PACE-2021
International Congress on the Phenomenological Aspects of Civil Engineering
Research Article 20-23 June 2021

Analysis of the relation between springs and structural, geomorphological and lithological factors (Case study: Gheshlagh catchment of Sanandaj)

Khabat Amani[1], Badie Moasses[2], Nesa Shayani[3], Mahsa Hojatjalaly,[4].*
[1]*Ph.D. Student, Dept. of Geomorphology, Faculty of Geography, Univ. of Tehran, Iran; Expert in A.P.N Consulting Eng. CO., Iran.*
[2]*M.Sc. Civil Engineering, Geotechnical Engineering Specialty, Expert in A.P.N Consulting Eng. CO., Iran.*
[3]*M.Sc. student, Dept. of Water Resources Management, Faculty of Agriculture, Univ. of Tarbiat Modares, Iran, Expert in A.P.N Consulting Eng. CO., Iran.*
[4]*M.Sc. Civil Engineering, Water Resources Engineering Specialty, Expert in A.P.N Consulting Eng. CO ,Iran.*

**Corresponding Author E-mail: mahsa.hjalaly@yahoo.com* *Corresponding Author ORCID: 0000-0002-0191-3886*

Keywords

Spring,
Discharge,
Fault,
River,
Gheshlagh.

Abstract

The distribution of springs and their flow rate are affected by different parameters. These parameters include tectonics, climate, geology, distance from the drainage network, geomorphology, etc. The aim of this study was to investigate the effect of structural, lithological and drainage network on two indicators related to springs, including the number and annual discharge in the Gheshlagh catchment of Sanandaj. In order to achieve the research objectives, data related to the discharge of basin springs, geological formations and fault location, Digital Elevation Model (DEM) and basin drainage network have been prepared and examined in relation to the two mentioned parameters. The results confirm that there is a close relationship between the number of springs and the distance from the fault with a correlation coefficient of 0.97. Also, the correlation between the number of springs and the distance from the river is significant and is about 0.66. But there is no significant relationship between these two parameters with the flow rate of springs. The discharge variable has a significant relationship with the genus of the formation, so that the formations that are composed of shale and another type of formation such as tuff and micritic lime have more discharge and the minimum discharge is related to Quaternary alluvial formations.

1.Introduction

Springs are the most substantial natural drainages of groundwater that appear on the surface of the earth under the influence of various parameters. The lives of many human communities, especially in rural regions, depend on these effects. Various researchers often infer subsurface hydrological conditions through surface indicators such as geological features and linear structures [1].

Each spring has several specific indicators, among these indicators, dispersion and discharge rate are very important. Tectonic fractures, geology, geomorphology, surface cover, etc. are among the factors affecting these indicators. The identification of lineaments is of special importance in the hydrogeology of hard formations, because these fractures of rock units are the place of transfer and concentration of groundwater [1].

Numerous studies have been done on the factors affecting the emergence and discharge of springs and each of them has examined different aspects of these effects. Kalantari et al. (2009) [2] researched on the effect of structural factors on the emergence and discharge of springs in the Izeh plain. The results showed that there is a close relationship between the location of the springs outcrop and the distance from the fractures, so that the location of the springs had a high agreement with the frequency of fractures.

Kazemi et al. (2016) [3] in a similar study found that there is a close relationship between lines, tectonic elements, etc. with the abundance of karstic water resources in the Lar region. Investigation of the role of tectonic elements and lines in the creation and development of water resources in Lar region, the occurrence of springs at close distances to tectonic elements and lines, as well as the downward trend, shows a decrease in frequency with increasing distance. Idris Nia et al. (2017) [4] conducted a study on the relationship between the lines extracted from satellite images, tectonic elements, hydrographic network and topographic factors with the abundance of karstic water resources in Maharloo region using GIS and remote sensing. Wu et al. (2021) [5] revealed that Butterfly Spring in Yunnan of China emerges in the Silurian limestone. Groundwater receives recharge from precipitation and snow-melting water in the western mountainous area, flows eastward along the fissures, and emerges on the lower slopes as a spring of shallow groundwater circulation type with ambient temperature. Ozdemir (2011) [6] used logistic regression method to locate potential regions for groundwater springs in Sultan Mountains using 17 factors related to spring. It was found that the completed model is consistent with the groundwater spring test data. Hence, this method can be normally used in groundwater exploration under favorable conditions. Hatim (1993) [7] indicated the physical bases of remote sensing, and the role and potential of remote sensing techniques used in occupational hydrogeological research in southern Turkey. Examples of these applications are related to the Kôprûçay karst areas River basin (Antalya) and Ovak on the Mediterranean coast of Turkey. Motlaq et al. (2010) [8] Investigated the role of tectonic control on the hydrogeological characteristics of karst aquifers in Kooh-e-Siah anticline in Zagros belt. The volumed of dynamic resources of karstic springs has been calculated in order to illustrate the basic relationship between Tectonics phenomena and karstic aquifers hydrogeology. Rahnamaei (2005) [9] conducted studies which showed that the results of daily rainfall and water level of Qara, Sabzpooshan and Kaftarak piezometers and daily discharge of Qom Palace karst spring can be compared with the physical properties of karst underground aquifers.

