Determination of Deep Well Using Resistivity Method_IJOG

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Determination of Deep Well Using Resistivity Method at the South Amanuban, Timor Tengah Selatan Regency, Indonesia.

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Abstract - South Amanuban area often drought in the dry season. The area is composed by quaternary deposit lithology with plain topography. This research aims to identify groundwater potential in the quaternary deposit, evaluate groundwater position, and determine deep well point. This research use geoelectrical method with resistivity value approach. Soil that has a high resistivity value is predicted as an aquifer layer. The deep well point is determined based on consideration of the aquifer position from the resistivity analysis. The results show that aquifer position can be found in the limited zone and 50-150 meters in depth. The aquifers have lenses shape that are not related to each other.

Keywords: Deep well, Geoelectrical, Resistivity, South Amanuban.

INTRODUCTION

Based on geological condition of the research area, it is necesary to do subsurface mapping to find out materials and aquifer position as a basis for consideration of the drilling point. Geoelectrical method can be applied to obtain an overview of subsurface condition and groundwater potential. This method is based on theory that each material has a different resistiviy value. The groundwater has lower resistivity value than the minerals of a rock. A 2D geoelectrical resistivity is an alternative method to map subsurface condition. This method used resistivity characteristics of rock layers as a tool for studying subsurface geological condition. Electric current inside rocks or minerals can be classified into 3 types:

1. Electronic conduction: a normal type of electric current inside rocks/minerals.
2. Electrolytic conduction: this type occurs in many porous rocks where the rock pores are filled with electrolyte solution.
3. Dielectric conduction: this type occurs in dielectric rocks which means they have fewer free electron or none (Hendrajaya and Arif, 1990).

Basic principle of resistivity method involves measurement of potential difference of a pair of electrodes that inject current into the ground. Deviations from the pattern of potential differences expected from homogeonus ground provide information on the form and electrical properties of subsurface inhomogeneities (Kearey et al., 2002). Every material in earth has a specific resistivity value that will display subsurface rock layers based on its resistivity value.

A various composition rock will produce a range of various resistivity values (Telford et al., 1990). Resistivity value of materials in earth can be seen in Figure 1.

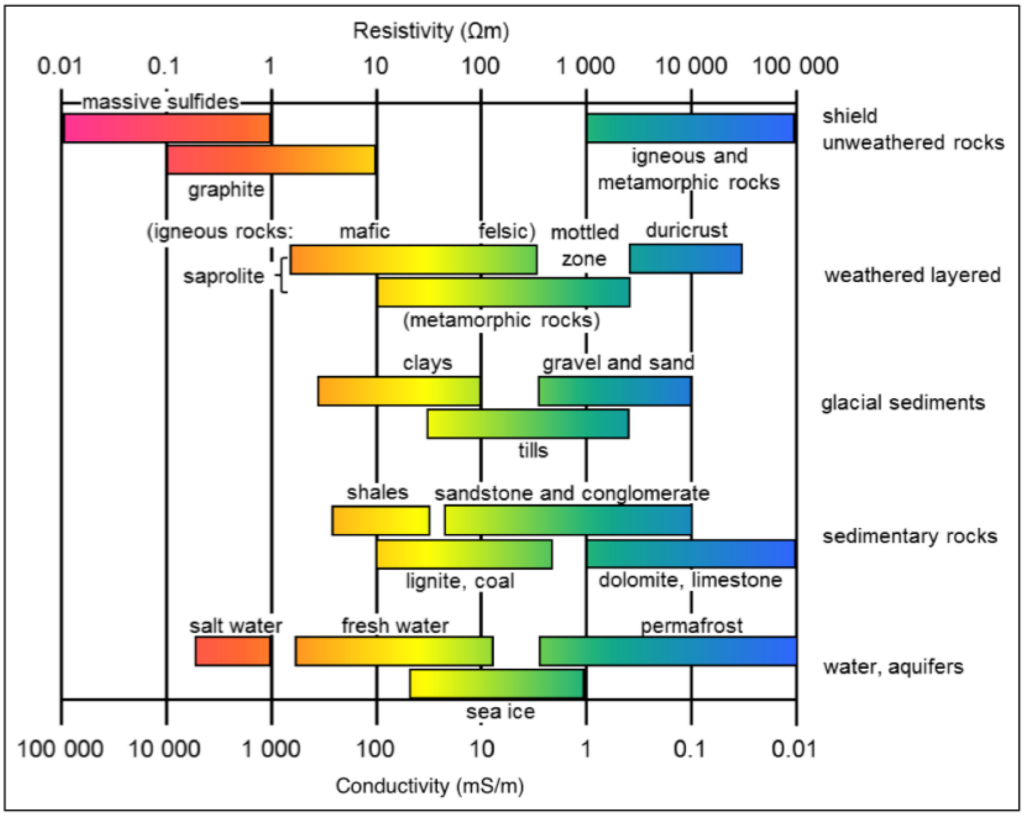

Figure 1. Resistivity value of materials in earth (Telford, 1976)

Resistivity is closely related to the subsurface water pattern. It is important because it is related to pore pressure. The relationship between resistivity values and rock types can be influenced by factors:

1. An unconsolidated sedimentary rock has lower resistivity value than a solid sedimentary rock.
2. Porosity of rock. A porous rock has lower resistivity than a non-porous rock.
3. pH of water inside rock pores. Low pH indicates acid rock with low resistivity.
4. The resistivity of rocks will vary depending on the depositional environment.
5. Resistivity can be very different between rock layers and in one layer rock.
6. A high temperature water (hot water) has lower resistivity than a low temperature water (fresh water).
7. Permeability or the ability of rocks to drain the fluids.

