Influence of Reservoir Water Level Fluctuations of Reservoir B (Rusunawa) on Groundwater Availability at the Environment of Lampung University

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Abstract
The presence of four reservoirs as rainwater collection infrastructure at the University of Lampung is expected to enhance the infiltration process and recharge the groundwater aquifers. However, the threat of water scarcity in the area may arise due to the reduction of recharge areas. Therefore, a comprehensive study is necessary to understand the important factors in maintaining groundwater availability. This research aims to analyze groundwater aquifers, identify fluctuations in the water level of Reservoir B, and analyze the relationship between the elevation of the water level in the reservoir and the availability of groundwater in the University of Lampung environment. The research methodology involves the interpretation of geoelectric data and the calculation of water level fluctuations in the reservoir. The analysis results indicate that the shallow groundwater aquifer is estimated to be located at depths ranging from 10 to 30 meters, while the deeper aquifer is situated at depths of 80 to 130 meters with a layer of sandy tuff. The highest fluctuation in water level is recorded at 14 cm during rainfall with an intensity of 52.1 mm/day. There were no significant changes in the water level observed during rainfall with intensities ranging from 0 to 2.4 mm/day, and the average fluctuation observed is approximately 0.5 cm every 8 hours.

Keywords: Reservoir water fluctuations, Water availability, Lampung University.

I. INTRODUCTION

Water is one of the vital resources in human life for various activities. It is not only essential for basic needs but also for other productive purposes. The use of water is still predominantly reliant on groundwater. Relying solely on groundwater usage poses a threat to its availability [1]. Considering the increasing importance of groundwater, its utilization should be based on the balance and preservation of groundwater itself. In other words, the utilization of groundwater must be environmentally conscious and sustainable [2].

Lampung University (Unila) currently relies on boreholes to utilize groundwater resources [3]. Generally, during the rainy season, there are no issues with water supply as the water pumps provide sufficient discharge. However, during the dry season, in some locations, the water discharge from the pumps becomes minimal, and in some cases, the water does not reach the storage tanks. To address this issue, one of the measures taken is to deepen the boreholes in search of groundwater with a higher discharge rate. The decrease in water discharge is indicated by the lowering or declining water table [4].

To ensure water availability during the dry season and as a conservation effort, in 2019, Unila constructed four reservoirs. These reservoirs are Reservoir A (Taman Rusa), Reservoir B (Rusunawa), Reservoir C (Kedokteran), and Reservoir D (Teknik), with a construction cost of ± 15 billion [3].

The researchers are interested in conducting an analysis on the influence of reservoir discharge on groundwater replenishment and the relationship between rainfall and water level fluctuations in the reservoir. This study utilizes data from Geoelectric resistivity VES (Vertical Electrical Sounding) and water level fluctuations in the reservoir.

II. MATERIALS AND METHODS

The research is conducted at Universitas Lampung, located at Jl. Prof. Dr. Ir. Soemantri Brojonegoro No. 1, Subdistrict Rajabasa, Bandar Lampung city. The geographical coordinates of the location are approximately 5°21'39,6" S and 105°14'22,2" E. Administratively, the research area is bordered by Soekarno Hatta (By Pass) to the North, Kedaton Subdistrict to the South, Rajabasa Permai Subdistrict to the West, and Labuhan Ratu Subdistrict to the East [5].

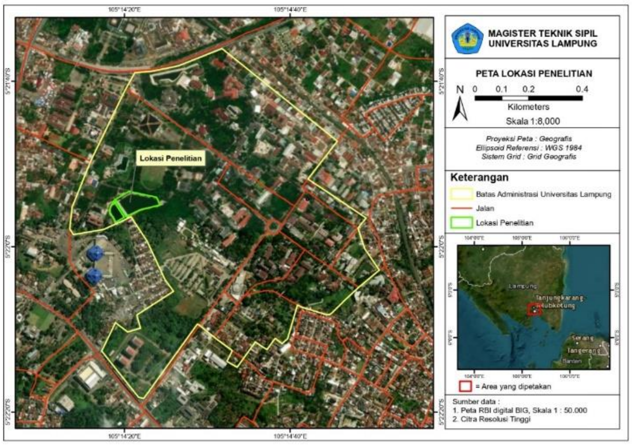

Figure 1. Design of water level measurement.