Since human, animal and plant life is dependent on water and one of the main sources of supply is the springs, it is necessary to study about them. The study region is tectonized and there are several fractures in it, it has also emerged from different geological formations and has seen many elevation changes due to its mountainous nature; Also, the climate of the region is semi-humid and the excess infiltration of rainfall has strengthened the groundwater aquifers and these factors have led to the emergence of several springs in this region. The aim of this study was to investigate the factors affecting the creation and discharge of springs and the effective factors in these two parameters have been calibrated according to the environmental conditions of the study region.

2. Case Study

Gheshlagh catchment is one of the basins of Kurdistan province which originates from the northern mountains of Sanandaj city (Figure 1). Gheshlagh River is one of the four main branch of the Sirvan River, which, after passing through the city of Sanandaj near the village of Hadiabad, joins the Gaveh Roud River and enters Kermanshah in the Howraman region after joining the Bel spring. It flows into the Darbandikhan Lake in Kurdistan of Iraq under the name of the Diyala River and eventually leads to the Tigris. The Gheshlagh River actually has two main branch called Gheshlagh (Bayakhi) and Chehelgazi at the dam upstream. These branches generally originate from altitudes that are more than 2500 meters high [10]

Chehel Gazi branch is located in the northeast of Sanandaj, which ends from the north to the heights of Yousef Shawan and Luglan mountain. The height of these mountains is more than 2600 meters. The location of Sanandaj city is located exactly in the central point of Gheshlagh river basin, that is, where the main and secondary rivers emerge from behind the valleys and straits and reach each other.

Gheshlagh consists of about 17 small rivers that are between 10 and 25 km long. The source of the main branch of this river is located in mountainous and snow-covered areas and therefore has a good nutritional support [11]

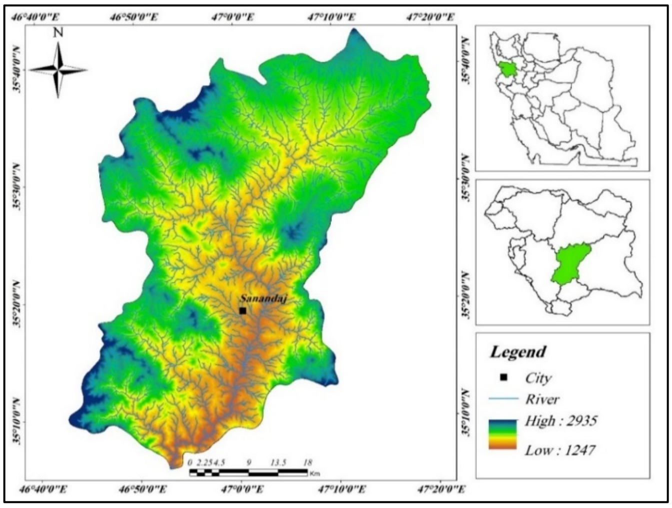

Figure 1: Study region

3. Methodology

To conduct this research, first a geological map of 1: 50000 study region has been prepared by the Geological Survey & Mineral Explorations of Iran (GSI). Then the layer of the main faults and tectonic fractures of the desired region is digitized in ARC GIS software. The drainage network of the desired catchment area was extracted from the DEM 12.5 m taken from the Vertex-Alaska site in the ARC HYDRO extension of ARC GIS software and the results were verified on Google Earth. Also, information about springs in the catchment area has been prepared by Iran Water Resources Management Company and after controlling the data and removing incomplete and irrelevant statistics in the EXCEL program, 3611 springs have been used as the basis for studies. Among the available variables related to springs, two variables of number and annual discharge based on cubic meters have been selected and the structural, lithological and drainage network parameters of the catchment have been studied.

