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Estimation of Aquifer Hydraulic Parameters and Operational Discharge of Raw Water in Woyla District, West Aceh District, Aceh Province

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Abstract. Groundwater is one of the most important natural resources because it fulfills the needs of daily life, agriculture, irrigation and industry. Population growth and regional development also increase the demand for and service levels of drinking water, which requires management of water distribution. According to reports, 25 villages in Woyla district are still facing water shortages and the water debt to meet this need is around 559,800 L/day. In terms of regional geology, the study area includes young floodplain strata consisting of silt deposits, sandy loam, fine sand, and coarse sand. The geoelectric method is a method for studying the nature of current flow in the earth according to the laws of electricity. The power log is a recorder for SP and resistivity is a record that must be kept at each well formation interval. The pumping test is the stage of testing the runoff capacity and physical parameters of the aquifer before the production stage is carried out on the well. The average MAT of the three villages is 2.26 meters from north to south. According to geoelectrical data GL7, GL8, GL9, GL10, GL11 and GL12, the resistivity of the sandy aquifer ranges from 59 – 809 ohm.m and a total thickness of 99 m. Cot Punti Village 430.27 m3/day, Jawi Village 473.27 m3/day and Alue Village 477.52 m3/day Well efficiency is 95.3 when using the Hantush-Bierschenk method (1964) assuming the average value of Cot village Punti processed test data for the multi-stage discharge pump %, which was 89.73% in Jawi village and 99.97% in Alue village, so that pumping was still effective. The average well efficiency based on the Ghost Bierschenk method is 94.9%, 1.76 m3/day for Cot Punti village, 3.73 m3/day for Jawi village and 3.66 m3/day for Alue village. The transmission rate is 56.5 m^2/day in Cot Punti village, 149.4 m^2/day in Jawi village and 88.1 m^2/day in Alue village. Woyla District has a resource load of 1,380,000 liters/day.

Keywords: *aquifer; conductivity; discharge; flux; groundwater; transmissivity.*

1 Introduction

One of the most vital natural resources is groundwater, which can support human requirements as well as those of agriculture, industry, and irrigation. The requirement for water services that need water allocation management also rises along with regional development and population growth. Humans explore and use groundwater in various ways, and it is stored in a water-carrying layer known as an aquifer. As a result, research is required to ascertain the potential of groundwater below the surface. Because meeting groundwater needs is a challenging challenge to tackle, technical planning for the groundwater system is essential.

A geoelectrical investigation is required to determine the need for groundwater in a given area. This investigation will aim to provide a detailed description of the groundwater potential that will later serve as a basis for planning, developing, using, and managing groundwater for both irrigation and raw water. The hydrogeological characteristics of a region, such as the depth of the subsurface rock strata and the size of the local aquifers, have a significant impact on the groundwater potential of that region. The electric log is a common technique for identifying the properties of rock layers (Rider, 2002). With this technique, physical parameters that are continuously measured in a well are displayed on a depth chart. The resistivity log and the self potential log, two different kinds of electric logs, were used in this investigation. (SP). Groundwater drilling is done after measuring the electricity log, and then a pumping test is conducted to ascertain the operational discharge of groundwater so that it may satisfy the people's raw water needs.

District was among the areas hit by the tsunami in 2004, yet Woyla District is seeing the fastest growth in terms of infrastructure and population. According to records, 25 villages in the Woyla District still lack access to water, and it would take about 559,800 liters of water per day to fill this need. The Woyla sub-district itself contains a river, but owing to mining and other communal activities that degrade the environment, the water in the Woyla river is currently extremely contaminated and unfit for human consumption. Drilled wells, on the other hand, are few and unable to supply the community's needs for water. The Krueng Woyla's water output has dropped throughout the dry season, and numerous residents' wells have experienced drought. Therefore, in order to satisfy the people's requirement for raw water, hydrogeological planning and research are required in the Woyla sub-district.

2 Research Methods

The research location is administratively located in Woyla District, Aceh Province and there are 25 villages which are the research target locations. In terms of regional geology, the study site belongs to the *Holocene quarter alluvial formation* consisting of silty sand, sandy loam, fine sand and coarse sand deposits. The deposition pattern at *the finning upwards* research location. The regional hydrogeology of the research location is included in the aquifer group with flow through inter-grain spaces with moderate productivity and wide distribution. In general, these aquifers show moderate continuity where the groundwater table or groundwater piezometry is near or above the ground surface.

