I. DEL:
RAZVOJ NA PODROČJU HIDROLOŠKEGA MONITORINGA

PART I:
DEVELOPMENTS IN THE FIELD OF HYDROLOGICAL MONITORING

SPREMEMBE V MREŽI HIDROLOŠKIH MERILNIH MEST V LETU 2009

mag. Roman Trček

Zaradi vsebinskih posebnosti delimo državno mrežo hidroloških opazovanj na mrežo za opazovanje površinskih voda, mrežo za opazovanje podzemnih voda, ki je sestavljena iz mreže na aluvialnih vodonosnikih in mreže na izvirih ter mrežo za opazovanje morja.

Površinske vode

V državni mreži za meritve površinskih voda je v letu 2009 delovalo 185 vodomernih postaj (v. p.). V tem letu sta bili avtomatizirani 2 merilni postaji (AMP), tako da se je njihovo skupno število povečalo na 47, kar predstavlja 25% vseh vodomernih postaj.

Novo zgrajeni AMP v letu 2009 sta:

- v.p. Železniki na Selški Sori: gradbena dela zaključena marca 2009 in
- v.p. Ranca na Pesnici: gradbena dela zaključena februarja 2009.

Na v.p. Iška vas je bil v mesecu septembru zgrajen talni prag, kar je vplivalo na pretočno krivuljo. Na v.p. Verd na Ljubiji in v.p. Potoki na Nadiži so se gradbena dela pričela konec leta 2009 in se zaključila v letu 2010.

Na omenjenih merskih mestih je bil začasno prekinjen niz podatkov. Meritve pretokov za potrebe izdelave pretočne krivulje so bile zgoščeno izvajane takoj po končanju gradbenih del. Kontinuirano spremljanje gladine je bilo izvedeno v obdobju parih mesecev po gradbenih delih.

Preko leta je bilo narejenih 1122 hidrometričnih meritev (10 manj kot v letu 2008), 625 z akustičnimi dopplerjevim merilnikom (ADMP) (6 več kot v letu 2008) in 484 z ultrazvočnim hidrometričnim krilom (FlowTracker – FT) (21 manj kot v letu 2008). Trinajstkrat je bil merski profil ob obisku vodomerne postaje suh. V letu 2009 ni bilo nobene meritve s klasičnim hidrometričnim krilom.

Na 134 v.p. so bili vodostaji zabeleženi zvezno, od tega z limnigrafskimi zapisi na papir na 83, s prenosom podatkov v realnem času (AMP) na 47 in z zapisom v podatkovni zapisovalnik ter kasnejšim vnosom v bazo na 4 v.p. 41 merilnih mest je bilo opremljenih zgolj z vodomerno letvijo. Meritve vodostaja se v teh primerih izvajajo ročno, enkrat dnevno, v času poplavnih valov pa tudi pogosteje.

Opazovanja so se vršila na 172 v.p. Od tega so se izvajala redna dnevna opazovanja na 98 v.p., na 74 v.p. pa so se izvajala 1-krat tedensko preko območnih opazovalcev vodnogospodarskih podjetij. Ob izrednih

CHANGES TO THE NETWORK OF HYDROLOGICAL GAUGING STATIONS IN 2009

Roman Trček, MSc

Due to its specific features, the national hydrological observation network is classified into the surface water observation network, the groundwater observation network (consisting of the alluvial aquifer observation network and spring observation network), and the sea observation network.

Surface waters

In 2009, 185 water gauging stations were operational within the national surface water observation network. In 2009, two new automatic gauging stations (AGS) were installed, increasing the total number of gauging stations to 47, which represents 25 % of all gauging stations.

The AGS installed in 2009 are:

- Železniki gauging station on the Selška Sora river: the construction work was completed in March 2009; and
- Ranca gauging station on the Pesnica river: the construction work was completed in February 2009.

In September, a sill was constructed at the Iška Vas water gauging station, which had an influence on the discharge curve. At the Verd gauging station on the Ljubija branch spring and the Potoki gauging station on the Nadiža river, the construction work started at the end of 2009 and was completed in 2010.

The gathering of datasets was temporarily halted at the aforementioned gauging stations. The discharge measurements for the formation of the discharge curve were carried out on a more frequent basis immediately after the completion of construction work. Continued monitoring of the water level was carried out a few months after the completion of construction work.

During the year, 1122 hydrometric measurements were conducted (10 fewer measurements than in 2008), of which 625 were carried out with the ADCP acoustic Doppler current profiler (6 more measurements than in 2008) and 484 with the FlowTracker FT ultrasonic velocimeter (21 fewer measurements than in 2008). During the visits to the water gauging station, the measurement profile was arid on 13 occasions. In 2009, no measurements were carried out with traditional current meters.

At 134 water gauging stations, the water levels were recorded continuously; at 83 stations they were recorded on paper by water level recorders, at 47 stations they were recorded by real-time data transmission (AGS), and at four water gauging stations the data were recorded with a data logger and razmerah je bilo narejeno veliko opazovanj visokovodnih stanj.

Vedno več merilnih mest ima po dva neodvisna merilnika vodostajev npr. ultrazvočni merilnik (sonar), mikrovalovni merilnik (radar), tlačna sonda ipd. Na ta način se poskuša zmanjšati verjetnost izpada podatkov, predvsem pa se omogoča sprotno, daljinsko prepoznavanje grobih napak odčitkov v realnem času. Za boljšo predstavo o razmerah na terenu in podporo odločitvam o ukrepanju predvsem v času v izrednih razmer, so bile na določene v.p. postavljene tudi spletne kamere.

Temperature vode so se v letu 2009 merile na 79 merilnih mestih - 46 postaj AMP na površinskih vodotokih in 2 AMP postaji na morju. Enkrat dnevna opazovanja (izjema je ena postaja, kjer so bila opazovanja enkrat tedensko) so se izvajala na 31 postajah. Nekaj termometrov je bilo živosrebrnih, nekaj pa alkoholnih.

V letu 2009 se je zajemalo vzorce vode za določanje vsebnosti in izračun transporta suspendiranega materiala na 11 vodomernih postajah. Na eni postaji se je zajem izvajal vsakodnevno - vzorcev je preko 300, na štirih postajah pa je bilo zajetih okoli 100 vzorcev. Na ostalih postajah je bil zajem vzorcev vode le občasen ob visokih vodah.

Podzemne vode

Meritve podzemnih voda v aluvialnih vodonosnikih so v letu 2009 potekale na 139 merilnih mestih. Poleg tega so na dodatnih treh merilnih mestih Ljubljanskega polja potekale kontinuirane meritve vodostajev in temperatur (Sojerjeva, Bravničarjeva in RTV). Omenjena merilna mesta so bila kasneje vključena v redni program za leto 2010.

Na merilnem mestu Skopice na Krškem polju je bila v letu 2009 dvakrat ugotovljena kraja merilne opreme. Ker je omenjeno merilno mesto nezaščiteno in izpostavljeno, tam nismo več postavljali merilne opreme in meritve so potekale le v obliki rednih in izrednih kontrolnih meritev. Tekom leta je bilo opravljenih še 11 zamenjav elektronske merilne opreme (okvare in problemi z dotrajanostjo obstoječe merilne opreme).

Meritve v letu 2009 so se izvajale na 5 avtomatskih merilnih postajah, 47 merilnih mest je bilo opremljenih z limnigrafskimi zapisovalniki, 33 pa s podatkovnimi zapisovalniki. Na ostalih merilnih mestih so potekala opazovanja ali občasne kontrolne meritve.

V letu 2009 je bilo izvedenih 6 novih merilnih mest (MM) za spremljanje količinskega in kakovostnega stanja podzemnih voda. Septembra 2009 so bila prevzeta sledeča MM:
MM Veščica in MM Zgornje Krapje na Murskem

subsequently entered into the database. Forty-one gauging stations were equipped only with staff gauges. In such cases, water level measurements are carried out manually once a day, even more frequently during flood tides.

Observations were conducted at 172 water gauging stations. At 98 water gauging stations regular daily observations were carried out, while at 74 gauging stations they were carried out once a week by local observers from water management companies. When extreme conditions occurred, several observations of flood conditions were carried out.

An increasing number of gauging sites have two independent water level gauges (an ultrasonic gauge (sonar), a microwave gauge (radar) and a pressure probe). This should reduce the probability of data loss and in particular provide for continuous, remote identification of serious errors in real time readings. In order to better present the situation in the field and to support the decisions on taking measures, in particular during extraordinary hydrological conditions, web cameras were also installed at certain gauging stations.

In 2009, water temperatures were measured at 79 gauging sites; at 46 automatic gauging stations on surface streams and at two automatic gauging stations at sea. Daily observations (except at one station where the observations took place once a week) were carried out at 31 stations. Some thermometers were classic mercury-in-glass thermometers, while others were alcohol thermometers.

In 2009, water sampling to determine the concentration of suspended material and to calculate the transmission of suspended material took place at 11 gauging stations. At one station sampling was performed daily: more than 300 samples were taken; while at four stations around 100 samples were taken at each station. The remaining stations performed only periodical sampling during high waters.

Groundwater

In 2009, groundwater measurements were carried out at 139 gauging stations in alluvial aquifers. At three additional gauging stations of the Ljubljana field aquifer continued measurements of water levels and temperatures took place (Sojerjeva, Bravničarjeva and RTV). The aforementioned gauging stations were later integrated in the regular programme for 2010.

In 2009, the gauging equipment at the Skopice gauging station on Krško field was stolen twice. Since this station is unprotected and exposed, no gauging equipment was re-installed and measurements only took place in the form of regular and extraordinary control measurements. During the year, 11 sets of gauging equipment were replaced (due to errors and problems with outdated existing gauging equipment).

Slika 1: Izvedba gradbenih del na v.p. Ranca in v.p. Železniki je bila kljub izrazito neugodnim vremenskim razmeram izvedena zelo kvalitetno in z minimalnim časovnim zamikom (foto: Primož Gajser)
Figure 1: Although the weather conditions were extremely unfavourable, the construction work at the Ranca and Železniki water gauging stations was executed at a high quality level and with minimum delay (photo: Primož Gajser)

Slika 2: Meritev visokovodnega pretoka 26.12.2009 na v.p. Litija na Savi (foto: Marko Burger)
Figure 2: Measurement of flood discharge, 26 December 2009, at the Litija water gauging station on the Sava river (photo: Marko Burger)

- polju,
- MM Rakičan in MM Odranci na Prekmurskem polju,
- MM Dornava na Ptujskem polju in
- MM Kungota na Dravskem polju.

Opazovanje izvirov je v letu 2009 potekalo na 15 merilnih mestih. Podrobnosti o delovanju mreže so pregledno podane v ločenem prispevku.

In 2009, measurements were carried out at five automatic gauging stations, 47 gauging stations equipped with water-level recorders and 33 gauging stations with data loggers. At all other gauging stations only observations or temporary control measurements took place.

Six new gauging sites for monitoring the chemical state and quantity of underground waters were installed during the year. In September 2009, the following gauging sites were put in operation:

- the Veščica and Zgornje Krapje gauging sites on Mura field,
- the Rakičan and Odranci gauging sites on Prekmurje field,
- the Dornava gauging site on Ptuj field, and
- the Kungota gauging site on Drava field.

