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Geological and hydrogeological characteristics and their implications for water resource management in North Rumpin, West Java

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Abstract

The Rumpin Utara region of West Java presents a complex geological and hydrogeological setting that is crucial for local water resource management. This study aims to analyze these characteristics and their implications for sustainable groundwater utilization. Through field surveys, borehole data, and geoelectric measurements, this research identifies significant lithological variations and three distinct resistivity zones affecting groundwater potential. The findings highlight the necessity of careful groundwater management to address challenges such as water scarcity and declining water quality, thus contributing to more effective resource planning in the area. Field surveys, borehole logs, and geoelectric surveys revealed significant lithological variations due to fault structures affecting groundwater distribution. The identification of three resistivity zones indicates substantial groundwater potential, reflecting variations in rock layers and groundwater availability. Low resistivity zones (< 24.8 Ω.m) include soil and clay, medium resistivity zones (24.8 – 60.0 Ω.m) consist of sand and silt, while high resistivity zones (> 60.0 Ω.m) encompass sandy claystone and compact claystone. The depth to the groundwater table in this area varies from –2.5 to –20 meters, with groundwater quality generally being fresh, with neutral to slightly acidic pH, and variable electrical conductivity. There are more than four aquifer layers with thicknesses ranging from 5 to 15 meters, indicating significant groundwater potential but requiring careful management to ensure sustainable water supply.

Keywords: Rumpin Utara, west java, groundwater management, resistivity zones, aquifer layers

Introduction

The Rumpin Utara region, located in the western part of Bogor Regency, West Java, is characterized by complex geological features and significant hydrogeological importance. This area is part of the Cisadane River Basin, serving as a primary water source for the local population (Directorate of Geology, 1970) [7, 5, 6]. With its undulating topography and varied lithology, including geological formations such as the Bojongmanik Formation and Genteng Formation (Sutaryo, 2021) [15, 17], the region faces challenges in water resource management, especially during dry seasons and groundwater utilization.

The presence of multiple aquifer layers in this region indicates substantial groundwater potential but also necessitates a deep understanding of groundwater distribution, quality, and sustainable use (Hadi *et al*., 2021) [9, 1, 2]. The groundwater conditions in this area are heavily influenced by local geological structures, such as faults, which cause lithological differences between the western and eastern parts of Rumpin (Kusuma & Jaya, 2022) [3, 4].

Additionally, the variability in subsurface rock resistivity, interpreted through geoelectric surveys (Pratama & Sari, 2022) [14, 12], provides a more detailed picture of the hydrogeological zonation in the area.

In the context of water resource management, a thorough understanding of the hydrogeological system is essential for optimizing groundwater use, ensuring clean water availability, and preventing negative impacts such as droughts or declining groundwater quality (Setiawan, 2020) [16]. Given the need to balance ecosystem sustainability and meet community water needs, this research is relevant for contributing to more effective and sustainable environmental management efforts.

Study Area

Rumpin Utara is a region in West Java that falls within the Cisadane River Basin, playing a crucial role in supporting local communities through groundwater and surface water supplies (Directorate of Geology, 1970) [7]. However, the utilization of water resources in this area faces various challenges due to its diverse geological and hydrogeological characteristics, as illustrated in Figure 1 (Turkandi *et al.*, 1992) [17].