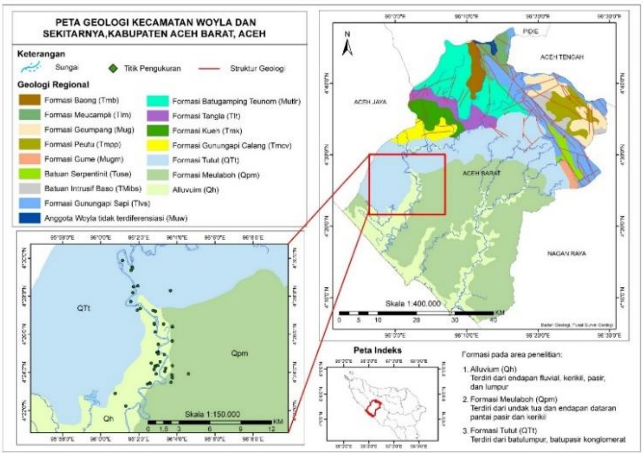


Figure 1 Regional Geological Map

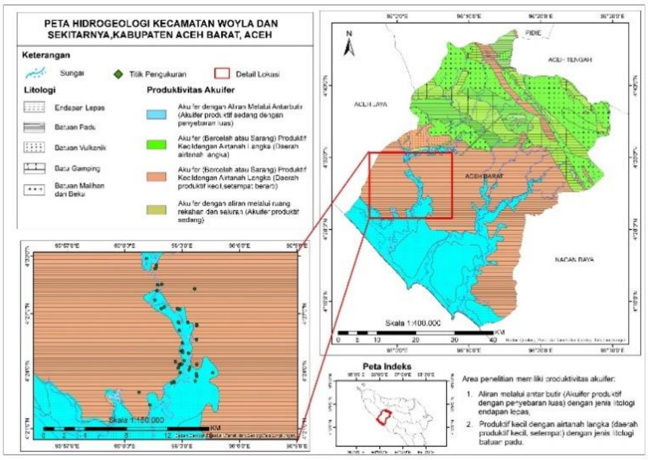


Figure 2 Regional Hydrogeological Map

The research approach involved gathering both primary and secondary data. To gauge the level of the groundwater at the study site, geological and hydrogeological surveys were first conducted. Next, a seven-point geoelectric survey using a Wenner configuration was completed. One of the geophysical approaches that examines the characteristics of electric currents in the earth based on electrical principles is the geoelectric method. By detecting the flow of electricity on the earth's surface, this geoelectric approach can also be used to ascertain the type of electricity flowing through the earth. This detection entails the measurement of electromagnetic, potential, and current fields that develop naturally or as a result of current injection. By injecting an electric current into the soil surface through a pair of electrodes and detecting the potential difference with a different pair of electrodes, the geoelectric method operates according to its basic principles. A medium's resistance value can be calculated by injecting an electric current into it and measuring the potential difference (voltage) that results (Hendrayana & Arif, 1990). While the Wenner design, which has spacing of the same length (r1=r4=a and r2=r3=2a), is one of the configurations frequently utilized in geoelectric exploration.

$$\rho a = K\frac{\Delta V}{I} \tag{1}$$

$$K = 2a\pi \tag{2}$$

The value of K for the Wenner configuration is substituted in equation (1) so that the value is apparent resistivity. The resistivity value obtained from the measurement is estimated using the inversion method so that the actual resistivity value and depth are obtained. In field data acquisition, the arrangement of current and potential electrodes is placed symmetrically with the sounding point. In the Wenner configuration, the distance between the current electrode and the potential electrode is the

$$\rho_a = 2\pi a\frac{\Delta V}{I} \tag{3}$$

same (Telford, et al., 1990). The electric log is the oldest recorded device used in the petroleum industry. SP and resistivity curves are standard records that must be present in every stratigraphic section of a wellbore. The use of the electric log is for lithology interpretation and can also be used to detect water-containing zones or not. And can be used as a basis in the correlation of subsurface rock layers. For rocks whose pores are filled with saltwater or clay minerals, they will conduct electricity and have a low resistivity compared to pores filled with oil, gas or fresh water.

$$Ro = F \times Rw \tag{4}$$

The resistivity value is low if the rock is easy to conduct electric current, while the resistivity value is high if the rock is difficult to conduct electric current. The SP log is a record of the difference in potential between an electrode placed on the ground surface and an electrode that moves in the wellbore. The SP log data collection process uses mud so that there is an electric current from the formation to the log tool.

