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HIDROGEOLOŠKE ZNAČILNOSTI OBMOČJA PRESIHAJOČIH PIVŠKIH JEZER

HYDROGEOLOGICAL CHARACTERISTICS OF THE AREA OF INTERMITTENT KARST LAKES OF PIVKA

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Metka Petrič & Janja Kogovšek: Hidrogeološke značilnosti območja presihajočih Pivških jezer

Poseben hidrološki pojav zahodnega dela kraškega masiva Javornikov so presihajoča Pivška jezera. Za celotno območje je značilna tesna povezava podzemnih in površinskih voda. V kraškem vodonosniku se vode pretakajo večinoma podzemno, ob močnejših in dolgotrajnejših padavinah pa se nivo podzemne vode dvigne in voda se na številnih mestih preliva na površje. Tako postanejo aktivni občasni kraški izviri ob reki Pivki, z vodo pa se napolnijo tudi kraške depresije in nastane večje število presihajočih kraških jezer. Nekatera se pojavljajo dokaj pogosto in imajo vodo tudi do pol leta, večinoma pa so bolj redka ali so zalita samo izjemoma v času močnejših poplav. V članku so predstavljene hidrogeološke značilnosti območja, ki se odražajo v režimu pretakanja kraške vode in načinih njenega pojavljanja na površju.

Ključne besede: hidrogeološka zgradba, presihajoča kraška jezera, občasni kraški izvir, Pivka, Slovenija.

Abstract

UDC: 556.538(497.4 Pivka)

Metka Petrič & Janja Kogovšek: Hydrogeological characteristics of the area of intermittent karst lakes of Pivka

A special hydrological feature of the western part of the Javorniki karst massif is the intermittent karst lakes of Pivka. For the whole area a close connection between underground and surface water is characteristic. In the karst aquifer water flows mostly underground, but after more intensive or long-lasting precipitation the water table rises and water emerges on the surface at different locations. Intermittent karst springs along the Pivka river are activated. Also karst depressions are filled with water and several intermittent karst lakes can be formed. Some of them appear very often and contain water for up to six months, but mostly they are very rare and filled up only exceptionally in the time of big floods. In the article the hydrogeological characteristics of the area are presented, which are reflected in the flow regime of karst water and in the forms of its appearance on the surface.

Key words: hydrogeological structure, intermittent karst lakes, intermittent karst springs, Pivka, Slovenia.

UVOD

Masiv Javornikov ima funkcijo kraškega vodonosnika, v katerem se vode pretakajo pretežno podzemno. Na zahodnem obrobju v dolini Pivke je vodonosnik v stiku z aluvialnimi in flišnimi kamninami, ki so slabše prepustne in predstavljajo lokalno hidrogeološko pregrado, ob kateri se predvsem ob visokem vodostaju pojavljajo kraški izviri. Debelina teh kamnin pa je relativno majhna in tudi pod njimi je razvit kraški vodonosnik, ki se pod Pivško kotlino razteza proti Vipavski dolini (Slika 1).

INTRODUCTION

The Javorniki range has a function as a karst aquifer in which groundwater flow is dominant. On the western border in the Pivka basin it is in contact with less permeable alluvial and flysch rocks. They act as a hydrogeological barrier at which karst springs emerge specially during high waters. And as their thickness is relatively small, a karst aquifer is developed also below them in the direction towards the Vipava valley (Figure 1).

Na jugu se Javorniki nadaljujejo v kraški masiv Snežnika. V tem delu poteka kraška razvodnica s prispevnim območjem rek Reke, Riječine in Kolpe, njen položaj pa je zaradi posebnih značilnosti krasa (podzemno pretakanje, bifurkacija) praktično nemogoče natančno določiti.

Na severni in vzhodni strani kraški vodonosnik omejuje območje med Planinskim in Cerkniškim poljem, ki ga gradijo predvsem zgornjetriasni dolomiti. Ti so slabše prepustni od apnencev, seka pa jih tudi prelomna cona Idrijskega preloma, ki ima zaradi zdrobljenega, milonitiziranega dolomita vlogo hidrogeološke pregrade, ob kateri podzemne vode v kraških izvirih iztekajo na površje.

V kraškem vodonosniku se podzemne vode pretakajo večinoma po razširjenih razpokah in kraških kanalih v različnih smereh proti izvirom na obrobju. Na osnovi hidrogeoloških raziskav, še posebej sledilnih poskusov (Sliki 1 in 2), so bile dokazane smeri odtekanja proti izvirom na Planinskem polju (Malenščica, Unica, Škratovka) in v Rakovem Škocjanu (Kotliči, Prunkovec), proti izvirom Vipave v Vipavski dolini ter proti kraškim izvirom ob reki Pivki. Območje južno od izvirov Pivke se vsaj deloma odteka proti izviru Podstenjšek in drugim kraškim izvirom v povodju reke Reke, vendar pa bolj podrobne raziskave o položaju razvodnice zaenkrat še niso bile opravljene.

HIDROGEOLOŠKA ZGRADBA

Ožje območje presihajočih Pivških jezer gradijo predvsem dobro zakraseli kredni apnenci, ki imajo značilnosti dobro prepustnih kamnin s kraško-razpoklinsko poroznostjo (Slika 2). V njih so razvite številne površinske in podzemne kraške oblike. Prsti na apnencih je relativno malo in še ta je pogosto nezvezna, zato je ponekod površje precej kamnito. Padavine s površja neposredno prenikajo v bolj ali manj vertikalni smeri skozi razpokane, zakrasele apnence vadozne cone globlje v kras, v stalno

On the southern side the Javorniki range traverses into the Snežnik karst massif. In this part is located the karst watershed with the catchments of rivers Reka, Riječina and Kolpa. Due to specific characteristics of karst (groundwater flow, bifurcation) it is practically impossible to define its position precisely.

On the northern and eastern side the karst aquifer is bordered by less permeable Upper Triassic dolomite in the area between the Planina and Cerknica karst poljes. This is intersected by the fault zone of the Idrija fault in which dolomite is crushed and millonitized. At this hydrogeological barrier underground water emerges through karst springs to the surface.

In a karst aquifer underground water flows mainly through widened fissures and karst channels in different directions towards the springs at the border. Based on hydrogeological researches, especially tracer tests (Figures 1 and 2), groundwater flow was proved towards the springs at the Planina polje (Malenščica, Unica, Škratovka) and in Rakov Škocjan (Kotliči, Prunkovec), and also towards the Vipava spring in the Vipava valley and karst springs in the Pivka basin. The area south from the Pivka springs is at least partly drained towards the Podstenjšek spring and other karst springs in the Reka river basin, but more detailed researches of the watershed position have not yet been done.

HYDROGEOLOGICAL STRUCTURE

The area of the karst intermittent lakes of Pivka is mostly of well karstified Cretaceous limestones, which are characterised as well permeable rocks with karst-fissured porosity (Figure 2). In these, numerous surface and underground karst features are developed. The layer of soil on the limestone is relatively thin and frequently not consolidated, so the surface is very rocky. Precipitation infiltrates directly from the surface in more or less vertical direction through the vadose zone deeper into the karst, zaliti coni vodonosnika pa se nato raztekajo v različnih smereh proti izvirom na obrobju kraškega masiva.

V dolini reke Pivke so na apnencih odložene kvartarne aluvialne naplavine, ki so relativno slabše prepustne in predstavljajo lokalno hidrogeološko pregrado. Ob njih se ob visokem vodostaju, ko se gladina podzemne vode v krasu dvigne nad nivo kontakta, pojavljajo občasni kraški izviri, iz katerih voda napaja površinski tok reke Pivke. V daljših obdobjih brez padavin pa se nivo podzemne vode spusti pod ta prelivni rob in izviri presušijo. Voda iz površinske Pivke se izgublja v podzemlje skozi številne ponore v strugi.

