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С о д р ж и н а

EXPLOITATION AND HYDROGEOLOGICAL PARAMETERS OF HYDROGEOTHERMAL SYSTEM SPA KEZHOVICA - STIP

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Abstract

This paper presents the exploitation and hydrogeological parameters of hydrogeothermal system of the spa Kežovica, which are calculated based on data obtained by the pump testing of the four exploitation wells that are located within this system, labeled as B-1, B-2 , B-3 and S-3.

The individual exploitation capacity of the wells is for B-1 - 1,7 l/s; for B-2 -12,5 l/s, B-3 - 8,9 l/s and for S-3 - 3,3 l/s, and the total capacity of exploitation of all wells is 26,4 l/s.

The coefficient of filtration of the aquifer medium is within ranges of 0,034 - 2,25 m/day, the transmissibility ratio is from the 3,3 to 38,29 m^2/s, and the radius of the influence of the wells is in range from 49 to 155 m.

The temperature of the thermomineral is from 52 to 62 ° C.

Key words: *exploitation wells, hydrogeothermal system, spa Kežovica, hydrogeological parameters, coefficient of filtration, radius of influence, coefficient of transmissibility.*

ЕКСПЛОАТАЦИОНИ И ХИДРОГЕОЛОШКИ ПАРАМЕТРИ НА ХИДРОГЕОТЕРМАЛНИОТ СИСТЕМ НА БАЊАТА КЕЖОВИЦА – ШТИП

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Апстракт

Во овој труд се презентирани експлоатационите и хидрогеолошките параметри на хидрогеотермалниот систем на бањата Кежовица, кои се пресметани врз основа на податоците добиени со тестирањето на четири експлоатациони бунари кои се наоѓаат во рамките на овој систем, означени како B-1, B-2, B-3 и S-3. Поединечниот експлоатационен капацитет за бунарите изнесува за B-1 1,7 l/s; B-2 12,5 l/s, B-3 8,9 l/s и за S – 3, 3,3 l/s, а вкупниот експлоатационен капацитет за сите бунари изнесува 26,4 l/s. Коефициентот на филтрација за водоносната средина се движи во рамките од: 0,034 – 2,25 m/den, коефициентот на трансмисивност од 3,3 – 38,29 m^2/s, а радиусот на влијание кај бунарите се движи од 49 – 155 m. Температурата во бунарите е во рамките од 52 – 62 °C.

Клучни зборови: *експлоатациски бунари, хидрогеотермален систем, бања Кежовица, хидрогеолошки параметри, коефициент на филтрација, радиус на влијание, коефициент на трансмисивност.*

1. Introduction

Hydrogeothermal system of the spa Kežovica is located in the eastern part of Macedonia near Novo Selo about 2,5 km southwest of the city of Stip (Fig.1).