Porosity of rock is a comparison between the volume of the cavity with the volume of a rock. High porosity means that the volume of the water stored is large.

A lot of research has been done by geoelectric method. The exploration activity using vertical electric sounding in the sedimentary rocks unit to find out groundwater potensial was conducted by Alile et al. (2008). Configuration method and automatic analysis is used in the research. Alile and Ujunabi (2009) applied the Dar Zarrouk parameters to evaluated aquifer transmissivity using configuration. Alile and Amadasun (2008) measured direct current probing into subsurface to identify subsurface layers by resistivity measurement. The stratigraphy characteristics of the soil layers is obtained from the research. Badmus and Olatinsu (2010) investigated aquifer system and characteristics, also groundwater characteristics based on the basement complex type. The research use Vertical Electrical Sounding (VES) and Schlumberger electrode array. Aizebeokhai et al. (2010) used 2D and 3D geoelectrical resistivity imaging for an engineering site investigation. In their work, they make use of orthogonal set of 2D geoelectrical resistivity field data that consist of six parallel and five perpendicular profiles which they collected in an investigation site using the conventional wenner array. Aizebeokhai (2010) carried out a research on basic theory and field design on application and importance of 2D and 3D resistivity imaging. Wisen et al. (2005) combined 1D laterally constrained inversion and 2D smooth inversion of resistivity data with a priori data from boreholes. In their work, the result shows that 2D smooth inversion resolve lateral changes well while 1D – LCI results in well defined horizontal layer interfaces.

Al-zoubi et al. (2007) used 2D geoelectrical resistivity imaging method to analyze stratigraphy profile with resistivity value profile approach. Deformation in the layer continuity and the direct contact between high resistive and low resistive layer can only appear in the subsidence area or active sinkhole zones. From their work, the result shows that dry soil or sand with gravels or asphalt roadway or buried known sinkholes have high resistivity material than soil with groundwater, silty with moisture and saturated clay.

GEOLOGY

Based in regional geology in Banjarmasin sheet (Sikumbang and Heryanto, 1994), the research area is located on the Tanjung Formation (Tet) consist of quartz sandstone, intercalated by claystone and coal (Figure 2). Quartz sandstone has fine to coarse grain with layer thickness 50-150 cm, with sedimentary structures of parallel lamination and and cross bedding. Grey claystone, shally in places, present as intercalation in the upper part of formation with the thickness of beds 30-150 cm. Coal seam is black, lustrunous, massive, found as intercalation in the lower part of formation with the thickness of seam 50-150 cm. In places lenses of limestone, brownish grey. The research was conducted in one of the overburden piles located in the low wall of active mines in the South Kalimantan, Indonesia. The geometry of pile has a height of 150 meters, tilt of layer 14°, and thickness of the pile around 50 meters. The materials have sand-boulder sized (50 cm - 100 m) with a little sandy materials. The boulder materials can be found at the toe of slope whereas the sandy materials at the top of the slope.

