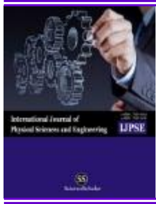
International Journal of Physical Sciences and Engineering
Available online at http://sciencescholar.us/journal/index.php/ijpse
Vol. 2 No. 2, August 2018, pages: 68~78
e-ISSN : 2550-6943, p-ISSN : 2550-6951
https://doi.org/10.29332/ijpse.v2n2.151

Aquifers Selection based on Geoelectric Method Data in the Framework of Drilling Wells: A Case Study on International Hospital Project in Nyitdah Tabanan Bali

I Nengah Simpen [a], I Wayan Redana [b], Ika Umratul [c]

Article history: Received 9 February 2018, Accepted in revised form 1 June 2018, Approved 22 July 2018, Available online 28 July 2018

Correspondence Author [a]

Keywords

Aquifers;
Constructing drilling;
Drill well;
Geoelectricity method;
Unconfined aquifer;

Abstract

The selection of aquifers based on Geoelectric Method data in constructing drilling wells was discussed in the present study. The research was conducted at the International Hospital Project in Nyitdah Tabanan Bali. The research position was around 8,5736 LS 115,1215 LE. Before the study was conducted, a well drill (well 1) has been made. The results showed that there were two types of aquifers, namely unconfined aquifers and unconfined aquifers. Related to this study, well 1 took water in the unconfined aquifers of 4 m depth. If the water kept taken for a long period, the quality and quantity of the water would be worse since well 1 was unconfined aquifers that took surface water. This would adversely affect the hospital building being built. The land around the building would be hollow due to the water loss, and the building would become unstable. Another drill well (well 2), based on geoelectricity data, can be made on 5,25 m - 18,75 m. In-depth 23 m, it was suspected that unconfined aquifers would have been found in well 2. After being drilled, aquifers were found in 23 m depth. Drilling was kept doing to 55 m depth. The new well (well 1) had TDS 205 mg/l and well 1 had TDS 350 mm/g. The number was still under the recommendation of Health Minister Regulation. The Minister recommendation was TDS 500 mg/I. However, well 1 had a hazardous state of pollution because it used water that seeps into the soil. A well 1 still had good water condition since there was fields rice around it while the aquifers of well 2 were not polluted because it was shrouded by hard layers. This means the quality of well 2, in a longer period, was better than the quality of well 1.

[a] Physics Department, Faculty of Mathematics and Science, Udayana University Denpasar, Bali-Indonesia
[b] Engineering Doctorate Program, Udayana University, Jl. P.B. Sudirman Denpasar, Bali-Indonesia
[c] Physics Department, Faculty of Mathematics and Science, Udayana University Denpasar, Bali-Indonesia

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1. Introduction

An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials where water is drawn and also produced economically (Warui, *et al.*, 2012; Tebbutt, 2002). Based on the water state, the aquifers can be grouped into three; they are unconfined aquifers, confined aquifers and semi-confined aquifers (Redana, 2012). Water quantity and quality is determined by aquifers. Therefore, it can be questioned: How to choose aquifers when a well is going to be drilled? Water in the aquifers is totally determined by the state of its aquifers. The infiltration region of unconfined aquifers is around the aquifers. The infiltration of confined aquifers is deep in the upstream of the aquifers, therefore it has undergone some filtering. The infiltration of semi-confined aquifers has both infiltrating area deep in the upstream, as well around the aquifers (Bear, 2009).

The geoelectric method is a geophysical method that works by injecting influx (I) into the earth and then be measured by measured potential (V) affected. Based on the two physical quantities, rock resistivity is obtained in the measurement area, either laterally or vertically. There are several factors that determine the magnitude of the resistivity value of rocks, namely types of materials, water content, the porosity of rocks, and chemical properties of fluid fillers (Sen *et al.*, 1988; Araffa, 2013; Simpen *et al.*, 2016). Thus, the geoelectric method is expected to help the selection of aquifers in the drilling wells to obtain good water based on the aquifers. This research conducted aquifers selection based on data of the geoelectric method. It was taking place for International Hospital Bali Project in Nyitdah Tabanan.

2. Research Method

2.1 Time and Place of Data Collected

This research was conducted on October 29th, 2016 in Nyitdah Tabanan for International Hospital Bali Project. Geographically, it was located in 8.573528^0 LS and 115.120702 LE, in 396 m *dpl* high (Figure 1).