In 2009, observations of springs were conducted at 15 gauging sites. The details on the functioning of the network are presented in a separate study.

Slika 3: Izvedba vrtin na merilnem mestu Rakičan, ki je v neposredni bližini klimatološke meteorološke postaje (foto: Roman Trček)

Figure 3: Execution of drillings on the Rakičan gauging site, located in the immediate vicinity of the climatological and meteorological station (photo: Roman Trček)

Morje

Opazovanje morja je v letu 2009 potekalo na 2 merilnih mestih. Podatki so bili posredovani brez večjih izpadov in znotraj meja območja dolgoletnih statistik.

Sea

In 2009, sea level observations were carried out at two gauging sites. No major data losses occurred during data transmission, and the collected data were within the limits of the multi-annual average.

SEZNAM OPAZOVALCEV V MREŽI MERILNIH MEST HIDROLOŠKEGA MONITORINGA
THE LIST OF OBSERVERS IN THE NETWORK OF THE HYDROLOGICAL GAUGING STATIONS

Preglednica 1: Seznam opazovalcev na površinskih vodah
Table 1: The list of observers on the surface waters

Opazovalec *Observer*	**Vodomerna postaja** *Gauging station*	**Reka, jezero** *River, lake*
Avšič Boštjan	Čatež	Sava
Balog Milena	Hotešček	Idrijca
Banič Janez	Podbočje	Krka
Baša Slavko	Podkaštel	Dragonja
Bevc Franc	Šoštanj	Velunja
Bevk Marija	Trzin	Pšata
Bizjak Marija	Rečica	Paka
Bizjak Nada	Okroglo	Sava
Blažič Filipina	Prestanek	Pivka
Bucaj Stanislav	Kubed	Rižana
Buh Ljudmila	Komin	Ljubljanica
Cankar Darinka	Medno	Sava
Čas Pavla	Solčava	Savinja
Černigoj Jože	Ajdovščina	Hubelj
Ferfolja Alojz	Miren I	Vipava
Fortuna Jožefa	Bistra	Bistra
Furlan Emil	Vipava	Vipava
Gabriel Miro	Rožni vrh	Temenica
Gabrijelčič Zlatko	Solkan	Soča
Glojek Marta	Kraše	Dreta
Gogala Dušan	Cerknica	Cerkniščica
Harbaš Marija	Kranjska Gora	Sava Dolinka
Heberle Olga	Mlino	Blejsko jezero
Heberle Olga	Mlino	Jezernica
Herzog Jerneja	Cankova	Kučnica
Horvat Ladislav	Središče	Ivanjševski potok
Ilijev Zlata	Jesenice	Sava Dolinka
Ive Anton	Preska	Tržiška Bistrica
Jereb Matevž	Žiri	Poljanska Sora
Jevševar Slavko	Škale	Lepena
Jurkošek Romana	Veliko Širje	Savinja
Kac Jože	Stari Trg	Suhadolnica
Kalič Matjaž	Otiški vrh	Meža, Mislinja
Kapš Stanko	Prečna	Prečna
Karničnik Elizabeta	Ruta	Radoljna
Kern Janez	Pšata	Pšata
Klemen Slanc Marija	Razori	Šujica
Koblar Alojzija	Železniki	Selška Sora
Kočevar Franc	Gradac	Lahinja
Košir Luka	Sodražica	Bistrica
Kovač Anica	Log pod Mangartom	Koritnica
Kovačec Ivana	Zamušani	Pesnica
Krajnik Rudolf	Suha	Sora
Leban Ivan	Tolmin	Tolminka
Lesjak Matilda	Levec	Ložnica
Leskovec Alojz	Podroteja	Idrijca
Malis Viljem	Hrastnik	Sava
Martinčič Andrej	Dolenje Jezero	Stržen
Mejač Antonija	Nevlje	Nevljica
Mesarič Gizela	Polana	Ledava

Opazovalec *Observer*	**Vodomerna postaja** *Gauging station*	**Reka, jezero** *River, lake*
Milavec Andrej	Malni	Malenščica
Milavec Ivanka	Hasberg	Unica
Mlinarič Franc	Gornja Radgona	Mura
Moličnik Vinko	Luče	Lučnica
Mudrinič Aleksander	Bodešče	Sava Bohinjka
Mustar Marija	Rašica	Rašica
Nemet Cvetka	Zagaj	Bistrica
Novak Jože	Postojnska jama	Pivka
Oberstar Vida	Prigorica	Ribnica
Obštetar Borut	Dolenja Trebuša	Trebuša
Omerzel Jože	Metlika	Kolpa
Pavša Silva	Golo Brdo	Idrija
Pažur Andrej	Petrina	Kolpa
Pec Franc	Loče	Dravinja
Potočnik Jože	Podnanos	Močilnik
Potokar Janez	Litija	Sava
Rovšček Milojka	Bača pri Modreju	Bača
Roženbergar Drago	Kranj	Kokra
Samec Oton	Polže	Hudinja
Sekljič Edvard	Pesje	Lepena
Skubic Anica	Mieniška vas	Radešča
Slavinec Angela	Škale	Sopota
Stegel Vida	Mali Otok	Nanoščica
Strniša Jure	Žebnik	Sopota
Šepec Terezija	Rakovec	Sotla
Šestan Boris	Trpčane	Reka
Šestan Boris	Trnovo	Reka
Šestan Boris	Cerkvenikov Mlin	Reka
Šetina Marija	Sveti Duh	Bohinjsko jezero
Škoflek Biserka	Velenje	Paka
Škrbec Simon	Branik	Branica
Šorn Stanislav	Vir	Rača
Štancer Drago	Črnolica	Voglajna
Šturm Albin	Kobarid	Soča
Šuštar Andreja	Mlačevo	Grosupeljščica
Švarc Janko	Dvor	Gradaščica
Tominec Franc	Medvode	Sora
Trauner Julijus	Celje	Voglajna
Tršinar Milka	Martinja vas	Mirna
Trunkelj Frančiška	Trebnja Gorica	Višnjica
Vodišek Ivanka	Vodiško	Gračnica
Vodopivec Jože	Dornberk	Vipava
Vošnjak Martin	Dolenja vas	Bolska
Vugrinec Štefanija	Videm	Dravinja
Zagorc Cveto	Nazarje	Savinja
Zajc Anton	Podbukovje	Krka
Zalokar Marjan	Domžale	Mlinščica Kanal
Žagar Bojan	Log Čezsoški	Soča
Žakelj Janez	Vrhnika	Ljubljanica
Žakelj Janez	Verd	Lubija

Preglednica 2: Seznam opazovalcev na podzemnih vodah
Table 2: The list of observers on the groundwater

Opazovalec *Observer*	**Postaja za podzemne vode** ***Groundwater observation station***
Artač Jože	Brezovica
Artenjak Stanko	Spodnja Hajdina
Beranič Ivan	Zg. Jablane
Beranič Slava	Brunšvik
Bizjak Ivan	Gotovlje
Bone Branko	Vipavski Križ
Cvetko Božidar Sandi	Trgovišče
Cvikl Anton	Zg. Grušovlje
Čih Elizabeta	Gornji Lakoš
Drobnič Frančiška	Malence
Erjavec Franc	Lipovci
Filipič Igor	Ključarovci
Fišer Ana	Zgornja Gorica
Galun Janez	Kungota
Jarkovič Frančiška	Drama
Jenko Marta	Meja
Jerebic Franc	Brezovica
Kač Tomašič Irena	Arja vas
Kaučič Anton	Plitvica
Kmecl Leopold	Škofja vas
Kološa Elizabeta	Radmožanci
Kovač Marija	Sinja Gorica
Kregar Marija	Dolenja vas
Krpan Adrijan	Ajdovščina
Krušec Ivana	Segovci
Lepej Darinka	Starše
Mali Jožefa	Šempeter
Medvešek Jožica	Hrvaški Brod
Merljak Luka	Renče

Opazovalec *Observer*	**Postaja za podzemne vode** ***Groundwater observation station***
Mesarič Feliks	Bakovci
Mulec Eda	Žepovci
Ouček Franc	Rankovci
Pečnik Franc	Spodnji Stari Grad
Pinter Ervin	Nemčavci
Pleško Jože	Kozarje
Plošinjak Franc	Stojnci
Rat Alojz	Letuš
Repnik Anica	Mengeš
Repnik Anica	Preserje
Repnik Anton	Parižlje
Rodošek Dušan	Veliki Podlog
Rojc Cvetka	Volčja Draga
Simončič Ivan	Gorica
Simonič Rajko	Dornava
Slapnik Milena	Podgorje
Stamničar Dejan	Veščica
Stropnik Marko	Medlog
Šavrič Daniela	Bukošek
Škraban Avguštin	Krog
Tement Lidija	Sobetinci
Tonja Helena	Sveti Duh
Toplak Marija	Renkovci
Vilčnik Avgust	Ptuj
Weingerl Jože	Mali Segovci
Zadobovšek Rudolf	Trnava
Zevnik Marija	Celje
Žibrek Jelena	Zgornje Krapje

OBLIKOVANJE IZVEDBENEGA KONCEPTA HIDROLOŠKIH PROGNOSTIČNIH SISTEMOV NA SAVI IN SOČI

Nejc Pogačnik, dr. Sašo Petan, Mojca Sušnik, Janez Polajnar

Obstoječi prognostični sistem

V sodelovanju hidroloških služb Slovenije in avstrijske Štajerske je bil leta 2006 izdelan čezmejni sistem za napovedovanje pretokov na reki Muri v okviru programa Evropske unije INTERREG IIIB CADSES Projekt Flussraumagenda Alpenraum. Operativni sistem omogoča širši pregled meteoroloških in hidroloških podatkov na povodju ter napoved pretokov reke Mure na izbranih hidroloških postajah. Podatki so zbrani iz več držav in sinhronizirani znotraj sistema, modelski rezultati pa so predstavljeni v realnem času. To je prvi hidrološki prognostični sistem, ki je bil vključen v operativno delo Oddelka za hidrološko prognozo. Pri osnovni rešitvi se je hitro pokazala potreba po širjenju prognostičnega sistema na druga porečja in vključevanju novih zamisli v operativno učinkovitejše ter informacijsko naprednejše rešitve. Agencija Republike Slovenije za okolje je leta 2006 začela tudi s kandidaturo in prijavo projekta za evropska kohezijska sredstva Operativni program razvoja okoljske in prometne infrastrukture za obdobje 2007–2013. Vključitev zasnove hidroloških prognostičnih sistemov na Savi in Soči v skupni projekt Agencije RS za okolje Boljše opazovanje za boljše ekološke rešitve (ali krajše BOBER) je bila zamišljena kot izhodišče za nadaljnji večletni razvoj hidrološke prognostične službe.

