Volume 11. Number 2. 207-218 OCTOBER 2022

Jurnal ilmiah pendidikan fisika Al-Biruni
https://ejournal.radenintan.ac.id/index.php/al-biruni/index
DOI: 10.24042/jipfalbiruni.v11i2.13895

P-ISSN: 2303-1832
e-ISSN: 2503-023X

Groundwater Survey Using Resistivity Method for Drought Mitigation in Bima Regency, West Nusa Tenggara

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Article Info

Article history:

Received: August 27, 2022
Accepted: October 18, 2022
Published: October 30, 2022

Keywords:

Drought Mitigation;
Geoelectrical;
Groundwater in Bima Regency;
Schlumberger.

ABSTRACT

Groundwater Survey in Bolo District, Palibelo District, Woha District, Langgudu District, Wawo District, Sape District, Wera District, Bima Regency, and West Nusa Tenggara for drought mitigation has been implemented. The study area is located in the majority of hilly areas with soil vulnerable to drought. Water is abundant during the rainy season. However, during the dry season, the ground surface is cracked, and there needs to be more clean water. This situation is troubling the community and the Regional Government of Bima Regency. The study was conducted using the Schlumberger resistivity geoelectric configuration method. The measurement point is in seven sub-districts, with a total of 18 measurement points. Research location at 118,6305833 SL; -8,3008888889 EL up to 119,01925 SL; -8,704638889 EL or covers an area of ± 1,961 km2. The length of the path used is a maximum of 400 meters. Based on the results of geoelectric resistivity data, two types of aquifers are found, open aquifers with depths ranging from 1 m to 26 m and aquifers depressed with depths ranging from 70 to 115 m. In addition to geoelectric information data, drilling data is also used at points that can be reached by heavy equipment in Lanta Barat Village, Lambu District. At the drilling point, the presence of an aquifer layer is obtained at a depth of about 80 meters. Residents then use the discovery of the wellbore to meet their need for clean water.

INTRODUCTION

Water is essential for humans and other living beings, needed for domestic, industrial, and public purposes. Limited availability of water can disrupt human survival. Increased clean water needs encourage humans to provide clean water with quality, quantity, and continuity standards (Mochammad, 2019; Simbolon & Malik, 2022).

Common water-related issues include the lack of access to clean water, climate change, soil conditions, or agricultural activities that require water. The imbalance between water demand and supply can lead to drought in areas with limited water availability. Bima Regency is one of the districts that often experience drought. Drought causes include soil types with a large to small potential to experience drought (Munir et al., 2015) and morphological conditions with hilly peaks (Ratman & Yasin, 1978; Fahmi, 2016; Maulana et al., 2021). Not to mention the impact of El Nino, there is a long drought and reduced clean water reserves (Simanjuntak et al., 2018; Wang et al., 2016). In addition, drought in Bima Regency is repeated every year during the transition of the rainy season to the dry season (transition) and almost evenly occurs in the Bima Regency.

How to cite Prabowo, A., Hartono, H., & Kaeni, O. (2022). Groundwater survey using resistivity method for drought mitigation in Bima Regency, West Nusa Tenggara. *Jurnal ilmiah pendidikan fisika Al-Biruni, 11*(2), 207-218.

Historically, this area is a basin. Volcano activities occur in the basin and produce volcanic rocks that are mainly andesite and basal (Budiman, 2010). Types of soil found in Bima Regency are alluvial deposits (7.17%), Litosol (22.08%), Regosol (40.89%), Mediterranean (26.44%), and others (3.42%) (Pusdatin ESDM, 2018). Judging from its nature, the soil type has a great to the small potential for drought occurrence (Munir et al., 2015). Because it is a hilly plane and has a type of soil vulnerable to drought, therefore, in the rainy season, water will be abundant. Still, in the prolonged dry season, the upper soil layer dries up, creating cracks. Therefore, the upper groundwater (open aquifer) may have a sour taste and odor as it directly receives the stored rainwater or brackish water due to seawater intrusion in coastal areas. The underwater part of the area is a confined aquifer that will taste and smell better.

To overcome these things, the local government manually collects data to identify areas affected by drought, then drops or distributes clean water to areas that report drought to the clean water crisis (Faizah & Buchori, 2019). The high drought rate makes the groundwater investigation need to be carried out at that location as a drought solution in the dry season and the domestic water supply to residents.

The geophysical method is non-invasive and utilizes physical parameters to analyze subsurface conditions. This technique often identifies various features such as landslides, mineral deposits, groundwater sources, geothermal activity, seepage zones, petroleum deposits, seawater intrusion, and archaeological evidence (Susilo, 2017).

