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PHYSICAL WATER QUALITY RESPONSE TO RAINFALL OF BETON KARST SPRING AT GUNUNGKIDUL REGENCY - YOGYAKARTA INDONESIA

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ABSTRACT

Beton karst spring is located in the Ponjong sub District Gunungkidul Regency, at the western part of Bribin undergorund river catchment area. The purpose of this study are: 1) to know the variations of rainfall and discharge in the research area, 2) to know the characteristics of the physical water quality of Beton spring and 3) to determine the relationship between the variations of the rainfall toward the discharge and the physical water quality of Beton spring. This study uses survey methods and the techniques of data collection using sample by purposive sampling. The variables are rainfall (the depth and intensity), spring discharge and physical water quality of spring (EC, T, TDS, turbidity). The data analysis is conducted graphically and descriptively to explain the relationship between the variations of rainfall to the discharge and physical water quality of spring. The results show the rainfall has variations include the pattern, events and the amount of rainfall. Beton spring has high discharge variations. The physical water quality of the spring meets to the water quality standards according to the Government Regulation number 82 years 2001. The strong correlation between rainfall variations to the discharge and the physical water quality of Beton spring can be seen clearly. It is reflected from the high value of R^2.

Key words: springs, rainfall, discharge, water quality, response

ABSTRAK

Mataair karst Beton terletak di Kecamatan Ponjong Kabupaten Gunungkidul, di bagian barat Daerah Tangkapan Air Sungai Bawah Tanah Bribin. Tujuan penelitian ini adalah: 1) untuk mengetahui variasi curah hujan dan debit di daerah penelitian, 2) mengetahui karakteristik kualitas air fisik Beton dan 3) untuk menentukan hubungan antara variasi curah *hujan terhadap debit dan kualitas air fisik mataair Beton. Penelitian ini menggunakan metode survei dan teknik pengumpulan data menggunakan sampel dengan purposive sampling. Variabel penelitian adalah curah hujan (jumlah dan intensitas), debit mataair dan kualitas fisik air mataair (EC, T, TDS, kekeruhan). Analisis data dilakukan secara grafik dan deskriptif. Hasil penelitian menunjukkan terdapat variasi curah hujan termasuk pola, kejadian dan jumlah curah hujan. Mataair Beton memiliki variasi debit tinggi. Kualitas fisik air memenuhi standar mutu air sesuai dengan Peraturan Pemerintah Nomor 82 tahun 2001. Korelasi kuat antara variasi curah hujan, debit dan kualitas fisik air mataair Beton dapat terlihat jelas.*

Kata kunci: mata air, curah hujan, debit, kualitas air, respon

INTRODUCTION

Karst is an area that has unique characteristics in geomorphology and hydrology. *Ford* and *Williams* [1989] defines karst as a field with the characteristics of karst hydrology and landforms which are caused by a combination of rock dissolving easily and having a well-developed secondary porosity. Some factors that characterize karst are: the presence of closed valleys which have various sizes and shapes, absence or scarcity of surface drainage or river, and the presence of caves of the underground drainage system [*Summerfield*, 1991].

On the other hand, karst aquifers are particularly vulnerable to contamination due to thin soil, the flow concentration within epikarst, and concentrated recharge through sink holes. As a result, contaminants may easily reach the groundwater and be rapidly transported in karst conduits over large distances [*Goldscheider*, 2005]. Therefore, it needs good management to protect groundwater from contamination. One of the important efforts to protect the karst groundwater is zoning of groundwater vulnerability to contamination. Although making zoning in karst area more difficult than in porous media because of aquifer heterogeneous and anisotropic.

This research related closely to the groundwater vulnerability to contamination. The main purpose is to study the response of the system to the rain and its effect on physical water quality of Beton spring. The spring is suspected a leak of Bribin underground river, located on the west side of the Bribin underground river watershed. Therefore, the dynamics of water quality change on Beton spring can indicate the travel time effect of the rainfall in the karst systems. The velocity of travel time also can indicate the development of flow system in the karst areas, especially in some research areas.

Referring to the definition of karst, the most important process within is dissolution which the main driving factor is the air and the water contained in the limestones [*Sweeting*, 1972]. Limestone has a water-soluble nature of many that contained carbon dioxide. The existence of this dissolution process causes the water fill the dissolution cavities. *Todd* [1980] defines groundwater as the water that fills the pores between rocks dynamically. The dynamic nature causes the groundwater moving and could come to the surface as springs. The appearance of these springs can occur due to cutting the topography, the force of gravitation and geological structure. In general, springs coming out of the karst aquifer mainly at the cavities as a dissolution result on the surface or subsurface [*White*, 1988].