Širitev prognostičnega sistema na druga porečja

Eden od ciljev projekta BOBER Boljše opazovanje za boljše ekološke rešitve je izboljšanje opazovanja in modeliranja posameznih procesov v hidrološkem krogu. Tako je bilo Oddelku za hidrološko prognozo s projektom omogočeno, da je sestavil razvojno skupino, ki bo pri projektu izoblikovala sodobne rešitve in orodje, potrebno za opravljanje vsakodnevnih nalog državne hidrološke službe. Predvideli smo izdelavo dveh hidroloških prognostičnih sistemov: prvega za porečje reke Save, ki zajema 53 odstotkov površine Slovenije, in drugega za porečje reke Soče, ki zajema 11 odstotkov državnega ozemlja. Tako bo imel Oddelek za hidrološko prognozo ob koncu projekta BOBER z novima in obstoječim prognostičnim sistemom na reki Muri možnost napovedovati hidrološke razmere za 70 odstotkov površja Slovenije.

DEVELOPMENT OF AN IMPLEMENTATION CONCEPT FOR HYDROLOGICAL FORECASTING SYSTEMS ON THE SAVA AND SOČA RIVERS

Nejc Pogačnik, Sašo Petan, PhD, Mojca Sušnik, Janez Polajnar

Existing forecasting system

In cooperation with the hydrological services in Slovenia and Styria, Austria, a trans-boundary flood forecasting system on the Mura river was developed within the EU Programme INTERREG IIIB CADSES. The project is called 'Flussraumagenda Alpenraum'. This operational system provides for a broader overview of meteorological and hydrological data in the drainage basin of the Mura river and the forecasting of its discharges at selected hydrological stations. The data are received from several countries and synchronised in the system, while the model results are presented in real time. This is the first hydrological forecasting system integrated into the operational work of the Hydrological Forecasting Department. The basic solution soon required an expansion of the hydrological forecasting system to other river basins and the integration of new ideas into operationally more efficient and advanced information technology solutions. In 2006, the Environmental Agency of the Republic of Slovenia (hereinafter: the agency) also started to compete for European cohesion funds for its project 'Operational Programme for Environmental and Transport Infrastructure Development 2007–2013'. The integration of the concept of hydrological forecasting systems on the Sava and Soča rivers into the joint project of the agency called 'Better Observation for Better Environmental Response' (BOBER) was envisaged as a starting point for further multi-annual development of the hydrological forecasting service.

Expansion of the forecasting system to other river basins

One of the objectives of BOBER is to improve the observation and modelling of individual processes in the hydrological circle. Through this project, the Hydrological Forecasting Department was given the opportunity to set up a development group that will (within the project) develop the advanced solutions and tools that are required for the performance of the daily tasks of the national hydrologic service. Two hydrological forecasting systems were planned: the first one for the Sava river basin, covering 53 % of Slovenia and the second for the Soča river basin, covering 11 %. After the completion of the BOBER project, the Hydrologic Forecasting Department will be able to forecast hydrological conditions for 70 % of Slovenia with the two new forecasting systems and the

Postavitev izvedbenega koncepta v letu 2009

Izhodišče zasnove prognostičnih sistemov je zagotovitev enostavnega in hitrega pregleda hidrološkega stanja ter napovedi v izbranih vodomernih profilih na porečjih Save, Soče in Mure. S pregledom konkurenčnih programskih rešitev smo se seznanili z obstoječimi rešitvami in dobili nove zamisli, ki bodo pripomogle k razvoju takih prognostičnih sistemov, ki bodo omogočali kakovostnejše in zanesljivejše hidrološke napovedi.

Nadgradnja in prenos že obstoječe rešitve na reki Muri, ki temelji na programski opremi MIKE skupine DHI kot računskem jedru sistema, bosta omogočila vzpostavitev enotnega hidrološkega in hidrodinamičnega modelskega pristopa. Odločitev o ohranitvi računskega jedra je pripravo projekta usmerila k pregledu podatkovnih virov ter njihovega stanja, načrtovanju obdelave in priprave podatkov za uporabo znotraj modelov, zasnovi prikaza modelskih rezultatov v spletni tehnologiji in njihovega shranjevanja za poznejše analize.

Načrtovani prognostični sistemi bodo vključeni v odprto in prožno informacijsko okolje, v katerem se lahko računsko jedro nadgradi z dodatnimi matematičnimi modeli za hidrološko ali hidrodinamično modeliranje. Delovanje sistemov bo zagotovljeno na podlagi grafičnih vmesnikov, ki bodo omogočali:
- pregled merjenih meteoroloških in hidroloških količin ter modelskih vhodnih podatkov,
- vpogled v delovanje sistema oz. posameznih matematičnih modelov in njihovo upravljanje,
- pregled časovnega poteka modelskih rezultatov v izbranih prognostičnih profilih: napovedanih pretokov, vodostajev in drugih spremenljivk modelskih stanj,
- spreminjanje in dodajanje geografskih informacijskih podlag in
- spletno prikazovanje modelskih rezultatov.

Zahtevana operativnost je pomenila tudi potrebo po povezovanju drugih vsebinskih, informacijskih in programskih rešitev, ki jih uporabljajo strokovne službe Agencije Republike Slovenije za okolje (ARSO). Hidrološki prognostični sistemi se bodo povezali z obstoječimi shemami relacijske podatkovne baze ORACLE, podatkovnim skladiščem meteoroloških številčnih napovedi ter geografskim informacijskim paketom ESRI – ArcGIS, hkrati pa pripravljali rezultate za nadaljnjo uporabo.

Na podlagi podatkov iz samodejnih merilnih postaj, ki so vključene v mreže hidroloških in meteoroloških opazovanj naše, pa tudi sosednjih držav, in prognostičnih produktov meteoroloških številčnih modelov bodo prognostični hidrološki sistemi izdelali napoved pretokov in vodostajev na izbranih prečnih profilih praviloma za 72 ur vnaprej oz. do največ 210 ur vnaprej, vendar s precej manjšo zanesljivostjo. Računsko jedro (slika 1), v katerem bodo združene posamezne modelske sestavine, bo oblikovano v tem zaporedju:
- hidrološki model s snežnim modulom,
- hidrodinamični model in

existing system on the Mura river.

Developing an implementation concept in 2009

The precondition for the development of a forecasting system concept is to provide a simple and fast overview of hydrological conditions and forecasts in selected gauging cross-sections of the Sava, Soča and Mura river basins. By reviewing competitive programme solutions, we were acquainted with the existing solutions and got new ideas that will contribute to the development of such forecasting systems, which will enable high-quality and more reliable hydrological forecasts.

The upgrading and the transfer of the existing solution on the Mura river which is based on the Mike Flood Watch software of the DHI Group (DHI Water&Environment) as the calculation core of the system will enable the development of a uniform hydrologic and hydrodynamic model concept. On the basis of the decision to preserve the calculation core, the preparation of the project was directed toward an overview of data sources and the state of the database, the planning of data processing and the preparation of data for their use within the models, toward the concept of presenting model results in web technology and their storage for further analyses.

The planned forecasting system will be integrated in an open and flexible information environment, in which the calculation core can be upgraded by additional mathematical models for hydrologic and hydrodynamic modelling. The system will operate on the basis of graphical interfaces which will provide:
- an overview of measured meteorological and hydrological quantities and model input data,
- an insight into the operation of the system and individual mathematical models and their management,
- an overview of the timeline of model results in the selected forecasting profiles: forecast discharges, water levels and other variables of model conditions,
- the changing and adding of geographic information baselines, and
- the presentation of the model on the web.

The required operating capacity also indicated the need for the integration of other substantive, information and programme solutions used by the professional services of the agency. The hydrological forecasting systems will be connected to the existing schema of the ORACLE relational database, the data archive of meteorological numerical forecasts and the ESRI–ArcGIS geographical information system package. At the same time, the systems will prepare results for further analysis.

On the basis of data from independent gauging stations integrated in the hydrological and meteorological monitoring networks in Slovenia and neighbouring countries, and the forecasting products of meteorological numerical models, the hydrological forecasting systems will draw up forecasts of discharges and water levels in the selected cross-sections, generally up to 72 hours in advance, but not

- modul za popravek napovedanih pretokov in vodostajev.

Konceptualni hidrološki model omogoča uporabo fizikalno značilnih parametrov, s katerimi skušamo opisati odtekanje vode s posameznega zalednega območja. Tako je poleg količine vode v tleh najpomembnejši rezultat hidrološkega modela pravilno oblikovan hidrogram odtoka. Snežni modul simulira taljenje snega in akumulacijo padavin v snežni odeji. Izračun temelji na izmerjeni in napovedani temperaturi zraka v stometrskih višinskih pasovih. Modul določi količino snežnice kot prispevek k celotnemu odtoku s posameznega zalednega območja ter akumuliranih padavin v snežni odeji. Rezultati hidrološkega modela so potrebni za zagon hidrodinamičnega modela, ki simulira časovno dinamiko površinskega odtoka vzdolž rečne mreže in izračuna gladinska stanja na posameznih rečnih odsekih. Hidrodinamični model bo zasnovan v eni dimenziji, kar omogoča razmeroma kratke računske čase in hiter dostop do rezultatov v prognostičnem sistemu. Modelski izračuni praviloma odstopajo od dejanskega hidrološkega stanja. Zaradi tega bo v zadnjem koraku modul za popravek napovedanih pretokov in vodostajev prilagodil rezultate dejanskim izmerjenim vrednostim. S prilagoditvami pričakujemo izboljšanje zanesljivosti in kakovosti napovedi vzdolž rečne mreže.

