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Groundwater Potential in the Candi Abang Area Berbah, Sleman, Yogyakarta Based on Geological Conditions

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Abstract

Groundwater is one of the sources of community water needs. Technically, groundwater potential in each area depends on the abiotic components' condition, which are the providers, distributors, and groundwater storage. Groundwater providing, distributing, and storing media are strongly controlled by geological conditions that describe the potential presence of groundwater. The geological conditions of each area are different from one another, so it is important to conduct research on groundwater potential based on geological conditions as one of the basic steps to fulfillment community water needs. Candi Abang area is a hilly area with constituent rocks in the form of pyroclastic products, which make it difficult for groundwater to be stored in it. This condition is interesting to know the groundwater potential as the basis for the fulfillment of community water needs. Research on groundwater potential in the Candi Abang Area was carried out by mapping and direct measurement of geological components, including; landform, soil thickness, lithology, groundwater level depth, rock weathering level, and density of discontinuity fields. Then, analyzed with a weighting method based on the level of influence. The results of the weighting analysis obtained the level of groundwater potential in the Candi Abang area are very difficult, difficult, easy, and very easy.

Keywords: Groundwater Potential, Groundwater, Geology, Candi Abang

I. INTRODUCTION

Water resources are very important to fulfill the needs of all living things on earth. These water resources can be divided into three types based on their existence and origin, namely atmospheric water, surface water, and subsurface water or commonly known as groundwater. The use of groundwater to fulfill community needs, especially as a source of clean water, has advantages compared to other water sources. According to Travis (1977, in Sudarmadji, 1990), three advantages of using groundwater are relatively good quality, groundwater reserves are larger and easy to obtain in a simple way, and does not require storage and transmission lines to distribute it, so the cost is lower. It is estimated that 70% of the population's and 90% of industrial water needs come from groundwater (Direktorat Geologi Tata Lingkungan dan Kawasan Pertambangan, 2004).

Water infiltration below the earth's surface through saturated and unsaturated water systems (Kristanto et al., 2020). Saturated groundwater systems are underground water that is contained in a rock layer and is in a groundwater basin (Sadjab et al., 2012, in Kristanto et al., 2020). According to Undang – Undang Nomor 17 Tahun 2019 concerning Water Resources, a groundwater basin is an area limited by a hydrogeological boundary, where all hydrogeological events such as the process of recharging, draining, and discharging groundwater takes place.

The existence of groundwater, according to Todd (1980, in Adji et al., 2014), is found in soil or rock, occupies the spaces between grains of rock, and is in rock cracks. Rock formations that can store and conduct water in sufficient quantities are called aquifers (Todd, 1980; in Fetter, 1988). The nature of aquifers to be able to store groundwater is called porosity, while the nature of aquifers to conduct groundwater is called permeability (Todd, 1980; in Fetter, 1988). Aquifers can be grouped into three groups based on their constituent geological structure, namely unconfined aquifers, semi-confined aquifers, and confined aquifers (Todd, 1980; Fetter, 1988, in Santosa & Adji, 2006).

Aquifers can be formed through past processes with the rock characteristics of an area, which greatly influence the aquifer formation process and aquifer type (Santosa, 2002). The characteristics of the constituent rocks referred to are lithology and stratigraphy factors. According to Todd 1959 in Walton, 1970, important information in the evaluation of groundwater resources is in the form of lithology, geological structure, and stratigraphy. These three factors are commonly known as geological conditions. Understanding the geological conditions in an area is important to determine the potential for groundwater in an area.

Sleman District, which is included in the aquifer system of the Yogyakarta-Sleman Groundwater Basin, has unconfined and semi-unconfined aquifer types that form one main aquifer system (Hendrayana et al., 2013). This aquifer system is formed by the Yogyakarta Formation and the Sleman Formation, which is called the Merapi Aquifer System (SAM) (Hendrayana et al., 2013).

Candi Abang, which is included in the Berbah sub-District, Sleman District, has low groundwater potential. According to Hendrayana et al. (2013), Berbah sub-District is one of the sub-districts with a low percentage of groundwater reserves compared to the value of groundwater utilization. The low percentage in Berbah sub-District, especially Candi Abang, because they are composed of constituent rocks in the form of pyroclastic products in the landform of hills, so groundwater is very difficult to store in it. The pyroclastic products in Candi Abang in the form of tuff and lapilli are included in the Semilir Formation, which is deposited unconformity with the Merapi Muda Formation, which is composed of tuff and ash (Hidayat et al., 2017). Therefore, it is interesting to research groundwater potential as the basis for the fulfillment of community water needs in the Candi Abang Temple area, Sleman, Yogyakarta, based on existing geological conditions.

II. LITERATURE REVIEW

This research uses six parameters obtained from field data collection with weight and rate, which refers to the parameters and criteria for groundwater potential mapping and the scoring results according to Kristanto et al. (2020), according to the Table 1.