A. *Primary data Collection*

Primary data collection was conducted through measurements water level at Reservoir. The data included the water level values focused at Reservoir B during the morning (around 08:00 AM local time) and afternoon (around 04:00 PM local time). The measurement is conducted using a sturdy measuring rod/tape that has been firmly installed at the edge of the reservoir where the water is still pooled (shallow) and easily accessible. The scale used for measurement is in millimeters (mm). The design and data collection can be seen at Figure 2 and 3.

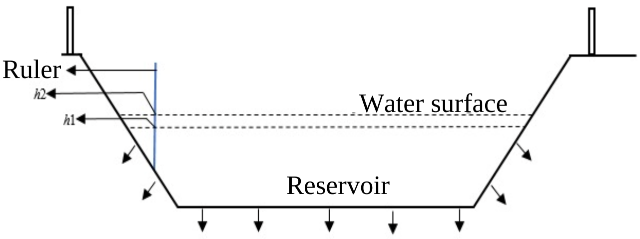

Figure 2. Installation of survey

Figure 3. Monitoring of water level

B. *Secondary data Collection*

The secondary data used in this study include rainfall data from the nearest weather station (Station 241B, Politeknik Negeri Lampung). This station is located at coordinates Latitude: 5°21'16,1" S and Longitude: 105°13'7,2" E. The specific resistivity data were obtained from geoelectric measurements using the Schlumberger configuration conducted by the research team in September 2012. The data or information on the thickness and depth of subsurface layers were obtained from monitoring well logs (near the Department of Geophysics building). This data is used for corrections in interpreting the measured resistivity values. Additionally, other supporting data are utilized to ensure the smooth progress of this research.

C. *Geoelectric data of VES*

The Vertical Electrical Sounding (VES) data used in this study consists of 9 measurement points scattered around the Unila. The data utilized are secondary data obtained from measurements conducted in the vicinity of the Unila. The measurements were performed using a geoelectric resistivity application with the Schlumberger configuration at 9 predetermined points, considering a suitable electrode spacing of 300 m. The data collection was limited to these 9 points due to land constraints, such as buildings, asphalt roads, and paved areas, which made it impractical to achieve a 300 m electrode spacing. The VES points areas can be seen at Figure 4. The field measurements involved recording electrical current (I) and potential difference (V) data. The modeling was carried out using the open-access software IP2WIN in 1D.

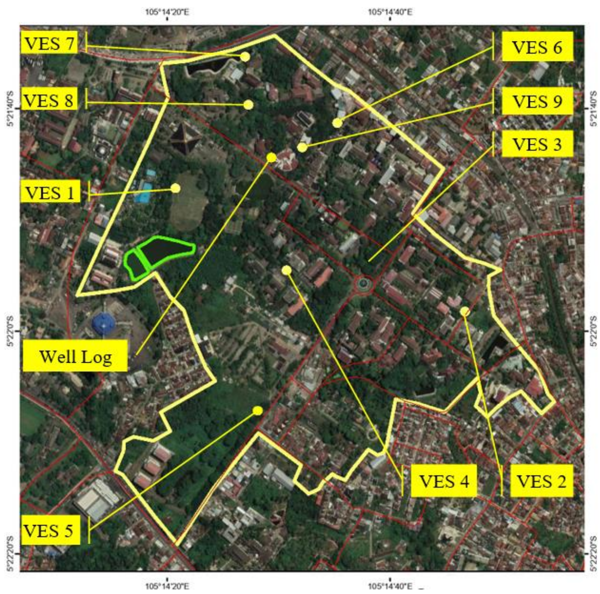

Figure 4. Design of geoelectric point survey

The field measurements involved recording electrical current (I) and potential difference (V) data. The modeling was carried out using the open-access software IP2WIN in 1D.