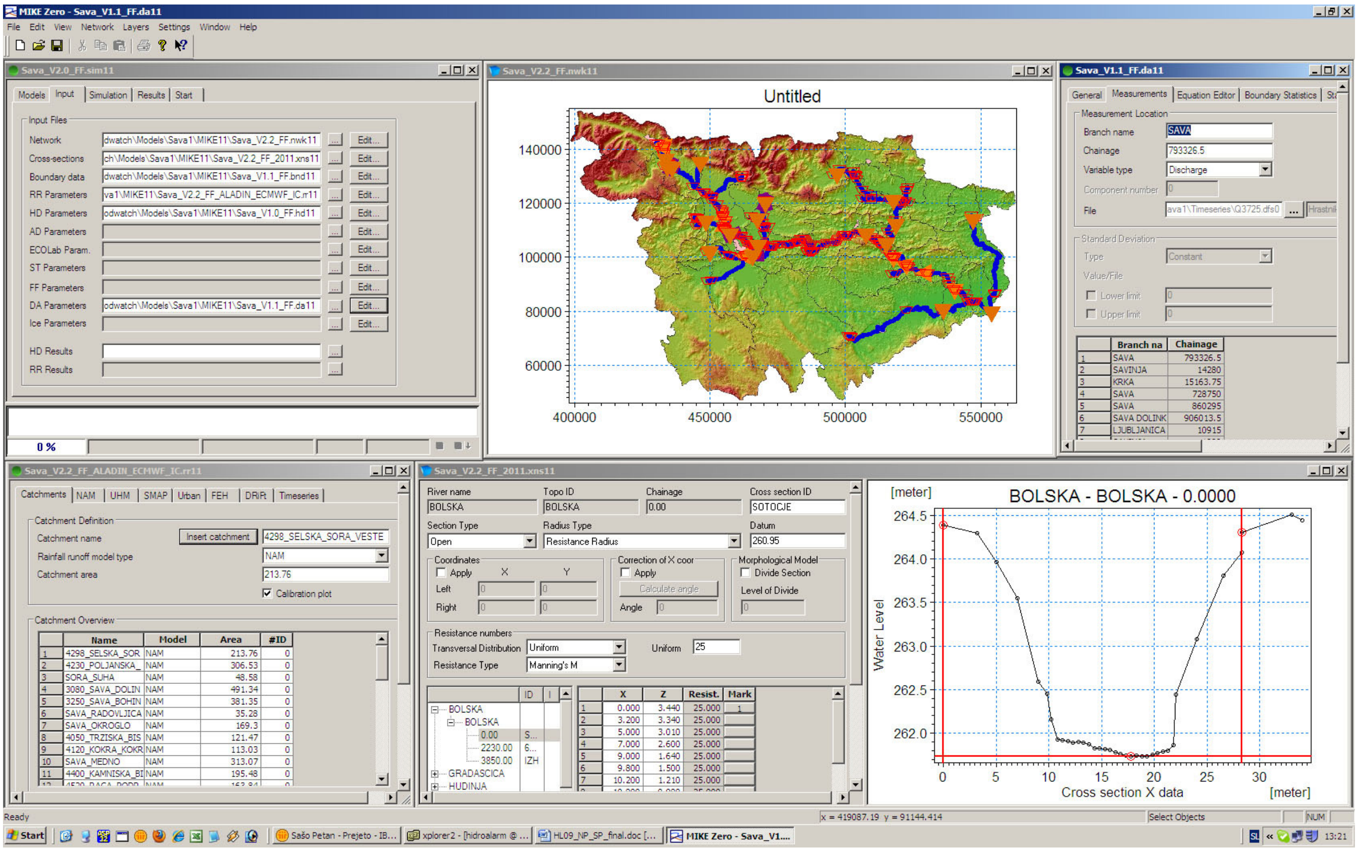
Rezultati hidroloških prognostičnih sistemov bodo poleg kakovostnejših napovedi hidrološkega stanja slovenskih rek omogočali tudi optimalnejše načrtovanje dela drugih strokovnih služb ARSO (kakovost voda, hidrometrija). Da bo sistem kar najuporabnejši za širši krog uporabnikov ARSO, smo veliko časa namenili načrtovanju spletnih vsebin. Spletni prikaz modelskih rezultatov bo zasnovan na prostorskem prikazu računskih enot (podporečij) in mest prognostičnih profilov na obstoječih geografskih podlagah, ki jih omogočajo različne spletne storitve in ponudniki. Za vsak prognostičen profil oz. pripadajoče podporečje bodo prikazane te izmerjene oz. napovedane hidrološke in meteorološke spremenljivke: pretok, vodostaj, padavine, temperatura zraka, količine vode v tleh in vode v snežni odeji. Na diagramih časovnega poteka pretokov in vodostajev bodo prikazane tudi opozorilne vrednosti, ki bodo usklajene s sistemom za opozarjanje pred visokimi vodami Hidroalarm. Na spletnem prikazu modelskih rezultatov bodo za vsak prognostičen profil na voljo tudi osnovne informacije o pripadajoči vodomerni postaji: mesto, izbor metapodatkov, delujoči merilni instrumenti, prečni profil, trenutna pretočna krivulja in izbor hidroloških značilnosti, kot so povratne dobe malih in velikih pretokov, obdobne letne statistike pretokov in temperatur ter kratek opis razmer ob treh najvišjih doseženih vodah.

more than 210 hours in advance, in which case the reliability is much lower. The calculation core (Figure 1) in which individual model components will be joined will be developed in the following order:

- a hydrological model with a snow module,
- a hydrodynamic model and
- data assimilation modul.

The conceptual hydrological model enables the use of characteristic physical parameters by way of which we try to describe the water runoff from each subcatchment. Apart from the water quantity in the soil, the most important result of the hydrological model is a correctly designed runoff hydrogram. The snow module simulates the melting of snow and the precipitation accumulation in the snow cover. The calculation is based on the measured and forecast air temperature in 100-meter altitude zones. The module defines the quantity of snow water as a contribution to the overall runoff from an individual catchment and the precipitation accumulated in the snow cover. The results of the hydrological model are required for the activation of the hydrodynamic model, which simulates the time dynamics of the water runoff along the river network and calculates the water levels on individual river sections. The one dimensional hydrodynamic model provides relatively short calculation times and quick access to the results in the forecasting system. As a rule, the model calculations deviate from the actual hydrological situation. As a result, in the last phase, the module for correcting forecast discharges and water levels will assimilate the results to the actually measured values. Through the assimilation, improvements can be expected in the interchangeability and the quality of forecasts along the river network.

The results of the hydrological forecasting systems will not only provide for high quality forecasts of the hydrological conditions of Slovenian rivers but also optimum planning of the work of other professional services of the agency (quality of water, hydrometry). In order to make the system as accessible as possible to a wider circle of users at the agency, we devoted much time to the planning of website contents. The presentation of model results on the website will be based on a spatial presentation of calculation units (sub-basins) and sites of forecasting profiles on the existing geographical charts, provided by different web services and providers. For each forecasting profile and the pertaining sub-river basin the following hydrological and meteorological variables will be presented, measured and forecast: discharge, water stage, precipitation, air temperature, water quantity in the soil and water quantity in the snow cover. Critical values will be also shown in the timeline chart presenting discharges and water stages. They will be harmonised with the Hidroalam flood warning system. For each forecasting profile, the website presentation of model results will also contain the basic information on the pertaining water gauging station: the site, the selection of meta-data, the operational measuring instruments, the cross-section, the currently valid discharge curve and the selection of hydrological characteristics, such as return periods of low and high discharges, periodical annual statistics of discharges and temperatures, and a short description of conditions for three cases of maximum water levels.



Slika 1: Računsko jedro MIKE ZERO (skupina DHI)
Figure 1: Calculation core MIKE ZERO (DHI Group)

Potek izvedbe projekta

Zaradi velikega obsega nalog pri osnovanem projektu smo pripravili splošno časovnico (slika 2), ki povzema glavne naloge in roke za učinkovito izvedbo. Priprava in izvedba hidrološkega prognostičnega sistema na porečju reke Save oz. Soče bosta potekali med 1. in 14. mesecem oz. med 13. in 21. mesecem, preizkušanje obeh sistemov pa do konca projekta (26 mesecev). Med izvedbo projekta želimo zagotoviti ustvarjalno in zanesljivo sodelovanje z izvajalcem projekta, s katerim bomo izpolnili postavljene cilje in oblikovali skupino usposobljenih strokovnjakov, ki bodo lahko po končanem projektu samostojno upravljali in posodabljali zasnovano strukturo hidroloških prognostičnih sistemov.

Konec leta 2009 smo za izoblikovano projektno nalogo izvedli javno naročilo s pogajanji z danskim podjetjem DHI kot razširitev že vzpostavljenega sistema za napovedovanje pretokov na reki Muri. Pri pogajanjih smo uspešno znižali ceno njihove ponudbe in sklenili pogodbo. Pogodba o izvedbi projekta Nadgradnja prognostičnega sistema na rekah Savi in Soči je bila podpisana 18. 12. 2009 in s tem smo prešli v izvedbeno fazo. V 26 mesecih bo potrebno zagotoviti rezultate. Hidrološka prognostična sistema za reki

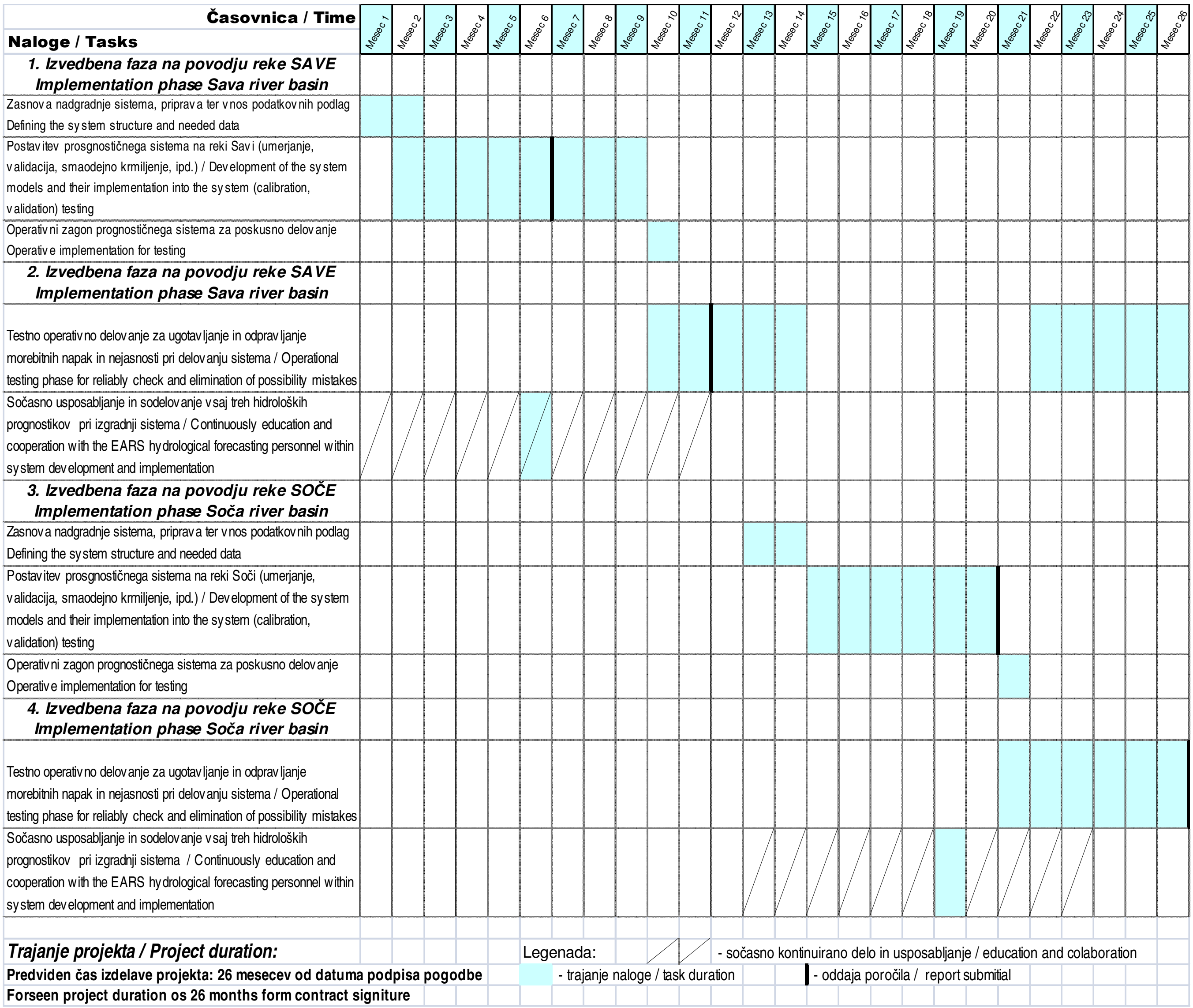
Course of project implementation

Due to the high scope of tasks related to the basic project, a general time schedule (Figure 2) was prepared. It summarises the main tasks and time limits for efficient implementation. The preparation and implementation of the hydrological forecasting system on the Sava and Soča rivers will be carried out between the 1st and the 14th month and between the 13th and the 21st month, whereas the testing of both systems will be performed until the completion of the project (26 months). During project implementation, we wish to assure creative and reliable cooperation with the project holder in order to jointly fulfil the set goals and establish a group of qualified experts who will be able to independently manage and update the set structure of hydrological forecasting systems after the completion of the project.