The pumping test is a stage to test the discharge capacity and physical parameters of the aquifer before the exploitation stage is carried out on the drilled well. In general, the pumping test consists of two methods, namely the aquifer test and the pump test. Preliminary Pumping (Preliminary Test), namely pumping is intended for the purpose of preparing for the implementation of further work, namely checking the function of the tool and making a design plan discharge (Q liters/second) for carrying out the step draw down test, by adjusting the valve rotation to get 4 stages of SDDT test discharge . In this preliminary pumping, we can simultaneously identify the faucet openings for discharge Q1, Q2, Q3, Q4 by experimenting with the rotation of the faucet, and this is marked so that it is not difficult to adjust the discharge.

In this study an analysis was carried out to determine the optimum pumping discharge and aquifer parameters, as well as a pumping simulation to determine the maximum discharge and optimum discharge . Staged pumping tests were carried out on all wells in the study location, while fixed discharge pumping tests were carried out on three wells representing the distribution of wells in the study location. The Hantush-Bierschenk (1964) method was used to determine the optimum pumping discharge based on a multilevel pumping test with a test duration of 2 hours and 3 levels/stages. Well parameters such as aquifer loss coefficient (B), well loss coefficient (C), aquifer loss (BQ), and well loss (CQ2) can be calculated from this method. In addition, a pumping simulation was also carried out to determine the resource discharge for the 25 villages.

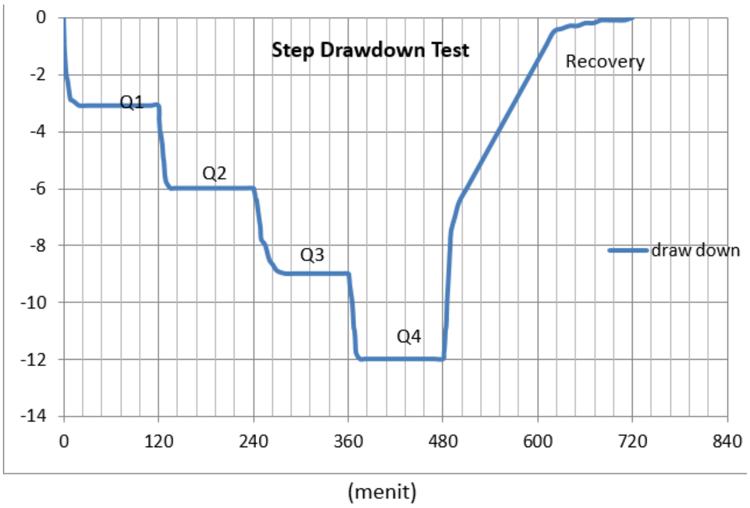


Figure 3 Determination of Drawdown Differences for Each Stage, modification from Kruseman and de Ridder (2000)

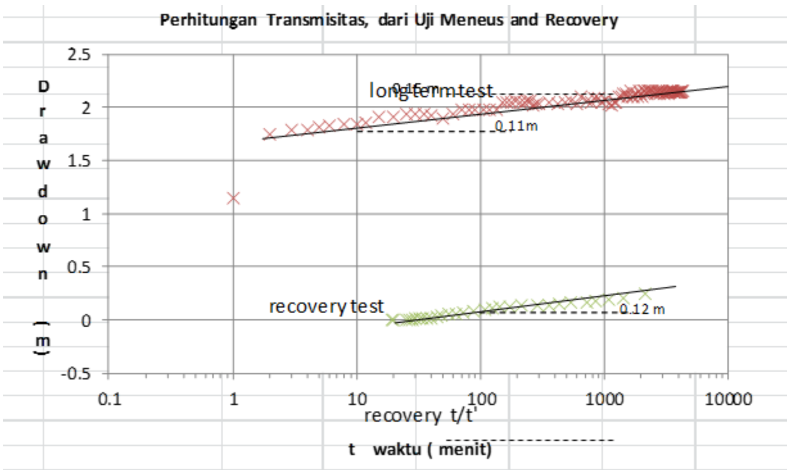


Figure 4 Determination of Parameters B and C, modification from Kruseman and de Ridder (2000)

Aquifer parameters such as transmissivity and hydraulic conductivity can be obtained through a fixed discharge pumping test on three wells which are considered to represent field conditions that allow for testing. While optimum debit , maximum discharge , and *well efficiency were also carried out at the same time with a* duration of 72 hours in each well, then aquifer parameters such as transmissivity were calculated based on the Cooper-Jacob method (1946).

