Groundwater Identification at East Sentani Auwena Formation (Tema) Based on Geoelectric

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Abstract. Jayapura City, Papua Province today is preparing to host the National Sport Week (Pekan Olahraga Nasional – PON in Indonesian) 2020 to be held here. For this event, on East Sentani District will build international swimming pool, football stadium and other facilities by government or private. This public facility needs fresh water source to come in useful as maximally. Fresh water from water local company is limited so the best solution is using groundwater. Groundwater is renewable resources, its volume and quality is influenced by vegetation, rainfall, slope, rock surface and others. This existence on subsurface can different based on geological conditions. For this issue, research did to identify groundwater potential on this area. This research used geoelectric 1D resistivity method, Schlumberger configuration. The acquisition held at three places: Kampung Kemiri, Kampung Harapan and Kampung Ifar Gunung. Data processing used IPI2win software, result is resistivity which is explaining lithology and depth. Based on resistivity distribution that groundwater located at Kampung Kemiri on depth 28.6 m with resistivity 81.1 ohm.m and at Kampung Harapan on depth 18.9 m with resistivity 8.9 ohm.m.

1. Introduction

Fresh water is most needed for human that must be met. However, in fact, there are still many people who have difficulty getting it. According to [1] in Indonesia’s society freshwater access is still around 67.1%. The lack of fresh water facilities has caused several problems, among others, high public expenditure and high rate of diseases experienced by the community such as diarrhea. Freshwater issue is responsibility of the government and must be immediately addressed by developing infrastructure including freshwater. According to [2] infrastructure development by the government must be a solution for the needs of various segments of society, because it will have an impact on economic growth both directly and indirectly.

East Sentani is one of location in Jayapura regency which is growing quite rapidly in terms of population, as well as physical and non-physical development. Physical construction of stadiums and swimming pools is a facility prepared for sports parties (Pekan Olahraga Nasional – PON in Indonesian, 2020), these facilities definitely require large amounts of water. So far, in East Sentani daily needs of water for community activities rely on surface water. However, with the passage of time the surface water managed by the Regional Water Supply Company (PDAM) is no longer sufficient. This condition is an impact of the inadequate carrying capacity of the Cycloop Mountain due to deforestation. This environmental impact raises a new phenomenon in the rainy season where floods occur and in the dry season the rivers experience drought.
Groundwater is the best alternative if there is insufficient surface water. Groundwater is widely used to meet human freshwater needs for several reasons, namely having relatively good quality and relatively more difficult to experience pollution compared to surface water. Subsurface groundwater is found in geological formations such as sand, gravel or a mixture of sand and gravel that act as aquifers. Aquifers have the nature of storing and passing groundwater in significant quantities to wells or springs.

According to [3] groundwater is found in a translucent geological formation known as aquifer, the distribution of groundwater in an area is not the same. According to [3] the presence of subsurface groundwater is not evenly distributed, this is controlled by, among others, vegetation, rainfall, surface rock structures and so on. In order to obtain groundwater, an investigation of the composition of the earth layer must be carried out so that it can be known whether or not there is a water carrier layer (aquifer). Several methods of surface investigation can be carried out, including geological methods, gravity methods, magnetic methods, seismic methods and geoelectric methods. From these methods, the geoelectric method is a method that is used a lot and the results are quite good. This method studies the nature of the flow of electricity in the earth and how to detect it in the earth's surface [4]. According to [5] geoelectric methods are widely used in hydrogeology because it has advantages in terms of accurate, fast, affordable prices. This study aims to identify aquifer layers based on the value of the type of resistance using geoelectric resistivity method.

Geoelectric estimation is intended to obtain an overview of the subsurface soil and the possibility of groundwater at a certain depth. The geoelectric method is one of the predictive geophysical methods but is recognized as having an important role in the search for natural resources including groundwater. The nature of this prediction is partly due to the interpretation of geophysical data known as ambiguity.