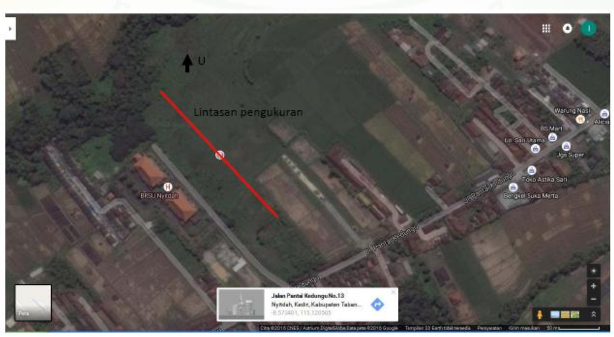

Figure 1.Research Location
Source: View Online

Simpen, I. N., Redana, I. W., & Umratul, I. (2018). Aquifers selection based on geoelectric method data in the framework of drilling wells. International Journal of Physical Sciences and Engineering, 2(2), 68-78. https://doi.org/10.29332/ijpse.v2n2.151

2.2 Research Materials and Instruments

Materials and instruments used in the research were: a set of *resistivimeter*, Laptop, *Software Res2Divn,* and TDS meter (Figure 2).

Figure 2. *Resistivimeter* Set

2.3 Method of Data Analysis

Data obtained through geoelectric measurement was injected high influx data (I) and measured potentially affected data (V). Next, data I and data V were processed by *Res2Divn* program. After that, contour cross-sectional resistivity was gained. The analysis was conducted on the color and shape of the contours of the cross-sectional resistivity image. Furthermore, it was determined the value of resistivity, type of rock, and depth with through the assistance of Table 1. Based on the analysis of the contour resistivity, the aquifers position was known, as well as the drilling point position, to get good quality and a good quantity of groundwater.

Table 1
Color, resistivity, and rock type

No.	Color	Resistivity	Rock Type
1		0 - 32,2	Soil clay, wet soft
2		32,2 - 38,7	Sand
3		38,7 - 40,8	Sand
4		40,8 - 45,95	Sand
5		45,95 - 51,1	Sand
6		51,1 - 57,6	Sand
7		57,6 - 64,1	Sand
8		64,1 - 72,2	Sand
9		72,2 - 80,3	Sand
10		80,3 - 90,65	Sand
11		90,65 – 101	Sand
12		101 - 113,5	Sand
13		113,5 – 126	Sand
14		126 - 142	Sand
15		142 - 158	Rocky basement consist of moist soil
16		158 - 162,5	Rocky basement consist of moist soil

17		162,5 – 167	Rocky basement contains moist soil

Source: Ridhwan, et al. (2009)

3. Results and Analysis

3.1 Geological research area

Hospital Project was located in Nyitdah Village, Tabanan Regency. There has been an impermanent borehole located in the north side of building. This project was located in the middle of rice fields. Around the project, there were only a few houses. Geographically, this area consists of tufa rock and lava sediment Buyan-Bratan and Batu (Hadiwidjojo, 1971).

3.2 Geoelectric data and data analysis

All data of the research result was obtained in the numeric form that was Influx result data (I) and measured potential data (v). Both physical quantities were then processed by *Res2Divn* program. The program gave contour resistivity cross section measurement trajectory Figure. Figure 3 is a Figure of contour resistivity cross section measurement trajectory in Nyitdah Tabanan for International Hospital Bali Project. Next, the contour resistivity was analyzed using Table 1. The results are as follows (Figure 4 – 13).

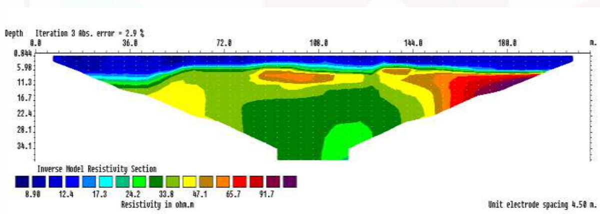

Figure 3. Contour resistivity cross section measurement trajectory in Nyitdah Hospital

Layer 1
The top layer was muddy soil as seen when the data were taken. It was marked by dark blue color (Figure 4), the resistivity value ranges from 12,4 – 17.3-ohm meters and located in 0 – 6 meters depth.

Layer 2
The second layer was a light blue resistivity cross-sectional layer (Fig. 5). This layer signifies a drier aqueous clay soil from the upper layer with a resistivity value approximately 17.3-ohm meters and located in 10 meters from the surface.

Layer 3
The third layer was light green (Figure 6). This layer has a resistivity value between 24.2 - 29 ohm-meters. This layer was a sand layer containing water.

