Groundwater as an important resources in emergency situations of the Republic of Serbia

Boris Vakanjac, Radoje Banković, Vesna Ristić-Vakanjac, Saša Milanović, Ljiljana Vasić, Saša Bakrač, Nikola Kozić

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PREFACE

Military Technical Institute, the first and the largest military scientific-research institution in the Republic of Serbia with over 75 years long tradition, has been traditionally organizing the OTEH scientific conference, devoted to defense technologies. The Conference is supported by the Ministry of Defense and it takes place every second year.

Its aim is to gather scientists and engineers, researchers and designers, manufactures and university professors in order to exchange ideas and to develop new relationships.

The 11th International Scientific Conference OTEH 2024 is scheduled as follows: lecture on the occasion of "Pavle Savic", given by Vladimir Cizelj, PhD, and two plenary lectures: "Energetic Materials", given by Prof. Thomas M. Klapoetke, PhD Eng, and "Anti-Drone Combat" given by Boban Sazdic Jotic, PhD , as well as working sessions according to the Conference topics.

The papers which will be presented at the Conference have been classified into the following topics:

- Aerodynamics and Flight Dynamics
- Aircraft
- Weapon Systems and Combat Vehicles
- Ammunition and Energetic Materials
- Integrated Sensor Systems and Robotic Systems
- Telecommunication and Information Systems
- Materials and Technologies
- Quality, Standardization, Metrology, Maintenance and Exploitation.

The Proceedings contain 130 reviewed papers which have been submitted by the authors from 11 different countries. I would also like to emphasize that we have 14 papers with authors from abroad. The quality of papers accepted for publication achieved very high standard. I expect stimulated discussion on many topics that will be presented online, during two days of the Conference.

On behalf of the organizer I would like to thank all the authors and participants from abroad, as well as from Serbia, for their contribution and efforts which made this Conference possible and successful.

I would also like to thank the Ministry of Science, Technological Development and Innovations of the Republic of Serbia for its financial support.

Finally, dear guests and participants of the Conference, I would like to wish you a pleasant and successful work during the Conference. I am looking forward to see you again at the Conference. All the best and stay healthy.

Belgrade, October, 2024

Col. Aleksandar Kari PhD Eng
President of the Scientific Committee
OTEH 2024

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GROUNDWATER AS AN IMPORTANT RESOURCES IN EMERGENCY SITUATIONS OF THE REPUBLIC OF SERBIA

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Abstract: *Groundwater is a renewable resource wholly or partially protected from external influences (pollutants) by nature. Currently, about 75% of the population of the Republic of Serbia meets its water needs by using underground water. Hence, this water represents an essential strategic resource of our country; according to data from the Water Management Foundation of the Republic of Serbia (VOS, 2001), water from existing sources is used in quantities of about 23 m^3/s. As 67.13 m^3/s is the estimated potential of underground water in Serbia, we state that only 1/3 of the total available potential of these waters is in usage. Therefore, we can count on these exceptional quality underground waters in emergencies. The problem is the need to monitor these waters that need to be captured and have their intended use. Monitoring water's quantitative and qualitative parameters is necessary to determine which reserves we are talking about. Whether it is easy to reach these resources (road and electrical infrastructure), making accompanying maps using GIS tools is essential. The paper will give an example of identifying hydrogeological objects in an area, establishing monitoring of selected hydrogeological objects, and determining which maps need to be made that would be important in emergencies.*

Keywords: *groundwater, spring, monitoring, emergency situation.*

1. INTRODUCTION

Groundwater is a water resource that, unlike surface water, is fully or partially protected from external influences and, therefore, pollution. Due to its quality, groundwater is preferred over surface waters in being used for any purpose, especially for water supply purposes [1].

We can say that the Republic of Serbia belongs to the group of countries in Europe that are richer in groundwater. The complexity of Serbia's geological structure led to specific hydrogeological conditions, so different types of aquifers are formed within them. The most significant in terms of size and, to some extent in terms of quality are the underground water resources formed within alluvial deposits. The capacity of these aquifers is about 44 m^3/s, and the biggest problem with these waters is the anthropogenic factor. More precisely, the largest settlements in the world, including in our country, are mainly located on the banks of rivers and their alluviums, so potential pollution is always present. The following water resource regarding available groundwater is karst outcrops formed within the Carpatho-Balkanides (eastern Serbia) and Internal Dinarides (western Serbia). The total capacity of these aquifers is about 14 m^3/s. These are high-quality waters, and for distribution to users, they usually only need to be pre-chlorinated. Some sources are captured for the water supply needs of the local population. The karst massifs are mostly uninhabited parts of Serbia, and the existing

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road infrastructure bypasses them, so potential pollutants are almost non-existent. The problem is that these resources are relatively far from big cities. The remaining estimated reserves of 9.5 m^3/s are related to less renewable water resources, i.e., aquifers within tertiary sediments. Therefore, the total available underground water potential is estimated at around 67.5 m^3/s [2]. It should be noted that the total discharge of all existing groundwater sources is about 23 m^3/s; only 1/3 of the available resources are currently used for water supply needs [3, 4] (Fig. 1 and Table 1).

