Indonesian Physical Review
Volume 07 Issue 03, September 2024
P-ISSN: 2615-1278, E-ISSN: 2614-7904

Groundwater Resource Estimation using Vertical Electrical Sounding and Resistivity Tomography in West Manokwari, West Papua, Indonesia

Kammarudin[1], Wahyudi[1], Richard Lewerissa[2*], Baina Afkril[2], Ishak S Erari[2]

[1] Department of Environmental Sciences, Postgraduate Program, Papua University, Manokwari, Papua Barat 98314, Indonesia

[2]Department of Physics, Faculty of Mathematics and Natural Sciences, Papua University, Manokwari, Papua Barat 98314, Indonesia

Corresponding Authors E-mail: r.lewerissa@unipa.ac.id

Article Info

Article info:
Received: 24-05-2024
Revised: 12-07-2024
Accepted: 19-07-2024

Keywords:
VES; ERT; Manokwari; Groundwater

How To Cite:
Kammarudin, Wahyudi, R. Lewerissa, B. Afkril, and I. S. Erari, "Groundwater Resource Estimation using Vertical Electrical Sounding and Resistivity Tomography in West Manokwari, West Papua, Indonesia," Indonesian Physical Review, vol. 7, no. 3, p 361-378, 2024.

DOI:
https://doi.org/10.29303/ipr.v7i3.340

Abstract

West Manokwari district in Manokwari Regency, West Papua province, Indonesia, is an area that continues to develop as part of the provincial capital region. Geologically, this area is located in three main formations: the Manokwari Formation, the Befoor Formation, and the Alluvium-littoral Formation at a depth radius between 0 and 500 meters. These formations comprise permeable sedimentary rocks that allow aquifer layers to develop. This study employed the geoelectric resistivity method, using both the Wenner and Schlumberger configurations, to identify the potential of groundwater in the West Manokwari district and address the scarcity of clean water sources for the local community. Subsurface interpretation was conducted on three measurement lines using forward modeling and inversion techniques, such as earth resistivity tomography and vertical electric sounding. The results of this interpretation indicate that the subsurface rock resistivity for the three lines is generally consistent and supports each other. The subsurface can be divided into four main layers: topsoil, limestone, sandstone, and bedrock. At the surface, rock resistivity is dominated by high values up to a depth of 6 m, after which it decreases to a depth of 30 m, which is considered a potential aquifer layer for exploration with medium to low resistivity. A bedrock layer with a resistivity of over 2000 Ωm is estimated to be at depths greater than 30 m. This study is expected to serve as a valuable resource for groundwater exploration in the West Manokwari district of West Papua Province.

Introduction

Manokwari is a regency in West Papua Province, Indonesia, and serves as the provincial capital. Following Minister of Home Affairs Regulation No. 137 of 2017, the area of Manokwari Regency covers 3,186.28 km^2. Presidential Decree No. 26 of 2011 concerning the designation of groundwater basins and Ministry of Energy and Mineral Resources Regulation No. 2 of 2017 on groundwater basins in Indonesia, approximately 46% of the Manokwari Regency area is located above groundwater basins. Groundwater accounts for only approximately 20% of the world's freshwater supply, which is approximately 0.61% of all water on Earth, including oceans and permanent ice [1]. Groundwater is the primary source of water needed for industrial, agricultural, and household purposes, thus making a significant contribution to the economic development of a region, especially in areas with dry and semi-dry climates where surface.

Exploiting groundwater resources is highly important and has become crucial in the last decades, especially in coastal areas of arid and semi-arid regions. The utilization of underground water supplies has become increasingly critical, particularly in dry and semi-dry coastal areas, over the past few decades [2]. Generally, the presence and distribution of groundwater sources in a region are determined by the area's rainfall patterns, geomorphology, and geology.

The occurrence and characteristics of groundwater in hard-rock aquifers are entirely different from those in unconsolidated or alluvial formations because of their highly heterogeneous nature beneath the surface [3]. Groundwater depletion has emerged as a significant global concern. Over the past two decades, numerous studies utilizing in-situ groundwater monitoring [4], regional to global-scale hydrological models [5], and satellite-based GRACE observations have revealed that many large aquifer systems in dry and semi-dry regions [6], often extensively used for irrigation, are experiencing significant depletion [7].

Several previous studies have been conducted on the aquifer potential in West Papua Province, specifically in Manokwari Regency. Determining the depth of boreholes based on geoelectric resistivity data has been carried out in several villages in Fak-fak Regency, and the results show that the average depth of groundwater potential obtained ranges from 10 m to 30 m, with the recommended maximum drilling depth of 40 m [8]. Water balance calculations in the Pami River watershed in the Manokwari Regency were also performed by Patandianan in 2020 [9]. In 2021, Maay and Supit interpreted and correlated resistivity data to determine the aquifer layer using the Dipole-dipole electrode configuration in the Amban village, Manokwari Regency. The results showed that the aquifer layer is located at a depth of 25 m - 44.5 m with a low resistivity value ranging from 1 Ohm.m - 1.5 Ohm.m, which was interpreted as sandstone [10].

Based on several previous related studies, it was found that the study of groundwater potential identification is still very limited in some areas within Manokwari Regency, mainly using the resistivity geoelectric method with a combination of several electrode configurations. Our research aims to identify potential groundwater layer zones and determine the depth of the aquifer using the geoelectric resistivity method, which is part of applied geophysics, in West Manokwari District, Manokwari Regency, West Papua Province. Geophysical methods are widely applied in various disciplines and studies, such as environmental, water resources, geotechnical, and exploration, at different spatial scales at relatively low costs [11]. Resistivity methods have often been used in the form of sounding and profiling. However, it has been developed into 2D, 3D, and 4D surveys. Earth resistivity is related to critical geological parameters, including rock type, soil porosity, and degree of saturation [12].

The resistivity method is commonly used for groundwater investigation, and it consists of vertical electrical sounding (VES) and electrical resistivity tomography (ERT). VES is a conventional approach for groundwater exploration that only offers subsurface resistivity information from the center of profile location as a vertical function. In contrast, ERT has been applied as a suitable tool for groundwater and near-surface exploration with complex and diverse geological conditions [1], [13]. ERT is a practical approach for spatially mapping variations in the electrical resistivity of soil and rock. This relies on the premise that rock and soil exhibit resistivity differences due to mineral content, fluid saturation, porosity, and permeability. Detailed subsurface resistivity measurements allow differentiating areas of dissolution or leaching from intact rock formations [14].

