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Citation: AIP Conference Proceedings 1862, 030164 (2017); doi: 10.1063/1.4991268
View online: http://dx.doi.org/10.1063/1.4991268
View Table of Contents: http://aip.scitation.org/toc/apc/1862/1
Published by the American Institute of Physics
Wellspring Characteristics in Rawapening Watershed

A. D. Hafidah, A. Damayanti, and T. Waryono

Department of Geography, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia

Corresponding author: astrid.damayanti@ui.ac.id

Abstract. Rawapening watershed is formed in a volcanic region and is the headwater of Tuntang River that disemboogues into Rawa Pening Lake. Rawa Pening Lake was formed due to gravitational tectonic events that form many faults and folds. Those events result in aquifers that create many wellsprings in Rawapening watershed. This research is conducted to determine the wellsprings distribution based on physical characteristics of the discharge area and the types of wellsprings in Rawapening watershed. Associative and descriptive analysis are used to explain the wellsprings' condition based on height, slopiness, geological formation, and the soil utilization.

INTRODUCTION

Rawapening watershed with the size of 274.3 km$^2$ [1] is a part of the headwater of Tuntang watershed (1300.36 km$^2$) that covers nine sub-districts. Almost all the sub-districts have wellsprings used by the society. According to Village Potential Data in 2008, 66% of the villagers in the area of Rawapening watershed take water from the wellsprings for daily needs, such as drinking and cooking.

Rawapening itself is a lake basin that was formed due to gravitational tectonic event—a friction caused by gravitation that conduces Mt. Telomoyo (now known as Mt. Soropati) to be torn and results in Klegung fault that is no longer active now. In the prehistoric era, the eastern part of Mt. Soropati shifted to the northeast, so the area between Mt. Telomoyo and Mt. Payungrong experienced depression and the base of it broke and was folded, forming a basin that was filled with rainwater and creates many wellsprings from aquifers [2]. The line of young volcanic mountains, such as Mt. Ungaran and Gajah Mungkur in the north, Mt. Gilipetung in the west, Mt. Telomoyo and Merbabu in the south, and Mt. Punggunungan Payungrong in the east, finally became the topographic border of Rawapening watershed.

The complex geological condition in Rawapening watershed causes the wellsprings to have different characteristics in types, discharge, and the distribution [3]. Productive aquifers have the discharge $10^{-4}$-$10^{-1}$ cm/second. The amount of that discharge can't be detached from soil permeability value due to weathering that is affected by volcanic-sedimentary aquifer system [3]. This is the same as [4] that the factors determining the value of one particular wellspring discharge is aquifer permeability (groundwater level), recharge area that fills aquifer, and groundwater recharge. Moreover, the older volcanic rocks are, the less likely they affect wellspring discharge. This happens because the older volcanic rocks are, the more intensive compaction and cementation occur. Those processes cause cavities between particles smaller, so that the value of the porosity and the permeability becomes smaller. Therefore, the wellspring discharge is smaller than the wellspring discharge in young volcanic mountains [5].

The difference in every types of wellsprings will affect the utilization. Seepage wellsprings usually come out of slopes and fault wellsprings usually come out of land [6]. Meanwhile, according to [7], fracture wellsprings’ water come out centrally through flat field, folds, fractures, faults, and other fractions that happen on consolidated rocks. Fracture wellsprings usually have water holes that can be seen clearly. Therefore, this research is conducted to determine the wellsprings distribution based on physical characteristics of Rawapening watershed area, the
wellspring discharge value and the distribution, and the types of wellspring and its distribution in Rawapening watershed.

RESEARCH METHODS

The research location consists of nine sub-districts in Rawapening watershed, Semarang Regency, Jawa Tengah, and some parts of Salatiga City. The variables in this research are regional morphological elements which consists of height and slopeness; geological formation which are lithology and fault structure; aquifer productivity; and soil utilization. Aquifer productivity is the ability of soil and rocks to save and release ground water. The value of it is highly affected by geological formation in that particular area. There are 102 points of wellsprings in the research location. Wellspring discharge data is obtained from 58 points through Department of Public Work, Semarang Regency. Wellsprings physical condition data is obtained from 44 surveyed sample points.

ArcMAP (ver. 9.3) and Global Mapper 10 are used to make basic map. Next, overlay technique is applied between basic maps and primary data, which is wellspring points. Wellspring types classification used in this research are seepage wellspring and fracture wellspring, based on Kersic and Stevanovic [7]. Associative and descriptive analysis are done to understand the correlation of wellsprings distribution with physical condition in that area, discharge, and the types of wellsprings.

RESULTS AND DISCUSSION

Wellsprings Distribution

Wellsprings of Rawapening watershed are located in almost every sub-districts in Semarang Regency. The sub-district which has the most wellsprings is Jambu Sub-district, with 24 wellsprings. Rawapening watershed is divided into nine sub-watersheds, and wellsprings can be found in almost every sub-watersheds. The most wellsprings are found in Galeh sub-watershed, with 35 wellsprings. Galeh sub-watershed is the biggest one in Rawapening watershed. It has a lot of faults that support the formation of wellsprings (Fig. 1a and 1b).