Na eocenskem flišu, ki je zelo slabo prepusten, se na območju med Prestrankom in Postojno vode pretakajo pretežno površinsko. Debelina tega fliša je relativno majhna in tudi v večjih globinah pod njim je razvit kraški vodonosnik. Eocenski fliš v dolini reke Reke je del Komenske narivne grude, na katero je narinjen masiv Javornikov (Snežniška narivna gruda) (Placer 1981). Predstavlja neprepustno podlago kraškega vodonosnika in se na površje prikaže tudi v tektonskem oknu pri Knežaku. Na stik apnenca in fliša so vezani kraški izviri, ki napajajo pritoke Reke.

ZNAČILNOSTI PODZEMNEGA PRETAKANJA

V zahodnem robu Javornikov je podzemna voda dosegljiva v jami Fužina pri Stari vasi, v Breznu v Kobiljih grižah in v Matijevi jami ob Palškem jezeru (Slika 2). V okviru raziskav za vodooskrbo so bile izvrtane tudi 3 vrtine, in sicer pri Fužini, pri Kobiljih grižah in pri Žejskih izvirih, kjer so v osemdesetih letih občasno spremljali nihanje nivoja podzemne vode (Habič 1989), kasneje pa so bile vrtine zamašene in merjenje ni več možno. Stalna je voda v vodnjakih v Pivki in Zagorju (Habič 1985). Geološki zavod Ljubljana je na območju med izviri Pivke, Koritnicami in Šembijami

and then in the phreatic zone groundwater flows in different directions towards the springs at the border of the karst massif.

In the Pivka basin Quaternary alluvial sediments are deposited on limestones. They are less permeable and act as a local hydrogeological barrier. As during high waters the water table in karst rises above this contact, intermittent karst springs emerge and supply the surface stream of the Pivka river. In longer periods without precipitation the water table falls below the contacts and springs become dry. Water from the surface flow of Pivka sinks in the underground through several ponors in the riverbed.

On very low permeable Eocene flysch in the area between Prestranek and Postojna surface drainage prevails. But the thickness of this flysch is relatively small and also in greater depths below it karst aquifer is developed. The Eocene flysch in the Reka valley belongs to the Komen thrust sheet on which the Javorniki massif (Snežnik thrust sheet) is thrust (Placer 1981). It has a role as an impermeable base of the karst aquifer and is visible on the surface also in the Knežak tectonic window. At the contact between limestone and flysch, karst springs emerge which supply the tributaries of the Reka river.

CHARACTERISTICS OF GROUNDWATER FLOW

In the western part of the Javorniki range groundwater is reachable in the caves Fužina pri Stari vasi, Brezno v Kobiljih grižah and Matijeva jama (Figure 2). Three boreholes were drilled near Fužina pri Stari vasi, Brezno v Kobiljih grižah and Žeje spring in order to research their potential for water supply. In the 1980s the water table was occasionally measured in them, but later they were plugged and measurements are no longer possible. Water is permanent in the wells in settlements Pivka and Zagorje (Habič 1985). Several boreholes were drilled in the area between the Pivka izvrtal več vrtin in v njih krajše obdobje spremljal nihanje nivojev podzemne vode (Juren & Krivic 1983). Znani so še nivoji stalnih kraških izvirov na obrobju masiva Javornikov. Ob visokem vodostaju gladina kraške vode doseže površje v občasnih izvirih ob Pivki in v presihajočih Pivških jezerih. Predvsem s stališča določitve maksimalnih nivojev so zanimivi podatki o gladini jezer, zbrani ob poplavah v novembru 2000 (Habič & Kovačič 2005, v tej knjigi).

Na osnovi vseh teh podatkov je mogoče sklepati o generalnih smereh pretakanja podzemne vode in okvirno tudi o razponu med najvišjimi in najnižjimi nivoji vode v različnih delih kraškega vodonosnika. Za območje reke Pivke je bilo tako ugotovljeno, da je ob nizkem vodostaju v njenem zgornjem toku podzemna voda okrog 10 m, v spodnjem toku pa tudi več kot 20 m pod suho strugo. Ob visokem vodostaju je struga zalita, aktivni pa so tudi izviri ob strugi. Glede na višino vodostaja je zalitih tudi več ali manj jezer. Na osnovi opravljenih občasnih opazovanj (Habič 1989) ocenjeni razponi izmerjenih gladin podzemne vode so zbrani v Tabeli 1.

springs and the villages Koritnice and Šembije, and during a short period of time the water table was occasionally measured in them by the Geological Survey of Ljubljana (Juren & Krivic 1983). Also the altitudes of permanent karst springs at the border of the karst massif are known. During high waters karst water reaches the surface in intermittent karst springs and lakes in the Pivka basin. To define maximum water levels the data on the altitudes of lakes gathered during the floods in November 2000 are specially interesting (Habič & Kovačič 2005, in this volume).

Based on the above mentioned data it is possible to make some general conclusions about the directions of groundwater flow and about the range between maximum and minimum levels of groundwater in different parts of the karst aquifer. The water table in the upper part of the Pivka basin is during low waters around 10 m below a dry riverbed, and in the lower part more than 20 m below it. After heavy rains the riverbed is filled with water, and karst springs nearby are active. Dependent on the height of the water table also, more or fewer karst lakes emerge. Based on the results of occasional measurements (Habič 1989) the ranges of water table oscillations are estimated (Table 1).

Tabela 1: Razpon izmerjenih gladin podzemne vode, določen na osnovi občasnih opazovanj

Table 1: The ranges of water table oscillations based on occasional measurements.

LOKACIJA/LOCATION	**NIVO VODE/WATER LEVEL**
Fužina pri Stari vasi - vrtina	513 – 525 m
Brezno v Kobiljih grižah	514 – 529 m
Žeje - vrtina	505 – 530 m
Matijeva jama	516 – 557 m

Ker pa so vse omenjene raziskave potekale le v krajših časovnih obdobjih in so bile meritve le občasne, je za podrobnejšo analizo značilnosti nihanja nivoja podzemne vode ob različnih hidroloških pogojih podatkov premalo. V prihodnjih raziskavah bi lahko

But as all mentioned measurements were performed only occasionally and in short time periods, there is not enough data for more precise analysis of the characteristics of water table oscillations at different hydrological conditions. In future researches useful information could be koristne informacije pridobili predvsem z zveznim spremljanjem nivojev vode na izbranih lokacijah.

Več o smereh in značilnostih podzemnega pretakanja smo izvedeli iz rezultatov do sedaj opravljenih sledilnih poskusov (Sliki 1 in 2). V jamo Požiralnik pod Kremenco so 26. septembra 1955 injicirali 10 kg uranina in ugotovili povezavo z izviri Unice in Malenščice (Jenko 1959). Navidezno hitrost pretakanja so ocenili na okrog 0,5 – 0,6 cm/s.

Vsa ostala sledenja so bila izvedena v okviru raziskav na Inštitutu za raziskovanje krasa ZRC SAZU. Ob visokem vodostaju 14. novembra 1967 so v ponor na Palškem jezeru injicirali 10 kg vijoličasto obarvanih trosov in ugotovili povezavo s Trnskimi izviri, navidezno hitrost pa ocenili na 9 cm/s. Naslednji dan so ponorne vode na Petelinjskem jezeru obarvali s 3,5 kg uranina, voda pa se je podzemno pretakala proti Žejskim izvirom z navidezno hitrostjo 1 cm/s. V Kneške ponikve so 26. februarja 1968 ob pretoku 5 l/s injicirali 1 kg uranina in ugotovili povezavo z izvirom Videmščica in navidezno hitrost pretakanja 1,2 cm/s (Habič 1975).