The VES approach in this research was conducted using the Schlumberger electrode configuration, while the ERT technique was performed based on the Wenner electrode configuration. The Schlumberger configuration was selected as it is the most widely adopted technique among various approaches for Vertical Electrical Sounding (VES), particularly when the target depth is significant and the sedimentary formation to be explored is relatively uniform [15], [16].

Meanwhile, the Wenner configuration was chosen for the ERT survey because it offers higher vertical resolution and stronger signal strength than the dipole-dipole or Schlumberger configurations. Additionally, the Wenner array has good horizontal stratification capability and is more suitable for stratigraphic structure division and detection of stable aquifers [17]. This study is expected to provide information and better understand the groundwater potential in the West Manokwari district, Manokwari regency, so that its use can be maximized while considering environmental factors.

Geological Setting

The study site in the West Manokwari district is situated on the regional geology of the Manokwari sheet (Figure 1), which features the Arfak volcanic block as its bedrock and is conformably overlain by the Lower-Middle Miocene Maruni Limestone [18]. Three distinct formations at the surface characterize the West Manokwari region's geology. These include the Manokwari Formation (Qpm), which comprises reef limestone, calcirudite, calcarenite, conglomerate, sandstone, nekbahan breccia, and calcareous breccia. This formation is a group of sedimentary rocks. The Manokwari Formation is a stratigraphic unit that refers to the uplifted coral reefs and calcareous sediments found in the Manokwari region, which is typically located near but occasionally distant from the coastline. This term is also applied to the uplifted calcareous deposits in the coastal regions to the southeast of Manokwari, particularly in the vicinity of Oransbari.

The Befoor Formation (Tqb) comprises sandstone, mudstone, a small amount of conglomerate, calcareous siltstone, non-calcareous siltstone, and occasionally calcarenite. This formation is a group of sedimentary rocks that is primarily found in the northeastern part of the Bird's Head peninsula around Manokwari, where it forms a hilly area [18]. The sandstones and conglomerates within the Befoor Formation are typically poorly sorted and feature diverse clastic types. The alluvial and coastal (Qa) formation comprises mud, sand, plant material, gravel, and calcareous coastal matter. This formation is relatively recent, so plant material remains are still evident in certain areas, with a distinct aroma of plant material mixing with groundwater. This formation is characterized by loose material or unconsolidated substances.

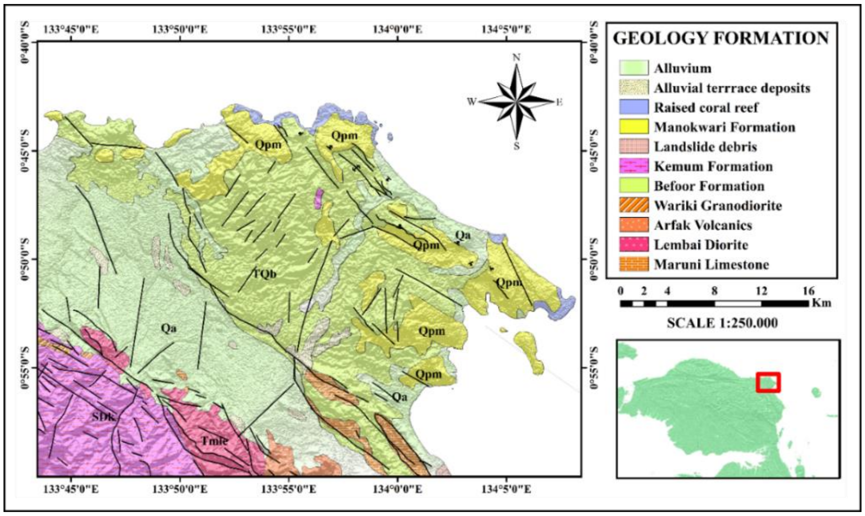


Figure 1. Geological map of the Manokwari sheet in Manokwari Regency, West Papua Province [19].

Method

Data Acquisition

This research is in the Manokwari Barat district of Manokwari Regency, West Papua province (Figure 2). Geoelectric resistivity measurements were carried out in the field using two different electrode arrangements, including the Wenner and Schlumberger configurations, to determine the groundwater potential.

The Wenner electrode configuration is utilized to obtain a two-dimensional (2D) subsurface model called Electrical Resistivity Tomography (ERT). At the same time, the Schlumberger approach is used for vertical one-dimensional (1D) investigations, known as Vertical Electrical Sounding (VES). ERT surveys are a non-invasive, efficient, and practical method of investigating subsurface properties and conditions. These surveys can be conducted quickly and easily in the field, offering several benefits over conventional point sampling techniques commonly used in environmental and geotechnical studies [20].

The VES technique assesses the vertical resistivity variation of subsurface rock layers in hard rock aquifers by injecting current into the ground through two electrodes. This method, popular in groundwater research for its technical simplicity and low cost, relies on rocks' electrical conductivity and resistivity. However, VES is limited by the survey depth, which depends on the distance between the current electrodes [21].

In the Wenner configuration, electrodes AM, MN, and BN are equally spaced, denoted as "a," and move simultaneously (Figure 3(a)). The Schlumberger configuration typically maintains fixed potential electrode dipoles (M and N) while the current electrodes (A and B) are more mobile. The Schlumberger configuration measurements are more time-efficient since only one dipole is moved, though it is less sensitive to lateral resistivity variations (Figure 3(b)).