Several geophysical techniques are available such as seismic reflection, electrical resistivity, and magnetic and gravity surveys. Seismic reflection utilizes reflected seismic waves to create an image of the subsurface, while electrical resistivity measures the subsurface's electrical resistivity to identify materials and structures. On the other hand, magnetic surveys measure changes in the Earth's magnetic field to identify subsurface structures. In contrast, gravity surveys measure changes in the Earth's gravitational field to identify subsurface structures (Susilo, 2018).

The geoelectric resistivity method is generally considered the most promising and suitable for groundwater investigations (Mohamaden et al., 2016). This is due to low cost and implementation time faster than other geophysical methods (Kearey et al., 2002; Oscar Kaeni, 2021). The use of resistivity geophysical methods for groundwater resource mapping and water quality assessment has increased dramatically over the past few decades due to rapid advances in electronic technology and the development of numerical modeling solutions (Akhter & Hasan, 2016; Metwaly et al., 2010; Ndlovu et al., 2010; Olayinka, 1992; Susilo et al., 2017). Many groundwater exploration studies use the geoelectric method, ranging from Desafatma et al.'s research on the interpretation of geoelectric data ves to identify groundwater in Batujajar, Bandung Regency, West Java (Desifatma et al., 2019). Febriana et al. regarding the identification of the distribution of underground water flow (groundwater) with the Vertical Electrical Sounding (VES) Schlumberger configuration method in the Cepu region, Blora, Central Java (Febriana et al., 2017). Harjito regarding the Vertical Electrical Sounding (VES) method to estimate the potential of water resources (Harjito, 2013). Yuwana et al. (2017) regarding the prediction of groundwater reserves based on the results of geoelectric estimates in Grobogan Regency, Central Java. Sutasoma et al. regarding the identification of groundwater with the geoelectric method of the Schlumberger configuration resistivity in Dasa Temple, Bali Province (Sutasoma et al., 2018). up to Zuhdi & Wahid's research on geoelectric methods of species prisoners for groundwater exploration on mount Tunak (Zuhdi & Wachid, 2021). These studies show a good correlation with geoelectric methods in groundwater investigations. However, geoelectrical methods in groundwater investigations are generally only limited to depth data (1 Dimension).

This study uses a lateral approach (3 dimensions) by connecting the sounding points with the interpolation process. Knowing the three-dimensional measurement of the geoelectric survey is important as it provides a more detailed picture of the subsurface structure and composition. Obtaining three-dimensional information allows a more accurate determination of subsurface structures' depth, shape, and size. This is useful in various geological applications such as aquifer mapping and rock layer mapping and can aid in planning natural disaster mitigation activities, specifically aquifer mapping. Hence, understanding geoelectric survey measurements in three dimensions can be highly beneficial in various fields of geology.

Therefore, the results of the interpretation of geoelectric data are expected to provide an overview of the subsurface condition of the research location and can provide a picture of the location that is possible for groundwater drilling to overcome the problem of clean water drought at the study site.

METHODS

The research utilizes a combination of approaches, including a literature review, surveys, and data collection methods. The research flowchart is shown in Figure 1.