Potok Stržen, ki ga napajajo vode izvira Fužina pri Stari vasi, je bil obarvan dvakrat. Najprej so ob nizkem vodostaju (pretok Stržena 30 l/s) 23. februarja 1982 v požiralnik v strugi Stržena pri Rakitniku injicirali 10 kg uranina in opazovali vodni tok v Planinski jami ter izvire Malenščice, Škratovko in Kotliče. Čeprav je opazovanje trajalo dalj časa, sledila nikjer niso zaznali (Habič 1989). Zato so sledenje Stržena izvedli še enkrat 9. avgusta 1988. Tudi v tem primeru je bil vodostaj nizek s pretokom Stržena 10 l/s. Injicirali so 20 kg rodamina in dodatno opazovali še izvire Vipave in Timave (Habič 1989). V prej omenjenih izvirih na obrobju Planinskega polja in Rakovega Škocjana se sledilo spet ni pojavilo, ugotovljena pa je bila podzemna vodna zveza z izviri Vipave (navidezna hitrost pretakanja okrog 0,4 cm/s). Na Timavi je bilo opazovanj premalo, da bi lahko rezultate uporabili kot zanesljive.

obtained above all by continuous monitoring of water levels at chosen locations.

More information about directions and characteristics of groundwater flow were obtained by tracer tests (Figures 1 and 2). In the cave Požiralnik pod Kremenco 10 kg of uranine were injected on 26 September 1955 and the underground connections with the Unica and Malenščica springs were proved (Jenko 1959). The apparent flow velocity was estimated to be around 0.5-0.6 cm/s.

All other tests were performed by the Karst Research Institute ZRC SAZU. During high waters on 14 November 1967 around 10 kg of coloured spores were injected in the ponor at the Palško jezero and the connection with the Trnski izviri spring was defined. The apparent flow velocity was estimated as 9 cm/s. On the next day sinking waters at the Petelinjsko jezero were coloured by 3.5 kg of uranine. Underground water flow with an apparent velocity of 1 cm/s towards the Žejski izviri spring was proved. 1 kg of uranine was injected on 26 February 1968 in the sinking stream near Knežak (discharge 5 l/s). The underground connection with the Videmščica spring and an apparent flow velocity of 1.2 cm/s were established (Habič 1975).

The Stržen brook, which is supplied by the Fužina spring, was traced twice, firstly during low waters (discharge 30 l/s) on 23 February 1982 when 10 kg of uranine were injected into the sinking stream near the village Rakitnik. Although water flow in the Planinska jama cave as well as Malenščica, Škratovka and Kotliči springs were observed in a longer period, no tracer was detected (Habič 1989). Therefore another tracer test was carried out on 9 August 1988. In the Stržen stream (discharge 10 l/s) 10 kg of rhodamine were injected and additionally the Vipava and Timava springs were observed. In the before-mentioned springs at Planina polje and Rakov Škocjan the tracer was again not detected, but the underground water connection with the Vipava springs (apparent velocity around 0.4 cm/s) was proved. The number of

Hkrati so 9. avgusta 1988 Pivko v Trnju obarvali z 20 kg uranina. Na tem mestu je v strugi več požiralnikov, v katere ob nizkem vodostaju Pivka v celoti ponikne, ob višjem pa je kapaciteta požiralnikov premajhna in vode delno odtekajo naprej po strugi. Sledenje je potekalo ob nizkem vodostaju, ko se je Pivka v celoti izgubljala v požiralnik. Z izjemo Vipave in Timave se je sledilo pojavilo v vseh ostalih opazovanih izvirih. Ugotovljene so bile naslednje navidezne hitrosti podzemnega pretakanja: proti vodnemu toku v Planinski jami in izvirom Malenščice okrog 0,5 cm/s ter proti Pivki pri Prestranku in Stržena pri Rakitniku okrog 0,2 cm/s.

Metodologija sledilnih poskusov je z leti še napredovala in zanesljivost rezultatov se veča. Zato so še posebej zanimivi rezultati sledenja, ki smo ga izvedli poleti 1997 (Kogovšek *et al.* 1999). Na območju vojaškega vadišča Poček na Javornikih smo ob nizkem vodostaju 10. junija v dnu skalne vrtače injicirali 4 kg uranina in nato na 11 točkah zajemali vzorce približno 1 leto (Kogovšek 1999; Kogovšek & Petrič 2004). Rezultati so pokazali, da se pomemben delež vode odteka podzemno proti izvirom Malenščice (55 % povrnjenega sledila) in izvirom Vipave (26% povrnjenega sledila). Navidezna dominantna hitrost toka v obeh smereh je bila okrog 0,7 cm/s. Tako je bil ugotovljen glavni tok podzemne vode iz kraškega vodonosnika Javornikov proti izvirom na Planinskem polju, potrjeno pa je bilo tudi podzemno odtekanje pod flišem Pivške kotline proti Vipavski dolini. V manjših deležih se je sledilo pojavilo še v drugih izvirih na Planinskem polju (Unica, Škratovka) in v Rakovem Škocjanu (Rak pred Prunkovcem, Prunkovec, Kotliči). Najbolj počasno, a zanesljivo dokazano, pa je bilo pretakanje proti najbližjemu zajetju v Stari vasi (navidezna dominantna hitrost 0,29 cm/s). Pojav sledila v Žejskih izvirih ter v Pivki pri Prestranku ni bil dovolj prepričljiv, da bi lahko podzemno vodno zvezo zanesljivo potrdili. Zanimiva je ugotovitev, da se je sledilo pojavljalo v izvirih Malenščice po vsakih močnejših padavinah še eno leto po injiciranju. Zaključimo torej lahko,

samples of the Timava spring was not sufficient to use the results as reliable.

At the same time on 9 August 1988 also the Pivka river near the village Trnje was coloured by 20 kg of uranine. There are several ponors in the riverbed in which the river disappears during low waters. At high waters the capacity of ponors is too low and the river at least partly continues its surface flow. The tracer test was performed during low waters and tracer was detected in all observed springs with the exception of Vipava and Timava springs. The following apparent velocities of groundwater flow were obtained: towards the stream in Planinska jama and the Malenščica spring around 0.5 cm/s, and towards the Pivka river near Prestranek and the Stržen stream near Rakitnik around 0.2 cm/s.

Due to the development of the methodology of tracer tests in recent years the quality of their results increases. Therefore the results of tracing in summer 1997 (Kogovšek *et al.* 1999) are especially interesting. On the military training site Poček on the Javorniki range 4 kg of uranine were injected at the rocky bottom of a doline on 10 June 1997 at low waters. Water samples were collected at 11 locations in the period of approximately 1 year (Kogovšek 1999; Kogovšek & Petrič 2004). It was proved that an important share of water flows underground towards the Malenščica spring (55 % of recovered tracer) and the Vipava spring (26 % of recovered tracer). The apparent dominant velocity in both directions was around 0.7 cm/s. In this way the main groundwater flow from the Javorniki karst aquifer towards the springs on the Planina polje, but also the underground flow below the flysch of Pivka basin towards the Vipava valley were proved. In lower concentrations the tracer was also detected in other springs at Planina polje (Unica, Škratovka) and Rakov Škocjan (Rak, Prunkovec, Kotliči). The slowest, but reliably proved, was the connection with the nearest Fužina spring (apparent dominant flow velocity 0.29 cm/s). The detection of tracer in the Žejski izviri and in the Pivka river near Prestranek da se vsako onesnaženje na kraškem površju deloma že zelo hitro pojavi v izvirih na obrobju, deloma pa se zadrži v podzemlju in ga potem vsake močnejše padavine v daljšem časovnem obdobju spet spirajo na površje. Tudi hitrosti pretakanja se spreminjajo s hidrološkimi pogoji.