4. Discussion

In this study, an attempt is made to investigate the relationship between discharge and the number of springs in relation to various parameters such as formation material, altitude factor, distance from the river and distance from the fault. For this purpose, each of the desired parameters is examined in relation to the two discharge indices and the number of springs, and their correlation is obtained and at the end, the results are analyzed.

4.1. Distance from the fault

Intense tectonic processes cause large seam and gap systems; These fault zones can establish hydraulic connections between shallow and deep regions in geological environments [12]. This relationship is variable in the set of fault zones in detrital sediments and is a function of sediment burial [13,14], fault expansion [15] and recrystallization along the fault plane [16].

In this regard, first the faults in the study basin were identified using information layers and geological maps and the springs adjacent to them up to 5 km from the fault were classified at distances of 500 meters (figure 2). Table 1 shows these parameters by class, based on which the diagrams in Figure 3 are drawn. As can be seen, there is a significant relationship between the distance from the fault and the number of springs with a correlation of 0.97. It can be noted that the largest number of springs are located closest to the faults and gradually the distance from these tectonic fractures decreases the number of springs. But there is no special relationship between the flow rate of springs and the distance from the fault.

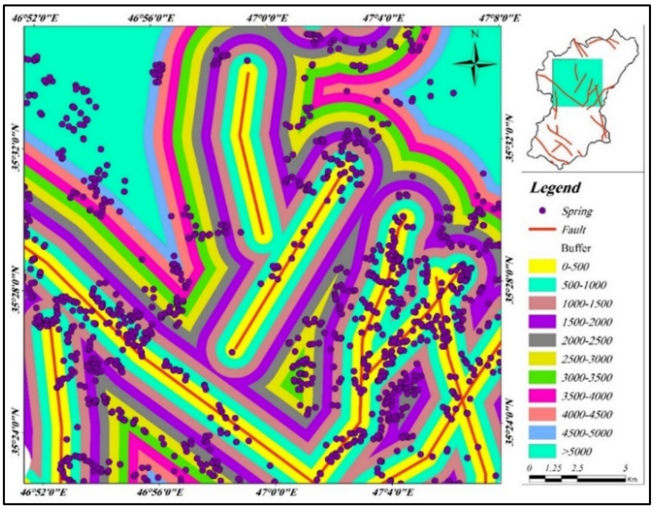

Figure 2: Classification of springs adjacent to fault lines

Table 1: Relationship between distance from the fault, number of springs and average annual discharge

	Distance from fault (meters)	Number of springs	Average annual discharge (m^3)
1	0-500	877	11768.28
2	500-1000	697	10462.94
3	1000-1500	677	10802.7
4	1500-2000	543	11326.03
5	2000-2500	482	12049.17
6	2500-3000	391	11572.13
7	3000-3500	297	11409.35
8	3500-4000	211	8937.96
9	4000-4500	109	5616.904
10	4500-5000	143	5751.835
	R^2	**0.9755**	**0.5472**

