Study of Hydrogeomorphological Springs in Tlegung Watershed, Kulonprogo Regency

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Abstract. The spring characteristics such as spring discharge, temperature, EC, TDS, pH, spring stream character, and spring emergence type can be linked to geomorphology. This link is the main study in this research. This research was conducted in Tlegung Watershed, which is mostly located in Samigaluh and Kalibawang District, Kulonprogo Regency. The purposes of this study are to determine the springs distribution pattern and the springs hydrogeomorphology characteristics, also to analyze the hydrogeomorphological factors which control the springs' emergence and characteristics. Data collection method which used in this research is survey method to determine the source of spring emergence, measure spring discharge, test springs’ physical and chemical quality, and validate geomorphological interpretation. The other method which used is collecting secondary data from institution such as RBI maps, geological maps, satellite imagery, etc. The result showed that all springs in Tlegung Watershed classified as perennial springs and gravitational springs with depression, contact, and fracture springs type. Springs discharge in the Tlegung Watershed are classified in Q3 class (10-100 liters/sec) to Q5 class (<1 liter/sec). Electric Conductivity (EC) of all springs are classified in the EC1 (fresh water) with an average of 229.24 µmhos/cm, whereas the average value of TDS is 116.09 mg/L. The value of EC and TDS in the upstream watershed tend to be lower than the value of EC and TDS in the middle and downstream watershed. Hydrogeomorphological factors that control the emergence and characteristic of springs, including rock contact between old vulcanic rocks and limestone, crack structures found in andesitic breccia rocks, and slope class changes between slope 13-20% and 20-55% and 20-55% and 55-140%.

1. Background
Groundwater is one type of water that is widely used by the people to fulfill their needs of clean water. That is because groundwater has good quality, doesn't require difficult processing, and it doesn't require a lot of cost to use it [1]. Groundwater is usually used through wells or naturally emerges to earth surface in the form of springs. However, the availability of groundwater in every region isn't always be the same, there are areas with limited groundwater and there are areas with abundant groundwater. Its availability is influenced by their region’s characteristic such as geomorphology, precipitation, land use, etc.

Geomorphological conditions, with landform as its main study are one of the factors that influence groundwater availability because it is a space of all physical element [2]. One of study that relate between physical element especially landform and water is hydrogeomorphology. Hydrogeomorphology is an interdicipliner science that studies the relationship between geomorphology and hydrology, both surface and groundwater hydrology [3][4]. More specifically, [5] explains that

[1] Groundwater
[2] Geomorphology
[3] Hydrogeomorphology
[4] Interdicipliner
[5] Science

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hydrogeomorphology is a study which related to the movement of groundwater that is controlled by geomorphological condition. Geomorphological control of groundwater movement is related to the recharge and discharge processes. The diversity of groundwater quantity and quality can also be reflected through control of relief, lithology, stratigraphy, and rock bed structures [6].

Kulonprogo Regency is one region which has various characteristic from coastal area and lowlands in southern with its abundance groundwater to hilly and mountainous area of Menoreh in the central and northern that people depend on springs to fulfill their water demands. Menoreh Hills are area that have theirs uniqueness such as wavy up to very steep topography with diverse geological conditions and structures [7][8]. Menoreh Hills that crossed by Progo River also have unique geomorphological characteristics, like the existence of dynamic tectonic and vulcanic processes in the past which led to form of various landscapes with each landform characteristic [9].

According to that various geomorphological conditions, this study focused on one area in Menoreh Hills and it is a tributary stream of Progo River. That area is Tlegung Watershed which is many springs founded as shown in figure 1. The aims of this research are to determine the distribution pattern and hydrogeomorphological characteristics of springs in Tlegung Watershed; also analyze hydrogeomorphological factors that control the appearance and characteristics of springs in Tlegung Watershed.

2. Method
This research was conducted in the Tlegung Watershed, which is located in a part of Samigaluh and Kalibawang Districts, Kulonprogo Regency. Tlegung Watershed has an area around 16,96 km². Tlegung
Watershed has flat slope in the southern and steep up to very steep slope in the middle and north of watershed.

2.1. Material and Equipment
The equipments used in this research are Global Positioning System (GPS), water checker, measuring cup, vessel, camera, checklist, stationery, laptop, and ArcGIS software. Collected data is primary and secondary data. The primary data included the absolute location of springs, physical quality (spring’s discharge, EC, TDS, and temperature), chemical quality (pH), geomorphological conditions, and DEM data of ALOS Palsar 12.5 m. Meanwhile, secondary data which is collected, such as springs relative location, village potential data, Geology Map of Yogyakata Sheet scale of 1:100.000, and RBI Map of Sendangagung Sheet scale of 1:25.000.