The wellsprings distribution based on height is related to the height of the mountain that becomes the recharge area of the particular wellspring. 47 out of 102 wellsprings in Rawapening watershed are located in the morphography area of the foot of the volcano with the elevation less than 500 meters above sea level. According to Arsyad and Rustiadi [8], the morphography area of the foot of the volcano is hydromorphologically a wellspring belt. Mountains near Rawapening watershed have the elevation ranging in 1200-3000 meters above sea level. This makes the foot of the mountain have the elevation ranging in 400-1000 meters above sea level (Fig. 2a).

40 wellsprings in Rawapening watershed are located in 2-8% slope. This is accurate according to Lobeck [9] and Arsyad and Rustiadi [8] who stated that wellsprings formation is related to the field’s form. In general, wellsprings are formed in foothills or slopes. Wellsprings are rarely found in flatland because the rocks’ pores are filled with water, hence the ground water only experiences little movements. On the other hand, the water that permeates into the soil in the highland experiences percolation fastly, and flows out of fractures (Fig. 2b). Almost all of the wellsprings in Rawapening watershed has water flowing throughout the year despite dry season.

![FIGURE 1](image-url). The number of wellsprings based on (a) sub-districts and (b) sub-watersheds.
According to field survey data, 18 wellsprings are located in local aquifer productivity area, 16 wellsprings located in high productivity area, 10 wellsprings located in moderate productivity area, 4 wellsprings located in low productivity area, and 9 wellsprings located in the area where groundwater is scarce (Fig. 3a). Wellsprings distribution in Rawapening watershed based on geological formation can be seen in Fig. 3b. Two example of wellsprings that has high aquifer productivity are Muncul wellspring that has the highest average discharge—2800 litres/second, and Ngembat wellspring that is used by PDAM to provide clean water for its precincts. Wellsprings located in in high aquifer area usually have constant water flow. On the other hand, wellsprings located in low aquifer area usually have fluctuative water flow and may be dry during dry season [10].
There are 38 wellsprings located in facies formation of young volcanoes, 23 in facies formation of old volcanoes, 22 in formation of alluvial deposit, and 19 in facies formation of old sediment. Wellsprings distribution based on geology is related to the porosity and the permeability of the rocks that compose that area. The area that has potency of large wellsprings due to its suitable geomorphology characteristics is volcanic area.

Most of the wellsprings (40 wellsprings) are located in plantation areas, 24 are located in irrigated farms and built-up area, 10 in productive fields, and 4 in the forests (Fig. 4). Wellsprings around the built-up area are utilized by the local people for daily needs, and wellsprings near the farms are utilized for irrigation.

The analysis result of the cross-section of a few sub-watersheds such as Panjang sub-watershed (Fig. 5a), Galeh sub-watershed (Fig. 5b), Legi sub-watershed (Fig. 5c), and Sraten sub-watershed (Fig. 5d), shows that the volcanic geological formation area has the most wellsprings, both facies geological formation of young volcanoes, like in Panjang and Sraten sub-watershed, and facies geological formation of old volcanoes, like in Galeh and Legi sub-watershed. In all sub-watersheds, especially near the foot of the mountains or in mountains that are under 1000 meters above the sea, there are a lot of wellsprings with medium to high productivity.

**Wellspring Discharge**

Overall, the distribution of each class of discharge classification in the research area looks even in every aquifer productivity area (Fig. 3a). According to Meinzer’s classification (1927) in Todd [11]. Most of the wellsprings in Rawapening watershed (34 Wellsprings) are classified into the fifth class, with the average discharge ranging from 1-10 l/s (Table 1). Muncul wellspring (3000 l/s) is located in high aquifer productivity area with alluvium (Ea) deposits, Rawapening Wellspring (1500 l/s) is located in facies formation of old volcanoes. The wellspring discharge of both of them are classified into the second class (1000-10,000 l/s).

Grunggungan wellspring has the discharge (300 l/s), Selongisor (186 l/s), and Kalibening (120 l/sec). These wellsprings are located in low aquifer productivity area that generally has lower discharge (the third class, 100-1000 m³/sec). However, due to geological factors, physical condition, and other supporting factors, those wellsprings can have higher discharge. Grunggungan wellspring is located in facies formation of old volcanoes, Selongisor in facies formation of young volcanoes, and Kalibening in facies formation of old sediments. Kayu Mas, Gadingan, and Kali Semak wellsprings are located in geological formation area of alluvium (Ea) deposits. Jeporo, Kali Kates, and Batur wellsprings are classified into the fourth class (10-100 l/s) and located in facies formation of old volcanoes. On the other hand, Ringinanom wellspring is located in facies formation of young volcanoes. Wellsprings in the fifth and sixth class are spread in all aquifer productivity areas.