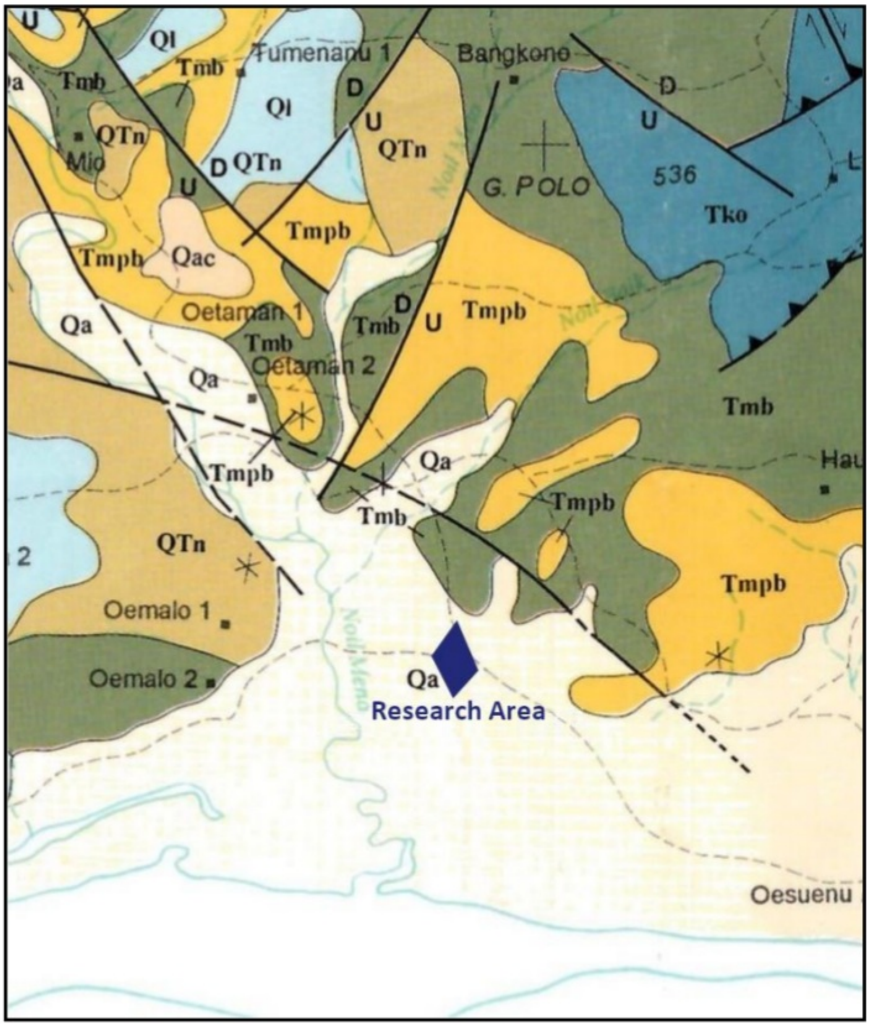

Figure 2. Research area in the regional geology map of Banjarmasin (Sikumbang and Heryanto, 1994)

METHODOLOGY

This research use geoelectrical method with primary data to obtain current and potential difference data. Based on resistivity value, litology variations, thickness and depth, distribution and groundwater aquifer potential can be identified. Geoelectrical measurement can be conducted by sounding geoelectric Wenner-Schlumberger array (600 meters) with 10 geoelectrical measurement total (Figure 3).

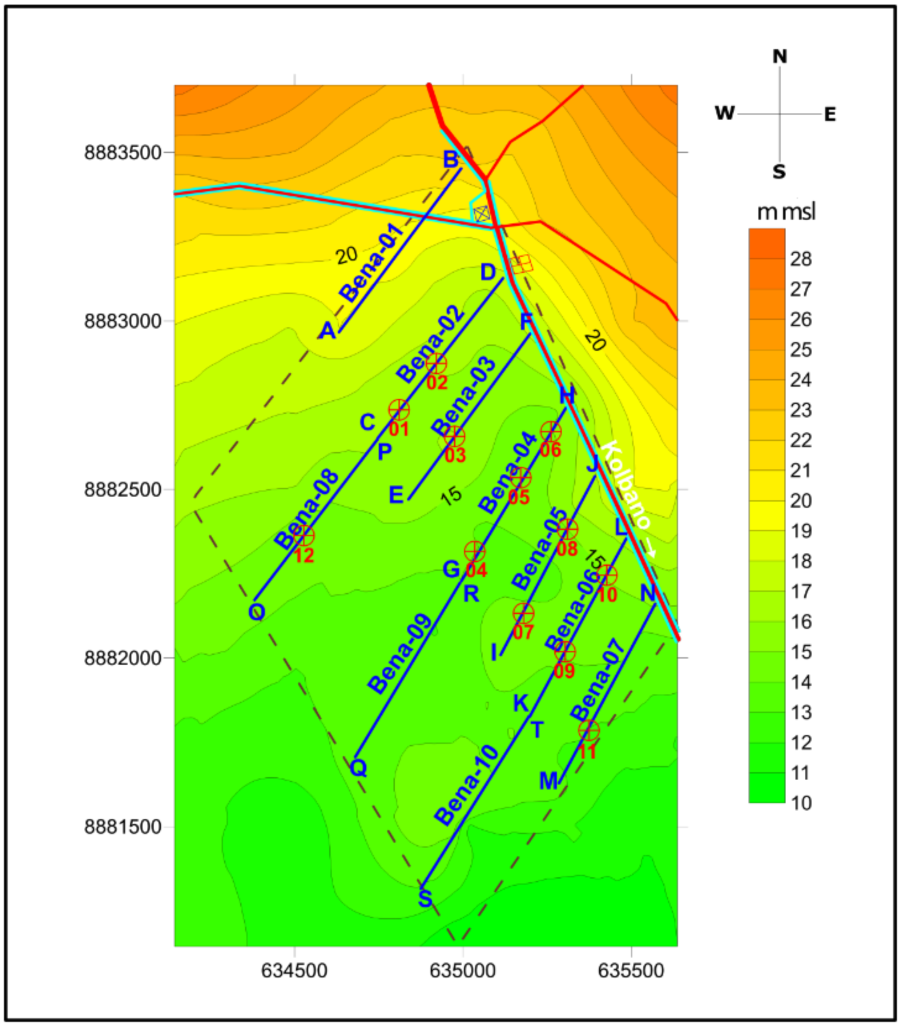

Figure 3. Geoelectrical measurement line map

Research tools in this research are resistivitymeter, two electrodes, four cable reels, two dry batteries, GPS, and measuring tape. The field data processing uses *Res2Dinv software. The data acquisition uses* Wenner-Schlumberger configuration method and standard operational procedure of ASTM D7852 – 13.