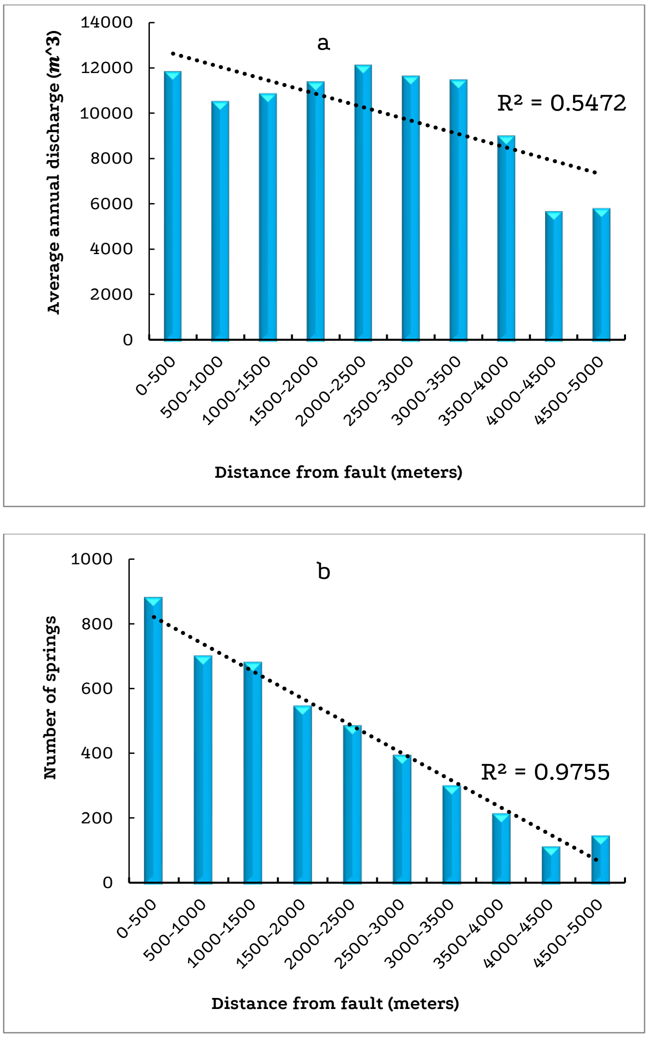

Figure 3: Diagrams of the relationship between distance from the fault and (a) average annual discharge (b) the number of springs

Table 2: Relationship between distance from the river and the number and flow of springs

	Distance from the river (meters)	Number of springs	Average annual discharge (m^3)	Percentage of total basin area	Number of springs in percentage of area
1	0-100	2303	12690.82	21.80	105.63
2	100-200	812	8965.16	19.54	41.55
3	200-300	683	9759.16	16.98	40.22
4	300-400	503	9099.61	14.05	35.79
5	400-500	328	7895.14	10.88	30.15
6	500-600	168	9733.07	7.62	22.04
7	600-700	81	9504.00	4.75	17.05
8	700-800	35	8929.51	2.44	14.32
9	800-900	15	8041.42	1.05	14.35
10	900-1000	1	2207.52	0.41	2.42
	R^2	**0.6607**	**0.5054**	**0.9836**	**0.7043**

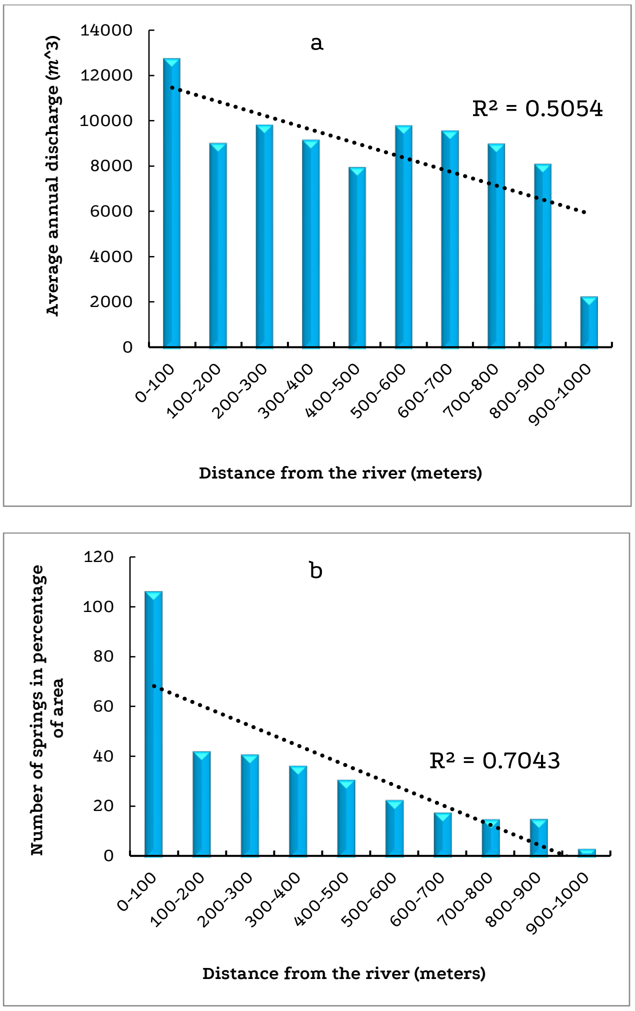

Figure 4: Diagrams of the relationship between distance from the river and (a) average annual discharge (b) number of springs in percentage of area