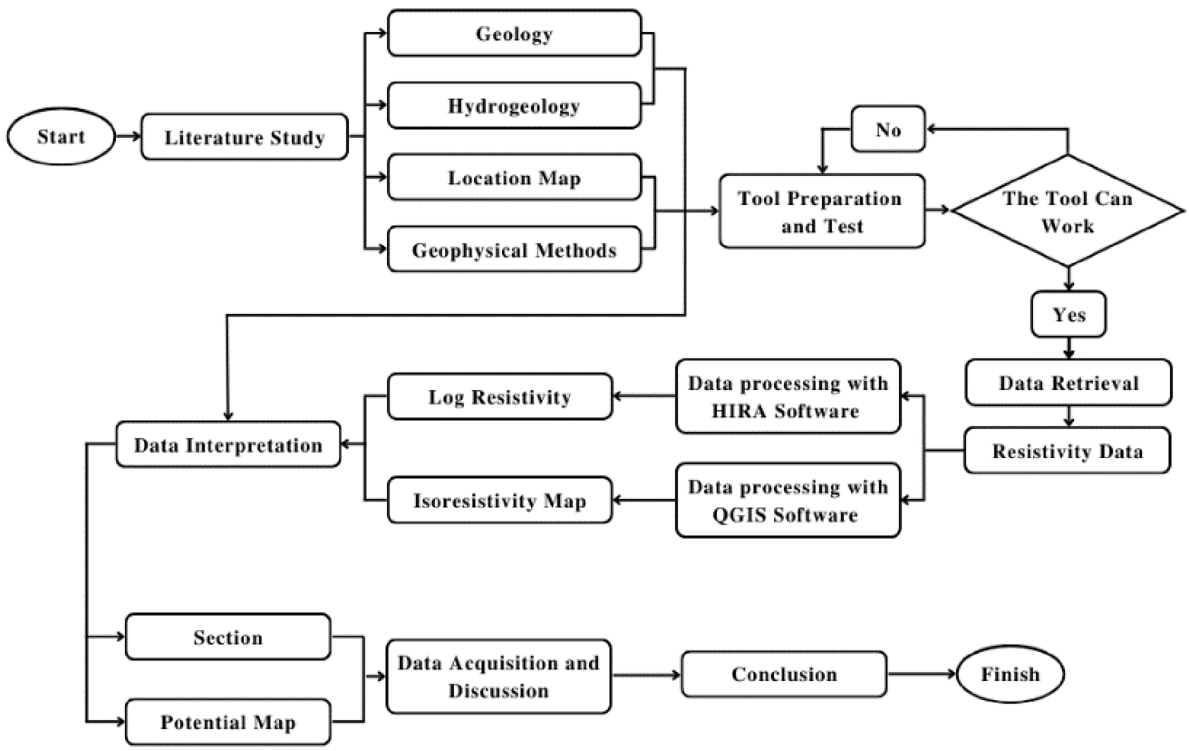

Figure 1. Geoelectric Survey Research

The study site is located on the east side of Sumbawa Island. Geologically, the area belongs to Bima Regency, West Nusa Tenggara, a hilly area that peaked in the south. In the north, the area is formed by two inactive Stratovolcanoes, namely Doro Lambuwu (1618 m) and Doro Maria (1484 m). Local Geology The study area, as shown in Figure 2, is the tertiary sedimentary area.

The Bima Regency Hydrogeology comprises volcanic rocks, solid stones, and lithology of loose deposits. The existence of groundwater is generally influenced by rock porosity and rock fracture caused by the process of dissolving and tectonic structures (Pusdatin ESDM, 2018). The hydrological condition of the Bima Regency is influenced by tides of 7 ha (0.002 %), and stagnant swamps occupy an area of 287 ha (0.066 %). Bima Regency flows many large and small rivers from 5 to 95 km, among them 20 rivers for irrigation (Budiman, 2010).

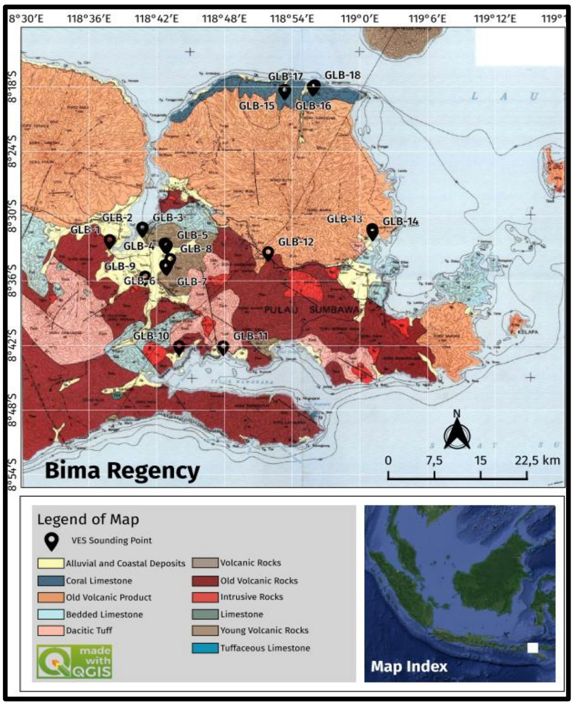

Figure 2. Regional Geological Map (Ratman & Yasin, 1978)

Field data collection is carried out using several tools, as shown in Figure 3, including 1 unit of Digital Resistivity meter and its accessories as follows: (a) Multi-Channel Resistivity meter is used to provide potential difference (V) and current strength (I); (b) 2 rolls of current-carrying cable with a length of 250 meters each; (c) 2 rolls of potential cable with a length of 50 meters each; (d) 2 stainless steel current electrodes; (e) 2 copper potential electrodes; (f) 2 pieces of insulating casing: (g) 4 pieces of the hammer to help stick the electrodes in the ground; (h) 4 cable connectors with electrodes; (i) 1 wet battery as a current source; (j) GPS as a shooter for geoelectric coordinates in the amount of 1 unit; (k) 1 laptop as input for field data results.


