Deep Groundwater Potential and Chemical Analysis Based on Well Logging Analysis at Kapuk-Cengkareng, West Jakarta, DKI Jakarta, Indonesia

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Abstract. The Special Capital Region of Jakarta is covered in densely growing infrastructure. However, little attention is paid towards its environmental conditions. This leads to social problems such the absence of a clean water supply. The conditions of contaminated shallow groundwater and river water makes layer analysis of deep groundwater carriers (aquifers) necessary. This research aims to provide insight about deep groundwater potential, and determine the depths and locations of aquifers in the Jakarta area, particularly for the benefit of the Kapuk-Cengkareng people. This research was conducted via well logging analysis. Well logging is a geophysical method designed to find out the subsurface lithology of an area using its physical characteristics. The result from this research can be used to interpret that there are four deep groundwater layer zones with different qualities. Good groundwater layers can be found in layers with good porosity and permeability. By analyzing the curves obtained using the well logging method, it can be known that most of the layers found in the wellbore are claystone with low resistivity and high gamma radiation. The resistivity value of the claystone layers is about 2-5 Ω•m with 65-80 cps. There are several layers with high resistivity and low gamma radiation (sandstone) that has the potential to be an aquifer. This is reinforced by the sand layer with a right-leaning SP log curve proving that this layer is permeable. These layers have a 4-9 Ω•m with 40-65 cps. These are mostly found as freshwater aquifers with (83-279) µ•S/cm EC, (7.61- 8.17) ph, and (56-188) mg/L TDS.

Keywords: Deep Groundwater Potential, Groundwater Chemical Analysis, Well Log Devices, Well Logging Analysis

1. Introduction

The Kapuk research area is located between 5°19’12”S to 6°23’54”S and 106°22’42”E to 106°58’18”E. This research area is part of Jakarta’s Groundwater Basin. Kapuk is part of the Northwest Java Beach, in the Jakarta Bay Area. Since the beginning of the 20th century, groundwater from the Greater Jakarta Basin has been used for drinking water and other water resources purposes [1]. The city’s high population and growing infrastructure rapidly creates social problems. The change in allocation from paddy field areas to settlement decreases area of water absorption in the region for groundwater sources. This triggers a lack of clean water supply. It has been estimated that only 38% of Jakarta’s population have access to clean water. Much of

Jakarta's river water is contaminated so deeper groundwater is an important water source [2]. This makes layer analysis of groundwater necessary.

Groundwater potential cannot be separated from the condition of the water carrying layer (aquifer). This research was conducted through the well logging analysis method to determine the aquifer zone based on the rocks' physical characteristics. The aquifer zone can be found in rock formations which are physically good for both porosity and permeability, such as sandstone. After determining the aquifer zone, samples were taken from several aquifers to determine their water quality using several parameters: electrical conductivity (EC), dissolved solids (TDS), and Cl- content. These tests were conducted using an electrical conductivity meter and a pH meter.

Well logging is a geophysical method used to determine the types of unknown rocks using physical parameters. There are three types of devices used in this method: a spontaneous potential log, resistivity log, and gamma ray log. The results from integrating and analyzing the data can be used to determine porosity, permeability, and water saturation. This research aims to provide insight regarding deep groundwater potential in Jakarta, particularly for those living in Kapuk, West Java Regency. Furthermore, this research aims to help people determine the location and depth of groundwater for deep groundwater drilling.

2. Well Logging Method

The observation was conducted by the well logging method using a testing wellbore. The three well devices used are:

1. Spontaneous Potential Log (SP Log)

SP log works by using the electrical potential ratio between two electrodes, one at the surface and one at the borehole or rock formation. The borehole must be filled with conductive mud for it to work well. The SP log curve will display a right-leaning curve when there is a permeable rock formation such as sandstone, and will show a left-leaning curve to depict impermeable rock formations such as claystone.

2. Gamma Ray Log (GR log)

GR log works by identifying the radioactivity level of rocks that contain thorium, uranium, or potassium substances. The function of GR logs is to differentiate between permeable and impermeable layers. Sandstone and limestone have low levels of radioactivity, whereas claystone and shale have high levels of radioactivity. This happens because of the radioactive elements abundant in claystone and shale. GR Logs are measured in counts per second (cps).