Resistivity geoelectric method uses the assumption that the earth is homogeneous isotropic. Through this assumption the measured type of resistance is actually not dependent on the electrode spacing. In fact, the earth consists of layers with different ρ. So that the measured potential is the influence of these layers. Therefore value of the measured type of prisoner is not just a type of resistance for one layer, this is mainly for wide electrode spacing. The measured resistance type is called apparent resistivity. Pseudo prisoners are formulated as [6];

\[
\rho_a = K \frac{\Delta V}{I} ; \quad R = \frac{\Delta V}{I}
\]

Where ρa is an apparent resistivity, K is a geometry factor, ΔV is the potential difference between the two potential electrodes and I is the current strength that is injected.

Based on equation (1) it can be seen that the apparent resistivity value depends on the geometry of the electrode configuration used. The type of resistivity geoelectric method has several configurations that can be used including Schlumberger configuration, Wenner configuration, dipole-dipole configuration etc. In this study, Schlumberger configuration was used. From equation (1) the value of geometry factor (K) for Schlumberger configuration is as follows:

\[
\rho_s = K_s \frac{\Delta V}{l} , \text{ with } K_s = \frac{\pi (L^2 - l^2)}{2l} \quad (2)
\]

Where L is the length of the current electrode (AB/2) while l is the potential electrode length (MN/2).

Generally, this Schlumberger configuration is carried out with the current electrode distance (C1, C2) made 10 times or more potential electrode distance (P1, P2). Each configuration has an unequal depth of penetration, so that in measuring depth penetration is one of the factors that are taken into consideration in the selection of electrode configurations, other factors are the type of structure, the sensitivity of the device, the level of noise available.

Several factors influence the price of this resistivity, including:
- The water content, the medium containing the resistivity water is getting smaller.
- Porosity, which is the ratio between the volume of cavities (pores) to the volume of the rock itself. Porosity is expressed in % volume. The large volume of rock pores will provide more fluid content so that the resistivity price will be smaller. In connection with this, there is an empirical formula referred to as Archie's Law, as follows:
\[ \rho = a \rho_w \theta^n S^m \]  

(3)

where \( \rho_w \) = resistivity of rock containing liquid (ohm.m), \( a \) and \( m \) are constants (0.5 < \( a \) < 2.5; 1.3 < \( m \) < 2.5), \( \rho_{(w)} \) = water resistivity (ohm.m), \( \theta \) = porosity, \( n = 2 \) and \( S \) are part of the pores of the rock containing fluid.

- Temperature, the resistivity of a rock is inversely proportional to its temperature, the temperature relationship with resistivity is shown by the following equation:

\[ \rho_w = k e^{0.00821 t} \]  

(4)

Where \( \rho_{(w)} \) is the fluid resistivity (ohm.m), \( k \) = constant, depending on the electrolyte concentration in the fluid and \( t \) = temperature. Based on this equation it can be seen that if the temperature rises, the resistivity will decrease exponentially.

2. Methodology

2.1. Research Location

The research location is East Sentani District, Jayapura Regency, which is administratively included in the Sentani District area. To reach the work site from Jayapura City can be reached by land by using two-wheeled vehicles or four-wheeled vehicles with very easy access of approximately 30 minutes.

Geographically, Jayapura Regency is located at coordinates 02°32'45"S to 02°36'07"S and 140°32'22"E to 140°37'10"E with an area of 17,516.6 Km².

2.2. Research Procedure

Before to the measurement, a preliminary survey was conducted to map the measurement points and the direction of the refractive geoelectric stretch. Based on these considerations, the total geoelectric stretch is 4 sounding points which include two located in the altitude area and 2 (two) in the flat area. The four sounding points are determined based on the results of the initial survey, considered representative and have a relatively long stretch. Field measurements are carried out by measuring the potential difference and current strength generated at each change in AB and MN electrodes. In this measurement the Schlumberger configuration is used, this configuration is good for mapping and sounding. For sounding resistivity, the spacing of the electrode is changed in graduation to a very large point.