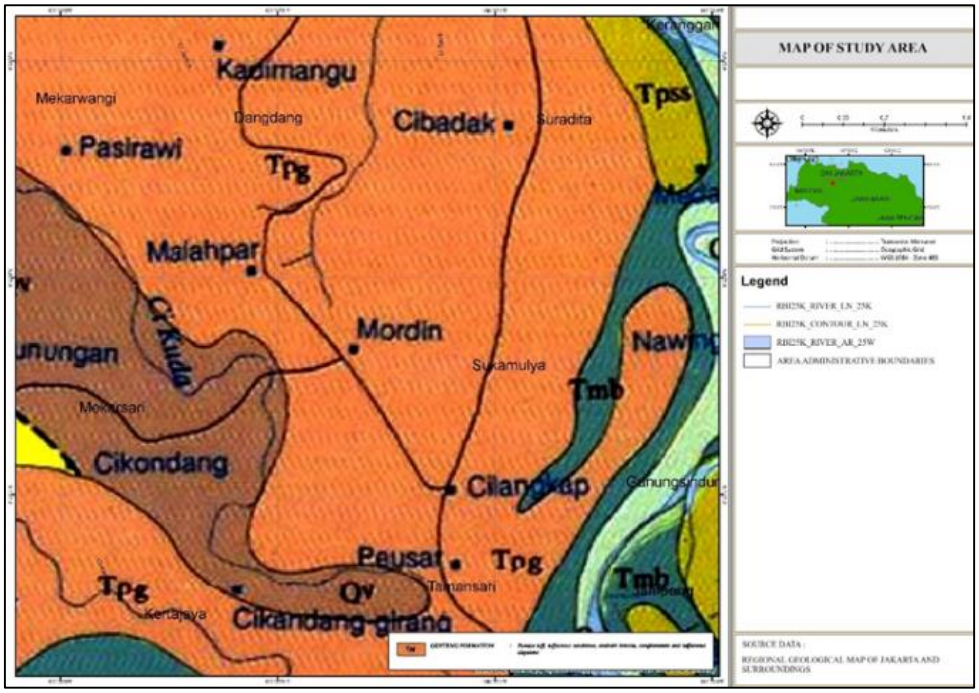

Fig 1: Map of the study area

Based on geological data and borehole logs, the lithological layers in this area vary from clay, limestone, to conglomeratic sand, indicating significant differences between the western and eastern parts of the study area (Sutaryo, 2021) [15]. This variation is likely due to fault structures that limit the distribution of these lithologies (Hadi *et al.*, 2021) [9]. Furthermore, geoelectric surveys reveal three distinct resistivity zones, each showing unique physical characteristics and groundwater potential (Pratama & Sari, 2022) [14].

Groundwater conditions in this area also vary, with different locations showing varying depths to the groundwater table and generally fresh groundwater with neutral to slightly acidic pH (Setiawan, 2020) [16]. The presence of more than four aquifer layers with varying thicknesses suggests significant potential but also requires careful management (Kusuma & Jaya, 2022) [10].

This study aims to analyze the geological and hydrogeological characteristics of the Rumpin Utara region and assess their implications for water resource management. By understanding the distribution and physical properties of rock layers and groundwater conditions, this research is expected to provide significant contributions to more effective and sustainable water management planning in Rumpin and its surroundings (Setiawan, 2020; Pratama & Sari, 2022) [16, 14].

Research Methodology

This study employs a methodological approach comprising several stages: data collection, data analysis, and result interpretation. The methods are designed to understand the geological and hydrogeological characteristics of the Rumpin Utara region and their implications for water resource management.

1. Data Collection

Geological data were obtained through field surveys, which included lithological mapping, sample collection, and drilling to produce borehole logs. Mapping was conducted to document the types and distribution of lithologies, including claystone, limestone, and conglomeratic sand identified in previous research (Sutaryo, 2021) [15]. Additionally, geoelectric data were collected to acquire information about the resistivity of rock layers and aquifers below the surface (Pratama & Sari, 2022) [14]. Groundwater data were gathered by measuring the depth to the groundwater table and water quality at several monitoring points in the Rumpin area (Setiawan, 2020) [16].

2. Data Analysis

Borehole logs were analyzed to identify geological layers and determine major formations such as the Bojongmanik Formation and the Genteng Formation (Directorate of Geology, 1970) [7, 8]. Geoelectric data were processed to interpret three resistivity zones—low, medium, and high—which provide insights into the physical properties of rock layers and aquifer potential (Hadi *et al.*, 2021) [9]. Groundwater quality was analyzed based on pH, electrical conductivity, and depth to the groundwater table to assess the

freshness and availability of water in the region.

3. Result Interpretation

The results from the borehole log and geoelectric analyses were integrated to create geological and hydrogeological cross-sections of the Rumpin Utara region. Interpretation was conducted to understand the impact of geological structures, such as faults, on lithological distribution and groundwater potential. Subsequently, groundwater quality data were used to evaluate existing water conditions and recommend necessary management measures to sustain water resources in the area (Kusuma & Jaya, 2022) [10, 11].

4. Evaluation and Recommendations

Based on the interpretation results, an evaluation of the hydrogeological system was carried out, including the identification of discharge centers and areas with significant aquifer potential. Recommendations were provided for more effective water resource management, focusing on sustainable groundwater use and drought risk management (Setiawan, 2020; Hadi *et al*., 2021) [16, 9].

Research Results

Based on borehole logs, geoelectric surveys, and groundwater quality measurements, the following are the findings related to the geological and hydrogeological characteristics of the Rumpin Utara region:

1. Lithology and Geological Structure

Borehole data reveal lithological variations in the Rumpin Utara region. Borehole log A-18 identifies a lithology of claystone alternating with limestone, interpreted as part of the Bojongmanik Formation. However, the presence of fault structures causes this lithology to not continue to the east (Directorate of Geology, 1970) [7]. Meanwhile, borehole log B-15 shows layers of tuff clay, tuff breccia, sandstone, and claystone with interbedded limestone, which also do not extend eastward as shown in Figure 2. Borehole log B-8 consists of conglomeratic sand, sandstone, and claystone (Sutaryo, 2021) [15].