4.2. Distance from the river

Rivers flow at the ends of slopes and form topographic Thalweg. Topography is a complex parameter that can be reflected in exterior features or in internal rock structures such as faults and fracture zones [17]. In the following, the relationship between the distance from the river and the discharge and the number of springs in the Study region is investigated. To do this, the existing springs up to a distance of one kilometer from the drainage network are classified into categories of 100 meters. It should be noted that due to the high density of the drainage network, the primary buffers cover a very high area of the study basin and the study of these two parameters alone reduces the certainty of the results; In order to eliminate this error, the percentage of area of each buffer in relation to the whole basin has been calculated and the number of springs in relation to the percentage of area has been studied (Table 2). The results of this parameter also show that the number of springs decreases with distance from rivers. But the correlation between these two parameters is less than the distance from the fault. There is no significant relationship between the average annual discharge and the distance from the river, moreover the correlation between these two parameters is less than the distance from the fault. It is interesting to note that the number of springs decreases almost uniformly with distance from the fault, but in relation to the river, the maximum number of springs is at a distance of 0-100 meters, and then the numbers gradually decreases (Figure 4); This point should be considered in relation to the hydraulic slopes of the underground layers.

4.3. Formation material

So far, the relationship between discharge and the number of springs with respect to the two parameters of distance from the fault and distance from the river has been investigated. From the results of the distance from the river, the relationship between the springs and the altitude factor can be understood to some extent. There was a significant correlation between the above two parameters and the number of springs, but these two parameters did not determine the flow rate. In the following, the geology parameter and formation material are examined in the amount of this factor. Due to the fact that the exact area of each formation is not measurable in relation to the whole basin, the number of springs index is not examined and it is mentioned in Table 3 to ensure the results of the flow rate of each formation.

In order to prepare the diagram, formations have been used in which the statistics of a large number of springs are available that can be commented on the basis of the results. According to the results of the diagram in Figure 5, it can be seen that the flow rate of the springs has a high relationship with the type and material of its geological formation. So that in the shale formation of Sanandaj there is the highest flow rate and in this formation, the average annual flow is 18673.62 cubic meters in 121 springs studied. After that, there are Micrite Shale & Lime and Sanandaj Tuff & Shale. Therefore, it can be mentioned that the discharge of springs in the combined formations of shale and another formation is the highest in the catchment. The lowest discharge is related to alluvial formations such as Trace and floodplains.

Another point mentioned in this diagram is the average height of springs related to each formation. Regardless of the altitude of each formation, for example, alluvial formations are dense in Thalweg and floodplains that have low elevations, but formations such as limestone and sandstone that often correspond to elevations; The average height of springs in different formations did not differ much and it can be said that there is a very low correlation between these two parameters.

Table 3: Comparison of spring discharge in different formations

Formation material	Average height of formation springs above sea level	Annual Discharge	Number of Springs
Splitt	2170.58	6639.16	19
Andesite - Splitt - Lava	2055.86	8549.39	189
Lime	2000.72	10200.37	222
Alluvium	1991.01	4390.27	97
Andesite	2128.78	13196.55	363
Micro-Fossilized Lime	1925.38	8668.84	216
Alluvium Trace	1782.27	5034.30	104
Periodicity of Dacite Tuff - Andesite	2025.85	4977.03	68
Tuff	2061.63	8201.56	59
Sanandaj Tuff & Shale	1980.17	15692.34	81
Andesite Tuff	1670.27	6233.08	51
Shale	1842.32	5873.20	277
Gray & Dark Shale	1832.28	12798.01	310
Sanandaj Shale	1845.75	18673.62	121
Volcanic Rocks	1894.67	8833.19	79
Micrite Shale & Lime	1891.91	17629.07	597
Conglomerate	1719.06	7187.66	138
Sand Stone	1595.19	14361.33	182
Andesite Compression Lava	1781.45	5677.64	104
Clay & Composition of Another Formation	1840.85	6815.87	334
Average	**1901.80**	**9481.62**	**180.55**
Standard Deviation	**151.84**	**4392.86**	**140.3**