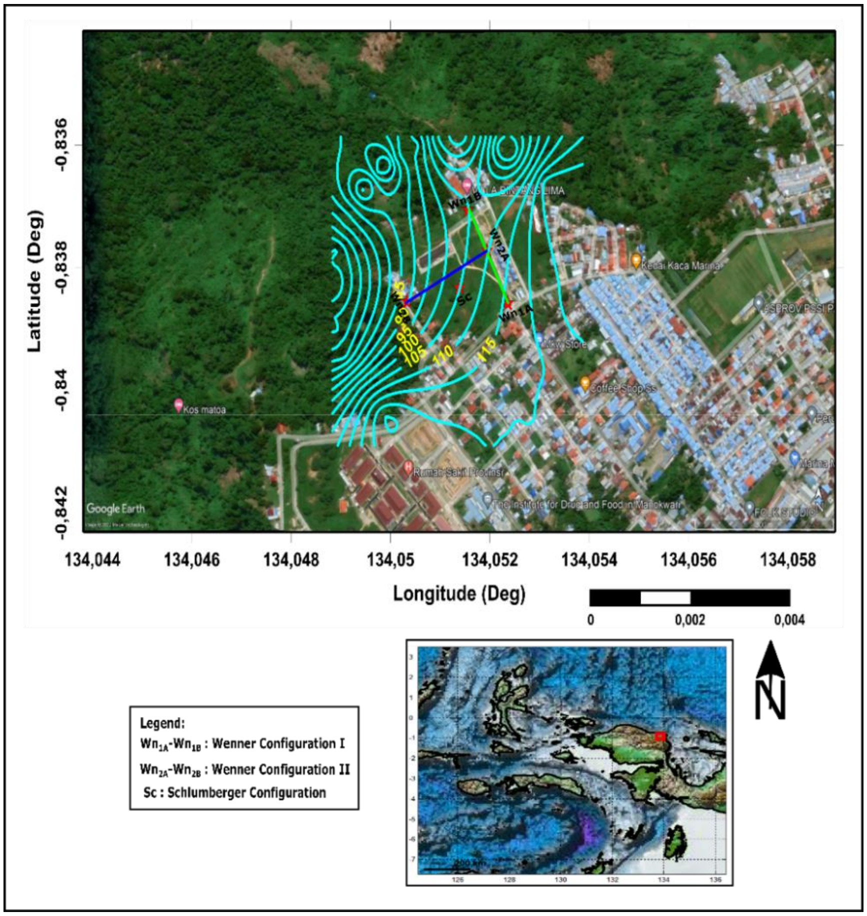


Figure 2. The location of the resistivity geoelectric research in West Manokwari District, West Papua, involved two Wenner configuration passes and one Schlumberger sounding point.

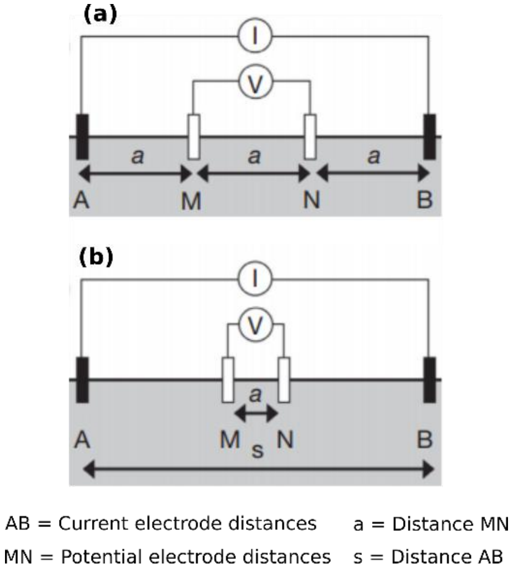


Figure 3. (a) Wenner configuration for ERT; (b) Schlumberger configuration for VES.

This study measured rock resistivity to evaluate groundwater potential in the area, employing a NANIURA NRD 300 plus resistivity meter with four electrodes (two for current and two for potential) and related accessories (Figure 4(a)). Two Wenner configuration measurement tracks (Wn_1 and Wn_2), each 200 m and perpendicular to each other, were used to assess lateral variations. In contrast, a 200 m Schlumberger (Sc) configuration track was employed for vertical variations. The minimum electrode spacing "a" for the Wenner configuration starts at 5 m and increases in multiples of 5 m to achieve the desired depth as per the procedure. Schlumberger configuration necessitates a minimum spacing of 3 m for the current electrode, which progressively expands to 200 m. The resistivity geoelectric data acquisition process using the Wenner and Schlumberger configurations is shown in Figures 4(b) – 4(d).

Figure 4. (a) NANIURA NRD 300 plus resistivity meter and accessories; (b) Resistivity geoelectric method measurement path at the study location; (c) Wenner configuration resistivity measurements; (d) Schlumberger configuration resistivity measurements.

Apparent resistivity and sensitivity equations

The resistivity technique employs four electrodes to detect spatial resistivity or conductivity variations. Two electrodes transmit electric current to form circuits, while the other two measure the potential difference, enabling pseudo-resistivity calculations. This study employs the geoelectric technique of resistivity using Wenner and Schlumberger electrode designs to determine subsurface rock resistivity through relevant mathematical equations for each configuration. The apparent resistivity equation in the Wenner configuration is as follows [22]:

$$\rho_{aw} = \frac{k_w \Delta V}{I}; k_w = 2\pi a \tag{1}$$

Where ρ_{aw} is the apparent resistivity of the Wenner configuration (Ohm.m), k_w is a factor in the geometry of the Wenner configuration (m), ΔV is the difference in the electric potential (Volts), and I is the electric current (Ampere). The apparent resistivity equation utilized in the Schlumberger configuration is [22]:

$$\rho_{as} = \frac{k_s \Delta V}{I}; k_s = \frac{\pi(s^2 - a^2)}{4a} \tag{2}$$

ρ_{as} is the apparent resistivity of the Schlumberger configuration (Ohm.m), k_s is a factor in the geometry of the Schlumberger configuration (m), s is the distance of the current electrode (m), a is the distance of the potential electrode (m), ΔV is the difference in the electric potential (Volts), and I is the electric current (Ampere). The electrical characteristics of rocks or soils can also be described as electrical conductivity values, where σ (Sm^{-1}) is the opposite of those expressed in the following equations ρ [23]:

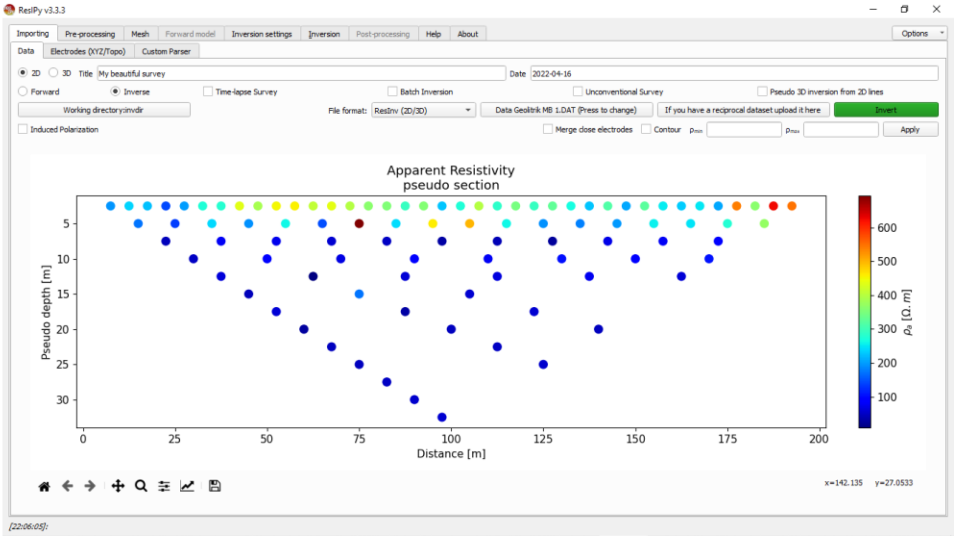
$$\sigma = \frac{1}{\rho} \tag{3}$$

Geometry factors have their advantages and disadvantages; therefore, the selection of electrode configurations should be based on the intended application and the expected signal strength. The sensitivity of the resulting model can be calculated using equation [22]:

