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The Hydrogeological investigation of Plajköy spring (Elazığ)

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Research Article

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ABSTRACT

Plajköy spring discharges at the close locations to the SE shore of Lake Hazar. Lake Hazar is a tectonic Lake in Elazığ city. Plajköy spring is a fault spring that is mainly recharging from the volcanites, dikes and blocky volcanosedimentary units of Middle Eocene Maden Complex. These units have gained secondary permeability and porosity related with the active tectonics that is effective in the studied area. The present catchment system of the spring could not collect the springs and leaks discharging from different points around the system. The discharge of the catchment is measured by specific volume method while the other springs' and leaks' is measured by using triangular weir. Before the discharge measurement of the leaks and the springs, they have been directed to a channel. The discharge of the present catchment system and the leaks have measured twice in a month during one year period beginning from October of 2012 to November of 2013. The discharge coefficient of the spring is calculated $1.33*10^{-3}$ day^{-1}. Discharge coefficient of the spring depends on the geometry and intensity of the active fracture systems in the region. Calculated discharge coefficient indicates that the spring discharge is related with the narrow fissures, fractures and pores. The total volume of discharged groundwater in the real regime of the Plajköy spring is calculated as $52*10^3$ m^3 during the period from 31[st] of March, 2013 to the 13[rd] of October, 2013 by Maillet formula. The spring water is Ca- Mg- HCO_3 type water related with the chemical analyses. The chemical and microbiological analyses of the spring water are correlated with the drinking water standarts of Turkey TS 266 (TSE, 2005) and World Health Organization (2004), and it is seen that the spring water is suitable for drinking. The Plajköy spring will be used more efficiently without exposed to pollution by the new catchment plan and protection zone map that are consequently proposed in the present study.

1. Introduction

Turkey is not a water-rich country. The increasing population and water requirements in the country have made it mandatory to search for and operate new water resources. To ensure the sustainability of current groundwater resources, rational use is necessary. As in general in Turkey, the study area of the province of Elazığ has an increasing population due to migration from surrounding provinces and as the available water resources are insufficient, there is a need for drinking water.

In recession period when the aquifer is not fed by external effects, the reserves above the aquifer discharge level of the springs are drained. In this period when the watershed of the resources does not have precipitation or if precipitation is too low to affect the aquifer, variations in discharges of springs may be shown on discharge variation graphs and discharge curves which have attracted the attention of many researchers. The basic formula for the discharge graph of the recession period of springs was given by Maillet (1905). After this basic study, studies were completed on more complicated systems involving two or more aquifers and the changes occurring on discharge graphs

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and the factors causing these changes were investigated by many researchers (Coutagne, 1968; Mangin, 1975; Padilla et al., 1994). In recent times, environments with different hydrogeologic characteristics have been modelled in laboratory conditions to draw and interpret discharge curves. According to these researches, the recession curve of a spring is related to geologic and hydrologic factors like precipitation in the region, and the geology of the recharge area, along with hydrogeologic characteristics of the aquifer (e.g., porosity, permeability, transmissivity) and situations like pumping from groundwater (Kovacs and Perrochet, 2008; Liu and Li, 2012; Farlin and Maloszewski, 2013; Azeez et al., 2015).

The study area is located south of Elazığ and southeast of Lake Hazar, which experiences intense summer tourism (Figure 1). Geologic studies with different aims have been performed in the study area and surroundings. Kaya (1992), in a study about the geology of the studied spring area and surroundings, stated the oldest unit in the region was the Upper Jurassic-Lower Cretaceous ophiolites, overlain above an angular unconformity by the Maastrichtian-Lower Eocene Hazar Group comprising red mudstone followed by flysch units to finally end in limestones, from bottom to top. A study by Gürocak (1993) on Sivrice county west of the study area mentions that the flysch of the Hazar Group is overlain above an unconformity by the Maden Complex comprising limestone, andesite, basalt, volcanic breccia and crosscutting diabase dikes. Güven (2013) studied the hydrogeology of the Lake Hazar region and stated that

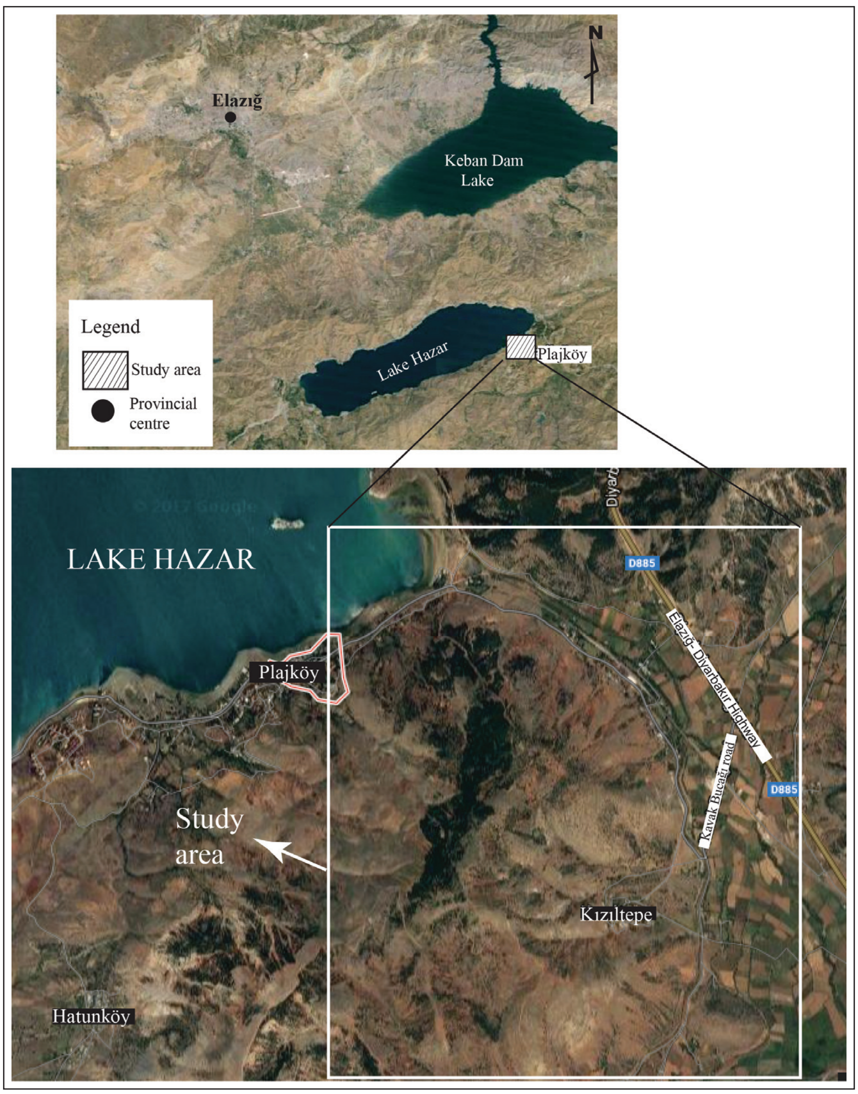

Figure 1- Location maps of the study area.