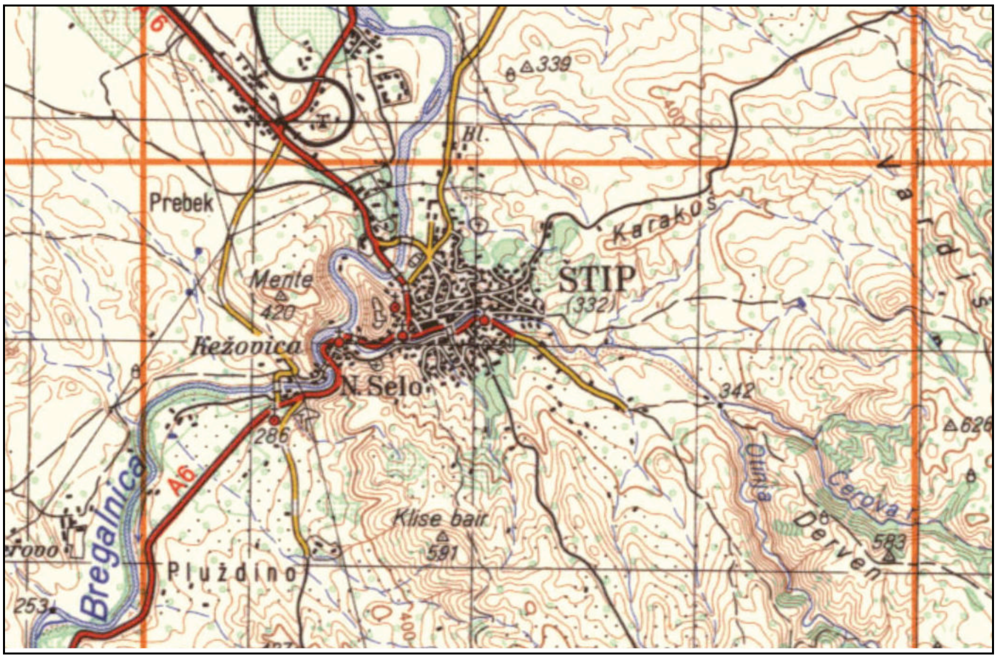

Figure 1. Geographical position of the hydrogeothermal system of the spa Kežovica

Within this hydrogeothermal system, there are four wells from which can be exploited thermalmineral water, labeled as B-1, B-2, B-3 and S3.

The wells B-1 and S-3 are located near the spa Kežovica Fig. 2 and thermomineral water are used for the spa and physical therapy. The other wells labeled as B-2 and B-3 are on site Ldzhi near the river Bregalnica (Fig.3). Thermomineral water from these two wells currently is not used. At this site near the well B-2 (Fig. 3) is located a spring with thermomineral water used by the local population of Novo Selo.

Fig.2. Exploitation wells B-1 and S-3 in the spa Kežovica yard.

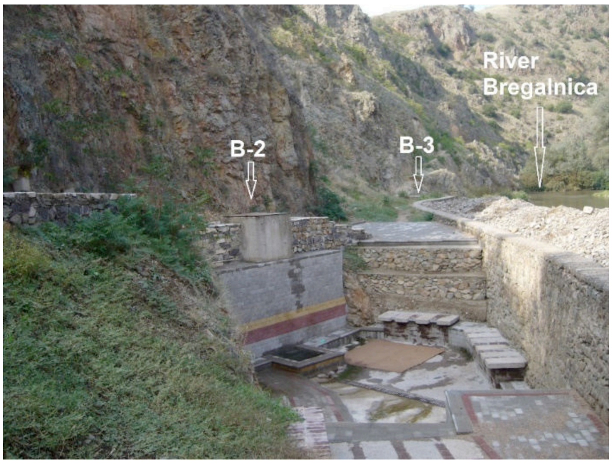

Fig.3. Exploitation wells B-2 and B-3 at a site Ldzhi near the river Bregalnica.

In the past, a growing number of researchers have studied the thermaomineral waters from the spa Kežovica and locality Ldzhi: Miloevik (1953), Miholik (1953), Baik (1955), Netkov (1968), Nastic (1968), Gjuzelkovski and Strackov (1973), Kotevski (1974, 1983), Kekik and Mitev (1973-1978), Gjordjieva (1995): Mirchovski et. all. (2001-2002, 2016).

2. Exploitation wells

All four wells are made from Geological Institute in Ljubljana. Well S-3 was made in 1953 and wells B-1, B-2 and B-3 in the 1976/77 year. The depth of well B-1 is 30.7 m, B-2 is 101.1 m, B-3 is 44 m, and S-3 is 22.5 m. Yield of wells is B-1 is 1.3 l/s, B-2 is 11.5 l/s, B-3 is 6.5 l/s and S-3 is 2.7 l/s. The total capacity of all wells measured at that time was 22 l/s.

The static level in the well B-1 is of 1.7 m, B-2 is 2.3 m, B-3 is 2.5 m, and S-3 is 2.3 m, which indicates that it is for sub artesian aquifer located in the Jurassic cracked granites (Soptrajanova 1967).

The temperature of the thermomineral water is in range between 52 - 62 ° C.

The wells B-1 and S-3 are very close to each other at a distance only by 4 m, from the wells B-2 and B-3 are distant 300 m, while the wells B-2 and B- 3 of one another are distant about 30 m.