$$Sensitivity = \frac{\partial \log(\rho_a)}{\partial \log(\rho)} \tag{4}$$

Rock resistivity modeling

This study employed one-dimensional VES modeling to assess the resistivity of subsurface rocks linked to groundwater potential (aquifers), identify bedrock or hard rocks, and conduct lateral ERT two-dimensional modeling. The 1D pseudoresistivity data were processed with the free Excel-based GeoVES 1.5 program for 1D inversion, utilizing Gosh linear filters for Schlumberger electrode design (http://www.geosearch.co.uk/resources/resources.htm). For 2D resistivity modeling inversions of subsurface rocks, we used the open-source program ResIPy version 3.3.3 for resistivity and induced polarization (IP) [24], as shown in Figure 5.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○ Forward ● Inverse ☐ Time-lapse Survey ☐ Batch Inversion ☐ Unconventional Survey ☐ Pseudo 3D inversion from 2D lines

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Figure 5. ResIPy 3.3.3 Interface Display (GUI) for resistivity and IP data modeling in 2D and 3D [24].

ResIPy is a Python GUI-based open-source software that handles all survey data processing, i.e., data import, data conditioning, reciprocal error modeling, and pseudo-section visualization [20], [24]. ResIPy can also enable modeling and inversion of geoelectric data sets under a Python interface, and its source code is available in the GitLab repository (https://gitlab.com/hkex/pyr2). ResIPy implements a structured quadrilateral and unstructured triangular finite element mesh for resistivity calculations. In addition, it can import complex meshes from Gmsh [25], [26].

In the Schlumberger configuration VES, the AB distance increases logarithmically, with results plotted as the logarithm of apparent resistivity versus the logarithm of AB/2. The data were then analyzed to derive a 1D resistivity structure, interpreted as layers of varying thicknesses and resistivities matching the measured response. Traditionally, 1D sounding data employs a curve type in which the inversion process manually matches the observed response (sounding curve) to theoretical responses.

Results and Discussion

Pseudoresistivity of the Wenner and Schlumberger configurations

The measurement of the resistivity geoelectric method in the study area using the Wenner configuration on two passes, each designated as Wn_1 and Wn_2, as well as a single-pass Schlumberger (Sc), yielded the distribution of the rock's pseudo-resistivity value at subsurface pseudo-depths. The quantity of measurement data points is 98, with a minimum distance between electrodes (a) of 5 m that progressively increases to achieve a deeper layer depth. The Wenner configuration pseudo-resistivity data distribution for the Wn_1 trajectory varied between 8.614 and 694.323 Ohm.m (Figure 6(a)). The measurements for Wn_1 were conducted at a topographic elevation ranging between 126 and 127 m above sea level (Figure 6(b)).

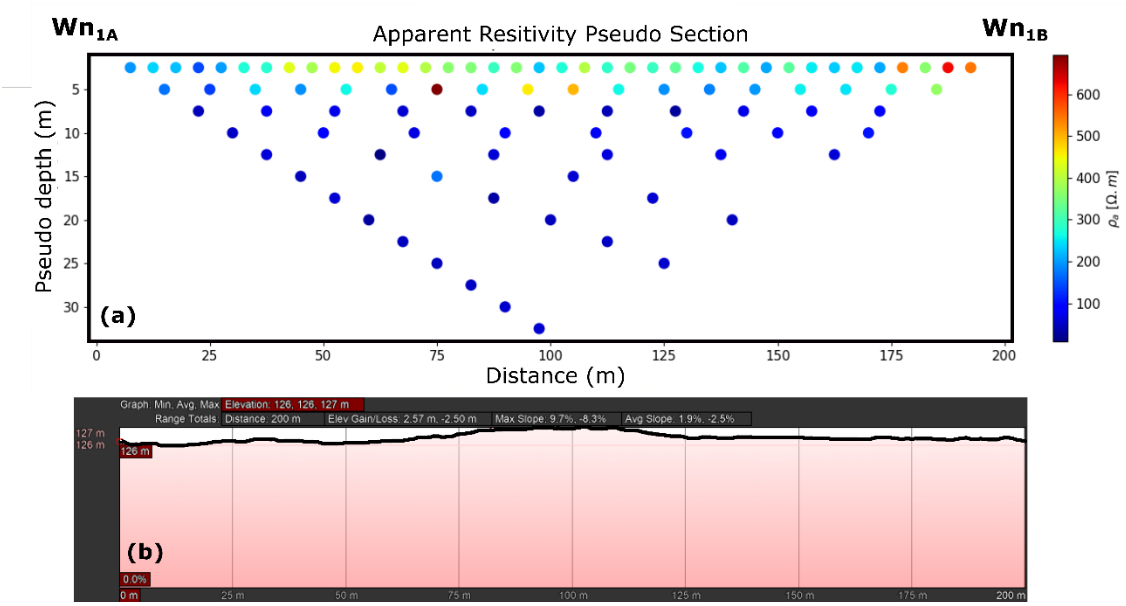

Figure 6. (a) Pseudo-resistivity field measurements using the Wenner electrode configuration for the Wn_1 trajectory; (b) topographic elevation profile of the Wenner Wn_1 lines.

Figure 6(a) illustrates the distribution of pseudoresistivity on the surface, which diminishes with depth. Figure 6b shows measurements for relatively flat terrain, permitting the exclusion of the height factor. The shadow depth is estimated to be about 30 m below the surface.

Moreover, the Wenner configuration pseudoresistivity data distribution for the Wn_2 trajectory spans from 41.724 to 583.910 Ohm.m. The number of measurement data points equaled 92, and the minimum distance between the electrodes (a) was 5 m, which increased gradually

(Figure 7(a)). Measurements on the Wn_2 trajectory were also performed at relatively flat topographic elevations, ranging from 126 to 128 m above sea level (Figure 7(b)). The pattern of the pseudo-resistivity distribution for the Wn_2 trajectory is identical to that of the Wn_1 trajectory. Both exhibit a high resistivity on the surface that decreases with increasing depth, with a maximum of over 30 m.