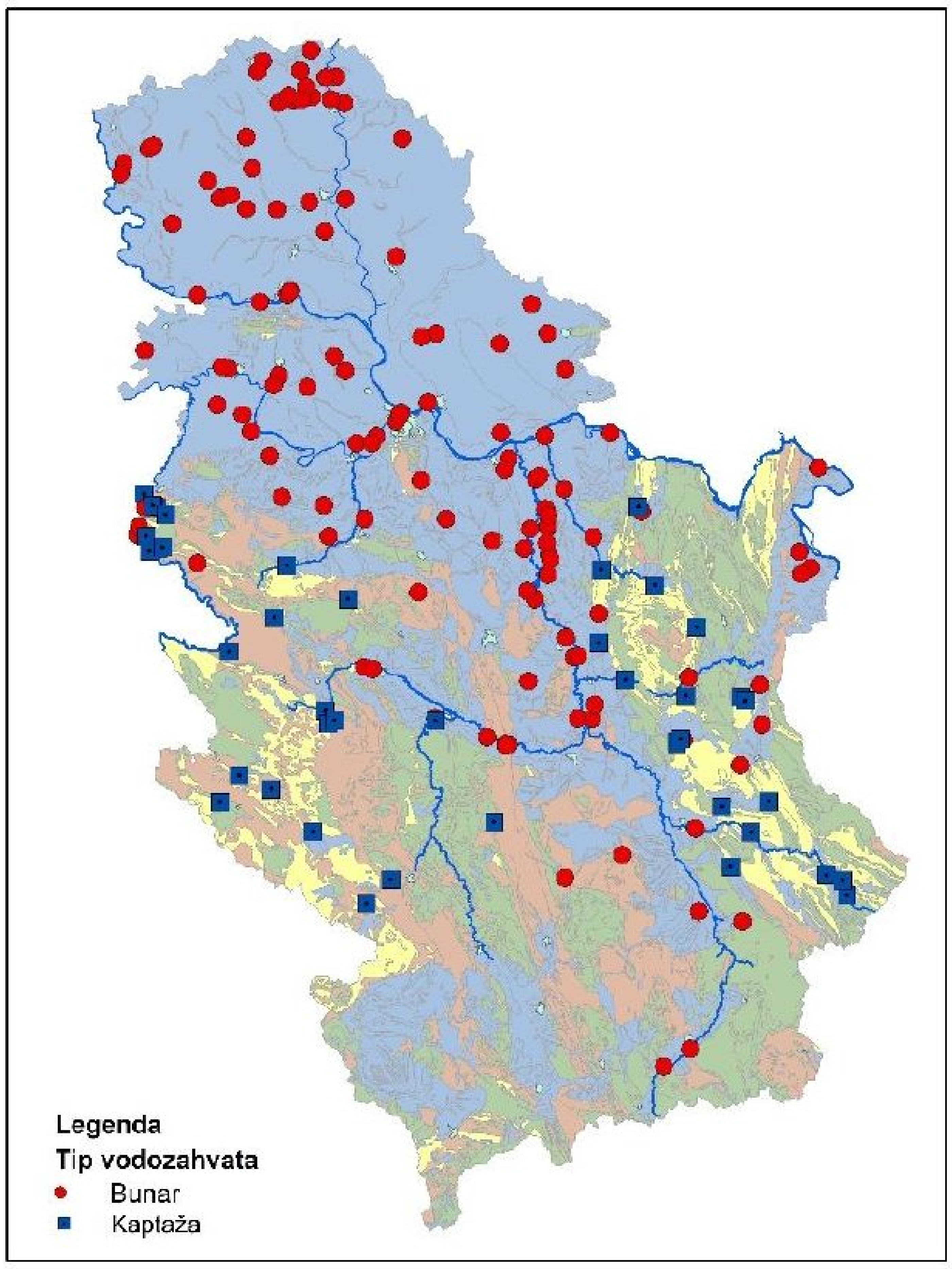


Figure 2. Hydrogeological map of Serbia with the positions of important springs and the method of groundwater captured water sources (wells/catchments) (taken from [1])

Table 1. Discharge of groundwater sources in Serbia according to the type of aquifer (m^3/s) taken and modified from [1])

	AD	BAC	ND	KE	FE	sum
1	1.45	3.57	0.43	0	0	5.45
2	6.97	0.34	0.50	0.03	0	7.84
3	2.58	0	0.84	0.43	0	3.85
4	0.62	0	0.06	1.71	0	2.39
5	0.24	0	0.14	1.61	0	1.99
6	1.05	0	0.06	0.40	0.02	1.53
sum	12.91	3.91	2.03	4.18	0.02	23.08

Note: AD - Alluvial deposits, BAC - basic aquifer complex (AP Vojvodina), ND - Neogene deposits, KE - karst environment, FE - Fissure environment, 1 - Bačka and Banat, 2 - Srem, Mačva, Sava/Tamnava, 3 - Central Serbia, 4 - Eastern Serbia, 5 - Southwestern Serbia, 6 - Western Serbia

It is important to note that over 75% of the inhabitants of the Republic of Serbia meet their water needs by using these waters. The importance of underground water is also indicated by the fact that Svetolik Radovanović published the book Ground Waters (Podzemne vode) in 1897 [5], while the Serbian Academy of Sciences asked Jovan Žujović to write the book "Supplying Villages with Water, springs and wells" which was published in 1931 [6].

Unfortunately, groundwater monitoring is still not at a satisfactory level. Although the monitoring of the underground water regime began in 1948 at 41 facilities, this number grew during the last century and reached 409 monitoring facilities (piezometers). Their arrangement, more precisely the coverage of water bodies in 2014, still needs to be improved because these observation stations mainly monitored the underground water regime of alluvial deposits. Out of 153 underground water bodies, only 34 were covered by existing piezometers. As for the qualitative properties of groundwater, their monitoring began in 1968. Currently, the situation is similar to that of quantitative parameters. Only at 32 water bodies is the regime of qualitative parameters monitored. Establishing monitoring is extremely important because, based on this data, one can gain insight into what quantities are available, what their quality is, and what the amplitudes (absolute maximum and minimum values) of the fluctuations of the selected parameters are [1, 2].

Considering the climate changes that significantly impact all water resources and, therefore, groundwater, the relationship between precipitation and groundwater is important for planning the use of these waters. In other words, the influence of the pluviographic regime on the regime of quantitative and qualitative groundwater parameters. One of the springs with the most extended monitoring series is the Mlava Spring, where the Republic Hydrometeorological Service of Serbia (RHMS) has monitored changes in the water level since 1949. Also, from 1966, flow measurements were carried out. For this reason, this spring is one of the most researched springs in Serbia, and the first hydrogeological studies were carried out by Jovan Cvijić and results was published in 1896 [7]. The investigation of this spring and a sufficiently long observation series influenced the fact that this spring was taken as a pilot area for many project including Climate Changes and Impact on Water Supply - CCWaterS [8]. The average yield of this spring is about 1,858 m^3/s, and a negative trend of this spring is evident from 1966 to 2010 [8] (Fig. 2). With this negative trend, it can be expected that at the end of this century, the discharge average of the Mlava spring will be 0.392 m^3/s [8] by applying the model for simulating the daily yield values of karst springs that were developed at the Department of Hydrogeology of the Faculty of Mining and Geology [9] and using forecast values of daily precipitation and mean daily temperatures obtained using regional climate models, for the end of this century, i.e. for 2100. year, the expected value of the discharge of this spring was obtained in the amount of about 1.6 m^3/s [8], which does not represent such a drastic reduction in the amount of water that will be discharged from the Mlava spring (Fig. 3).