the primary porosity of the volcanics within the Maden Group was very low. Due to tectonic activity affecting these rocks in the region they gained a fractured-fissured structure to provide secondary porosity and permeability. The study stated that the groundwater flow direction within these units was controlled by the distribution of fractures-fissures and by fault lines. Aksoy et al. (2007) investigated the Lake Hazar basin as part of the East Anatolian Fault System within the study area and described it as a negative flower structure on a strike-slip fault geometry. Çelik (2008) stated that there was nearly 30 km of offset between outcrops of an olistostromal unit from the Middle Eocene Maden Complex on the north and south blocks of the fault in the section of the East Anatolian Fault System between Palu- Lake Hazar (Elazığ).

The population living in the study area is low in the winter months and high in the summer months. The increasing population in the summer months is linked to camping tourism and summer housing sites around Lake Hazar. The drinking and useable water requirements of Plajköy are provided by two different drill wells with flows of 17 l/s and 22 l/s. In the summer months while the drinking and useable water requirements for the settled and temporary population are provided by both drill wells, in the winter the water requirements of the settled population are provided by a single drill well. However, in the summer months apart from the available water network, the local people and temporary population also obtain their drinking water from Plajköy spring, the topic of this study. The sedimentary units belonging to the Hazar Group (especially limestones) and the volcanics, sub-volcanic and volcanosedimentary units belonging to the Maden Complex outcropping in the area have gained discontinuities linked to active tectonism in the region and as a result are permeable. Coastal aquifers forming within these units have been polluted by soda water from Lake Hazar with the majority of wells drilled in these formations affected by this intrusion. Thus, due to the requirements for drinking and useable water, the formation of this spring, is very important for the area and especially for the increasing human population during the summer months and the settled population, even though the discharge is not high (mean 3.01 l/s). The spring has a current catchment; however it is not sufficient for the spring area. In fact on the east and west edges of the catchment there is flowing water outside the catchment. The current catchment does not collect the the water in the spring area into a single point. In this study the reserve above discharge level and hydrochemical properties of the Plajköy spring were investigated, the appropriateness of the spring water for drinking and using purposes were determined and a new catchment plan and protection areas of the spring were created.

1.1. Material and Method

The spring discharges from 4 fountains due to a 2x2 m cement manhole previously constructed in part of the spring. The discharges from these fountains and the other springs without catchments were measured twice a month for 1 year. The discharges from the fountains were measured with the specific volume method. The springs and leaks from other points outside the catchment were directed into a single channel and discharges were measured with a triangular weir. For chemical analysis of water, water samples were obtained in 100 mL polyethylene bottles twice during the year in the wet (May 2014) and dry (October 2014) periods. When sampling in the field, the temperature, pH and electrical conductivity of the water was measured with YSI 63 brand multiparameter measurement device. Water sampling in the field was completed according to TS EN ISO 5667 standards. For cation and anion analyses, water samples were taken in two separate bottles. After water sampling, the cation analysis bottle had HNO_3 added to bring pH<2. Chemical analyses of the water were completed in Hacettepe University Water Chemistry Laboratory. Cation analyses of water used a Dionex LC (liquid chromatography) 25 brand chromatography system, while anion analyses were completed with a Dionex ICS (ion chromatography system)-1000. Bicarbonate (HCO_3^-) was measured with the titration method using an automatic burette system. For microbiological analyses water samples were placed in sterile sample containers with 250 mL volume and sodium thiosulphate according to EN ISO 19458 standards. Microbiological analyses of water were completed with the membrane filtration method in Elazığ Municipality Water Quality Control Laboratory. Disturbed samples had porosity determined with the compression method (Canik, 1998), while permeability was determined with the box with holes in the base method (Schoeller, 1962) and with constant-head method. Orientation measurements of fractures were assessed with the stereographic projection technique using the DIPS (Diedrisch and Hoek, 1989) computer program. Mineral saturation indices of groundwater were calculated with Phreeqci 3.3.8 program (Parkhurst and Appelo, 1999).

2. Geology and Hydrogeology

The basement of the study area comprises the Maastrichtian-Lower Eocene Hazar Group, overlain by the Middle Eocene Maden Complex and Quaternary-aged alluvium covers the top of the sequence (Figure 2).

The Maastrichtian-Lower Eocene Hazar group was first called the "Hazar Complex" by Perinçek (1979) and Tuna and Dülger (1979), before being named the "Hazar Group" by Aktaş and Robertson (1984) (Kaya, 2004). The unit outcrops widely in the northeast of the study area, while the marl, clayey sandstone and claystone intercalations of the unit are observed in a narrow area of a roadcut east of Gezinistasyonu Neighbourhood (Figure 3). The Hazar Group units are overlain above an angular unconformity by the Middle Eocene Maden Complex near Kızıltepe village.