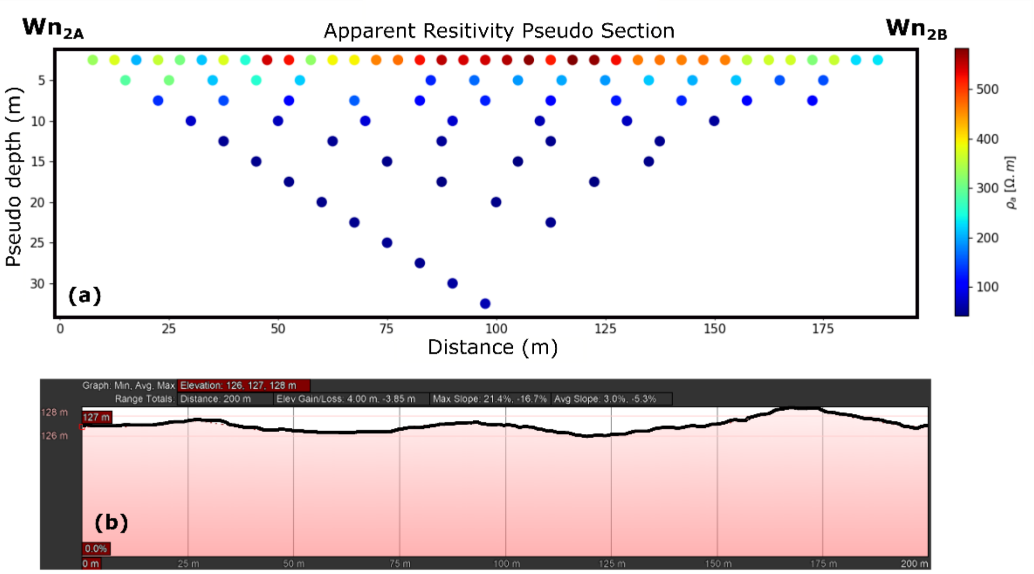

Figure 7. (a) Pseudo-resistivity field measurement results of the Wenner electrode configuration of the geoelectric method for the Wn_2 trajectory; (b) topographic elevation profile of the Wenner Wn_2 lines.

This research utilized the Schlumberger arrangement in applying the vertical electrical sounding (VES) technique to identify variations in electrical properties with depth at a specific location, presuming uniformity in these properties across the lateral dimension. Four electrodes, each positioned at increasing distances and centered in the exact location, were examined in a study. The total number of measurements collected was 27 data, and the resulting pseudoresistivity values ranged from 85.580 Ohm.m to 672.640 Ohm.m. Moreover, the data were graphed as a logarithmic curve of pseudo-resistivity (Ohm.m) against AB/2 (m), as depicted in Figure 8.

The pseudo-resistivity values of subsurface rocks generally correspond to those produced by the Wenner electrode configuration of the ERT method (Wn_1 and Wn_2). Therefore, these results are considered valid for subsequent processing to obtain resistivity models and aquifer layer geometries in the study area. The degree of pseudo-resistivity at the pseudo-cross section alters the accurate subsurface model picture and is heavily influenced by the type of electrode array arrangement.

Aquifer layer identification in the West Manokwari District

Porosity, permeability, temperature, clay content, and moisture content affect the electrical properties of soils and crust-forming rocks. Clay minerals in highly eroded rocks enhance conductivity through ion exchange. However, surface clay particles may impact resistivity measurements [14].

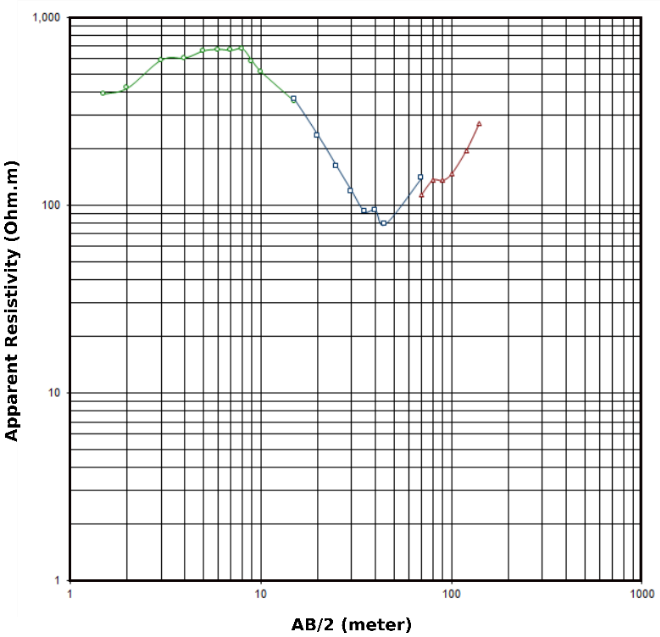

Figure 8. Logarithmic distribution of field data from the geoelectric VES Schlumberger method, showing apparent resistivity versus AB/2.

After identifying subsurface characteristics, geophysical modeling was conducted to determine the resistivity value and depth of the aquifer layer in West Manokwari. Two modeling techniques were used: forward modeling for the VES method (1D) and inverse modeling for the ERT method (2D). Figures 9 and 10 present the ERT inversion using RESIPY software for two Wenner lines (Wn_1 and Wn_2). The subsurface cross-sectional models are illustrated as resistivity, conductivity, and sensitivity models.

Figure 9(a) shows a subsurface resistivity model for the Wn_1 line, with values from 5 Ohm.m to 800 Ohm.m. High resistivity is mainly found up to 10 m depth. In contrast, medium to low resistivity dominates beyond 10 m. Potential groundwater in the study area on the Wn_1 line is thought to be present in three locations, especially at a distance of 75m - 100m from the starting point of the stretch with low resistivity values. The log resistivity pattern also follows the flow of rock resistivity values ranging from 1 to 4 (Figure 9b). The results of the rock resistivity cross-section for aquifer estimation on line Wn_1 are also supported by a lateral cross-section model of subsurface rock conductivity with a range of 5 mS/m to 115 mS/m (Figure 9c), which is the inverse of the resistivity value.

Low conductivity values are present at the surface up to 10m depth and high conductivity beyond 10m depth. The model's sensitivity is generally balanced between positive and negative values (Figure 9(d)), which suggests that it has successfully characterized the subsurface conditions. However, the maximum depth achieved in this modeling is 20 m, which indicates that the basement layer has not been identified in this model.

The Manokwari sheet's geological characteristics suggest that the lateral subsurface layer of the Wn1 track comprises three lithological units. The uppermost layer is topsoil with a thickness of up to 2 m. The second layer is limestone, and the third layer is sandstone, located at a depth of ± 10 meters in several zones. This layer is believed to be the groundwater aquifer layer at the study site. The deepest layer is composed of mudstone, extending to a depth of 20 m.

