Analysis of rainwater harvesting for toilet and landscaping needs of building B, Nusa Putra University

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Abstract. The increasing number of students at Nusa Putra University will lead to high water demand. The research objective was to plan the use of rainwater as an alternative source and design a rainwater harvesting tank. A quantitative descriptive method was used for data collection and analysis. With 1671 students 130 daily staff and a garden of 267.82 m2, efficient water management is necessary. Rainfall data from Ciraden Post for the past 10 years was used. The results showed a rainwater tank capacity of 300 m3 with a total rainwater storage of 1144.82 m3. This tank meets 23% of the toilet and garden water needs every month. The tank is designed using red bricks with a size of 15 m long, 5 m wide, and 4 m high. This research highlights the importance of rainwater utilization in addressing water needs in the campus environment.

1 Introduction

Population growth is expected to increase water demand despite the limited availability of water in its natural state [1]. In recent years, one of the issues that has been reported and has become a global concern is water insecurity [2]. The imbalance between increasing demand for water and limited water resources requires a new water management system [3]. In general, water demand will be higher in larger buildings (universities, companies, and public buildings) [4]. According to data from the United Nations Environment Program, around two-thirds of the world's population is projected to face a lack of clean water by 2025 . Additionally, the United Nations reported that approximately 4.2 billion individuals lacked access to safe sanitation in 2019 [4,5]. Furthermore, the Bappenas Report has indicated that water availability in most areas on Java and Bali has reached levels that are scarce or critical, while other regions, including South Sumatra, West Nusa Tenggara, and South Sulawesi, are expected to face similar challenges by 2045. Water demand and availability need to be managed sustainably to prevent water shortages and achieve water resource balance [3,5–7]. Wastewater reuse, desalination and rainwater harvesting as initiatives to manage water demand and seek alternative water sources continue to be undertaken by many organizations and river basin authorities [8].

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Currently, the phenomenon of rapid urbanization and climate crisis causes insecurity of air, food and energy resources [9,10]. Therefore, in overcoming these threats, attention and action are needed as a way for society to adapt and survive [11]. Indonesia, a country with high rainfall averaging more than 2 meters per year, has significant potential for utilizing rainwater as an alternative water source to meet community clean water needs [12–15]. However, a significant amount of rainwater is wasted due to inadequate utilization by the community. In order to overcome water shortages and reduce pressure on water resources in the future, this can be done by using rainwater harvesting [10,16–18]. Rainwater harvesting methods are widely known as complicated or easy techniques in the process of collecting and storing rainwater from roofs, ground surfaces, or water catchment areas that can be used for various purposes [18,19]. Rainwater harvesting techniques represent an effective solution to the problems of floods and droughts, as well as a means of providing clean water supplies for communities in need [20,21]. The method of intercepting and storing rainwater in a rainwater harvesting system provides water of non-potable quality, but is used for domestic purposes, including toilets, laundry and gardening [7,22]. Especially in dry and semi-arid areas, the rainwater harvesting process can be one of the most promising alternative sources of fresh water for use [21,23,24]. This approach has proven effective in countries such as Africa with low rainfall. In Indonesia, the regulation of rainwater utilization has been governed through the Decree of the Minister of Environment No. 12 of 2009, aiming to reduce waterlogging and flooding, and improve the quality and quantity of groundwater. Concrete steps are needed to maximize the potential of rainwater as a sustainable resource, including the implementation of supporting technologies and policies [25].