Lithological - hydrogeological profiles of exploitation wells as their technical characteristics are shown in Fig. 4.

From lithological - hydrogeological profiles can be seen that to the aquifer is located in Jurassic, tectonic cracked, biotite granites. These granites occur on the surface of the ground until the drilling distance to the depth of 101 m, and drain water from the subartesian aquifer.

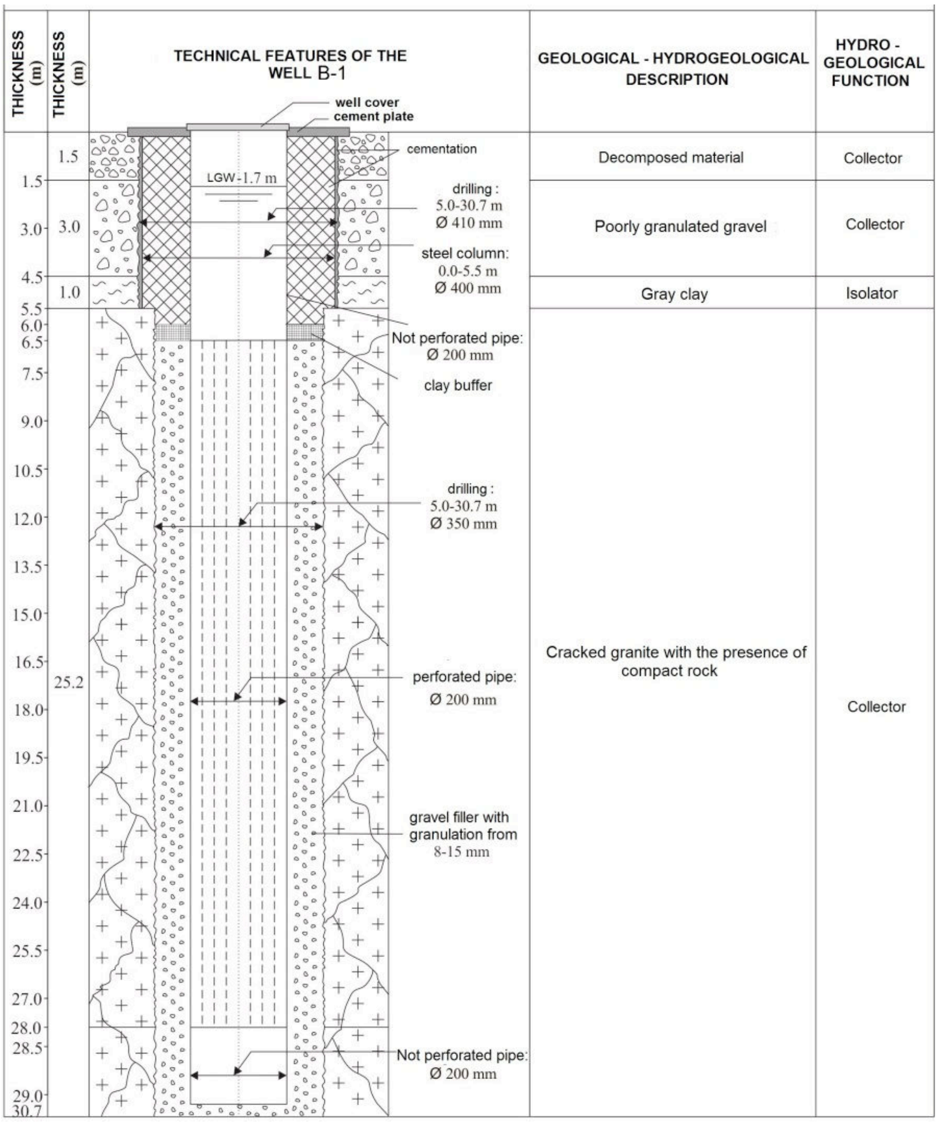

Figure 4. Lithological - hydrogeological profile and technical characteristics of the well B-1