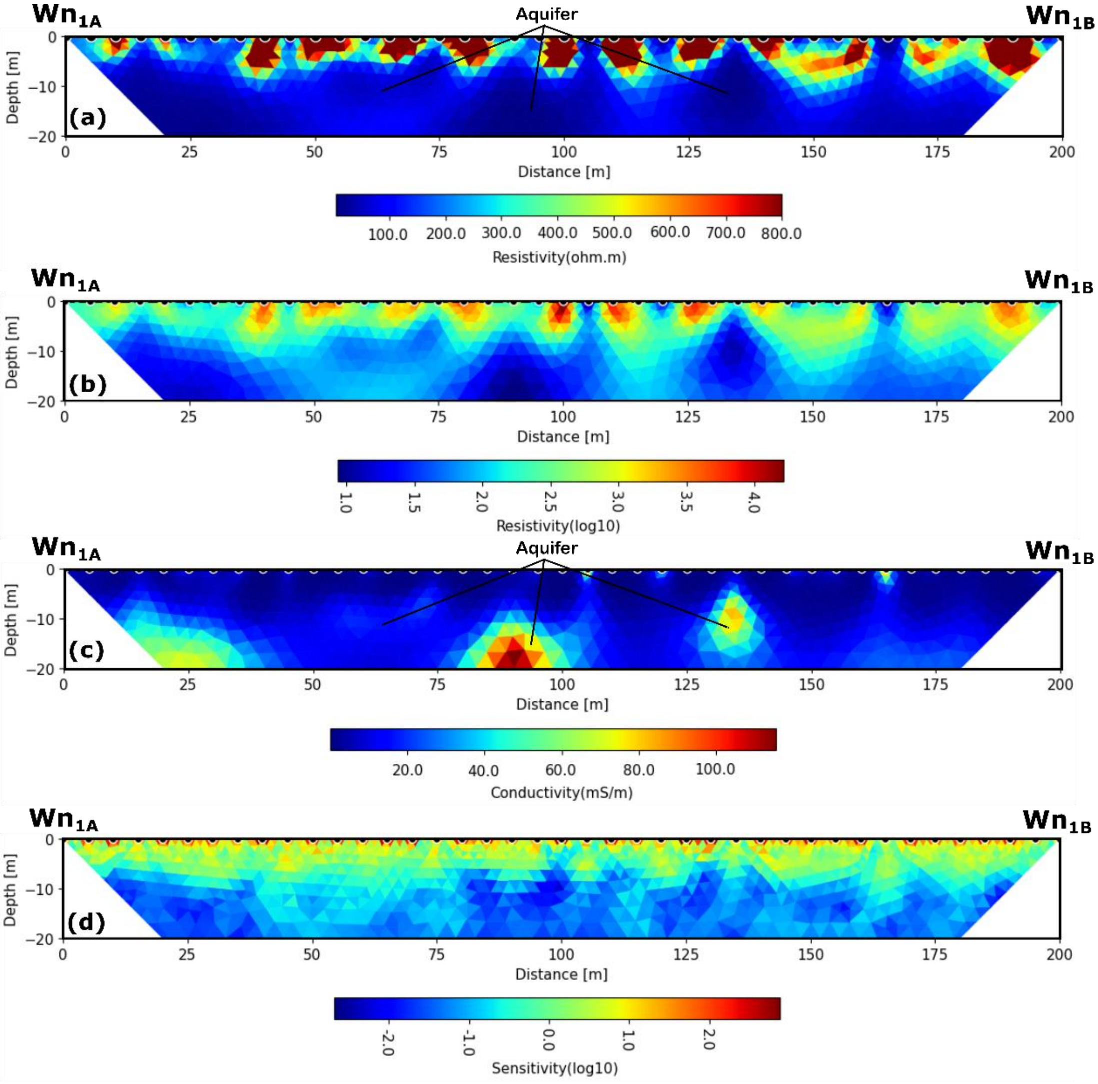

Figure 9. Subsurface lateral cross-section of Wenner configuration resistivity method trajectory Wn$_1$, showing (a) Resistivity; (b) Resistivity log; (c) Conductivity; (d) Sensitivity.

The resistivity tomography results on the Wn$_1$ track are also supported and consistent with direct measurement data of the depth of the groundwater table in several residents' wells around the research site. The healthy data shows that groundwater levels range from 114 to 118 m above sea level, equivalent to 8 to 16 m depth.

Figure 10a illustrates the resistivity distribution model in the subsurface of the Wn$_2$ line, with resistivity values ranging from 5 Ohm.m to 750 Ohm.m. Areas with high resistivity generally dominate in the surface layer to a depth of about ± 8 m. Below this depth, laterally dominated rocks with resistivity decreasing from medium to low are seen. The resistivity pattern seen is consistent with the subsurface cross-section on line Wn$_1$.

Potential groundwater or aquifer layers are considered at depths of more than 8 m, with the largest accumulations located at distances of 75 m and 150 m from the starting point of track Wn_2. The resistivity log model also follows the pattern of rock resistivity values (Figure 10(b)), which range from 1.2 to 3.8. The results of the rock resistivity cross-section for aquifer estimation are supported by a lateral cross-section model of rock conductivity in the subsurface (Figure 10(c)), with values ranging from 5 mS/m to 80 mS/m.

This cross-section depicts a different pattern from the resistivity cross-section, with a predominance of low conductivity at the surface up to 8 m depth and high conductivity below that depth. Overall, the model sensitivity shows consistency between positive and negative results (Figure 10(d)), which allows further interpretation of the model cross-section. The Wn_2 cross-section reveals a first layer with a resistivity value ranging from 50 Ohm.m to 100 Ohm.m, believed to be the topsoil layer extending from the surface to a depth of 3 meters. At the same time, a prevalent limestone layer with a resistivity value exceeding 500 Ohm.m is observed to extend laterally to a depth of 8 m. The depth of the groundwater aquifer layer is estimated to be over 8 meters, and the rock resistivity value is less than 100 Ohm.m in the presence of sandstone. The results of the lateral cross-section of the resistivity tomography of the Wn_2 line also correspond to the field measurement data of the depth of the groundwater table in several residents' wells around the research site. The Wn_2 lateral resistivity cross-section does not indicate the presence of bedrock, which is estimated to be at a depth of more than 20m.