The amount of flowing wellspring water is based on many factors, such as the size of gaps inside the rocks that hold the water, water pressure in aquifer, the size of wellspring cavity, rainfall intensity, and even human activity. When the water in catchment areas decreases, the pressure in aquifer will also decrease. Consequently, water in aquifer system will decrease, thus the waterflow will also decrease (USGS 2013). This shows that the wellspring discharge is not only affected by aquifer productivity factor and geological factor, but also by other factors such as groundwater levels, the width of recharge area, and also rainfall throughout the year. Other than that, the application of conservation method in the recharge area will also affect the amount of wellspring discharge.
TABLE 1. The amount of wellsprings based on Meinzer’s discharge classification (1927) [11].

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Average discharge</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>&gt;10,000 l/s</td>
<td>-</td>
</tr>
<tr>
<td>Second</td>
<td>1000 – 10,000 l/s</td>
<td>2</td>
</tr>
<tr>
<td>Third</td>
<td>100 - 1000 l/s</td>
<td>3</td>
</tr>
<tr>
<td>Fourth</td>
<td>10 - 100 l/s</td>
<td>7</td>
</tr>
<tr>
<td>Fifth</td>
<td>1 - 10 l/s</td>
<td>34</td>
</tr>
<tr>
<td>Sixth</td>
<td>0.1 - 1 l/s</td>
<td>12</td>
</tr>
<tr>
<td>Seventh</td>
<td>10 - 100 ml/s</td>
<td>-</td>
</tr>
<tr>
<td>Eighth</td>
<td>&lt;10 ml/s</td>
<td>-</td>
</tr>
</tbody>
</table>

*Source: Data Processing 2014

Wellspring Types

Wellspring distribution based on the type of the wellsprings is associated to the slope and the appearance of the holes where the water comes out. According to survey result in the field, 70 % of the samples (31 wellsprings) are fault wellsprings, caused by the domination of the flat slopes (0-2 %) and declivous slopes (2-8 %) with 16,559 hectares from the whole of Rawapening watershed. The rest 30 % (13 wellsprings) are seepage wellsprings that have slopeness over 8% and are also perennial wellsprings that flow throughout the year.
Wellsprings located near the cavity of Rawa Pening Lake are classified as fault wellsprings. Seepage wellsprings are mostly located in the mountains in the southern, western, and northern part of Rawapening watershed. Wellsprings are rarely found in the eastern part because most of the area has facies geological formation of old sediments.

Seepage wellsprings in the research area are located on wavy to steep slopes, and happened to unconsolidated sediment, such as sands and pebbles, or to loose soil with invisible water hole. One example of a seepage wellspring is Kali Pondok wellspring that is located in the slopes of Mt. Ungaran. This wellspring has 8-15 % slopenees with Qhg rocks (rocks of Gajahmungkur volcano) that consists of hornblende-augite andesites that is generally flows of lava (Fig. 6a). According to direct observation, the water of Kali Pondok wellspring doesn’t seem to come out of one point, but seeps out of the gaps of the rocks and the roots of the trees. That water will be accommodated in a reservoir and will be distributed to local people by pipes.

Fault wellsprings in the research area are located in flat to declivous slopes, happened to consolidated rock, and have visible water hole. One example of a fault wellspring is Muncul wellspring that is located near the cavity of Rawapening Lake. This wellspring has 2-8 % slopenees with Qa rocks (Alluvium) that consists of limestone andesites and a little of sandstones (Fig. 6b). According to direct observation in the field, the water of the wellsprings come out in clear points at the bottom of the reservoir. This indicates that the wellspring is a fault wellspring. Muncul wellspring has the highest discharge in Rawapening watershed. It has been utilized as a tourism object with open pools for all people. The water from Muncul wellspring never gets dry, even during dry seasons.

CONCLUSIONS

Wellspring discharge in Rawapening watershed is classified into the 2nd to 6th class of Meinzer classification with the discharge 1-10 litres/second. The high amount of wellspring discharge is produced in areas that have high aquifer productivity with alluvial deposits in its geological formation.

Wellsprings in Rawapening watershed are classified into fault wellsprings and seepage wellsprings. According to direct observation, 70 % of the samples (31 wellsprings) are fault wellsprings. The rest 30 % (13 wellsprings) are seepage wellsprings. Fault wellsprings are mostly located near Rawapening Lake, while seepage wellsprings are mostly located in the mountains.

Wellsprings in Rawapening watershed are mostly formed around the slopes and the foot of Mt. Ungaran, Mt. Gilipetung, Mt. Telomoyo, and Mt. Merbabu. The characteristics of the areas that have wellsprings are: located in less than 500 meters above sea level with the slope 2-8 %, located in facies geological formation of young volcanoes, located in aquifer productivity area, and near to plantations and gardens. Galeh sub-watershed has the most wellsprings (35 wellsprings).
REFERENCES