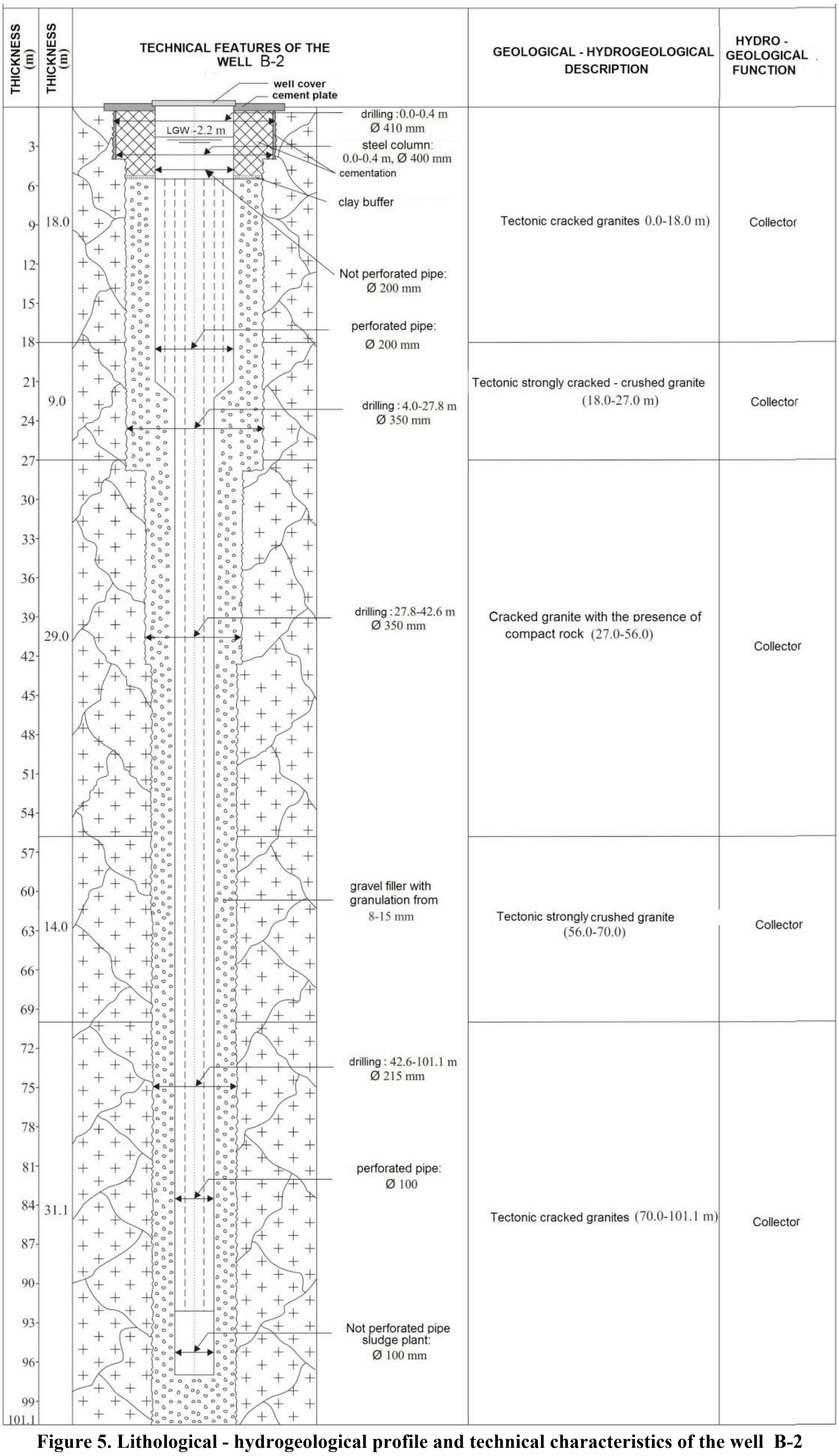

Figure 5. Lithological - hydrogeological profile and technical characteristics of the well B-2