Wenner-Schlumberger configuration is a constant spacing system configuration with notice that factor "n" is a spacing comparison between electrode C1-P1 (or C2-P2) with P1-P2 space (Figure 5). If the distance between the potential electrodes (P1 and P2) is "a" so the distance between current electrodes (C1 and C2) is 2na + *a*. The determination of resistivity value use 4 electrodes placed in a straight line (Sakka, 2002).

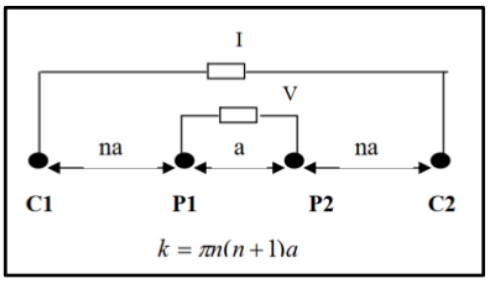

Figure 4. Electrodes setting on the Wenner-Schlumberger configuration

If a direct current is delivered through a medium then the ratio of potential difference (V) and current (I) is constant and it depends on its medium. This constant is resistance (R) that expressed as:

$$R = \frac{V}{I} \text{ (Ohm)}$$

The acquisition data in the field was conducted by making a straight line along 500 meters with target depth reaches up to 70 meters. The distance between measurement points is 15 meters with 10 pseudo layers. The data acquisition ilustration of 2D configuration can be seen in Figure 5.

Data processing includes resistivity data input supported by RES2DINV software. The data is processed using mathematical calculations so a geoelectric cross sections appear between the pseudo data and the calculated data. From those cross sections, the results are inverted to get the actual resistivity data. The result of 2D processing data is a cross section of subsurface resistivity distribution.

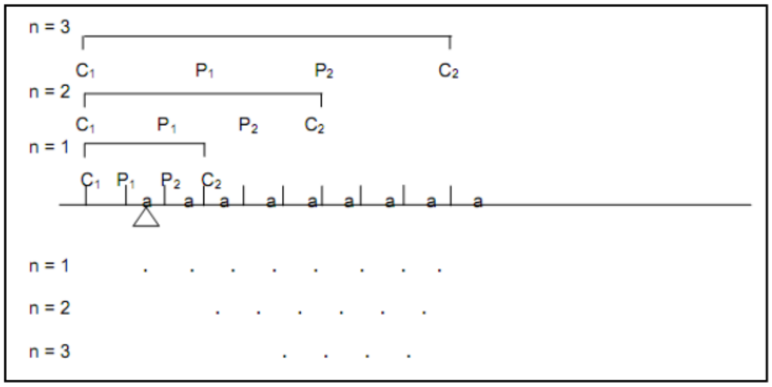

Figure 5. Data acquisition design of 2D configuration.

RESULT AND ANALYSIS

The research area is dominated by alluvium that consist of clay, sand, pebble, and cobble from floodplain in the western part of the reseearch area. The exploration area is a moderate productive aquifer area with local distribution and low field coefficient of permeability. The hydrogeological map of the research area can be seen in Figure 6. The aquifer is not continuous, thin, with shallow groundwater level and well debit less than 5 liters/second. It can be found agricultural activity in the exploration area. Plain morphology with height variation 10 - 28 masl. The survey area is about 169 hectares.

Resistivity measurement in the research area is a pseudo resistivity measurement. The pseudo resistivity data is processed using mathematical calculations to obtain real resistivity value. Data processing includes resistivity data input supported by RES2DINV software. Result of the pseudosection data processing is a real resistivity distribution to subsurface cross section. Result of the processing data is a resistivity cross section which reflects subsurface distribution value in each sounding point. On those cross section, changes in resistivity values are expressed in different colors with certain depth and thickness.