ERT cross-sections Wn_1 and Wn_2 indicate that the aquifer layer is characterized by low rock resistivity or high conductivity. In ERT surveys, current traverses the material between electrodes via an electrolytic process. Therefore, soils and rocks exhibit increased electrical conductivity when water saturates joints and pores, leading to lower resistivity values. Similarly, clay-rich zones display very low resistivity due to their high conductivity [14].

VES 1D modeling was conducted using the Schlumberger configuration, as illustrated in Figure 11, to develop a basement model at the study site. The observation data (blue dot) and the computational curve (red line) in Figure 11(a) align well, with the model exhibiting a calculation error of 8% relative to the data. This result demonstrates a strong correlation between the two data sets, allowing further interpretation. The geoelectric layer interpretation of a VES trajectory in the study area revealed four lithological units: topsoil, limestone, weathered material (aquifers), and basement rocks (Figure 11(b)). The topsoil thickness ranges from 0 to 1 m with an average resistivity of 300 Ohm.m. Beneath this, limestone extends from 1 to 5 m depth, exhibiting high resistivity exceeding 1000 Ohm.m.

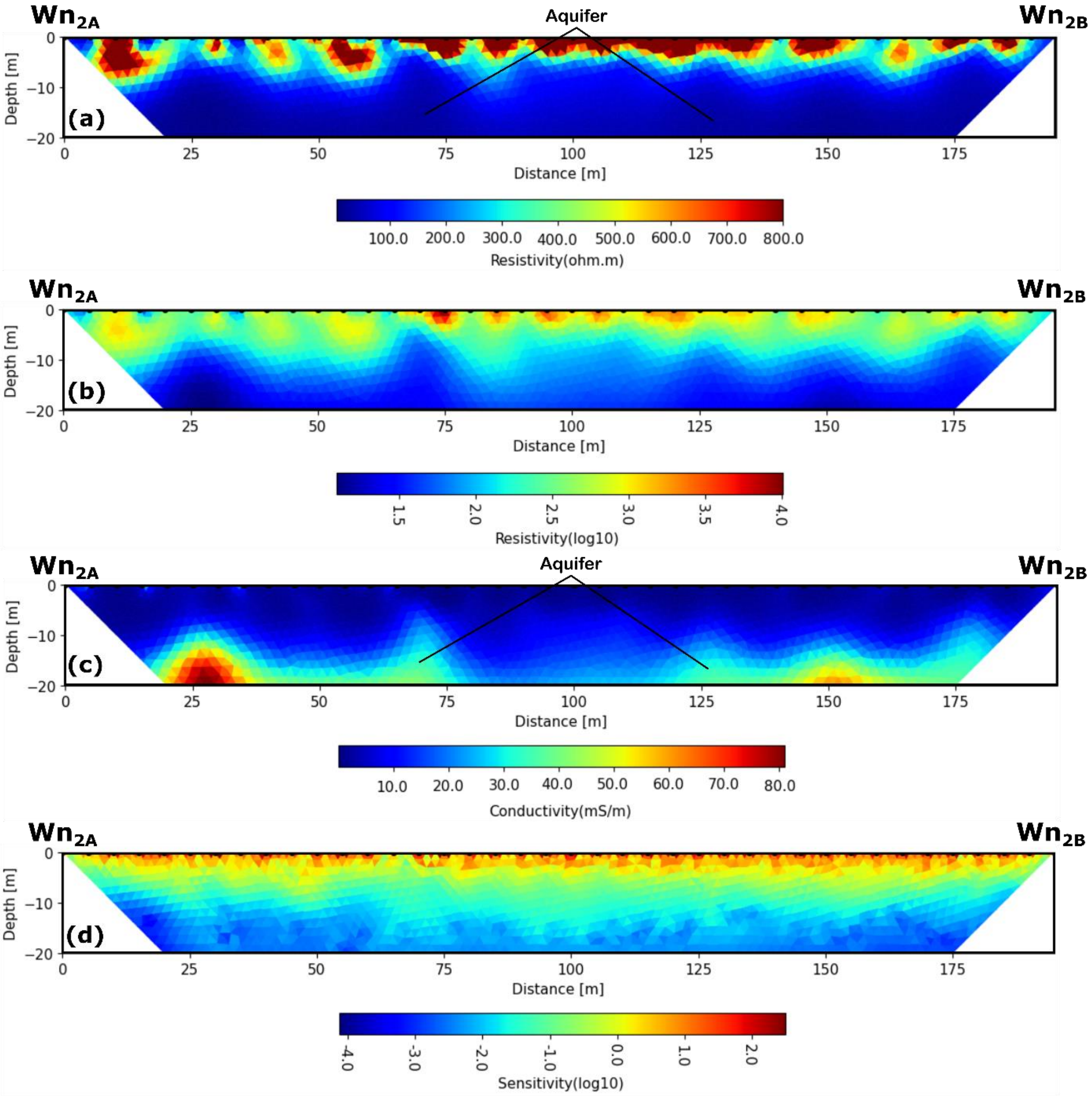

Figure 10. Subsurface lateral cross-section of Wenner configuration resistivity method trajectory Wn_2, showing (a) Resistivity; (b) Resistivity log; (c) Conductivity; (d) Sensitivity.

The aquifer layer is presumed to commence at 6–30 m depth, characterized by a low resistivity of 30 Ohm.m, indicating a sandstone layer.

The basement is estimated to be deeper than 30 m with a resistivity of 2000 Ohm.m. VES 1D data interpretation aligns with the lateral ERT 2D results for the Wenner Wn_1 and Wn_2 lines, indicating groundwater potential (aquifers) and the presence of basement formations in West Manokwari district, Manokwari regencies. The three models from ERT and VES modeling indicate that the aquifer layer is significantly thick, typically occurring at 6 m to 30 m depths. This layer can potentially supply clean water to the community, but its exploitation must consider the surrounding environmental conditions.

These results were contrasted with prior research employing the Dipole-dipole geoelectric approach in the neighboring Reremi region, unveiling a possible association between the aquifer zone and low-resistivity rocks at depths ranging from 7.5 m to 12 m [27]**.** Based on this study's ERT and VES modeling results, a lithological cross-section of the rock layers was created that connects the three measurement lines, revealing the presence of aquifer layers at the study site. The lithology in the study area is estimated to consist of topsoil, limestone, sandstone as an aquifer layer, mudstone, and siltstone (Figure 12).