Layer 4
The fourth layer was dark green (Figure 7) with resistivity values between 20.75 - 38.8-ohm meters. The depth was in two positions, namely the depth of 11.5 meters and 16.7 meters. This layer was a sand layer.

Layer 5
The green fifth layer (Fig. 8) indicating the presence of sand and the presence of water, the same as the fourth Layer. The water in this area was the seepage from the surrounding area, the resistivity value is between 33.8 - 40.45 ohm-meters at a depth of 6 - 28.1 meters.

Layer 6

The sixth layer was yellow (Figure 9) area containing small sand and gravel with resistivity values between 40.45 - 47.1-ohm meters with a depth of 10 - 22.4 meters.

Layer 7

The fourth layer was brown (Figure 10). The area containing sand and small pebbles was the same as layer 6 but had a different resistivity value that resistivity value ranges from 47.1 - 56.4-ohm meters. It was located in approximately 10 - 15 meters.

Layer 8

The eighth layer was an orange Layer (Figure 11) containing more sand and small pebbles than the previous one with resistivity values ranging from 47.1 - 65.7 ohm-meters. It was located in approximately 10 - 19.55 meters.

Layer 9

The ninth layer was a red layer (Fig. 12), a sand-containing area with a resistivity value of 65.7 - 91.7-ohm meters with 10 - 22.4 meters depth.

Layer 10

The purple tenth layer (Fig. 13) was an area containing small sand and gravels similar to Layers 7, 8 and 9. It had a different resistivity value that is more than 91.7 ohm-meters resistivity lies in depths ranging from 6 - 19.55 meters.

