This method involves measuring potential, naturally occurring currents as well as those due to injection [8]. One type involves injecting an electric current into the earth through a potential electrode based on current measurement results and calculating the potential difference to assess the annual price variation of the rock layer beneath the measurement point [9]. The purpose of this geologic method is to gather information about the groundwater carrier layer and to determine the existence of subsurface layers in the research area, ultimately serving as a reference for stakeholders interested in drilling wells.

Previous studies in neighboring regions, such as in Jatisari Village, South Lampung, have also utilized resistivity methods to explore groundwater aquifers, with findings revealing the presence of aquifers at varying depths ranging from 7.5 to 36 meters. These studies, such as the one conducted by Paembonan, identified aquifer layers with resistivity values ranging from 10 to 35 Ohm.m. However, the unique characteristics of the aquifer types and distribution in East Lampung Regency suggest regional variations in groundwater availability and quality that differ from those found in Jatisari Village [10].

East Lampung Regency is one of the districts in Lampung Province; part of the area is on the coast. East Lampung Regency has a coastline of 105 km, of which 70 km is in the Way Kambas National Park area and another 35 km is in the Labuhan Maringgai and Pasir Sakti areas. The research was conducted in East Lampung Regency to review groundwater and obtain basic data, which can be used for managing clean water supply in villages and surrounding settlements. In coastal areas, it is very difficult to obtain clean water; this condition is due to the influence of seawater, which causes groundwater to become brackish or even salty like seawater.

2. Methods

The methods used in the preparation of this report include measurement of geoelectric data, analysis of geoelectric data using IP2Win software, and 3D modelling using RockWork software. These methods aim to identify types of soil and rock layers, depict resistivity distribution in 3D, characterise lithology and aquifers, and analyse groundwater movement patterns. The following list outlines the main stages of the method used:

2.1. Geoelectric Measurement

The geoelectric method is a widely used geophysical technique employed to assess changes in the resistance of rock layers beneath the surface by inducing an electric current. This is done by placing electrodes A and B into the soil at a specified distance to measure the resistance of subsurface layers. The longer the distance between the electrodes, the deeper the flow of electric current will penetrate into the rock layer [11]. Geoelectric measurements are conducted by injecting an electric current into the soil and measuring the resulting voltage difference between the electrodes, which gives an estimate of the resistivity of the underlying rock formations [11, 12].

This method is grounded in the principle of measuring the difference in voltage and current strength generated by the injection of electric current into the soil. The resistivity of rocks is of particular importance in hydrogeology because it can differentiate between various types of water-bearing formations. Resistivity values can distinguish between freshwater and saltwater, different types of aquifers, such as sandy aquifers or soft rocks, as well as impermeable layers like claystones. Additionally, it helps in distinguishing solid rocks, porous aquifers, and cracks in rocks that may retain water [13, 14].

In the geoelectric method, two pairs of electrodes are used: the first pair (A and B) is responsible for injecting the electric current, while the second pair (M and N) measures the voltage difference, which is critical for calculating the resistivity of the subsurface layers [15]. In the resistivity geoelectric method, there are two methods of data collection: the resistivity mapping geoelectric method and the sounding resistivity geoelectric method [7]. The method is typically divided into two main types of data collection: resistivity mapping and sounding resistivity methods [7]. The resistivity mapping method is used to show the horizontal variation of resistivity in subsurface soil layers, while the sounding resistivity method provides an overview of vertical resistivity variations within the Earth's surface [16] [17].

In 1912, Conrad Schlumberger first introduced the geoelectric method, which has since become one of the most important tools in geophysical exploration. Geoelectricity is one of the geophysical methods that provides an overview of changes in the resistivity of rock layers below the ground surface by conducting a DC (direct current) electric current that has a high voltage in the soil [18]. It involves using direct current (DC) to generate a high-voltage electrical current that is injected into the soil, typically through two electrodes, A and B. As the distance between the electrodes increases, the electric current penetrates deeper into the subsurface, allowing for the detection of deeper geological layers. The electrical voltage generated is measured at the surface using a multimeter, connected through two voltage electrodes (M and N) positioned at a shorter distance than the current electrodes.