Figure 3. Geoelectric Survey Equipment

Data collection was carried out in Bolo District (covering two villages: Sanolo and Runggu), Palibelo District (covering three villages: Kalaki, Tonggondoa, and Roi), Woha District (Waduwani Village), Langgudu District (covering two villages: Laju and Rompo), Wawo District (Raba Village), Sape District (Lamere Village), and Wera District (covering three villages: Nanga Wera, Ranggasolo and Sangiang) in Bima Regency, West Nusa Tenggara. The survey was conducted at locations with UTM coordinates: (118.6305833; -8.3008888889) to (119.01925; -8.704638889) or covering an area of ±1.961 Km^2. Each village is represented by one to two sounding points: Vertical Electrical Sounding (VES). The number of sound points is 18 VES, with the distribution shown in Figure 4. The study or investigation of resistivity in the Bima District uses a Schlumberger configuration with a fixed potential electrode and a running electrode current to obtain the direction of depth variation (sounding). It is connected to each VES sounding point through an interpolation process to obtain lateral variations. The use of the Schlumberger configuration is the most appropriate choice for Vertical Electrical Sounding (VES), which refers to the Indonesian National Standard (SNI) (Tedja, 2012).

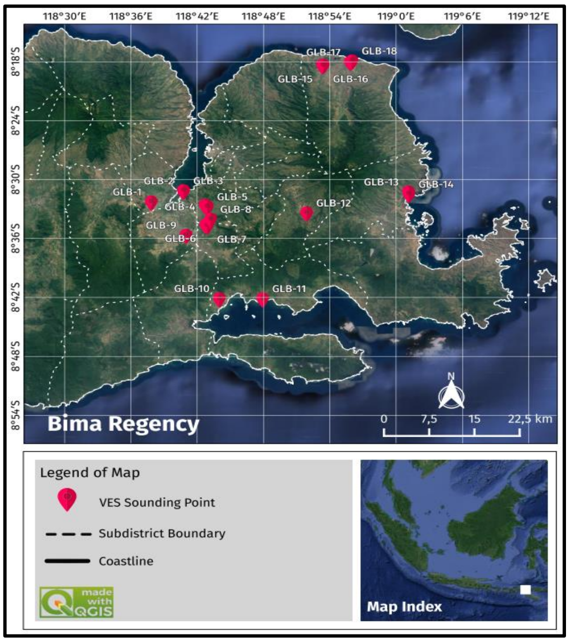

Figure 4. Map of the Research Area

Data processing was performed using HIRA and QGIS 3.24.1 software. The resulting data processing can obtain information about the possible distribution of underground aquifers from the geological and hydrogeological data of the area, which can then be used as reference data for drilling sites around the study area.

RESULTS AND DISCUSSION

Based on data processing results, the resistivity distribution at each depth was obtained using QGIS 3.24.1 software. Interpolation of resistivity contours is carried out at a depth of 10 to 115 meters, with a difference of 15 meters, to determine changes in low, medium, and high resistivity contours.

Figure 5-12 is a layer image based on resistivity values for each depth. The figures explain that low resistivity indicates a depth that has high conductivity. This area was once a basin area which then occurred sedimentation during the tertiary period, which is usually formed through deposition and deposited in the marine environment or lakes rich in minerals and organic. The water and mineral content in this sediment also affects the value of electrical resistance. The more water or minerals in the sediment, the lower the electrical resistance value. Therefore, tertiary sediments tend to have a low electrical resistance value because they contain a lot of water and electrical insulator minerals. Therefore, low resistivity can/must represent aquifers. The resistivity range can be divided into four parts, namely resistivity between 0-10 Ωm (Sandstone/ Clay/Claystone/Coral claystone), 10-27 Ωm (Sand/Clay sand/Sandstone/Limestone sandstone/ Hollow limestone sandstone), 27 - 40 Ωm (Breccia/Limestone), >40 Ωm (Stone/Andesite). Based on the available geological and hydrogeological information, the upper part of the investigated section is a Holocene deposit, and the lower part is a Pleistocene deposit. The resistivity values between 10 - 27 Ωm observed in the investigated part can be interpreted as a zone containing water (aquifer) (Oscar, 2021).

Based on the interpretation results, there are several open aquifers at the village sounding points, Sanolo, Kalaki 1, Tonggondoa 1, Runggu 2, Waduwani, Laju, Rompo, Raba, Lamere 2, Nanga Wera, Ranngasolo, Sangiang. with a depth ranging from 1-26 meters below the surface. In addition, the presence of depressed aquifers at VES points in Tonggondoa 2, Waduwani, Lamere 2, Ranggasolo, Runggu 1, and Rompo villages. A depth of 70-115 meters is also visible.