In general, karst aquifer hydrological systems can be divided into two, namely: diffuse and conduit flow system [*White*, 1988]. Both of these aquifers will show the activity differences of dissolution and velocity of flow, the first one is slow and another is fast. Spring hydrograph is useful to describe the flow system in the karst aquifer. This was confirmed by *White* [1993] that the characteristic of the karst underground river is unique, ie. rapid response to the external variations (rainfall, temperature, even though soil and plant activities). Karst aquifer system is dominated by the allogenic recharge and if its karstification process has been well developed which characterized by the conduit passage, it will have a very rapid response to rain; and vice versa.

The rain enters to the karst aquifer system hydrochemically under saturated to the carbonate rocks. It is still quite aggressive to dissolve the carbonate rock. Furthermore, in karst aquifers, rain water will be reacting to the carbonate rocks and raise the saturation index and decreases the force of solubility to the equilibrium point. The equilibrium will be reached within 10 days and can be compared to the length time of the moving rain water from the springs input [*White*, 1993]. The chemical composition of springs can fluctuate depending on the variation of discharge, rainfall and other activities in the catchment area [*Haryono and Adji*, 2004]. Through the chemograph analysis will be known the relation between rainfall even variation and discharge.

Based on direct observation in the field can be seen that Beton spring show a very different response after the rainfall even. Beton spring will look turbid shortly after rainfall even. Refer to those observations, the aims of the research determine: 1) the rainfall and spring discharge variations, 3) the characteristics of the physical water quality of Beton spring and, 4) the relationship between rainfall variation, spring discharge and physical water quality of Beton spring.

THE METHODS

Material

The object of the study is Beton spring water. The sampling frequency of water springs is conducted for 1 year and based on the season. Through the long period of measured data, it can be analyzed the response of the spring discharge and physical water quality to the rainfall. In the rainy season, water samples four times each month; in the transitional period between the rainy and dry seasons is taken twice per month, and during the dry season is taken once every month. Thus, it can be expected that the spring water samples represented the discharge fluctuation at the high, medium and low rate.

The main material this study is a sample of water. In addition several thematic maps supported are the Topographical Map scale 1: 25,000, Geological Map scale 1: 100,000, Hydrogeology Map 1: 250,000, and Landuse Map scale 1: 25,000. The variables that are examined include rainfall, spring flow and physical water quality. The rainfall data includes rainfall number and intensity; the spring flow includes water level and discharge, while physical water quality includes *EC* (Electrical Conductivity),T (Temperature), *TDS* Total Dissolved Solid), and Turbidity.

Method

The research equipments are for field tools, hardware and software for analysis. Some field equipment to measurements perform of several parameters, such as: GPS, roll meter, Hobo Water Level Data Logger, Mini Station Data Logger, current meter, EC meter, bottle samples, a camera, a set of computer. The field survey includes the rainfall thickness, spring water level, spring discharge and physical water quality (*EC*, and *T*), while the laboratory analyzed samples are *TDS* and turbidity.

Principally, the processing and analyzing set of data is in order to study the response of discharge and physical water quality of spring to the rainfall by using the EC, T, TDS, and turbidity. The main analysis is as follow.

1. **Correlation and Regression Analysis** between water level and measurable spring discharge to make Stage Discharge Rating Curve.
2. **Hydrograph Analysis**. The kind of hydrographs are stage hydrograph, discharge hydrograph) in one year of measurement.
3. **Chemograph Analysis** is to find out the variation of physical spring water quality measurements associated with rainfall events, spring discharge, so it can be seen the physical spring water quality response to the rainfall.
4. **Rainfall Data Analysis – Discharge Data – Physical Water Quality**, the analysis is done by matching the heavy rain (hourly, daily, monthly) and discharge rate variations of the spring (hydrograph), and physical water quality of spring (chemograph) so that it can be known the response of spring discharge to the rainfall.

The results of data analysis further are described graphically to determine the relationship between the spring discharge variations and physical water quality of springs to the rainfall variation. Then, it can be determined internal system of karst aquifer.