2.2. Procedure
This research is divided into 3 stages, namely the pre-field, field, and post-field stages. The pre-field stages include literature study, limitation of study area, geomorphological map making, and pre-field survey. Field stages include plotting the absolute location of springs using GPS, measuring water quality with a water checker, measuring spring discharge using the volumetric method and velocity area method, and validating geomorphological maps. Post-field stages include processing data from field measurements, map making and fixation, and data analysis. The results of discharge measurement also physical and chemical quality of springs in the field are classified by class in this following table [1][5][6].

The characteristics of springs that have been identified such as the spring power appearance, spring stream character, discharge, pH, EC, TDS, and temperature of springs are overlapped with a geomorphological map of the Tlegung Watershed, so that the spring hydrogeomorphology map becomes the main study in this study.

3. Result and Discussion
3.1. Geomorphology of Tlegung Watershed
Tlegung watershed has various topographic conditions, ranging from flat-gently undulating in downstream to steep-very steep in middle and upstream of watershed. Tlegung watershed are dominated by very steep hills with 20%-55% slope range. Tlegung Watershed has geomorphological conditions resulting from structural and denudational process in general.
Denudational landform are reflected in several processes such as landslides phenomenon in some villages that belong to the Tlegung Watershed, also physical and biological weathering processes that occur in several rock outcrops. Meanwhile, structural landform can be seen from morphological conditions of Tlegung watershed which has steep up to very steep slope and several local outcrops. Structural landforms were also identified based on past processes of uplift and subsidence in the Kulonprogo Mountains [10]. Based on delineation process and field survey, Tlegung Watershed divided into six landforms, that is colluvial plain, solusional dome, strongly degraded struktural mountain, moderately degraded struktural mountain, moderately degraded strutural hill, and weakly degraded structural hill. Generally, that landform in field can be seen in figure 2.

Figure 2. Landscape of Research Area in Menoreh Mountain.

There are five types of rocks formation that compose Tlegung Watershed start from tertiary to quaternary age. Those rocks formations are Kebobutak Formations (Tmok), Jonggrangan Formations (Tmj), Sentolo Formations (Tmps), Young Merapi Volcanic Deposits (Qmi), and Coluvium Deposits (Qc) [7]. Kebobutak Formations dominates most of the Tlegung Watershed, whereas Coluvium Formation dominates the downstream part of watershed. The existence of that various geological formations show the various bedrocks compilers with different permeability level too.

3.2. Characteristics of Springs and Distribution Pattern in Tlegung Watershed
3.2.1. Characteristic of Springs in Tlegung Watershed.
(a) Electrical Conductivity (EC).
Electrical conductivity of springs in the Tlegung Watershed have an average value of 229.24 µmhos/cm and are all classified as EC1 (freshwater) classification. Springs in the upstream part tend to have a lower EC value than springs in the middle or downstream. This can be caused by a more intensive process of transportation and sedimentation in the middle and downstream and more ramp topography. The dominant topographic and process conditions that occur in both parts of the watershed are able to increase the amount or concentration level of dissolved solids containing minerals with cation and anion elements.

(b) Total Dissolved Solid (TDS).
The average value of TDS springs in the Tlegung watershed is 116.09 mg/L. The TDS value of springs in the Tlegung watershed is directly proportional to the value of EC. That condition is caused by TDS concentration in the water affect the value of EC, because of the high concentration of soluble solids lead content of minerals in the concentration is also higher so that the elements of cations and anions that are capable of delivering an electric current also increased. There is an anomaly in spring’s TDS in the middle watershed, the Kaliringin spring. The conditions that occur in the Kaliringin spring can be
caused by the geological conditions in the form of Jonggrangan limestone. Limestone is possible to have higher soluble substances because they are weathered if exposed to water. Other research also states that areas where lithology is composed of limestone have higher TDS values [11].

(c) Acidity (pH).
The springs that are spread in the Tlegung watershed have normal or neutral pH values (pH1), which are between 5.4 and 7.96. The spring that has the lowest pH is Kluwihan Spring, while the spring that has the highest pH value is Tirto Lanceng 1 Spring. The normal pH value overall of springs in Tlegung Watershed, is influenced by the decomposition or decay of organic matter level in the water is relatively low. The low level of decomposition is reflected by the small amount of litter that found around and in the source of springs' emergence.