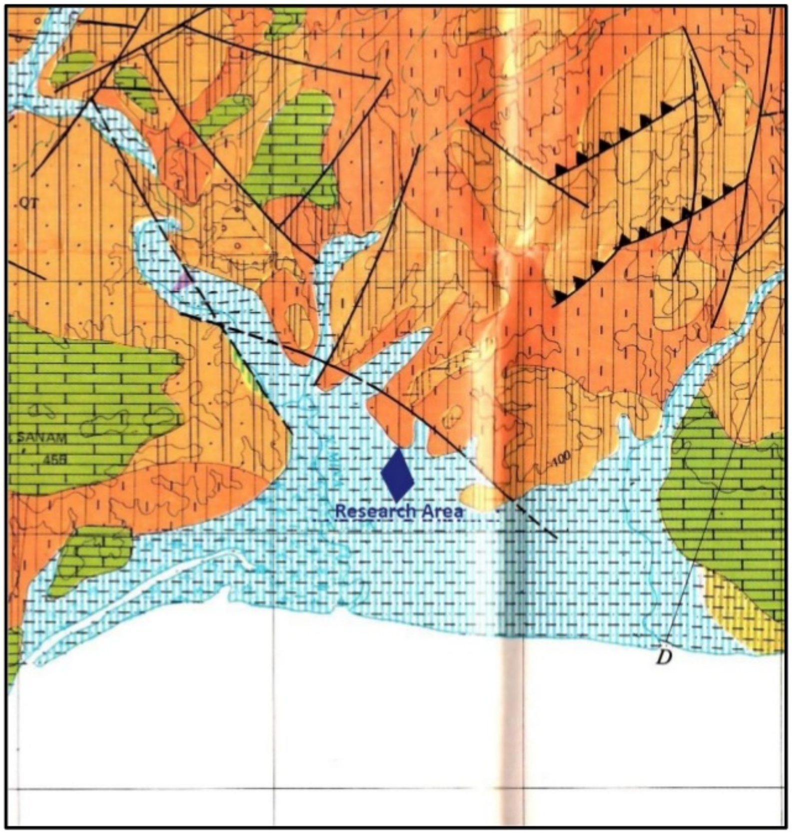

Figure 6. Hydrogeological map of research area

Result of the processing data in the Res2Dinv software can be classified into isoresistivity layers (same resistivity value) with RMS error about 10%. The A-B line (NE-SW) in the northern part of the research area is about 500 meters with elevation about 20 masl. Variation of the resistivity value in lateral with depth 100 meters is not much different (2 – 5 Ωm). The resistivity value is dominated by blue and light blue color (Figure 7).

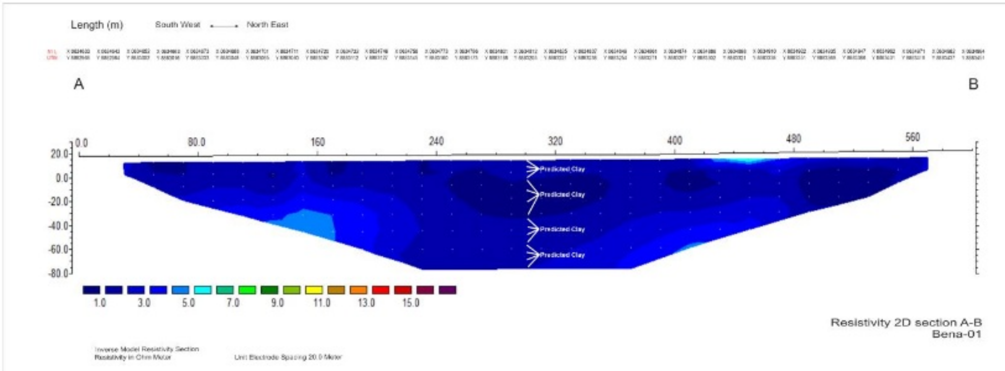

Figure 7. Resistivity cross section of A-B line

The C-D and O-P line is a 1.000 meters line that divided into 2 measurement points (Figure 8 and 9). The variation of resistivity value in lateral is 2 – 15 Ωm and still dominated by 2 – 15 Ωm. The resistivity value 10 – 16 Ωm is indicated the lenses aquifers that are not related to each other. The C-D and O-P line shows the 3 aquifer potential points with different dimension. In the C-D line, 2 aquifer points (Deep Well_01 & Deep Well_02) can be found while in the O-P line, 1 aquifer point can be found. The length of a large aquifer in the O-P line is 160 meters and the thickness is 70 meters (TRB_12). Debit estimation for each point in the Deep Well_01 and Deep Well_02 is 1-2 liters/second while in the Deep Well_12 is 2-3 liters/second.