At the end of 2009, an invitation to tender under a negotiated procedure with the Danish company DHI was carried out for the designed project task as the extension of the already established system for forecasting the discharges on the Mura river. During the negotiations, we successfully reduced the price of the company's offer and signed a contract. The contract on the implementation of the project 'Flood

Sava in Soča bo Hidrološka prognostična služba na Agenciji RS za okolje začela uporabljati v drugi polovici februarja 2012.

Forecasting System Upgrade for the Sava and Soča rivers' was signed on 18 December 2009; on this basis, the implementation phase started. The results must thus be provided within 26 months. The hydrological forecasting service at the agency will start to use the hydrological forecasting system for the Sava and Soča rivers in the second half of 2012.



Slika 2: Časovnica poteka projekta

Figure 2: Project time schedule

OCENJEVANJE NIZKIH ZALOG PODZEMNE VODE VODONOSNIH SISTEMOV KOČEVJE – GOTENIŠKA GORA IN POLJANSKA GORA V LETU 2009

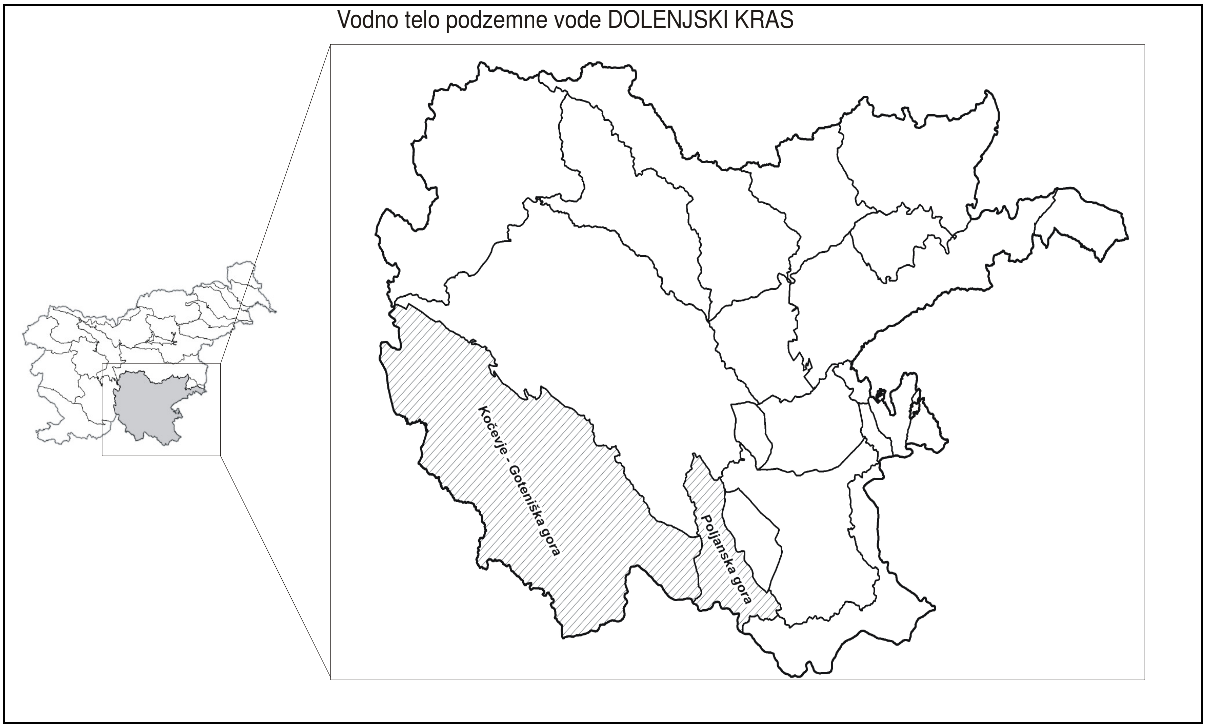
Niko Trišić, Urška Pavlič

Vodonosna sistema Kočevje – Goteniška gora in Poljanska gora sta dva od 21 vodonosnih sistemov vodnega telesa Dolenjski kras, katerih najpomembnejša drenažna cona je reka Kolpa (slika 1). Dolenjski kras je razširjen na ozemlju porečij Krke in Kolpe, na jugovzhodnem delu Slovenije s pretežno (več kot 80 odstotkov) razpoklinskimi in kraškimi vodonosniki z izrazito spremenljivo izdatnostjo.

EVALUATION OF LOW GROUNDWATER RESERVES FROM AQUIFER SYSTEMS KOČEVJE – GOTENIŠKA GORA AND POLJANSKA GORA IN 2009

Niko Trišić, Urška Pavlič

The Kočevje–Goteniška gora and Poljanska gora aquifer systems are two of the 21 aquifer systems of the groundwater body in the Dolenjski kras. Their most important drainage zone is the Kolpa river (Figure 1). The Dolenjska karst region extends over the territory of the Krka and Kolpa river basins in the south-eastern part of Slovenia with mainly (over 80 %) fractured and karstic aquifers, the yield of which is extremely variable.



Slika 1: Položaj in razmejitev VTPodV Dolenjski kras
Figure 1: Position and demarcation of the groundwater body Dolenjski kras

Med obdobjem nizkih voda v septembru 2009 so bile opravljene simultane meritve iztokov vode iz vodonosnih sistemov Kočevje – Goteniška gora in Poljanska gora. Z izvedbo sočasnih meritev pretokov ob ustaljenem nizkem iztoku na vseh iztočnih profilih iz omejenega vodonosnega sistema je namreč mogoča objektivna ocena zalog podzemnih voda v značilnem definiranem hidrološkem stanju v vodonosnem sistemu. Bazni tok sicer ni nujno vedno samo iztok podzemne vode v vodotok, količine vode, ki iztekajo v strugo v daljših obdobjih brez padavin ali brez taljenja snežne odeje, pa so posledica izcejanja izključno podzemnih voda. Za meritve tega pretoka vode so najprimernejši profili neposrednih iztokov iz

In September 2009, in the period of low water levels, simultaneous measurements of outflows of water from the Kočevje-Goteniška gora and Poljanska gora aquifer systems were carried out. Simultaneous measurements of discharges at low outflows on all outflow profiles from the limited aquifer system provide an objective estimate of reserves of groundwater for a typically defined hydrological condition in an aquifer system. The base flow is not necessarily always only the outflow of groundwater into a watercourse, while the water quantities flowing into the river bed in longer periods without precipitation or without the melting of the snow cover result exclusively from the outflow of underground water. For the measurements of the vodonosnikov, to so izviri oz. njihova neposredna bližina, časovno merilo pa je konec ali začetek hidrološkega leta, ko so porabljene zaloge snežne odeje.

Vodonosni sistem Kočevje – Goteniška gora

Geografsko zajema vodonosni sistem masive Velike gore, Goteniške gore in Goteniške doline ter masiv Stojne. Površina sistema obsega nekaj manj kot 600 km2 ozemlja, ki se drenira v Čabranko, Kolpo in Krko (slika 2). Najvišji vrhovi teh masivov presegajo 1200 m nadmorske višine, Ribniško in Kočevsko polje pa sta na višinah med 470 in 500 metrov nad morjem. Na jugu ležijo izviri Čabranke na višinah med 550 in 600 m n. m, struga Kolpe v Lazah na meji vodonosnega sistema pa se spusti pod 200 m n. m.

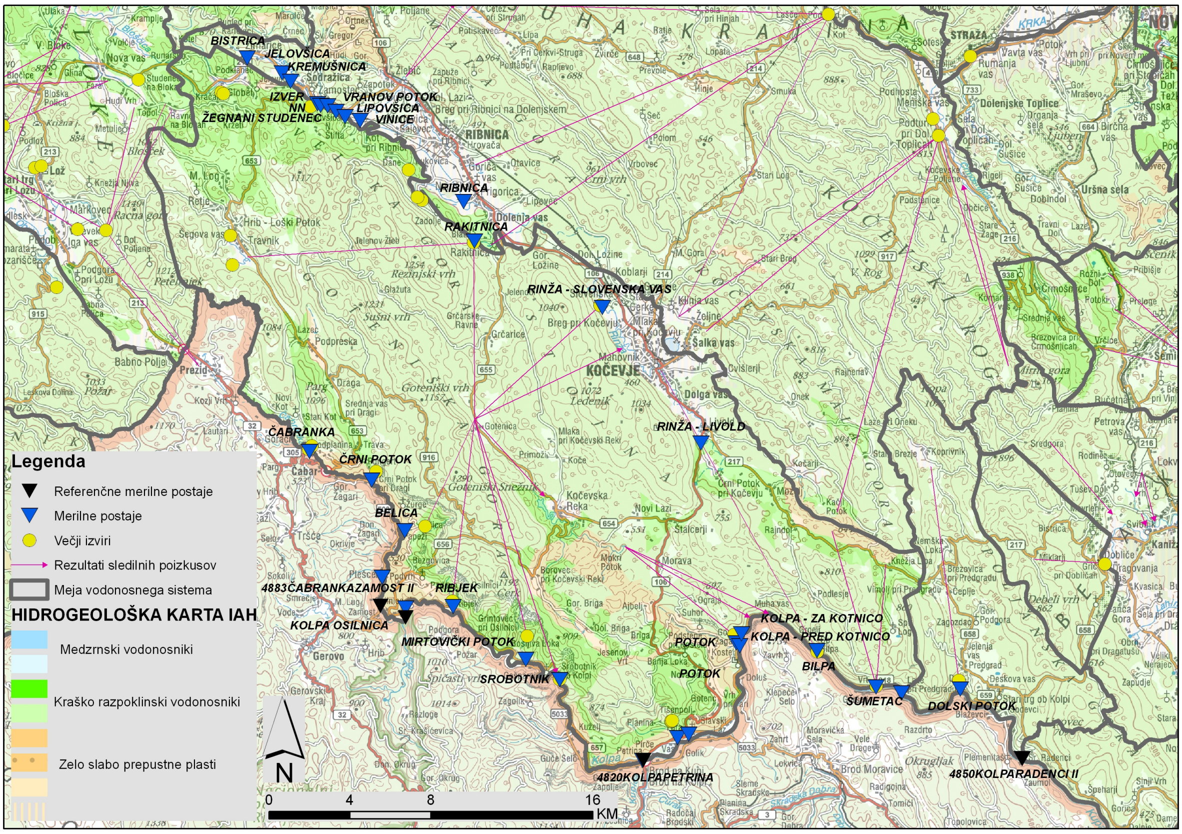
Vodonosni sistem sestavljata dva značilna tipa vodonosnikov. Dolomitni vodonosnik, pretežno zastopan kot glavni dolomit, je značilen razpoklinski in kraški slabo zakraseli sistem mezozojske starosti, ki s svojo vlogo relativne hidrogeološke pregrade vpliva na nastopanje in pretakanje podzemne vode v vodonosnem sistemu. Drugi tip vodonosnika je kraški, zelo do malo zakrasel, z izdatnimi vodonosniki mezozojskih apnencev in dolomitov. Vodonosniki v nekarbonatnih kamninah so le lokalnega pomena (slika 2).

discharge, the profiles of direct outflows from aquifers are most appropriate, i.e. springs and their direct vicinity, while the temporal criterion is the end or the beginning of the hydrological year when all water reserves in the snow cover are spent.