HIDROLOŠKE RAZMERE

Hidrološke razmere obravnavanega območja se odražajo v hidroloških značilnostih reke Pivke. Napajajo jo kraške vode in po različno dolgih odsekih površinskega toka spet ponika v kraško podzemlje. Izvira pri Zagorju in njena celotna dolžina je 26 km, od tega je le v spodnjem delu 11 km stalnega površinskega toka. V zgornjem delu je v sušnih obdobjih nivo podzemne vode tudi 10 in več metrov pod strugo Pivke, ki je zato večinoma suha. Po močnejših padavinah pa se nivo dvigne in aktivirajo se občasni kraški izviri, ki jo napajajo. Ob visokih vodah Pivka tudi poplavlja, in sicer obsegajo poplavne površine 7,5 km^2, od tega pripada presihajočim kraškim jezerom 2,2 km^2 (Kranjc 1985). Največ poplav je jeseni, razmeroma pogoste so zimske poplave, podobno tudi spomladi.

Hidrološke značilnosti Pivke so razvidne iz hidrograma za eno hidrološko leto 1985-1986 (Slika 3). Podatke o dnevnih pretokih smo pridobili na Agenciji Republike Slovenije za okolje. Prikazana je primerjava za dve postaji. V srednjem toku pri Prestranku Pivka ni stalna in se pojavlja le v obdobjih višjega vodostaja. Voda v strugi pri Prestranku pomeni, da kraški izviri delujejo in da so jezera vsaj deloma zalita. V spodnjem toku tik pred ponorom v Postojnsko jamo pa je Pivka suha le izjemoma. K značilno višjim pretokom v tem delu nekaj prinese pritok Nanoščice in drugih manjših potokov s fliša, pa tudi dodatno napajanje iz številnih kraških izvirov.

was not convincing enough to confirm the underground water connection. Also interesting is the increase of concentration of tracer in the springs after each precipitation event even one year after injection. We can conclude that each pollution at the surface can reach the springs at the border very fast, but is partly also retained in the underground and then washed out by each heavier precipitation event in a longer time period. Also flow velocities are influenced by hydrological conditions.

HYDROLOGICAL CONDITIONS

Hydrological conditions of the studied area are reflected in hydrological characteristics of the Pivka river. It is recharged by karst waters and at the ends of several sections of surface flow it sinks again in the karst underground. The Pivka river emerges near the village Zagorje and its total length is 26 km. Only 11 km in its lower part is permanent surface flow. In the upper part the water table is, during low waters, 10 m or more below the riverbed which is therefore mostly dry. After heavier precipitation the water table rises and also intermittent karst springs along the Pivka river are active. At very high waters some parts of the basin are flooded to an area of 7.5 km^2, about 2.2 km^2 of which belongs to intermittent karst lakes (Kranjc 1985). Floods are regular in autumn, and relatively often in winter and also in spring.

Hydrological characteristics of the Pivka river are presented on the hydrogram for one hydrological year 1985-1986 (Figure 3). Daily discharge data were obtained at the Environmental Agency of the Republic of Slovenia. Two gauging stations are compared. In the middle part of Pivka river near Prestranek the surface flow is not permanent and is limited to the periods of high waters. Surface flow of the Pivka near Prestranek indicates that also karst springs are active and intermittent lakes are at least partly flooded. In the lower part of the Pivka near the sinking point into Postojnska jama the riverbed is dry only exceptionally.

OBČASNI KRAŠKI IZVIRI OB PIVKI IN PRESIHAJOČA PIVŠKA JEZERA

Podatki o kraških izvirih ob Pivki so povzeti po starejši literaturi (Habič 1975) in EIONET bazi podatkov (Izviri 2004). Izviri so aktivni samo občasno ob višjih vodostajih. V izvirnem območju Pivke pri Zagorju je več izvirov (Slika 2), ki dajejo skupaj 3,5 m^3 vode na sekundo, ob nizkem vodostaju pa pretoka ni. Kot glavni vir pogosto navajajo izvir Pivščica s pretokom do 1,5 m^3/s, dobro poznan pa je tudi izvir Videmščica. Ob prvem je obzidan 9 m globok vodnjak, v katerem je zajeta stalna kraška voda.

Iz izvirov pri Kljunovem ribniku teče do 2 m^3 vode na sekundo. Na tem območju sta bili izvrtani tudi dve kaptažni vrtini K-1 (ob Kalskem jezeru) in K-3 (ob Kljunovem ribniku), od katerih je trenutno le prva v uporabi za vodooskrbo manjšega števila prebivalcev v občini Ilirska Bistrica. Edini levi kraški pritok Zgornje Pivke je Podlaznica s pretokom do 200 l/s.

Severno od vasi Parje so Parski studenec ter izvira Mlaka pri Parju in Mišnik, ki je po trajnosti in izdatnosti drugi najpomembnejši ob Pivki. Na Palškem jezeru sta izvir pod Palčjem in izvir iz Matijev jame, iz katere odteka do 6 m^3/s, ob nizkem vodostaju pa lahko nivo podzemne kraške vode spremljamo globlje v jami. S Palškim jezerom so dokazano povezani Trnski izviri, ki napajajo desni pritok Pivke. Neposredno ob Pivki pa je izvir pod Slovensko vasjo. Kot izvir je registrirana tudi estavela na Petelinjskem jezeru, ki je s podzemnimi tokovi povezano z Žejskimi izviri. To je najmočnejši in najtrajnejši izvir ob Pivki. Maksimalno daje 6 m^3 vode na sekundo, povprečno pa je aktiven vsaj pol leta (ko presahnejo Trnski izviri, imajo Žejski izviri še vedno pretok 3 m^3/s). Povezava s Petelinjskim jezerom je bila dokazana s sledenjem, dodatno pa se izvir napaja iz obsežnejšega kraškega zaledja. Manjši izvir je v vasi Žeje. Še bolj severno je izvir Fužina pri Stari vasi, ki daje vodo potoku Strženu. Pretok

Significantly higher discharges in this part are due to the inflows from the Nanoščica stream and other smaller tributaries from the flysch area, but also due to an additional supply from numerous karst springs.

INTERMITTENT KARST SPRINGS AND LAKES OF PIVKA

Data on karst springs along the Pivka river are collected from older literature (Habič 1975) and EIONET data base (Izviri 2004). Springs are active only occasionally during high waters. The spring area of the Pivka river near Zagorje includes several springs (Figure 2) with total discharge of up to 3.5 m^3/s, and no outflow at low waters. As the main source, the Pivščica spring with discharges up to 1.5 m^3/s is often mentioned, and the Videmščica spring is also well known. At Pivščica spring permanent water is captured in a 9 m deep well.

Springs near the Kljunov ribnik lake have discharges up to 2 m^3/s. In this area also two boreholes were drilled: K-1 (near the Kalsko jezero lake) and K-3 (near the Kljunov ribnik). At present only the first one is used for the water supply of a small number of inhabitants in the commune of Ilirska Bistrica. The only left karst tributary of the Upper Pivka is the Podlaznica spring with discharges up to 200 l/s.

North from the village of Parje are the springs Parski studenec, Mlaka and Mišnik. The latter is the second most important in the Pivka basin regarding its duration and capacity. At Palško jezero there are the Izvir pod Palčjem spring and the spring from the Matijeva jama, through which up to 6 m^3 of water per second outflows. At low waters there is no outflow and water table can be observed in the cave. The connection between Palško jezero and the Trnski izviri was proved by tracing. This spring supplies a right tributary of the Pivka river. Just near the riverbed is the spring below the Slovenska vas village. Also an estavelle on Petelinjsko jezero is registered as a spring.

ob visokih vodah preseže 2 m^3/s, ob nižjih vodostajih pa se nivo vode spusti globlje v kraško jamo na izviru.