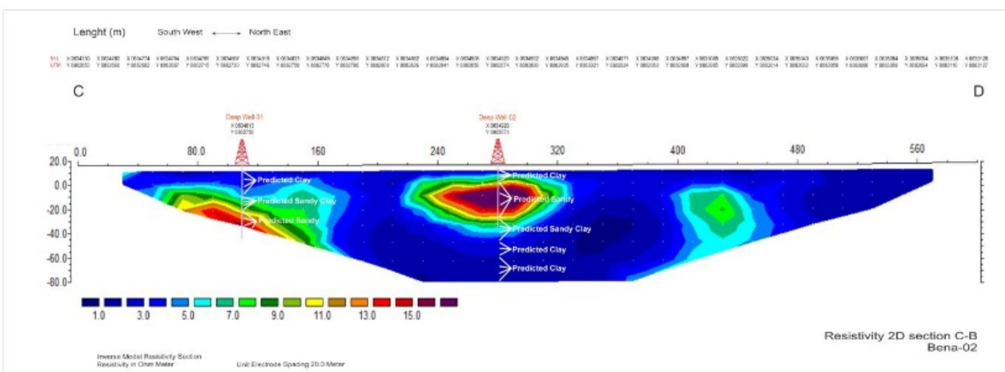

Figure 8. Resistivity cross section of C-D line

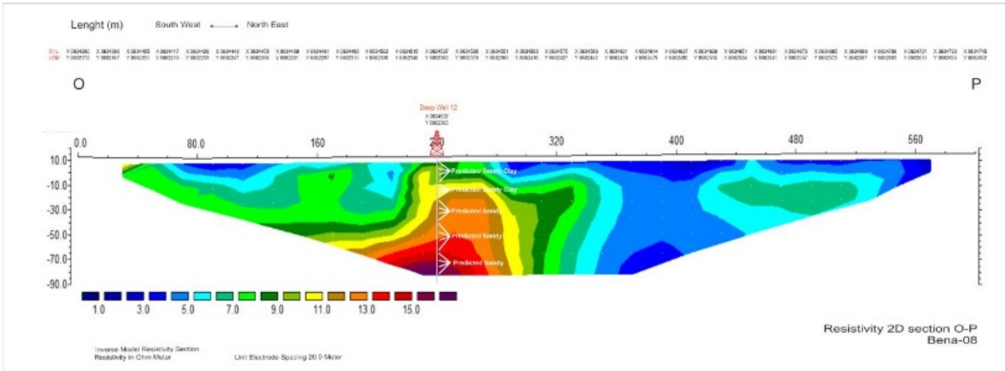

Figure 9. Resistivity cross section of O-P line

Aquifer potential can be found in the E-F line with depth about 40 meters and resistivity value 10 – 16 Ωm (yellow-red color) in Figure 10. The 500 meters of geoelectrical line can result cross section up to 80 meters. The resistivity value is dominated by 2 - 5Ωm with debit estimation about 1-2 liters/second.

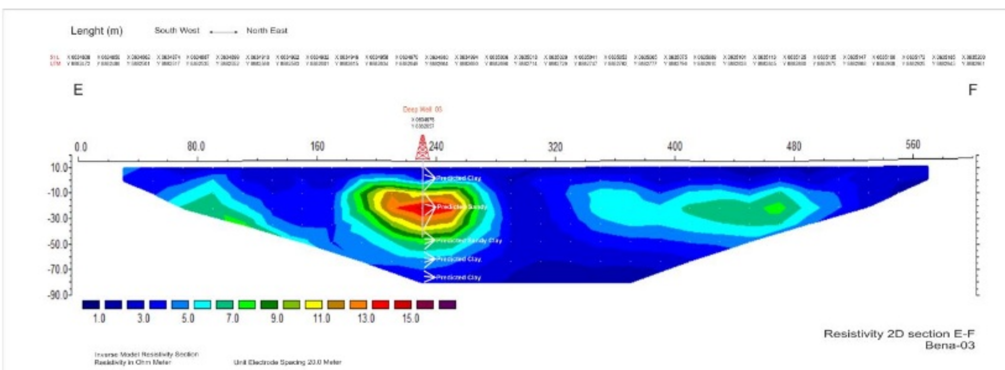

Figure 10. Resistivity cross section of E-F line

A lot of aquifer potentials can be found in the G-H line with different dimension and same relative depth. Potential aquifer has been identified at the Deep Well_04 and Deep Well_06 but additional data is required since exiting data both locations still missing. Detailing data on the both locations is important to make clear dimension of aquifer. Deep well_05 is predicted to have debit value 2-3 liters/second while the others are predicted to have debit value 1-2 liters/second. The debit estimation of Deep Well_05 dan Deep Well_06 still using existing data with limited dimension of aquifer but from preliminary data both aquifer having potential debit based on value of resistivity. Detailing data is important to identify dimension of aquifer. One aquifer potential is not recommended to drill due to the limit of the aquifer dimension. Recommendation of resistivity value for drilling is 10-16 Ωm. A G-H line is continous to Q-R line but the groundwater resources potential is not found (resistivity value 2-10 Ωm in Figure 11 and 12). A 1.000 meters of G-R line shows groundwater in the east. Detailing gathering data on Deep well GH and Q-R is important to make stratigraphy interpretation is deeper that existing condition. Maximum stratigraphy for deep well 04 up to 30 and potential upgraded up to -70m. Dimension aquifer on the deep well 04 will be clear if stratigraphy will be appear more than existing deep.