In Building B of Nusa Putra University, the water used for daily purposes is groundwater. The increase in the number of students at Nusa Putra University will substantially increase the demand for water resources. Based on data obtained from PPDIKTI, the number of students in 2023 is 8,374 people. The percentage increase in the number of students from 2019 to 2023 averaged 36%. Based on projections and calculations, it is estimated that the water demand in 2028 will reach 152.13 m3 per day. In Overcoming the increasing demand for water on an ongoing basis, it is necessary to manage water resources efficiently. One way to do this is by collecting rainwater, commonly referred to as rainwater harvesting. Rainwater harvesting provides benefits to water supply systems and flood risk management, as well as being a method to reduce stormwater runoff in urban areas [26–29]. Based on literature results, it was reported that runoff volume can be reduced from 13 to 91% [30]. This method involves the collection of rainwater in a catchment area, which in this final project is the roof of Building B, Nusa Putra University. The collected rainwater is then utilized to reduce the use of groundwater. The rainwater collection building serves to collect and utilize the wasted water, which is then channeled to the rain catchment area itself, namely Building B of Nusa Putra University. Furthermore, the utilization of rainwater is estimated to result in a reduction of up to 2.8% in water demand on an annual basis. This will assist in maintaining an equilibrium in the utilization of water resources, which are becoming increasingly scarce.

2 Material and Methods

2.1 Research Method

This research employs a quantitative descriptive methodology, which includes the data collection, analysis, and interpretation of data to obtain the information necessary to conclude.

2.2 Research Location

This research was conducted in building B of Nusa Putra University, located at Jl. Raya Cibolang No. 21, Cibolang Kaler, Kec. Cisaat, Sukabumi Regency, West Java, Indonesia. The location of the research is illustrated in Figure. 1.

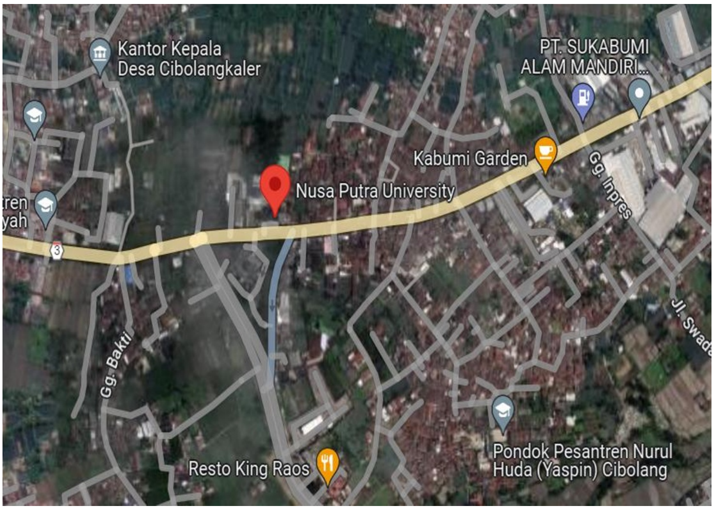

Fig. 1. Research Sites (google maps)

2.3 Research Data

2.3.1 Primary Data

The data was obtained directly from researchers through a variety of methods, including surveys, interviews, and document analysis. In this study, researchers surveyed the size of the garden area in Building B of Nusa Putra University.

2.3.2 Secondary Data

This data is obtained from several sources indirectly in the form of books, journals, or archives that are published or unpublished. Primary data needed in this study include planning drawing data for building B of Nusa Putra University, daily rainfall data for 10 years, and data on the number of students and staff of Nusa Putra University.

2.4 Research Flowchart

The following flow chart illustrates the stages of research implementation, from the initial stages of the process to its conclusion. The research flow chart can be seen in Figure. 2.