Field measurements are carried out by measuring the potential difference and current strength generated at each change in AB and MN electrodes. In this measurement the Schlumberger configuration is used, this configuration is good for mapping and sounding. For sounding resistivity, the spacing of the electrode is changed in graduation to a very large point. In order to Schlumberger electrode rule, spaced current electrodes are much larger than the spacing of potential electrodes. The stages of research activities that will be carried out in detail are data collection, processing, and data analysis.

2.3. Data Acquisition

To support the smoothness of data collection, a number of things must be prepared including the making of a permit, preparing equipment and a literature review. The equipment used includes geological maps, hydrogeological maps, GPS, one unit of geoelectric equipment and several other supporting tools. The types of activities carried out in detail at this stage are as follows:

i. Geoelectric measurement is preparing equipment, setting work functions for students involved in this research activity and preparing a permit. The next activity after arriving at the location is setting up geoelectric equipment components. In setting the mounting components all four electrodes and connectors can be controlled via a geoelectric monitor. After all equipment is properly connected, current injection can be carried out, followed by recording or filling in the data tables that have been prepared including current (mA), potential (volts) and length of the stretch.
ii. The measurement position can use several ways, but in this study the location of each region was chosen based on the displayed expanse. This method is carried out considering the groundwater in the aquifer layer spread laterally is relatively broad.

2.4. Processing and analysis of data

The data obtained will be processed to get apparent resistivity, the important thing to remember in processing or calculating the type of resistance is to do unit conversion. The output from this processing will be obtained in the form of a graph between the distance (AB/2) vs type resistance. The graph obtained is true resistivity, which is a graph that illustrates subsurface lithology, including resistance to type, thickness and depth of the layer. Data analysis is done by comparing the results of processing with some supporting data such as type resistance tables and some other supporting data. Type resistance table is a physical property that explains the relationship between electric current and several types of rock. The relationship is quantitatively as follows: igneous rock has a higher resistance price than compact sedimentary and sedimentary rocks. Loose sediments will have a relatively lower resistivity compared to compact sedimentary rocks. Measured type prisoners will be smaller in value if the rock contains hard water or salt.

3. Results and Discussion

Table 1. Actual resistivity values for three sounding points

| Sounding Point | Layers | Interpretation Result | Estimated Lithology              |
|----------------|--------|-----------------------|----------------------------------|
| Buffer-Waena   | 1      | 0.284 0.284 0.006     | Top soil (Humus)                 |
|                | 2      | 7.66 7.37 457         | Coarse fine sand                 |
|                | 3      | 15.5 7.89 46.6        | Coarse fine sand                 |
|                | 4      | 126 111 1328          | Basic rock                       |
|                | 5      | >126 ~ 10.8           | Coarse fine sand                 |
| Kampung Harapan| 1      | 2.075 2.08 269        | Top soil (gravel, sand)          |
|                | 2      | 10.53 8.46 122        | Coarse fine sand                 |
|                | 3      | 21.4 10.9 8.9         | Coarse fine grain size           |
|                | 4      | 42.39 21 104          | Sand fine grain size             |
|                | 5      | >42.39 ~ 0.14         | Coarse fine sand                 |
| Kampung Kemiri | 1      | 0.32 0.32 176         | Top soil (gravel, sand)          |
|                | 2      | 5.38 5.7 2783         | Sedimentary rocks, breccia       |
|                | 3      | 77.43 71.1 858        | Clay, Marl                       |
|                | 4      | >77.43 ~ 22.7         | Sand                             |
| Kampung Ifar   | 1      | 1.36 1.37 433         | Top soil (Gravel, Sand)          |
| Gunung         | 2      | 10.36 8.99 10.1       | Coarse fine sand                 |
|                | 3      | 35.11 24.8 756        | Compact sediment rock            |
|                | 4      | >35.11 ~ 3275         | Basic rock                       |

