Determination of aquifer distribution using resistivity method in South Tangerang, Banten Province

R S B Waspodo\textsuperscript{1,3,4}, A Asra\textsuperscript{1}, V A K Dewi\textsuperscript{2}

\textsuperscript{1}Department of Civil and Environmental Engineering, Faculty of Agricultural Technology and Engineering, IPB University (Bogor Agricultural University)
\textsuperscript{2}Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Technology and Engineering, IPB University (Bogor Agricultural University)
\textsuperscript{4}Corresponding author, Email : rohsbw@yahoo.com

Abstract. Water is an essential requirement for humans. The increase in population growth has an impact on the high demand for water. Surface water quality is declining due to human activities, which make people switch from surface water to groundwater. The excessive exploration of groundwater causes decreasing soil surface. Therefore, it is necessary to study the characteristics of groundwater. This study aimed to identify the lithology of soil, the position, and thickness of the aquifer, and to analyze aquifer distribution at the research location. The research method consisted of several stages which were preparation, implementation, data processing, data analysis, and result presentation. The result shown the depth of shallow aquifer at the research location was 3.00-44.73 m below the soil surface with a thickness of 2-12 m. The lithology of soil was clay and tufa sand. The depth of layers in the aquifer was 80-130 m, with a thickness of more than 75 m. Groundwater flow patterns headed toward the North.

1. Introduction
Water is a substance or material that is important for all life forms, almost 71\% of the earth's surface. Its form can be liquid, ice, and steam or gas. In other words, because of water, the Earth is the only planet in the solar system that has life [1].

The development of water resources is to provide fair access to all communities to get water in a healthy, clean, and productive way. Therefore, water must be adequately utilized for human welfare. All human water needs come from surface water and groundwater. Surface water is water that comes from river water, lake water, rainfall, and reservoirs, while groundwater is water that comes from free groundwater (free aquifer) and depressed groundwater (distressed aquifer) [2].

Indonesia is a tropical country that has sufficient water availability. But scientifically, Indonesia faces obstacles in meeting water needs because of uneven distribution, so that the water that can be provided will always be by the requirements, both in quantity and quality.

Increased population growth caused increasing water demand. The quality of surface water, which is declining due to human activities, causes humans using groundwater. According to Todd [3], groundwater is water that moves in the soil contained in the space between soil grains that seep into the soil and combine to form a layer of soil called aquifers. The layers that are easily traversed by groundwater are called permeable layers, such as the layers found in sand and gravel, while the layers that are difficult to groundwater are called impermeable layers, such as clay or loam layers. The impermeable layer consists of two types. One is the impermeable layer (aquifuge), and the other is the waterproof layer (aquiclude). Excessive groundwater exposure could result in land subsidence. For this reason, it is necessary to study the characteristics of groundwater.
Aquifer or water-bearing layer, geologically, is a layer of rock that contains water, where rocks in that layer have distinctive properties that have good water permeability and porosity. Usually, a layer of sand (Sandstone) or other layers containing sandstone [4]. One way to find out the presence of a water-bearing layer is to do the Geoelectric Geophysics (Resistivity) method [5]. In this way, the water carrier layer can be known as its depth, thickness, and spread.

This study aims to identify the lithology of soil layers, determine aquifer position and thickness, and analyze the distribution of aquifers at the study site. One way to find out the presence of a water-bearing layer is the resistivity method. Geoelectric is one method to determine the characteristics of groundwater by flowing a DC (Direct Current), which has a high voltage into the ground. The electric current injection uses two current electrodes, A and B, which are plugged into the ground with a certain distance. The longer distance of AB electrode will cause the flow of electric current to penetrate deeper rock layers. The geoelectrical method consists of several configurations. For example, the four electrodes are located in a straight line with symmetrical AB and MN electrodes that are symmetrical to the center on both sides, namely the Wenner and Schlumberger configurations [6]. Each configuration has its calculation method to determine the thickness value and resistivity of rock types below the surface. Schlumberger configuration method is a favorite method that is widely used to determine the thickness and resistivity value of subsurface rock types. Schlumberger configuration method also used to determine the characteristics of subsurface rock layers with relatively inexpensive survey costs [7].

2. Methodology

This research was conducted in seven districts in South Tangerang, Banten Province. Each sub-district is represented by two geoelectric measurement points, namely Setu District, Serpong District, Serpong Utara District, Pondok Aren District, Pamulang District, Ciputat District, and Ciputat Timur District. The scope of the research includes primary and secondary data analysis, observation and analysis of field data, and the making of aquifer models. Observations in the field include aspects of topography, hydrogeology, hydrology, geology, surface water in shallow aquifers and groundwater physics supported by the results of Geoelectric measurements.

