet these needs and also we can maintain the availability of clean water and ensure that water resources can be used sustainably and efficiently using quotation (6)

$$B = D \times P \times n \quad (6)$$

Where:
B : One month water demand (m^3)
D : Individual water demand per day (m^3)
P : Number of users (people)
n : number of days in a month

3. Storage Tank Capacity
Based on the rainfall discharge and clean water needs that have been obtained, the tank capacity of rainwater storage will then be planned. The capacity is planned based on the largest reliable rainfall volume obtained so that a capacity or size that can accommodate the highest rainfall is planned. In planning the volume of the storage tank must be in accordance with the supply and demand for water. The volume of the storage tank can be determined using the quotation (7).

$$V = S – B \quad (7)$$

Where:
V : Storage tank volume (m3)
S : Ability of the tank to collect rainwater for a month (m3)
B : Water demand in a month (m3)

3. RESULTS AND DISCUSSION

3.1. Hydrology Analysis

Reliable Rainfall Analysis

Rainfall data that has been sorted from the largest rainfall to the smallest rainfall will then be sought for reliable rainfall. The rainfall used is 11 years from the Soekarno-Hatta and Kemayoran rainfall stations. Calculation of the mainstay rainfall is done by processing annual rainfall data that has been sorted and then calculated the chances of each can be calculated by equation (1) is 8,33% and shown on table (1).

Table 1. Calculation Result of Chance of Predicted Rainfall

No.	Year	Rainfall (mm/day)	Max to min Rainfall	Reliable	Year
1	2012	105,2	423	8,33	2019
2	2013	193,4	277,5	16,67	2015
3	2014	147,9	277,5	25,00	2020
4	2015	277,5	204	33,33	2022
5	2016	147,6	193,4	41,67	2013

No.	Year	Rainfall (mm/day)	Max to min Rainfall	Reliable	Year
6	2017	179,7	179,7	50,00	2017
7	2018	104,6	147,9	58,33	2014
8	2019	423	147,6	66,67	2016
9	2020	277,5	105,2	75,00	2012
10	2021	94,1	104,6	83,33	2018
11	2022	204	94,1	**91,67**	**2021**

After obtaining the probability of each rainfall, one of the data that is close to an 90% chance is selected, namely rainfall in 2021 of 91,67% so that in this planning what is used is the 2021 rainfall so that the results are obtained as shown in table 2 below and graphic on figure 2:

Table 2. Reliable Rainfall Results

Month	2021	Predicted Rainfall (m)
January	358,83	0,36
February	536,40	0,54
March	222,80	0,22
April	143,83	0,14
May	173,10	0,17
June	95,53	0,10
July	43,67	0,04
August	81,73	0,08
September	71,23	0,07
October	131,70	0,13
November	115,37	0,12
December	231,07	0,23
Total	2205,267	

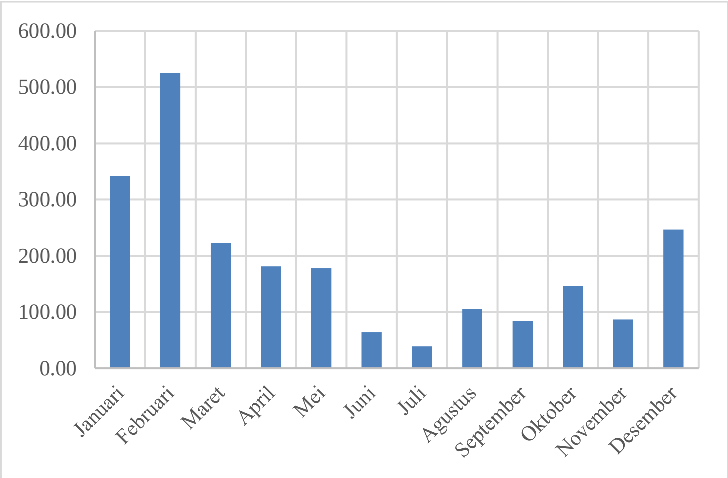

Figure 2. Reliable Rainfall Graphic

Based on the mainstay rainfall graph, it is known that the highest mainstay rainfall occurs in February, which is 536.40 mm/month. The reliable rainfall that has been obtained will be used to calculate the volume of rainwater that can be harvested each month.