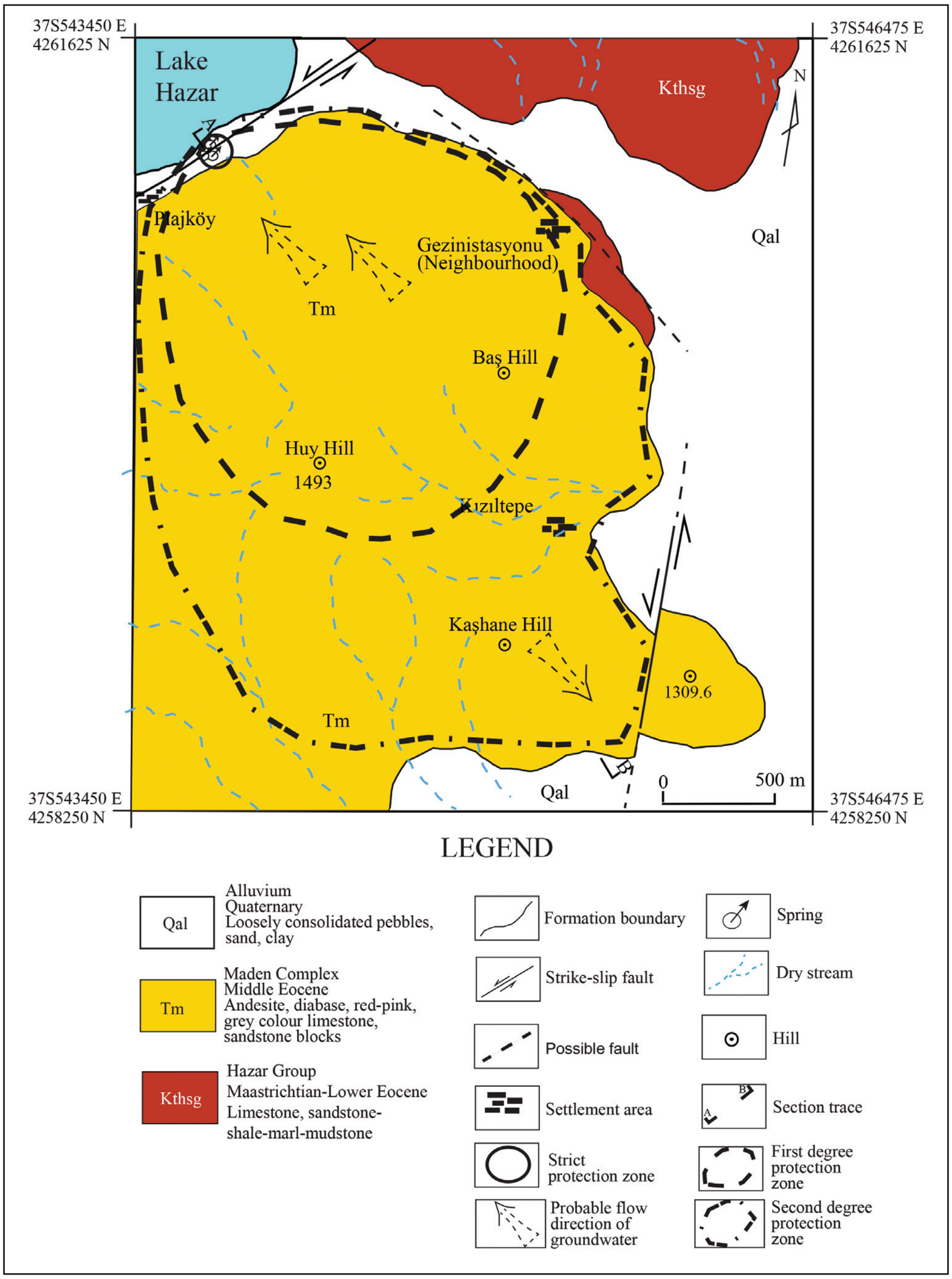

Figure 2- Geologic map of Plajköy spring and close vicinity and protection zones of the spring.

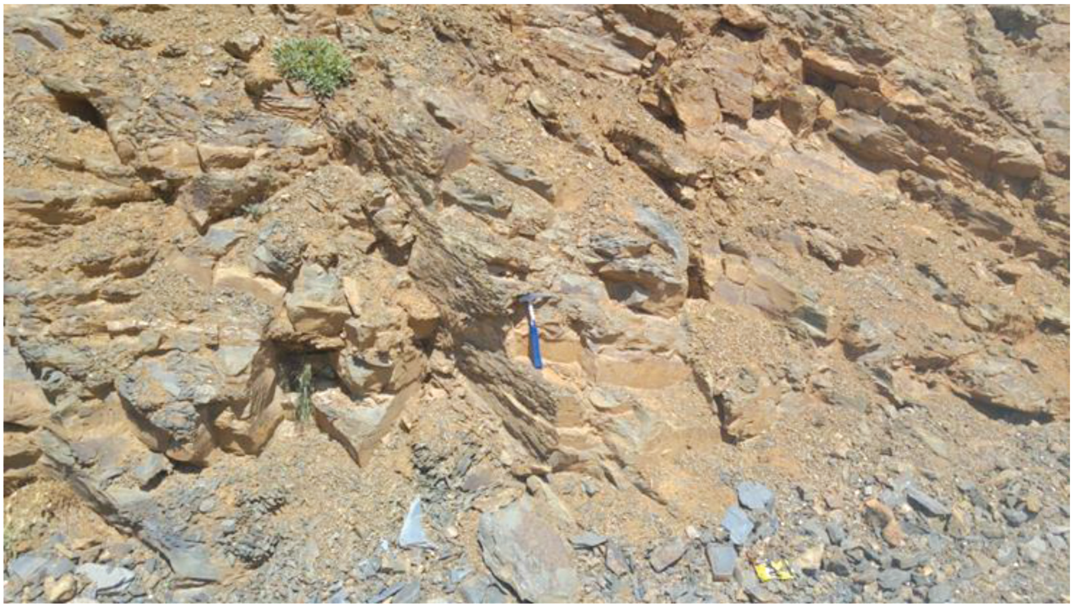

Figure 3- Flysch levels of the Hazar Group outcropping at the roadcut SE of Gezinistasyonu Neighbourhood (View direction NW, coordinates 37S545734E, 4260110N)

Units belonging to the Middle Eocene Maden Complex near Lake Hazar generally begin with conglomerate at the base, passing upward through sandstone layers, occasionally silicified reddish brown-grey coloured sandstone-mudstone-marl intercalations before grading up into grey neritic and micritic limestones. The very top of the unit comprises red-pink pelagic limestones. All these units display lateral and vertical transitions, accompanied by andesitic and basaltic volcanics in the form of interlayers (Kaya, 2004). With broad outcrops at Kızıltepe village, Baş Tepe, Huy Tepe, and Kaşhane Tepe in the study area, the Maden Complex is mainly represented by volcanics with occasional altered diabase dikes observed. The majority of the volcanics in the study area have andesitic composition. The volcanics and diabase rocks have intense fracturing and fissuring linked to the tectonism active in the region, and have a very weathered and altered appearance within valleys. The fractures and fissures developed within the volcanics and diabase are filled with secondary calcite (Figure 4 a,b,c). Due to the active tectonic activity in the region, there are blocks of very fractured sandstones and limestones found within the volcanics in the study area in narrow areas too small to map. The dominant lithologies in the recharge area of the spring are volcanics, diabase and volcanosedimentary units of the Maden Complex that have been intensely affected by the active tectonism in the region.