3. Resistivity Log

Resistivity logs are used to detect both hydrocarbons and water layers based on permeability and porosity characteristics. Principally, this method is the same as the geo-electric method which is used to determine rock layers based on their resistivities. Results from this method are inversely proportional to results from the GR log. For example, sandstone layers commonly have high resistivity and low cps.

3. Geological Condition

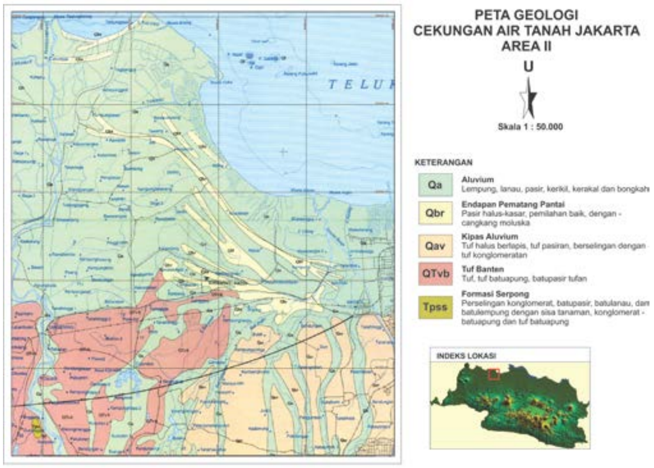

Figure 1. Geological Map of Jakarta’s Northwest Groundwater Basin (T. Turkandi et al, 1992)

According to Turkandi et al (1992), Jakarta’s Northwest Groundwater Basin is composed of alluvium deposits, beach embankment deposits, alluvium fan deposits, Banten tuff deposits, and Serpong formation deposits. The research area is dominated by alluvium deposits that consist of claystone, sandstone, siltstone, boulders, cobbles, and pebbles. This area also has an elevation of about 2-3 m above sea level. There are 4 kinds of lithology in Jakarta [3]:

1. Clayey sand and sandy clay with about 300 m thickness.

2. Clayey sand unit is embankment area deposit that sedimentation flocks gradually between sandy shale and clayey sand. The layer has 4.5-13 m thickness.

3. Sandy clay and clayey sand is river abundant flood deposit with 1.5-17 m thickness.

4. Silt clay and sandy silt is volcanic alluvial fan deposits (tuff and conglomerate soils) gradually from top to bottom with a thickness of between 3-13.5 m.

4. Hydrogeological Condition

Figure 2. Hidrogeological map of Jakarta’s Northwest Groundwater Basin (Soekardi, 1986)

Kapuk is located in the northwest beach of Java (Jakarta's Gulf) that is hydrogeologically included in Jakarta's Northwest Groundwater Basin. This basin consists of quaternary deposits with a thickness of about 250 m. Groundwater, particularly in quaternary deposits, flows through the intergranular spatial system. In coastal areas, shallow aquifers up to 40 m in depth are commonly salt water unless they are old river deposits.

The Special Capital Region of Jakarta has a tropical climate, with an inconspicuous temperature difference between day and night. Its temperature ranges between 25-32°C, with an average annual temperature of 25.50-27.20°C. The humidity is very high, at 77%. Annual rainfall ranges from 1762-2195 mm/year [4]. According to Fachri (2002), quaternary aquifer deposits in this basin can be separated into four groups [5]:

1. Zone 1 (Group Aquifer I): The aquifer group is not depressed at a depth of < 40m.
This aquifer group is an aquifer layer that is covered by an impermeable layer. Groundwater in this aquifer is classified as shallow groundwater which is the main source of clean water for citizens of Kapuk.

2. Zone 2 (Group Aquitard I): The aquifer group is depressed upon at a depth of 40-140m.
This group of aquifers is a layer of aquifer with a semi-escaped water layer above it and a waterproof layer underneath it.

3. Zone 3 (Group Aquifer II): The aquifer group is centrally depressed at a depth of 140-250m.
This aquifer group is classified as deep groundwater that is covered by an impermeable layer on the upper part.