Data processing and analysis, both from the field and secondary data, are carried out to obtain a picture of the distribution of aquifers, as well as shallow or deep groundwater drainage patterns. Data analysis using a cross-section of geoelectric results produce an aquifer water model. This compilation of groundwater aquifer models can be used to determine groundwater conservation zones.

Field data measurement using resistivity method uses Earth Resistivity Meter SAZ 3000 G100 type with input power from 12V, 45A batteries with outputs ranging from 5-500 A, as well as other supporting equipment such as 500 m of cable along with 2 units for current electrodes, 300 meters of cable as much as 2 units for potential electrodes, 4 units of stainless steel electrodes, AVO meters units, geological compasses, 4 meters of rollers for 50 meters, 4 hammers for hammer, 3 units of handy talky and 3 units of handy talky GPS.

Geoelectric shaving at the study site applies the Schlumberger configuration principle. In the Schlumberger configuration, ideally, the MN distance is made as small as possible so that the MN distance is theoretically unchanged, but because of the limitations of the measuring instrument sensitivity, then when the AB distance is relatively large later the MN distance should be changed. The change in MN distance should not be greater than 1/5AB distance. The electrical voltage (V) data obtained at the MN electrode (MiliVolt) and electric current (I) are injected through the AB electrode (mA). The data is then processed using the Schlumberger configuration equation to obtain rock resistivity values at the study site. According to Kashef (1997), to calculate the apparent resistivity value, we need a geometric factor number (K) that depends on the type of configuration, AB/2, and MN/2 distances. The calculation of constant numbers (K) is based on Equation 1.
Where, \( k \) (m) is a geometrical factor that depends on the arrangement of four electrodes, which have a conductivity value \((\rho_i)\) according to the Wenner-Schlumberger material with a unit length (m).

And from the parameters that have been obtained, is calculated pseudo resistivity values \((\rho_a)\), which has ohmmeter units. The calculated resistivity value is not the actual subsurface resistivity value but is an apparent value, which is the resistivity of the earth, which is considered homogeneous, which gives the same resistance value for the same electrode arrangement. To determine the actual subsurface resistivity value, it requires an inversion and forwards calculation process using computer assistance (Software progress Version 3.0).

Data from the field processed using Software Progress version 3.0. The data processing starts with entering data in the observed datasheet, estimating the parameter model on the forward modeling sheet, iterating on the inverse modeling sheet until the smallest RMS value is generated and interpreting the data that has been iterated.

Then, the data, where the estimation of the aquifer layer is based on the value of the rock resistivity measured, which is located in the rock layer containing sand, was processed. The data that has been processed using Software Progress 3.0 was correlated with the table of resistivity values of rock types (table 1), and with geological maps of the research location. So that rock lithology is obtained in the study area. To determine the existence of the aquifer layer, which is thought to lie in the rock layer containing sand was analyzed using a Vertical Electrical Sounding (VES) curve obtained from data processing using Software Progress 3.0. Furthermore, from the results of secondary and primary data analysis, then aquifer modeling is made.

| Rock Type          | Resistivity Value (ohmmeter) |
|--------------------|------------------------------|
| Igneous rock       | 100 - 1000000                |
| Metamorphic rock   | 15 - 1000000                 |
| Clay               | 1 - 11                       |
| Soft flakes        | 0.8 - 12                     |
| Hard flakes        | 2 - 500                      |
| Sand               | 13 - 1.000                   |
| Sandstone          | 50 - 2.000                   |
| Shaft limestone    | 50 - 2000                    |
| Solid limestone    | 5500 - 1000000               |

3. Result and Discussion

3.1. General situation of research location

South Tangerang is located in the eastern part of Banten Province, at the coordinates of 106°38' - 106°47' East Longitude and 06°13'30" - 06°22'30" South Latitude. Administratively, the area of South Tangerang consists of 7 (seven) districts, 49 (forty-nine) villages, and 5 (five) villages with an area 147.19 Km² or 14719 hectares. However, based on the digitization results, the area is 16506.8 hectares [8]. Most of the area of South Tangerang is lowland, where most of the area of South Tangerang has a relatively flat topography with an average slope of 0 - 3% while the height of the area is between 0 - 25 m above sea level.