Rainfall Intensity

With the assumption of the rain duration that occurs on the island of Java is 4 hours. The method used in the calculation of rainfall intensity is the Mononobe method. The results of the calculation of rainfall intensity can be seen in figure 3 below:

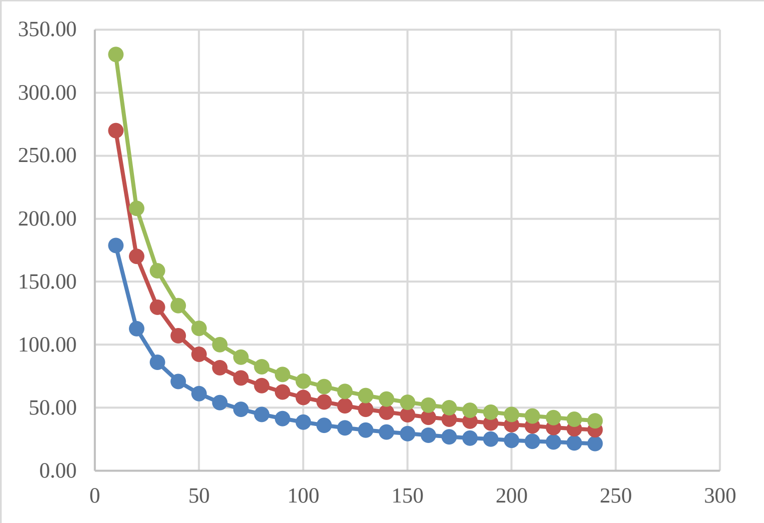

Figure 3. Rainfall Intensity Graphic

From the calculation results it can be seen that the longer the rainfall time the lower the rainfall intensity because time affects the intensity of the rainfall. The intensity obtained has loaded from the planned rainfall based on the Gumbel method in the planned rainfall period for 2 years, 5 years, and 10 years. The highest rainfall intensity in the two-year rainfall period is 178.90 mm/hour. The highest rainfall intensity in the 5-year plan rainfall period is 270.09 mm/hour. The highest intensity during the 10-year plan rainfall period is 330.46 mm/hour. The rainfall intensity obtained will be used for the calculation of discharge plans based on rainfall periods of 2 years, 5 years, and 10 years.

Calculation of Water Discharge

Using the rational method, after the rainfall intensity has been calculated based on a small research area with the rainfall intensity used, namely the highest rainfall intensity, the water discharge can be calculated using equation (4). Calculation of water discharge on the roof of the building with a return period of 2 years as shown on table 3.

Tabel 3. Annual Return Period Water Discharge Results

Year	**C**	**I**	**A**	**Discharge (m^3/sec)**
2	0,95	178,90	0,1024	0,05
5	0,95	270,09	0,1024	0,07
10	0,95	330,46	0,1024	0,09

3.2. Rainwater Analysis

Rainwater Availability

The calculation of rainwater availability is influenced by the area of rainwater catchment area or building roof, average rainfall, and runoff coefficient. The water availability in question is the potential rainwater that can be collected from the roof of the PLN Institute of Technology building.

In this research, the roof area is 1,024 m^2 with the runoff coefficient value used is 0.95. The determination of the runoff coefficient value is based on the nature of the material where the roof surface used in this study has impermeable properties. The amount of rainwater volume that can be collected from the roof is calculated using equation (5). The following are the results of the calculation of the potential rainwater that can be harvested at the research location:

Tabel 4. Potential Rainwater Harvesting Results

Month	Reliable Rainfall (m)	Runoff Coefficient	Roof Area (m^2)	Volume (m^3/month)
January	0,36	0,95	1.024	349,07
February	0,54	0,95	1.024	521,81
March	0,22	0,95	1.024	216,74
April	0,14	0,95	1.024	139,92
May	0,17	0,95	1.024	168,39
June	0,10	0,95	1.024	92,93
July	0,04	0,95	1.024	42,48
August	0,08	0,95	1.024	79,51
September	0,07	0,95	1.024	69,30
October	0,13	0,95	1.024	128,12
November	0,12	0,95	1.024	112,23
December	0,23	0,95	1.024	224,78
		Total Volume		2.145,28

Based on the calculation results, the volume of rainwater generated by the roof area of PLN Institute of Technology with an area of 1.024 m2 and the mainstay rainfall from 2012 to 2022 was found to total 2.145,28 m3 per year. The volume of rainwater that can be harvested based on the highest reliable rainfall is in February where the volume of rainwater harvested is 521,81 m^3/ month.