Neke vrste občasni kraški izviri so tudi presihajoča Pivška jezera (Slika 2). Te kraške depresije v zahodnem robu Javornikov so večinoma suhe in nivo kraške vode je globlje v podzemlju. Po močnejših ali dolgotrajnejših padavinah pa začne nivo naraščati in lahko ob ugodnih razmerah doseže tudi dno kotanj. Ob nadaljnjem naraščanju podzemna voda skozi razširjene razpoke ali kraške kanale v dnu ali na pobočju izteka na površje, kotlaste vrtače se začnejo polniti z vodo in nastajajo jezera. Z upadanjem nivoja podzemne vode pa se jezera začnejo prazniti in voda se spet izgublja v kraške kanale in razpoke - tudi v tiste, skozi katere je prej prihajala na površje.

Jezera se razlikujejo po velikosti, nadmorskih višinah in po času trajanja. Večinoma so aktivna samo kratek čas ob najvišjem vodostaju, najdlje pa se voda zadržuje v najnižjem Petelinjskem jezeru, ki ima vodo skoraj polovico leta. Največje je Palško jezero s površino več kot 1 km^2, ki lahko zbere tudi več kot 1,5 milijona m^3 vode. Po močnejšem dežju vre voda na površje predvsem na vzhodni strani. Najmočnejši je izvir iz Matijeve jame, ki ob visokih vodah deluje kot izvir, ob nizkih vodah pa lahko nivo podzemne vode opazujemo globlje v jami. Palško jezero je povprečno suho že okrog tri četrtine leta.

Ostala jezera so precej manjša, pojavijo se bolj redko oz. je obdobje, ko so zalita z vodo, krajše. Nekatera med njimi so aktivna samo ob izjemno visokih vodostajih. Take razmere so nastopile v novembru leta 2000 in obseg ter značilnosti jezer v teh izjemnih pogojih so predstavljeni v enem izmed člankov v tej knjigi (Habič & Kovačič 2005).

This lake is connected by underground flows with the Žejski izviri, which is a spring with the biggest capacity and longest duration in the Pivka area. With discharges up to 6 m^3/s it is active around six months a year (when Trnski izviri becomes dry the discharge of Žejski izviri is still 3 $m^{3/}s$). Underground water connection with the Petelinjsko jezero was proved by tracing, and additionally this spring is recharged from a broader karst catchment. There is a smaller spring near the village Žeje. Further to the north is the Fužina spring near Stara vas, which recharges the Stržen brook. At high waters the discharge reaches 2 m^3/s, but at low waters it is dry and the water table is deeper in the karst cave.

The karst lakes of Pivka are also some kind of intermittent karst springs (Figure 2). These karst depressions in the western part of the Javorniki range are mostly dry and the karst water table is deeper underground. After more intensive or long-lasting precipitation the water table begins to rise and it can reach the bottom of depressions. If this increase continues groundwater flows to the surface through karst fissures and channels at the bottom or on the slope of depressions, which in this way start to fill up with water and form karst lakes. With falling of the water table the lakes begin to empty and water sinks into fissures and channels underground, including those through which it was previously flowing to the surface.

The lakes differ in their size, altitude and duration. Mostly they are active only for a short period of time at the highest waters. Petelinjsko jezero has the longest duration of approximately six months. The biggest is Palško jezero with the area of more than 1 km^2, which can contain more than 1.5 km^3 of water. After heavy precipitation water flows to the surface mostly on its eastern side. The biggest source is the spring from Matijeva jama, which acts as a spring at high waters, but at low waters there is no outflow and the water table can be observed deeper in the cave. Palško jezero is on average dry almost three quarters of a year.

FIZIKALNO-KEMIČNE LASTNOSTI VODA

V okviru raziskav vodnih virov za oskrbo Postojne (Gospodarič *et al.* 1968) so bile v letih 1966 in 1967 opravljene za tisti čas kar obsežne meritve in analize voda na območju Pivških jezer. Zajele so Pivščico, izvire pri Kljunovem ribniku, Podlaznico, Matijevo jamo na Palškem jezeru, Petelinjsko jezero ter Trnske in Žejske izvire. Naročnik je bil tedanji Zavod za vodno gospodarstvo SRS, Ljubljana. Raziskave so obsegale meritve temperature voda na terenu z občasno oceno izdatnosti ter zajemom vzorcev, ki so bili analizirani na vsebnost karbonatov, kalcija in magnezija v času različnih hidroloških razmer. Decembra 1967 so bili zajeti še vzorci vode v Matijevi jami in izviru Pivščica za razširjeno kemično analizo, ki je podala tudi vsebnost nitratov, sulfatov, kloridov in fosfatov kot pokazateljev onesnaženja.

Meritve in zajem vzorcev so opravili sodelavci Inštituta za raziskovanje krasa, razširjene analize pa na Kemijskem inštitutu Borisa Kidriča in na Zavodu za kemične in tekstilne tehnološke raziskave. Pri ostalih analizah (določitve karbonatne, kalcijeve in celokupne trdote) izvajalec analiz ni naveden.

Opravljene analize kažejo, da se opazovani izviri bistveno razlikujejo. V času višjega vodostaja 31. oktobra 1966, ko je imela Pivščica pretok 400 l/s, izviri pri Kljunovem ribniku 200 l/s in Podlaznica 100 l/s, je Pivščica dosegla razmerje Ca/Mg 24, izviri pri Kljunovem ribniku le 3,6 ter Podlaznica 7,3. Razmerje Ca/Mg odraža značilnosti zaledja, iz katerega vode pritekajo. Tako lahko sklepamo na prisotnost dolomitov v zaledju izvirov pri Kljunovem ribniku, medtem ko v Pivščico doteka voda predvsem z apnenčastega območja. Ob upadanju pretokov, ki je sledilo, so se razlike nekoliko zmanjšale. Predvidevamo, da prek leta prihaja do večjih nihanj razmerja Ca/Mg, kar lahko odraža daljše oz. kratkotrajnejše zadrževanje padavin v zaledju oz. dotok voda z ožjega ali obsežnejšega dela zaledja, odvisno

Other lakes are smaller, they occur rarely or their duration is only short. Some of them are active only at extremely high waters, as in November 2000. The extent and characteristics of the lakes in this period are described in one of the articles in this volume (Habič & Kovačič 2005).

PHYSICO-CHEMICAL CHARACTERISTICS OF WATERS

Rather comprehensive measurements and analyses of waters in the broader area of Pivka lakes were carried out in the years 1966 and 1967 during the researches for water supply of the Postojna area (Gospodarič *et al.* 1968). The following points were observed: Pivščica spring, springs near the Kljunov ribnik, Podlaznica spring, Matijeva jama, Petelinjsko jezero, Trnski izviri, and Žejski izviri. Research was initiated by the Institute for Water Management of Slovenia. In the field water temperature was measured and occasionally discharges were estimated. Water samples for the analysis on carbonates, calcium and magnesium were taken at different hydrological conditions. In December 1967 also water samples in the Matijeva jama and Pivščica spring were taken for extended chemical analysis (nitrates, sulphates, chlorides and phosphates as indicators of pollution).

Measurements and sampling was performed by the co-workers of the Karst Research Institute, and extended chemical analysis was carried out at the National Institute of Chemistry Boris Kidrič and at the Institute for Chemical and Textile Technology. For all other analyses (carbonate, calcium and total hardness) it is not known who performed them.

Based on the results, some significant differences between the springs can be noticed. During high waters on 31 October 1966 the values of the Ca/Mg ratio were the following: the Pivščica spring 24 (discharge 400 l/s), springs near the Kljunov ribnik 3.6

od hidroloških razmer. V izvirih pri Kljunovem ribniku so v primerjavi s Pivščico višje tudi vrednosti karbonatne in celokupne trdote.

Temperatura vode v Matijevi jami niha prek leta v ozkem intervalu od 8,2 do 9,2 ºC. Po dostopnih podatkih pa je večje spreminjanje razmerja Ca/Mg, kar lahko kaže na časovno različne deleže dotekajoče vode iz apnenčastega oz. dolomitnega dela zaledja. Vrednost 6,6 v vzorcu 31. oktobra 1966 nakazuje pomemben dotok vode iz dolomitnega zaledja. Na Petelinjskem jezeru je nivo vode tedaj naraščal, razmerje Ca/Mg pa je bilo 9,5.