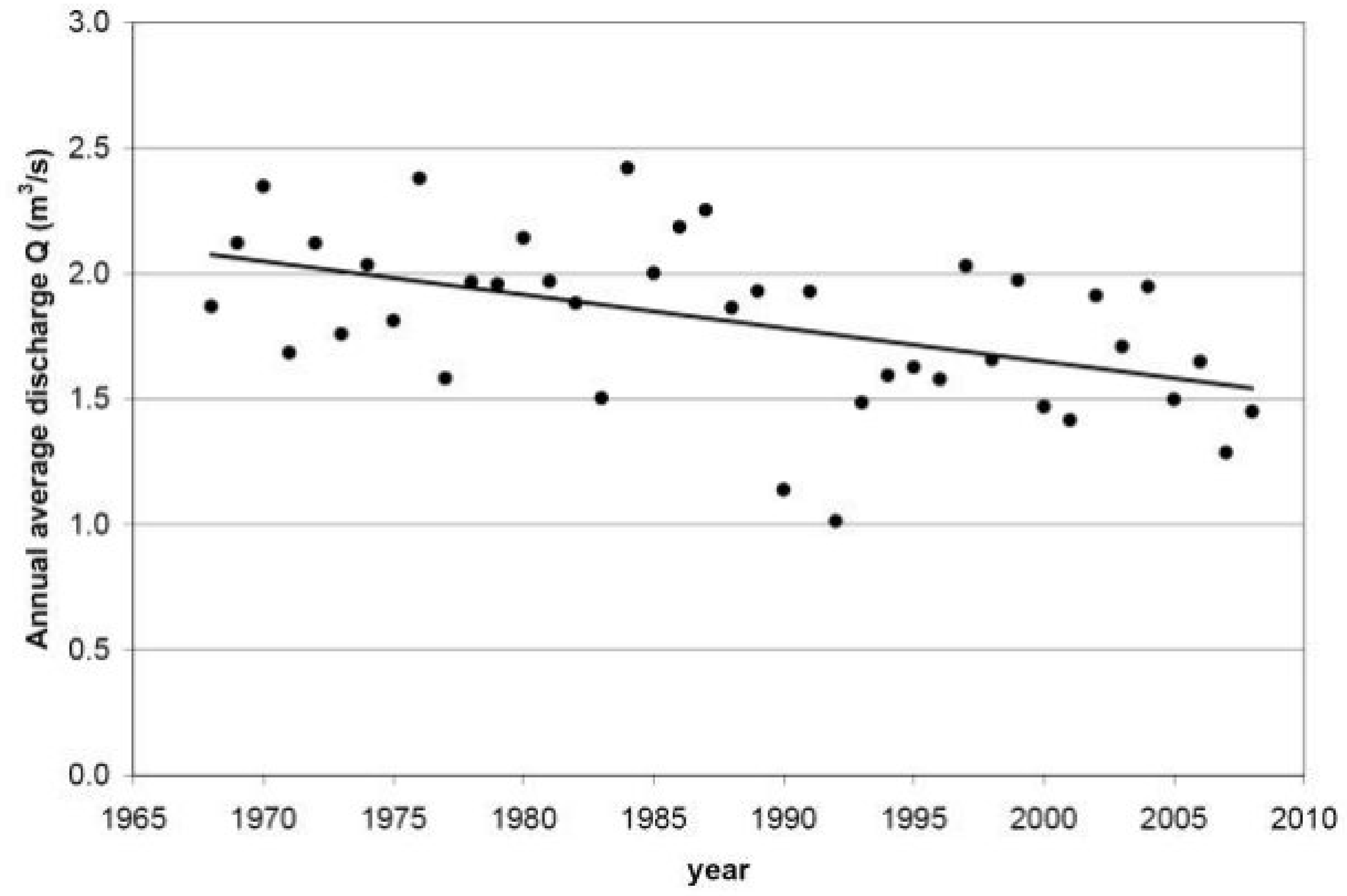


Figure 2. Annual discharge of Mlava spring [8]