(d) Temperature.
The springs temperature in the Tlegung Watershed are classified into two, those are t1 (normal) classification in the range of 22°C to 28°C and t2, (hot) in the range of 28°C to 34°C. The springs that classified in the t2, classification are Kalibibis and Kalilangel springs. Meanwhile, other springs are classified as t1 (normal). Spring temperatures in the Tlegung watershed, ranging from 24.5°C to 29.7°C and average temperatures is 26.44°C. Temperature and elevation in this study don't have any relationship, although the result of measurement in the field shows that the higher elevation, the lower springs temperature. That condition is because the measured springs temperature affected by air temperature and sunlight radiation around the source of springs' emergence.

(e) Springs Discharge.
Springs discharge in the Tlegung Watershed is classified into 3 classes, namely Q5 (<1 liter/sec), Q4 (1-10 liter/sec), and Q3 (10-100 liter/sec). The springs located in the upstream Tlegung watershed have a discharge ranging from 0.002 liters/second to 1.5312 liters/second. The springs that are spread in the middle Tlegung watershed have discharge between 0.065 liters/second to 0.2479 liters/second. Meanwhile, spring discharges in the downstream watershed ranges from 0.0763 liters/second to around 10 liters/second. There are 4 springs which cannot be measured for discharge, namely Kalijeruk, Njubuk, Clandkring, and Tirto Lanceng 2 Springs.

3.2.2. Distribution Patterns of Springs in Tlegung Watershed.
Tlegung Watershed has 33 springs which is spread in some land uses such as plantation land, settlements, shrubs, and dry field land use as presented in Figure 3. Many springs (22 springs) are found in land use with quite a lot of vegetation and shade because they have a reciprocal relationship where the trees maintain the sustainability and help the sustainability of the springs themselves [12]. Those springs are also spread over in 4 landforms, 19 springs in strongly degraded structural mountains, 6 springs in moderately degraded structural hill, 7 springs in weakly degraded structural hill, and only one spring (depression spring) in solusional dome landform as presented in Figure 4.

Springs which are mostly found in strongly degraded structural landform are depression springs (12 springs). Fracture springs (7 springs) are found in this landform too. Depression springs (23 springs) spread in every landforms because in the field, many springs are found in interhill valleys where groundwater level is cut off by topography and springs are located on break of slope or on significant slope differences. The cause of depression springs' emergence is in accordance with the explanation of [1] in their book. Meanwhile, springs in the moderately degraded structural hill are classified as depression and fracture springs.
3.2.3. Hydrogeomorphological Springs

Springs in the Tlegung Watershed are grouped into three classification based on their emergence type. Those are depression springs that spread across landforms, fracture springs that cluster in the strongly degraded structural mountains landform that have andesite breccia lithology, while contact springs are only in the moderately degraded hills landform (Figure 4). There are 23 depression springs that are found in the field and spread in every landform. Fracture springs (7 springs) are only found in strongly degraded structural mountain and 2 contact springs are also only found in the moderate degraded structural hills.

Depression springs in the Tlegung watershed on average arise due to differences in slope between the slope of 13-20% and 20-55% as well as 20-55% and 55-140%. Depression springs which cluster in the strongly degraded structural mountains landform are on average at slope difference of 20-55% and 55-140%. These conditions are relevant to the real conditions in the field where most springs are in interhill valleys or between very different heights and steep slopes to very steep slopes. In addition, the texture and color in the DEM ALOS Palsar image has a very rough texture and color that tends to be dark. Meanwhile, depression springs in the structural hills landform are mostly on slope differences of 13-20% and 20-55%. There are also a lot of springs that are located on the break of slope because the slope differences are quite significant and have a shift in use between gardens and wet rice fields or gardens and settlements such as Kalindeso, Kalipojok, Blumbang, Kalilanang, and Kaliwedok Spring. The existence of a significant slope difference and a lot of interhill valleys with steep-very steep slope differences
causes groundwater level can be cut off by topography so that many depression springs found in every landform.