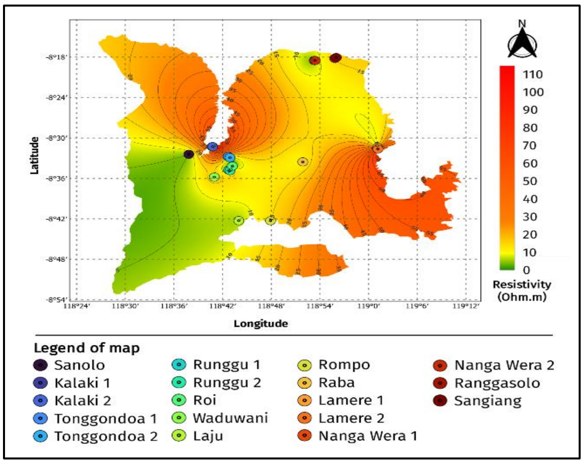

Figure 5. The resistivity contour at a depth of 10 meters. Free aquifers are in Tonggondoa 1, Runggu 2, Waduwani, Rompo, Raba, Ranggasolo, and Sangiang villages.

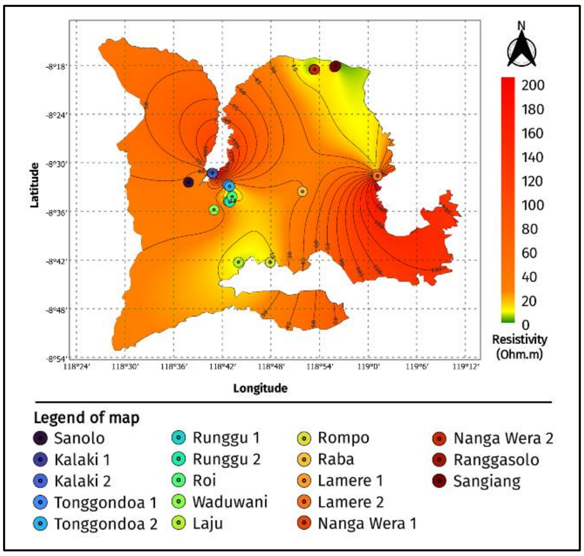

Figure 6. The resistivity contour at a depth of 25 meters. Free aquifers are in Runggu 1, Rompo, Lamere 1, Nanga Wera 2, and Ranggasolo.

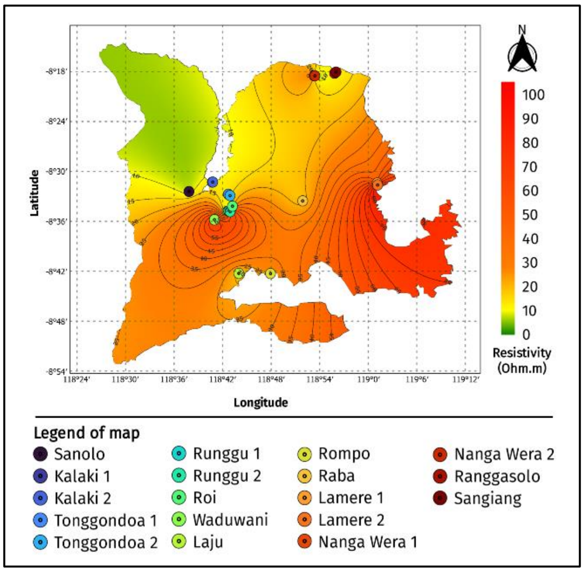

Figure 7. The resistivity contour at a depth of 40 meters. Most VES are open aquifers.

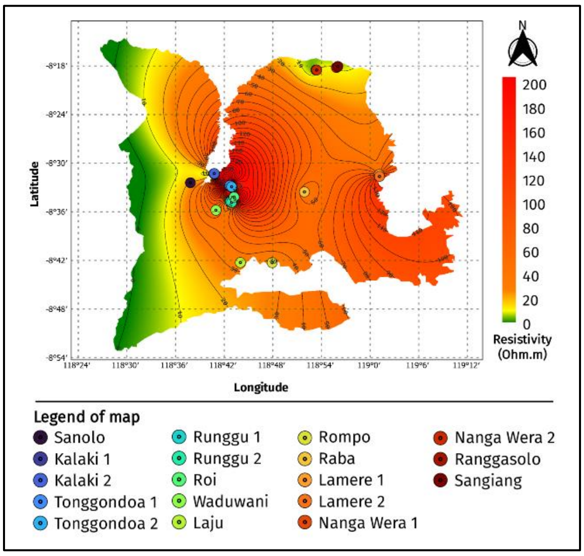

Figure 8. The resistivity contour at a depth of 55 meters. Most of the VES is breccia and andesite, while the aquifers are located at the village points of Tonggondoa 2, Runggu 1, and Nanga Wera 2.