Table 1. Parameters and criteria for mapping groundwater potential and scoring results (Kristanto et al., 2020)

Parameter	Sub-Parameter	Category	Rate	Weighted Value	Score
Rock Units	Sandstone Polymict Sand – Gravel Deposits	Very Good Aquifer	4	0,241	0,965
	Breccia and Conglomerate Clastic Limestone Polymict Sand – Silt Deposits Monomict Fine Sand – Clay Deposits	Good Aquifer	3		0,724
	Siltstone Lapili Nonclastic Limestone Monomict Clay – Medium Sand Deposits	Poorly Aquifer	2		0,483
	Igneous Rock Tuff Claystone	Very Poorly Aquifer	1		0,241
Landform	Flat	Very Good Catch Zone	4	0,138	0,553
	Almost Flat Valley	Good Catch Zone	3		0,415
	Ridge Hills Hill	Medium Catch Zone	2		0,276
	Highlands Steep Slopes	Poorly Catch Zone	1		0,138
Groundwater Level Depth	0 – 10,99	Shallow	4	0,110	0,441
	11 – 14,99	Medium	3		0,331
	15 – 20	Deep	2		0,220
	> 20	Very Deep	1		0,110
Soil Thickness	> 3	Very Thick	4	0,079	0,315
	2 – 2,99	Thick	3		0,237
	1 – 1,99	Thin	2		0,158
	0 – 0,99	Very Thin	1		0,079
Rock Weathering Level	Changed Physical >50%	High	4	0,216	0,863
	Changed Physical 25 – 50%	Medium	3		0,647
	Changed Color and Physical <25%	Low	2		0,431
	Fresh – Color Change on Surface	Very Low	1		0,216
Density of Discontinuity Fields	Nothing Joint	Very Low	4	0,216	0,863
	1 – 3/meter	Low	3		0,647
	3 – 10/meter	Medium	2		0,431
	> 10/meter	High	1		0,216

The weighting of the criteria carried out is then included in the groundwater potential classification and groundwater availability, according to Kristanto et al. (2020), according to Table 2.

Table 2. Groundwater potential classification and groundwater availability (Kristanto et al., 2020)

Class	Interval	Criteria
4	> 3,00	High groundwater potential (very easy groundwater)
3	2.50 – 3,00	Medium groundwater potential (easy groundwater)
2	2,00 – 2,50	Low groundwater potential (difficult groundwater)
1	< 2,00	Very low groundwater potential (very difficult groundwater)

The relationship between several parameters used with the classification of groundwater potential and groundwater availability in this study refers to the classification and criteria for groundwater potential and groundwater availability, according to Kristanto et al. (2020), according to Table 3.

Table 3. Classification and criteria for groundwater potential and groundwater availability

Groundwater Potential Classification	Criteria						Groundwater Availability
	Landform	Soil Thickness	Rock Units	Groundwater Level Depth	Rock Weathering Level	Density of Discontinuity Fields	
High	Flat, Valley, Almost Flat	Very Thick, Thick	Sandstone, Breccia, Conglomerate, Polymict Sand–Gravel Deposits	Shallow, Shallow-Medium	Changed Physical >50%	> 10/meter	Very Easy Groundwater
Medium	Almost Flat, Valley, Ridge, Hills, Hill	Thick	Breccia, Conglomerate, Clastic Limestone, Polymict Sand–Silt Deposits	Medium, Medium-Deep	Changed Physical 25–50%, Changed Physical >50%	3–10/meter, >10/meter	Easy Groundwater
Low	Ridge, Hills, Hill	Thin	Siltstone, Lapili, Nonclastic Limestone, Monomict Fine Sand–Clay Deposits Monomict Clay–Medium	Deep	Changed Color and Physical <25%, Changed Physical 25–50%,	1-3/meter, 3-10/meter	Difficult Groundwater
Very Low	Highland s, Steep Slopes	Very Thin	Sand Deposits, Igneous Rock, Tuff, Claystone	Very Deep	Fresh – Color Change on Surface	Nothing Joint	Very Difficult Groundwater

III. RESEARCH METHODOLOGY

The research method applied in this research is the descriptive-analytic method. The analytical descriptive research method is carried out by describing or giving an overview of the situation in the field, then conducting analysis in the laboratory to complement the data obtained in the field. The analytical descriptive research method has several stages of research. In this case, the research stages used in this research are the preparation stage, the collecting data stage, the data analysis stage, and the presentation of the data stage. Several stages of this research are briefly illustrated in the research flow diagram in Figure 1.