D. Geology Regional

Regionally, Regionally, the study area is located within the Lampung Formation (QTl). The Lampung Formation is a widespread unit of pyroclastic rocks in the Lampung region, with an estimated thickness of up to 200 m. This formation is composed of pumiceous tuff, rhyolitic tuff, welded tuff, tuffaceous claystone, and tuffaceous sandstone [6]

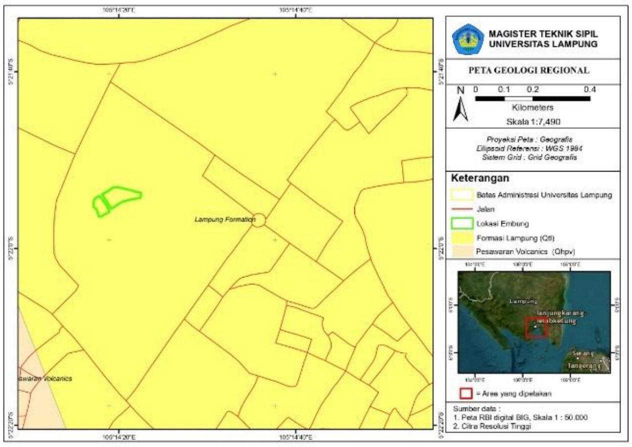

Figure 4. Regional geology of study area [6]

The stratigraphic sequence of the map sheet is divided into several groups, namely Pre-Tertiary Rocks, Tertiary Rocks, Quaternary Rocks, and Intrusive Rocks. Quaternary Rocks, formed from the Pleistocene to the Holocene, result in various rock units such as volcanic products, sediments, and surface deposits. During the Pleistocene, volcanic activities and widespread deposition of pyroclastic rocks formed the Lampung Formation (Qtl) unit, which is conformably overlain by sedimentary rock units of the Kasai Formation (Qtk) and the Terbanggi Formation (Qpt). During the Holocene, deposition includes alluvium and some swamp deposits.

III. RESULT AND DISCUSSION

A. Tophografy and Slope

The research area has an elevation ranging from 107 to 125 meters above sea level. It comprises four basin areas that remain inundated with water throughout the year and simultaneously serve as catchment areas for rainwater runoff. The central part is dominated by natural, large trees aged around several decades, with an elevation of 120 to 125 meters. The Northwest part remains a dense natural forest with an elevation of 113 meters. Meanwhile, the southern part is used as a parking area and green open space, with an elevation of 120 to 125 meters, as shown in Figure 4. Slope directly affects surface water flow and the infiltration rate of rainfall. Steep areas (high slope) have fast water flow, which increases surface runoff and reduces surface water infiltration. Conversely, flatter areas have higher infiltration rates and greater potential for groundwater.

B. Analisys Geoelectric

The analysis of the Vertical Electrical Sounding (VES) data, consisting of 9 VES geoelectric points, shows diverse interpretations. The distribution of sandy tuff, which is believed to be the groundwater aquifer, occurs at an average depth of 25 meters with resistivity values ranging from 30 to 100 ohm-meters. Resistivity values ranging from 0 to 30 ohm-meters indicate sandy clay, while resistivity values exceeding 150 ohm-meters indicate the presence of tuff layers. Higher resistivity values suggest more compacted welded tuff. The existence of the sandy tuff layer, as interpreted from the 9 data points, can be observed in Table 1.

Table 1. Interpretation of the Depth of the Sand Tuff Layer (Groundwater Aquifer) on VES 1 - 9

VES	Location	Depth (m)
1	Field of football	27,5 – 77,9
2	Foot stalls of FKIP	3,8 – 33,2
3	Beringin Park	4,6 – 16
4	Faculty of Agricultural	2,95 - 21,2
5	BNI	9,4 – 60
6	Civil engginering	8,7 – 34,4
7	Geophisyc engginering	13 – 28,5
8	Chemical enggineering	7,1 – 26,2
9	Enggineering mosque	1,8 – 22,4

Source: Calculation results (2023)

The hydrostratigraphy at the site reveals that the sandy tuff acts as an aquifer, which is a water-saturated porous rock layer beneath the ground surface that can store and transmit water in economically significant quantities. The basic principle of water flow is to follow gravity, meaning it will flow from areas with higher energy to areas with lower energy.

The lower boundary of the aquifer layer is assumed to be impermeable or has a lower water-transmitting capacity. Thus, the lower boundary of the aquifer's depth depicts the elevation of the groundwater, and it can be concluded that the direction of groundwater flow in the aquifer follows the lower elevation. From Table 1, it shows that the tendency of groundwater flow is from the direction of the Faculty of Agriculture, Civil Engineering, Geophysical Engineering, and Teknik's mosque towards the direction of the football field/ Reservoir B. Meanwhile, the direction from Beringin Park and the FKIP canteen is assumed to flow towards the East.