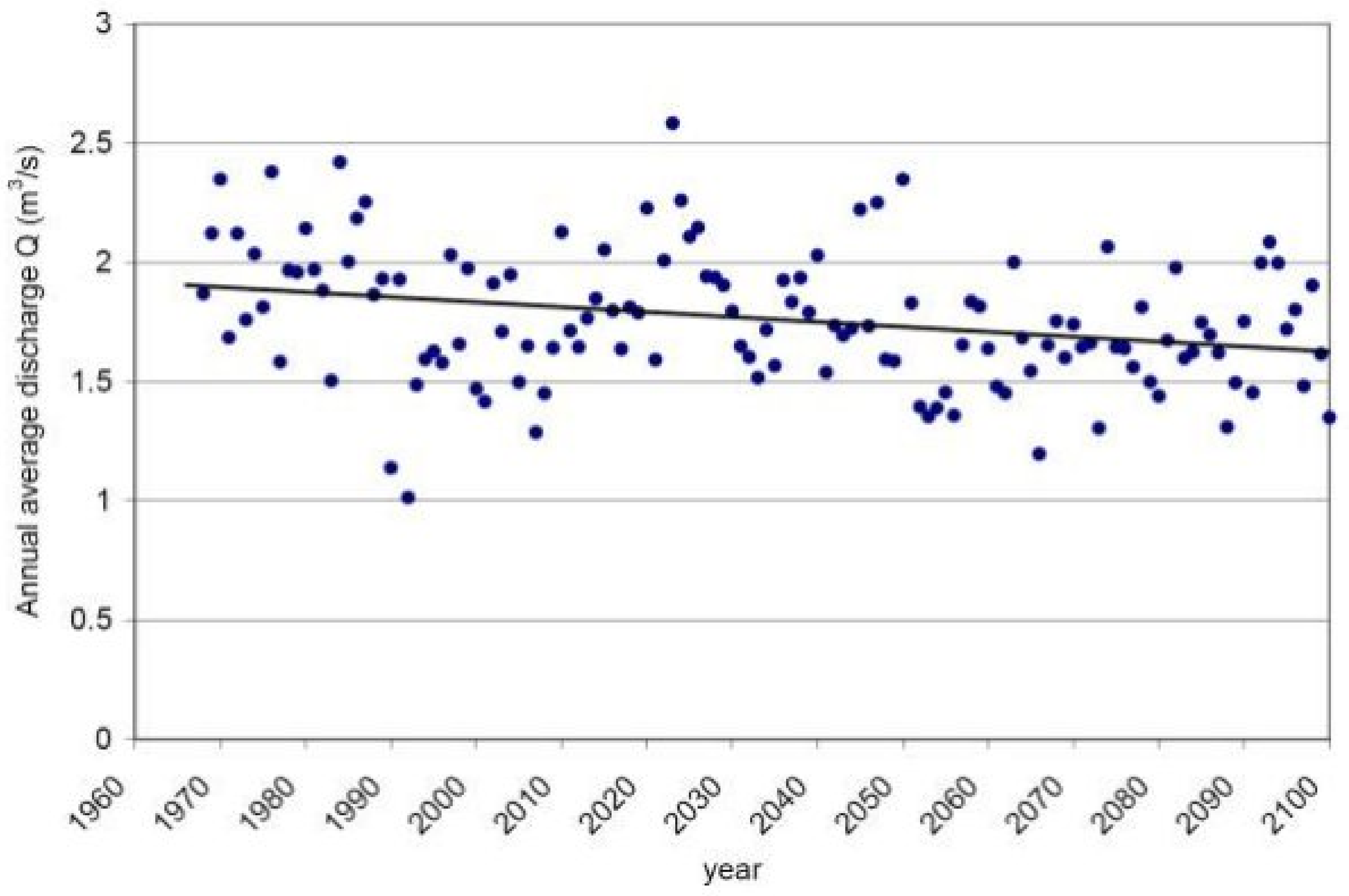


Figure 3. Annual average of discharges of karst spring Mlava and its trend line [8]

As 2/3 of underground water resources remain unused, these resources can be of great importance in emergencies as alternative drinking water sources or technical water if the water quality is not satisfactory.

2. METHODOLOGY

For the selected potential alternative sources, it is necessary, for a reason, to determine underground water reserves, as well as the amount of water available and its quality, to do the following:

1.Establish water level monitoring,

2.Periodically perform hydrometric measurements in the entire range of water level changes,

3.Define the flow curve - dependence of the flow as a function of the water level,

4.Perform water sampling at appropriate time intervals,

5.Provide reports for each hydrogeological object individually,

6.Produce maps of the appropriate scale with the road infrastructure presented in detail,

7.By agreement with the Republic Hydrometeorological Service of Serbia, monitor selected hydrogeological objects.

3. SELECTED CATCHMENT AREAS

In the case of emergencies that can be caused by natural risks (floods, landslides, fires, droughts, earthquakes, etc.) as well as anthropogenic factors (spills of pollutants in catchments areas, war operations and others), the most common problem is drinking water as well as technical water. We cannot predict these phenomena with great certainty (exact time and place of occurrence). Therefore, we cannot adequately prepare in advance for any of the listed situations that lead to an emergency in some part or of the country's entire territory; it is necessary to have a cadastre of alternative sources to distribute water to users who need it. Information on the spatial location of possible alternative sources exists; however, the problem of researching the watershed, the quantity and quality of these waters have not been collected adequately so far, and this is of crucial importance for whether these waters can be used for drinking or not, i.e. whether it is necessary to carry out their appropriate treatment.

The type of spring informs whether the spring regime is stable or whether there are rapid and sudden changes in certain qualitative and quantitative parameters. Thus, for example, small discharge oscillations within the year are generally present in ascending springs, quality parameters do not change over time, and these waters are generally protected from potential pollutants. On the other hand, gravity springs have a quick reaction to precipitation, mainly rapid propagation of precipitation through the hydrogeological basin, which results in abrupt changes in discharge (sudden discharge increase and decrease) as well as changes in quality (increase in turbidity, suspended sediment, total number of bacteria, etc.) [10, 11].

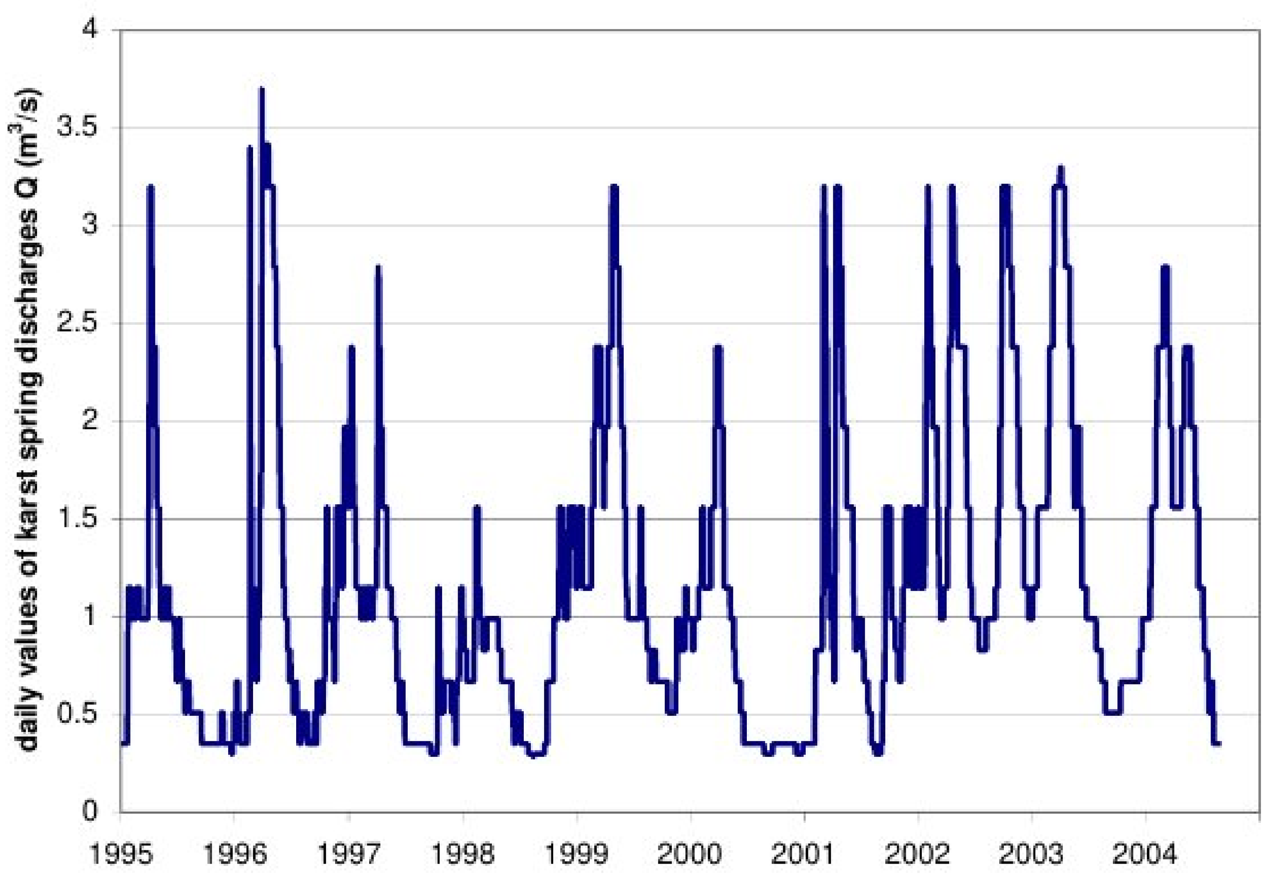
Whit this reasons, for this paper, we selected three karst springs on which various institutions carried out hydrogeological research several times. Those are:

1. Jelovica spring,

2. Veliko spring and

3. Andrić spring.

Andrić spring was chosen as a typical example of an ascending spring. It drains the eastern parts of Zlatibor and is the least explored compared to the other two. At this spring, observations were made during the period when the monitoring of the discharge and Veliko spring was carried out (1995 - VIII 2004). The catchment area of Andić spring consists of psammite-pelitic sediments of the Carboniferous age, carbonate formations of the Triassic age, diabase-chert formation of the Jurassic age and Quaternary sediments. The karst outcrop drained by this spring was formed in massive and clif limestones of the Triassic age; its recharge is done by directly infiltrating rainwater on the exposed part of the karst collector [12]. Drainage is on the right bank of the Prištavica river via this spring. The elevation is 490 meters above sea level, and the point of spring dischares is connected to the exit of Prištevica from its gorge. It is located near Ravni village. The average annual runoff volume from this spring for the observation period is 1,157 m^3/s. The absolute maximum was Qmax=3,417 m^3/s (April 1996), while the absolute minimum was recorded in August 1998 in the amount of Qmin=0,287 m^3/s [12] (Figure 4).



Slika 4. Mean daily discharge of the Andrić spring

The Veliko spring drains the southern part of the Beljanica karst massif. It is one of the major springs in the Carpathian karst of eastern Serbia. This typical gravity spring drains Tithonian age limestone massive. One of the most beautiful waterfalls has formed a few hundred meters from the discharge points, and today, it is protected as a natural monument. It was chosen as a typical representative of gravity springs. It was monitored from 1995 to 2006, with a four-month break from September to December 2004. For the CCWaterS project needs, monitoring of this spring was also established from August 2009 until the end of the project (2012). The water flows out at the bottom of a long talus between large limestone blocks at the top of a short and shallow valley. It occurs at an altitude of 415 m asl. However, during the maximum yields, the discharge zone moves to higher altitudes when the elevation of the discharge reaches a value of 445 m asl. Based on eight-hour data, it was established that on the year's level, on average, 0.584 m^3/s of water flowed, with the values ranging from 0.477 m^3/s (2000) to 0.762 m^3/s (1997). The absolute minimum daily value of the discharge of Veliko spring was recorded from September 5 to 7, 1998, in the amount of only 57 l/s, while the maximum value was 5.6 m^3/s (July 28, 1997) [13].