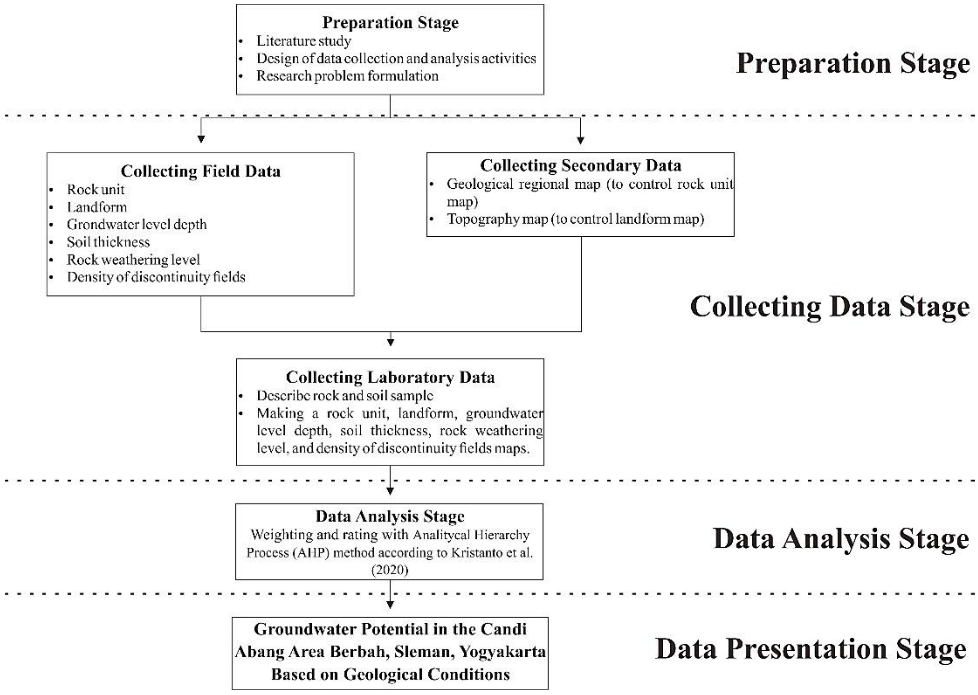

Figure 1. Research flow diagram

The preparation stage was carried out before collecting field data. This preparation stage includes a literature study and design of data collection and analysis activities. In addition, the research problem formulation is carried out at this stage. In this case, the formulation of the problem in this research is the low groundwater potential in the area of Candi Abang, Berbah, Sleman, Yogyakarta because the constituent rocks are pyroclastic products.

The collecting data stage is in the form of rock unit data collection, landform, groundwater level depth, soil thickness, rock weathering level, and density of discontinuity fields. Collecting rock unit data is intended to determine the constituent rocks at the research location related to the ability to store and conduct water. Collecting landform data is intended to determine the topography and morphology of the research location. Changes in surface topography affect the depth of the groundwater level and the direction of the groundwater movement (Adji et al., 2014). Collecting groundwater level depth data is intended to determine the direction of groundwater flow and provide an overview of the process of groundwater utilization. Collecting soil thickness data is intended to determine the potential for storing and infiltrating rainwater in aquifers (Sunarwan, 2014). The thicker the soil layer, the greater potential to store and infiltrate water into the aquifer. Collecting rock weathering level data is intended to determine the ability of rocks to store and conduct water. The higher the level of rock weathering, the greater the water content, porosity, and void ratio (Rahman et al., 2017). Collecting density of discontinuity field data is intended to determine the presence of secondary porosity as an aquifer that develops in the research location.

The data analysis stage used in this research is weighting and rating, which refers to the method proposed by Saaty in 1977 in the form of the Analytical Hierarchy Process (AHP) method. The AHP method is a weighting of the criteria by combining several criteria through a comparison matrix so that the value obtained by each criterion can be determined (Pandega & Hastuti, 2019).

Based on the relationship between several parameters used according to the classification and criteria for groundwater potential and groundwater availability, according to Kristanto et al. (2020), an area can be grouped into areas with high groundwater potential, areas with medium groundwater potential, areas with low groundwater potential, and areas with very low groundwater potential. The detailed character of each class group can be seen in Table 3.

IV. FINDING AND DISCUSSION

Research on groundwater potential based on geological conditions is carried out by collecting data directly in the field, in the form of rock unit data, landform, groundwater level depth, soil thickness, rock weathering level, and density of discontinuity fields.

IV.1. Rock Unit

The rock units in the research location are six types of rock units. These rock units were obtained based on direct mapping in the field. Lapilli rock units are in areas with high topography, then further down followed by tuff rock units, polymict sand-gravel deposits, polymict sand-silt deposits, monument fine sand-clay deposits, and monomict clay-medium sand deposits. Therefore, according to Figure 2, it can be seen that the distribution of these rock units follows the topographic control. In this case, rock units have an influence on the groundwater potential in the research location, where the greater the porosity and permeability of the rock, the greater the groundwater potential. Tuff and lapilli include in the very poorly aquifer category; monomict clay-medium sand deposits are categorized as poorly aquifers, monomict fine sand-clay, and polymict sand-silt deposits are in the good aquifer category, and polymict sand-gravel deposits are included in the very good aquifer category.