RESULT AND DISCUSSION

Research Area

Beton karst spring is located in the Ponjong sub District Gunungkidul Regency, at the western part and the upper of Bribin undergorund river catchment area (Figure 1).

It is suspected a leak of Bribin catchment area. Therefore, the research becomes an important as part of the validation step on the groundwater vulnerability assessment. The research is a part of a big research (PhD research), in the term of vulnerability assessment. Therefore, the data collection started when the PhD research began. The response of physical spring water quality to the rainfall indicates the velocity of pollutants to reach the subsurface system. Beton spring is one of the springs that occurred in the Bribin underground river watershed.

Rainfall Variation

The research is a small part of the PhD research. The data collecting started from year 2008. Rainfall monitoring station (logger) located in Tambakromo. Data recording rain is for a year in 2008 and 30 minutes duration. The results of the rainfall measurements are shown in the Figure 2.

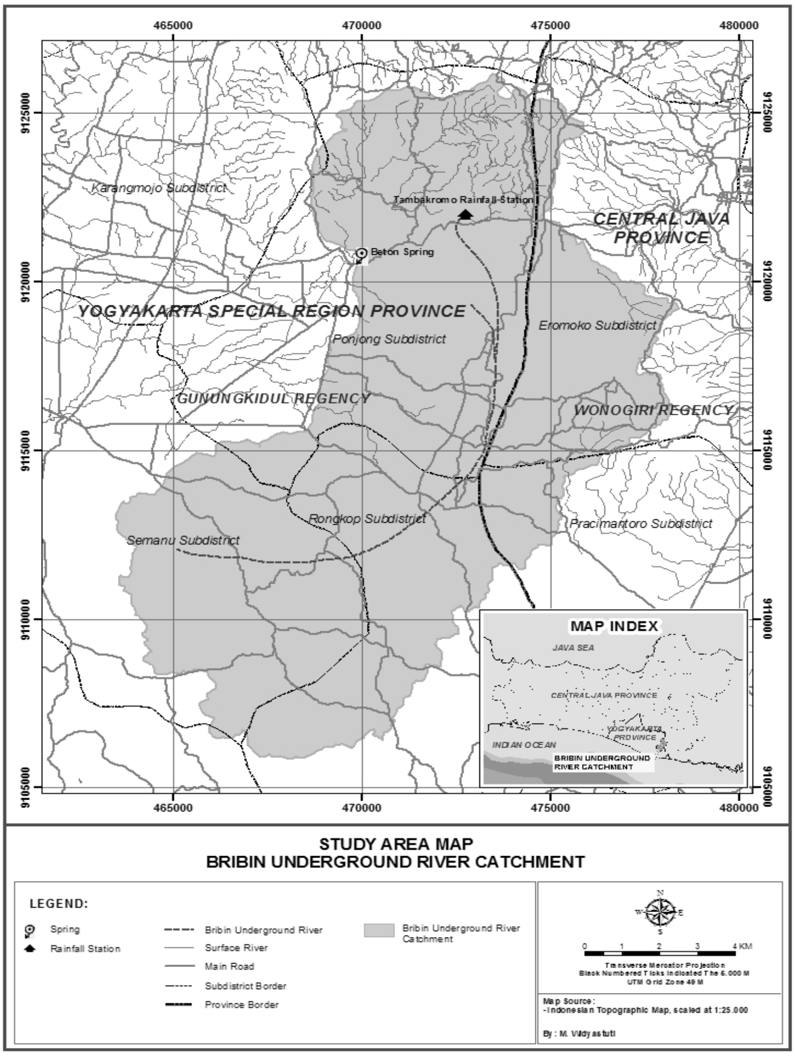

Figure 1. Research Area Map

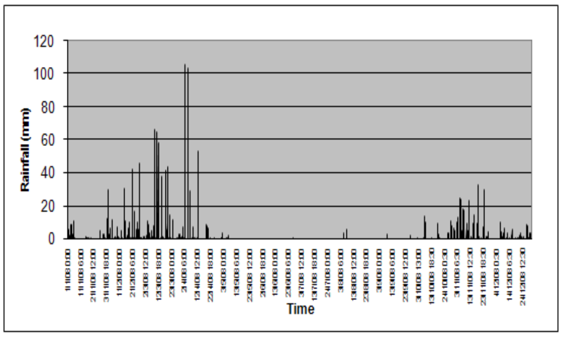

Figure 2. Rainfall Graph of Tambakromo Monitoring Station

The rainfall pattern showed the rainfall peak occurs in March-April. The rainfall thickness in March-April period exceeds 100 mm. The position of the Tambakromo station is at the upper of Bribin underground river watershed. During the observations in a year, the number of rainfall that occurs at the upper of watershed is more than the other stations which located at the downstream. The amount of rainfall in a year at Tambakromo station is 3332 mm, the number of rainy days is 156 to 1426 events every 30 minutes.