4. Zone 4 (Group Aquitard II): The aquifer group is depressed from below at a depth <250m.

5. The Investigation and Analysis Result

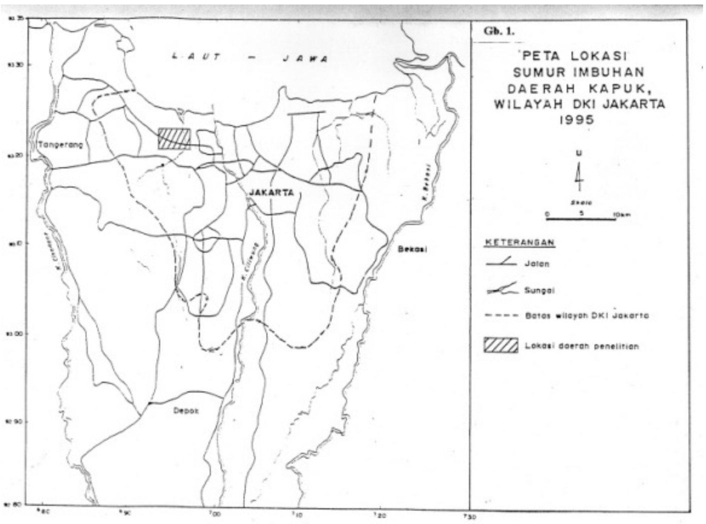

Figure 3. Well location map of Kapuk's area (*Anonymous*, 1996)

Data processing was done by integrating the SP log, resistivity log, and GR log data, and then interpreting and determining the log of the wellbore's lithology based on the suitability of physical parameters of each rock type.

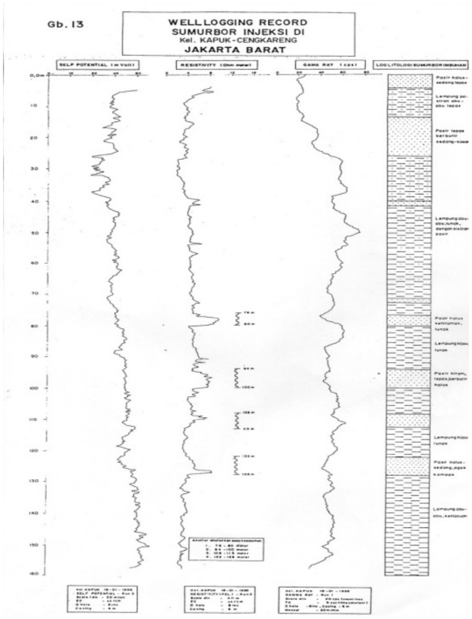

Figure 4. Well Logging Record at Kapuk-Cengkareng, West Java Regency (*Anonymous*, 1996)

From the results of the investigation obtained by analyzing the curves (Fig. 4), it can be noted that the layers found in this wellbore are generally clay layers with low resistivity and high gamma radiation. These clay layers have 2-4 Ω·m resistivity with 65-80 cps gamma radiation. There are several layers of high resistivity sand with low gamma radiation that have potential as aquifer layers. This is reinforced as a sand layer with a right-leaning SP log curve, proving that this layer is permeable. These layers have a 4-9 Ω·m resistance with 40-65 cps gamma radiation.

Table 1. Aquifer Potential Based on Well Logging Analysis

Depth (m)	**Resistivity (Ω·m)**	**Gamma Radiation (cps)**
76-80	5-9	40-60
94-100	4-8	40-50
108-113	4-7	50-65
122-126	4-8	40-50

Table 1 shows that there are four layers with potential to be aquifers. Layers at depths of 76-80 m and 122-126 m are the best aquifer layers because they have a high resistivity value with low gamma radiation. The layer at 94-100 m is classified as a fairly good layer with 4-8 Ω•m resistivity with 40-50 cps of gamma radiation. The layer at 108-113 m is estimated to contain high salinity water because it has a low resistivity along with the highest gamma radiation compared to the other layers.

6. Groundwater Chemical Analysis

Chemical analysis was used to determine the groundwater salinity level in the research area based on aquifer sample testing. The data obtained was correlated with the well logging analysis data which is used as data validation. According to groundwater classification by PAHIAA (Ad Hoc Salt Water Intrusion Committee) [5], groundwater chemical analysis is classified by taking the electrical conductivity (EC), dissolved solids (TDS), and Cl- content of samples into consideration. With this, the groundwater salinity levels in the research can be categorized into several levels: fresh, fresh-brackish, brackish, salt, and briny (connate) water [5].