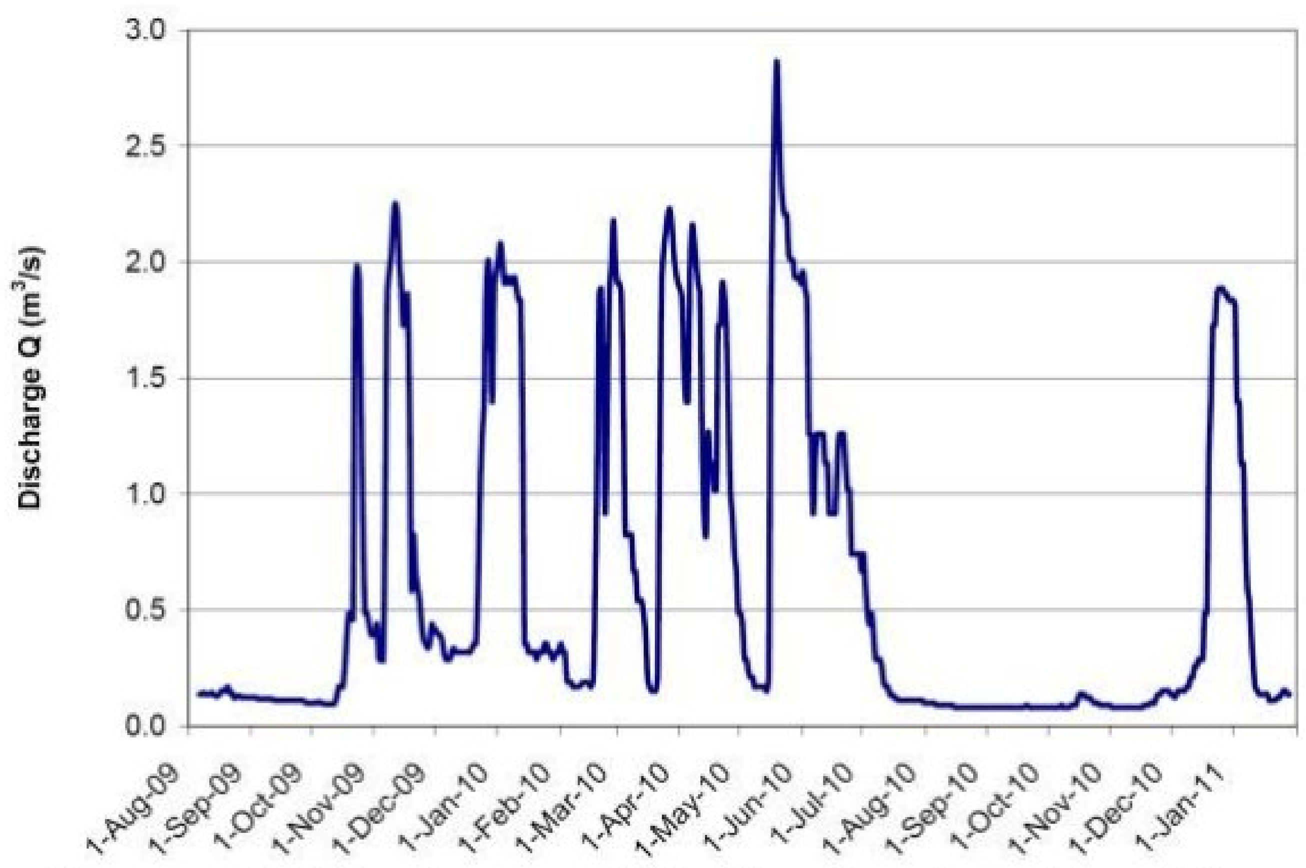


Figure 5. Discharge of Veliko karst spring [8]

Jelovičko spring is the largest karst spring in the southern part of Stara Planina, i.e. Vidlič, drains carbonate rocks of the Middle Triassic age. It was chosen because there was no monitoring on it until now. This ascending spring type appears in a minor depression (doline) that is laked and occurs at the height of the bed of the Jelovicka River (Figure 6). The stream formed by this spring, after only a few hundred meters, flows into the Jelovička River, and together with it, after a little less than 1 km, flows into the Dojkinačka River (catchment area of the Visočica River). Speleological diving has been carried out on several occasions to show the geometry and orientation of the channels and caverns through which the spring water moves in the discharge zone in as much detail as possible [14]. The Jelovica spring has never been systematically observed for a long time. However, due to its characteristics and importance, it would be necessary to establish constant underground water monitoring quantitatively and qualitatively. According to occasional observations of the spring made during hydrogeological research, its minimum yield falls below 80 l/s, with water temperatures of 9.5 to 12 ºC. This spring belongs to the typical karst siphon spring type with deep karst channels. It is considered that the maximum yield of the hot spring is over 5 m^3/s [15].

Figure 6. Jelovica spring (photo by V. Ristić Vakanjac)

4. DISCUSSION

Suppose the hydrogeological object is considered an alternative potential water source, in addition to the information on the spatial position of the hydrogeological object (coordinates and altitude). In that case, it is first necessary to establish the appropriate monitoring of quantitative parameters. If it is a spring, it is necessary to install a water meter bracket and hire an observer - a person who lives in the immediate vicinity of the selected object and who will read the water level of the water that flows out every day. If the discharge is less, a weir can be installed. If the project have good financial support, it is possible to install automatic stations - limnigraphs that can digitally record water level changes at appropriate time intervals (for example, every 5, 10, 30, 60, 120 minutes). With the establishment of water level monitoring, it is necessary to carry out hydrometric measurements periodically and cover the entire range of water level changes (small, medium-small, medium, medium-large, and large waters). Mentioned is necessary to establish the flow curve (graphic form and analytical in tabular form). The average daily amount of runoff at the spring can be obtained based on the defined flow curve and average daily water levels.

If we are dealing with ascending springs like Andrić spring, where there are no sudden changes in the water level, the water level can be monitored once a day or, even in extreme situations, once every five days. In the case of gravity wells (Veliko spring), the time intervals for observing the water level must be shorter, maximum once a day, and preferably twice a day or every 6 hours, even less. Mentioned is especially important for springs that drain small catchments areas and where rainfall propagation occurs within 24 hours.

As the quality of the water of the potential alternative water source is also important, it is necessary to carry out water sampling for ascending springs four times a year, while the author recommends 12 times a year for gravity springs. Suppose chemical analysis results indicate significant changes in specific parameters are present. In that case, it is necessary to carry out more frequent sampling with an emphasis on parameters with a variable concentration according to the pluviographic regime of the area of interest.

After the three-year monitoring, it is necessary to perform calculations of underground water reserves, the amount of water that can be used of and its quality. According to the completed reports, the established profiles on which monitoring was carried out should become part of the observation network of the Republic Hydrometeorological Service of Serbia, which would continue with water level observations and flow measurements, and the Environmental Protection Agency should continue sampling, i.e. checking water quality.

Finally, each report should be accompanied by appropriate maps on which the positions of the hydrogeological object and the road infrastructure would be highlighted, with the help of which the object can be easily found (Figures 7, 8 and 9).