3.3. Non-Domestic Water Demand at PLN Institute of Technology

Planning the calculation of non-domestic water demand at PLN Institute of Technology using the method of the number of occupants or population of the building. For data on the number of occupants based on the number of employees and students who are at the PLN Institute of Technology.

Calculation of non-domestic water demand at PLN Institute of Technology based on equation (6) with total user rounded 3.000 people.

Tabel 5. Water requirement of non-domestic water demand at ITPLN campus

Month	Water Requirement (m^3/Month)
January	81,2
February	75,2
March	81,2
April	78,2
May	81,2
June	78,2
July	81,2
August	81,2
September	78,2
October	81,2
November	78,2
December	81,2

Based on the use of water in universities per day for universities of 10 liters/student /day. The number of users at the location does not all use water every day, so the number of users is used as a percentage of the total number. Comparison of rainwater harvesting results with water requirements as shown on figure 4.

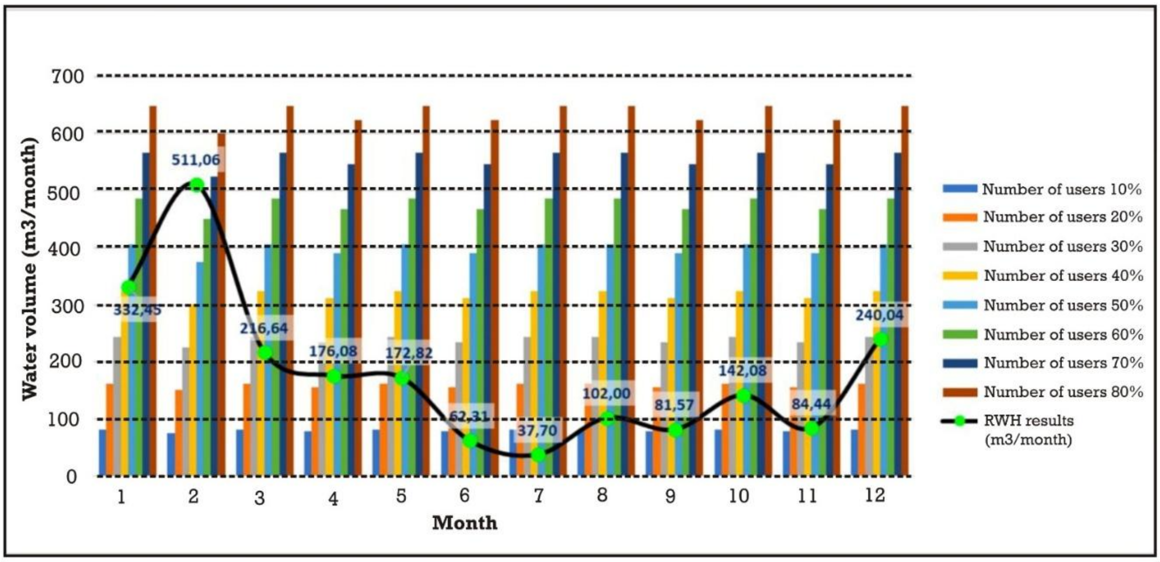

Figure 4. Comparison of Rainwater Harvesting Results with Water Requirements

3.4. Rainwater Tank Design

The rainwater harvesting basin is designed based on the largest reliable rainfall volume of 521.81 (m^3/ month). The basin will be designed to accommodate the largest volume of rainfall so that the basin is divided into two underground basins with a volume of 300 m^3. As shown on figure 5 and 6, the basin with a length of 15 meters a width of 10 meters and a depth of 2 meters.