Kočevje – Goteniška gora aquifer system

Geographically, the aquifer system covers the massifs of Velika gora, Goteniška gora and Gotenica valley, and the Stojna massif. The surface area of the system covers almost 600 km² of land that drains into the Čabranka, Kolpa and Krka rivers (Figure 2). The highest peaks of these massifs exceed heights of 1200 m above sea level, whereas Ribnica and Kočevje fields are at heights between 470 and 500 m above sea level. In the south, there are the springs of Čabranka at heights between 550 and 600 m above sea level, while the Kolpa riverbed goes down below the height of 200 m above sea level.

The aquifer system consists of two types of aquifers: a dolomite aquifer, mainly represented as the main dolomite, is a typical fractured and low karstified Mezozoic formation, which as a relative hydrogeological barrier influences the occurrence and flow of groundwater in the aquifer system, and a karstic aquifer system, high to low karstified, with abundant aquifers made up of Mesozoic limestones and dolomites. Aquifers in non-carbonate ground are of local importance only (Figure 2).



Slika 2: Hidrogeološka karta vodonosnih sistemov Kočevje – Goteniška gora in Poljanska gora
Figure 2: Hydrogeological map of aquifer systems Kočevje – Goteniška gora and Poljanska gora

Vodonosni sistem na jugu in jugozahodu omejuje drenažna hidravlična meja toka Kolpe in Čabranke, na zahodu potek državne meje in proti severu potek nejasne kraške razvodnice proti kraški Ljubljanici. Od Runarskega dalje do Dolenje vasi poteka meja telesa po litološki meji glavnega dolomita, od tu proti severovzhodu in vzhodu pa po razvodnici Rinže in razvodnici z vodonosnim sistemom Poljanske gore.

Vodonosni sistem je razmeroma dobro omejena hidrogeološka iztočna struktura, ki jo napajajo izključno padavine. Znotraj enote sta dve kraški polji s stalnim površinskim tokom, Loški potok in Kočevska reka, nekaj manjših kraških polj pa drenirajo nestalni tokovi. Smeri odtokov so delno dokazane s sledilnimi poskusi, novejši rezultat je povezava območja Retij z Velikim Obrhom, kar zmanjšuje določeno velikost vodonosnega sistema za nekaj km^2. Sledilni poskus na območju Gotenice je nakazal obsežno raztekanje podzemne vode v več smereh, podzemno pretakanje Rinže proti izvirom ob Kolpi pa je ob nizkih stanjih počasno in dolgotrajno.

Izviri na obrobju Ribniškega podolja in Kočevja izdanjajo na stiku s slabše prepustnimi glavnimi dolomiti, ki v podlagi jurskih in krednih skladov usmerjajo in vplivajo na iztok podzemne vode. Tudi izviri Čabranke pri Podplanini izdanjajo na stiku z glavnim dolomitom, druga hidrogeološka pregrada pa so permski klastiti v goteniški strukturni enoti, zaradi katerih izviri izdanjajo šele v višjih predelih nad strugama Čabranke in Kolpe. Ta strukturna enota z mladopaleozojskimi klastiti se konča pri naselju Žaga, zato je šele od tu dalje po dolini iztok iz kraške zaledne strukture v Kolpo neposreden.

Hidrološke značilnosti iztoka iz obravnavanih vodonosnih sistemov se v okviru državnega hidrološkega monitoringa ugotavljajo na območju Ribniško-Kočevskega polja s hidrološko postajo Prigorica na Ribnici, na območju Kolpe pa s postajo Sp. Bilpa na Bilpi. Hidrološke meritve se na območju raziskav na Kolpi izvajajo z merilnima mestoma Petrina na Kolpi in Radenci na Kolpi, na območju povodja Čabranke pa sta v preteklosti delovali merilni postaji Črni Potok na Čabranki in Papeži na Belici. Neposreden iztok iz vodonosnega sistema ima tako na območju iztokov v Kolpo le postaja Sp. Bilpa na Bilpi. Podatkovni niz zajema obdobje od septembra 2005, zato ni neposredno primerljiv z nizi drugih hidroloških postaj (slika 3).

Predstavljeni časovni razpored nizkih vodostajev je v obdobju štirih let že značilno razporejen. Na sliki 3 so prikazani najnižji mesečni vodostaji iz dnevnih najvišjih vrednosti, da se odpravi vpliv dnevnega ravnanja z zapornicami, ki so nameščene v strugi Bilpe malo pod izvirom. Dolgoletni podatkovni nizi delujočih hidroloških postaj so podlaga za ocenjevanje hidroloških razmer na območjih obeh vodonosnih sistemov (slika 4).

Podatki o najnižjih pretokih nQnk, doseženih na predstavljenih postajah:

Prigorica na Ribnici: 0,089 m^3/s
Petrina na Kolpi: 1,51 m^3/s
Radenci na Kolpi: 2,35 m^3/s

In the south and south-west, the aquifer system is limited by a drainage hydraulic barrier of the Kolpa and Čabranka watercourses, in the west by the course of the state border and towards the north by the course of an unclear karstic watershed divide toward the karstic Ljubljanica river. From Runarsko to Dolenja vas, the boundary of the water body runs along the lithologic border of the Main Dolomite and from there toward the north-east and the east along the Rinža watershed divide and the watershed divide with the aquifer system of Poljanska gora.

The aquifer system is a relatively clearly limited hydrogeological runoff structure exclusively supplied by precipitation. Within this unit, there are two karstic fields with a permanent surface flow, Loški Potok and Kočevska Reka, while some smaller karstic fields are drained by temporary streams. The directions of the runoffs have been partly proved by tracing tests, while the recent results show that the area of Retje is connected to Veliki Obrh, which further limits the specified area of the aquifer system by several square kilometres. The tracer test in the area of Gotenica shows an extensive groundwater bifurcation, whereas the groundwater flow of the Rinža river toward the springs along the Kolpa river is slow and long in low water conditions.

The springs along Ribniško Podolje and Kočevje rise from the ground at the point of contact with the less permeable Main Dolomites, which direct and influence the outflow of ground water in the Triassic and Jurassic layers. The Čabranka springs in Podplanina also rise from the ground at the point of contact with the Main Dolomite, whereas the second hydrogeological barrier are the Permian clastites in the Gotenica structural unit, because of which the springs arise in higher areas above the Čabranka and Kolpa riverbeds. This structural unit with younger Paleozoic clastites ends at the Žaga settlement; therefore, only from there does the water flow directly through the valley from the karstic hinterland structure into the Kolpa river.

The hydrological characteristics of the outflow from the aforementioned aquifer systems are determined within the national hydrological monitoring programme in the region of Ribnica and Kočevje fields at the Prigorica hydrological station on the Ribnica river, and in the area of the Kolpa river at the Sp. Bilpa hydrological station on the Bilpa stream. Hydrological measurements in the research area of the Kolpa river are carried out at the Petrina and Radenci gauging sites on the Kolpa river. In the past, two gauging sites, Črni Potok on the Čabranka river and Papeži on the Belica stream, operated in the Čabranka river basin. In the area of outflows into the Kolpa river, only the Bilpa gauging site on the Bilpa stream has a direct outflow from the aquifer system. The data series covers the period from September 2005 onwards, and is therefore not directly comparable to the series from other hydrological stations (Figure 3).

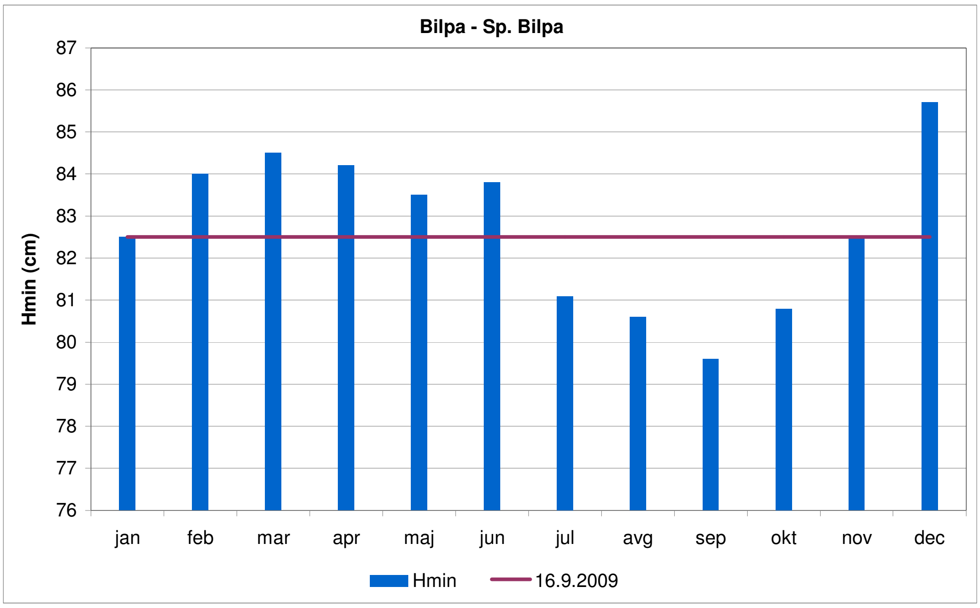
The presented timeline of the low water levels has already been characteristically distributed during the four-year period. Figure 3 presents the lowest monthly water levels. They are derived from the highest daily

Časovni razpored vodostajev na izviru Loškega potoka pri Travniku reprezentativno predstavlja hidrološke razmere v osrednjem območju vodonosnega sistema Kočevje – Goteniška gora. V letu 2009 se vodostaji baznega iztoka pozimi in spomladi gibljejo na nivojih okoli 40 cm, upadanje vodostajev pod vodostaji 40 cm se pojavi šele konec maja ter je prekinjeno le z nekaj manjšimi valovi še v juniju in izdatnejšim valom sredi julija (slika 5). Za tem dogodkom vodostaji upadajo do sredine septembra, ko dosežejo najnižje vrednosti v celotnem 5-letnem opazovalnem obdobju. Upadanje je v drugi polovici septembra prekinjeno s krajšim vodnim valom, za katerim spet nastopi nizko stanje z vodostaji v območju 20 cm.

values in order to eliminate the impact of the daily operation of the gates installed in the Bilpa riverbed slightly below the spring. Multi-annual data series for operational hydrological stations constitute the basis for the evaluation of hydrological conditions in the area of both aquifer systems (Figure 4).