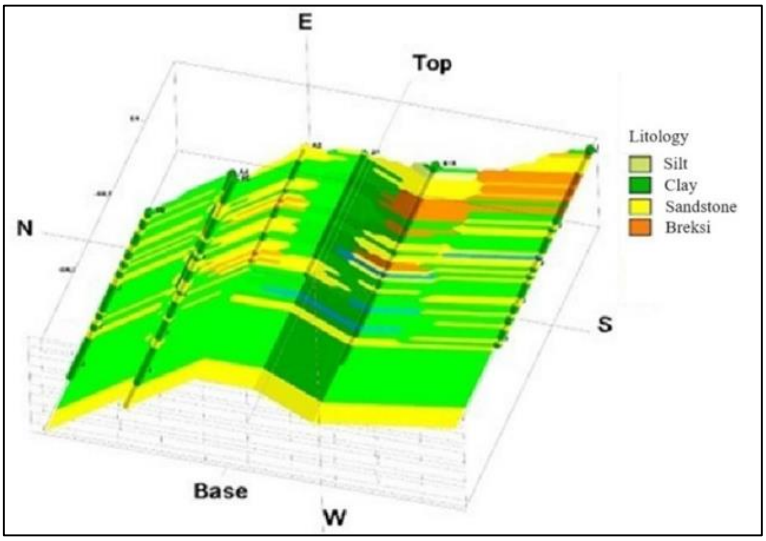

Fig 2: Borehole Log Correlation

2. Rock Layer Resistivity

The geoelectric survey identified three resistivity zones based on true resistivity values obtained from the data. The low resistivity zone (< 24.8 Ω.m) is presumed to be soil and clay, the medium resistivity zone (24.8 – 60.0 Ω.m) is sand and silt, and the high resistivity zone (> 60.0 Ω.m) is sandy clay and compact claystone (Hadi *et al*., 2021) [9]. This data reveals significant differences in the physical properties of rock layers affecting groundwater distribution (Table 1).

3. Groundwater Conditions

The depth to the groundwater table in the Rumpin Utara region ranges from –2.5 to –20 meters, with groundwater generally being fresh, pH ranging from 4.5 to 7.5, and electrical conductivity ranging from 22 to 567 µS. There are more than four aquifer layers with thicknesses ranging from 5 to 15 meters, indicating significant groundwater potential but requiring careful management to avoid drought or quality decline (Setiawan, 2020) [16].

Table 1: Lithological Interpretation of Geoelectric Measurements

No	ρ (Ω m)	Ketebalan/h (m)	Kedalaman/d (m)	Perkiraan Litologi
1	< 24,8	0,667	0,667	Soil and clay
2	24,8 – 60,0	11,2	16,7	Sand
3	> 60,0	15,8	32,5	Sandy Clay and Claystone

Discussion

The research results indicate that the Rumpin Utara region has significant geological and hydrogeological complexity. The presence of fault structures that limit the lithological distribution between the western and eastern parts affects groundwater distribution and quality. These lithological differences influence the geoelectric survey results, which identify three resistivity zones reflecting subsurface rock layer variability (Pratama & Sari, 2022) [14].

The low resistivity zone indicating soil and clay has limited water storage potential, while the medium resistivity zone consisting of sand and silt has higher water storage capacity.

The high resistivity zone, including sandy clay and compact claystone, tends to function as a more compact and less permeable basement rock, affecting groundwater flow and distribution (Kusuma & Jaya, 2022) [10].

The fresh groundwater with neutral to slightly acidic pH, and the varying depths to the groundwater table, indicate significant aquifer potential but also highlight the need for careful management to ensure water supply sustainability. Evaluation of discharge centers in Julepang – Prigi Lama and Jombang shows areas requiring special attention in groundwater management (Sutaryo, 2021) [15].

Analysis

Analysis of geological and hydrogeological data in the Rumpin Utara region suggests that water resource management must account for variations in lithology and rock layer resistivity. Understanding geological structures, such as faults, is crucial for anticipating differences in groundwater distribution and quality. Furthermore, groundwater management should consider the varied aquifer potential and ensure sustainable use to avoid negative impacts on water quality and resource availability in the region (Hadi *et al*., 2021; Setiawan, 2020) [9].

Conclusion

The study of geological and hydrogeological characteristics in the Rumpin Utara region leads to several key conclusions:

1. The Rumpin Utara region exhibits significant lithological variation, including claystone, limestone, tuff clay, tuff breccia, sandstone, and conglomeratic sand. Fault structures limiting lithological distribution between the western and eastern parts cause differences in subsurface rock layer characteristics.
2. Geoelectric surveys identify three resistivity zones reflecting variations in rock layer types and groundwater potential. The low resistivity zone (< 24.8 Ω.m) includes soil and clay, the medium resistivity zone (24.8 – 60.0 Ω.m) consists of sand and silt, and the high resistivity zone (> 60.0 Ω.m) includes sandy clay and compact claystone.
3. Groundwater depth in the area varies from –2.5 to –20 meters, with groundwater quality generally being fresh, pH neutral to slightly acidic, and electrical conductivity showing variability. There are more than four aquifer layers with thicknesses ranging from 5 to 15 meters, indicating substantial groundwater potential but requiring careful management to ensure a sustainable water supply.
4. Understanding the distribution of lithology and rock layer resistivity is crucial for sustainable groundwater management. Variability in geological and hydrogeological characteristics affects groundwater capacity and quality, which must be considered in resource management planning. Effective management will help address challenges such as drought and declining water quality while ensuring water availability for the Rumpin region and its surroundings.

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