Discharge Variation of Beton Spring

The discharge data of Beton spring are measured for a year. The discharge measurements are done using current meter instrument. The results showed the highest flow (5.55 m^3/sec) occurs in the mid of March year 2008, at the 1.08 m of water level. While the lowest of discharge is 0.1 m^3/sec at 0.25 of water level occurs in November 2008. Initial installation of the water level logger equipment is in January 2008 and the data recorded from 19 January to 31 December 2008. Using a pair of data between the water level and the discharge can be obtained their re-lationship in rating curve (Figure 3). The best relationships which generated from the pair data pair does not always linear but in curves. The best equation of the correlation between water level and discharge of Beton spring is a curve i.e. $y = 4802.4x^{2.4953}$ and the value of $R^2 = 0.9717$.

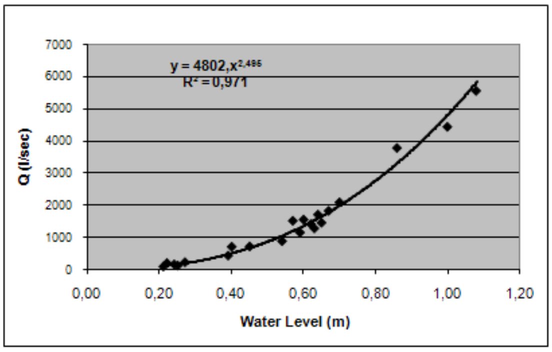

Figure 3. *Rating Curve* Mataair Beton

Physical Water Quality of Beton Spring

The analysis of physical spring water quality includes *T*, *EC*, *TDS* and turbidity. Quality standard referred to the Water Quality Standard of Government Regulation Number 82 year 2001 about Water Quality Management and Water Pollution Control, especially Class I water for drinking water. Overall sampling measurement is done 25 times for a year 2008.

Temperature

The temperature of the water body is influenced by many factors i.e. season, latitude altitude, time, air circulation, cloud cover, flow, and water depth [*Effendi*, 2003]. Temperature changes influence the processes that occur in water, such as the physics, chemistry and biology. The deviation of water temperature indicates the water pollution. Based on the direct field measurements of temperature fluctuations can be known Beton spring generally has a normal temperature of water. Temperature range is between 25 and 27.8 ºC. The difference of the temperature range is influenced by season and time of measurement. The measurement activities is conducted a year to cover two seasons namely the rainy and dry seasons, while the time measurement is in morning until noon.

Electrical Conductivity (*EC*)

Electrical Conductivity (*EC*) shows the number concentration of ions contained in water or a numerical illustration of the ability of water to continue the flow of electricity [*Effendi*, 2003]. Therefore, the higher the salt dissolved, the higher the value of *EC*. In addition to ion concentration, the temperature is also affected by EC. Both of them have positive correlation, which *EC* will increase if the value of water temperature increases. The results indicate that the value of EC's range from 200-528 μ mhos/cm. The value of spring *EC* fluctuate, the difference of water level of Beton spring is very strict. The range of *EC* value indicates the normal value. The low value of *EC* is affected by the rainy condition when the samples are taken.

Total Dissolved Solid (TDS)

Total dissolved solids (*TDS*) is dissolved materials (diameter <10-6 mm) and colloidal (diameter 10-6 - 10-3 mm) in the form of chemical compounds and other materials that are not filtered on filter paper in diameter 0.45 μ m *Rao*, [1992] in [*Effendi*, 2003]. *TDS* is usually caused by inorganic ions material where found in the waters. The laboratory analysis showed some samples (samples 2, 3, and 7) has a high *TDS* value i.e. exceed the threshold (1000 mg / l). When the *TDS* value is high, it does not always turbid water conditions, for example sample number 3 and 7. The *TDS* value meets to the water quality standards.