Based on the map of Jakarta and the Thousand Islands Number 1209 of 1992 issued by the Directorate of Geology at the Ministry of Mines and Energy, the geological conditions of the South Tangerang are generally formed by two rock formations namely Alluvium (Qa) which consists of river
alluvial and sand-shaped swamps, clay, silt, gravel, gravel, and plant residues. This type of soil is a fertile layer for crops. Volcano Rock in the form of loose material consists of andesite lava, dacite, tuff breccias, and tuff. Physically, the Andesite Lava is grey-black with excellent size, a fanatic and shows the flow structure, and the Tuff and Tuff Breccias are generally weathered, containing Andesite and Desit components. In general, this type of land is used as mixed gardens, settlements, and dry fields [9].

Based on the hydrogeological map of South Tangerang, the groundwater mandala can be grouped into two mandalas. And based on influential factors as mentioned above, namely the weak undulating hilly groundwater mandala where the lithology compilation of the weak undulating hilly groundwater mandala consists of tertiary and quaternary deposits. Tertiary deposits include clay, tuff and limestone inserts. Quaternary deposits consist of young volcanic rocks and old volcanic rocks consisting of breccia, lava, tuffs of pumice in the sloping area. The distribution of this mandala spring is slightly found with a general discharge of fewer than 10 Liters/sec. Aquifers in this mandala unit are generally grouped in low productivity aquifers, especially in areas with sharp slopes, which is a reflection of the flat passing rate of rocks, so that surface flow is more prominent than the permeation rate. The land use in this mandala is in the form of fields, shrubs, rice fields, settlements, rubber plantations. Whereas the second is the plain groundwater mandala, where lithology is a loose groundwater mandala unit in the form of free material in the way of coastal alluvial sediment and topography swamps in the form of coastal plains composed of material, sand, silt, clay, and mud. The aquifer system in the plain groundwater mandala is a system of flow between typologies of aquifer rock sediments and alluvial deposits. In general, people get clean water by making shallow wells in the plain groundwater mandala.

The aquifer typology in the study area is alluvial sedimentary. Or, surface sedimentary aquifer, and sedimentary with groundwater flow system through intergrain space. Shallow groundwater flow follows the general topographic form that is flowing northward. According to the Jakarta regional sheet hydrogeology map, the 1993 Center for Environmental Geology maps hydrogeology based on surface aquifer layers and bedrock aquifer layers. The surface sedimentary aquifer system is based on the study of alluvial river distribution, alluvial fan, the thickness of surface deposition obtained from observations in dug wells with depths reaching around 15 m. In general, surface sedimentary aquifer systems are found in quarterly deposits, and some parts are found in tertiary rock weathering areas. From the Jakarta regional hydrogeology map for surface deposits in the study area, the range is between 15-20 m. Surface sediment aquifers generally occupy riverine alluvial plains and young volcanic deposits.

The distribution area of 15 l/s wells is quite extensive, located in the northern and eastern regions of the Serpong area, starting from Rawa Mekarjaya and Cilenggang, while the south is Rawakalo and Pengasian. The arrangement rocks of the area are surface sedimentary rocks in the form of gravel and sandstone with a thickness of less than 10 m. The aquifer type is an unconfined aquifer system through inter-grain space, with a discharge reaching <5 l/s.

The area of the <1 l/s well distribution in the middle of the study area extends northward along the Cisadane River, especially in regions with corrugated hill morphology. Its distribution is in the west of Serpong to the Bogor area. The rocks making up the area are surface sedimentary rocks in the form of sand and a little gravel with a thickness of fewer than 7 m and are not continuous. The type of aquifer is an unconfined aquifer, an aquifer system through inter-grain space, with a discharge reaching 0.2 l/s, with a groundwater-surface depth of 10 m below ground level. Groundwater flow system in this aquifer through the inter-grain space, generally utilized through dug wells with a diameter of fewer than 2 m with a depth of the well up to 15 m. Aquifers usually consist of several layers, thickness less than 4 m with an interlude clay layer.

3.2. Identification of aquifers and estimation
Results of measurement data at 14 locations after correlating with local geological and hydrogeological data, the geoelectric estimation results were obtained from 0.64-198.13 ohmmeter. The types of resistivity can generally be grouped as presented in table 2.