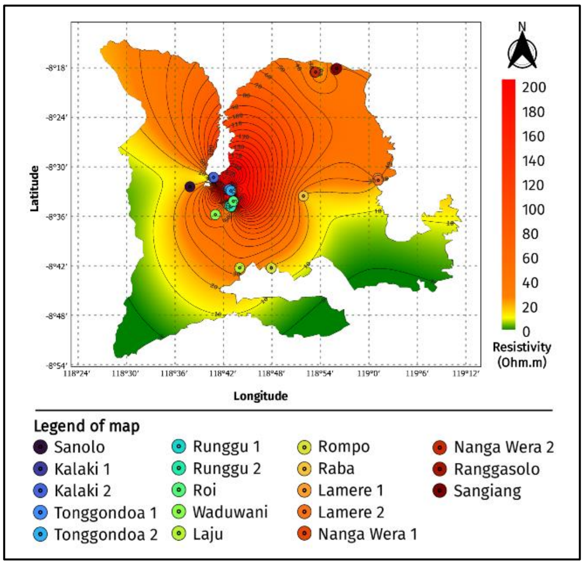

Figure 9. The resistivity contour at a depth of 70 meters. Confined aquifers are located at the points of Runggu 1, Rompo, Raba, and Lamere 2.

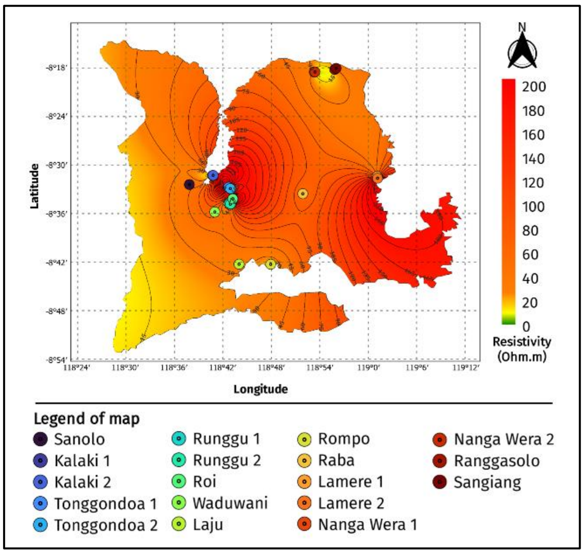

Figure 10. The resistivity contour at a depth of 85 meters. Confined aquifers are located at the points of Tonggondoa 2 and Rompo Villages.

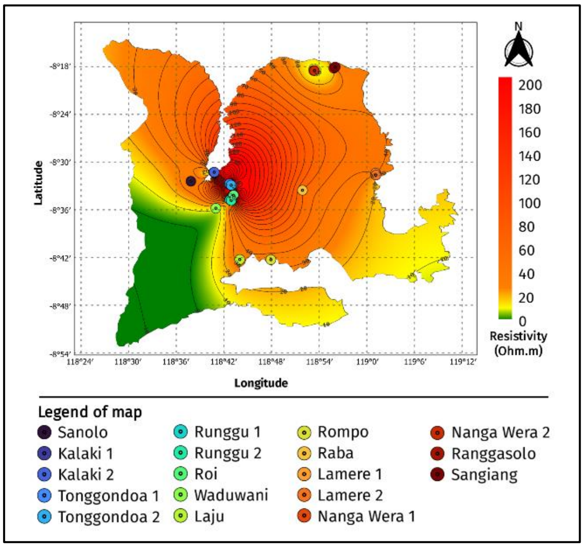

Figure 11. The resistivity contour at a depth of 100 meters. Indications of a depressed aquifer are at the points of Waduwani Village, Lamere 2, and Ranggasolo.

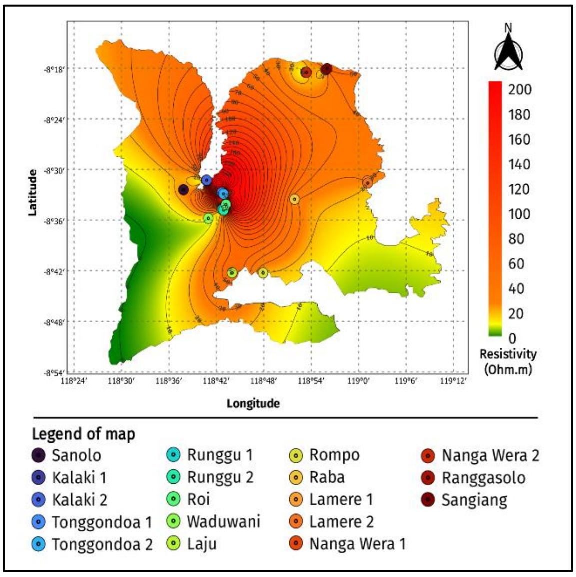

Figure 12. The contour of resistivity at a depth of 115 meters. The depressed aquifer is still at the points of Waduwani Village, Lamere 2, Ranggasolo plus Runggu 1, and Rompo.

Considering the location adjacent to residential areas and can be reached with drilling equipment and the location of the road access that vehicles can pass, the drilling is carried out in Lanta Barat Village, Lambu District. An aquifer layer was found at a depth of about 80 meters from the surface, as shown in Figure 13.