Turbidity

Turbidity indicates the optical properties of water which determined by the amount of light absorbed and emitted by the materials within the water. Turbidity is caused by the presence of organic and in-organic materials that are suspended and dissolved, and the organic and inorganic materials as plankton and other micro-organism *Davis* and *Cornwell*, [1991] in [*Effendi*, 2003]. Total Suspended Solid (*TSS*) has a positive correlation with turbidity, but the value of *TDS* does not always followed by the high turbidity. Fluctuation values occur in the period of January to March 2008, further the value is relatively stable until the end of December. Beton spring has a high turbidity value. When the rainfall occurs, then in the short the spring water became turbid. The highest turbidity value is 63 *NTU*.

The Correlation between Rainfall Variation, Discharge and Physical Water Quality of Beton Spring Rainfall and Spring Discharge Correlation

Based on Figure 4 can be seen that each rain event followed by discharge springs increasingly. This fact is found also in the field; at the time of discharge measu-rements after rainfall events directly there is an increase discharge springs. Travel ti-me for Beton springs shortly after rain events (hours - daily). The location of rainfall stations and Beton springs is so closed and the position of Tambakromo station is at the upper of Beton spring.

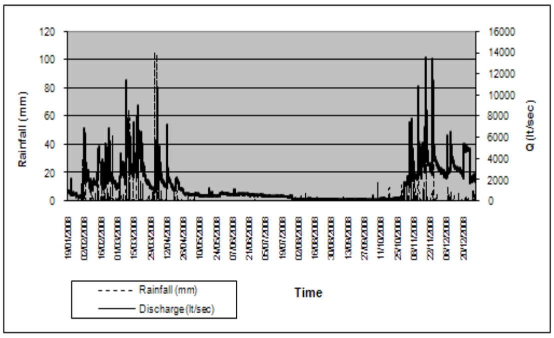

Figure 4. Rainfall and Discharge Correlation of Beton Spring

Discharge and Physical Water Quality Correlation

Spring water sampling is taken when the discharge measurements performed for a year. Based on the discharge and spring water quality, it can be made a curve that shows a relationship between discharge and water quality. The correlation does not is not always positive (discharge increase followed by the levels of elements an increase) and vise versa. The correlation between discharge and the physical water quality of Beton Spring can be seen in Figure 5. The high value of R^2 indicates strong correlation among variables. It is proved by correlation between discharge and physical water quality. Each R^2 value for that relationship is as follow: 0.868 for discharge to *EC*, 0.851 for discharge to T, 0.607 for discharge to *TDS*, and 0.936 for discharge to turbidity. The correlation of *EC*, *T* and discharge show a negative relationship. That means that the higher discharge will follow by the decreasing value of *EC* and *T*. The *EC* value of groundwater is higher than the surface water. Through the increasing of water input from the rain water, it will reduce the *EC* value.

The chart Figure 5 shows this condition, as well as discharge to the *T* value. In contrast correlation discharge to *TDS* and turbidity has a positive relationship. It means that the higher the discharge will follow by the higher value of *TDS* and turbidity. This fact is very clearly seen in the field after the rain event it will directly visible turbid water of Beton spring. Actually, the high *TDS* value does not always correlate with turbidity, but relate to *EC*. Both of them have a positive correlation, the higher *EC* value will be followed by the higher *TDS* value. The correlation between discharge and turbidity is stronger than the relationship between discharge and *TDS*.