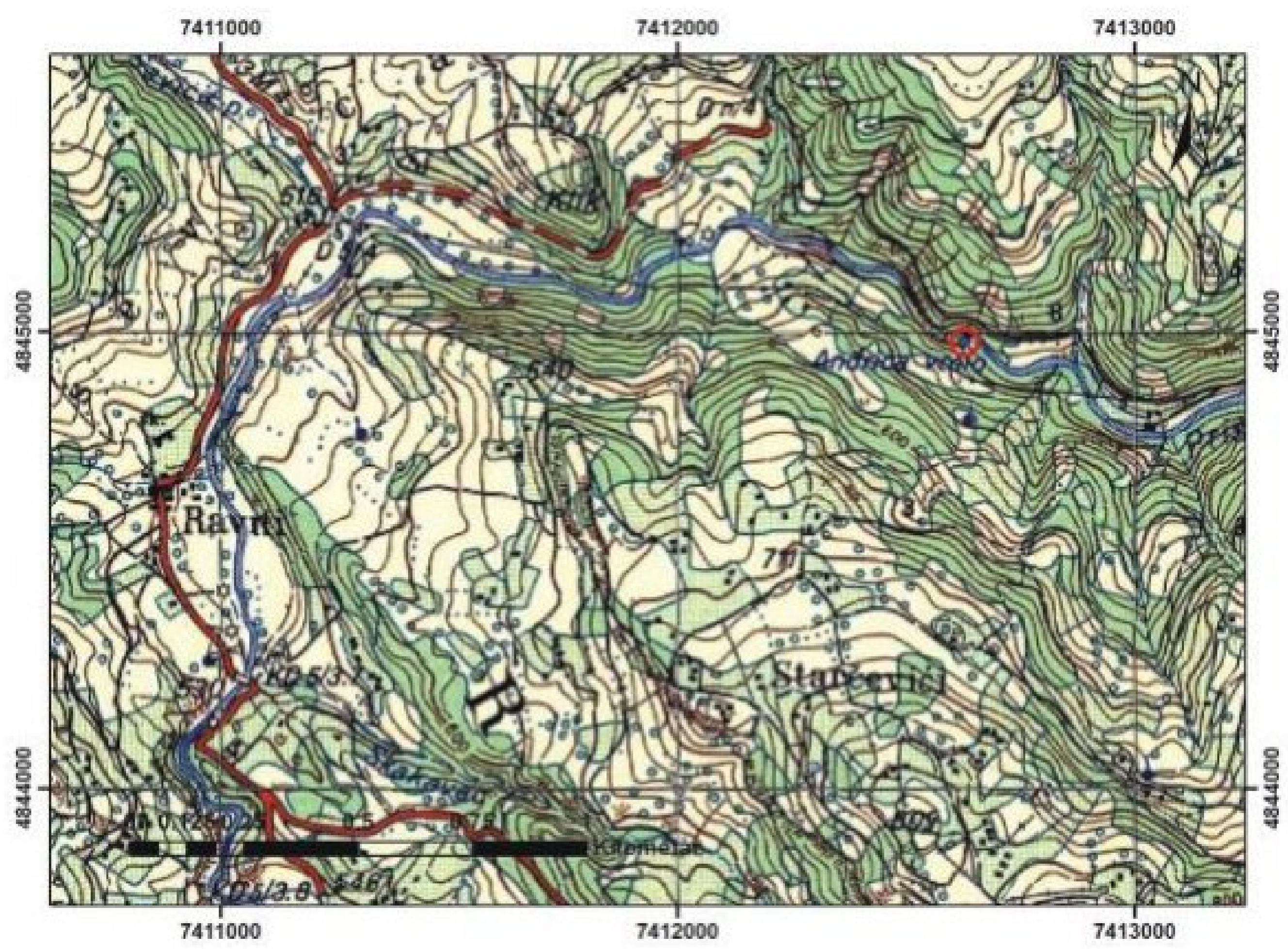


Figure 7. Spatial position of the Andrić spring (in red circle), raster base TK25 second edition, Military Geographical Institute "General Stevan Boškovič", part of sheet Ravni, modified

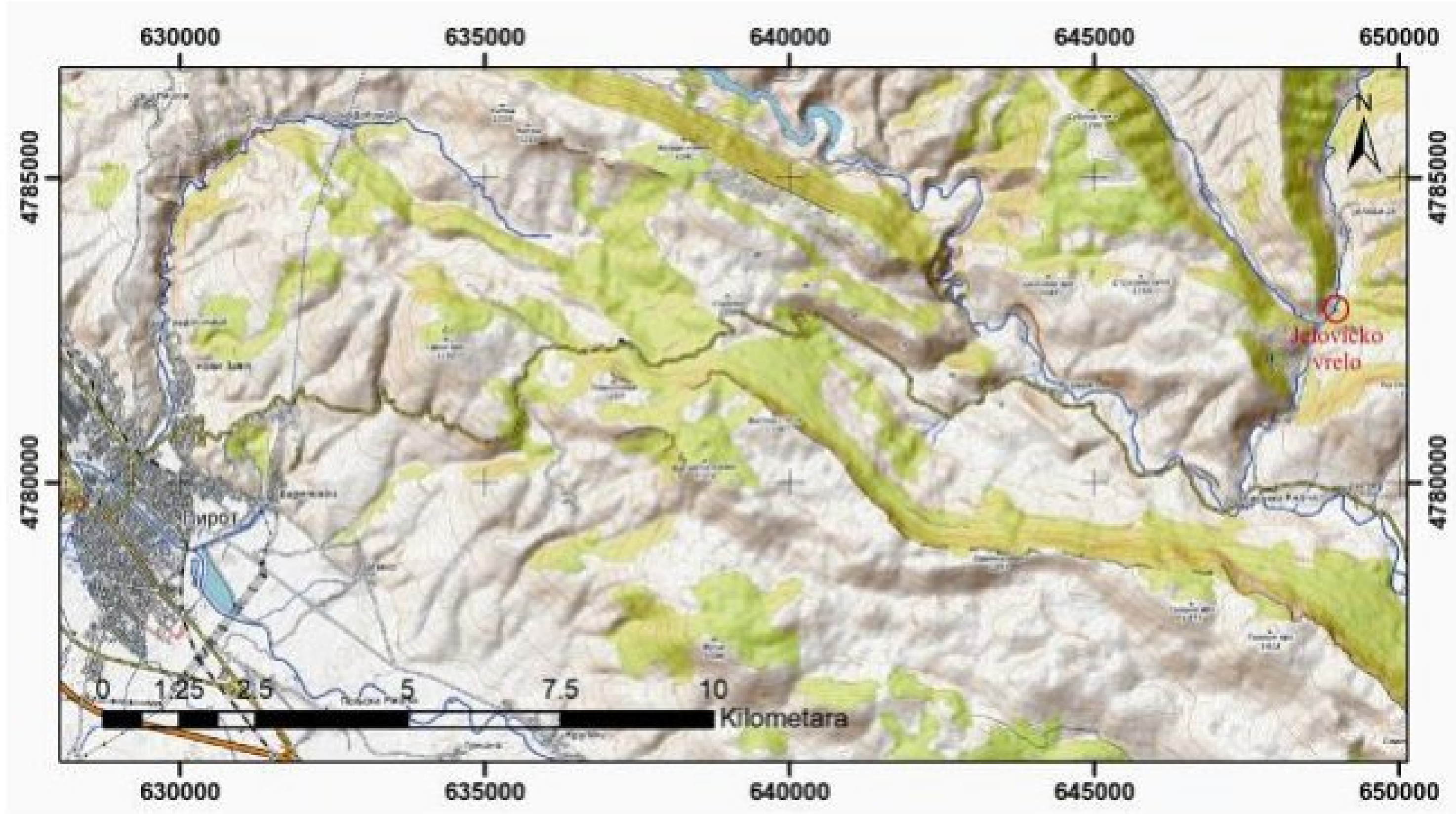


Figure 8. Spatial position of Jelovica spring, (in red circle), raster base © OpenStreetMaps contributors, CC-BY-SA, rendering opentopomap.org, modified