Figure 13. Drilling Results in Lanta Barat Village, Lambu District

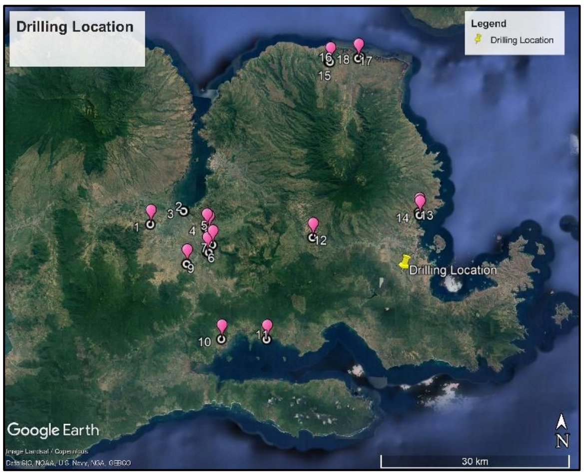

Figure 14. Drilling location. Yellow Pin is the drilling location; thirteen red balloons are recommendations for bore wells.

Figure 14 shows the location of measurement of resistivity (white circle), bore well (yellow pin), and recommendation of the wellbore (thirteen red balloons). Other drilling locations must consider locations close to residents and access roads for drilling equipment (mobilization and demobilization). Residents then use the borewell water to fulfill clean water.

Recommendations for drilling locations are described in Figure 14. Meanwhile, the drilling depth recommendations are shown in Table 1.

Table 1. *Recommendations for Drilling Depth*

No	Village Point	Drilling Depth (m)
1	Sanolo	60
2	Tonggondoa 1	60
3	Tonggondoa 2	90
4	Runggu	70
5	Roi	50
6	Waduwani	70
7	Laju	55
8	Rompo	90
9	Raba	70
10	Lamere 1	30
11	Lamere 2	85
12	Nanga Wera 2	100
13	Ranggasolo	100

The thirteen locations are based on geoelectric interpretation data detected as open aquifers, and aquifers are depressed, with aquifer thickness ranging from 9.02 to 55.06 meters.

Figure 15 shows that at a depth of 70 – 85 meters at the points of Raba Village, Rompo, and Lamere 2, resistivity is 10.83 – 20.15 Ωm. The resistivity range can be interpreted as sand/sand clay/sandstone. It is possible for the aquifer layer at that depth because Drilling in Lanta Barat, Lambu, at a depth of about 80 meters, found a water source. Difference depth is possible due to drilling in West Lanta through direct drilling at about 80 meters, but the aquifer's location can be about 70 meters. Here is an overview 2D cross-section for drilling points and three recommended points for drilling.

The seven sub-districts often experience clean water deficiencies with varying droughts, from childhood to moderate to severe. Every year, drought news in Bima Regency continues to occur. Clean water provided by the local government still needs to meet the need for clean water when the dry season arrives. One of the mitigation efforts that can be done is to drill wells based on this research information using geoelectric resistivity methods. Well drilling can be a water source the community needs because this aquifer tends to be stable and not affected by the season. Therefore, if other wells can be drilled, it can reduce the impact of drought in the dry season. In addition, due to the hilly research area conditions and characteristics of the soil type, increasing the volume of water catchment areas can be done by excavating trenches, reservoirs, or artificial reservoirs to trap and store excessive water during the heavy rainy season and use water this is for irrigation purposes in the dry season.