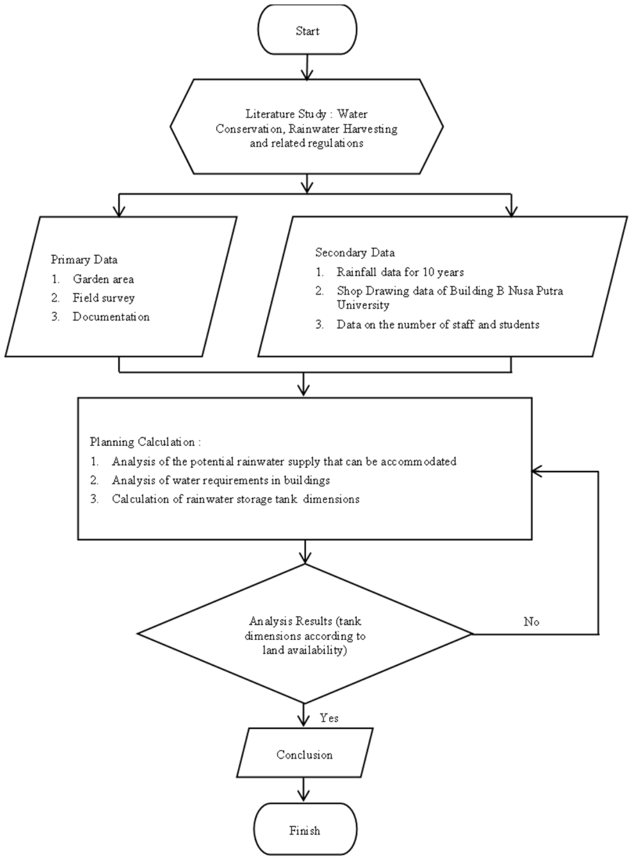

Fig. 2. Research Flow Chart

The flowchart you provided illustrates the general steps in conducting a study on water conservation, specifically rainwater harvesting. The study seems to focus on a particular building or area, in this case Building B of Nusa Putra University.

- Literature Review
  This initial stage involves gathering information from various sources such as journals, books, and regulations related to water conservation and rainwater harvesting. The goal is to gain a deep understanding of the concepts, techniques, and regulations in force.
- Primary Data Collection:
  This primary data collection consists of measuring the garden area which is one of the recipients of rainwater, field surveys to conduct direct observations at the location, making documentation (Collecting data in the form of photos, drawings, or sketches to support research analysis).
- Secondary Data Collection:
  This secondary data consists of rainfall data for the last 10 years to determine rainfall patterns, analyzing shop drawings of Building B to determine building characteristics such as roof area, roof type, and existing drainage systems, and collecting data on the number of staff and students to estimate water needs in the building.
- Calculation and Planning
  - Potential Analysis: Calculating the potential rainwater that can be accommodated based on roof area, rain intensity, and storage efficiency.

  - Needs Analysis: Determining water needs in the building, both for daily needs and for garden irrigation.
  - Tank Planning: Calculating the dimensions of the storage tank according to the required capacity and land availability
- Results Analysis
  - Tank Dimension Evaluation: Comparing the results of calculating the dimensions of the tank with the availability of land. If the tank dimensions do not match the land availability, then design adjustments need to be made.
- Conclusion

  Summarize all analysis results and provide conclusions regarding the feasibility of the rainwater harvesting project in Building B Nusa Putra University:
  - Analyze the potential for rainwater harvesting in Building B Nusa Putra University.
  - Design a rainwater harvesting system that suits local conditions.
  - Manage water resources more efficiently by utilizing rainwater

  The results of this study can be used as a basis for:
  - Implementing a rainwater harvesting system in Building B.
  - Saving the use of clean water from conventional sources.
  - Reducing the environmental burden by reducing energy use for water treatment.
  - Increasing drought resilience by having alternative water sources

3 Results and Discussion

3.1 Research Area

The research was conducted in Building B of Nusa Putra University. The building is utilized for a variety of purposes, including lectures, administrative activities, and teaching. Consequently, mobility within the building is relatively high. A calculation based on data obtained from each study program in 2023 indicates that the number of students is 1,671 per day. The same methodology was employed to determine the number of staff and lecturers in Building B, which was found to be 130 individuals per day. Concerning the garden area, direct measurement yielded a result of 267.82 m². To meet the water needs of Building B, it is necessary to implement effective water use management strategies that ensure the water requirements of Building B and the surrounding park are met during the dry season. The analysis of rainwater harvesting systems allows for the identification of opportunities to utilize rainwater that falls during the rainy month to meet the needs of toilets and parks. This is accomplished by calculating the quantity of water necessary to accommodate the rainwater collected on the roof of the building as a catchment area and channeled to the reservoir. The rainfall data was calculated from the nearest rain station to Nusa Putra University, based on the rainfall data for the previous 10 years.