Quaternary-aged alluvium unconformably overlies the Hazar Group and Maden Complex in the region. The Quaternary alluvium has a very broad distribution in the study area within the East Anatolian Fault Zone where tectonism is intense from northeast of Kızıltepe village to the area to the south. The unit is represented by badly sorted pebbles, sand, clay and silt with loose consolidation. With less clear layering, the alluvium has horizontal placement (Kaya, 1992).

With intense tectonism, the left-lateral strike-slip East Anatolian Fault Zone passes through the study area. The East Anatolian Fault forms a zone 5-6 km wide in the region. It is not observed as a single fault in the study area, but comprises several parallel, large faults with NE-SW strike (N60°E) (Kaya, 2004). The formation of Plajköy spring within the study area is related to this fault zone.

To determine the protection zones for the spring, disturbed samples of the altered volcanics and diabase rocks forming the recharge area were obtained and hydrogeological characteristics determined in the laboratory. The porosity and permeability experiments on samples taken from vertical trenches outcropping in the recharge area of the spring were performed in the laboratory. The porosity values for recharge lithology were from 45.95-46.88%, while the permeability values were between 3.61×10^{-3} m/s and 1.7×10^{-3} m/s. The porosity and permeability values of the unit are very high.

Figure 4 (a, b, c)- Fractures and fracture fill within volcanics of the Maden Complex. Northern slopes of Kaşhane Hill (View direction toward SE, coordinates 37S545407E, 4259214 N).

2.1. Formation of Plajköy Spring

Plajköy spring is recharged from the very fractured and fissured volcanic and sub-volcanic rocks (diabase) and blocky volcanosedimentary units of the Maden Complex. The fracture system developing linked to active tectonism in the region has provided the unit with secondary porosity and permeability. Orientation measurements from 103 fractures within the aquifer formation for the spring of the Maden Complex comprising volcanics, sub-volcanic and volcanosedimentary rocks were assessed with a computer program and it was determined that these rocks contained 3 joint sets (Figure 5). When the rose diagram is investigated, fractures in the unit mainly strike NW-SE and NE-SW and the joint sets were determined as 302/32, 208/10 and 54/13 according to density. These fractures and fissures are very intense in the upper levels and as they are linked they reduce and are lost as the depth increases. This situation allows the volcanics, sub-volcanic rocks and blocky volcanosedimentary units of the Maden Complex to form both the aquifer for the spring and the impermeable base of the aquifer. The flysch from the Hazar Group, outcropping in a very small area of the study area, is not considered to have any effect on the formation of the spring.

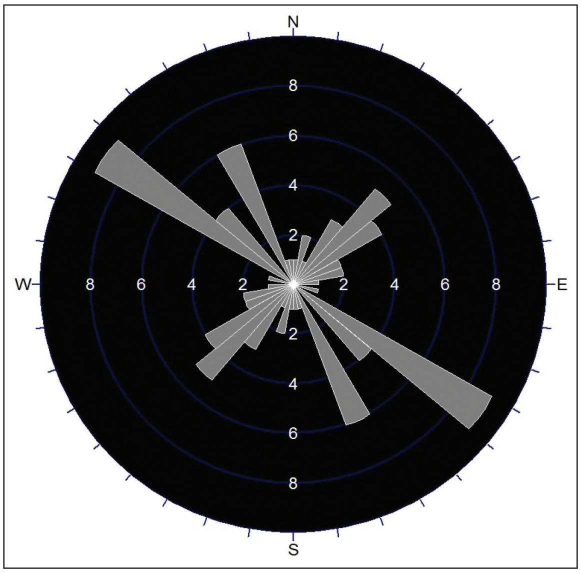

Figure 5- Rose diagram of fracture orientations measured in volcanic, sub-volcanic and volcanosedimentary rocks of the Maden Complex.

Precipitation moving within the very fractured volcanics, sub-volcanics and blocky volcanosedimentary rocks passes along a left-lateral strike-slip fault within the study area and forms a spring area rising to the surface through alluvium at different points (Figures 6 and 7).

Figure 6- Plajköy ppring, southeast coast of Lake Hazar (View direction toward NE, coordinates 37S544105E, 4261455N).

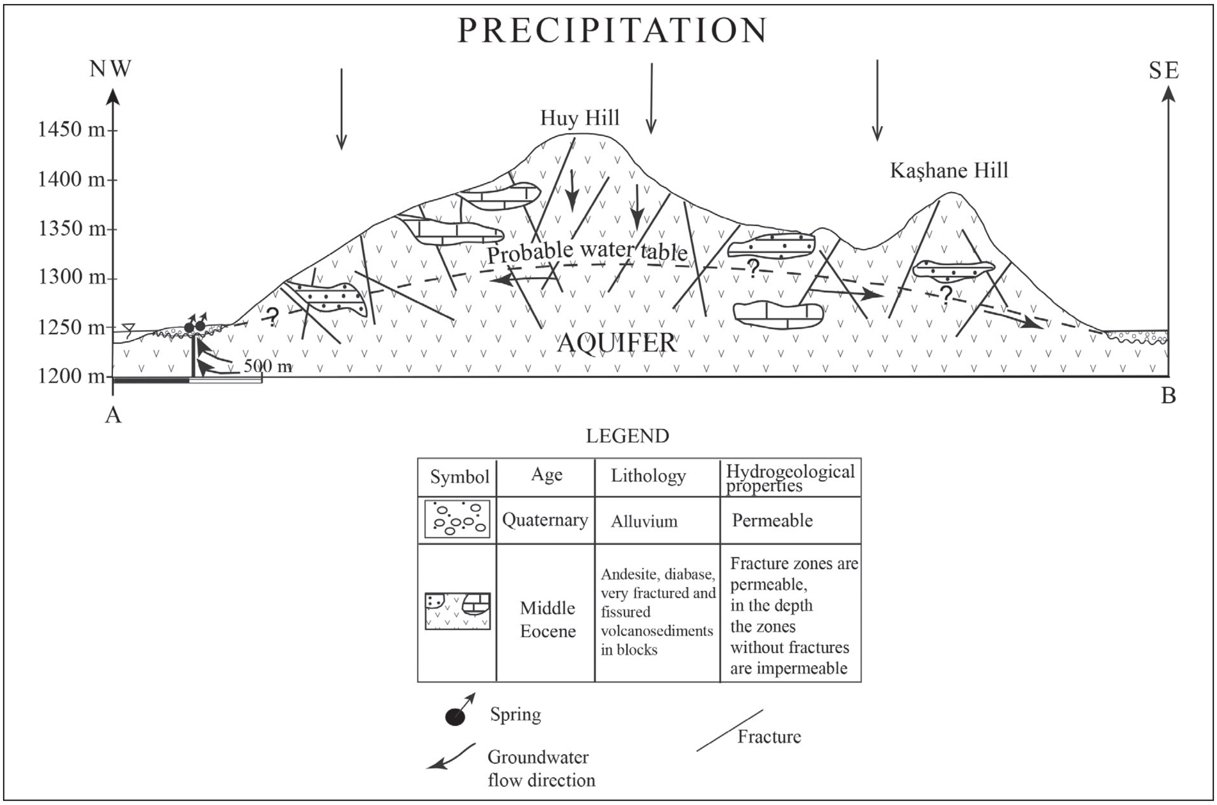

Figure 7- Hydrogeological section showing formation of Plajköy spring (thickness of lithologic units shown schematically).