IV.2. Landform

There are seven landforms in the research location. This landform is obtained based on topographic map analysis. Hills, plains, plateaus, slopes, valleys, slopes, and ridges are some of the landforms found in the research location (Figure 3). In this case, the landform has an influence on the groundwater potential in the research location, where areas with flat morphology store more water than areas with steep morphology. Due, water will flow quickly in areas with steep morphology. Highlands slopes are categorized as poor catch zones, hill, hills, and ridges are categorized as moderate catch zones, almost flat and valleys are categorized as good catch zones, and plains are categorized as very good catch zones.

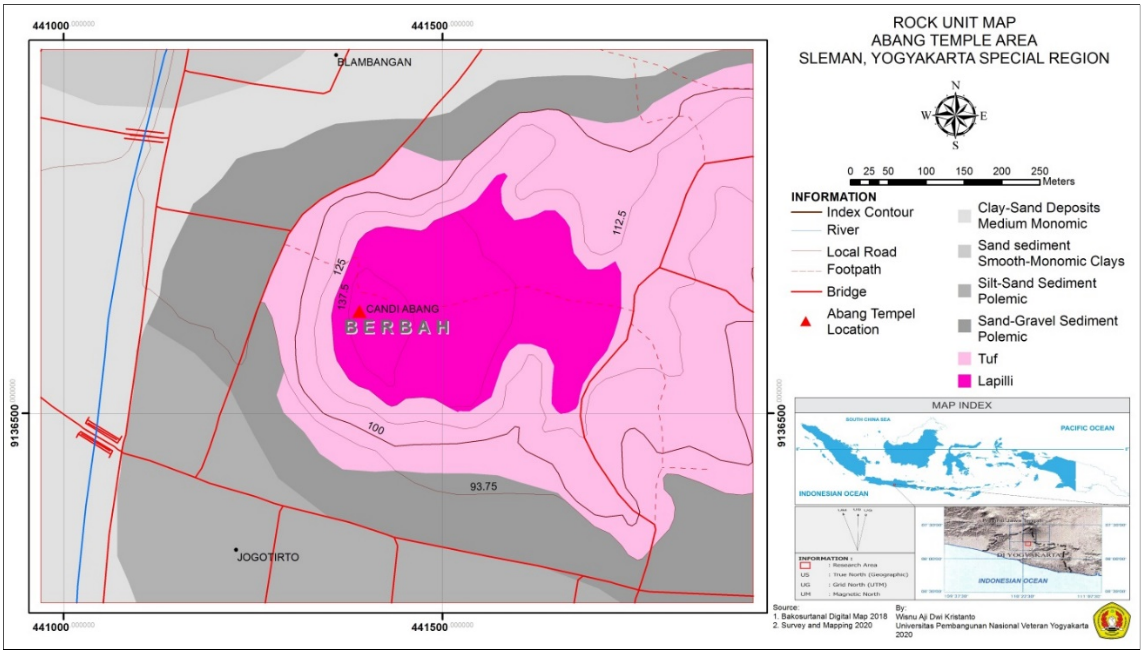

Figure 1. Map of the rock units in the Candi Abang area

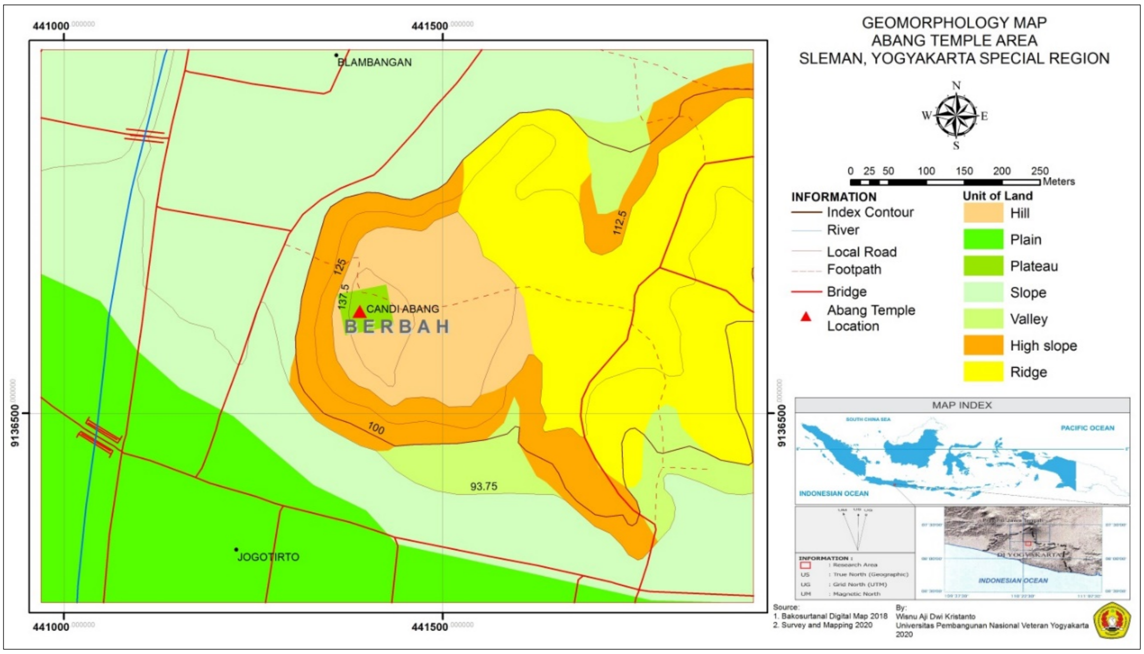

Figure 2. Map of the landform in the Candi Abang area

IV.3. Groundwater Level Depth