3.2 Calculation of Raw Water and Toilet Needs for Building B

The quantity of water required for human consumption and other activities that necessitate water is referred to as water demand. The determination of raw water requirements is based on data obtained from the number of active students and staff daily and the area of the garden in Building B, Nusa Putra University. The calculation of raw water demand is accomplished by multiplying the number of water users and the water usage per person. The details of the calculation of raw water requirements are presented in Table 1.

Table 1. Calculation of Raw Water Demand

No	Description	Total	Park Area (m^2)	Average Water Demand (l/ppl/day)	Total Water Demand (l/day)	Water Demand (m^3/day)	Total Water Demand 80% (m^3/day)
1	Student	1671		10	16710	16.71	13.37
2	Lecturer + Staff	130		10	1300	1.3	1.04
3	Park		267.82	0.80	214.26	0.21	0.17
Total					18224.26	18.22	14.58

Source : Calculation Results, 2024

The total water demand for Building B of Nusa Putra University is estimated to be 80% of the total water demand for the entire campus. This is due to the fact that not all occupants of the building use toilets simultaneously, and not all occupants of the building are on campus every day. The result of this estimation is that the raw water demand for Building B is 14.58 m^3 per day.

3.3 Rainfall Data

To ascertain the quantity of precipitation available and the maximum storage capacity, rainfall data was gathered from a single rainfall station situated near the study area. This data was then subjected to either average or arithmetic calculations to determine the aforementioned parameters. The rainfall station utilized in this study, the Ciraden rainfall station, has data on rainfall from 2013 to 2023. The arithmetic mean was employed to calculate the precipitation. This method is calculated by dividing the total rainfall data for a month by the number of days in a month. The rainfall data from the Ciraden rainfall station is presented in Table 2.

Table 2. Average Rainfall Data for Ciraden Rainfall Post

No	Year	Ciraden Rainfall Post (mm)	No	Year	Ciraden Rainfall Post (mm)
1	2013	205.167	7	2019	222.583
2	2014	173.917	8	2020	247.417
3	2015	159.917	9	2021	235.250
4	2016	253.417	10	2022	323.750
5	2017	190.500	11	2023	186.750
6	2018	186.333			

Source : PSDA Cisadea-Cibareno

The calculation of the balance between rainwater availability and water demand in Building B of Nusa Putra University can be used to calculate the storage volume from the total annual rainfall data at the Ciraden rainfall post. This latest monthly rainfall data is obtained through the determination of the mainstay rain. The mainstay rain is defined as the amount of monthly rainfall that occurs in a certain period with an almost 90% chance of

occurrence. The calculation of the mainstay rainfall is conducted by processing the current monthly rainfall data, which is sorted by the monthly average rainfall amount. An illustrative example of a calculation to obtain the probability of occurrence of the mainstay rain for sequence number 1 is as follows.

$$P(\%) = 1/((11+1)) \times 100\% = 8,3$$

Further calculations for the mainstay rainfall of Ciraden rainfall post can be seen in Table 3.

Table 3. Predicted Rainfall

Year	Average Rain (mm)	Sequence		Probability (%)	Year
		No	Rainfall (mm/month)		
2013	205.17	1	323.75	8.33	2022
2014	173.92	2	253.42	16.67	2016
2015	159.92	3	247.42	25.00	2020
2016	253.42	4	235.25	33.33	2021
2017	190.50	5	222.58	41.67	2019
2018	186.33	6	205.17	50.00	2013
2019	222.58	7	190.5	58.33	2017
2020	247.42	8	186.75	66.67	2023
2021	235.25	9	186.33	75.00	2018
2022	323.75	10	173.92	83.33	2014
2023	186.75	11	159.92	91.67	2015

Source : Calculation Results, 2024

After obtaining the probability, a probability close to 90% was selected, indicating that the mainstay rainfall data at PCH Ciraden occurred in 2015 with an average rainfall of 159.92 mm per year. Furthermore, the monthly rainfall data in 2015 will be used to determine the capacity of the PAH.