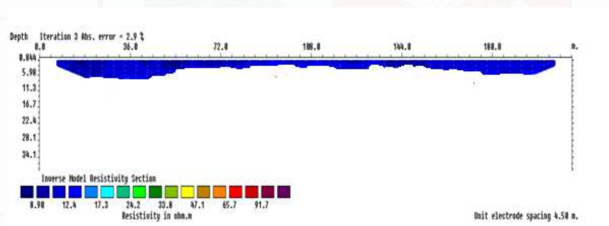

Figure 4. Layer 1

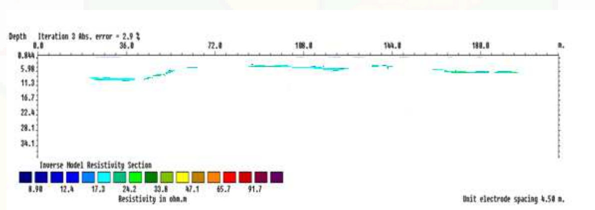

Figure 5. Layer 2

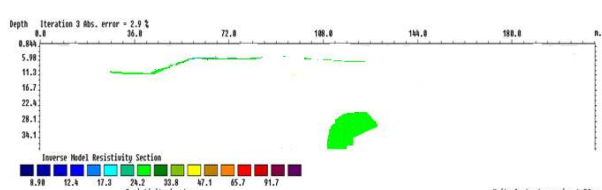

Figure 6. Layer 3

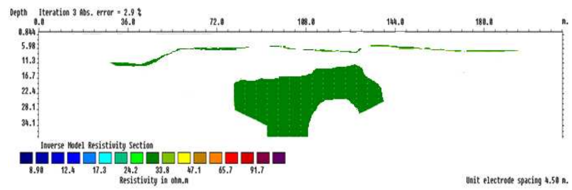

Figure 7. Layer 4

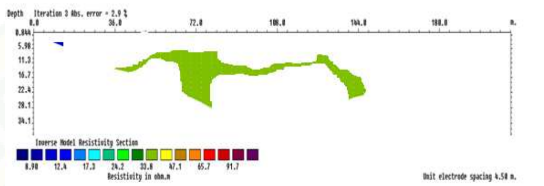

Figure 8. Layer 5

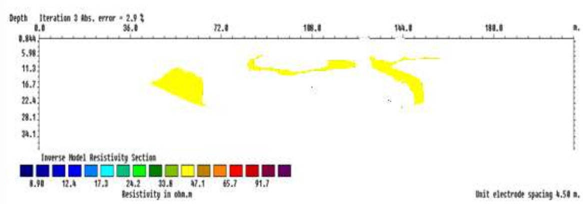

Figure 9. Layer 6

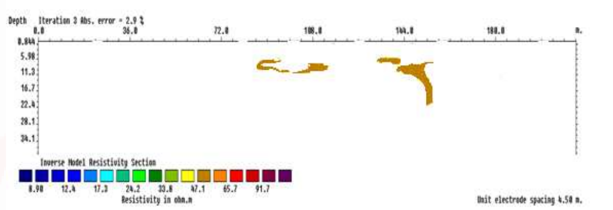

Figure 10. Layer 7

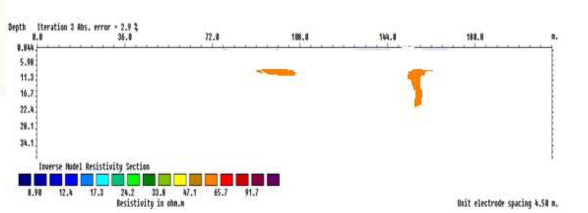

Figure 11. Layer 8

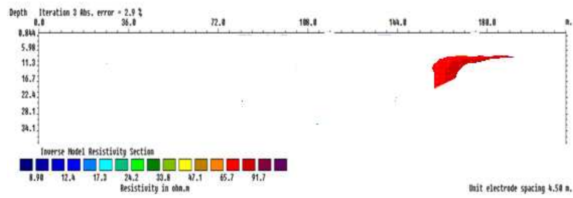

Figure12. Layer 9

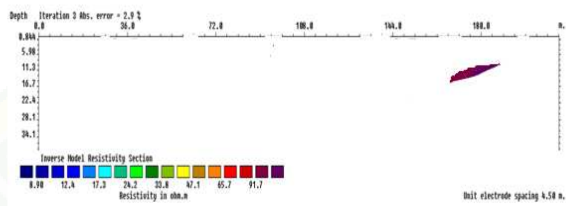

Figure 13. Layer 10

To summarize, the results of the cross-sectional contours resistivity Interpretation are presented in Table 2.

Table 2
The result of research data analysis

No	Color	Depth (m)	Resistivity (Ωm)	Type of soil / rock
1	Dark blue	0 – 6	12,4 – 17,3	wet and muddy
2	Light blue	10	17,3	Sand of loamy clay
3	Light green	1,3 and 25,25	24,2 – 29	Sand
4	Dark green	1,5 and 16,7	20,75 – 38,8	Sand
5	Green	6 – 28,1	33,8 – 40,45	Sand
6	Yellow	10 – 22,4	40,45 – 47,1	Sand and small pebbles
7	Brown	10 – 15	47,1 – 56,4	Sand and small pebbles
8	Orange	10 – 19,55	47,1 – 65,7	Sand and small pebbles
9	Red	10 – 22,4	65,7 – 91,7	Sand
10	Purple	6 – 19,55	91,7	Sand and small pebbles

3.4 Discussion

Before the research was conducted, there has been a well (well 1). Most rocks there have got a low resistivity value. The layer had properties as a water carrier layer (aquifers), and there were two types of aquifers, namely unconfined aquifers and confined aquifers. Based on Geoelectric data, well 1 took water in unconfined aquifers in 4 m depth and based on the cross-sectional contours of the trajectory resistivity, it was apparent that the most suitable drilling position is the light green area (Layer 3) - at the location of electrodes 24 to 29 or between 5.25 m to 18.75 m to the east of well 1. It was assumed that in-depth 23 m, good water condition would have been found. The area was confined aquifers area. The aquifers were assumed shrouded by harder layers (Layer 4) therefore the water in layer 3 would not be polluted.

On the other side (other than light green / Layer 3), there was a point to be drilled since the presence of water was detected, like in well 1 (depth 4 m). However, the water is a pervasive water. There are some factors that cause the absorption. First, the turn of the season; from the rainy season to the dry season; Second, the land conversion, that is when the rice fields land is used to build a house or to be a residential area. If the water is exhausted, then the water cannot be found again. Therefore the well drill was not made there.

If groundwater extraction is done in shallow areas such as in well 1, then groundwater will be continuously taken to meet hospital needs. As the consequent of it, there will be empty space in the ground, and the land inside will become hollow. Furthermore, the building on the unstable land will corrupt the building itself. The building will become tilted and impacting another area around it.

The harder layer was finally found (in-depth 20,5m) after drilling on 16 m from well 1 (Figure 14). In-depth 21,75 m the harder layer than before was also found. Next, in 23 m depth, aquifers was started to be found. Drilling process was kept done to depth 21, 75- 23 m. This drilling result was in accordance with the cross-sectional reesistivity contours in the study area. The new well (well 2) was expected to provide water with good quality and quantity. This research also conducting Total Dissolved Solids test (TDS). The TDS to each well are as follows. The TDS for well 1 was 1: 350 mg/l and the TDS to well 2 was: 205 mg/l. The value of those two well TDS was still under the recommendation of Indonesian Health Minister Regulation. The Minister recommendation was TDS 500 mg/I (PERMENKES RI No. 492/MENKES/PER/IV/2010). However, well 1 had a hazardous state of pollution because it used water that seeps into the soil. Well, 1 still had good water condition since there was fields rice around it while the aquifers of well 2 were not polluted because it was shrouded by hard layers. This means the quality of well 2, in a longea r period, was better than the quality of well 1.