Voda iz Trnskih izvirov je imela 9. novembra 1966 podobno nizko vrednost Ca/Mg = 5,2 kot voda v Matijevi jami. Za Žejske izvire je bilo 5. novembra 1966 določeno razmerje Ca/Mg = 8,6, kar je le nekoliko manj kot pri vodi v Petelinjskem jezeru. To kaže na medsebojno povezanost med Palškim jezerom in Trnskimi izviri ter med Petelinjskim jezerom in Žejskimi izviri, ki je bila dokazana tudi s sledenjem. Pokazalo pa se je, da predstavlja odtok iz Petelinjskega jezera le del vode Žejskih izvirov, preostalo vodo pa ti dobivajo iz širšega zaledja.

Voda v Breznu v Kobiljih grižah (po analizah od poletja 1988 do začetka leta 1989) je dosegala podobne nižje vrednosti Ca/Mg kot voda v Petelinjskem jezeru, v začetku decembra 1988 v sušnih razmerah s snegom pa opazno višjo vrednost 26. V tem času je voda v vrtini pri Fužini vzporedno dosegala opazno višje vrednosti. V celotnem obdobju opazovanja je bila celokupna trdota v tej vrtini značilno višja kot v Breznu v Kobiljih grižah. Občasni izvir Fužina pa dosega vmesne vrednosti tako celokupne trdote kot tudi razmerja Ca/Mg. To kaže (na osnovi razpoložljivih podatkov) na razlike v primerjavi z izvirnim območjem Pivke. Tudi s sledenjem na Počku v danih razmerah ni bila dokazana povezava z vrtino pri Žejah in z Žejskimi izviri.

Podatki o analizah, ki pokažejo kakovostno sliko voda, so zelo skromni. Analiza vzorca iz

(discharge 200 l/s), and the Podlaznica spring 7.3 (discharge 200 l/s). The Ca/Mg ratio reflects the characteristics of the recharge area. So the results indicate the presence of dolomite in the catchment of the springs near the Kljunov ribnik and the predominantly limestone catchment of the Pivščica spring. During a decrease of discharge in the next phase a reduction in these differences was detected. According to our supposition of bigger oscillations of the Ca/Mg ratio during the course of the year we can infer that infiltrated rainwater is retained in karst for longer or shorter time, or recharge water comes from narrower or broader parts of the aquifer, all dependent on hydrological conditions. In comparison with the Pivščica spring also the carbonate and total hardness is higher in the springs near the Kljunov ribnik.

Water temperature in the Matijeva jama oscillated through the year between 8.2 and 9.2ºC. Accessible data indicate larger oscillations of the Ca/Mg ratio which could be a result of different shares of recharge from the limestone and dolomite catchments. A value of 6.6 in the sample from 31 October 1966 indicates an important inflow from dolomite. Water level in Petelinjsko jezero was increasing at the same time and the value of the Ca/Mg ratio was 9.5.

On 9 November 1966 the Ca/Mg ratio 5.2 in the Trnski izviri was as low as in Matijeva jama. On 5 November 1966 the ratio in the Žejski izviri was 8.6 which is only slightly less than in Petelinjsko jezero. This indicates connections between Palško jezero and the Trnski izviri, and between Petelinjsko jezero and Žejski izviri, which were also proved by tracer tests. But we can also conclude that the outflow from Petelinjsko jezero represents only a part of discharge in Žejski izviri, which is additionally recharged from a broader area.

The Ca/Mg ratio in water from Brezno v Kobiljih grižah (according to the analyses from summer 1988 to the first months of 1989) was as low as in the Petelinjsko jezero. But in a dry period with snow at the beginning of December

Matijeve jame decembra 1967 je pokazala, da voda vsebuje 4,4 mg NO_3^-/l, 0,02 mg PO_4^{3-}/l, 0,6 mg Cl^-/l in 8,6 mg SO_4^{2-}/l. Ob ponovni analizi 1988 so bile določene nekoliko višje vrednosti fosfatov in kloridov.

Kasneje smo spremljali sestavo Pivke pred Žejskimi izviri in Žejskih izvirov po sušni zimi s snegom in prvem dežju ob močni odjugi decembra 1999. Na ta način smo ugotavljali vpliv akumuliranega onesnaženja, ki ga voda spira po daljšem sušnem obdobju, na signal fluorescence (Kogovšek 1999). Iz Slike 4 je lepo razvidno postopno spiranje onesnaženja in zniževanje vrednosti posameznih parametrov. Pivka je bila verjetno aktivna že dan pred prvim vzorčenjem, zato so bile izhodne vrednosti parametrov zelo verjetno še višje. Spiranje zaledja je bilo intenzivno, višina Pivke pod mostom v Prestranku je narasla do 2,89 m in le počasi upadala, Žejski izviri pa so bili ocenjeni na okoli 200 l/s. Spiranje je trajalo dva tedna. Vendar pa tudi po treh tednih spiranja zaledja Zgornje Pivke vrednosti merjenih parametrov niso dosegle vrednosti Žejskih izvirov ob začetku opazovanj. To kaže na pomemben vpliv poseljenosti ob zgornjem toku Pivke na njeno kakovost. Dosedanje analize čistih kraških voda so pokazale, da vsebujejo le do nekaj mg/l kloridov in nitratov, medtem ko so fosfati na meji detekcije (0,01 mg/l). Glede na ta merila imajo Žejski izviri nekoliko povišano vsebnost nitratov in fosfatov.

Razmerje Ca/Mg Pivke pred Žejskimi izviri, ki odraža razmere v zgornjem toku Pivke, je ob začetnem spiranju nekoliko poraslo, nato pa v vrhu poplavnega vala upadlo, kar lahko pripišemo večjemu dotoku voda iz dolomitnega zaledja.

Bakteriološka analiza vzorcev, zajetih 6. decembra 1967, je pokazala oporečno vodo tako v Matijevi jami kot v izviru Pivščice. Zaradi velike prepustnosti kraškega sveta so kraške vode običajno bakteriološko onesnažene, če že ne prek celega leta, pa vsaj ob določenih hidroloških razmerah.

1988 this value was significantly greater (Ca/Mg = 26). At the same time the values in the borehole at Fužina were considerably higher. In the whole period of observation the total hardness in this borehole was significantly higher than in Brezno v Kobiljih grižah. For the intermittent Fužina spring intermediate values of total hardness and Ca/Mg ratio are characteristic. This indicates (based on available data) some differences in the comparison with the spring area of the Pivka river. By tracing on Poček the connection with the Žejski izviri and the borehole nearby was not confirmed in the conditions of the time.

Data on water quality are scarce. The concentrations in the water sample from the Matijeva jama taken in 1967 (December) were the following: 4.4 mg NO_3^-/l, 0.02 mg PO_4^{3-}/l, 0.6 mg Cl^-/l and 8.6 mg SO_4^{2-}/l. Higher values of phosphates and chlorides were measured in 1988.