2.2. Discharge-Precipitation Relationship of Plajköy Spring

The discharge variation of the spring was measured two times per month from 28/10/2012 to 30/10/2013. The recession period is observed on the discharge variation graph of the spring for the studied period (Figure 8). The highest discharge from the spring was 3.48 l/s, lowest discharge was 2.60 l/s with mean discharge of 3.01 l/s. The low values for the spring discharge is due to the recharge area not being very large. The lowest discharge was measured on the 28 October 2012, with highest discharge measured on 31 March 2013 representing the period when the spring is recharged by precipitation. Argillitization linked to the alteration of the volcanics and sub-volcanic rocks found in the recharge area of the spring delays the precipitation from reaching the aquifer. As seen on Figure 8, the effect of increased rain in the months of September-October appears to be delayed by 28-30 days before the discharge of the spring increases.

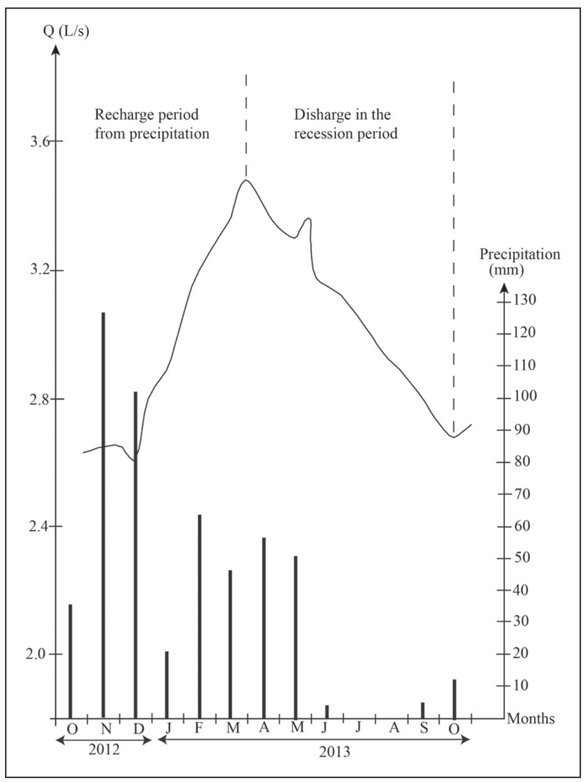

Figure 8- Discharge-precipitation graph of Plajköy ppring.

2.2.1. Calculation and Interpretation of Recession Coefficient and Storage Capacity

The recession period of the spring encompasses 31 March 2013 to 13 October 2013. The log Q = f(t) graph of the spring for this period was drawn with a straight line decreasing from time t_0 (Figure 9). The general equation for this curve is given by the exponential function recommended by Maillet.

$Q= q_0 * e^{-\alpha(t-to)}$

In the above equation;

q= discharge at time t (m^3/s)

q_0= discharge at the beginning of the recession (time t_o) (m^3/s)

a= recession coefficient (day^{-1})

$t-t_0$= duration since the start of recession (day)

The discharge at the start of recession was 3.48 l/s, while at the end of the dry period it was 2.68 l/s (Figure 9). The recession coefficient (α) is calculated from the recession curve with the following equation:

$\alpha = \log q_0 - \log q / (t-t_o) * \log e$

Taking the initial discharge of recession q_0= 3.48 l/s and q= 2.68 L/s, a was calculated as $1.33*10^{-3}$ day^1.

There are many scientific studies on interpreting the recession coefficients of springs. According to Schoeller (1962; 1967), in general recession coefficients with values around $n*10^{-3}$ represent springs with water discharged by laminar flow in very narrow fissures and fractures or in pores around grains, while values from $n*10^{-2}$ to $n*10^{-1}$ represent springs discharged by turbulently flowing water through broad fissures and dissolution channels. Smart and Hobbs (1986) and Liu and Li (2012) stated that discharge from karstic rocks was related to three variables. These are recharge (diffusive or concentrated), storage (significant or small volumes) and flow type. A study by Ebrahimi et al. (2007) stated that the recession coefficient of karstic limestone dominated by diffusive flow is proportionally lower compared to karstic systems dominated by turbulent flow. Fiorillo (2011) stated that different recession coefficients during the discharge duration of aquifers were related to differences in aquifer geometry or hydraulic character. There is a very close correlation between the recession coefficient and especially the effective porosity of the aquifer and the location of the water table. As a result, during the discharge period, variations in these two parameters will cause changes