If the distance between the electrodes A and B is increased, the electrical voltage at the voltage electrodes (M and N) will change, depending on the type of rock and the depth at which the electric current is penetrating. The depth that the electric current can penetrate is assumed to be half the distance between the electrodes, often referred to as AB/2, which forms a half-sphere with a radius of

AB/2. Typically, the geoelectric method involves using four electrodes arranged in a straight line symmetrically with respect to the central point, with two current electrodes (AB) on the outside and two voltage electrodes (MN) on the inside.

2.2. Geoelectric Data Analysis Using IP2WIN Software

IP2WIN software is a specialized geophysical data analysis tool designed to process and interpret geoelectric data. It operates by matching field data with master and auxiliary curves to determine resistivity and depth in the research area. This software automatically processes vertical electric soundings, induced polarization data, and semi-configuration data, which are essential for geoelectric estimation [19]. The software uses advanced inversion techniques to adjust the model parameters, aiming to reduce errors and ensure that the processed data matches the observed field data. This inversion process is crucial as it allows the software to resolve complex geological conditions and provide accurate estimations of subsurface resistivity and layer depths [20].

One of the main advantages of IP2WIN is its ability to perform manual interpretation and adjust model parameter [21]. This flexibility enables researchers to refine their models according to the specific geological characteristics of the study area. For example, the software allows users to modify model parameters and iterate the inversion process until the smallest root mean square (RMS) error is achieved, ensuring a high level of precision in the final resistivity and depth estimates. These adjustments are critical when dealing with noisy or incomplete field data, as they allow for a more accurate interpretation of subsurface conditions.

The IP2WIN software is particularly effective for identifying real subsurface resistivity using the inversion method. By correcting the combination of thickness and resistivity values, the software provides a detailed and accurate representation of the subsurface layers, which is essential for groundwater and aquifer analysis [22]. The inversion method also takes into account the quality of the field data and the number of parameters entered into the model. If the inversion results show a relatively large error, the software automatically adjusts the parameters and recalculates the model, ensuring that the most accurate resistivity values are used for further analysis.

In this study, IP2WIN was used to solve geological problems by providing an approximation curve that matches field data, allowing the researchers to interpret the geological features of the study area accurately. The results from this process are key to understanding the resistivity distribution of the subsurface and are essential for groundwater exploration and aquifer management. The software's ability to perform these complex calculations and provide clear, interpretable results makes it a critical tool in geoelectric surveys, offering significant advantages in both accuracy and efficiency in subsurface analysis [23].

2.3. 3D Modelling Using Rockwork Software

RockWorks software is a sophisticated geological data management and analysis tool, widely utilized for subsurface modeling, surface visualization, and reporting. Since its development, RockWorks has become an essential software in geological and hydrological studies for its robust capabilities in 3D modeling and data interpretation [24]. This software aids in visualizing the subsurface distribution of resistivity values, rock types, aquifer characteristics, and groundwater movement patterns, providing a detailed understanding of the geological environment. It employs various data integration methods to combine geophysical measurements, geological logs, and well data for a comprehensive modeling process.

To support its functionality, RockWorks includes two main data windows for organizing the input data, and three graphical display windows for visualization. The combination of these features enables users to analyze and display subsurface characteristics in 2D and 3D formats, offering intuitive insights into complex geological structures. The software processes input data such as resistivity values and rock types, then visualizes the results as 3D models that highlight the distribution of geological features across various depths. RockWorks software is used to see a 3D picture of the distribution of resistivity values, rock types, and aquifer characteristics, as well as groundwater movement patterns [24].