Later also the Pivka river (before the inflow of the Žejski izviri) and the Žejski izviri were monitored in a period of mild weather and first rain after a dry, snowy winter in December 1999. The aim was to estimate the influence of accumulated pollution, which is washed out by water after long dry periods, on the detection of fluorescence (Kogovšek 1999). In Figure 4 gradual washing out of pollution and decrease in concentrations of observed parameters can be seen. The Pivka river was probably already active one day before the first sampling, therefore the initial concentrations were even higher. Due to intensive emptying of the karst aquifer the level of the Pivka river below the bridge in Prestranek reached 2.89 m and was then decreasing very slowly. The discharge of the Žejski izviri was estimated to be 200 l/s. But even in the recession period of three weeks the concentrations of measured parameters did not reach the values of Žejski izviri at the beginning of observations. This indicates an important influence of urban pollution in the upper part of the Pivka on its quality. As measured by analyses of pure karst water made so far the

SKLEPI

Za območje presihajočih Pivških jezer je značilna tesna povezava podzemnih in površinskih voda. V zelo dobro prepustnem kraškem vodonosniku se vode pretakajo večinoma podzemno proti kraškim izvirom na obrobju. Z različnimi metodami je bilo dokazano tipično kraško raztekanje v različnih smereh ter spreminjanje smeri in značilnosti podzemnega toka ob različnih hidroloških pogojih.

V sušnih obdobjih je reka Pivka v zgornjem toku suha, podzemna voda pa je plitvo pod površjem. Po močnejših ali dolgotrajnejših padavinah se njen nivo dvigne in ponekod doseže površje. Tako se aktivirajo občasni kraški izviri in napolnijo strugo Pivke. Voda zapolni tudi kraške depresije in pojavijo se presihajoča kraška jezera.

Izvirno območje Pivke je pri vasi Zagorje, vzdolž njenega nadaljnjega toka pa so še številni občasni kraški izviri. Ponekod v strugi so ponori, skozi katere se površinska voda vsaj deloma spet izgublja v podzemlje. Neke vrste kraški izviri so tudi presihajoča Pivška jezera. Ko se nivo vode v podzemlju dviguje, lahko doseže tudi kraške depresije, skozi kraške razpoke in kanale v njihovem dnu ali na pobočju izteka na površje in polni jezera. Ta se razlikujejo po velikosti, nadmorskih višinah in po času trajanja, njihovo pojavljanje pa je odvisno od hidroloških pogojev. Z upadanjem vodostaja se začnejo spet prazniti in voda odteka skozi razpoke in kanale. Največje je Palško jezero, najdlje pa se voda zadržuje v najnižjem Petelinjskem jezeru. Ostala jezera so precej manjša in se pojavljajo bolj redko.

Podatkov o fizikalno-kemičnih lastnosti voda je malo, pa še ti so večinoma starejšega datuma. Iz obstoječih podatkov je razvidno, da se opazovani izviri med seboj precej razlikujejo, na tej osnovi pa lahko sklepamo na razlike v geoloških značilnostih njihovega zaledja. Nihanja vrednosti parametrov pri posameznih izvirih pa kažejo na vpliv hidroloških razmer concentrations of chlorides and nitrates are up to several mg/l, and the phosphates are at the detection limit (0.01 mg/l). In comparison with these standards the concentrations of nitrates and phosphates in the Žejski izviri are slightly higher.

The Ca/Mg ratio of the Pivka river (before the inflow of the Žejski izviri), which indicates conditions in the Upper Pivka, has initially increased and then decreased at the discharge peak due to increased inflow from dolomite part of catchment.

Inadequate water in Matijeva jama and the Pivščica spring was indicated by bacteriological analysis of samples taken on 6 December 1967. Due to high permeability of karst aquifers karst waters are usually bacteriologicaly polluted, at least in some periods with specific hydrological conditions.

CONCLUSIONS

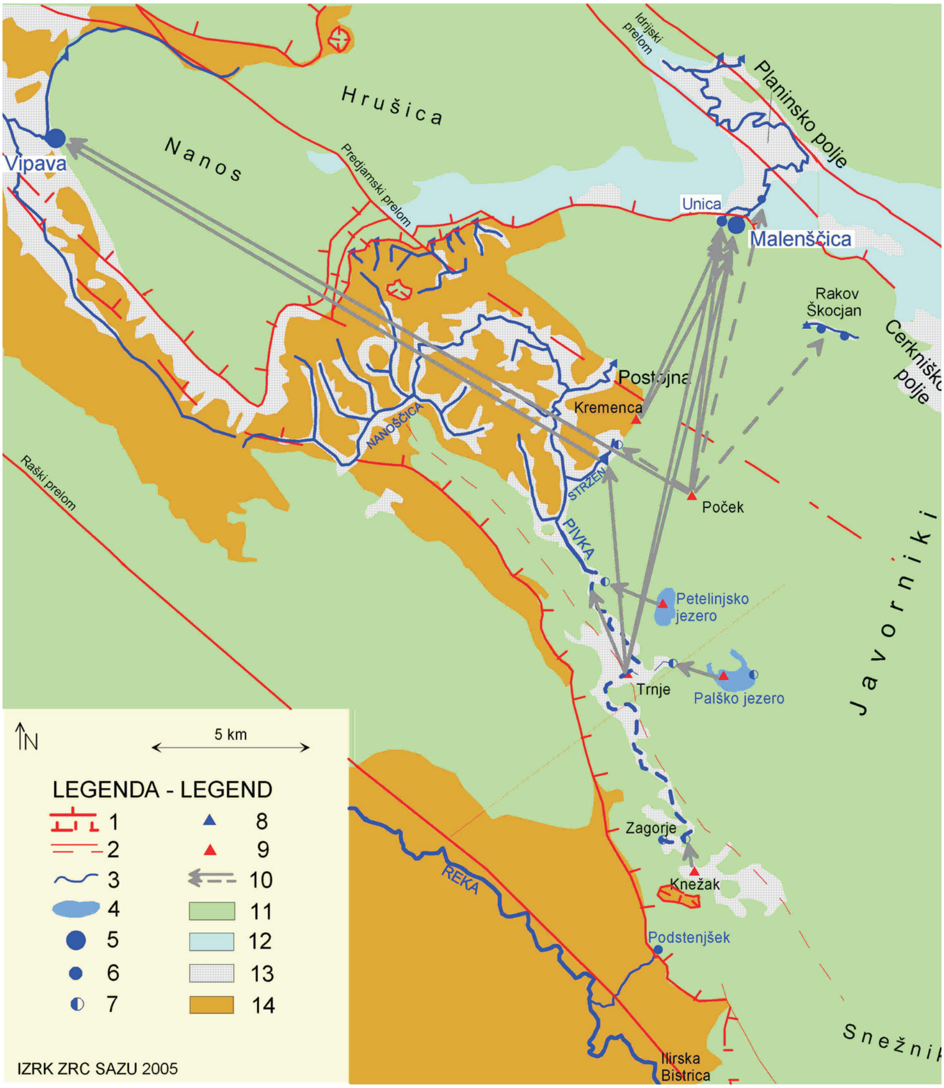
For the area of the intermittent Pivka lakes close connection between underground and surface waters in characteristic. In very well permeable karst aquifer water flows predominantly underground towards karst springs at the border. Typical karst regime with different directions and characteristics of groundwater flow at different hydrological conditions was proved by various research methods.

The Pivka river in its upper stream is dry during low waters, and the water table is close below the surface. After heavier and long-lasting precipitation water table rises and in some places it reaches the surface. In this way intermittent karst springs are activated and they recharge the river. Also karst depressions are filled by water and intermittent karst lakes are formed.

na čas zadrževanja vode v podzemlju in spreminjanje obsega zaledja. Tudi merjenja kakovosti vode so bila opravljena le občasno, vseeno pa nas dobljeni rezultati opozarjajo na veliko ranljivost kraških vodonosnikov na različne vire onesnaževanja.

The spring area of the Pivka river is near the village Zagorje, and along the river numerous intermittent karst springs are located. At least partly the surface flow sinks underground through several ponors in the riverbed. Some kind of karst springs are also intermittent karst lakes of Pivka. As the water table rises, it can also reach karst depressions and outflows to the surface through karst fissures and channels in the bottom or the slope and fills up the lakes. These differ regarding their size, altitudes and duration, and their occurance depends on hydrological conditions. In the recession period they begin to empty and water sinks through fissures and channels. The biggest lake is Palško jezero and the lowest, Petelinjsko jezero, has the longest duration. Other lakes are much smaller and they occur rather rarely.