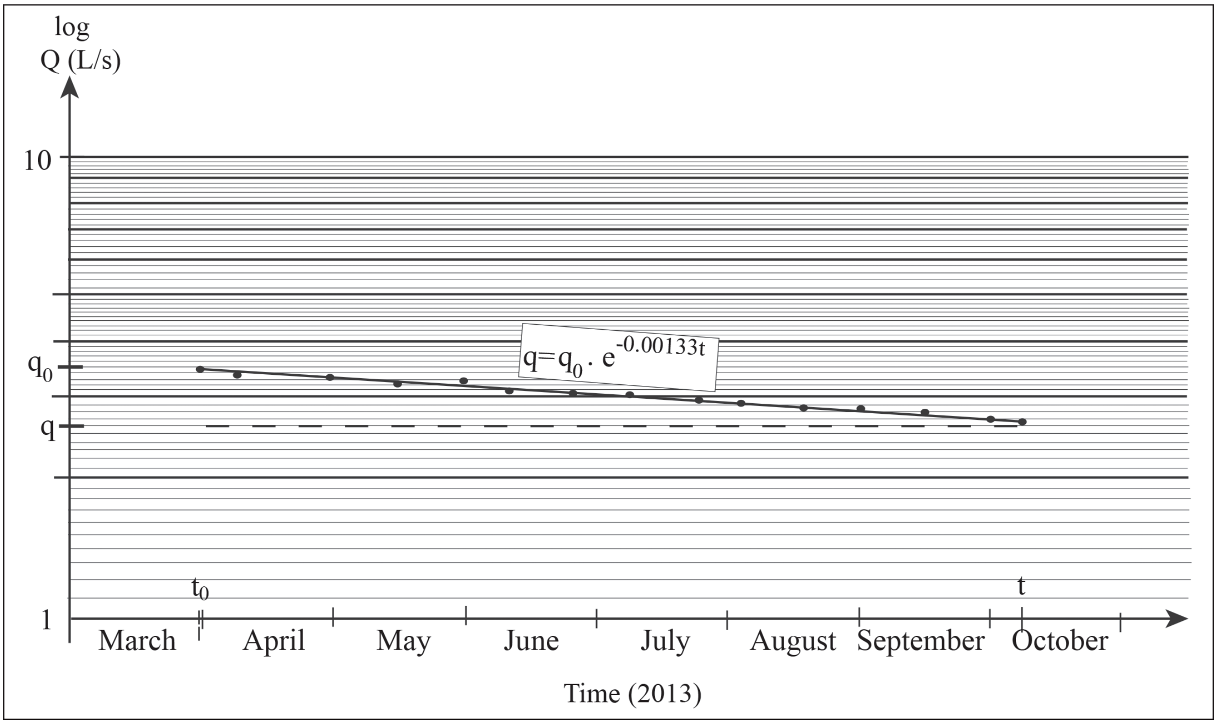

Figure 9- Discharge curve for recession period of the spring (2013).

in the recession curve (Fiorillo, 2011; Fiorillo et al., 2012). The recession coefficient of the studied spring is related to the geometry and density of the fracture system affecting the region with the calculated recession coefficient representing recharge of the spring through narrow fissures, fractures and pores (Çetindağ and Öztekin, 2001; Çetindağ, 2002; Kovack et al., 2005; Ebrahimi et al., 2007) .

The water storage capacity above the discharge level in the recession period of Plajköy spring for 2012 to 2013 was calculated using the following formula from Maillet (1905);

$$V_0 = (q_0/\alpha) * 86400$$

On the 31 March 2013 in the recession period, the water storage capacity of the spring (V_0) was calculated as $2.26*10^5$ m^3 above the discharge level. Between 31 March 2013 and 13 October 2013, the amount of water discharged from Plajköy spring in the recession period was calculated as $52*10^3$ m^3.

According to data from the Turkish Statistical Institute (2014), the amount of water for drinking and domestic using purposes per person is 203 L per day. In the study area, the spring is used for drinking and domestic usage by the local people and the temporary camping population especially in the summer months. The population of Plajköy is mean 5000 people in the summer months. If this spring alone was used for drinking and domestic usage by a population of 5000, the period of use in the dry period was calculated as 51 days.

2.3. Hydrochemical Characteristics of Plajköy Spring

The chemical and microbiological analysis results for water samples taken from fountain of the present catchment for the studied spring are given in table 1. For the wet and dry periods, the pH of the water is 7.03 and 8.30, while electrical conductivity is 421 and 438 µS/cm. The pH value of the spring varies in wet and dry periods (Table 1).

The pH of Plajköy spring is neutral in the wet period and alkaline in the dry period. The lower pH values in the wet period are considered to be related to the low pH of precipitation recharging the aquifer or to increasing CO_2 in the circulation region of the groundwater (Güler et al., 2017). The enrichment of water by CO_2 is very effective in areas close to the surface and at soil level. In regions close to the surface, CO_2 is created during the oxidation process added by organic material and microorganisms and by respiration of plant roots (Milanovic, 1981). The pine forest area found in the recharge area of the spring is thought to play an important role in enriching the groundwater in CO_2 during the rainy period. In the dry period, the increase in pH is related to the hydrolysis of silicates in reducing conditions affecting groundwater moving through fractures and fissures at depth (Garrels and Christ, 1965; Boughton and McCoy, 2006; Kebede et al., 2005). Additionally, in the period with low recharge, the increasing water-rock interaction linked to the low hydraulic gradient may cause an increase in pH.

The hydrolysis of silicates is represented by the following equation:

$$Rock + H_2CO_3 \rightarrow Cations + H_4SiO_4 + HCO_3^- + Secondary\ minerals$$ (Ako et al., 2011)

The saturation indices calculated for the spring water are given in table 2. In May when the dissolution mechanism is effective the spring water is not saturated with calcite, aragonite and dolomite minerals, but becomes saturated in October. The dissolution of carbonates and silicates is completed related to the decrease in CO_2 as water percolates to greater depths along fissures and fractures.

The electrical conductivity of the spring water is lower in May, while it is slightly higher in October (Table 1). The effect of precipitation on the recharge of the aquifer in May is shown in figure 8. The low electrical conductivity of water in the month of May

Table 1- Chemical and microbiological analysis results of Plajköy Spring (Analysis results in mg/l; no E. coli or coliform bacteria were encountered during microbiological analysis of water samples).

Sample name	T (°C)	pH	EC (µS/cm)	Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO_3^-	Cl-	SO_4^{-2}	NO_2^-	NO_3^-	PO_4^{-3}	NH_4^+	Hardness (d°h Fr)
Plajköy Spring (May, 2014)	16.40	7.03	421	10.96	1.07	62.78	16.24	260.10	2.13	15.46	<0.01	1.92	<0.01	0.17	22.45
Plajköy Spring (October, 2014)	15.50	8.30	438	10.64	1.11	63.93	19.33	274.50	2.20	14.27	<0.01	1.91	<0.01	0.47	24.00

Table 2- Saturation indices of Plajköy Spring.

Mineral	Saturation index	
	May, 2014	October, 2014
Anhydrite	-2.81	-2.87
Aragonite	-0.40	0.85
Calcite	-0.25	1.00
Dolomite	-0.87	1.70
Gypsum	-2.41	-2.46
Halite	-9.18	-9.18
Sylvite	-9.72	-9.68

representing the rainy period is related to the high hydraulic gradient and rapid flow linked to recharge by rain. During rapid movement of rain water, the water-rock interaction is lower. In the month of October, representing the dry period with low spring discharge, the water has higher electrical conductivity. In this period when the effect of rain on recharge is reduced, the hydraulic gradient decreases slowing the rate of groundwater flow causing an increase in the duration of water-rock interaction. The increase in water-rock interaction increases the electrical conductivity of water.