One of the key advantages of RockWorks is its ability to assist in well logging and well correlation using either drill data or related log data. RockWorks' software can effectively model subsurface conditions to accurately describe subsurface structures [25]. For example, RockWorks allows for the creation of 3D models that display how resistivity values correlate with different types of rock formations, helping to determine the nature of aquifers and groundwater movement in the study area.

At first glance, RockWorks may appear to have many panels and functions, but it is essential to understand how to navigate these features effectively to utilize the software's full potential.

Figure 1. Window Rockwork

Figure 1 shows the interface for RockWorks Software, which is a geological data management and analysis tool used for modelling, surface visualization, and reporting. The previous text describes the various main panels and tabs that support the functionality of this software, as depicted in this image. This image highlights some of the key features that are visible:

1. The Project Folder pane is used to store the project files that are being worked on.
2. The Borehole Manager tab is an important part of organizing the project's core data, including the processing of drill logs and their correlation.
3. The Processing tab is used to process the data that has been recorded, such as drill logs that will be visualized in graphical form.
4. The Editing tab allows users to edit the drill logs and add, select, or delete existing drill data.
5. The order of the drill logs that have been entered contains data that is ready for further editing.
6. Data Order to Be Entered functions to enter data ranging from location to the type of rock.
7. Edited view will change according to the selection of the input data sequence.
8. The Projection Coordinates tab shows the coordinate settings and output data to be exported.
9. The Output Constraints and Settings tab provides the output unit and sets the data limits to be used.

These panels and tabs are essential in navigating the RockWorks interface. They support various tasks from project management and data entry to final visualization, ensuring a smooth workflow throughout the modeling process.

The visual output from RockWorks strongly supports the information described in the text. It helps in well logging, well correlation, and modeling subsurface conditions, allowing users to visualize the geological structures and groundwater movement patterns in three dimensions. The graphical display of data, including resistivity values and rock types, is instrumental in interpreting subsurface geology, making RockWorks an indispensable tool for groundwater resource management.

By creating 3D models of resistivity distributions, RockWorks enables a deeper understanding of aquifer characteristics and groundwater behavior, which can significantly influence resource management decisions. Through these visualizations, the software provides a clearer picture of how geological formations interact with groundwater, aiding in the identification of productive aquifers and informing strategies for water resource management.

2.4. Water Quality Assessment of Each Aquifer Layer

The assessment of water quality in each aquifer layer in this study area is an essential component for providing a more comprehensive understanding of the groundwater conditions. Although the geoelectric method effectively identifies subsurface lithology and aquifer characteristics, the chemical composition of the groundwater must also be assessed to ensure that it is suitable for various uses such as drinking, irrigation, and industrial purposes. However, due to budgetary constraints and high costs associated with the collection and analysis of water samples in the laboratory, water quality testing was not carried out in this research. The absence of such testing represents a significant limitation, as it restricts the depth of analysis concerning the chemical and biological characteristics of the aquifers.

If water quality testing had been performed, critical parameters such as pH, total dissolved solids (TDS), heavy metal content, and microbial contaminants could have been analyzed. These parameters are essential for evaluating the potability, health risks, and suitability of groundwater for various applications. For instance, studies have shown that coastal aquifers subjected to anthropogenic influence require hydrochemical assessments that include pH, major ions, and trace metals to determine suitability for domestic use and irrigation [26]. Additionally, integration of groundwater quality index (WQI) with multivariate statistical methods helps to reliably categorise groundwater quality and its spatial–temporal variation [27]. Adding such water quality assessments would provide a clearer understanding of the degree of contamination or purity within each identified aquifer layer, which in turn could influence groundwater management and utilization decisions.

Therefore, the lack of water quality testing represents a significant weakness in the study, as it limits the ability to make conclusive statements about the suitability of the groundwater for different uses. The study relied solely on geophysical measurements using the geoelectric method, which provides valuable data on subsurface resistivity, but does not offer any insights into the chemical composition or contaminant levels of the groundwater. Previous research combining geophysical methods with hydro-geochemical assessments demonstrates increased reliability in aquifer characterisation and resource management [28].