C. Integration Model of VES with Well Logs

Based on the results of the 1D modeling at VES points 1 - 9, the subsurface layers are identified as topsoil, tuff, sandy tuff, and clayey tuff. The VES point 1 show resistivity values > 150 Ωm, indicating that this layer is likely composed of fine-grained and compact tuff. Resistivity values of 75 Ωm are found at depths of 2 - 27 m, suggesting the presence of tuffaceous sand. Coarse-grained tuff is located relatively shallow from the surface/at the bottom of the overlying soil and may serve as an aquifer. At depths of 27 - 77 m, the rock is still identified as tuff with lower resistivity values. This tuff contains sand with a medium to coarse grain size and is permeable with good porosity, potentially acting as a confined aquifer.

The lower boundary of this layer at this point has not been measured by VES. Thus, the groundwater potential below VES 1 is relatively good, with two aquifer layers indicated by their thickness. This is further supported by the presence of discharge areas, demonstrated by basin/lake/swamp features.

Based on the estimated rock layers, the depth of the shallow aquifer tends to be deeper towards VES 1 (westward direction). Following the basic principle of water behavior, it is assumed that the groundwater flows towards the football field/embung with an average aquifer thickness of 40 m. This flow direction confirms that Reservoir A, B, and D recharge the deep aquifer system. Therefore, the potential for meeting water needs in the Universitas Lampung environment (in addition to surface water) can be achieved by utilizing groundwater. The conceptual model of the subsurface layers around the research area can be seen at Figure 5.

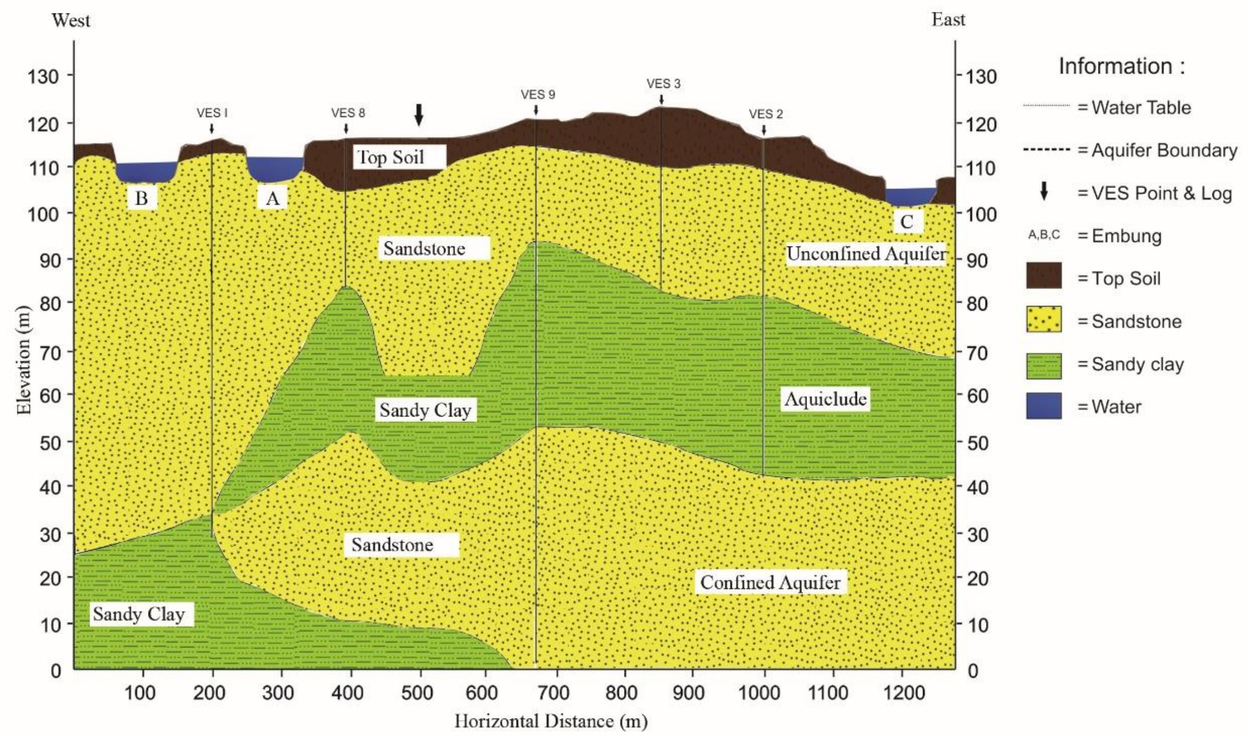

Figure 5. Results of point correlation with Well Log

To confirm the results of the subsurface layer inference using the passive method (VES), an approach with the active method from well log results (if possible) needs to be conducted. Universitas Lampung received a grant for a borehole complete with information about the well's composing layers from the Ministry of Public Works and Public Housing (PUPR) with a depth of 150 meters. Assuming that there are no significant changes in the geological structure in the research area, it is assumed that the aquifer and aquiclude layers are still consistent with the existing well data.