On the Schoeller diagram, the dominant cation found in the water is Ca^{+2}, with the dominant anion HCO_3^- and the water appears to be Ca-Mg-HCO_3 type. On the Piper diagram, the water is grouped in the 5th region. This region indicates groundwater with carbonate hardness above 50% containing $CaCO_3$ and $MgCO_3$. The chemical composition of the spring water does not show clear differences between wet and dry periods except in the ion concentrations of Ca^{+2}, Mg^{+2} and HCO_3^- (Figure 10a,b). In the dry period, the Ca^{+2}, Mg^{+2} and HCO_3^- ion concentrations are relatively high compared to the rainy period. In the dry period in addition to the increase in dissolution of carbonates linked to increasing water-rock interaction, the hydrolysis of silicates (like olivine, pyroxene, plagioclase, alkali feldspar) affects the increase in these ions' concentrations (Kimball, 1981; Kebede et al. 2005).

The sources of the Ca^{+2} ions in the spring water comprise dissolution of limestones outcropping in the region and dissolution of Ca^{+2} ions found in silicate minerals like anorthite, pyroxenite and amphibole within volcanic rocks. Additionally, the secondary calcite formations along fissures and fractures related to active tectonism in outcropping rocks in the region forms a source for Ca^{+2} ions in groundwater. The Mg^{+2} ion concentration in the spring water was 16.24 mg/l in May (2014), while it increased to 19.33 mg/l in October (2014) (Table 1). The source of the Mg^{+2} ions in the water is the dissolution of magnesium-composition minerals like olivine, biotite and hornblende within volcanic rocks of the Maden Complex. It is estimated that K^+ passes into groundwater due to dissolution of mica and feldspar minerals within volcanic rocks outcropping in the study area. The source of Na^+ in the studied spring water is related to dissolution of Na feldspars within volcanic rocks in the area. The increasing HCO_3^- ions in October, representing the dry period, is a result of dissolution of limestone

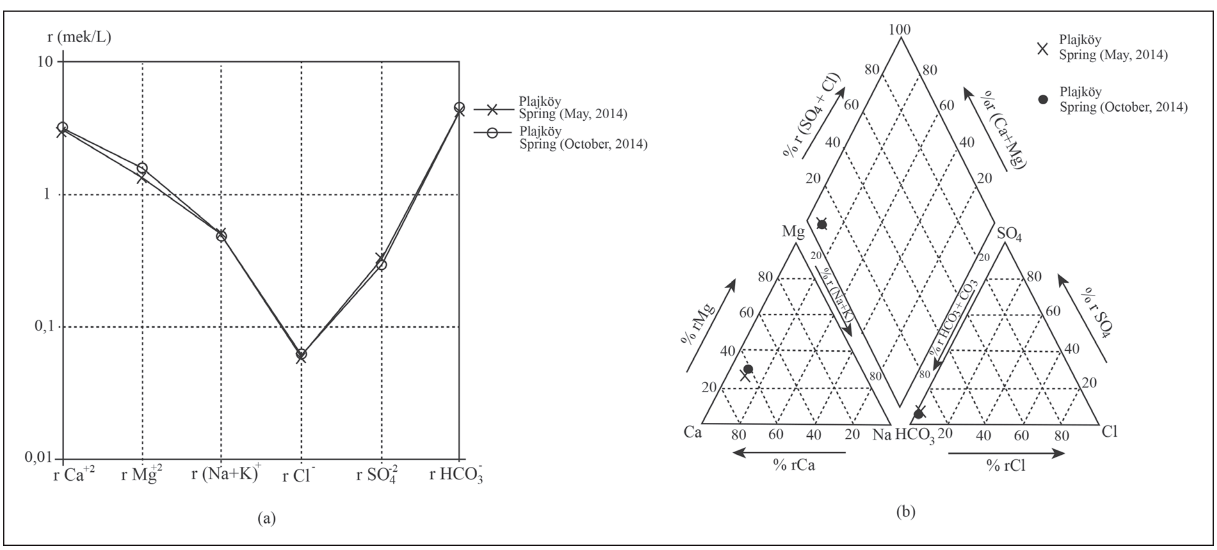

Figure 10- Schoeller (a) and Piper (b) diagrams of Plajköy spring.

outcropping in the region by CO_2-rich groundwater and the hydrolysis of silicate minerals. The source of SO_4^{-2} ions in the spring water is estimated to be $FeSO_4$ formed by oxidation of pyrite (FeS_2). Previous studies have identified pyrite within the Maden Complex (Altunbey and Sağıroğlu, 1995; Yıldırım and Eroğlu, 2015). The source of Cl^- ions in investigated spring water may be related to rainwater. When the water is assessed in terms of pH, electrical conductivity and analyzed ions according to the TS 266 (TSE, 2005) and WHO (2004) drinking water standards, it was determined to be appropriate for drinking (Table 3).

Microbiological analysis of water found no E. coli and coliform bacteria indicating the water is appropriate for drinking. However, the NH_4^+ concentration of the water is very close to the limit value (0.5 mg/L) stated in the TS 266 (2005) drinking water standards showing the water is polluted. The concentration of ammonium (NH_4^+) is considered to be related to the use of animal fertilisers used in garden agriculture by the local people in the settlement areas of Plajköy, Gezinistasyonu Neighbourhood and Kızıltepe within the recharge area of the spring.

2.4. Determination of Plajköy Spring Catchment Plan and Protection Zones

The Plajköy spring area comprises several water outlets in the form of a line. Part of the spring has had a catchment constructed; however this catchment does not have the capacity or features to drain all the water in the spring area. The current catchment only encompasses one point in the spring area, captures a small percentage of the water and was not designed to protect against surface pollutants. There are many frequent leaks over nearly 100 m in the field. A catchment was planned that can collect all springs and leaks within the fault zone.

Beginning from the current catchment in the spring area, two trenches should be opened with an east-west orientation, with width of 80 cm and depth of 1 m in a "V" shape from the spring area and the downstream side toward the manhole. These trenches should be extended to encompass all points of discharge. If the base of these trenches follows the groundwater, a fine pebble layer of rounded pebbles with diameter 0.5-1 cm (nearly 15 cm thick) should be placed in the base, while the downstream side of the trenches should be covered with cement. Porous pipes with appropriate diameter for the total flow of the springs should be placed within the trenches to ensure collection of groundwater within the pipes. The porous pipes should be covered with pebbles and as there is a possibility of surface pollutants that may contaminate the groundwater, a clay or weak cement layer should be laid above the pebble layer to prevent seepage of pollutants (Yüzer et al., 1992; Canik, 1998) (Figure 11 a,b).