There are two kinds of groundwater level depth in the research location. The groundwater level depth is obtained based on the mapping of the groundwater level directly in the field using dug well data. In this case, by using groundwater level depth data, groundwater flow direction can be identified and provides an overview of the process of groundwater utilization. Areas with high topography have a groundwater level depth of >3 meters, while areas with low topography have a groundwater level depth of 1-3 meters (Figure 4). Therefore, the groundwater flow in the study area spreads to the plains.

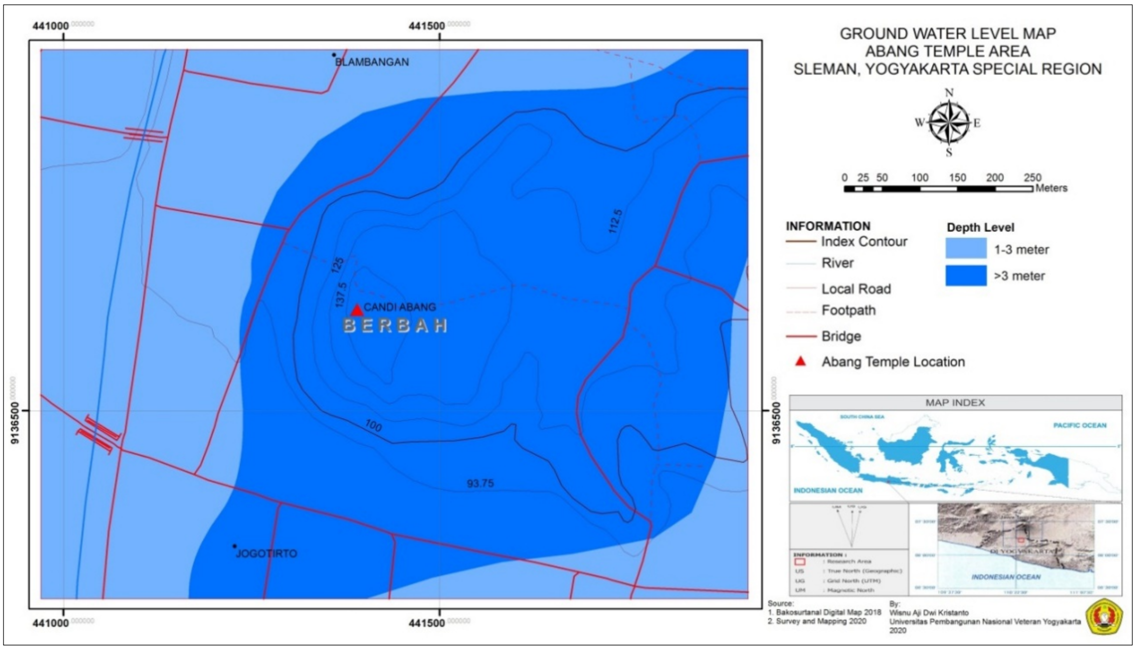

Figure 3. Map of the groundwater level depth in the Candi Abang area

IV.4.Soil Thickness

The soil thickness in the research location is four types of soil thickness. This soil thickness is obtained based on direct field surveys. <1 meter, 1-2 meter, 2-3 meter, and >3 meter is the variation in soil thickness in the research location (Figure 5). In this case, soil thickness has an influence on the groundwater potential in the research location, where areas with thick soil thickness are better at storing and infiltrating rainwater in aquifers.