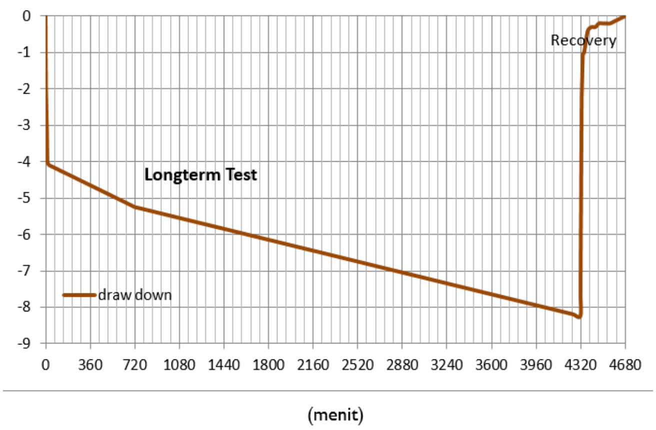


Figure 5 Determination of the Δ s value of the Fixed Discharge Pumping Test, modification from Kruseman and de Ridder (2000)

Then the aquifer parameter values (transmissivity, hydraulic conductivity, and *specific capacity*) from the fixed discharge pumping test can be calculated using the following equations:

$$T = \frac{2{,}3.Q}{4\pi.\Delta s} \tag{5}$$

$$K = \frac{T}{b} \tag{6}$$

$$E_w = \left(\frac{BQ}{BQ + CQ^2}\right) \times 100\% \tag{7}$$

Then, the value of the well efficiency (E_w) can be calculated using equation (7).

The symbol T stands for transmissivity, Q for pumping discharge, s for the reduction in groundwater level brought on by pumping in one logarithmic cycle, K for hydraulic conductivity, b for the length of the filter in the well, Sc for specific capacity, and Sw for the reduction in groundwater level brought on by pumping during the test. The confined aquifer being pumped is homogenous, has a roughly uniform thickness, and has an unrestricted lateral distribution, among other assumptions that were made throughout the pumping test. The next step is to create a simulation model for hydraulic conductivity and transmissivity, as well as for optimal discharge and maximum discharge.

3 Result and Discussion

Geoelectrical measurements on lines 7, 8, 9, 10, 11, and 12 show a resistivity value of 0.5 – 800 Ωm which is dominated by the Alluvium/Surface Sediment Formation, Beaches and Rivers, the soil type in this Formation consists of Gravel, Sand and Clay. Based on these geological conditions, the results of data processing can be interpreted in the first layer with resistivity values ranging from 30 – 800 Ωm with a depth of 0 – 30 m, interpreted as a top soil layer in the form of a layer of sand, clay/clay and gravel with the presence of surface water at a depth shallow. Then the second layer is thought to be clay with a resistivity value ranging from 0 – 15 Ωm at a depth of 30 – 95 m, which cannot/is not productive in storing good quality groundwater/aquifer. While the third layer with a resistivity value of 15 – 150 Ωm is a layer that is expected to contain groundwater in the form of a layer of sand/sand with good quality. This layer is located along the Geoelectric track at depths ranging from 95 – 150 m.

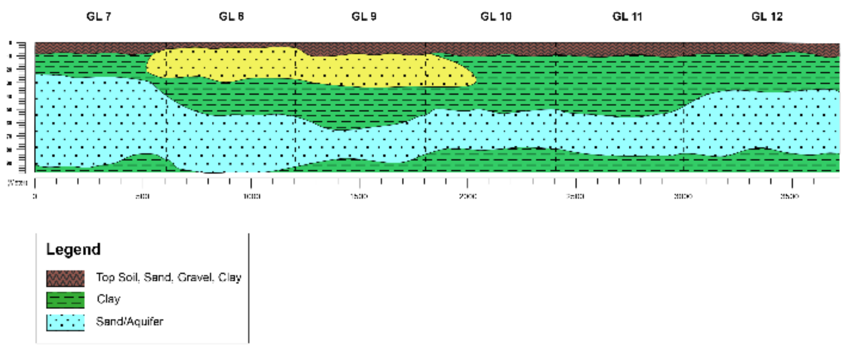


Figure 6 Geoelectric resistivity cross-section

Then electricity logging was carried out on two wells, namely in Jawi Village and Cot Punti, from the results of the logs it produced a graph of resistivity and self potential (SP) as listed in the appendix. Qualitative interpretation is carried out by comparing the results of measurements of Resistivity values and Spontaneous Potential values, then compared again with the cutting data of the drilled wells.