3.4 Calculation of Water Availability and Rainwater Storage Capacity

The quantity of rainwater collected on the roof of Nusa Putra University Building B serves as an indicator of the available water supply. The collected water is stored in the storage basin following its flow down the pipe through the gutter drain. The quantity of runoff from the roof is proportional to the roof plan area and the amount of rainfall. The demand fulfillment method is a means of storing or collecting rainwater to meet the water needs of the garden. This can be achieved by adjusting the supply of stored rainwater or by adjusting the capacity of the PAH tank. This method is adaptable to the conditions during the two seasons. During the rainy season, a portion of the water supply is stored to address water shortages, thereby maintaining a balance between supply and demand. The calculation of rainwater availability and rainwater storage capacity based on the Minister of Public Works Regulation on the Implementation of SPAM Development, rather than the Piping Network No. 01/PRT/M2009 at Ciraden rainfall post, can be seen in Table 4.

Table 4. Rainwater Tank Capacity Calculations

Month	Number Of Days	Average Rain (mm)	Roof Area (m^2)	Total Raw Water Needs (m^3/day)	Run off	The Large Amount of rainwater needed to be captured (m^3)	A lot of water needs (m^3)	Lack of Water (m^3)	To mach Water (m^3)	Information
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	
January	22	186	627.969	14.58	0.95	110.96	320.76	-209.80		(e) = obtained from the calculations in table 1
February	20	205	627.969	14.58	0.95	122.30	291.6	-169.30		
March	23	352	627.969	14.58	0.95	209.99	335.34	-125.35		(g) = c x d x f
April	20	218	627.969	14.58	0.95	130.05	291.6	-161.55		(h) = b x e
May	23	150	627.969	14.58	0.95	89.49	335.34	-245.85		(j) = if i > j
June	22	61	627.969	14.58	0.95	36.39	320.76	-284.37		(k) = if j > i
July	21	0	627.969	14.58	0.95	0.00	306.18	-306.18		
August	23	26	627.969	14.58	0.95	15.51	335.34	-319.83		
September	21	0	627.969	14.58	0.95	0.00	306.18	-306.18		
October	22	37	627.969	14.58	0.95	22.07	320.76	-298.69		
November	22	422	627.969	14.58	0.95	251.75	320.76	-69.01		
December	21	262	627.969	14.58	0.95	156.30	306.18	-149.88		
Total	260	1919				1144.82	3790.8	-2645.98		

Source : Calculation Results, 2024

The calculations indicate that the tank capacity is 2645.98 m3. The resulting tank dimensions, as determined by the tank capacity analysis, are notably large, measuring 25.7

m x 25.7 m x 4 m. However, the dimensions of the resulting tank are not aligned with the existing land availability, as determined by the results of the site survey. Consequently, a recalculation analysis is required to ascertain that the available supply is sufficient to meet the building's water needs and that the resulting dimensions are following the existing land. The recalculation of water requirements is conducted by reducing the percentage of raw water requirements and obtaining the appropriate percentage of 23%. The recalculation for water demand can be seen in Table 5.

Table 5. Comparison of Total Water Requirement with Water Requirement 23% of Total

Month	Rainfall (mm/month)	Raw Water Needs (m^3/month)	Raw Water Needs 23% of the total (m^3/month)
Januari	186	320.76	73.77
Februari	205	291.6	67.07
Maret	352	335.34	77.13
April	218	291.6	67.07
Mei	150	335.34	77.13
Juni	61	320.76	73.77
Juli	0	306.18	70.42
Agustus	26	335.34	77.13
September	0	306.18	70.42
Oktober	37	320.76	73.77
November	422	320.76	73.77
Desember	262	306.18	70.42

Source : Calculation Results, 2024

The water supply comparison calculation above indicates that the building's raw water needs can be met by 23% according to the available land. In addition, a reanalysis calculation can be performed to determine the optimal tank capacity for the available land around Building B. Given that the existing rainfall has not been sufficient to meet the water needs for parks and toilets, the objective of this study is to meet the water needs of Building B of Nusa Putra University, particularly during periods of high student attendance, such as the MABIM (new student guidance period). A comparison of the available and required quantities of rainwater is presented in Fig. 3.