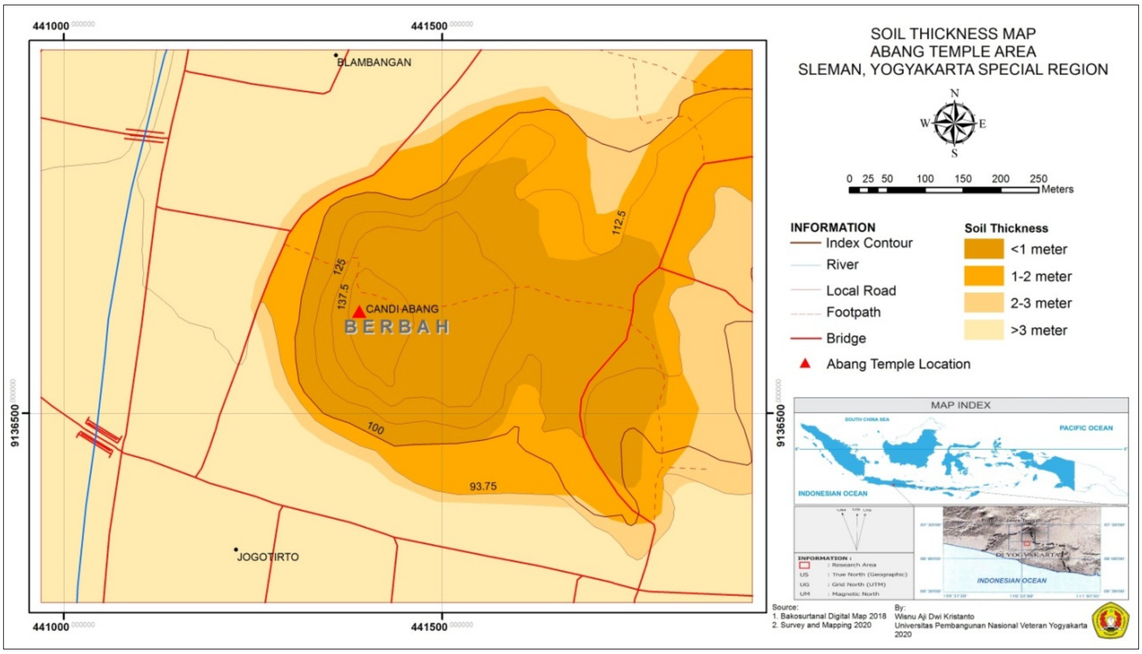

Figure 4. Map of the soil thickness in the Candi Abang area

IV.5. Rock Weathering Level

The level of rock weathering in the research location is four levels of rock weathering. The level of rock weathering is obtained based on direct surveys in the field. Low, moderate, extreme, and soil weathering levels are variations in the level of rock weathering found in the research location (Figure 6).

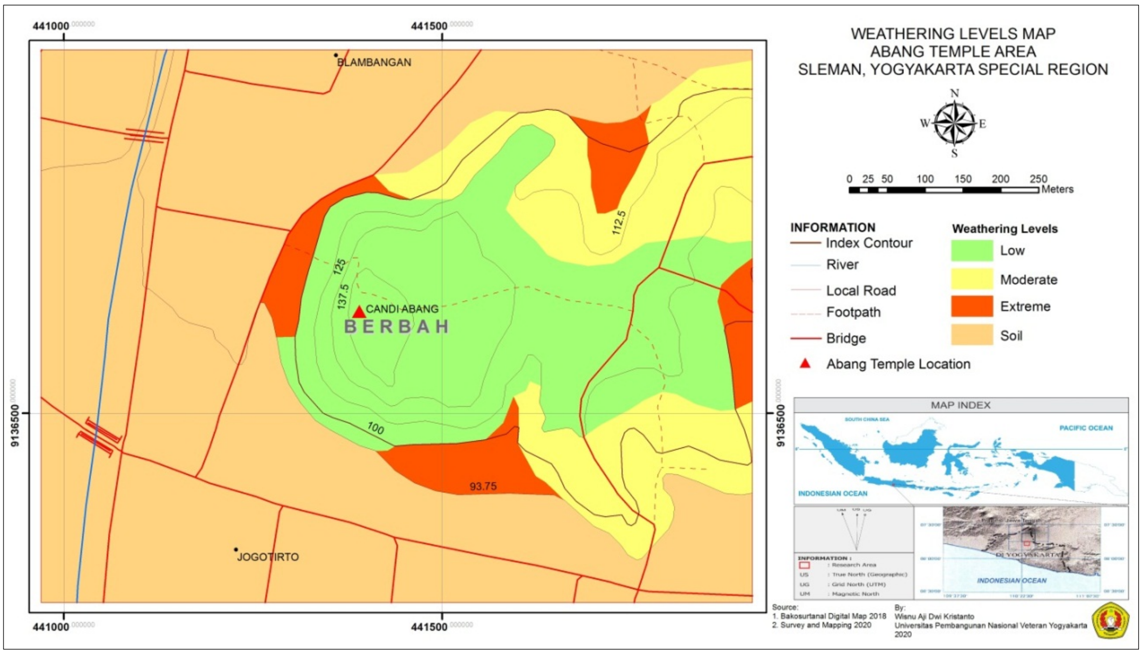

Figure 5. Map of the rock weathering level in the Candi Abang area

IV.6. Discontinuity Plane Density

The discontinuity plane density found in the research location is of four classes. Discontinuity plane density is obtained based on direct measurements in the field. 1-3/meter, 3-10/meter, >10/meter, and >10/meter (soil) are several classes of discontinuity plane density in the research location (Figure 7). In this case, the discontinuity plane density has an influence on the groundwater potential in the research location, where the more discontinuity plane density will make secondary porosity develop in the research location.