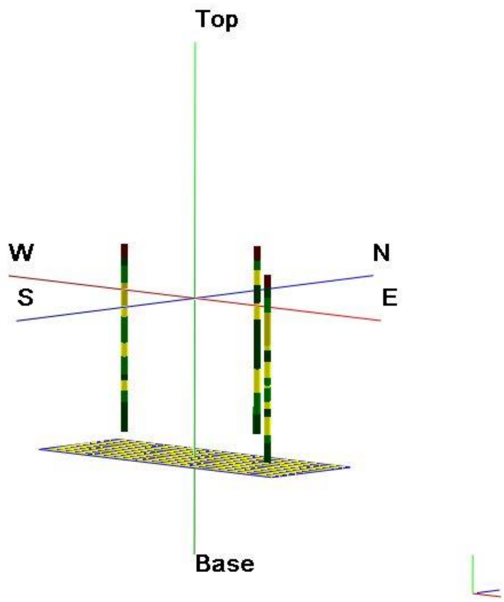


Figure 7 Model of the cutting results

Groundwater well drilling data and geoelectrical interpretation are used to determine subsurface geological and hydrogeological conditions at the study site. According to the correlation between cutting analysis and geoelectrical interpretation, the study site contains three types of rock: loam, sandy loam and sand. These three layers are covered by overburden, which is usually 10 to 50 meters thick. While aquicludes, aquitards, and aquifers are hydrogeological units found in the study area. From the results of this correlation, it is suspected that the type of aquifer at the study site is a confined aquifer. The confined aquifer serves the groundwater infrastructure at the study site. Each well in the study area has a distinct confined aquifer layer between 50 and 120 meters below the surface. The thickness of the aquifer in the production wells of Cot Punti Village is 32m, in Jawi Village is 40m and in Alue Village is 27m. This condition continues until the confluence with the Kreung Woyla River, the basic condition of groundwater is filled by the Krueng Woyla River so that it becomes the baseflow for the aquifer in the Woyla area. The aquifer is deep enough from the surface, so that when the flow intersects with the river flow, the aquifer is filled with river water or commonly called an influent stream (Todd, 1980). Based on these conditions, groundwater discharge using Darcy's Law method with the concept that a stream flows in a uniform cross-section with a gravitational force obtained from the hydraulic gradient of groundwater. Hydraulic conductivity (K) or often referred to as permeability is a unit of velocity of the ability of rock layers to allow water to pass (Todd, D.K., 1980). Hydraulic conductivity is influenced by physical properties, namely porosity, grain size, grain arrangement, grain shape, and their distribution. Based on the calculation of hydraulic conductivity in Cot Punti Village 1.76 m3/day, Jawi Village 3.73 m3/day and in Alue Village 3.66 m3/day.

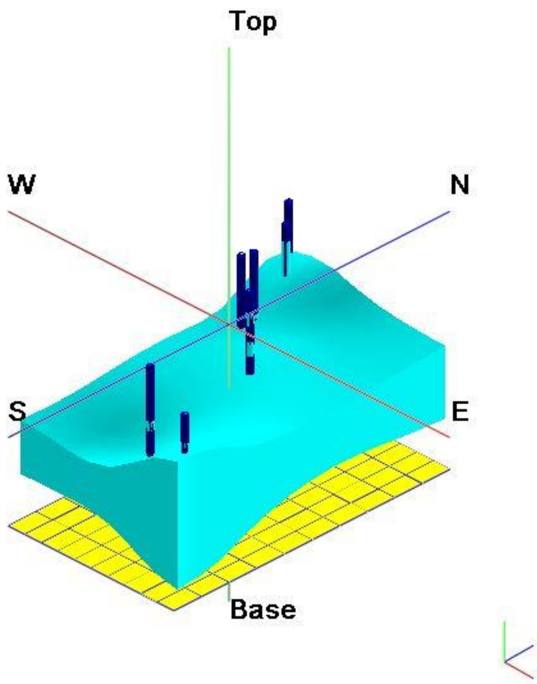
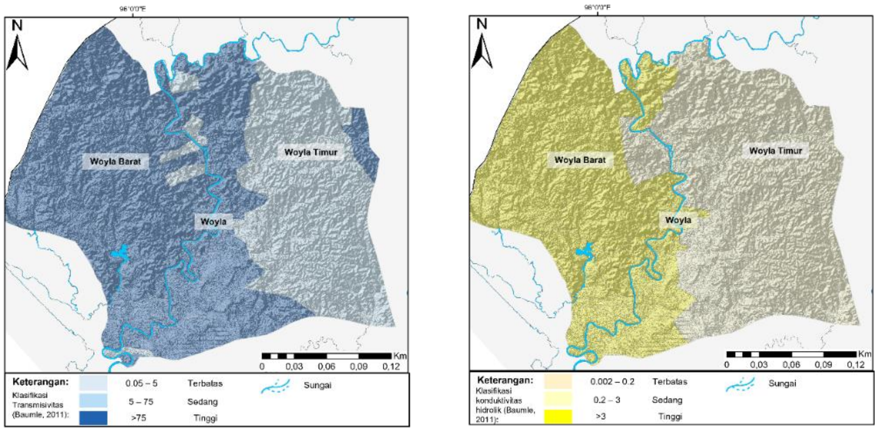