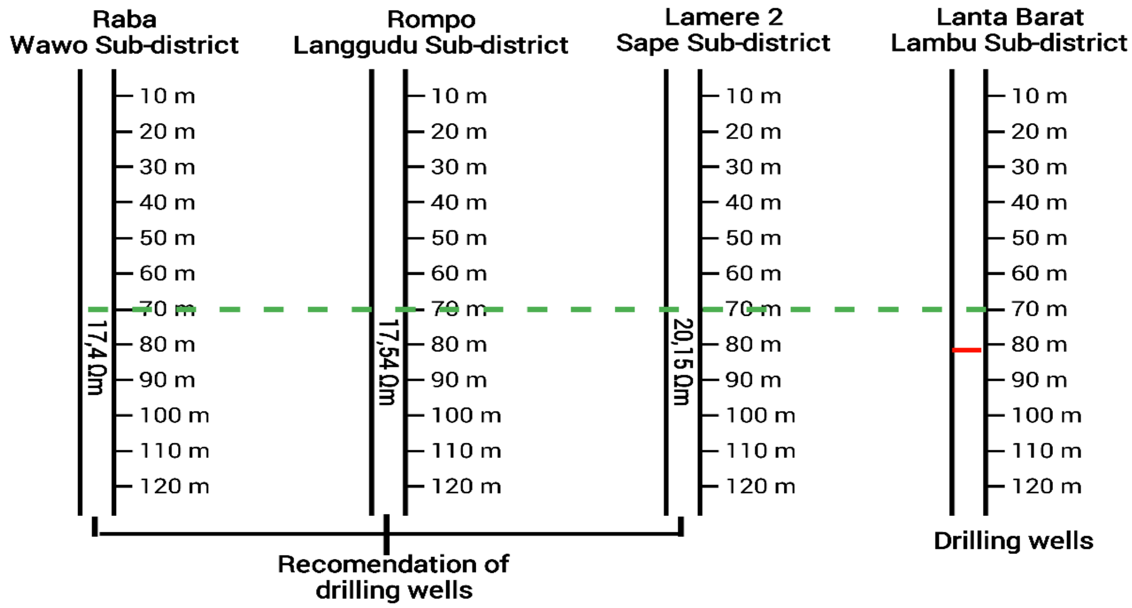

Figure 15. At a depth of 70-85 meters at the point of Raba, Rompo, and Lamere 2. Resistivity 17,4 - 20.15 Ωm. The resistivity range can be interpreted as sandstone

The results of this study are the same as the research conducted by M. Ziaul Fikar et al. in 2015 and by Hakim and Hairunisa in 2018. M. Ziaul Fikar et al.'s research occurred in Nata Village, Palibelo District, Bima Regency. The aquifer layer is a layer of sand at a depth of 3.75 - 41.70 meters with a thickness of 17.8 - 38 meters and a resistivity value between 1.55 – 17.70 Ωm (Fikar et al., 2015). Meanwhile, Hakim and Hairunisa's research occurred in Rada Village, Bolo District, Bima Regency. The aquifer layer in this study is also a layer of sand at a depth of 16 – 100.6 meters with a thickness of 4.2 – 62.2 meters with a resistivity value between 6 – 106 Ωm (Hakim & Hairunisa, 2018).

Differences in aquifer resistivity values can be caused by differences in measuring instruments and samples from the measurement site. It can also be caused by the use of different software in processing data. M. Ziaul Fikar et al.'s research used IPI2WIN and PROGRESS3 software, and Hakim and Hairunisa used IP2Win software. Whereas in this study using, HIRA and QGIS software because it is easier to use, and QGIS is free open-source software.

Differences in resistivity values can also occur because each rock has its resistivity value, and the same rock is not certain to have the same resistivity value (Telford et al., 1992).

The biggest difference between this study and the two previous studies is that it displays not only the results of depth but also the lateral distribution of the aquifer by connecting measurement points using interpolation so that the potential of the aquifer outside the vicinity of the measurement points can be identified.

Meanwhile, the drawback of this study is that the distribution of resistivity at each depth uses the interpolation method, so even though in West Lanta village, there is a match between the depth of groundwater with research results in the villages of Raba, Rompo, and Lamere 2 at a depth of 70 meters. But only sometimes in other places have the same suitability.

Although the results of the distribution of the depth of the aquifer are not necessarily following the results of drilling. However, the results of this study can still be used as initial information regarding strategies for determining drilling locations, especially in areas near measurement points, to overcome the problem of dry water in the research location.

CONCLUSION AND SUGGESTION

Based on the findings and analysis that has been done, it can be concluded that, based on the results of resistivity data, it is known that there are two aquifer models; The aquifer is open, and the aquifer is confined. This is supported by the discovery of an aquifer at a depth of 80 meters below the surface that can be used directly by residents of the village of Lanta Barat in the Lambu district. The discovery of aquifers has provided solutions to drought and groundwater shortages around the study area. Referring to the results of the interpretation, the possibility of a prospective location is at the point of Sanolo and Runggu 1 village in Bolo District, Tonggondoa Village, and Roi in Palibelo District, Waduwani Village in Woha District, Laju and Rompo Village in Langgudu District, Raba Village in Wawo District, Village Lamere in Sape District, and Nanga Wera 2 Village, Ranggasolo in Wera District. Furthermore, the prospective location can be followed up for drilling with varying drilling depths, according to recommendations based on the study

results due to the distribution of resistivity at each depth using the interpolation method. Further studies are needed with more evenly distributed measurement points throughout the Bima Regency, as well as by comparing the depth of the measurement results and the depth of the drilled aquifer.

ACKNOWLEDGMENTS

The author would like to thank you profusely for CV. Ardhipta Sona Persada, lecturers and friends of Epsilon Physics of Walisongo State Islamic University Semarang, for their assistance and support in preparing this study.

AUTHOR CONTRIBUTIONS

AP designed the study, processed and analyzed the data, and wrote the manuscript. H analyzed the data. OC carried out the laboratory work and analyzed the data.

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