Geoelectric measurement points are spread over 4 (four) locations, locations selected based on growth index, industry, and so on. The four locations include Buffer Waena, Kampung Harapan, Kapiri Kemiri, and Kampung Ifar Gunung.
and Ifar Gunung. Geoelectric data are different in shape and are used to calculate. The right types are the models used by each type and type of stone for each measurement. To find out the types of rocks that exist at each point with large numbers used and geological data in the study area. Data on the type of detainees that have gone through further sorting in Table 1. The results of the analysis of the models that produce the structure below are as follows:

Measurement location of Buffer Waena morphology is not flat (wavy), measurements using Schlumberger configuration geoelectric with a total stretch of 600 meters or AB/2 are 300 meters, the direction of the north-south stretch. Based on the results of data processing (Table 1), it was found that in general the existing rock layers had contrasting physical properties found in layer 4 (four). The type of resistivity value is 1328 ohm.m and is at a depth of 126 meters, the value indicates as a layer that is impermeable (water-resistant) the structure can be either bedrock or clay rock. This layer includes quite thick, which is 111 meters, this is reinforced by a topography that is not flat (bumpy). Layer 5 (five) which is at a depth of below 126 meters of resistivity type 10.8 ohm.m, this layer of structure is generally conductive or in the form of sediment deposits. Contrast types between layers 4 (four) and layer 5 (five) showed that in layer five was categorized as a layer of aquifers which were confined aquifers, this indication was partly strengthened by the condition of the research area where there were Sentani Lakes.

Measurements in Kampung Harapan location, based on Table 1, the aquifer layer is found in the type of resistivity 8.9 ohm.m and 0.14 ohm.m. Between the two layers there is a layer of 4 (four) with a type of resistivity of 104 ohm.m, this layer can act as an impermeable layer with a layering structure in the form of clay. The unconfined aquifer in layer 3 (three) is at a depth of 10.53 meters and has a thickness of 10.9 meters. The second aquifer layer was found in layer 5 (five) with a type of resistivity 0.14 ohm.m at a depth below 42.39 meters. At this measurement location it is about 100 meters from Sentani Lake, and is in the lowlands so that the quality of groundwater is not only affected by the structure of the land but also the water of Sentani Lake. The unconfined aquifer in the 3 (three) layer of material is an alluvial layer or dynamic sand and groundwater flowing from north to south. The Cycloop Mountains with existing vegetation function as catchment areas which drain groundwater graphically.

Measurements in Kampung Kemiri, based on Table 1 below, are high resistivity in layers 2 (two) and layers 3 (three). These two layers have a depth of up to 71.7 meters, presumably as an impermeable layer in the form of clay. The presence of the impermeable layer causes the conductive layer (layer 4) (22.7 ohm.m) to be classified as confined aquifer. Measuring locations that are not flat, and relatively close to the Cycloop Mountains (at altitude) cause unconfined groundwater not found.

Measurements in Ifar Gunung, based on the distribution of resistivity values (Table 1) consist of 4 (four) layers. Layer 2 (two) is a layer with relatively low (conductive) type resistance which is 10.1 ohm.m usually associated with groundwater. However, this type of low resistance occurs due to non-compact soil structure and is controlled by the activity of organisms and microflora and physical and chemical processes. The type of rock is a mixture of weathering results from native rocks and organic substances from older decomposition. The absence of groundwater is reinforced by a resistive structure with 3275 ohms and this is associated with bedrock.

4. Conclusions
Based on the height difference of the aquifer in this study, it can be said that groundwater is dynamic and the flow direction from north to south. The northern part of Sentani is formed by a Cycloop mountain range, this is a recharge area where groundwater flows towards the south as the output area. Ifar Gunung and Buffer Waena have the same layering structure, but groundwater at Ifar gunung is not obtained so that the possibility of groundwater at Buffer Waena is a catchment from Sentani Lake. This condition is reinforced by the location of the Buau Waena measurement area which is about 100 meters from Sentani Lake and continues to the measurement area in Kampung Harapan. Groundwater from the Cycloop Mountains is more dominant in the measurement area of Buena Waena and the Kampung Kemiri area. Whereas in the Kampung Harapan area the groundwater is more predominantly influenced by Sentani Lake water.
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