Figure 8 Aquifer model reconstruction results

In the pumping test stage, the aquifer test results will be obtained, namely the values of resistivity and hydraulic conductivity, while in the well test, the maximum discharge, optimum and well efficiency results will be obtained. The value of *transmissivity* is the ability of an aquifer to transmit water and is expressed in terms of the amount of water in unit time (m3 / hour) flowing through a vertical cross-section of one meter wide aquifer layers with a hydraulic foundation of 100%. While the value of the permeability coefficient is obtained from the quotient between *the transmissivity* and the thickness of the aquifer. The type yield value describes the level of yield of an aquifer expressed in the amount of water (m3 / hour) when the groundwater level is lowered in units of length (m) with units of (m3 / hour). In analyzing the observed data from pumping tests, both receding and recurring groundwater table using the Theis- Jacob method . The Theis-Jacob (1946) method was used to process data from a fixed discharge pumping test, and the results showed that the transmissivity value was 56.5m2/day in Cot Punti Village, 149.4m2/day in Jawi Village and 88.1m2/day in Alue Village. Hydraulic conductivity in Cot Punti Village 1.76 m3/day, Jawi Village 3.73 m3/day and in Alue Village 3.66 m3/day.



(a) (b)

Figure 9 (a) Transmissivity Map, (b) Hydraulic Conductivity Map

The findings of data processing from the fixed discharge pumping test are shown in the table. Based on transmissivity, hydraulic conductivity, and specific capacity of aquifers, (Baumle, 2011) separates groundwater potential into four categories: high, medium, limited, and scarce. Based on aquifer parameters identified through the processing of pumping test data for cascading and fixed discharges as well as optimal discharge for each well, groundwater potential in the research location is characterized as medium-high. Once some aquifer properties are known, pumping can begin. This test's pumping rate was 10 liters per second, and the pumping time was 72 hours.

From the values of T, K and layer thickness, krigging was carried out to see the distribution of the values of K, T and the thickness of the aquifer layer at the study site. After interpolation, the eastern part of Wolya has moderate T with a range of 7-75m2/day, while the middle part of Woyla is in the category of high T value >75m/day as well as the western part of Woyla which has a high T value of >75m. The K woyla value in the eastern part is included in the moderate category, namely the value is in the range of 0.2-3 m/day, in the middle woyla it is in the high category, namely > 3 m/day as well as in the western woyla.According to this study, the Woyla Regency discharged 1,380,000 liters of resources each day, with an average well efficiency of 94.9%, meaning that these three wells were able to supply the local community's water needs.

4 To Conclusion

The average MAT of the three villages is 2.26 meters from north to south. Based on geoelectrical data GL7, GL8, GL9, GL10, GL11, and GL12 the aquifer layer with sand material has a resistivity value range of 59 – 809 ohm.m and a total thickness of 99 m. Based on well logging data, the rock formations identified in the field are soil (clay), silty sand, sandy loam, sandstone, claystone. Meanwhile, based on the cutting data, it is more or less the same as the logging and geoelectric data, but most of the rocks found in the cutting data are sandy matrices. Screen pipe is installed along the depth of 50-120 and the pump is installed at a depth of 85m. The aquifer type in Woyla Regency is aquitard and aquifer while the groundwater system in this location is confined aquifer. Cot Punti village 430.27 m3/day, in Jawi village 473.27 m3/day and in Alue village 477.52m3/ and hydraulic conductivity in Cot Punti Village 1.76 m3/day, Jawi Village 3.73 m3/day and in Alue Village 3.66 m3/day. The transmissivity value in Cot Punti Village was 56.5m2/day, in Jawi Village it was 149.4m2/day and in Alue Village it was 88.1m2/day. Resource debit in Woyla Regency is 1,380,000 liters/day.

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