Figure 4. Hydrogeomorphological Springs Map in Tlegung Watershed, Kulonprogo Regency.
Fracture springs arising from cracks in rocks or the presence of rock structures are identified in the strongly degraded structural mountains landform. That springs are Ngapak, Nggrumbul, Njubuk, Klompedan, Tugu, Kluwihan, Curug, and Sumbersari Spring. The fracture springs in the Tlegung Watershed emerge through cracks formed between weathered andesite breccia rocks. The appearance of these springs in rock cracks can be influenced by past tectonic processes, rock types, or others. The whole structure springs are in the Kebobutak formation which has massive structure characteristics, gray color, and poor sorting and there is little silica in the rock components whose appearance. This is same as the explanation of other researches that springs can come out of cracks or cracks in rocks such as compact sedimentary rocks, breccias, conglomerates, igneous rocks, or lava flows [13][14]. Large cracks are often found at the point of appearance of the three springs and in the surrounding environment.

The contact springs identified in the Tlegung watershed are only 2 springs, namely Mbalong Spring and Pancuran Gondang Spring. Those two springs, which are located in the moderately degraded structural hills landform, are located on the border between two geological formations. Based on Geological Map of Yogyakarta Sheet [7], Mbalong Springs are between the Kebobutak formation and coluvial deposits, while the Kebobutak and Sentolo Formations are the cause of the emergence of the Gondang Spring because they are in between. Mbalong Spring emerges because the Kebobutak Formation which is below the Coluvium Deposit, has a more massive structure than the Coluvium Deposit. Thus, most of infiltrated water will appear as a spring due to the contact of two different rocks and the emergence of Mbalong Springs is also triggered by a groundwater level that cut off due to significant morphological differences. Meanwhile, Pancuran Gondang Spring emerges due to the Sentolo Formation which is above the Kebobutak Formation which has an older geological age. The

| Landform                  | Morpology     | Structure | Process                           | Lithology                      | Emergence Type                       | Spring Characteristics                                                                 | Springs' Name                        | Land Use     |
|---------------------------|---------------|-----------|-----------------------------------|--------------------------------|--------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------|--------------|
| Solusional Dome           | Mountainous   | Done, positive slope (convex) | Less intensive dissolution, breccia rock cracks | Limestone                      | Depression (break of slope)            | Q5 (<1 liter/sec)                                                                       | Ngapak, Nggrumbul, Njubuk, Klompedan, Tugu, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan | Settlement   |
| Strongly Degraded Mountain| Rocky, Wavy   | Straightness, rock crack, moderately step to steep slope | Intensive erosion, weathering andesite breccia rock cracks | Andesite breccia              | Depression (structure and breccia rock cracks) | Q4 (1-10 liter/sec) to Q5 (<1 liter/sec) | Mbanturan, Klompedan, Kluwihan, Curug, Suruhan, Suruhan | Settlement   |
| Moderately Degraded       | Wavy          | Contact   | Gally, well drained               | Andesite breccia, colluvial, limestone, sandstone | Depression (contact of for: sandstone and andesite breccia) | Q3 (10-100 liter/sec) to Q5 (<1 liter/sec) | Mbalong, Pancuran Gondang, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan | Settlement dan Settlement |
| Weakly Degraded Structural| Plain to Wavy | Break of slope | Less intensive dissolution, deposition, less intensive dissolution, deposition, colluvial | Marl sandstone, sandstone, colluvial | Depression (break of slope) | Q4 (1-10 liter/sec) to Q5 (<1 liter/sec) | Kembangsari, Semak, Wonog, Mbalong, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan, Suruhan | Plantation dan Settlement |

| Landform                  | Morpology     | Structure | Process                           | Lithology                      | Emergence Type                       | Spring Characteristics                                                                 | Springs' Name                        | Land Use     |
|---------------------------|---------------|-----------|-----------------------------------|--------------------------------|--------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------|--------------|
| Solusional Dome           | Mountainous   | Done, positive slope (convex) | Less intensive dissolution, breccia rock cracks | Limestone                      | Depression (break of slope)            | Q5 (<1 liter/sec)                                                                       | Ngapak, Nggrumbul, Njubuk, Klompedan, Tugu, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan | Settlement   |
| Strongly Degraded Mountain| Rocky, Wavy   | Straightness, rock crack, moderately step to steep slope | Intensive erosion, weathering andesite breccia rock cracks | Andesite breccia              | Depression (structure and breccia rock cracks) | Q4 (1-10 liter/sec) to Q5 (<1 liter/sec) | Mbanturan, Klompedan, Kluwihan, Curug, Suruhan, Suruhan | Settlement   |
| Moderately Degraded       | Wavy          | Contact   | Gally, well drained               | Andesite breccia, colluvial, limestone, sandstone | Depression (contact of for: sandstone and andesite breccia) | Q3 (10-100 liter/sec) to Q5 (<1 liter/sec) | Mbalong, Pancuran Gondang, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan | Settlement dan Settlement |
| Weakly Degraded Structural| Plain to Wavy | Break of slope | Less intensive dissolution, deposition, less intensive dissolution, deposition, colluvial | Marl sandstone, sandstone, colluvial | Depression (break of slope) | Q4 (1-10 liter/sec) to Q5 (<1 liter/sec) | Kembangsari, Semak, Wonog, Mbalong, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan, Suruhan | Plantation dan Settlement |