Table 3- Limit values for drinking water determined by the Turkish Standards Institute (TS 266, 2005) and the World Health Organisation (WHO, 2004) and Plajköy Spring chemical analysis results (na = no analysis).

Parameters	**Turkish Standards Institute TS 266-200**	**World Health Organization (WHO, 2004)**	**Plajköy Spring (October, 2014)**
pH	6.5 – 9.5	6.5 – 8.5	8.30
Electrical conductivity (µS/cm)	2.500	–	438
Ammonium (mg/l)	0.500	1.500	0.47
Sulphate (mg/l)	250.0	250.0	14.27
Magnesium (mg/l)	50	–	19.33
Sodium (mg/l)	200	200	10.64
Potassium (mg/l)	12	–	1.11
Calcium (mg/l)	200	–	63.93
Chloride (mg/l)	250.0	250.0	2.20
Hardness (Fs°)	–	50.0	24.00
Nitrit e(mg/l)	0.500	–	<0.01
Nitrate (mg/l)	50.0	50.0	1.91
MICROBIOLOGICAL PROPERTIES			
E. Coli	0/100 ml	–	0
Coliform	0/100 ml	–	0

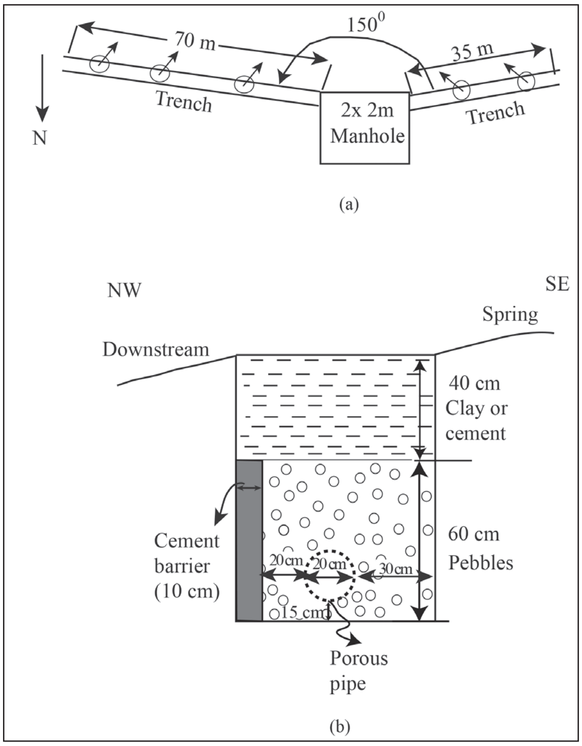

Figure 11- Plan view (a) and section along the trench (b) of the catchment system.

The collection manhole (2x2 m dimensions) should be used to provide water for use through perforations mounted on the downstream wall. To ensure hygienic conditions the inner wall of the catchment should be covered by glass or porcelain material. Excess drainage perforations should definitely be mounted in the upper levels of the perforations to prevent damage to the catchment due to excessive discharges. If the groundwater is to be transported to higher elevations, it is possible to place a pump appropriate to the discharge within the manhole. The discharge level of the spring will be reduced to 0.8 m with this recommended catchment plan, which is estimated to increase yield. Considering the swamp area (leaks) around the old catchment, it is estimated that the discharge from the new catchment will result in a nearly 50% increase.

The declaration published by the General Directorate of State Hydraulic Works about determining the protection zones for aquifers and springs providing drinking water determines the strict protection zone in fields with fractured and fissured aquifers as between 50 and 100 meters around the area of the discharge point of the spring or water drill well in the direction of groundwater flow depending on the properties of the fractured aquifer (Resmi Gazete, 2012). The strict protection zone for Plajköy spring is shown on figure 2 to cover an area with a radius of 100 m. Within the strict protection zone, permission should not be given for any structure, solid or liquid waste discharge or transmission. This area should be expropriated and protected by the authority or authorities using the drinking water with title deeds for the protection area processed and reported to the ministry. The area should be surrounded by barbed wire by the authority using the water.

The first degree protection zone is the region between the limit equal to the distance that the rain water travels from the recharge area at the surface to the discharge point for groundwater percolating through the aquifer in 50 (fifty) days and the strict protection zone (Resmi Gazete, 2012). The first degree protection zone for the fractured aquifer feeding the studied springs is determined by considering the orientations of the fracture systems developed within the recharge area, the flow direction of groundwater and the porosity and permeability values. The second degree protection zone is determined by considering the region from the outer limits of the first degree protection zone to the edge of the recharge area for the spring (Figure 2). Within the recharge area of the Plajköy spring, the domestic waste emptied by local people into the valleys is a potential pollutant for the spring water. It is necessary that this waste is stored in a region to be determined outside the first degree protection zone. Within the first degree protection zone, permission should not be granted for urban development (apart from recreational facilities); air strips and roads; railroads; urban and domestic waste (including solid and fluid waste) storage, production and destruction; cemeteries; mining activities, industrial factories and organised industrial zones; nuclear activities; use and storage of fertilisers and pesticides; fuel storage and transmission facilities e.g., LPG stations; and storage facilities (tailings dams) for solid waste and hazardous waste. Within second degree protection zones, permission should not be given for storage and extraction of material causing water pollution; nuclear activities; metallurgy and petrochemical facilities; and storage facilities (tailings dams) for solid waste and hazardous waste (Resmi Gazete, 2012).

3. Conclusion

Plajköy spring is a low-discharge fault spring in fractured and fissured volcanic, sub-volcanic and blocky volcanosedimentary units belonging to the Maden Complex. In the period when the spring was studied, the recession coefficient was calculated as $1.33*10^{-3}$ day^{-1} with this value indicating laminar flow through narrow fissures, factures and pores. On 31 March 2013 the amount of water storage above the discharge level for the recession period of Plajköy spring was calculated as (V_0) $2.26*10^5$ m^3. The amount of groundwater discharged from the spring during the recession period from 31 March 2013 to the 13 October was calculated as $52*10^3$ m^3. The dominant cation in spring water is Ca^{+2}, with dominant anion HCO_3^- and the water is Ca- Mg- HCO_3 type. The chemical and microbiological analyses of the spring water were determined as being appropriate for drinking when assessed according to drinking water standards.

Gaining great importance due to the increasing population especially in the summer months, the proposed catchment system for Plajköy spring is estimated to increase the yield by nearly 50%. Additionally, the spring protection zones determined for this catchment area within this study will ensure the sustainability of groundwater quality at high risk of being affected by surface pollutants.

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