2.5. Flowchart of the Research Methodology

To facilitate understanding of the steps taken in this research, the following flowchart systematically illustrates the methodology used, starting from the geoelectric data acquisition to further analysis using IP2WIN and RockWorks software. This diagram provides a clear visual representation of the procedure sequence and how each stage is interconnected and supports the research objectives.

Figure 2 shows that in the first stage, geoelectric measurements are carried out to identify the resistivity of rock layers beneath the surface using two sets of electrodes. Afterward, the geoelectric data obtained is analyzed using the IP2WIN software, which allows for inversion modeling to estimate resistivity and layer depth. Subsequently, the results of this geoelectric analysis are used to create a 3D model of the resistivity distribution, rock types, and aquifer characteristics using RockWorks. Water quality assessment for each aquifer layer is considered an optional stage, which could provide additional insights into the suitability of the groundwater resource for various uses.

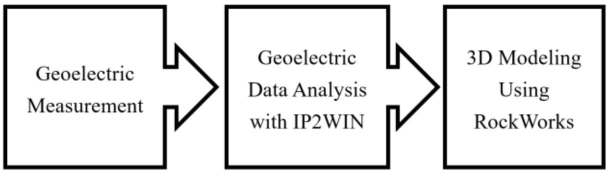

Figure 2. Research Methodology

3. Results and Discussion

Table 1 shows that 19 geoelectric measurement points have an electrode span of 150 meters. The meaning of the span value is that the current-conveying cable is plugged in at a distance from the electrode span on the left and right sides, so it requires a fairly long and easy area for the electrode to be plugged in.

Based on geoelectric data at 19 measurement points, the current strength of the electrode is connected to the ammeter, and the potential value of the potential electrode is connected to the voltmeter. The current strength value and the measurement potential are then used to calculate a pseudo-type resistance value using the following formulation:

$$\rho = k.\frac{\Delta v}{i}$$

Where: ρ = Resistance of the pseudo-type (ohm m)
Δv = Potential difference (millivolts)
I = Strong current (milli amperes)
k = Schlumberger constant

For example, in Pasir Sakti District, the measurement of a potential electrode of 0.5 m and a current electrode of 1.5 m was obtained with a potential difference value of 118.1 mV and a current strength of 6 mA. From the electrode span value, the Schlumberger constant is 6.28 thus:

$$\rho = 6.28 \times \frac{118.1}{6} = 123.6 \text{ ohm m}$$

Thereby, the quasi-type resistance value for the measurement of a potential electrode of 0.5 m and a current electrode of 1.5 m in Pasir Sakti District is 123.6 Ωm.

Table 1. East Lampung Regency Geoelectric Field Measurement Data Measuring Point

Measuring Point	Location	UTM Coordinates		Elevation (masl)	Electrode Span (m)
		X	Y		
1	Pasir Sakti	5 °32'22.96"	105 °47'6.56"	6	150
2	Jabung	5 °29'57.80"	105 °44'56.18"	11	150
3	Melinting	5 °23'8.41"	105 °44'40.71"	48	150
4	Bandar Sribawono	5 °17'19.70"	105 °44'55.40"	22	150
5	Mataram Baru	5 °14'51.08"	105 °42'34.89"	64	150
6	Braja Selebah	5 °10'52.09"	105 °45'39.40"	16	150
7	Jepara	5 °9'41.90"	105 °43'24.14"	20	150
8	Waway Karya	5 °26'34.45"	105 °37'21.45"	33	150
9	Marga Sekampung	5 °22'6.40"	105 °35'8.90"	38	150
10	Sekampung Udik	5 °18'40.73"	105 °29'43.03"	29	150
11	Metro Kibang	5 °12'48.41"	105 °18'35.44"	54	150
12	Marga Tiga	5 °10'20.80"	105 °34'8.40"	126	150
13	Labuhan Ratu	5 °8'48.19"	105 °37'41.30"	46	150
14	Sukadana	5 °7'58.40"	105 °36'34.50"	32	150
15	Bumi Agung	5 °7'48.50"	105 °33'2.40"	52	150
16	Sekampung	5 °8'28.64"	105 °28'36.18"	42	150
17	Pekalongan	5 °4'3.81"	105 °22'5.37"	42	150
18	Purbolinggo	4 °58'54.61"	105 °28'53.58"	25	150
19	Batanghari Nuban	4 °58'29.61"	105 °22'48.70"	29	150