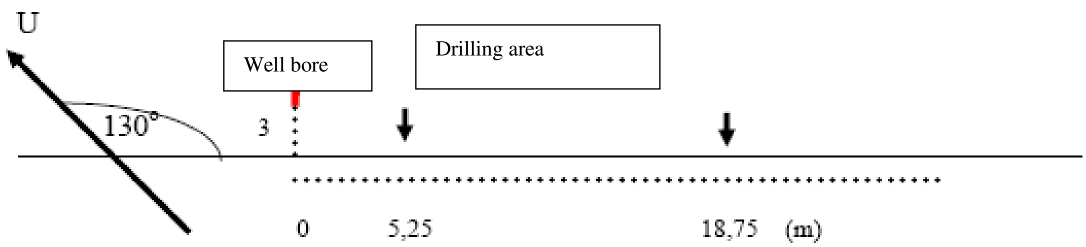

Figure 14. Sketch of drilling location

4. Conclusion

Based on the data of Geoelectrical Method, there were two types of aquifers at Nyitdah Tabanan Bali for the Hospital Project. The aquifers were unconfined aquifers and confined aquifers. Well 1, at the depth of 4 m took water on unconfined aquifers. The well water 1 was a surface water absorption. Here, aquifers were a hazard to be polluted, to be run out of water for the long term, and dangerous to the stability of the building. Another confined aquifers could be chosen to get water. In the research area, there was also a confined aquifer. Drilling was done to the confined aquifers (well 2). In 23 m depth, water was found. TDS test for each well showed well 1: 350 mg/l and well 2: 205 mg/l. The TDS value of those two wells was still under the standard of Indonesian Health Minister Regulation in PPERMENKES RI No. 492/MENKES/PER/IV/2010. The Minister recommendation was TDS 500 mg/I. However, well 1 had a hazardous state of pollution because it used water that seeps into the soil while the aquifers of well 2 were not polluted because it was shrouded by hard layers. This means the quality of well 2, in a longer period, was better than the quality of well 1.

Conflict of interest statement and funding sources
The authors declared that they have no competing interest. The study was financed by personal funding.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

Acknowledgments
This paper has been presented at the 2nd Annual Scientific Congress of the Indonesian Association Soil Experts (Congress and PIT PAAI 2), in Yogyakarta, September 13-15, 2017 and has been improved according to congressional suggestions. We would like to thank the Head of International Hospital Project in Nyitdah

Tabanan Bali for the opportunity given to do the researchers. We would also like to thank the Head of Soil Mechanics Laboratory of Civil Engineering Department of Udayana University Faculty of Engineering for lending Geoelectrical sets, and also thank the all 2nd Annual Scientific Congress participants for their suggestions. May this paper be more perfect.

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Biography of Authors

Dr. I Nengah Simpen, M.Si., was born in Karangasem August 2nd, 1960. A lecturer in Physics Department, Science and Mathematics Faculty, Udayana University Denpasar Bali. He obtained his M.Si from Bandung Institute Technology, Bandung in 1993, and his Dr. from Udayana University Denpasar Bali in 2016. He teaches at Civil Engineering Department, Faculty of Engineering, Udayana University Denpasar, Bali-Indonesia. He is interested in Geophysics/Groundwater.
His e-mail is simpen.nengah@yahoo.com.

Prof. Ir. I Wayan Redana, MA.Sc, Ph.D., IPU, was born in Denpasar on Oktober 25, 1959. Lecturer in Doctorate Engineer Program, Udayana University Denpasar Bali. He teaches at Civil Engineering Department, Faculty of Engineering, Udayana University Denpasar, Bali-Indonesia. He is a Professor of Engineering Geology. Teaching several subjects to include Philosophy of Science, Foundation Technique, Soil Mechanics, Ground Water, Engineering Dams, and Soil Dynamics. He is interested in Technical Geology field studies.

Ika Umratul Asni Aminy was born in Mamben Lauk Lombok, January 13th, 1997, She is Graduate Student in Physics Department, Science and Mathematics Faculty, Udayana University Denpasar Bali. She is interested in Earth Physics, especially in Groundwater and Geoelectrics. She will soon complete her studies in the Physics Department of Udayana University.