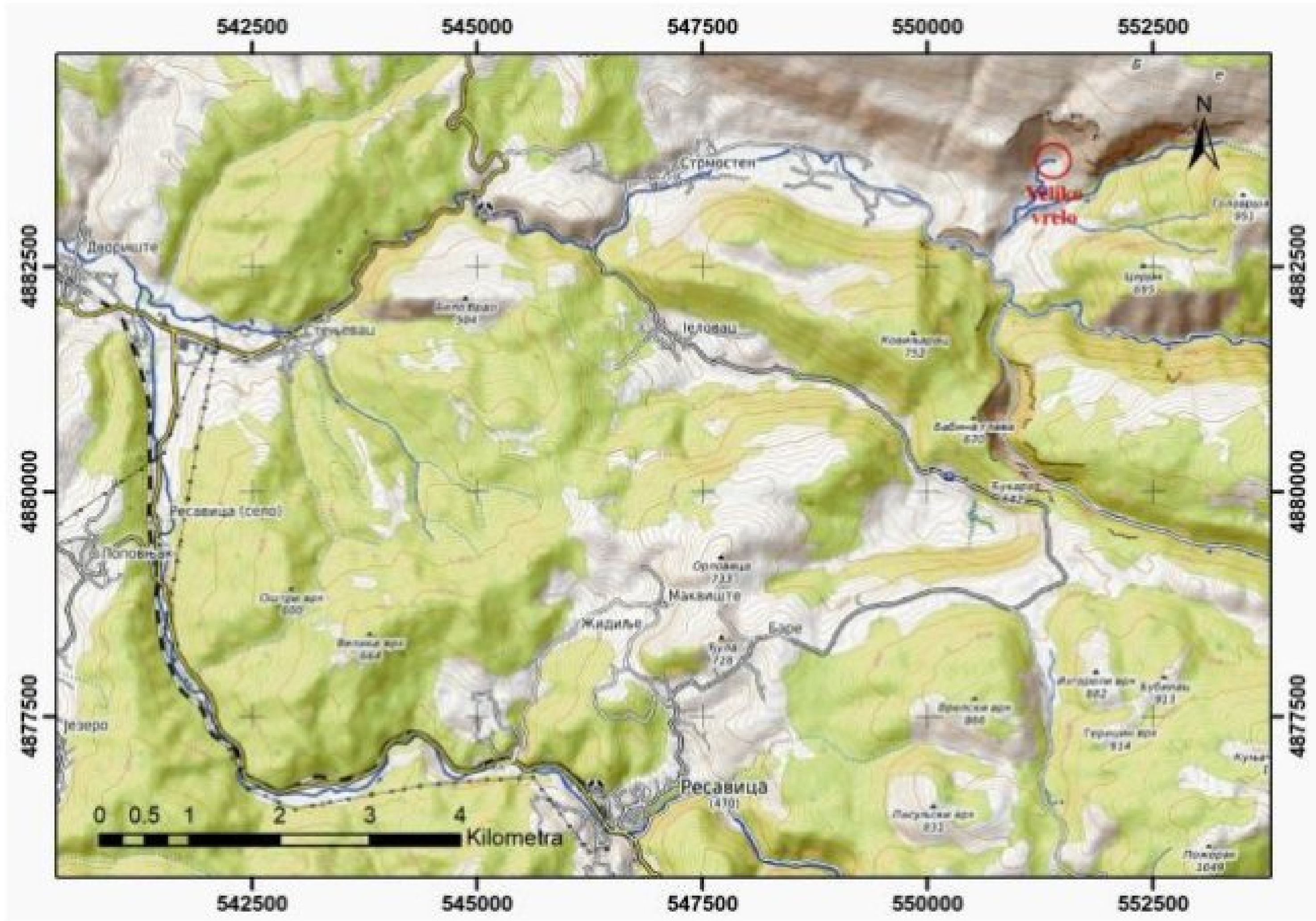


Figure 9. Spatial position of Veliko spring, (in red circle), raster base SAS.Planet, © OpenStreetMaps contributors, CC-BY-SA, rendering opentopomap.org, modified

5. CONCLUSION

Most of the water used for the water supply of the population of the Republic of Serbia is underground water. Serbia belongs to the countries of Europe that are richer in underground water. However, the research and monitoring of these resources could be more satisfactory. Today, only 1/3 of the underground water capacity is used for water supply, and the remaining 2/3, or 44.5 m^3/s, mostly high-quality water, goes unused through the river network. Therefore, in this case, alternative sources of water for water supply should be searched. A good example from the recent past is the problem of water supply in the city of Užice when a lot of algae formed in Lake Vrutci, giving the lake a red colour. The appearace of cyanobacteria in the water supply system caused a ban on water use from the water supply system. An alternative solution was Sušičko spring.

As regional climate change models indicate an increase in air temperature and a decrease in precipitation, the river flows that feed the lakes will provide less water to these reservoirs. Therefore, there is a high probability that the Vrutci reservoir scenario will repeat itself in the near or distant future. Also, the mentioned climate changes predict a more significant number of extreme events (drought and floods), for which you also need to be prepared because you don't know when or where exactly this will happen. More precisely, droughts affect the entire region, while floods can be extremely local. In these situations, it is necessary to have an alternative source.

It remains to define the hydrogeological objects that are of interest to the Republic of Serbia, to see the status of these objects (some of the mentioned are protected objects), to obtain information about the reserves and quantities of water that can be counted on, and if it is necessary to carry out appropriate construction preparations for a more straightforward approach to the object as well as easier taking of water from the hydrogeological object, and to allocate proper funds for a suitable strategic project.

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