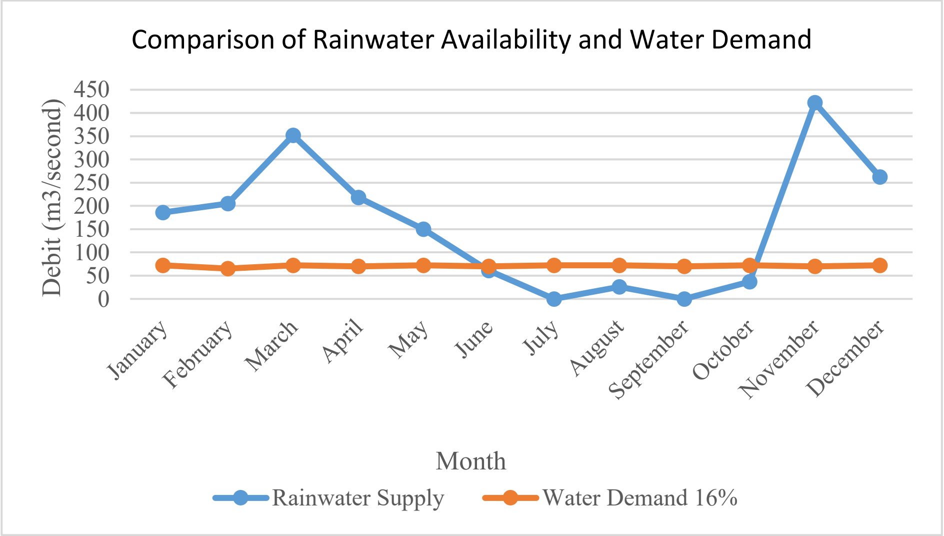

Fig. 3. Comparison of Rainwater Availability and Water Demand of Building B, Nusa Putra University

The tank capacity calculation is analyzed again to meet the water needs of building B of Nusa Putra University. With a raw water requirement of 23%. Calculation of rainwater availability and rainwater storage capacity based on the Minister of Public Works Regulation on the Implementation of SPAM Development instead of Piping Network No. 01/PRT/M2009 at Ciraden rainfall post can be seen in Table 6.

Table 6. Ciraden Rainfall Post PAH Capacity Calculation with 23% Total Raw Water Demand

Month	**Number Of Days**	**Average Rain (mm)**	**Roof Area (m^2)**	**Total Raw Water requirements (m^3/day)**	**Runoff Coefficient**	**The Large Amount of rainwater needed to be captured (m^3)**	**A lot of water needs 23% (m^3)**	**Lack of Water (m^3)**	**To match Water (m^3)**	**Information**
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	
January	22	186	627.969	14.58	0.95	110.96	73.77		37.19	(e) = obtained from the calculations in table 1
February	20	205	627.969	14.58	0.95	122.30	67.07		55.23	
March	23	352	627.969	14.58	0.95	209.99	77.13		132.86	(g) = c x d x f
April	20	218	627.969	14.58	0.95	130.05	67.07		62.98	(h) = b x e
May	23	150	627.969	14.58	0.95	89.49	77.13		12.36	(j) = if i > j

June	22	61	627.969	14.58	0.95	36.39	73.77	-37.38		(k) = if j > i
July	21	0	627.969	14.58	0.95	0.00	70.42	-70.42		
August	23	26	627.969	14.58	0.95	15.51	77.13	-61.62		
September	21	0	627.969	14.58	0.95	0.00	70.42	-70.42		
October	22	37	627.969	14.58	0.95	22.07	73.77	-51.70		
November	22	422	627.969	14.58	0.95	251.75	73.77		177.98	
December	21	262	627.969	14.58	0.95	156.30	70.42		85.88	
Total	260	1919				1144.82	871.88	-291.55	564.48	

Source : Calculation Results, 2024

The capacity of the PAH is calculated based on 23% of the total water needs of the garden and toilet. Based on the aforementioned calculations, it can be determined that the tank capacity is 291.55 m³ (approximately 300 m³).