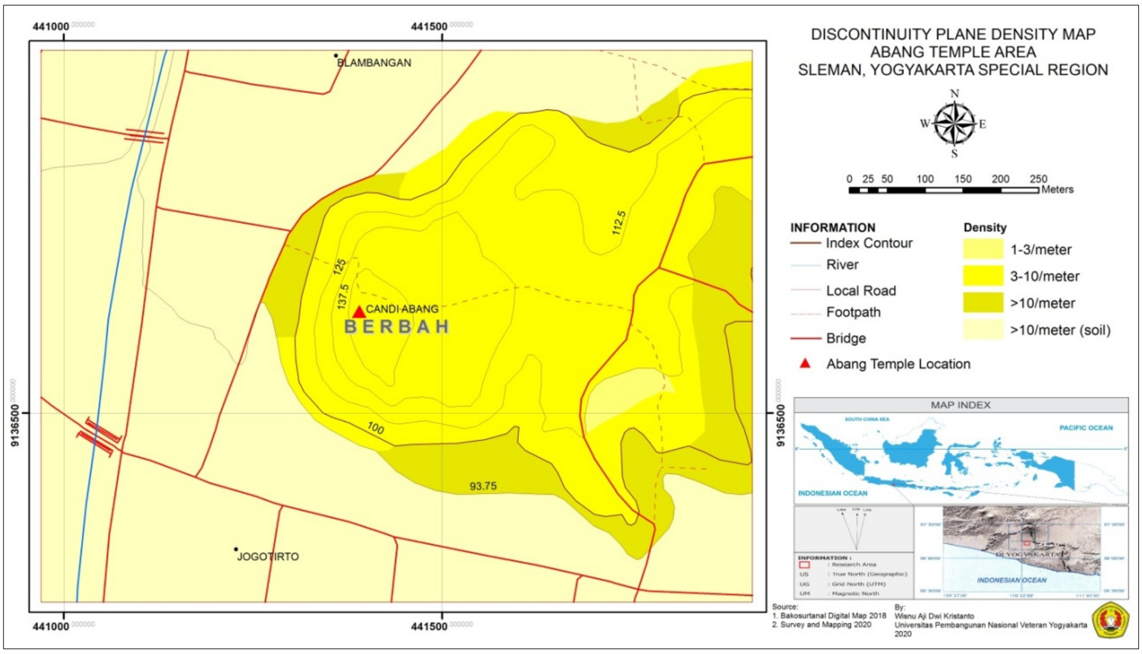

Figure 6. Map of the discontinuity plane density in the Candi Abang area

IV.7. Groundwater Potential and Groundwater Availability Area

Rating and weighting of several parameters, such as rock units, landform, groundwater level depth, soil thickness, rock weathering level, and density of discontinuity fields, produce a map of groundwater potential in the area of Candi Abang, Berbah, Sleman, Yogyakarta (Figure 8).