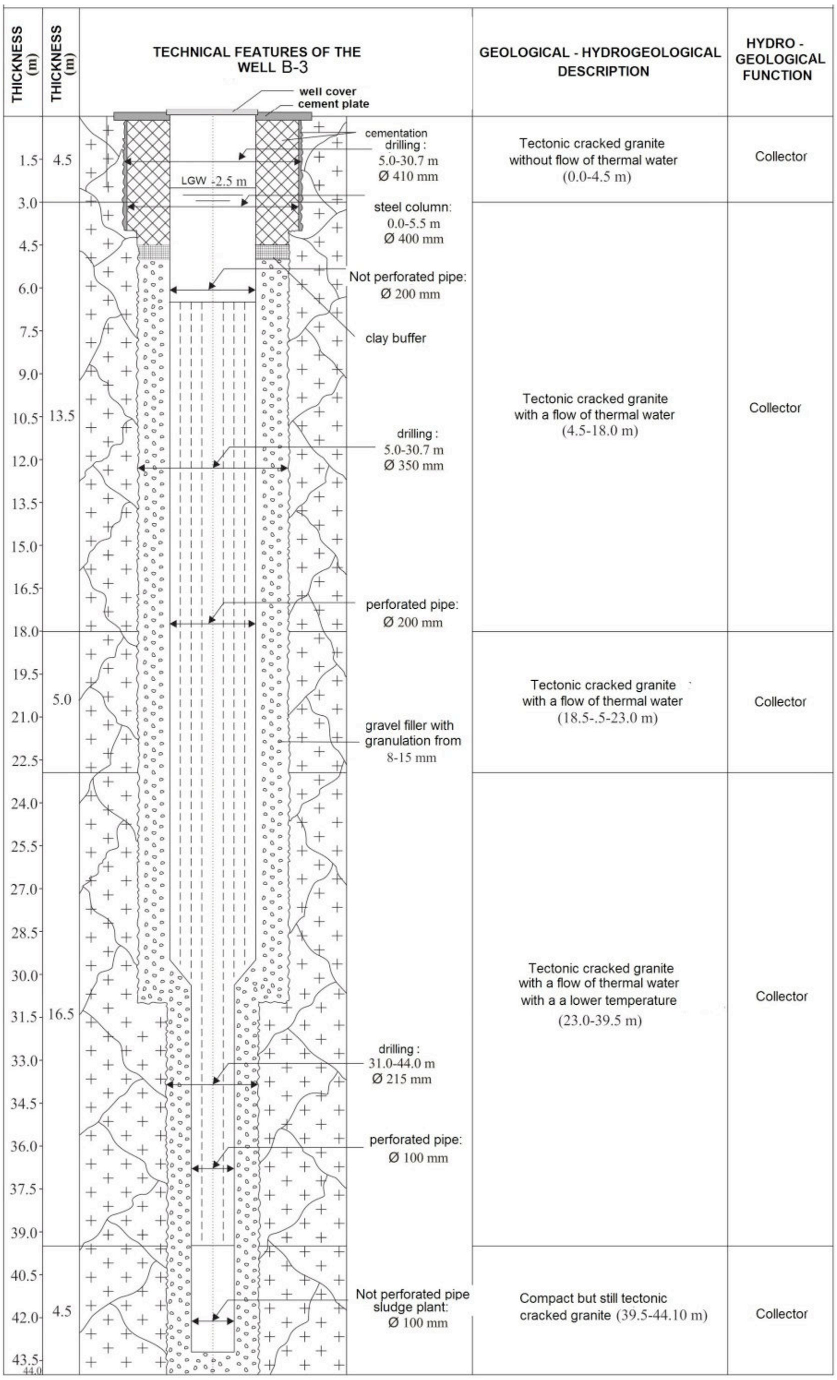

Figure 6. Lithological - hydrogeological profile and technical characteristics of the *well B-3*