The borehole has a depth of 150 meters and is located between the Technology, Information, and Communication (TIK) building and the Department of Geophysics Engineering building at Universitas Lampung. At depths of 0 - 10 meters, there are topsoil and clay, then at depths of 11 - 50 meters, there is sand with fine to coarse grains (with good porosity). This layer is a free aquifer with the ability to store and transmit water effectively. At depths of 51 - 70 meters, there is a layer of sandy clay (aquiclude) capable of conducting and storing water in limited amounts. At depths of 71 - 100 meters, there is fine to coarse sand, which can be interpreted as a confined aquifer (pressurized aquifer). Then, at depths of 101 - 110 meters, there is sandy clay (aquiclude). At depths beyond 100 meters up to an unknown boundary, the layers are still identified as aquifer layers.

The identification at VES 1, VES 8, VES 9, VES 3, and VES 2 can be illustrated in Figure 6. Sandstone layers ranging from fine to coarse dominate at depths of

4 - 30 meters, which are groundwater aquifers. The sandy clay layer, as a slightly impermeable layer, acts as a separator for the confined aquifer beneath it. Water in the embung (reservoir) exerts physical pressure on the aquifer around the Reservoir, thereby enhancing the infiltration process into the aquifer.

D. Groundwater Aquifers

The analysis of VES data and IP2WIN modeling, the presence of groundwater aquifers in the environment of Universitas Lampung is identified at depths ranging from 10 to 30 meters (shallow groundwater). Furthermore, deep groundwater is identified at depths of 80 to 130 meters, distributed in the western area (swimming pool and soccer field). Areas with good potential for groundwater aquifers are located in the northern area of the Faculty of Engineering and the southern area of the Faculty of Agriculture (thicker from west to east). This is supported by the stable water pump discharge in the areas of Geophysics Engineering and Chemical Engineering during low rainfall.

On the western and eastern sides, the aquifer layers are presumed to be deeper, despite the presence of Reservoirs C and B. These aquifers may be located deeper as deep groundwater. The water reservoirs in Unila are believed to indirectly influence the recharge of groundwater into the aquifers. This is supported by the fact that in the past 3 years, there have been few instances of low water pump discharge in the environment of the Faculty of Engineering and other faculties.

The process of recharging the groundwater aquifers occurs through infiltration. When the reservoirs are filled with rainwater or other surface water, the water will seep into the surrounding soil. The water will penetrate the soil layers until it reaches the aquifers below. In this context, the reservoirs can act as infrastructure to collect and store water temporarily, while the aquifers serve as a more sustainable source of water.

E. Analisys Debit

The watershed area in this study is relatively small, so the rainfall data used is from only one specific location/point. The maximum annual daily rainfall can be seen in Table 2.

Table 2. Maximum railfall data

Year	R (max)
2009	75,2
2010	81,5
2011	68,9
2012	106,3
2013	107,9
2014	102,8
2015	91,6
2016	87,5
2017	159,6
2018	75,4
2019	121
2020	115,4

Source: Calculation results (2023)

Referring to the study [7] the catchment area (DAS) in the research area is 0.266563 km² or 26.6563 Ha with a runoff coefficient of 0.520241. With this catchment area, according to [8], the calculation of planned discharge for catchment areas less than 2.5 km² is done using the rational method. The ideal return period for the calculation with an area of 10-100 Ha is 10 years. Assuming rainfall duration of two hours (120 minutes), the planned discharge can be calculated using the rational method as shown at Table 3.