The data on physico-chemical characteristics of water are scarce, and even those are quite old. But existing data reflect significant differences between observed springs which can be explained by differences in the geological characteristics of their catchment. Values of measured parameters at individual springs oscillate due to the influence of hydrological conditions on retention time of karst water and on changes of the extent of catchments. Also measurements of water quality were carried out only occasionally; nevertheless obtained results are a sufficient warning that karst aquifers are very vulnerable to different sources of pollution.

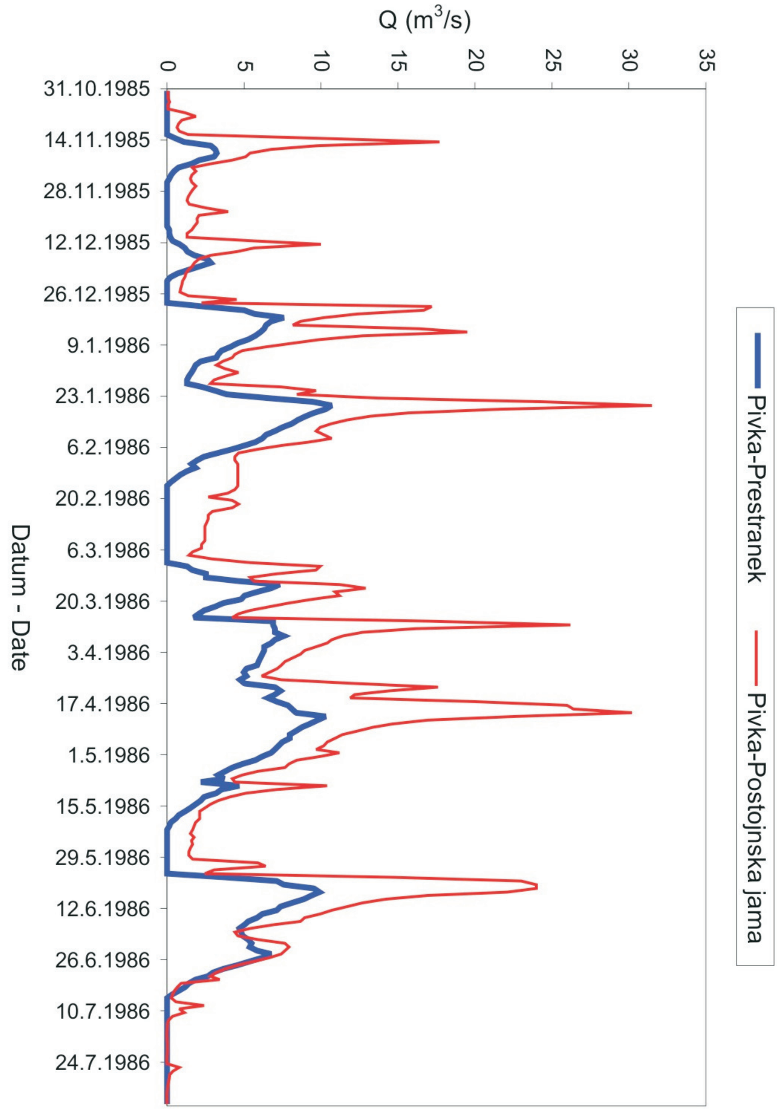


Slika 1: Hidrogeološka karta širšega območja (Legenda: 1. vidna in pokrita narivnica, 2. viden in pokrit prelom, 3. površinski tok, 4. presihajoče jezero, 5. večji izvir, 6. stalni izvir, 7. občasni izvir, 8. ponor, 9. točka injiciranja sledila, 10. s sledenjem dokazana glavna in stranska podzemna vodna zveza, 11. kraški vodonosnik, 12. razpoklinski vodonosnik, 13. medzrnski vodonosnik, 14. zelo slabo prepustne plasti).

Figure 1: Hydrogeological map of broader area (Legend: 1. Visible and covered thrust, 2. Visible and covered fault, 3. Surface flow, 4. Intermittent lake, 5. Big spring, 6. Permanent spring, 7. Intermittent spring, 8. Ponor, 9. Injection point, 10. Main and secondary direction of underground water flow, proved by tracing tests, 11. Karst aquifer, 12. Fissured aquifer, 13. Porous aquifer, 14. Very low permeable rocks).

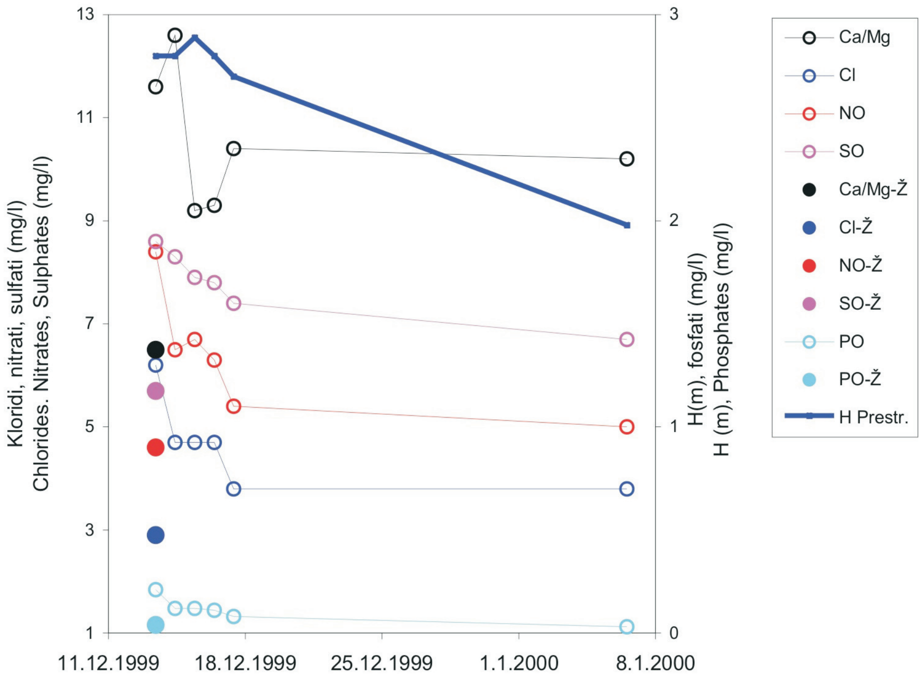
Slika 2: Hidrogeološka karta območja presihajočih Pivških jezer (Legenda: 1. kraški vodonosnik, 2. medzrnski vodonosnik, 3. zelo slabo prepustne plasti, 4. stalni površinski tok, 5. občasni površinski tok, 6. presihajoče jezero, 7. kraški izvir, 8. kraška jama, 9. ponor).

Figure 2: Hydrogeological map of the area of Pivka intermittent lakes (Legend: 1. Karst aquifer, 2. Porous aquifer, 3. Very low permeable rocks, 4. Permanent surface flow, 5. Intermittent surface flow, 6. Intermittent karst lake, 7. Karst spring, 8. Karst cave, 9. Ponor).



Slika 3: Pretoki reke Pivke pri Prestranku in pred ponorom v Postojnsko jamo v hidrološkem letu 1985-1986.

Figure 3: Discharges of Pivka near Prestranek and before sinking into the Postojnska jama cave in hydrological year 1985-1986.



Slika 4: Opazovanje višine Pivke v Prestranku ter kakovosti (nitratov, sulfatov, kloridov in fosfatov) Pivke pred Žejskimi izviri in Žejskih izvirov (Ž) po daljšem sušnem obdobju.

Figure 4: Data on water level of Pivka in Prestranek and on quality (nitrates, sulphates, chlorides and phosphates) of Pivka before the inflow from the Žejski izviri and of the Žejski izviri (Ž) after a longer dry period.

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