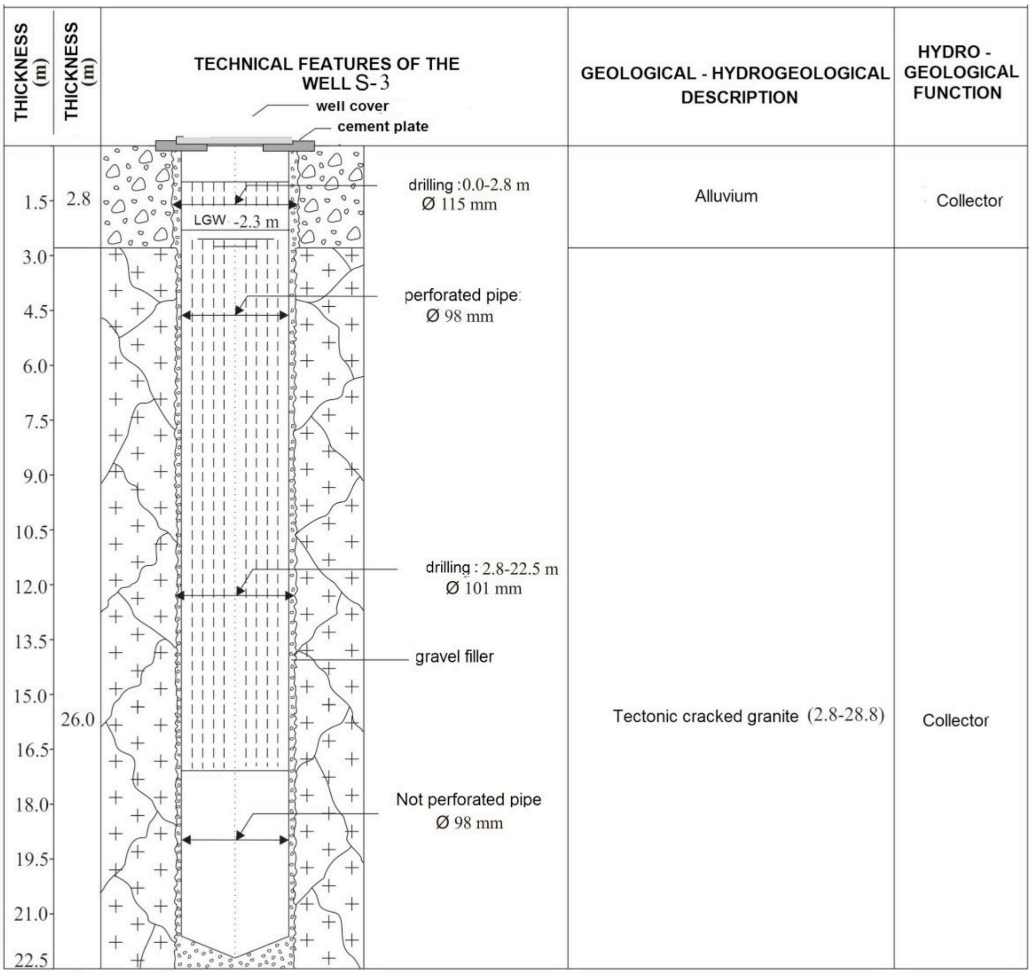

Figure 7. Lithological - hydrogeological profile and technical characteristics of the well S-3

2. Pump testing of the wells

In order to determine the yield of exploitation wells B-1, B-2, B-3 and S-3 in October 2015 was performed pump testing process of the wells. It was made for each well individually and duration of pumping test was 24 hours, or total, three pump tests for a period of 72 hours. Also, pump testing was carried out by three capacities (Q), obtained at three dynamic levels of the lowering (S). During pump testing for pumping water, in the wells was descended pipe with diameter φ 63 mm to a depth of 7,5 m, with which was limited dynamic level in the wells.

Based on the data obtained from pump testing for all exploitation wells, we prepared a diagram Q = f (S) and diagram q = f (S), and hydrograms of extraction which is displayed Q = f (t) and S = f (t).