Table 2 shows the results of soil resistivity measurements in Pasir Sakti District using iron electrodes with varying distances (0.5 m, 5 m, and 10 m). Each measurement produces a resistivity value (ρ) calculated based on the voltage difference (Δv) and current (i) applied to the soil, which is influenced by the geometric factor of the electrode distance. This resistivity value provides an indication of the soil's ability to conduct electricity, reflecting the characteristics of the soil layers, whether they are permeable or impermeable. The resistivity data is crucial for identifying the type of aquifer, groundwater distribution, and the potential water resource in the area, as well as assisting in the planning and management of groundwater resources in Pasir Sakti District.

3.1. Analysis of the Resistance Value of the Type of IP2Win Software Results

After obtaining the actual type of resistance price using IP2WIN software, the type of soil and rock layer contained in the research area can be determined. Based on the table of variations in the price of resistance of several types of rocks and sediments, the following results can be obtained:

Point 1 in Pasir Sakti District

The measurement point is located in Pasir Sakti District, with coordinates X = 5 °32'22.96", Y = 105 °47'6.56", and an elevation of 6 meters above sea level.

Table 3 shows the results of pseudo-resistivity measurements in Pasir Sakti District using IP2WIN software to determine the characteristics of soil and rock layers. Each row in the table lists the resistivity value (ρ in ohm-m), the thickness of the layer (Thickness), and the total thickness (Total Thickness). The varying resistivity values indicate differences in the physical properties of each soil or rock layer, which affect the aquifer potential. For example, the first layer has a resistivity of 62.7 ohm-m with a thickness of 0.758 m, while the second layer shows a higher resistivity (6,600 ohm-m) with a greater thickness (2.17 m), indicating differences in the type of layers that can influence groundwater storage and movement in the area.

3.2. 3D Modelling of Rock Type Resistance Values

The distribution of geoelectric measurement points represents the research area, so the information obtained can provide a complete description of it. Based on the cross-sectional image below, the existence of rock layers can be interpreted based on their resistivity and thickness values.

In Figure 3, which shows the value of the type resistance in the study area, a three-dimensional map is seen that illustrates the distribution of resistivity values in the area. This image is generated from geoelectric measurement data, which includes measurement points throughout the research area. The information shown in this image is essential to provide a complete description of the geological and hydrogeological characteristics of the site.

Table 2. The Value of Pseudo-Resistivity in Pasir Sakti District

Iron Electrode	**Geometric Factor**			**Δv (mV)**	**i (mA)**	**Rho (ohm-m)**
	0.5 m	**5 m**	**10 m**			
1.5	6.28			118.1	6	123.6
2.5	18.8			71.6	7	192.3
4	49.5			46.0	6	379.5
6	112.3			31.0	6	580.2
8	200.3			26.4	8	661.0
10	313.3			20.8	10	651.7
12	451.8			16.8	11	690.0
15	706.1			18.0	12	1,059.2
20	1,255.0			5.6	6	1,171.3
25	1,962.0			5.4	9	1,177.2
30	2,826.0			3.9	12	918.5
40	5,025.0			2.1	10	1,055.3
15		62.8		50.3	4	789.7
20		117.8		45.0	5	1,060.2
25		188.5		40.0	9	837.8
30		274.9		30.0	12	687.3
40		494.8		20.2	11	908.6
50		777.5		16.6	12	1,075.5
60		1,123.0		12.7	11	1,296.6
75		1,759.0		2.9	7	728.7
100		3,133.0		2.6	10	814.6
125		4,900.0		1.6	11	712.7
150		7,060.0		1.1	14	554.7
60			549.8	3.7	10	203.4
75			867.9	4.7	10	407.9
100			1,555	2.6	10	404.3
125			2,438	1.6	11	354.6
150			3,518	1	13	270.6