Before the water is collected through gutters or pipes that will be directed first into the control tub where the control tub is planned in order to reduce sedimentation in the rainwater storage tank. In the control basin, a filter can also be installed so that particles that flow with water can be inhibited.

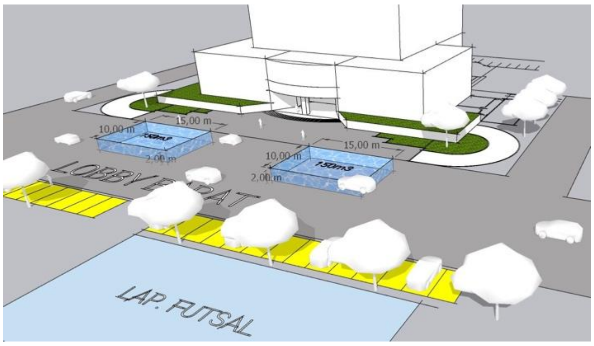

Figure 5. Rainwater ground tank

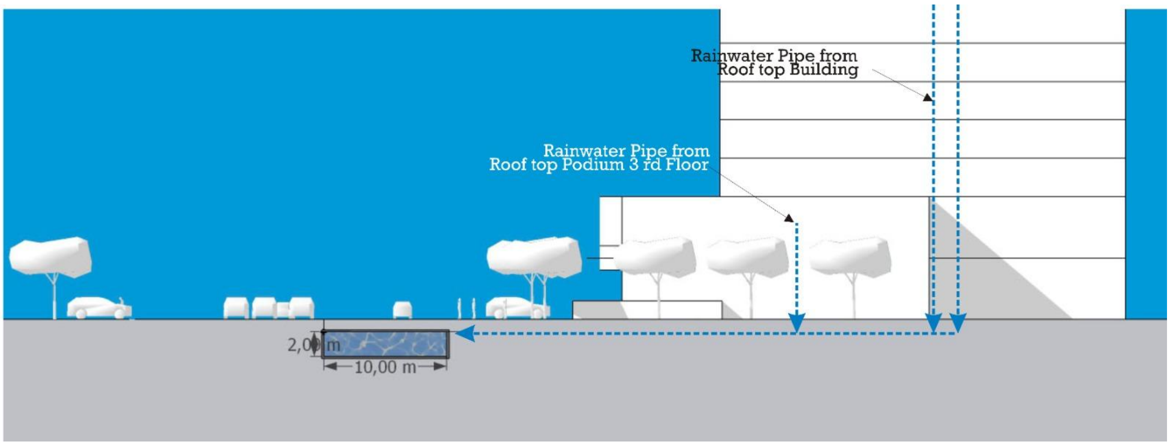

Figure 6. Rainwater ground tank cross section

4. CONCLUSION

Based on the calculation results, the volume of rainwater generated by the roof area of PLN Institute of Technology with an area of 1,024 m^2 and the mainstay rainfall from 2012 to 2022 was found to total 2,145.28 m^3 per year. Non-domestic water demand at PLN Institute of Technology is calculated based on the number of employees and students totaling 3.000. By using a percentage of the total number of employees and students, the water demand for 10% of the total employees and students is 956.4 m^3/year. water demand for 20% of the total employees and students is 1910.4 m3 / year. The largest water demand when the number of users is 80% of the total employees and students is 7634.4 m^3/year. By using a rainwater harvesting system at PLN Institute of Technology based on the calculation of the potential for meeting water needs, there is an excess of harvested rainwater of 1.188,88 m^3 when the number of users is 10% and as much as 234,88 m^3 when the number of users is 20% which can be accommodated for use. As for the number of users above 30% of the total number of students and employees, harvested rainwater cannot meet all the water needs at PLN Institute of Technology. In the calculation of rainwater harvesting results, the volume of rainwater that can be harvested using the mainstay rainfall is obtained the highest rainfall is in February of 521.81 (m^3/month). So that the planned storage basin becomes two storage basins placed on the right and left side of the building with a size of 15 meters long, 10 meters wide and 2 meters deep which can harvest rainwater.

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