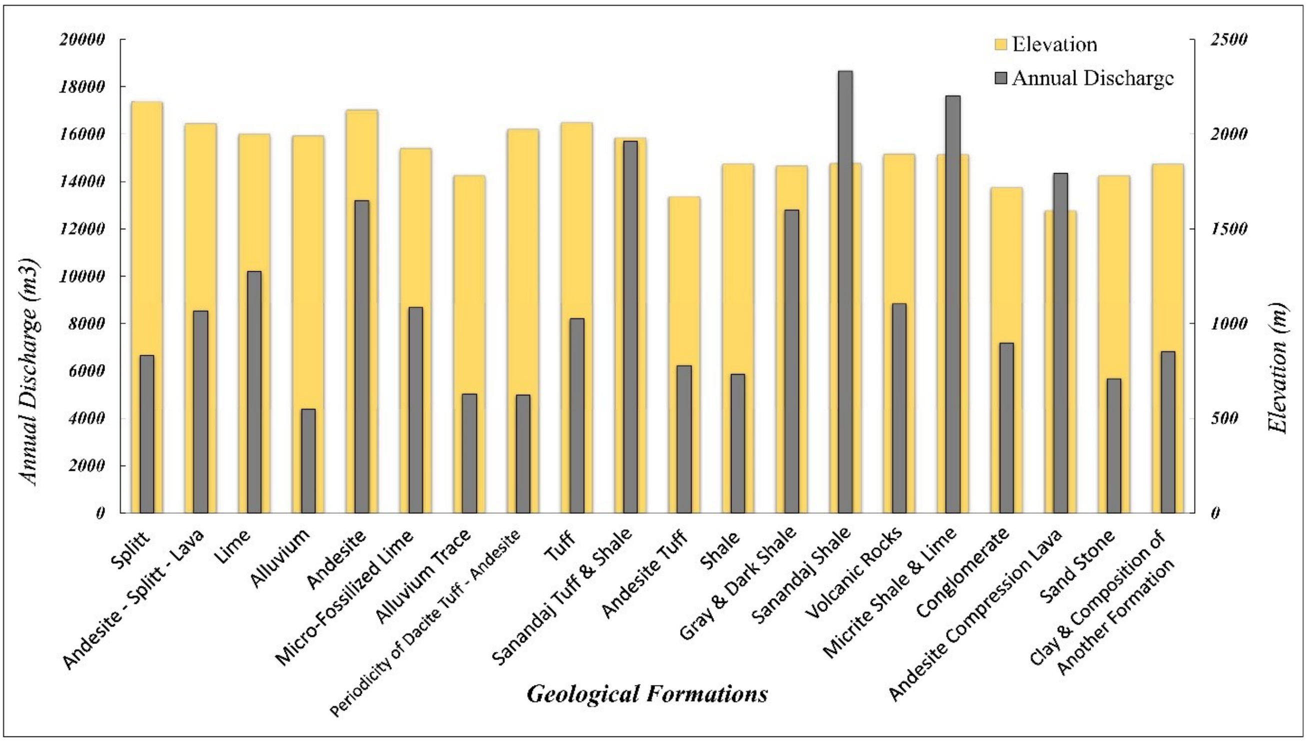

Figure 5: Comparison of the average spring discharge in different formations according to the average height of springs in each formation

5. Results

The distribution of springs and their flow rate are affected by various parameters. In the present study, the effect of structural, lithology and drainage network parameters of the catchment on two indicators related to springs, including the number and annual discharge has been investigated. The studies showed that there is a very close relationship between the number of springs and the distance from the faults, so that most of the studied springs were located near the fault lines. The correlation between these two parameters is 0.97, which indicates their close relationship. This relationship is weaker between the number of springs and the distance from the river, which is mainly due to two factors: the hydrological slope of the aquifers and the density of springs at lower altitudes. The correlation between the number of springs and the distance from the river is 0.6607. But there was no significant relationship between the two parameters of distance from the fault and the river with the flow rate of the springs. The only important point in this regard was the maximum discharge of springs located near rivers.