Table 3. Calculation of rainfall intensity

Periode (year)	R (mm)	I (mm/hour)	C	A (km²)	Q (m/s)
2	105,5	23,1	0,5	0,3	0,9
5	139,1	30,4	0,5	0,3	1,2
10	161,4	35,3	0,5	0,3	1,4
25	189,5	41,4	0,5	0,3	1,6
50	210,4	45,9	0,5	0,3	1,8
100	231,1	50,5	0,5	0,3	1,9

Source: Calculation results (2023)

Table 3 shows that the discharge (Q) for a 10-year return period is 1.3593 m³/s. A larger flood discharge indicates a higher rainfall intensity, thus increasing the potential for rainwater infiltration (recharging groundwater aquifers). In their study [9], it was concluded that when the recharge volume equals the discharge volume, the amount of water stored in the aquifer remains the same. Any changes in recharge or discharge will affect the amount of stored water and the groundwater level. Groundwater recharge occurs only when the accumulation of base flow, runoff, and evapotranspiration is smaller than the rainfall. Conversely, if the accumulation is greater than the rainfall, groundwater recharge does not occur. The volume of groundwater recharge indicates the potential or reserve of groundwater in the aquifer.

F. Analisys Fluctuation of The Water Level

The measurement of water level fluctuations at Reservoir B began on August 7 - November 8, 2022. The measurement point is located at UTM coordinates 526492, 9406994 with an elevation of 110 m (initial measurement point). Rainfall data was obtained from the rain gauge station at Polinela. The measurements were conducted over 100 days. The similarity in trends during the wet and dry months was also an important factor in representing the data for 100 days in one year.

The frequency of rainfall in the study area throughout 2022 did not show significant differences between the wet and dry months. There were 159 recorded rainfall events in 11 months, with an average of 15 rainy days per month. The highest frequency occurred in January with 20 rainy days. With nearly the same rainfall frequency each month, the data collected on water level fluctuations in the reservoir over a period of 3 months can represent the rainfall throughout the year. During the data collection period, there were 50 recorded rainfall events in the study area with varying intensities. The highest intensity occurred on November 10, 2022, with 64.9 mm of rainfall, and the daily average precipitation was 12.46 mm/day. The highest water level elevation occurred on November 14, 2022, at 110.221 m, while the lowest elevation occurred on September 18, 2022, at 109.945 m. The average daily rainfall was 6.23 mm/day, and it had an impact on the Reservoir water level changes of 1.051 cm, as shown in Figure 7. Thus, an approximation can be made that a change in rainfall of 1 mm/day corresponds to a water level rise of 0.16 cm.

Changes in the water level elevation in the reservoir indicate an increase in water volume in the reservoir. According to the study [11], a higher water level elevation in a reservoir leads to increased water pressure beneath the surface. This pressure will enhance the infiltration process, encouraging more water to fill the underlying aquifer system. The correlation test between rainfall and water level fluctuations in the Rusunawa Reservoir can be seen in Figure 6.