Data on the lowest discharges nQnk recorded at the aforementioned stations:

Prigorica on the Ribnica river: 0.089 m^3/s
Petrina on the Kolpa river: 1.51 m^3/s
Radenci on the Kolpa river: 2.35 m^3/s



Slika 3: Razporeditev najnižjih mesečnih vodostajev izvira Bilpa in vodostaj ob meritvi 16. 9. 2009

Figure 3: Distribution of the lowest monthly water levels of the Bilpa spring and the water level measured on 16 September 2009

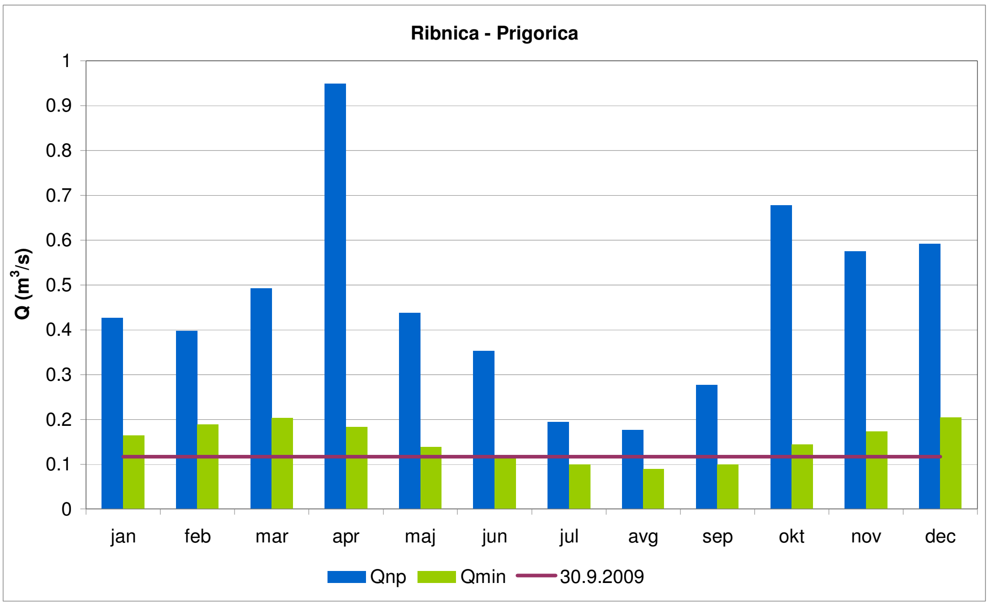
Nizki vodostaji oz. zaloge podzemne vode v septembru 2009 so najnižja dosežena hidrološka stanja v obdobju 2004–2009 na tem območju. Zaloge podzemne vode v obravnavanem sistemu smo se odločili oceniti na podlagi meritev pretokov 30. septembra 2009, s tem da so za profile rednih hidroloških postaj upoštevani podatki meritev, izvedenih 16. 9. 2009, pred visokovodnim valom v sredini septembra.

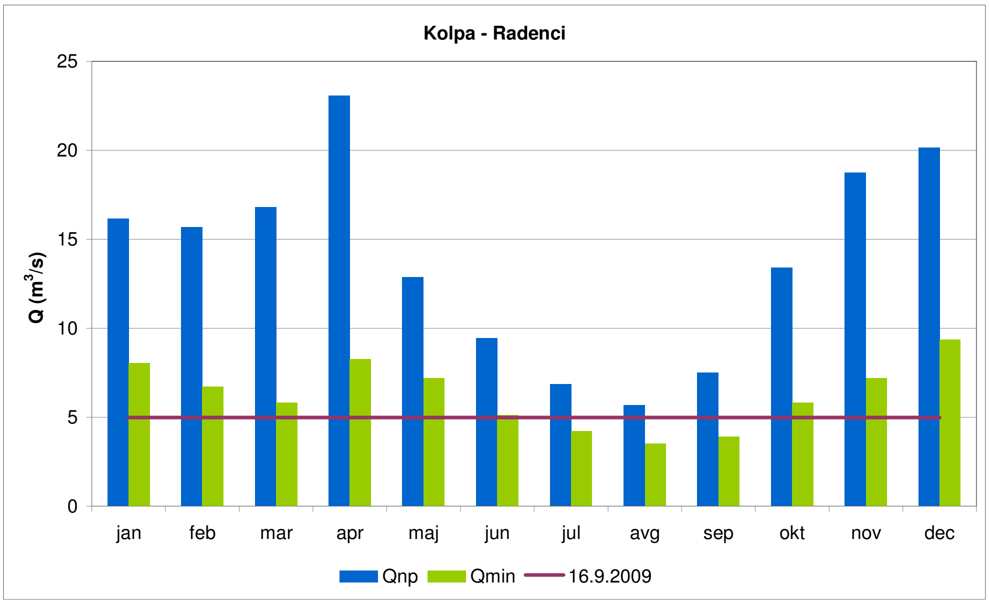
Zaledje izvira Čabranke sega na slovensko in hrvaško ozemlje, zato pri ocenjevanju iztoka iz vodonosnega sistema, ki je omejen tudi s potekom državne meje, privzeto upoštevamo polovico merjenega pretoka v profilu v Podplanini. Kolikšen je dejanski delež iztoka v izviru iz zaledja ene ali druge države, ni znano, saj položaj zaledja izvirov ni raziskan.

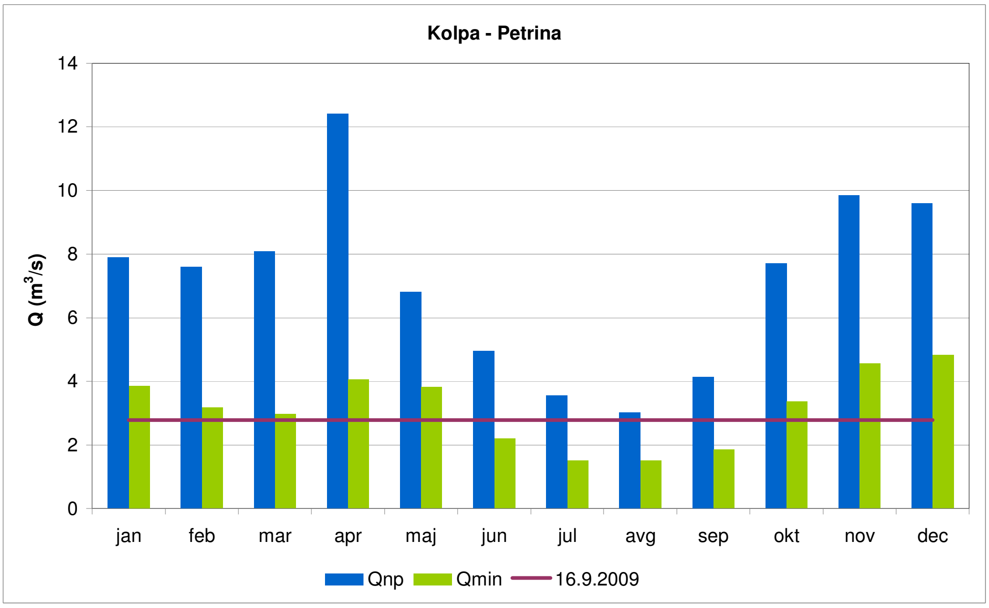
The timeline of water levels on the Loški potok spring near Travnik is a representative example of hydrological conditions in the central area of the Kočevje–Goteniška gora aquifer system. In the winter and spring periods of 2009, the water levels of the base flow fluctuated around 40 cm; only in May, did the water levels drop below 40 cm and were interrupted by some minor waves in June and a major wave in mid-July (Figure 5). After that event, the water levels decreased until mid-September, when they reached the lowest values in the entire five-year observation period. In the second half of September, the decrease was interrupted by a shorter water wave, which was then followed again by a period of low water levels at around 20 cm.

The low water levels and groundwater reserves in September 2009 show the lowest hydrological condition in the 2004–2009 period in that area. We decided to estimate the groundwater reserves in the considered system on the basis of measurements of discharges carried out on 30 September 2009, by which the profile of regular hydrological stations the measurements of 16 September 2009 were consideredprior to the high-water wave in mid-

September.

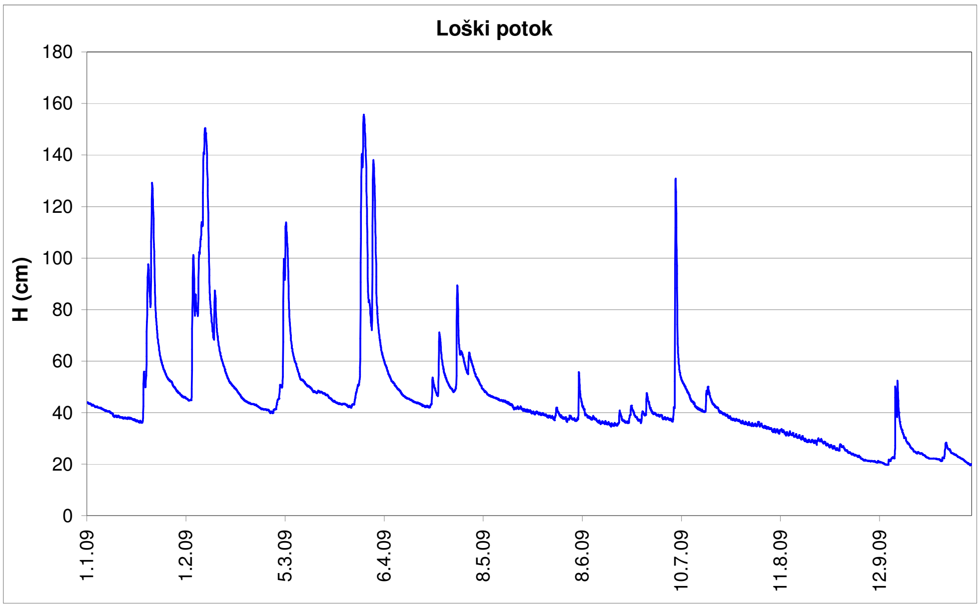






Slika 4: Časovna razporeditev nizkih mesečnih pretokov (Qnp) na hidroloških postajah Prigorica na Ribnici, Radenci na Kolpi in Petrina na Kolpi ter pretok ob meritvah v septembru 2009

Figure 4: Temporal distribution of low monthly discharges (Qnp) at hydrological gauging stations Prigorica on the Ribnica river, Radenci on the Kolpa river and Petrina on the Kolpa river and the discharges measured in September 2009



Slika 5: Razpored nihanja vodostajev Loškega potoka v letu 2009
Figure 5: Fluctuation of water levels in Loški potok in 2009

Meritve ali ocene pretokov so izvedene na vseh profilih, na katerih je opažen aktiven iztok, pretok izvirov Kotnice pa je izmerjen kot razlika pretokov Kolpe nad in pod območjem izvirov na območju Žage. Ker je vodonosni sistem iztočnega tipa, je s serijo meritev iztokov zajet celoten znan odtok z območja. Dober 1 m^3/s pretoka oz. okoli 2/3 celotnega nizkega pretoka iz sistema izteka na območju 5 najizdatnejših izvirov: Čabranki, Kotnici, Bilpi, Ribnici in Rakitnici, ki je tudi najpomembnejši vodni vir v sistemu vodne oskrbe ribniško-kočevskega območja. Ob upoštevanju odvzemov na izviru Rakitnica je 1/3 odtoka iz celotnega sistema ob nizkem hidrološkem stanju usmerjena proti Krki, preostali del iztoka se drenira v celoti proti Kolpi.