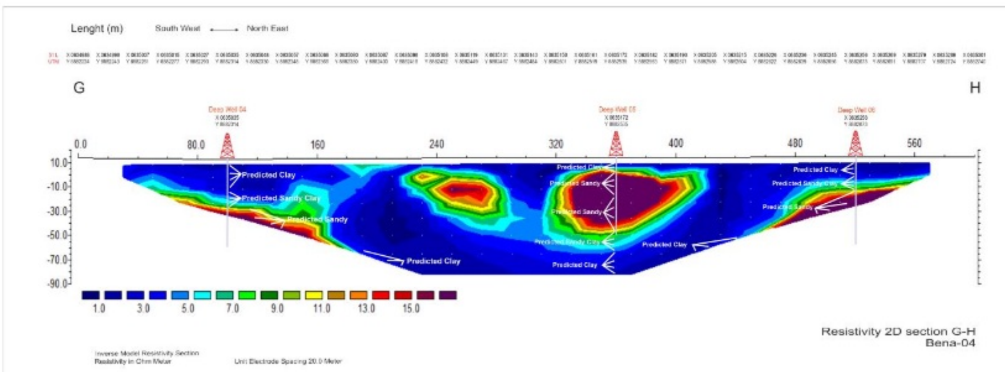

Figure 11. Resistivity cross section of G-H line

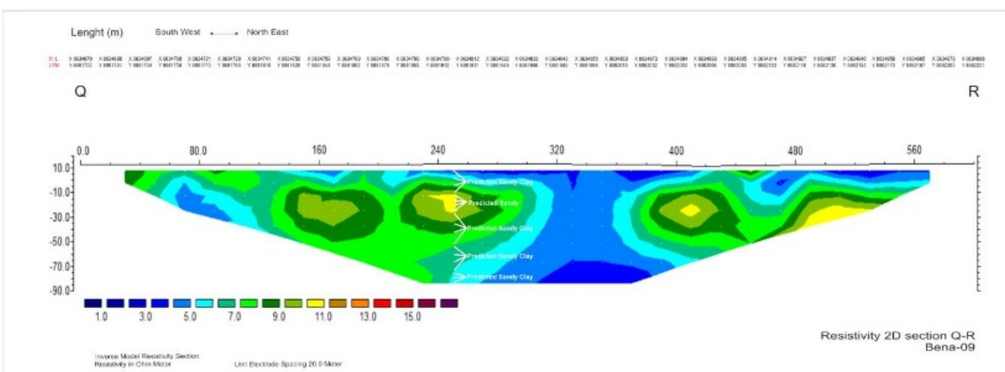

Figure 12. Resistivity cross section of Q-R line

There are 2 aquifer potential locations in the I-J line with depth about 40 meters from surface that indicated by resistivity value 11 – 16 Ωm (Figure 13). Both aquifers are found 400 meters apart. Both aquifers are predicted to have a debit 1-2 liters/second. They also have lenses shape with 80 meters in diameter.

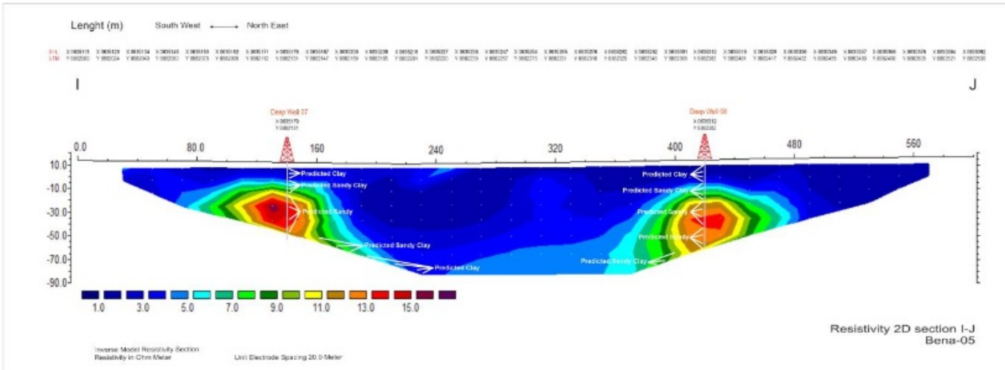

Figure 13. Resistivity cross section of I-J line

The K-L and S-T line have a total lenght about 1.100 metres (Figure 14 and 15). It is straight line with NE-SW direction. Aquifer can be found in the K-L line with 30 meters in depth. The 15-16 Ωm resistivity value shows large dimension of the aquifer. Diameter of the aquifer is about 100 meters and debit estimation is 2-3 liters/second. This aquifer is recommended because of its shallow position, large dimension, and large debit estimation. On the other hand, it can be found a relatively deep aquifer, about 8 meters dimension, unclear dimension, and 1-2 liters/second debit estimation.

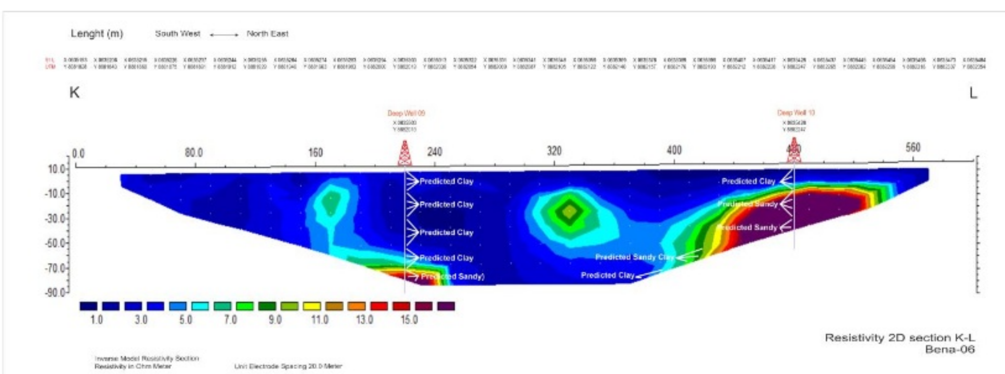

Figure 14. Resistivity cross section of K-L line

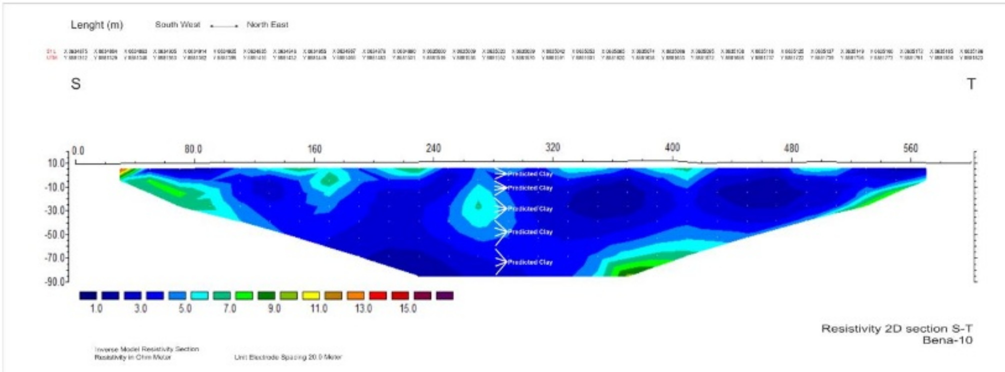

Figure 15. Resistivity cross section of S-T line

The aquifer in the M-N line is not clear and the depth of the aquifer is 80 meters (Figure 16). It has circular shape, 100 meters diameter, and 10 Ωm resistivity value.