Table 3. The Value of Pseudo-Resistivity in Pasir Sakti District

No	**ρ (ohm m)**	**Thickness (m)**	**Total Thickness (m)**
1.	62.7	0.758	0.758
2.	6,600	2.17	2.928
3.	1,999	6.25	9.178
4.	314	21.6	30.778
5.	983	29.7	60.478
6.	115	15.2	75.678

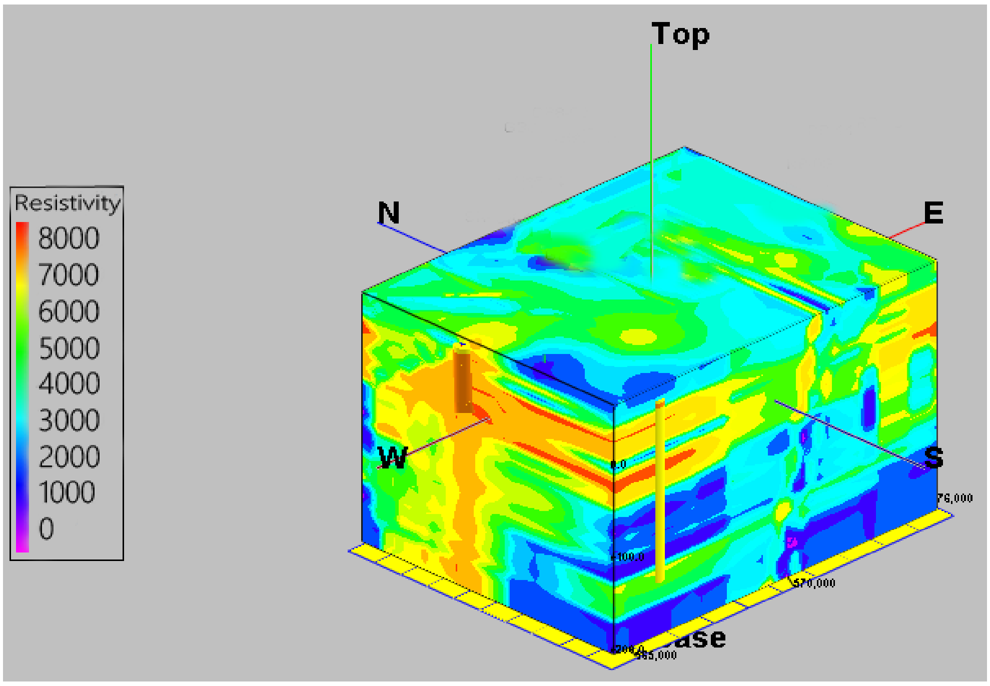

Figure 3. Value of Detention Type of Research Area

In this image, yellow and blue are dominant, which indicates a high resistance value. This high resistivity value indicates that the area has a considerable water content, as high resistivity is often associated with the presence of groundwater. The result supports the findings contained in the hydrogeological map, which shows that East Lampung Regency has good groundwater potential, with a fairly productive aquifer.

Thus, this image reinforces the interpretation that the area has significant groundwater resource potential that can be harnessed for local needs, and it provides a clearer picture of the distribution and characteristics of the aquifers in the study area.