3.5 Rainwater Harvesting Design

The volume of water storage in Building B of Nusa Putra University is determined by the equilibrium between the availability and demand of water, which is referred to as the water balance. In the selection of materials for the design of the reservoir, there are several options, including cement, masonry, and fiberglass, following applicable regulations. Based on previous calculations, a tank with a sufficient capacity of 300 m3 was selected using rectangular masonry. Further details regarding the dimensions of the rainwater harvesting tank can be found in Table 7.

Table 7. Rainwater Storage Size

Container Material	Volume (m3)	Long (m)	Wide (m)	Tall (m)	Thick Coment Floor (cm)	Wall Thickness (cm)
Brick Couple	300	15	5	4	2.5	15

Source : Calculation Results, 2024

The design of the rainwater reservoir and the cross-section of the rainwater reservoir can be observed in Figure. 4 and Figure. 5, respectively. For a more comprehensive understanding, Figure. 6 presents the rainwater reservoir in three dimensions.

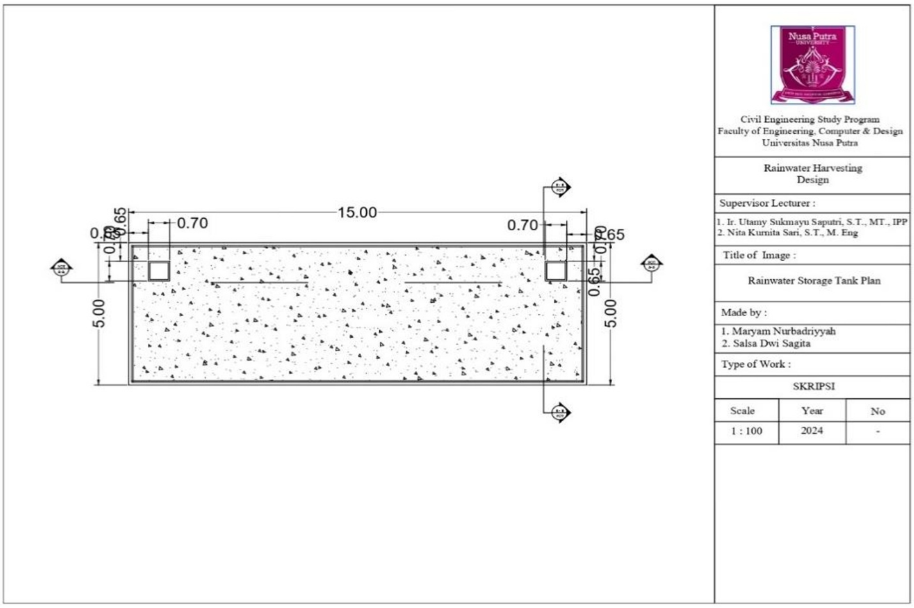

Fig. 4. Plan of Rainwater Storage Tank

Figure 4 is a top view of the plan of rainwater storage tank. Based on the figure, it is explained that the width of the Rainwater Storage Tank has dimensions of 5 meters and a length of 15 meters. Dimension of iron handle is 0,7x0,7 meters. The cover used in the plan of rainwater storage tank use a concrete.