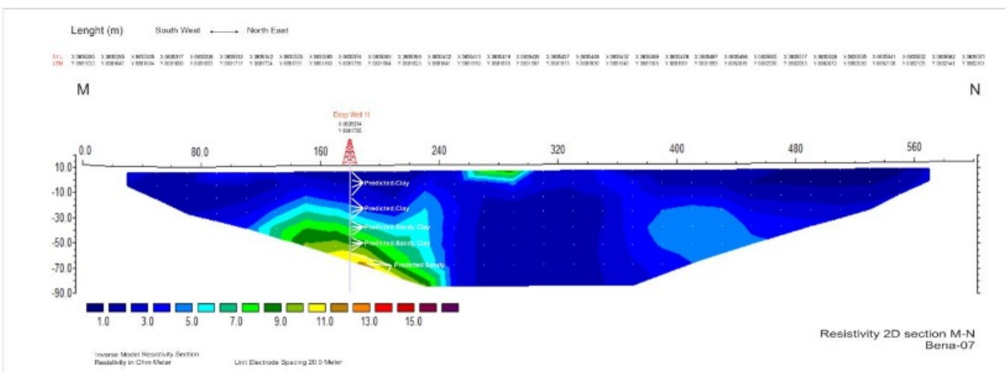

Figure 16. Resistivity cross section of M-N line

Based on the resistivity value data processing, the research area has the potential of a lenses-shaped aquifer that are not related to each other. The dimensions of lenses are tens to hundreds of meters with 20m – 95m in depth. The estimation of debit value is 1-3 liters/second and average of debit value is 1,5 liters/second. There are 3 aquifer locations that have 2-3 liters/second debit, namely Deep Well_05, Deep Well_10 and Deep Well_12. Other aquifers have 1-2 liters/second debit. The two largest aquifers are TRB_10 (30-65 meters in depth) and Deep Well _12 (40-95 meters in depth). Detailed measurements of the aquifer depth and debit estimation can be seen in Table 1.

Table 1. Aquifer depth and debit estimation

No	Point Code	Coordinate			Drill Target	Aquifer Depth	Debit Estimation
		UTM	X	Y	(m)	(m)	(lt/s)
1	Deep Well-01	51 L	634813	8882738	60	40 - 55	1 – 2
2	Deep Well-02	51 L	634920	8882874	50	20 - 45	1 – 2
3	Deep Well-03	51 L	634975	8882657	60	30 - 55	1 – 2
4	Deep Well-04	51 L	635035	8882314	70	40 - 65	1 – 2
5	Deep Well-05	51 L	635172	8882535	60	30 - 55	2 – 3
6	Deep Well-06	51 L	635256	8882673	60	30 - 55	1 – 2
7	Deep Well-07	51 L	635179	8882131	60	30 - 55	1 – 2
8	Deep Well-08	51 L	635312	8882383	70	35 - 65	1 – 2
9	Deep Well-09	51 L	635303	8882019	100	80 - 95	1 – 2
10	Deep Well-10	51 L	635428	8882247	70	30 - 65	2 – 3
11	Deep Well-11	51 L	635374	8881785	100	70 - 95	1 – 2
12	Deep Well-012	51 L	634527	8882363	100	40 - 95	2 - 3

CONCLUSION

Based on geoelectrical measurement that support by surface geological data in the South Amanuban Regency, Timor Tengah Selatan Regency, it can be concluded:

1. The survey area is a low undulating plain and a floodplain.
2. Lithology is dominated by alluvium that consist of clay, sand, pebble, and cobble from floodplain in the western part of the research area
3. The exploration area is a moderate productive aquifer area with local distribution and low field coefficient of permeability.
4. The aquifers have lenses shape with depth 50 – 80 meters, resistivity value 20 – 50 Ωm, and unconsolidated sand layers.
5. Drilling point priority can be conducted in the TRB-12 because it has a big aquifer with debit 2 – 3 liters/second. Coordinate and drill target can be seen in table below:

No	Point Code	Coordinate			Drill Target	Aquifer Depth	Debit Estimate
		UTM	X	Y	(m)	(m)	(lt/s)
1	Deep Well -05	51 L	635172	8882535	60	30 - 55	2 - 3
2	Deep Well -10	51 L	635428	8882247	70	30 - 65	2 - 3
3	Deep Well -12	51 L	634527	8882363	100	40 - 95	2 - 3

Additional data is required to detail some areas that have potential water resources so that estimation of groundwater reserves can be calculated.

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