3.3. 3D Modelling of Rock Coating Types of Research Area

The results of geoelectrical estimation and modelling using Rockwork Software 17 obtained a general picture of the rock layers in the study area consisting of sandy clay, sand, clay sand, and crystalline rock.

Figure 4 displays the results of geoelectric modelling using Rockwork Software 17. It illustrates the rock layers in the study area, which include sandy clay, sand, clayey sand, and crystalline rock. This information provides a clear visual picture of the composition and depth of the geological layers in the area.

In this image, it can be seen that the dominant layers are sand and clayey sand, which indicates that the study area has good aquifer potential. Sand and gravel are layers of rock that contain a lot of water, and this explains why these areas have productive aquifers. This image also illustrates the types of aquifers that exist in the study area, namely free, depressed, and semi-depressed aquifers. Free aquifers are visible in layers of sand and gravel that are close to the surface, indicating that groundwater in the area can flow freely without being obstructed by other, denser rock layers.

Thus, these images strongly support the information in the text regarding hydrogeological conditions in the study area and provide visual evidence that strengthens the findings regarding the presence of solid aquifers in the area.

3.4. 3D Modelling of Groundwater Conditions

Groundwater is water that moves in the soil. It is found in the spaces between the soil grains or in the cracks of rocks. In this study, geoelectric estimation was conducted to determine the condition of the rock coating and the materials contained within the rock. The resistance value of the type varies depending on the quality of the rock, the degree of density, and the soil moisture conditions.

In Figure 5, which shows the thickness of the aquifer in the study area, a three-dimensional model can be seen that illustrates the distribution of aquifer thickness within the area. This image was generated using Rockwork 17 software and provides a clear visualisation of how thick the aquifer layer is below the ground.

In this image, the aquifer marked with a light blue colour (Aquifer 1) is clearly visible, showing its thickness in the study area. This describes how groundwater is dispersed within the rock layer, which corresponds to the explanation in the text of groundwater's movement in the spaces between soil grains or rock cracks. The geoelectric estimation carried out in this study provides information about the rock coating and the materials contained in it, with variations in different types of resistance values. The resistance value of this type is influenced by the quality of the rock, the degree of density, and the soil moisture conditions, all of which affect the depth and thickness of the aquifer.

Thus, these images support the information in the text by providing a more concrete picture of the distribution and thickness of the aquifers in the study area, which is an important part of understanding the potential of groundwater resources at the site.