In order to find out the effective factor in the discharge rate of springs, the type of their geological formations was studied. And it was concluded that there is a significant correlation between these two indicators; So that the formations that are composed of shale and another type of formation such as tuff and micrite lime have more discharge. The highest annual discharge is related to Sanandaj shale formation and then there are two other shale formations. But interestingly, pure shale has very little discharge. In addition, Quaternary alluvial formations, tuffs and andesitic compact lavas have a minimum annual discharge. Also, studies showed that regardless of the nature of each formation at any altitude level, there is no significant correlation between the average height of springs in different formations.

References

[1.] Das D. Environmental appraisal for water resource development Proceedings. International Conference on Disaster Management (ICODIM) Guwahati: India Organized by Tejpur University. 1996;499-507.

[2.] Kalantari N A, Keshavarzi M R, Charchi A. Assessment of factors influencing occurrence of Izeh plain watershed springs, plain. Journal of Applied Geology.2009; No (2):147-135.

[3.] Kazemi R, Shadfar S, Bayat R. Investigation of the effective elements in water resource exploration of the hard formations, case study: Lar catchment. Watershed Engineering and Management. 2016; Vol (7(4)):389-401.

[4.] Edrisnia S, Pahlavanravi A, Moghadamneia A, Nazari Samani A, Amiri A. Investigation of the role of structural elements on water resource abundance in Maharloo karst region using RS and GIS. Journal of Range and Watershed Management (Iranian Journal of Natural Resources).2017; Vol (70(2)) :263-275.

[5.] Wu Y, Zhou X, Wang M, Zhuo L, Xu H, Liu Y. Comparison of hydrogeological characteristics and genesis of the Xiaguan Hot Spring and the Butterfly Spring in Yunnan of China. Journal of Hydrology. 2021 Feb 1; Vol (593):125-922.

[6.] Ozdemir A. Using a binary logistic regression method and GIS for evaluating and mapping the groundwater spring potential in the Sultan Mountains (Aksehir, Turkey). Journal of Hydrology. 2011 Jul 21; Vol (405(1-2)):123-36.

[7.] Hatim E. potential of remote sensing tech niquies in Karst areas southern Turkey. international Reasearch and application center of Karst water Resoures. Hecettepe Univerity Beytepe 06532 . Ankara Turkey . 1993 .

[8.] motlaq kh, Lashkaripour G R. Tectonic control on the appearance of Karst springs in Kooh – e – Siah (Dehdasht , south west iran), The 1 international Applied Geological Congress , Department of Geology , Islamic , azad University – Mashad Branch , April 2010: 28-26

[9.] Rahnamai MT. Environmental management of water resources of Gheshlagh river in Kurdistan, Tehran. 1997; Vol (2)

[10.] Amani kh. Hydrodynamics and stability of the Gheshlagh river and its effect on urban development in Sanandaj, Master's thesis. University of Tehran. 2015.

[11.] Rahnemaei, M. Application of spectral analysis of daily water level and spring discharge hydrographs data for comparing physical characteristics of karstic aquifers. Journal of Hydrology.2005; Vol (311): 106-116.

[12.] Benze V F, Gleeson T, Loveless S E. Fault Zone Hydrogeology, Earth-Science Reviews.2013; Vol (127): 171–192

[13.] Fulljames JR, Zijerveld JJ, Franssen RCMW. Fault SealProcesses: Systematic Analysis of Fault Seals over Geological andProduction Time Scales, in Hydrocarbon Seals: Importance forExploration and Production, Norwegian Petrol Soc Spec Publ, 1997; Vol (9): 51–59.

[14.] Rawling GC, Goodwin LB, Wilson JL. Internal Architecture, Permeability Structure, and Hydrologic Significance of Contrasting Fault Zone Types. Geology. 2001; Vol (27): 43–46.

[15.] Wieck J, Person M, Stayler L. A Finite Element Method for Simulating Fault Block Motion and Hydrothermal Fluid Flow within Rifting Basins, Water Resour Res. 1995; Vol (31): 3241–3258.

[16.] Fisher Q, Knipe R. Fault Sealing Processes in Siliciclastic Sediment, in Faulting, Fault Sealing and Fluid Flow in Hydrocarbon Reservoirs. Geol Soc Lond. Spec Publ. 1998; Vol (147): 117–134.

[17.] Henriksen H. The role of some regional factors in the assessment of well yields from hard rock aquifers of Fennoscandia. *Hydrogeology Journal.* 2003; *Vol (11):628-645.*