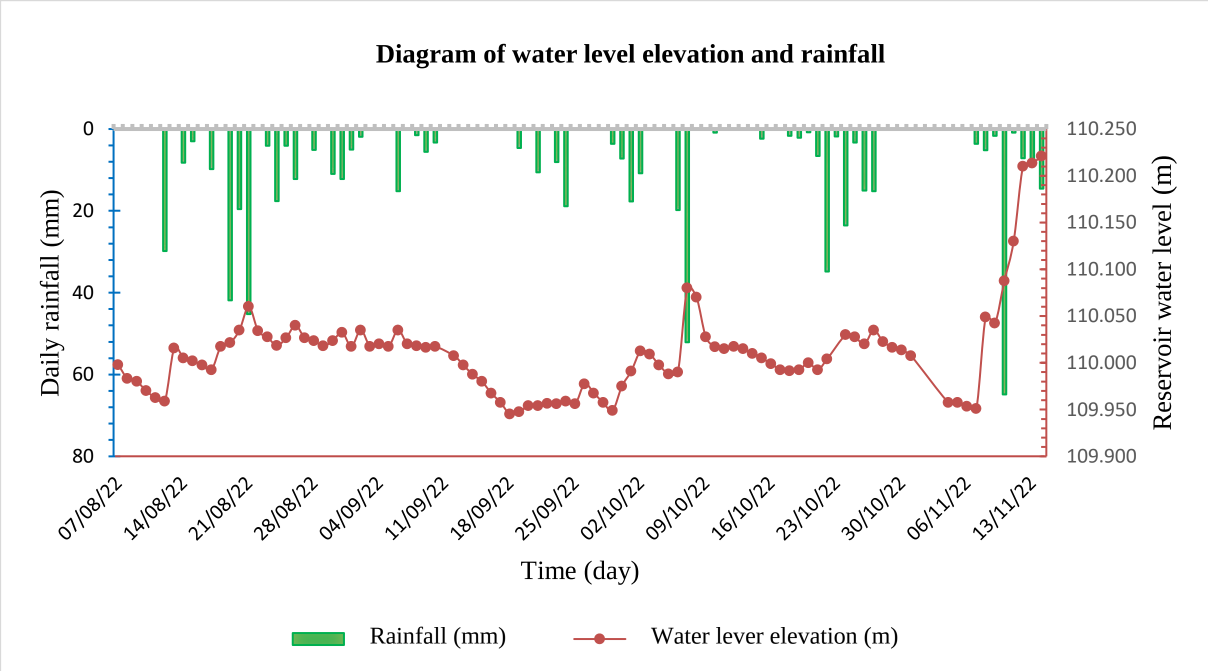

Figure 6. Diagram of water level elevation and rainfall

Figure 6 shows that rainfall directly influences the changes in the water level of the reservoir. The greater the rainfall intensity, the potential for runoff increases, and the amount of runoff collected in the reservoir will be larger compared to non-rainy periods, although this is not always the case in reality. The water level elevation in the reservoir represents the saturated zone (groundwater level), so changes in elevation are affected by both rainfall and evaporation processes.

Figure 6 shows that 60.16% of the variation in the dependent variable is influenced by the variation in the independent variable in this modeling. The remaining 39.1% is influenced by other variables outside the modeling (such as evaporation processes, inflow, and others). High rainfall has an impact on water level elevation in the following days, possibly due to the gradual inflow of rainwater runoff. On the other hand, small daily rainfall in some observations does not significantly affect the changes in water level fluctuation, which occurs because the outflow is greater than the inflow.

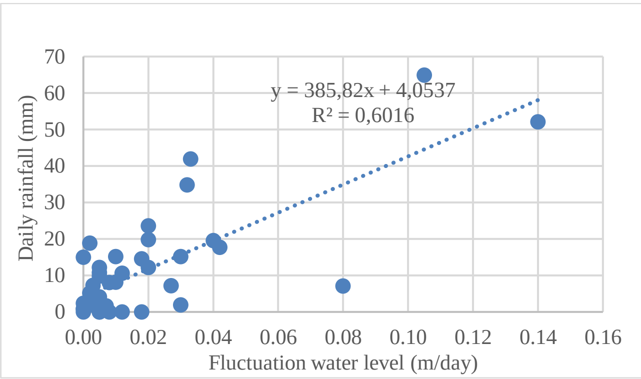

Figure 7. The graph R-square of the variables rainfall and water level elevation

The geological structure and the characteristics of the aquifer in the area also play a crucial role. If the embankment is located near a groundwater recharge zone directly from the embankment, the embankment water level fluctuation can influence groundwater availability. However, if there are impermeable layers or significant hydrogeological differences, the impact of embankment water level fluctuation on groundwater availability may be limited.

The distance and depth between the embankment and the aquifer can also affect the relationship between embankment water level fluctuation and groundwater availability. The closer the embankment is to the aquifer, the more likely there will be interaction and influence of embankment water level fluctuation on groundwater availability. The intensity and frequency of embankment water level fluctuation can also affect groundwater availability. Significant and frequent fluctuations can lead to rapid changes in groundwater levels, affecting the aquifer's ability to recharge and provide sustainable groundwater

IV. CONCLUSION

This study succeeded in calculating the highest fluctuation of water level at Reservoir B (Rusunawa) is 14 cm, which occurred during rainfall with an intensity of 52.1 mm/day. There were no changes in the water level observed 7 times during rainfall with intensities between 0 - 2.4 mm/day, and the average fluctuation was 0.5 cm/8 hours. The groundwater aquifer in the environment of Unila is found at depths ranging from 10 - 30 meters (shallow groundwater), while deep groundwater is identified at depths between 80 - 130 meters. Rainfall with an intensity of 1 mm/day in the research area increases the average water level elevation by 0.16 cm. The rise in water level elevation leads to an increase in pressure and pushes water into the aquifer system.

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