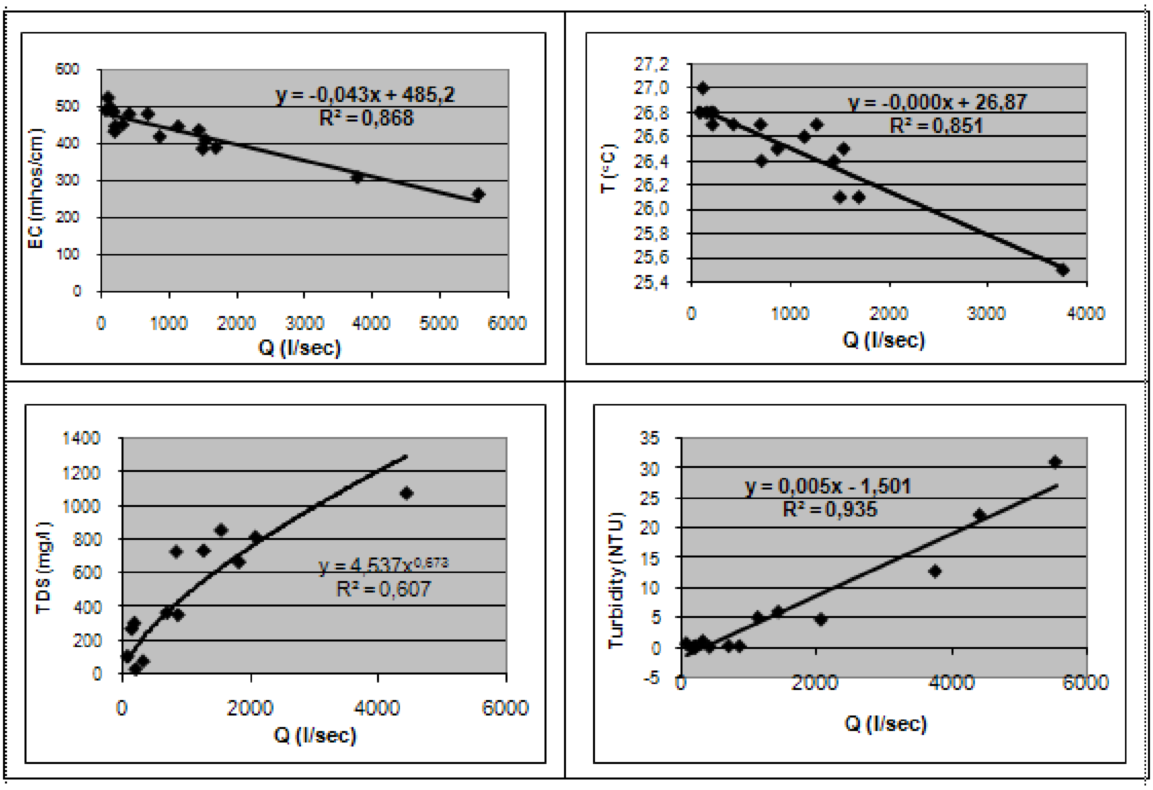

Figure 5. The Correlation between Discharge and Physical Water Quality of Beton Spring

Rainfall and Physical Water Quality Correlation

The pattern of the rainfall correlation to the physical spring water quality is identical to the correlation between discharge and physical water quality of spring. It can be seen a rapid response of the spring discharge at any rainfall event. The following analysis carried out on selected parameter, namely: *EC*, *T*, *TDS* and turbidity. Two tendencies are positive and the others tend to negative correlation. The *EC* value response is inversely proportional to the rainfall. It means that rainfall increase is followed by the decrease value of *EC*. This fact meets to theory that the *EC* value of groundwater is higher than surface water including the effect of rainfall. The correlation between rainfall and turbidity exemplified on Figure 6 for example, it shows that rainfall has a positive correlation to turbidity. It means that the rainfall increase is followed by turbidity increase. It shows the interval of the rainfall to the increasingly turbidity value occurred rapidly. It is such as the rainfall and *EC* correlation. The pattern is consistently for the turbidity value.

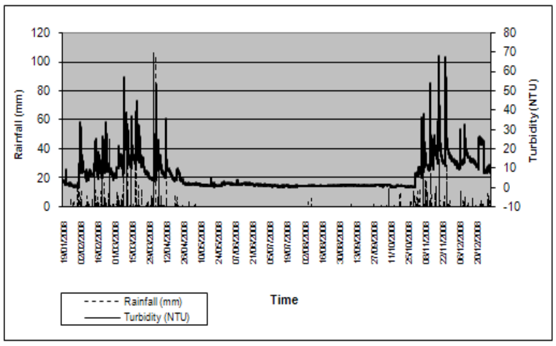

Figure 6. The Rainfall and Turbidity Correlation of Beton Spring

CONCLUSION

Based on the description of analysis in the discussion it can be concluded. Rainfall in the research area is classified into the high category and show variation. The rainfall peak occurs in March-April. The highly discharge variation of Beton spring is by flow characteristic of conduit shaft. The physical water quality of springs still meets to the water quality standard based on the Government Regulation Number 82 year 2001. The correlation between rainfall variation and discharge also physical water quality of Beton spring can be shown the increasing of discharge at any rainfall event in the short period. The influence of spring discharge on physical water quality seems in strong correlation of each physical water parameter value. The correlation between rainfall and physical spring water quality is identical to the correlation among discharge and physical water quality of Beton spring.

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