After completion of the pump test, it was also measured the recovery the level of the wells and from the received data are constructed diagrams S = f (t). Summary data of pump testing are shown in Tables 1,2,3,4,5,6,7 and 8:

Table 1. Data from pump testing of well B-1

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
1,7	Q_1 =0,8	4,95	S_1=3,25	24	0,246
	Q_2 = 1	5,9	S_2=4,20	24	0,238
	Q_3=1,25	7,1	S_3=5,40	24	0,231

Table 2. Data from pump testing of well S-3

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
2,30	Q_1 =1	3,60	S_1=1,30	24	0,769
	Q_2 = 2	5,20	S_2=2,90	24	0,689
	Q_3=2,8	6,90	S_3=4,60	24	0,608

Table 3. Data from pump testing of well B-2

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
2,20	Q_1 =3	3,00	S_1=0,80	24	3,75
	Q_2 =6	3,85	S_2=1,65	24	3,63
	Q_3=9	4,80	S_3=2,60	24	3,46

Table 4. Data from pump testing of well B-3

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
2,50	Q_1 =2,5	3,80	S_1=1,30	24	1,923
	Q_2 = 4	4,70	S_2=2,20	24	1,8181
	Q_3= 6,5	7,00	S_3=4,50	24	1,444

Table 5. Data for pump testing well B-1 and measuring the level of decrease in well S-3

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
1,7	1,3	7,30	5,6	24	0,232

Table 6. Data for pump testing well S-3 and measuring the level of decrease in well B-1

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
2,30	3	7,10	4,8	24	0,625

Table 7. Data for pump testing well B-2 and measuring the level of decrease in well B-3

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
2,20	6,5	4,1	1,9	24	3,42

Table 8. Data for pump testing well B-3 and measuring the level of decrease in well B-2

LGW Static	Yield Q (l/s)	LGW Dynamic (m)	Lowering S (m)	Time T (h)	Specific yield q (l/s/m)
2,50	6,2	6,05	3,55	24	1,746

During the pump testing of the the well B-1 was measured level of declining water in the well S-3 which is located at a distance of 4 m. In the well S-3 was measured a total decline in the level for 52 cm. During the pump testing of the the well S-3, level in the well B-1 was dropped by 35 cm. This shows that there is a radius of influence between these two wells.

During the pump testing of the the well B-2 which is located at a distance of 30 m from the B-3, was observed declining of the level in the well B-3, which was observed declining of the level in B-3 by 49 cm. During the pump testing of the the well B-3 also was observed declining levels in the well B-2 and it was concluded declining of the level in the well B-2 from 45 cm. Based on these data it can conclude that there is a radius of influence between wells B-2 and B-3.

The static groundwater level is measured from the mouth of the wells. Because the type of pump that was used to the pump testing and lowered pipe in a wells with a length of 7,5 m limit the dynamic level in wells and prevented to perform the test with greater capacity and lowering the dynamic level deeper, optimum, maximum and exploitation capacity of the wells are certain grapho-analytical.

In the testing procedure of the wells in all three capacities, it is also measured water temperature for each well:

Wills	B-1	B-2	B-3	S-3
Temperature ^{o}C.	58 ^{o}C.	52 ^{o}C.	61 ^{o}C.	62 ^{o}C.

By increasing the capacity of the wells is not noticed an increase in water temperature, and the temperature of the water was constantly in the process of testing. The smaller water temperature in wells B-1 and B-2 compared to wells B-3 and S-3 is likely due to the mixing of these water with cold water from the upper parts of the aquifer.

3. Exploitation capacity of the wells

Based on the performed pump testing of the wells and graphoanalytical analysis, is determined exploitation (Qexp), maximum (Qmax) and optimal (Qopt) yield of wells.

To determine the exploitation (Qexp), maximum (Qmax) and optimal (Qopt) yield of wells has been used is a graphoanalytical method by applying diagrams Q = f (S), which shows the functional relationship between yield of wells and lowering the level. During the determination of resource is used the principle that lowering in the exploitation wells should not be more than 1/3of the thickness of the aquifer (H) and maximum lowering (S) in the wells should not be more than 2/3 of the thickness of the aquifer collector. The optimal capacity of the wells is calculated by formula Qopt. = Qmax × α (where α is a coefficient which is 0.7), while the optimal lowering Sopt. is specified graphoanalytical from diagrams Q = f (S) by applying the optimal capacity Qopt.

In the table 9 are given the capacity for exploration wells through values: Qexp, Qopt, Qmax, Sexp, Sopt and Smax.