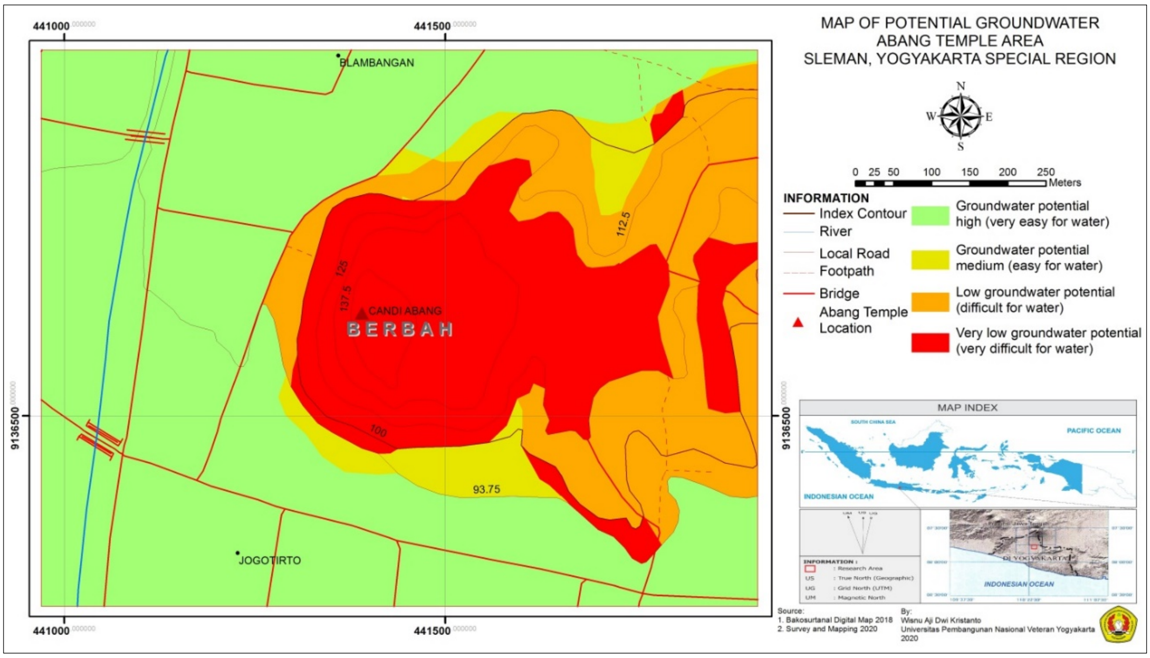

Figure 7. Map of the groundwater potential and groundwater availability in the Candi Abang area

This groundwater potential map illustrates the area of Candi Abang divided into four zones of groundwater potential, namely very easy groundwater, easy groundwater, difficult groundwater, and very difficult groundwater. The characteristics of each potential groundwater zone in the Candi Abang area are as follows:

a. The very difficult groundwater zone has an area of about 22% of the research location. The majority of this zone is in the middle of the research location, precisely at the top of Candi Abang. This very difficult groundwater zone is influenced by the presence of constituent rocks in the form of tuff and lapilli, which are rocks that have poorly to very poorly aquifer capabilities. In addition, the landform in the form of hills, highlands, and slopes is another factor that affects the groundwater potential in this zone. The tuff and lapilli rock units with hills, highlands, and slopes landforms will cause groundwater in this zone to flow to areas with lower topography. The constituent rocks in this zone are still very fresh, so the thickness of the soil formed is very thin. Therefore, the ability of this zone to store and conduct groundwater is very small, so the potential groundwater is very low. With this very low groundwater potential, it can be interpreted that groundwater availability in this zone is very difficult.

b. The difficult groundwater zone has an area of about 18% of the research location. This zone is in the lower topography of the very difficult groundwater zone. This zone has tuff and lapilli constituent rocks with slopes and ridges landform. The existing tuff and lapilli have the ability to store and escape groundwater poorly, coupled with the shape of slopes and ridges, making groundwater flow in lower topography areas. This can be proven by the groundwater level depth in this zone, which is more than >3 meters. However, with the rock weathering rate included in the low category with a soil thickness of 1-2 meters, groundwater is still stored in this zone, although measly. Therefore, this zone is included in a zone with low groundwater potential so that it can be interpreted as a difficult groundwater zone.

c. The easy groundwater zone has an area of about 5% of the research location. This zone has constituent rocks that are dominated by polymict sand-gravel deposits, which, of course, have the ability to store and conduct water goes well. In addition, valley landform dominates in this zone, so that groundwater comes from higher topography will flow into this zone. The extreme level of weathering causes the thickness of the soil formed in this zone to reach 2-3 meters, so that surface water infiltration takes place goes well. Therefore, the groundwater potential in the zone is moderate, so it can be interpreted that this zone has easy groundwater availability.

d. The very easy groundwater zone has an area of about 55% of the research location; in other words, this zone dominates in the research location. This zone is dominated by flat and almost flat landform, so groundwater comes from zones with higher topography that will accumulate in this zone. The rock units in this zone are deposits that have not been fully compacted, so they have the ability to store and conduct water properly. In addition, this zone is composed of soil which has a thickness of >3 meters with a density of discontinuity fields >10/meter. The groundwater level depth is only 1-3 meters, which will make it easier for the people in this zone to make use of it. Therefore, this zone has high groundwater potential, so that it is included in the very easy groundwater zone.

V. CONCLUSION AND FURTHER RESEARCH

Based on field data such as rock unit, landform, groundwater level depth, soil thickness, rock weathering level, and density of discontinuity fields, then analyzed using the AHP method, the areas of Candi Abang, Berbah, Sleman, Yogyakarta can be grouped into four groundwater potential zone and groundwater availability. The zones obtained are the very difficult groundwater zone, the difficult groundwater zone, the easy groundwater zone, and the very easy groundwater zone. Very easy groundwater zones in areas with low topography dominate the research location. Meanwhile, the very difficult groundwater zone is in an area with high topography, precisely at the top of Candi Abang. Therefore, the suggestion that the author gives to solve the problem of community groundwater difficulties in areas with high topography is to take water from areas that have a lower topography. Groundwater, which can be sourced from dug wells and boreholes, is then flowed with pipes to reach people who are in high topography and still have water difficulties. In addition, this zone grouping can be used as a reference in fulfillment of community water needs in the area of Candi Abang, Berbah, Sleman, Yogyakarta.

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