### Table 2. Estimated types of lithology in the study area

| Resistivity (Ohmmeter) | Estimation of the lithology | Hydrogeological properties |
|------------------------|-----------------------------|---------------------------|
| 0.64-198.13            | Ground cover                | Low permeability          |
| 2-5                    | Sand clay                   | Aquifer                   |
| < 2                    | Clay                        | Nir Aquifer               |
| 6-10                   | Tuff sand                   | Aquifer                   |
| > 10                   | Conglomerates sand          | Aquifer                   |

3.3. Sectional cross-section of primary measurement types

Based on the results of quantitative geoelectric interception correlated with geological data and local hydrogeological data, there are some differences in resistivity, which can be interpreted as changes in rock layers. The results of the interpretation of geoelectrical data can be seen in figure 1 and figure 2.

Data analysis using Software Progress 3.0 then overlaps with the table of resistivity values of rock types and geological maps of the study sites. The results of the analysis obtained the lithology of rock in the study area. Wherein, the South Tangerang, Banten Province has the lithology, sandy loam, sandy tuff, and conglomerate sand.

![Figure 1. Vertical cross-section geoelectric measurement (GL.1-GL.7)](image-url)
Figure 2. Vertical cross-section geoelectric measurement (GL.8-GL.14)

Figure 3. Cross-section of the aquifer in the South-North direction
Aquifers that develop in the South Tangerang, Banten Province, is administratively linked with clay sand, tuff sand, and conglomerate sand and can be distinguished by their depth into shallow and deep aquifers. Shallow aquifers are limited only to aquifers, which lie to depths of up to 50 m below ground level (BMT), and deep aquifers are aquifers that lie at depths of more than 50 m BMT.

Shallow aquifer thickness (at depth <50 m) in South Tangerang, Banten Province varies between 2-12 m at depths of 3-44.73 m, to thickness >75 m for deep aquifers (at depths >50 m). Shallow aquifers (at depths <50 m) are undifferentiated aquifers, and at deeper places they turn into semi-distressed aquifers. While deep aquifers (at depth >50 m) are depressed aquifers that are bounded by two impermeable layers (upper and lower tiers), the cross-section in figure 3 and figure 4 is an example of the distribution about the nature and thickness of the aquifer in South Tangerang, Banten Province.

The distribution of aquifers in South Tangerang, Banten Province, is suspected by mapping the measurement results on topographic maps, so that aquifer cross-sections are obtained according to the South-North and West-East directions. The free aquifer from the South to the North Tangerang is shallower due to the lowering topography.

4. Conclusion
The lithology of the constituent rocks is formed by two geological rock formations, namely alluvial rock and volcanic rocks. Shallow aquifer layer is at a depth of 3-44.73 m (bmt) with thicknesses ranging from 2-12 m. The lithology in this layer is dominated by the clay sand and the tuff sand having the resistivity values from 2-10 ohmmeters. The deep aquifer layer is at a depth of 80-130 m (bmt) with a thickness of >75 m. The lithologies that develop in this layer were tuff and sand conglomerate sand with a resistivity value of > 10-ohm meters. The distribution of aquifers in the study area is alluvial or surface sedimentary aquifer. And, sedimentary sediment with a groundwater flow system in this aquifer is through inter-grain space. Shallow groundwater flow follows the general form of topography, which is to flow northward whn the aquifer in its distribution is relatively evenly distributed with a thickness of >75 meters, so it has the potential to be utilized.
5. References

[1] Suripin 2001 Pelestarian Sumberdaya Air dan Tanah. Penerbit Andi: Yogyakarta
[2] Asdak C 1995 Hidrologi dan Pengolahan Air Sungai. Gajah Mada University Press: Yogyakarta
[3] Todd DK 1995 Groundwater Hydrology. Second Edition. John Wiley & Sons: Singapore
[4] Bowen R 1986 Groundwater. Elsevier Applied Science Publishers: London and New York
[5] Teikeu WA, Njandjock PN, Ndougsa-Mbarga T, Tabod TC. 2012. Geoelectric investigation for groundwater exploration in Yaoundé area, Cameroon. International Journal of Geosciences. 3(03): 640
[6] Kashef AAI.1997. Groundwater Engineers, Mc Graw-hill Book Co:Singapore.
[7] Santoso B, Prirahmayang N, Kirana KH. 2019. Identification of aquifer using geoelectric resistivity method of reciprocal schlumberger array (case study: Tanggamus, Lampung Province). IOP Conference Series: Earth and Environmental Science. 311(1)
[8] Anonim. 2007. Kabupaten Tangerang Dalam Angka Tahun 2007. Biro Pusat Statistik Kabupaten Tangerang.
[9] Rusmana E, Sukardi P. 2001. Peta Geologi Lembar Jakarta skala 1:100000. Pusat Penelitian dan pengembangan Geologi: Bandung