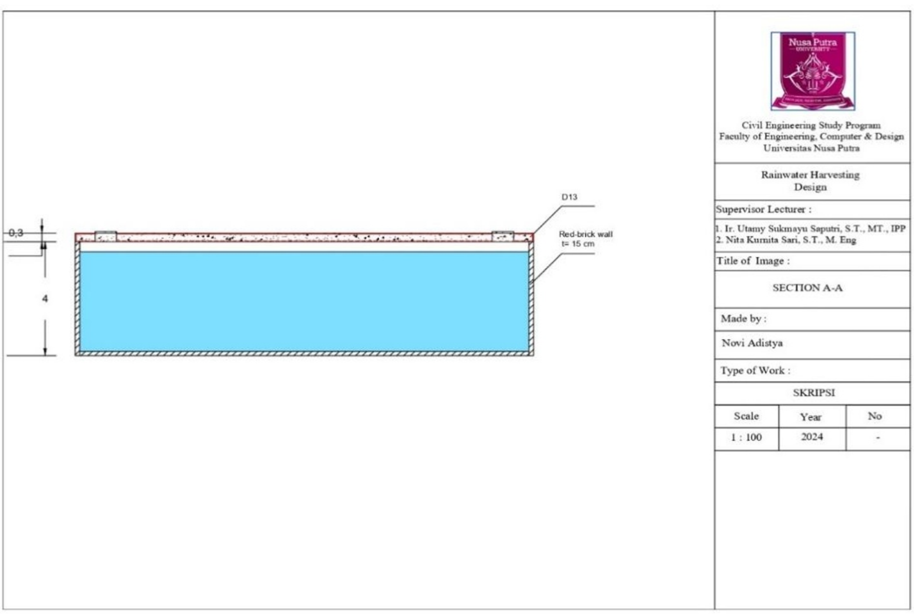

Fig. 5. Section A-A

Figure 5 is a section A-A of the plan of rainwater storage tank. The figure explains that the height of the plan of rainwater storage tank is 4 meters. Cover the plan of rainwater

storage tank using concrete with a thickness of 0.3 meters and a red brick wall with a thickness of 15cm.

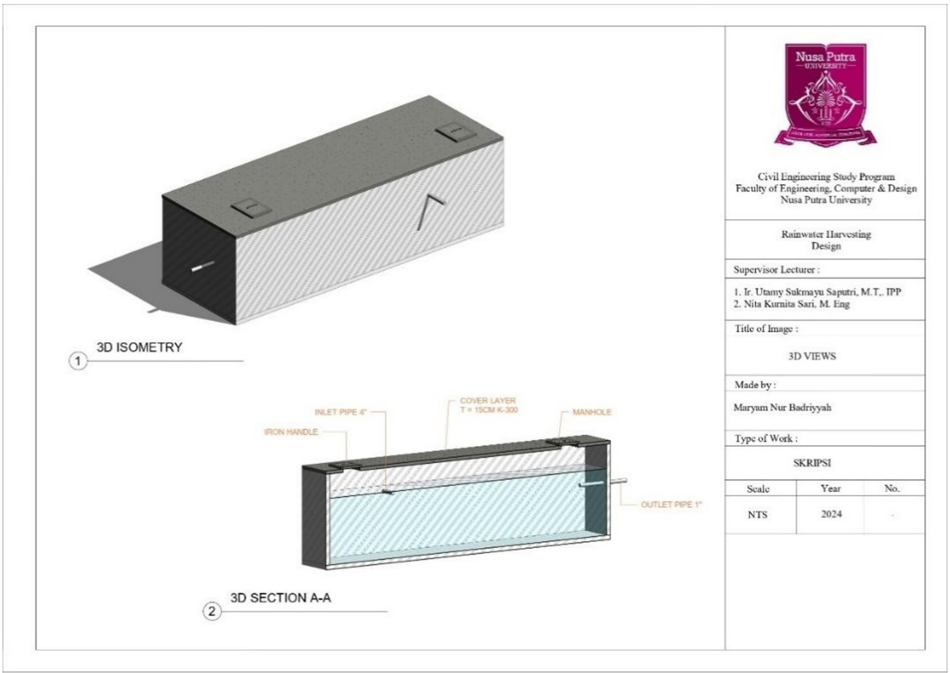

Fig. 6. 3D View

Figure 6 is a 3D isometry and 3D section A-A of the plan of rainwater storage tank. The figure explains that in the plan of rainwater storage tank there is a 4'' inlet pipe, 1'' outlet pipe, cover layer using K-300 concrete with a thickness of 15 cm, manhole, and iron handle.

4 Conclusion

A data analysis and discussion have led to the following conclusions regarding the potential of rainwater in Building B of Nusa Putra University:

- The amount of rainwater that can be accommodated in Building B of Nusa Putra University is 1144.82 m3 with a tank capacity of 300 m3. This calculation indicates that the rainwater collected can meet the water needs for toilets and landscaping by 23% every month.
- Field analysis indicates that a rainwater tank with a capacity of 300 m3 is required in Building B of Nusa Putra University. The tank is designed using red bricks with a length of 15 m, a width of 5 m, and a height of 4 m.

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