Skupni merjeni iztok iz vodonosnega sistema Kočevje – Goteniška gora dosega ob nizkem hidrološkem stanju 1,59 m^3/s. Odvzemi za vodno oskrbo (brez odvzemov na izviru Čabranke) dosegajo povprečno dnevno 0,086 m^3/s, s tem da so odvzemi čez dan bistveno višji, kot je dnevno povprečje.

Ob upoštevanju velikosti vodonosnega sistema 595 km^2 in ob odvzemih na izvirih, ki čez dan dosegajo okoli 150 l/s, znaša specifični odtok ob nizkem hidrološkem stanju in merjeni količini iztokov 1,59 m^3/s:

$$Q =\sim (1{,}59+0{,}15)\ m^3/s\ /\ 595\ km^2 = 2{,}92\ l/s/km^2$$

Ker je po novejših raziskavah območje vodonosnega sistema nekaj manjše, lahko kot vrednost nizkega specifičnega odtoka za območje vodonosnega sistema upoštevamo 2,95 $l/s/km^2$.

Vodonosni sistem Poljanska gora

V sklopu meritev za ocenjevanje statičnih zalog vodonosnega sistema Kočevje – Goteniška gora so

The hinterland of the Čabranka river covers both Slovenian and Croatian territory; therefore, half of the measured discharge in the profile in Podplanina has been considered for the estimation of the outflow from the aquifer system, which is also limited by the course of the state border. The exact quantity of the spring's outflow from the hinterland of the two countries is not known, because the hinterland of the springs has not yet been researched.

Measurements and estimates of discharges have been made at all profiles, where active outflows can be observed, while the discharge of the Kotnica springs has been measured as the difference between the discharges of the Kolpa river above and below the springs in the area of Žaga. Since the aquifer system is an outflow system, the series of outflow measurements covers the entirely known runoff from the area. Slightly more than 1 m^3/s of the discharge or around two thirds of the entire low discharge from the system flows out in the area of the five most abundant springs: Čabranka, Kotnica, Bilpa, Ribnica and Rakitnica. This area is also the most important sources in the water supply system of the Ribnica and Kočevje region. Taking into consideration the sampling at the Rakitnica spring, in low water level conditions, one third of the runoff from the entire system is directed toward the Krka river, while the rest drains in its entirety toward the Kolpa river.

During low hydrological conditions, the total runoff from the Kočevje-Goteniška gora aquifer system reaches 1.59 m^3/s. The water supply sampling values (the sampling at the Čabranka spring is excluded) reaches a daily average of 0.086 m^3/s, while the values of the samples taken during the day are significantly higher than the daily average.

izvedene še meritve pretoka Dolskega potoka v Dolu. Dolski potok drenira območje vodonosnega sistema Poljanska gora (F = 86 km^2), ki v tektonskem pogledu tudi pripada enoti Zunanjih Dinaridov. Je na območju luskaste narivne zgradbe enot Knežja lipa in Koprivnik. Prevladujejo apnenci in dolomiti zgornje jurske starosti, klastičen razvoj premskih skladov s peščenjaki in konglomerati pa nastopa na območju Knežje lipe. Dokazana je povezava območja Koprivnika z izvirom Dolskega potoka in na podlagi tega tudi določen položaj zaledja Dolskega potoka.

Podatka o pretoku Dolskega potoka 0,075 m^3/s, izmerjen 16. 9. 2009, ne moremo upoštevati kot edino vrednost za iztok iz vodonosnega sistema. Specifični odtok ob upoštevanju samo tega rezultata meritve ne doseže niti 1 l/s/km^2, kar pa ni realno. Upoštevanje rezultatov meritev pretoka Kolpe v Lazah in Radencih sicer da drugačno oceno, vendar pri tem ne poznamo količin iztoka v Kolpo na hrvaški strani, pa tudi meritvi nista bili opravljeni na isti dan.

Meritvi pretoka Dolskega potoka in Kolpe v Radencih sta bili opravljeni 16. 9. 2009, meritev pretoka Kolpe v Lazah pa 30. 9. 2009. Rezultati meritev se zato ne morejo z zanesljivostjo primerjati med seboj.

Meritev pretoka Kolpe v Gorenji Žagi 30. septembra 2009 (foto: P. Gajser)
Discharge measurement of Kolpa in Gorenja Žaga on 30 September 2009 (Photo: P. Gajser)

Sklepne ugotovitve

Območje vodonosnega sistema Kočevje – Goteniška gora je kot hidrogeološka enota z znanim položajem in velikostjo ustrezen poligon za ocenjevanje zalog podzemne vode v vodonosnem sistemu kraške razpoklinske poroznosti. Poleg znanega in omejenega položaja je izpolnjen tudi pogoj poznavanja iztočnih profilov in primernosti merskih profilov za meritve pretoka. Vodonosni sistem je v poteku meje na jugozahodu in jugu omejen z vodotokoma Čabranka in Kolpa, ki imata jasno vlogo efluentnega toka oz. drenaže celotnega levega brega. Jasna je tudi omejitev sistema na severu in severovzhodu, manj natančna pa na potezu kopne državne meje in razvodnice proti

Taking into account the area of the aquifer system, which is 595 km², and the values of the samples taken at the springs, which during the day reach around 150 l/s, the specific runoff in low hydrological conditions and for the measured runoff quantity 1.59 m³/s is as follows:

$$Q =\sim (1.59+0.15)\ m^3/s/595\ km^2 = 2.92\ l/s/km^2$$

According to recent studies, the area of the aquifer system is supposed to be smaller; therefore, 2.95 l/s/km² could be considered as the value of a low specific runoff for the area of the aquifer system.

Poljanska gora aquifer system

Within the framework of measurements for the estimation of static reserves of the Kočevje–Goteniška gora aquifer system, measurements of the discharge of Dolski potok in Dol have also been carried out. Dolski potok drains the area of the Poljanska gora aquifer system (F=86 km²), which tectonically also belongs to the unit of the Outer Dinarides mountain system. It is located in an area of overthrust land structure of the Knežja Lipa and Koprivnik units. The land structure is mainly composed of early Jurassic limestones and dolomites, although in the area of Knežja Lipa a classical development of Permian structures with sandstone and conglomerates can be observed. Studies have shown the connection of the Koprivnik area with the Dolski potok spring, the result of which is also the certain position of the Dolski potok hinterland.

The discharge of Dolski potok (0.075 m³/s measured on 16 September 2009) cannot be considered as the only value for the outflow from the aquifer system. By taking into consideration only this measurement result, the specific runoff does not even reach 1 l/s/km², which is not a realistic result. If the results of discharge measurements on the Kolpa river in Laze and Radenci are taken into consideration, we obtain a different estimate; however, we do not have exact data on the quantities of the outflow into the Kolpa river in Croatia. Moreover, the two measurements were also not made on the same day.

The discharge measurements for Dolski potok and Kolpa in Radenci were made on 16 September 2009, while the discharge measurement for Kolpa in Laze was made on 30 September 2009. Therefore, the measurement results cannot be reliably compared.

Conclusion

As a hydrological unit with a known location and size, the area of the Kočevje-Goteniška gora aquifer system is a relevant site for the estimation of groundwater reserves in the aquifer system of karstic-fractured porosity. In addition to the known and limited location, another condition is fulfilled: the outflow profiles and the appropriateness of measurement profiles for outflow measurements are known. Along the course of the border in the south-east and in the south, the aquifer system is limited by the Čabranka and Kolpa river basins, which clearly function as effluent streams and drainages of the entire left bank. The limitation of kraški Ljubljanici.

Serija meritev pretokov na vseh znanih iztočnih profilih iz sistema ob nizkem hidrološkem stanju je dala realen podatek o iztoku nizkih zalog podzemne vode iz vodonosnika. Ob upoštevanju količine odvzemov za vodno oskrbo ocenjujemo količino nizkih vodnih zalog v sistemu na 1,74 m^3/s in specifičen nizek odtok na 2,95 $l/s/km^2$.

Izvedeni pregledi terena in merskih profilov ter rezultati meritev so potrdili ustreznost ocenjevanja količin podzemne vode v posameznih vodonosnih sistemih na podlagi meritev iztoka ob navedenih pogojih. Kot zelo koristne so se izkazale tudi potezne meritve pretokov na glavnih drenažnih vodotokih (Kolpa) v več profilih, vendar morajo biti te meritve izvedene v istem dnevu in potezno dolvodno po vodotoku. Pri tem je nujno treba tudi poznati in upoštevati iztoke na obeh iztočnih conah, levem in desnem bregu. Ob njihovem poznavanju lahko natančneje ocenimo tudi iztoke na območju vodonosnega sistema Poljanska gora. Verjetno ne odstopajo bistveno od iztokov na območju Kočevje – Goteniška gora.

Pristop k obravnavi posameznih vodonosnih sistemov po opisanem postopku oz. merilih omogoča ocenjevanje nizkih zalog podzemne vode in specifičnih iztokov iz značilnih hidrogeoloških enot. Omogoča tipizacijo posameznih hidrogeoloških struktur glede na prevladujoči tip poroznosti ter glede na hidrografski in podnebni položaj enote. Predlog nadaljnjih meritev oz. programov zajema usmeritve na območja VTPodV Karavanke, VTPodV Vzhodne Alpe oz. njihove vodonosne sisteme, smiselno pa je tudi ponavljanje meritev na že obravnavanih sistemih in na njihovih sosednih enotah znotraj VTPodV Dolenjski kras.

the system in the north and north-east is also clear, while it is not so specific along the land border and the watershed divide toward the karstic Ljubljanica river.

The series of discharge measurements at all known outflow profiles from the system in low hydrological conditions provided objective data on the outflow of low reserves of groundwater from the aquifer. Taking into consideration the quantities of sampling values for the water supply, the quantity of low water reserves has been estimated at 1.74 m^3/s, while the specific low runoff has been estimated to 2.95 $l/s/km^2$.

The surveys of the ground surface and measurement profiles as well as the measurement results have confirmed the appropriateness of estimates related to the quantities of groundwater in individual aquifer systems on the basis of outflow measurements under the stated conditions. Simultaneous measurements of discharges on the main drainage watercourses (Kolpa) in several profiles have also proved to be very useful; however, these measurements must be carried out on the same day and simultaneously downstream along the watercourse. In this respect, it is also necessary to know and consider the outflows in both outflow zones, on the left and on the right river banks. By knowing them, the outflows in the area of the Poljanska gora aquifer system can also be more precisely estimated. They probably do not deviate significantly from the outflows in the Kočevje-Goteniška gora region.

The approach to the monitoring of individual aquifer systems according to the described procedure and criteria enables the estimation of low groundwater reserves and specific outflows from characteristic hydrogeological units. It enables the typification of individual hydrogeological structures with regard to the prevailing type of porosity and the hydrographic and climate location of a unit. The proposal for further measurements and programmes contains directions toward the groundwater body (VTPodV) of Karavanke, the Eastern Alps and their aquifer systems. It would also be reasonable to repeat the measurements in the already monitored systems and their neighbouring units within the VTPodV Dolenjski Kras.