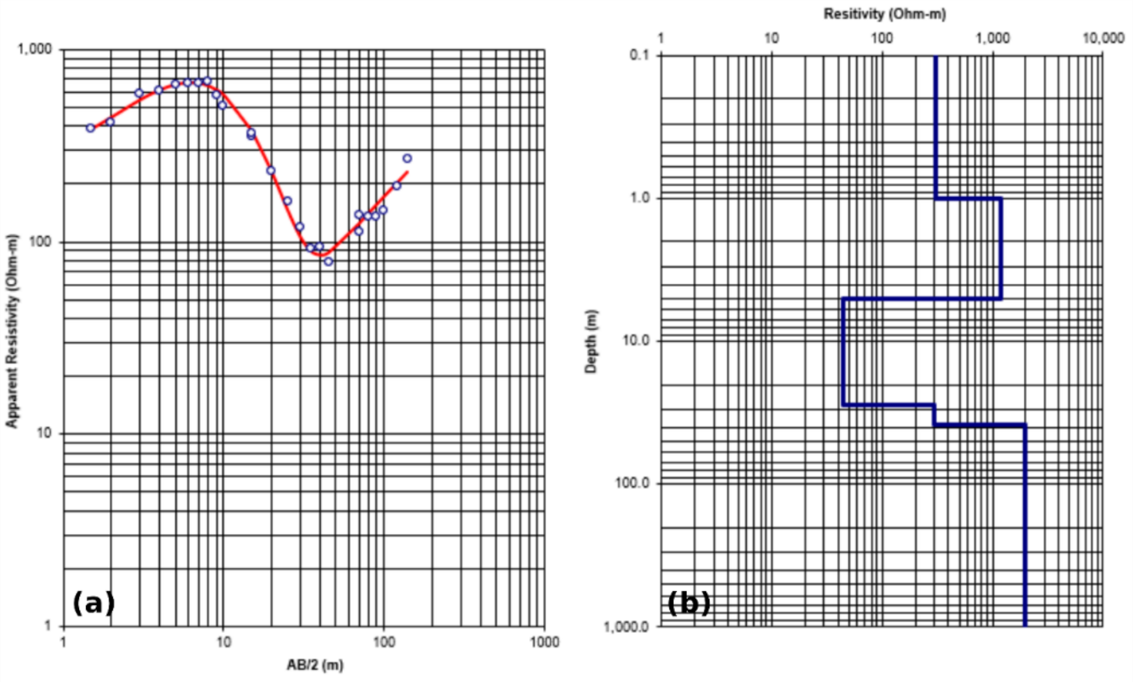

Figure 11. Forward modeling of the Schlumberger configuration of 1D VES resistivity data: (a) Computational curve match and measurement data, (b) subsurface cross-sectional model depicting resistivity variations with depth.

According to the specified lithologies, the topsoil is anticipated to possess the ability to retain a limited quantity of water. Both limestone and sandstone exhibit promising characteristics as significant aquifer layers, owing to their porosity and permeability, facilitating water storage and flow. Mudstone typically functions as a water-bearing stratum that impedes water flow, while siltstone operates as a transitional or semi-retentive layer in the direction of bedrock.

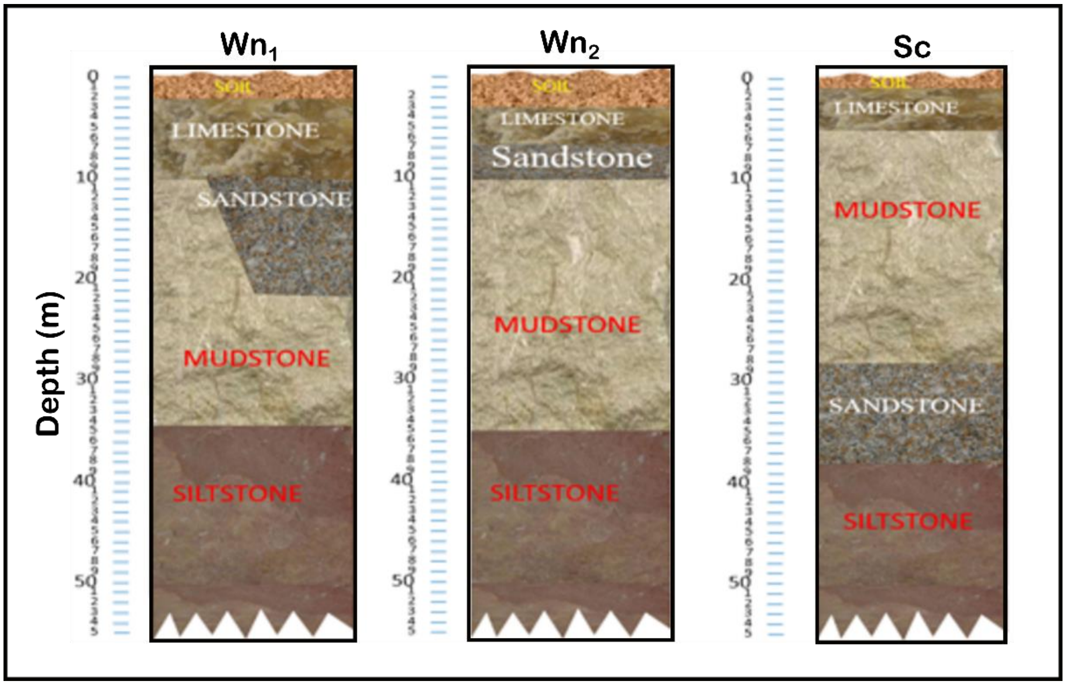

Figure 12. Lithologic model of aquifer layer based on ERT and VES approach in Manokwari Barat district, Manokwari regency.

Conclusion

Applying the resistivity geoelectrical method using Wenner configuration for 2D ERT and Schlumberger for 1D VES provides significant results in identifying groundwater potential in West Manokwari district, Manokwari regency, West Papua province, Indonesia. The interpretation of the resistivity model through ERT and VES generally provides consistent and mutually supportive results, where the study site is divided into four main layers: topsoil, limestone, sandstone as a potential groundwater layer (aquifer), and bedrock. Rock resistivity at the surface is dominated by high values up to 6 m depth, then decreases to 30 m depth, a potential aquifer layer for exploration. Bedrock layers with high resistivity of more than 2000 Ohm.m are estimated to be at depths of more than 30 m. Although it provides significant results for groundwater exploration, its utilization is expected to follow the surrounding environment's characteristics, and measurements can be carried out for a wider area with other geophysical techniques and approaches to obtain more comprehensive results.

Acknowledgment

This research forms part of a thesis within the postgraduate environmental science program at Papua University. The author extends gratitude to the head of the program for enabling timely completion of the studies. Additionally, thanks are due to the West Papua Provincial Forestry Service for allowing the author, as a state civil servant, to pursue further education.

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