Table 9. Capacities for the exploitation of wells B-1, B-2, B-3 and S-3

	B-1	B-2	B-3	S-3
Qexp (l/s)	1,7	12,5	8,9	3,3
Qopt (l/s)	1,99	9,6	6,8	2,9
Qmax (l/s)	2,85	13,8	9,8	4,15
Sexp (m)	8	33	13,6	6,56
Sopt (m)	9,6	3,52	5	4,92
Smax (m)	16	66	27,3	13,1

The total exploitation capacity (Qexp.) for all wells is as follows:

Qtotal = 1,7 + 12,5 + 8,9 + 3,3 = 26,4 l/s.

4. Hydrogeological parameters of aquifer environment

The main hydrogeological parameters of the aquifer environment: coefficient of filtration (K), the coefficient of transmissibility (T) and the radius of the depression (R) are calculated of conditions for stationary flow within the aquifer with level under pressure without the direct influence of surface water.
Coefficient of filtration is calculated according to the formula of Dupuit (1854, 1857) in case of wells, which drain groundwater aquifer under pressure:

$$k = 0.366 \frac{Q}{mS} \cdot \log \frac{\mathbf{R}}{r} \quad \text{[m/s]}$$

coefficient of filtration	K [m/s]
exploitation yield	Qexp (m^3/s)
lowering	S (m)
radius of wells	r = (m)
thickness of the aquifers	m (m)
radius of depression	R (m)

The coefficient of transmissibility (T) is determined at the formula:

$$T = K \times m \quad [m^2/s]$$

Radius of the influence (R) of wells was determined for exploitation capacity Q(exp) and exploitation lowering S (exp), according to formula:

$$R = 3000 \times S \times \sqrt{K} \quad \text{[m]}$$

coefficient of filtration	K [m/s]
lowering	S (m)
radius of the influence	R (m)

The obtained data for hydrogeological parameters are shown in Table 10.

Table 10. Hydrogeological parameters of to the aquifer environment

	B-1	B-2	B-3	S-3
Coefficient of filtration K_f (m/day)	0,688.	0,034	1,25	2,25
Coefficient of transmissibility T (m^2/s)	*16,67.*	*3,3*	*51,36*	*38,29*
Radius of the influence R (m)	68	62	155	49

The values of hydrogeological parameters as you can seen from the table is distinguish by well to well and show different values. That was due to the non homogenous cracking of the granites that is not homogeneous porosity in the aquifer environment.

The calculated values for the radius of influence show that there is a radius of influence between B-1 and S-3 and between the B-2 and B-3, because the distance between B-1 and S-3 is only 4 m, and between the B-2 and B-3 is 30 m.

While the radius of influence between wells B-1 and S-3 in terms of the wells B-2 and B-3 does not exist because the distance between B-1 and S-3 in terms of dupnatinite B-2 and B-3 exceeds 300 m.

The radius of influence of the wells, as previously stated, is registered with the simultaneous testing of the wells B-1 and S-3 and B-2 and B-3.

5. Conclusion

Based on the pump test of the wells and grafoanalytical analysis of the results of extraction are certain exploitation capacity by four wells located within the hydrogeothermal system of spa Kežovica. Individual wells capacities are: B-1 1,7 l/s; B-2 12,5 l/s; B-3 8,9 l/s and S-3 3,3 l/s, and the total exploitation capacity of the system amounted to 26,4 l/s.

The main hydrogeological parameters of the water supply environment: filtration coefficient (K), the coefficient of trasmissibility (T) and the radius of the influence (R) are calculated for conditions of stationary flow within the aquifer with level under pressure without the direct influence of surface water.

The coefficient of filtration to the aquifer environment is within ranges of: 0,034 - 2,25 m/day, the coefficient of transmissibility is 3,3 - 38,29 m^2/s, and the radius of the influence of the wells is between 49-155 m.

The difference of the values of hydrogeological parameters from well to well indicates the not homogenous porosity of the aquifer environment i.e. not homogenous cracking of the granite which carry the thermomineral water.

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