Table 2. Classification of Groundwater Salinity Level (PAHIAA, 1986)

No	**Water Characteristic**	**TDS (mg/L)**	**EC (μS/cm)**	**Cl^- Content (mg/L)**
1	Fresh	<1,500	<1,500	<500
2	Fresh-brackish	1,000 - 3,000	1,500 – 5,000	200 – 2,000
3	Brackish	3,000 – 10,000	5,000 – 15,000	2,000 – 5,000
4	Salty	10,000 – 35,000	15,000 – 50,000	5,000 – 19,000
5	Briny (Connate)	>35,000	>50,000	>19,000

In groundwater quality observation at the study area (Table 2), several samples of groundwater from different aquifer depths were tested. The groundwater test samples are in depths of 96-99 m (2017) and 126-129 m (2015 and 2016). The results of the analysis are loaded into a table, as follows.

Table 3. Chemical / Physical Analysis at Kapuk Urban Village - West Jakarta, CAT Jakarta

No.	**Year**	**EC μ·S/cm**	**pH**	**Cl^- mg/L**	**TDS mg/L**
			6.5-8.5	**250.0**	**500**
1	2015	279	8.17	63.5	188
2	2016	215	8.74	41.6	144
3	2017	83	7.61	15.0	56

From the data, it can be known that aquifer in 122-126 m depth is fresh aquifer from the sample test in 126-129 m depth that is in same part of aquifer. In 94-100 m depth is known as fresh aquifer according to sample test in 96-99 m depth. Aquifer in 76-80 m depth is estimated as fresh aquifer based on the same result of resistivity and gamma ray value in 122-126 m and 94-100 m depths. Aquifer in 108-113 m depth is estimated as not fresh aquifer based on the difference in resistivity and gamma ray value in 122-126 m and 94-100 m depths that has known as fresh aquifer. According to the Ministry of Health (Table 4), these aquifers are also classified as fresh water that can be used for general purpose.

7. Conclusion

Based on the well logging and groundwater chemical analysis performed in Kapuk-Cengkareng, West Jakarta, it can be stated that:

1. Well logging investigations using three methods (spontaneous potential log, resistivity log, and gamma ray log) have been able to describe potential layers as aquifers, based on the physical properties of the rocks.

2. Layers that are identified as fresh aquifers lie at depths of 122-126m, 94-100m, and 76-80m based on the samples tested. Aquifers at 108-113m are estimated as not freshwater aquifers.

Knowing an aquifer's potential can be used as a guide in groundwater exploitation. It should be noted that land subsidence will happen along with water exploitation. Aquifers at depths of 76-80 m and 108-113 m need to be identified first before exploiting them.

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ATTACHMENT

Table 4. Chemical/Physical analysis from the water samples at Research Area

No.	Year	Depth	Location	Muddy NTU	Colour TCU	Smell	Taste	EC µS/cm	pH	Kes mg/L $CaCO_3$
Maximum allowed (492/MENKES/PER/IV/2010)				5.0	15.0	tb	tb		6.5-8.5	500.0
1	2015	150	Kelurahan Kapuk (Depan rumah dinas), Kec. Cengkareng - Jakarta Barat	293.8	0.0	tb	tb	279	8.17	97.4
2	2016	150	Kelurahan Kapuk (Depan rumah dinas), Kec. Cengkareng - Jakarta Barat	325.5	0.0	tb	basic	215	8.74	50.2
3	2017	150	Kelurahan Kapuk (Depan rumah dinas), Kec. Cengkareng - Jakarta Barat	44.2	2.0	tb	tb	83	7.61	28.3

Ca^{2+} mg/L	Mg^{2+} mg/L	Fe^{3+} mg/L	Mn^{2+} mg/L	K^+ mg/L	Na^+ mg/L	Li^+ mg/L	NH_4^+ mg/L	$CO_3^=$ mg/L	HCO_3^- mg/L	Cl^- mg/L	$SO_4^=$ mg/L	NO_2 mg/L	NO_3^- mg/L	TDS mg/L	Zn mg/L	Cu mg/L	Pb mg/L
		0.30	0.40		200		1.5			250.0	250.0	3.00	50.0	500	3	2	0.01
36.4	1.5	5.39	0.19	15.2	38.8	0.0	1.1	0.0	139.8	63.5	19.5	0.00	0.2	188	8.039	0.147	1.09
17.2	1.7	0.14	0.01	1.2	25.1	0.0	1.0	0.0	43.5	41.6	5.3	0.00	2.0	144	7.305	0.028	1.27
10.3	0.6	0.65	0.00	3.6	12.5	0.0	0.2	0.0	46.5	15.0	0.6	0.00	0.0	56	6.614	0.082	0.27