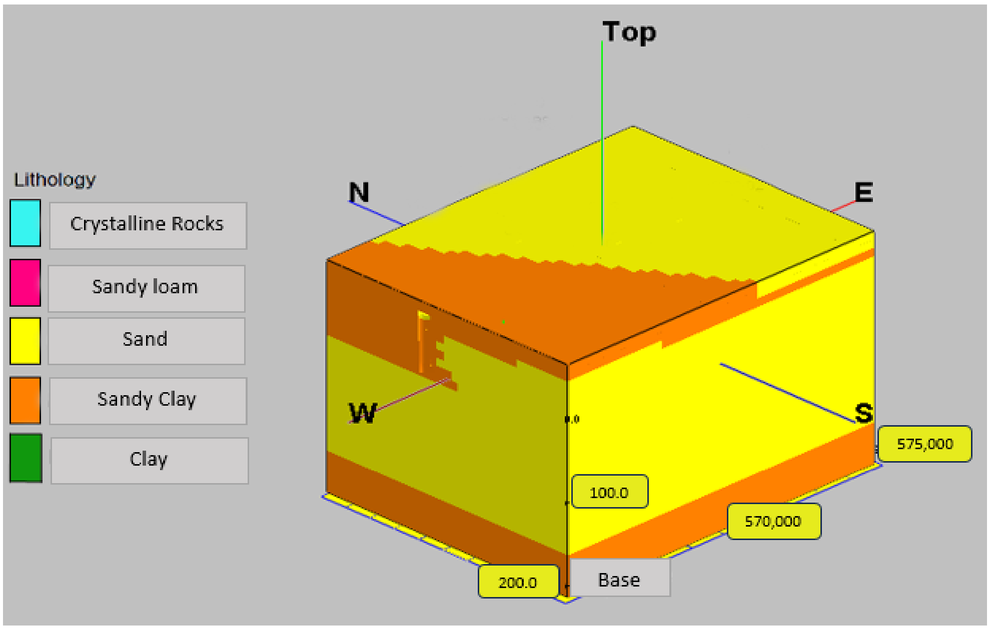

Figure 4. Rock Soil Coating in the Research Area

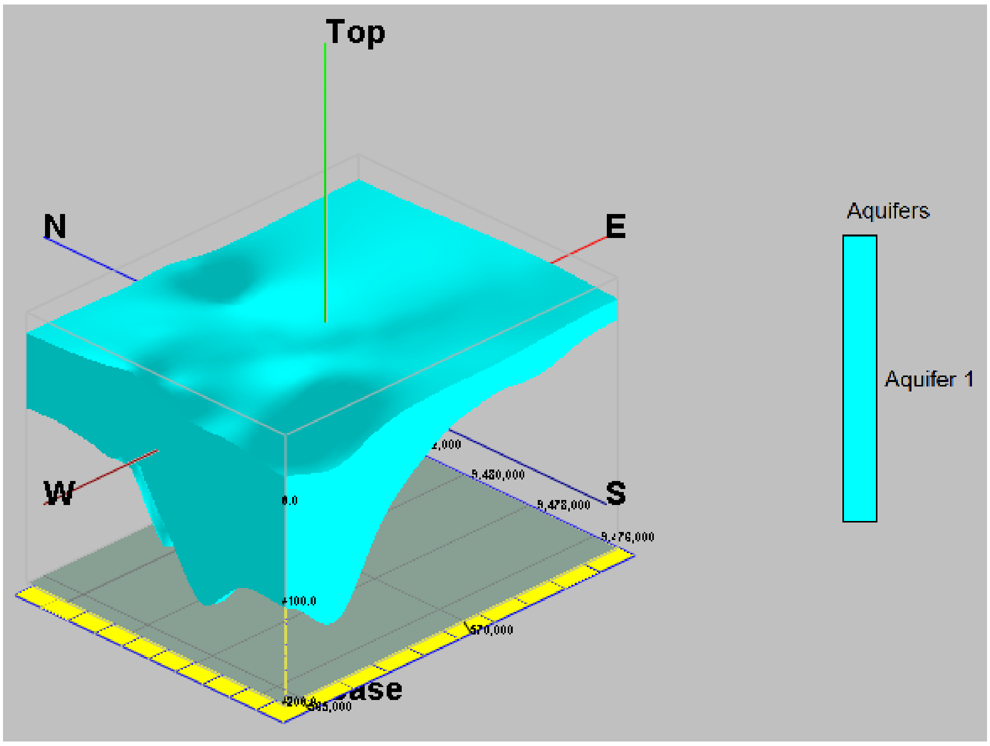

Figure 5. Aquifer Thickness in the Research Area

4. Conclusions

This study successfully identified and analyzed groundwater aquifers in East Lampung Regency using the geoelectric method, which helped to describe resistivity, lithology, and aquifer conditions. Based on data from 19 geoelectric measurement points, the identified aquifer types were classified into free, semi-depressed, and depressed aquifers, depending on the resistivity values of the underlying rock layers. The analysis shows that the region has significant groundwater potential, especially in areas with permeable soil and sand layers. Furthermore, 3D modeling using RockWorks software visualized the resistivity distribution, highlighting productive aquifers. However, water quality testing, which was not included in this study, could provide further clarification regarding the suitability of groundwater for various uses. This study provides valuable resources for local stakeholders in managing groundwater resources in the region.

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