| Landform                  | Morpology     | Structure | Process                           | Lithology                      | Emergence Type                       | Spring Characteristics                                                                 | Springs' Name                        | Land Use     |
|---------------------------|---------------|-----------|-----------------------------------|--------------------------------|--------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------|--------------|
| Solusional Dome           | Mountainous   | Done, positive slope (convex) | Less intensive dissolution, breccia rock cracks | Limestone                      | Depression (break of slope)            | Q5 (<1 liter/sec)                                                                       | Ngapak, Nggrumbul, Njubuk, Klompedan, Tugu, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan | Settlement   |
| Strongly Degraded Mountain| Rocky, Wavy   | Straightness, rock crack, moderately step to steep slope | Intensive erosion, weathering andesite breccia rock cracks | Andesite breccia              | Depression (structure and breccia rock cracks) | Q4 (1-10 liter/sec) to Q5 (<1 liter/sec) | Mbanturan, Klompedan, Kluwihan, Curug, Suruhan, Suruhan | Settlement   |
| Moderately Degraded       | Wavy          | Contact   | Gally, well drained               | Andesite breccia, colluvial, limestone, sandstone | Depression (contact of for: sandstone and andesite breccia) | Q3 (10-100 liter/sec) to Q5 (<1 liter/sec) | Mbalong, Pancuran Gondang, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan | Settlement dan Settlement |
| Weakly Degraded Structural| Plain to Wavy | Break of slope | Less intensive dissolution, deposition, less intensive dissolution, deposition, colluvial | Marl sandstone, sandstone, colluvial | Depression (break of slope) | Q4 (1-10 liter/sec) to Q5 (<1 liter/sec) | Kembangsari, Semak, Wonog, Mbalong, Kluwihan, Curug, Sumbersari, Suruhan, Suruhan, Suruhan | Plantation dan Settlement |

Table 6. Relationship Between Geomorphology and Springs in Tlegung Watershed.
rocks of Sentolo Formation have more porous porosity than the rocks of Kebobutak Formation. That condition causes part of infiltrated water emerge as a spring and that emergence is also triggered by groundwater level cuts by topography on the slope. The Sentolo Formation is dominated by limestone which has much of foraminifera and sandstone. Although the rocks of Sentolo Formation condition is relatively water-resistant, the rocks have a layered structure and there are dissolution holes [15].

4. Conclusion
The springs in the Tlegung watershed tend to agglomerate in the downstream and upstream watershed and spread in 4 landforms, namely strongly degraded structural mountains, moderate degraded structural hills, weakly degraded structural hills, and solusional dome. All springs in the Tlegung watershed are perennial and gravitative springs with contact, structures and depressions springs. Electric Conductivity (EC) springs are all classified in the EC1 (freshwater) classification with an average of 229.24 μmhos/cm. TDS values of springs have an average of 116.09 mg/L. The pH value of all springs in the Tlegung Watershed is classified as normal/neutral, which is between 5.4 and 7.96. Meanwhile, the spring temperatures in the Tlegung watershed are classified into two, namely t1 (normal) which ranges from 22°C to 28°C and t2+ (heat) in the range of 28°C to 34°C. Spring discharge in the Tlegung Watershed is classified into 3 classes, namely Q5 (<1 liter/sec), Q4 (1-10 liter/sec), and Q3 (10-100 liter/sec).

The emergence and characteristics of springs in the Tlegung watershed are influenced by rock contact between old volcanic rocks dominated by the andesite breccia of the Kebobutak Formation and limestone Jonggrangan Formation, the crack structures found in many andesite breccia rocks, and slope changes class between the slope of 13-20% and 20-55% also 20-55% and 55-140%.

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